

山东大学 实验团队及成果介绍

黄性涛

2018年“基本粒子和相互作用协同创新中心”牡丹江论坛

2018年9月15日 · 济南大学

实验团队

■ 教职工23人：

- 教授(13)：张学尧，许长补，冯存峰，王 萌，薛 良，祝成光，黄性涛，徐庆华，吴 群，马连良，李海峰，刘智青，易立
- 副教授/副研究员(4)：焦健斌，李晓玲，杨 驰，刘 栋
- 讲师/工程师等(6)：张 亮，董家宁，尹 娜，孙延生，李长裕，张 兰

■ 博士后12人：

- 韩艳良，刘剑，杨钱，张翼飞，冯华钰，聂茂武，赵永柯
- Irakli Chakaberia, Mario Jose, Vikasdh Ojha, James Daniel, Isaac Upsal

■ 研究生（实验+理论） 70人：

- 博士生：38人
- 硕士生：32人

参加实验



张学尧、黄性涛、刘智青、
焦建斌、李晓玲、.....



王萌、黄性涛、
吴群.....



张学尧、冯存峰、祝成光、
马连良、李海峰、.....



许长补、徐庆华、
易立、杨驰



王萌、张亮、.....

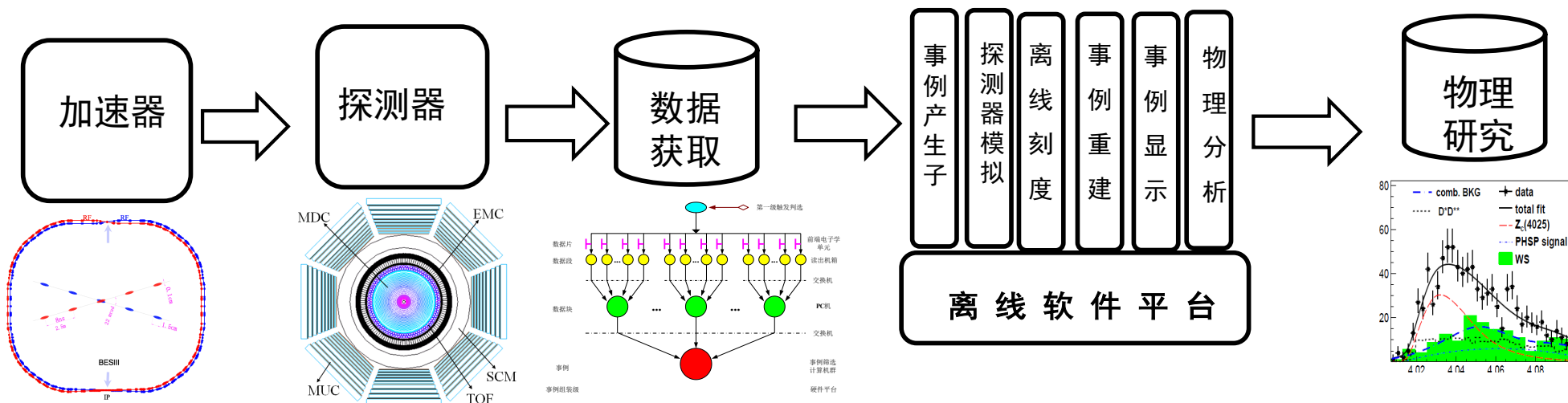


冯存峰、祝成光、
黄性涛、刘栋、.....

CEPC: 王萌、.....

STCF: 黄性涛、.....

研究工作



探测器、电子学等

- ATLAS
- STAR
- PandaX
- LHAASO
- CEPC

离线软件

- BESIII
- DayaBay
- JUNO
- LHAASO
- STCF

物理分析

- BESIII
- ATLAS
- STAR
- DayaBay

山大开展探测器相关工作

- Atlas Phase I: Muon New Small Wheel upgrade
- STAR-iTPC upgrade
- PandX-II Calibration & PandX-4Ton PMT system
- CEPC : CMOS Pixel Sensors
- LHAASO PMT System and ED Testing System

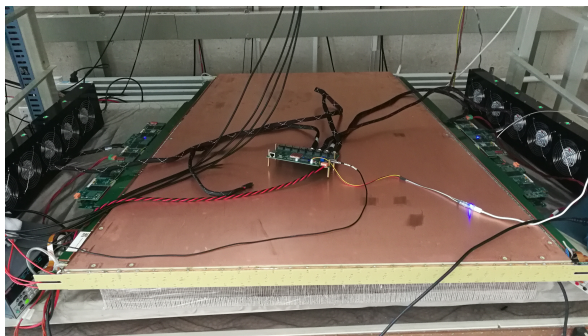
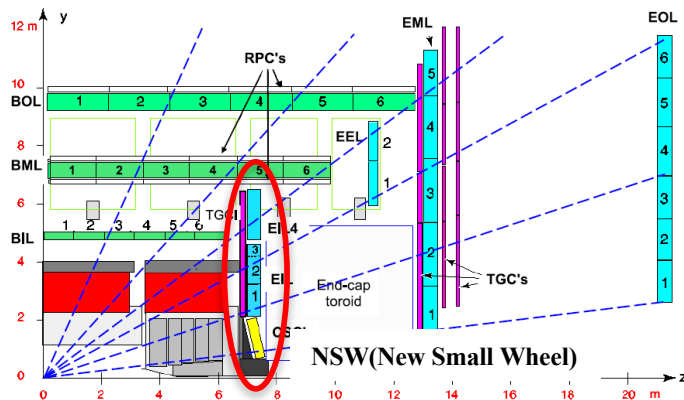
● China contribution:

- ❑ **128 sTGC** chambers @ SDU
- ❑ **1840 Front-end readout (FEB)** boards @ USTC

From Chengguang Zhu

● sTGC mass production @ SDU

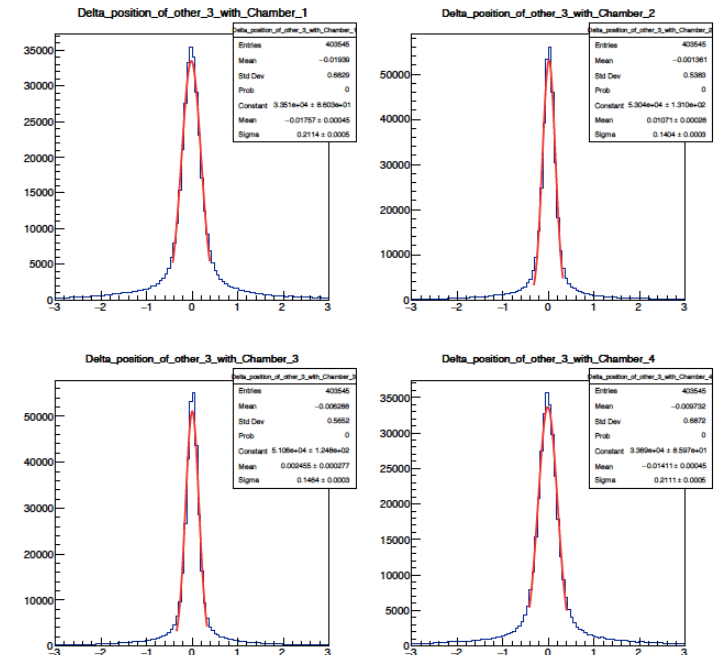
- ✓ 20% of chambers have been made
- ✓ First complete quadruplet arrived at CERN. It is the first completed quadruplet of sTGC community.



First module pass cosmic test

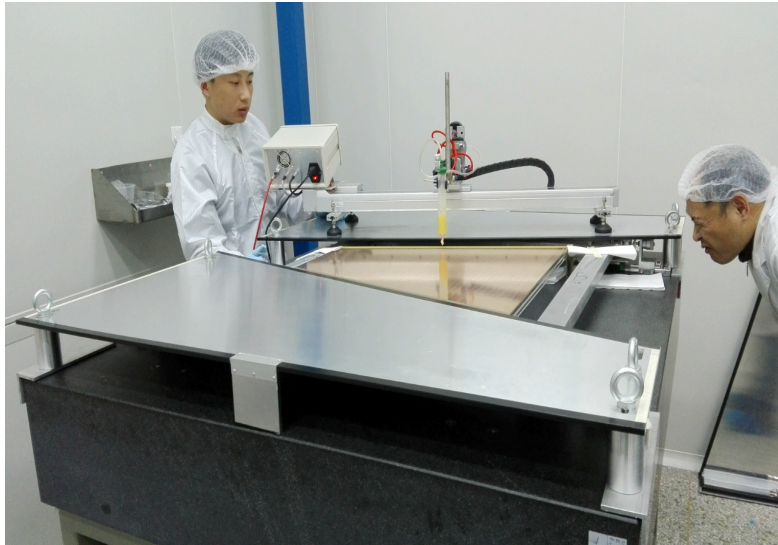
Position resolution of the 4 chambers are measured in the cosmic test to be $\sim 100\mu\text{m}$

The relative rotation of the 4 chambers are measured in the cosmic test to be less than 0.1mrad

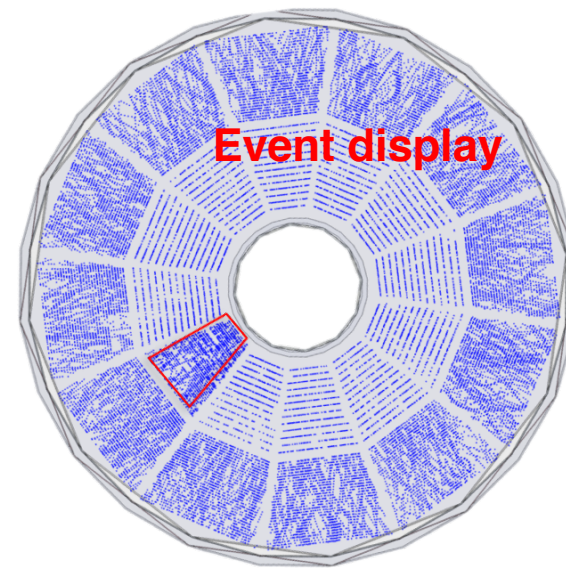
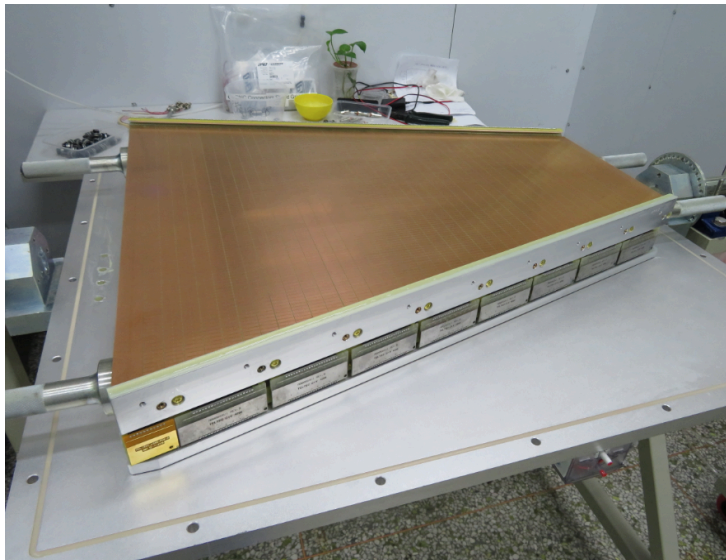


STAR-iTPC时间投影室升级丝室研制

From Qinghua Xu

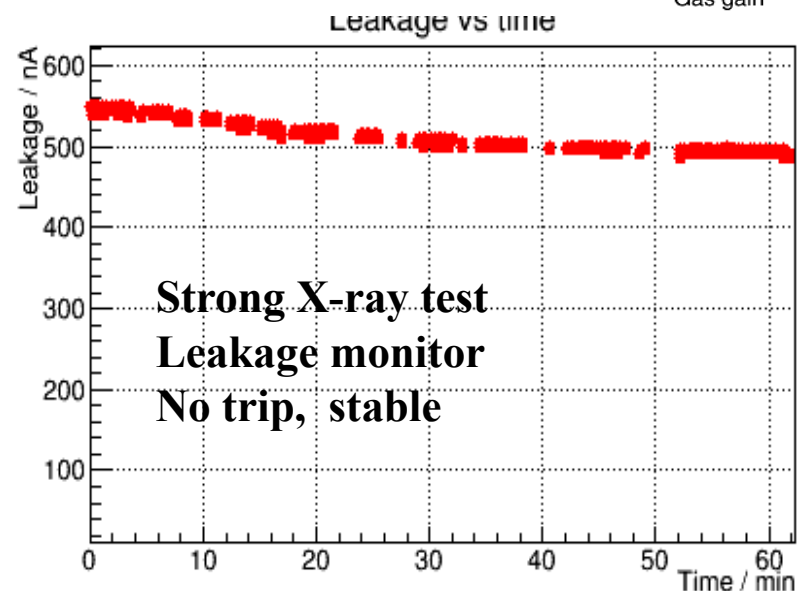
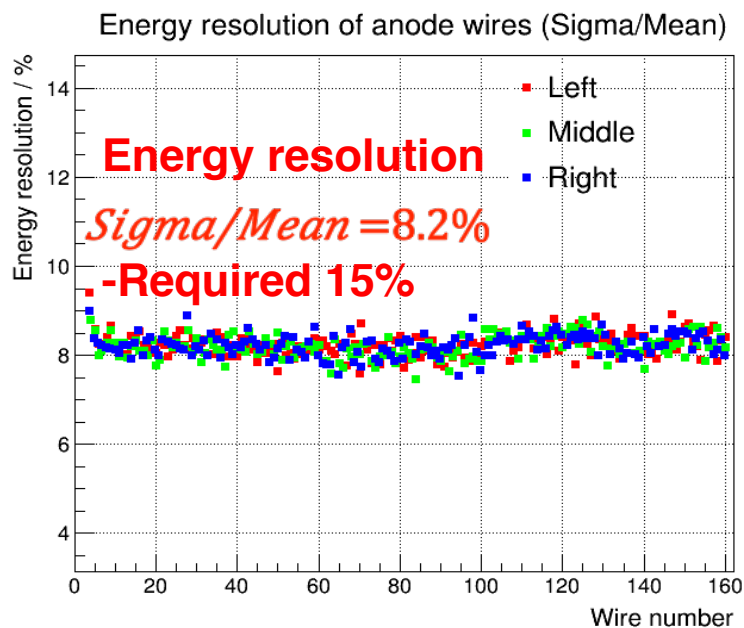
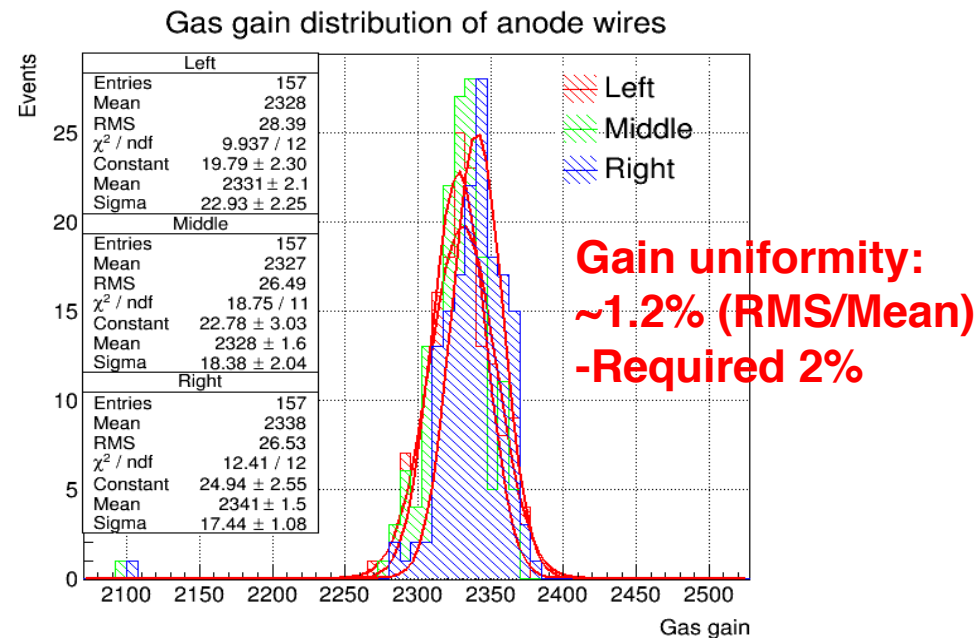
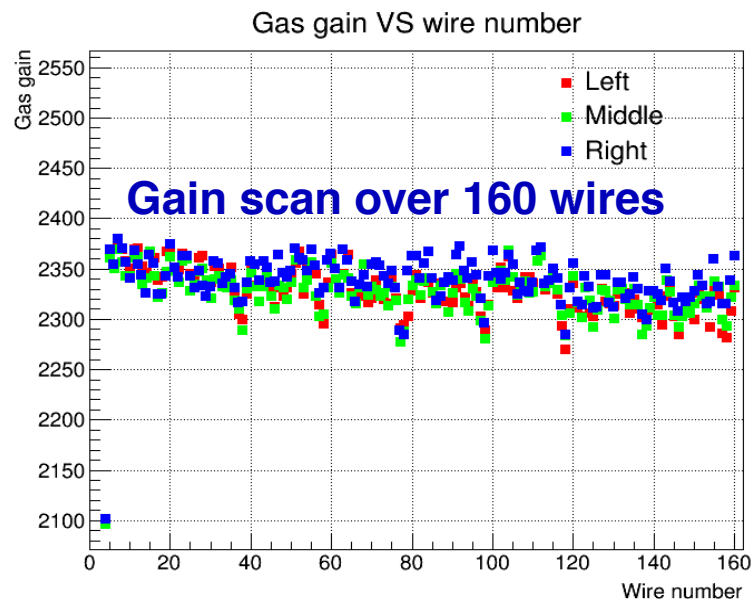


