Revisit X(17) production at BESIII

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In preparation

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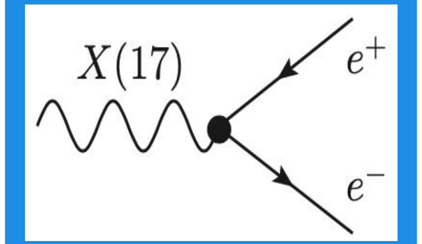
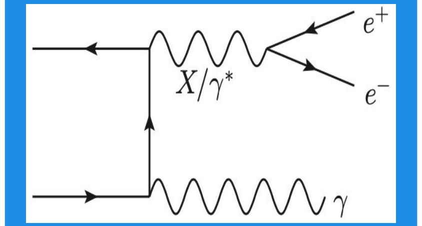
Motivation & Backgrond



Constrains on Xe^+e^- coupling



Revisit X(17) production @ BESIII

Summary

1.1 Motivation

New Physics (NP) must be somewhere and hides her light under the SM anomalies.

A. J. Krasznahorkay et al.: "**Observation of Anomalous Internal Pair Creation in Be8** : A Possible Indication of a Light, Neutral Boson"

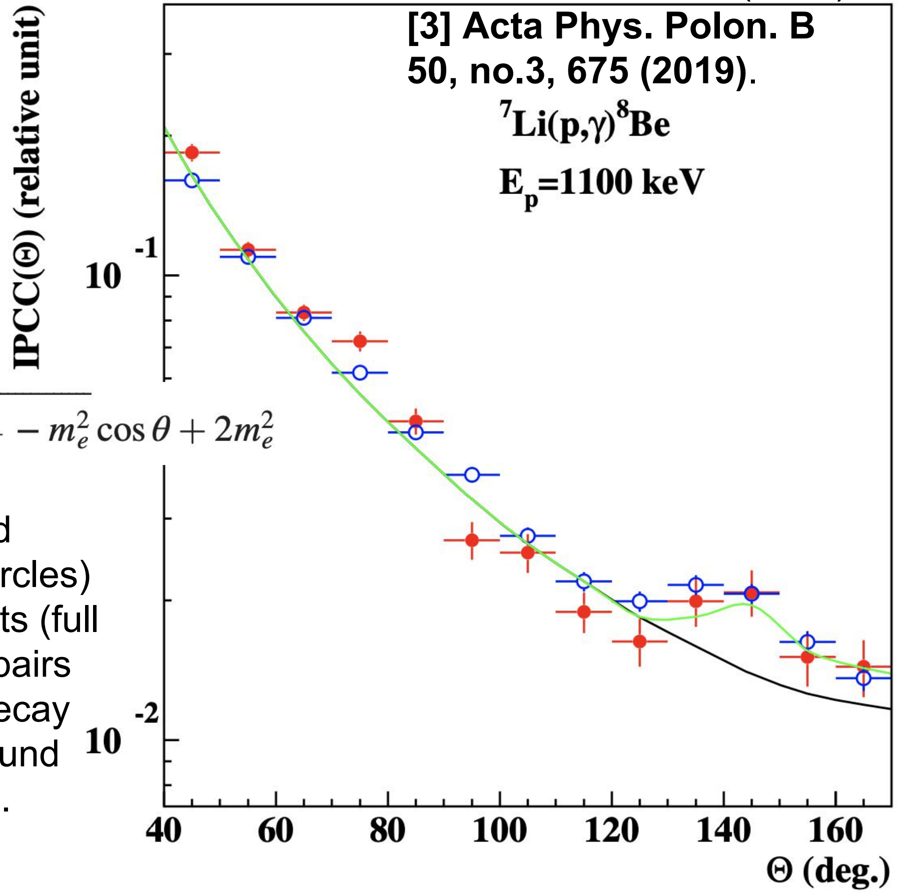
	Previous res. [1]	Exp1	Exp2	Average
m_0c^2 [MeV]	16.70(51)	16.86(6)	17.17(7)	17.01(16)
B_x	5.8×10^{-6}	$6.8(10)\times10^{-6}$	$4.7(21)\times10^{-6}$	$6(1)\times10^{-6}$
Significance	6.8σ	7.37σ	4.90σ	

A. J. Krasznahorkay et al.,
[1] Phys. Rev. Lett. 116, no.4, 042501 (2016) [arXiv:1504.01527].
inSpires citations: 236
[2] J. Phys. Conf. Ser. 1056, no.1, 012028 (2018).
[3] Acta Phys. Polon. B 50, no.3, 675 (2019).

J. L. Feng et al.: "Protophobic **Fifth-Force Interpretation** of the Observed Anomaly in Be8 Nuclear Transitions"

$$m_{ee}^2 = 2E_{e^+}E_{e^-} - 2\sqrt{E_{e^+}^2 - m_e^2}\sqrt{E_{e^-}^2 - m_e^2}\cos\theta + 2m_e^2$$

J. L. Feng et al., Phys. Rev. Lett. 117, no.7, 071803 (2016), [arXiv:1604.07411].
inSpires citations: 162



Measured angular correlations published previously [1] (blue circles) and the present results (full red dots) of the e^+e^- pairs originated from the decay of the 18.15 MeV ground state transition in ^{8}Be.

A. J. Krasznahorkay et al.: "**New evidence** supporting the existence of the hypothetic X17 particle," [arXiv:1910.10459].

1.2 Background on X(17)

J. L. Feng et al.: dynamical models (scalar, pseudoscalar, vector, axial vector, etc.), kenetic properties, constrains based on Nuclear Effective Theory.

Protophobic Fifth-Force Interpretation:

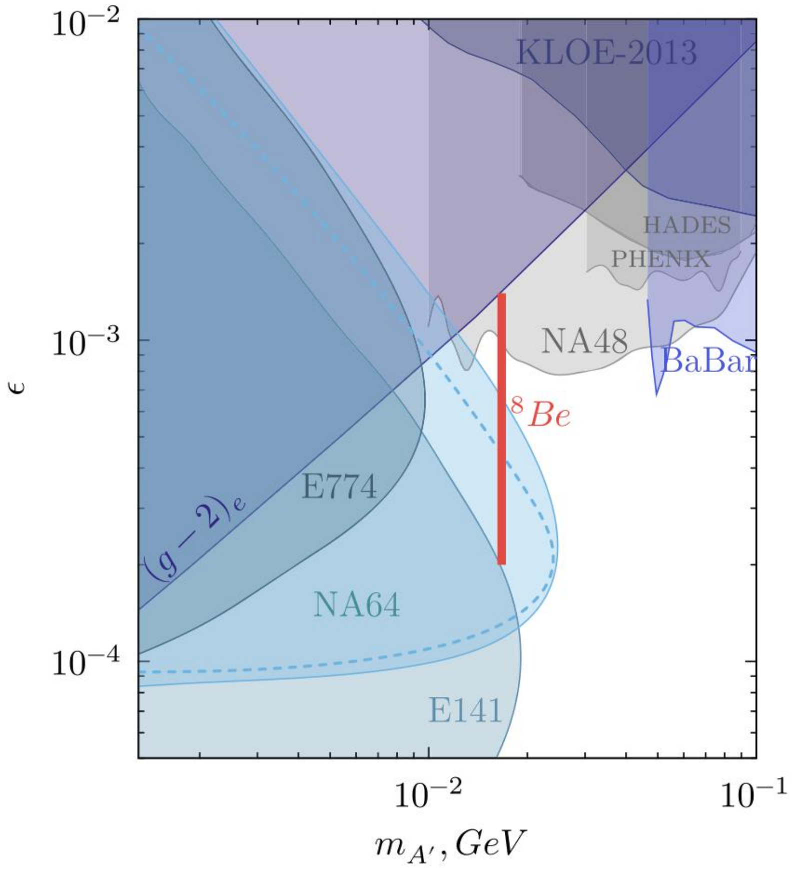
$$\varepsilon_u = -\frac{1}{3}\varepsilon_n \approx \pm 3.7\times 10^{-3},$$

$$\varepsilon_d = \frac{2}{3}\varepsilon_n \approx \mp 7.4\times 1($$

$$2\times 10^{-4} \lesssim |\varepsilon_e| \lesssim 1.4\times 10^{-3}$$

$$|\varepsilon_\nu \varepsilon_e|^{1/2} \lesssim 7\times 10^{-5},$$

NA64 collaboration:
explore the proposal of J. L. Feng et al.



[1] D. Banerjee et al., Phys. Rev. Lett. 120, no.23, 231802 (2018), [arXiv:1803.07748].
[2] Phys. Rev. D 101 (2020) 7, 071101, [arXiv: 1912.11389].
[3] Eur. Phys. J. C (2020) 80:1159, [arXiv: 2009.02756]

[1] J. L. Feng et al., Phys. Rev. Lett. 117, no.7, 071803 (2016), [arXiv:1604.07411].
[2] Phys.Rev.D 95 (2017) 3, 035017 [arXiv:1608.03591].
[3] Phys.Rev.D 102 (2020) 3, 036016 [arXiv: 2006.01151].

1.2 Background on X(17)

Battle: Trump or Biden ?

