Scattering and annihilation electromagnetic processes
ECT* Trento, 18-22 February 2013

$N\bar{N}$ physics at BESIII

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on behalf of the BESIII Collaboration

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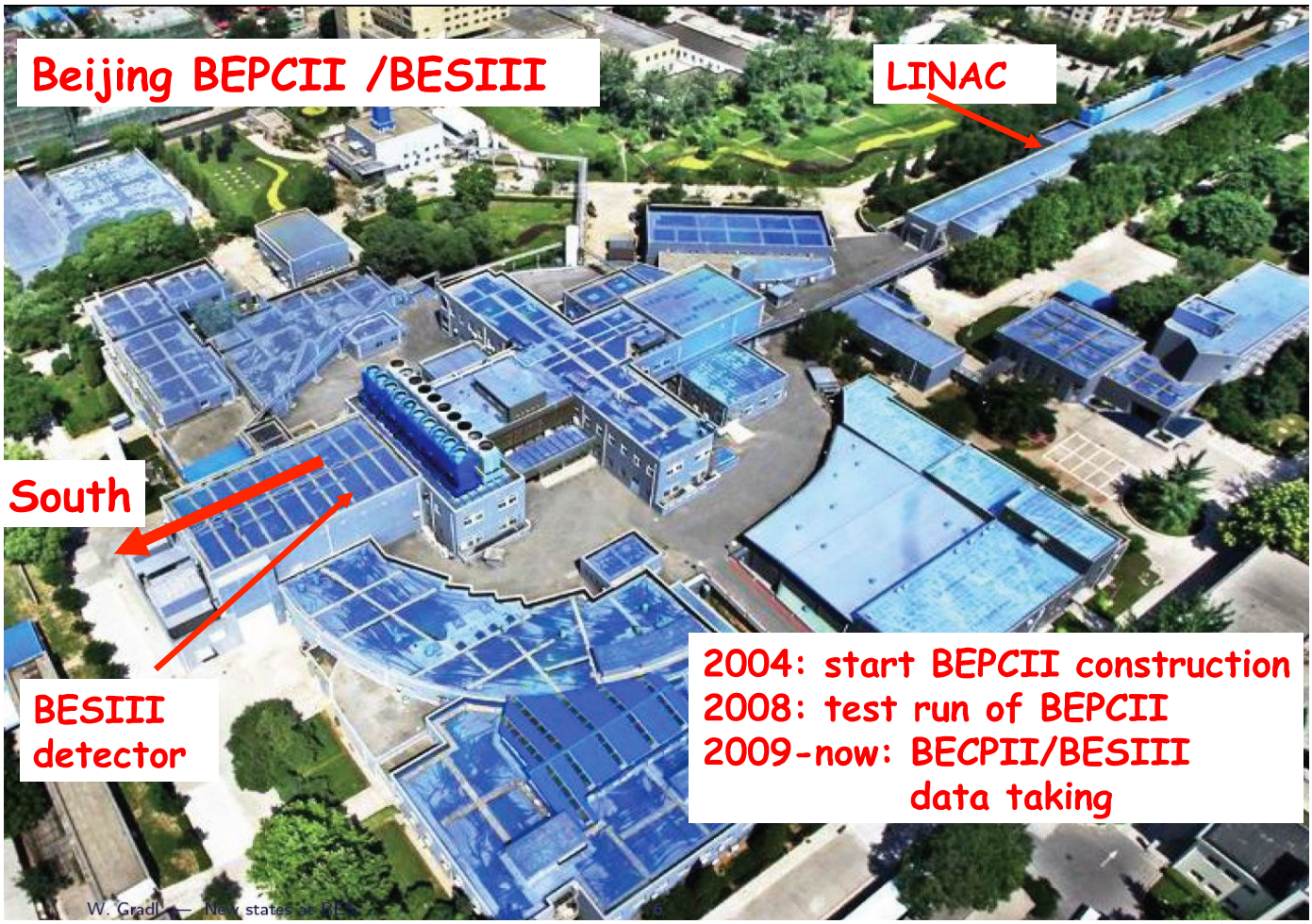
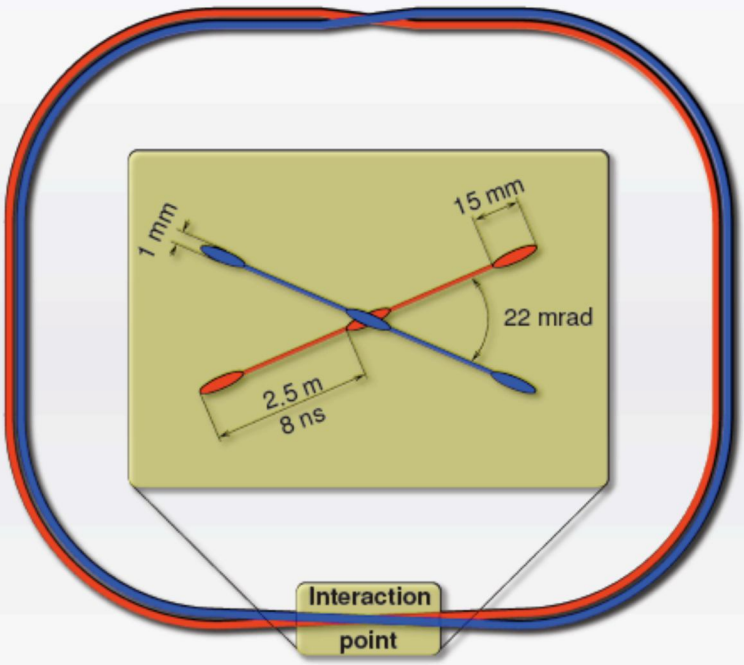
BESIII/BEPCII


Beijing BEPCII /BESIII
LINAC
South
BESIII
detector
2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BECPII/BESIII
data taking

BEPCII: Beijing e^+e^- double ring collider



Design Features

- Beam energy: **1.0** - **2.3** GeV
- Crossing angle: **22** 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: **15** mm
- Total current: **0.91** A
- Circumference: **240** m

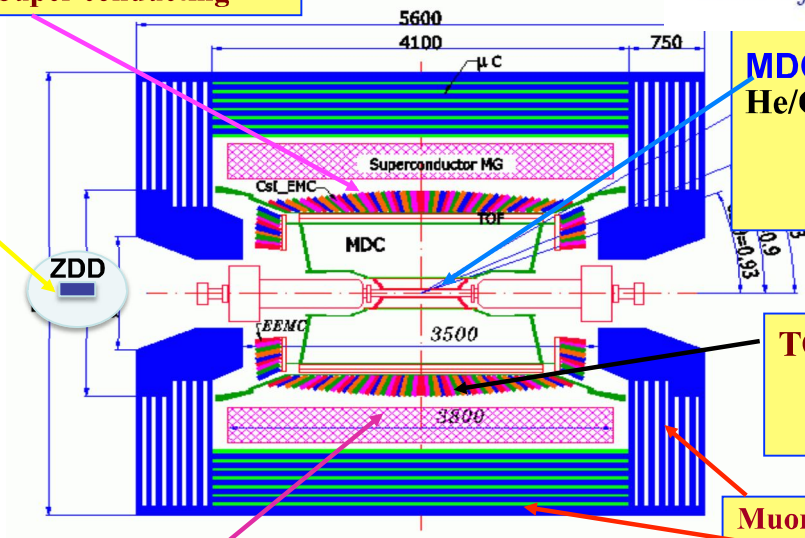
BESIII Detector

[NIM A614 (2010)345]

BESIIII detector: all new !

CsI calorimeter
Precision tracking
Time-of-flight + dE/dx PID

Magnet: 1 T Super conducting



Zero Degree Detector new (2011)

MDC: small cell & Gas: He/C_3H_8 (60/40), 43 layers
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σ_T = 100 ps Barrel
110 ps Endcap

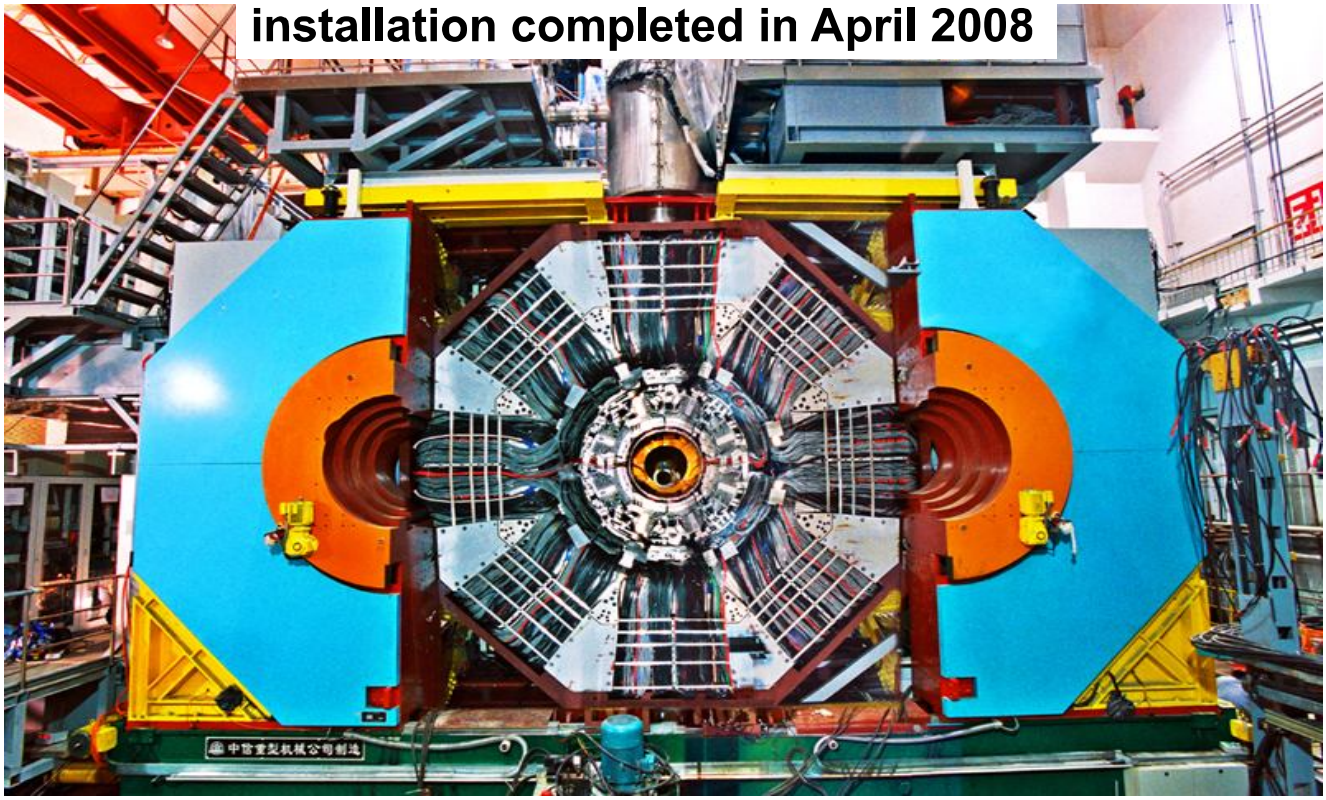
Muon ID: 9 layers RPC
8 layers for endcap

EMC: CsI crystal, 28 cm
ΔE/E = 2.5% @1 GeV
σz = 0.6 cm/√E

Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

The detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.

