The cLFV searches at BESIII

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International Workshop on Neutrinos from Accelerators
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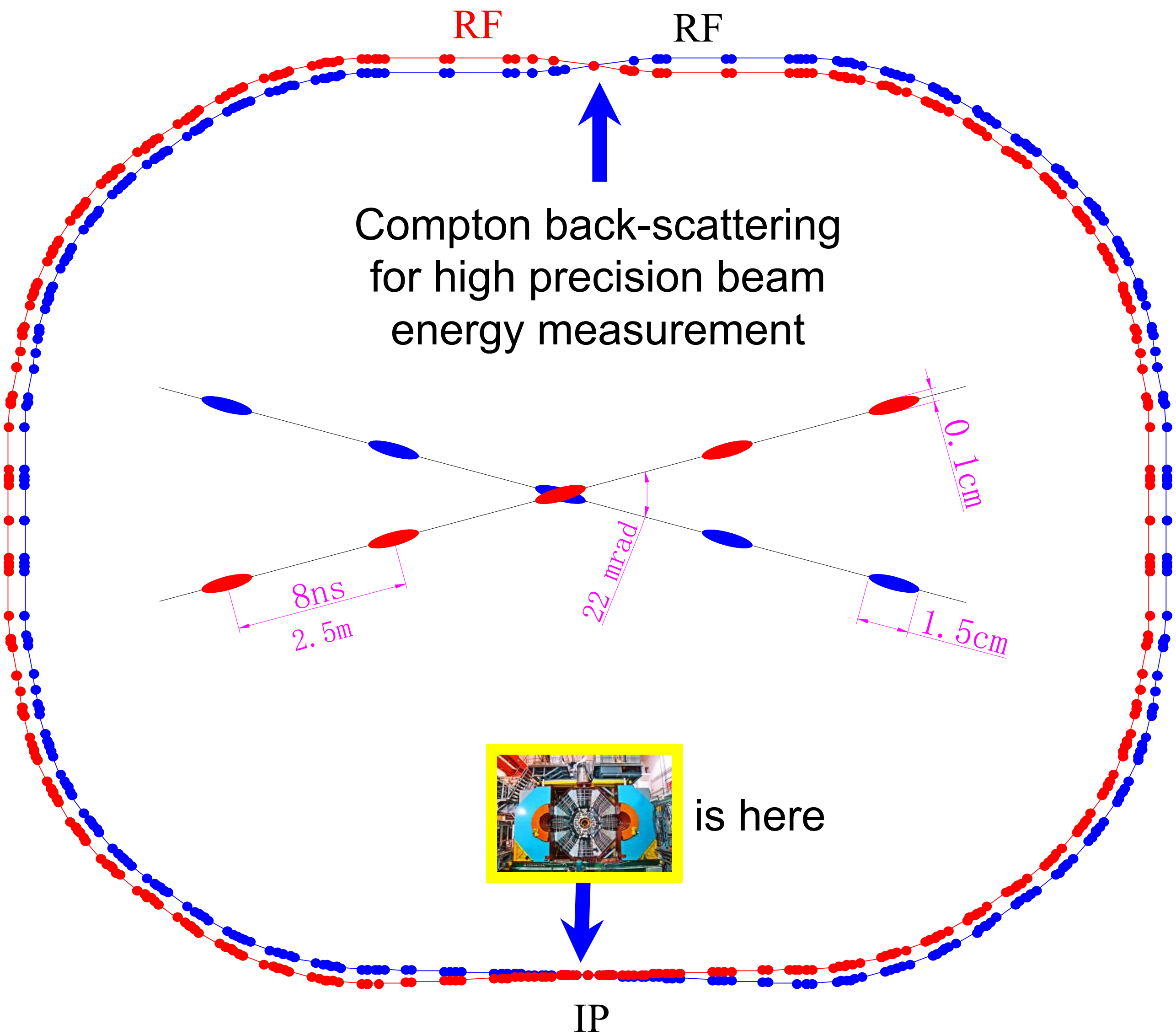
Beijing Electron Positron Collider II (BEPCII)

