BESIII $\pi\pi$ Form Factor Measurement and Perspective for 3π

Yaqian WANG

(on behalf of the BESIII Colaboration)

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

SFB 1044 THE LOW-ENERGY FRONTIER OF THE STANDARD MODEL

Johannes Gutenberg University Mainz

The 10th International Workshop on e^+e^- collisions from ϕ to ψ
23-26 Deptember, 2015
Hefei, China

Outline

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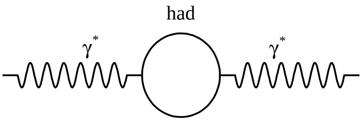
Hadronic VP and muon $g-2$

- Hadronic vacuum polarization



- $a_\mu^{\rm SM} = (\frac{g-2}{2})_\mu = a_\mu^{\rm QED} + a_\mu^{\rm had} + a_\mu^{\rm weak}$

γ and leptonic

Z, $W^\pm$, and Higgs

$$a_\mu^{\rm had,LO} = \frac{\alpha^2(0)}{3\pi^2} \int_{4m_\pi^2}^\infty {\rm d}s \frac{K(s)}{s} R(s)$$

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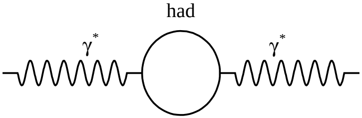


- $a_\mu^{\mathrm{SM}} = (\frac{g-2}{2})_\mu = a_\mu^{\mathrm{QED}} + a_\mu^{\mathrm{had}} + a_\mu^{\mathrm{weak}}$

a_μ^{QED} → γ and leptonic

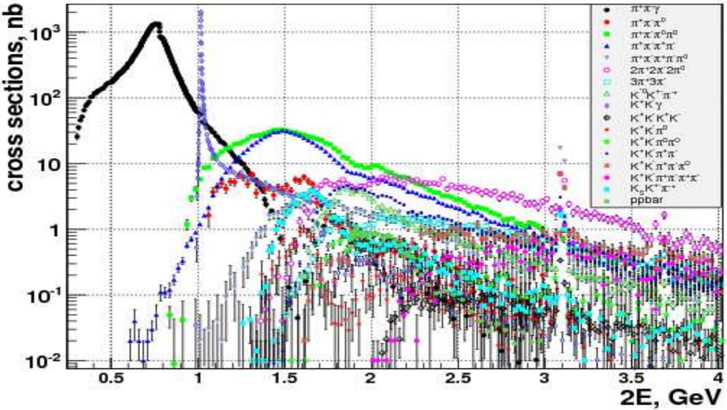
a_μ^{weak} → Z, $W^\pm$, and Higgs

a_μ^{had} →

$$a_\mu^{\mathrm{had,LO}} = \frac{\alpha^2(0)}{3\pi^2} \int_{4m_\pi^2}^{\infty} \mathrm{d}s \frac{K(s)}{s} R(s)$$

$$R(s) = \frac{\sigma(e^+e^- \to \mathrm{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$$

Initial State Radiation at BaBar



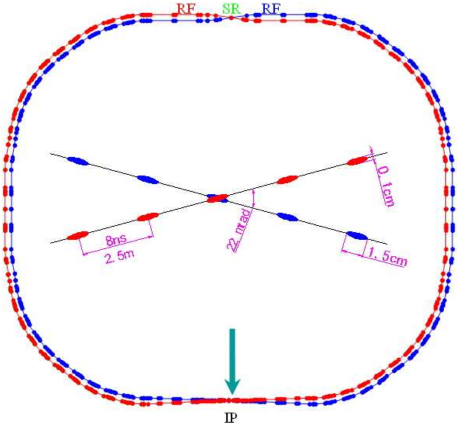
D. Bernard [BaBar Collaboration], PoS Hadron **2013**, 126 (2013) [arXiv:1402.0618 [hep-ex]].

