Baryon Electromagnetic Form Factor at BESIII

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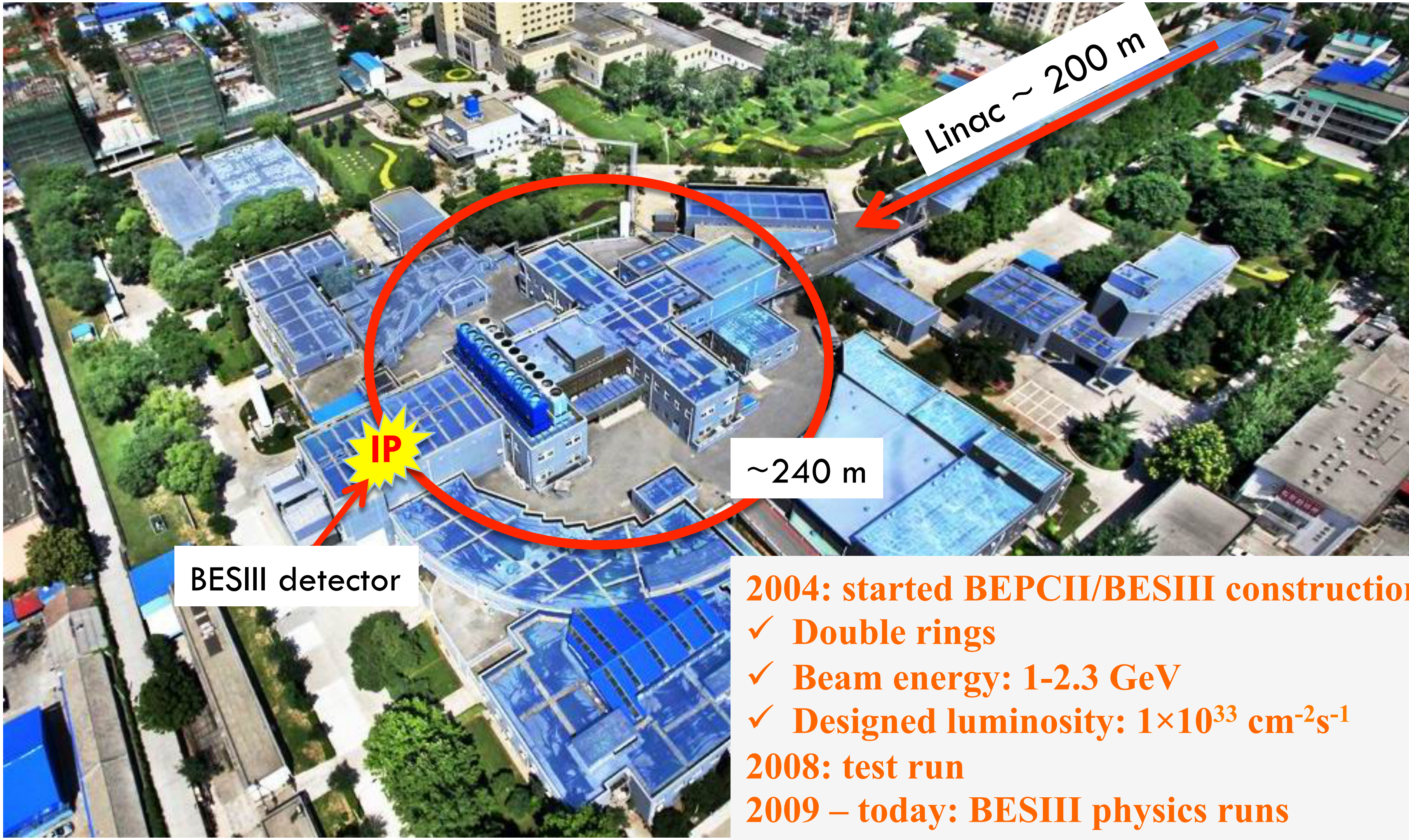
BESIII

OUTLINE

- ✓ INTRODUCTION:
  - The BESIII experiment and data sets
  - Electromagnetic Form Factors formalism
- ✓ Baryon Form Factors at BESIII
  - Proton Form Factor
    - $|G_E|/|G_M|$ measurements
    - ISR: taggend and untagged analysis
  - Λ Form Factors
    - Phase information (preliminary result)
  - Λ_C Form Factors
- ✓ Summary and Conclusions

Beijing Electron Positron Collider II

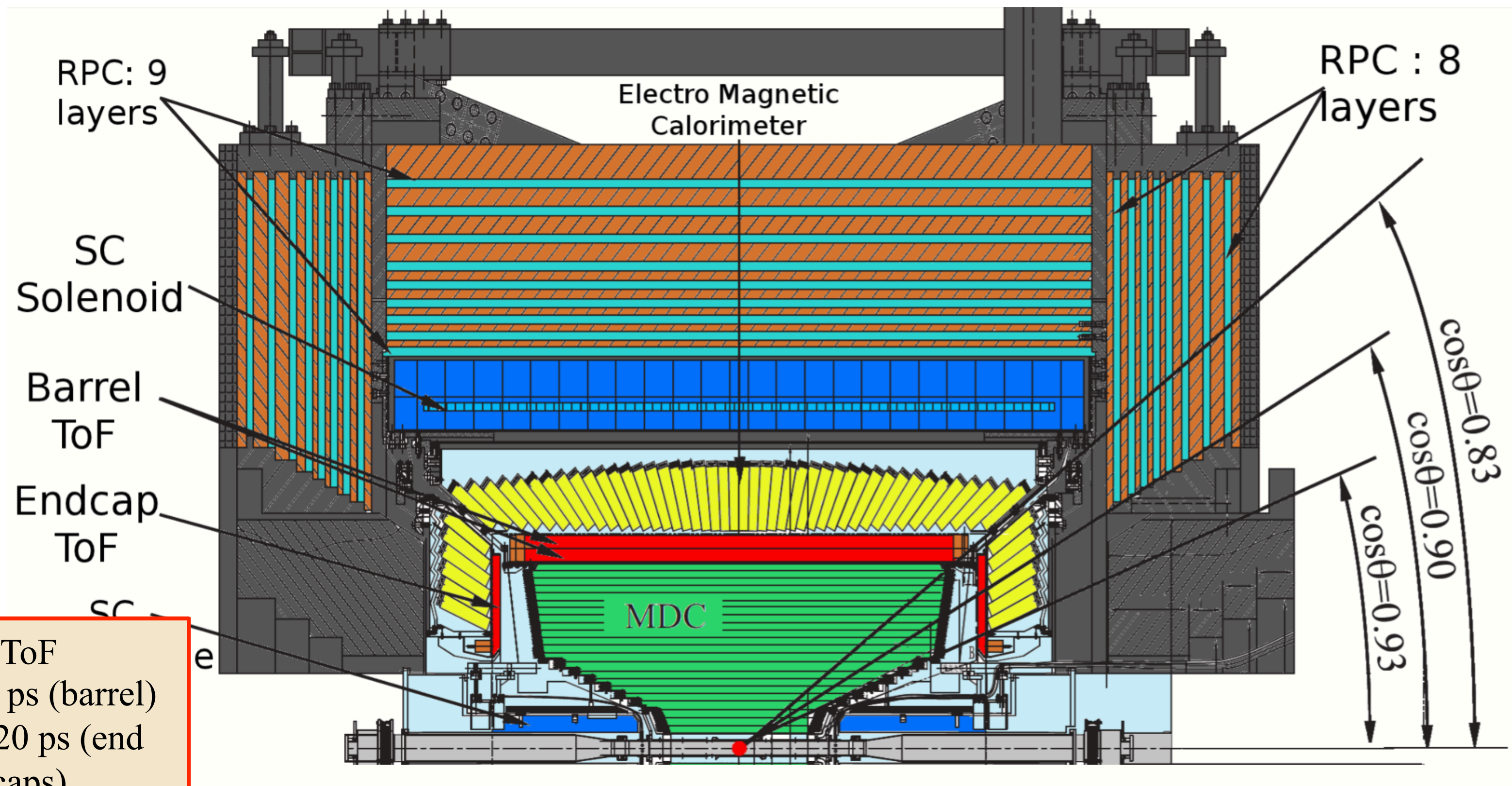


2004: started BEPCII/BESIII construction
- ✓ Double rings
- ✓ Beam energy: 1-2.3 GeV
- ✓ Designed luminosity: 1×10^{33} cm^{-2}s^{-1}

2008: test run
2009 – today: BESIII physics runs

The BESIII Detector

Nucl. Instr. Meth. A614, 345 (2010)



