Recent results on hyperon pair production and nucleon time-like form factors at BESIII

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ON BEHALF OF BESIII COLLABORATION

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BESIII Collaboration

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and nucleon time-like form factors at BESIII

16/July/2021
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50th International Symposium
on Multiparticle Dynamics (ISMD2021)

- The BESIII experiment

- Experimental results
  Nucleon electromagnetic form factors

- Experimental results
  Hyperon pair production

- Summary

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Beijing Electron-Positron Collider (started in 1984, first operation in 1989, upgrade to BEPCII in 2008)
BEPCII is a double ring machine with beam energy tunable (RECORD ECM 4.946 GeV in feb 2021)

Chin.Phys.C 44 (2020) 4, 040001

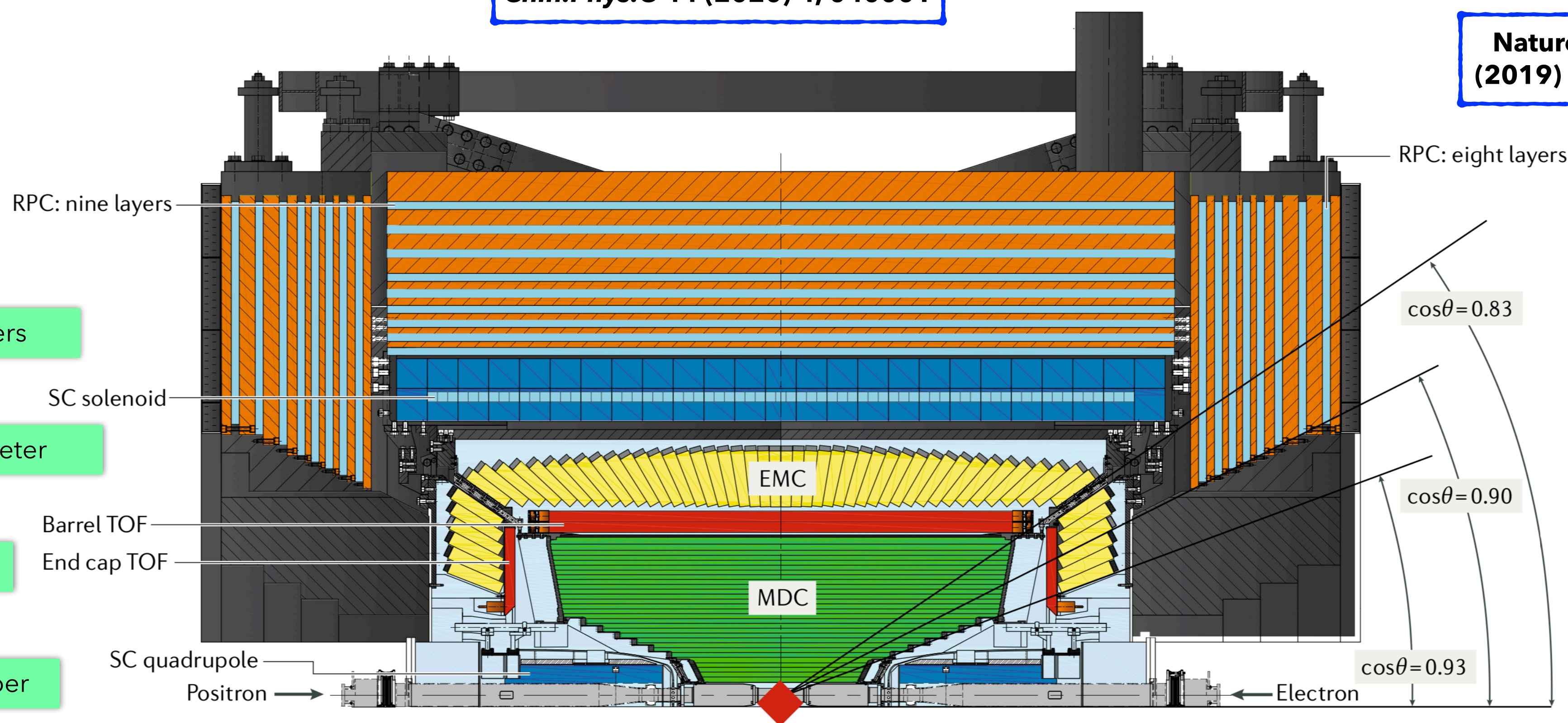**Nature Rev.Phys. 1 (2019) no.8, 480-494**

Solid angle:
93% of 4π
covered

Resistive Plate Chambers

Electromagnetic calorimeter

Time-Of-Flight

Multi-layer Drift Chamber

RPC: nine layers

RPC: eight layers

SC solenoid

EMC

Barrel TOF

End cap TOF

MDC

SC quadrupole

Positron

Electron

$\cos\theta = 0.83$

$\cos\theta = 0.90$

$\cos\theta = 0.93$

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Physics program:

⬤ Tests of electroweak interactions

⬤ Studies of light hadron spectroscopy and decay properties

⬤ Studies of the production and decay properties of the main charmonia

⬤ Studies of charm and τ-physics

⬤ Search for glueballs, quark-hybrids, multi-quark states and other exotic states

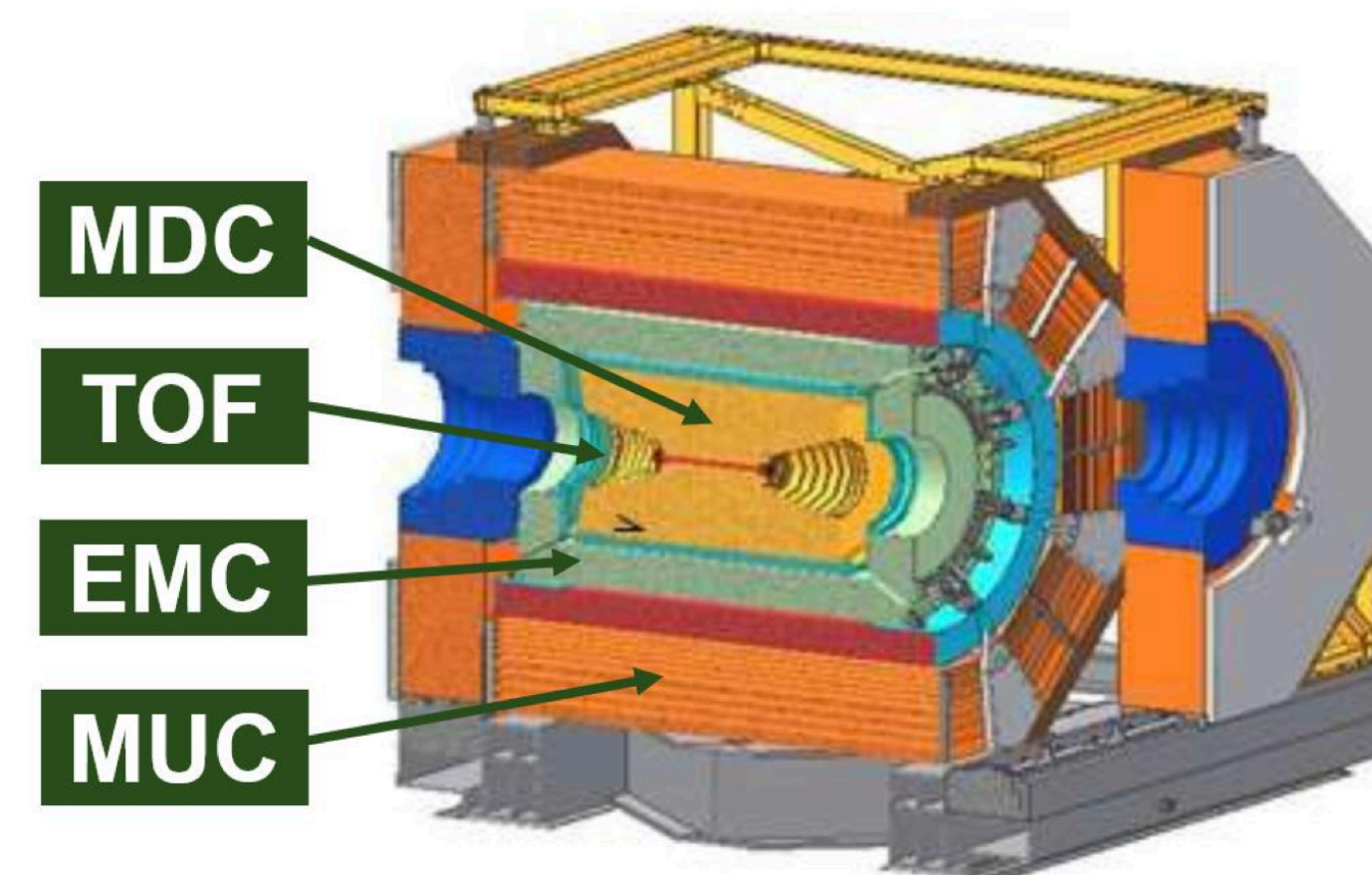⬤ Precision measurements of QCD and CKM parameters and search for new physics

