Measuring the phase between strong and EM J/ψ decay amplitudes

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on behalf of the BESIII Collaboration

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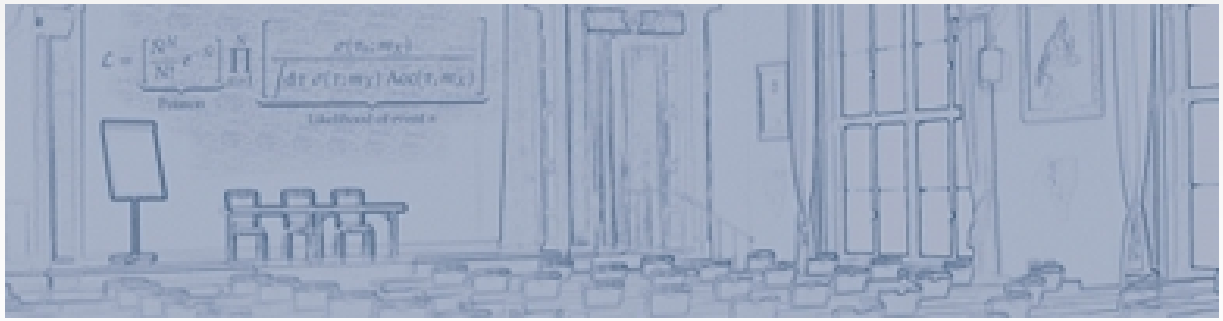
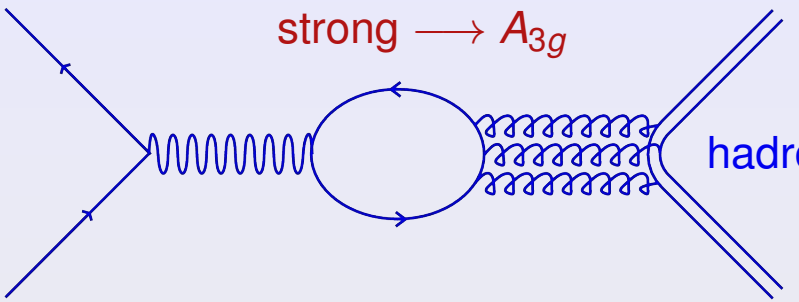
HADRON 2011

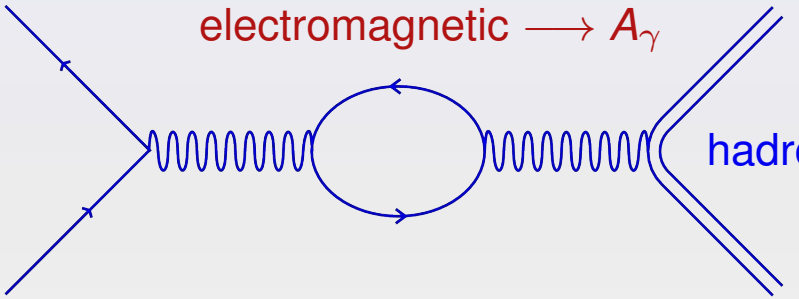
XIV International Conference on Hadron Spectroscopy

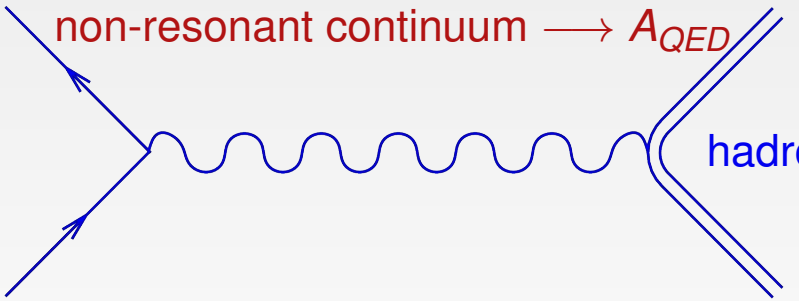


Künstlerhaus - Munich, June 13^{th} - 17^{th}, 2011

J/ψ strong and electromagnetic decay amplitudes







Resonant contributions

$$\Phi_p(G_p^M) \sim \Phi_\gamma \qquad \Phi_{3g} = 0$$

Φ_γ: relative $A_{3g} - A_p$

- $J/\psi \to N\bar{N}$ $\quad \Phi_p = \ 89^\circ \pm 15^\circ$ [1]
- $J/\psi \to VP\ (1^-0^-)$ $\quad \Phi_p = 106^\circ \pm 10^\circ$ [2]
- $J/\psi \to PP\ (0^-0^-)$ $\quad \Phi_p = 89.6^\circ \pm 9.9^\circ$ [3]
- $J/\psi \to VV\ (1^-1^-)$ $\quad \Phi_p = 138^\circ \pm 37^\circ$ [3]

NO INTERFERENCE!

Non-resonant continuum

- affects the measured BR [4]
- affects Φ_p [4]

INTERFERENCE WITH A_{3g}!

[1] R. Baldini, C. Bini, E. Luppi, Phys. Lett. B404, 362 (1997); R. Baldini et al., Phys. Lett. B444, 111 (1998).
[2] L. Kopke and N. Wermes, Phys. Rep. 174, 67 (1989); J. Jousset et al., Phys. Rev. D41,1389 (1990).
[3] M. Suzuki et al., Phys. Rev. D60, 051501 (1999).
[4] P. Wang, arXiv:hep-ph/0410028v2 and references therein.

J/ψ strong and electromagnetic decay amplitudes

IMAGINARY AMPLITUDES HARD TO BE EXPLAINED!

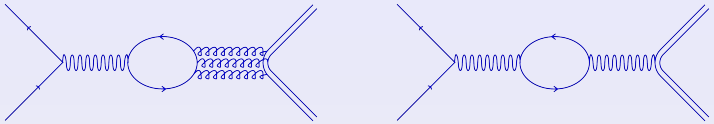
- $J/\psi \subset$ perturbative regime ($\longleftarrow \Gamma_{J/\psi} \sim 93 KeV$)
- pQCD $\longrightarrow$ real A_γ, A_{3g}
- QCD does not provide sizeable imaginary amplitudes (Φ_p 10° at most [1])
- a $J/\psi - V$ glueball mixing [2] may explain imaginary amplitudes; and ψ'?
- determination of phases Φ_p rely on theoretical hypotheses

EXPERIMENTAL DATA

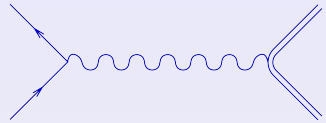
- no interference term in the inclusive J/ψ and ψ' production
- early evidence of an interf. term in $e^+e^- \to J/\psi \to \mu^+\mu^-$ @ SLAC [3]
- no clear evidence of interf. or glueball in $e^+e^- \to J/\psi \to \rho\pi$ @ BESII [4]

[1] J. Bolz and P. Kroll, WU B 95-35.
[2] S.J. Brodsky, G.P. Lepage, S.F. Tuan, Phys. Rev. Lett. 59, 621 (1987).
[3] M. Boyarski et al., Phys. Rev. Lett. 34, 1357 (1975).
[4] J.Z. Bai et al., Phys. Rev. D 54, 1221 (1996).

J/ψ strong and electromagnetic decay amplitudes



resonant



non resonant

$$x = \frac{M_{J/\psi} - \sqrt{s}}{\Gamma_{TOT}/2} \qquad A_R = \alpha\left(\frac{x}{1+x^2} + i\frac{1}{1+x^2}\right)$$

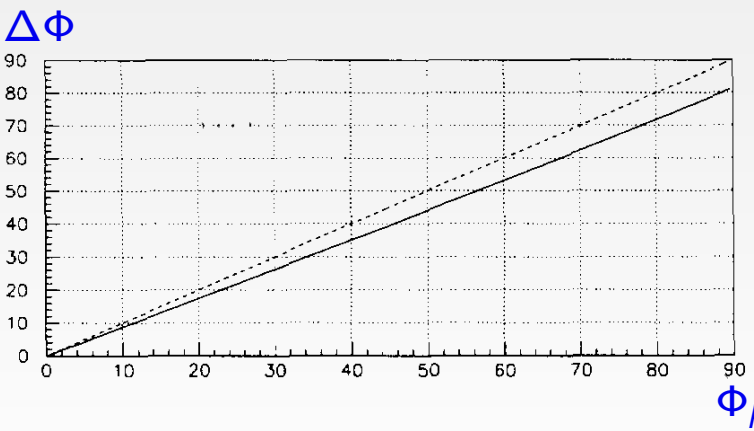
$$\Phi_\alpha = \arctan\frac{|A_\gamma|\sin\Phi_p}{|A_{3g}| + |A_\gamma|\cos\Phi_p}$$

$$\Phi_{A_\gamma} \sim \Phi_p = \Phi_{G_p^M} \qquad A_{NR} = -\beta e^{i\Phi_p}$$

$$\beta = \sqrt{\sigma\left(e^+e^- \Leftrightarrow p\bar{p}\right)}$$

G_p^M real @ $W \sim M_{J/\psi}$ [1]

