Status of BESIII and prospects for charm physics

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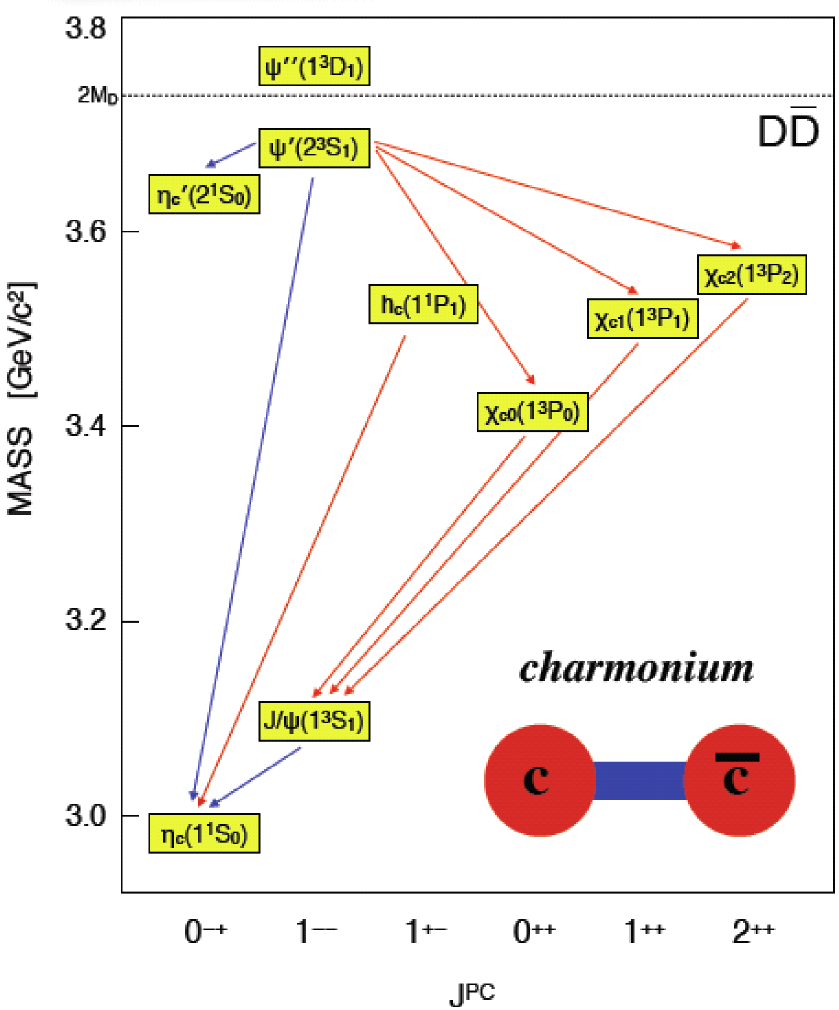
XVII SuperB Workshop and Kick Off Meeting, May 28 - June 2, 2011
in La Biodola, Isola d'Elba , Italy

Outline

- Status of BEPCII/BESIII
- 2009: Charmonium data samples… two sample results
- 2010-11: First open charm runs
- Charm Physics: advantage near threshold
- Conclusion

BESIII - physics using "charm"



Charmonium physics:
- Spectroscopy
- transitions and decays

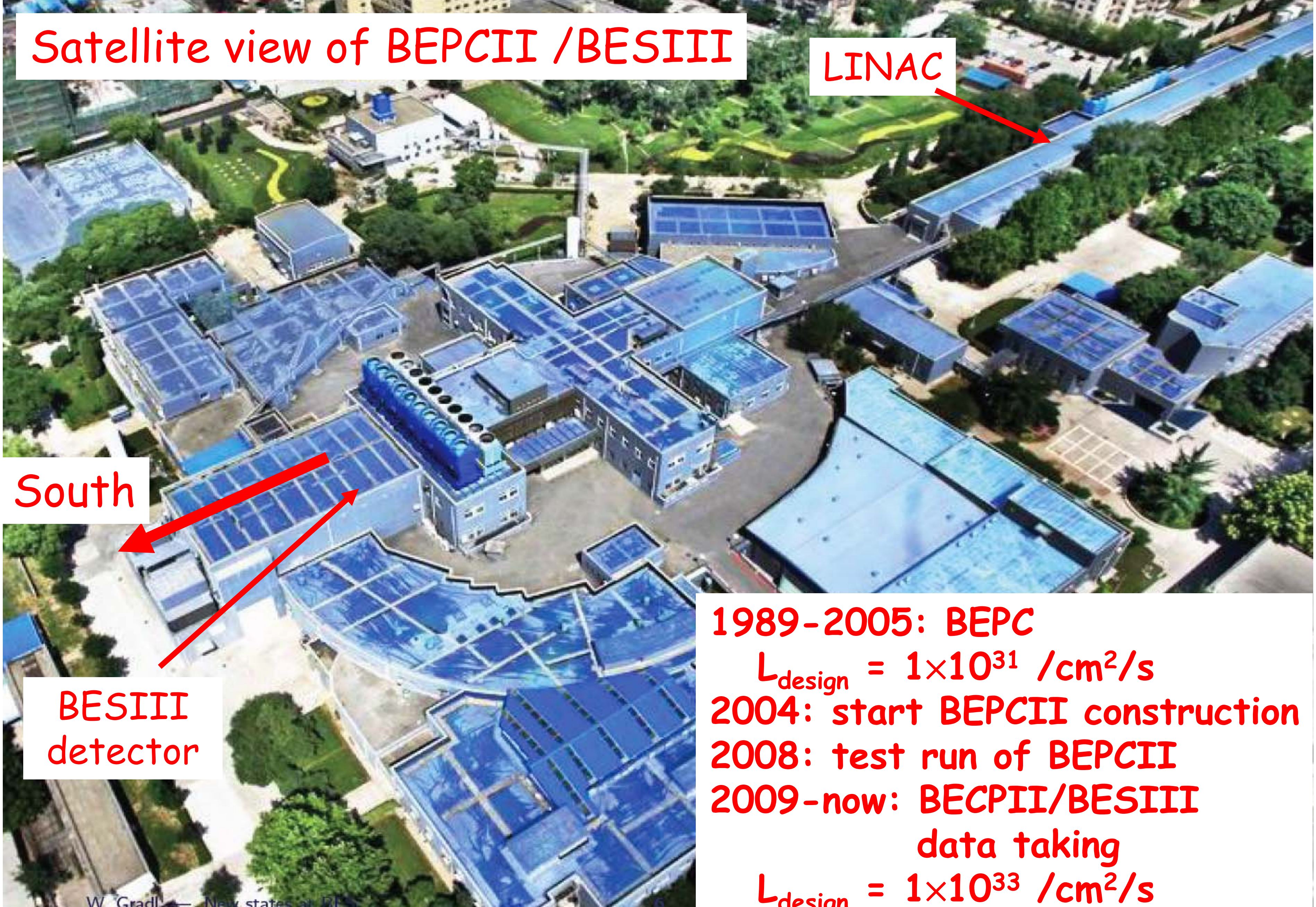
Light hadron physics:
- meson & baryon spectroscopy
- glueball & hybrid
- two-photon physics
- e.m. form factors of nucleon

Charm physics:
- (semi)leptonic + hadronic decays
- decay constant, from factors
- CKM matrix: Vcd, Vcs
- D^0-D^0bar mixing and CP violation
- rare/forbidden decays

Tau physics:
- Tau decays near threshold
- tau mass scan

…and many more.

