“粒子物理前沿”卓越中心

2019年高能量前沿工作报告

金山，赵政国，娄辛丑

Contributors: 高杰，阮曼奇，马连良，孙勇杰，曹庆宏，徐庆金，于润升，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
- 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”

- 汇聚人才：装置建设、科学研究
- 培养队伍：实战历练、国际视野
- 制度创新：突破瓶颈、高效运作
- 整合资源：资源共享、综合利用
- 长远部署：积极开拓、持续发展

加速原始创新力争国际领先

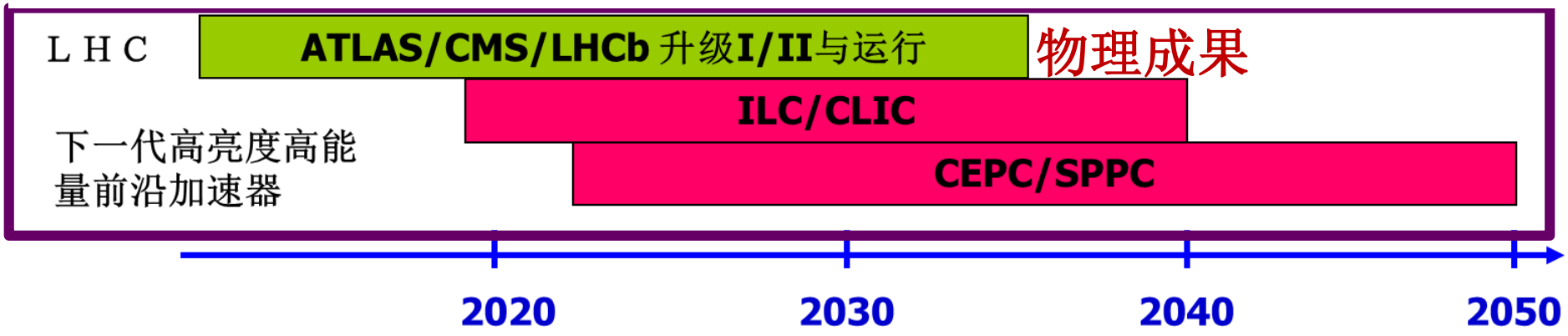
王贻芳(卓越中心答辩报告）

高能量前沿简介—研究方向

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）



新发展

- ILC 时刻表延后
- CERN FCC采用CEPC思想路线（先ee,后pp)
- 欧洲粒子物理战略规划考虑CEPC
- 中国政府拟启动大科学、大工程培育计划

平台3 – 高能量前沿简介—人员、经费支持

- 人员

重视"科学成果 产出"，"关键-前沿技术","人才引进-培育"

学术带头人

金山（南京大学）

赵政国（中国科学技术大学）

娄辛丑（高能所研究员）



~300+ 名关键、青年骨干、 博士后和研究生+工程技术人员

- 经费支持
  - 自带干粮
  - 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; 基金委ATLAS、CMS物理分析（2016, 19）
  - 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-）……

高能量前沿简介—长期规划

和整个卓越中心建设一起在细化考虑中。现期考虑的要点为：

- 瞄准国际前沿，敢于问鼎科学创新顶峰
- 围绕CEPC-SppC进行设计、关键技术、实验方案研究 立项、建设和实施、国际合作培育
- 培养年轻人才钻研创新能力，掌握技术和实验手段
- 增强高能物理研究队伍的规模
- 在LHC实验上： 出成果；学习探测器、电子学技术 和运行经验；培养有第一手经验的骨干
- 积极开展国际合作、交流，提高水平
- 争取适合于高能物理大科学的经费长期稳定支持

……

2019年科学研究进展

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

研究方向进展: 理论

Qinghong Cao

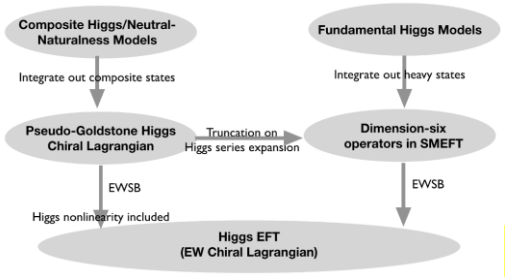
LHC唯象学及TeV新物理理论进展

实验对理论计算精度的要求进一步提高，各种有效场论方法与传统唯象学研究并重。

有效场论

EFTs meet Higgs nonlinearity, compositeness and (neutral) naturalness

Hao-Lin Li,[a] Ling-Xiao Xu,[b] Jiang-Hao Yu[a,c] and Shou-hua Zhu[b,d,e]



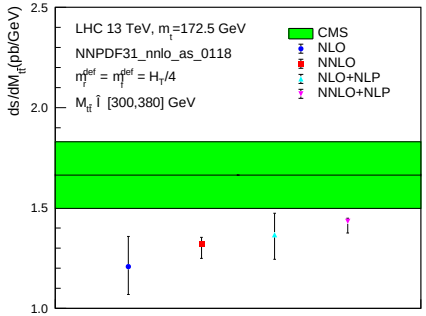
理论所
于江浩

精确计算

Invariant-mass distribution of top-quark pairs and top-quark mass determination

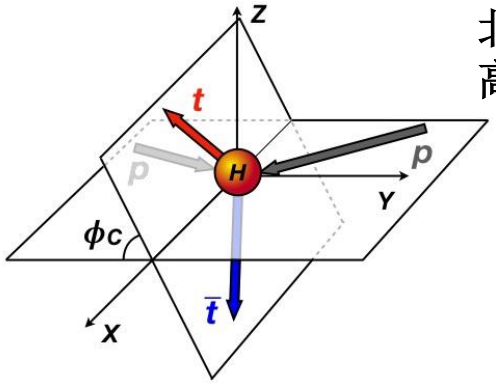
Wan-Li Ju,[1] Guoxing Wang,[1] Xing Wang,[1] Xiaofeng Xu,[1] Yongqi Xu,[1] and Li Lin Yang[1,2,*]

[1]School of Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China
[2]Center for High Energy Physics, Peking University, Beijing 100871, China



北京大学
杨李林

唯象学



北京大学曹庆宏、
高能所张昊

理论-实验互动

- ✓ 2018年组建的LHC理论实验联合讨论已步入正轨，每一到两个月定期讨论，并提供Vidyo远程参与服务。
- ✓ 讨论群邮列表：exp-ph-th-comm@maillist.ihep.ac.cn，召集人陈明水、黄燕萍、张昊 （申请加入请发邮件至zhanghao@ihep.ac.cn）。

研究方向进展: 理论

Qinghong Cao

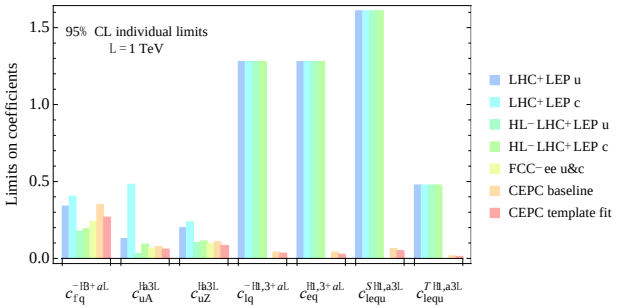
CEPC理论（国内）进展和状态

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

Probing the top quark flavor-changing couplings at CEPC*

Liaoshan Shi (石辽珊)[1] Cen Zhang (张岑)[1,2]

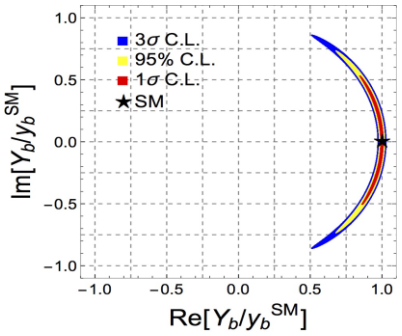


高能所
张岑

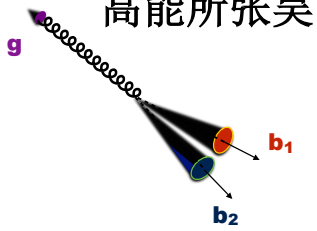
Higgs性质

Investigating Bottom-quark Yukawa Interaction at Higgs Factory *

Qi Bi[1,2], Kangyu Chai[1,2], Jun Gao[3,4], Yiming Liu[1,2], Hao Zhang[1,2,4], Edmond L. Berger[5]



上海交大高俊，
高能所张昊

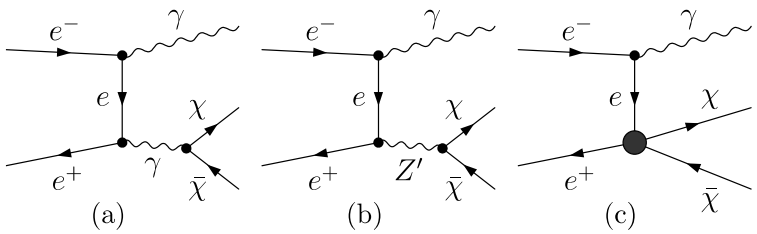


新物理（暗物质）

Probing dark matter particles at CEPC

南京大学
刘佐伟

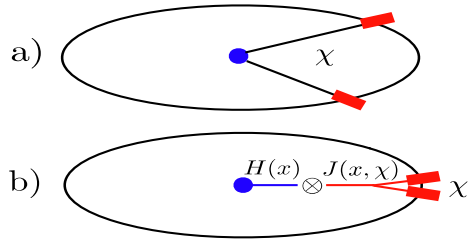
Zuowei Liu,[a,b,c] Yong-Heng Xu[a] and Yu Zhang[d,c]



QCD理论

The Collinear Limit of the Energy-Energy Correlator

Lance J. Dixon,[1] Ian Moult,[2,3] and Hua Xing Zhu[4]



浙江大学
朱华星

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44名教职员工，2019年新增4位

- 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18名
- 博士后28名
- 学生、工程师和技术人员

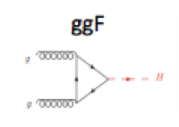
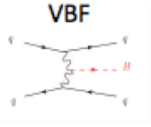
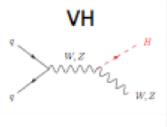
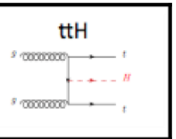
IHEP-NJU-THU Cluster(高能所-南大-清华联合组)

- 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（百人）
- Nanjing University（南大）
  金山（万人、杰青）、张雷、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
- Shandong University(山大)
  张学尧、冯存峰、祝成光、马连良（青千）、李海峰
- Shanghai Jiao Tong University(上海交大)
  杨海军（青千）、李亮（青千）、郭军（青千）、周宁（青千）、邬维浩
- T.D. Lee Institute(李政道研究所) 李数（青千）、刘坤

研究方向进展 ATLAS, CMS 实验

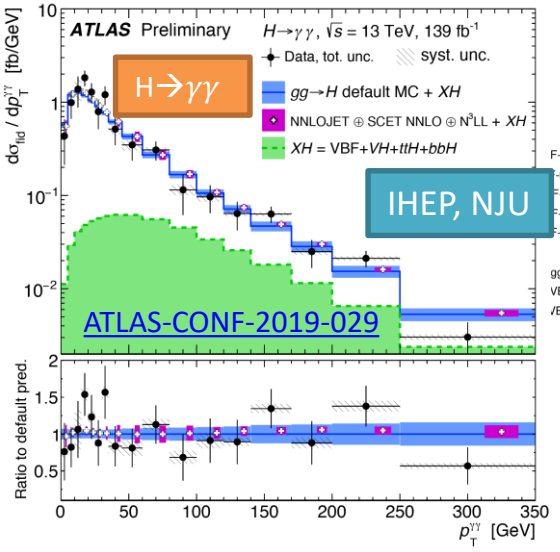
Channel	ggF 	VBF 	VH 	ttH 	Mass	CP	X-sec.	Width
γγ	★★	★★	★★	★★	★★	★★	★★	★
ZZ*(4l)	★★	★★	★★	★★	★★	★★	★★	★★
WW*(lνlν)	★★	★★	★★	★★		★★	★★	★★
ττ	★★	★★	★★	★		★★		
bb	★★		★★	★★				
Zγ	★★							
μμ	★★	★★	★★	★★				
invisible	★★	★★	★★					

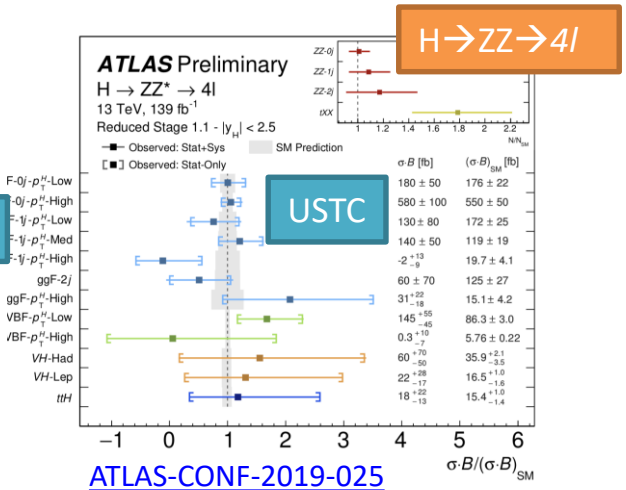
★ ATLAS进行的分析 ★中国组贡献的分析

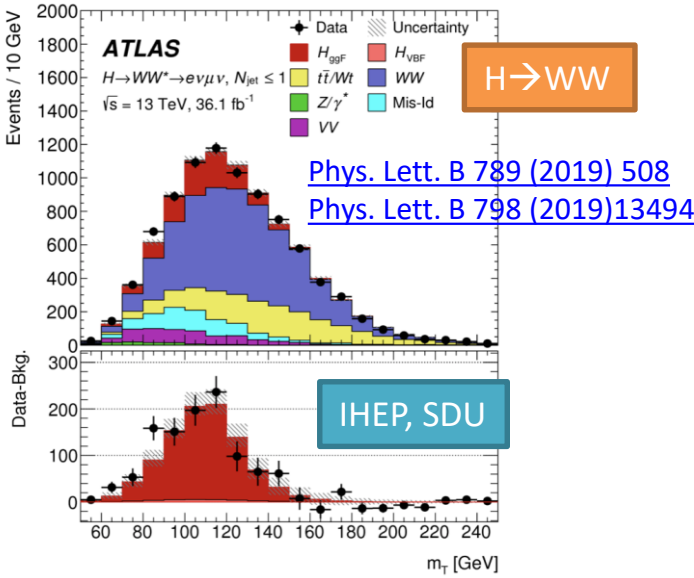
- 标准模型Higgs性质研究及相关新物理的寻找
- 标准模型物理过程的测量检验
- 新物理直接寻找：SUSY，Exotics

