Measurement of the $e^+e^- \to \pi^+\pi^-$ cross section using initial state radiation at BESIII

April 20, 2015 | Christoph Florian Redmer

Radio MonteCarLOW Workshop, Frascati 2015

Motivation

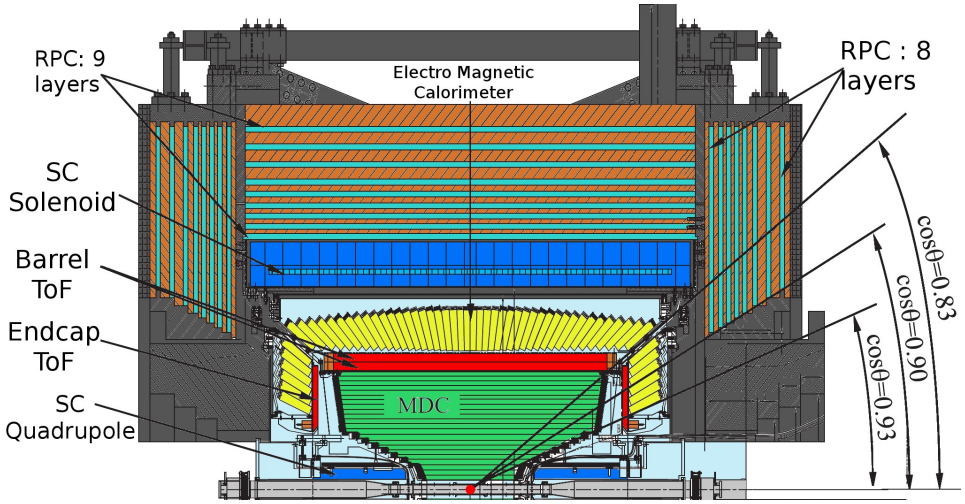
Our goal:

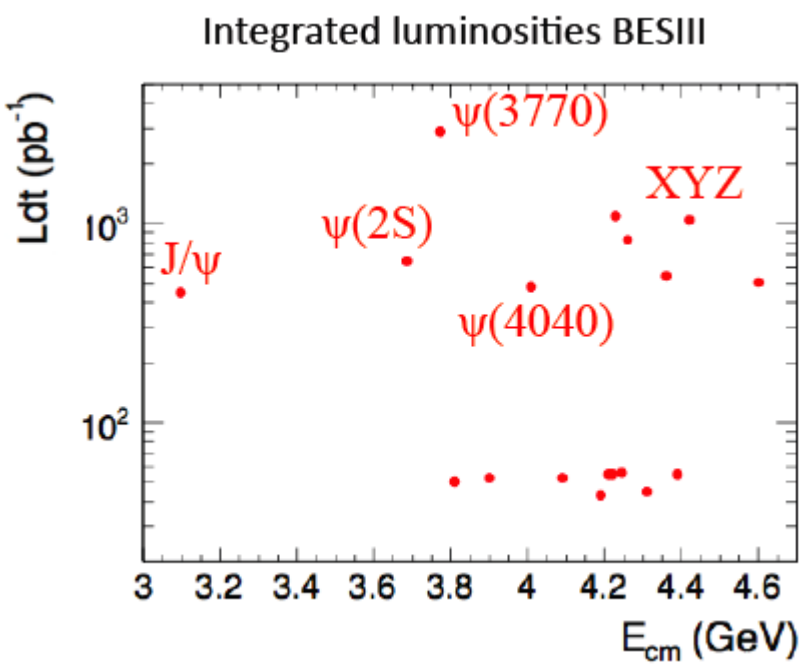
Measurement of the $e^+e^- \to \pi^+\pi^-$ cross section
at the BESIII experiment

with a precision

in the order of 1%

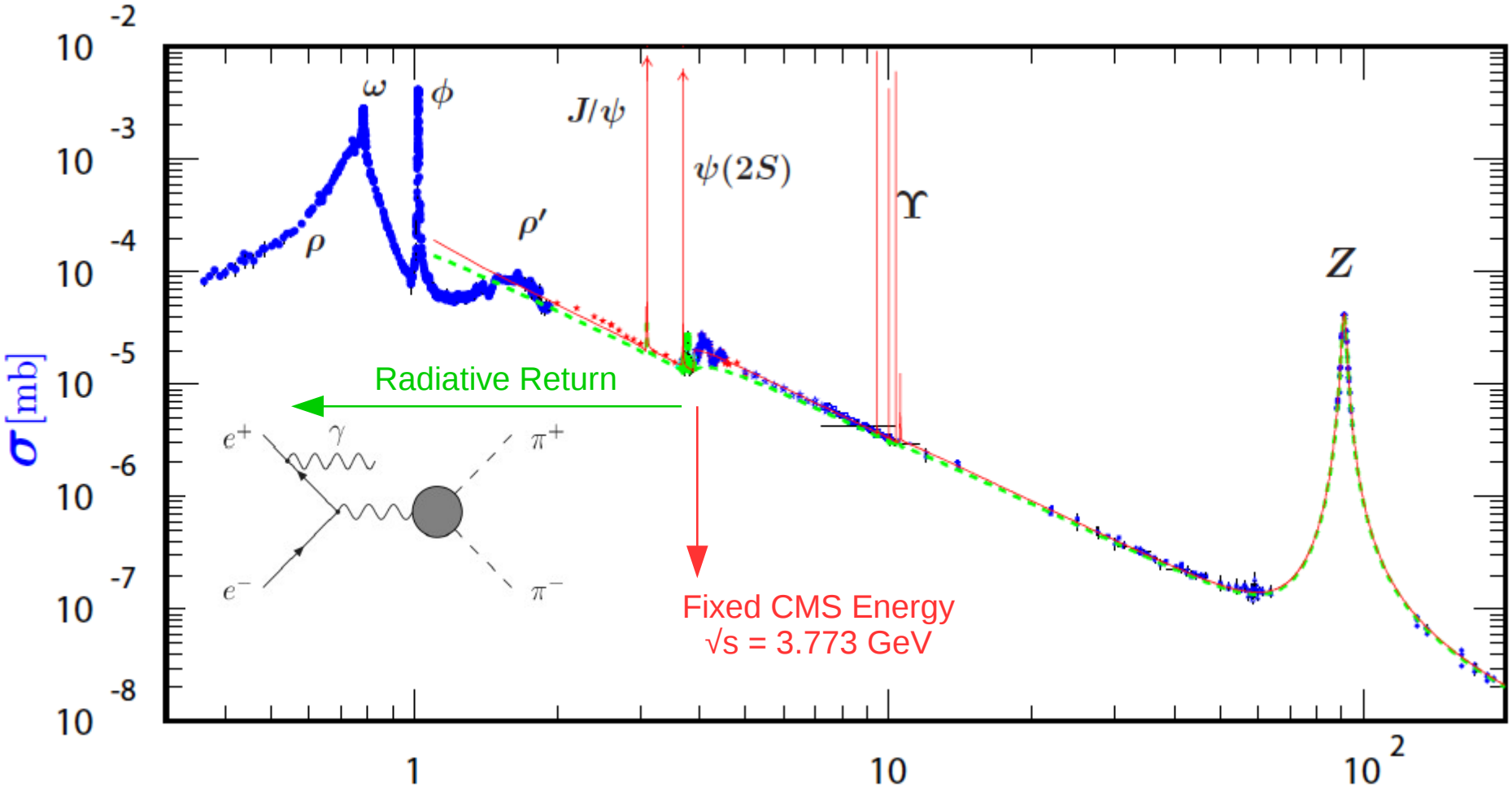
BESIII Data Sets





- BESIII Detector
- BEPCII Collider
  - $2.0 \leq \sqrt{s}$ [GeV] ≤ 4.6
- World's largest data sets on
  - Charmonium
  - Charm
  - Charmonium-like states
  - ....

