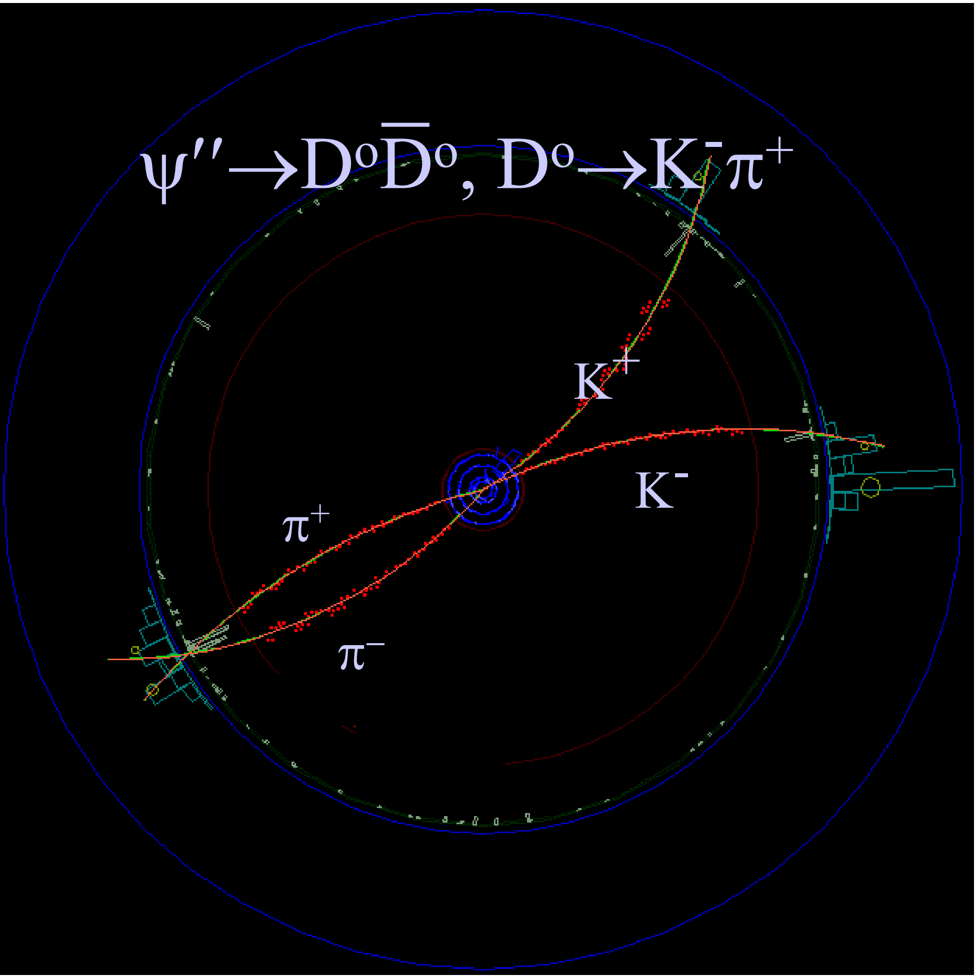
Measurement of f_{D^+} via $D^+ \rightarrow \mu^+\nu$

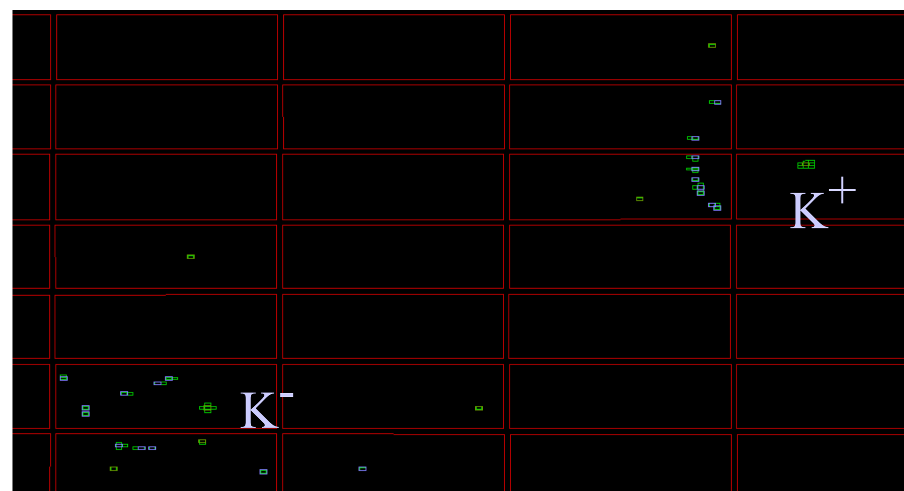


Sheldon Stone,

Syracuse University

"I charm you, by my once-commended beauty"

Julius Cæsar, Act II, Scene I



Importance of Measuring f_{D^+} and $f_{D_s^+}$

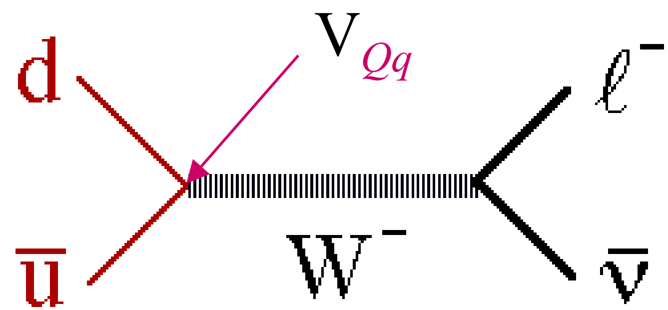
- We can compare theoretical calculations of f_D to our measurements and gain confidence in theory to predict f_B
- f_B is necessary to translate measurement of B^o-$\bar{B}^o$ mixing into value for $|V_{td}|$.
- If we $B^+ \to \ell^+ \nu$ was measured, then we would have a measurement of the product of $|V_{ub}|\, f_B$. Knowing f_B gives V_{ub}
- Similarly, can check f_{Ds}/f_D to learn about f_{Bs}/f_B

Leptonic Decays: D $\rightarrow \ell^+\nu$

Introduction: Pseudoscalar decay constants

Q and $\bar{q}$ can annihilate, probability is $\propto$ to wave function overlap

Example π^-:



In general for all pseudoscalars:

$$\Gamma(P^+ \rightarrow \ell^+\nu) = \frac{1}{8\pi} G_F^2 f_P^2 m_\ell^2 M_P \left(1 - \frac{m_\ell^2}{M_P^2}\right)^2 |V_{Qq}|^2$$