- Most important channels: $\pi^+\pi^-$, KK, $\pi^+\pi^-\pi^0$, $\pi^+\pi^-2\pi^0$
- Largest contribution to uncertainty: $\pi^+\pi^-$, $\pi^+\pi^-2\pi^0$, $KK\pi\pi$

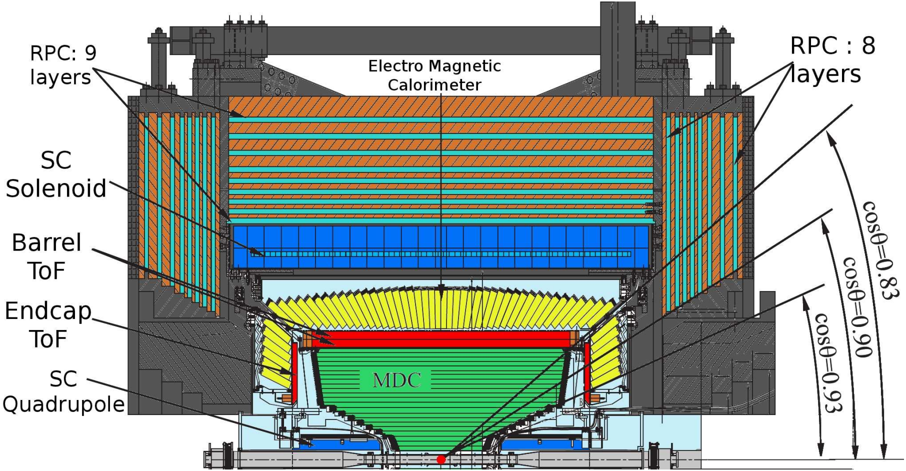
Outline

BEPCII

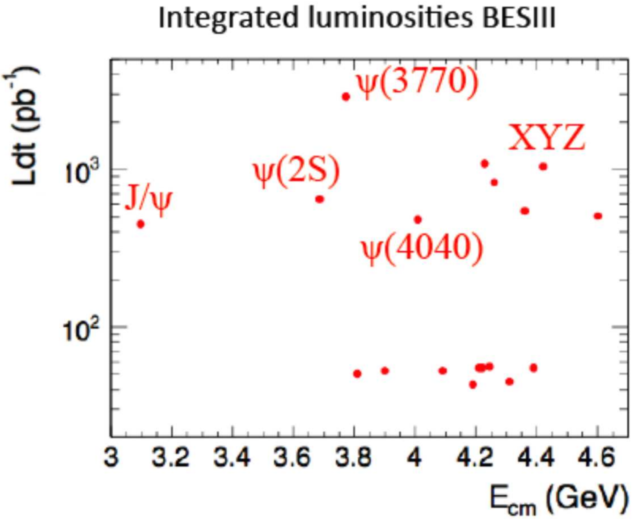
- τ-charm factory
- Beam energy: 2 - 4.6 GeV
- Design luminosity: 10^{33} cm$^{-2}s^{-1}$ (at 3.773 GeV)
- Linac + double storage ring



