

Recent result of baryon time-like form factors at BESIII

Weimin Song

(weiminsong@jlu.edu.cn)

on behalf of the BESIII Collaboration



Outline

□ Baryon and form factor

□ Recent publications

Nucleon ($I = \frac{1}{2}, S = 0$) [PRL 124, 042001; PLB 817, 136328; NP 17, 1200–1204]

Λ ($I = 0; S = -1$) [PRD 97, 032013; PRL 123, 122003; PRD 104, L091104]

Σ ($I = 1; S = -1$) [PLB 814, 136110; arXiv: 2110.04510]

Ξ ($I = 0; S = -2$) [PRL 124, 032002; PLB 820, 136557]

Λ_c ($I = 0; C = 1$) [PRL 120, 132001; PRD 100, 072004]

□ Summary

Baryon

□ Baryon is important:

Daily life is made of baryons;

Confinement system of QCD;

.....

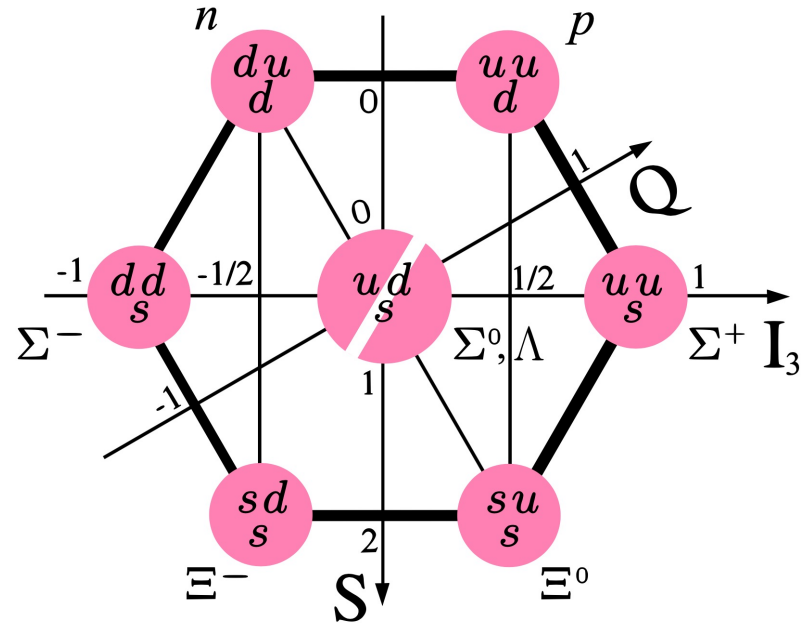
□ Baryon is complicated:

Out of the capability of first principle calculations;

Radius/spin of proton is not understood well;

.....

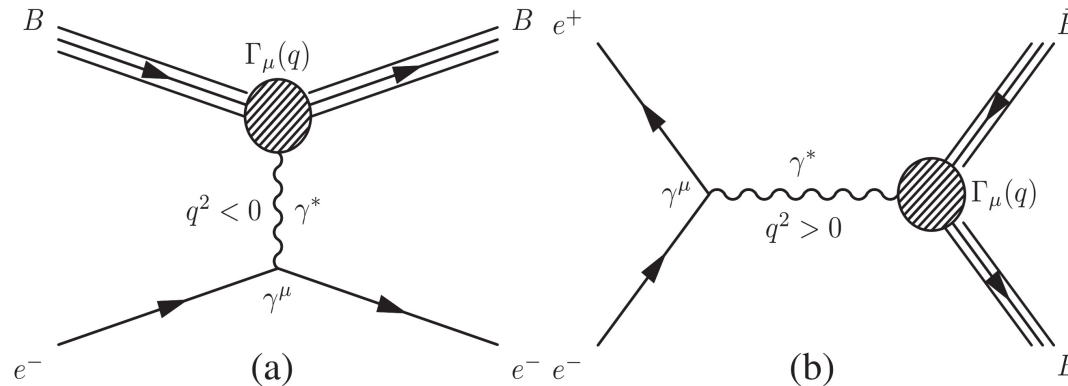
Picture from Wiki



Electric and Magnetic Form Factors of Baryon could reveal its internal structure and dynamics!

Form Factor

- Space-like FF from eB scattering, Time-like from e⁺e⁻ annihilation :

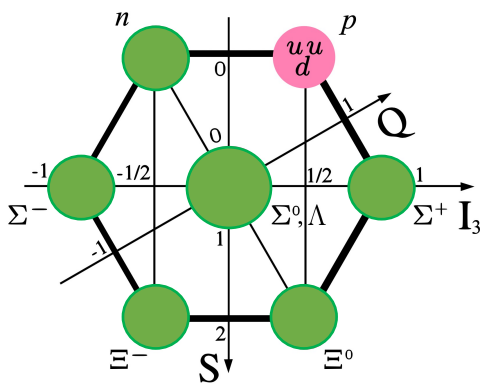


- FF and cross section:

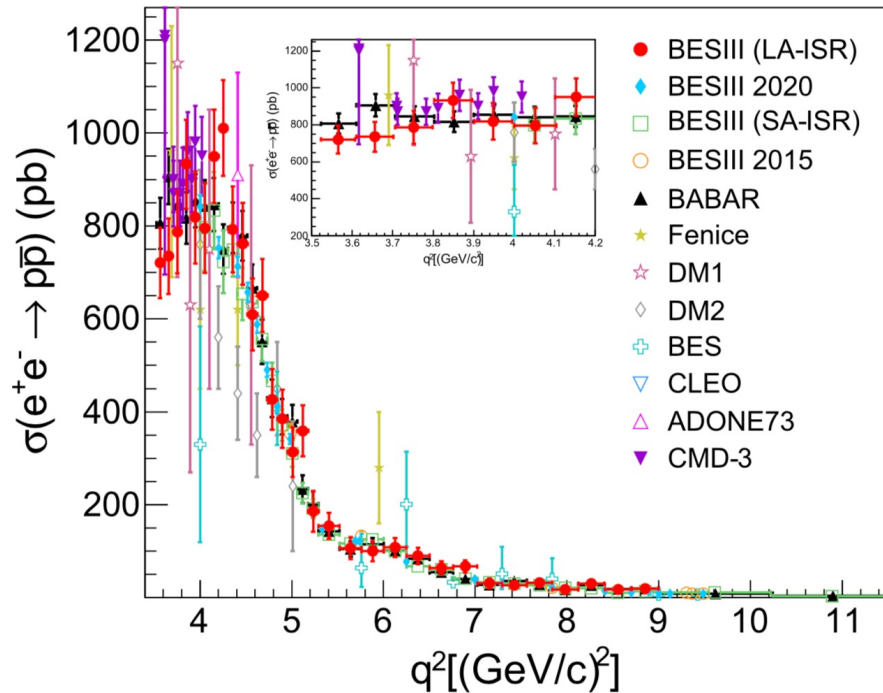
$$\sigma^B(s) = \frac{4\pi\alpha^2\beta C}{3s} \left[|G_M(s)|^2 + \frac{1}{2\tau} |G_E(s)|^2 \right] \quad |G_{\text{eff}}(s)| = \sqrt{\frac{\sigma(s)}{\frac{4\pi\alpha^2\beta C}{3s} \left[1 + \frac{1}{2\tau} \right]}}$$

TLFF could be measured at BESIII for both nucleon and hyperon.

