Recent New Physics Search Results at BESIII

Dayong Wang

dayong.wang@pku.edu.cn

北京大學
PEKING UNIVERSITY

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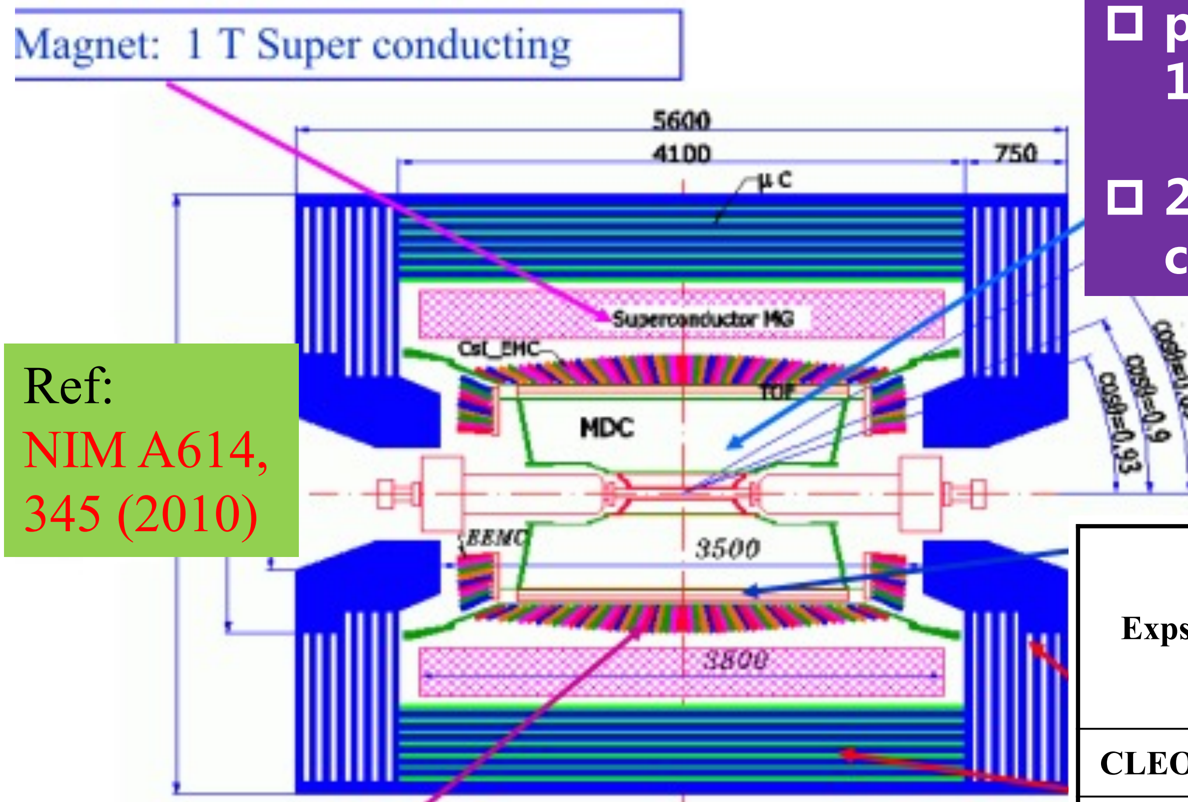
BESIII experiment@BEPCII



Ref:
NIM A614, 345 (2010)

