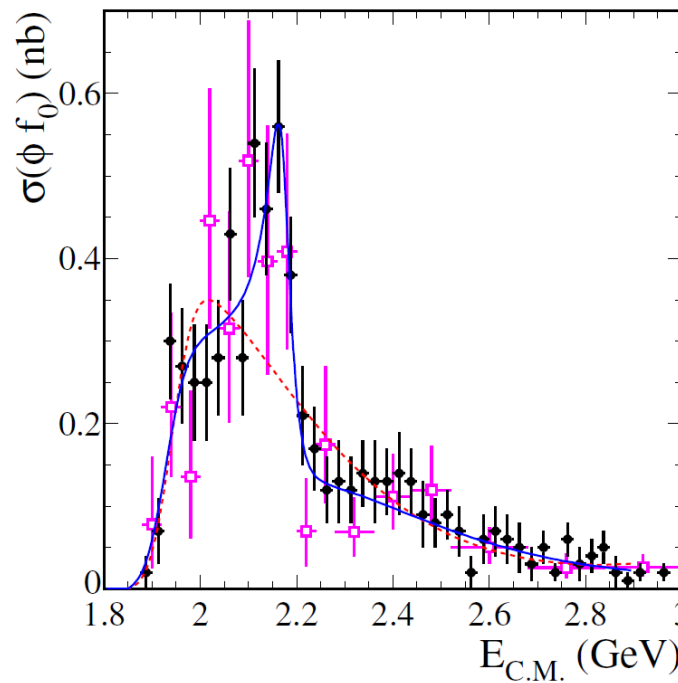# Study of $\phi(2170)$ at BESIII

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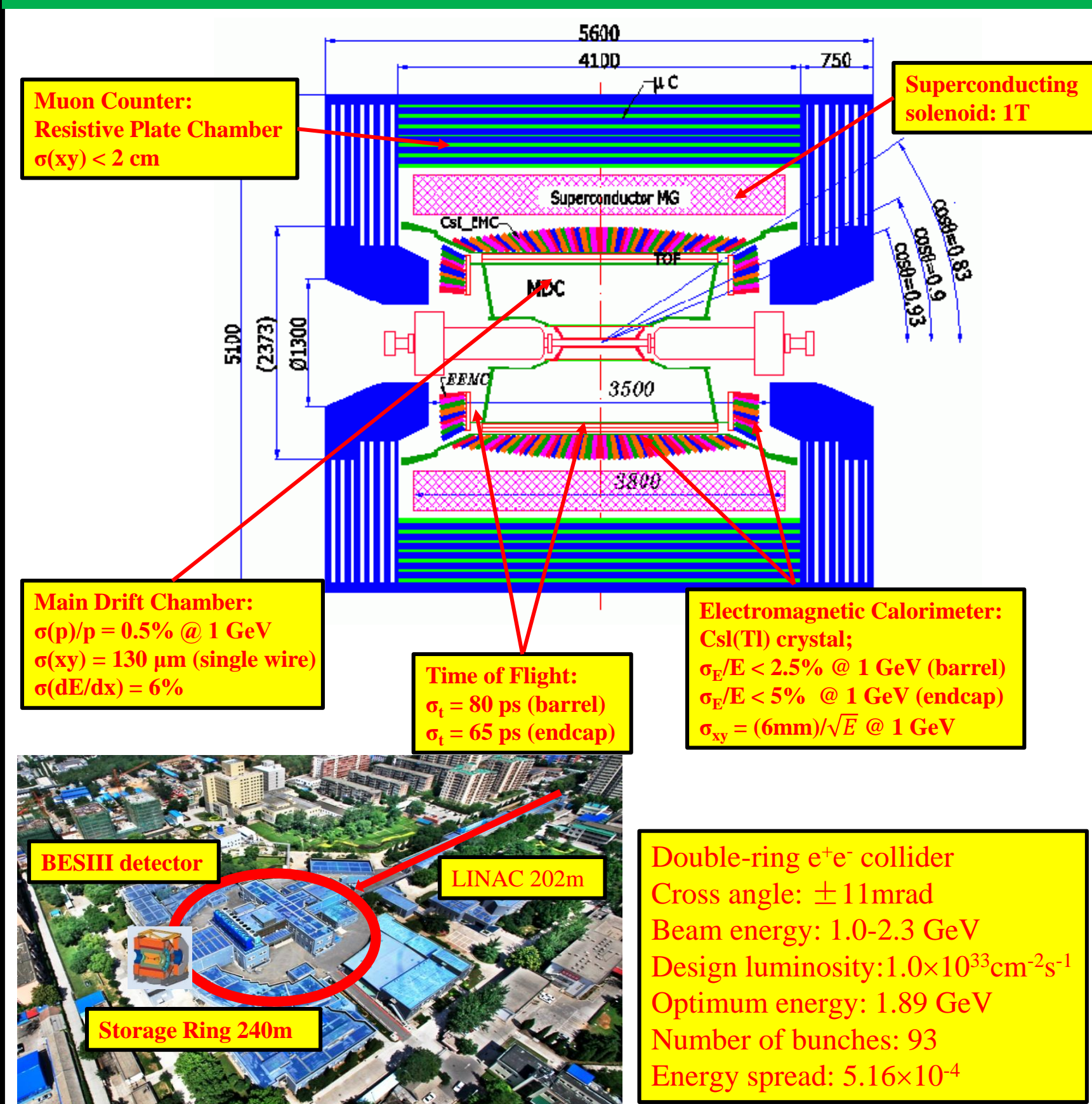## $\phi(2170)$ Physics Motivation

