Latest *D* Meson Hadronic Branching Fractions from CLEO

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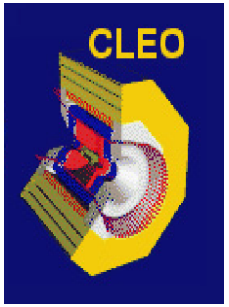
DPF, 16 August 2013

THE UNIVERSITY OF TEXAS AT AUSTIN



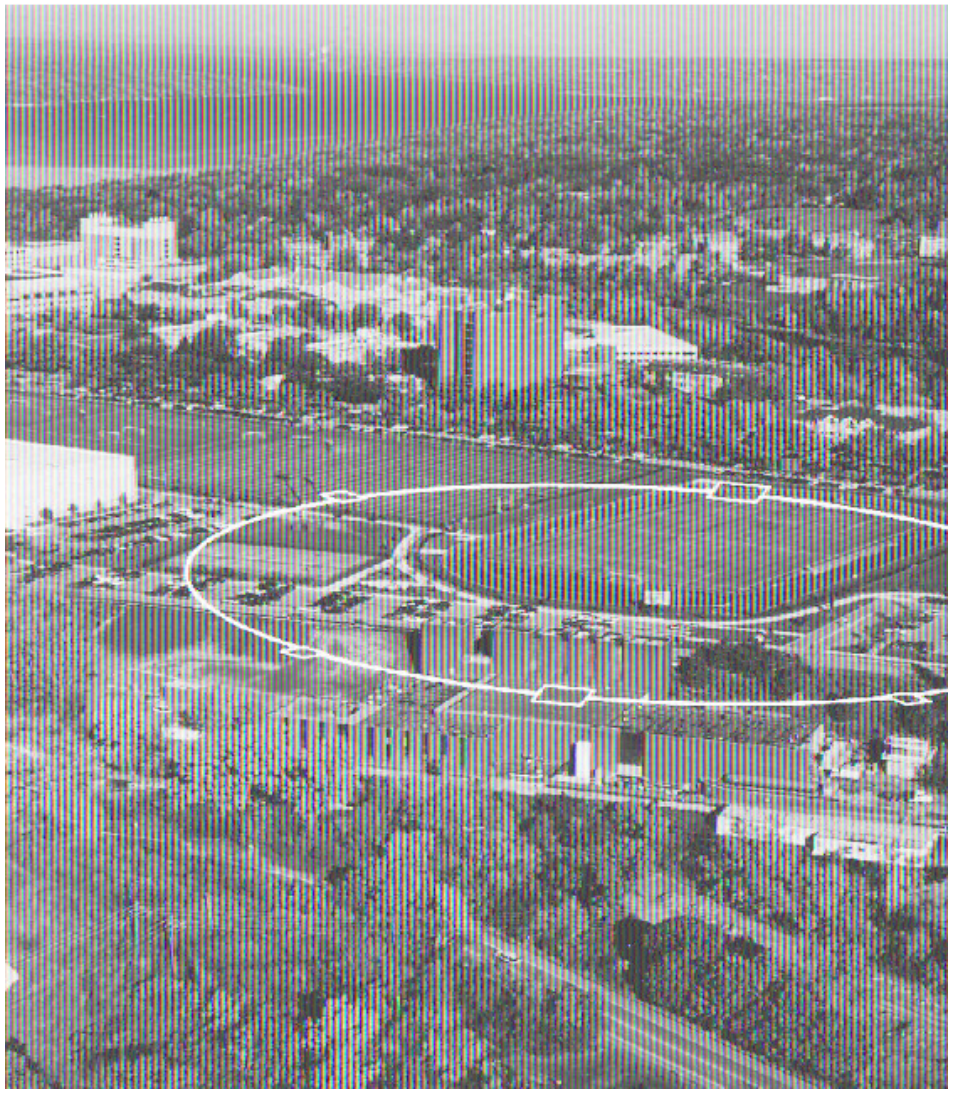
Motivation

Why D branching fractions to hadronic final states?

- Critical normalizations for processes involving charm quarks
  - e.g. $\Gamma(B_s \rightarrow D_s^+ D_s^-)$ for determining $\Delta\Gamma$ of B_s CP eigenstates
- Interesting in their own right: short distance weak decay and long distance QCD effects make hadronic D decays an interesting laboratory
  - weak annihilation effects? SU(3) breaking importance? etc.
- Other uses
  - e.g. tracking efficiency from reconstructed $D^0 \rightarrow K^- \pi^+ \pi^+ \pi^-$ vs. $D^0 \rightarrow K^- \pi^+$

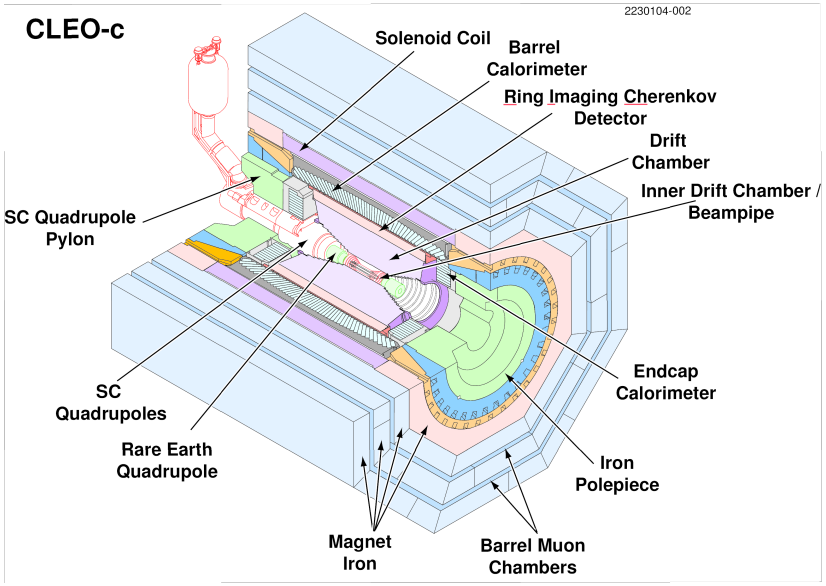
Here I will show updates with the full CLEO-c dataset

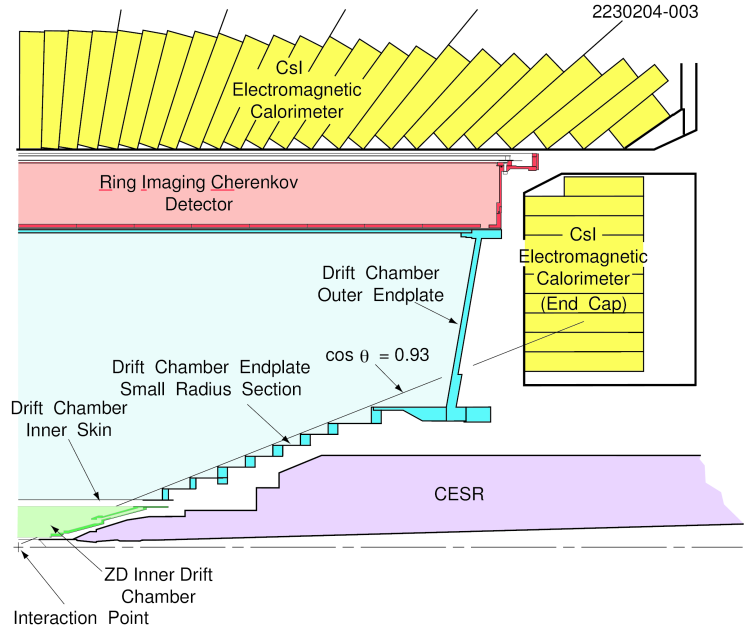
CESR



- 768 m symmetric e^+e^- storage ring on Cornell campus
- Long and fruitful history:
  - B physics @ Υ,
  - D physics @ ψ,
  - quarkonium,
  - light source,
  - accelerator testbed
- Energy tunable for various studies