- 2016年12月完成了丝室原型制作
- 2017年10月第一个成功安装到STAR
- 2018年6月完成全部30个模块制作
- 目前正在安装过程，参与2018年取数



iTPC丝室性能测试

From Qinghua Xu



- All meet the STAR requirements

F. Shen et. al., NIM A 896 (2018) 90

PandaX-II

From Meng Wang

■ PandaX-II 刻度

- 老的刻度方法, Am-Be 中子源, ^{60}Co , ^{137}CS 光子源
- 新的刻度源： ^{220}Rn 注入用做低能ER 刻度； ^{83}Kr 注入，可以用 42keV峰做探测器响应的修正

■ 正在准备PandaX-II的刻度文章

- PandaX-II 计划年底结束运行，负责结束运行之前的一些测试（新的刻度源，变化电场，循环流速，modified trigger，尝试low gain看 $0\nu\beta\beta$ 衰变等等）的现场协助

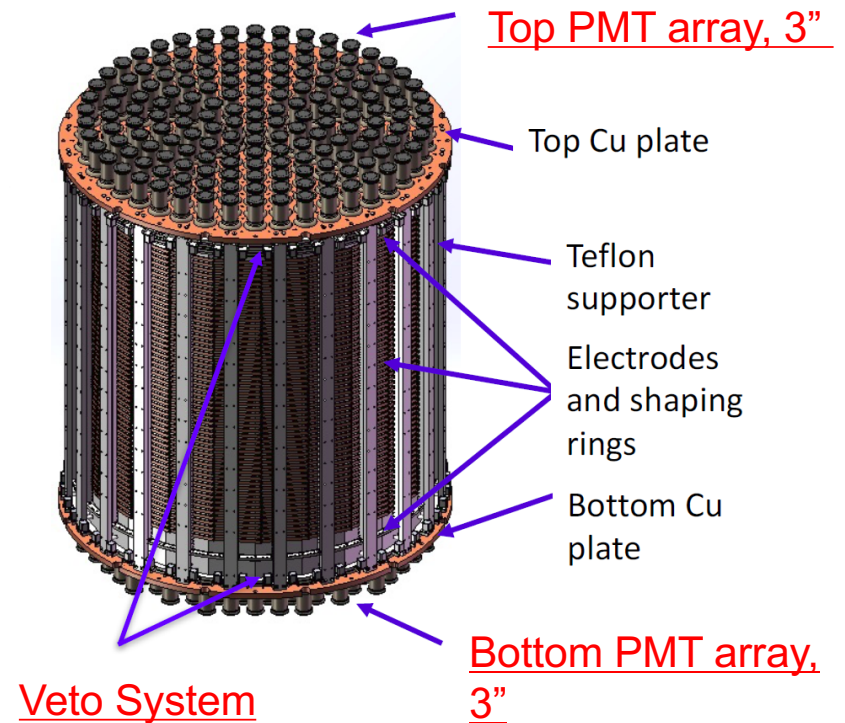
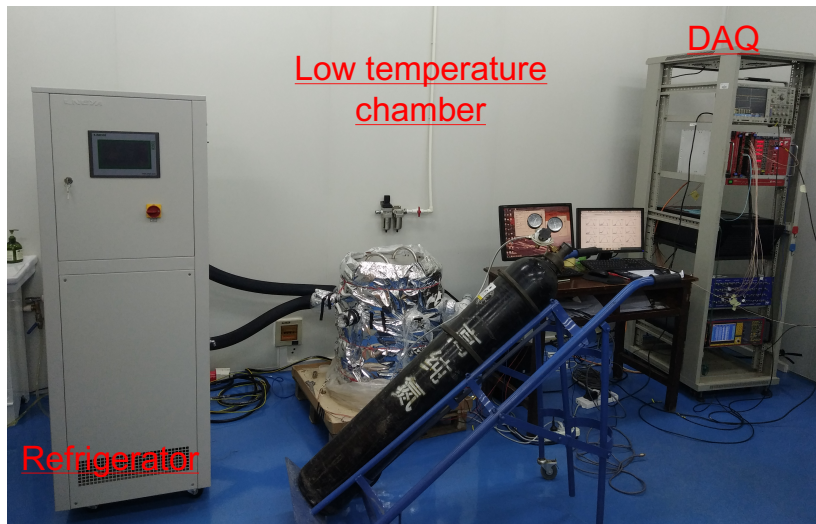
PandaX-4Ton

From Meng Wang

■ 山大负责PMT系统

- Top: 169 3-inch R11410-23
- Bottom: 199 3-inch R11410-23
- Veto system: ~140 1-inch R8520

Hamamatsu
3-inch R11410-23



Finished the CEPC CDR on silicon tracker

4 components

SIT – Silicon Inner Tracker

SET – Silicon External Tracker

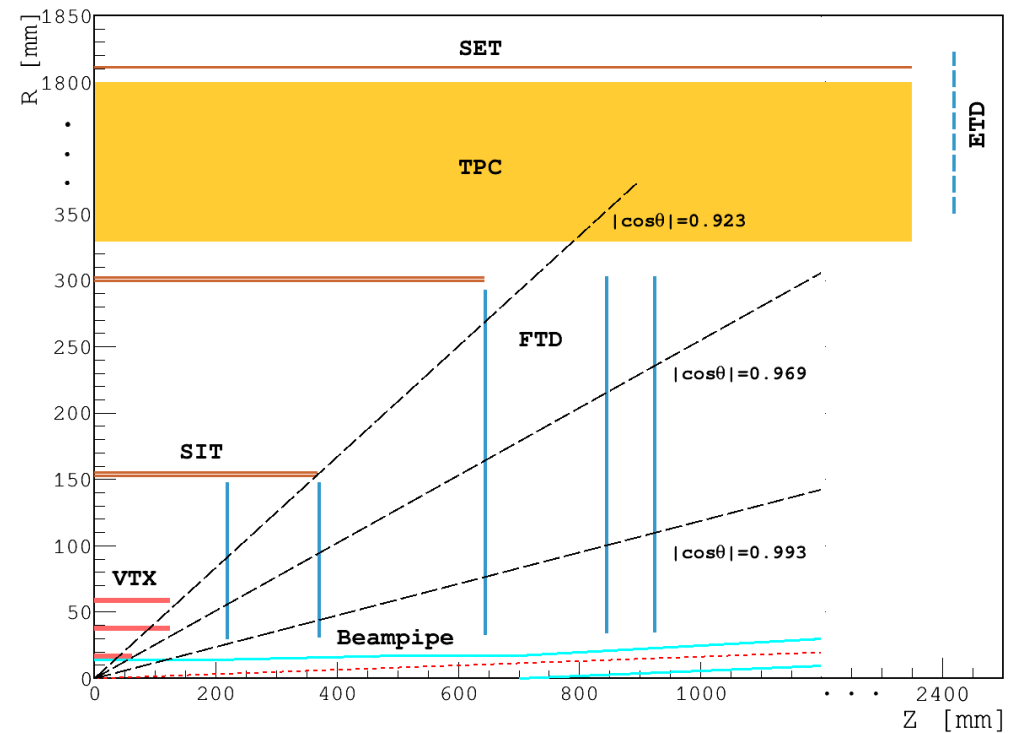
ETD – Endcap Tracking Detector

FTD – Forward Tracking Detector

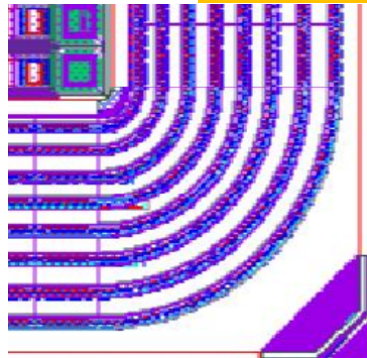
From Meng Wang

Detector		Radius R [mm]	z [mm]	Material budget [X_0]
SIT	Layer 1:	153	371.3	0.65%
	Layer 2:	300	664.9	0.65%
SET	Layer 3:	1811	2350	0.65%
FTD	Disk 1:	$R_{in} = 39$ $R_{out} = 151.9$	220	0.50%
	Disk 2:	$R_{in} = 49.6$ $R_{out} = 151.9$	371.3	0.50%
	Disk 3:	$R_{in} = 70.1$ $R_{out} = 298.9$	644.9	0.65%
	Disk 4:	$R_{in} = 79.3$ $R_{out} = 309$	846	0.65%
	Disk 5:	$R_{in} = 92.7$ $R_{out} = 309$	1057.5	0.65%
ETD	Disk:	$R_{in} = 419.3$ $R_{out} = 1822.7$	2420	0.65%

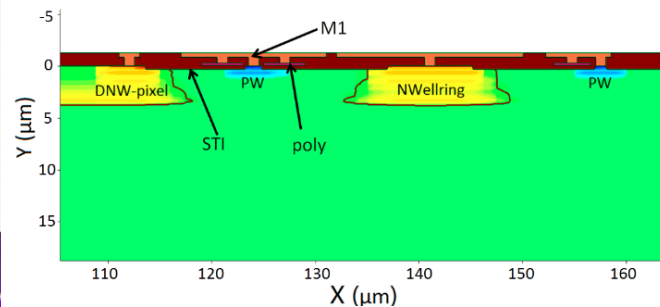
Table 4.5: Main parameters of the CEPC silicon tracker.



TCAD simulations for CMOS pixel sensors



Guard-ring layout

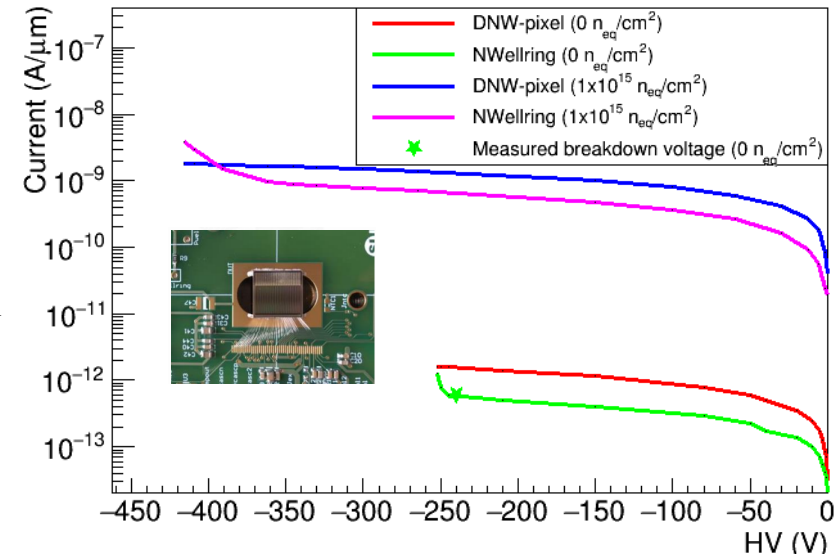


The partially pixel region implementation

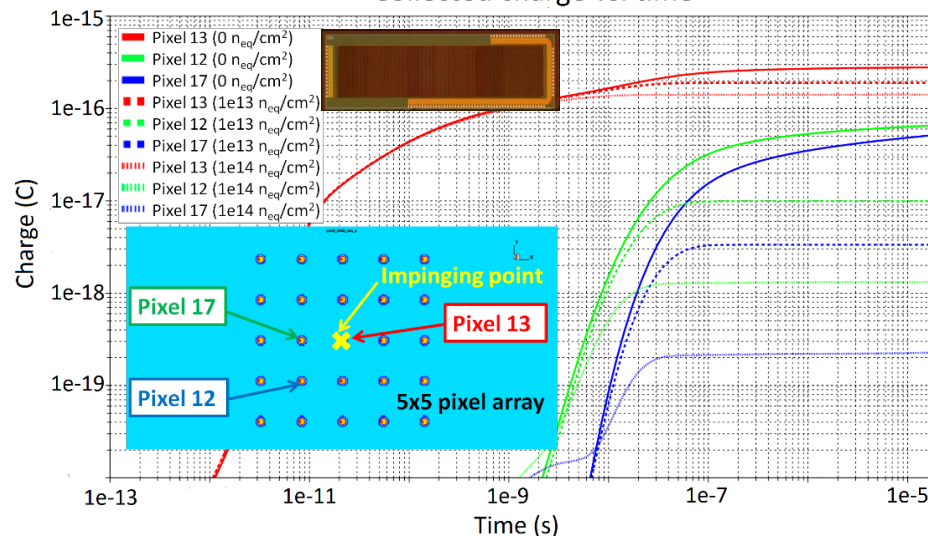
ATLAS Depleted CMOS sensor (guard-ring simulation):

- After optimization, the breakdown occurs at **-240 V** (previous -80 V).
- Breakdown voltage agrees with the TCAD simulations!
- **Improved BV achieved** → full depleted CMOS sensor → **enhanced radiation hardness**.

Leakage Current of LF CPIX V2



Collected charge vs. time



CEPC CMOS sensor (transient simulation):

- The “Pixel 13” could collect **1739 e-**, and reduces to 887 e- after $1e14 n_{eq}/cm^2$.
- The neighbors (“Pixel 12” and “Pixel 17”) collect charge by diffusion and lose the charge collection capability after $1e14 n_{eq}/cm^2$.

Fluence (n_{eq}/cm^2)	0	1×10^{13}	1×10^{14}
Pixel 13 (electron)	1739	1191	887
Pixel 12 (electron)	409	64	8
Pixel 17 (electron)	321	21	1

Publication:

Simulations of depleted CMOS sensors for high-radiation environments, J. Liu et al, 2017 JINST 11 C11013

R&D for a CPS based telescope

From Meng Wang

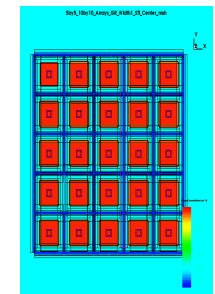
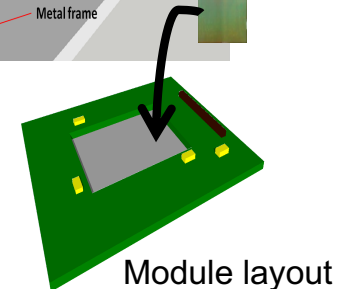
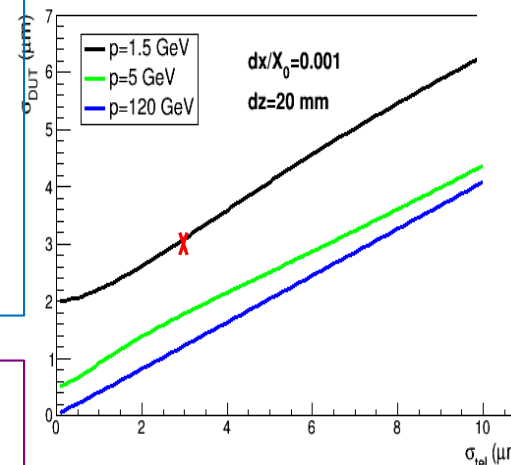
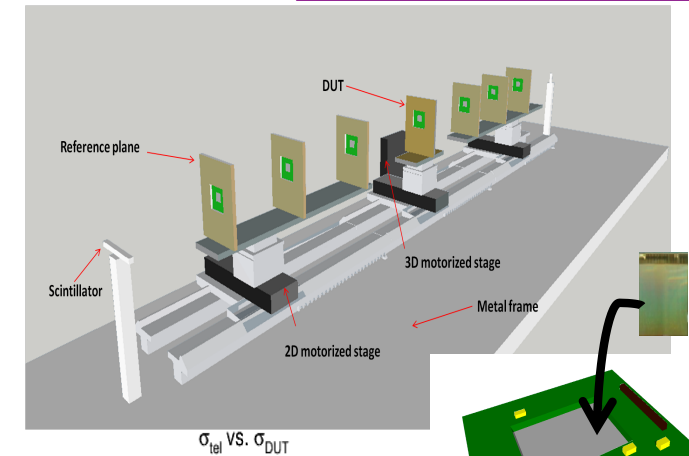
The position requirements for the next generation collider experiments will reach a level of a few microns, for instance,

- ILC(<4 μm),
- CLIC(3 μm vertex, 7 μm tracker),
- CEPC(3-5 μm)

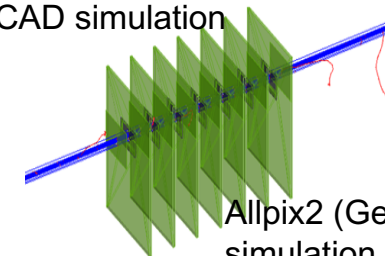
The telescope mainly consists of:

- Two arms, each hosting 3 reference planes
- One or four high spatial resolution CMOS pixel sensors on each plane. Pixel pitch 16 μm by 16 μm \rightarrow ~ 3 μm spatial resolution
- DUT mounted between the two arms
- Crossed scintillators for trigger
- DAQ

A new beam telescope which could offer the spatial resolution of 3 μm with a 1.5 GeV electron test beam (BEPC test beam) is under R&D.