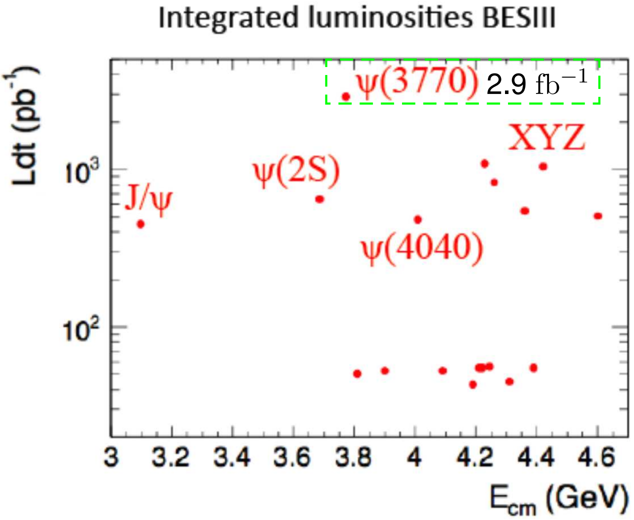
BESIII Detector



Data samples

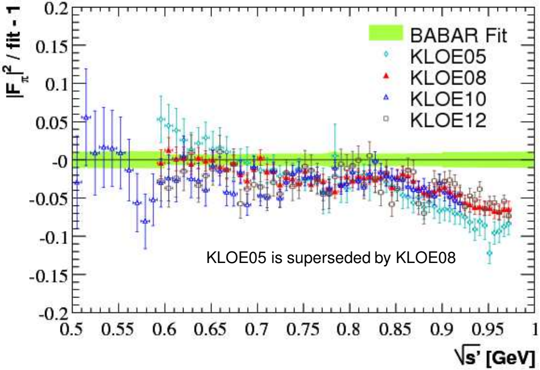


Data samples



Outline

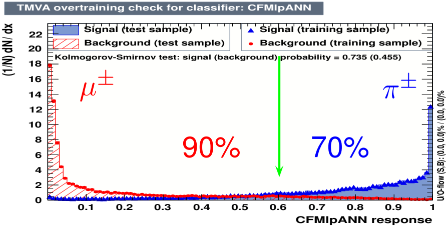
$\pi^+\pi^-$ at BaBar and KLOE

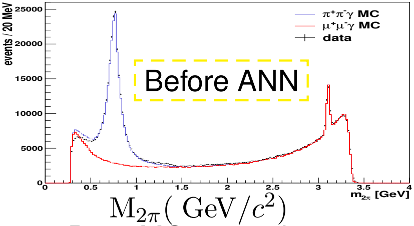


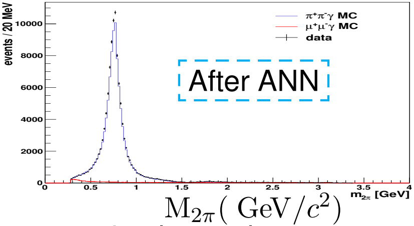
- Obvious discrepancy between BaBar and KLOE
- High precision measurement @ BESIII

Event Selection and Particle Identification

- Kinematic Fit for $\pi^+\pi^-\gamma_{ISR}$
- MDC, TOF, and EMC for electron rejection
- Artificial Neuronal Network for $\mu - \pi$ separation