Satellite view of BEPCII /BESIII



1989-2005: BEPC

$L_{design} = 1\times10^{31}\ /cm^2/s$

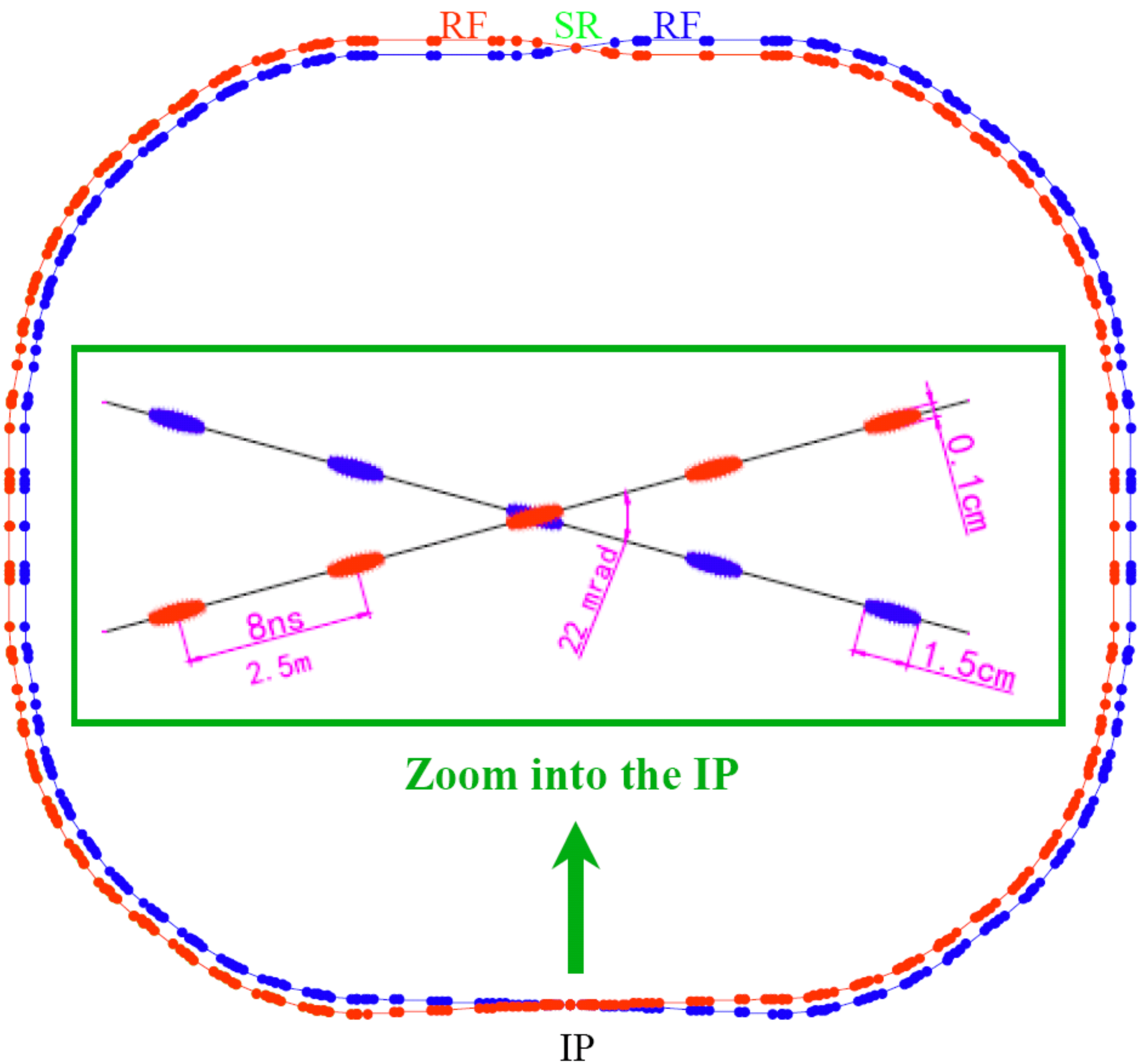
2004: start BEPCII construction

2008: test run of BEPCII

2009-now: BECPII/BESIII data taking

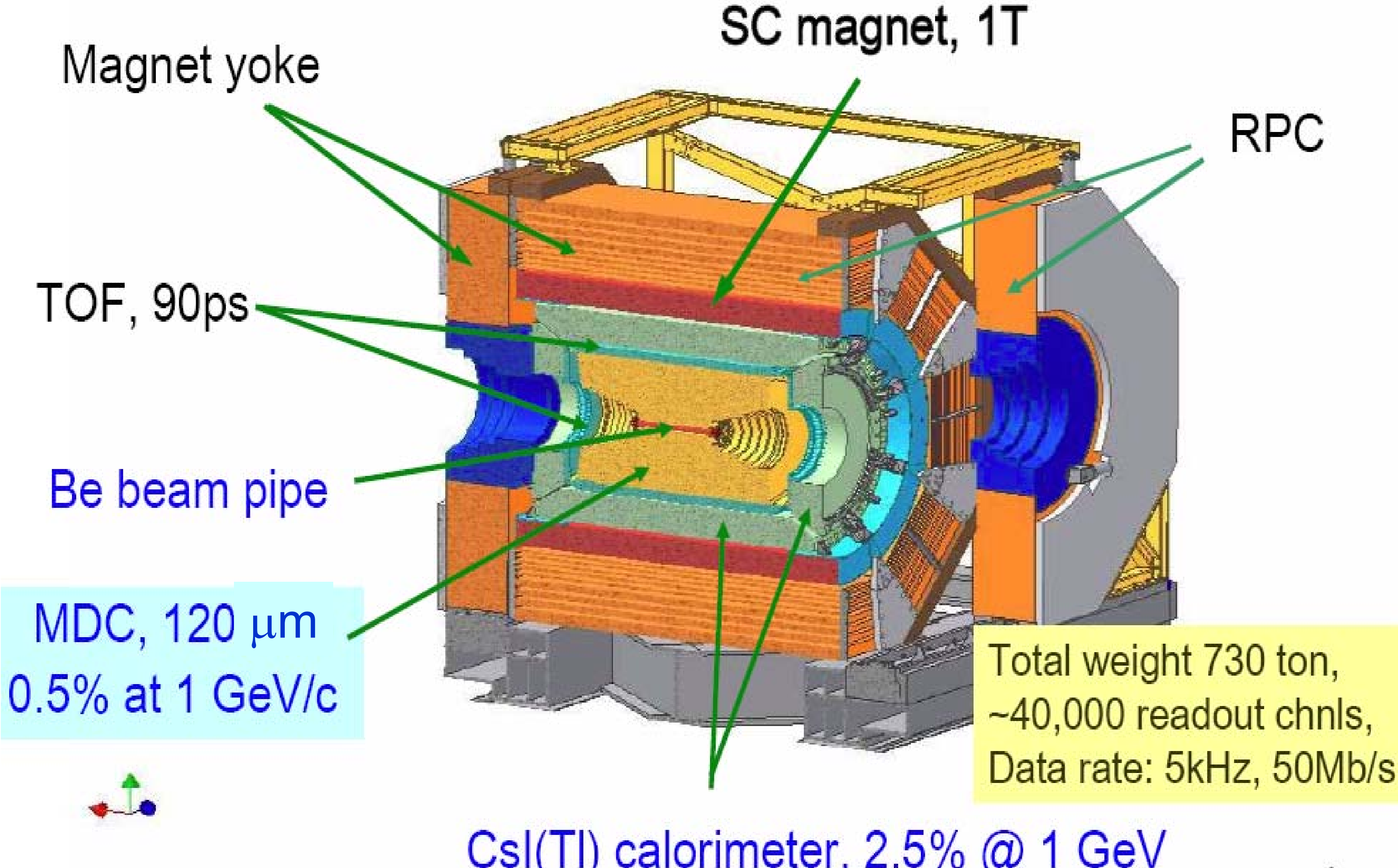
$L_{design} = 1\times10^{33}\ /cm^2/s$

BEPCII storage rings



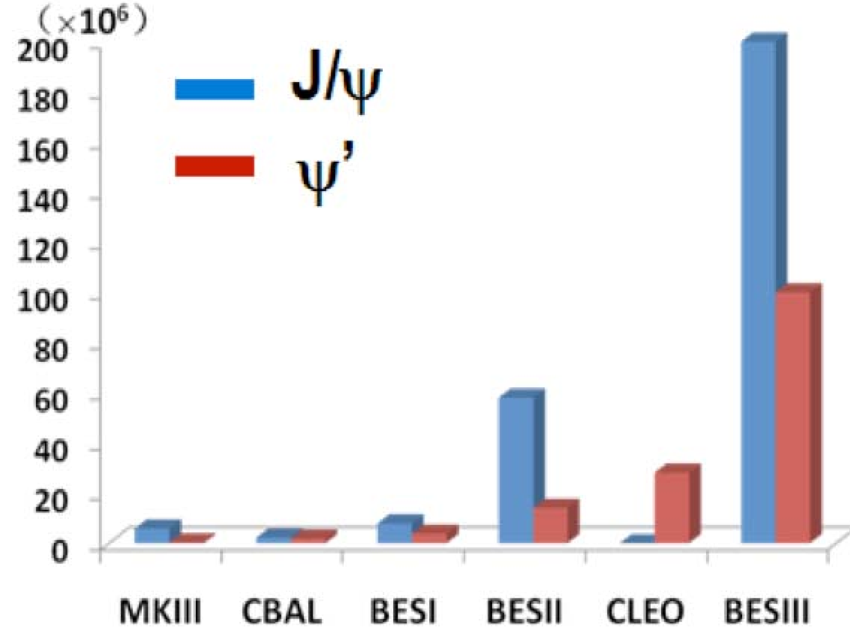
Beam energy:
1.0-2.3 GeV
Design Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
Circumference:
237m

BESIII detector

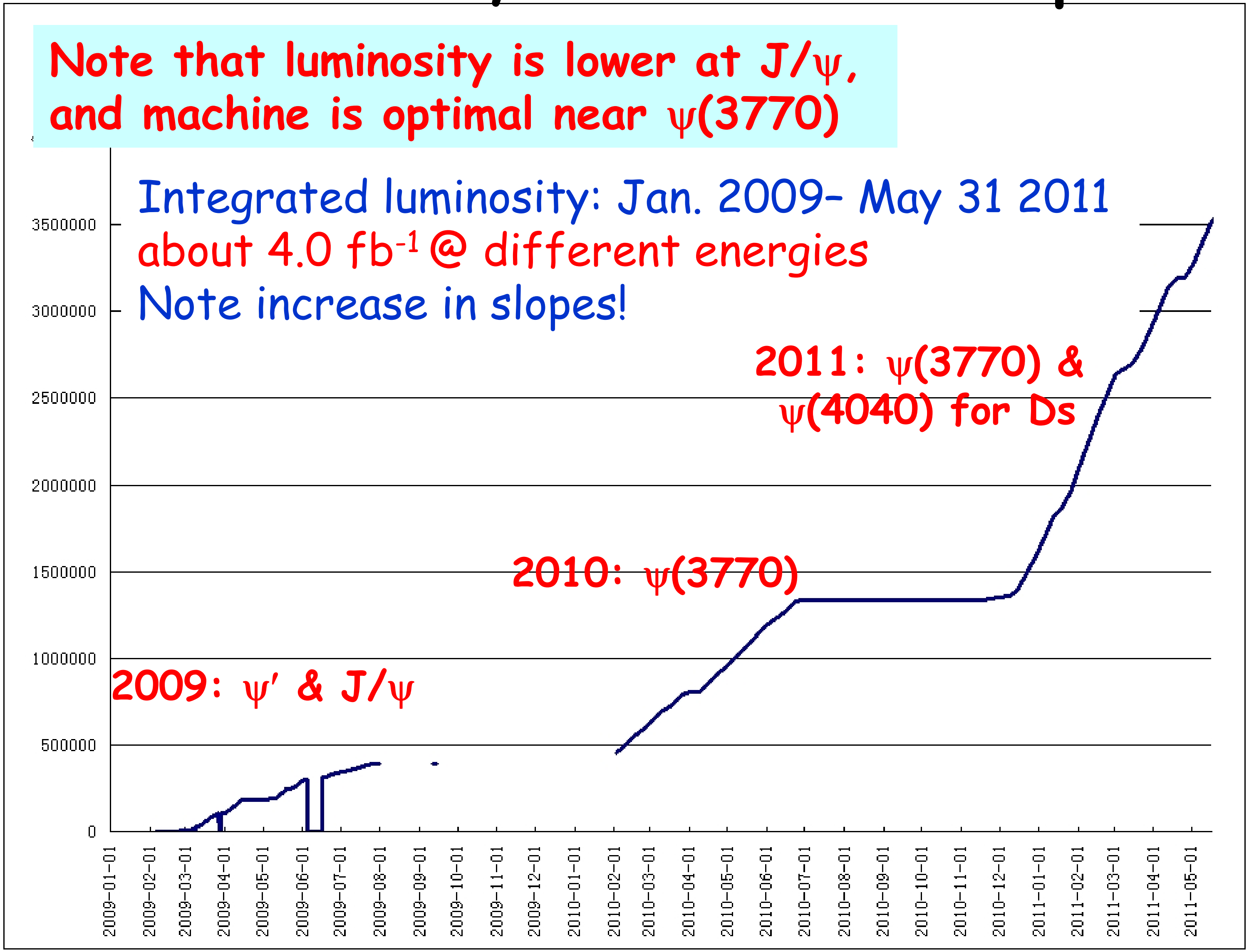


Data samples

- So far BESIII has collected :
  - 2009: 220 Million J/ψ
  - 2009: 106 Million ψ'
  - **2010-11: 2.9 fb^{-1} $\psi(3770)$ (3.5 $\times$ CLEO-c 0.818fb^{-1})**
  - **May 2011: 0.5fb^{-1} @4010 MeV (one month) for Ds and XYZ spectroscopy**
- BESIII will also collect:
  - more J/ψ, ψ', $\psi(3770)$
  - data at higher energies （for XYZ searches, R scan and Ds physics）

