Charm Program at BESIII

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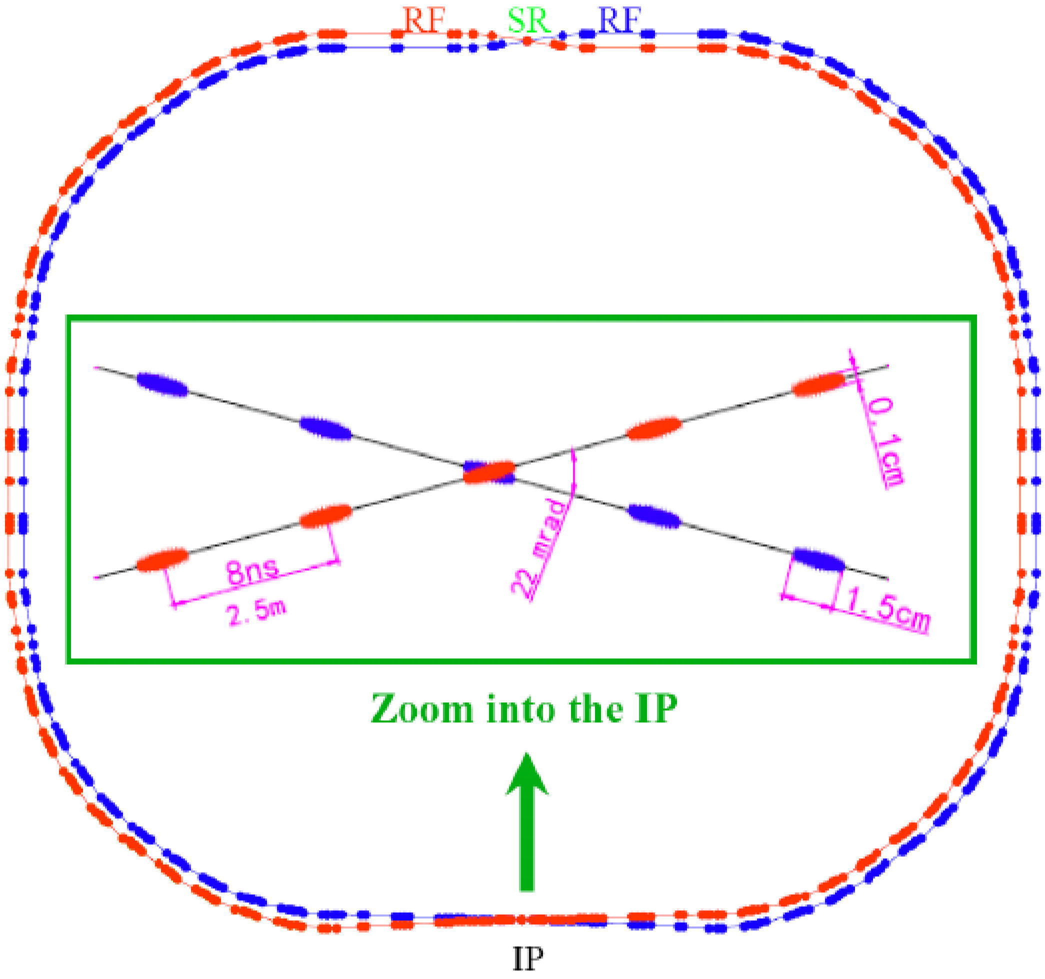
Outline