Beijing Spectrometer III (BESIII)



BESIII Collaboration:

http://bes3.ihep.ac.cn

US (6)
Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

EUROPE (12)
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Univ. of Giessen, GSI,
J. Gutenberg Univ. Mainz; Helmholtz In. Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: INFN Frascati National Lab (LNF),
Univ. of Torino and Perugia
Netherland: KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

Korea (1)
Seoul Nat. Univ.

Japan (1)
Tokyo Univ.

Pakistan (2)
Univ. of Punjab
Comsats IIT

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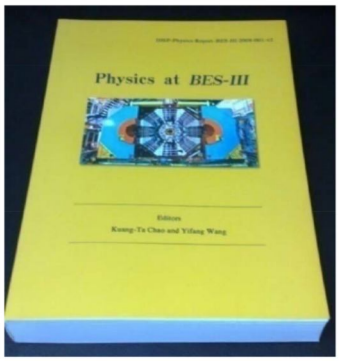
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.
Univ. of South China, UCAS.

52 institutes from 11 countries
> 300 collaborators

Physics in the tau-charm region



arXiv: 0809.1869

- **Light hadron physics**
  - Spectroscopy: normal and exotic hadrons **QCD**
  - How quarks form hadron ? **non-pQCD**
  - Baryon e.m. form factors
- **Charm physics**
  - Full spectra CKM matrix elements → **SM and beyond**
  - $D\bar{D}$ mixing and CPV →**SM and beyond**
- **Charmonium physics**
  - Spectroscopy and transition →**pQCD & non-pQCD**
  - New states above open charm thresholds →**exotic hadrons?**
  - pQCD: ρπ puzzle → a probe to **non-pQCD or?**
- **Tau physics and QCD**
  - Precision measurement of the tau mass and R measurement
- **Search for rare and forbidden decays**

Precision tests of SM and search for new physics

BESIII timeline

- July 19, 2008: first e^+e^- collision event in BESIII
- Nov 2008: ~14M $\psi(2S)$ events for detector calibration

- 2009: 106M $\psi(2S)$ 4xCLEOc
  225M J/ψ 4xBESII
- 2010-11: 2.9 fb^{-1} ψ (3770) 3.5xCLEOc
- 2011: 0.5 fb^{-1} @4.01GeV (D_s, XYZ)
- 2012: 0.4B $\psi(2S)$
  J/ψ: 1B events, lineshape fine scan,
  scan for J/ψ phase measurement, 14pb^{-1}/point, tot 5 points
  - R scan @ 2.23, 2.4, 2.8, 3.4 GeV
- 2013: 515 pb^{-1} @ 4260 MeV
  40 pb^{-1} @ 4190, 4210, 4230 MeV

the world's largest set of
J/ψ $\psi(2S)$ $\psi(3770)$
and still growing!

- Peak luminosity: 6.5×10^{32} $cm^{-2}s^{-1}$ @ 3770MeV

BESIII plans

- **Current run: December 2012 – June 2013**

  >500 pb^{-1} @ 4360 MeV *almost done*
  5 days Y(4360) scan
  60 days R scan: ~ 100 pts > 3.8 GeV, 5-8 pb^{-1}/pt, 2-3% precision
  10 days τ scan
  additional $\psi(3770)$

- **foreseen luminosity: → 10^{33} $cm^{-2}s^{-1}$ @ 3770 MeV**

Published BESIII results

χ_{cJ} decays and transitions

1) Search for hadronic transition $\chi_{cJ} \to \eta_c \pi^+\pi^-$ and observation of $\chi cJ \to K\bar{K}\pi\pi\pi$. PRD87, 012002 (2013)
2) Measurement of χ_{cJ} decaying into $p\bar{p}\pi^-$ and $p\bar{p}\pi^-\pi^0$. PRD86, 052011 (2012)
3) Observation of χ_{cJ} Decays to $\Lambda\bar{\Lambda}\ \pi^+\pi^-$. PRD86, 052004 (2012)
4) Two-photon widths of the $\chi_{c0,2}$ states and helicity analysis for $\chi_{c2} \to \gamma\gamma$. PRD85, 112008 (2012)
5) Observation of χ_{c1} decays into vector meson pairs $\varphi\varphi$, $\omega\omega$, and $\omega\varphi$. PRL107, 092001 (2011)
6) Study of χ_{cJ} radiative decays into a vector meson. PRD83, 112005 (2011)
7) First Observation of the Decays $\chi_{cJ} \to \pi^0\pi^0\pi^0\pi^0$. PRD83, 012006 (2011)

Studies of η, η, $\eta(1405)$, η_c and η_c' mesons

8) Observation of $\eta^c(2S)$ in $\psi' \to \gamma K_s K^+ \pi^+\pi^-\pi^-$. [arXiv:1301.1476]
9) Search for weak decays of η and η' in $J/\psi \to \phi\eta(\eta')$. [arXiv:1211.3600]
10) Measurements of Baryon pair decays of χ_{cJ} mesons. [arXiv:1211.2283] accepted by PRD
11) Observation of η_c decaying into $\Sigma^+\Sigma^-$ and $\Xi^-\Xi^+$. PRD87, 012003 (2013)
12) The analysis on h_c exclusive decays into $\gamma\eta_c$. PRD86, 092009 (2012)
13) Search for η and η' Invisible Decays in $J/\psi \to \varphi\eta$ and $\varphi\eta'$. [arXiv.1209.2469]
14) Observation of $e^+e^- \to \eta J/\psi$ at center-of-mass energy $s^{1/2}$=4.009 GeV. PRD86, 071101 (2012)
15) Evidence for $\eta_c \to \gamma\gamma$ and Measurement of $J/\psi \to 3\gamma$. [arXiv.1208.1461]
16) First observation of $\eta(1405)$ decays into $f^0(980)\pi^0$. PRL108,182001 (2012)
17) Measurements of the mass and width of the ηc using $\psi' \to \gamma\eta c$. PRL108, 222002 (2012)
18) Search for η'_c decays into vector meson pairs. PRD84, 091102 (2011)
19) $\eta\pi^+\pi^-$ Resonant Structure around 1.8 GeV/c^2 and $\eta(1405)$ in $J/\psi \to \omega\eta\pi^+\pi^-$. PRL107, 182001 (2011)
20) Search for CP and P violating pseudoscalar decays into $\pi\pi$. PRD84, 032006 (2011)
21) Measurement of the Matrix Element for the Decay $\eta' \to \eta\pi^+\pi^-$. PRD83, 012003 (2011)

Published BESIII results

Decays of $c\bar{c}$ mesons

22) Partial wave analysis of $J/\psi \to \gamma\eta\eta$. [arXiv:1301.0053]
23) PWA of $J/\psi \to \gamma\phi\omega$. [arXiv:1211.5668] accepted by PRD
24) Measurements of $\psi' \to \bar{p} K^+\Sigma^0$ and $\chi_{cJ} \to \bar{p} K^+\Lambda$
25) Measurement of $\psi' \to \gamma p K\Lambda$. [arXiv:1211.563] accepted by PRD
26) Measurement of branching fractions for J/ψ an $\psi(3686)$ to to $\Lambda\bar{\Lambda}\pi^0$ and $\Lambda\Lambda\eta$. [arXiv:1211.4682]
27) Precision measurement of branching fractions of $\psi' \to \pi^0 J/\psi$ and $\eta J/\psi$. PRD86, 092008 (2012)
28) Determination of the number of $\psi(2S)$ events at BesIII. [arXiv:1209.6199]
29) Experimental study of ψ' decays to $K^+K^-\pi^0$ and $K^+K^-\eta$. PRD86, 072011 (2012)
30) First observation of the isospin violating decay $J/\psi \to \Lambda\bar{\Sigma}^-_0$+c.c.. PRD86, 032008 (2012)
31) Determination of the number of J/ψ events with $J/\psi \to$ inclusive decays. [arXiv:1207.2865]
32) Observation of two new N* resonances in $\psi(3686) \to p\bar{p}\pi^0$. [arXiv:1207.0223]
33) First observation of the M1 transition $\psi(3686) \to \gamma\eta c(2S)$. PRL109, 042003 (2012)
34) Study of $J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$. PRD86 (5), 032014 (2012)
35) Evidence for the Direct Two-Photon Transition from ψ' to J/ψ. [arXiv:1204.0246]
36) Precision measurement of the branching fractions of $J/\psi \to \pi^+\pi^-\pi^0$ and $\psi' \to \pi^+\pi^-\pi^0$. PLB710, 594 (2012)
37) Spin-Parity Analysis of $p\bar{p}$ Mass Threshold Structure in J/ψ and ψ' Radiative Decays. PRL108 112003 (2012)
38) Higher-order multipole amplitude measurement in $\psi(2S) \to \gamma\chi c2$. PRD84, 092006 (2011)
39) Evidence for ψ' decays into $\gamma\pi^0$ and $\gamma\eta$. PRL105 261801 (2010)

