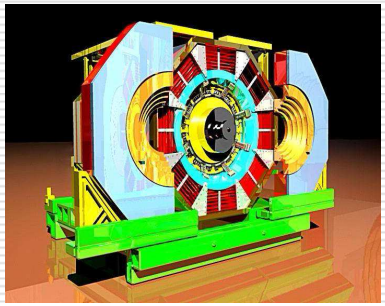
Imaginary Charmonium Decay Widths ?

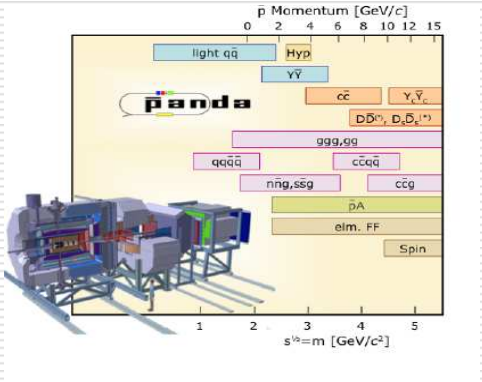
A proposal for PANDA

The BESIII Italian Collaboration [1,2,3,4,5]

Wang Ping[5], Wang Yadi[1], Zhu Kai[5]

1 – Laboratori Nazionali di Frascati, Italy
2 – Università degli Studi di Torino and INFN, Italy
3 – Università degli Studi di Ferrara and INFN, Italy
4 – Università degli Studi di Perugia and INFN, Italy
5 – Institute of High Energy Physics, GUCAS, Beijing, P.R.C.

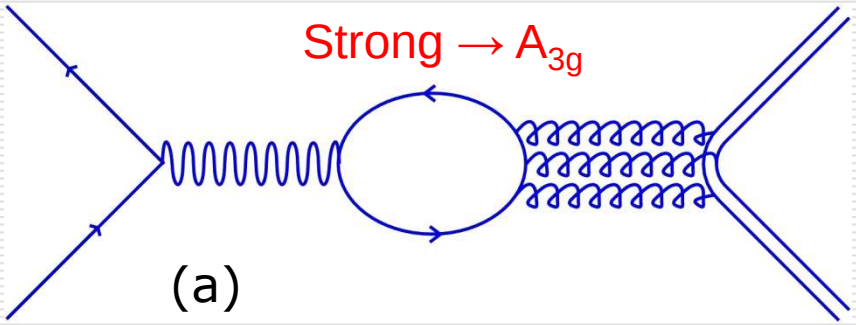


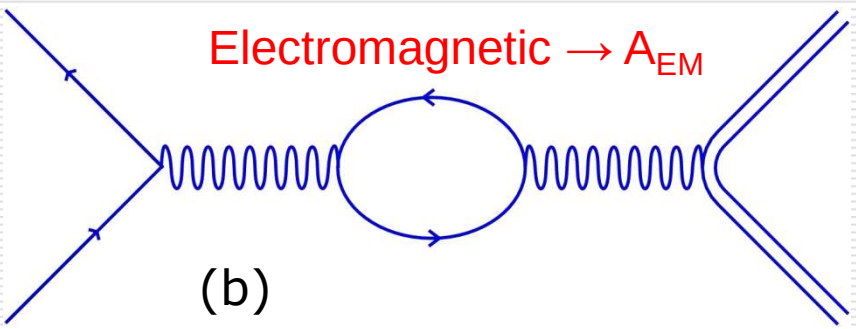


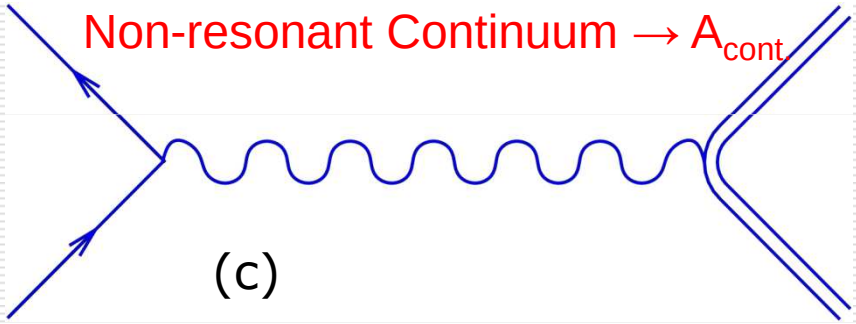
Outline

- Vector Charmonium decay mechanisms
- J/ψ strong imaginary decay widths, experimental evidences:
  - Vector+Pseudoscalar, Pseudoscalar+Pseudoscalar: $|\Phi| \sim 90^0$
  - Energy scan, close to the J/ψ looking for interference, by BESIII: $|\Phi| \sim 90^0$
  - A possible way to get the continuum phase
- Controversial evidences for ψ'(2S)
- ψ''(3770) experimental evidences : $\Phi \sim -90^0$
- A model for strong imaginary decay widths
- **A proposal for PANDA: a ppbar -> J/ψ -> hadrons / μμ scan**

Vector Quarkonium Decay Mechanisms







(a) $e^+e^- \to J/\psi \to$ *hadrons* via strong mechanism (b) via em mechanism

(c) non-resonant $e^+e^- \to$ *hadrons* via a virtual photon.

pQCD regime: all amplitudes real (apart BW resonance behaviour),

while data are as if there is an additional (i) in front of the BW

Experimental Evidences for Imaginary Strong Decay Widths

Model dependent experimental evidences (old data)

SU3 and SU3 Breaking in 1^-0^-, 0^-0^-, 1^-1^- decay : $\Phi \sim 90^\circ$

$J/\Psi \rightarrow VP\ (1^-0^-)$ $\quad \Phi = 106^\circ \pm 10^\circ$ [1]

$J/\Psi \rightarrow PP\ (0^-0^-)$ $\quad \Phi = 89.6^\circ \pm 9.9^\circ$ [2]

$J/\Psi \rightarrow VV\ (1^-1^-)$ $\quad \Phi = 138^\circ \pm 37^\circ$ [2]

More recently:

If $A(e^+e^- \rightarrow nn_{bar}) \sim -A(e^+e^- \rightarrow pp_{bar})$ [3]

$B(nn_{bar})/B(pp_{bar}) = 0.98 \pm 0.08 \rightarrow \Phi \sim 89^\circ \pm 8^\circ$ [4] (BESIII)

[1] L. Kopke and N. Wermes, Phys. Rep. 174, 67 (1989); J. Jousset et al., Phys. Rev. D41,1389 (1990).

[2] M. Suzuki et al., Phys. Rev. D60, 051501 (1999).

[3] FENICE Coll. NP B517(1998)3, SND Phipsi Rome, Sep (2013).

[4] M. Ablikim et al., Phys. Rev. D 86, 032014 (2012).

VP decay
updated and revisited

SU3 and SU3 Breaking Amplitudes

Use reduced amplitudes $B=B_0 / P^{*3}$

Process $J/\psi \rightarrow$	Amplitude
$\rho^+\pi^-, \rho^0\pi^0, \rho^-\pi^+$	$g+e$
$K^{*+}K^-, K^{*-}K^+$	$g(1-s)+e$
$K^{*0}\bar{K}^0, \bar{K}^{*0}K^0$	$g(1-s)-2e$
$\omega\eta$	$(g+e)X_\eta + \sqrt{2}rg(\sqrt{2}X_\eta + Y_\eta)$
$\omega\eta'$	$(g+e)X_{\eta'} + \sqrt{2}rg(\sqrt{2}X_{\eta'} + Y_{\eta'})$
$\phi\eta$	$(g(1-2s)-2e)Y_\eta + rg(\sqrt{2}X_\eta + Y_\eta)$
$\phi\eta'$	$(g(1-2s)-2e)Y_{\eta'} + rg(\sqrt{2}X_{\eta'} + Y_{\eta'})$
$\rho^0\eta$	$3eX_\eta$
$\rho^0\eta'$	$3eX_{\eta'}$
$\omega\pi^0$	$3e$
$\phi\pi^0$	0

J/Ψ
Vector +Pseudoscalar

Parameter		Fit
SU_3 strong Amplitude	g	7.22 ± 0.38
SU_3 breaking strange	s	0.18 ± 0.04
SU_3 breaking DOZI	r	-0.04 ± 0.02
E.M. Amplitude	e	0.75 ± 0.04
Phase	f	**81.51± 6.75**

J/ψ
Vector + Pseudoscalar

Decay	Amplitude	PDGx10⁴	Fitx10⁴	$\Delta\chi^2$
$\rho^0\,\pi^0$	$g\,e^{i\phi}+e$	169.0 ±15.0	133.00	1.13
$K^{*+}\,K^-$	$g\,(1-s)\,e^{i\phi}+e$	51.2 ± 3.0	51.5	0.01
$K^{*0}\,K^0$	$g\,(1-s)e^{i\phi}-2e$	43.9 ± 3.1	48.5	0.48
$\omega\,\eta$	$(g\,X+d)e^{i\phi}+eX$	17.4 ± 2.0	18.5	0.06
$\phi\,\eta$	$(g\,(1-2s)Y+d)e^{i\phi}-2eY$	7.5 ± 0.8	3.9	4.02
$\rho\,\eta$	$3eX$	1.9 ± 0.2	2.2	0.30
$\omega\,\pi$	$3e$	4.5 ± 0.5	4.1	0.11
$\omega\,\eta'$	$(g\,X'+d')e^{i\phi}+eX'$	7.0 ± 7.0	11.9	0.10
$\phi\,\eta'$	$(g\,(1-2s)Y'+d\,`\,)e^{i\phi}-2eY'$	4.0 ± 0.7	6.1	1.87
$\rho\,H$	$3eX'$	1.1 ± 0.2	1.1	0.04

PP decay
updated and revisited

Pseudoscalar Pseudoscalar Decay Revisited

- Open question about $J/\Psi \to \pi\pi$ decay, since pure em :

  $B^{\pi\pi} = |E^{\pi\pi}|^2$, , while

  $B^{\pi\pi}$ = **$(1.47 \pm .23)\ 10^{-4}$** *from PDG*

  $|E^{\pi\pi}|^2 = B^{\mu\mu}\ \sigma(e^+e^- \to \pi^+\pi^-)/\ \sigma(e^+e^- \to \mu\mu) =$

  = **$(0.46 \pm .23)\ 10^{-4}$** *extrapolated from BaBar*

  $B^{\pi\pi}$ ǂ $|E^{\pi\pi}|^2$ by 3 s.d.

