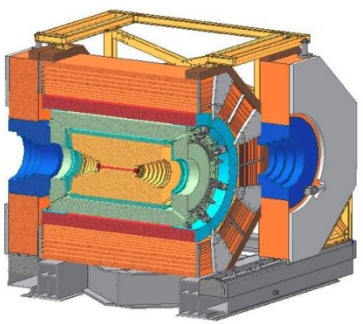
Prospects of charm physics at BESIII and beyond



BESIII

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2015年7月24日

第十三届重味物理与CP破坏研讨会

现有实验装置（国际竞争）

- 强子对撞实验（粲强子产生截面巨大，能量Boost）
  - Tevetron (CDF, D0) 已停止运行
  - LHCb （~3 fb^{-1}：59 x 10^{11} 个$c\underline{c}$）
    - 劣势：测量包含中性末态粒子ν, γ, π^0的衰变道
- 正负电子对撞实验（触发效率接近100%）
  - B工厂（能量Boost，已停止运行）
    - BaBar
    - Belle （亮度世界纪录：2.1 x 10^{34} 积分亮度： ~1000 fb^{-1}）
  - 阈值产生 (CLEOc已停运, BESIII：亮度8 x 10^{32})
    - 在粲强子统计量上无法与LHCb及B工厂实验竞争

阈值产生实验的研究优势

粲强子在**质心系能量阈值**上成对产生

- 没有额外的质心系能量产生多余的π介子

  ⇒ 更低的本底

- 干净的量子关联数据和CP标记技术是其他类型实验所没有的

  ⇒ 特色的物理分析技术

- 同时在数据中重建粲强子对时，部分系统误差可以抵消

  ⇒ 更小的系统误差

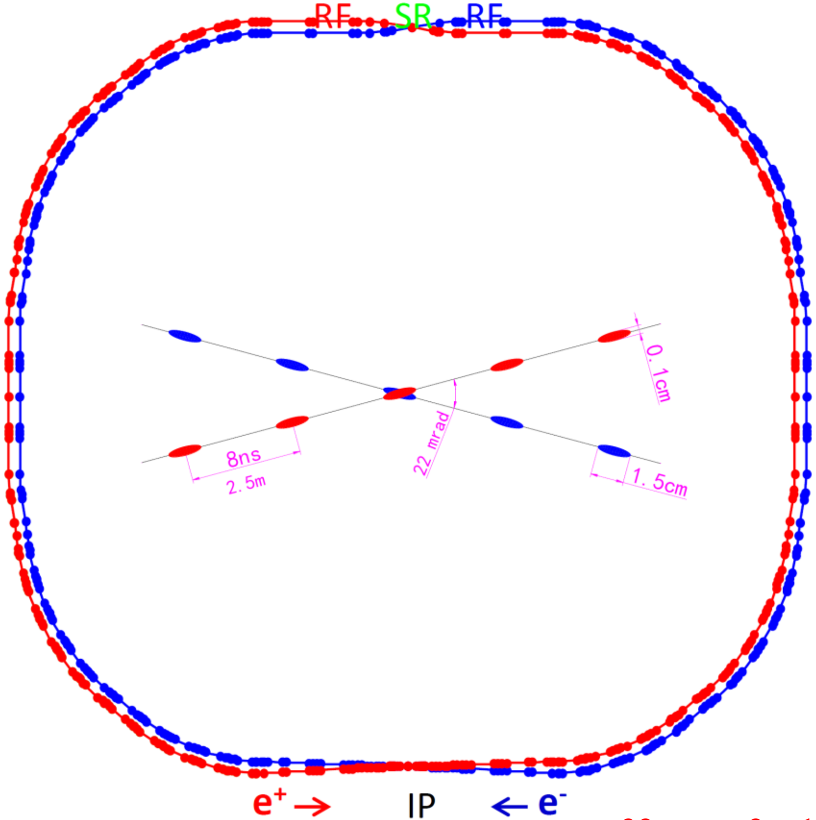
Outline

- Current BEPCII/BESIII
  - Operations and data taking plans
- Detector upgrade
  - Endcap TOF
  - Inner tracking detector
- Prospects for charm physics
  - BESIII
  - Super Tau-charm factory
- Summary

Please see Xiaorui's talk for more details.

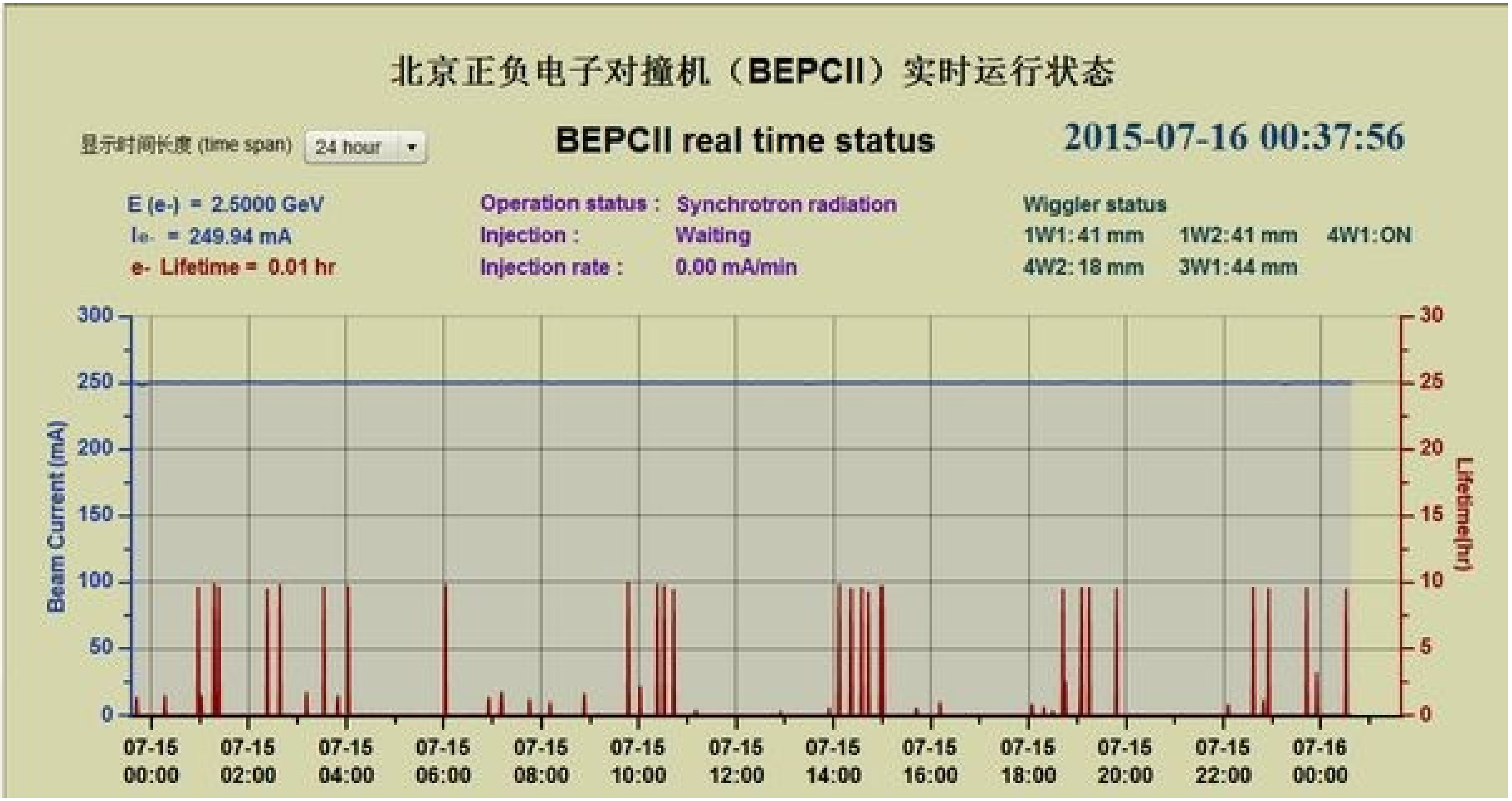
Current status of BEPCII

- BEPCII: A double ring e^+e^- collider



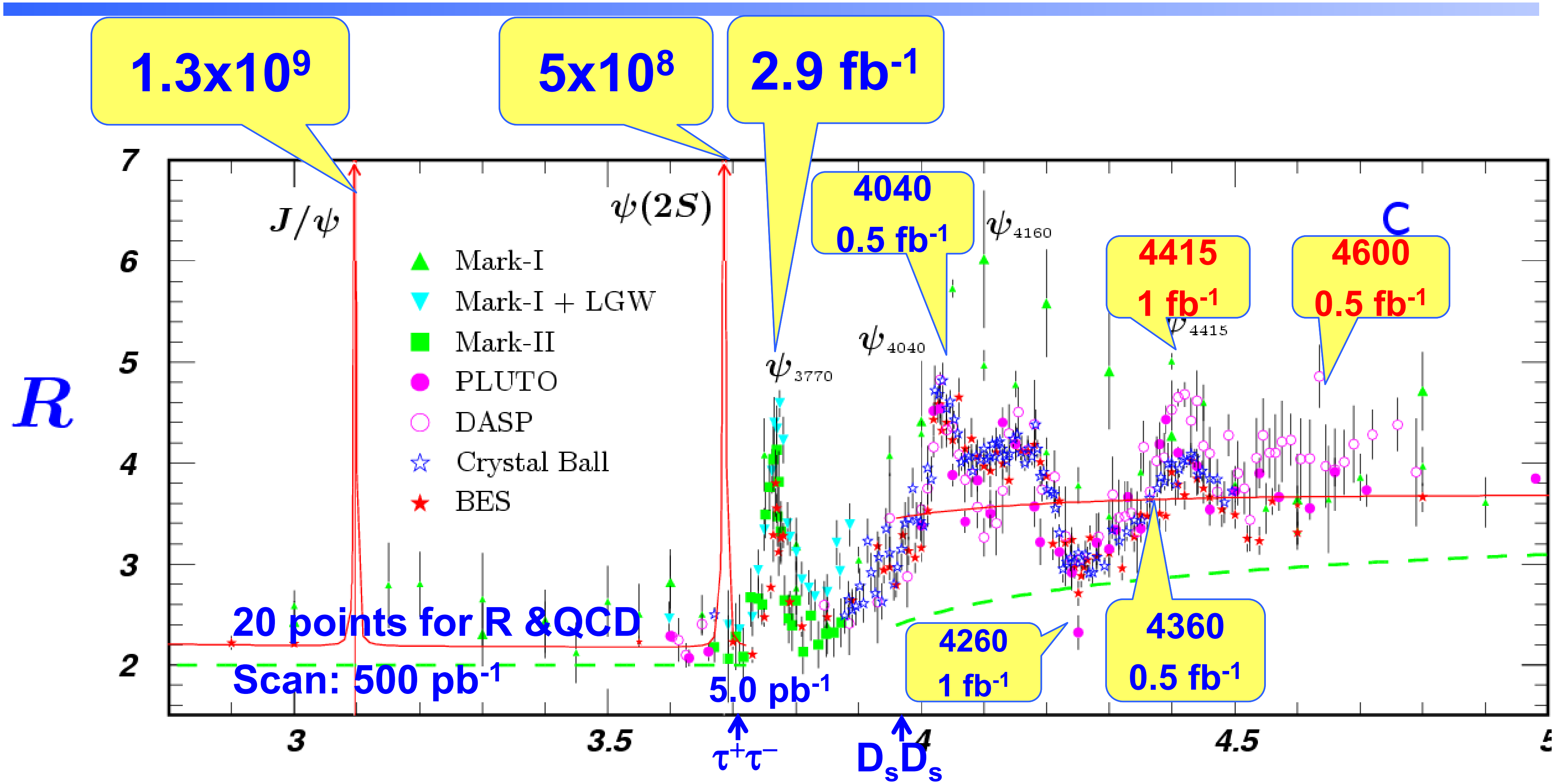
- A record $L_{peak} = 8.5\text{x}10^{32}\ cm^{-2}s^{-1}$ @ 3.773 GeV reached in Nov. 20, 2014
- Weekly record luminosity: 169 pb^{-1}, Average of daily lumi： >17 pb^{-1}
- 500 pb^{-1} data collected @4.6 GeV : the limit of BEPCII energy region
- Bunch crossing time: 8ns $\rightarrow$ 6ns

