Status of the BESIII Experiment

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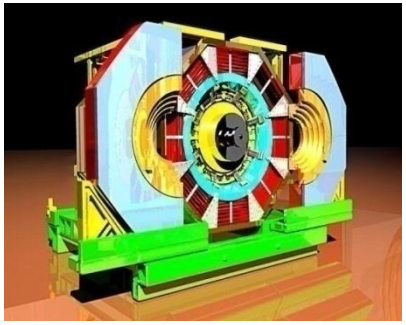
on behalf of the BESIII Collaboration



IFAE2018 – XVII Edizione

Milano, Italia

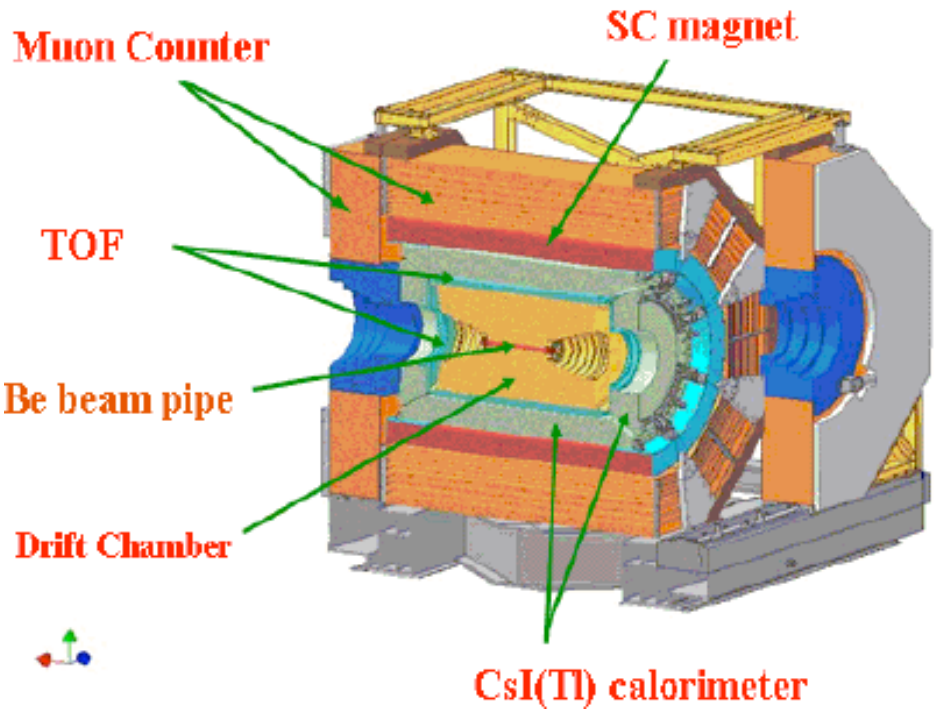
April 04-06, 2018

The BESIII Spectrometer @ IHEP

BEijing Spectrometer III

e^+e^- collisions

$\sqrt{S}$ tuned depending on energy



Physics program

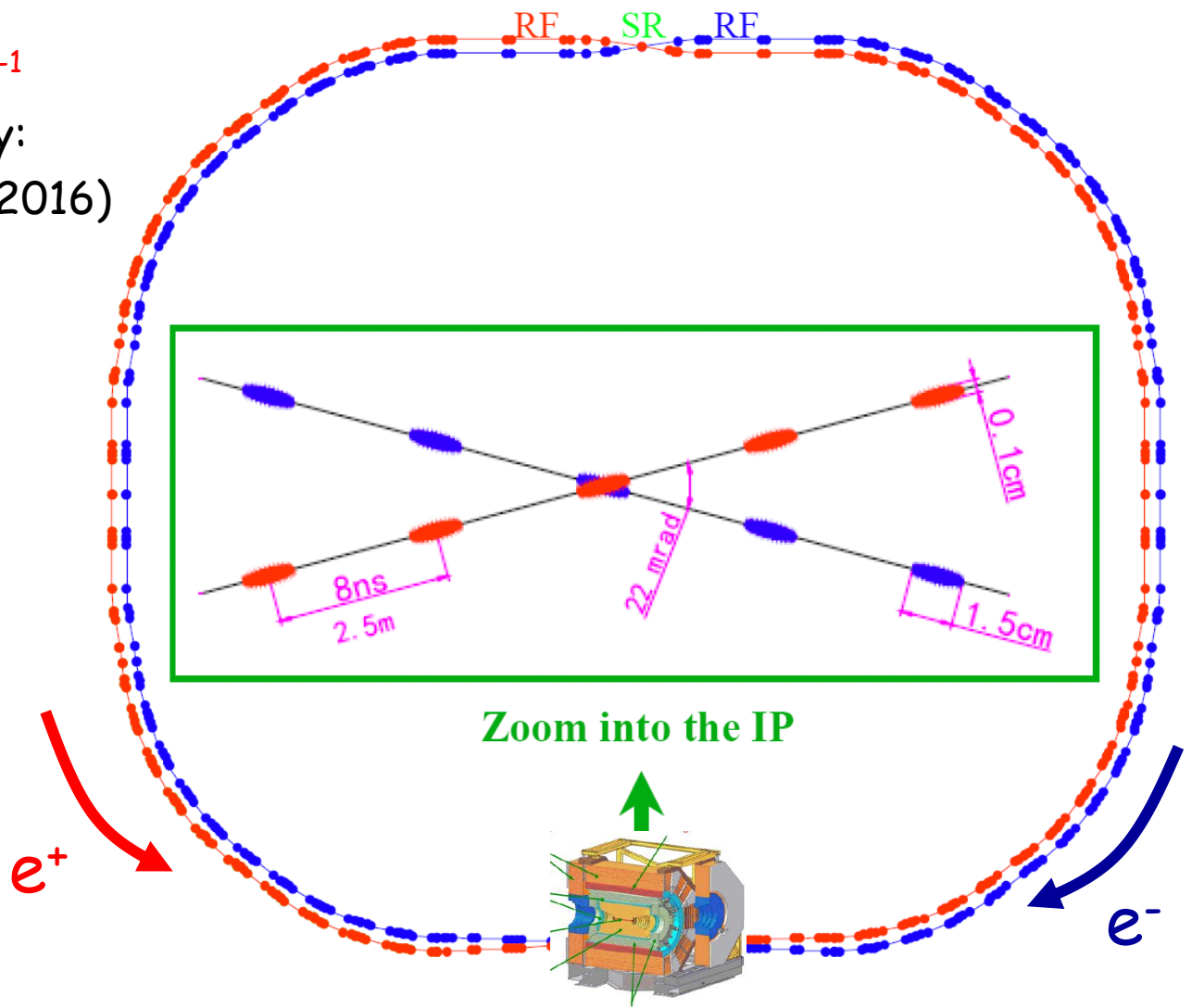
- Charmonium Physics
- D-Physics
- Light Hadron Spectroscopy
- τ-Physics
- ...

