“粒子物理前沿”卓越中心

2020年高能量前沿工作报告

金山，赵政国，娄辛丑

Contributors: 高杰，阮曼奇，庄胥爱，陈明水，曹庆宏，张照茹等

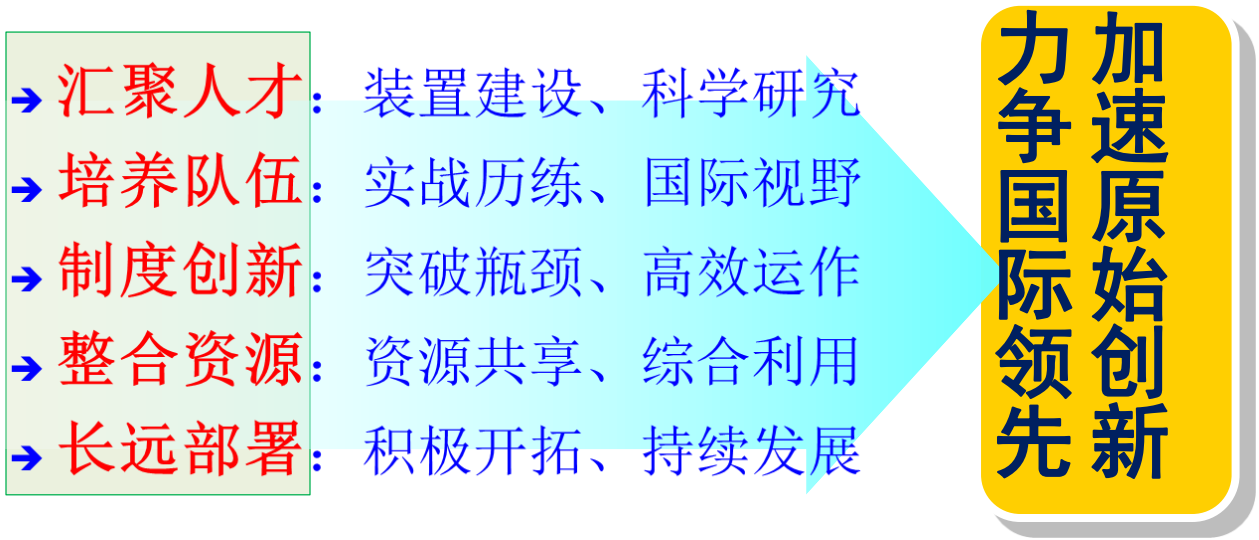
主要内容

- 高能量前沿：简介、发展
- 科学研究
- 设施和前沿
- 技术、研发
- 人才成长
- 小结

高能量前沿简介— 宗旨

focus:
high energy frontier

“规划和实现中国高能物理发展的核心力量”



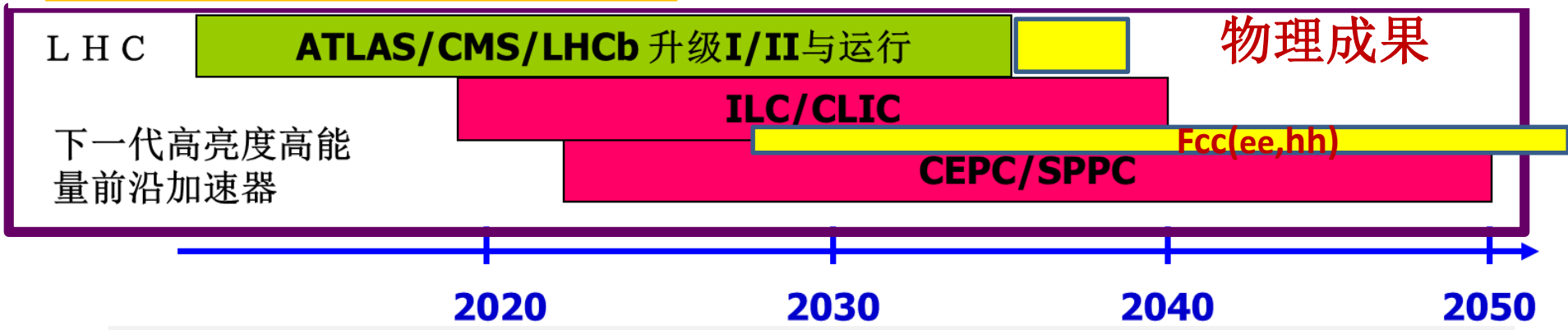
王贻芳(卓越中心答辩报告）

高能量前沿简介—研究方向和发展

通过本卓越中心20-30年的努力：

- 在国际最前沿开展粒子物理创新，实现实验技术提高
- 建成具有国际领先水平的实验装置+获得具有突破性的科研成果
- 成为世界最高水平的高能物理中心之一

王贻芳(卓越中心答辩报告）+ 更新



国内外新发展

- 2020.6欧洲粒子物理战略规划更新：重点为ee希格斯工厂；布局、支持R&D
- 美国启动Snowmass2021，规划2021-2029高能物理发展
- ILC 着手pre-lab，组织-队伍-国际合作
- 中国规划粒子物理未来
- COVID-19 疫情：现有实验、国际交流、可能的经费减少

平台3 – 高能量前沿简介—人员、经费支持

- **人员**

”科学成果 产出”，”关键-前沿技术”,“人才引进-培育”

学术带头人

娄辛丑（高能所）

金山（南京大学）

赵政国（中国科学技术大学）

~400 名职工、博士后和研究生+工程技术人员 (ATLAS,CMS,CEPC)

- **经费支持**

- 自带干粮、争取经费、扩大体量
- 科学院海外创新团队 （2015); 科学院重点研究、培育经费（2016, 2017）
- 高能所自筹创新经费（2014，CEPC初步预研究）
- 科技部973经费(LHC分析,已结题),科技部重点研发ATLAS、CMS (2018)
- 科技部重大研发经费 （CEPC 预研究- 2016MOST1, 2018MOST2)
- 基金委、科技部对ATLAS/CMS升级支持（2017, 19,20）NEW!
- 基金委ATLAS、CMS物理分析（2016, 19,20）NEW!
- 基金委创新团队 （2017-2022 ），基金委面上项目经费
- 北京市加速器平台支持（2017），北京市科委（2018，2019）
- 科学院王贻芳万人计划工作室（2017-）
- 科学院粒子物理卓越中心（2014-）……

2020年科学研究进展

- 理论(CEPC、LHC实验-理论互动、TeV新物理)
- ATLAS,CMS物理分析

LHC唯象学及TeV新物理理论进展

有效场论方法进一步广泛应用，非传统新物理模型和信号在对撞机上的寻找得到发展。

有效场论

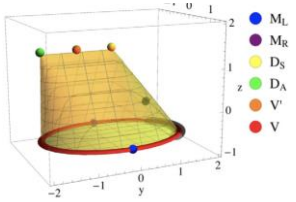
PHYSICAL REVIEW LETTERS 125, 201601 (2020)

Convex Geometry Perspective on the (Standard Model) Effective Field Theory Space

Cen Zhang*
Institute for High Energy Physics, and School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China and Center for High Energy Physics, Peking University, Beijing 100871, China

Shuang-Yong Zhou†
Interdisciplinary Center for Theoretical Study, University of Science and Technology of China, Hefei, Anhui 230026, China and Peng Huanwu Center for Fundamental Theory, Hefei, Anhui 230026, China

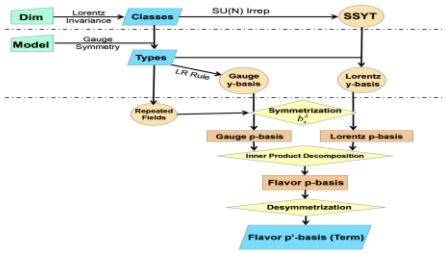
(Received 16 May 2020; accepted 8 October 2020; published 12 November 2020)



高能所张岑
中科大周双勇

Complete Set of Dimension-9 Operators in the Standard Model Effective Field Theory

Hao-Lin Li[a1], Zhe Ren[a,b], Ming-Lei Xiao[a2], Jiang-Hao Yu[a,b,c3], Yu-Hui Zheng[a,b]



理论所
于江浩

唯象学

JHEP
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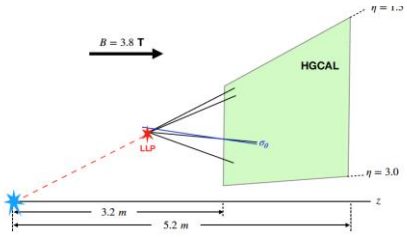
PUBLISHED: November 13, 2020

Enhancing sensitivities to long-lived particles with high granularity calorimeters at the LHC



北京大学刘佳
北航王小平 等

理论-实验互动

✓ 大量成员参与疫情下CLHCP2020会议的组织举办工作，确保线上会议成功举办。

CEPC理论（国内）进展和状态

新物理寻找、Higgs性质研究、QCD理论和有效算符研究均有新进展

有效算符

An unambiguous test of positivity at lepton colliders

Jiayin Gu,[1] Lian-Tao Wang,[2,3] and Cen Zhang[4,5]

[1] *PRISMA$^+$ Cluster of Excellence, Institut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, 55128 Mainz, Germany*

[2] *Department of Physics and Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA*

[3] *Kavli Institute for Cosmological Physics, University of Chicago, Chicago, IL 60637, USA*

[4] *Institute for High Energy Physics, and School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China*

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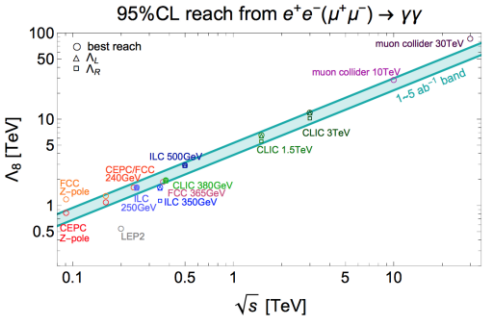
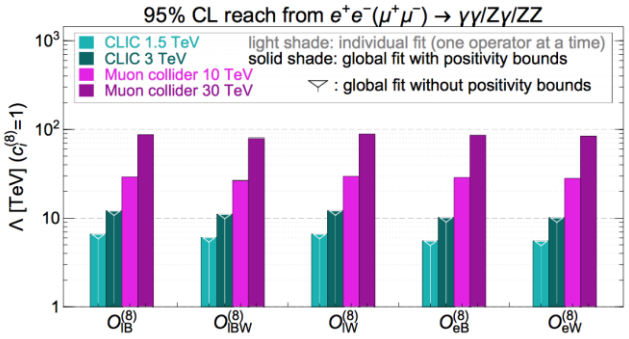


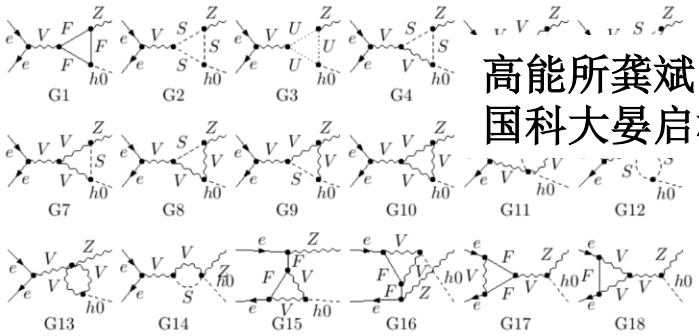
高能所 张岑 等



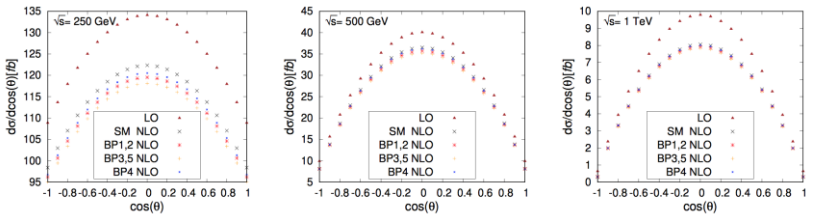
新物理与精确计算

One-loop radiative corrections to $e^+e^- \to Zh^0/H^0A^0$ in the Inert Higgs Doublet Model

Hamza Abouabid[1]*, Abdesslam Arhrib[1]†, Rachid Benbrik[2]‡, Jaouad El Falaki[3]§ Bin Gong[4,5]¶ Wenhai Xie[4,5]‖ Qi-Shu Yan[5,6]**



高能所龚斌 国科大晏启树 等



研究方向进展 ATLAS, CMS 实验

ATLAS 中国组

- 两个clusters，7家单位，中国参加LHC实验最大的研究队伍
- 现有48名教职员工，2020年新增4位，新晋青千5位

总人数200多人：

- 院士1名
- 万人计划领军人才2名
- 千人计划3名
- 杰青3名
- 优青1名
- 青千百人22名
- 地方人才4名
- 博士后26名
- 学生、工程师和技术人员若干

■ ***IHEP-NJU-THU Cluster（高能所-南大-清华联合组）***

- **Institute of High Energy Physics (高能所)**

  娄辛丑（千人A）、 Joao Costa （外专千人）、欧阳群、庄胥爱（百人）、方亚泉（青千）、朱宏博（青千） 、黄燕萍（青千） 、梁志均（百人）、史欣（青千） 、李一鸣（青千）、吕峰、单连友、徐达、刘佩莲（青千）
- **Nanjing University (南大)**

  金山（万人、杰青）、张雷（登峰B计划），陈申见、祁鸣、闵天觉
- **Tsinghua University （清华）**

  陈新（青千）

■ ***USTC-SDU-SJTU Cluster（科大-山大-交大联合组）***

- **University of Science and Technology of China (科大)**

  赵政国（院士、千人）、韩良（万人、杰青）、蒋一、刘衍文（优青）、刘建北（青千） 、彭海平（杰青、百人）、朱莹春、刘明辉、吴雨生（青千） 、孙勇杰、Rustem Ospanov、Antonio Baroncelli、徐来林（青千）、林箐（青千）
- **Shandong University (山大)**

  张学尧、马连良（青千） 、冯存峰、祝成光、李海峰（齐鲁青年学者）、李冰（齐鲁青年学者）
- **Shanghai Jiao Tong University（上海交大）， T.D. Lee Institute（李所）**

  杨海军（青千）、李亮（青千）、郭军（青千）、周宁（青千）、邬维浩（青千）
  李数（青千）、刘坤（浦江人才计划）、许金祥（青千）

ATLAS实验研究方向进展

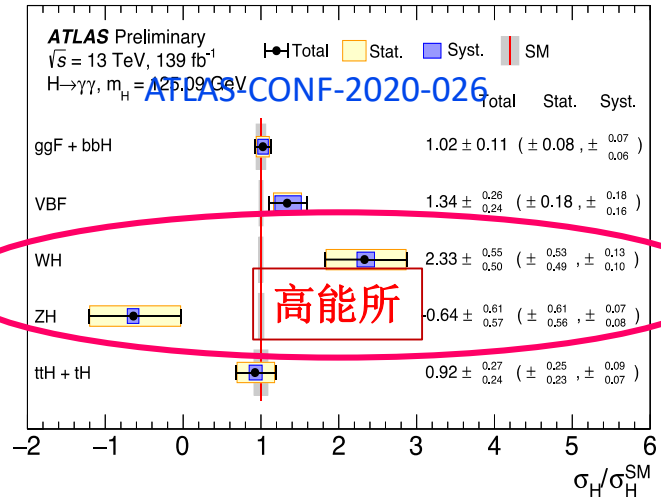
Channel	ggF	VBF	VH	ttH	Mass	CP	X-sec.	Width
γγ	★★	★★	★★	★★	★★	★★	★★	★
ZZ*(4l)	★★	★★	★★	★★	★★	★★	★★	★★
WW*(lvlv)	★★	★★	★★	★★		★★	★★	★★
ττ	★★	★★	★★	★		★★		
bb	★★		★★	★★				
Zγ	★★							
μμ	★★	★★	★★	★★				
invisible	★★	★★	★★					

希格斯物理研究： ★ ATLAS进行的分析 ★ 中国组贡献的分析

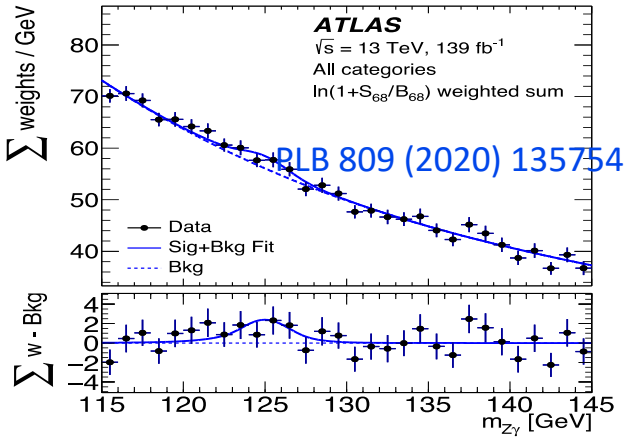
- 标准模型Higgs性质研究及相关新物理的寻找
- 标准模型物理过程的测量检验
- 新物理直接寻找：SUSY，Exotics

ATLAS实验研究进展：希格斯粒子衰变到玻色子末态

H→γγ信号强度测量

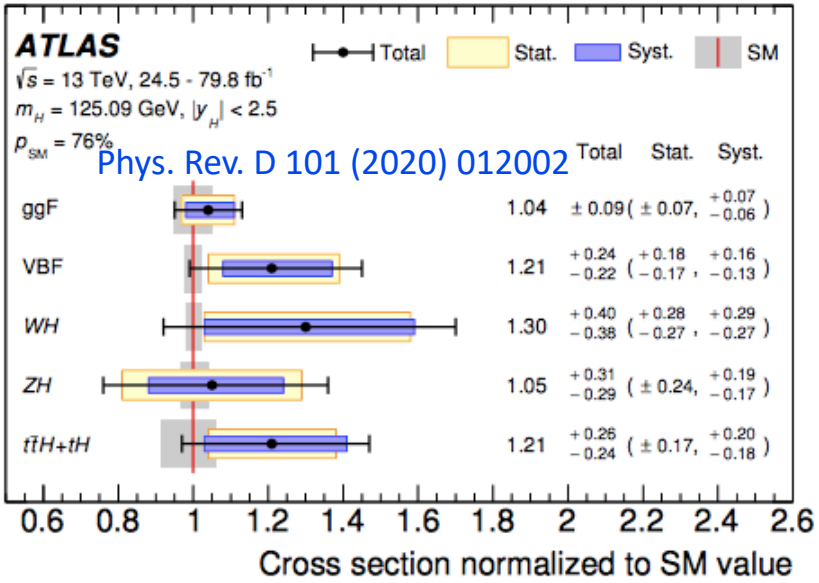


在Zγ末态中寻找Higgs和新物理



- 给出了H→Zγ最严格的束缚
- 高能所作出主导贡献

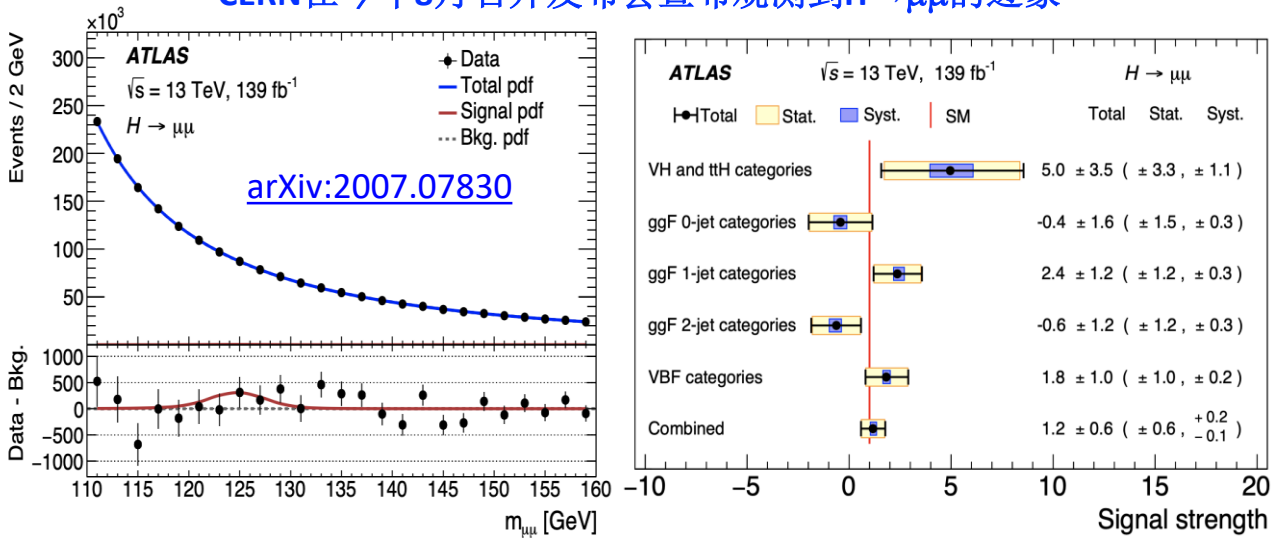
VBF H→VV首次观测



- VBF H→γγ/WW/ZZ综合信号敏感度超过6.5/5.3σ
- 高能所在最灵敏的H→γγ作出主导贡献

ATLAS实验研究进展：希格斯粒子衰变到费米子末态

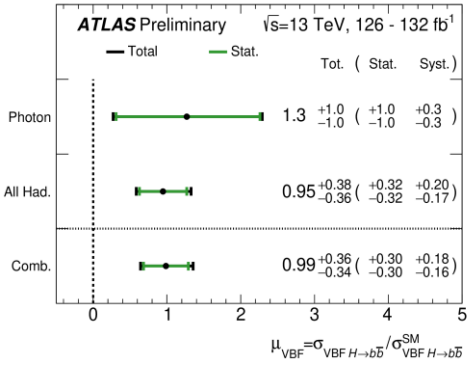
CERN在今年8月召开发布会宣布观测到H→μμ的迹象



- ATLAS信号强度的测量值为1.2±0.6，信号显著性为2.0s（预期1.7s）；CMS为3.0s（预期2.5s）
- 山大、科大（清华）作出主导（主要）贡献

