

# 粒子物理卓越中心工作汇报

2018.10-2019.10

北京大学技术物理系 王大勇

长聘副教授

2019.12.7



# 基本情况

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## □ 教育经历

- ✓ 1997年-2001年，中国科学技术大学近代物理系，学士
- ✓ 2001年-2006年，中国科学院高能物理研究所，博士

## □ 工作经历：粒子物理实验，BESIII和CMS合作组成员

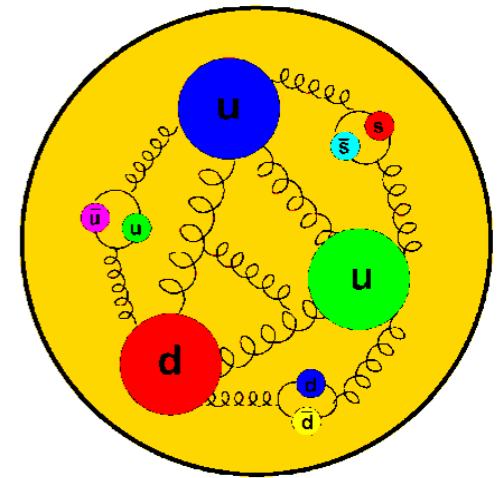
- ✓ 2003年-2007年，BES合作组成员，BESIII合作组成员
- ✓ 2006年-2009年，在美国佛罗里达大学物理系任研究助理，作为CSCTF系统现场负责人常驻欧洲核子中心 (CERN), CMS合作组成员
- ✓ 2009年-2011年10月，在美国佛罗里达大学物理系，CMS合作组成员
- ✓ 2011年11月-2012年5月 中央研究院物理所研究助理
- ✓ 2012年6月起，担任北京大学物理学院百人计划研究员
- ✓ 2018.8起，北京大学物理学院院长聘副教授

# 主要研究方向

## 强子物理:

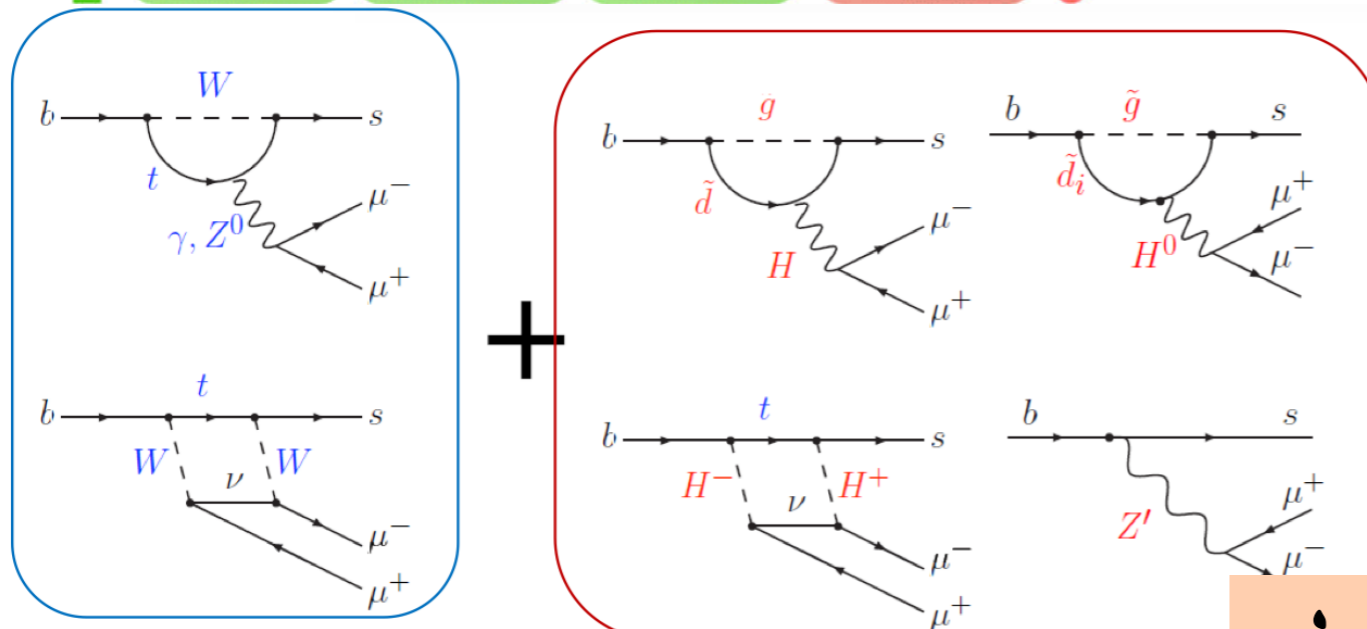
### 奇特态, 深入理解介子结构

QUARKS	$\approx 4.8 \text{ MeV}/c^2$ -1/3 1/2 <b>d</b> down	$\approx 95 \text{ MeV}/c^2$ -1/3 1/2 <b>s</b> strange	$\approx 4.18 \text{ GeV}/c^2$ -1/3 1/2 <b>b</b> bottom	0 0 1 <b><math>\gamma</math></b> photon
	$0.511 \text{ MeV}/c^2$ -1 1/2 <b>e</b>	$105.7 \text{ MeV}/c^2$ -1 1/2 <b><math>\mu</math></b>	$1.777 \text{ GeV}/c^2$ -1 1/2 <b><math>\tau</math></b>	0 1 <b>Z</b>



## 间接寻找新物理

### 味道改变中性流, 暗物质/暗光子

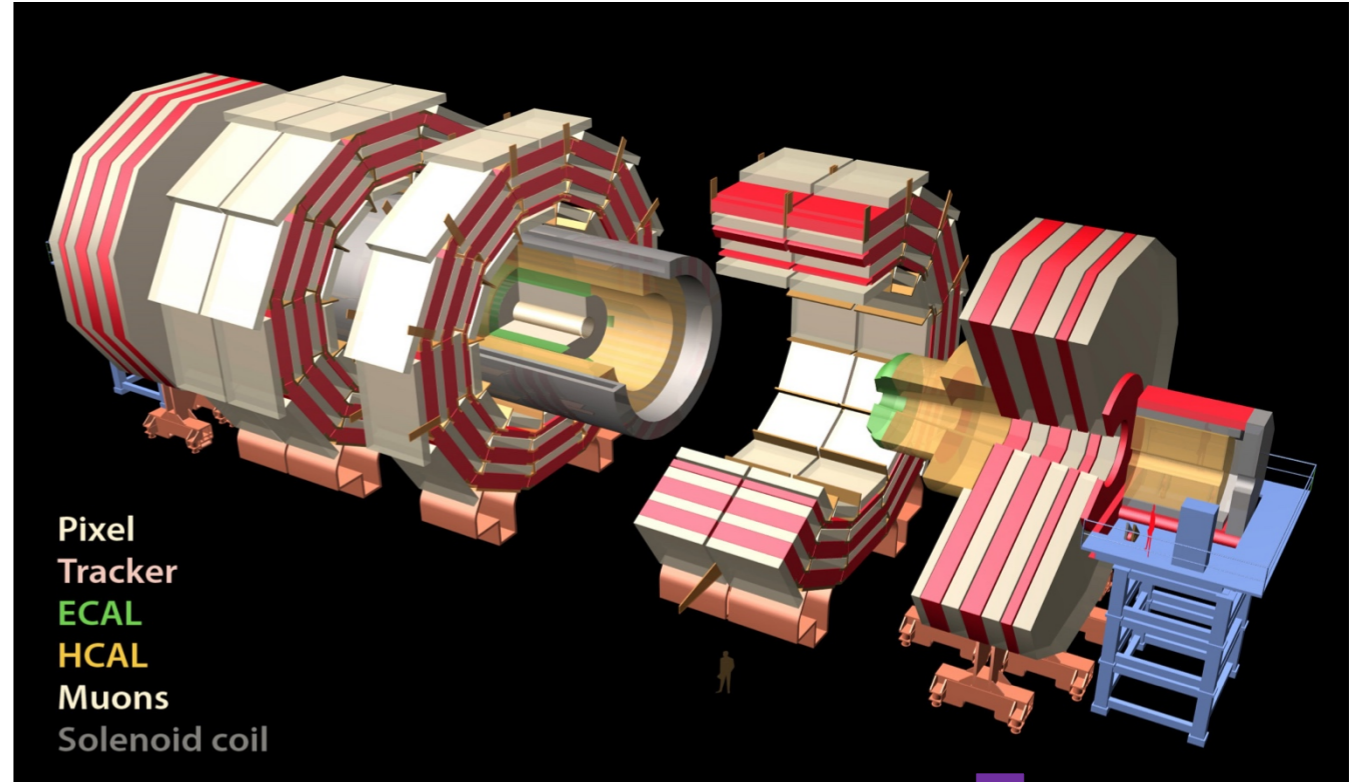
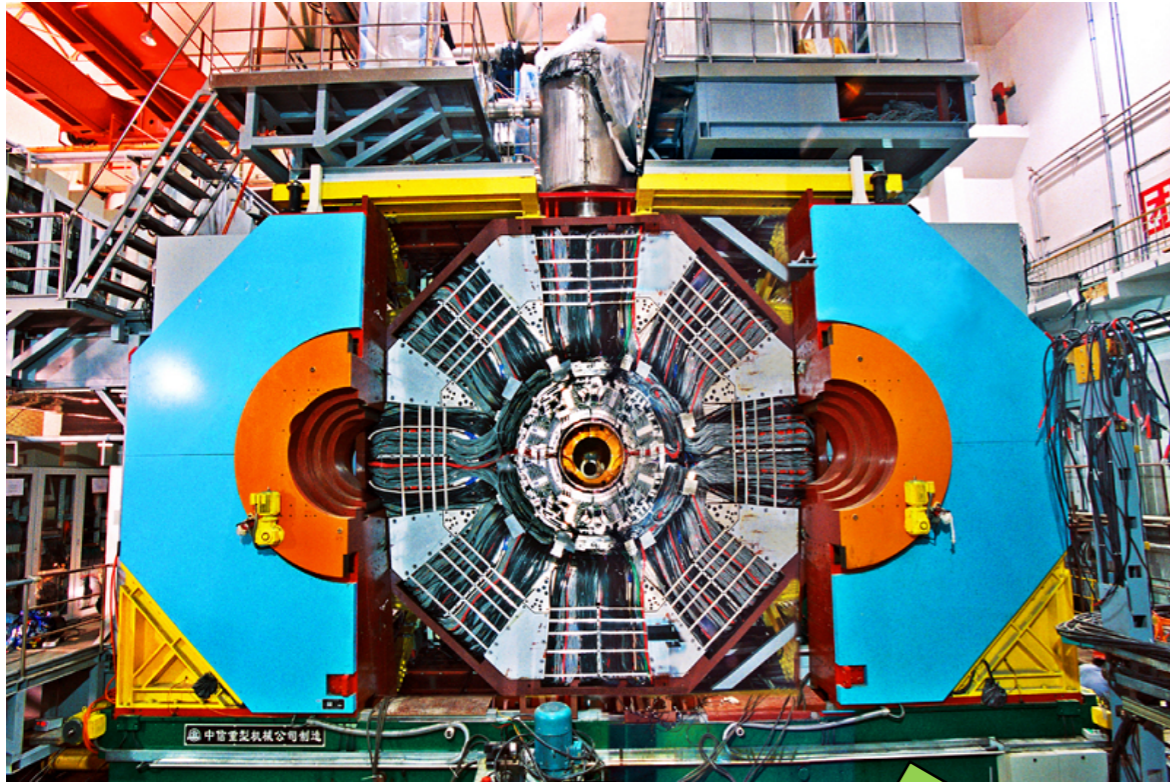


