Phase difference between strong and electromagnetic amplitudes via the lineshape scan of the J/ψ resonance

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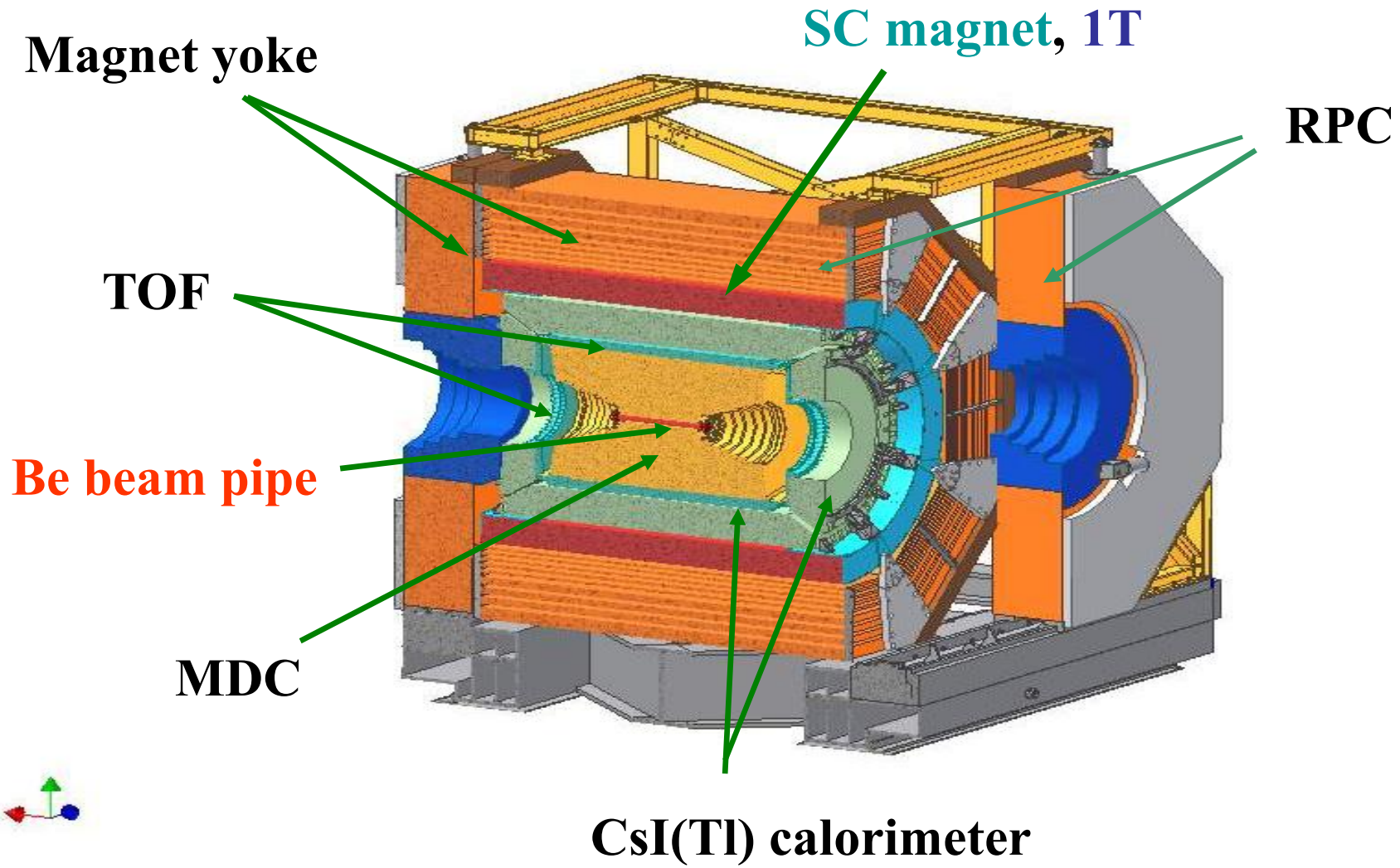
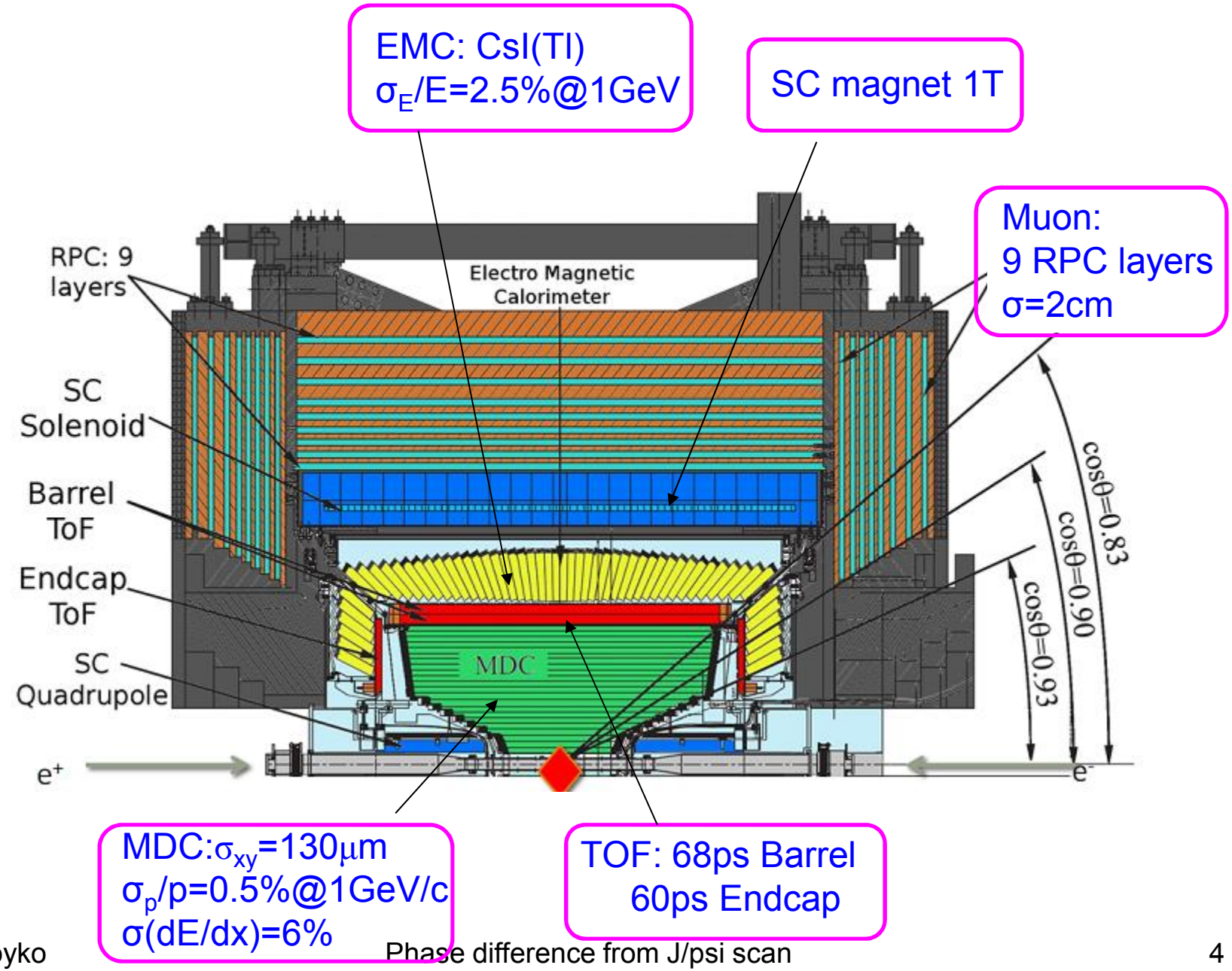
Beijing Electron-Positron Collider (BEPCII)