Initial State Radiation

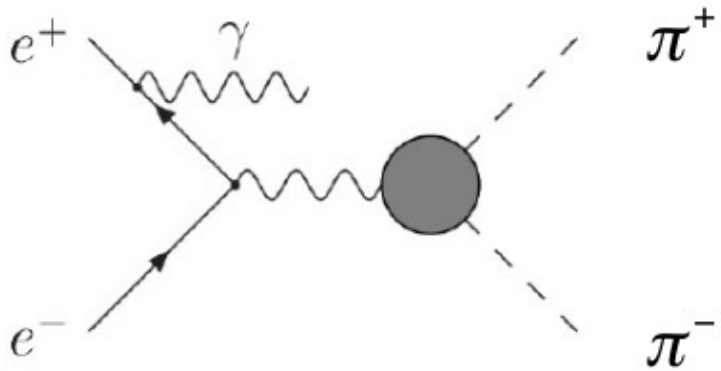


- Photon emitted in initial state
  - Available CMS energy reduced

Initial State Radiation

Study the channel

$$e^+e^- \rightarrow \pi^+\pi^-\gamma_{ISR}$$



to measure the cross section of $e^+e^- \rightarrow \pi^+\pi^-$

via

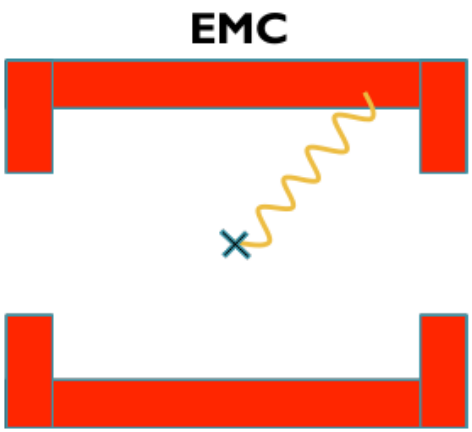
$$\frac{d\sigma_{ISR}(M_{2\pi})}{dM_{2\pi}} = \frac{2M_{2\pi}}{s} W(s,x,\theta_\gamma) \cdot \sigma(M_{2\pi})$$

(neglecting FSR)

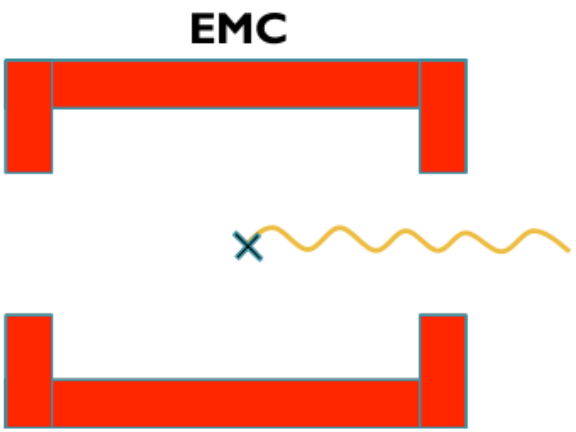
invariant mass of 2π

Radiator function

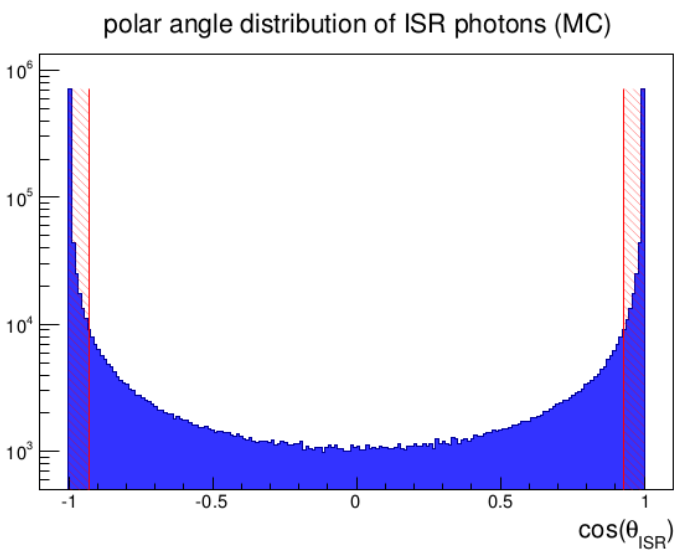
Tagging the ISR Photon



tagged:
photon hits EMC



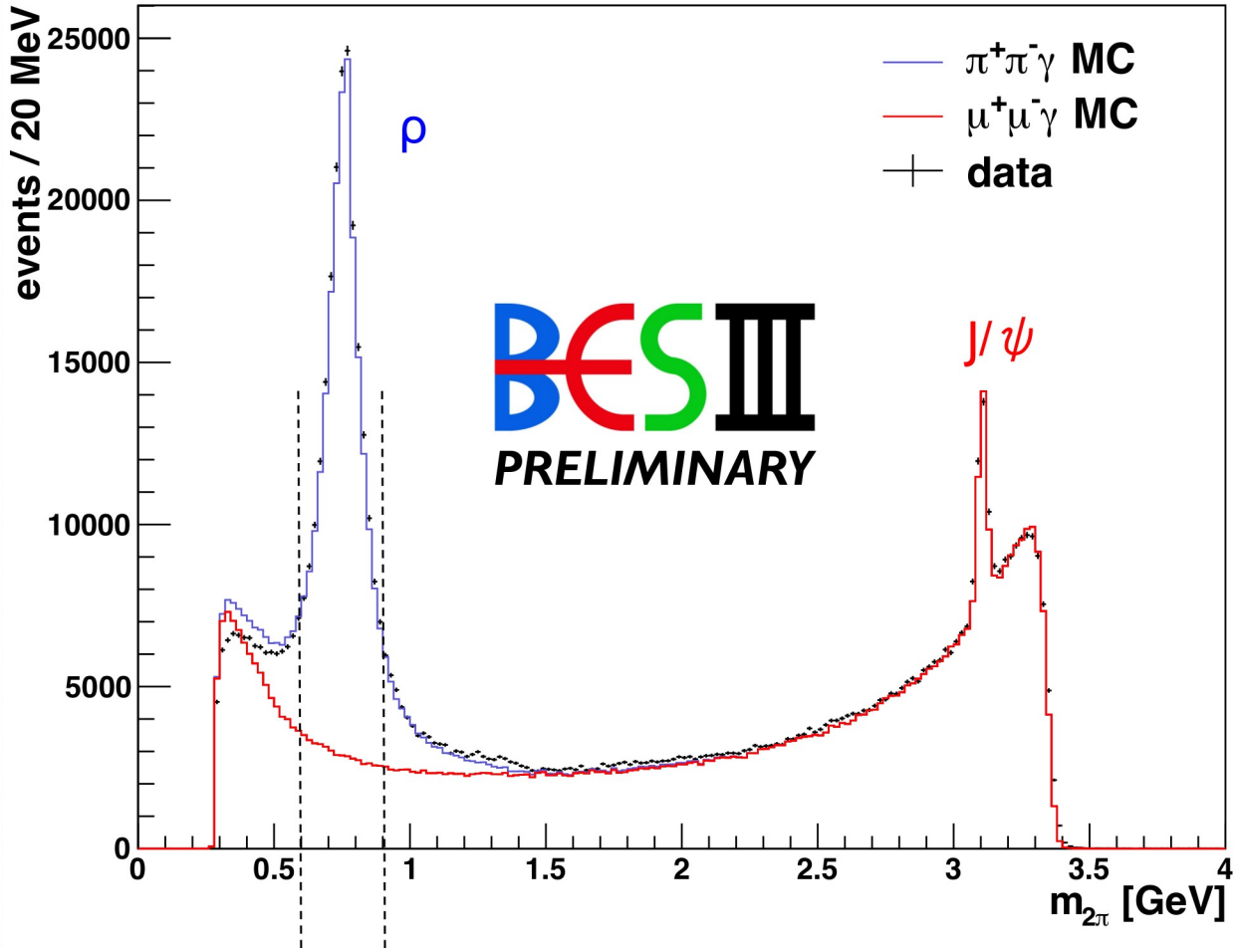
untagged:
photon leaves the detector



- **Tagged Analysis**
  - Acceptance for $\pi^+\pi^-$ down to threshold
- **Untagged Analysis**
  - Higher cross section
  - Acceptance only from $m_{\pi\pi}$ > 1GeV