ordinary photon & can mix

$$\Delta\mathcal{L} = \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu} \quad \text{“Kinetic Mixing”}$$

# 新型微结构探测器研发

# 参加实验: BESIII@BEPCII 与 CMS@LHC



强子物理

寻找新物理

探测器升级

寻找新  
强子态

理解介  
子结构

稀有衰变  
暗物质/暗光子  
守恒律破坏

Higgs粒子  
不可见衰变

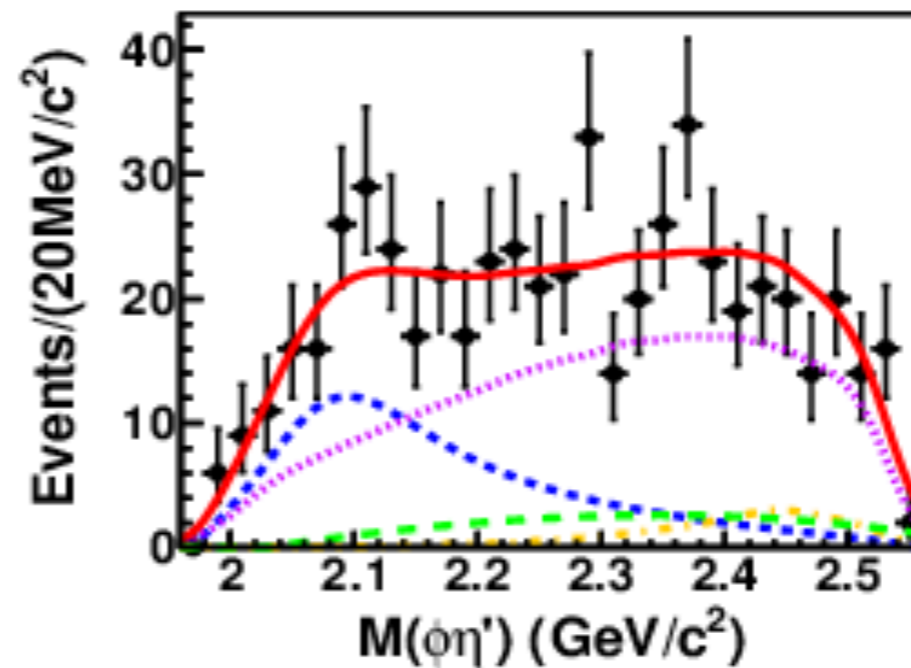
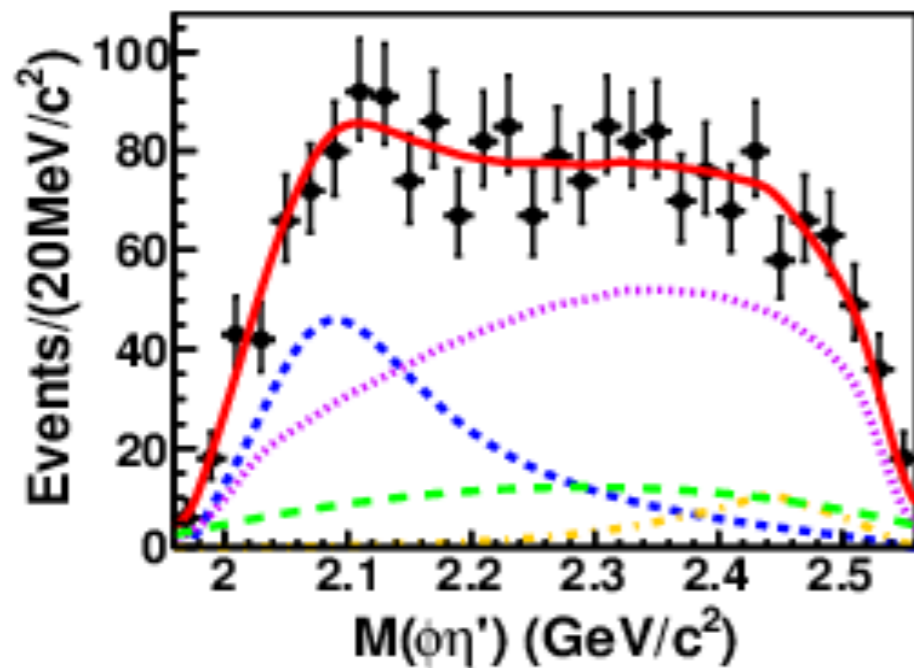
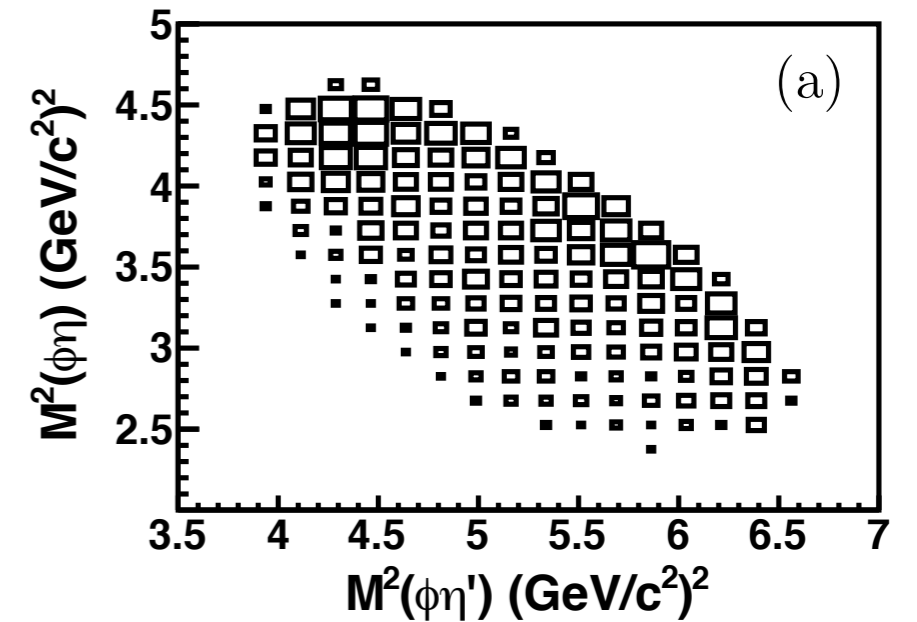
MET重建算  
法与性能

