北京谱仪 III

Rare Charm Decays from BES III

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4th SuperB Collaboration Meeting

Outline

- **BEPCII and the BESIII Experiment**
- **Charm Program at BESIII**
- **Preliminary Results on *D* rare/forbidden decays**
- **Summary**

The BEPCII Collider

Beam energy: 1.0 − 2.3 GeV

Peak Luminosity:

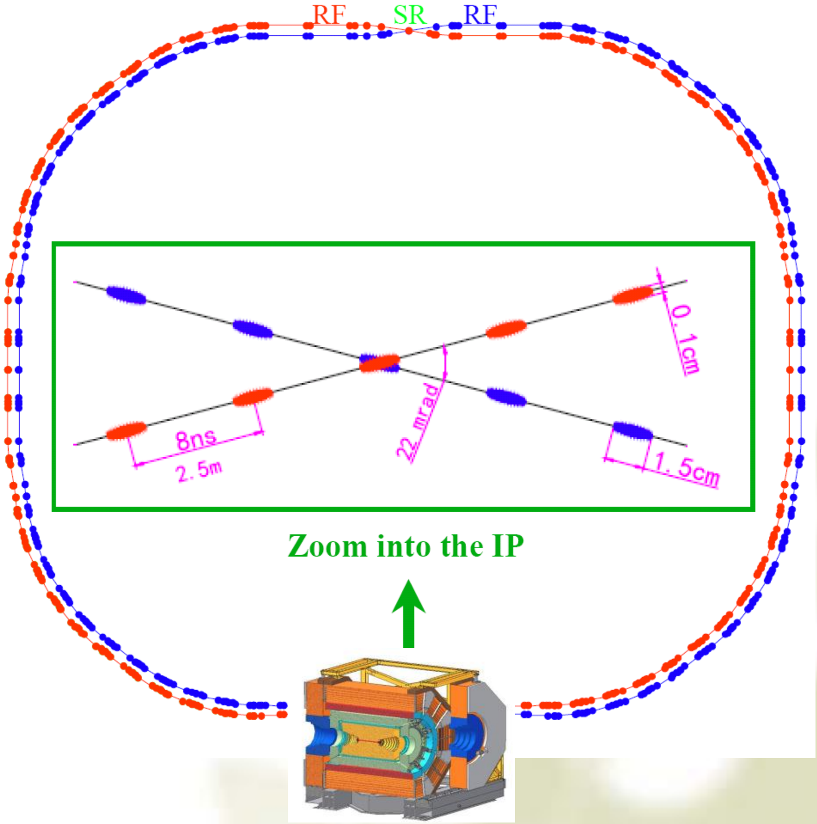
Design: **1×10^{33} cm^{-2}s^{-1}**

Achieved: **0.65×10^{33} cm^{-2}s^{-1}**

Optimum energy: 1.89 GeV

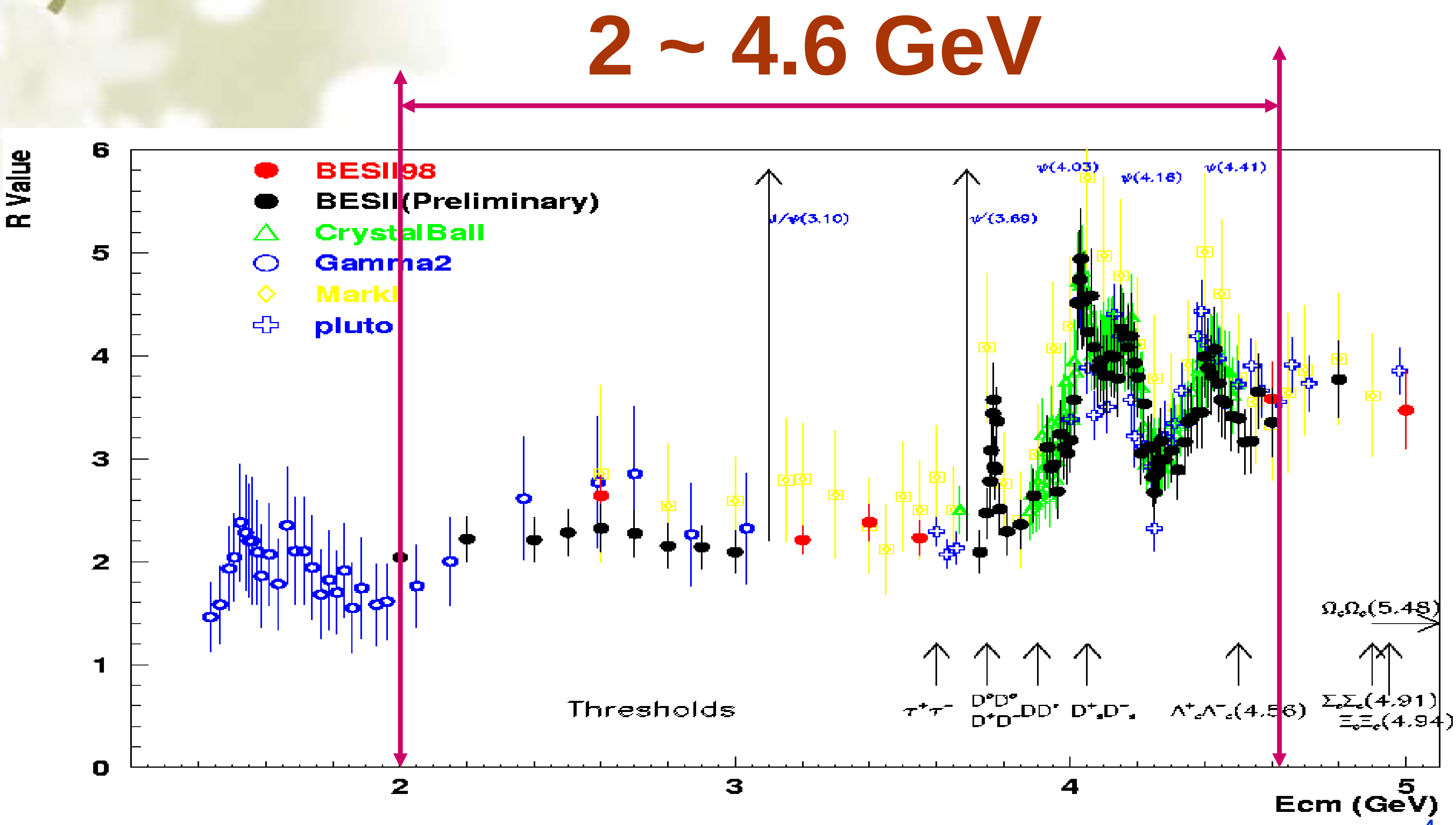
Energy spread: 5.16×10^{-4}

Circumference: 237 m



Beam energy measurement: Using Compton backscattering technique. Accuracy up to **5×10^{-5}**

