Status and Physics Prospects of the

Beijing Spectrometer III

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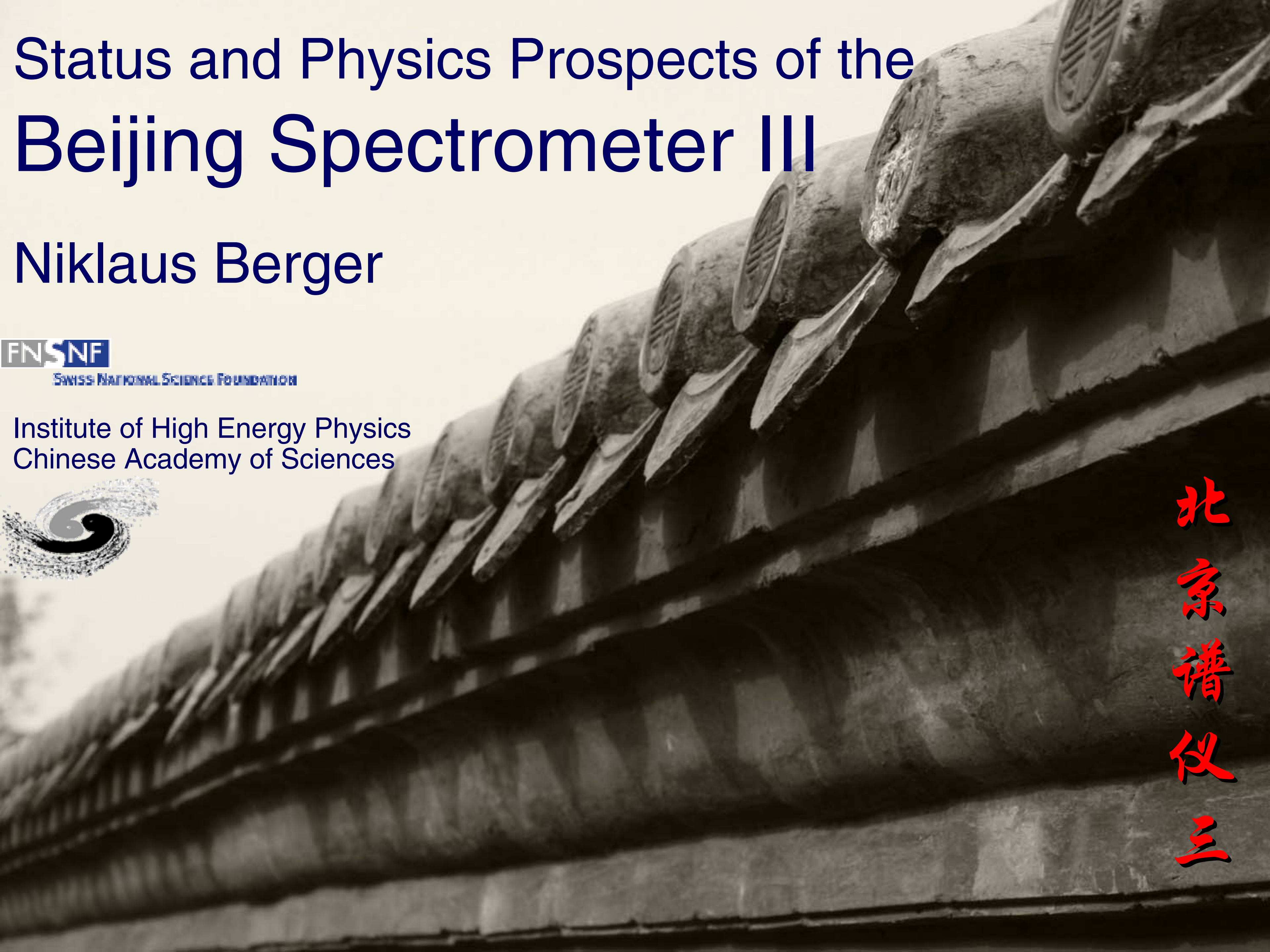
北京谱仪三



Overview

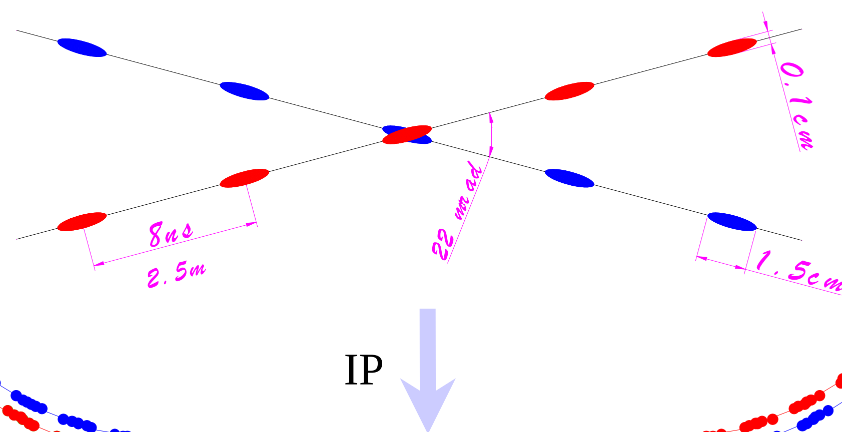
- Our tools:
  - The BEPC II collider
  - The BES III experiment
- Our goals
  - Light hadron spectroscopy
  - Charmonium physics
  - Charm physics
  - And beyond…
  - (Tau physics and QCD)

- Summary

The BEPC II Collider

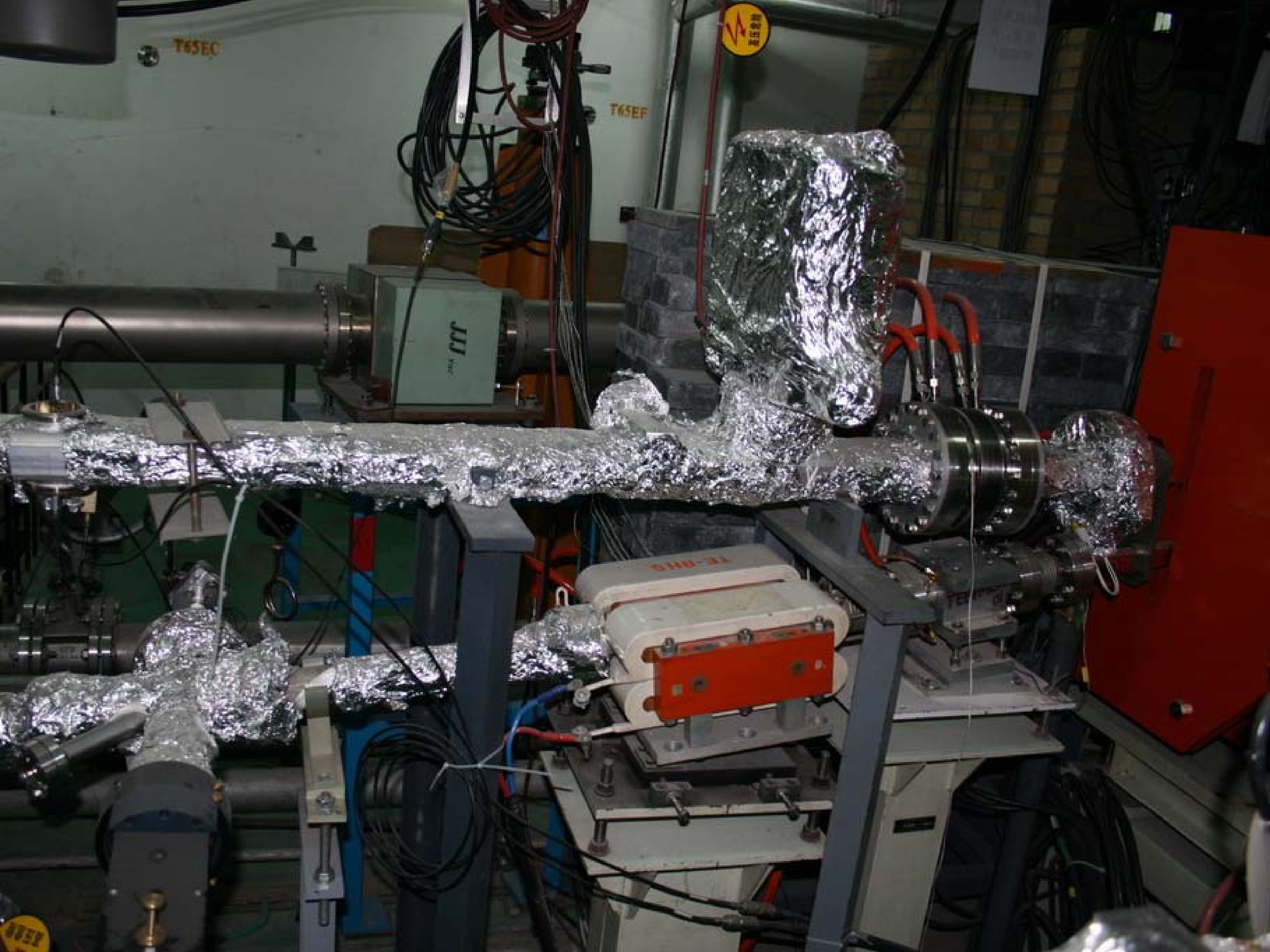
The BEPC II Collider

- Beijing Electron Positron Collider II
- Double ring, 11 mrad crossing angle
- Beam energies 1 – 2.3 GeV
- 93 Bunches
- Design current: 2 x 0.91 mA
- Design luminosity at 1.89 GeV: 10^{33} $cm^{-2}s^{-2}$



BEPC II Commissioning so far

Nov. 2006	Beam was stored in the storage ring Accumulated beam ~ 6 A·hrs., beam life time ~ 1.5 hrs @ 60mA.
Dec. 2006	Start to provide SR beams for users
Mar. 2007	First e^+e^- collision, Lumi ~ 10^{30} cm^{-2} s^{-1}
June 2007	Provide SR beams for users at 2.5GeV, 200 mA with a lifetime of 5.5 hr
Aug. 2007	Beam current reached 500 mA
Sep. 2007	SCQ moved to the interaction region
Jan. 2008	BEPCII collided 500mA$\times$500mA (in 93 Bunches) Lumi estimated as $10^{32}cm^{-2}s^{-1}$
Mar. 2008	Beam pipe installed in BES III
Mai 2008	BES III moved to interaction region


T65EC
T65EF


R20-M800


R10-Q S R
R10-M

BEPC II charm production

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

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

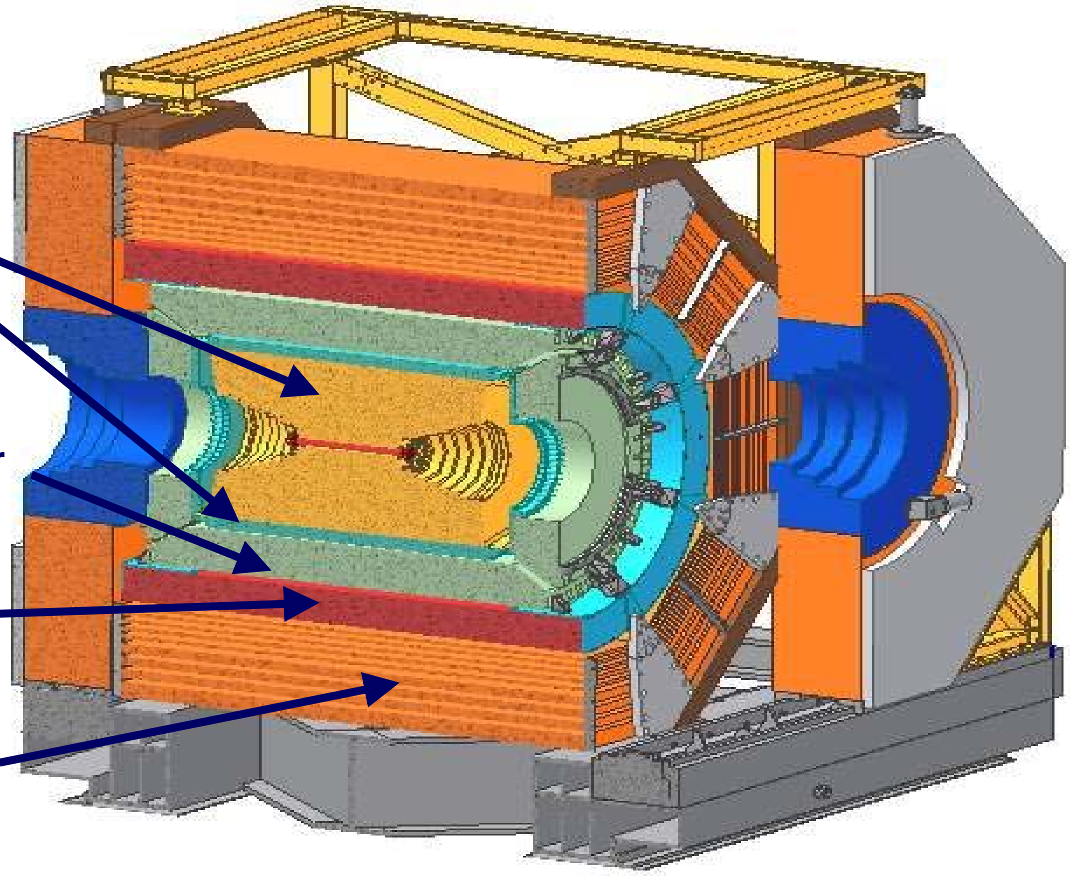
Physics	Mass(GeV) CMS	Peak Lum. ($10^{33}cm^{-2}s^{-1}$)	Cross Section (nb)	Events/year
J/ψ	3.097	0.6	3400	10×10^9
$\tau^+\tau^-$	3.670	1.0	2.4	12×10^6
$\psi(2S)$	3.686	1.0	640	3.2×10^9
D^0D^0bar	3.770	1.0	3.6	18×10^6
D^+D^-	3.770	1.0	2.8	14×10^6
DsDs	4.030	0.6	0.32	1.0×10^6
DsDs	4.170	0.6	1.0	2.0×10^6

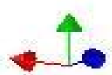
The Beijing Spectrometer III

The Beijing Spectrometer III

Typical small collider experiment with:

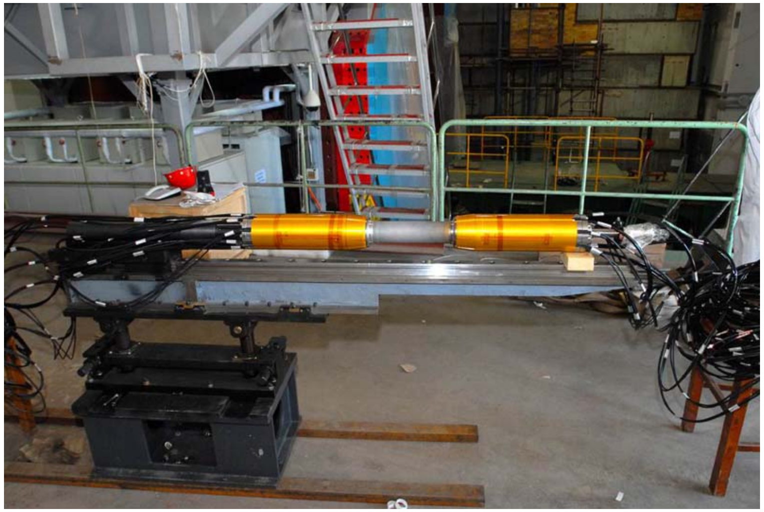
- Drift chamber
- Time of flight scintillators
- CsI (Tl) Crystal calorimeter
- 1 Tesla SC magnet
- RPC based Muon system

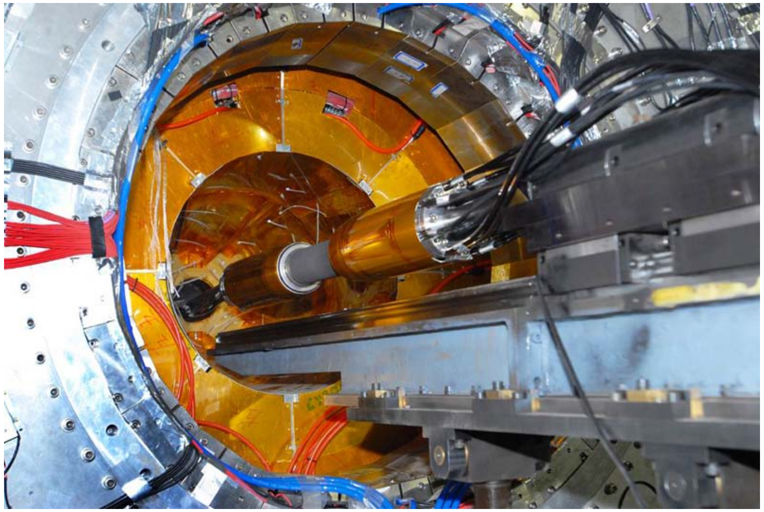




Beryllium Beam Pipe

- Two Be cylinders (0.8 mm and 0.5 mm thick, 0.8 mm gap), cooled by paraffin
- 14.6 μm gold on the inner surface
- The beam pipe was installed on March 27, 2008, as the last component of the BES-III detector



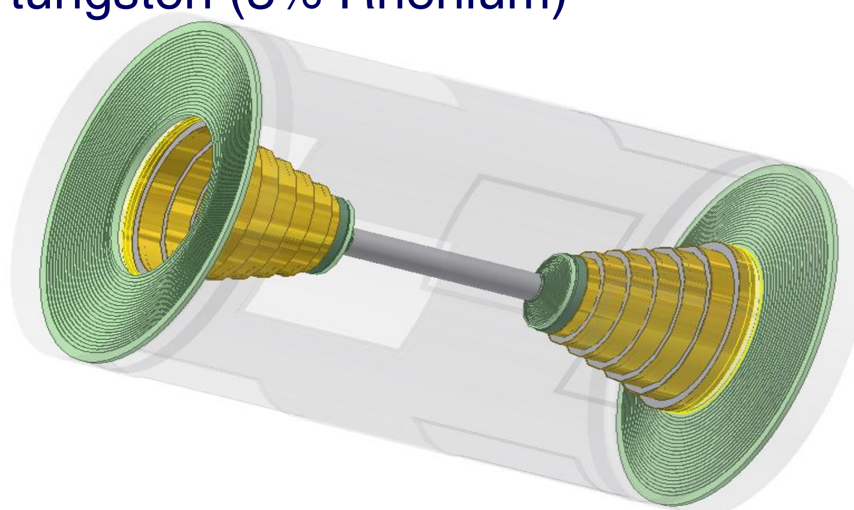


Drift Chamber

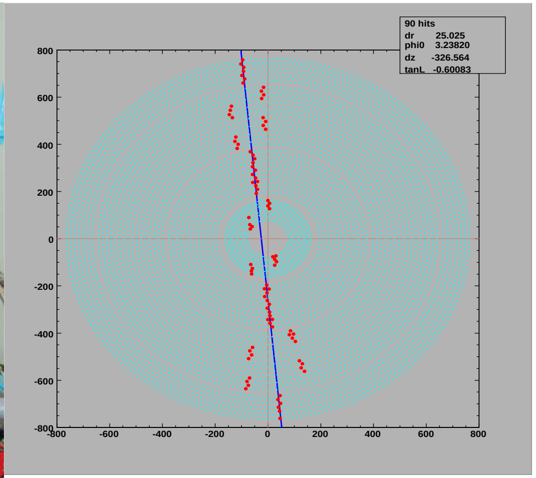
- Measure the momentum of charged particles
- Design spec:

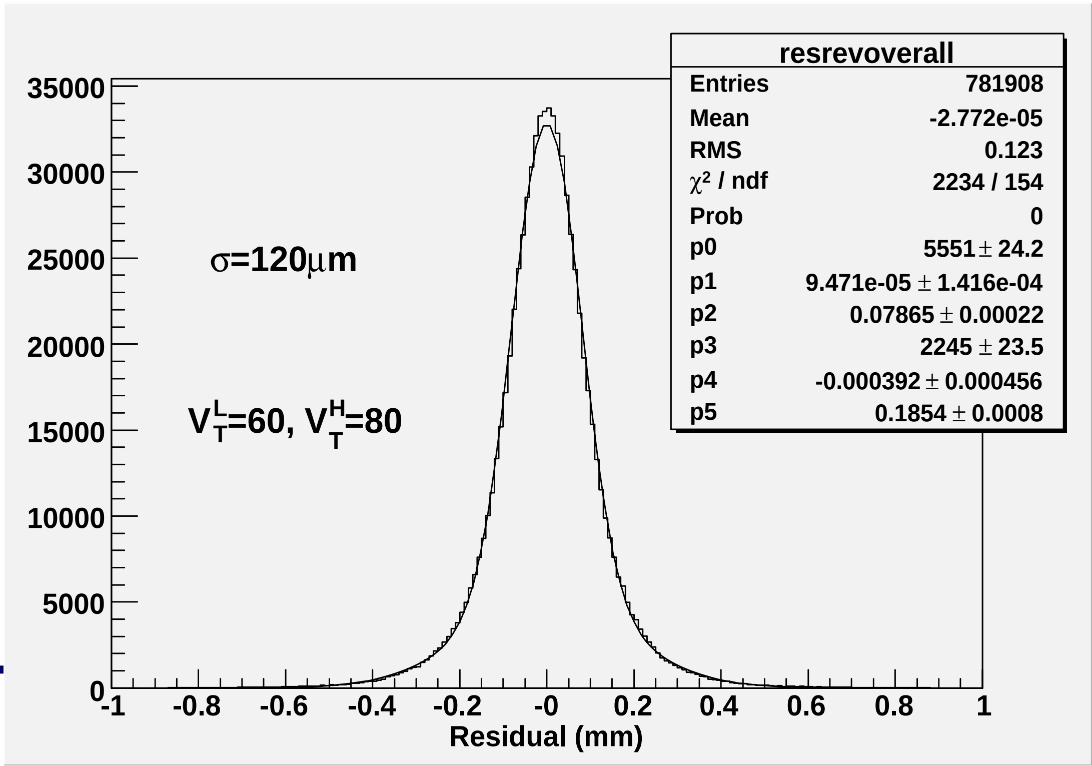
	Single wire resolution	dE/dx resolution.
CLEO:	~110 μm,	5.7 %
Babar:	~110 μm,	6.2 %
Belle:	~130 μm,	5.7 %
BESIII	~120 μm	6 %