BEPCII Top-up injection



- 同步辐射实验中成功实现(电子注入)
- 期待在对撞模式中实现（电子+正电子注入)
  - 积分亮度预期增加约30%

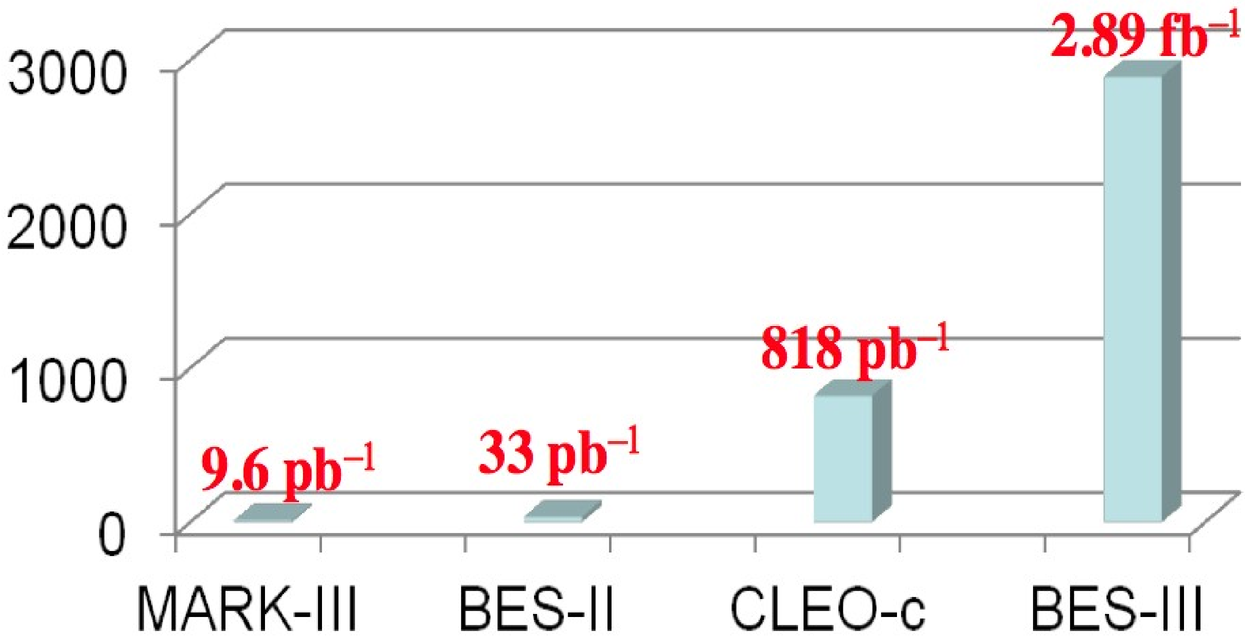
Data samples available



- 20 points for R &QCD Scan: 500 pb^{-1} finished in May 1^{st}, 2015
- Y(2175) resonance: 100 pb^{-1} : finished in June 15, 2015

Data samples @ charm threshold

- CLEO-c: 818 pb^{-1} @ $\psi(3770)$
- BESIII: 2.9 fb^{-1} (~3.5 x CLEO-c data) @$\psi(3770)$



- BESIII: 0.5 fb^{-1} @ $\psi(4040)$
- BESIII: 0.5 fb^{-1} @ 4600 MeV (Λ_c pair threshold)
- In 2015-2016 run period: 3 fb^{-1} @4.17 GeV

Data taking plan

Approved plan for 2015/2016 run period

- 4170 data taking 3 fb^{-1}, 5 months
- Data taking at around χ_{c1} mass 25 days
  - e+e- → χ_{c1}, Collins fragmentation function

    2-3 points, 3.5136 (3 MeV below, 20 pb^{-1})

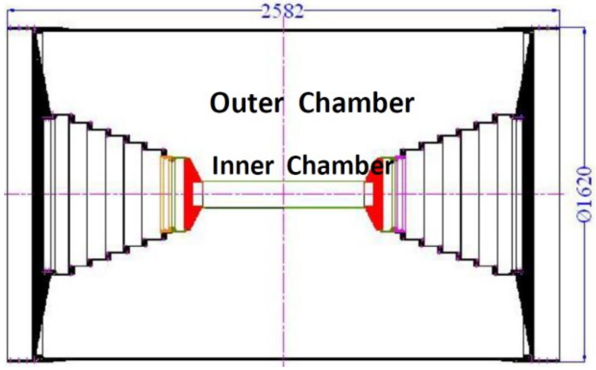
    3.5106 (180 pb^{-1})

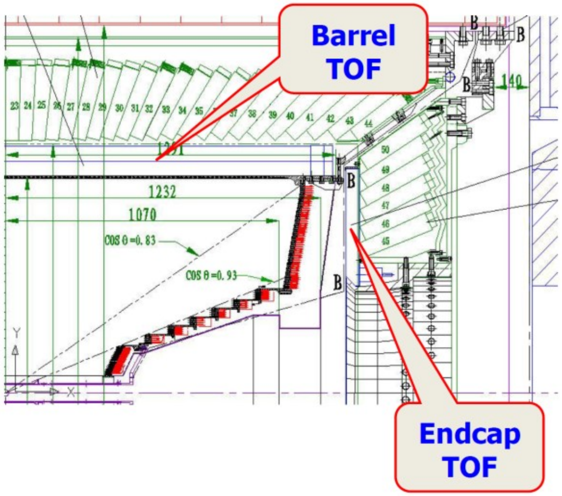
    3.5100 (0.5 MeV below) or χ_{c1} mass for 180 pb^{-1}
- Psi' scan 500 pb^{-1} 25 days

Final goal for data set at threshold: ~20 fb^{-1}

BESIII detector upgrade

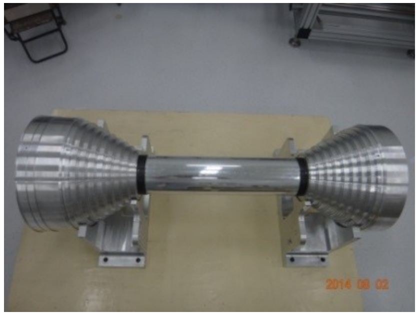
- Inner Drift Chamber appeared aging effect
  - Cathode aging → Malter discharge
    - Adding ~2000ppm water vapor into the gases
  - Anode aging → gain drop 14% - 26%
  - Short-term upgrade plan: a new inner drift chamber
  - Long-term upgrade plan: a 3-layer CGEMs inner tracker
- Endcap TOF (ETOF: scintillator + PMT)
  - To improve PID
  - Upgrade with MRPC
    - Less affected by scattering
    - Tracking with more readout pads
    - Total resolution: ~140ps → <80ps



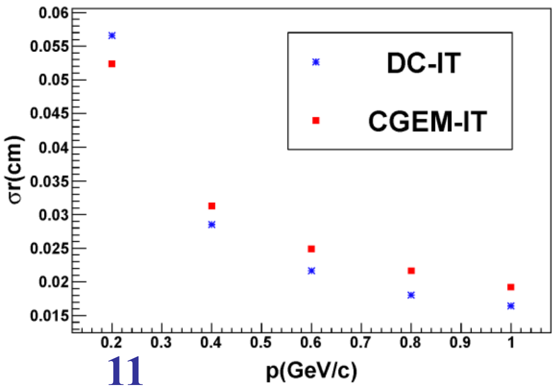


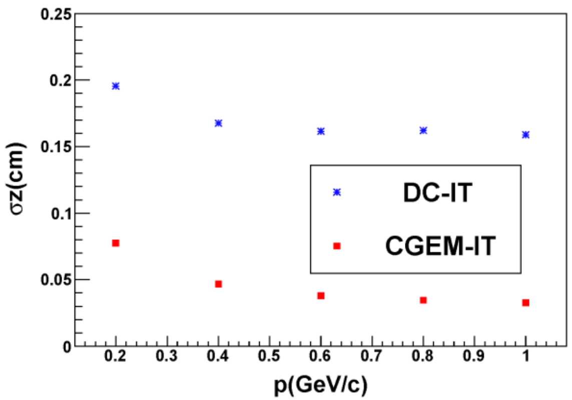
Upgrade for inner tracking detector

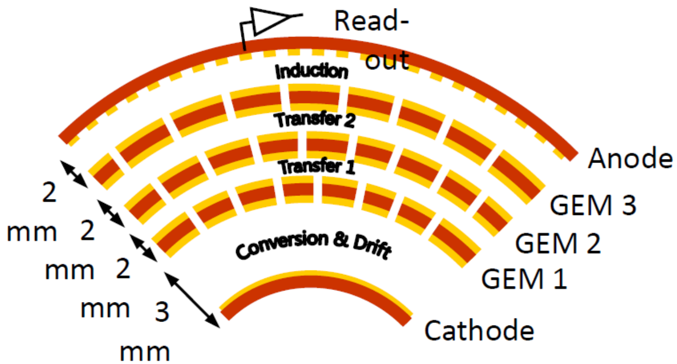
- New inner drift chamber
  - Chamber wiring finished in January, 2015
  - Ready for installation



- CGEM inner tracker
  - Proposed by the Italy group;
  - 3-Layer CGEM foils (KLOE2-like);
  - The design is coming to a conclusion;
  - construction of the layer 2 has started;
  - beam test of the prototype is ongoing;
  - software: progress in simulation and reconstruction.

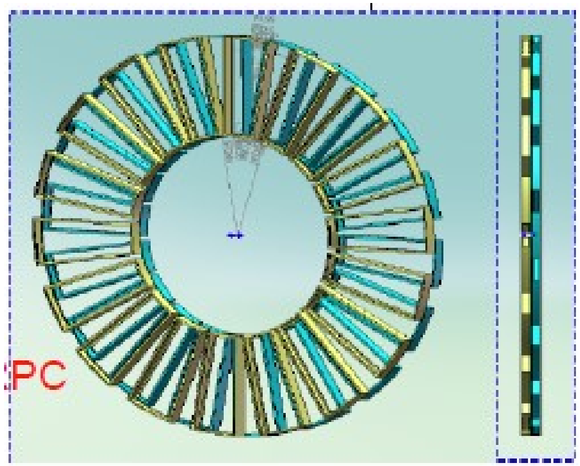


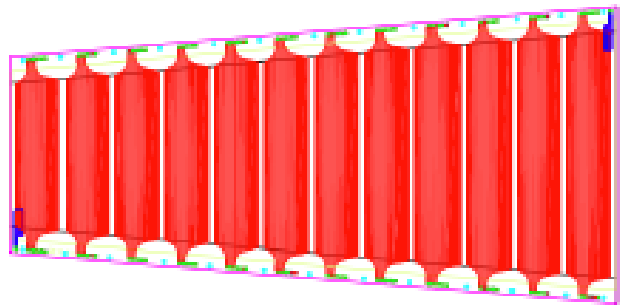




Conceptual view of the C-GEM

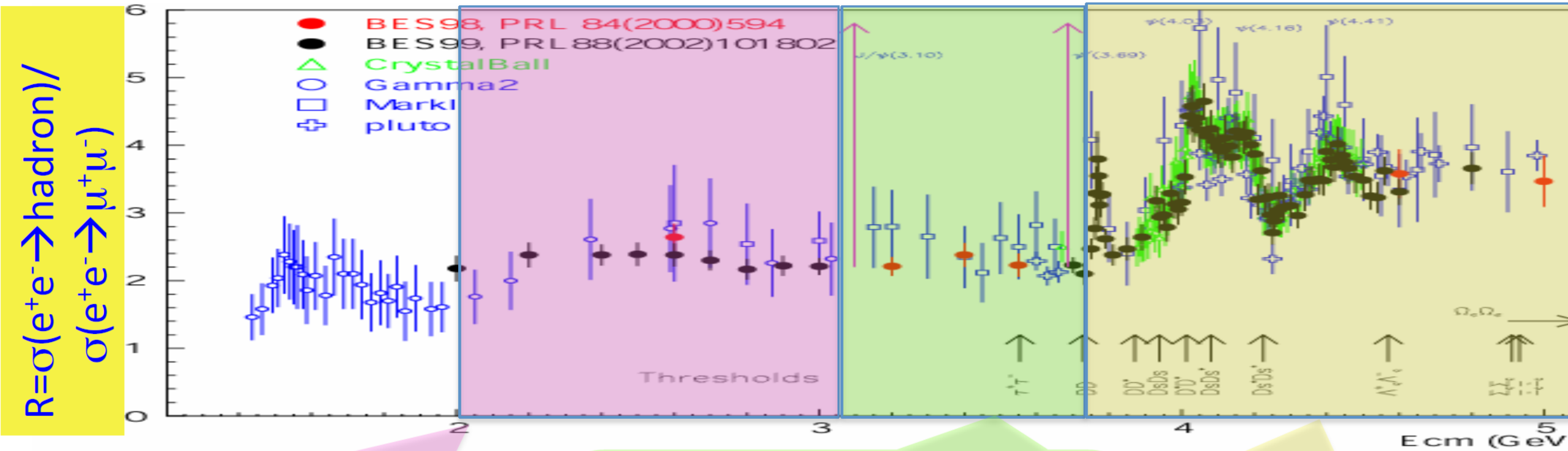
Endcap TOF upgrade





- Two MRPCs has been installed.
  - Testing with real data
  - A VERY preliminary calibration ⇒ time resolution ~70 ps
- The production of the whole ETOF system: finished
- Performance and stability test is carrying on
  - ~4 months cosmic-ray test
- Full installation will start on August, 2015.

