Recent BES Results and Future Prospects

Xiaoyan SHEN

Representing BES Collaboration
Institute of High Energy Physics, Beijing

shenxy@ihep.ac.cn

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Outline

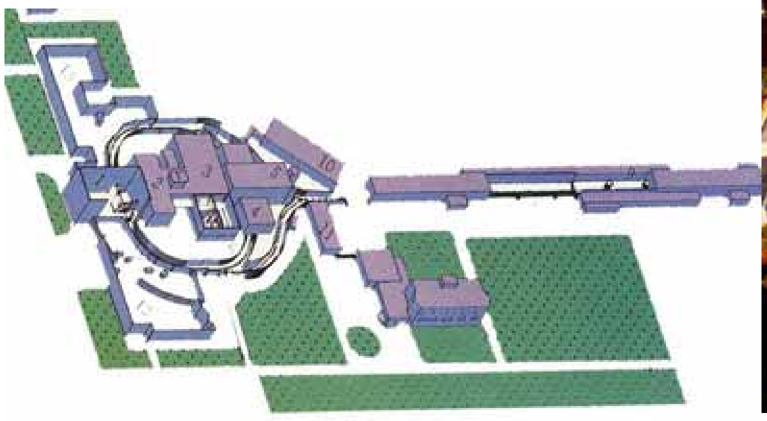
- Light hadron spectroscopy
- First measurements of $\psi(2S)$ radiative decays
- $\psi(3770)$ non-$D\bar{D}$ decays
- Search for $\eta/\eta' \rightarrow$ Invisible from $J/\psi \rightarrow \phi\eta/\eta'$
- BESIII/BEPCII project

Beijing Electron Positron Collider (BEPC)

$L \sim 5 \times 10^{30} /cm^2 \cdot s$

at J/ψ

$E_{beam} \sim 1 - 2.5$ GeV

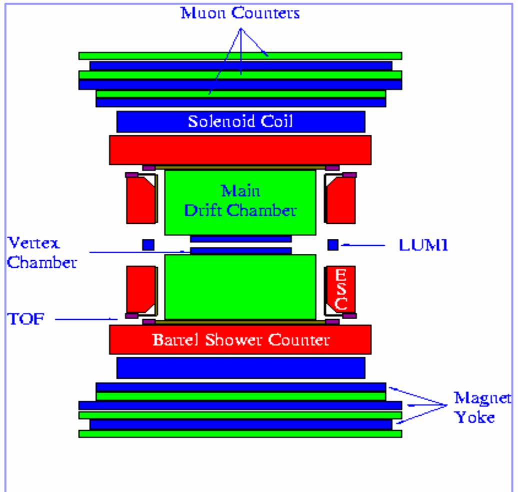


BESI started running in 1989

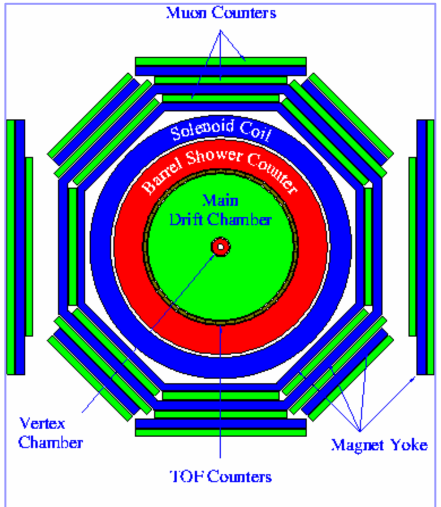
BESII started in 1997

BESIII will start in 2008

BESII Detector



Side view of the BES detector



End view of the BES detector

VC: σ_{xy} = 100 μm — TOF: σ_T = 180 ps

MDC: σ_{xy} = 220 μm — BSC: $\Delta E/\sqrt{E}$ = 21 %

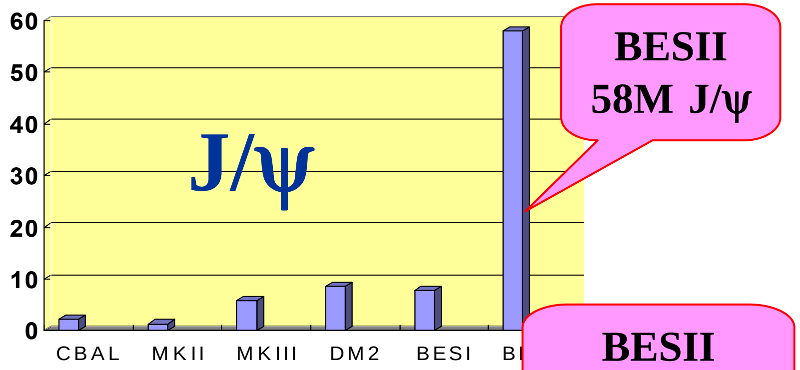
$\sigma_{dE/dx}$ = 8.5 % — σ_ϕ = 7.9 mr

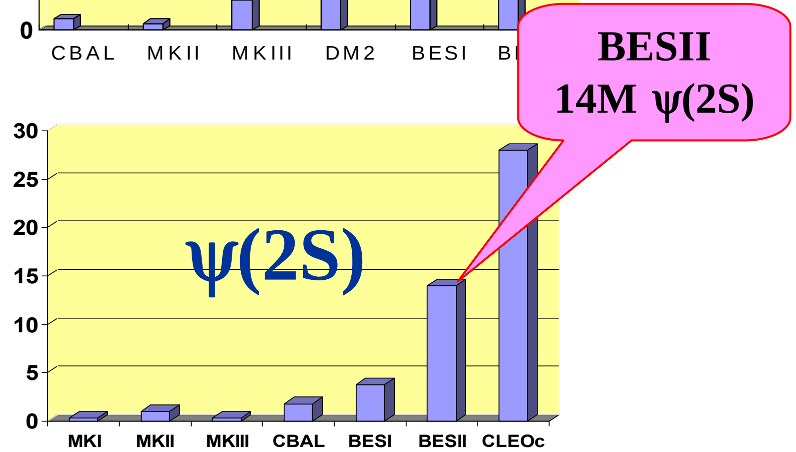
$\Delta p/p = 1.78\sqrt{(1+p^2)}$ — σ_z = 2.3 cm

μ counter: $\sigma_{r\phi}$ = 3 cm — B field: 0.4 T

σ_z = 5.5 cm

World J/ψ and ψ(2S) Samples (×10⁶)



