Baryon/Lepton number violation searches at BESIII

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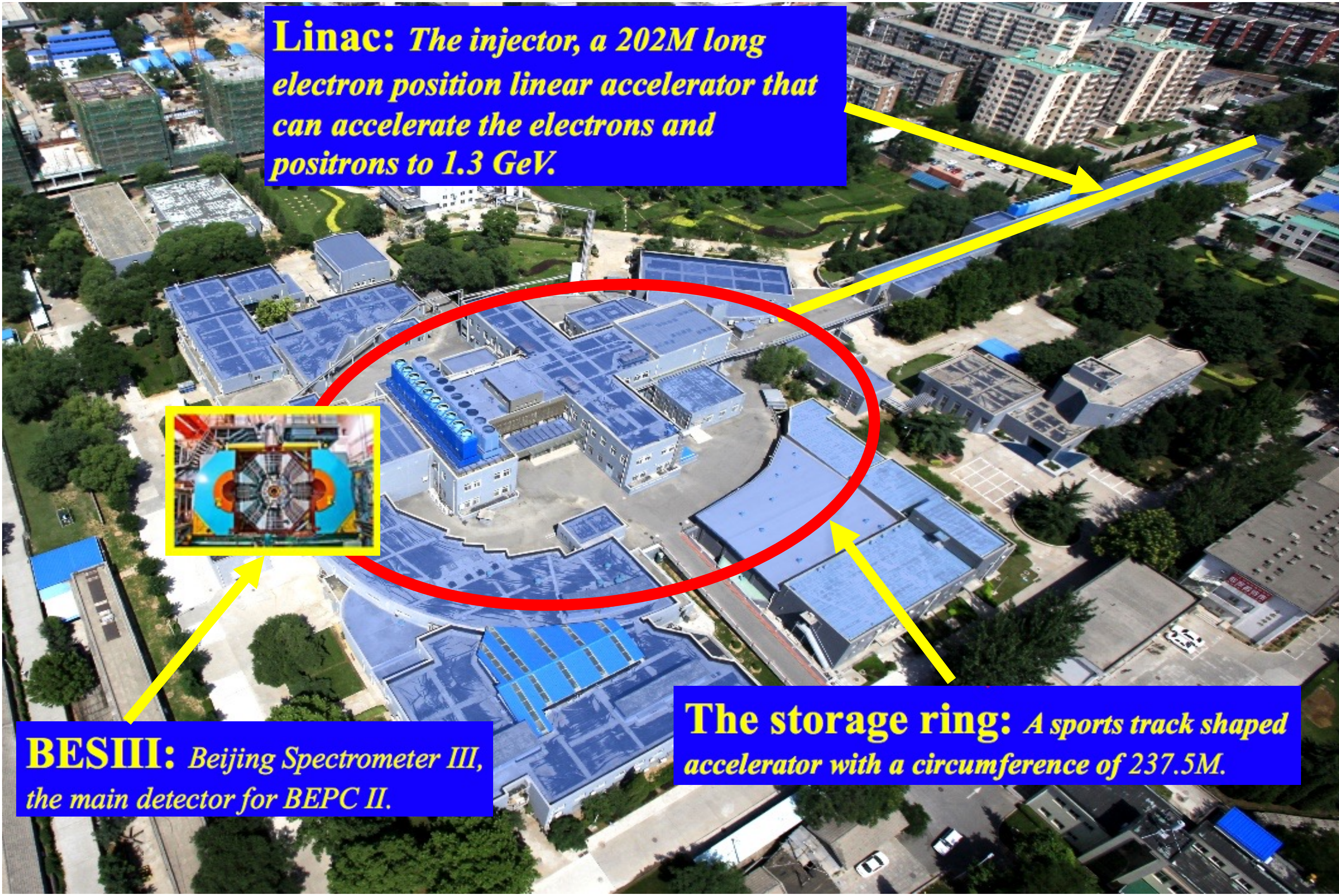
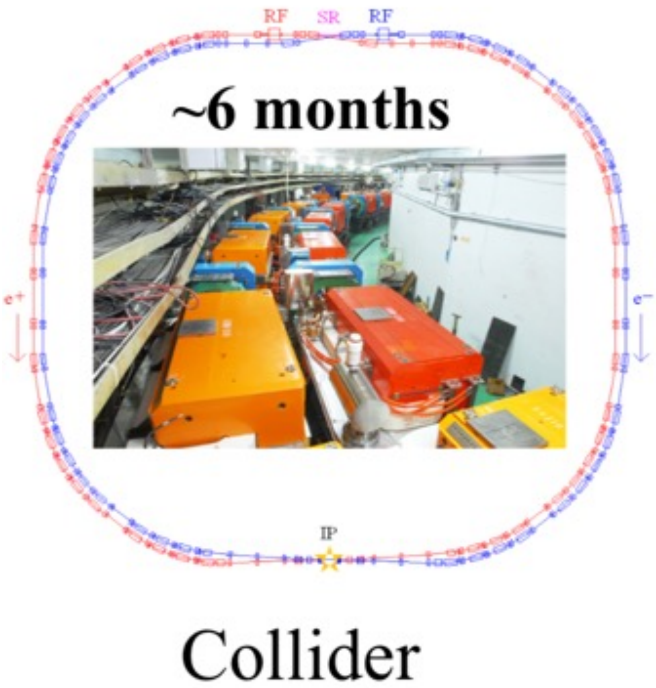
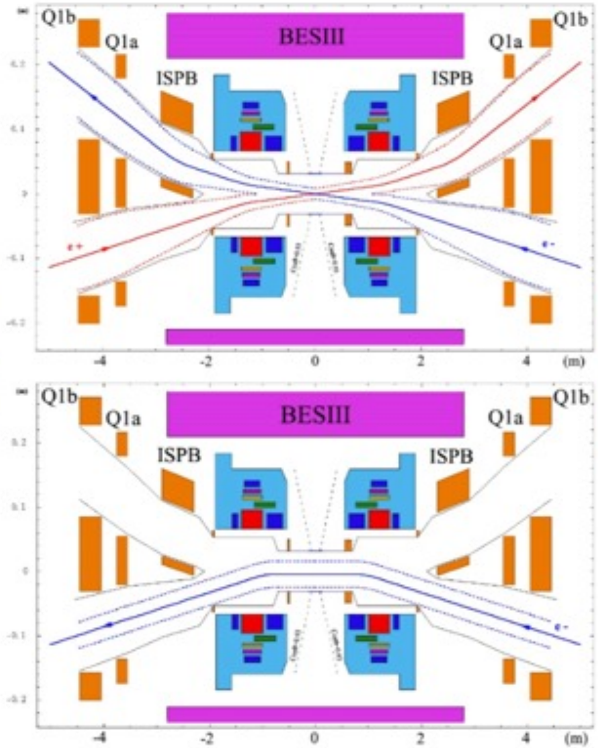
05 Summary