Energies of the BEPCII Collider



Data Samples

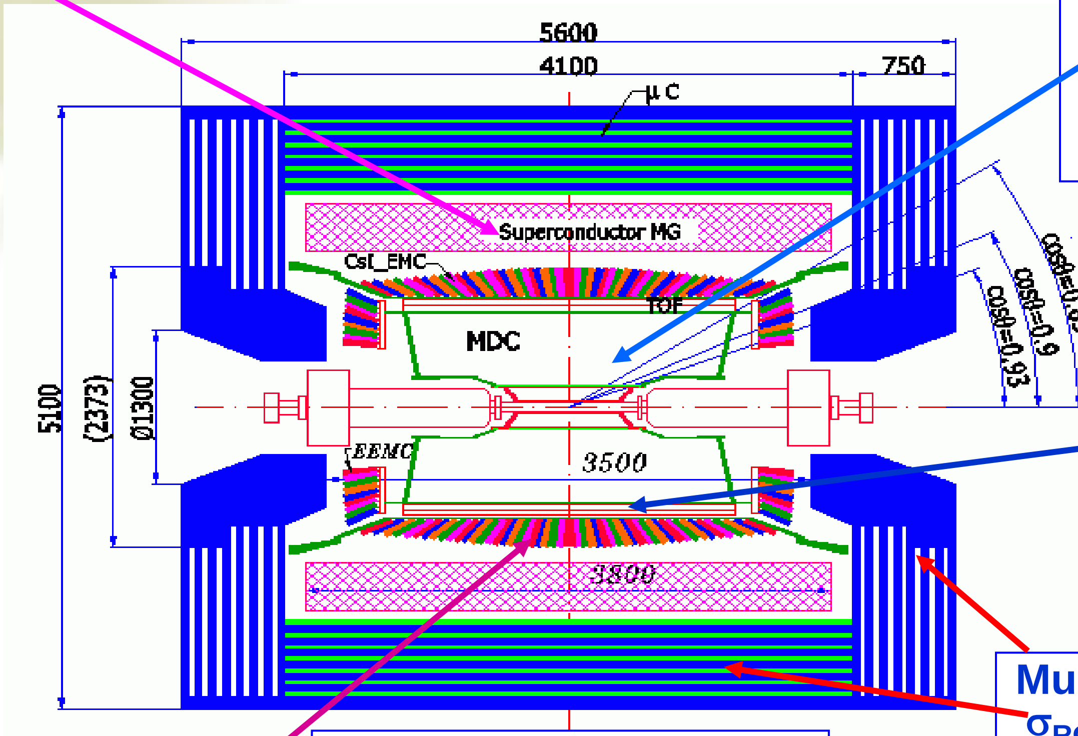
- So far BESIII has collected :
  - 2009: 220 Million J/ψ (4×BESII)
  - 2009: 106 Million ψ' (4×CLEOc)
  - 2009: 42 pb^{-1} @3.65 GeV
  - **2010-11: 2.89 fb^{-1} $\psi(3770)$ (3.5 × CLEO-c 0.818fb^{-1})**
  - **2011: 0.5fb^{-1} @4010 MeV for Ds and XYZ spectroscopy**
  - **2012: tau mass measurement; 0.4 billion Ψ'; 1 billion J/ψ (by May 25)**
- ***BESIII data-taking plans (preliminary)***
  - **2013: Ds physics (@4170 MeV) + R scan (Ecm > 4 GeV)**
  - **2014: ψ'/τ /R scan (Ecm> 4 GeV);**
  - **2015: $\psi(3770)$: 5-10 fb^{-1} for *DD***

World's largest samples of on-threshold J/ψ, $\psi(3686)$ and $\psi(3770)$ data

NIM A614, 345 (2010)

The BESIII Detector

Magnet: 1 T Super conducting



MDC: small cell & He gas
σ_{xy}=130 μm
s_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σ_T = 90 ps Barrel
110 ps Endcap

Muon ID: 8~9 layer RPC
$\sigma_{R\Phi}$=1.4 cm~1.7 cm

EMCAL: CsI crystal
$\Delta E/E$ = 2.5% @1 GeV
$\sigma_{\varphi,z}$ = 0.5~0.7 cm/$\sqrt{E}$

Data Acquisition:
Event rate = 3 kHz
Throughput ~ 50 MB/s

Trigger: Tracks & Showers
Pipelined; Latency = 6.4 μs

The new BESIII detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.

The BESIII Collaboration

>300 physicists

50 institutions from 10 countries

Physics at BESIII

Many exciting ways to use higher luminosity !

Charmonium states: J/ψ, $\psi(2S)$, $\eta_C(1S)$, $\eta_C(2S)$, χ_{cJ}, and h_C

Exotics: hybrids, glueballs and other exotics in J/ψ and $\psi(2S)$ radiative decays;

Open charm physics: D, D^+, D_s (like CLEO-c)

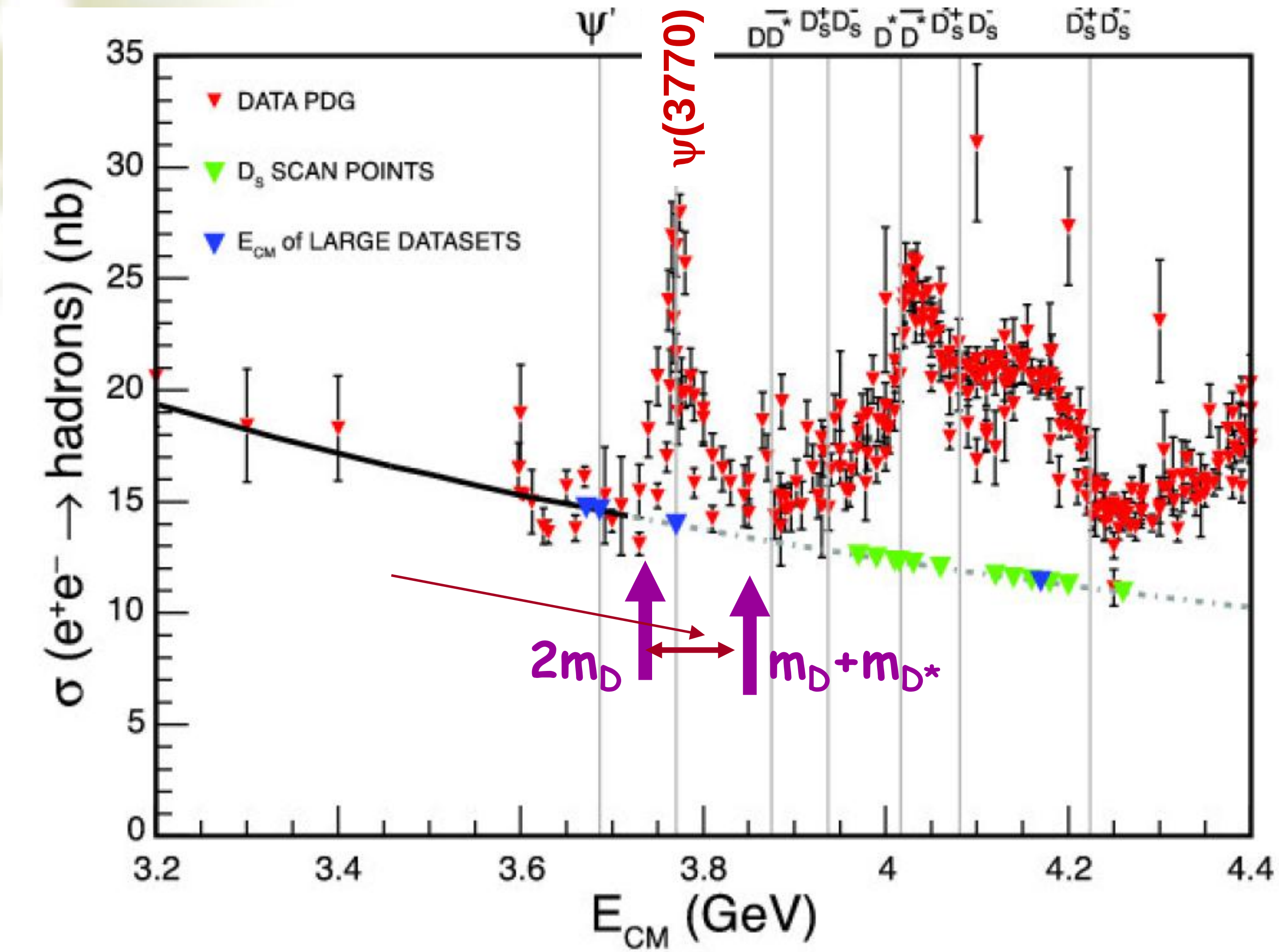
- Improve statistics-hungry analyses
- Improved reach for mixing, rare decays, CP violation
- Quantum correlations, strong $K\pi$ phase, ...
- Spectroscopy via Dalitz plots