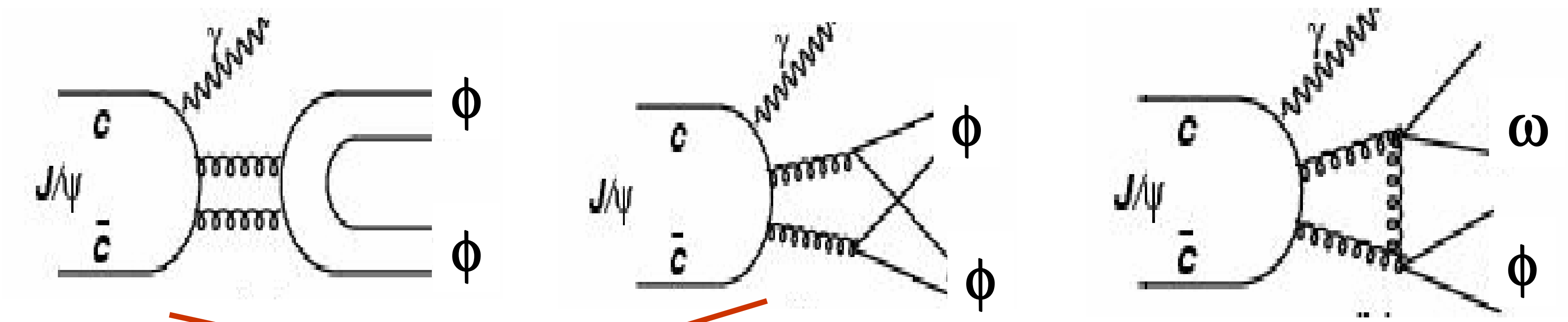


33 pb^{-1} ψ(3770) data

Light Hadron Spectroscopy

Observation of ωϕ threshold enhancement in J/ψ → γωϕ

$$(\omega \to \pi^+\pi^-\pi^0, \phi \to K^+K^-)$$



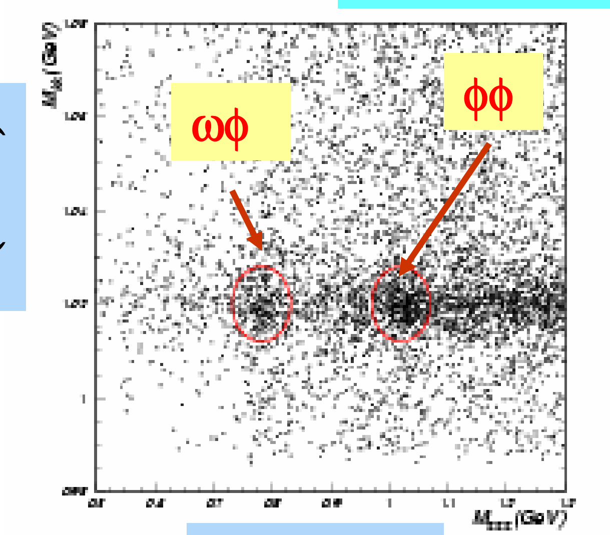
OZI

$J/\psi \to \gamma\phi\phi, \phi \to K^+K^-$

DOZI

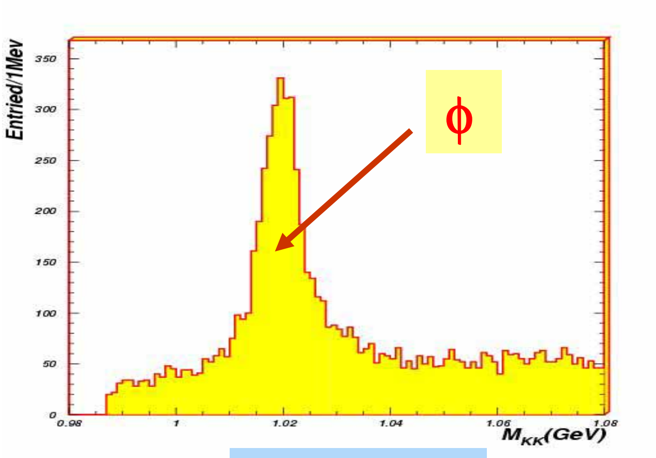
$J/\psi \to \gamma\omega\phi$

Clear ϕ and ω signals

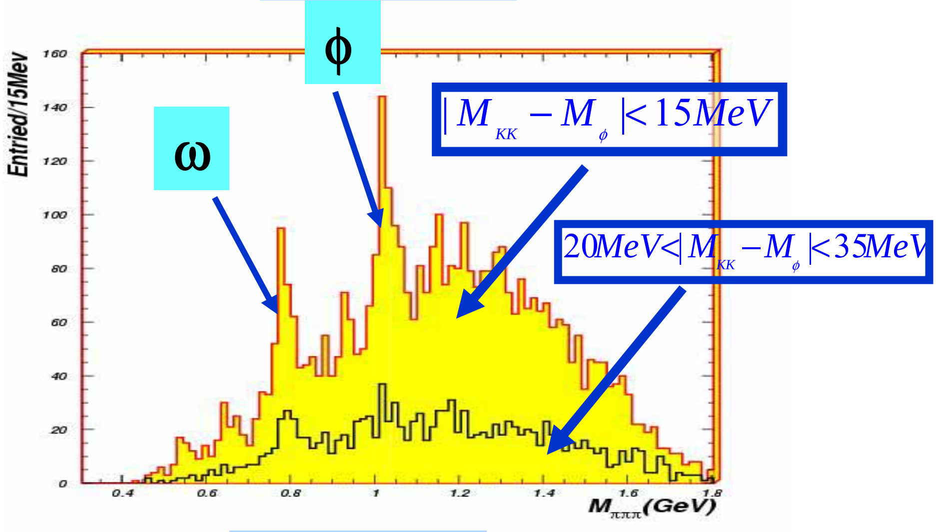


M(K⁺K⁻)

M(π⁺π⁻π⁰)

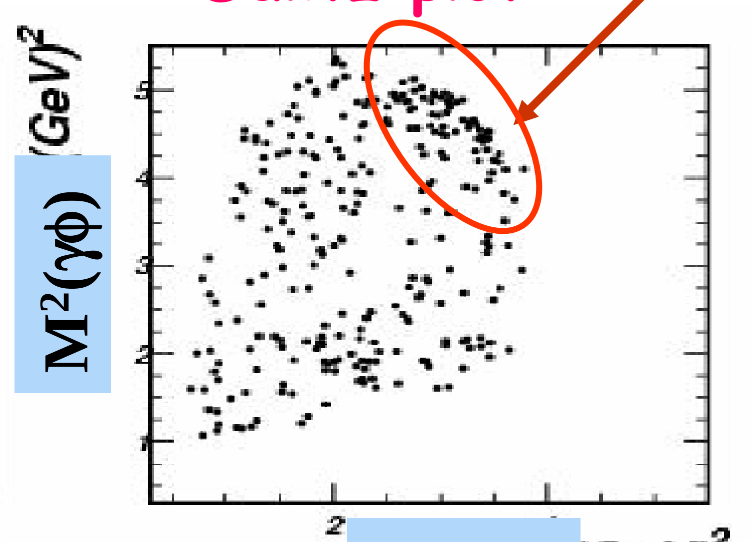


M(K⁺K⁻)



M(π⁺π⁻π⁰)

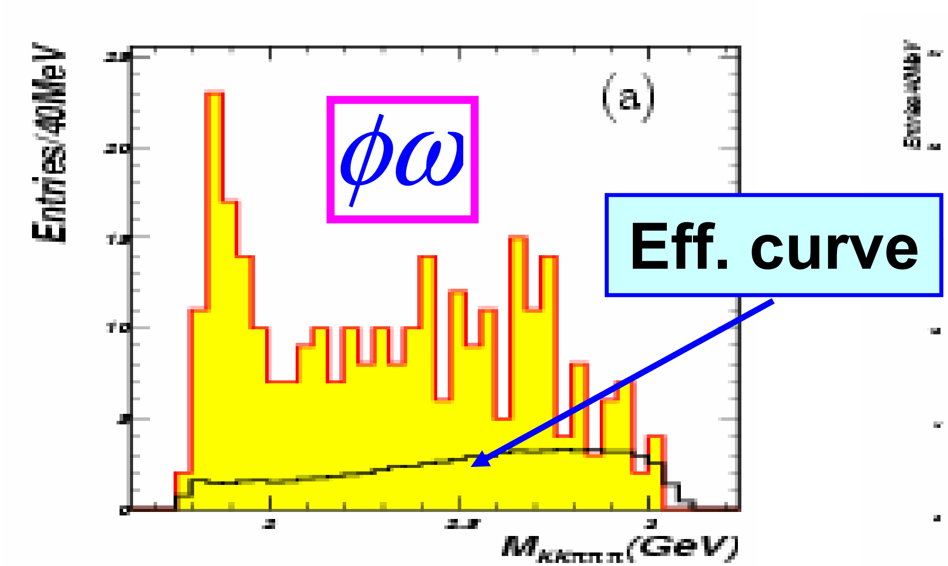
Dalitz plot

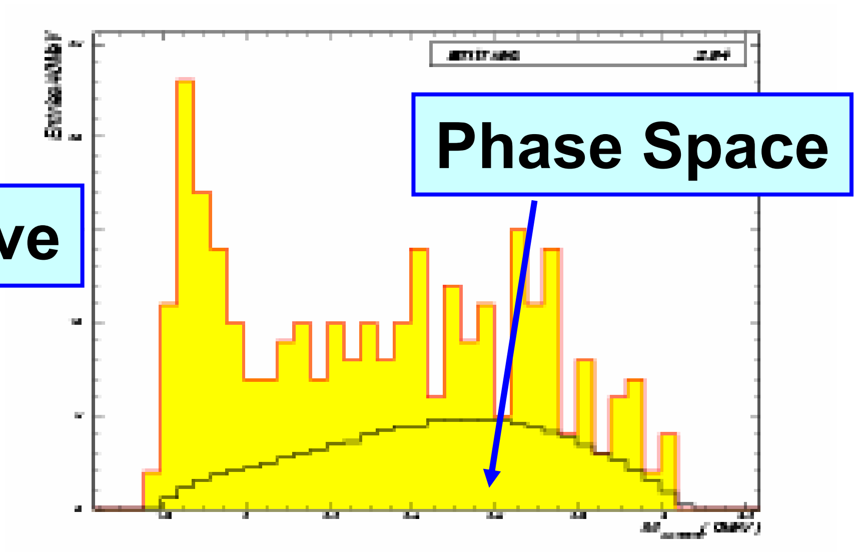


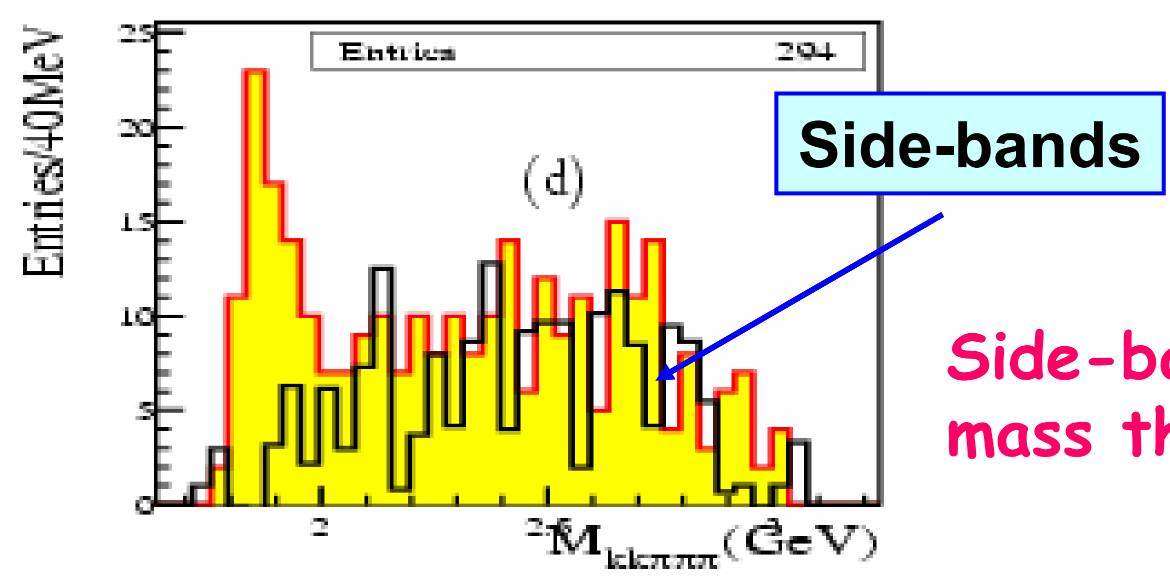
M²(γϕ)

M²(γω)

A clear threshold enhancement is observed







Side-bands do not have mass threshold enhancement!

