Prospects for Hyperon Physics with BESIII

Tord Johansson
Uppsala University
for the BESIII collaboration

Workshop on
Many Manifestations of Nonpertubative QCD
Cabury, São Paolo 2018

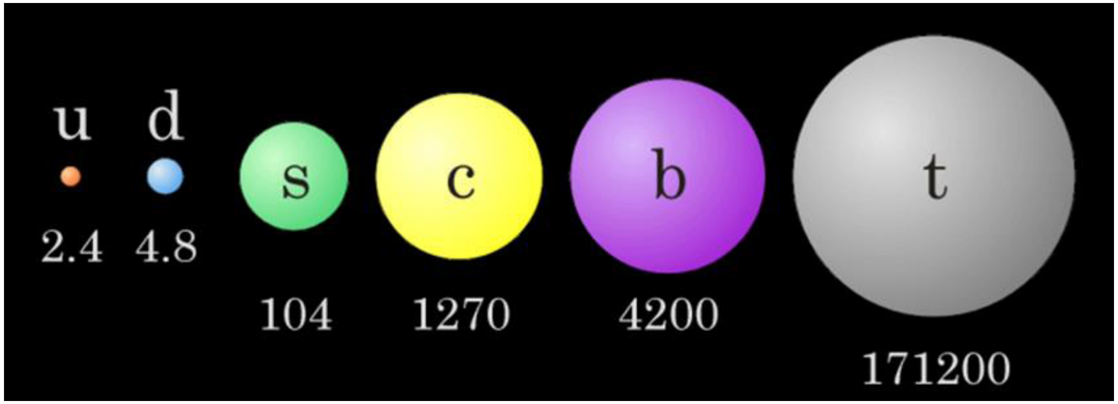
UPPSALA UNIVERSITET

Hyperons are a laboratory for strong interaction physics.

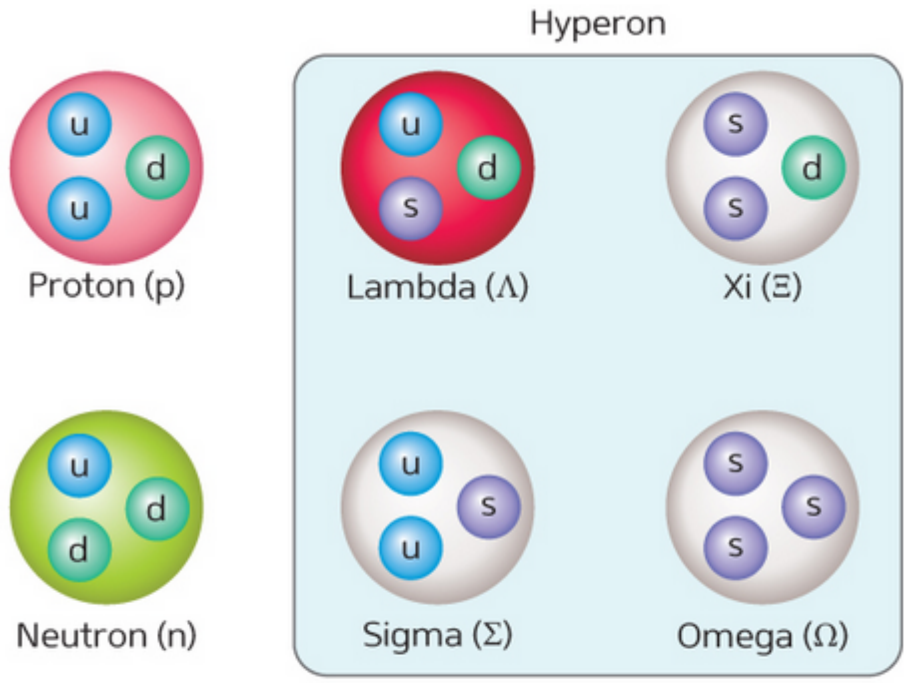
- Production
- Structure
- Spectroscopy
- Decay pattern
- Interaction
-
-

- Systems with strangeness
  - Scale: $m_s \approx 100$ MeV $\Lambda_{QCD} \approx 200$ MeV.
  - Probes QCD in the confinement domain.

- Systems with charm
  - Scale: $m_c \approx 1300$ MeV
  - Probes QCD approaching pQCD.



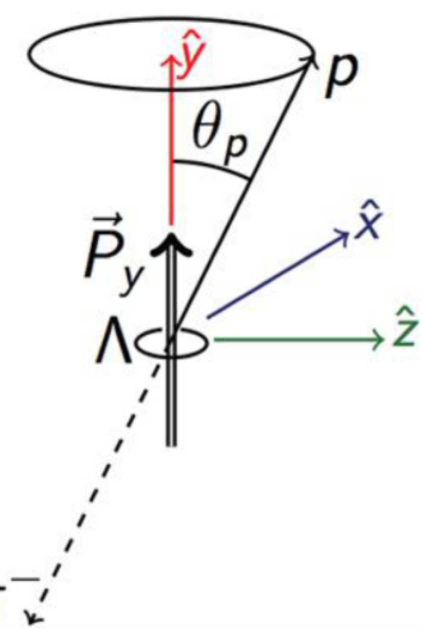
"How are baryons affected by replacing light quarks by strange quarks?"



"What is the role of spin?"

The parity-violating weak hyperon decay gives access to spin observables.

$$\Lambda \rightarrow p + \pi^-$$



$$I(\cos\theta_p) = N(1 + \alpha_\Lambda P_\Lambda \cos\theta_p)$$

P = Polarisation,

α = decay asymmetry parameter

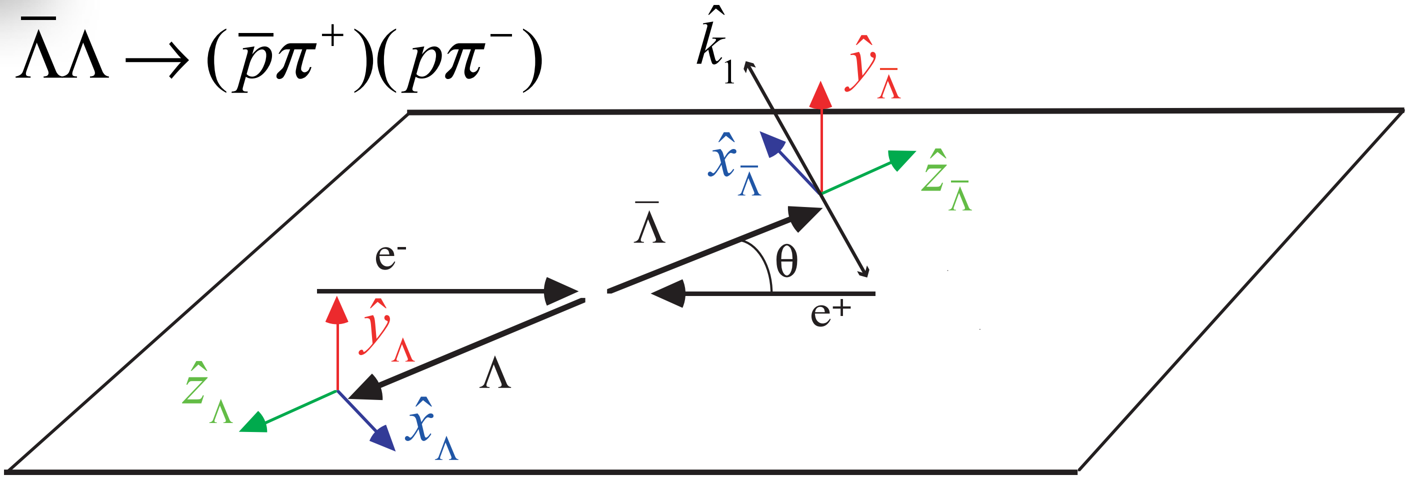
➡ Hyperon decays acts as a **Polarimeter**

without polarisation filter

with polarisation filter

Spin observables, upolarised beam and target

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



$$I_{\bar{\Lambda}\Lambda}\left(\theta,\hat{\boldsymbol{k}}_1,\hat{\boldsymbol{k}}_2\right)=\frac{I_0^{\bar{\Lambda}\Lambda}}{64\pi^3}\begin{bmatrix}1\\+P_y\left(\bar{\alpha}k_{1y}+\alpha k_{2y}\right)\\+C_{xx}\left(\bar{\alpha}\alpha k_{1x}k_{2x}\right)\\+C_{yy}\left(\bar{\alpha}\alpha k_{1y}k_{2y}\right)\\+C_{zz}\left(\bar{\alpha}\alpha k_{1z}k_{2z}\right)\\+C_{xz}\left(\bar{\alpha}\alpha\left(k_{1x}k_{2z}+k_{1z}k_{2x}\right)\right)\end{bmatrix}$$

I_0 = σtot

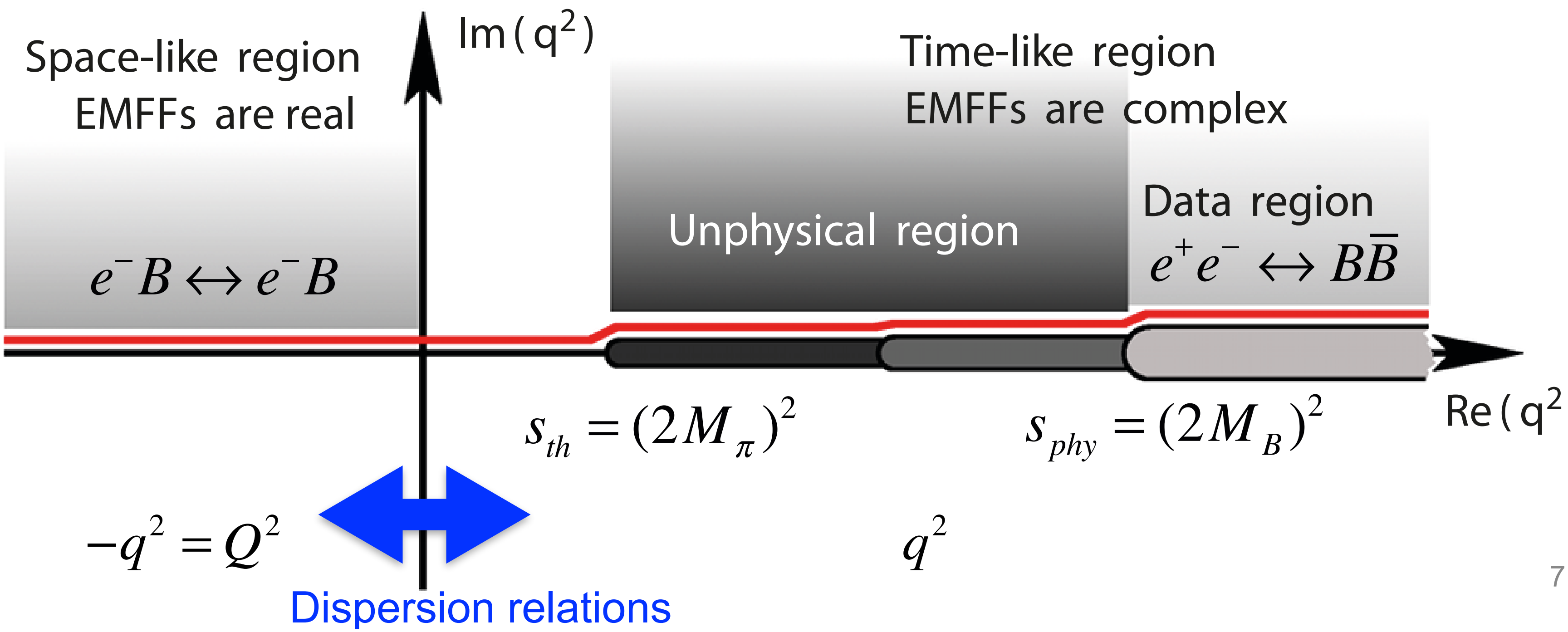
$I(\theta)$ = dσ/dΩ

P_y = Polarisation

C_{ij} = Spin correlations

Electromagnetic Form Factors

- Electromagnetic Form Factors (EMFF) of hadrons are among the most basic quantities containing information about hadron internal structure. They provide access to the spatial charge and magnetisation distributions.