CLEO-c Detector



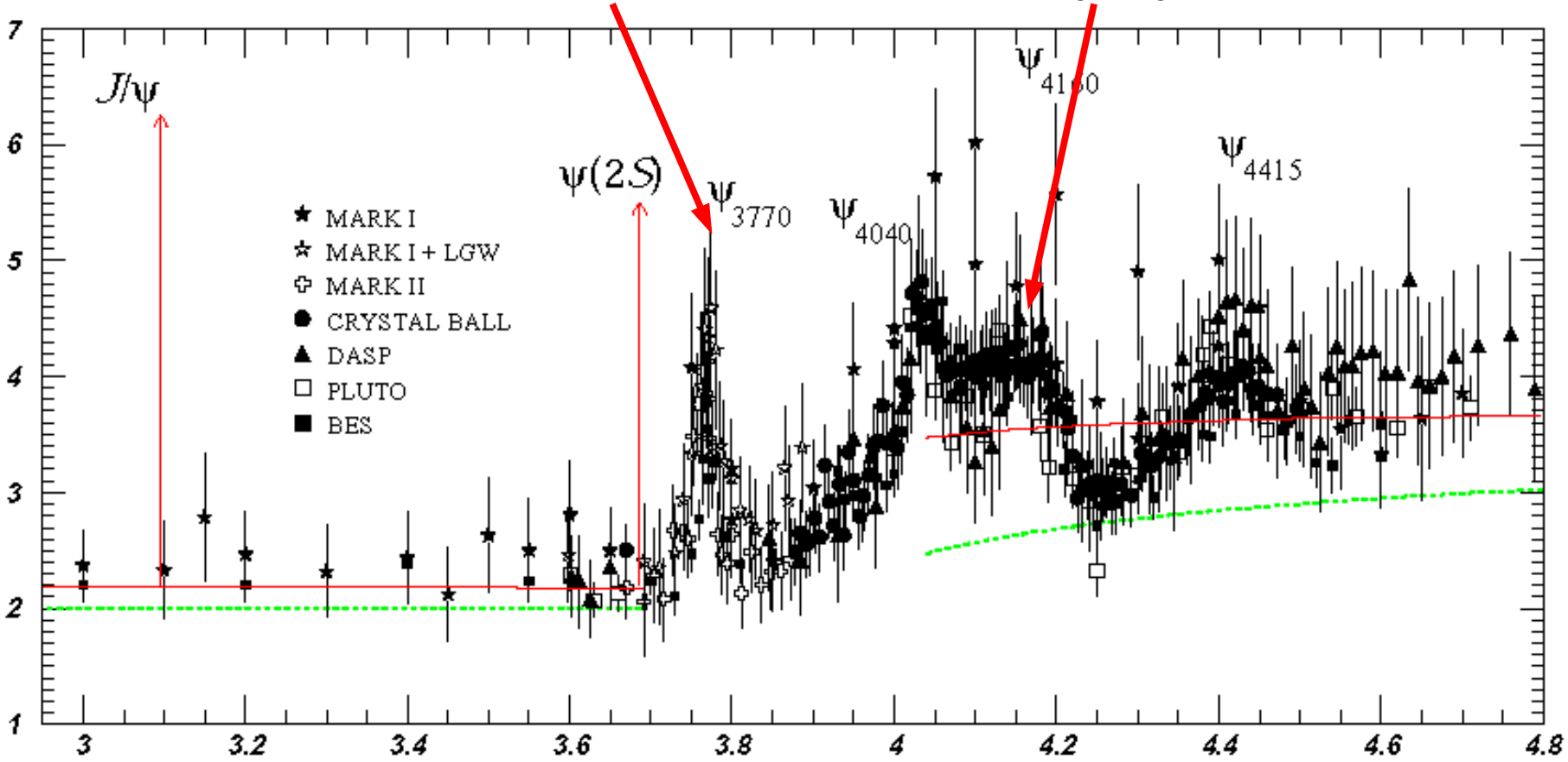


- General purpose symmetric detector
- Tracking, EM cal for $|\cos\theta| < 0.93$
- Ring Imaging Cherenkov (RICH) for $|\cos\theta| < 0.8$
- Particle ID via RICH and dE/dx in drift chamber