$$\Delta\Phi = \Phi_p - \Phi_\alpha \sim \Phi_p$$



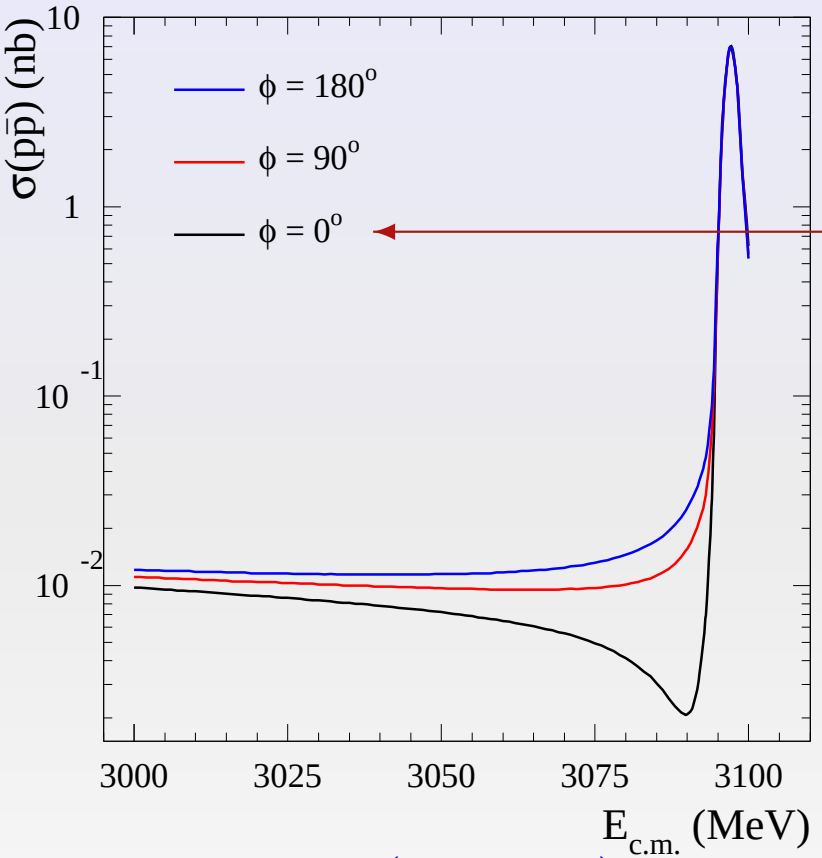
$$I(x) = |A_R + A_{NR}|^2$$

$$= \frac{\alpha^2}{1+x^2} + \beta^2 - \frac{2\beta\alpha}{1+x^2}\left(x\cos\Delta\Phi + \sin\Delta\Phi\right)$$

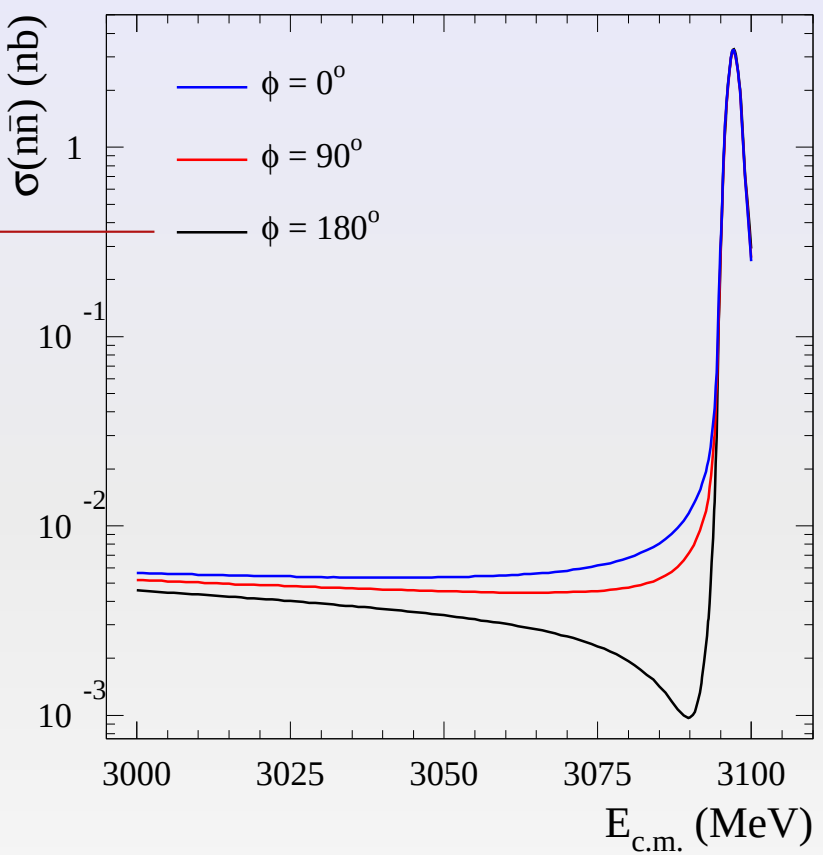
[1] S.J. Brodsky, G.P. Lepage, S.F. Tuan, Phys. Rev. Lett. 59, 621 (1987).

Simulated $e^+e^- \to N\bar{N}$ @ $s \sim M^2_{J/\psi}$

interference must have opposite sign as magnetic moments



continuum reference: $\sigma\left(e^+e^- \to p\bar{p}\right) \sim 11\ pb$ [1]

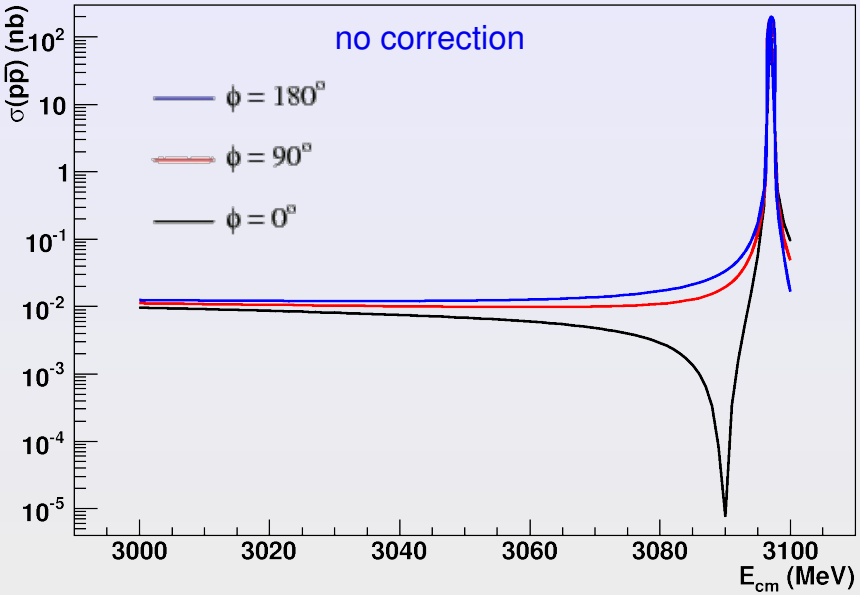


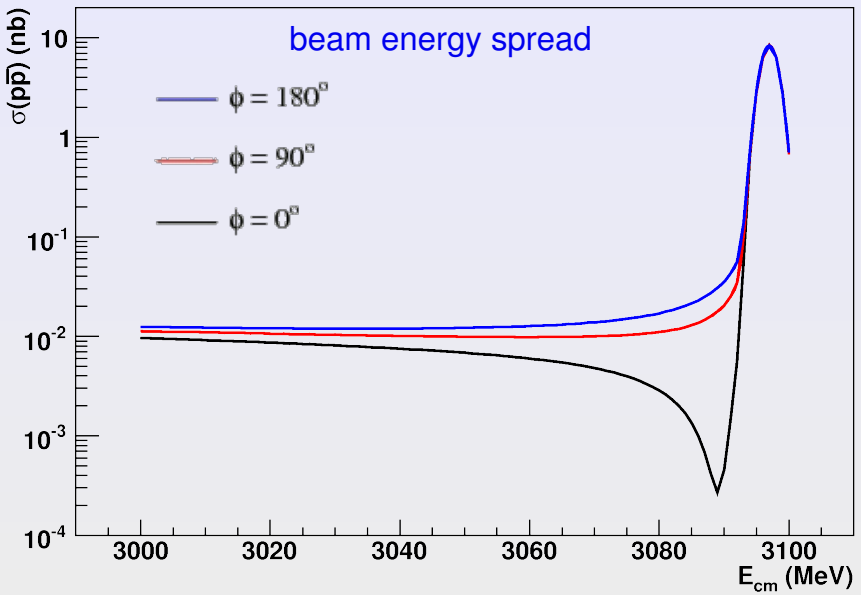
continuum reference: $\sigma\left(e^+e^- \to n\bar{n}\right) \sim 5\ pb$ [1,2]

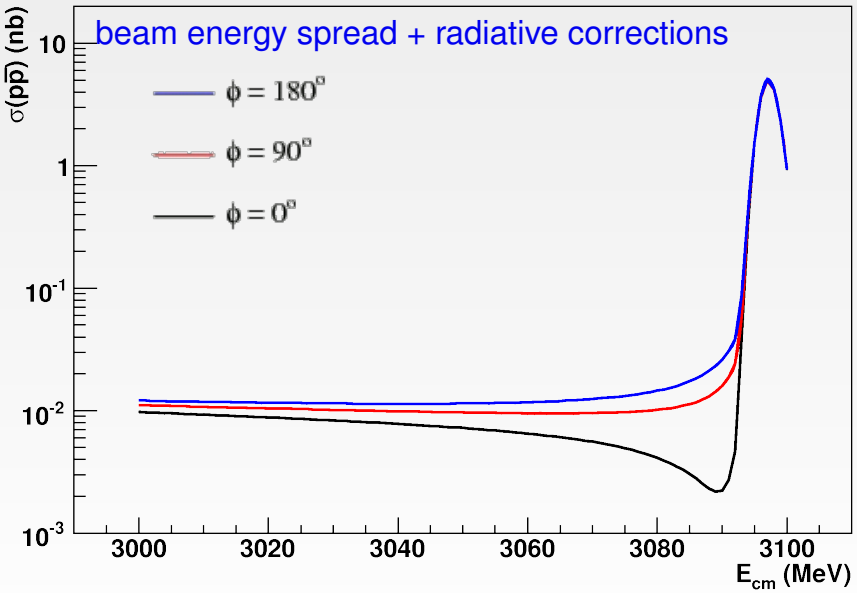
radiative corrections and beam energy spread (BESIII) included!