UPPSALA UNIVERSITET

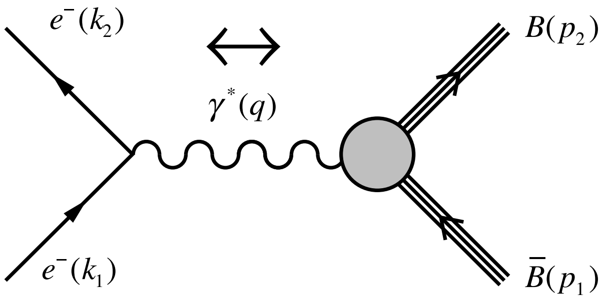
Not much is experimentally known about hyperon EM structure. Basically only static properties.

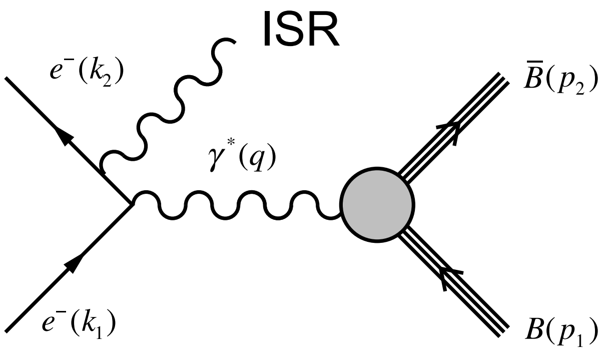
Why?

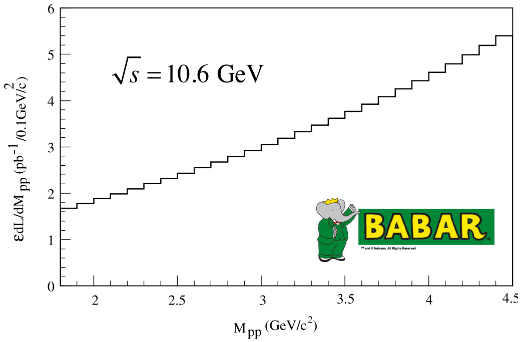
The short hyperon life-times makes it impossible to measure Space-Like (SL) FF's.
=> Only hyperon Time-Like (TL) EMFF's are accessible in experiments. Small cross sections.

→ e^+e^--collisions are currently the best way to investigate hyperon EMFF's.

$$e^+e^- \leftrightarrow \bar{B}B$$

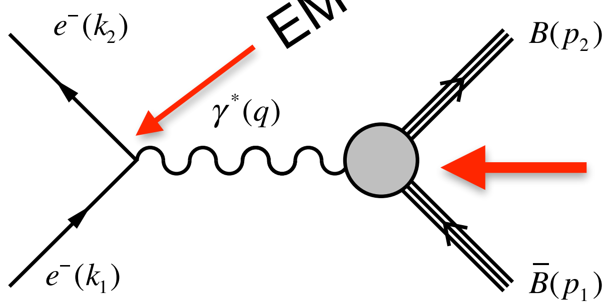






Non-zero momentum of final state particles at threshold.

EM vertex well known



Baryon vertex

Baryon vertex matrix element: $$\Gamma^\mu = F_1^B(q^2)\gamma^\mu + \frac{\kappa}{2M_B} F_2^B(q^2) i\sigma^{\mu\nu} q_\nu$$

The Dirac ($F_1(q^2)$) and Pauli ($F_2(q^2)$) EMFF's is related to the charge (G_E) and magnetization (G_M) (Sachs) EMFF's via the relations:

$$G_E = F_1 - \tau F_2 \quad ; \quad \tau = \frac{q^2}{4M_B^2}$$

$$G_M = F_1 + F_2$$

$$G_E(0) = Z$$

$$G_M(0) = Z + \kappa = \mu_B$$

UPPSALA UNIVERSITET

- Time-like FF's are complex due to inelasticity:

$$\mathrm{Re}\left[G_E(q^2)G_M^*(q^2)\right] = \left|G_E(q^2)\right|\left|G_M(q^2)\right|\cos\Delta\phi$$

$$\mathrm{Im}\left[G_E(q^2)G_M^*(q^2)\right] = \left|G_E(q^2)\right|\left|G_M(q^2)\right|\sin\Delta\phi$$

$\Delta\phi$ = the relative phase between G_E and G_M.

➡ Three observables determine the Time-Like Form Factors.

- A relative phase between G_E and G_M gives polarisation effects on the final state even if the initial state is unpolarised.

The differential cross section in the one-photon exchange picture is given by:

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

$$\tau = \frac{q^2}{4m_B^2},\ \beta = \sqrt{1-1/\tau},\ C = \text{Coulomb factor} = \mathrm{y/(1\text{-}e^{-y})}, y = \pi\alpha/\beta$$

- The differential cross section at one energy is sufficient to extract the modulii of $|G_E|$ and $|G_M|$ 😊.

- Increasingly difficult to measure $|G_E|$ as q^2 increases due to the $1/\tau$ term ☹️.

Only $^3S_1$ and $^3D_1$ waves are allowed in the final state.

UPPSALA UNIVERSITET

pQCD predicts:

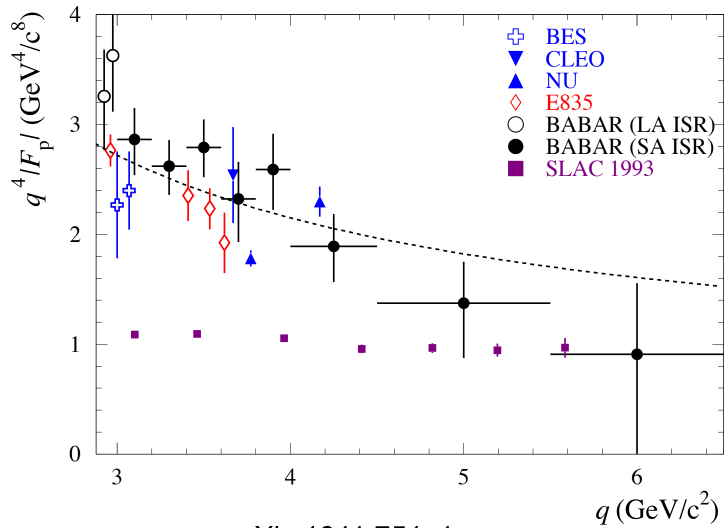
$$\lim_{Q^2\to\infty} G_{E,M}\left(Q^2\right)_{Q^2\to\infty} = \lim_{q^2\to\infty} G_{E,M}\left(q^2\right)$$

➪ Space-Like FF = Time-Like FF.

➪➪ Time-Like FF become real.

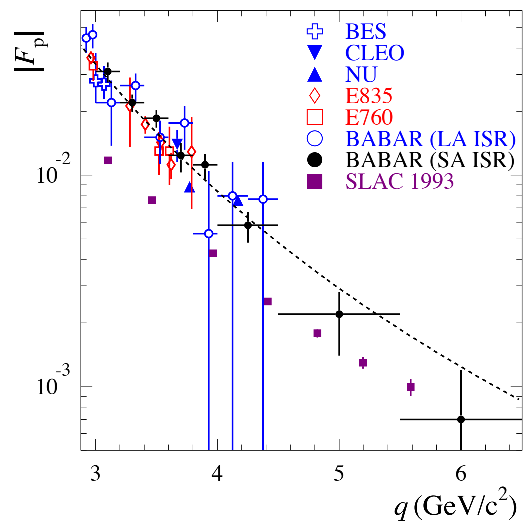
$$G_{E,M}(q^2) \propto q^{-4}$$

Proton EMFF features



arXiv:1311.751v1

pQCD region reached at $Q \approx 6$ Gev/c^2?



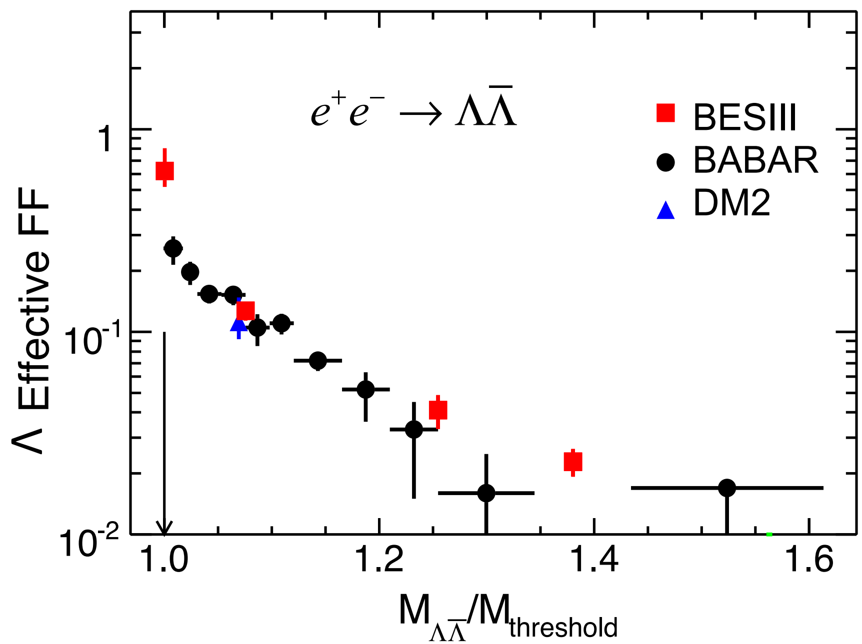
TL $|F_p|$ = 2x SL $|F_p|$?

Sign of a diquark-quark structure of the proton?