- BESIII introduction
- Charm prospects at BESIII
- Ongoing analyses
- Summary

BEPCII: e^+e^- Double Ring Collider



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

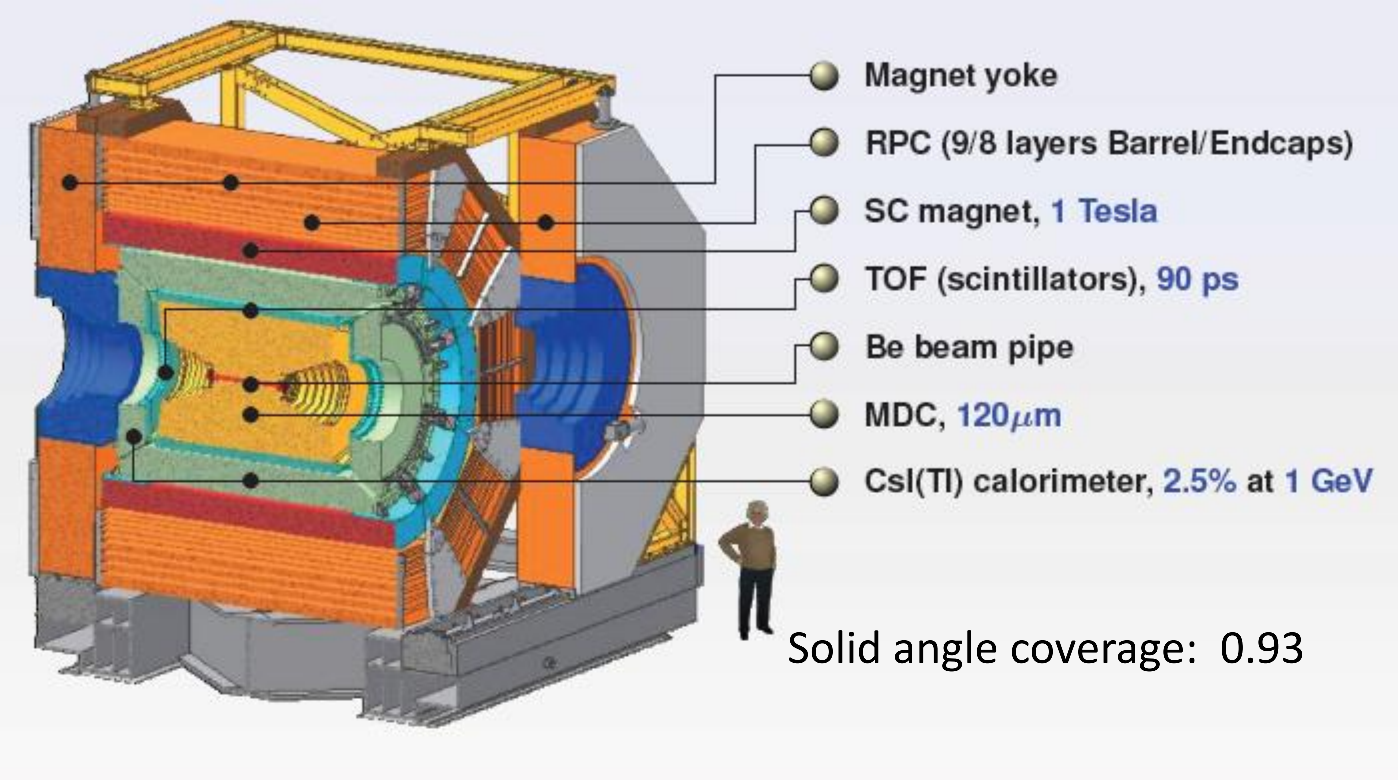
Bunch length:
1.5 cm

Total current:
0.91 A

Circumference:
237m

Good news: already achieved 2/3 of the design luminosity 3 years into running

BESIII: General-Purpose Detector



A new detector , utilizing advanced detector technologies developed over the past two decades.