- PWA shows: the enhancement favors 0^{++} over 0^{-+} and 2^{++}

.

$$M = 1812^{+19}_{-26} \pm 18\ \mathrm{MeV/c^2}$$

$$\Gamma = 105 \pm 20 \pm 28\ \mathrm{MeV/c^2}$$

$$Br(J/\psi \to \gamma X) \cdot Br(X \to \omega\phi) = (2.61 \pm 0.27 \pm 0.65) \times 10^{-4}$$

- Is it the same 0^{++} observed in $\gamma K\bar{K}$ or $\phi\pi\pi$ ($f_0(1710)$, or $f_0(1790)$), or is it a glueball, or a hybrid …..?

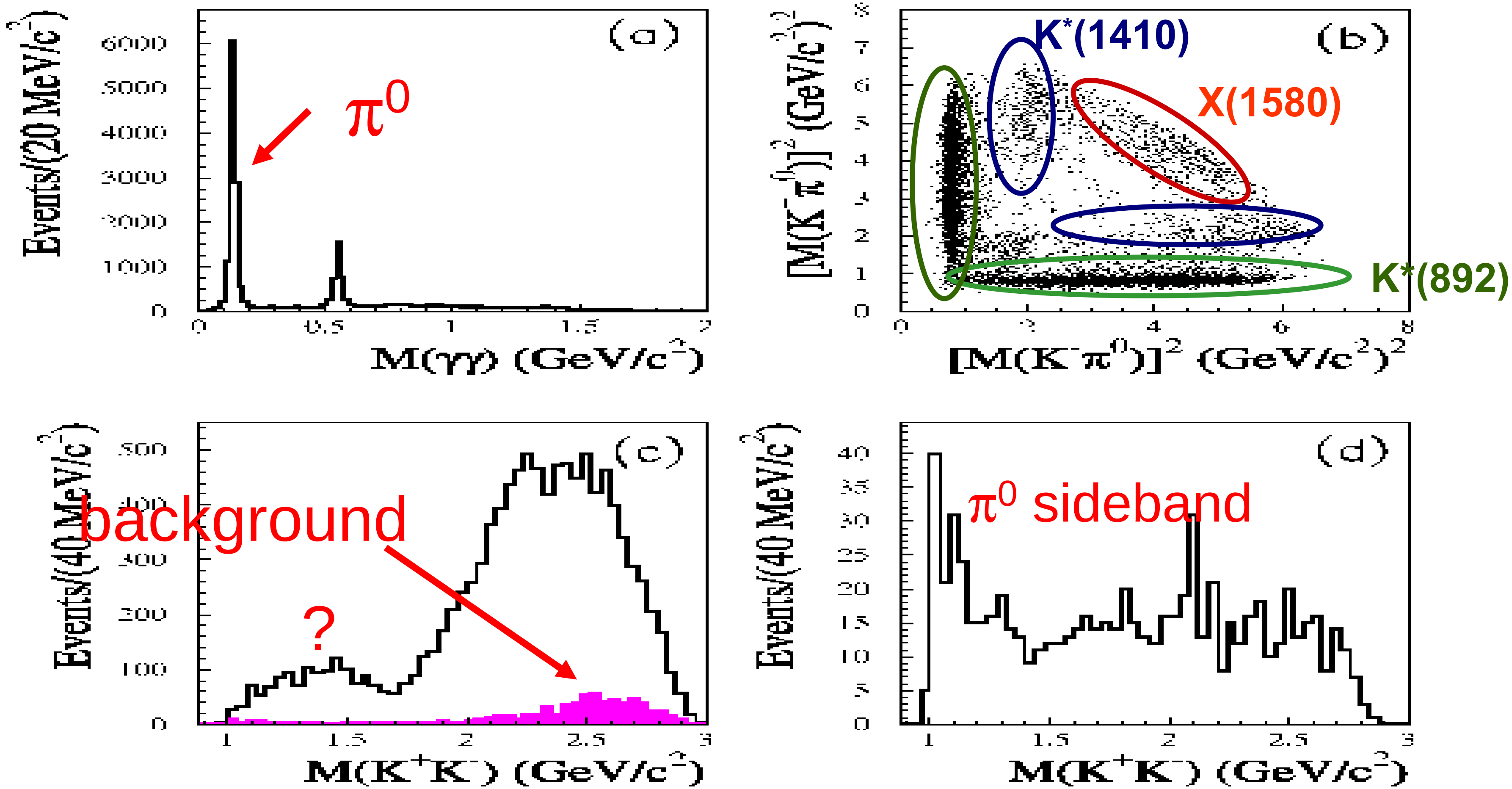
Further look in $\omega\omega$, $K^*\bar{K}^*$, $\phi\phi$ …. is desirable !

Phys. Rev. Lett., 96 (2006) 162002

Observation of a broad 1^{--} resonance in $J/\psi \rightarrow K^+K^- \pi^0$

Phys. Rev. Lett. 97 (2006) 142002

$J/\psi \to K^+K^-\pi^0$



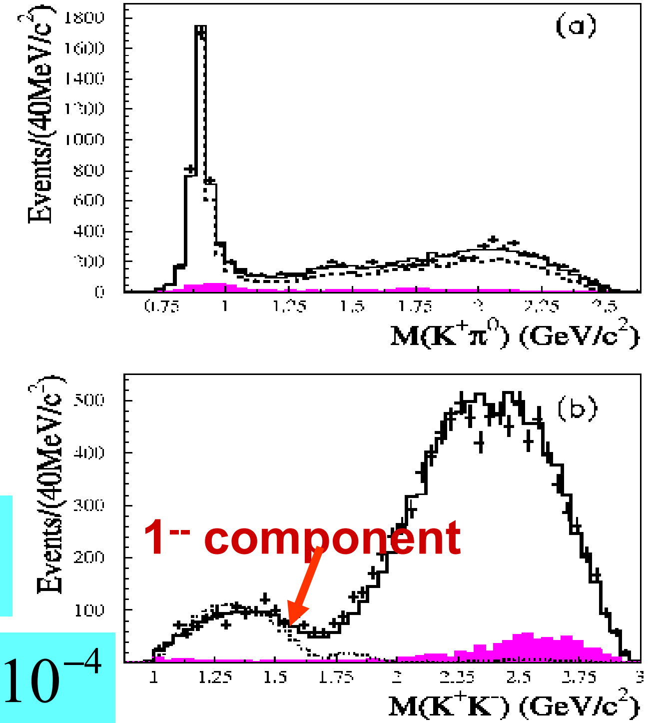
PID and kinematic fit can significantly reduce the dominant background from $J/\psi \to \pi^+\pi^-\pi^0$.

What is this broad structure?

- J^{PC} should be 1^{--}, 3^{--}, …(Parity conservation)
- PWA results
  - Following components are needed $K^*(892)$, $K^*(1410)$, $\rho(1700)$, X
  - 1^- is much better than 3^{--}
  - Pole position of X is

$$(1576^{+49}_{-55}{}^{+98}_{-91}) - i(409^{+11}_{-12}{}^{+32}_{-67})\ \mathrm{MeV/c^2}$$

$$\mathrm{Br}(J/\psi \to X\pi^0, X \to K^+K^-) = (8.5 \pm 0.6^{+2.7}_{-3.6}) \times 10^{-4}$$



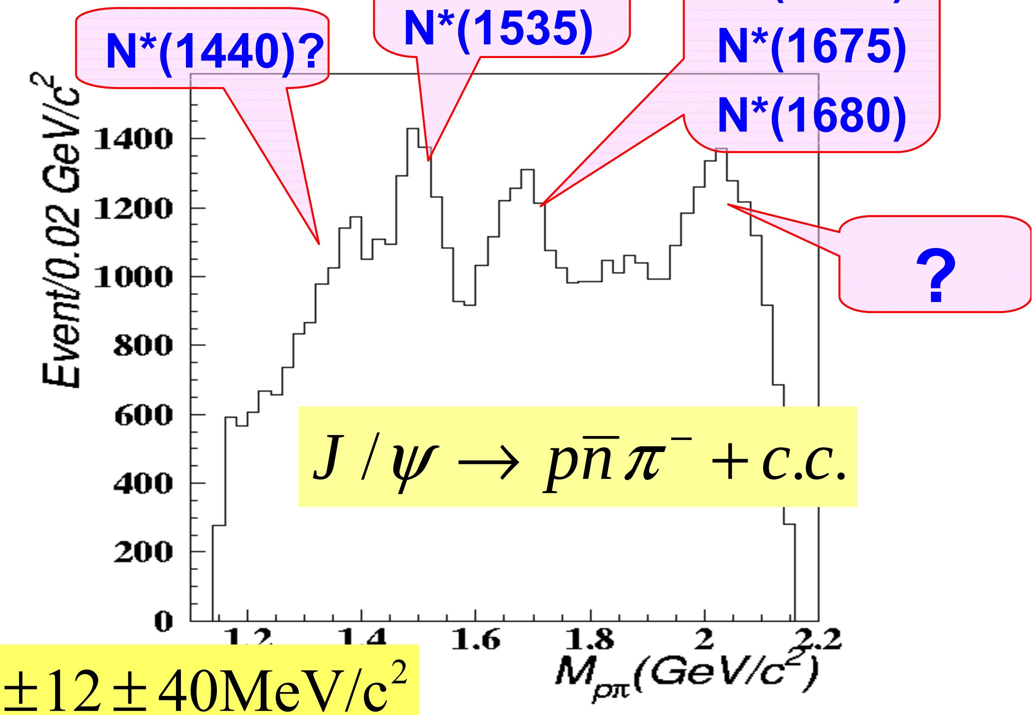
  - Big destructive interference among X, $\rho(1700)$ and PS

Broad width → multiquark state?