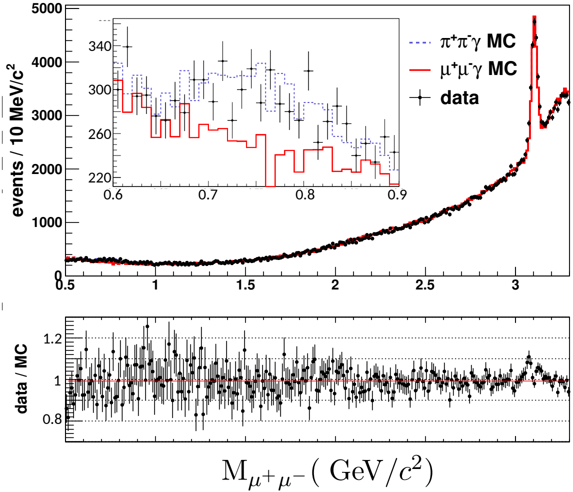




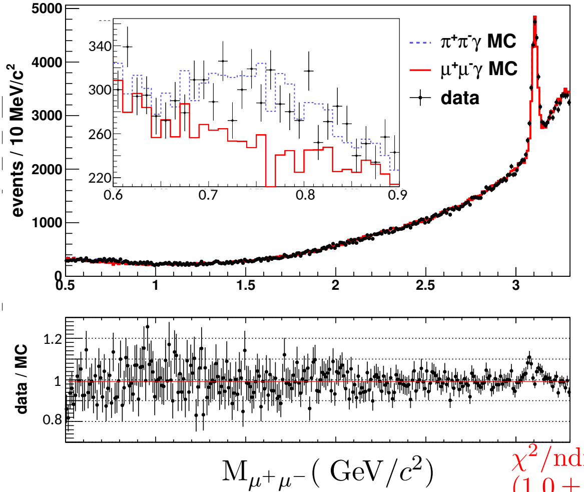


- Data-MC corrections vs. momentum and polar angle

QED test $e^+e^- \to \mu^+\mu^-\gamma$



QED test $e^+e^- \to \mu^+\mu^-\gamma$



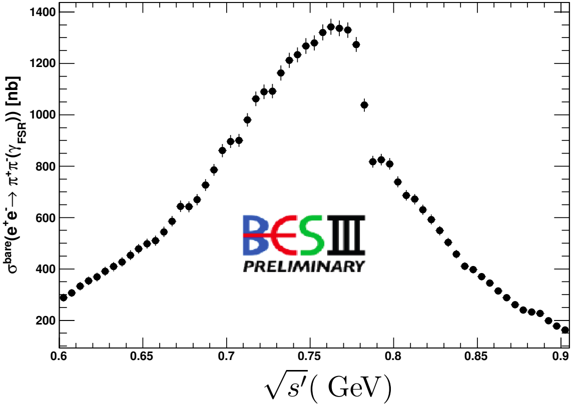
$\chi^2/\mathrm{ndf} = 134/139$
$(1.0 \pm 0.3 \pm 0.9)\%$

Systematic Uncertainties

Source	Uncertainty (%)
Photon efficiency	0.2
Tracking efficiency	0.3
Pion ANN efficiency	0.2
Pion e-PID efficiency	0.2
Angular acceptance	0.1
Background subtraction	0.1
Unfolding	0.2
FSR correction δ_{FSR}	0.2
Vacuum polarization correction δ_{vac}	0.2
Radiator function	0.5
Luminosity $\mathcal{L}$	0.5
Sum	**0.9**

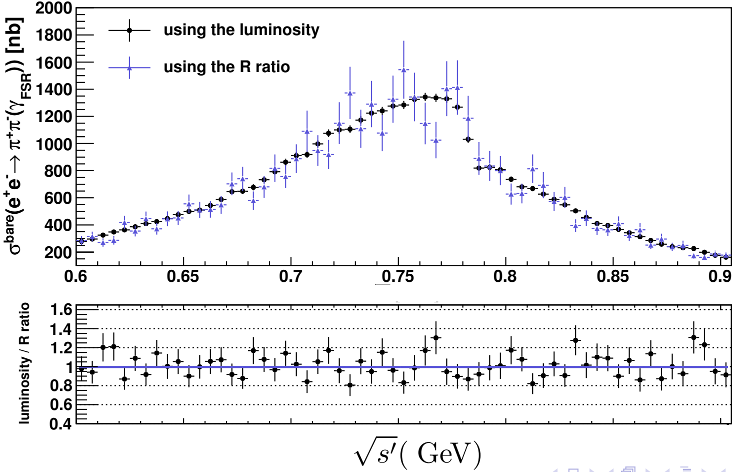
$\pi^+\pi^-$ Cross Section

- $\sigma^{\text{bare}}_{\pi\pi(\gamma_{\text{FSR}})} = \frac{N_{\pi\pi\gamma}\cdot(1+\delta^{\pi\pi}_{\text{FSR}})}{\mathcal{L}\cdot\epsilon^{\pi\pi\gamma}_{\text{global}}\cdot H(s)\cdot\delta_{\text{vac}}}$
- ρ-ω interference clearly visible



Comparison Nomalized by $\sigma_{\mu^+\mu^-}$

- $\sigma^{\text{bare}}_{\pi\pi(\gamma_{\text{FSR}})} = \frac{N_{\pi\pi\gamma}}{N_{\mu\mu\gamma}} \cdot \frac{\epsilon^{\mu\mu\gamma}_{\text{global}}}{\epsilon^{\pi\pi\gamma}_{\text{global}}} \cdot \frac{1+\delta^{\mu\mu}_{\text{FSR}}}{1+\delta^{\pi\pi}_{\text{FSR}}} \cdot \sigma^{\text{bare}}_{\mu\mu}$