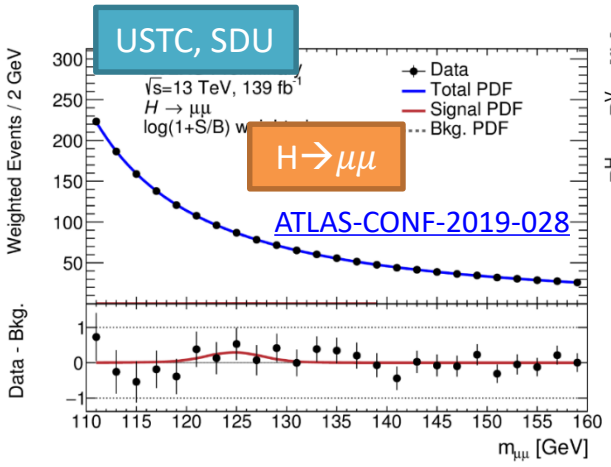
研究方向进展 ATLAS, CMS 实验

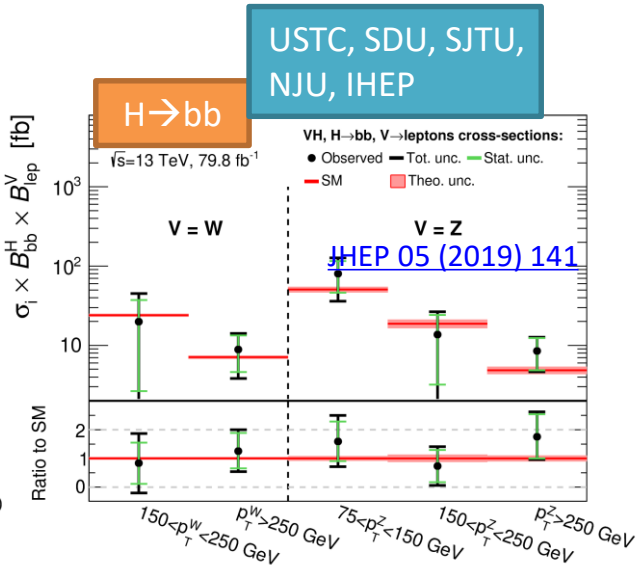
希格斯衰变到玻色子或轻子过程







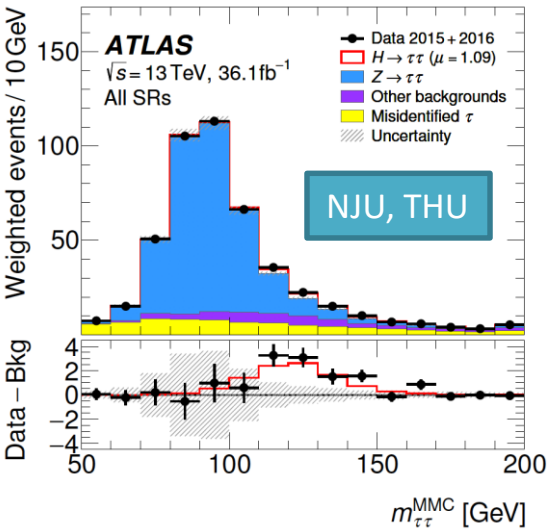




研究方向进展 ATLAS, CMS 实验

希格斯衰变到双tau末态和ttH过程

Phys. Rev. D 99 (2019) 072001

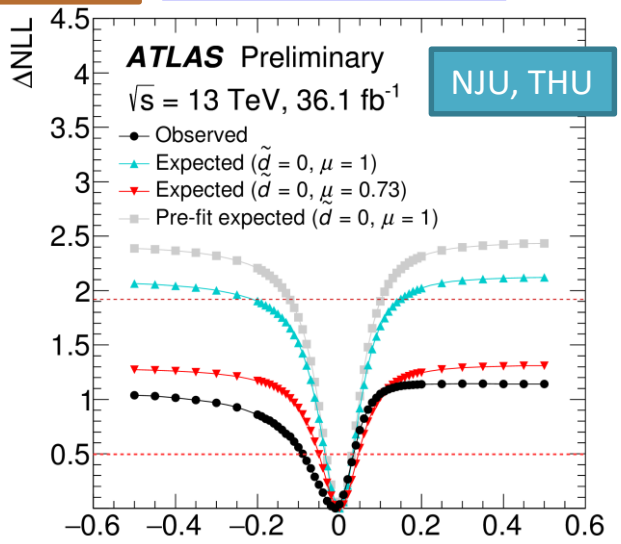


36/fb数据： 4.4σ （预期4.1σ）

联合Run−1： 6.4σ （预期5.4σ）

H→ττ

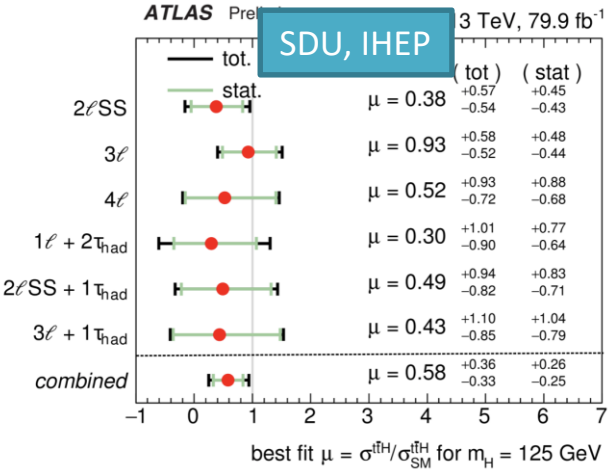
ATLAS-CONF-2019-050



36/fb数据：通过测量最优变量$\tilde{d}$寻找可能的CP破坏：$\tilde{d} \neq 0$

ttH,H→multi-lepton

ATLAS-CONF-2019-045

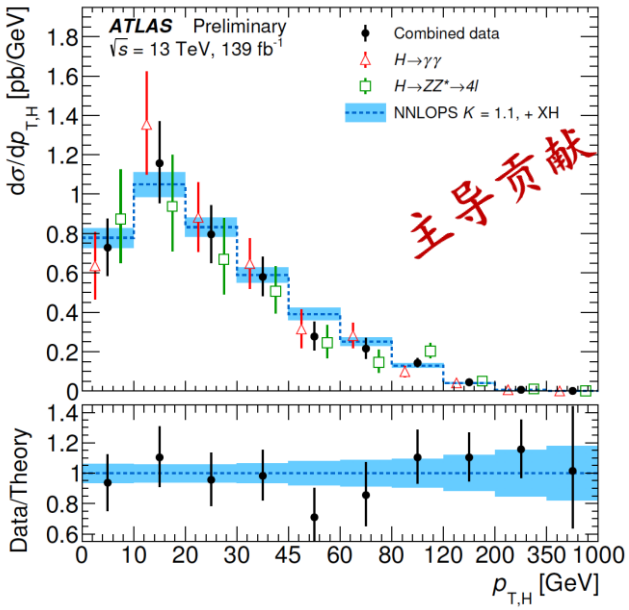


1.8σ （预期3.1σ）

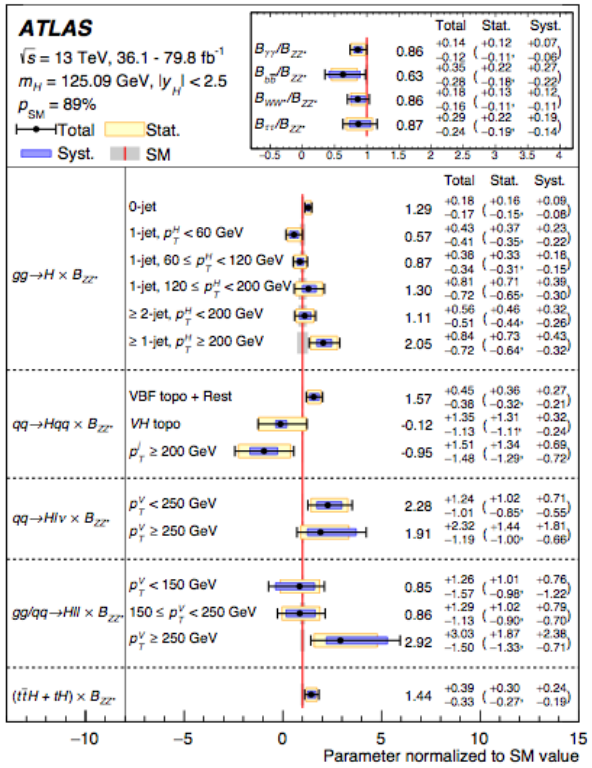
研究方向进展 ATLAS, CMS 实验

希格斯联合统计分析

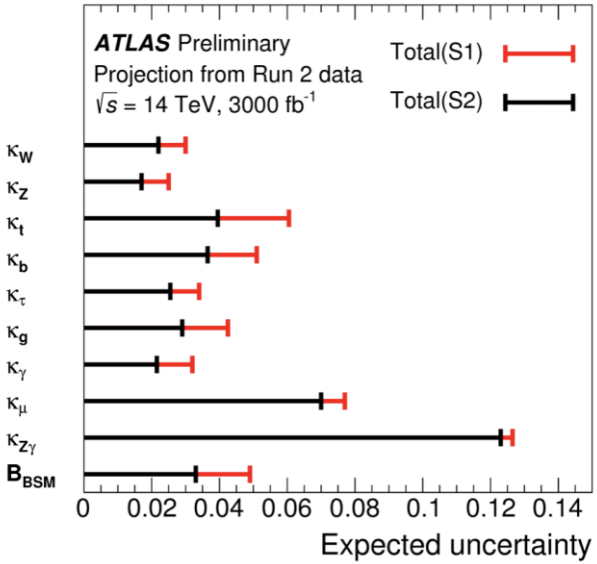
ATLAS-CONF-2019-032



arXiv:1909.02845



ATL-PHYS-PUB-2018-054



- 联合H→ZZ*和H→γγ
- 测量截面pp→H+X：

$55.4^{+4.3}_{-4.2}$ pb ($\pm 3.1(\text{stat.})\ ^{+3.0}_{-2.8}(\text{sys.})$)

- 理论截面：55.6 ± 2.5 pb
- **高能所**作出主导贡献

- 全局信号强度μ=$1.1^{+0.09}_{-0.08}$，
- 给出Stage-1最简化模式截面测量
- **高能所、交大(/李所)**作出主要贡献

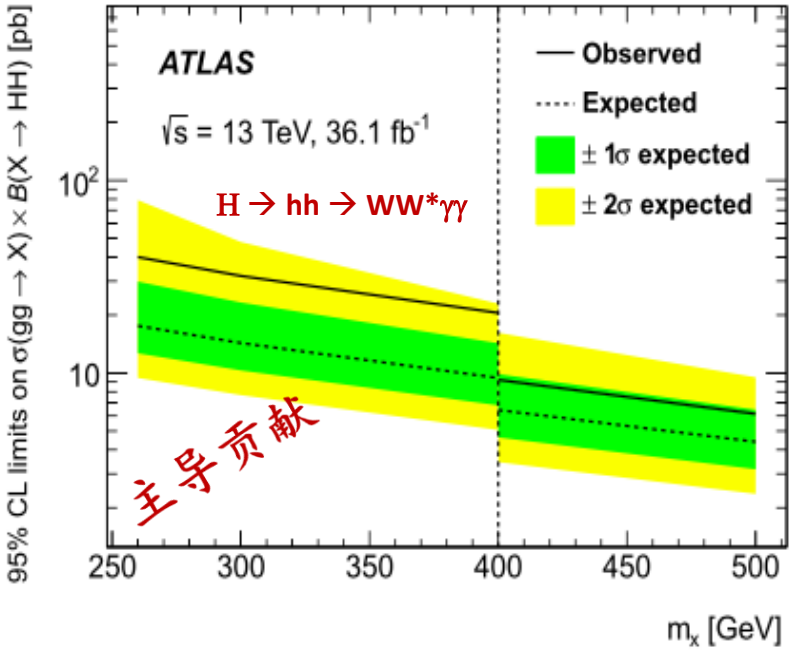
- 利用Run-2部分数据分析的初步结果推算HL-LHC可以得到的测量精度
- 山大作出主要贡献

研究方向进展 ATLAS, CMS 实验

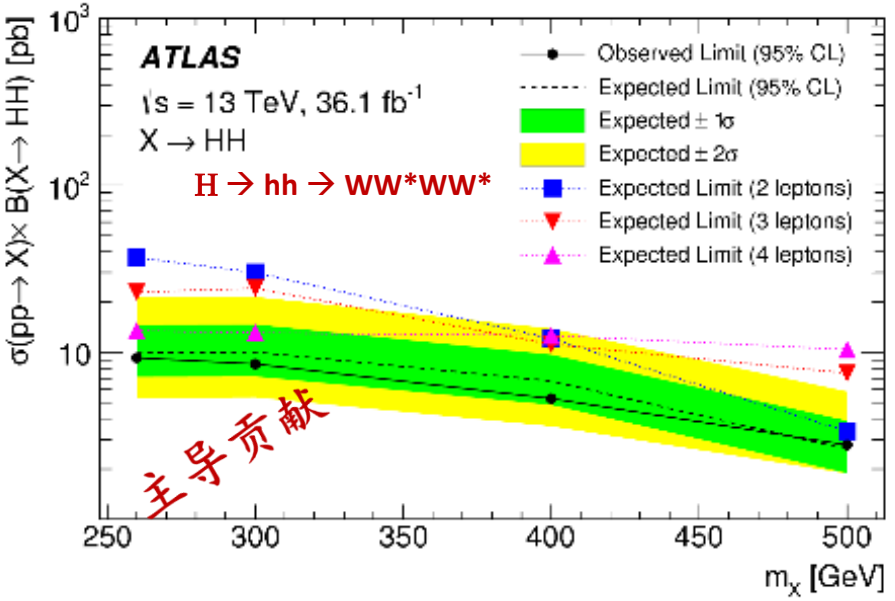
双希格斯过程寻找

- 利用WW*γγ和WWWW末态寻找希格斯粒子对产生过程
- 标准模型预言双希格斯产生过程，截面为33.4 fb；新物理则可出现在双希格斯共振态或者不同与标准模型预言的产生截面
- 高能所、交大作出主导贡献

Eur. Phys. J. C 78 (2018) 1007

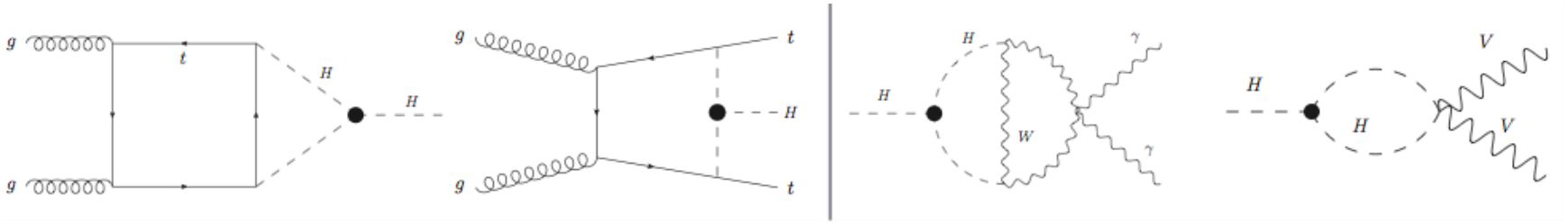


JHEP 05 (2019) 124

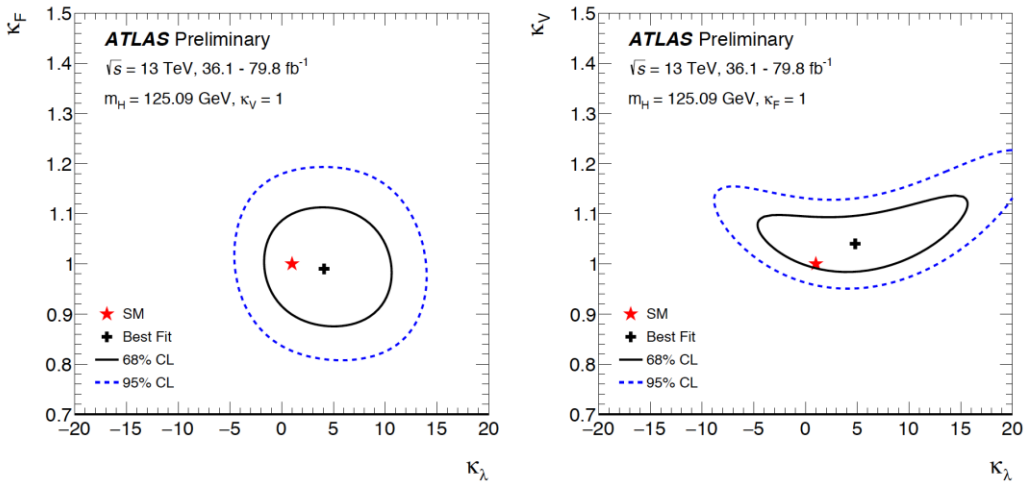


研究方向进展 ATLAS, CMS 实验

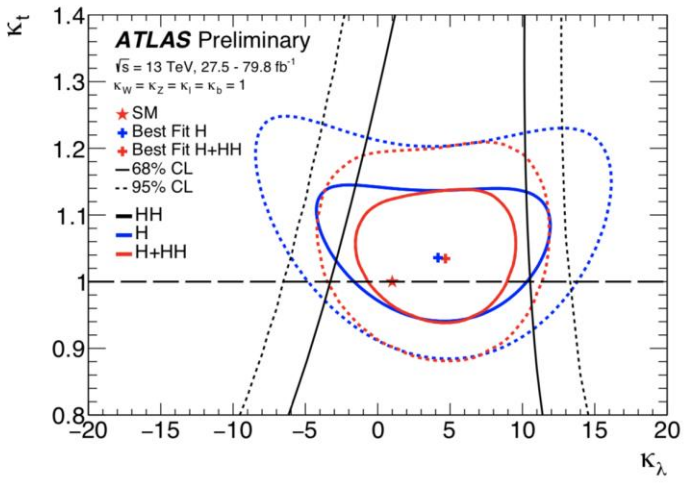
希格斯自耦合测量



ATL-PHYS-PUB-2019-009



ATLAS-CONF-2019-049



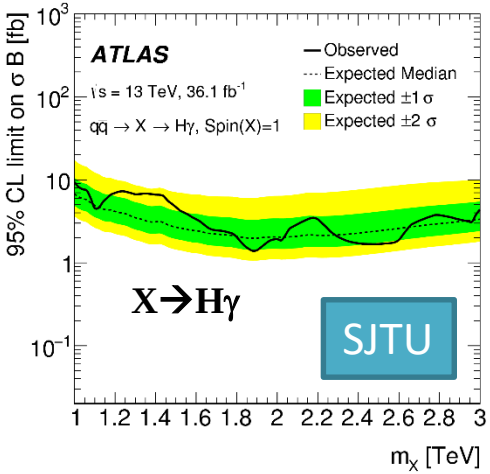
- 在single Higgs 过程中考虑电弱修正从而间接地测量Higgs self-coupling，采用这种新方法的相关结果首次发表（ $\mu_{if}(\kappa_\lambda) = \mu_i(\kappa_\lambda) \times \mu_f(\kappa_\lambda) \equiv \frac{\sigma_i(\kappa_\lambda)}{\sigma_{\mathrm{SM},i}} \times \frac{\mathrm{BR}_f(\kappa_\lambda)}{\mathrm{BR}_{\mathrm{SM},f}}$ ）
- Di-Higgs和single Higgs的联合统计分析给出更加严格$\kappa_\lambda = \kappa_{HHH} / \kappa^{SM}_{HHH}$的束缚
- 高能所、南大作出主要贡献

$$-2.3 < \lambda_{HHH}/\lambda^{\mathrm{SM}}_{HHH} < 10.3$$

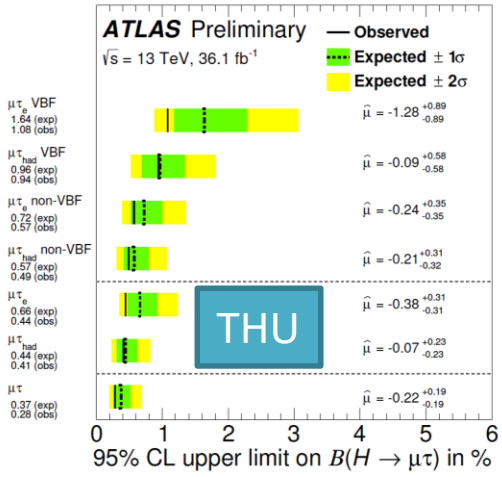
研究方向进展 ATLAS, CMS 实验

通过希格斯粒子寻找新物理

PRD 98 (2018) 032015



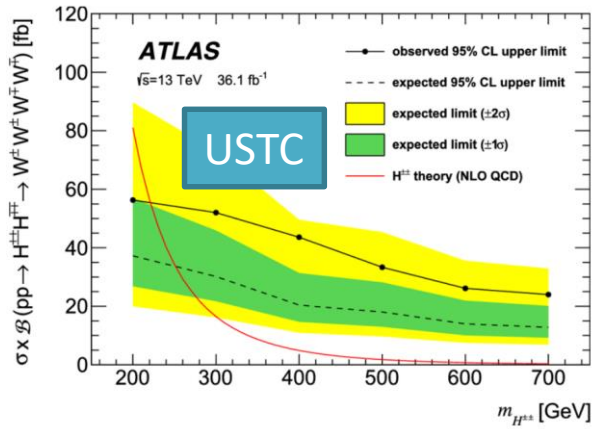
➢LHC实验上首个通过H+ γ 末态寻找可能的共振态



arXiv:1907.06131

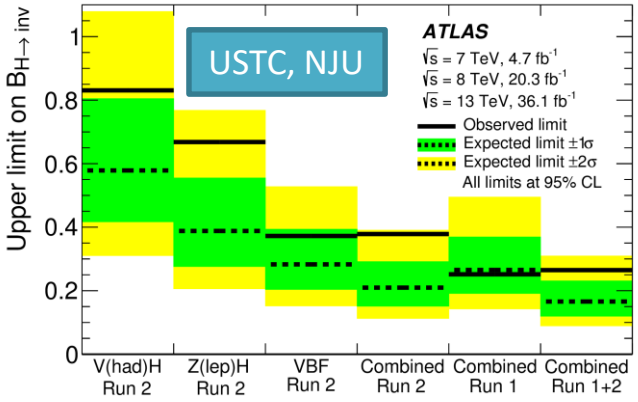
- Upper limits at 95% CL:
  - Br(H→eτ): <0.47%
  - Br(H→$\mu\tau$): <0.28%