The Angular Correlations in the e^+e^- Decay of Excited States in 8Be

A.C. Hayes (Los Alamos), J.L. Friar (Los Alamos), GM. Hale (Los Alamos), GT. Garvey (Los
Seattle) (Jun 12, 2021)

e-Print: 2106.06834 [nucl-th]

pdf cite

reexamine angular distribution

"We find that this resonance is dominated by M1 and E1 decay, and that the ratio of M1 to E1 strength is a strong function of energy. This is in contract to the original analysis of the e^+e^- angular distributions, where the M1/E1 ratio was assumed to be a constant over the energy region Ep = 0.8~1.2 MeV. We find that the existence of a 'bump' in the measured angular distribution is strongly dependent on the assumed M1/E1 ratio, with the present analysis finding the measured large-angle contributions to the e^+e^-- angular distribution to be lower than expectation. Thus, in the current analysis we find no evidence for axion decay in the 18.15 MeV resonance region of ^{8}Be."

Can a protophobic vector boson explain the ATOMKI anomaly? #1

Xilin Zhang (Ohio State U.), Gerald A. Miller (Washington U., Seattle) (Aug 25, 2020)

Published in: *Phys.Lett.B* 813 (2021) 136061 • e-Print: 2008.11288 [hep-ph]

pdf DOI cite 11 citations

"The net result is that X production is dominated by direct transitions induced by $E1^X$ and $L1^X$ (transverse and longitudinal electric dipoles) and $C1^X$ (charge dipole) without going through any nuclear resonance (i.e. Bremsstrahlung radiation) with a smooth energy dependence that occurs for all proton beam energies above thresh- old. This contradicts the experimental observations and invalidates the protophobic vector boson explanation."

Can nuclear physics explain the anomaly observed in the internal pair production in the Beryllium-8 nucleus? #2

Xilin Zhang (Washington U., Seattle), Gerald A. Miller (Washington U., Seattle) (Mar 14, 2017)

Published in: *Phys.Lett.B* 773 (2017) 159-165 • e-Print: 1703.04588 [nucl-th]

pdf DOI cite 39 citations

"...We then study the possibility of using the nuclear transition form factor to explain the anomaly."

1.2 Background on X(17)

Battle: Trump or Biden ?

Implications of last NA64 results and the electron $g_e - 2$ anomaly for the X(16.7) boson survival

N.V. Krasnikov (Moscow, INR and Dubna, JINR) (Dec 25, 2019)

Published in: *Mod.Phys.Lett.A* 35 (2020) 15, 2050116 • e-Print: 1912.11689 [hep-ph]

pdf DOI cite 8

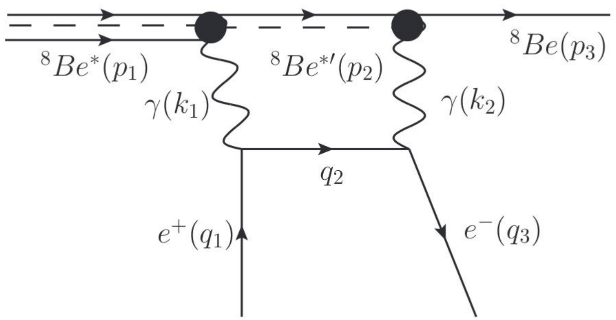
We point out that last NA64 bound on coupling constant of hypothetical X(16.7 MeV) vector boson with electrons plus the recent value of the anomalous electron magnetic moment exclude at 90% C.L. purely vector or axial–vector couplings of X(16.7) boson with electrons. Models with nonzero $V \pm A$ coupling constant with electron survive and they can explain both the electron and muon g−2 anomalies.

X17: A new force, or evidence for a hard $\gamma + \gamma$ process? #1

Benjamin Koch (Chile U., Catolica and Vienna, Tech. U.) (Mar 24, 2020)

Published in: *Nucl.Phys.A* 1008 (2021) 122143 • e-Print: 2003.05722 [hep-ph]

pdf DOI cite 7 citations



Submission history

From: Benjamin Koch [view email]

[v1] Thu, 12 Mar 2020 12:11:55 UTC (165 KB)

[v2] Sat, 14 Mar 2020 22:30:00 UTC (175 KB)

[v3] Tue, 24 Mar 2020 17:28:51 UTC (175 KB)

[v4] Thu, 17 Sep 2020 11:22:28 UTC (299 KB)

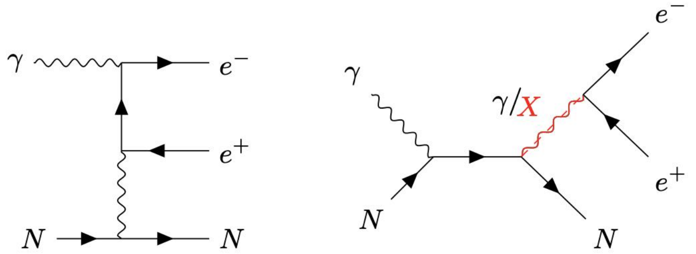
[v5] Thu, 12 Nov 2020 12:05:21 UTC (372 KB)

V1:This would be the first experimental evidence for inelastic scattering of two highly energetic photons.

V5: It is found that the corresponding kinematics fits perfectly to the experimental result. Also the conversion rates of this process are reasonable. **However,** the assumed nuclear chain reaction is not favored in the established nuclear models and no explanation for the isospin structure of the signal can be given. Thus, it has to be concluded that the process studied in this paper does not give a completely satisfying explanation of the "X17 puzzle".

1.2 Background on X(17)

Battle: Trump or Biden ?



X17 discovery potential in the $\gamma N \to e^+e^- N$ process at electron scattering facilities #1

Johannes Backens (Mainz U., Inst. Kernphys. and U. Mainz, PRISMA), Marc Vanderhaeghen (Mainz U., Inst. Kernphys. and U. Mainz, PRISMA) (Oct 12, 2021)

e-Print: 2110.06055 [hep-ph]

pdf cite

Tests of the Atomki anomaly in lepton pair decays of heavy mesons

G. López Castro (CINVESTAV, IPN), Néstor Quintero (Santiago de Cali U. and Tolima U.) (Jan 5, 2021)

Published in: *Phys.Rev.D* 103 (2021) 9, 093002 • e-Print: 2101.01865 [hep-ph]

pdf DOI cite

Decays of <u>D^{*+} and Ds^{*+} mesons can be importantly enhanced</u> relative to the dominant photon-mediated contributions.

And other proposals/explainations ...

We suggest identifying X(17) in **(1) $e^+e^- \to$ X(17) + γ , (2) J/$\psi \to$ X(17)+ γ**, where X(17) is reconstructed by e^+e^- pairs.

- The coupling of X(17) to e^+e^- is a “V - A” type and the coupling parametes are simply set: $\varepsilon_V = \varepsilon_A \in [10^{-3}, 10^{-4}]$.
- The **J/$\psi \to$ X(17)+ γ** could be an ideal channel to explore the spin-0 X hypothesis, since one can distinguish the signal from the background by iden- tifying the ISR photon.

J. Jiang, L. B. Chen, Y. Liang and C. F. Qiao: Eur. Phys. J. C 78, no. 6, 456 (2018), [arXiv:1607.03970]; J. Jiang, H. Yang and C. F. Qiao, Eur. Phys. J. C 79, no. 5, 404 (2019), [arXiv:1810.05790].

1.3 New force mediator search @ BESIII

BESIII experiment works at C.M.S energy 2~4.6 GeV, and has accumulated 10 billion J/Ψ's, 0.5 billion Ψ(3686)'s, 2.9 fb^{-1} at Ψ(3773).

Dark photon (U) search

- $\mathcal{B}(J/\psi \to U'\eta') \times \mathcal{B}(U' \to \pi^0\gamma)$ → [1] $(0.8 - 6.5) \times 10^{-7}$ for $0.2 \leq m_{U'} \leq 2.1$ GeV$/c^2$.
- $J/\psi \to \eta^{(\prime)} U$ followed by $U \to e^+e^-$
- $e^+e^- \to e^+e^-\gamma_{ISR}$ and $e^+e^- \to \mu^+\mu^-\gamma_{ISR}$

[1] arXiv:2002.07486;
[2] PRD 99, 012006 (2019) [arXiv:1810.03091];
[3] PRD 99, 012013 (2019) [arXiv:1809.00635];
[4] PLB 774, 252 (2017).

Upper limts for mixing parameters ε:

[2] $10^{-2} - 10^{-3}$ for $0.01 \leq m'_\gamma \leq 2.4$ GeV$/c^2$

[3] 3.4×10^{-3} to 2.6×10^{-2} for $0.1 < m_{\gamma'} < 2.1$ GeV.

[4] 10^{-3} to 10^{-4} for $1.5 < m_{\gamma'} < 3.4$ GeV.

CP-odd Higgs-like paritcle (A^0) search

- $\psi' \to J/\psi\pi^+\pi^-, J/\psi \to A^0\gamma, A^0 \to \mu^+\mu^-$
- $J/\psi \to A^0\gamma, A^0 \to \mu^+\mu^-$

[5] PRD 85, 092012 (2012);
[6] PRD 93, 052005 (2016);
[7] arXiv: 2109.12625.

Upper limts for the product-branching fractions of $J/\psi \to A^0\gamma, A^0 \to \mu^+\mu^-$:

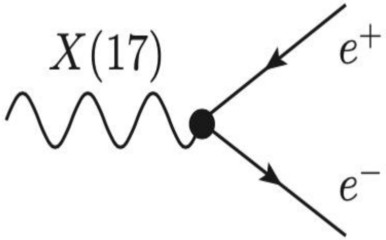
[5] 4×10^{-7} near threshold to 2.1×10^{-5} near 3 GeV

[6] $(2.8 - 495.3) \times 10^{-8}$ for $0.212 \leq m_{A^0} \leq 3.0$ GeV$/c^2$

[7] $(1.2 - 778.0) \times 10^{-9}$ for $0.212 \leq m_{A^0} \leq 3.0$ GeV$/c^2$.