[1] B. Aubert et al. [BABAR Collaboration], Phys. Rev. D 73, 012005 (2006).
[2] R. Baldini, S. Pacetti, A. Zallo, arxiv:0812.3283 [hep-ph].

Simulated $e^+e^- \to p\bar{p}$ @ $s \sim M^2_{J/\psi}$ - **BESIII** scenario



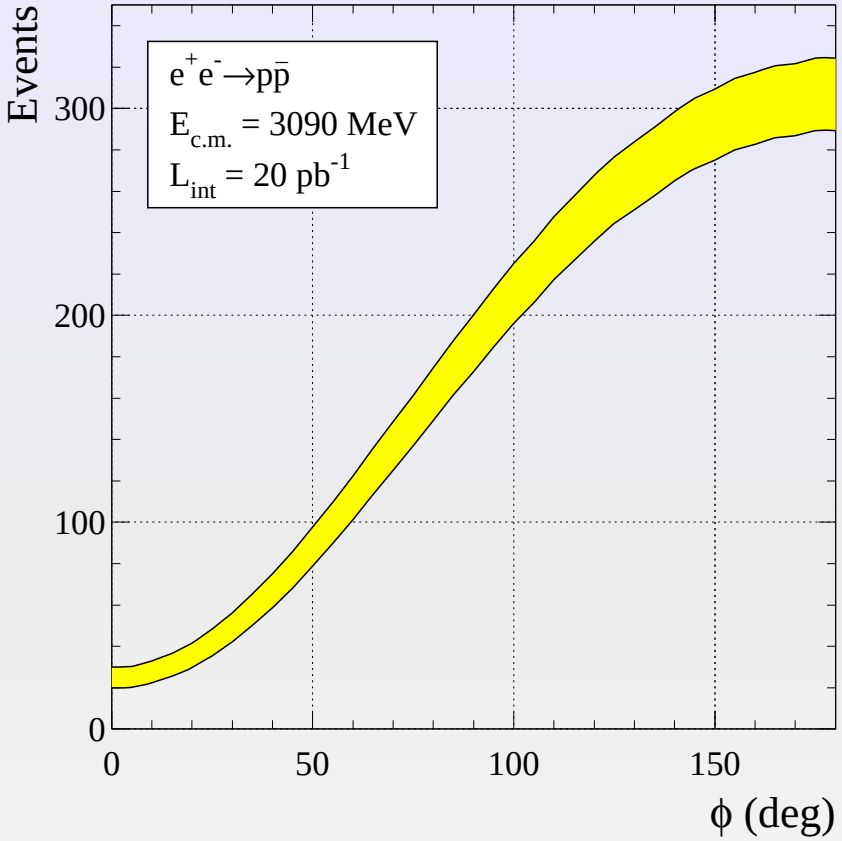


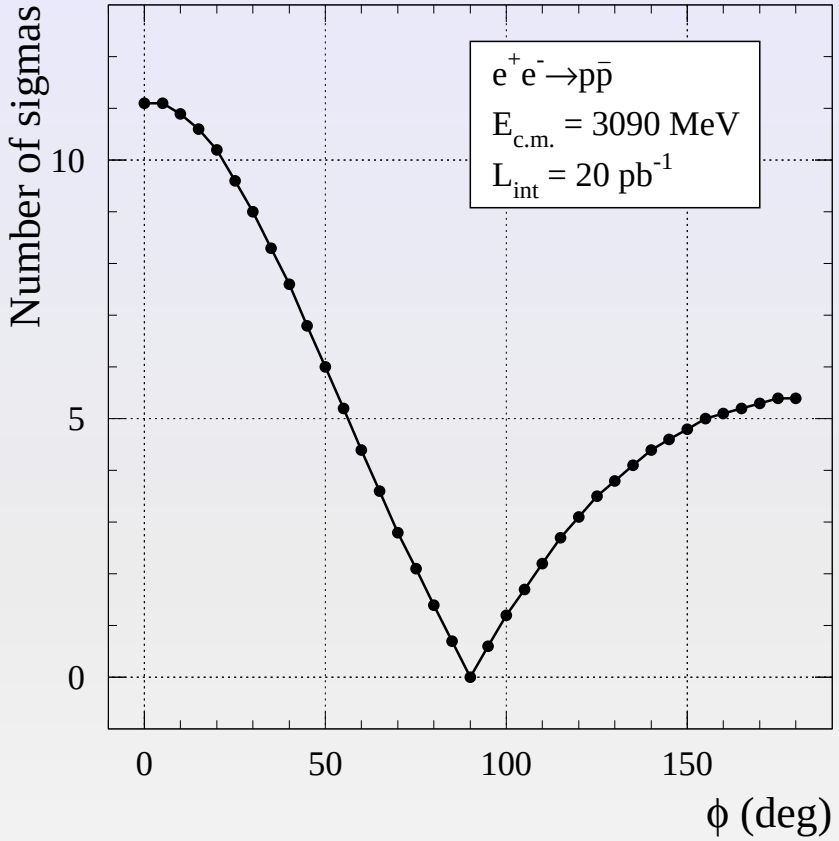


CORRECTIONS NEEDED!

- small effects from beam energy spread
- significant suppression from radiative corrections

Simulated $e^+e^- \to p\bar{p}$ @ $s \sim M^2_{J/\psi}$ ($20\ pb^{-1}$)





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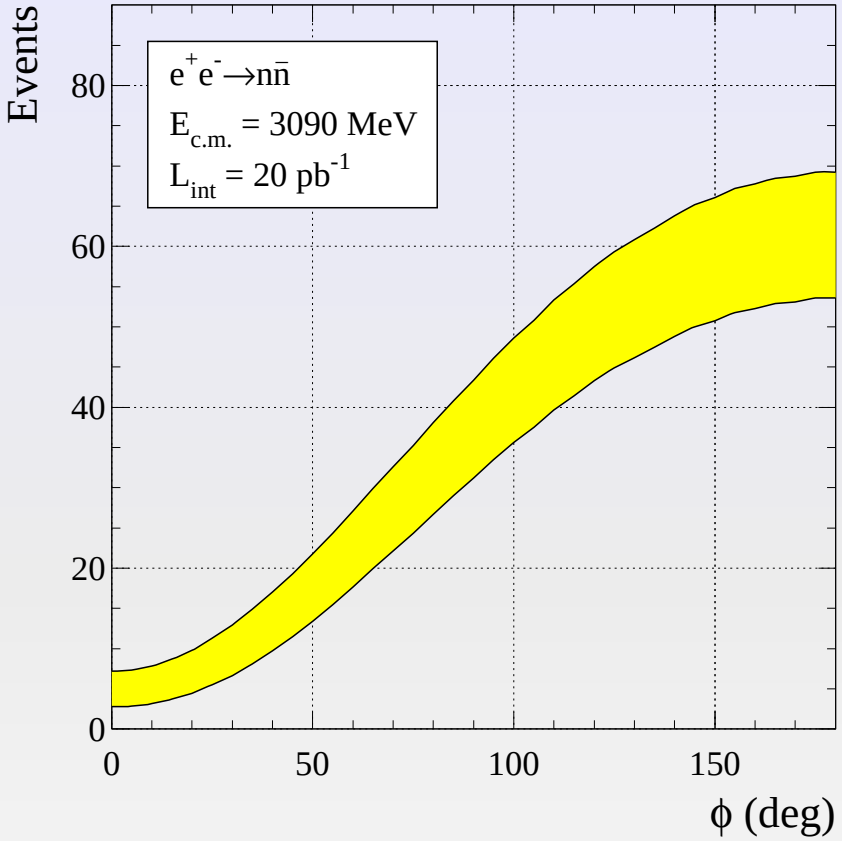