Eur. Phys. J. C 79 (2019) 58



➢ 利用多轻子末寻找double charged Higgs

Phys. Rev. Lett. 122 (2019) 231801



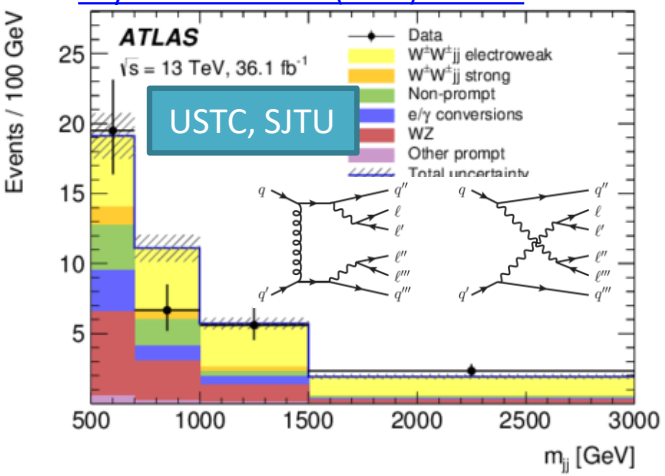
➢ 希格斯衰变到不可见末态上限：Br<26%

研究方向进展 ATLAS, CMS 实验

5σ Observation on SM Physics processes

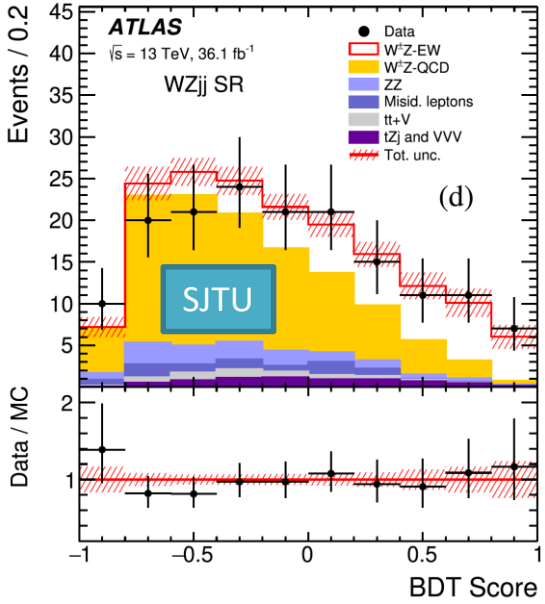
VBS WWjj 6.5 σ

Phys. Rev. Lett. 123 (2019) 161801



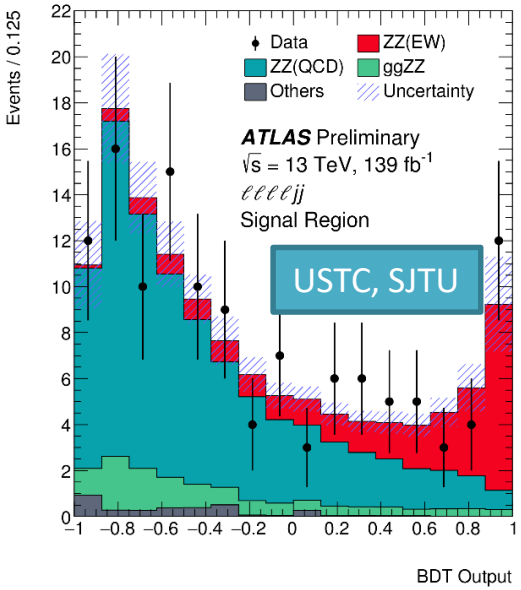
VBS WZjj 5.3 σ

Phys. Lett. B 793 (2019) 469



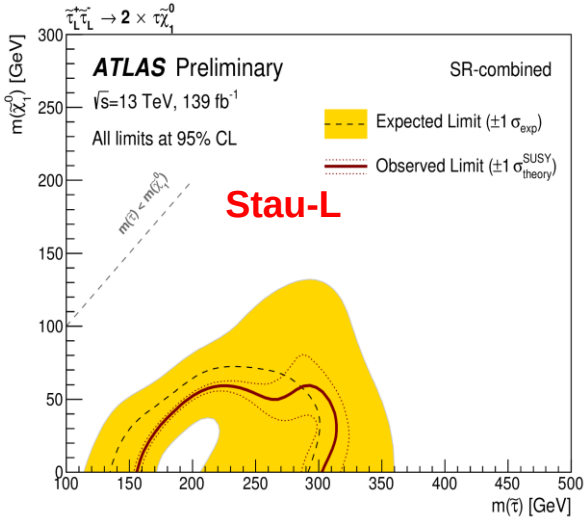
VBS ZZjj 5.5σ

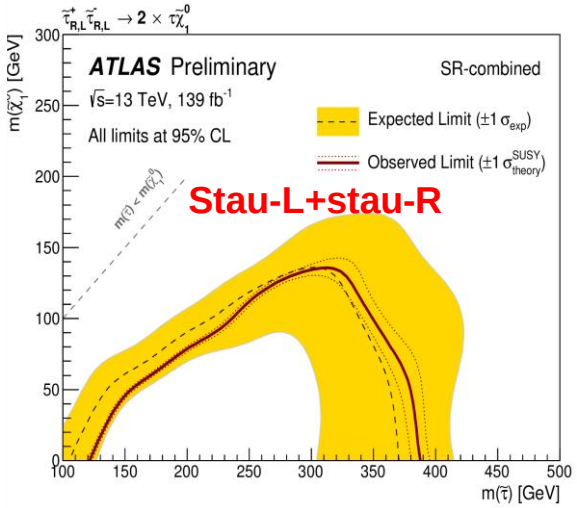
ATLAS-CONF-2019-033



研究方向进展 ATLAS, CMS 实验

SUSY粒子的寻找



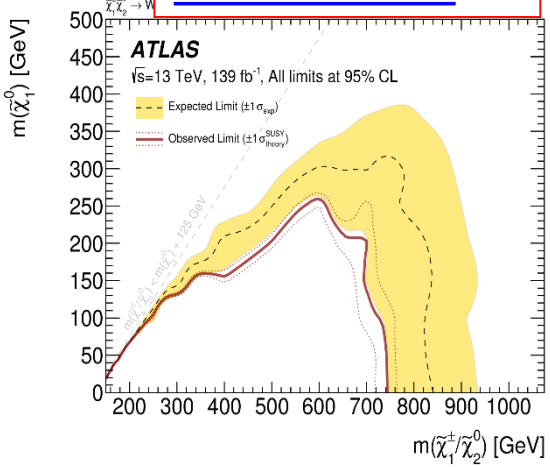


Direct stau Run-2:
ATLAS-CONF-2019-018

首次给出LHC实验stau粒子的排除上限

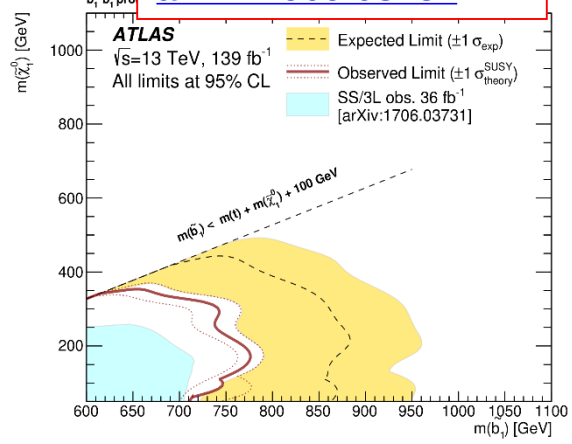
IHEP, NJU

Wh (lvbb) Run-2:
arXiv:1909.09226

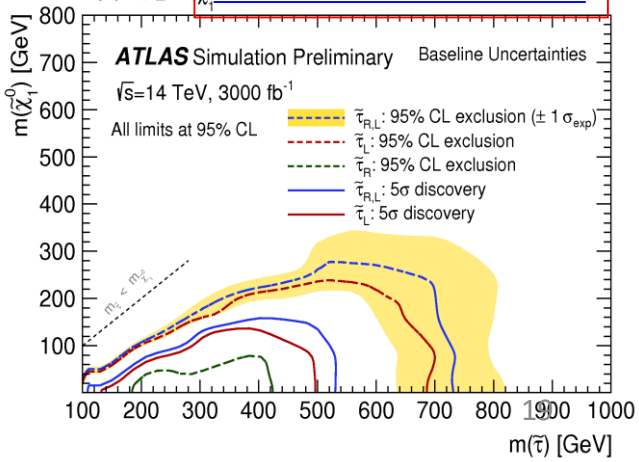


SS/3L Run-2:
arXiv:1909.08457

IHEP



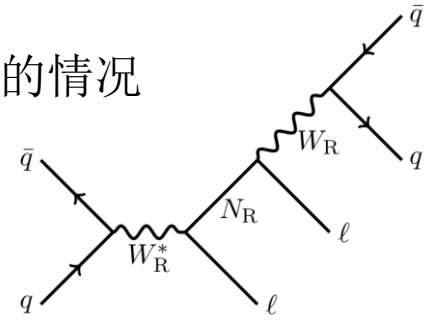
arXiv:1812.07831
ATL-PHYS-PUB-2019-006



研究方向进展 ATLAS, CMS 实验

新物理寻找：Exotic

- 通过双轻子+双喷注末态寻找右手Majorana/Dirac重中微子N_R或者右手重玻色子W_R
- 首次考虑了N_R比W_R质量重的情况
- 科大作出主要贡献



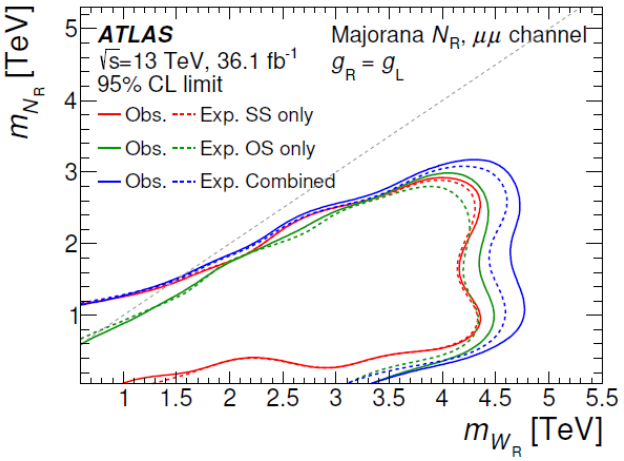
- 清华首次开展$\tau\tau$末态的分析，联合其它分析末态发表了世界上最严格上限：

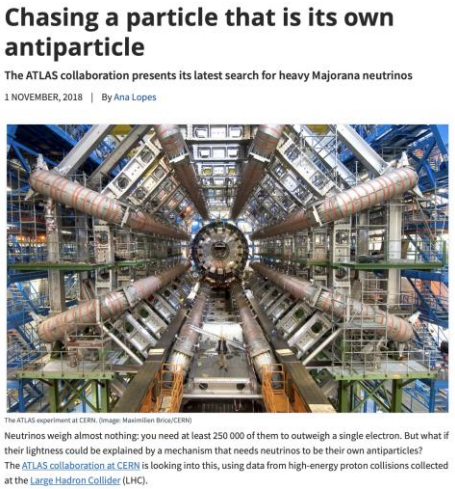
$$B(t\to Hq) < 1.1\times10^{-3}$$

- 清华作出主导贡献

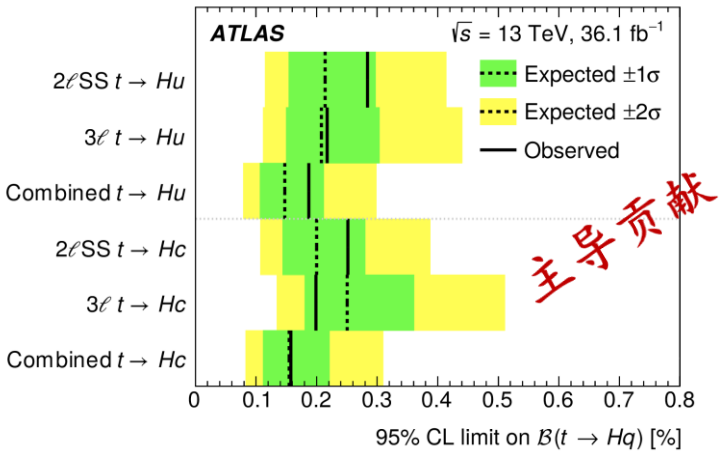
Phys. Rev. D 98 (2018) 032002

JHEP 01 (2019) 016





CERN 新闻



研究方向进展 ATLAS, CMS 实验

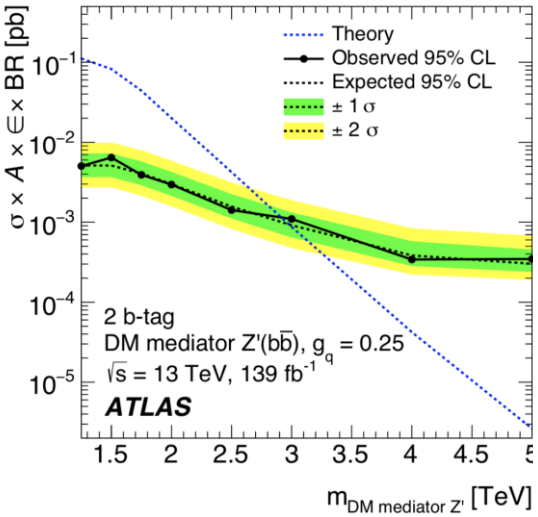
暗物质寻找:dijet + X

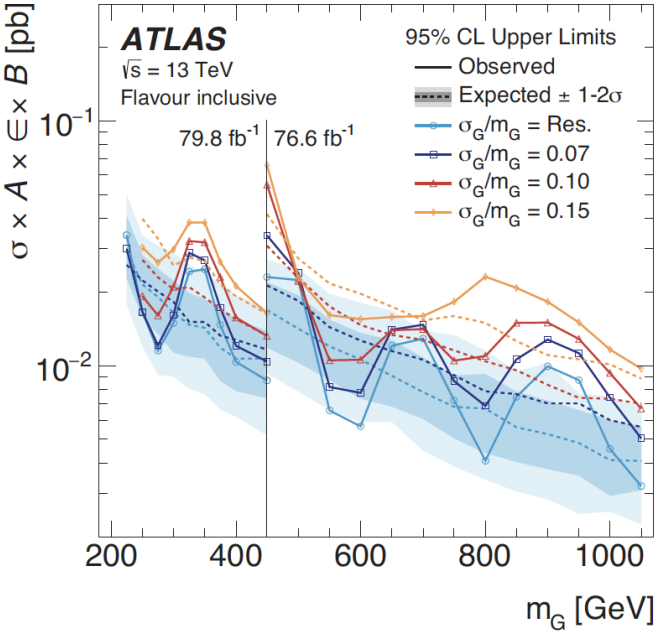
- 分析全部Run-2数据来寻找新物理预言的双喷注共振态
- 交大、清华作出主导贡献

- 利用双喷注+1个光子寻找Z' (axial-vector dark-matter)
- 利用初态辐射光子覆盖低质量区间
  - Dijet mass： 225 GeV–1.1 TeV
- 清华、交大作出主要贡献

Phys. Lett. B 795 (2019) 56

arXiv:1910.08447





研究方向进展 ATLAS, CMS 实验

CMS中国组

单位	职工人数	博士后人数	学生人数	总人数	Authors
高能所	17	6	16	39	13
北大	5	3	20	28	11
北航	1		5	6	3
清华	4	2	5	11	4
中山大学	1		4	5	
浙江大学	3	0	3	6	1
总数	31	11	53	95	32

CMS文章签名人数占CMS总签名人数1.5%

其中浙江大学（肖朦）今年2月份正式加入CMS合作组。

另外复旦大学今年9月份已经申请加入CMS合作组，目前有两个职工（沈成平和大川英希）、一个博士后和数名学生；

南京师范大学（易凯）也将申请加入。

研究方向进展 ATLAS, CMS 实验

CMS-IHEP

- 发表以高能所为主（分析contact）的CMS文章3篇，约占同期CMS文章的3%
- 发表有其他重要贡献的CMS文章6篇
- 代表CMS在国际会议Plenary 报告8个，parallel和poster 8个
- 希格斯性质研究：H-->ZZ-->4l, H-->γ γ 质量和截面，ttHWW, ttHbb，ttH γ γ
- 新粒子寻找：低质量额外H--> γ γ， X-->HH,VH
  特殊规范玻色子，激发态b夸克，leptoquark,
  vector-like-quark
- 标准模型：underlying event

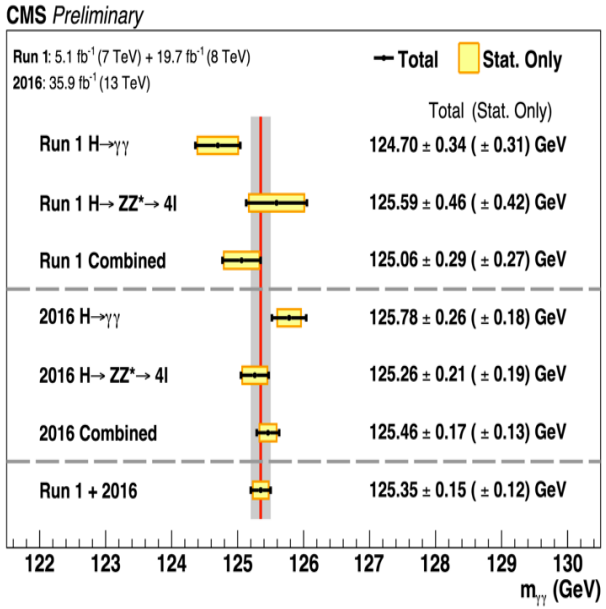
研究方向进展 ATLAS, CMS 实验

CMS-IHEP

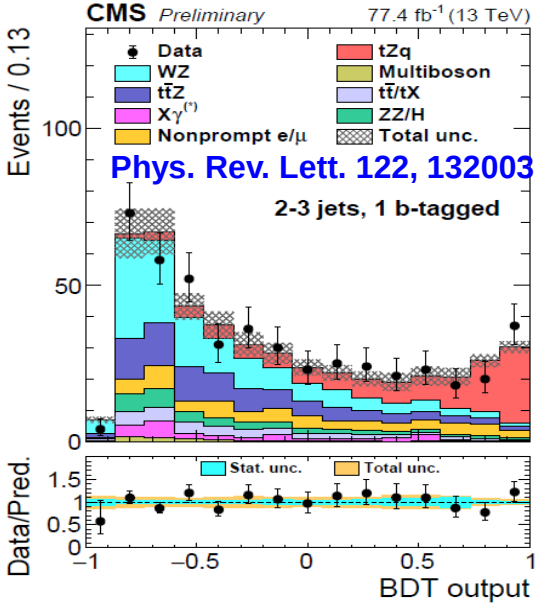
H->γγ与H->4l 合并测量得到

m_H = 125.35±0.12(stat)±0.09(syst) GeV

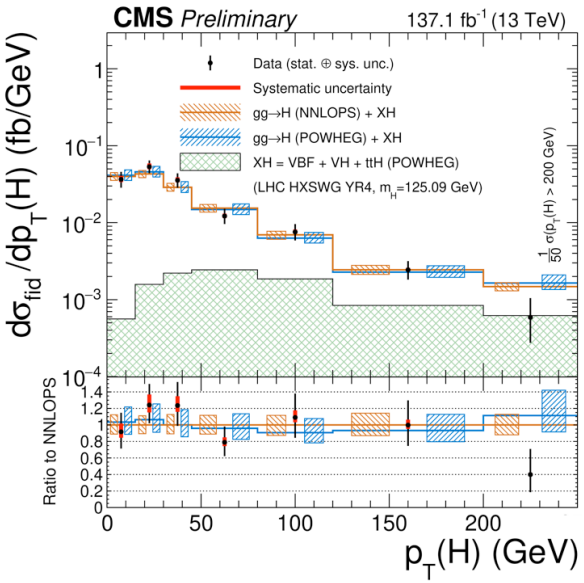
CMS给出当前世界上最精确的测量结果，精度为： 0.12%



高能所在测量中起到关键作用，该结果由陈明水代表合作组于10月1日在牛津大学举办的Higgs Couplings 2019 大会上首次公开



5 σ 发现标准模型tZq过程



H->ZZ->4l: 产生截面测量

研究方向进展 ATLAS, CMS 实验

电弱物理研究进展

3个北大作为负责人的CMS分析

- SMP-18-007 (Meng Lu) VBS Zγ
- SMP-19-002 (A. Levin) Inclusive Wγ
- SMP-19-008 (Q. Huang) VBS Wγ

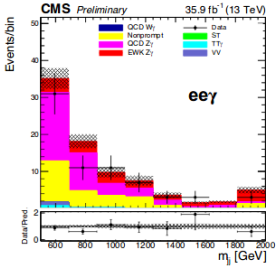
VBS Zγ及VBS Wγ预期敏感度都超过5倍标准偏差。

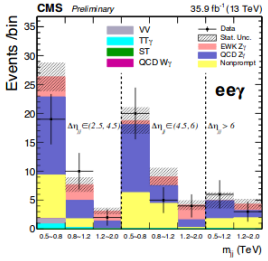
VBS: EWK Zγ production with two jets

Vector boson scattering directly probes EWK SM gauge structure

- Selection reduces contribution from strong production
- Signal extracted from 2D fit to properties of the djiet system: m_{jj} and $\Delta\eta_{jj}$

SMP-18-007 NEW!



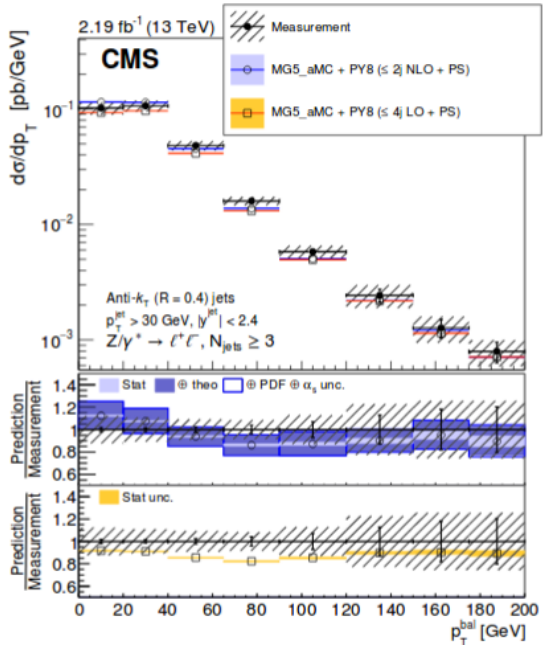


Obs (exp) significance
- this analysis: 3.9 (5.2) s.d.
- combination with 8TeV: 4.7 (5.5) s.d.