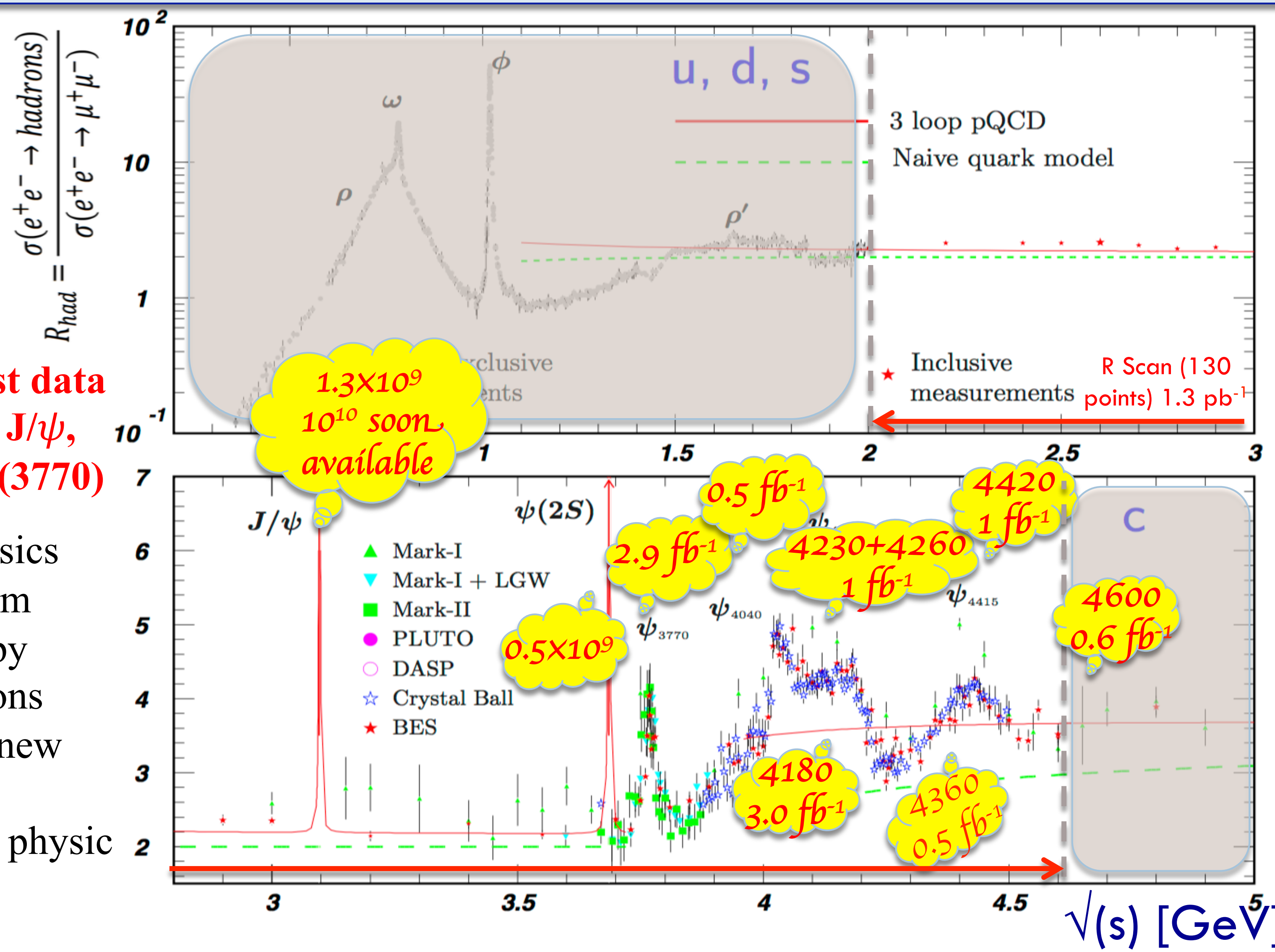
ToF
$\sigma_t \sim 90$ ps (barrel)
$\sigma_t \sim 120$ ps (end caps)

Drift Chamber
$\sigma_{r\phi} \sim 130$ µm (single wire)
$\sigma_{pt}/p_t \sim 0.5$ % @ 1 GeV

Electromagnetic CsI(Tl) Calorimeter
$\sigma_E/E < 2.5\%$ @ 1 GeV (barrel)
$\sigma_E/E < 5\%$ @ 1 GeV (end caps)
$\sigma_{xy} \sim (6\ \text{mm})/E^{1/2}$ @ 1 GeV

RPC Muon Detector
$\Delta\Omega/4\pi = 93\%$

The BESIII data set



World largest data sample for J/ψ, ψ(2S) and ψ(3770)

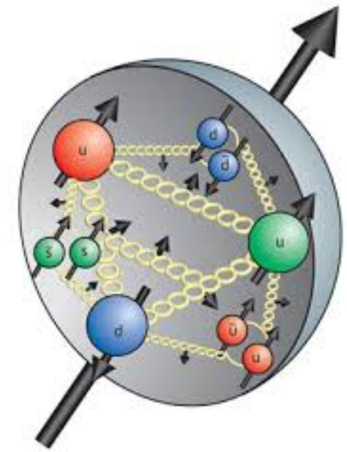
- Charm physics
- Charmonium spectroscopy
- Light hadrons
- Search for new physics
- τ and QCD physic
- …

http://pdg.lbl.gov/2017/reviews/rpp2017-rev-cross-section-plots.pdf

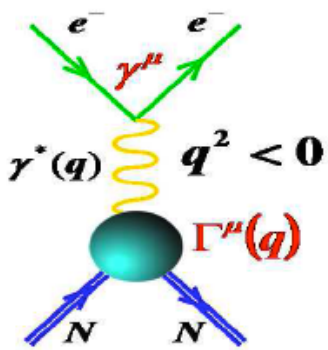
Electromagnetic form factors

Hadrons are not point-like particles
- Internal structure
- Internal dynamic → $M_{hadron} \neq \sum m_{q\text{-valence}}$

➢ Form Factors (FFs) used to parametrize the structure and internal dynamics: 2 FFs involved for s=1/2 baryons



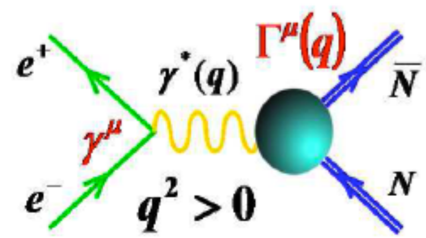
SPACE-LIKE FF
(Real functions)



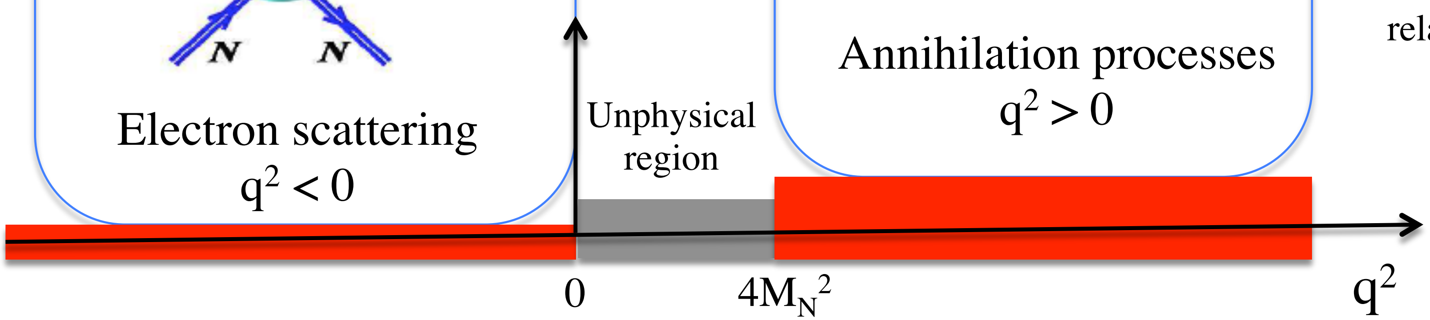
Electron scattering
$q^2 < 0$

Unphysical region

TIME-LIKE FF
(Complex functions)



Annihilation processes
$q^2 > 0$



$$\Gamma^\mu = \gamma^\mu \boldsymbol{F_1} + \frac{i\sigma^{\mu\nu} q_\nu}{2M} \boldsymbol{F_2}$$

Dirac FF: related to the charge

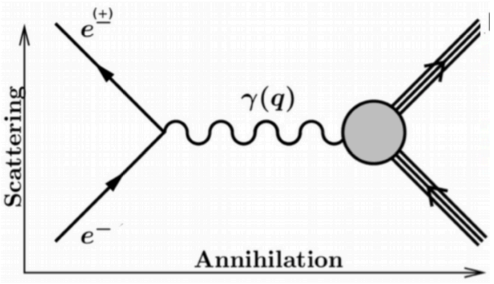
Pauli FF: related to the magnetization

Time-like Electromagnetic FFs

- Sachs parameterization:

$$G_E(q^2) = F_1(q^2) + \frac{q^2}{4M_B}F_2(q^2) \qquad G_M(q^2) = F_1(q^2) + F_2(q^2)$$

Electric FF   Magnetic FF



- Differential cross section:

$$\left[\frac{d\sigma}{d\Omega_{CM}}\right] = \frac{\alpha^2\beta^2 C}{4q^2}\left[(1+\cos^2\theta)\boxed{|G_M|^2} + \frac{1}{\tau}\sin^2\theta_B\boxed{|G_E|^2}\right]$$

$$\beta = \sqrt{1-\frac{1}{\tau}},\ \tau = \frac{q^2}{4M^2}, C = \frac{y}{(1-exp(-y))},\ y = \frac{\alpha\pi}{\beta},$$

- Total cross section:

C=0 for neutral point-like baryon

$$\sigma(q^2) = \frac{2\pi\alpha^2\beta C}{3q^2\tau}\left(2\tau|G_M|^2 + |G_E|^2\right)$$

- The measurement of the differential cross section at fixed energy allows the determination of the ratio $|G_E|/|G_M|$. From the total cross section the effective FF can be measured:

$$|G_{eff}| = \sqrt{\frac{2\tau|G_M|^2 + |G_E|^2}{2\tau+1}}$$

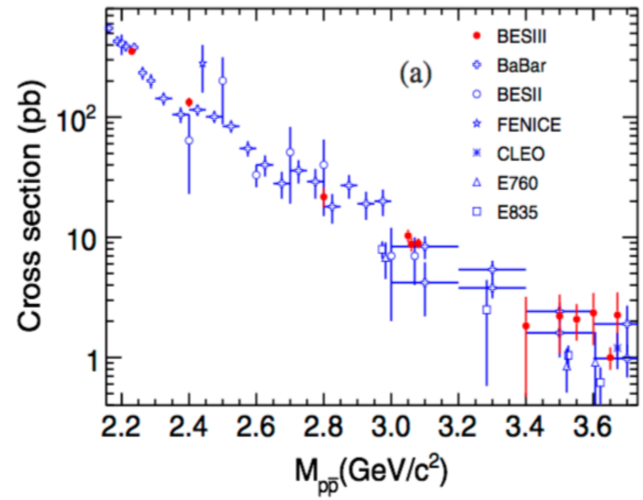
⇒ equivalent to $|G_M|$ under the assumption $|G_E|=|G_M|$