Device for TCAD simulation



$p = 1.5 \text{ GeV}$, $dz = 20 \text{ mm}$, $dx/X_0 = 0.001$, $\sigma_{tel} = 3 \mu\text{m} \rightarrow \sigma_{dut} = 2.88 \mu\text{m}$

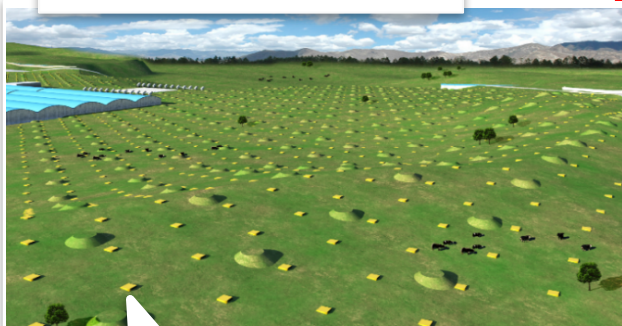
From Dong Liu

Large High Altitude Air Shower Observatory **LHAASO**

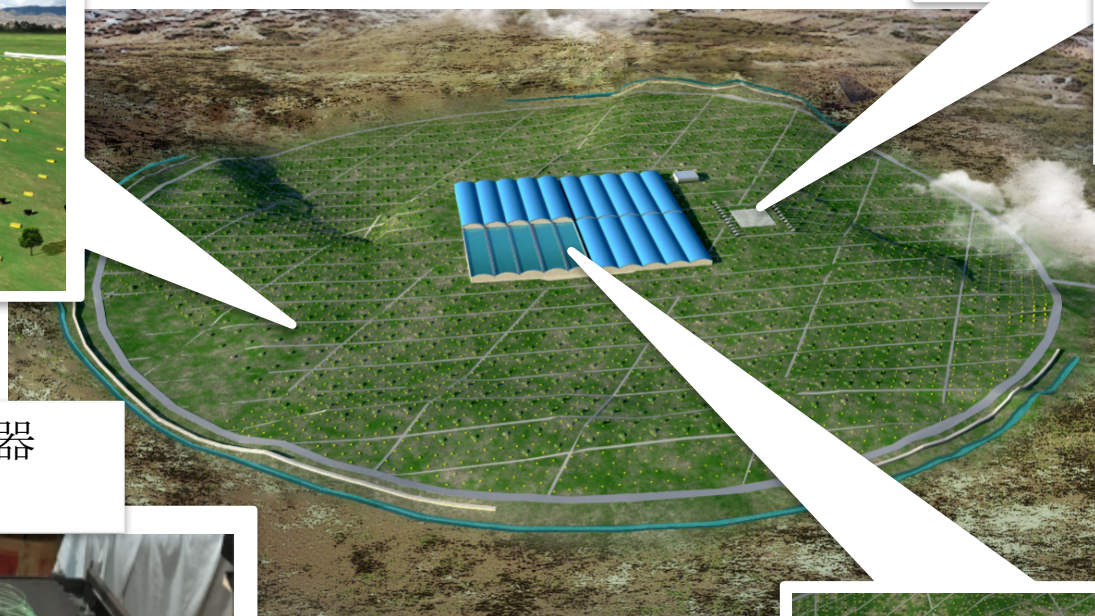
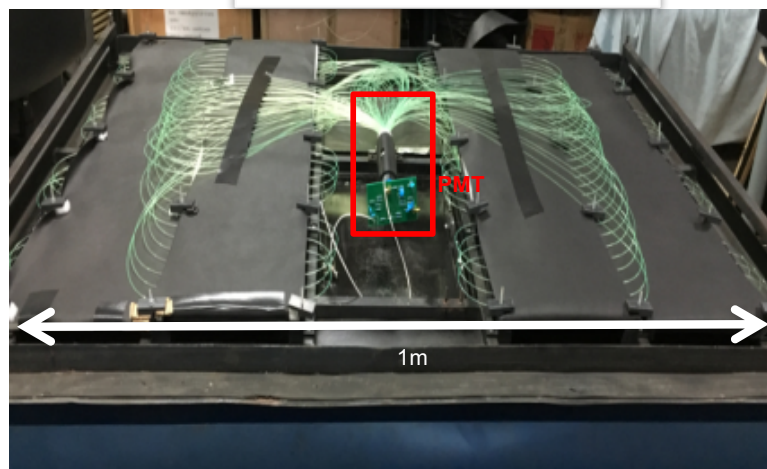
地面簇射粒子阵列

KM2A:

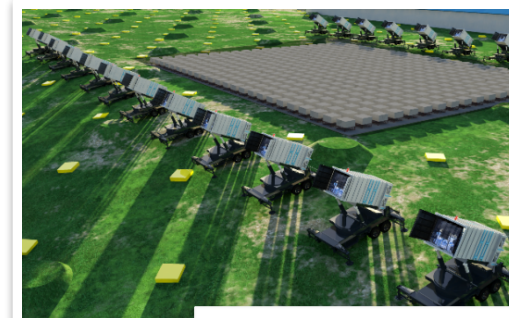
- 5195 **EDs**
- 1171 **MDs**



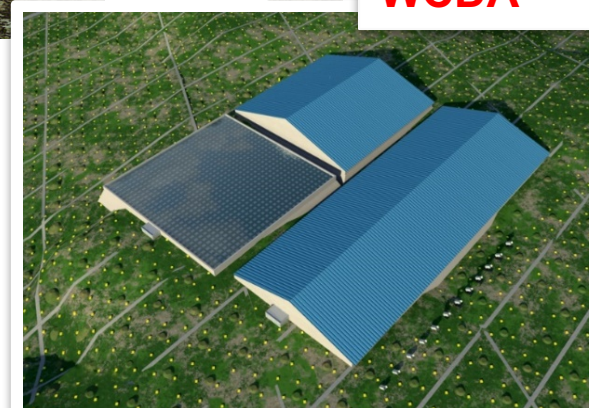
电磁粒子探测器
ED



广角切伦科夫
望远镜阵列
WFCTA



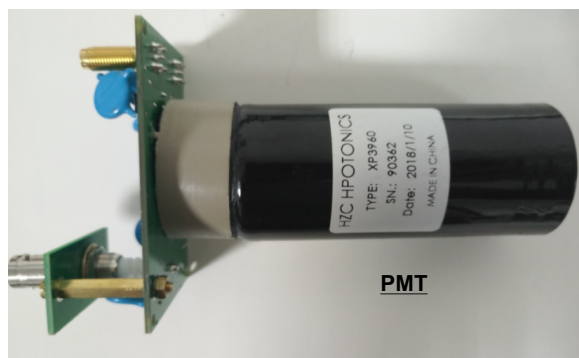
水切伦科夫
探测器阵列
WCDA



小尺寸光敏探头的研制

From Dong Liu

- LHAASO实验中，山东大学承担了ED和WCDA++的小尺寸光敏探头研制任务
- 将为LHAASO实验提供：5195支ED的PMT和945支WCDA++的PMT



- 参加PMT的选型和分压器设计
- 中国制造1.5英寸PMT，型号XP3960
- PMT增益: 4×10^5
- 采用阳极、打拿极同时读出
- 实现4个量级的动态范围



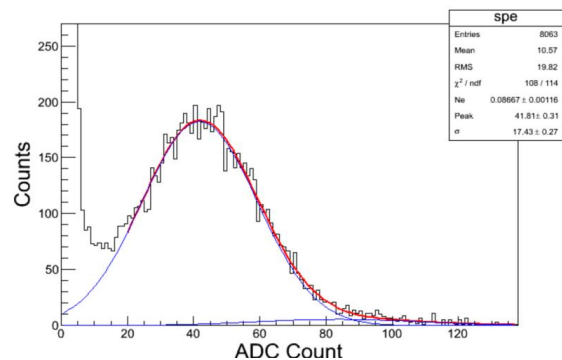
PMT批量测试平台

- 批量测试系统可以实现PMT的各项测试任务
- 测量工作一键式操作，测试精度达到要求
- 每月为LHAASO建设提供300支合格的PMT

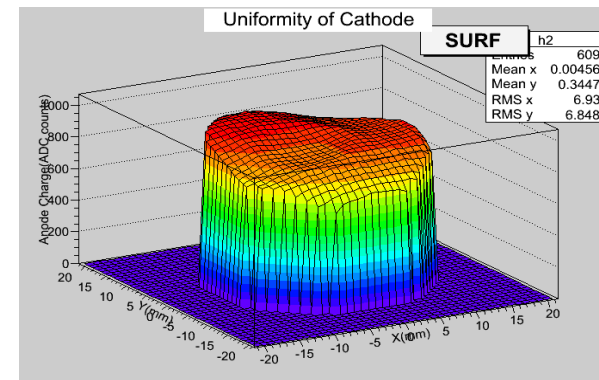
PMT批量测试

From Dong Liu

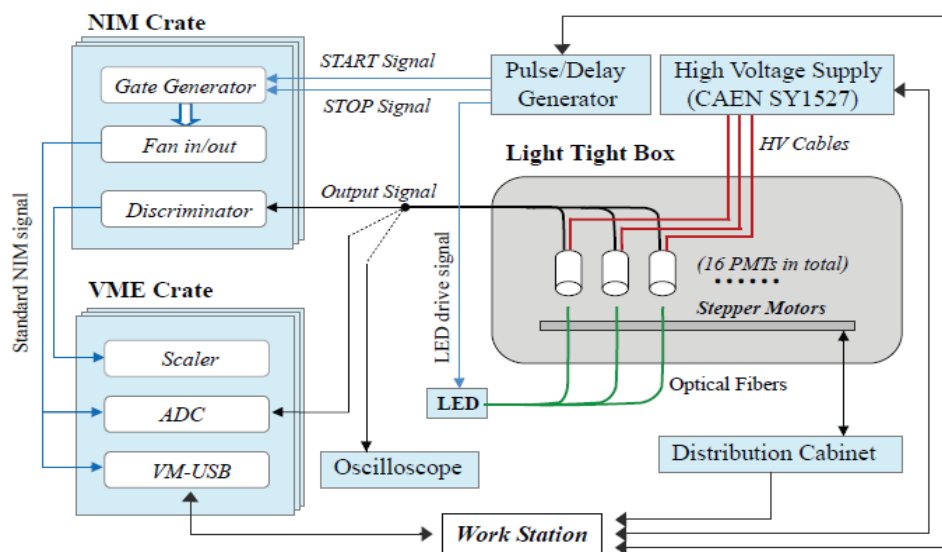
- 同时可测8-16个PMT
- VME DAQ系统
- 光源：LED/ps脉冲激光发生器
- 光阴极面二维扫描系统
- 使用双距离法测线性范围



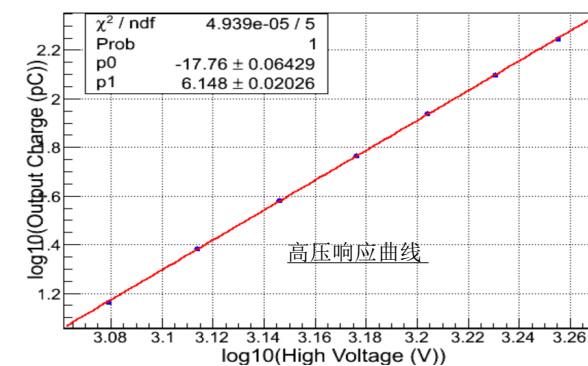
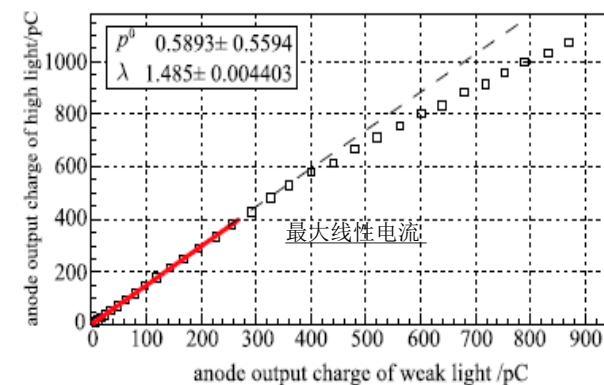
单光电子峰



光阴极面均匀性扫描图



测试平台工作原理

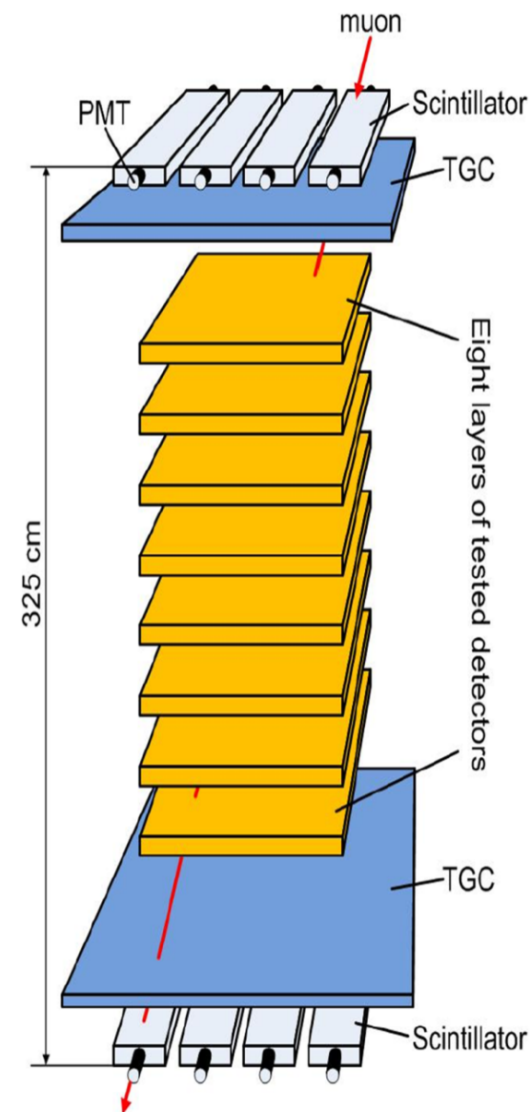


ED宇宙线测试系统CoRaRS

From Dong Liu

- 使用条形闪烁体触发
- TGC:监测 μ
 - ATLAS μ 探测器
 - 山东大学制
- 每次检测8片ED探测器
- 可以满足ED批量测试

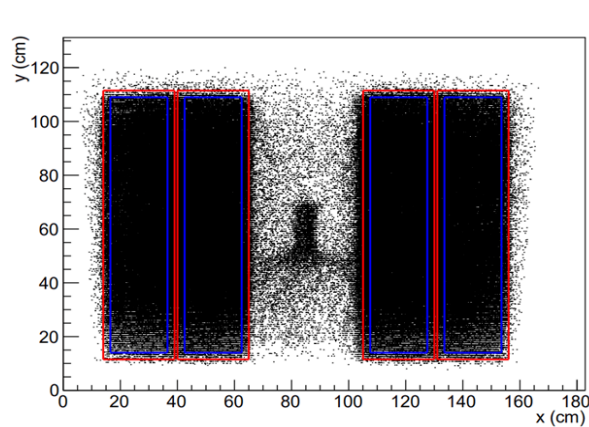
CoRaRS (Cosmic Ray Reference System)