Signal strength (fid. region): $0.64^{+0.23}_{-0.21}$

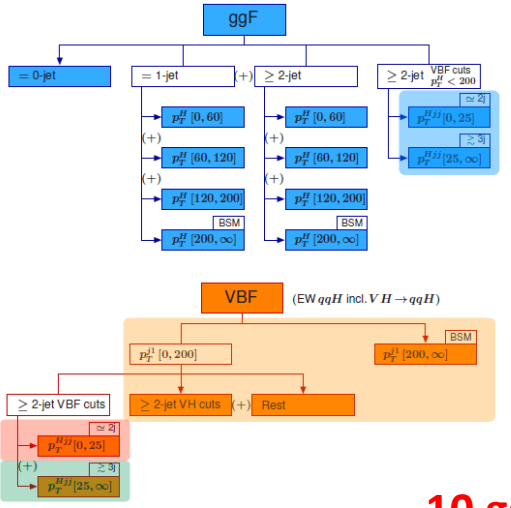
Limits on anomalous QGC parameters:
- the analysis sets the most stringent limits to date on two of these parameters ($F_{T,8}/\Lambda^4$ and $F_{T,9}/\Lambda^4$)

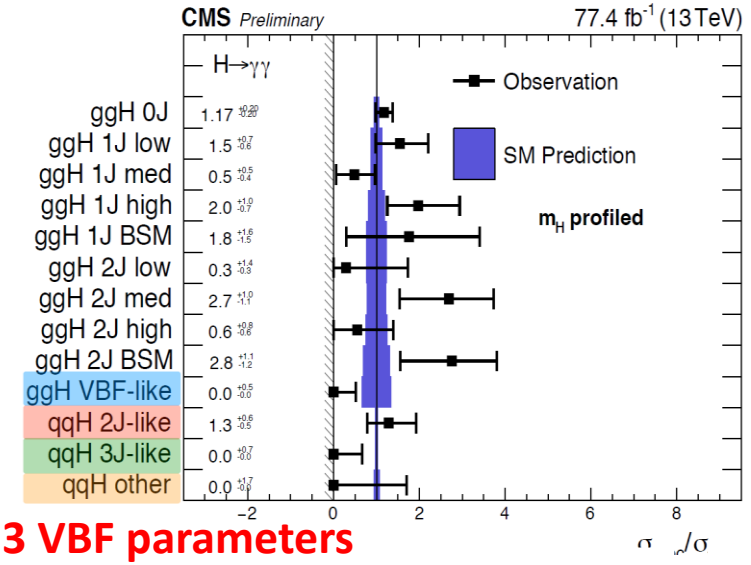
Z+Jets精细测量



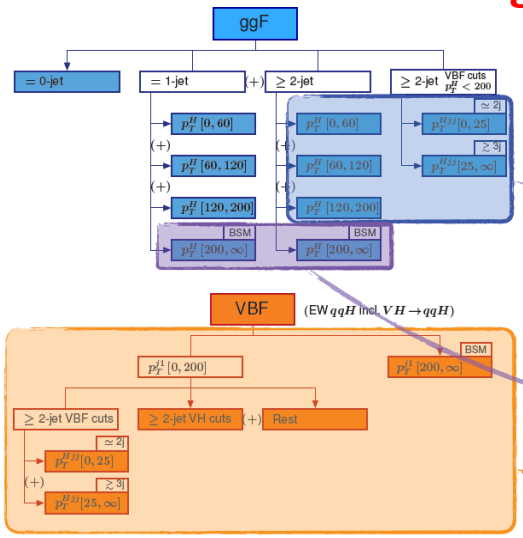
H->γγ：STXS Simplified Template Cross Sections 测量

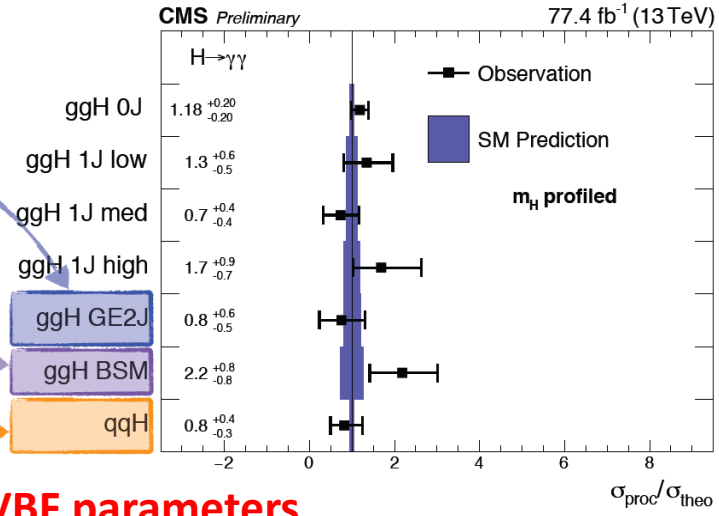
基于2016、2017两年的13TeV 77.4 fb^{-1}的数据,测量Stage-1 H→γγ 的简约模板截面





10 ggH + 3 VBF parameters



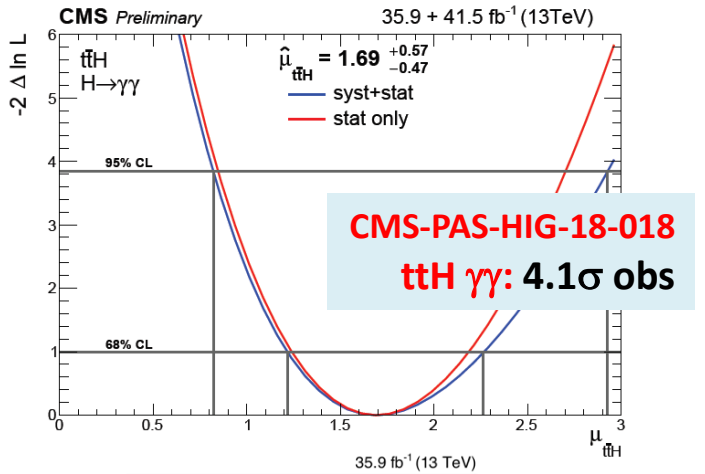


6 ggH + 1 VBF parameters

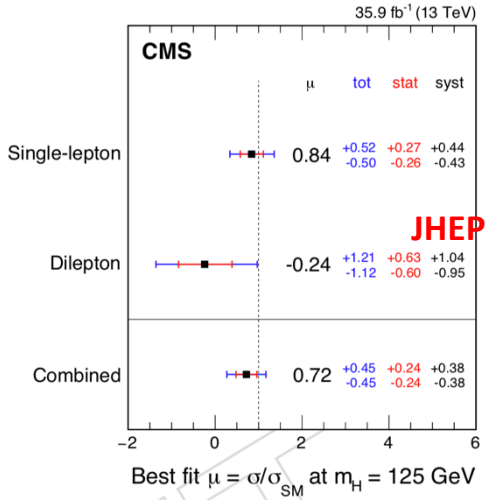
ttH实验测量

- 直接研究和证明希格斯粒子和顶夸克之间的汤川相互作用，对理解费米子的质量起源有着重要的意义。在观测到ttH之后，实验上仍需直接在各单衰变道测量、检验 topYukawa 耦合
- 中国组在多轻子衰变道、双底夸克衰变道以及双光子衰变道加强了布局
  - 正反底夸克道 **高能所**
  - 双光子道 **高能所、浙大**
  - 多轻子道 **高能所、北大**

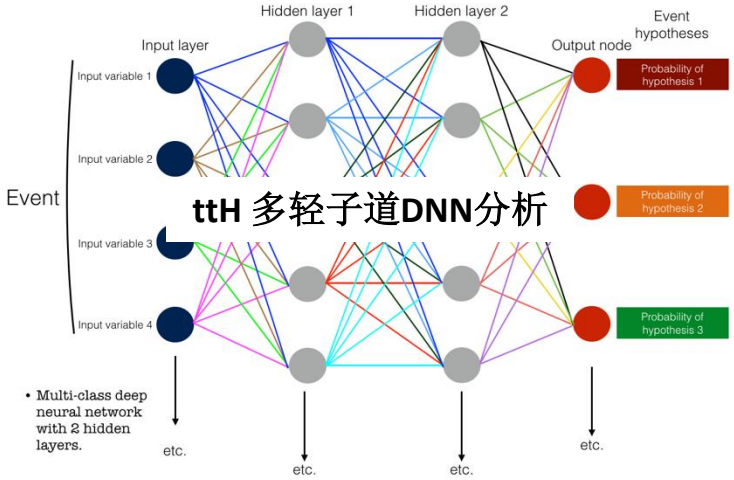
正在推进多个分析的文章发表



CMS-PAS-HIG-18-018
ttH γγ: 4.1σ obs



JHEP 03 (2019) 026
ttH bb



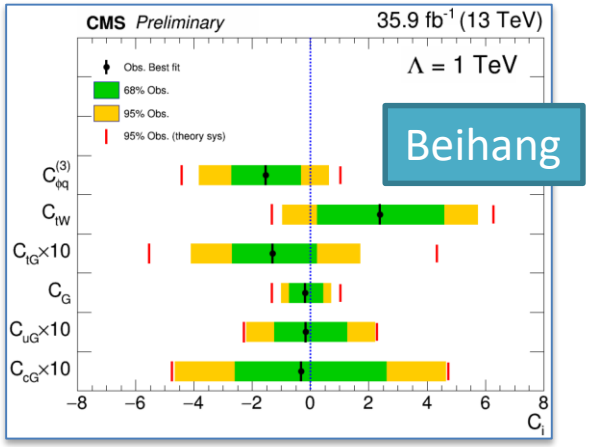
ttH 多轻子道DNN分析

研究方向进展 ATLAS, CMS 实验

新粒子寻找

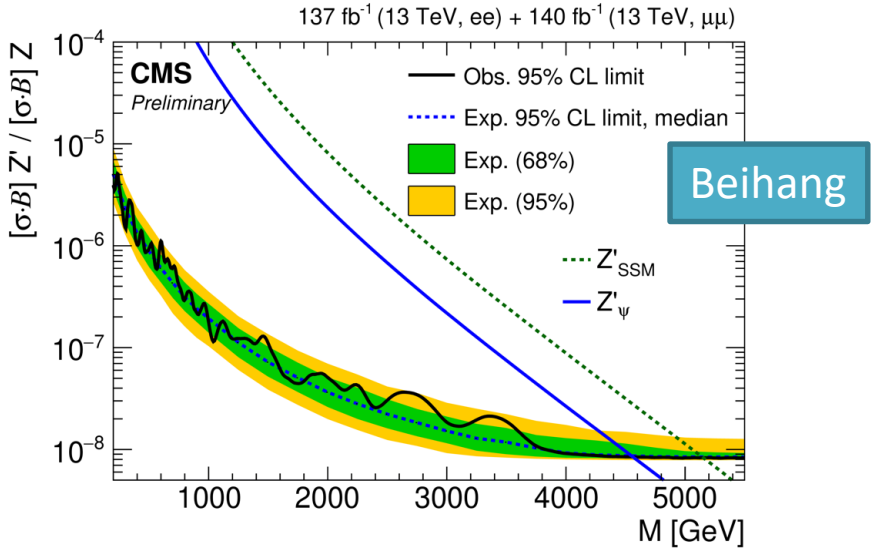
arXiv:1903.11144

双轻子末态tW寻找含top产生过程

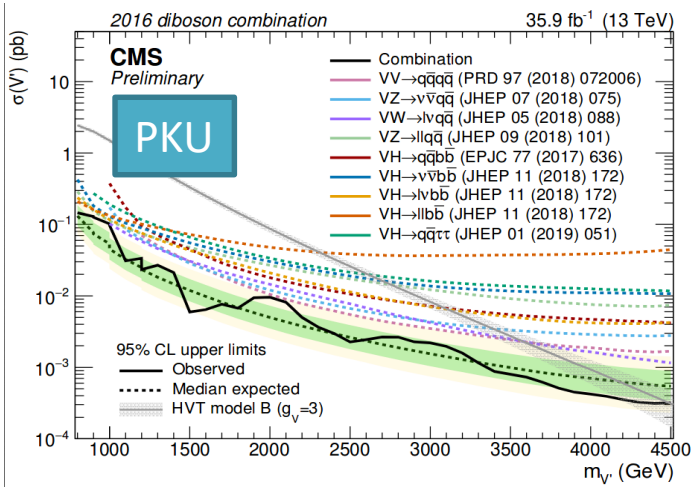


Beihang

大质量 Z’ CMS-EXO-19-019



Beihang



PKU

双、多玻色子共振态

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**

Progress and updates – CEPC Day

CEPC Day – post CDR monthly team meeting on progress, problems and issues, plus CEPC **Steering Committee Meeting,** held since February, this year.

¼-1/3 of the overall CEPC will be covered each CEPC Day, complete coverage 3-4 months

Set aside time for detailed discussions

example **morning—afternoon sessions are open to all CEPC stakeholders**

September 27, 2019

9:00 – 12:00 Detector, Software, Physics

12:00 – 13:45 Steering Committee Meeting

14:00 --17:30 Accelerators

Vidyo link:

http://vidyo.ihep.ac.cn/flex.html?roomdirect.html&key=P1kF5j5SQDoTFh2veKCFcXJGPGQ

Room Extension: 0020188011001

Indico Page:

https://indico.ihep.ac.cn/event/10617/

CEPC Development – expert committees

- **Accelerator review committee** – recommended by the IAC, established and will meet in this week at this workshop (November, 2019) **help with CEPC TDR**
- **Detector R&D committee** – recommended by the IAC, a large committee (~16 members) has been established; first meeting November,2019， **help with detector R&D, selection of detector LOC, detector collaborations, and more**

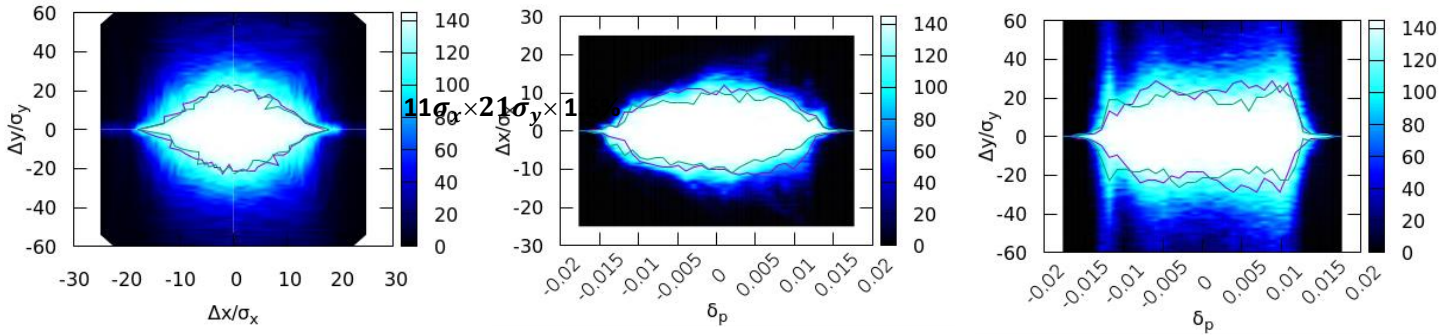
We expect to benefit greatly from these committees

CEPC design enhancement

Dynamic aperture optimization

5/3 improvement over CDR luminosity

- Dynamic aperture optimized with the new lattice aiming at luminosity of $5 \times 10^{34}/cm^2/s$.
  - Effects of nonlinearity in lattice, synchrotron radiation, beam-beam interaction are included.
  - Multi-Object Deferential Evolution (MODE) algorithm used to make global optimization.
  - DA goal $8\sigma_x \times 15\sigma_y \times 1.7\%$
- More efforts will be made to enlarge the momentum acceptance.
- The goal will be adjusted with further beam lifetime study which is under going.

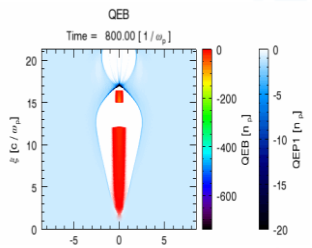


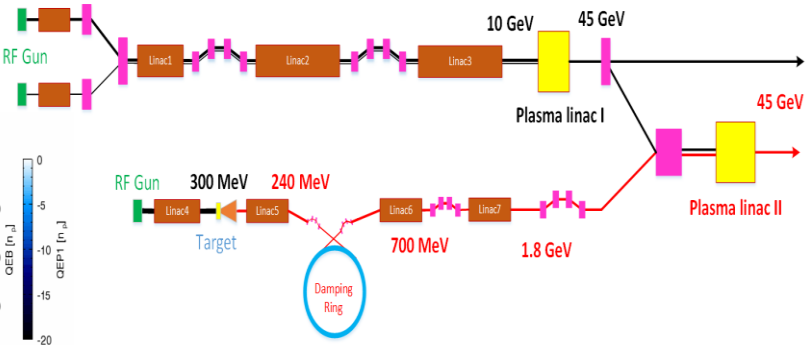
Jie GAO

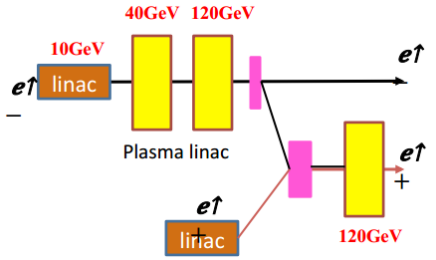
CEPC design enhancement

Experimental Verification Planfor CEPC Plasma Injector Scheme

A dedicated budget of 8Million has been alocated by IHEP



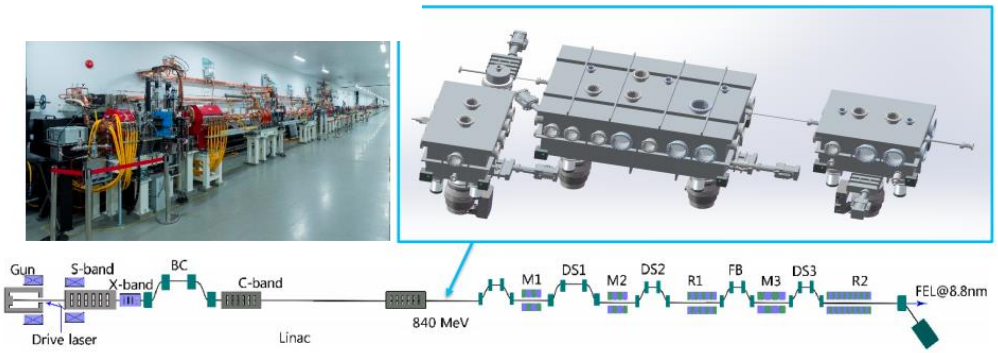




Technical design review has been done (August 22,2019)

Plasma density $n_0(cm^{-3})$	5.15×10^{16}
Driver charge $Q_d(nC)$	6.47
Driver energy $E_d(GeV)$	10
Driver length $L_d(\mu m)$	285
Driver RMS size $\sigma_d(\mu m)$	10
Driver normalized emittance $\epsilon_{nd}(mm\ mrad)$	10
Trailor charge $Q_t(nC)$	1.25
Trailor energy $E_t(GeV)$	10
Trailor length $L_t(\mu m)$	35
Trailor RMS size $\sigma_t(\mu m)$	5
Trailor normalized emittance $\epsilon_{nt}(mm\ mrad)$	100

Trailor energy $E_t(GeV)$	45.5
Trailor normalized emittance $\epsilon_{nt}(mm\ mrad)$	98.9
TR	3.55
Energy spread $\delta_E(\%)$	0.7
Efficiency (driver -> trailor)	68.6%



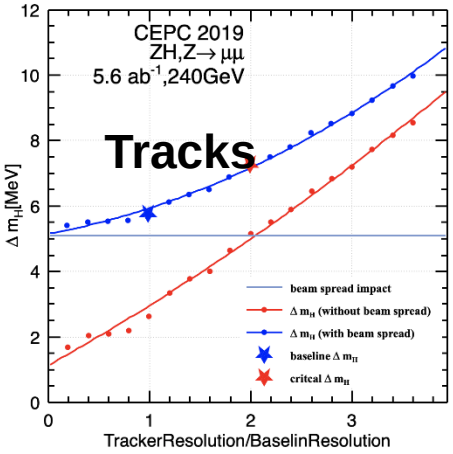
- **Electron plasma acceleration will be tested in Shanghai's Soft XFEL Facility**
- **Positron plasma acceleration scheme will be tested at FACET-II at SLAC**