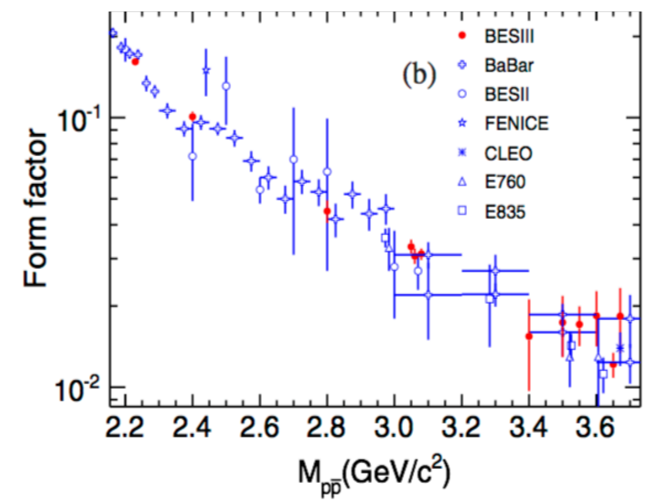
Proton FF in TL region - Scan data 2012

PRD91, 112004 (2015)

- Direct production channel $e^+e^- \to p\bar{p}$
- R-scan data @ 12 points ($\mathcal{L}$ = 157 pb^{-1}) collected between 2.22 to 3.67 GeV in 2012
- Event selection:
  - ➢ Two charged tracks
  - ➢ PID for proton and antiproton
  - ➢ Kinematic fit constraints
  - ➢ Background subtracted
- Cross section and effective FF measurements:

$$\sigma_{\rm Born} = \frac{N_{\rm obs} - N_{\rm bkg}}{L \cdot \varepsilon \cdot (1+\delta)}, \quad |G| = \sqrt{\frac{\sigma_{\rm Born}}{86.83 \cdot \frac{\beta}{s}(1 + \frac{2m_p^2}{s})}},$$





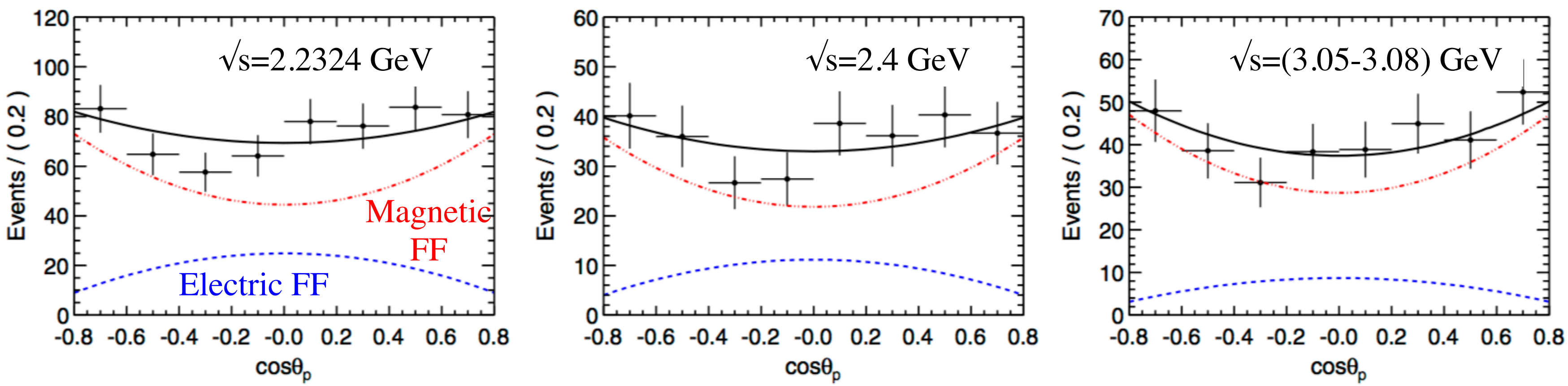
- ➢ Good agreement with previous measurements
- ➢ Overall improvement of the uncertainties by ~ 30%

$|G_E|/|G_M|$ Ratio - Scan data 2012

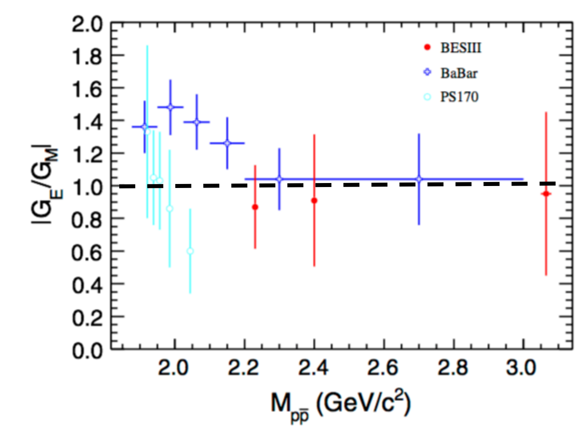
PRD91, 112004 (2015)

Extraction of $|G_E|/|G_M|$ ratio from the study of the proton polar angle distribution at those points with largest statistics

- Detection efficiency correction vs. $\cos\theta_p$ are applied

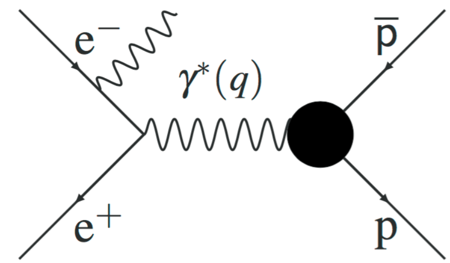


$\sqrt{s}$ (MeV)	$\lvert G_E/G_M\rvert$	$\lvert G_M\rvert$ ($\times 10^{-2}$)	χ^2/ndf
	Fit on $\cos\theta_p$		
2232.4	$0.87 \pm 0.24 \pm 0.05$	$18.42 \pm 5.09 \pm 0.98$	1.04
2400.0	$0.91 \pm 0.38 \pm 0.12$	$11.30 \pm 4.73 \pm 1.53$	0.74
(3050.0, 3080.0)	$0.95 \pm 0.45 \pm 0.21$	$3.61 \pm 1.71 \pm 0.82$	0.61



- ➢ $|G_E|/|G_M|$ ratio consistent with 1
- ➢ Agreement with BaBar data (PRD**87**,092005)
- ➢ BESIII limited statistic: new scan data?

Using the Initial State Radiation (ISR)

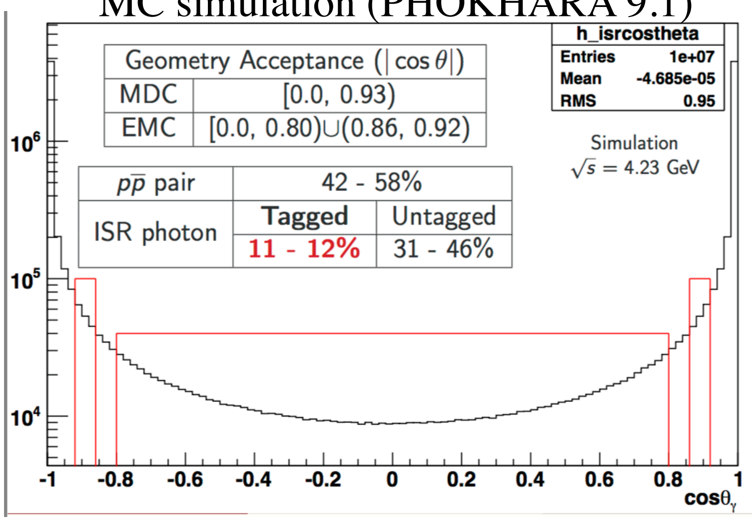


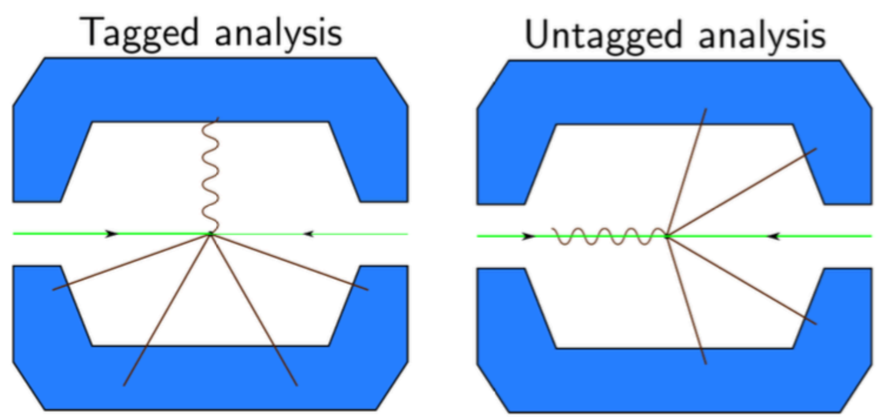
e^+e^- annihilation is mostly accompanied by emission of one or several photons from the initial state → events with ISR photons have a lower c.m. energies

- Continuous q^2 range
- Complementary approach to the energy scan technique

➢ Two complementary methods:
  - ➢ ISR-Tagged
  - ➢ ISR-Untagged

MC simulation (PHOKHARA 9.1)