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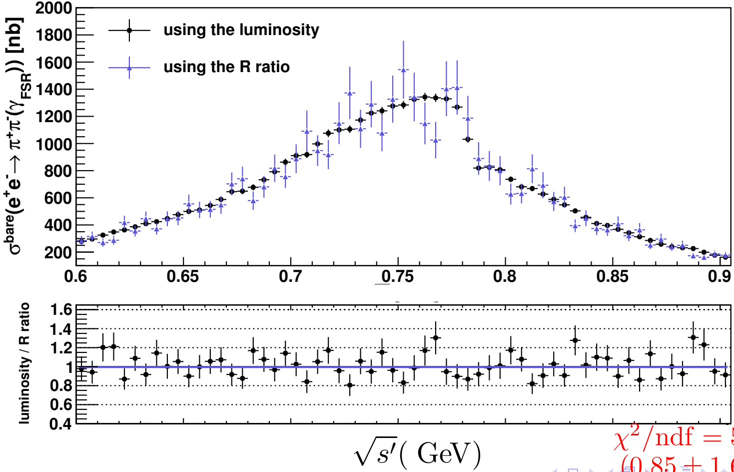
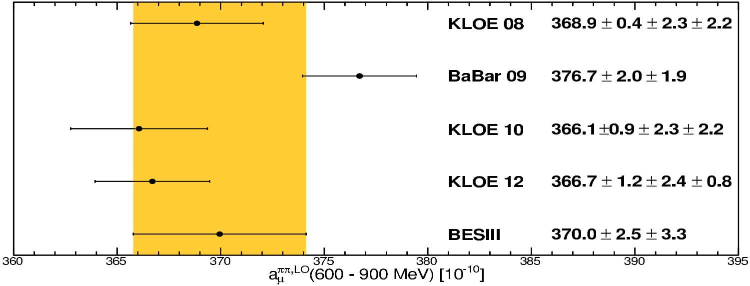


$\chi^2/\text{ndf} = 50/60$

$(0.85 \pm 1.68)\%$

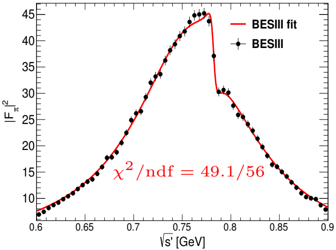
Contribution to $a_\mu^{\text{VP,LO}}$

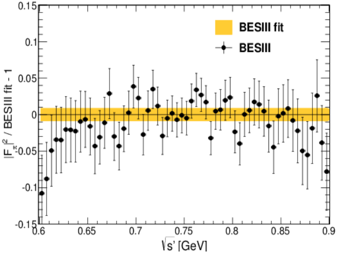


- $a_\mu^{\pi\pi,\text{LO}}(600 - 900\,\text{MeV}) = (370.0 \pm 2.5_{\text{stat}} \pm 3.3_{\text{sys}}) \cdot 10^{-10}$
- Precision competitive with previous measurements
- BESIII measurement between BaBar and KLOE
- Confirmed deviation between experiment and theory
- arXiv:1507.08188 and submitted to PLB

$\pi^+\pi^-$ Form Factor (Gounaris-Sakurai Parameterization)

- Issue with extraction of $|F_\pi|^2$ from cross section measurement
- Updated $|F_\pi|^2$ with respect to arXiv:1507.08188