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

BEPCII Storage Rings

Beijing Electron-Positron Collider II

- 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

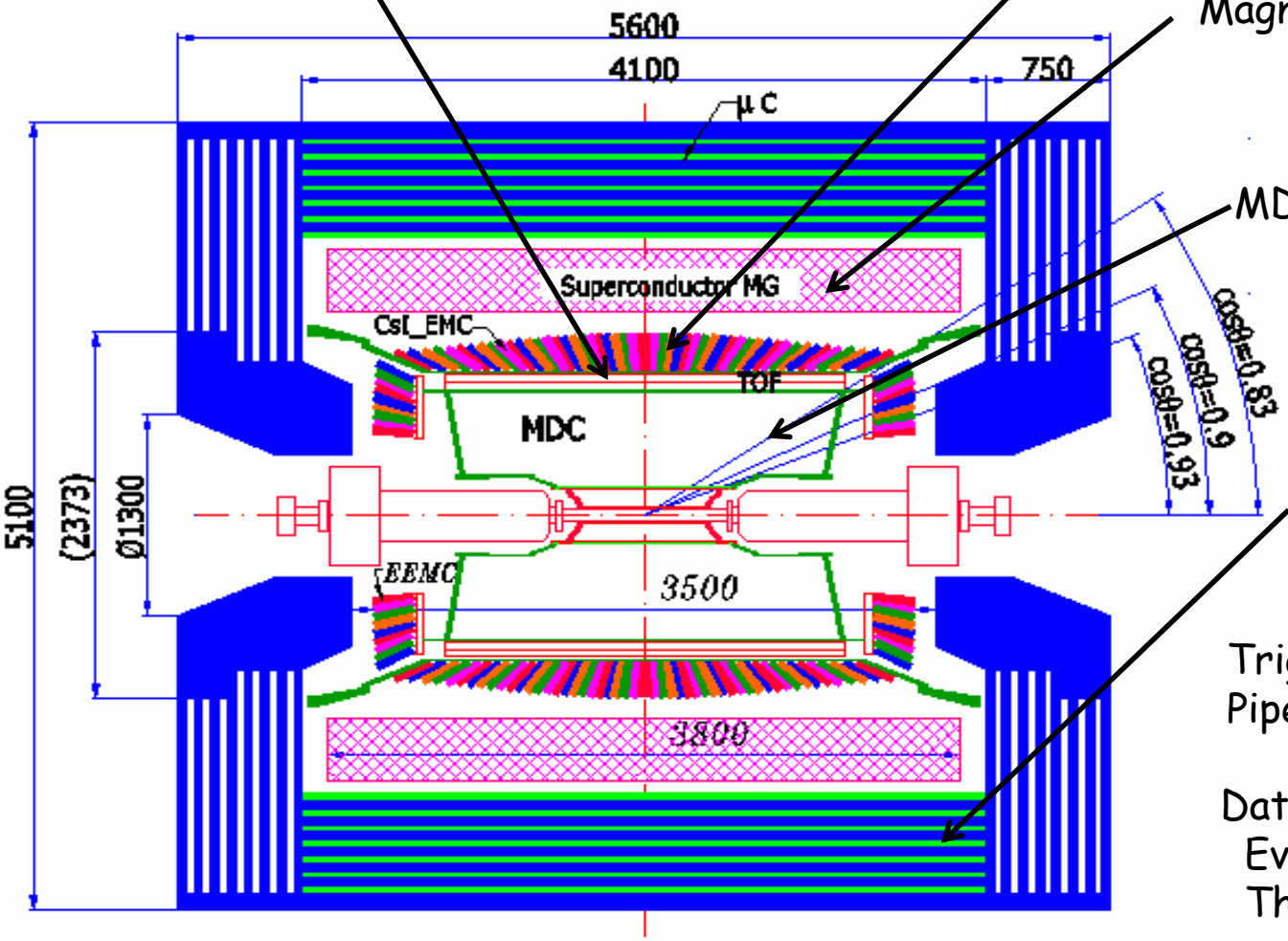


BESIII Detector

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%

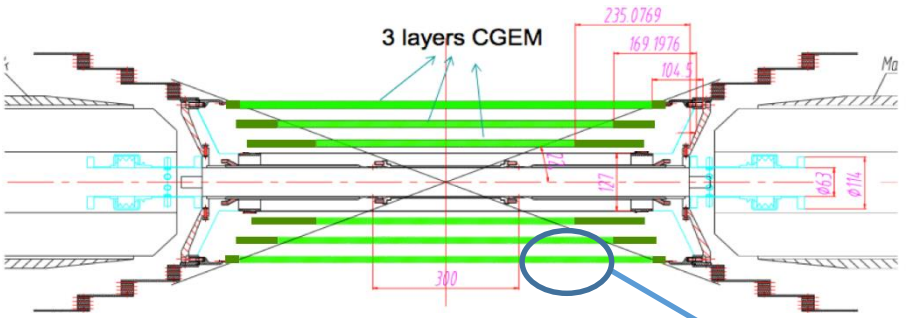
Muon: 9 layer RPC

Trigger: Tracks & Showers
Pipelined; Latency = 2.4 ms

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

Cylindrical GEM Inner Tracker

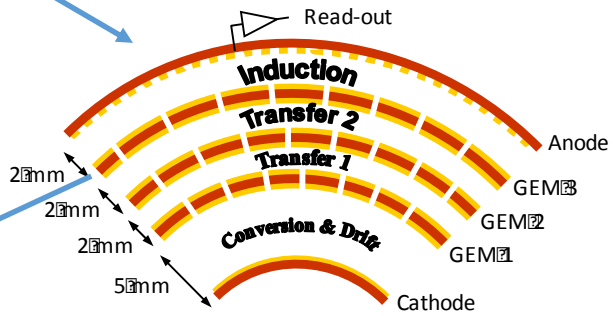
The idea is to build a new Inner Tracker based on three layers of cylindrical GEM using the same construction technique developed for the KLOE-2 CGEM detector.

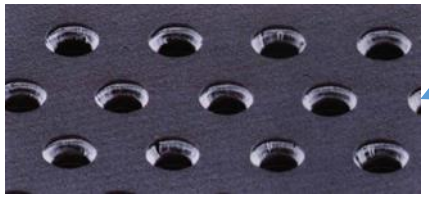


- Low Material budget ≤ 1.5% of X_0 for all layers
- Momentum resolution:: σ_{pt}/P_t =~0.5% @1 GeV
- High Rate capability: ~10^4 Hz/cm^2
- Coverage: 93%
- Spatial resolution $\sigma_{r\phi}$ 130-150 μm, σ_z <1 mm
- 1 T magnetic filed
- Operation duration at least 5 years

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

each layer composed by a cylindrical triple GEM





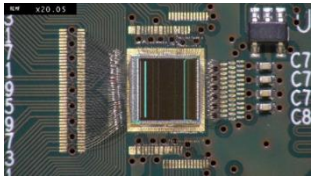
Also funded by the RISE BESIIICGEM European Project

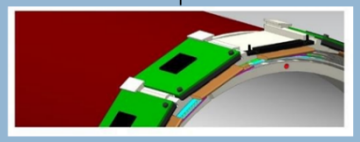
Peculiarities of the BESIII CGEM

	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

More detail on planar GEM performances: «Studio delle prestazioni di camere GEM planari condizioni di fascio ad alta intensità» - I. Balossino