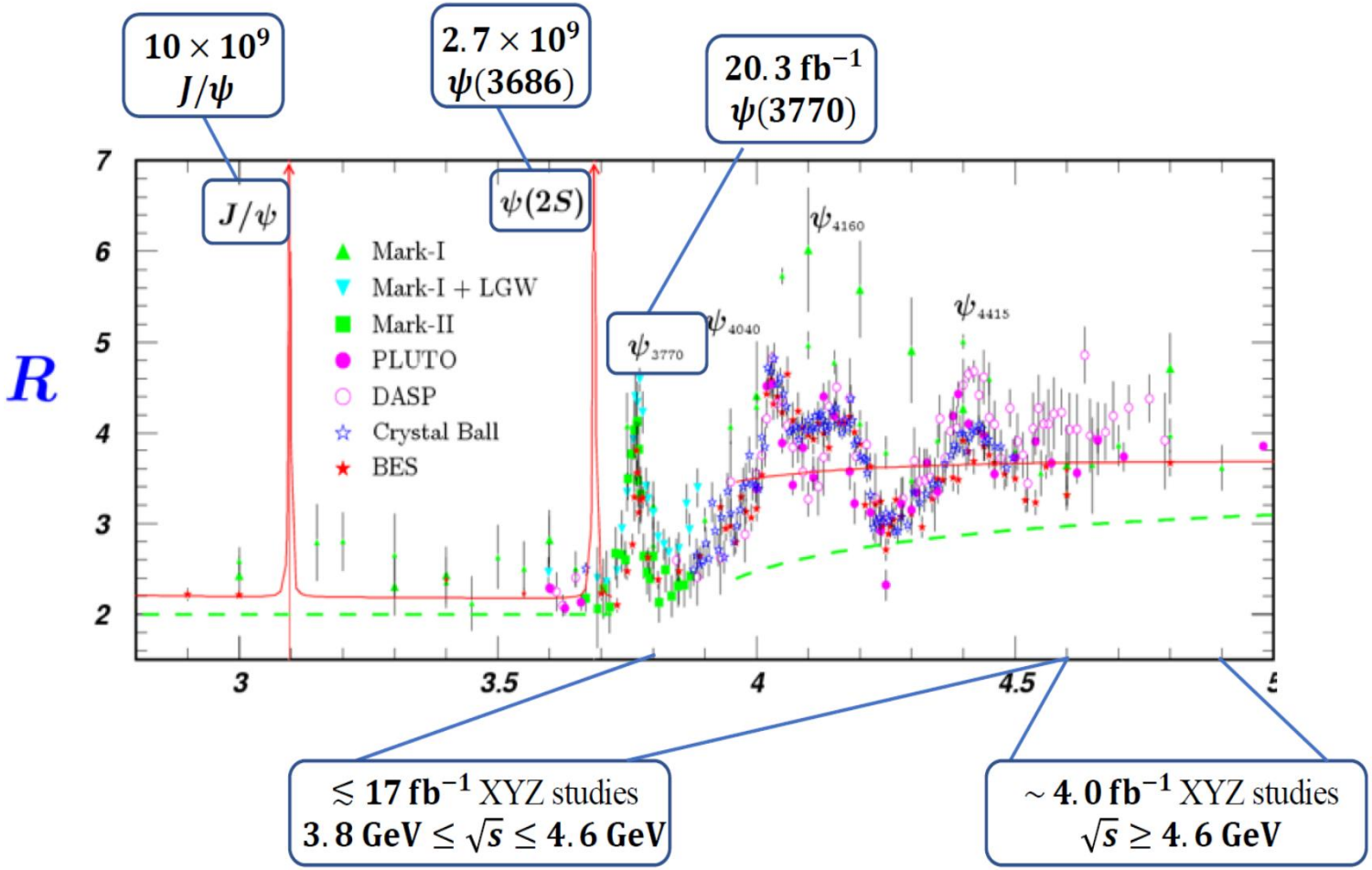
- Construction: 2004 - 2008
- Data taking: 2009 – now
- Energy range: 2.0 – 4.9 GeV
- Peak luminosity: $1.0\times10^{33}cm^{-2}s^{-1}$ (design) $1.1\times10^{33}cm^{-2}s^{-1}$ (reached)
- Energy spread: ~$3x10^{-4}$ @J/ψ
- Circumference: 237m