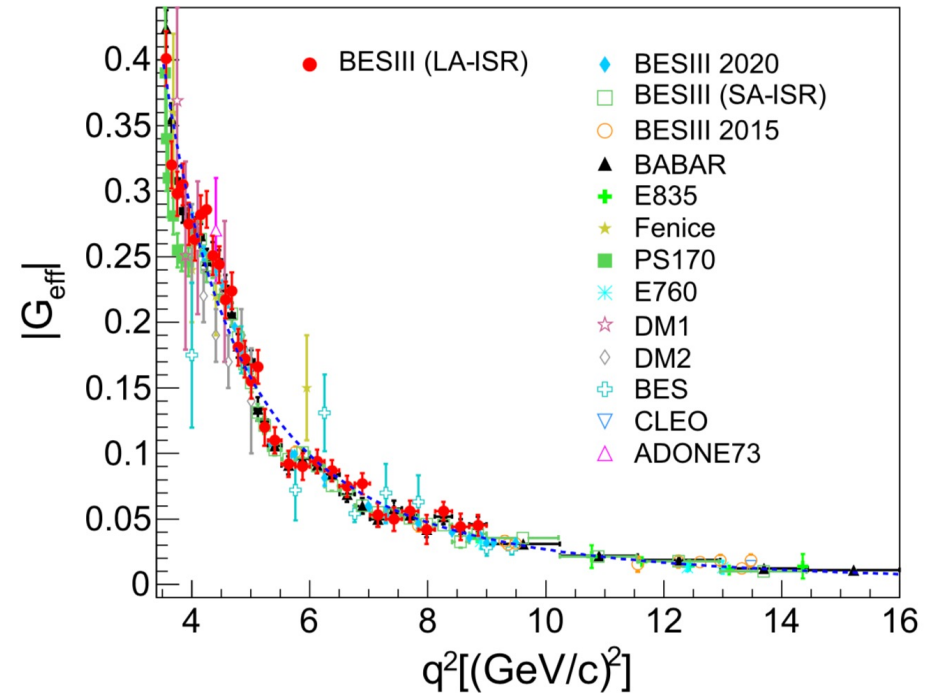
Proton



Cross Sections

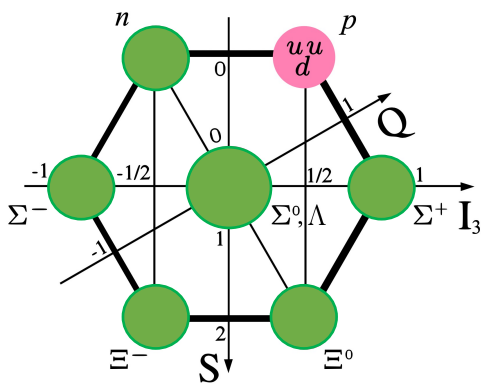


Effective FFs

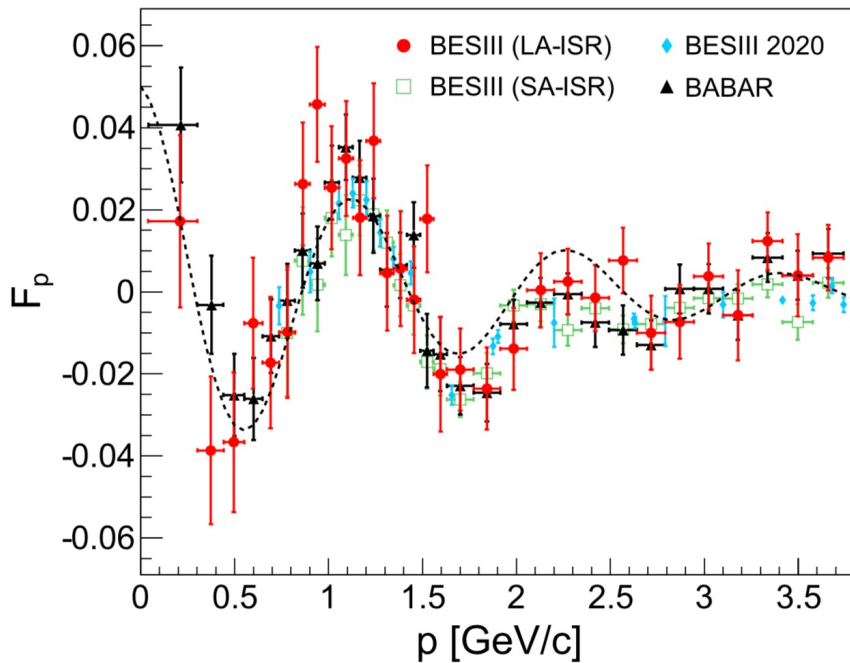


- ❖ Cross sections are measured with both ISR and energy scan method, and enhancement near threshold is observed;
- ❖ Effective FF is measured with cross sections as input.

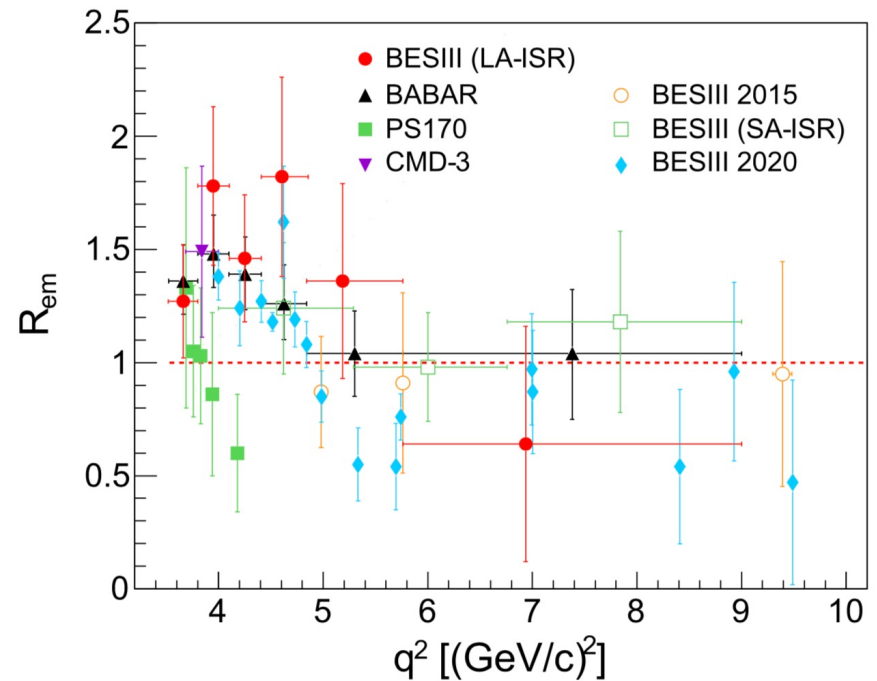
Proton



Effective FFs - dipole law

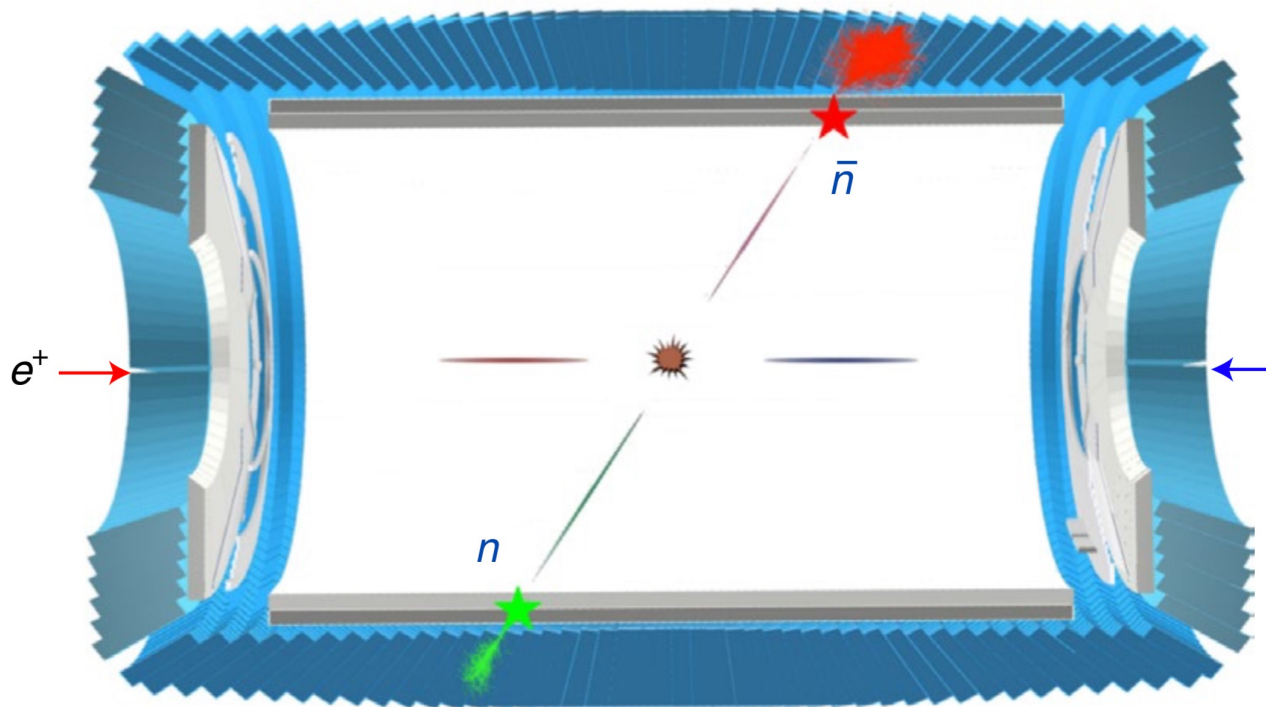
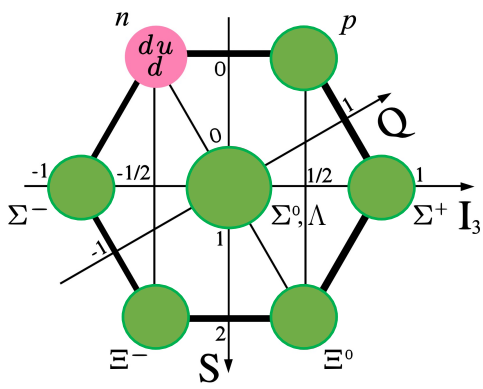