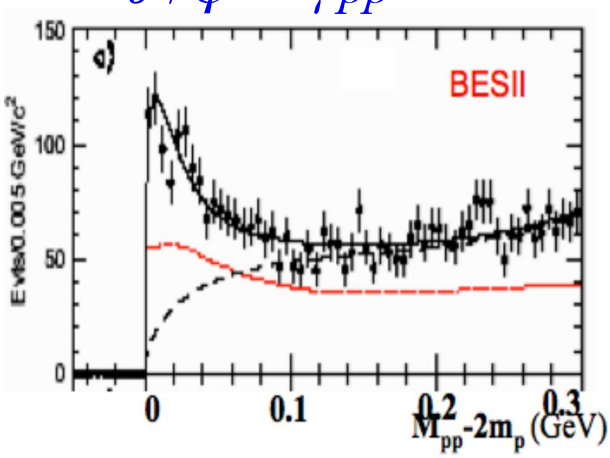
Scalar mesons and new states

39) Search for a light Higgs-like boson A_0 in J/ψ radiative decays. PRD85 092012 (2012)
40) Study of $a_0^0(980)$–$f_0(980)$ mixing. PRD83, 032003 (2011)
41) Confirmation of the X(1835) and observation of the resonances X(2120) and X(2370) in $J/\psi \to \gamma\pi^+\pi^-\eta'$. PRL106, 072002 (2011)

Baryonium (?) and new structures at BESIII

Anomalous $M_{p\bar{p}}$ threshold enhancement @ BESII

$J/\psi \rightarrow \gamma p\bar{p}$



$M = 1859^{+3}_{-10}{}^{+5}_{-25}$ MeV/c²

$\Gamma < 30$ MeV/c² (90% CL)

PRL 91 (2003) 022001

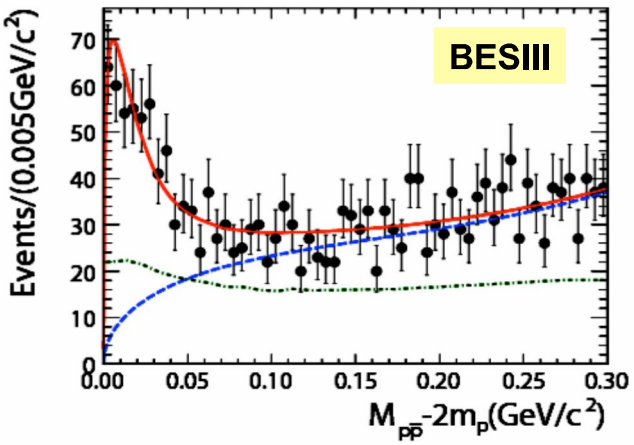
Theoretical interpretation:

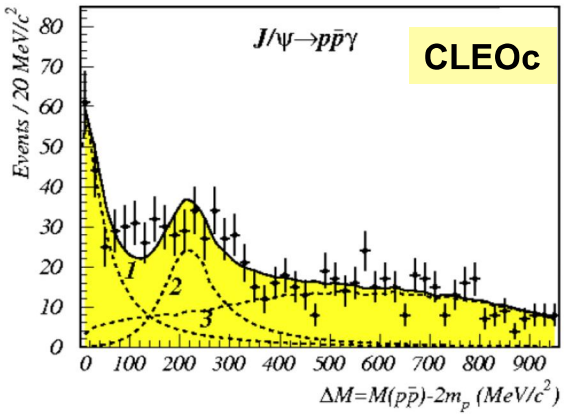
- conventional meson?
- ppbar bound state/ multiquark/Baryonium?
- glueball
- Final state interaction (FSI)
- …

Confirmation @ BESIII and CLEOc

Fit with one resonance at BESIII:

$\psi' \to \pi^+\pi^- J/\psi, J/\psi \to \gamma p\bar{p}$





$M = 1861^{+6}_{-13}{}^{+7}_{-26}$ MeV/c²

$\Gamma < 38$ MeV/c² (90% CL)

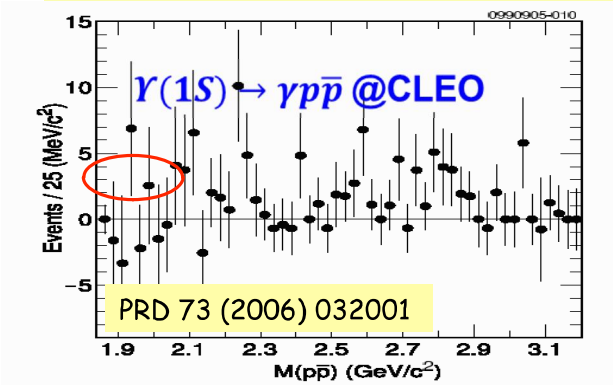
$M(R_{thr}) = 1861^{+6}_{-16}$ (MeV), $\Gamma(R_{thr}) = 0^{+32}_{-0}$ (MeV),

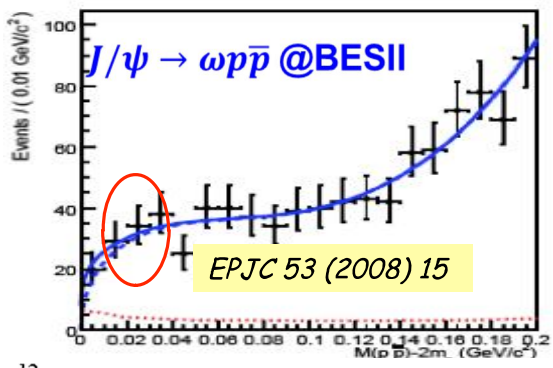
$B_1(J/\psi \to \gamma R_{thr}) \times B_2(R_{thr} \to p\bar{p}) = (5.9^{+2.8}_{-3.2}) \times 10^{-5}$

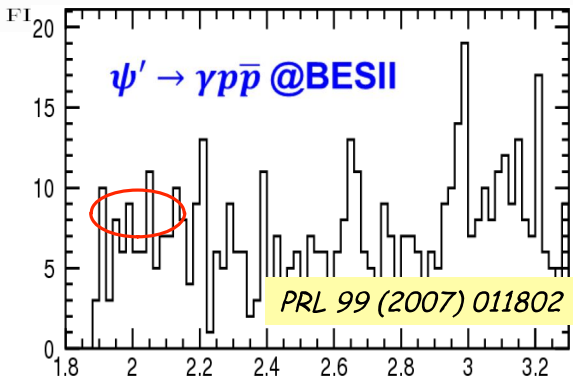
Chinese Physics C 34, 421 (2010)

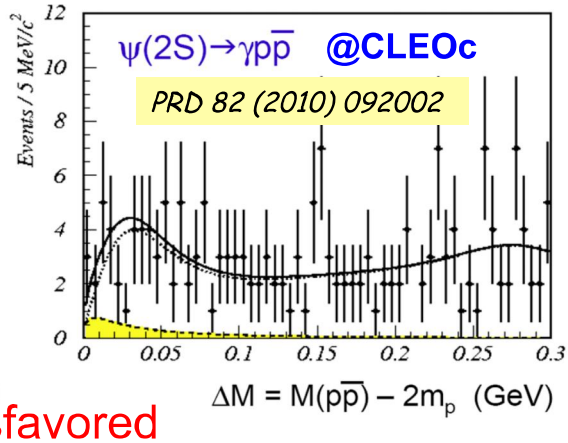
PRD 82, 092002(2010)

Several non-observations





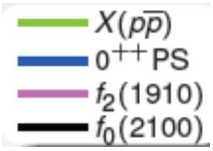


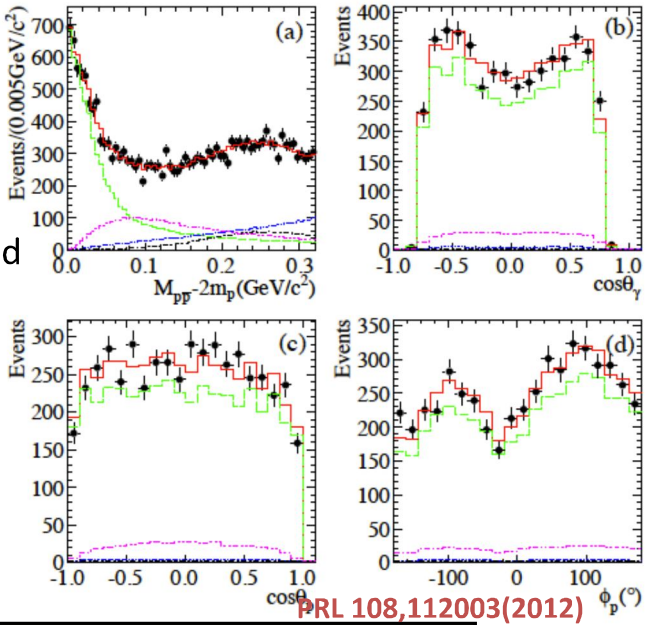


Pure FSI interpretation is disfavored

PWA of J/ψ→γpp̄ @BESIII

- PWA of J/ψ→γpp̄





PRL 108,112003(2012)

- The fit with a BW and S-wave FSI(I=0) factor can well describe ppb mass threshold structure.
- It is much better than that without FSI effect
- Different FSI models→Model dependent sys. uncertainty

- X(pp̄) Spin-parity, mass, width and B.R.:

$J^{pc} = 0^{-+}$ → **>6.8σ better than other J^{pc} assignments**

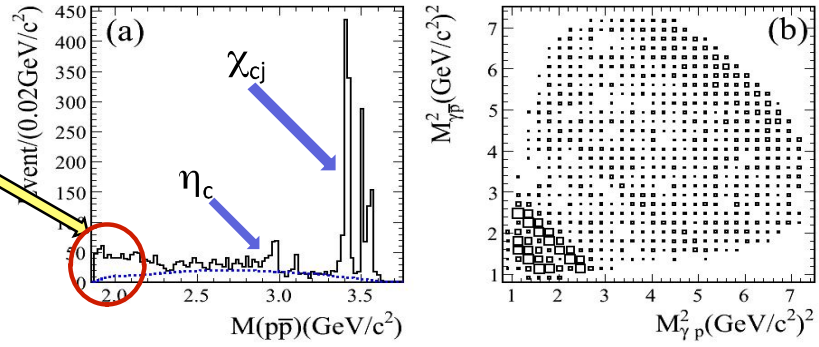
$$M = 1832^{+19}_{-5}(\text{stat})^{+18}_{-17}(\text{syst}) \pm 19(\text{mod})\text{MeV/c}^2$$

$$\Gamma = 13 \pm 20(\text{stat})^{+11}_{-33}(\text{syst}) \pm 4(\text{mod})\text{MeV/c}^2 \text{ or } \Gamma < 76\text{MeV/c}^2 \text{ @}90\%\, C.L.$$

$$B(J/\psi \to \gamma X(p\bar{p}))B(X(p\bar{p}) \to p\bar{p}) = (9.0^{+0.4}_{-1.1}(\text{stat})^{+1.5}_{-5.0}(\text{syst}) \pm 2.3(\text{mod})) \times 10^{-5}$$