- R_{in} = 63mm; R_{out} = 810mm; length = 2400 mm
- 7000 Signal wires: 25μm gold-plated tungsten (3% Rhenium)
- 22000 Field wires: 110 mm Al
- Gas: He + C3H8 (60/40)
- Momentum resolution@1GeV: 0.5%



Standalone Cosmic Ray Test

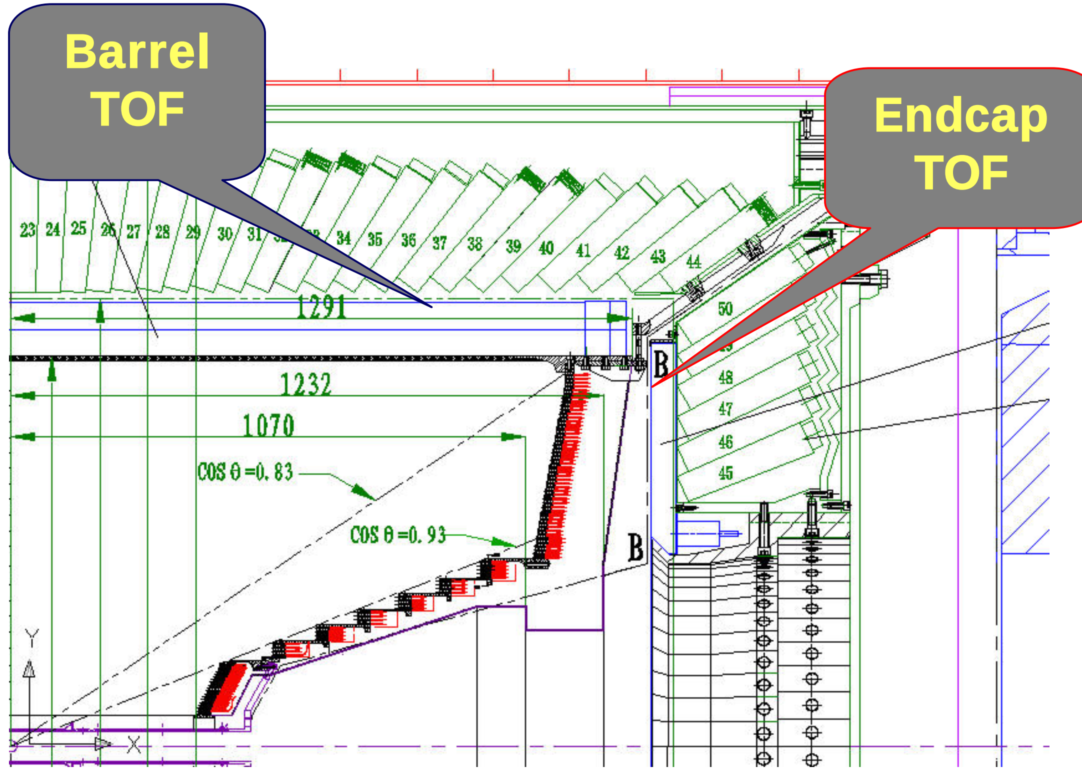


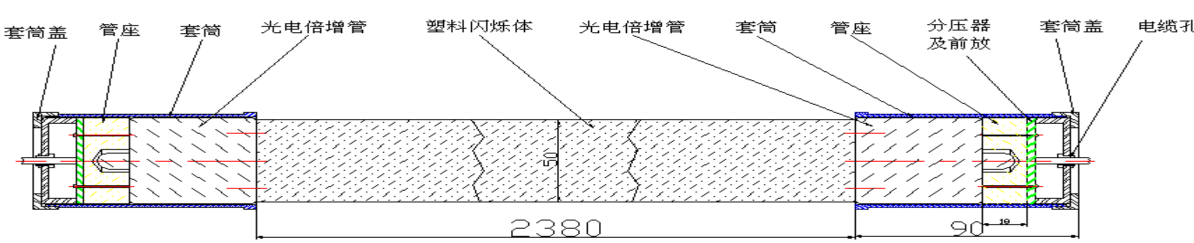


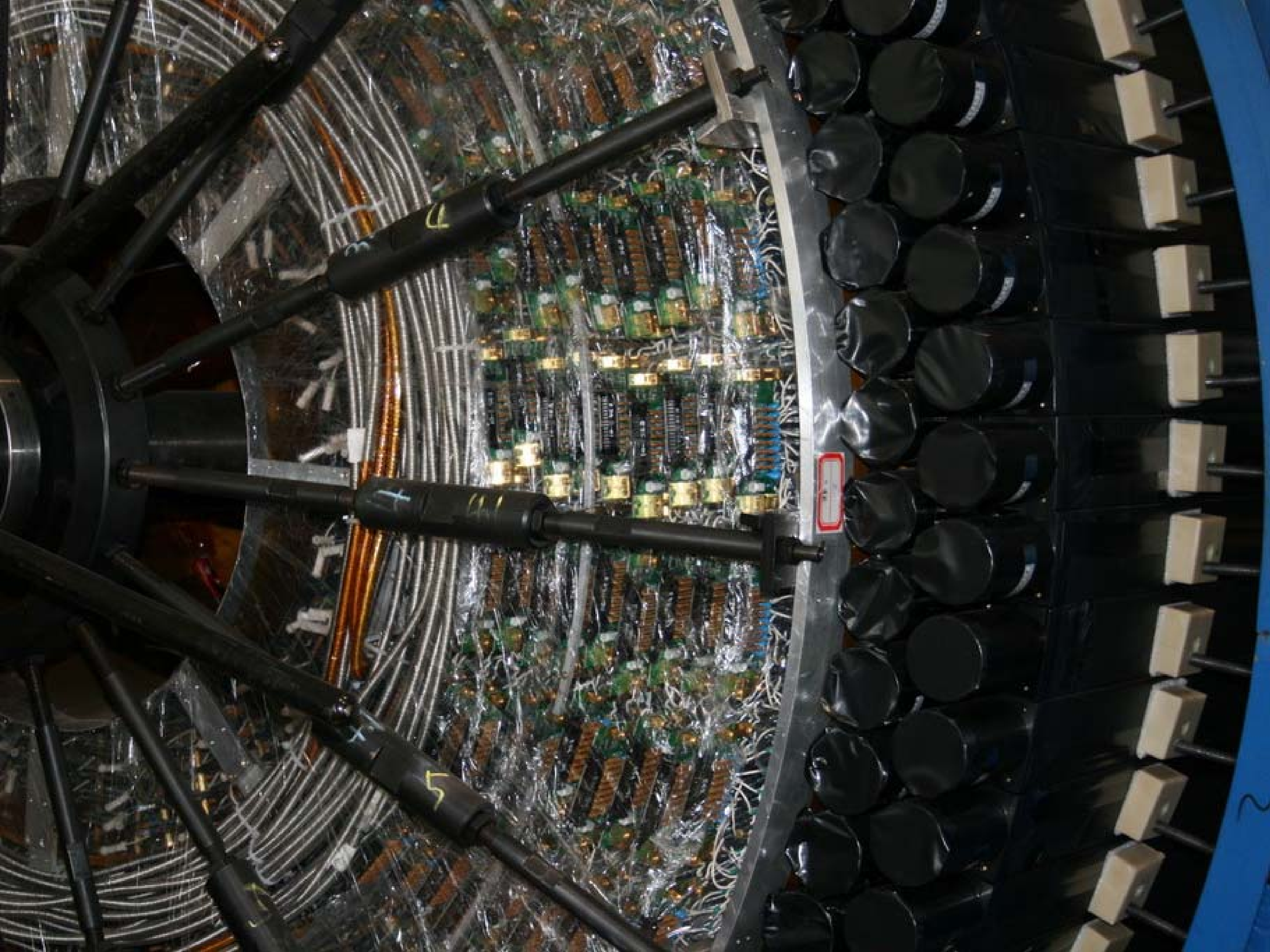
Time Of Flight System

- Double layers at barrel of 88 counters/layer, readout at both ends
- High quality plastic scintillator, 2.4 m long, 5 cm thick
- 100 ps timing, 90 ps for two layers

- Endcaps each have 48 counters, read out at the inner end, one layer
- 120 ps timing

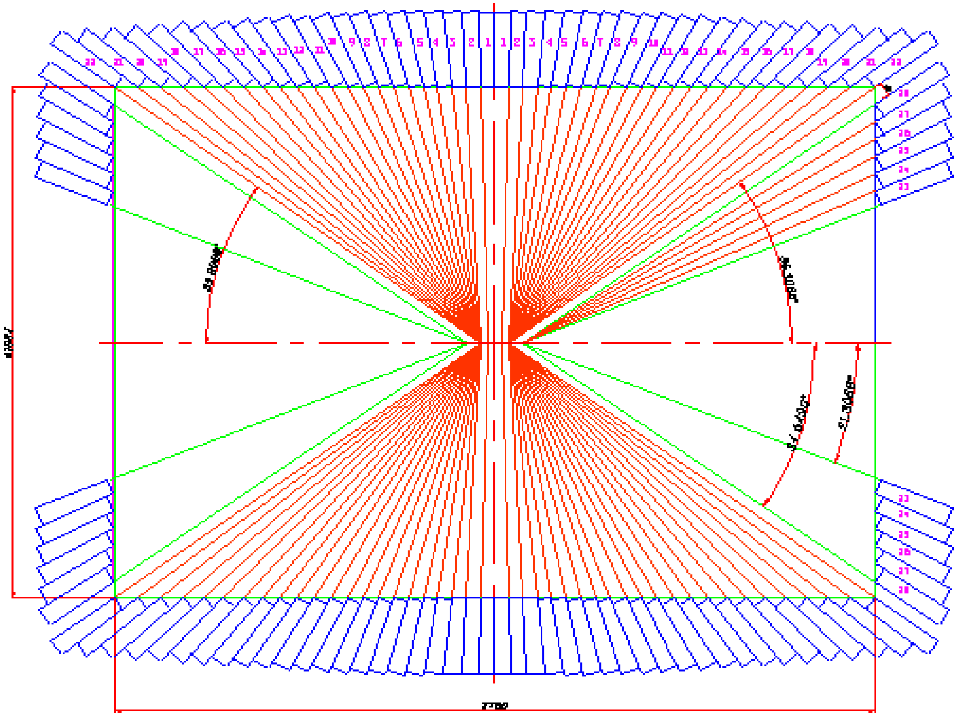






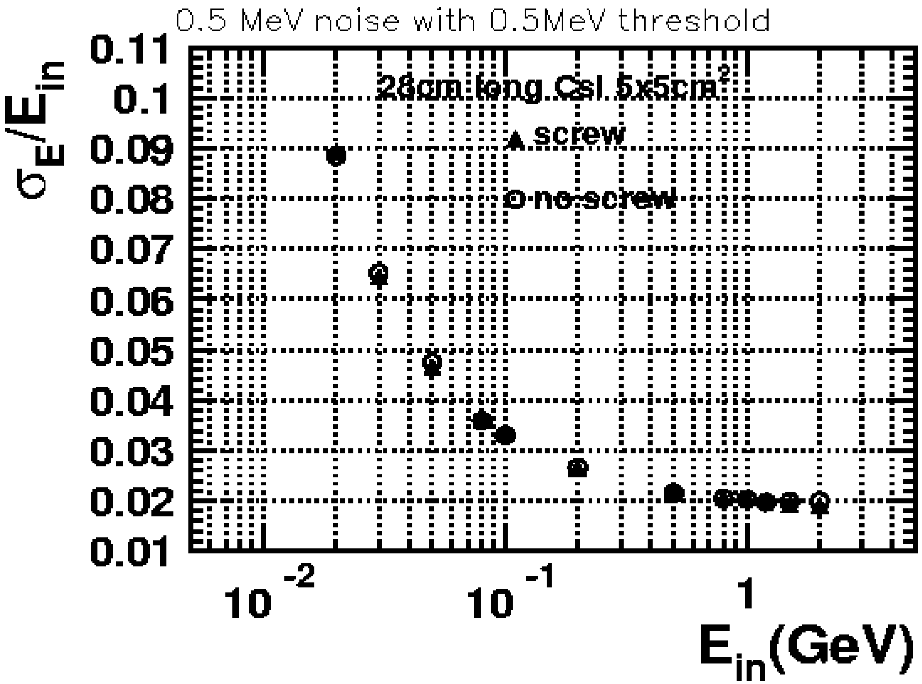
Crystal Calorimeter

- Measure the energy of electromagnetic particles
- CsI (Tl)
- Barrel: 5280 crystals，
  Endcap: 960 crystals
- Crystal: (5.2 x 5.2 – 6.4 x 6.4) x 28 cm^3
- Readout: ~13000 Photodiodes, 1 cm×2 cm,
- Energy range：20MeV – 2 GeV
- position resolution:
  6 mm@1GeV

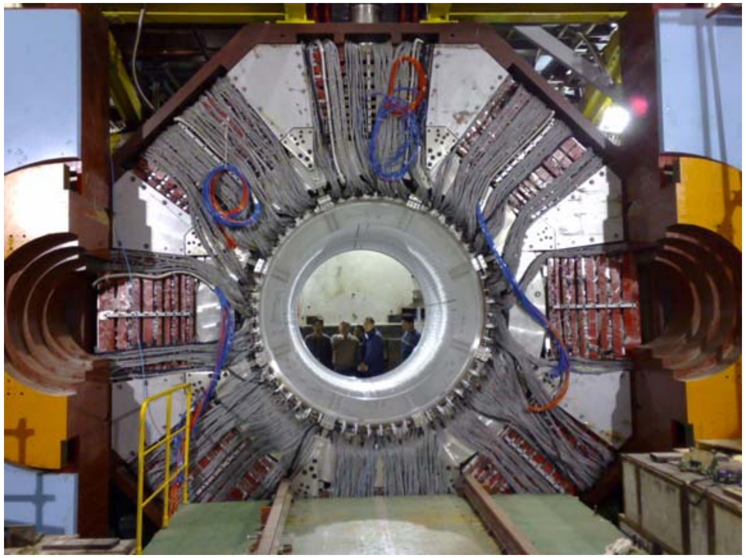


Crystal Calorimeter Performance

BES II:	22% @1GeV
Babar:	2.67% @1GeV
BELLE:	2.2% @1GeV
CLEO:	2.2% @1GeV
BESIII:	2.5% @1GeV

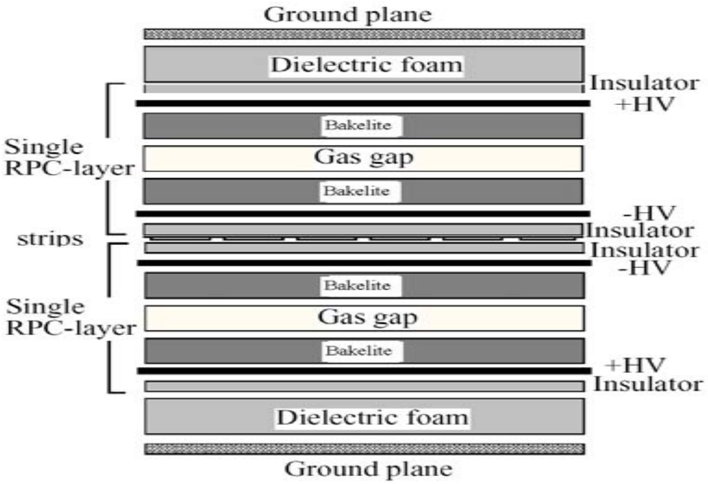


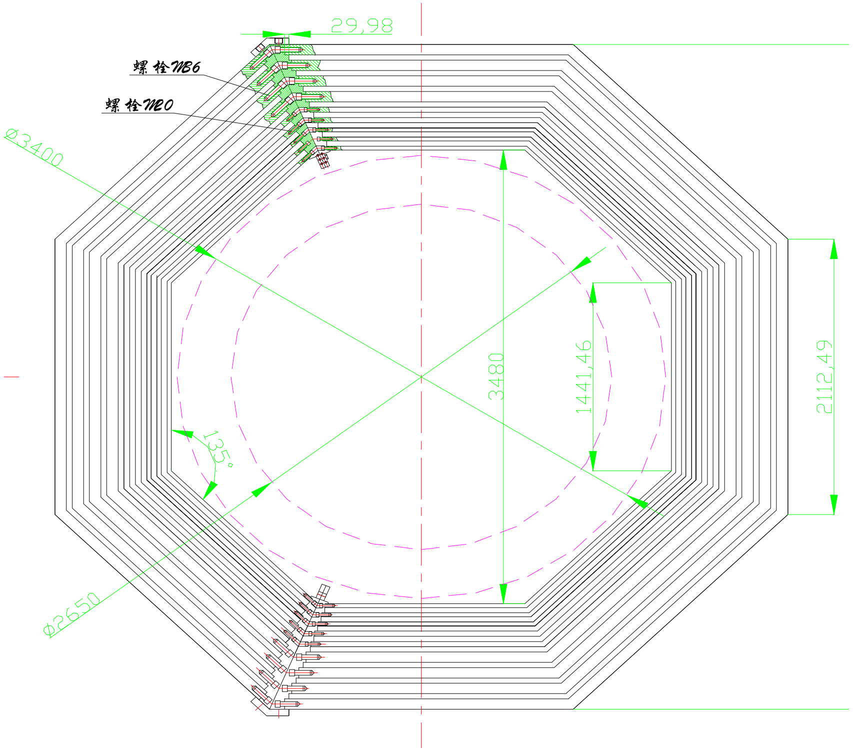
Barrel Calorimeter Installation

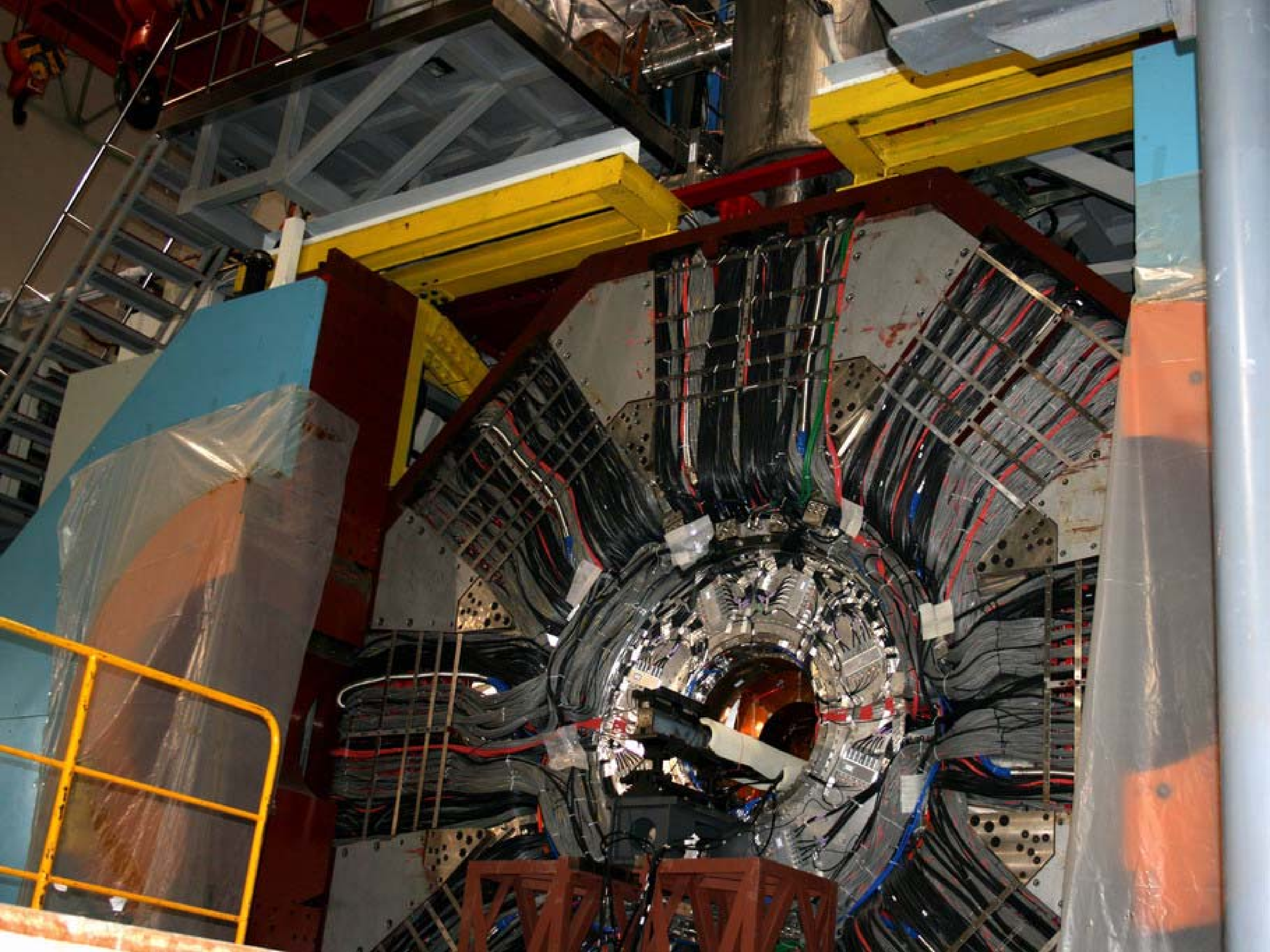


Muon System

- 9 layer, 2000 m^2
- Special bakelite plate without linseed oil
- 4cm strips, ~10000 channels
- Noise less than 0.1 Hz/cm^2