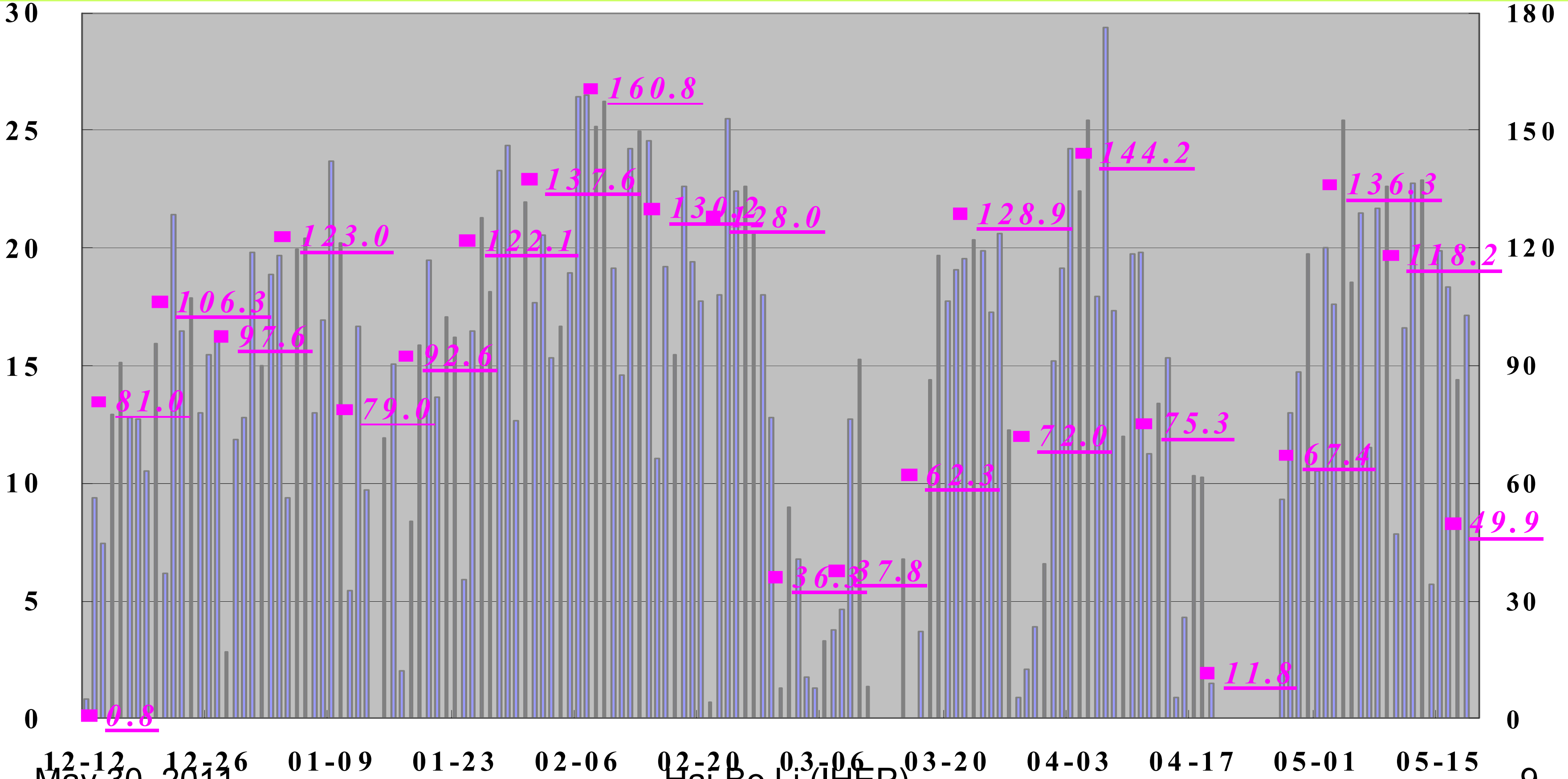


luminosity since startup

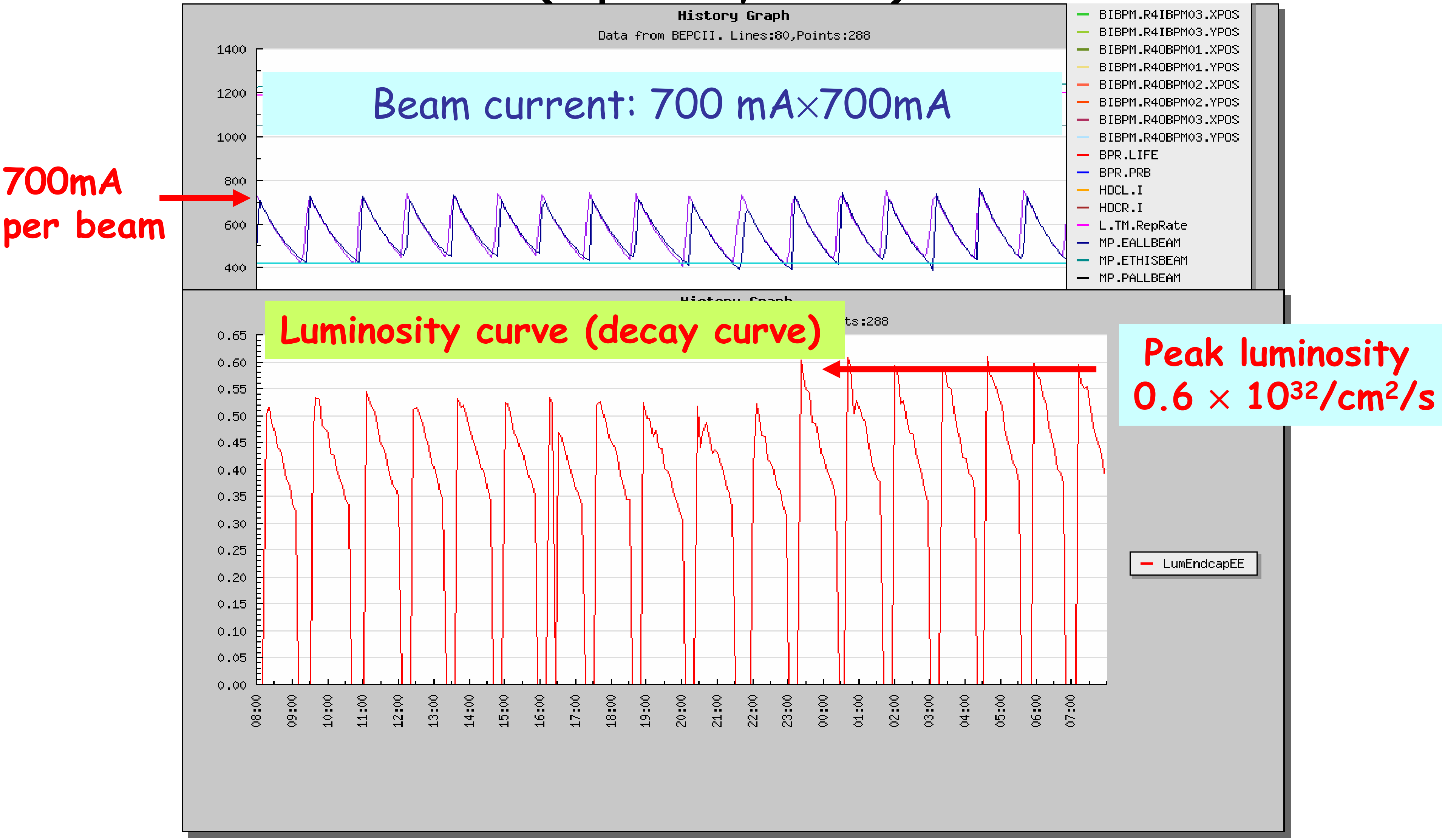


Recent ψ(3770) running

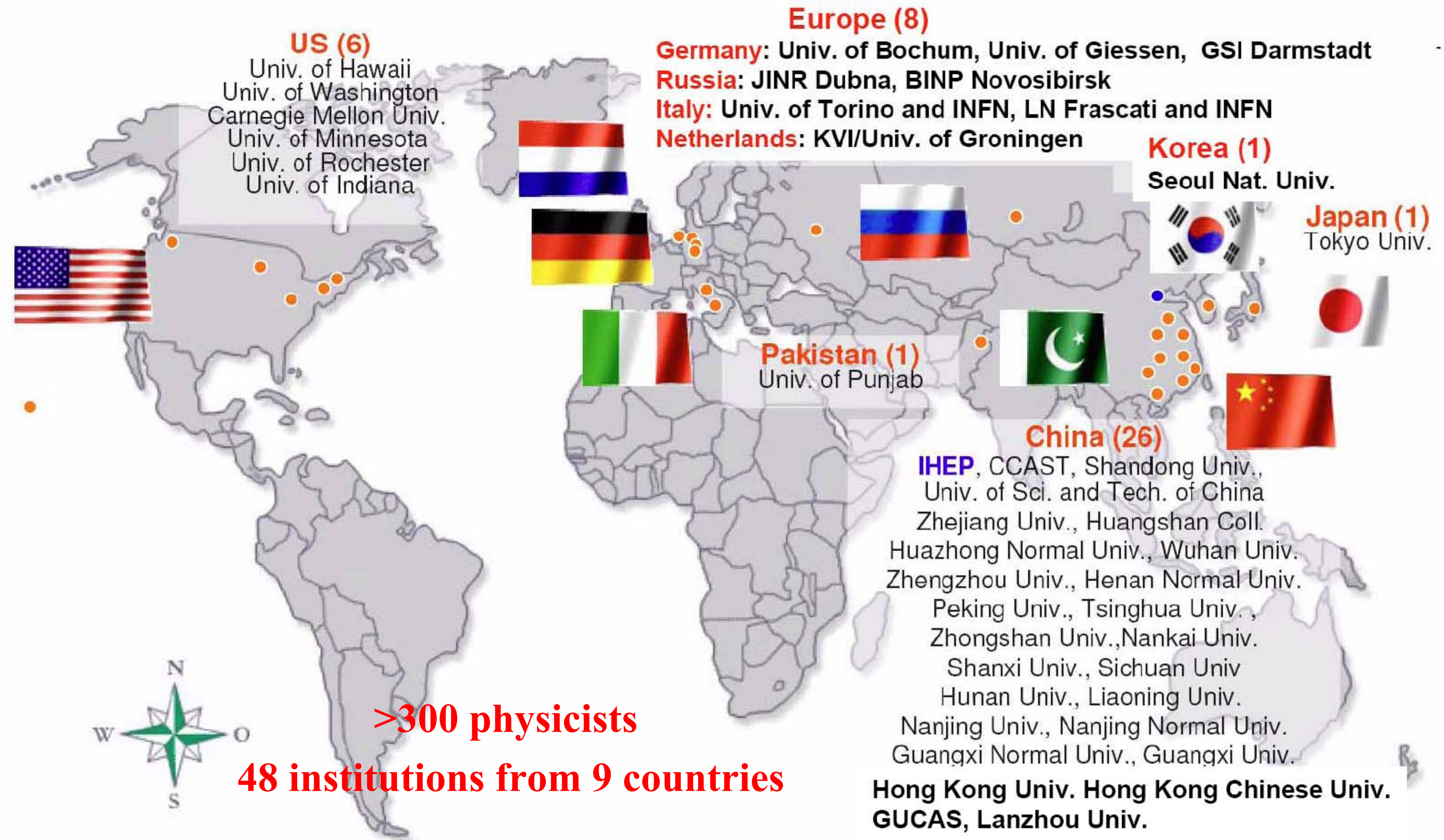
Reference point: $\mathcal{L}$ = 0.5 × 10^{33} /cm^2/s (maximum 0.65 × 10^{33})
theoretically lumi: 43 pb^{-1} /day
But, filling beam, HV ramp, lumi. decay and down time loss 40%
Best week : 160.8 pb^{-1}
Best day : 29 pb^{-1}



Luminosity vs beam current for best day (April 7, 2011)



BESIII Collaboration



Released results of BESIII

- Charmonium Spectroscopy and Transitions
  - Properties of the hc *(PRL 104, 132002 (2010))*
  - $\psi(2S) \to \gamma\gamma J/\psi$ *(preliminary)*
- Charmonium Decays
  - $\chi_{cJ} \to \pi^0\pi^0, \eta\eta$ *(PRD 81, 052005 (2010))*
  - $\chi_{cJ} \to \gamma\rho, \gamma\omega, \gamma\phi$ *(accepted by PRD)*
  - $\chi_{cJ} \to \omega\omega, \phi\phi, \omega\phi$ *(submitted to PRL)*
  - $\psi(2S) \to \gamma\pi^0, \gamma\eta, \gamma\eta'$ *(PRL 105, 261801 (2010))*
  - $\chi_{cJ} \to 4\pi^0$ *(PRD 83, 012006 (2011))*
  - **Observation of χ_{cJ}-> ppbarK^+K^-(submitted to PRD)**
- Light Quark States
  - $a_0(980) - f_0(980)$ mixing *(PRD 83, 032003 (2011))*
  - $\eta' \to \eta\pi^+\pi^-$ matrix element *(PRD 83, 012003 (2011))*
  - X(1860) in $J/\psi \to \gamma(pp)$ *(Chinese Physics C 34, 4 (2010))*
  - X(1835) in $J/\psi \to \gamma(\eta'\pi^+\pi^-)$ *(PRL 106, 072002 (2011))*
  - X(1870) in $J/\psi \to \omega(\eta\pi^+\pi^-)$ *(preliminary)*

9 papers published

More than 20 analyses are under internal review!

Property of h_c (1P1)

PRL104, 132002 (2010)