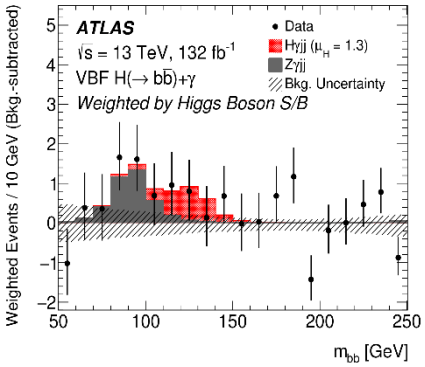
VBF H(→bb)

CERN-EP-2020-195



VBF H(→bb)+γ

arXiv:2010.13651



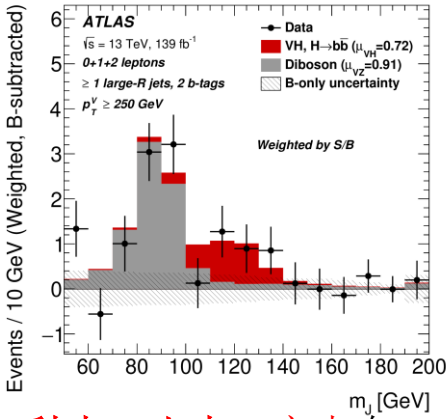
- VBF H→bb观测显著度首次达到3σ
- 高能所提出原创性课题VBF H(→bb)+γ并作出主导贡献

VH, H(→bb)

arXiv: 2007.02873

arXiv:2008.02508

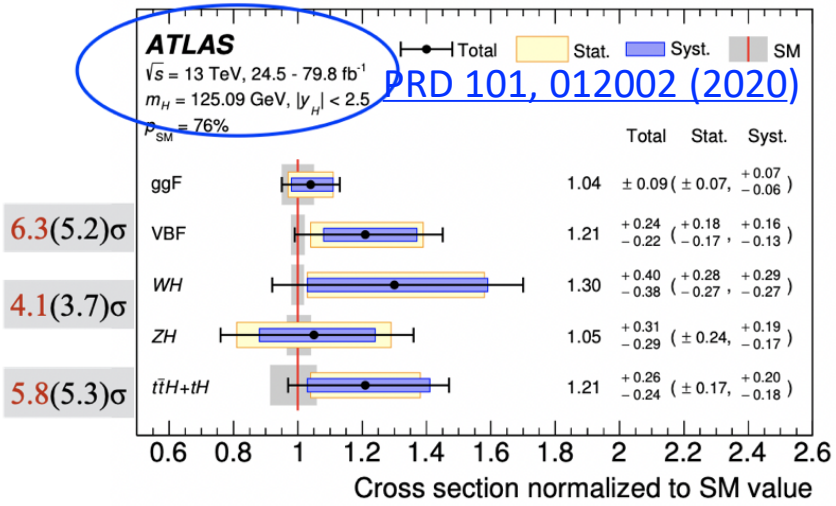
5.3 sigma

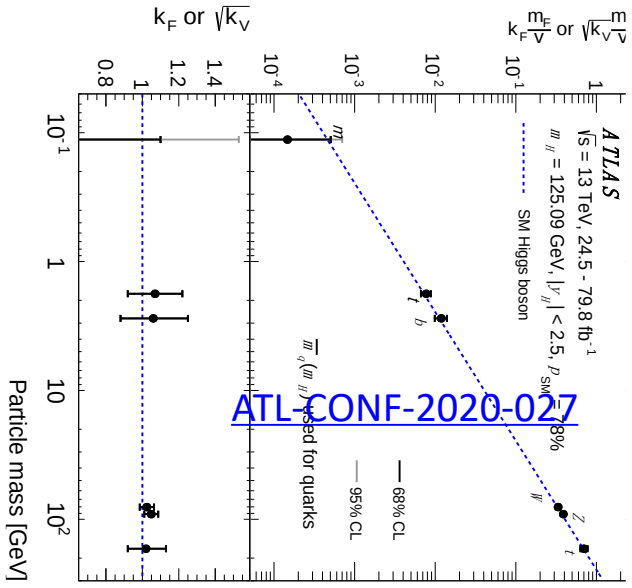


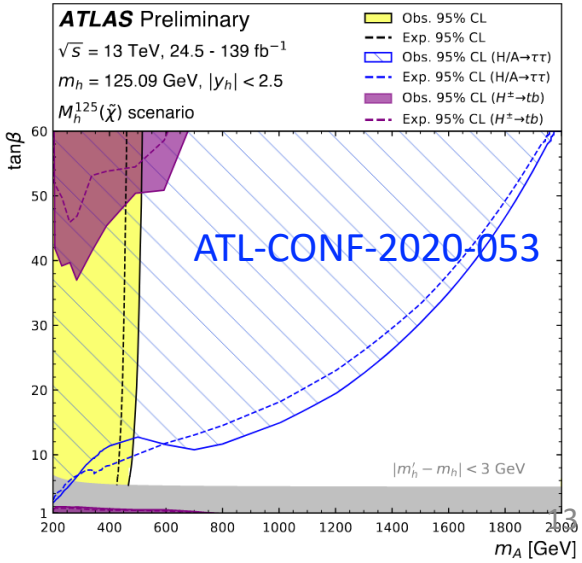
- 科大、山大、交大在VH(→bb)作出主要贡献

ATLAS实验研究进展：希格斯粒子联合测量

Analysis	Integrated luminosity (fb^{-1})
$H \to \gamma\gamma$ (including $t\bar{t}H$, $H \to \gamma\gamma$)	79.8
$H \to ZZ^* \to 4\ell$ (including $t\bar{t}H$, $H \to ZZ^* \to 4\ell$)	79.8
$H \to WW^* \to e\nu\mu\nu$	36.1
$H \to \tau\tau$	36.1
$VH, H \to b\bar{b}$	36.1
$H \to \mu\mu$	79.8
$t\bar{t}H$, $H \to b\bar{b}$ and $t\bar{t}H$ multilepton	36.1







- 全局信号强度为μ=1.13+0.09-0.08 (8%)，给出至今最精确的希格斯耦合联合测量
- ttH产生模式>5σ，VBF>6σ
- **对κ，MSSM等模型参数进行了更严格的限制**
- 高能所作出主导贡献，交大、南大作出主要贡献

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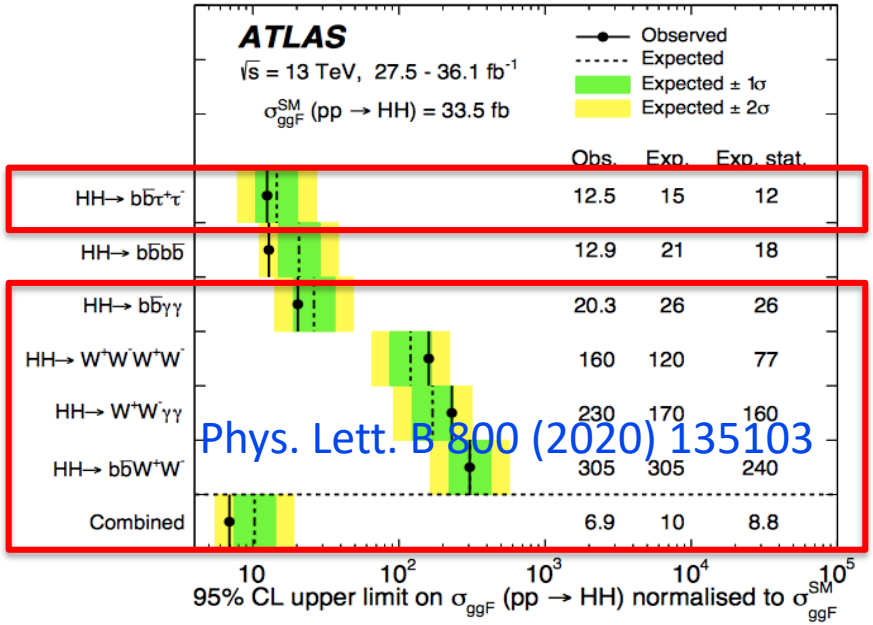
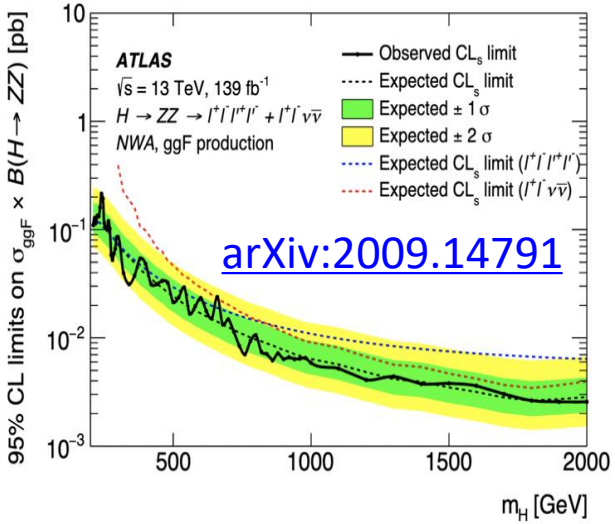
ATLAS实验研究进展：Di-Higgs测量和重Higgs粒子的寻找

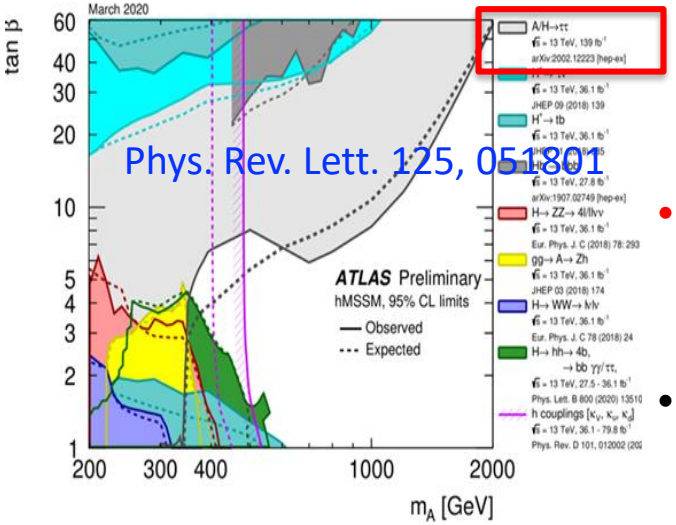


- 对di-higgs的除4b末态的所有衰变道做出主导或主要贡献，并参与所有衰变道的联合测量
- 目前36.1 fb^{-1}结果对di-Higgs 排除的～10 SM di-Higgs理论预言
- 高能所、交大作出主导/主要贡献

重希格斯衰变到ZZ



重希格斯衰变到$\tau\tau$



- 重希格斯粒子是很多新物理的重要预言之一，研究了H→ZZ/$\tau\tau$两个重要的衰变过程
- 科大(交大）在H→ZZ 主导（主要）贡献，南大在H→$\tau\tau$作出主导贡献
- 以科大为主导的(学生许含霖当analysis contact)带电的希格斯寻找，2020

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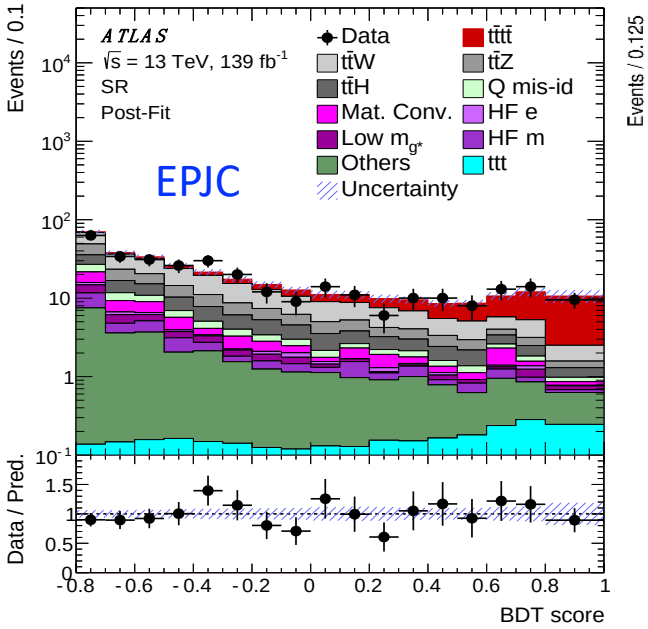
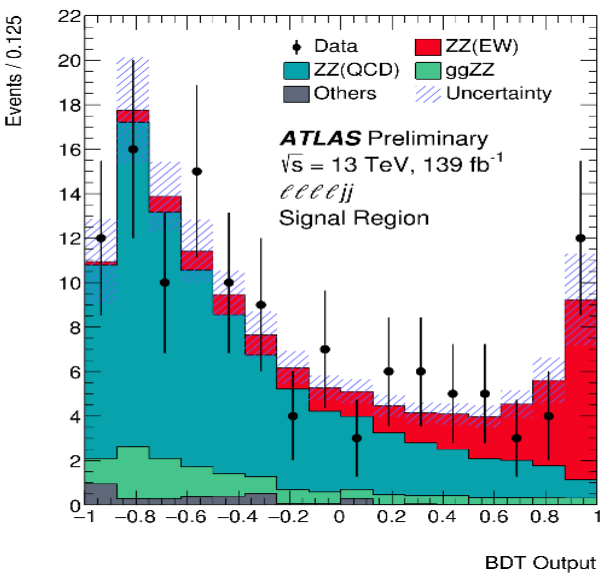
ATLAS实验研究进展：标准模型稀有过程的寻找

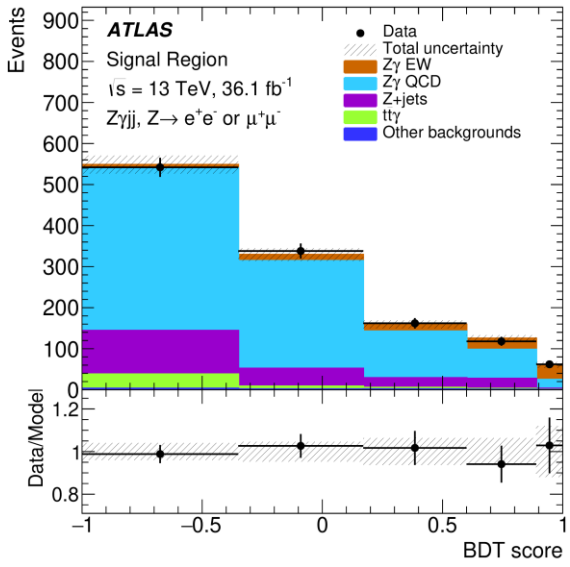
四顶夸克产生过程



矢量玻色子对ZZ散射



VBS Zγ 散射



- 首次发现四个顶夸克协同产生过程的迹象(4.3σ)。四夸克过程截面为 24+7(-6)fb，与标准模型预言基本符合
- 交大作出主要贡献

arXiv:2004.10612

- 首次发现ZZ玻色子对散射过程(5.5σ)，submitted to Nature Physics
- 科大作出主导贡献，交大作出主要贡献

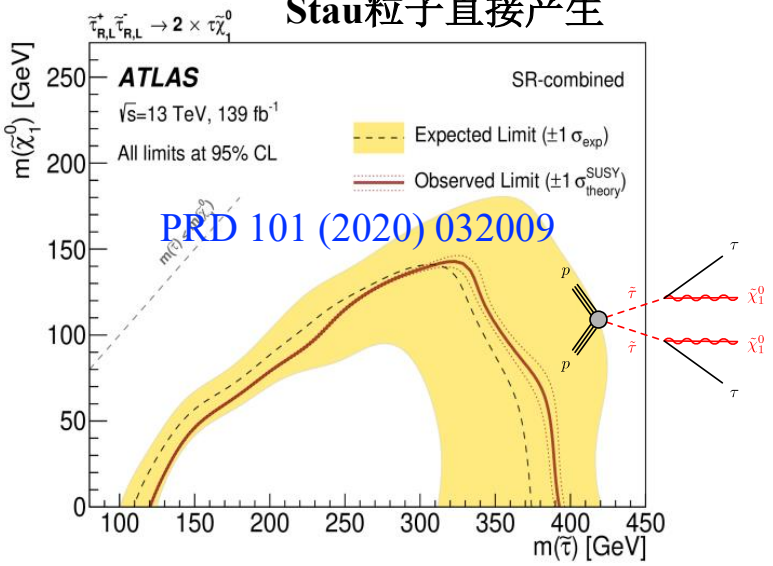
Phys. Lett. B 803 (2020) 135341

- 获得VBS Zγ散射过程在ATLAS实验中的首次显著性测量4.1σ(exp&obs)
- 交大作出主要贡献

15

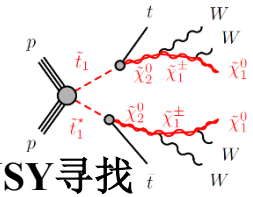
ATLAS实验研究进展：新物理：SUSY粒子的寻找

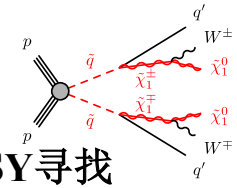
Stau粒子直接产生



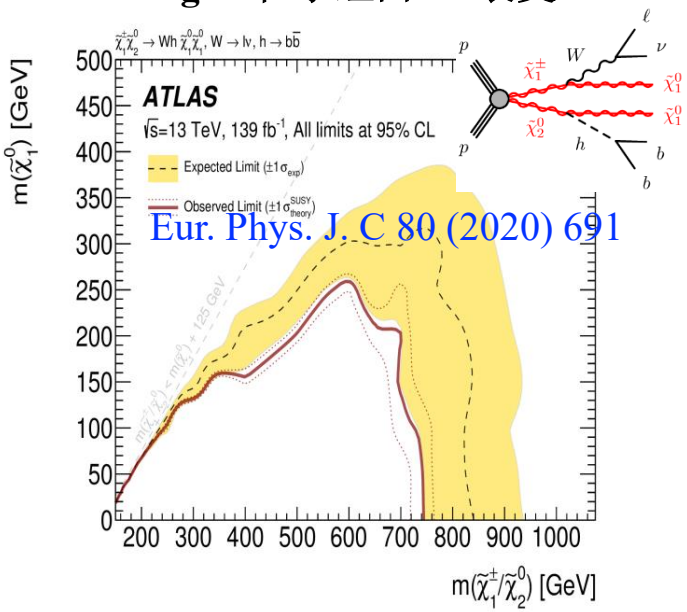
PRD 101 (2020) 032009

- 通过含轻子的黄金衰变道来广泛寻找stau，gaugino，squark和gluino粒子
- Stau coannihlation模型给出的暗物质残遗密度与宇宙观测值一致，stau粒子寻找是SUSY研究重点
- **给出了世界上最强的stau粒子排除限**
- **高能所**在上述所有课题作出主导贡献，**南大**在stau寻找作出主要贡献