Calculate, or measure if V_{Qq} is known

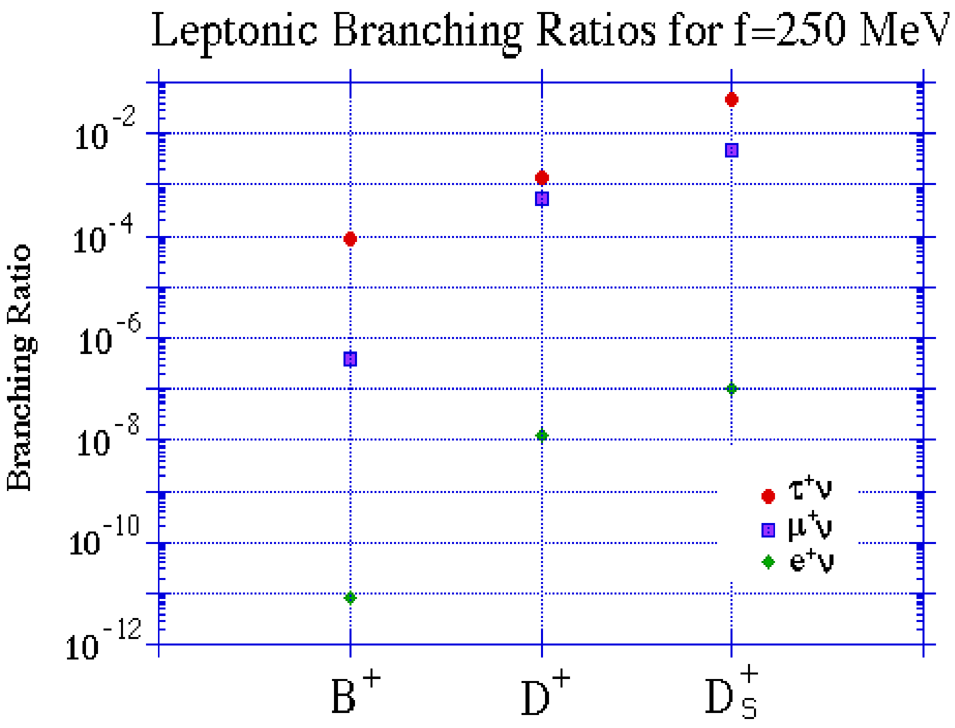
Expected $\mathcal{B}$ for $P^+ \to \ell^+\nu$ decays

- We know:

$f_\pi = 131.73 \pm 0.15$ MeV

$f_K = 160.6 \pm 1.3$ MeV

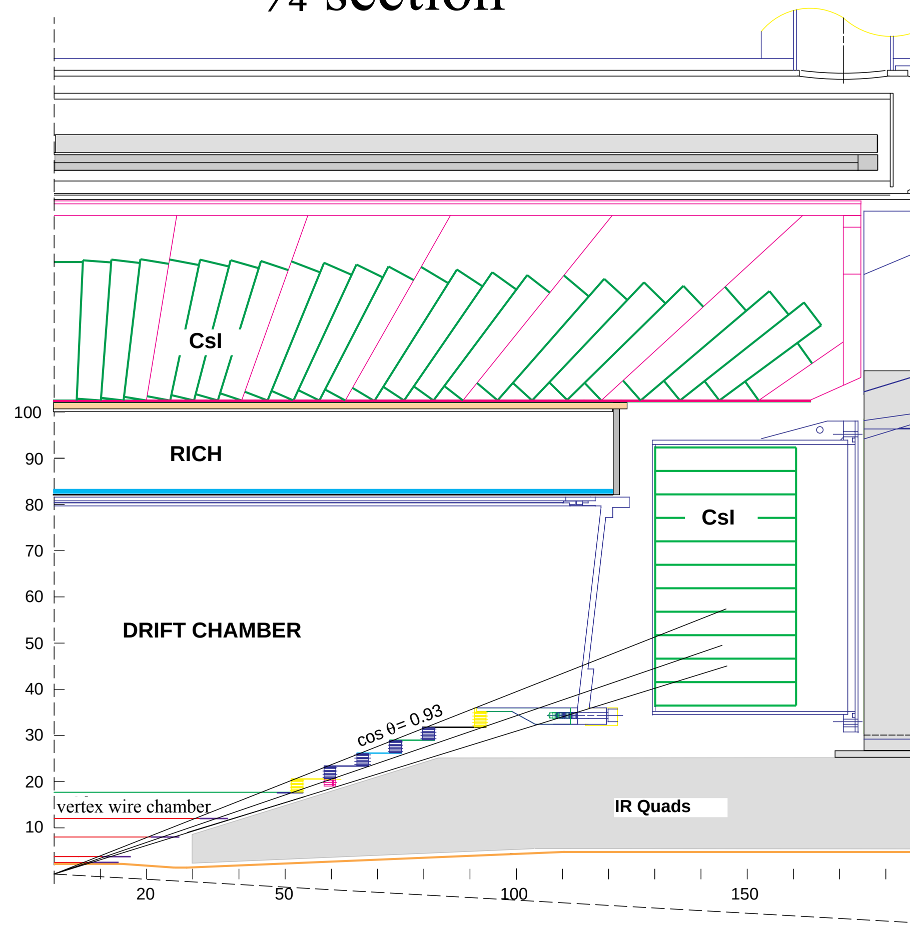
- The D_s has the largest $\mathcal{B}$, the $\mu^+\nu$ rate is ~0.5%
- f_{Ds} Measured by several groups, best CLEO II, but still poorly known
- For D^+ also use $\mu^+\nu$



CLEO-c Detector

- Upgrade of CLEO II. Kept CsI EM calorimeter, magnet & muon system
- New charged particle tracking
- New particle id via RICH
- New inner wire chamber
- B now 1 T, lowered from 1.5T

¼ section



Kinematical Niceties

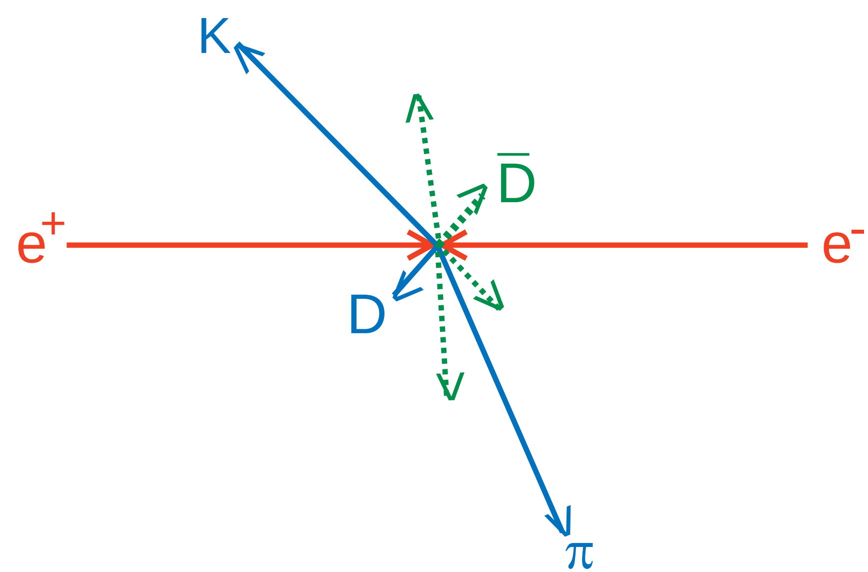
- Ease of $\mathcal{B}$ measurements using "double tags“

