New Physics

Dayong Wang

On behalf of BESIII New Physics group

Peking University

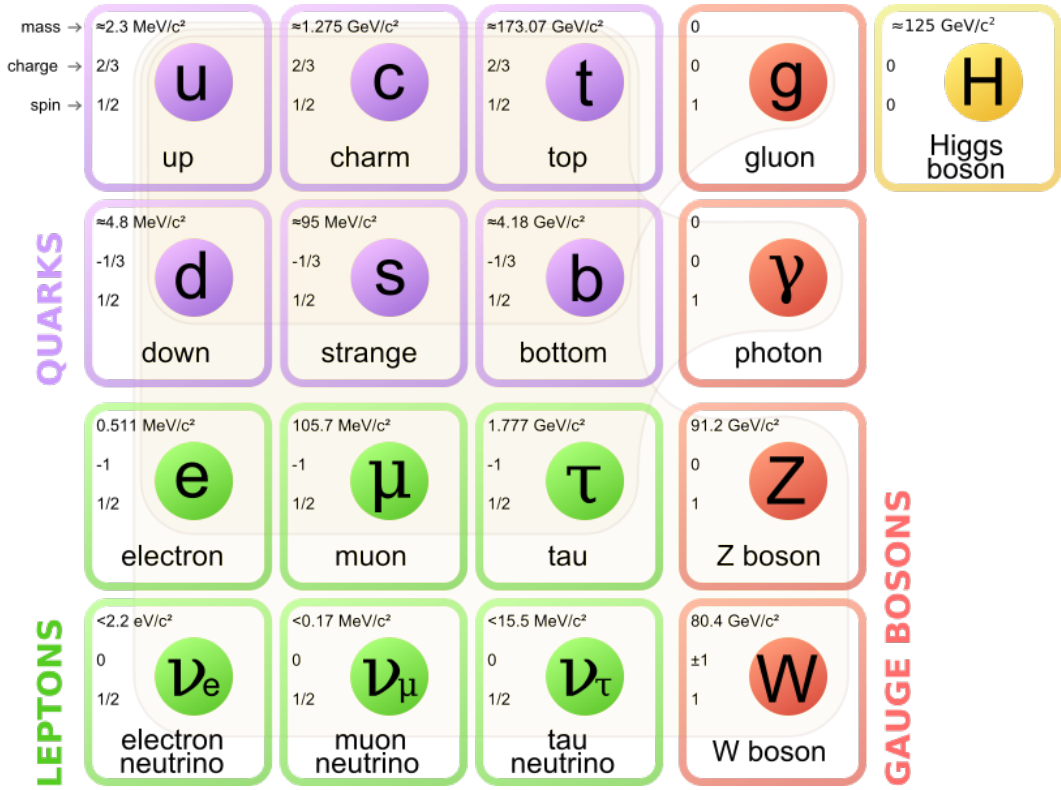
Symposium on 30 years of BES Physics

Sep 6 2019

Standard Model of particle physics

30 years of BES programs contribute a lot from the rich potential of τ-c region

- Rich of **resonances**, charmonia and charmed mesons.
- **Threshold** characteristics (pairs of τ, D, D_s, charmed baryons…).
- **Transition** between perturbative and non-perturbative **QCD**.

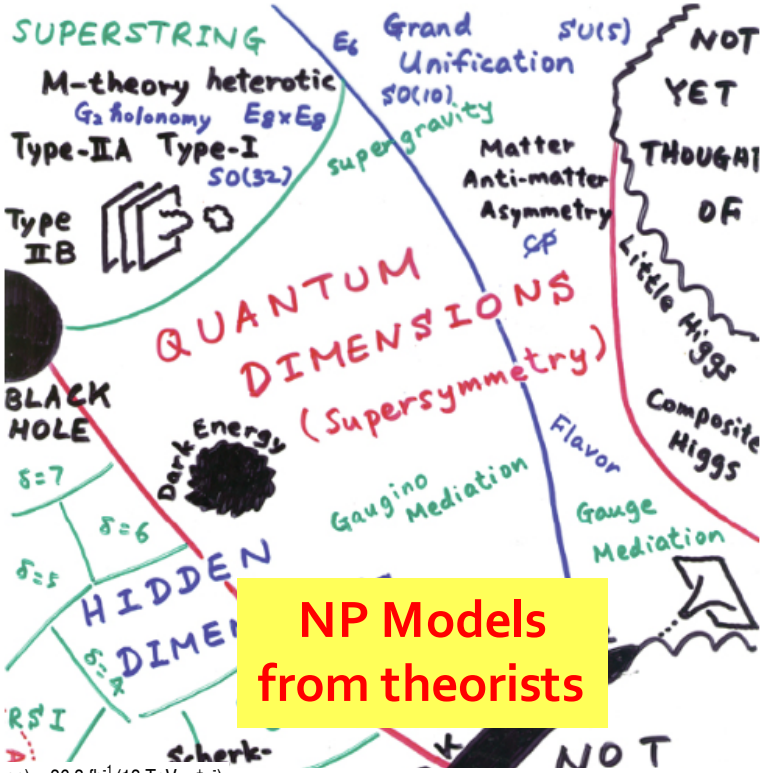


Standard model of particle physics

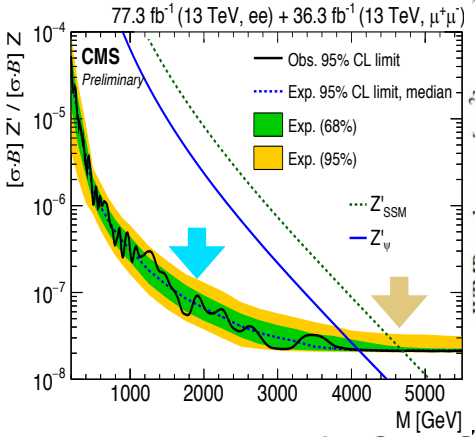
Search for new physics beyond SM

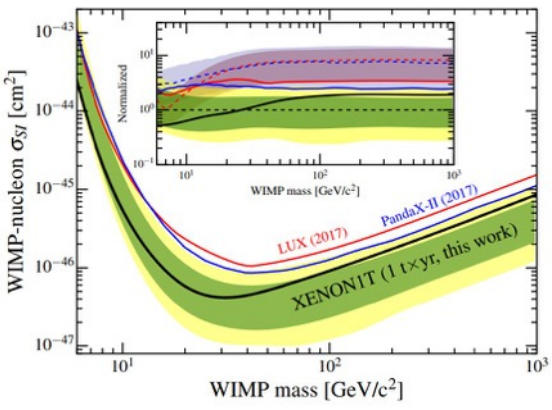
big questions to address beyond SM:

- Why three generations?
- Mass hierarchy among fermions?
- Why SU(3)xSU(2)xU(1)?
- Why B and L number conserved?
- Why C, P, CP symmetry violated?
- What is the origin of neutrino mass?
- What is dark matter ?
- Matter-antimatter asymmetry in Universe?
- … …



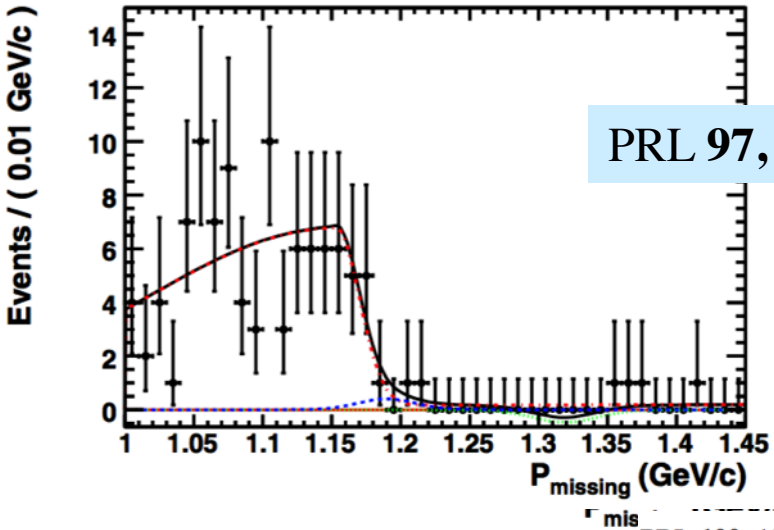
NP Models from theorists



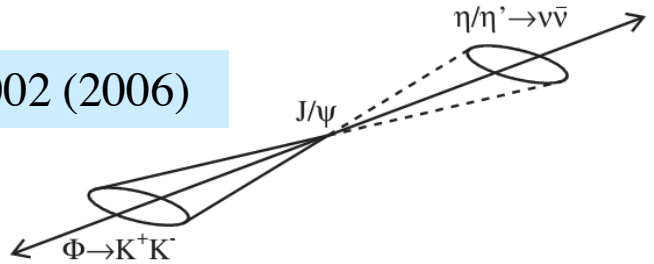


Intensity frontier expts come into play: BES

BESII efforts on rare decays &NP: examples



PRL **97,** 202002 (2006)



$$\frac{\mathcal{B}(\eta \to \text{invisible})}{\mathcal{B}(\eta \to \gamma\gamma)} < \frac{n_{UL}^{\eta}/\epsilon_{\eta}}{n_{\gamma\gamma}^{\eta}/\epsilon_{\gamma\gamma}^{\eta}} \frac{1}{(1-\sigma_{\eta})}$$

PRL **100,** 192001 (2008) PHYSICAL REVIEW LETTERS

Search for the Invisible Decay of J/ψ in $\psi(2S) \to \pi^+\pi^- J/\psi$

Physics Letters B 561 (2003) 49–54

www.elsevier.c

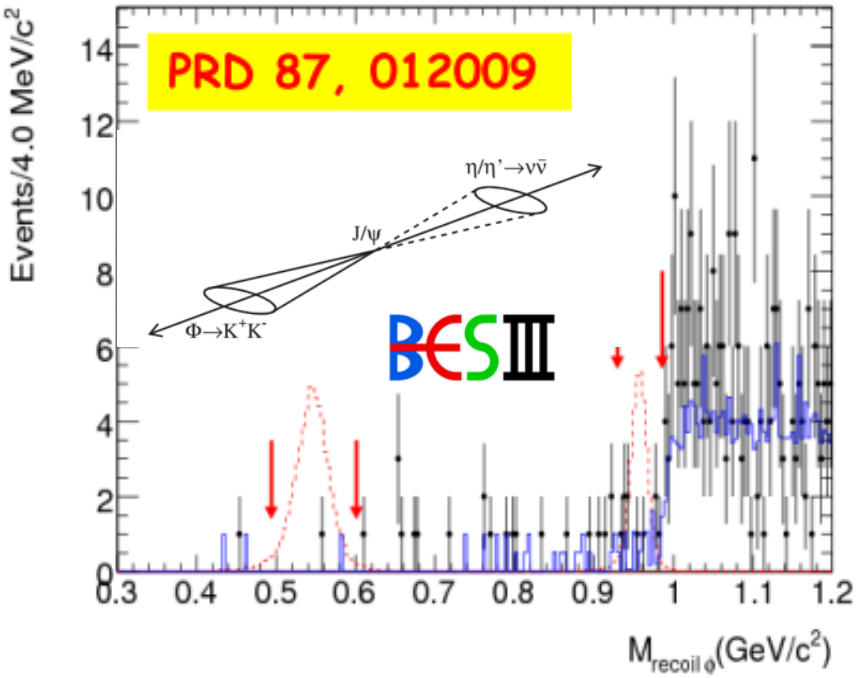
Search for lepton flavor violation process $J/\psi \to e\mu$

Physics Letters B 598 (2004) 172–177

www.elsevier.com/locate/physletb

Search for the lepton flavor violation processes $J/\psi \to \mu\tau$ and $e\tau$

η /η′ invisible decays: BESIII （2013）



Br(η′→invisible)/Br(η′→γγ)<2.39×10⁻²
Br(η →invisible)/Br(η→γγ)<2.58×10⁻⁴

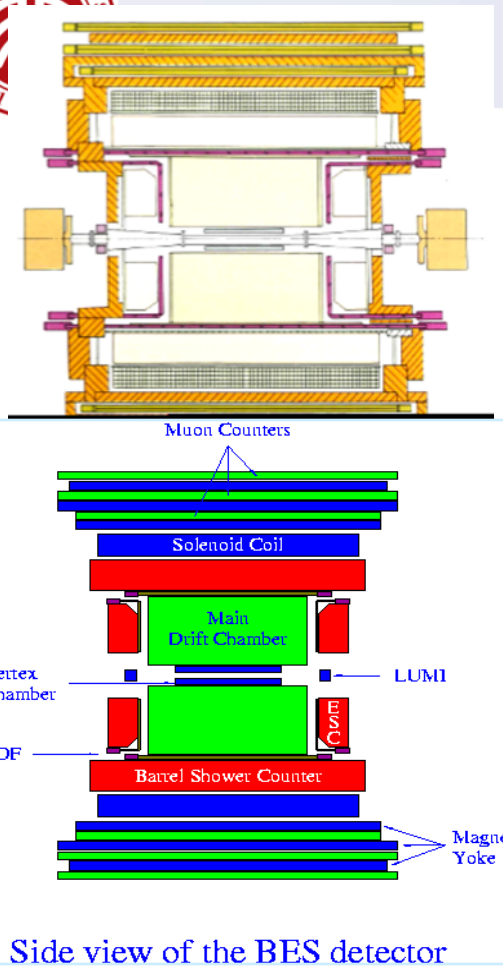
Br(η′→invisible)<5.21×10⁻⁴@90%C.L.
Br(η →invisible)<1.01×10⁻⁴@90%C.L.
Improved PDG Values

PDG : Br(η′→invisible)<9×10⁻⁴@90%C.L
Br(η →invisible)<6×10⁻⁴@90%C.L.