First observation of N(2050)

- quark model predicts: N(2050)

  Not observed.



$J/\psi \to p\bar{n}\pi^- + c.c.$

N(2050): 1/2⁺ or 3/2⁺

$$M = 2065 \pm 3^{+15}_{-30}\mathrm{MeV/c^2} \quad \Gamma = 175 \pm 12 \pm 40\mathrm{MeV/c^2}$$

N(1440): N(1440) peak never been seen directly before).

$$M = 1358 \pm 6 \pm 16\,\mathrm{MeV/c^2}, 179 \pm 26 \pm 50\,\mathrm{MeV/c^2}$$

Phys. Rev. Lett. 97 （2006）062001

The study of σ

- evidence for a low mass pole in the early DM2 and BESI data on $J/\psi \to \omega\pi\pi$.
- huge event concentration in the I=0 S-wave $\pi\pi$ channel seen in $M_{\pi\pi}$ ~ 500 – 600 MeV in the pp central production exp.
- to explain $\pi\pi$ scattering phase shift data□σ should be introduced in chiral perturbative theory.
- FNAL E761 exp. $D^+ \to \pi^+\pi^-\pi^+$ data

$$M = 478^{+24}_{-23} \pm 17\,\text{MeV}, \Gamma = 324^{+42}_{-40} \pm 21\,\text{MeV}$$

The σ pole in $J/\psi \to \omega\pi^+\pi^-$ at BESII

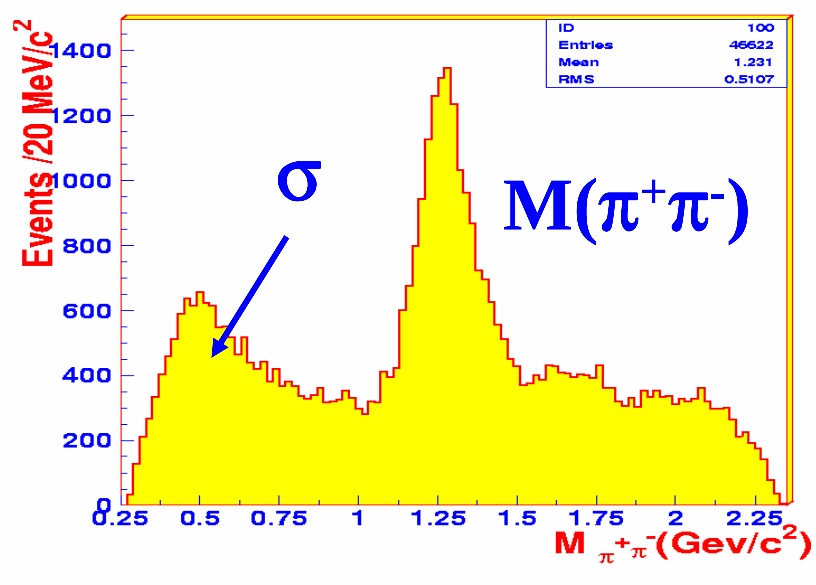
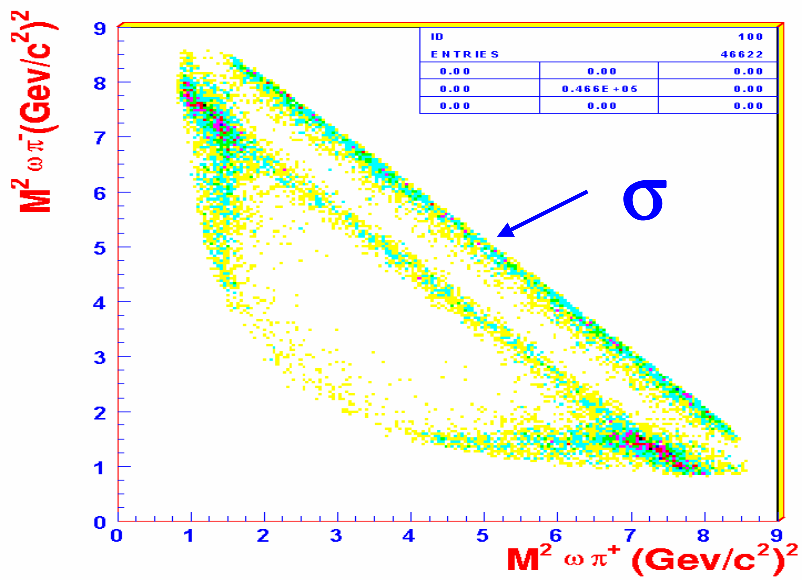


Figure 3: The invariant mass spectrum of $\pi^+\pi^-$



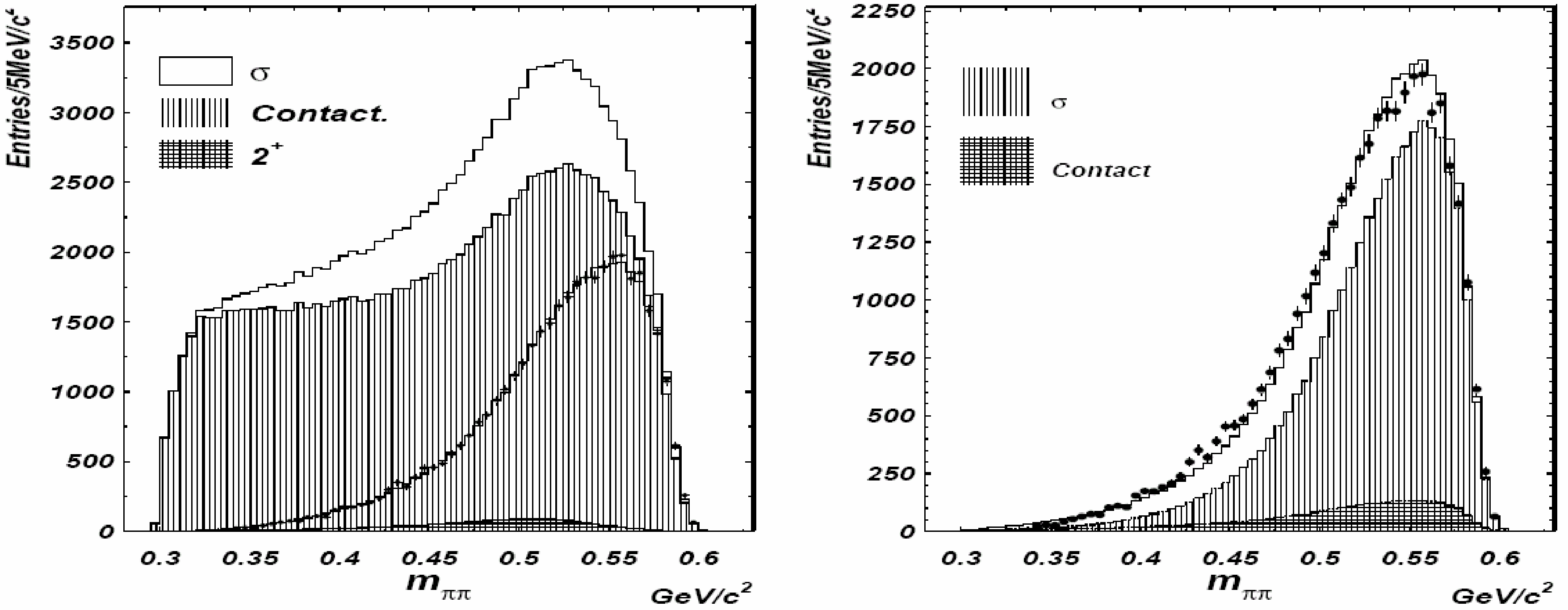
Different parameterizations of BW are used in PWA.

Averaged pole: $(541 \pm 39) - i(252 \pm 42)\ \mathrm{MeV}$

BES, PLB 598 (2004) 149

observation of σ in $\psi' \to \pi^+\pi^- J/\psi$

- Measure the universal pole position (552 - i232 MeV)
- World largest σ signal (with ~ 40,000 tagged events)



Phys. Lett. B 645 (2007) 19

The study of κ

A possible κ pole is controversial.

- Some analyses of LASS $K\pi$ scattering data needs $\kappa(800)$, some don't.
- Scadron et al. favors a nonet made up of σ, $\kappa(800)$, $f_0(980)$ and $a_0(980)$.
- Julich group used t-channel exchanges to explain $K\pi$ scattering data.

