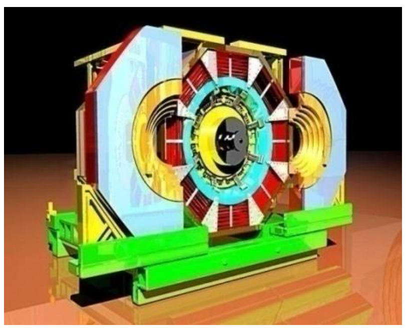
Status Update from BESIII Experiment

Marco Destefanis
Università degli Studi di Torino e INFN

on behalf of the BESIII Collaboration



HEPMAD 18 – 10th High-Energy Physica International Conference

Antananarivo, Madagascar

September 06-11, 2018

Overview

- Introduction

BEPCII and the BESIII experiment

BESIII dataset

- Physics highlights

Charmonium-like states: XYZ states

Baryon spectroscopy

Dark photon and μ anomalous magnetic moment

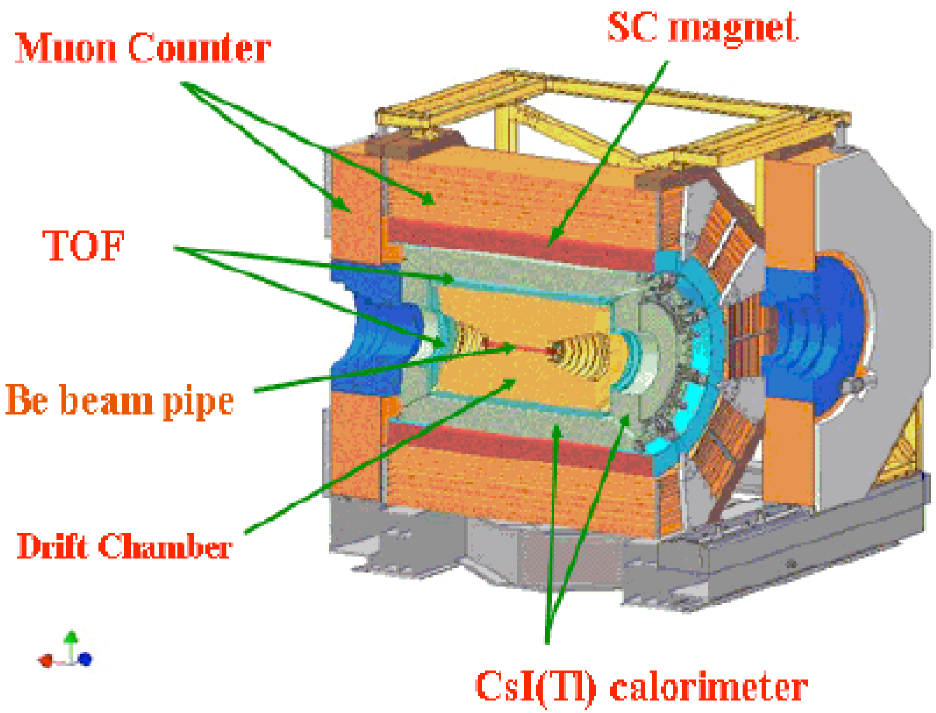
- Summary

The BESIII Spectrometer @ IHEP

BEijing Spectrometer III

e^+e^- collisions

$\sqrt{S}$ tuned depending on energy



Physics program

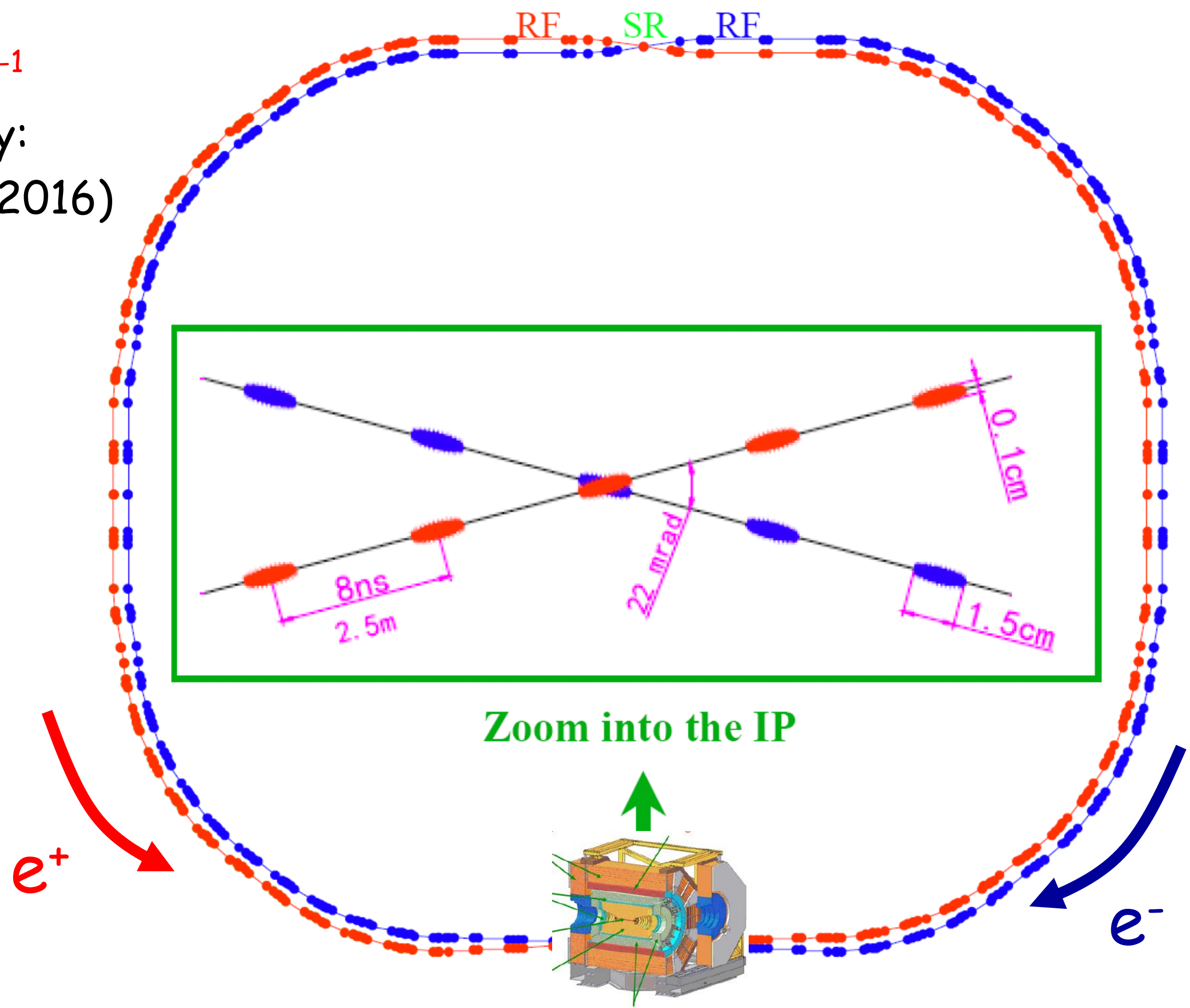
- Charmonium Physics
- D-Physics
- Light Hadron Spectroscopy
- τ-Physics
- ...

D.M. Asner et al, Physics at BES-III, arXiv:0809.1869v1 [hep-ex] (2008)

BEPCII Storage Rings

- Beam energy:
  1.0-2.3 GeV
- Design Luminosity:
  1×10^{33} cm^{-2}s^{-1}
- Achieved Luminosity:
  1×10^{33} cm^{-2}s^{-1} (2016)
- Optimum energy:
  1.89 GeV
- Energy spread:
  5.16×10^{-4}
- No. of bunches:
  93
- Bunch length:
  1.5 cm
- Total current:
  0.91 A
- Circumference:
  237m

Beijing Electron-Positron Collider II



BESIII Detector

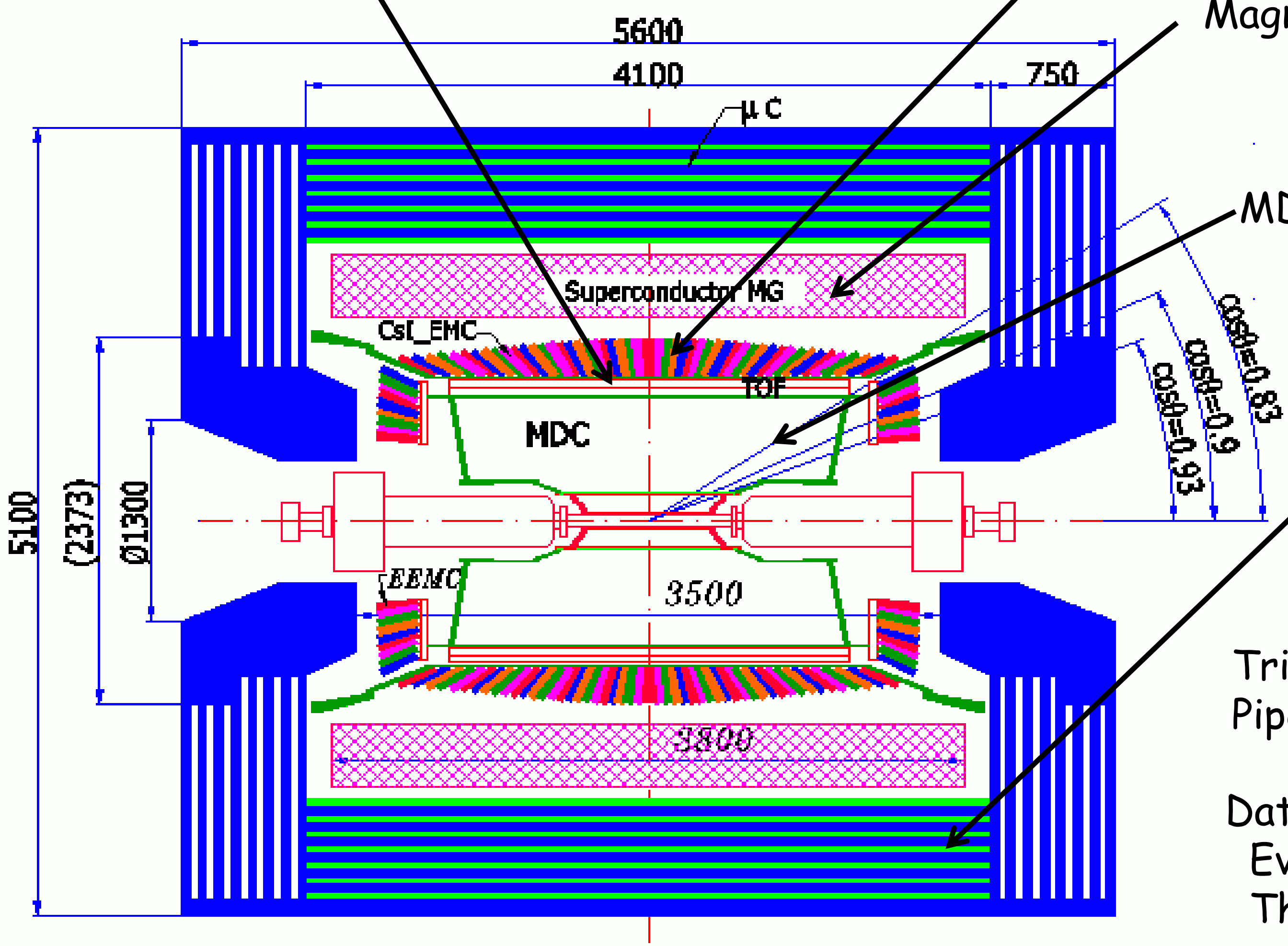
TOF:
σ_T = 80 ps Barrel
110 ps Endcap

EMC: CsI crystals, 28 cm
$\Delta E/E$ = 2.5% @1 GeV
σ_z = 0.6 cm/$\sqrt{E}$

Magnet: 1T Superconducting

MDC: small cell & He gas
σ_{xy}= 130 μm
σ_p/p = 0.5% @1GeV
dE/dx = 6%

Muon: 9 layer RPC



Trigger: Tracks & Showers
Pipelined; Latency = 2.4 ms

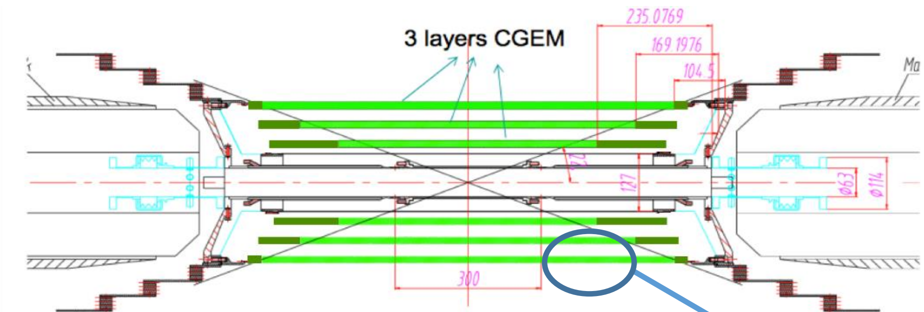
Data Acquisition:
Event rate = 3 kHz
Thruput ~ 50 MB/s

Cylindrical GEM Inner Tracker

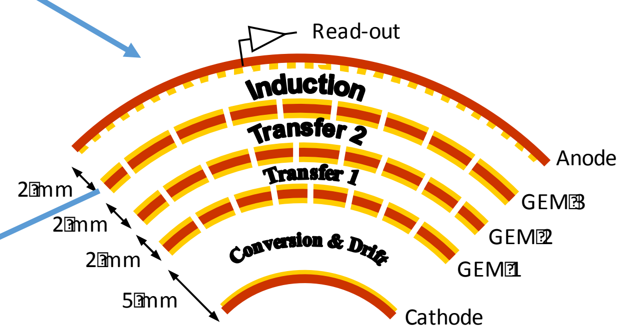
The current Inner Tracker suffers from aging. Italy, Germany, Sweden and China are building a new Inner Tracker based on three layers of cylindrical GEM using the same construction technique developed for the KLOE-2 CGEM detector.

