CLEO-c

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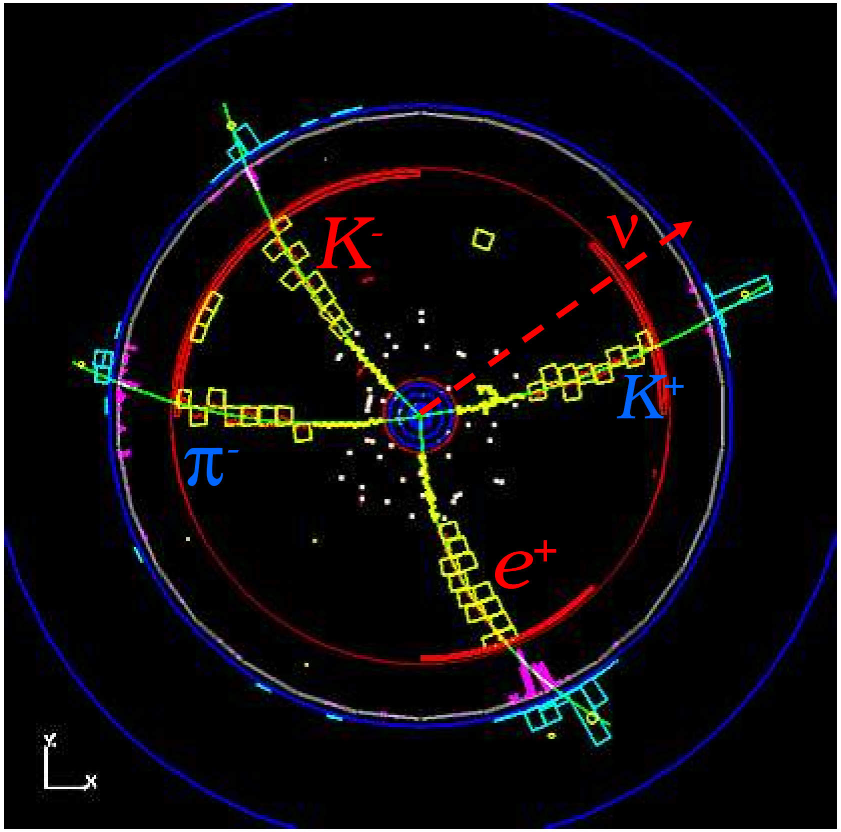
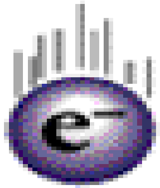
$$e^+e^- \to c\bar{c} \to D^0\bar{D}^0$$

$$\bar{D}^0 \to K^+\pi^-,\ D^0 \to K^-e^+\bar{\nu}$$





Outline

- CLEO-c experiment and the physics program
- Some early results
  - D^+-> $^+$
  - Absolute hadronic branching fractions
  - Semileptonic decays

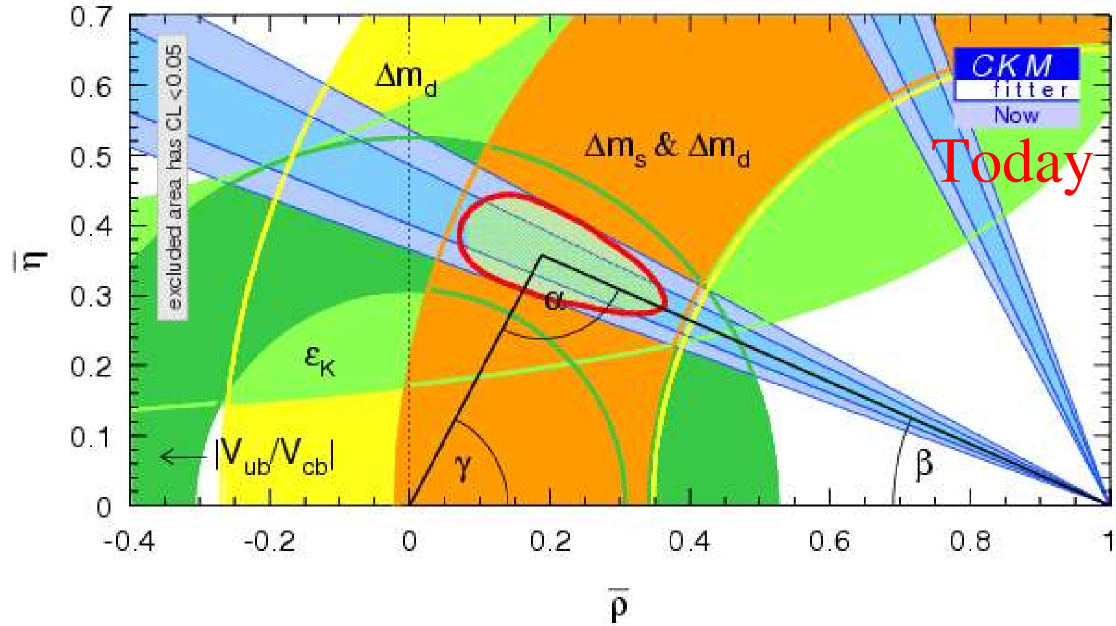
Testing the quark mixing (CKM) matrix

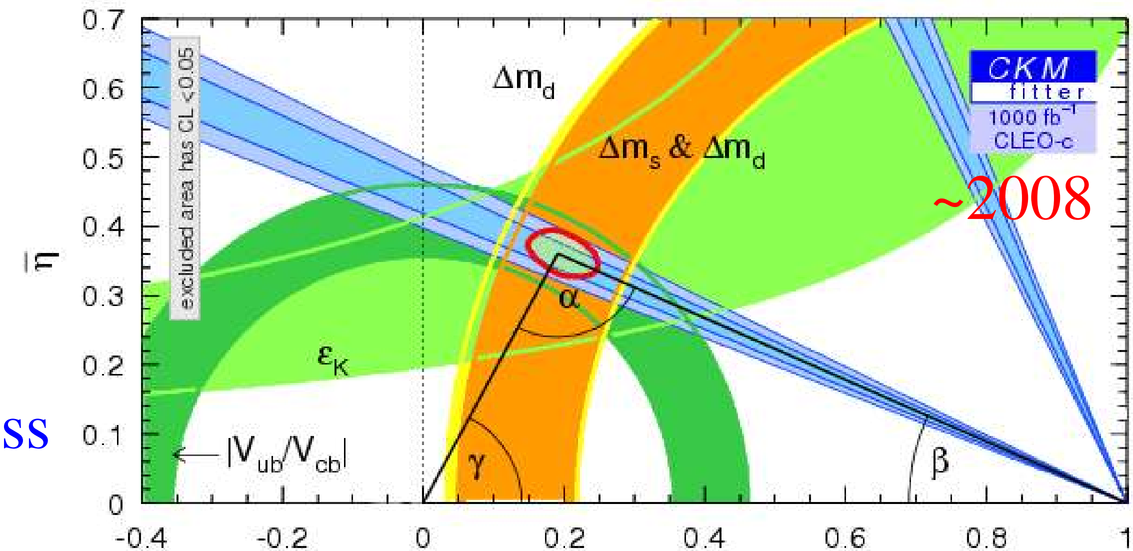
For example, consider the parameters and in the CKM matrix

The extraction of constraints in the plane is limited by theory.

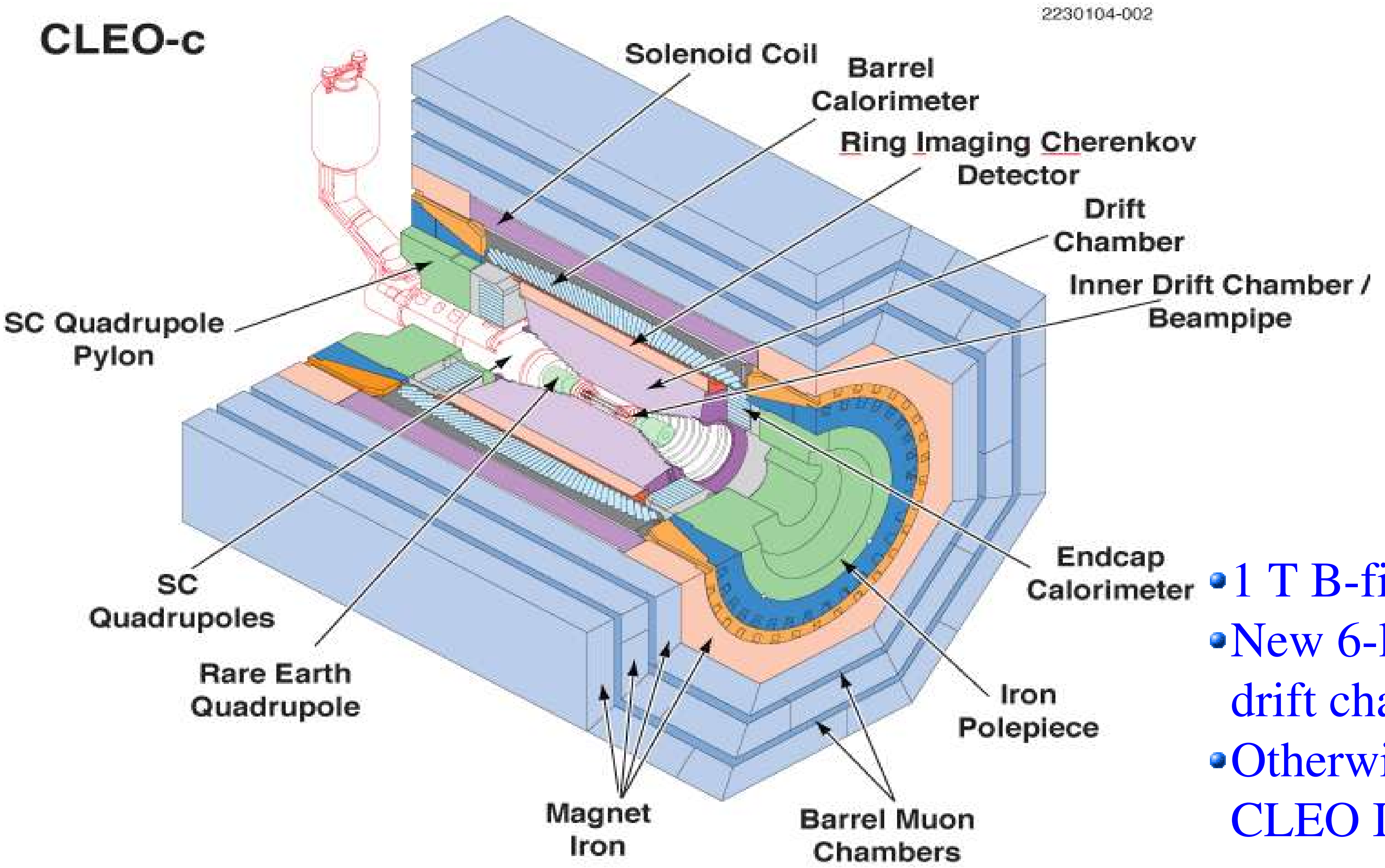
Non-perturbative strong effects limit our ability to extract the fundamental parameters from the measurements.

CLEO-c can provide unique measurements that will address this current limitation.



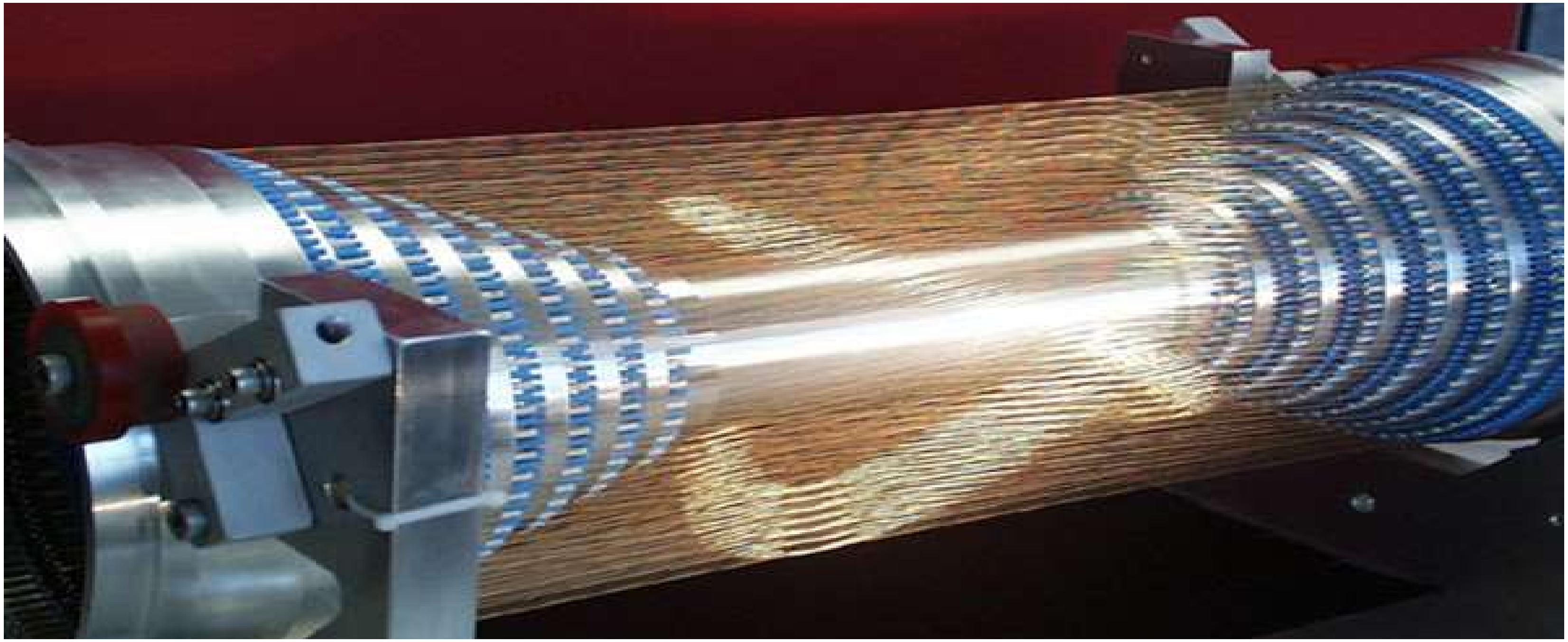


CLEO-c detector



- 1 T B-field.
- New 6-layer inner drift chamber.
- Otherwise the CLEO III detector