味道改变  
中性流  
b->sl

# $J/\psi \rightarrow \phi\eta\eta'$ 衰变研究

PRD 99, 112008(2019), w/ Yunfei Long et al

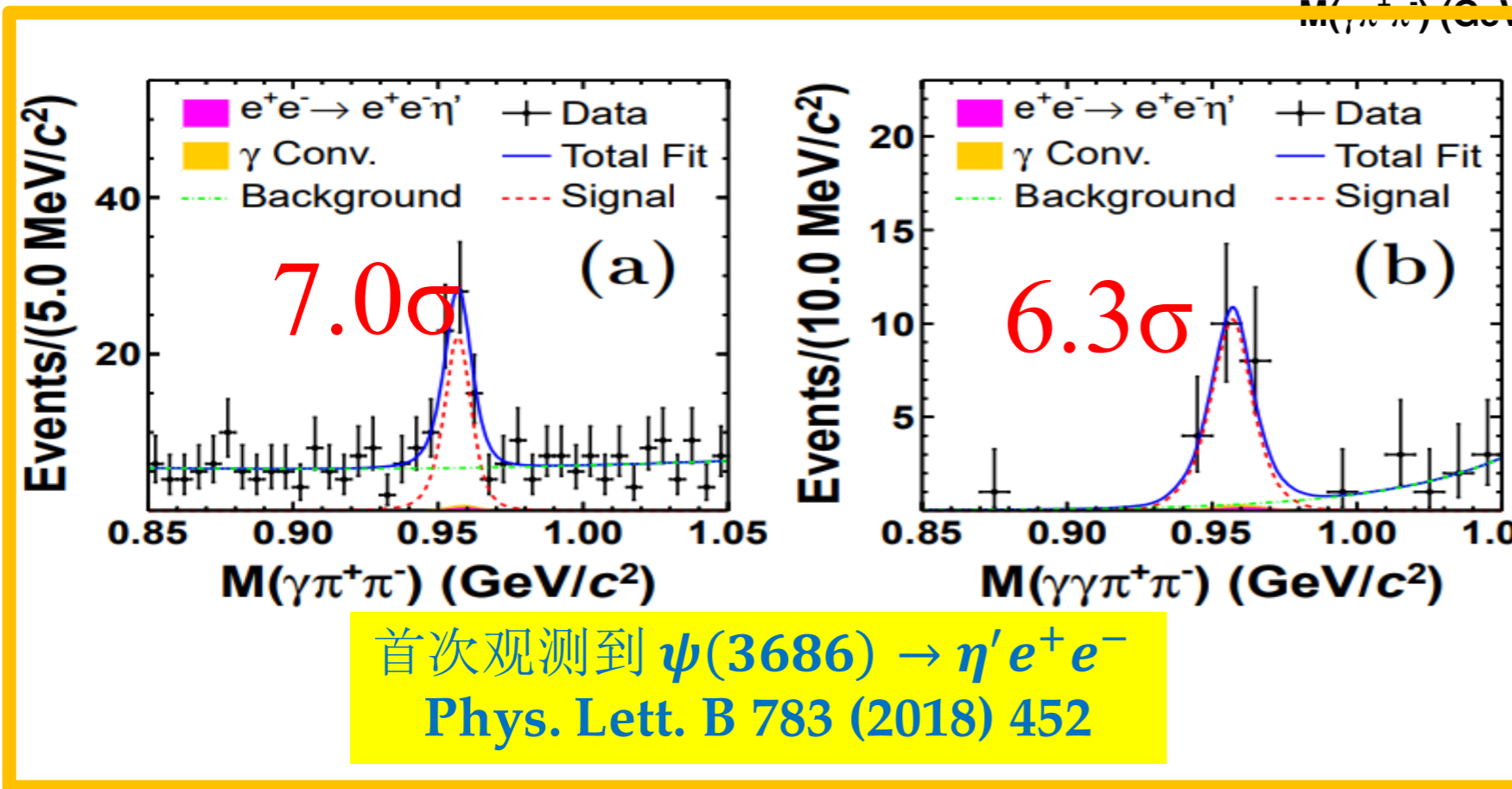
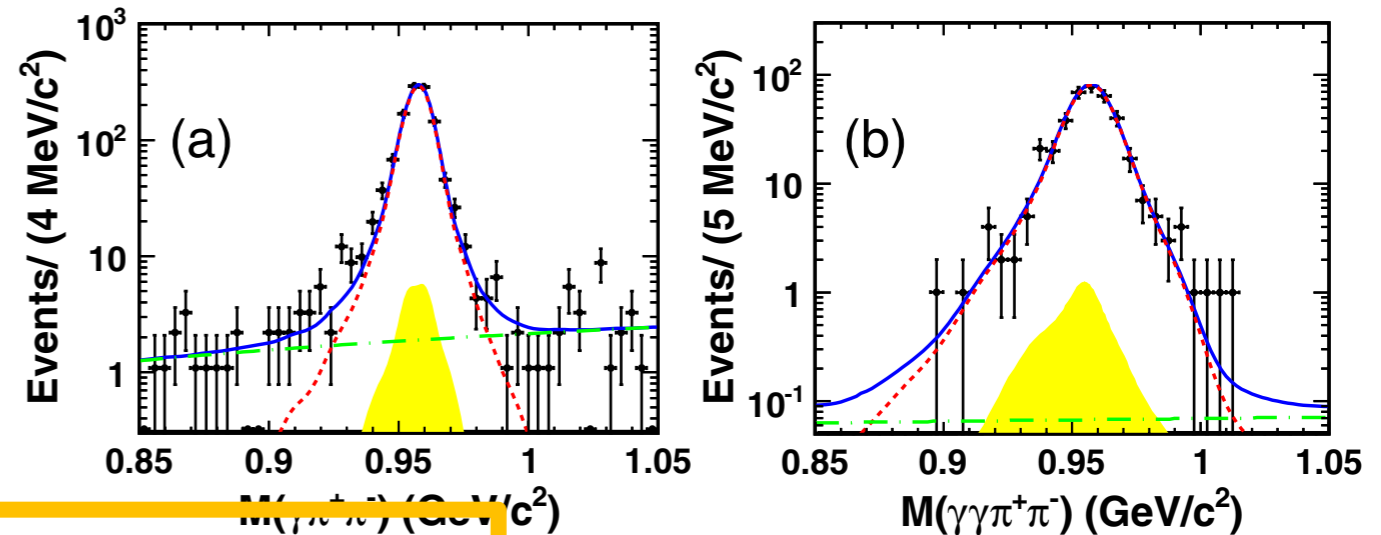
- 首次测量该三体过程分支比
- $\phi\eta'$  谱质量 2.1 GeV/c<sup>2</sup> 新结构 X(2100)
- 对深入理解奇特强子态有重要意义



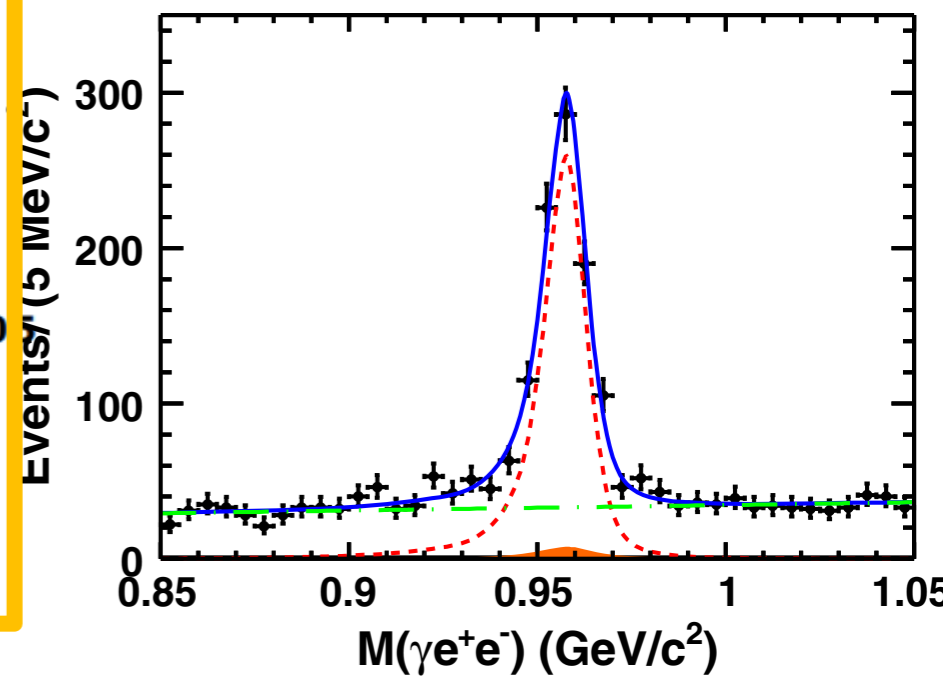
# 粲偶素电磁Dalitz衰变的观测

测量分支比, 研究光子与介子相互作用, 理解强子结构

首次观测到  $J/\psi \rightarrow P e^+ e^-$   
 $P: \eta', \eta, \pi^0$   
*Phys. Rev. D 89, 092008 (2014)*



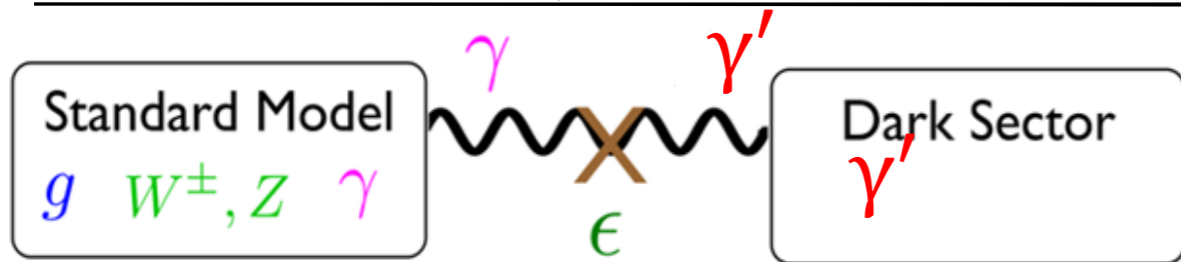
首次观测到  $\psi(3686) \rightarrow \eta' e^+ e^-$   
*Phys. Lett. B 783 (2018) 452*