Kroll et al., PLB 316 (1993) 546

Data (so far) has not allowed for a statistically significant extraction of the modulii of $|G_E|$ and $|G_M|$ for hyperons. One therefore defines an effective Form Factor from the total cross section:

$$\sigma_{tot} = \frac{4\pi\alpha^2\beta C}{3q^2}\left[\left|G_M\right|^2 + \frac{\left|G_E\right|^2}{2\tau}\right] \Rightarrow \left|G_{eff}\right| = \left(\frac{2\tau\left|G_M\right|^2 + \left|G_E\right|^2}{2\tau+1}\right)^{\frac{1}{2}} \Rightarrow \left|G_{eff}\right| \propto \sqrt{\sigma_{tot}}$$



BESIII
PRD 94 (2018) 032013

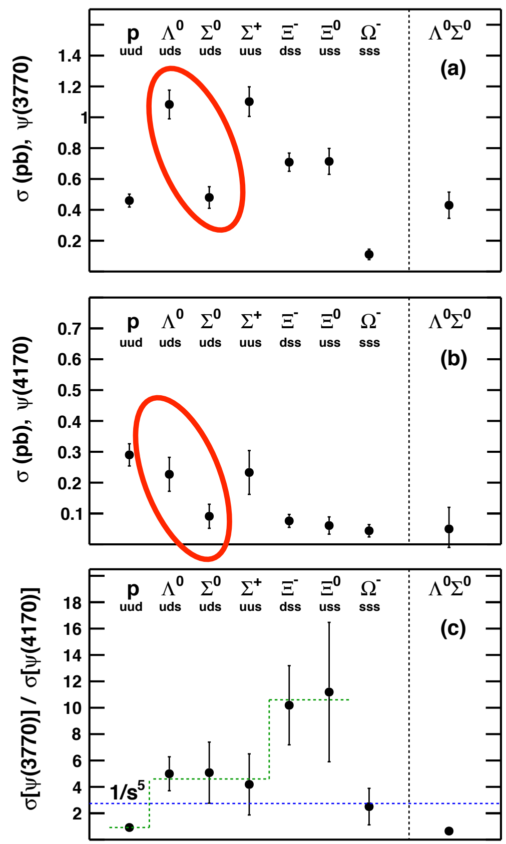
UPPSALA UNIVERSITET

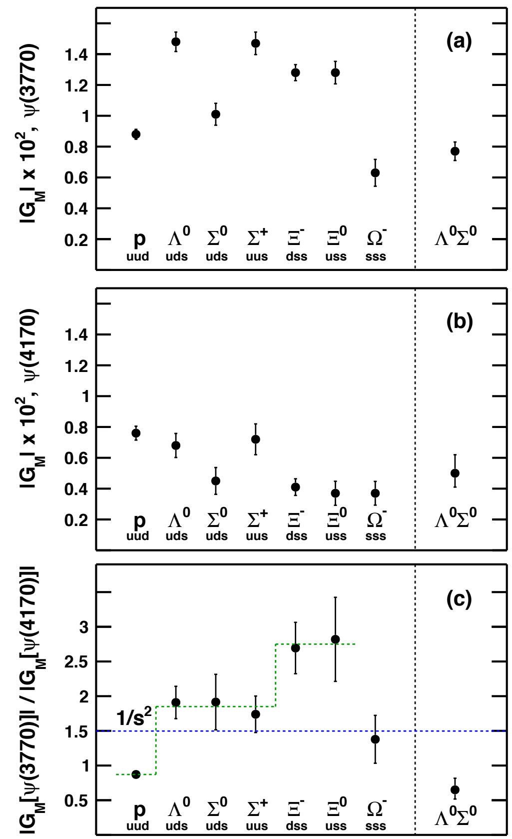
$e^+e^- \to Y\bar{Y}$ @ CLEO-c

$G_E = 0$ assumed

"Good" diquark (Λ)
vs,
"Bad" diquark (Σ^0) ?

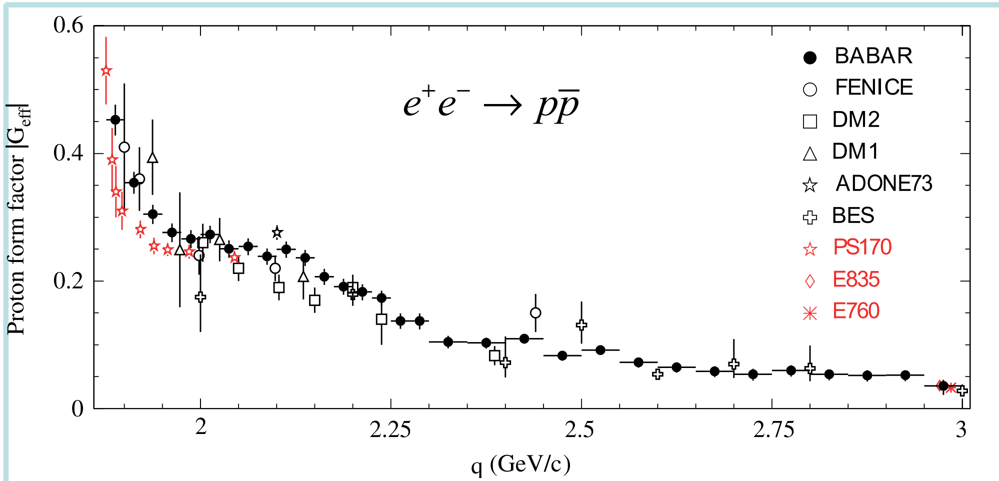
Jaffe & Wilczek, PRL 91 (2003) 232003



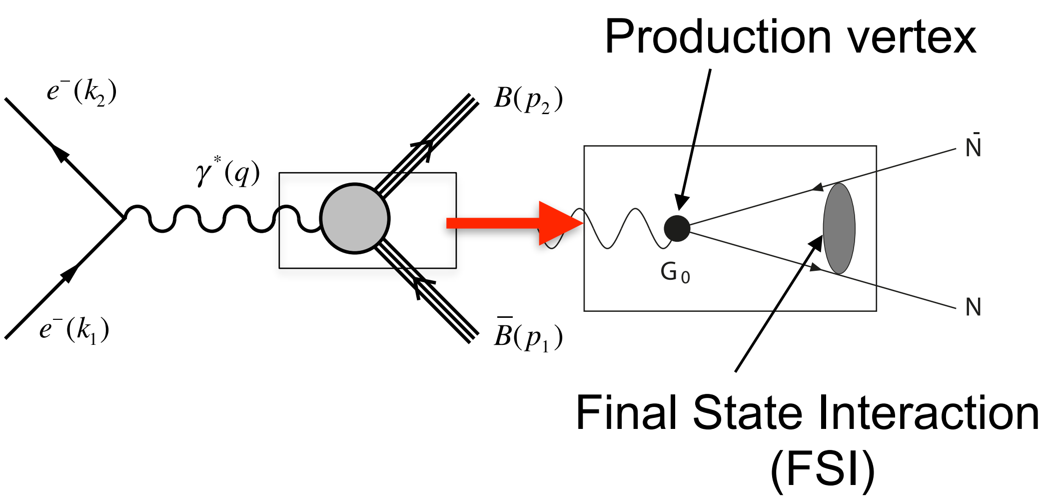


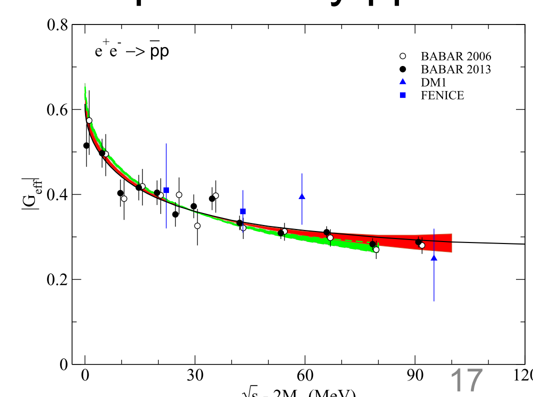
PRD 96 (2017) 092004

Threshold enhancements in e⁺e⁻ →BB̄ ?



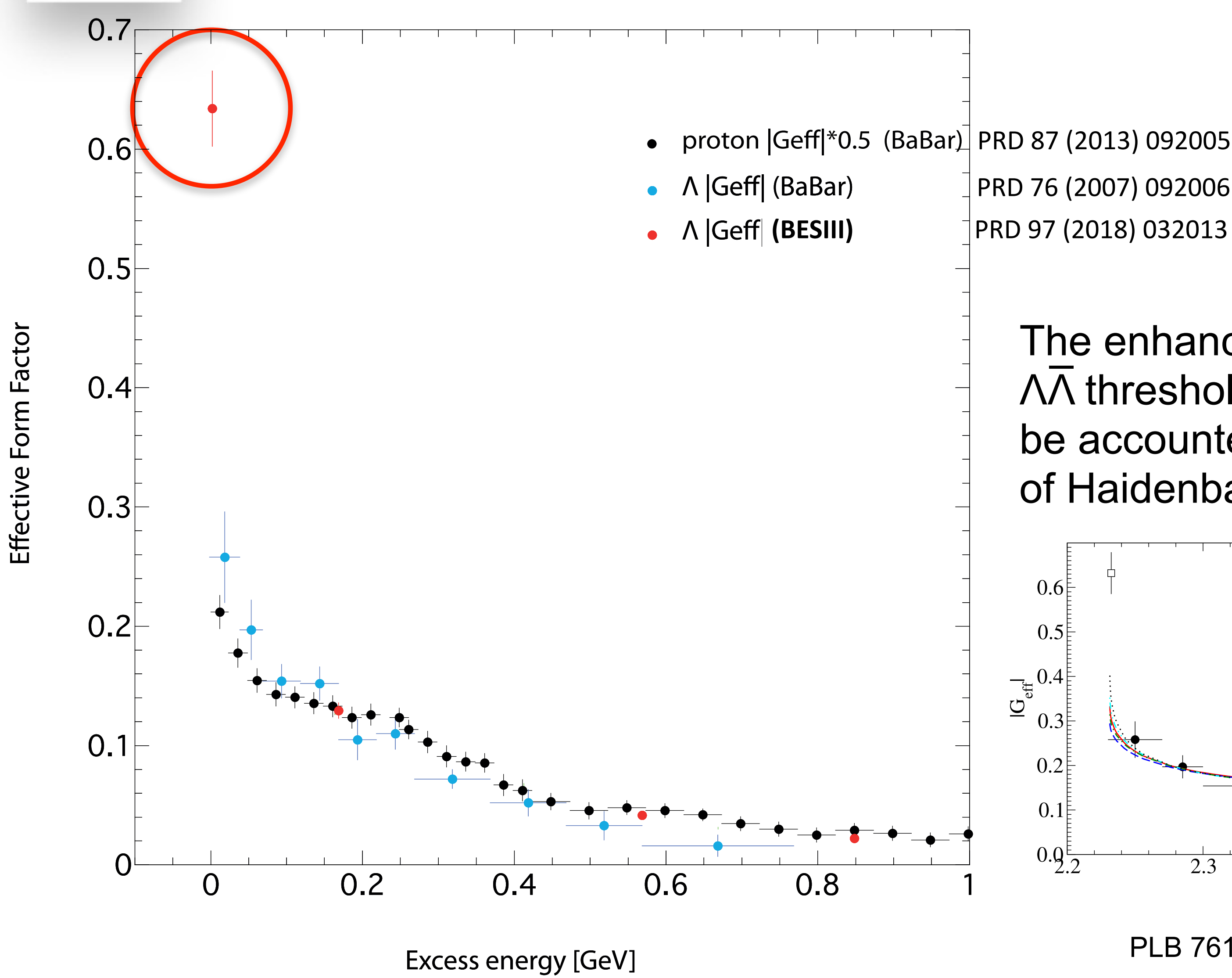
The enhancement at pp̄ threshold can been explained by pp̄ FSI.