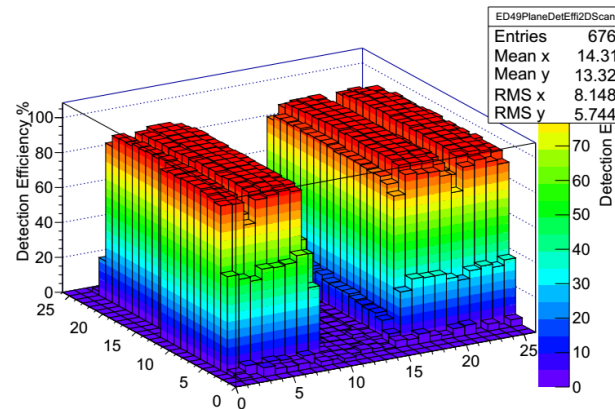
CoRaRS测试系统性能

覆盖面积	1.2m x 1.5m
触发率	25Hz
时间分辨精度	~640ps
位置分辨精度	<1cm
测试速度	156/月

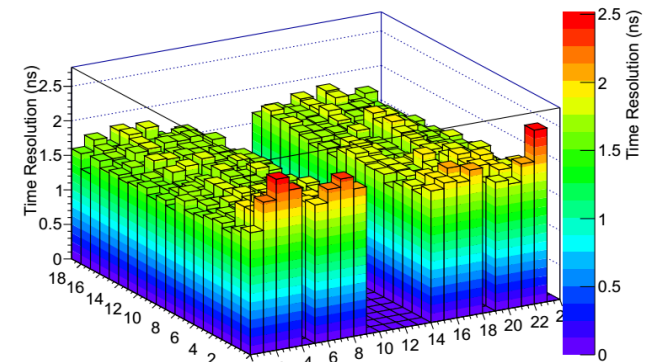
ED测试结果



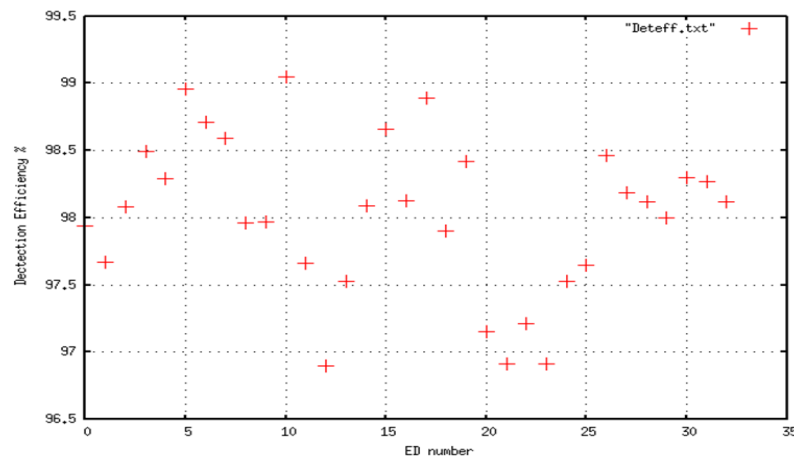
CoRaRS扫描出的ED内部结构



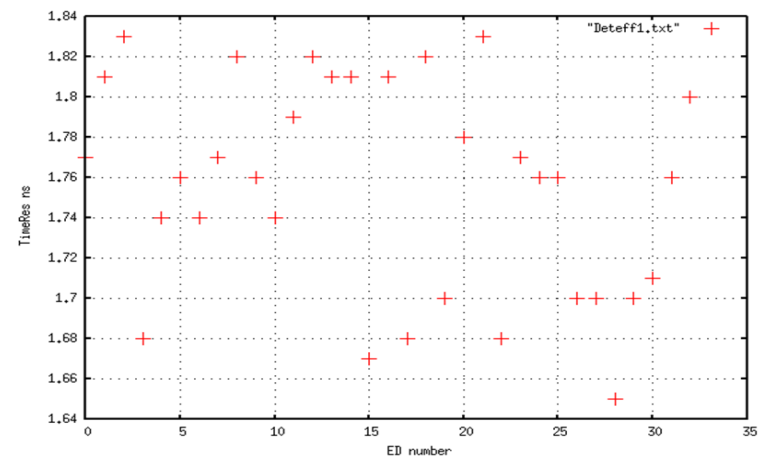
探测效率



时间分辨



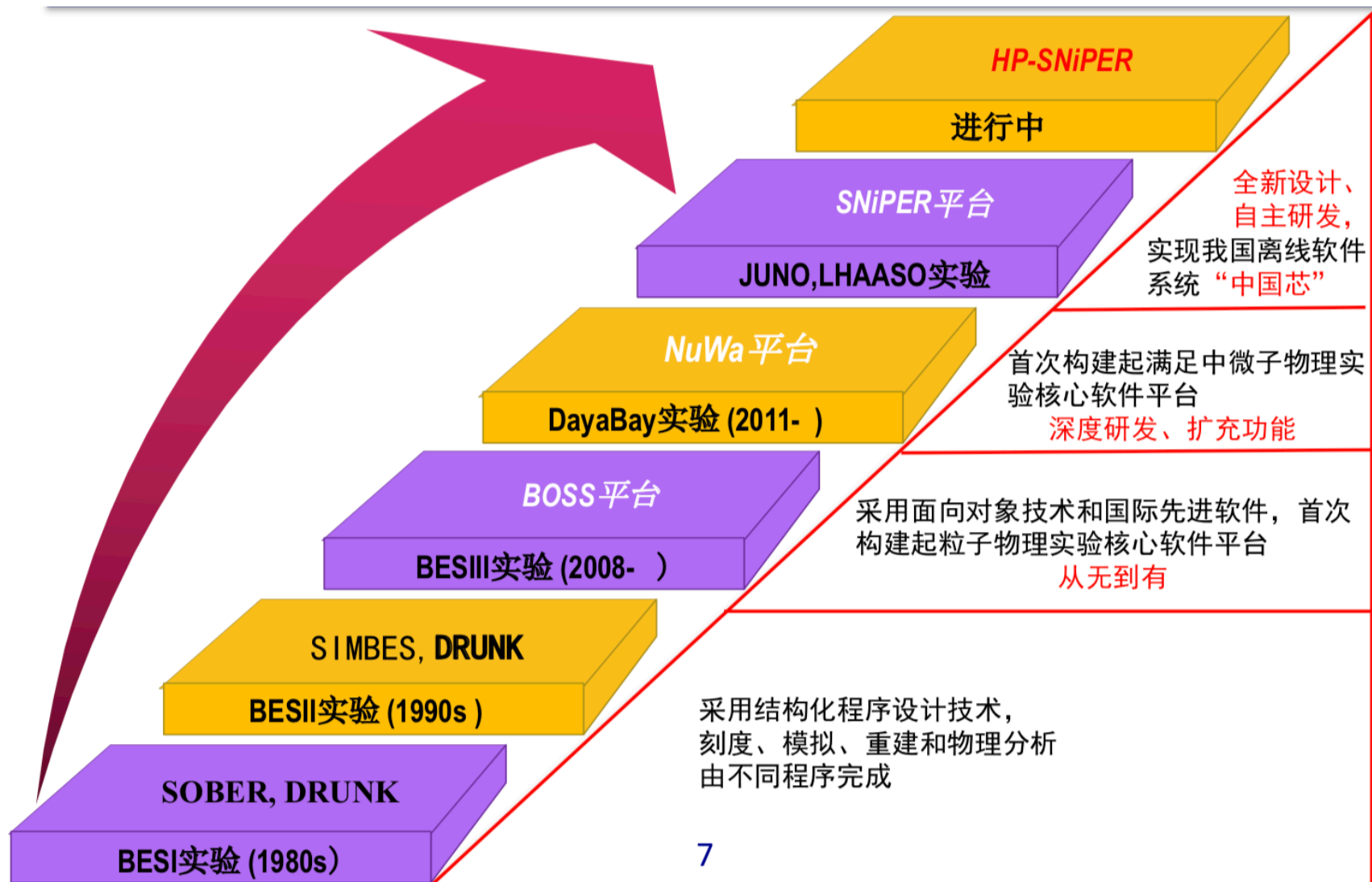
33个ED探测器的探测效率



33个ED探测器的时间分辨

山大开展软件工作

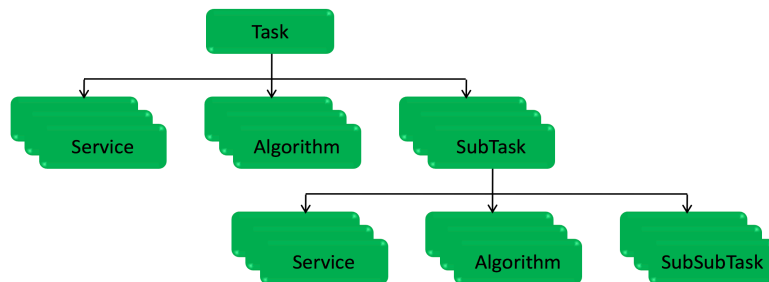
山东大学参与离线软件平台的研发



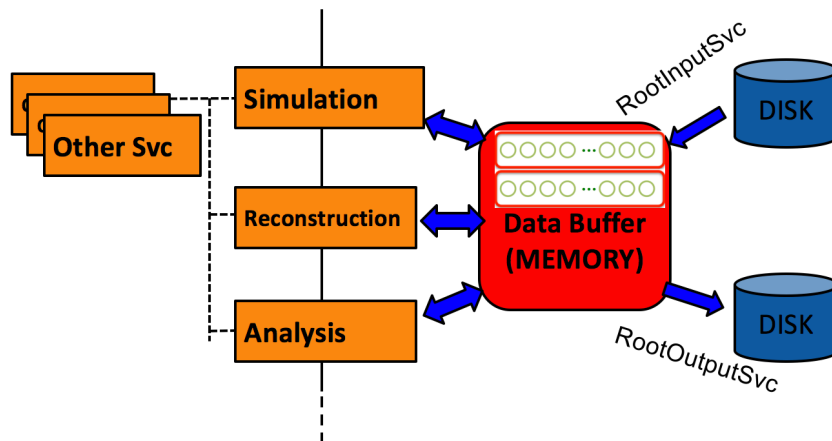
SNiPER软件平台的研发

■ 全新设计和开发

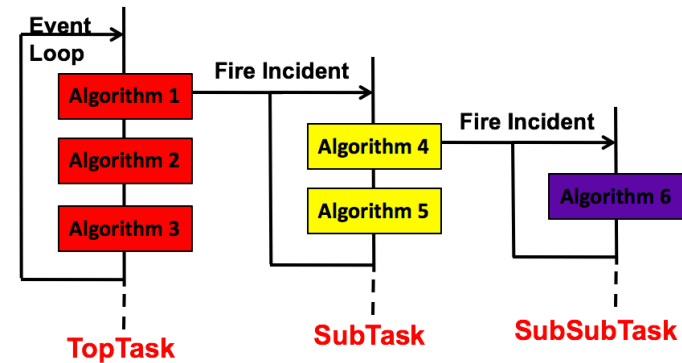
- C++ & Python
- Modular Design



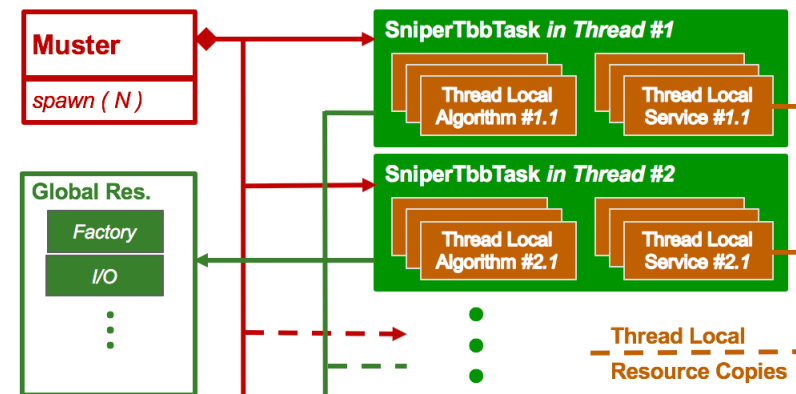
● 数据缓存机制



● 灵活的控制流程



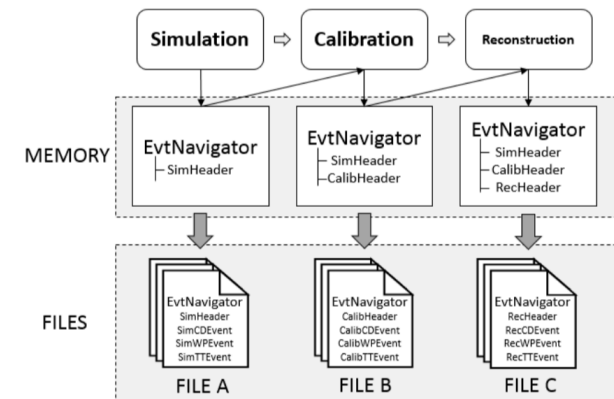
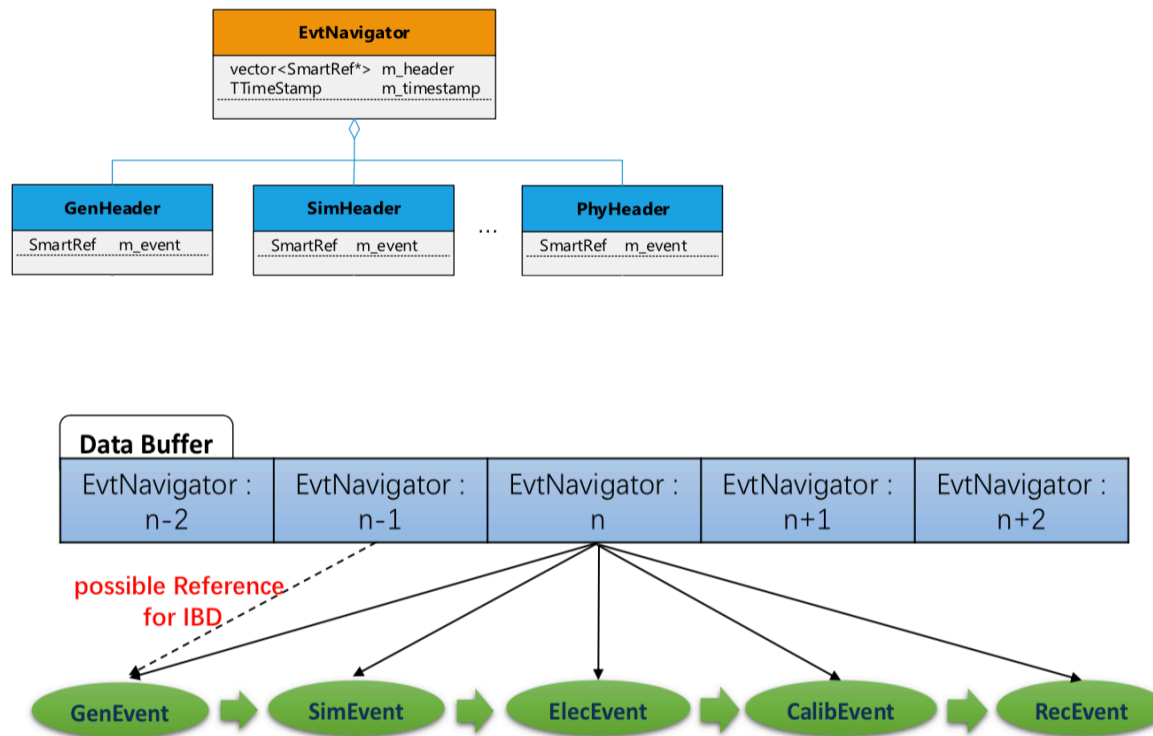
● 支持并行处理