BESIII detector

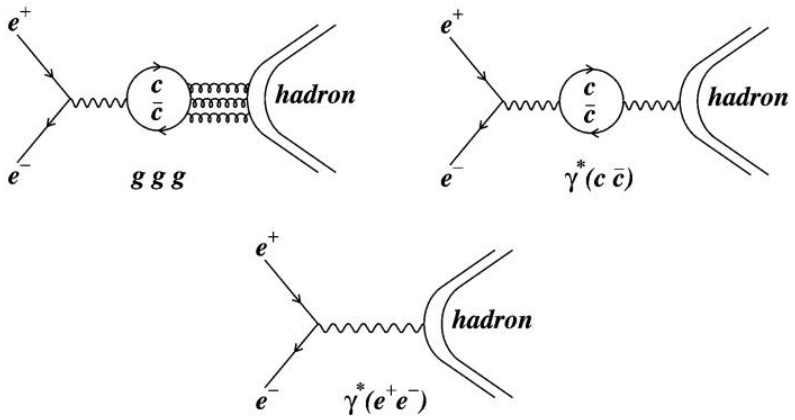



EMC: CsI(Tl)
σ_E/E=2.5%@1GeV
SC magnet 1T
Muon:
9 RPC layers
σ=2cm
RPC: 9 layers
Electro Magnetic Calorimeter
SC Solenoid
Barrel ToF
Endcap ToF
SC Quadrupole
MDC
cosθ=0.83
cosθ=0.90
cosθ=0.93
e+
e-
MDC:σ_{xy}=130μm
σ_p/p=0.5%@1GeV/c
σ(dE/dx)=6%
TOF: 68ps Barrel
60ps Endcap

BESIII datasets



Hadron production near charmonium resonance

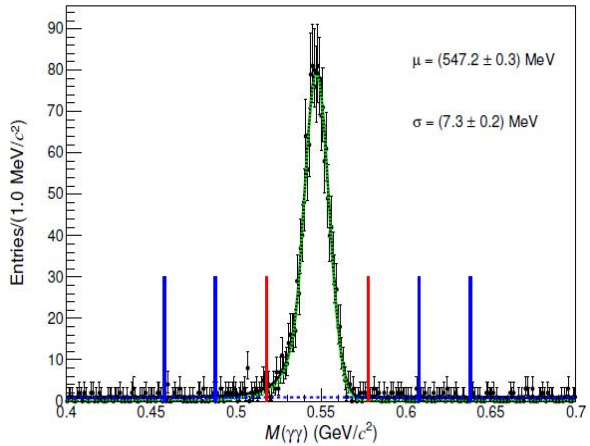


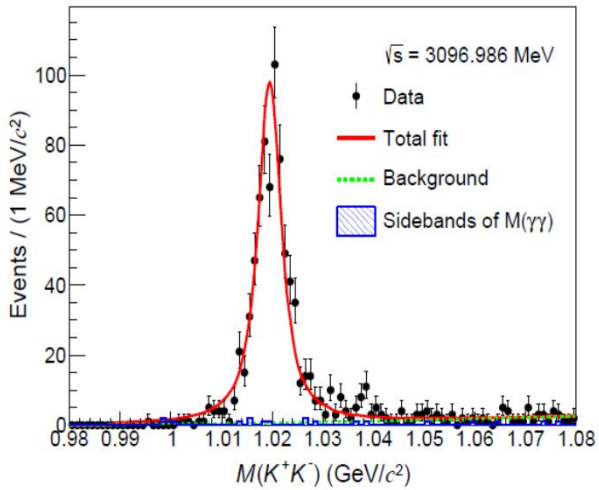
$$\sigma_{tot}(s) \propto \left|\mathcal{A}_{QED}(s) + \mathcal{A}_{\gamma}(s) + \mathcal{A}_{3g}(s)\right|^2$$
$$= \left|\mathcal{A}_{QED}(s) + \mathcal{A}_{R}(s)(1 + Ce^{i\phi_{\gamma,3g}})\right|^2$$

