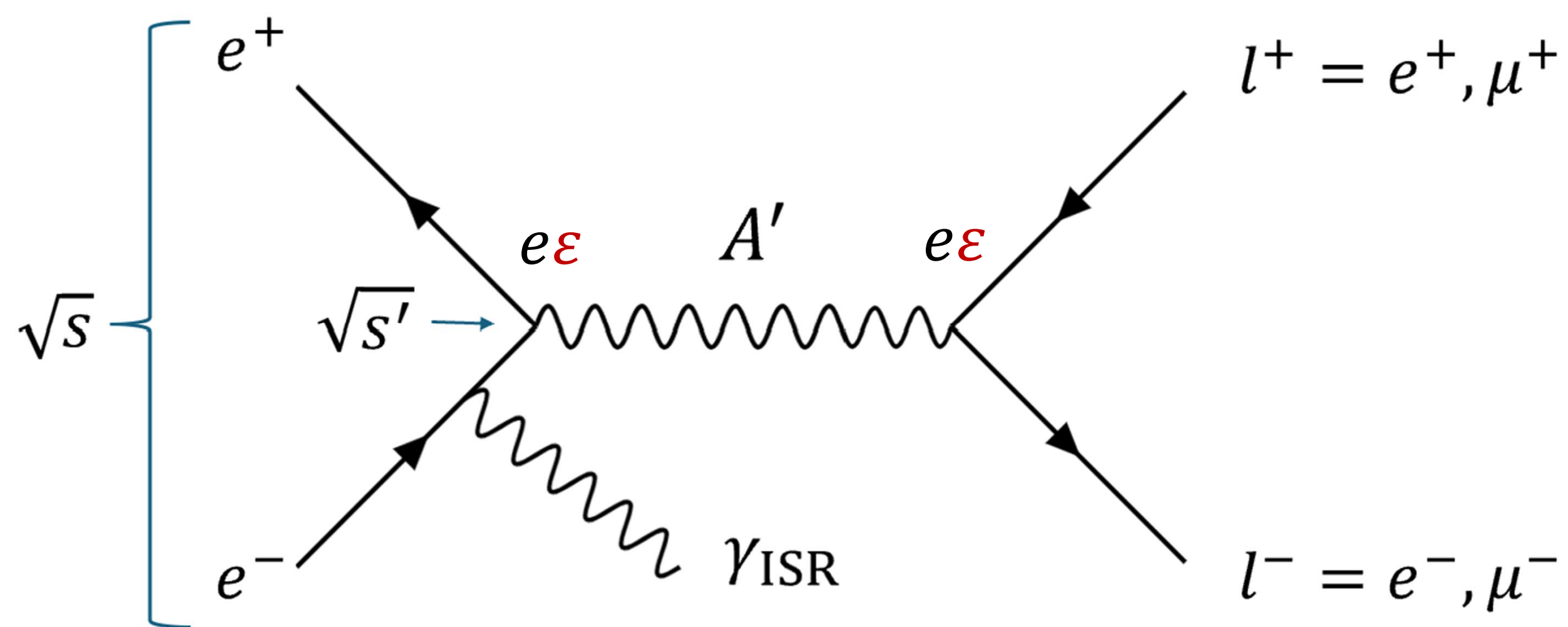


Analysis Goal

- **Dark Photon A'** : $U(1)$ gauge boson of Dark Sector
- **Kinetic mixing** $\Rightarrow$ coupling with Standard Model [5,7]
- Search for **visible decay** at BESIII: $A' \rightarrow e^+e^-, \mu^+\mu^-$



- Scan final state invariant mass with **ISR**
- This analysis: **semi-blinded strategy**
- Recreate old analysis with 2.9 fb^{-1} data at $\psi(3770)$ [2]
- Unblind $\Rightarrow$ analyze full (new) 20.3 fb^{-1} data set