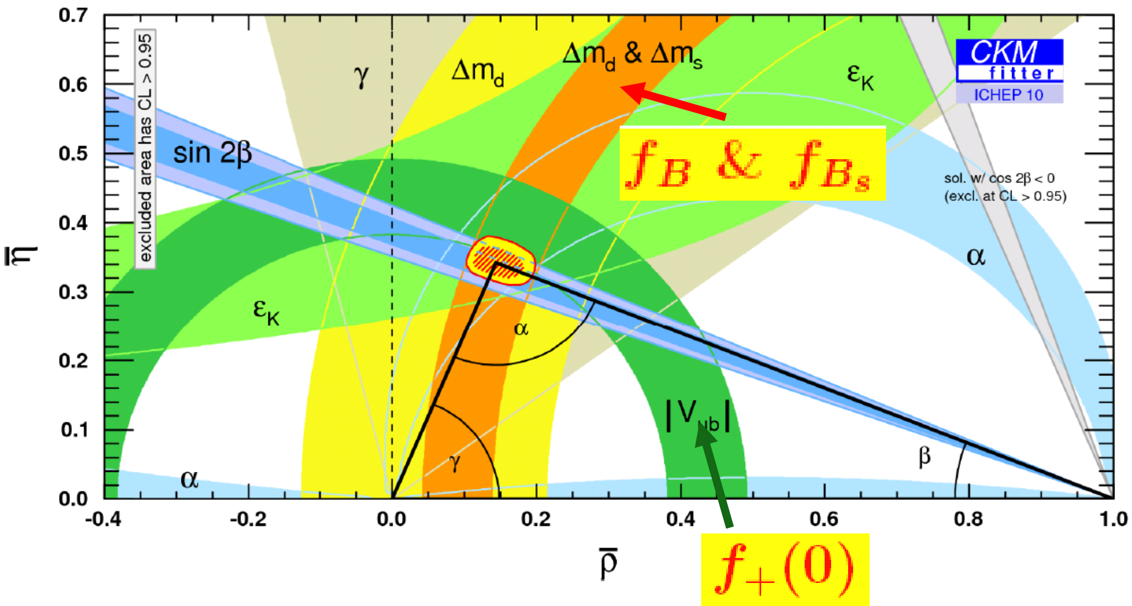
Data Taken

- Apr. 2009: 106 M ψ' events (~150 pb^{-1})
  (plus ~42 pb^{-1} at 3.65 GeV)
- Jul. 2009: 225 M J/ψ events (~65 pb^{-1})

- Jun. 2010: ~923 pb^{-1} at $\psi(3770)$
  (plus ~70 pb^{-1} scan data around $\psi(3770)$)
- Apr. 2011: ~ 2 fb^{-1} at $\psi(3770)$
  (~2.9 fb^{-1} $\psi(3770)$ together, 3.5 times of CLEO-c data)

- May. 2011: ~ 0.5 fb^{-1} at 4010 MeV (for D_s and XYZ)

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

Charm decay measurements

decay constants

form factors

V_{CKM} clean extraction

validate QCD.

over-constrain V_{CKM}

Inconsistency → New Physics

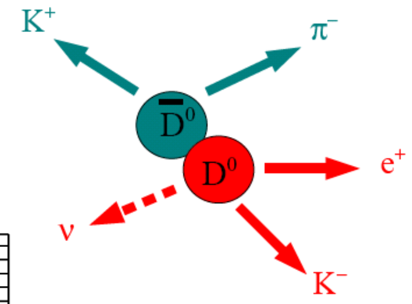
Advantage of Open Charm at Threshold

- e^+e^- colliders at threshold: CLEO-c, BESIII, super-tau-charm

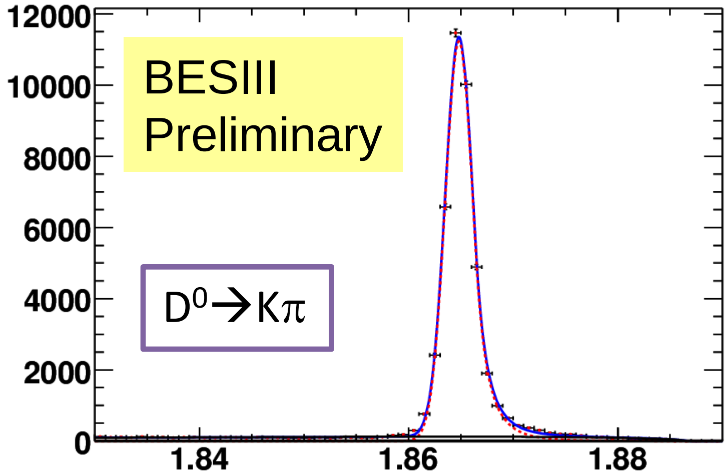
$$e^+e^- \to \psi(3770) \to D\bar{D}$$

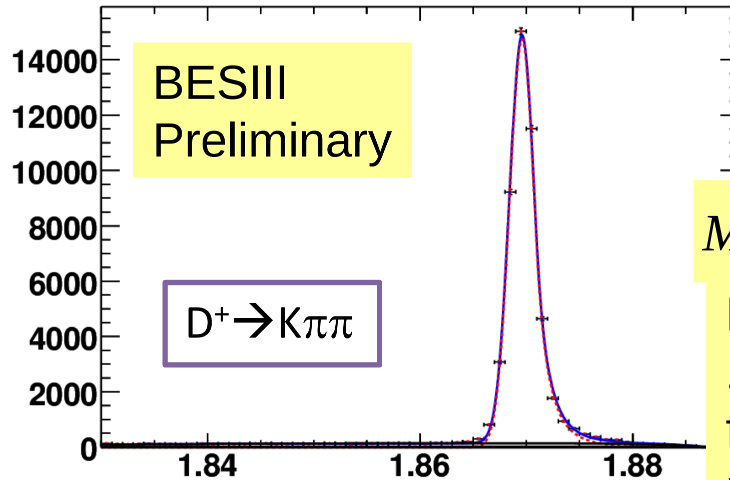
- Benefits for charm physics:
  - Threshold production is clean
  - Known initial energy and quantum number
  - Both D and DDar fully reconstructed
  - Absolute measurement