2 Constrains on Xe^+e^- Coupling

2.1 Lagrangian added to Standard Model



Mixing of V & A: $$\mathcal{L}_X = -\frac{1}{4}X_{\mu\nu}X^{\mu\nu} + \frac{1}{2}m_X^2 X_\mu X^\mu - \sum_f e\bar{f}\gamma_\mu(\varepsilon_f^v - \varepsilon_f^a\gamma_5)fX^\mu$$

The combination of latest NA64 experiment and recent value of the electron anomalous magnetic momentum exclude the pure vector and axial-vector couplings of X(17) boson to electrons at the 90% C.L., but the model with “V ± A” interaction still survives and can further explains both the electron and muon anomalous magnetic momentum.

N. V. Krasnikov, Mod.Phys.Lett.A 35 (2020) 15, 2050116 [arXiv:1912.11689].

2.2 Constrains on Xee coupling from experiments

- Two Atomki experiments

A. J. Krasznahorkay et al., Phys. Rev. Lett. 116, no.4, 042501 (2016) [arXiv:1504.01527].

2016 $m_X = 16.7 \pm 0.35(\text{stat.}) \pm 0.5(\text{sys.})$ MeV,

$$\frac{\Gamma\left({}^8Be^* \to {}^8 BeX\right)\mathrm{Br}\left(X \to e^+e^-\right)}{\Gamma\left({}^8Be^* \to {}^8 Be\gamma\right)} = 5.8 \times 10^{-6}.$$

With $\Gamma({}^8Be^* \to {}^8Be\gamma) = 1.9 \pm 0.4\ eV$ $\quad Br(X \to e^+e^-) \approx 1$

Tilley et al., Nucl. Phys. A 745, 155 (2004).

We obtain $\Gamma({}^8Be^* \to {}^8BeX) = (1.1 \pm 0.23) \times 10^{-5}\ eV$

With J^P of ^{8}Be*: 1^+, J^P of ^{8}Be: 0^-, we have **J^P of X(17): 1^+ or 0^-** with orbital angular momentum L=0 or 1, respectively.

Decay length

$$L = \frac{\hbar \times c}{\Gamma(X \to e^+e^-)} \times \frac{v}{\sqrt{1-v^2}},$$

$$\Gamma(X \to e^+e^-) \approx \frac{\alpha m_X}{3}\left((\varepsilon_e^v)^2 + (\varepsilon_e^a)^2\right),$$

$$\mathcal{O}\left(\frac{m_e^2}{m_X^2}\right) \approx 0.1\%$$

Requiring L < 1 cm gives $\quad (\varepsilon_e^v)^2 + (\varepsilon_e^v)^2 \gtrsim 1.8 \times 10^{-10}$

2 Constrains on Xe^+e^- Coupling

- Two Atomki experiments

2019

$$m_X = 16.84 \pm 0.16(\text{stat}) \pm 0.20(\text{sys}) \ \text{MeV},$$

$$\frac{\Gamma\left({}^4He^* \to {}^4 HeX\right) \text{Br}\left(X \to e^+e^-\right)}{\Gamma\left({}^4He^* \to {}^4 He\gamma\right)} = 0.118.$$

A. J. Krasznahorkay et al., arXiv:1910.10459.

With $\Gamma({}^8He^* \to \ {}^8He\gamma) = (3.3 \pm 1) \times 10^{-4} \ eV$ $\quad Br(X \to e^+e^-) \approx 1$

T. Walcher, Phys. Lett. B 31, 442-444 (1970).

We obtain $\Gamma({}^8He^* \to \ {}^8HeX) = (3.9 \pm 1.2) \times 10^{-5} \ eV$

With J^P of ^{8}He*: 0^-, J^P of ^{8}He: 0^+, we have **J^P of X(17): 1^+ or 0^-** with orbital angular momentum L=1 or 0, respectively. **Same implications with the Be experiment.**

Decay length

Requiring L < 1 cm gives $\boxed{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2 \gtrsim 3. \times 10^{-10}}$

2 Constrains on Xe^+e^- Coupling

■ Electron anomalous magnetic momentum

The new force mediator X(17) will contibute to the electron anomalous magnetic momentum (AMM).

The latest improved fine structure constant

$$\alpha^{-1} = 137.035999046(27)$$

R. H. Parker et al., Science 360, 191 (2018). [arXiv:1812.04130].
H. Davoudiasl and W. J. Marciano, Phys. Rev. D 98, no. 7, 075011 (2018), [arXiv:1806.10252].

leads to 2.4σ discrepancy of electron AMM

$$\Delta a_e \equiv a_e^{\mathrm{exp}} - a_e^{\mathrm{SM}} = (-0.87 \pm 0.36) \times 10^{-12},$$

The X(17) boson would contribute to electron AMM of Δa_e through the leading one-loop triangle diagram

$$a_e^X = \frac{\alpha}{3\pi}\left(\frac{m_e}{m_X}\right)^2\left[(\varepsilon_e^v)^2 - 5(\varepsilon_e^a)^2\right].$$

J. P. Leveille, Nucl. Phys. B 137, 63-76 (1978).

Requiring that this contribution can diminish the 2.4σ discrepancy between the measurement and SM prediction

$$\boxed{(-1.2 \pm 0.5) \times 10^{-6} \lesssim (\varepsilon_e^v)^2 - 5(\varepsilon_e^a)^2 \lesssim 0}$$

The pure vector hypothesis of X(17) boson will enlarge the discrepancy of electron AMM!

2 Constrains on Xe^+e^- Coupling

- Beam dumb experiments

Bremsstrahlung reaction $e^- Z \rightarrow e^- Z X$, X(17) is produced by initial or final state radiation off a single electron.

Within the errors of $\mathcal{O}\left(\frac{m_e^2}{m_X^2}\right) \approx 0.1\%$, the production rate depends on the coupling parameters only through the argument $(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2$

Recently, the NA64 collaboration searched for the X(17) boson twice and set limits on the Xee coupling parameter ε_e, i.e., $\sqrt{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2}$ at the 90% C. L.

D. Banerjee et al., Phys. Rev. Lett. 120, no.23, 231802 (2018), [arXiv:1803.07748].
D. Banerjee et al., Phys. Rev. D 101 (2020) 7, 071101, [arXiv: 1912.11389].

Excluded region: $1.3 \times 10^{-4} < \sqrt{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2} < 4.2 \times 10^{-4}$

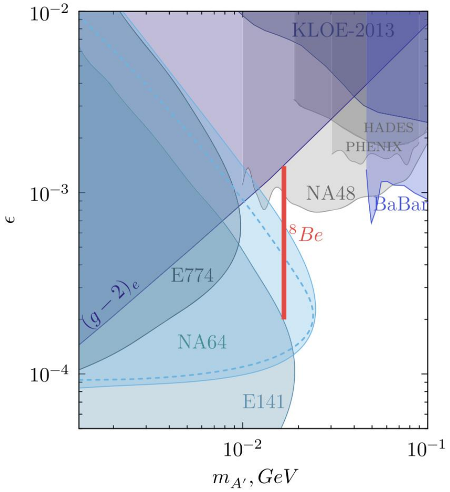
Excluded region: $1.2 \times 10^{-4} < \sqrt{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2} < 6.8 \times 10^{-4}$
(2017&2018 data combined)

Around 17 MeV, E137, E144 Beam dumb experimets **Excluded region**:

$$8 \times 10^{-8} < \sqrt{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2} < 3 \times 10^{-4}$$

Survival region (lower limit):

$$\boxed{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2 \gtrsim 4.6 \times 10^{-7}}$$



- KLOE-2 experiment

The KLOE-2 experiment searched for a low-mass vector boson U in $e^+e^- \to U\gamma,\ U \to e^+e^-$ and set a upper bound on Xee coupling around 17 MeV at the 90% C. L.,

$$\boxed{(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2 \lesssim 4 \times 10^{-6}}$$

Within the errors of $\mathcal{O}\left(\frac{m_e^2}{m_X^2}\right) \approx 0.1\%$, the production rate depends on the coupling parameters only through the argument $(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2$