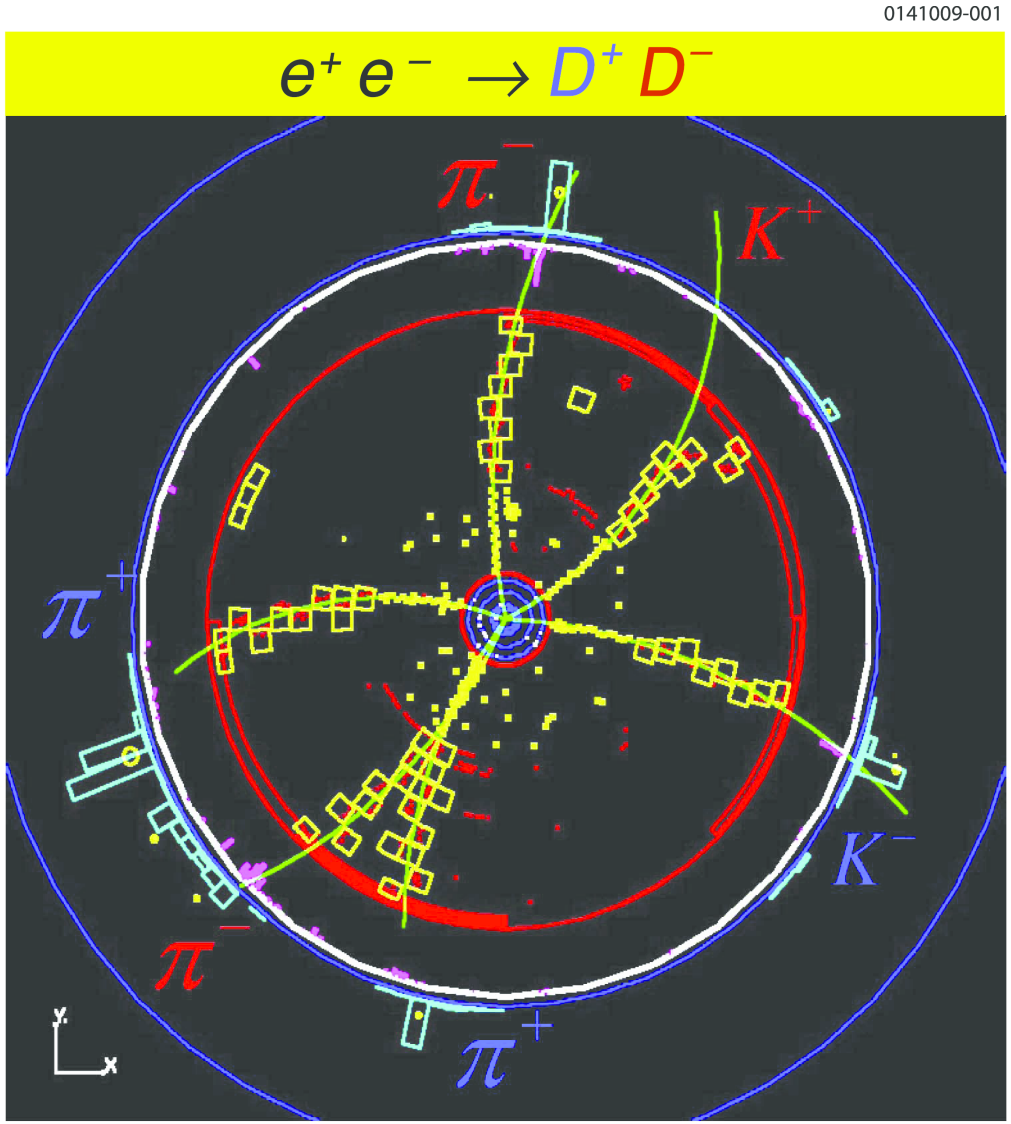
Datasets

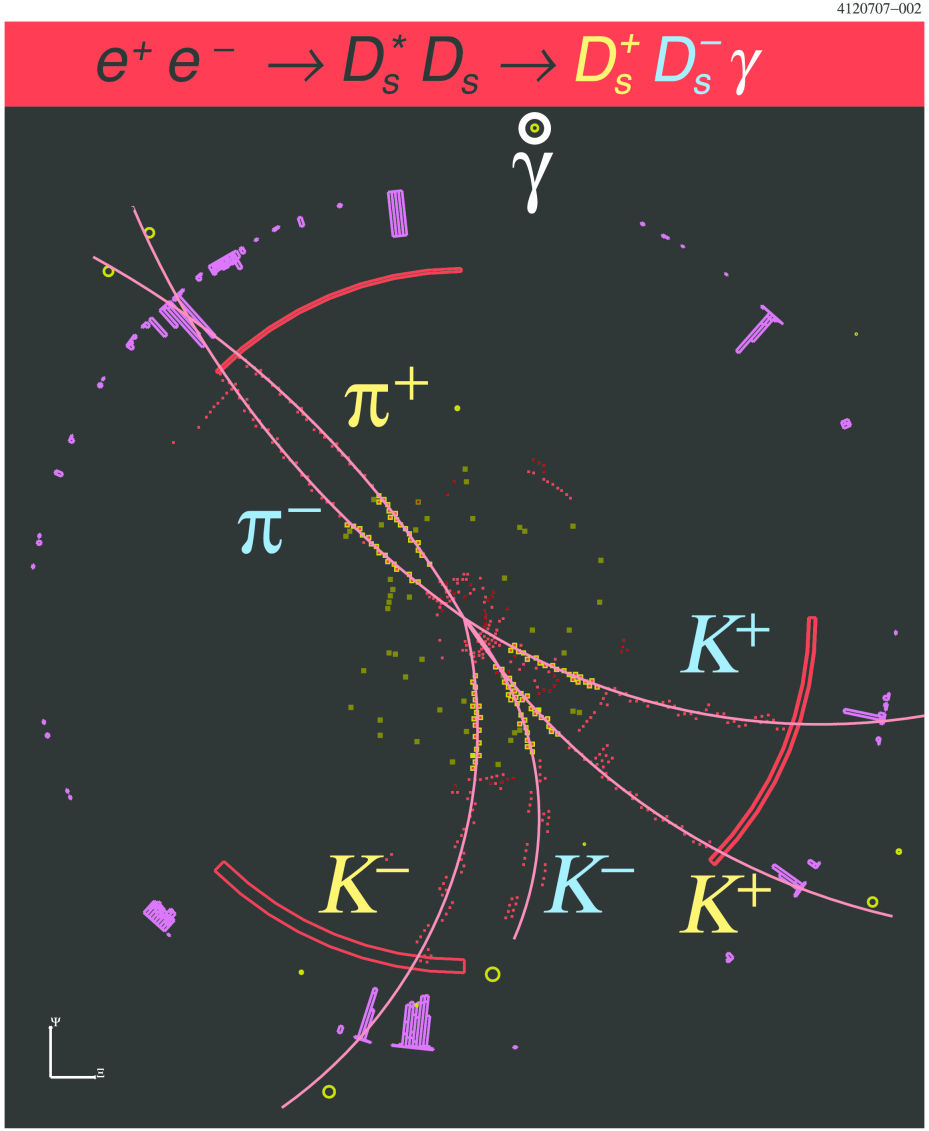
818 pb^{-1} @ 3.77 GeV
$D^0\bar{D}^0$, D^+D^-

586 pb^{-1} @ 4.17 GeV
$D_s^*D_s$



Fully Reconstructed Events





Basic Technique

- Run at energies where we only produce X with $\overline{X}$:
  - 3.77 GeV: $D^0\overline{D}^0$, D^+D^- (below DDπ threshold)
  - 4.17 GeV: D_s^* D_s (below D_sDK threshold)
- So reconstructing a D in an event forces the rest of the event to have a $\overline{D}$: we can then get the branching fractions from

"double tags"

$$\mathcal{B}(D \to X) = \frac{N(D\overline{D}, D \to X)/\epsilon(D \to X \text{ given } \overline{D})}{N(\overline{D})}$$

"single tags"

- In practice we count reconstructed D, $\overline{D}$, and $D\overline{D}$ events and use a fit to extract the branching fractions

Pioneered by Mark III

Systematics

$$\mathcal{B}(D \to X) = \frac{N(D\overline{D}, D \to X)/\epsilon(D \to X \text{ given } \overline{D})}{N(\overline{D})}$$

- Limited by
  - single D reconstruction efficiency
  - yield determination
  - correlation between single and double tag reconstruction
- For $D^0 \to K\pi$ and $D_s \to KK\pi$, biggest systematic is per-track reco efficiency
  - for $D^0 \to K\pi$, almost equal systematic is final state radiation modeling ($D^0 \to K\pi$ + soft γ)

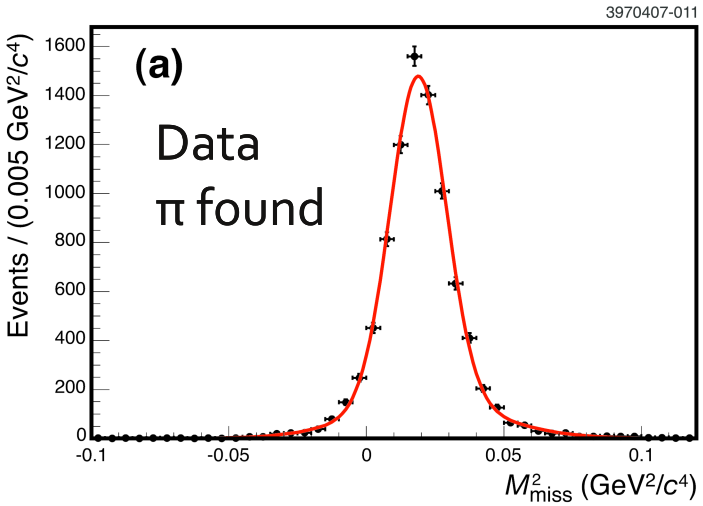
Tracking Systematics

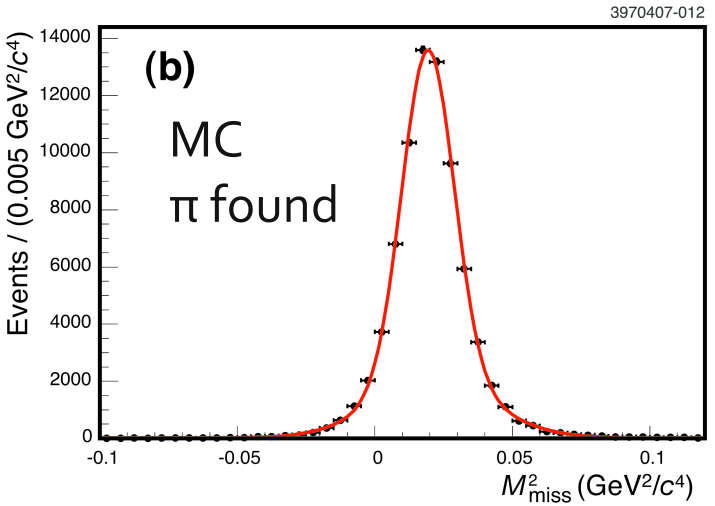
- Kaon, pion MC-data differences studied using partial vs full reconstruction of $D\overline{D}$ events

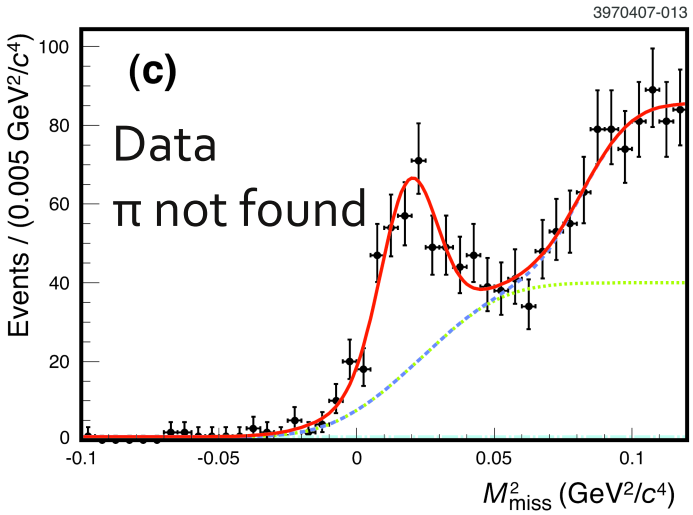
$D^+ \longrightarrow K\pi\pi$

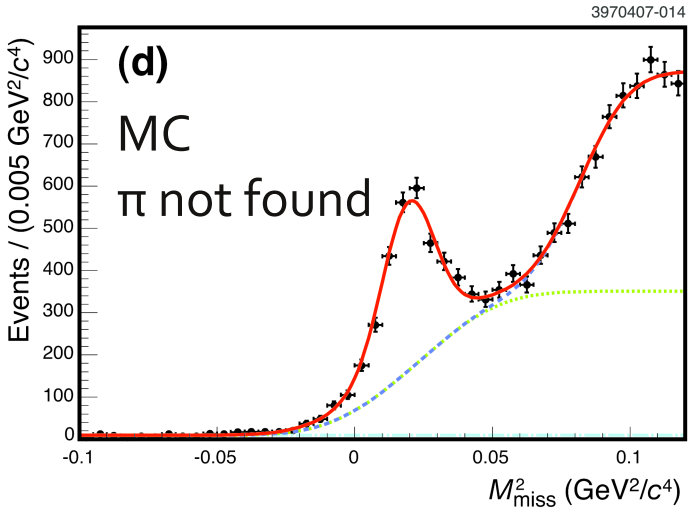
Missing mass in partial reconstruction (excluding one π)