G_E/G_M



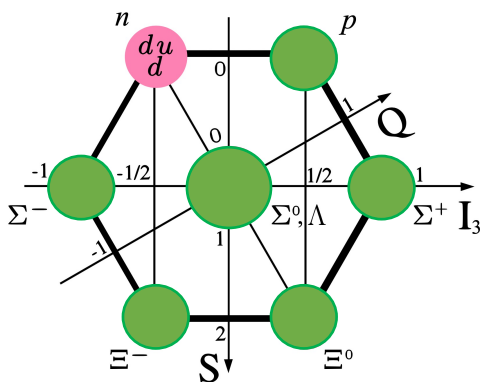
- ❖ **Clear oscillating structure: interference effect involving rescattering processed in the final state? Resonant structures?**
- ❖ **The G_E/G_M is measured by angular distribution of proton: unity.**

Neutron

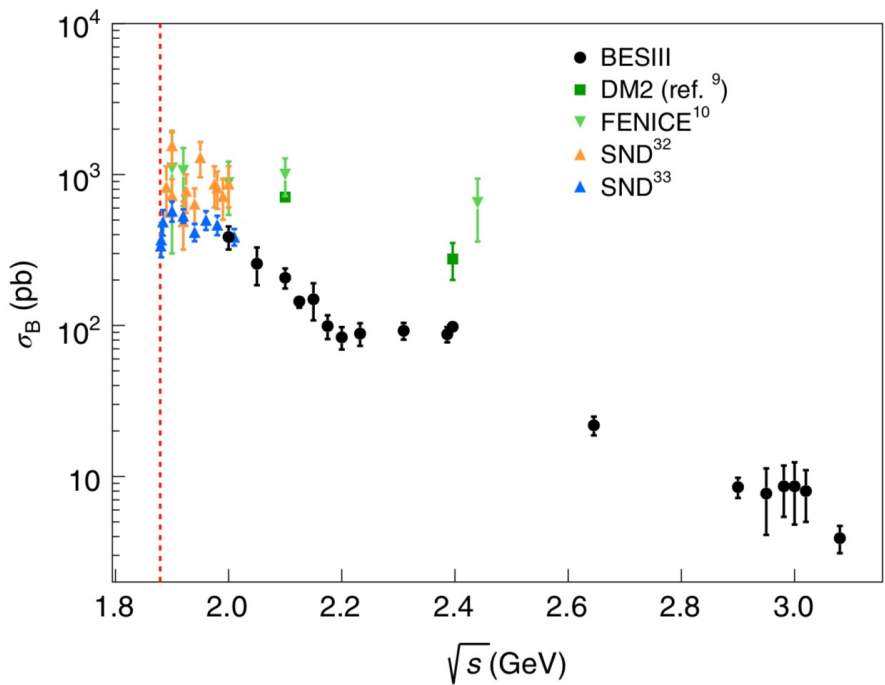


❖ The analysis is challenging: no charged tracks in the final states.

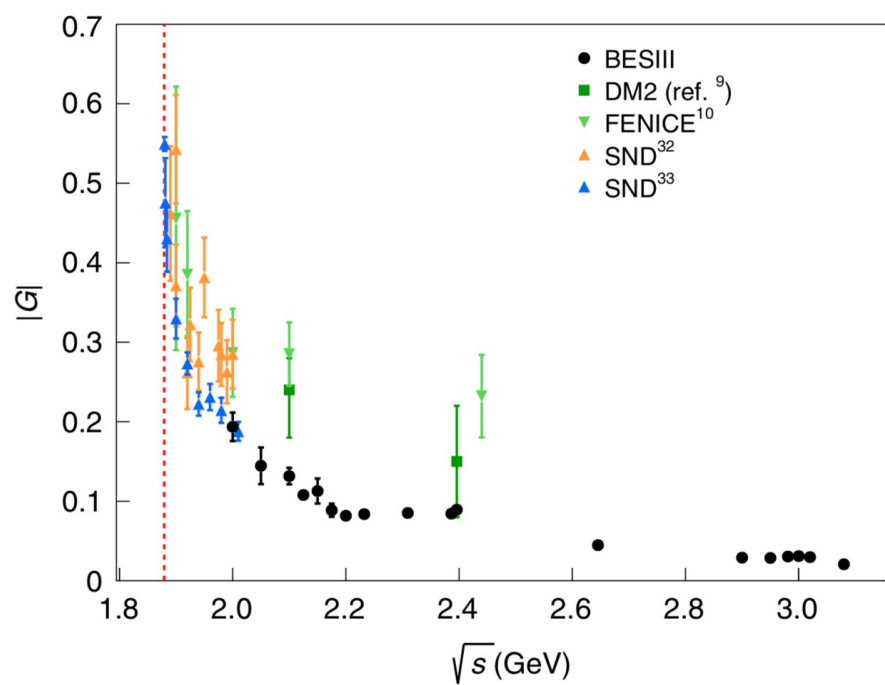
Neutron



Cross Sections

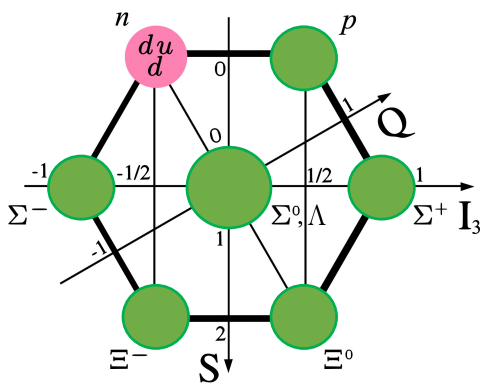


Effective FFs

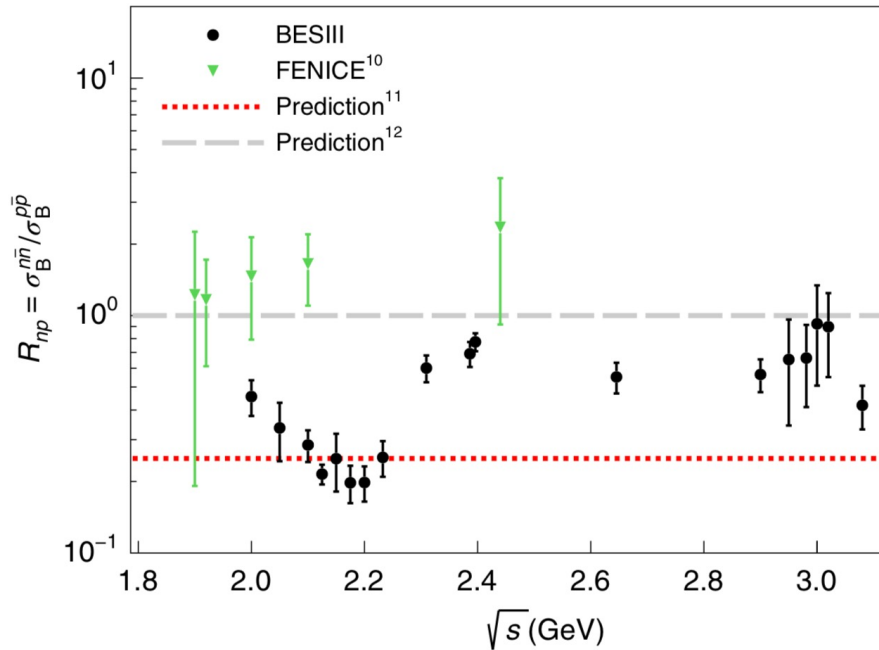


❖ Enhancement near thershold.