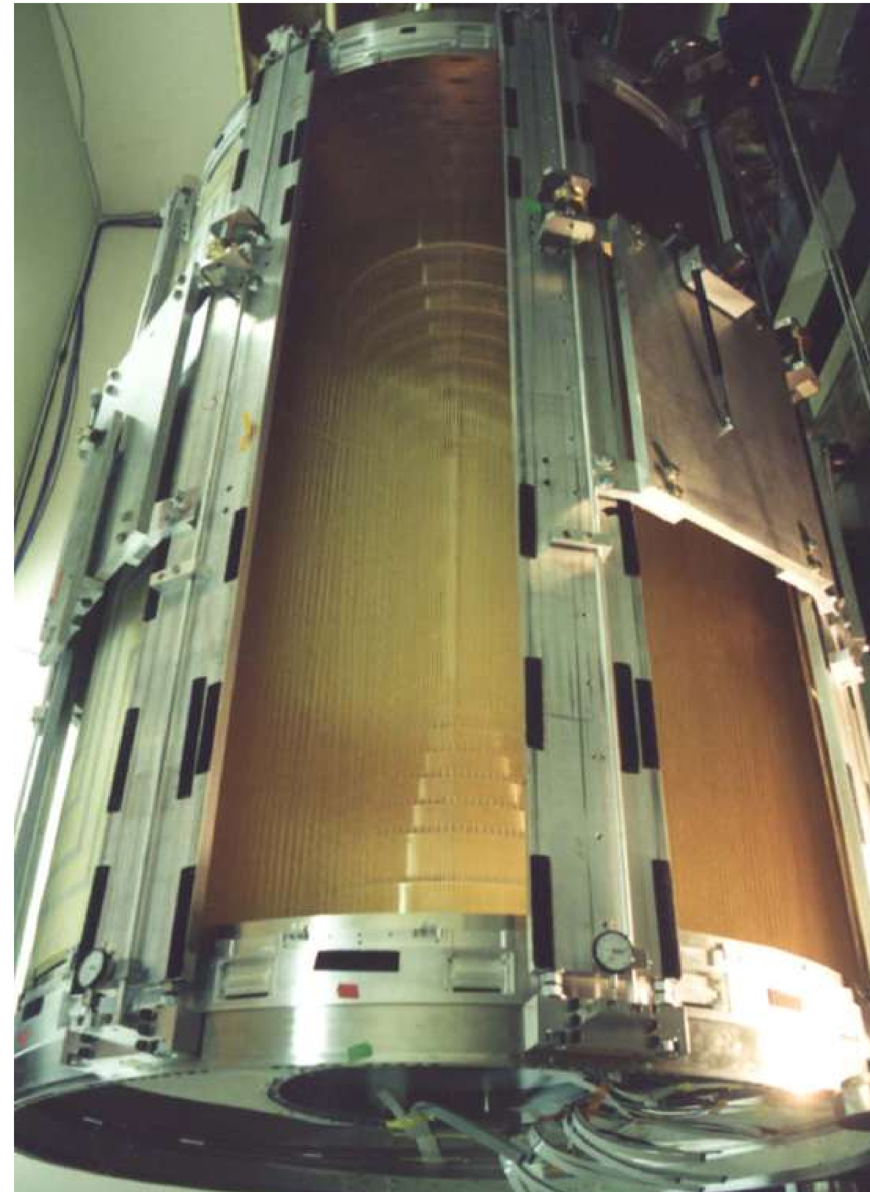
ZD: new inner drift chamber



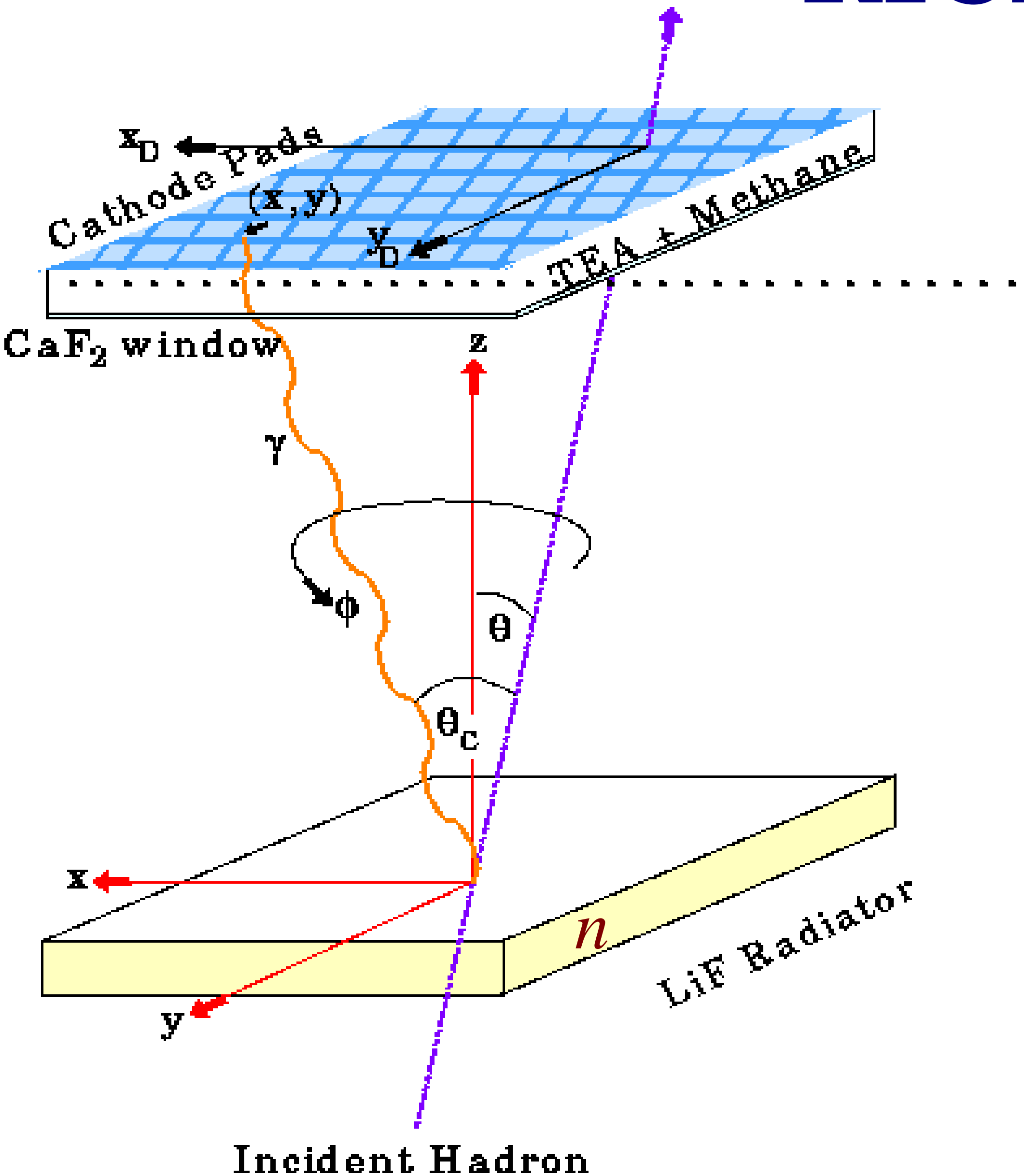
- Replace CLEO III silicon vertex detector.
- Less material – important for the lower momentum particles at charm threshold.
- Detector was installed in summer '03 and is working well.

DR: Main drift chamber

- Same as CLEO III
- B=1.0 T
- Renewed efforts in calibration
  - Used cosmic muons to align DR and ZD
  - Cosmic muons have high momentum and do not all come from the IP
  - Understand effects to ~10   m now. However, a 10   m 'rotation' allow for a 2 MeV split in the measured momentum of the positive and negative track in Bhabha or   -pair.



Ring Imagine Cherenkov Detector RICH



$$v_{light} = c/n$$

$$\theta_C = \arccos\left(\frac{v_{light}}{v_{particle}}\right)$$

- RICH measures velocity.
- Combined with a measurement of momentum we can determine the mass and type of particle, *K*, , *p*.
- Combined with dEdx, CLEO-c has excelent /K separation

CLEO-c program

- The CLEO-c physics program is outlined in the 'Yellow' book.
- The project is finite in time – 3 years (April '05 to April '08):
  - 1 year at (3770) for DD physics
  - 1 year at $D^+_s D^-_s$ threshold for D_s physics
  - 1 year (10^9 J/) at the J/ for glueball searches
- At the (3770) and $D^+_s D^-_s$ we want to
  - Measure the decay constants to a few percent
  - Absolute branching fraction measurements
  - Semileptonic decays
  - Other things like Dalitz plot studies etc.
- So far we have recorded ~280 pb^{-1} at the (3770).
- Results presented here are on 56 pb^{-1}.
  - Results this summer will use use 280 pb^{-1}.

Early physics results with 56 pb^{-1}

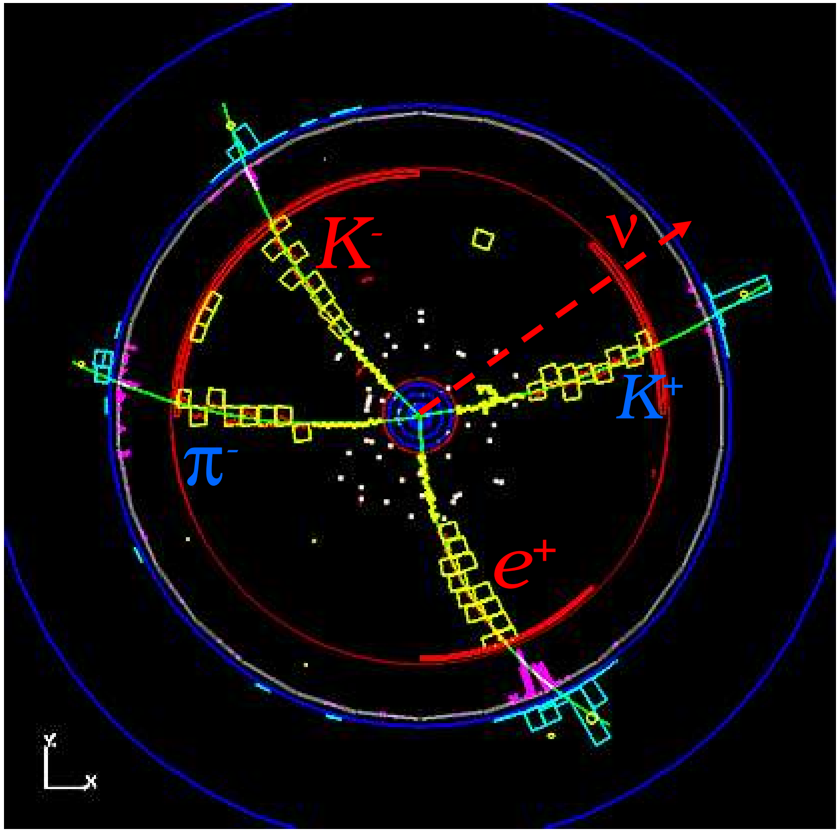
- I will present results from CLEO-c on
  - $Br(D^+ \to \mu^+ \nu_\mu)$ and determination of f_{D^+},
  - absolute hadronic *D* branching fractions,
  - the $\sigma(e^+e^- \to D\overline{D})$ cross section at E_{cm}=3.77 GeV, and
  - semileptonic *D* decays.
- These measurements make use of '*D*-tagging', in which one *D* is exclusively reconstructed.

Doing physics at $c\bar{c}$ threshold

$$e^+e^- \to c\,\bar{c} \to D^0\,\overline{D}^0$$

$$\overline{D}^0 \to K^+\pi^-, D^0 \to K^- e^+ \overline{\nu}$$

- We run at E_{cm}=3.77 GeV
  - the (3770) resonance.
- Producing $D\overline{D}$ pairs
  - and no other particles.
- Makes this a very clean experiment for studies of charm decays.
- Most analysis uses a tagging technique
  - one of the produced D mesons are fully reconstructed.



'Initial state radiation'

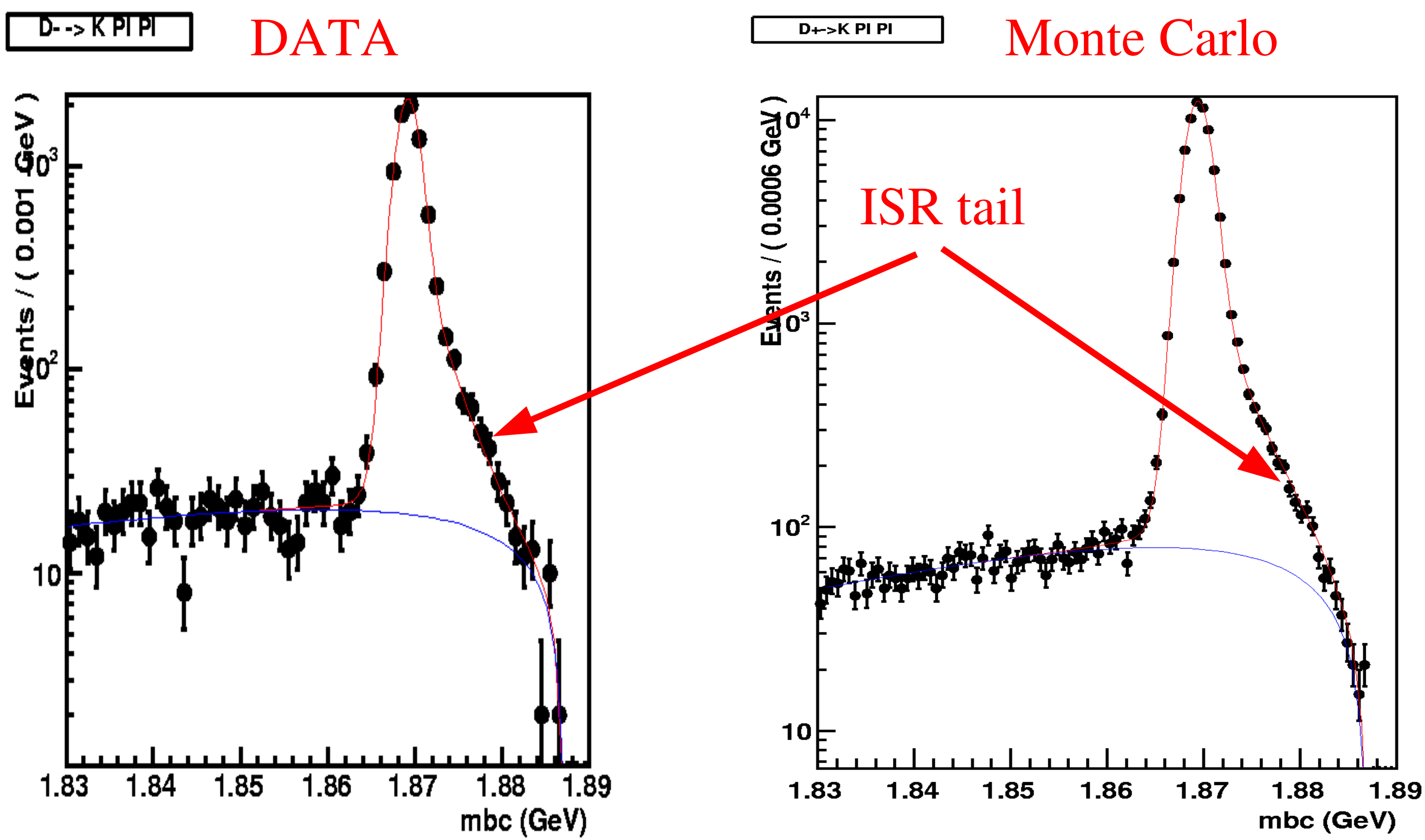
- We run at E_{cm}=3.77 GeV to produce the (3770)
  - The spread in E_{cm} is about 2 MeV
  - The width of the (3770) is about 25 MeV
- However, the beam particles can radiate a photon and produce the (3770) at a lower energy.
  - In fact in every interaction many photons are emitted, but at such a low energy that we can not detect it. The distribution of energy radiated by photons is given by:

$$f(E_\gamma) \propto E_\gamma^{\beta-1}$$

$$\beta = \frac{2\alpha}{\pi}\left[2\ln\frac{E_{cm}}{m_e} - 1\right] \approx 0.07$$