About 500 members
78 institution
16 countries

BESIII Detector

MDC

TOF

EMC

MUC

Remarkable results:

☑ BESIII accumulates 10 billion J/ψ events (2019-02-11)

☑ BESIII observes polarization of baryons in J/ψ decay (2019-05-07)

(based on 1.3 billions of J/ψ)   **Nature Phys. 15 (2019) 631-634**

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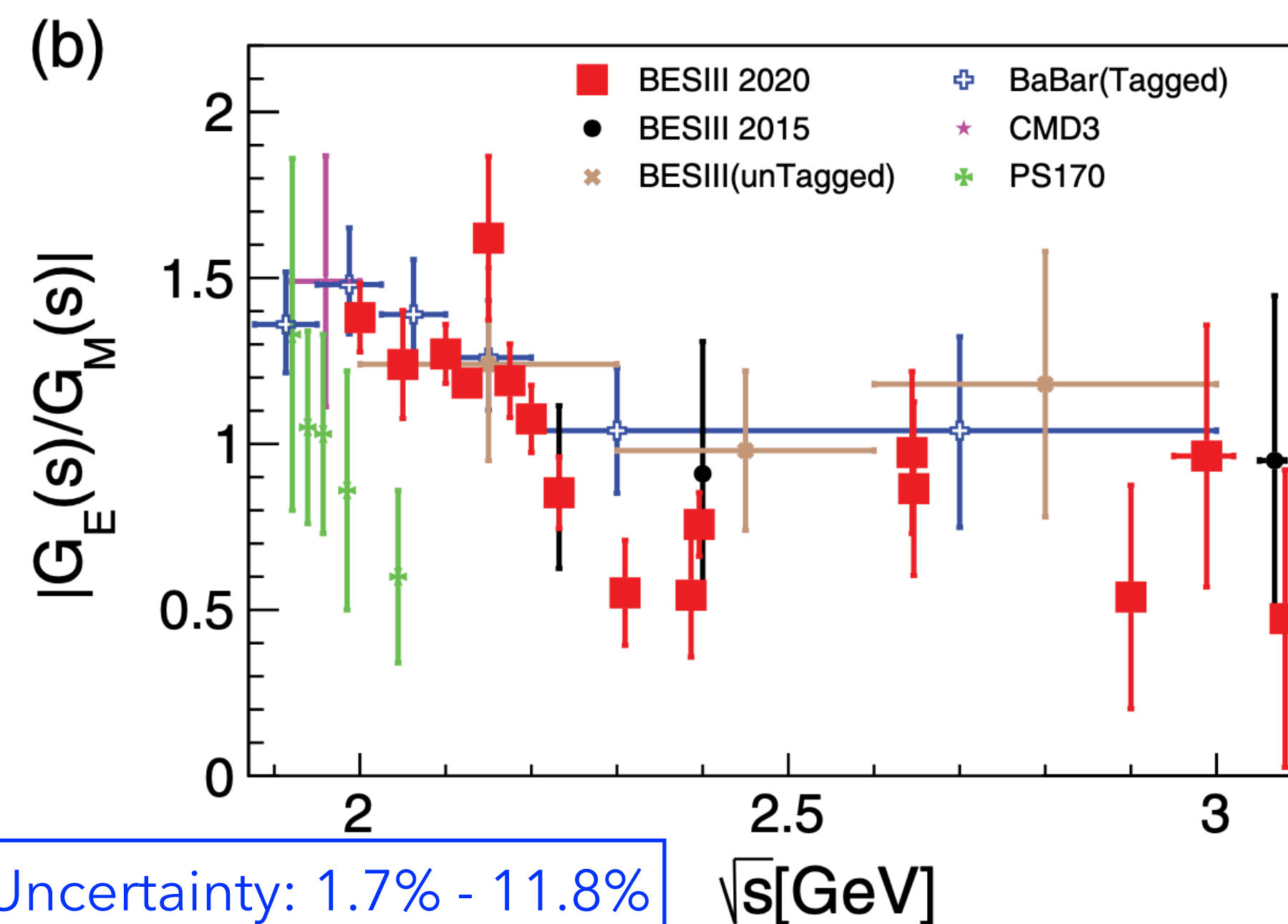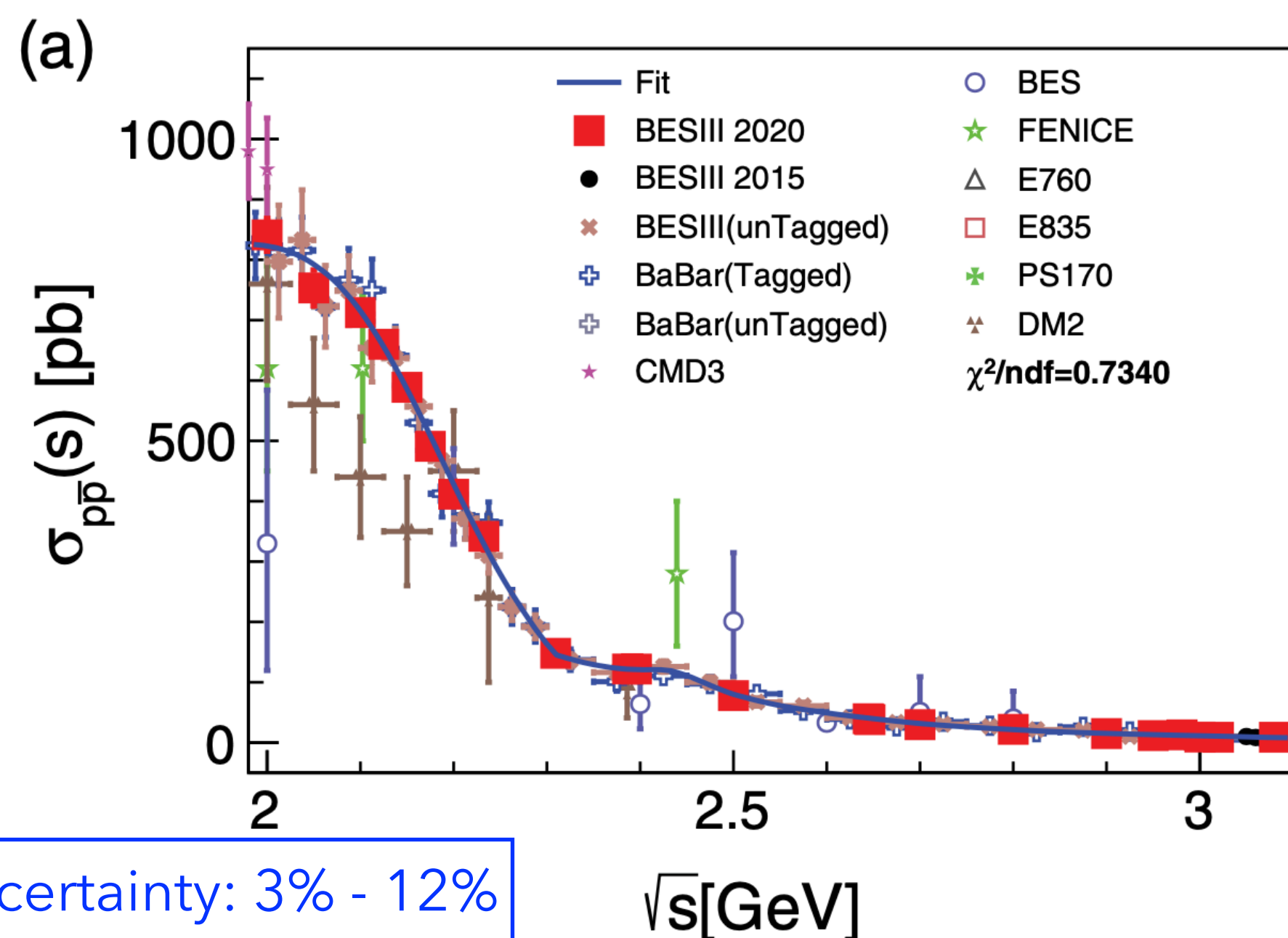alessio.mangoni@pg.infn.it   50th International Symposium
on Multiparticle Dynamics (ISMD2021)

