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S-wave charmonium decays at BESIII

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OUTLINE

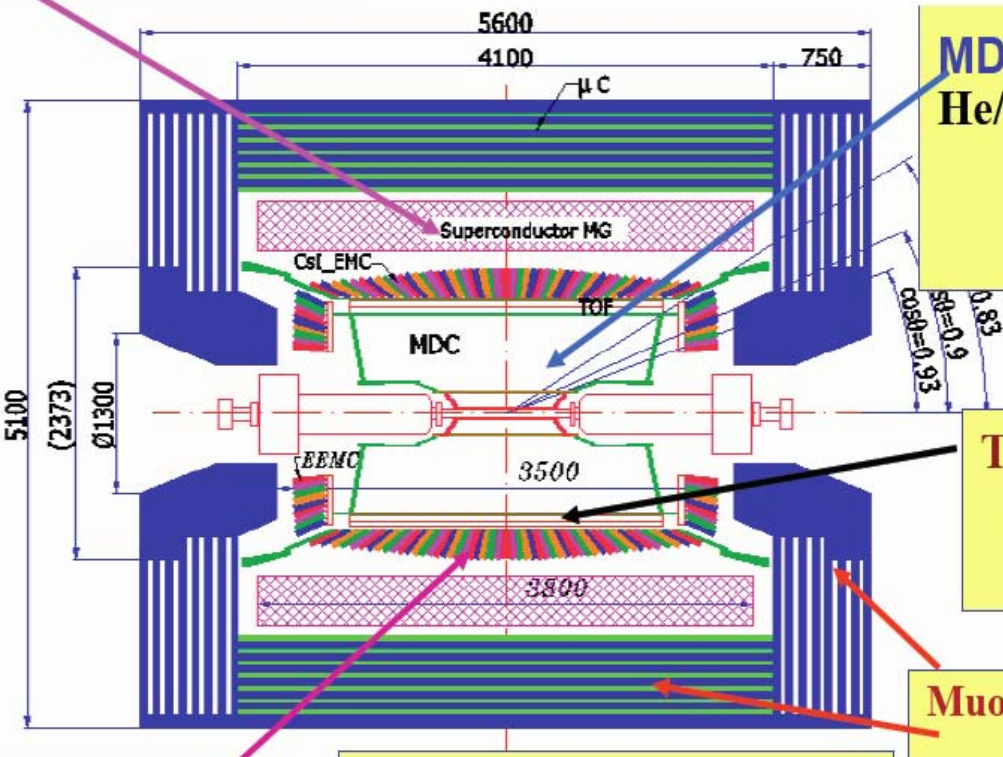
- **Introduction**
- **Latest results on S-wave charmonium decays**
  - ✓$J/\psi \rightarrow$ ppbar, nnbar
  - ✓$J/\psi \rightarrow 3\pi$
  - ✓$\psi' \rightarrow \gamma P$ decay
  - ✓$\eta'_c \rightarrow VV$
  - ✓$\eta_c \rightarrow PP$
- **Summary**

BESIII Detector

BESIIII detector: all new !

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

Magnet: 1 T Super conducting



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

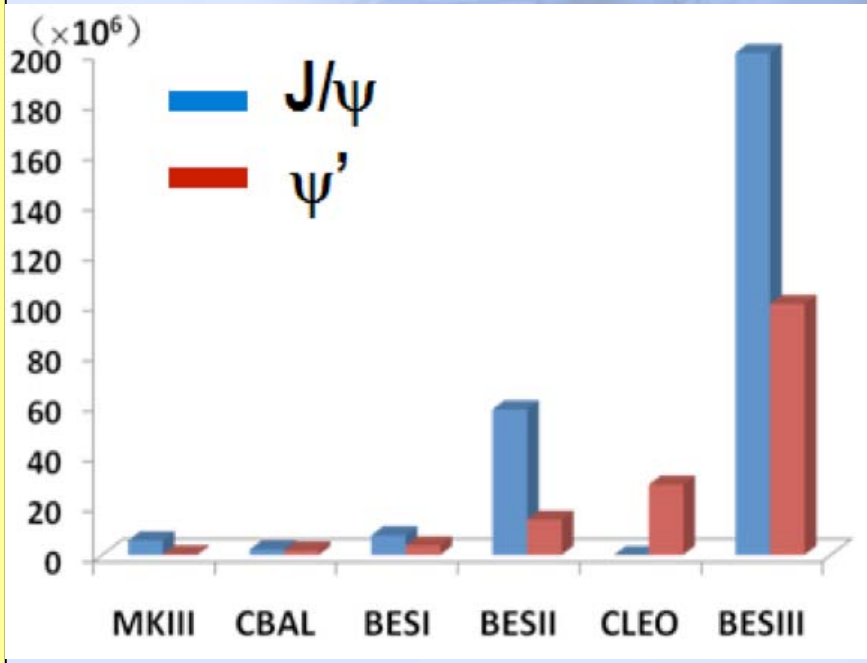
Muon ID: 9 layers RPC
8 layers for endcap

