The BES-III Experiment

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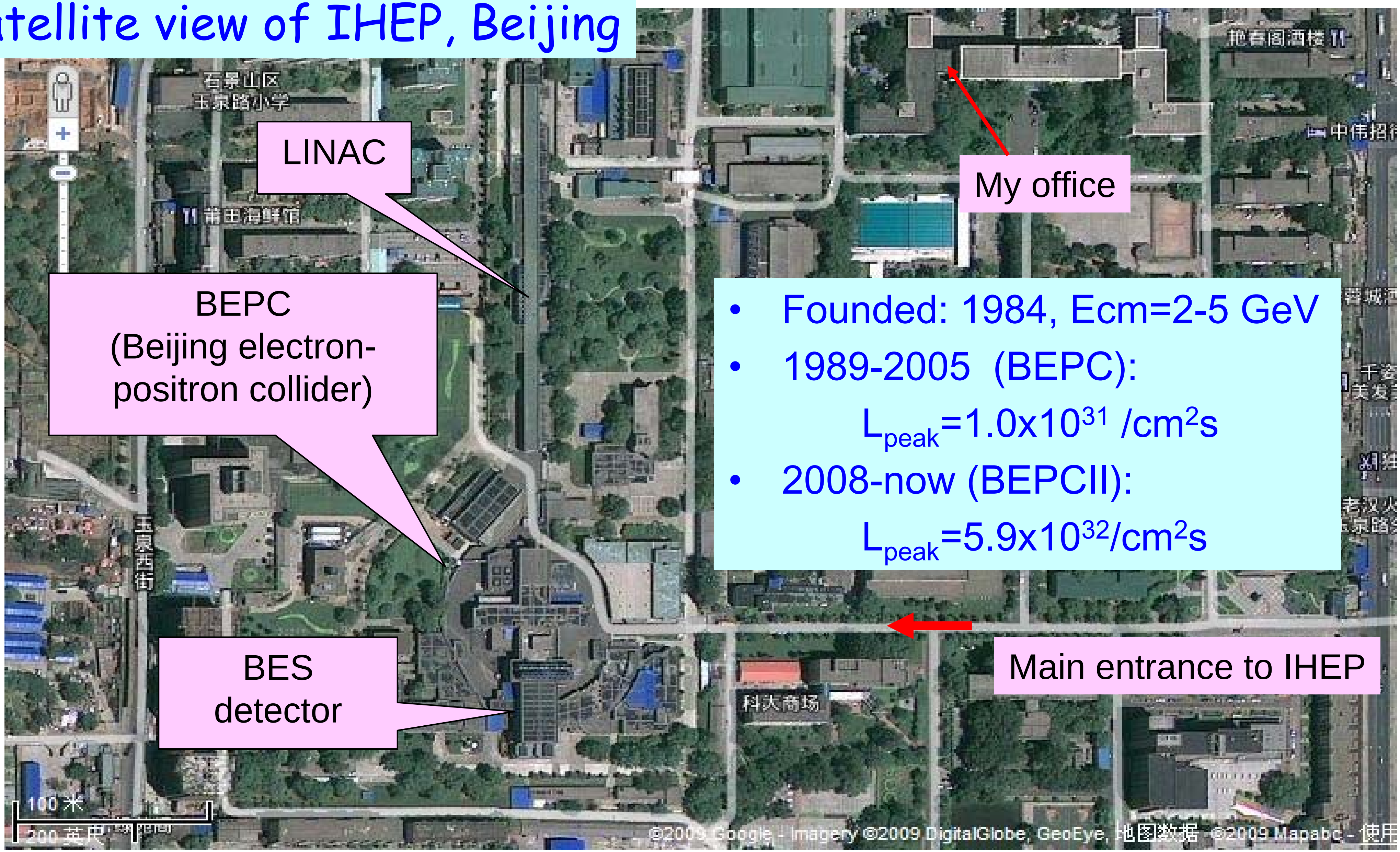
(for the BESIII Collaboration)
IHEP, Beijing

Jinan, April 7-9, 2011

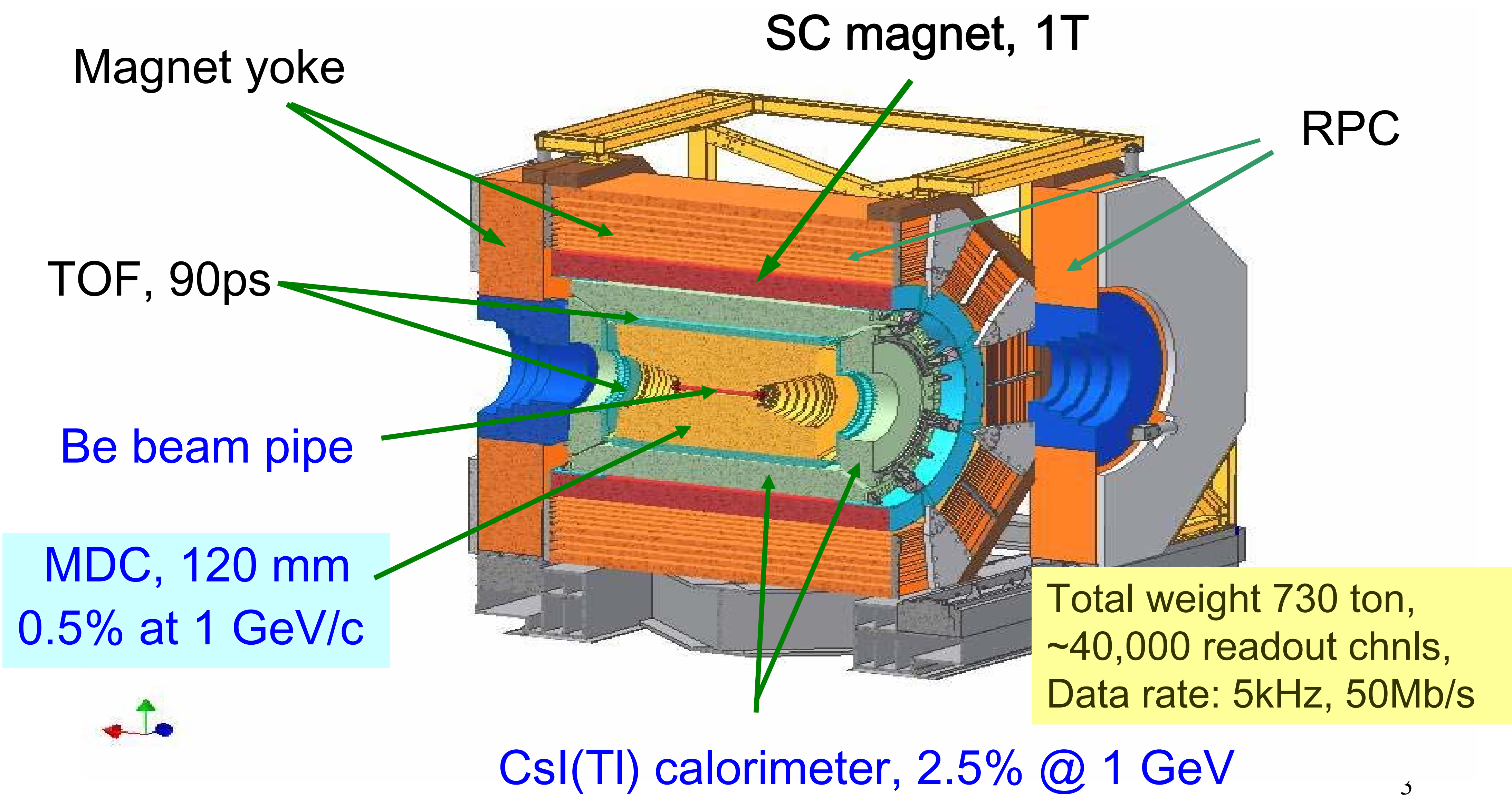
The Beijing Electron Positron Collider

Satellite view of IHEP, Beijing



- Founded: 1984, Ecm=2-5 GeV
- 1989-2005 (BEPC):
  L_{peak}=1.0x10^{31} /cm^2s
- 2008-now (BEPCII):
  L_{peak}=5.9x10^{32}/cm^2s

BESIII Detector



BESIII Physics Programs

BEST

- B (looks like DD for D or charm physics)
- E (looks like cc for charmonium physics)
- S (for light hadron Spectroscopy)
- T (for tau physics, looks like a Roman number “III”)

BESIII [and BESII, CLEOc] data

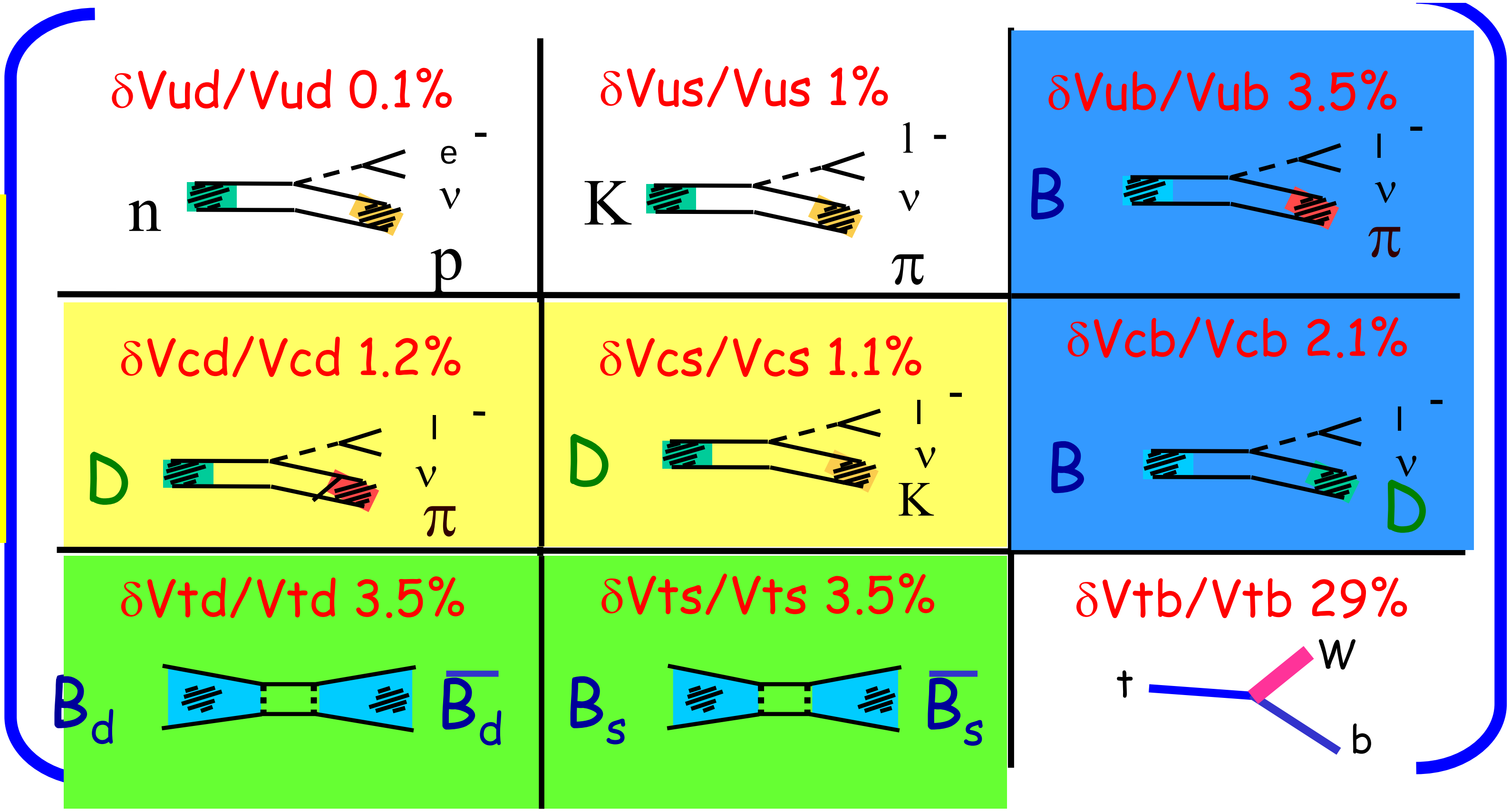
Data	BESII	CLEOc	BESIII (2012)
J/ψ	58 M	--	225 M (x5)
ψ'	14 M	26 M	106 M (x5)
ψ''	0.033 fb^{-1}	0.818 fb^{-1}	2.5 fb^{-1} (2.9 fb^{-1})
Continuum	6.4 pb^{-1} ($\sqrt{s}$=3.65 GeV)	21 pb^{-1} ($\sqrt{s}$=3.67 GeV)	42 pb^{-1} ($\sqrt{s}$=3.65 GeV)

Performance	BESII	CLEOc	BESIII
$\sigma p/p$	$1.7\%/\sqrt{1+p^2}$	0.6%@p=1GeV	0.5%@p=1GeV
$\sigma E/E$	$22\%/\sqrt{E}$	2.2%@E=1GeV	2.5%@E=1GeV
PartID	dE/dx+TOF	dE/dx+RICH	dE/dx+TOF
Coverage	80%	93%	93%

Charm Physics: CKM matrix

20 fb^{-1} DDbar pairs at $\psi(3770)$ and 20 fb^{-1} $D_s^{(*)+}D_s^{(*)-}$ pairs at $\psi(4040)$ or $\psi(4160)$ for high precision charm physics.