Expected Signal

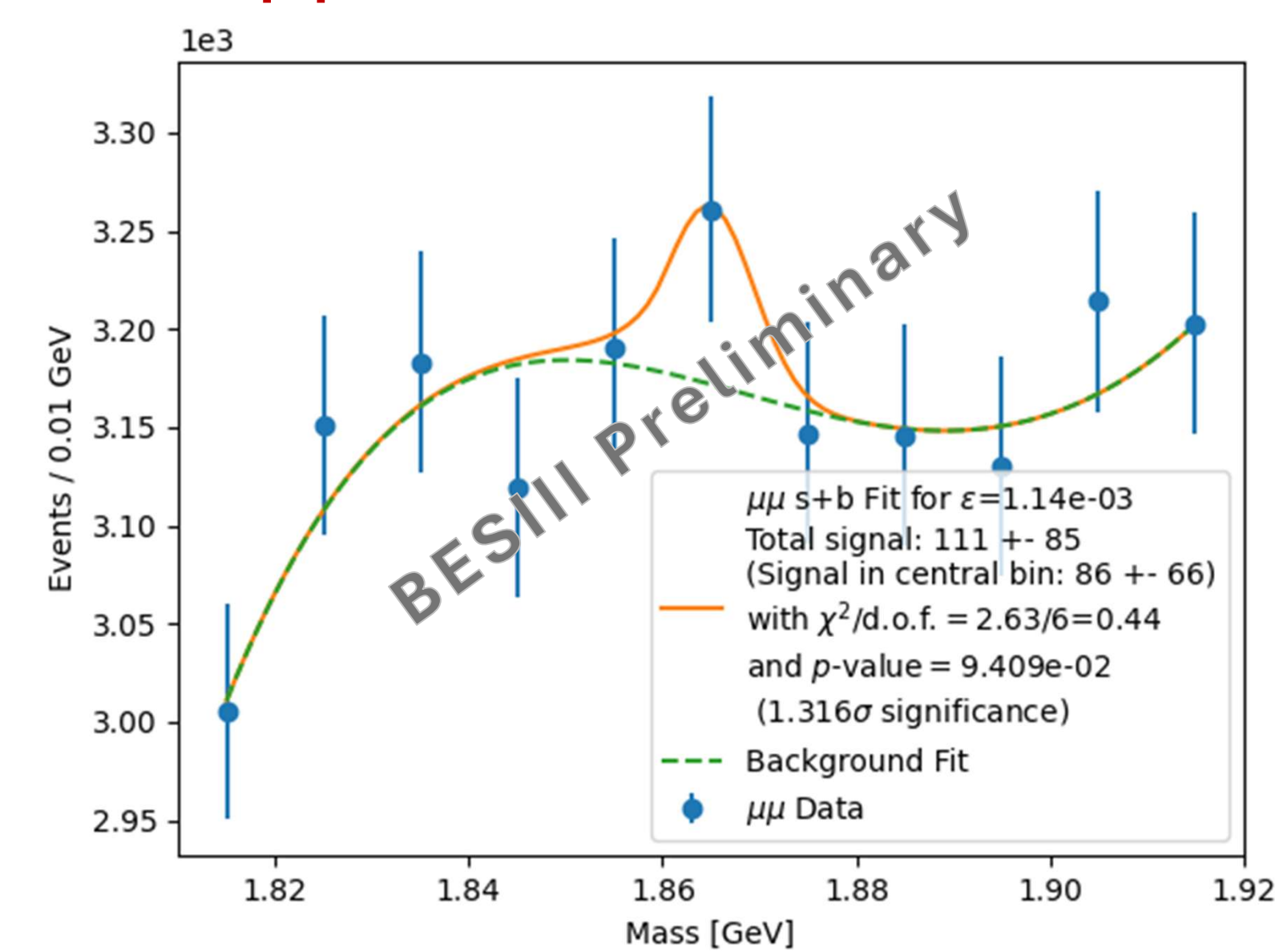
- **Signal-to-background ratio** $\Leftrightarrow$ Cross section ratio [4]

$$\frac{s_{ll}}{b_{ll}} = \frac{d\sigma_{\text{dark}}}{d\sigma_{\text{QED}}} \Rightarrow s_{ll} = \varepsilon^2 \cdot (b_{ll} \cdot f) \cdot \frac{\pi}{2\tilde{\Gamma}} \cdot \frac{m_{A'}^2}{\delta m}$$