PDG (2016)

$\phi(2170)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	e^+e^-	seen
Γ_2	$\phi\eta$	
Γ_3	$\phi\pi\pi$	seen
Γ_4	$\phi f_0(980)$	
Γ_5	$K^+K^-\pi^+\pi^-$	
Γ_6	$K^+K^-f_0(980) \to K^+K^-\pi^+\pi^-$	
Γ_7	$K^+K^-\pi^0\pi^0$	
Γ_8	$K^+K^-f_0(980) \to K^+K^-\pi^0\pi^0$	seen
Γ_9	$K^0K^\pm\pi^\mp$	not seen
Γ_{10}	$K^*(892)^0\bar{K}^*(892)^0$	not seen

- **Published experimental information**
  - ✓ Limited decay modes
  - ✓ Inconsistence on mass & width
- **Nature of $\phi(2170)$**
  - ✓ $s\bar{s}g$ hybrid
  - ✓ 2^3D_1 or 3^3S_1 $s\bar{s}$
  - ✓ tetraquark $s\bar{s}s\bar{s}$
  - ✓ Molecular state $\Lambda\bar{\Lambda}$
  - ✓ $\phi f_0(980)$ resonance with FSI
 - ✓ Three body system ϕKK
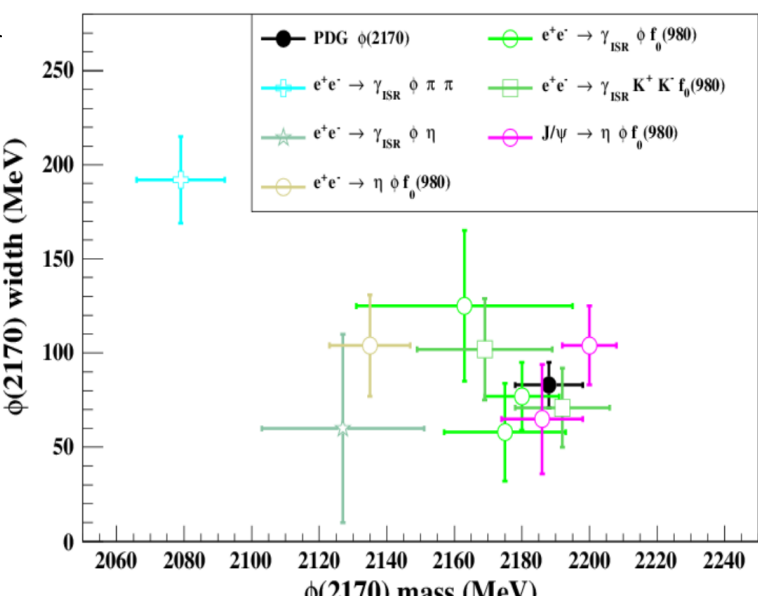
- **After 12 years, aspects of $\phi(2170)$ are still not fully understood.**
- **BESIII provide the opportunity to perform the further study to $\phi(2170)$**