Theory : Br(η′→χχ) ~8.1×10⁻⁷
Br(η →χχ)~7.4×10⁻⁵
B. McElrath, PRD 72, 103508 (2005)

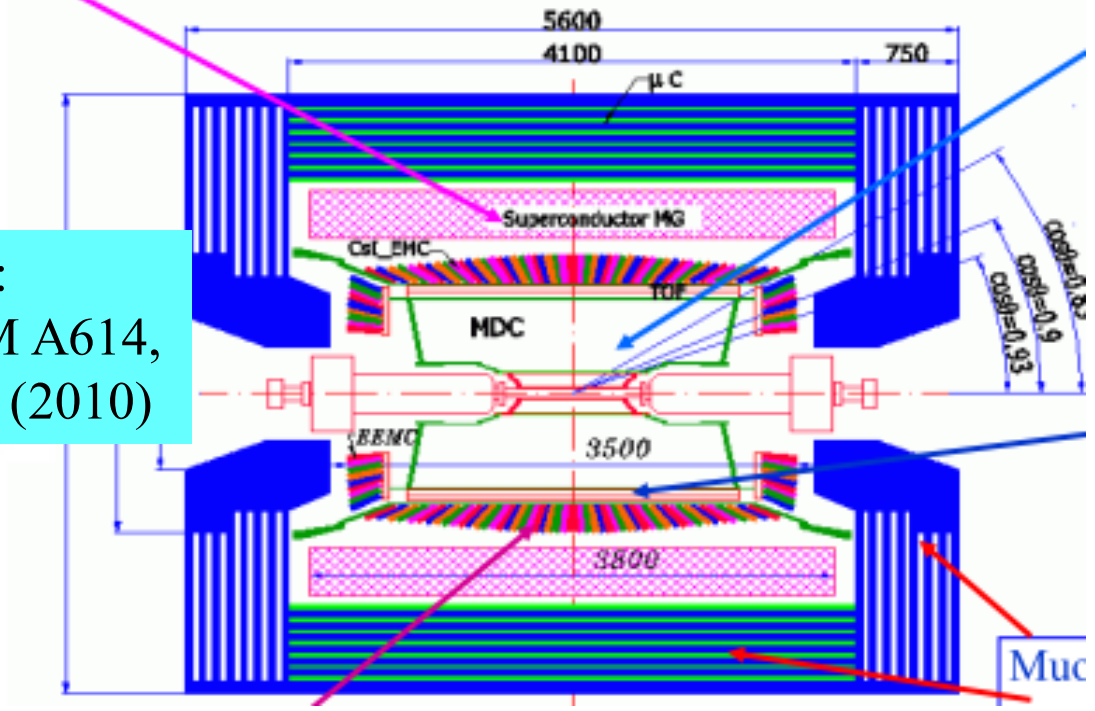
Only 2.3% of the full data set

From BESI/II to BESIII



Side view of the BES detector

Magnet: 1 T Super conducting



Ref:
NIM A614, 345 (2010)

~ 1.3B +**8.7B** J/ψ ~ 180×BESII
~ 0.5 B $\psi(3686)$ ~ 24×CLEO-c
~ 2.9/fb $\psi(3770)$ ~ 3.5×CLEO-c

Major datasets for NP so far

high lumi, large datasets, hermetic detector with good performance and clean environment at BESIII are helpful for probing BSM physics

competitive in channels with low energy electron/photons, neutrons, pi0's

η /η' invisible: efficiencies

Quantity	Value η	Value η'
$n_{\rm UL}^{\eta}$ ($n_{\rm UL}^{\eta'}$)	3.56	5.72
ϵ_{η} ($\epsilon_{\eta'}$)	23.5%	23.2%
$n_{\gamma\gamma}^{\eta}$ ($n_{\gamma\gamma}^{\eta'}$)	1760.2 ± 49.3	71.6 ± 13.2
$\epsilon_{\gamma\gamma}^{\eta}$ ($\epsilon_{\gamma\gamma}^{\eta'}$)	17.6%	15.2%
$\sigma_{\eta}^{\rm stat}$ ($\sigma_{\eta'}^{\rm stat}$)	2.8%	18.5%
σ_{η} ($\sigma_{\eta'}$)	8.1%	21.6%

BESII:2006

Thanks to the much improved EMC

Quantity	Value η	Value η'
$N_{\gamma\gamma}^{\eta}(N_{\gamma\gamma}^{\eta'})$	13390 ± 136	400 ± 25
$N_{\rm bkg}^{\rm non\text{-}\phi\eta}(N_{\rm bkg}^{\rm non\text{-}\phi\eta'})$	2514 ± 64	1482 ± 46
$N_{\rm bkg}^{\rm non\text{-}\phi}(N_{\rm bkg}^{\rm non\text{-}\phi})$	1132 ± 70	10 ± 15
$N_{\rm bkg}^{\rm non\text{-}\eta}(N_{\rm bkg}^{\rm non\text{-}\eta'})$	313 ± 54	159 ± 26
$\epsilon_{\gamma\gamma}^{\eta}(\epsilon_{\gamma\gamma}^{\eta'})$	36.3%	31.7%

BESIII: 2013

Systematic errors

Source of uncertainties	Sys. error (%) η	η'
PDF shapes in the ML fit	3.4	7.3
MC statistics	1.0	1.0
Requirement on $N_{\rm BSC}$	5.0	5.0
Photon efficiency	4.0	4.0
4C fit for $\eta(\eta') \to \gamma\gamma$	1.0	5.2
Background shape for $\eta(\eta') \to \gamma\gamma$	2.0	1.0
Total	7.7	11.1

Source of uncertainties	Systematic error (% η	η'
Requirement on $N_{\rm shower}$	0.3	0.3
ϕ mass window	1.5	1.5
$J/\psi \to \gamma\eta_c$, $\eta_c \to K_L K^{\pm}\pi^{\mp}$ background	1.2	...
Background shape of $J/\psi \to \phi f_0(980)$	...	1.0
Background shape of $J/\psi \to \phi K_L K_L$	...	2.9
4C fit for $\eta(\eta') \to \gamma\gamma$	0.4	0.8
Photon detection	2.0	2.0
Signal shapes for $\eta(\eta') \to \gamma\gamma$	0.1	1.0
Background shape for $\eta(\eta') \to \gamma\gamma$	0.1	0.6
Total systematic errors	2.8	4.1
Statistical error of $N^{\eta}_{\gamma\gamma}(N^{\eta'}_{\gamma\gamma})$	1.0	6.0
Total errors	3.0	7.4

BESII 2006

BESIII 2013

Simulation/reconstruction and detector performance understanding is greatly improved

BESIII NP Group established in 2015

- Organized efforts with unified standards, shared tools, methods and studies. Open for all collaborators.
- ~20 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

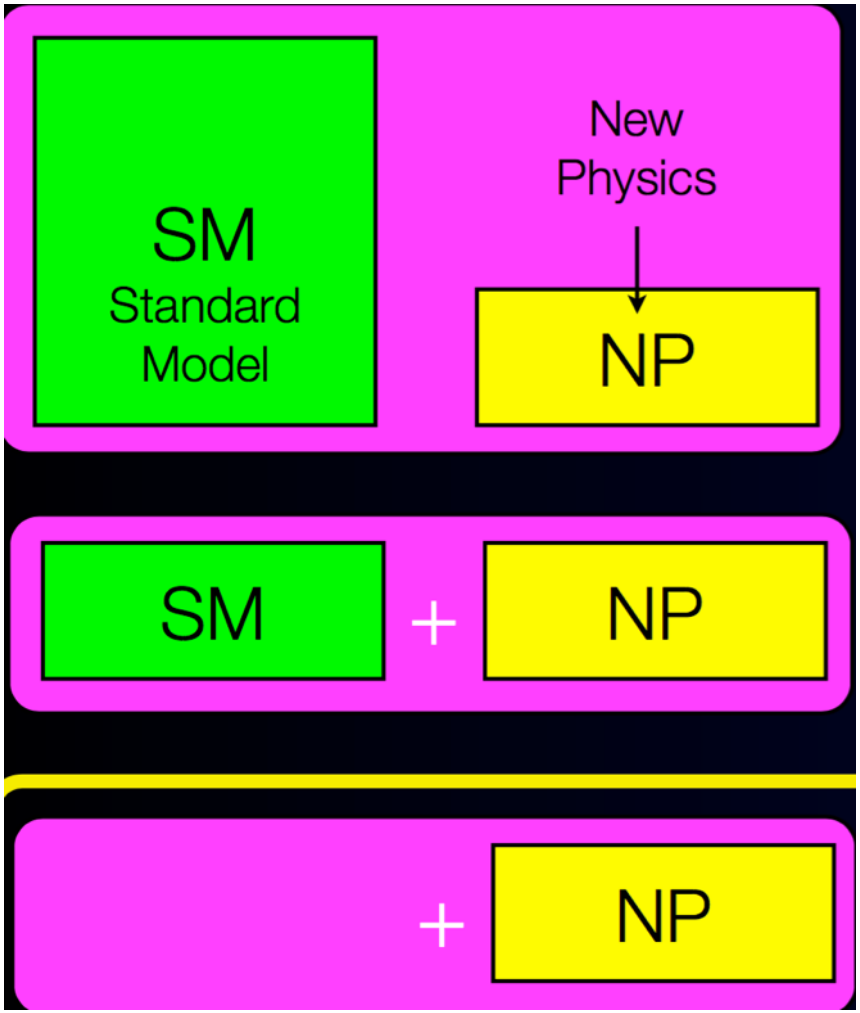
Stable team ~20 active members from all over: Chinese universities, IHEP and foreign institutes

PKU workshop, Dec. 2016

USC workshop, Oct. 2018

General strategy for NP searches

New physics effects may be very small.



SM contribution is dominant.