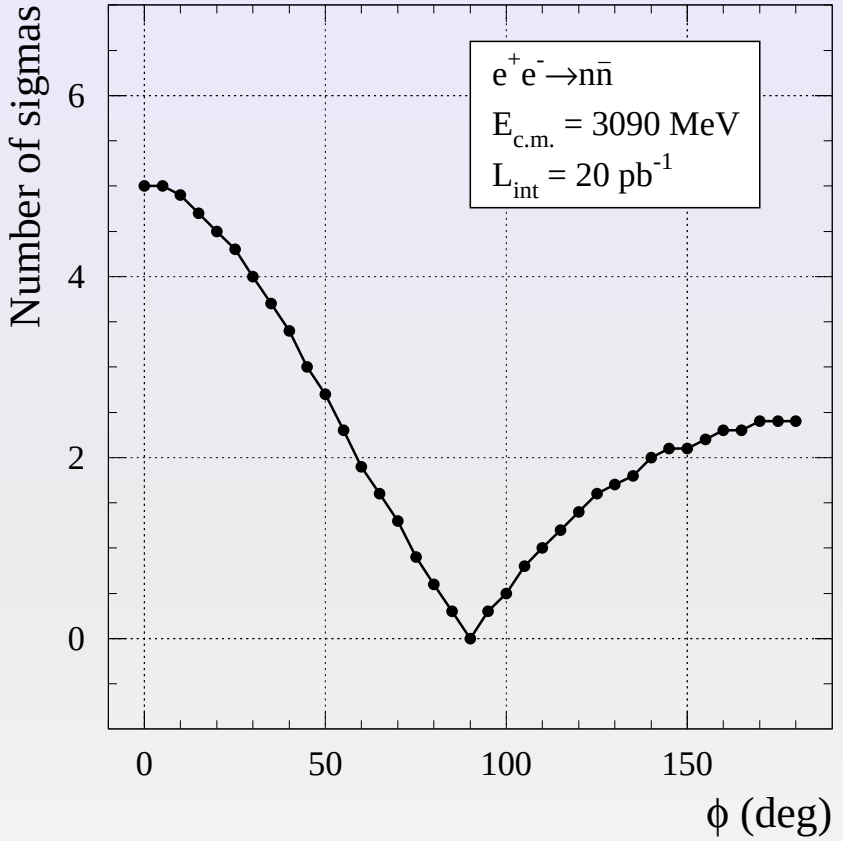

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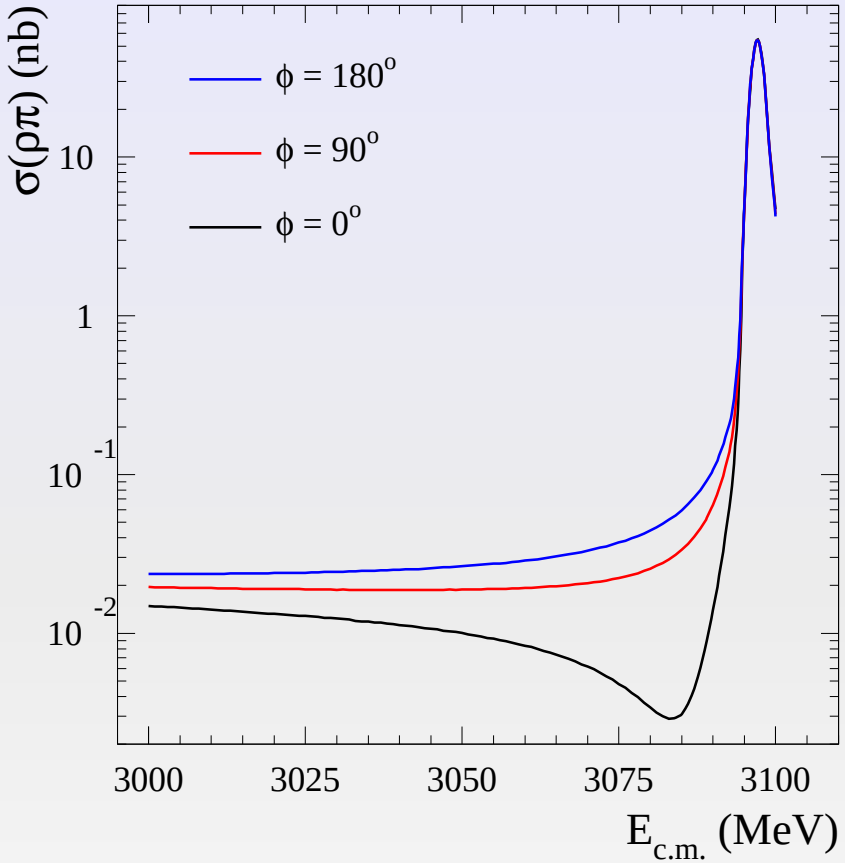
[2] R. Baldini, S. Pacetti, A. Zallo, hep-ph0812.328v2.

Simulated $e^+e^- \to \rho\pi$ @ $s \sim M^2_{J/\psi}$



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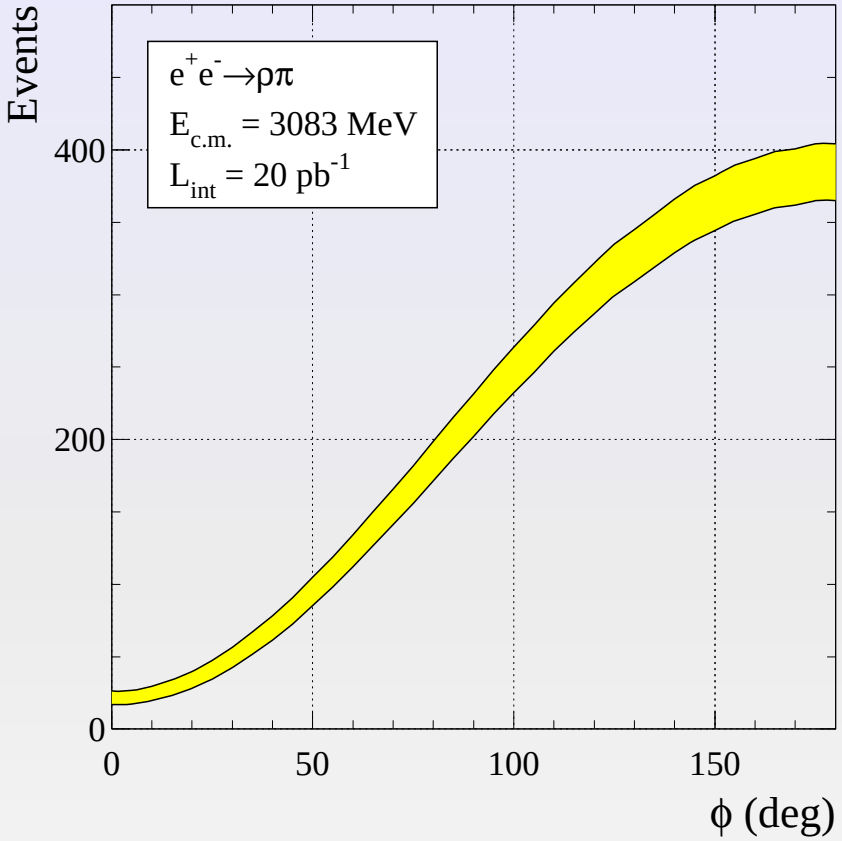
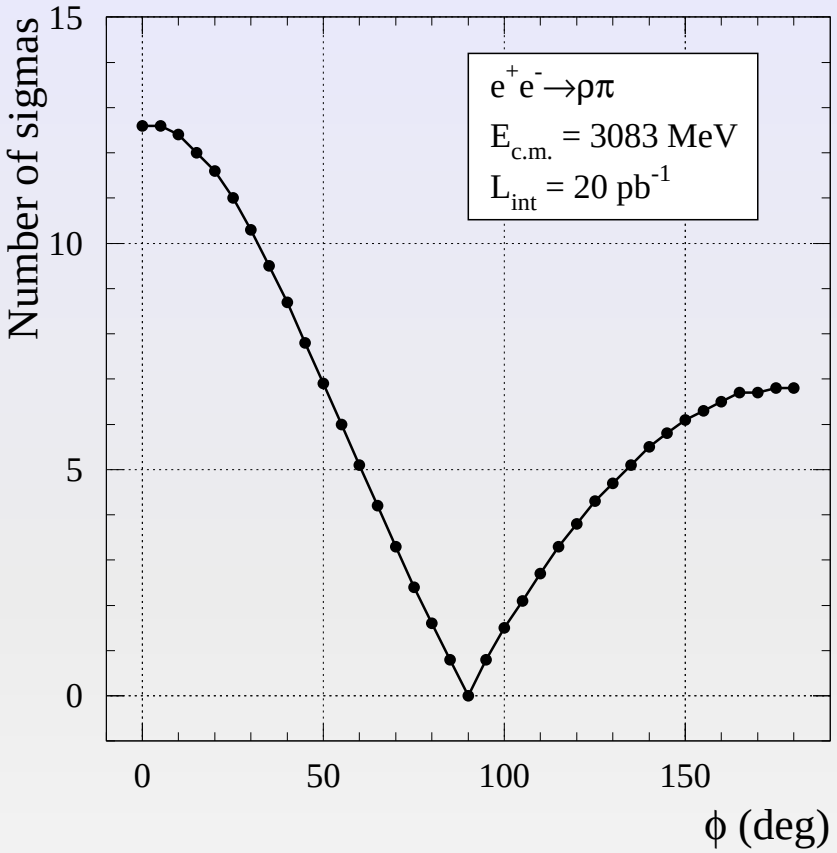
[1] J.Z. Bai et al., Phys. Rev. D 54, 1221 (1996).