Systematic:
0.3% per π
0.6% per K









3.77 GeV: D^0, D^+

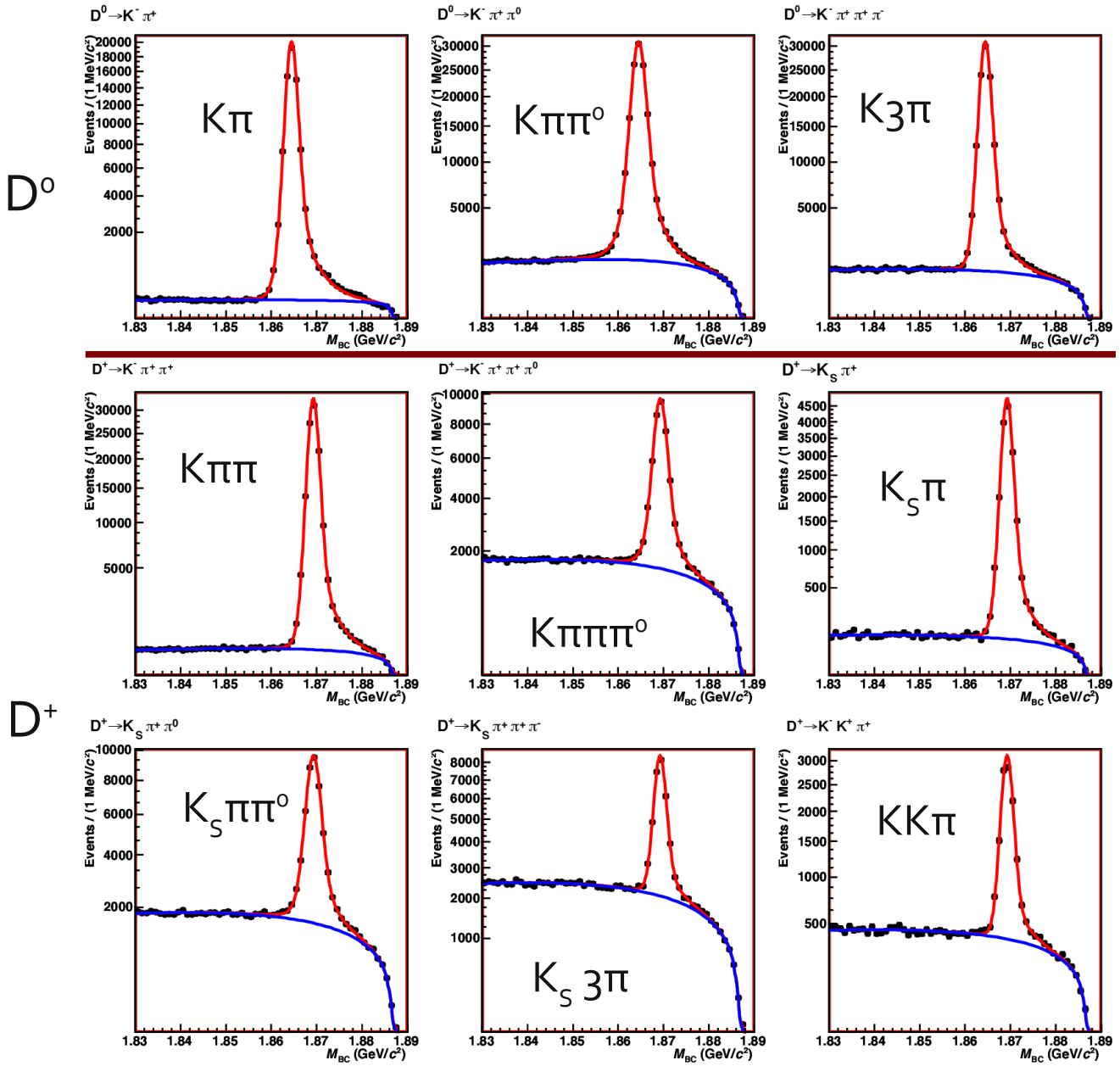
- Two body production: $D^0\overline{D}^0$, D^+D^-; momenta, energy fixed in CM frame
- Use "ΔE" and "beam constrained mass" variables for selection:

$$\Delta E = E_D - E_{\rm beam} \qquad m_{\rm BC} = \sqrt{E^2_{\rm beam} - \vec{p}^2_D}$$