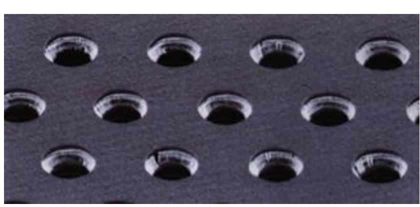
- Low Material budget ≤ 1.5% of X_0 for all layers
- Momentum resolution:: σ_{pt}/P_t =~0.5% @1 GeV
- High Rate capability: ~10^4 Hz/cm^2
- Coverage: 93%
- Spatial resolution $\sigma_{r\phi}$ 130-150 μm, σ_z <1 mm
- 1 T magnetic filed
- Operation duration at least 5 years

- Inner radius: 78 mm
- Outer radius: 178 mm



each layer composed by a cylindrical triple GEM





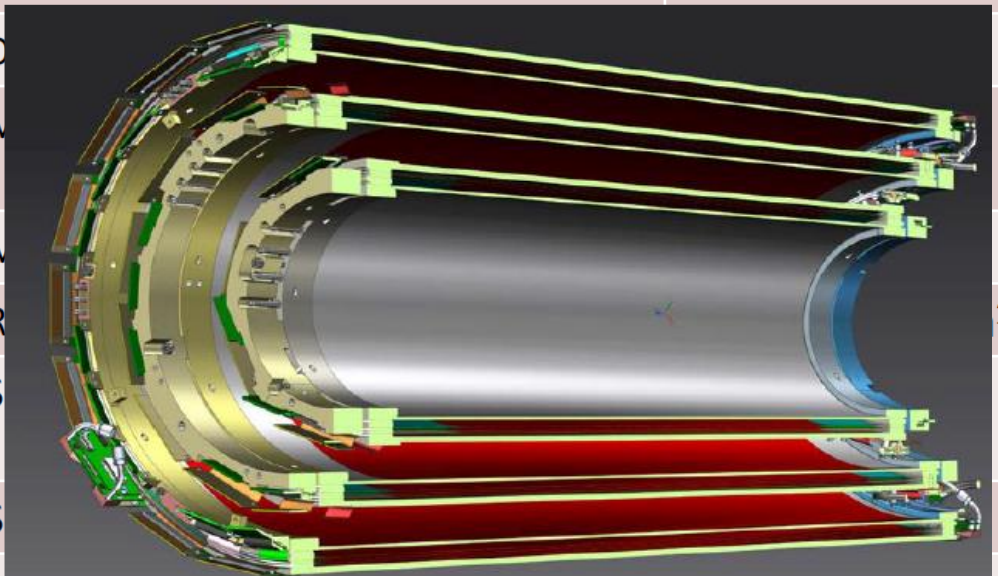
Also funded by the RISE BESIIICGEM European Project

Peculiarities of the BESIII CGEM

	KLOE-2	BESIII	action
Number of detector layers	4	3	→ 5 mm drift gap
Drift gap	3 mm	5 mm	also for μTPC
Material budget per layer	0.5% X_0	0.4% X_0	rohacell and anode
Momentum resolution @1 GeV	not used	σ_{pt}/P_t =~0.5%	
Rate capability – radiation hardness	< 10 kHz/cm^2	few 10 kHz/cm^2	
Spatial resolution ϕ	250-350 μm (B=0.5T)	100-150 μm (B=1T)	with μTPC
Spatial resolution Z	~1 mm	<500 μm	with μTPC
Magnetic filed	B = 0.52 T	B = 1 T	→ μTPC
Internal/external diameter	244/440 mm	156/356 mm	higher rate
Readout	digital	charge + time	new ASIC chip

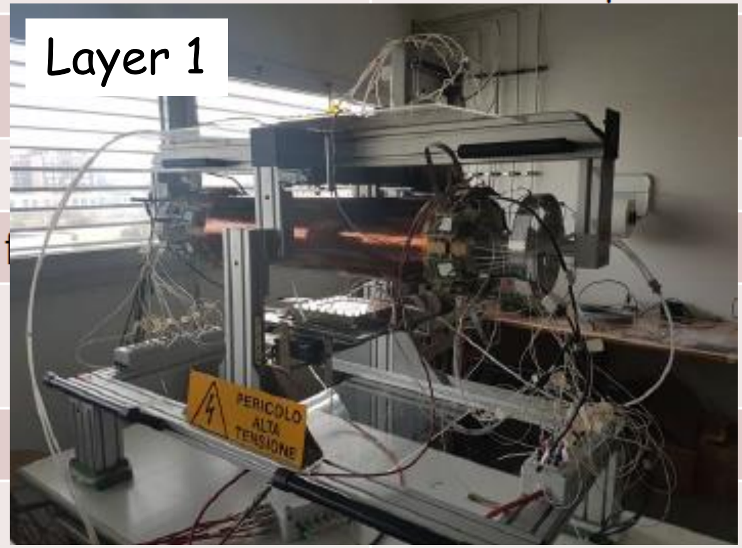
Peculiarities of the BESIII CGEM

	KLOE-2	BESIII	action
Number of detector layers	4	3	→ 5 mm drift gap
D		5 mm	also for μTPC
M		0.4% X_0	rohacell and anode
M		σ_{pt}/P_t =~0.5%	
R	2	few 10 kHz/cm^2	
S		100-150 μm (B=1T)	with μTPC
S		<500 μm	with μTPC
Magnetic filed	B = 0.52 T	B = 1 T	→ μTPC
Internal/external diameter	244/440 mm	156/356 mm	higher rate
Readout	digital	charge + time	new ASIC chip

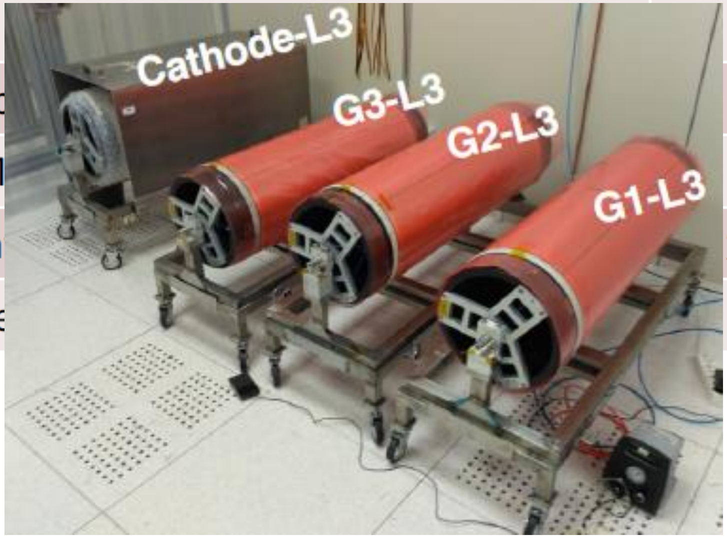


Peculiarities of the BESIII CGEM

	KLOE-2	BESIII	action
Number of detector layers	4	3	→ 5 mm drift gap
Drift gap	3 mm	5 mm	also for μTPC
Material budget per layer	0.5% X_0		
Momentum resolution @1 GeV	not used		
Rate capability – radiation hardness	< 10 kHz/cm^2		
Spatial resolution ϕ	250-350 μm (B=0.5T)		
Sp	~1 mm		
M	B = 0.52 T		
In	244/440 mm	156/356 mm	higher rate
Re	digital	charge + time	new ASIC chip

