D^o mixing at CLEO-II

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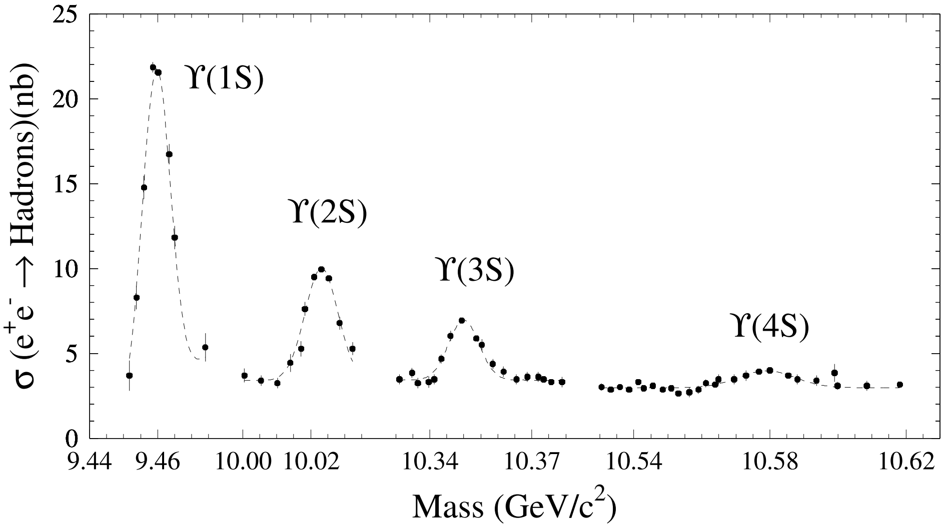
for the CLEO Collaboration

Outline:

- Detector Overview
- Silicon Vertex Detector
- D^o mixing

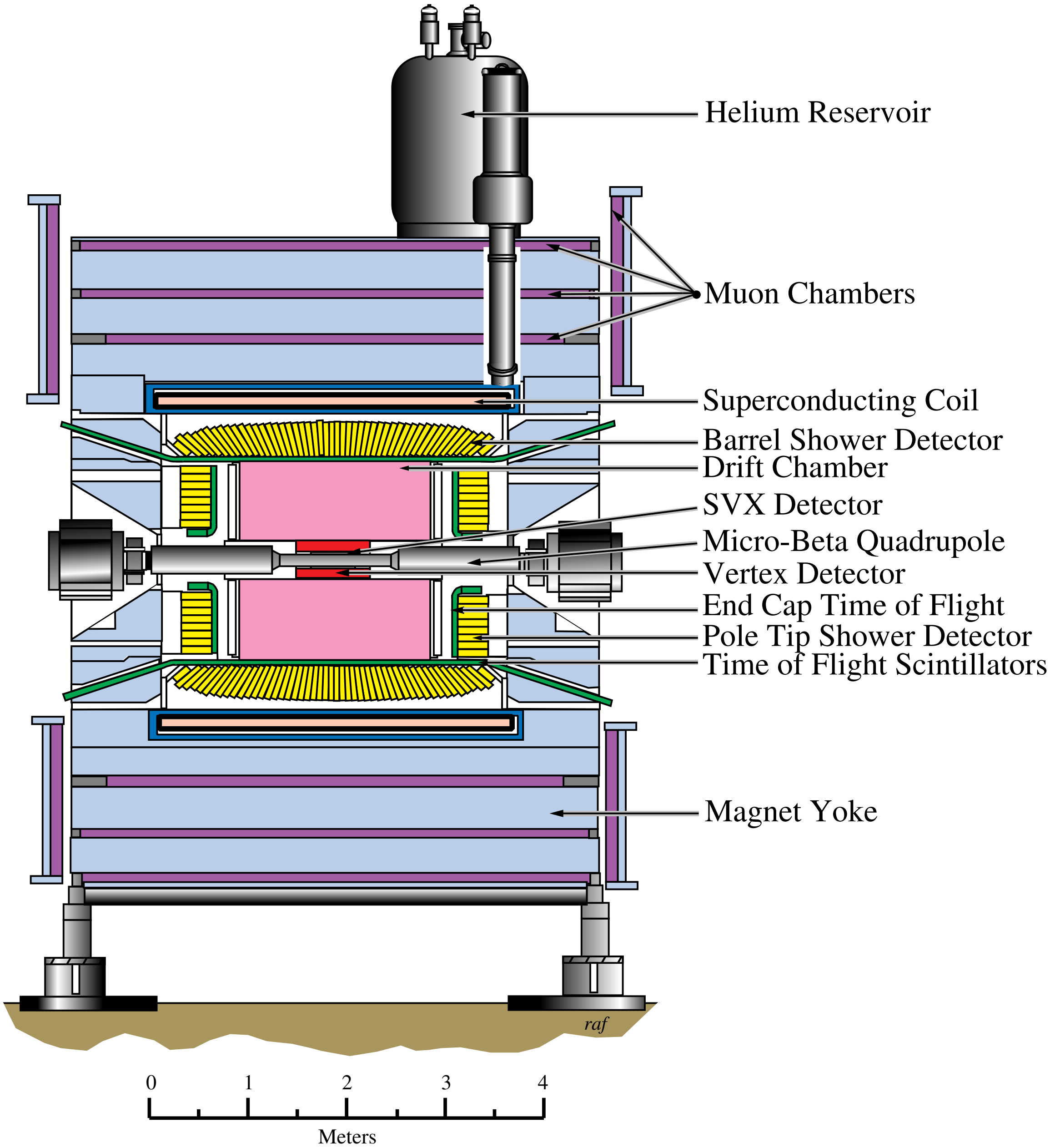
CESR - Cornell Electron Storage Ring

e^+e^- collider - $L_{\text{peak}} \sim 7.0 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$ at the $\Upsilon(4S)$

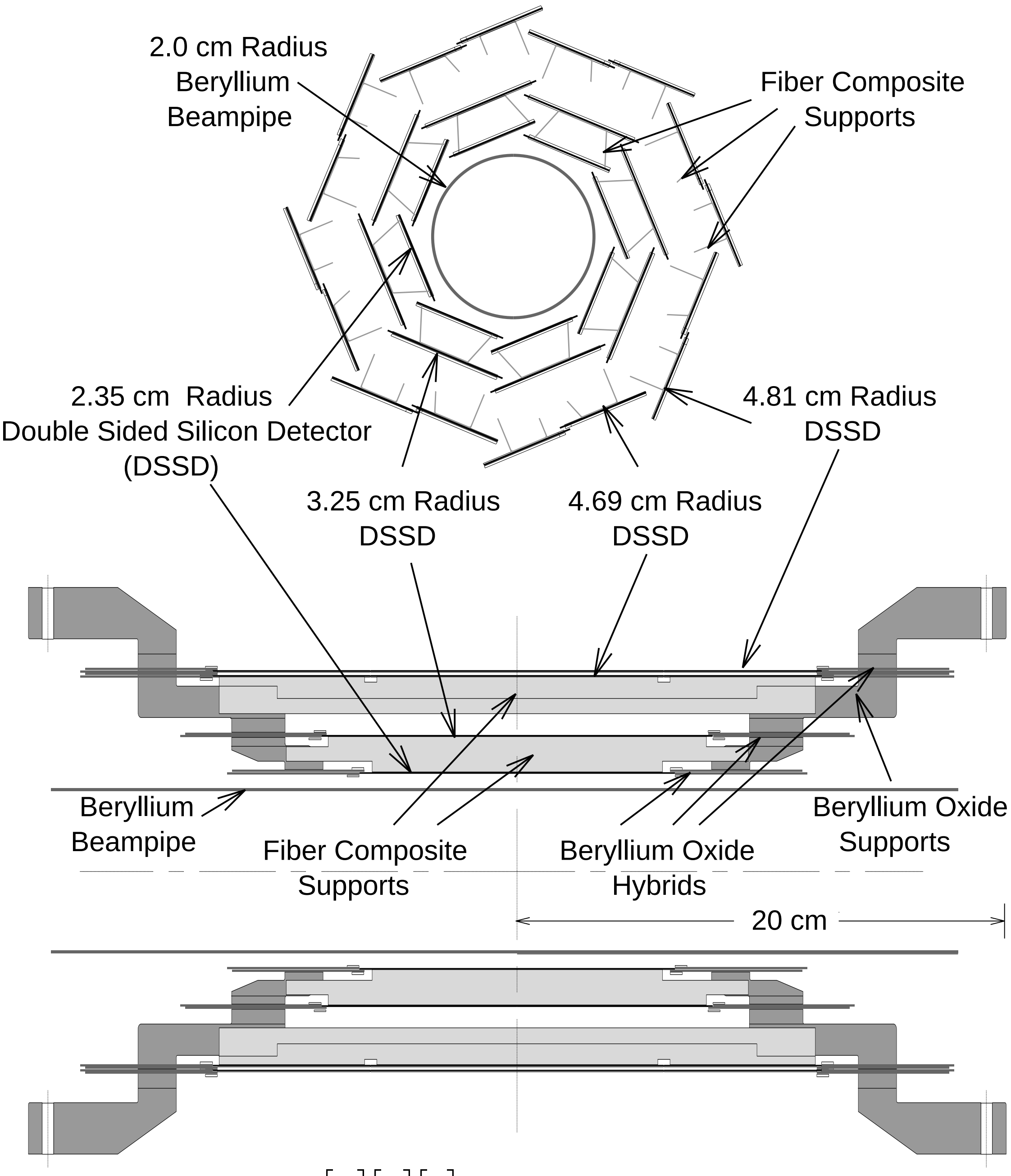


Operating point:	$\int L$ fb^{-1}	
	CLEO II (pre SVX)	CLEO II.V (w/SVX)
$\Upsilon(4S)$	3.1	5.6
Continuum	1.6	2.4