Physics at tau-charm Energy Region



- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- D mesons
- f_D and f_{Ds}
- D_0-D_0 mixing
- Charm baryons

Physics at Charm threshold

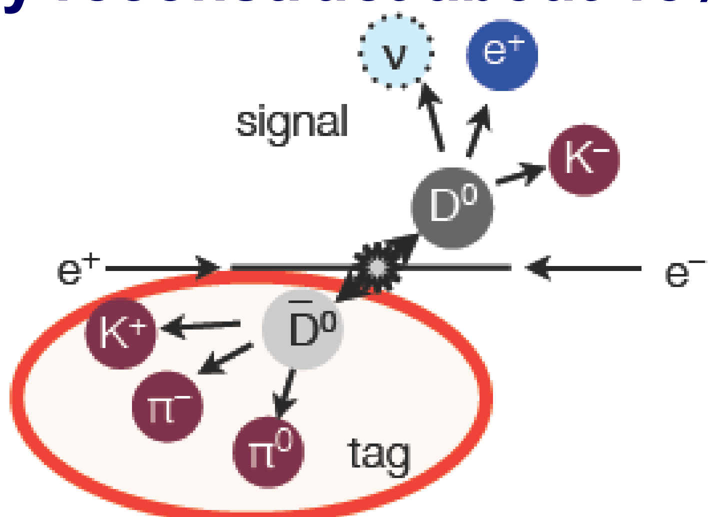
- Decay constants & form factors for Charm meson
- Quantum correlations at $\psi(3770)$
  - CPV measurements
  - Strong phase measurements
- Rare decays
- Charm baryons
- D^0-$\underline{D}^0$ mixing & CPV @$\psi(4040)$

Many new BESIII results have been released!

Selected results will be shown!

Double Tag (DT) techniques

- 100% of beam energy converted to D pair (Clean environment, kinematic constrains ν Recon.)
- D generated in pair $\Rightarrow$ absolute Branching fractions
- At ψ(3770) charm production is $D^0\bar{D}^0$ and D^+D^-
- Fully reconstruct about 15% of D decays

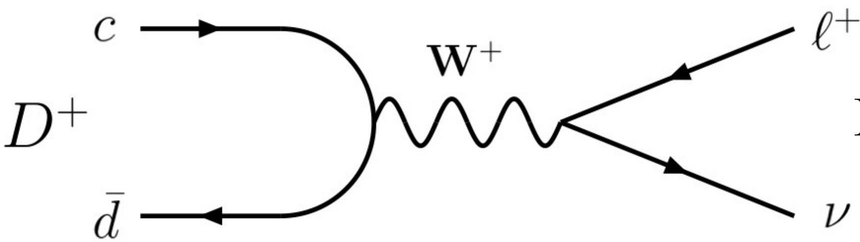


$$\Delta E = E_D - E_{\text{Beam}}$$

$$M_{\text{BC}} = \sqrt{E_{\text{Beam}}^2 - p_D^2}$$

- Double tag techniques: Hadronic tag on one side, on the other side for leptonic/semileptonic studies. Neutrino is reconstructed from missing energy and momentum (Double tag efficiency is high.)

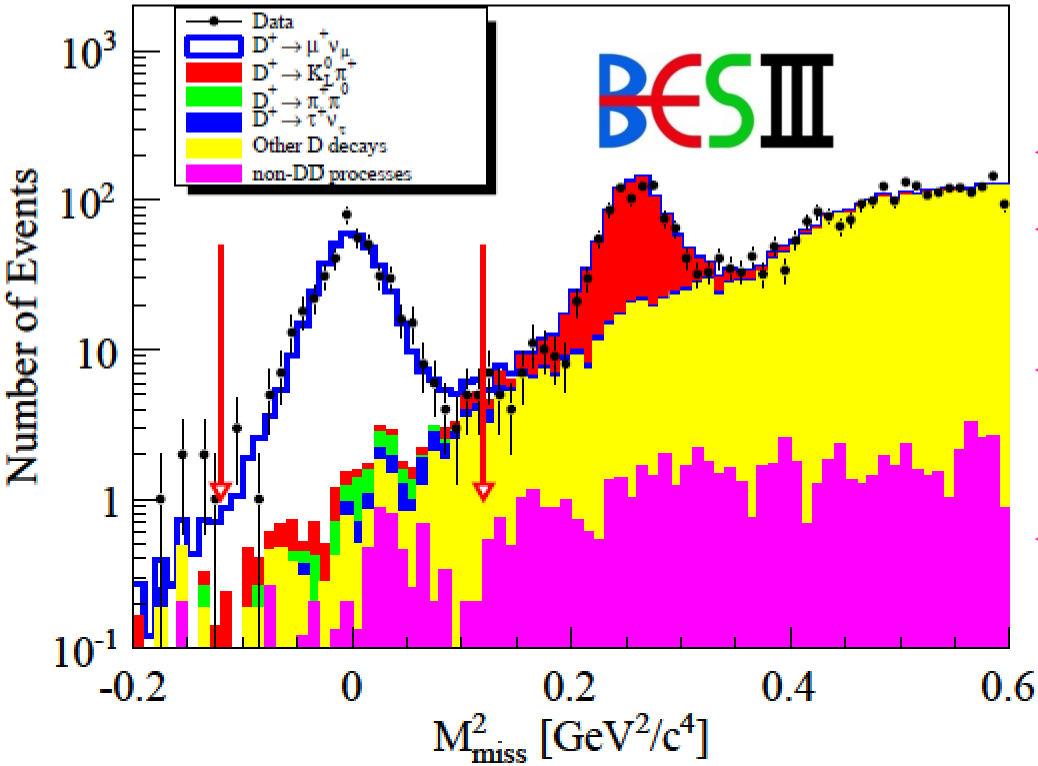
$f_{D(s)+}$: Leptonic decays



$$\Gamma\left(D^+ \to \ell^+ \nu_\ell\right) = f_D^2 \left|V_{cd}\right|^2 \frac{G_F^2}{8\pi} m_D m_\ell^2 \left(1 - \frac{m_\ell^2}{m_D^2}\right)^2$$

- **Extract decay constant $f_{D(s)}$ incorporates the strong interaction effects (wave function at the origin)**
  - **Multiple tests with charm: f_D, f_{Ds} and f_D/f_{Ds}**
- **To validate Lattice QCD calculation of $f_{B(s)}$ and provide constrain of CKM-unitarity**
- **Sensitive to New Physics (Charged Higgs contribution, …)**

f_{D+} Results ($D^+ \to \mu^+\nu$)



Phy. Rev. D89, 051104

- **2.92fb^{-1} @3.773 GeV**
- **Muon counter information applied**
- **Kinematic variable: M^2_{miss}**

$$M^2_{miss} = \left(E_{Beam} - E_{\mu}\right)^2 - \left(-\vec{p}_{tag} - \vec{p}_{\mu}\right)^2 \square 0$$

- **451 $D \to \mu\nu$ candidates observed**
  - **Low background**

$N(D^+ \to \mu^+\nu) = 409.0 \pm 21.2 \pm 2.3$

$B(D^+ \to \mu^+\nu) = (3.71 \pm 0.19 \pm 0.06) \times 10^{-4}$

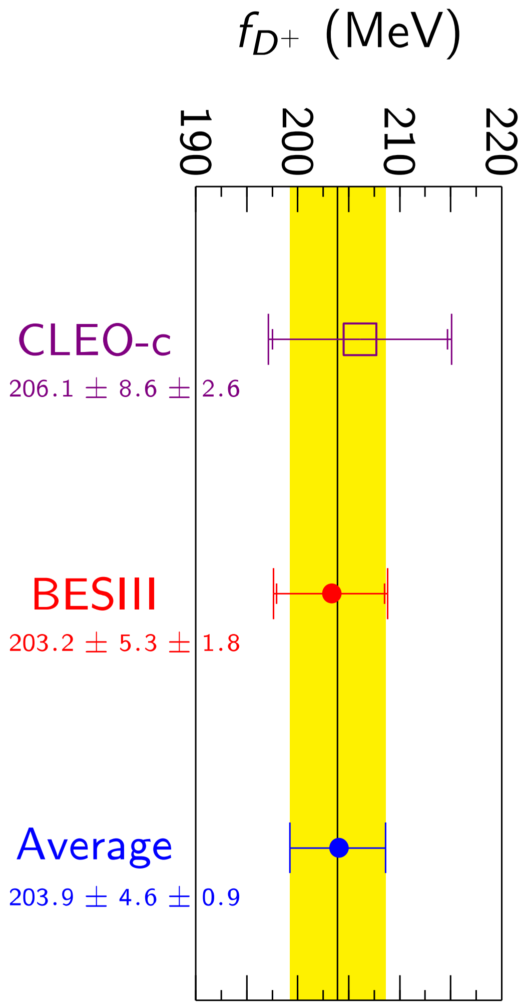
$f_{D+} = (203.2 \pm 5.3 \pm 1.8)$ ⇐ |Vcd| of CKM-Fitter Input

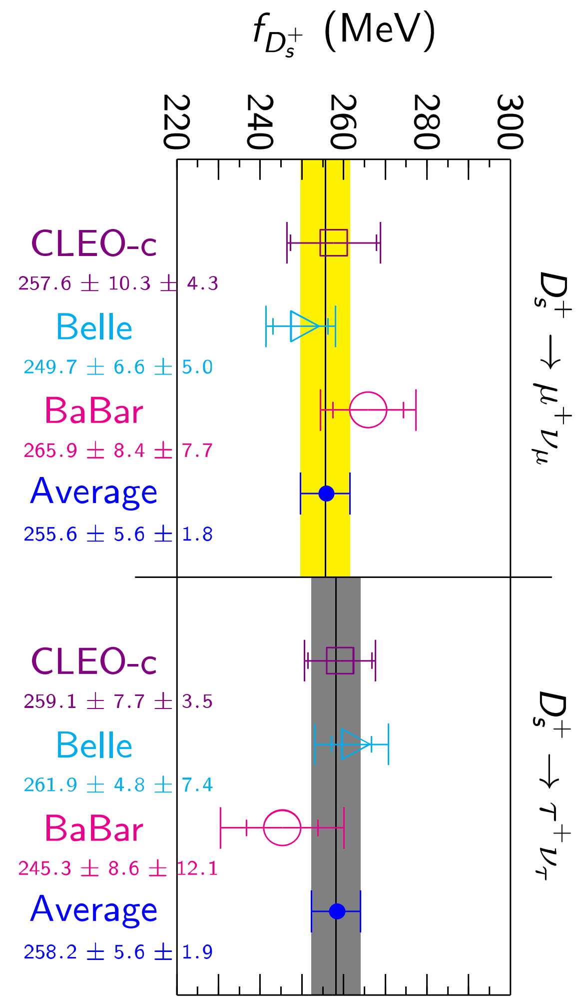
$|Vcd| = 0.221 \pm 0.006 \pm 0.005$

⇐ LQCD calculated $f_D = 207 \pm 4$ MeV[PRL100(2008)062002]

The error is still dominated by statistics! More data is needed.

$f_{D(s)+}$ Comparison





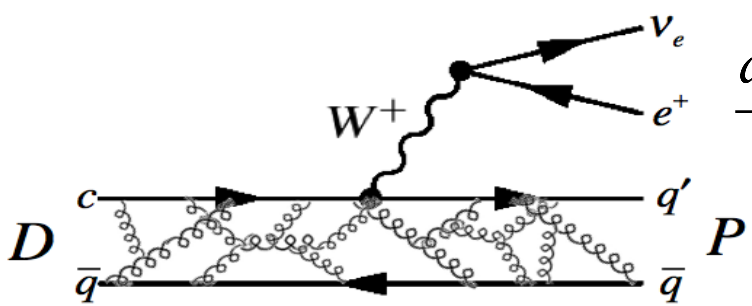
BESIII: 2.7% with 2.92fb^{-1}

BESIII final: 1.5% with 10 fb^{-1}

CLEO-c: 2.5% with 0.68fb^{-1}

BESIII final: 1.25% with 5 fb^{-1}

Form Factors: Semileptonic decays



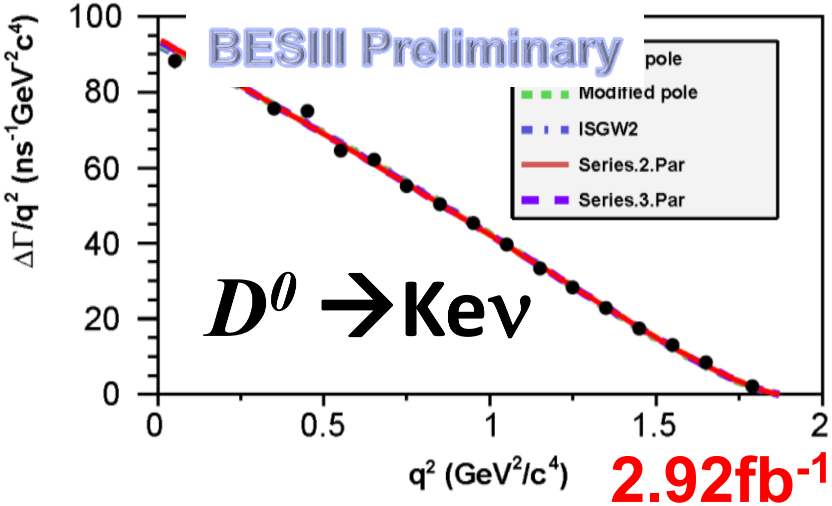
$$\frac{d\Gamma\left(D\to K(\pi)e\nu\right)}{dq^2}=\frac{G_F^2\left|V_{cs(d)}\right|^2 P_{K(\pi)}^3}{24\pi^3}\left|f_+\left(q^2\right)\right|^2$$