M_{ppbar} threshold structure of $\psi' \to \gamma p\bar{p}$ @BESIII

Obviously different line shape of ppbar mass spectrum near threshold from that in J/ψ decays



PWA results:

- Significance of X(ppbar) is > 6.9σ.
- The production ratio R:

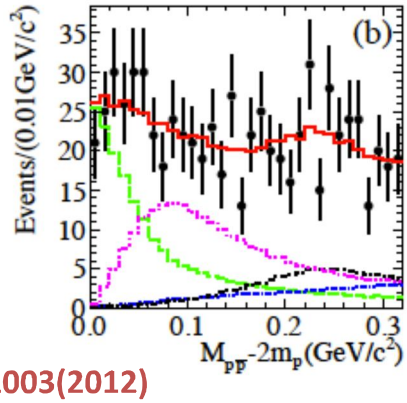
first measurement

$$R = \frac{B(\psi' \to \gamma X(p\bar{p}))}{B(J/\psi \to \gamma X(p\bar{p}))}$$

$$= (5.08^{+0.71}_{-0.45}(\text{stat})^{+0.67}_{-3.58}(\text{syst}) \pm 0.12(\text{mod}))\%$$

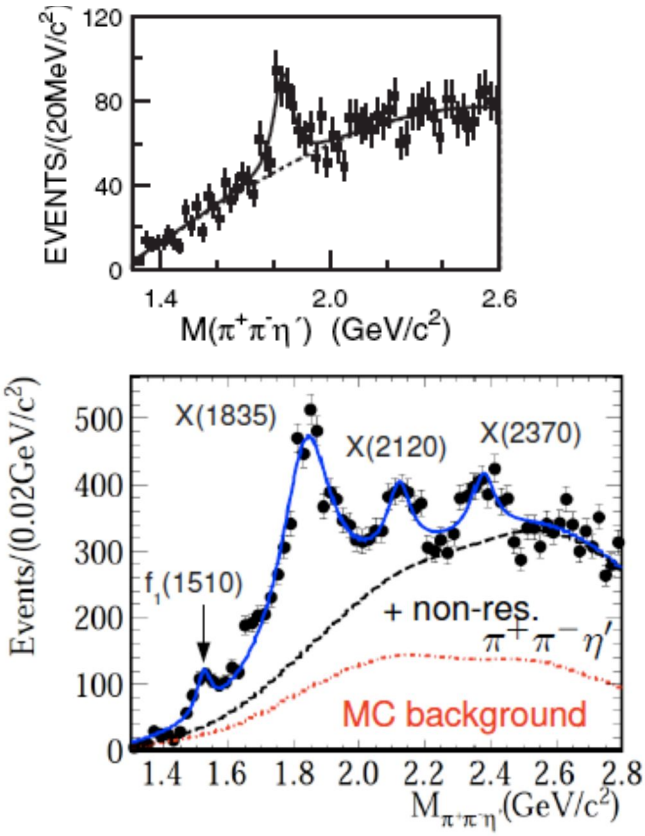
- It is suppressed compared with "12% rule".

PWA Projection:



PRL 108,112003(2012)

Confirmation of X(1835), and new observation of X(2120), X(2370) in $J/\psi \to \gamma\eta`\pi^+\pi^-$

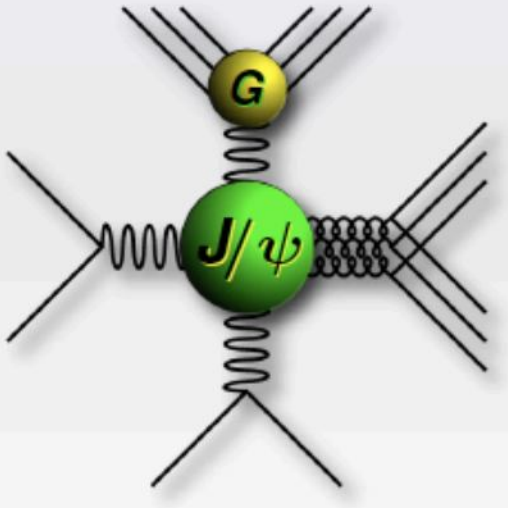


[PRL 106, 072002 (2011)]

- **BESII** *result [PRL95, 262001 (2005)] observation* of **X(1835)** *with significance*: ~7.7σ
- **BESIII** ***[PRL 106, 072002 (2011)]*** confirmation:
  - M = 1836.5±3.0(stat)$^{+5.6}_{-2.1}$(sys) MeV/c^2
  - Γ = 190.0±9.0(stat) $^{+38}_{-36}$(syst) MeV/c^2
  - Significance: >20σ
- Two additional new resonances, **X(2120)** and **X(2370)**, are observed with significance larger than 7.2σ and 6.4σ, respectively.

- **X($p\bar{p}$) and X(1835) are consistent to be the same state but different widths**
- **further sudies foreseen**

J/ψ strong and electromagnetic phase



J/ψ Strong and Electromagnetic Decay Amplitudes

Resonant contributions

$\Gamma_{J/\psi} \sim 93\text{KeV} \rightarrow$ pQCD

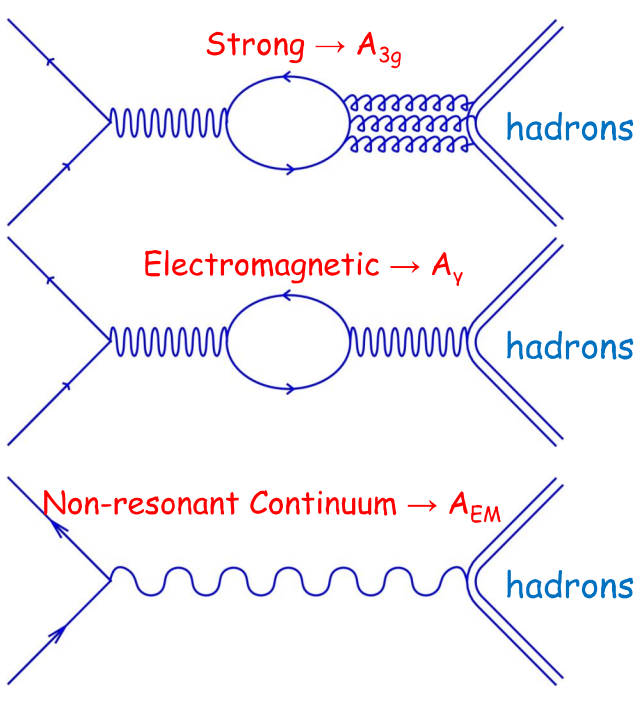
pQCD: all amplitudes almost real [1,2]

QCD -> $\Phi_p \sim 10°$ [1]

Non-resonant continuum

pQCD regime

$A_{EM} \in \Re$



[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).

J/ψ Strong and Electromagnetic Decay Amplitudes

- If both real, they must interfere ($\Phi_p \sim 0°/180°$)
- On the contrary $\Phi_p \sim 90° \rightarrow$ No interference
- $J/\psi \rightarrow NN\ (\frac{1}{2}^+\frac{1}{2}^-)$ $\Phi_p = 89° \pm 15°$ [1]; $89° \pm 9°$[2]
- $J/\psi \rightarrow VP\ (1^-0^-)$ $\Phi_p = 106° \pm 10°$ [3]
- $J/\psi \rightarrow PP\ (0^-0^-)$ $\Phi_p = 89.6° \pm 9.9°$ [4]
- $J/\psi \rightarrow VV\ (1^-1^-)$ $\Phi_p = 138° \pm 37°$ [4]

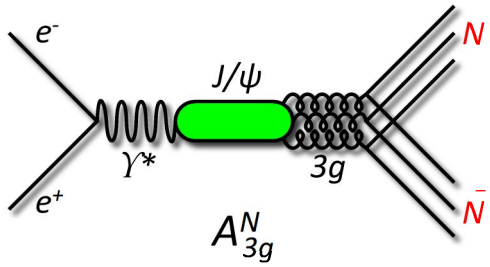
Imaginary amplitudes hard to be explained!

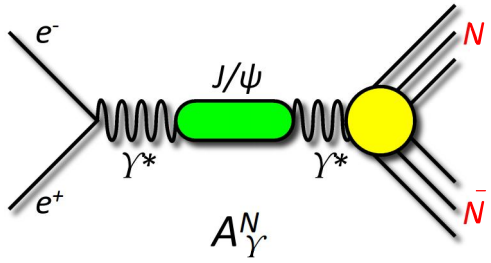
- Results are model dependent
- Model independent test:

interference with the non resonant continuum

[1] R. Baldini, C. Bini, E. Luppi, Phys. Lett. B404, 362 (1997); R. Baldini et al., Phys. Lett. B444, 111 (1998).
[2] M.Ablikim, J/ψ -> ppbar and J/ψ -> nnbar measurement by BESIII, PRD86 (5), 032014 (2012).
[3] L. Kopke and N. Wermes, Phys. Rep. 174, 67 (1989); J. Jousset et al., Phys. Rev. D41,1389 (1990).
[4] M. Suzuki et al., Phys. Rev. D60, 051501 (1999).