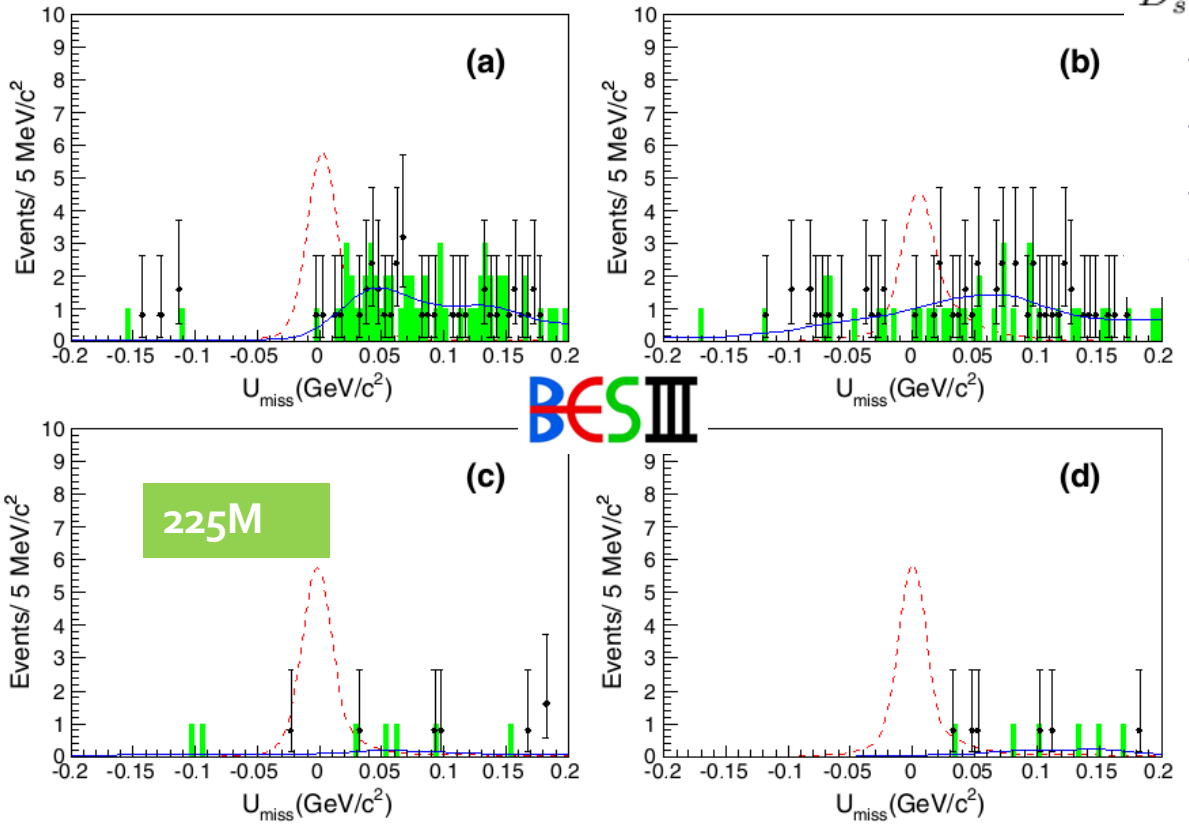
SM contribution is highly suppressed.

SM contribution is forbidden.

Probing NP: wide searches at BESIII

- C1:the processes that are allowed in the SM,but rare
  - Charmonia weak decays
  - Charm meson rare radiative and leptonic decays
  - Very rare processes beyond prediction
- C2:processes that are not allowed in the SM at tree level
  - FCNC processes
  - Violation of CP and other symmetries in hyperon decays and D-mixing
  - Charged lepton flavor violation(CLFV) processes
- C3:processes that are not allowed/existent in the SM
  - C-violation EM processes and C and CP violation decays
  - Lambda oscillations: from Jpsi->ΛΛbar, pKΛbar
  - LNV/BNV processes: indirect probe of exotic mediators
  - Exotic resonance search: light Higgs/Dark photon etc
  - Processes with Invisible signatures
  - Off-resonance searches

J/ψ weak decays: semileptonic



D_s^- mesons are reconstructed by:

- $D_s^- \to K^+K^-\pi^-$
- $D_s^- \to K^+K^-\pi^-\pi^0$ & $\pi^0 \to \gamma\gamma$
- $D_s^- \to K_s^0K^-$ & $K_s^0 \to \pi^+\pi^-$
- $D_s^- \to K_s^0K^-\pi^+\pi^-$ & $K_s^0 \to \pi^+\pi^-$

$$D_s^{*-} \to D_s^-\gamma.$$

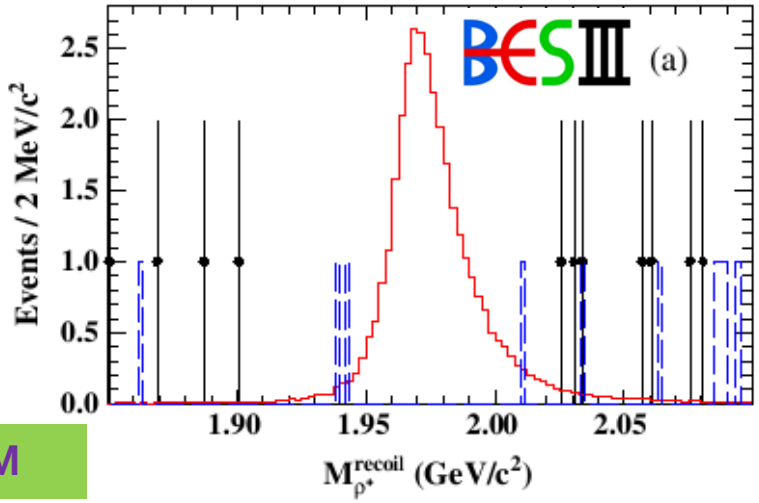
$$\mathcal{B}(J/\psi \to D_s^- e^+\nu_e + \text{c.c.}) < 1.3 \times 10^{-6}$$
$$\mathcal{B}(J/\psi \to D_s^{*-} e^+\nu_e + \text{c.c.}) < 1.8 \times 10^{-6}$$

PHYSICAL REVIEW D90,112014 (2014)

BESII: PLB 639,418 (2006)

J/ψ weak decays: hadronic

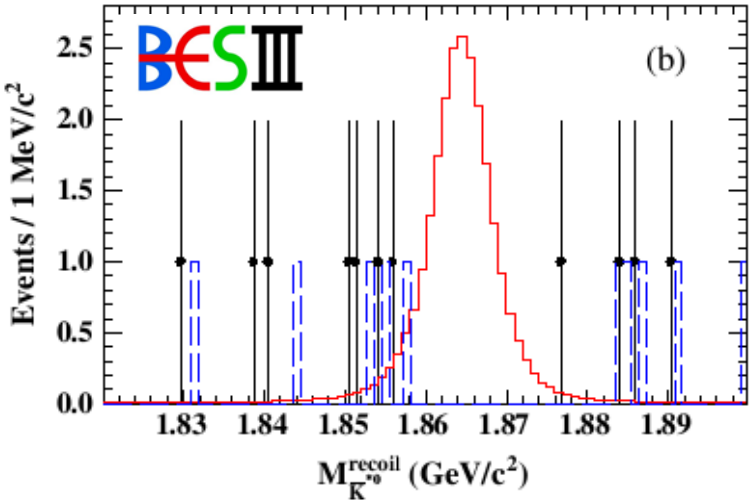
- $J/\psi \to D_s^- \rho^+$
- $\rho^- \to \pi^+ \pi^0$
- $D_s^+ \to \phi e^- \overline{\nu}_e$
- $\phi \to K^+ K^-$



225M

$\mathcal{B}(J/\psi \to D_s^- \rho^+) < 1.3 \times 10^{-5}$

- $J/\psi \to \overline{D}^0 \overline{K}^{*0}$
- $\overline{K}^{*0} \to K^- \pi^+$
- $\overline{D}^0 \to K^+ e^- \overline{\nu}_e$



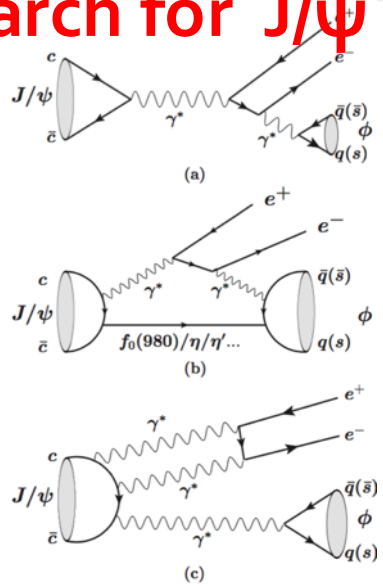
$\mathcal{B}(J/\psi \to \bar{D}^0 \bar{K}^{*0} + \text{c.c.}) < 2.5 \times 10^{-6}$

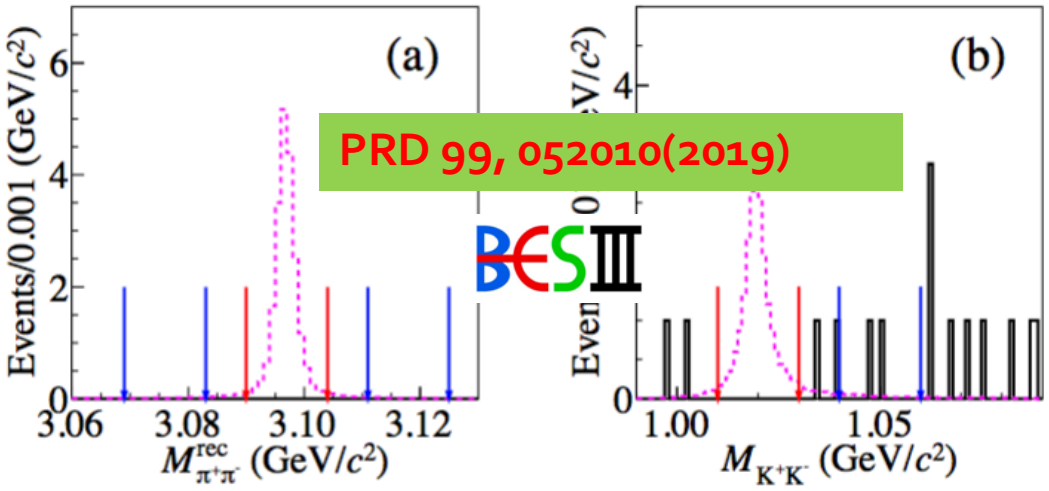
PHYSICAL REVIEW D89,071101(R) (2014)

BESII: PLB 663, 297(2008)

Search for rare J/ψ decays

- Search for $J/\psi \to \phi e^+e^-$

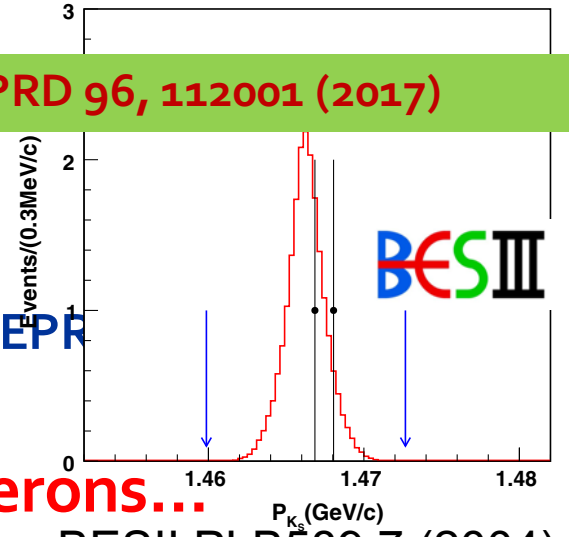




PRD 99, 052010(2019)

450M ψ(3686): $B(J/\psi \to \varphi e^+e^-) < 1.2 \times 10^{-7}$

- Search for $J/\psi \to K_S K_S$
  - CP and Bose-Einstein statistics violating process
  - EPR: ~ 10^{-8} level
  - K^0 oscillation model: 10^{-9}
  - the UL is improved by 10^2 and reaches the order of EPR expectation



PRD 96, 112001 (2017)