- 完备服务体系
- 友好用户接口

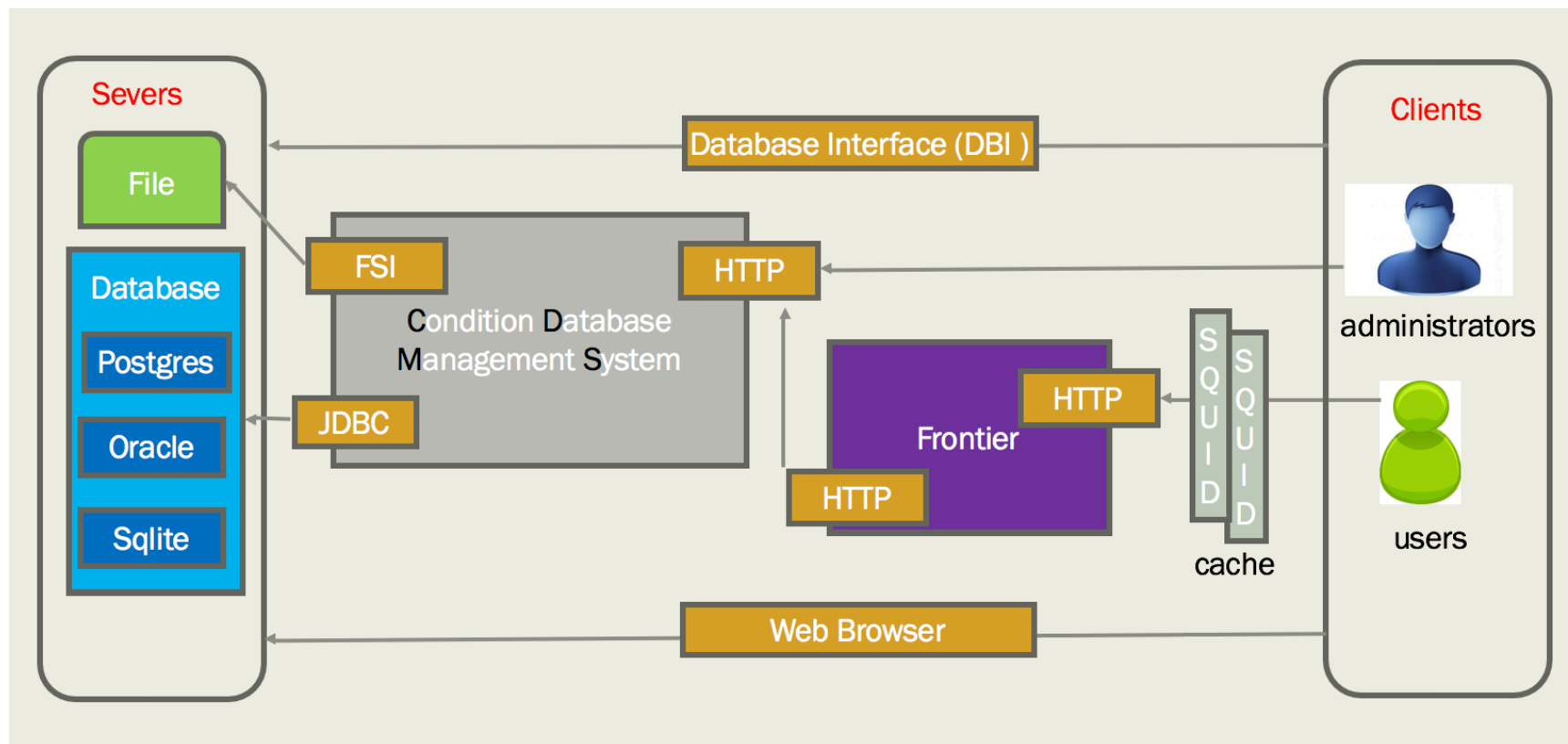
新型智能指针和数据模型的设计

- 数据关联机制是粒子物理实验构建事例数据模型的关键技术
- 基于ROOT全局统一标识符(UUID)开发新型智能指针Smart Reference
- 设计了JUNO实验的数据模型，实现了JUNO模拟数据的复杂关联问题，提升了I/O性能
- 设计了LHAASO实验的数据模型，正在进行测试



CPC 41(6): 066201 (2017)

数据库管理系统的设计



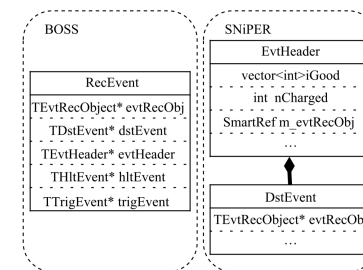
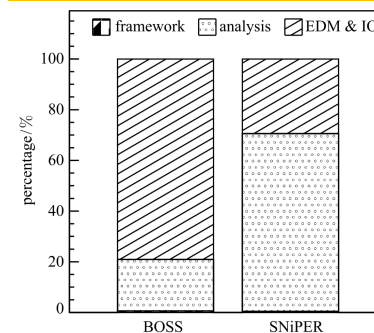
- Client-Server Structure, they are separated
- In server side, underlying database is flexible
- In client sides, several methods available
- July, 2018: First review by JUNO collaboration
- The system will be used by other experiments.

SNiPER平台推广应用

- 搭建起JUNO实验整个离线软件系统，16年通过合作组专家评审
- 以SNiPER为底层架，重新设计BESIII重建事例模型，测试了IO速度

	framework	EDM & I/O	analysis
BOSS /min	1.0	135.0	34.6
SNiPER /min	0.18	13.1	31.2
gains	5.6	10.3	1.1

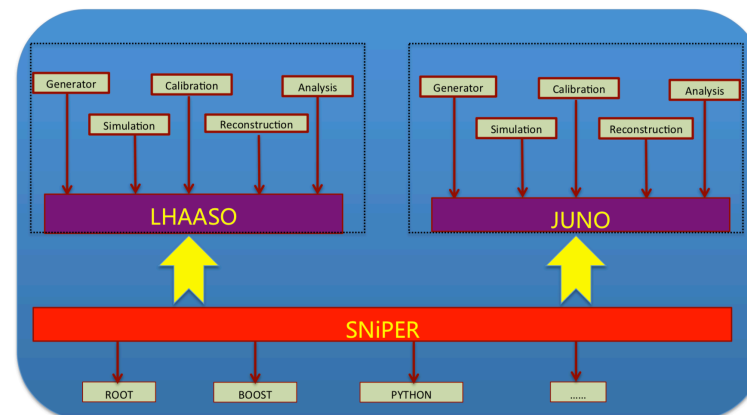
CPC 41(5): 056202 (2017)



- 搭建起LHAASO实验离线系统LodeStar，开始探测器模拟研究

- 美国nEXO实验正在进行应用测试

- 推广到更多的实验中.....



山大开展物理研究工作

BESIII Physics at SDU

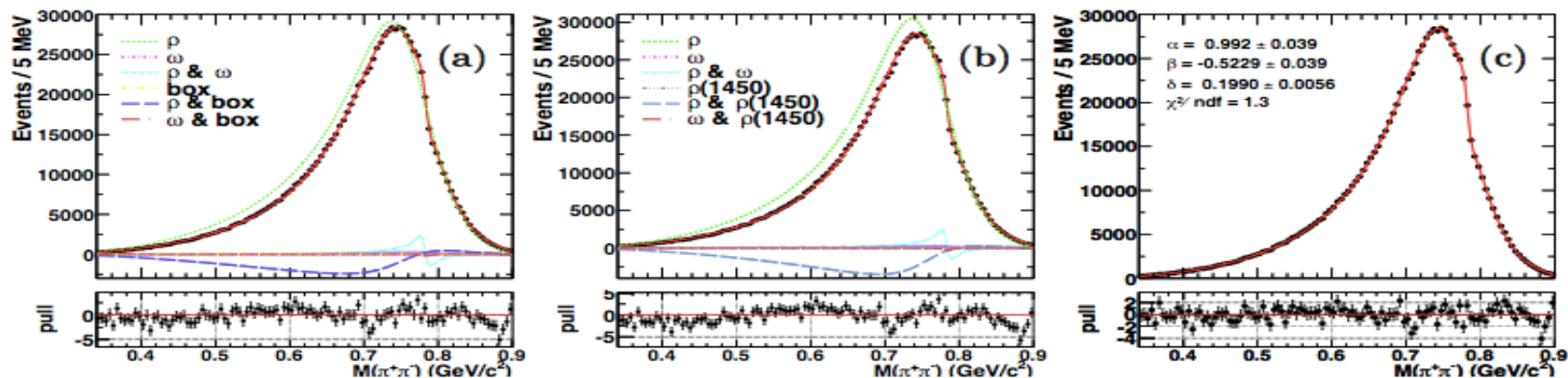
- **Study of J/ψ and $\psi(3686) \rightarrow \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$** , Jianbin Jiao, etc. ,Published in P.R.D 95, 052003 (2017)
 - The branching fractions are determined, with much improved precision,
 - The polar angular distributions of $\psi(3686)$ decays are measured for the first time,
 - Testing the “12% rule.”
- **Branching fraction measurements of $\psi(3686) \rightarrow \gamma \chi_{cJ}$** , Fred Harry, Jianbin Jiao, etc.,Published in P.R.D 96,032001 (2017)
 - The branching fractions of $\psi(3686) \rightarrow \gamma \chi_{c0,1,2}$ are measured with improved precision.

TABLE II. Branching fraction results. The indicated uncertainties are statistical only.

Branching Fraction	Events ($\times 10^6$)	Efficiency	Branching Fraction (%)
$\mathcal{B}(\psi(3686) \rightarrow \gamma \chi_{c0})$	4.6871 ± 0.0068	0.4692	9.389 ± 0.014
$\mathcal{B}(\psi(3686) \rightarrow \gamma \chi_{c1})$	4.9957 ± 0.0054	0.4740	9.905 ± 0.011
$\mathcal{B}(\psi(3686) \rightarrow \gamma \chi_{c2})$	4.2021 ± 0.0055	0.4104	9.621 ± 0.013
$\mathcal{B}(\psi(3686) \rightarrow \gamma \chi_{c0}) \times \mathcal{B}(\chi_{c0} \rightarrow \gamma J/\psi)$	0.0123 ± 0.0081	0.4920	0.024 ± 0.015
$\mathcal{B}(\psi(3686) \rightarrow \gamma \chi_{c1}) \times \mathcal{B}(\chi_{c1} \rightarrow \gamma J/\psi)$	1.8881 ± 0.0053	0.5155	3.442 ± 0.010
$\mathcal{B}(\psi(3686) \rightarrow \gamma \chi_{c2}) \times \mathcal{B}(\chi_{c2} \rightarrow \gamma J/\psi)$	0.9828 ± 0.0041	0.5150	1.793 ± 0.008
$\mathcal{B}(\chi_{c0} \rightarrow \gamma J/\psi)$			0.25 ± 0.16
$\mathcal{B}(\chi_{c1} \rightarrow \gamma J/\psi)$			34.75 ± 0.11
$\mathcal{B}(\chi_{c2} \rightarrow \gamma J/\psi)$			18.64 ± 0.08

BESIII Physics at SDU

- **Observation of e^+e^- to $\phi\chi_{c1}$ and $\phi\chi_{c2}$ at 4.6 GeV**, Qiyun Li, Changzheng Yuan, Xueyao Zhang, etc. , Published in P.R.D 97, 032008 (2018)
 - Observed $e^+e^- \rightarrow \phi\chi_{c1}$ and $\phi\chi_{c2}$ for the first time and their Born cross sections were measured
 - No obvious signals for $e^+e^- \rightarrow \gamma Y(4140)$ ($\sigma^B < 1.2$ pb)
- **Measurement of the absolute branching fraction of $D_{s0}^*(2317)^\pm \rightarrow \pi^0 D_s^\pm$** , Ke Li, Changzheng Yuan, Xingtao Huang, etc. , Published in P.R.D 97, 051103(R) (2018)
 - Observed $D_{s0}^*(2317)^-$ signal with $> 5.8\sigma$ in $e^+e^- \rightarrow D_s^+ D_{s0}^*(2317)^-$ process.
 - Measured the absolute branching fraction of $D_{s0}^*(2317)^\pm \rightarrow \pi^0 D_s^\pm$ for the first time .
- **Precision Study of $\eta' \rightarrow \gamma\pi^+\pi^-$ Decay Dynamics**, Liqing Qin, Shuangshi Fang, Xingtao Huang, etc. , Published in P.R.L 120, 242003 (2018)
 - Both model-dependent and model-independent approaches are used



BESIII Physics at SDU

- Measurement of asymmetry parameters of Λ and $\bar{\Lambda}$ decays, (Jianbin Jiao etc.),[submitted to Nature Physics](#).
- Measurement of BF's for eta' exclusive decays using gamma conversion,(Yuming Ma, Shuangshi Fang, Xingtao Huang) [SP's Approval](#)
- PWA of $\Psi(2S) \rightarrow K_S K_{\pi}$ (Xiaoling Li) , [Draft polishing](#)
- Confirmation of the X(1840) in $J/\psi \rightarrow \gamma 3(\pi^+ \pi^-)$ (Liqing Qin, Shuangshi Fang, Xingtao Huang), [Memo reviewing](#)
- PWA of $J/\psi \rightarrow \bar{p} K^+ \Sigma^0 + c.c.$, (Yuming Ma, Shuangshi Fang, Xingtao Huang),[Memo preparing](#)
- Analysis of $\Psi(2S) \rightarrow \Omega^+ \Omega^-$, angular distribution and branching ratio,(Jiaojiao Song, Changzheng Yuan, Xueyao Zhang), [Memo preparing](#).
- Search for $e^+ e^- \rightarrow \gamma \chi_{c0,1,2}$ with the data > 4 GeV, (Houbin Jiang, Qiyun Li, Changzheng Yuan, Xingtao Huang) [Memo preparing](#)
- Precise measurement of $e^+ e^- \rightarrow \pi^+ \pi^- J/\psi$ cross section and Y(4260) parameters, (Houbing Jiang, Zhiqing Liu , Xingtao Huang), [Memo preparing](#)
- PWA of $J/\psi \rightarrow \gamma \gamma \phi$ (Tingting Han, Bei Jiang Liu , Xingtao Huang)
- Study of X(1835) and X(2370) (Houbing Jiang, Yanping Huang, Xingtao Huang)
- Tracking and PID Efficiency of Kaon (Tingting Han , Xiaoling Li , Xingtao Huang)
- Tracking and PID Efficiency of proton and pion (Jiaojiao Song, Changzheng Yuan, Xueyao Zhang)

➤ Topics: (2017-2018共发表10篇文章)

– SM Higgs and top physics

- VH/VBF, $H \rightarrow bb$ (马延辉, 徐钟煜坤, 李通, Mario Jose)
- ggF/VBF, $H \rightarrow WW$ (杜东硕, 王双庚)
- ttH, $H \rightarrow \text{Multi-lepton}$ (王超, 李直, 杨轩)
- $H \rightarrow \mu\mu$ (李海峰)

– Search for new physics beyond SM physics

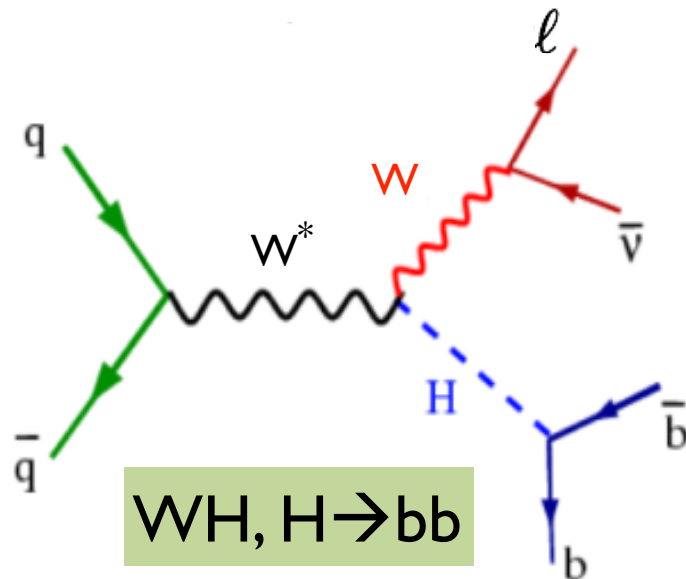
- Search for heavy Higgs in WW (赵永柯, 李直)
- Search for di-jet resonance (张登峰)
- Search for $W' \rightarrow tb$ (袁睿)
- Search for resonances of VH and WW (马延辉, 徐钟玉坤, 李通, Mario Jose)