  $\mathcal{B}_A$ = # of A/# of D's

- Possible because
  - relatively large $\mathcal{B}$ (many %),
  - multiplicities typically small

    $\langle n_{charged} \rangle = \sim 2.5$, $\langle n_{\pi^o} \rangle \sim 1.2$,
  - enough luminosity
- Reconstruct D mesons using:

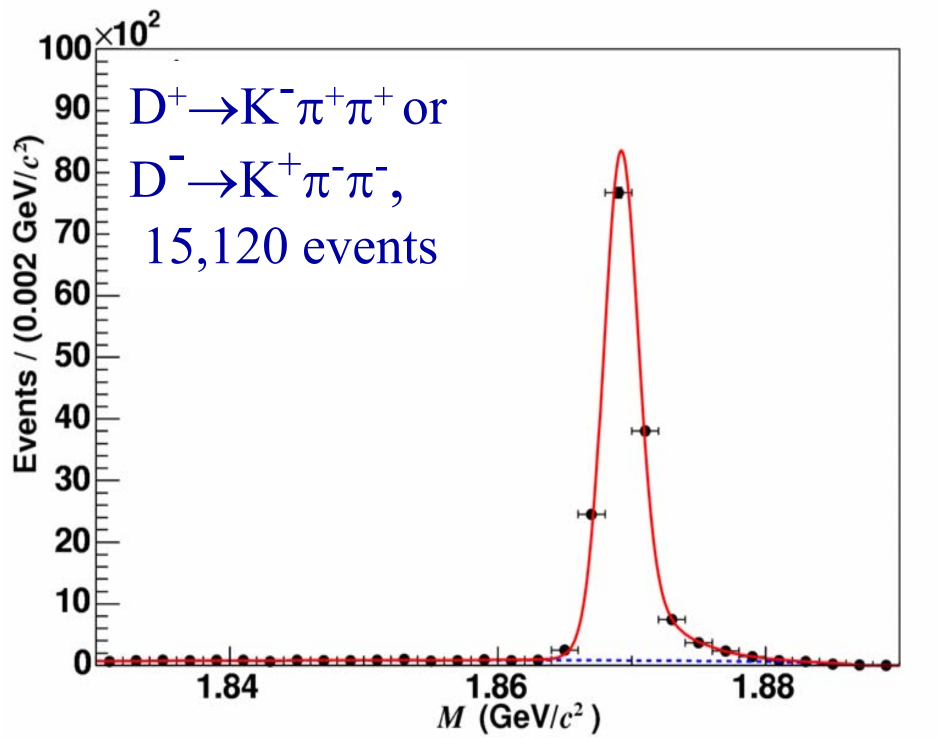
$$M_D^2 = \sum E_i^2 - \sum \vec{P}_i^2 = E_{beam}^2 - \sum \vec{P}_i^2$$



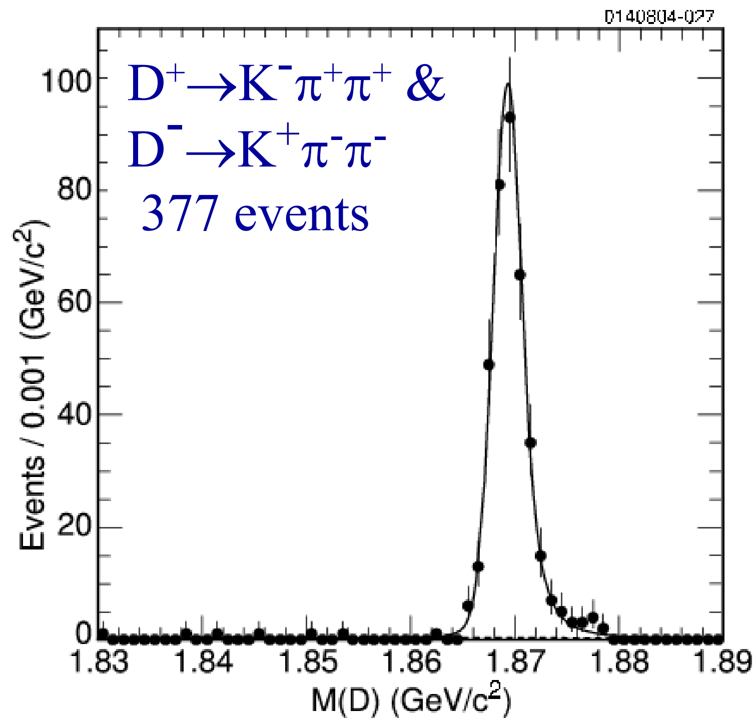
•System is over constrained if all particles are observed:
$\Sigma p_i \Rightarrow 3$, $E_{tot} \Rightarrow 1$, $m_D = m_{\bar{D}} \Rightarrow 1$