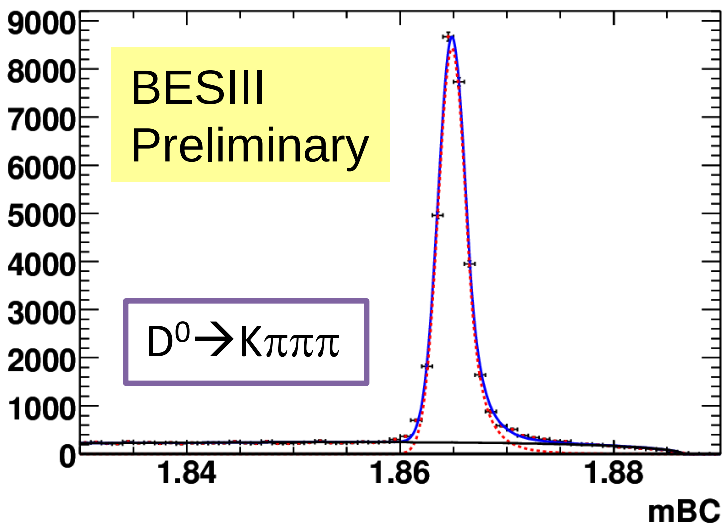
Clean single tag at BESIII

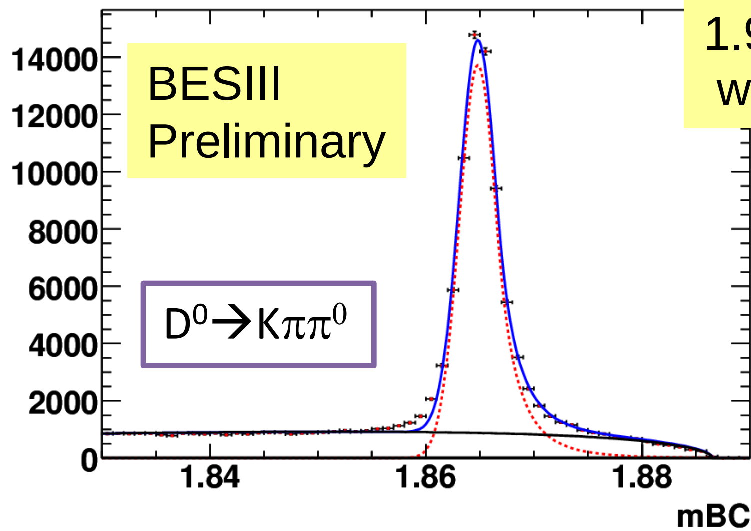


@ψ(3770) with 420pb^{-1} first clean single tagging sample:







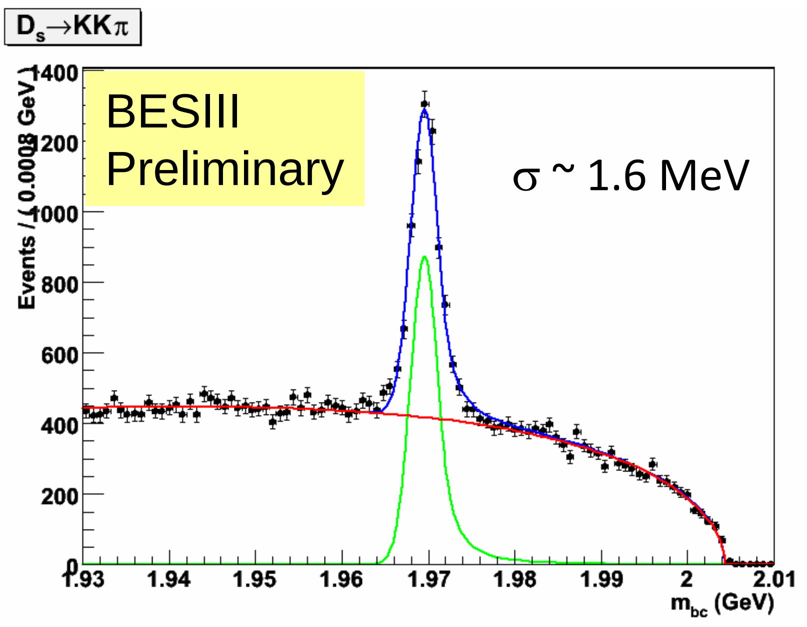


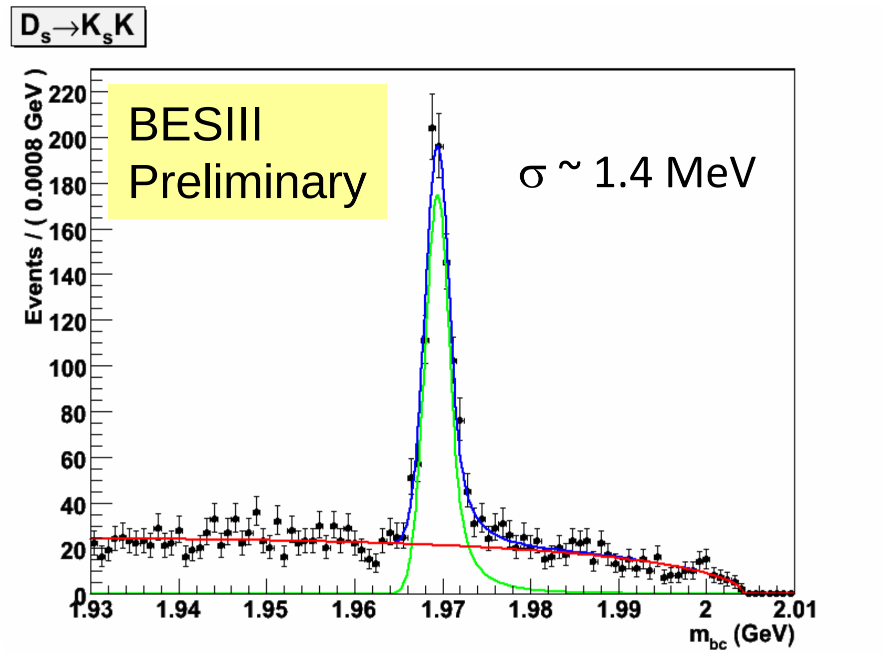
$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$

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

mBC of D_s Single Tag

part of data @ 4010 MeV





Prospects for Charm at BESIII

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$1.7% (stat.)
$f_\pi(0)$ ($D^0 \to \pi l \nu$):	$\pm$5.3% (stat.) $\pm$ 0.7%(sys.)	$\pm$2.1% (stat.)
BR($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 D_s physics with 600pb^{-1}@4170 MeV		
f_{Ds} ($Ds^+ \to \mu^+ \nu, \tau \nu$):	$\pm$2.5% (stat.) $\pm$ 1.2% (sys.)	$\pm$0.9% (stat.)
BR($Ds^+ \to KK\pi$):	$\pm$4.2% (stat.) $\pm$ 2.9%(sys.)	$\pm$1.5% (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) → BESIII 0.5 fb^{-1}
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.

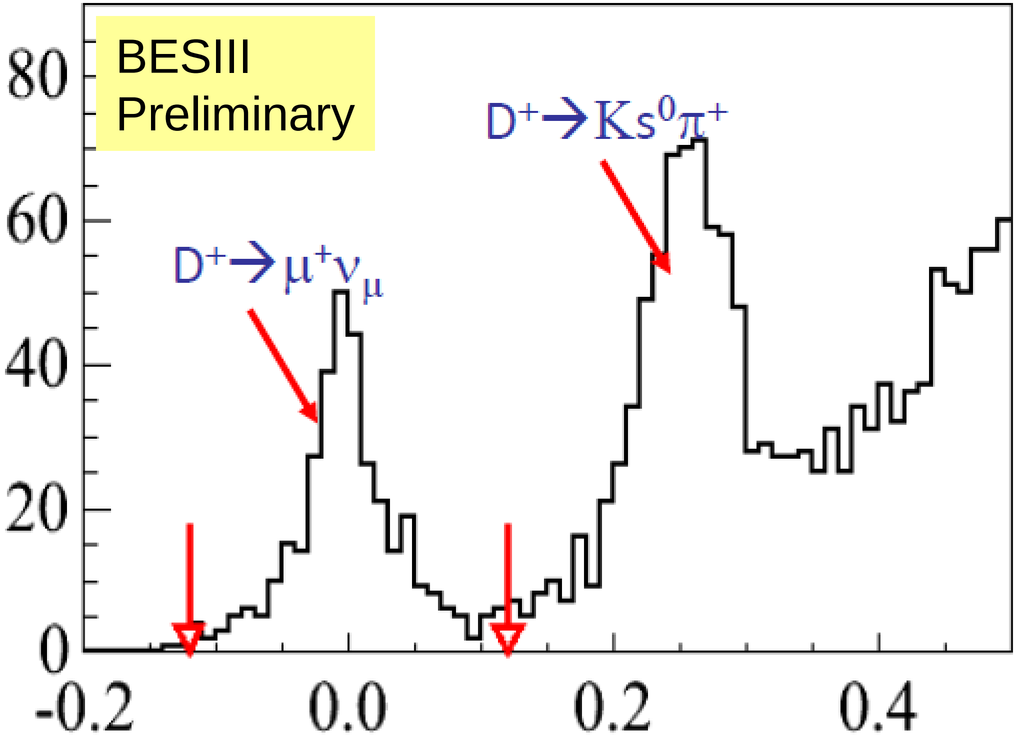
Ongoing Analyses
(using data up to 2.9 fb^{-1})