- Predictions of the relative phase $\varphi_{\gamma,3g}$ between γ and gluon exchange:
  - pQCD: 0^o or 180^o
  - SU(3) flavor symmetry: 90^o
  - [Phys. Rep. 174 67 (1989)]
- Phase between resonant and non-resonant γ exchange is expected to be zero
  - [Phys. Rev. Lett. 34 1357 (1975)]
- We report a determination of $\varphi_{\gamma,3g}$ from $e^+e^- \to \varphi\eta$, $\varphi \to K^+K^-$, $\eta \to \gamma\gamma$

Signal selection

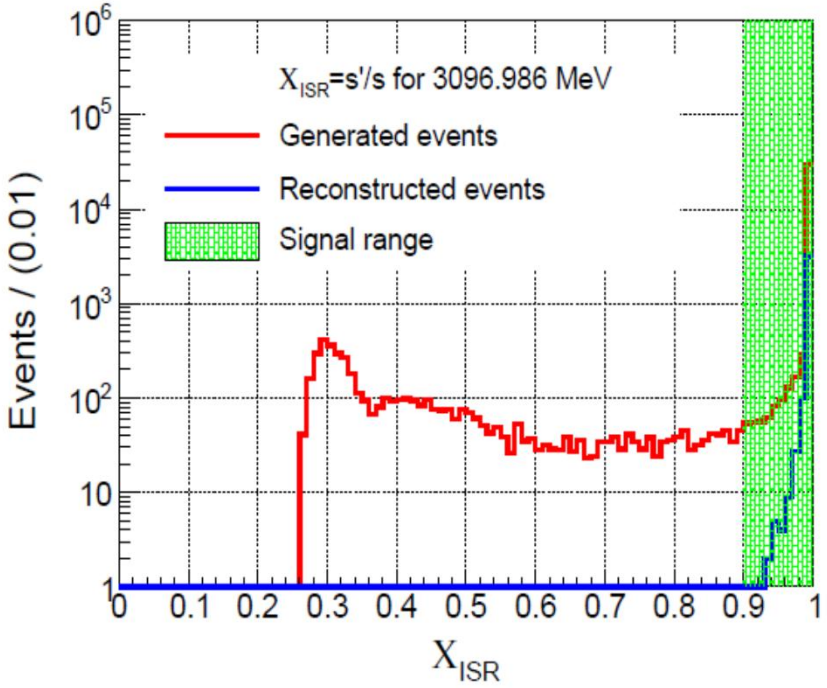
- Two opposite-charge tracks identified as kaons
- Two well-reconstructed photons not associated with showers from charged particles.
  - $E\gamma$ >25MeV (barrel)
  - $E\gamma$>50 MeV (end-caps)
- 4C kinematic fit.
  - 4-momentum of $K^+K^-\gamma\gamma$ is constrained to e^+e^- system.
  - χ^2_{4c}<85
- Signal is extracted from a fit to $M(K^+K^-)$ distribution, within η window of $M(\gamma\gamma)$. Sidebands of $M(\gamma\gamma)$ are used to subtract background