BESIII
one year
Lumi. 5 fb^{-1}
at $\psi(3770)$
peak

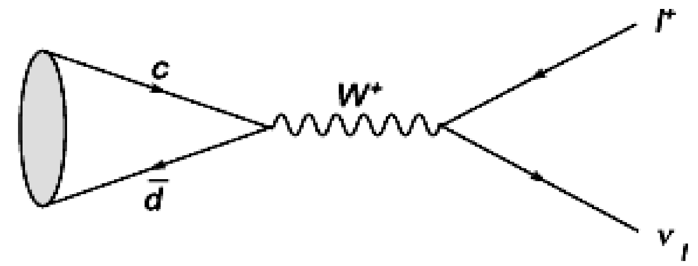


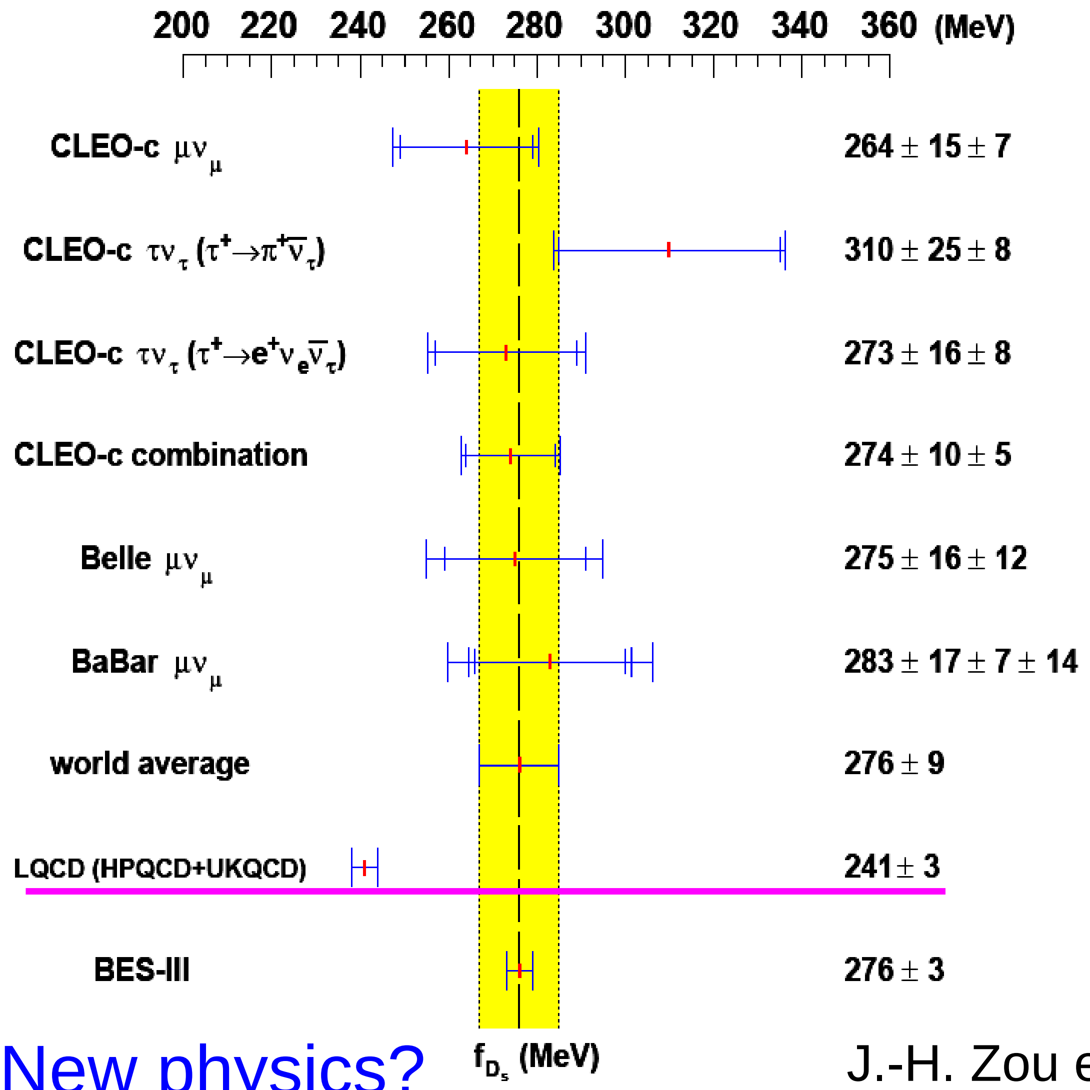
BESIII (yellow) | BESIII + Lattice QCD +B factories (blue) | BESIII + Lattice QCD +B-factories+pp/ppbar (green)

The Goal: Measure all CKM matrix elements and associated phases in order to over-constrain the unitary triangles.

Charm Physics: decay constants

$$\Gamma(D_{(s)} \to \ell\nu) = f^2_{D_{(s)}} |V_{cq}|^2 \frac{G_F^2}{8\pi} m_{D_{(s)}} m_\ell^2 \left(1 - \frac{m_\ell^2}{m^2_{D_{(s)}}}\right)^2$$





There is no fun in f_D since data agree with LQCD ☺

Will the ~3σ difference between data and LQCD persists?

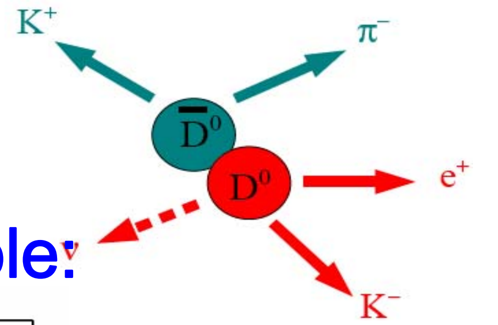
Table 3. Expected errors on the branching fractions for leptonic decays and decay constants at the BES-III with 20 fb^{-1} at $\psi(3770)$ peak and $E_{CM} = 4170$ MeV, respectively.

Observable	Error	Measurement	Error
$\mathcal{BR}(D^+ \to \mu^+\nu)$	2.0%	$f_D\|V_{cd}\|$	1.1%
$\mathcal{BR}(D_s^+ \to \mu^+\nu)$	2.0%	$f_{Ds}\|V_{cs}\|$	1.0%
$\frac{\mathcal{BR}(D_s^+\to\mu^+\nu)}{\mathcal{BR}(D^+\to\mu^+\nu)}$	2.6%	$\left\|\frac{V_{cs} f_{Ds}}{V_{cd} f_D}\right\|$	1.3%

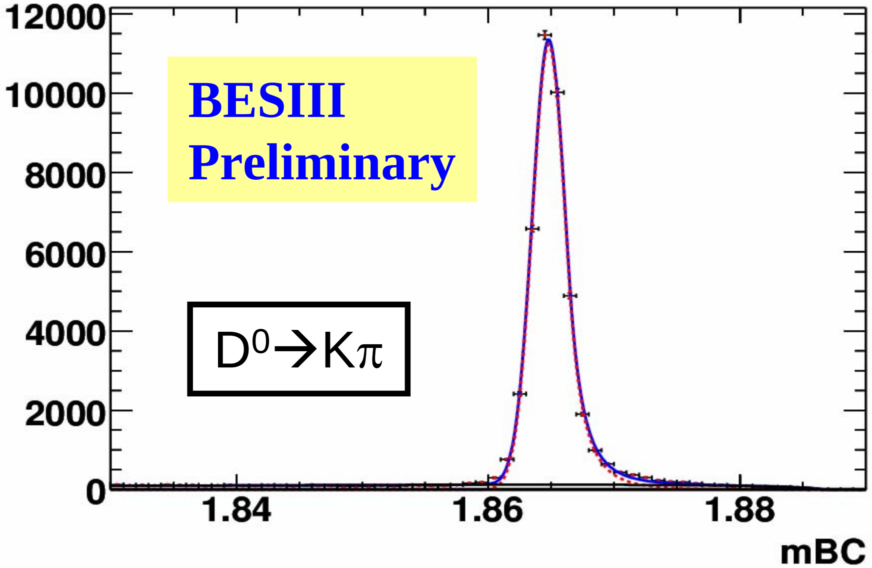
New physics?

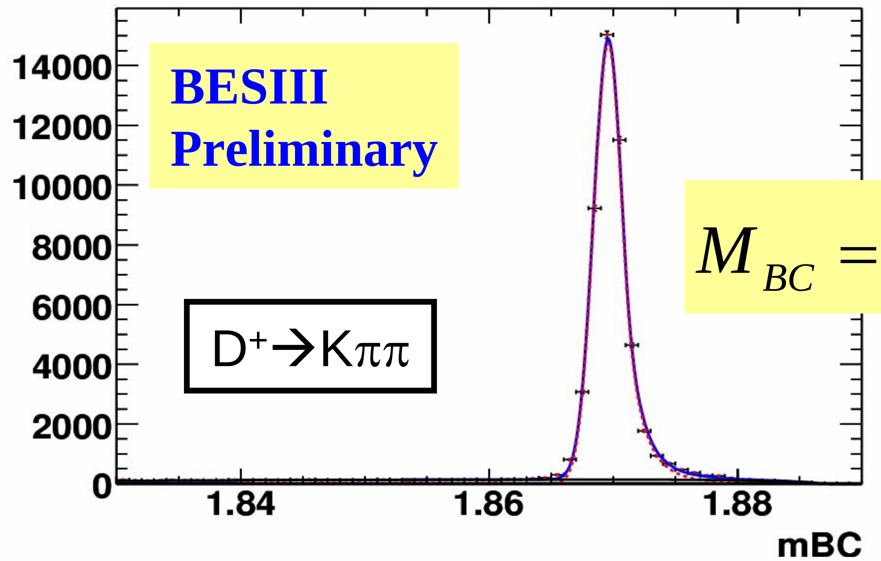
J.-H. Zou et al., arXiv: 0804.1822 [hep-ex]

Charm Program

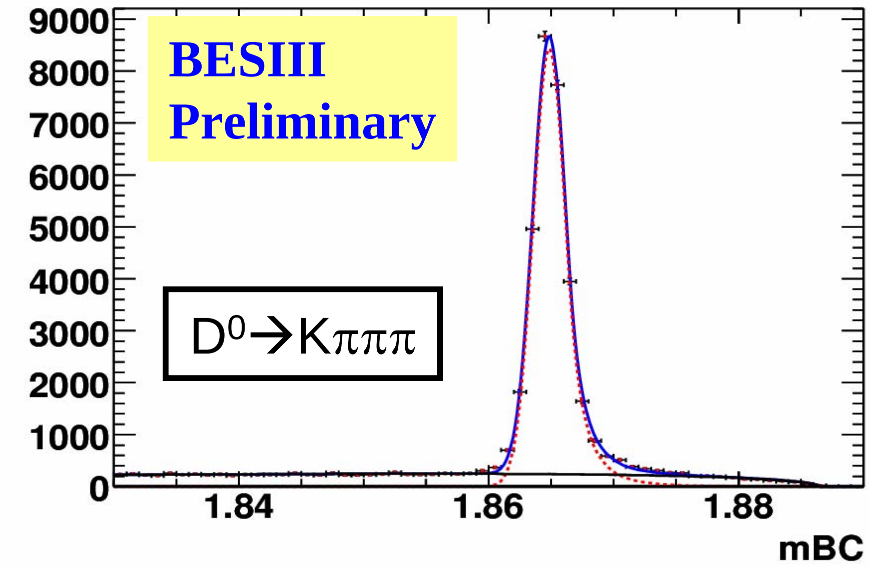


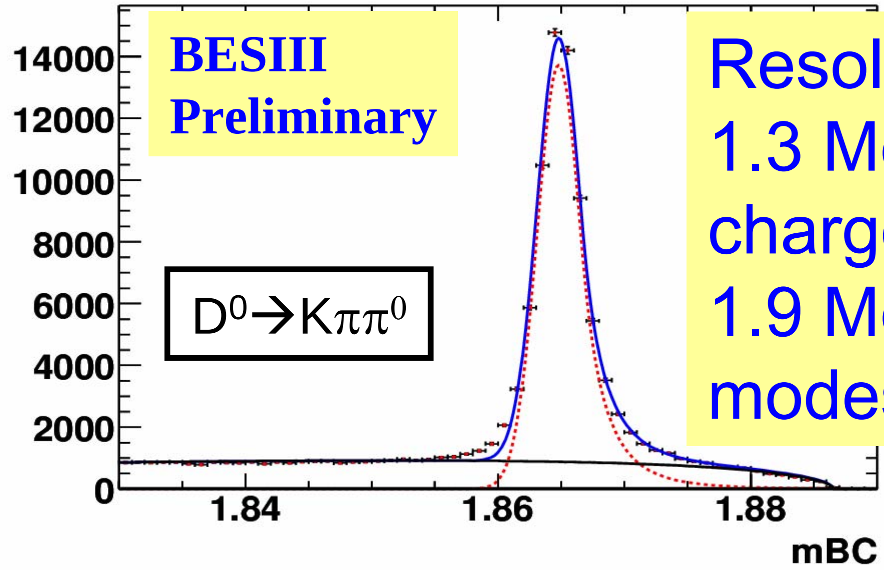
@ $\psi(3770)$ with 420 pb^{-1} first clean single tagging sample:





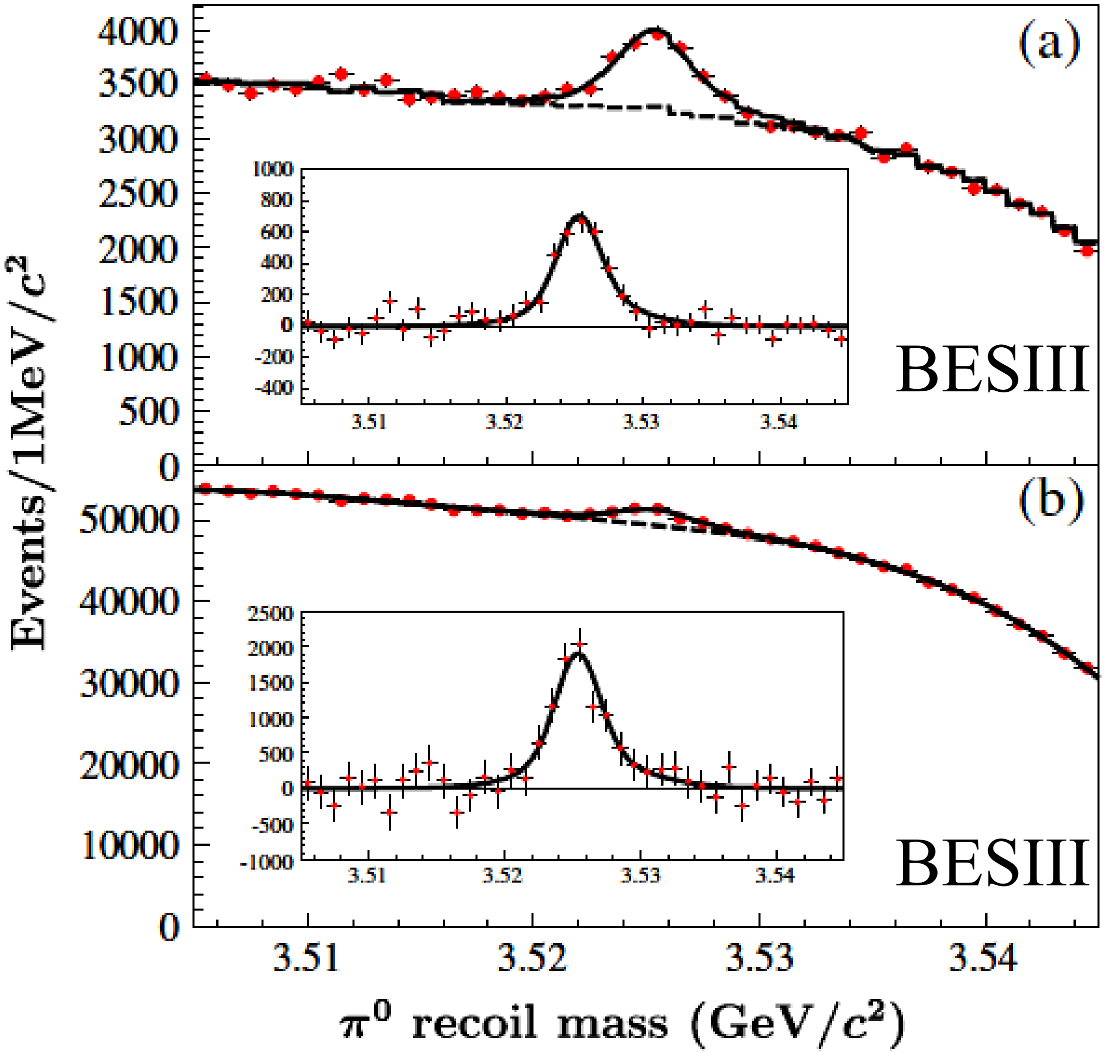
$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$





Resolution:
1.3 MeV for pure charged modes;
1.9 MeV for modes with one π^0.

$\psi(2S) \rightarrow \pi^0 h_c$ transition



BESIII: PRL 104, 132002 (2010)
Mass: 3525.40±0.13±0.18 MeV
Width: 0.73±0.45±0.28 MeV
(<1.44 MeV @ 90% C.L.)

CLEOc: PRL101, 182003 (2008)
Mass: 3525.28±0.19±0.12 MeV
Width: fixed to 0.9 MeV

ΔM_{hf}= <M(^3P_J)>-M($^1P_1$)
Agrees with zero within ~0.5 MeV

Information on spin-spin interaction.

Combined inclusive and E1-photon-tagged spectrum (First measurements)

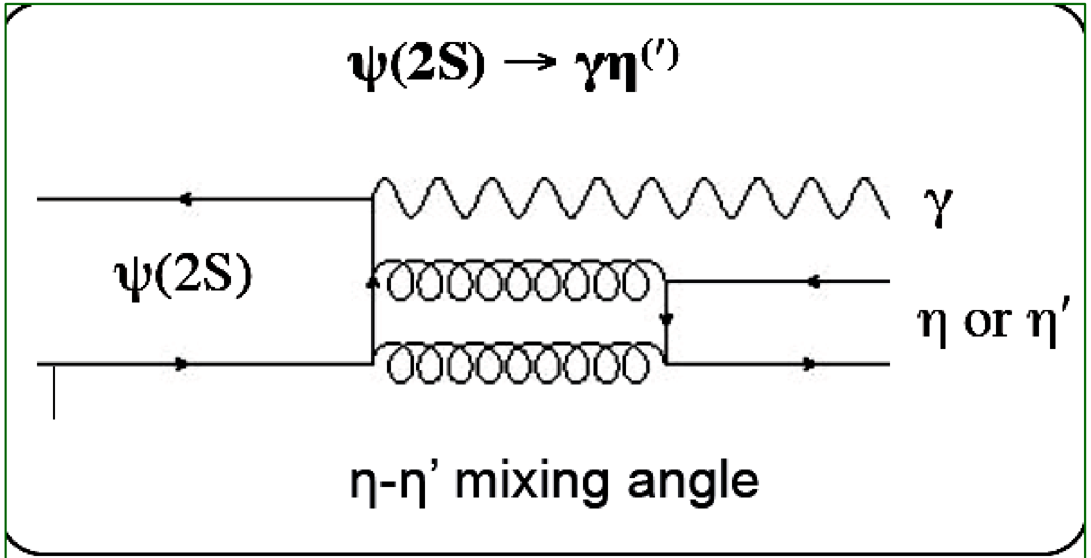
$B(\psi' \rightarrow \pi^0 h_c)$ = [8.4±1.3(stat.) ±1.0(syst.)]×10^{-4}

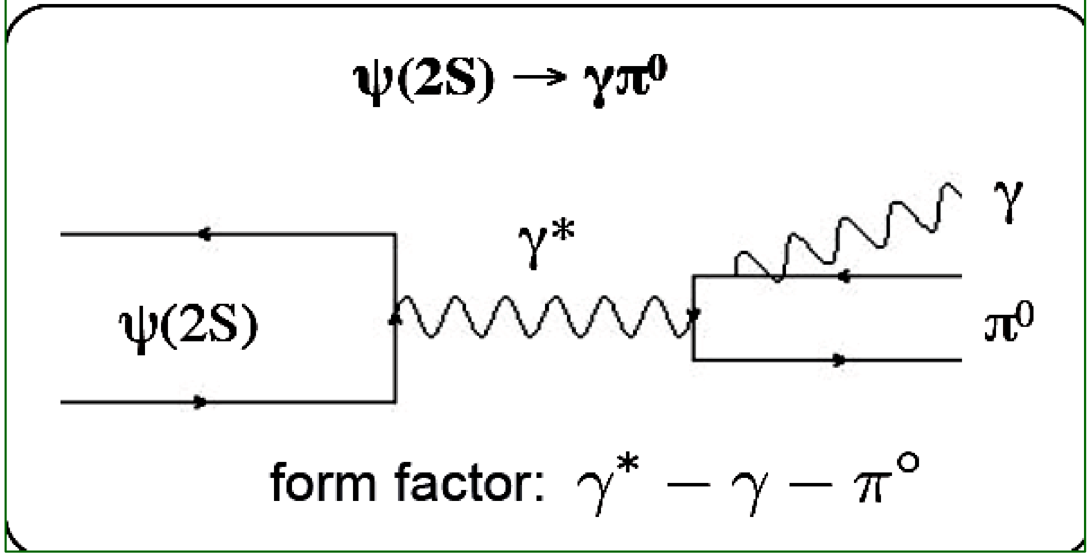
$B(h_c \rightarrow \gamma \eta_c)$ = [54.3±6.7(stat.) ±5.2(syst.)] %

Agree with predictions of Kuang, Godfrey, Dudek, et al.

J/ψ & ψ'→γπ^0, γη & γη'

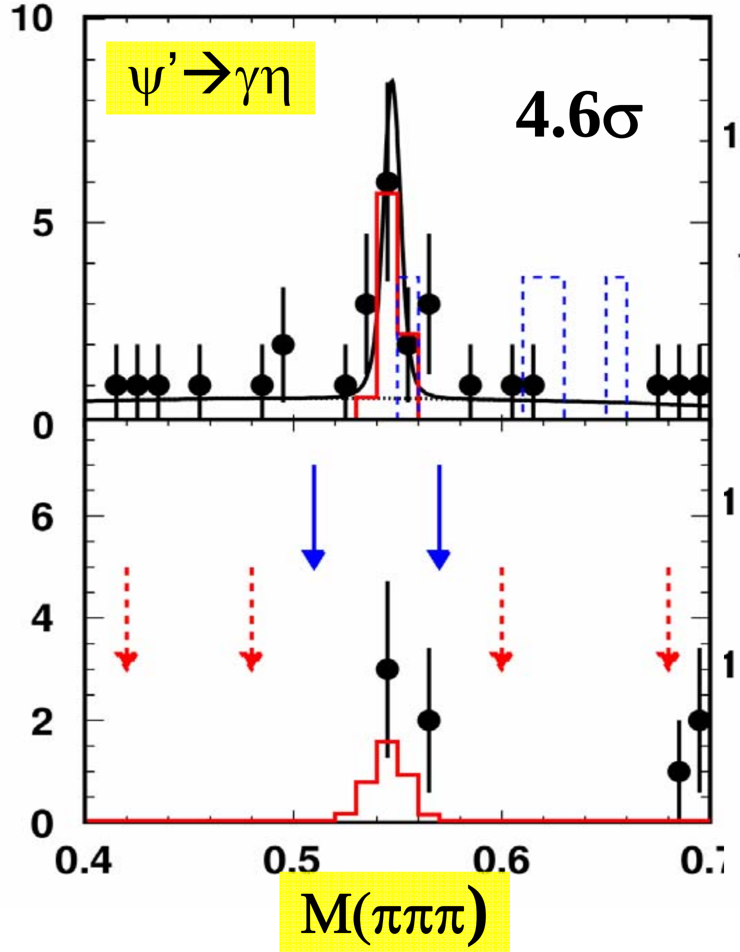
- Nature of charmonium & pseudoscalars
- Pseudoacalar mixing
  - η-η'
  - η-η'-η_c
- Vector Meson Dominance
- FSR from quark
- $\pi^0\gamma\gamma^*$ form factor at $Q^2 \sim 14\ \text{GeV}^2$
- "12% rule" & "ρπ puzzle"