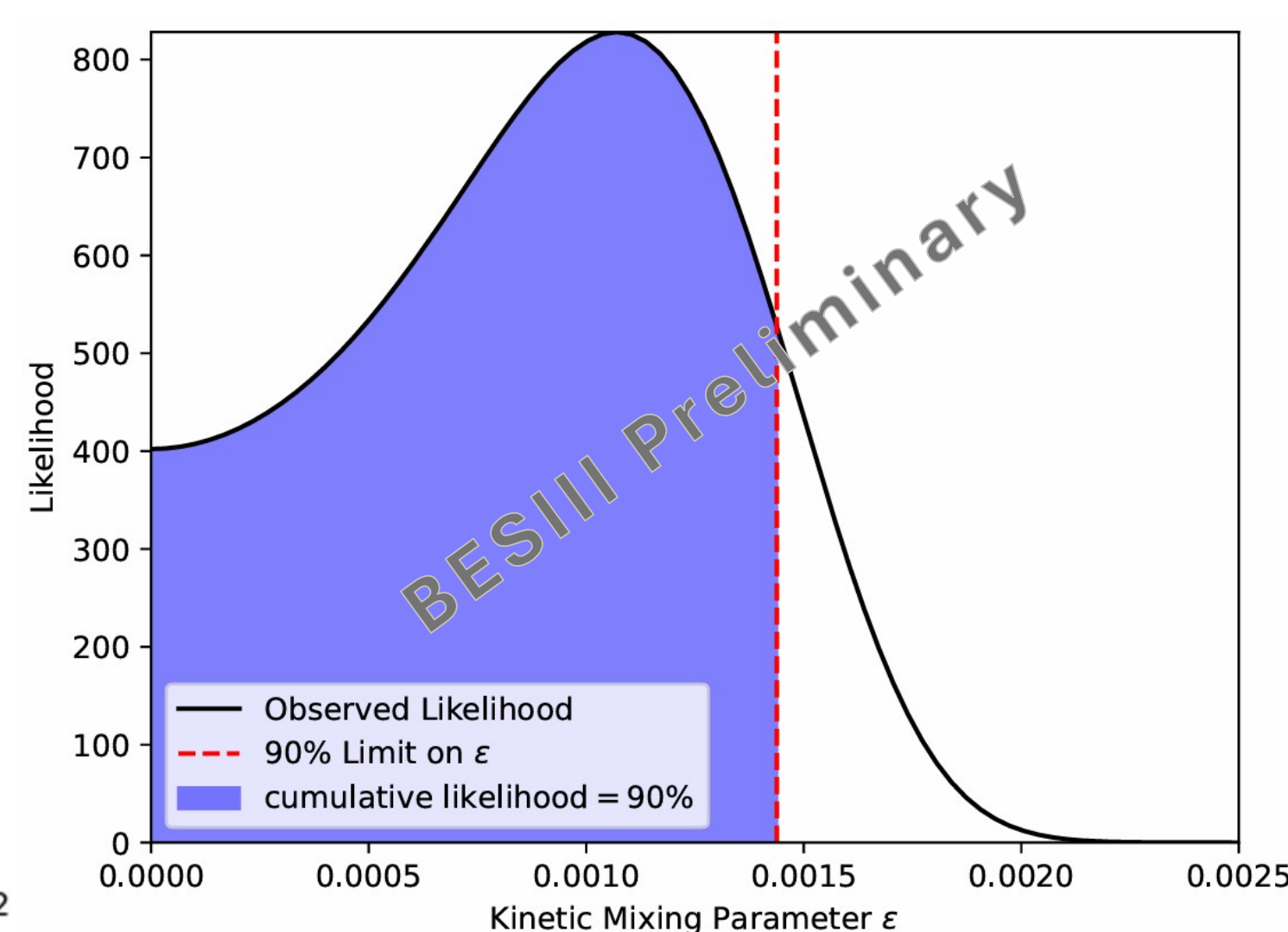
- f : t -channel suppression factor for e^+e^-
- $\tilde{\Gamma} = \Gamma/\varepsilon^2$: total visible decay width

Fits to Invariant Mass Spectra

- **Signal + background fits** for different ε
- Sliding mass window (width δm)
- Likelihood $L = e^{-\frac{1}{2}\chi^2}$
- No signals with significance: $Z = \sqrt{-2 \ln \left(\frac{L_0}{L_{\text{max}}} \right)} > 3\sigma$
 $\Rightarrow$ **upper limit $\varepsilon^{\text{limit}}$** with 90% CL