- $\pi\pi$ cross section slope B ,

  asymptotically it is expected B= -2-4 x n_q = -6

  $B^{\pi\pi} \sim -10 \pm 2$

Pseudoscalar Pseudoscalar Decay Revisited

- It is possible to avoid $\pi\pi$ and complications from s quark by means of KK BR's and $|E^{KK}|$ only

- $B^{+-} = |S|^2 + |E^{+-}|^2 + 2\,|S||E^{+-}| \cos\Phi$
  $B^{SL} = |S|^2 + |E^{SL}|^2 - 2\,|S||E^{SL}| \cos\Phi$

- $|E^{+-}|^2 = B^{\mu\mu}\ \sigma(e^+e^- \to K^+K^-)/\ \sigma(e^+e^- \to \mu\,\mu)$
  $|E^{SL}|^2 \sim 0$, since $\sigma(e\,e \to K_S\,K_L) << \sigma(e\,e \to K^+\,K^-)$
  $\sigma(e^+\,e^- \to K_S\,K_L) \sim$ 0.6 pb at J/ Ψ
  $B^{+-} = (2.37 \pm 0.31)\ 10^{-4}$ $B^{SL} = (1.66 \pm 0.26)\ 10^{-4}$
  $|E^{+-}|^2 = (1.3 \pm 0.6)\ 10^{-4}$ *from BaBar*
  $\Phi = 83.7^0 \pm 9.0^0$

The ψ' Puzzle

Ψ'
Vector + Pseudoscalar

Parameter		Fit
SU_3 strong Amplitude	g	0.49 ± 0.04
SU_3 breaking strange	s	-0.04 ± 0.13
SU_3 breaking DOZI	r	-0.04 ± 0.08
E.M. Amplitude	e	0.18 ± 0.02
Phase	f	**159.± 12.**

χ^2/DFR =0.96

Φ at the Ψ' from K*(892)K Decay Only

- $K^*(892)$ K decay: possible to avoid SU_3 assumptions and complications from s quark mass, since CLEOc measured the continuum cross sections
- CLEOc (arXiv:hep-ex/0509011v2):

  $\sigma(e\,e \to K^{*0}\,K^0 + cc) = (23.5 \pm 5.3)$ pb at W=3.67 GeV

  $\sigma(e\,e \to K^{*+}\,K^- + cc) \sim (1 \pm 0.9)$ pb

  $|E^{+-}|^2 \sim 0.1 \times 10^{-5}$ $|E^{00}|^2 \sim 28. \times 10^{-5}$

- $B^{+-} = (1.7 \pm 0.8) \times 10^{-5}$ $B^{00} = (10.9 \pm 2.0) \times 10^{-5}$

  $B^{+-} = |S|^2 + |E^{+-}|^2 + 2 \times |S||E^{+-}| \cos\Phi$

  $B^{00} = |S|^2 + |E^{00}|^2 - 2 \times |S||E^{00}| \cos\Phi$

$\Phi = 159^0 \pm 24^0$ again like VP !

Pseudoscalar Pseudoscalar Decay

- Ψ' :

  $B^{+-} = (6.30 \pm 0.70)\ 10^{-5}$ $B^{SL} = (5.26 \pm 0.25)\ 10^{-5}$

  $|E^{+-}|^2 = (0.7 \pm 0.4)\ 10^{-5}$ *from BaBar*

  $\Phi = 95^0 \pm 11^0$ **(6.3~ 5.26+0.7+3.8x$\cos\Phi$)**

- **But Nambu wrote Ψ' might be different**

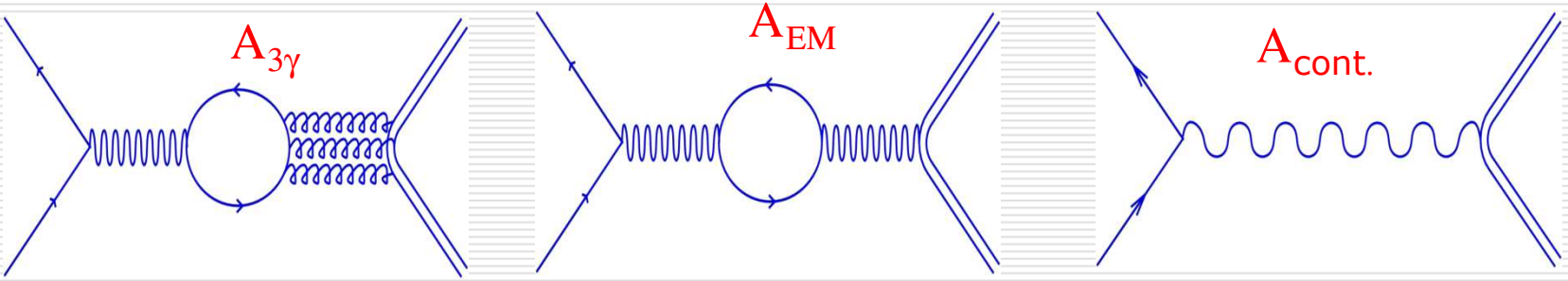
Experimental evidences for Ψ(3770) imaginary strong decay widths

ψ”(3770):

- non DDbar (small) -> throught the interfence with continuum
- For a wide resonance Φ from interference at the peak
  - $2|A_{3g}|/\Gamma_{tot}$ sin Φ x continuum
- CLEOc and BESIII: $\Phi \sim -90^\circ$, since continuum sign

decay	continuum	Ψ''(3770)	sign	
ρ π	13.1±2.8	7.4±1.3	-	CLEOc, PRD 73(2006)012002
ϕ η	2.1±1.6	4.5±0.7	+	CLEOc, PRD 73(2006)012002
p p̲	0.74±0.08	0.4±0.02	-	BESIII Y.Liang, Nov (2012)

Model independent
from interference in q^2 behavior

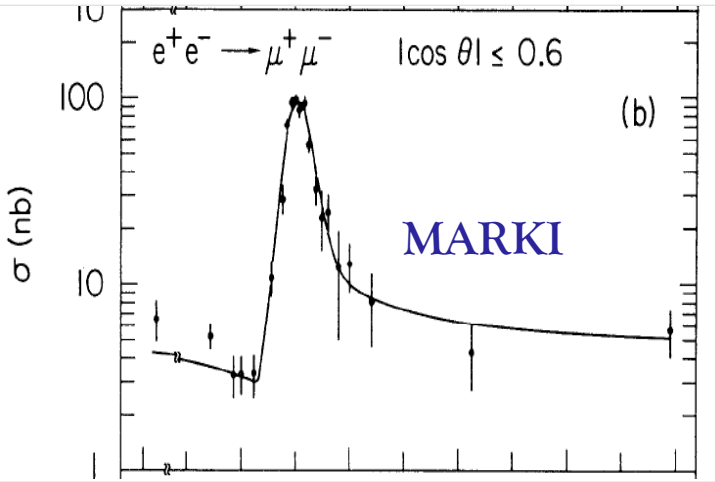


$$\sigma_{born} = |A_{3g} + A_{EM} + A_{cont}|^2 = ||A_{3g}|e^{i\varphi} + |A_{EM} + e^{i\varphi}\,'A_{cont}||^2$$

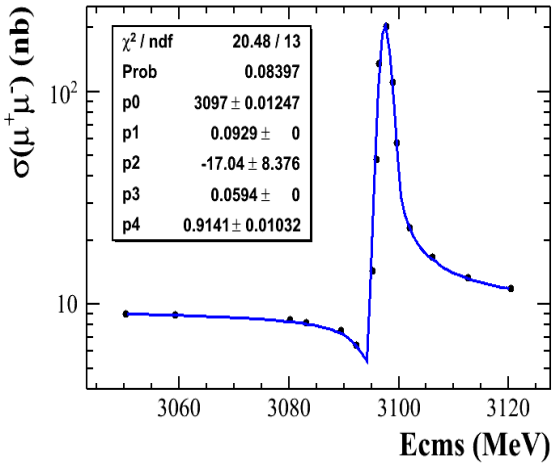
Actually $\Phi_{meas} = \Phi - \delta_{cont}$ and $|\Phi_{meas}|$ only is measured, since it is difficult to get the sign

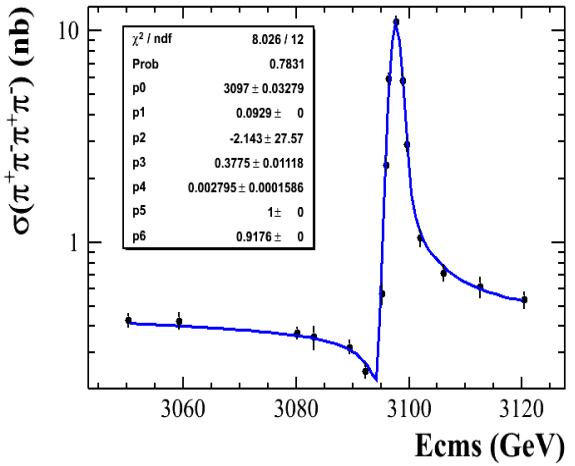
The full interference between A_{EM} and A_{cont} has been observed , as expected, at MARKI(1975), BESII (1995), KDER (2010).