01 Introduction: BEPCII/BESIII experiment

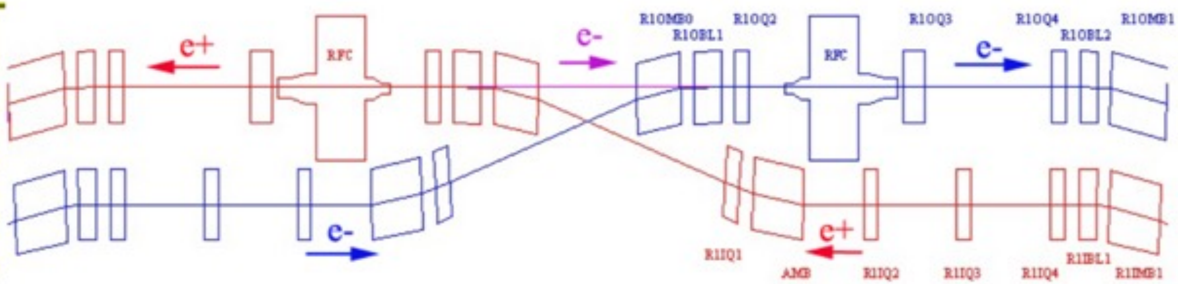


01 Introduction: BEPCII Collider

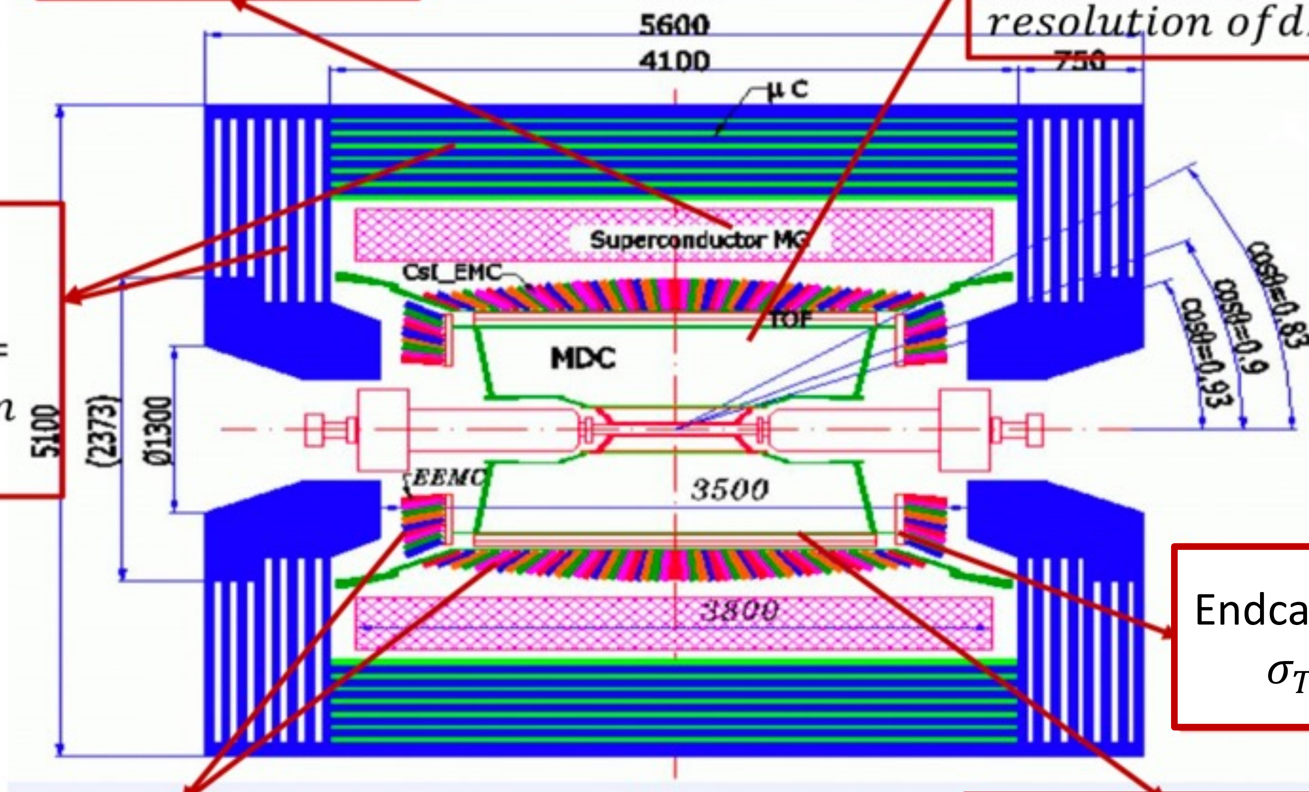




January 2004	Construction started
Mar.28, 2008	Installation of detector started
Jun. 22, 2008	BEPCII Commissioning started
May 13, 2009	Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$
Apr. 5, 2016	Luminosity reached $1.0\times10^{33}cm^{-2}s^{-1}$



01 Introduction: BESIII Detector



SC Magnet: 1T

MDC: $\sigma_{r\phi} = 115\mu m$
$\Delta p/p = 0.47\%@1GeV$
$resolution\ of dE/dx = 5.2\%$

Barrel and endcap Muon counter: $\sigma_{r\phi} = 14mm{\sim}15mm$
$\sigma_z{\sim}17mm$

Endcap TOF: MRPC
$\sigma_T = 70\ ps$

Barrel and endcap EMCAL
$\Delta E/E = 2.5\%\ @1GeV, \sigma = 6\ mm/\sqrt{E}$

Barrel TOF: Scintillator
$\sigma_T = 80\ ps$

- General purpose detector at BEPCII, $E_{cm} \approx$ 2-4.6 GeV, $L_{peak} \approx 10^{33}/cm^2/s$
- Versatile researches in τ-charm physics

01 Introduction: BESIII Collaboration

Europe (18)

Germany(6): Bochum University, GSI Darmstadt, Helmholtz Institute Mainz, Johannes Gutenberg University of Mainz, Universitaet Giessen, University of Münster

Italy(3): Ferrara University, INFN, University of Turin,

Netherlands(1):KVI/University of Groningen

Russia(2): Budker Institute of Nuclear Physics, Dubna JINR

Sweden(1): Uppsala University

Turkey (1): Turkish Accelerator Center Particle Factory Group

UK(3): University of Manchester, University of Oxford, University of Bristol

Poland(1): National Centre for Nuclear Research

Pakistan(2)

COMSATS Institute of Information Technology

University of the Punjab

India(1)

Indian Institute of Technology madras

China (54)