Study of the process $e^+e^- \rightarrow p\bar{p}$ at BESIII

Phys.Rev.Lett. 124, 042001 (2020)

energy-scan technique

Accurate measurement of cross section
from 2.0 to 3.08 GeV (22 points)

$|G_E|/|G_M|$
determined with high accuracy

(a)

Uncertainty: 3% - 12%

(b)

Uncertainty: 1.7% - 11.8%

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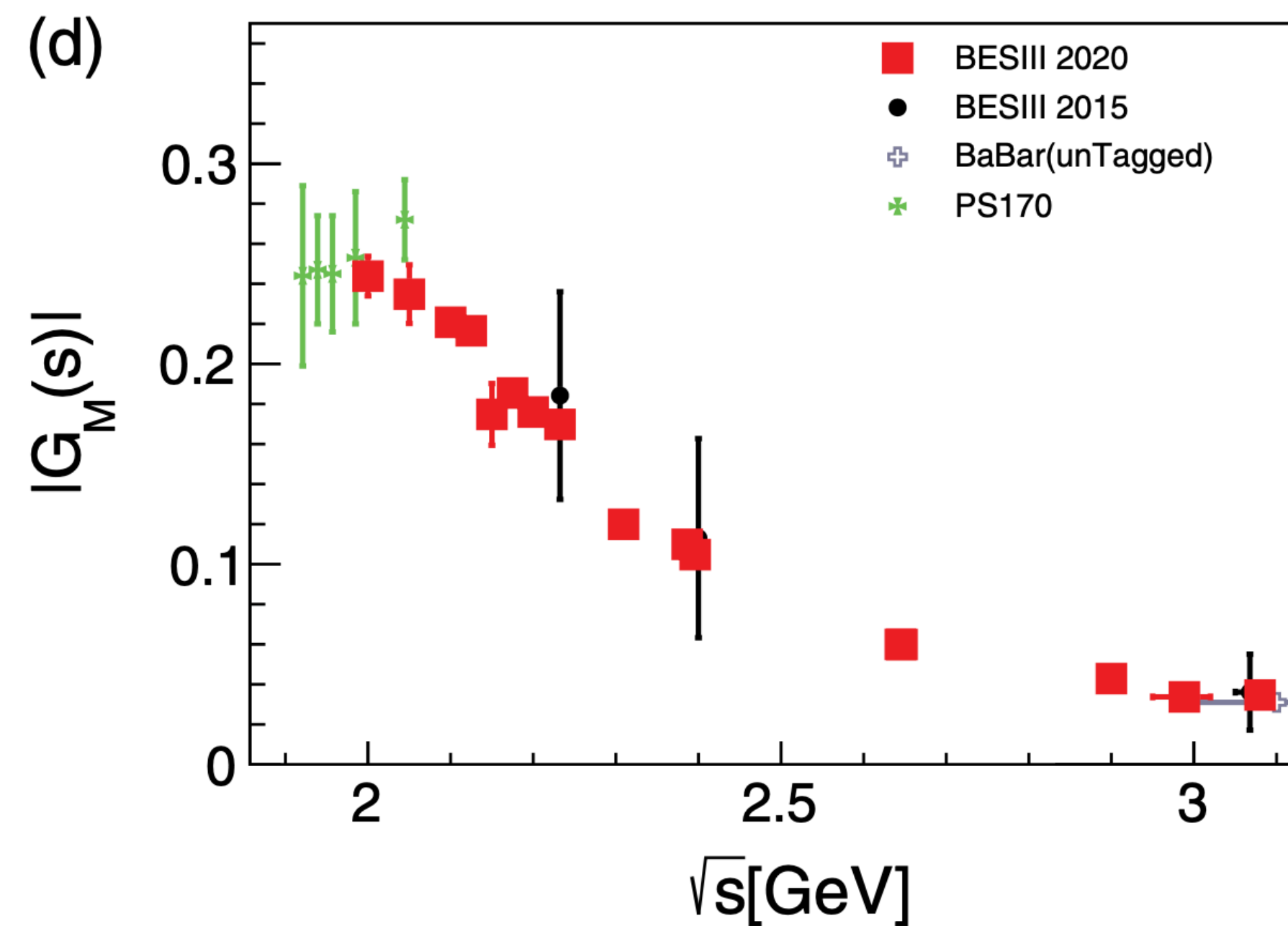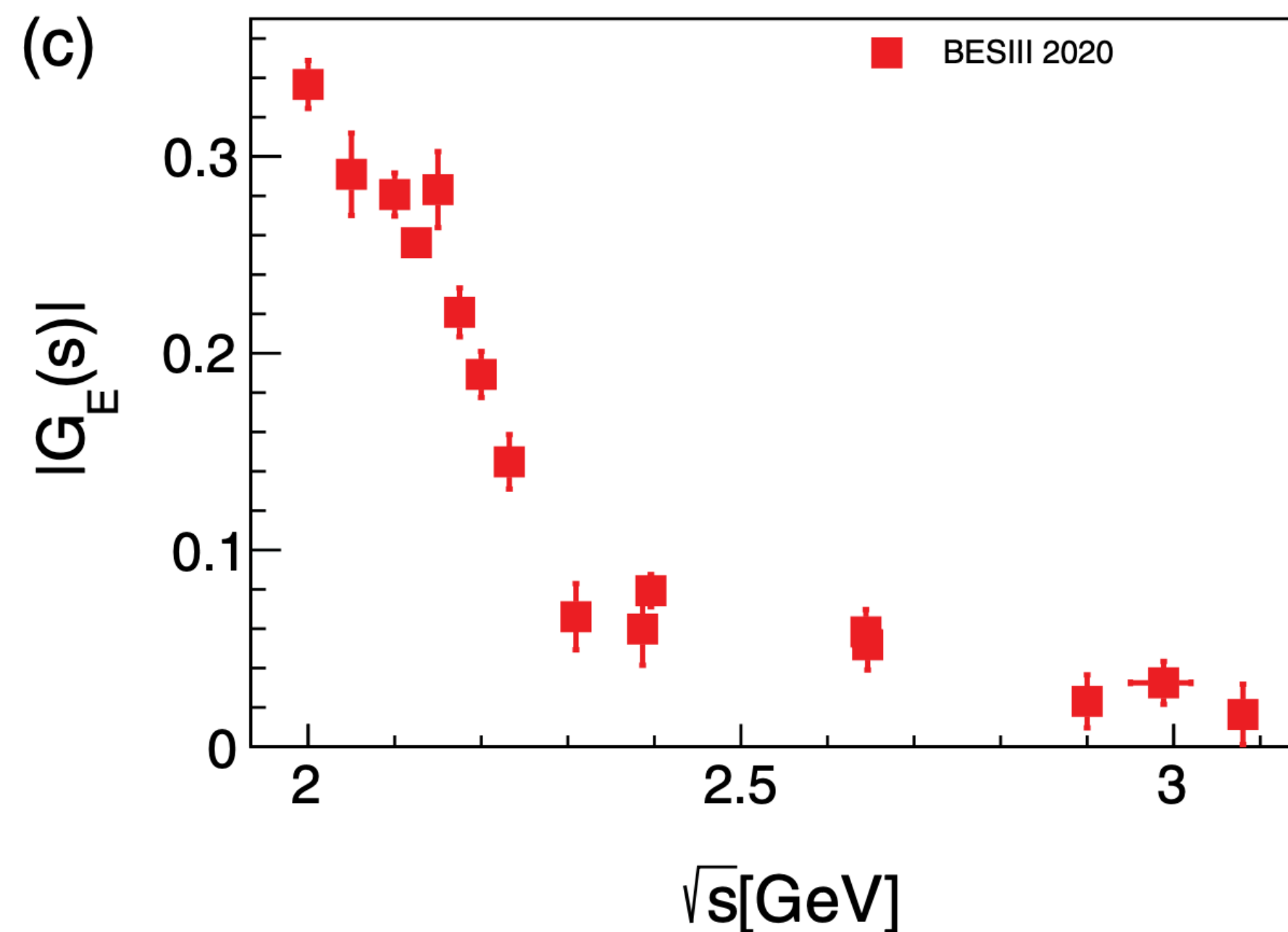on Multiparticle Dynamics (ISMD2021)