Study isospin forbidden transition

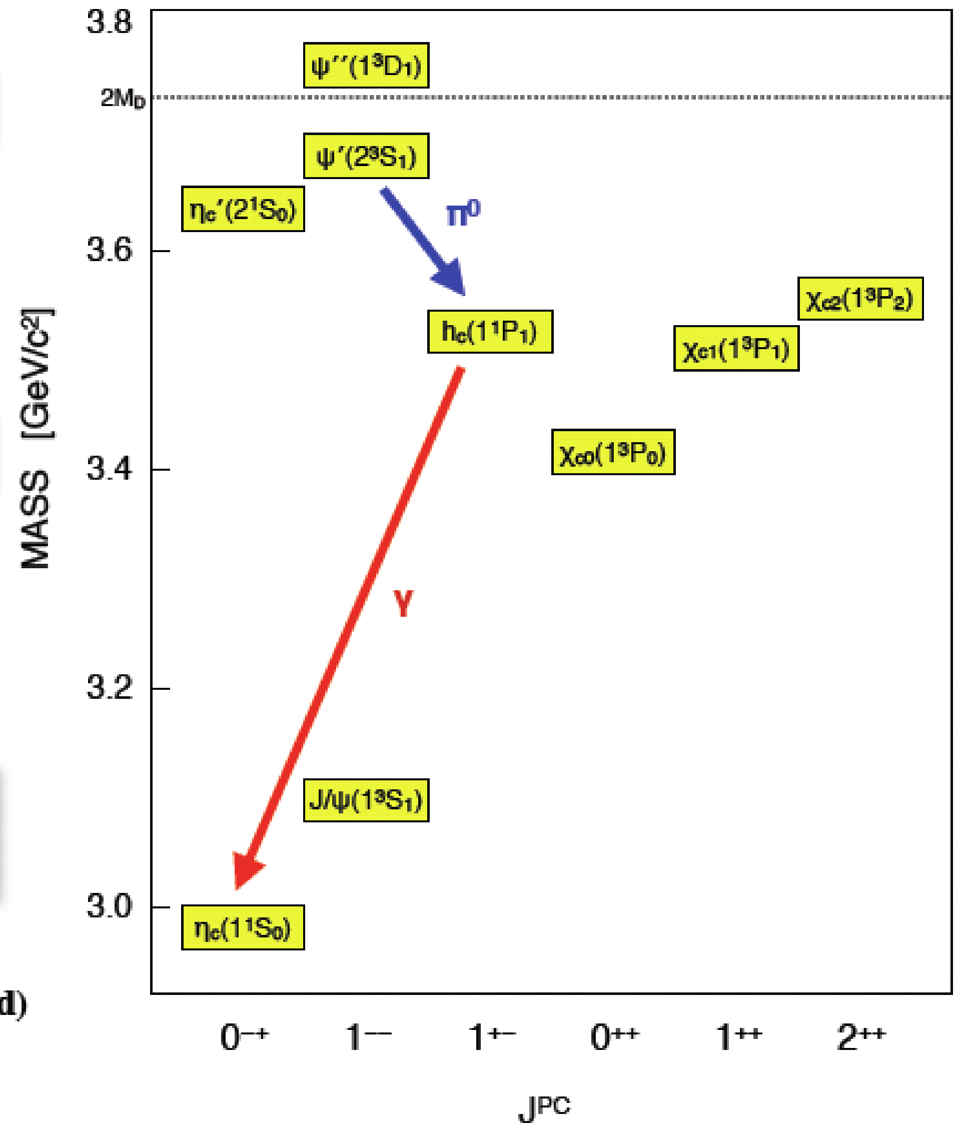
$$B(\Psi' \to \pi^\circ h_c)$$

Measure as well the E1 transition

$$B(h_c \to \gamma\eta_c)$$

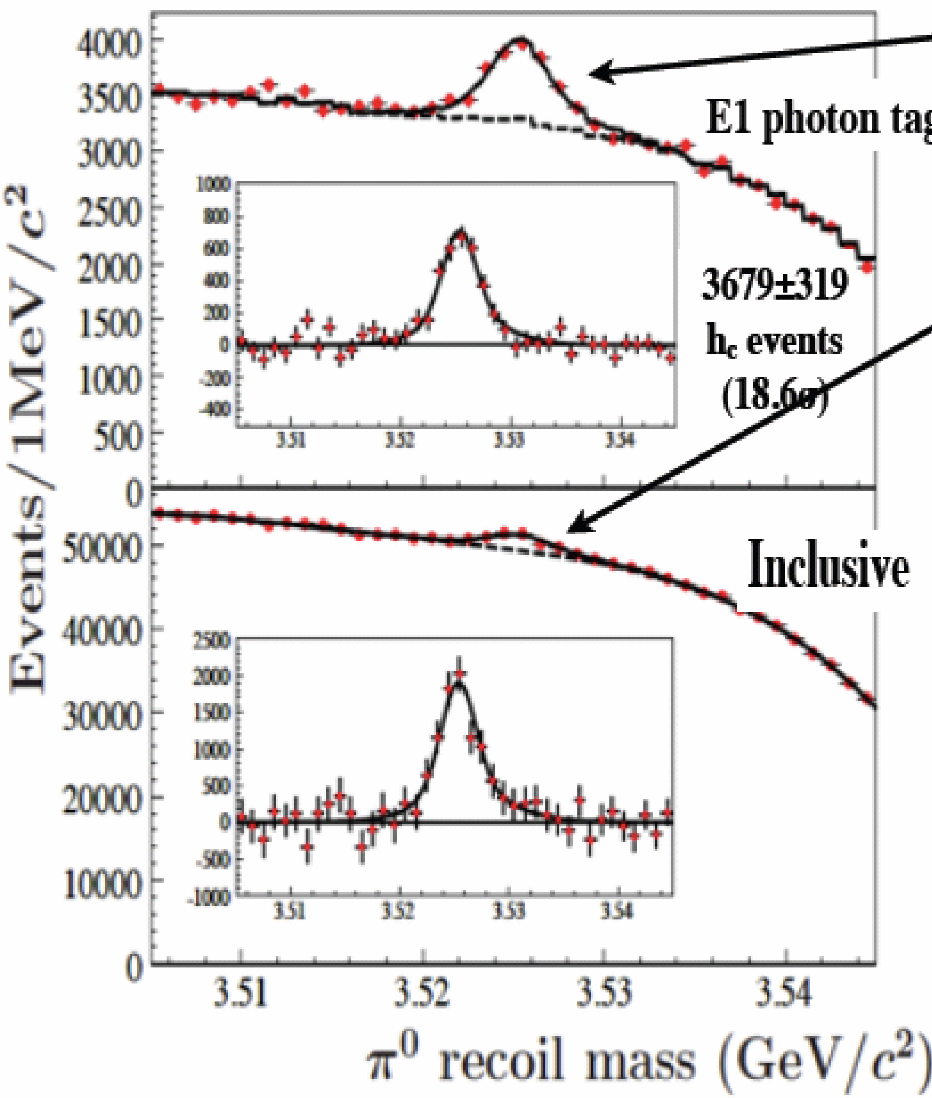
Hyperfine splitting of the 1P states (spin-spin interaction term):

$$M(h_c(1P)) - \langle M(\chi_{cJ}(1P))\rangle_{(spin\text{-}weighted)}$$



Property of h_c (1P1)

PRL104, 132002 (2010)



Tag the E1 photon, yields:

$\psi(2S) \to \pi^0 h_c) \times B(h_c \to \gamma\eta_c)$
$= (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$
(consistent with CLEO-c)

Inclusive analysis provides:

$B(\psi(2S) \to \pi^0 h_c)$ (first measurement)
$= (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$

Combining the two results:

$B(h_c \to \gamma\eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$
(first measurement)

Natural width of h_c:

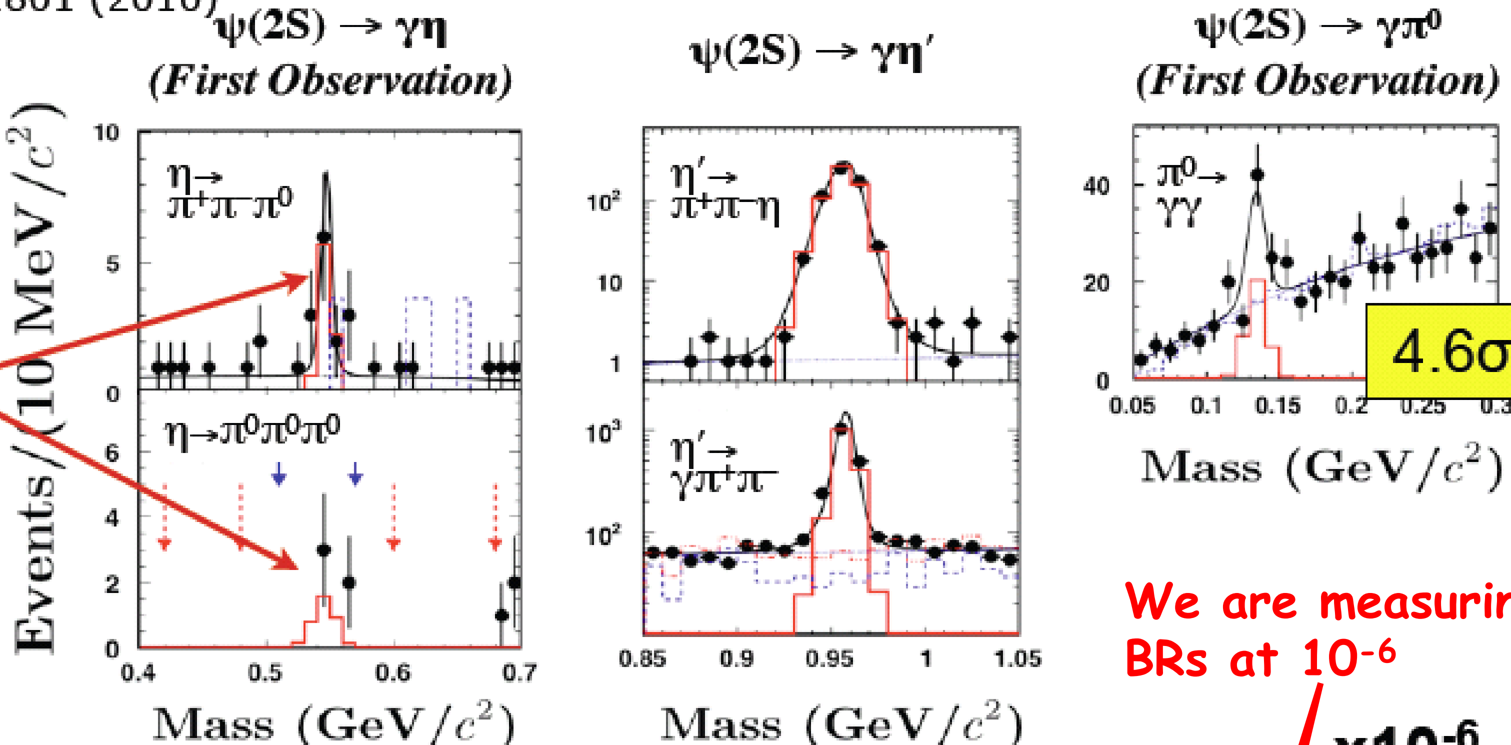
$\Gamma(h_c) = 0.73 \pm 0.45 \pm 0.28\,\mathrm{MeV}/c^2$
(first measurement)

Hyperfine splitting:

$\Delta M_{hf} = -0.10 \pm 0.13 \pm 0.18\,\mathrm{MeV}/c^2$
(consistent with zero)

Evidence for Ψ' Decays into $\gamma\pi^0/\gamma\eta$

PRL108, 261801 (2010)



strange depletion!

4.3σ

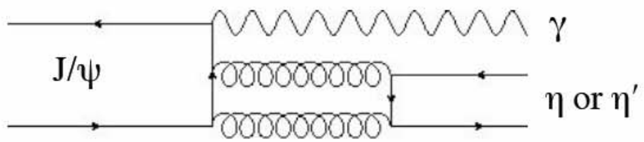
We are measuring BRs at 10^{-6}

x10^{-6}

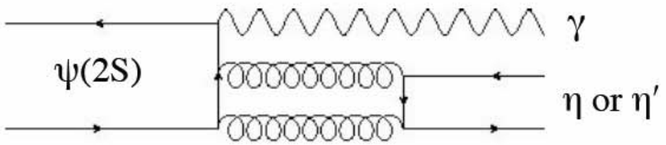
BR [10^{-6}]	BESIII	Combined BESIII	PDG10
$\Psi' \to \gamma\pi^0$	$1.58 \pm 0.40 \pm 0.13$	$1.58 \pm 0.40 \pm 0.13$	≤ 5
$\Psi' \to \gamma\eta(\pi^+\pi^+\pi^0)$	$1.78 \pm 0.72 \pm 0.17$		
$\Psi' \to \gamma\eta(\pi^0\pi^0\pi^0)$	$1.07 \pm 0.65 \pm 0.08$	$1.38 \pm 0.48 \pm 0.09$	≤ 2
$\Psi' \to \gamma\eta'_{(958)}(\pi^+\pi^+\eta)$	$120 \pm 5 \pm 8$		
$\Psi' \to \gamma\eta'_{(958)}(\pi^+\pi^+\gamma)$	$129 \pm 3 \pm 8$	$126 \pm 3 \pm 8$	121 ± 8

Some surprises

PRL108, 261801 (2010)



VS



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

PRD79, 111101 (2009)

$$R_{J/\Psi} = \frac{B(J/\psi \to \gamma\eta)}{B(J/\psi \to \gamma\eta')} = (21.1 \pm 0.9)\ \%$$

(consistent with other measurements of η-η′ mixing angle and LO-pQCD)

BESIII

$$R_{\Psi'} = \frac{B(\psi(2S) \to \gamma\eta)}{B(\psi(2S) \to \gamma\eta')} = (1.10 \pm 0.38 \pm 0.07)\ \%$$

(consistent with upper limit from CLEO-c)

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

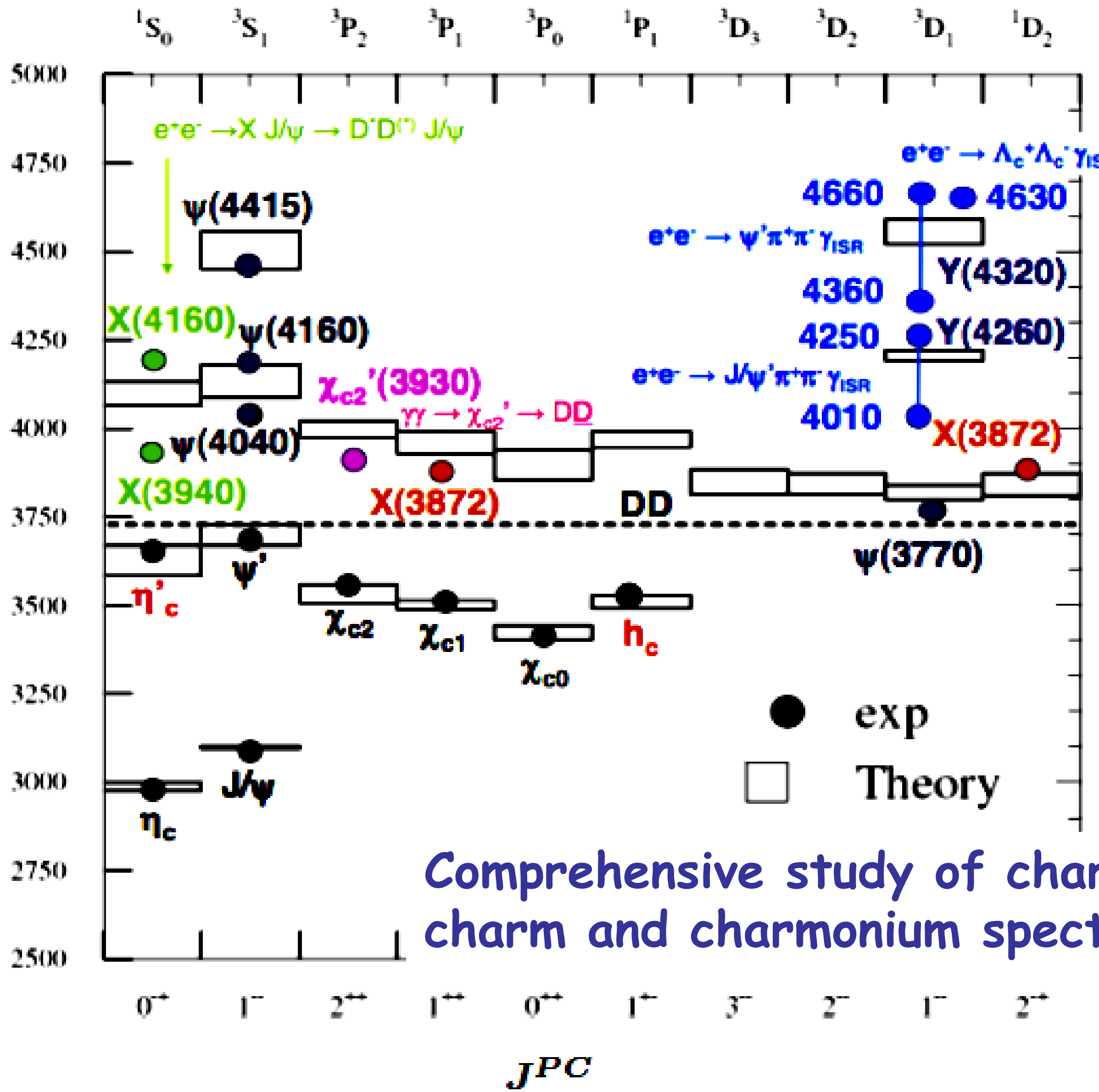
Difference?: Other processes contributing? Related to ρπ puzzle, ... ??