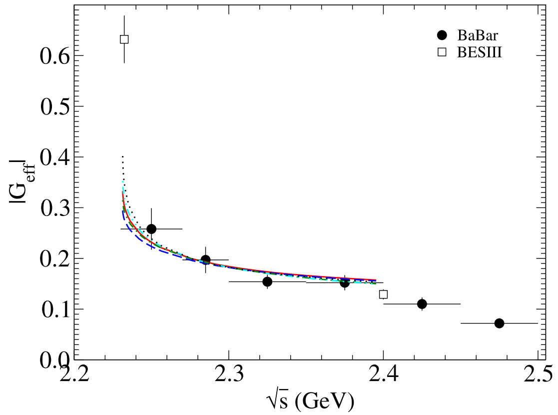


Haidenbauer et al., NPA 929 (2014) 102

Threshold enhancement in $e^+e^- \to \Lambda\bar{\Lambda}$

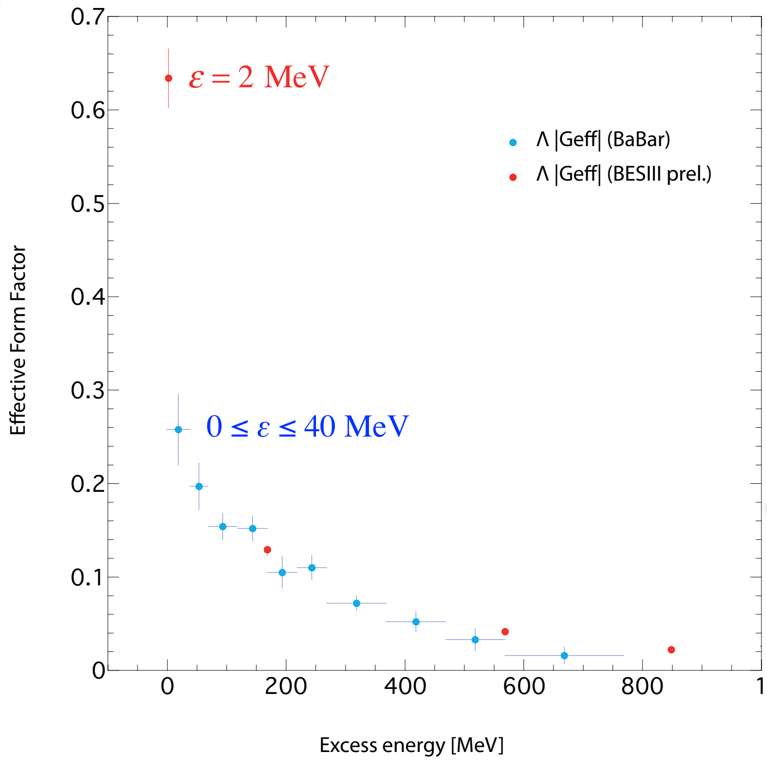


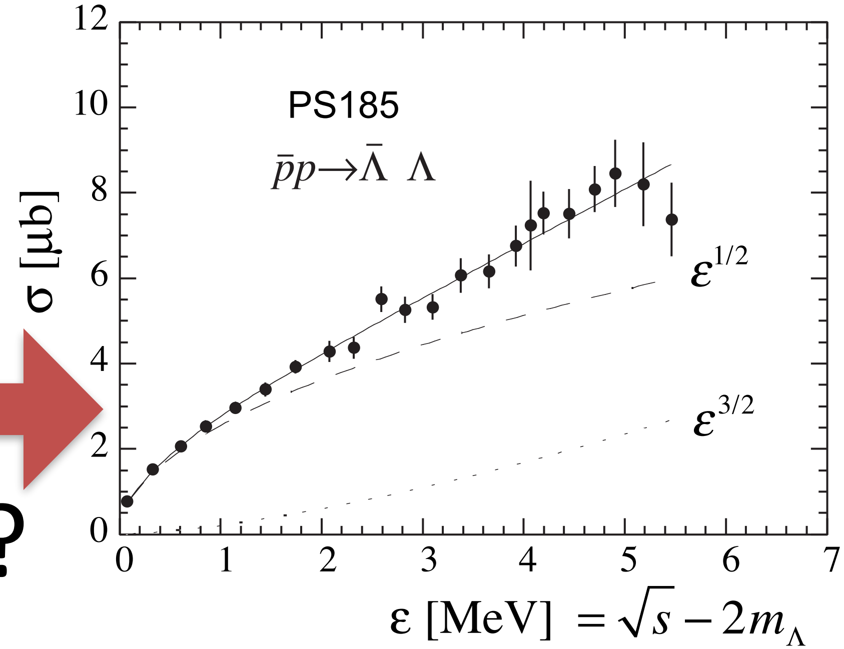
The enhancement at $\Lambda\bar{\Lambda}$ threshold can not be accounted by the FSI of Haidenbauer & Meißner.



PLB 761 (2016) 456

Threshold enhancement due to $\Lambda\bar{\Lambda}$ FSI ?





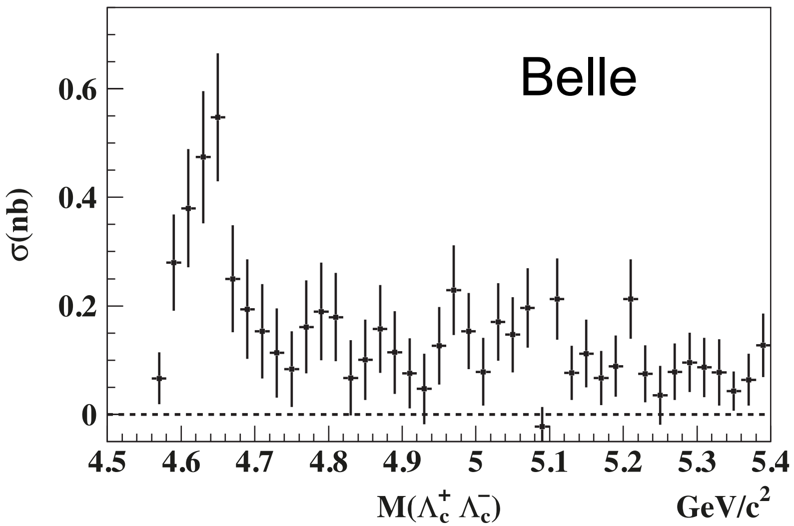
PRC 62(2000) 055203

Difficult to reconcile BESIII and PS185 data.

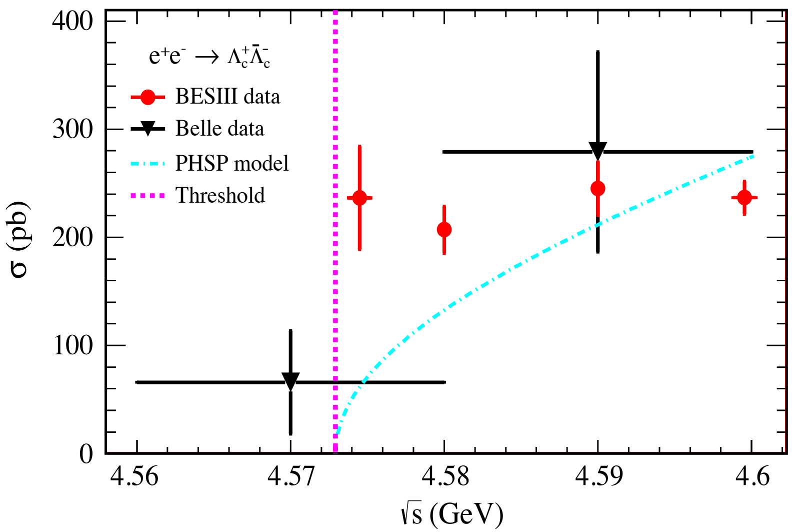
More data needed! (BESIII!)

Threshold enhancement in $e^+e^- \to \Lambda_c^+\Lambda_c^-$

Strong influence from X(4630)

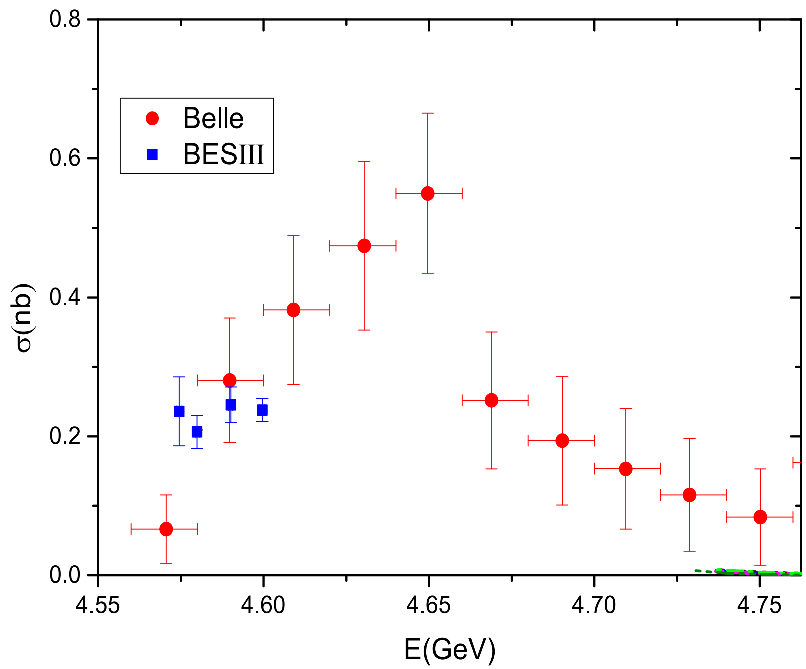


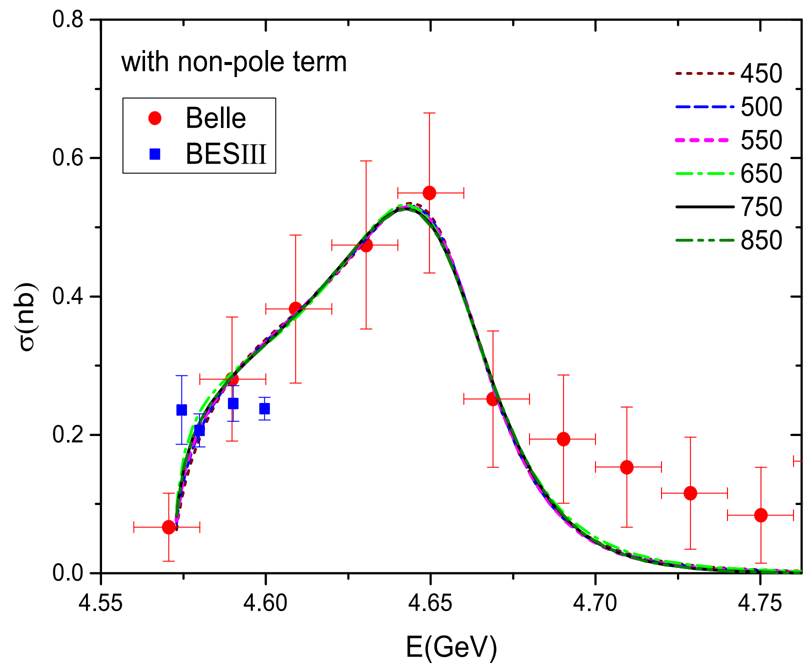
PRL 101 (2008) 172001



PRL 120 (2018) 111101

$$e^+e^- \to \Lambda_c^+\Lambda_c^-$$

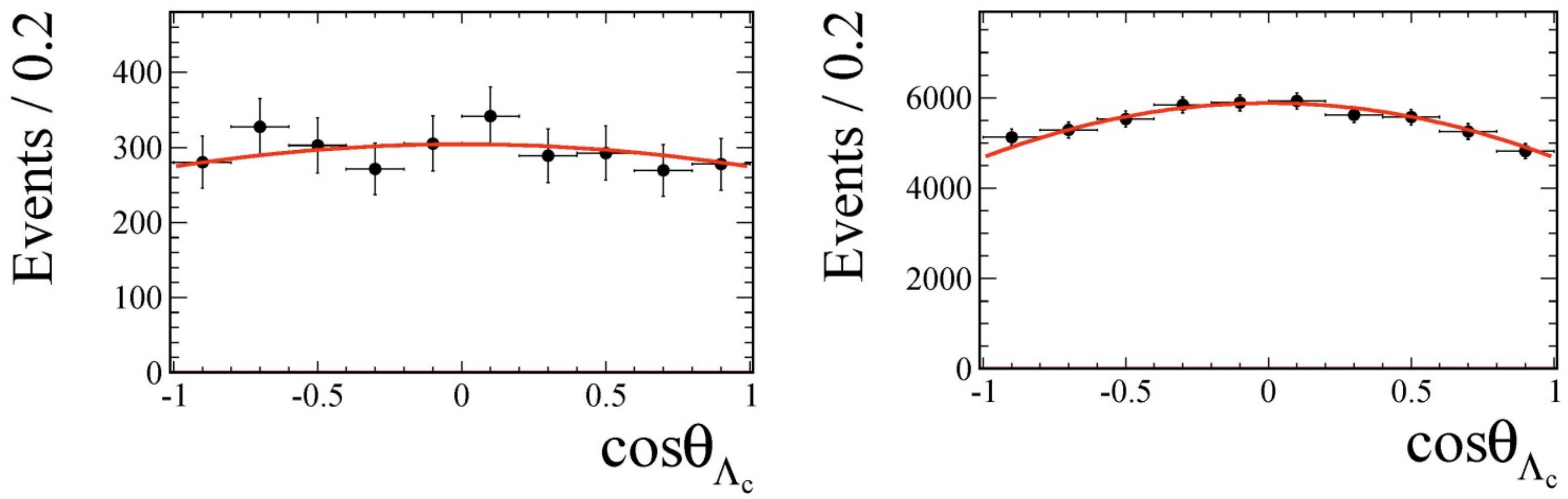




Shape of theory curve primarily given by X(4630)

Dai et al., PRD 96 (2017) 116001

More data needed! (BESIII!)