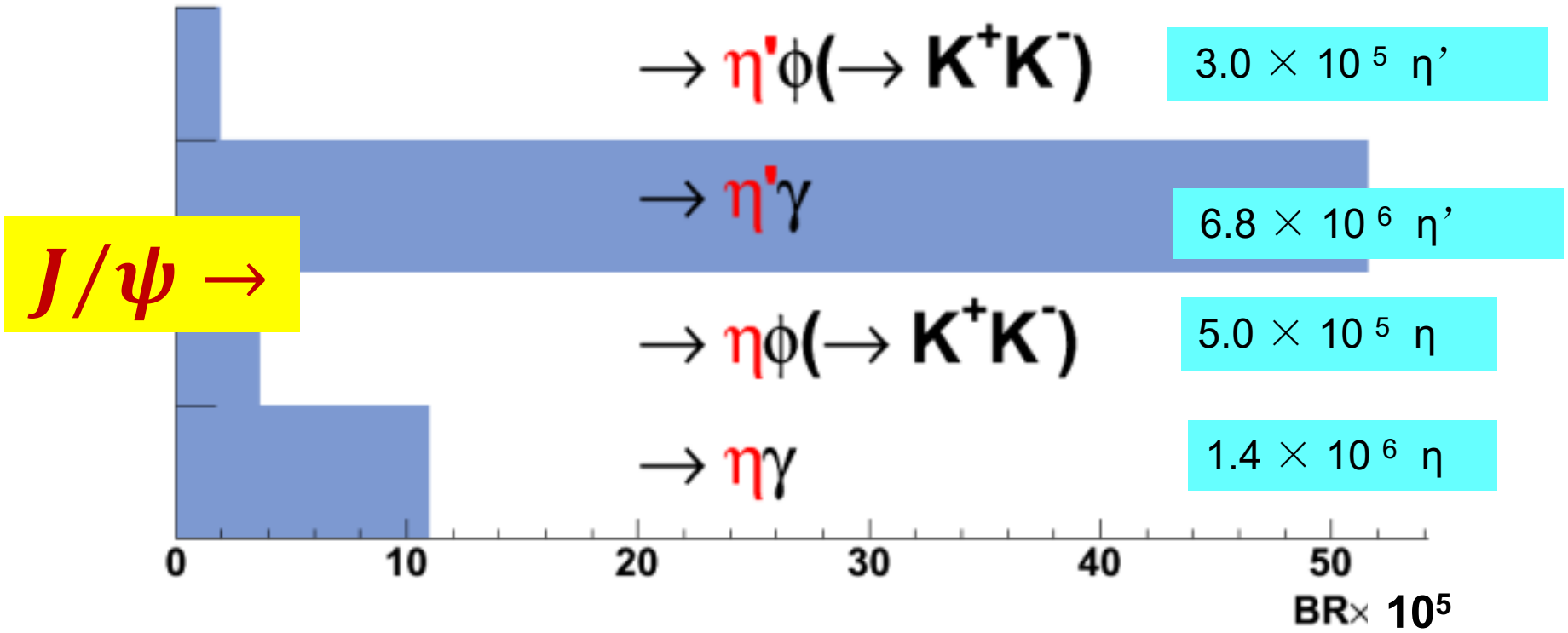
- Also rare decays from secondary η'/η/hyperons…

BESII:PLB589,7 (2004)

Rich samples of secondary particles η and η′

η and η′ yields with J/ψ data set

In 1.3B Jpsi(09+12)



3.0×10^5 η’

6.8×10^6 η’

5.0×10^5 η

1.4×10^6 η

Now we have 10B J/ψ on tape!

...Also hyperons

Hai-bo Li, *Front. Phys.* **12,** 121301 (2017).

current 10-6

projection 10^{-8}

Decay mode	$\mathcal{B}(\times 10^{-3})$	N_B $(\times 10^6)$
$J/\psi \to \Lambda\bar{\Lambda}$	1.61 ± 0.15	16.1 ± 1.5
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	1.29 ± 0.09	12.9 ± 0.9
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	1.50 ± 0.24	15.0 ± 2.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$ (or c.c.)	0.31 ± 0.05	3.1 ± 0.5
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$ (or c.c.)	1.10 ± 0.12	11.0 ± 1.2
$J/\psi \to \Xi^0\bar{\Xi}^0$	1.20 ± 0.24	12.0 ± 2.4
$J/\psi \to \Xi^-\bar{\Xi}^+$	0.86 ± 0.11	8.6 ± 1.0
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	0.32 ± 0.14	3.2 ± 1.4
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	0.59 ± 0.15	5.9 ± 1.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.05 ± 0.01	0.15 ± 0.03

Decay mode	$\mathcal{B}(\times 10^{-4})$	N_B $(\times 10^6)$
$J/\psi \to pK^-\bar{\Lambda}$	8.9 ± 1.6	8.9 ± 1.6
$J/\psi \to \Lambda\bar{\Lambda}\pi^+\pi^-$	43 ± 10	43 ± 10
$J/\psi \to pK^-\bar{\Sigma}^0$	2.9 ± 0.8	2.9 ± 0.8
$J/\psi \to \Lambda\bar{\Sigma}^-\pi^+$ (or c.c.)	8.3 ± 0.7	8.3 ± 0.7
$J/\psi \to \Lambda\bar{\Sigma}^+\pi^{-*}$ (or c.c.)	8.3 ± 0.7	8.3 ± 0.7
$J/\psi \to pK^-\bar{\Sigma}(1385)^0$	5.1 ± 3.2	5.1 ± 3.2

Decay mode	(90	
$\Lambda \to ne^+e^-$		
$\Sigma^+ \to pe^+e^-$	< 7	< 0.4
$\Xi^0 \to \Lambda e^+e^-$	7.6 ± 0.6	< 1.2
$\Xi^0 \to \Sigma^0 e^+e^-$	–	< 1.3
$\Xi^- \to \Sigma^- e^+e^-$	–	< 1.0
$\Omega^- \to \Xi^- e^+e^-$	–	< 26.0
$\Sigma^+ \to p\mu^+\mu^-$	$(0.09^{+0.09}_{-0.08})$	< 0.4
$\Omega^- \to \Xi^-\mu^+\mu^-$	–	< 30.0
$\Lambda \to n\nu\bar{\nu}$	–	< 0.3
$\Sigma^+ \to p\nu\bar{\nu}$	–	< 0.4
$\Xi^0 \to \Lambda\nu\bar{\nu}$	–	< 0.8
$\Xi^0 \to \Sigma^0\nu\bar{\nu}$	–	< 0.9
$\Xi^- \to \Sigma^-\nu\bar{\nu}$	–	$-^*$
$\Omega^- \to \Xi^-\nu\bar{\nu}$	–	< 26.0
$\Sigma^- \to \Sigma^+e^-e^-$	–	< 1.0
$\Sigma^- \to pe^-e^-$	–	< 0.6
$\Xi^- \to pe^-e^-$	–	< 0.4
$\Xi^- \to \Sigma^+e^-e^-$	–	< 0.7
$\Omega^- \to \Sigma^+e^-e^-$	–	< 15.0
$\Sigma^- \to p\mu^-\mu^-$	–	< 1.1
$\Xi^- \to p\mu^-\mu^-$	< 0.04	< 0.5
$\Omega^- \to \Sigma^+\mu^-\mu^-$	–	< 17.0
$\Sigma^- \to pe^-\mu^-$	–	< 0.8
$\Xi^- \to pe^-\mu^-$	–	< 0.5
$\Xi^- \to \Sigma^+e^-\mu^-$	–	< 0.8
$\Omega^- \to \Sigma^+e^-\mu^-$	–	< 17.0

FCNC virtual-γ penguin

FCNC virtual-Z penguin

ΔL=2 process

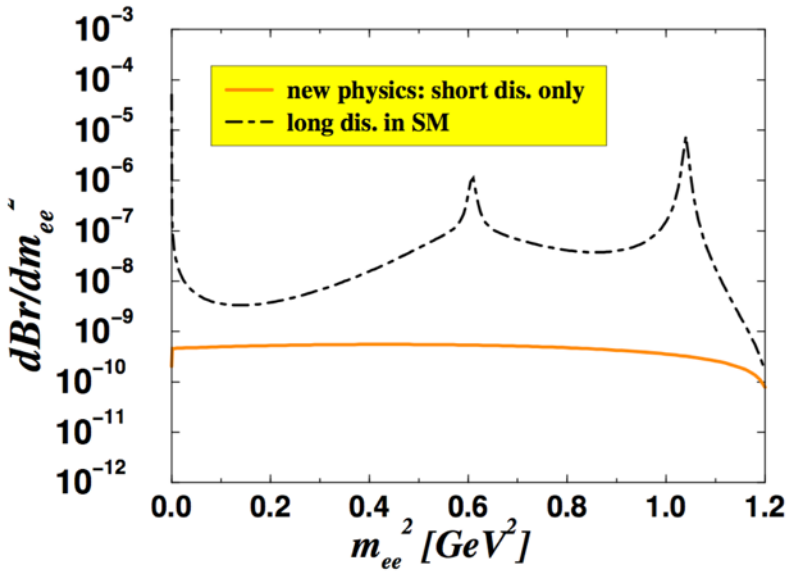
FCNC is suppressed in SM

PHYSICAL REVIEW D VOLUME 2, NUMBER 7 1 OCTOBER 1970

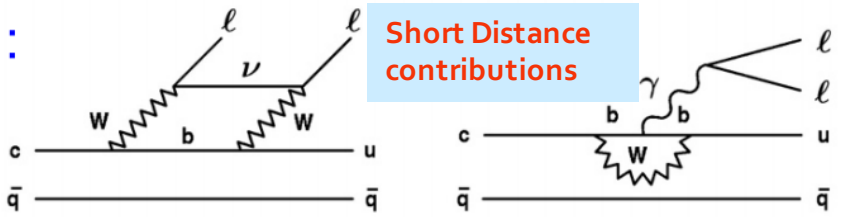
Weak Interactions with Lepton-Hadron Symmetry*

S. L. GLASHOW, J. ILIOPOULOS, AND L. MAIANI†
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02139

(Received 5 March 1970)

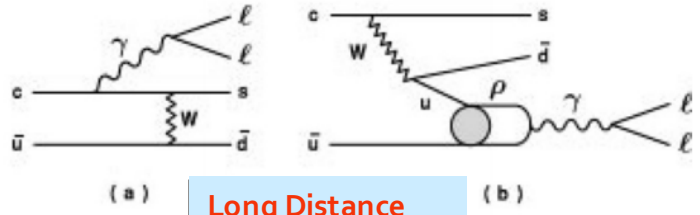


BESIII can probe c→ ull, esp c→ uee
Stronger diagram cancellation than down-types



$$\mathcal{L}_{eff}^{SD} = \frac{G_F}{\sqrt{2}} V_{cb}^* V_{ub} \sum_{i=7,9,10} C_i Q_i,$$

Sensitive to new physics



J/ψ[ψ(3686)] → $D^0 e^+ e^-$ search **PRD96,111101(2017) (RC):** 2 orders improvement
$\psi(3686) \to \Lambda_c^+ \bar{p}\, e^+ e^-$ search **PRD 97, 091102(2018) (RC): first search**
D→h(h′)ee search **PRD 97, 072015 (2018):** 2 orders improvement

Rare charm decays

PRD91, 112015 (2015): $D^0 \to \gamma\gamma$
PRD 95, 071102(R) (2017): $D^+ \to \gamma e^+ \nu_e$
PRD 99, 072002 (2019): $D_s^+ \to \gamma e^+ \nu_e$

SM predictions

10^{-1}
10^{-2} Cabibbo favored
10^{-3} Singly Cabibbo suppressed
10^{-4} Doubly Cabibbo suppressed
10^{-5}
10^{-6} Radiative decays $D^0 \to \overline{K}^{*0}\gamma / \phi\gamma / \rho\gamma / \omega\gamma$
$D^+ \to K^{*+}\gamma / \rho^+\gamma \quad D_S^+ \to K^{*+}\gamma / \rho^+\gamma$
10^{-7} Long distance:
10^{-8} Vector meson Dominance $D^0 \to \gamma\gamma / VV'(\to ll) / hV(\to ll) / hh'V(\to ll)$
10^{-9}
10^{-10}
10^{-11} Short distance FCNC $D^0 / D^+ \to \gamma\gamma / Vl^+l^- / hl^+l^- / hh'l^+l^-$
10^{-12} $D^0 \to \mu^+\mu^-$
10^{-13} $D^0 \to e^+e^-$
10^{-14}
10^{-15} Forbidden decays: LNV, LFV, BNV $D \to (h)\mu^+e^-$
$D \to (hh)e^+e^+ / (hh)\mu^+\mu^+$

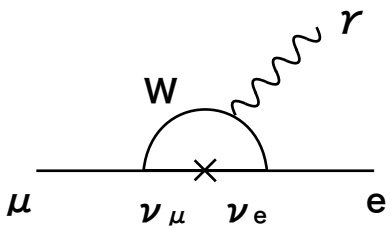
Experimental reaches

- CLEO-c
- BESIII
- BESIII final/B factory
- LHCb
- Super-B
- Super-τ-charm

BESIII is more competitive in channels with low energy electron/photons, neutrons, π^0's