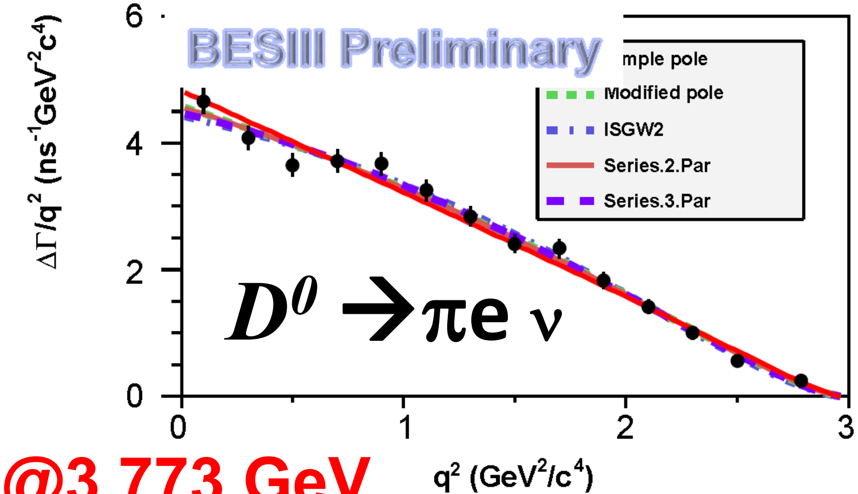
$q^2=(p_l+p_\nu)^2 \Rightarrow M^2_{inv}$ **of lepton pair**

- $D_{(s)} \rightarrow P\, l\, \nu$ (Theoretically clean)
  - Measure $|V_{cx}|$ x FF
  - Charm physics:
    - CKM-unitarity ⇒ $|V_{cx}|$, extract FF, test LQCD
    - Input LQCD FF to test CKM-unitarity
  - B physics: Validate LQCD for form factor, extract $|V_{ub}|$ to test CKM-unitarity
    - Example: $B\rightarrow\pi\, l\, \nu \Rightarrow |V_{ub}| = 3.92\pm0.09\pm$**0.45(Theory)** rely on LQCD Form Factor calculations (provide perfect calibration)

Form Factors fit results ($D^0 \to K/\pi\, e^+\nu$)

Decay rate



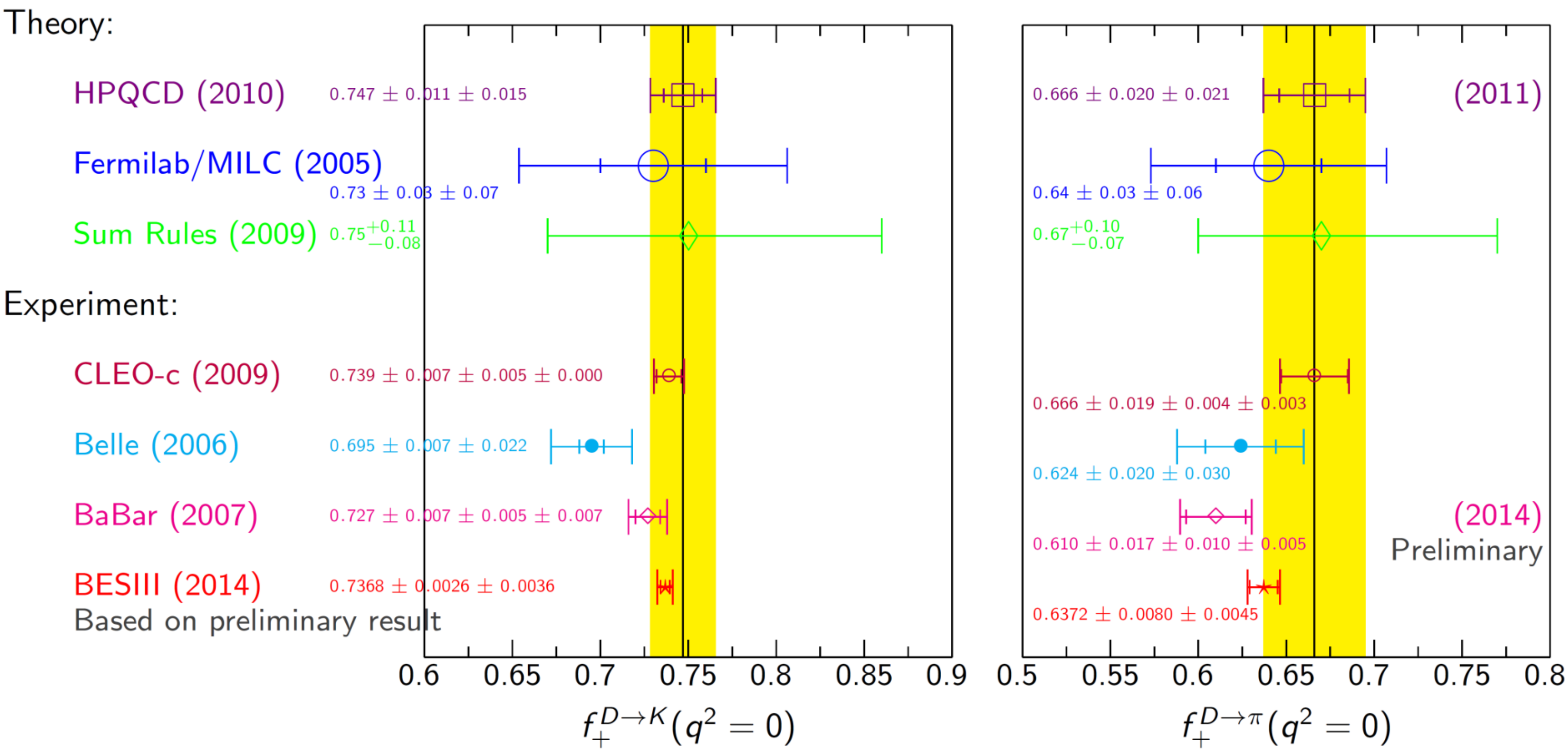


2.92fb^{-1} @3.773 GeV

		$D^0 \to K^- e^+ \nu$		$D^0 \to \pi^- e^+ \nu$
Simple Pole	$f_K^+(0)\|V_{cs}\|$	0.7209±0.0022±0.0033	$f_\pi^+(0)\|V_{cd}\|$	0.1475±0.0014±0.0005
	M_{pole}	1.9207±0.0103±0.0069	M_{pole}	1.9114±0.0118±0.0038
Mod. Pole	$f_K^+(0)\|V_{cs}\|$	0.7163±0.0024±0.0034	$f_\pi^+(0)\|V_{cd}\|$	0.1437±0.0017±0.0008
	α	0.3088±0.0195±0.0129	α	0.2794±0.0345±0.0113
ISGW2	$f_K^+(0)\|V_{cs}\|$	0.7139±0.0023±0.0034	$f_\pi^+(0)\|V_{cd}\|$	0.1415±0.0016±0.0006
	r_{ISGW2}	1.6000±0.0141±0.0091	r_{ISGW2}	2.0688±0.0394±0.0124
Series.2.Par	$f_K^+(0)\|V_{cs}\|$	0.7172±0.0025±0.0035	$f_\pi^+(0)\|V_{cd}\|$	0.1435±0.0018±0.0009
	r_1	-2.2278±0.0864±0.0575	r_1	-2.0365±0.0807±0.0260
Series.3.Par	$f_K^+(0)\|V_{cs}\|$	0.7196±0.0035±0.0041	$f_\pi^+(0)\|V_{cd}\|$	0.1420±0.0024±0.0010
	r_1	-2.3331±0.1587±0.0804	r_1	-1.8434±0.2212±0.0690
	r_2	3.4223±3.9090±2.4092	r_2	-1.3871±1.4615±0.4677

Comparison of Form Factors

Gang Rong
CKM2014

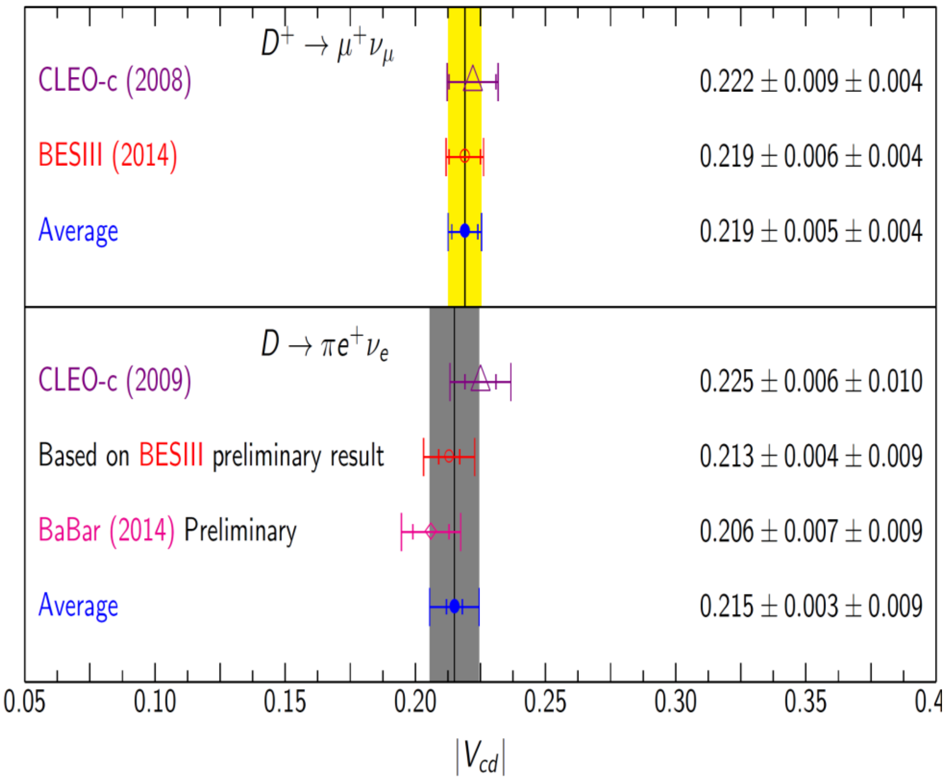


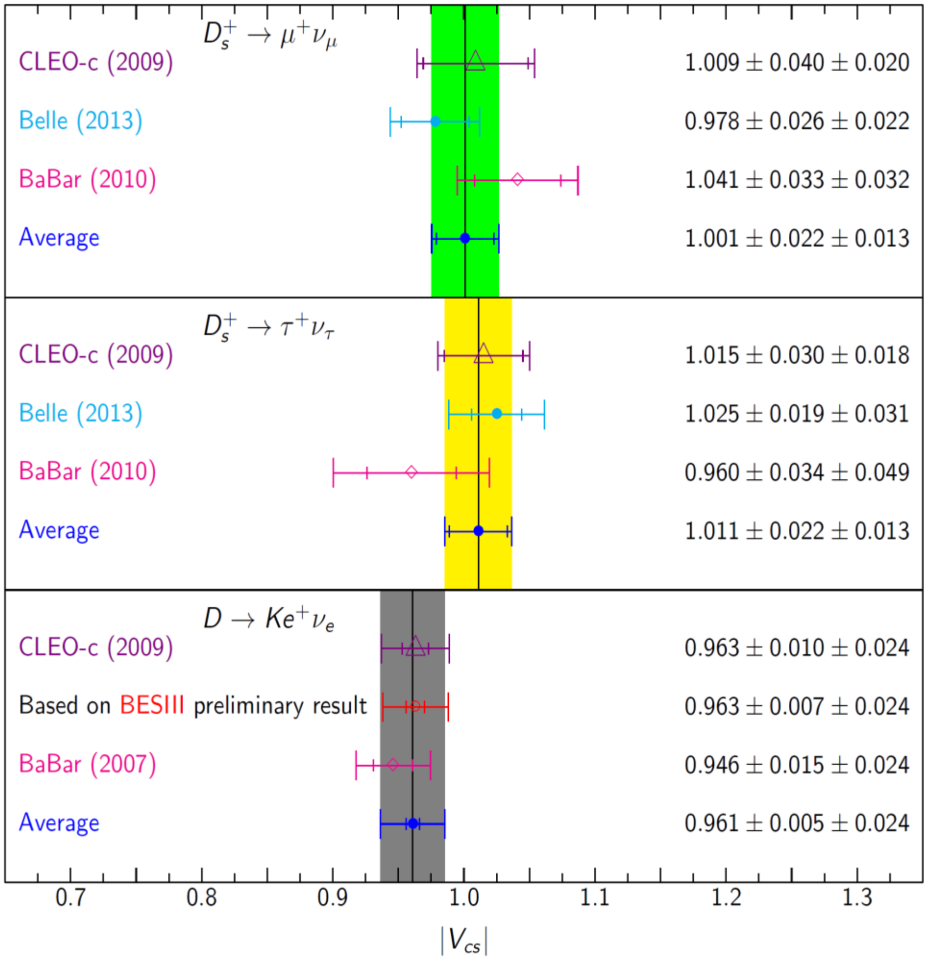
BESIII: the most precise measurements

The error of $f_+^{D\to\pi}$ is still dominated by statistics.

CKM matrix elements $|V_{cd(s)}|$

Gang Rong
CKM2014





BESIII: the most precise measurements

Reaches for rare charm decays?