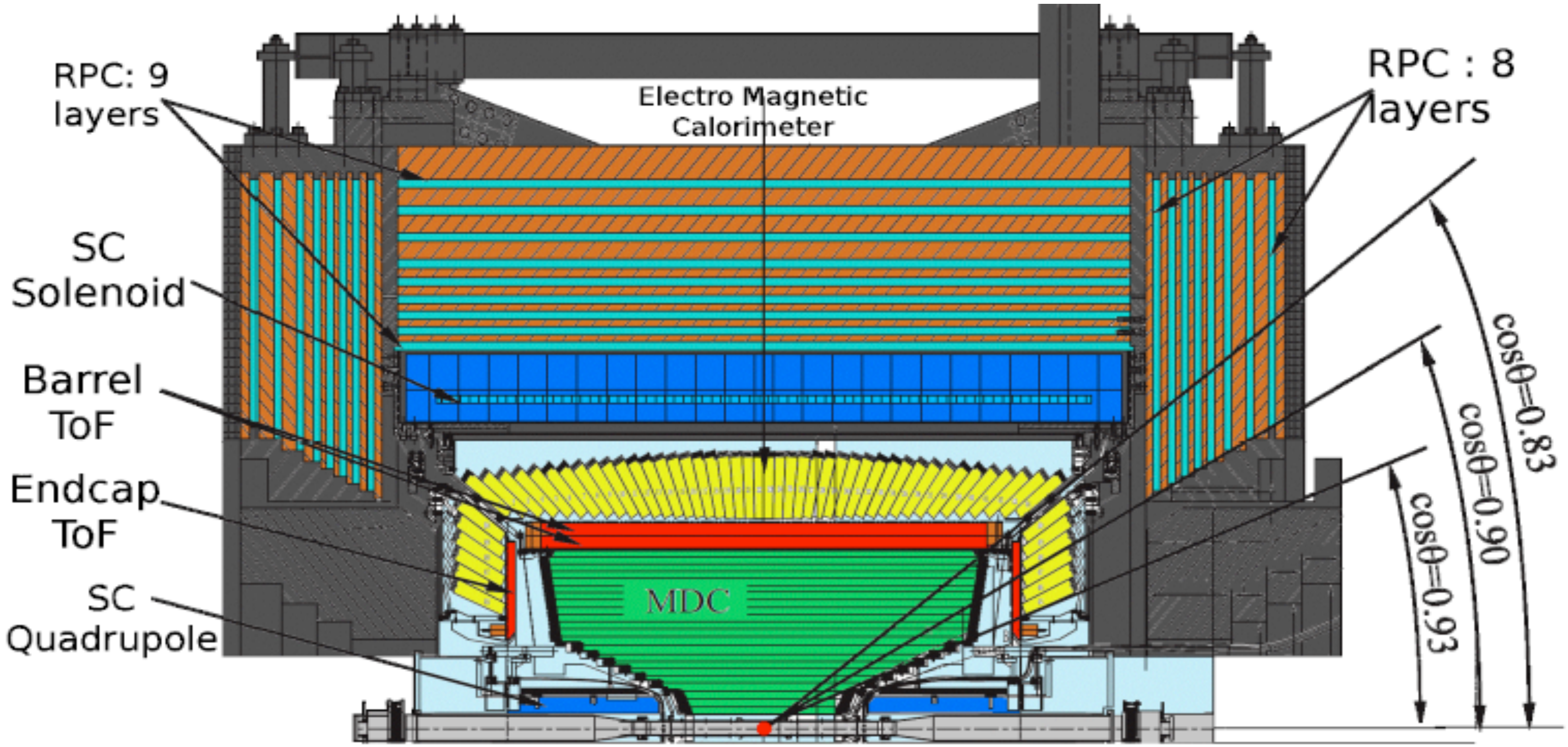
BEPCII: a double-ring machine



Beam energy:
1-2.3 GeV
Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

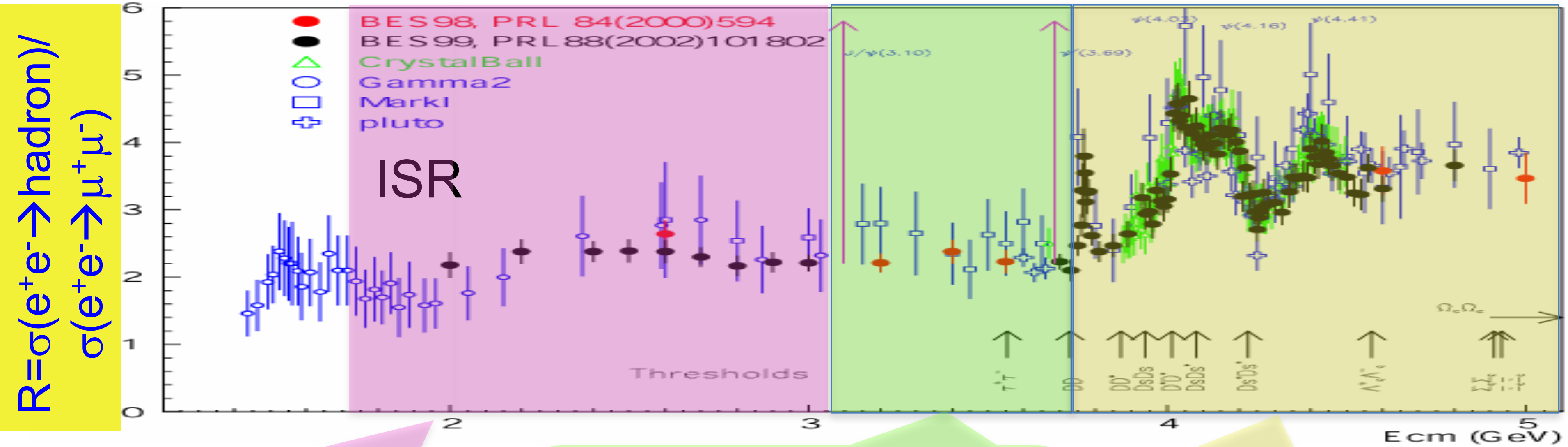

/home21/home/zhaozhuo/setup/liferateNew.edl
2016/04/05 22:29:41
Luminosity 10.00 E32/cm^2/s
e+
e−
Energy [GeV]
1.8833
1.8830
Current [mA]
849.97
852.83
Lifetime [hr]
1.52
2.27
Inj.Rate [mA/min]
0.00
0.00

BESIII Detector



Wire tracker (no Si); TOF + dE/dx for PID; CsI Ecal; RPC muon

Physics in τ-c energy region



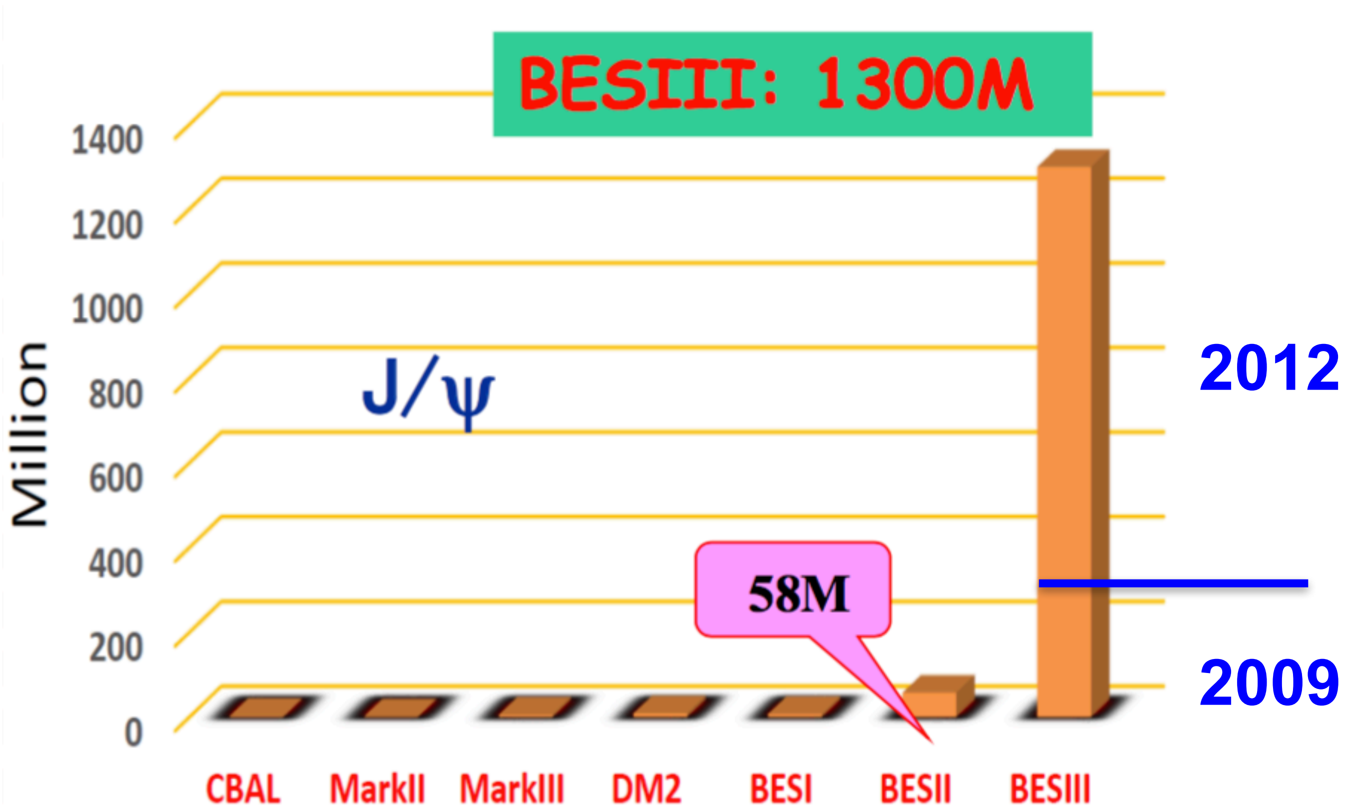
- Nucleon form factors
- Y(2175) resonance
- Exotic states with s quark, Zs
- MLLA/LPHD and QCD predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Rare and forbidden decays
- Physics with charmonium and τ lepton

- XYZ particles
- |Vcd|,|Vcs|
- f_D and f_{Ds}
- D_0-$\bar{D}_0$ mixing, CPV
- Charmed baryons

R scan: precision $\Delta\alpha_{QED}$, a_μ, charm quark mass extraction.