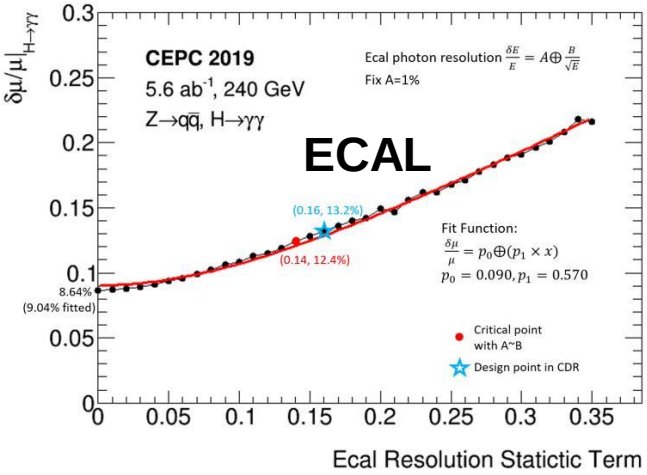
Jie GAO

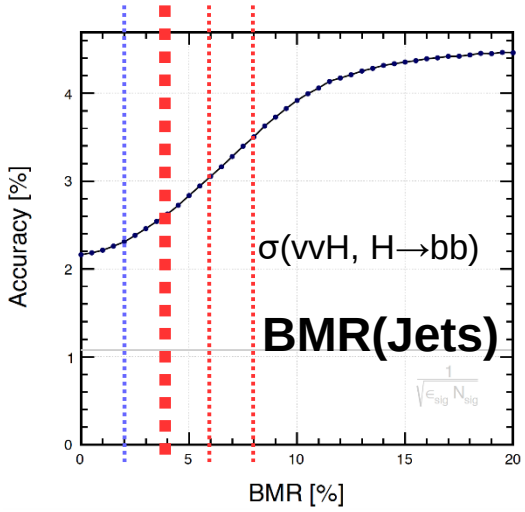
CEPC 探测器物理需求分析

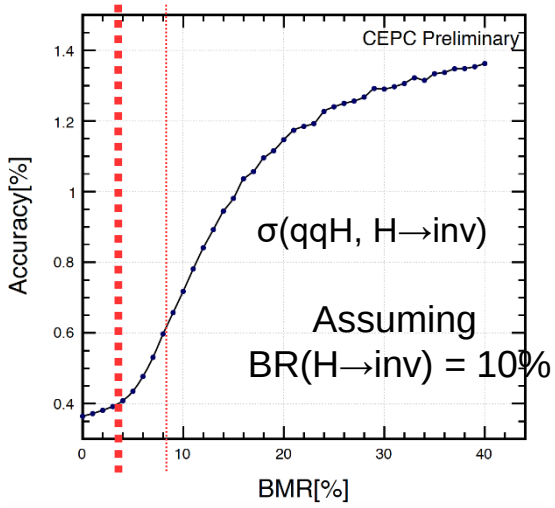
CEPC探测器和Higgs物理测量分析精度分析。

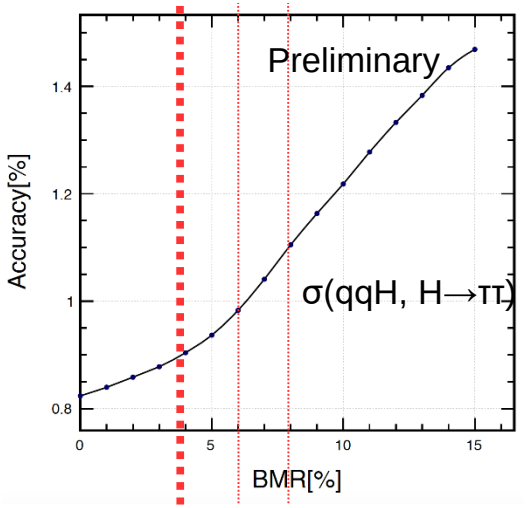
开展味物理和QCD物理需求分析











未来设施、前沿：CEPC

软件框架

New Software Prototype

- Since Oxford workshop in April, we began to evaluate a new framework for CEPC experiment
- In June, at Bologna workshop, we reached the agreement of one Common Software Stack (Key4HEP) for future collider experiments (CEPC, FCC , ILC, CLIC, STCF, SCT)
  - To maximize the software sharing between experiments

[Ref]: André Sailer, etc. , CHEP2019

- Interfaces to tracking and reconstruction libraries (PandoraPFA, ACTS)
- (More or less) experiment specific event data model libraries
- Experiment core orchestration layer, which controls everything else: Marlin, Gaudi, CMSSW, AliRoot
- Packages used by many experiments: DD4hep, Pythia, …
- Usual core libraries (ROOT, Geant4, CLHEP, …)
- Non-HEP libraries: boost, python, cmake …

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Summary

- CEPC distributed computing system works well and member sites are from:
  - IHEP, IPAS, LANCASTER, QMUL and SJTU
- CEPCSW prototype has been developed using Gaudi, DD4hep, Geant4 and PLCIO, etc.
  - both detector simulation and tracking algorithm can be run successfully
  - ready to add more algorithms to the prototype by following given examples
  - future development will be based on Key4HEP collaborating with CERN

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面向未来国际高能物理实验的共同需求，平台三成员积极加入了未来计算-软件框架的国际讨论和共同研发。

面向**CEPC**、组织软件框架的开发和算法移植工作。

Progress and updates – Intl Collaboration

- Strengthen cooperation with CERN
- Joined CALICE collab., ILD TPC collab., RD collab.s

- 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
  https://indico.in2p3.fr/event/20053/

- First US workshop at UChicago, September 16-18, 2019
- Second US workshop planned for April 22-23, 2020 (TBC）
  Catholic University in Washington DC, USA

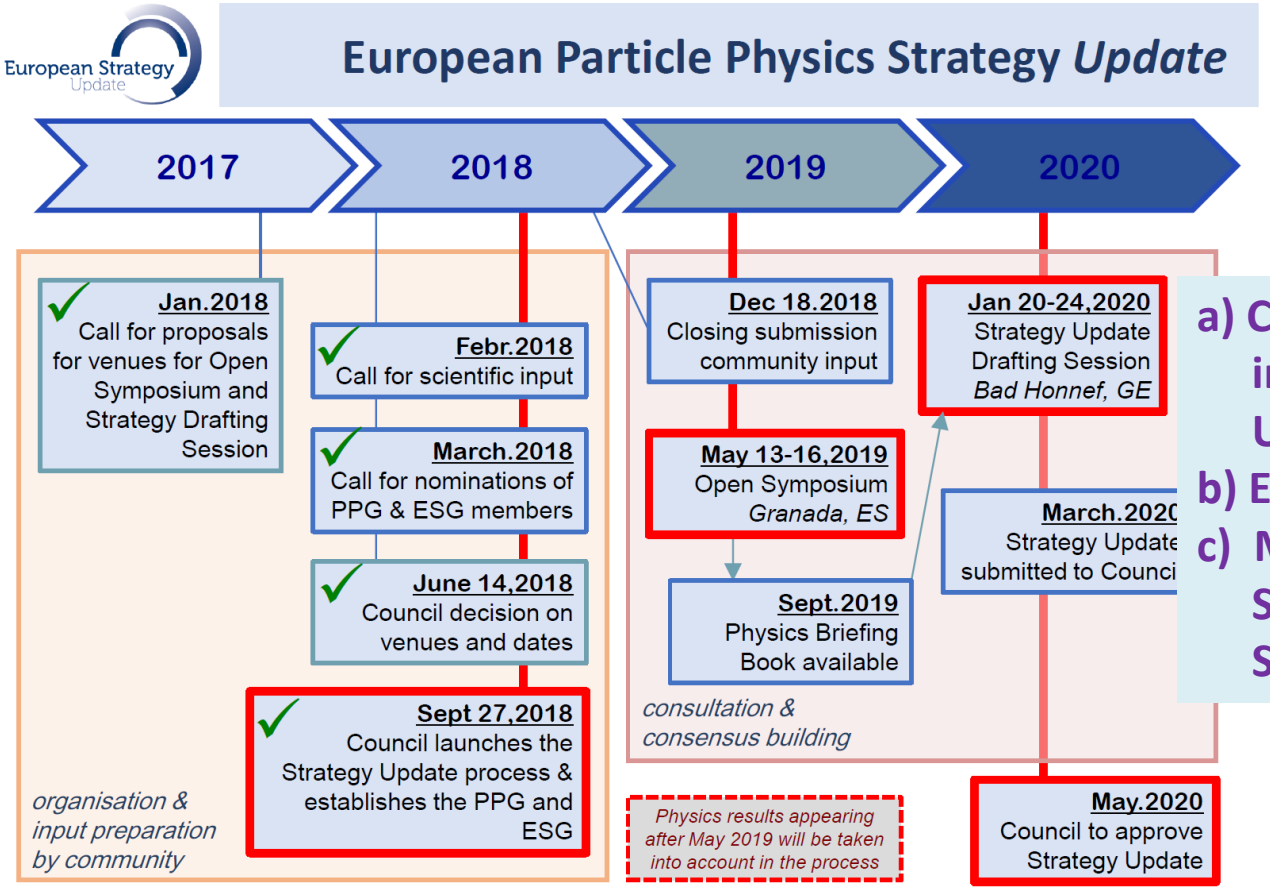
- HongKong IAS HEP Program (～200人参会)， January 2019
- 2019 CEPC International workshop at IHEP (~360) Nov. 20-21, 2019
- Fifth CEPC IAC meeting (Nov. 21-22, 2019)

Progress and updates – Intl Collaboration

Preparation for European Strategy for Particle Physics update

Inputs (CEPC accelerator, physics-detector) have been submitted

CEPC accelerator: ArXiv: 1901.03169, CEPC Physics/Detector: 1901.02170



a) CEPC team submitted two input documents to the USPPU;
b) Engaging with PPG and ESG;
c) Many attended the Open Symposium in Granada, Spain.

未来设施、前沿：CEPC

CEPC项目被正式提交至欧洲战略讨论

arXiv.org > physics > arXiv:1901.03169

Search... Help | Advanced

Physics > Accelerator Physics

The CEPC input for the European Strategy for Particle Physics - Accelerator

The CEPC Accelerator Study Group

(Submitted on 10 Jan 2019)

In this manuscript, we provide a summary of accelerator design and the key challenges of the CEPC accelerator, both of which are laid out in detail in the Conceptual Design Report (CDR) released in November 2018. We also outline future directions and challenges. In the Addendum, we briefly describe the planning and the international organization of the CEPC. The next step for the CEPC team is to perform detailed technical design studies. Effective international collaboration would be crucial at this stage. This submission for consideration by the ESPP is part of our dedicated effort in seeking international collaboration and support.

Comments: arXiv admin note: substantial text overlap with arXiv:1809.00285
Subjects: **Accelerator Physics (physics.acc-ph)**; High Energy Physics - Experiment (hep-ex)
Cite as: arXiv:1901.03169 [physics.acc-ph]
(or arXiv:1901.03169v1 [physics.acc-ph] for this version)

arXiv.org > hep-ex > arXiv:1901.03170

Search... Help | Advanced

High Energy Physics - Experiment

The CEPC input for the European Strategy for Particle Physics - Physics and Detector

CEPC Physics-Detector Study Group

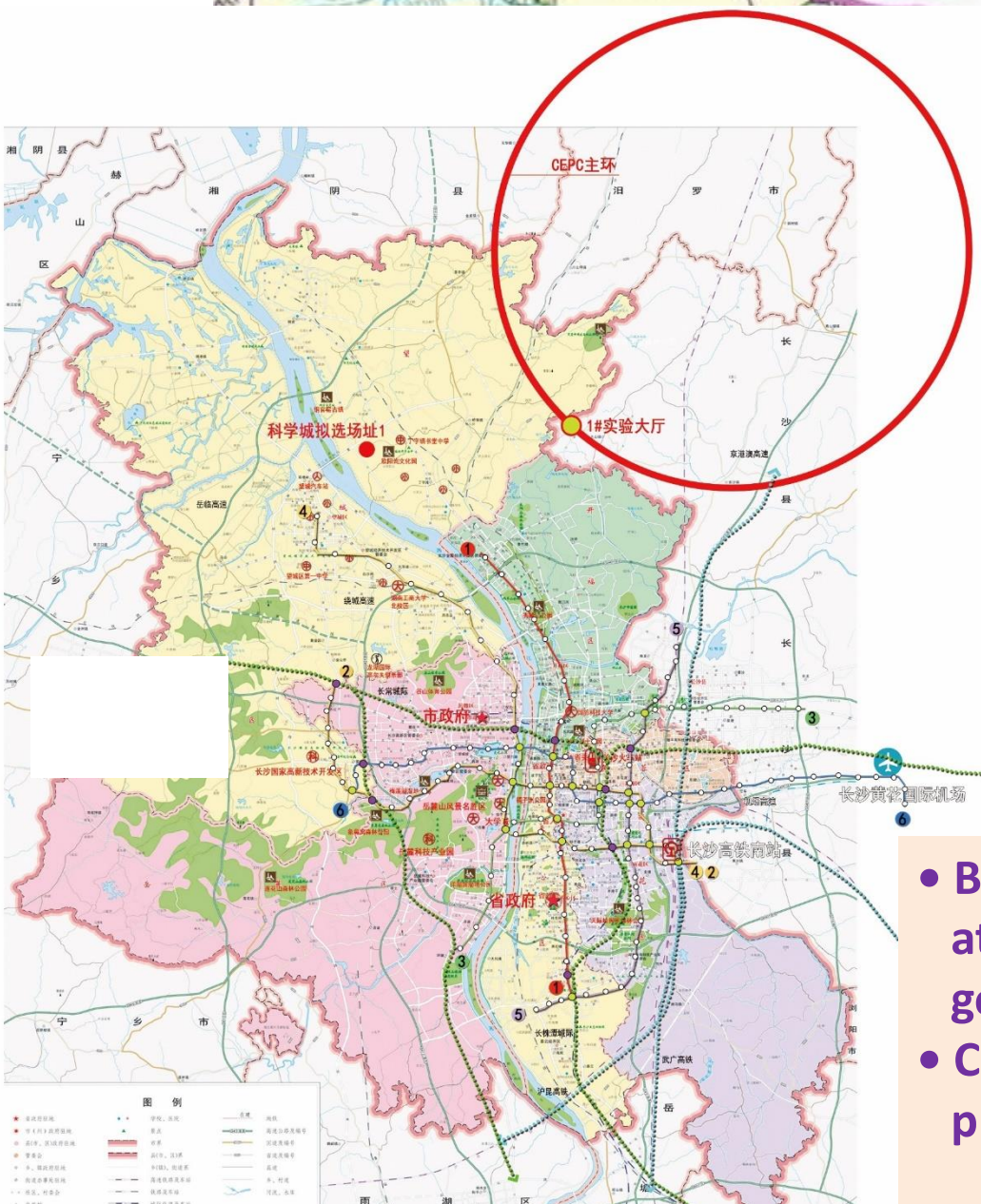
(Submitted on 10 Jan 2019)

The Circular Electron Positron Collider (CEPC) is a large-scale future collider facility that can serve as a factory of the Higgs boson, the W boson and the Z boson. This document provides a brief summary of the CEPC physics potential and the detector design concepts, both of which are laid out in detail in the Conceptual Design Report (CDR) released in November 2018. We also outline future directions and challenges. In the Addendum, we briefly describe the planning and the international organization of the CEPC. The next step for the CEPC team is to perform detailed technical design studies. Effective international collaboration would be crucial at this stage. This submission for consideration by the ESPP is part of our dedicated effort in seeking international collaboration and support. Given the importance of the precision Higgs boson measurements, the ongoing CEPC activities do not diminish our interests in participating in the international collaborations of other future electron-positron collider based Higgs factories.

Subjects: **High Energy Physics - Experiment (hep-ex)**; High Energy Physics - Phenomenology (hep-ph)
Cite as: arXiv:1901.03170 [hep-ex]
(or arXiv:1901.03170v1 [hep-ex] for this version)

国内约10位物理学家参加了2019.5.12-17在西班牙格拉纳达进行的公开论坛。
娄辛丑研究员作为会议物理小组准备成员组织了相关分会讨论

CEPC site investigation and facility study



- Begins site study in Changsha长沙 at the request of the provincial government;
- Collaborative MOUs signed to prompt CEPC and HEP

CEPC site investigation and facility study

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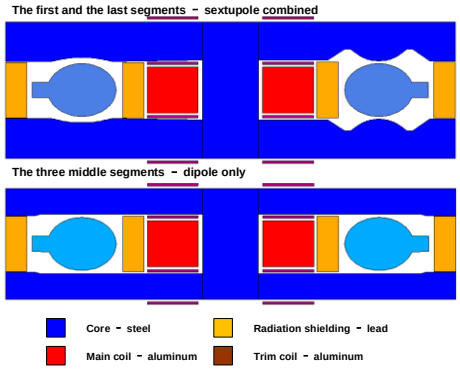
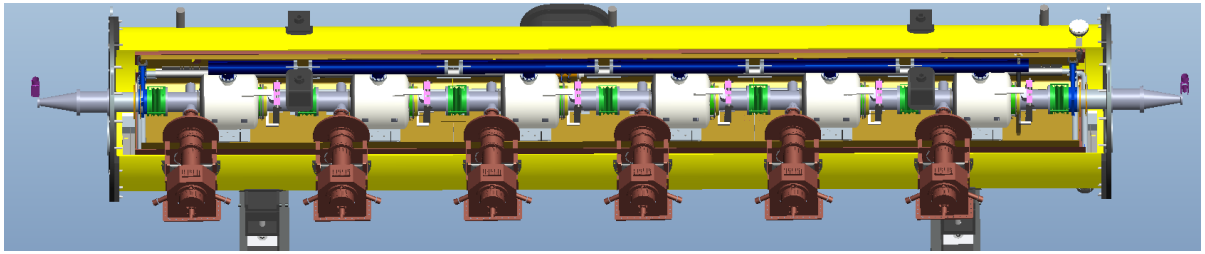
Changsha (Hunan Provice)

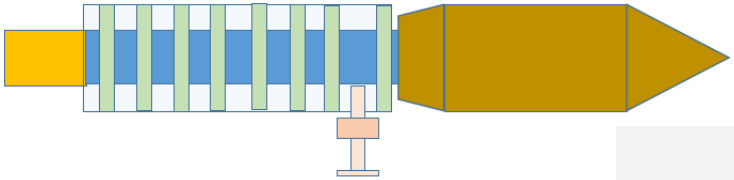
CEPC Industrial Promotion Consortium (CIPC)

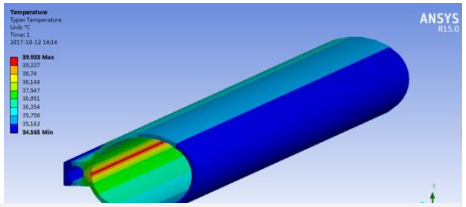
was established in 2017 to prepare for CEPC

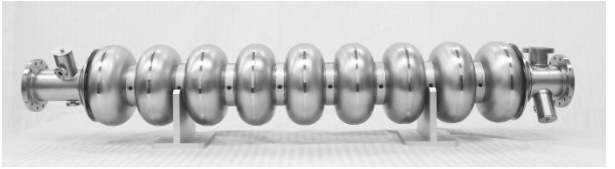
2019年CIPC扩大至70多个单位











High Efficiency RF cavity section

Progress and updates – path to realization

积极牵头组织国际大科学计划和大科学工程项目培育建议书

Suggested Large International Science & Engineering Project for Cultivation

项目名称： 环形正负电子对撞机培育 **Cultivation of CEPC**

所属领域： 物质科学

申报单位： 中国科学院高能物理研究所 **Host: IHEP**

项目负责人： 王贻芳 **PI: YiFang Wang**

Cultivation proposal submitted in November, 2019

技术、研发

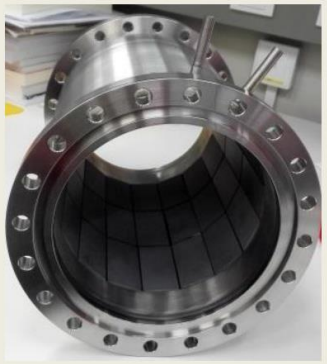
- **CEPC-SppC： CDR， R&D， 品质提升，…**
- **HL-LHC升级： 探测器， 加速器**
- 国际研发合作