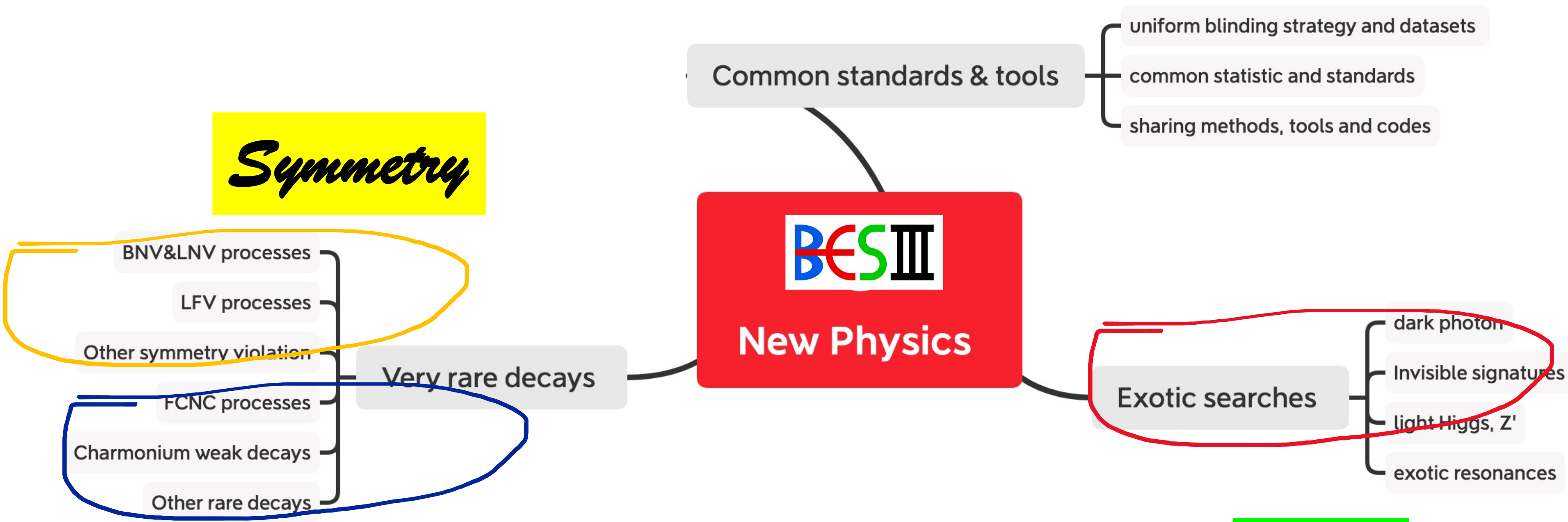
- peak lumi of 1×10^{33} $cm^{-2}s^{-1}$ at 1.89GeV reached in April 2016
- 2019-2021: top-up injection , c.m.s. E=>4.94GeV

2024: Inner tracker upgrade

Exps.	MDC Spatial resolution	MDC dE/dx resolution	EMC Energy resolution
CLEO-c	110 μm	5%	2.2-2.4 %
BaBar	125 μm	7%	2.67 %
Belle	130 μm	5.6%	2.2 %
BESIII	115 μm	<5% (Bhabha)	2.4%

Clean environment, high luminosity, large acceptance and high efficiency at BESIII are helpful for indirect probe of new physics

BESIII New Physics Program



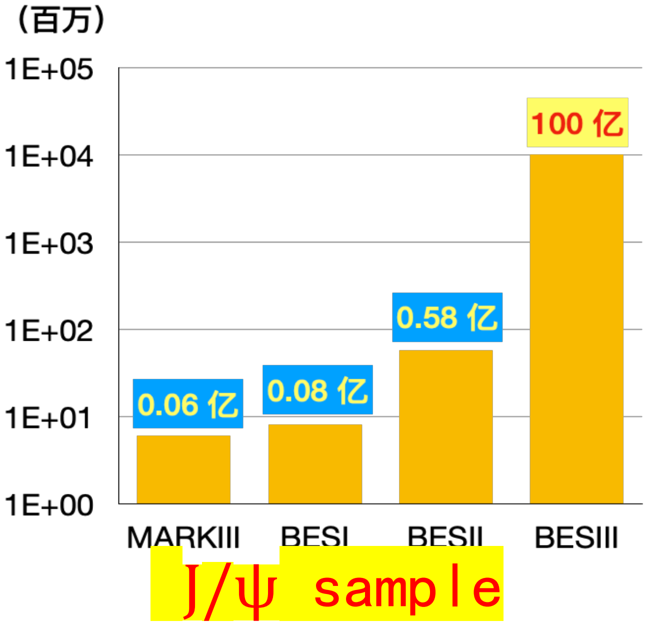
Rare

Exotic

More details, r.f.

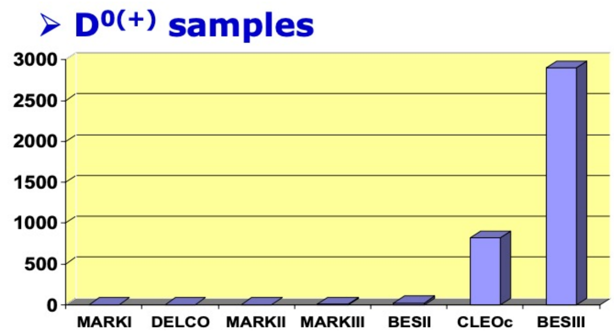
- ✓ New Physics Searches at the BESIII Experiment， Shenjian Chen and Stephen Olsen，NSR, arXiv:2102.13290
- ✓ New Physics Program of BES，Dayong Wang，in 《30 Years of BES Physics》