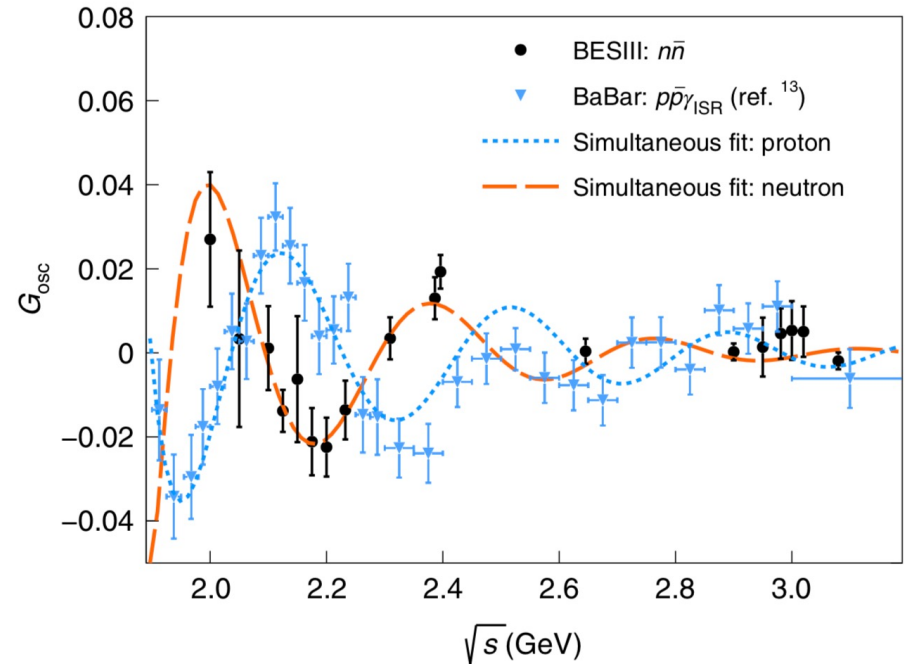
Neutron



Cross section ratio

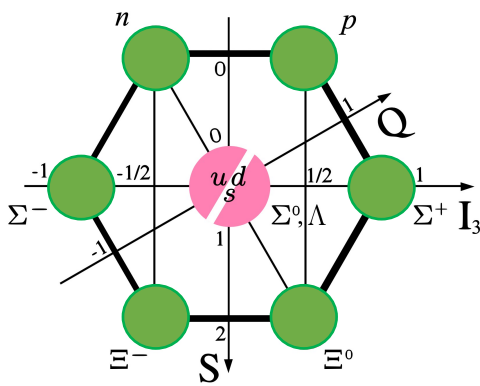


Effective FFs - dipole law

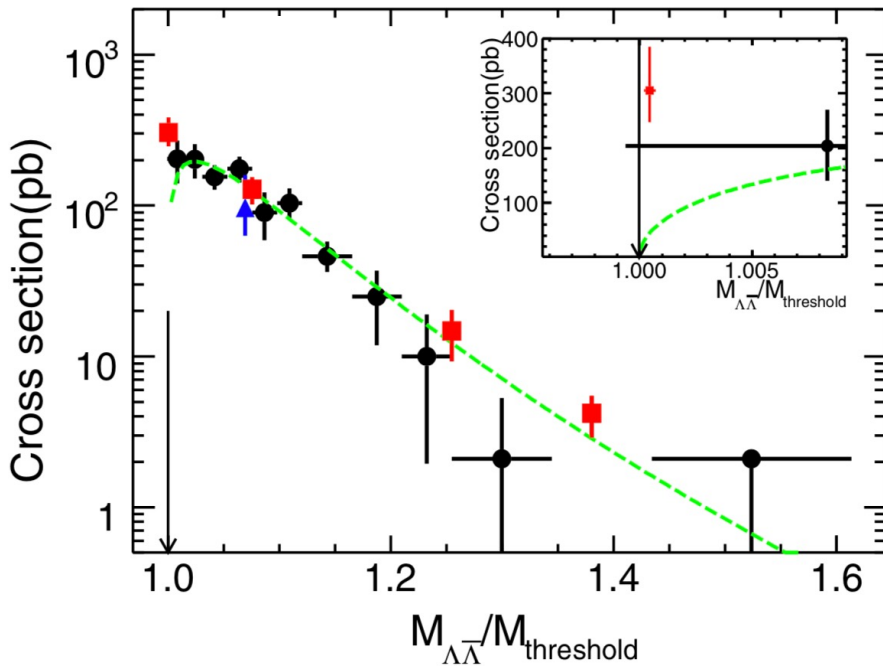


- ❖ Photon-proton interaction is stronger than photon-neutron;
- ❖ Oscillatory for neutron, with similar frequency but different phase to proton.

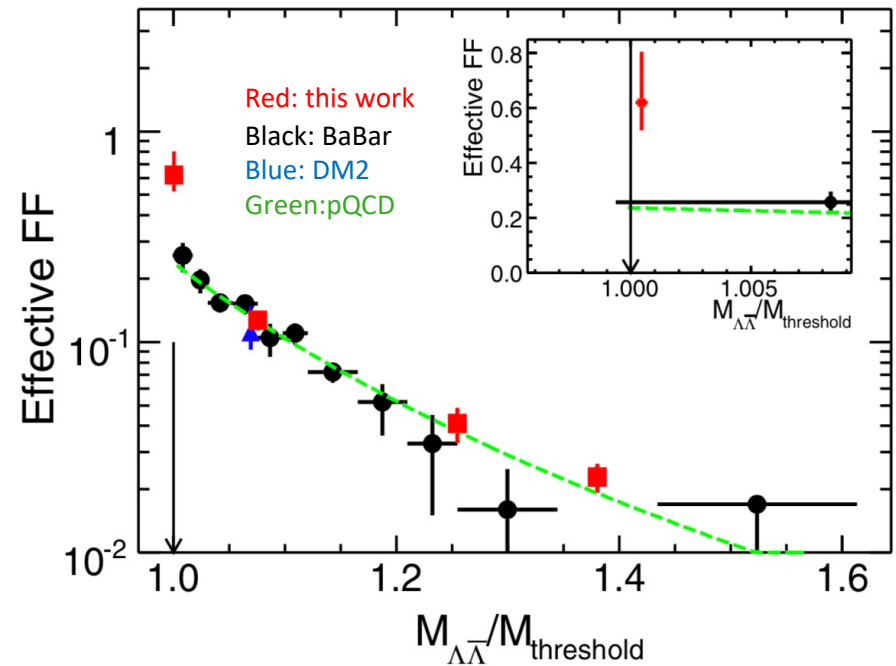
Λ near threshold



Cross Sections

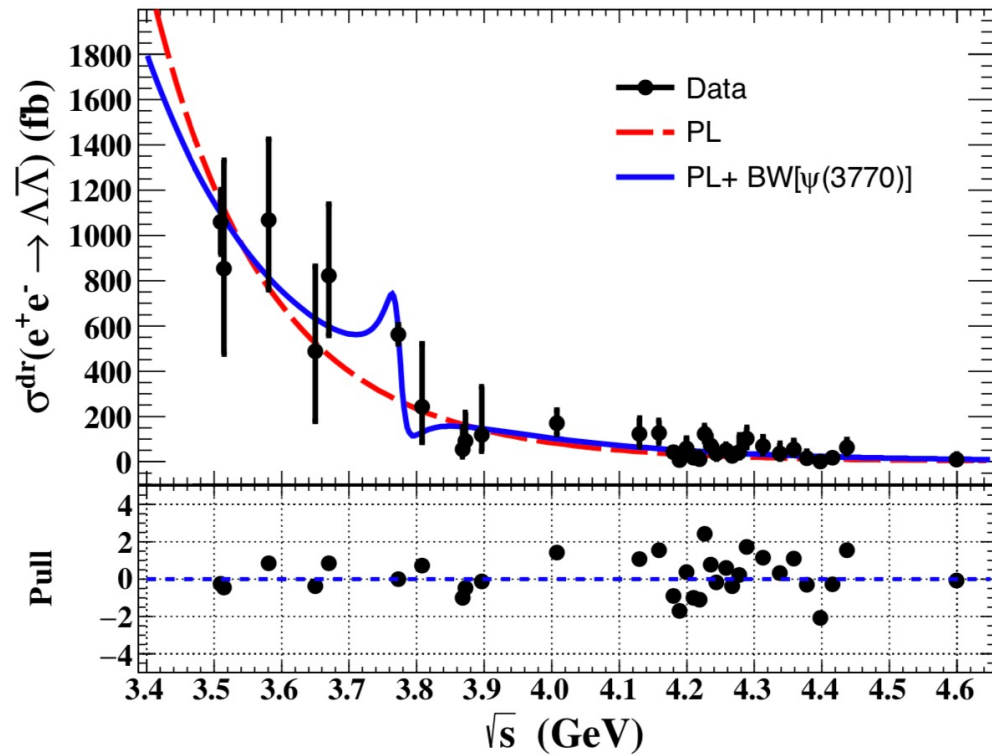
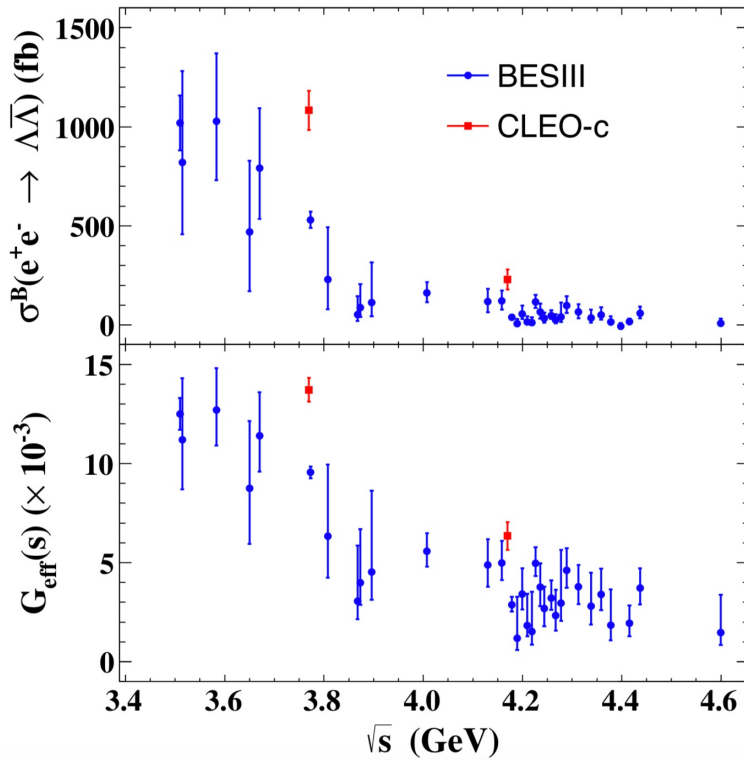
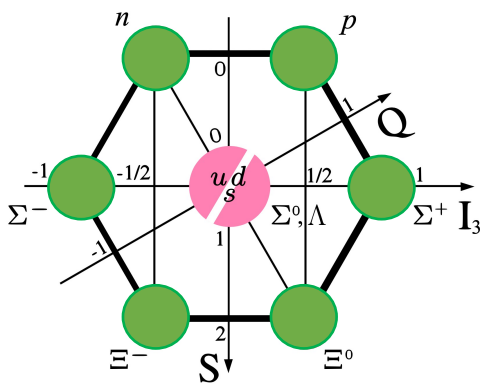