CGEM Electronics: General Overview





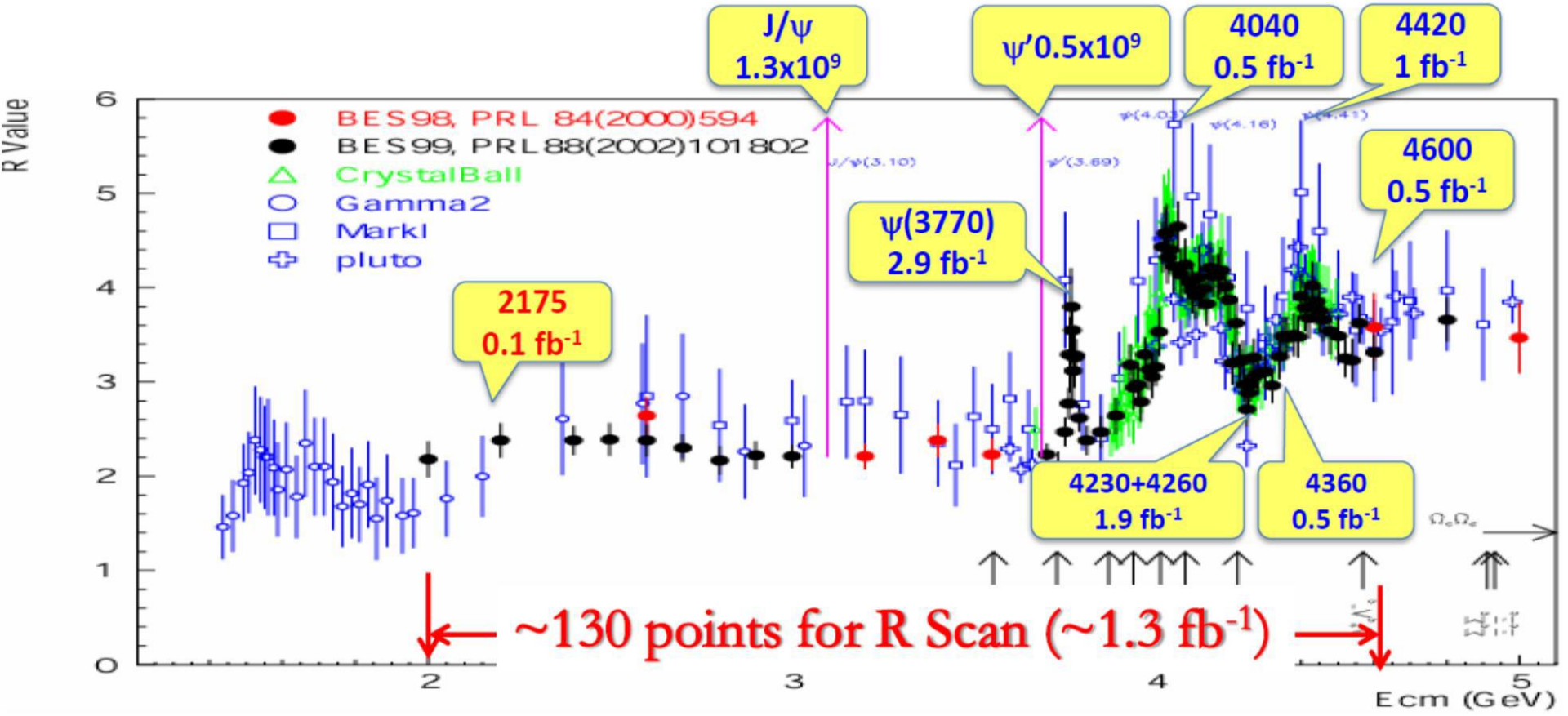
Analog readout

reduce strip pitch

10000 channels

More detail: «Elettronica di lettura TIGER per il nuovo tracciatore interno a GEM cilindriche dell'esperimento BESIII» - A. Bortone

BESIII Datasets



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

Published and Submitted Results since May 2017

1)Measurement of e^+e^- --> D Dbar Cross Sections at the psi(3770) Resonance [arXiv:1803.06293]
2)Measurement of Singly Cabibbo-Suppressed Decays D^0 -> $\pi^0\pi^0\pi^0$, $\pi^0\pi^0\eta$, $\pi^0\eta\eta$ and $\eta\eta\eta$ [arXiv:1803.05769]
3)Study of the decays D^+ -> $\eta^{(\prime)}e^+\nu_e$ [arXiv:1803.05570]
4)Measurement of absolute branching fraction of the inclusive decay Λ_c^+ -> Λ + X [arXiv:1803.05706]
5)Measurements of Absolute Branching Fractions for Λ_c^+ -> Ξ^0K^+ and $\Xi(1530)^0K^+$ [arXiv:1803.04299]
6)Measurement of the Integrated Luminosities of Cross-section Scan Data Samples Around the ψ(3770) Mass Region [arXiv:1803.03802]
7)Observation of the Semileptonic Decay D^0 -> $a_0(980)^-e^+\nu_e$ and evidence for D^+ -> $a_0(980)^0e^+\nu_e$ [arXiv:1803.02166]
8)Observation of ψ(3686) -> nnbar and improved measurement of ψ(3686) -> ppbar [arXiv:1803.02039]
9)Study of two-photon decays of pseudoscalar mesons via J/ψ radiative decays [arXiv:1802.09854]
10)Search for the rare decays D -> h(h')e^+e^- [arXiv:1802.09752]
11)Measurement of the branching fraction for the semi-leptonic decay $D^{0(+)}$ -> $\pi^{-(0)}\mu^+\nu_\mu$ and thest of lepton universality [arXiv:1802.05492]
12)Measurements of absolute branching fractions for D mesons decays into two pseudoscalar mesons [arXiv:1802.03119]
13)Observation of e+e- -> KKbarJ/ψ at center-of-mass energies from 4.189 to 4.600 GeV [arXiv:1802.01216]
14)Observation of $a_0^0(980)$-$f_0(980)$ Mixing [arXiv:1802.00583]
15)Search for a strangeonium-like structure Z_s decaying into φπ and a measurement of the cross section e^+e^- -> φππ [arXiv:1801.10384]
16)Measurements of the branching fractions of the singly Cabibbo-suppressed decays $D^0\to\omega\eta$, $\eta^{(\prime)}\pi^0$ and $\eta^{(\prime)}\eta$, PRD 97, 052005 (2018)
17)Search for $h_c\to\pi^+\pi^-J/\psi$ via $\psi(3686)\to\pi^0\pi^+\pi^-J/\psi$, PRD 97, 052008 (2018)
18)Study of η(1475) and X(1835) in radiative J/ψ decays to γϕ, PRD 97, 051101(R) (2018)
19)Observation of $e^+e^-\to\phi\chi_{c1}$ and $\phi\chi_{c2}$ at $\sqrt{s}$=4.600 GeV, PRD 97, 032008 (2018)
20)Precision Study of η' -> $\gamma\pi^+\pi^-$ [arXiv:1712.01525]
21)Measurement of the absolute branching fraction of $D^{*}_s{}^0(2317)^\pm$ -> $\pi^0D^\pm_s$, PRD 97, 051103(R) (2018)
22)Measurement of e^+e^- ->$\pi^0\pi^0\psi(3686)$ at $\sqrt{s}$ from 4.009 to 4.600 GeV and observation of a neutral charmoniumlike structure, PRD 97, 052001 (2018)
23)Improved measurements of χ_{cJ} -> $\Sigma^+\bar{\Sigma}^-$ and $\Sigma^0\bar{\Sigma}^0$ decays [arXiv:1710.07922]
24)Branching fraction measurement of J/ψ -> K_SK_L and search for J/ψ -> K_SK_S, PRD 96, 112001 (2017)
25)Search for the rare decays J/ψ -> $D^0e^+e^-$+c.c. and ψ(3686) -> $D^0e^+e^-$+c.c., PRD 96, 111101(R) (2017)