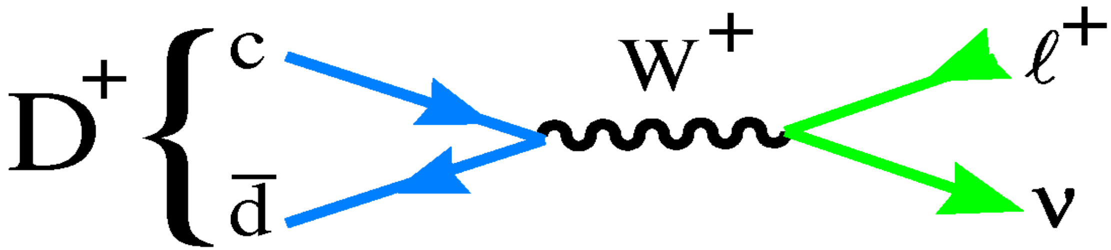
ISR in data *vs.* MC

$$D^+ \to K^- \pi^+ \pi^+$$



$$M_{\mathrm{BC}} = \sqrt{E_{\mathrm{beam}}^2 - |p(D)|^2}$$

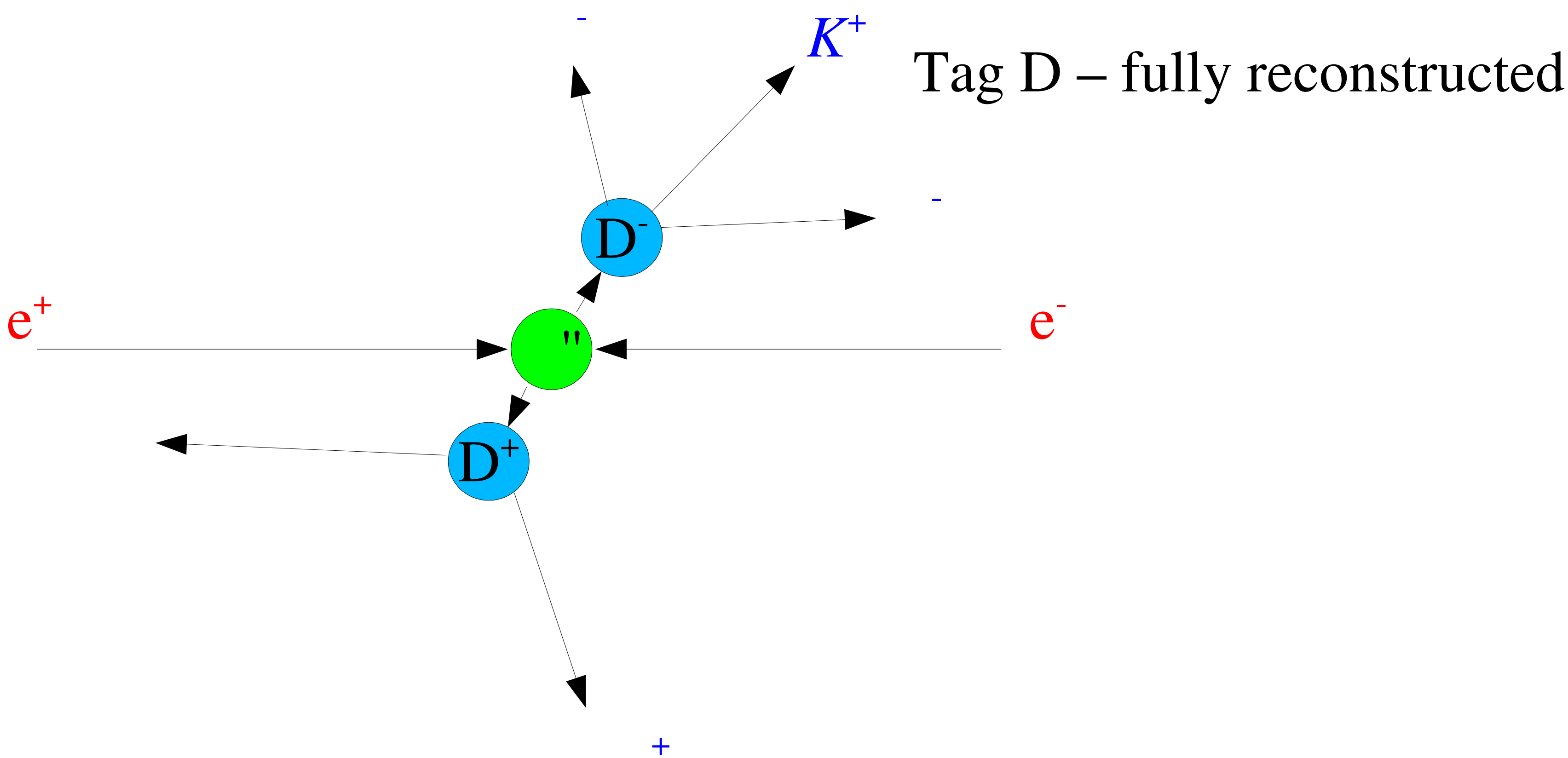
$D^+ \to \mu^+ \nu_\mu$ and f_{D^+}



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

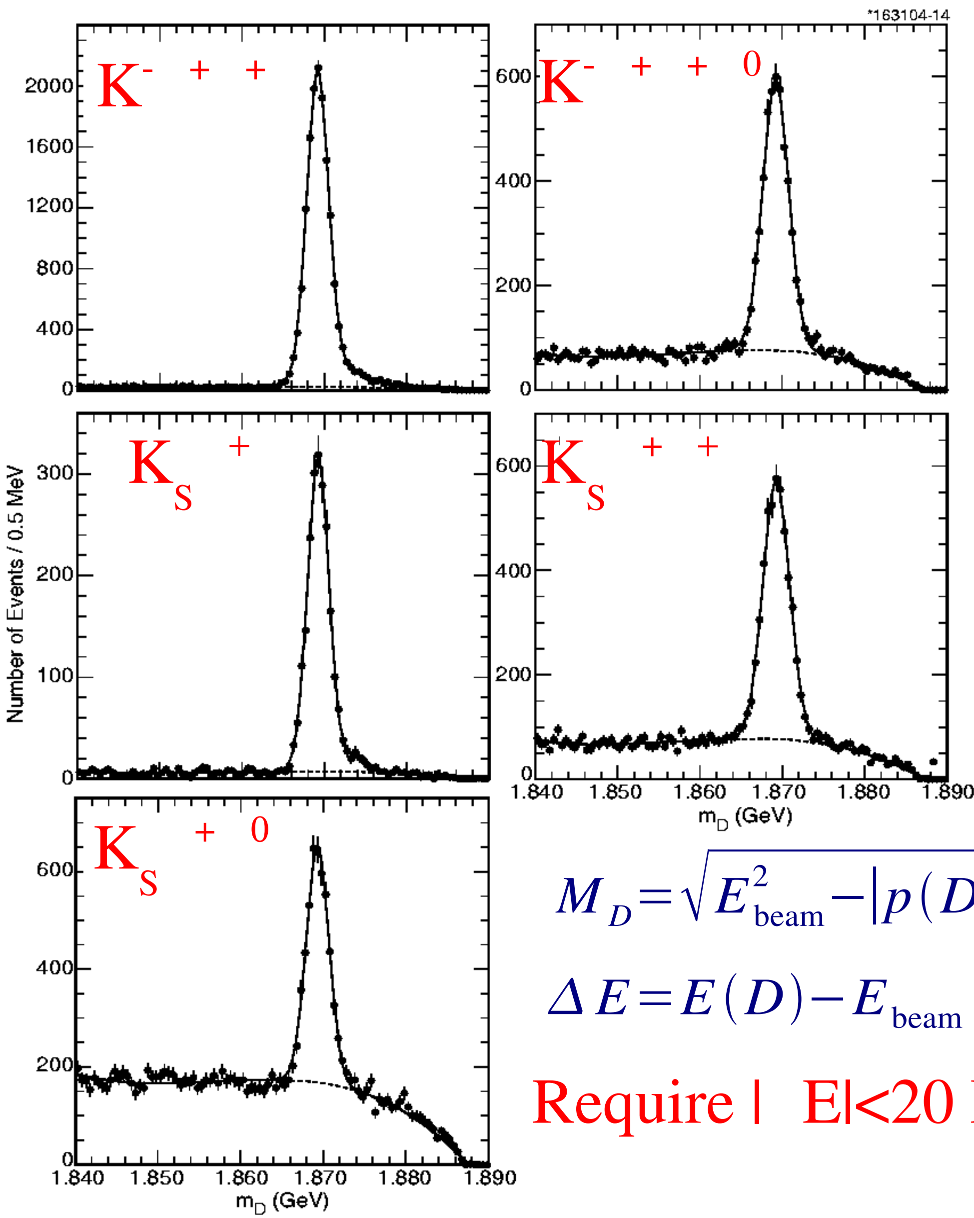
- A precise measurement of f_{D^+} allows precise comparison with theoretical calculations, such as lattice QCD.
- This will help determining f_B, which currently can not be measured in leptonic B decays.

Analysis technique



- At threshold produce only D^+D^-, no additional pions.
- Detect muon and make sure it recoiled against neutrino.
  - Extract signal in M^2_{miss} which peaks at 0.

Charged *D*-tag reconstruction



Mode	Signal	Background
$K^+\pi^-\pi^-$	15 173 ± 140	583
$K^+\pi^-\pi^-\pi^o$	4082 ± 81	1826
$K_S\pi^-$	2124 ± 52	251
$K_S\pi^-\pi^-\pi^+$	3975 ± 81	1880
$K_S\pi^-\pi^o$	3297 ± 87	4226
Sum	28 651 ± 207	8765

In 57 pb^{-1} we have 28,574 D^+ or D^- tags

$$M_D=\sqrt{E_{\text{beam}}^2-|p(D)|^2}$$

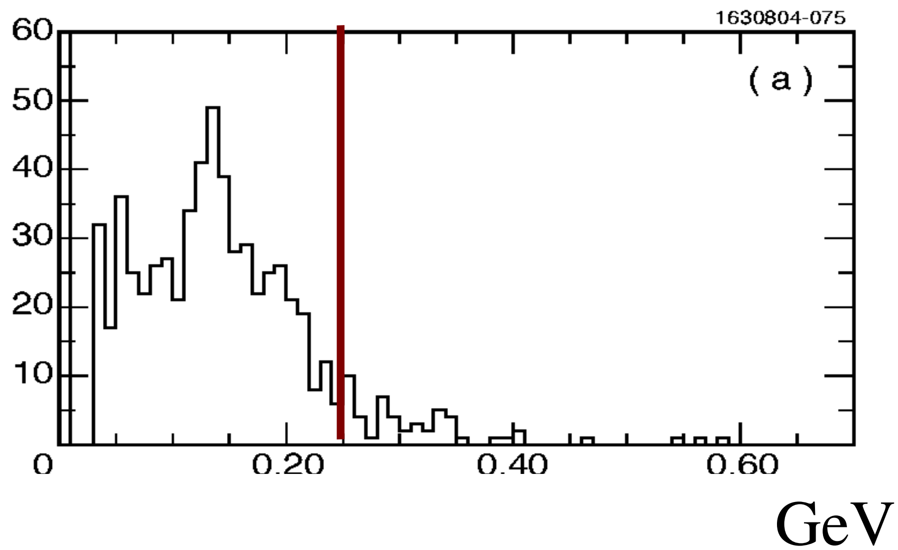
$$\Delta E=E(D)-E_{\text{beam}}$$

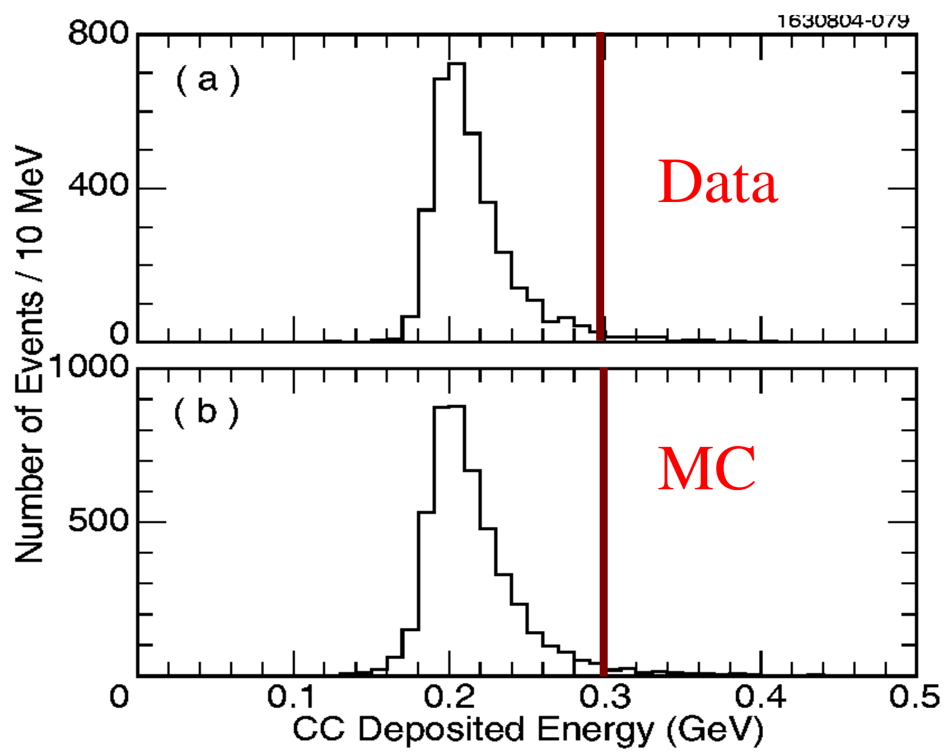
Require | E|<20 MeV

Signal side selection

- Require one track consistent with coming from the IP for the muon.
  - Muon candidate deposit less than 300 MeV in EM calorimeter
- No additional track from IP
- Require no unmatched showers over 250 MeV
  - Veto background from D^+-> $^{+}$ ^{0}

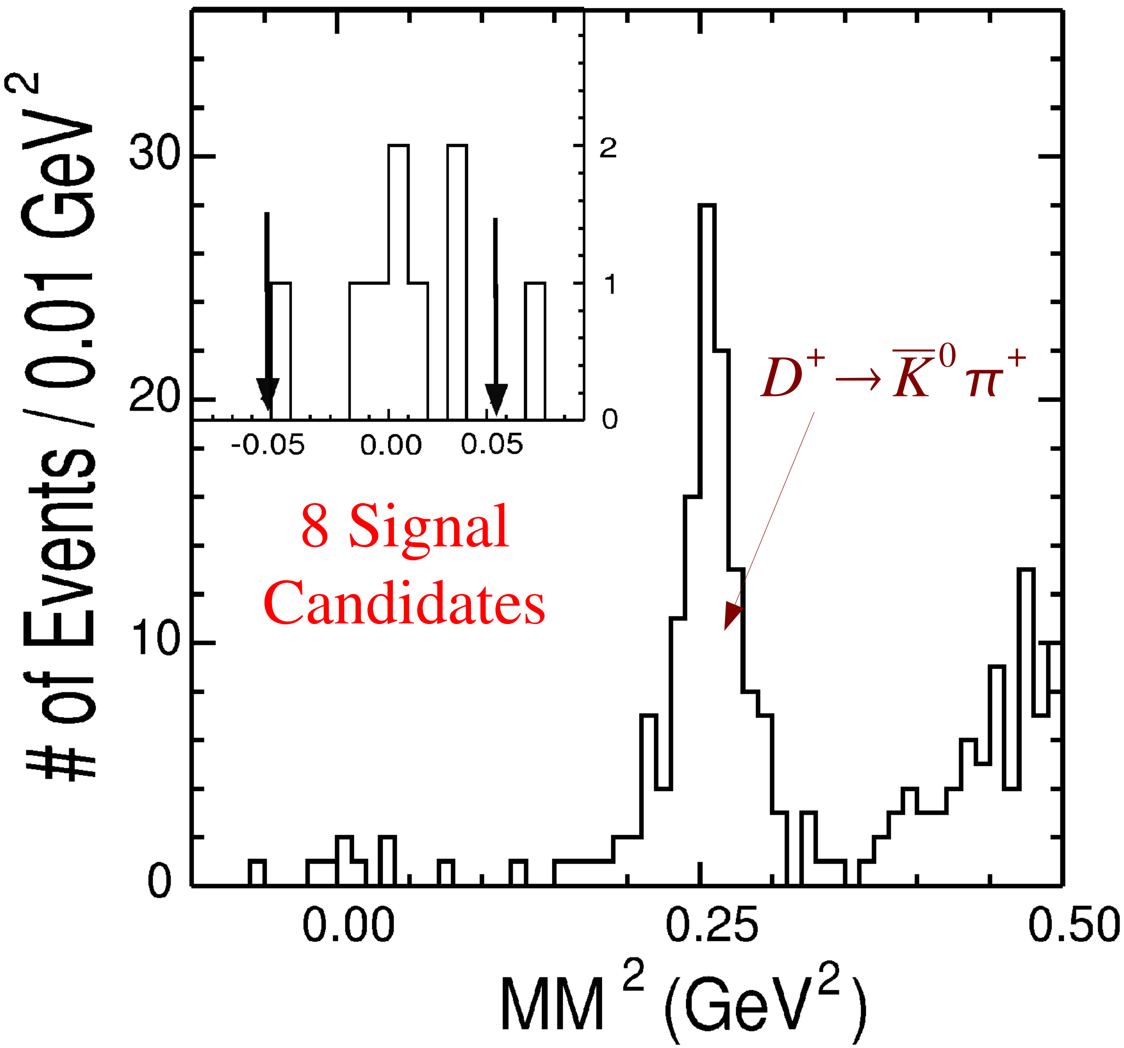
Highest energy unmatched cluster





Signal extraction

- For events with candidate form $MM^2=(E_{\text{beam}}-E_\mu)^2-(-\vec{p}_{D^-}-\vec{p}_\mu)^2$
- Signal will peak at $MM^2=m^2=0$



$D^+ \to \mu^+ \nu_\mu$ results

- 8 signal candidate events with the following backgrounds

Background	$\mathcal{B}$ (%)	# of events
$D^+ \to \pi^+\pi^0$	0.13 ± 0.02	0.31 ± 0.04
$D^+ \to K^0\pi^+$	2.77 ± 0.18	0.06 ± 0.05
$D^+ \to \tau^+\nu$	$2.6 \times \mathcal{B}(D^+ \to \mu^+\nu)$	0.30 ± 0.07
$D^+ \to \pi^0\mu^+\nu$	0.25 ± 0.15	negligible
$D^0\bar{D}^0$	—	0.16 ± 0.16
continuum	—	0.17 ± 0.17
Total		1.00 ± 0.25

- Due to simulation uncertainties we take background as 1.0 ± 1.0 events
- With 28,574 D^+ tags and an efficiency of 69.9% for signal events to satisfy the selection criteria given a D^+ tag we obtain:

$$Br(D^+ \to \mu^+ \nu) = (3.5 \pm 1.4 \pm 0.6) \times 10^{-4} \quad f_{D^+} = (202 \pm 41 \pm 17)\,\text{MeV}$$

(PRD 70, 112004)

- Theoretical predictions for f_D are in the range 190 to 260 MeV.