- Survival regions for Xe⁺e⁻ coupling

Combining above constrains,

Beam dumb experiments

KLOE-2 experiment

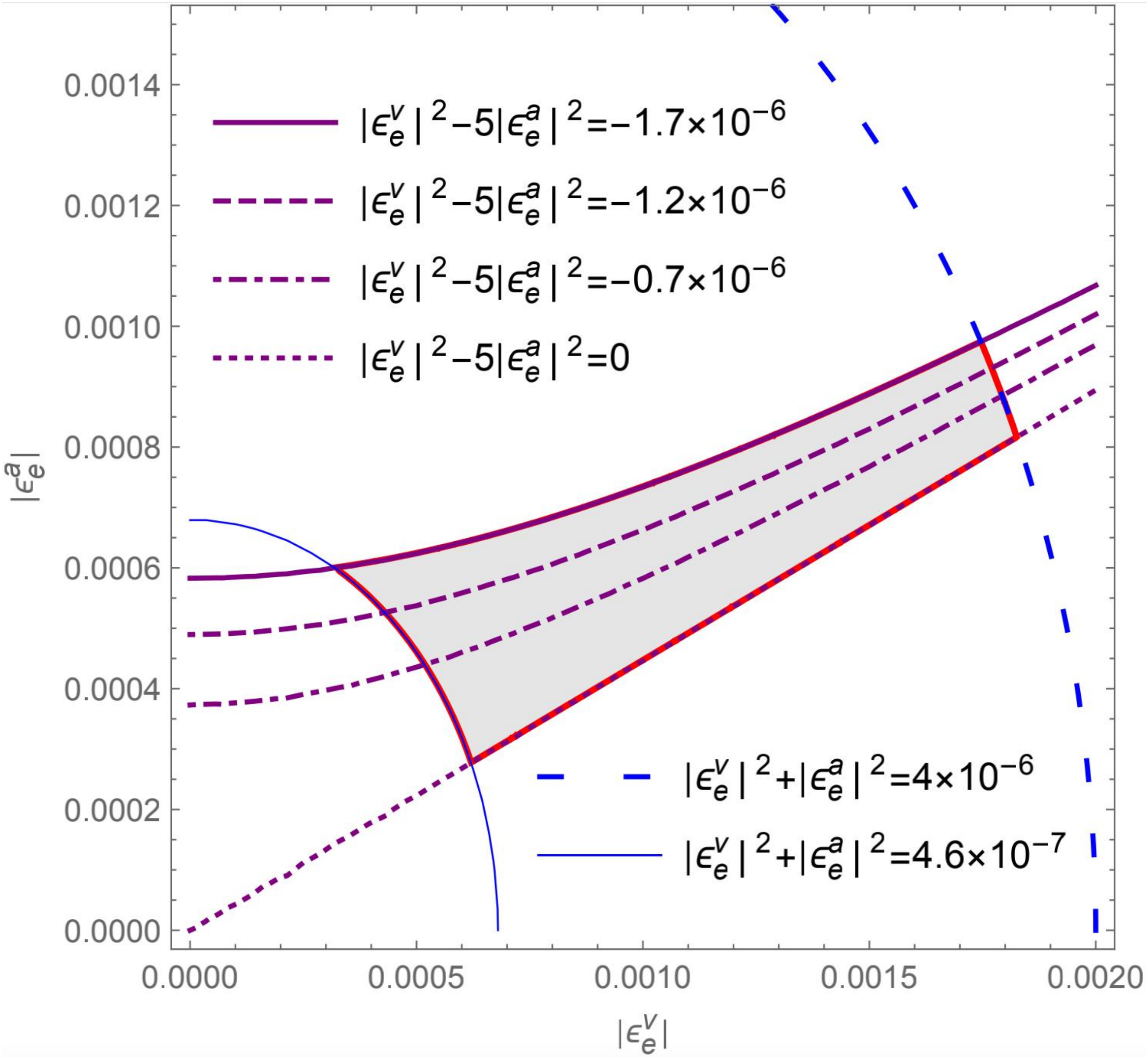
$$\begin{aligned} 4.6\times10^{-7} \lesssim (\varepsilon_e^v)^2 + (\varepsilon_e^a)^2 \lesssim 4\times10^{-6}, \\ (-1.2\pm0.5)\times10^{-6} \lesssim (\varepsilon_e^v)^2 - 5(\varepsilon_e^a)^2 \lesssim 0, \end{aligned}$$

Electron AMM.

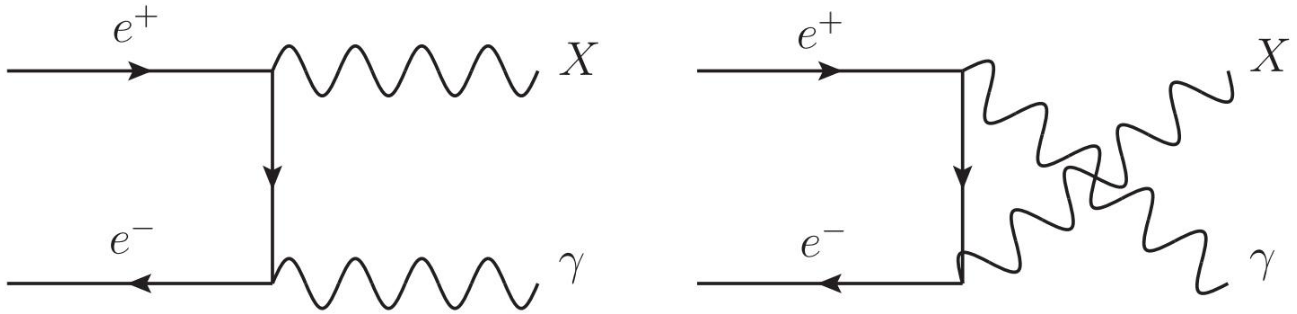
Pure V hypothesis: disfavored by Electron AMM.
Pure A hypothesis:

$$6.8\times10^{-4} \lesssim |\varepsilon_e^a| \lesssim (4.9\pm3.2)\times10^{-4}.$$

Upper and lower bounds almost overlap with each other.



3.1 X(17) + γ **production**



Within the errors of $\mathcal{O}\left(\frac{m_e^2}{m_X^2}\right) \approx 0.1\%$, the differential cross section depends on the coupling parameters only through the argument $(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2$

$$\frac{d\sigma}{d\cos\theta} = \frac{2\pi\alpha^2}{s}\left((\varepsilon_e^v)^2 + (\varepsilon_e^a)^2\right)\left(\frac{1+cos^2\theta}{1-cos^2\theta}\right) + \mathcal{O}\left((\frac{m_e}{m_X})^2, (\frac{m_X}{\sqrt{s}})^2, (\frac{m_e}{\sqrt{s}})^2\right).$$

The integrated cross section:

$$\sigma = \frac{4\pi\alpha^2}{s}\left((\varepsilon_e^v)^2 + (\varepsilon_e^a)^2\right)\left(\mathrm{Log}[\frac{s}{m_e^2}] - 1\right) + \mathcal{O}\left((\frac{m_e}{m_X})^2, (\frac{m_X}{\sqrt{s}})^2, (\frac{m_e}{\sqrt{s}})^2\right).$$

The leading order results are the argument $(\varepsilon_e^v)^2 + (\varepsilon_e^v)^2$ times the differential and total cross sections of $e^+e^- \to \gamma\gamma$

3.1 X(17) + γ production

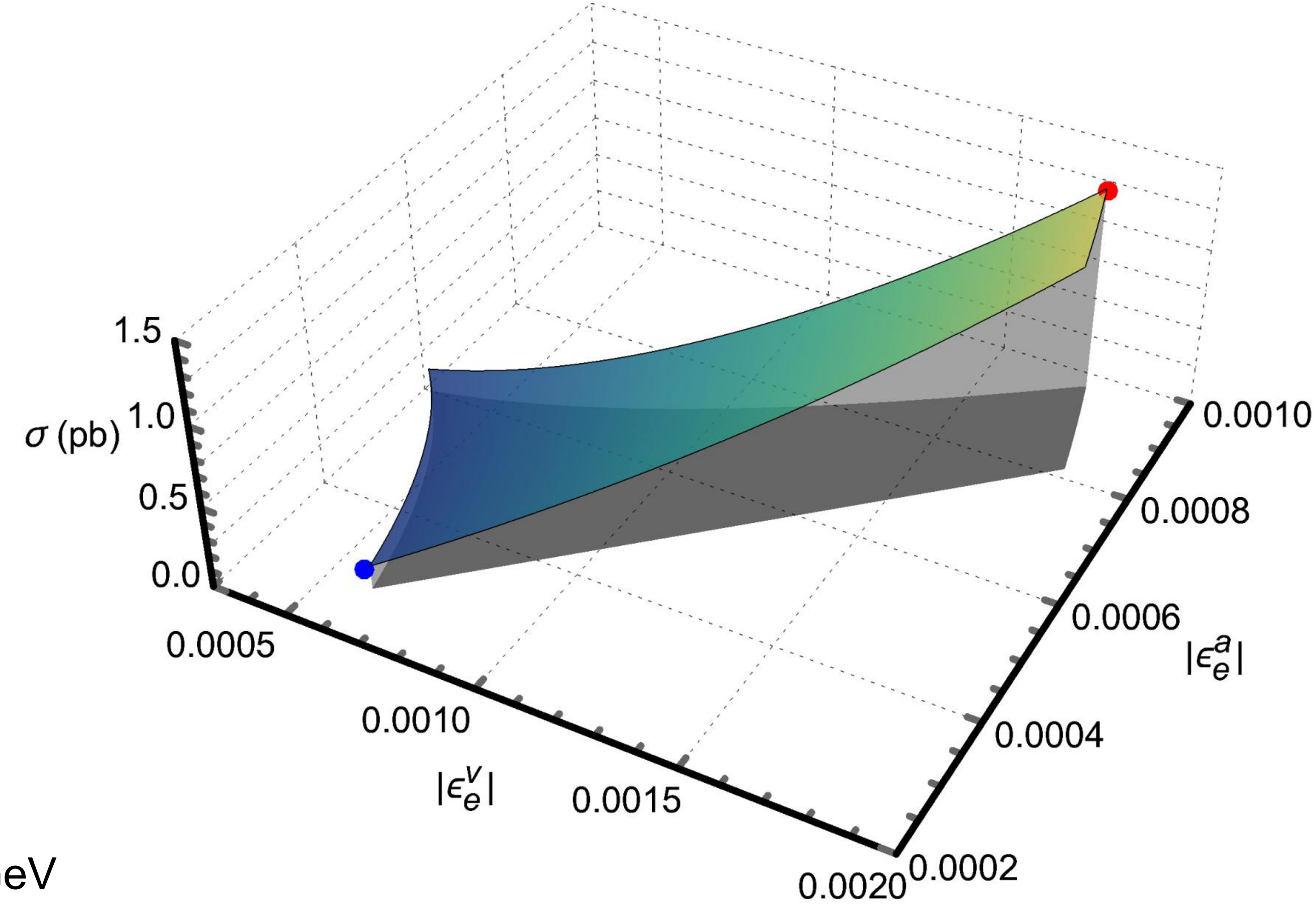
At c.m.s energy $\sqrt{s}$ = 3.7 GeV, and coupling parameters constraind by experiments,the integrated cross section:

$$0.144 \text{ pb} \lesssim \sigma(e^+e^- \to X\gamma) \lesssim 1.28 \text{ pb}.$$