Published and Submitted Results since May 2017

26)Precision measurement of the e^+e^- -> $\Lambda_c^+\Lambda_c$bar$^-$ cross section near threshold [arXiv:1710.00150]
27)Observation of a cross-section enhancement near mass threshold in e^+e^- -> Λλbar, PRD 97, 032013 (2018)
28)Improved measurements of two-photon widths of the χ_{cJ} states and helicity analysis for χ_{c2} -> γγ, PRD 96, 092007 (2017)
29)Measurement of the matrix elements for the decays η' -> $\eta\pi^+\pi^-$ and η' -> $\eta\pi^0\pi^0$, PRD 97, 012003 (2018)
30)Observation of e^+e^- -> ηY(2175) at center-of-mass energies above 3.7 GeV [arXiv:1709.04323]
31)Measurements of the branching fractions for the semileptonic decays $D^+_s\to\phi e^+\nu_e$, $\phi\mu^+\nu_\mu$, $\eta\mu^+\nu_\mu$ and $\eta'\mu^+\nu_\mu$, PRD 97, 012006 (2018)
32)Determination of the number of ψ(3686) events at BESIII, Chin. Phys. C 42, 023001 (2018)
33)Study of J/ψ and ψ(3686) decays to $\pi^+\pi^-\eta'$, PRD 96, 112012 (2017)
34)Search for the rare decay D^+ -> $D^0e^+\nu_e$, PRD 96, 092002 (2017)
35)Measurement of branching fractions for ψ(3686) -> γη', γη, and $\gamma\pi^0$, PRD 96, 052003 (2017)
36)Observation of χc2 -> η′η′ and χc0,2 -> ηη′, PRD 96, 112006 (2017)
37)Search for ψ(3686)→γηc(η(1405))→γπ+π−π0, PRD 96, 112008 (2017)
38)Measurement of cross sections of the interactions $e^+e^-\to\phi\phi\omega$ and $e^+e^-\to\phi\phi\phi$ at center-of-mass energies from 4.008 to 4.600 GeV, PLB 774, 78-86 (2017)
39)Determination of the Spin and Parity of the Zc(3900), PRL 119, 072001 (2017)
40)Observation of the decay Λ_c^+ -> $\Sigma^-\pi^+\pi^+\pi^0$, PLB 772, 388-393 (2017)
41)Measurement of integrated luminosity and center-of-mass energy of data taken by BESIII at sqrt(s) = 2.125 GeV, Chin. Phys. C 41, 113001 (2017)
42)Evidence for e^+e^- -> $\gamma\eta_c(1S)$ at center-of-mass energies between 4.01 and 4.60 GeV, PRD 96, 051101(R) (2017)
43)Dark photon search in the mass range between 1.5 and 3.4 GeV/c^2, PLB 774, 252-257 (2017)
44)Observation of e^+e^- ->ηh_c at center-of-mass energies from 4.085 to 4.600 GeV, PRD 96, 012001 (2017)

Decays of *cc* mesons

Scalar mesons and new states

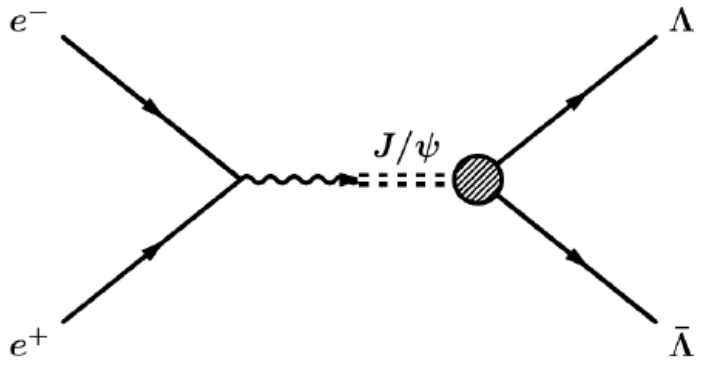
Studies of η, η', $\eta(1405)$, η_c and η_c' mesons

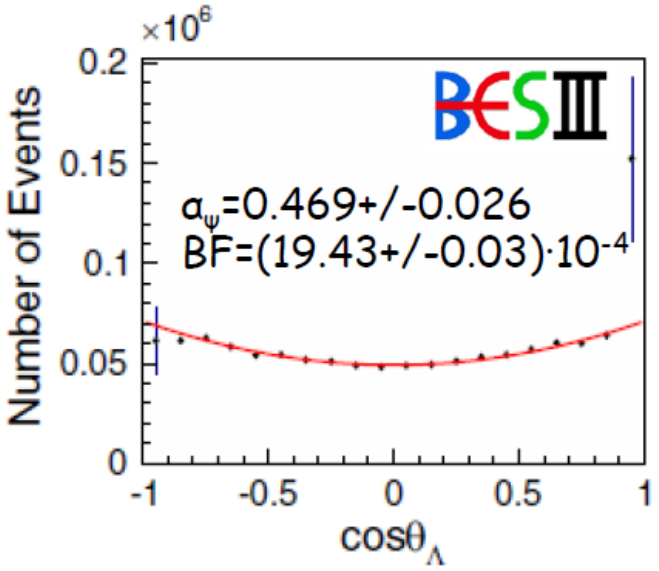
More detail on XYZ states: «Stato degli stati esotici XYZ a BESIII» - R. Farinelli

χ_{cJ} decays and transitions

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

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





BESIII,PRD 95, 052003 (2017)