Search for Charge flavor lepton violation(cFLV) process

Considering neutrino mixing, extended vSM

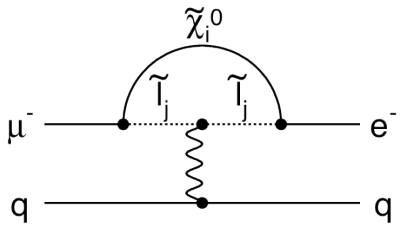


$$\mathcal{M} \propto \sum_j U_{ej} U^*_{\mu j} \frac{m_j^2}{M_W^2}$$

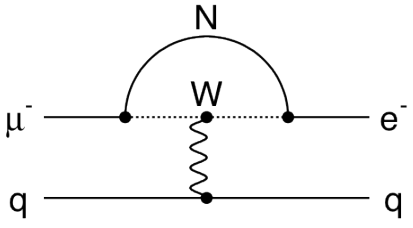
$$\sim \mathcal{O}(10^{-54})$$

Possible CLFV from NP models

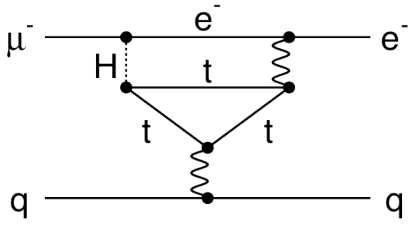
Loops



Supersymmetry

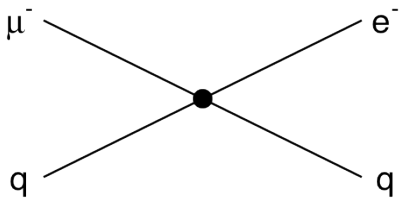


Heavy Neutrinos

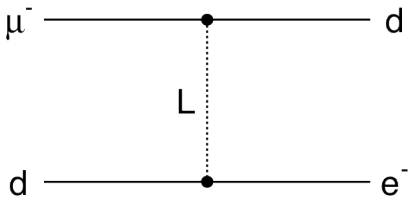


Extended higgs models

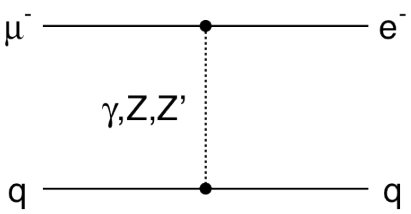
Contact Terms



Compositeness

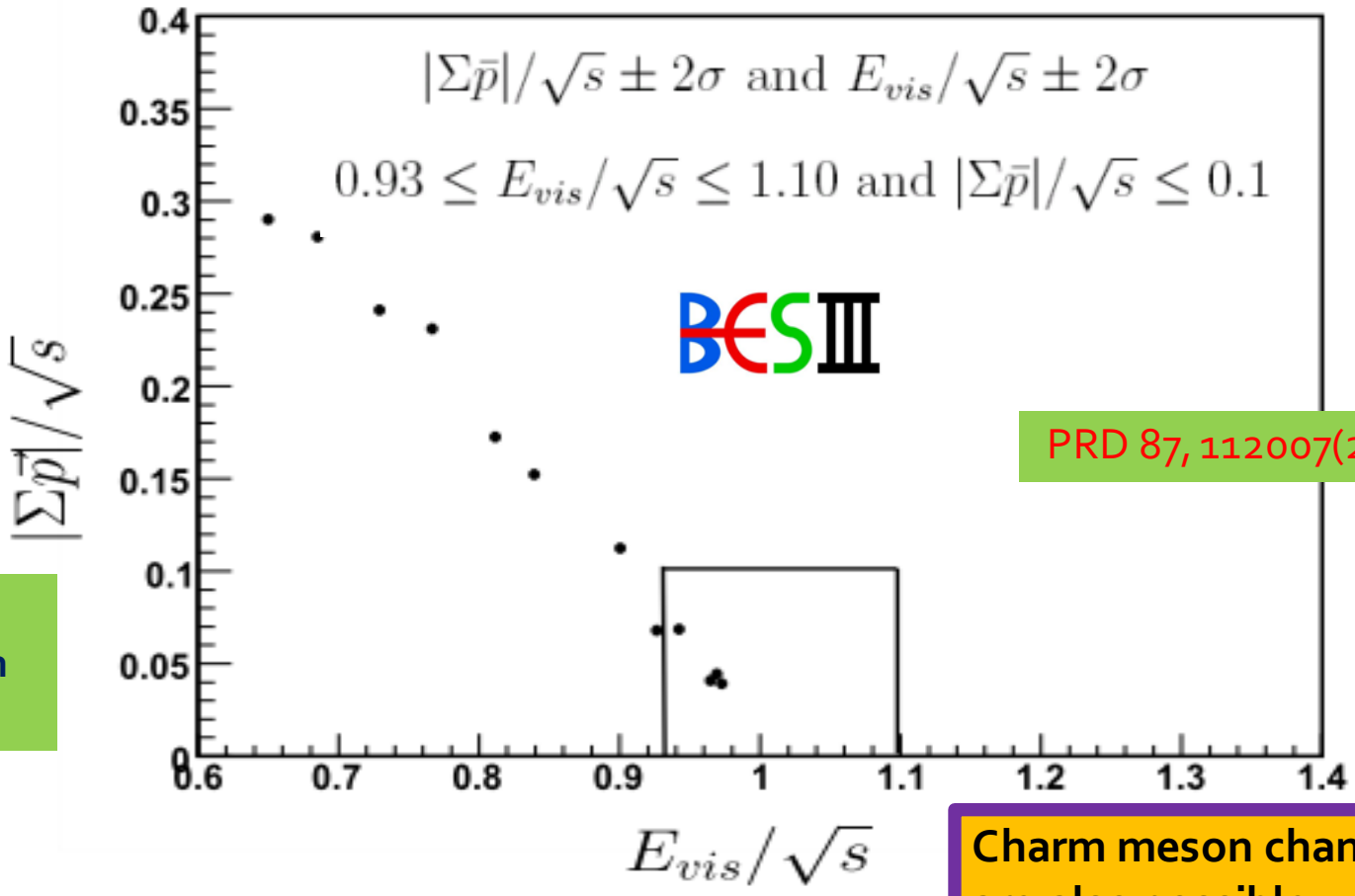


Leptoquarks



New Heavy Bosons / Anomalous Couplings

J/ψ → eμ: Unblinded Data and Results



PRD 87, 112007(2013)

Among 225M J/ψ, 4 events in the signal box

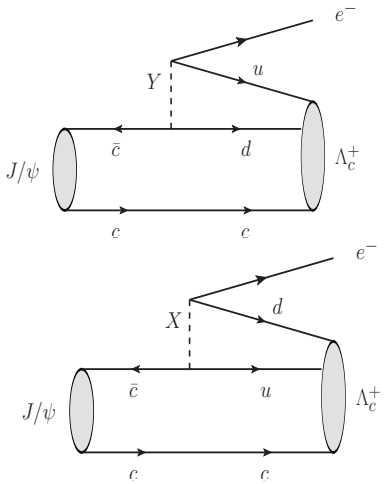
Charm meson channels are also possible

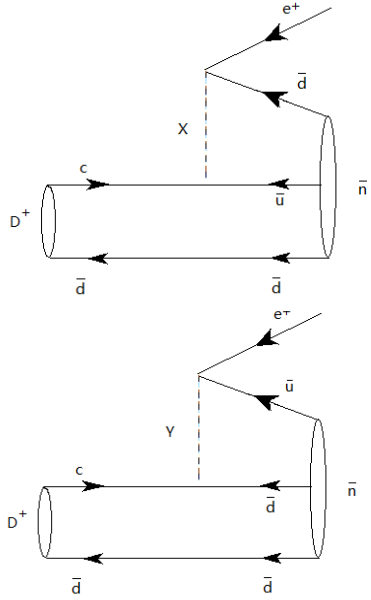
$$\mathcal{B}(J/\psi \to e\mu) < 1.6 \times 10^{-7} \text{ (90\% C.L.)}$$

Search for BNV process

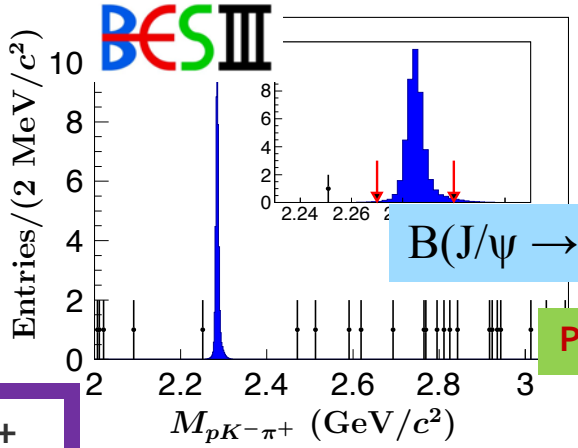
$\Delta B=1, \Delta(B-L)=0$

- The first of "Sakharov conditions": "there must be BNV process"
- Many theory could have BNV, such as Georgi–Glashow GUT model, there are X and Y bosons with charges 4/3 and 1/3, which couples quarks and leptons and thus BNV and LNV





Phys.Rev.Lett. 32 (1974) 438-441



$B(J/\psi \rightarrow \Lambda_c^+ e^-) < 6.9 \times 10^{-8}$

PRD 99, 072006(2019)

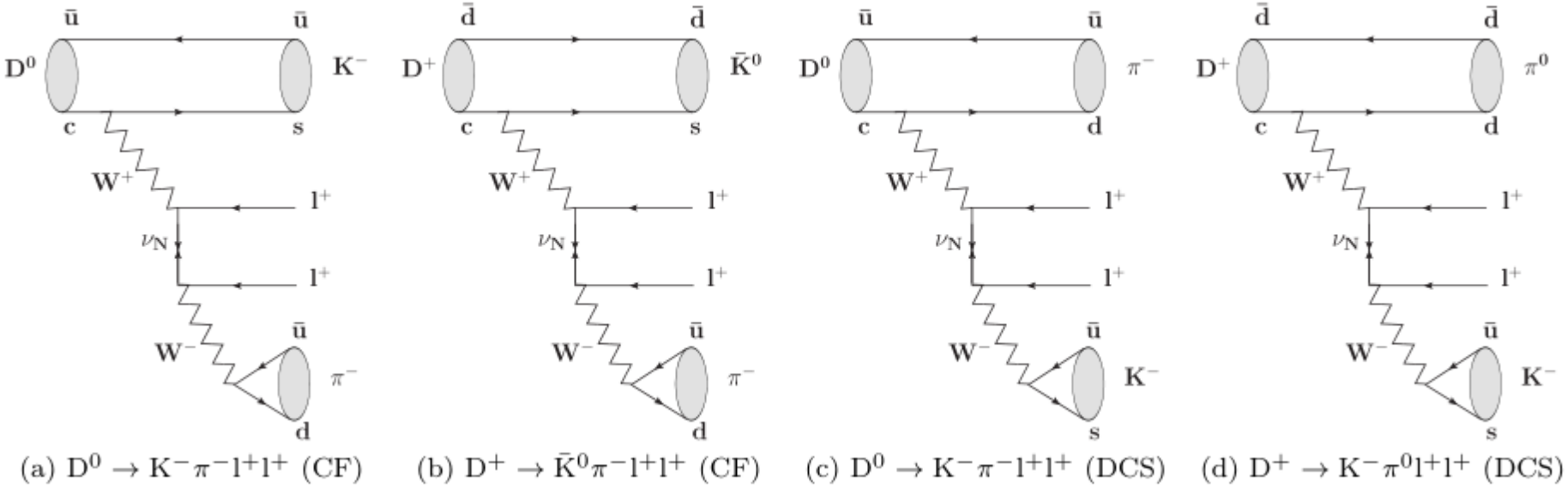
$D^+ \rightarrow \Lambda$-bar(Σ-bar)e^+
$D_s \rightarrow \Lambda$ e
$D^+ \rightarrow$ nbar e^+
$D^0 \rightarrow$ pbar e^+
will benefit from the final charm dataset

expected UL with $10^{10} J/\psi$: 10^{-9}

$\Delta B=2$ **process:** $\Lambda - \bar{\Lambda}$ oscillation

Search for LNV: $D \to K\pi e^+e^+$

H.R. Dong et al Chin, Phys. C 39 013101 (2015).