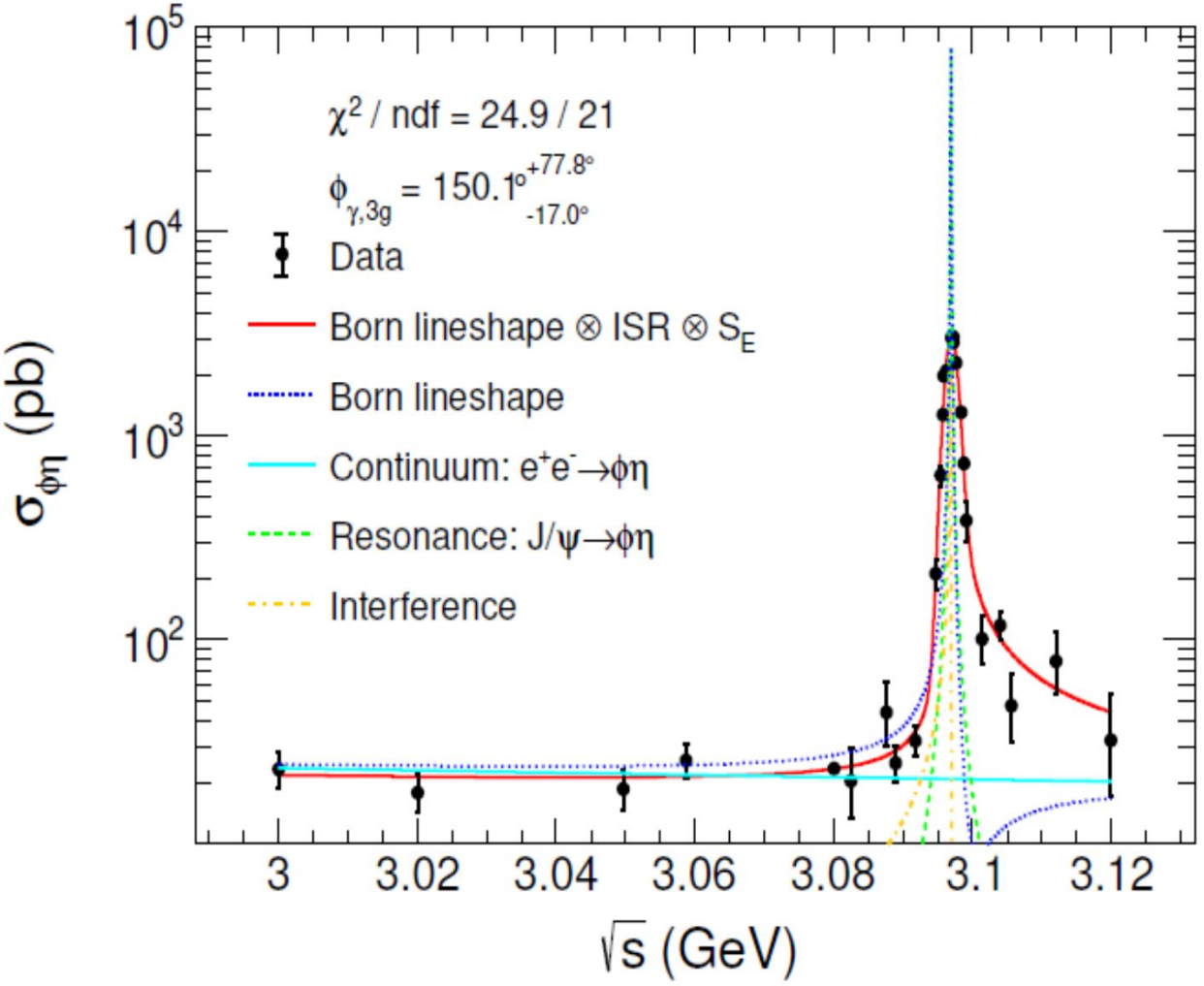


Initial-state radiation

- An ISR photon can be radiated by a beam particle, reducing the actual collision energy from nominal $\sqrt{s}$ to a lower value $\sqrt{s'}$.
- Due to the 4C fit, only the events with $x=s'/s$ close to 1 survive the selection.
- The measured cross-section σ^{obs} is reported for the $x>0.9$ fiducial region.



Measured cross-sections



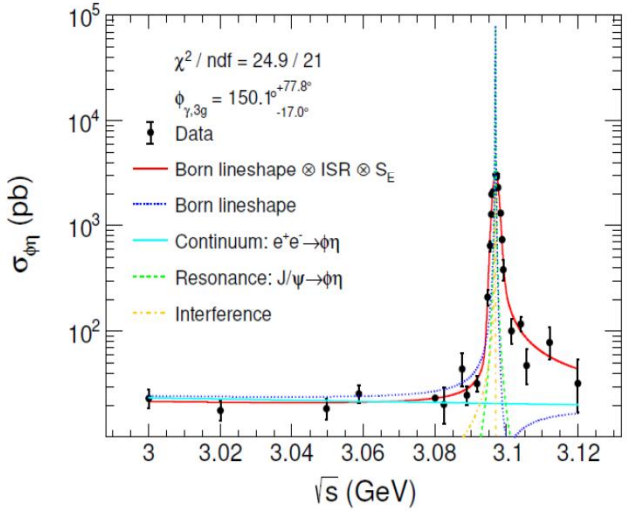
Fit to the measured cross-sections

$$\sigma^{Born}(s) = \mathcal{P}_{\phi\eta}(s) \cdot \left(\frac{\mathcal{F}}{s^{1.5}}\right)^2 \cdot \frac{4\pi\alpha^2}{3s} \cdot \left|1 + \frac{3}{\alpha}\frac{s}{M}\frac{\Gamma_{ee}}{s - M^2 + iM\Gamma}\left(1 + C \cdot e^{i\phi_{\gamma,3g}}\right)\right|^2$$