技术研发: CEPC 加速器

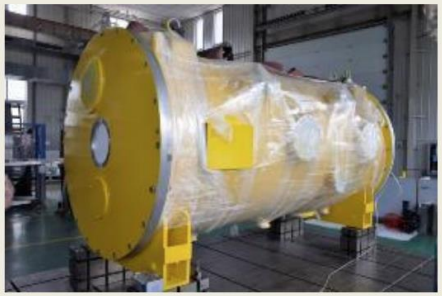
CEPC SCRF R&D in Progress

High power coupler

HOM



Absorber



CEPC 650 MHz Cryomodule

技术研发: CEPC 加速器

1st CEPC 650MHz Klystron Prototype Manufacture

① Components

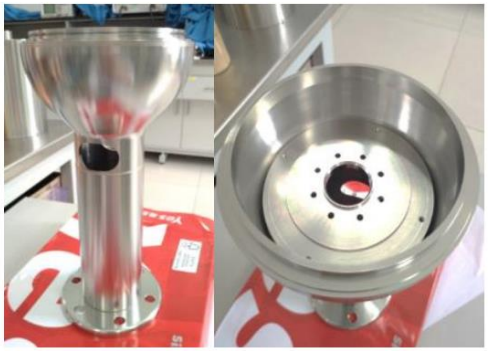
De-gassing facility

Modulator anode

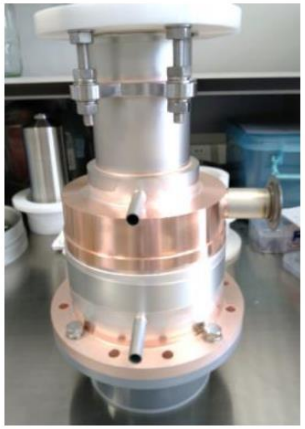
Pumping out pipe

Input coupler

Cavity

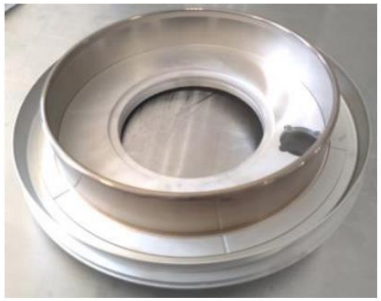


Focusing electrode



Output window

Cathode



Gun support

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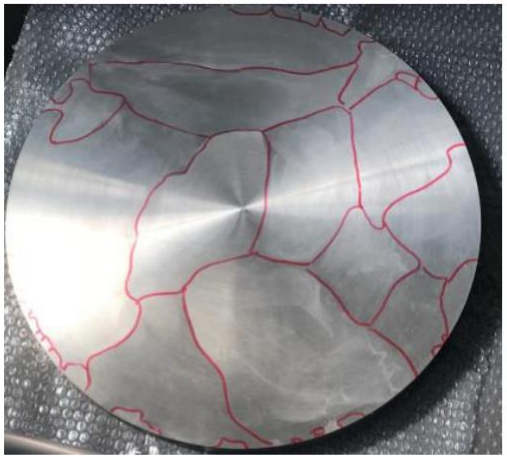
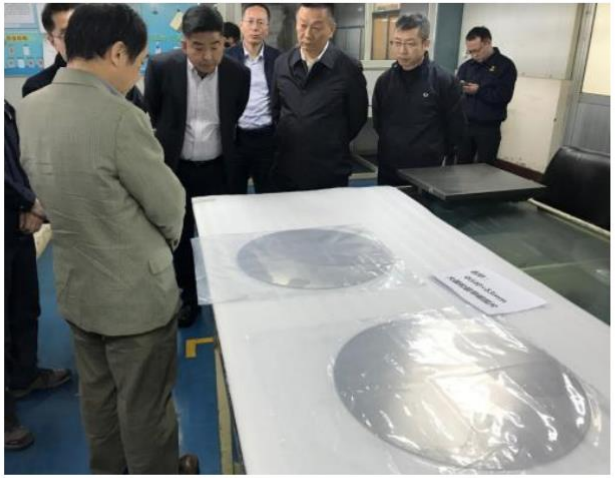
技术研发: CEPC 加速器

650 MHz 1-Cell Cavity (Large Grain)

- 650 MHz 1-cell cavity (large grain) is favorable for HL-Z, which have higher Q and gradient than fine grain.
- Target of Vertical test: **5E10 @ 42MV/m at 2.0 K**.
- Four cavities are under fabrication now, which will be tested in the middle 2019.



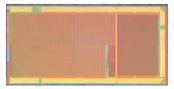


Large grain Nb sheets made by OTIC

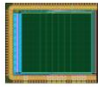
技术研发: CEPC 探测器

CEPC探测器预研究

Prototype	Pixel size (μm²)	Readout time	Power Consumption	In-pixel circuit	R/O architecture	Main goals	Status
JadePix1	33 × 33 16 × 16	~100 μs	~ 100 mW/cm²	SF/amplifer, analog output	Rolling shutter	Sensor optimization	Lab. and beam test finished
JadePix2	22 × 22	~100 μs	< 100 mW/cm²	amp., discriminator, binary output	Rolling shutter	Small pixel, Power < 100 mW/cm²	Electrical functionality verified
MIC4	25 × 25	~10 μs	<26mW/cm²	Low power front-end, address encoder	Data-driven, Asynchronous	Small pixel, fast readout for ZH run	Electrical functionality verified
JadePix3	16 × 26 16 × 23.11	~10 μs	<26mW/cm²	Low power front-end, binary output	Rolling shutter with end of col. priority encoder	Small pixel, low power	In fabrication
Taichu-1	25×25	~50ns	100~200 mW/cm²	binary output	Data-driven, Priority encoder	Full Functionalities Fast readout for Z pole	Fabricated, To be tested

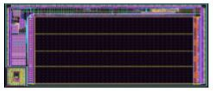


JadePix1 (IHEP)
3.9 × 7.9 mm²

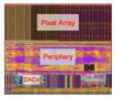


JadePix2 (IHEP)
3 × 3.3 mm²

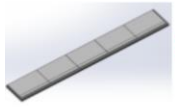
MIC4 (CCNU & IHEP)
3.2 × 3.7 mm²



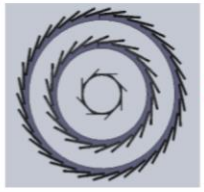
JadePix3
IHEP, CCNU, Dalian Minzu Unv., SDU
6.1 × 10.4 mm²



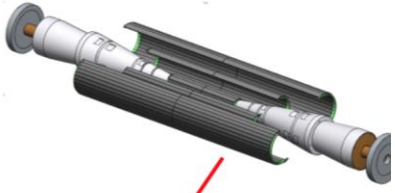
Taichu-1
IHEP, SDU, NWPU, IFAE & CCNU
5 × 5 mm²



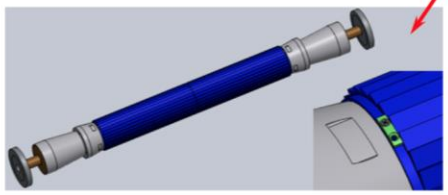
Detection unit

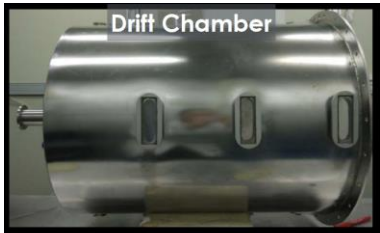


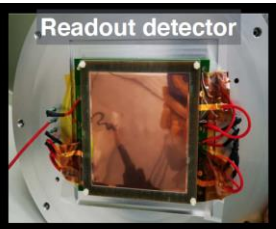
Ring arrangement

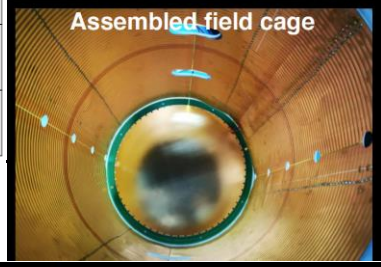


Half ring structure









Readout electronics and DAQ

ECAL Calorimeter — Particle Flow Calorimeter

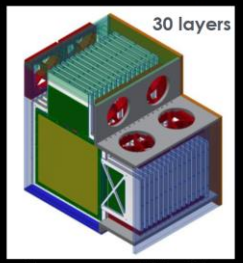
Scintillator-Tungsten Sandwich ECAL

Prototype to be built and lab test by August 2020
Test beam at DESY to follow

Designed and developed new version of front-end PCB with SPIROC-2e chips

Mass production of scintillator strips and wrapping established

Mechanical and structural design of the prototype



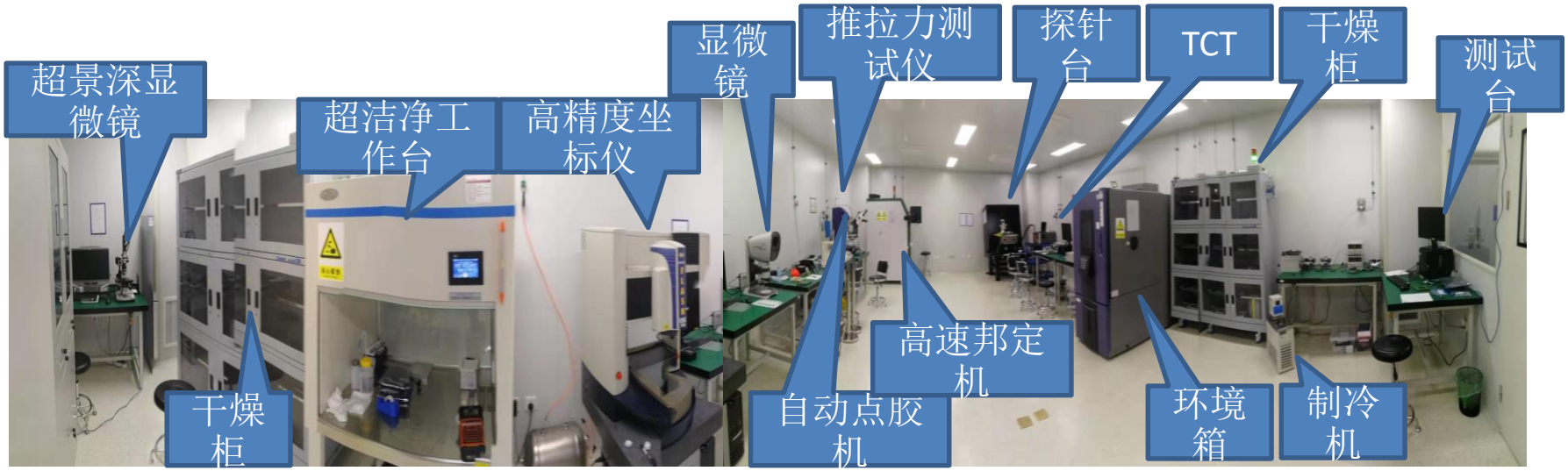
active area: ~ 25 x 25 cm²

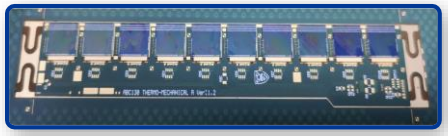
顶点（左）、TPC（右上）、ECAL（右下）的探测器技术及原型机研究

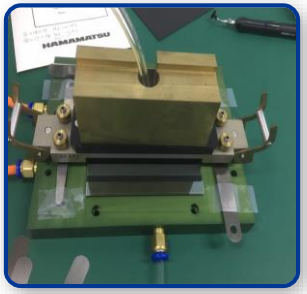
技术研发: CEPC 探测器

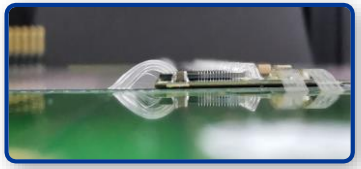
高能所洁净间：用于ATLAS升级和CEPC探测研发

- Additional +80平米万级洁净间与2019年4月份验收投入使用
- 已制电子学级别的模块



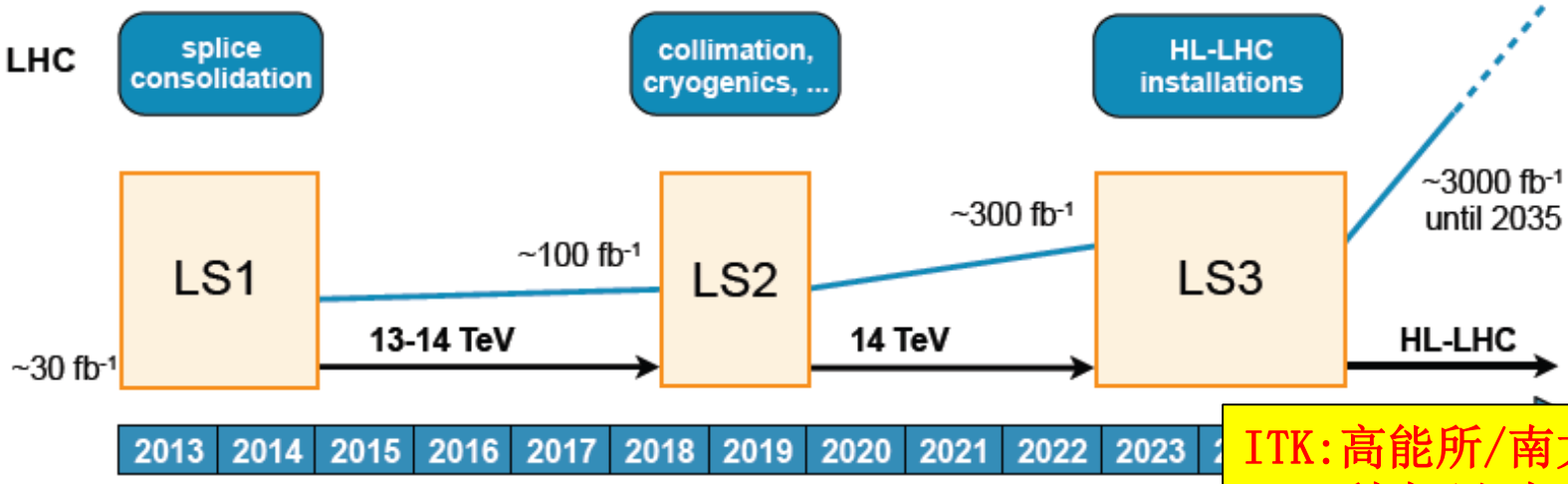






技术研发: HL-LHC ATLAS探测器

HL-LHC ATLAS 计划



ITK:高能所/南大/清华
RPC:科大/山大/交大
HGTD:所有7家单位

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

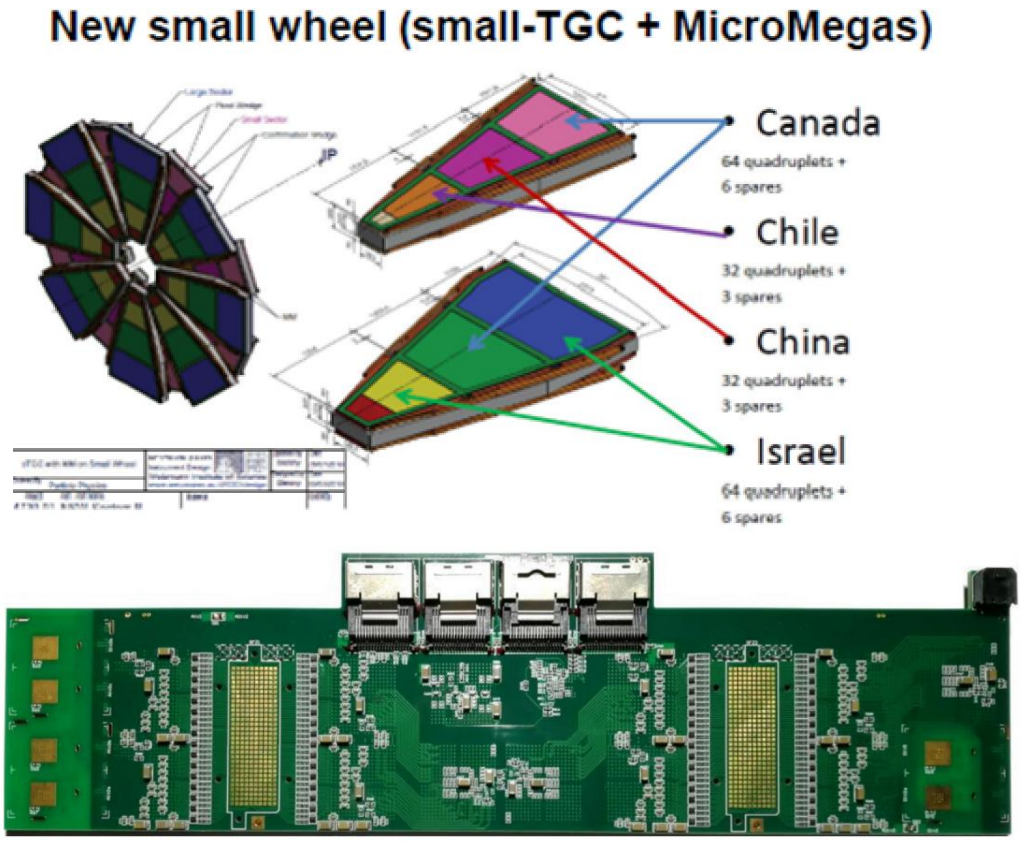
ATLAS Phase-2

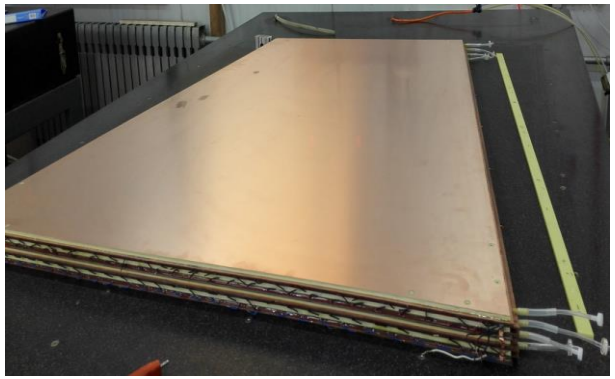
Prepare for 140-200 pile-up events
Replace Inner Tracker
New L0/L1 trigger scheme
Upgrade muon/calorimeter electronics
Upgrade of DAQ detector readout

技术研发: HL-LHC ATLAS探测器

中国组NSW项目

- 山大承担生产128 sTGC QS2 chambers，预期下个月完成
- 科大承担生产1840 Front-end readout (FEB) boards





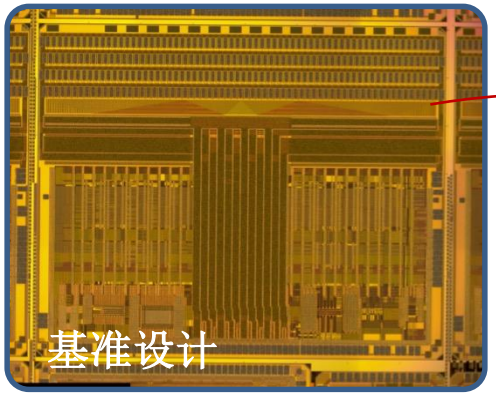
技术研发: HL-LHC ATLAS探测器

ATLAS Phase-2 硅径迹探测器升级

- 针对国内急缺硅探测系统设计与建造经验的现状，通过参与国际合作直接参与最前沿的抗辐照硅探测器研究。通过项目掌握关键技术、积累经验。
- 项目专用洁净间投入运行。按照课题拟定目标，在主要方向上均取得重要进展：