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

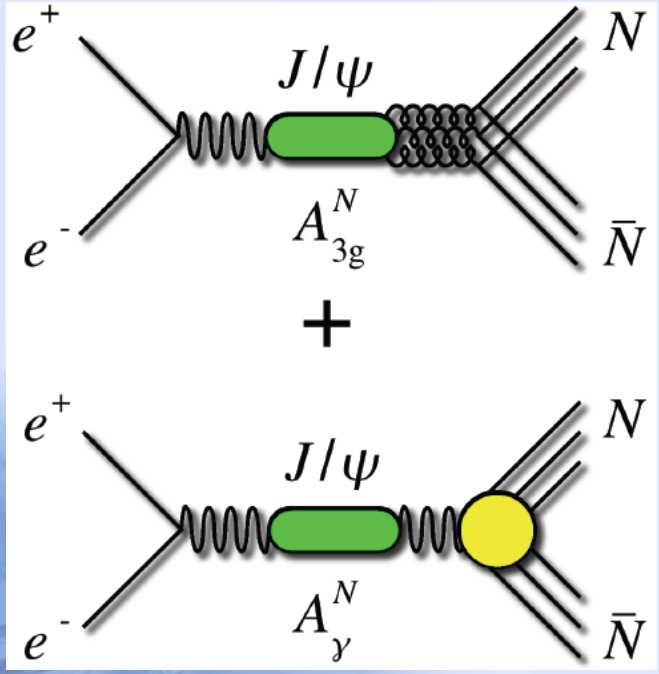
Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

Data samples

- **So far BESIII has collected :**
  - **2009: 106 Million ψ'**
  - **2009: 225 Million J/ψ**
  - **2010-11: 2.9 fb^{-1} ψ(3770)**
    (3.5 × CLEO-c 0.818fb^{-1})
  - **May 2011: 0.5fb^{-1} @4009 MeV for Ds and XYZ spectroscopy**
- **BESIII will also collect:**
  - **more J/ψ, ψ', ψ(3770)**
  - **data at higher energies (for XYZ searches, R and Ds physics)**



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



pQCD → both amplitudes real

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

A_{3g}, A_{γ} ∋ ℜ R<<1

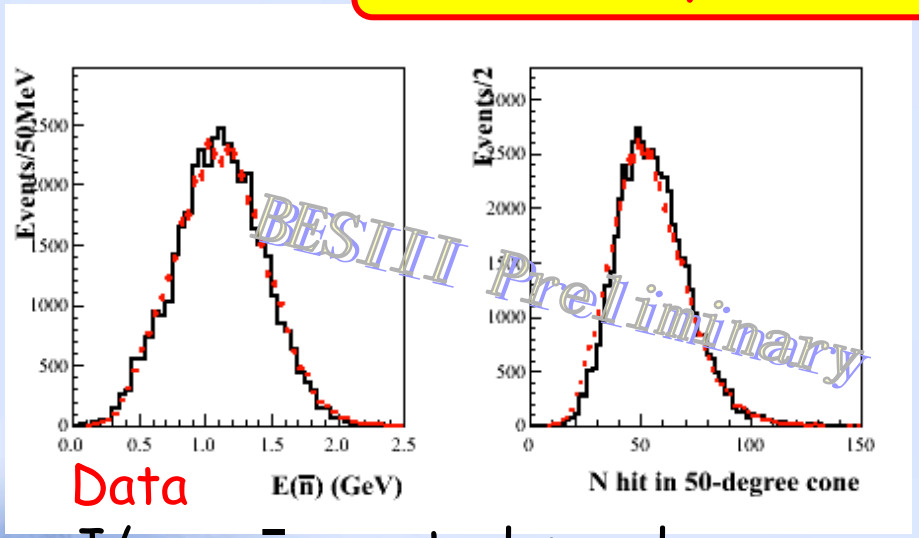
$A_{3g} \perp A_{\gamma}$ R ≈1

High precision

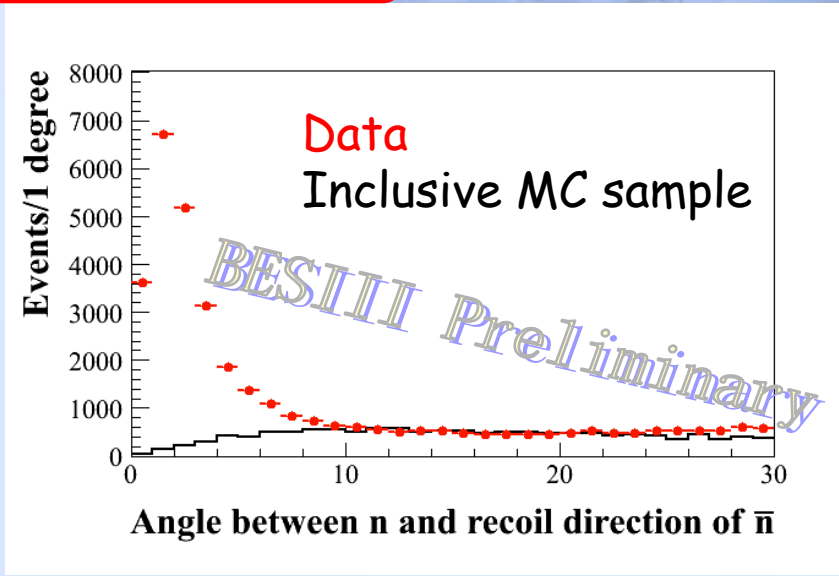
- BESII: $Br(J/\psi \to \bar{p}p) = (2.26 \pm 0.01 \pm 0.14) \times 10^{-3}$ (PLB591,42)
- FENICE: $Br(J/\psi \to \bar{n}n) = (2.31 \pm 0.49) \times 10^{-3}$ (PLB444,111)