Yields: Single Tags

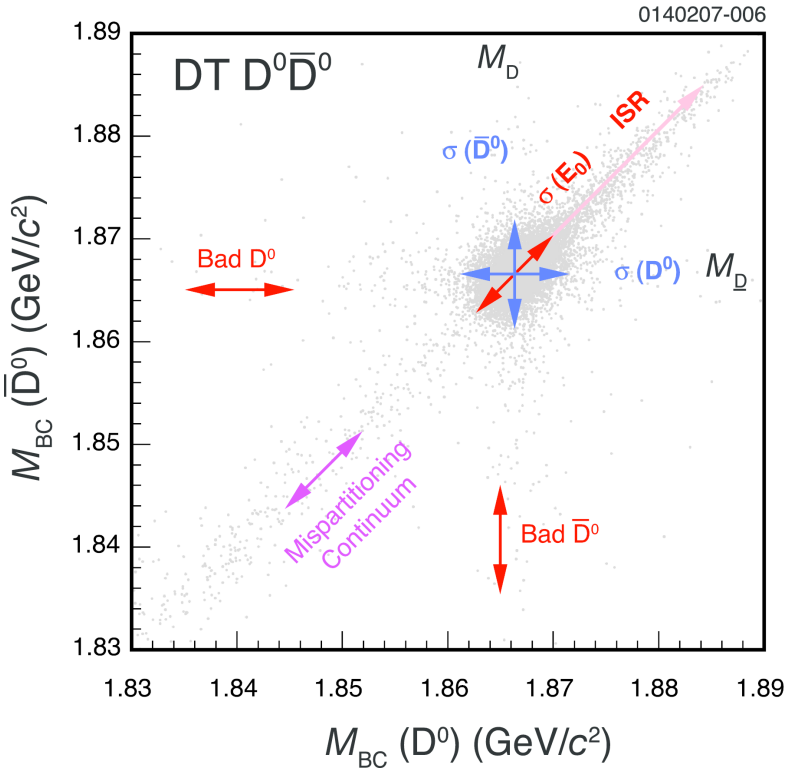
Charges combined

"Square root" vertical scales

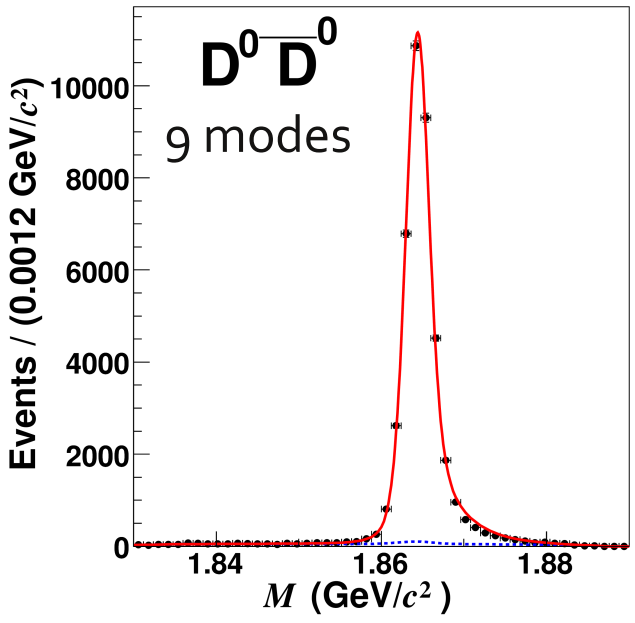


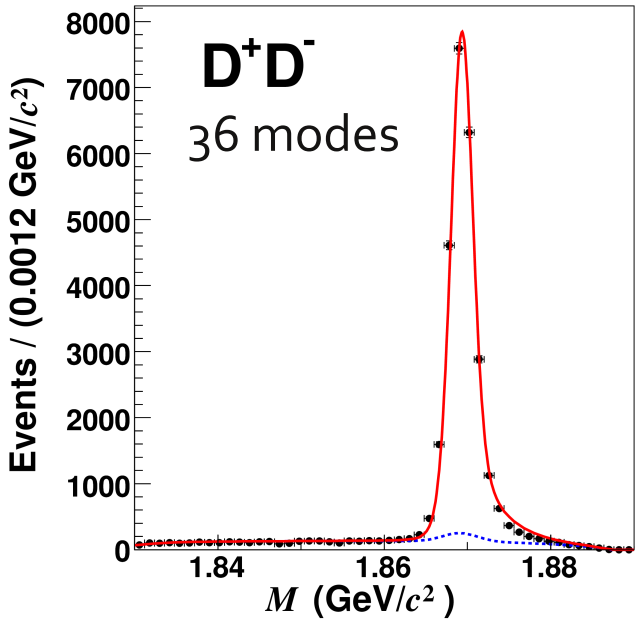
Yields: Double Tags

- 2D fit in $m_{BC}(D)$ vs $m_{BC}(\overline{D})$ incorporating various effects (correlation via initial state radiation, beam energy spread, mispartitioned events, other combinatorics)



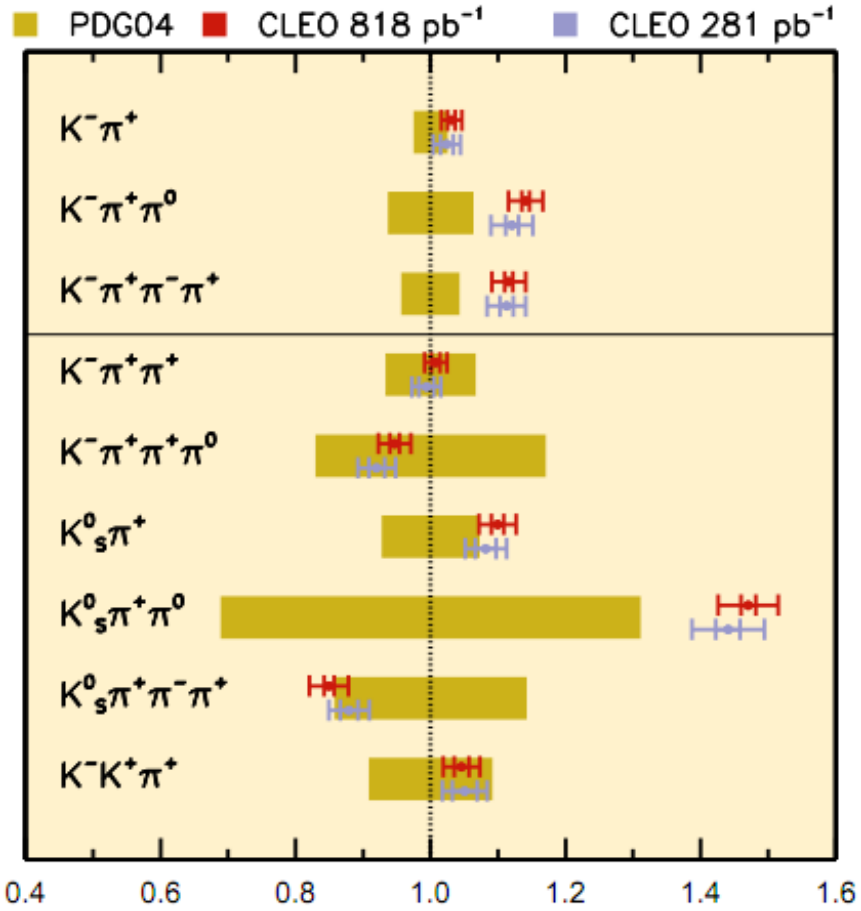
Fit projections summed over $D^0\overline{D}^0$ and D^+D^- modes





Results (D^0, D^+)

- PDG04 comparison (more recent editions have CLEO results in them)



Source	$B(D^0 \to K^- \pi^+)$
CLEO 2007 (281 pb^{-1})	3.891 ± 0.035 ± 0.069
BaBar 2008	4.007 ± 0.037 ± 0.072
This result (818 pb^{-1})	3.935 ± 0.021 ± 0.061

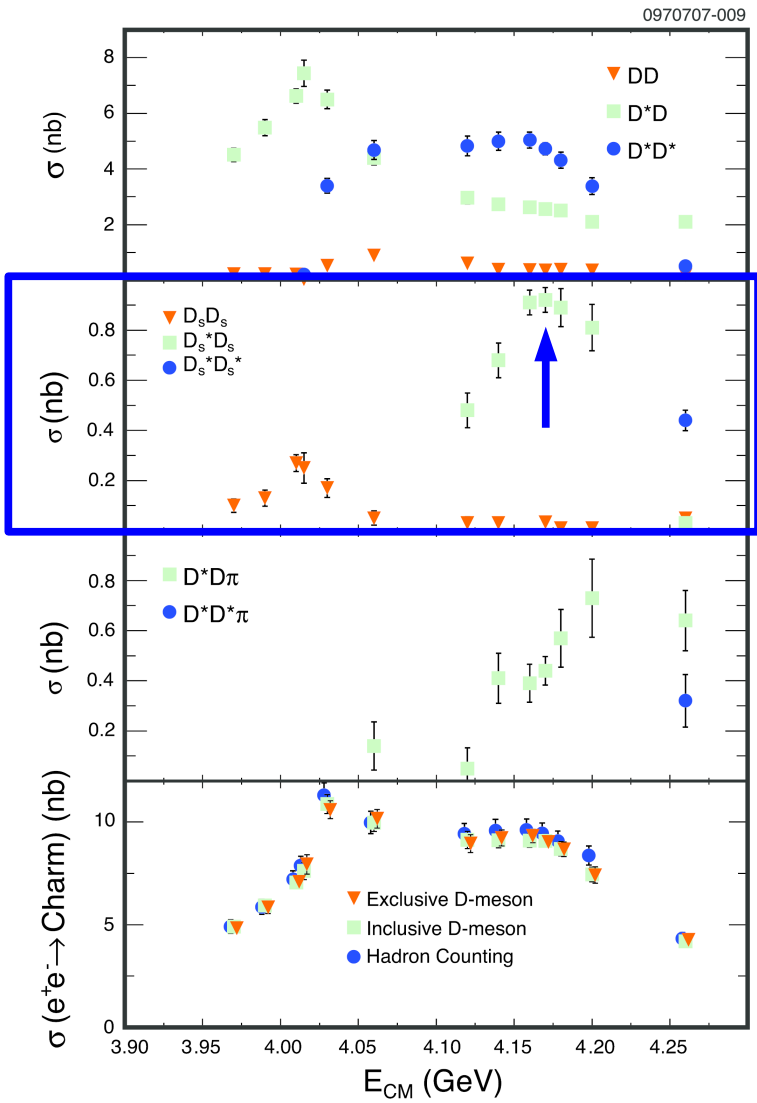
Preliminary

4.17 GeV: D_s^+

- Dominant production mode is $D_s^* D_s$, $D_s^* \to D_s \gamma$.
  - we do not reconstruct the photon: incomplete kinematic information on one of the D_s mesons
- Kinematic variables: "recoil mass" and candidate invariant mass

$$m^2_{\rm rec} = \left(E_{\rm cm} - \sqrt{\vec{p}^{\,2}_{D_s} + m^2_{D_s}}\right)^2 - (\vec{p}_{\rm cm} - \vec{p}_{D_s})^2$$