Study of the process $e^+e^- \to p\bar{p}$ at BESIII

Phys.Rev.Lett. 124, 042001 (2020)

$|G_E|$ **measured for the first time**

$|G_M|$ determined with high accuracy

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Study of the process $e^+e^- \to p\overline{p}$ at BESIII

Phys.Rev.Lett. 124, 042001 (2020)

Oscillating behavior observed in effective FF as function of relative momentum p between proton and anti-proton
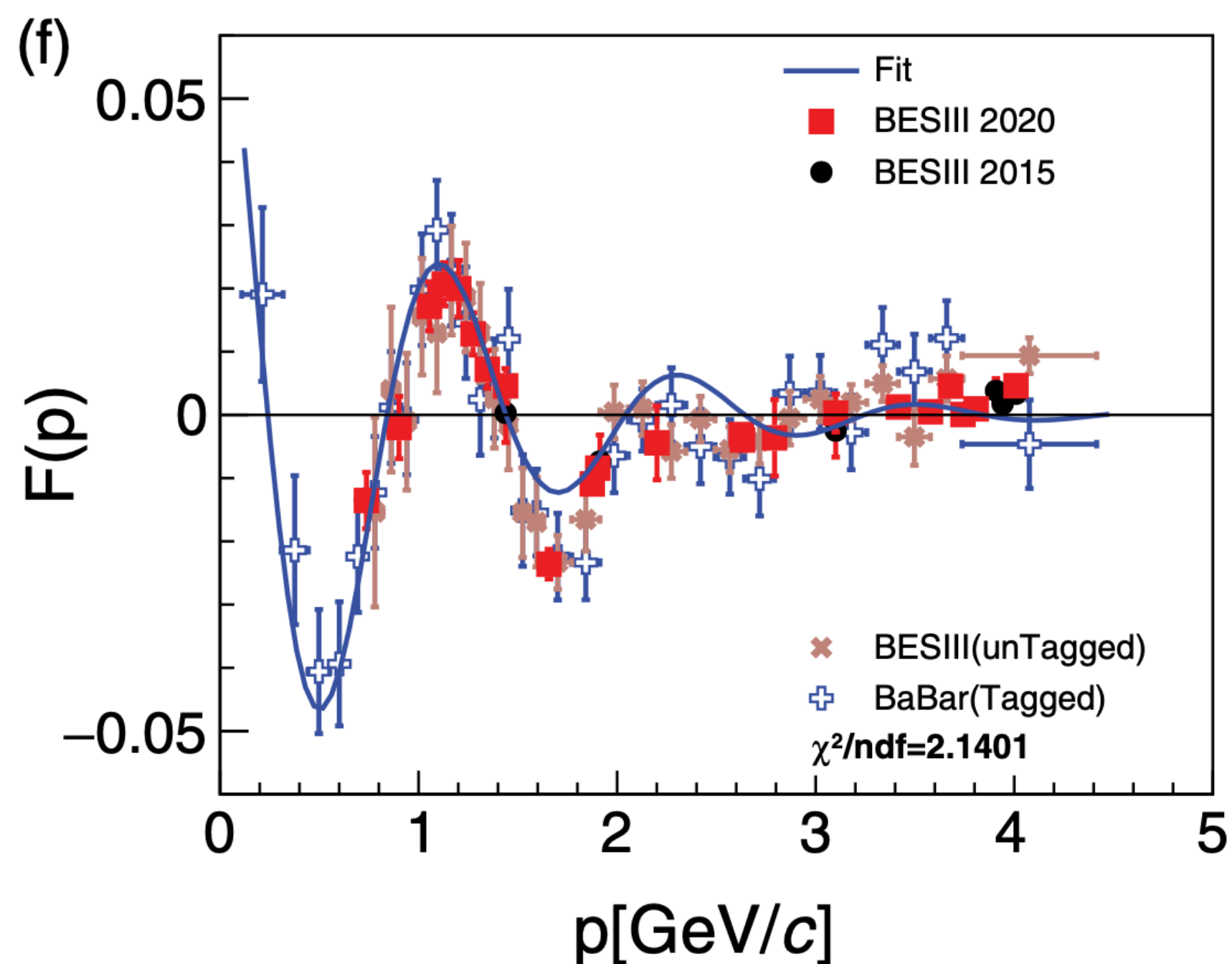
Observed also by further BESIII analysis and BABAR experiment