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

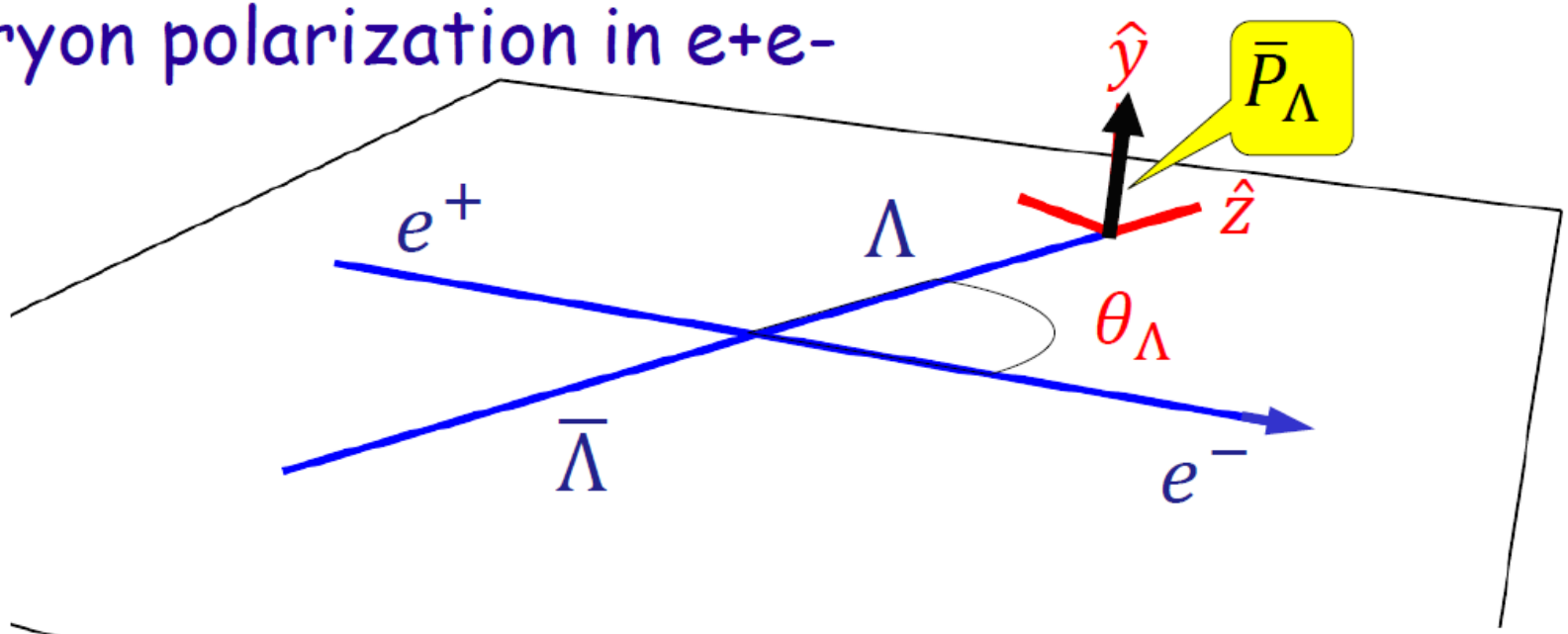
$$\frac{d\Gamma}{d\Omega} \propto 1 + \alpha_\psi \cos^2\theta$$

BF, α_ψ and phase $\Delta\Phi$

Similar studies from Italian members on $J/\psi \to \Sigma^+\Sigma^-$

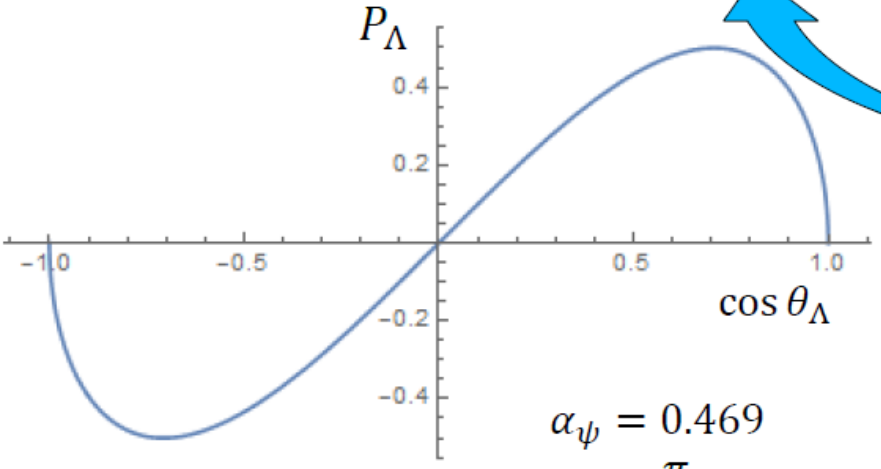
Dubnickova, Dubnicka, Rekalo Nuovo Cim. A109 (1996) 241
Gakh, Tomasi-Gustafsson NPA771 (2006) 169
Czyz, Grzelinska, Kuhn PRD75 (2007) 074026
Fäldt EPJ A51 (2015) 74; EPJ A52 (2016)141
Fäldt, Kupsc PLB772 (2017) 16

Baryon polarization in e+e-



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

$\Delta\Phi \neq 0$

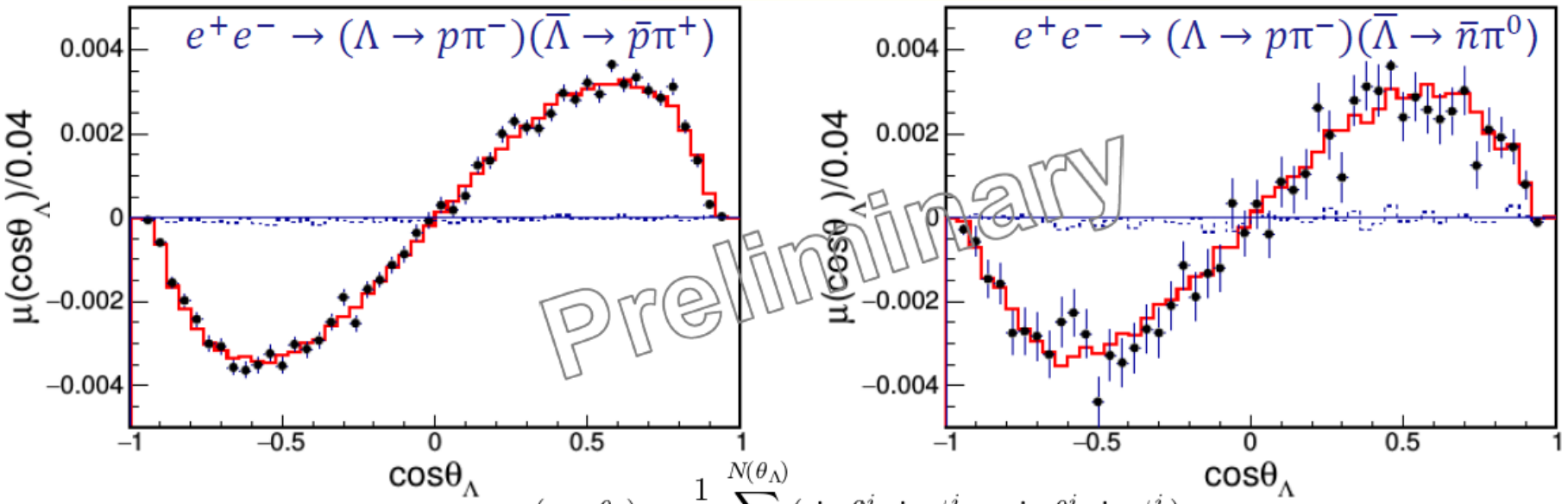


$\alpha_\psi = 0.469$

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

Fit results

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



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

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
$\bar{\alpha}_0/\alpha_+$	$\mathbf{0.913 \pm 0.028 \pm 0.012}$	–	