The maximum and minimum cross sections are located at the coupling points

$$(|\varepsilon_e^v|, |\varepsilon_e^a|) = (1.8, 0.97) \times 10^{-3}$$

$$(|\varepsilon_e^v|, |\varepsilon_e^a|) = (0.61, 0.27) \times 10^{-3}$$



Given the luminosity of BESIII at $\sqrt{s}$ = 3.7 GeV $\mathcal{L} = 10^{33} cm^{-2} s^{-1} \approx 10^4 pb^{-1} year^{-1}$ and BESIII cover 93% solid angle, we roughly estimate $(1.3 \sim 12) \times 10^3$ X(17) events per year.

3.2 **Reconstruction** of X(17) in $X \to e^+e^-$ decay

- $X \to e^+e^-$ decay

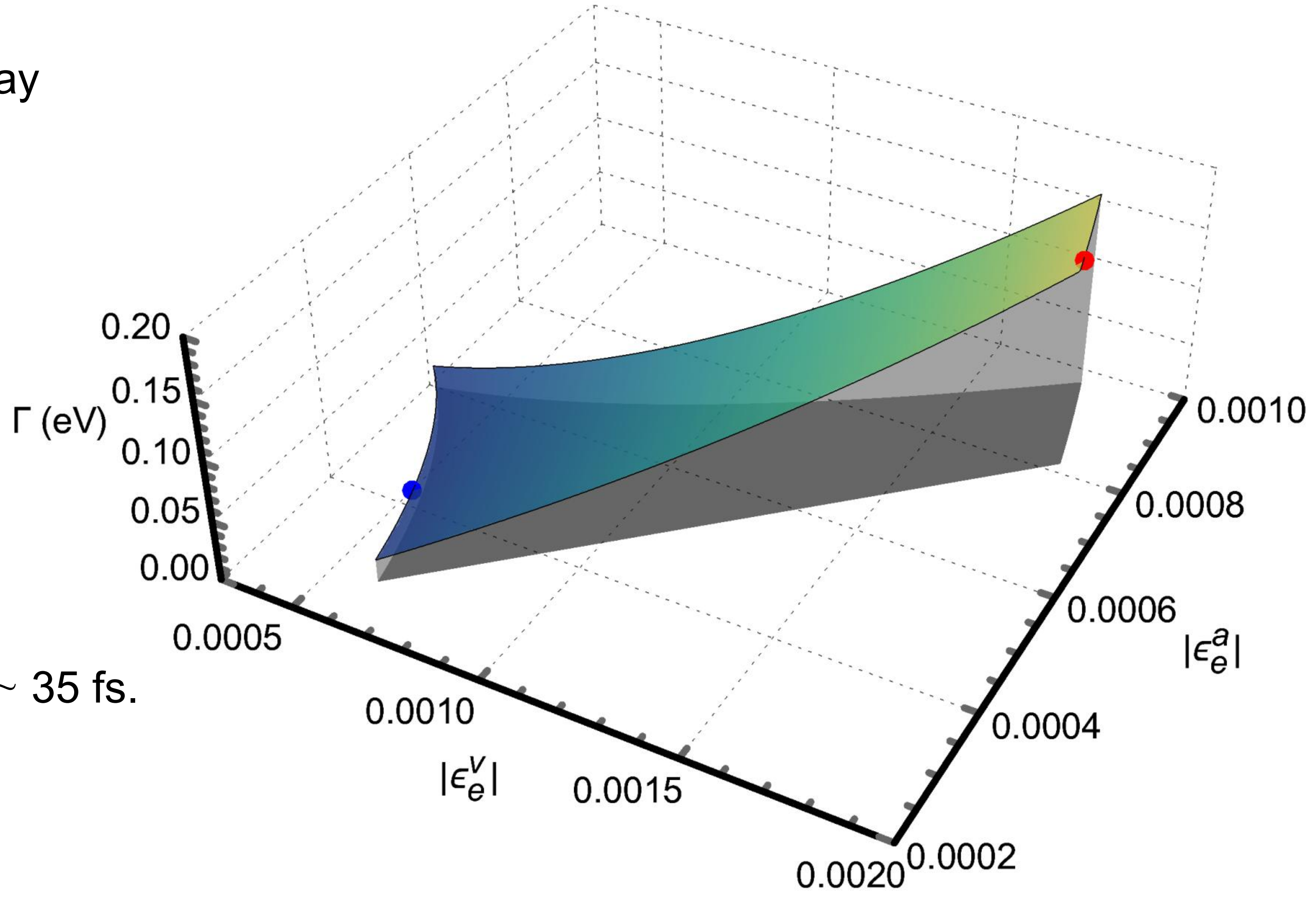
The decay width,

$$0.0189\ \text{eV} \lesssim \Gamma(X \to e^+e^-) \lesssim 0.166\ \text{eV}.$$

The maximum and minimum are located at

$$(|\varepsilon_e^v|, (|\varepsilon_e^a|) = (1.8, 0.84) \times 10^{-3}$$
$$(|\varepsilon_e^v|, (|\varepsilon_e^a|) = (0.55, 0.39) \times 10^{-3}$$

Assuming $Br(X \to e^+e^-) \approx 1$
the the lifetime of X(17) boson would be 4.0 ~ 35 fs.



In e^+e c.m.s., X travels with

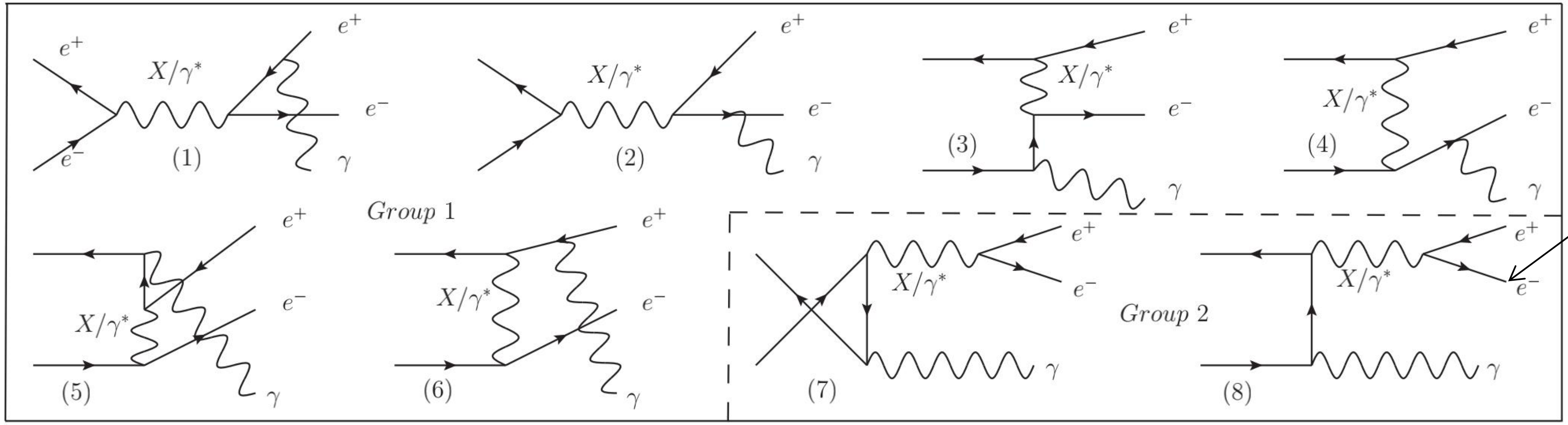
$$v = \frac{|\vec{p}_X|}{\sqrt{|\vec{p}_X|^2 + m_X^2}} \quad |\vec{p}_X| = E_\gamma = \frac{s - m_X^2}{2\sqrt{s}}$$

This boosts the lifetime of X(17) at $\sqrt{s}$ = 3.7 GeV by about two orders to 0.43 ~ 3.8 ps.

This gives the decay length of X(17): L ≈ (0.13 ~ 1.1) mm, which implies X created at the primary vertex in BESIII chamber.

3.2 Reconstruction of X(17) in X → e^+e^- decay

- Identify X in $e^+e^- \to e^+e^-\gamma$



Signal diagrams of Group 2 dominate near the resonance due to the tiny decay width in the Breit-Wigner propagator for X(17).