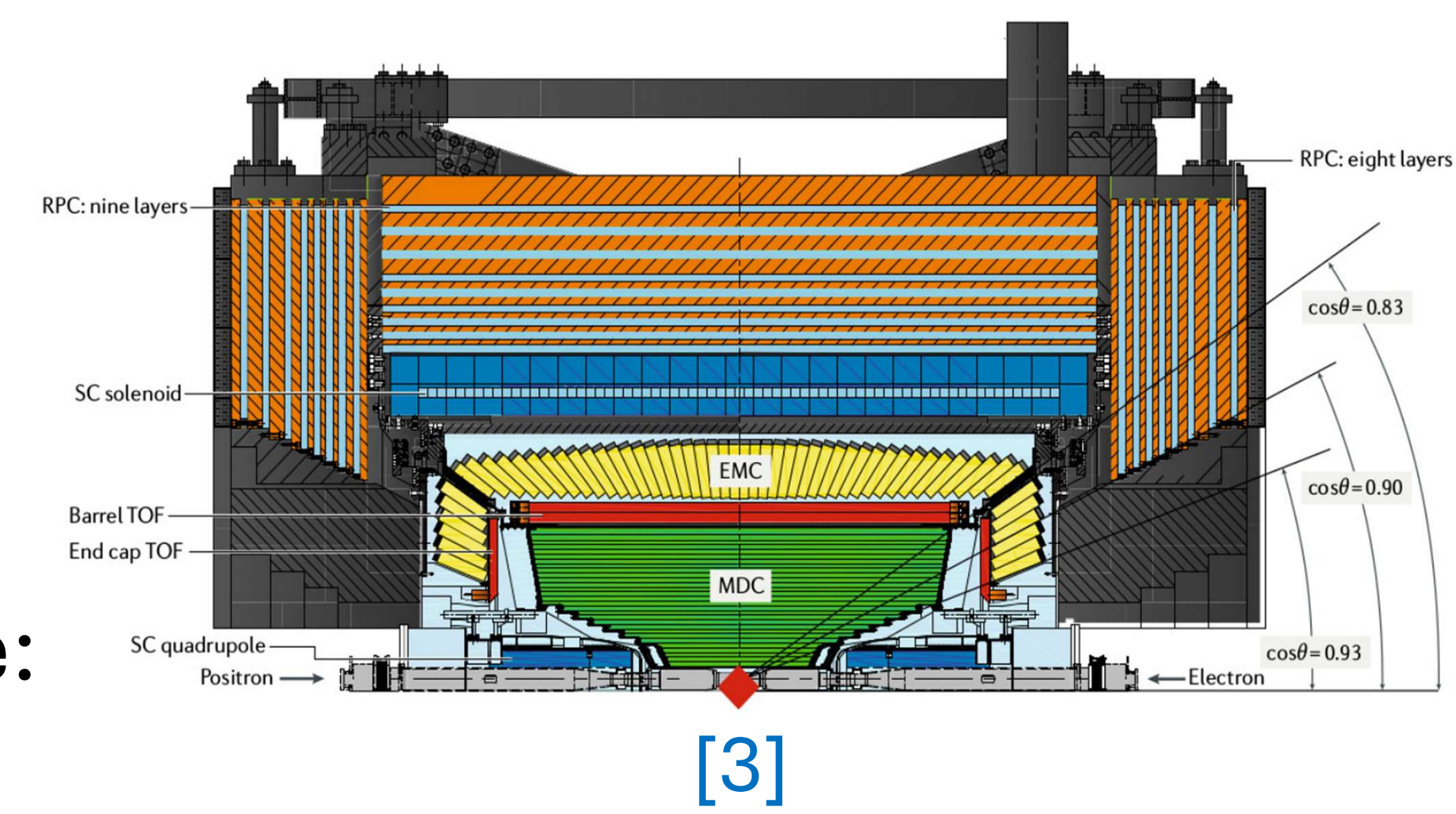
Example fit at $m_{\mu\mu} = 1.865 \text{ GeV}$