◆ evidence of κ in FNAL E791 data on $D^+ \to K^-\pi^+\pi^+$

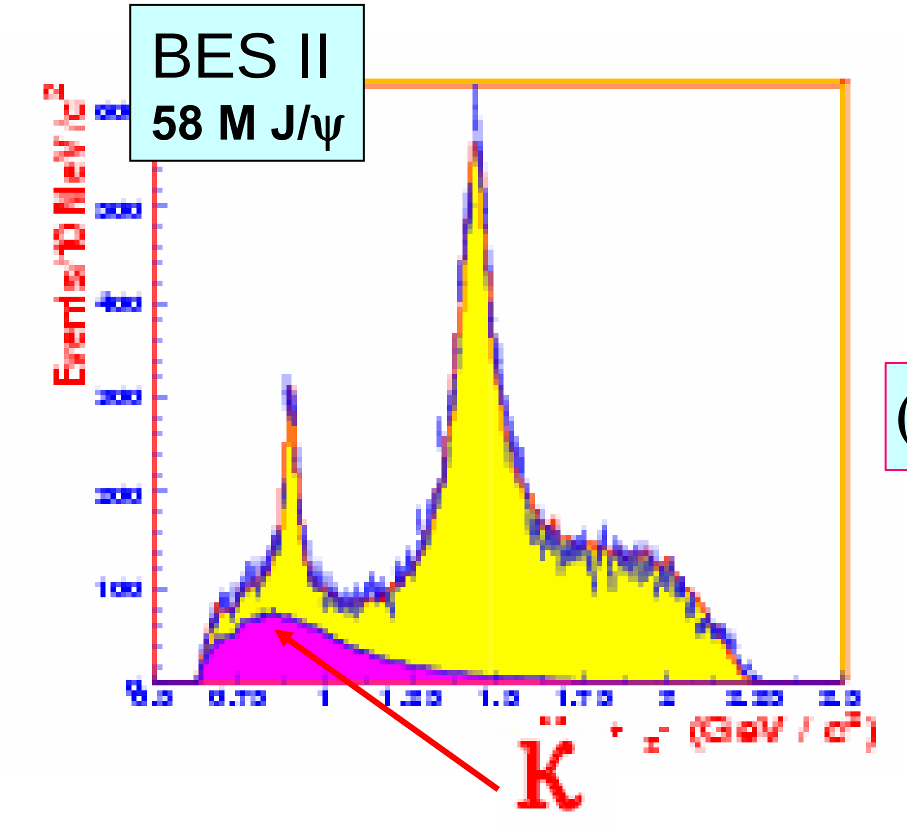
$$M = 797 \pm 19 \pm 43\,\mathrm{MeV}, \Gamma = 410 \pm 43 \pm 87\,\mathrm{MeV}$$

◆ slightly lower statistics of CLEO $D^0 \to K^-\pi^+\pi^0$ data find no evidence of κ

◆ FOCUS data on $K^+ \to K^-\pi^+\mu^+\nu$ require K^{*0} interfere with either a constant amplitude or a broad 0^+ resonance in $K\pi$

BES observed κ in J/ψ→K*Kπ→KπKπ

A possible κ pole is controversial.



PWA result:

κ is needed in the fit.

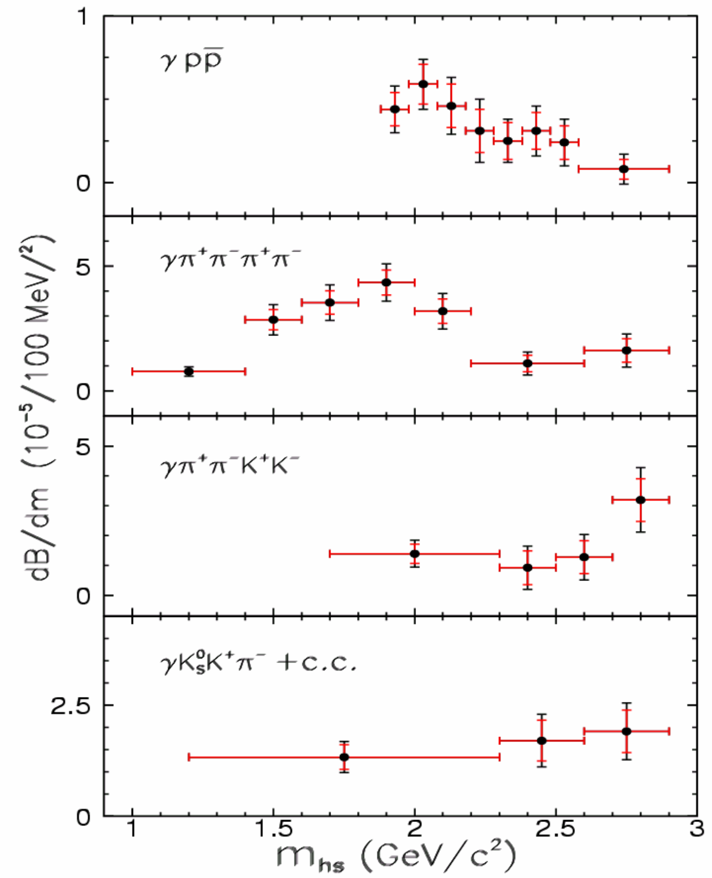
Pole position of κ:

$$(841 \pm 30^{+81}_{-73}) - i(309 \pm 45^{+48}_{-72})\ \mathrm{MeV/c^2}$$

Phys. Lett. B 633 (2006) 681

First measurements of ψ' radiative decays

- Expected 1% BR, but only 0.05% observed.
- Potential channels for hadron spectroscopy study, including non-qqbar states search, if statistics is enough.
- ~ 0.1% more observed modes in this analysis.

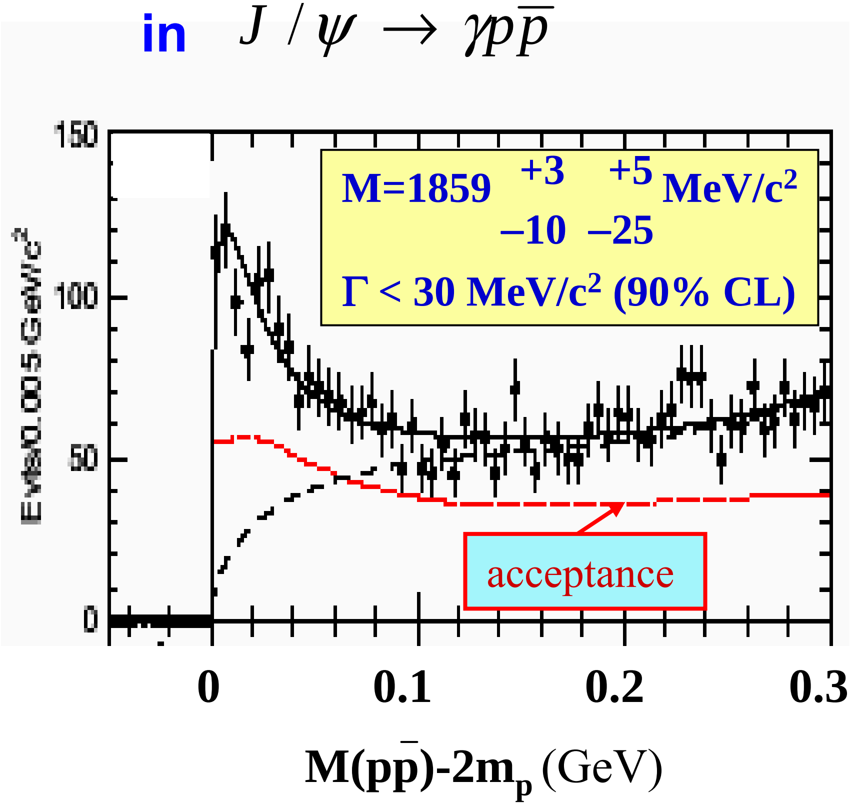


Mode	$\mathcal{B}(\times 10^{-5})$
$\gamma p\bar{p}$	2.9±0.4±0.4
$\gamma 2(\pi^+\pi^-)$	39.6±3.2±5.4
$\gamma K^0_S K^+\pi^- + c.c.$	24.7±3.4±3.5
$\gamma K^+K^-\pi^+\pi^-$	19.1±2.8±4.8
$\gamma K^{*0}K^+\pi^- + c.c.$	37.0±6.1±7.3
$\gamma\pi^+\pi^- p\bar{p}$	2.8±1.2±0.4
$\gamma K^+K^-K^+K^-$	< 4.0
$\gamma 3(\pi^+\pi^-)$	< 17
$\gamma 2(\pi^+\pi^-)K^+K^-$	< 6.4

hep-ex/0612016

Search for the strong $p\bar{p}$ mass threshold enhancement X(1860) in $\psi(2S) \to \gamma p\bar{p}$

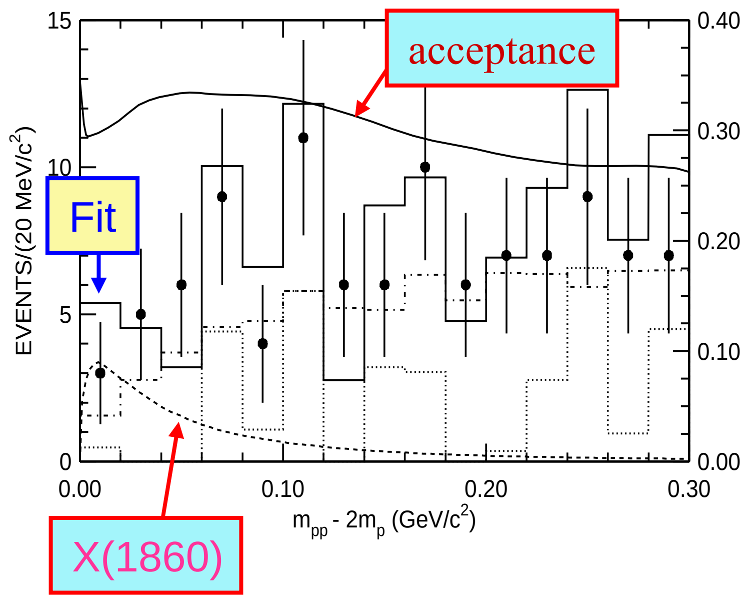
- A strong $p\bar{p}$ mass threshold enhancement was observed in $J/\psi \to \gamma p\bar{p}$



$B(J/\psi \to \gamma X(1860) \to \gamma p\bar{p})$

$\sim 7\times 10^{-5}$

- No obvious strong $p\bar{p}$ mass threshold enhancement was observed in $\psi(2S) \to \gamma p\bar{p}$



$B(\psi(2S) \to \gamma X(1860) \to \gamma p\bar{p})$

$< 5.4\times 10^{-6}$ @ 90% CL

$\psi(3770)$ non-$D\bar{D}$ decays

- $\psi(3770)$ decays most copiously into $D\bar{D}$.
- $\psi(3770)$ is a mixture of the 1^3D_1 and 2^3S_1, other $\psi(2S)$-like decays for $\psi(3770)$ are expected. (mixing angle 12 ± 2^o).
- Many theoretical calculations estimate the partial width for $\psi(3770) \to \pi^+\pi^- J/\psi$. (Lipkin, Yan, Lane, Kuang, Rosner)
- BES observed $\psi(3770) \to \pi^+\pi^- J/\psi$ decays. Further confirmed by CLEO-c.