SM predictions and experimental reaches

10^{-0}

10^{-1}

Cabibbo favor

10^{-2}

10^{-3} Single Cabibbo suppressed

10^{-4} Doubly Cabibbo suppressed

CLEO-c

10^{-5}

Radiative decays

$$D^0 \to \overline{K}^{*0}\gamma / \phi\gamma / \rho\gamma / \omega\gamma$$

BESIII

10^{-6}

$$D^+ \to K^{*+}\gamma / \rho^+\gamma \quad D_S^+ \to K^{*+}\gamma / \rho^+\gamma$$

BESIII final/B factory

10^{-7}

Long distance:

10^{-8} Vector meson Dominance

$$D^0 \to \gamma\gamma / VV'(\to ll) / hV(\to ll) / hh'V(\to ll)$$

LHCb

Super-B

10^{-9}

Super-τ-charm

10^{-10}

Short distance FCNC

$$D^0 / D^+ \to \gamma\gamma / Vl^+l^- / hl^+l^- / hh'l^+l^-$$

10^{-11}

$$D^0 \to \mu^+\mu^-$$

10^{-12}

$$D^0 \to e^+e^-$$

10^{-13}

10^{-14}

10^{-15}

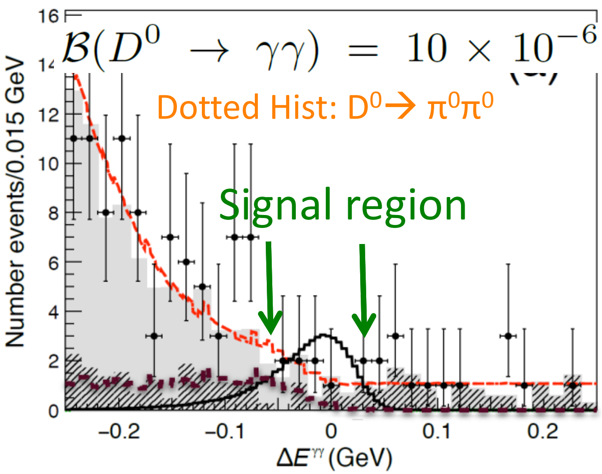
$$D \to (h)\mu^+e^-$$

Forbidden decays: LNV, LFV, BNV

$$D \to (hh)e^+e^+ / (hh)\mu^+\mu^+$$

Rare decays ($D^0 \rightarrow \gamma\gamma$)

PRD91 (2015) 11, 112015



Double tag method

Tag modes

$\bar{D}^0 \rightarrow K\pi$

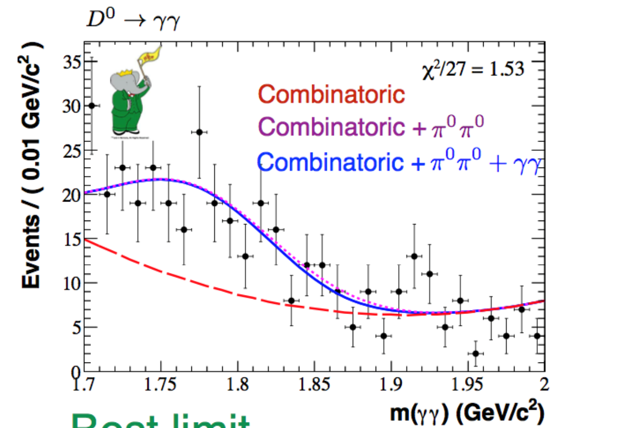
$\bar{D}^0 \rightarrow K\pi\pi^0$

$\bar{D}^0 \rightarrow K3\pi$

$\bar{D}^0 \rightarrow K3\pi\pi^0$

$\bar{D}^0 \rightarrow K\pi2\pi^0$

} $D^0 \rightarrow \gamma\gamma$



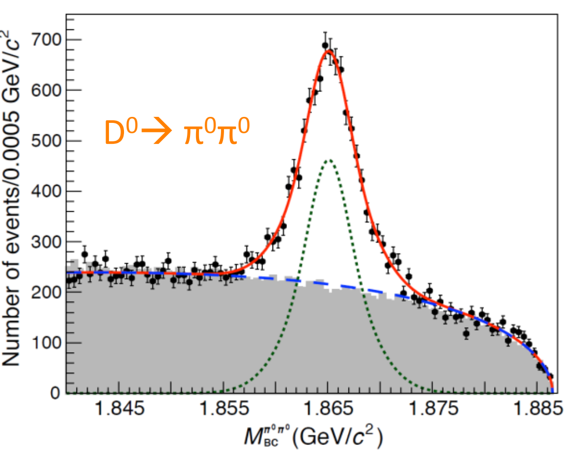
Best limit

$\mathcal{B}_{D^0 \rightarrow \gamma\gamma} < 2.2 \cdot 10^{-6}$ @ 90% C.L.

BaBar $470 fb^{-1}$ @ $\Upsilon(4S)$

PRD85,091107(2012)

$$\mathcal{B}(D^0 \rightarrow \pi^0\pi^0) = (8.24 \pm 0.21(\text{stat.}) \pm 0.30(\text{syst.})) \times 10^{-4}$$



BESIII 2.92fb^{-1}@3770:

$$\mathcal{B}(D^0 \rightarrow \gamma\gamma) < 3.8 \times 10^{6} @ 90\% C.L.$$

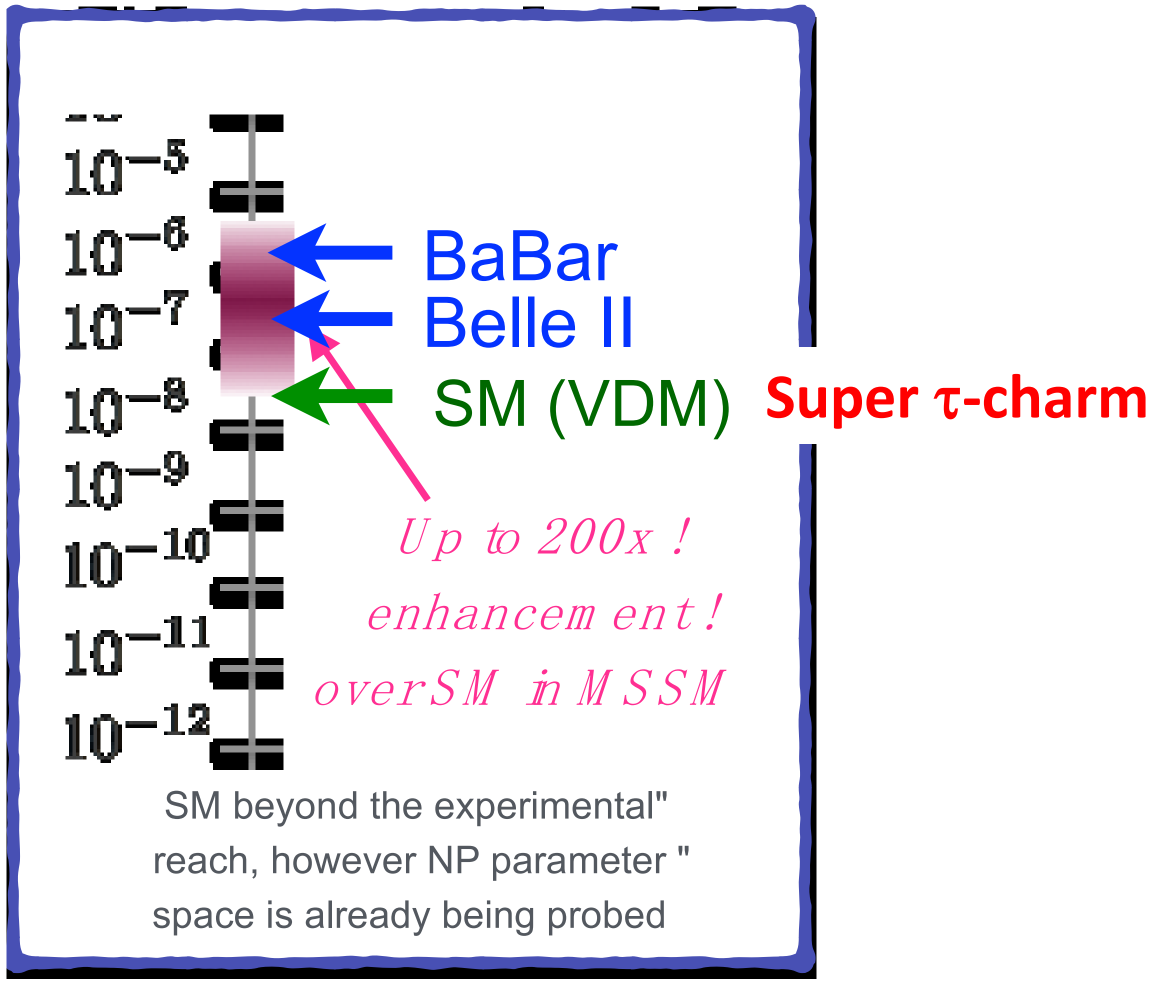
BESIII 10fb^{-1}@3770:

$$B_{D^0 \rightarrow \gamma\gamma)} < 1.0 \times 10^{-6}$$

BESIII has much smaller background than that at B factory, peaking background from $D^0 \rightarrow \pi^0\pi^0$ is under control.

$D^0 \to \gamma\gamma$ reach at super τ-charm

1 ab $^{-1}$ at threshold at **super τ-charm** factory will reach Long Distance contribution: about 60 events are expected per year.



δ and γ/ϕ_3 input

- D hadronic parameters for a final state

$$f: \frac{A(\bar{D}^0 \to f)}{A(D^0 \to f)} \equiv -r_D e^{-i\delta_D}$$

- Charm mixing parameters: $x = \frac{\Delta M}{\Gamma}$, $y = \frac{\Delta\Gamma}{2\Gamma}$
  - Time-dependent WS $D^0 \to K^+\pi^-$ rate $\Rightarrow$ $y' = y\cos\delta_{K\pi} - x\sin\delta_{K\pi} = (0.72 \pm 0.24)\%$ (LHCb 2012)
  - $\delta_{K\pi}$: QC measurements from Charm factory
- γ/ϕ_3 measurements from $B \to D^0 K$
  - b→u : $\gamma/\phi_3 = \arg V^*_{ub}$
  - most sensitive method to constrain γ/ϕ_3 at present
  - GLW, ADS method
    - r_D, δ_D : QC measurements from Charm factory
  - GGSZ method
    - c_i, s_i : QC measurements from Charm factory

Time-integrated decay rates

- No time dependent information at Charm threshold
- Anti-symmetric wavefuction:

  $\Gamma^2_{ij} = \left|\langle i|D^0\rangle\langle j|\bar{D}^0\rangle - \langle j|D^0\rangle\langle i|\bar{D}^0\rangle\right|^2$
- Double tag rates:

  $A_i^2 A_j^2\left[1 + r_i^2 r_j^2 - 2 r_i r_j \cos(\delta_i + \delta_j)\right]$
  - CP tag: r=1, δ=0 or π; $l^{\pm}$ tag: r=0
- Single and Double tag rates
  - $z_f \equiv 2\cos\delta_f$, $r_f \equiv \frac{A_{DCS}}{A_{CF}}$, $R_M \approx \frac{x^2+y^2}{2}$

$$\psi(3770) \to [D^0\bar{D}^0 - \bar{D}^0 D^0]/\sqrt{2}$$

$$= -[D_{CP+}D_{CP-} - D_{CP-}D_{CP+}]/\sqrt{2}$$

$$D_{CP\pm} = [D^0 \pm \bar{D}^0]/\sqrt{2}$$

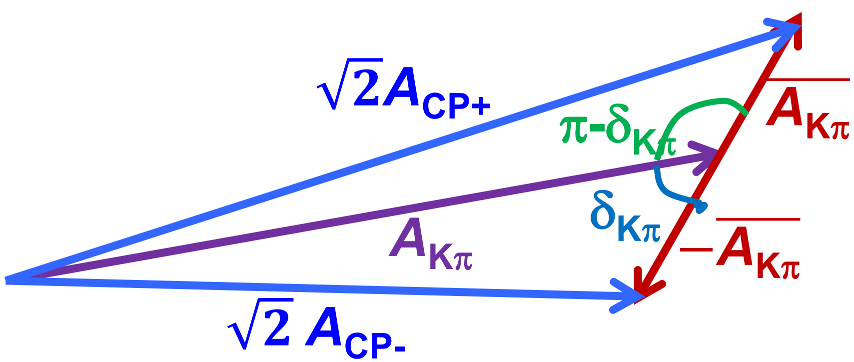
C-odd	f	$\bar{f}$	l^+	l^-	CP+	CP-
f	$R_M[1 + r_f^2(2 - z_f^2) + r_f^4]$					
$\bar{f}$	$1 + r_f^2(2 - z_f^2) + r_f^4$	$R_M[1 + r_f^2(2 - z_f^2) + r_f^4]$				
l^+	r_f^2	1	R_M			
l^-	1	r_f^2	1	R_M		
CP+	$1 + r_f(r_f + z_f)$	$1 + r_f(r_f + z_f)$	1	1	0	
CP-	$1 + r_f(r_f - z_f)$	$1 + r_f(r_f - z_f)$	1	1	4	0
Single Tag	$1 + r_f^2 - r_f z_f(A - y)$		1		$2[1 \pm (A - y)]$	

$\delta_{K\pi}$ in $D \to K\pi$ (BESIII: 2.9 fb^{-1})

PLB 734, 227(2014)