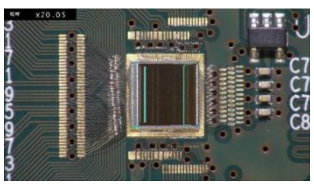


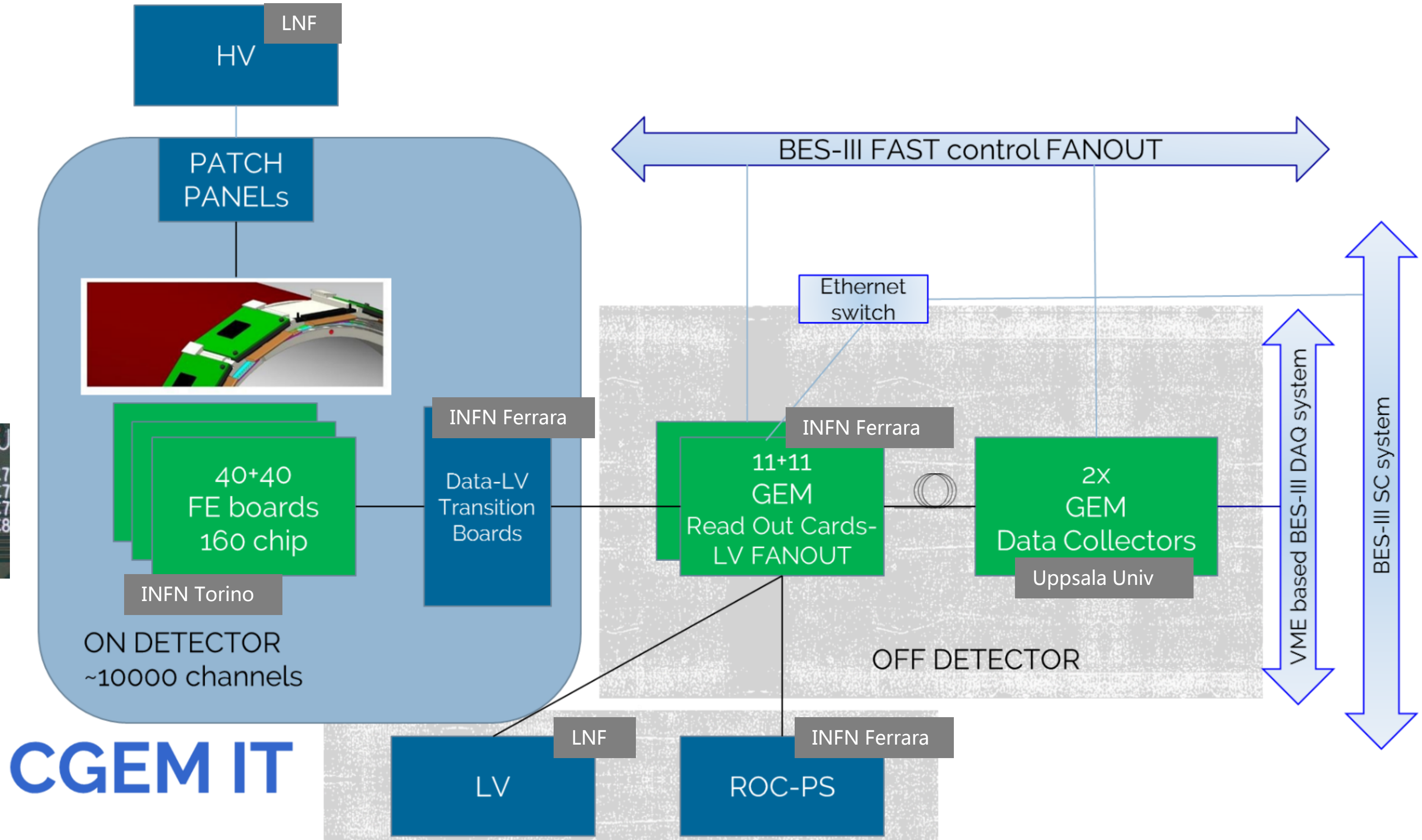
Layer 1



Layer 3

CGEM Electronics: General Overview



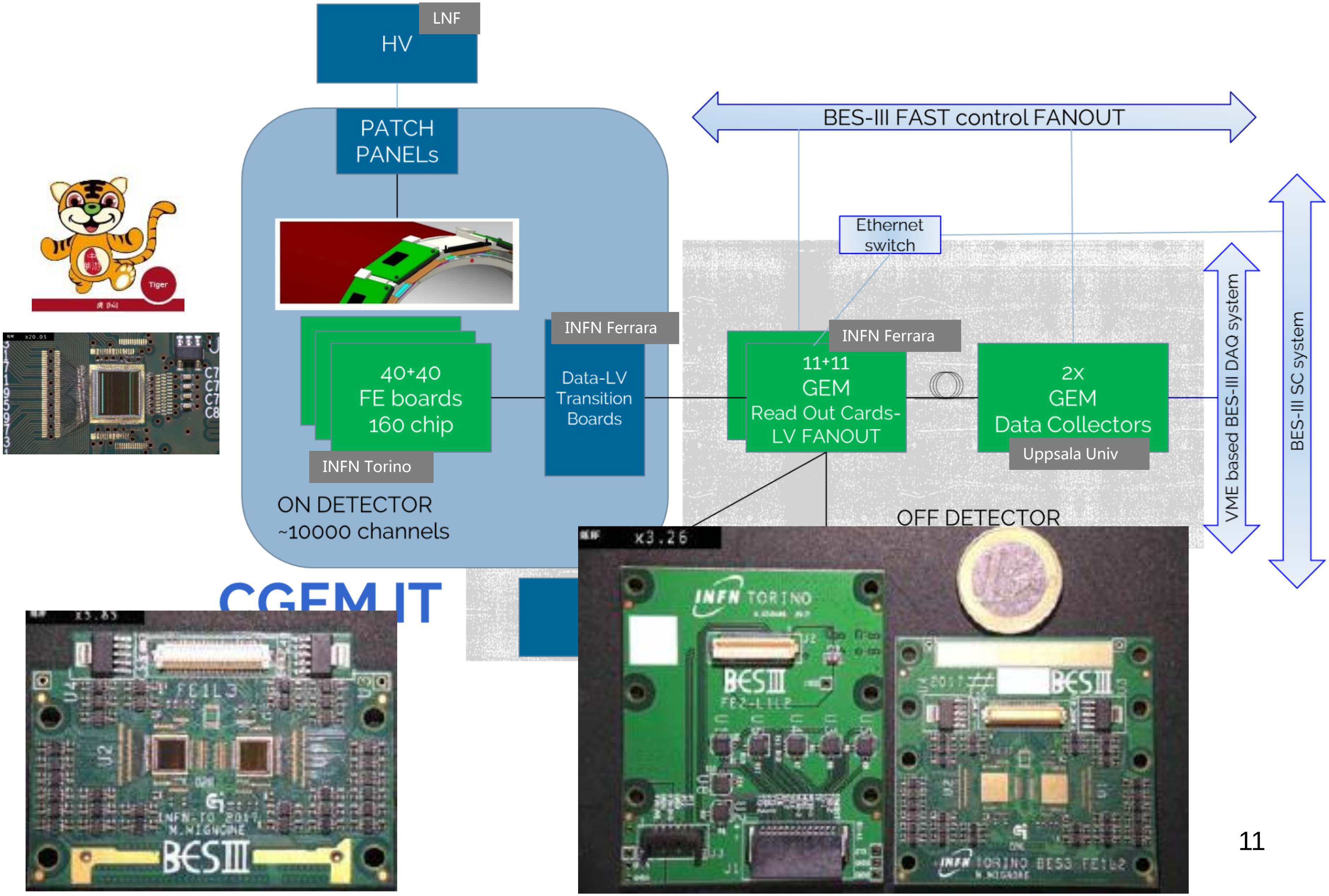


Analog readout

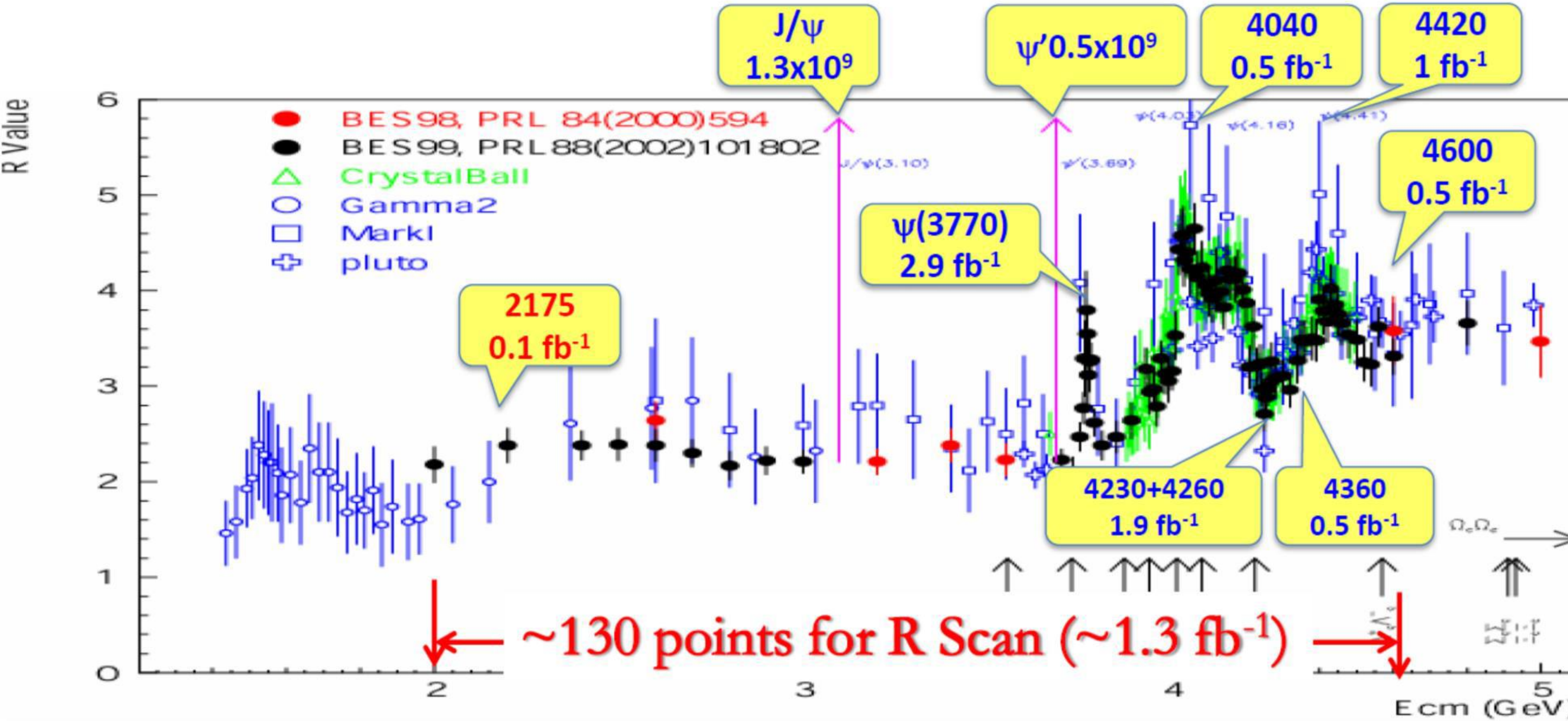
reduce strip pitch

10000 channels

CGEM Electronics: General Overview



BESIII Datasets



- World largest data sample on J/ψ, ψ(2S), ψ(3770), Y(4260)… in e^+e^- collisions
- From light meson spectroscopy to $\Lambda_c\bar{\Lambda}_c$
- Fine and coarse scan of the accessible energy region

BESIII Data Taking 2017

- J/ψ data taking, 4 months
- τ mass measurement, 1 month
- ψ(3686) scan for relative phase measurement, 1 month
  - 500 pb^{-1} of data
  - from J/ψ scan all phases compatible with 90 degrees (or 0 if a EM decay with the ππ exception)
  - from the present ψ(3686) measurements:
    SU3 on VP decay 180 degrees
    cont+BR PP decay 0 degrees
  - hence scan to get a phase direct measurement

XYZ States

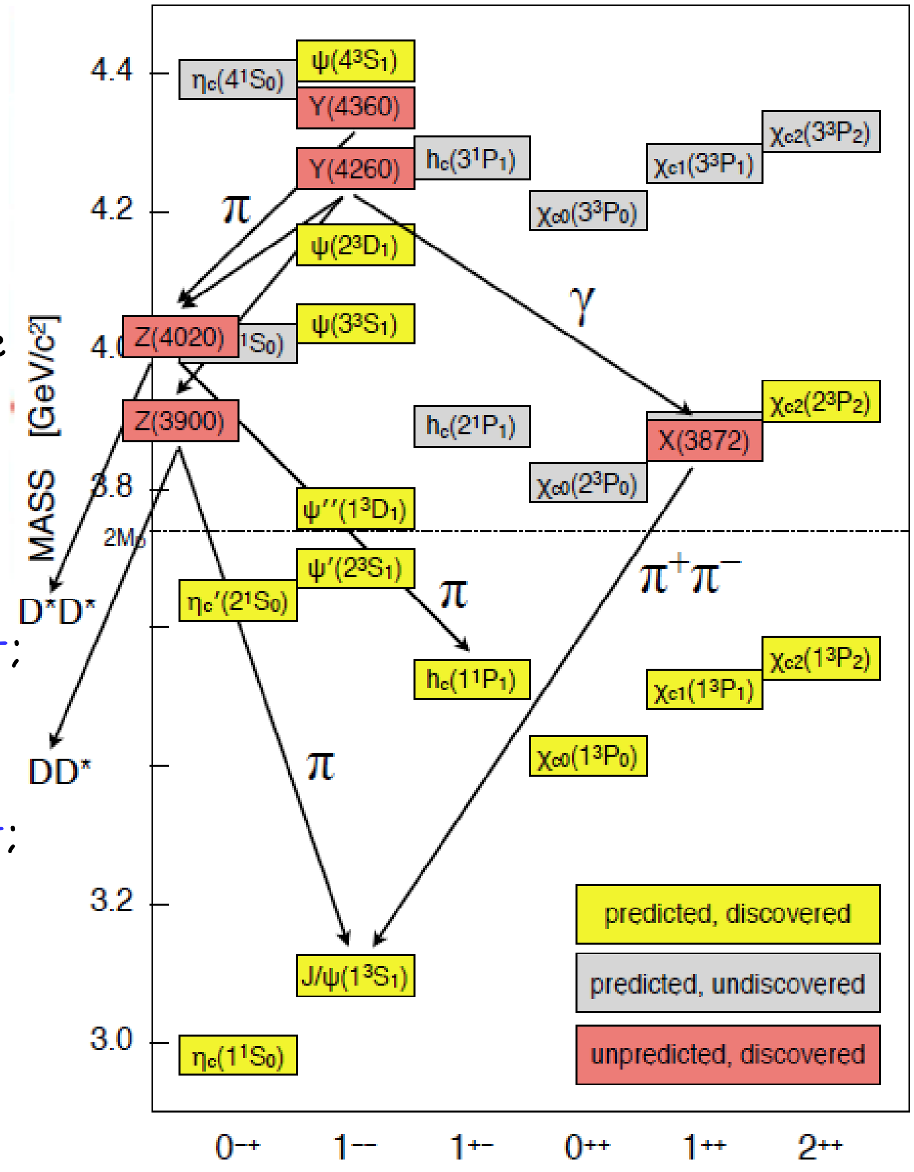
Below DD threshold: all the states have been observed and described by the $c\bar{c}$ potential Model

Above the threshold: more complex situation
• only a few of the predicted states above the threshold have been found
• Many new states have been observed with properties that are not consistent with the expectation for charmonium: X, Y, Z

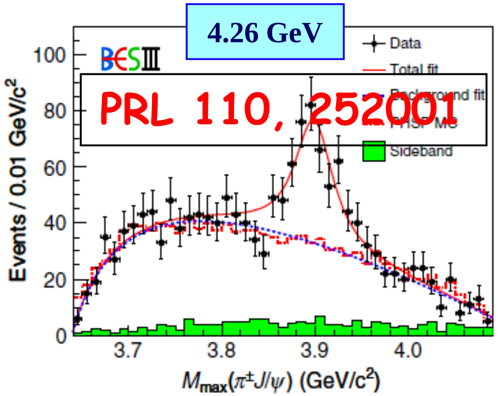
X states: charmonium-like states with $J^{PC} \neq 1^{--}$; observed in B decays, proton-proton, and proton-antiproton collisions.

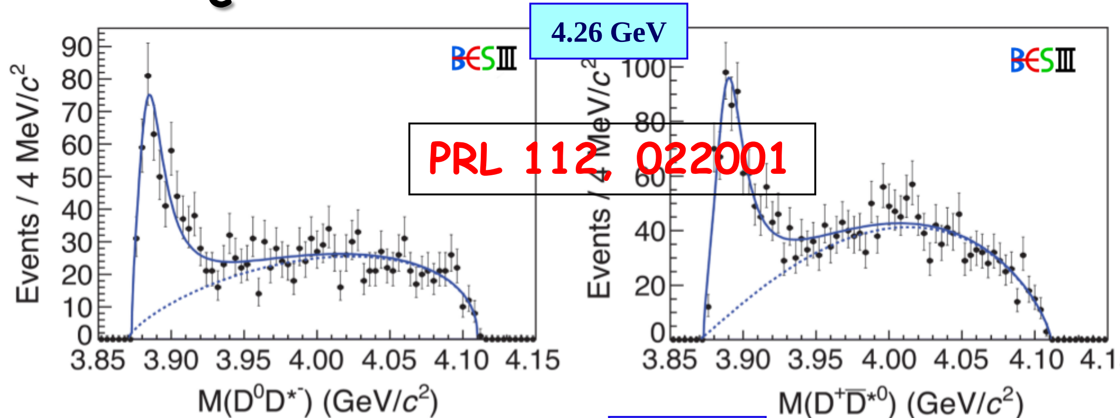
Y states: charmonium-like states with $J^{PC} = 1^{--}$; Observed in direct e^+e^- annihilation or initial state radiation (ISR).

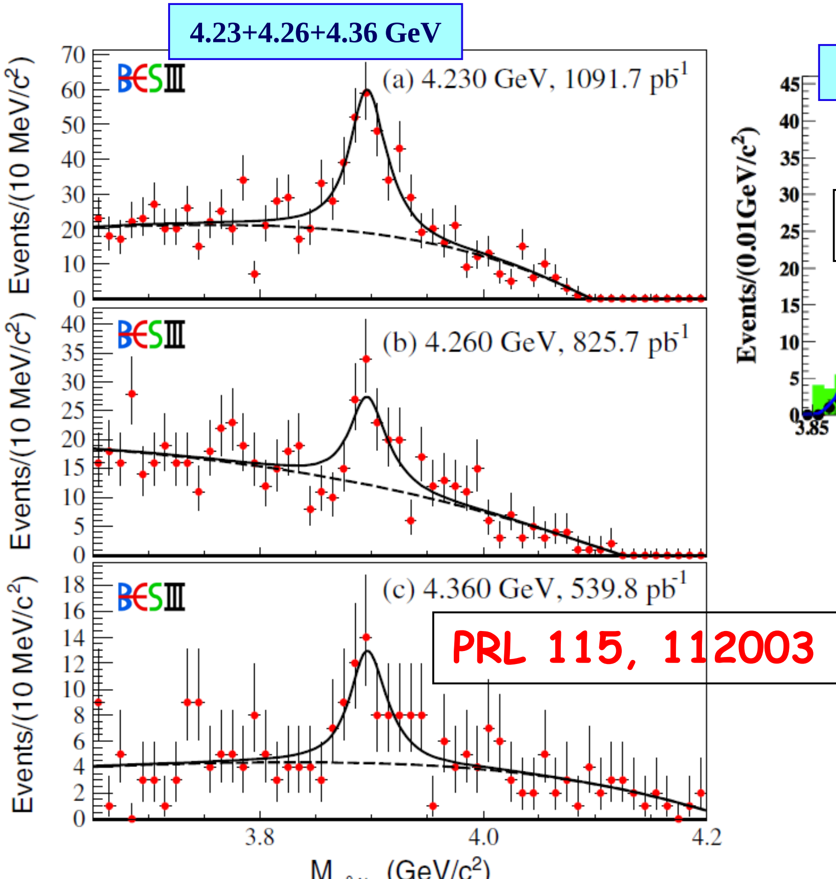
Z states: charmonium-like states **carrying electric charge**; must contain at least $c\bar{c}$ and a light $q\bar{q}$ pair

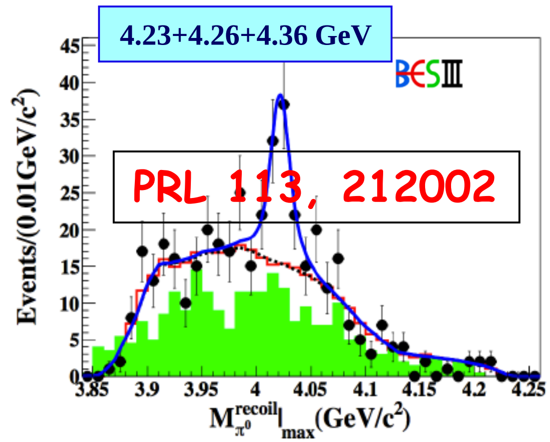


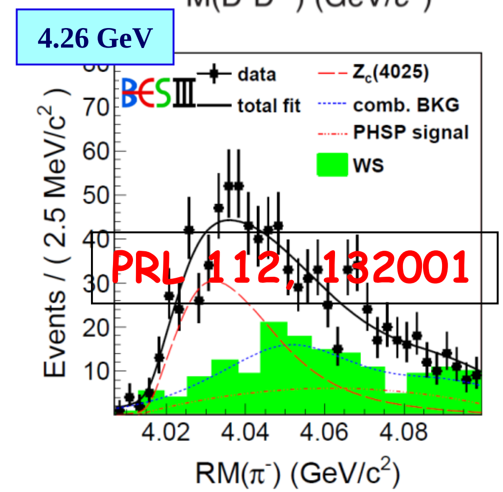
BESIII: Z_c Results

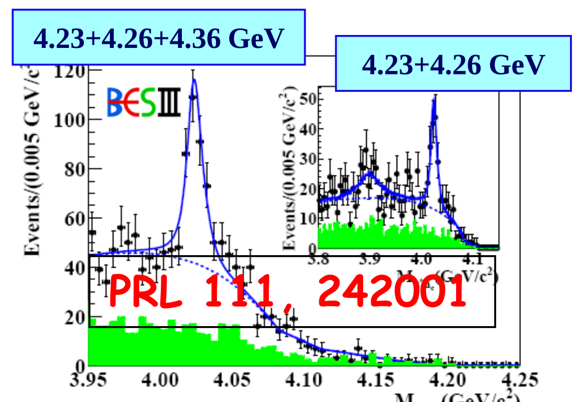










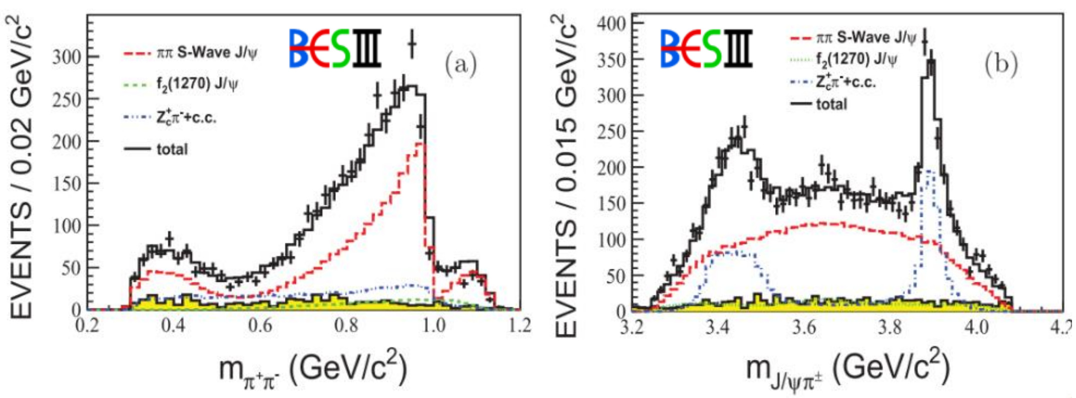


Determination of Spin Parity of $Z_c(3900)$

Determination of spin-parity -> discrimination between theoretical models

PWA performed on two different data samples (at 4.23 GeV and 4.26 GeV)

$$A = |A(\sigma J/\psi) + A(f_0 J/\psi) + A(f_0(1370)J/\psi) + A(f_2(1270)J/\psi) + A(Z_c\pi)|$$



σ and $f_{0,2}$ components were tested in the J/ψ recoil spectrum to understand if such states can produce rescattering peaks

PRL 119, 072001

Hypothesis of 1^+ is favoured

Compatible with the picture that

$Z_c(3900) = Z_c(3885)$ observed in DD*

Hypothesis	$\Delta(-2\ln L)$	Δ(ndf)	Significance
1^+ over 0^-	94.0	13	7.6σ
1^+ over 1^-	158.3	13	10.8σ
1^+ over 2^-	151.9	13	10.5σ
1^+ over 2^+	96.0	13	7.7σ

Y States

- The observed charmonium-like states Y(4260), Y(4360), and Y(4660) can not interpreted as conventional charmoniums.
- New decay modes searching and the line shape measurement is useful for understanding the nature of these Y-states.
- Hadronic transitions (by an η or π^0) to lower charmonia like J/ψ are regarded as sensitive probes to study the properties of these Y-states.
- Nature of these Y-states:

  hybrids ?

  tetraquarks?

  hadro-charmonium?