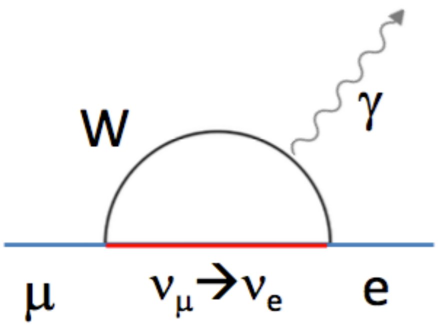
J/ψ Data Sample



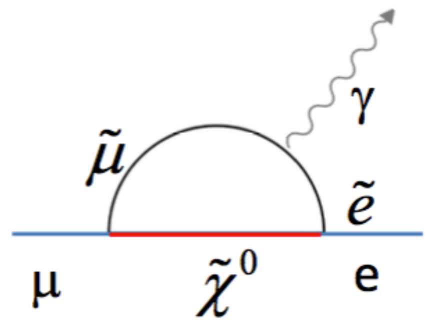
- Huge and clean data which provide a good lab to probe rare decays such as LFV process.
- More data will be taken in the next run.

Why charged Lepton Flavor Violation?

- The non-zero neutrino masses and mixing can introduce flavor transitions, but the expected branching fractions are at an extremely rare level.
- Thus, searching for the cLFV events which are SM forbidden would be clear signal of physics beyond the SM.
- For example,



B: 10^{-54} ~ 10^{-55}



B: 10^{-15} ~ 10^{-12}

- SM prediction
- SM + ν oscillation

- Beyond SM (e.g. SUSY)

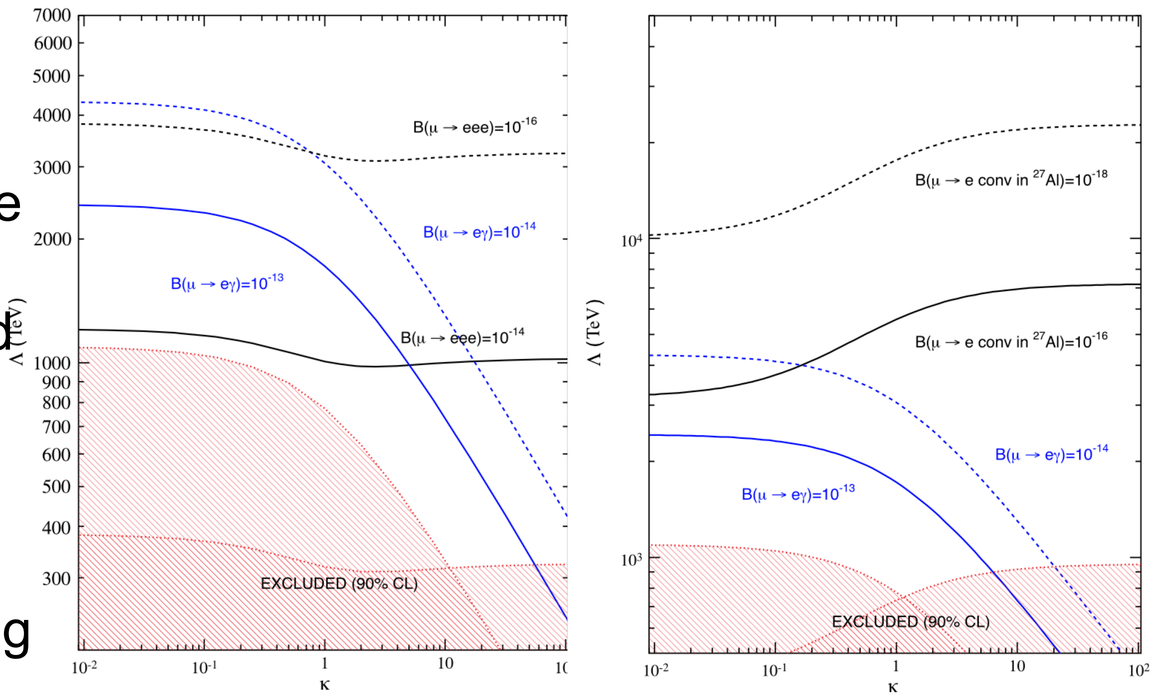
Why charged Lepton Flavor Violation?

- Theoretical prospects for μ→e, μN→eN and μ→3e

Phys. Rept. 532 (2013) 27

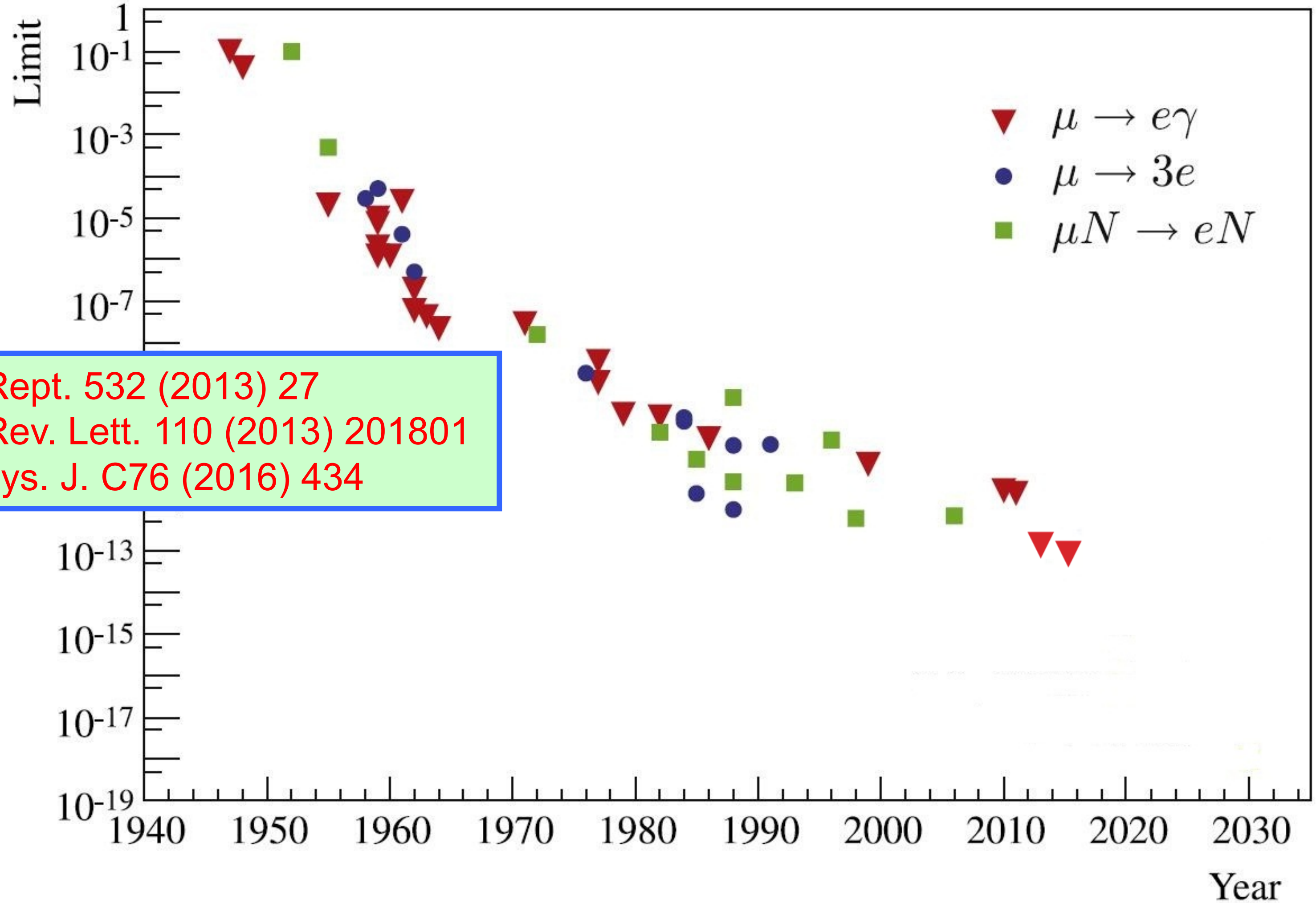
- Sensitivity of μ→e conversion in ^{27}Al experiment that can probe a normalized captured capture rate of 10^{-16} and 10^{-18} , and μ→γe : 10^{-13} and 10^{-14}