First measurement of $|G_E/G_M|$ for Λ_c^+

√s [MeV]	$|G_E/G_M|$
4574.5	1.10 ± 0.14 ± 0.07
4599.5	1.23 ± 0.06 ± 0.03

PRL 120 (2018) 111101

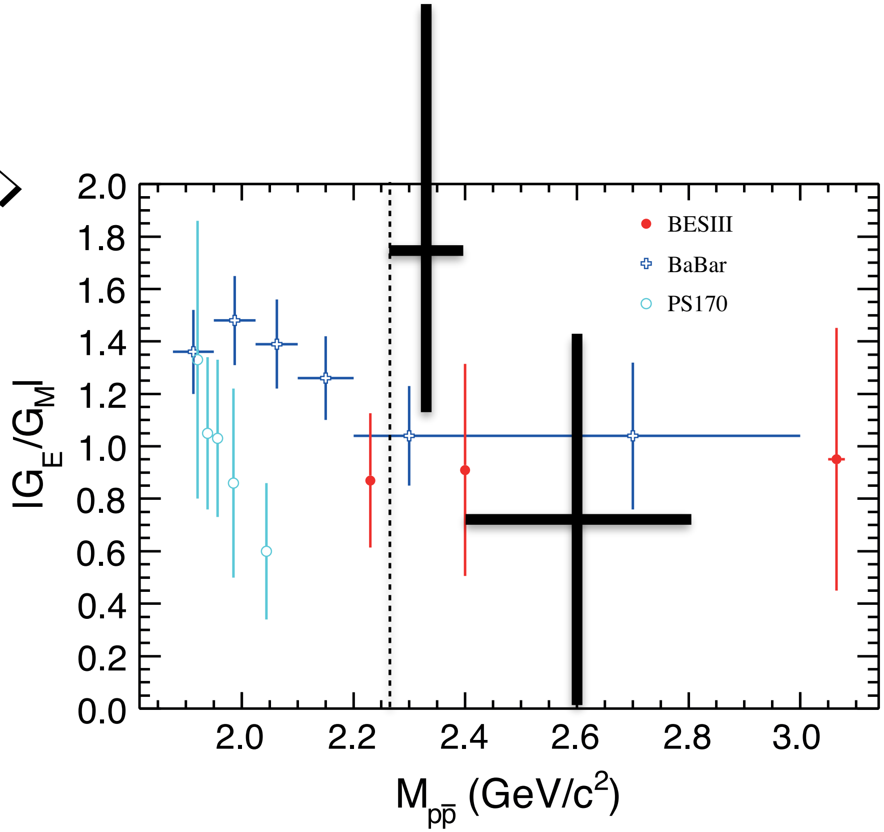
What is known about apart from Effective FF´s for Λ hyperons?

BaBar ≈ 200 events in total ⇨

$$1.16 < \frac{|G_E|}{|G_M|} < 2.72 \quad q < 2.4 \text{ GeV}$$

$$0 < \frac{|G_E|}{|G_M|} < 1.37 \quad 2.4 \leq q < 2.8 \text{ GeV}$$

$$-0.76 < \sin\Delta\phi < 0.98$$



⇨ Practically nothing.

Until now!

Recap

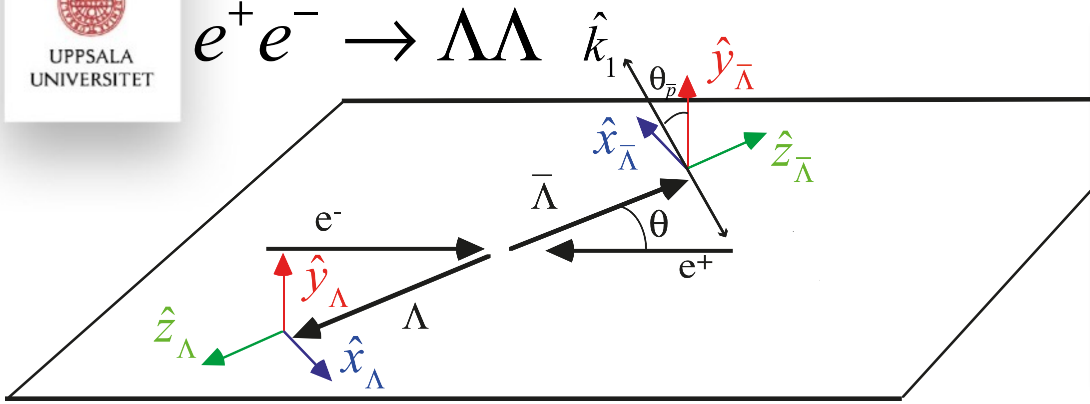
The differential cross section in the one-photon exchange picture is given by:

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

$$\tau = \frac{q^2}{4m_B^2},\ \beta = \sqrt{1-1/\tau},\ C = \text{Coulomb factor} = \text{y/(1-e}^{-y}\text{)}, y = \pi\alpha/\beta$$

The polarisation arises from the interference between the $^3S_1$ and $^3D_1$ waves in the final state.

$$e^+e^- \to \Lambda\bar{\Lambda}$$



Method of moments:

$$P_y = \frac{3}{\bar{\alpha}}\left\langle \cos\theta_{\bar{p}_y} \right\rangle$$

$$C_{zx} = \left(\frac{9}{\alpha\bar{\alpha}}\right)\left\langle \cos\theta_{p_z}\cos\theta_{\bar{p}_x} \right\rangle$$

$$P_y = -\frac{\sin 2\theta \,\mathrm{Im}\left[G_E G_M^*\right]/\sqrt{\tau}}{\left(\left|G_E\right|^2 \sin 2\theta\right)/\tau + \left|G_M\right|^2\left(1+\cos^2\theta\right)} = -\frac{\sin 2\theta \sin\Delta\phi/\tau}{R\sin^2\theta + \left(1+\cos^2\theta\right)/R}; \quad R = \frac{\left|G_E\right|}{\left|G_M\right|}$$

=> gives modulus of the phase ϕ

$$C_{zx} = -\frac{\sin 2\theta \,\mathrm{Re}\left[G_E G_M^*\right]/\sqrt{\tau}}{\left(\left|G_E\right|^2 \sin 2\theta\right)/\tau + \left|G_M\right|^2\left(1+\cos^2\theta\right)} = -\frac{\sin 2\theta \cos\Delta\phi/\tau}{R\sin^2\theta + \left(1+\cos^2\theta\right)/R}$$

=> gives the sign of the phase ϕ

Nuov. Cim. A109(96)241

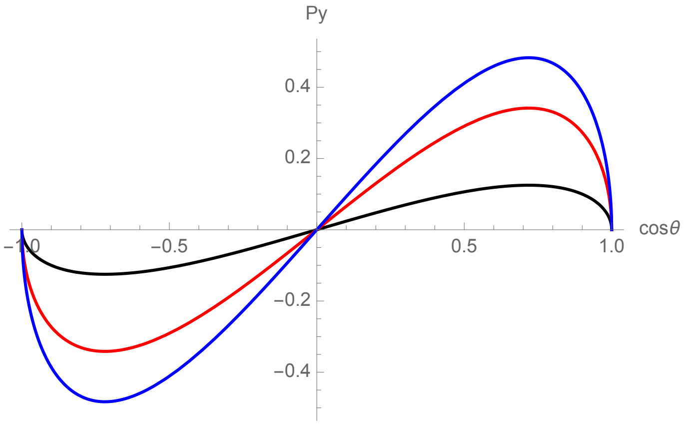
A complete determination of the Λ Time-Like Form Factor from $e^+e^- \to \Lambda\bar{\Lambda}$ is possible!

$$P_y = -\frac{\sin 2\theta \sin \Delta\phi / \tau}{R\sin^2\theta + \left(1+\cos^2\theta\right)/R}; \quad R = \frac{|G_E|}{|G_M|}$$

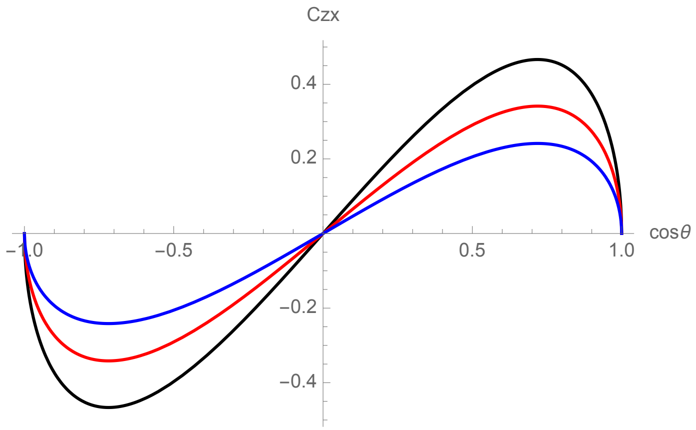
$$C_{zx} = -\frac{\sin 2\theta \cos \Delta\phi / \tau}{R\sin^2\theta + \left(1+\cos^2\theta\right)/R}$$

$$\sqrt{s} = 2.386 \text{ GeV}$$

R=1
|Δϕ|= 15, 45, 60



R=1
|Δϕ|= +15, +45, +60



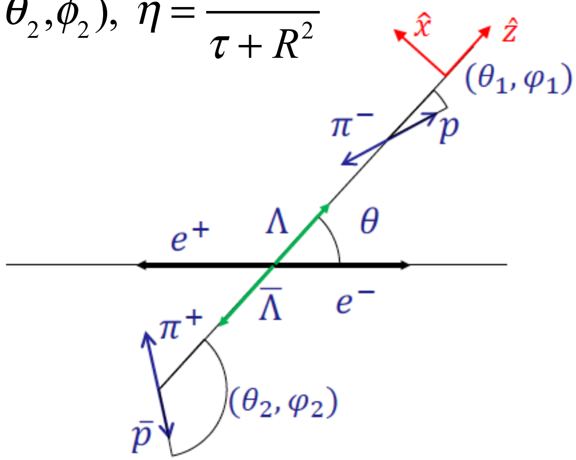
Need statistics to determine C_{zx}, i.e the sign of Δϕ 🙁.
sufficient to add the data for -1<cosθ<0 and 0<cosθ<1 🙂.