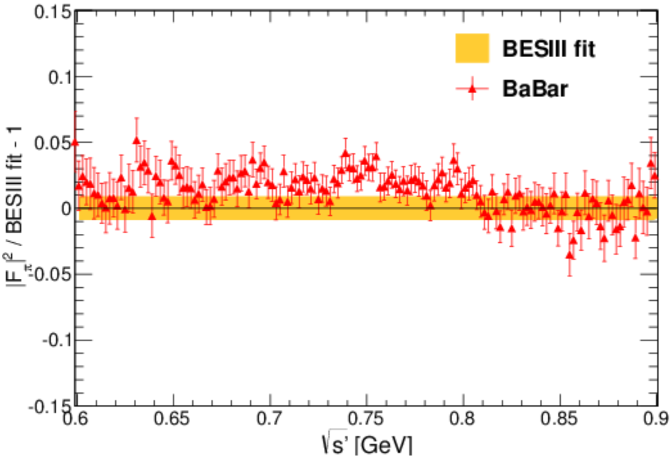




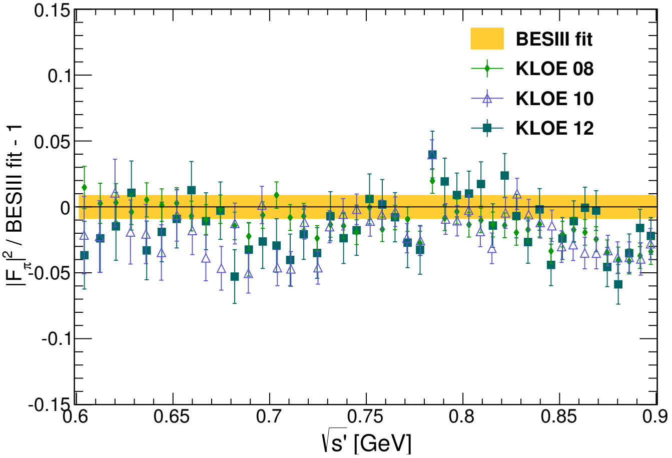
Parameter	BESIII value	PDG 2014
m_ρ [MeV/c^2]	776.0 ± 0.4	775.26 ± 0.25
Γ_ρ [MeV]	151.7 ± 0.7	147.8 ± 0.9
m_ω [MeV/c^2]	782.2 ± 0.6	782.65 ± 0.12
Γ_ω [MeV]	fixed to PDG	8.49 ± 0.08
$\lvert c_\omega\rvert$ [10^{-3}]	1.7 ± 0.2	-
$\lvert\phi_\omega\rvert$ [rad]	0.04 ± 0.13	-

2.9σ

Comparison with BaBar



Comparison with KLOE

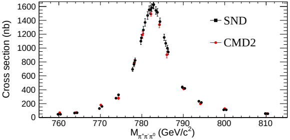


Outline

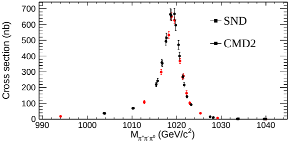
1. Introduction
2. Data samples and BESIII Machine
3. $\pi^+\pi^-$
4. $\pi^+\pi^-\pi^0$
5. Summary

$e^+e^- \to \pi^+\pi^-\pi^0$

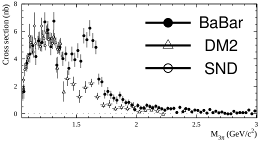
- History of σ for $e^+e^- \to \pi^+\pi^-\pi^0$:
  - $\sqrt{s} \lesssim 1$ GeV: $\omega(782)$ and $\phi(1020)$
  - Published results above ϕ :
    - SND : up to 1.4 GeV
    - DM2 : $1.34 \sim 2.40$ GeV
    - BaBar : $1.05 \sim 3.00$ GeV