首次观测到  $\eta' \rightarrow \gamma e^+ e^-$   
*Phys. Rev. D 92, 012001(2015)*

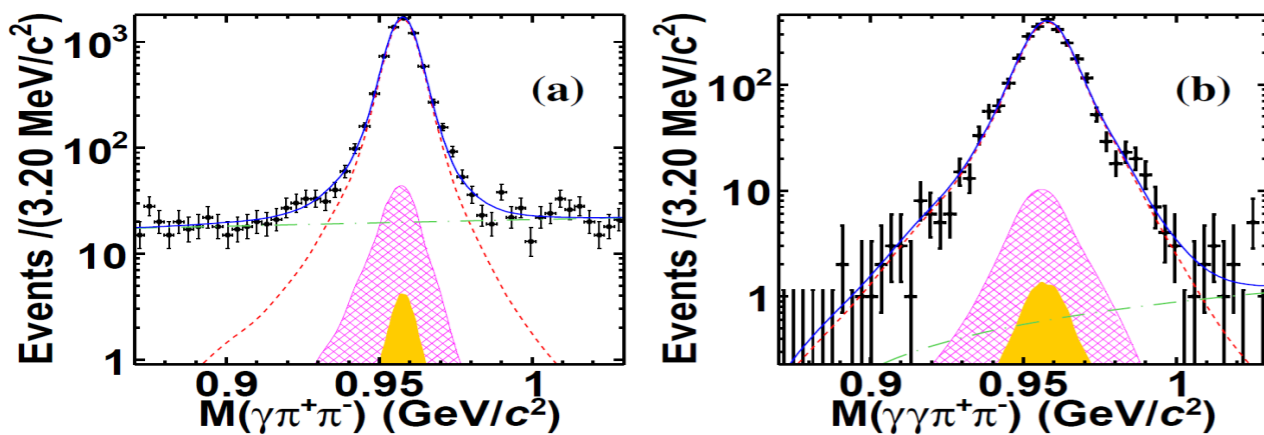
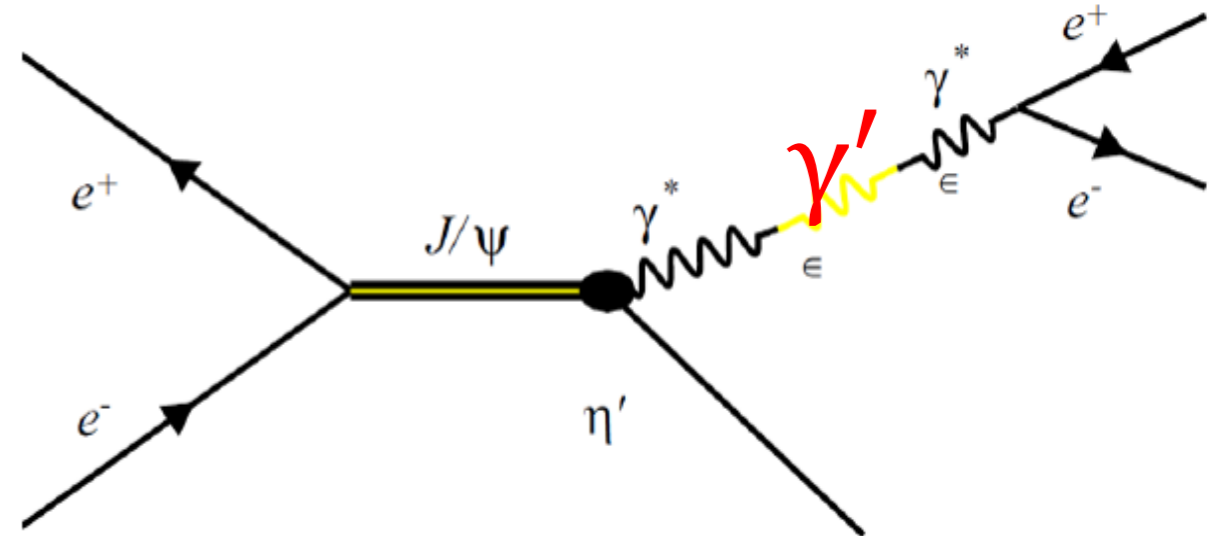
# 通过 $J/\psi \rightarrow \eta' e^+ e^-$ 过程寻找暗光子 ( $\gamma'$ )

寻找新物理；解释暗物质相互作用



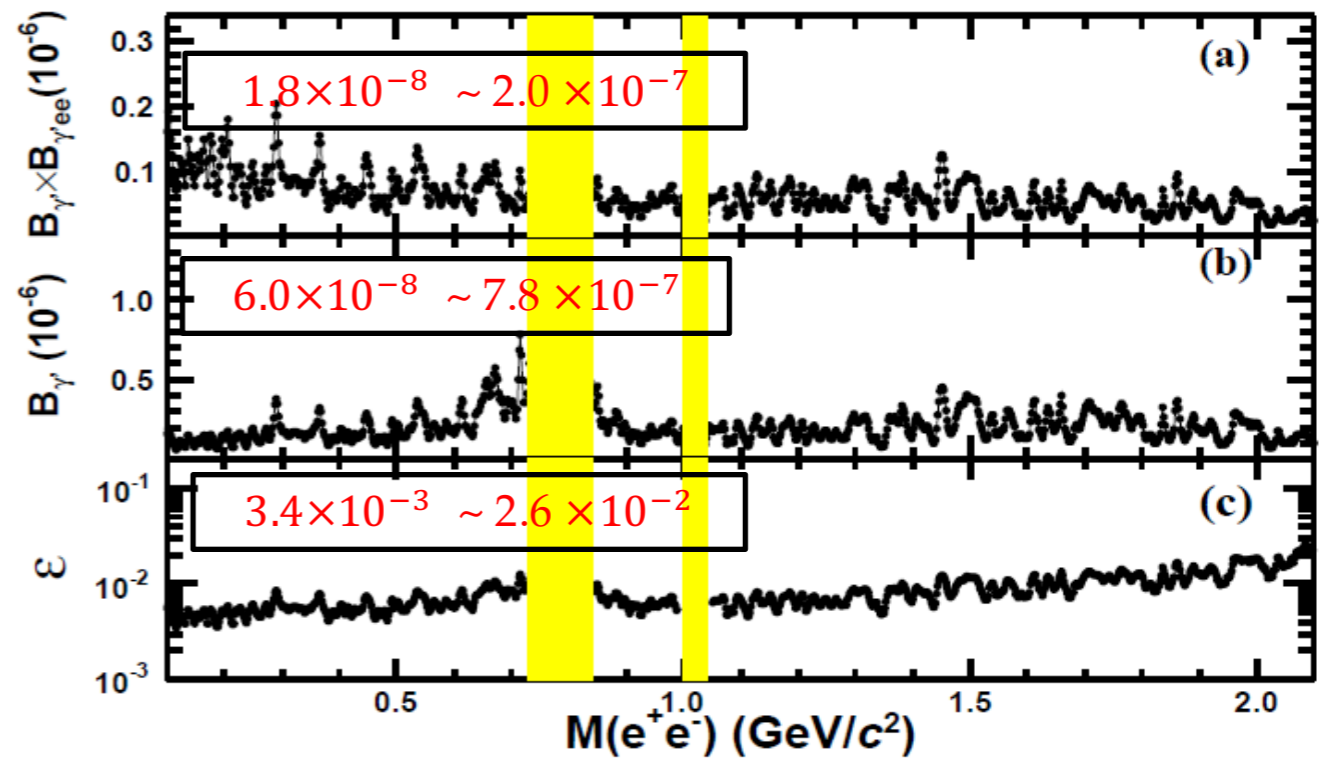
ordinary photon &  $\gamma'$  can mix

$$\Delta\mathcal{L} = \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu} \quad \text{“Kinetic Mixing”}$$



PRD 99, 012013 (2019),  
w/ Fengyun Li et al

- ✓ 1.3B Jpsi数据更新分支比，测量精度提高一倍
- ✓ 首次通过粲偶素衰变寻找暗光子



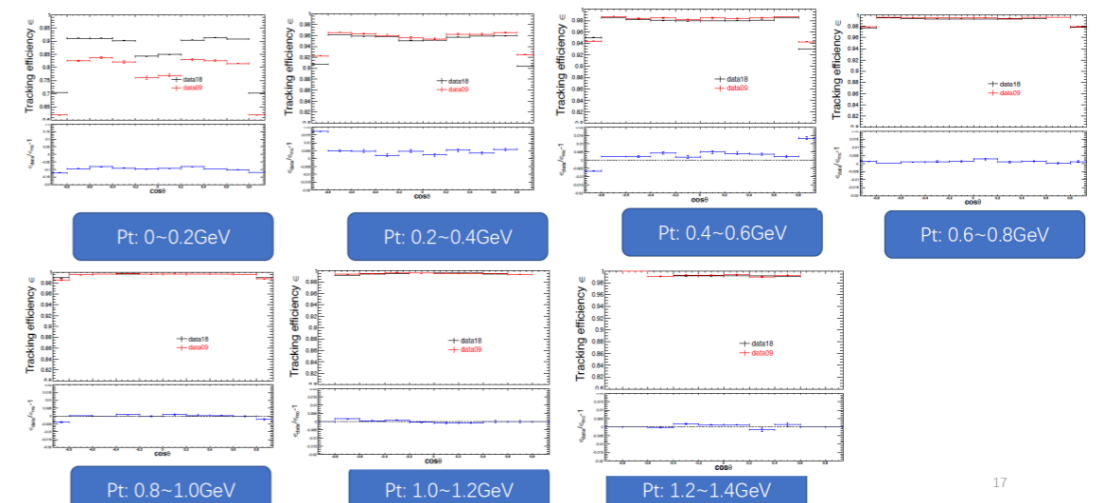
## 其他在研课题 & service

- ✘ Search for cFLV in  $J/\psi \rightarrow e^- \tau^+$  (BAM406)
- ✘ Search for Lambda invisible decays (preparing memo)
- ✘ Search for Jpsi invisible decays (BAM194, 与IHEP, NJU合作)
- ✘ Search for cLFV in  $J/\psi \rightarrow \gamma \mu^+ \tau^-$  and  $J/\psi \rightarrow \gamma e^- \tau^+$  (prep memo)
- ✘ Search for eta'  $\rightarrow 2(e^+e^-)$  (BESIII PS workshop)
- ✘ Search for X(17) at BESIII (preliminary memo)
- ✘ Jpsi  $\rightarrow K^0 K^{*0}$  to understand eta(1405/1475) (group meeting)
- ✘ 2018/2019 Jpsi data quality check

+ e+/e- tracking & PID:

- ✘ STCF simulation  $\tau \rightarrow \gamma \mu$

Compare 09/18 data in different  $p_T$  region



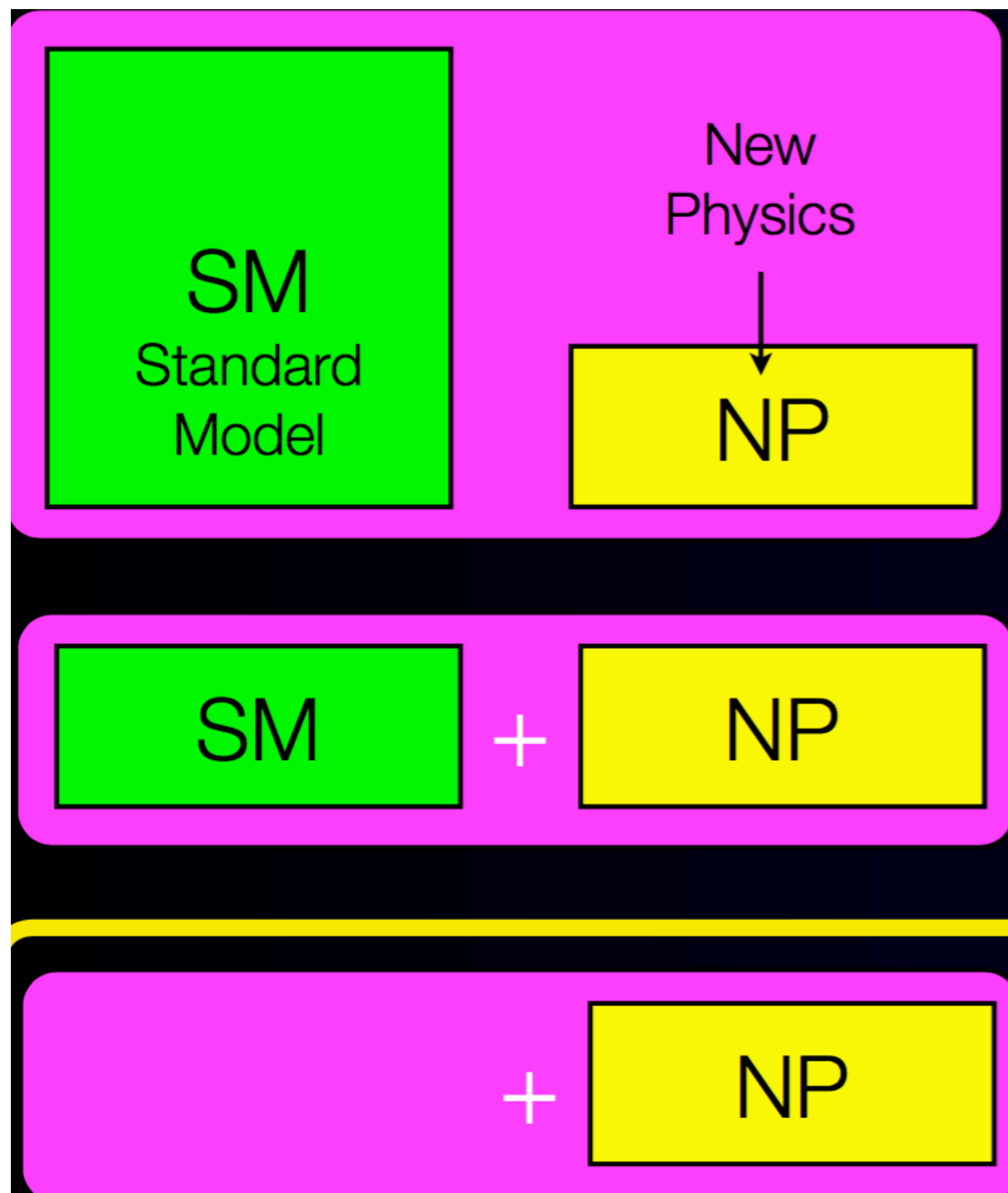
- ✘ BESIII 10B Jpsi数据获取: 担任周运行负责人





# General strategy for NP searches

New physics effects may be very small.



SM contribution is dominant.

SM contribution is highly suppressed.

SM contribution is forbidden.



# BESIII NP Group established in 2015

- Organized efforts with unified standards, shared tools, methods and studies. Open for all collaborators.
- 19 publications** in total, another ~20 active analyses
- Workshops: ideas, discussions, communication with theorists**
  - 2015 .3 .27 - 28 , Nanjing U: 19
  - 2015.12. 22 - 23 , USTC: 22
  - 2016.4 Nanjing U: 24
  - 2016.12 Peking U : 52
  - 2017.9 UCAS: 33
  - 2018.10 USC : 35
  - 2019.5.24-26, USTC: 50

**Stable team ~20 active members from all over: Chinese universities, IHEP and foreign institutes**

USC workshop, Oct. 2018

BESIII新物理研讨会  
2018年10月15-17日 南华大学·湖南衡阳



PKU workshop, Dec. 2016



# BESIII 物理白皮书

## Exotic Decays and New Physics

- 1.1 Introduction . . . . .
- 1.2 Rare decays of charmonia and charmed hadrons . . . . .
  - 1.2.1 Weak decays of charmonium states . . . . .
  - 1.2.2 Rare radiative and rare leptonic  $D_{(s)}$  decays . . . . .
- 1.3  $CP$  violation in baryon decays and charm mixing . . . . .
  - 1.3.1 Probing  $CP$  asymmetry in  $\Lambda$  decays . . . . .
  - 1.3.2 Constraint on BNV from  $\Lambda - \bar{\Lambda}$  Oscillation . . . . .
  - 1.3.3 More symmetry violation in hyperon decays . . . . .
  - 1.3.4  $CP$  and  $CPT$  violation in charm mixing . . . . .
- 1.4 Charged Lepton Flavor(Number) Violation decays . . . . .
  - 1.4.1 Decays of  $J/\psi, \psi(2S) \rightarrow l_1 l_2, l_1 l_2 \gamma$  . . . . .
  - 1.4.2  $\chi_c \rightarrow l_1 l_2$  via photon tagging in  $\psi(2S) \rightarrow \gamma \chi_c, \gamma \eta_c$  . . . . .
  - 1.4.3 (radiative) Leptonic decays of  $D^0 \rightarrow l_1 l_2, \gamma l_1 l_2$  . . . . .
  - 1.4.4 CLFV and LNV  $D_{(s)}$  decays with light mesons . . . . .
- 1.5 Searches for light (invisible) NP particles . . . . .
  - 1.5.1 Physics of the Dark Sector . . . . .
  - 1.5.2 (radiative) Invisible decays of charmonia . . . . .
  - 1.5.3 Invisible decays of  $D$  mesons . . . . .
  - 1.5.4 Invisible decays of light mesons . . . . .
- 1.6 Off-resonance searches . . . . .
  - 1.6.1 Rare charm production:  $e^+e^- \rightarrow D^*(2007)$  . . . . .
  - 1.6.2 Dark photon and dark Higgs searches . . . . .
  - 1.6.3 Axion-Like particles with displaced vertex . . . . .
  - 1.6.4 Searches for fractionally charged particles . . . . .

## Part Six: Exotic Decays and New Physics

Conveners: Shenjian Chen, Alexey Petrov, Dayong Wang

....在这些研究中 BESIII 取得了很有竞争力的结果。

此工作组是 BESIII 实验中最年轻的组，成立于仅仅在四年多以前。从那时开始，大约 20 篇发表的论文已经证明了 BESIII 一流的能力和竞争力。同时，此组规模的不断增长为利用已有的数据集取得更大影响力，以及在预期要取的更多的数据提供了广阔的空间。...

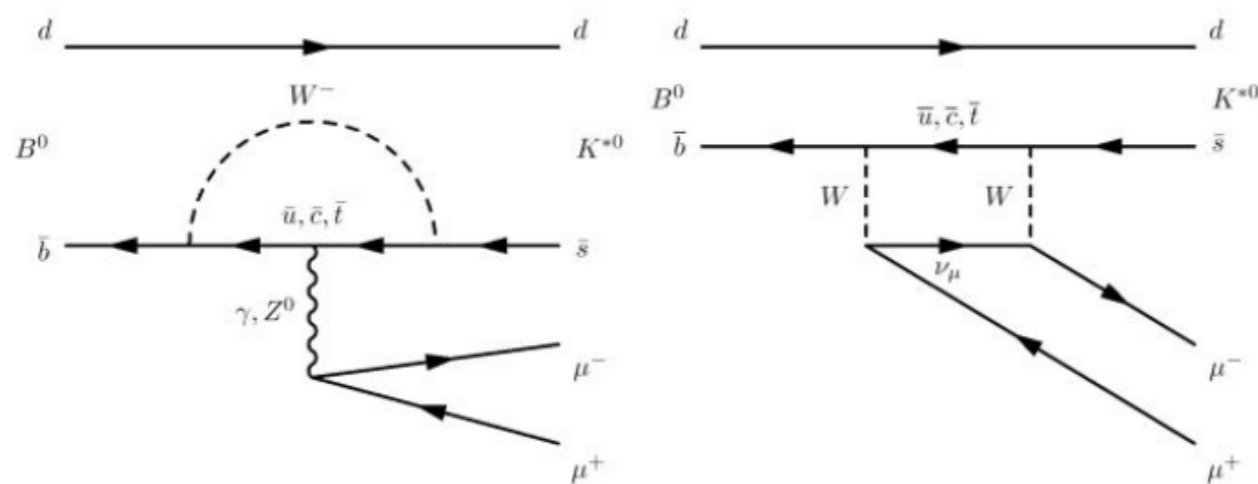
### 国际评审报告节选

The scientific goals are grouped in three areas: precision measurements of tree-level decays, measurements of or searches for rare decays, and searches for forbidden decays. The first group includes tests of lepton universality, where BESIII is currently world-leading in the charm sector. The second group includes a number of flavour-changing neutral current measurements and radiative decays, for which BESIII has produced world's best limits. The final group includes searches for decays involving invisible particles, for which BESIII has produced competitive results.