1/2 photon propagators require $\varphi' = 180^o$

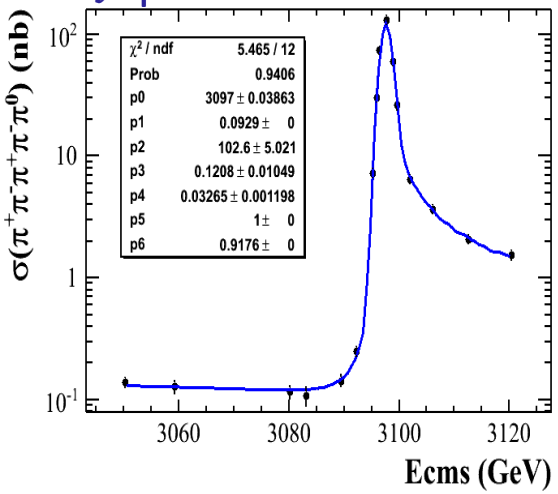


BESIII J/Ψ scan

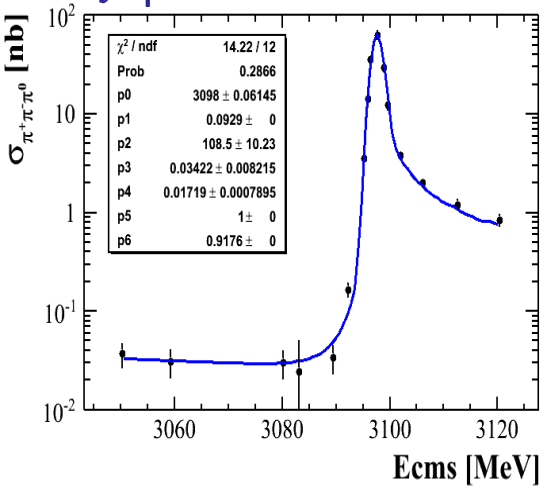




J/ψ→π+π−π+π−π0



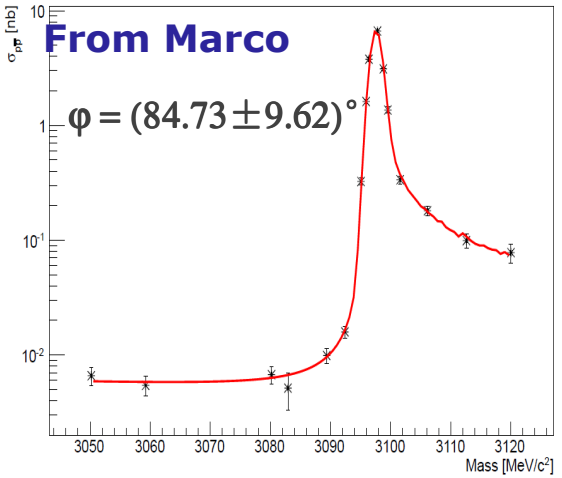
J/ψ→π+π−π0



J/ψ→pp

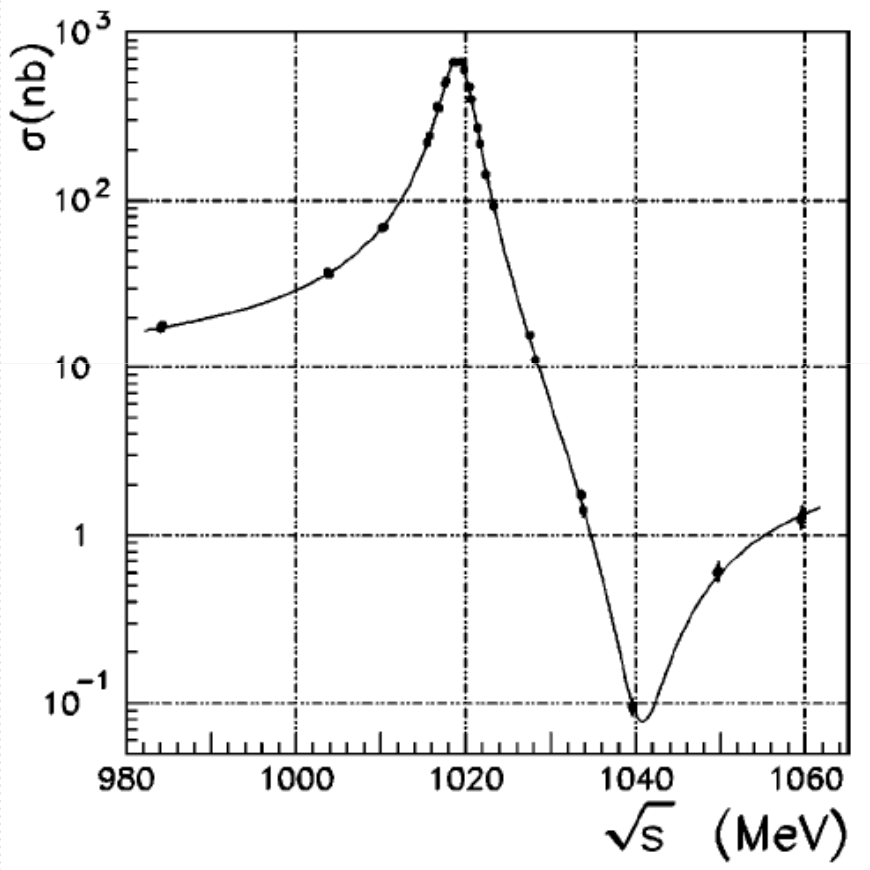
From Marco

φ = (84.73 ± 9.62)°



The interference pattern is not always the same.

$e^+e^- \rightarrow \pi^+\pi^-\pi^0$ @ VEPP2M



φ~180°

Phys. Rev.D 63, 072002

A possible way to get the continuum phase (work in progress)

Continuum phase d(s)

- Continuum amplitudes should be almost real : $\delta(s) \sim 0^0$ or 180^0
- Logarithm Dispersion Relations
  relating modulus $|F(s)|^2 \sim \sigma(s)$ and $\delta(s)$ might help:

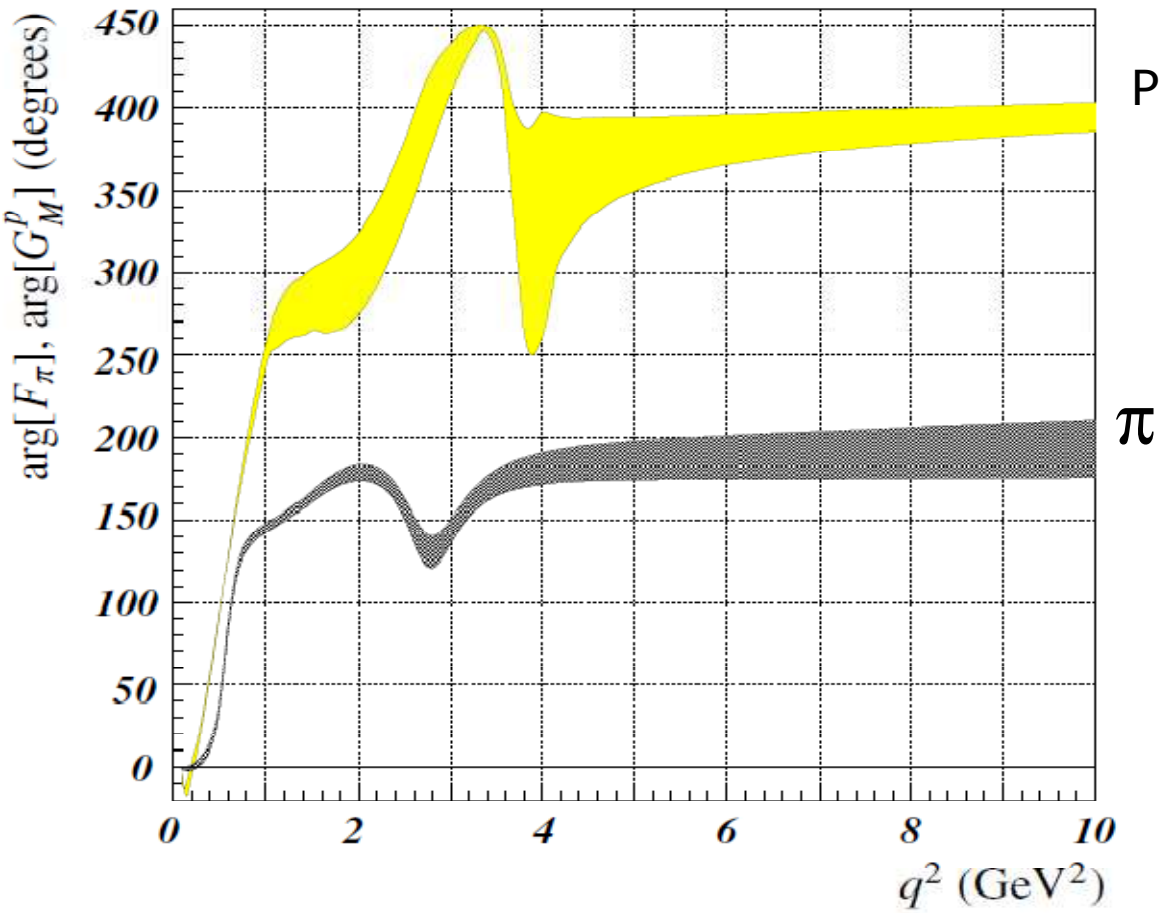
$$\delta(s) = -\frac{\sqrt{s-q_t^2}}{\pi} \mathrm{PV} \int_{q_t^2}^{\infty} \frac{\ln|F(t)/F(0)|}{(t-s)\sqrt{t-q_t^2}} dt ,$$

$$\delta(s) = -\frac{\sqrt{s-q_t^2}}{\pi} \mathrm{PV} \int_{q_t^2}^{\infty} \frac{\ln|F(t)/F(0)|}{(t-s)\sqrt{t-q_t^2}} dt .$$