Simulated $e^+e^- \to \rho\pi$ @ $s \sim M^2_{J/\psi}$ ($20\ pb^{-1}$)





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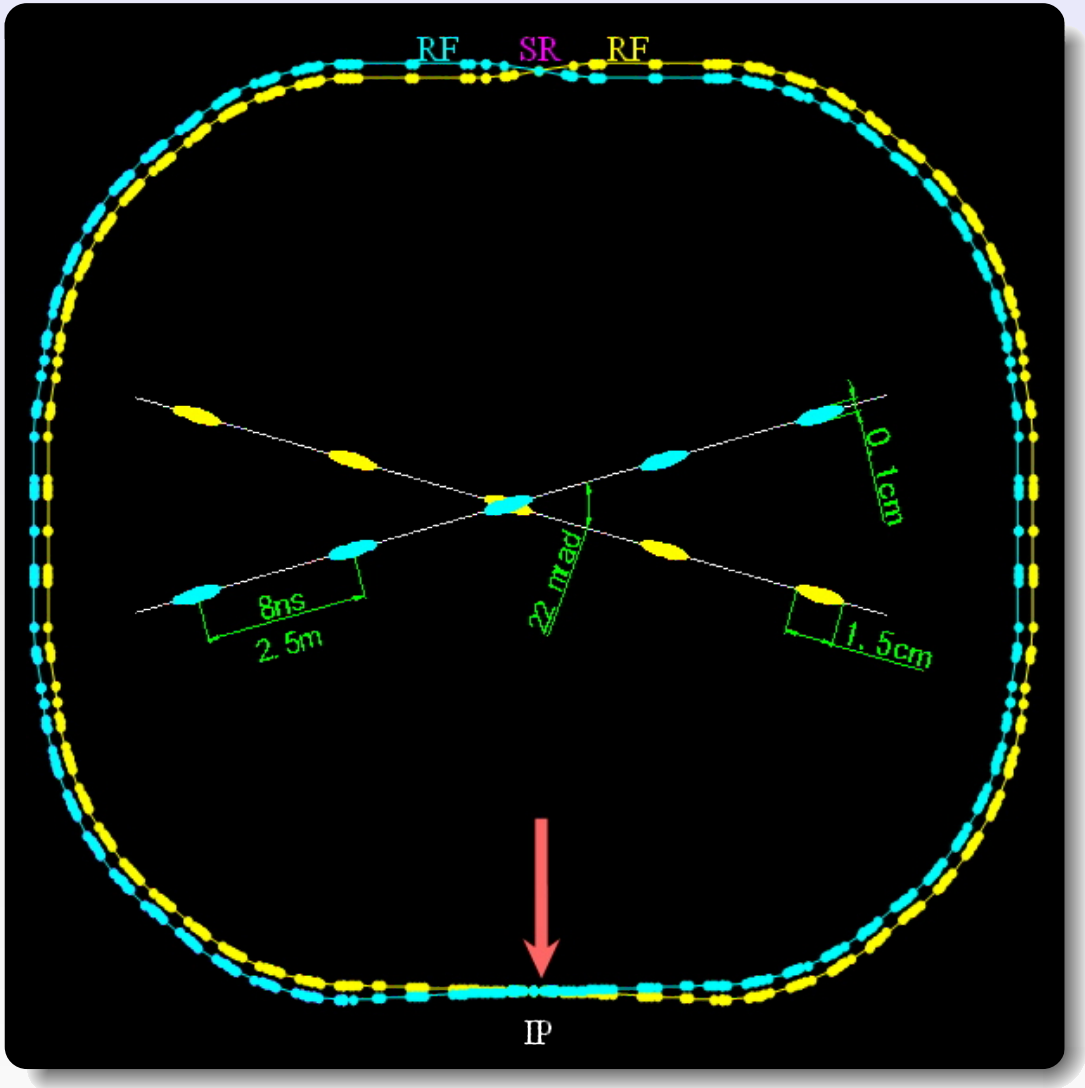
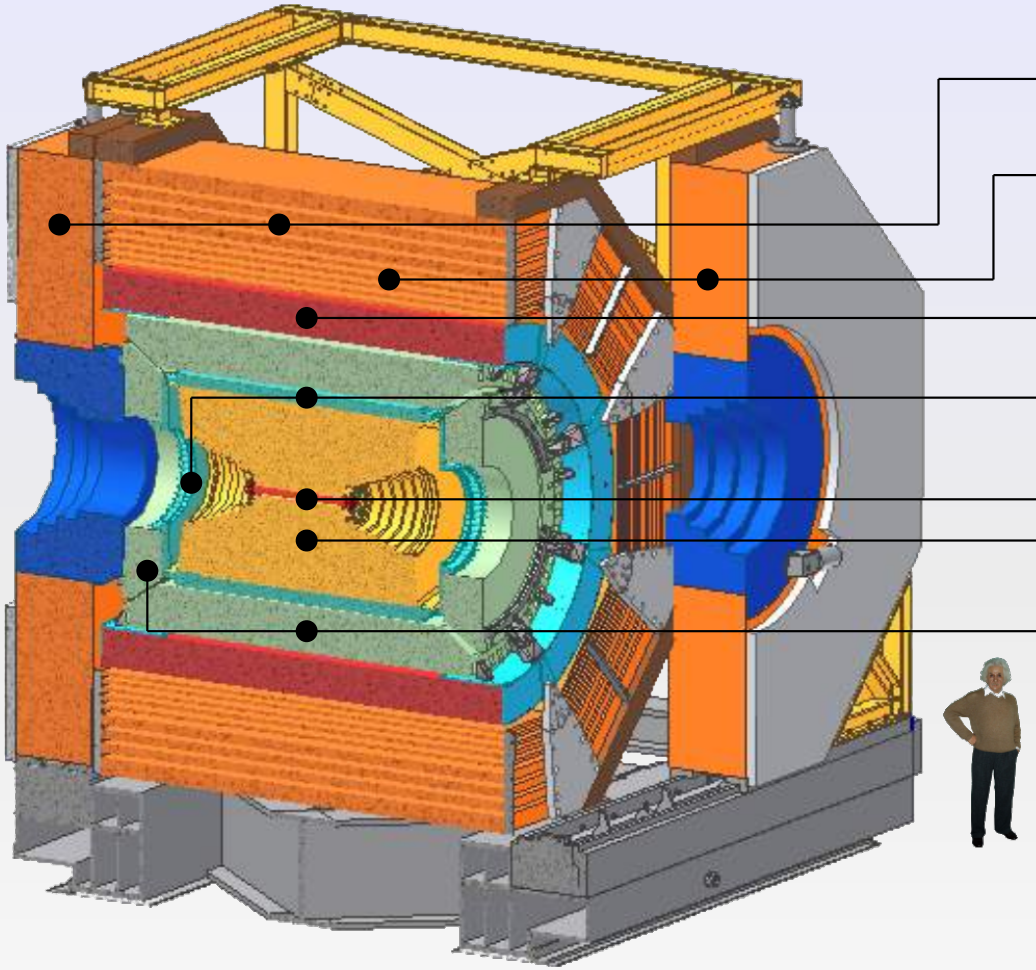
BEPCII: e^+e^- double ring collider



Design Features

- Beam energy: **1.0** - **2.3** GeV
- Crossing angle: **22** mrad
  (DAΦNE 50 mrad)
- **Luminosity: 10^{33} cm^{-2}s^{-1}**
- **Optimum energy: 1.89 GeV**
- Energy spread: **5.16** $\times$ **10^{-4}**
- Number of bunches: **93**
- Bunch length: **1.5** cm
- Total current: **0.91** A

The **BESIII** detector

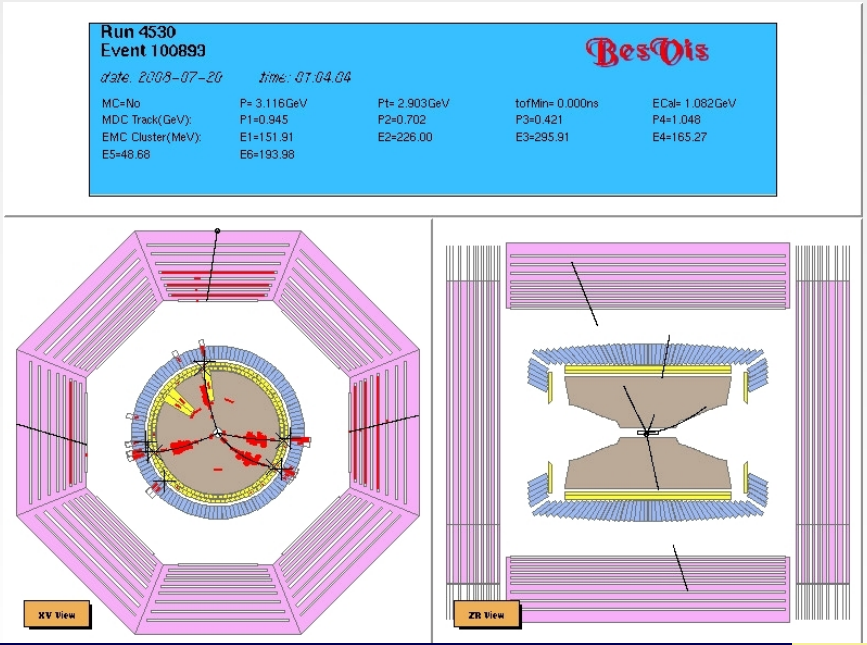


- Magnet yoke
- RPC (9/8 layers Barrel/Endcaps)
- SC magnet, 1 Tesla
- TOF (scintillators), 90 ps
- Be beam pipe
- MDC, 120μm
- CsI(Tl) calorimeter, 2.5% at 1 GeV