Tagged analysis:
- Low statistics
- Large bkg

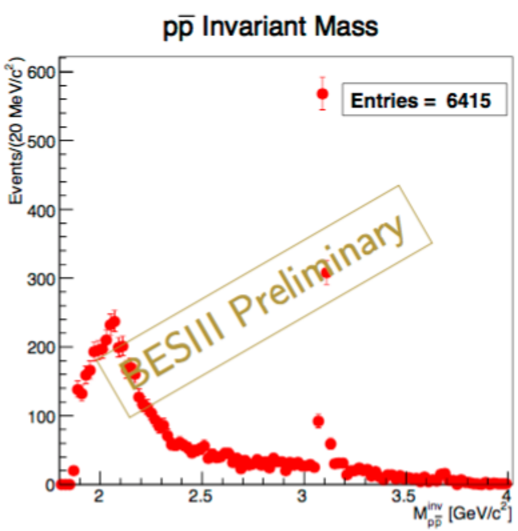
Untagged analysis:
- High statistics
- $\sqrt{s'} > 1$GeV
- Low bkg

Proton FF from ISR

- 7.4 fb^{-1} at c.m. energies between 3.773 GeV and 4.6 GeV
- ISR-Tagged and Untagged analysis exploited

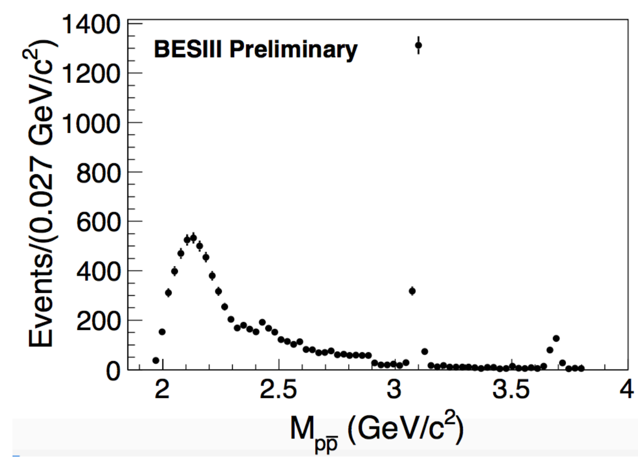
TAGGED ANALYSIS: LARGE ANGLE (**LA**)

- Two tracks, one cluster in EMC
- Kinematic constraints applied (4C fit)
- 5C veto fit with additional γ

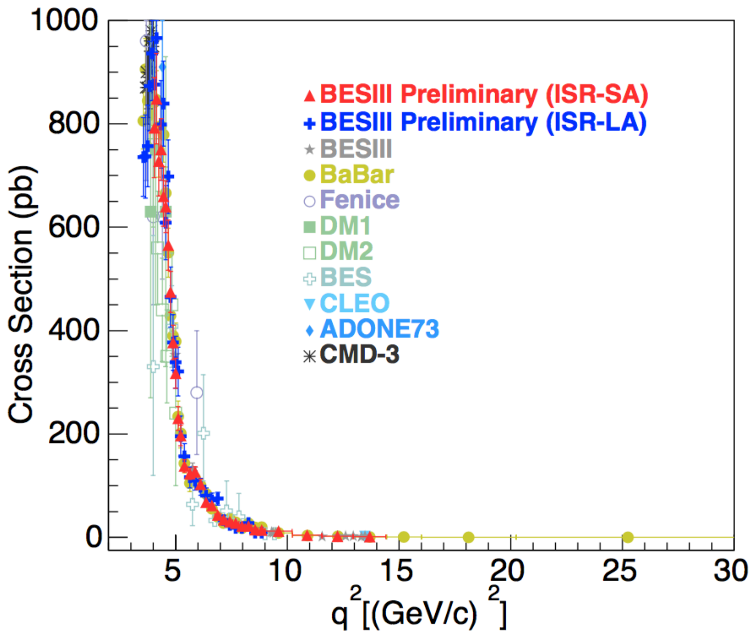


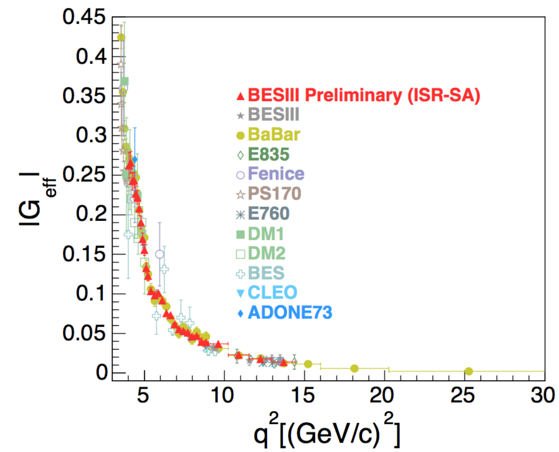
UNTAGGED ANALYSIS: SMALL ANGLE (**SA**)

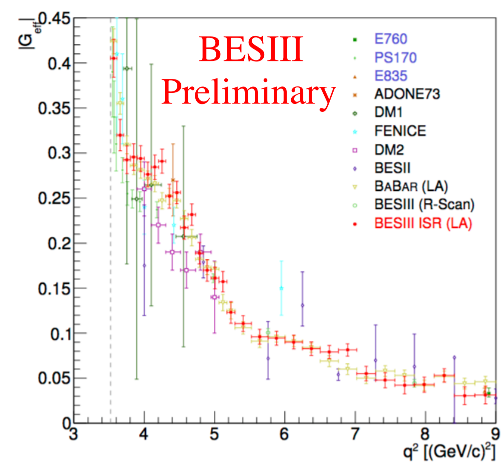
- Two tracks, PID by dE/dx and TOF
- Polar angle of missing momentum and missing mass squared distributions to identify non-detected ISR γ



Proton FF from ISR: total cross section and $|G_{eff}|$







- Cross section and $|G_{eff}|$ measurements
  - LA: 31 intervals in $1.877 \leqq \sqrt{s} \leqq 3.0$ GeV
  - SA: 30 intervals in $2 \leqq \sqrt{s} \leqq 3.8$ GeV
- Consistent with previous measurements
- Total relative uncertainties on the cross section is between 8% and 37%
- SA results competitive in statistic with BaBar (PRD88,072009; PRD87,092005)

Proton FF from ISR: $R=|G_E|/|G_M|$ extraction

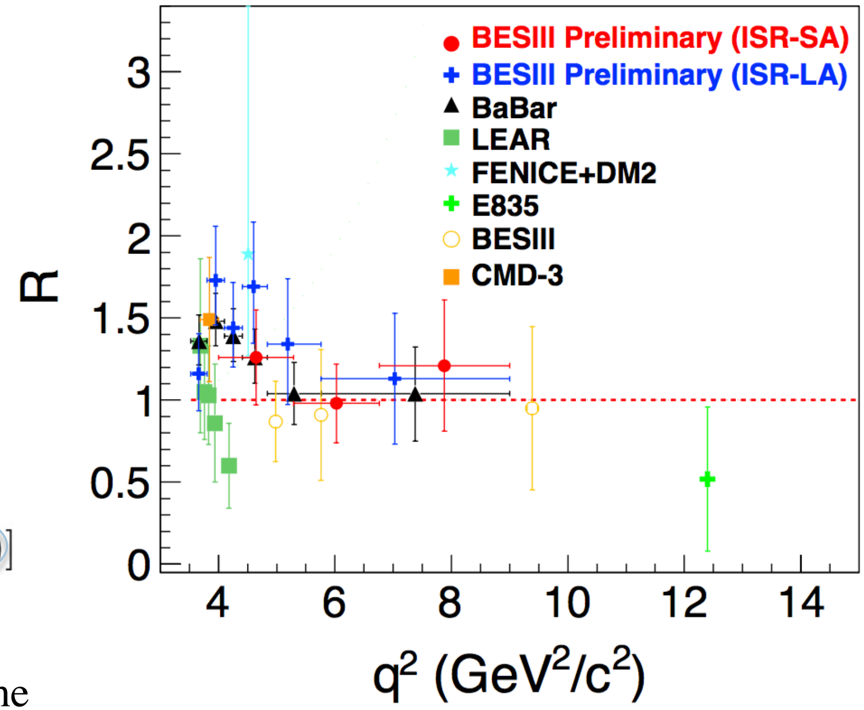
- $R=|G_E|/|G_M|$ measurements can be extracted form the analysis of the θ_p distribution, the angle between the proton momentum in the ppbar rest frame and the momentum of the ppbar system in the e^+e^- c.m. frame
  - LA: 6 intervals in $1.877 \leqq \sqrt{s} \leqq 3.0$ GeV
  - SA: 3 intervals in $2 \leqq \sqrt{s} \leqq 3.8$ GeV

$$\frac{d\sigma}{d\cos\theta_p} = A[H_M(\cos\theta_p, M_{p\bar{p}}) + \frac{R}{\tau} H_E(\cos\theta_p, M_{p\bar{p}})]$$

From MC under the hypothesis $|G_E| = 0$

From MC under the hypothesis $|G_M| = 0$

They are the equivalent forms of $1+\cos^2\theta_p$ and $\sin^2\theta_p$ in the case of $e^+e^- \to p\bar{p}$

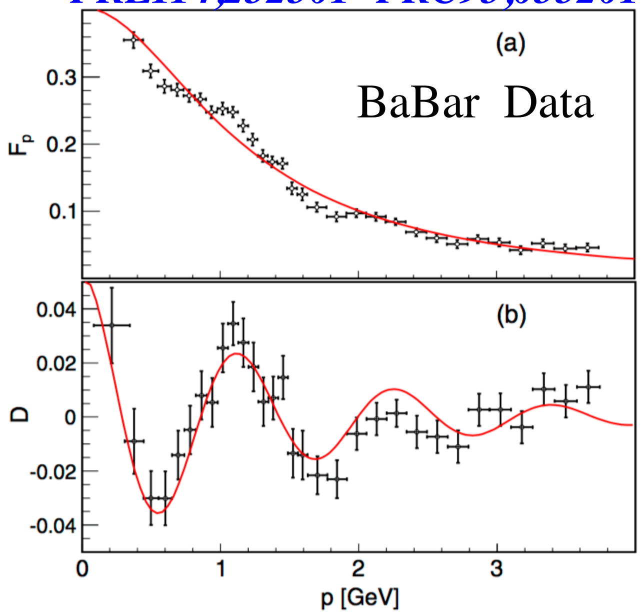


- **Competitive accuracy**
- Total uncertainty dominated by statistical uncertainty
- **Agreement with BaBar and BESIII scan data**