- Sensitivity of μ→3e experiment that is sensitive to branching ratios 10^{-14} and 10^{-16} , and μ→γe : 10^{-13} and 10^{-14}



Why charged Lepton Flavor Violation?

- And experimental results for μ→e, μN→eN and μ→3e



Phys. Rept. 532 (2013) 27
Phys. Rev. Lett. 110 (2013) 201801
Eur. Phys. J. C76 (2016) 434

Experimental status

- LFV in Meson decays

Channel	Upper limit	Experiment
$\pi^0 \to \mu^\pm e^\mp$	3.59×10^{-10}	KTeV
$\eta \to \mu^\pm e^\mp$	6×10^{-6}	Saturne SPES2
$K_L^0 \to \pi^0 \mu^\pm e^\mp$	7.56×10^{-11}	KTeV
$K_L^0 \to 2\pi^0 \mu^\pm e^\mp$	1.64×10^{-10}	KTeV
$K_L^0 \to \mu^+ e^-$	4.7×10^{-12}	BNL E871
$K^+ \to \pi^+ \mu^+ e^-$	1.3×10^{-11}	BNL E865, E777
$D^+ \to \pi^+ \mu^\pm e^\mp$	3.4×10^{-5}	Fermilab E791
$D^+ \to K^+ \mu^\pm e^\mp$	6.8×10^{-5}	Fermilab E791
$D^0 \to \mu^\pm e^\mp$	8.1×10^{-7}	BaBar
$D_s^+ \to \pi^+ \mu^\pm e^\mp$	6.1×10^{-4}	Fermilab E791
$D_s^+ \to K^+ \mu^\pm e^\mp$	6.3×10^{-4}	Fermilab E791
$B^0 \to \mu^\pm e^\mp$	9.2×10^{-8}	Babar (347 fb^{-1})
$B^0 \to \tau^\pm e^\mp$	1.1×10^{-4}	CLEO (9.2 fb^{-1})
$B^0 \to \tau^\pm \mu^\mp$	3.8×10^{-5}	CLEO (9.2 fb^{-1})
$B^+ \to K^+ e^\pm \mu^\mp$	9.1×10^{-8}	BaBar (208 fb^{-1})
$B^+ \to K^+ e^\pm \tau^\mp$	7.7×10^{-5}	BaBar (348 fb^{-1})
$B_s^0 \to e^\pm \mu^\mp$	6.1×10^{-6}	CDF (102 fb^{-1})

Experimental status

- LFV in quarkonium decays

$l_1 l_2$	$\mu\tau$	$e\tau$	$e\mu$
$B(\Upsilon(1S) \to l_1 l_2)$	6.0×10^{-6}	–	–
$B(\Upsilon(2S) \to l_1 l_2)$	3.3×10^{-6}	3.2×10^{-6}	–
$B(\Upsilon(3S) \to l_1 l_2)$	3.1×10^{-6}	4.2×10^{-6}	–
$B(J/\psi \to l_1 l_2)$	2.0×10^{-6}	8.3×10^{-6}	1.6×10^{-7}
$B(\phi \to l_1 l_2)$	n/a	n/a	4.1×10^{-6}

Experimental status

- LFV in quarkonium resonances decay

$l_1 l_2$	$\mu\tau$	$e\tau$	$e\mu$
$B(\Upsilon(1S) \to l_1 l_2)$	6.0×10^{-6}	–	–
$B(\Upsilon(2S) \to l_1 l_2)$	3.3×10^{-6}	3.2×10^{-6}	–
$B(\Upsilon(3S) \to l_1 l_2)$	3.1×10^{-6}	4.2×10^{-6}	–
$\boxed{B(J/\psi \to l_1 l_2)}$	2.0×10^{-6}	8.3×10^{-6}	1.6×10^{-7}
$B(\phi \to l_1 l_2)$	n/a	n/a	4.1×10^{-6}

Experimental status

- LFV in quarkonium resonances decay

$l_1 l_2$	$\mu\tau$	$e\tau$	$e\mu$
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58 M J/ψ events BESII

Experimental status

- LFV in quarkonium resonances decay

$l_1 l_2$	$\mu\tau$	$e\tau$	$e\mu$
$B(\Upsilon(1S) \to l_1 l_2)$	6.0×10^{-6}	–	–
$B(\Upsilon(2S) \to l_1 l_2)$	3.3×10^{-6}	3.2×10^{-6}	–
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$B(J/\psi \to l_1 l_2)$	2.0×10^{-6}	8.3×10^{-6}	1.6×10^{-7}
$B(\phi \to l_1 l_2)$	n/a	n/a	4.1×10^{-6}

58 M J/ψ events BESII

225M J/ψ events BESIII

$J/\psi \to e\mu$ at BESIII (1)

Phys. Rev. D 87 (2013) 112007

- $J/\psi \to e\mu$ at **BESIII**, 225M J/ψ events are used.
- Event topology: two opposite, back-to-back, charged tracks, no obvious extra EMC showers
- Most of the backgrounds are from $J/\psi \to e^+e^-$, $J/\psi \to \mu^+\mu^-$, $J/\psi \to \pi^+\pi^-$, $J/\psi \to K^+K^-$, $e^+e^- \to e^+e^-(\gamma)$ and $e^+e^- \to \mu^+\mu^-(\gamma)$
- To suppress these backgrounds, several powerful criteria are employed.