- Check: phase as expected, if $|F(s)|^2 \sim$ BW $\sim \sigma(s)$ / IPS
- Applied to $\sigma(e^+e^- \to 3\pi)$: $\delta(s) \sim 180^0$
  $\sigma(e^+e^- \to p\bar{p})$ (unphysical region): $\delta(s) \sim 360^0$
  $\sigma(e^+e^- \to \pi\pi)$: $\delta(s) \sim 180^0$
- If $\delta(s) \neq 0$ and it is known how 180^0 or 0^0 is asymp reached, from $|\Phi_{meas}| = |\phi - \delta|$ the sign (+/- 90^0) might be established

$\pi^+ \pi^-$ and pp_{bar} (throught the unphysical region.) phases

(S.Pacetti, R. Baldini… EPJC 11(1999)709… long time ago)



Open Issues related to Unitarity

- **No explanation for imaginary strong decay J/ Ψ widths has been put forward until now**
- J/ Ψ description as a Breit Wigner might have some difficulties , dealing with imaginary decay widths
- Optical theorem : $\mathrm{Im}\ T_{el} = W/8\pi \cdot \sigma_{tot}$ implies $\mathrm{Im}\ T_{el} > 0$
- $\Gamma(J/\Psi \rightarrow p\bar{p})$ imaginary: $\mathrm{Im}\ T_{el}(p\bar{p} \rightarrow J/\Psi \rightarrow p\bar{p}) < 0$
- $p\bar{p}$ continuum could restore unitarity, even if unrelated to J/ Ψ ?
- Looking for a different J/ Ψ description
- $\sigma_{el}(p\bar{p} \rightarrow J/\Psi \rightarrow \text{hadrons})$: a test of the following model

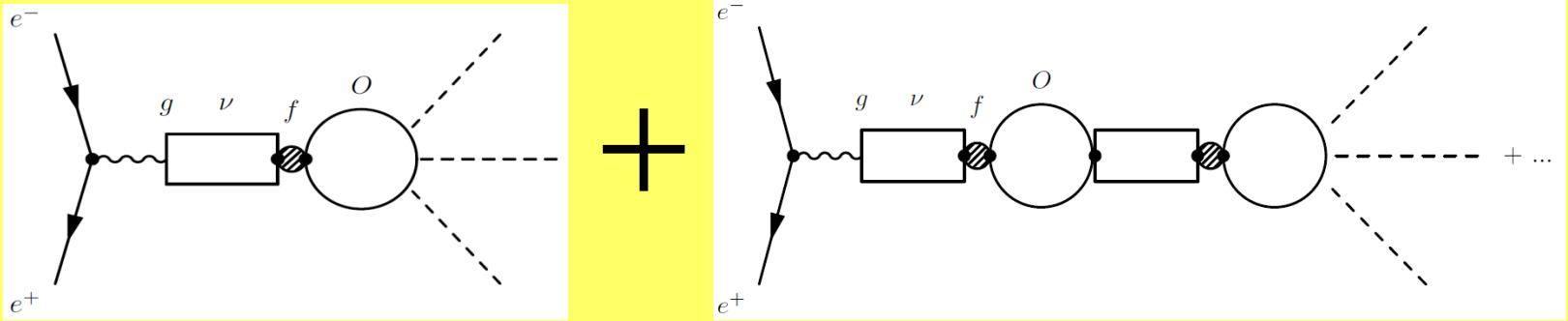
A model to explain imaginary widths

Quarkonium OZI breaking decay

as Freund and Nambu (PRL 34(1975), 1645)

- Quarkonium as a superposition of
  - A narrow V (coupled to leptons, but not directly to hadrons)
  - A wide one (a glueball O)
    (not coupled to leptons, but strongly coupled to hadrons)

***f* is the coupling between ν and $\mathcal{O}$**



iterated in f

Quarkonium OZI breaking decay

as Freund and Nambu (PRL 34(1975), 1645)

- Quarkonium as a superposition of V and O:

$$A_{strong} = G_e\, O^{-1}\, f\, V^{-1}\, f\, O^{-1}\, G_f + \text{iterations}$$

$$A_{strong} = G_e\, O^{-1}\; 1/\,(1- V^{-1}\, O^{-1}\, f^2\,)\; G_f$$

- $A_{em} = G_e\, V^{-1}\, G_l + G_e\, O^{-1}\, f\, V^{-1}\, f\, O^{-1}\, G_l + \text{iterations}$

$$A = G_e\, V^{-1}\; 1/\,(1- V^{-1}\, O^{-1}\, f^2\,)\; G_l \sim BW_{ee}$$

- An infinity of radial O recurrences

- This model mainly used to explain $Br(\psi')\,/Br(J/\psi)$ anomalies
  S. J. Brodsky, G. P. Lepage, S. F. Tuan, PRL 59, 621(1987)
  W.S. Hou, C.Y. Ko, NTUTH-97-11, 1997

Narrow V and wide glueball O superposition

P.J.Franzini, F.J.Gilman, PR D32, 237 (1985)

$$A_{strong} = \frac{\sqrt{\Gamma_{ee}} M_V M_O f \sqrt{\Gamma_O}}{(M_V^2 - W^2 - i M_V \Gamma_V)(M_O^2 - W^2 - i M_O \Gamma_O) - M_V M_O f^2}$$

assuming $\Gamma_O >> \Gamma_{J/\psi}$, $f^2 \sim \Gamma_O (\Gamma_{J/\psi} - \Gamma_V)$

$$A_{strong} \sim \frac{i \sqrt{B_{ee}}\, M_V f\, \sqrt{B_h}}{M_{J/\Psi}^2 - W^2 - i M_{J/\Psi} \Gamma_{J/\Psi}} \qquad A_{em} = \frac{\sqrt{B_{ee}}\, M_V \Gamma_{J/\Psi}\, \sqrt{B_{em}}}{M_{J/\Psi}^2 - W^2 - i M_{J/\Psi} \Gamma_{J/\Psi}}$$

- **The additional 90º phase is naturally achieved**
- J/ψ shape reproduced if: $|f| \sim$ 0.012 GeV , $M_O \sim M_{J/\psi}$, $\Gamma_O \sim 0.65$ GeV i
- Cross section affected far from the J/ψ (no contradiction with BES, PR 54(1996)1221)
- ψ "(3770) decay phases agree with Nambu suggestion.
- **ψ ' unclear; ψ ' -> J/ψ ππ (?)**

SND $\Phi \to \pi^+ \pi^- \pi^0$

SND measured $\Phi \to \pi^+\pi^-\pi^0$.

ϕ interferes with ω and ω' tails:

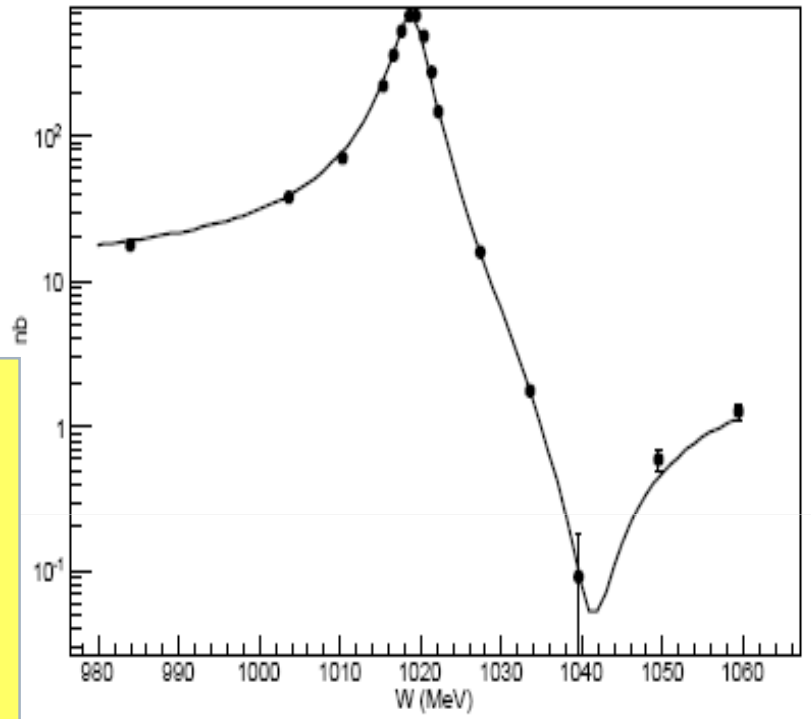
$\varphi \sim 180$ (interference dip is after the Φ)

Fit SND Φ and continuum data with

$f = -0.016$ GeV (close to J/Ψ !)