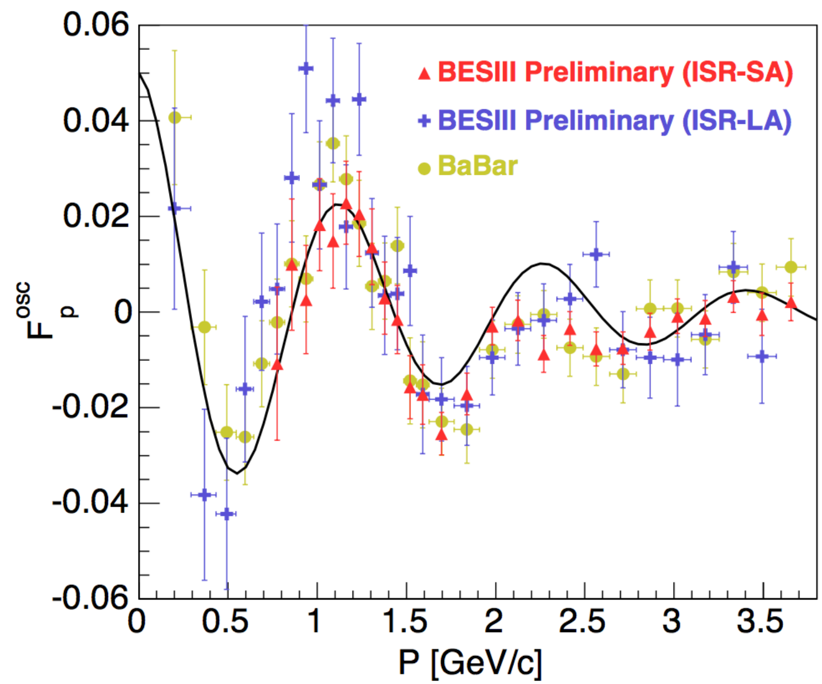
Structure in Effective proton FF

- Effective proton FF as a function of the 3-momentum (p) of the relative motion of the $p\bar{p}$ pair: damped oscillatory behaviour observed by BaBar and then confirmed in BESIII

PRL114,232301- PRC93,035201



$$F_{osc}(p) \equiv A \exp(-Bp) \cos(Cp + D)$$

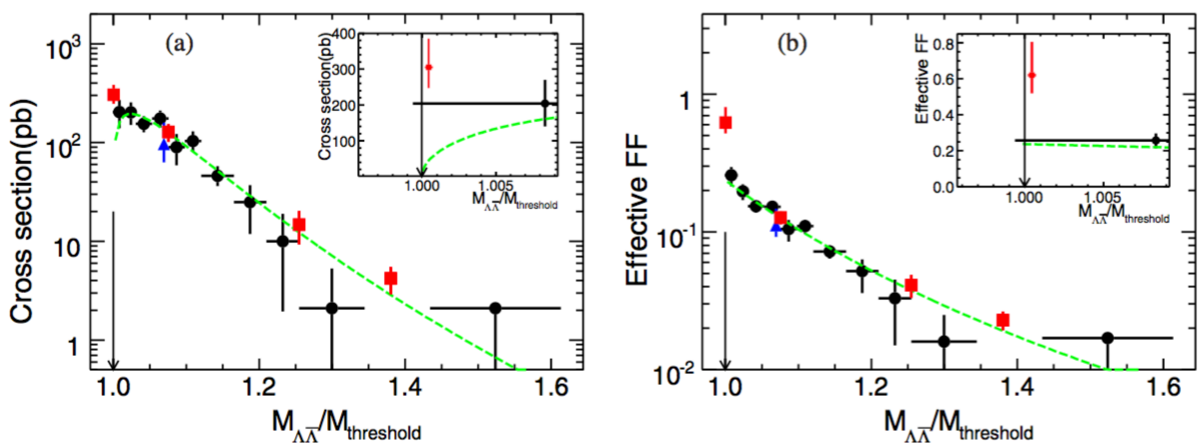


Due to a possible interference effect involving rescattering processes at moderate kinetic energies of the outgoing hadrons (when the center-of-mass of the produced hadrons are separated by ~ 1 fm)

Measurement of Λ FF at BESIII

PRD97, 032013(2018)

- $e^+e^-\to\Lambda\bar{\Lambda}$, $\Lambda\to p\pi^-$, $\bar{\Lambda}\to\bar{p}\pi^+$ ($\bar{\Lambda}\to\bar{n}\pi^0$, $\Lambda\to X$, with X=inclusive decays)
  - Indirect search for the antiproton (search for mono-energetic π^0)
- 4 energy scan points: 2.2324 GeV, 2.4 GeV, 2.8 GeV and 3.08 GeV
  - 1 MeV above the $\Lambda\bar{\Lambda}$ mass threshold
- Cross section and effective electromagnetic FF determined



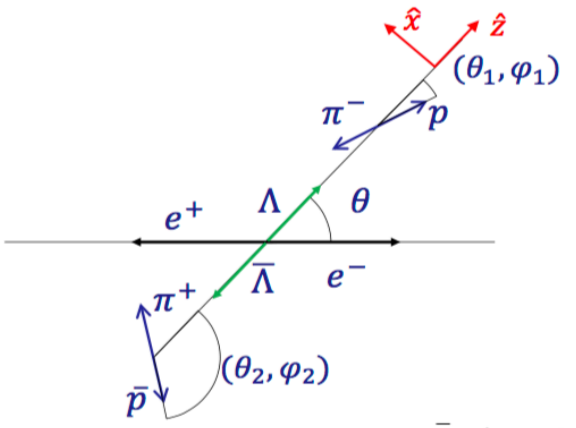
BESIII (PRD97)
BaBar (PRD76,092006)
DM2 (Z. Phys. C. 48,23)
pQCD prediction

No Coulomb effect for neutral baryons BUT **unexpected rise at the threshold**

- Good agrement with BaBar and DM2 data
- The observed threshold enhancement underlying a more complicated physics scenario
- These results could help to understand the mechanism of baryon production and test theory hypotheses based on threshold enhancement effect

Λ FF at BESIII: phase information

BESIII Preliminary

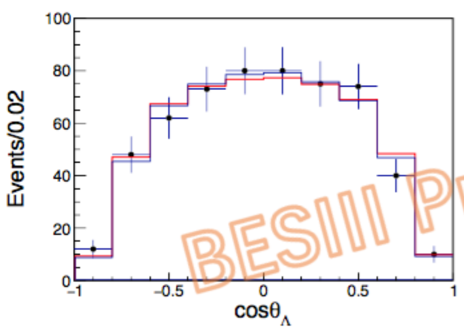


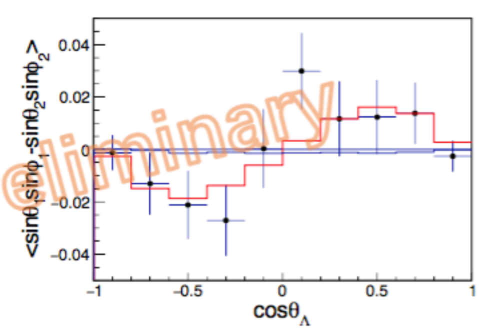
- Multidimensional analysis needed for a complete decomposition of G_E and G_M
- 66.9 pb^{-1} @ $\sqrt{s}$=2.396 GeV
- Complex form of FF:
  - $G_E = |G_E|e^{i\phi_E}$, $G_M = |G_M|e^{i\phi_M}$
  - **First measurement of the relative phase $\Delta\phi=\phi_E-\phi_M$**

$$\bar{P}_Y(\cos\theta_\Lambda) = \frac{\sqrt{1-\alpha_\psi{}^2}\cos\theta_\Lambda\sin\theta_\Lambda}{1+\alpha_\psi\cos^2\theta_\Lambda}\sin(\Delta\Phi)$$

$\Delta\phi \neq 0 \Rightarrow$ polarization effect on the final state even for unpolarized initial state

- Polarization and spin-correlation parameters determined ⇒ they allow to determine the relative phase between G_E and G_M





$$R = 0.94 \pm 0.16_{\rm stat} \pm 0.03_{\rm syst} \pm 0.02_{\alpha_\Lambda}$$

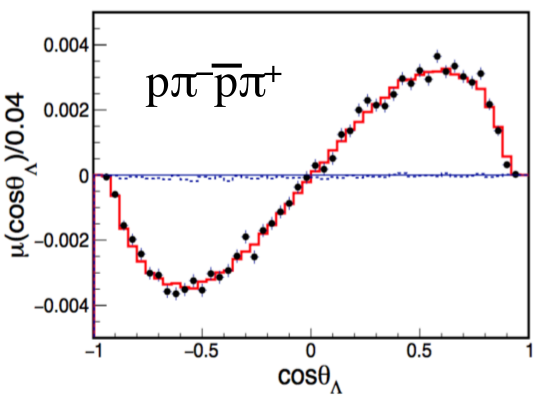
$$|\Delta\Phi| = 42^\circ \pm 12^\circ_{stat} \pm 8^\circ_{syst} \pm 6^\circ_{\alpha_\Lambda}$$