BEPCIII and BESIII

Muon Counter:
Resistive Plate Chamber
$\sigma(xy) < 2$ cm

Superconducting
solenoid: 1T

Main Drift Chamber:
$\sigma(p)/p = 0.5\%$ @ 1 GeV
$\sigma(xy) = 130$ μm (single wire)
$\sigma(dE/dx) = 6\%$

Time of Flight:
$\sigma_t = 80$ ps (barrel)
$\sigma_t = 65$ ps (endcap)

Electromagnetic Calorimeter:
CsI(Tl) crystal:
$\sigma_E/E < 2.5\%$ @ 1 GeV (barrel)
$\sigma_E/E < 5\%$ @ 1 GeV (endcap)
$\sigma_{xy} = (6mm)/\sqrt{E}$ @ 1 GeV

BESIII detector

LINAC 202m

Storage Ring 240m

Double-ring e⁺e⁻ collider
Cross angle: ±11mrad
Beam energy: 1.0-2.3 GeV
Design luminosity: $1.0 \times 10^{33} cm^{-2} s^{-1}$
Optimum energy: 1.89 GeV
Number of bunches: 93
Energy spread: 5.16×10^{-4}

$J/\Psi \to \eta\phi(2170) \to \eta\phi f_0(980)$

- More measurements needed to clarify the nature of $\phi(2170)$
- Huge J/Ψ events collected at BEIII: 2.25×10^8
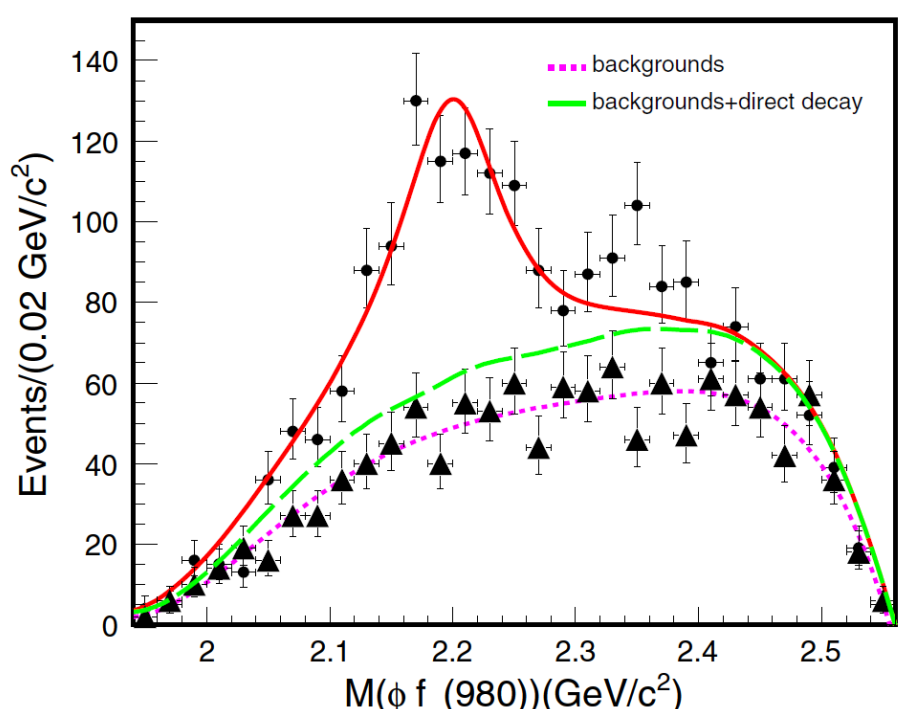
PRD 91 052017 (2015)