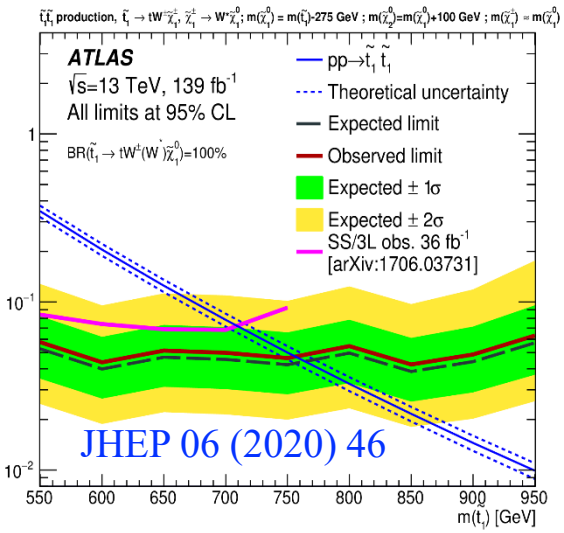


Gaugino粒子经由Wh衰变



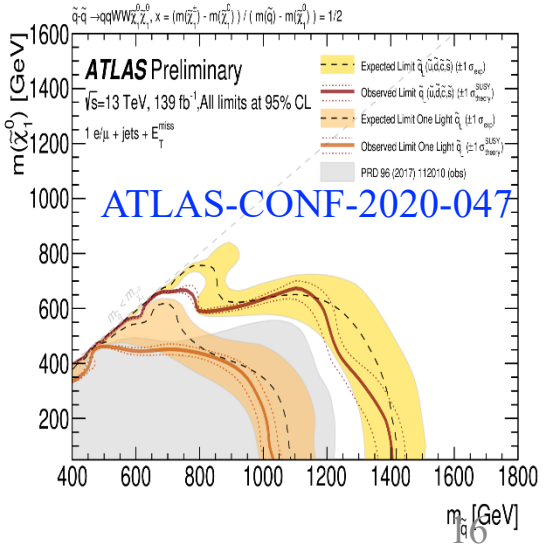
Eur. Phys. J. C 80 (2020) 691

同号两轻子末态SUSY寻找



JHEP 06 (2020) 46

单轻子末态SUSY寻找

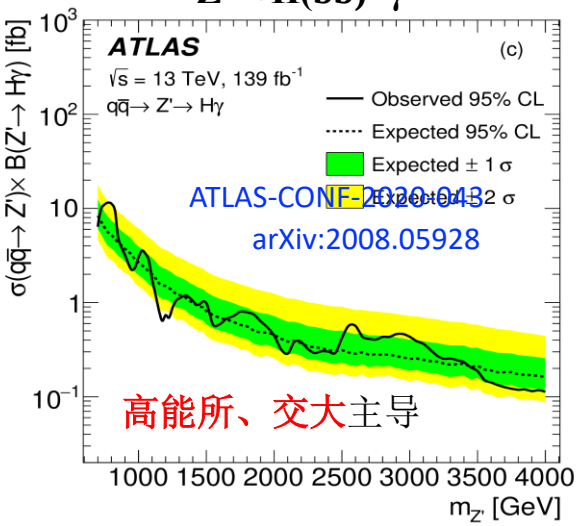


ATLAS-CONF-2020-047

16

ATLAS实验研究进展：新物理：Exotics粒子的寻找

Z'→H(bb)+γ

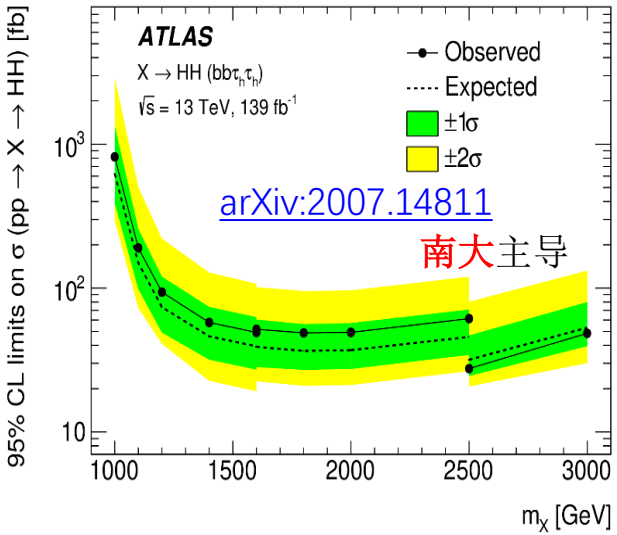


ATLAS-CONF-2020-043

arXiv:2008.05928

高能所、交大主导

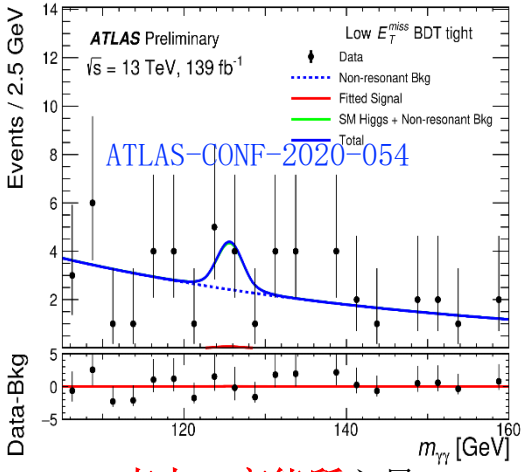
X→HH→bbττ



arXiv:2007.14811

南大主导

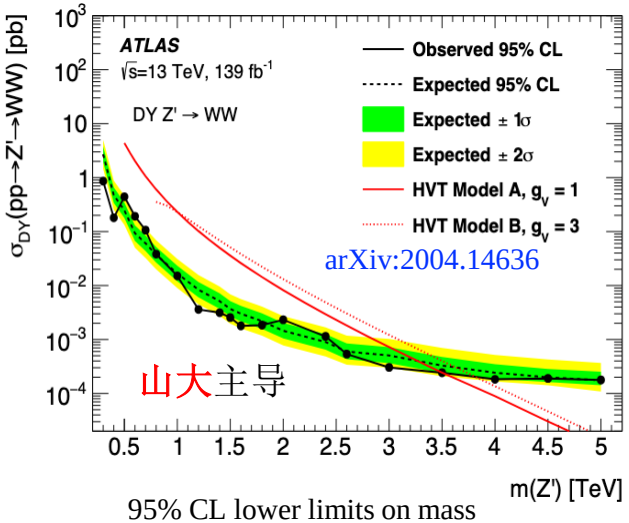
DM: Mono-Higgs to γγ



ATLAS-CONF-2020-054

南大、高能所主导

X→VV→lep+had

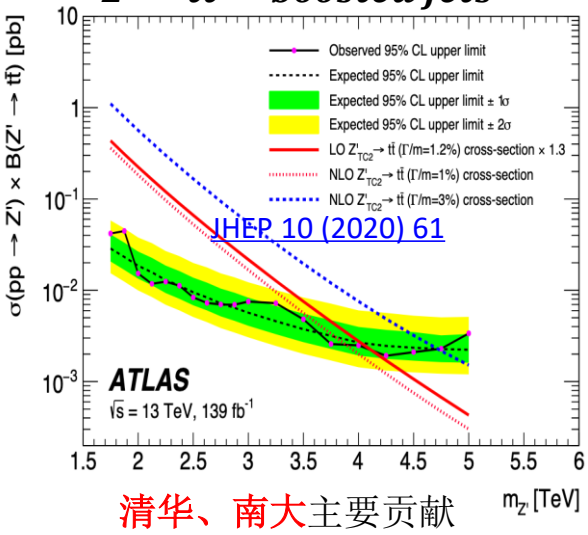


arXiv:2004.14636

山大主导

95% CL lower limits on mass

Z′ → tt̄ → boosted jets



JHEP 10 (2020) 61

清华、南大主要贡献

- 通过tt, VV, HH, Hγ, H等衰变道来广泛寻找DM, W', Z'等exotics粒子
- 给出了模型无关及相关的限制
- 中国组做出了主导或主要贡献

研究方向进展 ATLAS, CMS 实验

CMS中国组

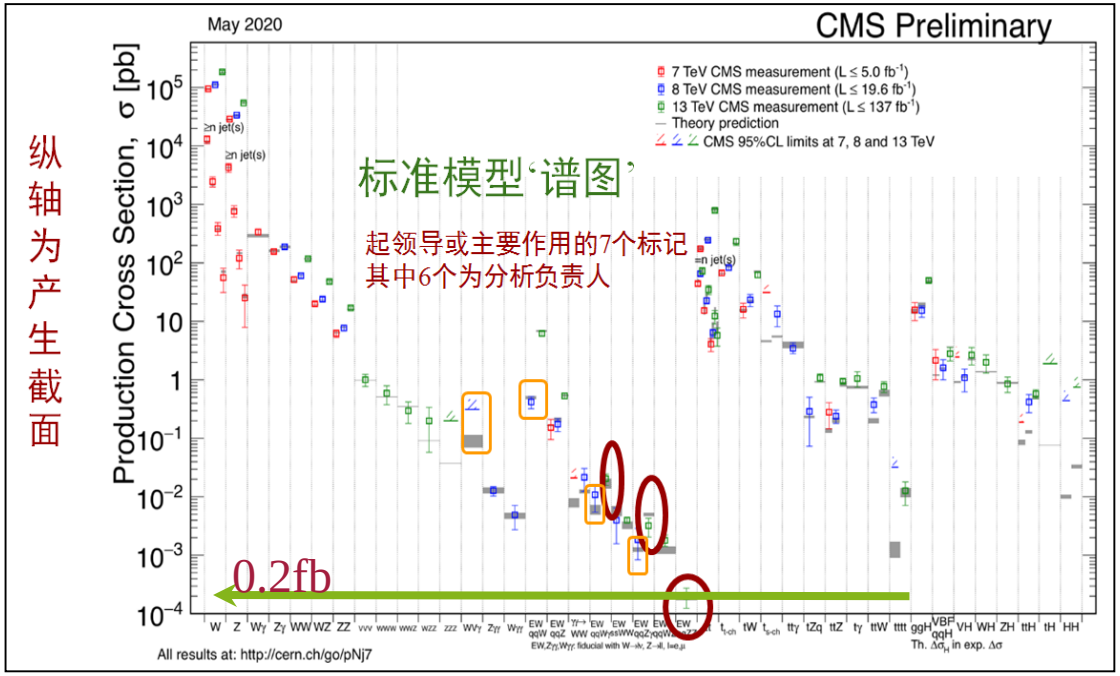
- 7个正式单位，CMS文章签名人数占CMS总签名人数2.2%
- 现有37名职工，2020年新增3位

单位	职工人数	博士后人数	学生人数	总人数	Authors
高能所	19	5	15	39	15
北大	5	4	21	30	12
北航	2	2	2	6	6
清华/南师大	5	5	24	34	7
中山大学	1	0	3	4	1
浙江大学	3	0	3	6	1
复旦大学	2	2	1	5	2
总数	37	18	69	**124**	**44**

其中：复旦大学2019年12月正式加入CMS合作组。

CMS物理研究：双玻色子散射过程测量

- 标准模型谱图内容非常丰富
- 北大组深度挖掘数据、计算潜力，发展创新技术，主导了一批极低截面的标准模型过程(0.2fb)的探测



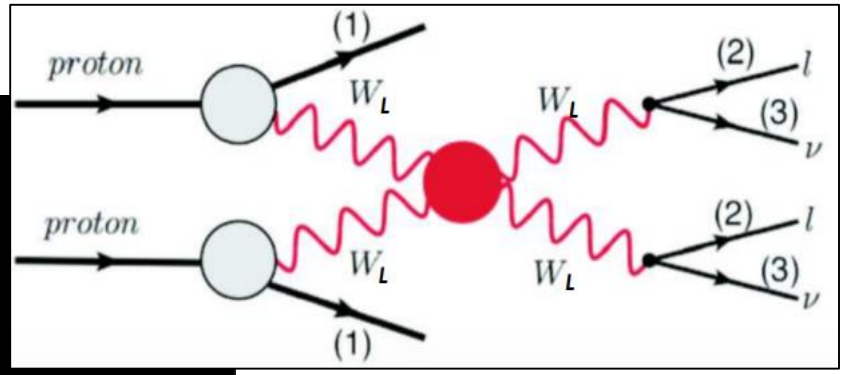
- W与光子散射在5倍标准偏差水平被观测到
  - arXiv:2008.10521
- Z与光子散射在接近5倍标准偏差水平被观测到
  - JHEP 06 (2020) 076
- ZZ玻色子散射给出4倍标准偏差的迹象
  - arXiv:2008.07013
- Inclusive Wγ产生截面的精细测量
  - CMS-PAS-SMP-19-002

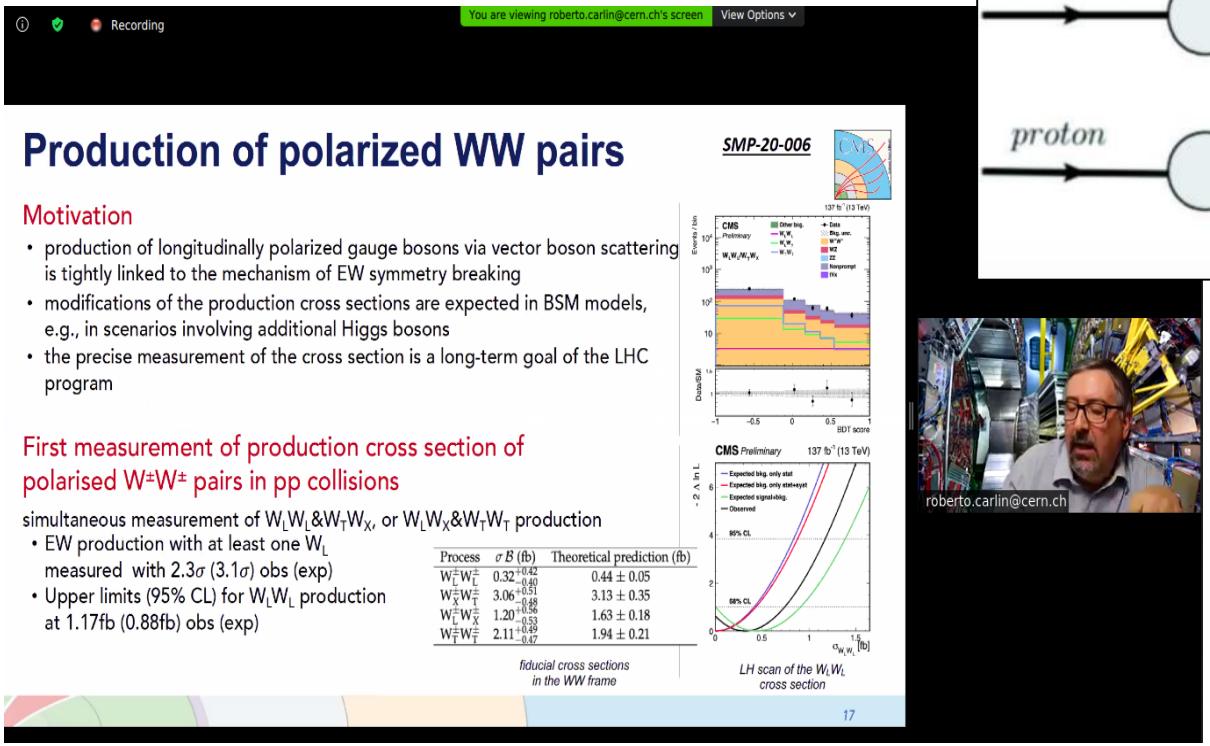
这批工作在EPS-HEP2019、LHCP2020、ICHEP2020等会议上作为亮点被多次展示

CMS新闻通稿 A boson-boson collider hiding inside proton-proton collisions

CMS物理研究：首次观测玻色子极化散射过程

- 同电荷WW玻色子极化散射，是LHC及HL-LHC最重要的物理目标之一。
- CMS近期进行了世界首次测量，北大组做了该工作审核报告。
  arXiv:2009.09429, submitted to PLB

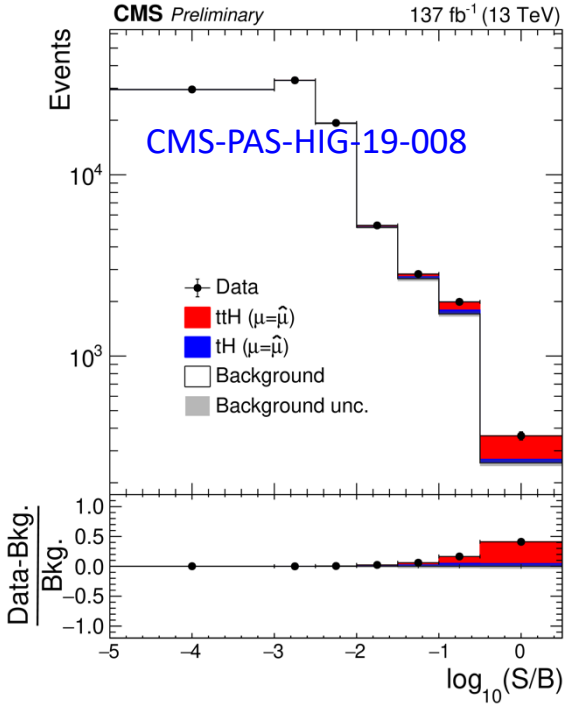




CMS发言人Roberto Carlin教授在国际高能物理2020大会上highlight该工作

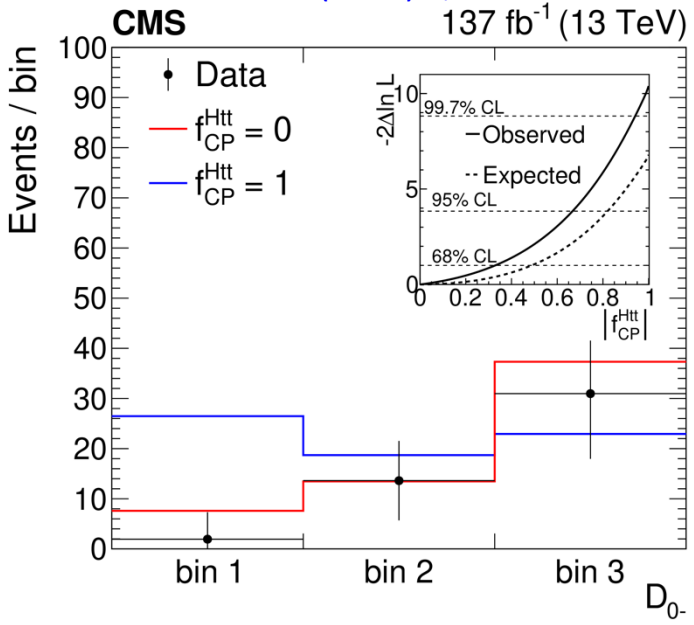
CMS物理研究：希格斯粒子的性质测量

- 深入研究希格斯粒子与顶夸克的相互作用性质
  - 在多轻子末态和双光子末态两个单衰变道分别观测到ttH产生过程
  - CMS实验组针对上述两个分析分别发表新闻通稿



- 在多轻子末态分析中首先尝试区分tH和ttH过程
- 高能所主推的DNN方案成为新的分析基准，并给予unblinding报告

PRL 125 (2020) 6, 061801

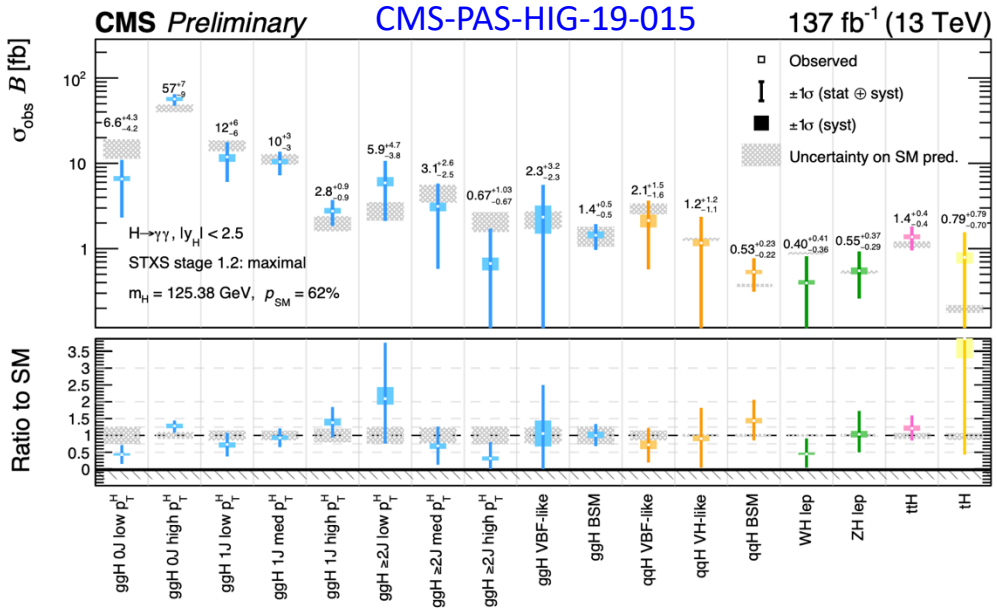


- 首次在单衰变道观测到ttH信号（显著性为6.6σ）
- 同时利用双光子清晰信号首次研究ttH过程中希格斯CP性质
- 浙大、高能所组作出主要贡献

CMS物理研究：希格斯粒子的性质测量

H→ $\gamma\gamma$产生截面测量

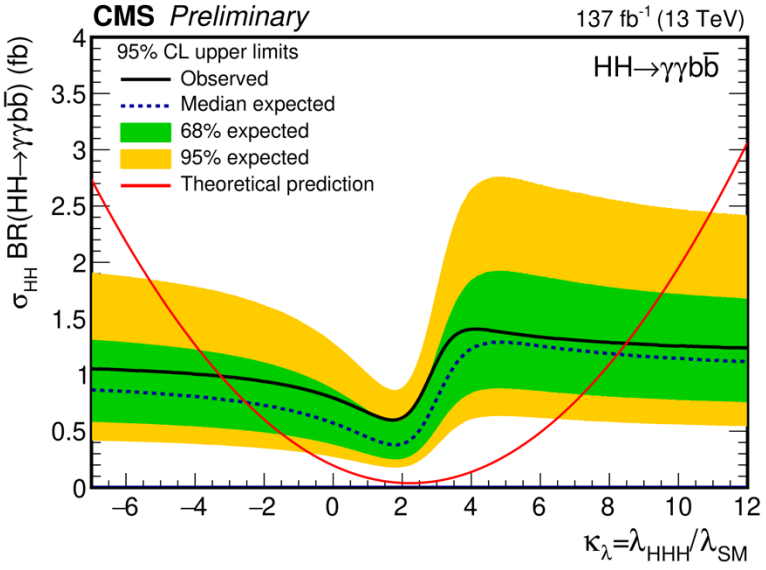
针对希格斯粒子产生及衰变的许多性质（例如横动量、赝快度、伴随产生的喷注等）进行简化模式截面测量



HH → $bb\gamma\gamma$ 测量

通过双希格斯过程研究希格斯自相互作用并获得目前最严格限制

CMS-PAS-HIG-19-008



当前对希格斯自耦合最严格的限制$\kappa_\lambda \in$[-3.3, 8.5]@95%CL

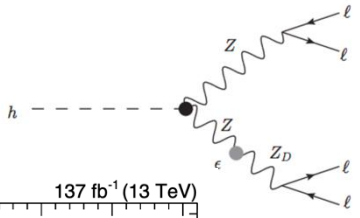
高能所在分析框架、事例触发、光子鉴别、MC模拟修正、光子能量刻度、电子的排除以及效率等方面做出贡献，是CMS内部文章的编辑之一