$J/\psi \to e\mu$ at BESIII (2)

Phys. Rev. D 87 (2013) 112007

- To suppress backgrounds from electron mis-ID from $J/\psi \to e^+e^-$, $e^+e^- \to e^+e^-(\gamma)$,

(1) no associated hits in the MUC;

(2) 0.95 <E/p< 1.50 GeV, where E is the energy deposit in the EMC and p the momentum measured by the MDC;

(3) the absolute value of $\chi^e_{dE/dx}$ (the difference between measured and expected dE/dx for electron hypothesis over its resolution) should be less than 1.8;

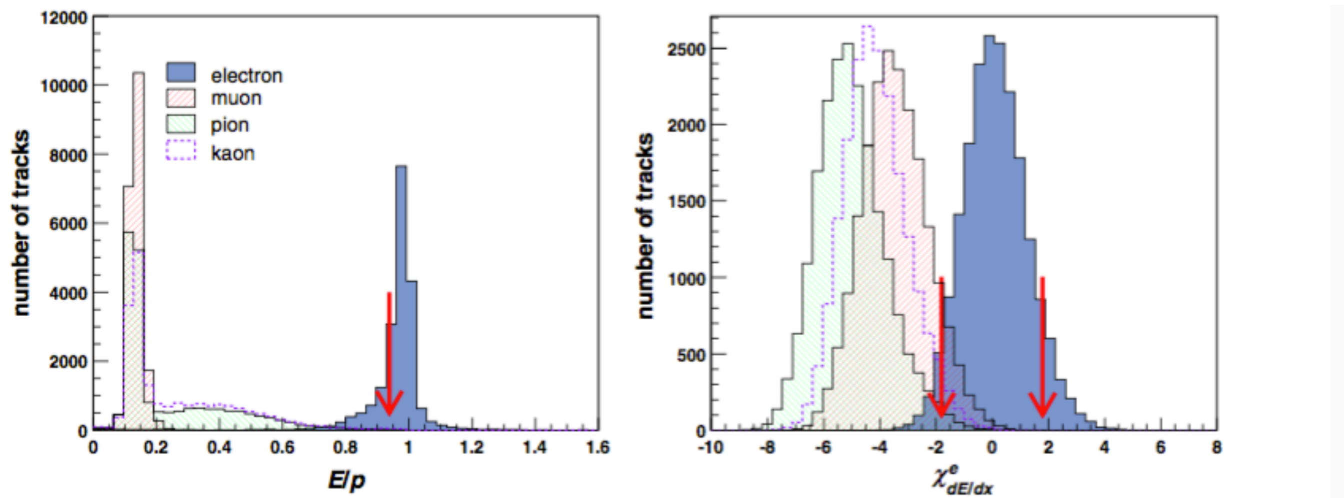


FIG. 1 (color online). The distributions of E/p (left) and $\chi^e_{dE/dx}$ (right) for the simulated electron, muon, pion, and kaon samples.

$J/\psi \to e\mu$ at BESIII (3)

Phys. Rev. D 87 (2013) 112007

- To suppress backgrounds from muon mis-ID from $J/\psi \to \mu^+\mu^-$, $e^+e^- \to \mu^+\mu^-(\gamma)$,

(1) Penetration depth in the MUC larger than 40 cm;

(2) E/p<0.5 GeV and 0.1 <E< 0.3 GeV

(3) the value of $\chi^e_{dE/dx}$ (the difference between measured and expected dE/dx for electron hypothesis over its resolution) should be less than -1.8;

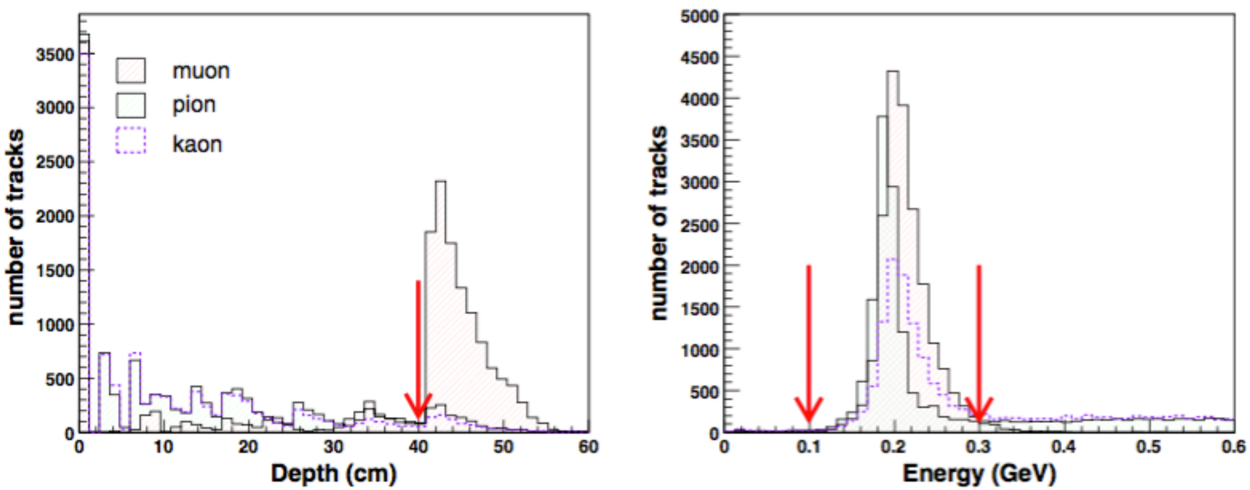


FIG. 2 (color online). The distributions of the penetration depth in the MUC (left) and the deposited energy in the EMC (right) for the simulated muon, pion, and kaon samples.

$J/\psi \to e\mu$ at BESIII (4)

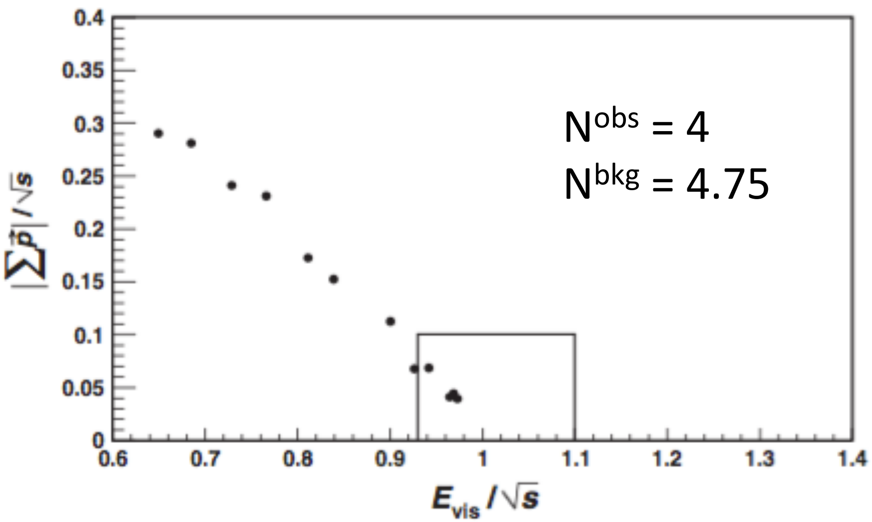


FIG. 3. A scatter plot of $E_{\rm vis}/\sqrt{s}$ versus $|\Sigma\vec{p}|/\sqrt{s}$ for the J/ψ data. The indicated signal region is defined as $0.93 \le E_{\rm vis}/\sqrt{s} \le 1.10$ and $|\Sigma\vec{p}|/\sqrt{s} \le 0.1$.

Phys. Rev. D 87 (2013) 112007

TABLE I. Summary of systematic uncertainties (%).