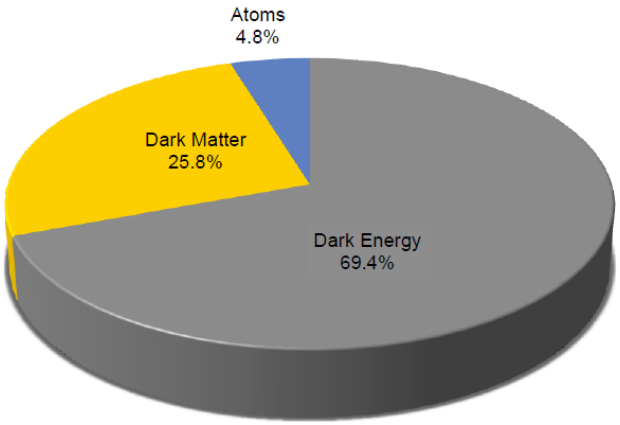
CP asymmetry:

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

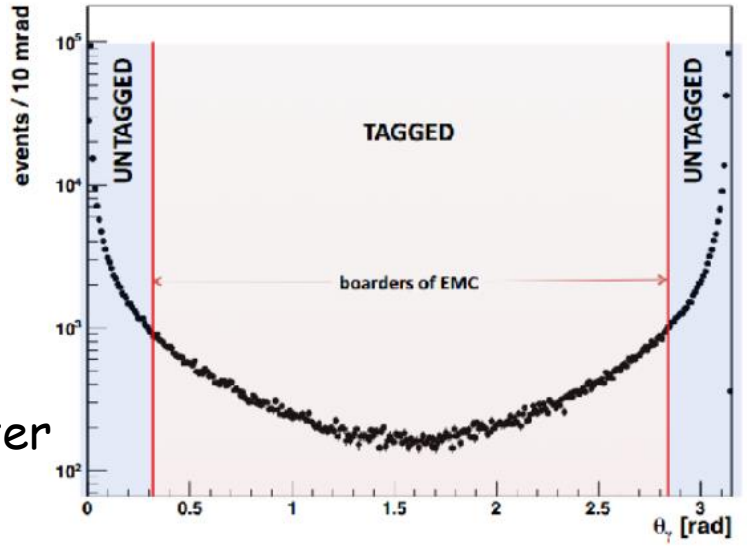
Dark Photon search in e^+e^- -> γe^+e^- and $\gamma\mu^+\mu^-$

PLB 774, 252 (2017)

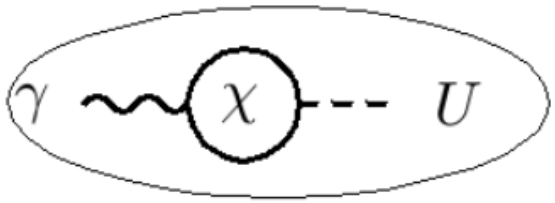
Composition of universe



BESIII spectrometer

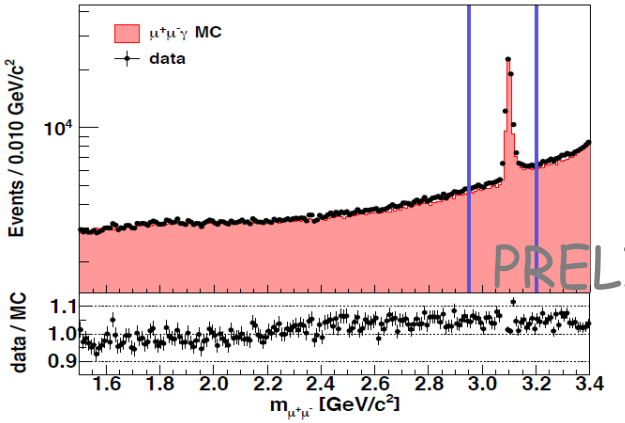


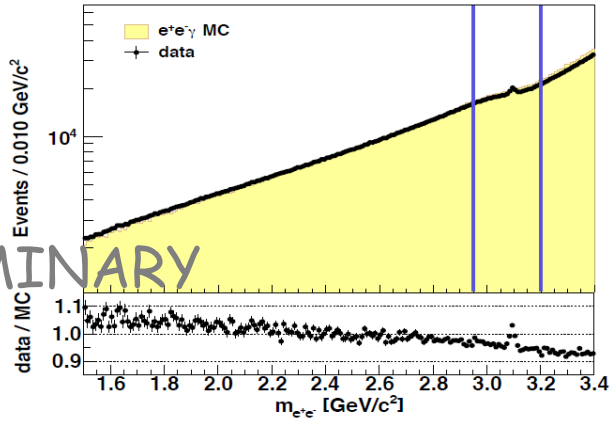
Portal	Particles	Operator(s)
"Vector"	Dark photons	$-\frac{\epsilon}{2\cos\theta_W}B_{\mu\nu}F'^{\mu\nu}$
"Axion"	Pseudoscalars	$\frac{a}{f_a}F_{\mu\nu}\tilde{F}^{\mu\nu}$, $\frac{a}{f_a}G_{i\mu\nu}\tilde{G}_i^{\mu\nu}$, $\frac{\partial_\mu a}{f_a}\bar{\psi}\gamma^\mu\gamma^5\psi$
"Higgs"	Dark scalars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



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

PLB 774, 252 (2017)



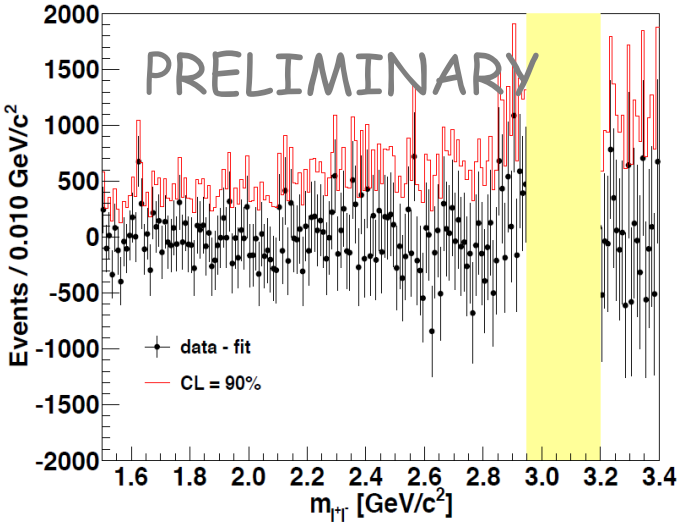


2.9fb^{-1} at ψ(3770)