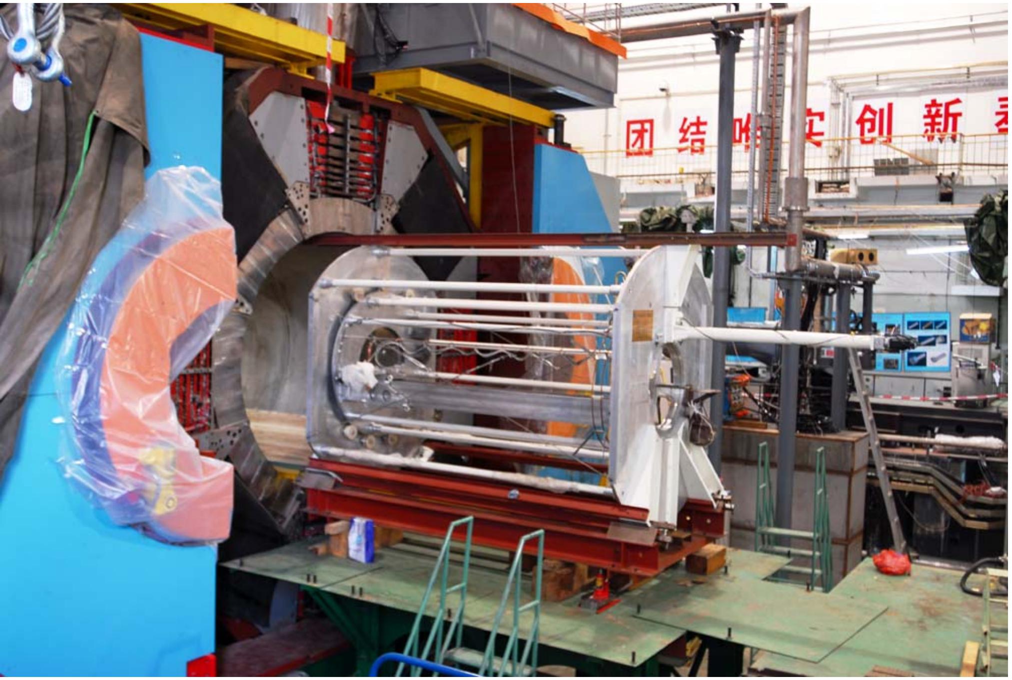


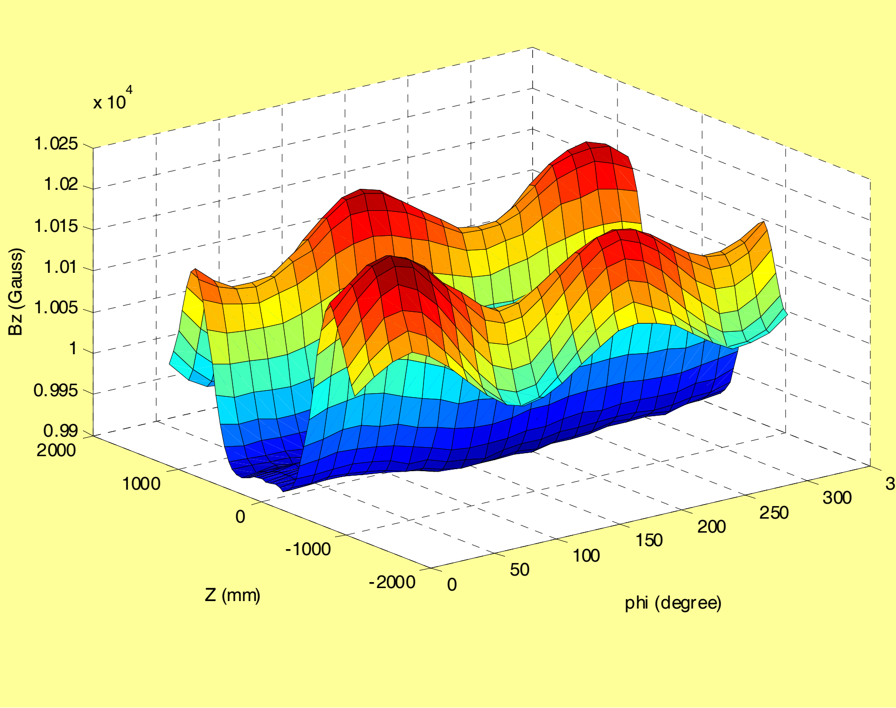




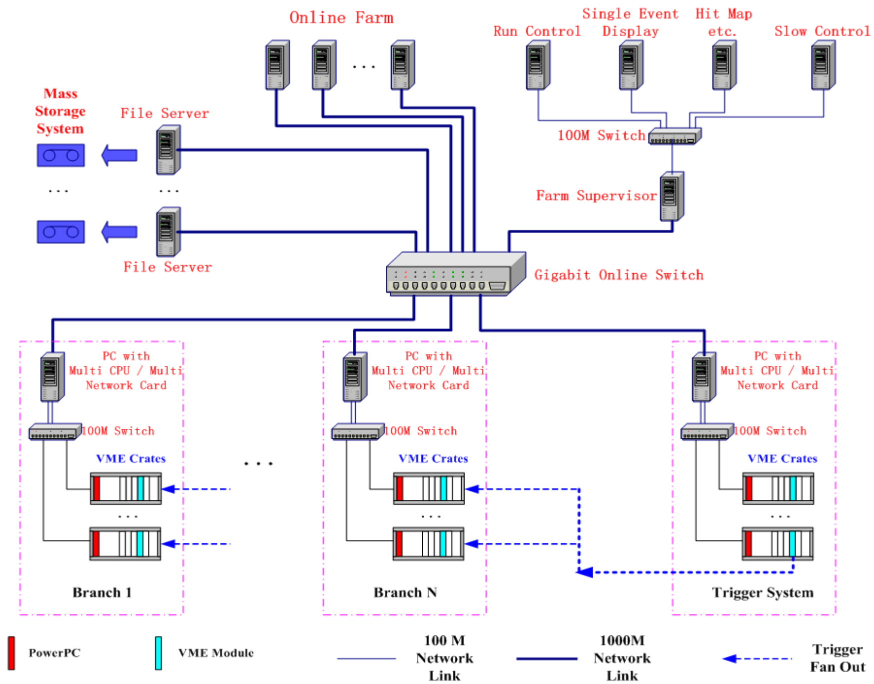
Magnet

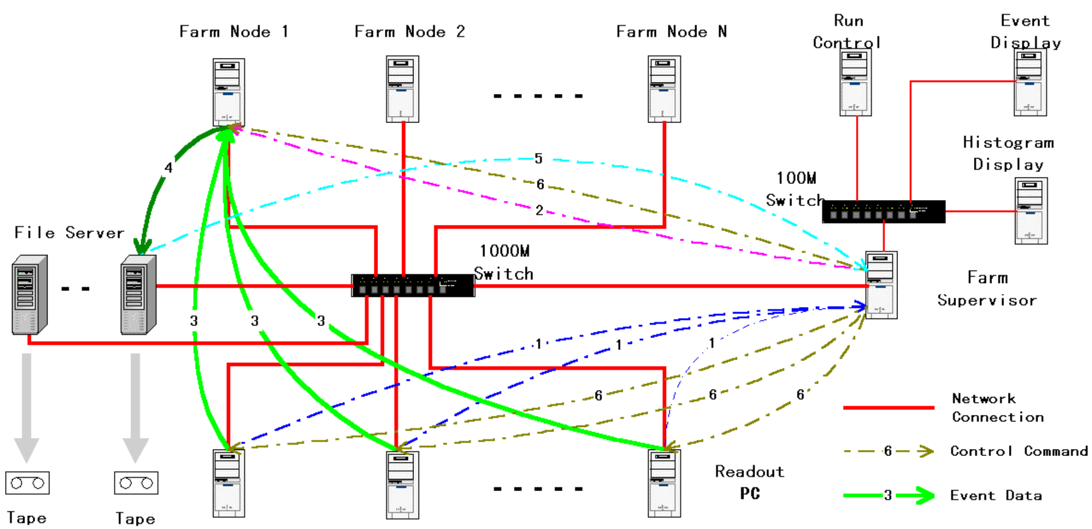
- Magnet reached 1 Tesla (3364 A) in September 2006
- Mapped the field including BEPC SC quadrupoles in August 2007





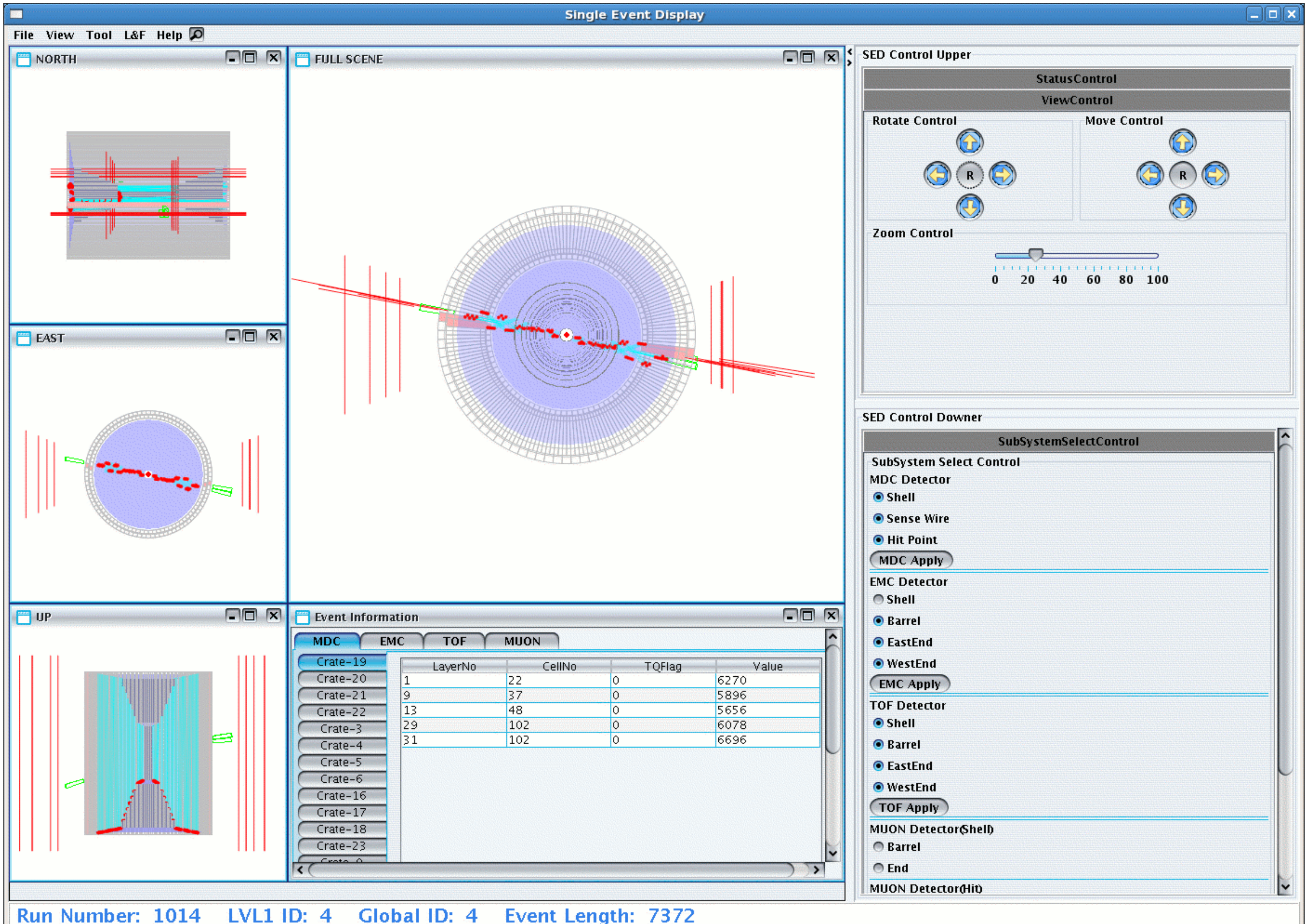
Data Acquisition





- Capable of 4000 Hz
- ~ 50 MB/s
- 10x B-Factories
- 1000x BES II
- At the edge of what is possible via VME

Cosmics


Single Event Display
File View Tool L&F Help
NORTH
FULL SCENE
EAST
UP
Event Information
MDC EMC TOF MUON
Crate-19
Crate-20
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Crate-22
Crate-3
Crate-4
Crate-5
Crate-6
Crate-16
Crate-17
Crate-18
Crate-23
LayerNo CellNo TQFlag Value
1 22 0 6270
9 37 0 5896
13 48 0 5656
29 102 0 6078
31 102 0 6696
SED Control Upper
StatusControl
ViewControl
Rotate Control
Move Control
R
Zoom Control
0 20 40 60 80 100
SED Control Downer
SubSystemSelectControl
SubSystem Select Control
MDC Detector
Shell
Sense Wire
Hit Point
MDC Apply
EMC Detector
Shell
Barrel
EastEnd
WestEnd
EMC Apply
TOF Detector
Shell
Barrel
EastEnd
WestEnd
TOF Apply
MUON Detector(Shell)
Barrel
End
MUON Detector(Hit)
Run Number: 1014 LVL1 ID: 4 Global ID: 4 Event Length: 7372

The BES III Collaboration

Totally 37 institutions now

USA (7)
University of Hawaii
University of Washington
Carnegie Mellon University
Univ. of Florida
Univ. of Minnesota
Rensselaer Polytechnic Institute
University of Rochester

Europe (5)
GSI, Germany
University of Bochum, Germany
University of Giessen, Germany
JINR, Dubna, Russia
Budker institute of Nuclear Physics Russia

Japan (1)
Tokyo University

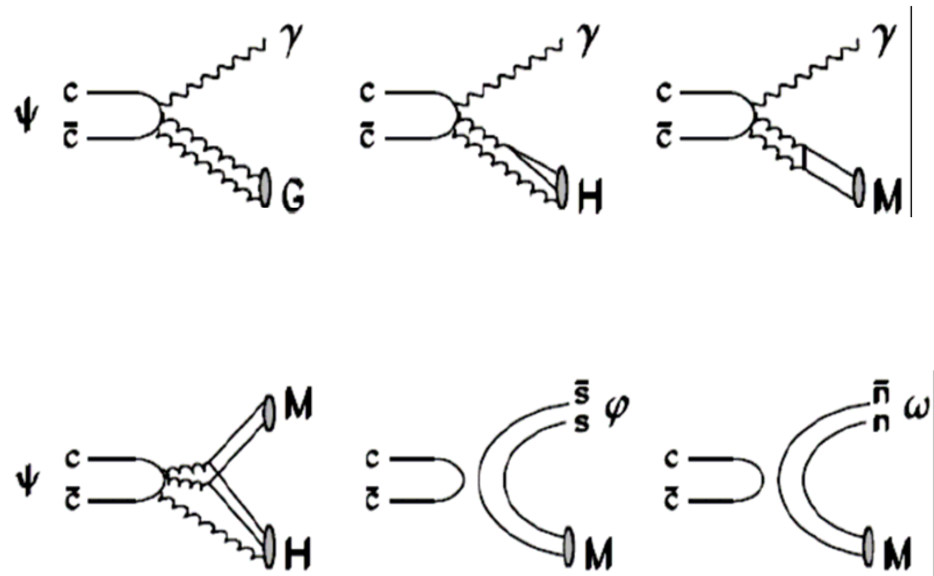
China (24)
IHEP, CCAST, GUCAS,
Univ. of Sci. and Tech. of China
Shandong Univ., Zhejiang Univ.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Hong Kong University
Chinese Univ. of Hong Kong

“Spectators”: four institutes from Italy

Light Hadron Spectroscopy

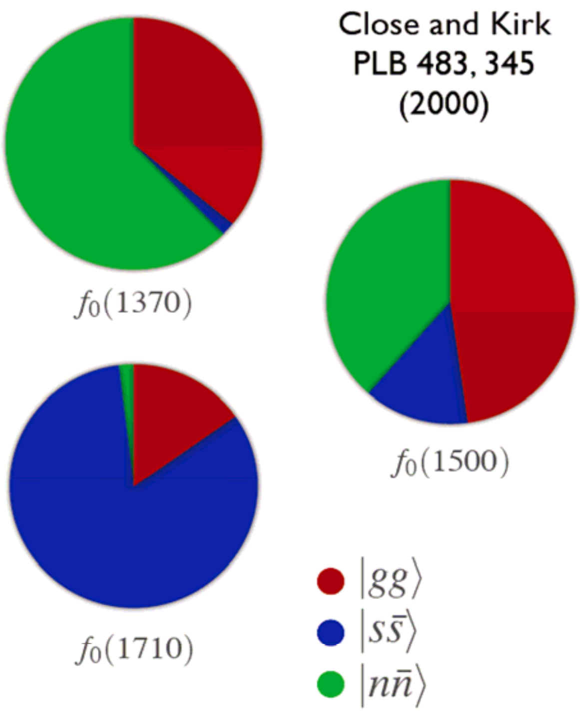
Light Hadron Spectroscopy

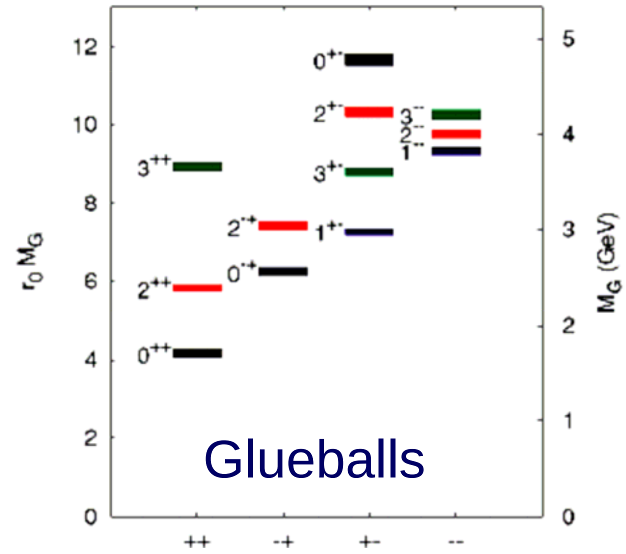
- 10^{10} J/ψs are probably enough to answer most questions about light hadron spectroscopy
- Meson spectroscopy
- Baryon spectroscopy
- Glueballs and hybrids
- Checks on all the things seen with BES II
  - Y(2175) in $J/\psi \to \eta\phi f_0(980)$
  - X(1580) in $J/\psi \to K^+K^-\pi^0$
  - X(1860) in $J/\psi \to \gamma pp$
  - X(1835) in $J/\psi \to \gamma\eta'\pi^+\pi^-$
  - Partial wave analyses



Glueballs

- Lightest glueball predicted by lattice at ~ 1710 MeV
- Scalar state
- Expected to mix with qqbar f_0 states





Spectrum from quenched LQCD

Y. Chen *et al.*
PRD73:014516,2006
(updates Morningstar & Peardon, '99)

0^{++} : 1710 ± 50 ± 80

Also:
1611 ± 30 ± 160 Michael '98
1550 ± 50 ± ? Bali et al. '93

- Indeed: Find three f_0 states nearby (two expected from qqbar)
- Study of decay branching fractions allows to estimate glue component

M. R. Shepherd
Charm Physics Workshop, Beijing
November 27, 2007

Partial Wave Analysis

- However: Resonances concerned are mostly broad
- Large non-scalar contributions

- Take into account angular dependences and interference by performing a partial wave analysis
- Very powerful tool, especially with large statistics
- Computationally extremely expensive
- Massive parallel calculations using graphics cards (GPU)