Energy scans: R_{had}, resonances, DD composition, ...

Tau Physics

No doubt many more innovations...

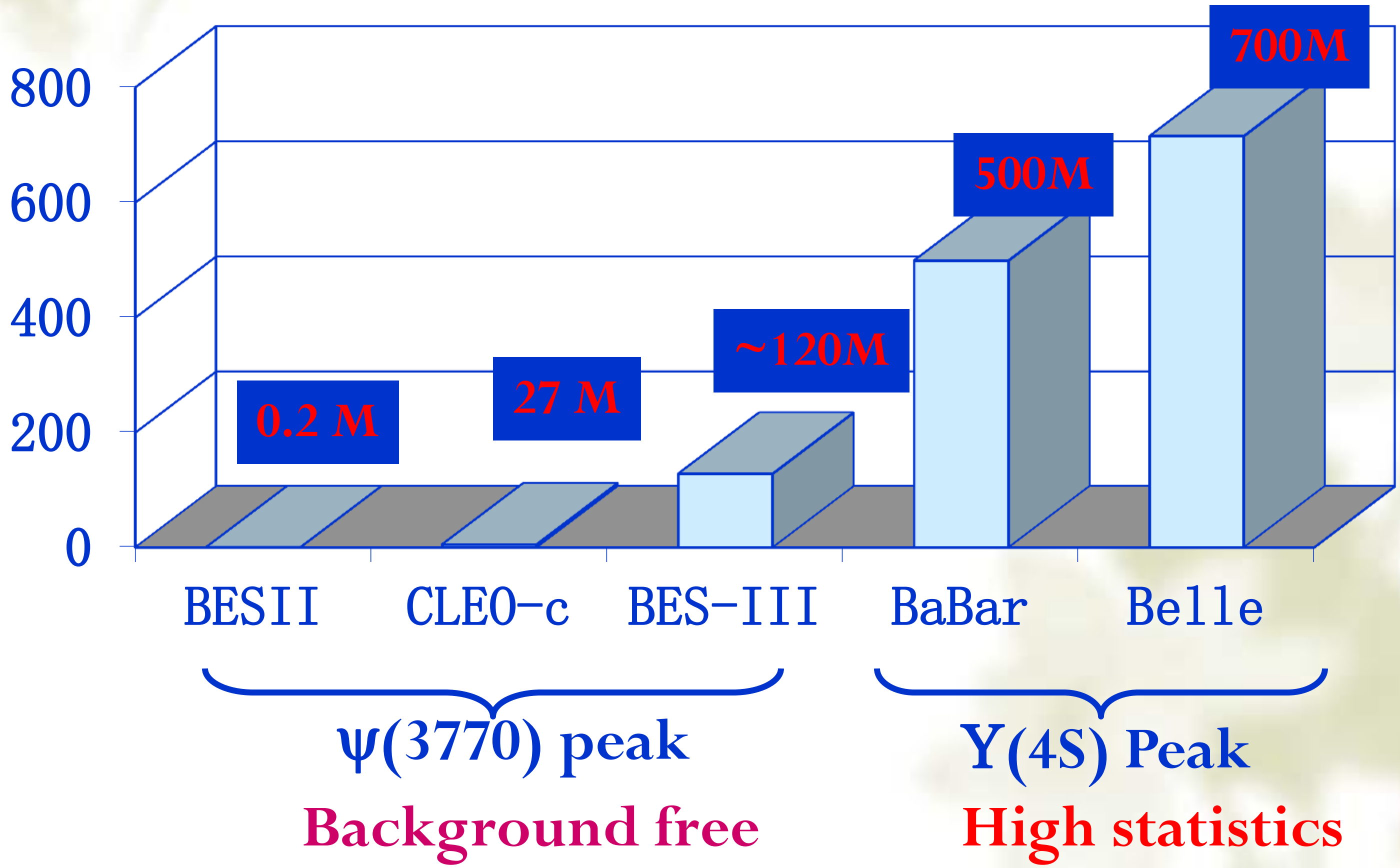
Charm Physics



If a *D* meson is produced here it must recoil from a D meson & nothing else: *not enough energy to make any other particles*

Charm Physics

65 millions DD pairs are expected at BESIII with 10fb^{-1} @3770MeV, while 5 millions at CLEO-c until 2008. <u>But SuperB will produce about 3.2 billions …</u>

