Absolute *D* Hadronic Branching Fractions at CLEO-c

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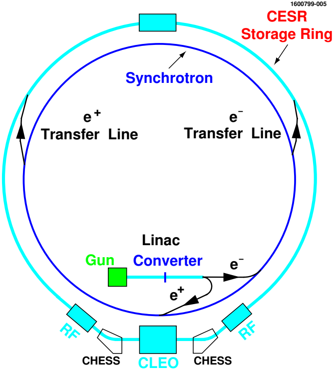
Outline

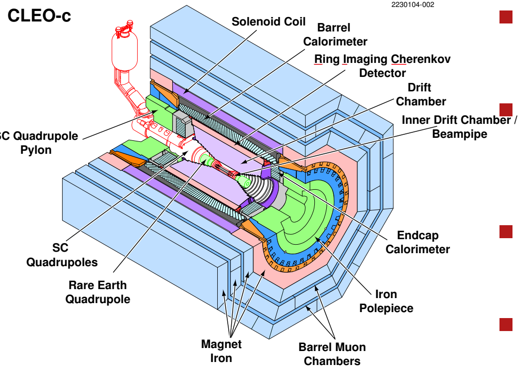
Cornell Electron Storage Ring (CESR)

- Depth: 14m, Circ: 0.77km.
- Ran for HEP: 1979 - 2008.



- E_{cm}: 3.5 – 12 GeV.
- Still running for CHESS and CesrTA.

CLEO-c Detector Properties



- Momentum resolution of tracking: 0.6% @ 1 GeV
- Excellent photon detection: π^0 mass resolution $\sim$ 6 MeV (200 MeV < E_{π^0} < 1 GeV)
- Particle ID: RICH(Cherenkov) & dE/dx $\Rightarrow$ π/K separation $\gtrsim$ 90%
- Collides $e^+ e^-$ primarily @ E_{cm} = 3.77 GeV for $D\,\overline{D}$ and @ E_{cm} = 4.17 GeV for D_s

D Hadronic Branching Fraction analysis

- This analysis uses all CLEO-c $\psi(3770)$ data (818 pb^{-1}).
- Measurement of D hadronic branching fractions sets absolute branching fraction scale for most D and B decays.
- We measure 3 neutral and 6 charged D decay modes, including the two reference modes $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$.

$D^0 \to K^-\pi^+$
$D^0 \to K^-\pi^+\pi^0$
$D^0 \to K^-\pi^+\pi^-\pi^+$
$D^+ \to K^-\pi^+\pi^+$
$D^+ \to K^-\pi^+\pi^+\pi^0$
$D^+ \to K^0_S\pi^+$, $K^0_S \to \pi^+\pi^-$
$D^+ \to K^0_S\pi^+\pi^0$, $K^0_S \to \pi^+\pi^-$
$D^+ \to K^0_S\pi^+\pi^+\pi^-$, $K^0_S \to \pi^+\pi^-$
$D^+ \to K^+K^-\pi^+$

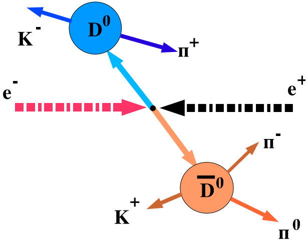
- Published results with 56 pb^{-1} [PRL 95, 121801(2005)] and with 281 pb^{-1} [PRD 76, 112001 (2007)].

Analysis Technique

- Identify D 's from "beam-constrained mass" and ΔE:

$$M_{BC} \equiv \sqrt{E_{beam}^2 - |\vec{p}_D|^2} \text{ (peaks at D mass)}$$

$$\Delta E \equiv E_D - E_{beam} \text{ (peaks at zero)}$$



- Reconstruct Single Tags and Double Tags in $D\bar{D}$ events:

$$N_i = \epsilon_i \mathcal{B}_i N_{D\bar{D}}, \ \bar{N}_j = \bar{\epsilon}_j \mathcal{B}_j N_{D\bar{D}}$$

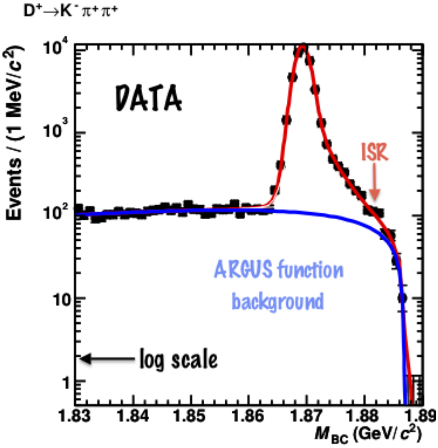
$$N_{ij} = \epsilon_{ij} \mathcal{B}_i \mathcal{B}_j N_{D\bar{D}}$$

$$\Rightarrow N_{D\bar{D}} = \frac{N_i \bar{N}_j}{N_{ij}} \frac{\epsilon_{ij}}{\epsilon_i \bar{\epsilon}_j}, \ \mathcal{B}_i = \frac{N_{ij}}{\bar{N}_j} \frac{\bar{\epsilon}_j}{\epsilon_{ij}}$$

- Independent of knowing the luminosity.