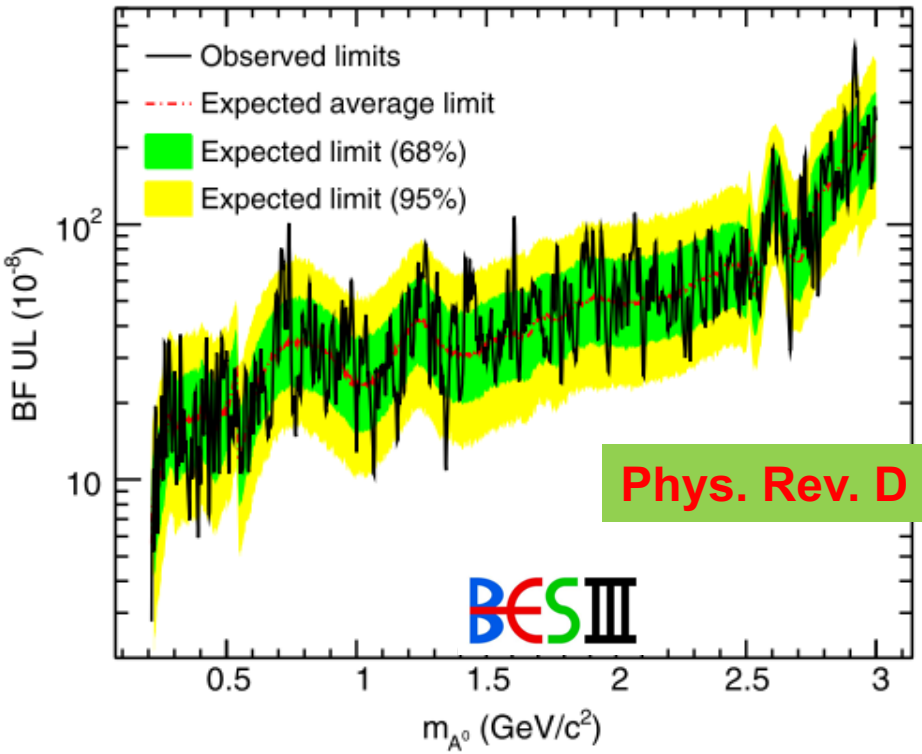


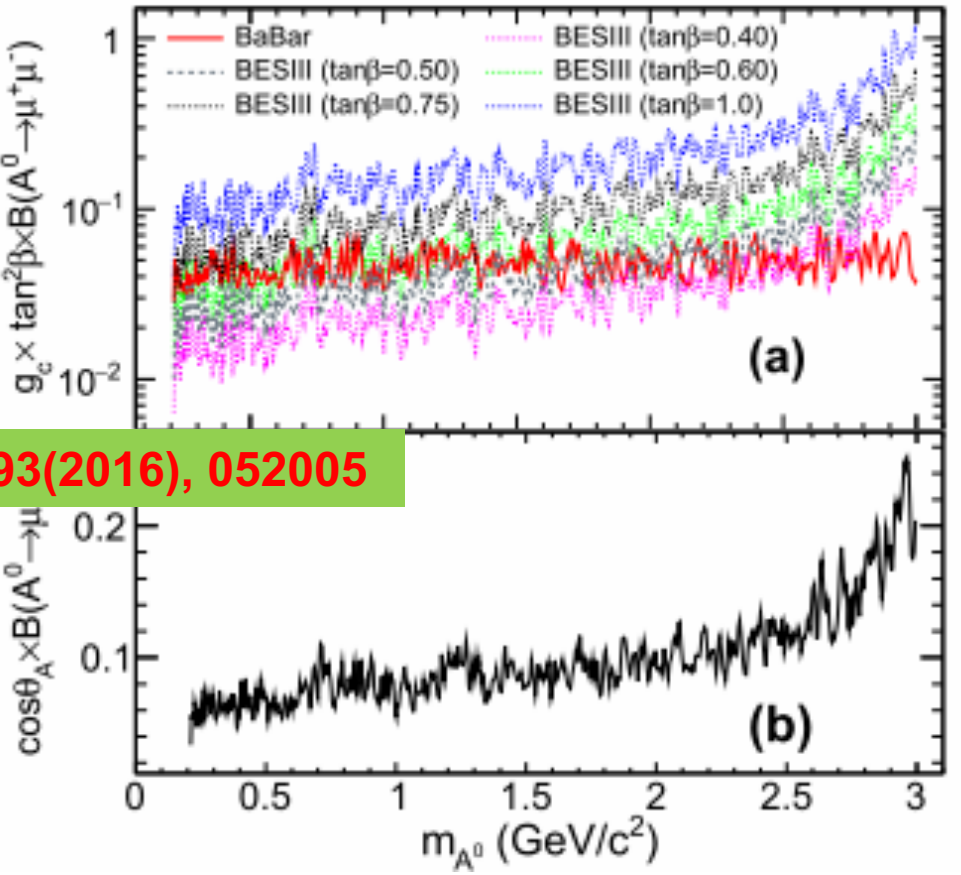
- Lepton number violating(LNV) process ($\Delta L = 2$)
  - possibly due to a single Majorana neutrino exchange

PRD 99, 112002(2019)

- The best BR limit around 10^{-4} ~10^{-5} level by E791[PRL 86, 3969(2001)].
- BESIII has improved them to ~10^{-6}
- Further constrain mass-dependent $D \to Ke^+\nu_N(\pi e^+)$ decay
  - constrain mixing matrix element $|V_{eN}|^2$
- More channels could be probed with future charm dataset

Light Higgs search with 225M J/ψ)





Phys. Rev. D 93(2016), 052005

The new limits are five times below previous results with 106M Psi'

BESIII [PRD 85, 092012 (2012)]

PRD 87, 031102 (R) (2013) (BaBar experiment)

BESIII vs. BaBar measurements comparison and combination,A0 is mostly singlet

Dark sector and portal

Energy
Intensity
Cosmic

BSM (heavy)

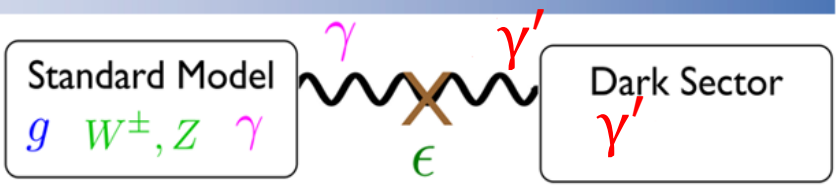
SUSY, extra dim…?
Unification?

Standard model

portal

dark sector (light)

New bosons?
Light dark matter ?



ordinary photon & γ' can mix

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

Portal	Particles	Operator(s)
"Vector"	Dark photons	$-\frac{\epsilon}{2\cos\theta_W} B_{\mu\nu} F'^{\mu\nu}$
"Axion"	Pseudoscalars	$\frac{a}{f_a} F_{\mu\nu}\widetilde{F}^{\mu\nu}$, $\frac{a}{f_a} G_{i\mu\nu}\widetilde{G}_i^{\mu\nu}$, $\frac{\partial_\mu a}{f_a}\overline{\psi}\gamma^\mu\gamma^5\psi$
"Higgs"	Dark scalars	$(\mu S + \lambda S^2) H^\dagger H$
"Neutrino"	Sterile neutrinos	$y_N L H N$

NATURE news

The Jefferson Lab's Free-Electron Laser is a low-cost option in the bid to discover dark-sector forces.

PARTICLE PHYSICS

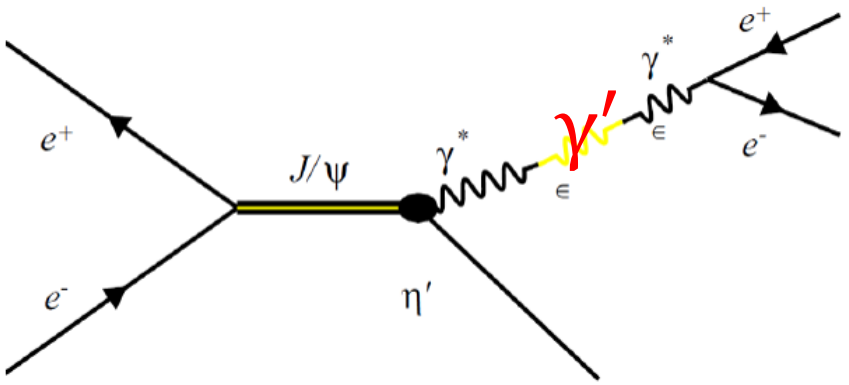
Physicists hunt for dark forces

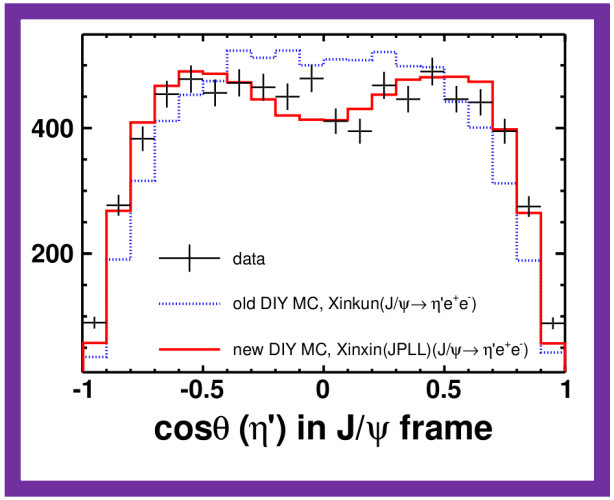
Dark Sectors 2016 Workshop: Community Report

Jim Alexander (VDP Convener),[1] Marco Battaglieri (DMA Convener),[2] Bertrand Echenard (RDS Convener),[3] Rouven Essig (Organizer),[4,*] Matthew Graham (Organizer),[5,†] …lan Krnjaic (DMA… …DS Convener),[9] Tim… …Pyle (DD Convener),[10] Adam Ritz (DMA Convener),[11] Philip Schuster (Organizer),[5,6,¶] Brian Shuve (RDS Convener),[5] Natalia Toro (Organizer),[5,6,**] Richard G Van De Water (DMA Convener),[12] Daniel Akerib,[5,13] Haipeng An,[3] Konrad Aniol,[14] Isaac J. Arnquist,[15] David …

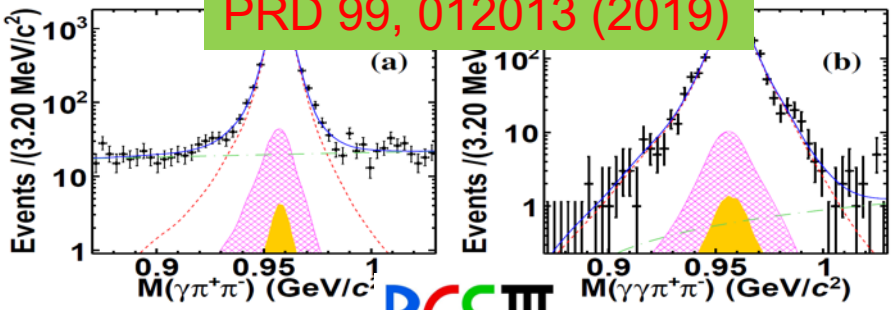
arxiv: 1608.08632

DP (γ') search in $J/\psi \to \eta^{(\prime)} e^+ e^-$



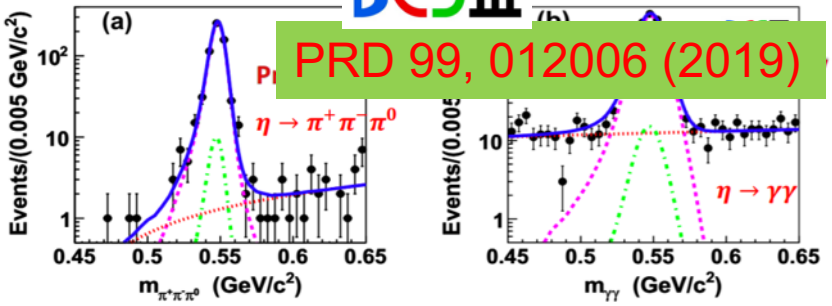


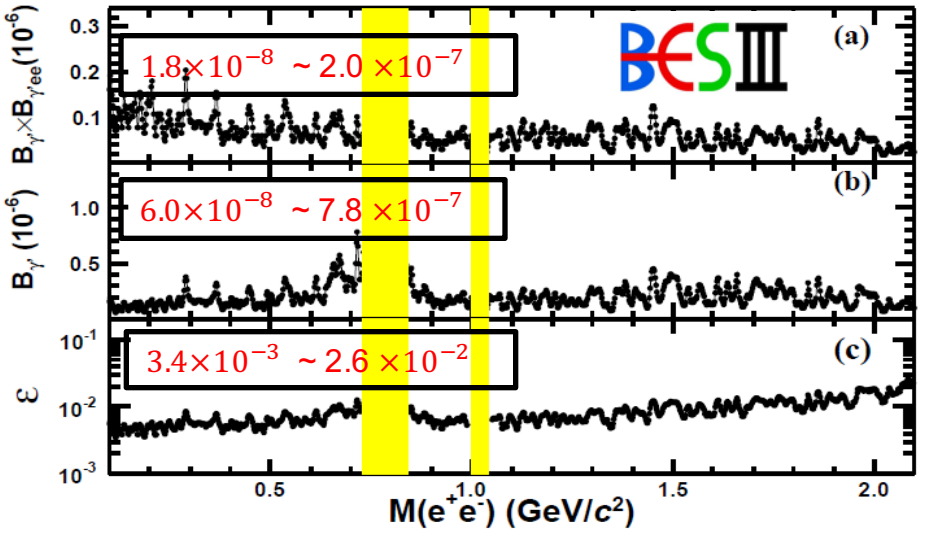
PRD 99, 012013 (2019)