L vs. ε at $m = 1.865 \text{ GeV}$

BESIII Detector

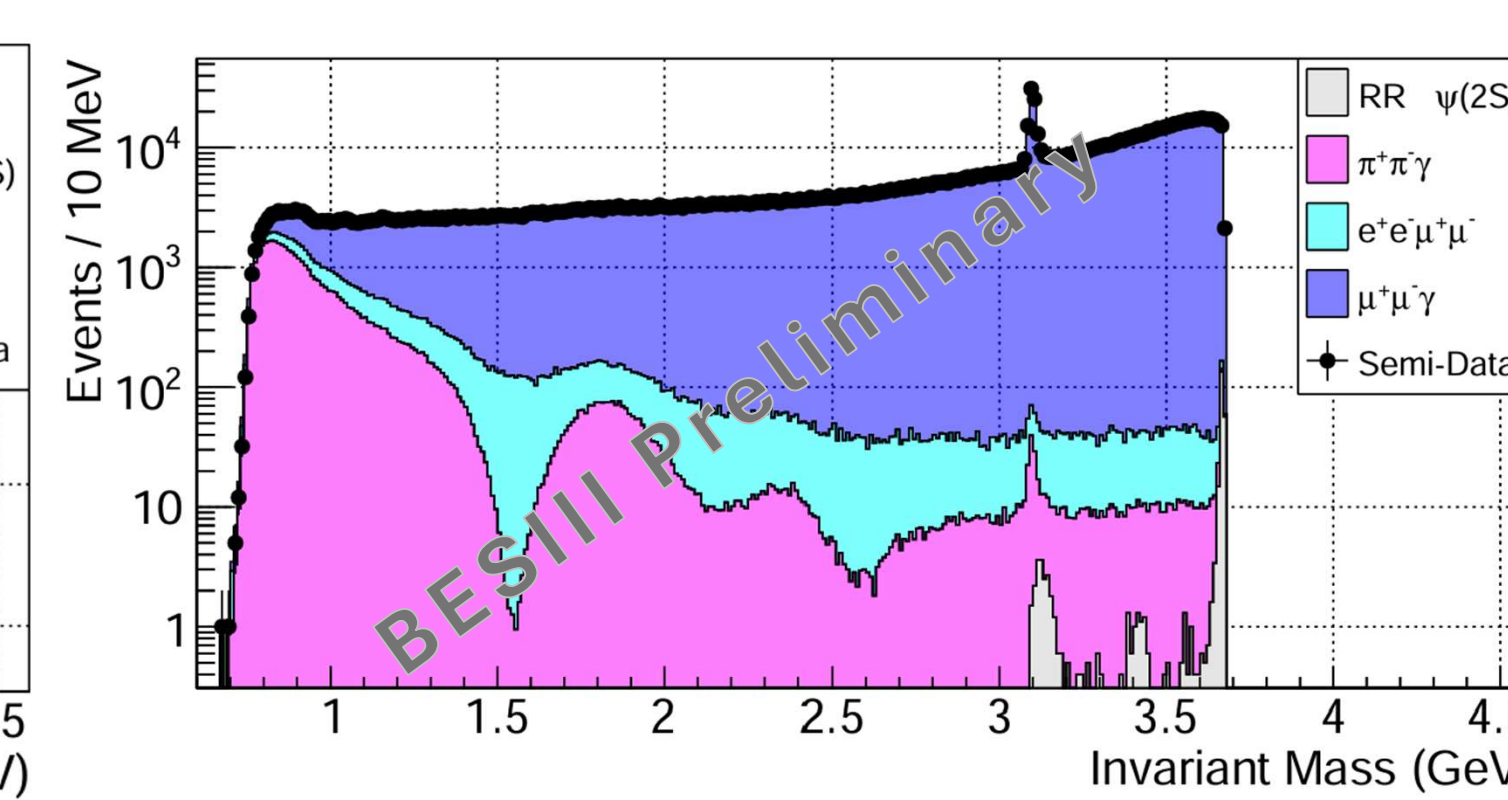
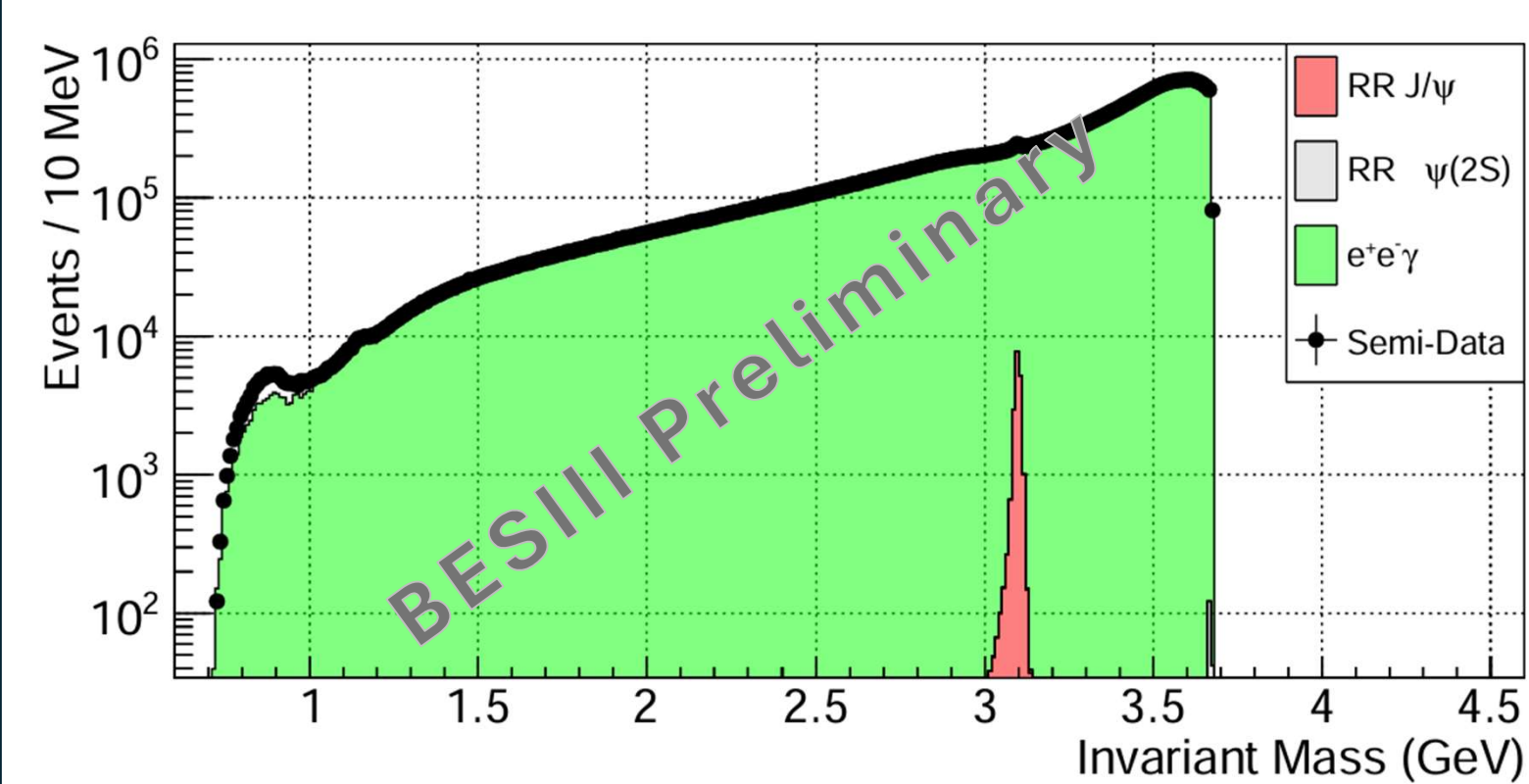
- e^+e^- Collisions at $\sqrt{s} \approx 2 - 5 \text{ GeV}$
- Peak luminosity: $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ at $\sqrt{s} = 3.773 \text{ GeV}$
- Solid angle coverage: $\Delta\Omega/4\pi = 93\%$