A simple picture: $\dfrac{\langle K\pi|\overline{D^0}\rangle}{\langle K\pi|D^0\rangle} \equiv \dfrac{\overline{A_{K\pi}}}{A_{K\pi}} \equiv rK_\pi e^{i\delta_{K\pi}}$

$$\langle K\pi|D_{CP\pm}\rangle = (\langle K\pi|D^0\rangle \pm \langle K\pi|\overline{D^0}\rangle)/\sqrt{2} \Rightarrow \sqrt{2}A_{CP\pm} = A_{K\pi} \pm \overline{A_{K\pi}}$$



$\Rightarrow$

$$2r_{K\pi} \cdot \cos\delta_{K\pi} \approx A_{CP\to K\pi} \equiv \frac{|A_{CP-}|^2 - |A_{CP+}|^2}{|A_{CP-}|^2 + |A_{CP+}|^2}$$

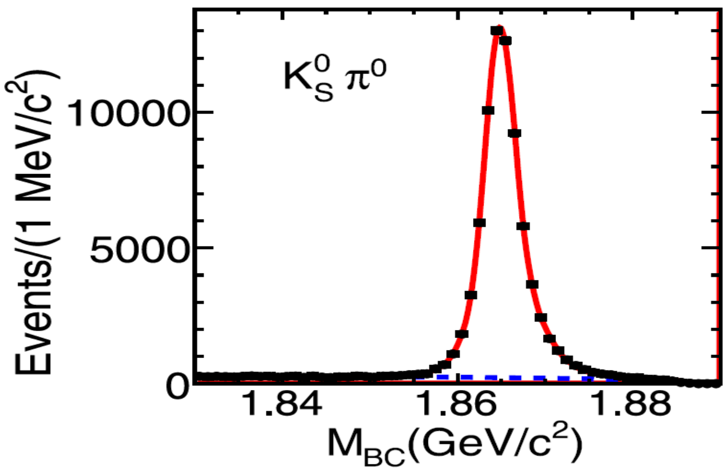
$$= \frac{Br(D_{CP-}\to K\pi) - Br(D_{CP+}\to K\pi)}{Br(D_{CP-}\to K\pi) + Br(D_{CP+}\to K\pi)}$$

- Measuring $\delta_{K\pi}$ from rate differences if using external $r_{K\pi}$
- Reconstructed modes:
  - Flavor tags: $K^-\pi^+$, $K^+\pi^-$
  - CP+ tags (5 modes): K^-K^+, $\pi^+\pi^-$, $K_S^0\pi^0\pi^0$, $\pi^0\pi^0$, $\rho^0\pi^0$
  - CP- tags (3 modes): $K_S^0\pi^0$, $K_S^0\eta$, $K_S^0\omega$

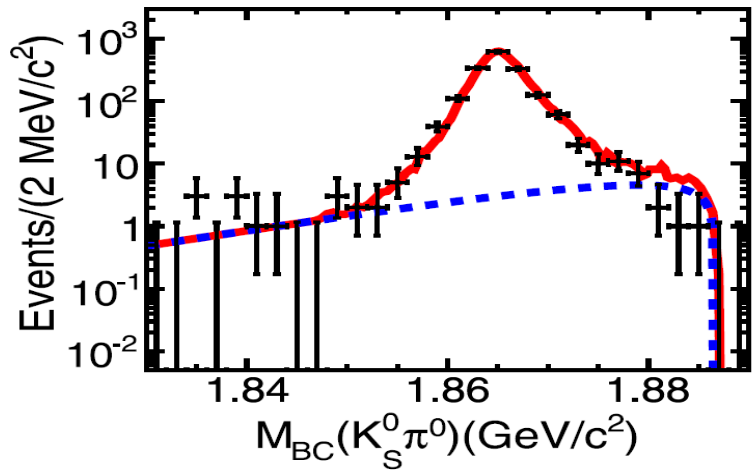
$\delta_{K\pi}$ in $D \to K\pi$ (BESIII: 2.9 fb^{-1})

PLB 734, 227(2014)

Single Tags



Double Tags



Direct result:

$$A_{CP\to K\pi} = (12.7 \pm 1.3(\text{Stat.}) \pm 0.7(\text{sys.}))\%$$

$$2r_{K\pi}\cos\delta_{K\pi} + y = (1 + R_{WS}) \cdot A_{CP\to K\pi}$$

Using external input for $r^2_{K\pi}$, y, R_{WS} we extract:

$$\cos\delta_{K\pi} = 1.02 \pm 0.11 \pm 0.06 \pm 0.01$$

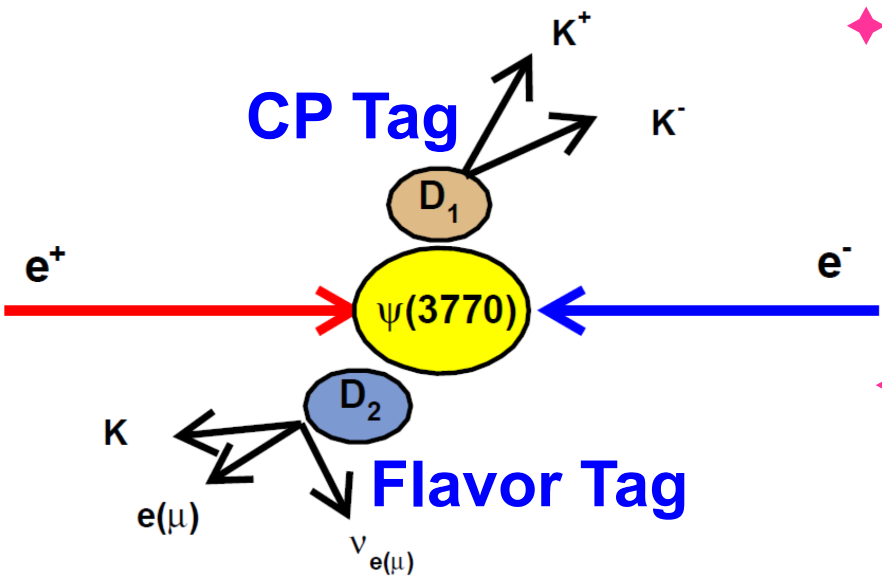
If BESIII accumulate 10 fb^{-1} on threshold D data:

sensitivity of $\cos\delta_{K\pi} \sim 0.06$

y_{CP} measurement (BESIII: 2.9 fb^{-1})

PLB 744, 339(2015)

We measure the y_{CP} using *CP*-tagged semi-leptonic *D* decays, which allows to access *CP* asymmetry in mixing and decays.

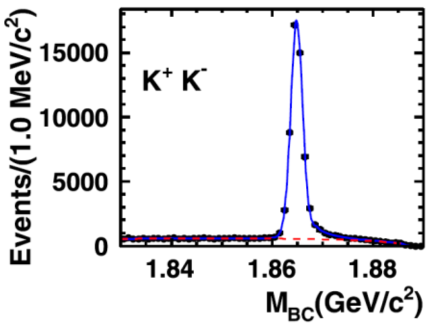


- Single Tag decay rate (CP tags)
  - $\Gamma_{CP\pm} \propto 2|A_{CP\pm}|^2(1 \mp y)$
- Double Tag decay rate (Flavor tags + CP tags)
  - $\Gamma_{l;CP\pm} \propto |A_l|^2|A_{CP\pm}|^2$
- Neglect term y^2 or higher order
  - $y_{CP} \approx \frac{1}{4}\left(\frac{\Gamma_{l;CP+}\Gamma_{CP-}}{\Gamma_{l;CP-}\Gamma_{CP+}} - \frac{\Gamma_{l;CP-}\Gamma_{CP+}}{\Gamma_{l;CP+}\Gamma_{CP-}}\right)$
- Reconstructed modes:
  - Flavor tags: $Ke\nu_e$, $K\mu\nu_\mu$
  - CP+ tags (3 modes): K^-K^+, $\pi^+\pi^-$, $K_S^0\pi^0\pi^0$
  - CP- tags (3 modes): $K_S^0\pi^0$, $K_S^0\eta$, $K_S^0\omega$

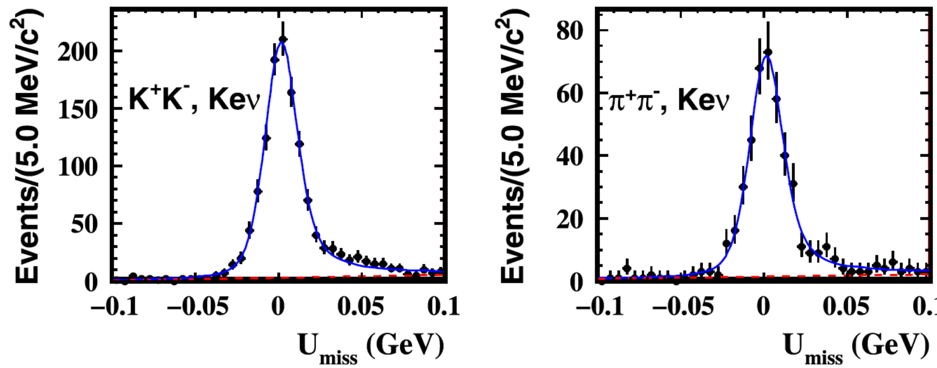
y_{CP} measurement (BESIII: 2.9 fb^{-1})

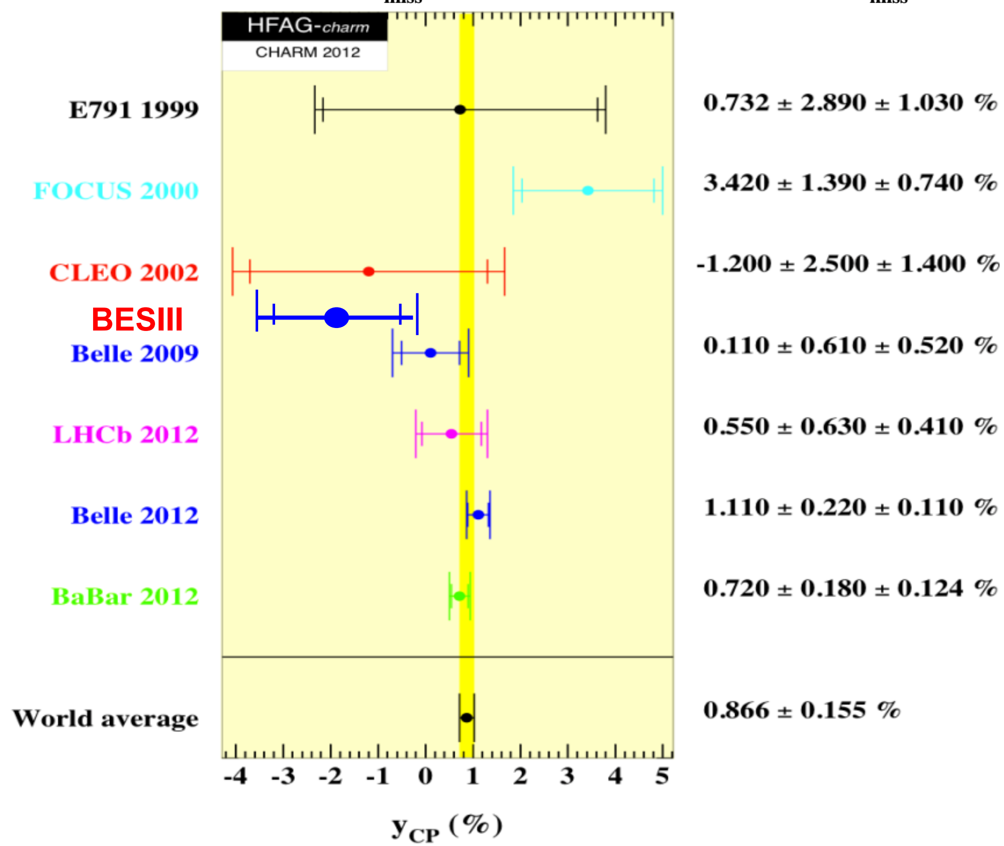
PLB 744, 339(2015)