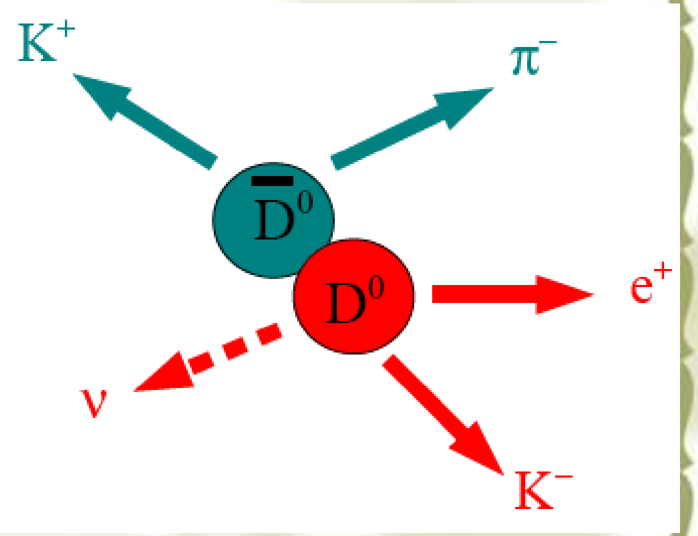


Charm Physics

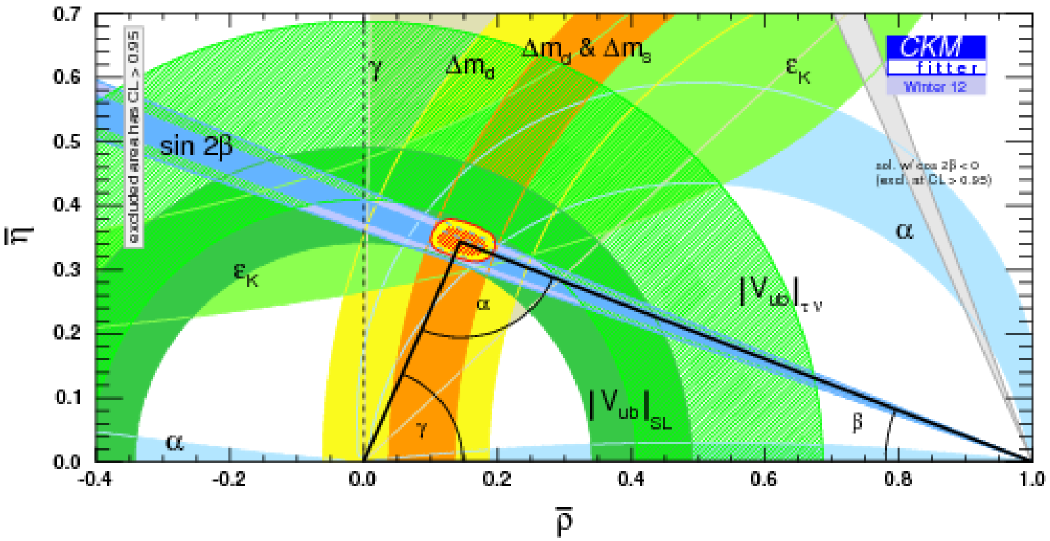
- **Threshold production at 3.773, 4.03, 4.17 GeV**

$$e^+e^- \to D\overline{D}, D_sD_s, D_sD_s^*$$

- **Double Tag techniques: (partial-)reconstruct both D mesons**
- **Charm events at threshold are very clean**
  - Ratio of signal to background is optimum
  - Lots of systematic uncertainties cancellation while applying double tag method



Charm’s Role in the Big Picture



Flavor Physics:

* Over-constrain CKM matrix
* Search for New Physics

Difficulties:

* Mixing is not theoretically clean
* V_{ub} is not theoretically clean

Example: V_{ub} from $B \rightarrow \pi\, l\, \nu$

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

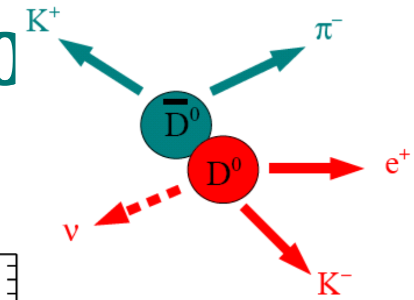
Latest result:

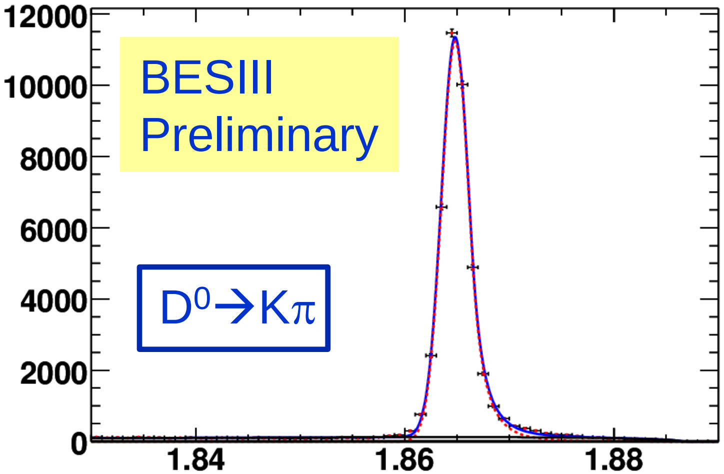
$V_{ub} \times 10^3 =$ 3.92 +/-0.09(exp) +/-0.45(theory)

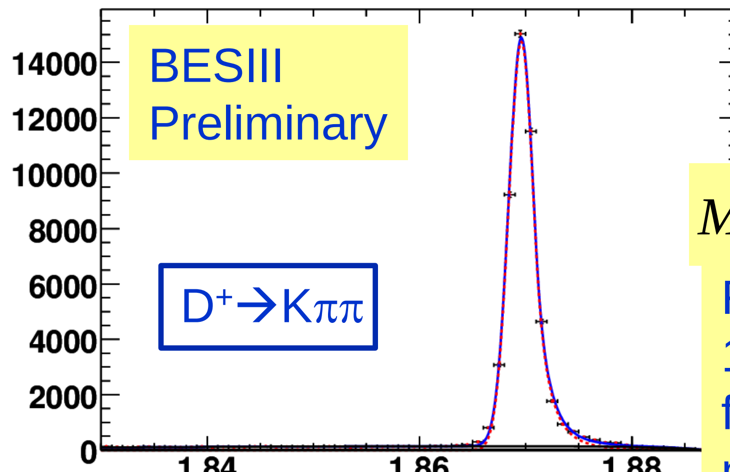
* Needs inputs from Lattice QCD
* Charm physics provides perfect calibration