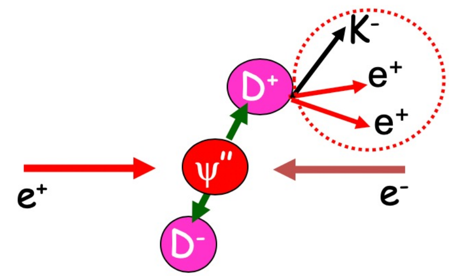
Features for NP search@BESIII

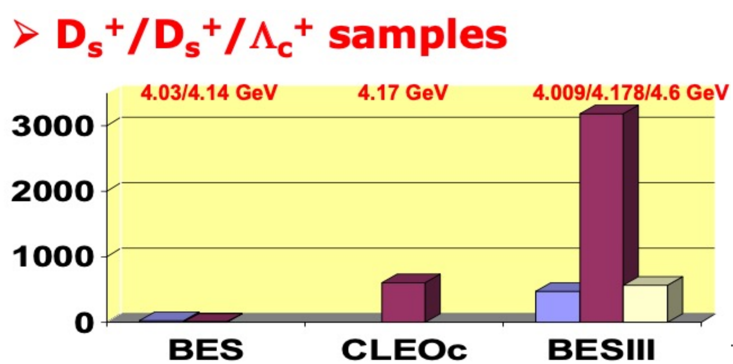


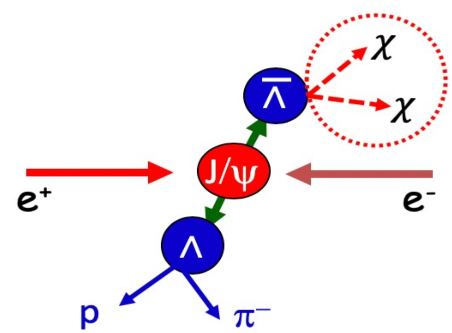
- Event is very clean
- High tagging efficiency
- Many systematic uncertainties can be cancelled
- Could measure absolute BFs

2019/2/11



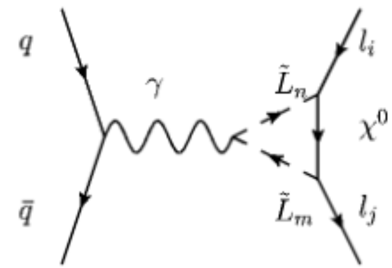


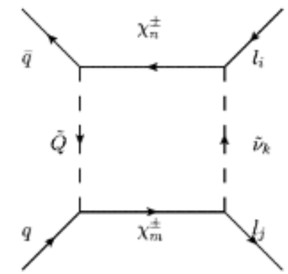




Charged LFV in J/ψ decays

- New physics models predicting BR($J/\psi \to e\mu$) to 10^{-16}~10^{-9}, BR($J/\psi \to e\tau(\mu\tau)$) to 10^{-10}~10^{-8}.
  - model-independent prediction [1, 2]
  - rotating mass matrix [3]
  - unparticle physics [4]
  - effective Lagrangian [5]
  - MSSM with gauged baryon and lepton number [6]
  - …





- Experimental results

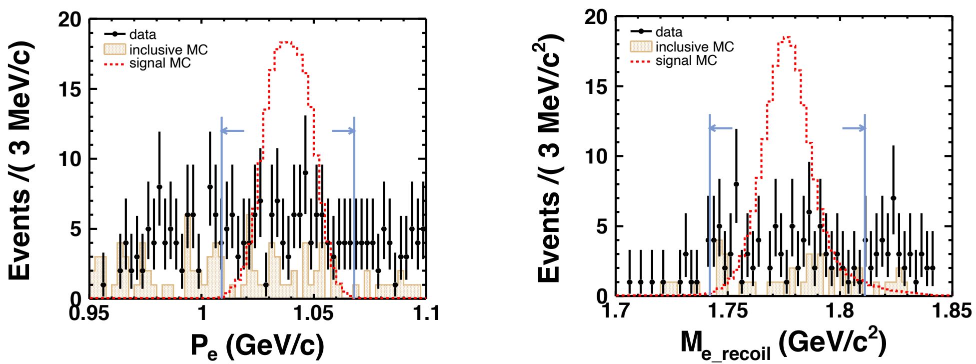
	J/ψ number	$J/\psi \to e\mu$	$J/\psi \to e\tau$	$J/\psi \to \mu\tau$
BES	58 million	$< 1.1\times10^{-6}$ [7]	$< 8.3\times10^{-6}$ [8]	$< 2.0\times10^{-6}$ [8]
BESIII	225 million	$< 1.6\times10^{-7}$ [9]	-	-

[1] X. M. Zhang et al, Phys. Rev. D 63, 016003 (2000).
[2] T. Gutche et al, Phys. Rev. D 83, 115015 (2011).
[3] J. Bordes and H. M. Chan, Phys. Rev. D 63, 016006 (2000).
[4] K. S. Sun et al, Mod. Phys. Lett. A 27, 1250172 (2012).
[5] D. E. Hazard and A. A. Petrov, Phys. Rev. D 94, 074023 (2016).
[6] X. X. Dong et al, Phys. Rev. D 97, 056027 (2018).
[7] BES Collaboration, Phys. Lett. B 561, 112007 (2003).
[8] BES Collaboration, Phys. Lett. B 598, 172 (2004).
[9] BESIII Collaboration, Phys. Rev. D 87, 112007 (2013).