Predictions

Model	f_{D^+} (MeV)
Lattice QCD (Fermilab and MILC) [2]	$225^{+11}_{-13} \pm 21$
Quenched lattice QCD (UKQCD) [3]	$210 \pm 10^{+17}_{-16}$
QCD spectral sum rules [5]	203 ± 20
QCD sum rules [6]	195 ± 20
Relativistic quark model [7]	243 ± 25
Potential model [4]	238
Isospin mass splittings [8]	262 ± 29

CLEO-c result in good agreement with predictions

$$f_{D^+} = (202 \pm 41 \pm 17)\,\mathrm{MeV}$$

Future projections for f_D

- For this summer we will have about 5 times more data (280 pb^{-1}).
- We have 3 more years of CLEO-c running.
- The analysis is so far statistics limited. The main systematic errors can be reduced with more data.

	Systematic error (%)
MC statistics	0.8
Track finding	3
cut	1
Minimum ionization cut	1
Extra showers cut	4
Total	5.3

Precision measurements

- Many CLEO-c measurements aims for rather precise measurements that require a detailed understanding of the detector - and simulation of the detector.
- One of the analysis that is pushing the state of the art is the measurement of the hadronic branching fractions of *D*-mesons.
- The decays D^0->K^- $^+$ and D^+->K^- $^+$ $^+$ are the normalization modes for practically all charged and neutral *D* decays
- The D^0->K^- $^+$ branching fraction has been measured by CLEO and LEP experiments using a technique in which a *D* is tagged by the presence of a slow pion from a *D** decay
  - This technique suffers from hard to estimate systematic uncertainties.

Hadronic *D* decays and $\sigma(e^+e^- \to D\overline{D})$

- In order to measure the cross section and absolute branching fractions we need to determine the number of produced $D\overline{D}$ events
  - Use a 'double tag' technique, pioneered by MARK III

$$N_i = 2\epsilon_i B_i N_{D\overline{D}}$$

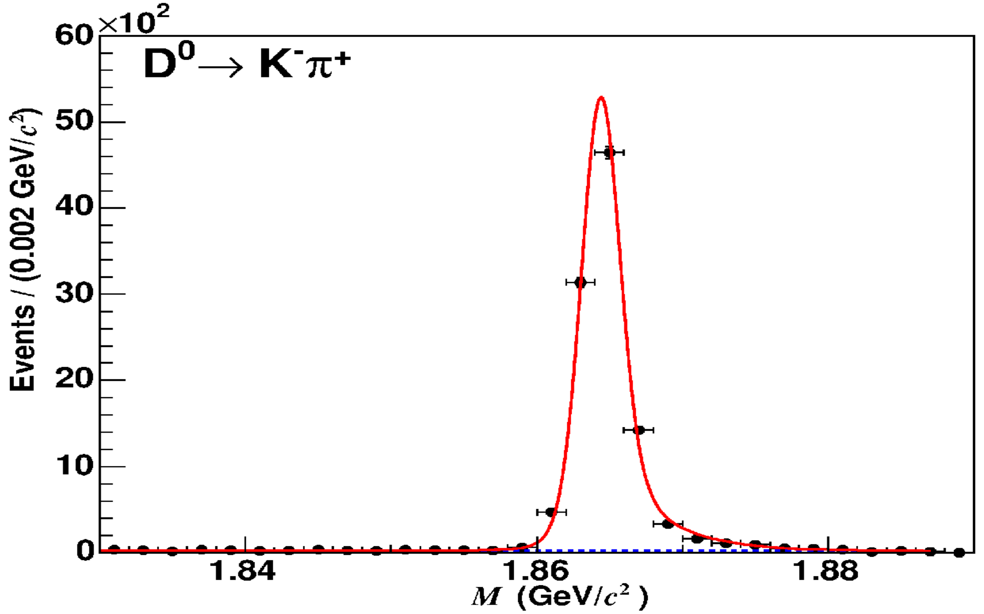
$$N_{ii} = \epsilon_{ii} B_i^2 N_{D\overline{D}}$$

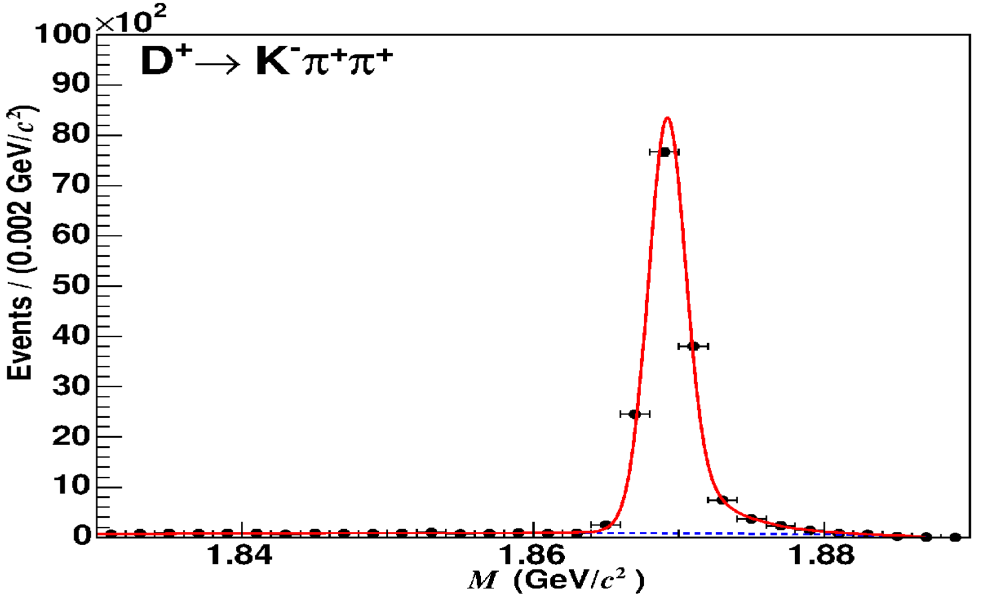
$$N_{D\overline{D}} = \frac{N_i^2}{4N_{ii}} \frac{\epsilon_{ii}}{\epsilon_i^2}$$

- Use 3 D^0 modes ($K^-\ {}^+$, $K^-\ {}^+\ {}^0$, and $K^-\ {}^+\ {}^-\ {}^+$) and 6 D^+ modes ($K^-\ {}^+\ {}^+$, $K_s\ {}^+$, $K^-\ {}^+\ {}^+\ {}^0$, $K_S\ {}^+\ \ {}^+$, $K_S\ {}^+\ {}^0$, and $K^-K^+\ {}^+$)
- Determine separately the *D* and *D̄* yields
  - This gives 18 single tag yields and 45 ($=3^2+6^2$) double tag yields
- In a combined ^{2} fit we extract 9 branching fractions and $D^0\overline{D}^0$ and D^+D^- yields. The fit includes the systematic errors.
- Many systematics cancel in the $D\overline{D}$ yields.

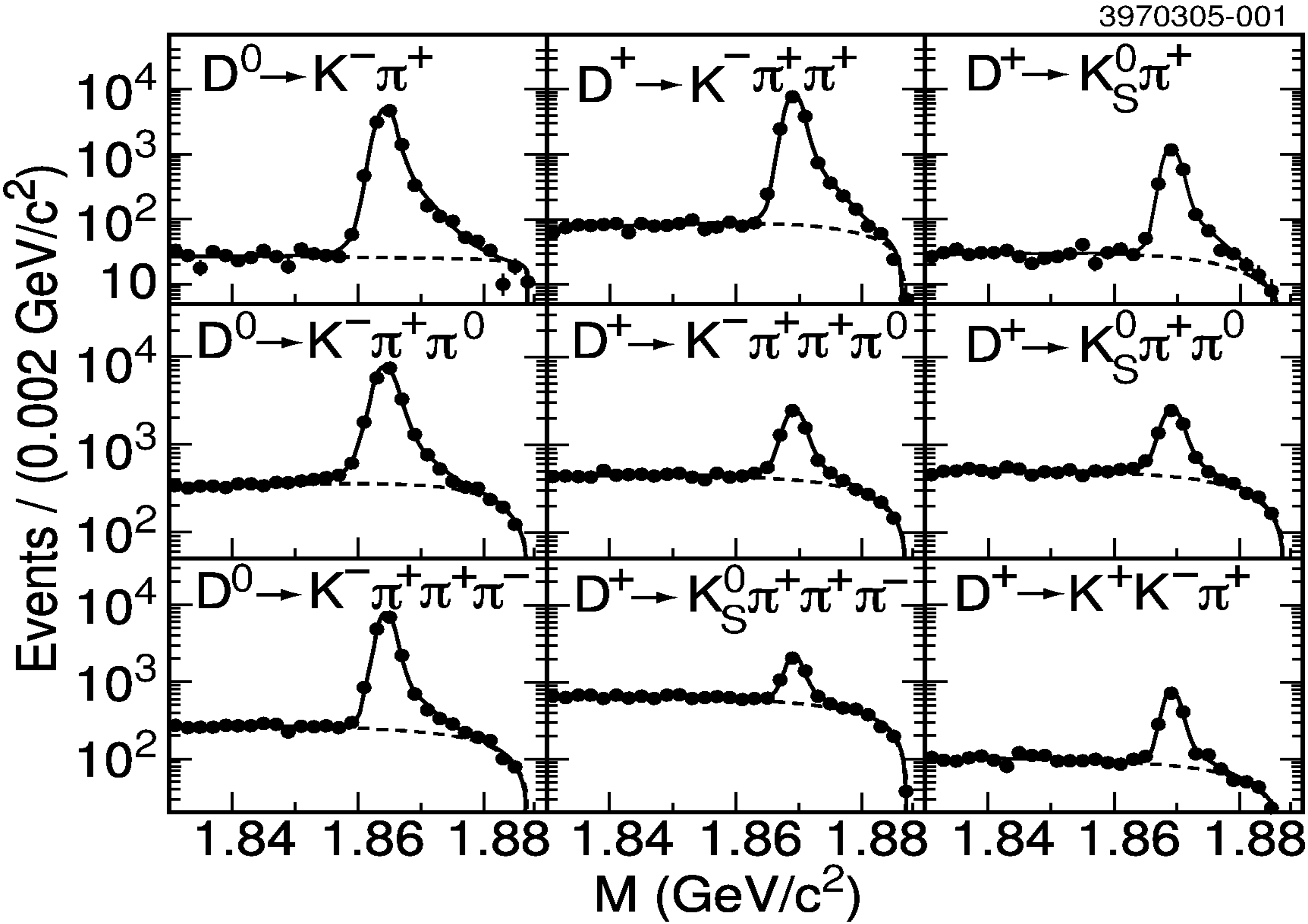
Single tag yields

D or $\bar{D}$ Mode	Yield (10^3)	Efficiency (%)
$D^0 \to K^-\pi^+$	5.11 ± 0.07	64.6 ± 0.3
$\bar{D}^0 \to K^+\pi^-$	5.15 ± 0.07	65.6 ± 0.3
$D^0 \to K^-\pi^+\pi^0$	9.51 ± 0.11	31.4 ± 0.1
$\bar{D}^0 \to K^+\pi^-\pi^0$	9.47 ± 0.11	31.8 ± 0.1
$D^0 \to K^-\pi^+\pi^+\pi^-$	7.44 ± 0.09	43.6 ± 0.2
$\bar{D}^0 \to K^+\pi^-\pi^-\pi^+$	7.43 ± 0.09	43.9 ± 0.2
$D^+ \to K^-\pi^+\pi^+$	7.56 ± 0.09	50.7 ± 0.2
$D^- \to K^+\pi^-\pi^-$	7.56 ± 0.09	51.3 ± 0.2
$D^+ \to K^-\pi^+\pi^+\pi^0$	2.45 ± 0.07	25.7 ± 0.2
$D^- \to K^+\pi^-\pi^-\pi^0$	2.39 ± 0.07	25.7 ± 0.2
$D^+ \to K^0_S\pi^+$	1.10 ± 0.04	45.5 ± 0.4
$D^- \to K^0_S\pi^-$	1.13 ± 0.04	45.9 ± 0.4
$D^+ \to K^0_S\pi^+\pi^0$	2.59 ± 0.07	22.4 ± 0.2
$D^- \to K^0_S\pi^-\pi^0$	2.50 ± 0.07	22.4 ± 0.2
$D^+ \to K^0_S\pi^+\pi^+\pi^-$	1.63 ± 0.06	31.1 ± 0.2
$D^- \to K^0_S\pi^-\pi^-\pi^+$	1.58 ± 0.06	31.3 ± 0.2
$D^+ \to K^+K^-\pi^+$	0.64 ± 0.03	41.4 ± 0.5
$D^- \to K^+K^-\pi^-$	0.61 ± 0.03	40.8 ± 0.5