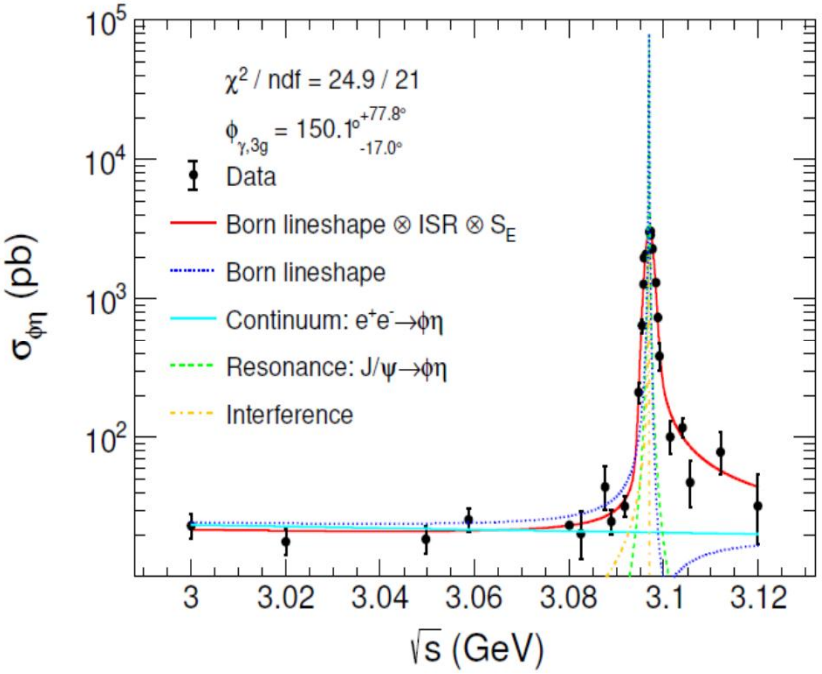
$$\sigma^{exp}(s) = \int_{\sqrt{s}-5S_E}^{\sqrt{s}+5S_E} d\sqrt{s'}\, GS(s', S_E) \int_0^{1-X_{ISR}} dx\, F(s', x) \cdot \sigma^{Born}(s' \cdot (1 - x))$$

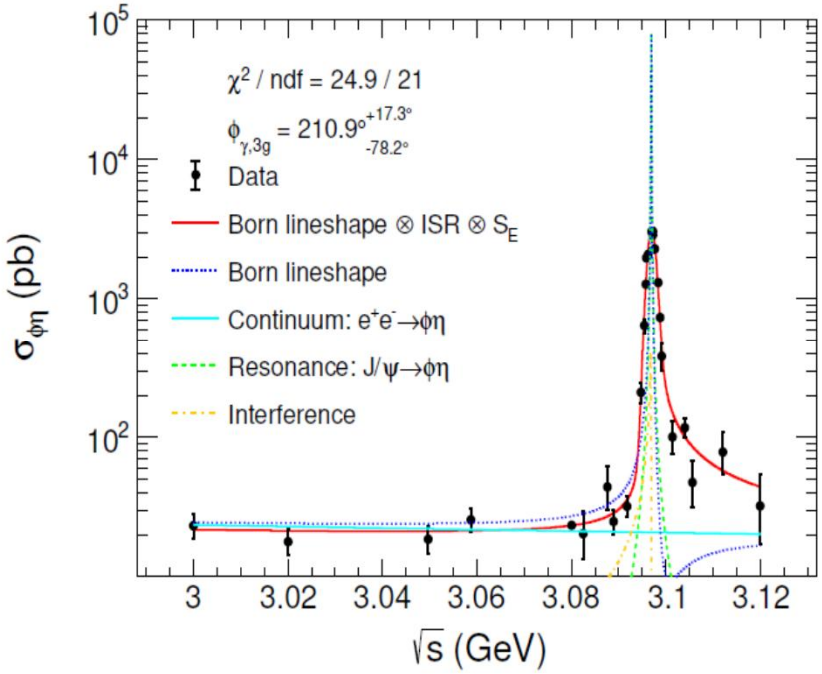
- $\mathcal{P}_{\phi\eta}(s) = \left(\frac{\left(s - M_\phi^2 - M_\eta^2\right)^2 - 4M_\phi^2 M_\eta^2}{s}\right)^{3/2}$: phase space of final states