Suffering from a large error

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



$J/\psi \to p\bar{n}\pi^-$ control sample



BESIII Preliminary Results

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

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

PDG

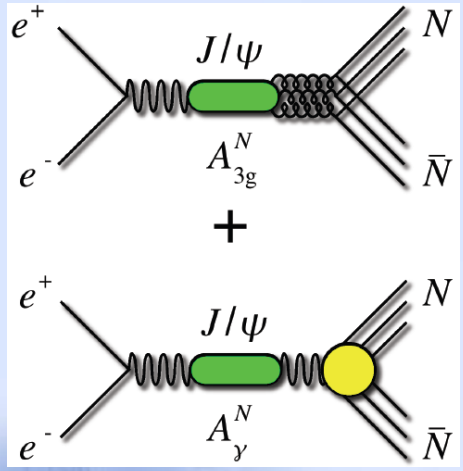
$B(J/\psi \to n\bar{n}) = (2.2 \pm 0.4) \cdot 10^{-3}$

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

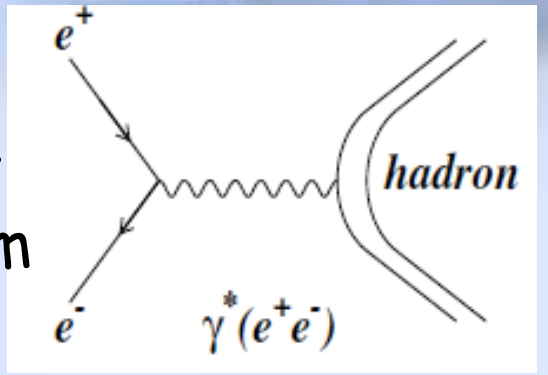
$B(J/\psi \to n\bar{n}) \approx B(J/\psi \to p\bar{p})$

indicate a phase ~ 90° between strong and e.m. amplitudes

Measuring the phase between strong and em amplitudes



both interfere differently
with non-resonant continuum

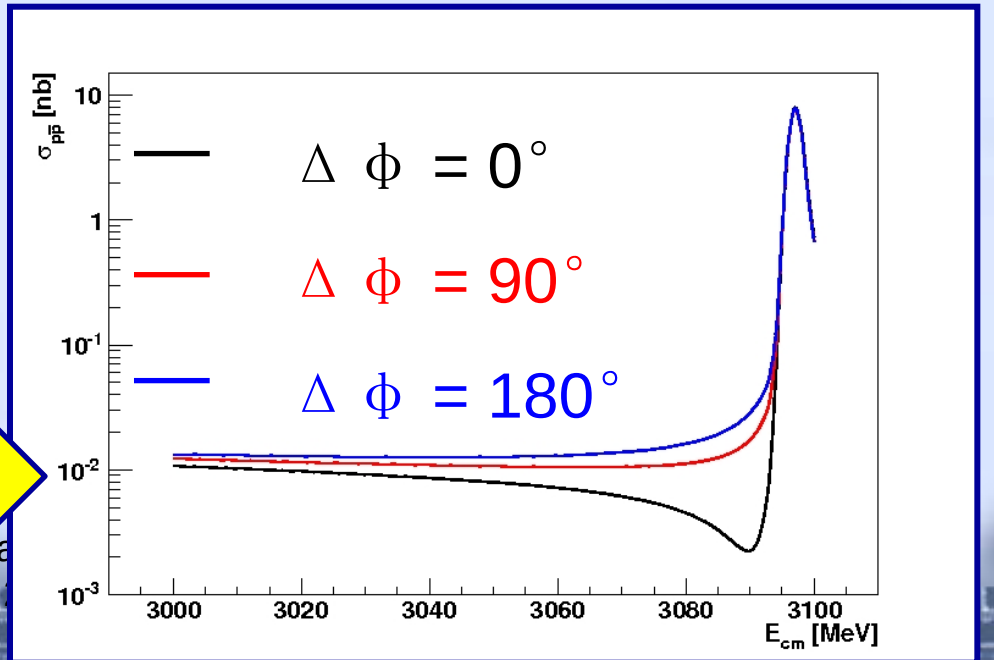


Proposed:

J/ψ line-shape scan

Look for interference pattern

(model independent)