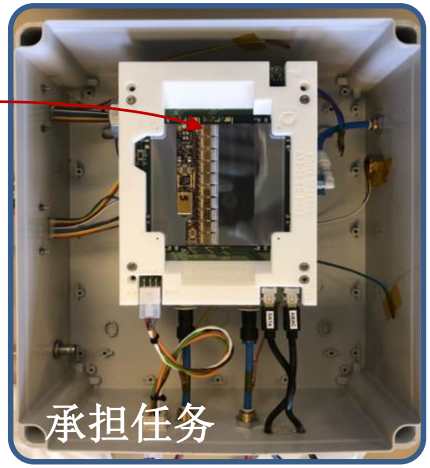
高能所/清华

I. 前端电子学ASIC设计



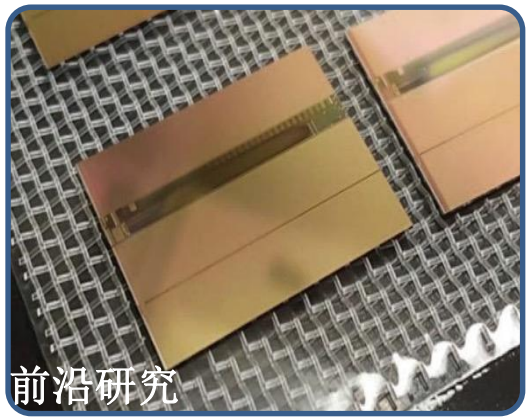
承担抗辐照、高速数字模块设计，已流片投入使用

II. 模块设计与建造



已完成多个探测器模块原型制作及测试，准备预生产

III. CMOS硅探测器研究



初步完成新型CMOS硅探测器性能研究

技术研发: HL-LHC ATLAS探测器

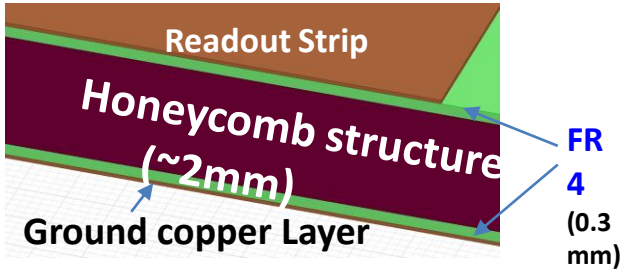
科大/山大/交大

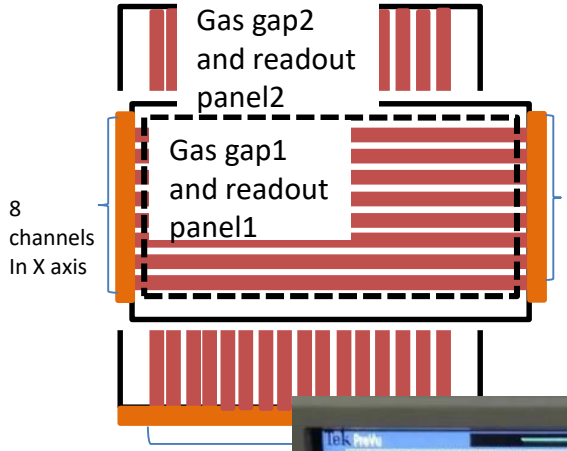
科大-山大-交大RPC升级

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

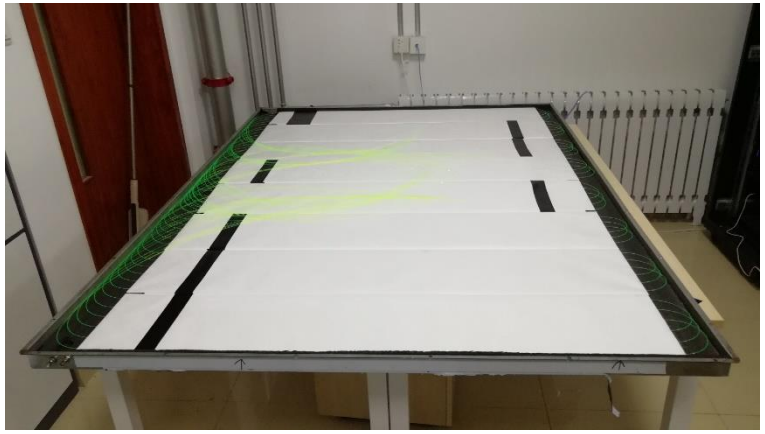
- 计划2020年底完成设计，尝试以读出条两端时间差得到位置信息
- 孙勇杰担任Level-3协调人，负责读出板的设计和生产

提议1:
蜂窝结构读出板提高机械性能和信号质量





提议2：用单面双端读出代替双面单端读出



用于宇宙线性能测试的大面积触发探测器

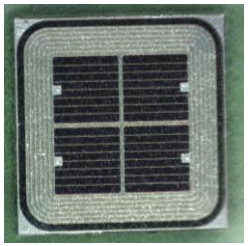
16 chan
readout

RPC测试

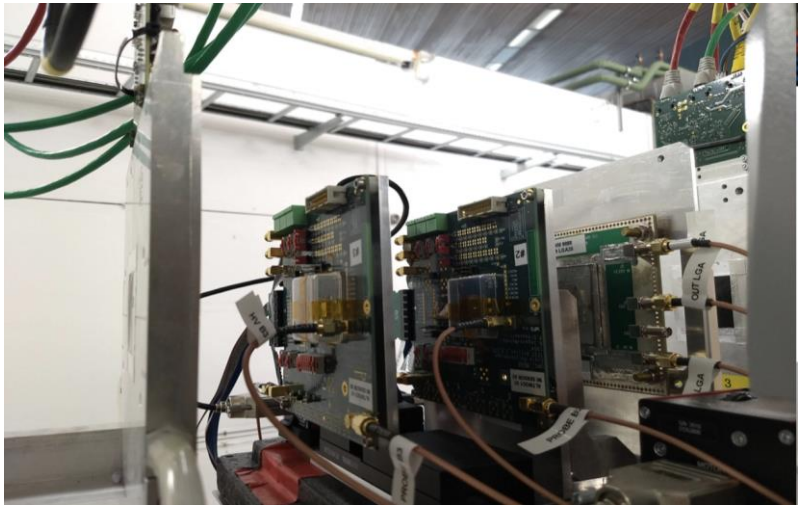
技术研发: HL-LHC ATLAS探测器

高能所组HGTD项目工作简介

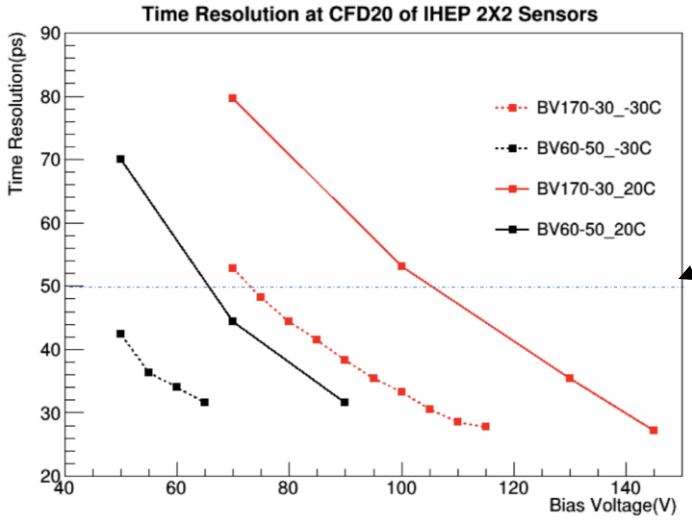
- 高能所成员已经在HGTD项目的最高管理层中担任要职
  - 项目资源管理与风险管理召集人（Joao Guimaraes Da Costa）
  - 触发与数据获取组召集人（Juanan Garcia ，IHEP）
  - HGTD技术设计报告（TDR）编辑（梁志均,Joao, Juanan）
- 高能所研发出首批(目前唯一）基于ALTIROC1芯片的HGTD的探测器模块
  - 将是HGTD技术设计报告（TDR）模块研制的主要结果
- 高能所所研发的LGAD传感器
  - 对单电子响应时间25~30皮秒，符合HGTD项目的要求
- 高能所参与超快读出ASIC芯片（ALTIROCv2）的数字逻辑电路设计



高能所研制的HGTD探测器模块在束流测试



高能所所研发的的LGAD传感器

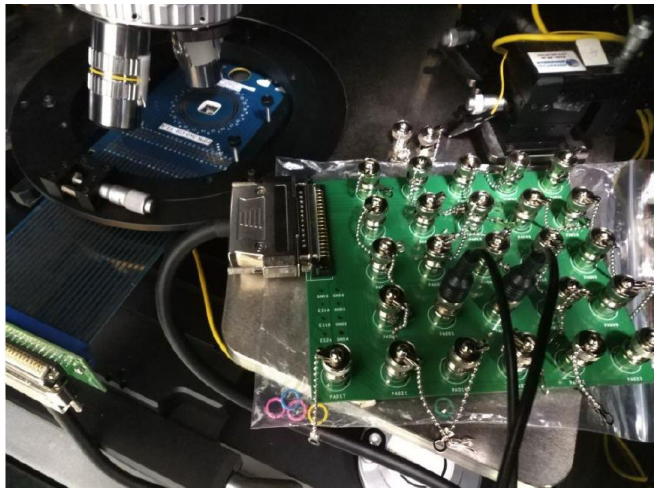


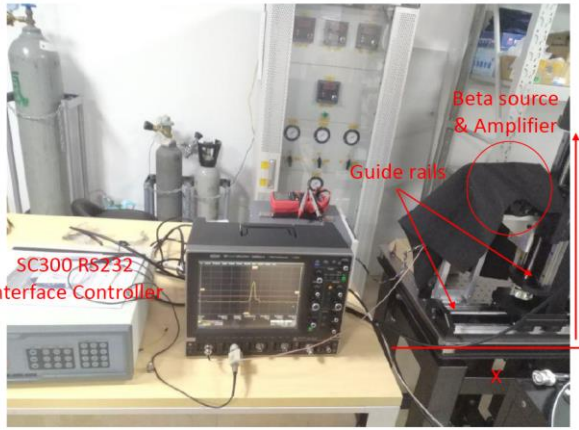
技术研发: HL-LHC ATLAS探测器

科大HGTD进展情况

- 科大组织团队（探测器、电子学、模拟与重建人员）参加HGTD项目 --- Expression of Interest 报告 (2019年1月23日）
- 已成为LGAD测试地点之一
- 参与ASIC测试工作
- 联合苏州纳米所研究组装技术
- 参与束流测试，并做数据分析
- 完成读出模拟软件编写
- 研究sensor设计和制作（在国内流片）

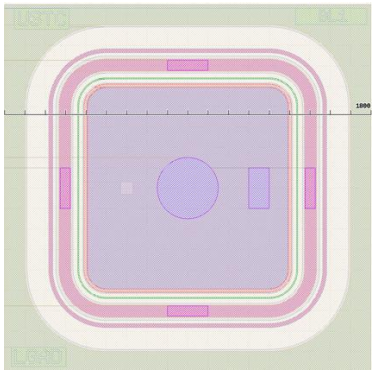
在探针台上测试LGAD 电学特性



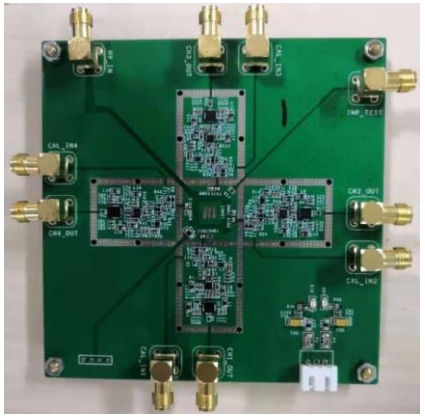


用^{90}Sr测量增益、位置扫描， 测试均匀性

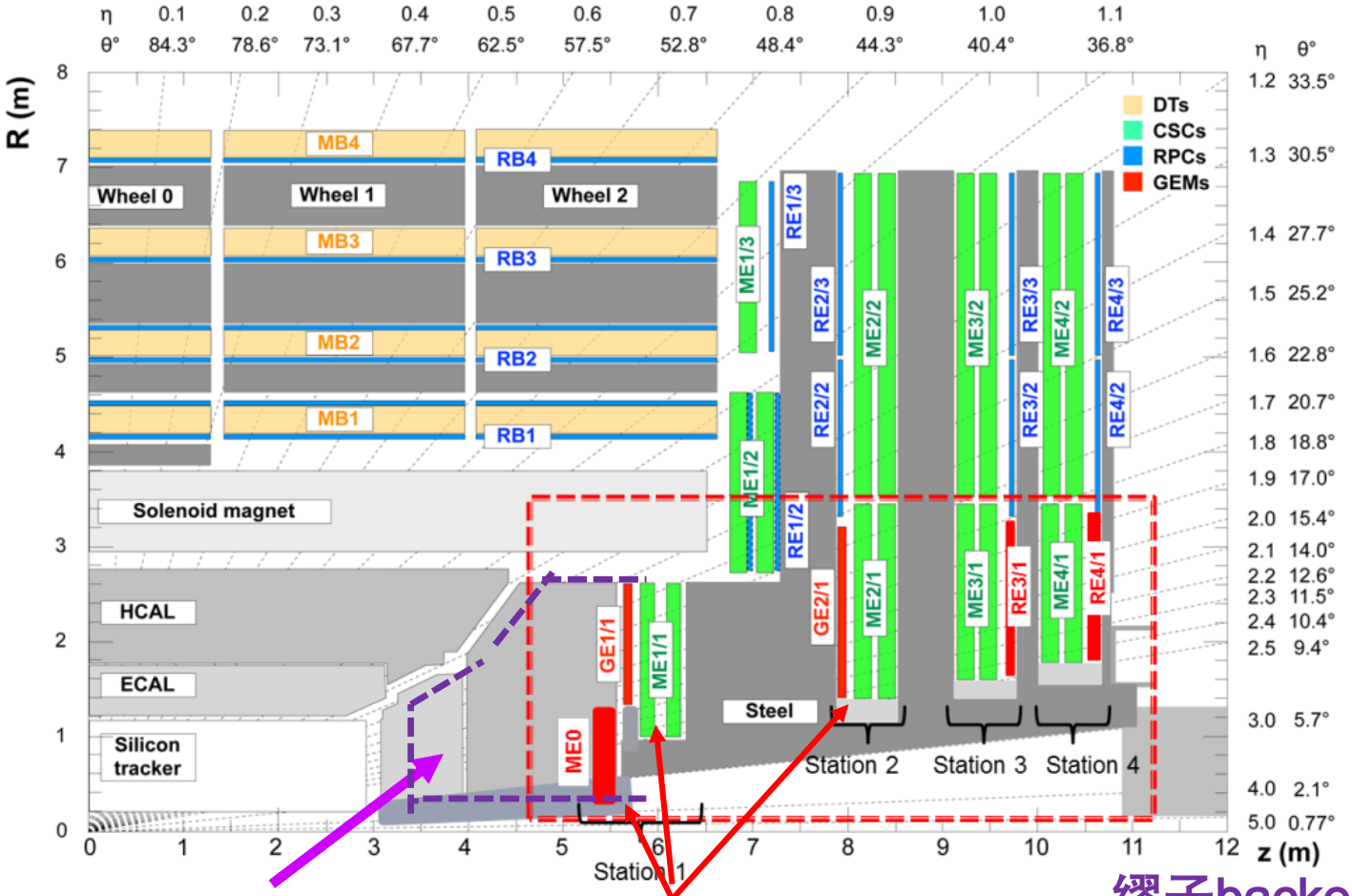
USTC LGAD



USTC设计读出电路板



技术研发: HL-LHC CMS探测器



端部量能器升级

高能所

已经完成洁净间建设

端盖μ触发探测器升级, GEM

北大

已经完成GE1/1建造

缪子backend

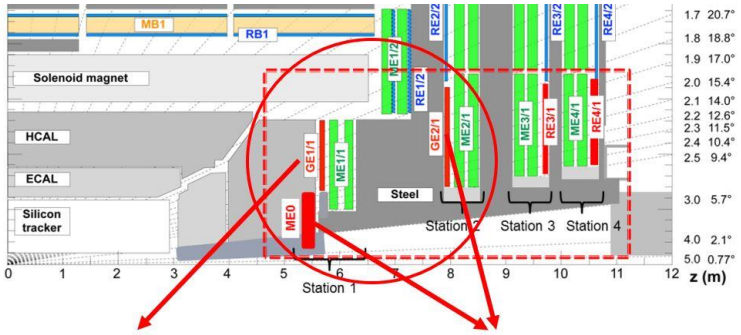
电子学及触发 高能所

已经完成设计，并建成开发和测量系统

技术研发: HL-LHC CMS探测器

CMS-GEM 升级工作进展

北大、清华、中山大学



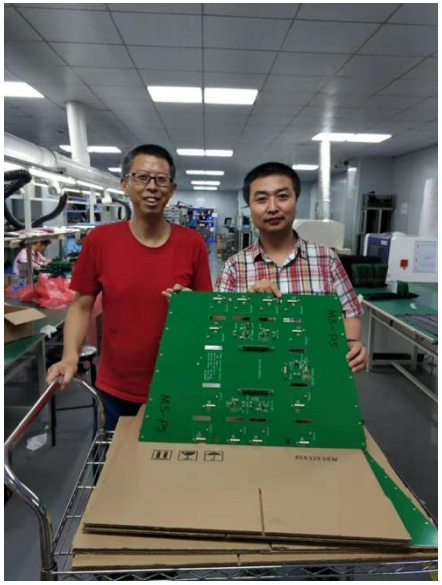
GE1/1: Peoduction and test of GEB

GE2/1+ME0:

- **Design, Peoduction and test of GEB**
- **Assembly and test of GEM**

GE1/1 GEB (前端电子学板) 生产测试:

- 已经在中国深圳鑫诺捷公司生产了~200套GEB
- 最后一批 50 套 GE1/1 GEB 2019年10月生产完成，这周正在测试，完成后发往CERN



2019年7月在深圳鑫诺捷公司生产了6块 M5 GEB 样机, 3 块发往Rice 大学, 2块发往CERN,1块带回北大继续测试

GE2/1 GEB 设计与预研:

- 两种型号的GE2/1 GEM 探测器(长、短)每种分为4端，共8种型号GEB: M1 – M8
- 我们已经完成了M1 – M5的设计和样机生产, 每种型号生产了5-6 块GEB, 分别发往CERN 和美国Rice大学进行测试
- M6-M8 的设计已经完成并通过联合检查, 样机生产本周开始。

* 清华大学理科发展双E基金资助了CMS GEM-GEB项目（40万材料费，30万设备费）

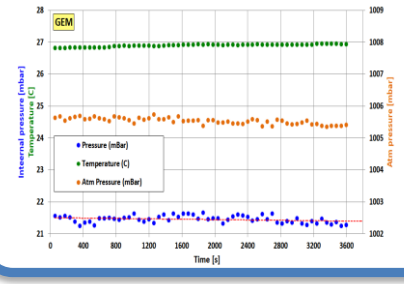
技术研发: HL-LHC CMS探测器

CMS-GEM 升级工作进展

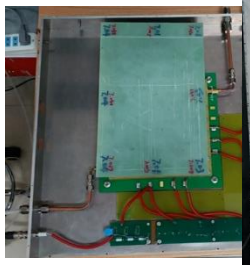
北大、清华、中山大学

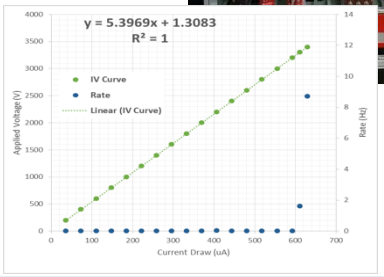
GEM 探测器生产基地建设: 组装测试质量控制（QC）流程与指标设立

QC3: 探测器气密性检测

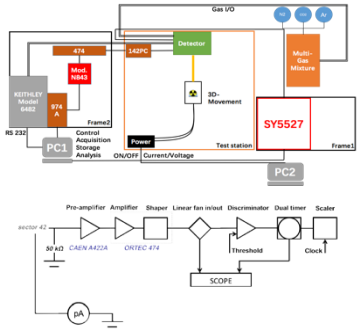


QC4: 高压测试:

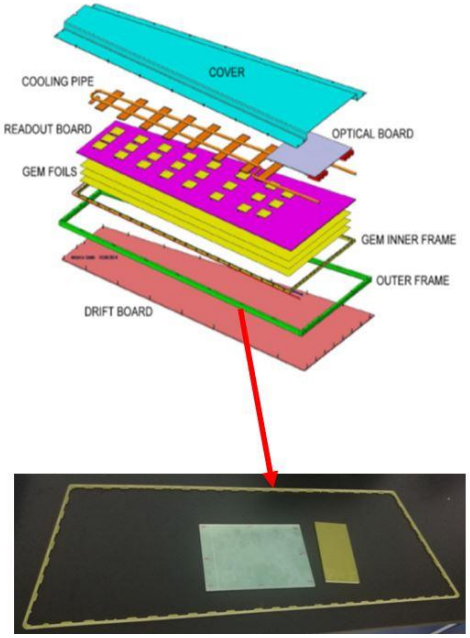




QC5: X射线增益测试



- amplifier settings
  - *Coarse gain* 4, *Fine gain* 4.5,
  - *Integrate* 100*ns* and *Differential* 100*ns*
- the discriminator threshold
  - -100mV



FR4材料的GE2/1边框样品

GEM 探测器边框试生产:

- 两家公司生产了若干GE2/1 边框样品, 两套运往CERN 进行了测试。Axicomb公司生产的边框几何公差符合CMS-GEM标准，但需要对边框厚度进行更精密的刻度
- 下一步: 试生产全套GE2/1 边框(8 种型号) 进行进一步测试，11月份在CERN全面评估后确定是否在中国生产

技术研发: SPPC Magnet Design Scope

Fabrication and test of the 1st IBS solenoid coil at 24T

The 1st solenoid coil with IBS tape fabricated and tested with up to 24T background field. Performance is more than expected.