General idea:

$$I(\Omega) = \left|\sum_{\alpha} V_\alpha A_\alpha(\Omega)\right|^2$$

Coherent sum of amplitudes

Decay amplitude

Observed intensity (number of Events) as function of location in phase space

Fit parameter: production amplitude (complex)

Location in phase space

Likelihood:

$$\mathcal{L} = \frac{e^{-\mu}\mu^n}{n!}\prod_{i=1}^{n}\frac{I(\Omega_i)}{\int \eta(\Omega) I(\Omega)\, d\Omega}$$

Single event intensity

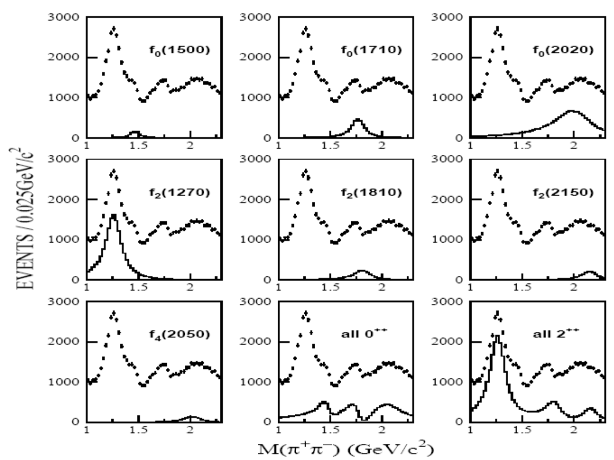
Normalisation integral

Log likelihood

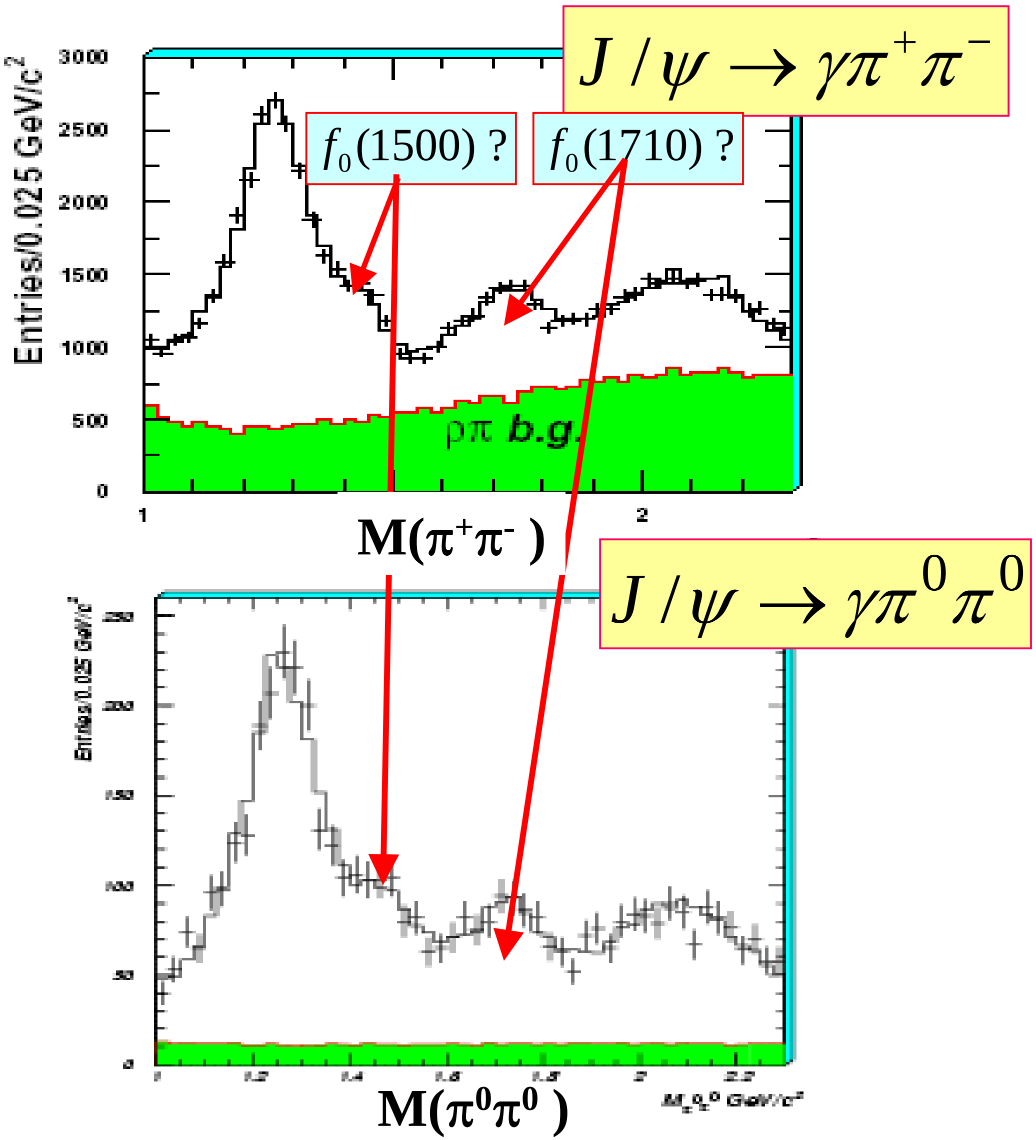
$$-\ln\mathcal{L} \propto = \sum_{i=1}^{n} \ln\left(\sum_{\alpha,\alpha'} V_\alpha V^*_{\alpha'} A_\alpha(\Omega_i) A^*_{\alpha'}(\Omega_i)\right) + \sum_{\alpha,\alpha'} V_\alpha V^*_{\alpha'}\left(\frac{1}{N^{Gen}_{MC}}\sum_{i=1}^{n} A_\alpha(\Omega_i) A^*_{\alpha'}(\Omega_i)\right)$$

Digression: GPU based computing

- 3D computer games require lots of manipulations on floating-point 4-vectors
- Gaming market drives hardware – 320 fold parallel processors available for less than 200 Euros
- Recently double precision became available
- Make use of this: General Purpose Computing on Graphics Processing Units (GPGPU)
- Application to PWA at BES



Partial wave analysis of $J/\psi \to \gamma\pi^+\pi^-$ and $\gamma\pi^0\pi^0$



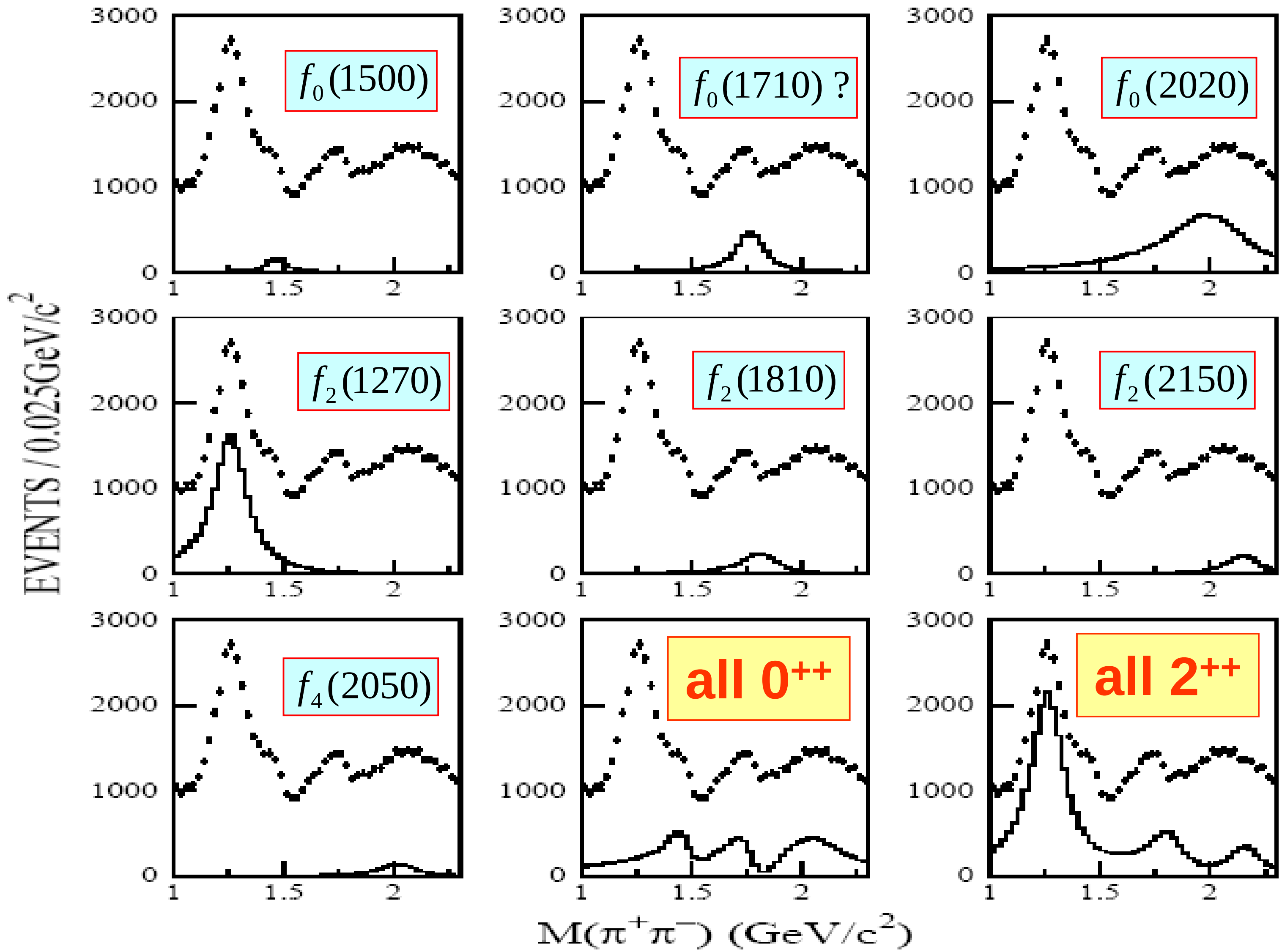
Channels fitted in the PWA:

$$
\begin{aligned}
J/\psi &\to \gamma f_2(1270) \\
&\to \gamma f_0(1500) \\
&\to \gamma f_0(1710) \\
&\to \gamma f_2(1810) \\
&\to \gamma f_0(2020) \\
&\to \gamma f_2(2150) \\
&\to \gamma f_4(2050).
\end{aligned}
$$

Phys. Lett. B 642 (2006) 441

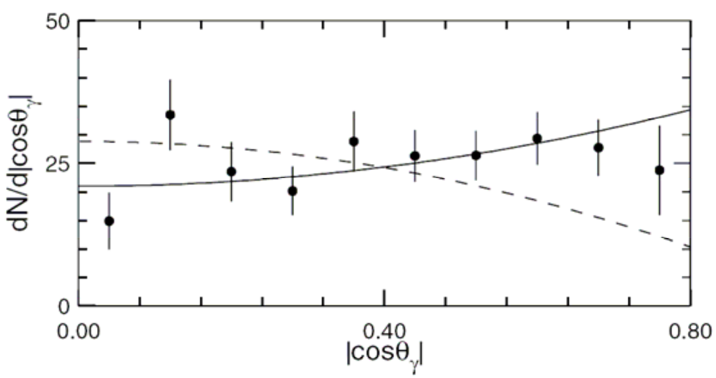
Partial wave analysis of $J/\psi \to \gamma\pi^+\pi^-$ and $\gamma\pi^0\pi^0$

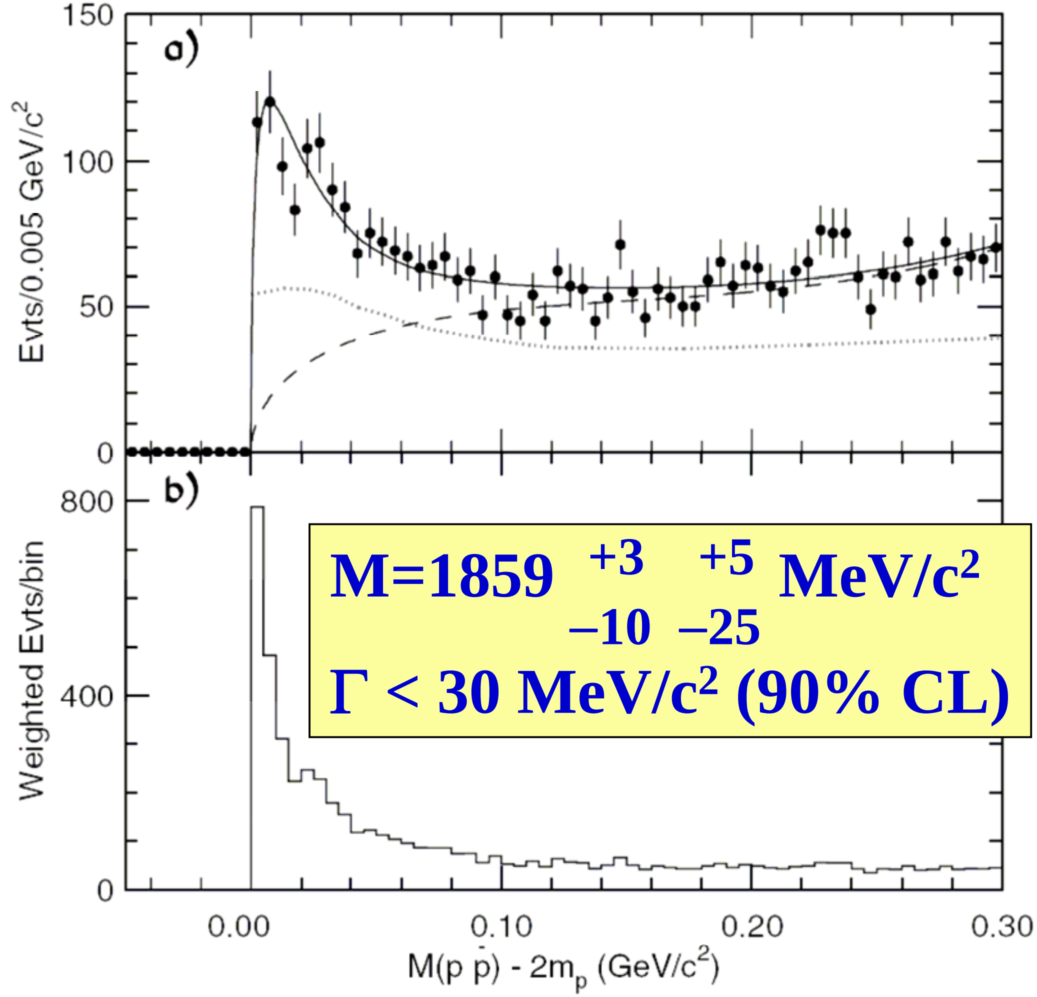
PWA components:



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

- Enhancement at (below) $p\bar{p}$ threshold
- Clarify angular structure
- Baryonium? Fragmentation?





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

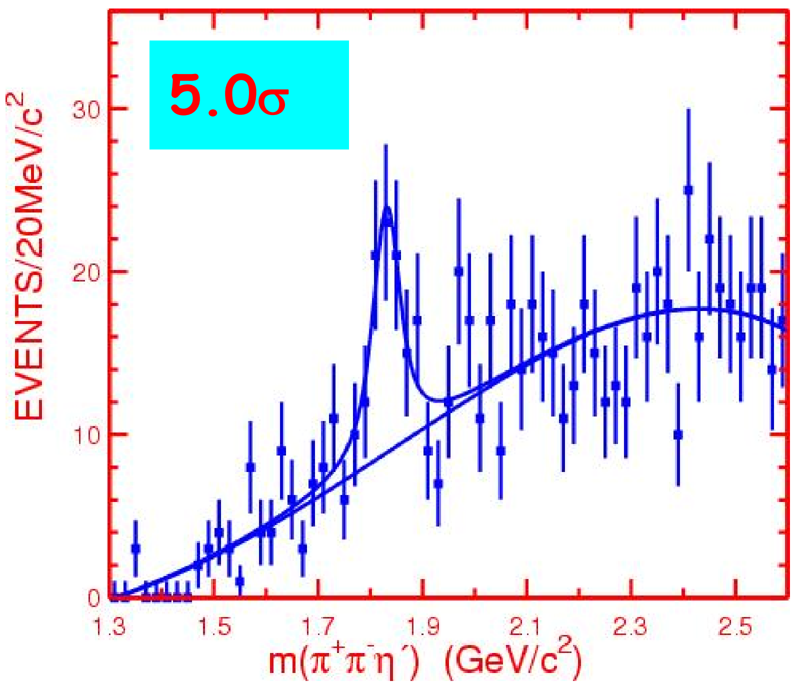
$\Gamma < 30$ MeV/c² (90% CL)

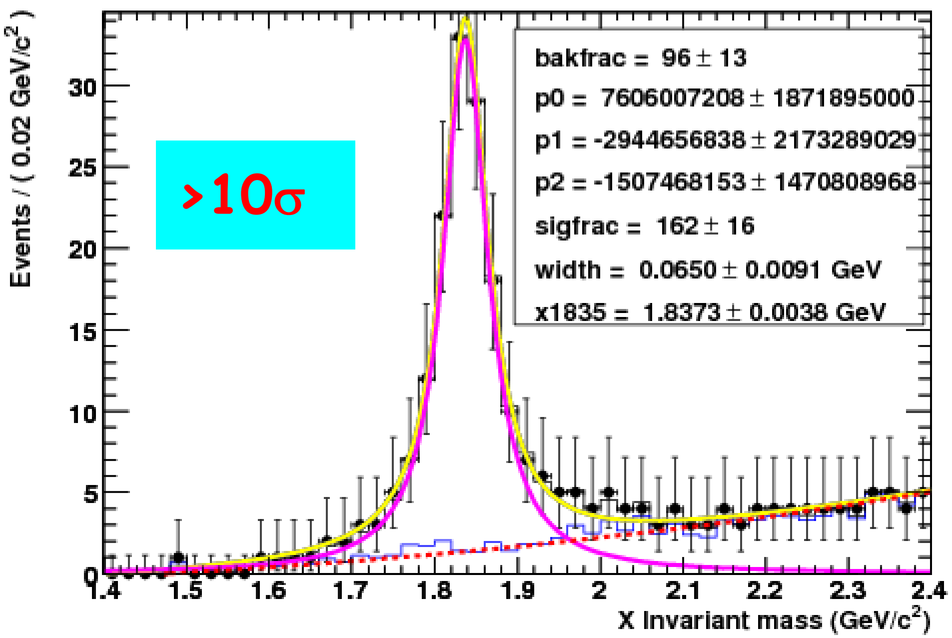
Phys. Rev. Lett. 91, 022001 (2003)

X(1835) in $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$, $\eta' \rightarrow \eta\,\pi^+\pi^-$

- Same resonance as X(1860)?
- BES III has much improved photon reconstruction

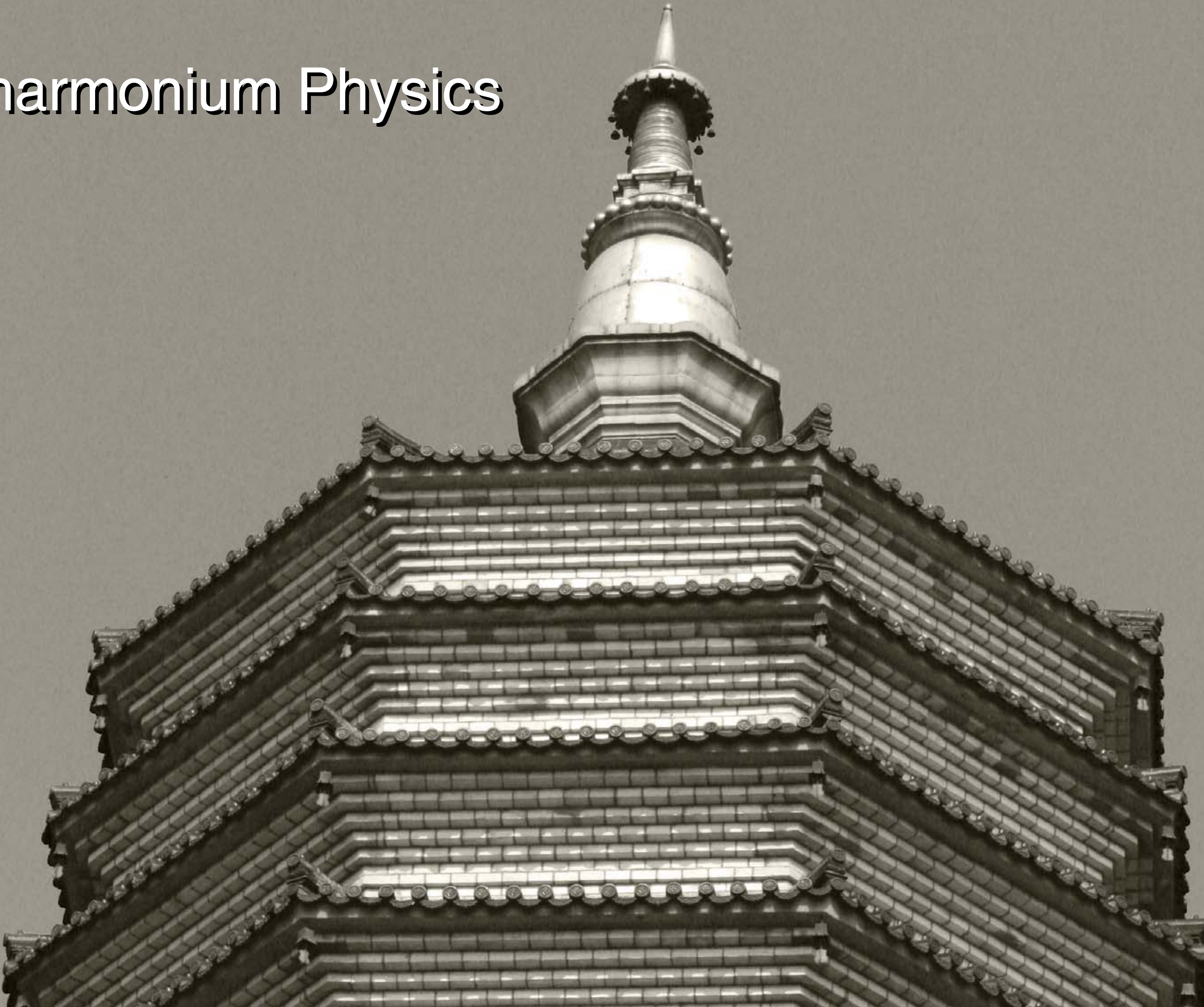
BES III MC study, $3\mathrm{x}10^9$ J/ψs