- Pioneered by MARK III.
- N_i: single tag yields
- N_{ij}: double tag yields
- ϵ: efficiencies from signal MC (i/j for single tag, ij for double tag)

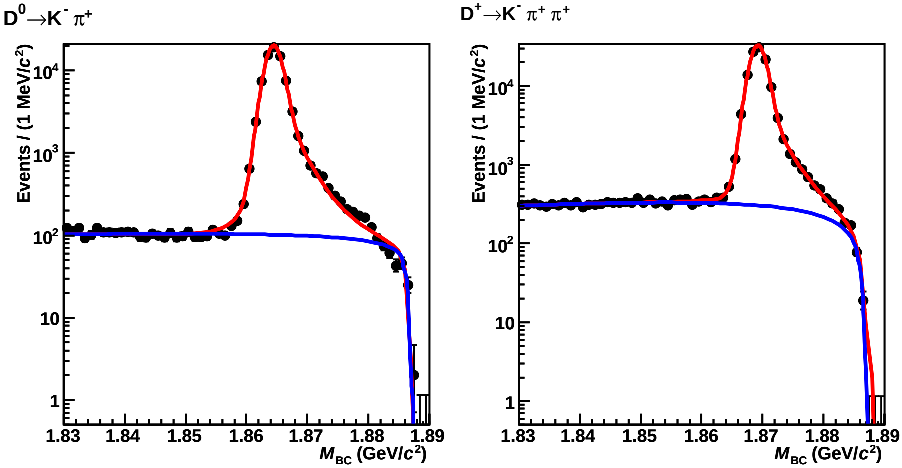
Yield Extraction



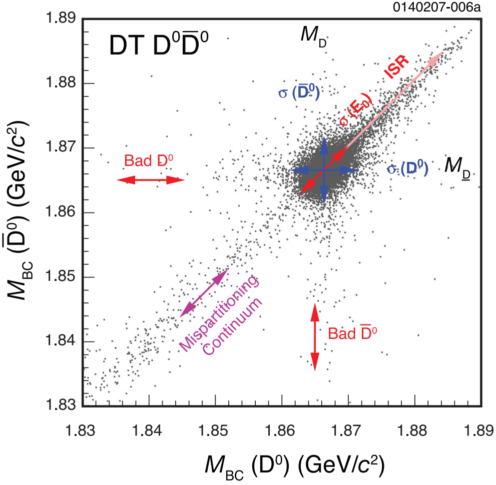
- We fit signal with a theoretically derived M_{BC} peak shape that includes the effects of :
  1. Initial state radiation (ISR),
  2. ψ(3770) line shape (width and mass),
  3. Beam energy spread,
  4. Momentum resolution (sum of 3 Gaussians).

M_{BC} fitting for data – Single Tag

- Single tag yields are obtained from a 1-dimensional fit of M_{BC}

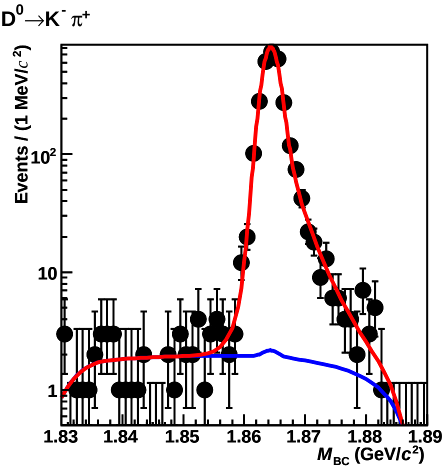


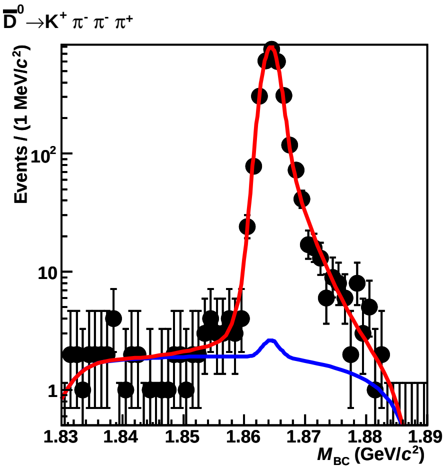
Double Tag Yield Fits



- Double tag yields are obtained from a 2-dimensional fit of $M_{\rm BC}$ (D) vs. $M_{\rm BC}$ ($\bar{D}$)
- Fit components:
  - Signal peak
  - One D correct, one incorrect
  - Both D's incorrect
  - Mispartitioning
- Separates effects of:
  - beam energy spread (correlated between D's)
  - detector resolution (uncorrelated)

M_{BC} fitting data – Double Tags





- Combinatorial and peaking backgrounds (blue) are very small.