ISR Analysis

kinematic requirements only



Initial Publication

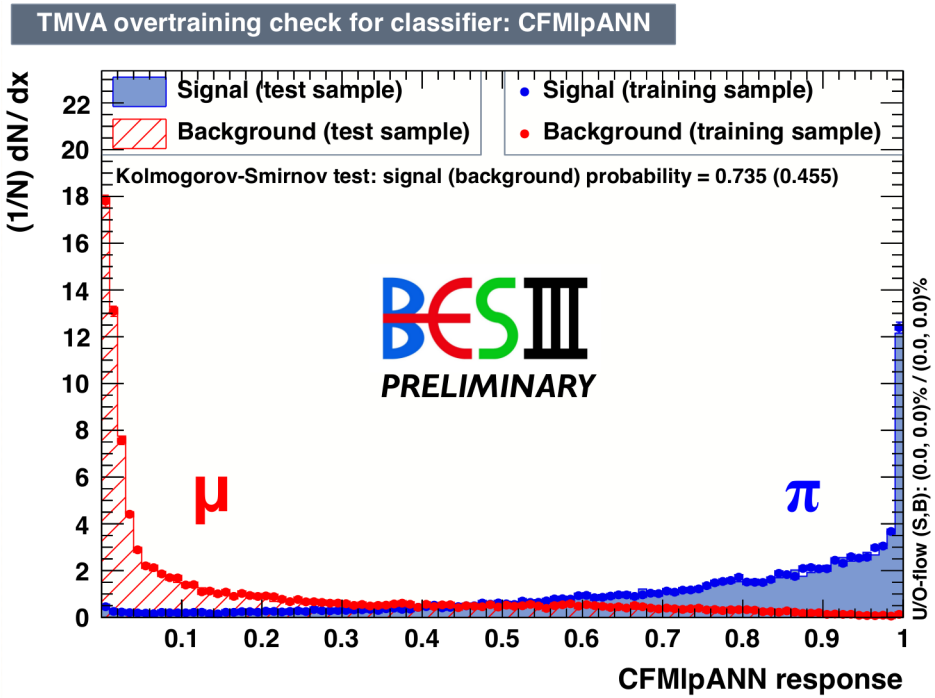
- 2.9 fb^{-1}, taken at 3.773 GeV
- Tagged ISR analysis
- Main background:
- Data-MC differences

- Initial publication: 600 – 900 MeV

ISR Analysis

Muon suppression:

- Artificial Neural Network
- Trained with MC events
- Efficiency matrix (p,Θ) for data-MC
- Track-based data-MC corrections
- Cross checked with different TMVA methods



ISR Analysis

Muon suppression:

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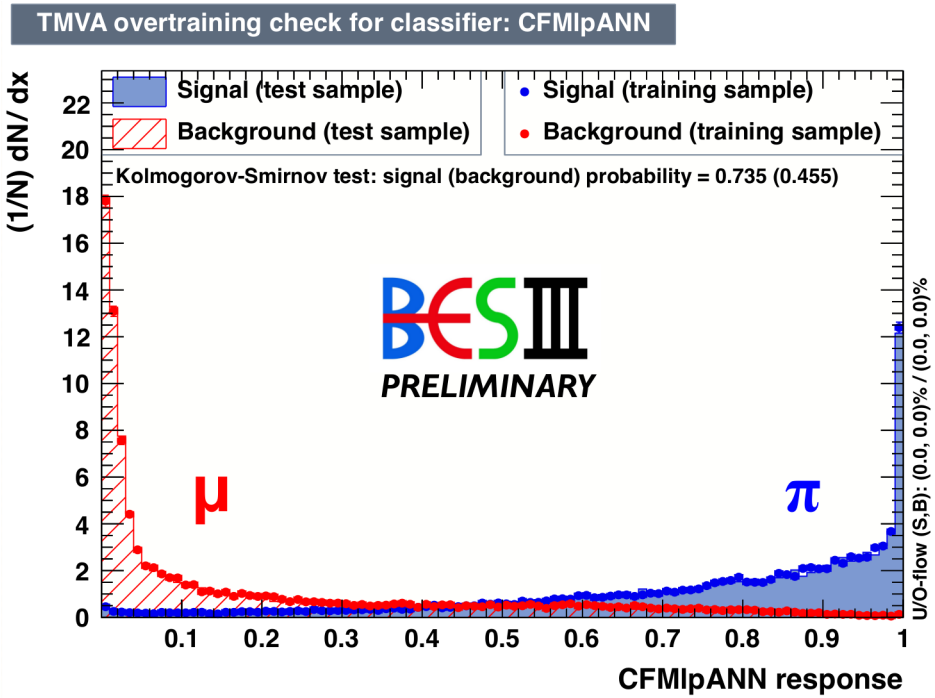
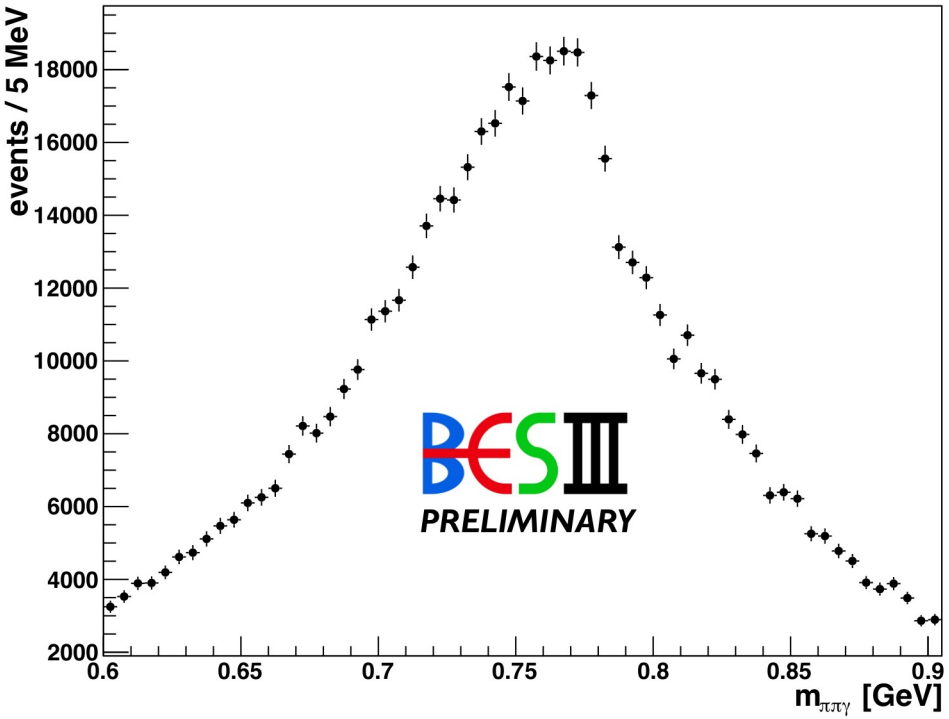
Event Yield:

- Efficiency Corrected for data-MC Differences
- Divided by global efficiency

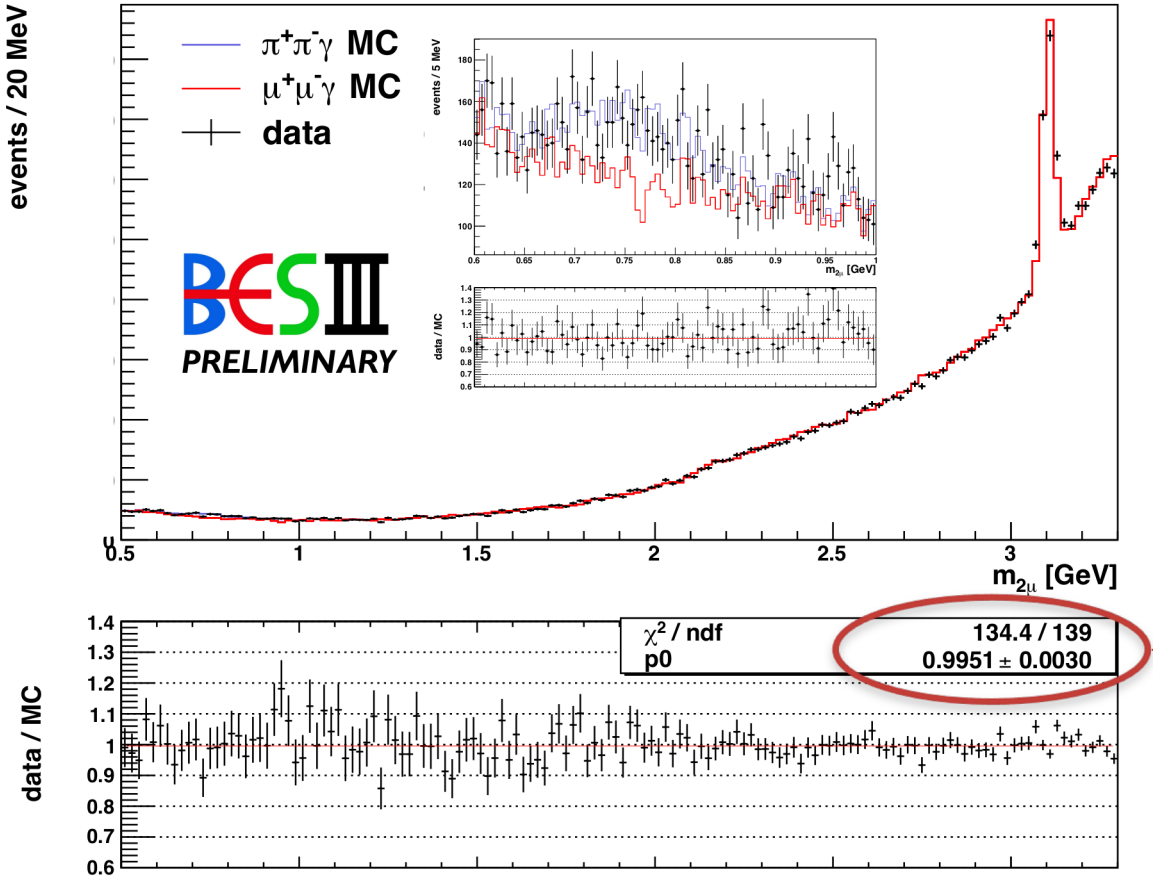




Test of ANN

Compare ANN result for $\mu^+\mu^-\gamma$ with QED prediction

- Revert selection



- $\pi+\pi-\gamma$ background very small
- data-MC efficiency corrections
- PHOKHARA accuracy < 0.5%
- luminosity accuracy 1.0%

Excellent agreement:

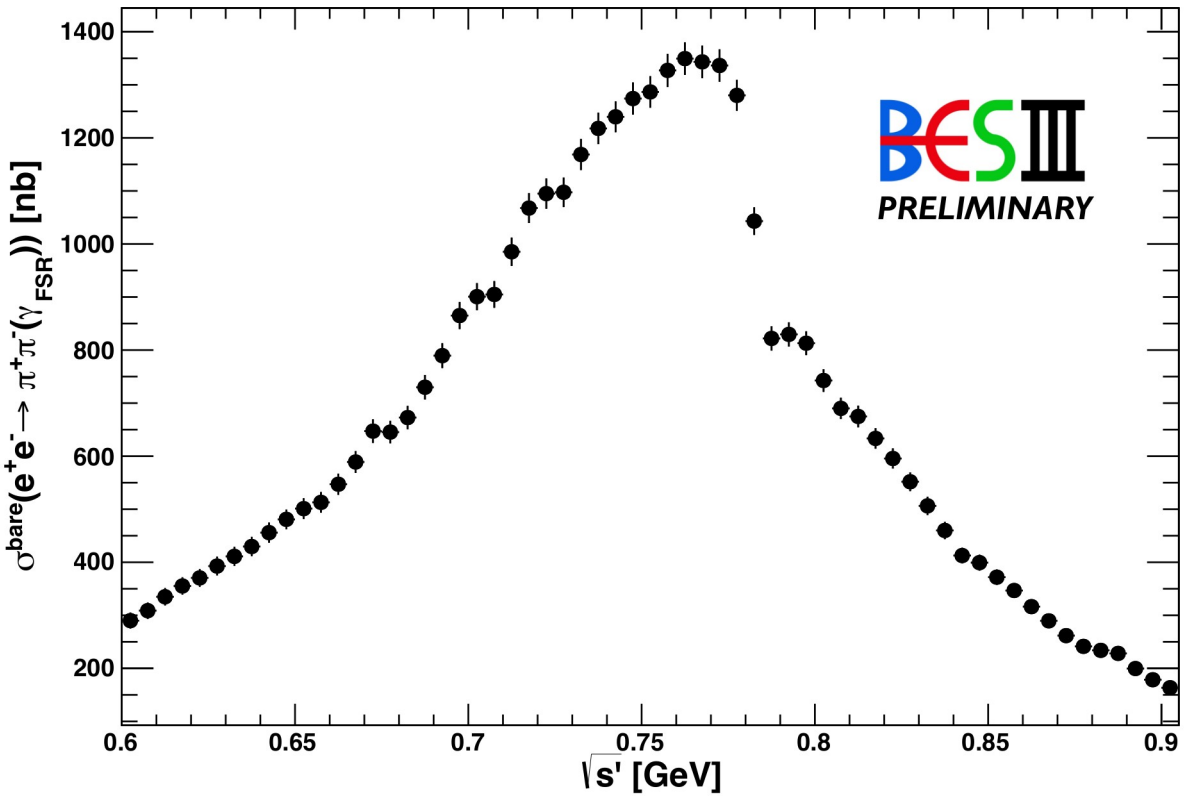
Δ(Data/QED) = (0.49 ± 0.30)%

Statistical only

Normalization

- **To integrated Luminosity:**

$$\sigma_{bare}(e^+e^- \to \pi^+\pi^-) = \frac{N_{\pi\pi\gamma}/\epsilon_{exp}}{L_{int} \cdot H_{rad} \cdot \delta_{vac} \cdot (1+\delta_{FSR})}$$

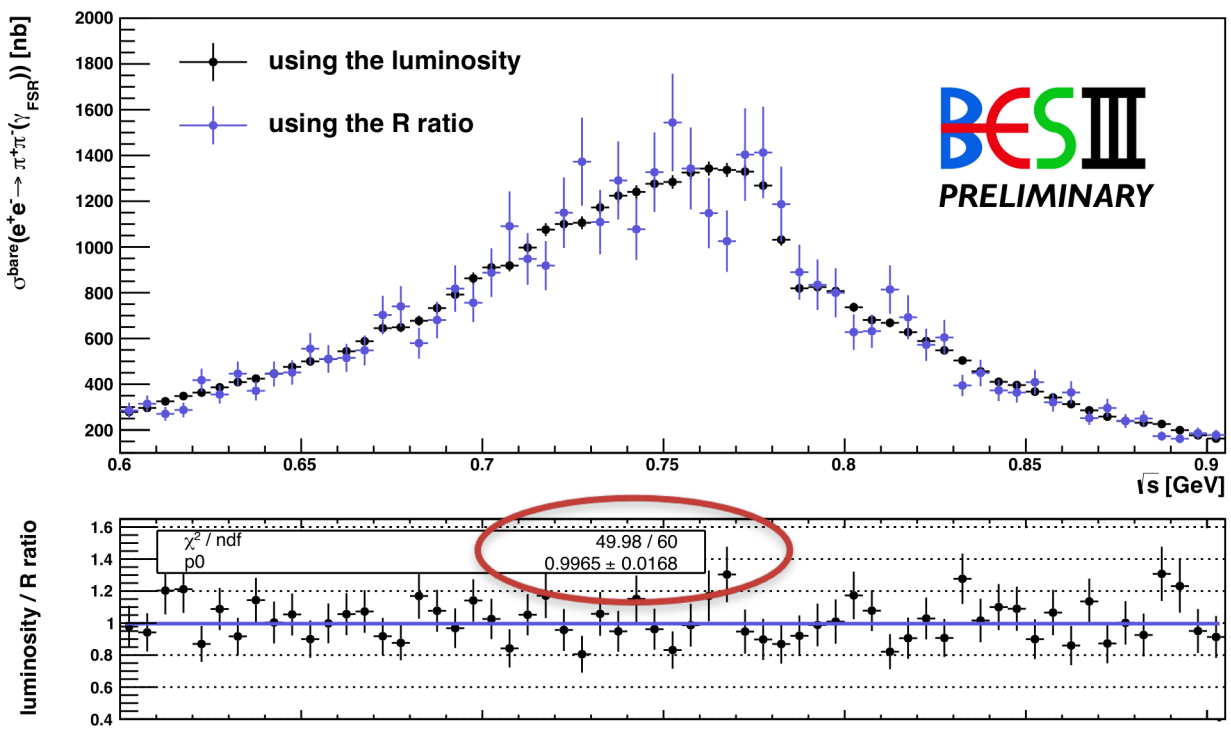


Normalization

- **To integrated Luminosity:**

$$\sigma_{bare}(e^+e^- \to \pi^+\pi^-) = \frac{N_{\pi\pi\gamma}/\epsilon_{exp}}{L_{int} \cdot H_{rad} \cdot \delta_{vac} \cdot (1+\delta_{FSR})}$$

- **To R – Ratio:**
  - L_{int}, H_{rad}, and δ_{vac} cancel
  - Limited by statistics



Relative Difference of Normalization Methods:

(0.35 ± 1.68)%

Summary: Systematic Uncertainties

BESIII PRELIMINARY

source	uncertainty (%)
photon efficiency correction	0.2
pion tracking efficiency correction	0.3
pion ANN efficiency correction	0.2
pion e-PID efficiency correction	0.2
ANN	negl.
angular acceptance	0.1
muon background subtraction	0.06
non-muon background subtraction	0.03
unfolding	0.2
FSR correction δ_{FSR}	0.2
vacuum polarization correction δ_{vac}	0.2
radiator function	0.5
Luminosity $\mathcal{L}$	1.0
sum	**1.3**

Luminosity is the limiting Factor!