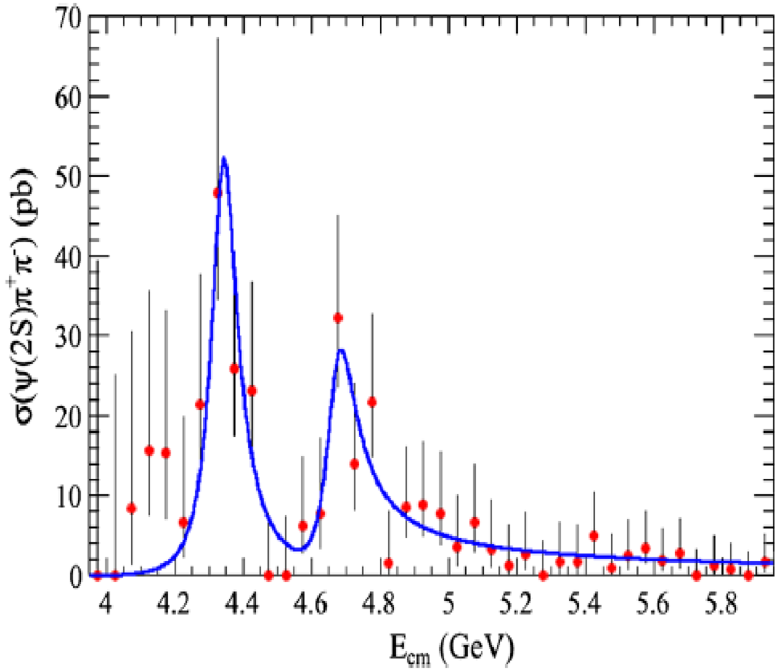
  hadronic molecule?

$e^+e^- \to \psi(3686)\ \pi^+\pi^-$

BaBar

M=4669 ± 22 MeV
Γ=104 ± 49 MeV

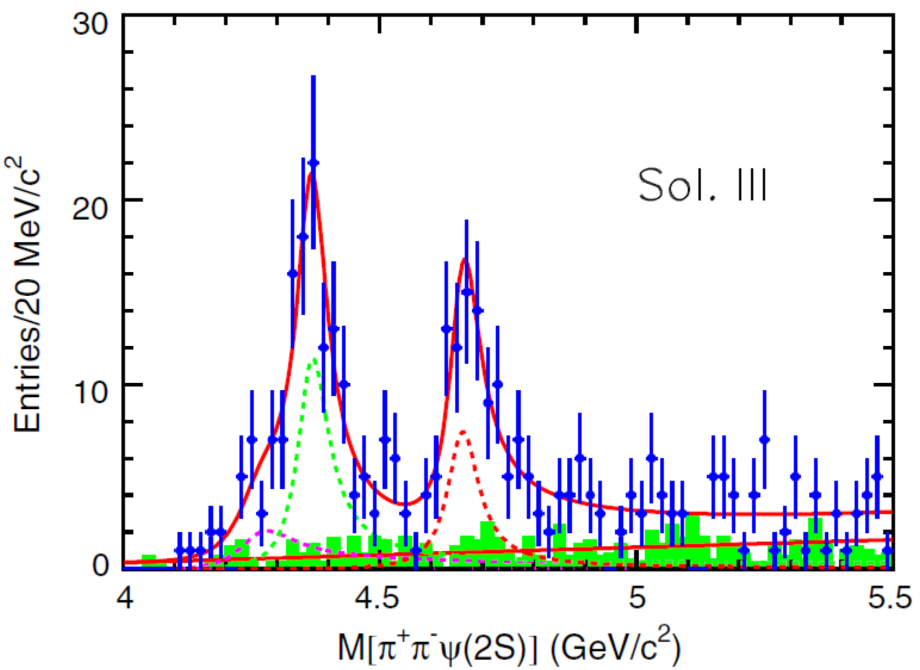
PHYSICAL REVIEW D **89**, 111103(R) (2014)



Belle

M=4652 ± 13 MeV
Γ=68 ± 11 MeV

PHYSICAL REVIEW D **91**, 112007 (2015)



M=4667 ± 7 MeV

Γ=36 +32(-14) MeV (updated in PDG 72 ± 11 MeV)

$B\Gamma_{ee}$ = 1.4 ± 0.5 eV

Y(4660): Hidden Charmed Barionium?

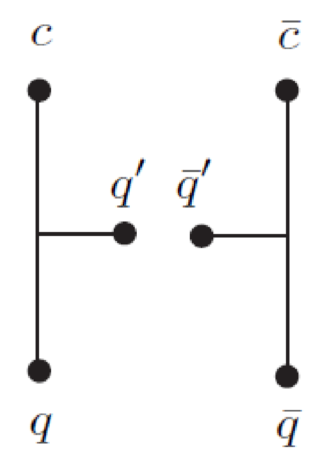
According to R. Faccini et al., PRL 104, 132005 (2010)
[see also L. Maiani et al., PRD 72, 031502 (2005)]

Y(4660) in $e^+e^- \to \psi(3686)\pi^+\pi^-$ cross section:

$\sigma_{peak} = 12\,\pi / M^2\, B\Gamma_{ee} / \Gamma \times 1.5$ (incl $\pi^0\,\pi^0$) ~ **0.04** ± 0.025 nb
to be compared to $e^+ e^- \to \Lambda_c\, \Lambda_{cbar}$ σ_{peak} ~ **0.55** nb

Y(4660) baryonic coupling ≥ 10 mesonic coupling -> Unexpected!
– Is it a hidden charmed baryonium?

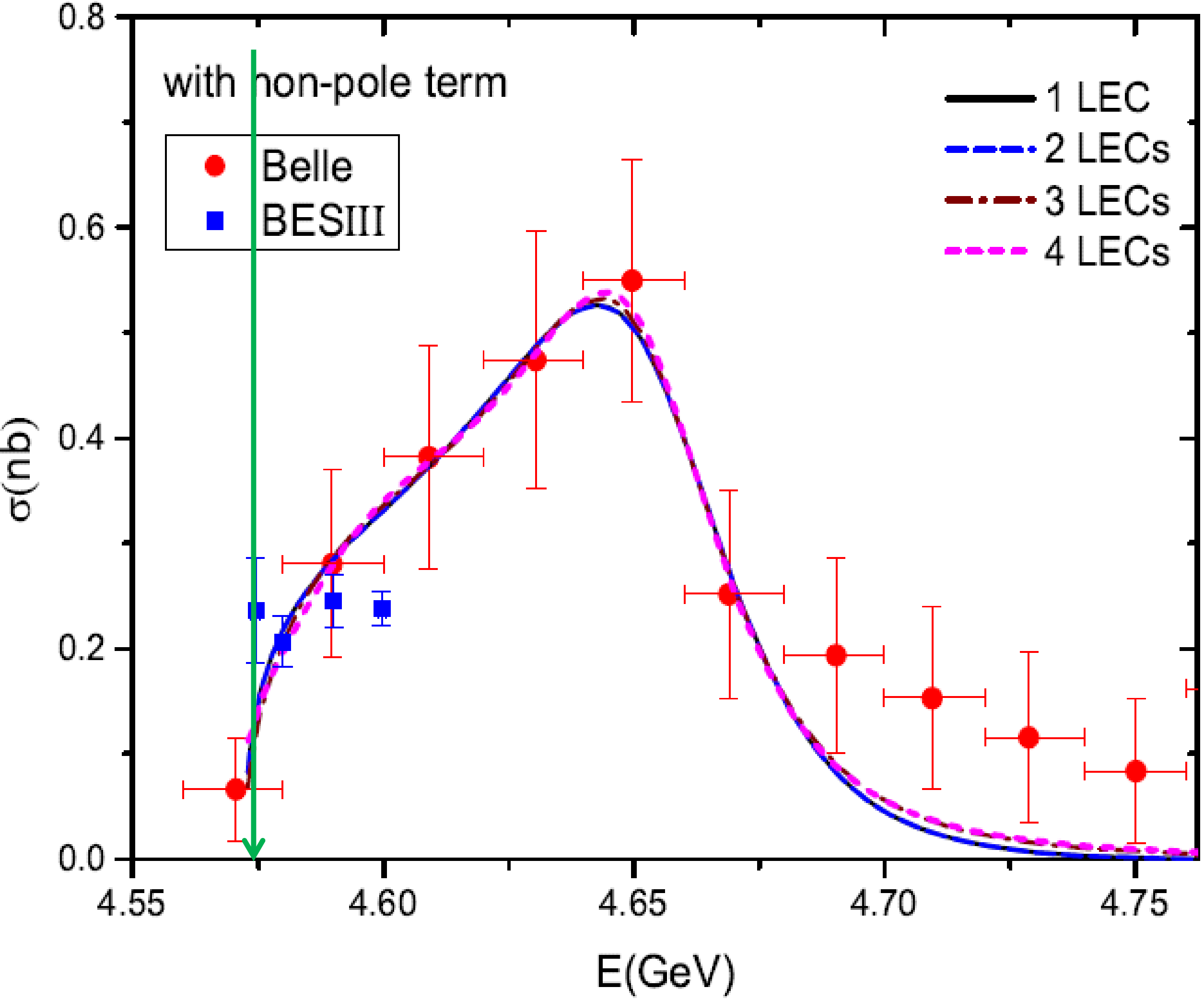
Y(4660) fulfills the old Rossi Veneziano, G.F. Chew paradigm
[Nucl.Phys. B123, 507(1977), G.F.Chew Nucl.Phys. B79, 365 (1974)]
of a charm tetraquark (hidden charm baryonium) decay:
mostly popping up from the vacuum a light quark pair and
falling apart as a charmed baryon pair



Y(4660): data on $e^+e^- \to \Lambda_c\bar{\Lambda}_c$

Belle G. Pakhlova et al., [Belle Collaboration], PRL 101, 172001 (2008)

BESIII Ablikim et al., PRL 120, 132001 (2018)



Λ_c weak decay -> good detection efficiency at threshold

Jump in $\sigma_{\Lambda c \Lambda cbar}$

Plateau in BESIII data

Region sensitive to Coulomb interaction

At thr, σ closed to pointlike value

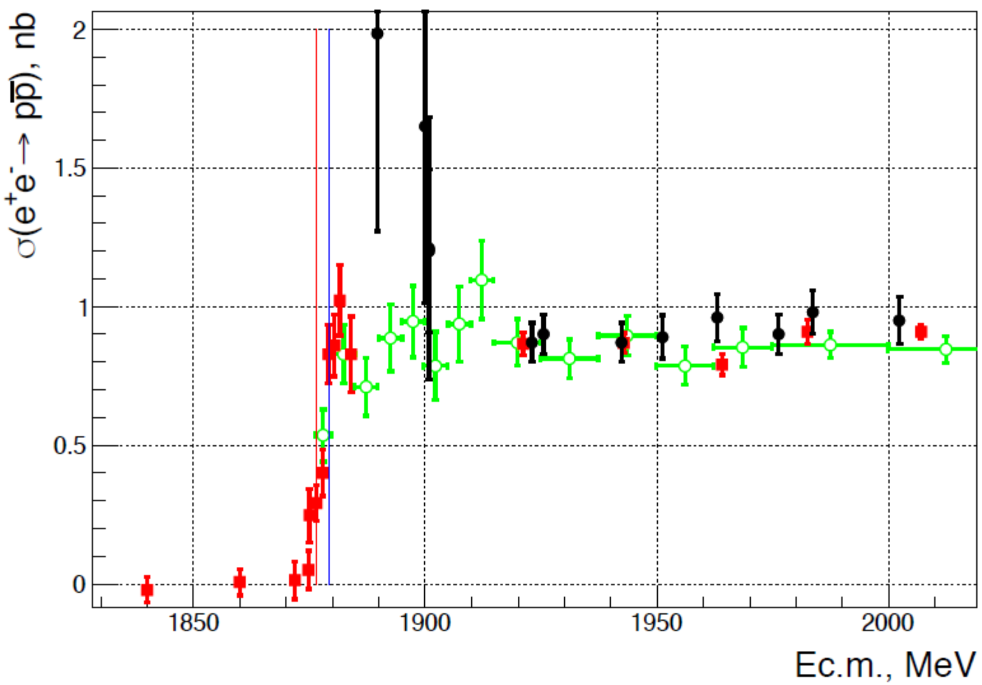
$$\sigma_{(e+e- \to \Lambda c \bar{\Lambda} c)} \approx \frac{\pi^2 \alpha^3}{2 M_B} \approx 145 \text{ pb}$$

Similar to $p\bar{p}$ cross section

$p\bar{p}$ Cross Section

CMD3 new results

e+e- -> ppbar Born cross section



Our new 2017 data in comparison with BaBar and CMD-3 2011-2012 scans
(R.R. Akhmetshin et al., (CMD-3 Collaboration), Phys. Lett. B759, 634 (2016).)

BESIII vs BELLE

Not settled yet, since there is some tension between BESIII and Belle in $\sigma(e^+e^- \to \Lambda_c\Lambda_{cbar})$), as pointed out by Ulf Meißner and his collaborators

In particular:

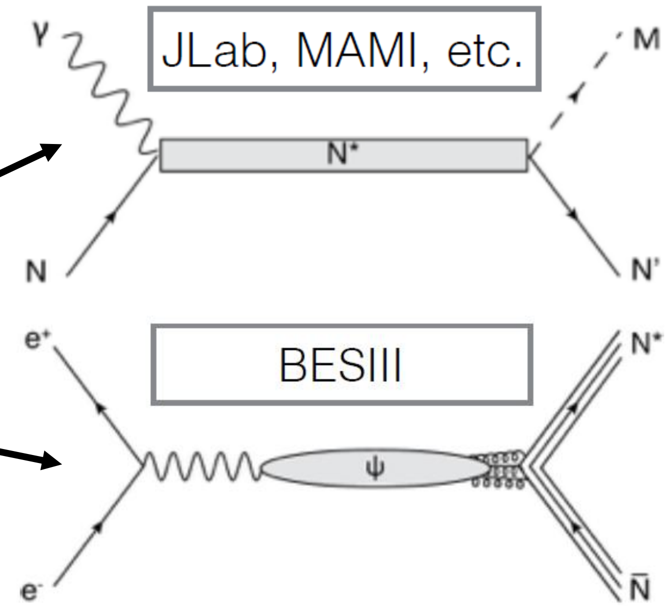
- Belle data show a wide resonance, consistent with the Y(4660), seen by BaBar and Belle in $e^+ e^- \to \psi(3686)\pi^+\pi^-$, hardly compatible with BESIII flat behaviour up to 4.6 GeV
- Belle data are fit by means of a resonance on top of $\Lambda_c\Lambda_{cbar}$ FSI, that predicts again a fast rise at thr, but not a jump.