实验上首次发现 $H \rightarrow bb$

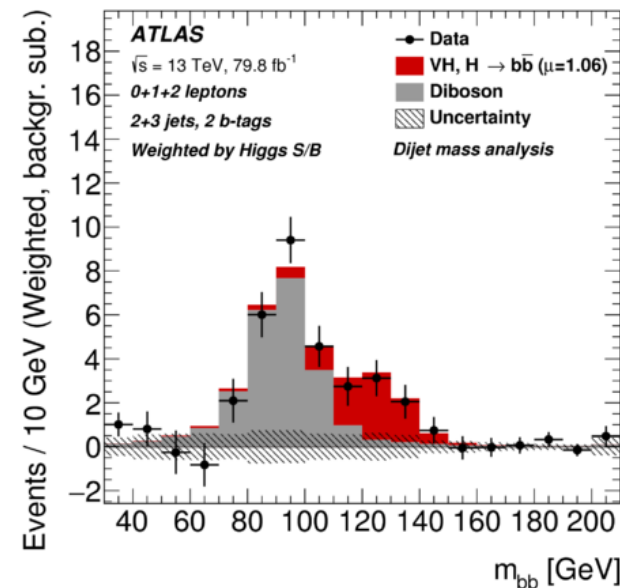
From Lianliang Ma

- 意义：寻找分支比最大衰变道 $H \rightarrow bb$ ，测量希格斯粒子与底夸克耦合
- 参加人员：马延辉，Mario Sousa，李通，马连良，
- 实验上观察到 $VH, H \rightarrow bb$ 信号： 4.9σ （预期 4.3σ ），联合VBF和 ttH 过程得到 5.4σ （预期 5.5σ ），[arXiv:1808.08238](https://arxiv.org/abs/1808.08238) (accepted by PLB).
- 主要贡献：在 $WH, H \rightarrow bb$ 中QCD本底估计和分析灵敏度优化， VH 分析的联合统计分析，马延辉代表工作组做Approval Talk，担任main note的编辑

[arXiv:1808.08238](https://arxiv.org/abs/1808.08238)



[JHEP12 \(2017\) 024](https://arxiv.org/abs/1808.08238)

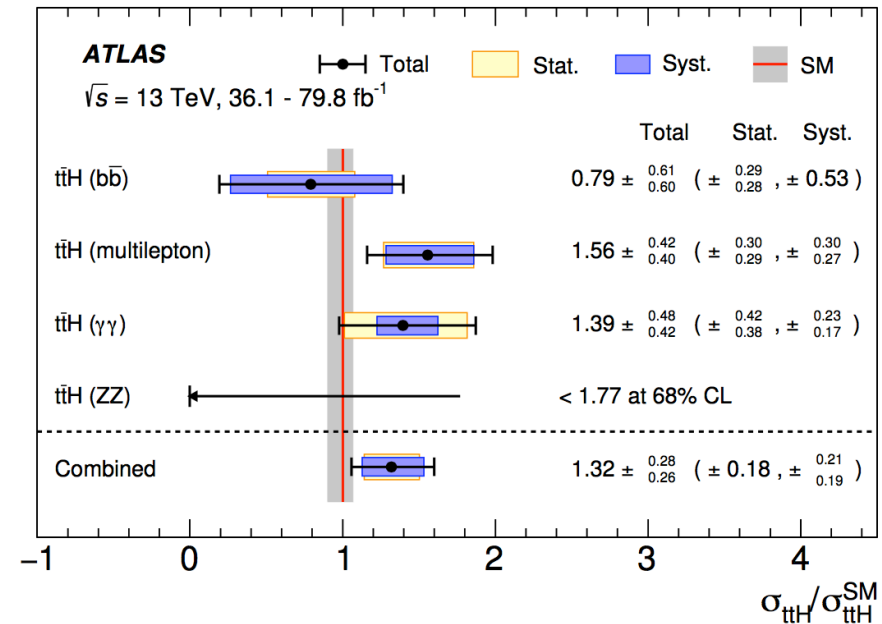
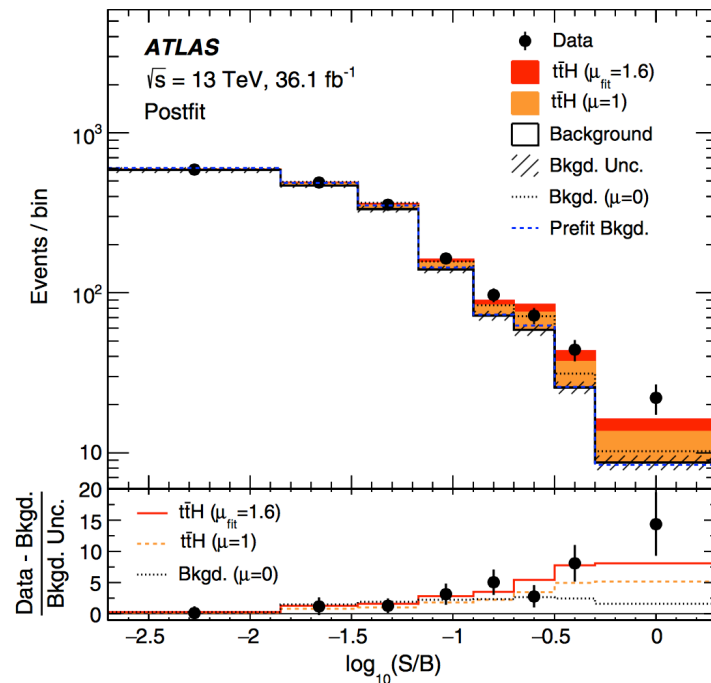


bb 不变质量谱

首次观察到ttH的产生过程

From Lianliang Ma

- 意义：寻找ttH产生过程，和测量希格斯粒子与顶夸克耦合
- 参与人员：王超，马连良
- 首次在多轻子末态观察到ttH信号迹象： 4.1σ (预期 2.8σ)，联合其他分析结果得到 6.3σ (预期 5.1σ)
- 主要贡献：含赭轻子(non-prompt)本底估计和多变量分析



[Phys. Rev. D 97 \(2018\) 072003](#) (multi-lepton)

[Phys. Lett. B 784 \(2018\) 173](#) (combination)

SM Higgs: $H \rightarrow \mu\mu$

From Lianliang Ma

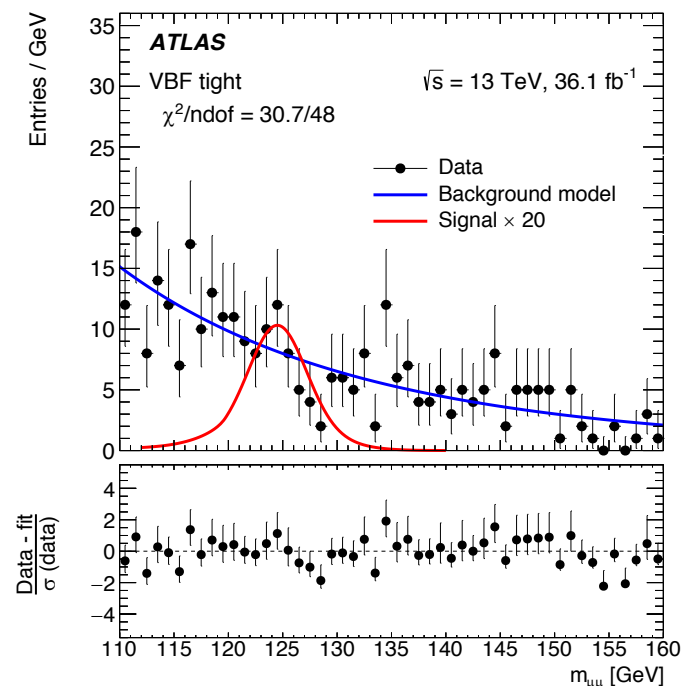
- ✧ 意义：测量Higgs和muon的耦合
- ✧ 参加人员：李海峰
- ✧ 主要贡献：分析协调人，文章contact editor，统计分析，ATLAS和CMS联合分析
- ✧ [Phys. Rev. Lett. 119, 051802](#) (PRL 编辑推荐文章)

Upper limit on signal strength

	Observed	Expected
Run-2	3.0	3.1
Run-1&Run-2	2.8	2.9

Measurement of signal strength

	$\hat{\mu}$
Run-2	-0.1 ± 1.5
Run-1&Run-2	-0.1 ± 1.4

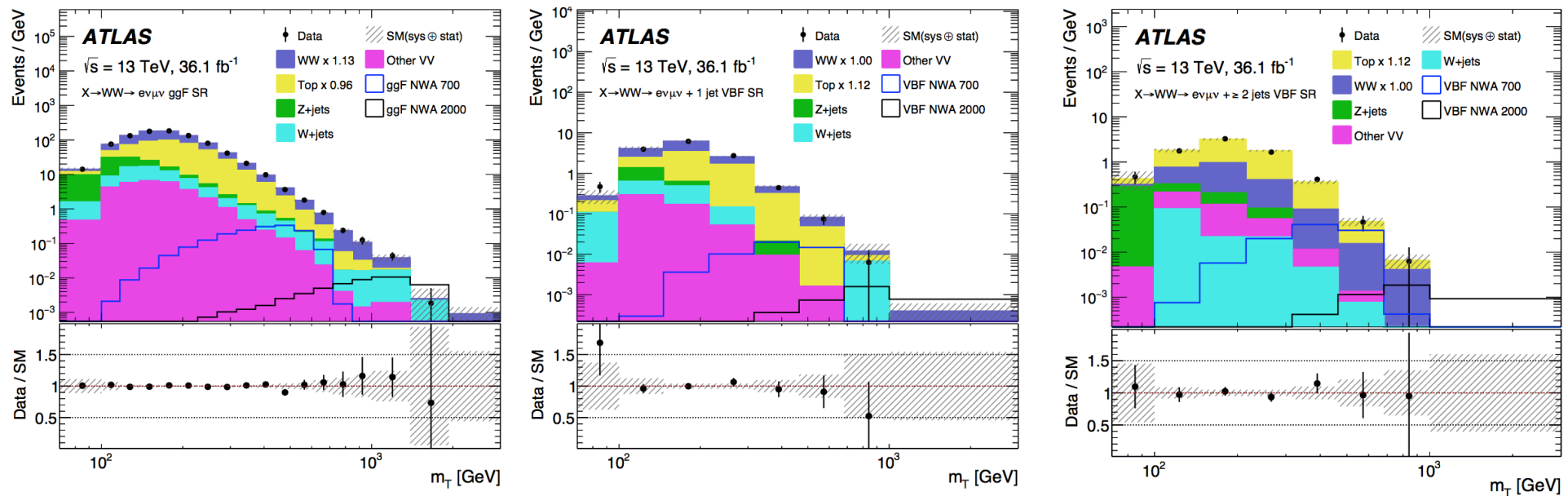


Search for a Heavy Higgs with $H \rightarrow WW \rightarrow l\nu l\nu$

From Lianliang Ma

- 意义：寻找超出标准模型的衰变到 WW 末态的高质量粒子(NWA, LWA, ...)
- 参与人员：赵永柯，宋维民，李直，徐钟煜坤，张学尧，马连良
- 主导贡献：事例优化， W +jets估计，本底理论误差估计，物理结果统计分析，做所有的Approval talks，Support note的编辑，文章Contact editor

Eur. Phys. J. C 78 (2018) 2



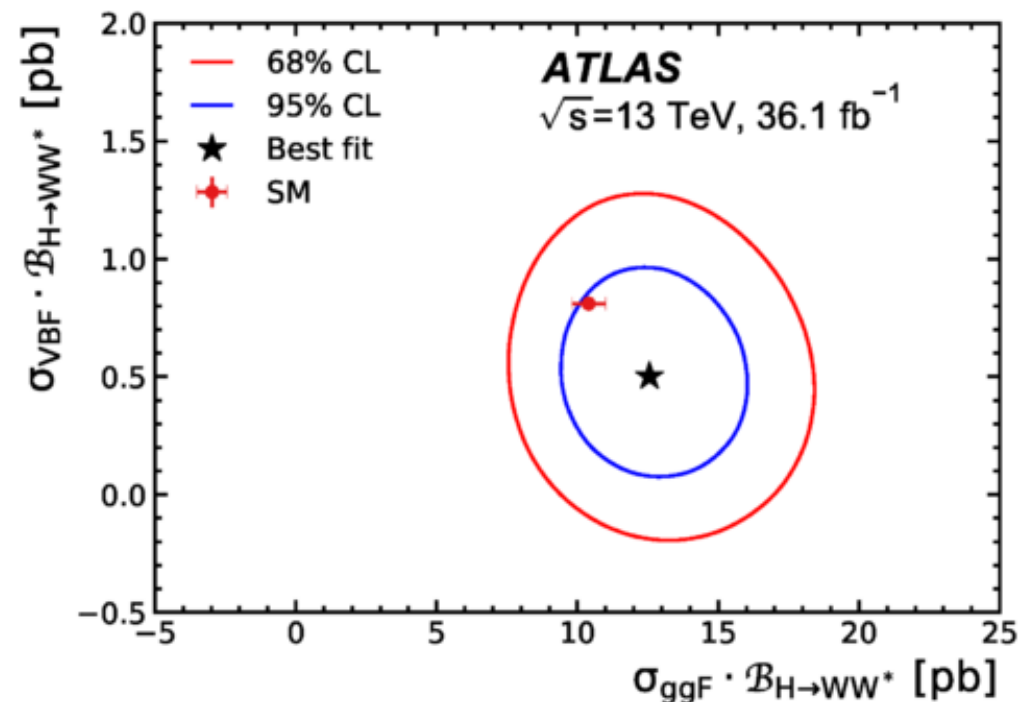
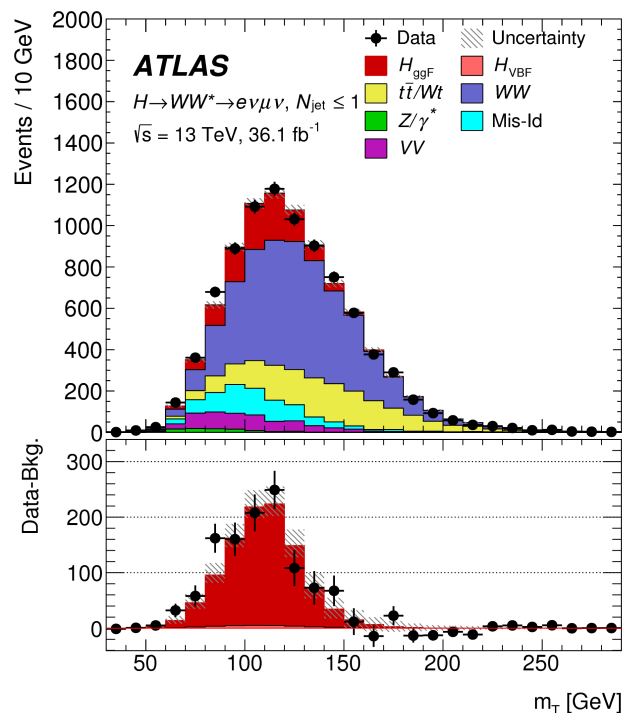
三个信号区间横向质量分布图: ggF-inclusive, VBF 1J, and VBF 2J.