QWG'11, Da

$J/\psi, \psi' \rightarrow 3\pi$

- 3π is the largest hadronic decay modes of J/ψ

  $B(J/\psi \rightarrow 3\pi)=(2.07 \pm 0.12)\%$

- Highly suppressed in ψ' decays

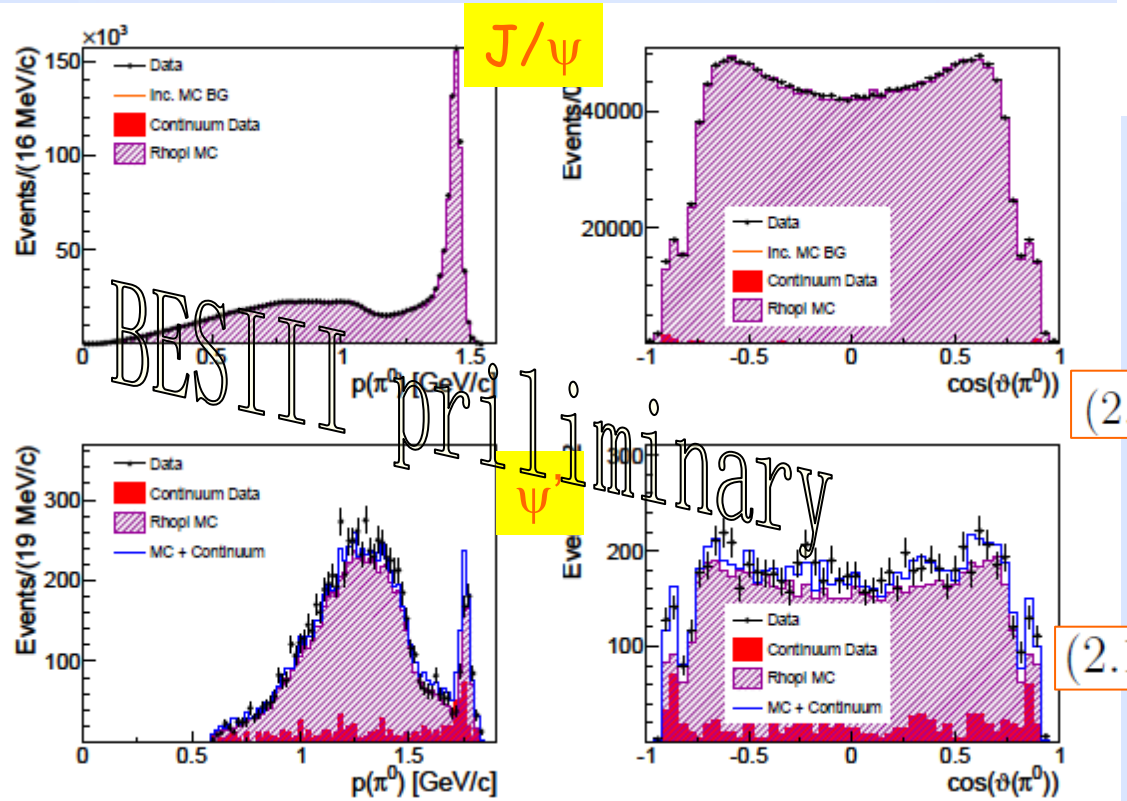
  $B(\psi' \rightarrow 3\pi)=(0.00168 \pm 0.0026)\%$

  (large error due to limited statistics)

$R= B(\psi' \rightarrow 3\pi)/ B(J/\psi \rightarrow 3\pi) <1\%<<12\% \rightarrow \rho\pi$ puzzle

- The puzzle can be investigated based on 106M ψ' and 225M J/ψ at BESIII

J/ψ, ψ'→3π



$$BF = \frac{N_{sel} - N^{BG}_{continuum} - N^{BG}_{resonance}}{N_{\psi} \cdot \epsilon_{MC} \cdot \epsilon_{trig} \cdot BF(\pi^0 \to \gamma\gamma)},$$

B(J/ψ→3π)

$$(2.137 \pm 0.004\ (stat.)^{+0.064}_{-0.062}\ (syst.)) \times 10^{-2}$$

B(ψ'→3π)