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

Single tags



Double Tags



57 pb^{-1} of data, we now have 280 pb^{-1}

Leptonic Decays

- Ease of leptonic decays using double tags & MM^2 technique

$$MM^2 = (E_D - E_\ell)^2 - (\vec{p}_D - \vec{p}_\ell)^2$$

We know $E_D = E_{beam}$, $\vec{p}_{\bar{D}} = -\vec{p}_D$

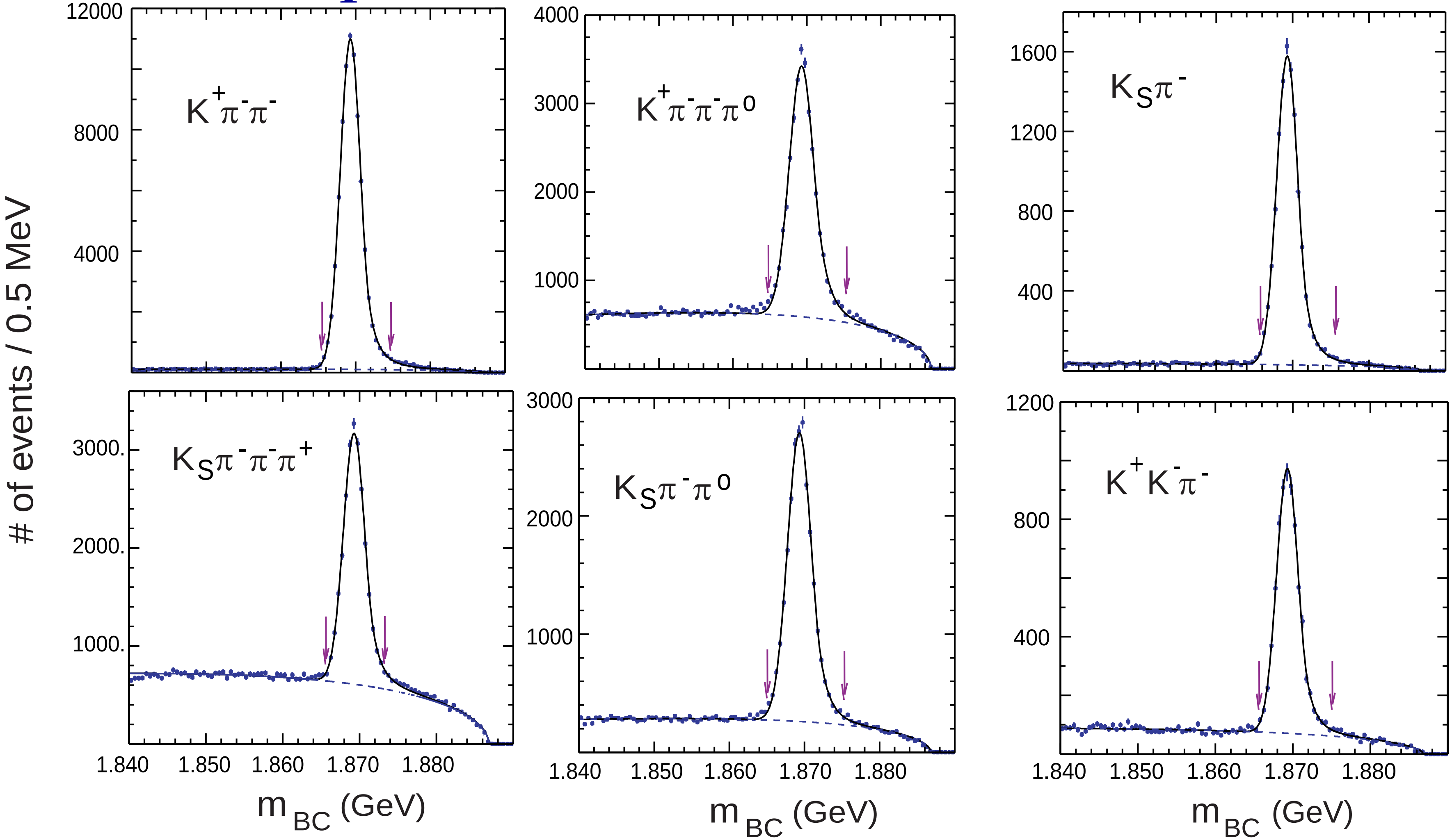
- Search for peak near $MM^2=0$
- Since resolution ~ $M^2_{\pi^0}$, reject extra particles with calorimeter & tracking
- Note that this method is used to evaluate systematic errors on the tracking efficiency, simply by using double tags with one missing track

Technique for $D^+ \rightarrow \mu^+\nu$

- Fully reconstruct one $D^\pm$
- Seek events with only one additional charged track and no additional photons > 250 MeV to veto $D^+ \rightarrow \pi^+\pi^o$
- Charged track must deposit only minimum ionization in calorimeter
- Compute MM^2
  - If close to zero then almost certainly we have a $\mu^+\nu$ decay.
    - Can identify electrons to^{2}check background level
    - Expect resolution of $\sim M_{\pi^o}$
  - If $MM^2 > 0$, candidate for $\tau^+\nu$, but this is difficult