Beihang University, Central China Normal University, Central South University, China Center of Advanced Science and Technology, China University of Geosciences, Fudan University, Guangxi Normal University, Guangxi University, Hangzhou Normal University, Hebei University, Henan University, Henan Normal University, Henan University of Science and Technology, Henan University of Technology, Huangshan College, Hunan University, Hunan Normal University, Inner Mongolia University, Institute of High Energy Physics, Institute of Modern Physics, Jilin University, Lanzhou University, Liaoning Normal University, Liaoning University Nanjing Normal University, Nanjing University, Nankai University, North China Electric Power University,Peking University, Qufu Normal University, Renmin University of China, Shanxi University, Shanxi Normal University, Sichuan University, Shandong Normal University, Shandong University, handong University of Technology,Shanghai Jiao Tong University, Soochow University,South China Normal University, Southeast University, Sun Yat-sen University, Tsinghua University, University of Chinese Academy of Sciences, University of Jinan, University of Science and Technology of China, University of Science and Technology Liaoning, University of South China, Wuhan University, Xinyang Normal University, Yantai University , Yunnan University , Zhejiang University, Zhengzhou University

Thailand(1)

Suranaree University of Technology

Mongolia(1)

Institute of Physics and Technology

Korea(1)

Chung-Ang University

USA(3)

Carnegie Mellon University

Indiana University

University of Hawaii

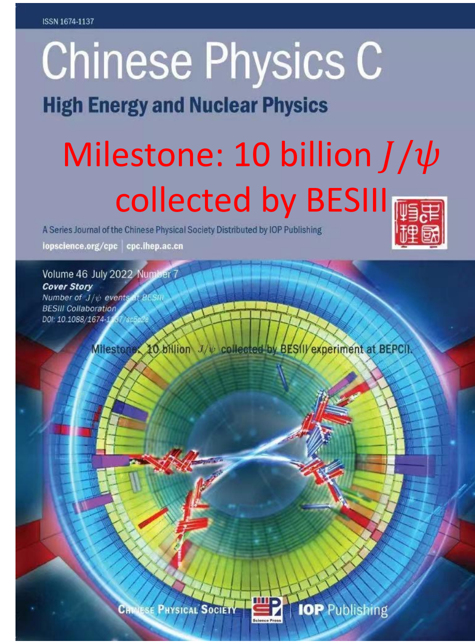
Chile(1)

University of Tarapaca

BESIII: ~600 members

85 institutes, 17 countries.