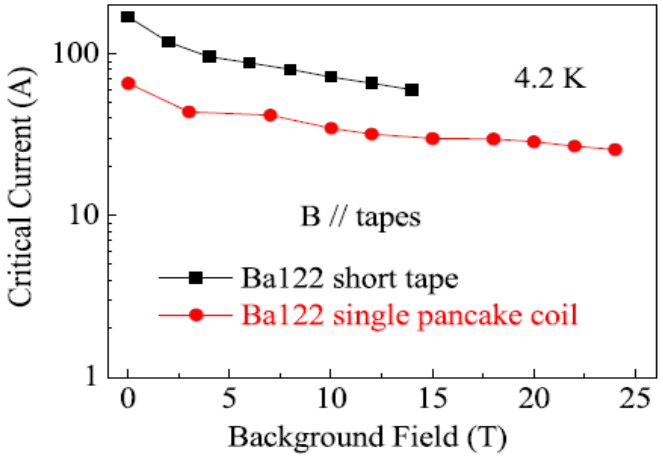
IOP Publishing Superconductor Science and Technology
Supercond. Sci. Technol. 32 (2019) 04LT01 (5pp) https://doi.org/10.1088/1361-6668/ab09a4

Letter

First performance test of a 30mm iron-based superconductor single pancake coil under a 24T background field

Dongliang Wang[1,2,5], Zhan Zhang[3,5], Xianping Zhang[1,2], Donghui Jiang[4], Chiheng Dong[1], He Huang[1,2], Wenge Chen[4], Qingjin Xu[3,6] and Yanwei Ma[1,2,6]

[1] Key Laboratory of Applied Superconductivity, Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing 100190, People's Republic of China
[2] University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[3] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[4] High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, People's Republic of China



Viewpoint by NHMFL

'From a practical point of view, **IBS are ideal candidates for applications**. Indeed, some of them have quite a **high critical current density, even in strong magnetic fields**, and a low superconducting anisotropy.

Moreover, **the cost of IBS wire can be four to five times lower than that of Nb_3Sn**……

IOP Publishing Superconductor Science and Technology
Supercond. Sci. Technol. 32 (2019) 070501 (3pp) https://doi.org/10.1088/1361-6668/ab1fc9

Viewpoint

Constructing high field magnets is a real tour de force

Jan Jaroszynski
National High Magnetic Field, Laboratory, Tallahassee, FL, 32310, United States of America
E-mail: jaroszy@magnet.fsu.edu

This is a viewpoint on the letter by Dongliang Wang *et al* (2019 *Supercond. Sci. Technol.* **32** 04LT01).

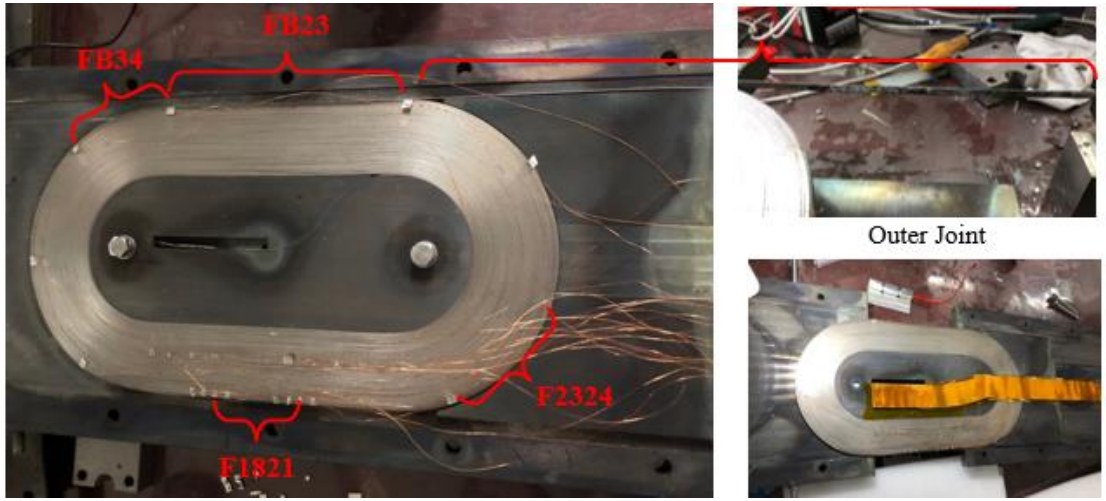
Following the discovery of superconductivity in 1911, Heike Kamerlingh Onnes foresaw the generation of strong magnetic fields as its possible application. He designed a 10 T electromagnet made of lead–tin wire, citing only the difficulty

技术研发: SPPC Magnet Design Scope

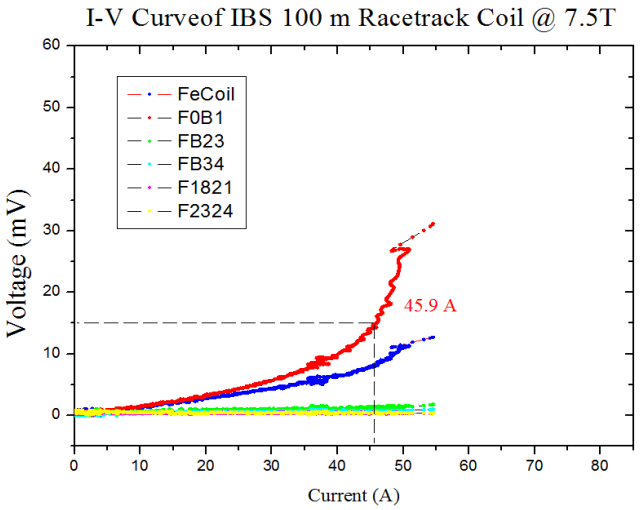
From Qingjin Xu

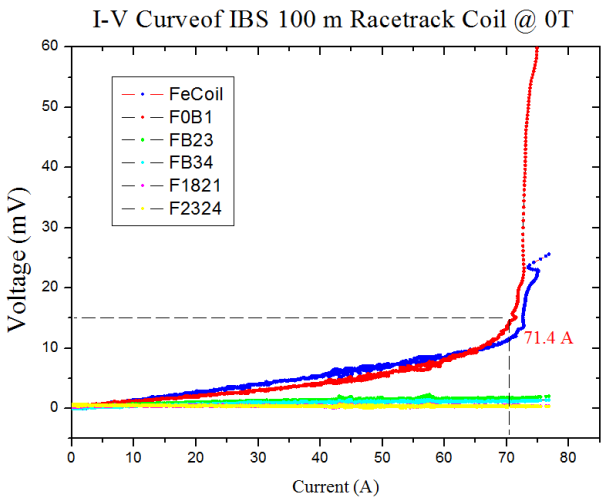
Fabrication and test of the 1st IBS racetrack coil at 8T

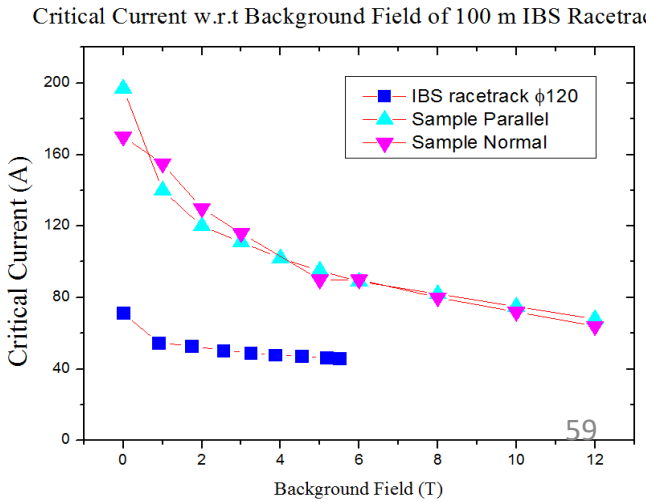
- ***The 1st racetrack coil with 100m long IBS tape fabricated and tested with up to 8T background field. Performance limited by unsatisfying joints.***
- ***The 2nd IBS racerack coil has been fabricated and to be tested at 10-12T.***



Outer Joint







技术研发: SPPC Magnet Design Scope

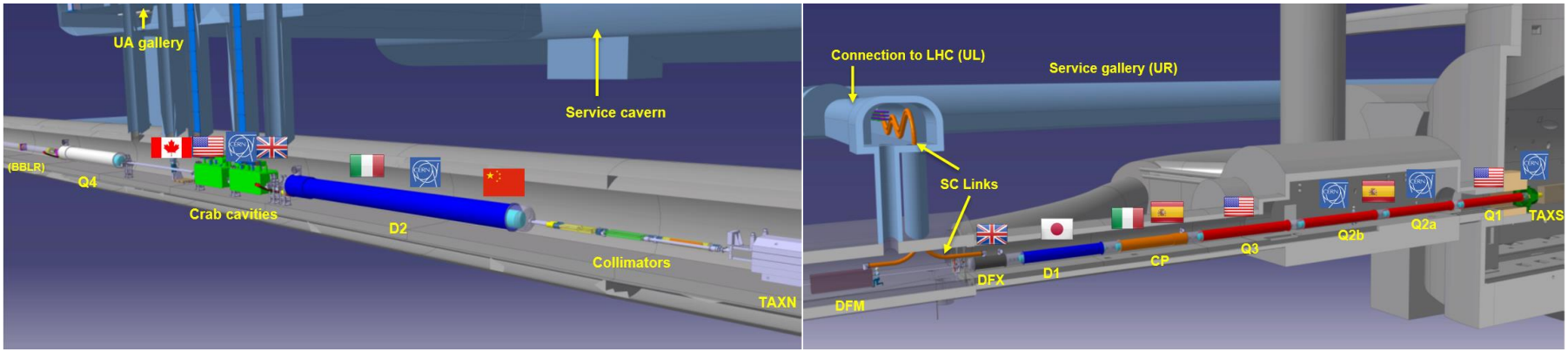
From Qingjin Xu

R&D of HL-LHC CCT Magnets

China provides 12+1 units CCT corrector magnets for HL-LHC before 2022

2*2.6T dipole field in the two apertures. 2.2m prototype being fabricated.

Agreement For HL-LHC CCT Magnets Signned in Sep 2018



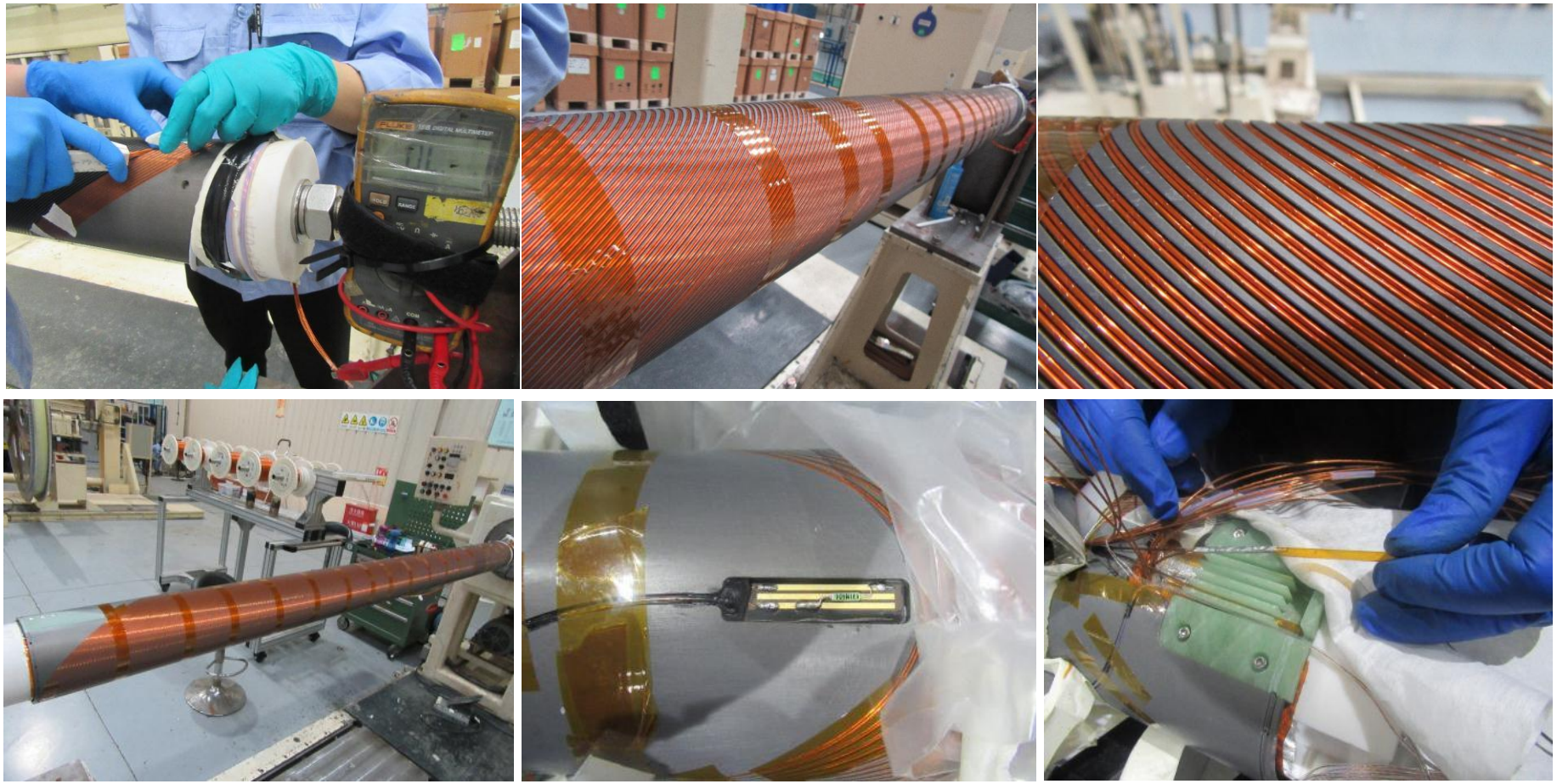
Layout of the HL-LHC Magnets and Contributors

技术研发: SPPC Magnet Design Scope

From Qingjin Xu

R&D of HL-LHC CCT Magnets

0.5m prototype completed. 2.2m prototype being fabricated and to be tested and delivered to CERN by Feb. 2020. Prodution to be started in spring 2020.



Fabrication of the 2.2m prototype CCT Magnet

2019“威海高能物理暑期学校”8.23-8.28

- 强大的专家阵容
  - Peter Jenni,
  - John Ellis,
  - Andrey Korytov,
  - Glen Cowan,
  - Iacopo Vivarelli,
  - Christophe Grojean.
- 远超预期的学员数目（预计60人，实到90余人）
- 小组合作 & 组间竞争-优秀小组评比

授课专家签署优秀学员证明

优秀学员同授课专家、LoC的合影

国际合作：

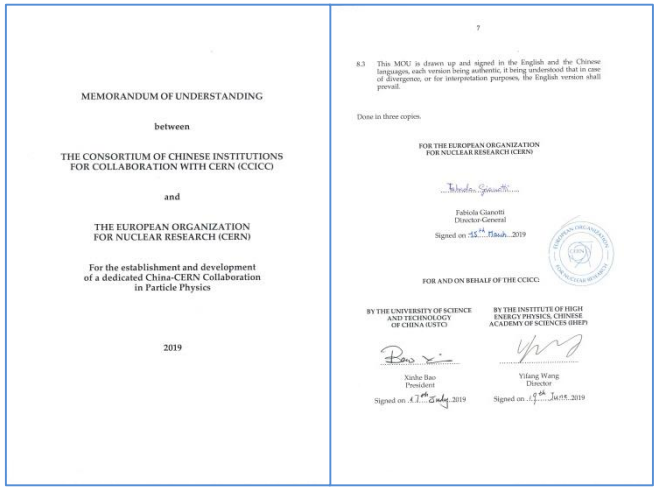
From Runsheng Yu

中国-欧洲核子中心合作深化

- 推进新的合作机制
  - 2018年9月16日，China-CERN Collaboration Meeting 在高能所召开。双发同意共建联合研究中心，及年度会谈机制。
  - 2019年2-3月，完成China-CERN合作中方机构联盟章程签署。
  - 2019年3-7月，完成China-CERN建立和发展粒子物理专项合作的谅解备忘录的签署。
  - 2019年10月17日，China-CERN Collaboration Meeting在欧洲核子研究中心召开。中科院副秘书长高鸿钧参加。
  - 2019年6月，组织基金委基础科学中心项目申报（未通过）。

国际合作：

From Runsheng Yu



MEMORANDUM OF UNDERSTANDING

between

THE CONSORTIUM OF CHINESE INSTITUTIONS FOR COLLABORATION WITH CERN (CCICC)

and

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

For the establishment and development of a dedicated China-CERN Collaboration in Particle Physics

2019

8.3 This MOU is drawn up and signed in the English and the Chinese languages, each version being authentic, it being understood that in case of divergence, or for interpretation purposes, the English version shall prevail.

Done in three copies.

FOR THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

Fabiola Gianotti
Director-General
Signed on 15th March 2019

FOR AND ON BEHALF OF THE CCICC:

BY THE UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA (USTC)

Xinhe Bao
President
Signed on 4th July 2019

BY THE INSTITUTE OF HIGH ENERGY PHYSICS, CHINESE ACADEMY OF SCIENCES (IHEP)

Yifang Wang
Director
Signed on 6th June 2019

中国-CERN关于建立和发展粒子物理专项合作的谅解备忘录

（CERN Fabiola Gianotti
高能所 王贻芳所长
中科大 包信和校长 ）

中国与欧洲核子研究中心（CERN）合作机构联盟章程

（草案）

第一章 总则

第二章 联盟任务

中国-CERN合作中方机构联盟章程

（高能所 王贻芳 所长 2019-3-1
中科大 包信和 校长 2019-2-28
国科大 李树深 校长 2019-3-8
北京大学 郝 平 校长 2019-3-1
南京大学 吕 建 校长 2019-3-9
华中师大 赵凌云 校长 2019-3-8）

国际合作：

From Runsheng Yu

China-CERN Collaboration Meeting 2018 @IHEP

China-CERN Collaboration Meeting 2019 @CERN

国际合作：

From Runsheng Yu

CEPC-FCC (CERN) Collaboration

- Workshops: participations in FCC, CEPC workshops in Europe, US, China (including HK)
  many FCC members presented talks and actively participated in the CEPC workshops; and vice versa
  annual workshops in Hong Kong on common science, technology & design issues for future e^+e^- colliders
  plan to continue the Hong Kong workshop series on the beautiful HKUST campus, including joint workshops

- Editing and reviews of CEPC CDRs
  detector design – IDEA conceptual detector explored both at CEPC and FCC, among others

- FCC(CERN) scientists in CEPC IAC, Accelerator Review Committee, and Detector R&D Committee
  IAC –Michelangelo Mangano, , Lucie Linssen, Peter Jenni +7 other European scientists (5^{TH} meeting in Nov.)
  ARC – Steinar Stapnes, K. Oide + 5 other European scientists (1^{st} meeting in Nov.)
  DRDC – Ariella Cattai, Schopper Andreas, Steinar Stapnes +8 other European scientists (1^{st} meeting in Nov.)

- Planning for a common software framework for FCC-ee and CEPC
  First meeting in Bologna, June 2019

- Physics goals and potentials

An example: joint effort-paper

Data-taking strategy for the precise measurement of the W boson mass with threshold scan at circular electron positron colliders

P. X. Shen, P. Azzurri, M. Boonekamp, P. Z. Lai, B. Li, G. Li, H. N. Li, Z. J. Liang, B. Liu, J. M. Qian, L. S. Shi, C. X. Yu

https://arxiv.org/abs/1812.09855

- Hope for more close collaboration on the circular e^+e^- collider program
- HTS program in China may have beneficial technological and financial impact on a future FCC(pp)

小结

- 围绕当前ATLAS，CMS实验
  - 争取多出新物理成果和科学创新
  - 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
  - 瞄准“卓越”，培育我国发起的CEPC国际大科学合作
  - 建设下一代对撞机设施，开展科学创新

谢谢所有的同事