Sources	Error
$e^{\pm}$ tracking	1.00
$\mu^{\pm}$ tracking	1.00
$e^{\pm}$ ID	0.62
$\mu^{\pm}$ ID	0.04
Acollinearity, acoplanarity	5.36
Photon veto	1.19
$N_{J/\psi}$	1.24
Total	5.84

With 225 M J/ψ data

$B(J/\psi \to e\mu) < N^{UL}_{obs}/(N_{J/\psi}\varepsilon) < \mathbf{1.6 \times 10^{-7}}$ @ 90% C.L.

where N^{UL}_{obs} is calculated based on the POLE program which is a Feldman-Cousins method including the number of observed events, the number of background events and its uncertainty, and the systematic uncertainties.

Prospect for $J/\psi \to e\tau$ at BESIII

Simulated based on BESIII software and hardware systems

- $J/\psi \to e\tau$, $\tau \to \mu\upsilon_\mu\upsilon_\tau$
- Event topology: two opposite charged tracks, missing momenta
- Most of the backgrounds are from $J/\psi \to \pi^+ K_L K^-$, $J/\psi \to K_L K_L$, $J/\psi \to K^{*0} K^0$
- After background suppression, the detection efficiency is estimated to be 14%

With 1300 M J/ψ MC events

$$B(J/\psi \to e\tau)^{\text{sensitivity}} < N^{UL}_{obs}/(N_{J/\psi}\varepsilon) < 6.3\times 10^{-8} \text{ @ } 90\% \text{ C.L.}$$

where N^{UL}_{obs} is calculated based on the POLE program which is a Feldman-Cousins method including the number of background events and its uncertainty, and the systematic uncertainties (assumed to be 5%), where the number of observed events is set to be zero.

Prospect for J/ψ → eτ at BESIII

Simulated based on BESIII software and hardware systems

- J/ψ → eτ, $\tau \to \mu \upsilon_\mu \upsilon_\tau$
- Event topology: two opposite charged tracks, missi… momenta
- Most of the backgrounds are from J/ψ→… $J/\psi \to K^{*0}K^0$
- After background suppressio… …iency is estimated to be 14%

…0 M J/ψ MC events

B(J/ψ → eτ)… …$_{J/\psi}\varepsilon$)< 6.3×10^{-8} @ 90% C.L.

where N^{UL}… …the POLE program which is a Feldman-Cousi… …number of background events and its u… …ematic uncertainties (assumed to be 5%), where the nu… …events is set to be zero.

Result with experimental data is on the way

Prospect for $J/\psi \to \mu\tau$ at BESIII

Simulated based on BESIII software and hardware systems

- $J/\psi \to \mu\tau$, $\tau \to e\upsilon_e\upsilon_\tau$
- Event topology: two opposite charged tracks, missing momenta
- Most of the backgrounds are from $J/\psi \to \pi^+ K_L K^-$, $J/\psi \to K_L K_L$, $J/\psi \to K^{*0} K^0$
- After background suppression, the detection efficiency is estimated to be 19%

With 1300 M J/ψ MC events

$$B(J/\psi \to \mu\tau)^{sensitivity} < N^{UL}_{obs}/(N_{J/\psi}\varepsilon) < 7.3\times 10^{-8} \text{ @ } 90\% \text{ C.L.}$$

where N^{UL}_{obs} is calculated based on the POLE program which is a Feldman-Cousins method including the number of background events and its uncertainty, and the systematic uncertainties (assumed to be 5%), where the number of observed events is set to be zero.

Prospect for $J/\psi \rightarrow \mu\tau$ at BESIII

Simulated based on BESIII software and hardware systems

- $J/\psi \rightarrow \mu\tau$, $\tau \rightarrow e\upsilon_e\upsilon_\tau$
- Event topology: two opposite charged tracks, missing momenta
- Most of the backgrounds are from $J/\psi \rightarrow \pi$ … $J/\psi \rightarrow K^{*0}K^0$
- After background suppression, … … ncy is estimated to be 19%

… M J/ψ MC events

$B(J/\psi \rightarrow \mu\tau)^{sen}$ … $)< 7.3\times10^{-8}$ @ 90% C.L.

where N^{UL} … he POLE program which is a Feldman-Cousins … umber of background events and its unc … atic uncertainties (assumed to be 5%), where the numb … vents is set to be zero.

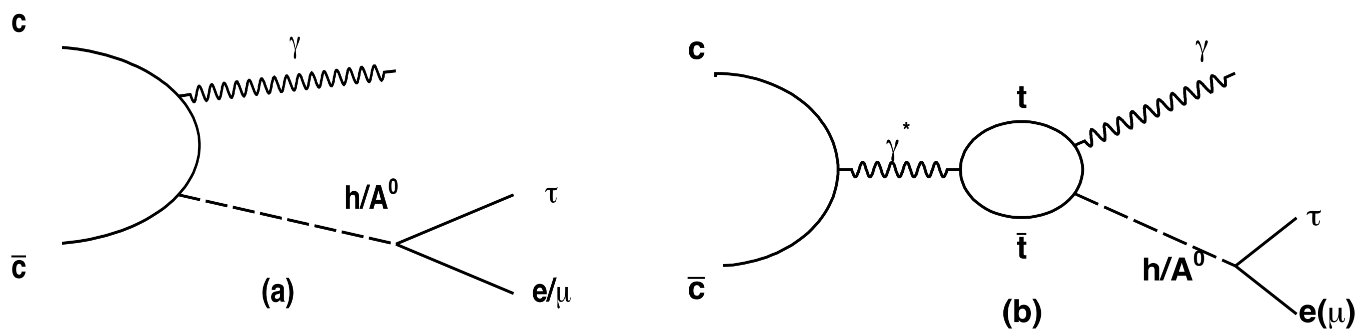
Result with experimental data is on the way

Prospect for $J/\psi \to \gamma e\tau$; $\gamma\mu\tau$ at BESIII

Simulated based on BESIII software and hardware systems

- $J/\psi \to \gamma e\tau$, $\tau \to \mu\upsilon_\mu\upsilon_\tau$
- $J/\psi \to \gamma\mu\tau$, $\tau \to e\upsilon_e\upsilon_\tau$
- Event topology: two opposite charged tracks, missing momenta, one photon.