Ling-Yun Dai, Johann Haidenbauer, Ulf-G. Meißner, PRD 96, 116001 (2017)

- Resonance Y(4660) [called X(4660) in this paper] + FSI @thr:
  M = (4652.5 ± 3.4) MeV Γ = (62.6 ± 5.6) MeV
  σ_{peak} ~ 0.55 nb [comparable to $\sigma(e^+ e^- \to pp_{bar})$ ~ 0.8 nb @ threshold]
- Concerning BESIII measurements they write: "*While they agree with the Belle data, as for as cross sections magnitude, they indicate a different trend in energy.*
  It is impossible to fit both data.
  Hopefully BESIII will extend their measurements at higher energies and thereby clarify the situation."

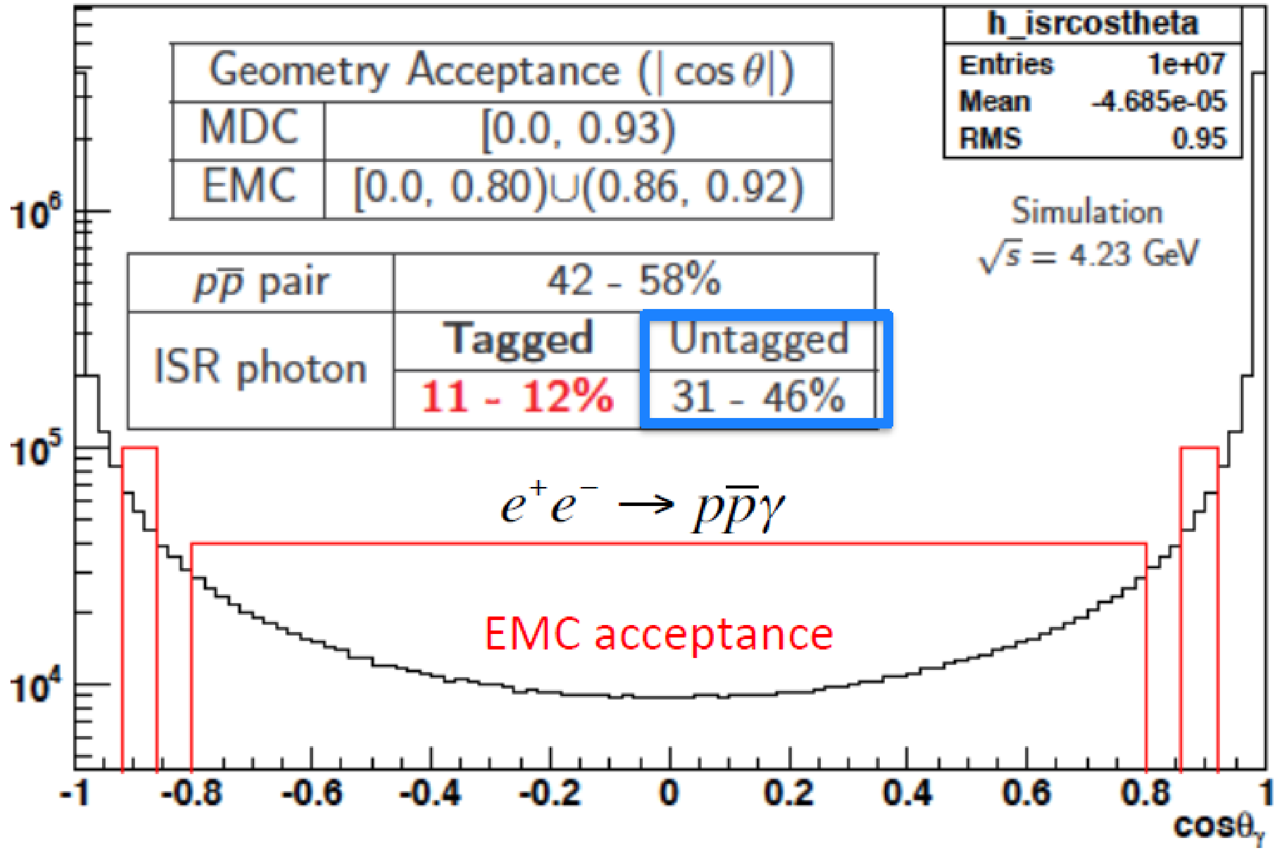
BESIII: Baryon Production

- Charmonium decays offer complementary information to existing data
  - Coupling of unobserved states through conventional production channels could be small, but coupling may be large to gggN:
    $\psi \longrightarrow N\bar{N}\,(\pi/\eta/\eta'/\omega/\phi)$, $\bar{p}\Sigma\pi$, $\bar{p}\Lambda K$
  - High statistics available at BESIII



$e^+e^- \to p\bar{p}\gamma$

Angular distribution of the ISR photon in the Lab. Frame:

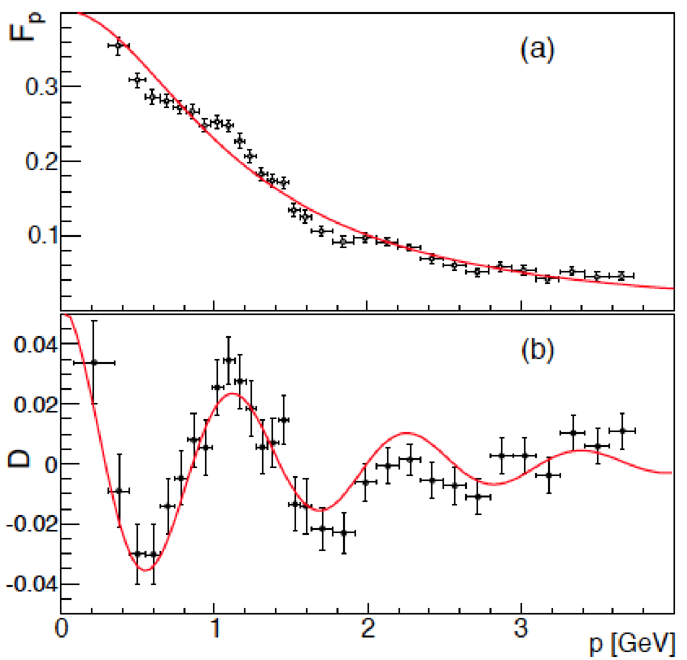


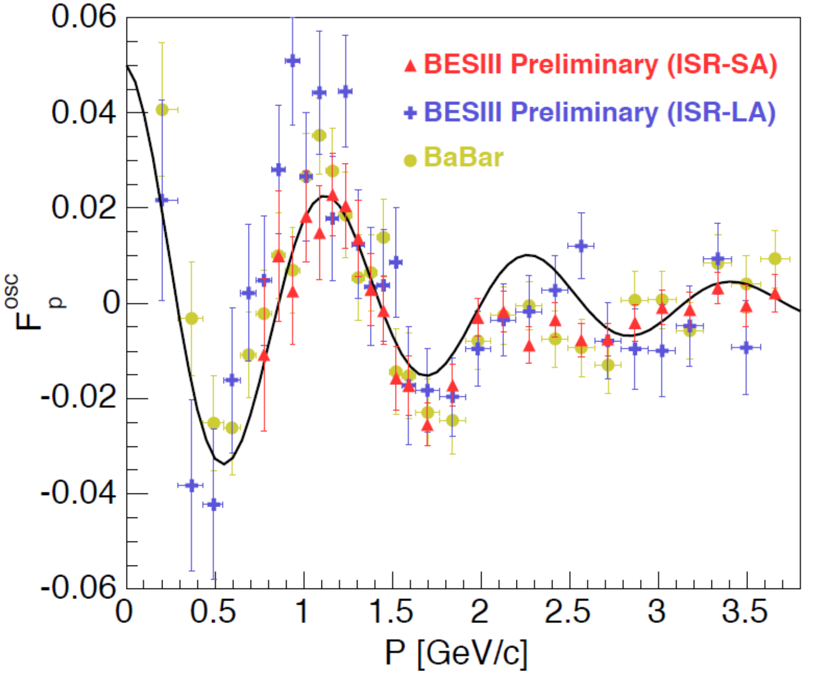
- **ISR analysis**: continuous q^2 range is available from the threshold (study of the q^2 dependence of the cross section and the proton form factors)

- **Untagged ISR analysis**: high cross section of the signal (high statistics)

$e^+e^- \to p\bar{p}\gamma$: Effective FF Structure

- Effective Form Factor as a function of the 3-momentum (P) of the relative motion of the two protons
- The oscillations can be extracted from the effective form factor as $F^{osc} = |G_{eff}| - F^0$ (F^0 describes the regular behavior of the form factor over the long range of the ppbar invariant mass)



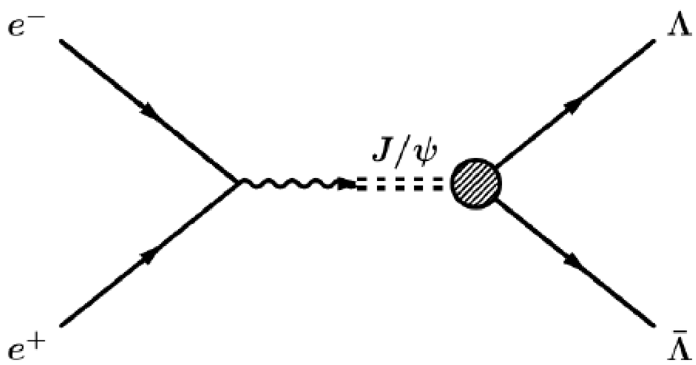


PRL 114, 232301 (2015); Phys. Rev. C 93, 035201 (2016)

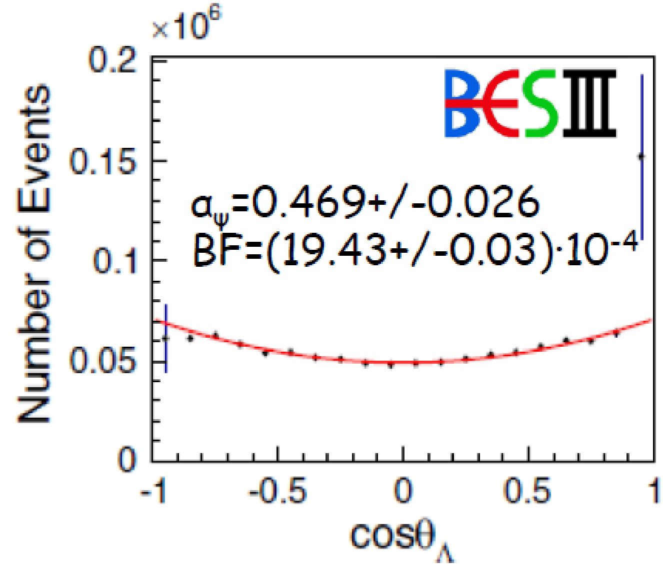
Oscillations seen in eff. FF by Babar reproduced by both ISR tagged and untagged method

Observation of Spin Polarization in $J/\psi \to \Lambda\bar{\Lambda}$

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



arXiv:1808.08917 (2018)



BESIII,PRD 95, 052003 (2017)

Process described by two Form Factors (two complex numbers) i.e. three real parameters:

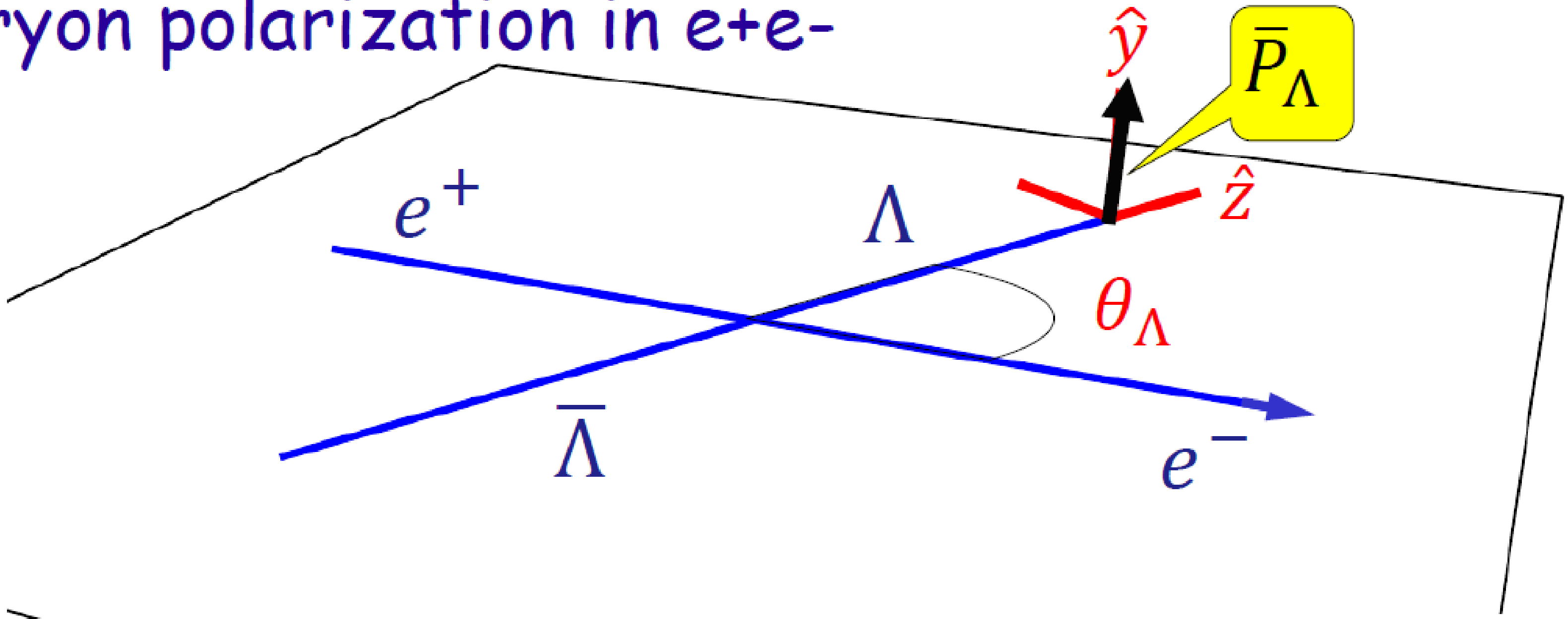
$$\frac{d\Gamma}{d\Omega} \propto 1 + \alpha_\psi \cos^2\theta$$

BF, α_ψ and phase $\Delta\Phi$ (G_E/G_M) → Measured for the first time!