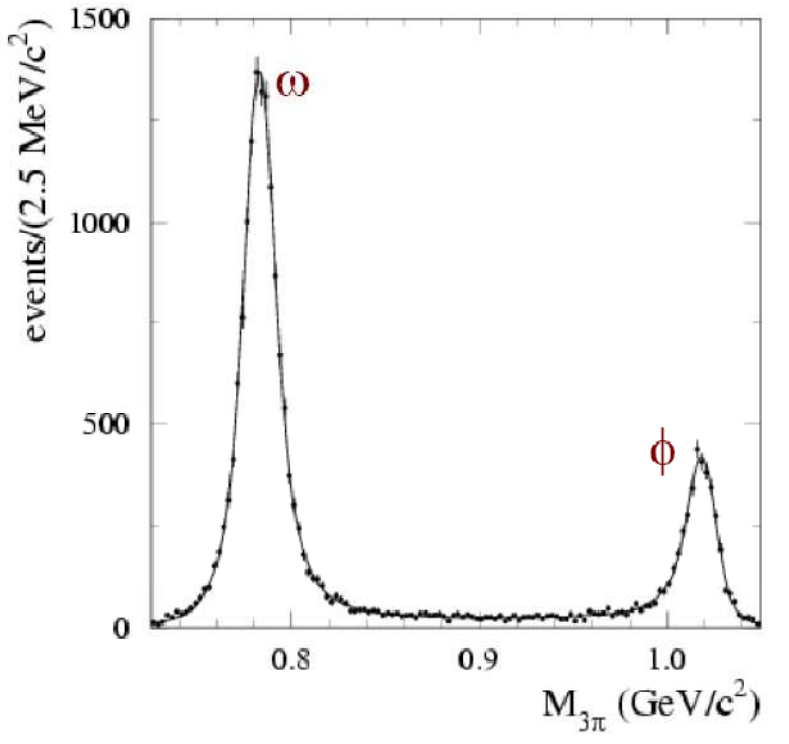
$M_O = 1.34$ GeV

$\Gamma_O \sim 0.5$ GeV

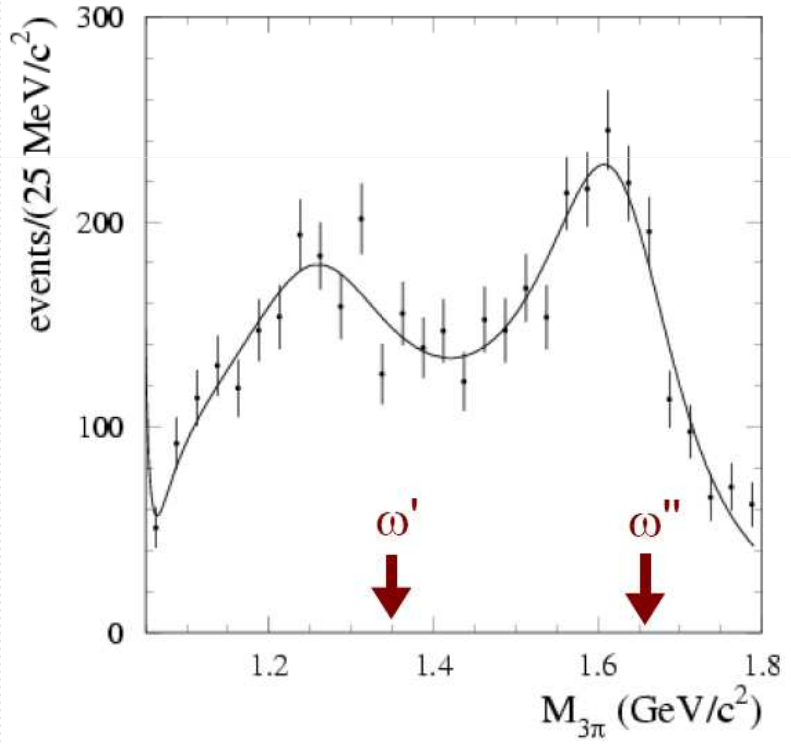


SND data on 3π and present model prediction

BaBar $\pi^+ \pi^- \pi^0$ PR D69(2004) 011103



BaBar found indeed an unexpected resonance (O ?)
at 1.35 GeV , wide 0.45 GeV



Masses and widths

$$M_{\omega'} = (1350 \pm 20 \pm 20)\,\mathrm{MeV}/c^2$$
$$\Gamma_{\omega'} = (450 \pm 70 \pm 70)\,\mathrm{MeV}/c^2$$
$$M_{\omega''} = (1660 \pm 10 \pm 2)\,\mathrm{MeV}/c^2$$
$$\Gamma_{\omega''} = (230 \pm 30 \pm 20)\,\mathrm{MeV}/c^2$$

A proposal for PANDA: a J/Ψ scan

A Proposal for PANDA

- Expected σ (p p_{bar} -> J/Ψ –> hadrons) ~ 1 μb

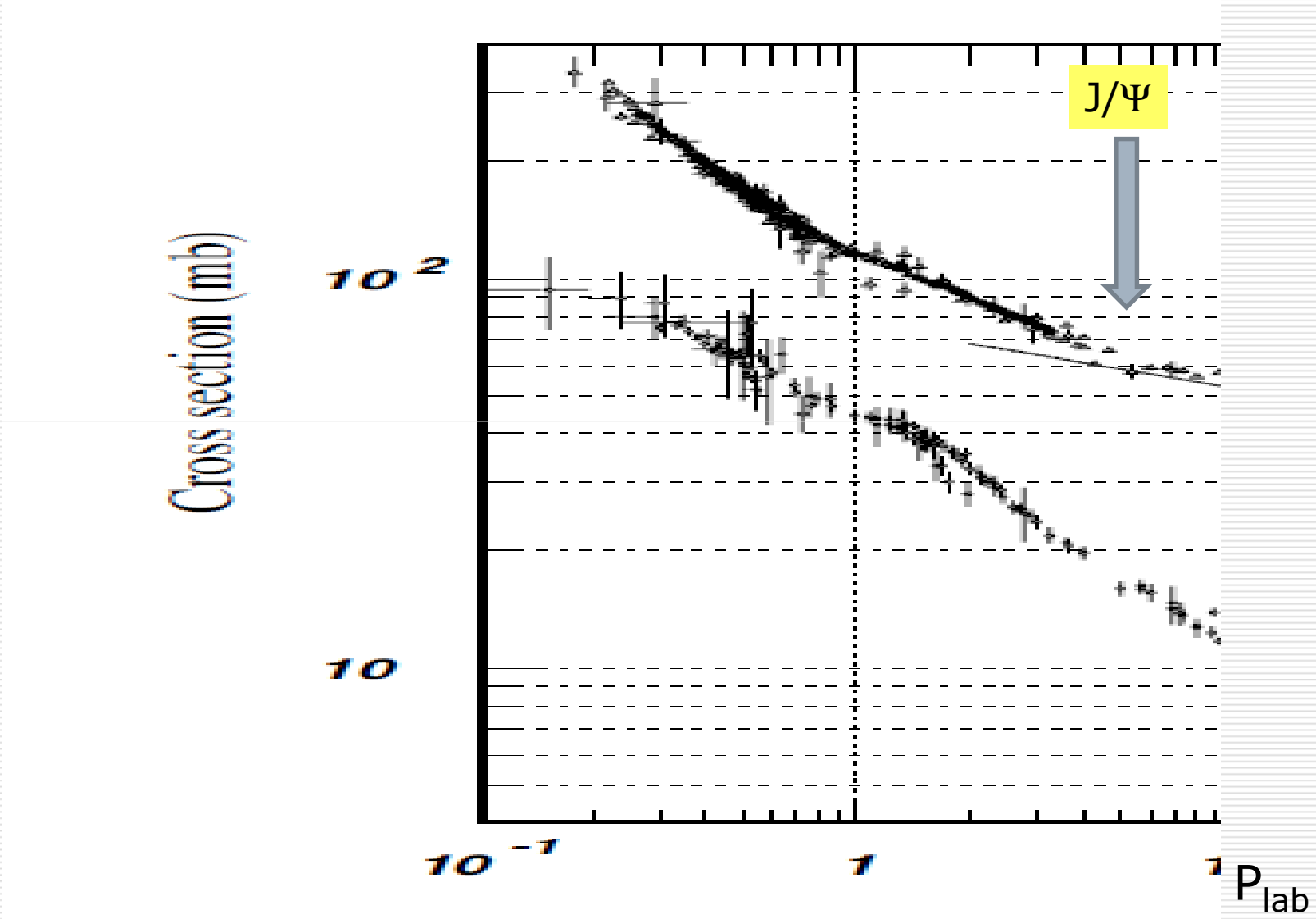
  while σ (p p_{bar} -> hadrons) ~ 70 mb

- No J/ Ψ exclusive production evidence in present data

  (too small cross section + p p_{bar} c.m. energy spread)

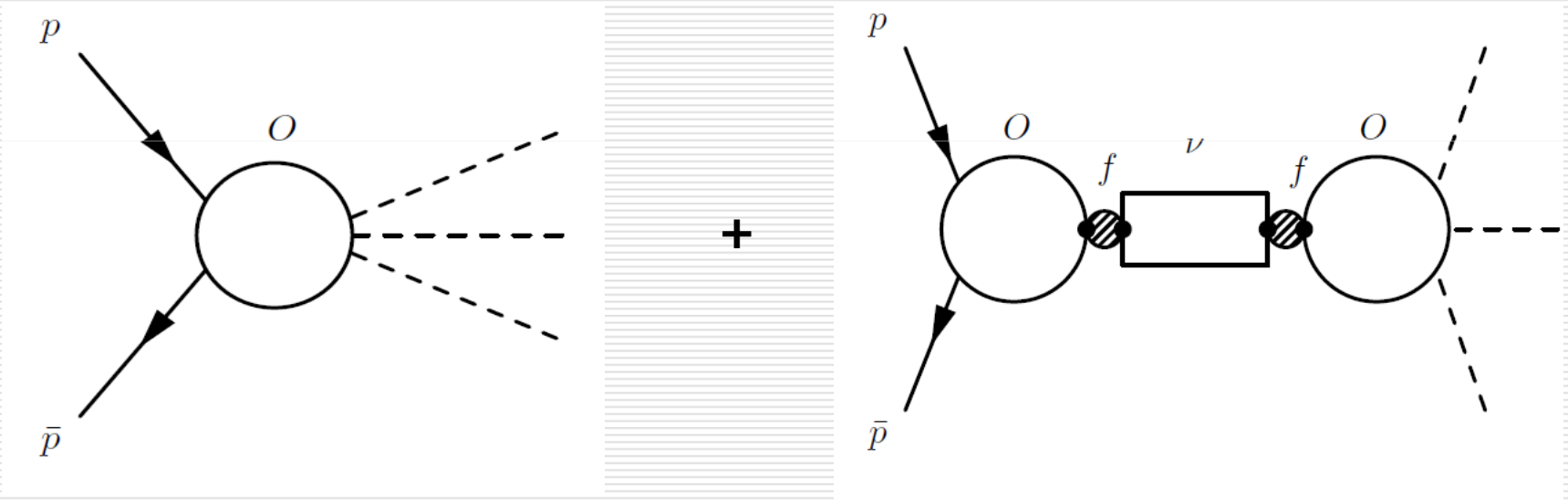
- Different mechanism in inclusive or exclusive production:
  - Inclusive production: direct coupling to gluons or virtual photon
  - Exclusive production: hadronic -> apply FN model

p p_{bar} Total and Elastic cross section (PDG2012)