Single Tags



Double Tags

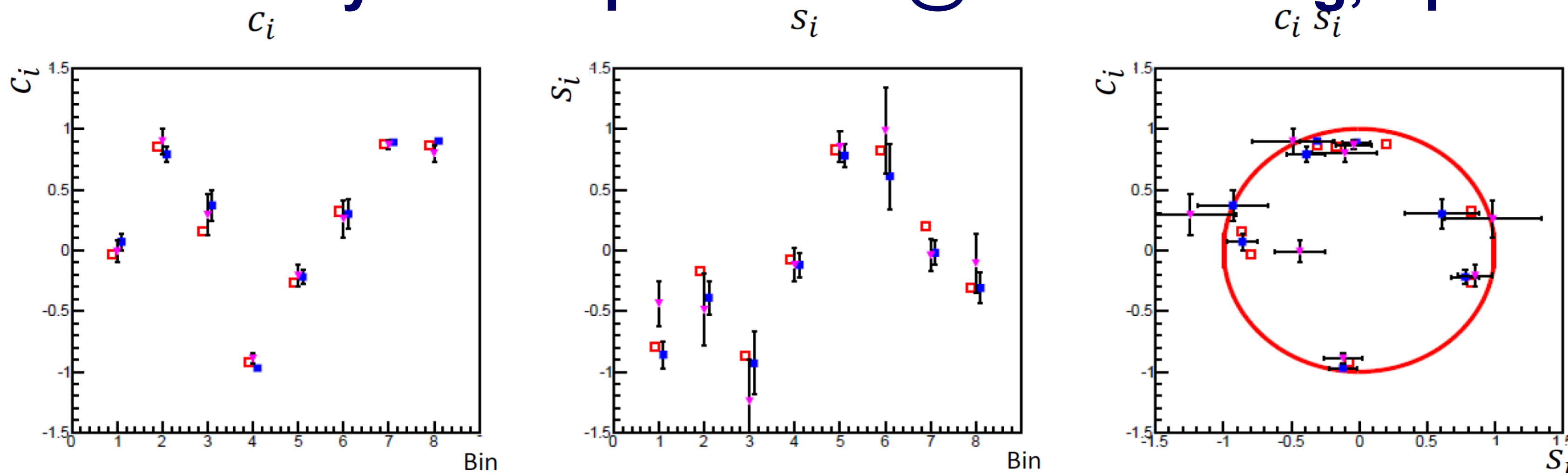




- **BESIII results:**
  $y_{CP} = (-2.0 \pm 1.3 \pm 0.7)\%$
- **Result is statistically limited**
- **Systematic uncertainty is relative small**
- **Most precise measurement with QC charm mesons**
- **In the limit of no CP violation:**
  $y_{CP} = y$
- **Super τ-C: $\Delta(y_{CP}) \sim 0.1\%$**

$K_s\pi^+\pi^-$ (BESIII preliminary: 2.9 fb^{-1})

- Extract c_i, s_i for "γ/ϕ_3GGSZ method"
- Preliminary results presented @ APS meeting, Apr. 2014



Bins	c_i BES-III	c_i CLEO-c	s_i BES-III	s_i CLEO-c
1	0.066 ± 0.066	-0.009 ± 0.088	-0.843 ± 0.119	-0.438 ± 0.184
2	0.796 ± 0.061	0.900 ± 0.106	-0.357 ± 0.148	-0.490 ± 0.295
3	0.361 ± 0.125	0.292 ± 0.168	-0.962 ± 0.258	-1.243 ± 0.341
4	-0.985 ± 0.017	-0.890 ± 0.041	-0.090 ± 0.093	-0.119 ± 0.141
5	-0.278 ± 0.056	-0.208 ± 0.085	0.778 ± 0.092	0.853 ± 0.123
6	0.267 ± 0.119	0.258 ± 0.155	0.635 ± 0.293	0.984 ± 0.357
7	0.902 ± 0.017	0.869 ± 0.034	-0.018 ± 0.103	-0.041 ± 0.132
8	0.888 ± 0.036	0.798 ± 0.070	-0.301 ± 0.140	-0.107 ± 0.240

***Only statistical uncertainty is listed

BESIII Preliminary

Model prediction
BESIII
CLEO-c

Consistent agreement with CLEO-c measurements.

Source: CLEO Collaboration, Physical Review D, vol 82., pp. 112006 - 112035

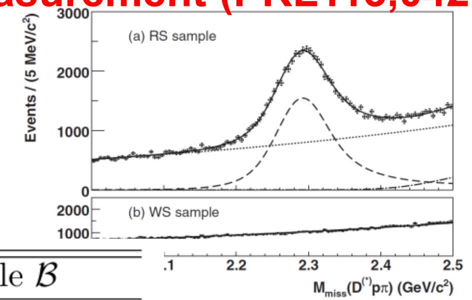
Improved errors w.r.t. CLEO-c

Slide from Dan Ambrose, APS 2014

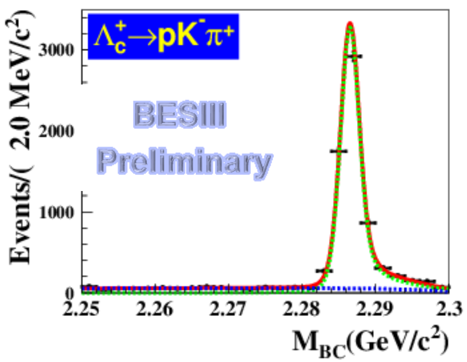
Charm baryon $\Lambda_c^{\pm}$ decays

- BESIII: $\Lambda_c^{\pm}$ Pair production at threshold (4.6GeV)
- Largest data set @4.6 GeV
- Double Tag ⇒ Model-independent absolute $\Lambda_c^{\pm}$ decay Branching fractions

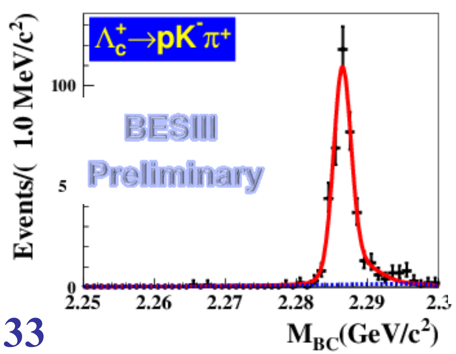
Belle: first model-independent Measurement (PRL113,042002)



ST $\Lambda_c^{\pm}$ yields



DT $\Lambda_c^{\pm}$ yields

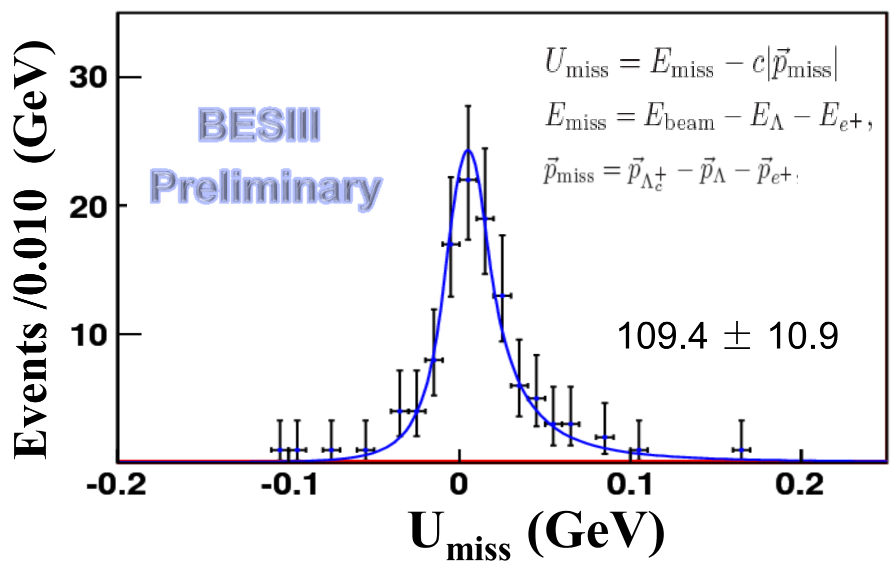


Decay modes	global fit $\mathcal{B}$	PDG $\mathcal{B}$	Belle $\mathcal{B}$
pK_S	1.48 ± 0.08	1.15 ± 0.30	
$pK^-\pi^+$	5.77 ± 0.27	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S\pi^0$	1.77 ± 0.12	1.65 ± 0.50	
$pK_S\pi^+\pi^-$	1.43 ± 0.10	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	4.25 ± 0.22	3.4 ± 1.0	
$\Lambda\pi^+$	1.20 ± 0.07	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	6.70 ± 0.35	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	3.67 ± 0.23	2.6 ± 0.7	
$\Sigma^0\pi^+$	1.28 ± 0.08	1.05 ± 0.28	
$\Sigma^+\pi^0$	1.18 ± 0.11	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	3.58 ± 0.22	3.6 ± 1.0	
$\Sigma^+\omega$	1.47 ± 0.18	2.7 ± 1.0	

Preliminary results: statistical error only!

Absolute BR for $\Lambda_c^+ \to \Lambda e^+ \nu_e$

- Dominated process: $\Lambda_c^+ \to \Lambda e^+ \nu_e$
- Input for LQCD calculations
- First direct absolute BF measurement
- Theoretical predictions: 1.4% ~ 9.2%



$$B(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.63 \pm 0.38 \pm 0.??)\%$$

Statistical error only!

Statistical limited measurement!

Prospects for Λ_c decays

Can BEPCII challenge the CM energy limit at 4.6 GeV?

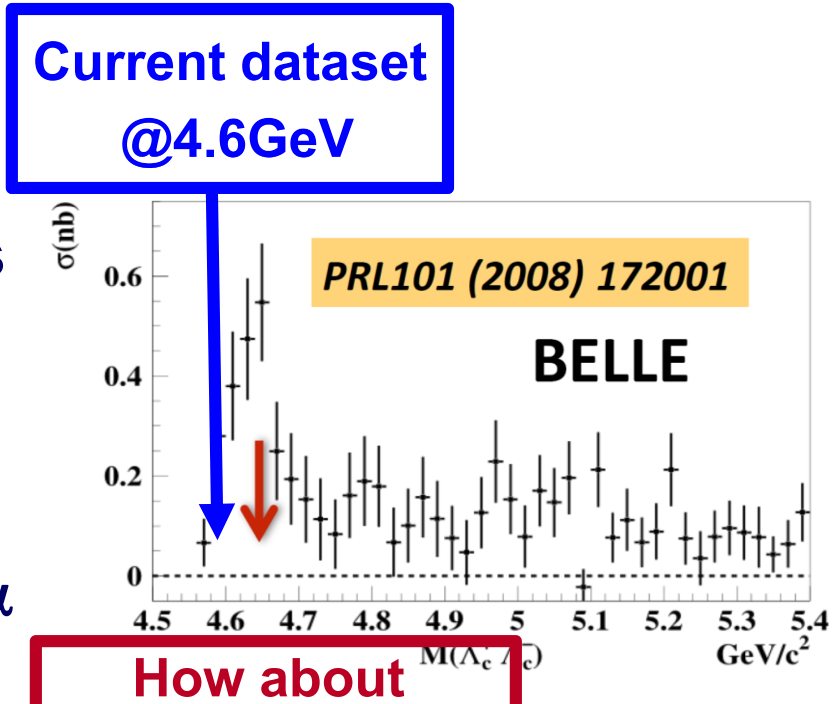


FIG. 4: The cross section for the exclusive process $e^+e^- \rightarrow$

With larger Λ_c data sample

- PWA $\Rightarrow$ intermediate structures in 3-body decays
- More semileptonic decays: $n l \nu$, $\Lambda^* l \nu$, $\Sigma X l \nu$ …
- Decay asymmetry parameters $\alpha \Leftarrow \Lambda_c^+ \rightarrow BP/BV$
- Λ_c^+ Rare decays search
  - Weak radiative decay $\Lambda_c^+ \rightarrow \gamma \Sigma^+$
  - FCNC $\Lambda_c^+ \rightarrow p l^+ l^-$
  - LNV $\Lambda_c^+ \rightarrow p e \mu$