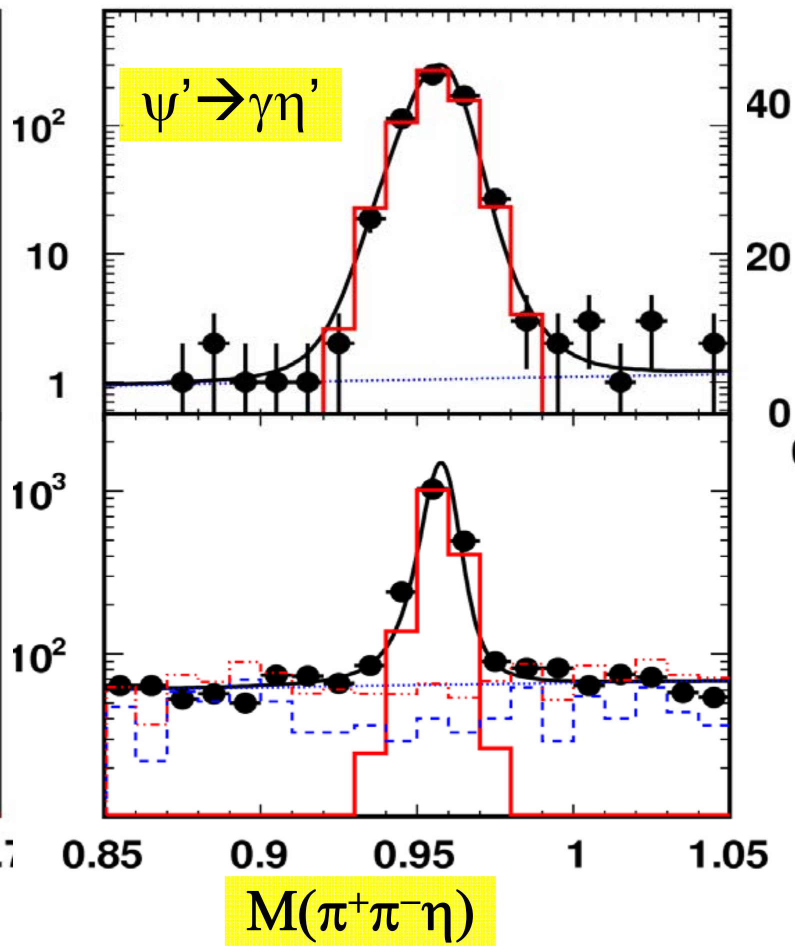


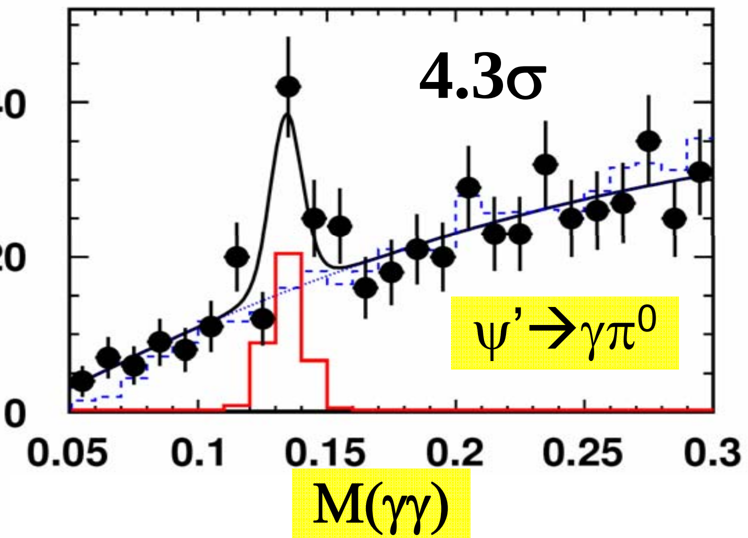


J/ψ & ψ'→γπ⁰, γη & γη'

PRL105, 261801 (2010)







$$R_V = \frac{B(V \to \gamma\eta)}{B(V \to \gamma\eta')}$$

$$R_{J/\psi} = (20.9 \pm 0.9)\%$$

$$R_{\psi'} = (1.10 \pm 0.39)\%$$

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

Interpretation by Q. Zhao, PLB697, 52 (2011)

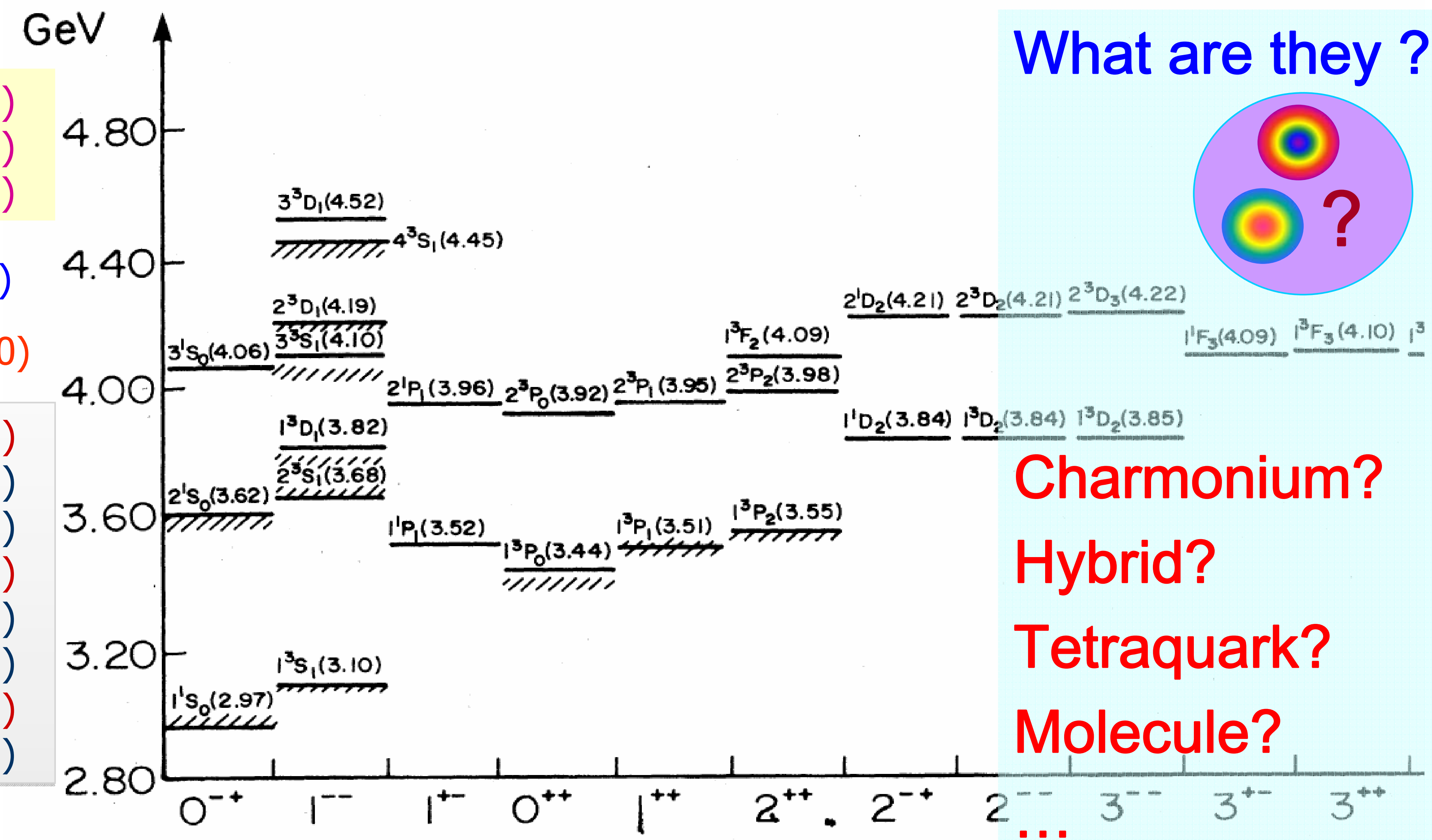
Charmonium + XYZ states

Z(4430)
Z(4250)
Z(4050)

X(3872)

XYZ(3940)

X(3915)
X(4160)
Y(4008)
Y(4140)
Y(4260)
Y(4360)
X(4350)
Y(4660)



What are they ?

Charmonium?

Hybrid?

Tetraquark?

Molecule?

...

Not all XYZ states are charmonia!

Production Rates of XYZ at BESIII

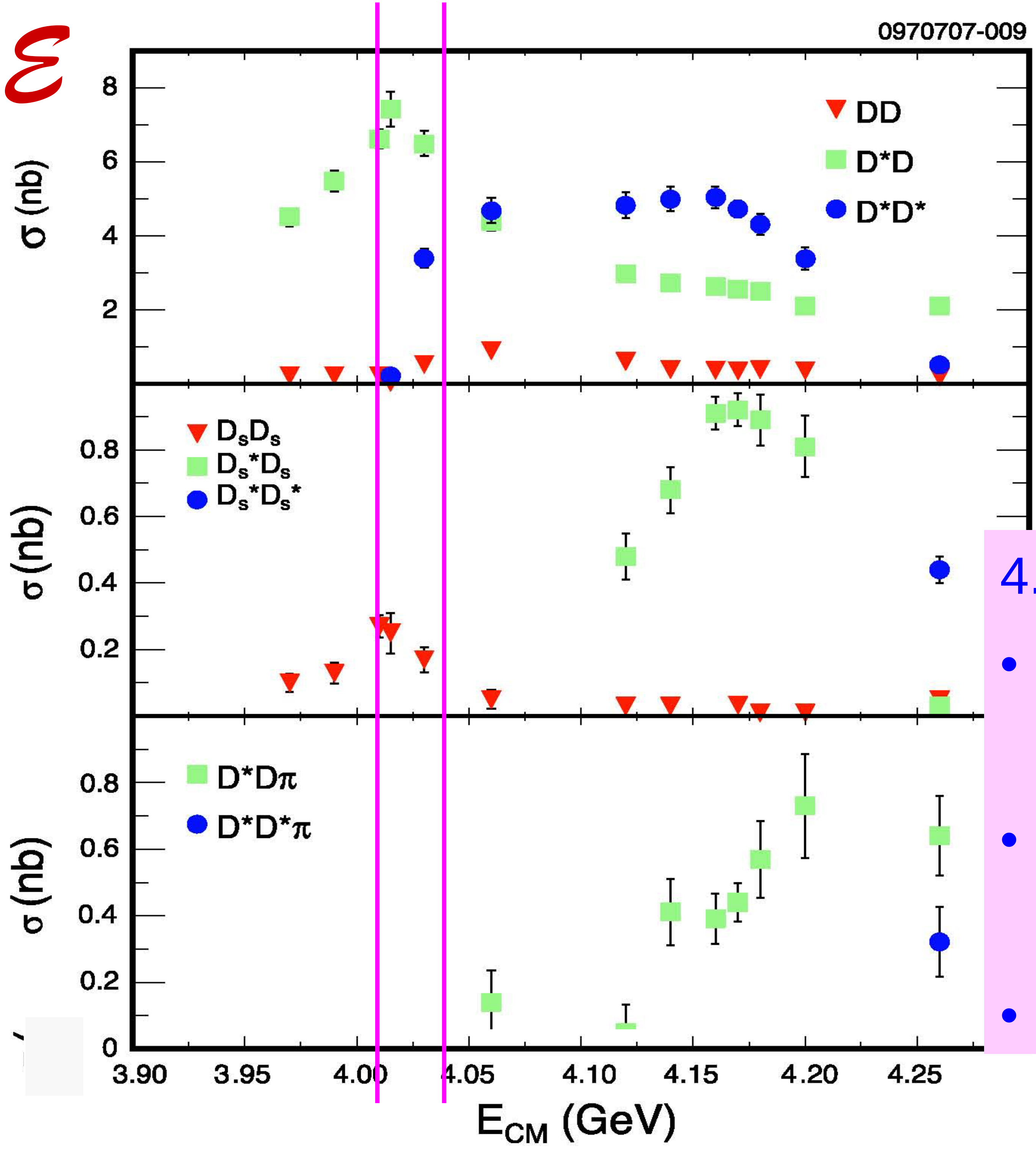
- No theoretical calculation on $\psi(3S) \rightarrow \gamma + XYZ$ if they are exotic states
- Assuming $M(\chi_{cJ}(2P)) \sim 3930$ MeV
  - $B(\psi(3S) \rightarrow \gamma\chi'_{cJ}) = (7, 3, 1) \times 10^{-4}$ for J=2,1,0

    [T. Barnes & S. Godfrey, PRD69, 054008 (2004)

    E. Eichten et al., Rev. Mod. Phys. 80, 1161 (2008)]

    - As masses of the $\chi_{cJ}(2P)$ states are very different from the expectation of the potential models. S-D mixing will also affect the predictions. BRs could be very different.
- Can we observe the X(3872) if it is the χ'_{c1} and the production rate is 3×10^{-4}?