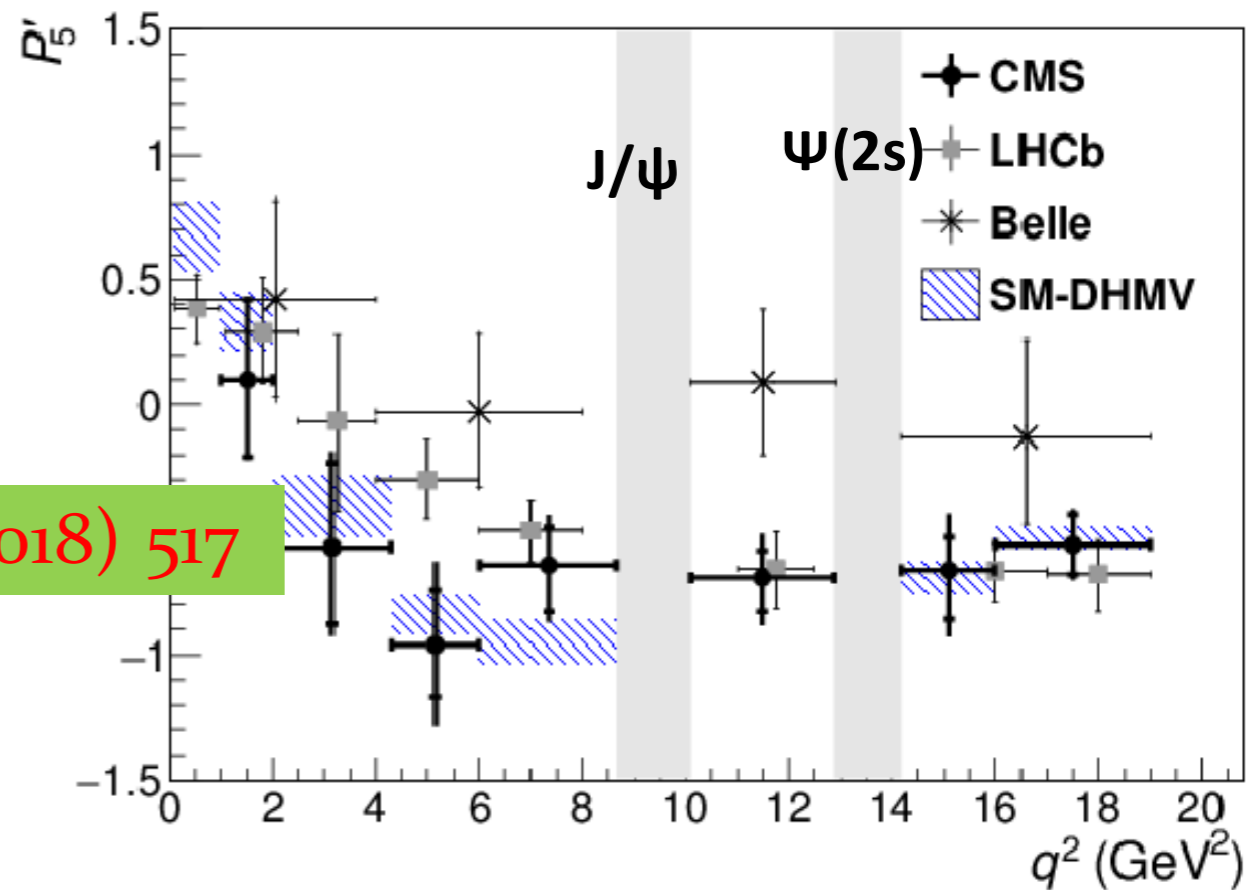
The Working Group is the youngest in the experiment, having been established just over four years ago. Since then, around 20 publications have demonstrated the first-class capability and competitiveness of BESIII. At the same time, the continued growth of the group leaves room for even greater impact based on existing data sets as well as essential improvements with the foreseen additional data taking periods.

# 对 $B \rightarrow K^{(*)} \mu^+ \mu^-$ 的测量和角度分析

味道改变中性流过程，对新物理极敏感



Phys. Lett. B 781 (2018) 517



□ 本人与学生代表CMS在一系列重要国际会议上报告:

ICHEP2016

LHCP2017

BEAUTY2018

BEACH2018

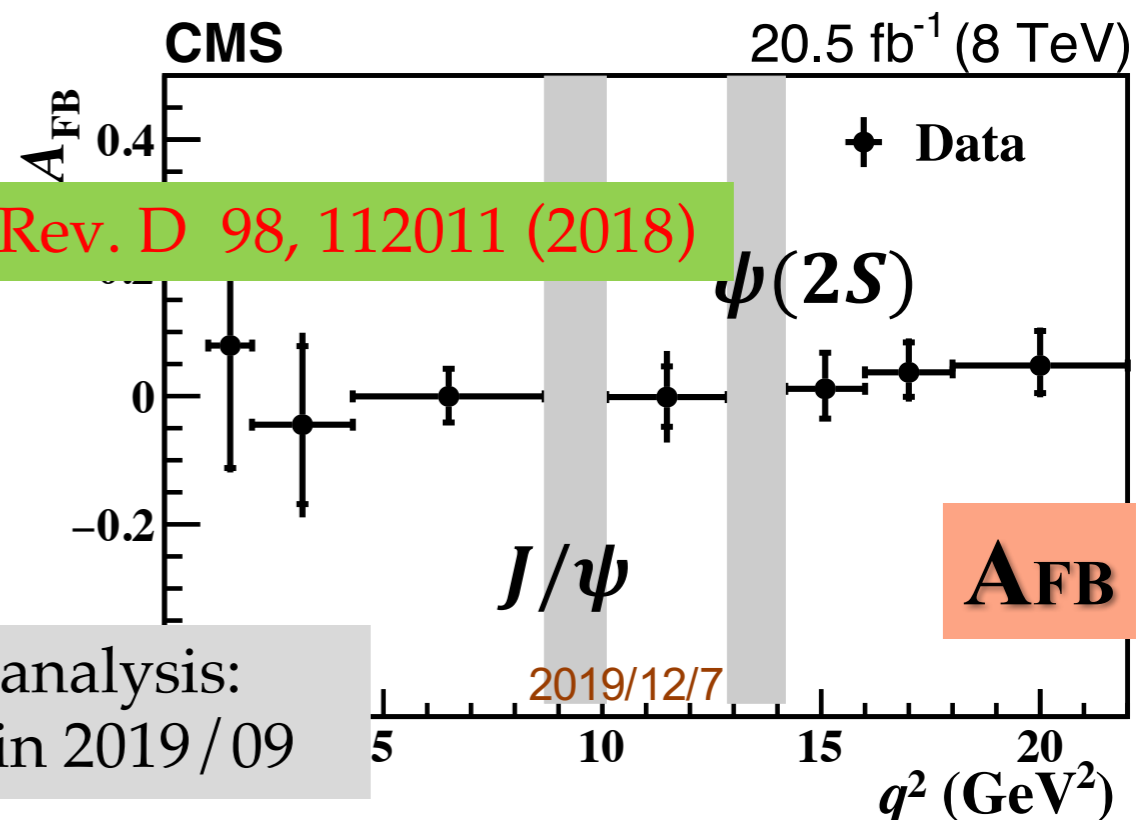
ICHEP2018

LeptonPhoton2019

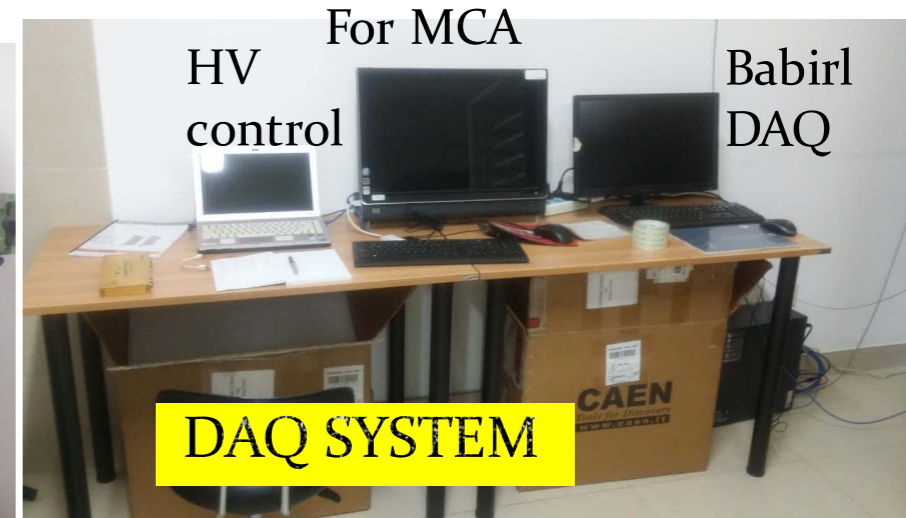
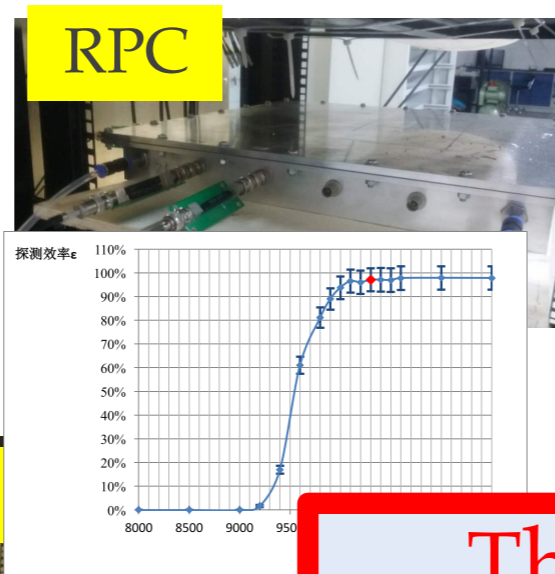
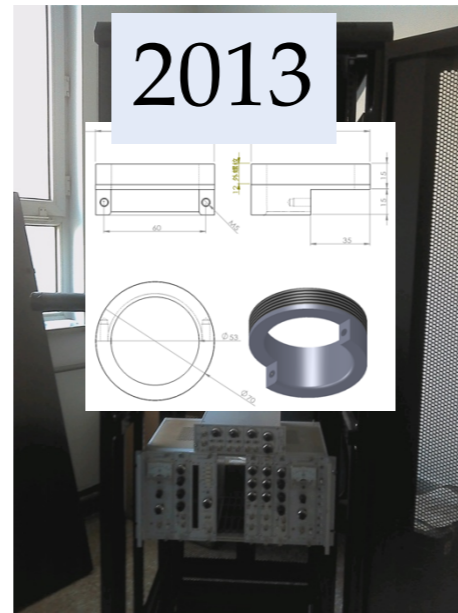
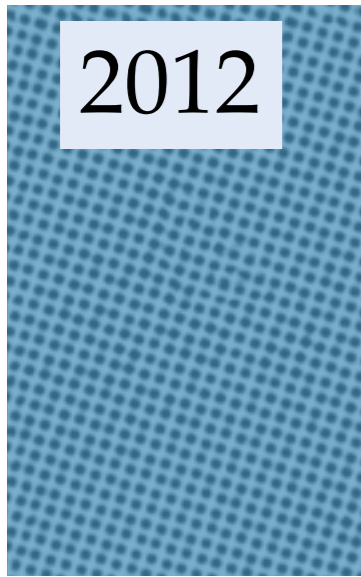
□ 2019.9 起担任CMS BPH 国际会议联络人, 负责遴选和审核国际会议报告