Update in the full dataset

- Improved Monte Carlo simulation using the latest PDG.
- Updated background study with 20x Generic MC.
- Updated systematical uncertainties study:
  - Single Tag Background modeling
  - Δ E requirement
  - Signal lineshape
  - Final State Radiation (FSR)
  - K/π tracking
  - π^0 efficiency
  - Double DCSD corrections

Branching Fraction Fit

$$N_i = \epsilon_i \mathcal{B}_i N_{D\bar{D}}, \ \bar{N}_j = \bar{\epsilon}_j \mathcal{B}_j N_{D\bar{D}}$$
$$N_{ij} = \epsilon_{ij} \mathcal{B}_i \mathcal{B}_j N_{D\bar{D}}$$
$$\Rightarrow N_{D\bar{D}} = \frac{N_i \bar{N}_j}{N_{ij}} \frac{\epsilon_{ij}}{\epsilon_i \bar{\epsilon}_j}, \ \mathcal{B}_i = \frac{N_{ij}}{\bar{N}_j} \frac{\bar{\epsilon}_j}{\epsilon_{ij}}$$

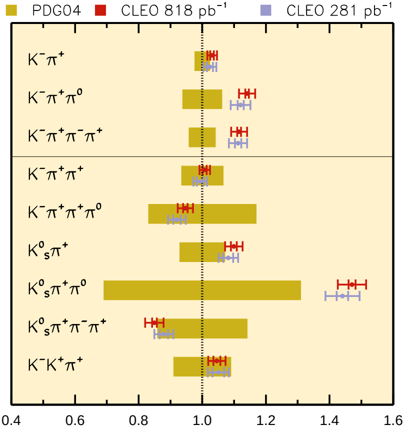
- N_i: single tag yields
- N_{ij}: double tag yields
- ϵ: efficiencies from signal MC

- From 18 single tag and 45 double tag yields, we use a χ^2 fit to determine 9 branching fractions ($\mathcal{B}_i$) and the number of $D\,\overline{D}$ pairs ($N_{D^0\bar{D}^0}$ and $N_{D^+D^-}$).
- The fit includes:
  - Peaking background subtractions from the yields,
  - Cross-feeds between modes,
  - Systematic errors.

Branching Fractions Results – Preliminary

Mode	$\mathcal{B}$ (%)
$D^0 \to K^-\pi^+$	$3.92 \pm 0.02 \pm 0.05$
$D^0 \to K^-\pi^+\pi^0$	$14.83 \pm 0.07 \pm 0.32$
$D^0 \to K^-\pi^+\pi^-\pi^+$	$8.32 \pm 0.04 \pm 0.18$
$D^+ \to K^-\pi^+\pi^+$	$9.27 \pm 0.06 \pm 0.14$
$D^+ \to K^-\pi^+\pi^+\pi^0$	$6.15 \pm 0.05 \pm 0.15$
$D^+ \to K^0_S\pi^+$	$1.55 \pm 0.01 \pm 0.04$
$D^+ \to K^0_S\pi^+\pi^0$	$7.13 \pm 0.05 \pm 0.21$
$D^+ \to K^0_S\pi^+\pi^+\pi^-$	$3.02 \pm 0.03 \pm 0.10$
$D^+ \to K^+K^-\pi^+$	$0.93 \pm 0.01 \pm 0.02$

Cross Sections (σ)	Values (nb)
$e^+e^- \to D^0\bar{D}^0$	$3.63 \pm 0.02 \pm 0.06$
$e^+e^- \to D^+D^-$	$2.88 \pm 0.02 \pm 0.04$



- Consistent with 281 pb^{-1} results.
- PGD04 does not have CLEO result.

Summary

- Measured the absolute *D* hadronic branching fractions using full CLEO-c 818 pb^{-1} $\psi(3770)$ data.
- Updated background study and major systematics uncertainties.
- Preliminary results are consistent with the previous measurement.

- CLEO finished data taking in 2008.
- Looking forward to see the results from BESIII.