SM Higgs: $H \rightarrow WW^*$

From Lianliang Ma

- ✧ 意义：深入理解对称自发破缺机制，寻找新物理的存在迹象。
- ✧ 参与人员：杜东硕，李直，宋维民，赵永柯，马连良
- ✧ 主要贡献：top和WW本底，赝轻子本底的估计，以及MC样本产生。
- ✧ 马连良作了Approval talk，文章在ATLAS合作组内审查中

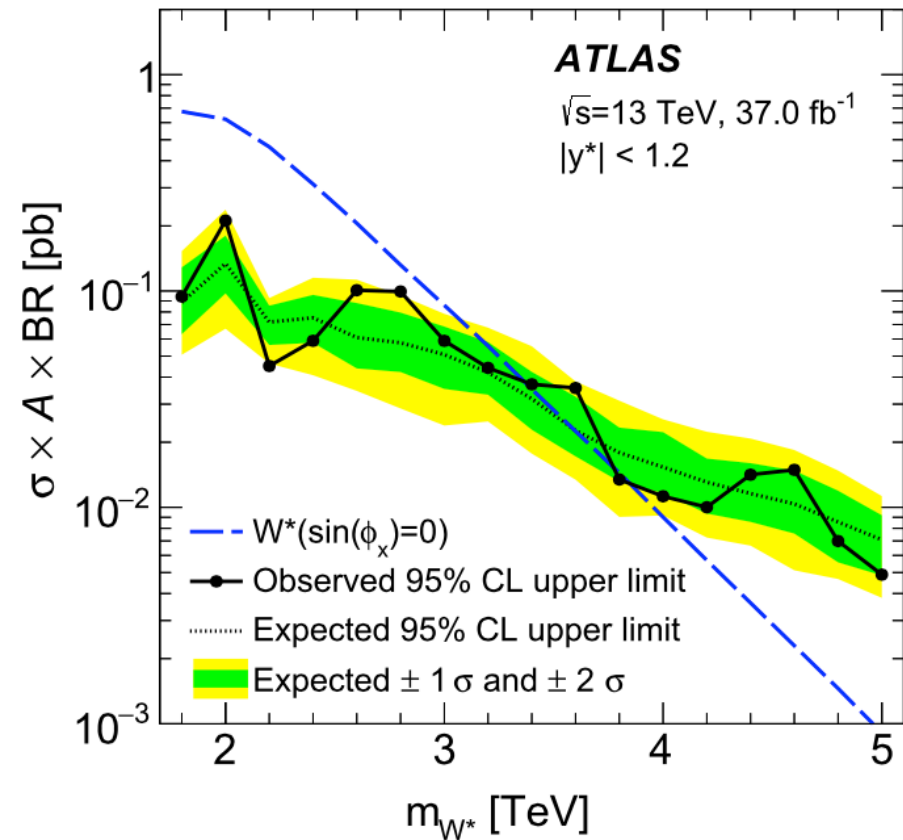
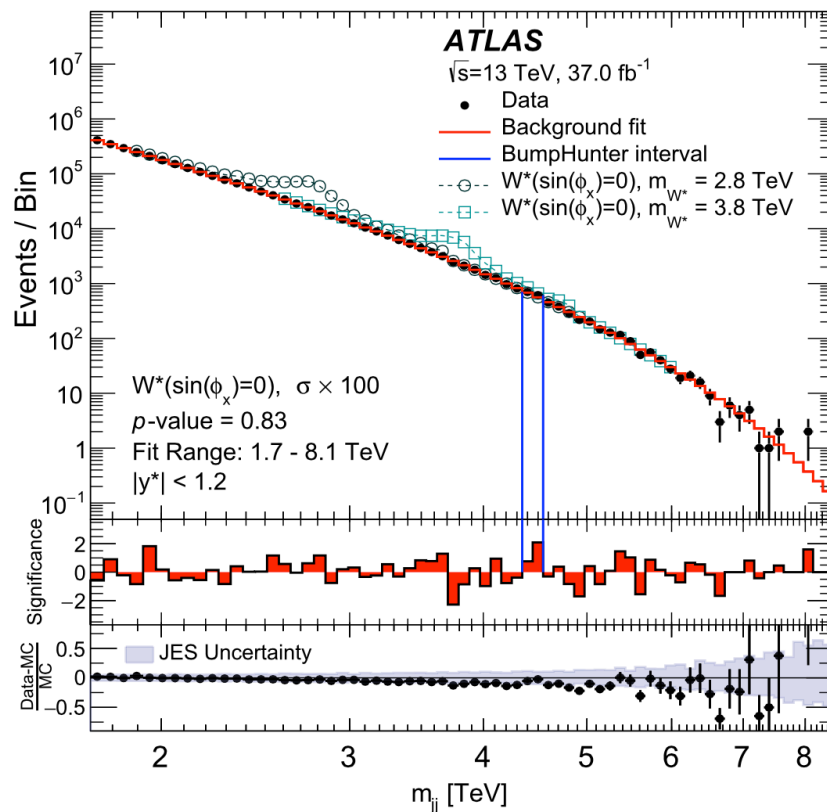
arXiv:1808.09054



Search for Di-jet Resonance

From Lianliang Ma

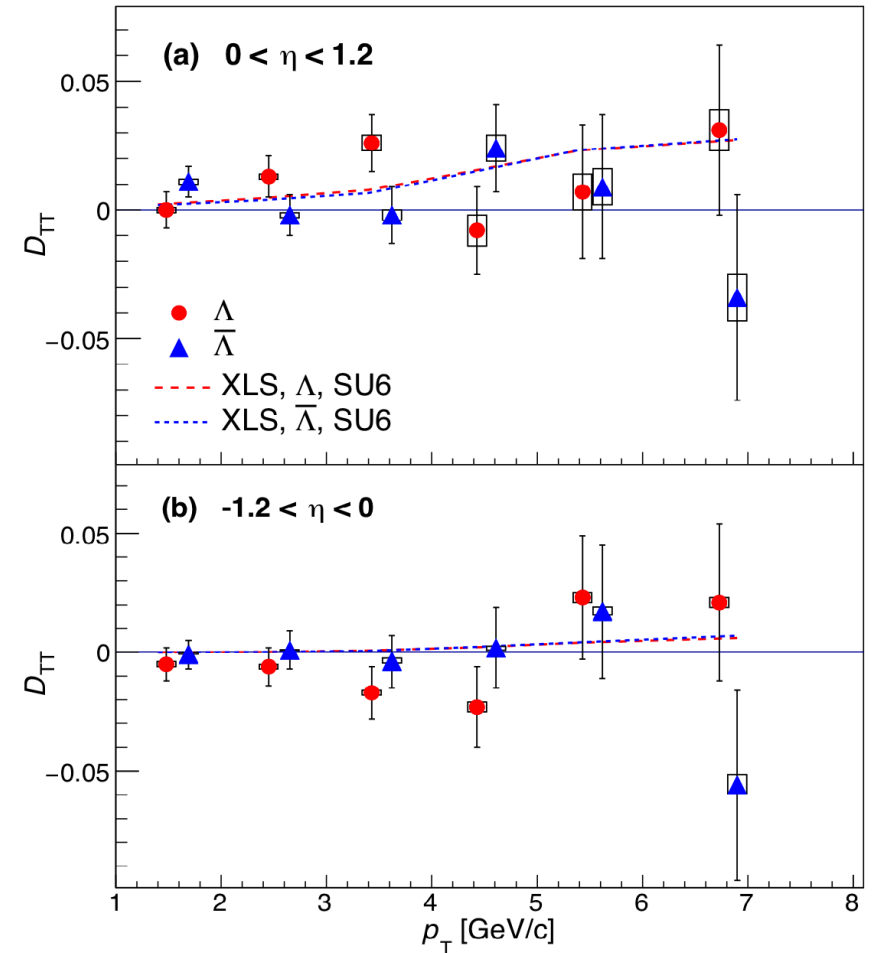
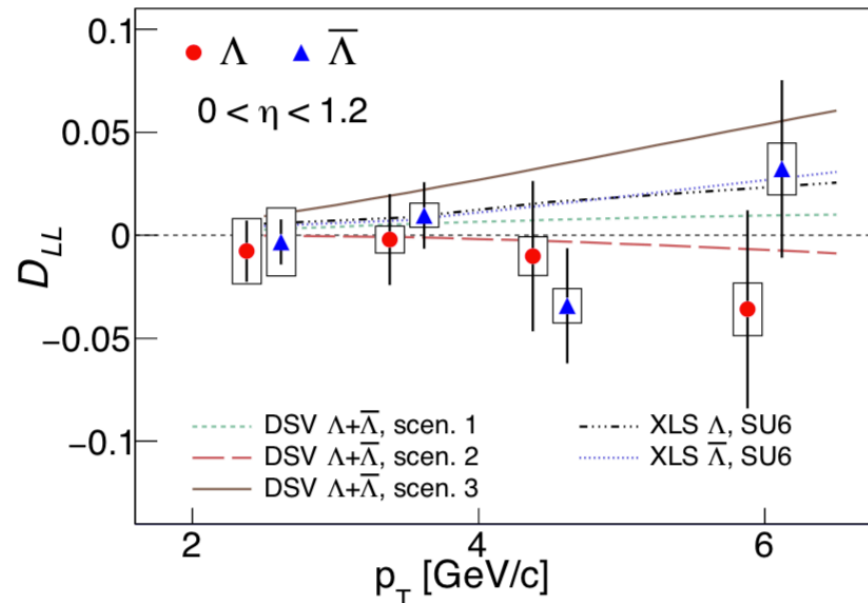
- 意义：寻找新物理中可以衰变到两个强子喷注的共振态。
- 参与人员：张登峰，祝成光
- 主要贡献：负责了 W^* 的分析



STAR自旋物理研究

- 1) RHIC上首次超子的横向自旋转移测量，提供核子横向自旋结构研究的新途径。
- 2) 超子纵向自旋转移的新测量，测量精度比2009年发表的结果大幅提高。
- 3) 质子-质子对撞W玻色子自旋不对称的测量，是目前精度最高的测量，发现极化海夸克SU(2)对称破缺。
- 4) 前向 π^0 戒子单自旋不对称的测量。

From Qinghua Xu



-STAR, arXiv: 1808.08000

-submitted to PRD.

-STAR, arXiv: 1808.07634, submitted to PRD.

STAR电磁探针物理分析

From Qinghua Xu

1. 测量了低横动量下的双电子相干光致产生，结果已经被PRL接收。
arXiv: 1806.02295

- ✓ 在有强相互作用过程的偏心碰撞中，也存在着相干光致产生。
- ✓ 这种产生的双电子对于重离子碰撞产生的磁场来说是一个很好的探针。
- ✓ 模拟研究表明理论预期与实验测量的差距可能是由于一个高达 10^{14}T 的磁场引起的。

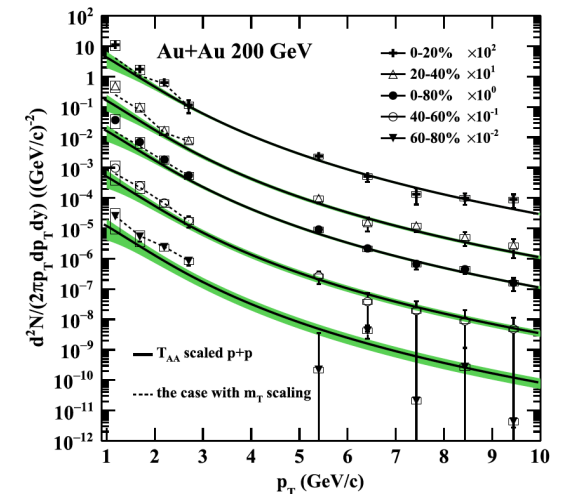
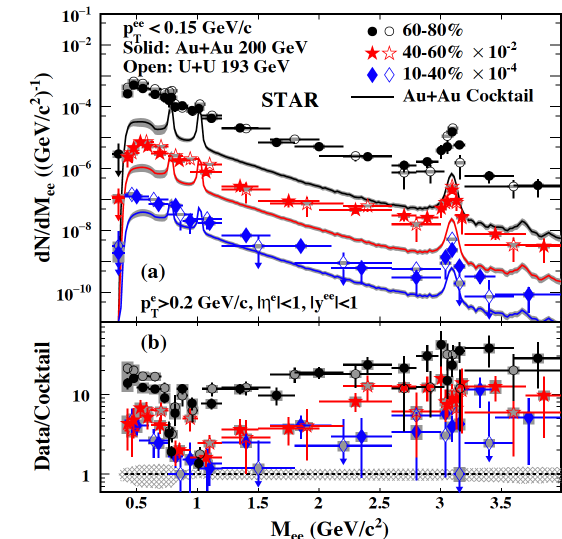
2. 测量了STAR上的直生虚光子（direct virtual photon）。

Physics Letters B 770 (2017) 451–458

- ✓ 在低横动量区观测到了QGP热辐射和强子气体的贡献。
- ✓ 在高横动量区，测量结果与碰撞初始强过程的预期一致。

3. STAR上Run17 54GeV Au+Au的双电子物理分析。

- ✓ 已经重建出原初信号
- ✓ 正在进行效率修正分析

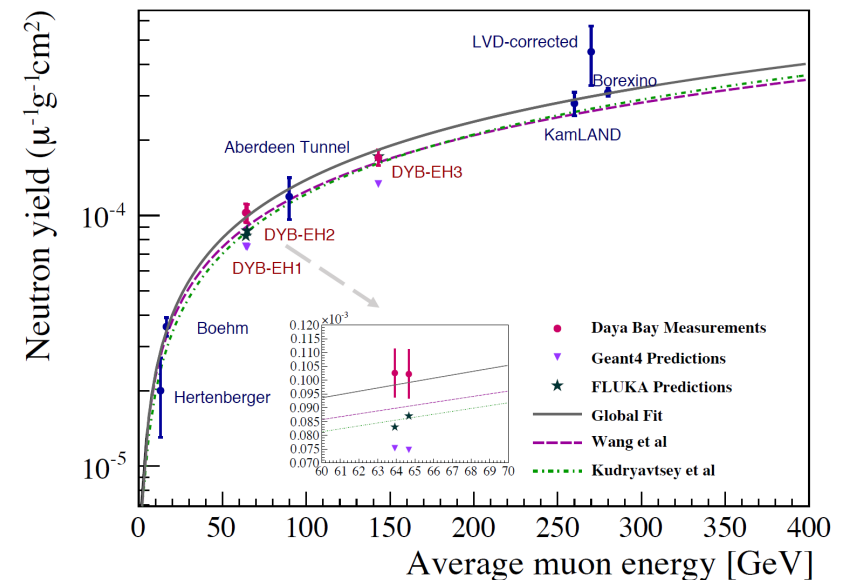


Cosmogenic neutron production at Daya Bay

- Muon induced neutrons and isotopes are major background for underground low background experiments

$$Y_n = \frac{N_n}{N_\mu L_{avg} \rho}$$

- N_μ : number of muons traversing the GdLS target
- N_n : number of neutrons produced in association with N_μ
- L_{avg} : the average path length of muons in the GdLS from simulation
- ρ : the measured density of Daya Bay's GdLS

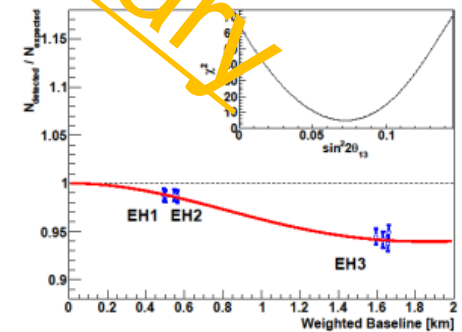
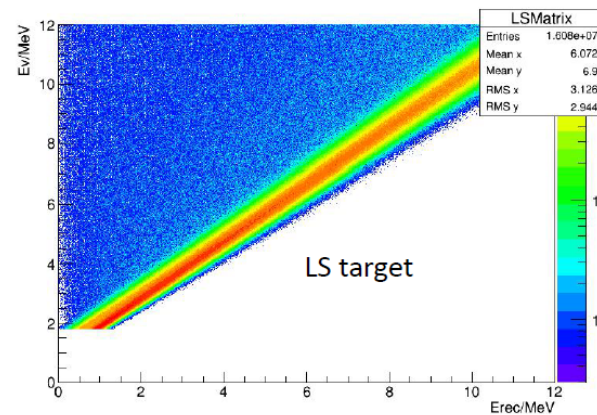
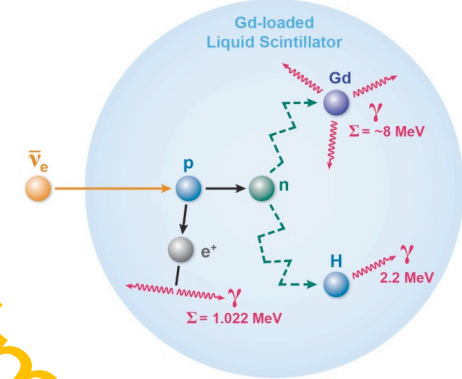
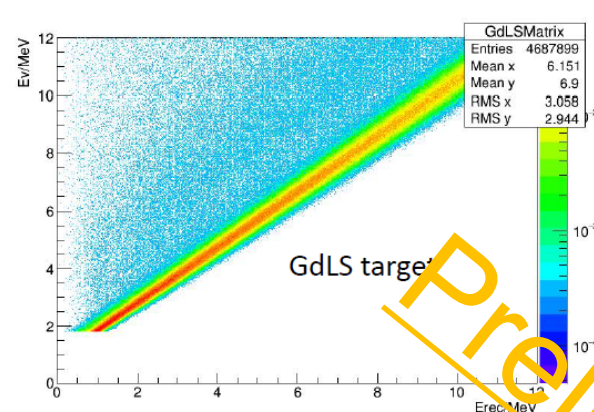


- Jie Cheng, Xingtao Huang etc. , Published in P.R.D 97, 052009 (2018)