UPPSALA UNIVERSITET

A multivariate parameterisation have been derived by G.Fäldt & A.Kupsc* to make **maximum use** of $e^+e^- \to \Lambda\bar{\Lambda}$ ***exclusive data***:

$$W(\xi) = F_0(\xi) + \eta F_5(\xi)$$
$$+ \sqrt{1-\eta^2}\sin(\Delta\Phi)\left(\alpha_\Lambda F_3(\xi) + \alpha_{\bar{\Lambda}} F_4(\xi)\right)$$
$$+ \alpha_\Lambda \alpha_{\bar{\Lambda}}\left(F_1(\xi) + \sqrt{1-\eta^2}\cos(\Delta\Phi) F_2(\xi) + \eta F_6(\xi)\right);\ \xi = (\theta, \theta_1, \phi_1, \theta_2, \phi_2),\ \eta = \frac{\tau - R^2}{\tau + R^2}$$

$$F_0(\xi) = 1$$
$$F_1(\xi) = \sin^2\theta \sin\theta_1 \sin\theta_2 \cos\phi_1 \cos\phi_2 + \cos^2\theta \cos\theta_1 \cos\theta_2$$
$$F_2(\xi) = \sin\theta \cos\theta (\sin\theta_1 \cos\theta_2 \cos\phi_1 + \cos\theta_1 \sin\theta_2 \cos\phi_2)$$
$$F_3(\xi) = \sin\theta \cos\theta \sin\theta_1 \sin\phi_1$$
$$F_4(\xi) = \sin\theta \cos\theta \sin\theta_2 \sin\phi_2$$
$$F_5(\xi) = \cos^2\theta$$
$$F_6(\xi) = \cos\theta_1 \cos\theta_2 - \sin^2\theta \sin\theta_1 \sin\theta_2 \sin\phi_1 \sin\phi_2$$



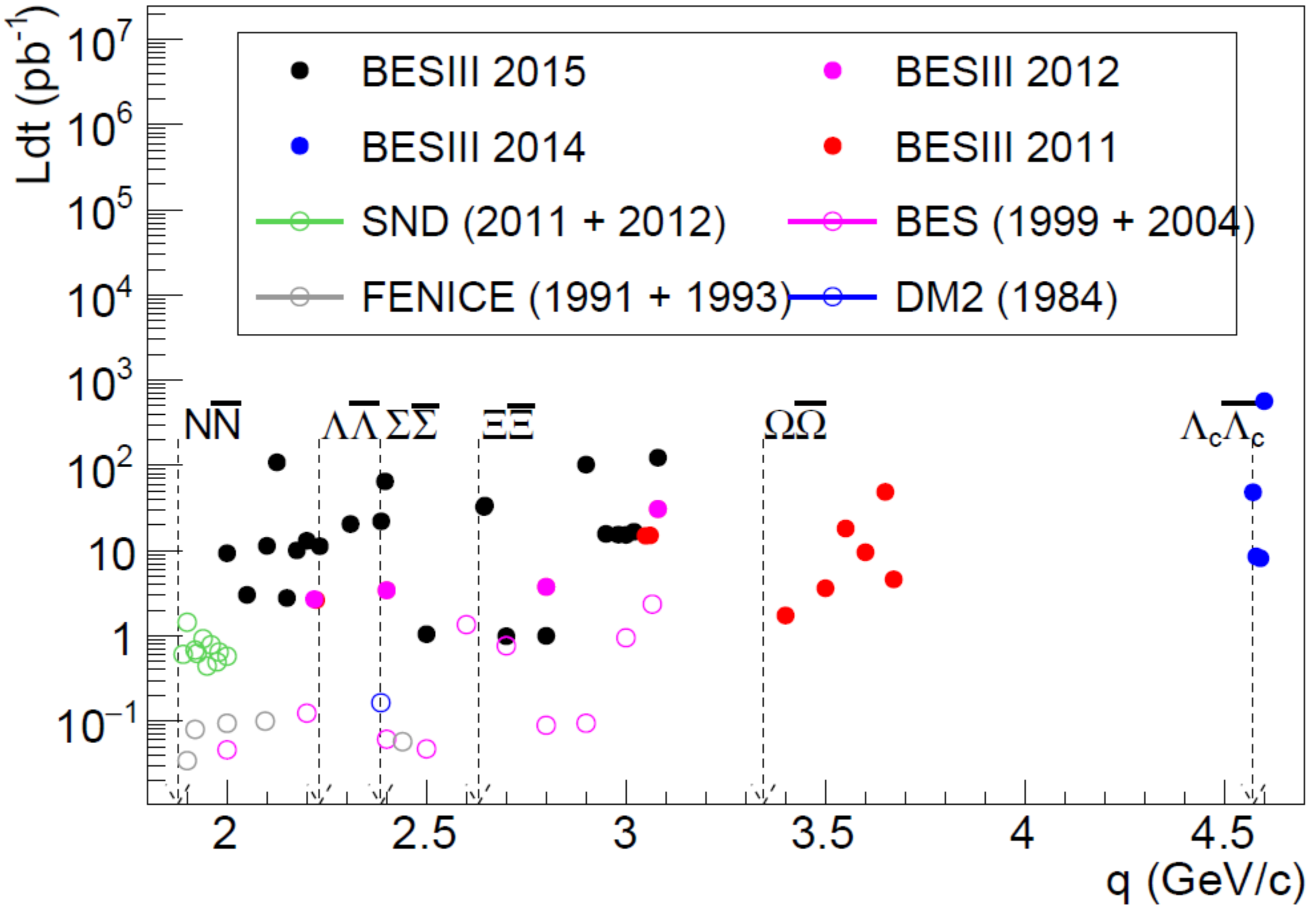
- Allows for an unbinned ML fit.😊
- No need for acceptance corrections.😊😊
  (except for an overall normalisation factor)

*PLB 772(2017) 16

Energy scan 2014-2015

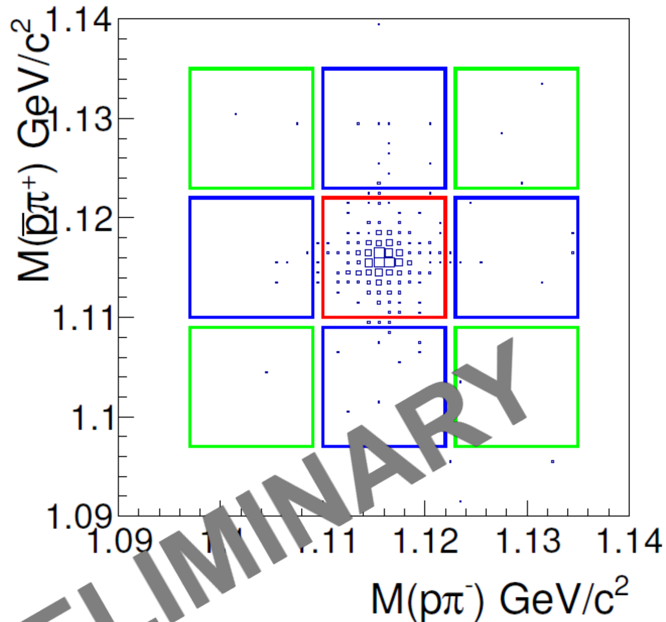
- World leading data sample between 2.0 and 3.08 GeV.

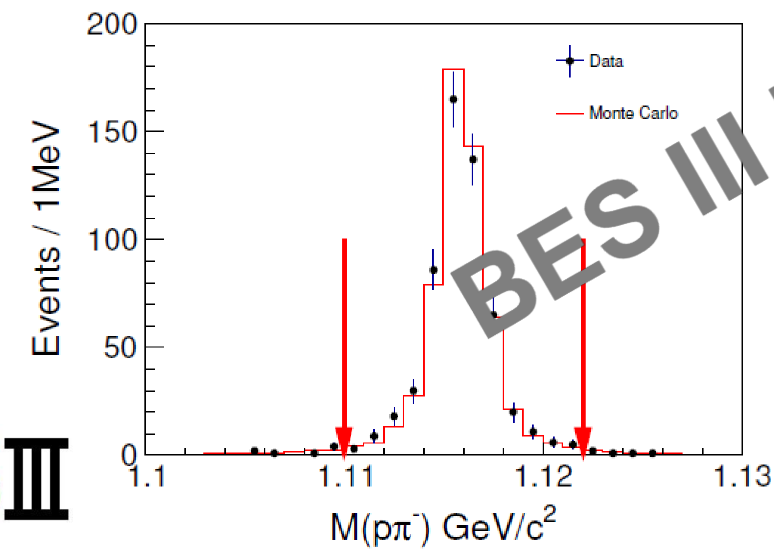
- Nucleon and strange hyperons EMFF's available.

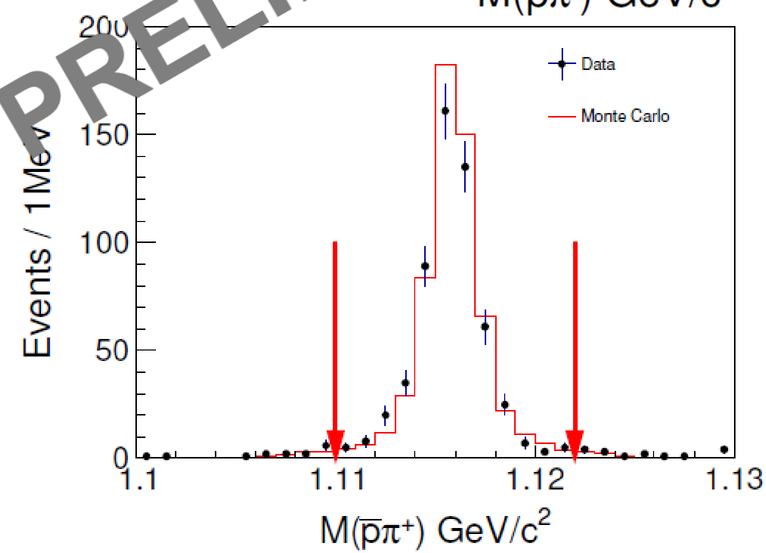


Exclusive measurement of $e^+e^- \rightarrow \Lambda\bar{\Lambda}$ @ 2.386 GeV

- Invariant mass cut:
  $|M(p\pi) - M_\Lambda| < 0.006$ GeV/c^2
- $N_{signal} = 555 \pm 24$
- $N_{sidebands} = 14 \pm 4$







Exclusive measurement of $e^+e^- \rightarrow \Lambda\bar{\Lambda}$ @ 2.386 GeV

UPPSALA UNIVERSITET

Cross section:

$$\sigma = \frac{N_{signal}}{L\varepsilon(1+\delta)BR(\Lambda \rightarrow p\pi^-)BR(\bar{\Lambda} \rightarrow \bar{p}\pi^+)} = \mathbf{119.0 \pm 5.3 \pm 7.3\ pb}$$

- $(1+\delta)$ ISR correction based on model by Czyz* *et al.*
- $\varepsilon = 17.7\%$
- $L = 66.9 \pm 0.02 \pm 0.5\ pb^{-1}$
- $BR(\Lambda \rightarrow p\pi^-) = BR(\bar{\Lambda} \rightarrow \bar{p}\pi^+) = 0.64\%$

Effective form factor:

$$|G(q^2)| = \sqrt{\frac{\sigma}{1+\frac{1}{2\tau}(\frac{4\pi\alpha^2\beta}{3q^2})}} = \mathbf{0.123 \pm 0.003 \pm 0.002}$$