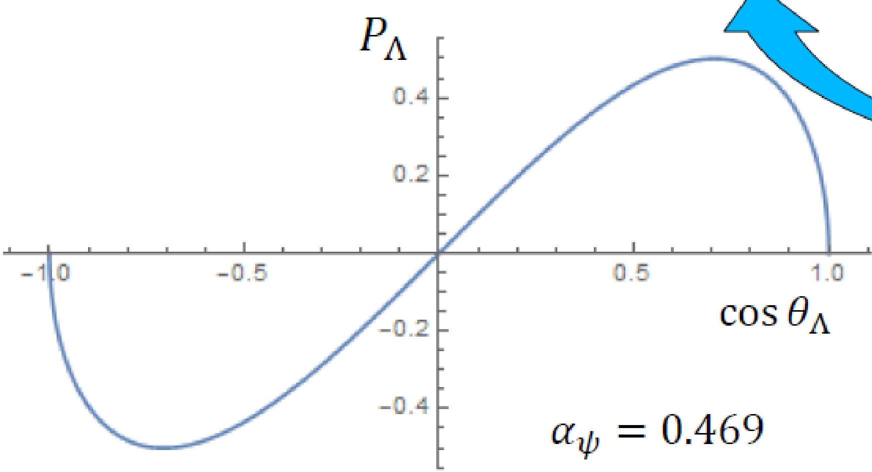
Dubnickova, Dubnicka, Rekalo Nuovo Cim. A109 (1996) 241
Gakh, Tomasi-Gustafsson NPA771 (2006) 169
Czyz, Grzelinska, Kuhn PRD75 (2007) 074026
Fäldt EPJ A51 (2015) 74; EPJ A52 (2016)141
Fäldt, Kupsc PLB772 (2017) 16

Similar studies from Italian members on $J/\psi \to \Sigma^+\bar{\Sigma}^-$ ("$\Sigma^+\Sigma$bar$^-$")

Baryon polarization in e+e-



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



$\alpha_\psi = 0.469$

$\Delta\Phi = \frac{\pi}{2}$

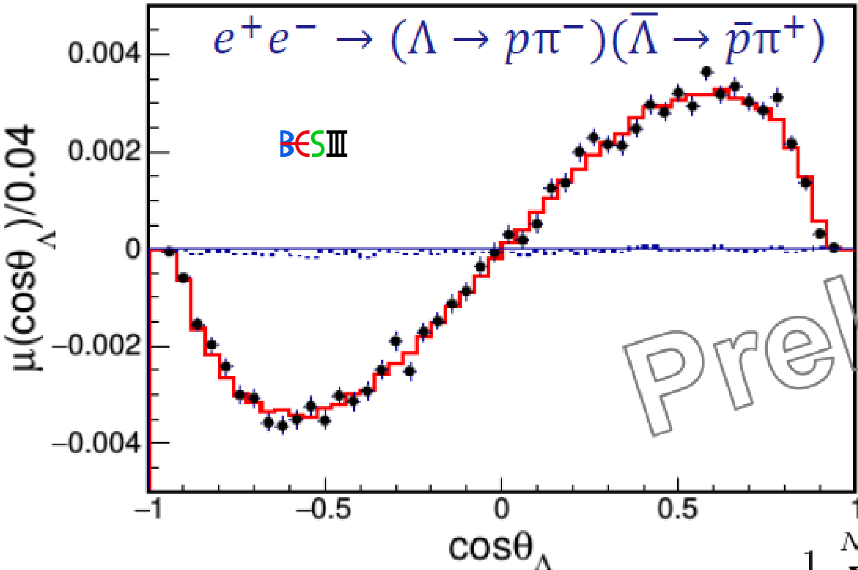
$\Delta\Phi \neq 0$

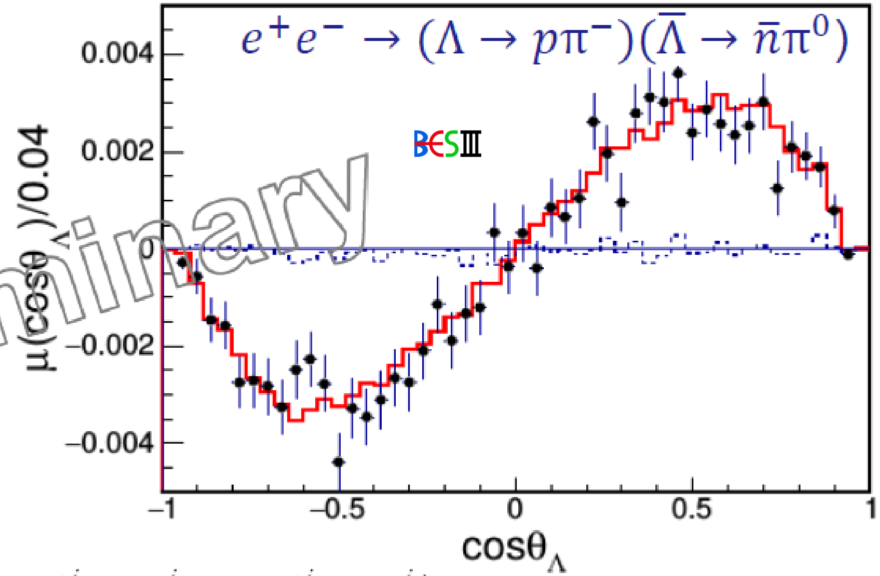
arXiv:1808.08917 (2018)

Fit results

arXiv:1808.08917 (2018)

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





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

Parameters	This work	Previous results	
α_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
$\bar{\alpha}_0/\alpha_+$	$\mathbf{0.913 \pm 0.028 \pm 0.012}$	–	

CP asymmetry:

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

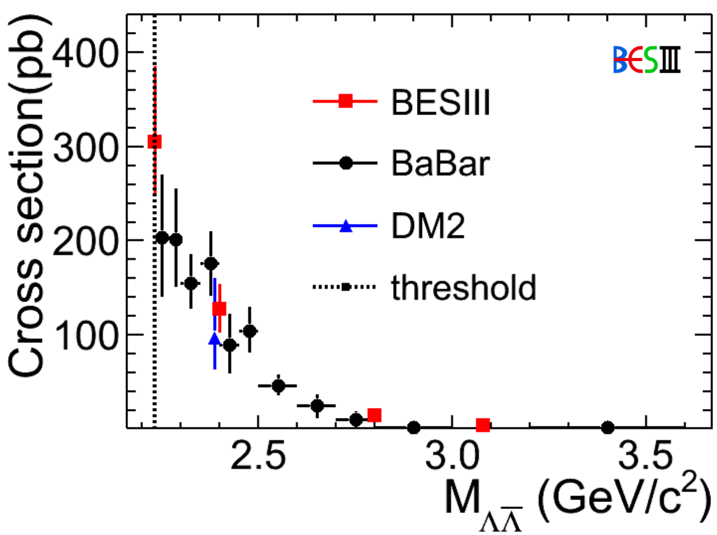
Observation of an enhanced production of $\Lambda\bar{\Lambda}$ pairs near threshold

PRD 97, 032013 (2018)

Mode 1: $\Lambda \to p\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$ Mode 2: $\Lambda \to X$, $\bar{\Lambda} \to \bar{n}\pi^0$

Mode c: combined mode

$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}$ (pb^{-1})	$N_{\rm obs}$	$\epsilon(1+\delta)$ (%)	σ^B (pb)	$\lvert G\rvert$ ($\times 10^{-2}$)
2.2324_1	2.63	43 ± 7	12.9	$312 \pm 51^{+72}_{-45}$	
2.2324_2	2.63	22 ± 6	8.25	$288 \pm 96^{+64}_{-36}$	
2.2324_c				$305 \pm 45^{+66}_{-36}$	$61.9 \pm 4.6^{+18.1}_{-9.0}$
2.400	3.42	45 ± 7	25.3	$128 \pm 19 \pm 18$	$12.7 \pm 0.9 \pm 0.9$
2.800	3.75	8 ± 3	36.1	$14.8 \pm 5.2 \pm 1.9$	$4.10 \pm 0.72 \pm 0.26$
3.080	30.73	13 ± 4	24.5	$4.2 \pm 1.2 \pm 0.5$	$2.29 \pm 0.33 \pm 0.14$



Large cross section near threshold

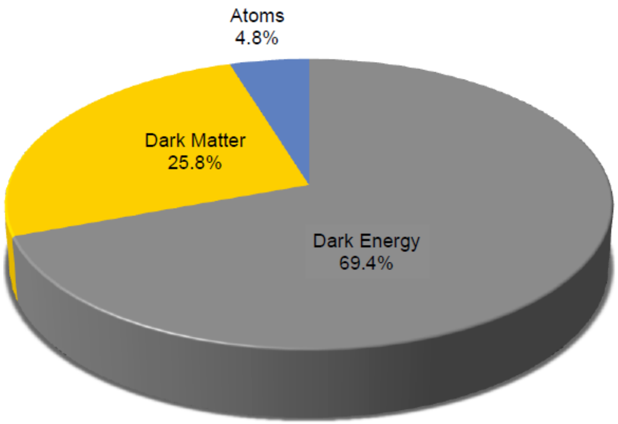
D. Bisello et al., Z. Phys. C 48, 23 (1990)

B. Aubert et al., Phys. Rev. D 76, 092006 (2007)

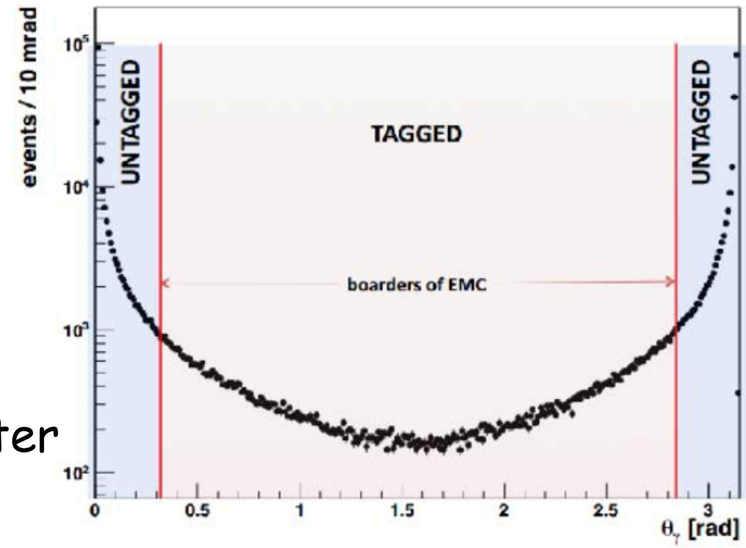
Dark Photon search in $e^+e^- \to \gamma e^+e^-$ and $\gamma\mu^+\mu^-$

PLB 774, 252 (2017)

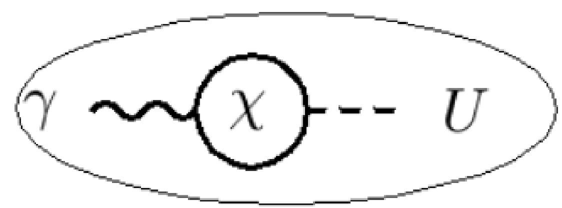
Composition of universe



BESIII spectrometer

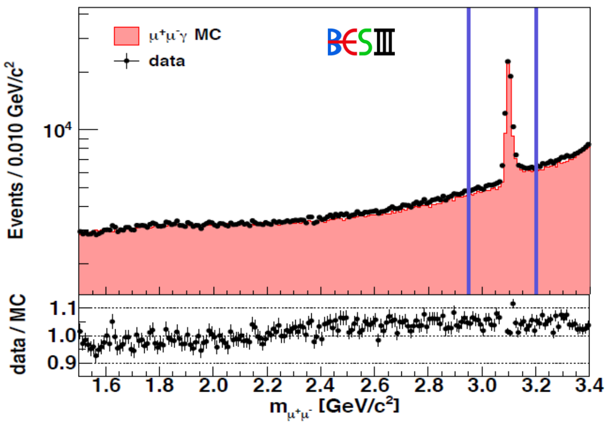


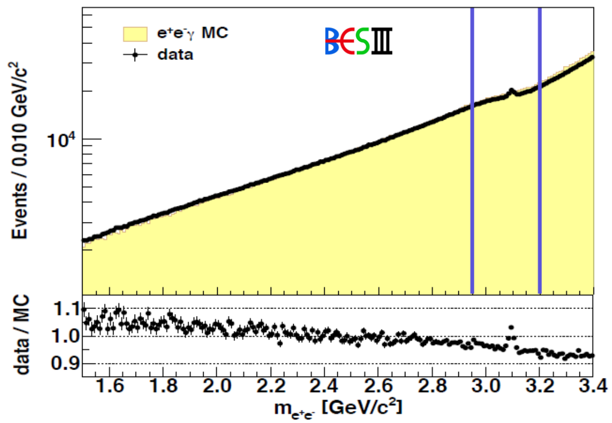
Portal	Particles	Operator(s)
"Vector"	Dark photons	$-\frac{\epsilon}{2\cos\theta_W} B_{\mu\nu} F'^{\mu\nu}$
"Axion"	Pseudoscalars	$\frac{a}{f_a} F_{\mu\nu}\widetilde{F}^{\mu\nu},\ \frac{a}{f_a} G_{i\mu\nu}\widetilde{G}_i^{\mu\nu},\ \frac{\partial_\mu a}{f_a}\overline{\psi}\gamma^\mu\gamma^5\psi$
"Higgs"	Dark scalars	$(\mu S + \lambda S^2) H^\dagger H$
"Neutrino"	Sterile neutrinos	$y_N L H N$



Dark Photon search in $e^+e^- \to \gamma e^+e^-$ and $\gamma\mu^+\mu^-$

PLB 774, 252 (2017)



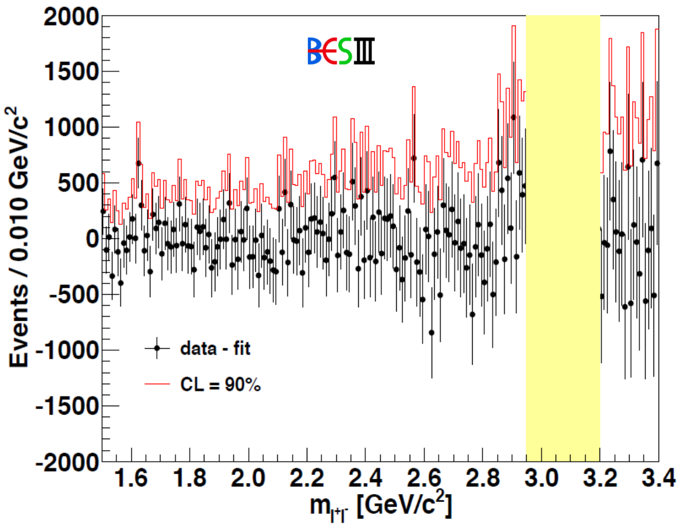


$2.9 fb^{-1}$ at $\psi(3770)$

Mass region: 1.5 – 3.4 GeV/c^2

- < 1.5 GeV/c^2: $\pi^+\pi^-$ background dominates
- > 3.4 GeV/c^2: hadronic q-qbar process