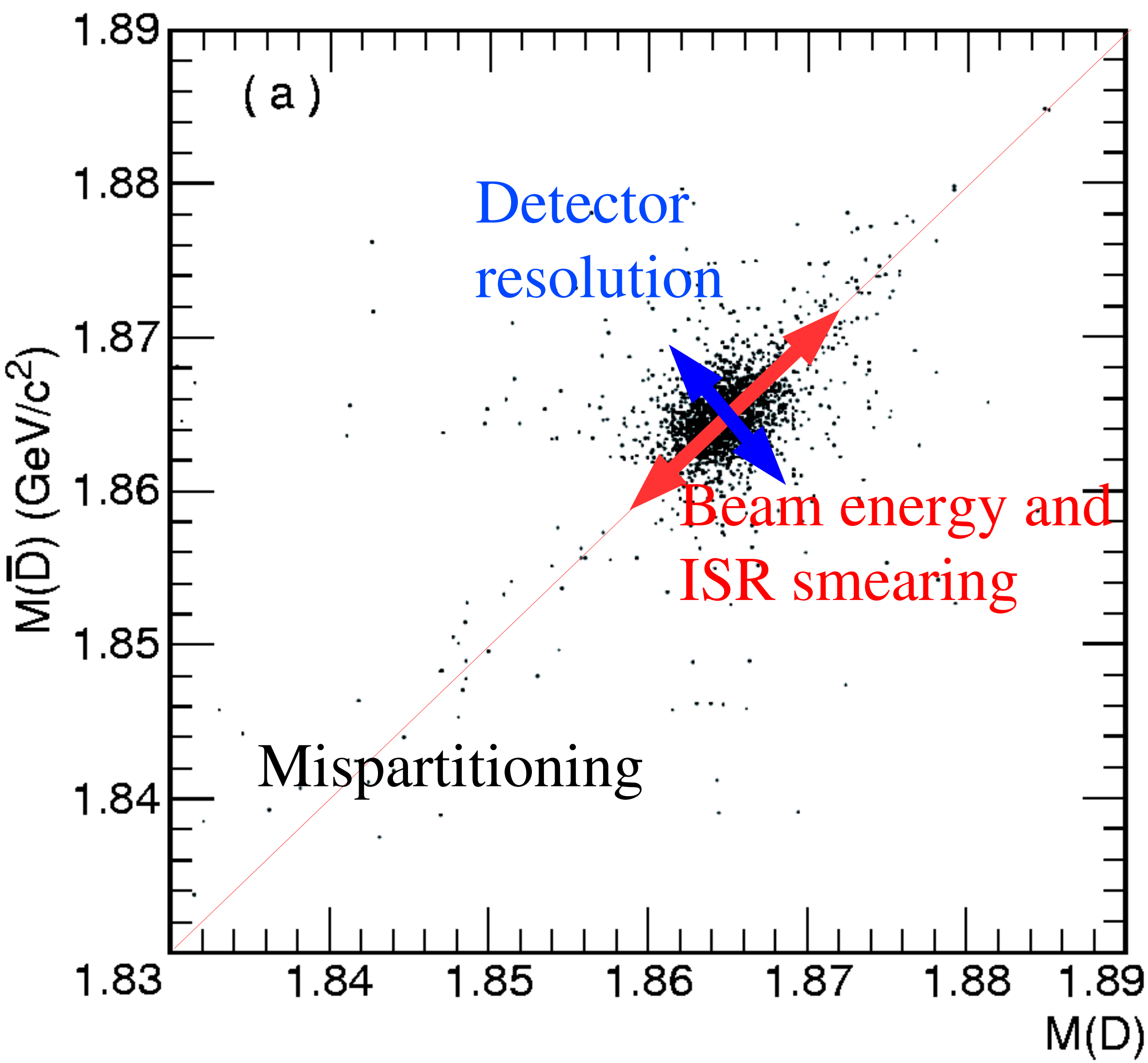




Single tag yields



Double Tag Fits

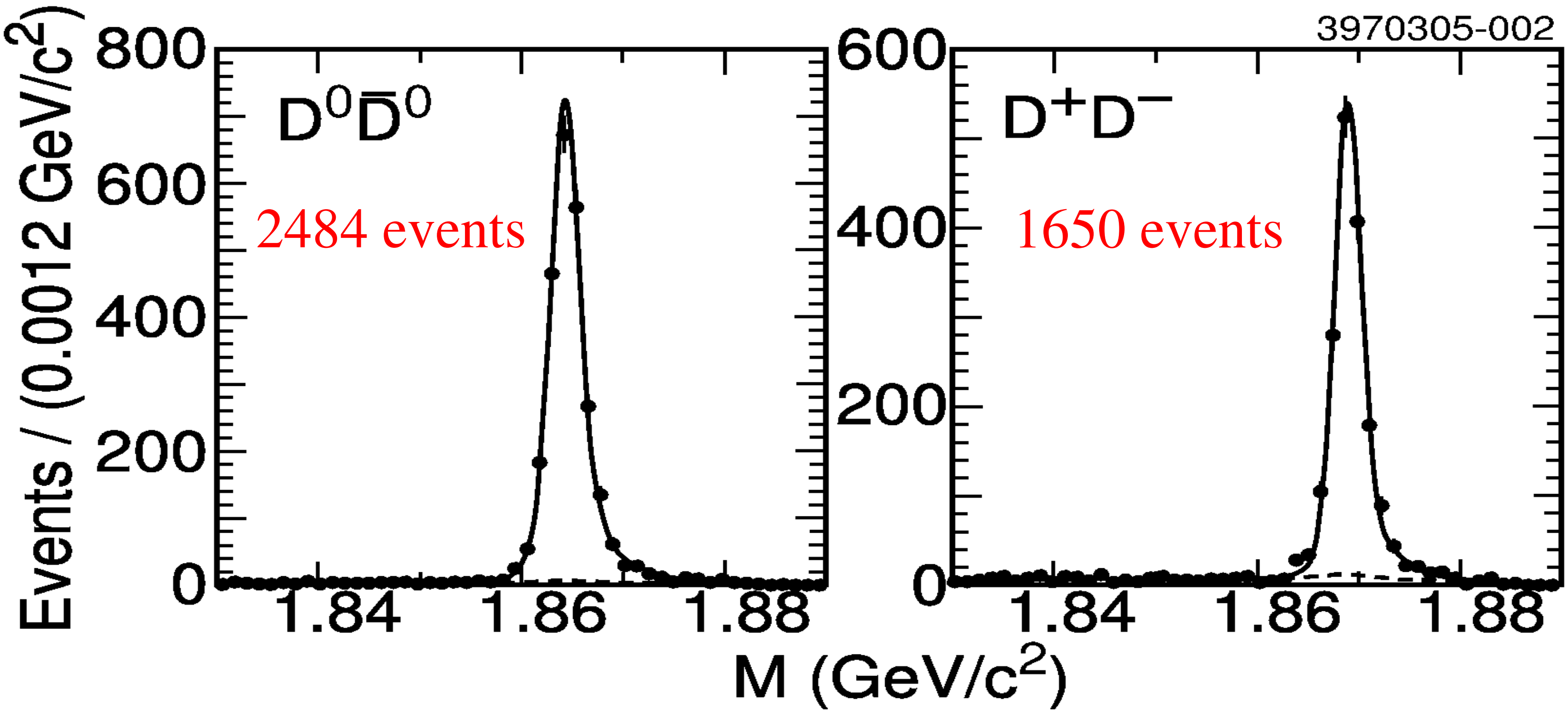


- Beam energy spread causes a correlated effect in the mass of the two D-mesons
- Resolution is uncorrelated among the two D-mesons
- A two dimensional fit allow us to separate the effects of beam energy smearing and detector resolution.

MC $\sigma_E = (2.08 \pm 0.01)\,\mathrm{MeV}$

Data $\sigma_E = (2.11 \pm 0.02)\,\mathrm{MeV}$

Double tag yields



- The statistical errors on the double tag yields set the errors on the branching fractions (assuming the single tag yields don't dominate the errors).

Results

Parameter	Fitted Value	$\Delta_{\rm FSR}$	PDG 2004*
$N_{D^0\bar{D}^0}$	$(2.01 \pm 0.04 \pm 0.02) \times 10^5$	-0.2%	
$\mathcal{B}(D^0 \to K^-\pi^+)$	$(3.91 \pm 0.08 \pm 0.09)\%$	-2.0%	$(3.85 \pm 0.09)\%$
$\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$	$(14.9 \pm 0.3 \pm 0.5)\%$	-0.8%	
$\mathcal{B}(D^0 \to K^-\pi^+\pi^+\pi^-)$	$(8.3 \pm 0.2 \pm 0.3)\%$	-1.7%	
$N_{D^+D^-}$	$(1.56 \pm 0.04 \pm 0.01) \times 10^5$	-0.2%	
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$	$(9.5 \pm 0.2 \pm 0.3)\%$	-2.2%	$(9.2 \pm 0.6)\%$
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+\pi^0)$	$(6.0 \pm 0.2 \pm 0.2)\%$	-0.6%	
$\mathcal{B}(D^+ \to K^0_S\pi^+)$	$(1.55 \pm 0.05 \pm 0.06)\%$	-1.8%	
$\mathcal{B}(D^+ \to K^0_S\pi^+\pi^0)$	$(7.2 \pm 0.2 \pm 0.4)\%$	-0.8%	
$\mathcal{B}(D^+ \to K^0_S\pi^+\pi^+\pi^-)$	$(3.2 \pm 0.1 \pm 0.2)\%$	-1.4%	
$\mathcal{B}(D^+ \to K^+K^-\pi^+)$	$(0.97 \pm 0.04 \pm 0.04)\%$	-0.9%	

*Our branching fractions are corrected for FSR, PDG values are not.

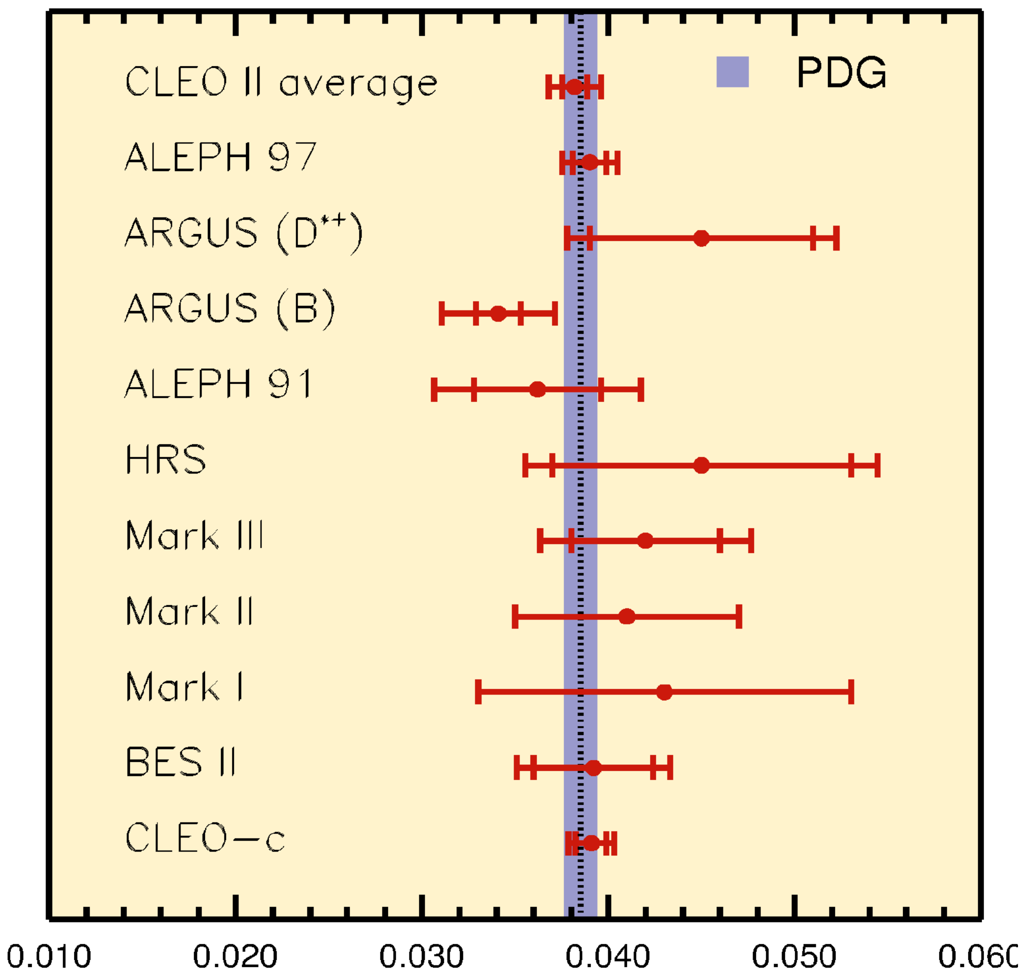
Using our measured luminosity of $55.8 \pm 0.6\,\mathrm{pb}^{-1}$ we obtain:

$\sigma(D^0\overline{D}^0) = (3.60 \pm 0.07 \pm 0.07)\,\mathrm{nb}$ $\quad$ $\sigma(D^+D^-) = (2.79 \pm 0.07 \pm 0.10)\,\mathrm{nb}$

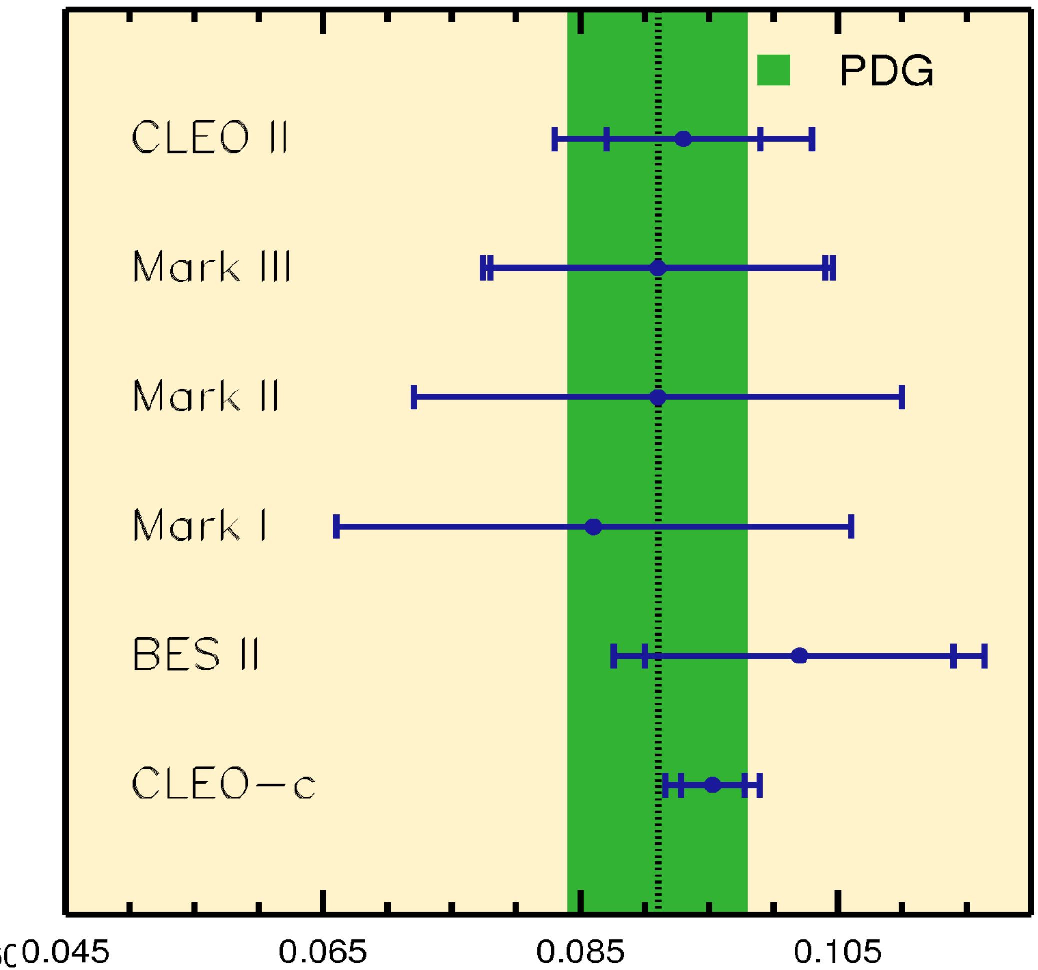
$\sigma(D\overline{D}) = (6.39 \pm 0.10 \pm 0.17)\,\mathrm{nb}$

Comparison with other exp.