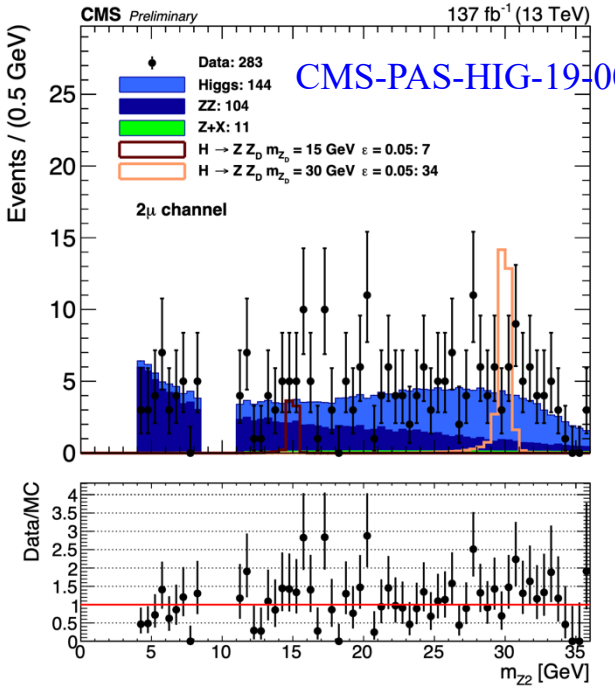
CMS物理研究：新粒子寻找

寻找暗光子/类轴子：

基于H→ZZ→4l分析寻找希格斯的奇异衰变模式

$H \rightarrow ZX$ or $H \rightarrow XX$



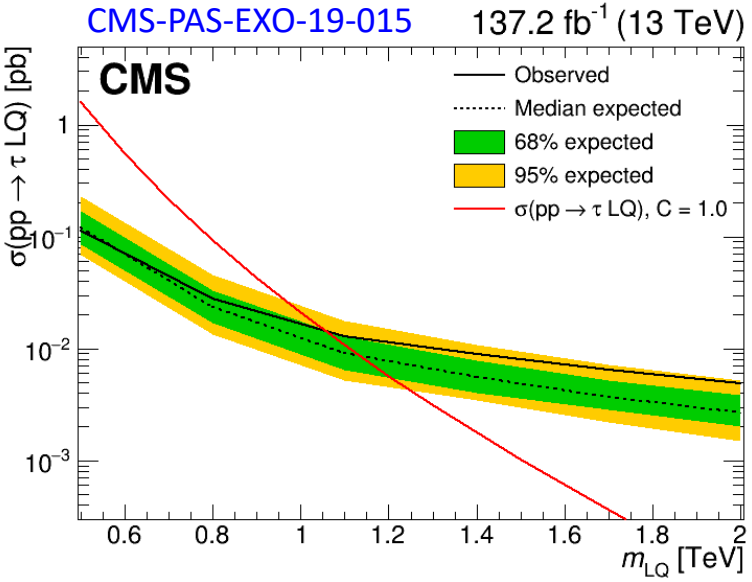


CMS-PAS-HIG-19-007

高能所、北航

轻子夸克：

高能所提出并主导了在全新的顶夸克+陶子+中微子末态利用单个产生和对产生模式寻找轻子夸克



给出了目前LQ产生截面的最严格的上限

未来设施、前沿

- CEPC 高能环形正负电子对撞机
- HL-LHC 高亮度大型强子对撞机
- ILC 国际直线加速器

Confirmation of CEPC Performance with Errors

CEPC CDR Parameters

	Higgs	*W*	*Z (3T)*	*Z (2T)*
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	242 (0.68μs)	1524 (0.21μs)	12000 (25ns+10%gap)	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	30	30	16.5	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^*/β_y^* (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	1.35	0.4	0.23	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.1	0.05	0.023	
Lifetime _simulation (min)	100			
Lifetime (hour)	0.67	1.4	4.0	2.1
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP L ($10^{34}cm^{-2}s^{-1}$)	2.93	10.1	16.6	32.1

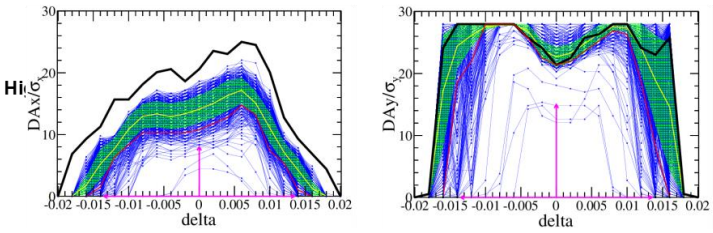
CEPC CDR Lattice DA with Errors

Achieved DA (with errors)@ Higgs: 10σx/21σy/0.00 (on momentum), 2σx/9σy/0.0135 (off momentum)

Design DA goal (with errors)@Higgs: 8σx/15σy/0.00 (on momentum), 1σx/1σy/0.0135 (off momentum)

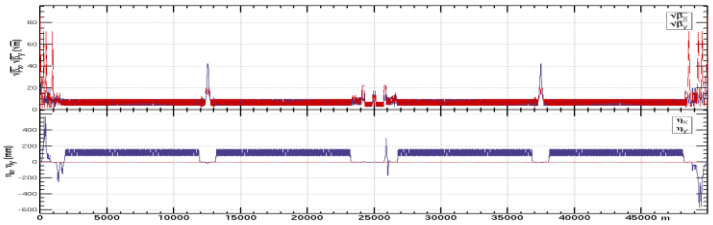
Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.1	0.01%
Arc Quadrupole	0.10	0.10	0.1	0.02%
IR Quadrupole	0.05	0.05	0.05	
Sextupole	0.10	0.10	0.1	

CDR lattice design with errors reached the DA design goal



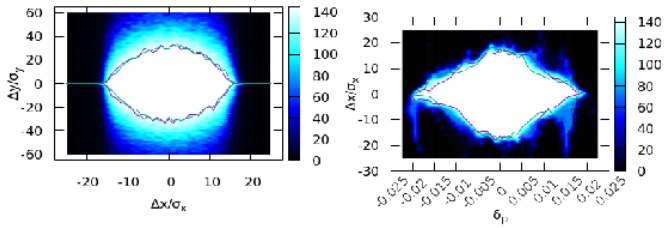
CEPC High Luminosity Parameter after CDR

	Higgs (high_lum.)	*Z (high_lum.)*
Number of IPs	2	2
Beam energy (GeV)	120	45.5
Circumference (km)	100	100
Synchrotron radiation loss/turn (GeV)	1.8	0.036
Crossing angle at IP (mrad)	16.5	16.5
Piwinski angle	4.87	18.0
Number of particles/bunch N_e (10^{10})	16.3	16.1
Bunch number (bunch spacing)	214 (0.7us)	10870 (27ns)
Beam current (mA)	16.8	841.0
Synchrotron radiation power /beam (MW)	30	**30**
Bending radius (km)	10.2	10.7
Momentum compact (10^{-5})	7.34	2.23
β function at IP β_x^* / β_y^* (m)	0.33/0.001	0.15/0.001
Emittance e_x/e_y (nm)	0.68/0.0014	0.52/0.0016
Beam size at IP σ_x/σ_y (μm)	15.0/0.037	8.8/0.04
Beam-beam parameters ξ_{sx}/ξ_{sy}	0.018/0.115	0.0048/0.129
RF voltage V_{RF} (GV)	2.27	0.13
RF frequency f_{RF} (MHz)	650	650
Natural bunch length σ_z (mm)	2.25	2.93
Bunch length σ_z (mm)	4.42	9.6
Energy spread (%)	0.19	0.12
Energy acceptance requirement (%)	1.7	1.4
Energy acceptance by RF (%)	2.5	1.5
Beamstruhlung lifetime /quantum lifetime (min)	41	-
Lifetime (hour)	0.35	1.8
Luminosity/IP L (10^{34}cm^{-2}s^{-1})	**5.0**	**101.1**

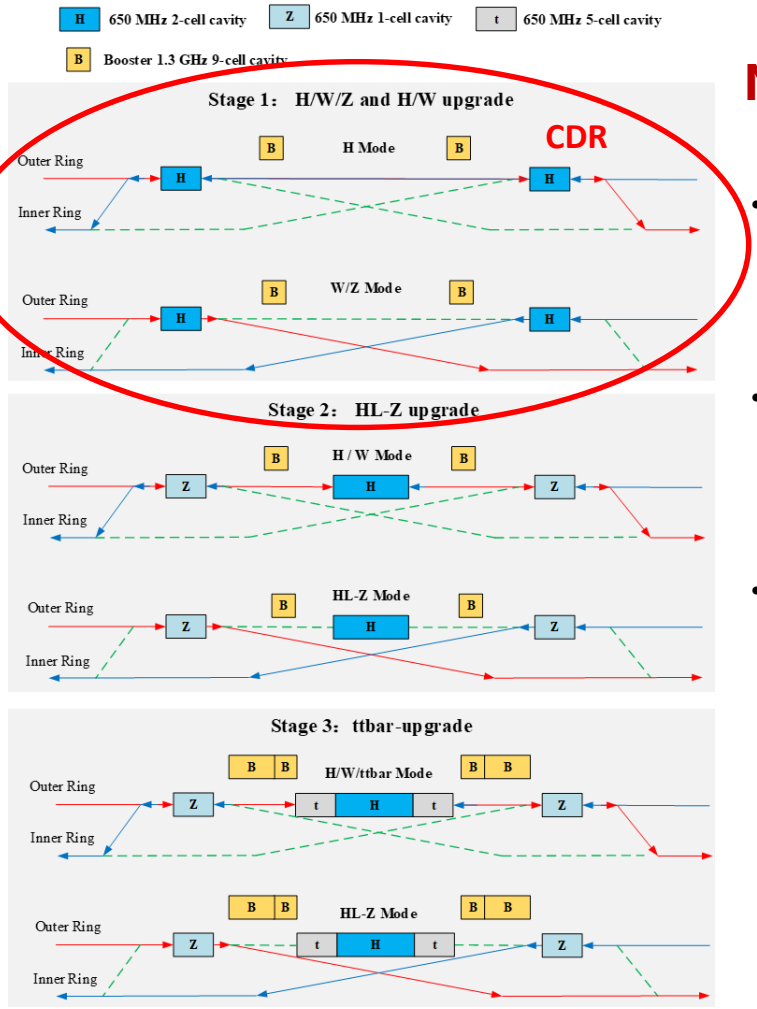


Goal (w/ error): $8\sigma_x \times 15\sigma_y \times 1.7\%$

Achieved (w/o error): $16\sigma_x \times 32\sigma_y \times 1.9\%$



* High luminosity Z's lattice is same as Higgs CDR lattice. but high luminosity Higgs has a new lattice than that of CDR



New RF Staging & By-pass Scheme for CEPC

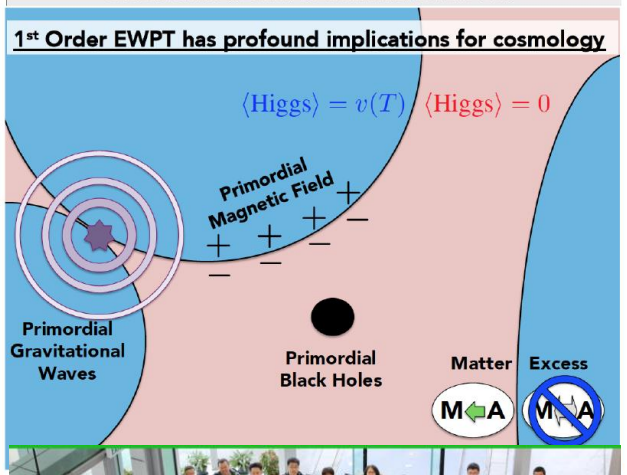
- **Stage 1 (H/W run for 8 years):** Keep CDR RF layout for H(HL-H)/W and 50 MW upgrade. Common cavities for H. Separate cavities for W/Z. Z initial operation for energy calibration and could reach CDR luminosity. **Minimize phase 1 cost and hold Higgs priority**.
- **Stage 2 (HL-Z upgrade)**: Move Higgs cavities to center and add high current Z cavities. **By-pass low current H cavities**. International sharing (modules and RF sources): Collider + 130 MV 650 MHz high current cryomodules.
- **Stage 3 (ttbar upgrade):** add ttbar Collider and Booster cavities. International sharing (modules and RF sources): Collider + 7 GV 650 MHz 5-cell cavity. Booster + 6 GV 1.3 GHz 9-cell cavity. Both low current, high gradient and high Q, Nb_3Sn etc. 4.2 K?

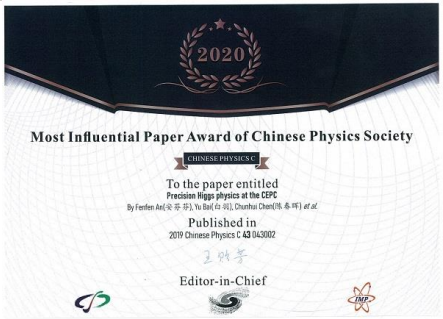
Unleash full potential of CEPC with flexible operation. **Seamless mode switching** with unrestricted performance at each energy until AC power limit. **Stepwise cost, technology and international involvement with low risk.**

CEPC物理研究

- 惟象-模拟研究进展显著
  - SMEFT
    - Zgamma differential measurements (H. He, etc)
  - Higgs 物理
    - Higgs -> invisible (Y. Tan, etc, CPC)
    - Higgs -> bb, cc, gg with llH channel (Y. Bai, etc, CPC)
    - Higgs -> tautau (D. Yu, etc, EPJC)
  - EW
    - W mass measurement (P.Shen, etc, EPJC）
  - Flavor
    - Bc -> tauv (T. Zhen, etc, CPC)

  …
- 针对EWPT等热点课题举行了专题研讨会
- 和香港IAS高能物理工作月、Snowmass LoI等研究有机结合



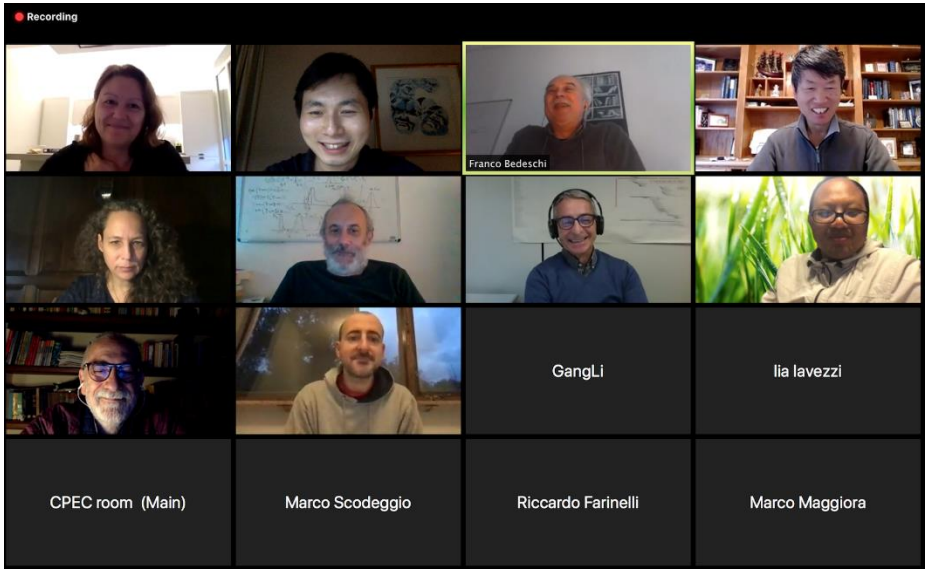


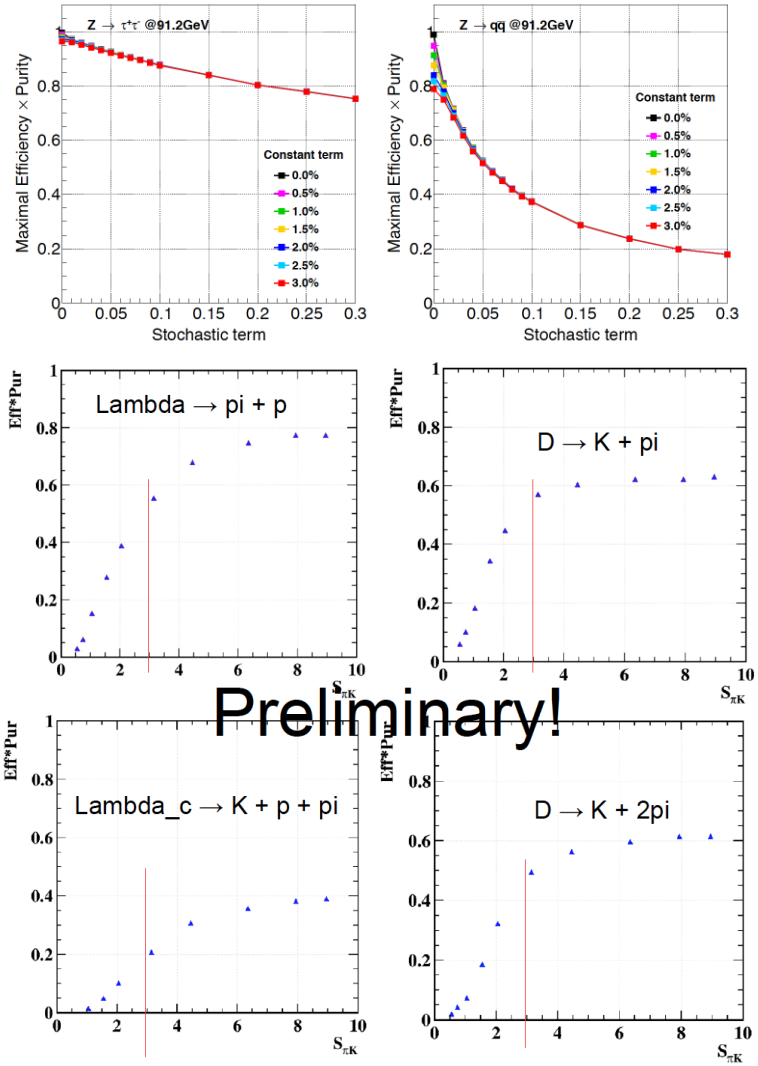
CEPC物理研究团队《**Precision Higgs Physics at CEPC**》文章获得中国物理学会“2020年度最有影响论文奖”

Chinese Physics C, Vol. 43, NO. 4 (2019), 043002

CEPC物理研究

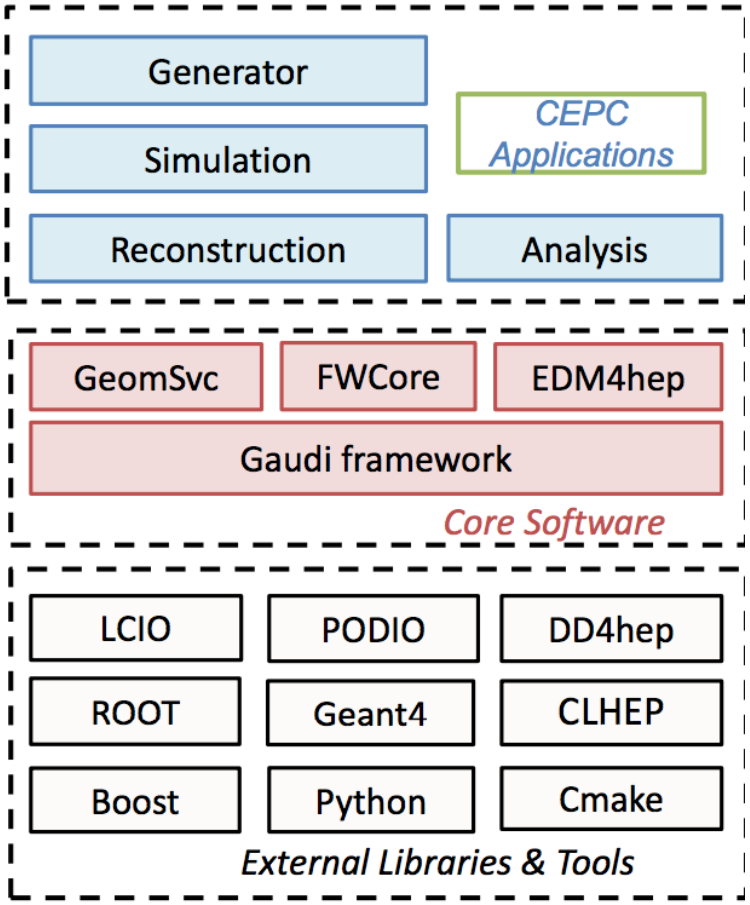
- 针对CEPC上的物理测量、特别是味物理测量，重新审视了探测器的物理需求：
  - 强调了粒子鉴别（dEdx）性能（要求pion-kaon 分离性能好于3σ）、
  - 量化了电磁量能器能量分辨率对Pi0的重建性能影响。
  - 对c-tagging性能提出了新的需求
- 于CEPC工作会议期间进行了专题讨论。





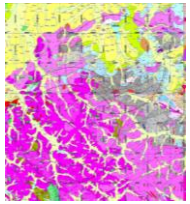
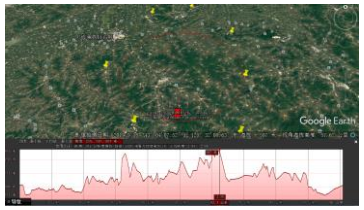
CEPC Software

- The CEPC software (CEPCSW)
  - encompasses core software and CEPC applications for simulation, reconstruction and analysis which were built on the top of external libraries
  - is fully integrated with the Key4hep, a turnkey software stack developed for the future experiments i.e. CEPC, FCC, ClIC and ILC etc.
- Core software
  - Gaudi was employed as the underlying framework which defines interfaces to all software components and controls their execution.
  - FWCore was used to manage event data objects defined by EDM4hep. Both FWCore and EDM4hep are Key4hep packages.
  - DD4hep-based geometry service was implemented to provide a unified way to access detector geometry data.