Possible explanations:
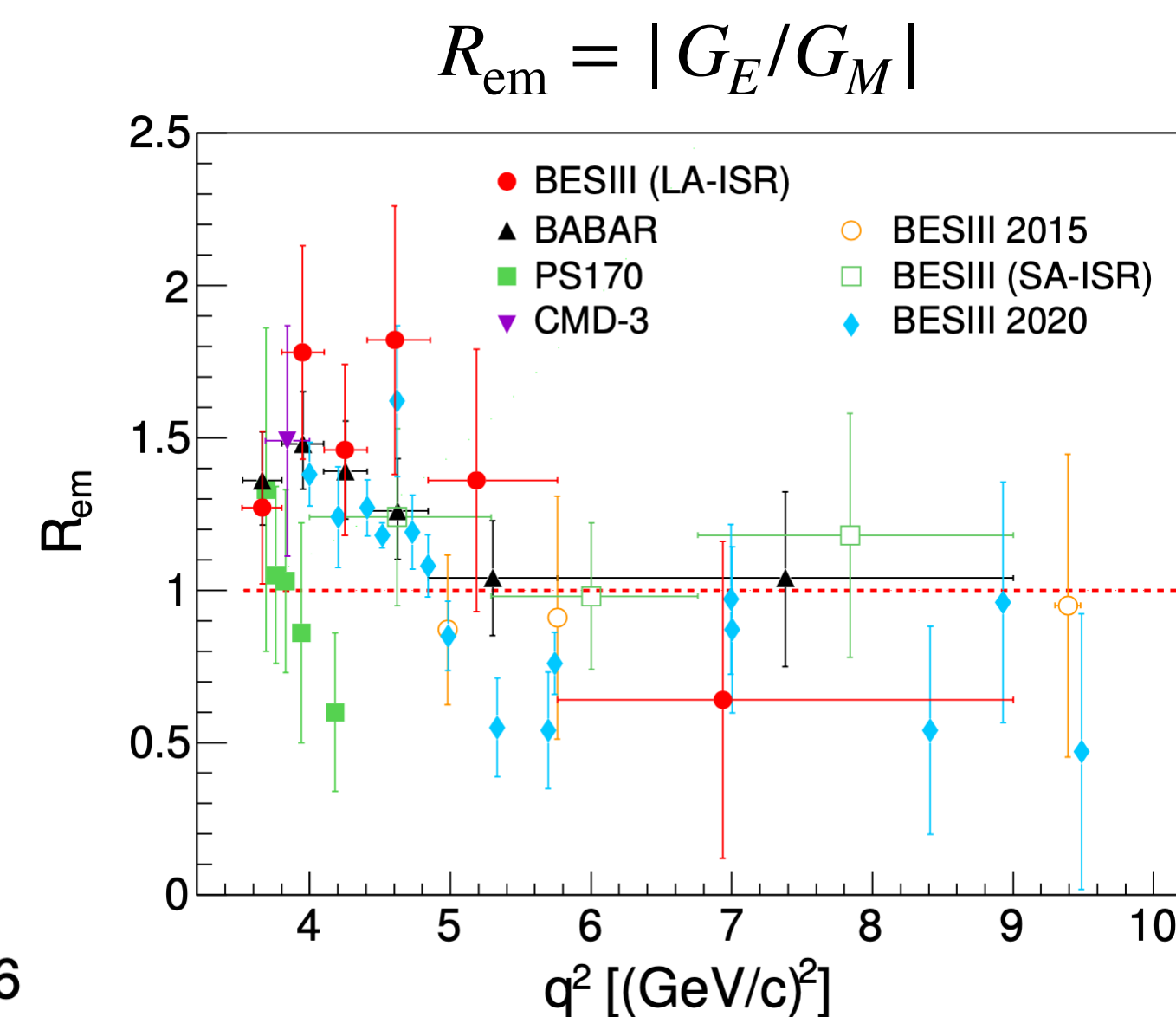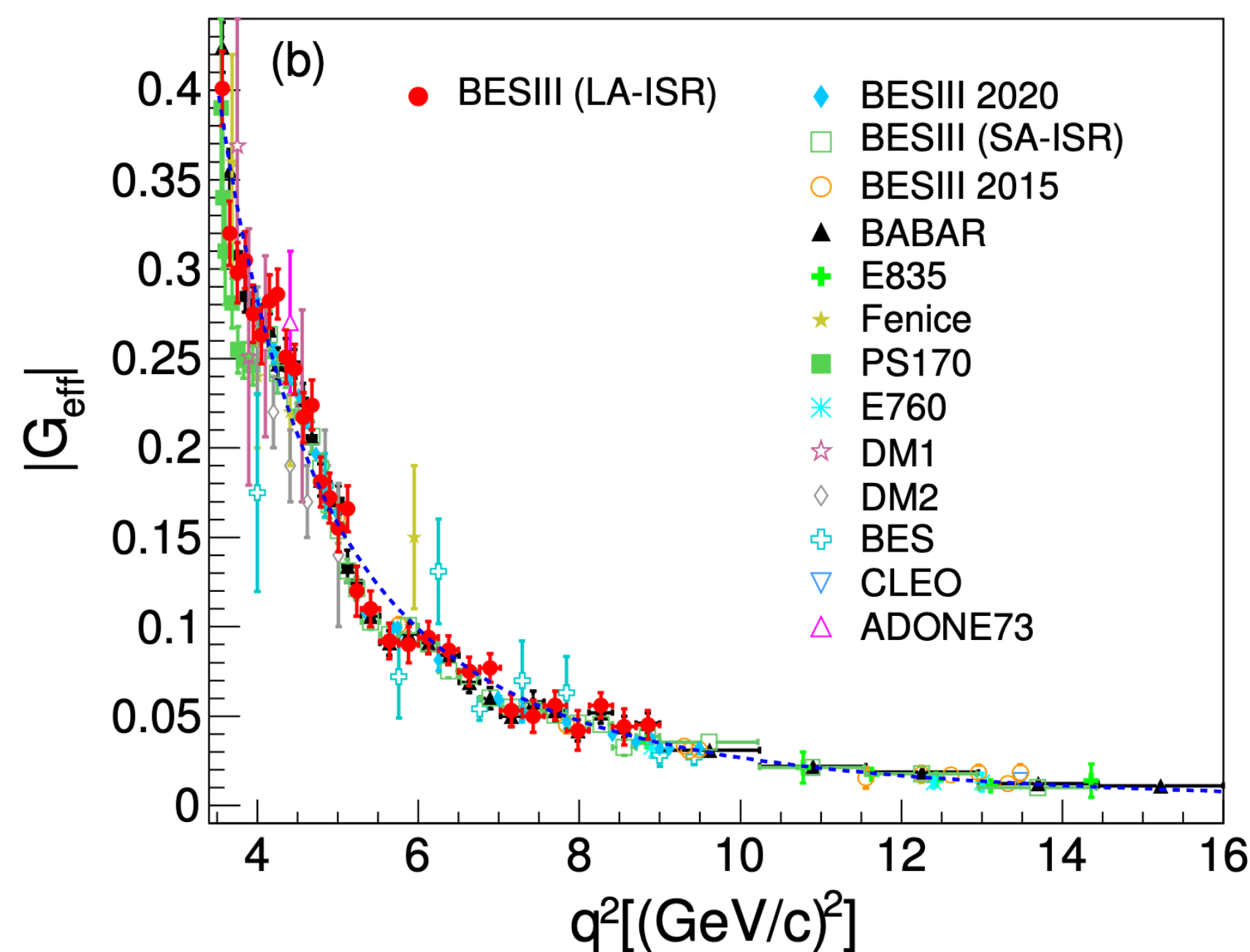
- resonant structures;   **Phys.Rev.D 92 (2015) 3, 034018**

- interference effects in the final state.   **Phys.Rev.C 103 (2021) 3, 035203**

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Study of the process $e^+e^- \rightarrow p\bar{p}$ at BESIII

Phys.Lett.B 817, 136328 (2021)

initial-state-radiation (ISR) technique

Measurement of cross section from 3.773 to 4.600 GeV (7 points)

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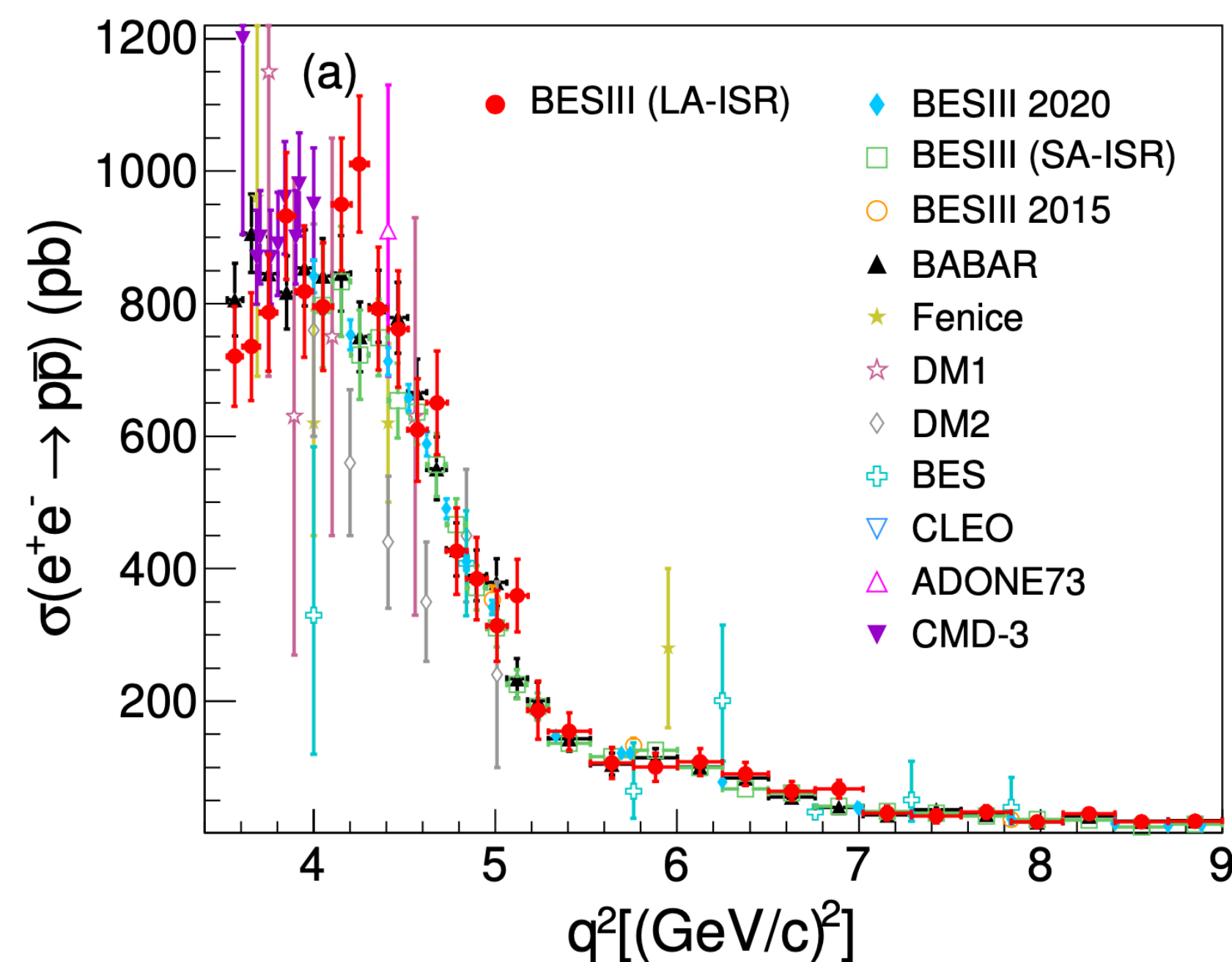
Study of the process $e^+e^- \to n\bar{n}$ at BESIII