Search for $J/\psi \to e^{\pm}\tau^{\mp}$

Phys. Rev. D 103, 112007 (2021)

- Based on 10 billion J/ψ data set:
  1310.6M collected @2009+2012 (sample I), 8774.01M collected @2017-2019 (sample II).
- $J/\psi \to e\tau$, $\tau \to \pi\pi^0\nu$.
  - Select one electron and one charged pion.
  - At least two photon showers and one π^0.
  - Two-body-decay:



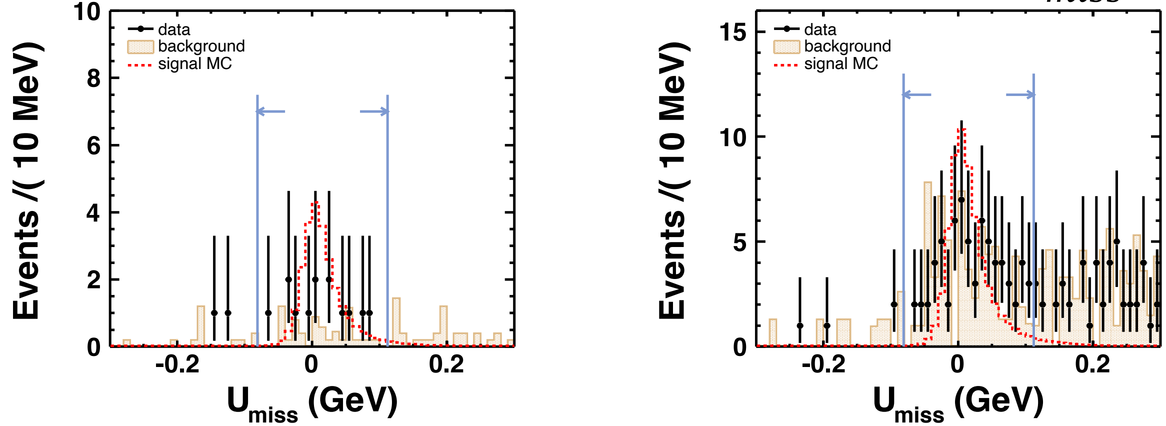
  - One undetected neutrino with missing energy $E_{miss} > 0.43GeV$.

- Blind analysis to avoid possible bias.

Search for cLFV: $J/\psi \to e^{\pm}\tau^{\mp}$

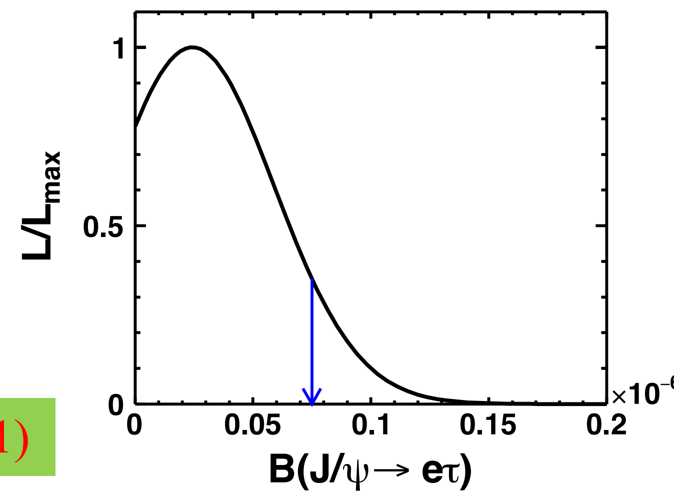
- No excess of events is observed over the background.

$$U_{miss} = E_{miss} - c|\vec{P}_{miss}|$$

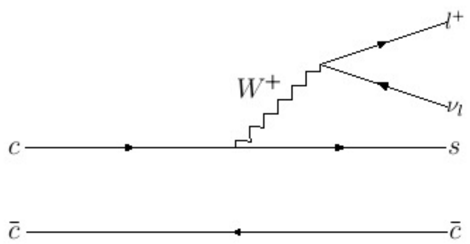


- Determination of upper limit at 90% confidence level (C.L.) with Bayesian method. Combined result:
  - $BR(J/\psi \to e\tau) < 7.5\times10^{-8}$ @ 90% C.L.
- This result improves the previous published limits by two orders of magnitude and comparable with the theoretical predictions.
- The 1st submitted paper based on full 10 billion J/ψ data of BESIII