- 围绕未来对撞机在软件/计算方面的共性需求，CEPC团队和高能所积极参加了未来软件框架的国际合作，推动CEPC软件框架的发展。

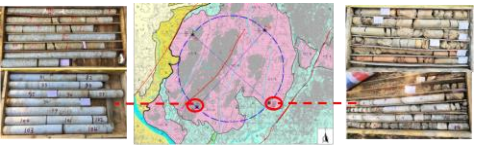
CEPC Site Selection Status

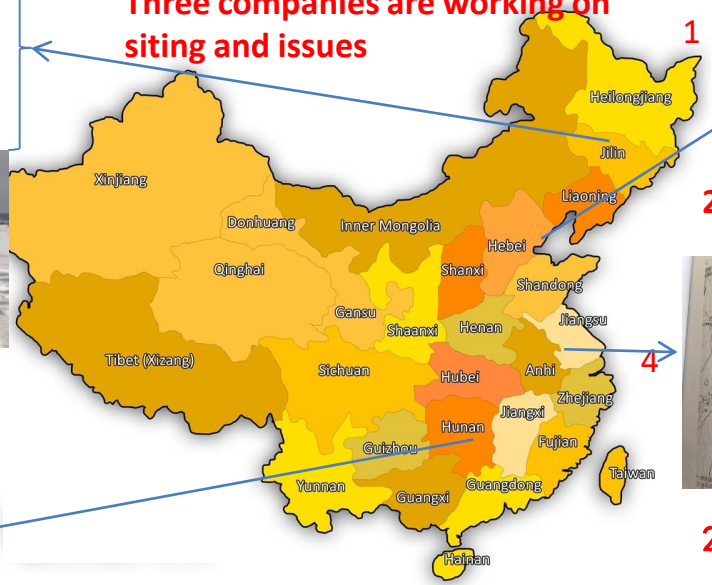



5

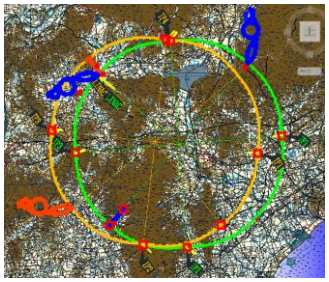
Three companies are working on siting and issues

2019.12月8-11 and 2020.1.8-10 Chuangchun sitings update



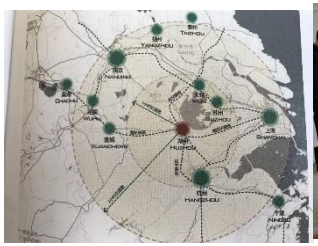


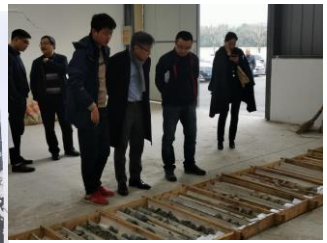
1



2020.9.14-18 Qinhuangdao updated

4





2019.12.16-17 Huzhou siting update

6

2019.08.19-20 Changsha siting update

1) Qinhuangdao, Hebei Province（Completed in 2014）
2) Huangling, Shanxi Province（Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Huzhou, Zhejiang Province (Started in March 2018)
5) Chuangchun, Jilin Province (Started in May 2018)
6) Changsha, Hunan Province (Started in Dec. 2018)

The red color sites are more focused with strong local government support

CIPC and CEPC Promotion Fund

Established in Nov. 7 , 2017

Task forces for CEPC and SppC R&D: Institutions such as IHEP +CIPC (>70 companies)

Now:

-Huanghe Company,Huadong Engineering Cooperation Company,and Zhongnan Company on CEPC civil engineering design, site selection, implementation...

-Shenyang Huiyu Company on CEPC MDIRVC design

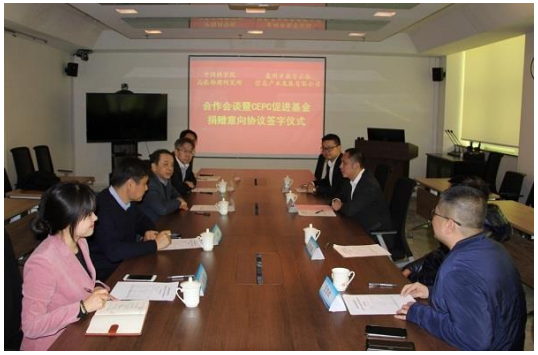
-Keye Compant on CEPC magntes desgins and SC Quadupole, DR cavity, detector hall...

-.Wuhan University:Alignmnent,

-Kuanshan Guoli on CEPC 650MHz high efficiency klystron

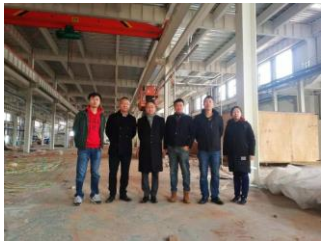
-Huadong Engineering Cooperation Company,on CEPC alignement and installation logistics...

-Beijing Pudaditai company: on Alignment and instatation



2020.1.2

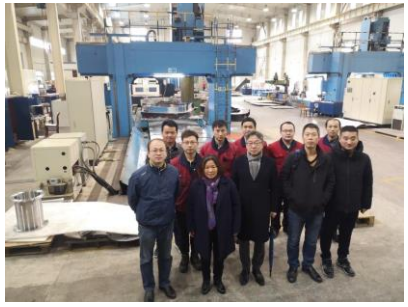
Fujian Digital Valey on information signed CEPC Propmotion Fund Contribution with IHEP



2019.12.25-26,Nanchong, Sichuan Jiutian Vacuum company

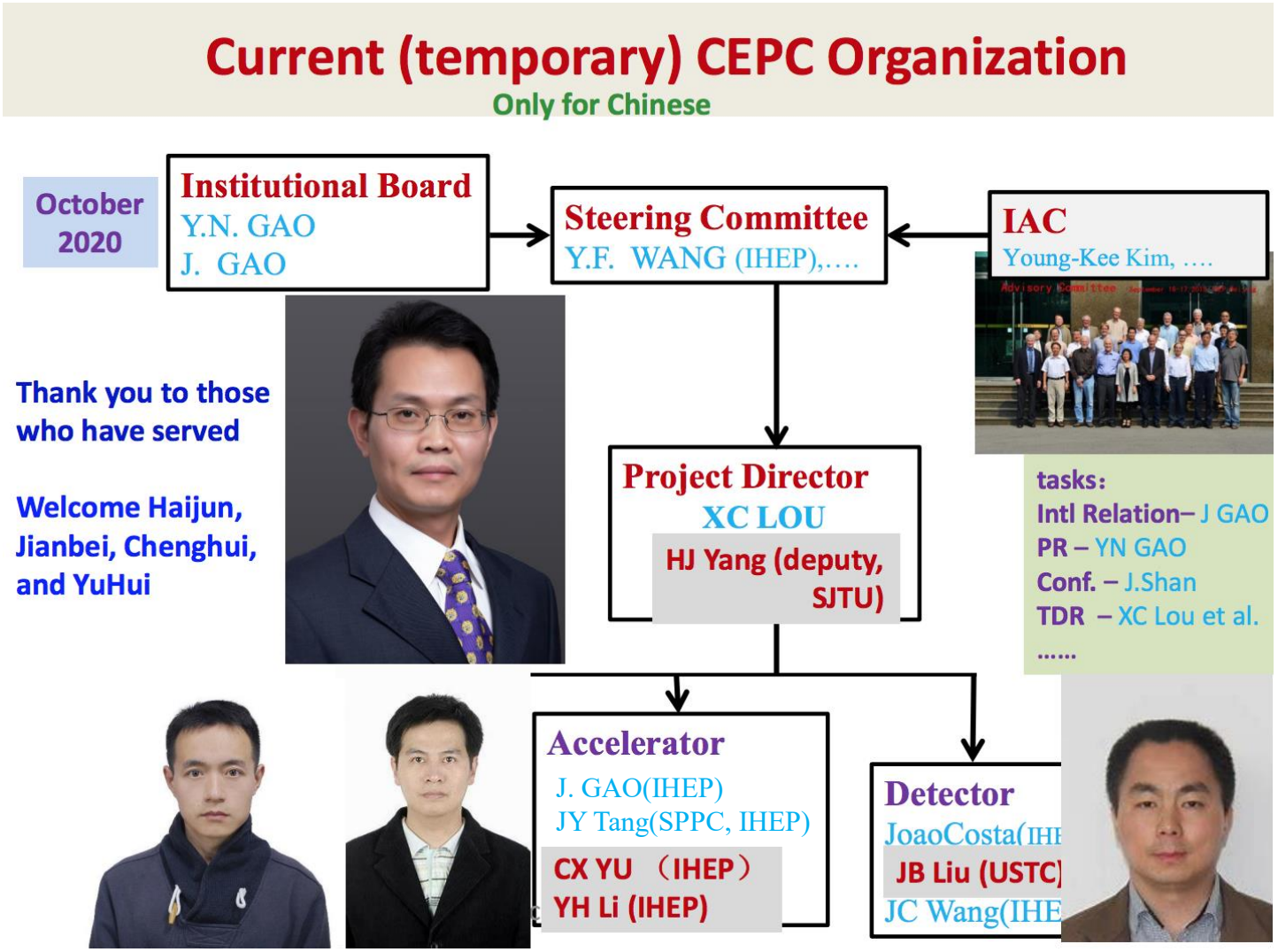
2020.6.5

Hefei Keye and Beijing Puda Ditai Company signed CEPC Propmotion Fund Contribution with IHEP



2019.1218-19 visit Keye Company

CEPC 组织-人员变动



积极进行CEPC相关的人才引进

高能量加速器规划

赵政国副主任受基金委和科学院委托负责组织“中国学科及前沿领域发展战略研究（2021-2035）”中的“中国基于加速器的粒子物理发展战略规划”撰写，同时赵政国副主任受高能物理分会委托负责组织“中国高能物理发展战略研讨”。高能分会筹备会讨论撰写“中国基于加速器的粒子物理发展战略”的相关事宜，最终为我国基于加速器的高能物理发展提供一个中长期战略规划路线图。

高能量前沿工作组

牵头人 - 娄辛丑，金山
科学秘书 - 阮曼奇
顾问兼审稿人 - 王连涛（理论，芝加哥大学），钱剑明（实验，密西根大学），高杰（加速器，高能所），高原宁（实验，北京大学）

- 科学
  - Higgs：陈新（清华），方亚泉（高能所），陈明水（高能所）
  - 电弱 +Top：李强（北大），张华桥（高能所），梁志均（高能所）
  - BSM：庄胥爱（高能所），李田军（理论所），武雷（南师大）
  - 重味 + 强子：王建春（高能所），沈成平（复旦），杨振伟（清华）
  - QCD：朱华星（浙大），高俊（上交），李钊（高能所）
- 技术
  - 加速器：秦庆（高能所），张源（高能所），徐庆金（高能所）
  - 探测仪器：杨海军（上交），刘建北（科大），朱宏博（高能所），王萌（山大）
  - 电子学 + 数据获取：魏微（高能所），赵雷（科大）
  - 计算 + 软件：李卫东（高能所），黄性涛（山大）
- 其他
  - 人才培育：娄辛丑
  - 经费支持、渠道及规模：金山
  - 大加速器及社会 - 文化和经济效应：阮曼奇

- 由多个实验、多个单位的一线科研人员组成
- 追求基础尽可能广的最大共识。在未来一年，通过广泛的讨论和工作会议推动战略规划撰写

Editors：陈明水，李强

中国基于加速器的粒子物理发展战略研究

第一章：中国基于加速器的粒子物理领域的科学意义和战略价值
（整体要求：一是本领域能够解决的我国经济社会发展及国家安全领域中的关键科学问题和关键技术问题，尤其是对该领域能够解决的制约我国产业结构升级的关键技术问题、制约我国提高国际竞争力的卡脖子技术问题等所起到的作用进行具体、深入论证。二是本领域对于国家科学事业本身的意义和价值。重点回答该领域对于带动相关科学技术领域发展的贡献等问题。）

一、中国基于加速器的粒子物理领域的科学意义（分高能量前沿和高亮度前沿阐述）

二、中国基于加速器的粒子物理领域的战略价值（分高能量前沿和高亮度前沿阐述）

Editors：刘建北，魏微，阮曼奇，张源

第三章：中国基于加速器的粒子物理领域的关键科学问题，关键技术问题与发展方向
（整体要求：一是从前沿领域发展态势、国家战略需求以及如何应对国际竞争的角度，前瞻未来15年、特别是未来5年领域的发展趋势，提出未来5~15年前沿领域的关键科学问题和关键技术问题、发展思路、发展目标、优先发展领域或重要研究方向。二是结合上述角度，对以上优先发展领域的战略重要性进行研判并排序，并对其理由进行充分阐述。）

一、高能量前沿

二、高亮度前沿

Editors：高杰，阮曼奇

第二章：中国基于加速器的粒子物理领域的现状及其形成
（整体要求：一是对该前沿领域的形成进行回溯，从该前沿领域发展历程出发，回答是哪些内生性的动力和外在性的需求促成了该前沿领域的出现？由哪些关键科学发现、科学问题、技术问题或者哪些人物推动了该前沿领域的出现、使该领域成为前沿研究领域？二是对本前沿领域的研究现状进行综合回顾，从主要研究成果、专利、期刊著述、研究学会、研究人员的学科背景、人才培养、研究组织形式、经费与投入、资助管理模式等方面，系形成关于本领域发展现状的综合性认识。三是立足国际，对于本前沿领域在国际上的位置和竞争力进行综合评估，包括本前沿领域在国际上的发展状况。本领域在国际上的地位和发展态势等。）

一、中国基于加速器的粒子物理领域的形成（分高能量前沿和高亮度前沿阐述）

二、中国基于加速器的粒子物理领域的现状（分高能量前沿和高亮度前沿阐述）

Editors：金山，秦庆，杨海军

第四章：围绕中国基于加速器的粒子物理领域发展的相关政策建议

一 中国基于加速器的粒子物理领域发展的政策建议

（针对关键科学问题、关键技术问题和优先发展领域的表述，提出前沿领域发展的资助策略等政策建议。）

一 中国基于加速器的粒子物理领域资助战略实现的配套措施

（从能力建设、队伍建设、制度建设、法规建设、环境建设、国际合作政策、组织保障等方面出发，提出有利于前沿领域资助战略实现的配套措施。）

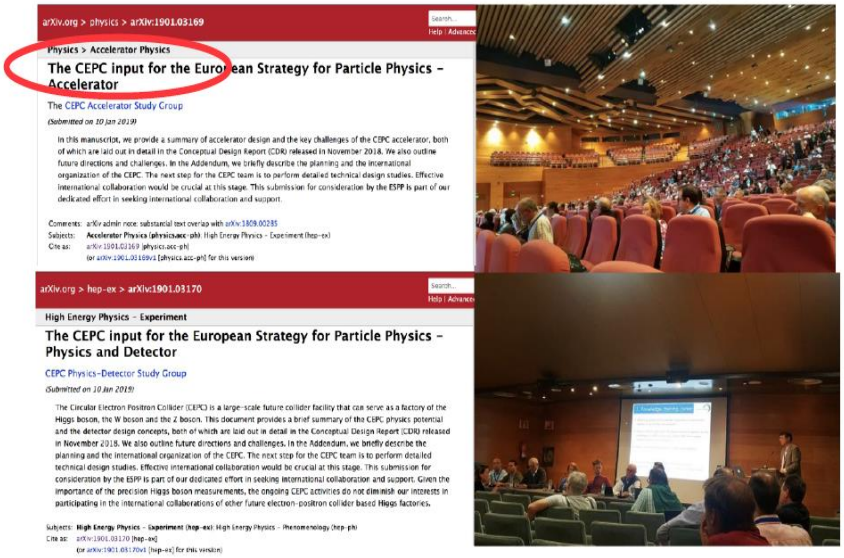
Editors：娄辛丑，朱宏博

第五章：中国基于加速器的粒子物理领域发展路线图

（总结前面四章内容，对我国基于加速器的粒子物理领域发展给出一个明晰的路线图。）

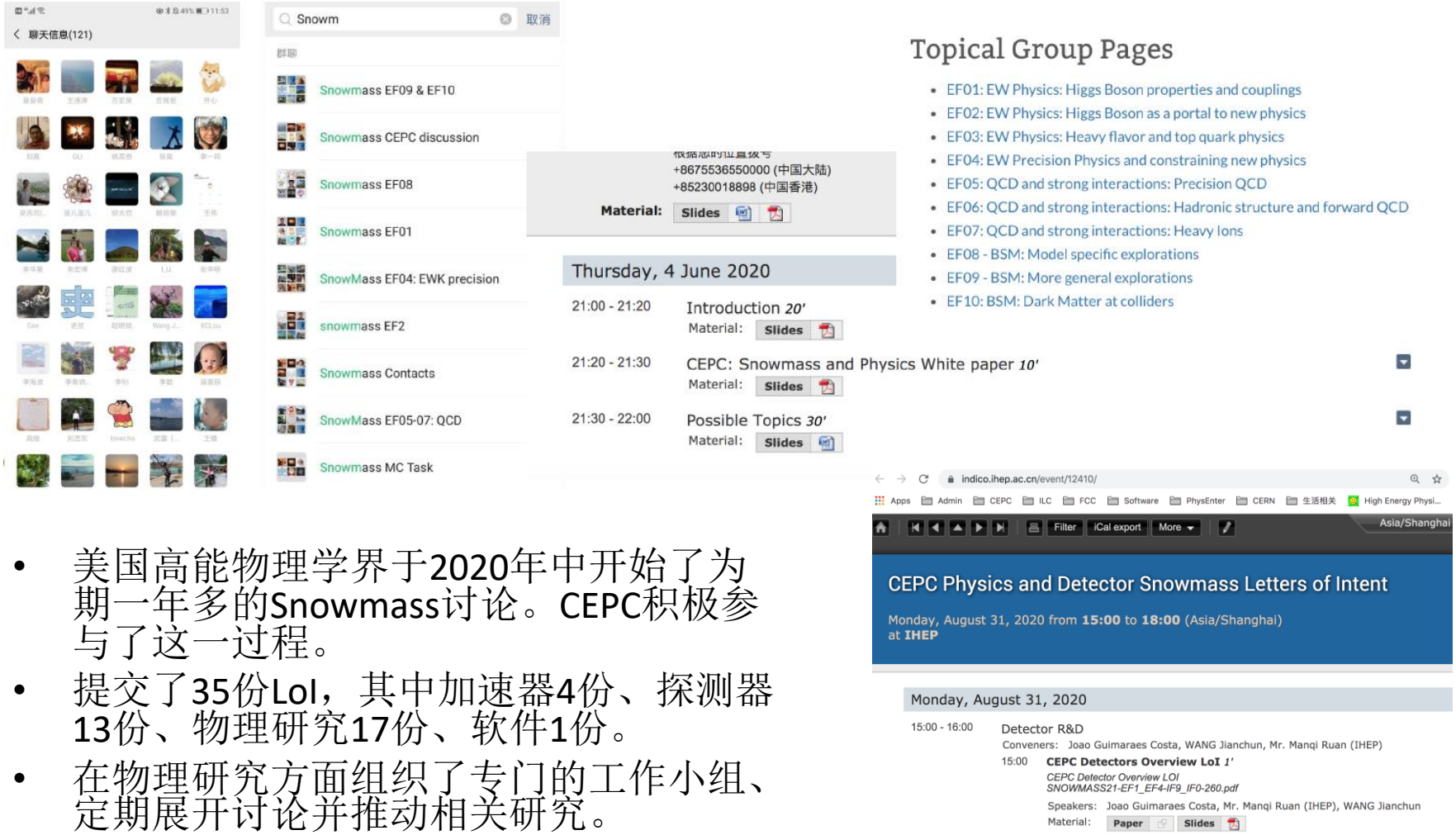
- 针对基于对撞机的高能量前沿的粒子物理战略、组织了多次讨论，完成了战略报告的初步版本、并于2020年8月的青岛战略会议上进行了报告。

欧洲粒子物理战略讨论



- CEPC项目积极参加了欧洲粒子战略讨论、提供了加速器及探测器-物理方面的输入、促成了欧洲粒子战略报告及Physics Briefing Book的完成。
- **欧洲粒子战略更新视正负电子Higgs工厂为对撞机物理发展的最高优先级，倡议建设能量尽可能高的质子对撞机，并展开包括高场磁体在内的一系列关键技术预研；其技术路线和CEPC-SPPC一致。**

美国粒子物理战略讨论：Snowmass



- 美国高能物理学界于2020年中开始了为期一年多的Snowmass讨论。CEPC积极参与了这一过程。
- 提交了35份LoI，其中加速器4份、探测器13份、物理研究17份、软件1份。
- 在物理研究方面组织了专门的工作小组、定期展开讨论并推动相关研究。

CEPC submissions to Snowmass21

CEPC Input to the ESPP 2018

-Accelerator

LOI

CEPC Accelerator Study Group

Executive summary

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for a large-scale accelerator. Due to the low mass of the Higgs, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with reasonable luminosity, technology, cost and power consumption. The Higgs boson is a crucial cornerstone of the Standard Model (SM). It is at the center of some of its biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, and many other related questions. Precise measurements of the properties of the Higgs boson serve as excellent tests of the underlying fundamental physics principles of the SM, and they are instrumental in explorations beyond the SM. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies. The tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies beyond the LHC.

The CEPC is a large international scientific project initiated and hosted by China. It was presented for the first time to the international community at the ICFA Workshop "*Accelerators for a Higgs Factory: Linear vs. Circular*" (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, the *White Report*)[1]was published in March 2015, followed by a Progress Report (the *Yellow Report*)[2] in April 2017, where CEPC accelerator baseline choice was made. The Conceptual Design Report (CEPC Accelerator CDR, the *Blue Report*) [3]has been completed in July 2018 by hundreds of scientists and engineers after international review from June 28-30, 2018 and formally released on Sept 2, 2018.

Including SppC and siting

CEPC -Accelerator Technologies to Snowmass2021 AF7

Technologies

CEPC Accelerator Study Group

Executive summary

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for a large-scale accelerator. Due to the low mass of the Higgs, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with reasonable luminosity, technology, cost and power consumption. The Higgs boson is a crucial cornerstone of the Standard Model (SM). It is at the center of some of its biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, and many other related questions. Precise measurements of the properties of the Higgs boson serve as excellent tests of the underlying fundamental physics principles of the SM, and they are instrumental in explorations beyond the SM. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies. The tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies beyond the LHC.
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Collider Design
SCRF
Klystron
Linac+plasma
accelerator injector
Cost

国际会议

IAS HEP ConferenceJan. 20-23, 2020 (Since 2015)

Mini-workshop: Accelerator - Machine Detector Interface (MDI) for Future Colliders
Dates: Jan 16-17, 2020

For 2021, HKIAS mini workshop on plasma accelerator physics an technologies Jan. 14-15, 2021) and HKIAS HEP conference (Jan. 18-21, 2021) will take place online.