Effective FFs

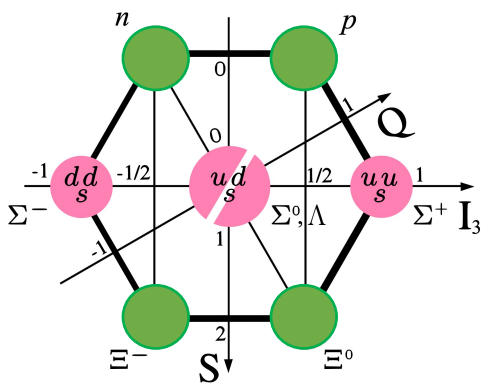


❖ Near threshold enhancement is observed, and beyond the pQCD predictions.

Λ away from threshold



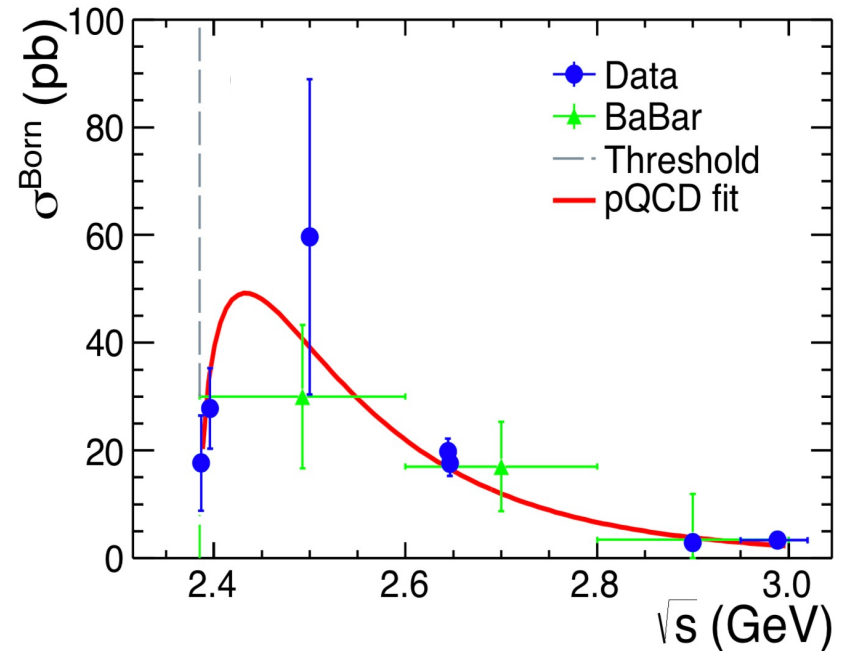
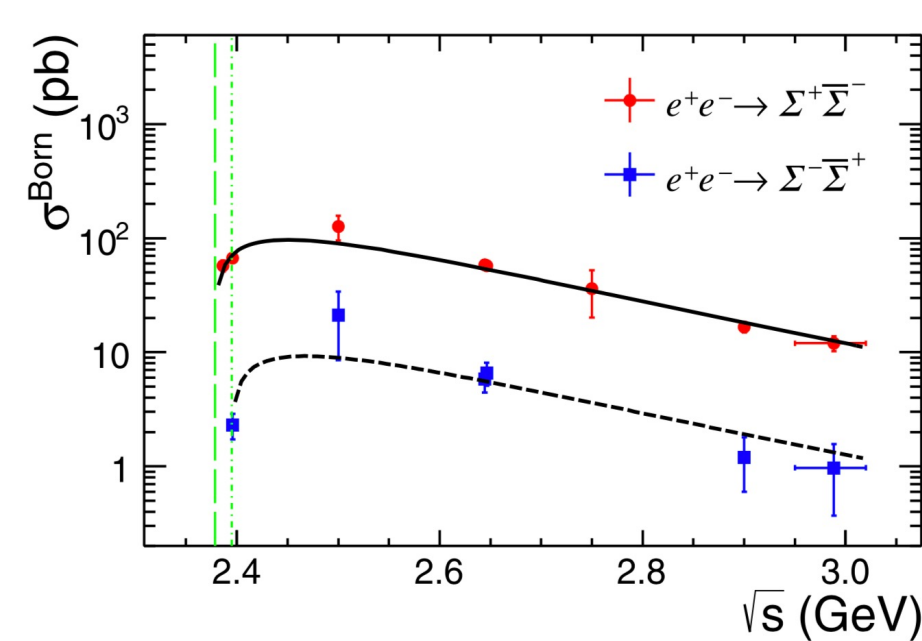
❖ Evidence of $\psi(3770) \rightarrow \Lambda \bar{\Lambda}$ is observed ($>4.5 \sigma$).