Measurement of cross section
from 2.0 to 3.08 GeV (18 points)
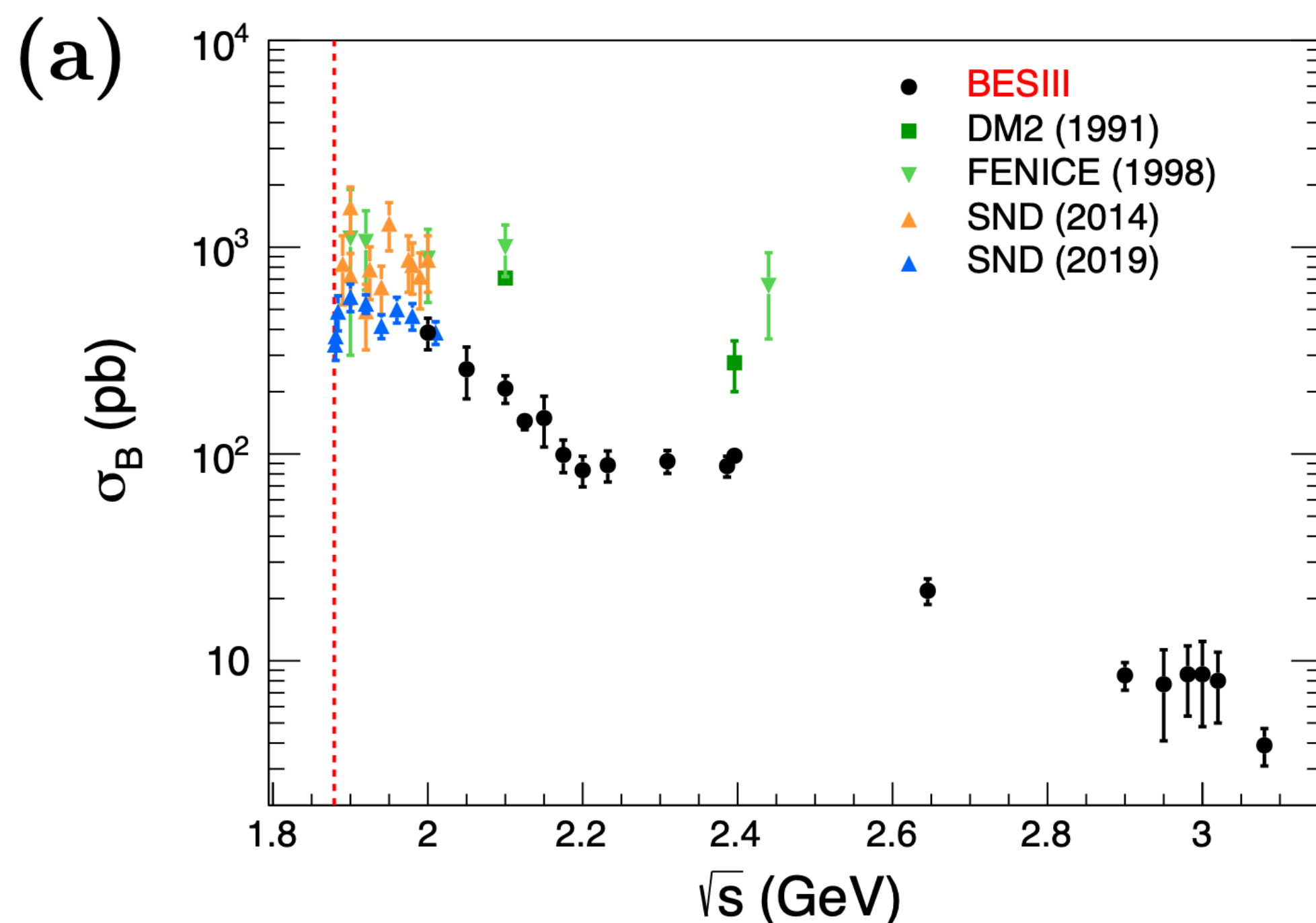
Best precision for the cross section of 8.1%
at energy 2.396 GeV

(a)

- BESIII
- DM2 (1991)
- FENICE (1998)
- SND (2014)
- SND (2019)

σ_B (pb)

$\sqrt{s}$ (GeV)

(b)

- BESIII
- DM2 (1991)
- FENICE (1998)
- SND (2014)
- SND (2019)

|G|

$\sqrt{s}$ (GeV)