$J/\psi \to p\bar{p},\ n\bar{n}$

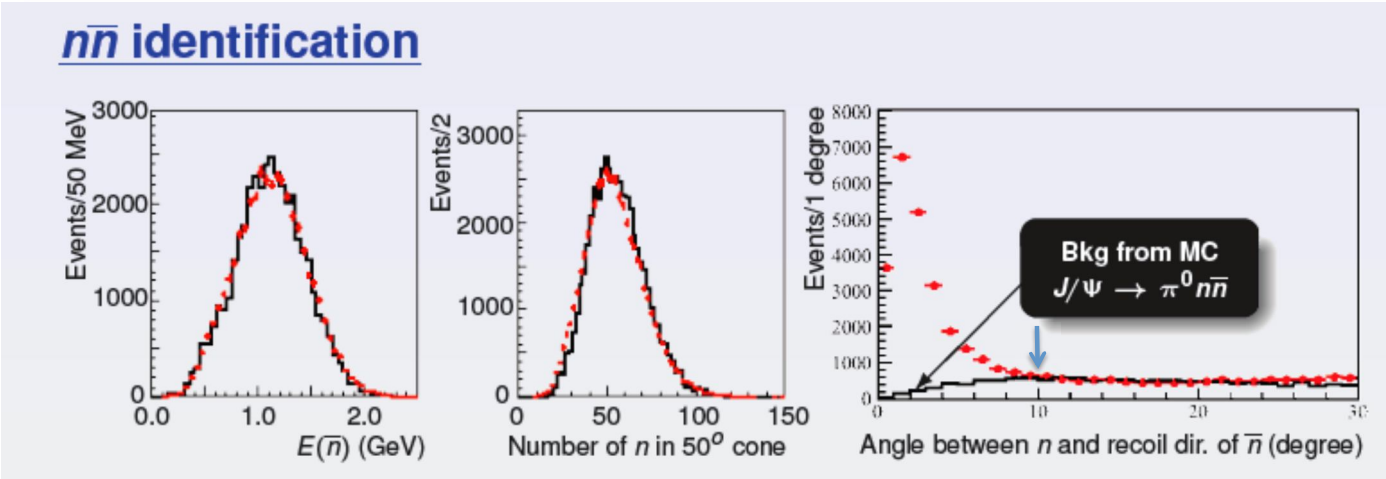




- The $J/\psi \to N\bar{N}$ is a very good test of pQCD
- The 3 gluons in the OZI-violating strong amplitude just match the 3 $q\bar{q}$ pairs of NN final states
- dominant strong amplitude: $|A^N_{3g}| > |A^N_\gamma|$
- isospin symmetry $\Longrightarrow$ $|A^p_{3g}| \simeq |A^n_{3g}|$
- A^p_γ and A^n_γ have opposite sign just as magnetic moments
- assuming pQCD: <u>strong and e.m. amplitudes are Real</u> $\Longrightarrow$ maximum interference and:

$$R = \frac{BR(J/\psi \to p\bar{p})}{BR(J/\psi \to n\bar{n})} = \left| \frac{A^p_{3g} + A^p_\gamma}{A^n_{3g} + A^n_\gamma} \right|^2 \simeq 2$$

BESIII results: $J/\psi \to p\bar{p}$, $n\bar{n}$ [PRD86 (5), 032014 (2012)]



Recent BESIII results:

$BR(J/\psi \to p\bar{p}) = (2.112 \pm 0.004 \pm 0.027)\times 10^{-3}$

$BR(J/\psi \to n\bar{n}) = (2.07 \pm 0.01 \pm 0.14)\times 10^{-3}$

published: PRD86 (5), 032014 (2012)

PDG:

$BR(J/\psi \to p\bar{p}) = (2.17 \pm 0.07)\times 10^{-3}$

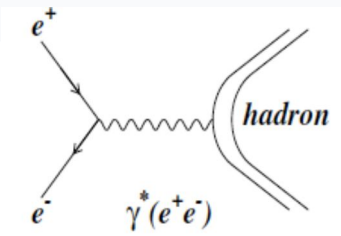
$BR(J/\psi \to n\bar{n}) = (2.2 \pm 0.4)\times 10^{-3}$

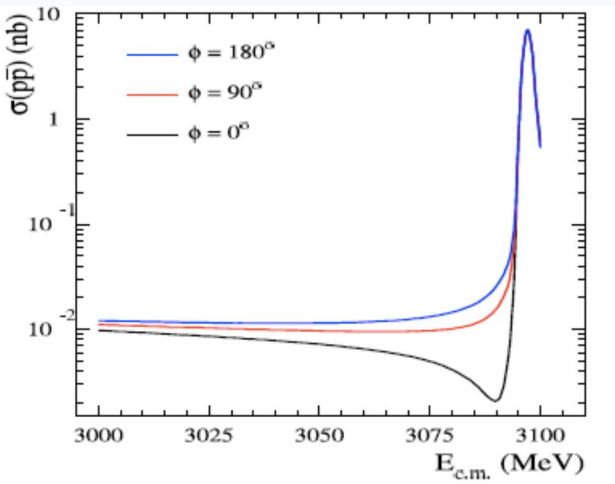
$BR(J/\psi \to p\bar{p}) \sim BR(J/\psi \to n\bar{n})$:

$A^N_{3g} \perp A^N_{\gamma}$ Large relative phase $89° \pm 9°$!

A model independent way to measure the phase between strong and e.m. decay amplitudes

- So far experimentally: $\Phi_p \sim 90°$ → Imaginary strong amplitudes hard to explain but results are model dependent
- Model independent test: look for interference pattern between the resonant amplitude and the non resonant continuum through a c.m. energy scan, i.e. out of J/ψ peak





- ***No interference:*** **$\Phi_p \sim 90°$, (Imaginary strong amplitude!)**
- **Maximum interference: $\Phi_p \sim 0°$, 180°**
  (Real strong amplitude)

Simulated Yields for $e^+e^- \rightarrow p\bar{p}$

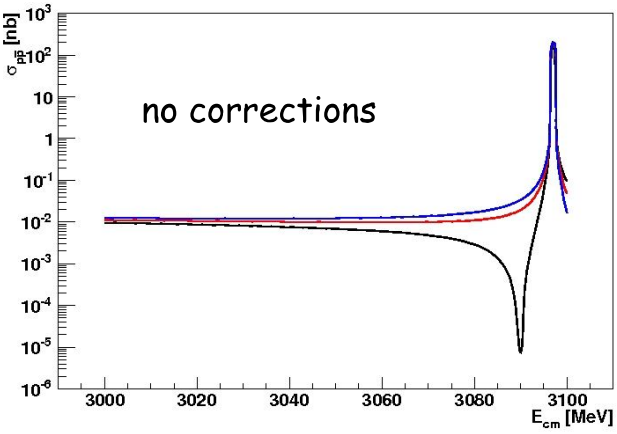
[M.Destefanis talk on Monday]

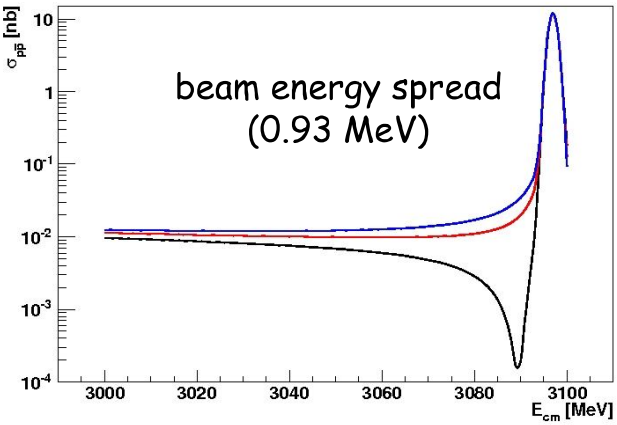
— $\Delta\varphi = 0°$

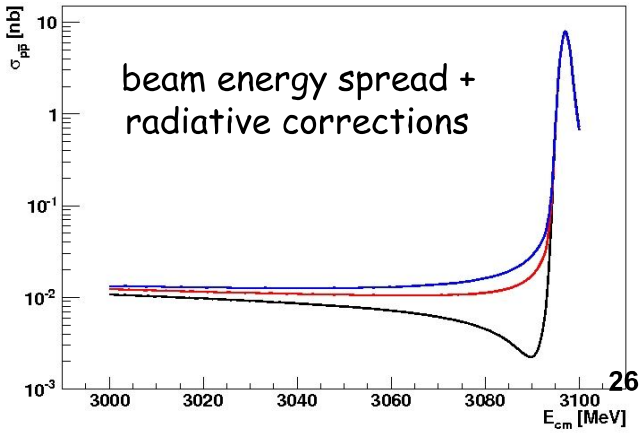
— $\Delta\varphi = 90°$

— $\Delta\varphi = 180°$

continuum reference
$\sigma \sim 11$ pb

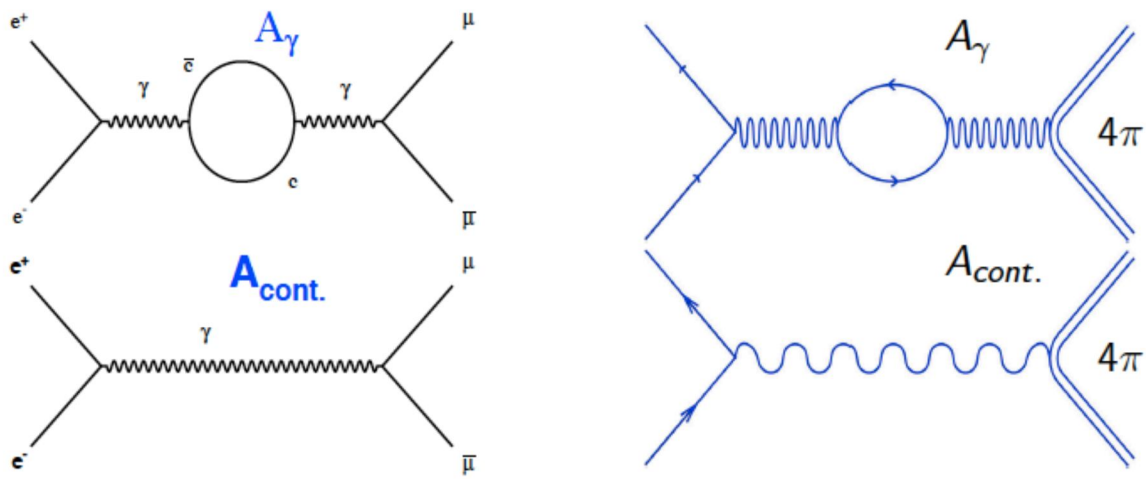






Full Interference in $e^+e^- \to J/\psi \to \mu^+\mu^-, 2(\pi^+\pi^-)$

No A_{3g} in $e^+e^- \to \mu^+\mu^-$ due to leptonic decay. No A_{3g} in $e^+e^- \to 2(\pi^+\pi^-)$ due to G-parity. Only A_γ and $A_{cont.}$ contributions.