Σ

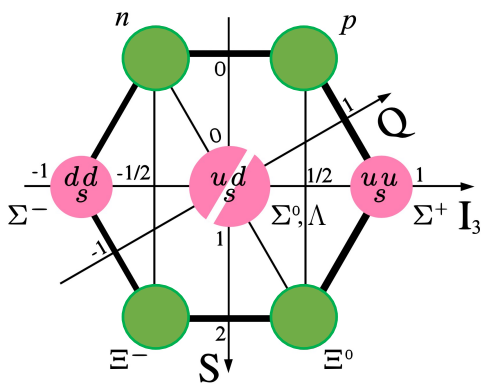
Charge mode

Neutral mode

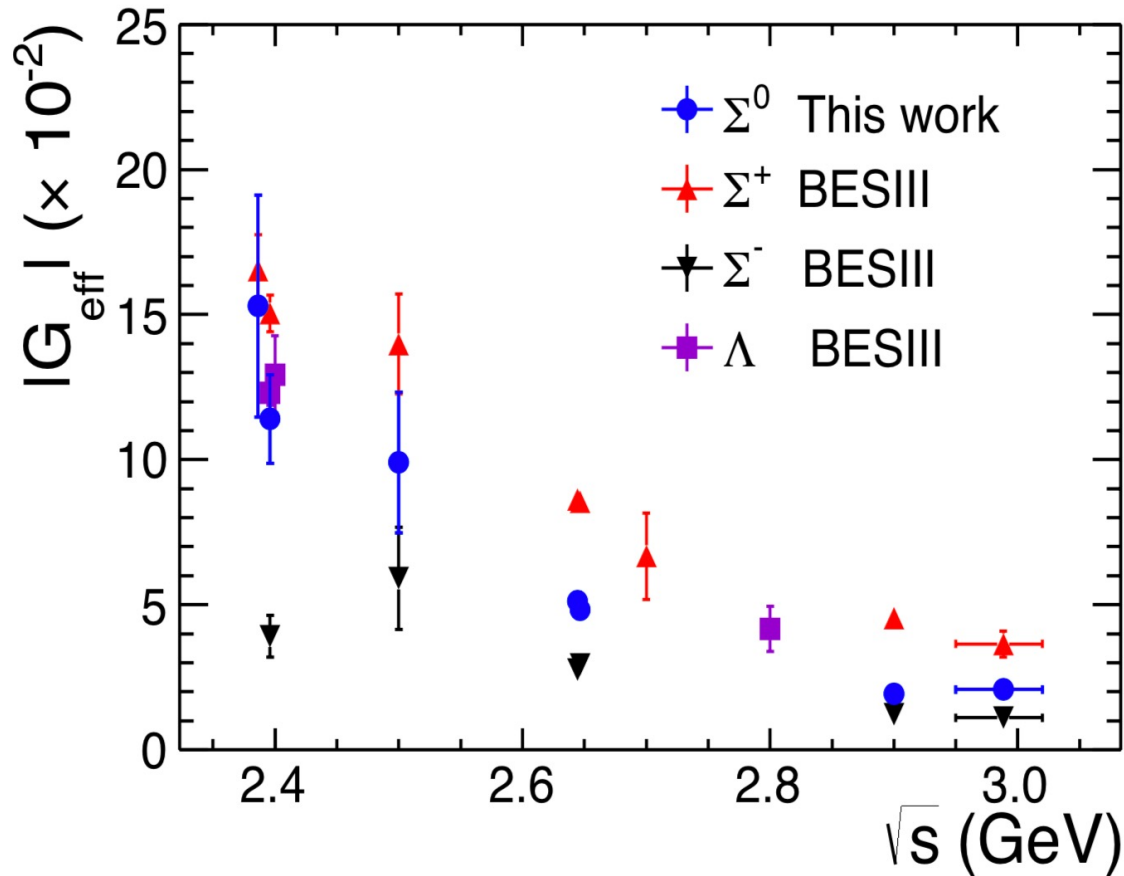


❖ No cross section enhancement near threshold;

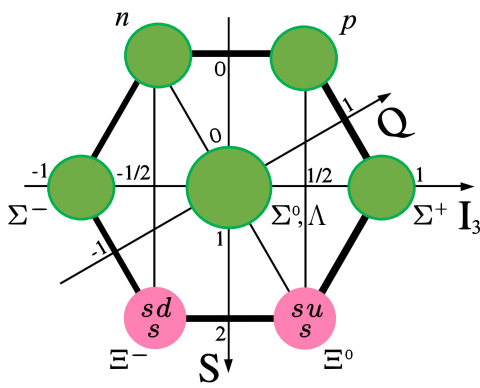
❖ The cross section ratio is consistent with the expectation that FF is proportional to sum squared charge of the valence quarks.