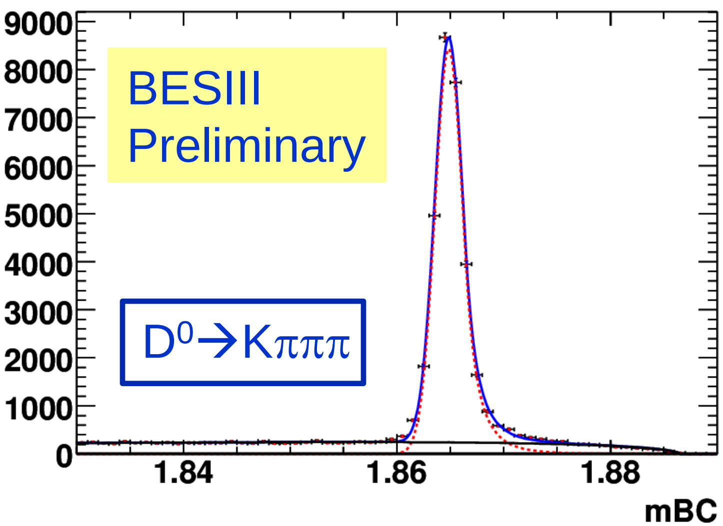
Tag Mode Reconstruction

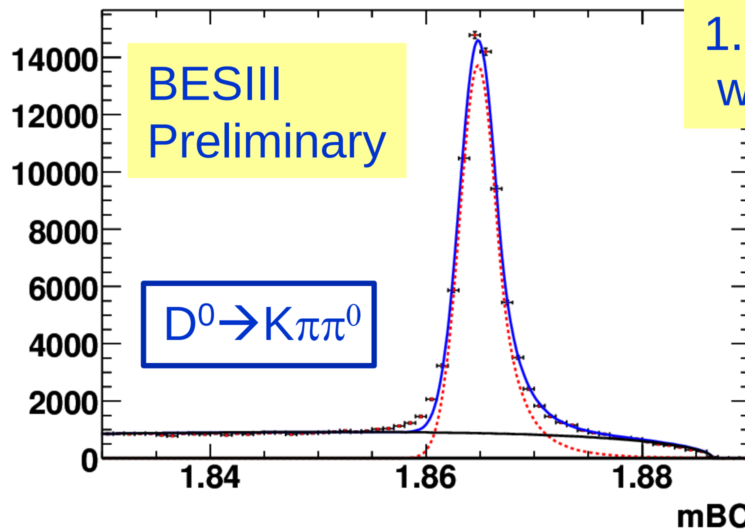
@ψ(3770) with 420pb^{-1} first clean single tagging sample:











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

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

Measurements with Tagged DD

- Absolute branching fractions
- Semileptonic decays
  - $|V_{cs}|$ and $|V_{cd}|$ CKM matrix elements
- Purely leptonic decays
  - f_D and f_{Ds} decay constants
- D-D oscillations
  - Exploiting quantum correlations @ the $\psi(3770)$
- CP violation
- Rare/Forbidden decays

Prospects for Charm at BESIII

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

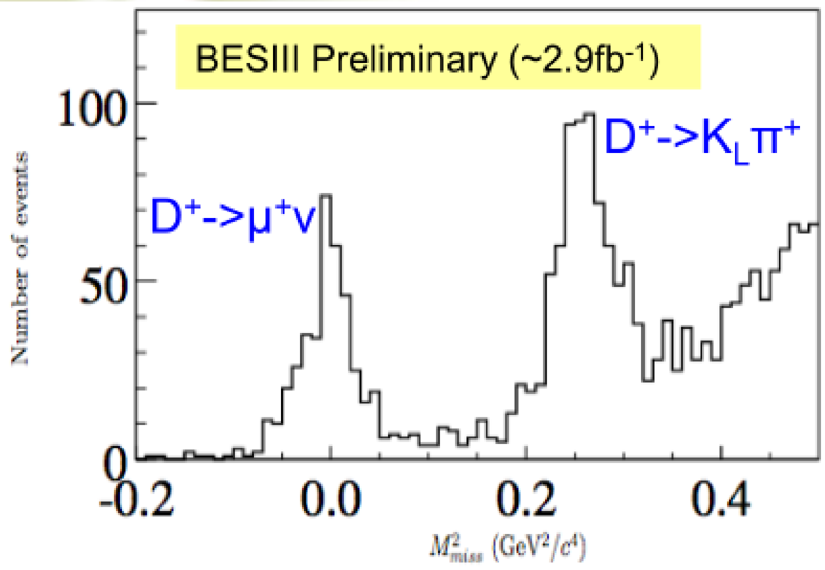
CLEO-c errors for D^0/D^+ physics with $818 pb^{-1}$@3770MeV		BESIII ($5 fb^{-1}$)
f_{D+} ($D^+ \to \mu^+ \nu$):	$\pm$4.1% (stat.) $\pm$ 1.2% (sys.)	$\pm$2.0% (stat.)
$f_\pi(0)$ ($D^0 \to \pi l \nu$):	$\pm$5.3% (stat.) $\pm$ 0.7%(sys.)	$\pm$2.3% (stat.)
BR($D^0 \to K\pi$):	$\pm$0.9% (stat.) $\pm$ 1.8%(sys.)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

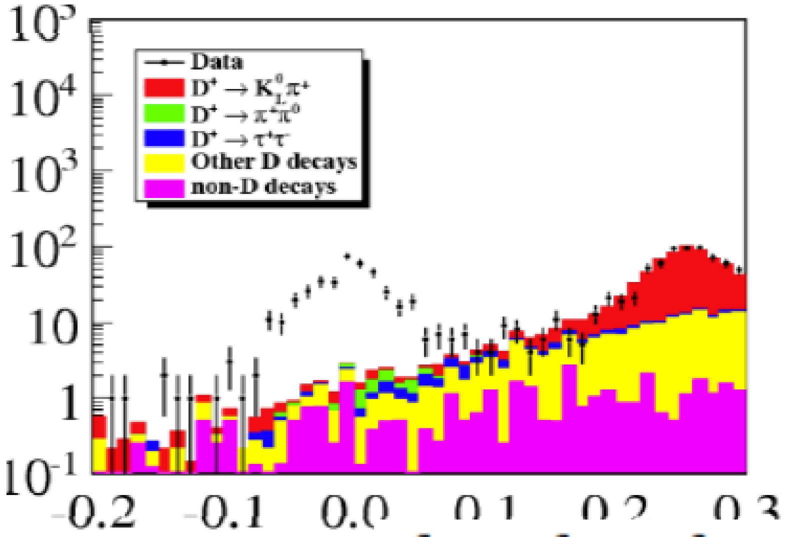
CLEO-c errors for Ds physics with $600 pb^{-1}$@4170 MeV		
f_{Ds} ($Ds^+ \to \mu^+ \nu, \tau\nu$):	$\pm$2.5% (stat.) $\pm$ 1.2% (sys.)	$\pm$0.8% (stat.)
BR($Ds^+ \to KK\pi$):	$\pm$4.2% (stat.) $\pm$ 2.9%(sys.)	$\pm$2.0% (stat.)

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.

Preliminary Results of D→ μ v





$M^2_{miss} = E^2_{miss} - p^2_{miss}$

Results: N($D^+ \to \mu^+ v$)= 377.3±19.4

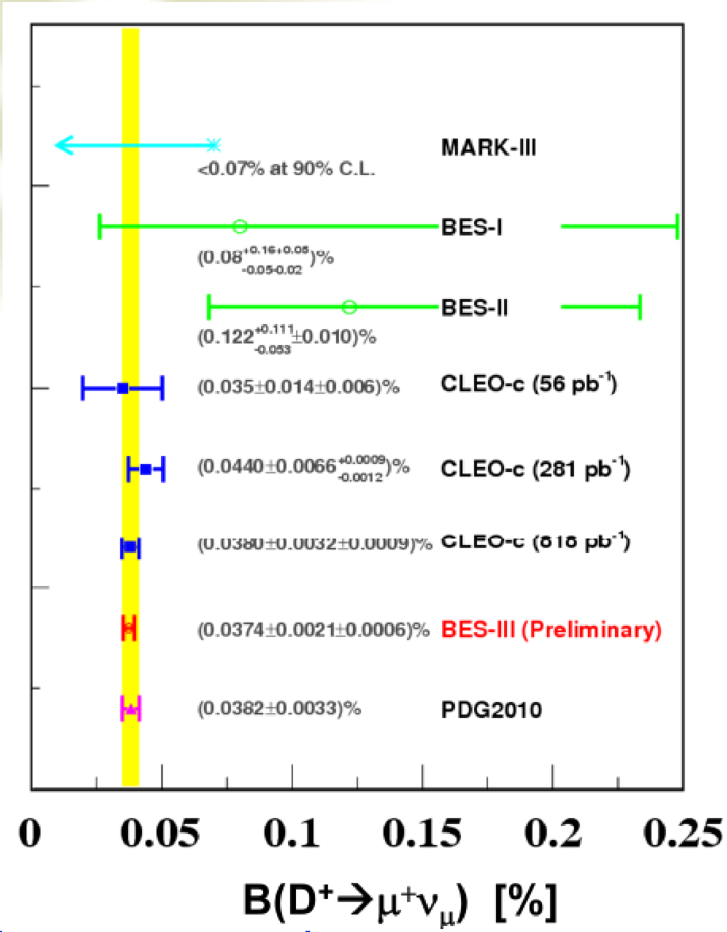
BF($D^+ \to \mu^+ v$) =$(3.74\pm0.21\pm0.06)\times10^{-4}$