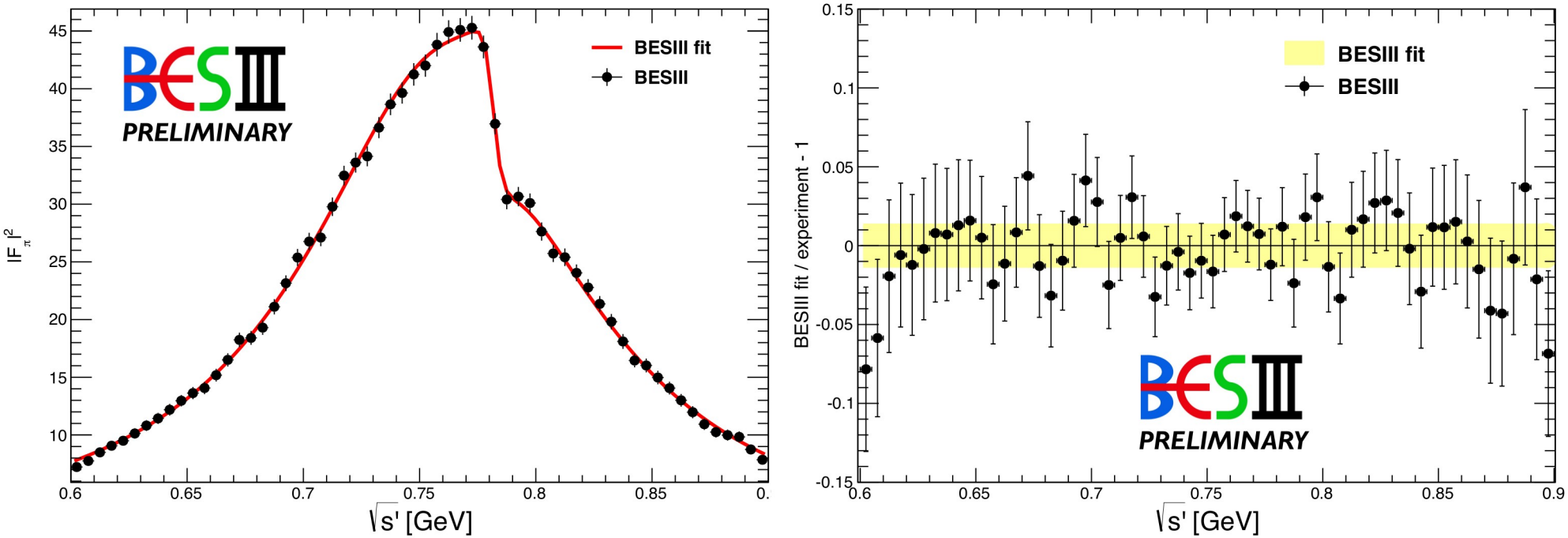
- Redo luminosity measurement

→ Andreas' talk

- Improve luminosity measurement by approx. factor two
- Reduce systematics of $\sigma_{\text{bare}}(e^+e^- \to \pi^+\pi^-(\gamma_{\text{FSR}}))$ to approx. 1.0%

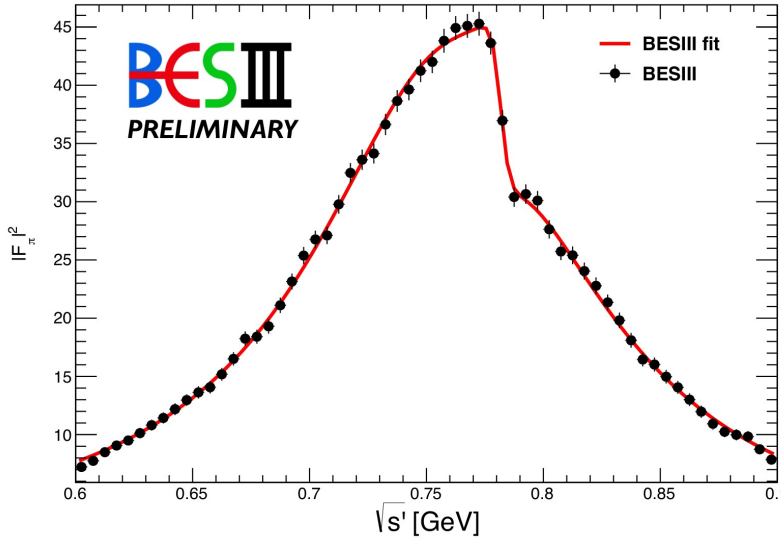
Form Factor

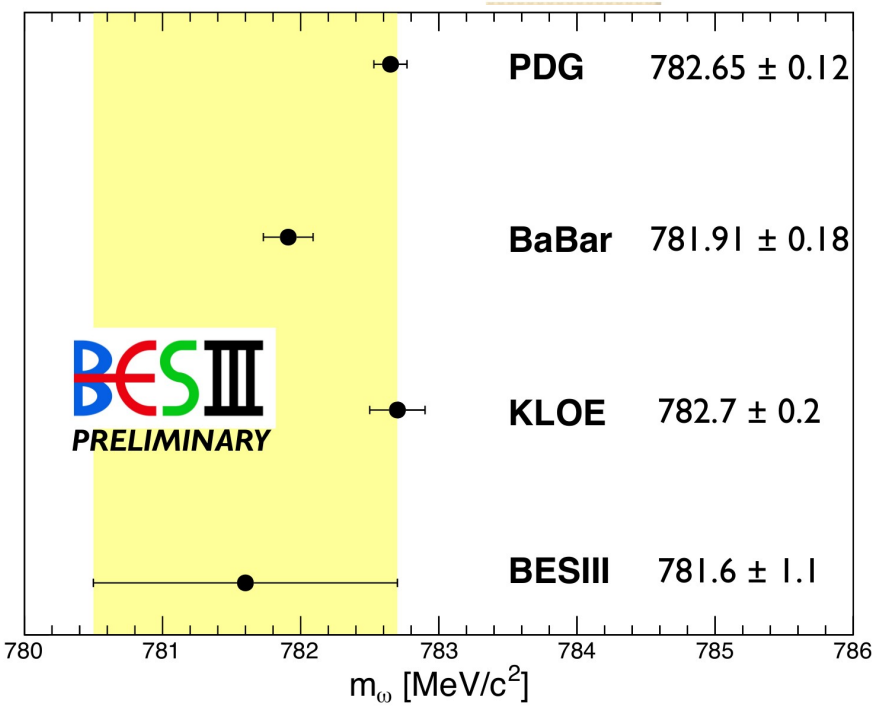
$$|F_\pi|^2(s') = \frac{3s'}{\pi\alpha\beta_\pi^3(s')}\sigma(e^+e^- \to \pi^+\pi^-)(s')$$