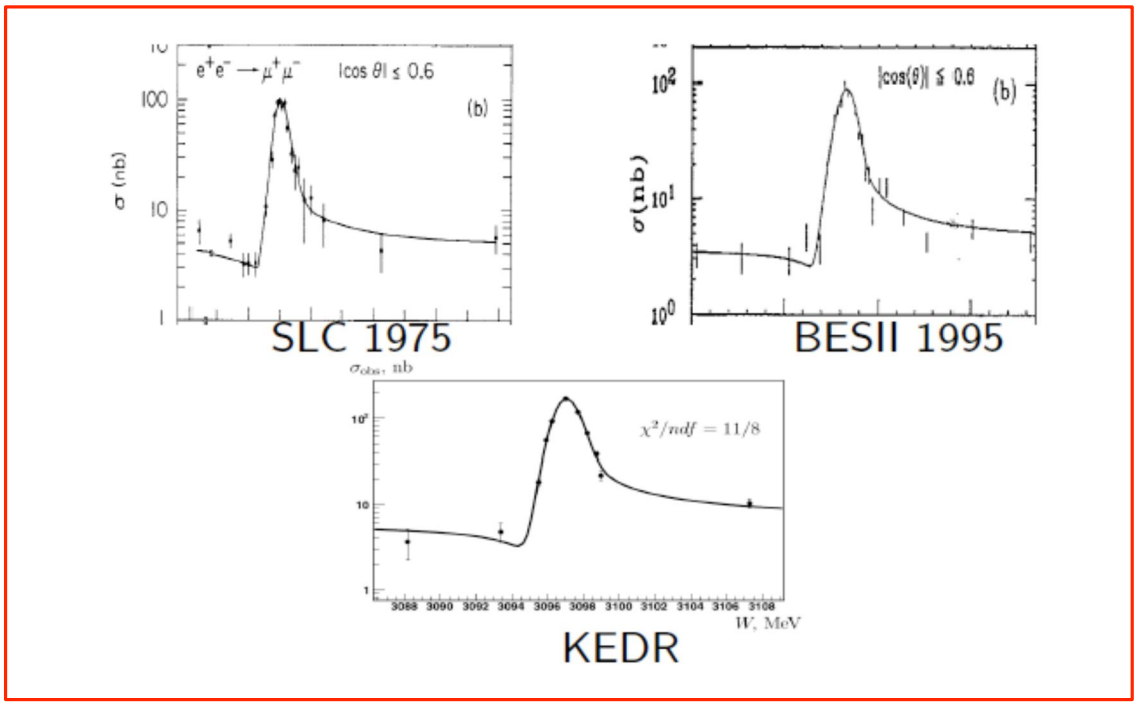


$\sigma_{tot} \sim |A_\gamma + A_{cont.}| = |A_\gamma|^2 + |A_{cont.}|^2 + 2Re[A_\gamma^\star A_{cont.}]$.

$A_{cont.}$ has the same phase as $A_\gamma \to \phi \sim 0^\circ$ expected

Interference observed in $e^+e^- \to J/\psi \to \mu^+\mu^-$?

Interference pattern between J/ψ decay and the non-resonant decay amplitudes first observed at SLAC [PRL 33,1406] in 1975. Confirmed by BESII and KEDR,



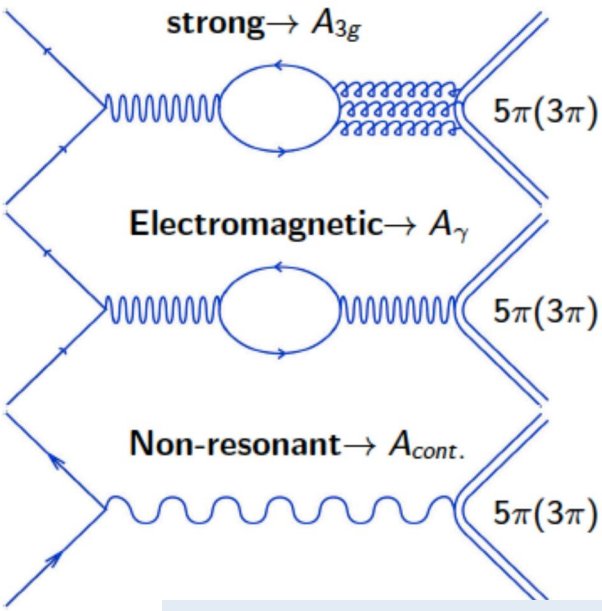
BESIII analysis in progress…

Interference in $e^+e^- \to \pi^0\pi^+\pi^-\pi^+\pi^-$ ($\pi^+\pi^-\pi^0$)

G-parity conserves. A_{3g} contributes.

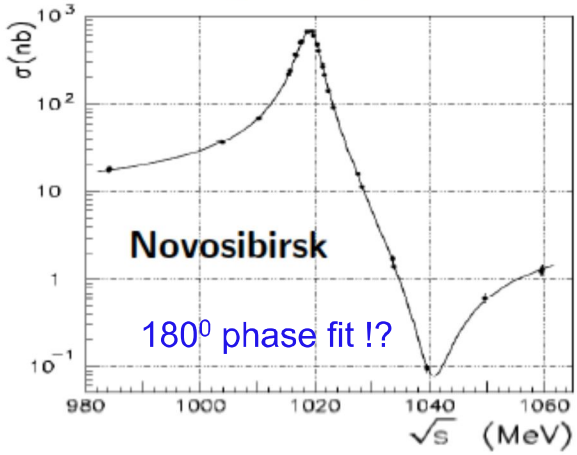
$\sigma_{tot} \sim |A_{strong} + A_{EM}|^2 = |A_{strong}|^2 + |A_{EM}|^2 + 2Re|A^*_{strong}A_{EM}|$

A_{EM} **includes** A_γ **and** $A_{cont.}$.



$e^+e^- \to \pi^+\pi^-\pi^0$ **around** ϕ

Phys.Rev.D 63, 072002



What about $e^+e^- \to \pi^0 2(\pi^+\pi^-)$ around J/ψ ?

BESIII analysis in progress…

Investigated processes in BESIII

➢ **Exclusive scenario:** no interference ?

- $e^+e^+ \to J/\psi \to p\bar{p}, n\bar{n}$ $N\bar{N}$ BR ~ 2.17×10^{-3} σ_{cont}~ 11 pb
- $e^+e^- \to J/\psi \to \rho\pi$ VP BR ~ 1.69% σ_{cont}~ 20 pb
- $e^+e^- \to J/\psi \to 2(\pi^+\pi^-)\pi^0$ BR ~ 5.5% σ_{cont}~ 500 pb

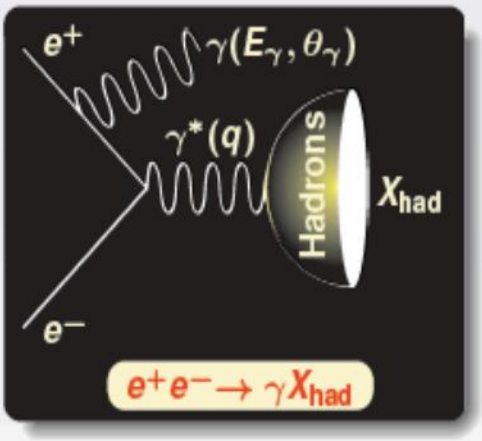
➢ **Check processes where expected interference:**

- $\mu^+\mu^-$ full interference expected (A_{3g}=0)
- even number of π : no strong contribution due to G parity

➢ **BESIII analysis in progress**

➢ **STAY TUNED !**

ISR


e^+
$\gamma(E_\gamma, \theta_\gamma)$
$\gamma^*(q)$
Hadrons
X_{had}
e^-
$e^+e^- \to \gamma X_{had}$

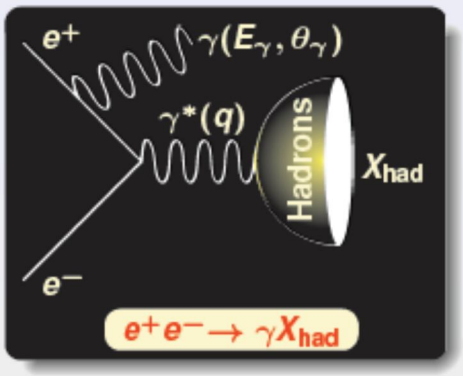
Initial State Radiation: Physics Motivations

- **Existing results, mainly from BABAR (ISR) show interesting and unexpected behaviors expecially at threshold for $e^+e^- \rightarrow p\bar{p}$, $e^+e^- \rightarrow \Lambda\bar{\Lambda}$**
- **Scarse measurement (energy scan) for $e^+e^- \rightarrow n\bar{n}$**

Physical limits in reaching threshold of many of these channels via energy scan (stable hadrons produced at rest cannot be detected)

The ISR technique provides a unique tool to access threshold regions working at higher resonances

Initial State Radiation



- $\frac{d^2\sigma}{dE_\gamma d\theta_\gamma} = W(E_\gamma, \theta_\gamma) \cdot \sigma_{e^+e^- \to X_{had}}(s)$
- $W(E_\gamma, \theta_\gamma) = \frac{\alpha}{\pi x}\left(\frac{2 - 2x + x^2}{\sin^2\theta_\gamma}\right)$

- $s = q^2$, q ..... X_{had} momentum
- E_γ, θ_γ ... CM γ energy, scatt. ang.
- E_{CM} ..... CM e^+e^- energy
- $x = E_\gamma / 2E_{CM}$

Advantages

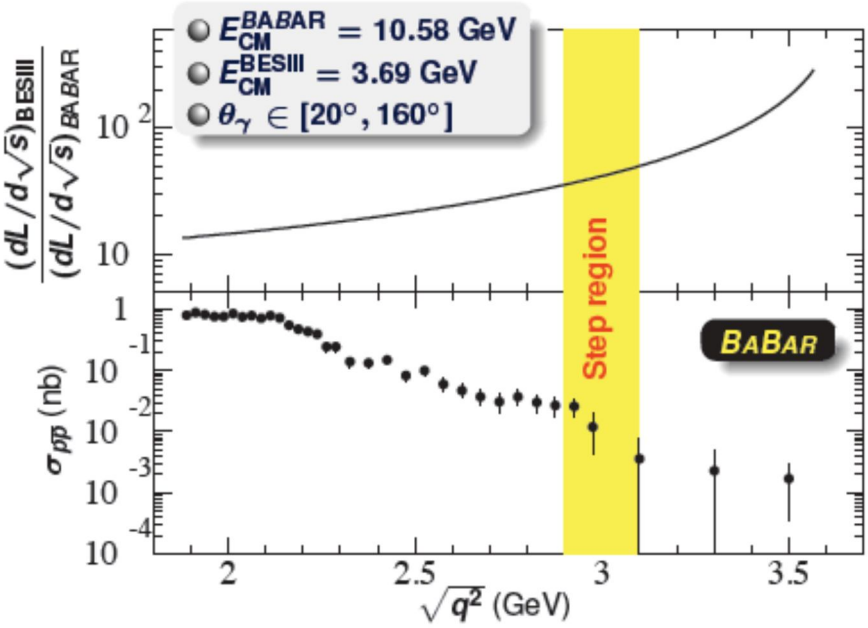
- **all energies (q^2) at the same time → better control on systematics**
- **detect ISR photon → full X_{had} angular coverage**
- **CM boost → at threshold Ɛ#0, energy resolution~1 MeV**