Running plan

- The luminosity of BEPCII is better than expected.
- Data taking for open charm:
  - $\psi(3770)$: 1.82 fb^{-1} (2011)+0.923 fb^{-1} (2010) = 2.743 fb^{-1}
  - 4010 MeV : 0.5 fb^{-1} in May 2011 for Ds physics

Year	Running
2012	J/ψ: 1 billion / $\psi(2S)$: 0.5 billion (approved)
2013	4170 MeV: Ds decay + R scan (E > 4 GeV)
2014	$\psi(2S)/\tau$ / R scan (E > 4 GeV)
2015	$\psi(3770)$: 5-10 fb^{-1} (our final goal)

Charmonium spectroscopy after the B-factories



BESIII final goal
J/ψ – 10^{10}
$\psi(2S)$ – 3×10^{9}
$\psi(3770)$ – 6×10^{8}
Higher ψ's – 10^{7}

In decays:
$\eta_c(1S)$-10^{8}
χ_{cJ} – 10^{8}
h_c – 10^{7}
$(\psi(2S)\to h_c\pi^0)$
10^{8} η/η' samples
Rare η/η' decays

Comprehensive study of charmonium decays
charm and charmonium spectroscopy

Prospect of charm physics at BESIII

Charm data at e^+e^- experiments

			10^{33}	10^{35} cm^{-2}s^{-1}
	CLEO-C		BES-III/ year	τ-charm/year
J/ψ	–	–	10×10^9	
$\psi(2S)$	54 pb^{-1}	27×10^6	3×10^9	$\times100$
$\psi(3770)$	818 pb^{-1}	5×10^6 D-pair	3×10^7	
4.17 GeV	586 pb^{-1}	7×10^5 D_s-pair	2×10^6	
$\tau^+\tau^-$ (4.25)		4×10^6	3×10^7	

Super B-Factories (10^{36}cm^{-2}s^{-1}) will produce about 10^{10} charmed hadrons and 10^{10} τ pairs/year at $\Upsilon(4S)$ peak.

Advantage of open charm at threshold

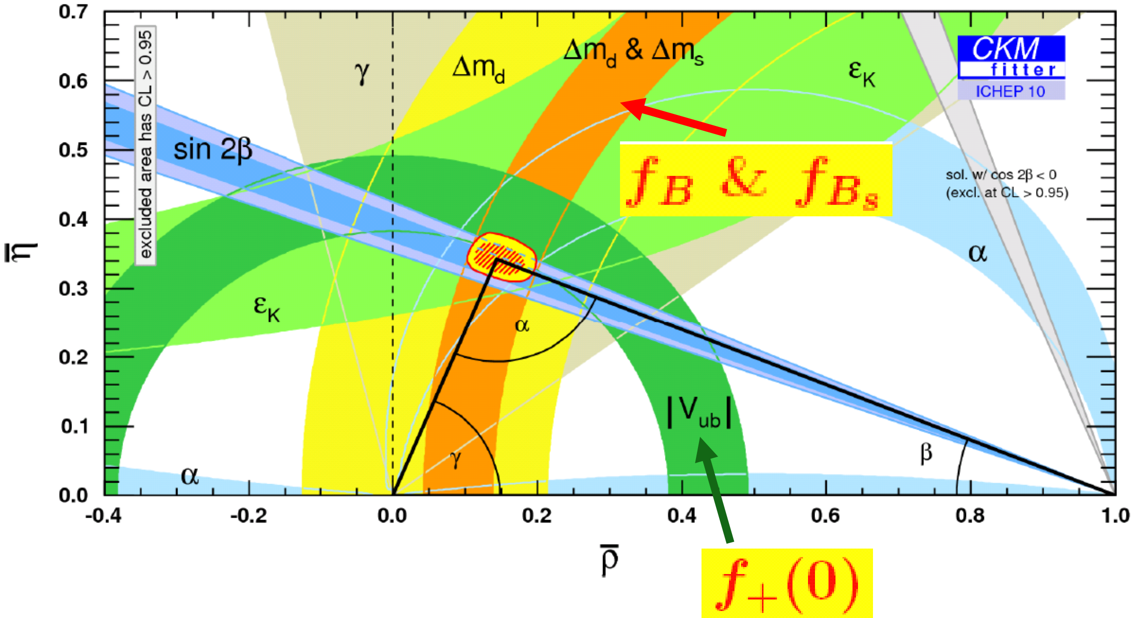
e^+e^- Colliders@threshold: CLEO-c, BESIII, Super-tau-charm

$$e^+e^- \to \psi(3770) \to D^0\bar{D}^0 \quad [C = -1] \qquad \text{OR} \qquad e^+e^- \to \gamma^* \to D^0\bar{D}^0\gamma \quad [C = +1]$$

Good for charm flavor physics:

- Threshold production: clean
- Known initial energy and quantum numbers
- Both D and Dbar fully reconstructed (double tag)
- Absolute measurements

Charm role in flavor physics



Theoretical errors dominate width of bands

$|V_{ub}|$ from $B \rightarrow \pi \ell \nu$:

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{ub}|^2 p_\pi^3 |f_+(q^2)|^2$$

Form factor $f(q^2)$:

- Hard to calculate
- Limits $|V_{ub}|$ precision
- Lattice QCD can do from first principles

precision QCD calculations tested with *precision* charm data at threshold
➔theory errors of a few % on B system decay constants & semileptonic form factors

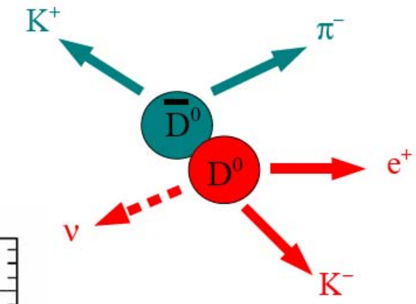
Charm decay measurements

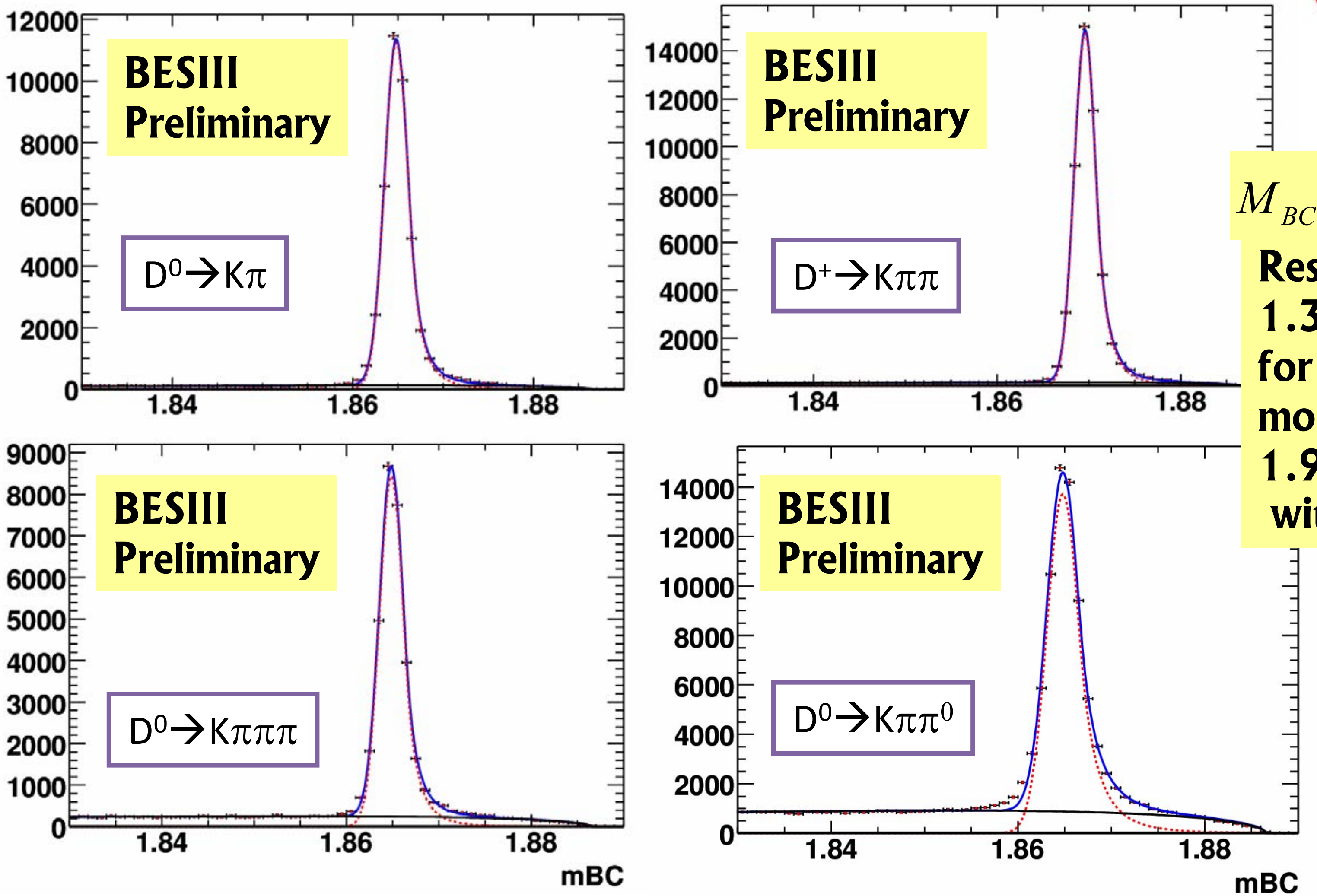
decay constants
form factors
V_{CKM} clean extraction
validate QCD.

over-constrain V_{CKM}
Inconsistency → New Physics

Clean single tag at BESIII

@ψ(3770) with 420pb⁻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.

Prospects for Charm at BESIII

Look for the size of the statistics/systematic/FSR errors for precision measurements at BESIII after CLEO-c.

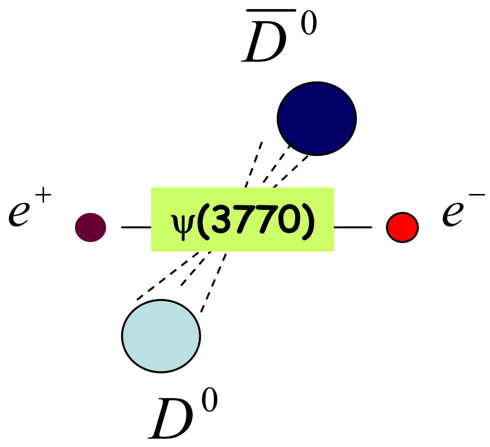
CLEO-c errors for D^0 / D^+ physics with 818 pb^{-1}@3770		BESIII (5fb^{-1})
f_{D+} ($D^+ \to \mu^+ \nu$):	$\pm$4.1% (stat.) $\pm$ 1.2% (sys.)	$\pm$2.0% (stat.)
$f_\pi(0)$ ($D^0 \to \pi l \nu$):	$\pm$5.3% (stat.) $\pm$ 0.7%(sys.)	$\pm$2.3% (stat.)
BR($D^0 \to K\pi$):	$\pm$0.9% (stat.) $\pm$ 1.8%(sys.)	limited by sys.
BR($D^+ \to K\pi\pi$):	$\pm$1.1% (stat.) $\pm$ 2.0%(sys.)	limited by sys.

CLEO-c errors for Ds physics with 600pb^{-1}@4170 MeV		
f_{Ds} ($Ds^+ \to \mu^+ \nu, \tau\nu$):	$\pm$2.5% (stat.) $\pm$ 1.2% (sys.)	$\pm$0.8% (stat.)
BR($Ds^+ \to KK\pi$):	$\pm$4.2% (stat.) $\pm$ 2.9%(sys.)	$\pm$2.0% (stat.)

For Ds physics, BESIII are taking data at both 4010 and 4170 MeV:
4010 MeV (clean single tag, lower cross section 0.3 nb) 0.5 fb^{-1} in May 2011
4170MeV (dirty single tag, maximum cross section 0.9 nb) → CLEO-c 0.6 fb^{-1}

Significant gains will be made with increased luminosity at BESIII.

Coherence physics @threshold



D^0 mixing: $R_M = (x^2+y^2)/2 \sim 10^{-4}$

Strong phase can be accessed, helpful for mixing measurements at super-B factories:

Sensitivity on x will be improved by a factor 3 (Brain Meadows ICHEP2010 see back-up slides and discussion in morning session on June 1);

Uncertainty of γ due to unknown ralative phase on Dalitz decay $D^0 \rightarrow K_s h^+h^-$ will be reduced to less than 1^0.

CP violation in D sector : 10^{-3}

Sensitivity of rare D decays at BESIII

- Flavor Changing Neutral Current ($c \to u\, l^+ l^-$)
  - $D^0 \to \mu^+\mu^-$ SM $<10^{-12}$ NP $\sim 10^{-6}$
    - CDF BR$< 4.3\times10^{-7}$
  - $D \to X_u l^+ l^-$ SM $<10^{-8}$ NP $\sim 10^{-6}$
    - D0 BR($D^+ \to \pi^+\mu^+\mu^-$)$< 3.9\times10^{-6}$
    - CLEO-c BR($D^+ \to \pi^+ e^+ e^-$)$< 7.4\times10^{-6}$
- Lepton Flavor Violation NP $\sim 10^{-6}$
    - BABAR BR($D^0 \to \mu^+ e^-$) $<0.81 \times10^{-6}$
    - BABAR BR($D^+ \to \pi^+ e^+ \mu^-$) $<1.1 \times10^{-5}$

With 5-10fb^{-1} @$\psi(3770)$
BESIII will provide 10^{-7} -10^{-8} sensitivity.