[3]

Event Selection

- Tracks:
 - **2 good tracks**, total charge 0, $p_T > 0.3 \text{ GeV}$
 - Opening angle: $5^\circ < \angle(l^+l^-) < 178^\circ$
- Untagged ISR Photon:
 - **Kinematic fit** with **missing photon** ($\chi^2 < 35$)
 - Small polar angle: $\theta_\gamma^{1C} < 0.1 \text{ rad}$ or $\theta_\gamma^{1C} > (\pi - 0.1) \text{ rad}$
- $e^+e^-\gamma$: $0.8 < E/p < 1.2$
- $\mu^+\mu^-\gamma$: $0.05 < E/p < 0.3$

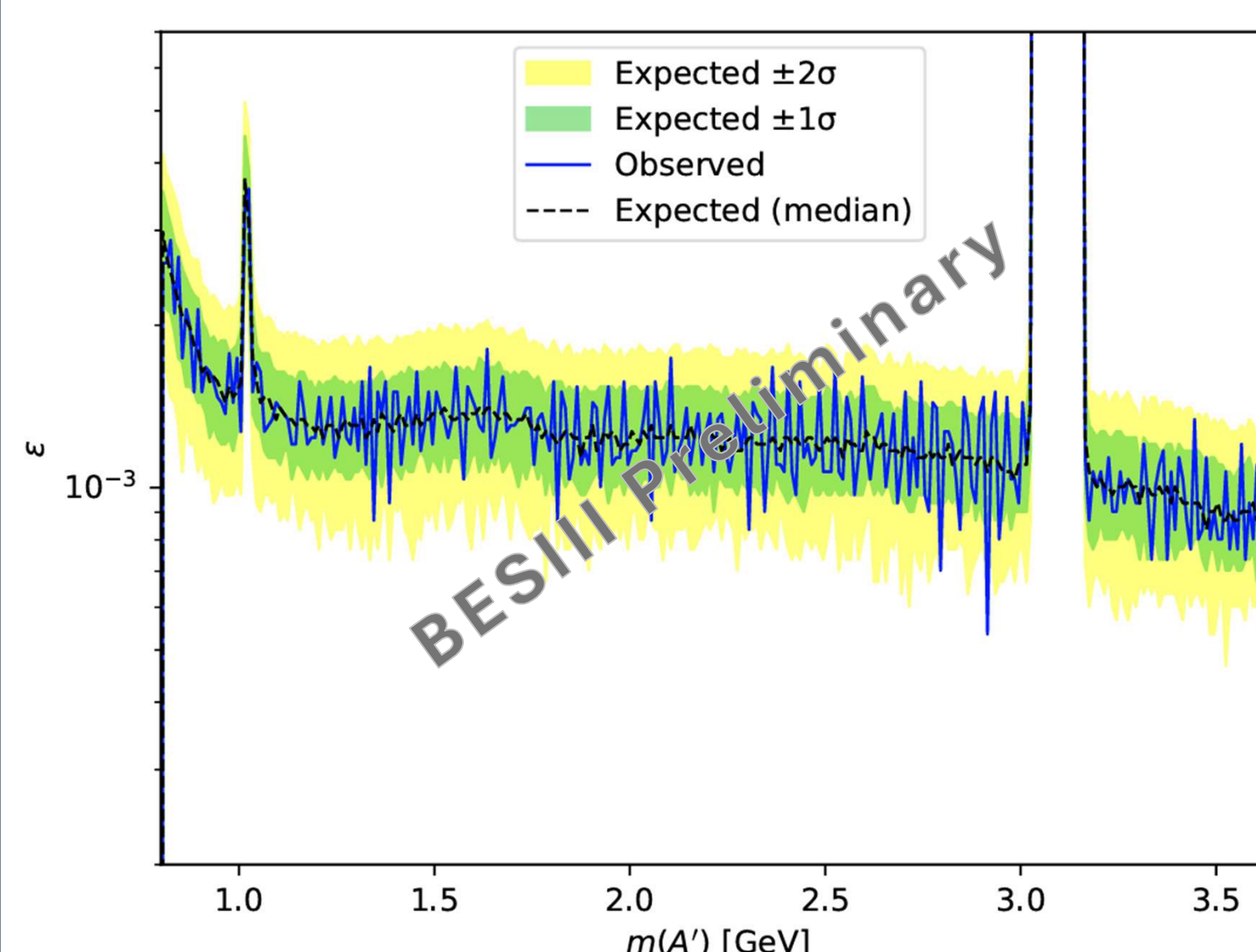


- Mass range: $0.8 - 3.66 \text{ GeV}$ (exclude J/ψ and $\psi(2S)$)