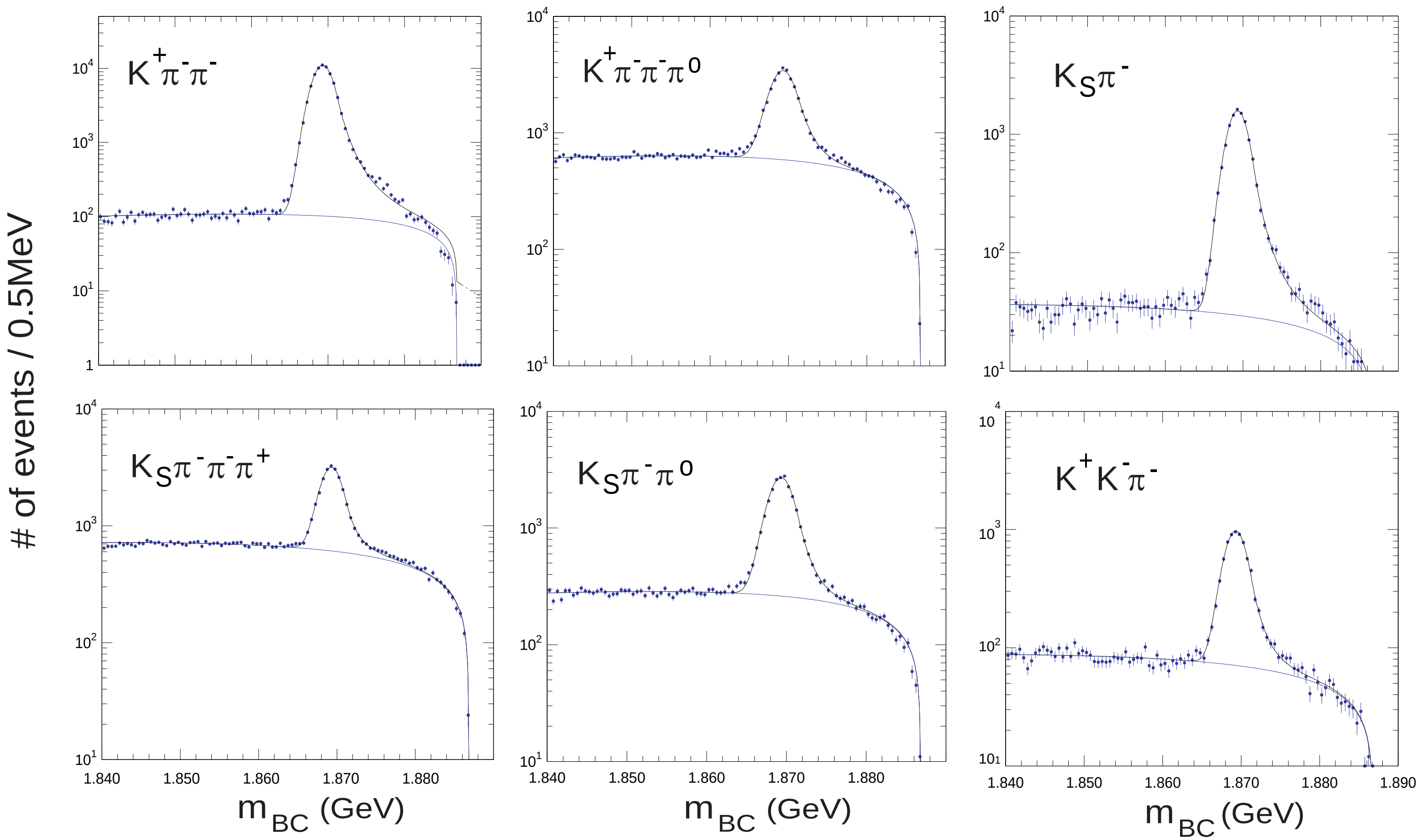
Single Tag Sample

- From 280 pb^{-1}



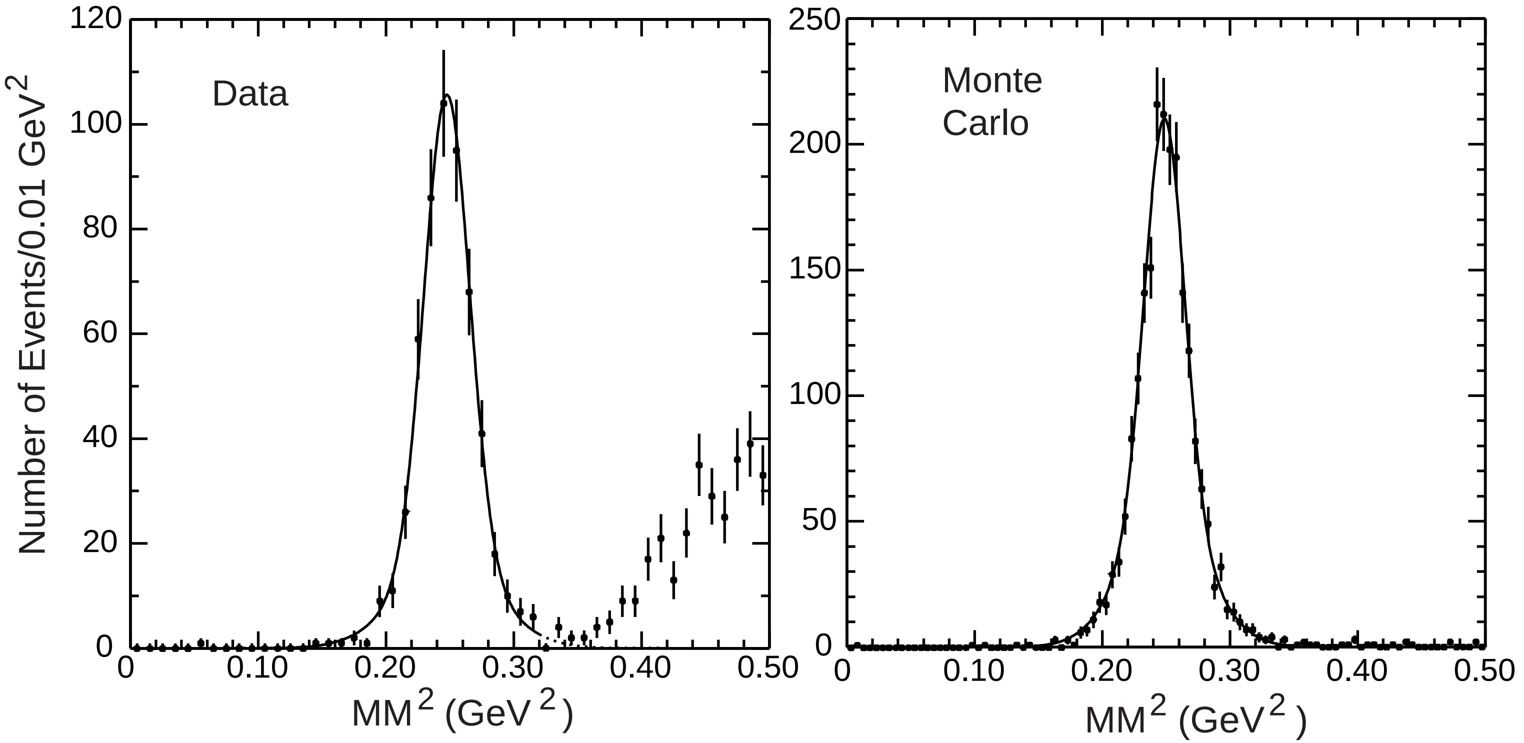
Problem: how many events?

- Fits to Asymmetric signal function (Crystal Ball shape) plus smooth background shape (ARGUS function) – error in tags ±0.3%



MM^2 resolution

- MM^2 from $K_S\ \pi^-$ from data & MC



σ=0.0233±0.0009 GeV^2 → σ=0.0222±0.0005 GeV^2

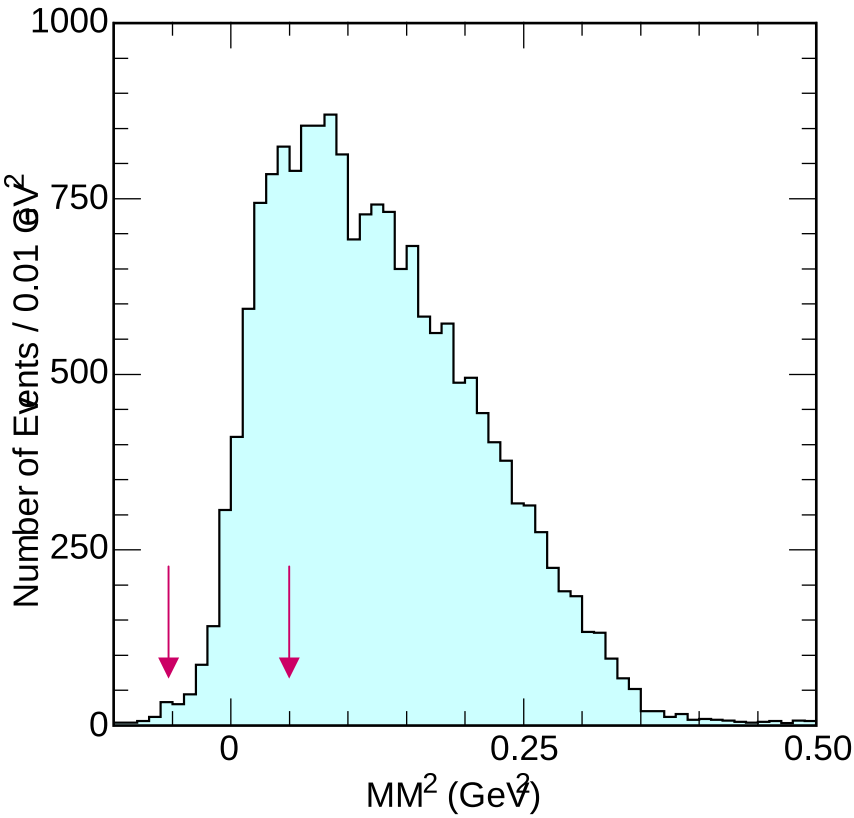
Consistent now, for 1st analysis data was 15% larger