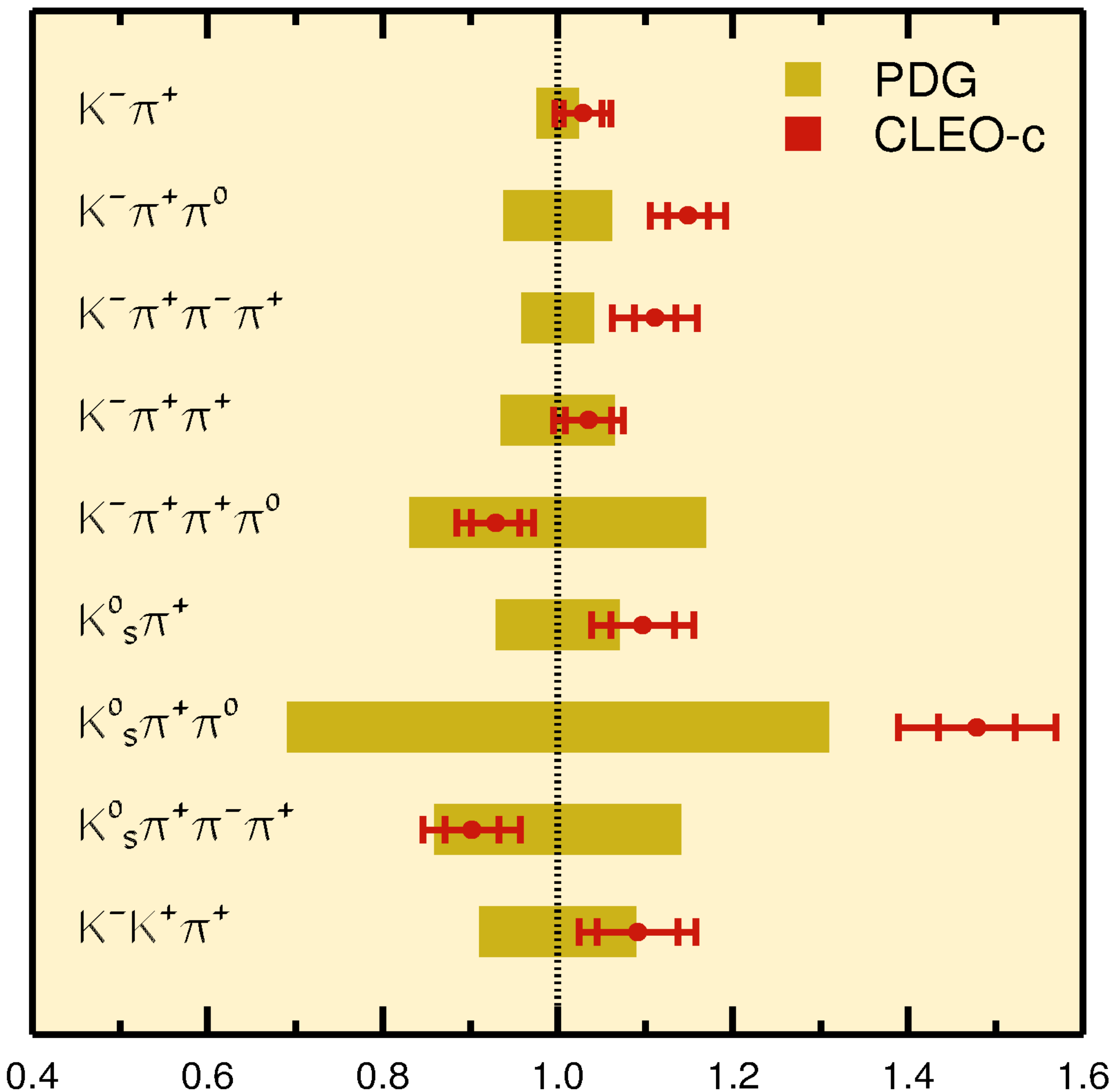
$Br(D^0 \to K^- \pi^+)$



$Br(D^+ \to K^- \pi^+ \pi^+)$



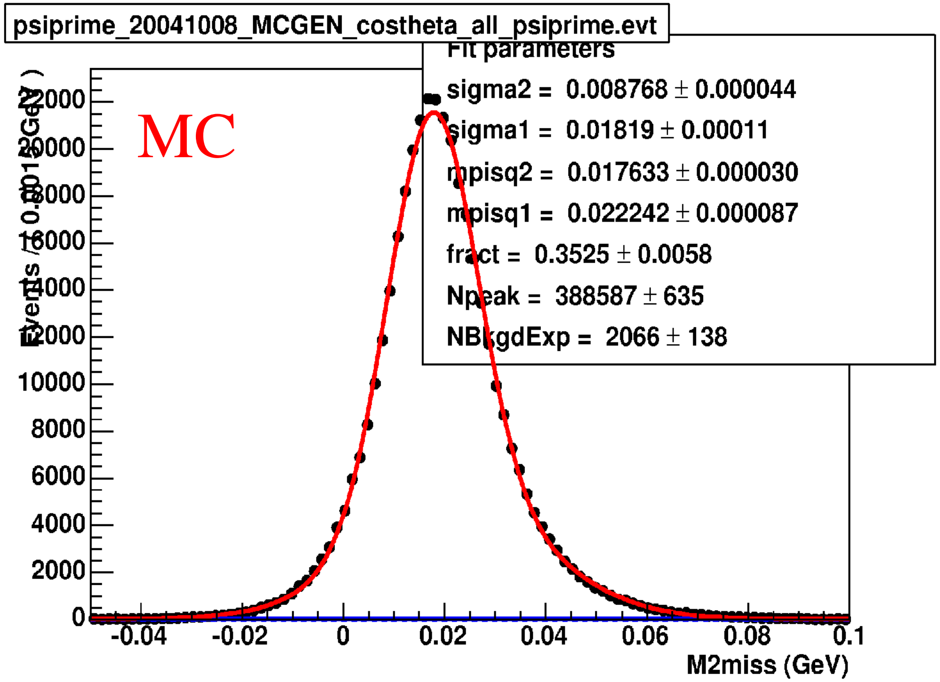
Comparison to PDG

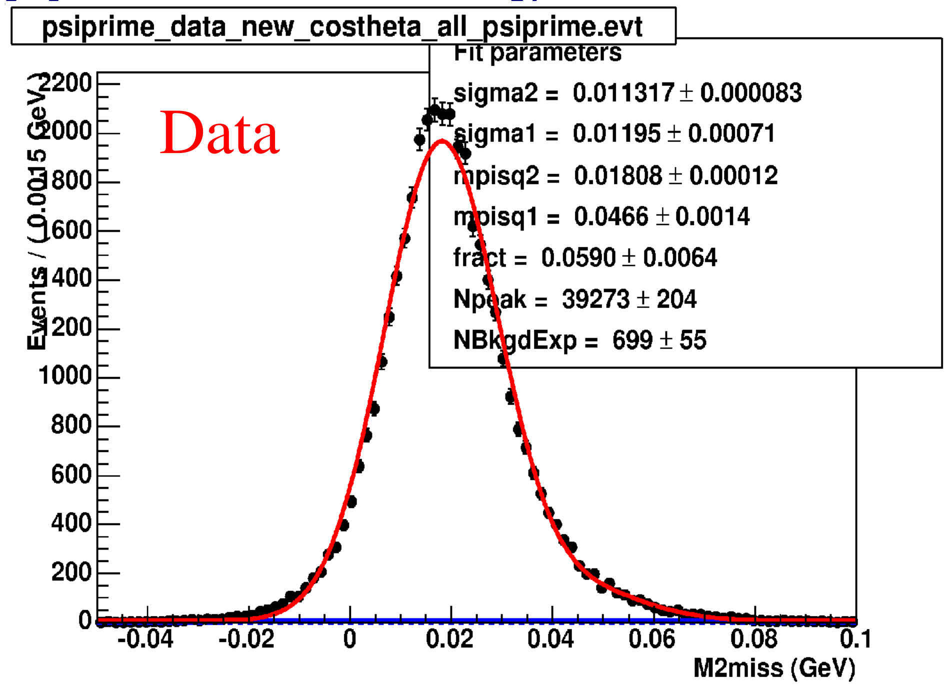


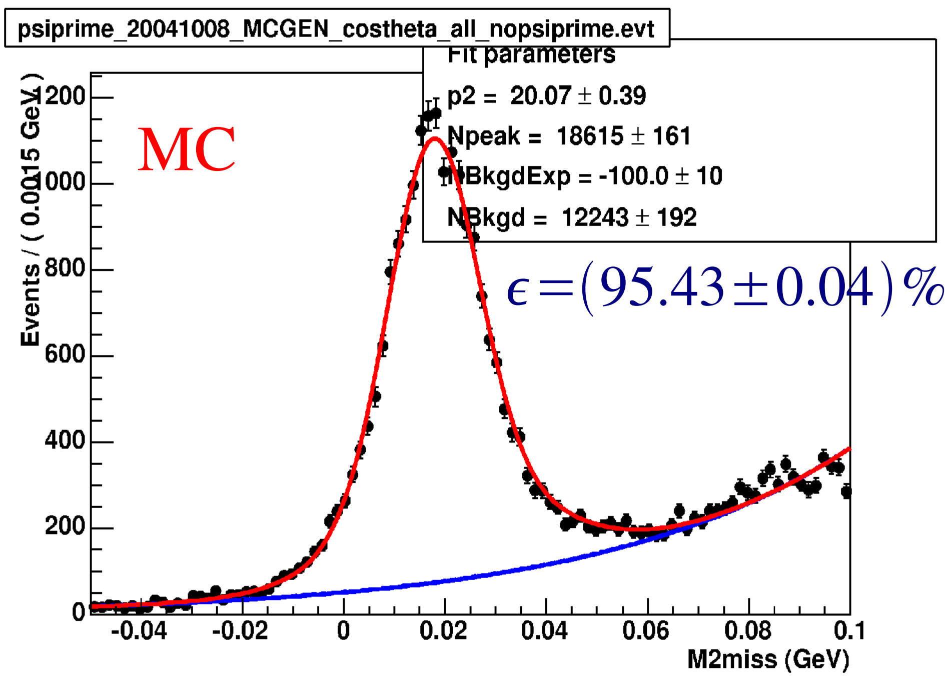
Tracking efficiencies

- For example, we want to measure B(*D*->*K*) to better than 1%
- We need to measure the tracking efficiency to ~0.3% in order achieve this goal.
- Luckily, we have data samples that allow crosschecks at this level.
- A very clean sample is the '->J/ $^+$, with J/ ->e^+e^- or $^+$ $^-$.
  - To measure the, *e.g.*, the efficiency for finding a $^+$ we reconstruct the J/ and the $^-$. Then we check if the J/ and $^-$ are consistent with a missing $^+$.
  - This allows us to count the number of events of the type '->J/ $^+$ without actually finding the $^+$.
  - Now we can simply measuring the efficiency be seeing how often we actually find the $^+$ in the event.