Open charm analysis at BESIII

Significant interests at
- IHEP (although most people at IHEP in light hadron, charmonium)
- Some US groups (CMU, Minnesota, Rochester) from CLEO-c
- Some European groups (?)

Popular topics
- leptonic, semileptonic decays (with high priority)
- $\psi(3770)$ lineshape, non-DDbar decays….

So far only modest interests on strong phase, mixing and CPV …
- We are still in calibration of data
- Analyses are in progress
- Other analysis will help prepare analysis tools
- We hope to increase interest!

BESIII is open to interacting with B factories and LHCb about analysis of mutual interests. Some UK CLEOns had visited IHEP, We help it will continue.

Conclusion

- Charm provides a natural and clean testing ground for QCD techniques
- Maximizing the sensitivity of heavy quark flavor physics: Super-B/LHC-b to achieve precision determinations of the CKM matrix
- Charm near threshold undertake complementary studies of D mixing and CPV
- We expect rich physics results in the coming years from BESIII.
- Super-τ-charm will provide us many opportunities

Finally, I thank my BESIII and CLEO-c Colleagues:
David Asner, Roy Briere, Dan Hennessy, Jim Libby, Ron Polling


虞美人
秦觀
碧桃天上栽和露，不是凡花數。
亂山深處水縈迴，可惜一枝如畫為誰開？
輕寒細雨情何限，不道春難管。
為君沉醉又何妨，只怕酒醒時候斷人腸。
After 36 years of discovery,
Charm is still charming!
Thanks！

Back up slides

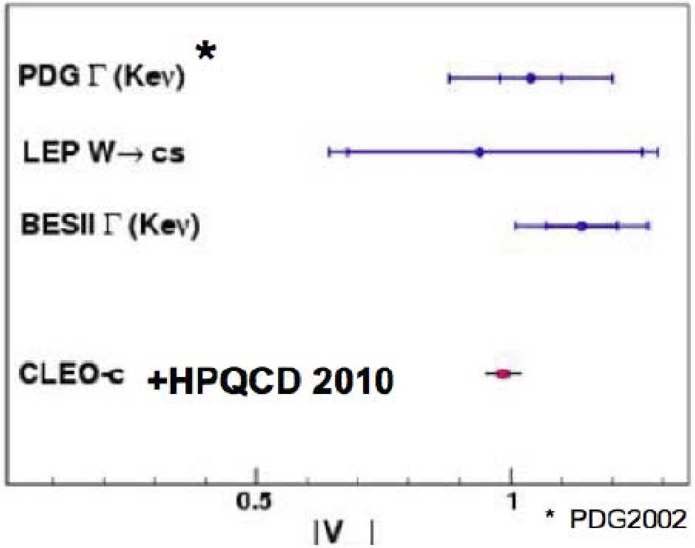
Vcs / Vcd from semileptonic D decays

From Bo Xin

The data determine $|V_{cs(d)}|f_+(0)$.
To extract $|V_{cs(d)}|$, *we combine the measured* $|V_{cs(d)}|f_+(0)$ *values using the Becher-Hill parameterization with (FNAL-MILC-HPQCD) for* $f_+(0)$

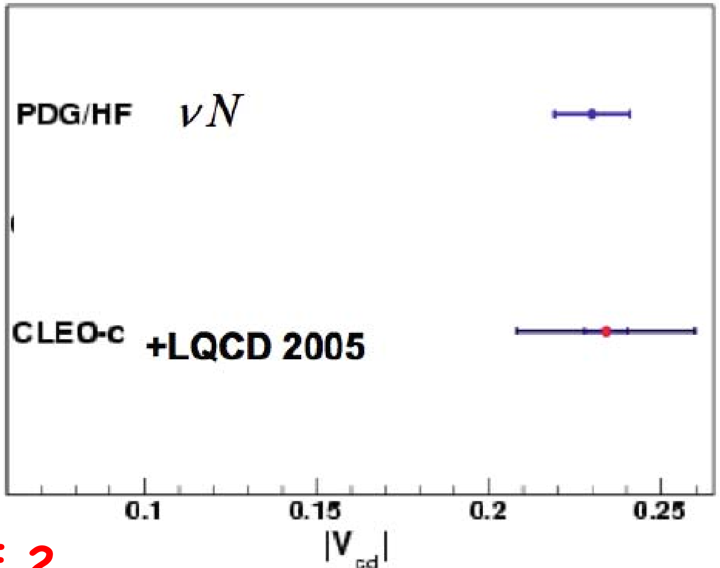
CLEO-c: the most precise *direct* determination of $|V_{cs}|$ $\sigma(|V_{cs}|)/|V_{cs}| \sim 1.1\%(\text{expt}) \oplus 2.5\%(\text{theory})$

$CLEO-c$	$\lvert V_{cs} \rvert$
$(818\ \text{pb}^{-1})$	$0.963 \pm 0.009 \pm 0.006 \pm 0.024$
	stat syst theory



CLEO-c: $\sigma(|V_{cd}|)/|V_{cd}| \sim 3.1\%(\text{expt}) \oplus 10\%(\text{theory})$
νN remains most precise determination

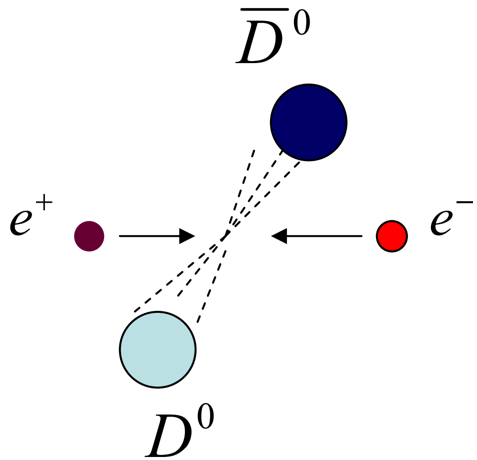
$CLEO-c$	$\lvert V_{cd} \rvert$
$(818\ \text{pb}^{-1})$	$0.234 \pm 0.007 \pm 0.002 \pm 0.025$
	stat syst theory



Vcd will be improved at BESIII by a factor of 2.

$D^0 D^0$bar quantum correlation @$\psi(3770)$

For a physical process producing $D^0 \bar{D}^0$ such as



$$e^+e^- \to \psi'' \to D^0\overline{D}^0$$

The quantum number of ψ'' is $J^{PC} = 1^{--}$

$\therefore$ For a correlated state C=-1:

$$\psi_- = \frac{1}{\sqrt{2}}(|D^0\rangle|\overline{D}^0\rangle - |\overline{D}^0\rangle|D^0\rangle)$$

$$\hat{C}|D^0\rangle = |\overline{D}^0\rangle$$
$$\hat{C}|\overline{D}^0\rangle = |D^0\rangle$$

Z.Z . Xing, PRD55, 196(1997)

The correlated amplitude:

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

$$\frac{\langle K^-\pi^+|\overline{D^0}\rangle^{\text{DCS}}}{\langle K^-\pi^+|D^0\rangle_{\text{CF}}} = -\boxed{r_{K\pi}}e^{-i\delta_{K\pi}}$$

~0.06

$\delta_{K\pi}$ connects measurements of y and y'

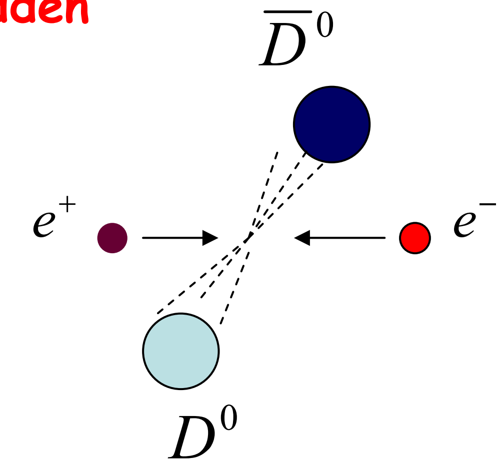
D^0 strong phase is necessary input for D^0 mixing and CKM measurements at B factories and LHCb

Measure D^0 mixing at threshold

Z.Z . Xing, PRD55, 196(1997)

Without mixing in D^0, the following process is forbidden due to Boson-Einstein statistics :

$$\boxed{e^+e^- \to \psi(3770) \to D^0\overline{D}^0 \to (K^\pm\pi^\mp)(K^\pm\pi^\mp)}$$



With mixing happened, it is allowed:

$$\boxed{e^+e^- \to \psi(3770) \to D^0_H D^0_L \to (K^\pm\pi^\mp)_H (K^\pm\pi^\mp)_L}$$

At $\psi(3770)$ $R_M=(x^2+y^2)/2$ can be measured using the ratios

$$R_M = \frac{N[D^0\overline{D}^0 \to (K^-\pi^+)(K^-\pi^+)]}{N[D^0\overline{D}^0 \to (K^-\pi^+)(K^+\pi^-)]}, \quad \frac{N[D^0\overline{D}^0 \to (K^-e^+\nu)(K^-e^+\nu)]}{N[D^0\overline{D}^0 \to (K^-e^+\nu)(K^+e^-\nu)]}$$

For 10^8 D-pairs about 10 events will be detected.
Sensitivity to R_M is about 1×10^{-4}

Expected sensitivity to mixing parameters:
1 ab^{-1} at tau-charm factory = 10 ab^{-1} at Super B-factory

CPV in D decay at BESIII

Direct CP violation in D decays is expected to be small in SM.

For CF and DCS decays direct CP violation requires New Physics.
Exception: $D^{\pm} \rightarrow K_{S,L}\pi^{\pm}$ with $A_{CP}=-3.3\times10^{-3}$.

For Singly Cabibbo Suppressed (SCS) decays SM CPV could reach 10^{-3}.

$$A_{CP} = \frac{\Gamma(D\rightarrow f)-\Gamma(\bar{D}\rightarrow \bar{f})}{\Gamma(D\rightarrow f)+\Gamma(\bar{D}\rightarrow \bar{f})}$$

D.S.Du , EPJC5,579(2007)
Y. Grossman et al
PRD75, 036008(2007)

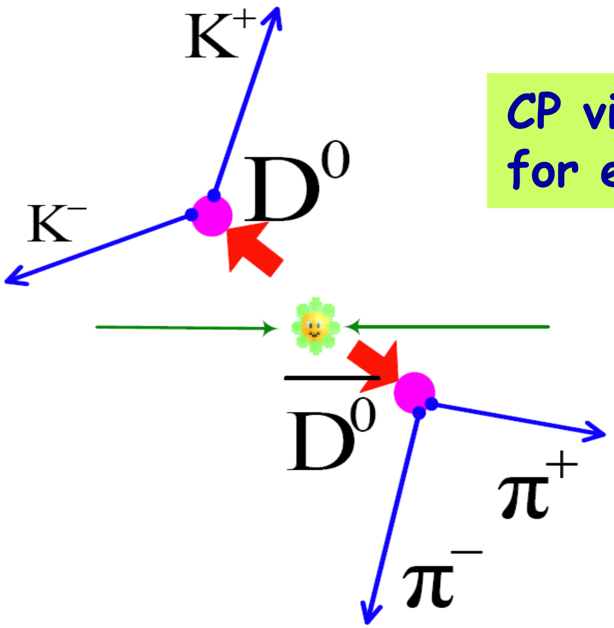
Best limits:

Belle: $D^0 \rightarrow K^+K^-, \pi^+\pi^-$
$A_{CP}(K^+K^-)=(0.43\pm0.30\pm0.11)\%$
$A_{CP}(\pi^+\pi^-)=(0.43\pm0.52\pm0.12)\%$

BABAR: $D^+ \rightarrow K_S\pi^+$
$A_{CP}(K_S\pi^+)=(-0.44\pm0.13\pm0.10)\%$
CLEO-c : $K_S\pi^+\pi^0$
$A_{CP}(K_S\pi^+\pi^0)=(0.3\pm0.9\pm0.3)\%$

At BESII, CP asymmetry can be tested with 10^{-3} sensitivity for many final states.

CP violation near threshold



CP violating asymmetries can be measured by searching for events with two CP odd or two CP even final states:

$\pi^+\pi^-$, K^+K^-, $\pi^0\pi^0$, $K_S\pi^0$,

for the decay of $\psi'' \to D^0\overline{D}^0 \to f_1 f_2$

$$CP(f_1 f_2) = CP(f_1) \cdot CP(f_2) \cdot (-1)^L = -$$

$$CP(\psi'') = +$$

A_{CP} sensitivity : $\Delta A \sim 10^{-3}$

CP violation in mixing can be measured with:

$$A_{SL} = \frac{\Gamma_{l^+l^+} - \Gamma_{l^-l^-}}{\Gamma_{l^+l^+} + \Gamma_{l^-l^-}} = \frac{1 - |q/p|^4}{1 + |q/p|^4}$$

With 10^8 D pairs in $(K^+e^-\nu)(K^+e^-\nu)$ mode, |q/p| can be measured with (10-15)% accuracy. Current world averaged value is 0.86±0.16 .