- $GS(s', S_E)$ is the Gaussian function
- S_E is the energy spread
- $F(s', x)$ is the ISR function
- $\sqrt{s'}$ is an integration parameter



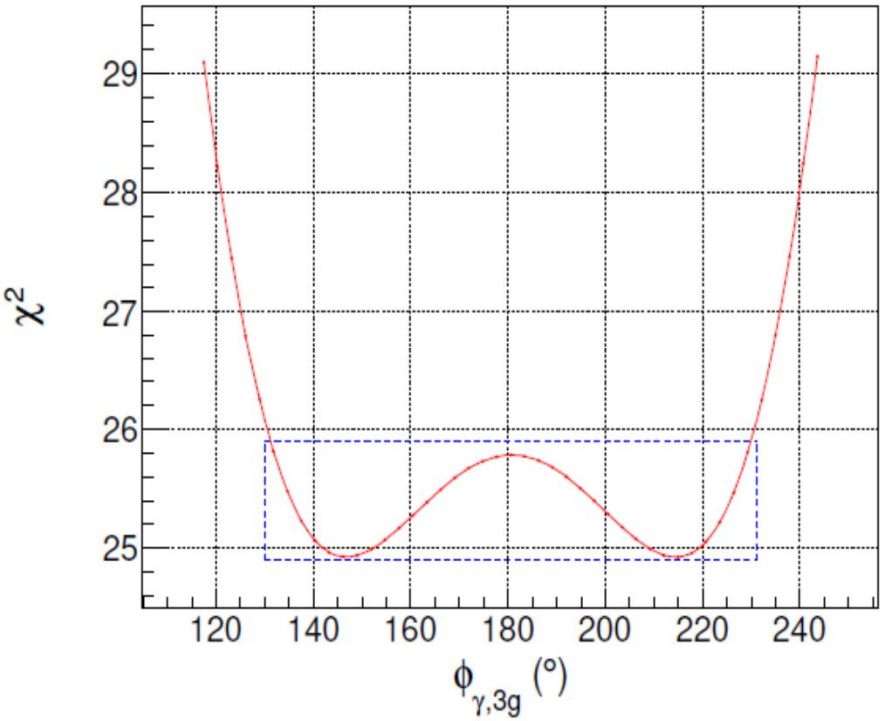
Two solutions from the fit





Fit results

	Positive phase	Negative phase
χ^2/ndf	24.9/21	24.9/21
$\phi_{\gamma,3g}$ (°)	$150.1^{+77.8}_{-17.0}$	$210.9^{+17.3}_{-78.2}$
$\mathcal{F}$	0.11±0.01	
C	3.3±0.4	
S_E (MeV)	0.88±0.03	
f	0.99±0.04	
M (MeV)	3096.89±0.03	
Γ (keV)	92.6±0.1	
Γ_{ee} (keV)	5.53±0.06	



Summary

- BESIII has performed a scan of $e^+e^- \to \varphi\eta$ production near the **J/ψ** resonance.
  - Total 26 energy points between 3.00 and 3.12 GeV with integrated luminosity 0.45 fb^{-1} have been explored.
- From a fit to the measured lineshape, we obtained the relative phase between the strong and electromagnetic amplitudes of **J/ψ** decay.
- The allowed range of $\varphi_{\gamma,3g}$ is [133°,229°] (68% CL).
- The result is consistent with pQCD calculations.