BESIII will take 0.5/fb data at 4010 MeV!

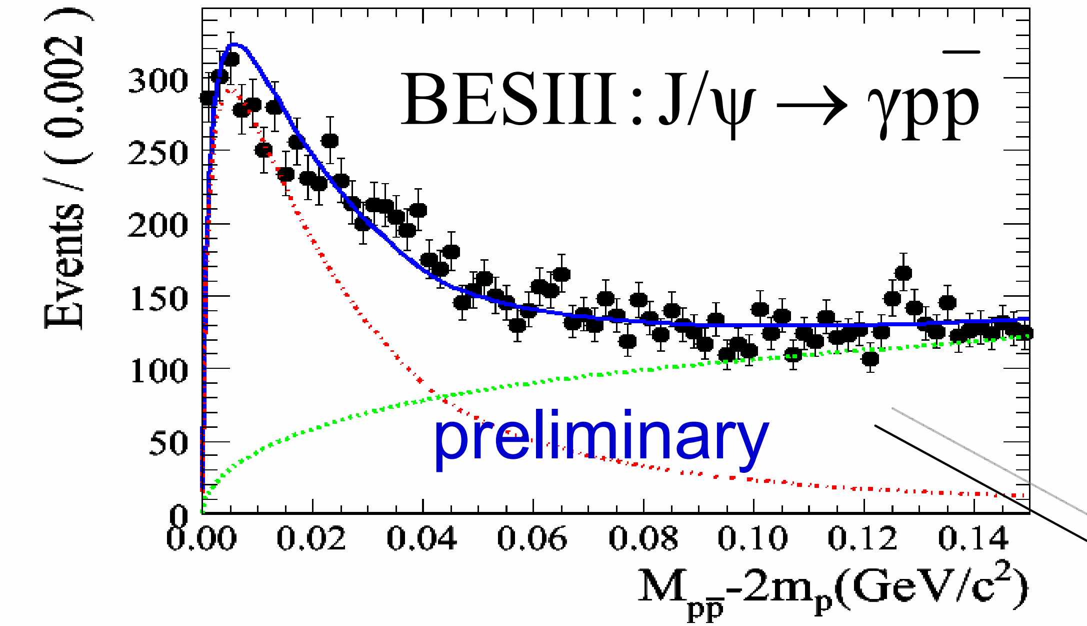


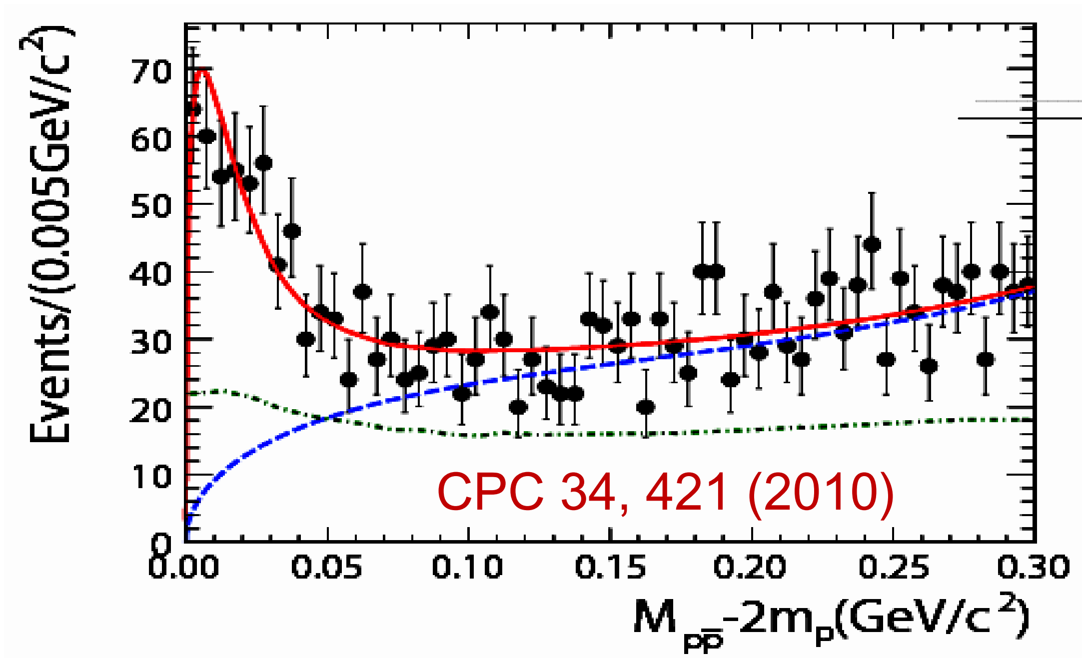
CLEOc
PRD80, 072001 (2009)

4.04 GeV vs. 4.01 GeV:

- No D*D*!
  - bkg for X3872→DD*
- More Ds!
  - Chance for f_{Ds} meas.!
- Data taking in May 2011!

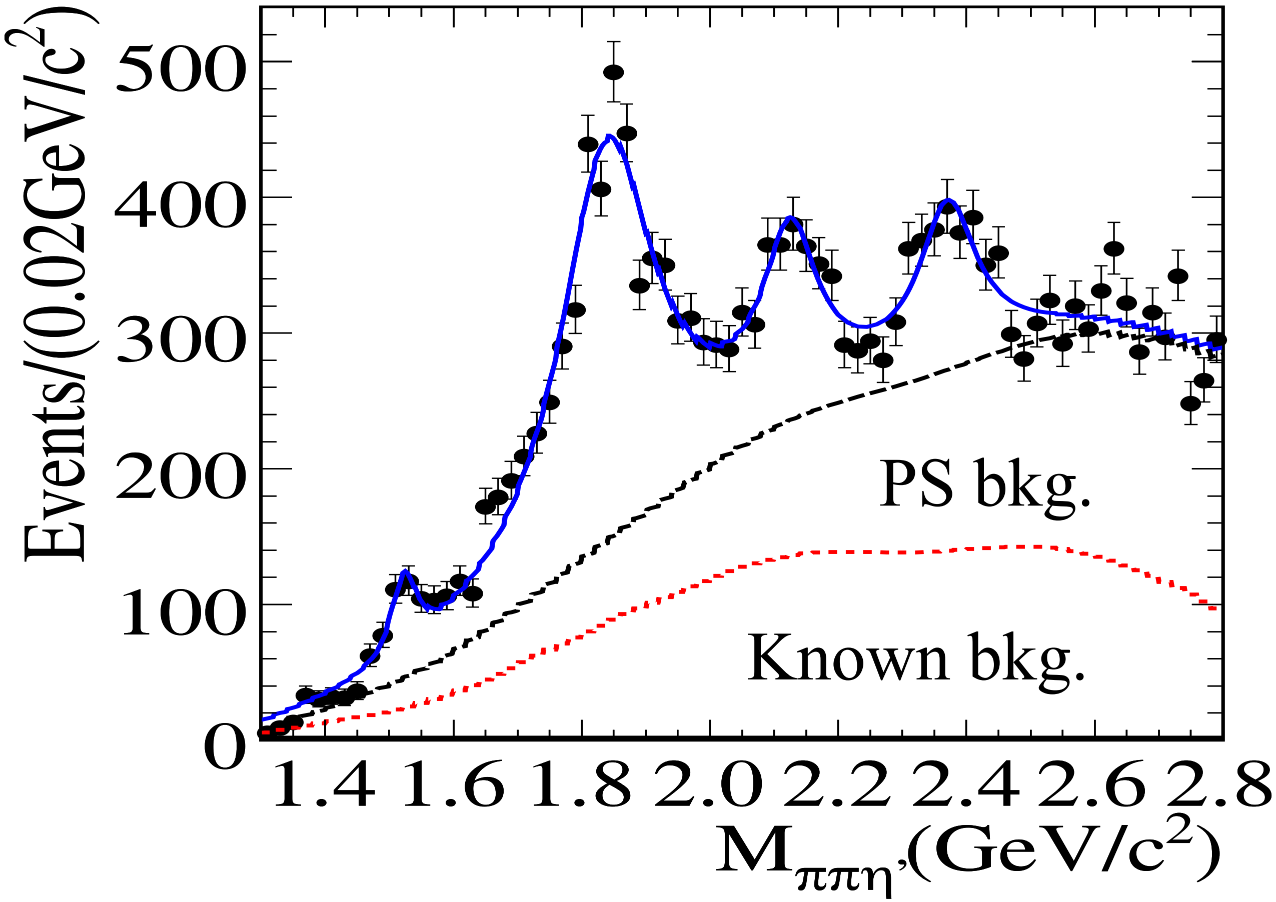
Enhancement at ppbar threshold





- Observed at BESII in 2003
  - PRL91, 022001
  - $M=1861^{+3}_{-10}{}^{+5}_{-25}$ MeV
  - Width < 38 MeV (90% CL)
  - Agree with spin zero expectation
- Confirmed at BESIII (& CLEOc)
  - $M=1861.6\pm0.8$ (stat.) MeV
  - Width<8 MeV @ 90% C.L.
  - $M=1859^{+6}_{-13}{}^{+7}_{-26}$ MeV
  - Width < 30 MeV (90% CL)
- Many possibilities:
  - Normal meson?
  - ppbar bound state/ multiquark/ glueball/ …

More states decays into $\eta'\pi^+\pi^-$



- X(1835) at BESII
- Confirmed at BESIII, width much larger
- Two more peaks!!
- JP unknown, need PWA
- Nature?
  - X1835=X1859=ppbar bound state?
  - Pseudoscalar glueballs?
  - Excited η or η' states?
  - …

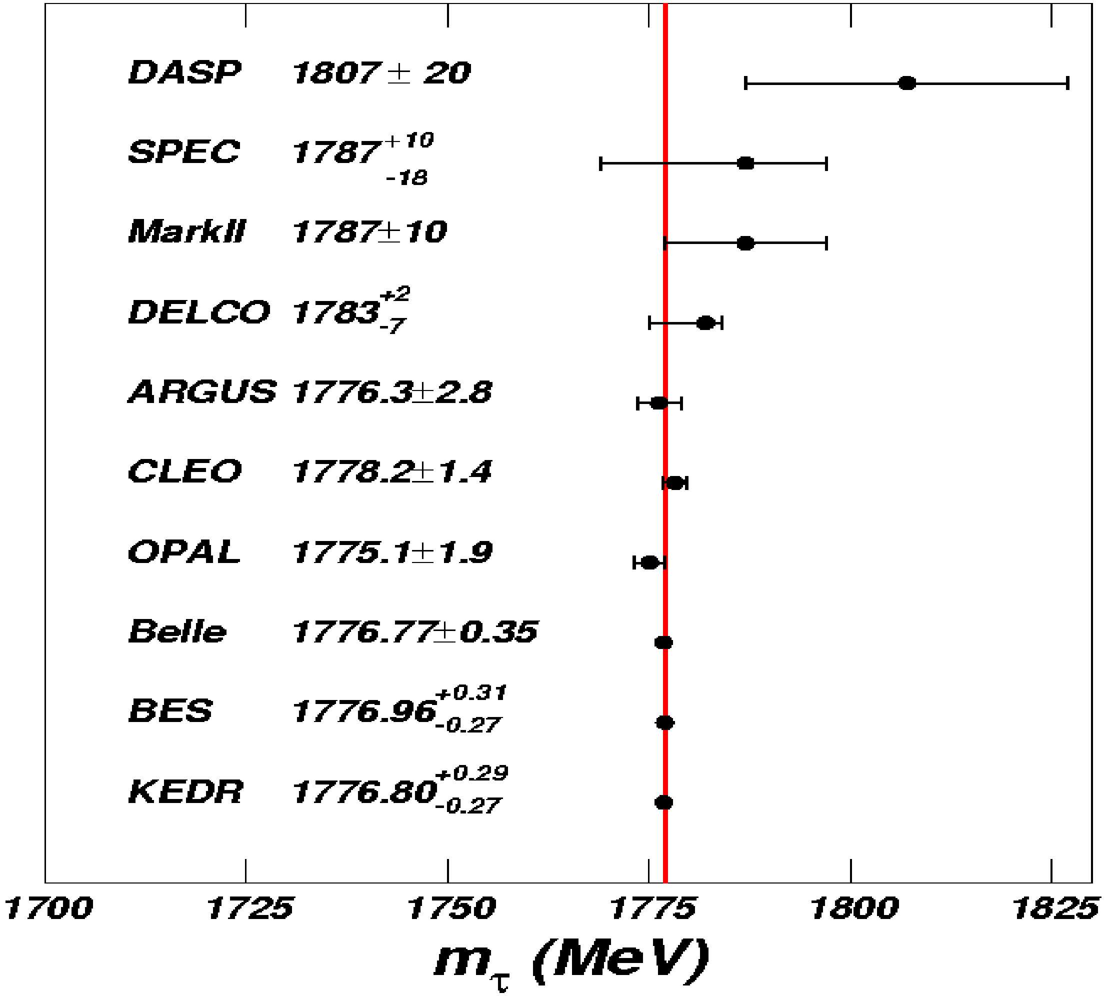
BESII X(1835): $M = 1833.7 \pm 6.1 \pm 2.7$ MeV/c^2