$$(2.14 \pm 0.03\ (stat.)^{+0.12}_{-0.11}\ (syst.)) \times 10^{-4}$$

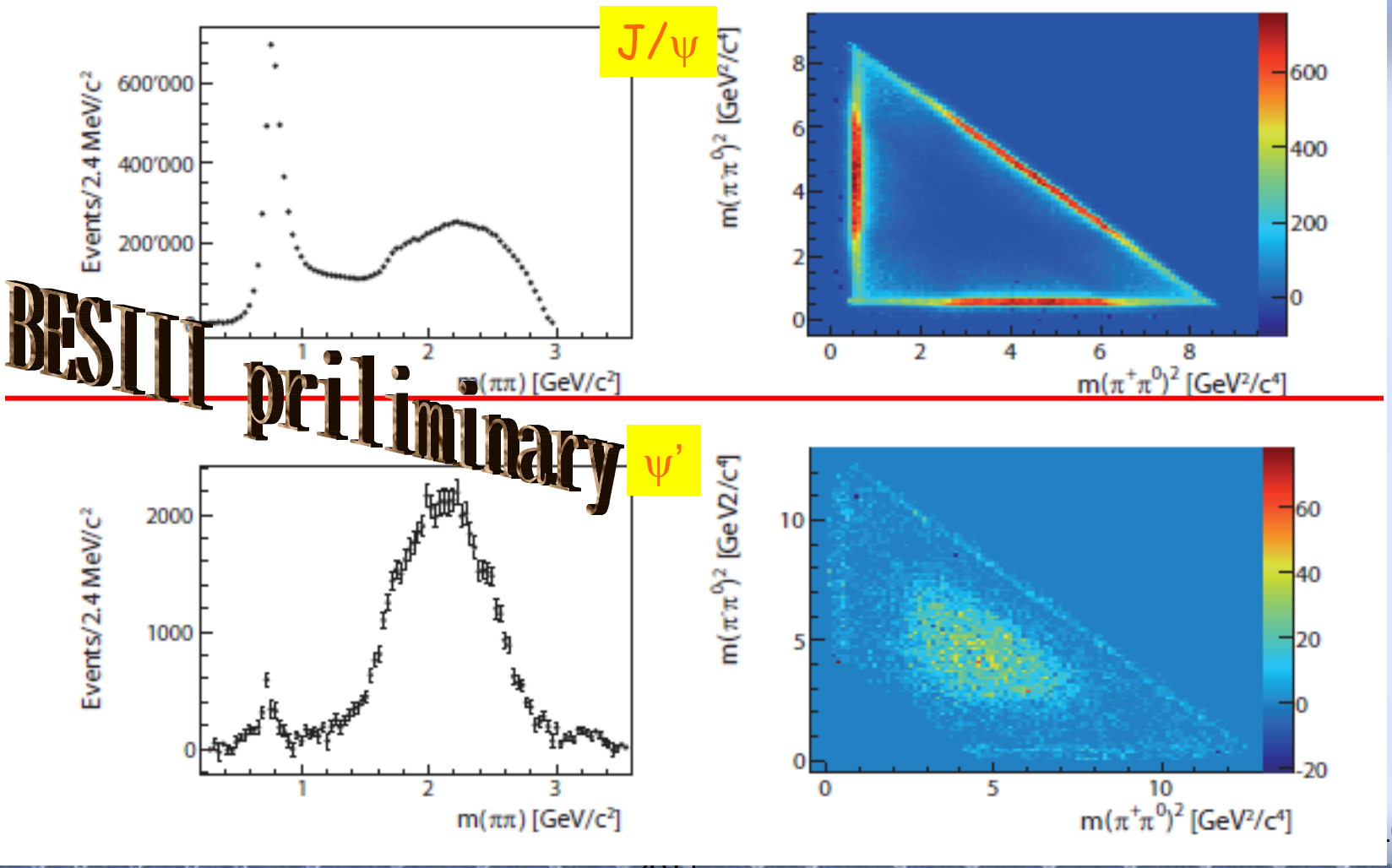
R=B(ψ'→3π)/ B(J/ψ→3π)

$$(1.00 \pm 0.01\ (stat.)^{+0.06}_{-0.05}\ (syst.))\%$$

Violating the 12% rule

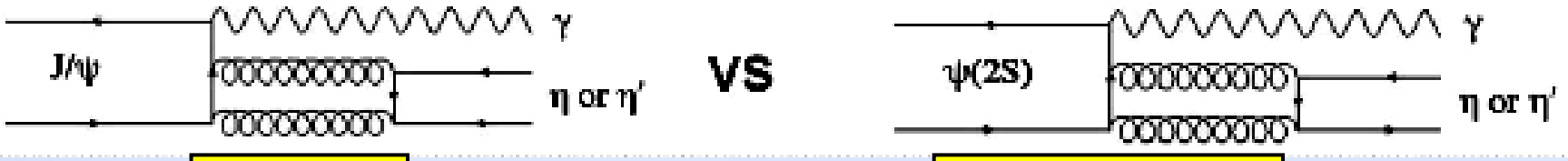
PWA will be performed

to investigate the intermediate resonances



$\psi' \to \gamma P(\pi^0,\eta,\eta')$, arise surprises

$V \to \gamma$ P are important tests for various mechanisms:
Vector meson Dominance Model (VDM); Couplings & form factor; Mixing of η-η' ($-\eta_c$); FSR by light quarks; 12% rule and "$\rho\,\pi$ puzzle".



theory

$$R_{(c\bar{c})} = \frac{Br((c\bar{c}) \to \gamma\eta)}{Br((c\bar{c}) \to \gamma\eta')}$$

LO-pQCD

$$\Downarrow$$

$$R_{\psi'} \simeq R_{J/\psi}$$

PRP 112,173 (1984)

experiment

CLEO-c: J/ψ, ψ', ψ'' $\to \gamma$ P

$R_{J/\psi}$ = (21.1 ± 0.9)%

No Evidence for $\psi' \to \gamma\,\pi^0$ or $\gamma\,\eta$

$Br(\psi' \to \gamma\eta')$=(1.19 ± 0.09)%

$R_{\psi'}$ < 1.8% at 90% CL

$$\Downarrow$$

$R_{\psi'} << R_{J/\psi}$

PRD 79, 111101 (2009)