ω

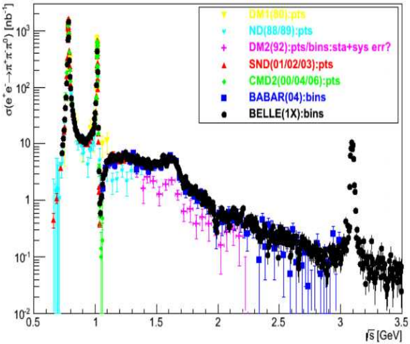


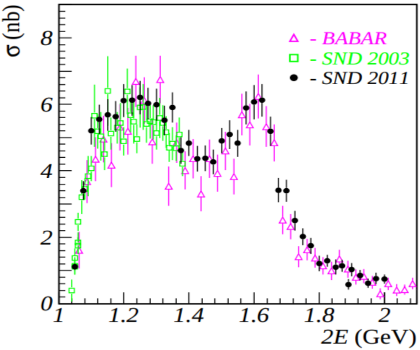
ϕ



ω' and ω''

Belle and SND

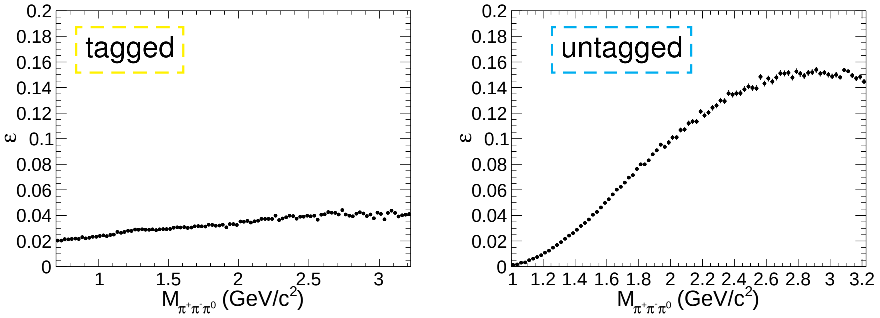




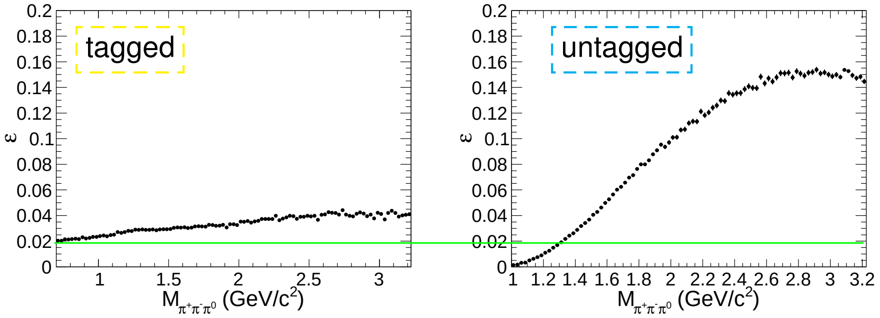
$e^+e^- \to \gamma_{\rm ISR}\pi^+\pi^-\pi^0$ from Belle