Leptonic Analysis

- Two ongoing measurements:
  - $D^+ \to \mu^+\nu$,
  - $D_s \to \mu^+\nu$
- Motivations:
  - Clean way to measure f_{D+} and f_{Ds} (by Branch Fraction) in SM
  - Good agreement between expt. f_{D+} and LQCD calculations
  - ~1.6 σ difference between expt. f_{Ds} and LQCD calculations
  - Precise f_{D+} and f_{Ds} measurements are important inputs for theory

$D^+ \to \mu^+\nu$ Measurement

- Tag side: 9 D^+ hadronic modes ($K\pi\pi$, $k\pi\pi\pi^0$, $K_s\pi$, etc)
- Signal side:
  1. one charged track only and muon PID satisfied
  2. no isolated EMC shower
- Key variable: $M^2_{miss} = E^2_{miss} - P^2_{miss}$



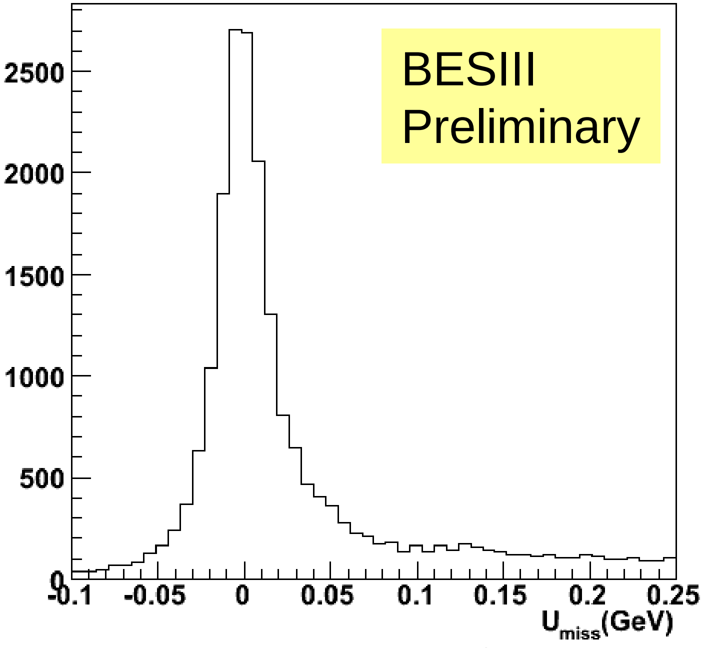
M^2_{miss} Distribution (part of data)