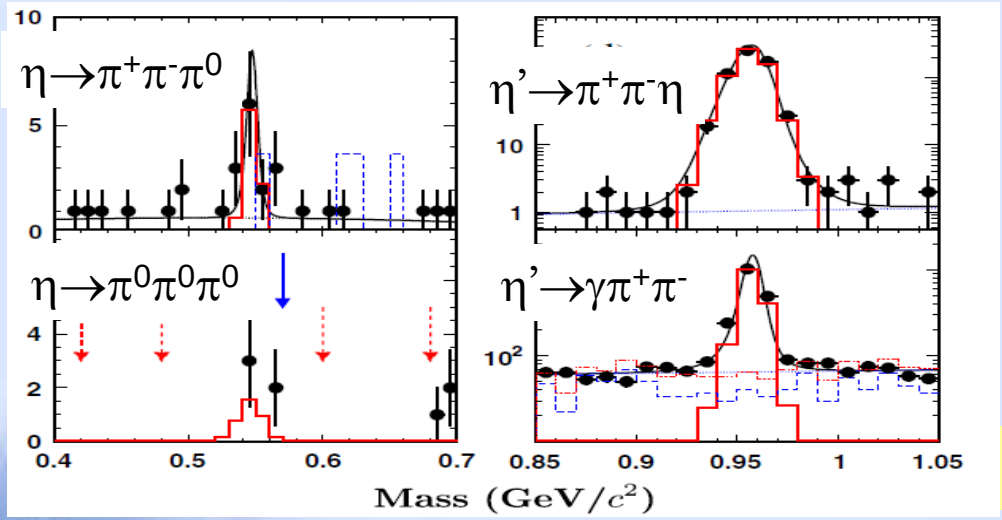
$\psi' \to \gamma$ P at BESIII

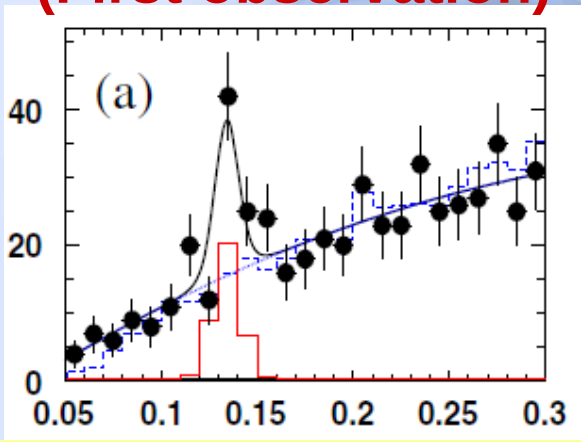
PRL 105, 261801 (2010)

$\psi' \to \gamma\ \eta$ (First observation)

$\psi' \to \gamma\ \eta'$

$\psi' \to \gamma\ \pi^0$ (First observation)





$R_{\psi'} = 1.10 \pm 0.38 \pm 0.07\% << R_{J/\psi}$

Mode	B(ψ') [x10^{-6}]	B(J/ψ) [x10^{-4}]	Q (%)
$\gamma\pi^0$	1.58±0.42	0.35±0.03	4.5 ± 1.3
$\gamma\eta$	1.38±0.49	11.04±0.34	0.13 ± 0.04
$\gamma\eta'$	126±9	52.8±1.5	2.4 ± 0.2

Possible interpretation: Q. Zhao, Phys. Lett. B697, 52 (2011)