The differential cross section of $e^+(p_a)e^-(p_b) \to e^+(p_1)e^-(p_2)\gamma(p_3)$ can be formulated as

$$d\sigma = \frac{1}{4\sqrt{(p_a\cdot p_b)^2 - m_e^4}} \bar{\sum} |\mathcal{M}_{\rm sg} + \mathcal{M}_{\rm bg}|^2 \, d\Phi_3,$$

where $\bar{\sum}$ stands for the average on initial spins and sum over final spins, $\mathcal{M}_{\rm sg}$ and $\mathcal{M}_{\rm bg}$ are the amplitudes of the signal and background Feynman diagrams respectively, and $d\Phi_3$ is the three-particle phase space.

3.2 Reconstruction of X(17) in X → e^+e^- decay

- Identify X in $e^+e^- \to e^+e^-\gamma$

The differential distribution vs the invariant mass of e^+e^-

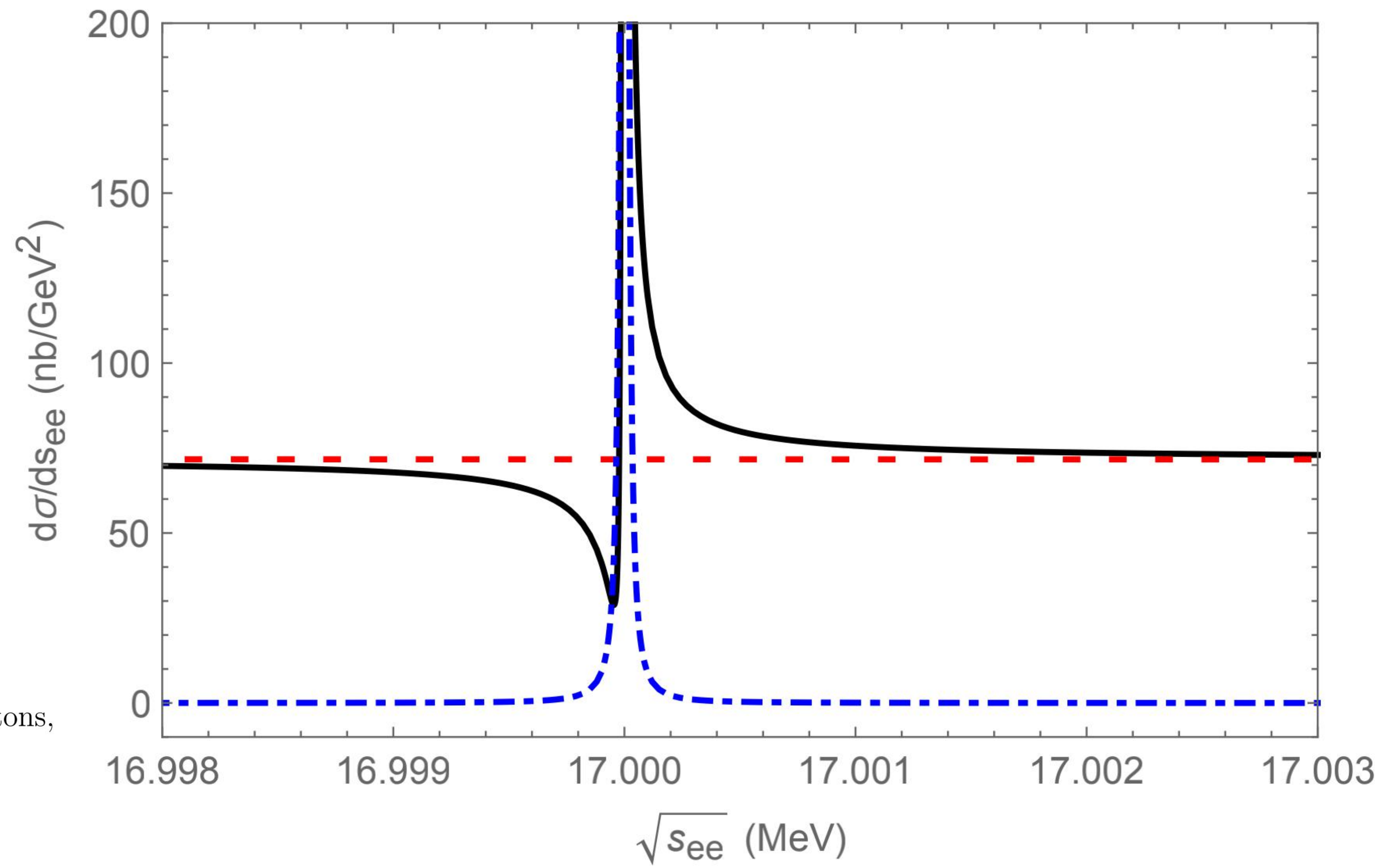
The coupling parameters for maximum cross section of $X\gamma$ are adopted,

$$(|\varepsilon_e^v|, |\varepsilon_e^a|) = (1.8, 0.97) \times 10^{-3}$$

The basic BESIII cuts are also assumed,

$|cos\alpha| < 0.93$ for electrons/positrons,

$|cos\alpha| < 0.8$ and $E_\gamma > 25$ MeV for photons,



3.2 Reconstruction of X(17) in X → e^+e^- decay

- Identify X in $e^+e^- \to e^+e^-\gamma$

The energy resolution at 20 MeV: $\delta(E)/E = 9\%$ $\quad \delta(17MeV) \approx 1.5MeV$

M. Ablikim et al., Nucl. Instrum. Meth. A 614 (2010), 345-399, [arXiv:0911.4960]

Energy resolution (MeV)	1	1.5	3
Mass ranges (MeV)	[14, 20]	[12.5, 21.5]	[8, 26]
B ($\times 10^4$ year^{-1})	14.8	22.5	48.8
S ($\times 10^4$ year^{-1})	1.2 (0.13)		
$S/\sqrt{S+B}$	30 (3.4)	25 (2.7)	17 (1.9)

For the Gaussian distribution, 3σ deviation away from the expectation account for 99.73% of the set.

Values outside (inside) the parentheses are for the maximum (minimum) events in $e^+e^- \to X\gamma$.

The SNR differs by one order of magnitude at the maximum and minimum coupling points.

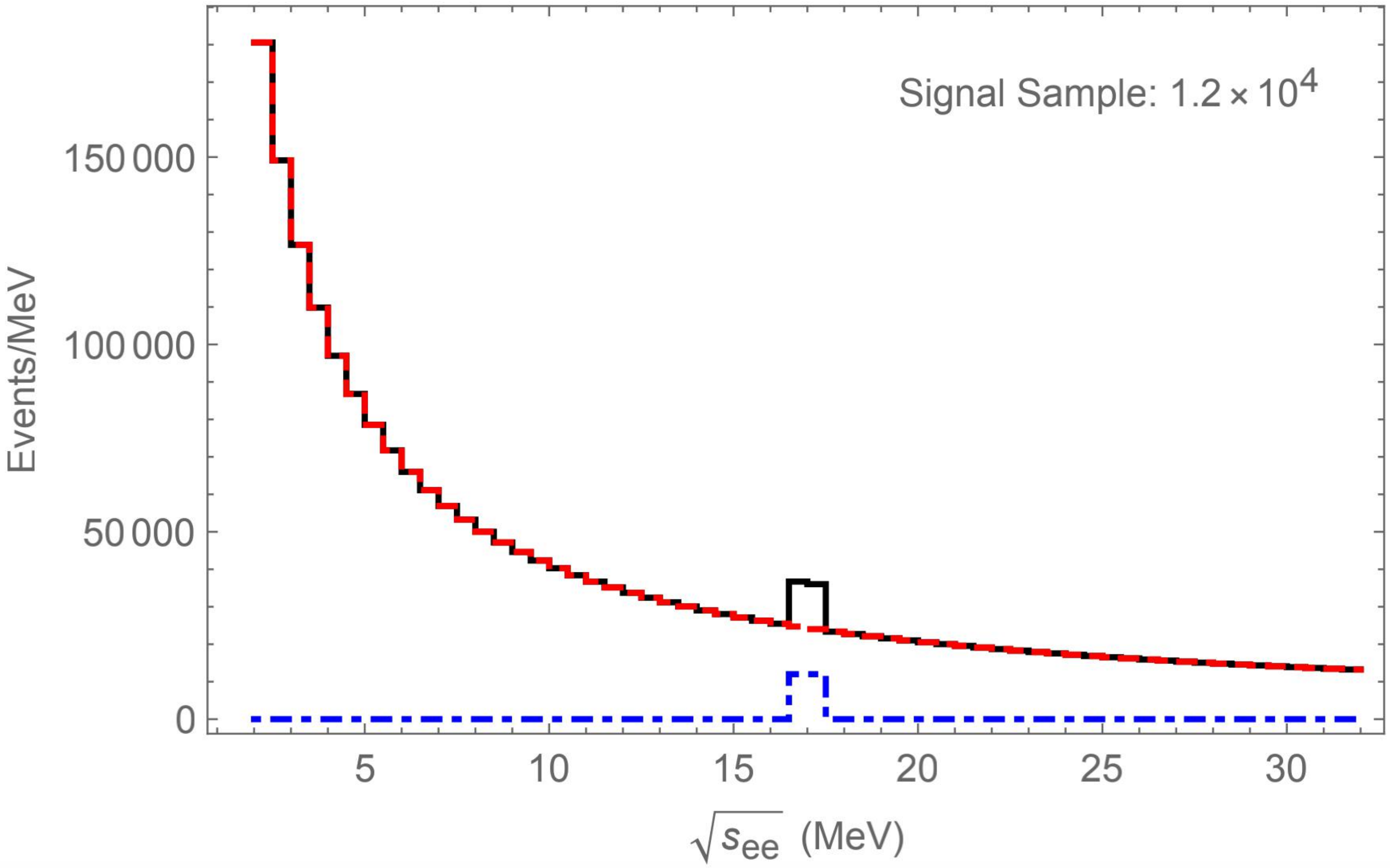
3.2 Reconstruction of X(17) in $X \to e^+e^-$ decay

- Identify X in $e^+e^- \to e^+e^-\gamma$

The invariant mass spectrum distribution **before smearing**

The bin size: 0.5 MeV
Maximum Sample: 1.2×10^4

If the minimum sample (0.13×10^4) was adopted, the height of X(17) bump will be about 10% of that and become a shoulder unless we adopt smaller bin size.