Phys.Rev.Lett.95:262001,2005

Charmonium Physics

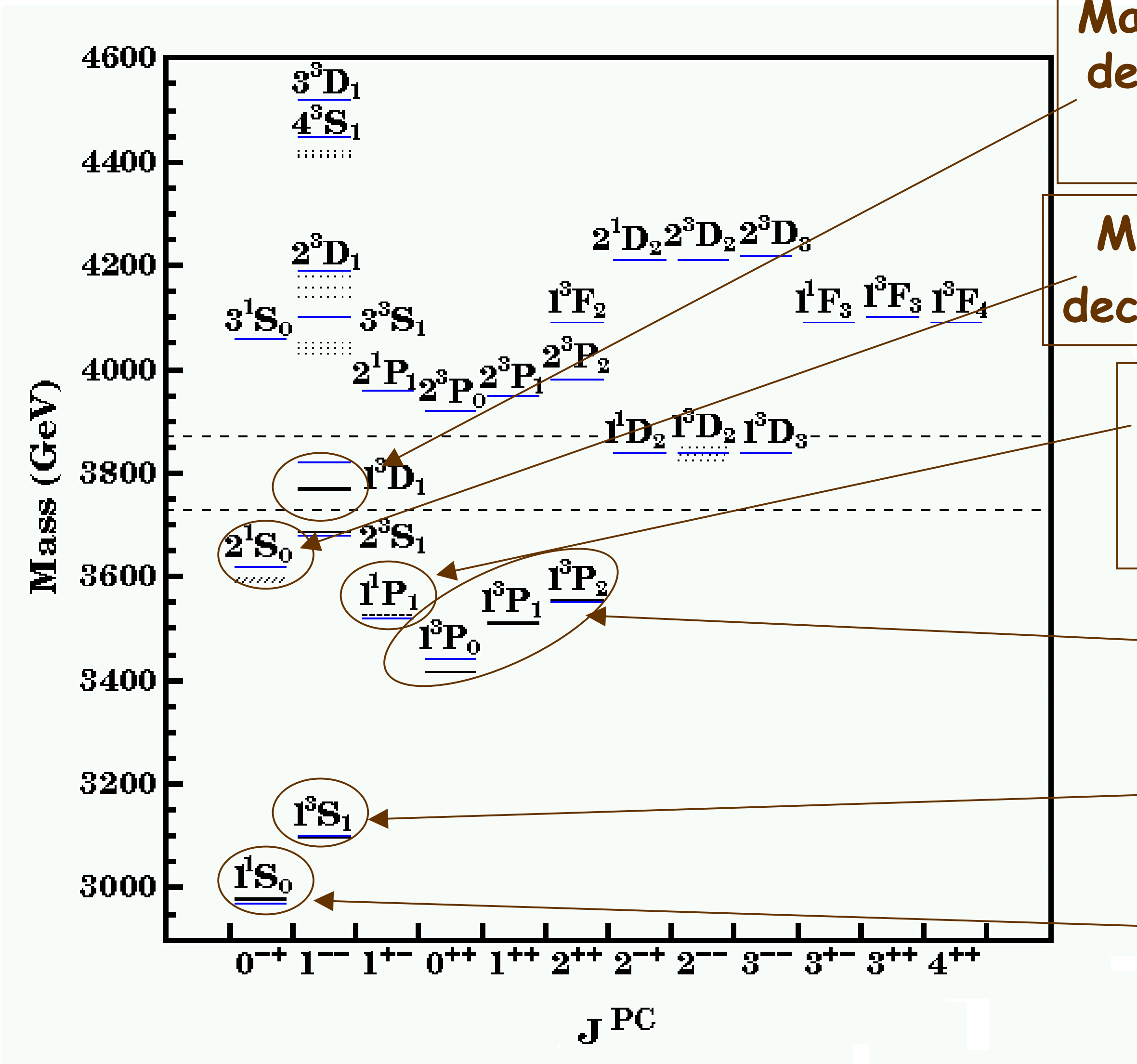


Charmonium Physics

- Understand charmonium spectroscopy and charmonium decay dynamics
  - Hadronic transition (54%)
  - Radiative transition (28%)
  - Study of spin-singlets (h_c, η_c, η_c')
  - Hadronic decays (15%)
  - Leptonic decays (2%)
  - Radiative decays (2%)

3×10^9 $\psi(2S)$ events /year at BES-III

Charmonium Physics at BES III



Mass, width, non-DD decays & $\Gamma(\pi\pi J/\psi)$ of the ψ''

Mass width & other decay modes of the η_c'

Mass of the h_c
Rel. to χ_{cn} c.o.g.
other decay modes

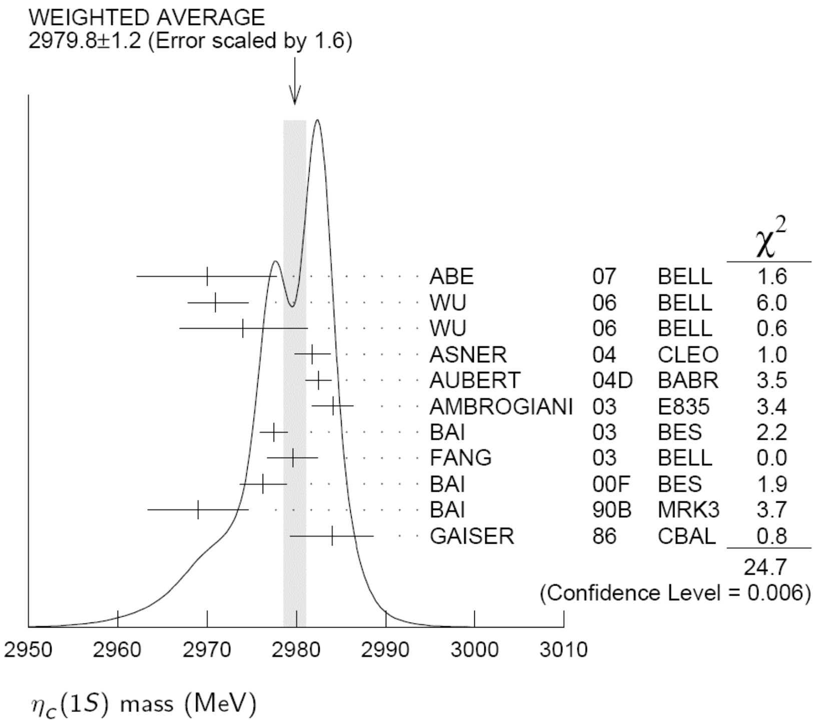
M2 components in $\chi_{cJ} \rightarrow \gamma J/\psi$?

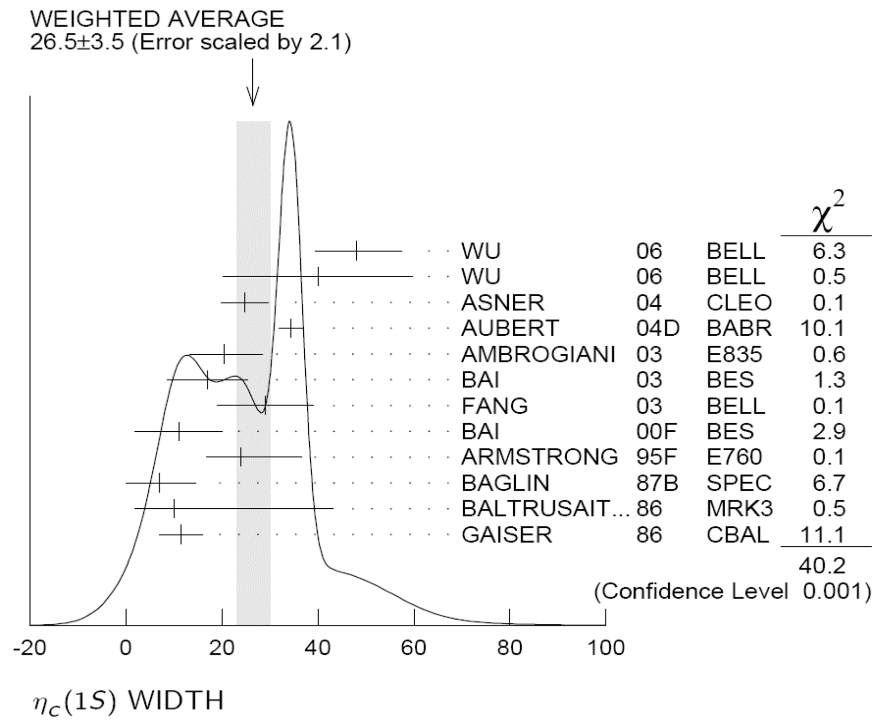
$\Gamma(J/\psi \rightarrow \gamma\eta_c)$=?

Mass & width of the η_c

η_c mass and width

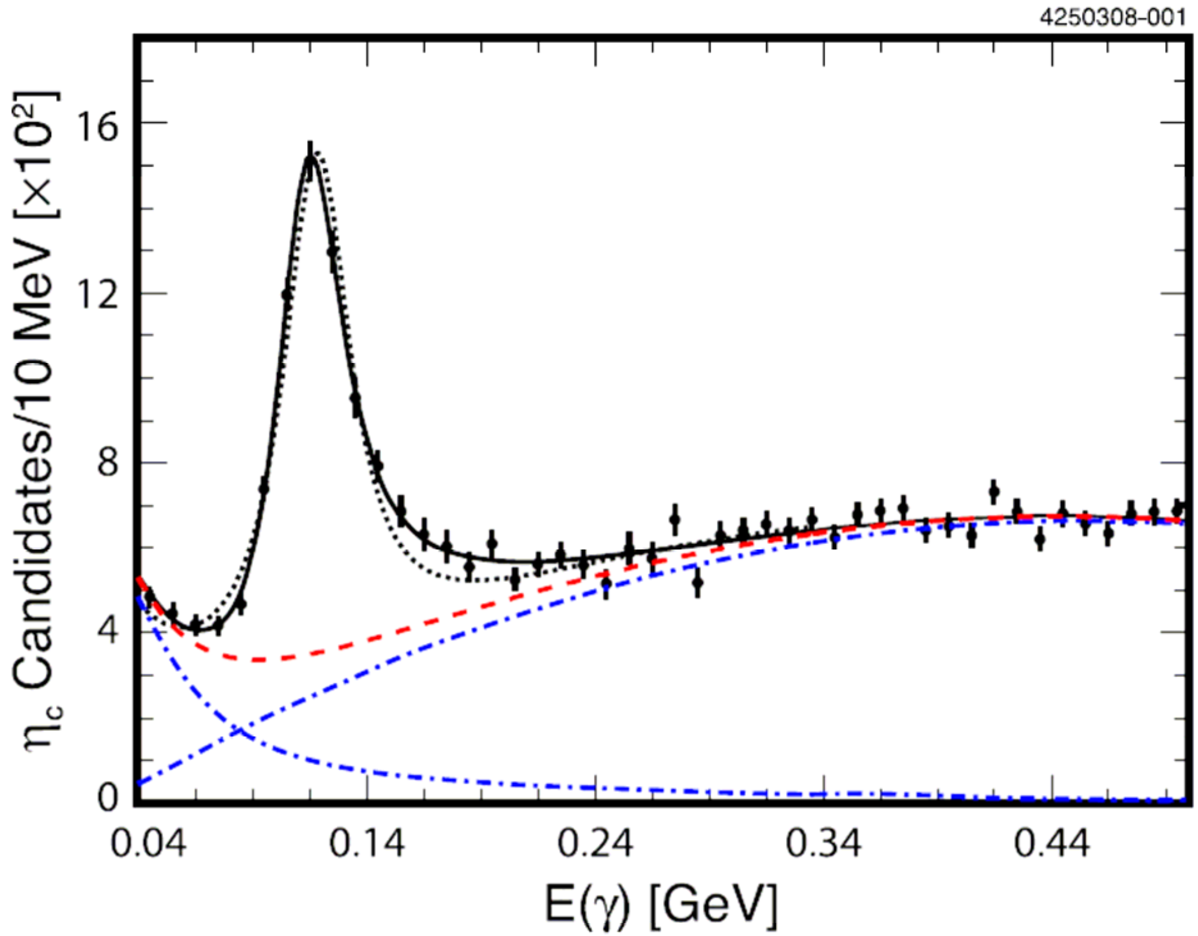
- Not well understood – previous measurements inconsistent
- May be due to line shape – see recent CLEO-c publication





η_c mass and width

- Only ad-hoc phenomenological model seems to work for lineshape



Cleo: arXiv:hep-ex:0805.0252

M(J/ψ) - M(η_c) - Lattice

S.Choe et al, QCD-TARO hep-lat0307004

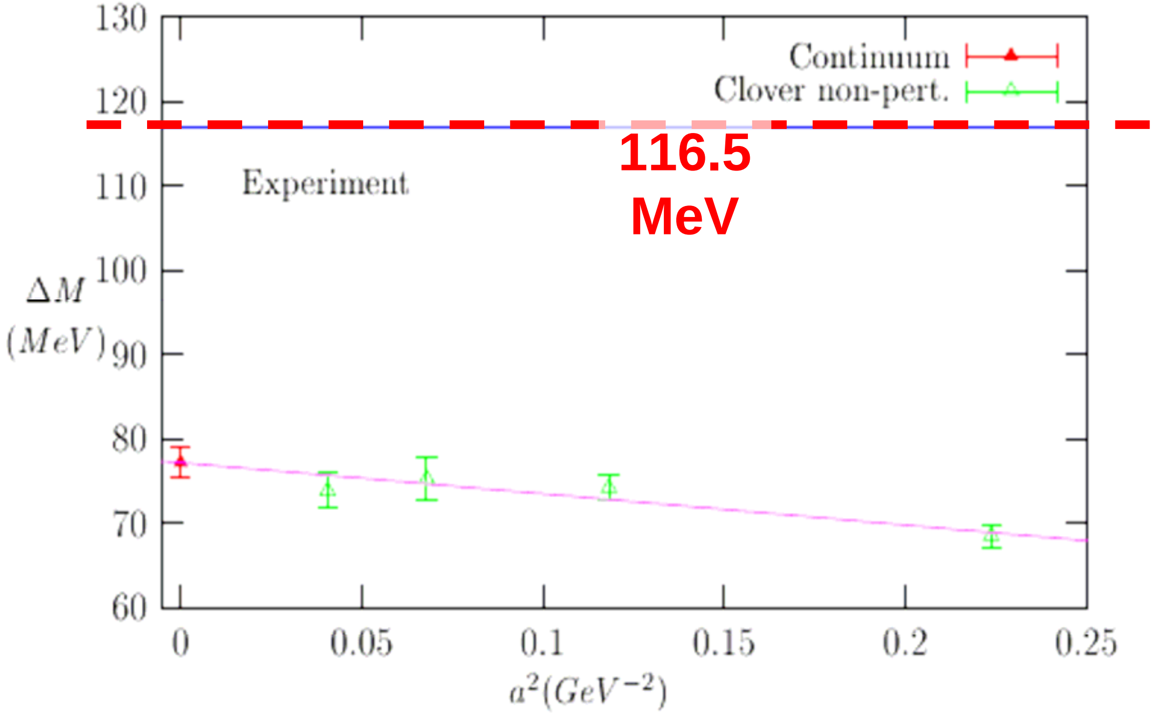
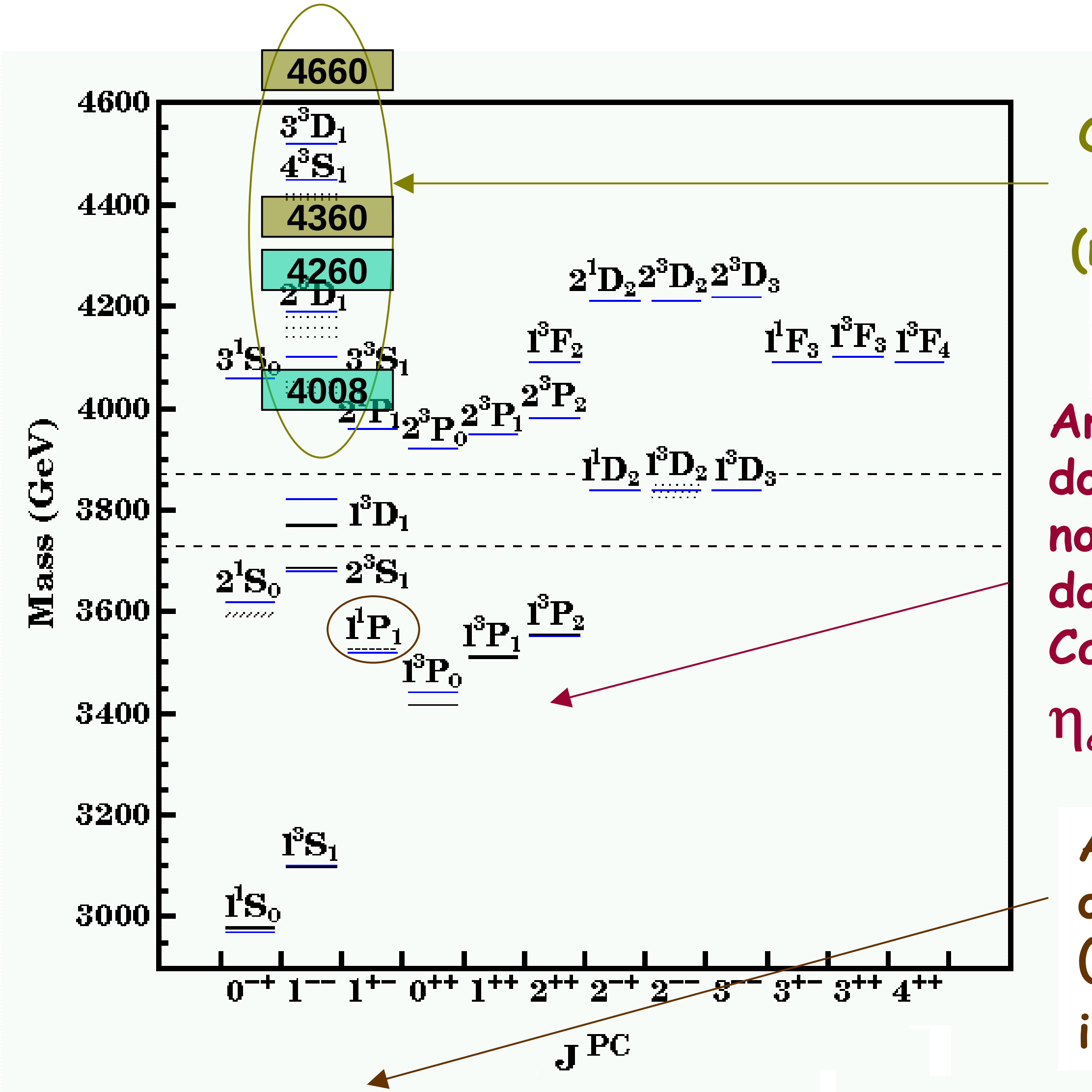


Figure 3: Continuum extrapolation of the hyperfine splitting with the non-perturbatively improved clover Dirac operator. The bare quark mass is tuned to maintain an approximately constant mass $M(^3S_1) \approx 3095$ MeV $\forall a$.