Backgrounds: $D^+ \to \pi^+ \pi^o$

- We don't specifically identify muons, only reject hadronic interactions in the crystals.
- This mode has a $\mathcal{B}$=(0.13±0.02)%
- Eliminate by requiring muon candidate be in good barrel region & reject events with an extra γ with E > 250 MeV. Residual effect is 0.3 events in 57 pb^{-1} and 1.4 events for 280 pb^{-1}.

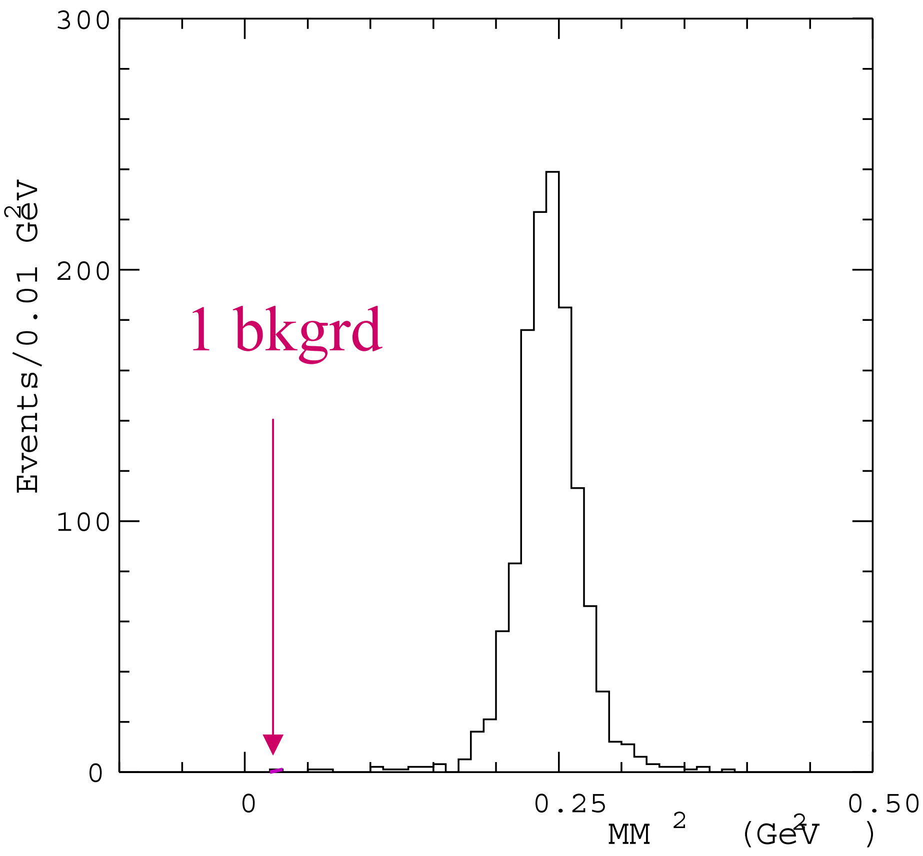
Backgrounds: $D^+ \to \tau^+ \nu$, $\tau^+ \to \pi^+ \nu$

- Because D^+ is nearly at rest can get some very fast π^+.
- $\mathcal{B}$ is 2.65 x $\mathcal{B}(D^+ \to \mu^+ \nu)$
- Background is calculated via MC with small error, 0.2 events for 57 pb^{-1} and 1.08 events for 280 pb^{-1}