$Br(J/\Psi \to \eta\phi(2170) \to \eta\phi f_0(980))$
$= (1.20 \pm 0.14 stat \pm 0.37 syst) \times 10^{-4}$

M = 2200 $\pm 6_{stat} \pm 5_{syst}$ MeV/c²
**Γ = 104 $\pm 15_{stat} \pm 15_{syst}$ MeV**

- ✓ $\phi(2170)$ observed with significance greater than 10σ
- ✓ Consistent with the previous measurements and improve the precision of mass and width.

TABLE V. Comparison of $Y(2175)$ parameters as measured by different experiments.

Collaboration	Process	M (MeV/c^2)	Γ (MeV)
BABAR [2]	$e^+e^- \to \phi f_0$ (ISR)	$2175 \pm 10 \pm 15$	$58 \pm 16 \pm 20$
BESII [3]	$J/\psi \to \eta\phi f_0(980)$	$2186 \pm 10 \pm 6$	$65 \pm 23 \pm 17$
BELLE [4]	$e^+e^- \to \phi f_0$ (ISR)	$2079 \pm 13^{+79}_{-28}$	$192 \pm 23^{+25}_{-61}$
BABAR (updated) [5]	$e^+e^- \to \phi f_0$ (ISR)	$2172 \pm 10 \pm 8$	$96 \pm 19 \pm 12$
BESIII	$J/\psi \to \eta\phi f_0(980)$	$2200 \pm 6 \pm 5$	$104 \pm 15 \pm 15$

$e^+e^- \to \eta\phi(2170) \to \eta\phi f_0(980)$

- The predicted conventional $s\bar{s}$ states, 3^3S^1 and 2^3D^1, are significantly broader than measured $\phi(2170)$. Remain mysterious.
- Generated modes are limited to e^+e^- annihilation and $J/\Psi \to \eta\phi(2170)$
- Tetraquark state? Possible states Z_s in $\phi\pi$ mass spectrum in $\phi(2170) \to \phi\pi\pi$ decay.
- World's largest integrated luminosity at 3.686-4.6 GeV

$\sqrt{s}$ (GeV)	$\mathcal{L}_{int}$ (pb⁻¹)
3.686	666
3.773	2917
4.008	482
4.226	1092
4.258	826
4.358	540
4.416	1029
4.600	567

arXiv:1709.04323, submitted to PRD

Simultaneous fit to 3.773-4.600 with unbinned maximum likelihood method.

M = 2135 $\pm 8_{stat} \pm 9_{syst}$ MeV/c²
Γ = 104 $\pm 24_{stat} \pm 12_{syst}$ MeV

- ✓ First observation of $e^+e^- \to \eta\phi(2170)$ with significance greater than 10σ
- ✓ Consistent with the previous measurements with larger width and smaller mass
- ✓ No significant $\psi(3686) \to \eta\phi(2170)$ observed, in violation of 12% rule

1.5σ

- ✓ From dalitz plot, $\phi f_0(980)$ is dominant in $\phi(2170)$ decay
- ✓ **No significant Z_s observed**