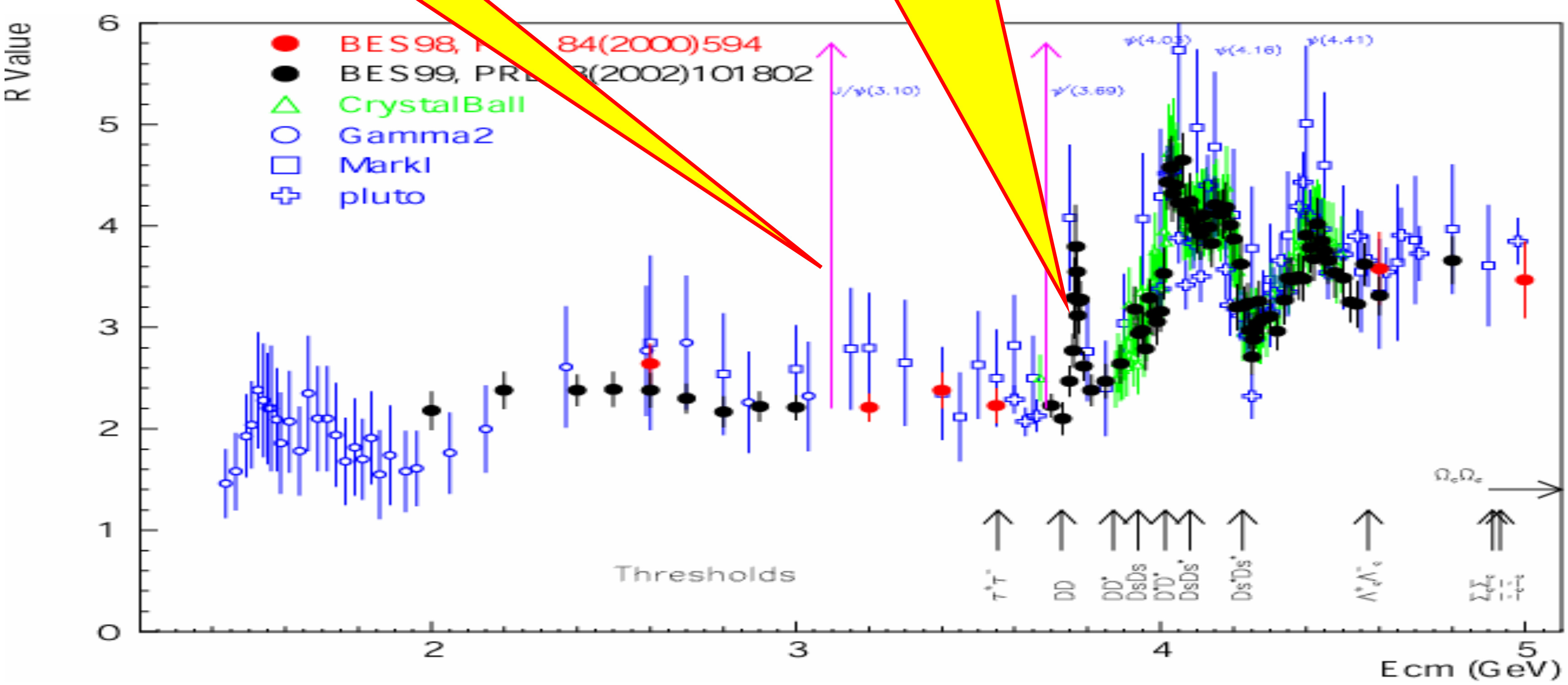
01 Introduction: Data Samples



World largest charmonium data sets directly produced from e^+e^- collision at J/ψ resonance, 10 billion; ψ(3770) peak, 2.9 fb^{-1};