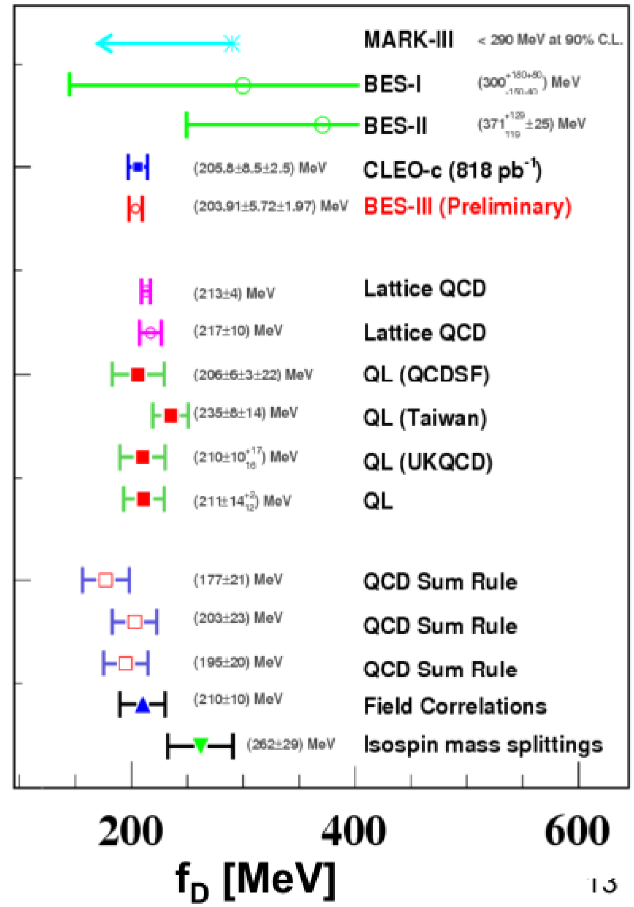
$$\Gamma(D^+ \to l^+ \upsilon_l) = \frac{G_F^2 f_{D^+}^2}{8\pi} |V_{cd}|^2 m_l^2 m_{D^+} (1 - \frac{m_l^2}{m_{D^+}^2})^2$$

f_{D+} = (203.91±5.72±1.97) MeV

$|V_{cd}|$ = (0.222±0.006±0.005)

D→ μ ν: Comparison of BF and f_D





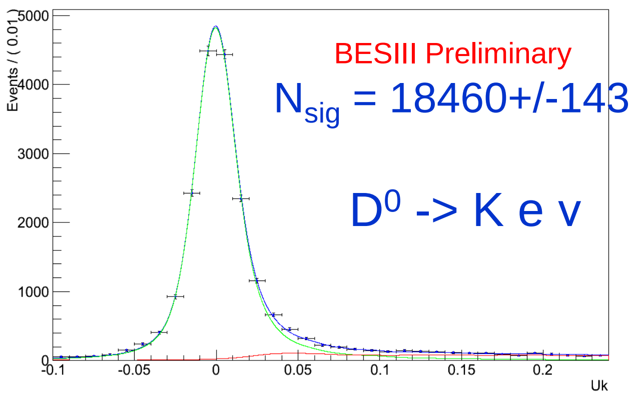
- The most precise measurement is provided by BESIII
- The error is still dominated by statistics, even with $10 fb^{-1}$ D data.

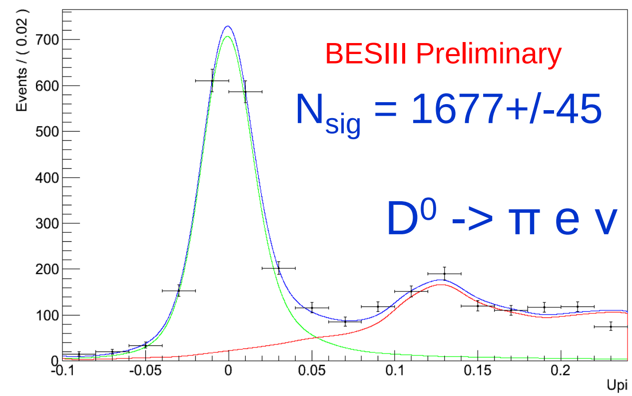
D→ K/π e ν (BF, form factor)

BESIII, ~2.93 fb-1 data taken at ψ(3770), ~923 pb-1 analyzed (by two groups, partially blind analysis)

- Double tag technique
- Simple differential decay rate function (massless lepton assumed)

$$\Delta\Gamma(D \to \pi(K) e\nu) \quad = \quad G_F^2 \, |V_{cd(s)}|^2 \; p^3 \, |f_+(q^2)|^2$$





Mode	measured branching fraction(%)	PDG	CLEOc
$\bar{D}^0 \to K^+ e^- \bar{\nu}$	3.542 ±0.030±0.067	3.55 ±0.04	3.50 ±0.03 ±0.04
$\bar{D}^0 \to \pi^+ e^- \bar{\nu}$	0.288 ±0.008±0.005	0.289 ±0.008	0.288 ±0.008±0.003

* Preliminary systematics
* Will improve using full (3x) data set in the near future

Rare and Forbidden decays

Search for New Physics in Charm Sector:

- **Lepton flavor and lepton number violating decays of D decays**
- Flavor Changing Neutral Current ($c \rightarrow u\ l^+ l^-$) **~10^{-8}**
- **Charm Mixing (Large CPV in mixing indicates New Physics)**
- **CP Violation - Direct (New Physics could be ~%)**

Experimental status:

- **the Charm factory is NOT always dominating in these area, especially with LHCb and Super B factories**
- **the Charm factory (like BESIII) has unique advantage in some particular processes**

Search for $D^0 \to \gamma\gamma$

- FCNC transition (i.e., $c \to u + \gamma$) and is forbidden at tree level.
- Extremely suppressed in decays of K and B mesons
- Decays of the D mesons: diluted by long-distance contributions