$\Gamma = 67.7 \pm 20.3 \pm 7.7$ MeV/c^2

PRL106, 072002 (2011)

State	X(1835)	X(2120)	X(2370)
Mass (MeV)	$1836.5\pm3.0^{+5.6}_{-2.1}$	$2122.4 \pm6.7^{+4.7}_{-2.7}$	$2376.3 \pm8.7^{+3.2}_{-4.3}$
Width (MeV)	$190\pm9^{+38}_{-36}$	$83 \pm16^{+31}_{-11}$	$83 \pm17^{+44}_{-6}$

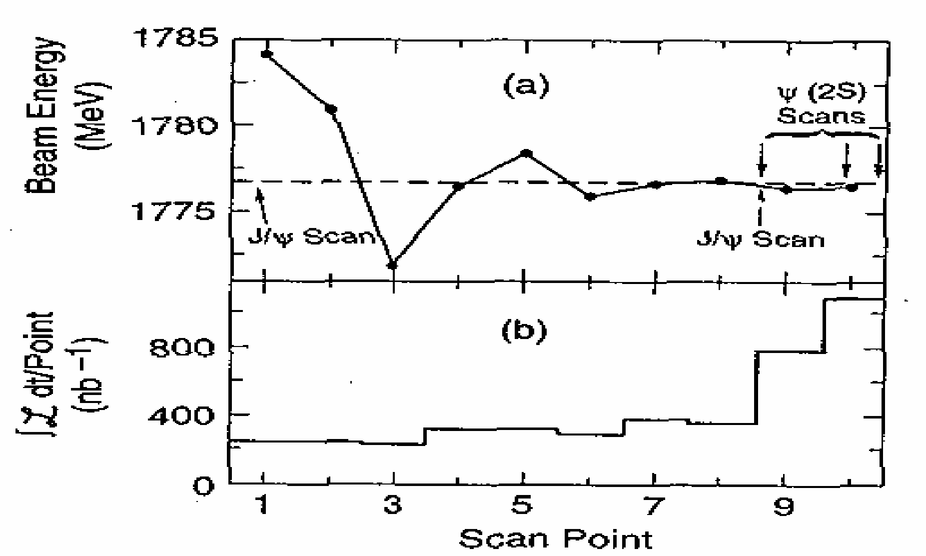
τ mass



$$M_\tau = 1776.96 \begin{smallmatrix} +0.18 & +0.25 \\ -0.21 & -0.17 \end{smallmatrix} \text{ MeV}$$

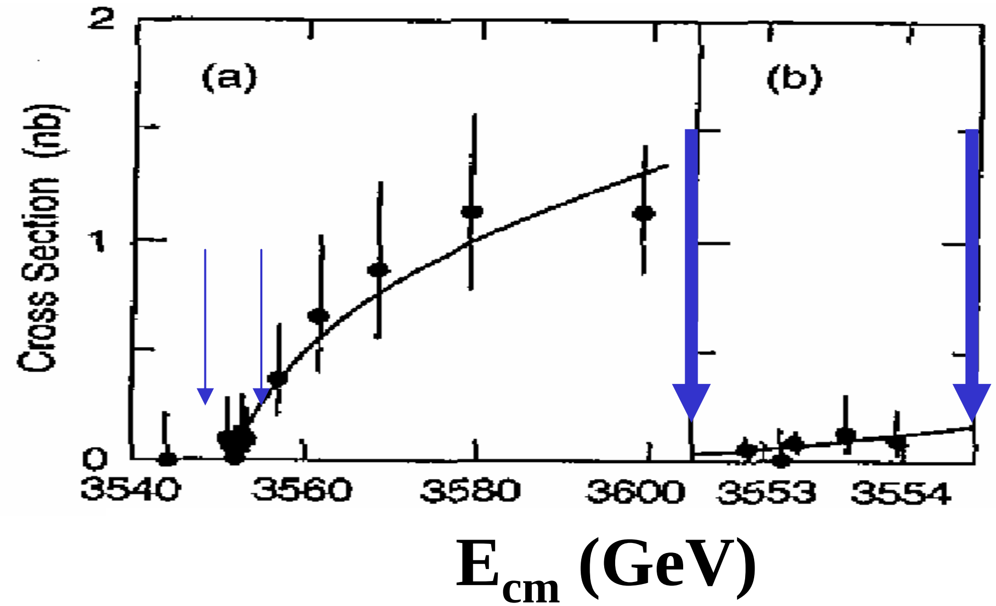
$$\sigma M_\tau / M_\tau = 1.7 \times 10^{-4}$$

PDG10: 1776.82±0.16 MeV



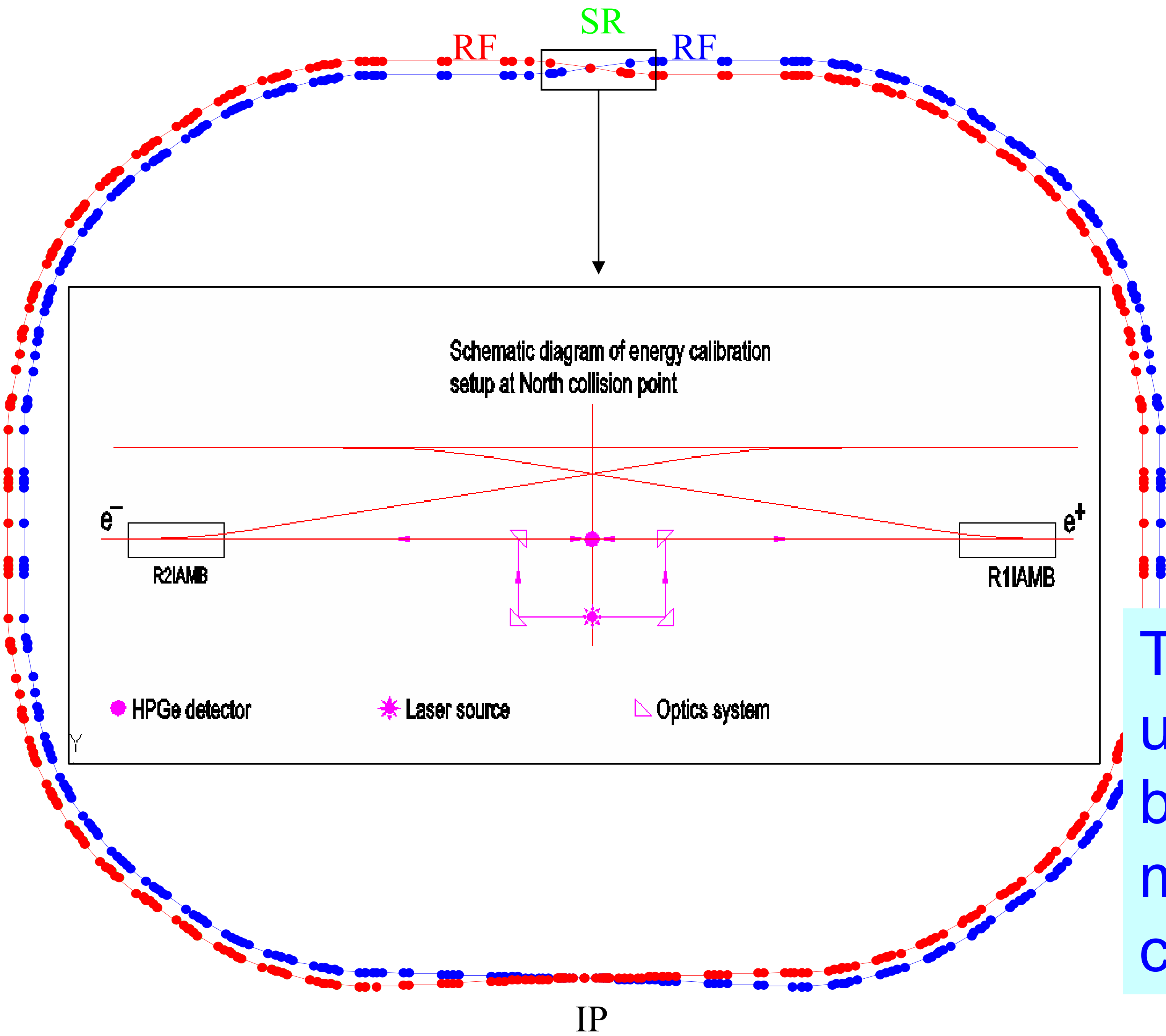
PRD 53 (1993)20

12 points, Lum.: 5 pb^{-1}



BESI results: stat. err. $(0.18 \oplus 0.21)$
is compatible with syst. $(0.25 \oplus 0.17)$