A Proposal for PANDA

Contributions to p p_{bar} -> J/Ψ -> hadrons, according to the FN model



A Proposal for PANDA

- $A = G_P\, O^{-1}\, G_h + G_p\, O^{-1}\, f\, V^{-1}\, f\, O^{-1}\, G_h$ + iterations

  $A = G_p\, O^{-1}\; 1/\,(1- V^{-1}\, O^{-1}\, f^2)\; G_h$

  $A = G_P\, G_h\; V\,/\,(V\, O - f^2)$

- Still assuming
  - $\Delta W \sim \Gamma_{J/\Psi}$ -> $(M_O{}^2 - W^2)/M_O << \Gamma_O$
  - $f^2 \sim \Gamma_O\,(\Gamma_{J/\Psi} - \Gamma_V)$
  - Amplitudes $p\ p_{bar}$ -> V , V-> $p\ p_{bar}$ are neglected

A Proposal for PANDA

- According to the FN approach

$$\sigma_{FN} = \frac{B_p \;\; [(M_{J/\Psi}^2 - W^2)^2 + (M_{J/\Psi}\Gamma_V)^2)] \;\; B_h}{(M_{J/\Psi}^2 - W^2)^2 + (M_{J/\Psi}\Gamma_{J/\Psi})^2}$$

Taking into account that $\Gamma_V << \Gamma_{\vartheta/\Psi}$

$$\sigma_{FN} = \frac{B_p \;\; (M_{J/\Psi}^2 - W^2)^2 \;\; B_h}{(M_{J/\Psi}^2 - W^2)^2 + (M_{J/\Psi}\Gamma_{J/\Psi})^2}$$

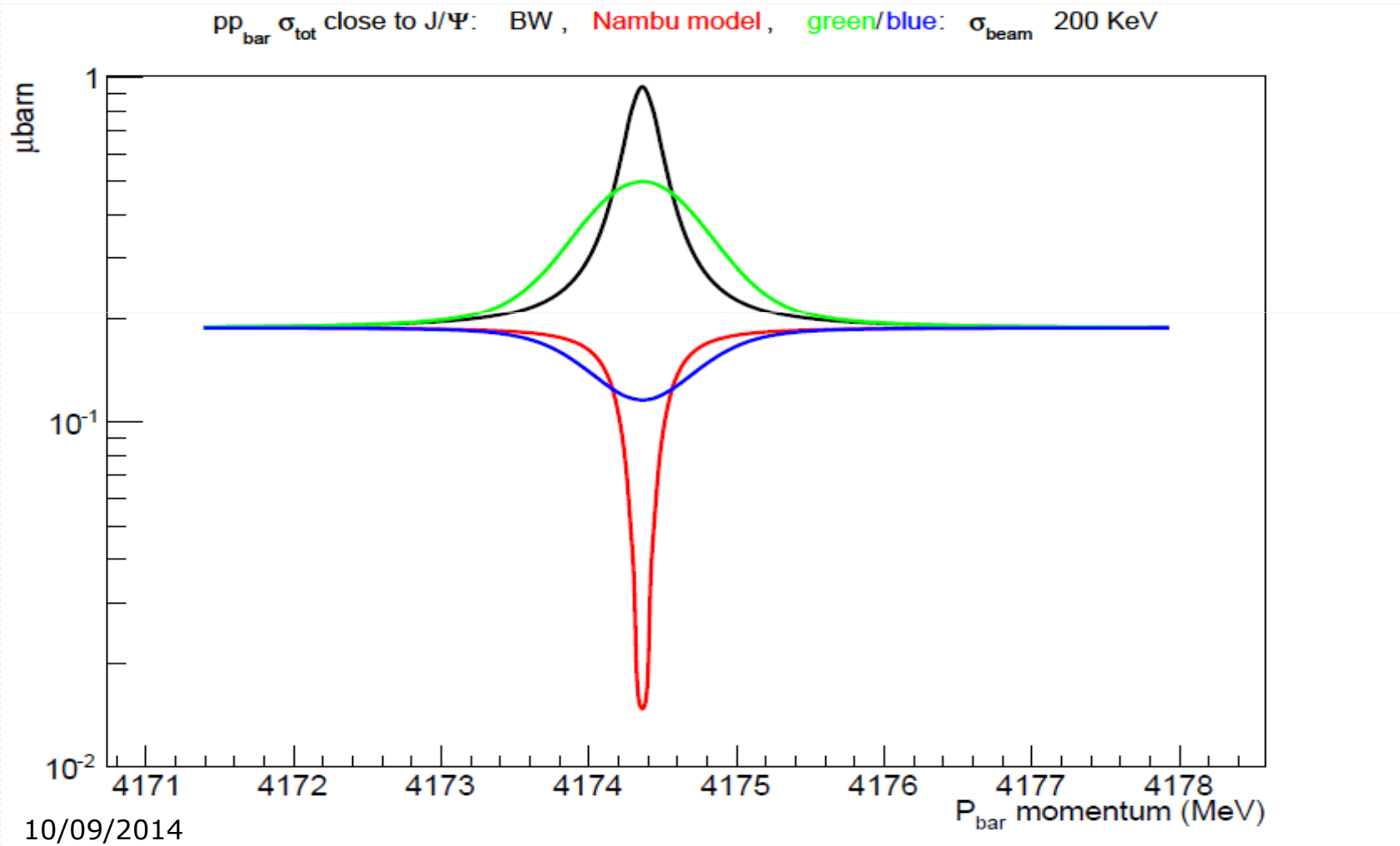
a zero -> a dip in σ_h

- To be compared to a Breit Wigner

$$\sigma_{BW} = \frac{B_p \;\; \Gamma_{J/\Psi}^2 \;\; B_h}{(M_{J/\Psi}^2 - W^2)^2 + (M_{J/\Psi}\Gamma_{J/\Psi})^2}$$

A Proposal for PANDA

PANDA inv mass resolution: small beam energy spread and no ISR



A Proposal for PANDA

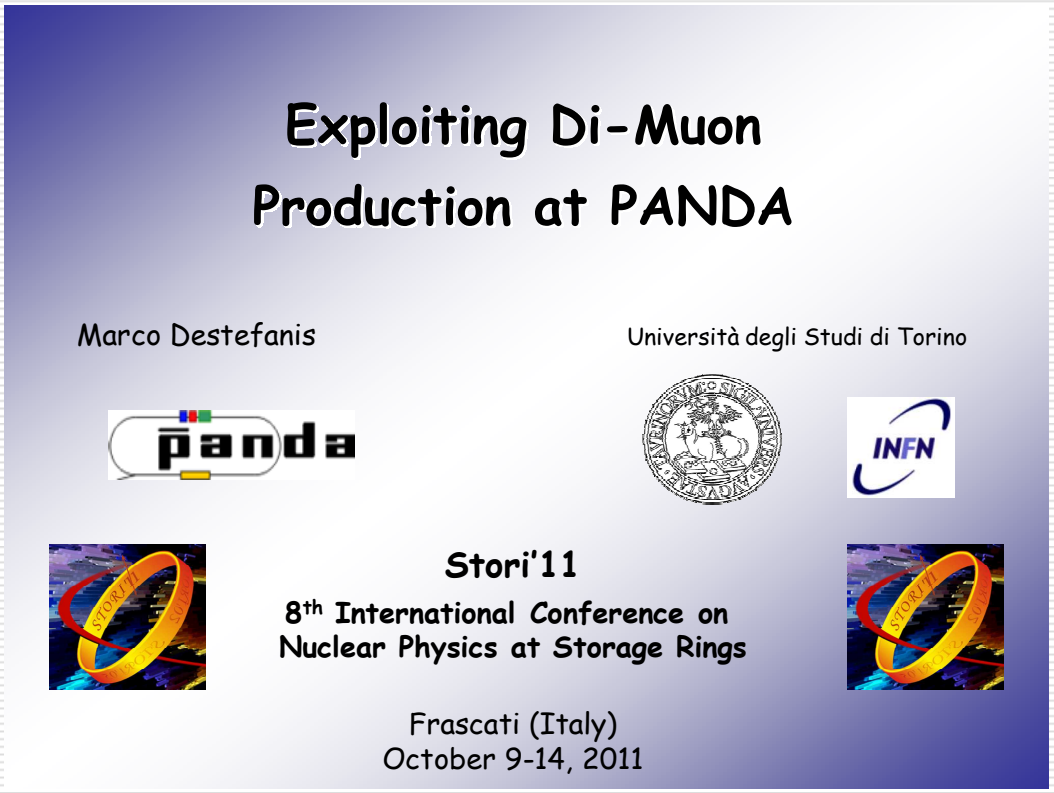
- Rough estimation of the integrated luminosity:
  - Signal ~ 0.2 μb
  - Background ~ $5 \cdot 10^4$ μb
  - L ~ 10^{31} cm^{-2} sec^{-1}
- S ~ n · √B , after T -> 0.2 · T · L ~ n √ ($5 \cdot 10^4 \cdot T \cdot L$)

  T ~ some months, if n ~ 4, assuming a 10 points scan

  (efficiency and dead time to be included)
- Of course time available for any other measurement at J/Ψ