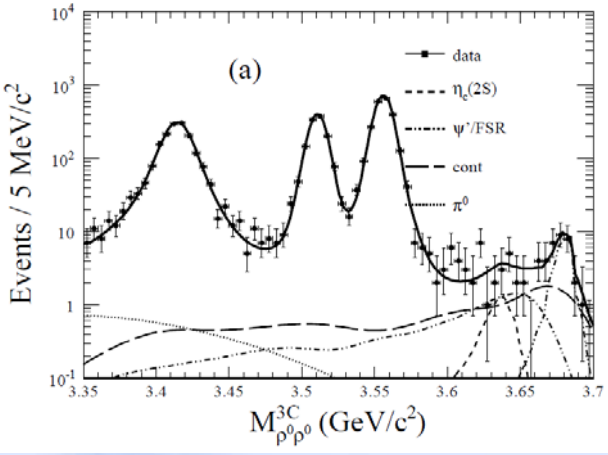
Search for $\eta'_c \to VV$

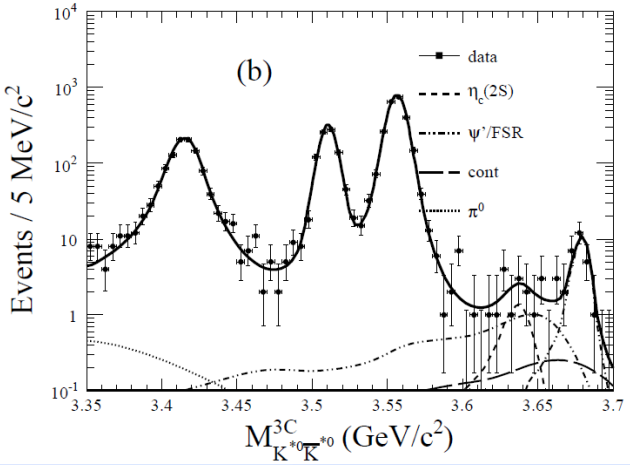
- First reported by Crystal Ball in 1982 from radiative decay of $\psi\prime$
  - $M_{\eta_c(2S)} = 3.592\ \mathrm{GeV}/c^2$
  - $\mathcal{B}(\psi\prime \to \gamma\eta_c(2S)) = 0.2\% \sim 1.3\%$
- Published results about $\eta_c(2S)$:
  - $B^{\pm} \to K^{\pm}\eta_c(2S), \eta_c(2S) \to K_S K^{\pm}\pi^{\mp}$ Belle
  - $\gamma\gamma \to \eta_c(2S) \to K_S K^{\pm}\pi^{\mp}$ CLEO
  - $\gamma\gamma \to \eta_c(2S) \to K_S K^{\pm}\pi^{\mp}$ BaBar
  - $e^+e^- \to J/\psi c\bar{c}$ BaBar
- Averaged value:
  - $M_{\eta_c(2S)} = 3638.1 \pm 1.5\ \mathrm{MeV}/c^2$
  - $\Gamma_{\eta_c(2S)} = 12.3 \pm 3.1\ \mathrm{MeV}/c^2$
- BESIII: $\mathcal{B}(\psi\prime \to \gamma\eta_c(2S)) = 4.4 \pm 0.9 \pm 2.8 \times 10^{-4}$

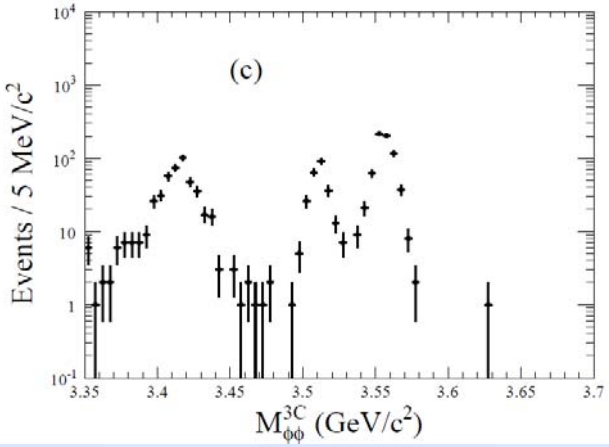
Talk of H.Liu

- $\eta'_c \to VV$ supposed to be highly suppressed by HSR
- High decay rate of $\eta'_c \to VV$ predicted by Q. Wang in **arXiv:1010.1343**

BESIII priliminary







The upper limits obvious smaller than the predictions, disfavor!

V	$N^{up}_{\gamma VV}$	ε (%)	$\mathcal{B}^{up}(\psi' \to \gamma\eta_c' \to \gamma VV)$ (10^{-7})	$\mathcal{B}^{up}(\eta_c' \to VV)$ (10^{-3})	$\mathcal{B}^{theory}(\eta_c' \to VV)$ (10^{-3})
ρ^0	19.2	14.3	12.7	3.1	6.4~28.9
K^{*0}	15.2	16.5	19.6	5.4	7.9~35.8
ϕ	3.9	19.9	7.8	2.0	2.1~9.8

arXiv:1110.0949, submitted to PRD

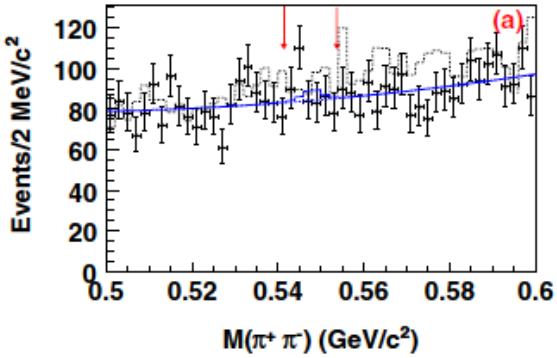
Search for P and CP violation in $\eta_c/\eta/\eta' \rightarrow \pi\pi$

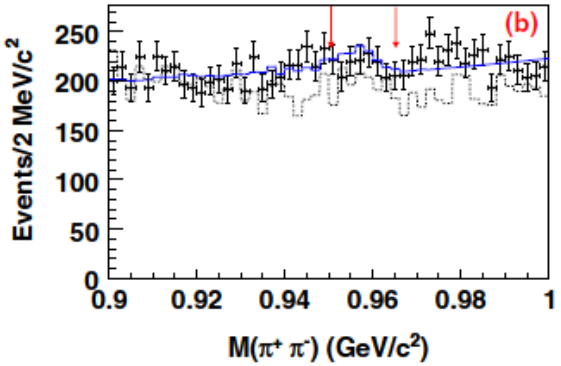
- $\eta_c/\eta/\eta' \rightarrow \pi\pi$ violate the P and CP , provide an excellent laboratory for testing the validity of symmetries, because
- The branching fractions of potential processes, for examples via weak interaction, less than 10^{-15}
- The detection of these decays at any level accessible today would signal P and CP violations from **new sources**