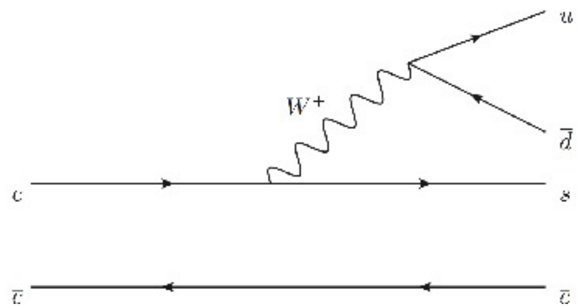
Phys. Rev. D 103, 112007 (2021)

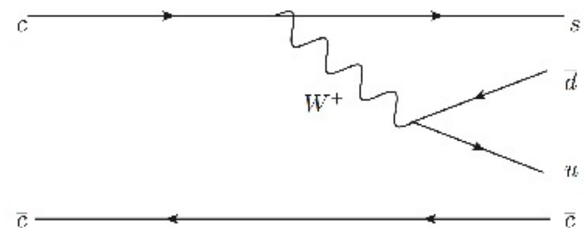


J/ψ weak decays



$J/\psi \to D_s^{(*)-} e^+ \nu_e$





$J/\psi \to D_s^- \rho^+$ and $J/\psi \to \bar{D}^0 \bar{K}^{*0}$

- Hadronic, electromagnetic, and radiative decays of the J/ψ have been widely studied, weak decays seldom searched before, especially for purely hadronic processes.
- Kinematically, the J/ψ cannot decay to a pair of charmed D mesons, but can decay to a single D meson.
- The weak decay of charmonium are rare decays. Searches for weak decays of charmonium to single D or D_s mesons provide tests of standard model (SM) theory and serve as a probe of new physics.

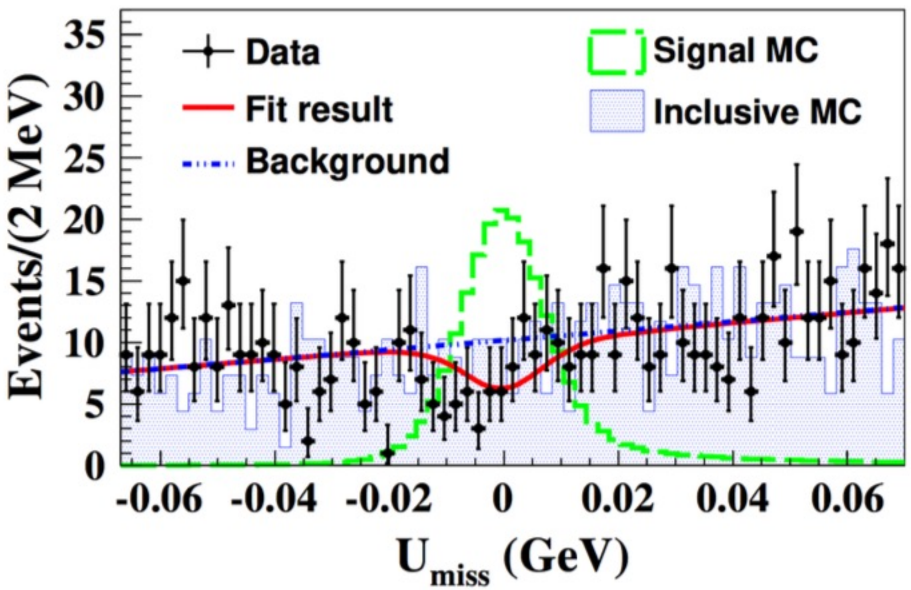
Search for $J/\psi \to D^- e^+ \nu_e$, $D^- \to K^+ \pi^- \pi^-$

$$U_{miss} = E_{miss} - c|p_{miss}|$$

- A search based on 10B Jpsi sample
- a fit on ***Umiss*** distribution to extract the signal.
- Two main backgrounds:
  - Gamma conversion with ***e*** misid: $J/\psi \to \rho\pi \to \gamma\gamma\pi\pi \to \gamma ee\pi\pi$;
  - π/K misid : $J/\psi \to \gamma\eta(1405) \to \gamma K K^0 \pi \to \gamma\pi\pi\pi K$

$$\sum \mathcal{PDF}^i_{sig} \times \frac{n^i}{N} + Poly(c_0)$$

$$\mathcal{B}(J/\psi \to D^- e^+ \nu_e + \text{c.c.}) = \frac{N_{\text{signal}}}{N_{J/\psi} \times \epsilon \times \mathcal{B}_{\text{sub}}}$$