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

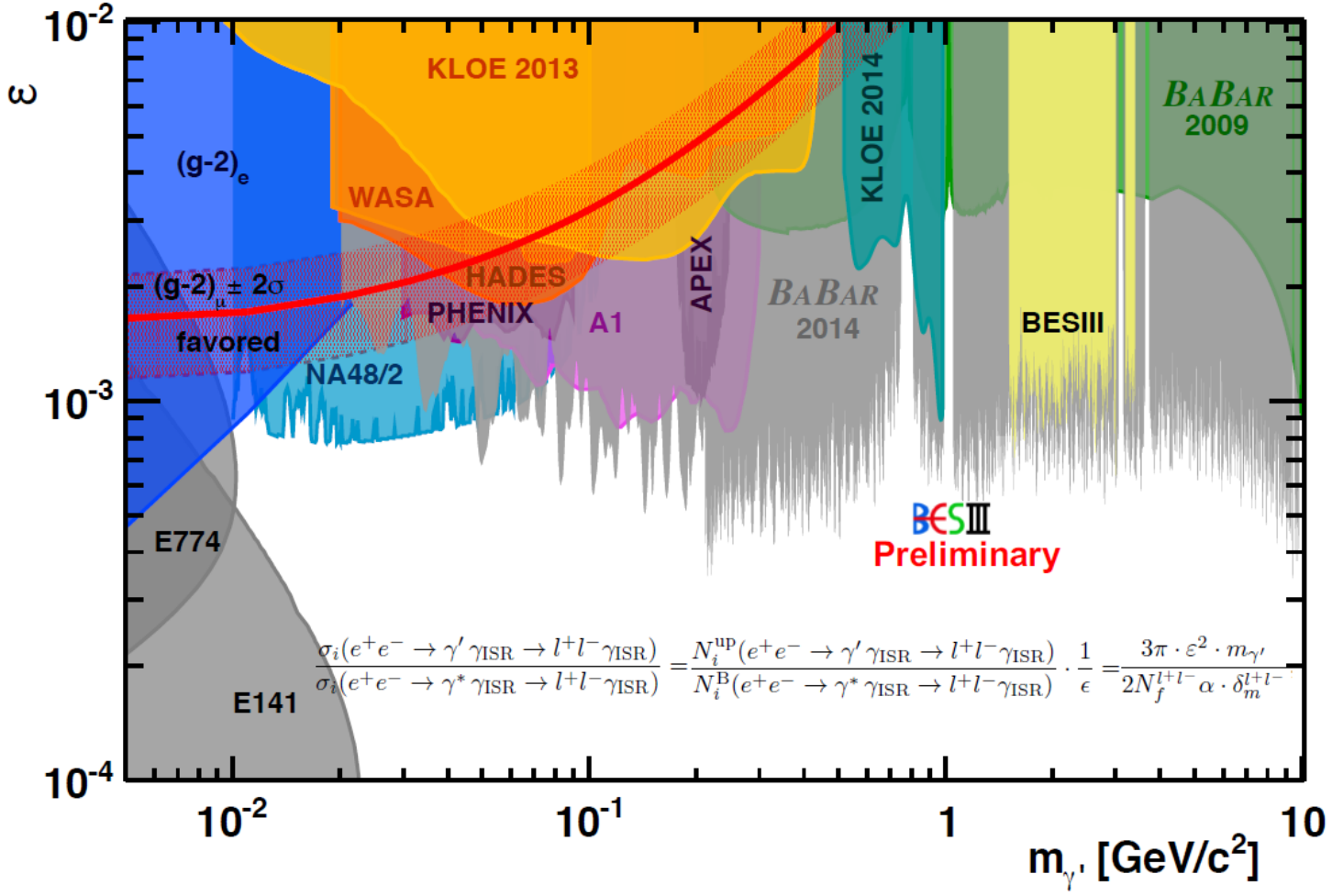
Combined statistics

90% confidence level

J/ψ region removed

Dark Photon search in e^+e^- -> γe^+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

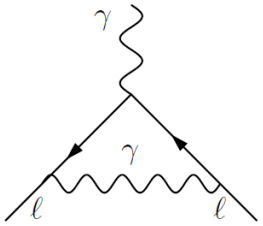
Lepton magnetic moment: $\bar{\mu} = g\frac{Qe}{2m}\bar{s}$

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

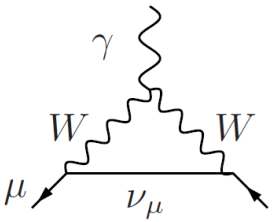
$$a_\mu = \frac{g_\mu - 2}{2}$$

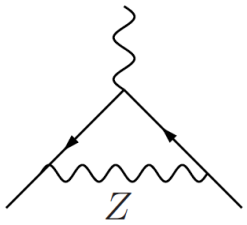
Muon anomaly arises from quantum fluctuations

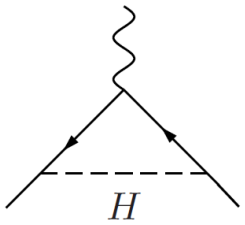
QED contribution (largest):



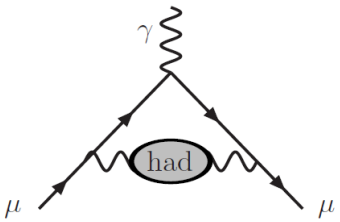
Weak contribution:

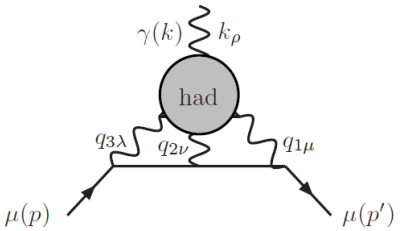






Hadronic contribution:





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

Prediction limited by hadronic contributions

Perturbative method cannot be applied in the relevant energy regime

Muon Magnetic Moment

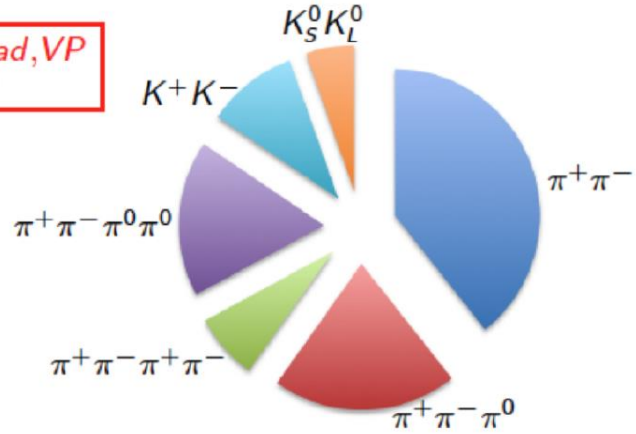
Hadronic Contributions

Vacuum Polarization

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

$a_\mu^{had,VP}$

$\delta a_\mu^{had,VP}$



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)

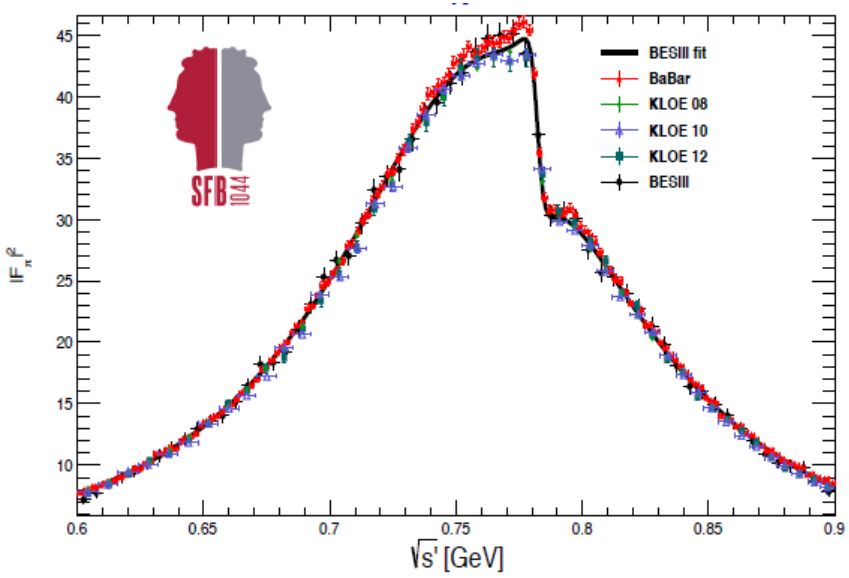
[2] F. Ambrosino et al. Phys. Lett. B 670, 285 (2009). F. Ambrosino et al. Phys. Lett. B 700, 102-110 (2011). D. Babusci et al. Phys. Lett. B 720, 336-343 (2013).