- $\tau = \frac{q^2}{4m_\Lambda^2}$, $\beta = \sqrt{1-\frac{1}{\tau}}$, $\alpha = \frac{1}{137}$

BESIII

*PRD 75 (2007) 074026

Exclusive measurement of $e^+e^- \to \Lambda\bar{\Lambda}$ @ 2.386 GeV

- Data fitted with an unbinned ML fit using the PDF from Fäldt & Kupsc.

$$W(\xi) = F_0(\xi) + \eta F_5(\xi)$$
$$+ \sqrt{1-\eta^2}\sin(\Delta\Phi)\left(\alpha_\Lambda F_3(\xi) + \alpha_{\bar{\Lambda}} F_4(\xi)\right)$$
$$+ \alpha_\Lambda \alpha_{\bar{\Lambda}}\left(F_1(\xi) + \sqrt{1-\eta^2}\cos(\Delta\Phi) F_2(\xi) + \eta F_6(\xi)\right); \ \xi = (\theta, \theta_1, \phi_1, \theta_2, \phi_2), \ \eta = \frac{\tau - R^2}{\tau + R^2}$$

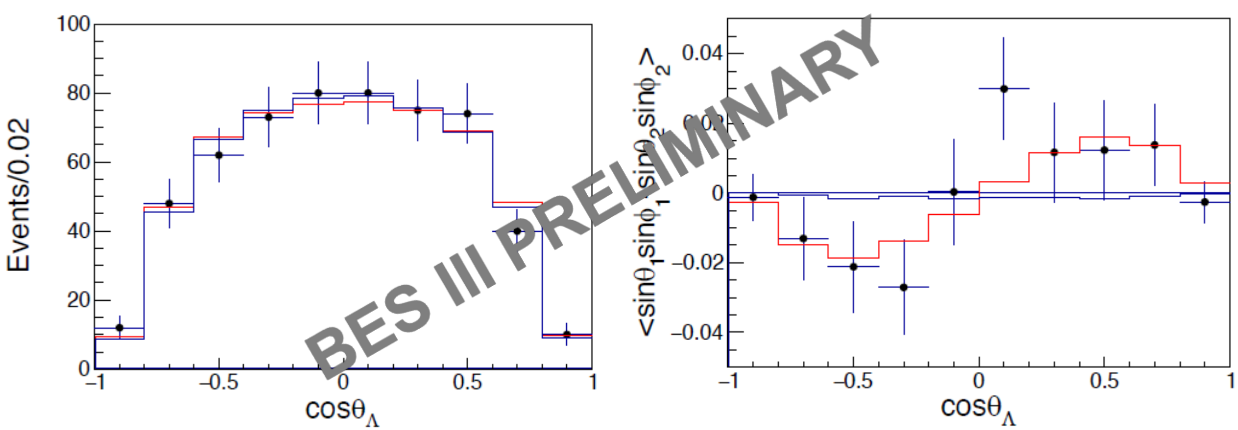
Exclusive measurement of $e^+e^- \to \Lambda\bar{\Lambda}$ @ 2.386 GeV

- Data fitted with an unbinned ML fit using the PDF from Fäldt & Kupsc.
- Result:
  - $R = \mathbf{0.94 \pm 0.16 \pm 0.03}\ (\pm 0.02\ \alpha_\Lambda)$
  - $\Delta\Phi = \mathbf{42^o \pm 16^o \pm 8^o}\ (\pm 6^o\ \alpha_\Lambda)$

  ←BES III PRELIMINARY
- Most **precise** result on *R*

  (BaBar: $R = 1.73^{+0.99}_{-0.57}$ in $2.23 < q < 2.40$ GeV*)
- **First** conclusive result on $\Delta\Phi$

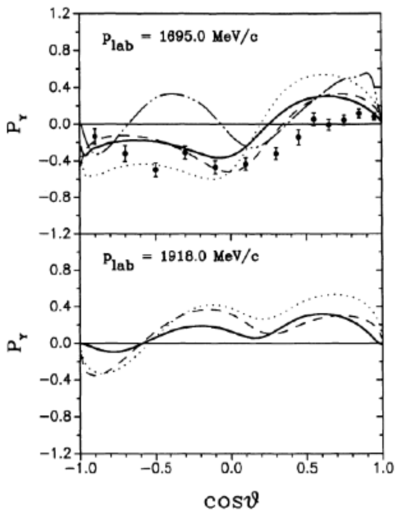
  (BaBar: $-0.76 < sin\Delta\Phi < 0.98$ in $2.23 < q < 2.80$ GeV*)



*PRD 76 (2007) 092006.

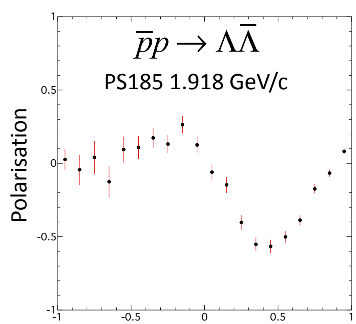
The polarisation is induced by the interference between $^3S_1$ and $^3D_1$ waves between the final state hyperons.

$e^+e^- \to Y\bar{Y}$ are perfect reactions to learn about the hyperon-antihyperon interaction.

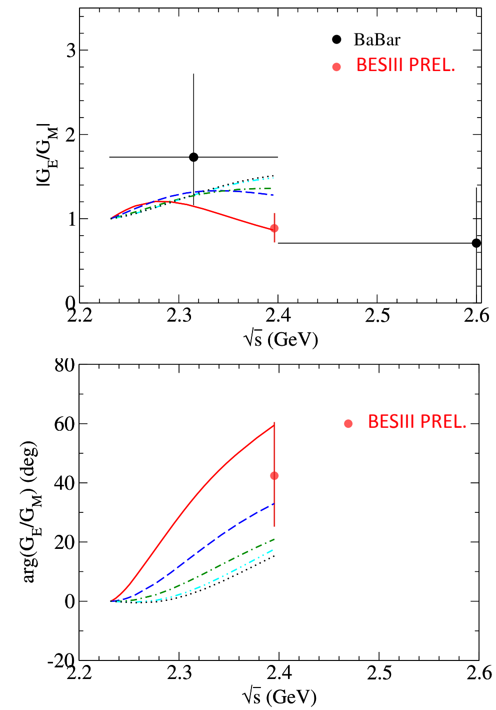


PRC 45 (1992) 931

Predictions have been made for R and the phase using potentials employed for the $\bar{p}p \to \Lambda\bar{\Lambda}$ reaction by Haidenbauer & Meißner.