$e^+e^- \to \phi(2170) \to \phi\pi\pi$

- $\phi(2170)$ behaving similarly to that of $Y(4260)$ and $Y(10860)$, unique process $\phi(2170) \to \phi\pi\pi$ to search for Z_s in $\phi\pi$ mass spectrum
- Ideal channel to search for Z_s, as conventional $s\bar{s}$ state to $\phi\pi$ suppressed by isospin symmetry, conventional $u\bar{u} + d\bar{d}$ state suppressed by OZI rule
- Huge data collected around $\phi(2170)$ peak, ($\mathcal{L} = 108.49$ pb⁻¹ at 2.125 GeV)
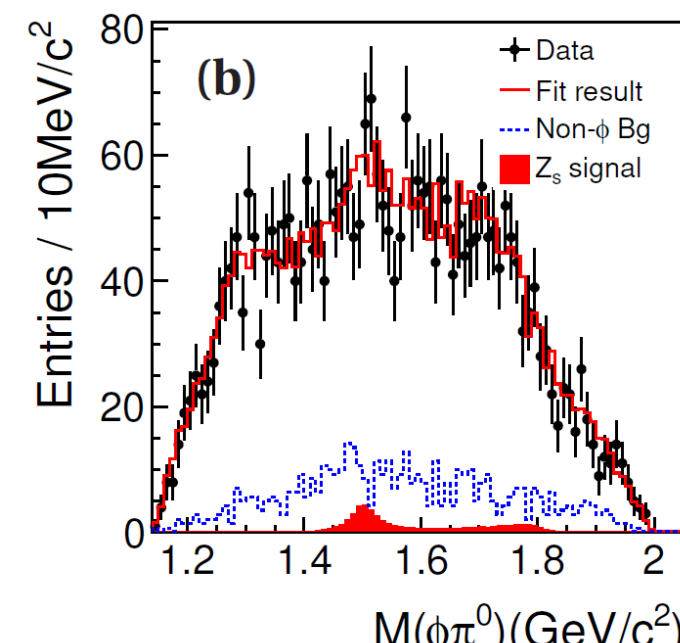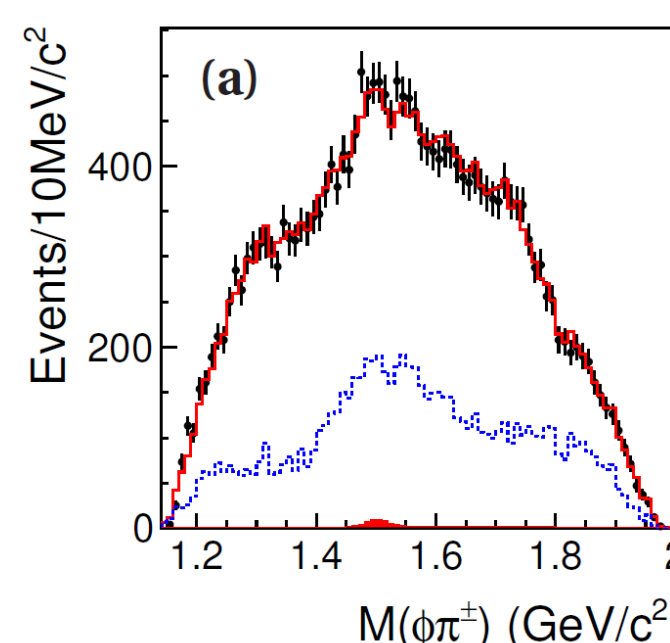