Backgrounds: tail of $D^+ \to K^o \pi^+$

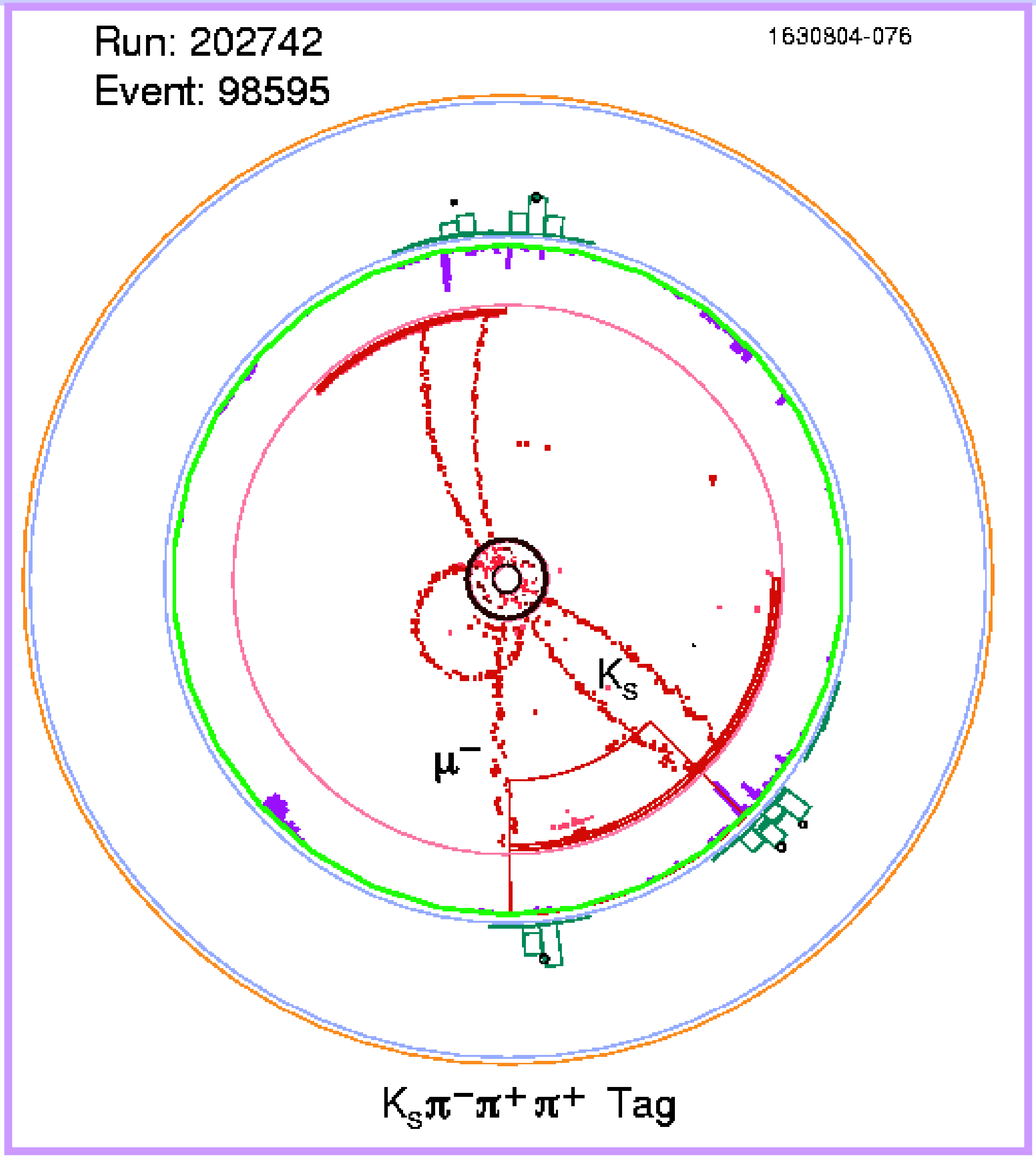
- Two methods
  - Monte Carlo: Simulation gives 0.44±0.22 events for 280 fb^{-1}
  - Measurement using double tag events with one $D^o \to K^- \pi^+$ gives 0.44±0.44 events for 280 fb^{-1}



Other Backgrounds

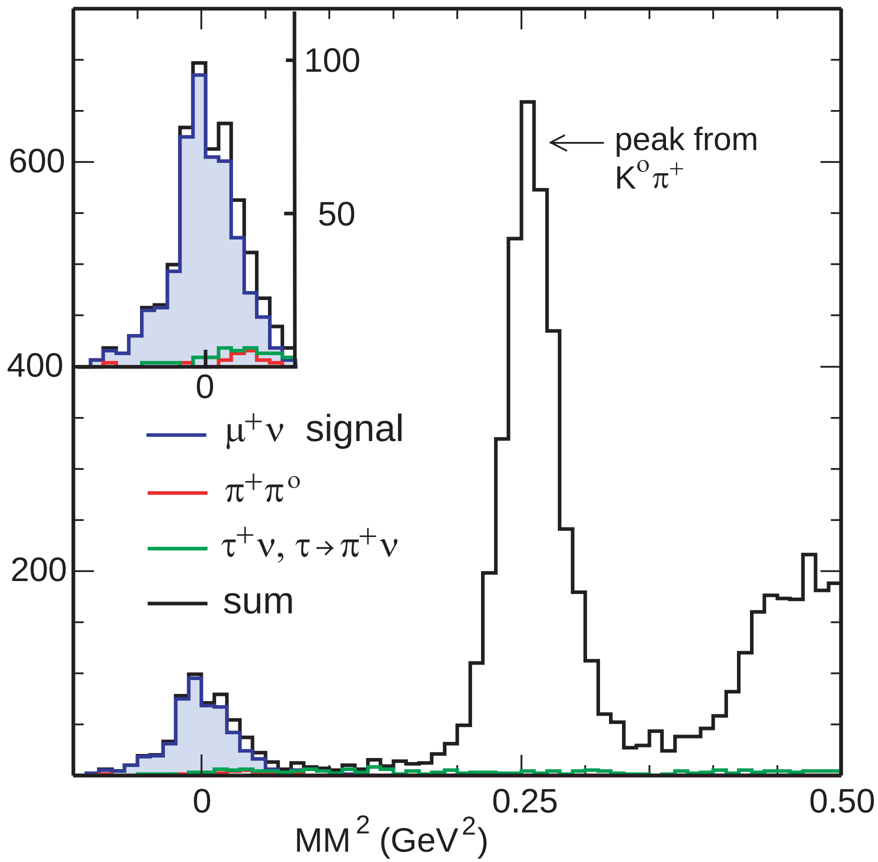
- Simulate:
- Continuum sample 540 pb^{-1} gives 0 events
- $D^o\overline{D}^o$ sample 540 pb^{-1} gives 0 events
- D^+D^- 1700 pb^{-1} gives 0 events, other than the 3 modes we have already considered.