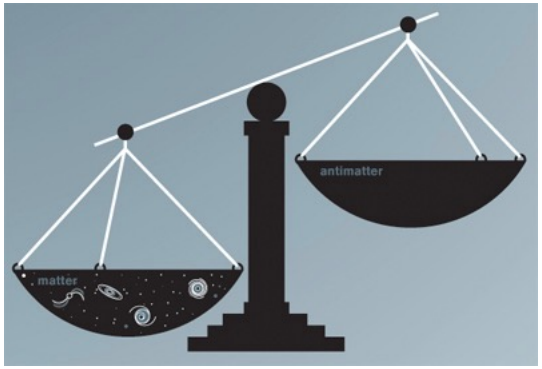
J/ψ: 10^{10}

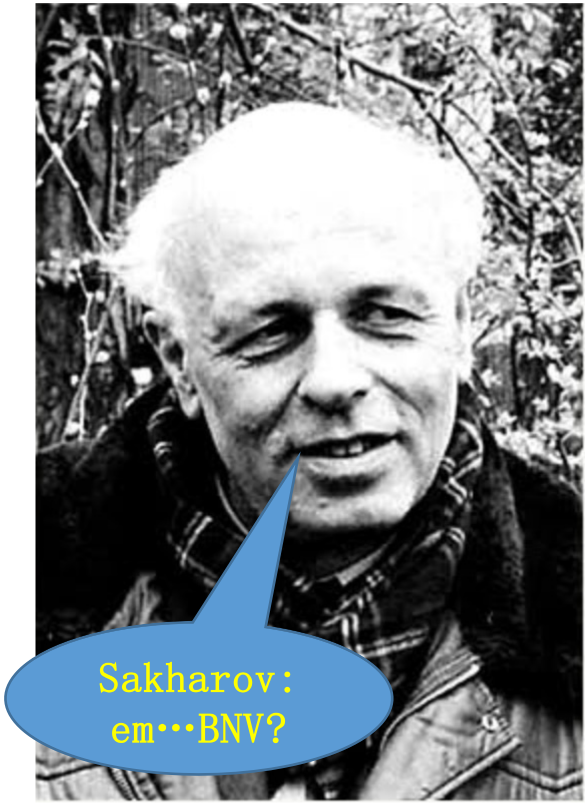
ψ(3770): 2.9 fb^{-1}



01 Introduction: BNV Searching

- Asymmetry of matter and anti-matter: big problem in the universe evolution.
- BNV: even a small amount would have major consequences on the universe and its evolution, as many theories have suggested.
- For example, in the Grand Unified Theory, proton can decay into several modes through leptoquarks, such as $p \to e^{+}\pi^{0}$. Such mechanism simultaneously breaks BN and LN while conserving $\Delta(B-L)$.
- Searches for physics BSM with collider experiments are complementary to searches with specifically designed precision detection experiments.
- The two independent ways of searching for new physics are fruitfully supporting each other.





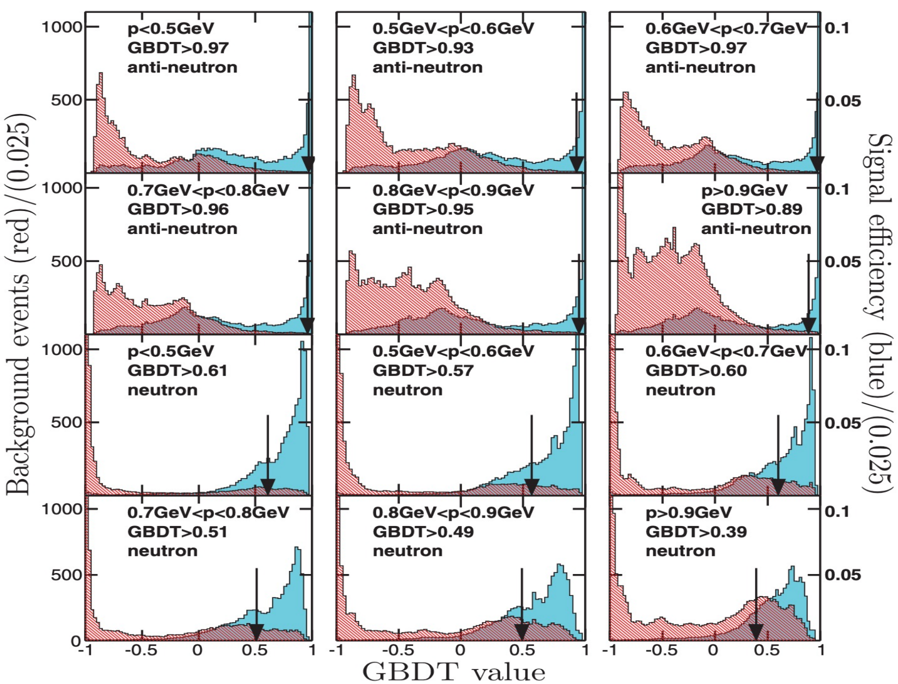
01 Introduction: Status for BNV/LNV @hadrons