BESIII

PRD 99, 012006 (2019)

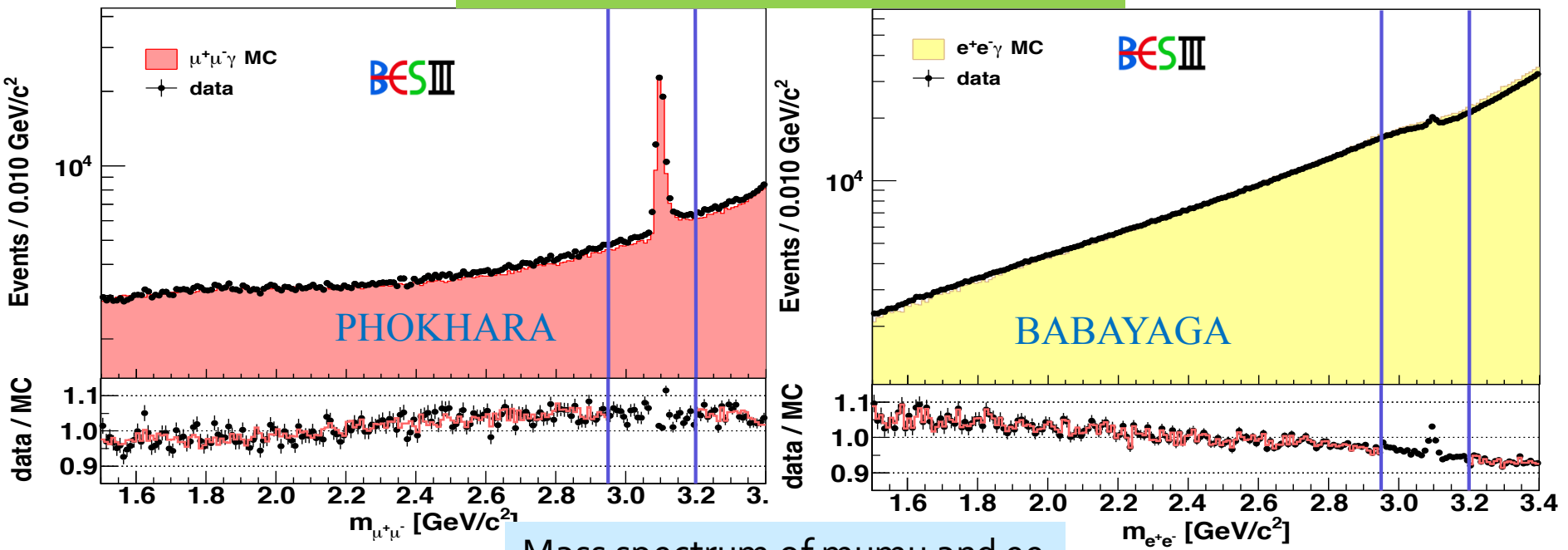




Dark photon search with ISR

Search for narrow structure on top of the continuum QED background

2.9fb^{-1} psi(3773) dataset(2010+2011)



Mass spectrum of mumu and ee

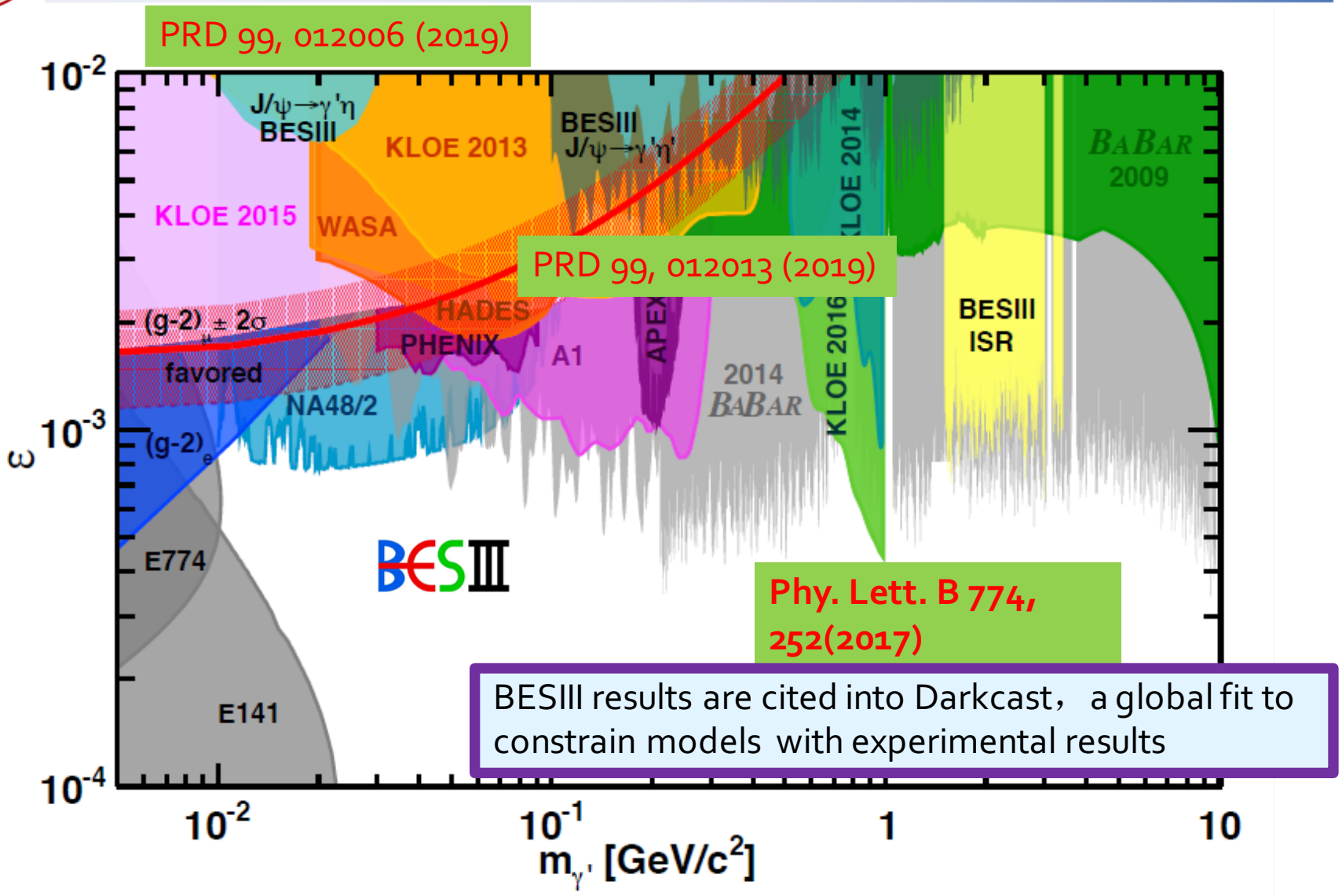
Cover mass region: 1.5 GeV/c 2 ~ 3.4 GeV/c

- <1.5 GeV/c 2 : $\pi^+\pi^-$ background dominates
- >3.4 GeV/c 2 : hadronic qq-bar process

Phy. Lett. B 774, 252(2017)

$$\frac{\sigma_i(e^+e^- \to \gamma' \gamma_{\rm ISR} \to l^+l^- \gamma_{\rm ISR})}{\sigma_i(e^+e^- \to \gamma^* \gamma_{\rm ISR} \to l^+l^- \gamma_{\rm ISR})} = \frac{N_i^{\rm up}(e^+e^- \to \gamma' \gamma_{\rm ISR} \to l^+l^- \gamma_{\rm ISR})}{N_i^{\rm B}(e^+e^- \to \gamma^* \gamma_{\rm ISR} \to l^+l^- \gamma_{\rm ISR})} \cdot \frac{1}{\epsilon} = \frac{3\pi \cdot \varepsilon^2 \cdot m_{\gamma'}}{2N_f^{l^+l^-} \alpha \cdot \delta_m^{l^+l^-}}$$

Dark photon search results from BESIII



Omega and phi invisible decay

The first search of invisible decays of light vector mesons

PRD 98, 032001(2018)

PHYSICAL REVIEW D **98,** 113006 (2018)

Note on invisible decays of light mesons

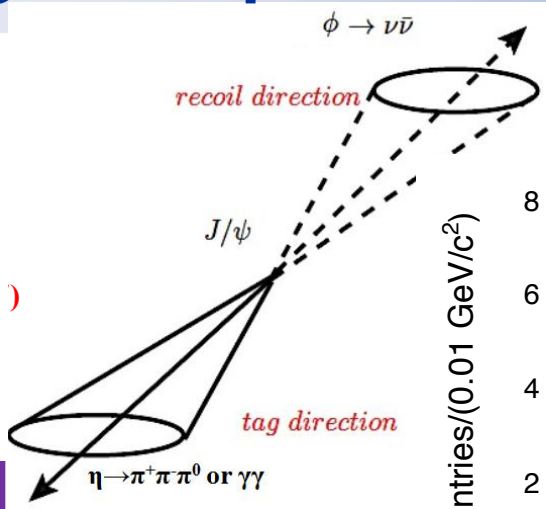
Dao-Neng Gao*

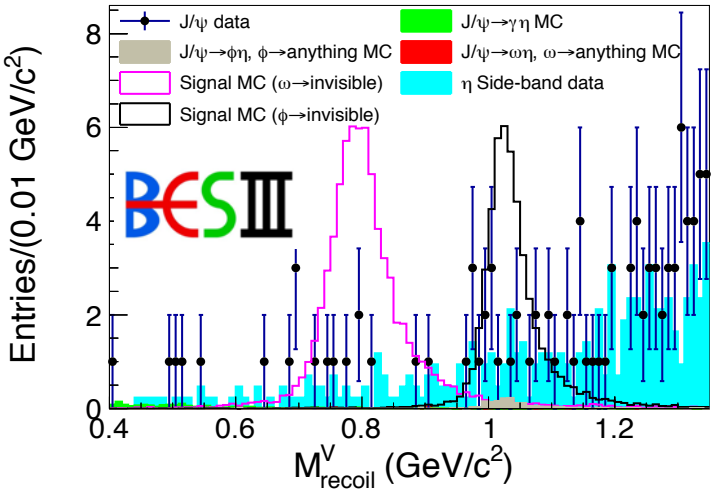
PHYSICAL REVIEW D **90,** 077501 (2014)

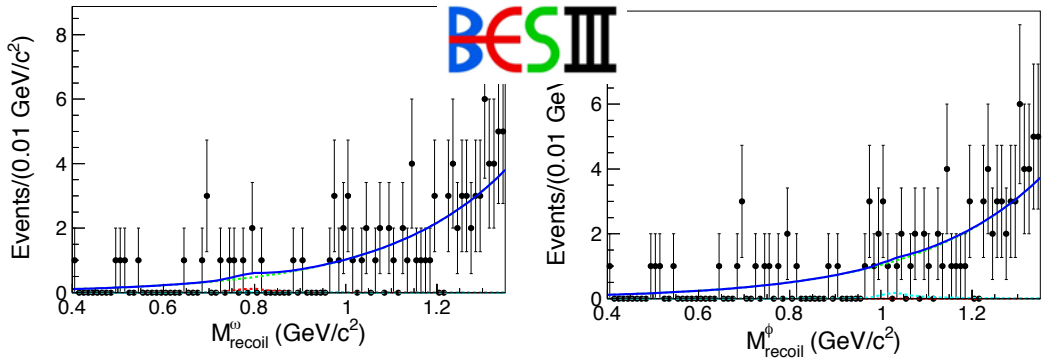
Analysis of $J/\psi(\eta_c) \to \gamma +$ invisible decays in the standard model

Dao-Neng Gao*

Also presented in NPWS2016
Data analysis ongoing







Upper limits set at 90% C.L.

$$\frac{\mathcal{B}(\omega\to\text{invisible})}{\mathcal{B}(\omega\to\pi^+\pi^-\pi^0)} < 8.1\times10^{-5} \qquad \frac{\mathcal{B}(\phi\to\text{invisible})}{\mathcal{B}(\phi\to K^+K^-)} < 3.4\times10^{-4}$$

$$\mathcal{B}(\omega \to \text{invisible}) < 7.3\times10^{-5} \qquad \mathcal{B}(\phi\to\text{invisible}) < 1.7\times10^{-4},$$

Future of BESIII new physics: Whitepaper

Exotic Decays and New Physics

- ✓ Demonstrators, not final nor exclusive, but open
- ✓ Further explore BESIII NP potential
  - ✓ Near-threshold production
  - ✓ High lumi
  - ✓ Clean signals
- ✓ There may appear new ideas and surprises

Summary

- There were already great NP search efforts with BESII
- BESIII continue to perform wide range study of exotic decays and new physics. ~20 publications, with many first search or best constraint
- BESIII has great potential with unique datasets and analysis techniques …More to come!
- Open for new ideas and surprises!