One $D^+ \rightarrow \mu^+ \nu$ Candidate

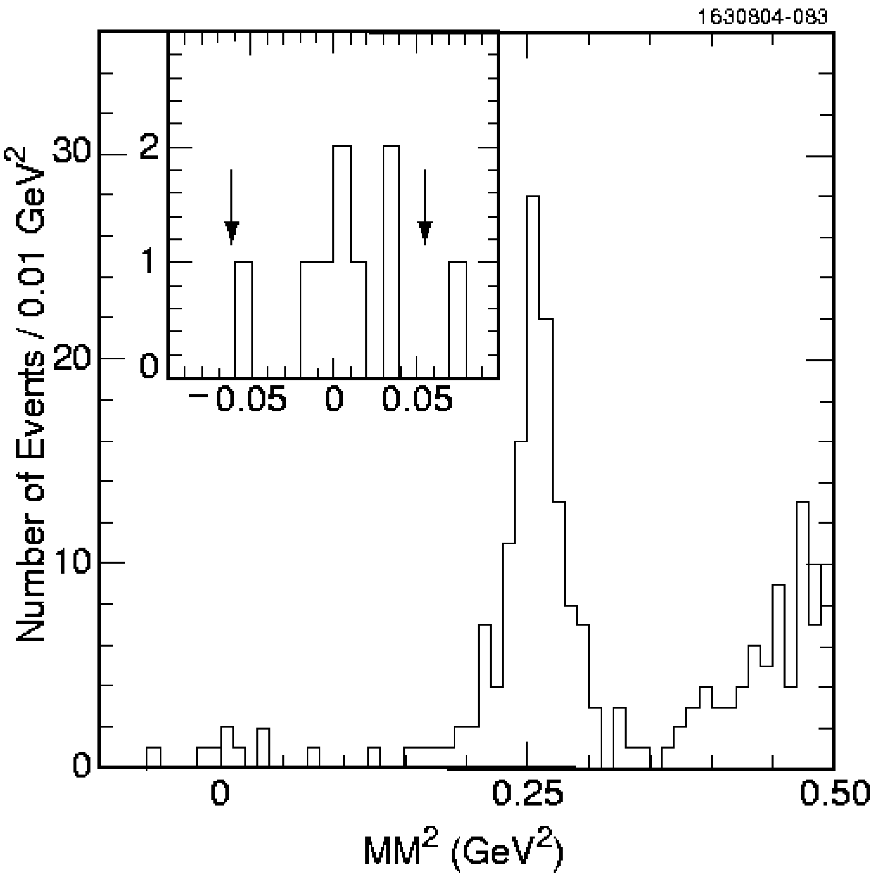


Measurement of f_{D^+}

MC Expectations from 1.7 fb^{-1}, 30 X this sample



Data show 8 events in the signal region in 57 pb^{-1}



CESR CLEO

Deriving a Value for f_{D^+}

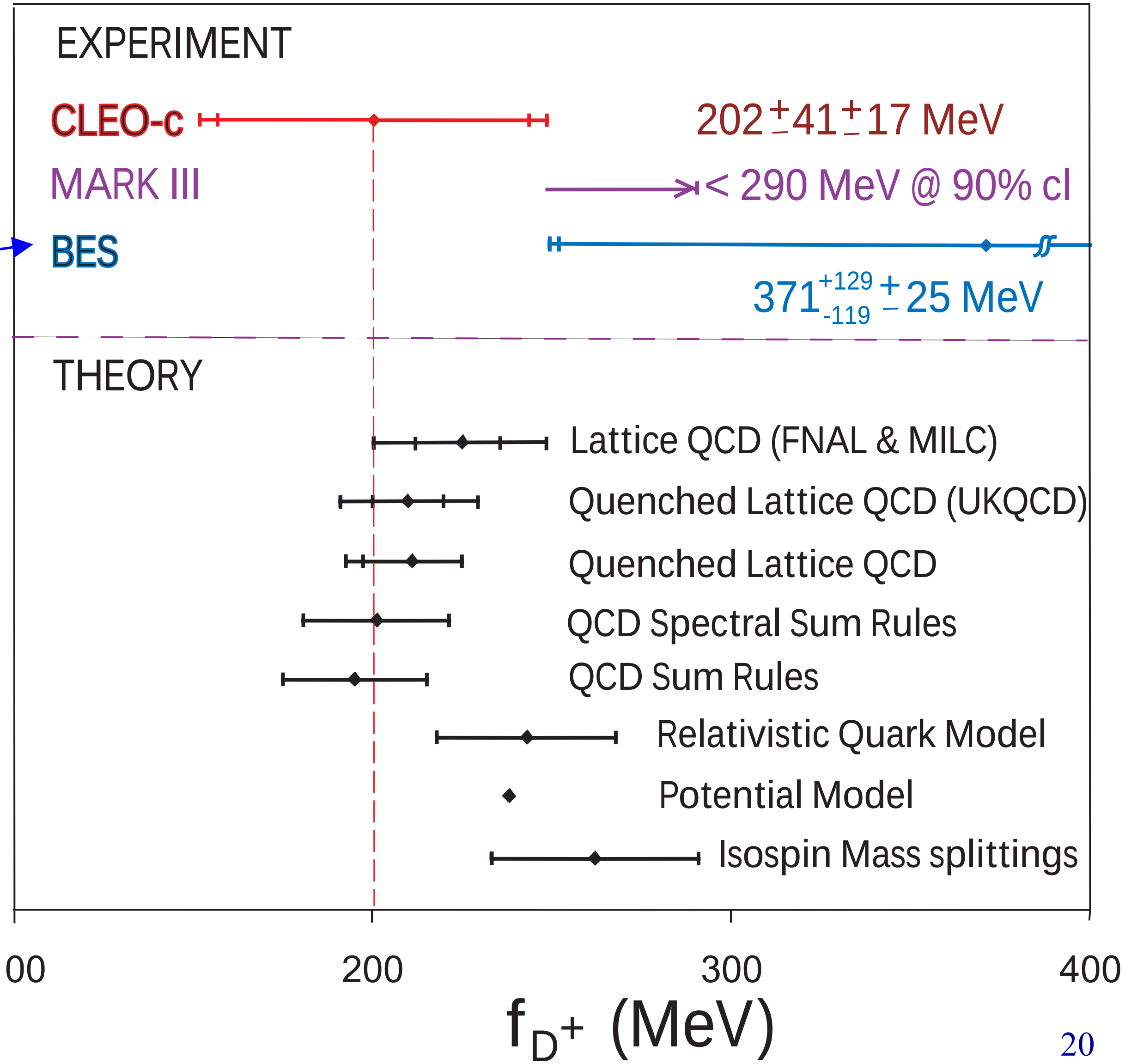
For 57 pb^{-1}

Backgrounds		
Mode	$\mathcal{B}$(%)	# Events
$\pi^+\pi^0$	0.13±0.02	0.31±0.04
$K^0\pi^+$	2.77±0.18	0.06±0.05
$\tau^+\nu$ ($\tau \rightarrow \pi^+\nu$)	2.64*$\mathcal{B}(D^+ \rightarrow \mu^+\nu)$	0.30 ±0.07
$\pi^0\mu^+\nu$	0.25 ±0.15	negligible
Continuum	(old estimate)	0.33 ± 0.23
Total		1.00±0.25

- Tags are 28,575 events, ε= 69.9%
- $\mathcal{B}(D^+ \rightarrow \mu^+\nu)$ =(3.5±1.4±0.6)x10^{-4}
- f_{D^+} = (202±41±17) MeV
- No $D^+ \rightarrow e^+\nu$ events seen

Comparison to Theory

- CLEO-c measurement – 8 events
- BES measurement based on 2.67±1.74 events
- Current Lattice measurement (unquenched light flavors) is consistent
- But errors on theory & data are still large



Systematic Errors (Current)

	Systematic errors (%)
MC statistics	0.4
Track finding	0.7
PID cut	1.0
MM^2 width	1.0
Minimum ionization cut	1.0
Number of tags	0.3
Extra showers cut	0.6
Total	2.0

Much smaller than statistical errors

New Data

- Now have ~50 events in peak around $MM^2=0$
- New value will be announced at Lepton-Photon conference in Artuso's talk. Error will be $\pm 16^{+9}_{-7}$ MeV
- New Unquenched Lattice result to also appear
- Thus we will have an interesting comparison