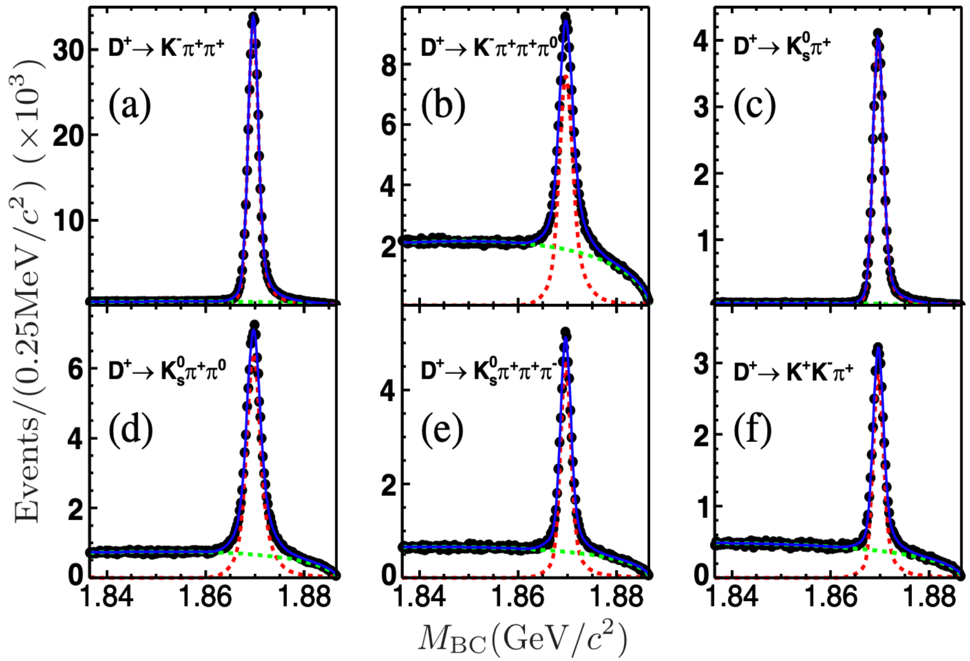
Decay Mode	$B_{90\%}^{UP}$ $(\times 10^{-8})$	Latest Experiment	Year
$D^0 \to pe^-/\bar{p}e^+$	220/120	BESIII [PRD105, 032006]	2022
$\Sigma^- \to pe^-e^-$	6700	BESIII [PRD103, 052011]	2021
$D^+ \to \Lambda(\Sigma^0)e^+$	110 (170)	BESIII [PRD101, 031102(R)]	2020
$D^+ \to \bar{\Lambda}(\bar{\Sigma}^0)e^+$	65 (130)		
$D^0 \to K^-\pi^-e^+e^+$	280	BESIII [PRD99, 112002]	2019
$D^+ \to K_S^0\pi^-e^+e^+$	330		
$D^+ \to K^-\pi^0e^+e^+$	850		
$J/\psi \to \Lambda_c^+e^- + c.c.$	6.9	BESIII [PRD99, 072006]	2019
$\Lambda \to K^\pm e^\mp(\mu^\mp)$	200 (300)	CLAS [PRD92, 072002]	2015
$\Lambda \to \pi^\pm e^\mp(\mu^\mp)$	40 (60)		
$\Lambda \to \bar{p}\pi^+$	90		
$\Lambda \to K_S^0\nu$	2000		
$B^0 \to p\mu^-$	0.26	LHCb [PRD108, 012021]	2023
$B_S^0 \to p\mu^-$	1.21		
$B^0 \to \Lambda_c^+\mu^-(e^-)$	140 (400)	BABAR [PRD83, 091101(R)]	2011
$B^+ \to \Lambda\mu^+(e^+)$	6 (3.2)		
$B^+ \to \bar{\Lambda}\mu^+(e^+)$	6 (8)		

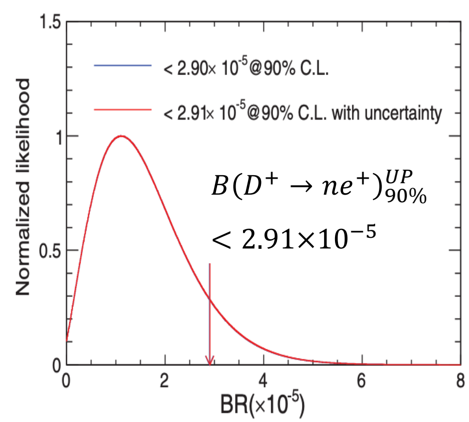
02 Search for $D^+ \to ne$

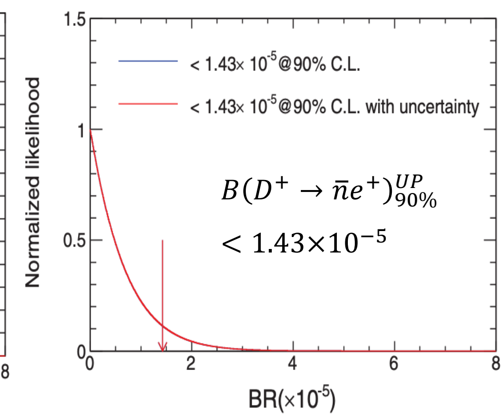
PRD106, 112009 (2022)

- First constraint on $\boldsymbol{D^+ \to ne}$
- Double tag method, 1.5×10^6 single tag D^- mesons (from 2.9 fb^{-1} $\psi(3770)$ data)
- Gradient BDT algorithm based on EMC shower information trained with $n/\bar{n}/K_L^0/\gamma$ control samples is used for $n/\bar{n}$ identification
- zero signal events in the signal region