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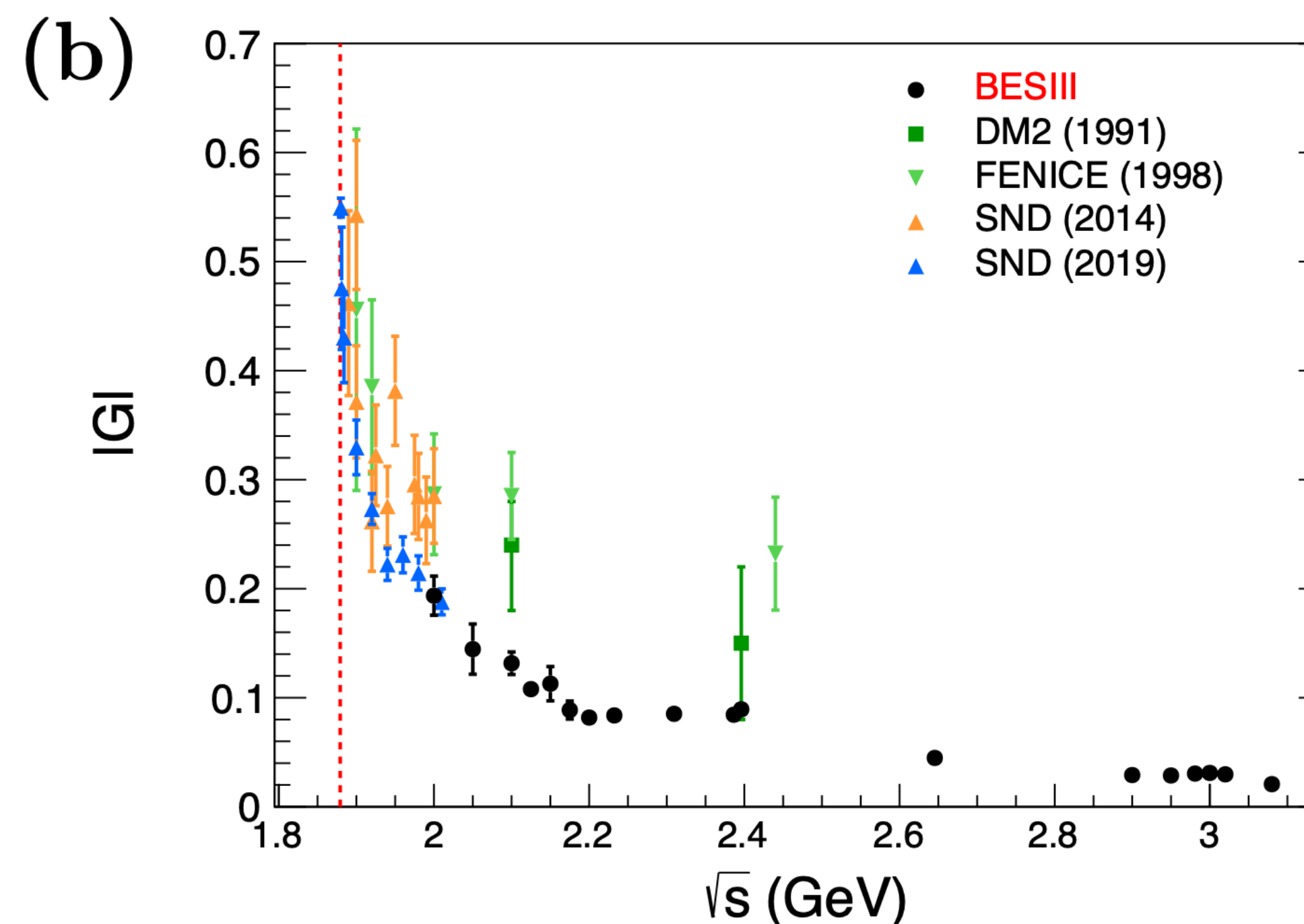
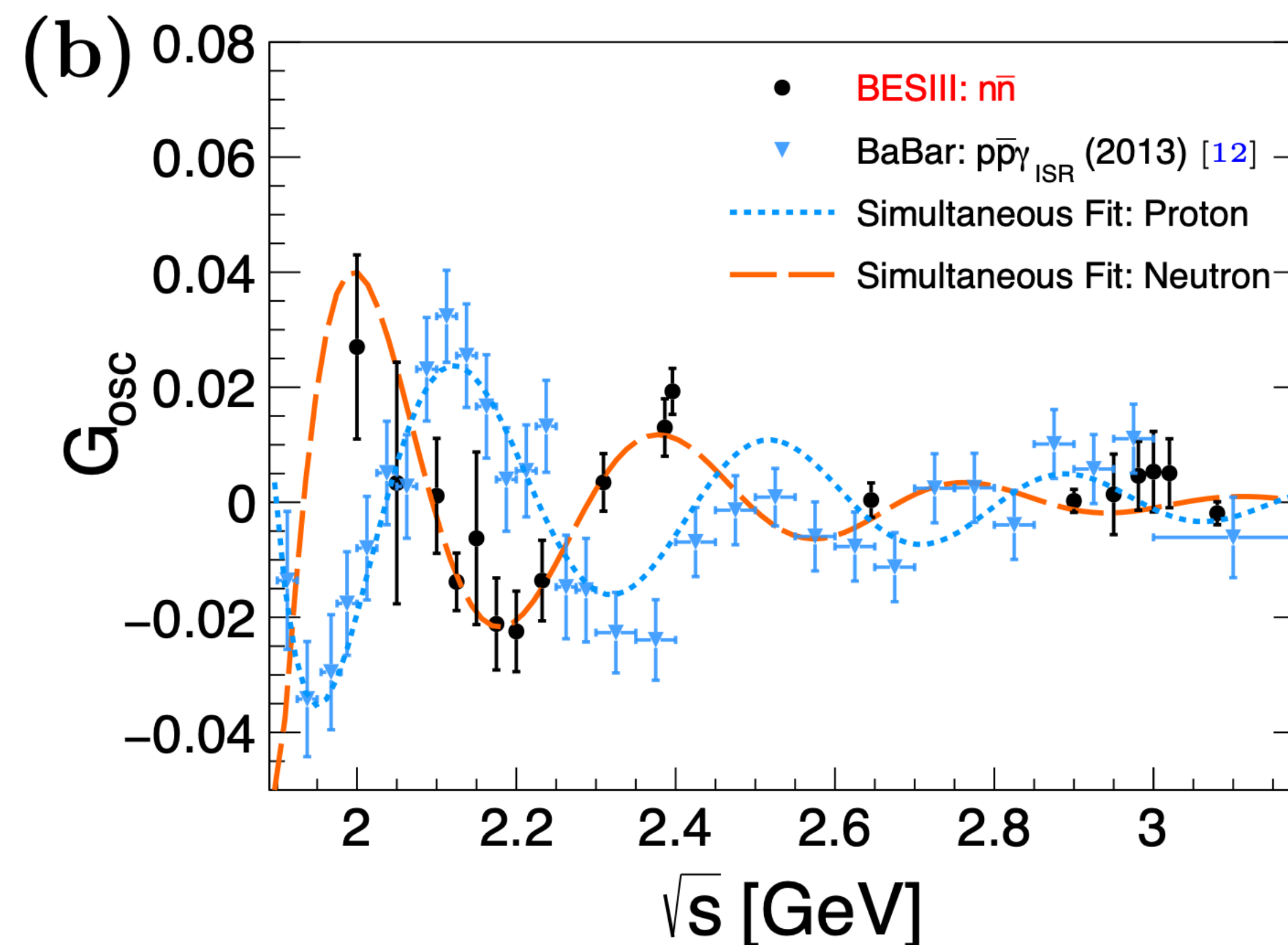Study of the process $e^+e^- \rightarrow n\bar{n}$ at BESIII

arXiv:2103.12486 (2021)

Measurement of cross section
from 2.0 to 3.08 GeV (18 points)

Oscillation observed in the effective FF
of the neutron

$$G_{osc}(q^2) = |G| - G_D,$$

$$G_D(q^2) = \frac{\mathcal{A}_n}{(1 - \frac{q^2}{0.71(\text{GeV}^2)})^2}$$

(b)

Legend:
- BESIII: $n\bar{n}$
- BaBar: $p\bar{p}\gamma_{ISR}$ (2013) [12]
- Simultaneous Fit: Proton
- Simultaneous Fit: Neutron

G_{osc} vs $\sqrt{s}$ [GeV]

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Hyperons are ideal probes for studying the strong interaction in the transition region where the regime is not completely perturbative; **Phys.Rev.Lett. 125 (2020) 5, 052004**

The polarization of Λ baryons in the process $e^+e^- \to J/\psi \to \Lambda\overline{\Lambda}$ was recently measured by BESIII; *Nature Phys.* **15 (2019) 631-634**

Considering the process $e^+e^- \to J/\psi \to \Sigma^+(p\pi^0)\overline{\Sigma}^-(\bar{p}\pi^0)$, the polarization of Σ hyperons can be determined analyzing the two-body weak decays $\Sigma^+ \to p\pi^0$ and $\overline{\Sigma}^- \to \bar{p}\pi^0$

The $e^+e^- \to \psi \to \Sigma^+\overline{\Sigma}^-$ production process is described by the psionic electric and magnetic FFs G_E^ψ and $G_{M'}^\psi$ related to the parameters α_ψ and $\Delta\Phi$

$\alpha_\psi \to$ angular decay asymmetry parameter

$\Delta\Phi \to$ relative phase between FFs

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▸ Determination of the polarization parameters α_0, $\overline{\alpha}_0$ and the FFs relative phase $\Delta\Phi$

▸ The parameter $\overline{\alpha}_0 = 0.990 \pm 0.037$ (stat) ± 0.011 (syst) has been measured **for the first time**

The FFs relative phases are determined to be

$$\Delta\Phi_{J/\psi} = (-15.5 \pm 0.7 \text{ (stat)} \pm 0.5 \text{ (syst)})°$$
$$\Delta\Phi_{\psi(2S)} = (21.7 \pm 4.0 \text{ (stat)} \pm 0.8 \text{ (syst)})°$$