Background: MC shape with Phokara



ISR technique

Fit QED background with 4 order polynomial

Difference γe^+e^- and $\gamma\mu^+\mu^-$ yelds

No peaking structure observed -> no dark photon signature

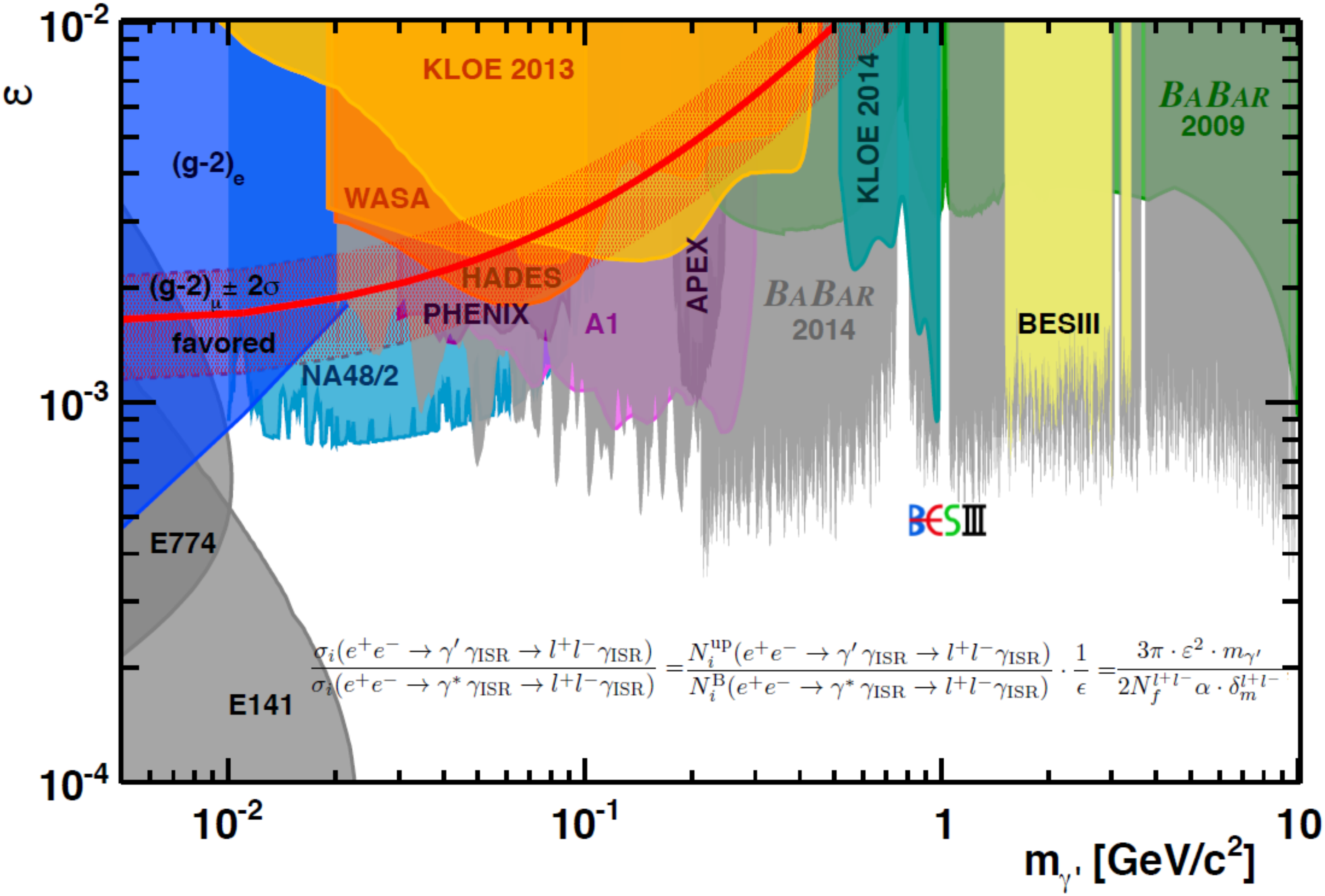
Combined statistics

90% confidence level

J/ψ region removed

Dark Photon search in $e^+e^- \to \gamma e^+e^-$ and $\gamma\mu^+\mu^-$

PLB 774, 252 (2017)



BESIII exclusion limit for mixing parameter:

$\varepsilon = 10^{-3} - 10^{-4}$

Dark photon possible cause of $(g-2)_\mu$

Muon Magnetic Moment

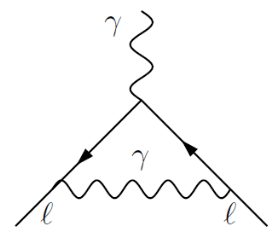
Lepton magnetic moment: $\bar{\mu} = g \frac{Qe}{2m} \bar{s}$

Dirac theory prediction: $g = 2(1 + a)$

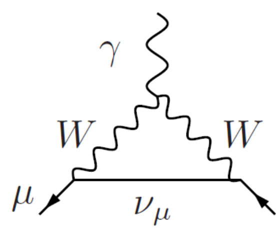
$$a_\mu = \frac{g_\mu - 2}{2}$$

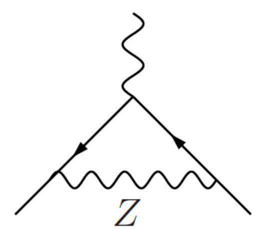
Muon anomaly arises from quantum fluctuations

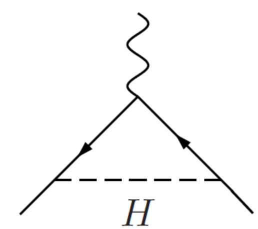
QED contribution (largest):



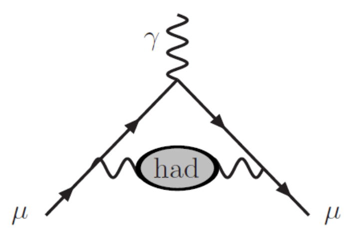
Weak contribution:

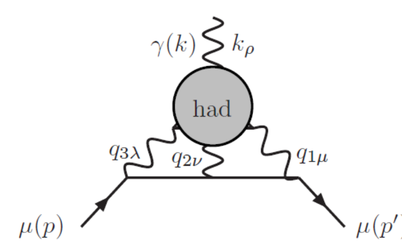






Hadronic contribution:





Muon Magnetic Moment

$$a_\mu = \frac{g_\mu - 2}{2} = \frac{\alpha}{2\pi} + \cdots = 0.001161$$

$$a_\mu^{theo} = a_\mu^{QED} + a_\mu^{weak} + a_\mu^{hadr}$$

Contribution	Results in 10^{-10} units		
QED (leptons)	11658471.885	± 0.004	Kinoshita et al. (2012)
Weak	15.4	± 0.2	Czamecki et al. (2003)
HVP (LO)	692.3	± 4.2	Davier et al. (2001)
HVP (HO)	-9.84	± 0.07	Hagiwara et al. (2009)
HLBL	11.6	± 4.0	Jegerlehner, Nyffler (2009)
Total	11659181.3	± 5.8	
Experiment	11659208.9	± 6.3	

Discrepancy: 27.6 ± 8.5

Prediction limited by hadronic contributions

Perturbative method cannot be applied in the relevant energy regime

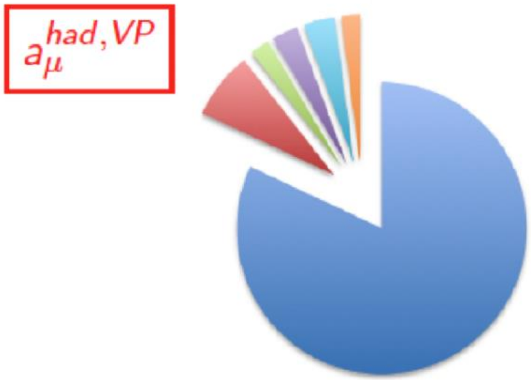
PRL 92, 161802 (2004)
Nuclear Physics B (Proc. Suppl.) 144 (2005) 191-200

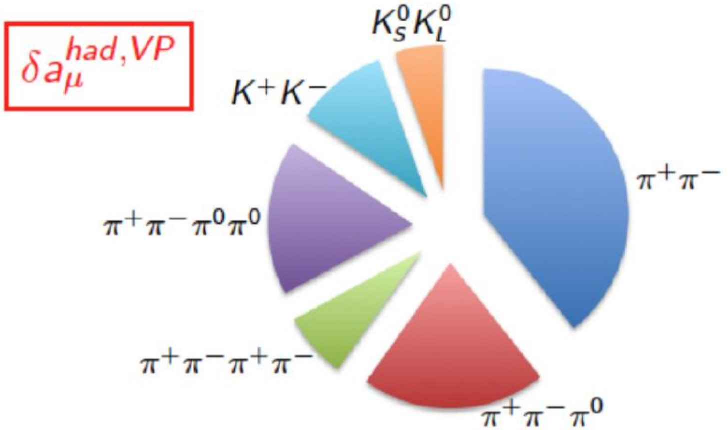
Muon Magnetic Moment

Hadronic Contributions

Vacuum Polarization

M. Ripka, *Initial State Radiation Measurement at BESIII*, PhiToPsi2017 proceedings, in press





KLOE[1] and BABAR[2] measurement discrepancy 3-5%

Another high precision measurement needed -> BESIII

Wider mass range than KLOE

Closer to $\sqrt{s} \lesssim 2$ GeV than BABAR -> lower suppression of ISR events

Untagged ISR mode can be used above $\sqrt{s} \gtrsim 1$ GeV
-> no problem for ≥ 4π

[1] B. Aubert et al., Phys. Rev. Lett. 103, 231801 (2009). J.P. Lees et al., Phys. Rev. D86, 032013 (2012)

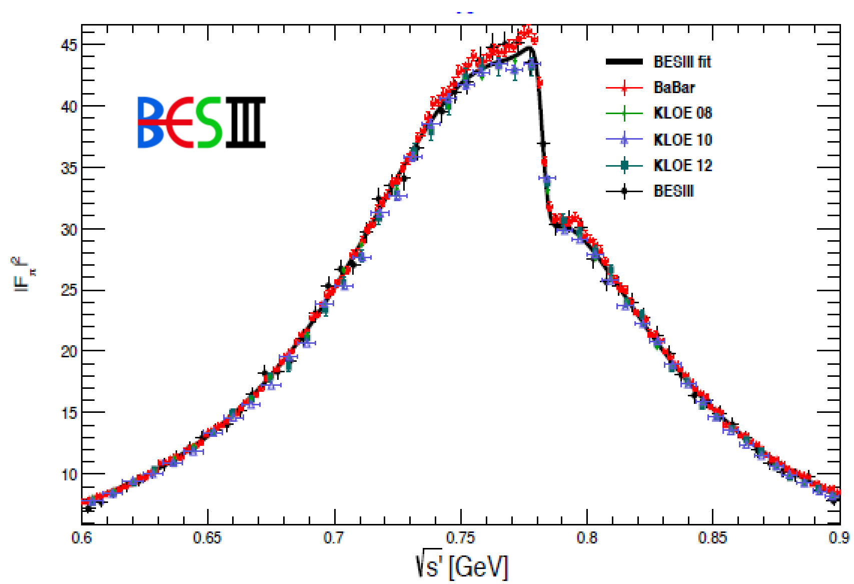
[2] F. Ambrosino et al. Phys. Lett. B 670, 285 (2009). F. Ambrosino et al. Phys. Lett. B 700, 102-110 (2011). D. Babusci et al. Phys. Lett. B 720, 336-343 (2013).

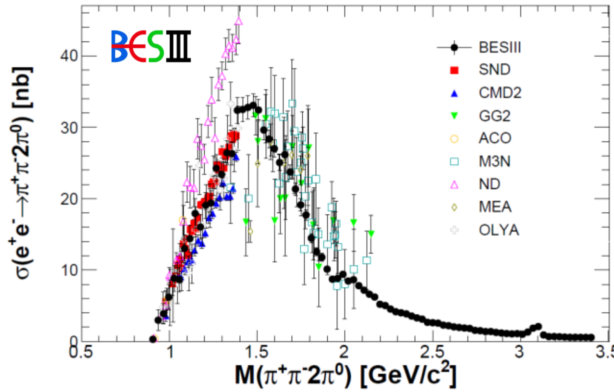
Comparison of $\pi^+\pi^-$ and $\pi^+\pi^-2\pi^0$ Form Factors

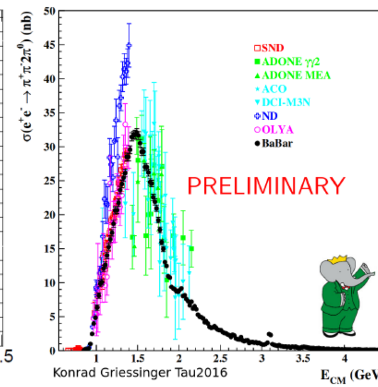
PLB 753, 629 (2016)

PRELIMINARY

Pion Form Factor F_π







- Error: weighted mean of tagged and untagged events
- ≈ 3% precision like BABAR

	$a_\mu^{\pi^+\pi^-2\pi^0[0.92-1.8\,GeV],LO}/10^{-10}$
BESIII (preliminary)	18.63 ± 0.27 ± 0.57
BABAR (preliminary)	17.9 ± 0.1 ± 0.6

- New BESIII measurement agrees with KLOE[1] and BABAR[2]
- Small shift wrt BABAR above ρ-ω interference

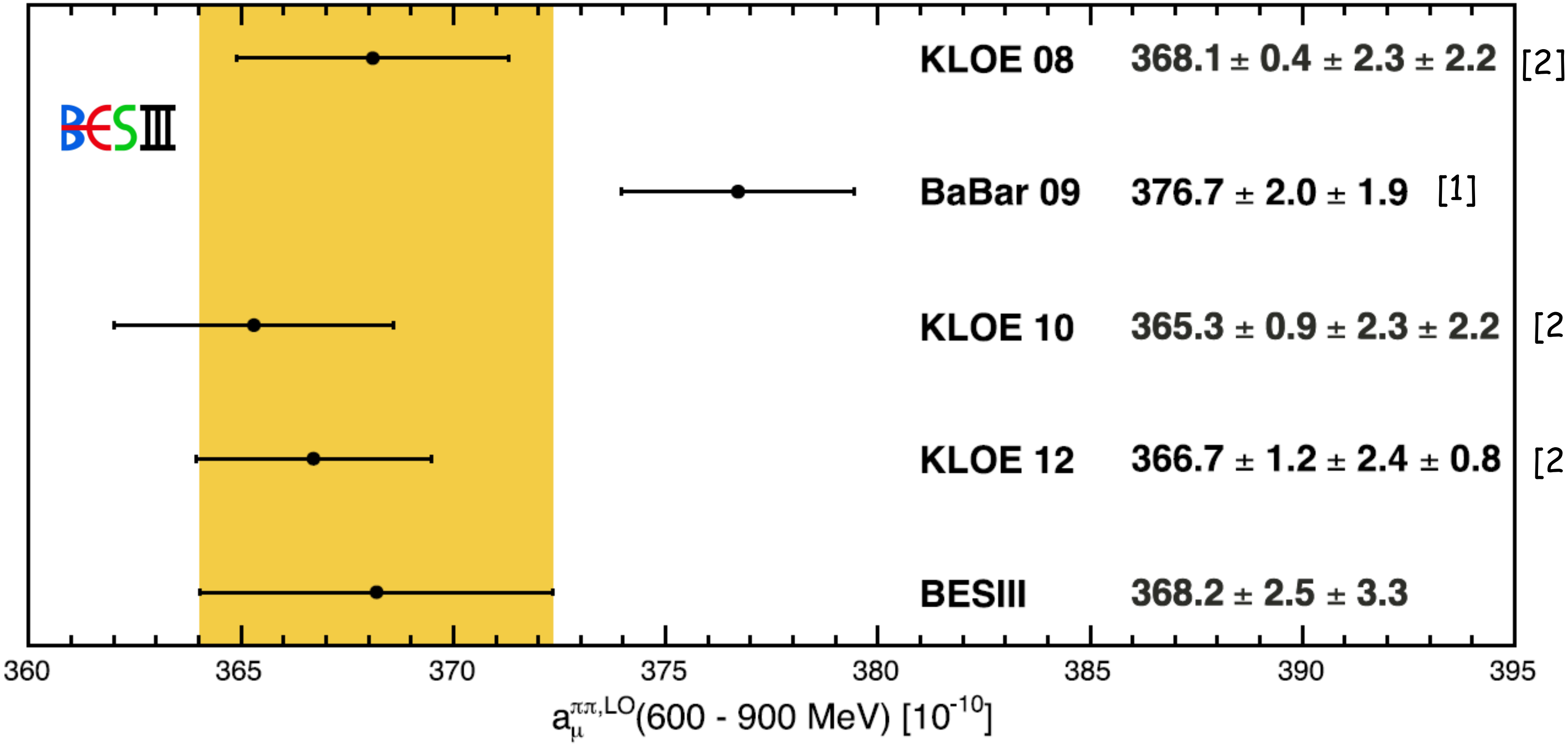
[1] B. Aubert et al., Phys. Rev. Lett. 103, 231801 (2009).
J.P. Lees et al., Phys. Rev. D86, 032013 (2012)

[2] F. Ambrosino et al. Phys. Lett. B 670, 285 (2009).
F. Ambrosino et al. Phys. Lett. B 700, 102-110 (2011).
D. Babusci et al. Phys. Lett. B 720, 336-343 (2013).