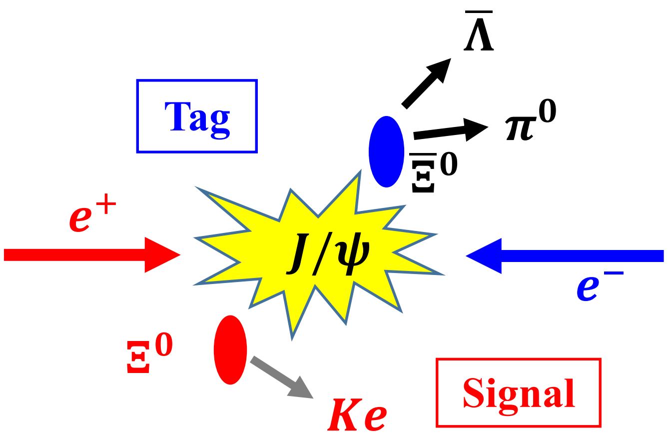




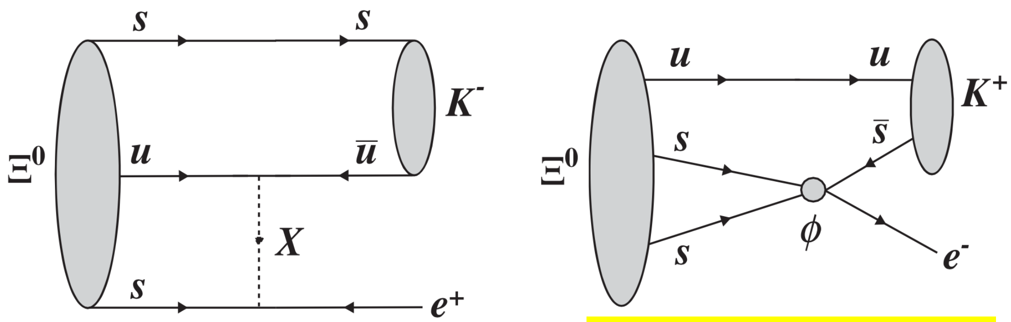


03 Search for $\Xi^0 \to Ke$

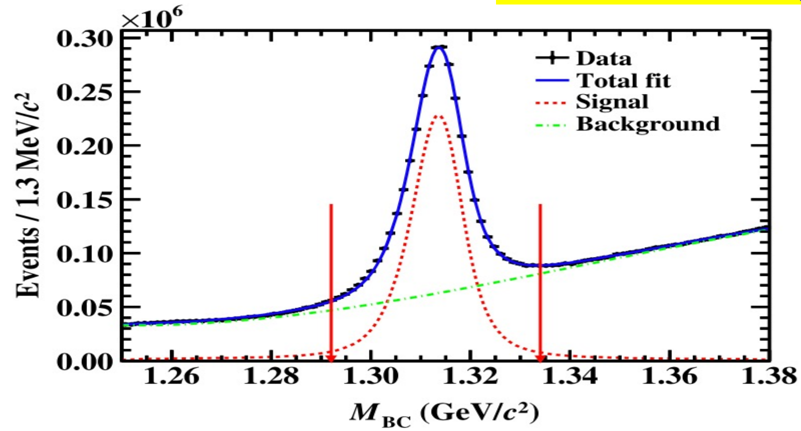
- 10 billion J/ψ events
- First search of BNV in Ξ decay
- Double tag method, background free analysis

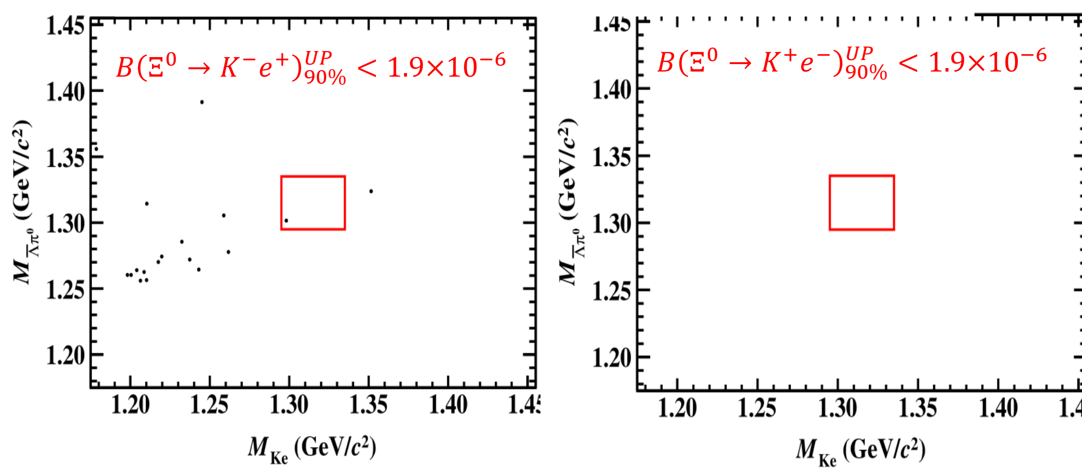


- No obvious signal observed
- Low systematic uncertainty (3.4%)



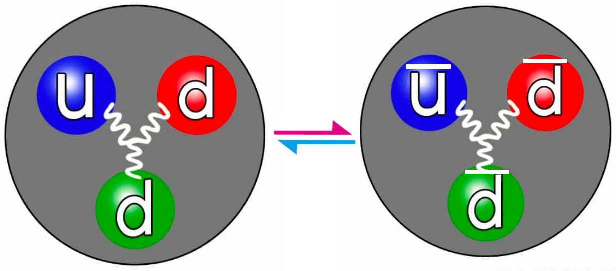
PRD108, 012006 (2023)





04 Search for $\Lambda - \bar{\Lambda}$ Oscillation

- Since 1980[PRL44,1316], there have been many experiments searching for BNV through $n - \bar{n}$ oscillation[PDG2019] with upper limit results, while few results from other baryons.