A significant improvement with respect to BESII

BEPCII / BESIII milestones

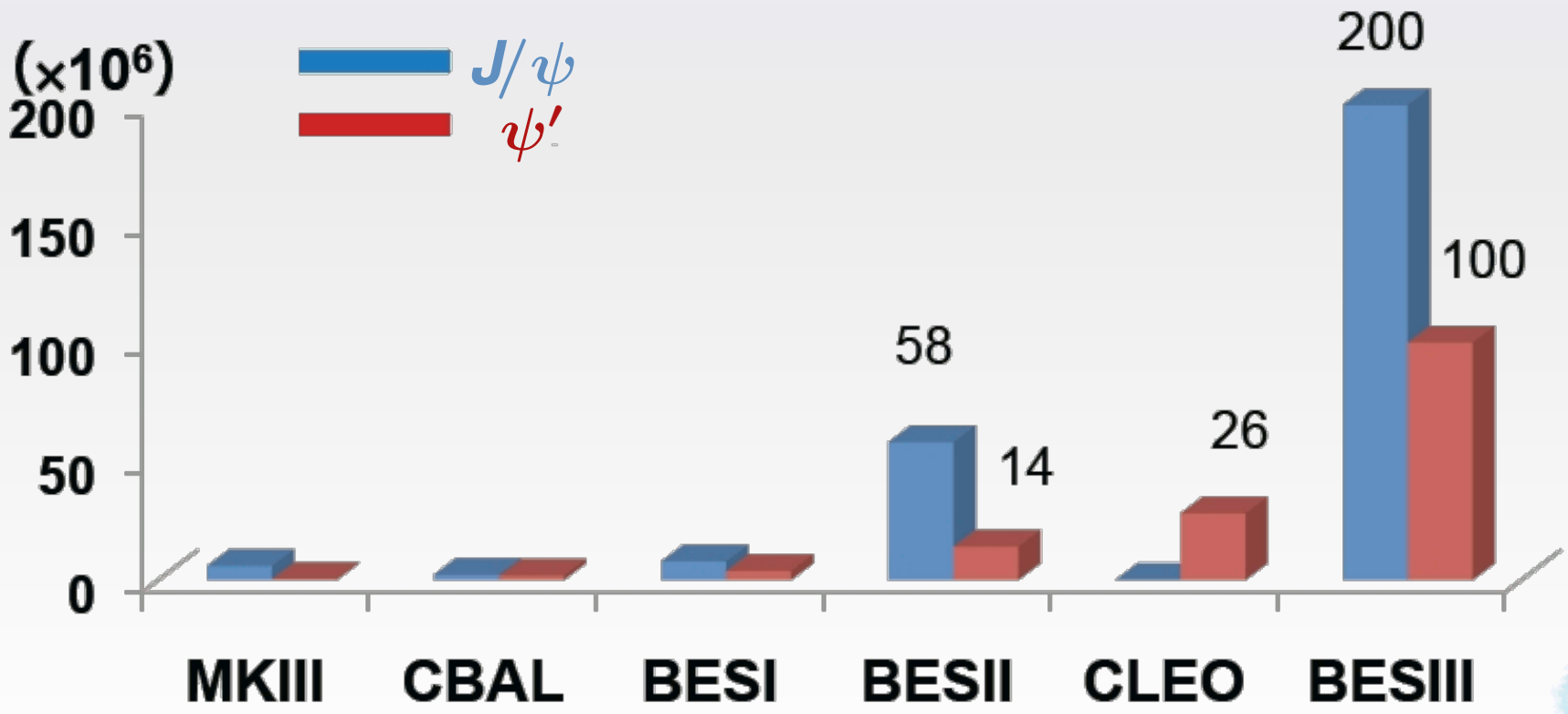
- **Mar. 2008:** Collisions at 500 mA $\times$ 500 mA, Luminosity: $1 \times 10^{32} cm^{-2} s^{-1}$
- **Apr. 30, 2008:** Move BESIII to IP
- **July 18, 2008:** First e^+e^- collision event in BESIII
- **Apr. 14, 2009:** $\sim$ 106 M ψ' events ($150 pb^{-1}$) ($\sim 42 pb^{-1}$ at 3.65 GeV)
- **July 28, 2009:** $\sim$ 225 M J/Ψ events ($65 pb^{-1}$)
- **2010-2011:** $\sim 2.9 fb^{-1}$ at ψ'' ($\sim 70 pb^{-1}$ scanning in the ψ'' energy region)
- **May, 2011:** $\sim 0.5 fb^{-1}$ at 4.01 *GeV* (Ds and XYZ spectroscopy)



Record Luminosity on Apr 7, 2011
$6.0 \times 10^{32} cm^{-2} s^{-1}$
or
$8 \times$ CESRc
$45 \times$ BEPC

World J/Ψ and ψ' Samples ($\times 10^6$)

- **BESIII:** $\sim$ 106 M ψ'events (150pb^{-1})
  BESII: $\sim$ 14 M ψ'events
- **BESIII:** $\sim$ 225 M J/Ψ events (65pb^{-1})
  BESII: $\sim$ 58 M J/Ψ events



HESR - High Energy Storage Ring @ FAIR

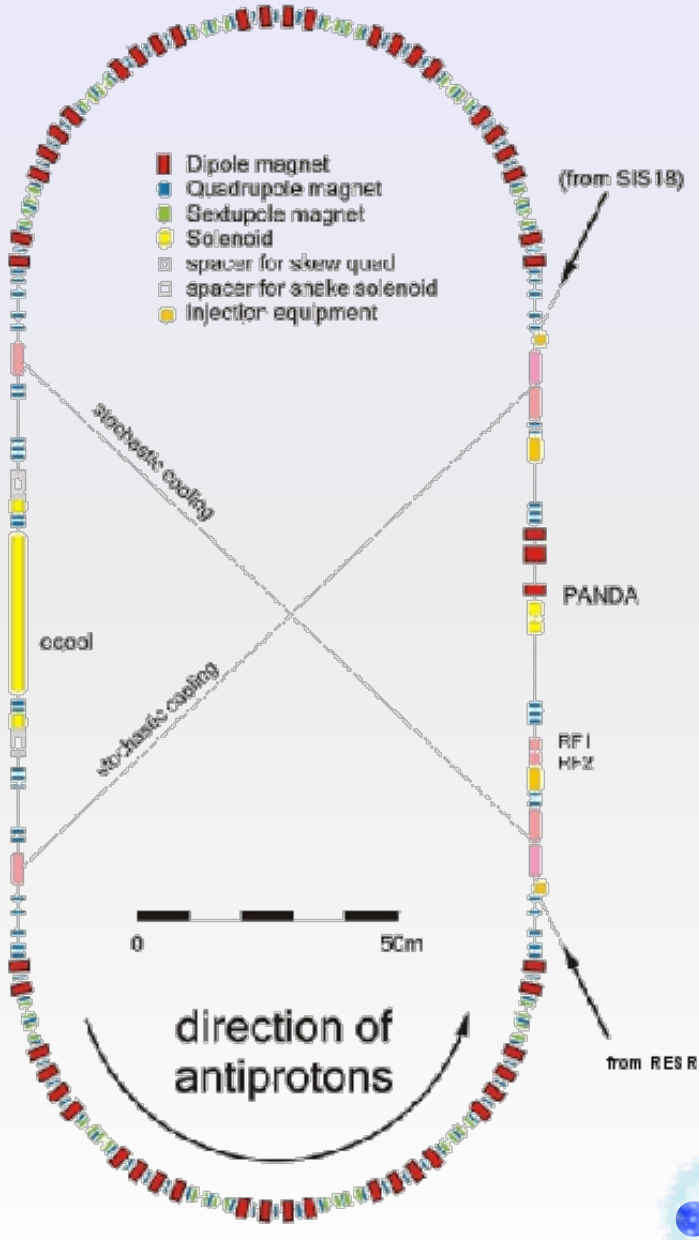
- Production rate $2 \times 10^7/s$
- $p_{beam} = 1 \div 15\ Gev/c$
- $N_{stored} = 5 \times 10^{10}\ \bar{p}$
- Internal pellet target

High resolution mode

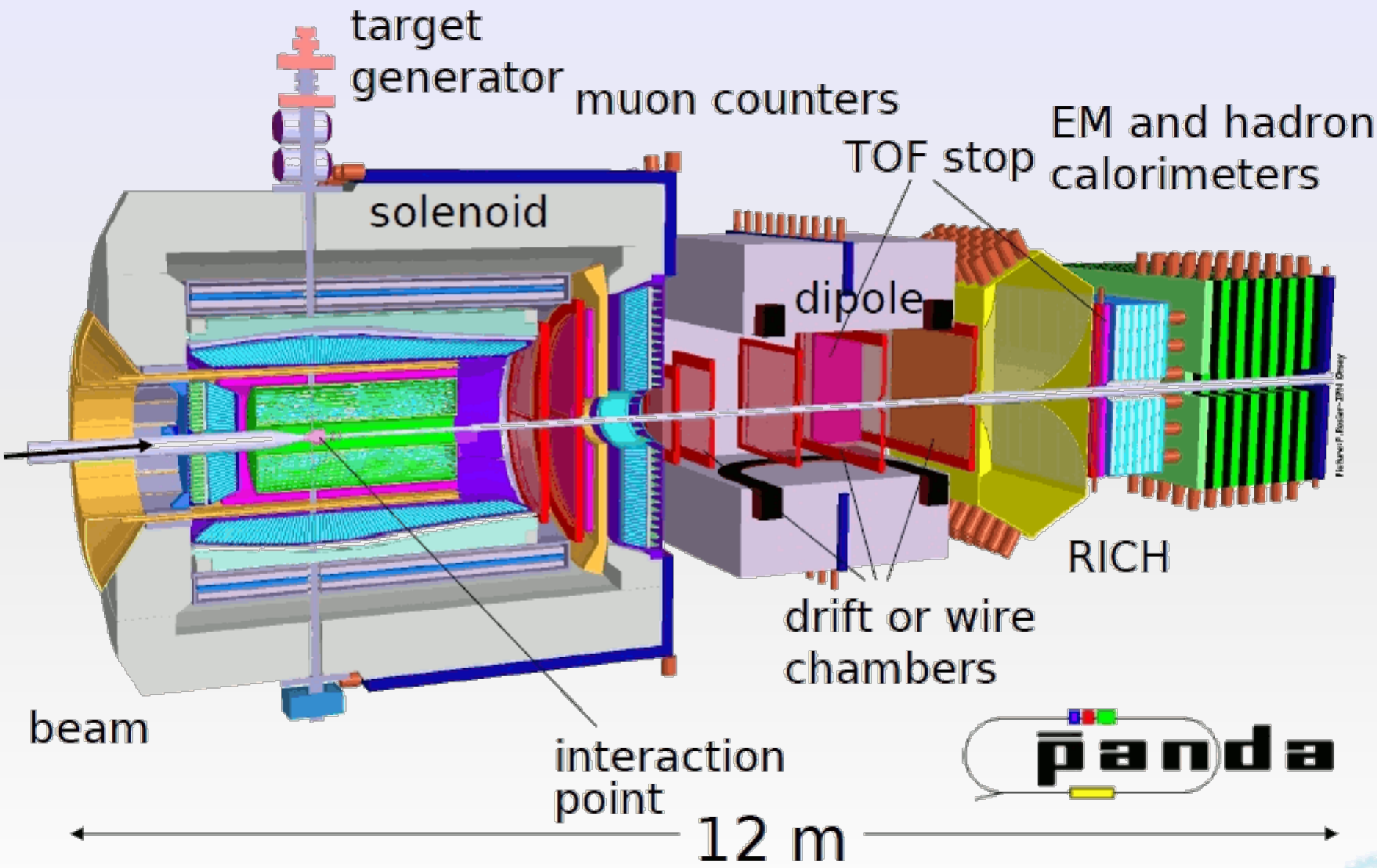
- $\delta p/p \sim 10^{-5}$ (electron cooling)
- Luminosity $10^{31} cm^{-2} s^{-1}$