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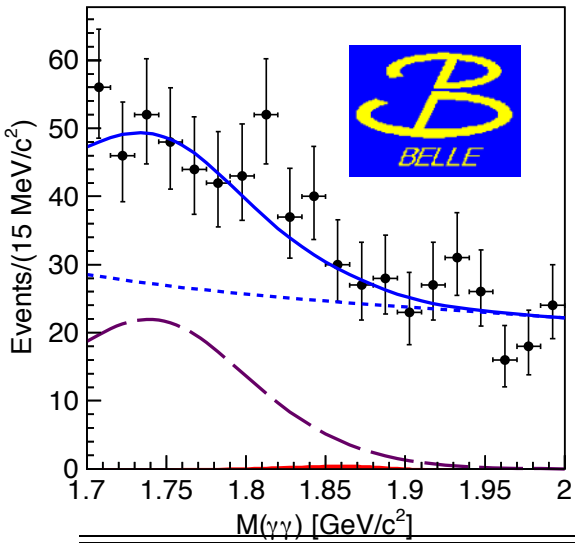
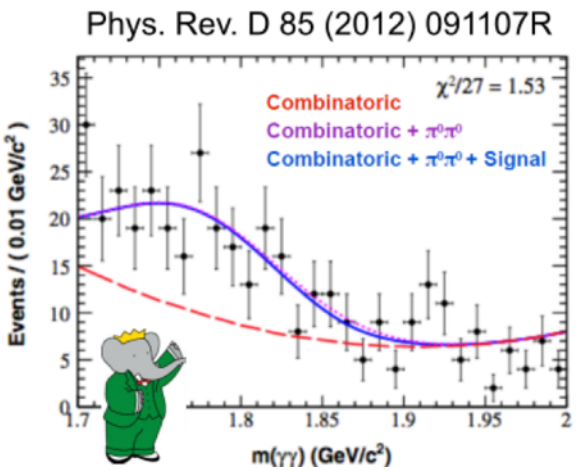
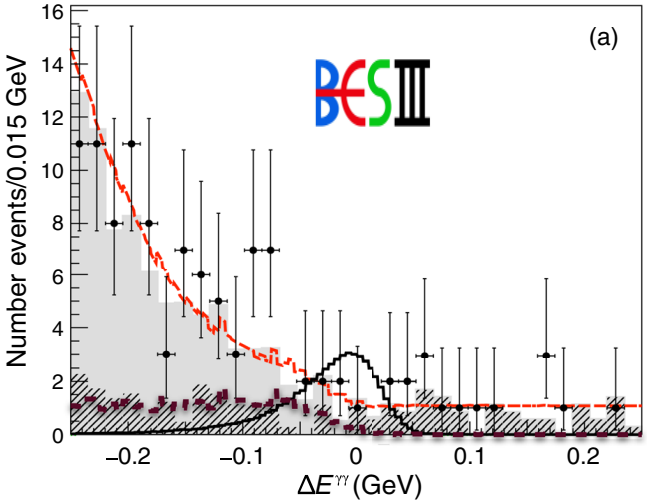
Happy 30-year anniversary
Thank all make it possible &
March for the bright future

Comparison and prospects

PhysRevD(2016).93.051102







Source	Contribution
Cut variation	±6.8%
PDF shape	$^{+4.0}_{-2.4}$ events
Photon detection	±4.4%
K^0_S reconstruction	±0.7%
π^0 identification	±4.0%
$\mathcal{B}(D^0 \to K^0_S\pi^0)$	±3.3%

Uncertainties independent of fitting procedure

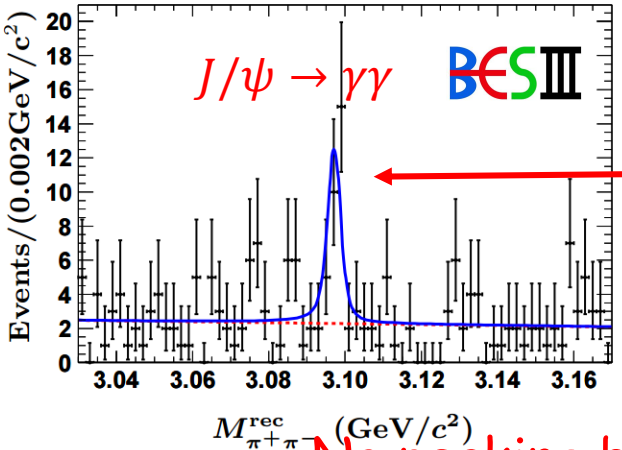
Source	Relative uncertainty (%)
Photon reconstruction	2.0
$M^{\gamma\gamma}_{\rm BC}$ requirement	3.1
ST D^0 yields	1.0
Total	3.8

- BESIII has the least background contamination
- and very good control of systematics
- Could still be competitive with the final DDbar sample

Detailed projection study is needed to check what is the critical points for DDbar sample size

Search for C-violation EM processes

PRD **90**,092002(2014)

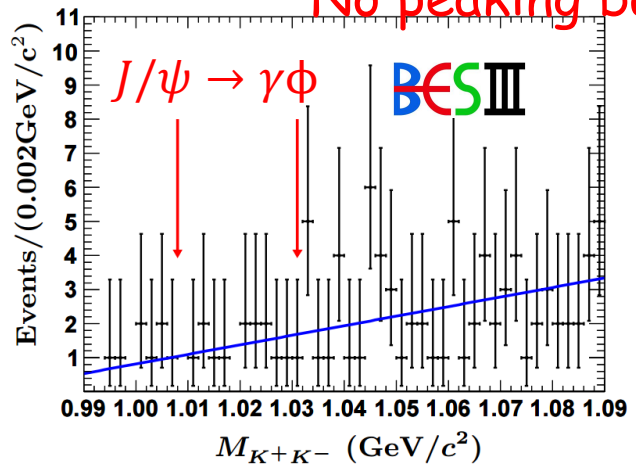


Peaking background

Background channel	Expected counts (N^{bkg})
$J/\psi \to \gamma\pi^0, \pi^0 \to 2\gamma$	18.5 ± 1.9
$J/\psi \to \gamma\eta, \eta \to 2\gamma$	24.6 ± 1.6
$J/\psi \to \gamma\eta_c, \eta_c \to 2\gamma$	1.3 ± 0.3
$J/\psi \to 3\gamma$	0.9 ± 0.3
Total	45.3 ± 2.5

$$\mathcal{B}(J/\psi \to f) < \frac{N^{up}_{sig}}{N^{tot}_{\psi(3686)} \times \epsilon \times \mathcal{B}_i \times (1-\Delta_{sys})}$$

No peaking background



B($J/\psi \to \gamma\gamma$) < 5×10^{-6} CLEO: PRL 101, 101801 (2008)

B($J/\psi \to \gamma\gamma$) < 2.7×10^{-7}

- Improve a magnitude for $J/\psi \to \gamma\gamma$

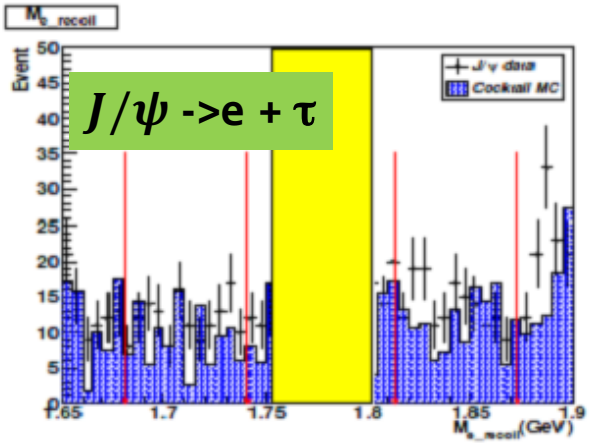
B($J/\psi \to \gamma\phi$) < 1.4×10^{-6}

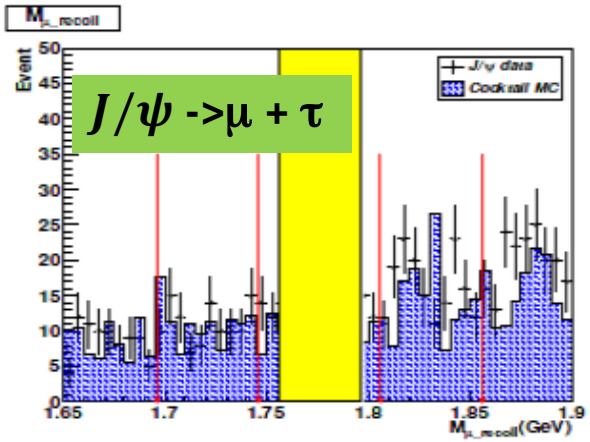
- Unique report for $J/\psi \to \gamma\phi$

BESII: PRD76，117101（2007）

cFLV searches in J/ψ: Prospects

$$\mathcal{A}(V \to \ell_1\bar{\ell}_2) = \overline{u}(p_1, s_1)\left[A_V^{\ell_1\ell_2}\gamma_\mu + B_V^{\ell_1\ell_2}\gamma_\mu\gamma_5 + \frac{C_V^{\ell_1\ell_2}}{m_V}(p_2 - p_1)_\mu + \frac{iD_V^{\ell_1\ell_2}}{m_V}(p_2 - p_1)_\mu\gamma_5\right] v(p_2, s_2)\ \epsilon^\mu(p)$$





$J/\psi \to e(\mu)\,\tau$
$J/\psi \to e\,\mu$
$J/\psi \to \gamma\, e(\mu)\,\tau$
$\psi(2s) \to \gamma\, e(\mu)\,\tau$

PRD 87, 112007(2013)

$\ell_1\ell_2$	$\mu\tau$	$e\tau$	$e\mu$
Current UL	2.0×10^{-6}	8.3×10^{-6}	1.6×10^{-7}
BESIII projected(CC)	3.0×10^{-8}	4.5×10^{-8}	1.0×10^{-8}
BESIII projected(MVA/ML)	1.5×10^{-8}	2.5×10^{-8}	6.0×10^{-9}

Expected to *improve the UL by ~10^2*

Wilson coeff (GeV^{-2})	Leptons $\ell_1\ell_2$	Constraints Current	Projected
$\left\|C_{VL}^{cc\ell_1\ell_2}/\Lambda^2\right\|$	$\mu\tau$	5.5×10^{-5}	$[5.0, 7.1] \times 10^{-6}$
	$e\tau$	1.1×10^{-4}	$[6.5, 8.7] \times 10^{-6}$
	$e\mu$	1.0×10^{-5}	$[2.8, 3.7] \times 10^{-6}$

efficiencies ~30-35%

Sensitivty projections