- 原定于2020年5月在法国马赛进行的第三次CEPC欧洲会议因疫情顺延。
- 以线上+线下相结合的形式，成功在上海进行了2020年CEPC国际研讨会。注册人数近400人。

- First international workshop on CEPC in Europe – Rome May, 2018
- Second CEPC workshop (EU) in Oxford, UK, April 15-17, 2019
- **Third planned for Marseille, France, May 4-6, 2020**
  postponed to 2021 due to the COVID-19 pandemic
- **First US workshop at UChicago, September 16-18, 2019**
- **Second US workshop April, 2020 (online)**
  Catholic University in Washington DC, USA

- **HongKong IAS HEP Program, 2019, 2020, …**
- **2019 CEPC International workshop at IHEP (~360)**
- **Fifth CEPC IAC meeting (Nov. 21-22, 2019), 6th Oct. 29-30,2020**

CEPC-SppC International Collaboration

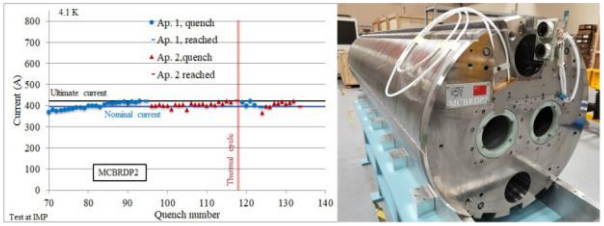
IAS HEP ConferenceJan. 20-23, 2020 (Since 2015)

Mini-workshop: Accelerator - Machine Detector Interface (**MDI**) for Future Colliders

China-CERN HL-LHC CCT Project

China will provide 12+1 units CCT superconducting magnets for the HL-LHC project

After more than 1 month test and training at 4.2K, both apertures reached the design current and ultimate current, and the field quality is within the limit.



The 1st prototype CCT magnethas been sent to CERN. A good start for the 12 units series production. 18

For 2021, HKIAS mini workshop on plasma accelerator physics an technologies Jan. 14-15, 2021) and HKIAS HEP conference (Jan. 18-21, 2021) will take place online.

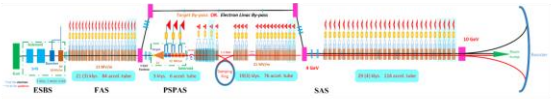
技术、研发

- CEPC-SppC：CDR， R&D， 品质提升，
- HL-HL-LHC ATLAS探测器：探测器，加速器
- 国际研发合作

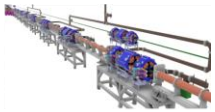
CEPC加速器预研

CEPC Injector Scheme Comparison

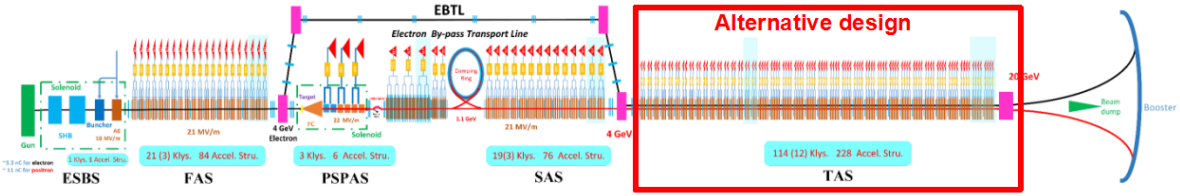
CEPC Linac Injector (CDR)



Parameter	Symbol	Unit	Baseline	Design reached
e⁻/e⁺ beam energy	E_{e^-}/E_{e^+}	GeV	10	10
Repetition rate	f_{rep}	Hz	100	100
e⁻/e⁻ bunch population	N_{e^-}/N_{e^-}		>9.4×10⁹	1.9×10¹⁰ / 1.9×10¹⁰
		nC	>1.5	3.0
Energy spread (e⁻/e⁺)	σ_E		<2×10⁻³	1.5×10⁻³ / 1.6×10⁻³
Emittance (e⁻/e⁺)	ε_r	nm·rad	<120	5 / 40 –120
Bunch length (e⁻/e⁺)	σ_l	mm		1 / 1
e⁻ beam energy on Target		GeV	4	4
e⁻ bunch charge on Target		nC	10	10



CEPC 20-GeV Linac Injector Alternative Scheme



S-band Accelerating structure

C-band Accelerating structure

Parameter	Symbol	Unit	Baseline	Alternative
e⁻ /e⁺ beam energy	E_e/E_{e+}	GeV	10	20
Repetition rate	f_{rep}	Hz	100	100
Bunches/pulse			1	1
e⁻ /e⁺ bunch population	Ne-/Ne+	nC	>1.5 (3)	>1.5 (3)
Energy spread (e⁻ /e⁺)	σ_E		<2×10⁻³	<2×10⁻³
Emittance (e⁻ /e⁺)	ε_r	nm	40	20

Parameter	Unit	S-band	C-band
Frequency	MHz	2860	5720
Length	m	3.1	1.8
Cavity mode		2π/3	3π/4
Aperture diameter	mm	20~24	11.8~16
Gradient	MV/m	21	45

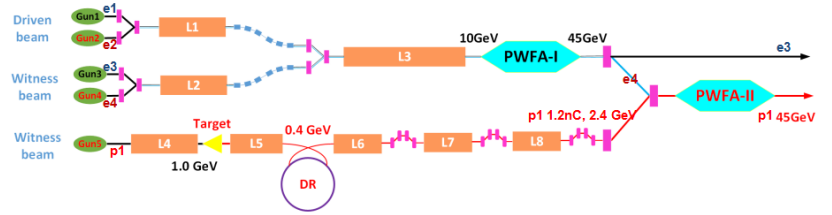
CEPC booster iron core magnets

If S+C Band injector is used, the iron core dipole magnet in booster can be used with lower cost compared with S-band injector

CEPC加速器预研

CEPC Plasma Injector Scheme and Experiments

CEPC Plasma Injector Design



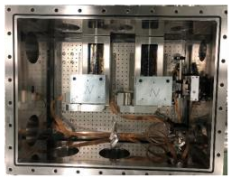
	e1/e3 Before PWFA-I	e3 After PWFA-I	e2/e4 Before PWFA-I	e4 After PWFA-I	p1 Before PWFA-II	p1 After PWFA-II	Booster Requirement
Energy (GeV)	10/10	45.5	10/10	45.5	2.4	45.5	45.5
Bunch Charge (nC)	5.8/0.84	1	15/4.5	>3	1.2	1	0.78
Bunch length (ps)	2/0.257	<1	3/0.7	<1	0.07	<1	<10
Energy Spread	~/0.2%	~1%	~/0.2%	1%	0.2%	~1%	0.2%
E_{normal} (μm rad)	<20*/<100	~100	<50*/<100	~100	<50	~100	<800
Bunch Size (μm)	3.87/8.65	<20	30/20	<20	20	<20	<2000

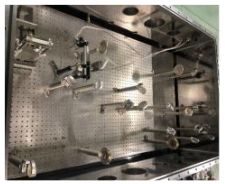
The plasma accelerator performance has been checked with the real linac beam quality, and it almost reached the design goal

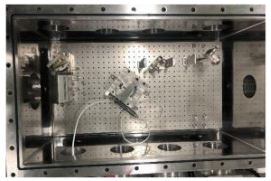
CEPC Plasma Injector Experimental Platform

Facilities: Shanghai S-XFEL facility for electron acceleration and FACETII at SLAC for positron

- Plasma experimental station: preliminary set up on Shanghai Soft XFEL facility
  - Vacuum system: installation & testing
  - Light path
  - Beam diagnostic system


Beam test room

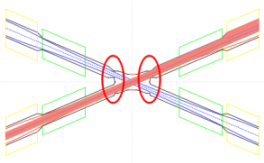

main room


Laser compressor

CEPC加速器预研

CEPC MDI Optimized Design

CEPC CDR MDI updated Design: Beam Pipe and Vacuum Chamber-1



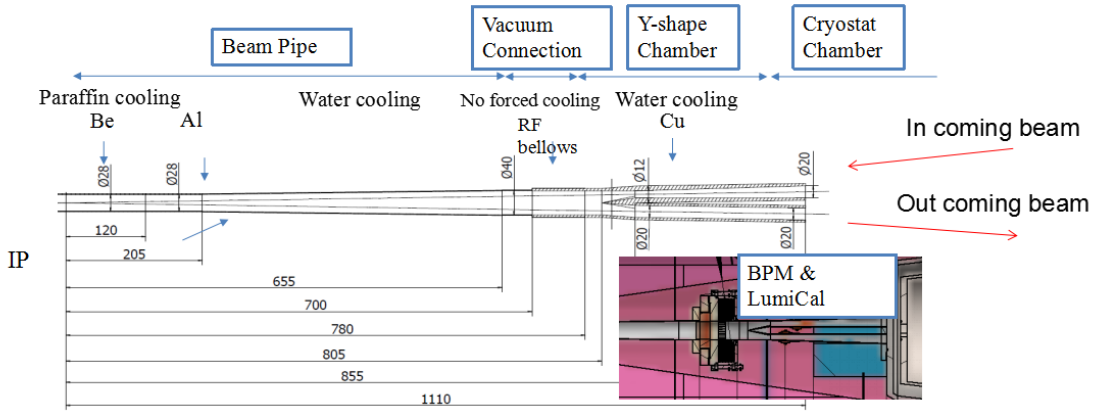
- **Most important update:** **asymmetric up & down stream beampipe apertures**

Feasibility confirmed by accelerator physics and mechanics design

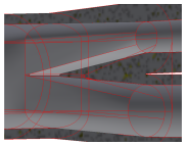
Guaranteed: no SR power deposition between ±0.855 m

	Power Deposition	Average Power Density
0.855m~1.11m	36.53 W	39.79 W/cm²
1.11m~2.2m	2.24 W	0.57 W/cm²
QD0	4.34 W	0.6 W/cm²
QD0~QF1	48.04 W	58.02 W/cm²
QF1	4.56 W	0.86 W/cm²

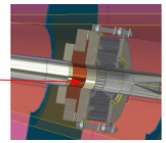
CEPC CDR MDI updated Design: Beam Pipe and Vacuum Chamber-2



Asymmetric design to prevent direct hitting of synchrotron radiation photons

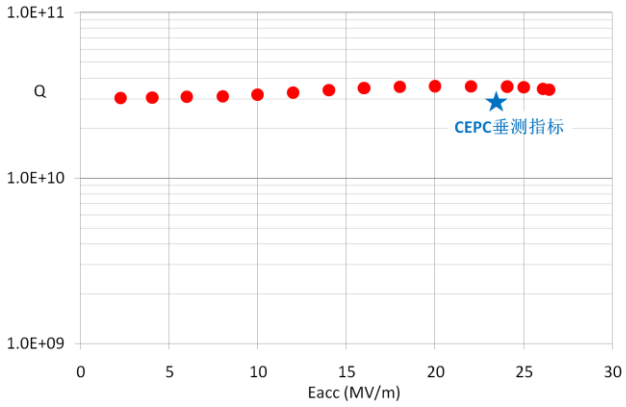


Remaining issue: difficult to dissipate the heat around the RF finger

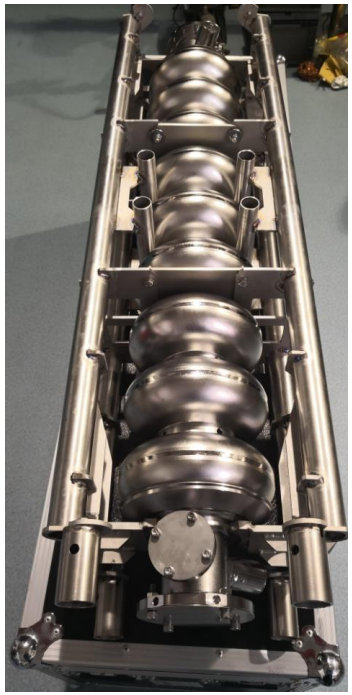


CEPC加速器预研

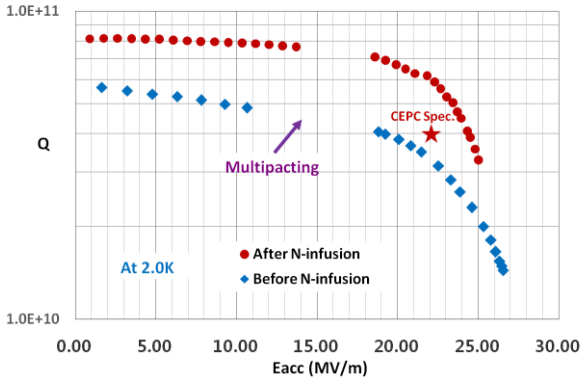
CEPC 650MHz 2cell and 1.3 GHz 9-cell Cavities reached Design Goals

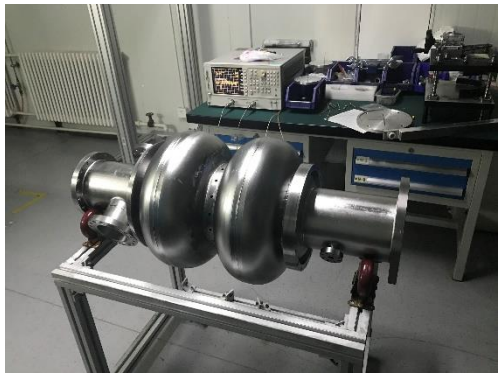


在国际上首次实现了1.3 GHz 9-cell超导腔的中温退火工艺，垂测结果达到3.4E10@26.5MV/m，超过了CEPC增强器1,3GHz9-cell超导腔的垂测指标（3E10@24MV/m）。



Booster 1.3GHz 9 cell cavity





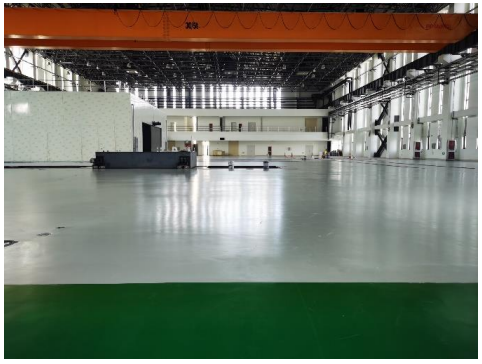
Collider ring 650Mhz 2 cell cavity

650 MHz 2-cell超导腔经过掺氮后，垂测结果达6.0E10@22MV/m，超过了CEPC的垂测指标（4E10@22MV/m）。

CEPC加速器预研

IHEP New SC Lab PAPS under Construction (Status in 2020)

Facility: CEPC SCRF test facility (lab) is located in IHEP Huairong Area of 4500m^2



CEPC 2*2cell 650MHz cryomodule with beam test later

New SC Lab Design (4500m^2) **SC New Lab will be available in 2021**

Crygenic system hall in Jan. 16, 2020

Vacuum furnace (doping & annealing)

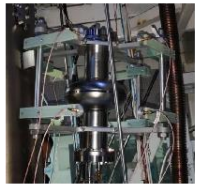
Nb3Sn furnace

Nb/Cu sputtering device

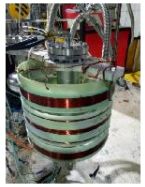
Cavity inspection camera and grinder

9-cell cavity pre-tuning machine

Temperature & X-ray mapping system



Second sound cavity quench detection system



Helmholtz coil for cavity vertical test

Vertical test dewars

Horizontal test cryostat

CEPC加速器预研

CEPC 650MHz High Efficiency Klystron Development

Facility: CEPC high power and high efficincy test facility (lab) is located in IHEP

Established "High efficiency klystron collaboration consortium", including IHEP & IE(Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.

- 2016 – 2018: Design conventional & high efficiency klystron
- 2017 – 2018: Fabricate conventional klystron & test
- 2018 - 2019 : Fabricate 1st high efficiency klystron & test
- 2020 - 2021 : Fabricate 2nd high efficiency klystron & test
- 2021 - 2022 : Fabricate 3rd high efficiency klystron & test

Parameters	Conventional efficiency	**High efficiency**
Centre frequency (MHz)	650+/-0.5	**650+/-0.5**
Output power (kW)	800	**800**
Beam voltage (kV)	80	-
Beam current (A)	16	-
Efficiency (%)	~ 65	**> 80**

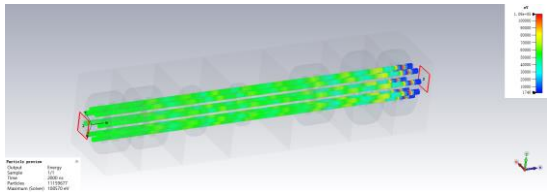
800kW Load

On March 10, 2020, the first CEPC650Mhz klystron output power has reached pulsed power of 800kW (400kW CW due to test load limitation), efficiency 62% and band width>+-0.5Mhz.

1st Klystron of 62% efficiency fabricated

2nd Klystron of 77% efficiency

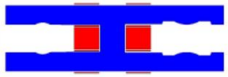
3rd Klystron of 80% efficiency



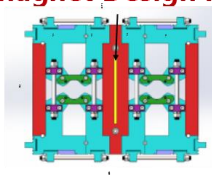
CEPC加速器预研

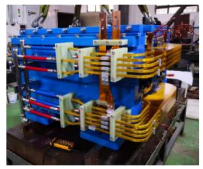
CEPC Collider Ring and Booster Magnets and Vacuum Systems

CEPC Collider Ring dual Aperture Dipole, Quadrupole and Sextupole Magnet Design Progress

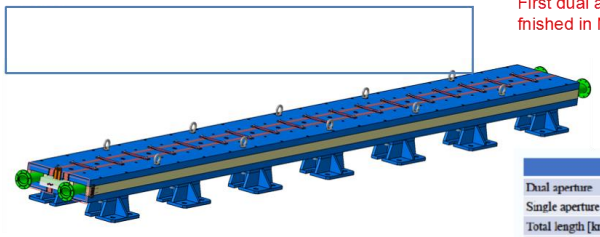


First dual aperture dipole test magnet of 1m long has been fnished in Nov, 2019





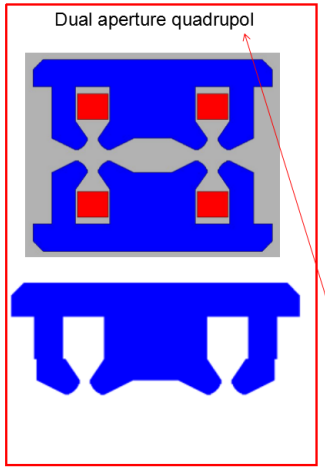
First dual aperture quadrupole magnet has been fnished in Nov, 2019



The mechanical design of a full size CEPC collider ring dual aperture dipole of 5.7m long has been designed and be fabricated at the end of 2021.

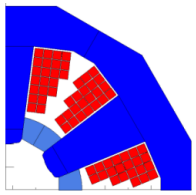
	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34

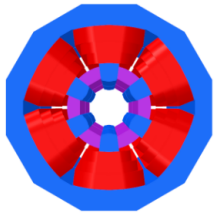
CEPC Collider Ring Quadropole and Sextupole Designs



Key R&D item

- **Further physical optimization of the sextupole magnet.**
  - **Wedge-shaped magnetic poles are used to reduce magnetic pole saturation and improve excitation efficiency**
  - **Further optimization to the position of the lead block and the arrangement of coil wires to reserve space for magnet assembly.**
- **Mechanical design is in progress.**



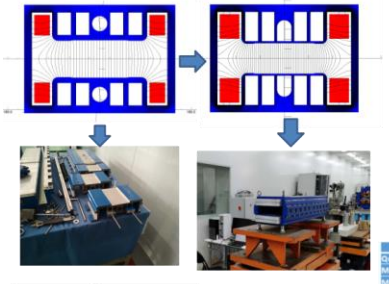


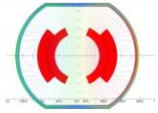
Field harmonics

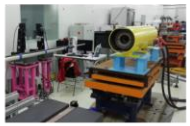
n	B_nL/B_3L
3	10000
9	1.0
15	-0.5
21	-0.1

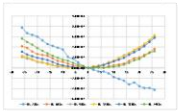
Booster High Precision Low Field Dipole Magnets

Two kinds of the dipole magnet with diluted iron cores and without iron core (CT) are proposed and designed



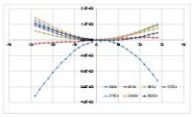






1m long CT test booster dipole magnet without iron core completed in Oct. 2019, and the test result shows that CT design reached the design goal.

	BST-63B
Quantity	16320
Minimum field (Gs)	28
Maximum field (Gs)	338
Gap (mm)	63
Magnetic Length (mm)	4700
Good field region (mm)	55
Field uniformity	0.1%
Field reproducibility	0.05%



The first 1m long test booster dipole magnet with iron core, completed in Nov. 2019, and not yet reached design goal, improvement is under way

A full scale CT dipole magnet of 5.1m long is under design, and fabrication will be completed at the end of 2021

CEPC Vacuum System R&D

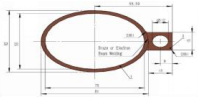
Facility: CEPC vaccum test facility (lab) is located in IHEP Dongguan CSNS

NEG coating suppresses electron multipacting and beam-induced pressure rises, as well as provides extra linear pumping. Direct Current Magnetron Sputtering systems for NEG coating was chosen.

The vacuum pressure is better than 2 x 10-10 Torr

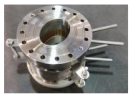
Total leakage rate is less than 2 x 10-10 torr.l /s.

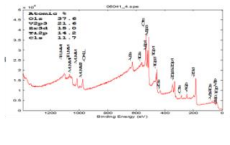
Positron ring

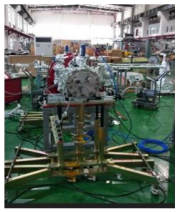


Copper vacuum chamber (Drawing) elliptic 75×56, thickness 3, length 6000)

Two 6m long vacuum chambers both for copper and aluminum







CEPC加速器预研

CEPC Injector Linac, Seperator and MDI Vacuum Chamber

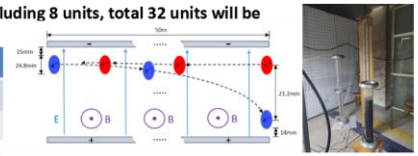
CEPC Electrostatic-Magnetic Deflector

The Electrostatic-Magnetic Deflector is a device consisting of perpendicular electric and magnetic fields.