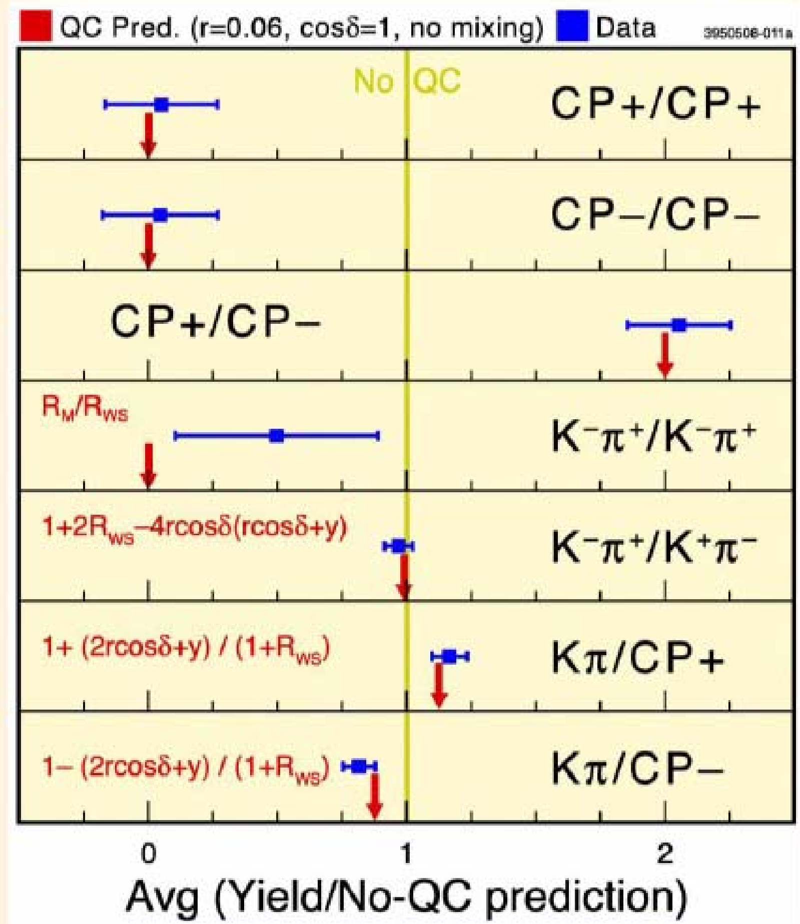
Quantum correlation @ $\psi(3770)$

$C = -1$

$$e^+e^- \to \boxed{\gamma^* \xrightarrow{\psi(3770)} D^0\bar{D}^0}$$

Quantum correlations are seen in data!

Forbidden by CP conservation	*CP+*	*CP+*
	CP−	*CP−*
Maximal enhancement	*CP+*	*CP−*
Forbidden if no mixing	$K^-\pi^+$	$K^-\pi^+$
Interference of CF with DCS (gives $\cos\delta_{K\pi}$)	$K^-\pi^+$	*CP±*
	CP±	$K^-\pi^+$
Single Tags Unaffected	*CP±* $K^-\pi^+$ *SL*	X



David Asner Charm2010

CLEO-c did a simultaneous fit to these combinations

PRL 100, 221801(2008)

D. Asner Charm2010

CLEO-c Preliminary

Fit Results [$\delta_{K\pi}$]

- 51 free parameters
  - N_{DD}, 21 branching fractions
  - 24 amplitude/phase parameters for $K^0_S\pi^+\pi^-$
  - 5 $K\pi$ and mixing parameters
- Fit performed with and without external measurements of y, x, y' (same as in HFAG May 2010 avg)
- Statistical uncertainties on y and $r_{K\pi}\cos\delta_{K\pi}$ (w/o ext. meas.) 3x smaller than 2008 analysis.
  - Estimated impact on HFAG average: $\sigma(y)$ reduced by ~10%
  - First direct measurements of $r_{K\pi}^2$ and $\sin\delta_{K\pi}$
- Preliminary systematic uncertainties

Parameter	Previous: PDG, HFAG, or CLEO	Fit: no ext. meas.	Fit: with ext. y, x, y'
y (10^{-2})	0.79 ± 0.13	$3.0 \pm 2.0 \pm 1.2$	0.635 ± 0.118
x^2 (10^{-3})	0.037 ± 0.024	$1.5 \pm 2.0 \pm 0.9$	0.022 ± 0.017
$r_{K\pi}^2$ (10^{-3})	3.32 ± 0.08	$4.12 \pm 0.92 \pm 0.23$	3.32 ± 0.08
$\cos\delta_{K\pi}$	1.10 ± 0.36	$0.98^{+0.27}_{-0.20} \pm 0.08$	$1.15 \pm 0.16 \pm 0.12$
$\sin\delta_{K\pi}$	---	$-0.04 \pm 0.49 \pm 0.08$	$0.55^{+0.36}_{-0.40} \pm 0.08$
$\delta_{K\pi}$ (°) [derived]	$22^{+11}_{-12}\,^{+9}_{-11}$	$0 \pm 22 \pm 6$	$15^{+11}_{-17} \pm 7$

Average of y and $y' = y\cos\delta_{K\pi} - x\sin\delta_{K\pi}$ (now limited by $\sin\delta_{K\pi}$)

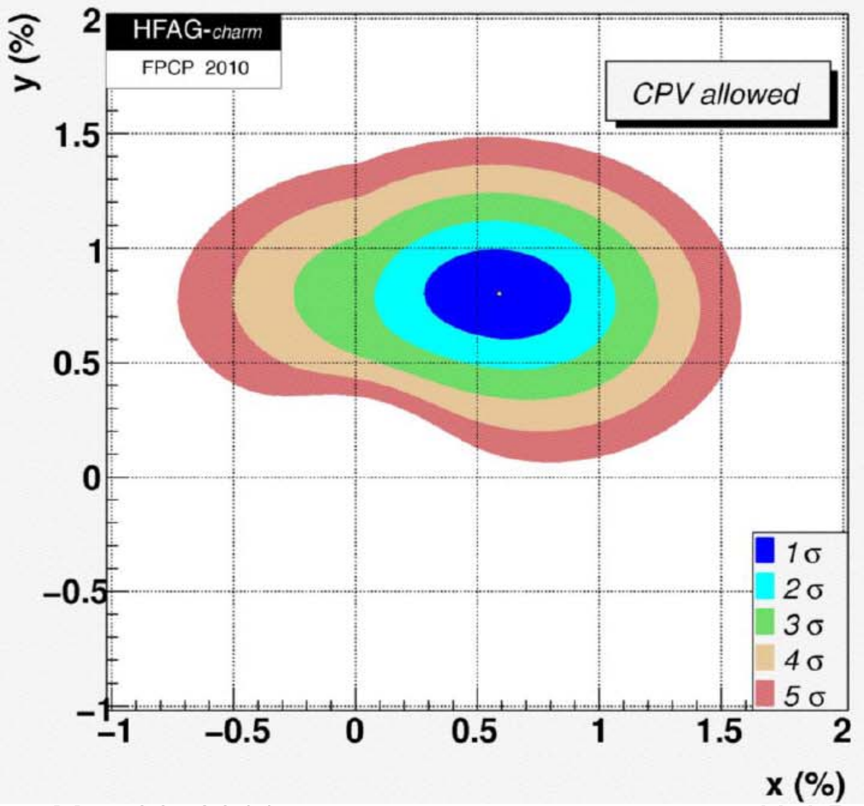
HFAG: new charm mixing with CLEO-c

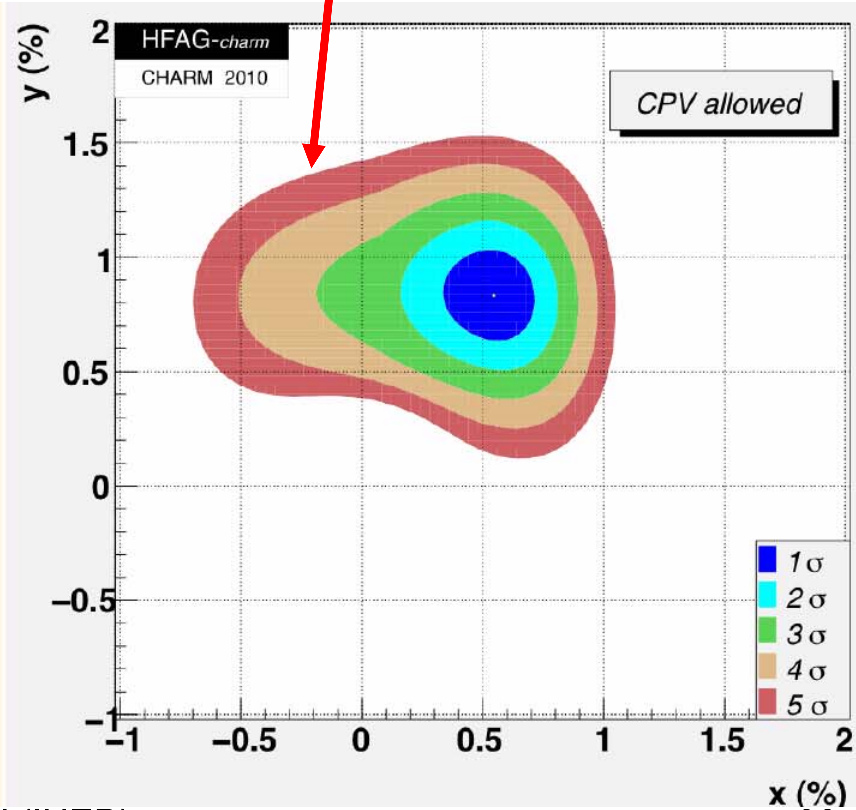
D. Asner
Charm 2010

Parameter	HFAG:FPCP2010	HFAG:CHARM2010
y (10^{-2})	0.79 ± 0.13	0.83 ± 0.13
x (10^{-2})	0.59 ± 0.20	$0.55^{+0.12}_{-0.13}$
$r_{K\pi}^2$ (10^{-3})	3.32 ± 0.08	3.32 ± 0.08
$\delta_{K\pi}$ ($^\circ$)	$27.6^{+11.2}_{-12.2}$	$31.0^{+10.7}_{-12.2}$

Consider CLEO-c results

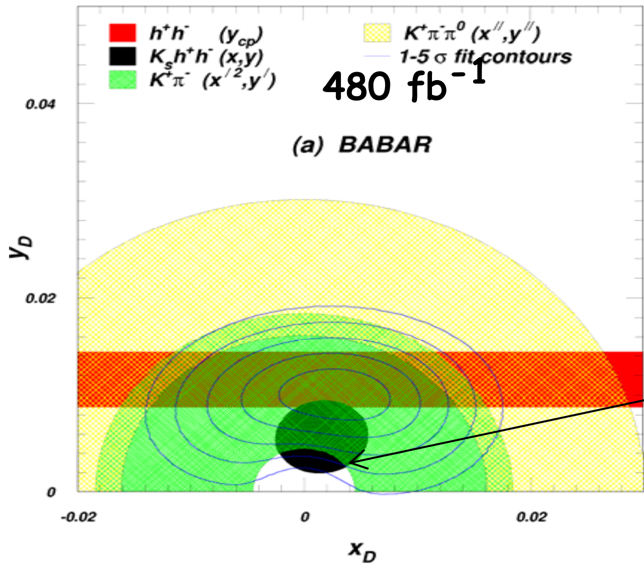
Surprising? Large impact on x uncertainty

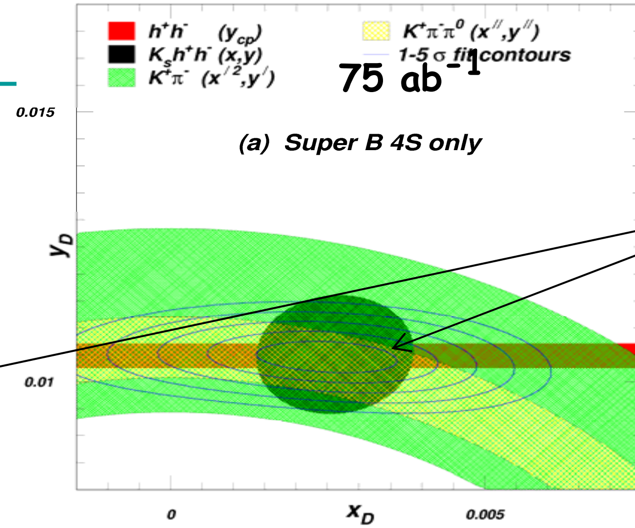




Brian Meadows ICHEP2010

Project to $75ab^{-1}$@$\Upsilon(4S)$:





Golden channels

Min. χ^2 fits (blue contours)

$$x_D = (5.5 \pm^{1.3}_{1.2}) \times 10^{-3}$$
$$y_D = (8.3 \pm 1.3) \times 10^{-3}$$

$$x_D = (xxx^{+0.72}_{-0.75}) \times 10^{-3}$$
$$y_D = (xxx \pm 0.19) \times 10^{-3}$$

Uncertainties shrink: but are limited by the irreducible model uncertainty (biggest effect on x_D)

Strong phase measurement from $\psi(3770)$ can greatly reduce this.