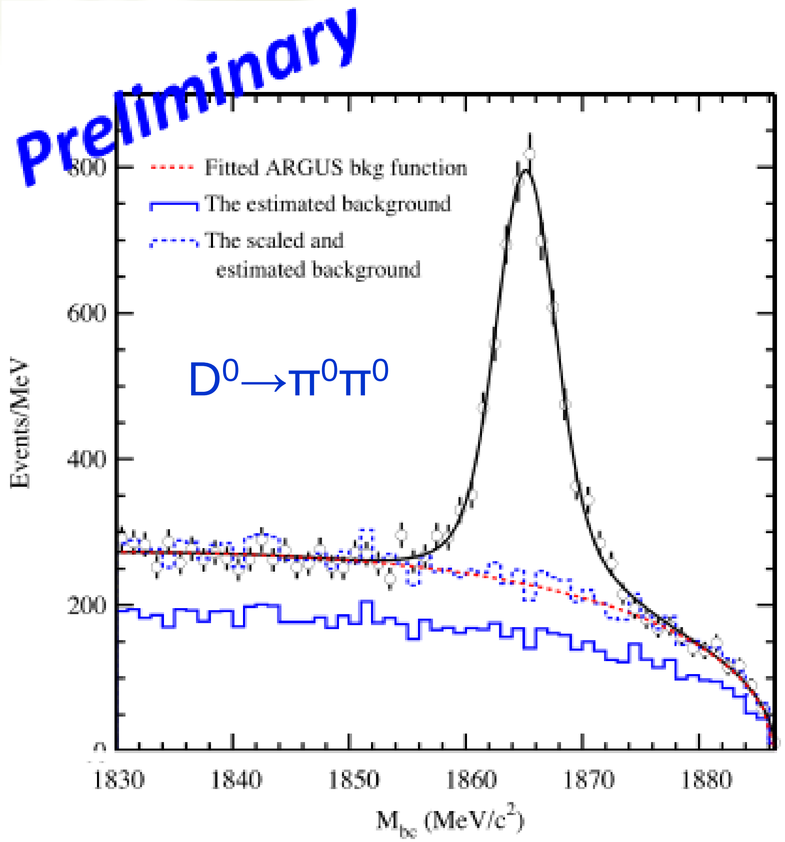
- This small transition rate due to the short distance effect is enhanced by long distance effect, bringing the overall $B(D^0 \to \gamma\gamma)$ larger.
  SM: $B(D^0 \to \gamma\gamma) \sim 10^{-8}$ or less (i.e., see Fajfer et al. PRD64, 074008 (2001)).
- But, for instance, the minimal super-symmetric standard model predicts the rate could be enhanced by a factor of 100 by exchanging gluino (i.e., see Prelovsek and Wyler, PLB500, 304 (2001)) or $BR(D^0 \to \gamma\gamma) \sim 10^{-6}$.

Three experimental results so far:

- CLEO2 looked for this with 13.8/fb taken around Υ(4S).
  → $B(D^0 \to \gamma\gamma) < 2.9\times10^{-5}$ @ 90% CL (PRL90, 101801 (2003)).
- CLEO-c also looked for based on 818/pb taken at ψ(3770).
  → Preliminary result: $B(D^0 \to \gamma\gamma) < 8.63\times10^{-6}$ @ 90% CL (Charm 2010).
- BaBar also has a result with 470.5/fb taken around Υ(4S).
  → $B(D^0 \to \gamma\gamma) < 2.2\times10^{-6}$ @ 90% CL (hep-ex:1110.6480).

Search for $D^0 \to \gamma\gamma$

- Measure with $D^0 \to \pi^0\pi^0$ decays which share some of the common backgrounds (i.e., continuum such as $e^+e^- \to \gamma^* \to$ qqbar).

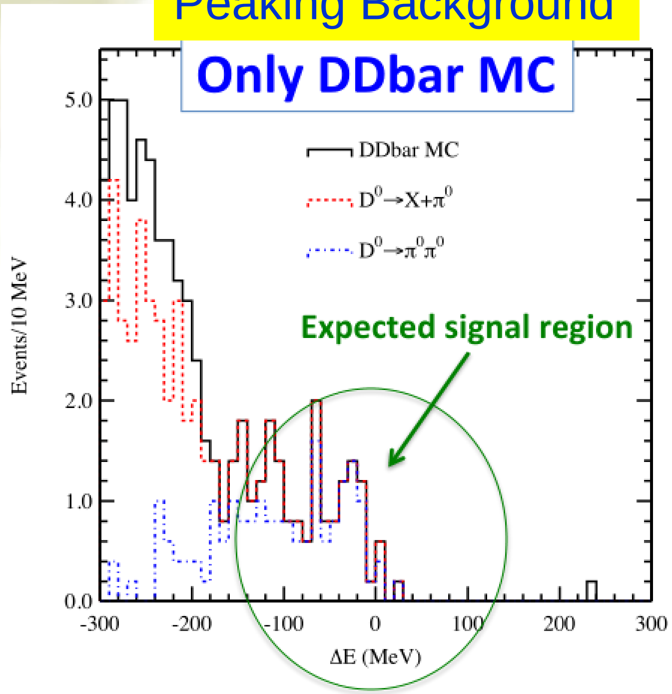


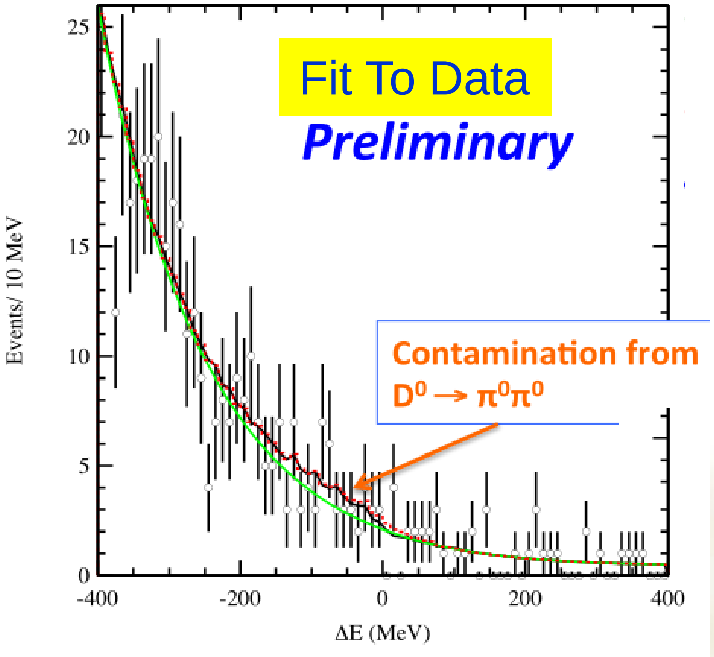
- **4081±117 signal events.**
- **The resultant preliminary $B(D^0 \to \pi^0\pi^0)$ is consistent with the known value (PDG and the latest result from BaBar).**

- **The total MC-based background (solid-blue) underestimates the one seen in data:**
  Needed to scale it UP(dashed-blue) by (49±2)% to match to data!
  We attribute this to poor simulation of "non-DDbar" components.