基于Run-II数据的相应分析进行中, 计划2020完成预审

$B^+ \rightarrow K^{*+} \mu^+ \mu^-$  analysis:  
pre-approved in 2019/09



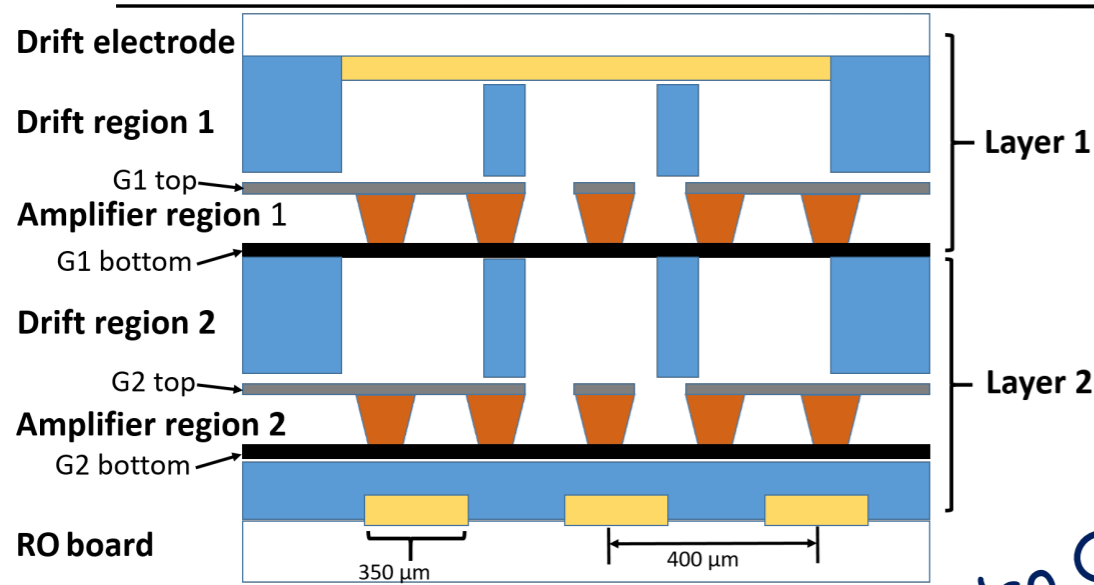
# 探测器研发实验室建设



## The Detector R&D Lab NOW



# 微结构气体探测器研发 (模拟与小模型)



会议报告:

CLHCP 2017, 南京师范大学.

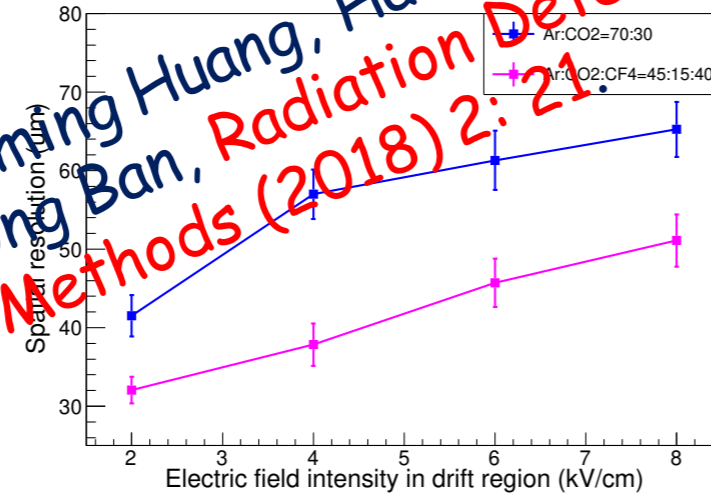
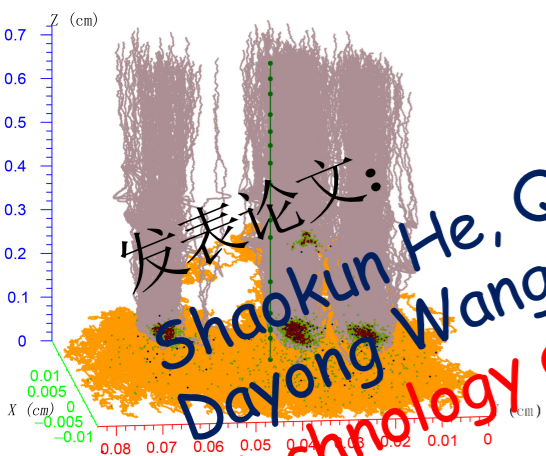
第七届全国先进气体探测器研讨会, 2017年12月, 广西大学

第八届全国先进气体探测器研讨会, 2018年10月, 衡阳

CLHCP 2018, 华中师范大学.

第九届全国先进气体探测器研讨会, 2019年10月, 东莞

CLHCP 2019, 大连理工大学.



发表论文:  
 Shaokun He, Qianming Huang, Hao Qiao,  
 Dayong Wang, Yong Ban, Radiation Detection  
 Technology and Methods (2018) 2: 21.

## New Membership

- Peking University, Beijing (China)  
Dayong Wang
- Natural Science Research Institute, University of Seoul, (South Korea)

2019.10 北大组 (包括核物理团队)  
正式加入RD51国际研发

- Royal Holloway, University of London (UK)  
Alexander Deisting

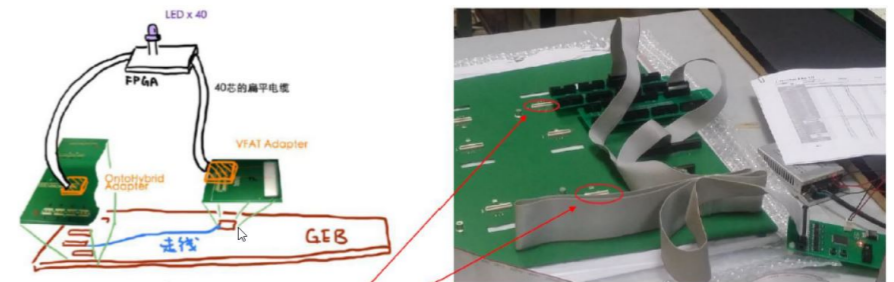
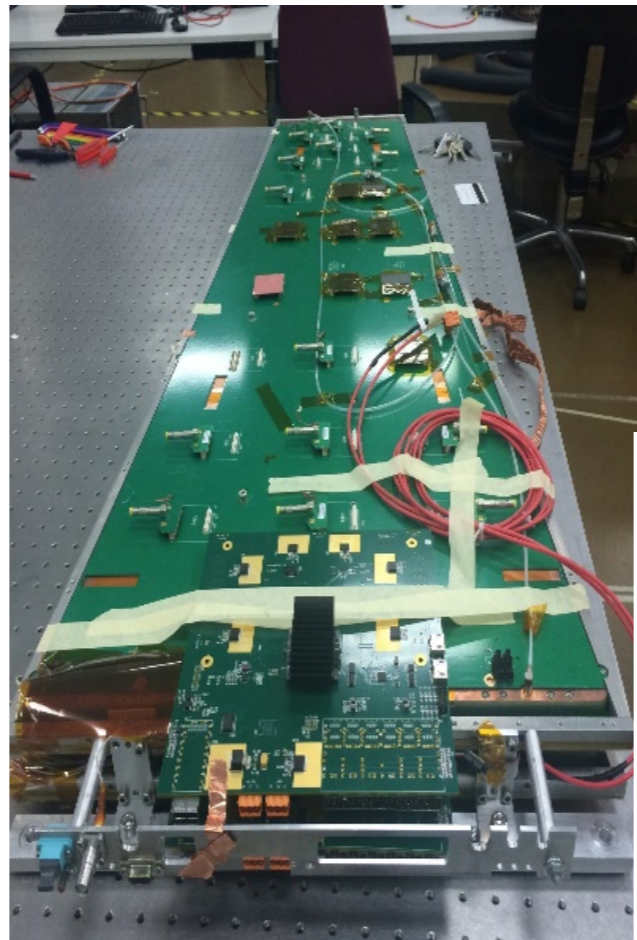
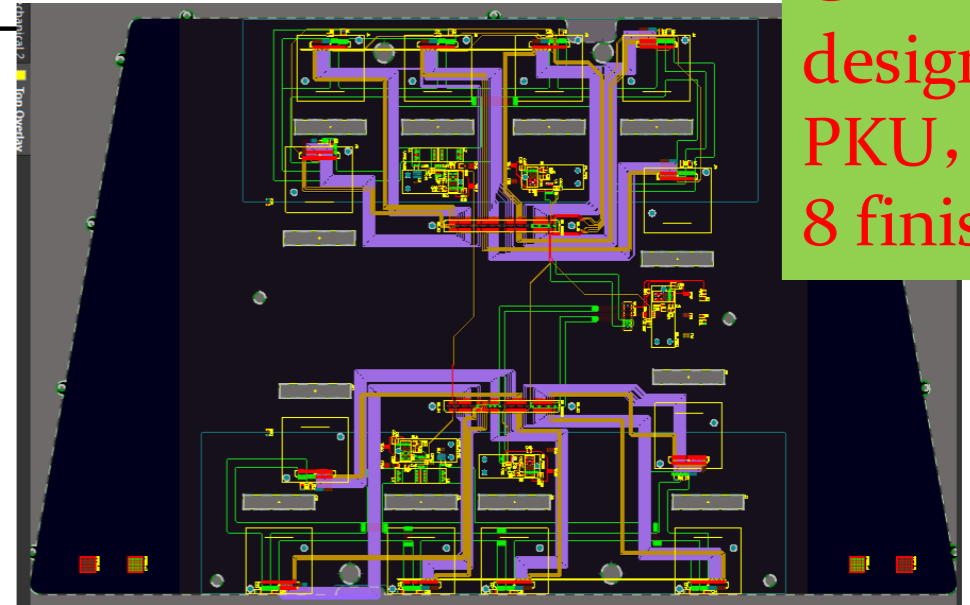