Semi-leptonic Analysis

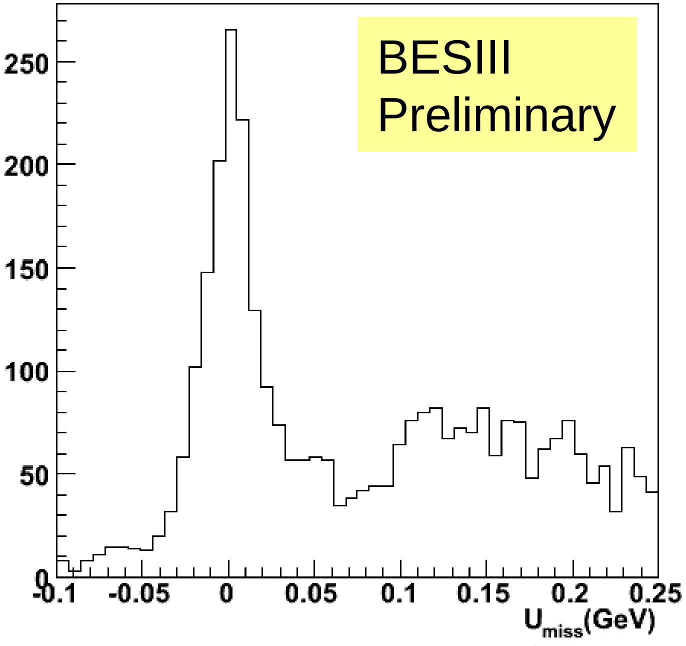
- Three ongoing measurements:
  - $D^0 \to K^-/\pi^- e^+ \nu$
  - $D^+ \to \pi^0/\eta\ e^+ \nu$,
  - $D^+ \to \omega/\phi\ e^+ \nu$, $\omega \to \pi^+\pi^-\pi^0$, $\phi \to KK$
- Motivations
  - Measure form factors and check theory
  - Test iso-spin symmetry in $D^0/D^+ \to \pi^-/\pi^0 e^+\nu$
  - Branch fraction measurements (large error for PDG value of $D^+ \to \omega e^+\nu$, and only upper limit for $D^+ \to \phi e^+\nu$.)

$D^0 \to K^- / \pi^- e^+ \nu$ Measurement

- Tag side: Three D^0 modes ($K\pi$, $K\pi\pi^0$, $K\pi\pi\pi$)
- Signal side:
  1. two good tracks with opposite charges
  2. K/π PID and electron PID requirements
  3. electron has opposite charge as the tag side kaon
- Key variable: $U_{miss} = E_{miss} - P_{miss}$



U_{miss} Distribution of $D^0 \to K e \nu$ mode (part of data)

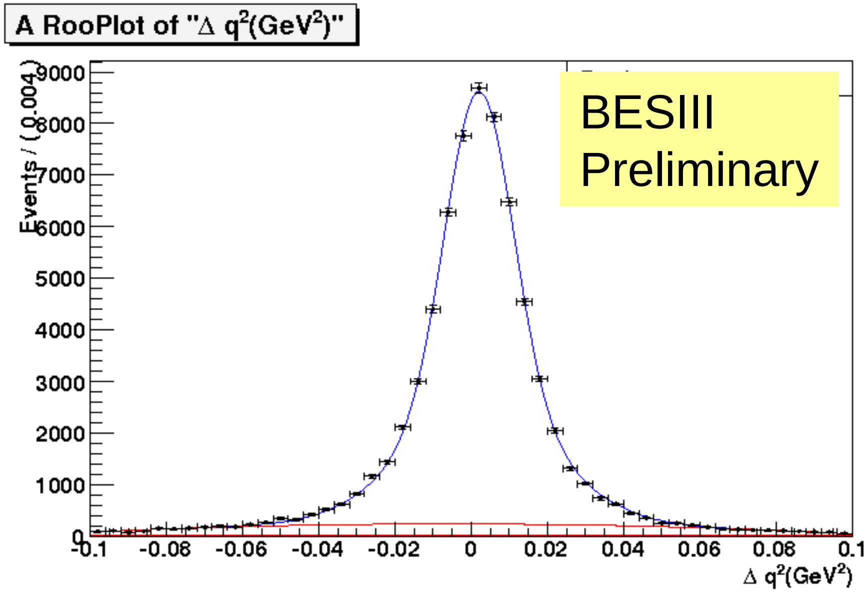


U_{miss} Distribution of $D^0 \to \pi e \nu$ mode (part of data)

q^2 Resolution

$$\frac{d\Gamma(D \to Pe\nu)}{dq^2} = X\frac{G_F^2\left|V_{cd(s)}\right|^2}{24\pi^3}p^3\left|f_+\left(q^2\right)\right|^2$$

Where q^2 is invariant mass of lepton-neutrino system



$\Delta q^2 = q^2 - q^2_{truth}$

From signal Monte Carlo

- To extract form factors, need to fit yields in q^2 bins.
- Less than 10 bins in q^2 from 0 to 3 GeV^2
- Excellent resolution according to MC: $\sigma \sim 0.015\ GeV^2$

D Branch Fraction Measurement

•Motivation:

(1) Important to normalize decay fractions of D and B mesons

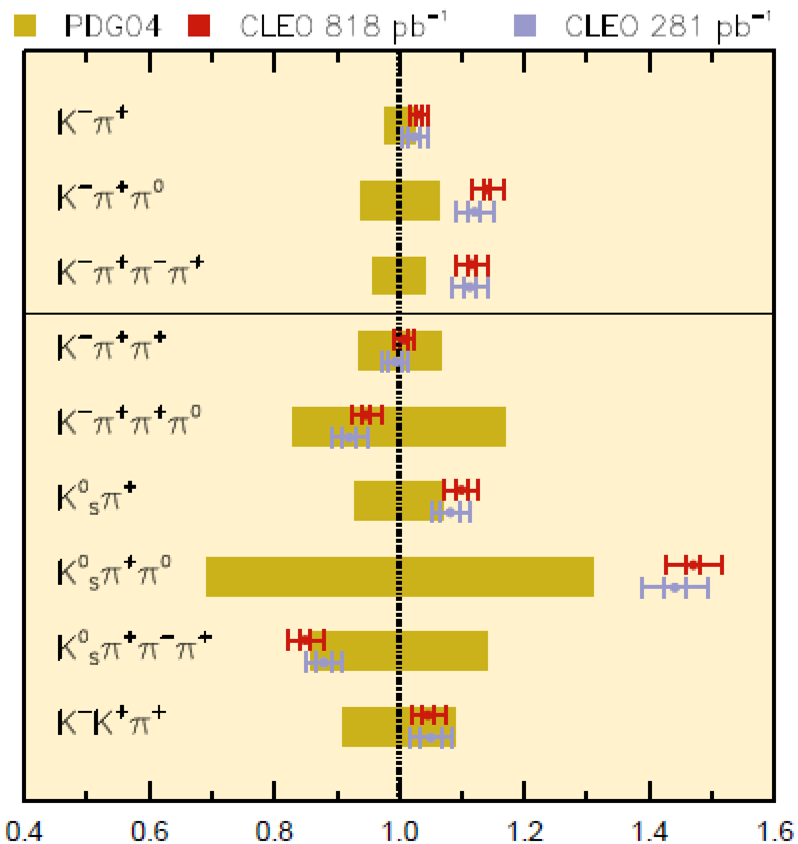
(2) precise measurements of $\mathcal{B}(D^0 \to K\pi)$ and $\mathcal{B}(D^+ \to K\pi\pi)$ can directly improve precisions of CKM elements

(3) Check CLEO-c measurements

•Current status:

(1) Luminosity measurement
(2) K/π tracking, π^0, K^0_s efficiency measurements
(3) PID efficiency measurement

•All other analyses at BESIII would benefit from systematics studies



Xin Shi, 2011 Lake Louise Winter Institute (preliminary)

DDbar Cross Section Measurement

- Motivation
  - Measure ratio of D^0 and D^+ cross section to check theory calculation
  - To extract non-DDbar Brach Fraction
- previous results at E_{cm} ~ 3773 MeV:
  - BESII, ~5.93+/-0.59 nb (PRL, 97:121801,2006)
  - CLEO-c, ~6.51+/-0.08 nb (xinshi, 2011 LLWI)
- Both single tag and double tag techniques are used to measure the DDbar cross sections at BESIII

Other Analyses at BESIII

- Dalitz plot analysis ($D^0 \to K\pi\pi^0$, $D^+ \to K^0_s\pi\pi^0$, $D^0 \to K\pi\eta$, $D^+ \to KK\pi$) :
  - Study the $K\pi$ system, search for the low mass scalar resonance κ
  - Develop the Dalitz plot analysis software for Charm physics at BESIII
- Search for CP violation through T-violation in modes: $D^+ \to K^0_s K^+\pi^+\pi^-$ and $D^+ \to K^+K^-\pi^+\pi^0$

Summary

- BESIII is accumulating data at record speed
- Charm prospects at BESIII is great
- Rich results are coming out soon

Back Up

Non-DDbar Brach Fraction

- ψ(3770) (mixture of S and D waves) expected to decay to DDbar entirely
- However, long history of non-DDbar branch fraction measurements:
  - ~1988, Mark III/II, Lead-Glass Wall: ~50% non-DDbar
  - ~2006-2008, BESII: 14.7% +/- 3.2%
  - ~ 2010, CLEO-c: no evidence of non-DDbar, set upper limit <9% at 90%CL

Non-Ddbar Measurement at BESIII

- Use same p(3770) data as charm physics
- Inclusive measurement
- Exclusive measurement:
  - ψ(3770)->$\gamma\chi_{cJ}$
  - ψ (3770)-> J/$\psi\pi\pi$, J/$\psi\pi^0$, J/$\psi\eta$
  - ψ (3770)-> VP
  - ψ (3770)-> light hadrons