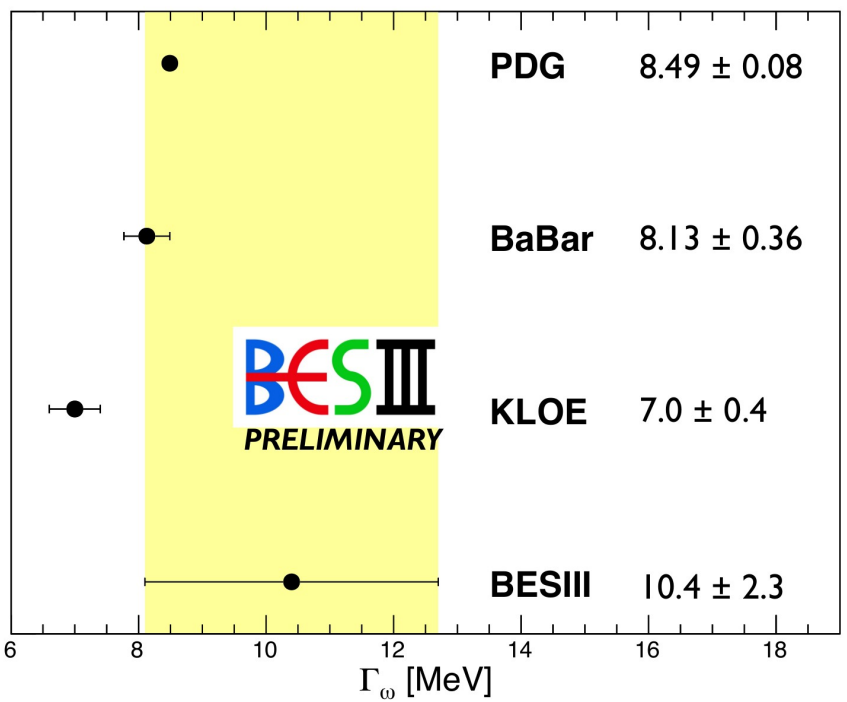


- Fit with Gounaris – Sakurai parametrization
  - Free Parameters: $m_\rho, \Gamma_\rho, m_\omega, \Gamma_\omega, \phi_\omega, |c_\omega|$
  - Other parameters fixed
  - χ^2 / n.d.f. = 33.2 / 51