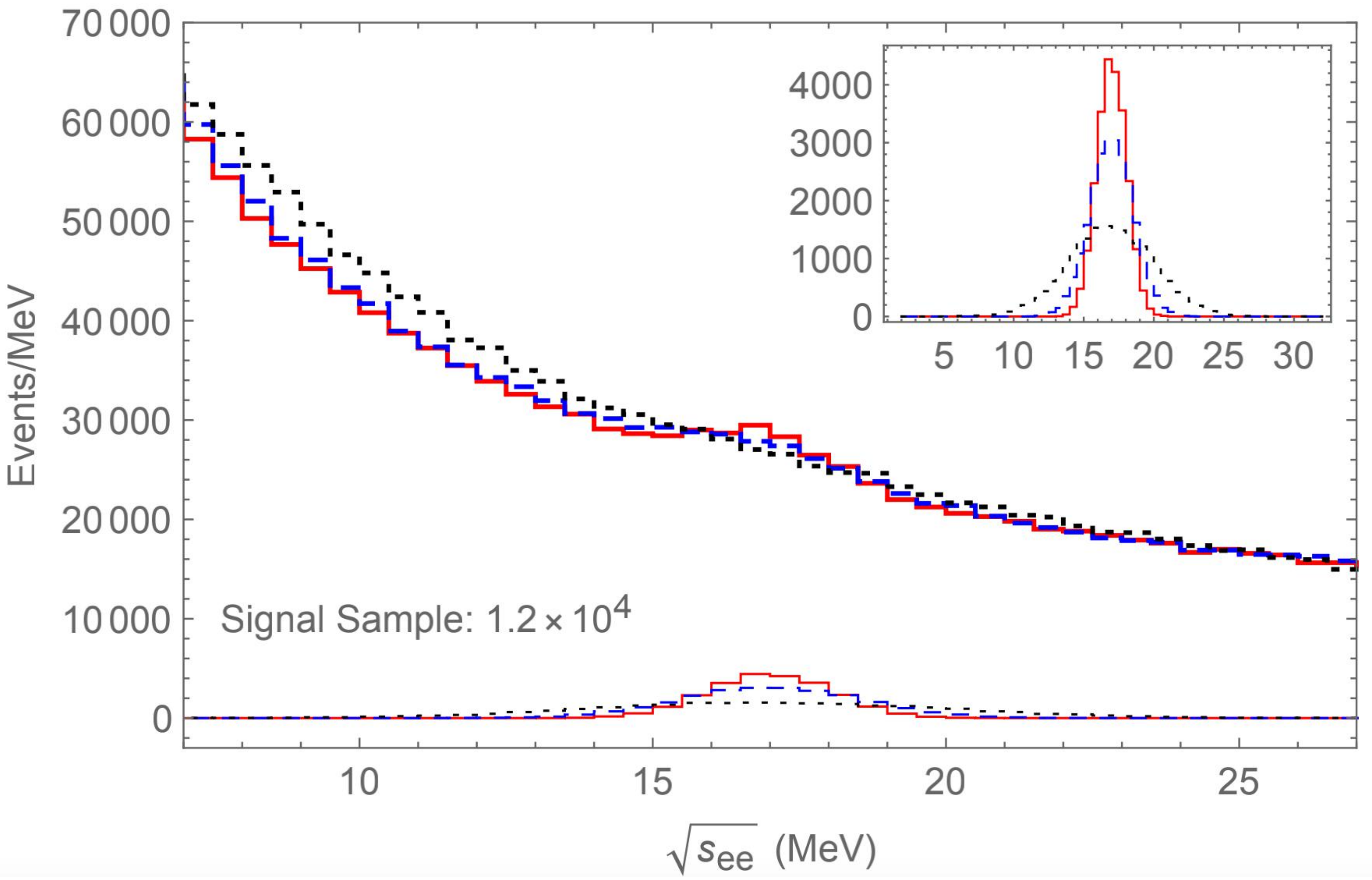
3.2 Reconstruction of X(17) in $X \to e^+e^-$ decay

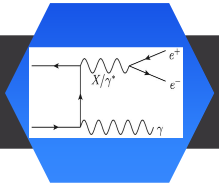
- Identify X in $e^+e^- \to e^+e^-\gamma$

The invariant mass spectrum distribution **After smearing**

The bin size: 0.5 MeV
Maximum Sample: 1.2 × 10⁴
Energy resolutions: 1, 1.5, 3 MeV

Only the 93% coverange of solid angle is considered. The efficiencies etc. are not taking into account. Modifying the bin size will not make the bump sharper after smearing.





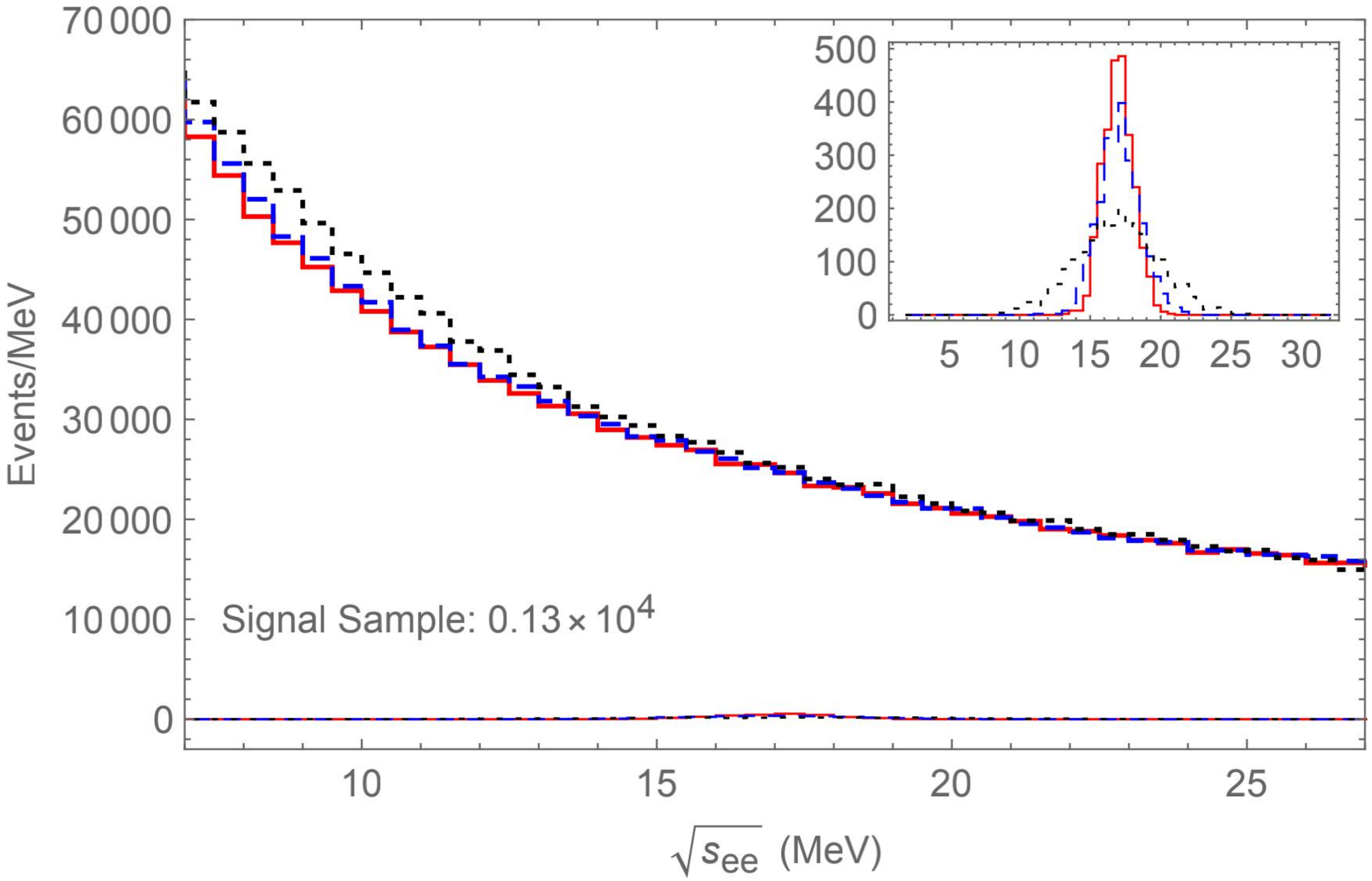
3.2 Reconstruction of X(17) in $X \to e^+e^-$ decay

- Identify X in $e^+e^- \to e^+e^-\gamma$

The invariant mass spectrum distribution **After smearing**

The bin size: 0.5 MeV
Minimum Sample: 0.13×10^4
Energy resolutions: 1, 1.5, 3 MeV

The height of the bump decreases by about 90% in comparison with the maximum sample, and we can not identify the X(17) signals over the background events.