ISR: BESIII vs BABAR for σ ($p\bar{p}$)

$$\frac{d^2L}{d\cos\theta_\gamma\, d\sqrt{s}} = \frac{2\sqrt{s}\,L_{e^+e^-}}{E_{CM}^2}\,\frac{\alpha}{\pi x}\left(\frac{2-2x+x^2}{\sin^2\theta_\gamma}-\frac{x^2}{2}\right)$$

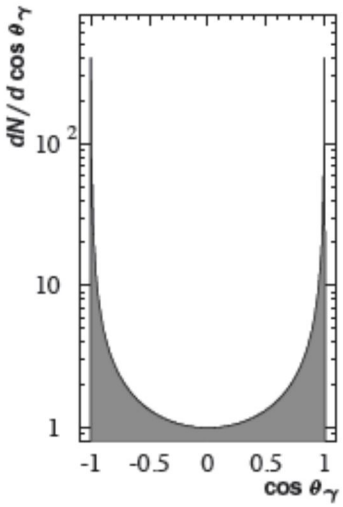
$L_{e^+e^-}$ = luminosity

$$x = \frac{2E_\gamma}{E_{CM}} = 1-\frac{s}{E_{CM}^2}$$



ISR: angular distribution and zero degree photon tagging

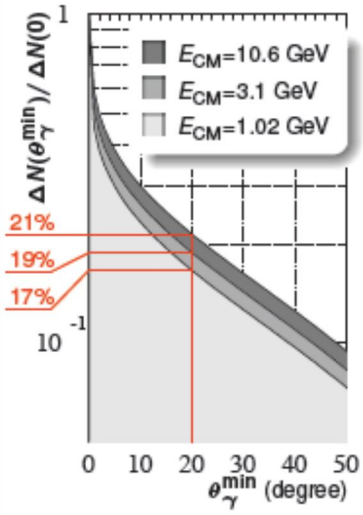
ISR angular distribution peaked at low angles



$$\frac{dN}{d\cos\theta_\gamma} = \frac{1-\cos\theta_\gamma^2}{\left(1-\beta_e^2\cos^2\theta_\gamma\right)^2}$$

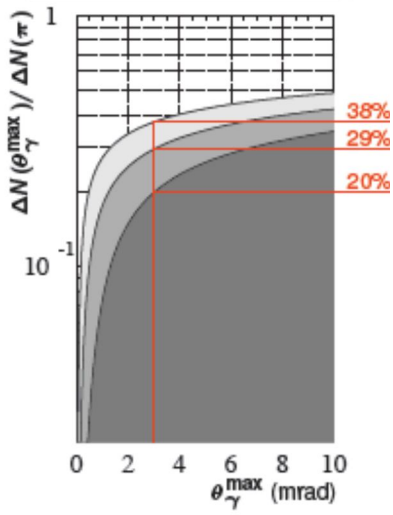
$$\beta_e = \sqrt{1 - 4m_e^2/E_{CM}^2}$$

$$\Delta N(\theta^{min}) \propto \int_{90^o}^{\theta_\gamma^{min}} d\theta_\gamma \frac{dN}{d\theta_\gamma}$$



With a typical $\theta_\gamma^{min} = 20^o$ $\sim$ 80% of events is lost!

$$\Delta N(\theta^{max}) \propto \int_{0}^{\theta_\gamma^{max}} d\theta_\gamma \frac{dN}{d\theta_\gamma}$$



With $\theta^{max} = 3$ mrad more statistics than at wide angle!

BESIII zero degree detector

- J/Ψ, $\Psi(2S)$, $\psi(3770)$ resonances decay with high BR's to final states with π^0 and γ_{FS} (final state)
- At BESIII these decay channels represent severe backgrounds for typical ISR final states with γ_{IS} detected at wide angle

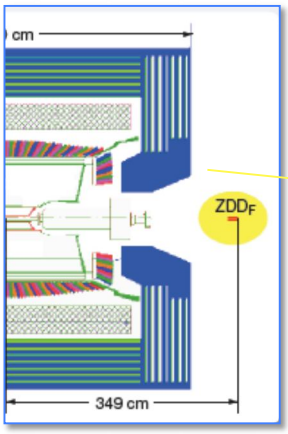
- π^0 and final γ angular distributions are isotropic
- ISR angular distribution is peaked at small angles

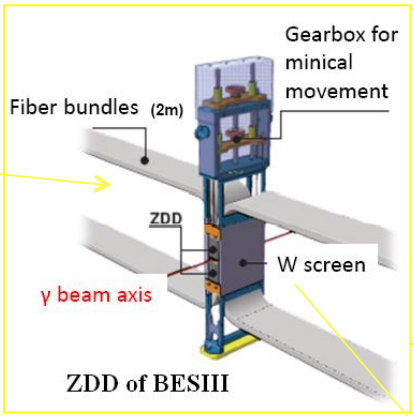
$\Rightarrow$

A zero-degree radiative photon tagger will suppress most of these backgrounds

A new zero-degree detector (ZDD), has been installed on summer 2011 at BESIII to tag ISR photons as well as to measure the luminosity

ZDD: structure module and segmentation

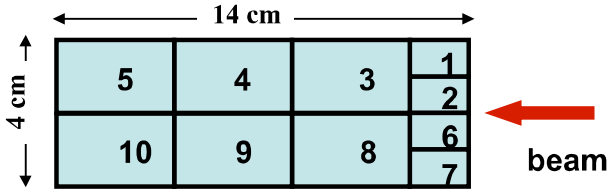




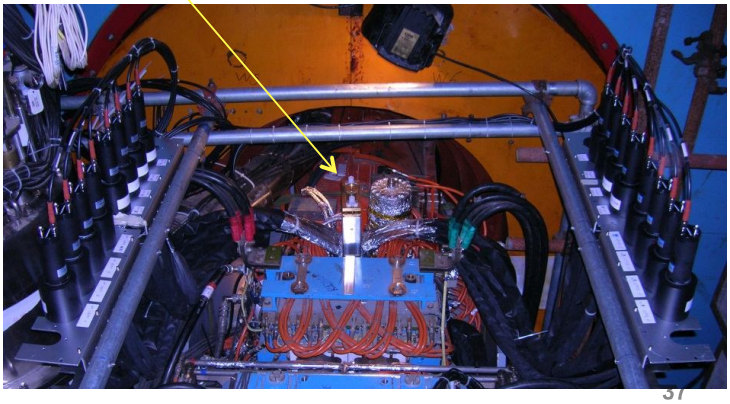
Pb/Sci.Fi Array a` la KLOE scintillating material 60% of total (in volume)

two modules (up and down the beam) dimensions:14×4×6cm^3

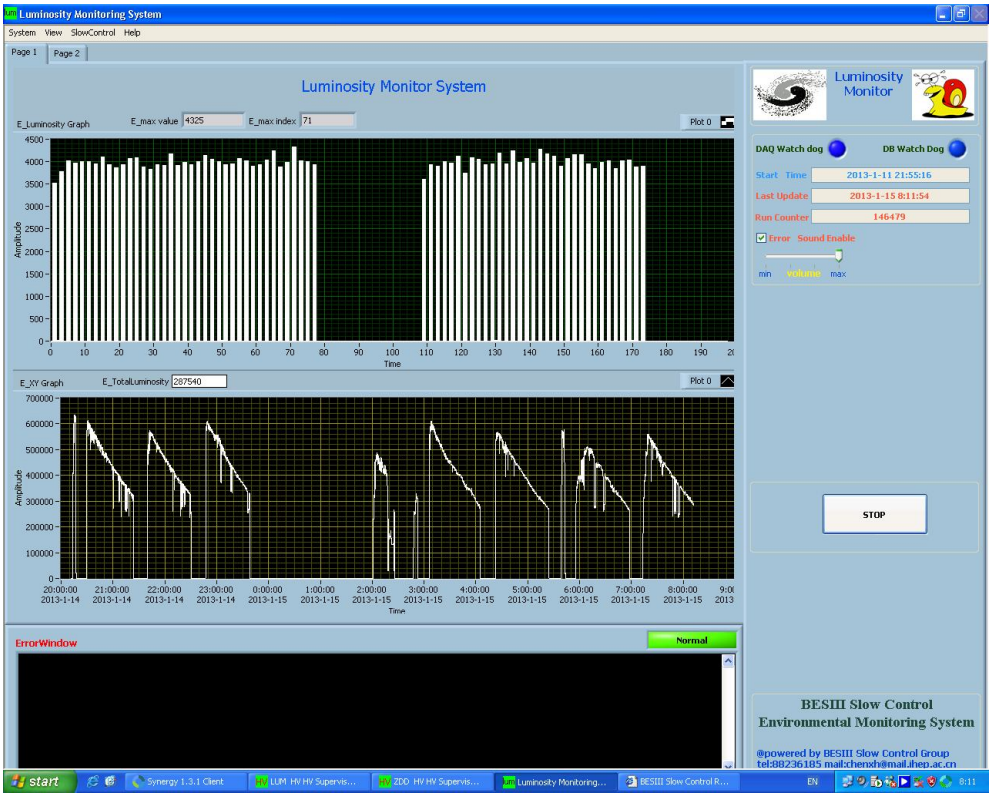
signal extracted and channeled to PM through bundles of clear optical fibers (2m long)