The obtained decay asymmetry parameters are

$$\alpha_0 = -0.998 \pm 0.037 \text{ (stat)} \pm 0.009 \text{ (syst)}$$
$$\overline{\alpha}_0 = 0.990 \pm 0.037 \text{ (stat)} \pm 0.011 \text{ (syst)}$$

where $\overline{\alpha}_0$ has been measured for the first time

Based on 1310.6×10^6 J/ψ and 448.1×10^6 $\psi(2S)$ events collected by the BESIII collaboration

Phys.Rev.Lett. 125 (2020) 5, 052004

Parameter	Measured value
$\alpha_{J/\psi}$	$-0.508 \pm 0.006 \pm 0.004$
$\Delta\Phi_{J/\psi}$	$-0.270 \pm 0.012 \pm 0.009$
$\alpha_{\psi'}$	$0.682 \pm 0.03 \pm 0.011$
$\Delta\Phi_{\psi'}$	$0.379 \pm 0.07 \pm 0.014$
α_0	$-0.998 \pm 0.037 \pm 0.009$
$\overline{\alpha}_0$	$0.990 \pm 0.037 \pm 0.011$

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Study of the processes $e^+e^- \to \Sigma^+\overline{\Sigma}^-$ and $e^+e^- \to \Sigma^-\overline{\Sigma}^+$ at BESIII

Phys.Lett.B 125 (2021) 814, 136110

Measurements for CM energies from 2.3864 to 3.0200 GeV

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2\beta C|G_M|^2}{4s}\left[1 + \cos^2\theta + \frac{1}{\tau}\left|\frac{G_E}{G_M}\right|^2\sin^2\theta\right]$$

$$\Sigma^+ \to uus \qquad p \to uud$$
$$\Sigma^- \to dds \qquad n \to udd$$

FFs ratio of Σ hyperons could provide guidance for the nucleons

$$\beta = \sqrt{1 - \frac{4m^2}{s}} \qquad \tau = \frac{s}{4m^2}$$

m is the mass of the baryon in the final state
C is the Coulomb correction factor

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Phys.Lett.B 125 (2021) 814, 136110

Study of the processes $e^+e^- \to \Sigma^+\overline{\Sigma}^-$ and
$e^+e^- \to \Sigma^-\overline{\Sigma}^+$ at BESIII

$\Sigma^+ \to |G_E/G_M| = 1.83 \pm 0.26$
is significantly higher than 1

First time measurement for the cross section in the off-resonance region
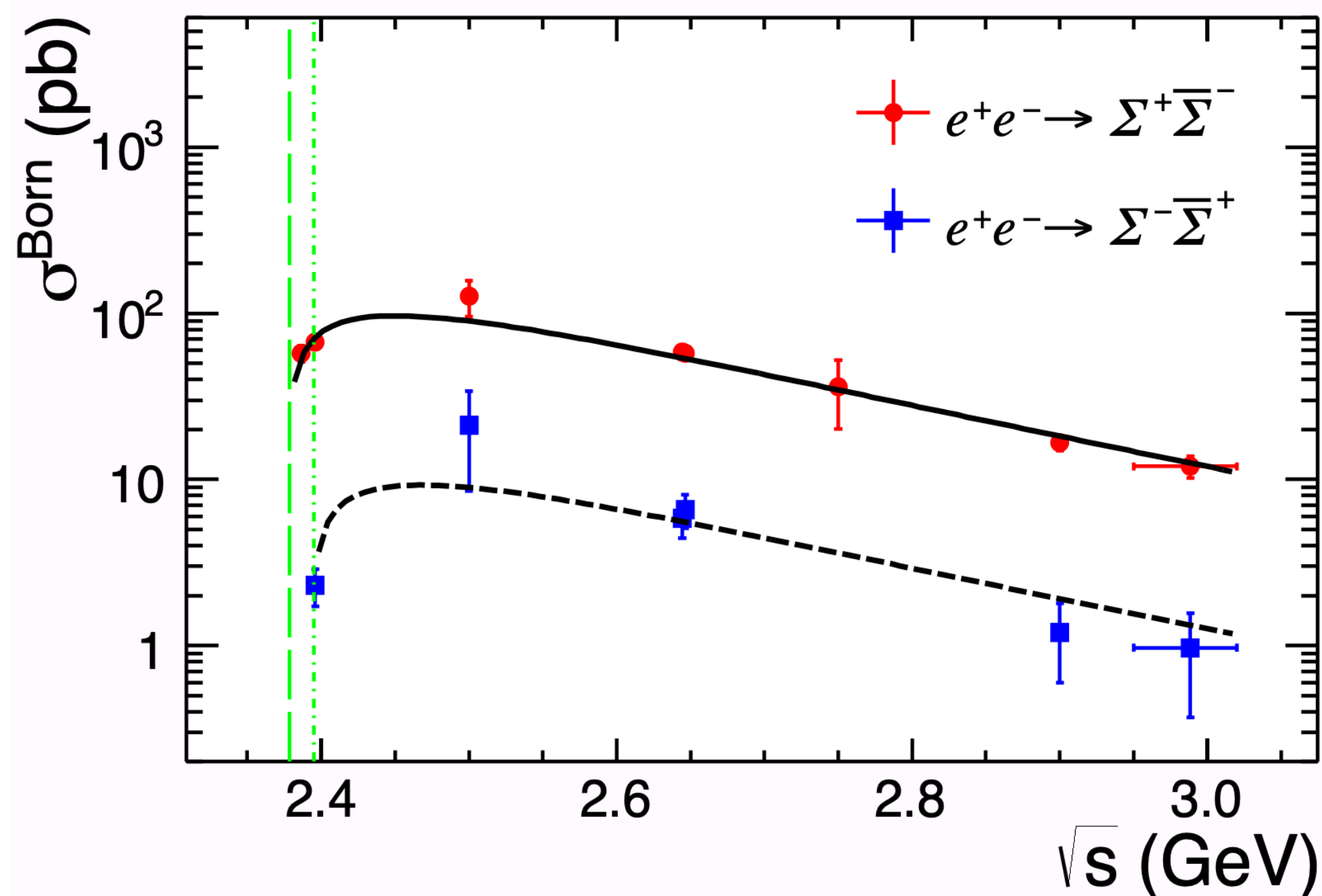
Cross sections near threshold disagree with the point-like expectations as has been seen for the proton

Eur.Phys.J.A 39 (2009) 315-321 **Eur.Phys.J.A 48 (2012) 33** **Phys.Rev.D 87, 092005 (2013)** **Phys.Lett.B 759, 634 (2016)**

$$\frac{\sigma^{\text{Born}}(e^+e^- \to \Sigma^+\overline{\Sigma}^-)}{\sigma^{\text{Born}}(e^+e^- \to \Sigma^-\overline{\Sigma}^+)} = 9.7 \pm 1.3$$

consistent with the prediction of **Phys.Lett.B 799 (2019) 135041**

inconsistent with predictions from various models,
Phys.Rept.112, 173 (1984), Rev.Mod.Phys.65, 1199 (1993), Z. Phys.Phys.C42, 569 (1989),
Phys.Rev.Lett.91, 232003 (2003), Phys.Rept.409, 1 (2005), Phys.Rev.D 101, 014014 (2020)

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- BESIII can precisely measure the nucleon FFs.
- The $e^+e^- \to p\bar{p}$ process has been studied to obtain the differential cross section, the EM FFs, $|G_E|$ and $|G_M|$, and their ratio $|G_E/G_M|$.
- The moduli of electric and magnetic proton FFs has been measured for the first time for the proton.
- The $e^+e^- \to n\bar{n}$ process has been studied to obtain the cross section and the ratio of EM FFs, $|G_E/G_M|$.
- An oscillating behavior has been observed in the effective FF of proton and neutron.
- The processes of hyperon pairs production can be used to study their polarization, this represents a unique opportunity for studying polarization phenomena.
- BESIII has measured for the first time all the Λ and Σ polarization parameters.