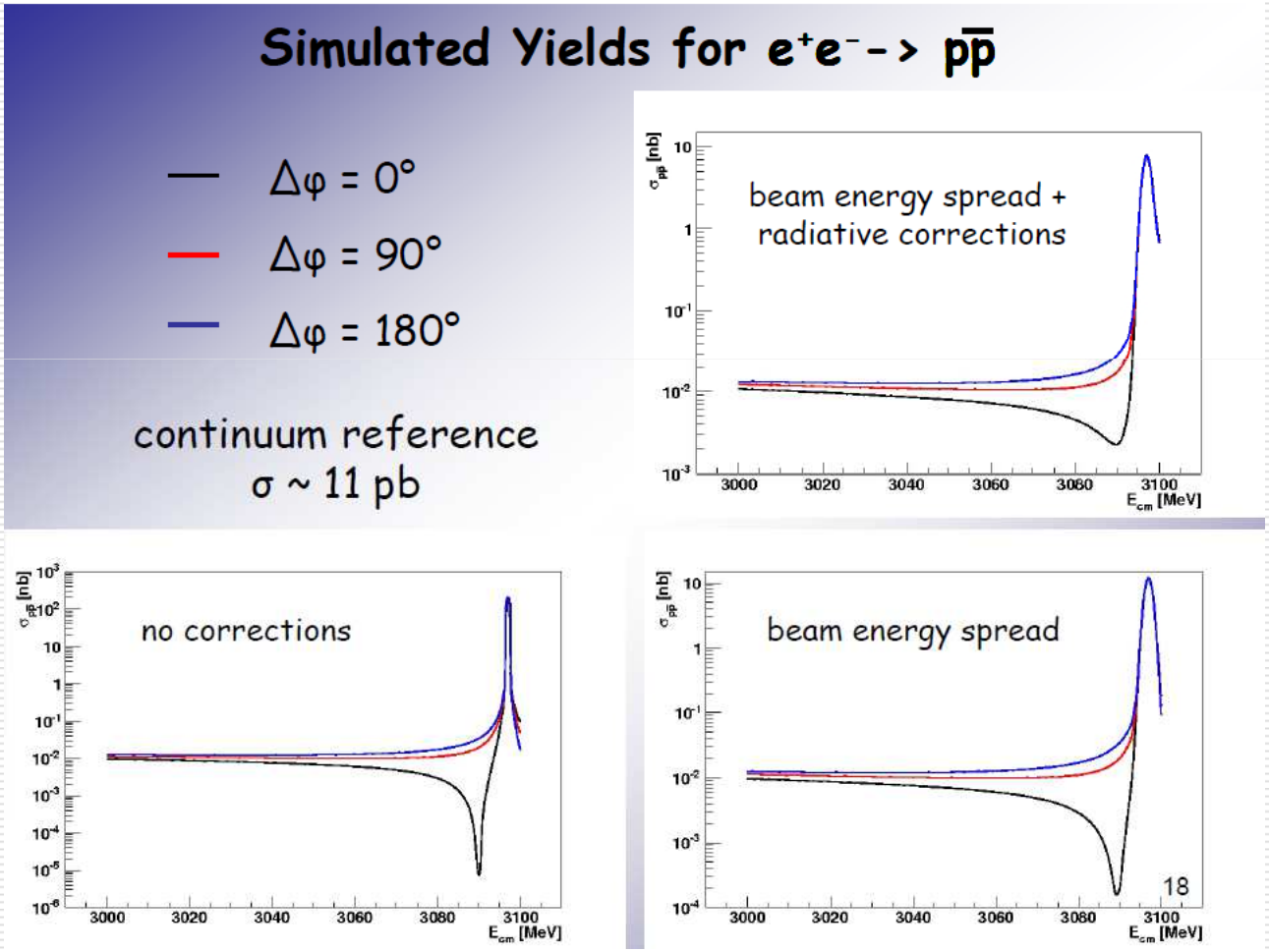
A Proposal for PANDA

Marco Destefanis already proposed to look for $J/\Psi \rightarrow \mu\mu$ in PANDA , exploiting the very good inv mass resolution (no ISR)



J/Ψ invariant mass resolution in e+e--> p p_{bar} in BESIII

(Marco Destefanis at STORI11)



J/Ψ invariant mass resolution in p p_{bar}-> μμ in PANDA

(Marco Destefanis at STORI11)

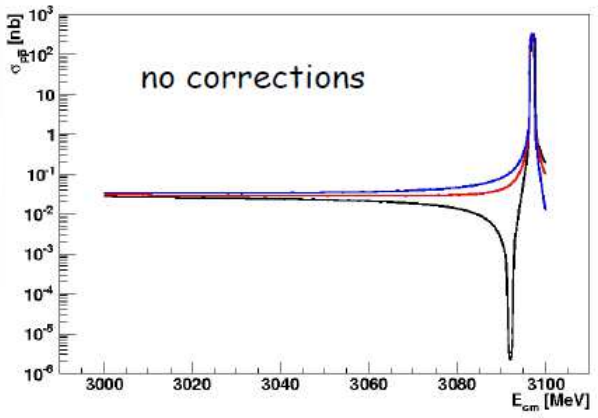
Simulated Yields for $\bar{p}p$ -> $\mu^+\mu^-$

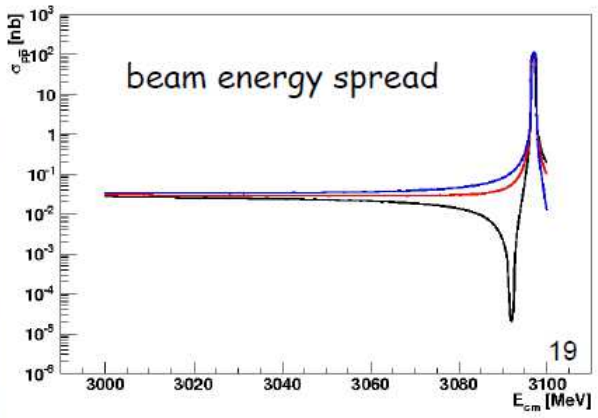
— $\Delta\varphi = 0°$

— $\Delta\varphi = 90°$

— $\Delta\varphi = 180°$

continuum reference
$\sigma \sim 18$ pb





Conclusions

- Unexpected imaginary J/Ψ strong decay widths ($\Phi \sim |90^0|$)
- Updated VP and PP J/Ψ decays data show this result
- J/Ψ scan by BESIII confirms that $\Phi \sim |90^0|$
- Ψ(2S) present data contradictory: Ψ(2S) scan by BESIII
- Ψ''(3770) present data suggest $\Phi \sim -90^0$
- A model has been developed to explain this unexpected phase

Conclusions

- A proposal for PANDA:
  - p p_{bar} -> J/Ψ -> hadrons seen as a dip
  - p p_{bar} -> J/Ψ -> $\mu\mu$ seen as a peak

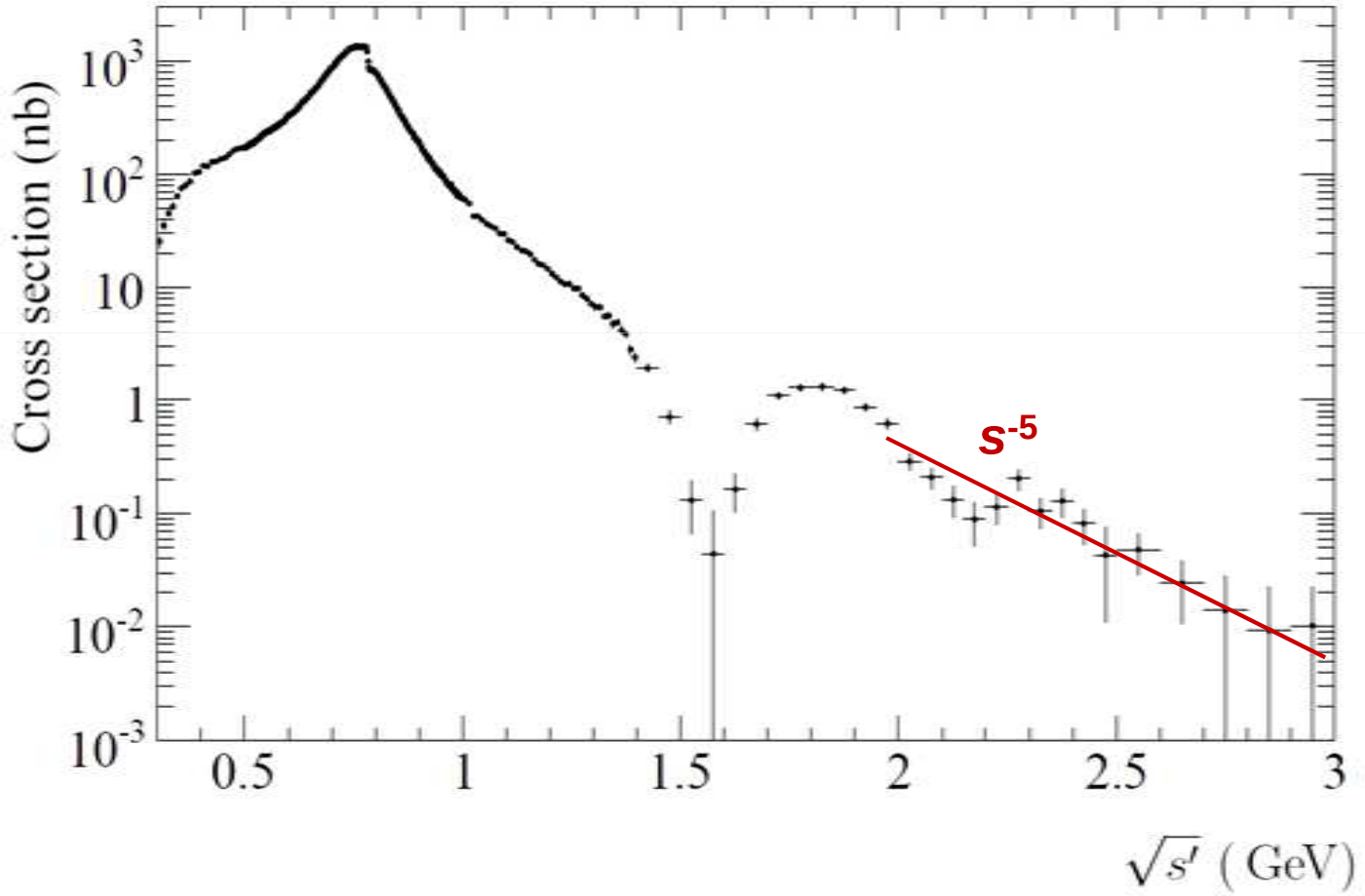
  (exploiting PANDA very good inv mass resolution)

Thanks for your attention

(谢谢)