The XYZ states

States above D threshold found, which mostly decay to charmonia

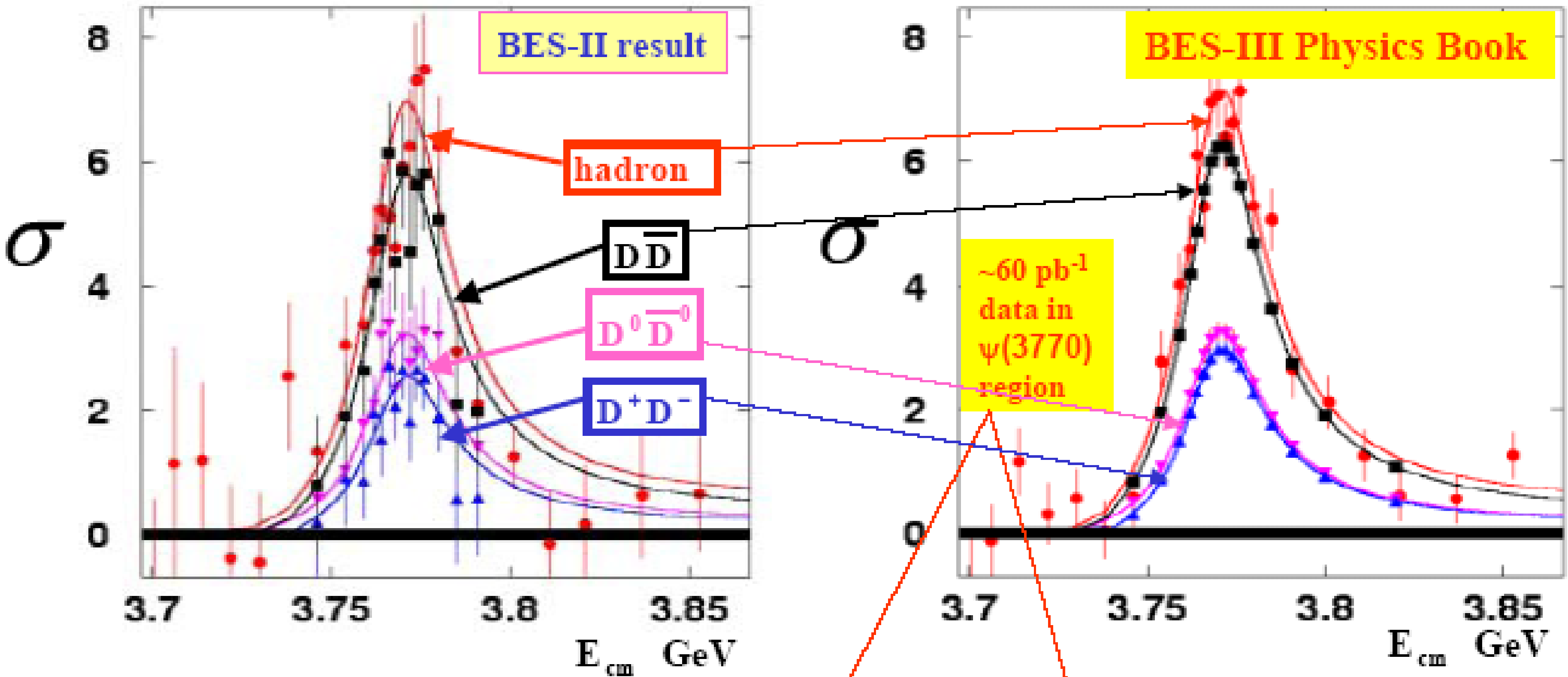


Other decay modes of the 1^- states (need detailed scan)

Are there XYZ states down here that are not seen (because they don't decay to J/ψ or ψ')? Can BESIII see them in η_c decay channels?

Are there ss versions of the XYZ states (i.e. Y(2175)) to be seen in ϕ & η' final states?

Scan of ψ(3770) peak



	Measured value	Input value
$\Gamma^{tot}_{\psi(3770)}$	26.8 ± 0.5 MeV	26.9 MeV
$\Gamma^{ee}_{\psi(3770)}$	256 ± 9 eV	251 eV

$B[\psi(3770) \to D\bar{D}]$

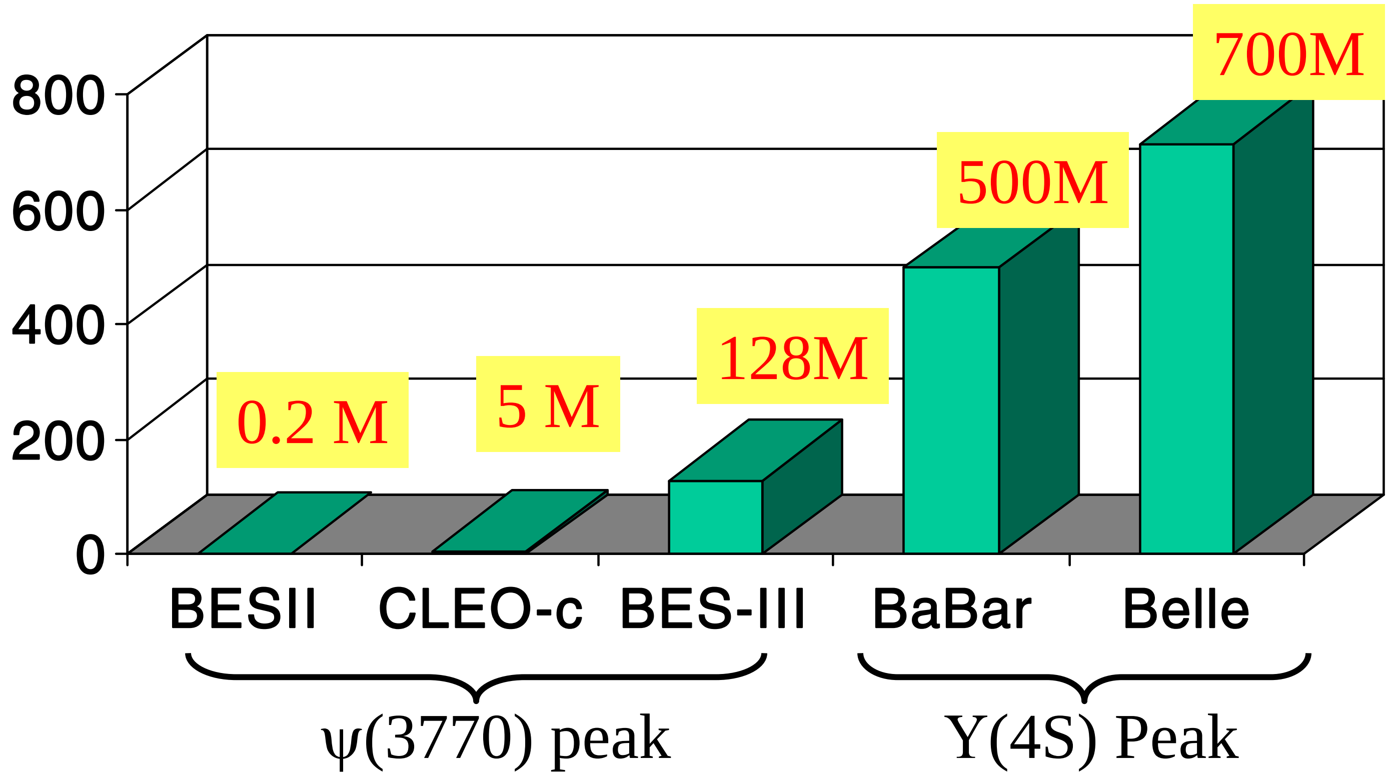
$(88.2 \pm 2.4 \pm \sim 2.0)$ % Measured value

89 % Input value


Charm Physics

Charm Physics

128 million $D\bar{D}$ pairs are expected at BES-III with 4 years' luminosity.
5 M at CLEO-c until 2008.



Background free

Higher statistics

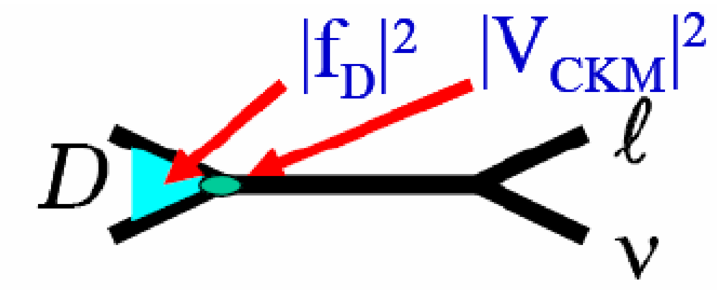
Charm physics, CKM and QCD

Interplay with B-factories:

- Constrain CKM with B and K measurements, check with measurements in charm sector
- Many B measurements depend on lattice QCD calculations of e.g. f_D, f_{Ds}
- BES can measure these decay constants with good precision
- Check/calibrate the lattice calculations

- D_0 mixing and possible CP violation in the D system

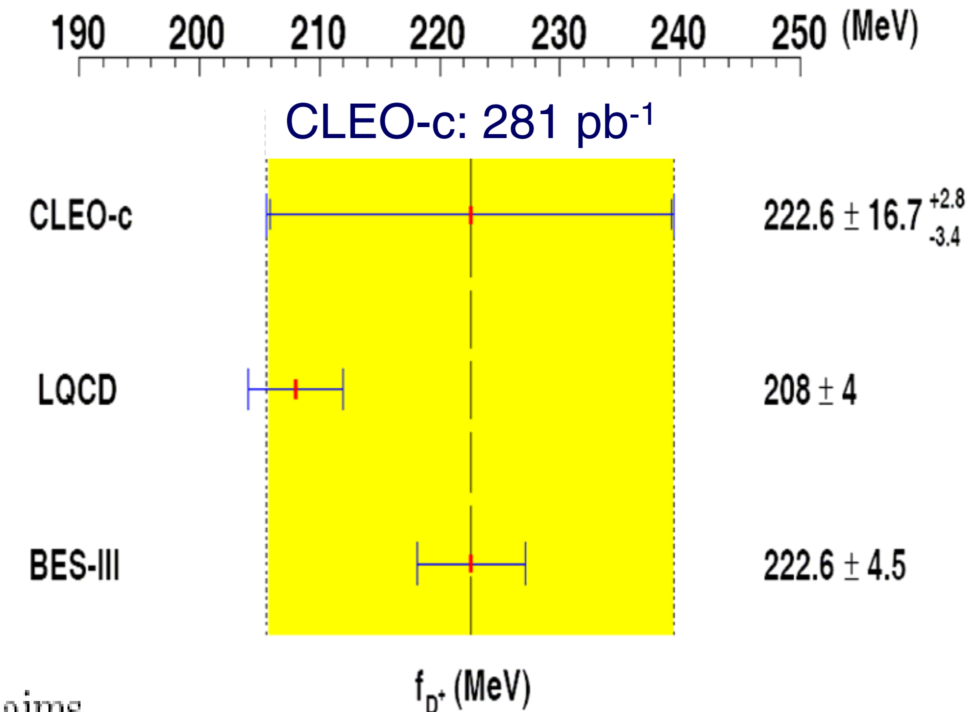
D-Meson decay constants – test LQCD



$$\Gamma(D_s^+ \to l^+\nu) = \frac{G_F^2 m_{D_s^+} m_l^2 f_{D_s^+}^2}{8\pi}|V_{cs}|^2 \left(1-\frac{m_l^2}{m_{D_s^+}^2}\right)^2$$

Recently, the HPQCD+UKQCD collaboration claims better than 2% precision for their unquenched calculations [11]

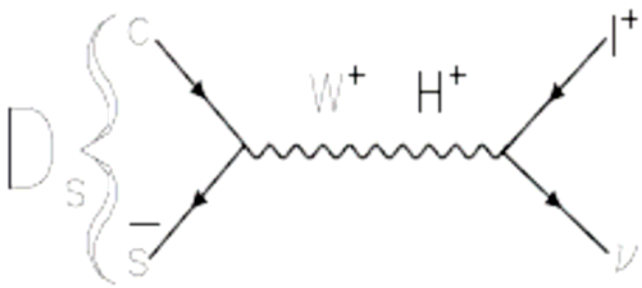
$$(f_{D+})_{QCD} = (208 \pm 4)\text{MeV},$$
$$(f_{D_s^+})_{QCD} = (241 \pm 3)\text{MeV}, \quad (7)$$



BES-III reaches 2% with 20 fb^{-1} data @ $\psi(3770)$.

Precise determination of f_{Ds} – challenge LQCD

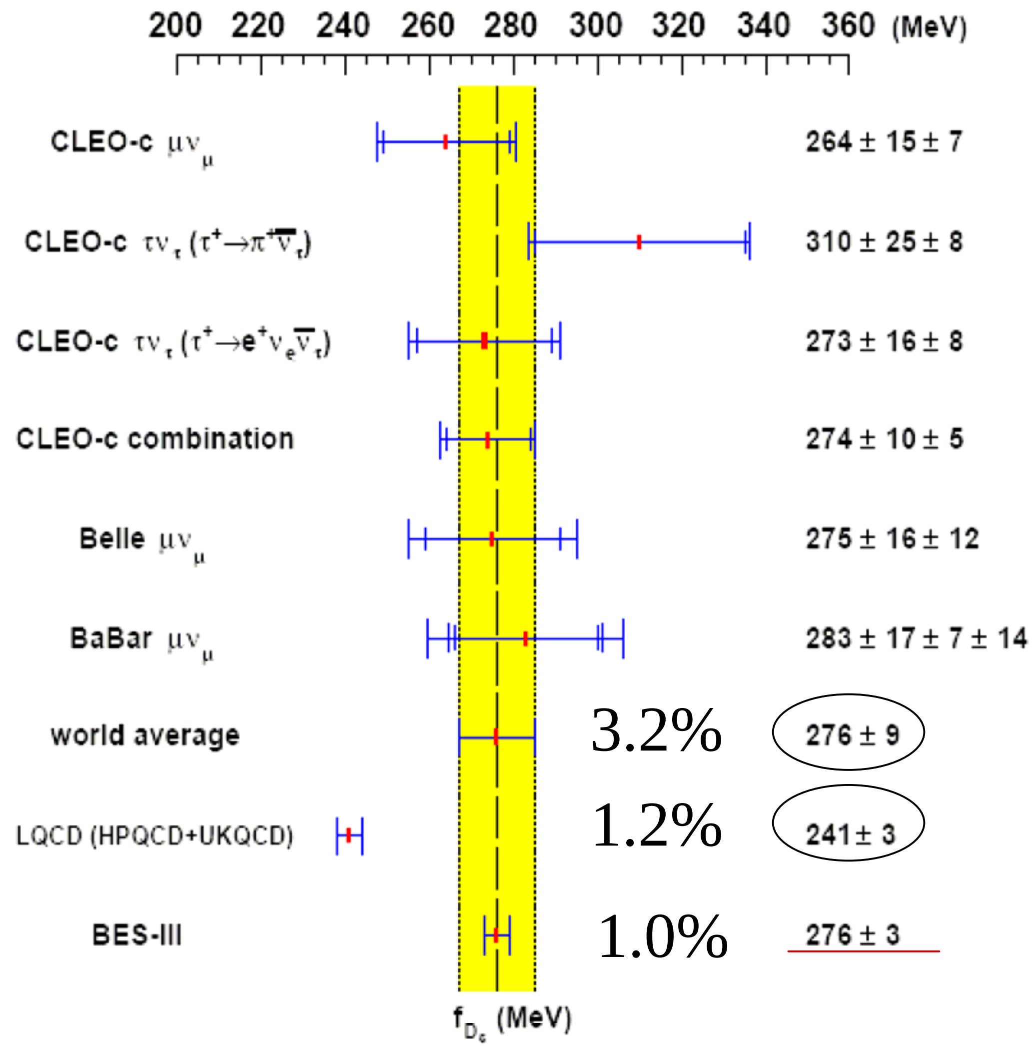
See Hewett [hep-ph/9505246] & Hou, PRD 48, 2342 (1993).



4.0 sigma discrepancy between LQCD and experimental determination in the SM.

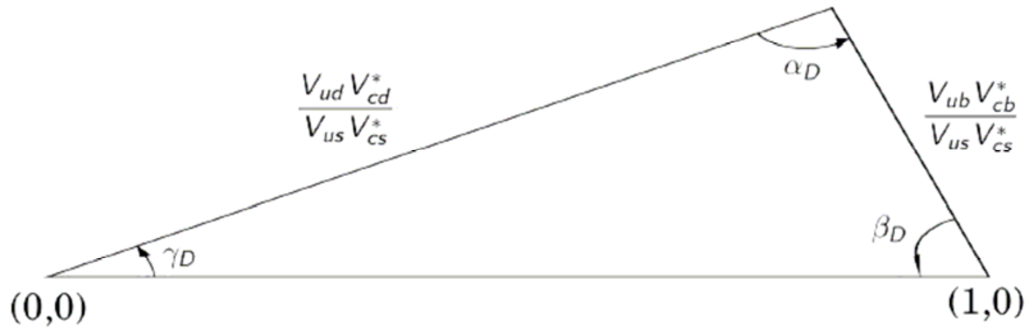
f_D/f_{Ds} ratio is especially interesting

H.B.Li ,J.H.Zou arXiv:0804.1822



The D-meson unitarity triangle

$$\frac{V_{ud}V_{cd}^*}{V_{us}V_{cs}^*} + 1 + \frac{V_{ub}V_{cb}^*}{V_{us}V_{cs}^*} = 0$$



can be used to define a (squashed) D-meson unitarity triangle

- $\bar{\rho}_D + i\bar{\eta}_D = -\frac{V_{ud}V_{cd}^*}{V_{us}V_{cs}^*}$
- $\alpha_D = \arg\left(-\frac{V_{ub}V_{cb}^*}{V_{ud}V_{cd}^*}\right) = \arg\left(-\frac{V_{ub}V_{ud}^*}{V_{cb}V_{cd}^*}\right) = -\gamma$
- $\gamma_D = \arg\left(-\frac{V_{ud}V_{cd}^*}{V_{us}V_{cs}^*}\right) = O(\lambda^4)$
- $\beta_D = \arg\left(-\frac{V_{us}V_{cs}^*}{V_{ub}V_{cb}^*}\right) = \pi - \alpha_D - \gamma_D = \pi + \gamma + O(\lambda^4)$

The D-meson unitarity triangle

$$\frac{V_{ud}V_{cd}^*}{V_{us}V_{cs}^*}+1+\frac{V_{ub}V_{cb}^*}{V_{us}V_{cs}^*}=0$$

can be used to define a (squashed) D-meson unitarity triangle

- $\bar{\rho}_D + i\bar{\eta}_D = -\frac{V_{ud}V_{cd}^*}{V_{us}V_{cs}^*}$
- $\alpha_D = \arg\left(-\frac{V_{ub}V_{cb}^*}{V_{ud}V_{cd}^*}\right) = \arg\left(-\frac{V_{ub}V_{ud}^*}{V_{cb}V_{cd}^*}\right) = -\gamma$
- $\gamma_D = \arg\left(-\frac{V_{ud}V_{cd}^*}{V_{us}V_{cs}^*}\right) = O(\lambda^4)$
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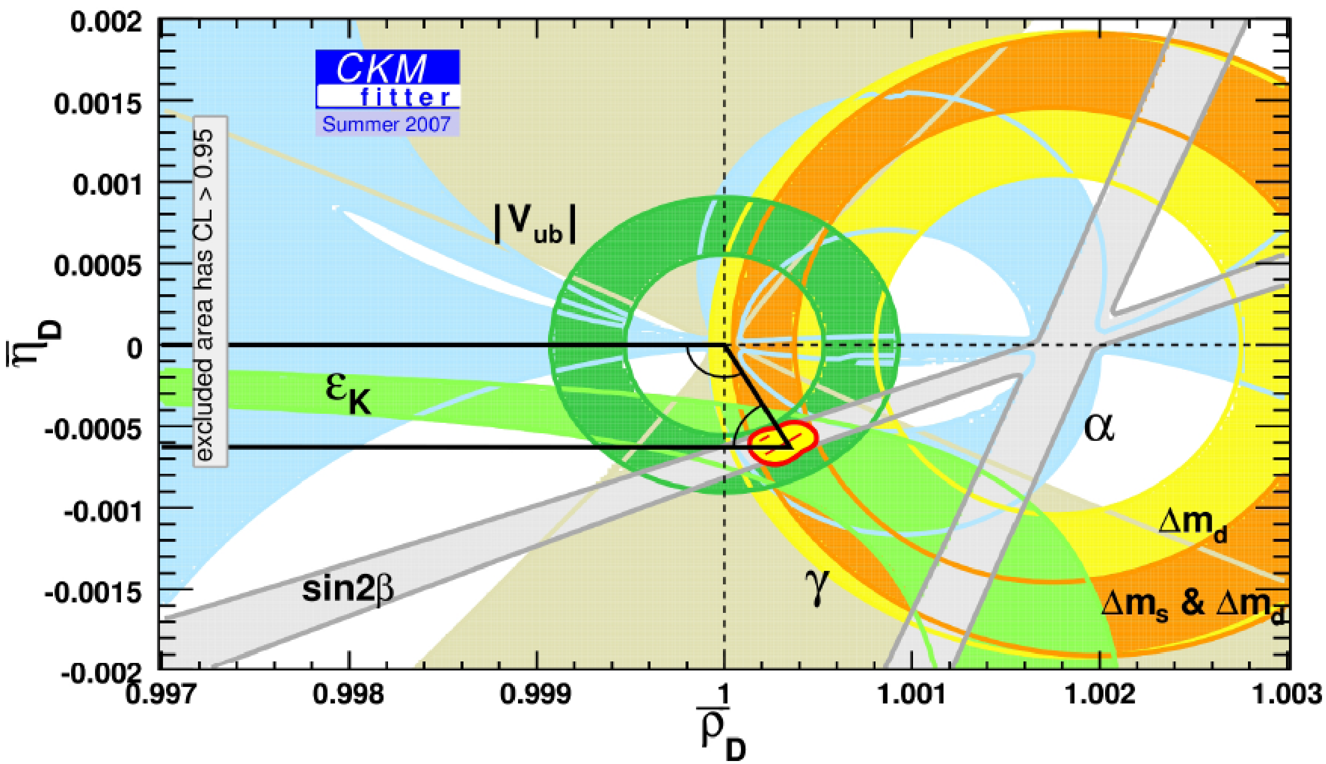
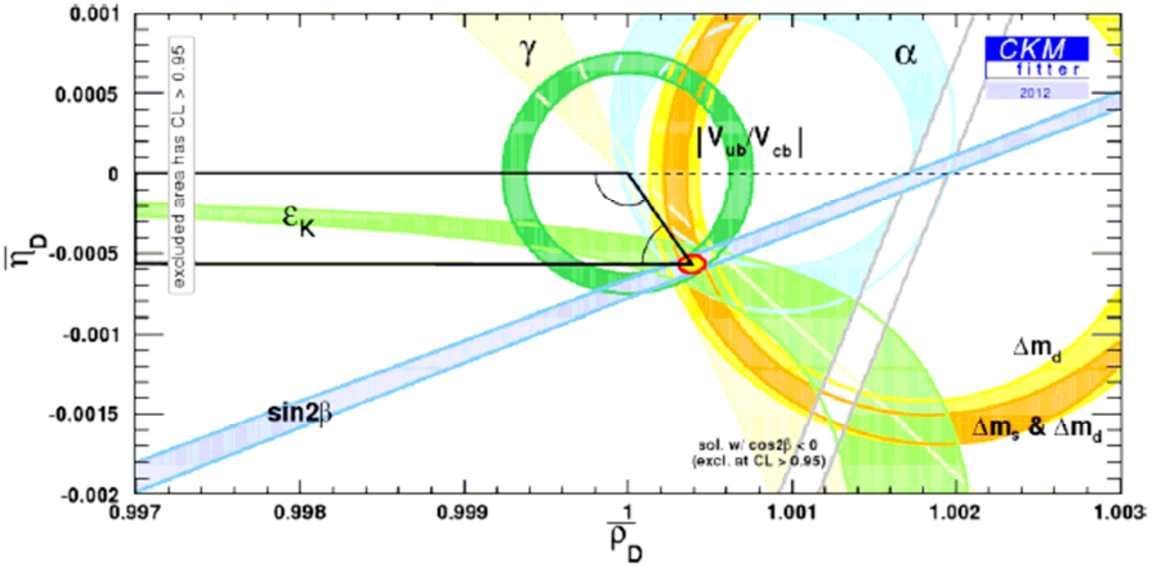
The D-meson unitarity triangle

In the SM, kaon or B-processes constrain strongly D-UT through CKM

- $|V_{us}|$ constrains (in a first approximation) λ
- $B \to DK$ constrains γ and thus β_D ...