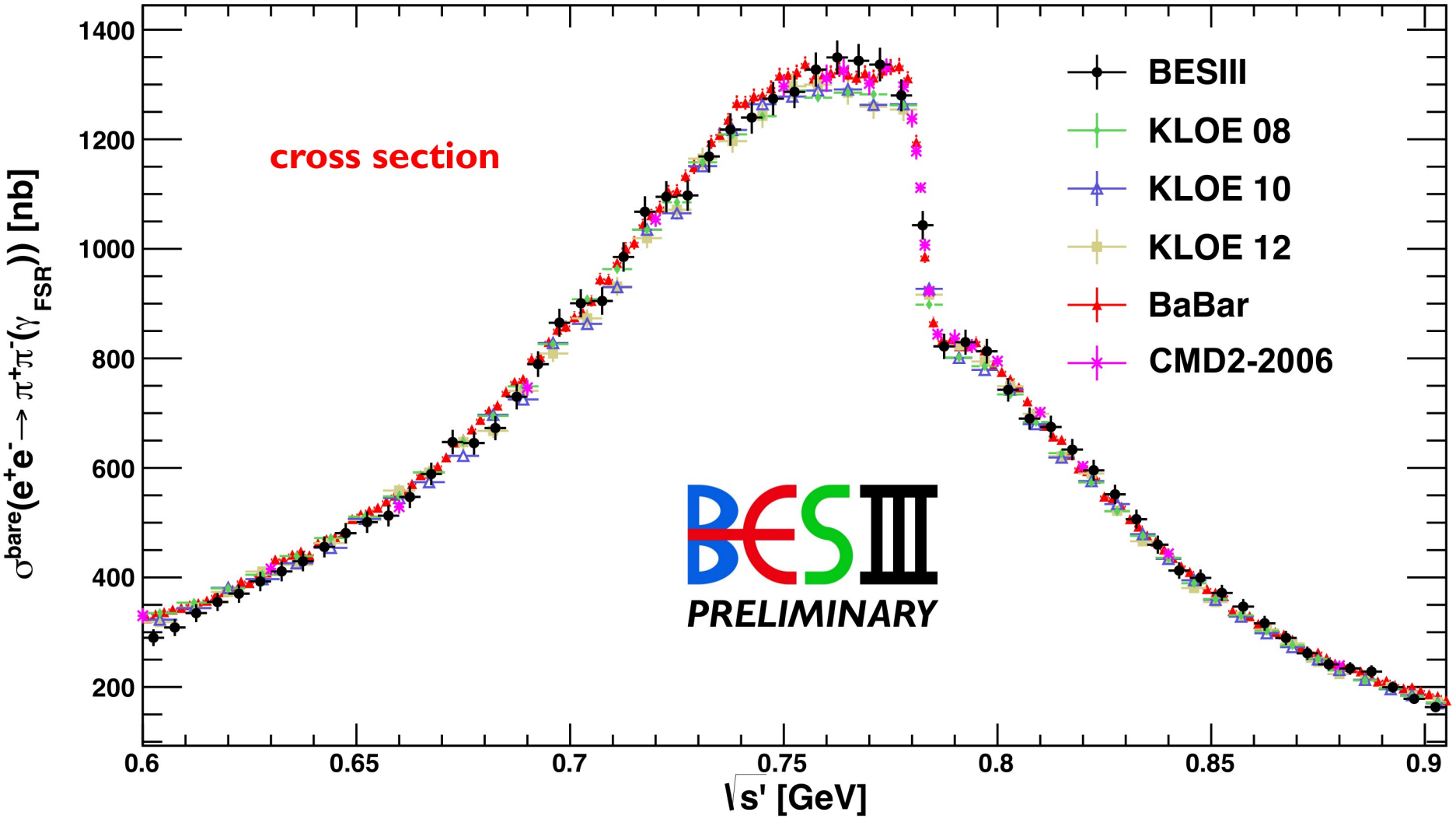
Fit Parameters



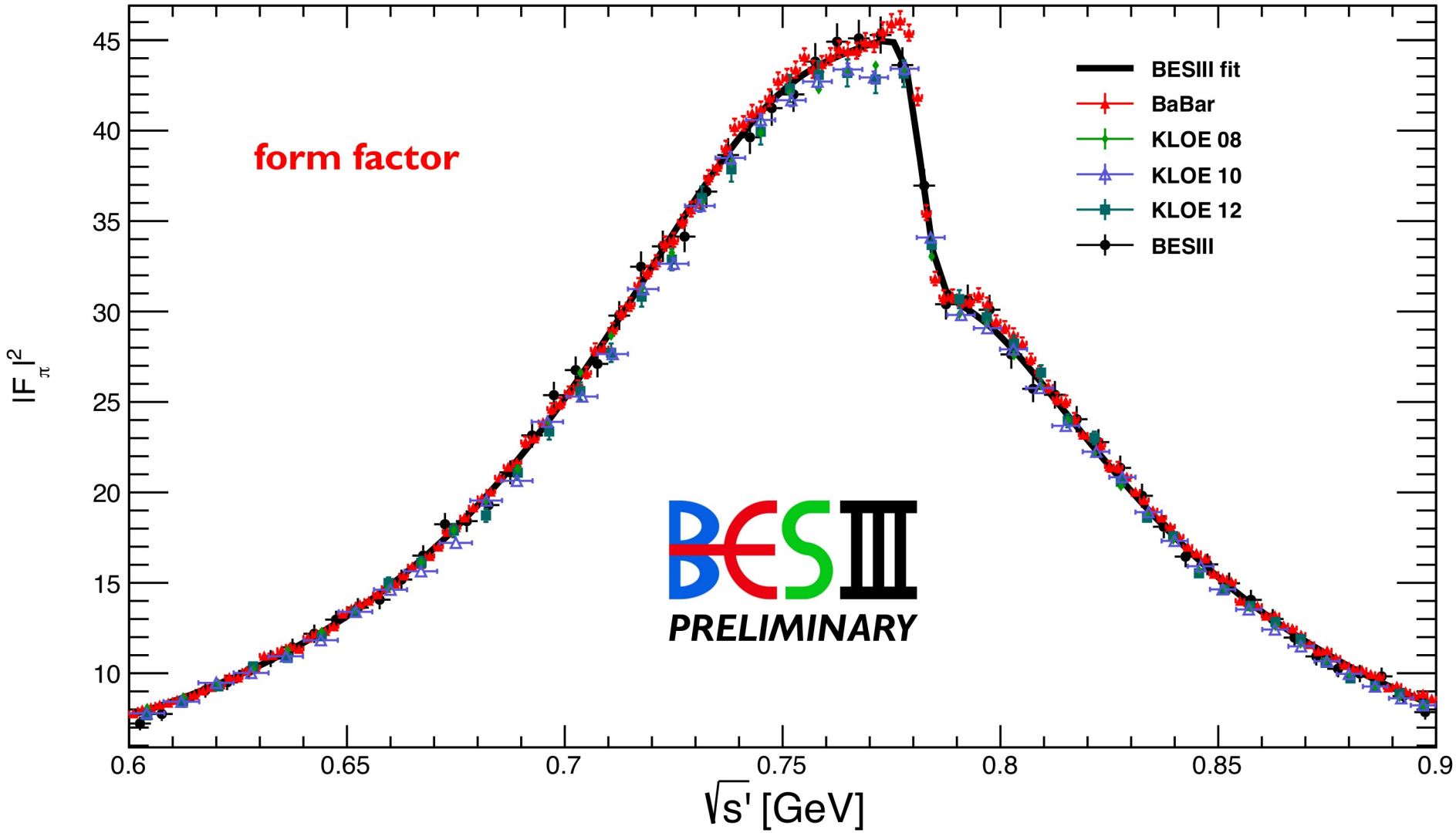




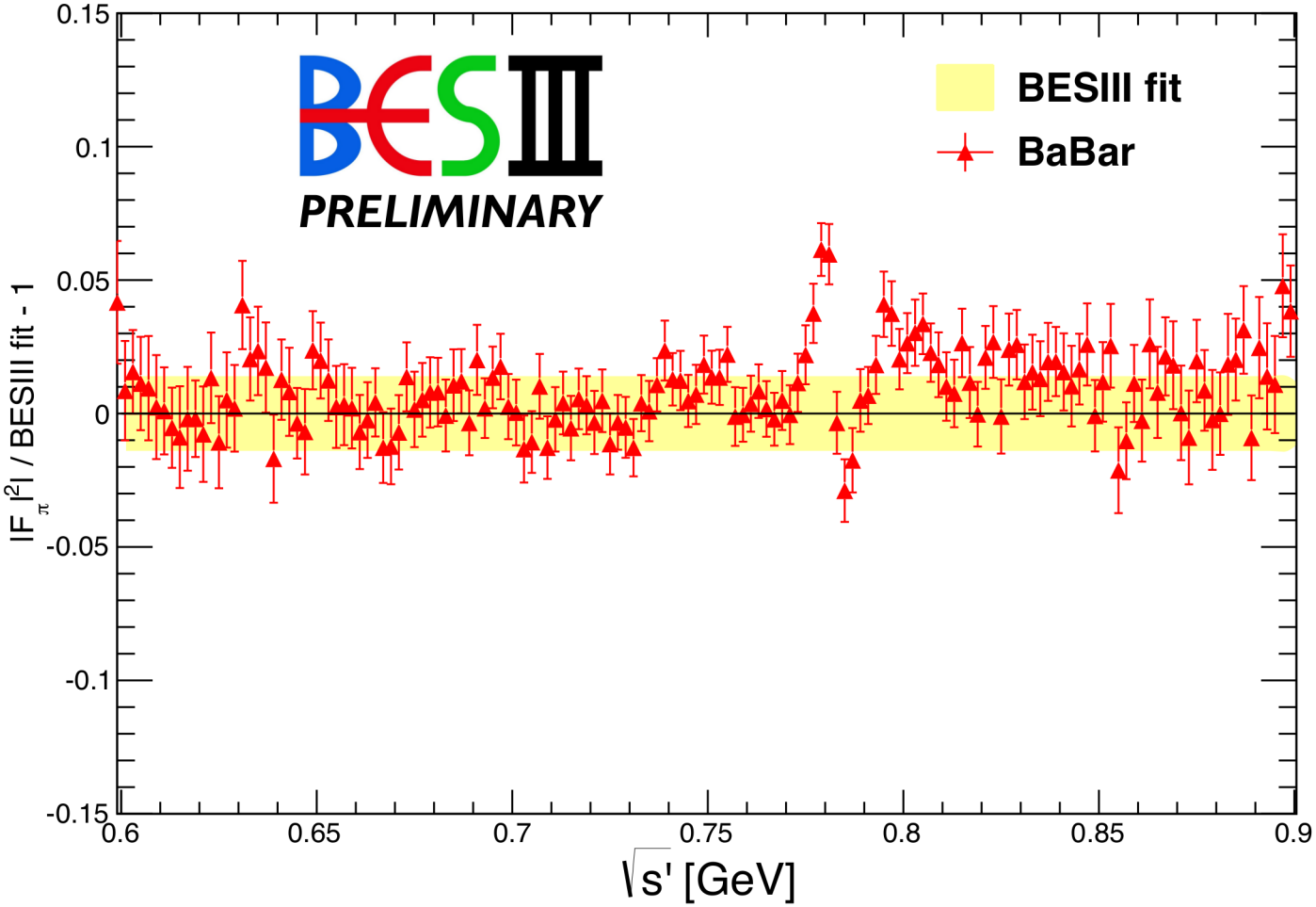
Comparison: Cross Section



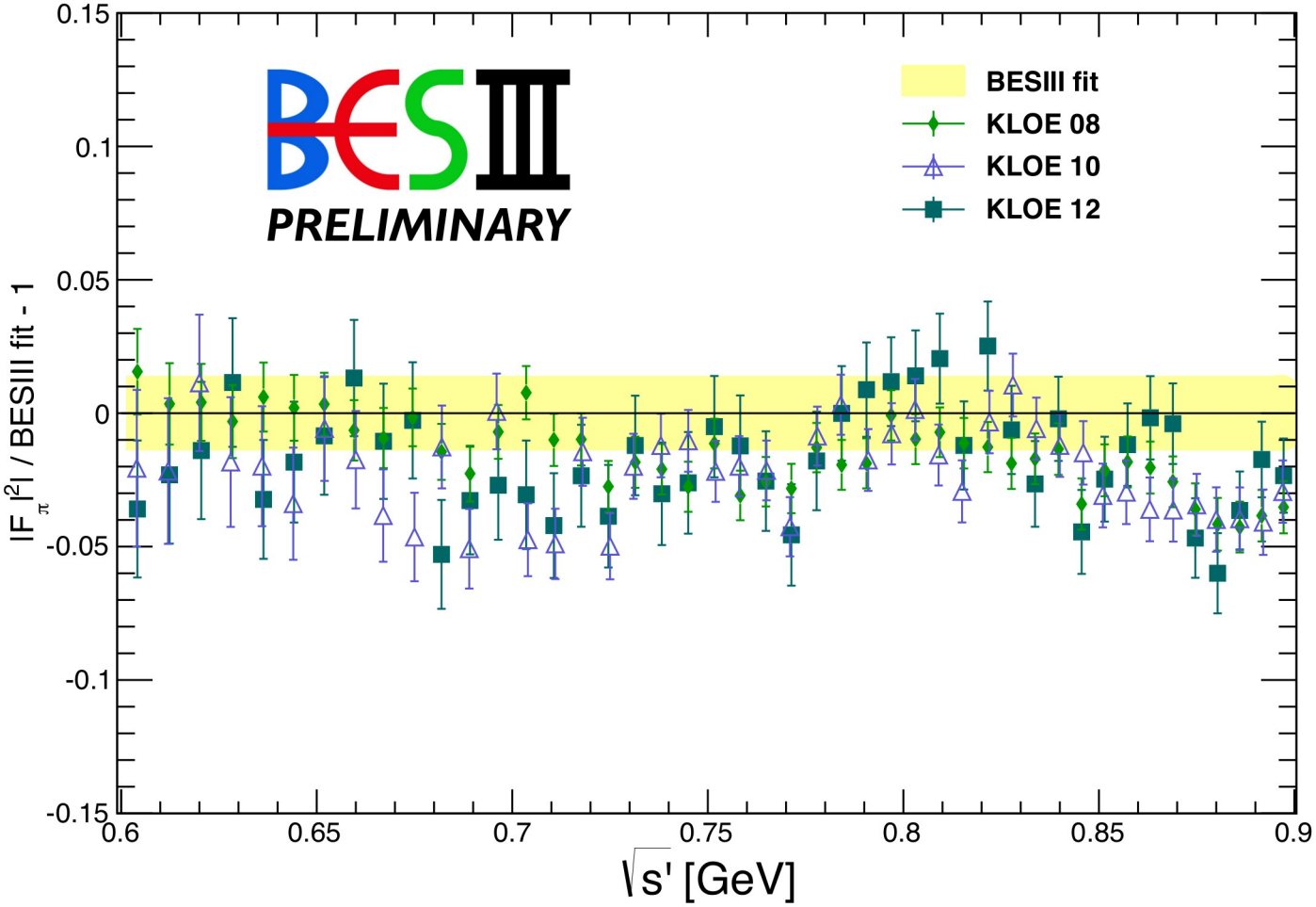
Comparison: Form Factor



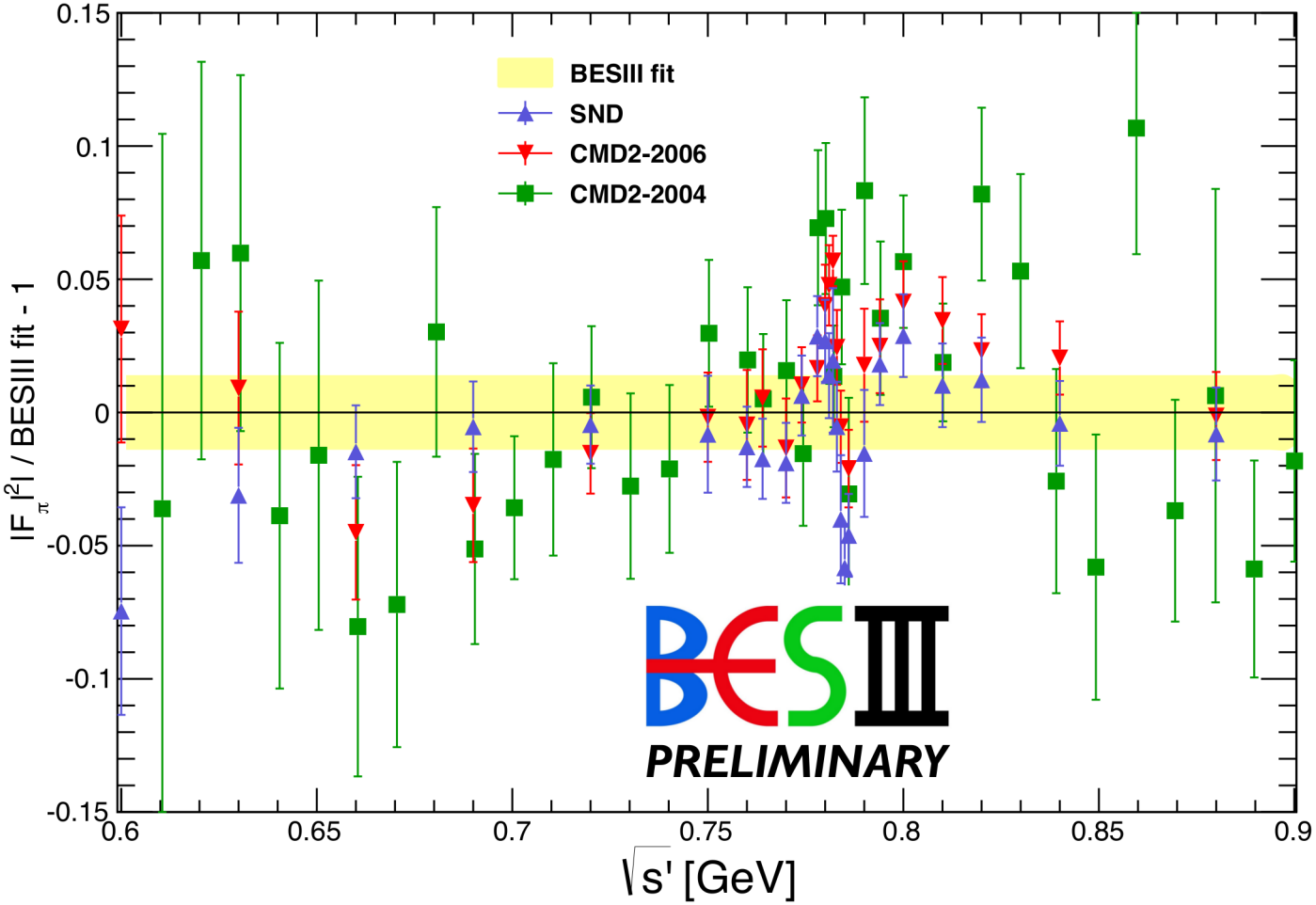
Comparison to BaBar



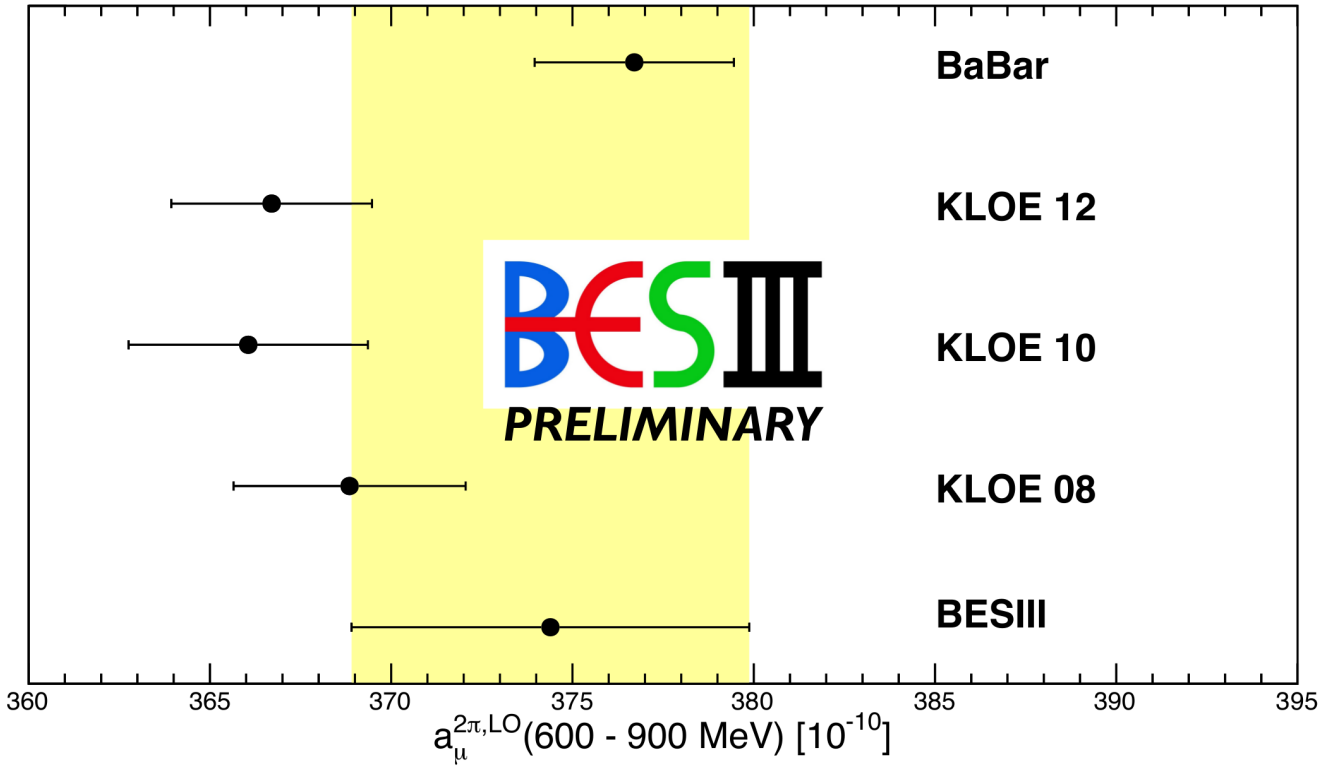
Comparison to KLOE



Comparison to CMD and SND



Result for $(g-2)_\mu$



Experiment	$a_\mu^{2\pi,LO}$ (600 – 900 MeV) [10^{-10}]
BaBar	$376.7 \pm 2.0_{stat} \pm 1.9_{sys}$
KLOE 08	$368.9 \pm 0.4_{stat} \pm 2.3_{sys,exp} \pm 2.2_{sys,theo}$
KLOE 10	$366.1 \pm 0.9_{stat} \pm 2.3_{sys,exp} \pm 2.2_{sys,theo}$
KLOE 12	$366.7 \pm 1.2_{stat} \pm 2.4_{sys,exp} \pm 0.8_{sys,theo}$
BESIII (preliminary)	$374.4 \pm 2.6_{stat} \pm 4.9_{sys}$

Summary

- BESIII measurement confirms Δa_μ^{had}
- Systematic uncertainty dominating
  - Current precision: 1.3 %

- Outlook
  - Reduce contribution of luminosity measurement
  - Factor three more statistics available at BESIII
  - Investigate full mass range
  - Tagged and untagged measurements