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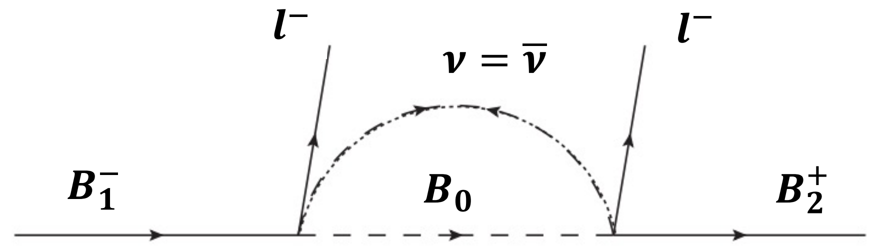
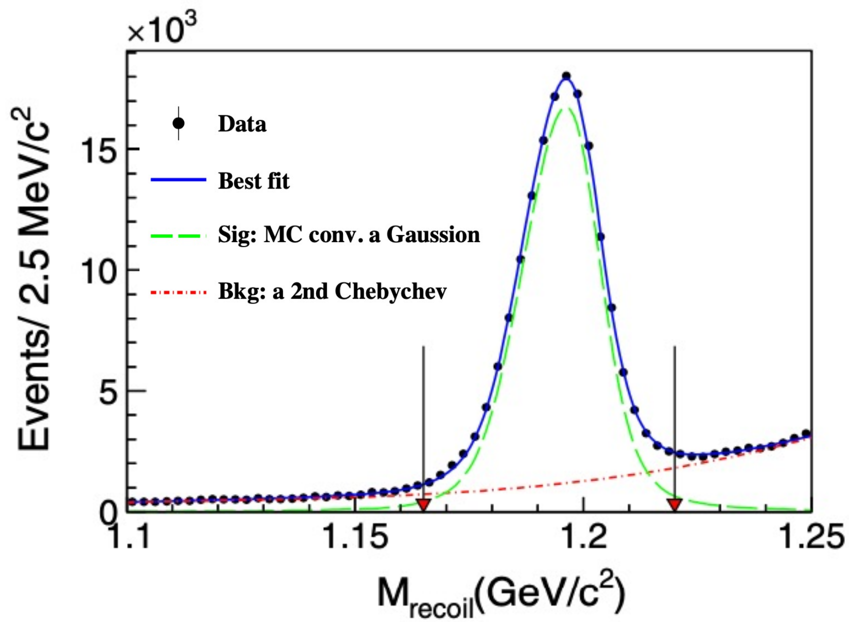
$J/\psi \to D^- e^+ \nu_e + c.c. < 7.1 \times 10^{-8}$ @ 90% CL

- ✓ the most sensitive search
- ✓ improves the limit by a factor of 170.
- ✓ stringent constraint for NP models

Search for $\Sigma^- \to p e^- e^-$ and $\Sigma^- \to \Sigma^+ X$

- Two down-type (d or s) quarks convert up-quarks[1-2], similar to $0\nu\beta\beta$
- Blind analysis
- Double tag (DT)
  - ✓ ST events: $J/\psi \to \bar{\Sigma}(1385)^+\Sigma^- + c.c.$, $\bar{\Sigma}(1385)^+ \to \pi^+\bar{\Lambda}(\to \bar{p}\pi^+)$, save all $\bar{\Sigma}(1385)^+$ candidates; fit the recoil mass of $\bar{\Sigma}(1385)^+$.





$N_{ST} = 147743 \pm 563_{stat.}$

$B(J/\psi \to \bar{\Sigma}(1385)^+\Sigma^-) = (3.21 \pm 0.07_{stat.})\times 10^{-4}$

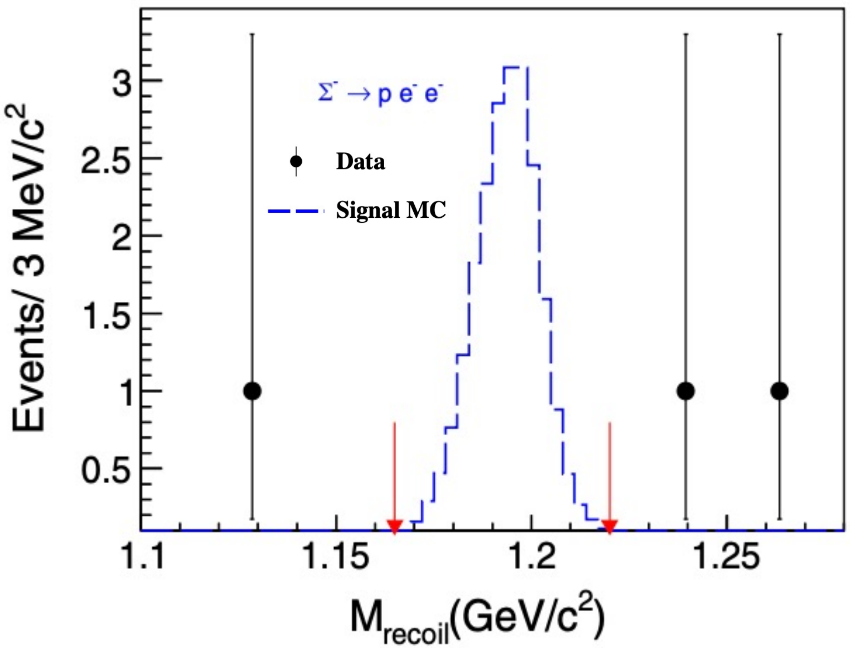
PRD 103 (2021) 052011

[1] C. Barbero, G. Lopez Castro, and A. Mariano, Phys. Lett. B 556, 98 (2003).
[2] C. Barbero, L. F. Li, G. Lopez Castro, and A. Mariano, Phys. Rev. D 76, 116008 (2007); Phys. Rev. D 87, 036010 (2013).