- ✓ No Z_s signal observed in $\phi\pi$ mass spectrum. Significance less than 3σ in explored region; $M(Z_s^0) = 1.5$ GeV/c², $\Gamma(Z_s^0) = 50$ MeV in 3.3σ significance.
- ✓ Upper limits on the Z_s cross section at 90% confidence level.
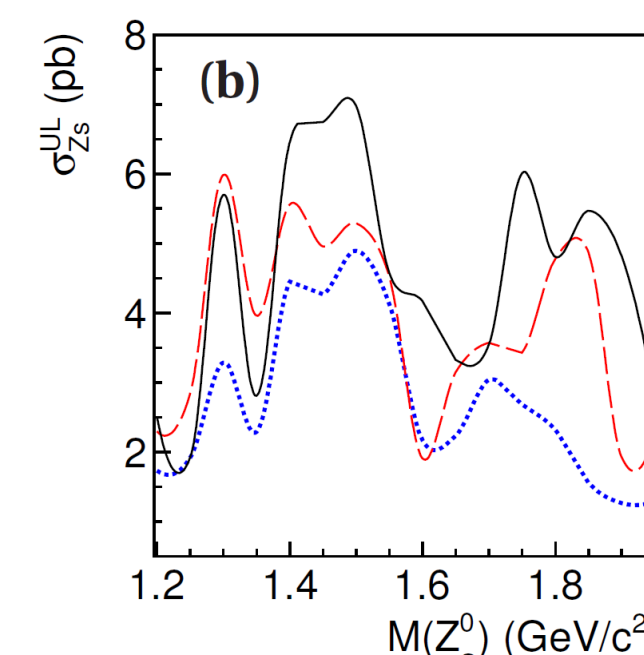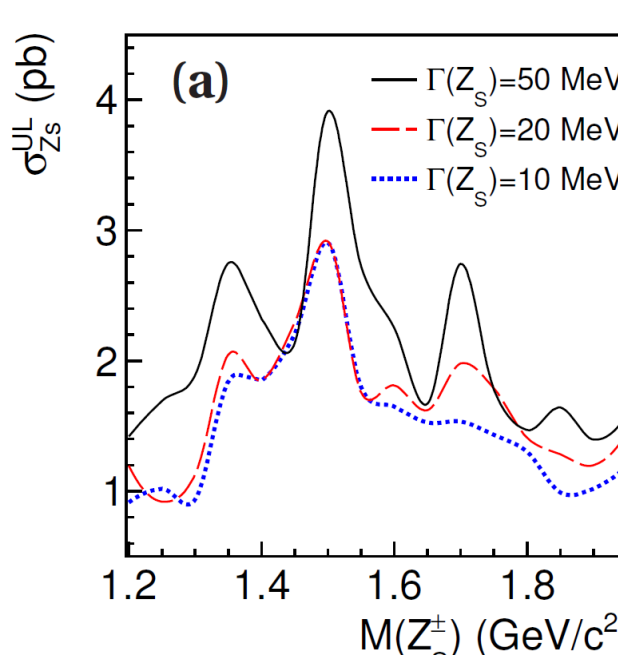
- ✓ Upper limits on the Z_s cross section at 90% confidence level.
- ✓ ISPE mechanism at threshold is not as significant as predicted.

$e^+e^- \to \omega\eta$

- $\phi(2170)$ state still remains mysterious and limited to final decays with ϕ, more decay modes may shed light on its natures.
- $s\bar{s}$ states have relative weak branching fractions to all accessible non-rstrance modes.
- Large data collected at 2-3.08 GeV, use $\omega\eta$ to search for $\phi(2170)$ resonance