- 2007, K.-B. Luk pointed out that $\Lambda - \bar{\Lambda}$ oscillation may also exist.
- 2010, X.-W. Kang and H.-B. Li[PRD81,051901] give a prospect of searching for $\Lambda - \bar{\Lambda}$ oscillation at the BESIII experiment.
- 2017, the LHCb experiment presented the first constraint on $\Xi_b^0 - \bar{\Xi}_b^0$ oscillation.
- The theoretical advantage for using $\Lambda - \bar{\Lambda}$ is it has a second generation quark, which can give further information compared with the result of proton decay which only have the first generation quark.

04 Search for $\Lambda - \bar{\Lambda}$ Oscillation

- Result based on 1.3 billion J/ψ events
- An oscillation event (c.c. implied)

$$J/\psi \to pK^-\bar{\Lambda} \xrightarrow{oscillating} pK^-\Lambda$$

- Time integrated oscillation rate

$$\mathcal{P}(\Lambda) = \frac{\mathcal{B}(J/\psi \to pK^-\Lambda)}{\mathcal{B}(J/\psi \to pK^-\bar{\Lambda})} = \frac{N_{WS}^{obs}/\epsilon_{WS}}{N_{RS}^{obs}/\epsilon_{RS}}$$

- Bkg free, sys. uncertainty very low (1%)
- Upper limit on oscillation rate at 90% CL

$$\mathcal{P}(\Lambda) = \frac{N_{WS}^{obs}/\epsilon_{WS}}{N_{RS}^{obs}/\epsilon_{RS}} < 4.4\times10^{-6}$$

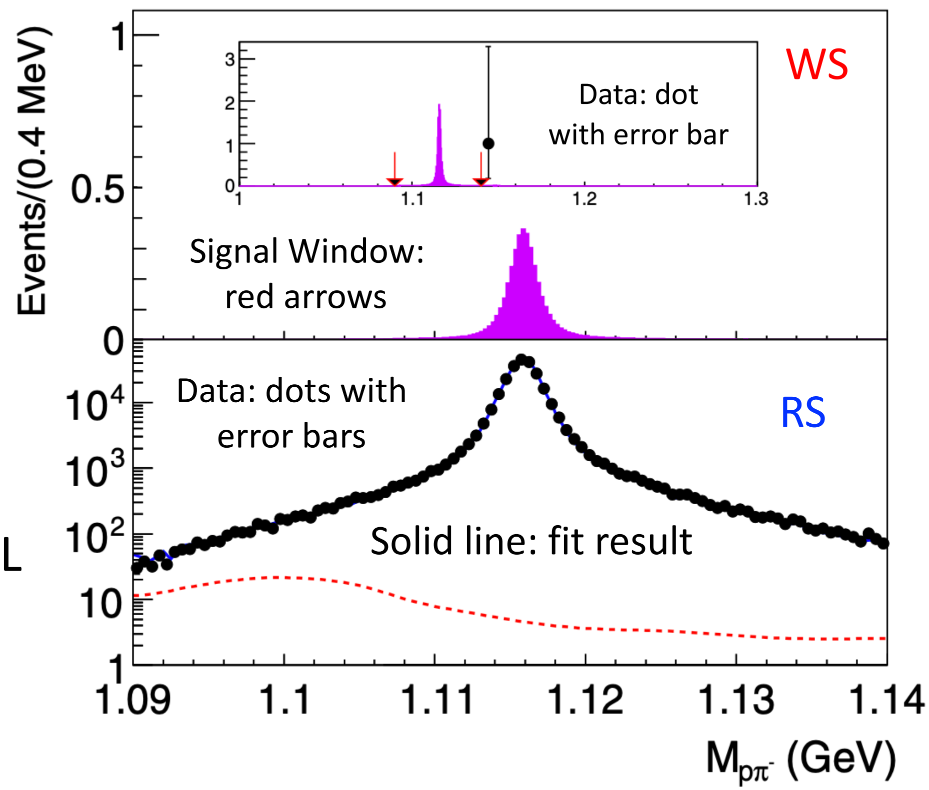
- Oscillation parameter (90% CL)

$$\delta m_{\Lambda\bar{\Lambda}} = \frac{\mathcal{P}(\Lambda)}{2\tau_\Lambda^2} < 3.8\times10^{-18}\ \text{GeV}$$

Wrong Sign Channel (Same Charge)

$$J/\psi \to pK^-\Lambda \to pK^-(p\pi^-)$$

PRL131, 121801 (2023)



Right Sign Channel (Opposite Charge)

$$J/\psi \to pK^-\bar{\Lambda} \to pK^-(\bar{p}\pi^+)$$

04 Summary

- With the world largest threshold produced $\psi(3770)$ data with 2.9 fb^{-1} and J/ψ data with 10 billion events, the BESIII collaboration presented the first constraints on $D^+ \to ne$, $\Xi^0 \to Ke$ and $\Lambda - \bar{\Lambda}$ oscillation, no BSM signals found.
- New data taking plan and more charmonium data sets at other CM energy have been approved! Better/more constraints on BNV/LNV processes are coming soon.

Nankai University


Děkujeme!
谢谢！