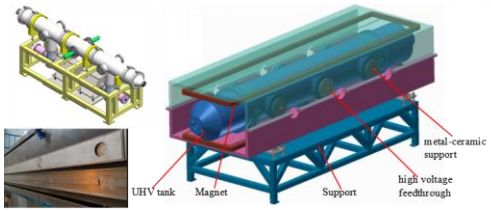
One set of Electrostatic-Magnetic Deflectors including 8 units, total 32 units will be need for CEPC.

	Filed	Effective Length	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	46mm × 11mm	5×10⁻⁴
Dipole	66.7Gauss	4m	46mm × 11mm	5×10⁻⁴

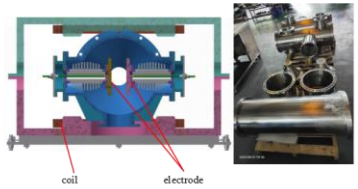
under fabrication



Schematic of Electrostatic-Magnetic Deflector



structure drawing of Electrostatic-Magnetic Deflector

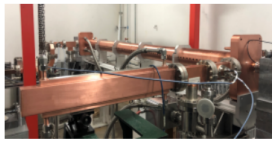


CEPC Linac and damping ring key technology R&D

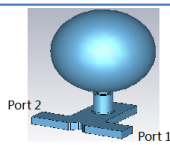
Facility: CEPC injection linac test facility (lab) is located in IHEP

Accelerating structure

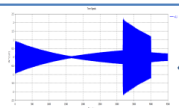
- The structure is 3 meters long with constant gradient design which work mode is 2π/3
- The high power test has finished and the gradiet is up to 33 MV/m



The acclelerating strucutre on high power test bench



Simulation model



Simulated waveform

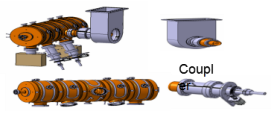
Pulse compressor: Spherical cavity pulse compressor has devoloped The TE_{113} mode is selected and the RF design is finished. The Q value is about 140000 The Maximum Energy Multiplication Factor M=1.84.

Positron source R&D

The mechanical design of FLUX concentrator

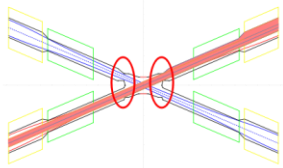
The finished FLUX concentrator

The test bench of the FLUX concentra tor



Damping Ring 5 cell cavity: The The 1.1 GeV damping ring need the RF system provide 2 MV.Two 5 cell constant temperature cavities have recommended and the frequency is 650 MHz. According to the simulation, each cavity can provide 1.2 MV cavity voltage when the cavity consumption is 54 kw

CEPC CDR MDI updated Design: Beam Pipe and Vacuum Chamber-1



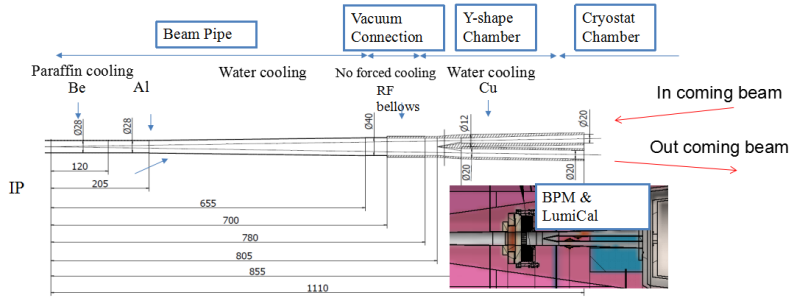
- **Most important update: asymmetric up & down stream beampipe apertures**

Feasibility confirmed by accelerator physics and mechanics design

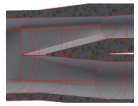
Guaranteed: no SR power deposition between ±0.855 m

	Power Deposition	Average Power Density
0.855m~1.11m	36.53 W	39.79 W/cm²
1.11m~2.2m	2.24 W	0.57 W/cm²
QD0	4.34 W	0.6 W/cm²
QD0~QF1	48.04 W	58.02 W/cm²
QF1	4.56 W	0.86 W/cm²

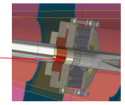
CEPC CDR MDI updated Design: Beam Pipe and Vacuum Chamber-2



Asymmetric design to prevent direct hitting of synchrotron radiation photons

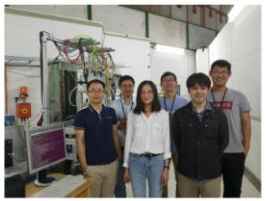


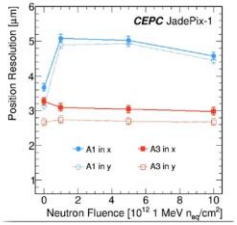
Remaining issue: difficult to dissipate the heat around the RF finger



CEPC探测器预研

- 在MOST项目的支持下，子探测器样机建造完成，进行了实验测试（受疫情影响，赴DESY的束流测试实验推迟到明年年初）
- 作为ATLAS升级计划的高精度时间测量探测器进展显著；也为CEPC探测器进行了技术储备
- 开始对DAQ、Trigger系统进行系统研究



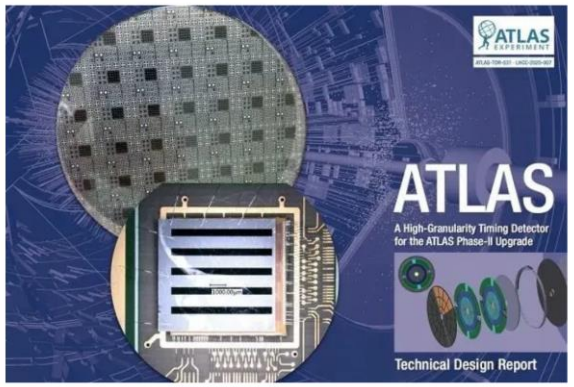


硅像素探测器进展（高能所创新项目支持）：填补空白。

高粒度电磁量能器样机

科技部第一期支持下：
将很快进行束流测试

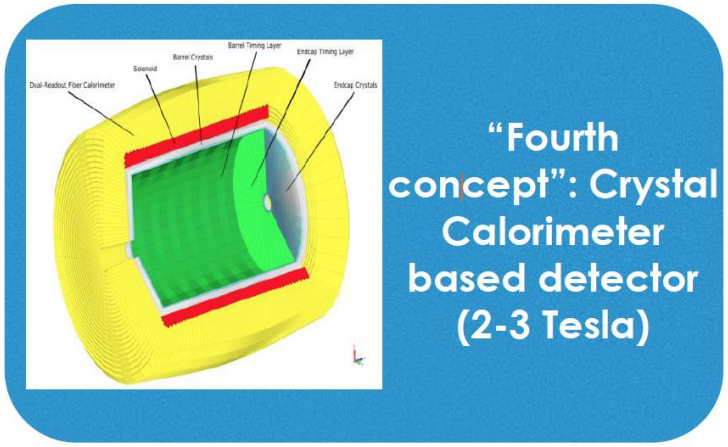
ATLAS实验高颗粒度时间探测器项目获欧洲核子研究中心批准 高能所科学家发挥关键作用

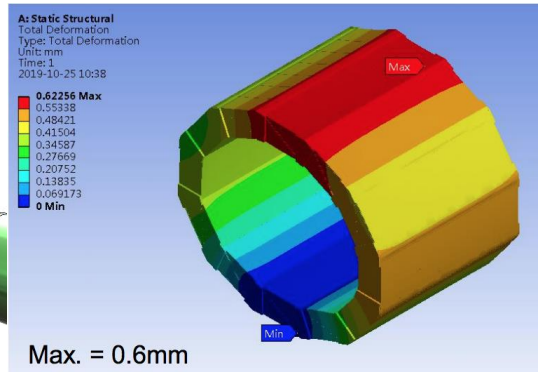


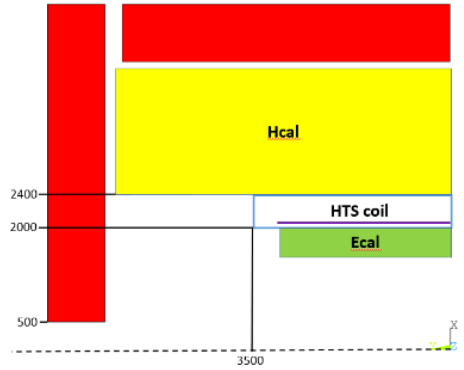
9月16日，欧洲核子中心（CERN）的研究委员会（Research Board）委员会批准了ATLAS实验的高颗粒度时间探测器项目（HGTD）的建设。这标志着该项目完成了预研和准备，

CEPC探测器预研

- 于2020年8月末在东莞举行了CEPC机械讨论会：开始就探测器的整合、安装等问题进行系统讨论
- 倡议新的探测器概念设计







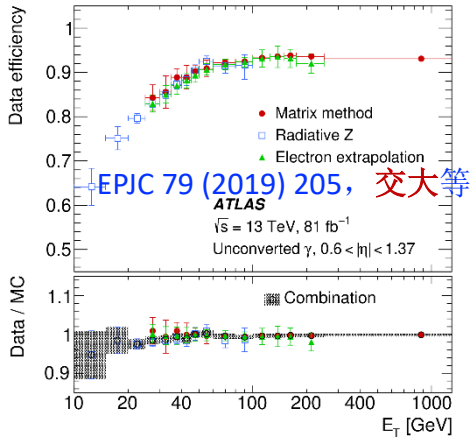
ATLAS实验研究进展：探测器研发

科大/山大

探测器研发与Performance

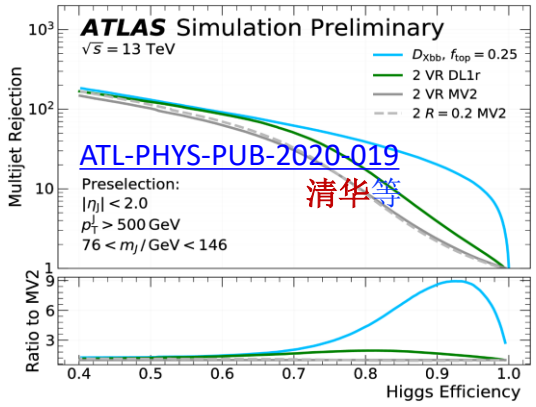
- 探测器各部分的刻度、甄别等performance的工作对于物理分析的展开起到非常大的重要的作用
- **ATLAS中国组各单位都通过探测器Performance、硬件研发和升级等对ATLAS的发展作出特别的贡献**

光子track iso.效率研究



EPJC 79 (2019) 205，交大等

Xbb Tagger研究



ATL-PHYS-PUB-2020-019

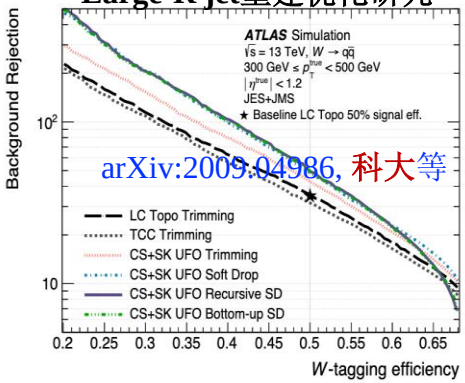
清华等

ATLAS硬件研发

JINST 15 p03013 (2020)，交大邬维浩等

(b) FELIX hardware for ATLAS Phase I Upgrade

Large-R jet重建优化研究

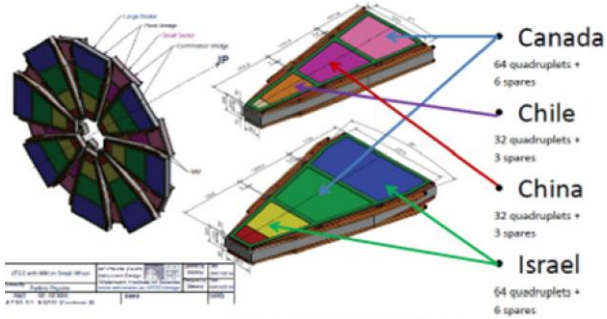


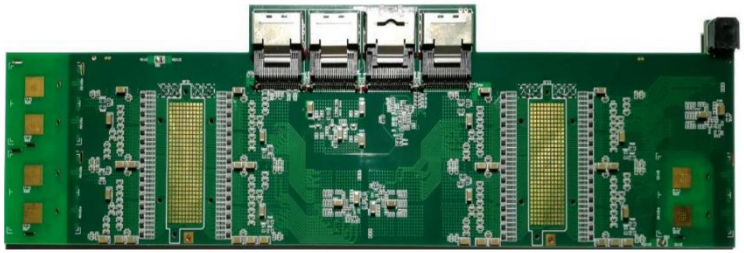
arXiv:2009.04986, 科大等

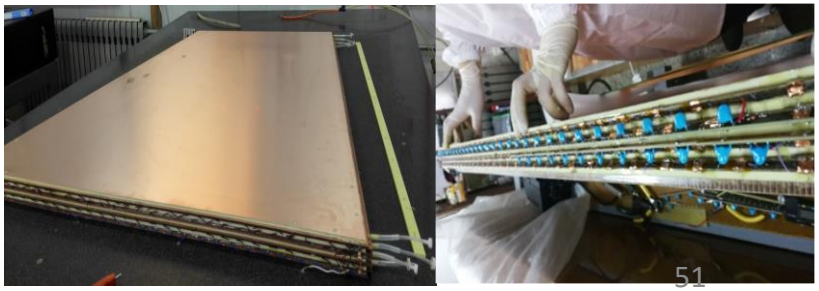
中国组NSW项目

- 山大完成全部160 sTGC chambers生产
- 科大承担生产1840 Front-end readout (FEB) boards

New small wheel (small-TGC + MicroMegas)



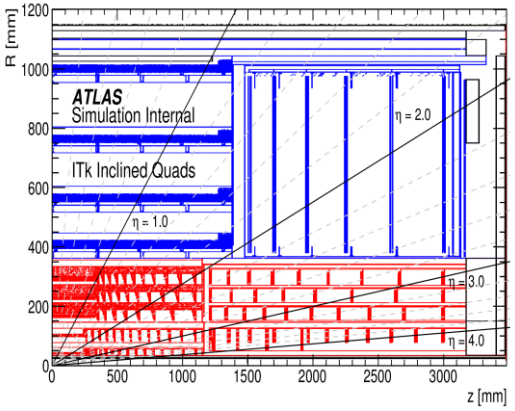




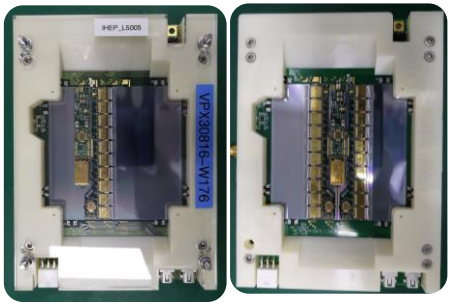
ATLAS研究进展：Phase-2 硅径迹探测器和RPC升级

硅径迹探测器升级

高能所/清华



ATLAS将建造全硅径迹探测器（ITk）：

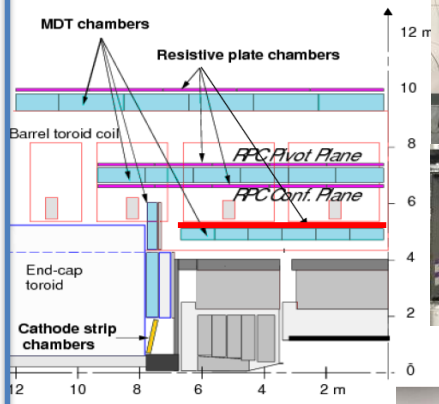


Assembled modules

- 协议生产1000个硅微条探测器模块，占桶部硅微条模块的大约**10%** (美国 50% +英国 40%)
  - 进口问题(抗辐照ASIC芯片) 已完全解决
  - 项目进展顺利: 组装了LS/SS模块 (完成了原型项目)；年末site qualification将完成;即将进入 (pre-)production阶段
- 任务拓展：**module loading** (at RAL); Strip barrel **system integration**, **installation** and **commissioning** (at CERN)

PRC 升级

科大/山大/交大



Adding Inner layer to RPC barrel to improve resolution / trigger selectivity

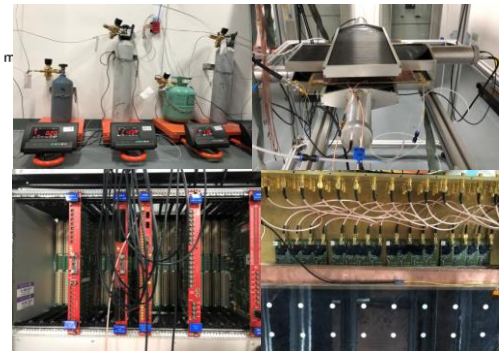


图1 配气、触发、测试、读出系统

图2 RPC探测器测试平台

中国组承担ATLAS缪子探测器RPC升级课题：负责RPC Phase-2 中 50% 前放板以及 50% singlet chamber制作和测试

- 科大孙勇杰担任Level-3协调人（读出板设计生产)
- 提议蜂窝结构读出板，和用单面双端读出代替双面单端读出
- 科大金革 sTGC前端读出电子学FEB系统研发负责人
- 山大大学 祝成光 sTGC子探测器QS2制造负责人
- Rustem （科大）是RPC 数据质量监控方面的协调人

ATLAS实验研究进展：HGTD项目

高能所、科大等

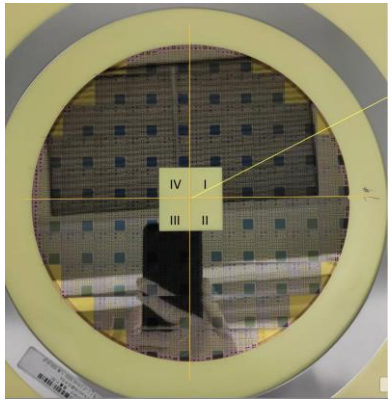
HGTD探测器被CERN批准立项，高能所在HGTD项目主导作用：

- Joao costa担任HGTD项目副经理
- 梁志均任探测器模块组Level2协调人，研制出首批探测器模块
- Juan An担任数据获取组协调人，张杰任外围电路组协调人
- 高能所与北师大研发超快硅传感器，抗辐照性能取得进展
  - $2.5*10^{15} N_{eq}/cm^2$超高中子辐照后，对时间分辨仍可达30皮秒
- 高能所与微电子研发超快硅传感器流片成功（高能所设计）
- 高能所与南京大学合作研制首批探测器模块emulator

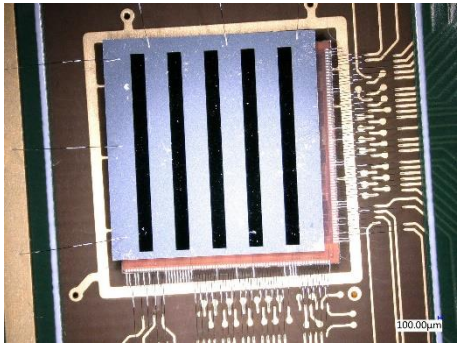
科大亮点工作：

- 吴雨生担任HGTD sim/perf/physics coordinator (2019.3-2021.2)
- LGAD探测器在IME制作完成，时间分辨率和HPK相当
- 平台：探针台电学测试平台、放射源性能测试平台
- 开展大面积探测器阵列性能研究，探讨阵列中少数坏通道对运行和整体探测性能的影响
- 科大与微电子研发超快硅传感器流片成功（科大设计）科大与苏州纳米所合作做成