Mass = 2175 $\pm$ 13MeV
Γ = 75 $\pm$ 24MeV
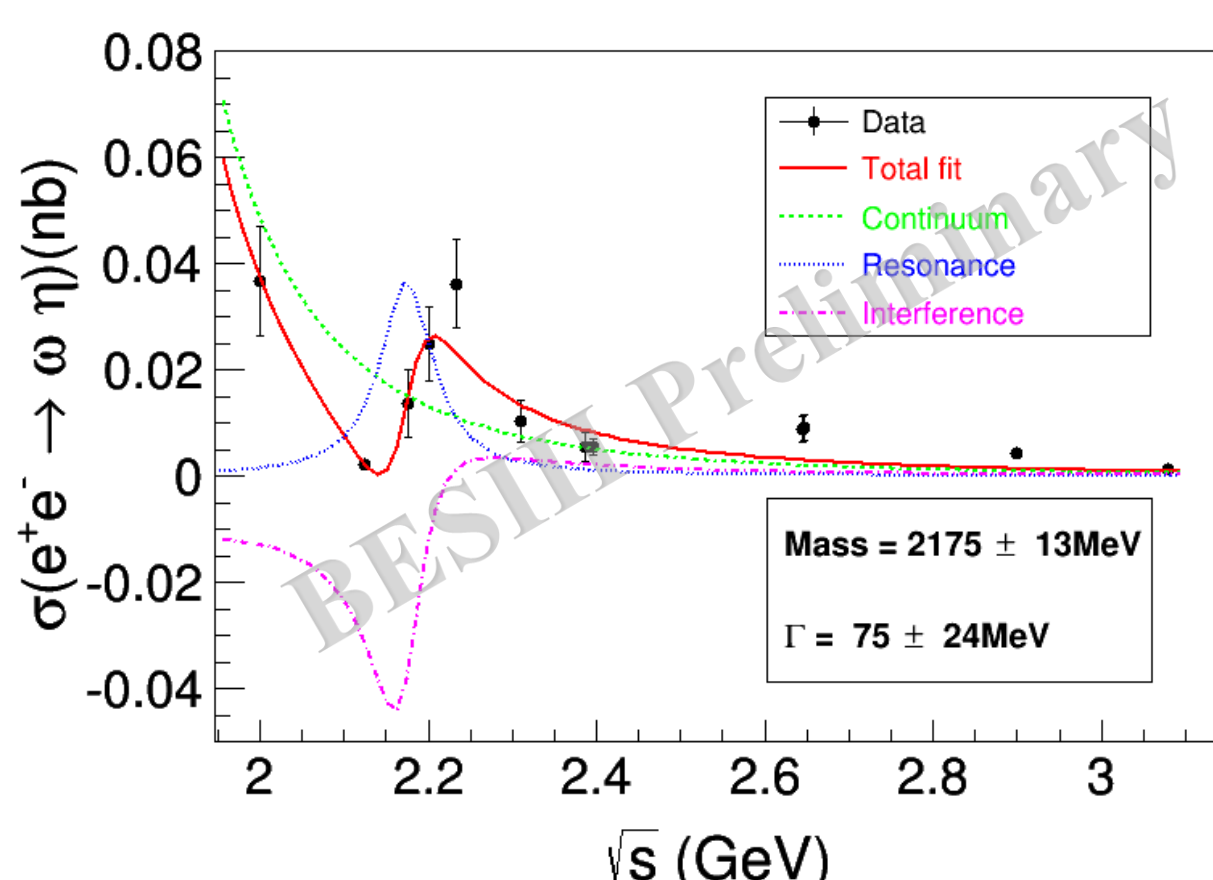
M = 2175$\pm 13_{sta} \pm 43_{sys}$ MeV
Γ = 75$\pm 24_{sta} \pm 5_{sys}$ MeV
Significance: 6.7σ