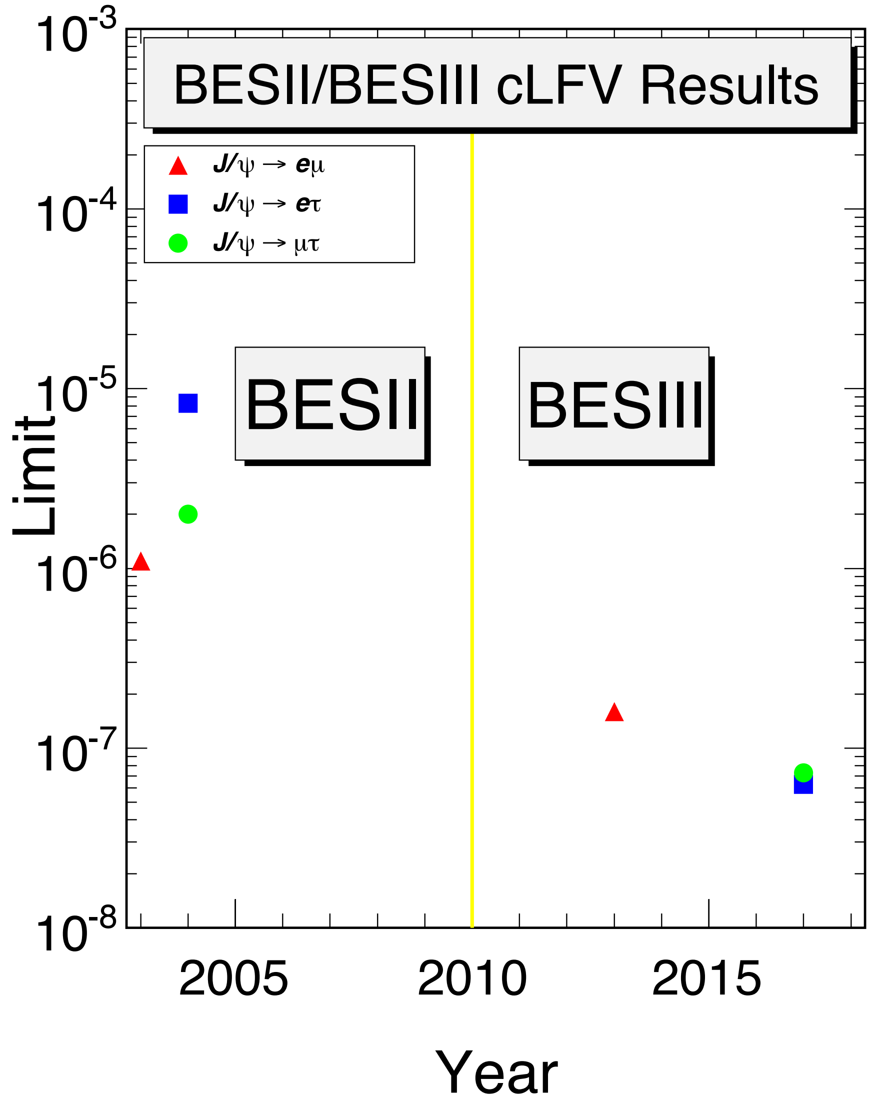
With 1300 M J/ψ data



Result with experimental data is on the way

Summary

- BESIII collaboration got the leading upper limit on **$J/\psi \to e\mu$** decay with 225 M J/ψ.
- Better upper limits on **$J/\psi \to e\tau$** and **$J/\psi \to \mu\tau$** are coming soon.
- upper limits on **$J/\psi \to \gamma e\tau$** and **$J/\psi \to \gamma\mu\tau$** are coming soon.
- New data taking plan has been approved! Better constraints can be expected.



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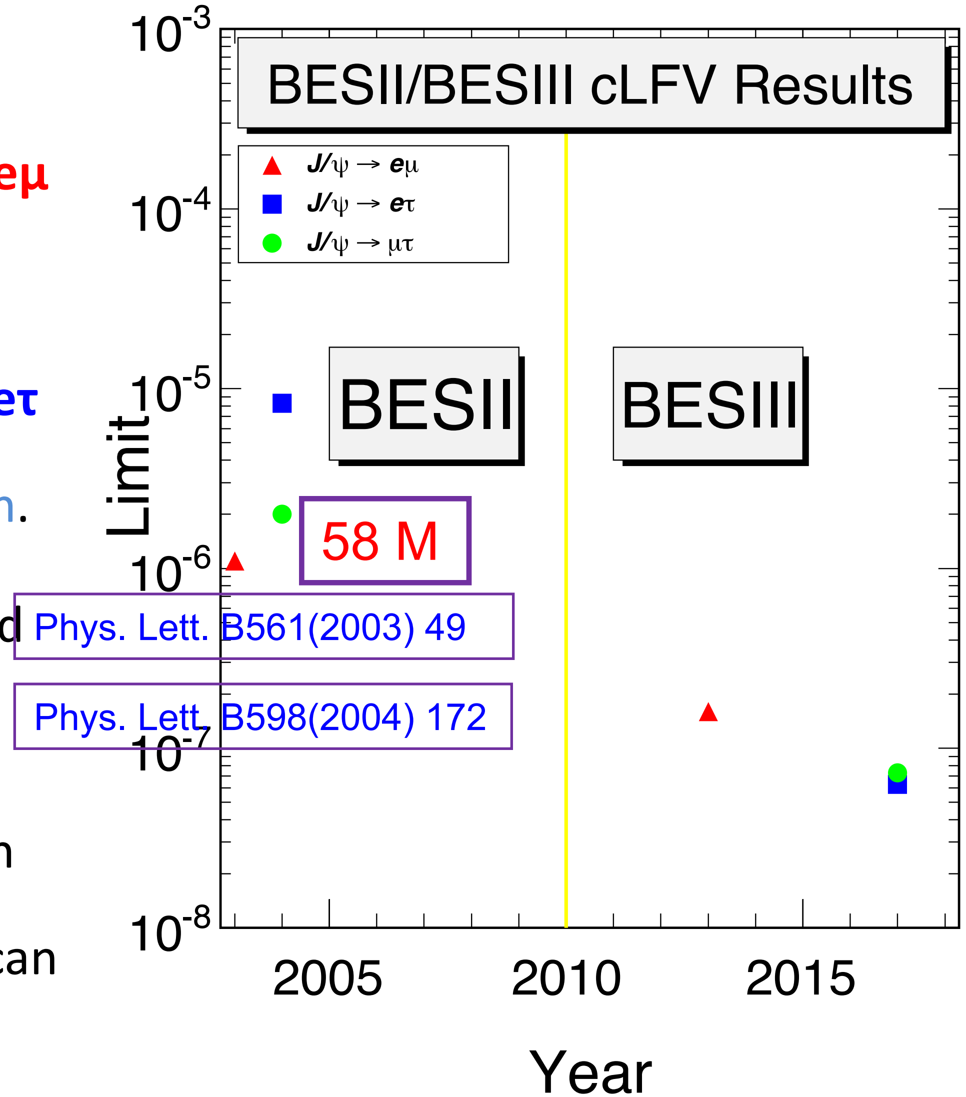