- Resolution, signal/background not as good as for D^0 and D^+ @ $\psi(3770)$



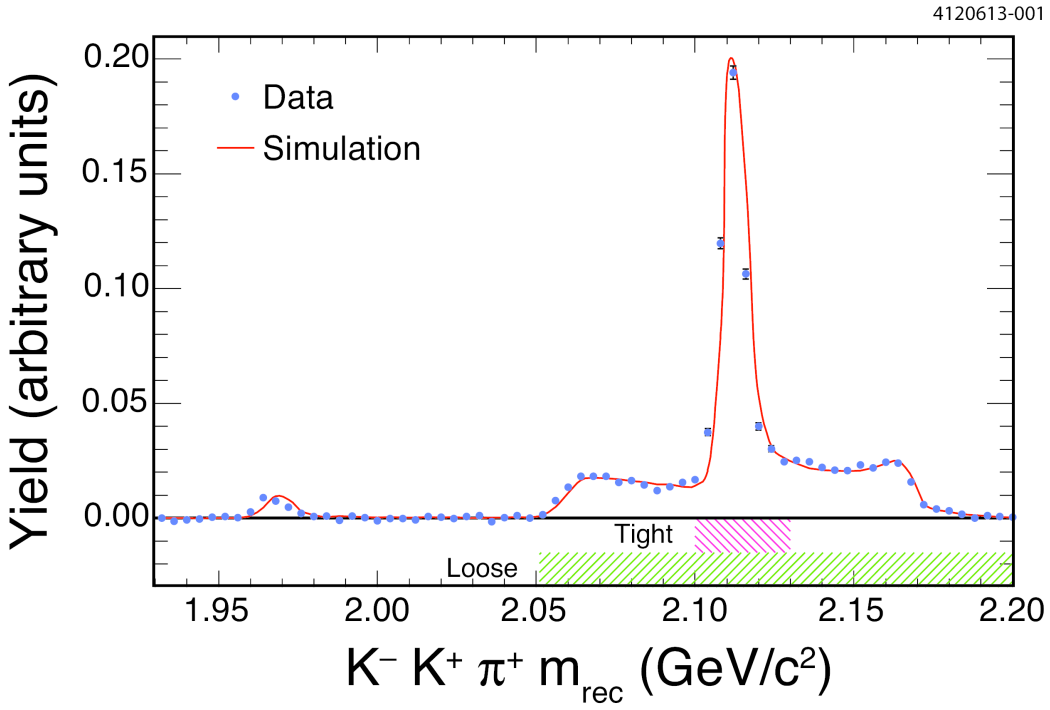
Modes

- 16 reconstructed final states, 13 branching fractions
- We do not do a $D_s \to \phi\pi$ measurement
  - Very good $D_s \to KK\pi$ Dalitz plot analyses done, implementations available in EvtGen
  - We recommend that you compute your acceptance for $\phi\pi$ with your cuts and the Dalitz plot, then normalize with our $KK\pi$ branching fraction

$D_s^+ \to K_S^0 K^+$	$D_s^+ \to K^- K^+ \pi^+$	$D_s^+ \to K_S^0 K^+ \pi^0$
$D_s^+ \to K_S^0 K_S^0 \pi^+$	$D_s^+ \to K^- K^+ \pi^+ \pi^0$	$D_s^+ \to K_S^0 K^+ \pi^+ \pi^-$
$D_s^+ \to K_S^0 K^- \pi^+ \pi^+$	$D_s^+ \to \pi^+ \pi^+ \pi^-$	$D_s^+ \to \pi^+ \eta_{\gamma\gamma}$
$D_s^+ \to \pi^+ \eta_{3\pi}$	$D_s^+ \to \pi^+ \pi^0 \eta_{\gamma\gamma}$	$D_s^+ \to \pi^+ \eta'_{\gamma\gamma}$
$D_s^+ \to \pi^+ \eta'_{3\pi}$	$D_s^+ \to \pi^+ \eta'_{\rho\gamma}$	$D_s^+ \to \pi^+ \pi^0 \eta'_{\gamma\gamma}$
$D_s^+ \to K^+ \pi^+ \pi^-$		

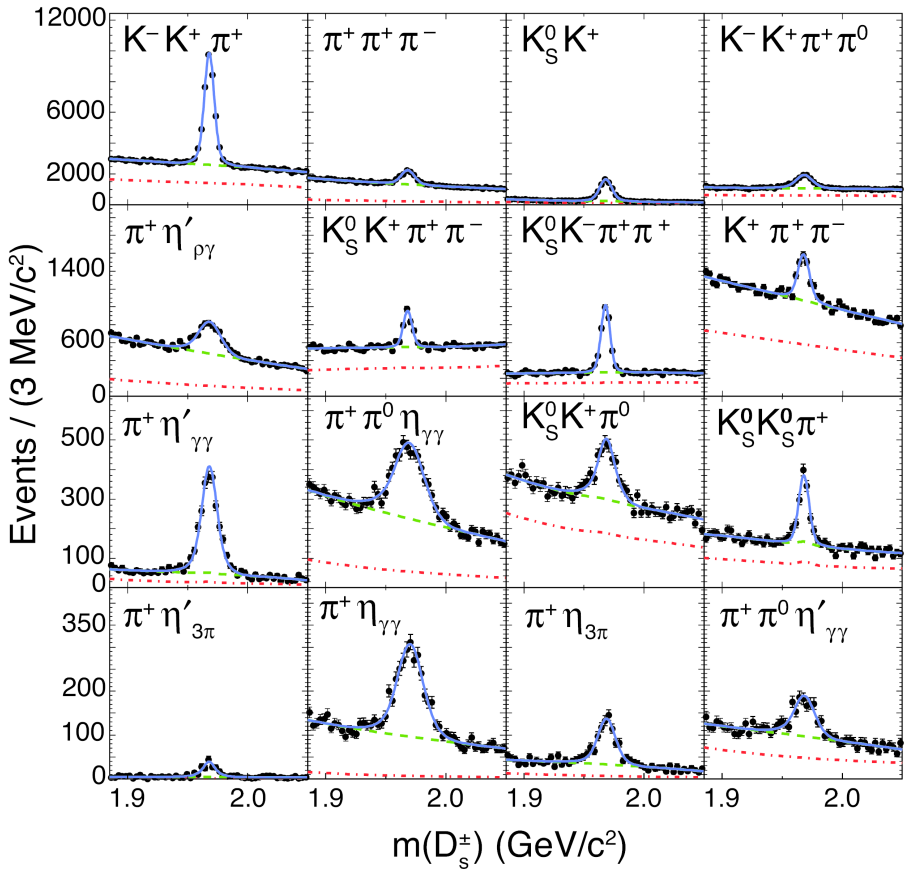
Kinematic Selection

- Recoil mass peaks at m(D_s*) for "direct" D_s (those that are *not* daughters of D_s*); is smeared around this for "indirect" D_s
  - Tight cut for good S/B
  - Loose cut for good efficiency
- Then use D_s invariant mass