High luminosity mode

- Luminosity $2 \times 10^{32} cm^{-2} s^{-1}$
- $\delta p/p \sim 10^{-4}$ (electron cooling)

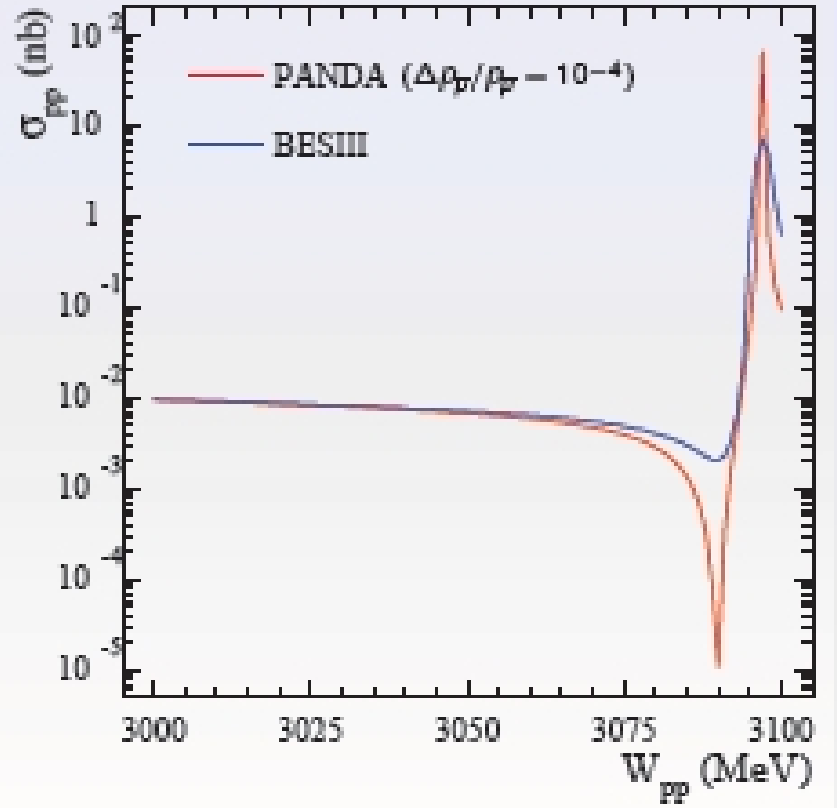


The PANDA Detector



[1] Physics Performance Report for PANDA: Strong Interaction Studies with Antiprotons, arXiv:0903.3905.

Simulated $e^+e^- \to p\bar{p}$ @ PANDA and **BESIII**



BESIII scenario

- strong suppression of interference
- many channels accessible

PANDA scenario

- large un-suppressed interference
- $p\bar{p}$ only

Summary

- scan around interference dip (all exclusive channels for free!)
- at least one point far enough from $M_{J/\psi}$ ($\sim 100 MeV$) for continuum reference
- model independent evaluation of interference
- reference channel: $e^+e^- \to p\bar{p}$

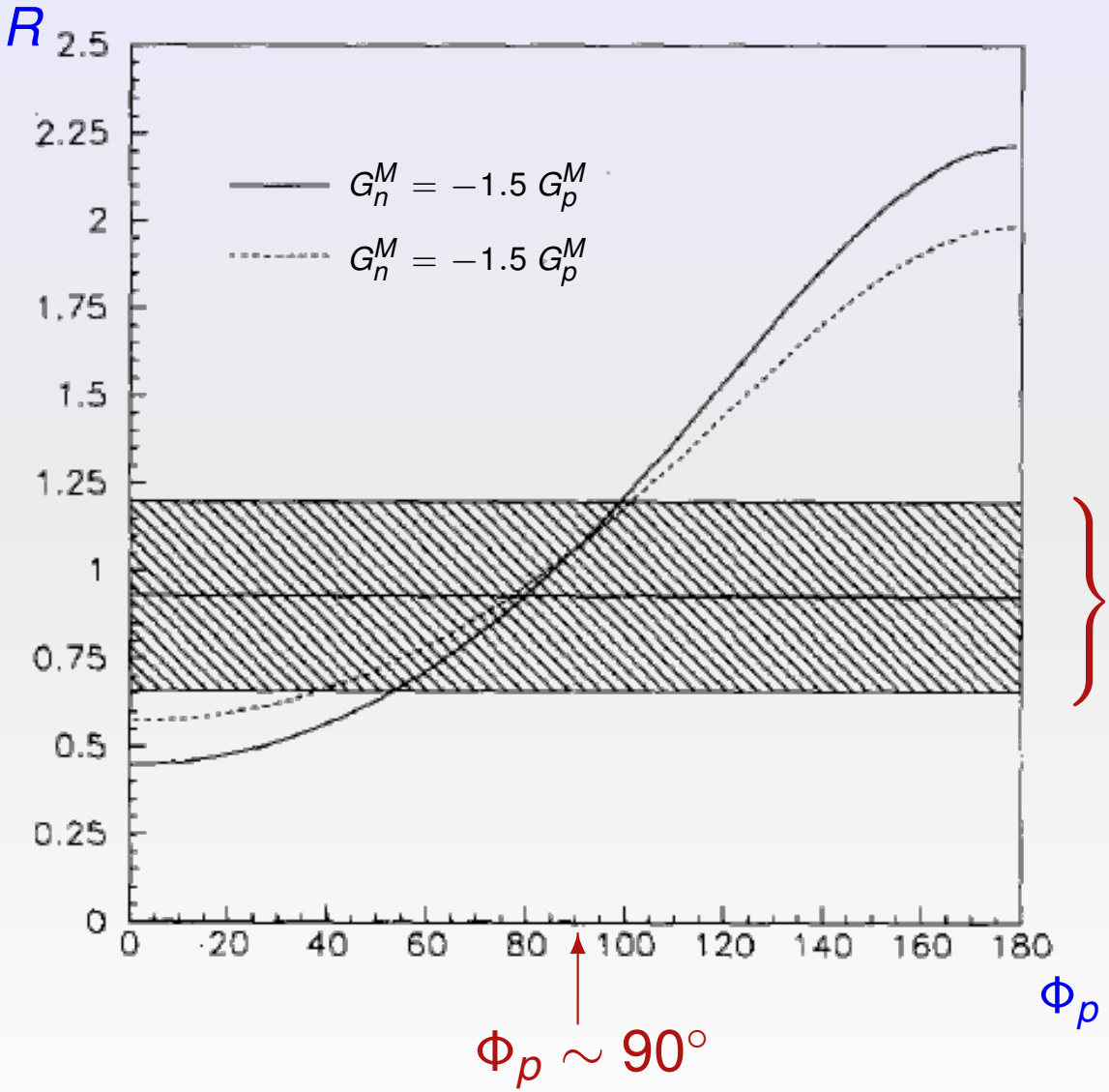
QUOTED RESULTS relative to 20 pb^{-1}

Thank you!