[1] R. R. Akhmetshin et al., Phys. Lett. B 466, 392 (1999).
[2] S. I. Dolinsky et al., Phys. Rept. 202, 99 (1991).
[3] C. Bacci et al., Nucl. Phys. B 184, 31 (1981).
[4] L. M. Kurdadze et al., J. Exp. Theor. Phys. Lett. 43 643 (1986).
[5] M. N. Achasov et al., Preprint BUDKER-INP-2001-34 (Novosibirsk, 2001).
[6] G. Cosme et al., Phys. Lett. B 63, 349 (1976).
[7] G. Cosme et al., Nucl. Phys. B 152 215 (1979).
[8] B. Esposito et al., Lett. Nuovo Cim. 31, 445 (1981).

Contribution of $\pi^+\pi^-$ to $a_\mu^{VP,LO}$

PLB 753, 629 (2016)



- Precision compatible with previous measurements
- $a_\mu^{\pi\pi,LO}(600 - 900\ \mathrm{MeV}) = (368.2 \pm 2.5_{stat} \pm 3.3_{syst}) \cdot 10^{-10}$
- Confirmation of deviation of > 3σ between experiment and theory

[1] B. Aubert et al., Phys. Rev. Lett. 103, 231801 (2009). J.P. Lees et al., Phys. Rev. D86, 032013 (2012)

[2] F. Ambrosino et al. Phys. Lett. B 670, 285 (2009). F. Ambrosino et al. Phys. Lett. B 700, 102-110 (2011). D. Babusci et al. Phys. Lett. B 720, 336-343 (2013).

BEPCII Upgrades

- Possible improvement in MAX beam energy 2.3 GeV → 2.45 GeV
  - CMS energy upper limit 4.9 GeV
  - In 2018 from 4.6 GeV to 4.7 GeV
  - In 2020 from 4.7 GeV to 4.9 GeV

- New physics topics from higher energies
  - ✓ Exotics Y(4660), Y(4630), $Z_c^+(4430)$, $Z_c^+(4250)$, X…
  - ✓ $D_s^* D_{s2}^*$ threshold @ 4.68 GeV
  - ✓ $\Lambda_c \Sigma_c$ threshold @ 4.74 GeV
  - ✓ We will be a bit below $\Sigma_c \Sigma_c$ threshold (4.91 GeV)

- Improvement in integrated luminosity of 20-30%
  - In 2020? A bit more data

Summary

- Huge statistics

  J/ψ, $\psi(2S)$, $\psi(3770)$

  XYZ studies

  R scans

  Hadron form factors

- Near future

  Collect data at higher energies to complete scans

  Higher luminosity expected from BEPCII

  Analyse the full data sample

  Many PWA to be completed

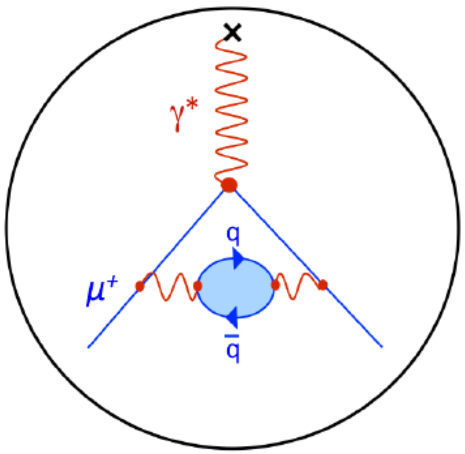
- Stay tuned for new results!!

Backup Slides

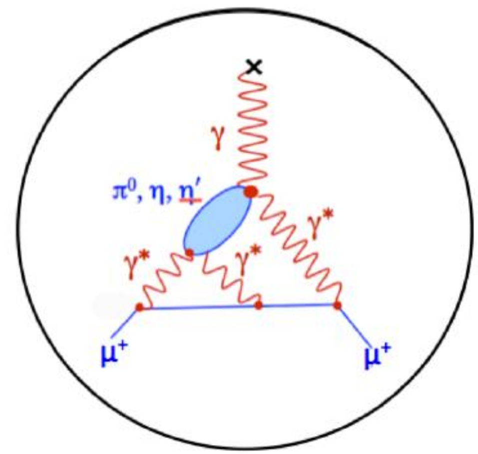
Muon Magnetic Moment

Hadronic Contributions

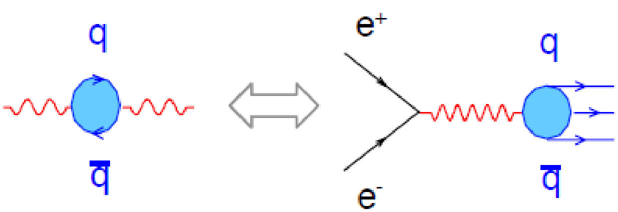
Hadronic Vacuum Polarization



Hadronic Light-by-Light



Optical theorem



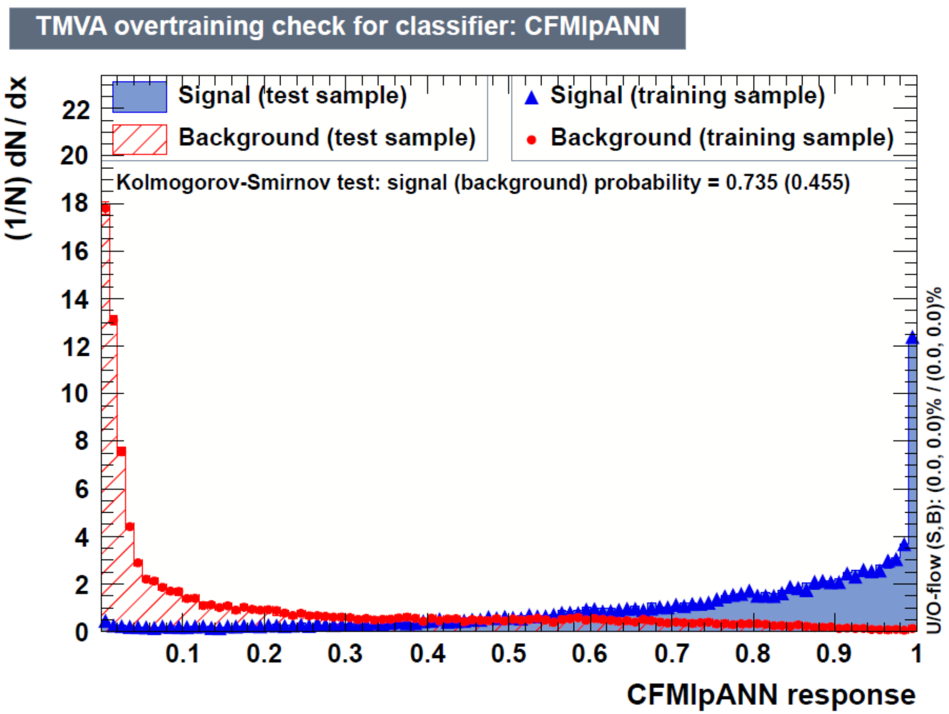
Two-photons collisions

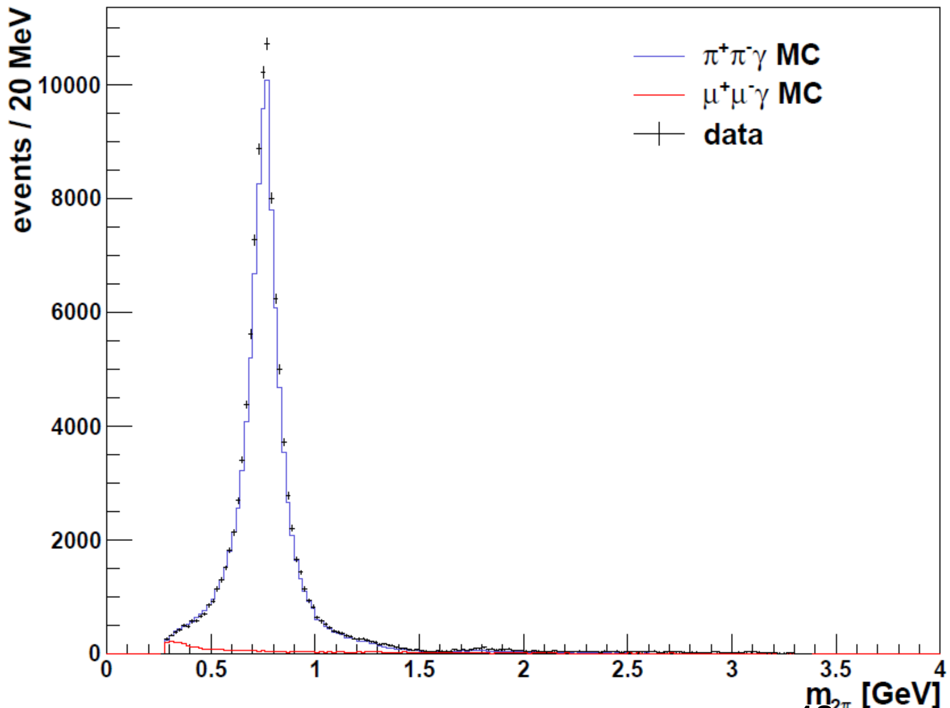
Dispersion integral: $a_{\mu,LO}^{HVP} = \frac{1}{4\pi^3}\int_{m_{\pi^0}}^{\infty} ds\, K(s)\, \sigma_{had}(s)$

$e^+e^- \to \gamma\pi^+\pi^-$ Selection

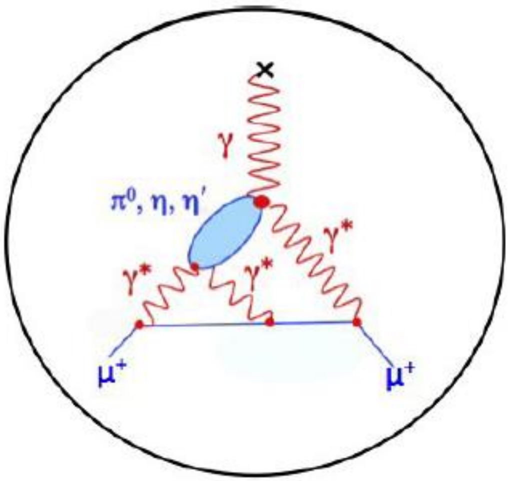
PLB 753, 629 (2016)

- Muons and pions have different shower shape in EMC
- Artificial Neural Network (ANN) for μ-π separation
- Very clean sample after ANN
- ρ-ω interference clearly visible





Hadronic Light-by-Light Contribution



Interaction of virtual mesons with real/virtual photons

a_μ^{hLBL} not directly related to measurable quantities

- Hadronic models
    - ChPT at lowest energies
    - pQCD at high energies
    - Intermediate region?

Glasgow Consensus, arXiv:0901.0306
Jegerlehner/Nyffeler, Phys. Rept. 477,1

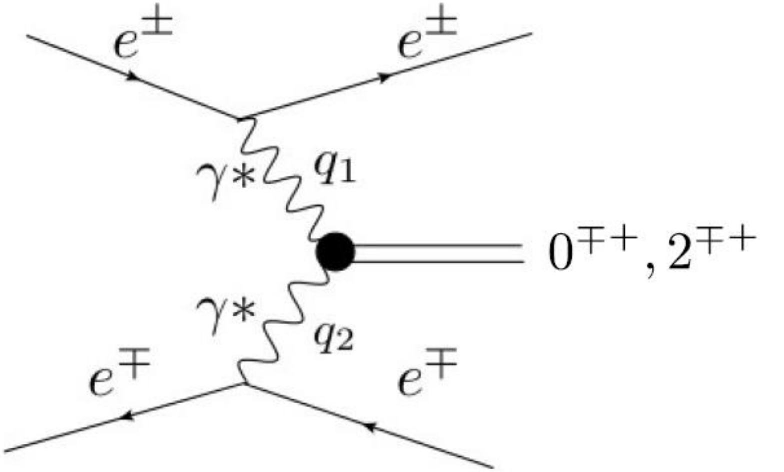
- Data driven approaches
    - Based on dispersion relations
    - Reduce model dependency
    - Reliable error estimates

Colangelo, Hoferichter et al. (Bern)
Vanderhaeghen, Pauk et al. (Mainz)

- Transition FF as experimental input

Two-Photon Collisions

- Exchange of 2 photons in e^+e^- collisions
- Pseudoscalar, axial, and tensor states accessible
- $M_x \ll \sqrt{s}$
- $\sigma \propto \alpha^2 \ln^2 E$
- $\sigma \propto F^2(Q_1^2, Q_2^2)$, with $Q_1^2 = -q_i^2$
- Forward peaked kinematic
    - Experimentally challenging
    - Special tagging detectors



Contributions to a_μ

- Current accuracy of a_μ: ~ $6.3 \cdot 10^{-10}$
- Contribution of π^0: ~ $7 \cdot 10^{-10}$

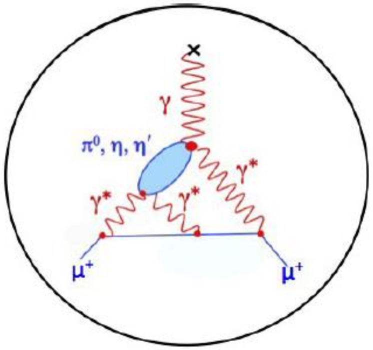
Knecht, Nyffeler
Phys. Rev. D65, 073034 (2002)

- Expected accuracy of new experiments at FNAL and J-PARC: ~ $1.6 \cdot 10^{-10}$
- Contribution of η and η' relevant!

$\eta \sim 1.5 \cdot 10^{-10}$

$\eta' \sim 1.5 \cdot 10^{-10}$

Knecht, Nyffeler
Phys. Rev. D65, 073034 (2002)



Two-photons physics program exstabilished at BESIII

Untagged, single-tagged, and double-tagged measurements are ongoing