The D-meson unitarity triangle



BES accuracy

- For leptonic D decays

$$\sigma(|V_{cd}|)/(|V_{cd}|) = 2.3\%$$
$$\sigma(|V_{cs}|)/|V_{cs}| = 1.7\%$$
$$\frac{\sigma(|V_{cd}|/|V_{cs}|)}{|V_{cd}|/|V_{cs}|} = 1.3\%$$

- For semileptonic D decays ($D_s \to K$ and $D_s \to \phi$):

$$\sigma(|V_{cd}|)/(|V_{cd}|) = 2.4\%$$
$$\sigma(|V_{cs}|)/|V_{cs}| = 1.3\%$$

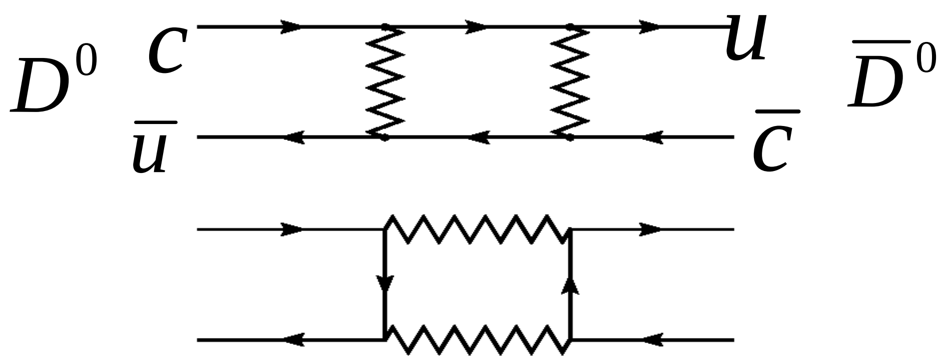
Observable	CKM	QCD	Lattice	Exp meas	Exp err
$Br(D \to \ell\nu)$	$\lvert V_{cd}\rvert$	f_D	2%	$f_D\lvert V_{cd}\rvert$	1.1%
$Br(D_s \to \ell\nu)$	$\lvert V_{cs}\rvert$	f_{Ds}	1.5%	$f_{Ds}\lvert V_{cs}\rvert$	0.7%
$\frac{Br(D_s\to\ell\nu)}{Br(D\to\ell\nu)}$	$\left\lvert\frac{V_{cs}}{V_{cd}}\right\rvert$	$\frac{f_{Ds}}{f_D}$	1%	$\left\lvert\frac{V_{cs}f_{Ds}}{V_{cd}f_D}\right\rvert$	0.8%
$d\Gamma(D^0 \to \pi^-)$	$\lvert V_{cd}\rvert$	$F_{D\to\pi}(0)$	4%	$\lvert V_{cd}\rvert F_{D\to\pi}(0)$	0.6%
$d\Gamma(D^0 \to K^-)$	$\lvert V_{cs}\rvert$	$F_{D\to K}(0)$	3%	$\lvert V_{cs}\rvert F_{D\to K}(0)$	0.5%
$d\Gamma(D_s \to K)$	$\lvert V_{cd}\rvert$	$F_{D_s\to K}(0)$	2%	$\lvert V_{cd}\rvert F_{D_s\to K}(0)$	1.2%
$d\Gamma(D_s \to \phi)$	$\lvert V_{cs}\rvert$	$F_{D_s\to\phi}(0)$	1%	$\lvert V_{cs}\rvert F_{D_s\to\phi}(0)$	0.8%

Neutral D meson mixing

- D_0 and $\bar{D}_0$ can transform into each other (like Kaons an Bs)
- The mass eigenstates are

$$\left|D_1\right\rangle = p\left|D^0\right\rangle + q\left|\overline{D}^0\right\rangle$$

$$\left|D_2\right\rangle = p\left|D^0\right\rangle - q\left|\overline{D}^0\right\rangle$$



+ long distance physics (Kaon loop)

- With eigenvalues

$$\mu_1 = m_1 - \frac{i}{2}\Gamma_1$$

$$\mu_2 = m_2 - \frac{i}{2}\Gamma_2$$

$$m \equiv \frac{m_1 + m_2}{2}, \qquad \Delta m \equiv m_2 - m_1$$

$$\Gamma \equiv \frac{\Gamma_1 + \Gamma_2}{2}, \qquad \Delta\Gamma \equiv \Gamma_2 - \Gamma_1$$

$$x \equiv \frac{\Delta m}{\Gamma}, \qquad y \equiv \frac{\Delta\Gamma}{2\Gamma}$$

Quantum Correlation

At BES-III:

$D\overline{D}$ pair with L =1 must be in anti-asymmetric state

$$|D^0\overline{D}^0\rangle^{C=-1} = \frac{1}{\sqrt{2}}\left[|D^0\rangle|\overline{D}^0\rangle - |\overline{D}^0\rangle|D^0\rangle\right]$$

the interference comes for free:

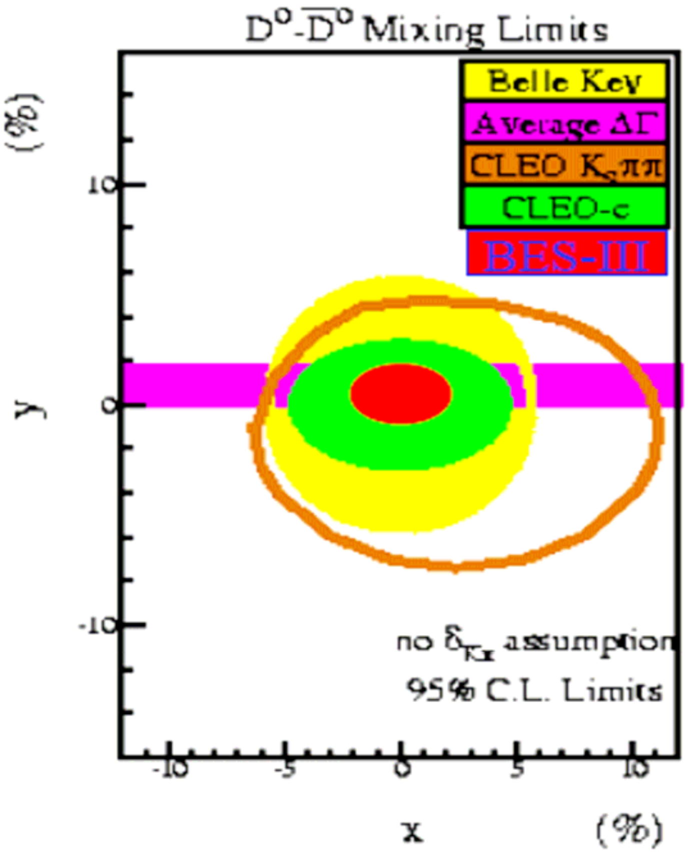
$$M_{ij}^2 = \left|\langle i|D^0\rangle\langle j|\overline{D^0}\rangle - \langle j|D^0\rangle\langle i|\overline{D^0}\rangle\right|^2$$

PRD 73, 034024 (2006)
Asner and Sun
I.I.Bigi SLAC report-33, 1989 page 169

(C=–1) $e^+e^- \to \psi(3770) \to$	D	$\overline{D}$
Forbidden if no mixing	$K^-\pi^+$	$K^-\pi^+$
Forbidden if no mixing	$K^-l^+\nu$	$K^-l^+\nu$
Forbidden by CP conservation	CP+	CP+
Forbidden by CP Conservation	CP–	CP–

Mixing Rate R_M

Sensitivity in 20 fb^{-1} data at BES-III:



$\psi(3770) \to D^0\bar{D}^0 \to (K^-\pi^+)(K^-\pi^+)$

$$R_M = \frac{x^2 + y^2}{2} = \frac{N[(K^\pm\pi^\mp)(K^\pm\pi^\mp)]}{N[(K^\pm\pi^\mp)(K^\mp\pi^\pm)]}$$

Background estimate done for 20 fb^{-1} :

2 events in the signal region due to mis-ID. (the mis-ID rate for pi as a Kaon is 1%).

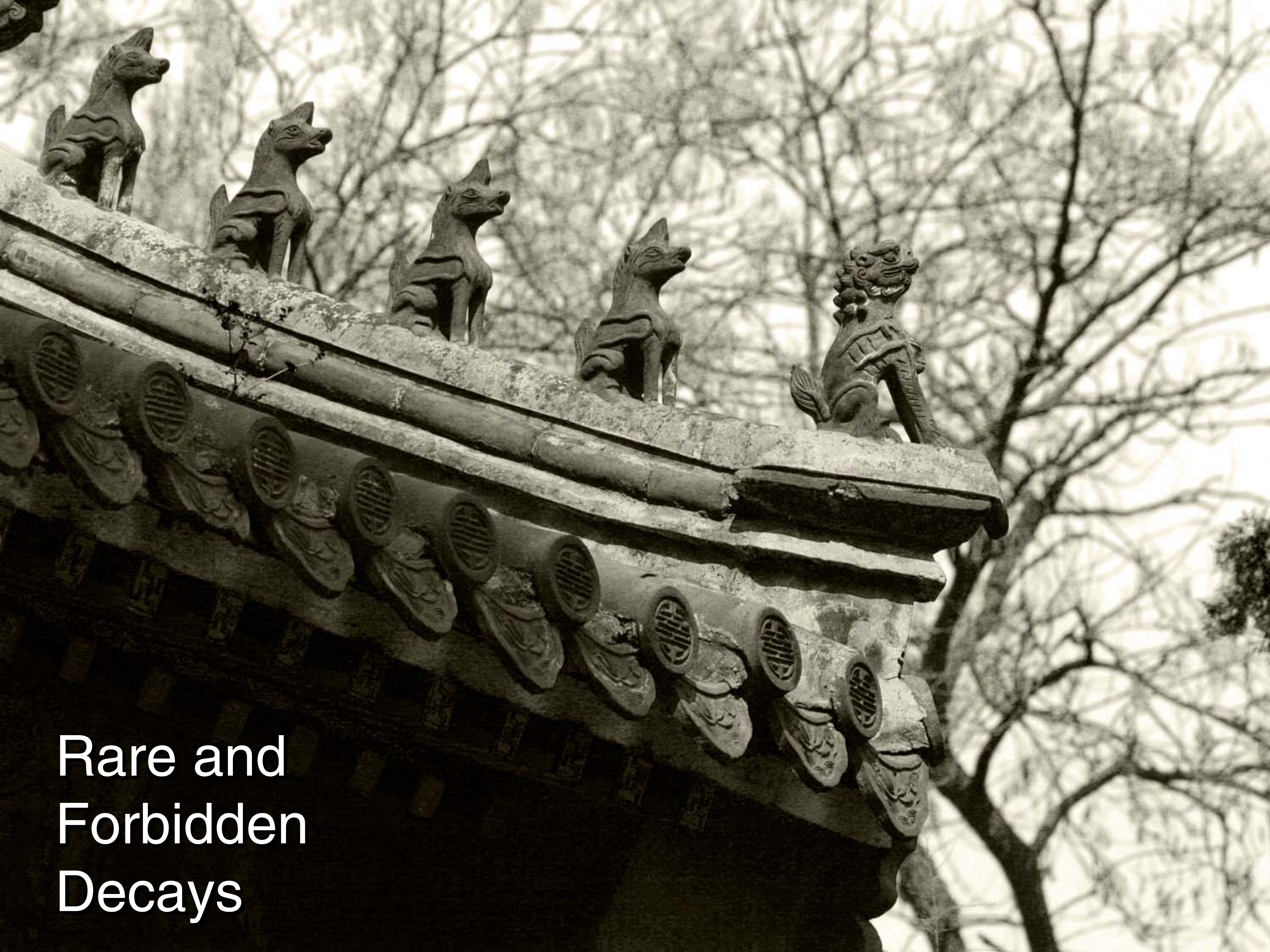
$R_M < 1.5 \times 10^{-4}$

CP violation in the D system

- CP violation in the mixing
- CP violation in D decays
- CP violation in interference
- All clean ways to probe new physics since the SM predicts an unobservable asymmetry of $\sim 10^{-4}$

- 1% level CPV likely indicates new physics.

However: Needs extremely good control of systematic effects at the 10^{-3} level – very challenging!


Rare and
Forbidden
Decays

Rare and forbidden decays

Search for New Physics in Charm Sector:

- Lepton flavour and lepton number violating decays of charmonium and open charm
- Rare charm decays heavily GIM suppressed: BF($c \to ull$)~10^{-8}
- Loops different from B and K systems because *c* is an up-type quark
- Weak charmonium decays: J/$\psi \to$ DX – BES almost reaches down to rates predicted in SM

- Charm Mixing (Large CPV in mixing indicates New Physics)
- CP Violation - Direct (New Physics could be ~%)

Lepton flavour violating decays of the J/ψ

- Lepton flavor violating (LFV) processes are strongly suppressed in the Standard Model by powers of the (small) neutrino masses. Such decays signal new physics.

BESII upper limit

$BR(J/\psi \rightarrow e\mu) < 1.1\times10^{-6}$

$BR(J/\psi \rightarrow e\tau) < 8.3\times10^{-6}$

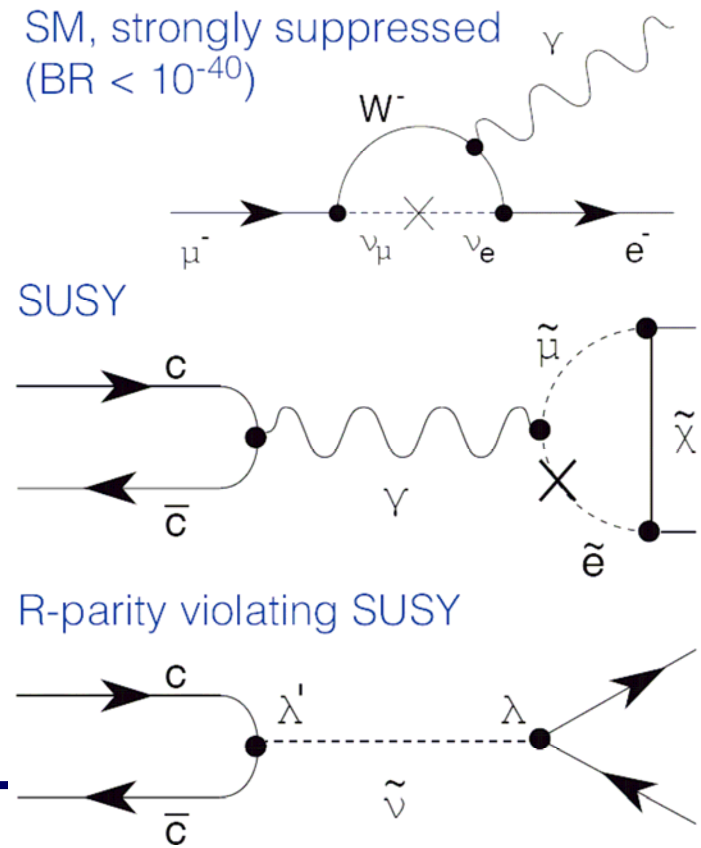
$BR(J/\psi \rightarrow \mu\tau) < 2.0\times10^{-6}$

with 58M J/ ψ sample

BESII
PLB561, 49 (2003)
PLB598, 172(2004)

$J/\psi \rightarrow e\mu, e\tau, \tau\mu$, the sensitivity can be $10^{-8} - 10^{-9}$ at BES-III with 10^{10} J/ψ events per year

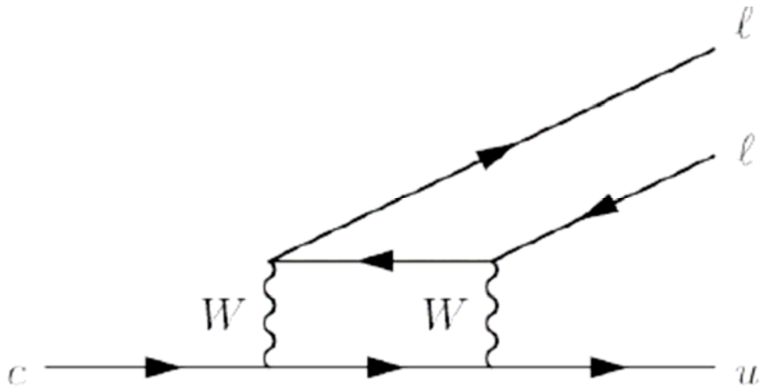
$J/\psi \rightarrow e^-$ proton +c.c, $J/\psi \rightarrow \mu$ proton +c.c can also be searched for.