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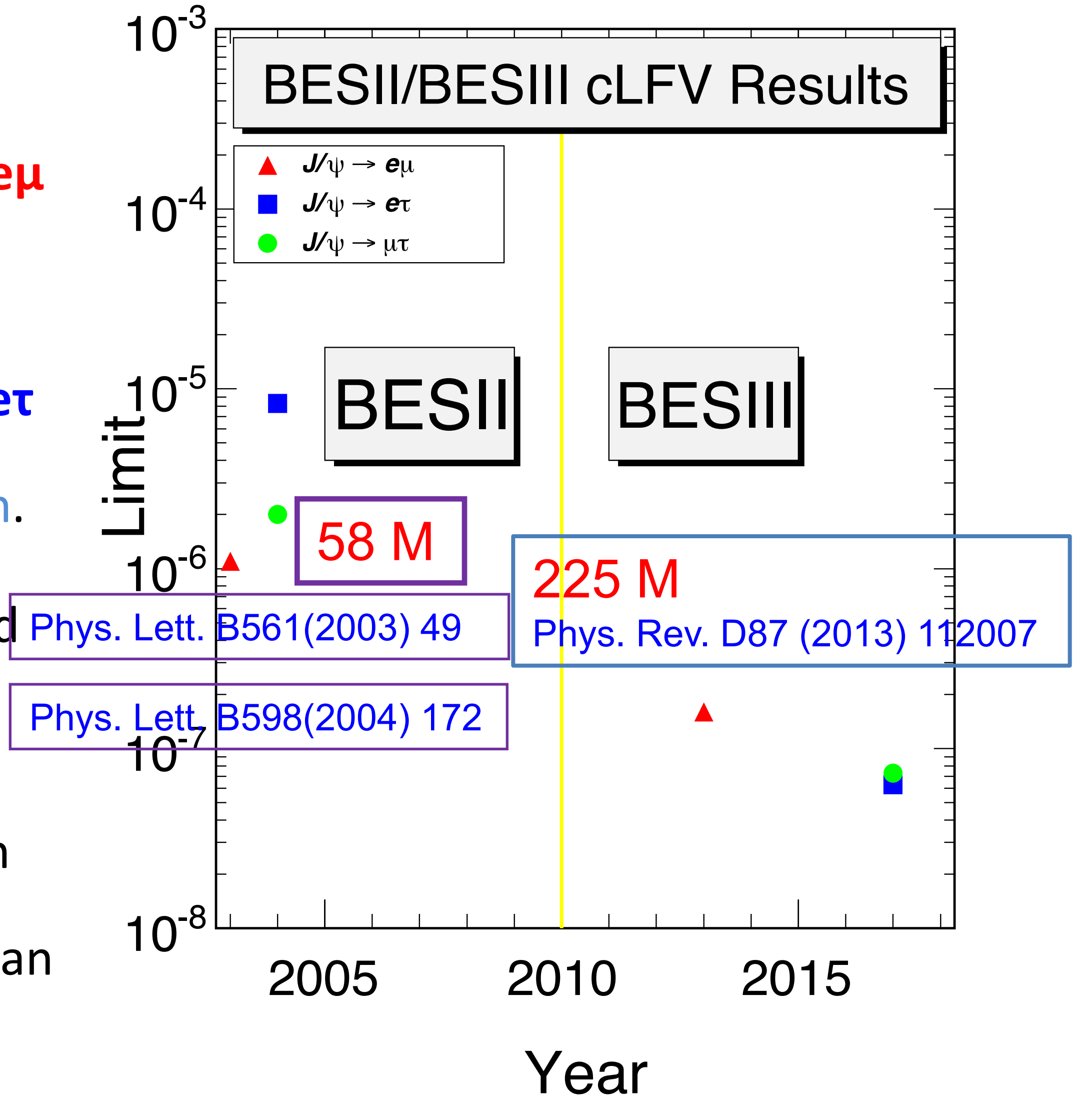
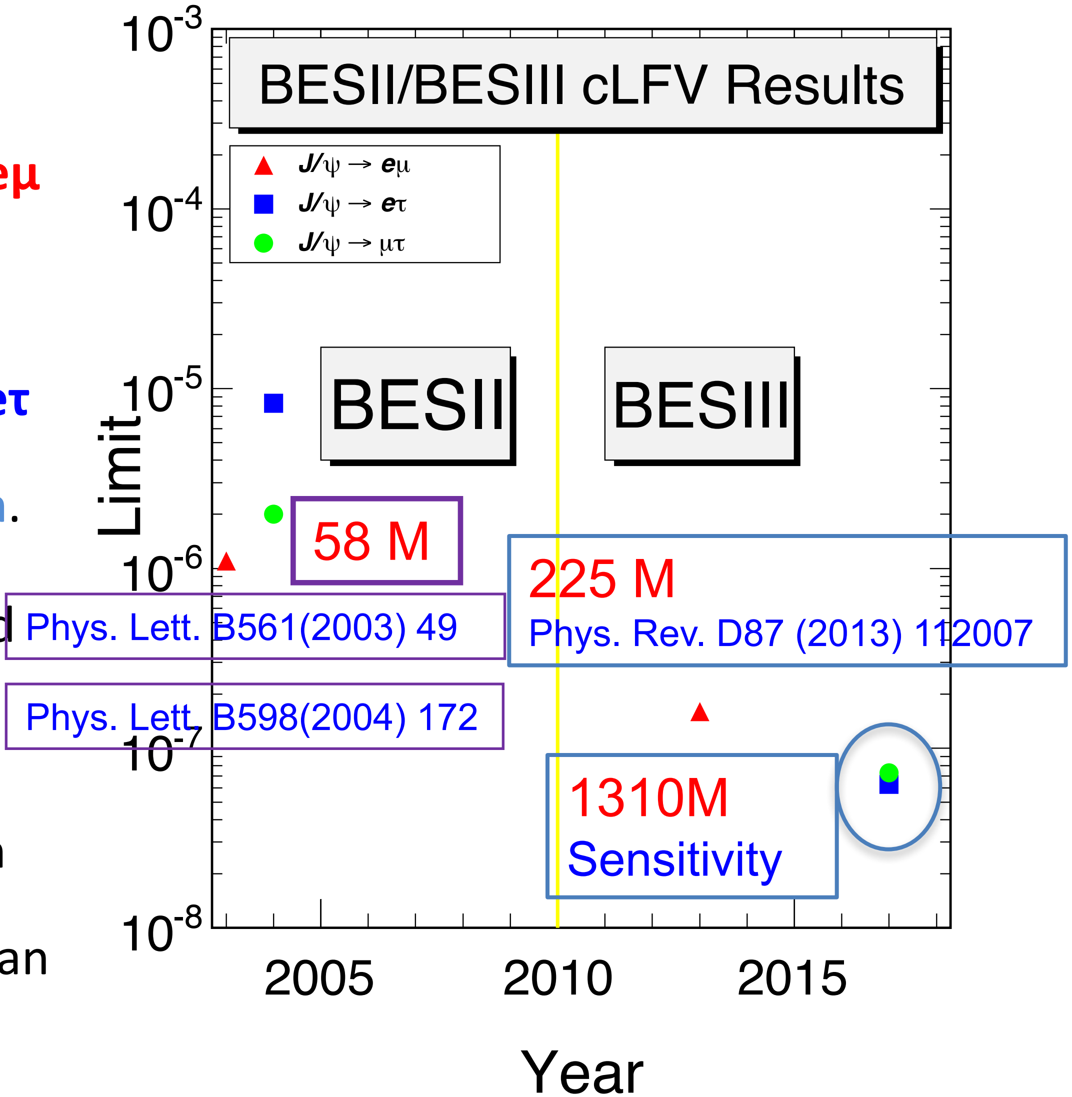


Summary

- BESIII collaboration got the leading upper limit on **J/ψ → eμ** decay with 225 M J/ψ.
- Better upper limits on **J/ψ → eτ** and **J/ψ → μτ** are coming soon.
- upper limits on **J/ψ → γeτ** and **J/ψ → γμτ** are coming soon.
- New data taking plan has been approved! Better constraints can be expected.




THANK YOU

Backup

For the polar and azimuthal angles of the two charged tracks, these conditions should hold: $|\Delta\theta| < 0.9^\circ$, where $|\Delta\theta| = |180^\circ - (\theta_1 + \theta_2)|$ and $|\Delta\phi| < 1.4^\circ$, where $|\Delta\phi| = |180^\circ - |\phi_1 - \phi_2||$.

"back-to-back"