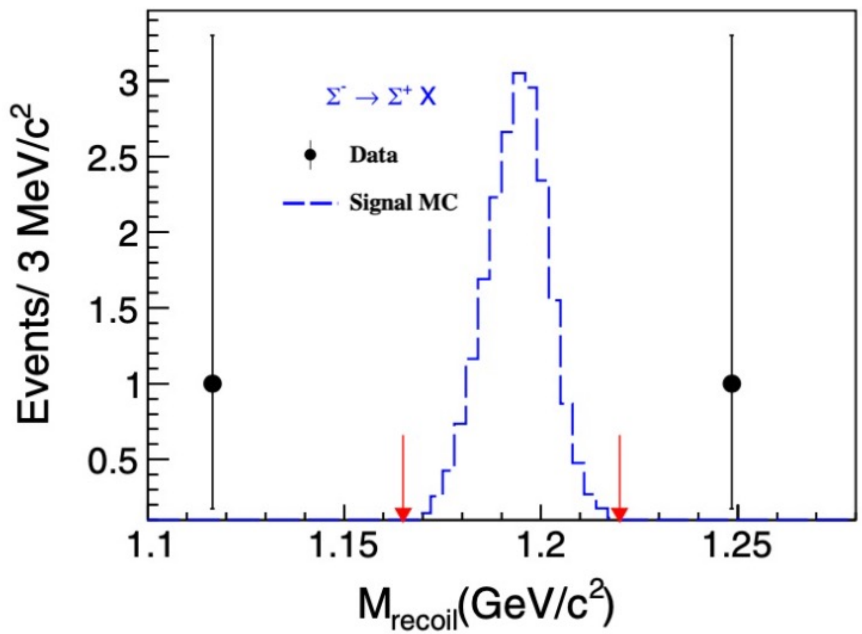
Results: $\Sigma^- \to pe^-e^-$ and $\Sigma^- \to \Sigma^+ X$

- ✓ **DT events:**
  - ✓ **in the recoil side of the selected ST events**
  - ✓ $\Sigma^- \to pe^-e^-; \Sigma^- \to \Sigma^+(\to p\pi^0)X;$
  - ✓ **ULs @90 CL： Frequentist method with unbounded profile likelihood treatment of systematic uncertainties.**

PRD 103 (2021) 052011



$B(\Sigma^- \to pe^-e^-) < 6.7 \times 10^{-5}$



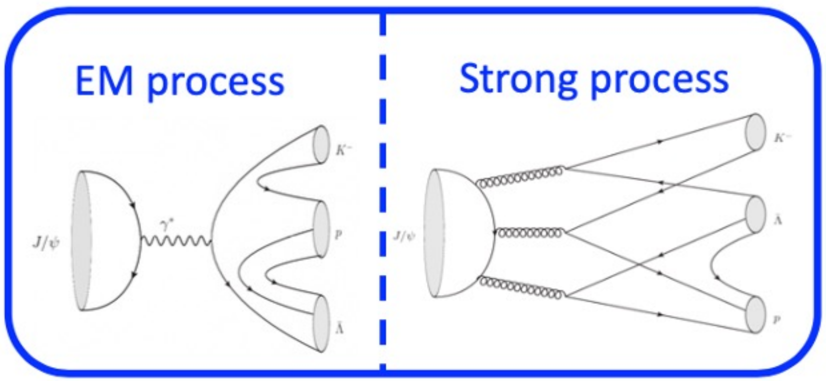
$B(\Sigma^- \to \Sigma^+ X) < 1.2 \times 10^{-4}$

Search $for \;\; \Lambda - \bar{\Lambda}$ *oscillation*

- Oscillation event (charge conjugation implied)