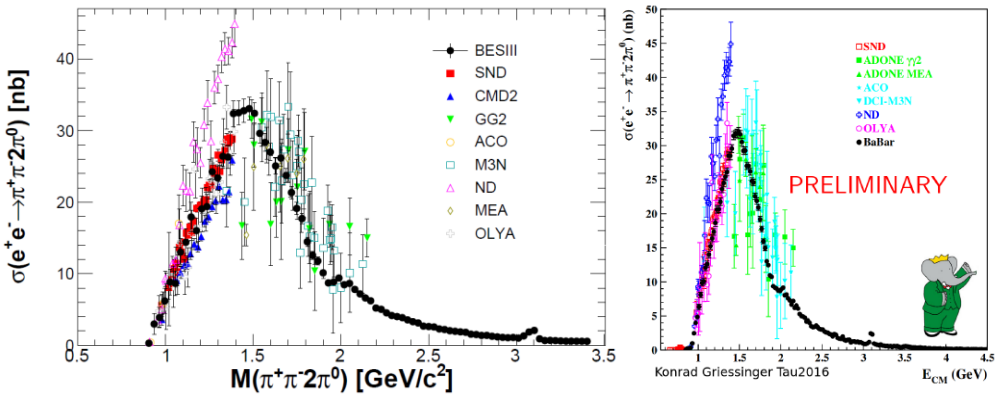
Comparison of $\pi^+\pi^-$ and $\pi^+\pi^-2\pi^0$ Form Factors

PLB 753, 629 (2016)

PRELIMINARY

Pion Form Factor F_π





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

- 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

[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).

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

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

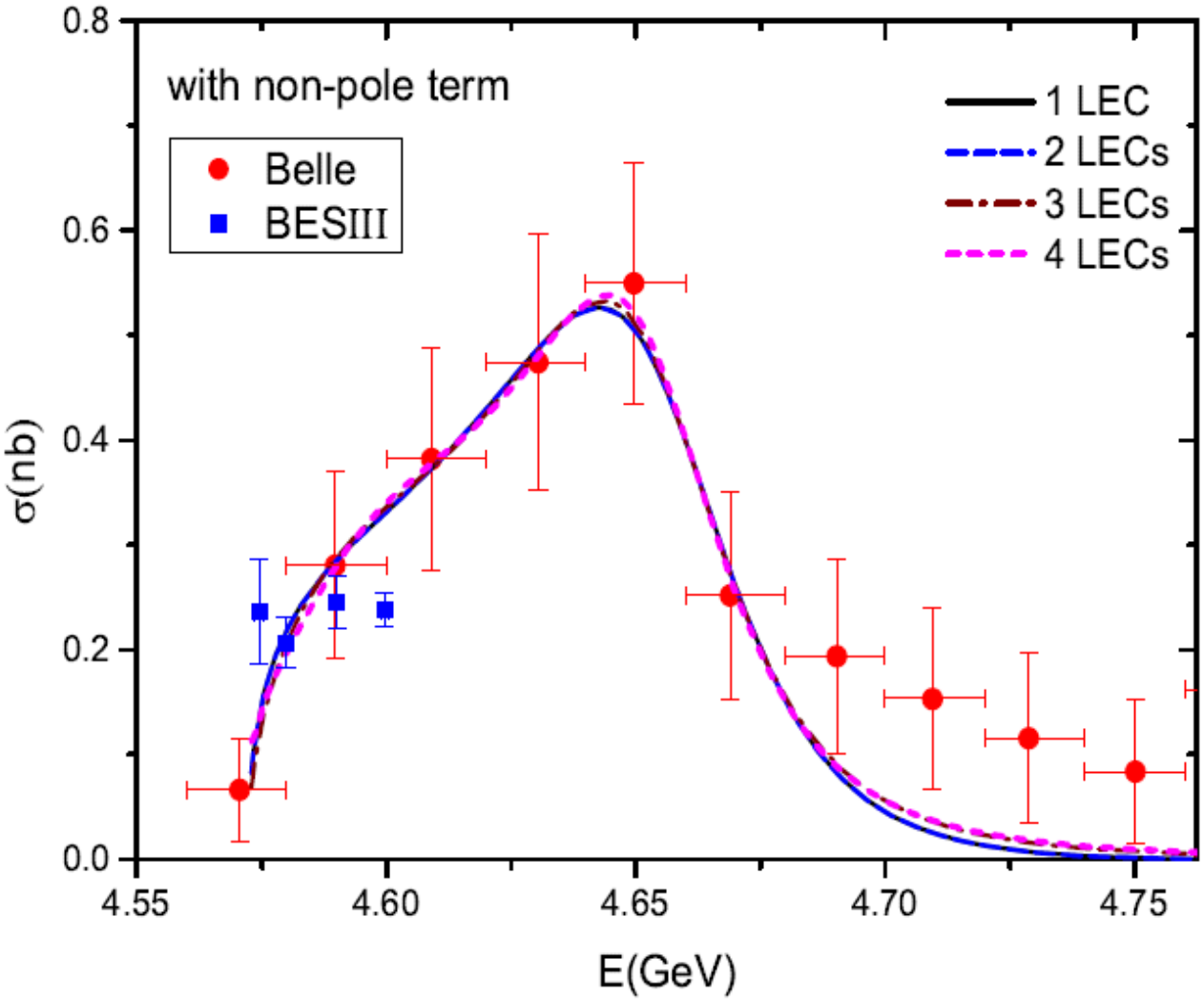
- New physics topics from higher energies
  - ✓ Exotics Y(4660), Y(4630), $Z_c^+(4430)$, $Z_c^+(4250)$, X…
  - ✓ $D_s^* D_{s2}^*$ threshold @ 4.68 GeV
  - ✓ $\Lambda_c \Sigma_c$ threshold @ 4.74 GeV
  - ✓ We will be a bit below $\Sigma_c \Sigma_c$ threshold (4.91 GeV)

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

Present data on e^+e^- -> $\Lambda_c\bar{\Lambda}_c$

Belle G. Pakhlova et al., [Belle Collaboration], Phys. Rev. Lett. 101, 172001 (2008).

BESIII Ablikim et al., arXiv:1710.00150 [hep-ex].



More detail on Λ_c: «Studi sul barione charmato Λ_c a BESIII» - G. Mezzadri

Summary

- Il più grande set di J/ψ, ψ(2S) e ψ(3770) al mondo
- Più di 25 articoli pubblicati nell'ultimo anno
- Circa 20 articoli in attesa di pubblicazione
- Costruzione CGEM come tracciatore centrale
- Parecchie analisi in fase di review interna
- Scan della ψ(3686) previsto per il 2018
- Upgrade dell'acceleratore BEPC-II