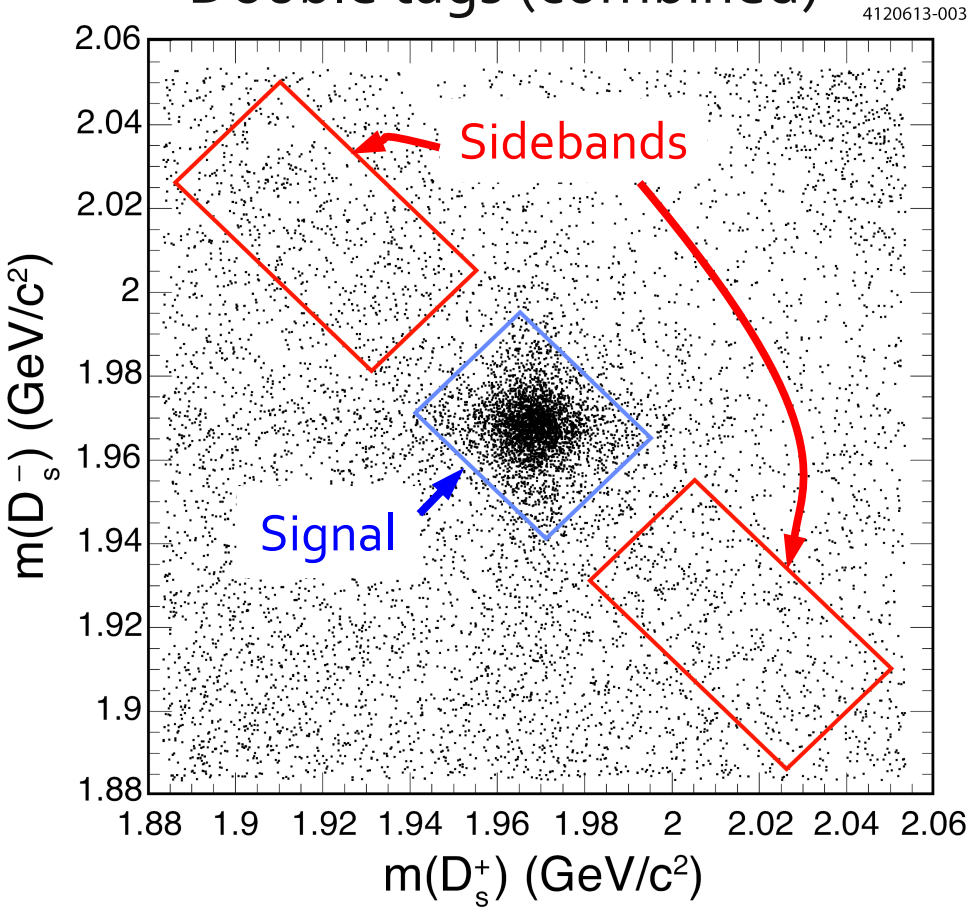
Signals

Single tags



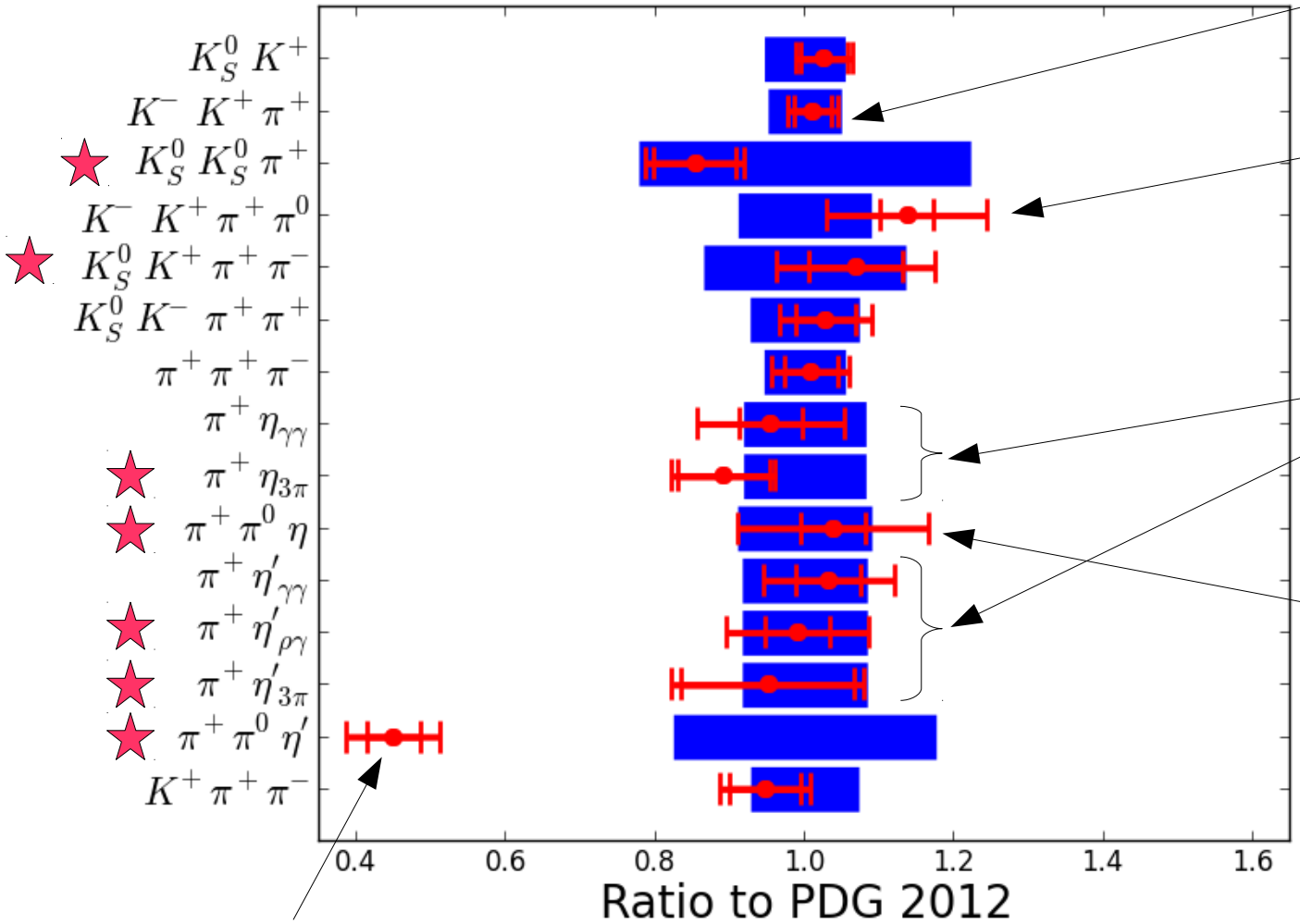
All bgs Open charm bkgs only

Double tags (combined)



Results (D_s)

★ new mode added since to 298 pb^{-1} result



previous value was wrong

Error down from 4.9% to 3.4%

Caused by changed π^0 correction, resonant substructure in MC

Consistent results for different η, η' decay modes

Previous CLEO analysis with smaller phase space, more aggressive systs

PDG η' incl: (11.7 ± 1.8)%
Σ PDG η' excl: (18.6 ± 2.3)%
New Σ η' excl: (11.7 ± 0.9)%
(tension noted by Gronau & Rosner)