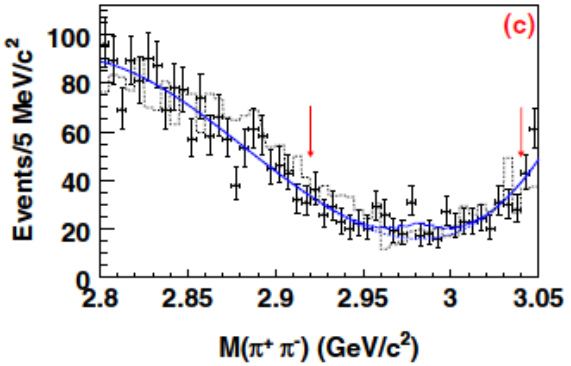
- See references:
  - C. Jarlskog and E. Shabalin, Phys. Scr. T99, 23 (2002)
  - E. Shabalin, Phys. Scr. T99, 104 (2002).

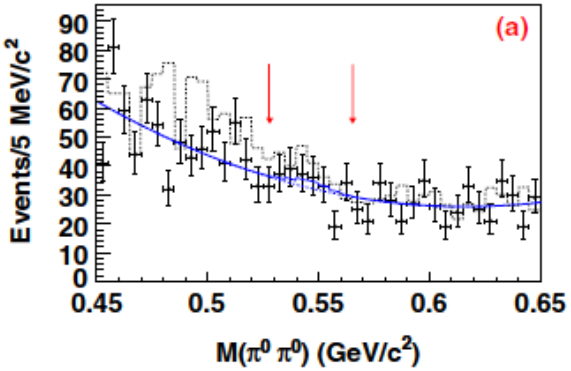
- Such kind of search benefits from 225M J/ψ data

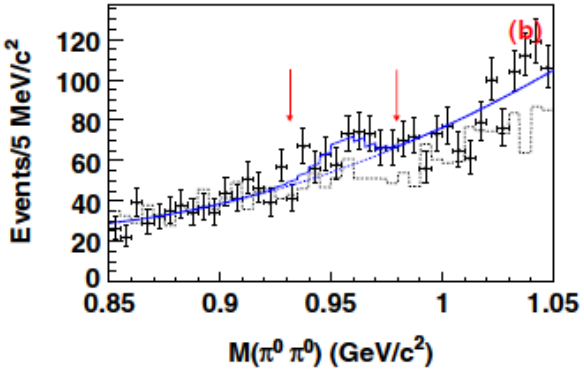
Upper limits determination

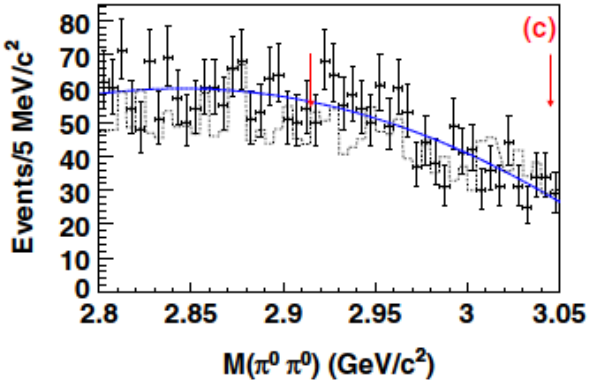












Numerical results

Process	N_{sig}^{UP}	ε (%)	σ_{sys} (%)	S	$\mathcal{B}^{UP}$	$\mathcal{B}_{PDG}^{UP}$
$\eta \to \pi^+\pi^-$	48	54.28	7.3	0.8σ	3.9×10^{-4}	1.3×10^{-5}
$\eta' \to \pi^+\pi^-$	32	53.81	8.6	0.1σ	5.5×10^{-5}	2.9×10^{-3}
$\eta_c \to \pi^+\pi^-$	92	25.27	27	1.5σ	1.3×10^{-4}	6×10^{-4}
$\eta \to \pi^0\pi^0$	36	23.75	8.6	0.6σ	6.9×10^{-4}	3.5×10^{-4}
$\eta' \to \pi^0\pi^0$	110	23.18	8.5	2.6σ	4.5×10^{-4}	9×10^{-4}
$\eta_c \to \pi^0\pi^0$	40	35.70	28	0.1σ	4.2×10^{-5}	4×10^{-4}

- The lowest upper limits obtained
- Provide experimental limits for the theoretical predictions

summary

- BESIII is successfully operation since 2008:
  1. collected huge data samples at J/ψ, ψ', ψ(3770), and ψ(4040).
  2. more data (also at higher energies) in future.

- Important results obtained on S-wave charmonium J/ψ, ψ', η_c, η_c(2S)

- More exciting/interesting results are coming.

many thanks for your attention !

Charmonium spectrum below open charm threshold