Search for $D^0 \to \gamma\gamma$

Peaking Background





$B(D^0 \to \gamma\gamma)/B(D^0 \to \pi^0\pi^0)$
$< 5.8\times10^{-3}$ UL @ 90% CL

- **Gives: -2.9±7.1 events**
- **No significant signals.**
- **Larger stat. error than MC's due to the underestimated non-DD components:**

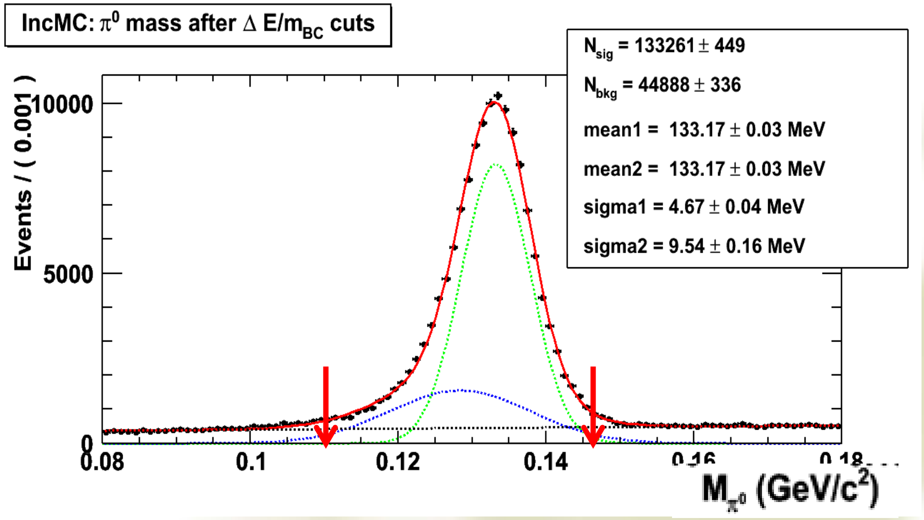
corresponds to
$B(D^0 \to \gamma\gamma) < 4.6\times10^{-6}$ UL @ 90% CL.

- to improve systematics of $D^0 \to \pi^0\pi^0$
- to test with double tag method

FCNC Process: $D^0 \to \pi^0 \nu \bar{\nu}$

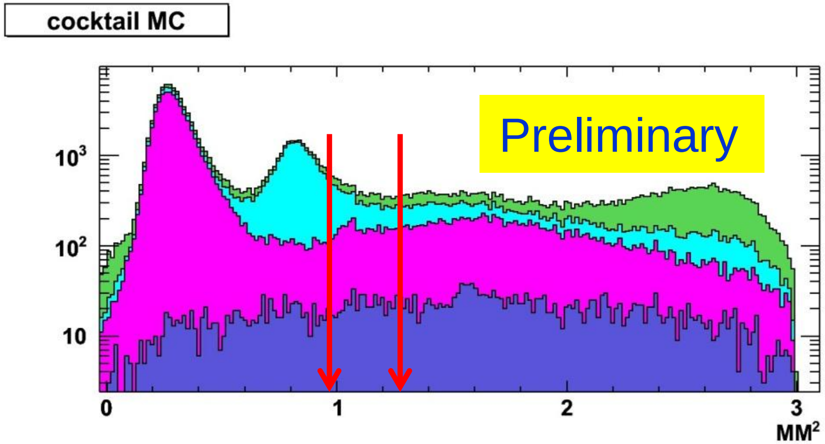
- Another typical FCNC process
- First mseasurement
- Unique measurement in the Charm factory
- Double tag technique and blind analysis
- Tag modes: $D \to K\pi, D \to K\pi\pi^0, D \to K\pi\pi\pi$

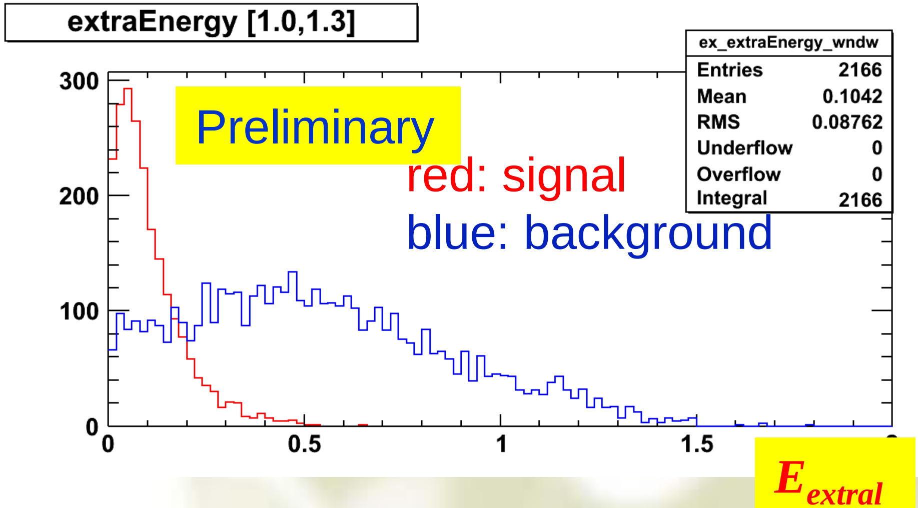
To select the signals:
- reconstruct pi0 with the two leading showers among the unused shower
- no additional charged tracks

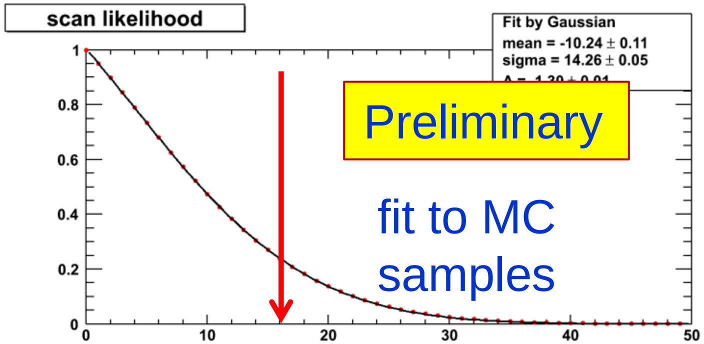


FCNC Process: $D^0 \to \pi^0 \nu \bar{\nu}$

- Define $MM^2 = (E_{cms} - E_{tagD} - E_{\pi^0 fit})^2 - (P_{cms} - P_{tagD} - P_{\pi^0 fit})^2$
  - choose $MM^2 \in [1.0, 1.3]$ as our signal region to keep away from the peaking of K_L (hot pink) and K*(aqua).
- Define E_{extral} as the total energy of the rest of the showers in the EMC







Preliminary Results based on MC study:

BF($D^0 \to \pi^0 \nu \bar{\nu}$): 1.4×10^{-3}@90% C.L.

Summary

- **BEPCII/BESIII with successful commission and data taking**
- **Lots of interesting physics at *D* energies**
- **Many measurements are unique to BESIII**
- **We expect rich physics results in the coming years from BESIII.**
- **Super-τ-charm will provide us many opportunities**

Thank You!