Determination of

BF[ψ(3770) → $D^0\bar{D}^0$, D^+D^-, $D\bar{D}$ and non-$D\bar{D}$]

with the measured R values at 3.650, 3.6648 and 3.773 GeV

Single tag method

$$\sigma^{obs}_{D\bar{D}} = \frac{N_{D_{tag}}}{2\ L\ Br\ \varepsilon}$$

$$\sigma^{Born}_{\psi(3770)} = 9.323 \pm 0.253 \pm 0.801 \quad \mathrm{nb}$$

$$\sigma^{obs}_{D\bar{D}} = 6.14 \pm 0.12 \pm 0.50\,\mathrm{nb}$$

PLB 603(2004)130

$$BF(\psi(3770) \to D\bar{D}) = \frac{N^{prd}_{D\bar{D}}}{N^{prd}_{\psi(3770)}} = \frac{\sigma^{Born}_{D\bar{D}}}{\sigma^{Born}_{\psi(3770)}} = \frac{\sigma^{obs}_{D\bar{D}}}{g_{BES-II}\ \sigma^{Born}_{\psi(3770)}}$$

Some systematic uncertainties can be canceled out

Radiative correction factor $g = \frac{\sigma^{obs}}{\sigma^{B}}$

$$g_{BES-II} = 0.770 \pm 0.014$$

Radiative correction factor obtained based on new ψ(3770) resonance parameters measured by BES-II, hep/0605107.

$$BF(\psi(3770) \to D^0\bar{D}^0) = (49.9 \pm 1.3 \pm 3.8)\%$$

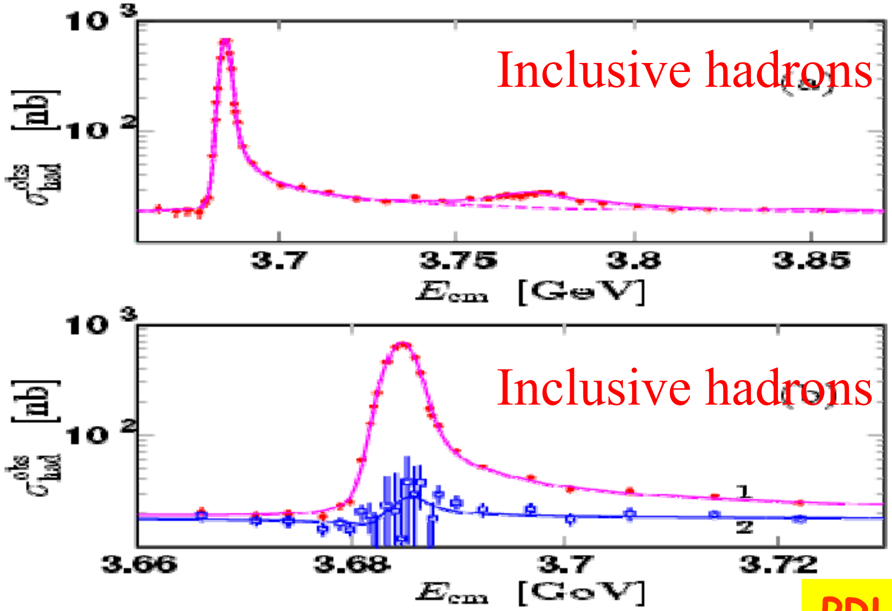
$$BF(\psi(3770) \to D^+D^-) = (35.7 \pm 1.1 \pm 3.4)\%$$

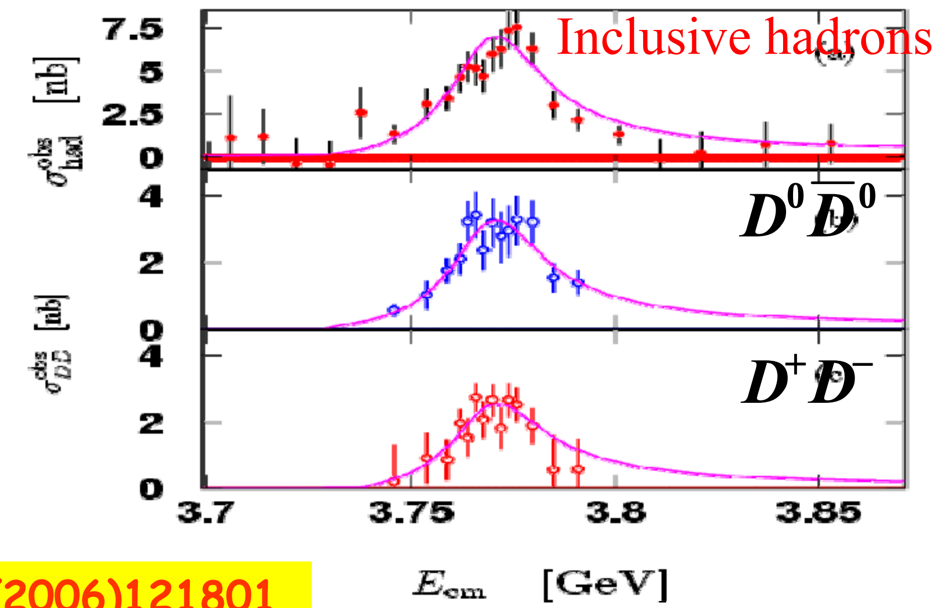
$$BF(\psi(3770) \to D\bar{D}) = (85.5 \pm 1.7 \pm 5.8)\%$$

$$BF(\psi(3770) \to non - D\bar{D}) = (14.5 \pm 1.7 \pm 5.8)\%$$

PLB641(2006)145

Line shape of the cross sections for hadron and DD-bar production





PRL(2006)121801

Mar. 2003 data set

Simultaneously.fitting to the inclusive hadron and the DD-bar production cross sections

◆ **Branching fractions**

$$BF(\psi(3770) \to D^0\bar{D}^0) = (46.7 \pm 4.7 \pm 2.3)\%$$

$$BF(\psi(3770) \to D^+D^-) = (36.9 \pm 3.7 \pm 3.1)\%$$

$$BF(\psi(3770) \to D\bar{D}) = (83.6 \pm 7.3 \pm 4.7)\%$$

$$BF(\psi(3770) \to non - D\bar{D}) = (16.4 \pm 7.3 \pm 4.7)\%$$

Search for η/η' → Invisible from J/ψ → $\phi\eta/\eta'$

First attempt to search for the evidence of dark matter from J/ψ decays.

Phys. Rev. Lett., 97 (2006) 202002

Theoretical estimation:

B.McElrath PRD 72, 103508 (2005)

$Br(\Upsilon(1S) \to \chi\chi) \sim 0.61\%$

$Br(J/\psi \to \chi\chi) \sim 0.037\%$

$Br(\chi_{c0} \to \chi\chi) \sim 3.9\times10^{-7}$

$Br(\eta_c \to \chi\chi) \sim 2.8\times10^{-7}$

$Br(\eta \to \chi\chi) \sim 7.4\times10^{-5}$

$Br(\eta' \to \chi\chi) \sim 8.1\times10^{-7}$

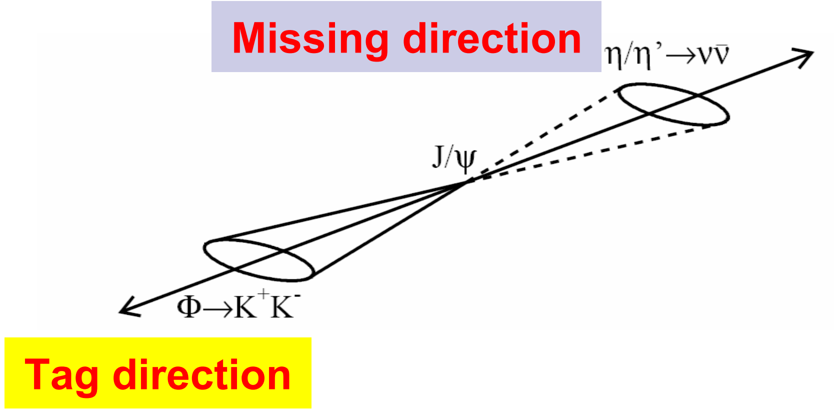
$Br(\eta(1405) \to \chi\chi) \sim 1.4\times10^{-8}$