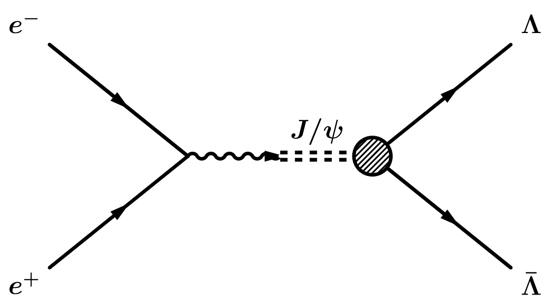
PRC 54 (1996) 1877

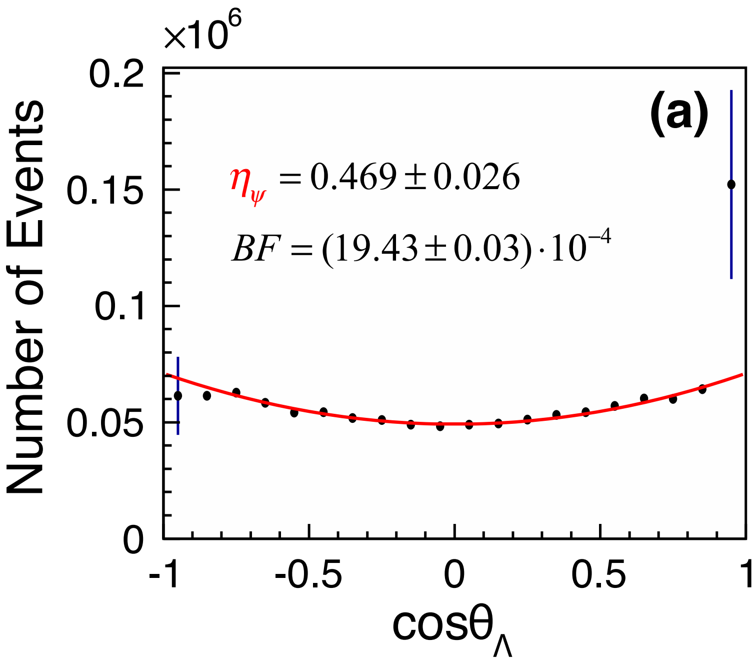


PLB 761 (2016) 456

The formalism of Fäldt & Kupsc has also been applied to BESIII data on

$$e^+e^- \to \gamma^* \to J/\psi \to \Lambda\bar{\Lambda}$$

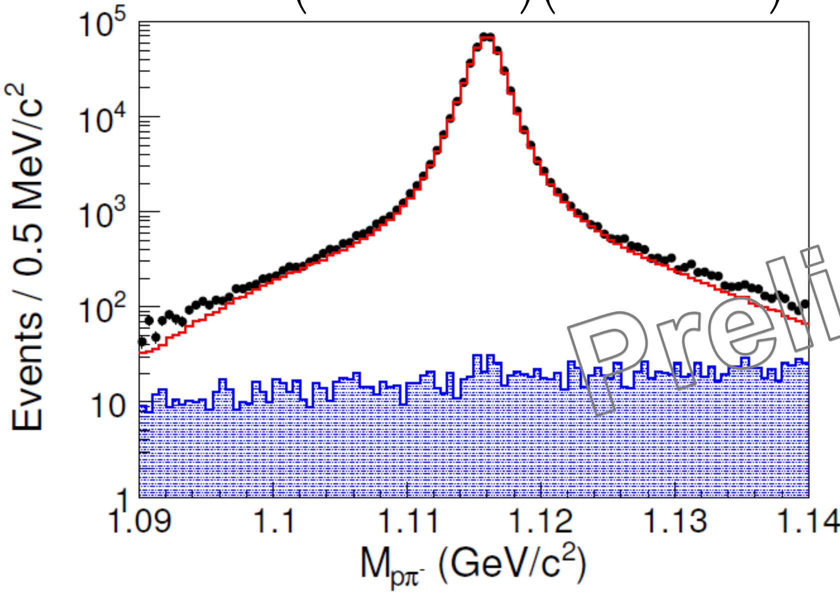




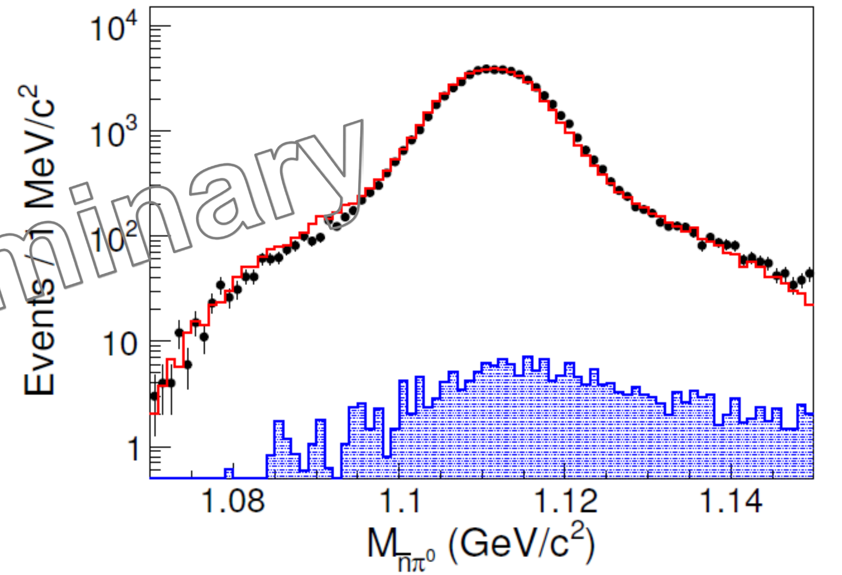
PRD 95 (2017) 052003

$$\frac{d\Gamma}{d\cos\theta} \propto 1 + \eta_\psi \cos^2\theta$$

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



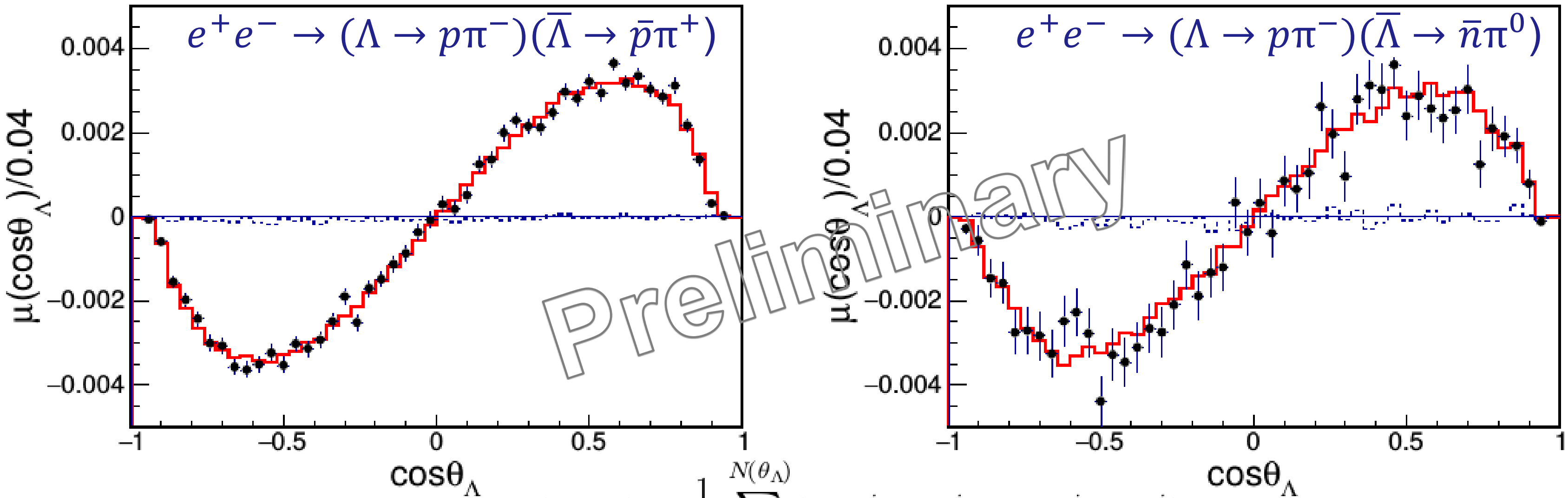
$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{n}\pi^0)$



$$
\begin{aligned}
W(\xi) &= F_0(\xi) + \eta F_5(\xi) \\
&+ \sqrt{1-\eta^2}\sin(\Delta\Phi)\left(\alpha_\Lambda F_3(\xi) + \alpha_{\bar{\Lambda}_{\bar{p},\bar{n}}} F_4(\xi)\right) \\
&+ \alpha_\Lambda \alpha_{\bar{\Lambda}_{\bar{p},\bar{n}}}\left(F_1(\xi) + \sqrt{1-\eta^2}\cos(\Delta\Phi) F_2(\xi) + \eta F_6(\xi)\right);\ \xi = (\theta, \theta_1, \phi_1, \theta_2, \phi_2),\ \eta = \frac{\tau - R^2}{\tau + R^2}
\end{aligned}
$$

Fit results

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



$$\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_{i}^{N(\theta_\Lambda)} (\sin\theta_1^i \sin\phi_1^i - \sin\theta_2^i \sin\phi_2^i)$$

Parameters	This work	Previous results	
η_ψ	$\mathbf{0.461 \pm 0.006 \pm 0.007}$	0.469 ± 0.027	BESIII
$\Delta\Phi$ (rad)	$\mathbf{0.740 \pm 0.010 \pm 0.008}$	–	
α_-	$\mathbf{0.750 \pm 0.009 \pm 0.004}$	0.642 ± 0.013	PDG
α_+	$\mathbf{-0.758 \pm 0.010 \pm 0.007}$	-0.71 ± 0.08	PDG
$\bar{\alpha}_0$	$\mathbf{-0.692 \pm 0.016 \pm 0.006}$	–	
A_{CP}	$\mathbf{-0.006 \pm 0.012 \pm 0.007}$	0.006 ± 0.021	PDG
$\bar{\alpha}_0/\alpha_+$	$\mathbf{0.913 \pm 0.028 \pm 0.012}$	–	

$\alpha_- = \alpha_{\Lambda \to p\pi^-}$

$\alpha_+ = \alpha_{\bar{\Lambda} \to \bar{p}\pi^+}$

$\bar{\alpha}_0 = \alpha_{\bar{\Lambda} \to \bar{n}\pi^0}$

CP asymmetry:

$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

UPPSALA UNIVERSITET

Parameters	This work	Previous results	
η_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027	BESIII
$\Delta\Phi$ (rad)	$0.740 \pm 0.010 \pm 0.008$	–	
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013	PDG
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08	PDG
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–	
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021	PDG
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–	

Preliminary

First: Phase measurement between G_M^ψ and G_E^ψ
$\bar{\alpha}_0$ decay asymmetry parameter

$\alpha_{\Lambda \to p\pi^-}$ decay parameter is measured to be (17±3)% larger than the PDG value (> 5σ)

Improved upper limit on A_{CP}

$\bar{\alpha}_0 / \alpha_+$ deviates 3σ from isospin symmetry prediction

PRELIMINARY

UPPSALA UNIVERSITET

No theoretical predictions exist for the phase and and R (η_ψ) for

$$e^+e^- \to \gamma^* \to J/\psi \to \Lambda\bar{\Lambda}$$

→ The floor is open for theorists!

Prospects and conclusions

BESIII has taken data at 10 energies from $\Lambda\bar{\Lambda}$ threshold to 2.9 GeV.

To come: Effective FF's for Σ^0, Σ^+, Ξ + transition FF for $\Lambda\Sigma^0$.

Published data on $J/\psi, \psi(2S) \to Y\bar{Y}$ have, so far, focused on Branching Ratios and hyperon angular distributions based on 1.3x10^9 J/ψ and 0.45x10^9 $J/\psi(2S)$ events from BESIII.
There is a lot more to be analysed here!

A non-zero phase between spin 1/2 hyperons allows for a determination of their decay parameters and CP violation tests in the baryon sector.

UPPSALA UNIVERSITET

Prospects and conclusions

The multivariate formalism has now been extended in Uppsala to handle J/ψ decays to spin 3/2 + 3/2, 3/2 + 1/2 hyperons and 1/2 + 1/2 including decay chains.

Available data samples from BESIII

Decay mode	Events	$\mathcal{B}(\times 10^{-4})$
$J/\psi \to \Lambda\Lambda$	440675 ± 670	$19.43 \pm 0.03 \pm 0.33$
$\psi(2S) \to \Lambda\bar{\Lambda}$	31119 ± 187	$3.97 \pm 0.02 \pm 0.12$
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	111026 ± 335	$11.64 \pm 0.04 \pm 0.23$
$\psi(2S) \to \Sigma^0\bar{\Sigma}^0$	6612 ± 82	$2.44 \pm 0.03 \pm 0.11$
$J/\psi \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	102762 ± 852	10.71 ± 0.09
$J/\psi \to \Xi^0\bar{\Xi}^0$	134846 ± 437	11.65 ± 0.04
$\psi(2S) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	2214 ± 148	0.69 ± 0.05
$\psi(2S) \to \Xi^0\bar{\Xi}^0$	10839 ± 123	2.73 ± 0.03
$J/\psi \to \Xi^-\bar{\Xi}^+$	42811 ± 231	10.40 ± 0.06
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$	42595 ± 467	10.96 ± 0.12
$J/\psi \to \Sigma(1385)^+\bar{\Sigma}(1385)^-$	52523 ± 596	12.58 ± 0.14
$\psi(2S) \to \Xi^-\bar{\Xi}^+$	5337 ± 83	2.78 ± 0.05
$\psi(2S) \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$	1375 ± 98	0.85 ± 0.06
$\psi(2S) \to \Sigma(1385)^+\bar{\Sigma}(1385)^-$	1470 ± 95	0.84 ± 0.05

Potential data samples from BESIII

	$\mathcal{B}(\times 10^{-4})$
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	5.9 ± 1.5
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	3.3 ± 1.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$	3.1 ± 0.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.47 ± 0.10

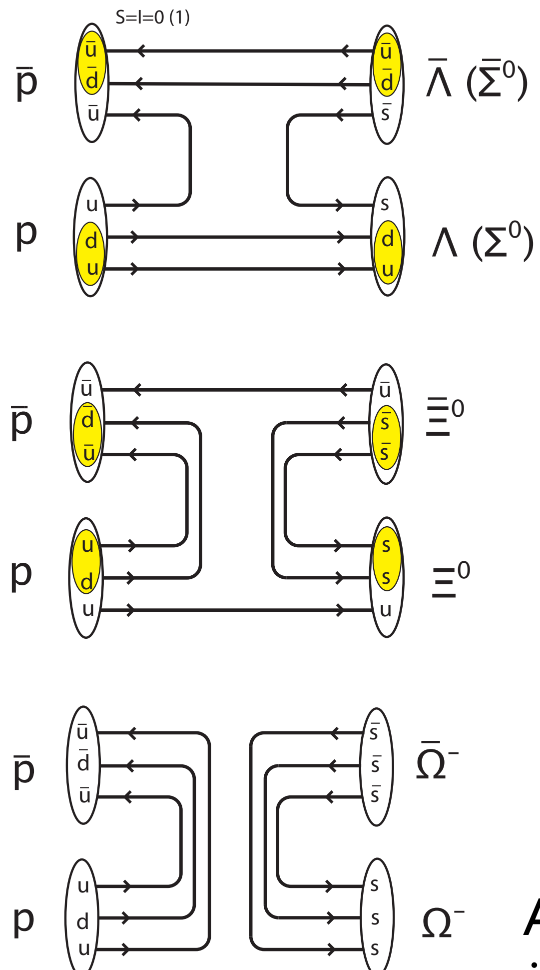
≈ $5\text{x}10^9$ J/ψ events are now collected @ BESIII

UPPSALA UNIVERSITET

There is a lot more to come!

Stay posted!!

Antiproton-proton reactions are a hyperon factory via $\bar{p}p \rightarrow \bar{Y}Y$ reactions, both for ground state and excited hyperon.



- Strong interaction processes ➪ High cross sections.

- Baryon number = 0 ➪ No extra kaons needed.
  ➪➪ Low energy threshold.

- Same pattern in Y and $\bar{Y}$ channels ➪ Consistency.

Antihyperons/hyperon-pairs are accessible up to < 2740 MeV/c², i.e. up to $\bar{\Xi}_c^* \Xi_c^*$.

The Prospects for Hyperon Physics are good!!