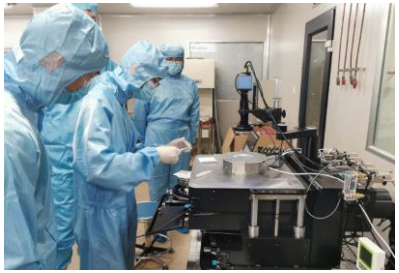
高能所设计传感器

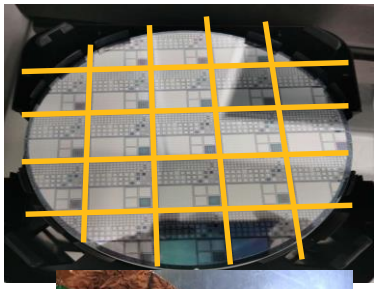


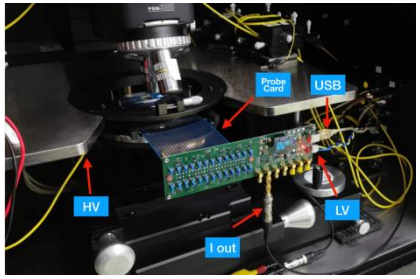
探测器模块研制

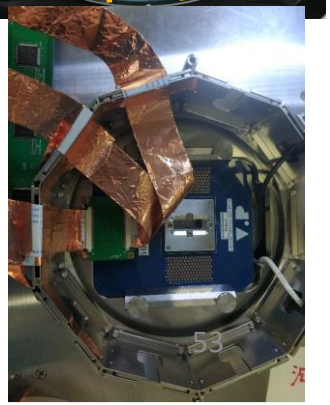


探测器模块
Emulator
高能所/南大



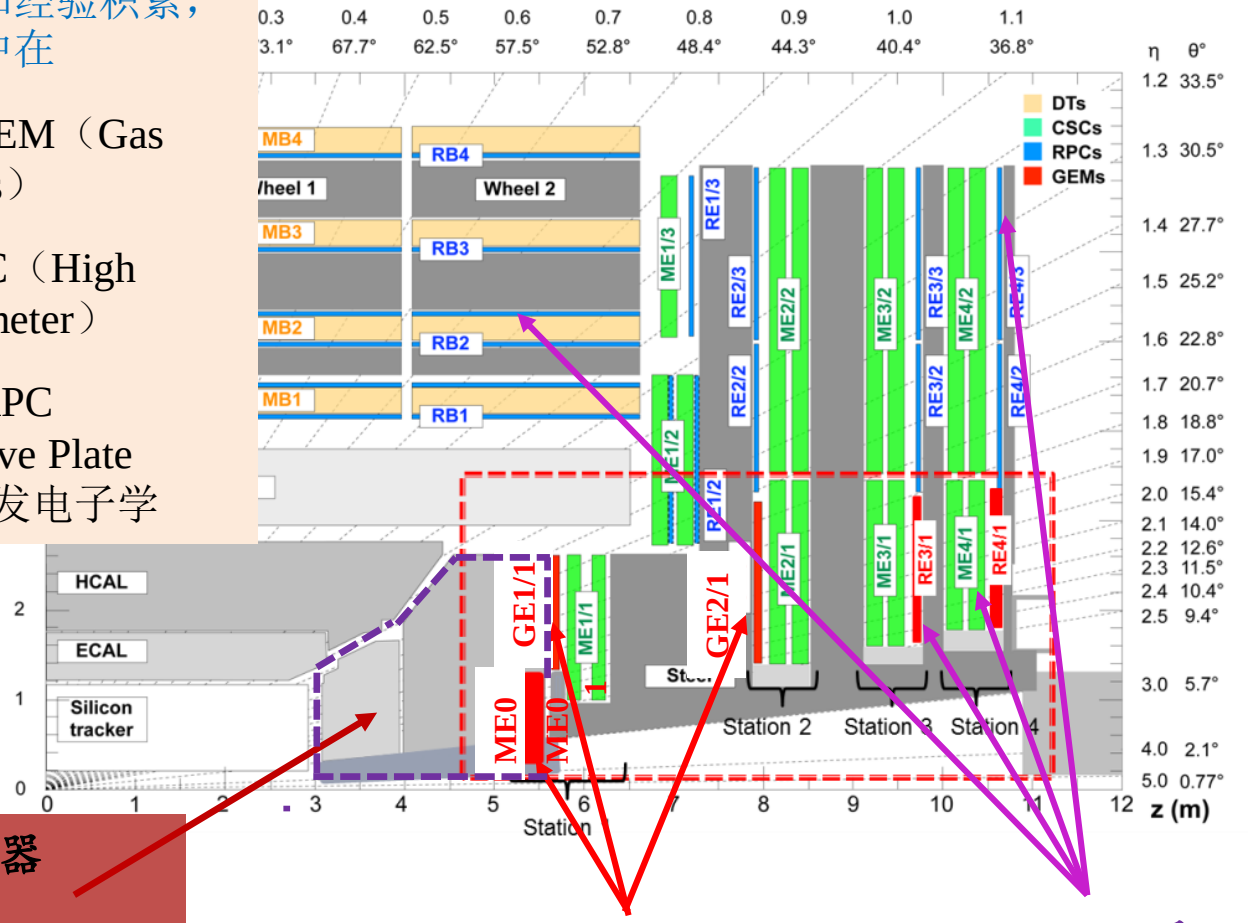






CMS实验中国组承担的二期升级（2016-2026）任务

- 根据中国组前期工作和经验积累，目前二期升级工作集中在
  - 端盖缪子探测器GEM（Gas Electron multipliers）
  - 高粒度量能器HGC（High Granularity Calorimeter）
  - 端盖缪子探测器iRPC（improved Resistive Plate Chamber）后端触发电子学



端部高粒度量能器
HGCal升级
(高能所、清华、浙大、复旦)

端盖μ探测器GEM升级
GE1/1,GE2/1,ME0
(北大、清华、中山、北航)

iRPC/RPC系统
backend电子学
（高能所）

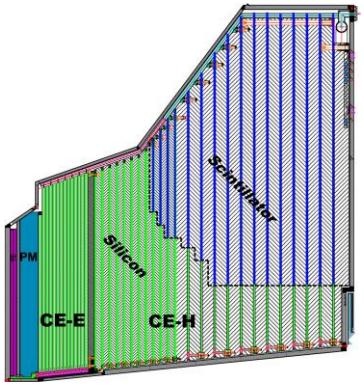
54

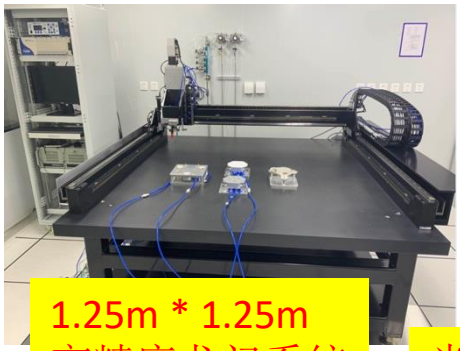
CMS-高粒度量能器升级年度进展

参加单位：高能所、清华、浙大、复旦

中国组的主要任务：在高能所建立一个HGCal硅模块中心

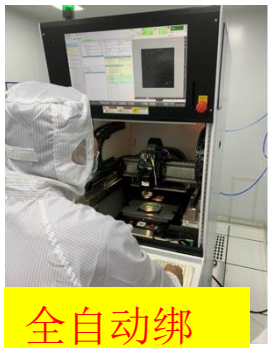
- 140 m²专用千级洁净间搭建完成：
  - 恒温、恒湿，真空和压缩空气系统，监控系统
- 主要仪器设备已到位，并初步完成调试及人员操作培训





1.25m * 1.25m
高精度龙门系统

光学测量仪OGP ZIP 635



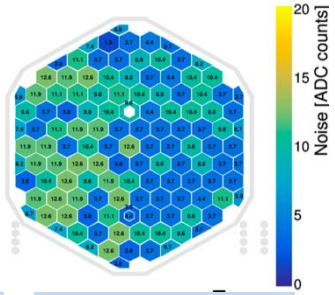
全自动绑定机BJ855

封装用mini gantry

- 按计划进行各项测试及工艺研究,预计明年3月份生产中心认证

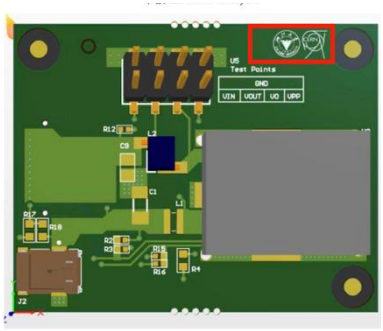
优化点胶模式

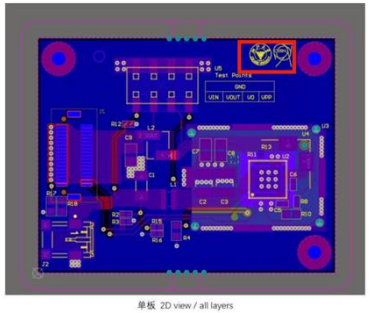
打线及拉力测试



模块测试

- 浙大承担整体模块和电源(DCDC)电路的设计，已生产60块电源电路板原型并进行测试

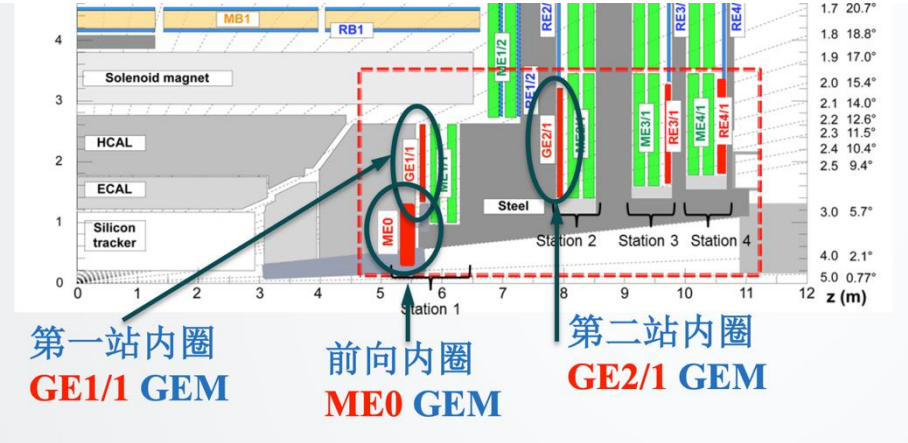




CMS-GEM探测器升级年度进展

CMS-GEM升级参加单位：

北大、清华、中山大学、北航



➢ **在中国研制FR4探测器内框架样机**并在CERN通过测试，2020年底将在中国批量生产

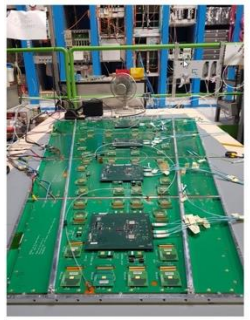
➢ 对第一站GEM样机进行了高压性能、X射线增益等测试，达到CERN指标。

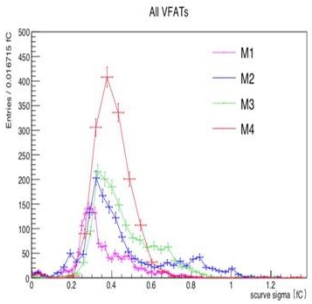
样机在北大进行测试

→ 北京大学GEM批量生产测试基地建设基本完成

➢ GEM探测器前端电子学板研发

- 设计、研发成功端部第二站全部8种型号GEM前端电子学板。样机经过CERN及美国初步测试达到要求：噪声<0.5fC，一小时实测误码率<10^{-13}。预计2020年年底开始批量生产。
- 完成了第一版ME0 GEM前端电子学板设计并通过了合作组审核，目前正在深圳鑫诺捷公司进行样机生产。





四种型号(M1-M4) GEB 2/1样机、测试平台和噪声测试结果

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平台3人才培养、成长-发展和特征

- ATLAS

大量青千，技术人才

获奖、晋升：

卓越中心拔尖人才奖1名（陈新），优秀奖若干

新晋青千5名，晋升研究员/教授1名

新职位任命：

10人次新任项目副经理、顾问组成员、召集人协调人等重要职位

……

更多的国际合作组任职

- CMS

人员获奖

北航成曈光、高能所博士后Efe Yazgan获CMS Achievement Award

合作组任职

本年度6人次任L2召集人，20多人次任L3召集人及联系人等

……

- CEPC

成为优秀的青年学术带头人

朱宏博：高能所探测器一组副组长，CEPC MDI Convener
阮曼奇：高能所高能量组组长，CEPC Simulation Convener
庄胥爱：高能所高能量组副组长
翟纪元：高频组组长；
徐庆金：超导磁铁组组长
马永胜：CEPC真空负责人
……

收集到的信息
信息不全
标准不统一

小结

- 围绕当前ATLAS，CMS实验
  - 争取多出新物理成果和科学创新， 加强了理论
  - 关键加速器(HL-LHC), 探测器(升级）
  - 运行经验，实验手段，国际合作和管理
- 未来
  - CEPC-SppC引领我们的R&D
  - 走出去参加加速器、探测器等方面的技术创新
  - 下一代对撞机设施，开展科学创新
  - 瞄准“卓越”，在科学上做出优异的成绩，努力突破

谢谢所有的同事

- Backup

ATLAS实验研究进展：更多方面

- **参加运行和实验活动：**
  - 高能所JuanAn Pascual担任了Pixel运行协调人以及HGTD项目触发与数据获取组召集人，科大参与了RPC的刻度和数据获取，**积累了探测器运行和数据获取方面的经验**
  - 中国组人员普遍参加了探测器升级（NSW, ITK, RPC, HGTD：包含设计、建造、安装调试、相关软件以及data quality等方面的研究），探测器性能研究（多人次担任召集人）和其他各类值班任务，做了大量的硬件、软件和服务性工作
- **经费活动：**
  - 科技部重点研发项目 (2018，物理+升级)
  - 基金委ATLAS物理分析，ATLAS实验探测器Phase 2 升级（2020）
  - 基金委面上项目和其他人才经费
- **遇到的问题和解决途径及方案：**
  - 计算资源老化，缺乏维护Tier2的经费来源，Tier3资源也亟需扩充
  - 经费不足，无法招聘博士后等
- **获奖、晋升：**
  - 卓越中心拔尖人才奖1名（陈新），优秀奖若干
  - 新晋青千4名，晋升研究员/教授1名
- **新职位任命：10人次新任项目副经理、顾问组成员、召集人协调人等重要职位**

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经费、人才引进培养及其它

- 经费
  - ✓ **基金委重点项目1项：**触发升级
  - ✓ **基金委重大国际合作项目3项：**
    GEM+HGCal升级项目
    CMS物理研究两项
- 人才引进
  - ✓ 北航新引进**成瞳光**
  - ✓ 北大新引进**孙小虎**
- 合作组任职
  - ✓ 本年度6人次任L2召集人，20多人次任L3召集人及联系人等
- 举办第22届CMS数据分析国际学校
  - ✓ 北京大学于2019年12月举办
  - ✓ LHC实验组类似学校首次在中国大陆举行

- 人员获奖
  - ✓ **北航成瞳光、高能所博士后Efe Yazgan获CMS Achievement Award**

Citation for T. G. Cheng

For his decisive role and achievements in the Alignment Calibration and Database group, first as AlCa-HLT contact to coordinate on the event selection needed to calibrate CMS, and then as leader of the AlCaDB group, and for the development and commissioning of the automated workflow determining the pixel quality during data taking.

Citation for E. Yazgan

For his work in the validation tools for generators and for sample production.

遇到的问题和解决途径及方案

CMS Tier 2网格站点问题：

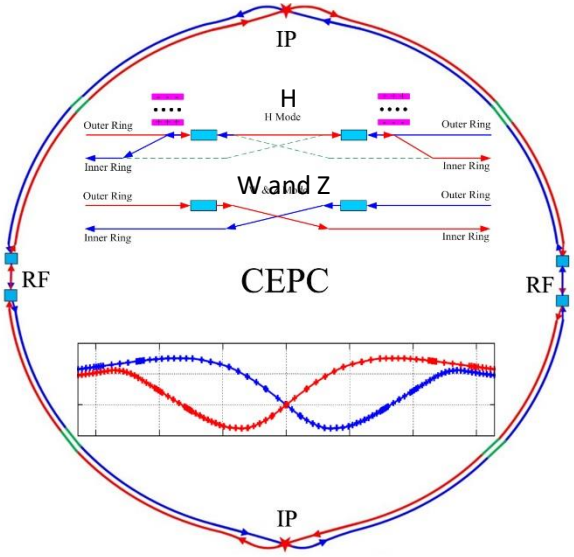
- 规模(444核、540 TB) 仅为应有贡献的四分之一或五分之一
  - 相对CMS总体资源的占比为CPU 0.6%、存储 0.5%
- 资源老化、设备已全部过保

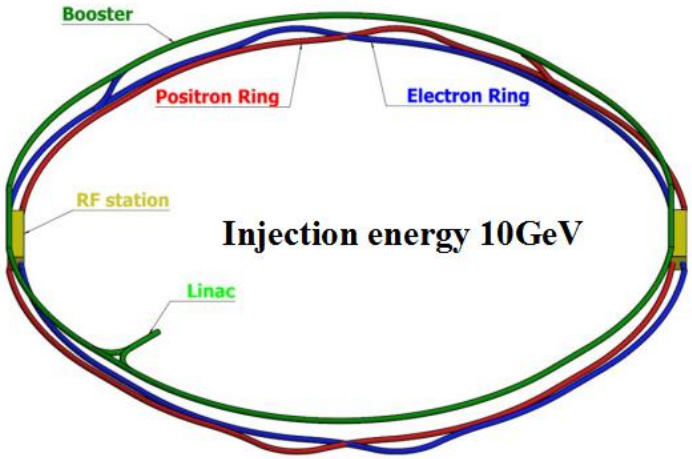
解决途径：

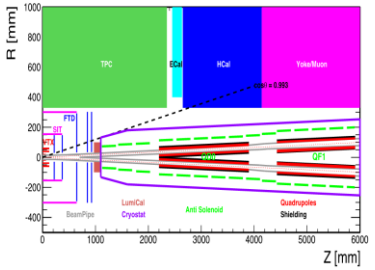
- ✓ 高能所CMS课题组先行调用现有经费采购600 TB存储，确保数据安全
- ✓ 鼓励高校提供CPU、存储设备于高能所托管，用于网格计算
  - ✓ 北航200核CPU近期已在高能所计算中心上架
- ✓ 中国组协商以缴纳T2资源使用费的方式参与支持T2的长期运行维护
  - ✓ 纳入本期及未来各类经费申请预算
- ✓ 积极争取其它途径经费支持站点的扩大

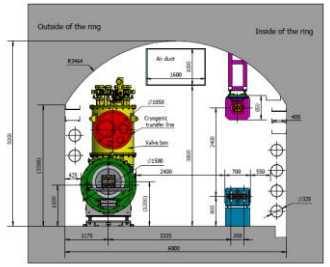
CEPC CDR Baseline Layout

CEPC as a Higgs Factory： H, W, Z, followed by a SppC ~100TeV



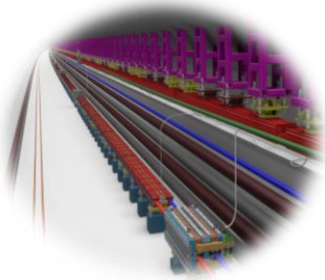


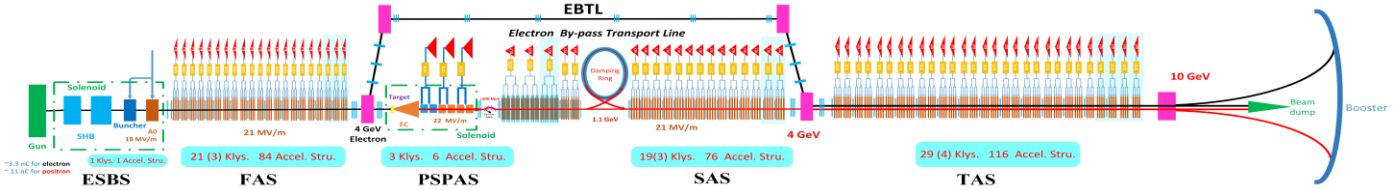




CEPC collider ring (100km)

CEPC booster ring (100km)





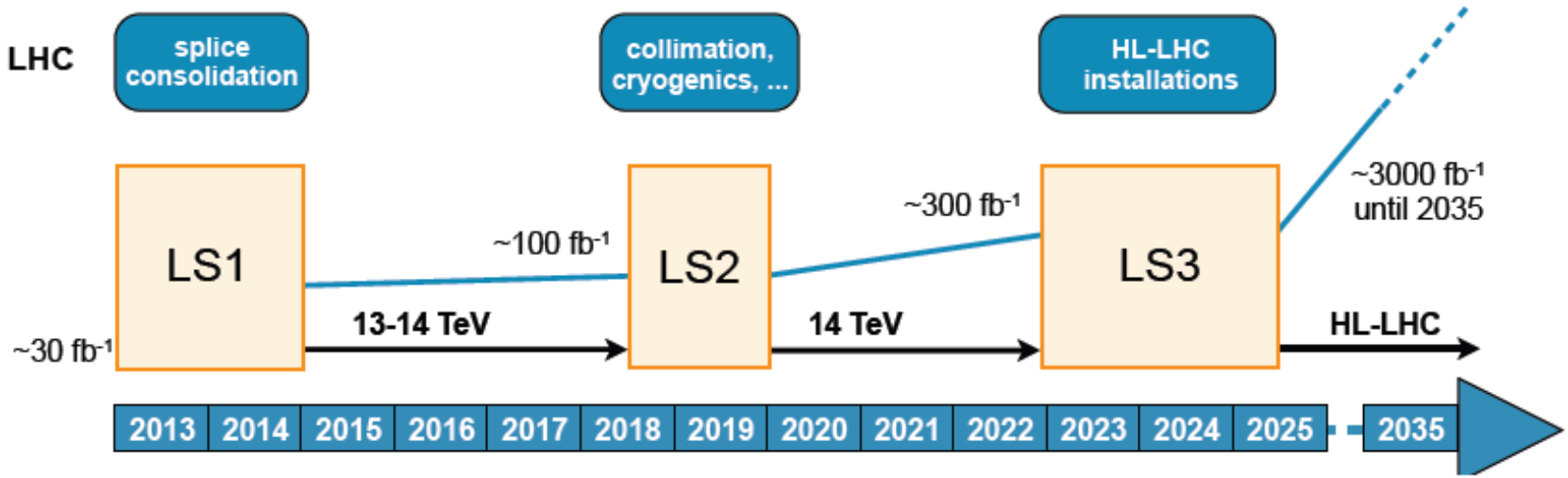
CEPC Linac injector (1.2km, 10GeV)

Backup

➢2020年新职位任命：

- ATLAS合作组委员会顾问组成员：黄燕萍（高能所， 2020-2021）
- HGTD 探测器项目副经理： Joao Guimaraes da Costa (高能所， 2020-）
- HGTD Steering Committee：Joao Guimaraes da Costa，梁志均， Juan Antonio Garcia，张杰（高能所）
- Speakers committee (deputy) chair：吴雨生（科大， 2020-2021）
- BSM Higgs convener：张雷 （南大，2020-）
- ATLAS Higgs Working Group Physics Validation Coordinator: Chikuma Kato (李政道研究所/上海交通大学，2020-)
- ATLAS Fake Tau group convener： Mohamad Kassem Ayoub （高能所，2020-）
- HGTD simulation/performance/physics convener：吴雨生（科大， 2020-）
- HGTD项目探测器模块Level-2组召集人：梁志均 （高能所，2020-)
- HGTD项目外围电路Level-3协调人：张杰（高能所，2020-)

LHC升级计划



ATLAS Phase-0

New inner pixel layer
Detector consolidation
2015: FTK deployment

ATLAS Phase-1

Improve L1 Trigger, NSW and LAr electronics to cope with higher rates

NSW：科大/山大

ATLAS Phase-2

Prepare for 140-200 pile-up events
Replace Inner Tracker
New L0/L1 trigger scheme
Upgrade muon/calorimeter electronics
Upgrade of DAQ detector readout

ITK： 高能所/清华
RPC： 科大/山大/交大
HGTD： 6家单位

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