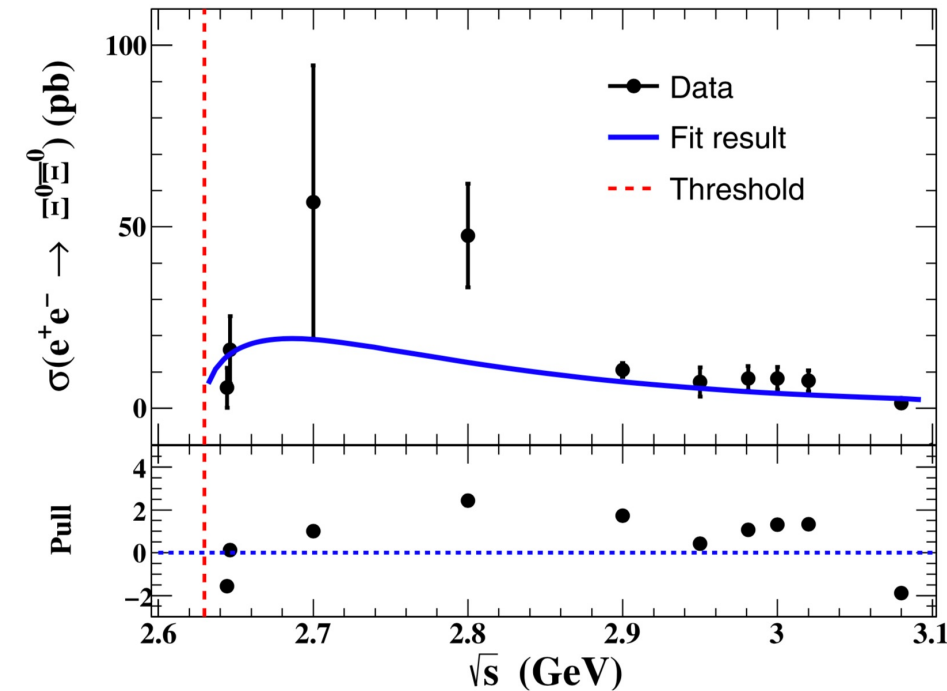
Effective FFs



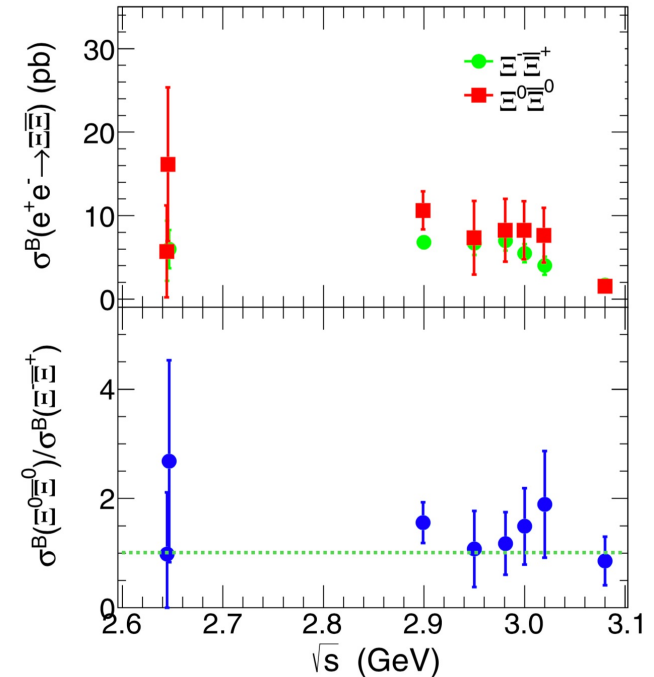
Ξ near threshold



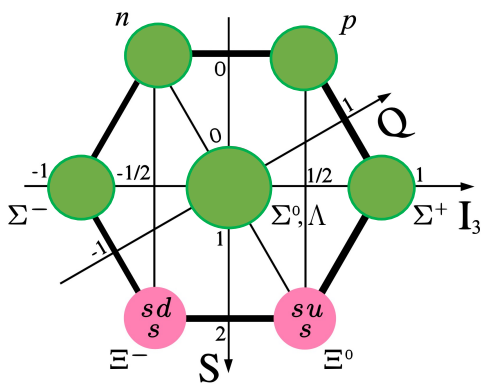
Cross Sections Fit



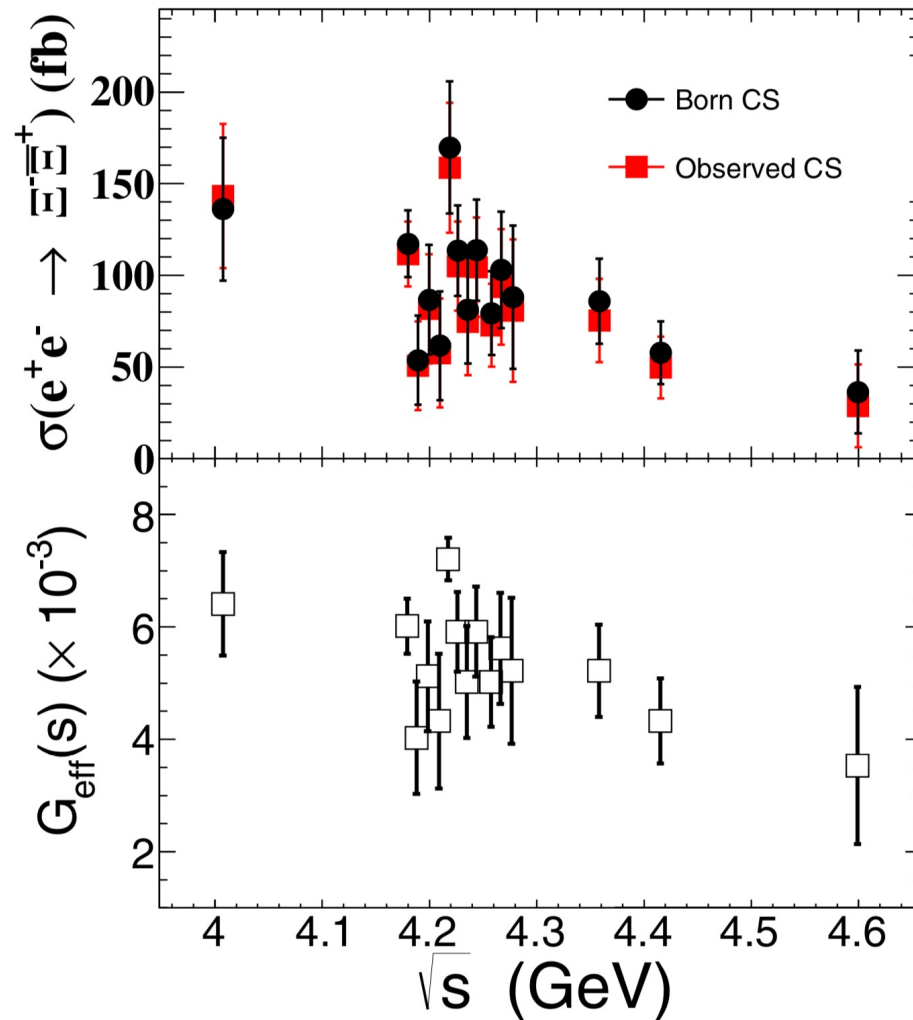
Cross Sections Ratio

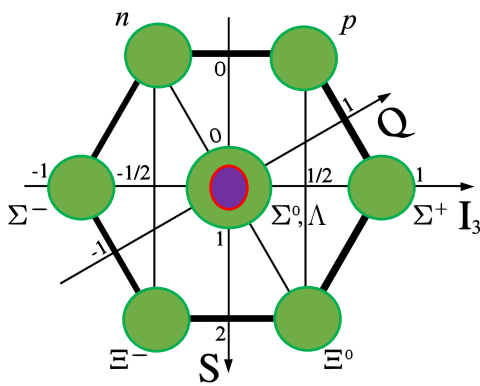


- ❖ No cross section enhancement near threshold;
- ❖ The cross section ratio is consistent with the isospin symmetry expectation.

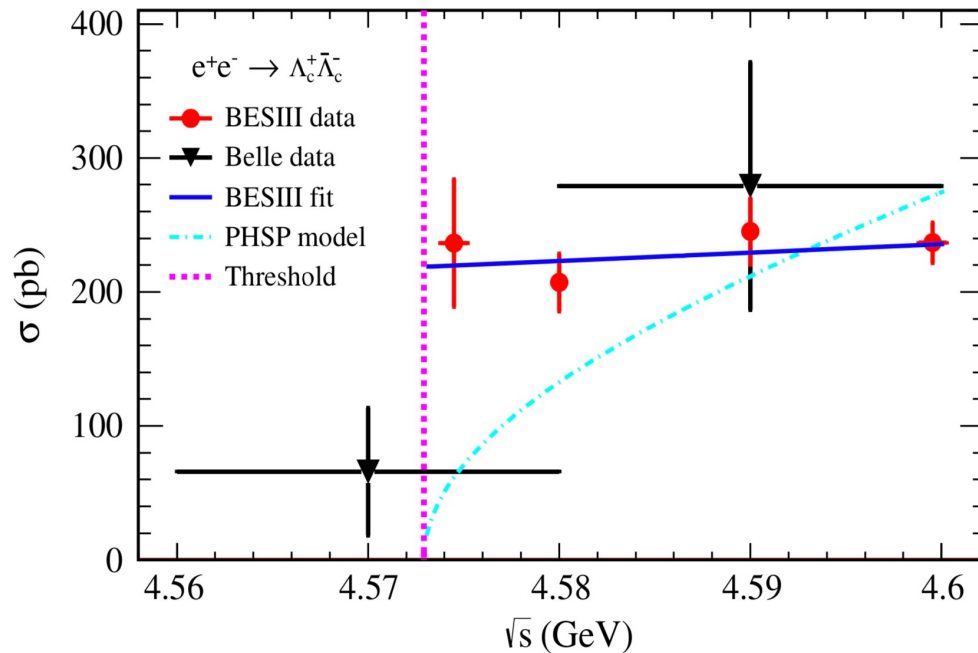


Ξ away from threshold



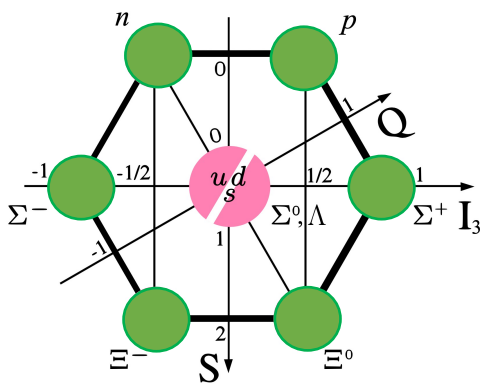

 Λ_c

Cross Sections



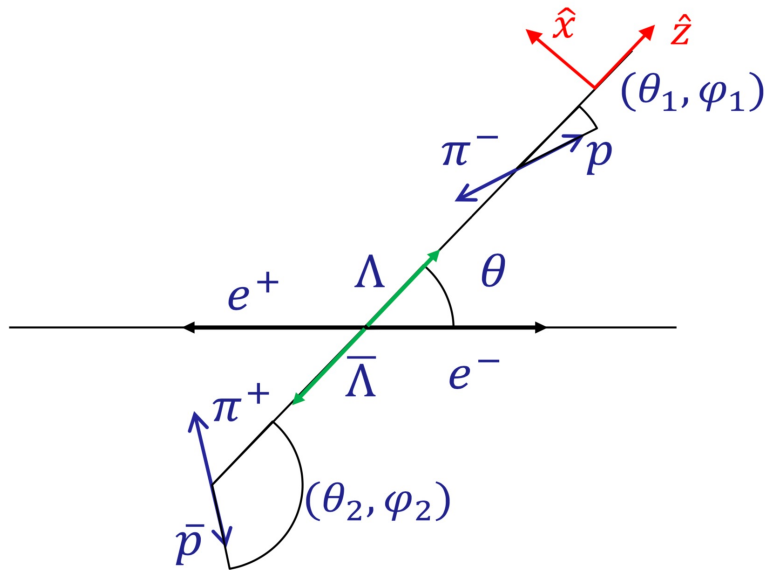
- ❖ Near threshold enhancement is observed, and beyond the pQCD predictions;
- ❖ The ratio of G_E/G_M is measured by analyzing the angular distributions.

\sqrt{s} (MeV)	α_{Λ_c}	$ G_E/G_M $
4574.5	$-0.13 \pm 0.12 \pm 0.08$	$1.14 \pm 0.14 \pm 0.07$
4599.5	$-0.20 \pm 0.04 \pm 0.02$	$1.23 \pm 0.05 \pm 0.03$

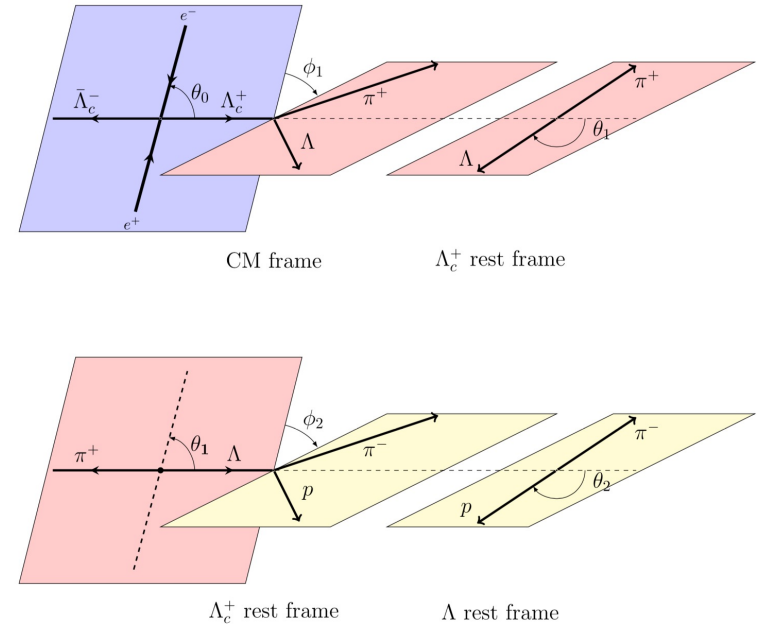


Phase of G_E and G_M

Λ case

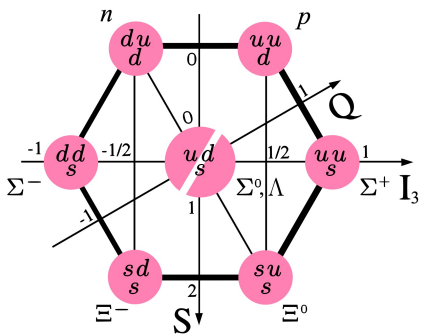


Λ_c case



❖ **Multidimensional analysis with a complete decomposition of the spin structure of the reaction, and the relative phase could be measured;**

❖ Λ case: $\Delta\Phi = 37^\circ \pm 12^\circ$ (stat) $\pm 6^\circ$ (syst); Λ_c case: $\sin \Delta\theta = -0.28 \pm 0.13$ (stat) ± 0.03 (syst).