- ✓ The fitted mass and width have large discrepancy with possible ω^* resonances
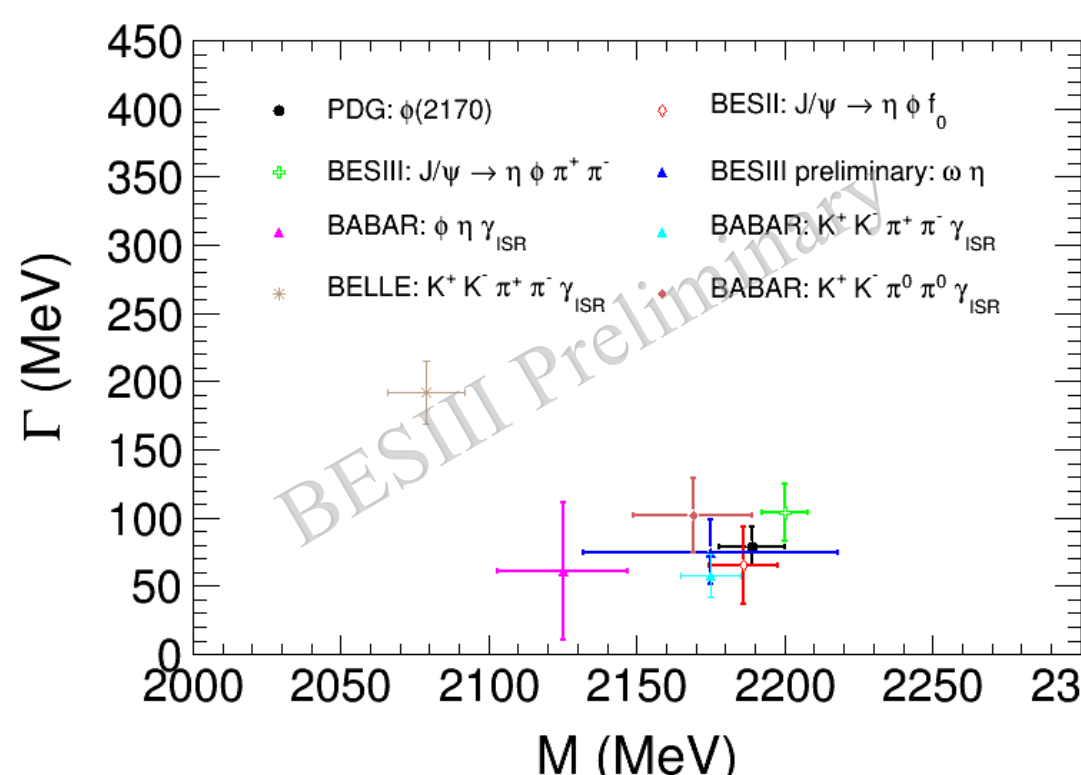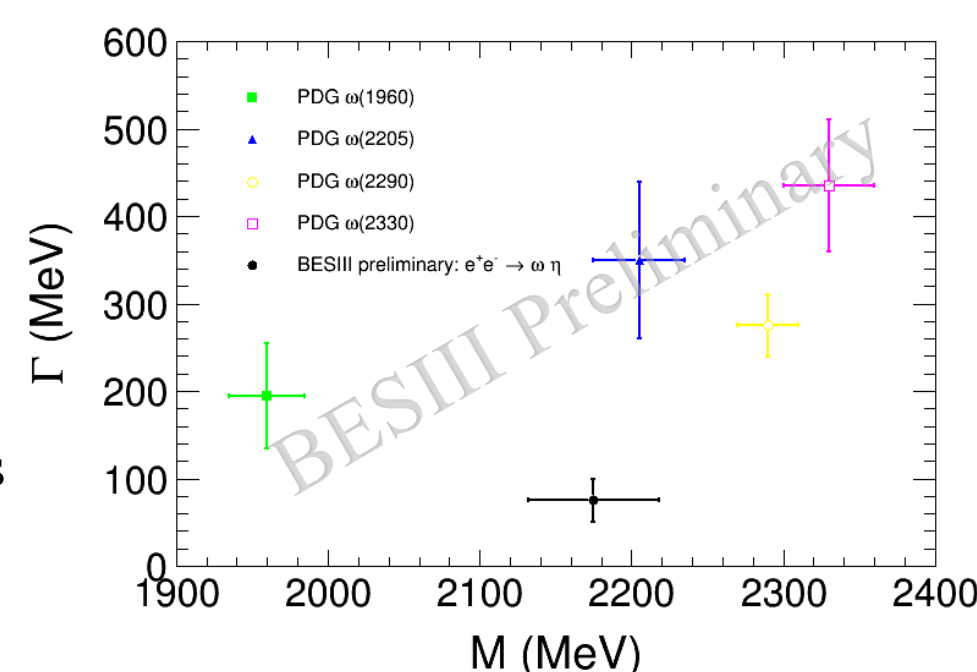
- ✓ The fitted mass and width are highly consistent with the previous $\phi(2170)$ measurements.
- ✓ **Possible a new decay mode of $\phi(2170)$**

Summary

Reference