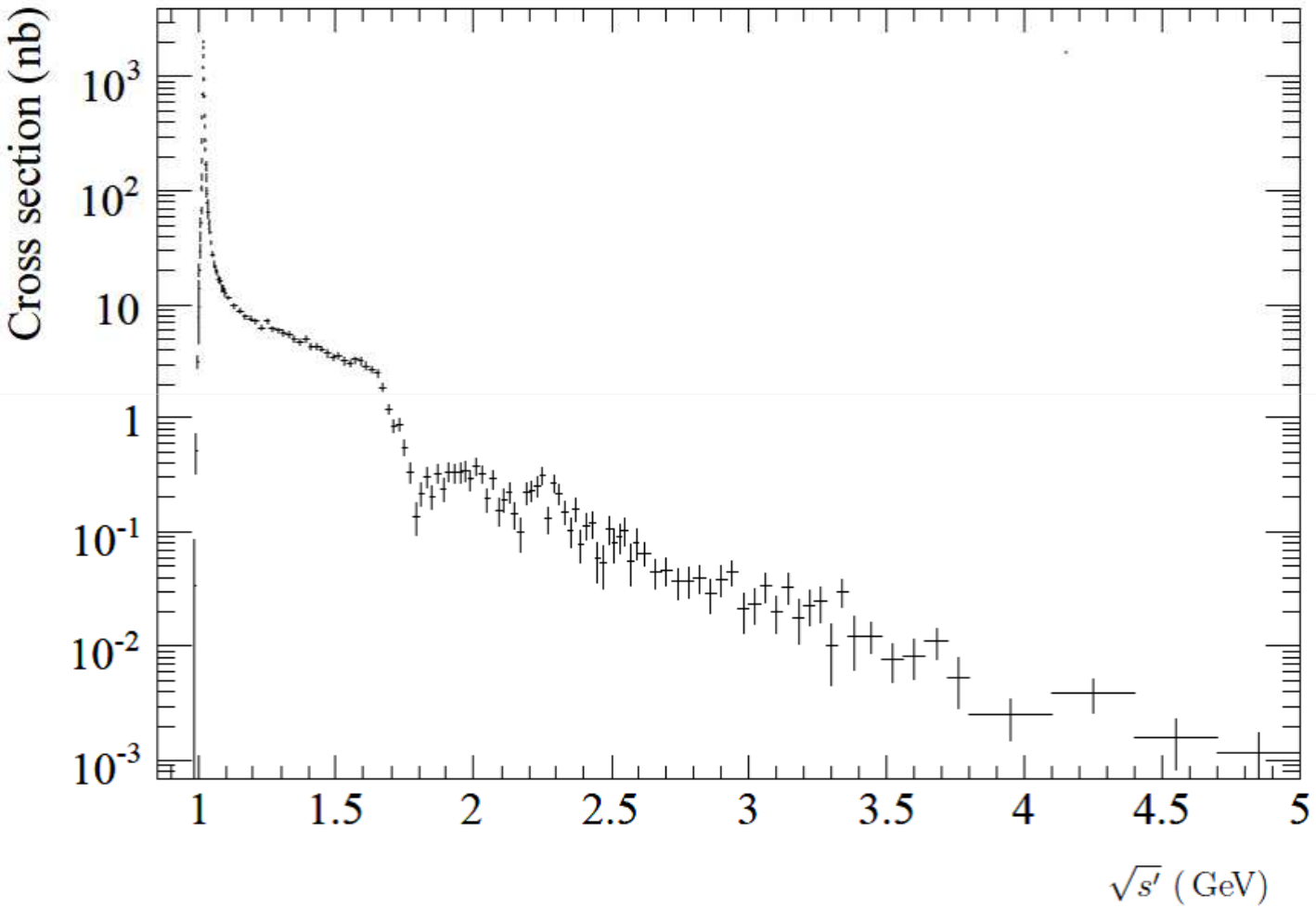
BaBar: e^+e^- -> $\pi^+\pi^-$ cross section

arXiv:1205.2228v1

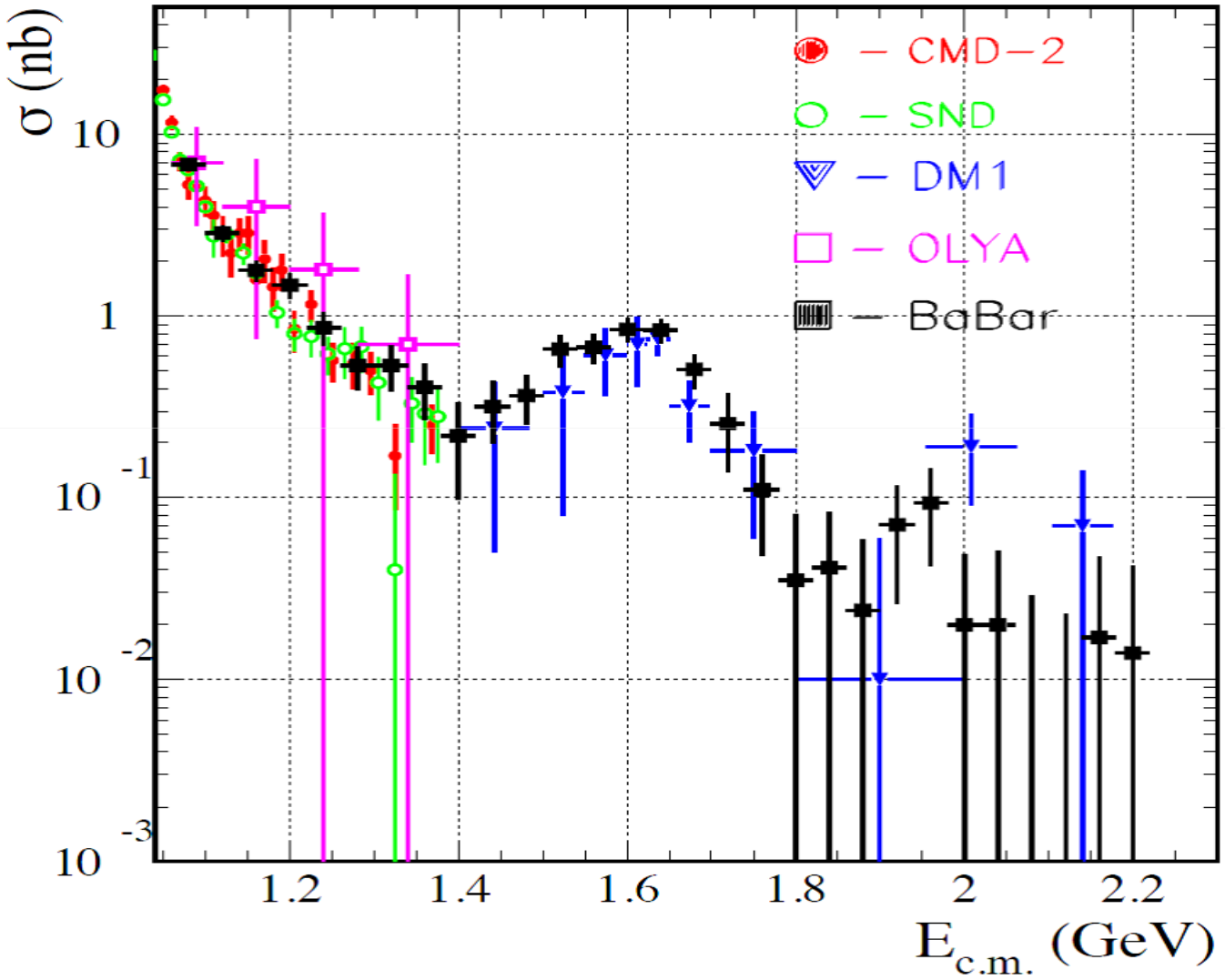


$e^+ e^- \to K^+ K^-$

arXiv:1306.3600v1



$e^+ e^-$ -> KS KL


σ (nb)
10
1
10^-1
10^-2
10^-3
1.2
1.4
1.6
1.8
2
2.2
E_c.m. (GeV)
– CMD–2
– SND
– DM1
– OLYA
– BaBar

Summary of fit results

Channel	$M_{J/\psi}$	Γ (KeV)	φ'
$\mu^+\mu^-$	3097.33±0.01	92.9 (fixed)	0° (fixed)
$\pi^+\pi^-\pi^+\pi^-$	3097.46±0.03	92.9 (fixed)	(–2.14±27.59)°
$\pi^+\pi^-\pi^+\pi^-\pi^0$	3097.50±0.04	92.9 (fixed)	0° (fixed)
$\pi^+\pi^-\pi^0$	3097.50±0.06	92.9 (fixed)	0° (fixed)
$p\bar{p}$	0.3+3096.9	––	––
Channel	**Φ**	**Br_{out}**	**Br_{PDG}**
$\mu^+\mu^-$	––	5.94×10^{-2} (fixed)	5.94×10^{-2}
$\pi^+\pi^-\pi^+\pi^-$	––	$(3.04\pm0.17)\times10^{-3}$	$(3.55\pm0.23)\times10^{-3}$
$\pi^+\pi^-\pi^+\pi^-\pi^0$	(102.6±5.1)°	$(3.55\pm0.13)\times10^{-2}$	$(4.1\pm0.5)\times10^{-2}$
$\pi^+\pi^-\pi^0$	(108.4±10.1)°	$(1.87\pm0.08)\times10^{-2}$	$(2.07\pm0.12)\times10^{-2}$
$p\bar{p}$	(84.73±9.62)°	$(1.90\pm0.05)\times10^{-3}$	––

Channel	σ_{cont} (nb)	S_E (MeV)	
$\mu^+\mu^-$	––	0.92±0.01	
$\pi^+\pi^-\pi^+\pi^-$	0.465±0.014	0.92 (fixed)	
$\pi^+\pi^-\pi^+\pi^-\pi^0$	0.153±0.013	0.92 (fixed)	
$\pi^+\pi^-\pi^0$	0.040±0.010	0.92 (fixed)	
$p\bar{p}$	0.006±0.001	0.92±0.01	