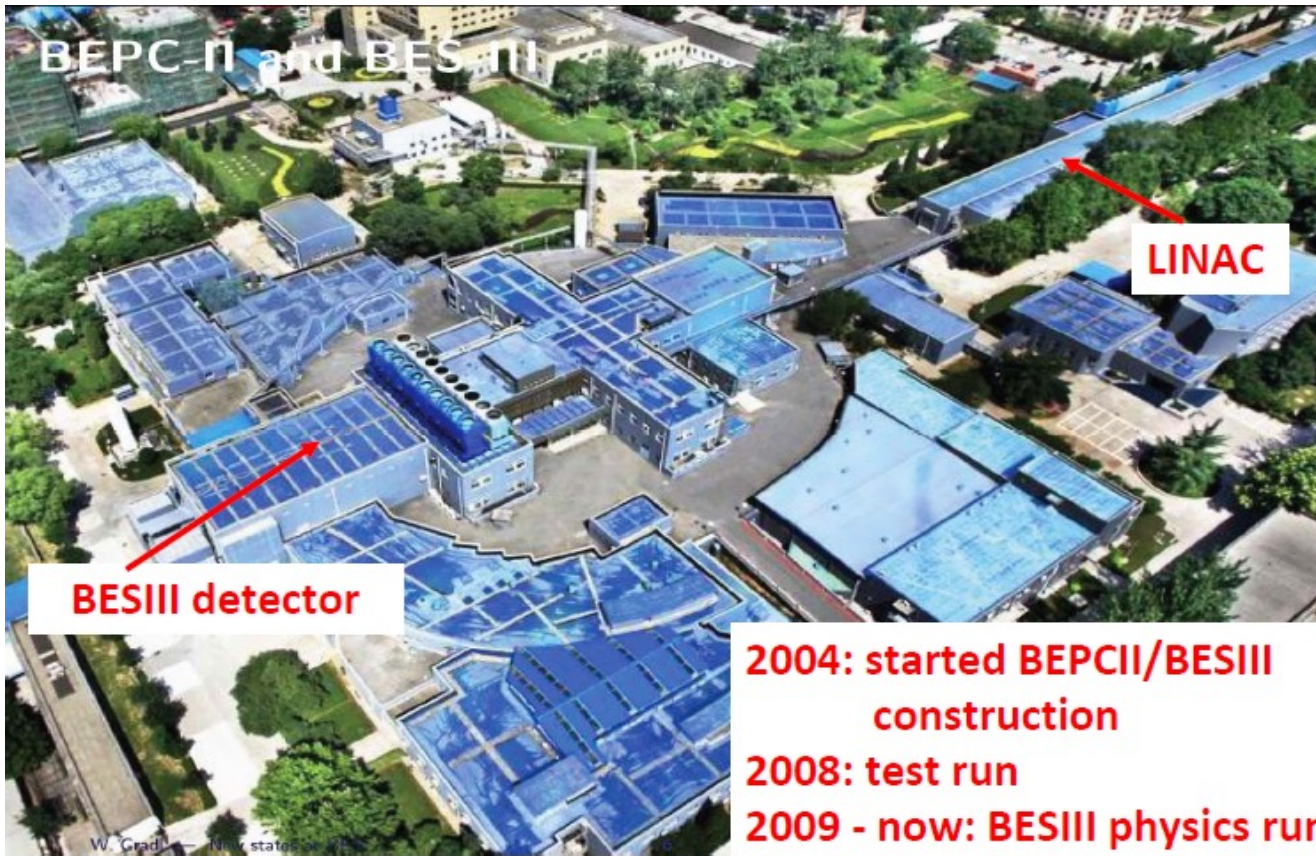
Summary



- Based on world largest electron-positron annihilation data in the charm region, the time-like FFs of baryons are measured in a systematic way
- Oscillation feature of effective FFs is observed for both neutron and proton, which needs further theoretical explanations
- Cross section enhancement is observed for some baryon pairs near the threshold, but not all

THANK YOU!

Upgraded Beijing Electron Positron Collider (BEPCII)



Beam energy:
1-2.5 GeV

Design luminosity:
 $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
 5.16×10^{-4}

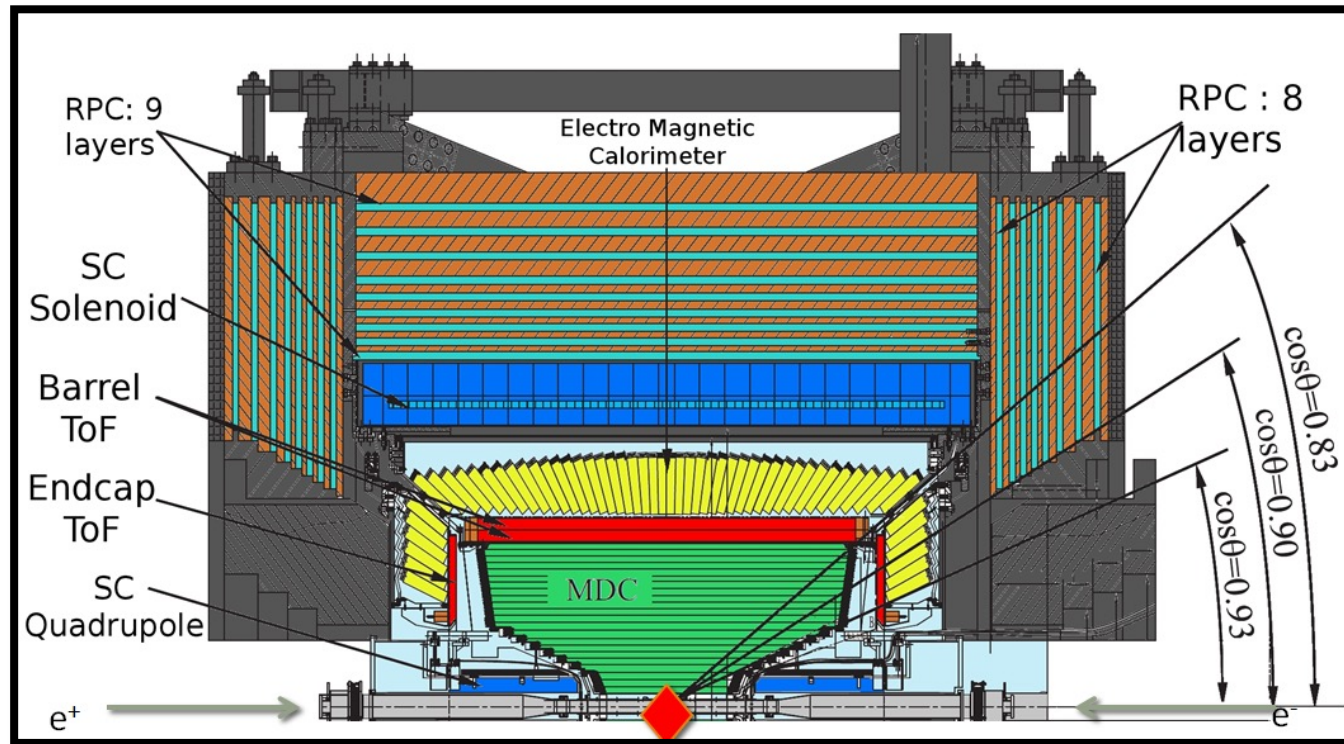
Bunch length: 1.5
cm

Total current: 0.91
A

Linac: ~200 m

Circular: ~240 m

BESIII Detector



Charged-particle momentum resolution@1GeV: 0.5%

Photon energy resolution@1 GeV: 2.5% (5%) for barrel (endcap); position resolution 6mm

dE/dx resolution: 6% for electrons from Bhabha process

Time resolution of TOF: 68 ps (60 ps) for barrel (endcap)

SC magnetic: 1 T

Trigger and DAQ: 4 kHz, with event size 12 Kbytes

Collaboration >500 Members from 72 institutions in 15 countries!