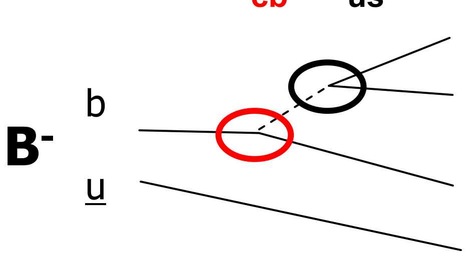
$$x_D = (xxx \pm 0.20) \times 10^{-3}, \quad y_D = (xxx \pm 0.12) \times 10^{-3}$$

The weak phase γ (ϕ_3)

From A. Bondar CHARM2010

Interference between tree-level decays; theoretically clean

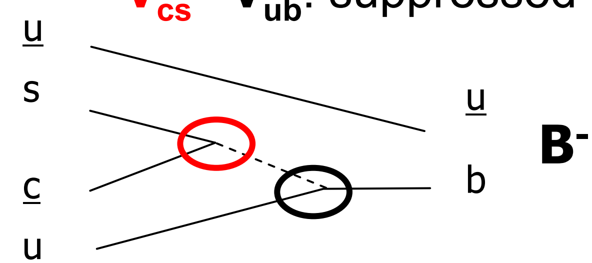
Favored: V_{cb} V_{us}^*



$K^{(*)-}$ Common final state $K^{(*)-}$

$D^{(*)0} \longrightarrow f \longleftarrow \bar{D}^{(*)0}$

V_{cs}^* V_{ub}: suppressed



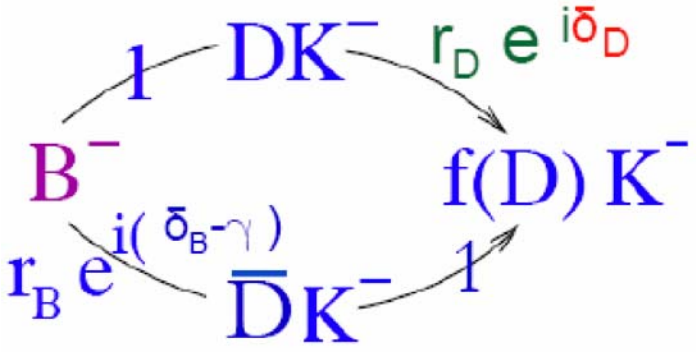
$$\frac{A\left(B^- \to \bar{D}^0 K^-\right)}{A\left(B^- \to D^0 K^-\right)} = r_B e^{i\delta} e^{-i\phi_3}$$

Parameters: ϕ_3, (r_B, δ) per mode

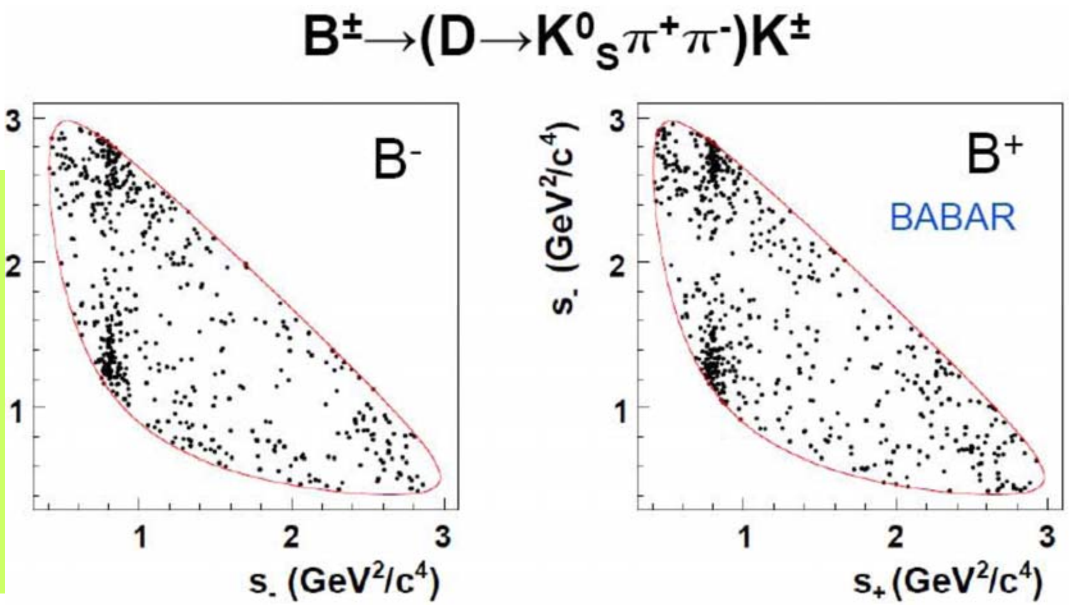
Three methods for exploiting interference (choice of D^0 decay modes):

- Gronau, London, Wyler (GLW): Use CP eigenstates of $D^{(*)0}$ decay, e.g. $D^0 \to K_s \pi^0$, $D^0 \to \pi^+ \pi^-$
- Atwood, Dunietz, Soni (ADS): Use doubly Cabibbo-suppressed decays, e.g. $D^0 \to K^+ \pi^-$
- Giri, Grossman, Soffer, Zupan (GGSZ) / Belle: Use Dalitz plot analysis of 3-body D^0 decays, e.g. $K_s \pi^+ \pi^-$

$B^- \to D(K_s h^+ h^-)K^-$ Dalitz plot for γ at B factory



A powerful choice of common state f(D) in $K_s h^+ h^-$
BABAR: PRL 105, 121801 (2010)
Belle : PRD 81, 112002 (2010)



Differents between B^- and B^+ Dalitz plots allow γ extracted in unbinned fit. However, need to understand different amplitudes from D^0 and D^0bar decay modes across Dalitz space, esp. variation in strong phase.

Approach of B factories: construct Dalitz plot model of D with flavor-tagged decays, estimated model uncertainty of 30-90, which is << statistical error.

But super-B and LHC-b will start to be limited by this model uncertainty –
Highly desirable to have precision model independent approach!

Binned Model-Independent Fit

Binned fit proposed by Giri *et al.* [PRD 68 (2003) 054018] and developed by Bondar & Poluektov [EPJ C 55 (2008) 51; EPJ C47 (2006) 347] removes model dependence by relating events in bin i of Dalitz plot to *experimental observables.*

$B^{\pm}$ events in bin i of Dalitz plot

Number of events for flavour-tagged D sample

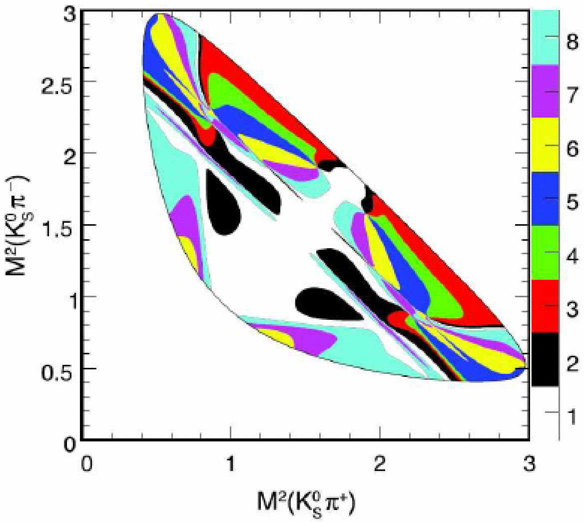
$x_{\pm} = r_B \cos(\delta_B \pm \gamma)$

$y_{\pm} = r_B \sin(\delta_B \pm \gamma)$

$$N_i^{\pm} = h(K_{\pm i} + r_B^2 K_{\mp i} + 2\sqrt{K_i K_{-i}}(x_{\pm} c_i \pm y_{\pm} s_i))$$

c_i, s_i : average in bin of cosine, sine of strong phase δ_D

Can be measured in quantum correlated decays at ψ(3770)!



Choosing bins of *expected* similar strong phase difference maximises statistical precision

Here take 8 bins of equal spacing in $\Delta\delta_D$ (using as reference model: BaBar, PRL 95 (2005) 121802)

Loss in statistical sensitivity w.r.t. unbinned result…(here ~20%) but no model error!

From Jim Libby CHARM2010

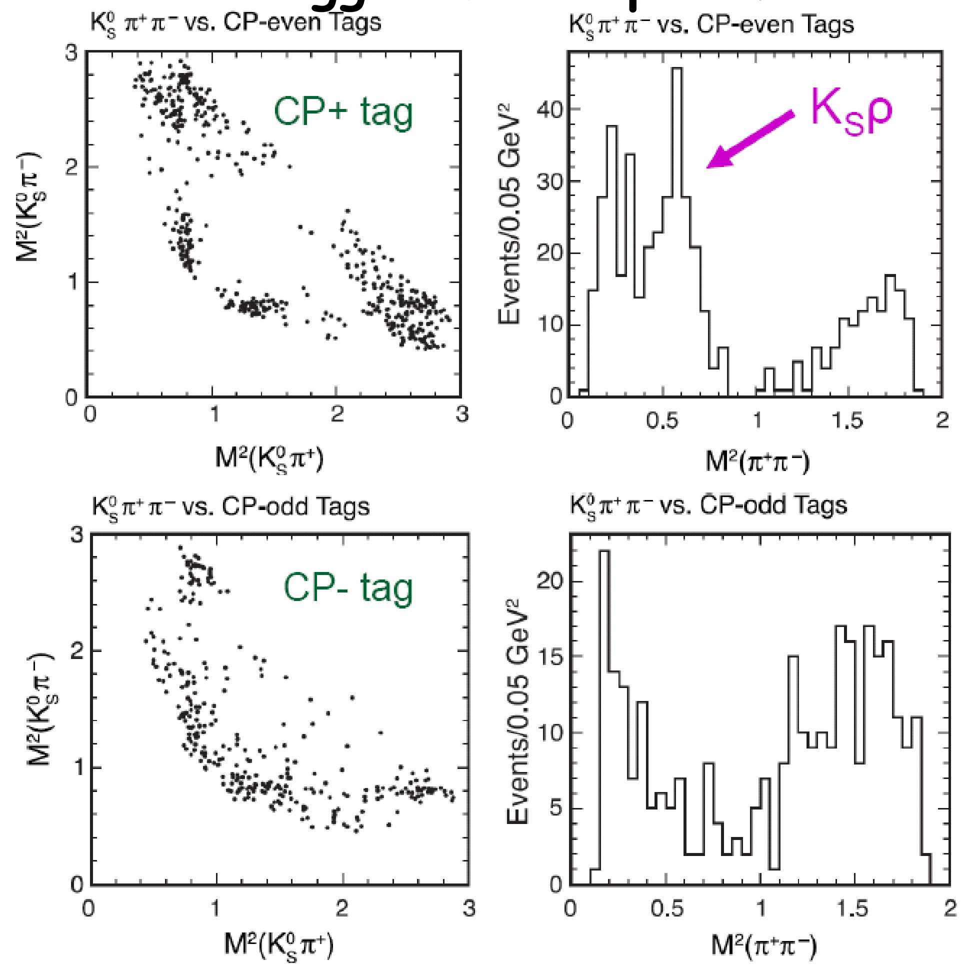
CP-tagged Dalitz plots

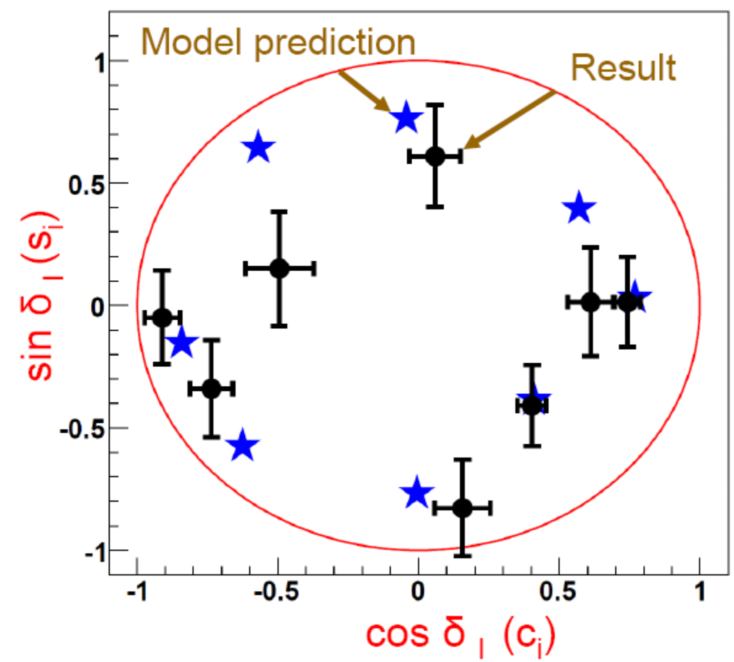
Clear difference between CP-even and CP-odd tagged Dalitz plots.

R. Briere *et al.*, PRD 80 (2009) 032002

(model = BABAR PRL 95 (2005) 121802)

CLEO-c, PRD 80 (2009) 032002





Projected uncertainty on γ arising from uncertainty on c_i & s_i is 1.7^o :

- Smaller than model error

BESIII will reduce this error to less than 1^0