Each sector is sent to a PM, sectors 1&2 (6&7) are sent to the same PM

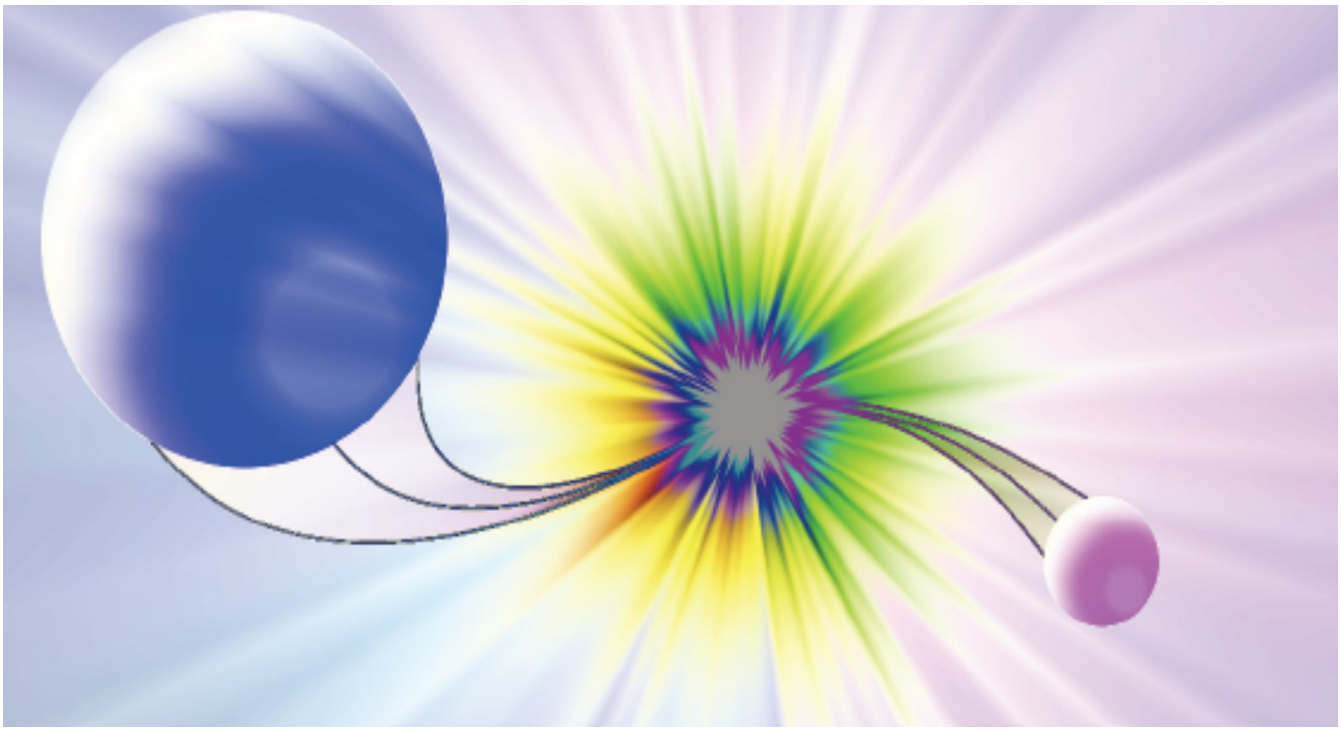


ZDD as luminometer



ZDD rate for 72 bunches

Prospects for baryon form factors

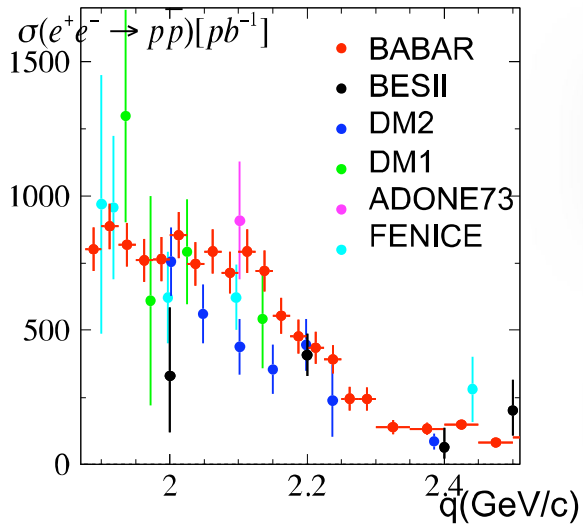


$e^+e^- \to p\bar{p}$

EPJA39, 316 [R.Baldini talks, F.Maas]]

$$\sigma(e^+e^- \to p\bar{p}) = \frac{4\pi\ \alpha^2 \beta_p C}{3q^2}\left[|G_M|^2 + \frac{2M_p^2}{q^2}|G_E|^2\right]$$

Coulomb factor: $C \underset{\beta_p \to 0}{\sim} \left(\frac{\pi\alpha}{\beta_p}\right)$



At threshold:

$$\sigma(e^+e^- \to p\bar{p})(4M_p^2) = \frac{\pi\ \alpha^3}{2M_p^2}\frac{\cancel{\beta_p}}{\cancel{\beta_p}}|G^p(4M_p^2)|^2\ nb$$

$$\sigma(e^+e^- \to p\bar{p})(4M_p^2) = 850\,|G^p(4M_p^2)|^2\ pb$$

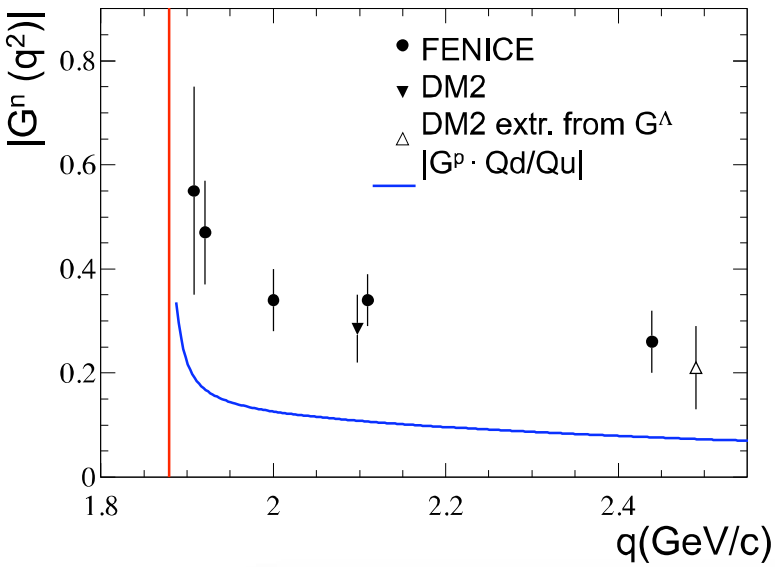
$\Downarrow$

$|G_p(4M^2_p)|=1$
as pointlike fermion pairs !

Using ISR technique with only few fb^{-1} of integrated luminosity BESIII can easily achieve the BABAR statistics

$e^+e^- \rightarrow n\bar{n}$

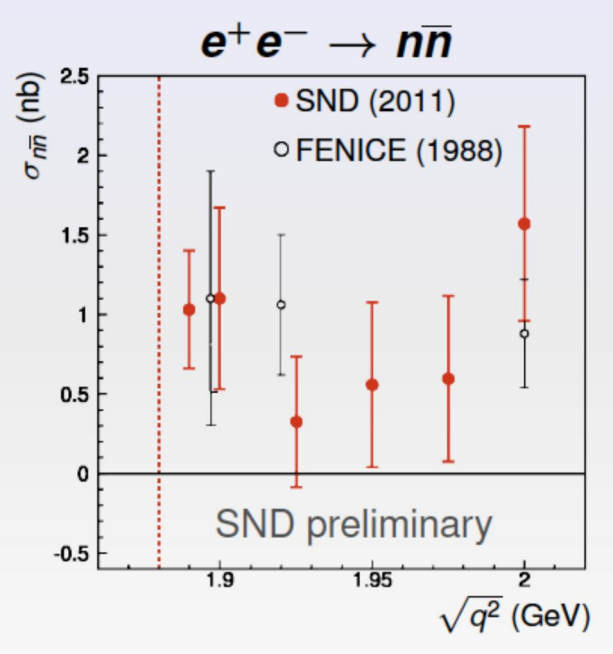
Nucl.Phys. B517,3 (1998)



	$\lvert G_M^n / G_M^p \rvert$
Data	~ 1.5
Naively	$\sim \lvert Q_d / Q_u \rvert$
pQCD	< 1
Soliton models	~ 1
VMD (Dubnicka)	$\gg 1$

only SND, CMD2(?) and BESIII have the possibility to measure this cross section

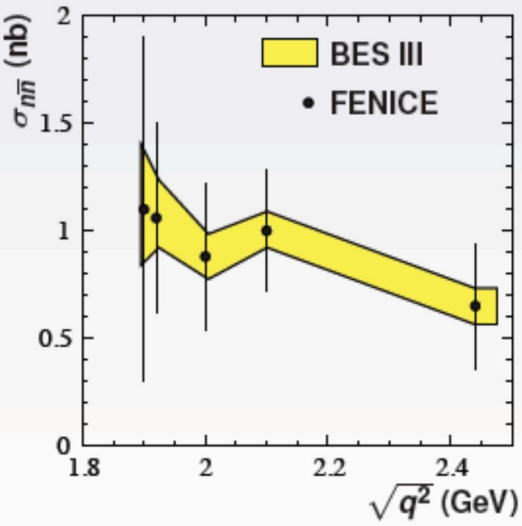
$e^+e^- \rightarrow n\bar{n}$



- **measured by FENICE at ADONE** Nucl.Phys. B517,3 (1998)
- **recently confirmed by SND** eCONF C110613(11)
- **$\sigma(n\bar{n})>\sigma(p\bar{p})$?**
- **Not zero at threshold?**

Expectations for $n\bar{n}$, $p\bar{p}$ at BESIII

- One year of data taking: $T = 1.5 \times 10^7$ s
- Average luminosity: $\overline{\mathcal{L}} = 3 \times 10^{32}$ cm^{-2}s^{-1}
- Center of mass energy: $E_{c.m.} = 3.77$ GeV
- Detection efficiences: $\epsilon_{n\bar{n}} = 0.4$ $\epsilon_{p\bar{p}} = 0.8$
- Number of events: $N_{n\bar{n}} \simeq 1000$ $N_{p\bar{p}} \simeq 2000$



Conclusions

- **BESIII is running successfully**
- **Many interesting physics analyses going on and new ones to start**
- **More precise data on σ_{pp-} above 3GeV**
- **Unique possibility to measure the $n\bar{n}$ cross section with ISR and scan**
- **Measurement of the relative phase between e.m. and strong amplitudes in J/ψ, ψ' decays**
- **First BESIII result confirms a large phase scenario and considerably improve PDG data on J/ψ→ $N\bar{N}$**