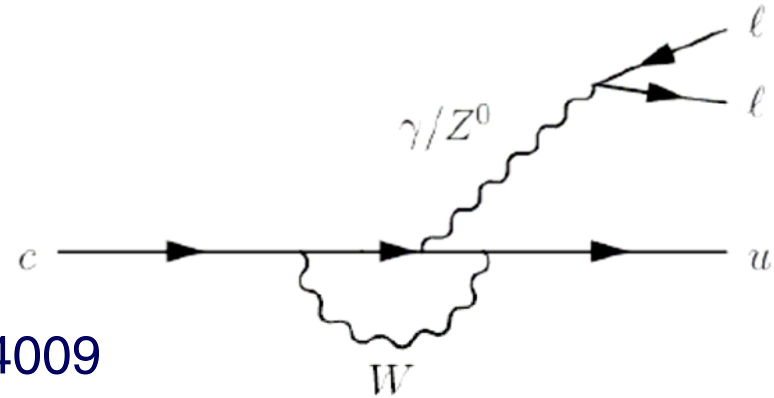
Rare and forbidden charm decays

Charm FCNC decays heavily GIM suppressed in SM:

$BF(c \rightarrow ull) \sim 10^{-8}$



Burdman et. al., PRD66(2002)014009



New Physics can contribute in loop, loop is different from B and K mesons

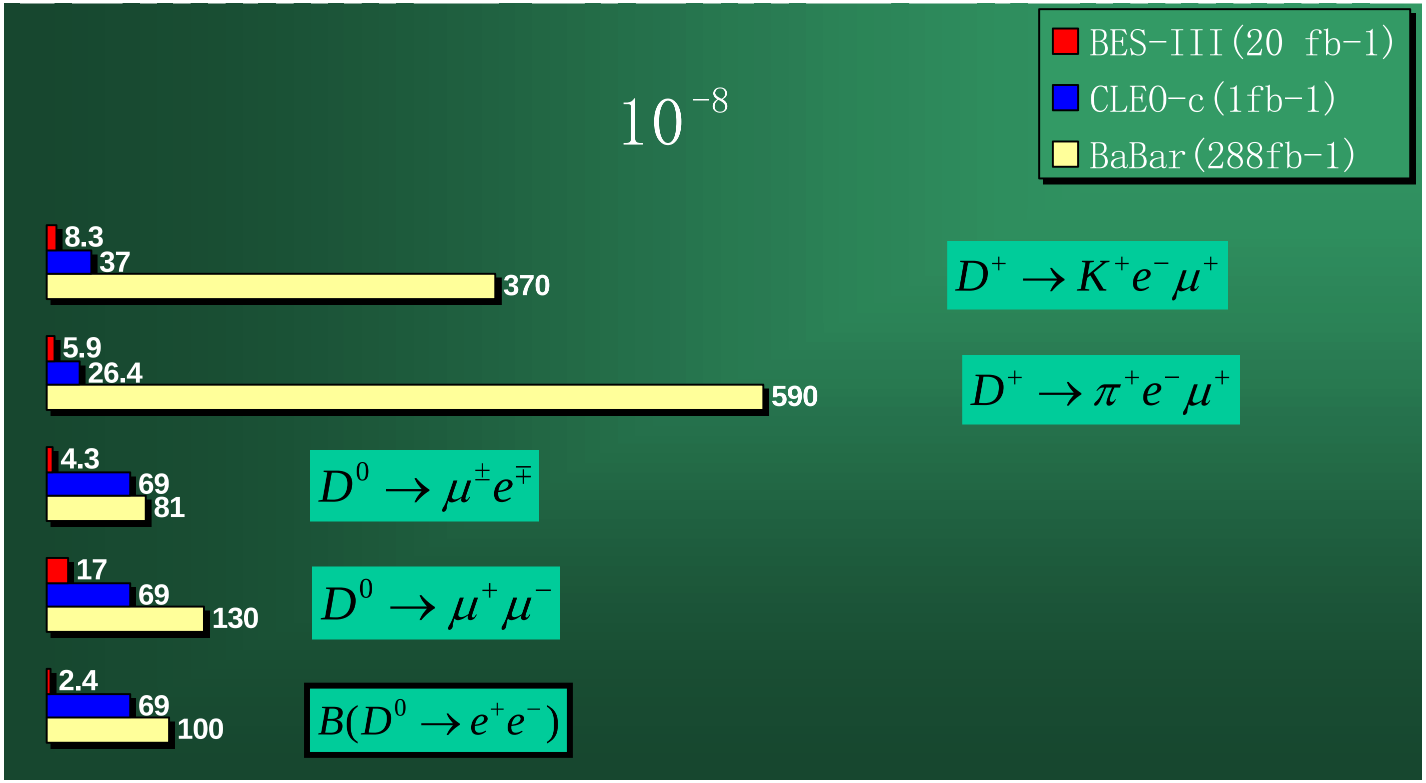
Lepton decays: $D_0 \rightarrow l^+l^-$ (l = e,μ);

GIM suppressed decays: $D_0^{(\pm)} \rightarrow M_0^{(\pm)}\ l^+l^-$ (M is an allowed meson);

LFV decays: $D^0 \rightarrow e^+\ \mu^-$, $D_0^{(\pm)} \rightarrow M_0^{(\pm)} e^+\ \mu^-$;

LNV decays: $D^\pm \rightarrow M^\pm\ l^+\ l^+$ (l = e, μ; same signed di-lepton);

Sensitivity to rare and forbidden charm decays

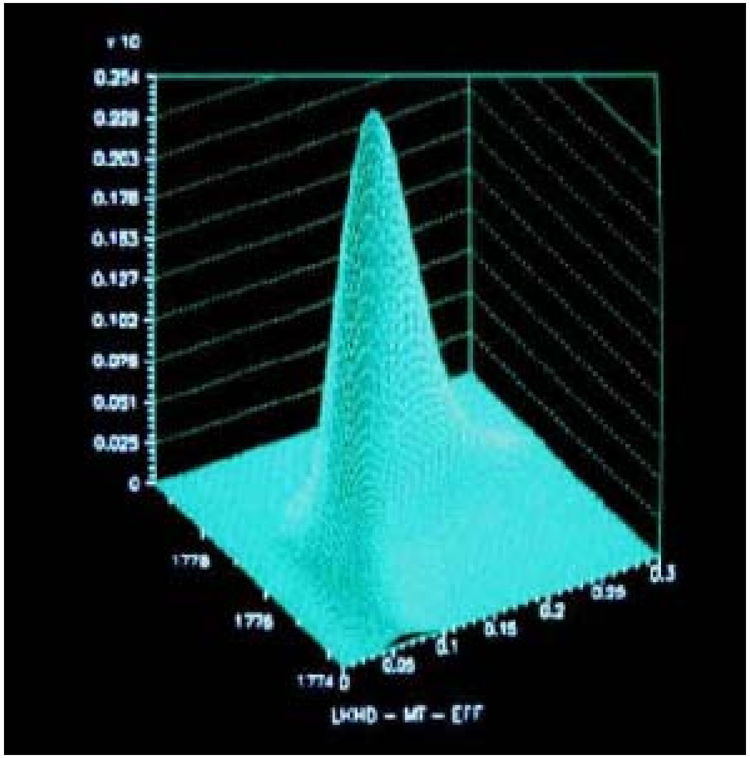


LFV and LNV are "smoking guns", any indication of a deviation from zero will indicate New Physics.


Summary

Many things just skipped…

- Measurement of τ mass and branching fractions – requires precise beam energy measurement
- Precise R measurements, including spectroscopy above $D\bar{D}$ threshold
- Hundreds of branching fraction measurements
- Studies of invisible decays
- …



- Upgrades planned:
  - Beam energy
  - Better ToF

Summary

- There is a lot of interesting physics at charm energies
- Many measurements are unique to BES III
- BES III will contribute to
  - Hadron spectroscopy
  - Charmonium physics
  - Charm physics
  - Tau physics
- BES III will mostly be systematically limited
  – a lot of work in front of us
- First beam time from June to end of year
- First results by next year – if things go moderately well, could have the worlds largest J/ψ sample by then

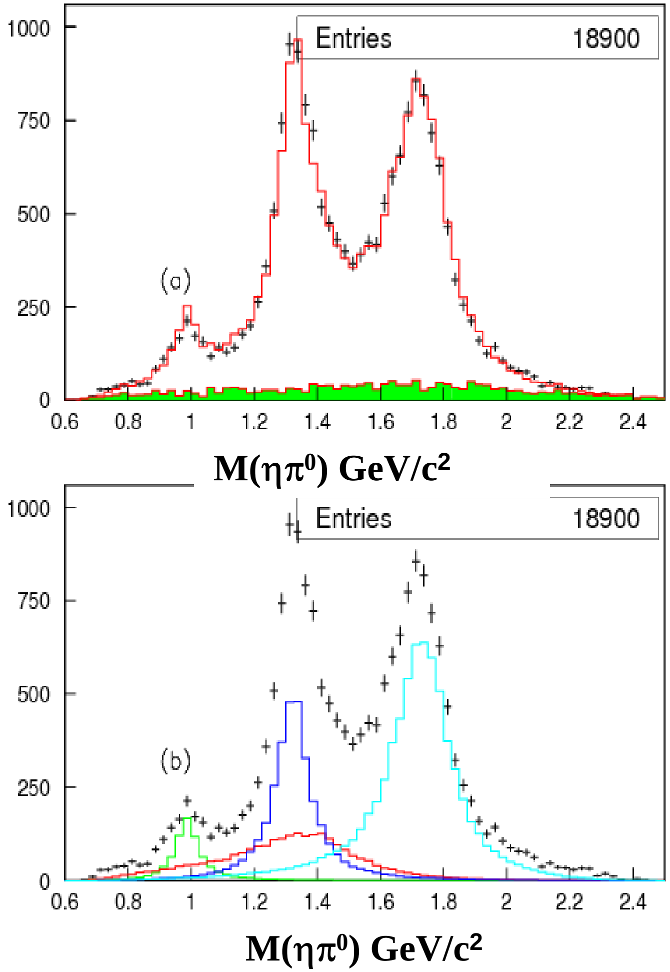
谢谢大家

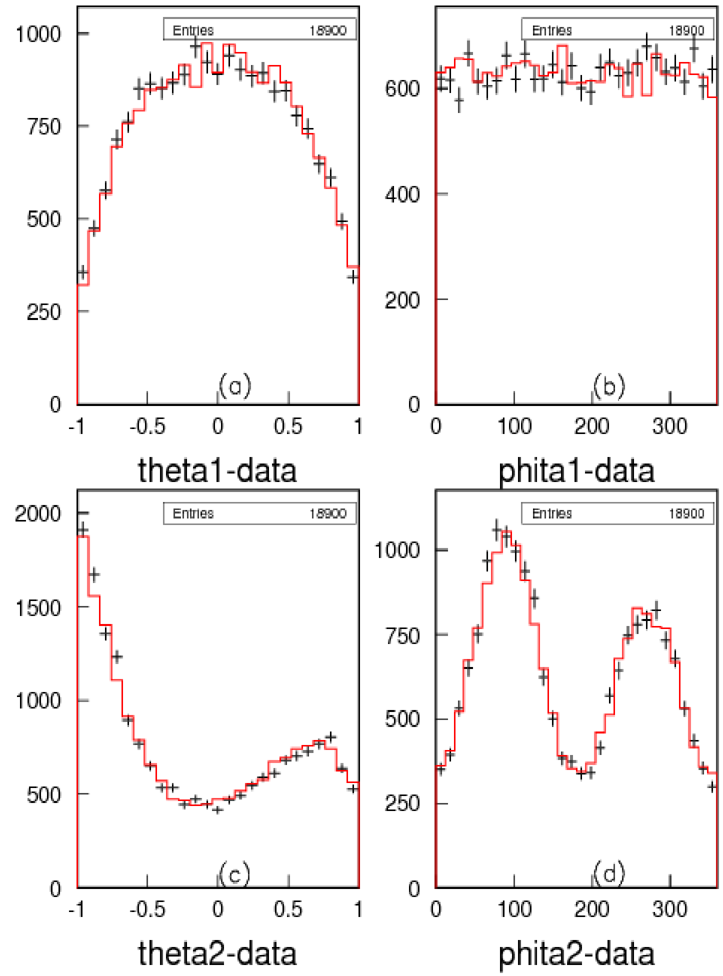
Many thanks for slides and advice to

Li Haibo, Steve Olsen, Shen Xiaoyan, Sébastien Descotes-Genon, Matthew Shepherd


温系统正在运行
禁止踩踏

Search for 1^{-+} in $J/\psi \to \rho^0 X$, $X \to \eta\pi^0$





Requires Partial Wave Analysis

[2] D.R. Thompson *et al.*, Phys. Rev. Lett. **79**, 1630 (1997).
[3] S.U. Chung *et al.*, Phys. Rev. D **60**, 092001 (1999).
[4] A. Abele *et al.*, Phys. Lett. B **423**, 175 (1998).

Sensitivity to y and y_{CP} at BES-III

y can be probed with first order sensitivity:

- ✓ Reconstruct *K+K-* (*CP*+) decay → other side must be D_1 (*CP*-)

$$n_{KK} = 2B_{KK}\Gamma_1 = 2B_{KK}(1-\eta y)\Gamma \quad \text{where } \eta = \pm 1 \text{ for CP} = \pm$$

$$1 - y = \frac{n_{KK}}{2N_{DD}} \frac{1}{B_{KK}}$$

- ✓ y_{CP} in semileptonic tag + CP tags:

PRD 75, 094019 (2007)
Cheng, He, Li , Wang and Yang

$$y_{CP} = \frac{\Gamma(CP+) - \Gamma(CP-)}{\Gamma(CP+) + \Gamma(CP-)} = y\cos\phi + x \cdot \Delta \sin\phi$$

No CPV in mixing →

$$y_{CP} \approx y\cos\phi$$

With 20 fb $^{-1}$ data at BES-III, and a CP tag rate of 1.1%, the sensitivity to y_{CP} is 0.003, which would be 4.3 σ with the current world average

$$y_{CP} = (1.12 \pm 0.32)\%$$

$$\Delta(y) = \frac{\pm 26}{\sqrt{N(D^0\bar{D}^0)}} = \pm 0.003.$$

Neutral D mixing – current state

Semileptonic and hadronic D decays

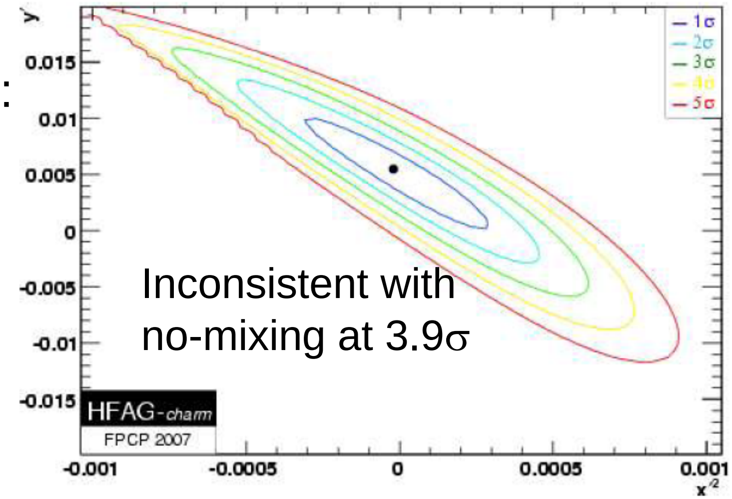
$$R_M = \frac{x^2 + y^2}{2} = \frac{x'^2 + y'^2}{2}$$

$$R_M = (2.1 \pm 1.1) \times 10^{-4}$$

Averaged y_{CP} from KK, ππ lifetime ratio

$$y_{CP} = (1.12 \pm 0.32)\% \quad (3.9\ \sigma)$$

Combined contour in (x'^2, y'):



Averaged WS Kπ mixing results (time-dependent):

$$x'^2 = (-0.1 \pm 2.0) \times 10^{-4}$$

$$y' = (0.55^{+0.28}_{-0.37})\%$$

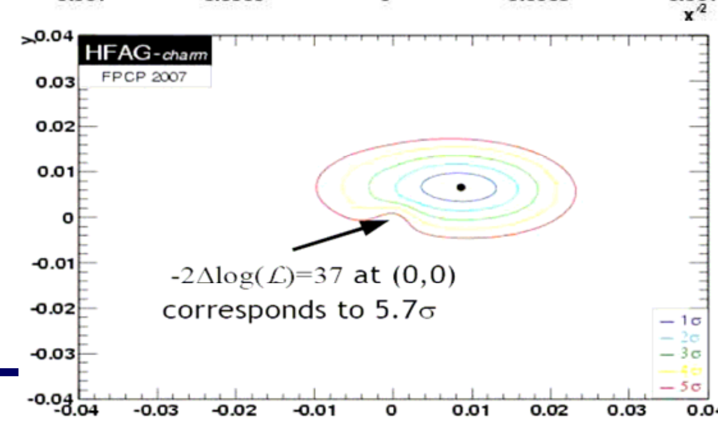
$$R_D = (0.330^{+0.014}_{-0.012})\%$$

Averaged mixing results (time-dependent):

$$x = (0.87^{+0.30}_{-0.34})\%$$

$$y = (0.66 \pm 0.21)\%$$

This average include preliminary CLEO-c measurement of $\cos\delta_{K\pi} = 1.09 \pm 0.66$



Strong phase

CP even:

$$D_1 = \frac{1}{\sqrt{2}}\left(D^0 + \overline{D}^0\right)$$

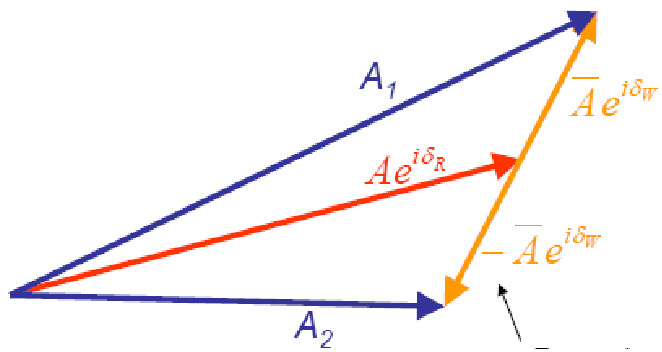
CP odd :

$$D_2 = \frac{1}{\sqrt{2}}\left(D^0 - \overline{D}^0\right)$$

Consider the amplitudes for these mass eigenstates decaying to $K^-\pi^+$:

$$A_1 = \langle K^-\pi^+ | D_1 \rangle = \frac{1}{\sqrt{2}}\left(\langle K^-\pi^+ | D^0 \rangle + \langle K^-\pi^+ | \overline{D}^0 \rangle\right) \equiv \frac{1}{\sqrt{2}}\left(Ae^{i\delta_R} + \overline{A}e^{i\delta_W}\right)$$

$$A_2 = \langle K^-\pi^+ | D_2 \rangle = \frac{1}{\sqrt{2}}\left(\langle K^-\pi^+ | D^0 \rangle - \langle K^-\pi^+ | \overline{D}^0 \rangle\right) \equiv \frac{1}{\sqrt{2}}\left(Ae^{i\delta_R} - \overline{A}e^{i\delta_W}\right)$$



i.e. the CP even & CP odd rates to a specific final state will not be the same !

$$r = \frac{\overline{A}}{A}, \quad \delta = \delta_R - \delta_W$$

CP tagged Kπ decay:

$$\frac{\mathrm{B}(D_{CP+} \to K^-\pi^+) - \mathrm{B}(D_{CP-} \to K^-\pi^+)}{\mathrm{B}(D_{CP+} \to K^-\pi^+) + \mathrm{B}(D_{CP-} \to K^-\pi^+)} = 2r\cos(\delta)$$

At BES-III, 20 fb^{-1} data, the sensitivity: δ (cosδ) = 0.04

Important for unitarity triangle γ

Rare D decays – BES III sensitivities

	SM ($\times 10^{-6}$)	RPV ($\times 10^{-6}$)	Current limit ($\times 10^{-6}$)	BESIII 10^{-8}
$D^+ \to K^+ \mu^- \mu^+$	-	-	9.2 (FOCUS)	10.5
$D^+ \to \pi^+ \mu^- \mu^+$	1.9	15	8.8 (FOCUS)	8.7
$D^+ \to \rho^+ \mu^- \mu^+$	-	-	560 (E653)	24.0
$D^0 \to \pi^0 \mu^- \mu^+$	-	-	180 (E653)	12.3
$D^0 \to \rho^0 \mu^- \mu^+$	1.8	8.7	22 (E791)	13.7
$D^0 \to \overline{K^0} \mu^- \mu^+$	-	-	260 (E653)	10.6
$D^+ \to K^+ e^- e^+$	-	-	6.2 (CLEO-c)	6.7
$D^+ \to \pi^+ e^- e^+$	2.0	2.3	7.4 (CLEO-c)	5.6
$D^+ \to \rho^+ e^- e^+$	-	-	-	15.4
$D^0 \to \pi^0 e^- e^+$	-		45 (CLEO-II)	7.9
$D^0 \to \rho^0 e^- e^+$	1.8	5.1	100 (CLEO-II)	10.3
$D^0 \to \overline{K^0} e^- e^+$	-	-	110 (CLEO-II)	7.5

90%CL

PRD66(2002)014009

LFV and LNV D Decays

90%CL

	Decay	SM 10^{-6}	RPV 10^{-6}	Current limit 10^{-6}	BESIII 10^{-8}
LNV	$D^+\to K^-\mu^+\mu^+$	0	--	13 (653)	10.4
LNV	$D^+\to \pi^-\mu^+\mu^+$	0	-	4.8 (FOCUS)	8.7
LNV	$D^+\to \rho^-\mu^+\mu^+$	0	-	56 (E653)	19.4
LNV	$D^+\to K^-e^+e^+$	0	-	4.5 (CLEO-c)	6.7
LNV	$D^+\to \pi^-e^+e^+$	0	-	3.6 (CLEO-c)	5.6
LNV	$D^+\to \rho^-e^+e^+$	0	-	-	12.4
LFV	$D^+\to K^+e^-\mu^+$	0	-	68 (E791)	8.3
LFV	$D^+\to \pi^+e^-\mu^+$	0	30	34 (E791)	5.9
LFV	$D^+\to \rho^+e^-\mu^+$	0	-	-	15.5
LFV	$D^0\to \pi^0e^-\mu^+$	0	-	86 (CLEO-II)	9.7
LFV	$D^0\to \rho^0e^-\mu^+$	0	14	49 (CLEO-II)	11.0
LFV	$D^0\to \overline{K}^0e^-\mu^+$	0	-	100 (CLEO-II)	9.6

PRD66(2002)014009