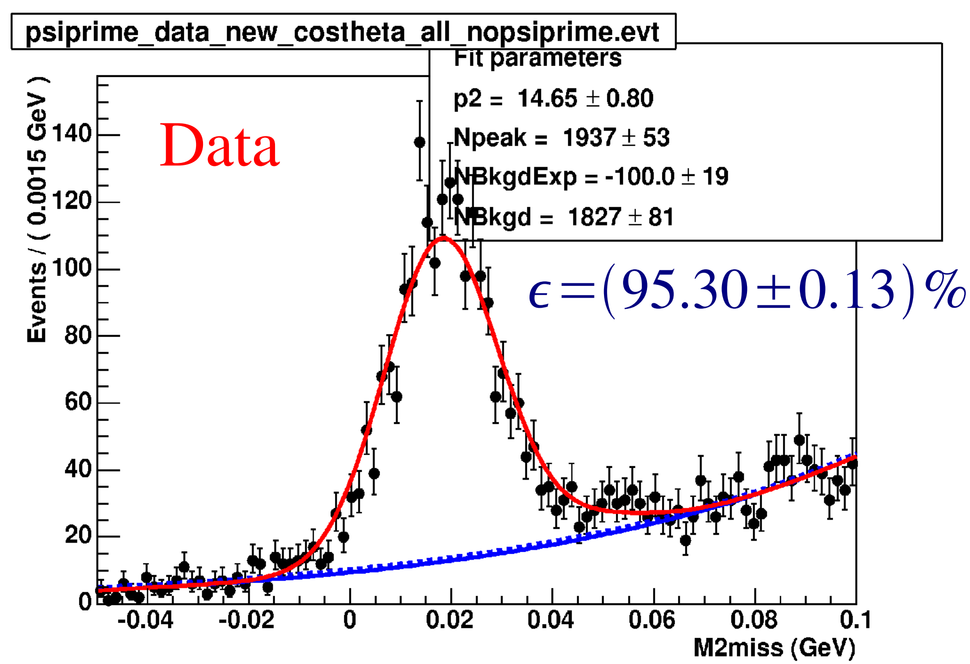
Pion tracking efficiency





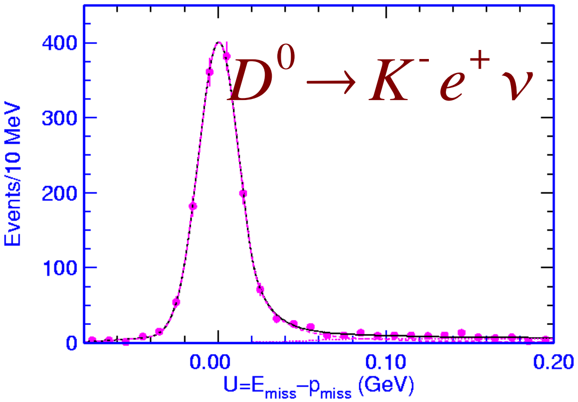


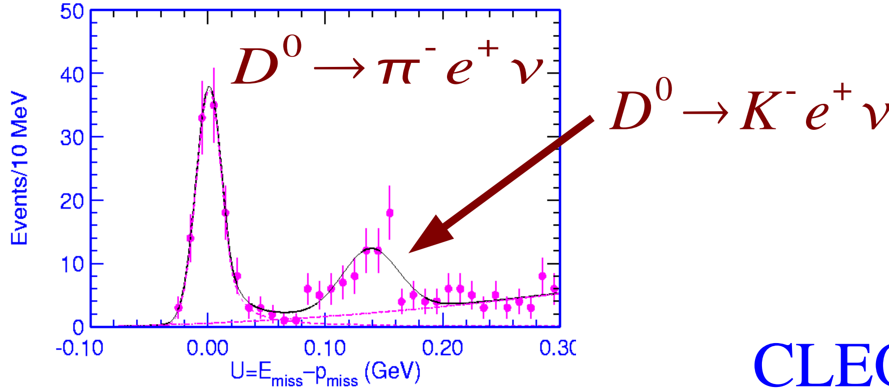
$\epsilon = (95.43 \pm 0.04)\%$

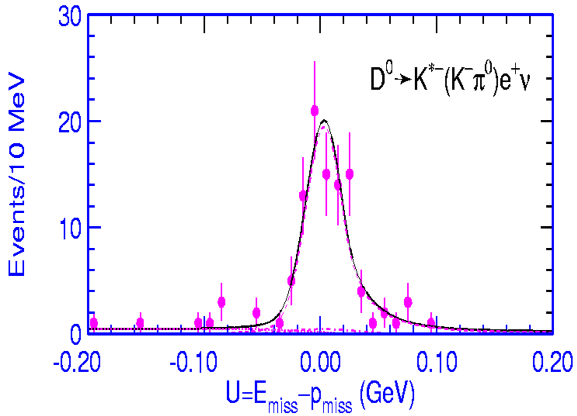


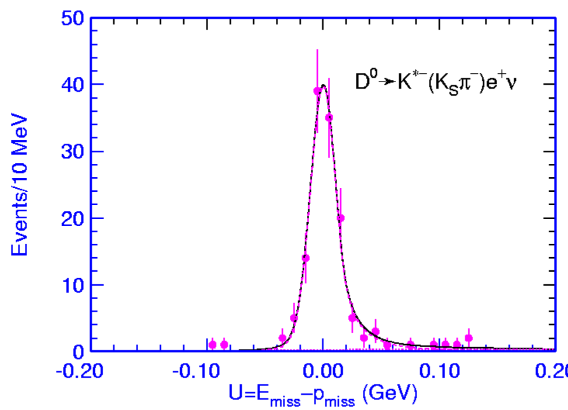
$\epsilon = (95.30 \pm 0.13)\%$

Semileptonic decays in 56 fb^{-1}

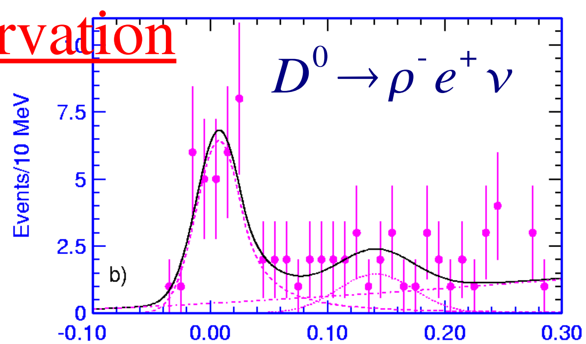




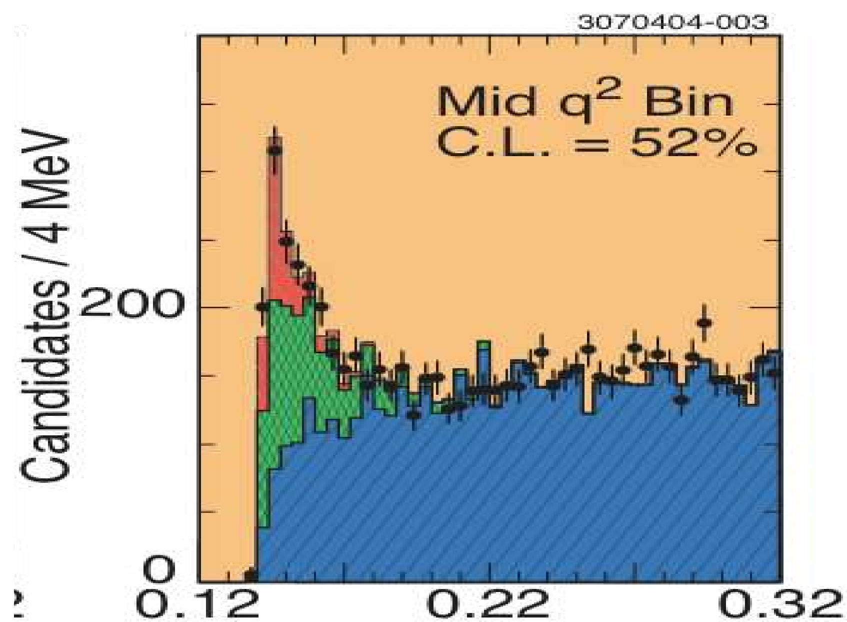




First observation



CLEO-III analysis of D-> l . Signal much cleaner at CLEO-c

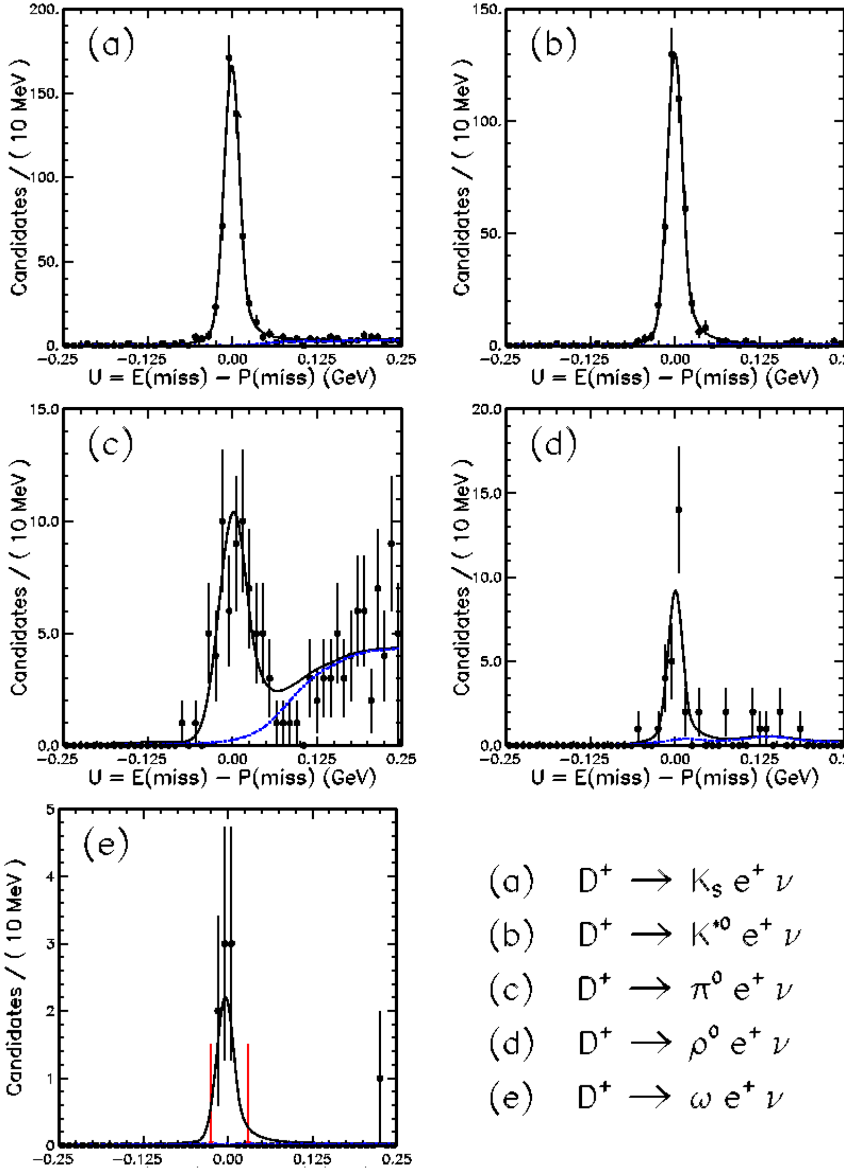


D^0 branching fractions

D^0 Decays	ϵ (%)	yields	$\mathcal{B}$	PDG
$K^- e^+ \nu_e$	65.15±0.34	1416.3±37.5	$(3.41 \pm 0.09 \pm 0.10)\%$	$(3.58 \pm 0.18)\%$
$\pi^- e^+ \nu_e$	76.85 ± 0.53	121.0±10.6	$(2.51 \pm 0.22 \pm 0.08) \times 10^{-3}$	$(3.6 \pm 0.6) \times 10^{-3}$
$K^{*-}(K^- \pi^0) e^+ \nu$	23.32±0.33	93.7±10.3	$(1.94 \pm 0.21 \pm 0.10)\%$	
$K^{*-}(K_S \pi^-) e^+ \nu$	41.29±0.41	127.5 ± 11.6	$(2.16 \pm 0.20 \pm 0.11)\%$	
$K^{*-} e^+ \nu_e$			$(2.06 \pm 0.14 \pm 0.08)\%$	$(2.15 \pm 0.35)\%$
$\rho^- e^+ \nu_e$	28.31±0.36	37.9±7.1	$(2.18 \pm 0.40 \pm 0.18) \times 10^{-3}$	

PRELIMINARY!

D^+ semileptonic branching fractions



(a) $D^+ \to K_s e^+ \nu$
(b) $D^+ \to K^{*0} e^+ \nu$
(c) $D^+ \to \pi^0 e^+ \nu$
(d) $D^+ \to \rho^0 e^+ \nu$
(e) $D^+ \to \omega e^+ \nu$

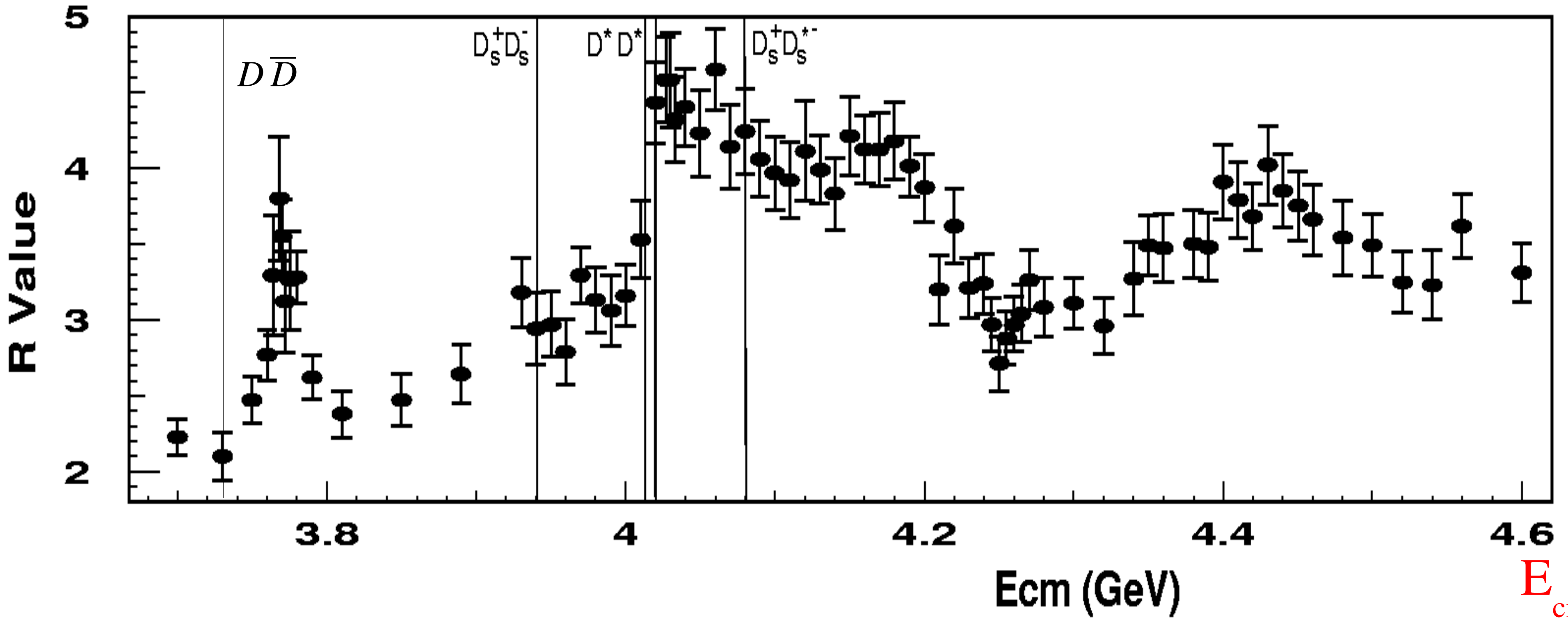
Decay Mode	yield	ϵ (%)	$\mathcal{B}$ (%)	$\mathcal{B}$ (%) PDG
$D^+ \to \bar{K}^0 e^+ \nu_e$	545 ± 24	57.1 ± 0.4	$8.71 \pm 0.38 \pm 0.37$	6.7 ± 0.9
$D^+ \to \bar{K}^{*0}(K^-\pi^+) e^+ \nu_e$	422 ± 21	34.8 ± 0.3	$5.70 \pm 0.28 \pm 0.25$	5.5 ± 0.7
$D^+ \to \pi^0 e^+ \nu_e$	63 ± 9	45.2 ± 1.0	$0.44 \pm 0.06 \pm 0.03$	0.31 ± 0.15
$D^+ \to \rho^0(\pi^+\pi^-) e^+ \nu_e$	27 ± 6	40.0 ± 1.1	$0.21 \pm 0.04 \pm 0.02$	0.25 ± 0.1
$D^+ \to \omega(\pi^+\pi^-\pi^0) e^+ \nu_e$	8.0 ± 2.8	16.4 ± 0.6	$0.17 \pm 0.06 \pm 0.01$	N/A

PRELIMINARY!

Physics 'opportunities'

- The charm energy range, ~3.1 to ~4.6 GeV provides many different physics opportunities:
  - From the J/ψ to $\Lambda_c \overline{\Lambda}_C$ threshold.
- Will do a scan to determine best point to run at for D_S.

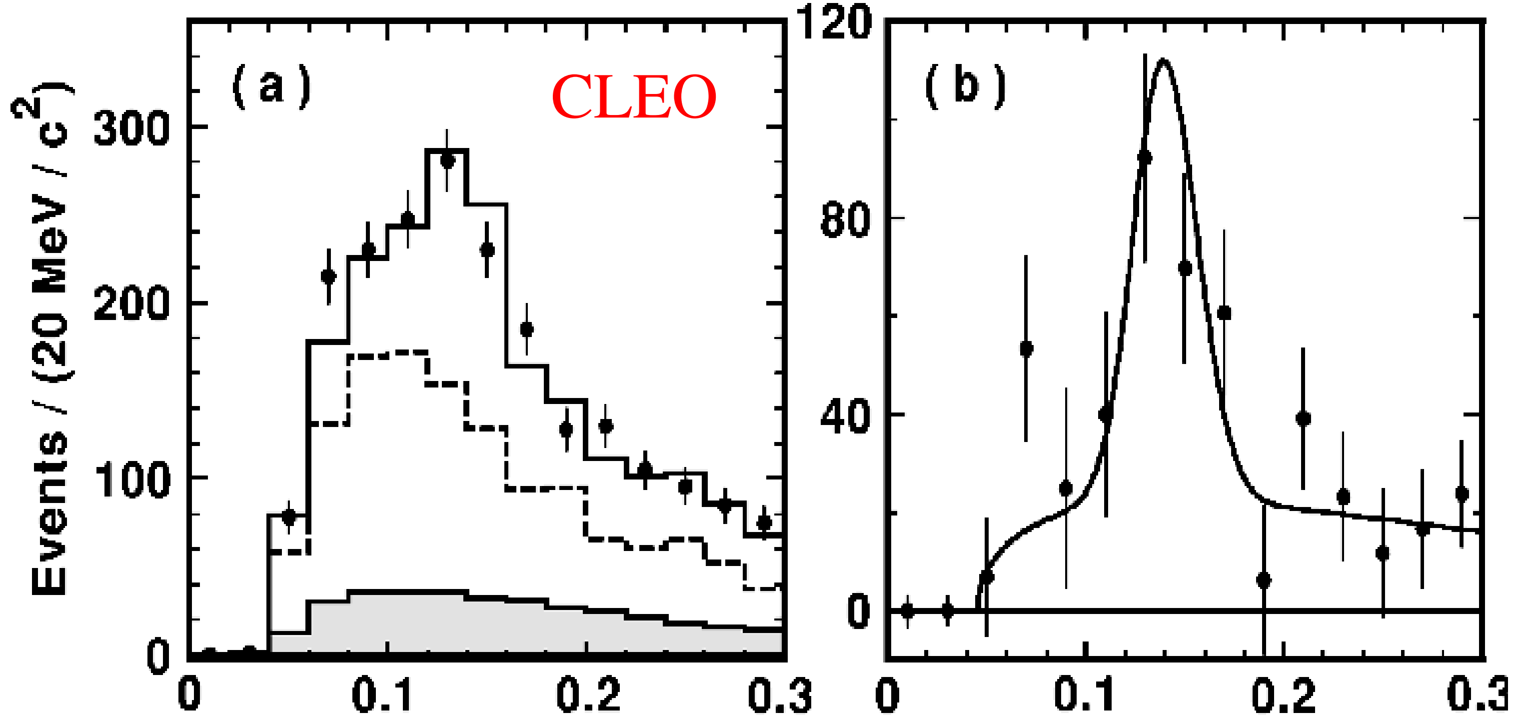
BES R scan



E_{cm}

CLEO-c prospects for f_{Ds}

- Has been studied previously at CLEO at the Υ(4S) and other experiments (WA75, E653, L3, BEATRICE, OPAL, ALEPH)



- CLEO sees large signal, but have to understand background subtraction
  - Branching fractions tied to the D_s branching fraction scale
- BES has also studied this decay but have only 3 signal events.

CLEO-c projections for f_{Ds}

- The analysis technique for measuring D_s-> is similar to D-> .
- One uncertainty here is the cross section for D_s production.
  - BES measured a cross-section of ~0.5 nb at E_{cm}=4.03 GeV.
  - This cross-section is used in the estimates.
- We will perform a scan to determine the optimal running point.

D_s yields

D and Daughter Decay Modes		$\mathcal{B}$ (%)	Produced	ϵ_{MC} (%)	ϵ_S (%)	Detected
$D_s^+ \to K^-K^+\pi^+$		4.40	54,405	40.4	36.8	21,965
$D_s^+ \to K^-K^+\pi^+\pi^0$		4.43	57,026	19.8	23.9	11,314
$D_s^+ \to \eta\pi^+$		1.70				
	$\eta \to \gamma\gamma$	0.67	6,738	57.1	53.3	3,849
	$\eta \to \pi^0\pi^0\pi^0$	0.54	5,520	25.0	22.5	1,378
	$\eta \to \pi^+\pi^-\pi^0$	0.39	4,122	43.5	35.8	1,793
$D_s^+ \to \eta\rho^+$		10.8				
	$\eta \to \gamma\gamma$	4.24	41,731	37.4	34.6	15,612
	$\eta \to \pi^0\pi^0\pi^0$	3.46	34,066	18.4	14.6	6,260
	$\eta \to \pi^+\pi^-\pi^0$	2.48	25,306	26.8	23.3	6,791
$D_s^+ \to \eta'\pi^+$		3.9				
$\eta' \to \eta\pi^+\pi^-$	$\eta \to \gamma\gamma$	0.68	6,191	28.2	35.8	1,743
$\eta' \to \eta\pi^+\pi^-$	$\eta \to \pi^0\pi^0\pi^0$	0.55	5,232	11.9	15.1	624
$\eta' \to \eta\pi^+\pi^-$	$\eta \to \pi^+\pi^-\pi^0$	0.40	3,872	17.8	24.1	690
$\eta' \to \gamma\rho$		1.15	11,277	40.6	44.5	4,583
$D_s^+ \to \eta'\rho^+$		10.1				
$\eta' \to \eta\pi^+\pi^-$	$\eta \to \gamma\gamma$	1.8	17,011	16.6	23.3	2,819
$\eta' \to \eta\pi^+\pi^-$	$\eta \to \pi^0\pi^0\pi^0$	1.4	13,982	7.9	9.8	1,108
$\eta' \to \eta\pi^+\pi^-$	$\eta \to \pi^+\pi^-\pi^0$	1.0	10,417	10.4	15.7	1,086
$\eta' \to \gamma\rho$		3.0	30,072	29.1	28.9	8,747
			326,968			90,362

Predictions for 1 fb^{-1}

This would give ~400 D_s->

and ~600 D_s->

In 1 fb^{-1} we could determine f_{Ds} to about 2%.

Conclusions

- CLEO-c has analyzed ~60 pb^{-1} of data at the (3770)
  - Three early analysis will be published on this sample
- Using this sample we have obtained the preliminary results
  - $Br(D^+ \to \mu^+ \nu) = (3.5 \pm 1.4 \pm 0.6) \times 10^{-4}$ $\quad f_{D^+} = (202 \pm 41 \pm 17)\,\mathrm{MeV}$
  - $Br(D^0 \to K^+ \pi^-) = (3.91 \pm 0.08 \pm 0.09)\%$ $\quad Br(D^+ \to K^- \pi^+ \pi^+) = (9.5 \pm 0.2 \pm 0.3)\%$
  - At E_{cm}=3.773 GeV we measured the e^+e^- cross sections
    - $\sigma(D^0 \overline{D}^0) = (3.60 \pm 0.07 \pm 0.07)\,\mathrm{nb}$ $\quad \sigma(D^+ D^-) = (2.79 \pm 0.07 \pm 0.10)\,\mathrm{nb}$
    - $\sigma(D \overline{D}) = (6.39 \pm 0.10 \pm 0.17)\,\mathrm{nb}$
- Using all tagging modes we have a *D*-tagging efficiency of 25%.
- For the summer we should have 280 pb^{-1}.