$Br(\eta(1475) \to \chi\chi) \sim 2.9\times10^{-9}$

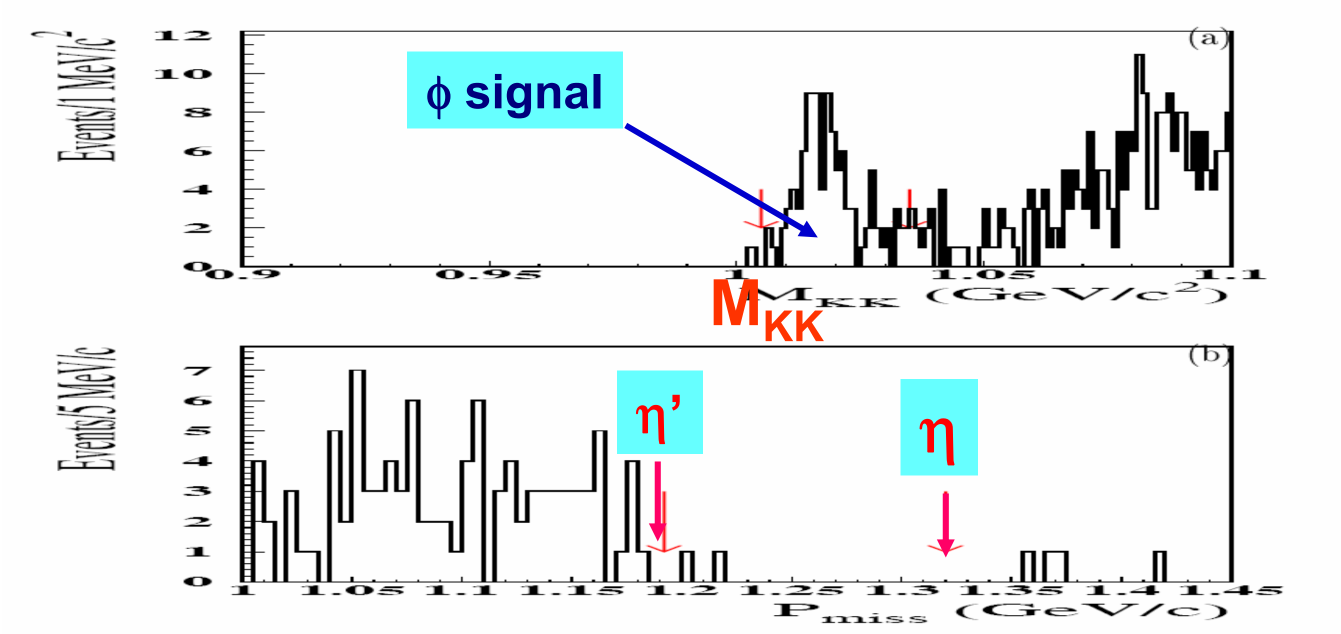
$Br(\omega \to \chi\chi) \sim 1.1\times10^{-7}$

$Br(\phi \to \chi\chi) \sim 2.7\times10^{-6}$

Event Selection



- Two good charged K;
- No any detector hits outside of 30^0 decay core;
- $\cos(\theta_{missing}) < 0.7$;
- $1.005 < m(K^+K^-) < 1.035$ GeV;



Missing momentum

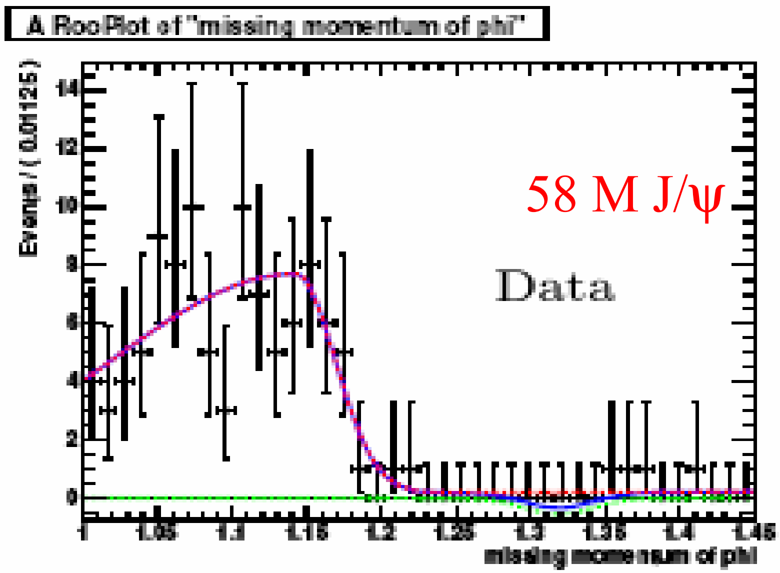
Search for η/η' → Invisible decays in J/ψ→φη/η'

An unbinned extended Maximum Likelihood Fit:

$$\mathcal{L}(N^{\eta}_{sig}, N^{\eta'}_{sig}, N_{bkgd}) = \frac{e^{-(N^{\eta}_{sig}+N^{\eta'}_{sig}+N_{bkgd})}}{N!} \times \prod_{i=1}^{N}[N^{\eta}_{sig}\mathcal{F}^{\eta}_{sig}(P^{i}_{miss}) + N^{\eta'}_{sig}\mathcal{F}^{\eta'}_{sig}(P^{i}_{miss}) + N_{bkgd}\mathcal{F}_{bkgd}(P^{i}_{miss})],$$

Br(η → invisible) < 6.4×10^{-4} @ 90% C.L.

Br(η' → invisible) < 1.4×10^{-3} @ 90% C.L.



Phys. Rev. Lett., 97 (2006) 202002

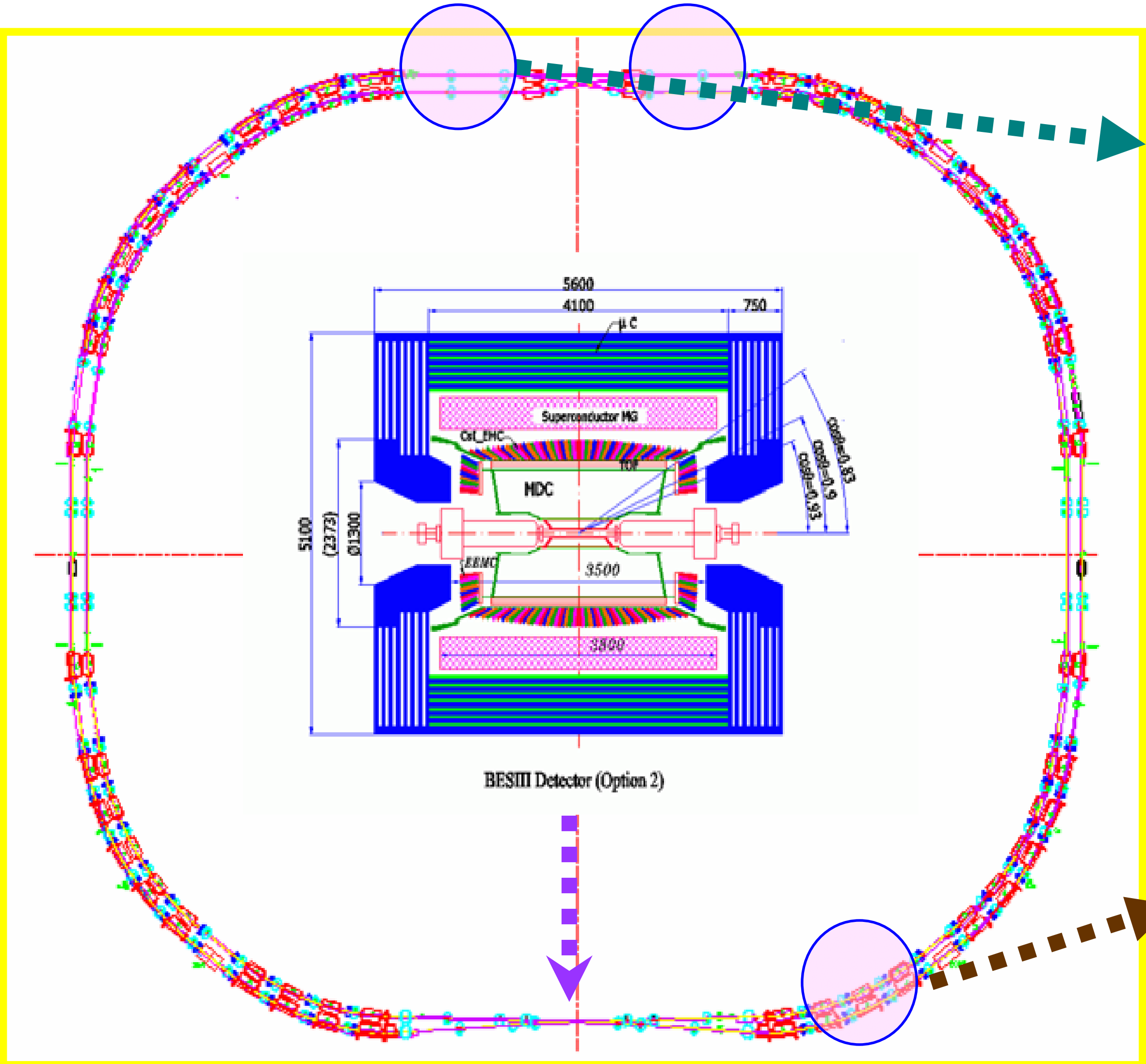
The sensitivity can be improved at BESIII

Future Prospects

BESIII/BEPCII project.

Government approved. Started construction from the end of 2003.