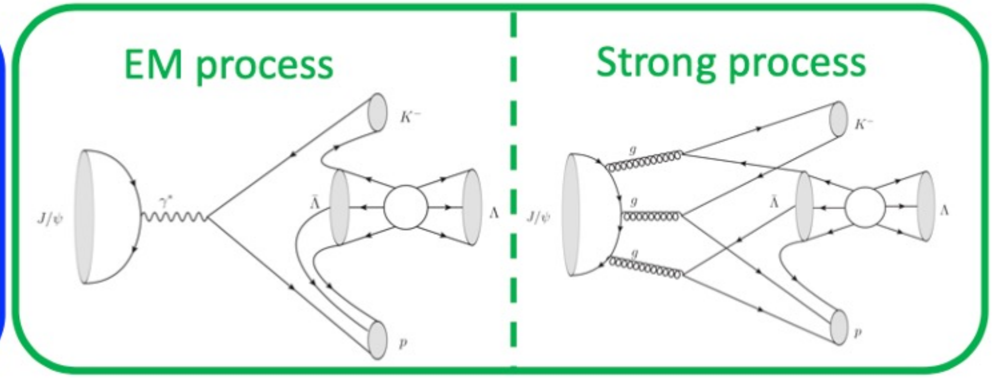
$\Delta B=2$ process

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



Right Sign Channel (Opposite Charge)

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



Wrong Sign Channel (Same Charge)

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

- Time integrated oscillation rate

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

Most of the systematic uncertainties cancelled.

- The oscillation parameter

$$(\delta m_{\Lambda\bar{\Lambda}})^2 = \frac{\mathcal{P}(\Lambda)}{2\cdot(\tau_\Lambda/\hbar)^2}$$

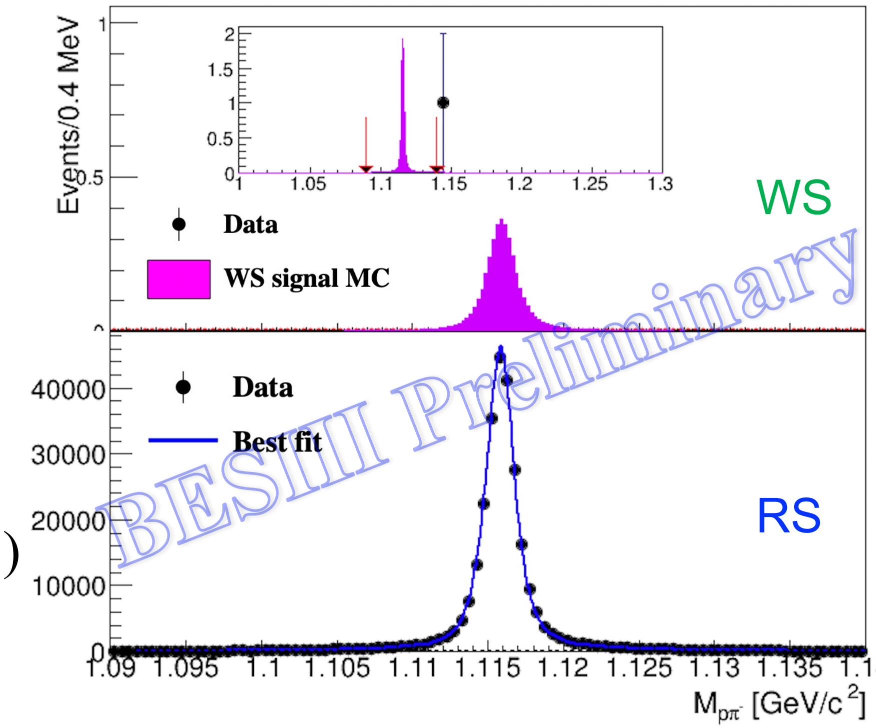
Preliminary : $\Lambda - \bar{\Lambda}$ oscillation

- Result based on 1.3 billion J/ψ events.
- Total systematic uncertainty (~1%).
- Upper limit is obtained by utilizing a frequentist method.
- Upper limit on oscillation rate (90% C.L.)

$$P(\Lambda) < 4.4\times10^{-6}$$

- Oscillation parameter (90% C.L.)

$$\delta m_{\Lambda\bar{\Lambda}} < 3.8\times10^{-15}\ \text{MeV}$$



WS:
Data: the dot with error bar
MC: the pink filled histogram, normalized arbitrarily
RS:
Data: the dots with error bars
Signal shape: MC shape ⊗ Gaussian
Background shape: inclusive MC sample after excluding RS events

Summary

- BESIII performed wide range study of exotic decays and new physics, with many first search or best limit
- The latest searching results are reported
  - Charged LFV decay $J/\psi \to e^{\pm}\tau^{\mp}$ — Phys. Rev. D 103, 112007 (2021)
  - Charmonium weak decay: $J/\psi \to D^{-}e^{+}\nu_e$ — JHEP 06 (2021) 157
  - LNV and BNV : $\Sigma^{-} \to pe^{-}e^{-}$ and $\Sigma^{-} \to \Sigma^{+}X$ — PRD 103 (2021) 052011
  - ΔB=2 process : $\Lambda - \bar{\Lambda}$ oscillation — Preliminary
- BESIII has great potential with unique datasets and analysis techniques

...More to come!

Future Physics Programme of BESIII
Chinese Phys. C **44**, 040001 (2020).

Thanks!