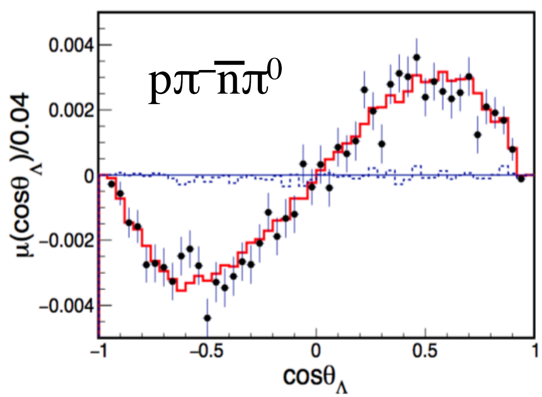
BESIII Preliminary

Λ polarization measurement

arXiv:1808.08917

- $J/\psi \to \Lambda\bar{\Lambda}$, $\Lambda \to p\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$ and $\bar{\Lambda} \to \bar{n}\pi^0$
- With hyperons, the polarization is experimentally observable by their weak parity violating decay → extracted from the angular distributions of its decay products
  - The magnitude of the polarization depends on θ_Λ
- **$\Delta\phi = (42.4 \pm 0.6 \pm 0.5)°$: consistent and more precise than $\sqrt{s}$=2.396 GeV analysis**





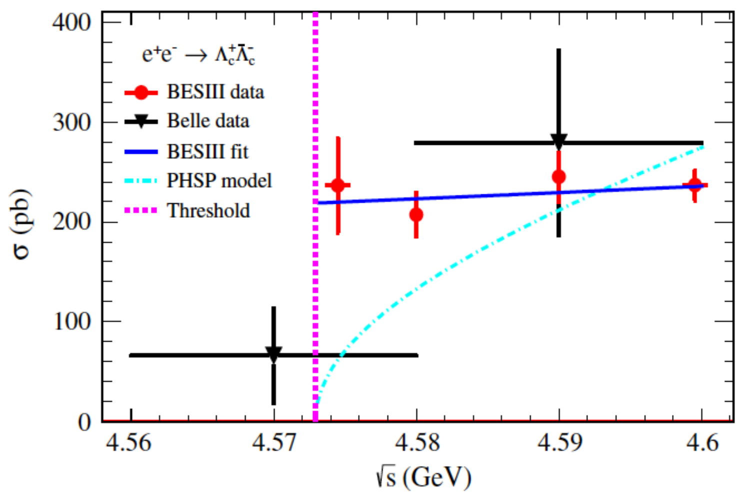
Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [25]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)°$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [27]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [27]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [27]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

- $\mu(\cos\theta_\Lambda) \sim 1 - \alpha_\psi 2\alpha\_ \sin\Delta\Phi \cos\theta_\Lambda \sin\theta_\Lambda$ ⇒ clear polarization effect observed
- ***Asymmetry parameter for the $\Lambda \to p\pi^-$ decay mode $\alpha\_$: 5σ deviation from the PDG value***
  - This means that all published results on Λ polarization, determined from the product of α_ and and the polarization, are 17(3)% too large

Measurement of Λ_c FF at BESIII

PRL120, 132001(2018)

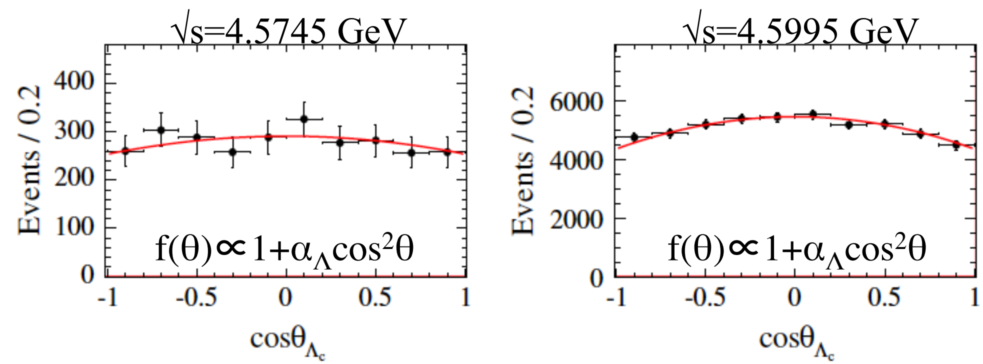
- 4 c.m. energies: 4.5745, 4.5800, 4.5900, 4.5995 GeV (631.3 pb^{-1})
- 10 Cabibbo-favored + c.c. hadronic decay modes considered
- Total cross section: weighted average over all the 20 decay modes
  - Very high precision achieved (1.3% @ 4.6 GeV)



$$|G_E/G_M|^2 = (1-\alpha)/(\frac{4m^2_{\Lambda_c^+}}{s}\alpha + \frac{4m^2_{\Lambda_c^+}}{s})$$

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

- Polarization and spin-correlation parameters determined ⇒ they allow to determine the relative phase between G_E and G_M
- **Step at threshold + plateau region**: indicate the complexity of production behaviour of the Λ_c
- **$|G_E|/|G_M|$ measured for the first time**



Conclusions

- BESIII provides an ideal environment to measure baryon FFs.

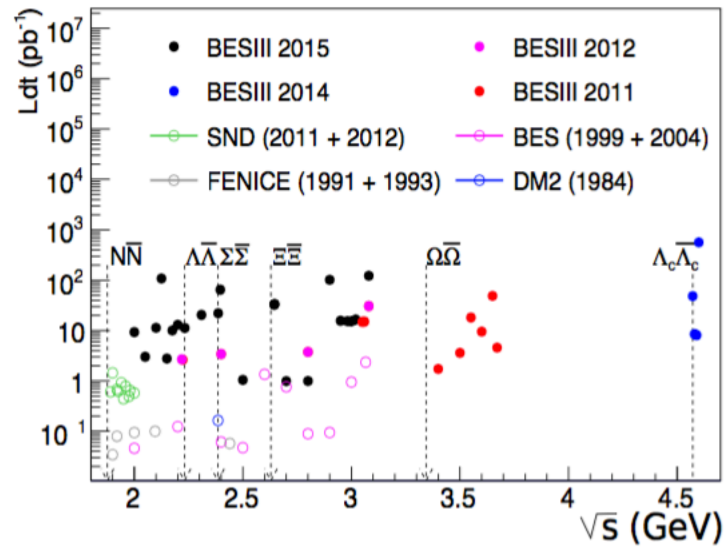
- Two complementary approaches can be used
  - Energy scan
  - ISR technique

- p, Λ, Λ_c cross sections and FFs measured with very high precision
  - Intriguing enhancement observed at threshold
  - Oscillating behaviour of proton FF
  - First measurement of the relative phase of EM FFs for Λ (preliminary result)

Plans

Near future:

- Present theory is missing something
- $e^+e^-\to p\bar{p}$: more data from BESIII and CMD3
- $e^+e^-\to \Lambda\bar{\Lambda}$: more data at threshold
- $e^+e^-\to \Lambda_c\bar{\Lambda}_c$: more data at threshold and above by BESIII



- $e^+e^-\to n\bar{n}$: more data from SND and CMD3; BESIII preliminary soon available
- BR($J/\psi\to\gamma n\bar{n}$): BESIII preliminary soon available
- $|G_E|/|G_M|$ phase: more data from BESIII

Back-up slides

The BESIII Collaboration

EUROPE

Bochum University, Budker Instituteof Nuclear Physics, **Ferrara University**, GSI Darmstadt, Helmholtz Institute Mainz, **INFN, Laboratori Nazionali di Frascati**, Johannes Gutenberg University of Mainz, Joint Institute for Nuclear Research (JINR), KVI/ University of Groningen,Turkish Accelerator Center Particle Factory Group (TAC-PF),Universitaet Giessen, University of Münster, **University of Turin**, Uppsala University

USA

Carnegie Mellon University; Indiana University; University of Hawaii; University of Minnesota; University of Rochester

CHINA

IHEP, CCAST, UCAS, Beijing Institute of Petro-chemical Technology, Beihang Univ., Guangxi Normal Univ., Guangxi Univ., Hangzhou Normal Univ., Henan Normal Univ., Henan Univ. of Science and Technology, Huazhong Normal Univ., Huangshan College, Hunan Univ., Lanzhou Univ., Liaoning Univ., Nanjing Normal Univ., Nanjing Univ., Nankai Univ., Peking Univ., Shanxi Univ., Sichuan Univ., Shandong Univ., Shanghai Jiaotong Univ., Soochow Univ., Southeast Uny., Sun Yat-sen Univ., Tsinghua Univ., Univ. of Jinan, Univ. of Science and Technology of China, Univ. of Science and Technology Liaoning, Univ. of South China, Wuhan Univ., Zhejiang Univ., Zhengzhou Univ.