GEM prototype construction in the new clean room (~45m<sup>2</sup>)

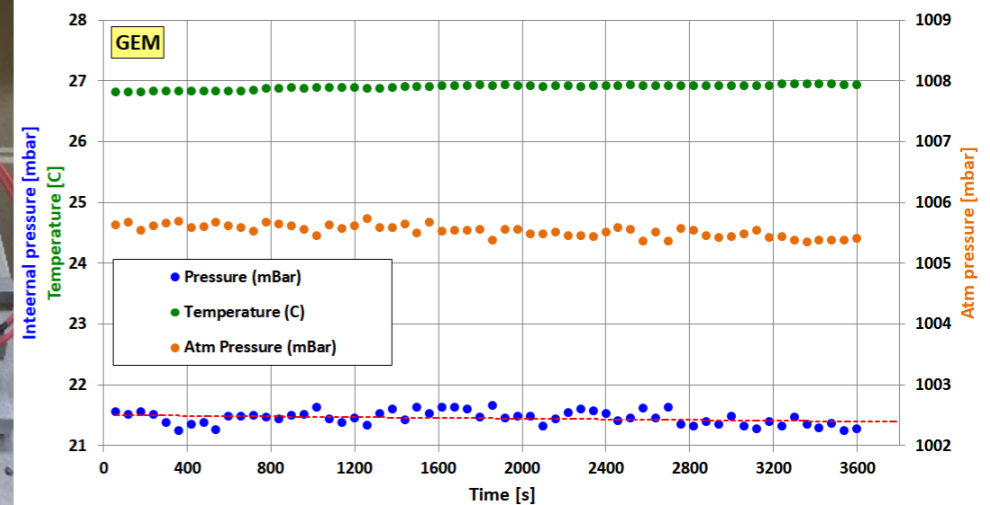
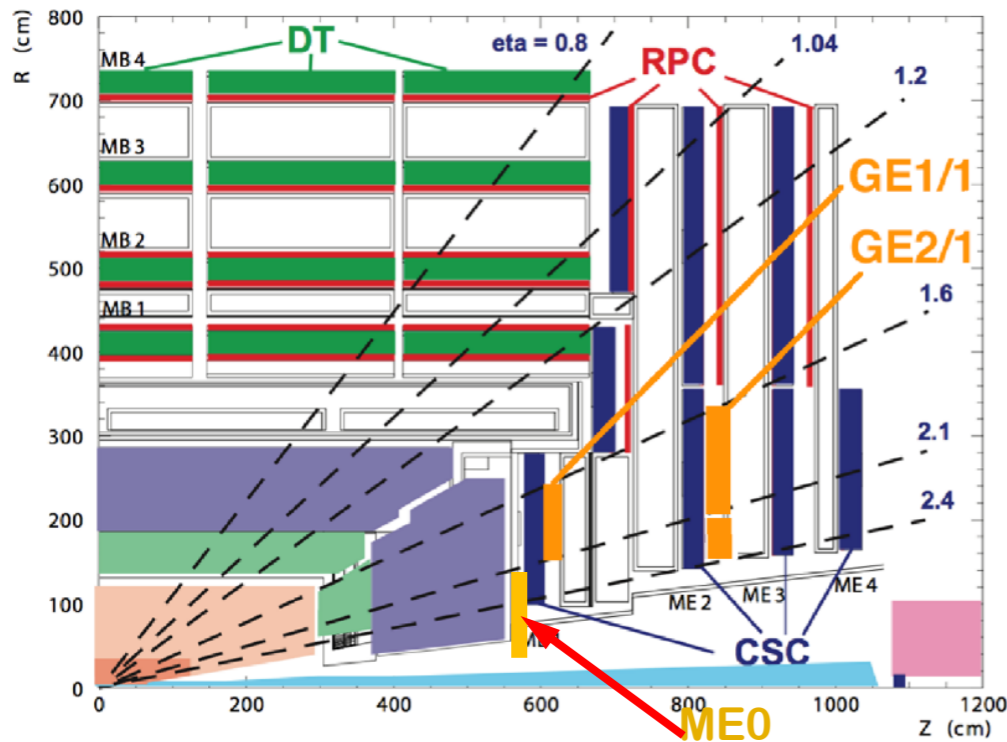
# 参与CMS二期升级: GE1/1、GE2/1 & ME0

2019.3 起担任GE2/1 triad电子学项目协调人, 负责相关研发和原型试制的组织协调

GE21 GEB design by PKU, all 8 finished



Conductivity test device developed by PKU



# 重要报告、会议组织与学术服务

## 重要学术会议报告 (10)

- ✘ 2018.10.15 Hengyang, Talk “New physics searches at BESIII”, BESIII new physics workshop
- ✘ 2018.10.26 Zhengzhou, Talk “Recent results of BESIII”, 16<sup>th</sup> HFCPV conference
- ✘ 2019.3.24 UCAS, Talk “Some new physics topics at STCF”, STCF physics workshop
- ✘ 2019.4.22 Hefei, Talk “New physics searches at BESIII”, joint meeting of SKLNPT and SKLNDE
- ✘ 2019.5.25 Hefei, Talk “New physics searches at BESIII”, BESIII new physics workshop
- ✘ 2019.5.31 TDLee Institute, Talk “Experimental searches of dark photons”, Workshop on FCP, monopole and DP
- ✘ 2019.8.6 Toronto, “Search for rare FCNC decays at BESIII”, Lepton-Photon 2019 conference
- ✘ 2019.8.8 Toronto, “Study of rare decays at CMS”, Lepton-Photon 2019 conference
- ✘ 2019.9.4 IHEP, Talk “Exotic decay and new physics”, International review of BESIII white paper
- ✘ 2019.9.4 IHEP, Talk “New physics”, Symposium on 30 years of BES physics

✓ 担任QWG BSM session 召集人

## ✓ 参与组织会议

- BESIII新物理研讨会, 2018.10 & 2019.5
- 6th “International Summer school on TeV Experimental Physics (iSTEP)”, 2019/7
- CMS data analysis school at PKU

## 合作组内审稿

- ✘ BESIII: (12篇, 评审主席4篇) 2018-2019发表1篇, 1篇在PRD审稿
- ✘ CMS: 担任两个分析ARC委员, 1篇已发布PAS

## 教学与院系服务

- ✘ 教材: 《核物理实验》第四章、第五章实验18
- ✘ 讲授课程: 《核与粒子物理实验方法二》《对撞物理》
- ✘ 本科生综合指导 ~20人次
- ✘ 多次参与本科生、研究生学术活动



# 主持和参加的科研项目

起讫时间	项目名称	项目来源	总经费/本人负责 (万)	项目完成人	备注
2013.1-2015.12	通过不可见衰变寻找与研究暗规范玻色子	基金委	60	王大勇	主持
2012.9-2014.12	探测器实验室搭建以及BESIII和CMS数据分析	985计划	95	王大勇	主持
2015.1-2019.8	轻强子谱的系统研究	科技部	561/224	黄性涛 王大勇 房双世等	参与单位 负责人
2019.1-2022.12	BESIII大统计量 J/psi 样本中基本守恒律的实验检验	基金委大重 装置联合重 装点	248/92	王大勇 赵明刚 焦健斌	主持

## 其他在研参与项目：

科技部大科学装置前沿研究专项“CMS 实验 Run-2 数据的物理研究”，2018.5-2023.4，参与

# 总结一年来科研进展，规划未来

- 开展间接寻找新物理研究，担任BESIII新物理组和国际QWG工作组BSM convener
- 新论文发表(主要或者通讯作者)
  - The CMS Collaboration, Phys. Rev. D 98, 112011 (2018): Angular analysis of the decay  $B^+ \rightarrow K^+ \mu^+ \mu^-$  in proton-proton collisions at  $\sqrt{s} = 8$  TeV.
  - The BESIII Collaboration, Phys. Rev. D 99, 012013 (2019): Measurement of  $B(J/\psi \rightarrow \eta' e^+ e^-)$  and search for dark photon search.
  - The BESIII Collaboration, Phys. Rev. D 99, 112008(2019): Observation and study of the decay  $J/\psi \rightarrow \phi \eta \eta'$ .
- 建成探测器实验室，探测器研发顺利起步，参与CMS探测器升级项目进展顺利。
- 新科研项目（大装置联合重点）开始，执行进展符合计划
- 中期规划：瞄准前沿，继续在既有研究课题与方向上深耕，追求卓越！