Proposed future charm facilities

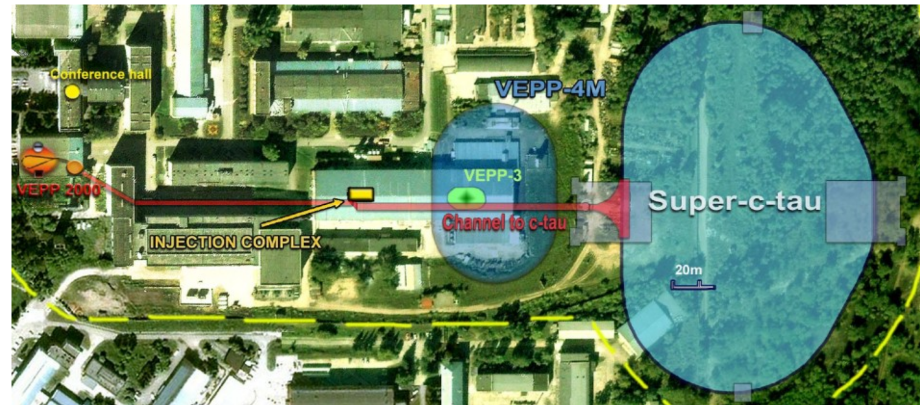
Future charm facilities

Marcello A. Giorgi

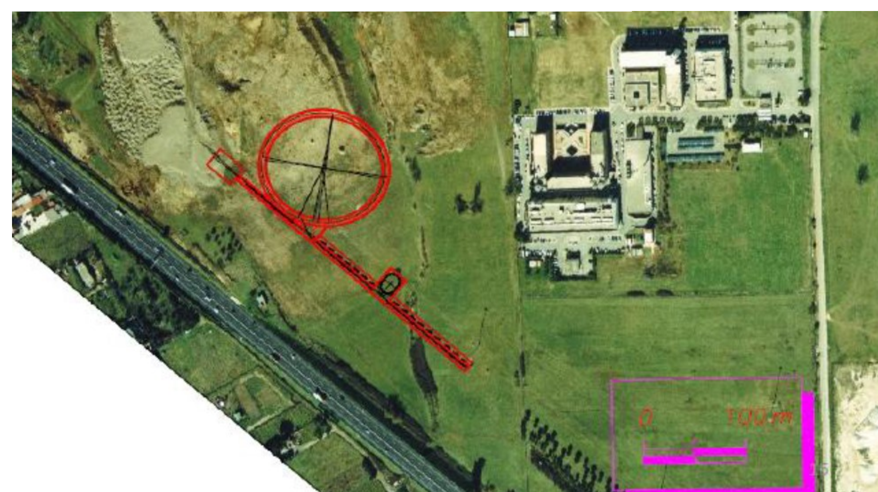
INFN and Università di Pisa

CHARM 2013- Manchester 31 August-4 September , 2013

Novosibirsk machine



The Italian Tau-Charm



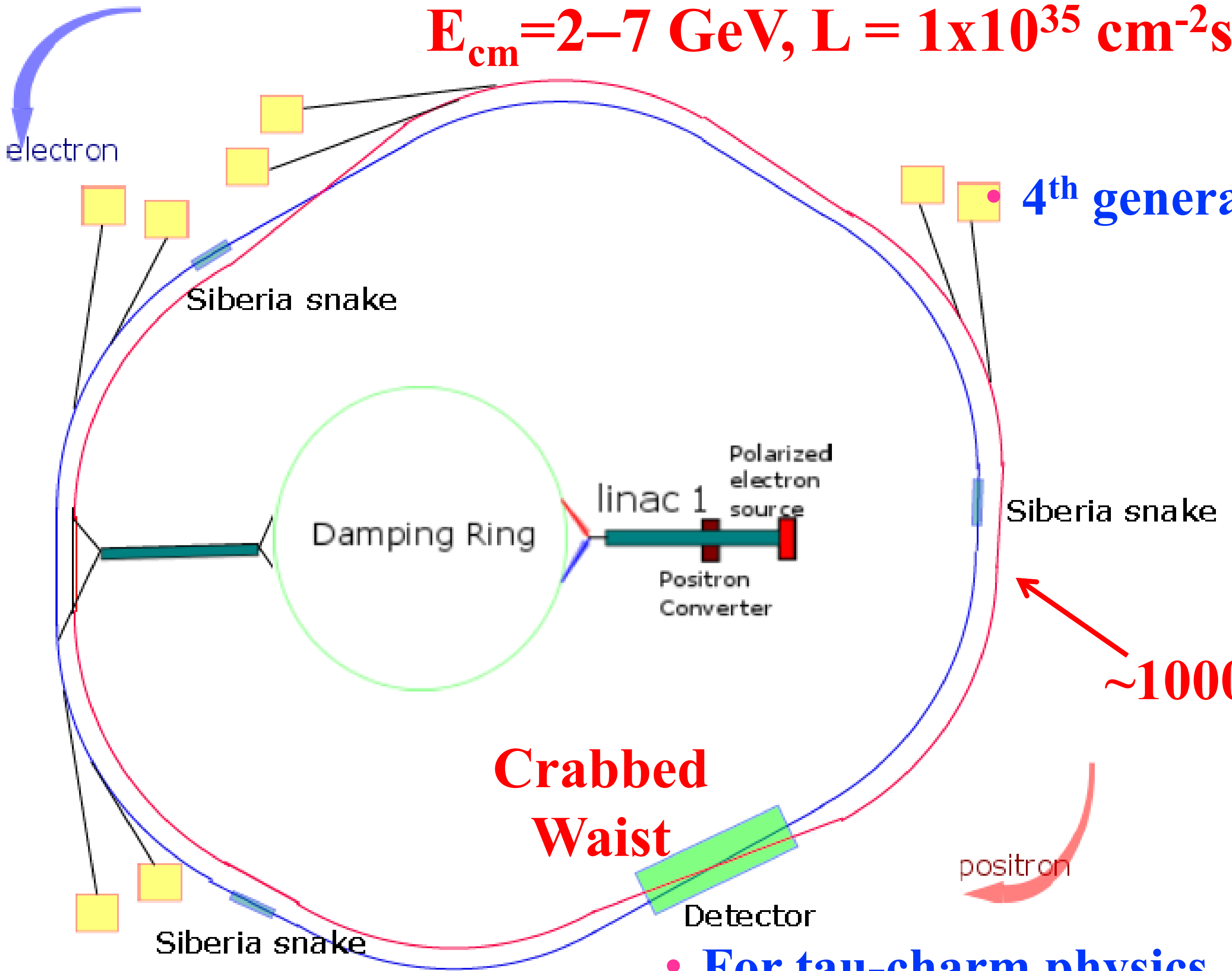
Another proposed Machine

- In China
- e+e- collider
- Wide c.m. energy coverage: 2 – 7 GeV
- Collider + 4th generation SR source
  - Symmetric two ring collision
  - Collision & SR: sharing mode feasible
- Peak luminosity: 1×10^{35} $cm^{-2}s^{-1}$ (Optimized @ E_{cm} = 4 GeV)
- Data set: 1 ab^{-1} /year at Charm threshold
- Polarized beam
  - Polarized electron beam source
  - Siberian Snake curing depolarization

High Intensity Electron Positron Accelerator

HIEPA project

E_{cm}=2–7 GeV, L = 1×10^{35} $cm^{-2}s^{-1}$ at 4 GeV



- **4^{th} generation SRF**

~1000M double ring

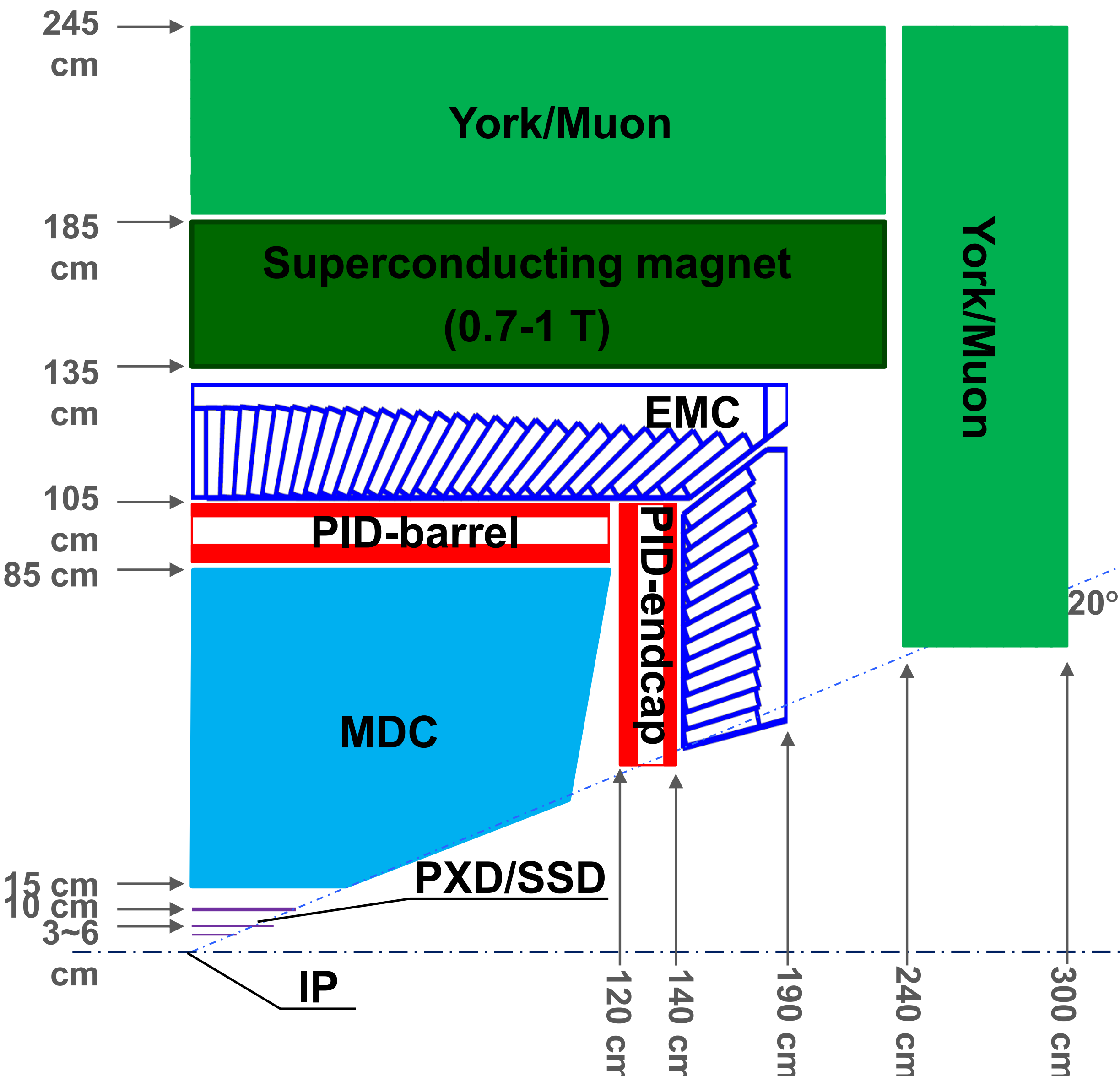
Crabbed Waist

- **For tau-charm physics**

A potential location: Hefei

- University of Science and Technology of China (USTC)
- National Synchrotron Radiation Lab and Hefei Light Source, operated by USTC
- The only National Lab operated by University in China. (Totally Four National Labs in China)

Detector



MUD
- μ/π suppression power >10/30

EMC
- Energy range: 0.02-2.5 GeV
- At 1 GeV σ_E (%)
  - Barrel(Cs(I): 2
  - Endcap (Cs): 4

PID
- π/K (and K/p) 3-4σ separation up to 2GeV/c

MDC
- σ_{xy}=130 mm
- dE/dx<7%, σ_p/p =0.5% at 1 GeV

PXD
- Material budget ~0.15%X_0/layer
- σ_{xy}=50 mm

Expected Key features

- Vertex – very low material budget ~0.15-0.3%X_0/layer, <50μm position resolution;
- MDC – pT resolution @1GeV/c 0.5~0.7%, dE/dx resolution <7%, low material budget ;
- PID – π/K (and K/p) 3-4σ separation up to 2GeV/c, low material (<0.5X_0);
- EMC – stochastic term <2%/√E, constant term <0.75%;
- MUD - μ/π suppression power >10.

ψ(4040)阈上的粲介子混合与CP破坏参数测量

- ψ(3770)在$D^0\bar{D}^0$产生阈值（中性粲介子对系统C=-1）
  - 时间积分测量⇒ 混合参数只能测量$R_M = \frac{x^2+y^2}{2}$
- ψ(4040)在$D^0\bar{D}^{0*}$产生阈值（中性粲介子对系统C=±1）
  - Bondar, Poluektov, Vorobiev, PRD 82,034033(2010)
  - $D^0\bar{D}^0\gamma$系统： C=+1， $D^0\bar{D}^0\pi^0$系统： C=-1
  - $D^0\bar{D}^0\gamma$系统的时间积分测量 ⇒ 混合参数x和y！
- 在HIEPA上的敏感度估计（参考超级B工厂的估计）

	ψ(4040)	LHCb	Belle-II
积分亮度	3 ab^{-1}	50 fb^{-1}	50 ab^{-1}
x (%)	0.03	0.015	0.08
y (%)	0.03	0.01	0.04
|q/p| (%)	0.9	1	5
arg(q/p) (°)	0.8	3	2.6

HIEPA上的一些敏感度估计

HIEPA上一年的ψ(3770)数据：1 ab^{-1}

- y_{CP}测量（CP守恒近似 ⇒ $y_{CP} = y$）
  - BESIII：$y_{CP} = (-2.0 \pm 1.3 \pm 0.7)\%$ PLB 744,335(2015)
  - 首次利用量子关联数据测量（系统误差相对小）
  - HIEPA: $\Delta(y_{CP}) \sim 0.1\%$
- 混合参数的时间积分测量（利用Kπ, Keν衰变道）
  - $R_M = \frac{x^2+y^2}{2}$ 的测量敏感度~ 10^{-5}
- 测量$D \to K^-\pi^+$的强相角差$\delta_{K\pi}$
  - 测量敏感度：$\Delta(\cos\delta_{K\pi}) \sim 0.007$; $\Delta(\delta_{K\pi}) \sim 2^o$
- $D^+ \to hh$直接CP破坏测量的敏感度: $10^{-3} \sim 10^{-4}$
- 丰富的物理研究课题，在实验上与超级B工厂及升级后的LHCb互补

HIEPA related activities

- Several domestic workshops
- Jan 13-16, 2015, HIEPA International Workshop on Physics at Future High Intensity Collider @ 2 – 7 GeV in Hefei, China
- June 3 – 4, 2015, Domestic workshop on "Physics, applications and Key technologies on 2 – 7 GeV HIEPA",
  - more "official" discussions within HEP community in China
- CDR for accelerator & detector in progress (Will be ready by 2016)

Summary

- Many BESIII Charm results are released recently! It's just the beginning!
- Charm at threshold provides opportunities for both QCD and New Physics
  - Very active on XYZ analyses
  - Will provide best measurements: $f_{D(s)}$ & FF
  - Unique access to strong phases & ability to extract model-independent results with charm at threshold
  - Charm baryon results
- BESIII team has learned and developed technology with charm at threshold.
- BESIII will continue to run 6 – 8 years.
- It is natural to propose the e+e- intensity frontier for the τ-charm energy region in China $\Rightarrow$ High Intensity Electron Positron Accelerator (HIEPA)

Thank you

Backup slides