~350 members
66 institutions from
14 countries

OTHER IN ASIA

COMSATS Institute of Information Technology (CIIT), Institute of Physics and Technology, Mongolia; Tokyo University; Seoul National University; University of the Punjab

http://bes3.ihep.ac.cn

BESIII physics programme

Light hadron physics
- Meson and baryon spectroscopy
- Multiquark states
- Threshold effects
- Glueballs and hybrids
- two-photon physics
- Form factors

QCD and τ
- Precision R measurement
- τ decay

Charmonium physics
- Precision spectroscopy
- Transitions and decays

XYZ meson physics
- Y(4260), Y(4360) properties
- $Z_c(3900)^+$, …

Charm physics
- Semi-leptonic form factors
- Decay constants f_D and f_{Ds}
- CKM matrix: $|V_{cd}|$ and $|V_{cs}|$
- D^0-$\overline{D}^0$ mixing, CPV
- Strong phases

Precision mass measurements
- τ mass
- D, D^* mass

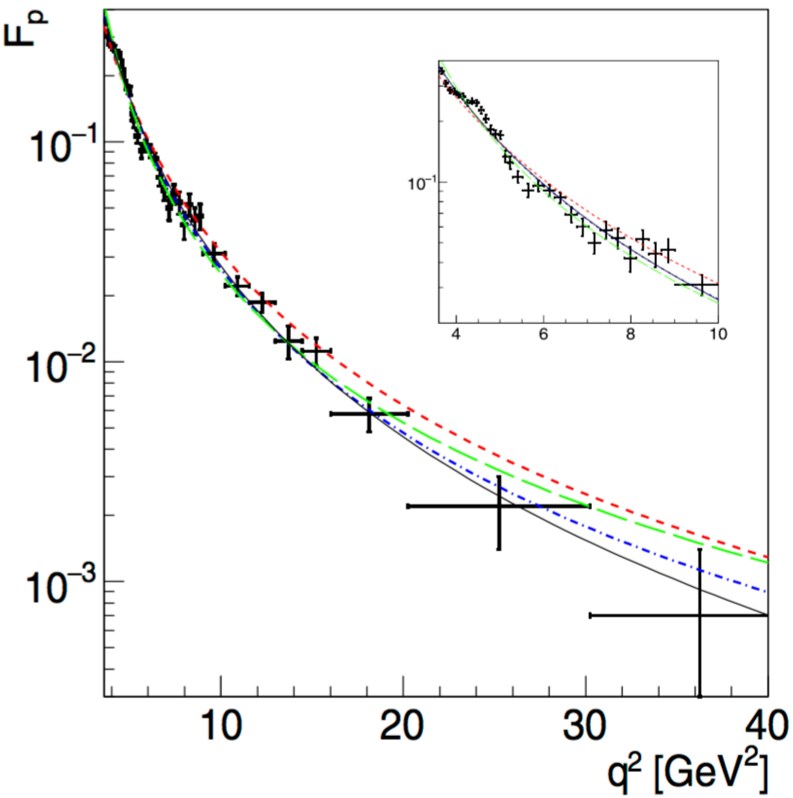
ppbar

$$\frac{d^2\sigma_{e^+e^-\to\bar{p}p\gamma}(q^2)}{dq^2 d\cos\theta^*_\gamma} = \frac{1}{s} W(s,\, x,\, \theta^*_\gamma)\sigma_{\bar{p}p}(q^2),$$

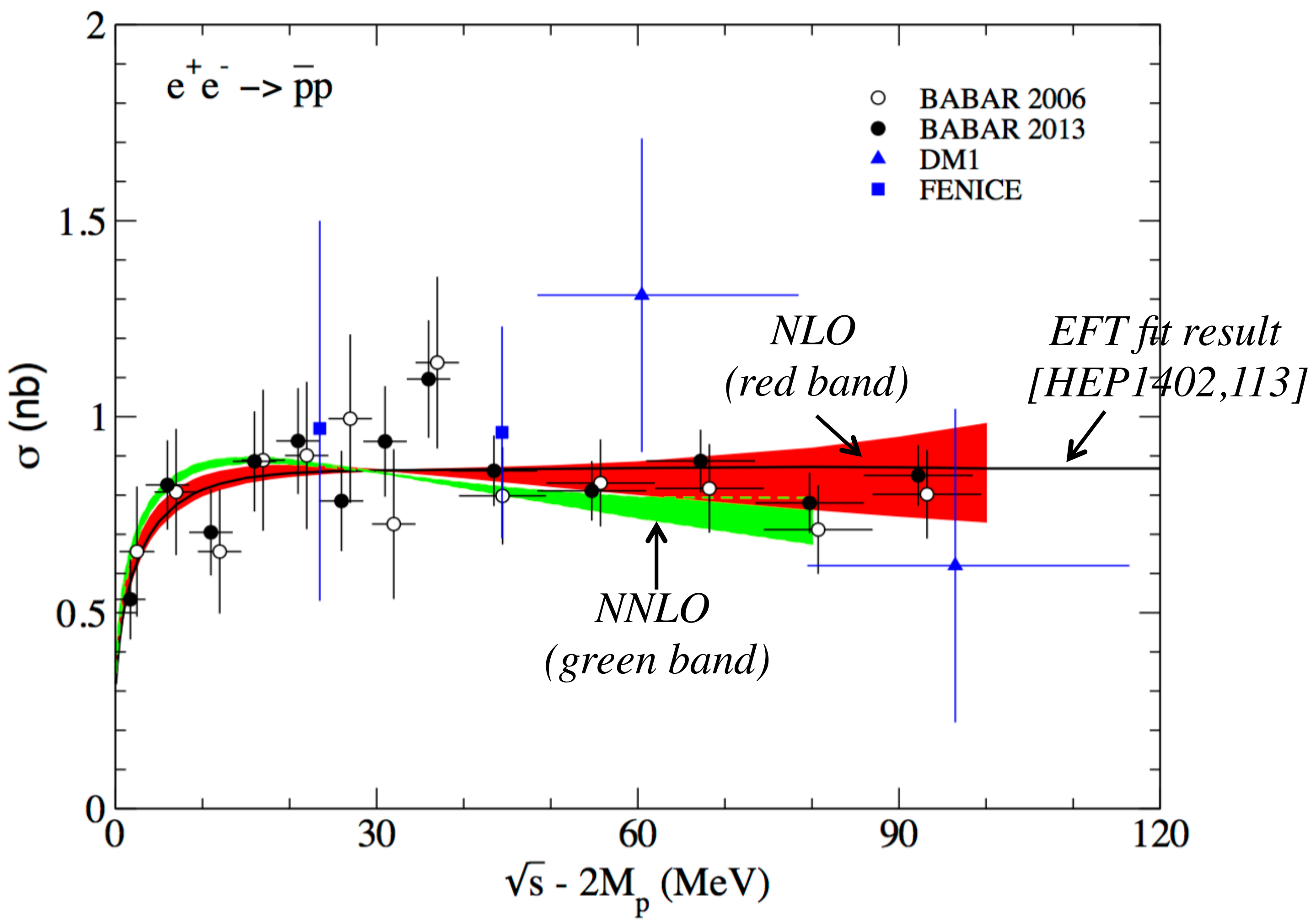
$$W(s,\, x,\, \theta^*_\gamma) = \frac{\alpha}{\pi x}\left(\frac{2-2x+x^2}{\sin^2\theta^*_\gamma} - \frac{x^2}{2}\right),\; x = \frac{2E^*_\gamma}{\sqrt{s}} = 1 - \frac{q^2}{s}$$

Proton FF Oscillation

PRL114,232301- PRC93,035201

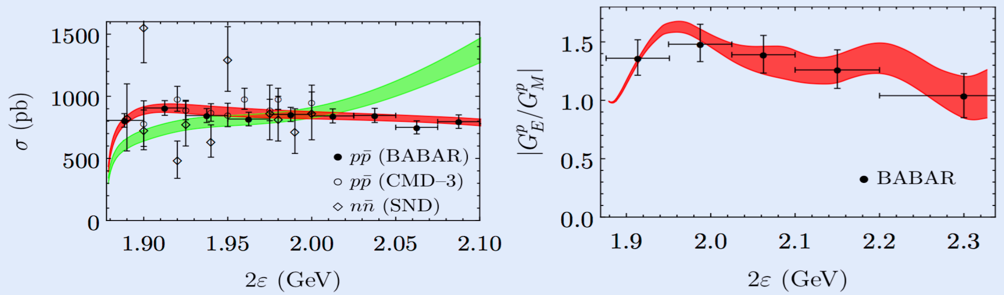


Final State interaction [NPA 929, 102]



Final State interaction [A. Milstein, PhiPsi2017, Maitz]

Predictions for the cross section of $e^+e^- \to N\bar{N}$ near the threshold

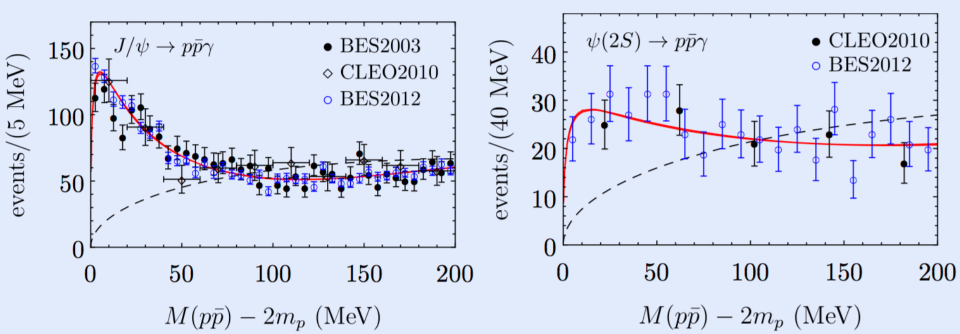


Left: the cross sections of $p\bar{p}$ (red line) and $n\bar{n}$ (green line) production, Right: G_E^p/G_M^p for proton. The experimental data are from J.P.Lees et al., BaBar, Phys.Rev. D 87, 092005 (2013), R.R. Akhmetshin et al., CMD3, Physics Letters B759, 634 (2016) M.N. Achasov et al.,SND, Phys. Rev. D 90, 112007 (2014).