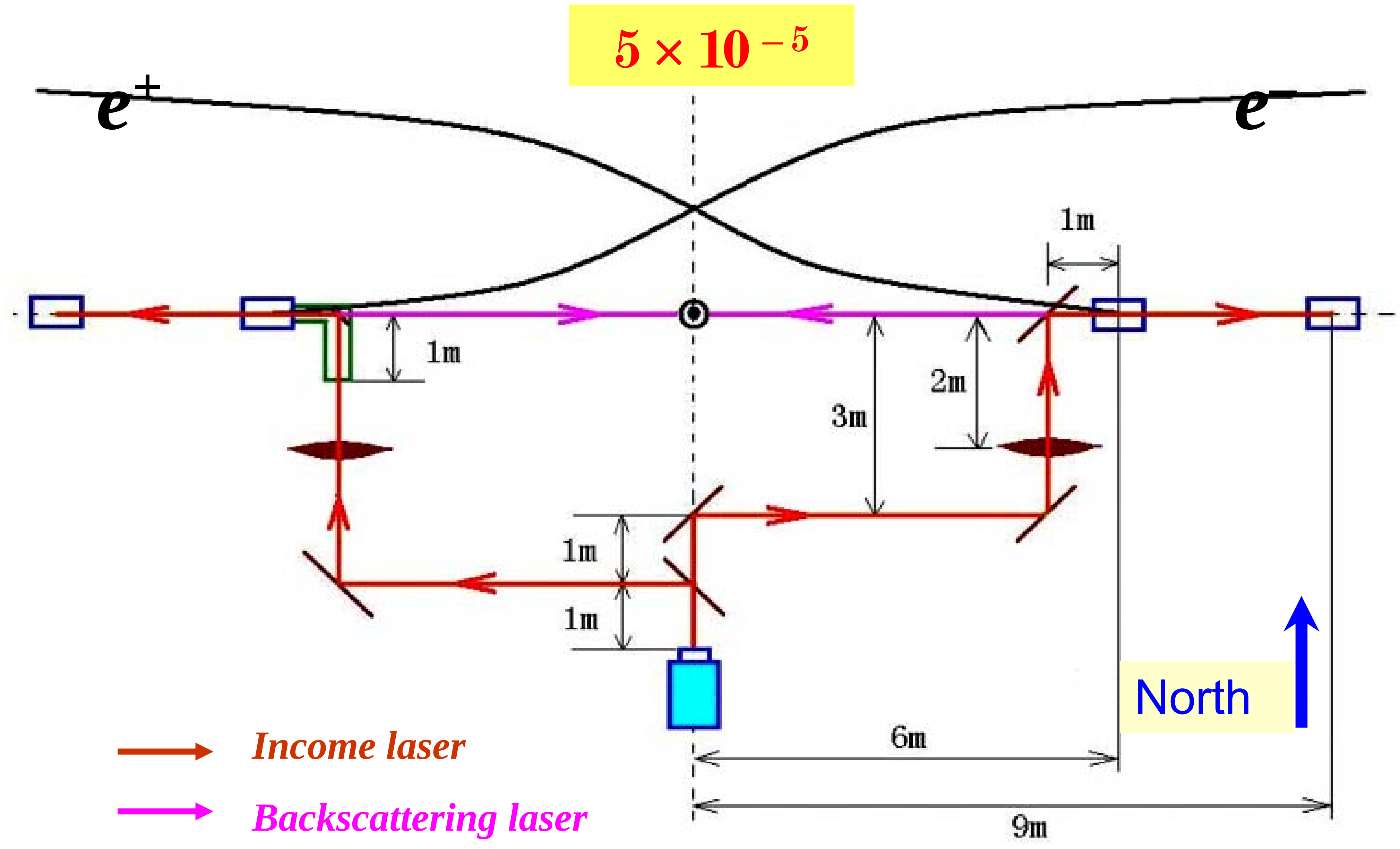
BEPCII Storage Ring



Compton backscattering technique, accuracy up to 5×10^{-5}

Total systematic uncertainty on beam energy measurement can reach 90keV

Sketch of energy measurement system

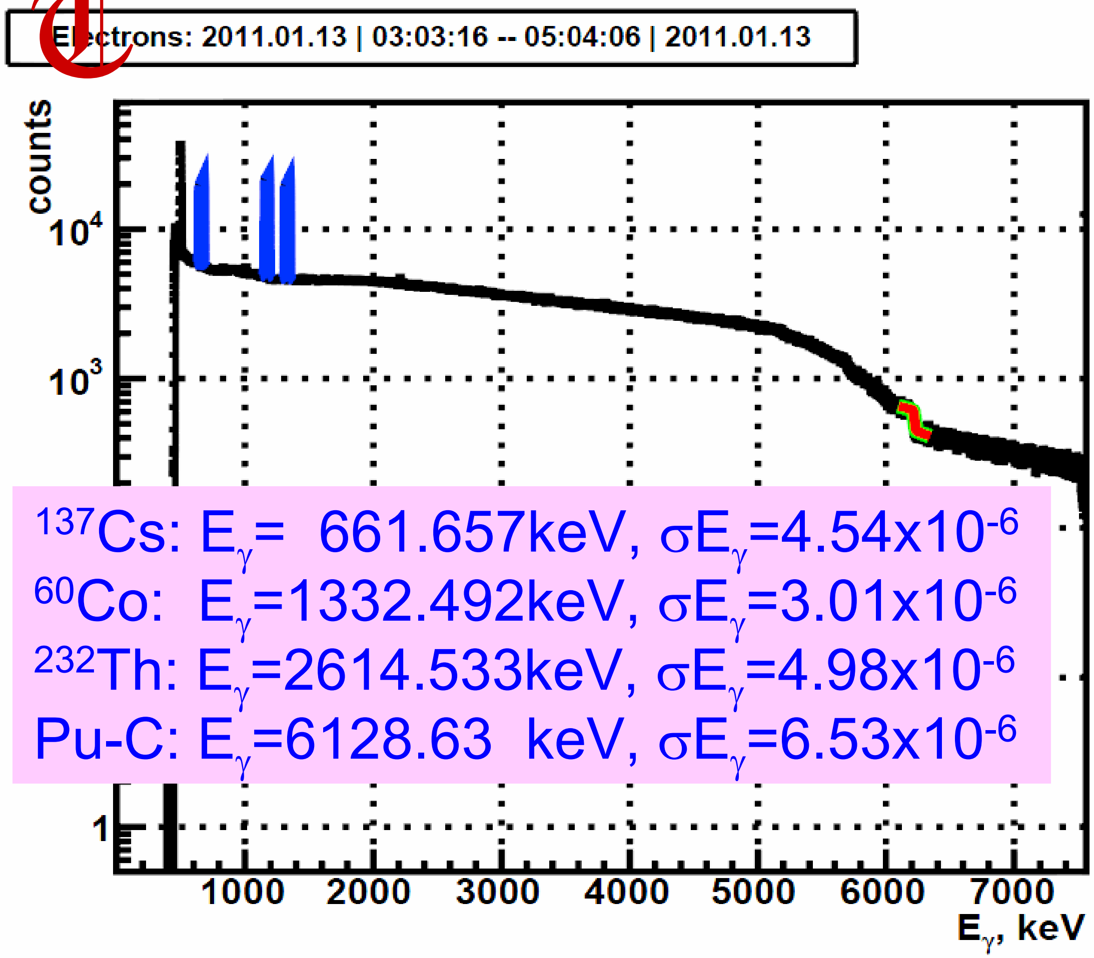


$$E_{edge} = 6217.137 \pm 0.568 \text{ keV}$$

$$\sigma_{E_{edge}} = 6.97 \pm 0.93 \text{ keV}$$

$$E_{beam} = 1886.478 \pm 0.086 \text{ MeV}$$

$$\sigma_{E_{beam}} = 1058.0 \pm 140.6 \text{ keV}$$

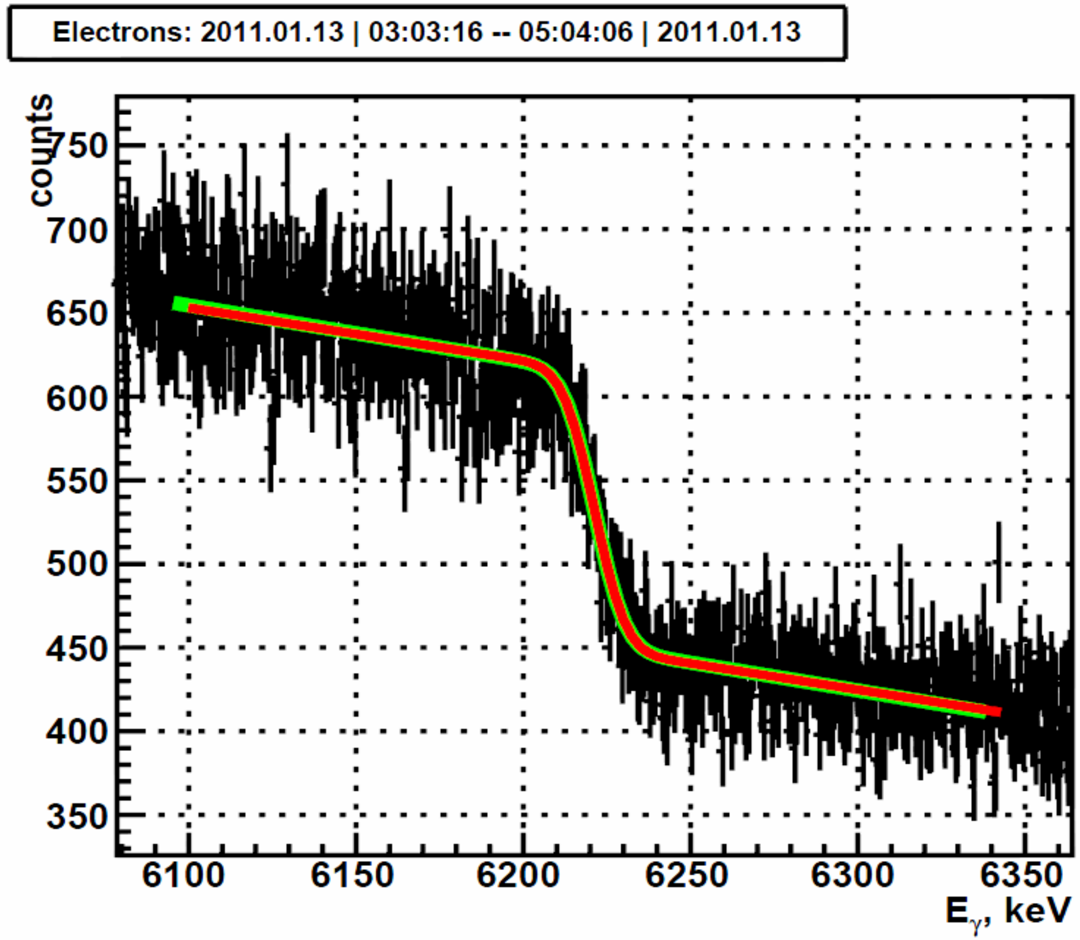


^{137}Cs: E_γ = 661.657keV, $\sigma E_\gamma = 4.54\text{x}10^{-6}$

^{60}Co: E_γ=1332.492keV, $\sigma E_\gamma = 3.01\text{x}10^{-6}$

^{232}Th: E_γ=2614.533keV, $\sigma E_\gamma = 4.98\text{x}10^{-6}$

Pu-C: E_γ=6128.63 keV, $\sigma E_\gamma = 6.53\text{x}10^{-6}$

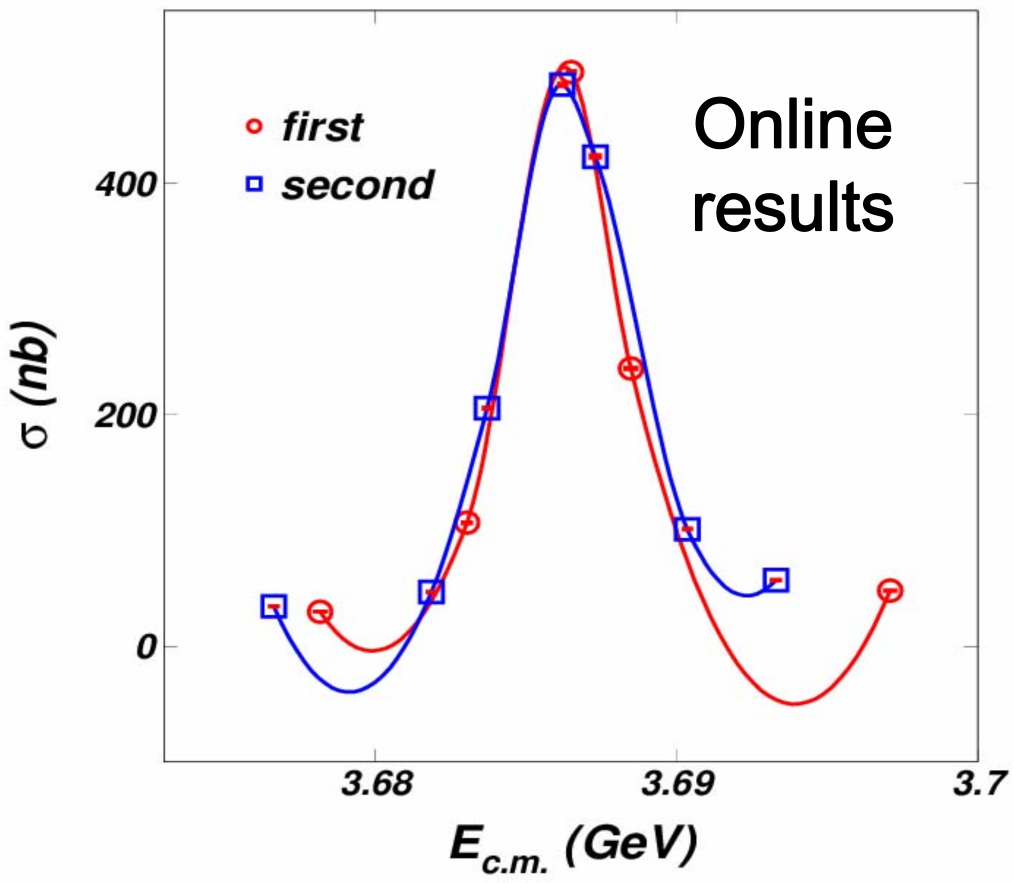


Relative error:

Meas.: 4.6×10^{-5}

Design: 5×10^{-5}

ψ(3686) Cross Section Scan

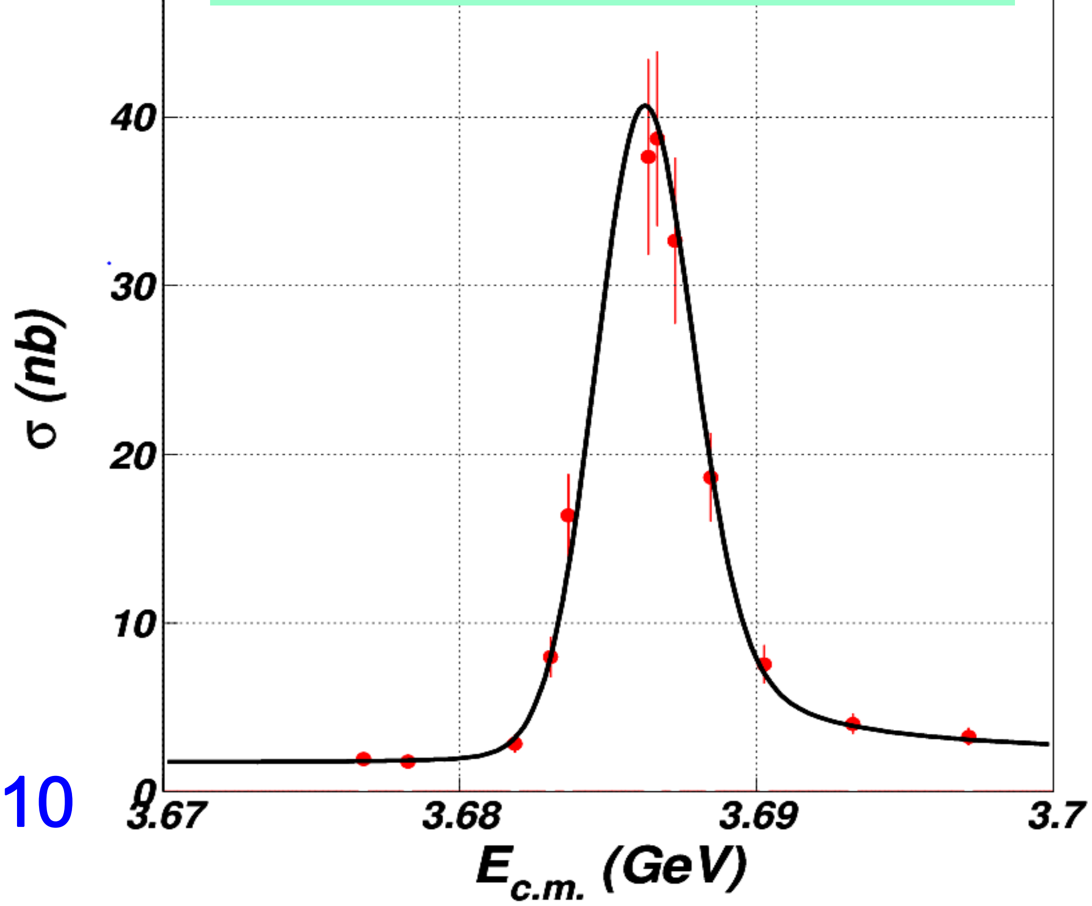


Offline fit:

3686.08 ± 0.02 MeV

PDG2010:

3686.09 ± 0.04 MeV



- No efficiency correction
- Cross section in arbitrary unit
- Errors enlarged by a factor of 10

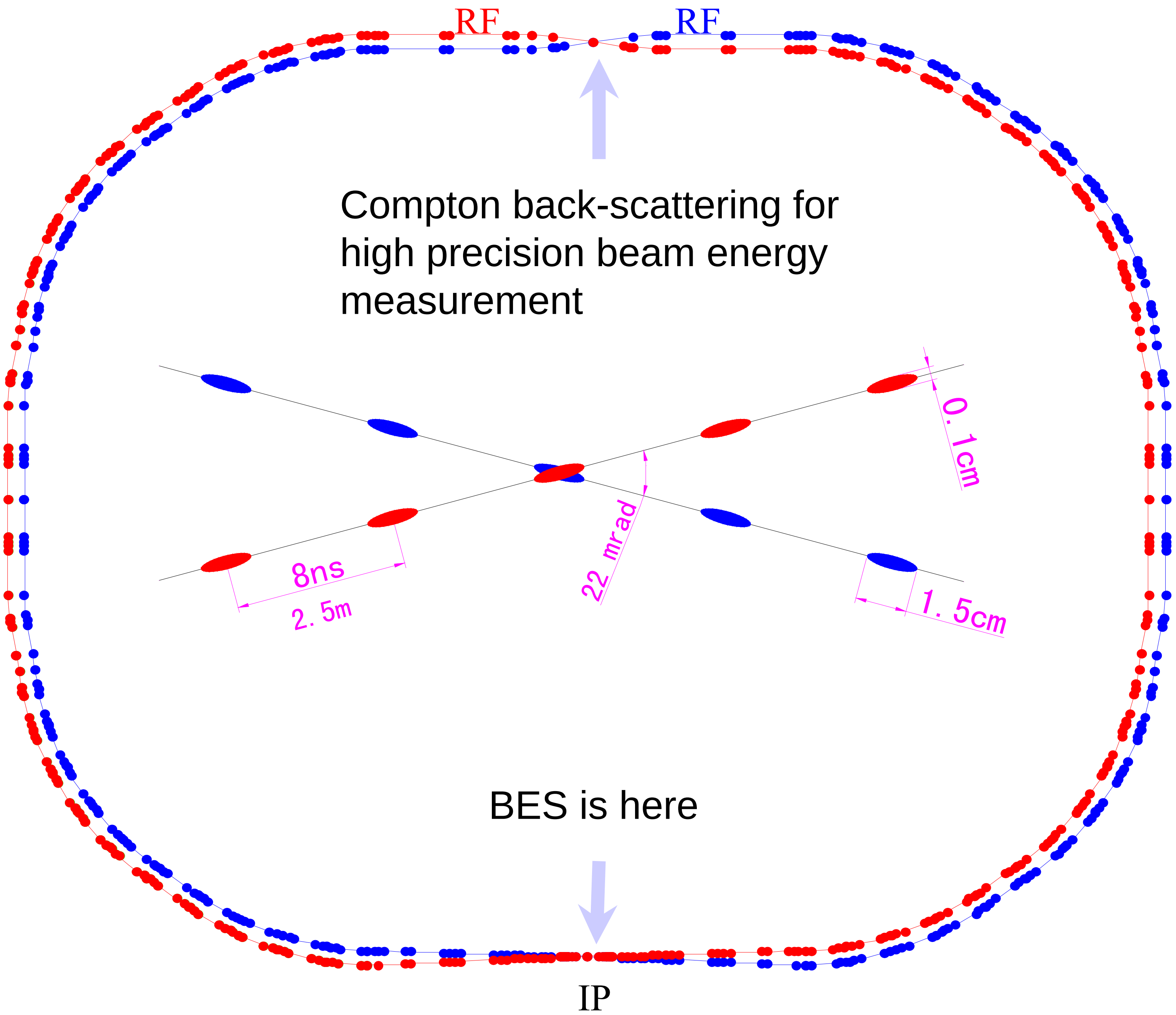
Summary

- BEPCII has reached 59% of its designed luminosity goal of $10^{33}/cm^2/s$, and is accumulating data at ~20 pb^{-1}/day now.
- BESIII is running very well and has accumulated world largest data samples at J/ψ, ψ', and ψ'' peaks.
- Lots of results have been published and more to come soon!

谢谢/Merci!

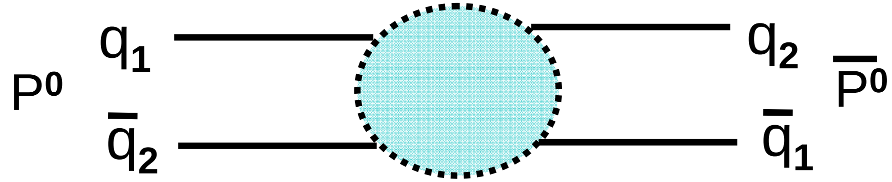
backup

BEPC II: Large crossing angle, double-ring



Beam energy:
1-2.3 GeV
Luminosity:
1×10^{33} cm^{-2}s^{-1}
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

$D^0\,\overline{D^0}$ mixing & CPV



$P^0 = K^0, B_d^0, B_s^0$ and D^0

Up-type quark flavour changing neutral current (FCNC):

The reason for time evolution:

flavour eigenstate $\neq$ mass eigenstate
(charm) (m$_{1,2}$ & $\Gamma_{1,2}$)

$$\left|D_{1,2}\right\rangle = p\left|D^0\right\rangle \pm q\left|\overline{D}^0\right\rangle$$

$$\left|D_{1,2}(t)\right\rangle = e^{-i\lambda_{1,2}t}\left|D_{1,2}(t=0)\right\rangle$$

$$x \equiv \frac{m_1 - m_2}{\overline{\Gamma}};\; y \equiv \frac{\Gamma_1 - \Gamma_2}{2\overline{\Gamma}};$$

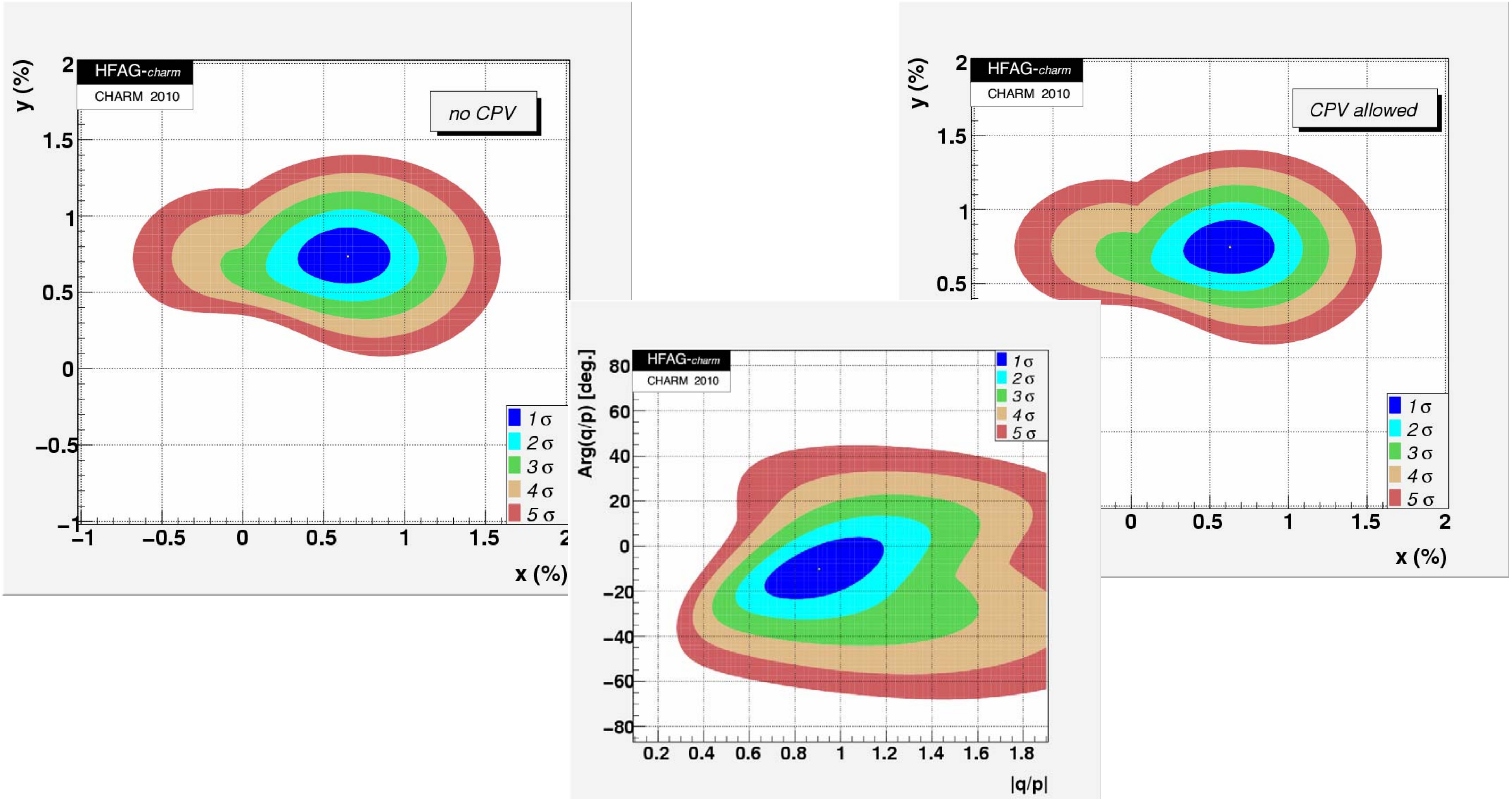
$$\left|D^0(t)\right\rangle = \left[\left|D^0\right\rangle \cosh\left(\frac{ix+y}{2}\overline{\Gamma}t\right) - \frac{q}{p}\left|\overline{D}^0\right\rangle \sinh\left(\frac{ix+y}{2}\overline{\Gamma}t\right)\right] e^{-i\overline{m}t-\frac{\overline{\Gamma}}{2}t}$$

SM: $|x|, |y| \leq \mathcal{O}(10^{-2})$

$$|x|, |y| \ll 1 \Rightarrow \quad \frac{dN(D^0 \to f)}{dt} \propto e^{-\overline{\Gamma}t}\left|\left\langle f\left|D^0\right.\right\rangle + \frac{q}{p}\frac{ix+y}{2}\left\langle f\left|\overline{D}^0\right.\right\rangle\right|^2$$

D^0 decay time distribution depends on x,y.
x, y are sensitive to new physics!

HFAG : world average



No experiment observes significant signal (>5σ)

BESIII may reach mixing & CP violation at 0.1% level.