BEPCII: a high luminosity double–ring collider



SC RF

Two rings tunnel

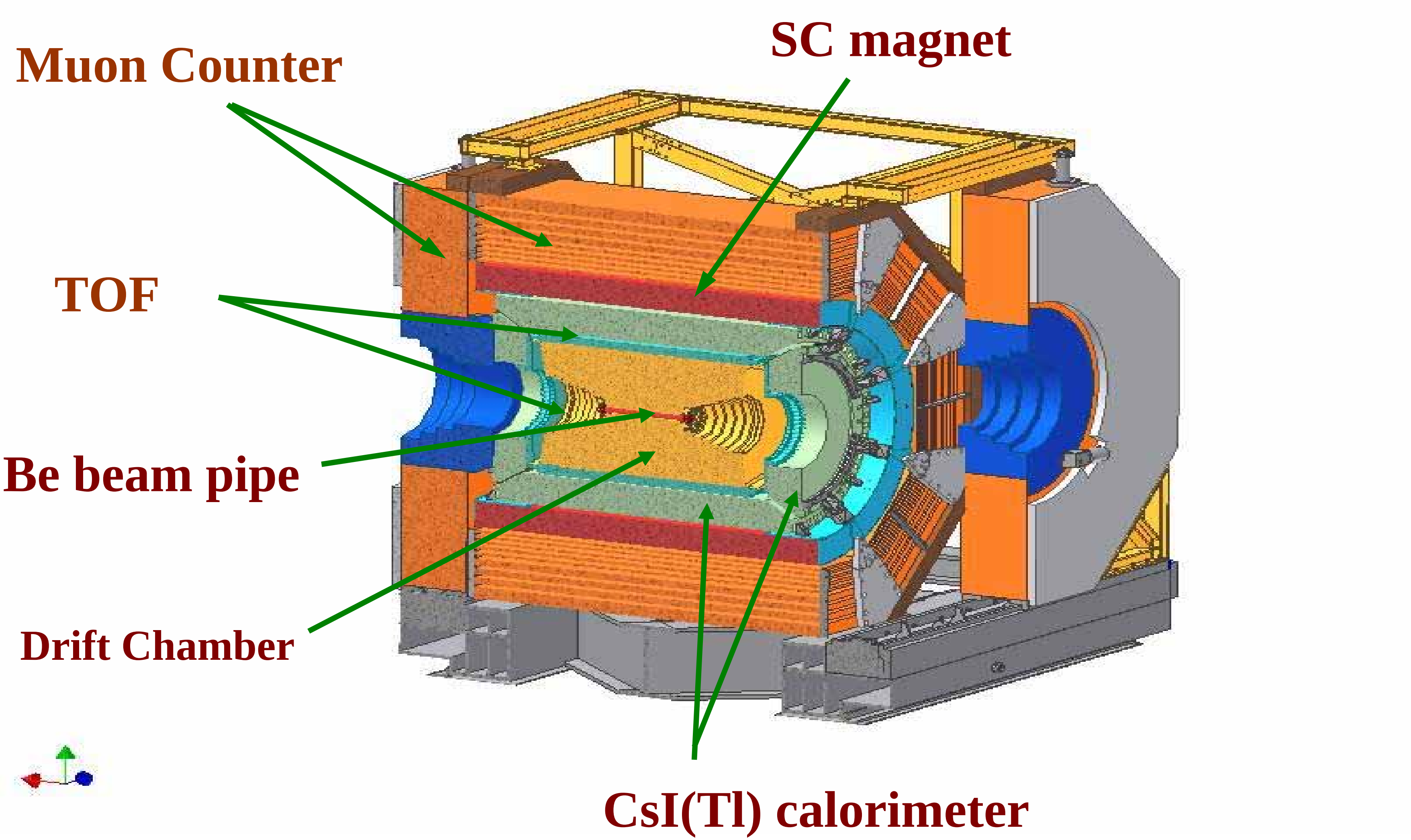
BEPCII Design goal

Energy range	1 – 2.1 GeV
Optimum energy	1.89 GeV
Luminosity	1×10^{33} $cm^{-2}s^{-1}$ @ 1.89 GeV
Injection	Full energy injection: 1.55 – 1.89 GeV Positron injection speed > 50 mA/min
Synchrotron mode	250 mA @ 2.5 GeV

Dual purpose machine

May achieve to Ebeam = 2.3 GeV

BESIII Detector

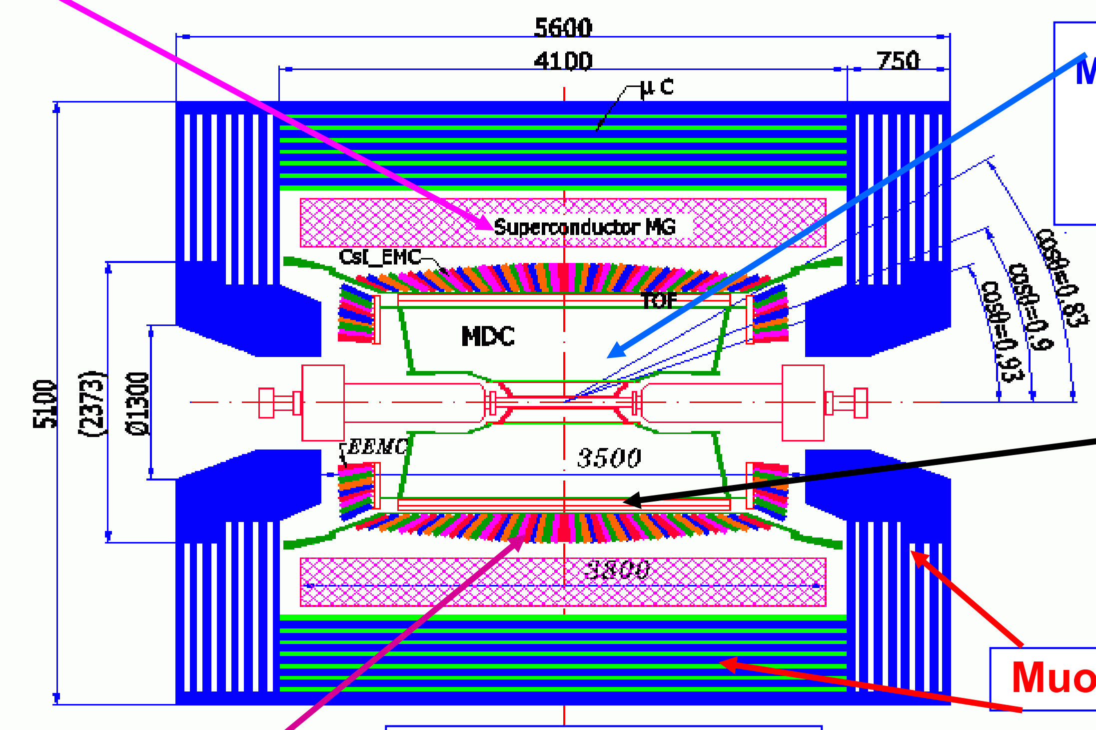


BESIII Detector

Two rings, 93 bunches:

- **Luminosity**
  - 10^{33} cm^{-2} s^{-1} @1.89GeV
  - 6×10^{32} cm^{-2} s^{-1} @1.55GeV
  - 6×10^{32} cm^{-2} s^{-1} @ 2.1GeV

Magnet: 1 T Super conducting



MDC: small cell & He gas
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σT = 100 ps Barrel
110 ps Endcap

Muon ID: 9 layer RPC

EMCAL: CsI crystal
$\Delta E/E$ = 2.5% @1 GeV
σz = 0.6 cm/$\sqrt{E}$

Data Acquisition:
Event rate = 3 kHz
Thruput ~ 50 MB/s

Trigger: Tracks & Showers
Pipelined; Latency = 6.4 μs

BEPCII Status and Plan

- Dec. 2006, ring commissioning, beam accumulation, Synchrotron run.

- Aug. 07, BESIII moved to the beam line.
- Sep. 07, Commissioning ring and detector together.
- Dec. 07 , test run.
- Dec. 08, to achieve a lum. of $3 \times 10^{32} cm^{-2} s^{-1}$.

BESIII Collaboration

Institute of High Energy Physics
University of Science and Technology
Peking University
Tsinghua University
Shangdong University
Nankai University
Central China Normal University
University of Anhui
University of Zhejiang
University of Zhengzhou
Nanjing Normal University
Nanjing University
Shanxi University
Sichuan University
Henan Normal University

University of Hawaii
University of Washington
University of Tokyo
Joint Institute of Nuclear Research, Dubna
GSI
University of Bochum
University of Giessen

Yearly Event Production

Average Lum: $\mathcal{L}$ = 0.5×Peak Lum.; data taking time: T = 10^7s/year

$$\sigma_{exp}(W) = \int_0^\infty dW' \sigma_{r.c.}(W') G(W', W)$$

$$N_{event}/\text{year} = \sigma_{exp} \times \mathcal{L} \times T$$

Resonance	Energy(GeV)	Peak Lum. ($10^{33}cm^{-2}s^{-1}$)	Physics Cross Section (nb)	Nevents/yr
J/ψ	3.097	0.6	3400	10×10^9
τ	3.670	1.0	2.4	12×10^6
$\psi(2S)$	3.686	1.0	640	3.2×10^9
D^0D^0bar	3.770	1.0	3.6	18×10^6
D^+D^-	3.770	1.0	2.8	14×10^6
DsDs	4.030	0.6	0.32	1.0×10^6
DsDs	4.140	0.6	0.67	2.0×10^6

Huge J/ψ and $\psi(2S)$ samples at BESIII

Summary

- An $\omega\phi$ mass threshold enhancement was observed in $J/\psi \to \gamma\omega\phi$. $J^{PC}=0^{++}$ is favored.
- A very broad 1^{--} resonance X(1580) is observed in

  $J/\psi \to K^+K^- \pi^0$.
- σ and κ
- Measurements of psi' radiative decays
- Psi(3770) non-Ddbar decays
- Search for $\eta/\eta' \to$ Invisible from $J/\psi \to \phi\eta/\eta'$
- BESIII/BEPCII will start taking data in 2008.

Thank you