$\sin^2 2\theta_{13}$ and Δm^2_{ee} measurement with n-H

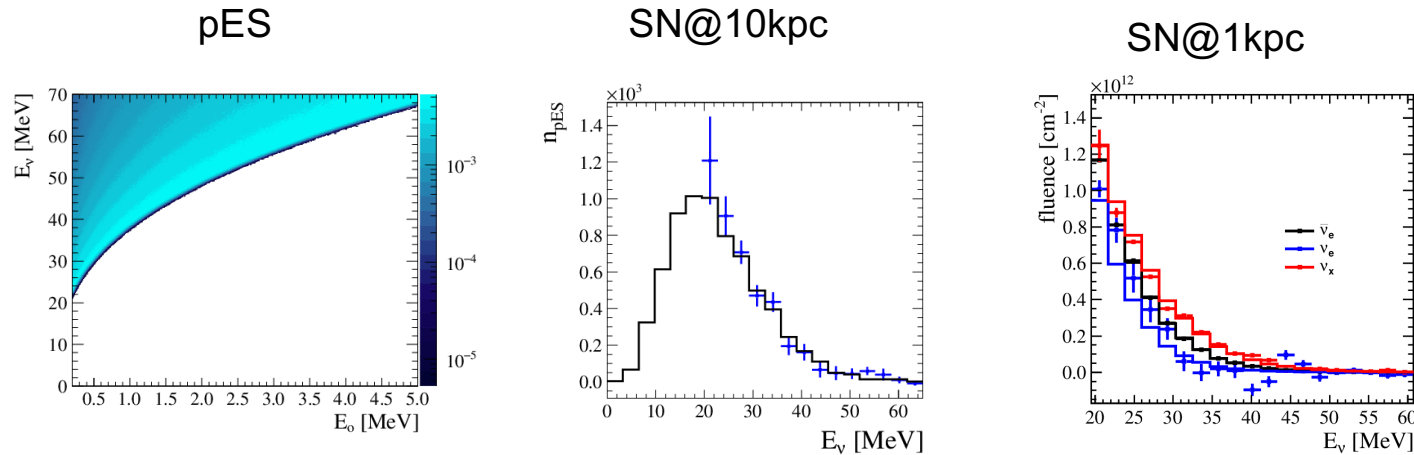
From Qun Wu

- Comparison of rate and positron spectrum between measurement and prediction
- Detector Energy Model
 - More energy leakage
- Complete analysis chain:
 - Signal rate and shape
 - Background rate and shape
 - Predicted signal shape with detector response considered
 - Full systematic error analysis
 - Fitter is built and working
- Current status :
 - Rate preliminary result is ready
 - Shape analysis is in the finalizing stage



大型液闪探测器中超新星中微子能谱重建

From Meng Wang



- ◆ 提出利用更接近**真实探测情况**的**SVD反解算法**重建不同反应道能谱。
- ◆ 联合IBD、pES和eES反应道，同时实现了**全味道**超新星中微子的能谱重建。

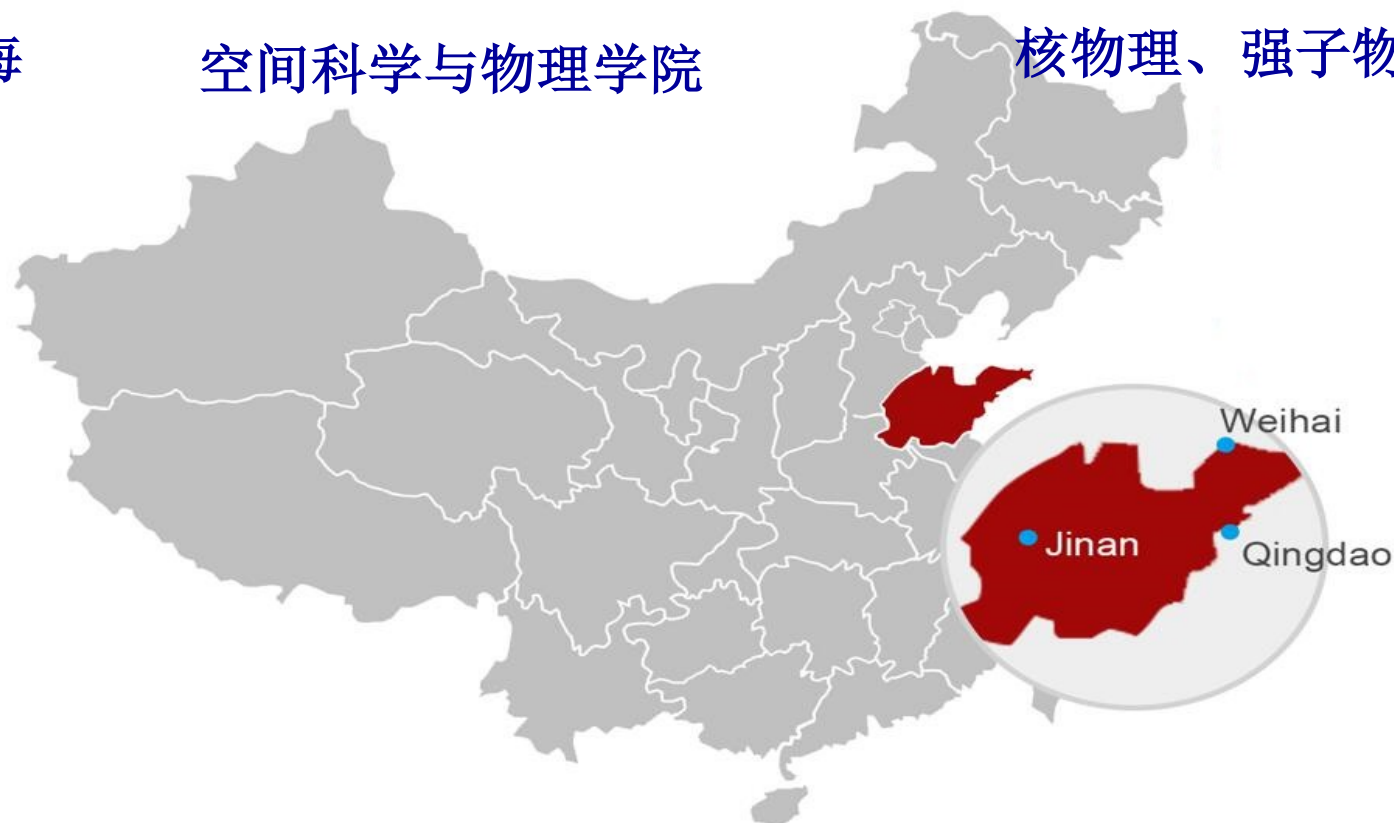
文章: **Hui-Ling Li et.al, *Towards a complete reconstruction of supernova neutrino spectra in future large liquid-scintillator detectors*, Phys. Rev. D 97, 063014**

山东大学粒子物理与原子核物理学科

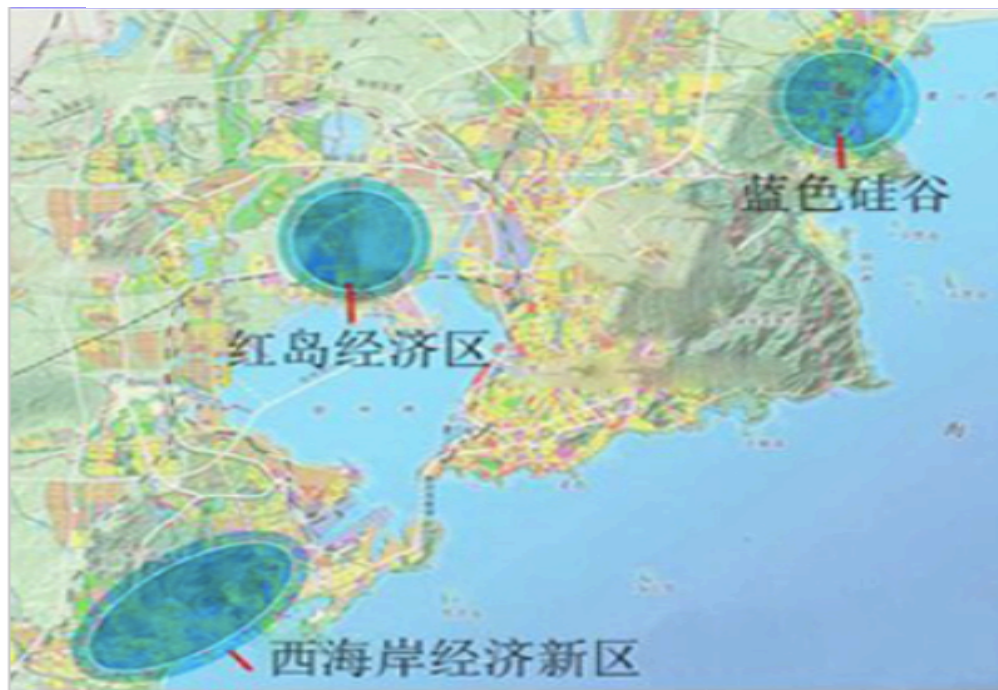
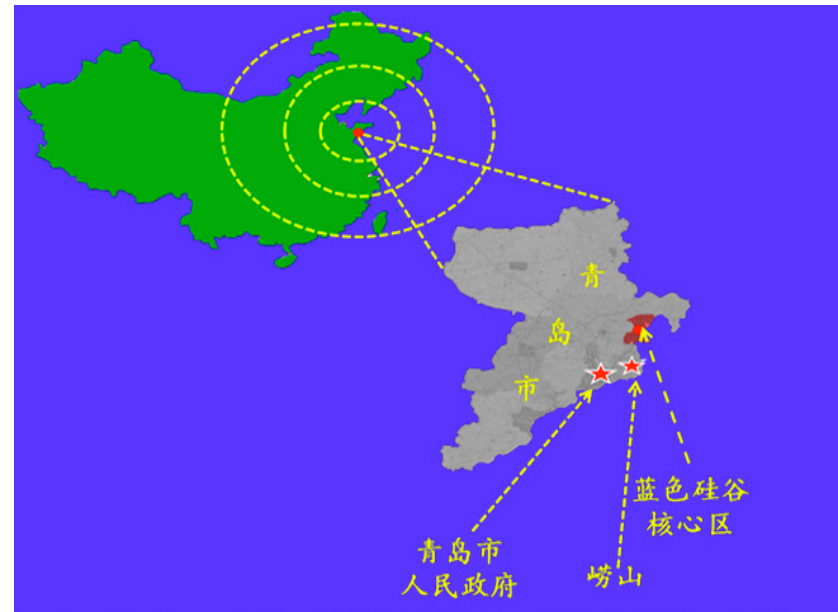
济南 物理学院 粒子物理理论分支方向

青岛 前沿交叉科学
青岛研究院 粒子科学技术研究中心

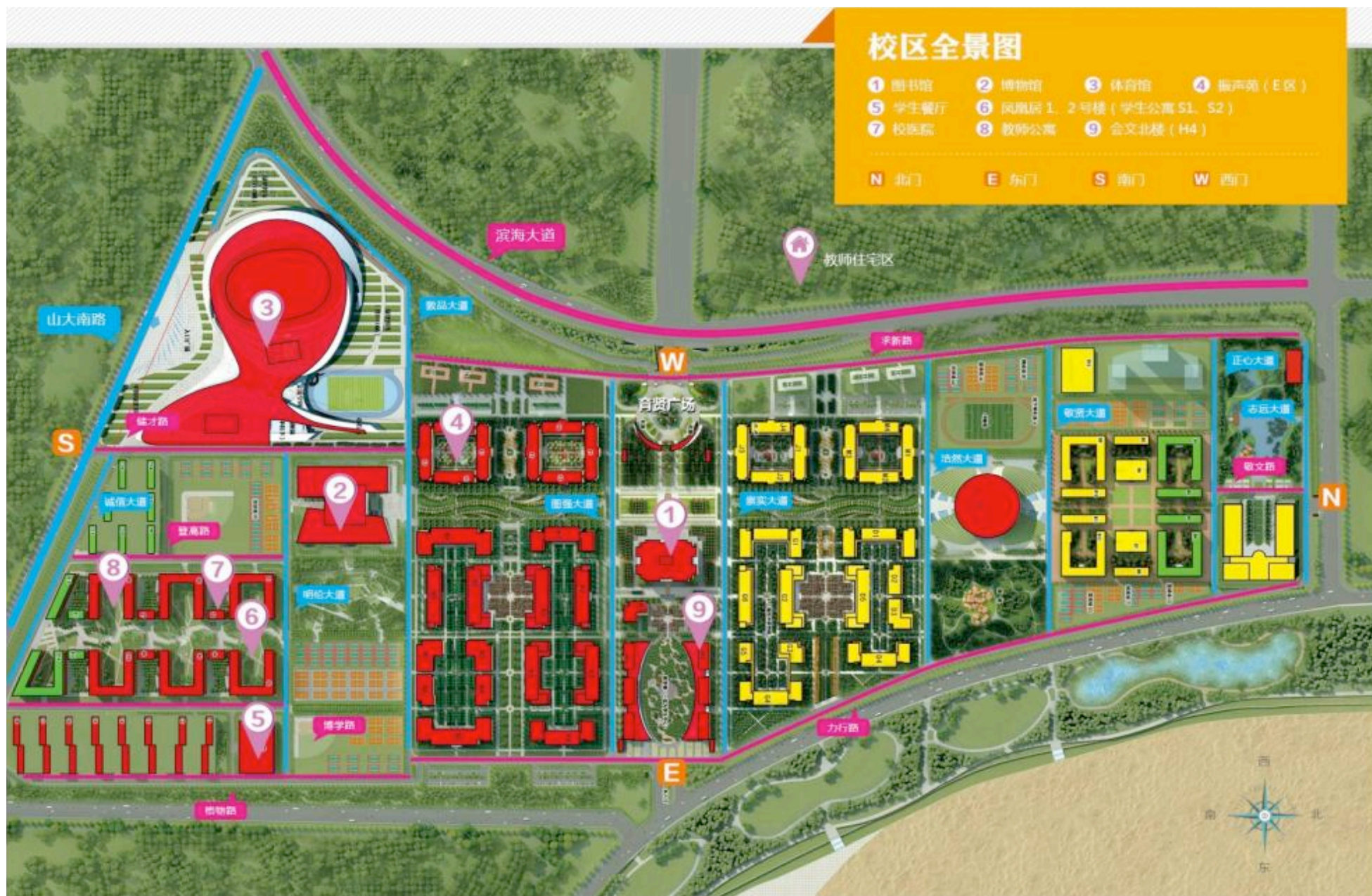
威海 空间科学与物理学院 核物理、强子物理



山东大学青岛校区



青岛校区布局图



青岛校区实景



粒子科学技术中心



青岛校区实景图

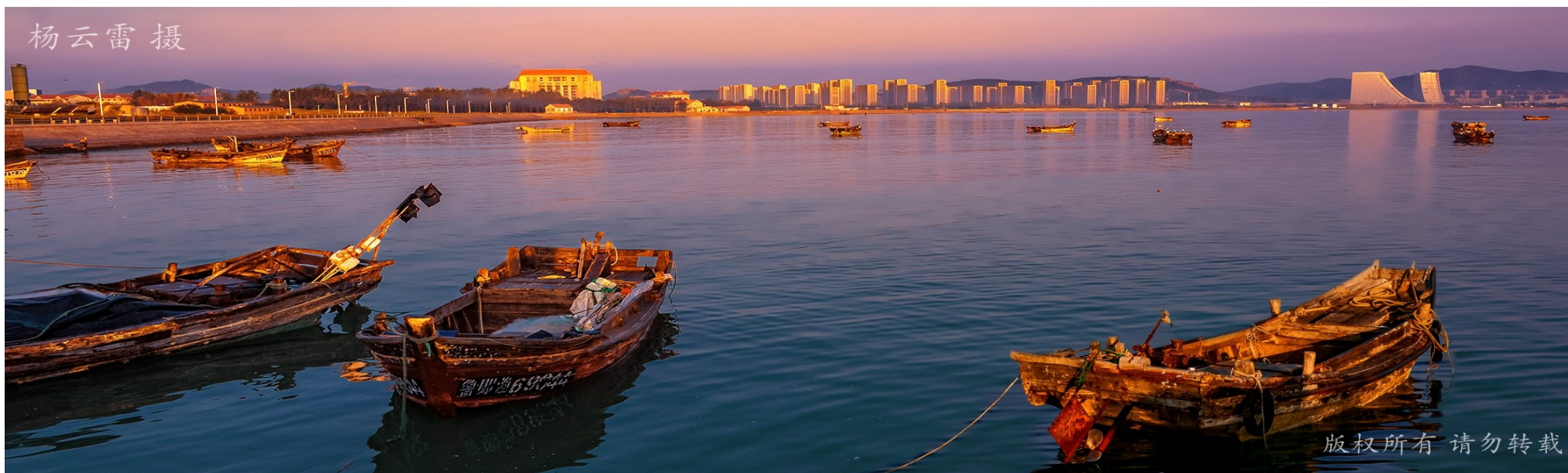
粒子科学技术研究中心

山大乐水居

蓝色硅谷中心



杨云雷 摄



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