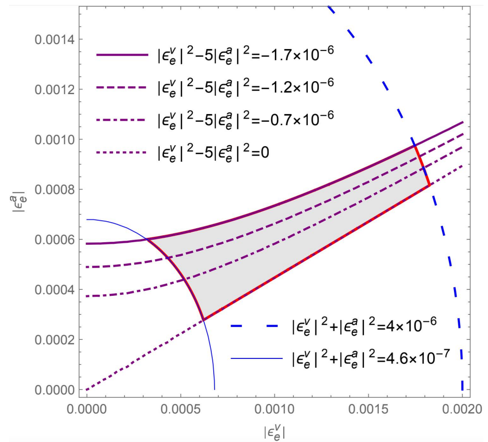
- The ^{8}Be/^{4}He anomalies reported by Atomki experiments can be explained by introducing the X(17) boson with “Vector ± Axial-vector” (V ± A) interaction with quarks and leptons.

- With the exiting experimental data, we give the **constrains on the couplings of X(17) to the first generation of leptons** within this V ± A model.

✓ Under the constrains, we revisit the X(17) production accompanied by a photon at BESIII experiment, where X(17) is reconstructed by e^+e^- mass spectrum.

✓ The **SNR**, the **invariant mass spectrum distribution before and after smearing** within maximum and minimum samples are analyzed.

✓ BESIII experiment has the ability to give a decisive conclusion on X(17) by confirm or exclude the constrain region of X(17).



Thank You!

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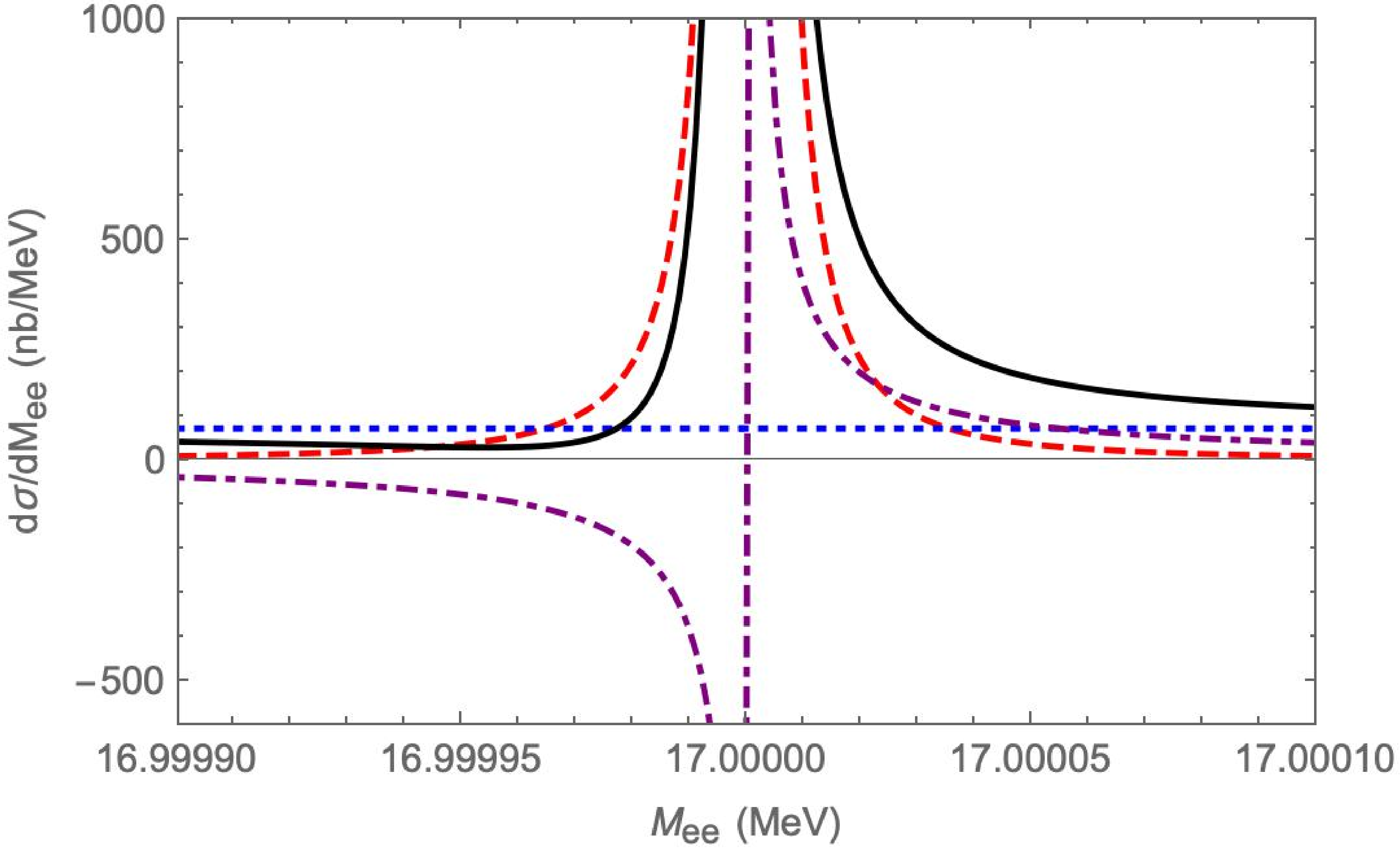
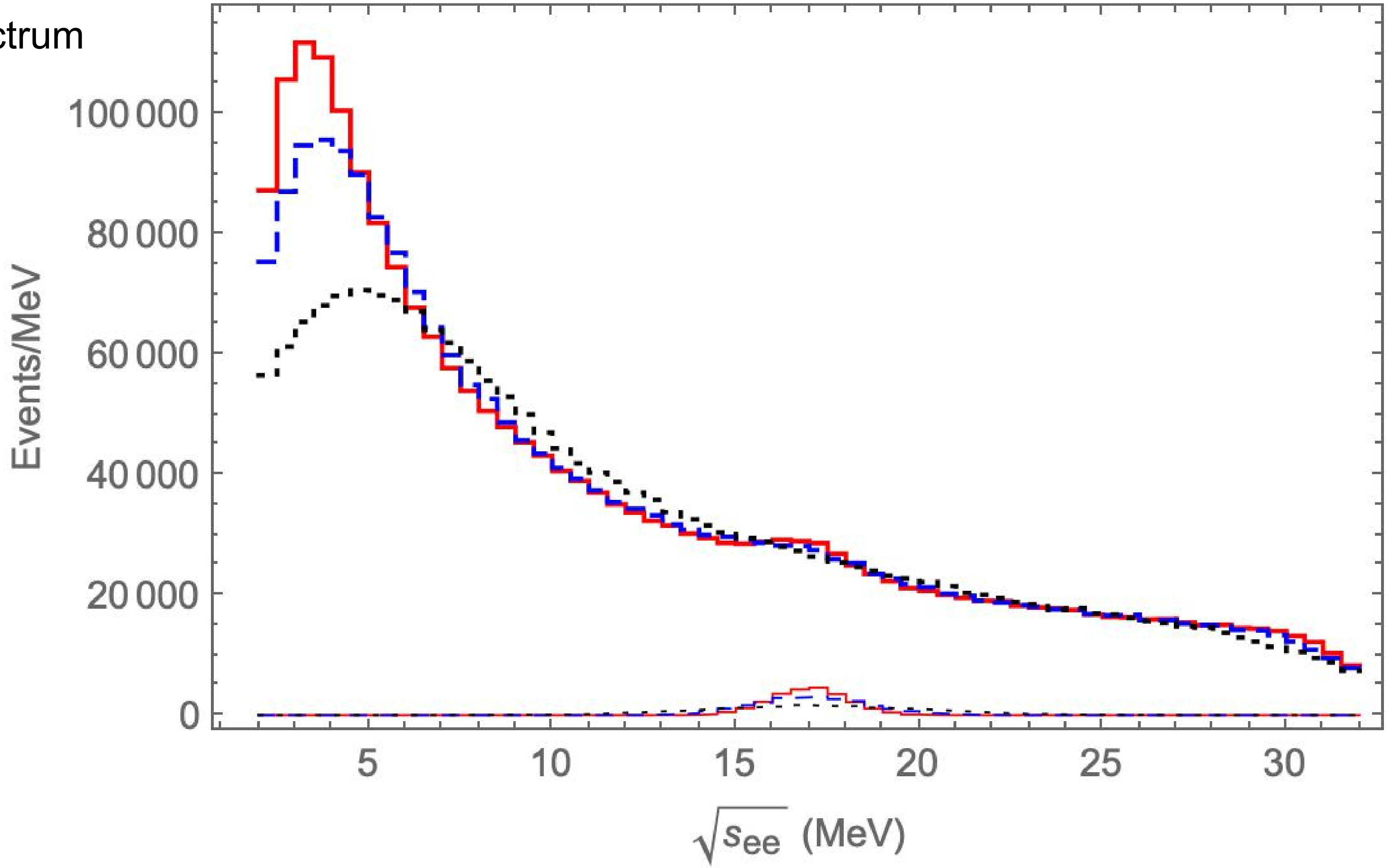
Shandong University
2021-11-05 @ 青岛

1. The differential distribution vs the invariant mass of e^+e^-



2. The invariant mass spectrum distribution After smearing (**maximum sample**)



3. The invariant mass spectrum distribution After smearing (**minimum sample**)