$e^+e^- \to \pi^+\pi^-\pi^0$ from SND

$e^+e^- \to \gamma_{\text{ISR}}\pi^+\pi^-\pi^0$ at BESIII

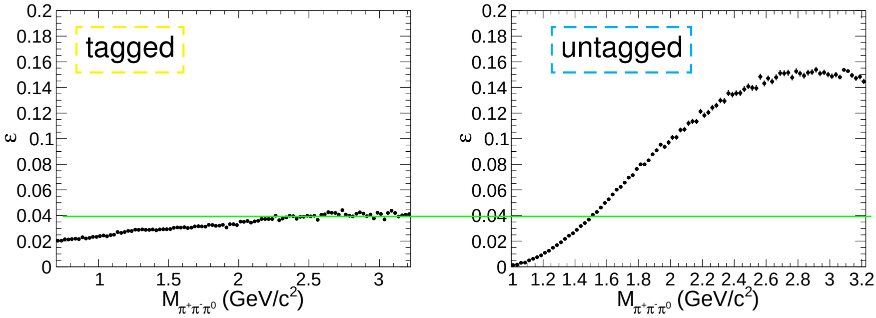


$e^+e^- \to \gamma_{\rm ISR}\pi^+\pi^-\pi^0$ at BESIII



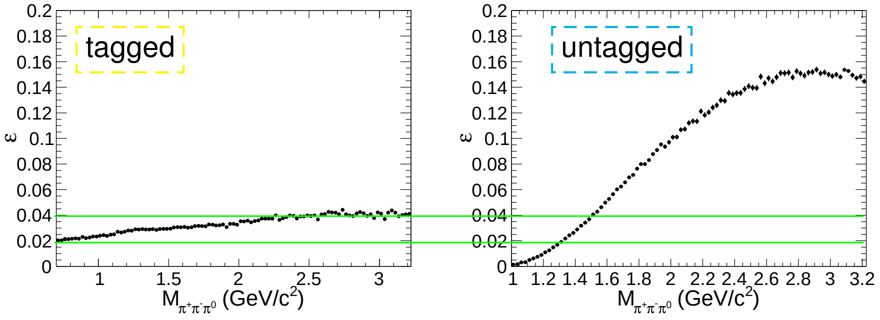
- Tagged is necessary in low mass range

$e^+e^- \to \gamma_{\rm ISR}\pi^+\pi^-\pi^0$ at BESIII



- Tagged is necessary in low mass range
- Untagged is more efficient in high mass range

$e^+e^- \to \gamma_{\rm ISR}\pi^+\pi^-\pi^0$ at BESIII



- Tagged is necessary in low mass range
- Untagged is more efficient in high mass range
- Both tagged and untagged are feasible at BESIII. Our goal: $< 5\%$

Outline

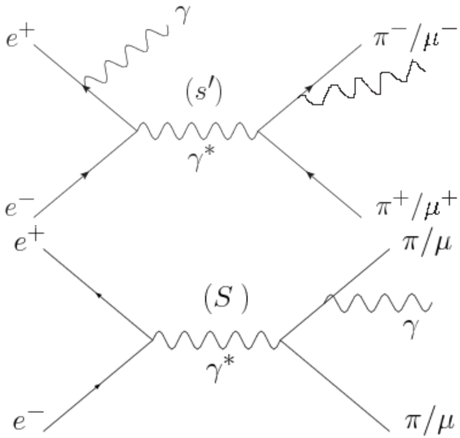
Summary

- $e^+e^- \to \pi^+\pi^-$
  - Cross section is measured at BESIII with sys. below 1%
  - Δa_μ is confirmed
- $e^+e^- \to \pi^+\pi^-\pi^0$
  - Feasible study at BESIII
  - Benefit from both tagged and untagged
- Outlook
  - Extend tagged $\pi^+\pi^-$ ISR study to threshold region
  - Untagged ISR for $\pi^+\pi^-$ cross section at higher mass range
  - Analyze $\pi^+\pi^-$ form factor from R-scan data (130 points, $\mathcal{L} \approx 1.3\text{fb}^{-1}$)
  - Ongoing Analysis of $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$

Thank you very much!

Back up

FSR Correction



Theoretical calculation of a_μ

$$a_\mu^{theo} = a_\mu^{\text{QED}} + a_\mu^{\text{weak}} + a_\mu^{\text{QCD}}$$
$$a_\mu^{\text{QED}} = (116584718.104 \pm 0.148) \times 10^{-11}$$
$$a_\mu^{\text{weak}} = (153.2 \pm 1.0 \pm 1.5) \times 10^{-11}$$
$$a_\mu^{\text{QCD}} = a_\mu^{\text{LbL}} + a_\mu^{\text{VP,LO}} + a_\mu^{\text{VP,HO}}$$
$$a_\mu^{\text{VP,LO}} = (6949.1 \pm 42.7) \times 10^{-11}$$
$$a_\mu^{\text{VP,HO}} = (-97.9 \pm 0.9) \times 10^{-11}$$
$$a_\mu^{\text{LbL}} = (105 \pm 26) \times 10^{-11}$$ (Glasgow consensus)