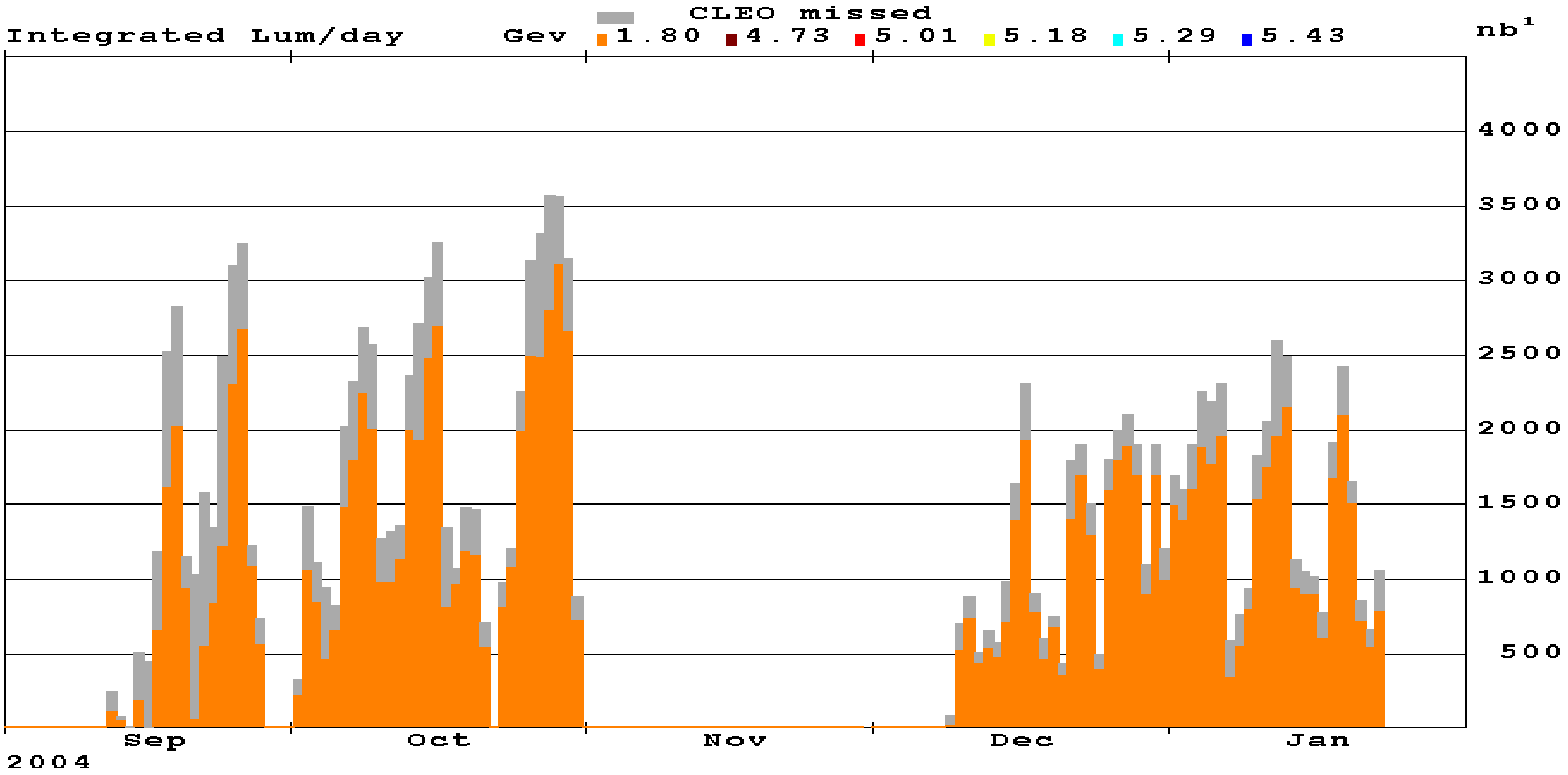
First CESR-c and CLEO-c run

During the period from Dec. '03 to April '04 CLEO-c recorded ~57 pb^{-1} on the (3770) resonance

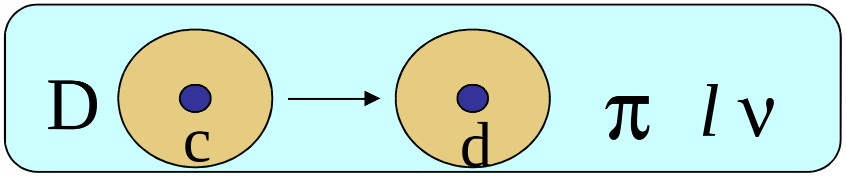
I will show some results from this run.

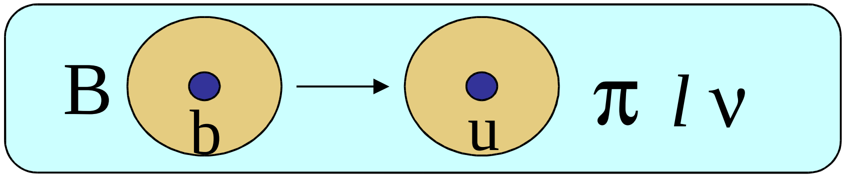
In addition we took data at the '. This data was in fact used in the first publication based on CLEO-c data.

We are currently recording more data at the (3770).



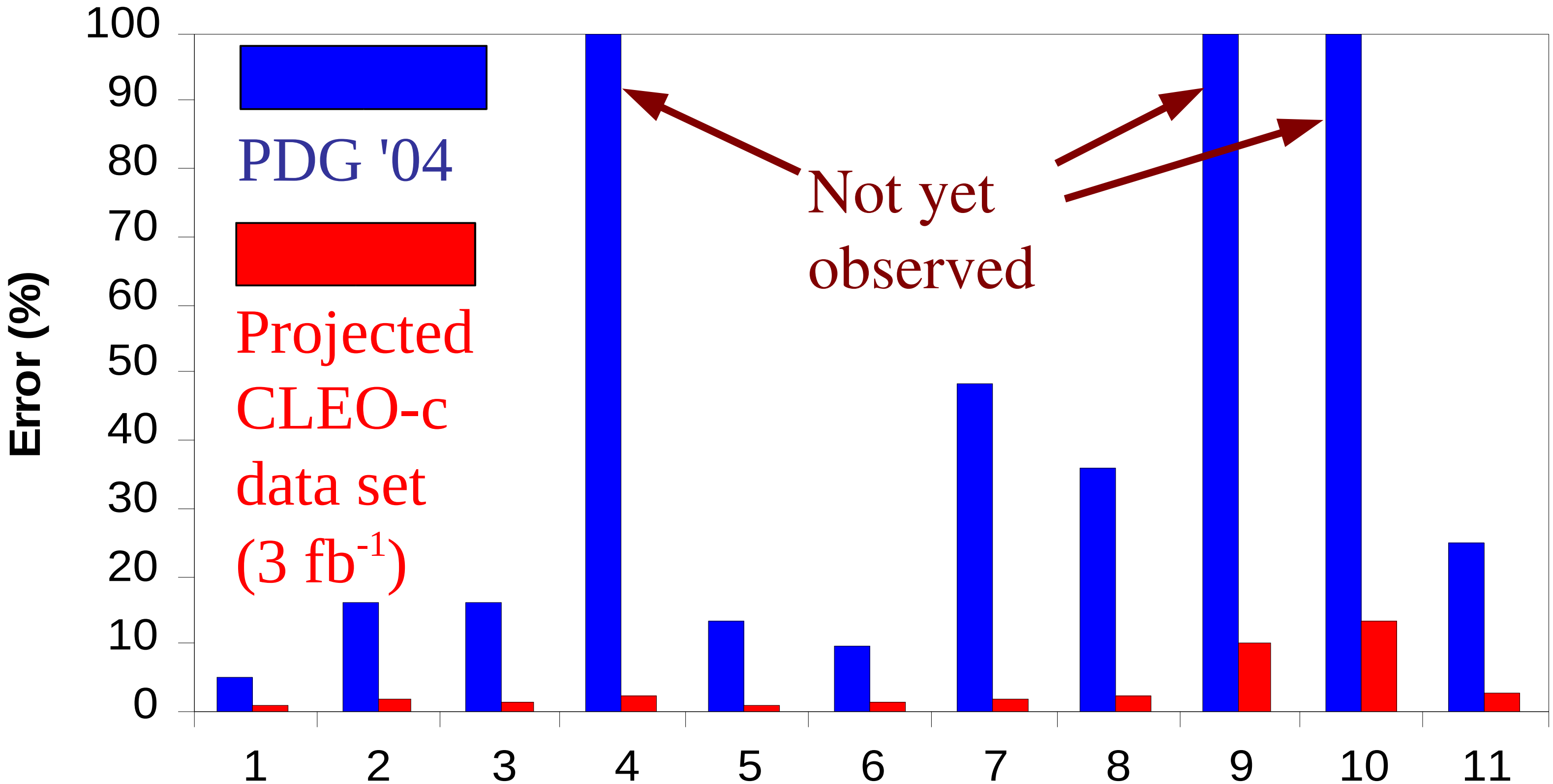
Semileptonic *D* decays





- The determination of Vub is important as a test of the parameters in the CKM matrix.
- *V*ub is best determined in semileptonic *B* decays
  - CLEO has made major progress in this area since the first observation of inclusive semileptonic decays in the early 90s.
- Today one of the most promising approaches involves the exclusive decay *B*-> 1 .
- Experimentally we measure the branching fraction to this final state – this relies very little on theory.
- However, relating the measured rate or branching fraction to *V*ub requires theoretical input on the transition of a B meson to a pion.
  - Lattice QCD makes predictions for this rate.
- The decay *D*-> 1 is very similar, we replace a *b* quark with a *c* quark. Lattice predictions can be compared to CLEO-c measurements.

CLEO-c projections for semileptonic decays



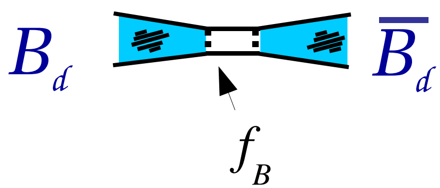
$1: D^0 \to K^- e^+ \nu$ $\quad 2: D^0 \to K^{*-} e^+ \nu$ $\quad 3: D^0 \to \pi^- e^+ \nu$ $\quad 4: D^0 \to \rho^- e^+ \nu$

$5: D^+ \to K_S^0 e^+ \nu$ $\quad 6: D^+ \to \overline{K}^{*0} e^+ \nu$ $\quad 7: D^+ \to \pi^0 e^+ \nu$ $\quad 8: D^+ \to \rho^0 e^+ \nu$

$9: D_S^+ \to K_S^0 e^+ \nu$ $\quad 10: D_S^+ \to \overline{K}^{*0} e^+ \nu$ $\quad 11: D_S^+ \to \phi e^+ \nu$

Lattice QCD and CLEO-c

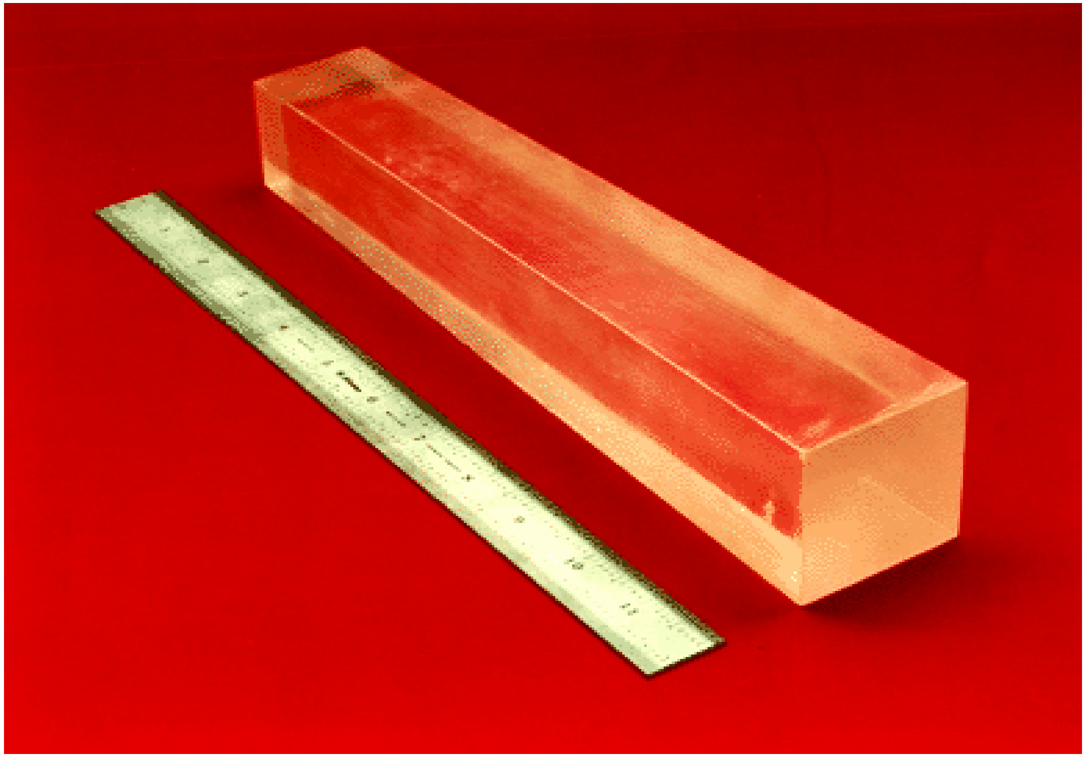
- Lattice QCD is a powerful computational tool for solving QCD in the non-perturbative regime.
- For example, in the case of B_d mixing we can use Lattice QCD to calculate the decay constant, f_B



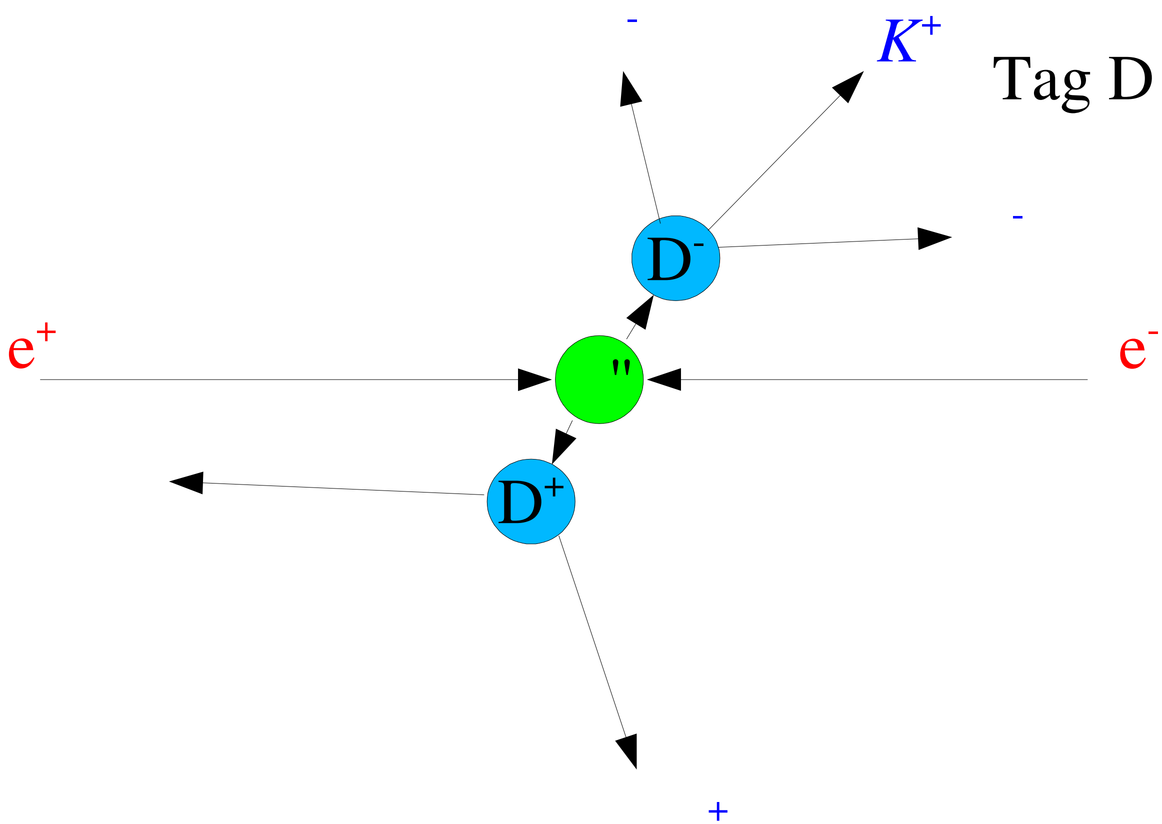
- CLEO-c plays a crucial role in that we can provide measurements that allow a direct test of how well the lattice calculations work.
- The decay D^+-> $^+$ allow a direct measurement of the decay constant which can be compared to lattice calculations.

Electromagnetic calorimeter

- The CsI(Tl) doped calorimeter covers 93% of 4 .
  - 7800 crystals
- Measures energy of photons and electrons
  - $_E$/E=2% at 1GeV



Analysis technique



Tag D – fully reconstructed

- At threshold produce only D^+D^-, no additional pions.
- Detect muon and make sure it recoiled against neutrino.
  - Extract signal in M^2_{miss} which peaks at 0.