Sum of measured modes: (40.7 ± 1.8)% of D_s decays

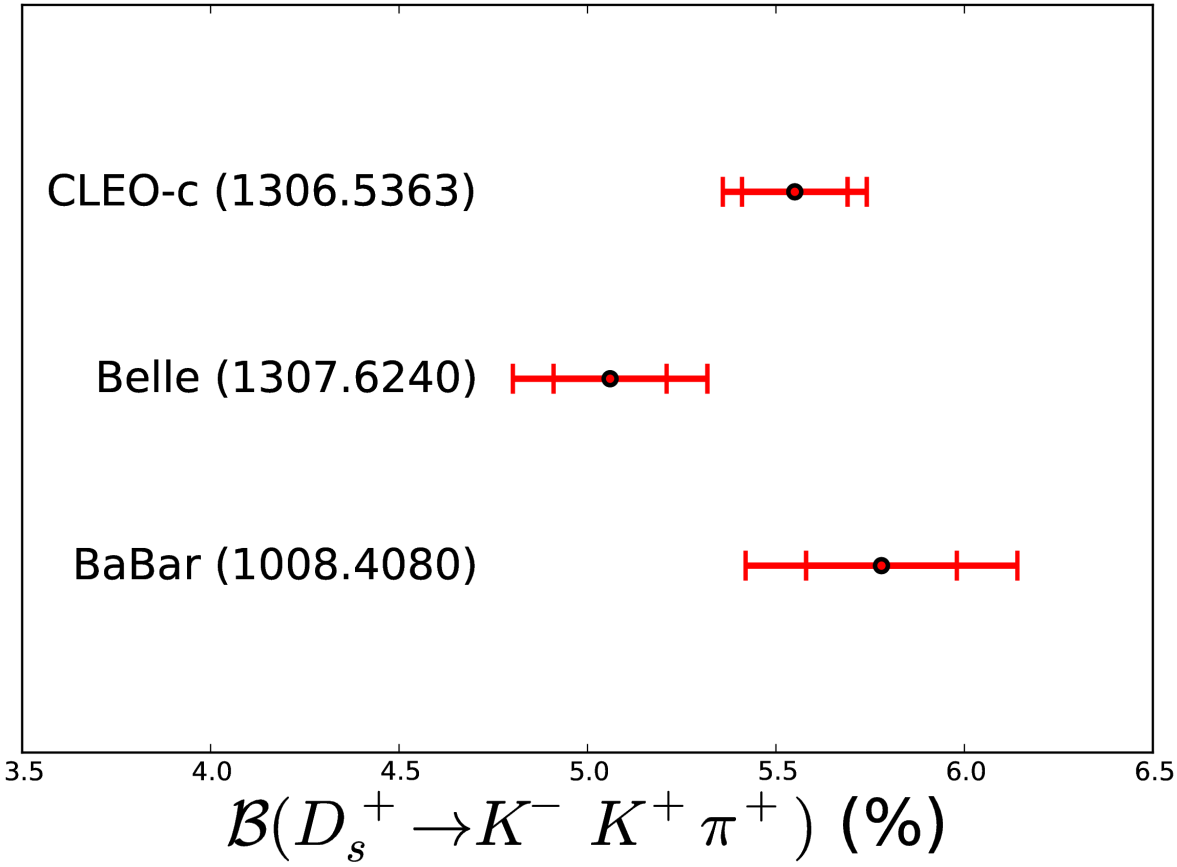
arXiv:1306.5363, accepted by PRD

Summary

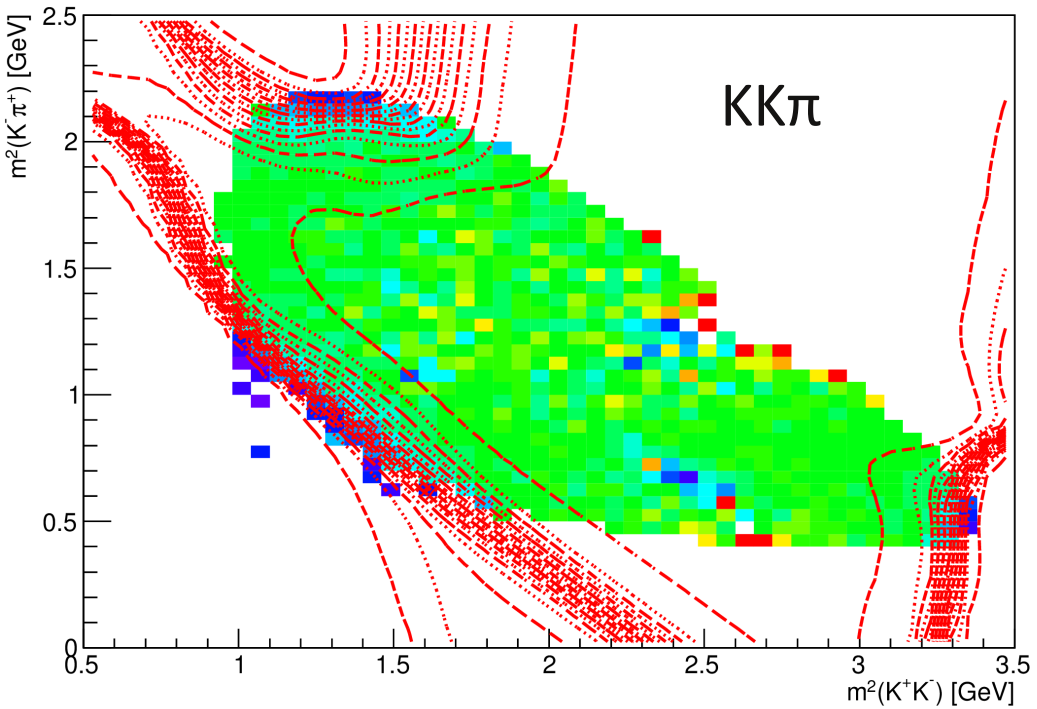
- CLEO is updating reference D hadronic branching fractions to full dataset
  - D^0/D^+: 818 pb^{-1}; preliminary results shown here
  - D_s: 586 pb^{-1}; arxiv:1306.5363
- Results are most precise values available

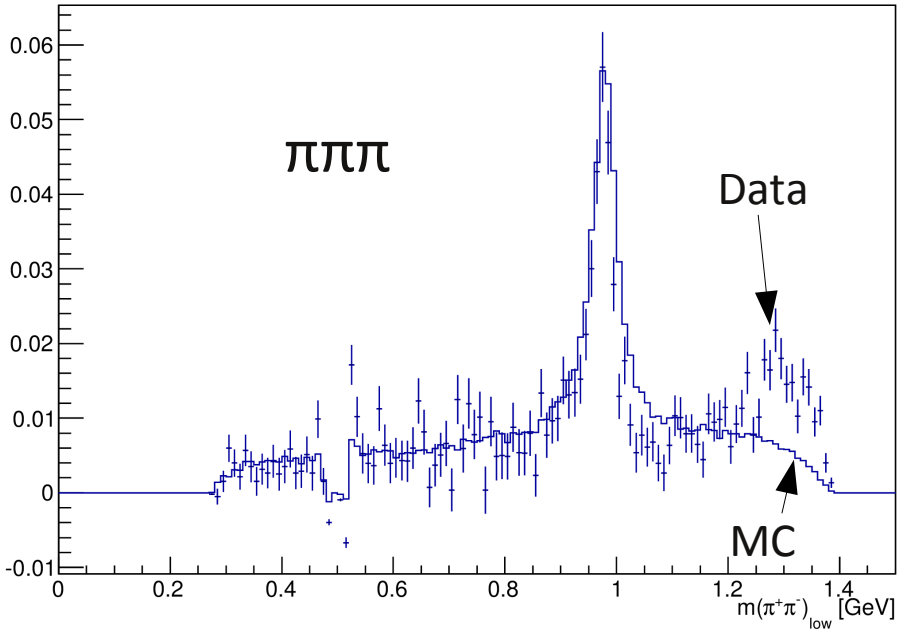
Extra

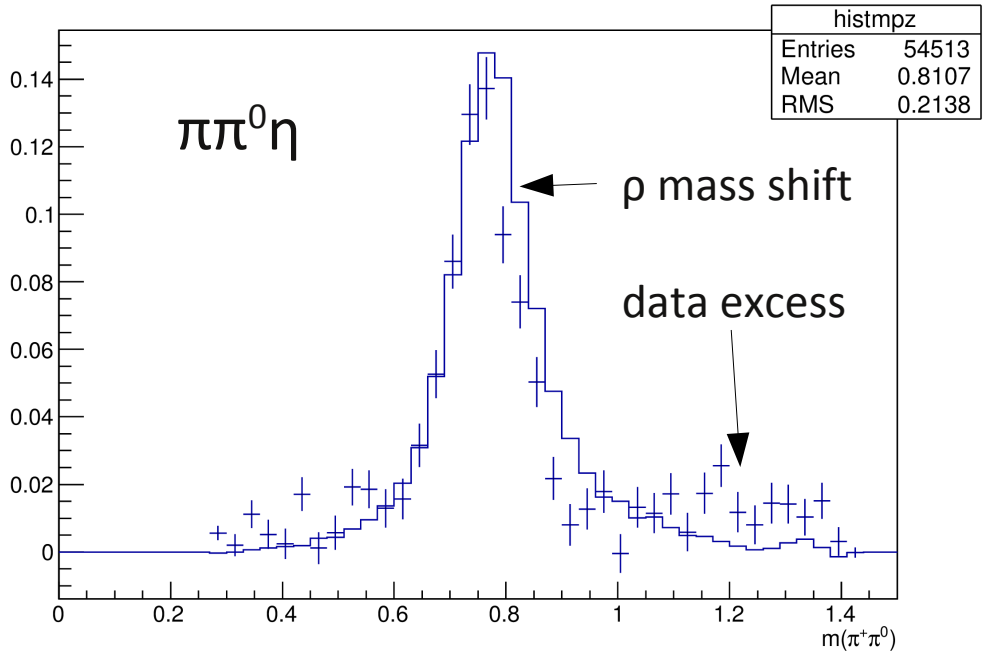
D_s: Belle


CLEO-c (1306.5363)
Belle (1307.6240)
BaBar (1008.4080)
3.5
4.0
4.5
5.0
5.5
6.0
6.5
$\mathcal{B}(D_s^+ \to K^- K^+ \pi^+)$ (%)

Resonant Structure







color = efficiency from MC (as ratio histogram);
blue low, red high
lines = contours of NN efficiency function

KKπ uncertainty 0.6%

Corrections for πππ, $\pi\pi^0\eta$