BACK-UP SLIDES

FENICE data on $e^+e^- \to N\bar{N}$ @ $s \sim M^2_{J/\psi}$

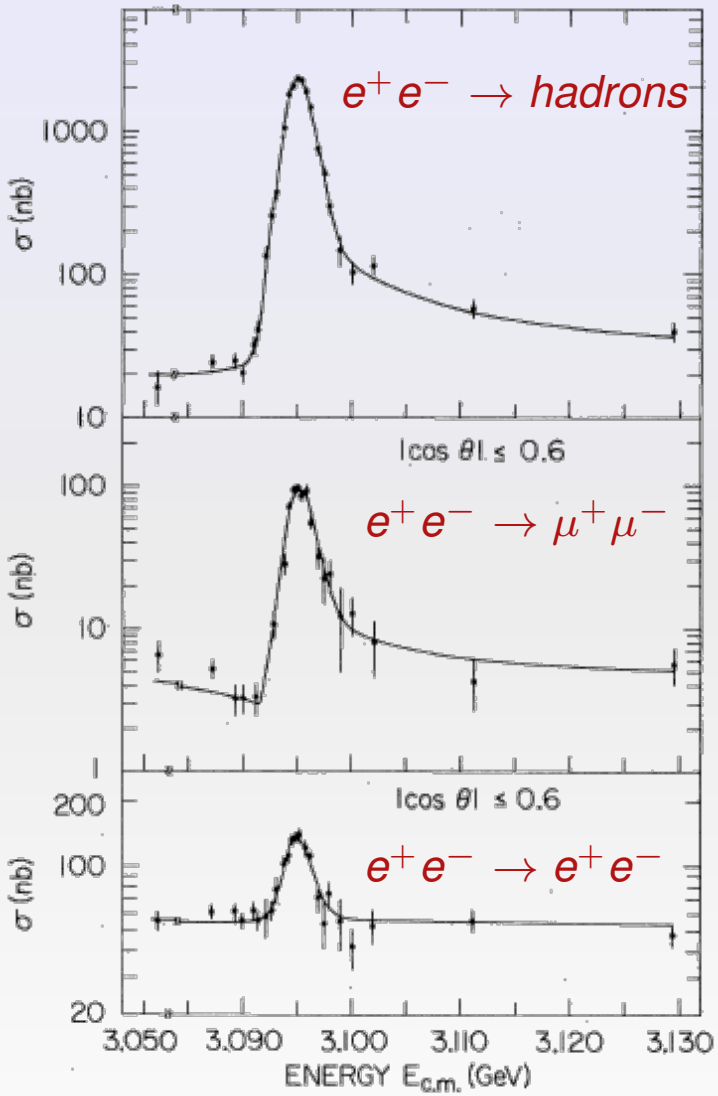
Predictions for Φ_p making use of FENICE data



$$R = \frac{\sigma\,(e^+e^- \Leftrightarrow n\bar{n})}{\sigma\,(e^+e^- \Leftrightarrow p\bar{p})}$$

[1] R. Baldini, C. Bini, E. Luppi, Phys. Lett. B404, 362 (1997).

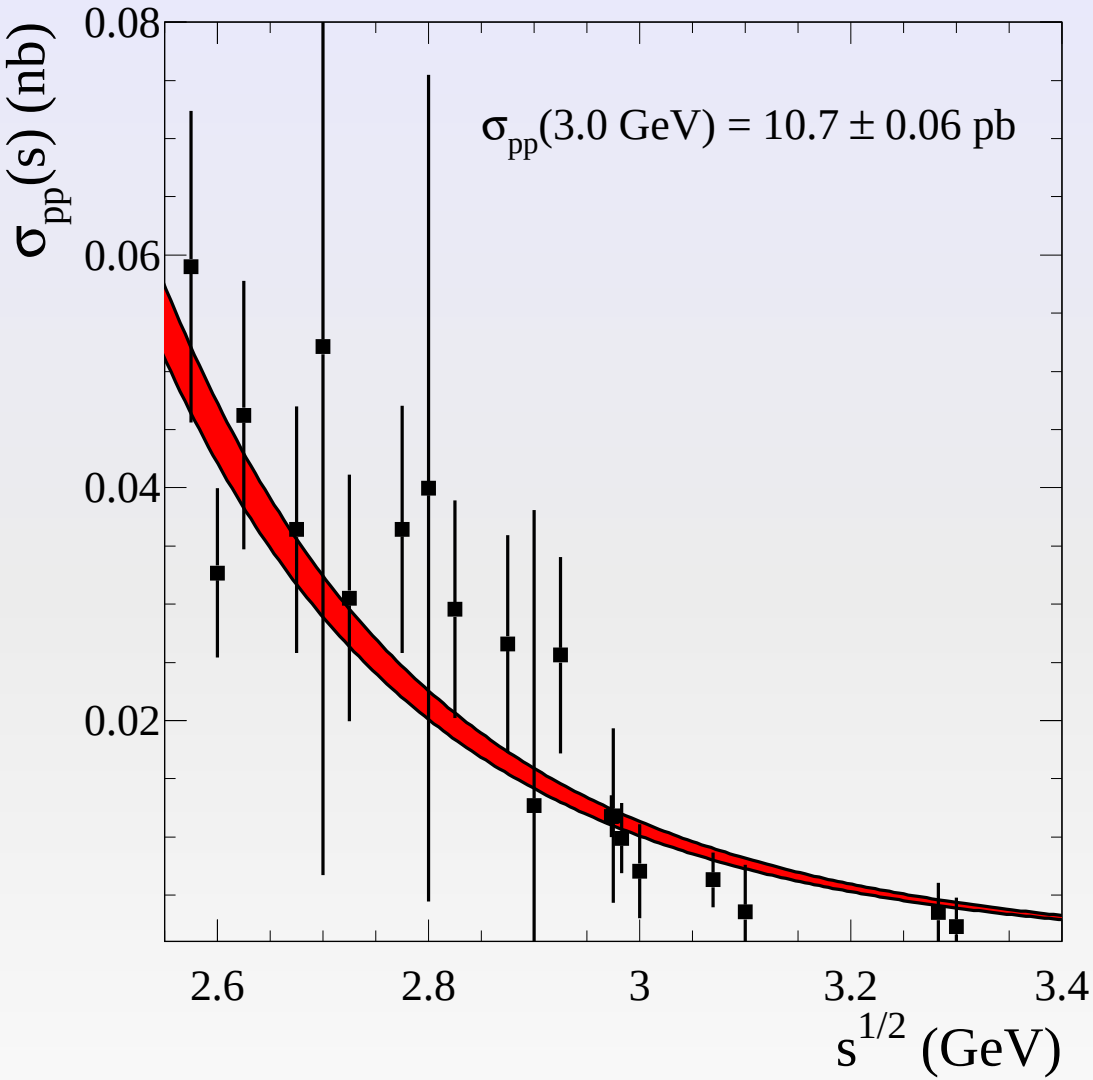
Early evidence of interference in $e^+e^- \to \mu^+\mu^-$



J/ψ production
@ SPEAR (SLAC) [1]

[1] R. Baldini, C. Bini, E. Luppi, Phys. Lett. B404, 362 (1997).

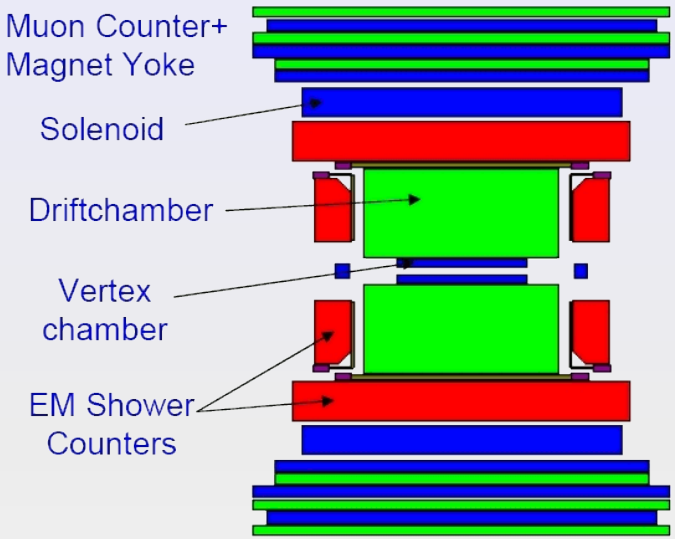
Simulated $e^+e^- \to p\bar{p}$ @ $s \sim M^2_{J/\psi}$ ($20\ pb^{-1}$)



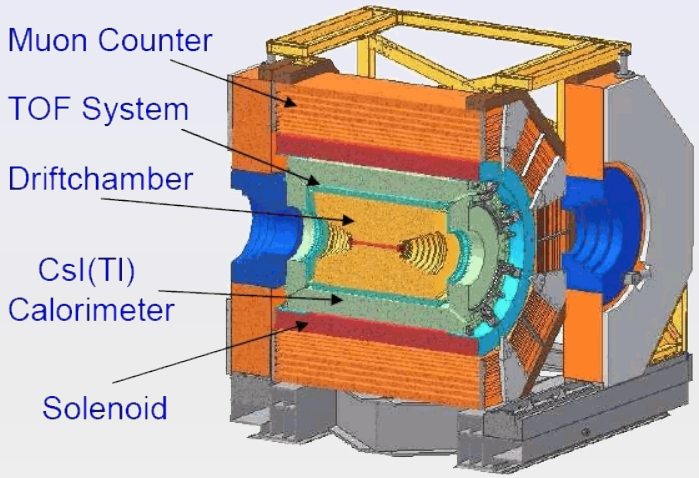
[1] B. Aubert et al. [BABAR Collaboration], Phys. Rev. D 73, 012005 (2006).

The **BESII** and **BESIII** detectors

BESII @ BEPC



BESIII @ BEPCII



Device	Performance
MDC	$\sigma_p/p = 1.7\%\sqrt{1+p^2}$, $dE/dx = 8\%$
TOF	180 ps (bhabha)
EMC	$\sigma_E/E < 22\%/\sqrt{E}$
MUC	3 layers
Magnet	0.4 T Solenoidal

Device	Performance
MDC	$\sigma_p/p = 0.5\%$, $dE/dx < 6\%$
TOF	80 ps barrel (bhabha), 100 ps endcap
EMC	$\sigma_E/E < 2.5\%/\sqrt{E}$
MUC	9 barrel + 8 endcap layers
Magnet	1 T Solenoidal