FSI expect a sharp rise but not a jump on thr and no relationship with the pointlike FF

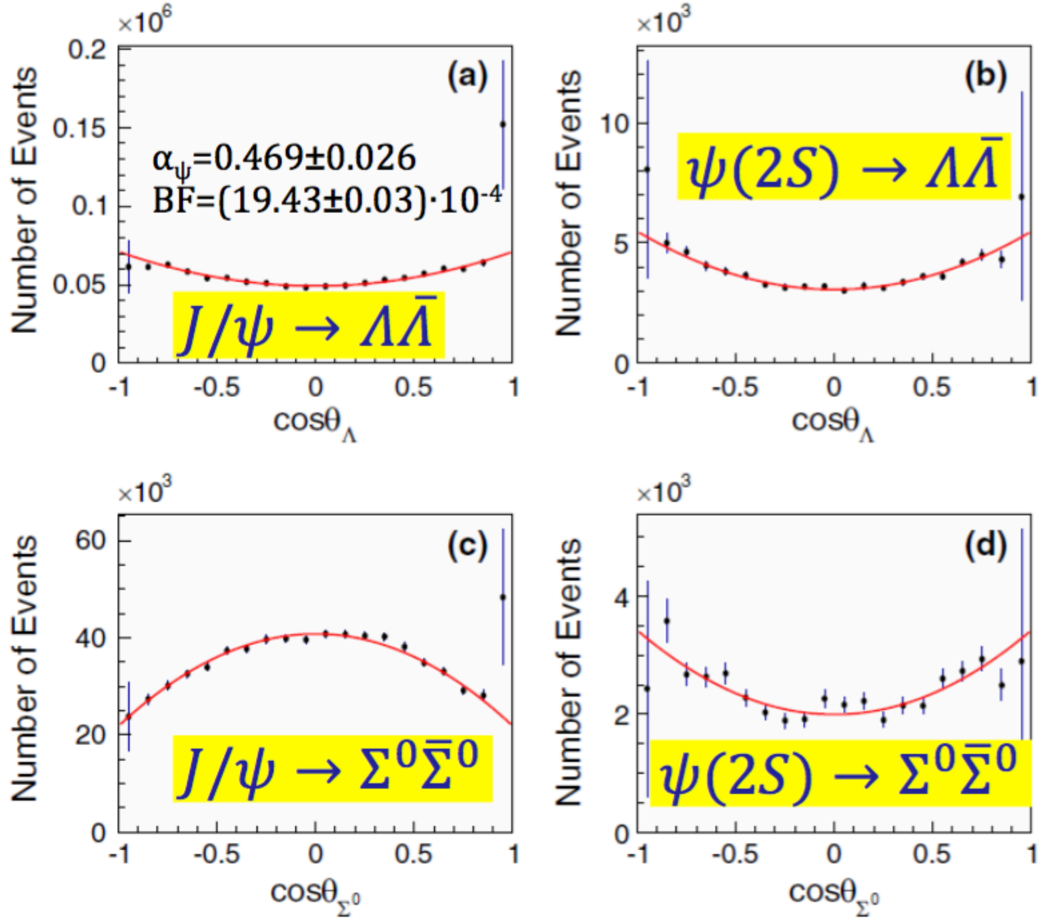
J/ψ, $\psi(2S) \to p\bar{p}\gamma$ decay

The invariant mass spectra in $J/\psi(\psi(2S) \to p\bar{p}\gamma$ decays:



Left: $J/\psi \to p\bar{p}\gamma$ decay. Right: $\psi(2S) \to p\bar{p}\gamma$ decay.

$J/\psi, \psi(2S) \to B\bar{B}$



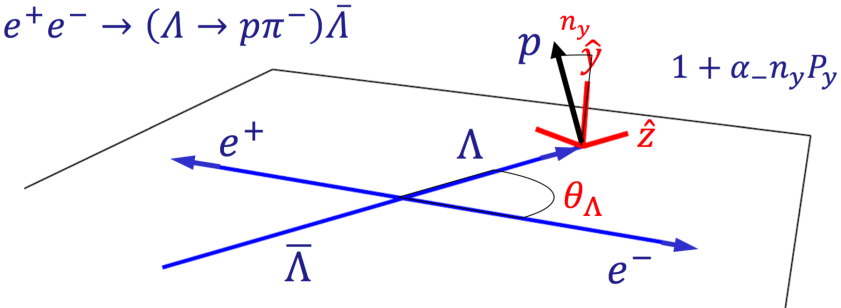
α_ψ measurements at BESIII

BESIII,PRD 95, 052003 (2017)

$J/\psi \to \Lambda\,\bar{\Lambda}$: Andrzej Kupsc, ICHEP 2018

Inclusive angular distributions

$e^+e^- \to (\Lambda \to p\pi^-)\bar{\Lambda}$



$$\frac{d\Gamma}{d\cos\theta_\Lambda d\Omega_1} \propto \left(1 + \alpha_\psi \cos^2\theta_\Lambda\right)\left\{1 + \alpha_1 P_\Lambda(\theta_\Lambda)\sin\theta_1 \sin\phi_1\right\}$$

$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$: $\alpha_1 \to \alpha_-$

Hyperon polarization determined from
angular distribution of the nucleon from the weak decay

Exclusive angular distributions

Two decay modes for $\bar{\Lambda}$:

$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$: $\alpha_2 \to \alpha_+$

$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{n}\pi^0)$: $\alpha_2 \to \bar{\alpha}_0$

$\bar{\Lambda} \to \bar{p}\pi^+ (or\ \bar{n}\pi^0)$: $\Omega_2 = (\cos\theta_2, \phi_2)$

$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$: $\alpha_1 \to \alpha_-$

$d\Gamma \propto \mathcal{W}(\boldsymbol{\xi})d\boldsymbol{\xi} = \mathcal{W}(\boldsymbol{\xi})d\cos\theta_\Lambda d\Omega_1 d\Omega_2$ $\boldsymbol{\xi}$: $(\cos\theta_\Lambda, \Omega_1, \Omega_2)$ 5D PhSp

Cross section

Spin correlations

Polarizations

$$\begin{aligned}
\mathcal{W}(\boldsymbol{\xi}) = {} & 1 + \alpha_\psi \cos^2\theta_\Lambda \\
& + \alpha_1\alpha_2 \left(\sin^2\theta_\Lambda \sin\theta_1 \sin\theta_2 \cos\phi_1 \cos\phi_2 + \cos^2\theta_\Lambda \cos\theta_1 \cos\theta_2\right) \\
& + \alpha_1\alpha_2 \sqrt{1 - \alpha_\psi^2}\cos(\Delta\Phi)\left\{\sin\theta_\Lambda \cos\theta_\Lambda \left(\sin\theta_1 \cos\theta_2 \cos\phi_1 + \cos\theta_1 \sin\theta_2 \cos\phi_2\right)\right\} \\
& + \alpha_1\alpha_2\, \alpha_\psi \left(\cos\theta_1 \cos\theta_2 - \sin^2\theta_\Lambda \sin\theta_1 \sin\theta_2 \sin\phi_1 \sin\phi_2\right) \\
& + \sqrt{1 - \alpha_\psi^2}\sin(\Delta\Phi)\sin\theta_\Lambda \cos\theta_\Lambda \left(\alpha_1 \sin\theta_1 \sin\phi_1 + \alpha_2 \sin\theta_2 \sin\phi_2\right)
\end{aligned}$$

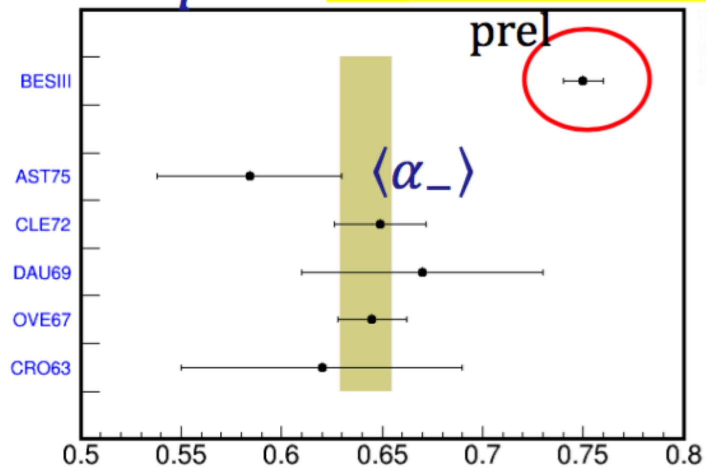
$\Delta\Phi \neq 0$ $\Rightarrow$ independent determination of α_1 and α_2!

Fäldt, Kupsc PLB772 (2017) 16

$J/\psi \to \Lambda\,\Lambda$: Andrzej Kupsc , ICHEP 2018

Summary of the $J/\psi \to \Lambda\bar{\Lambda}$ analysis

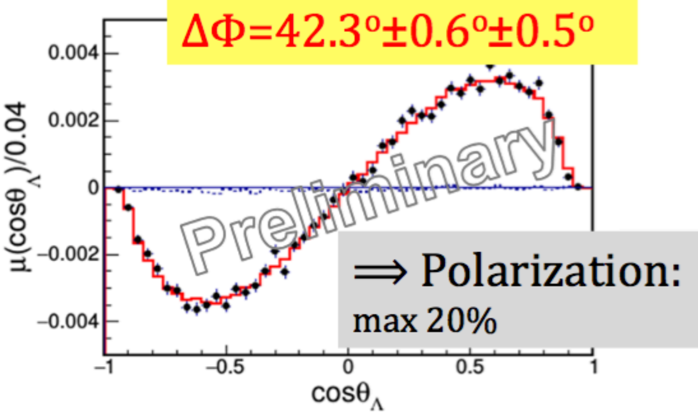
$\Lambda \to p\pi^-$: $\alpha_- = 0.750 \pm 0.009 \pm 0.004$



BESIII

17(3)% larger than PDG average
> 5 σ difference

$\Delta\Phi = 42.3^{o} \pm 0.6^{o} \pm 0.5^{o}$



⟹ Polarization:
max 20%

CP test: $A_{CP} = \dfrac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$

$\boxed{A_{CP} = -0.006 \pm 0.012 \pm 0.007}$ prel

Previous result (using αP product):

$A_{CP} = 0.013 \pm 0.021$
PS185 PRC54(96)1877

CKM $A_{CP} \sim 10^{-4}$

PREDICTION FOR $\Delta\phi$