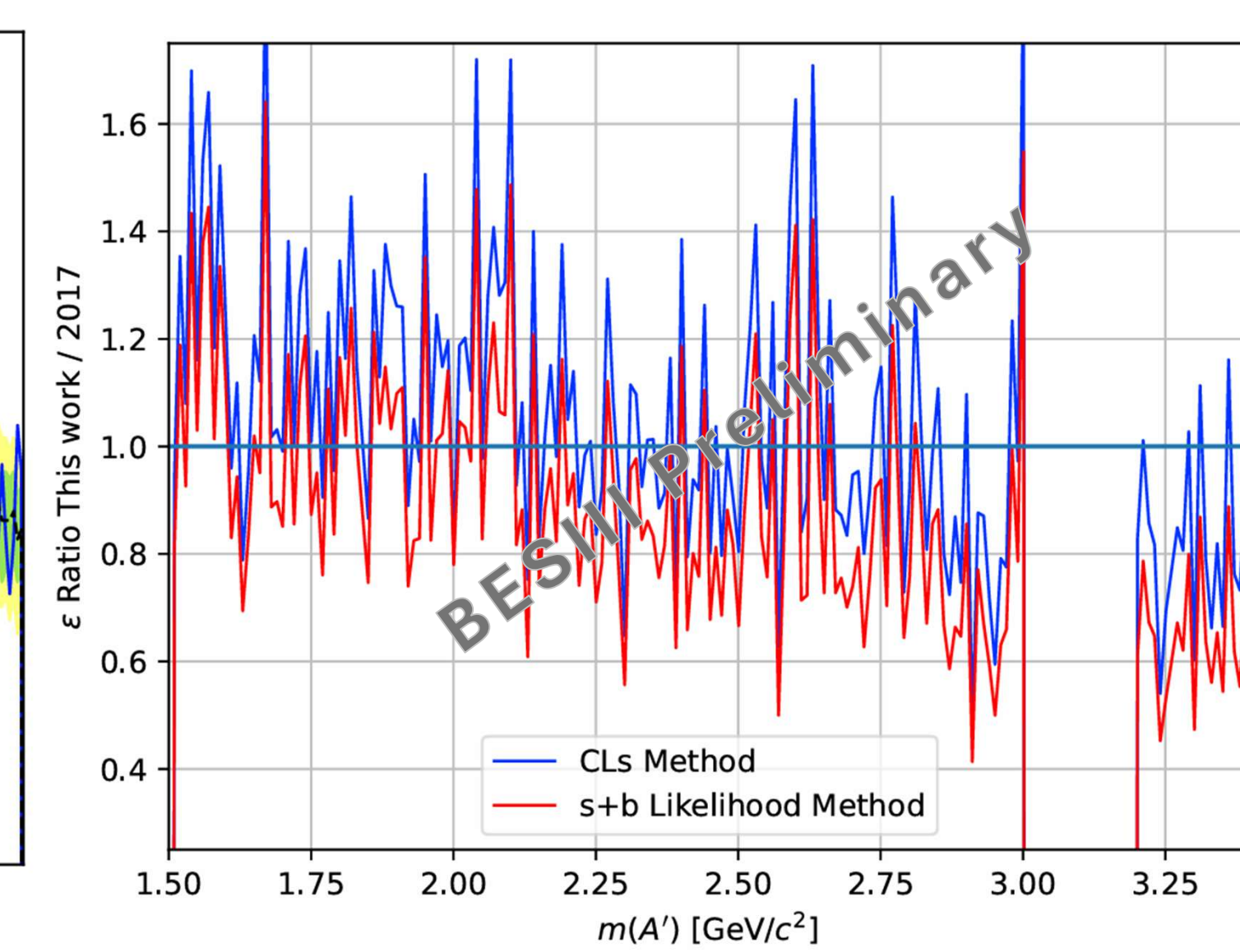
Cross-check: CL_s Method

- Modified frequentist **CL_s method** [9]
- Exclusion limit on ε : where **$CL_s = 0.1$**
- Observed ε limits within expected statistical fluctuations
 $\Rightarrow$ **consistent with null hypothesis**

$$CL_s \equiv \frac{CL_{s+b}}{CL_b}$$



ε Upper limits



Comparison with BESIII 2017

- **Overall agreement** between analyses of 2.9 fb^{-1} data

Analysis of Total Data Set

- Full **20.3 fb^{-1}** data set: $7 \times$ statistics
 - Exclusion limit (90% CL) improvement: $\varepsilon^{\text{limit}} \propto \sqrt{\frac{s^{\text{limit}}}{b}} \propto \sqrt{\frac{1}{7 \times b}}$
- **New BESIII exclusion limits**:
 - improve upon BESIII (2017) [2], BABAR (2014) [8], LHCb (2019) [1]
 - complement CMS (2023) [6] for $m = 2.54 - 3.64 \text{ GeV}$