CLEO-II detector

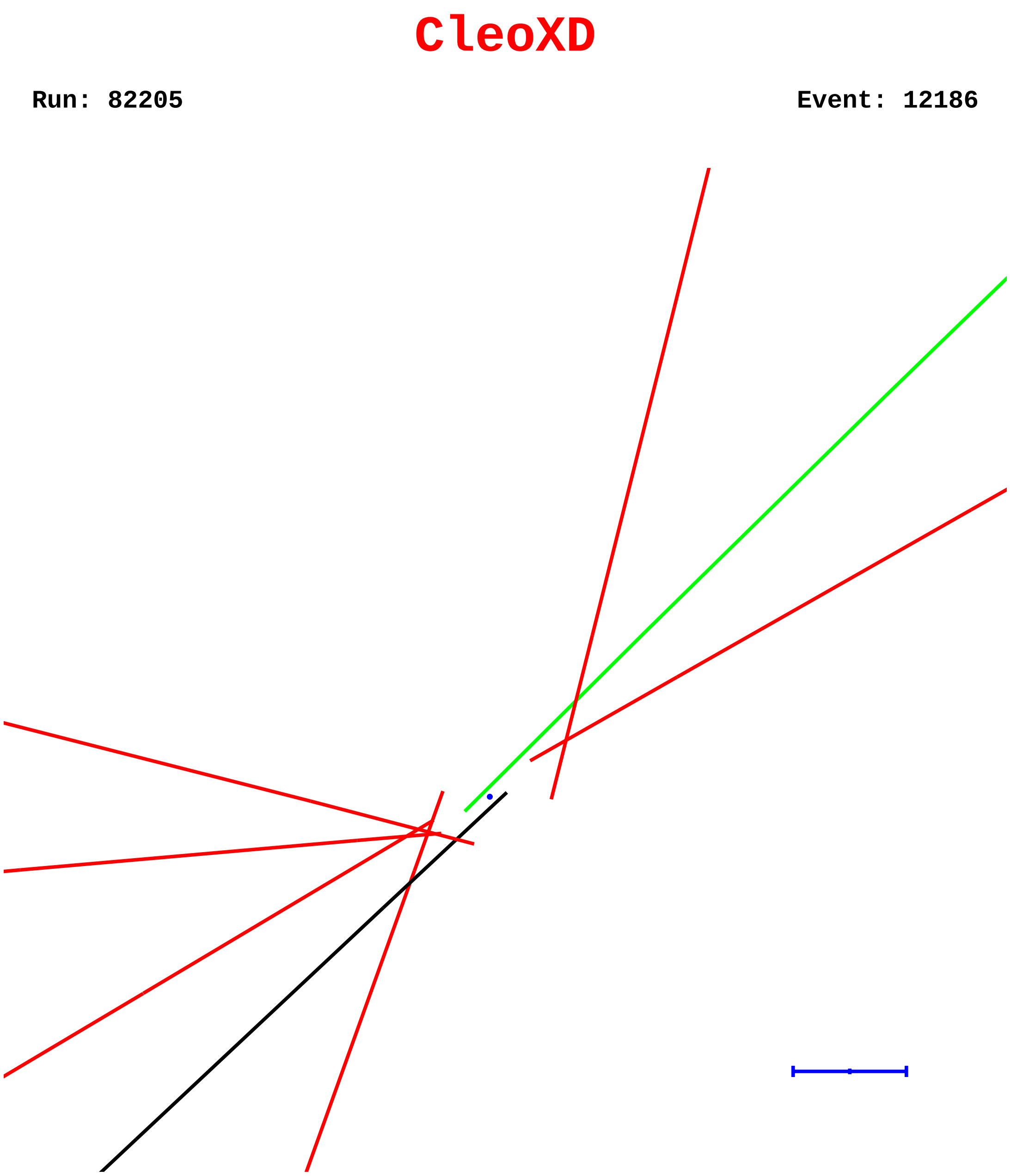


CLEO-II Silicon Vertex Detector



$\begin{bmatrix} u \\ \end{bmatrix}\begin{bmatrix} c \\ s \end{bmatrix}\begin{bmatrix} \\ b \end{bmatrix}$ *High Energy Physics*

CLEO II Up Close



The lower left vertex is the D^0 decay, the upper right vertex is the D^0 decay from the $D^{*+} \to D^0\pi$ decay where the slow π is the green track, the black track is a fragmentation track. The blue scale is $1\,mm$.

D^o mixing

$$\mathrm{R}_{\mathrm{mixing}} = \frac{\mathcal{B}(D^o \to \overline{D}^o \to \overline{f})}{\mathcal{B}(D^o \to f)}$$

- Expected to be small in the standard model, 10^{-7} to 10^{-3}
- If mixing is anomalously large it is a signal of new physics

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Two kinds of mixing

$\Delta\Gamma$ mixing

Proceeds through ordinary intermediate states

not particularly interesting

$$\mathbf{D}^o \rightleftarrows \boxed{\begin{array}{l}\text{Box diagrams}\\ \pi\pi,\text{KK},\ldots\end{array}} \rightleftarrows \overline{\mathbf{D}}^o$$

$$y = \frac{\Delta\Gamma}{2\Gamma}$$

ΔM mixing

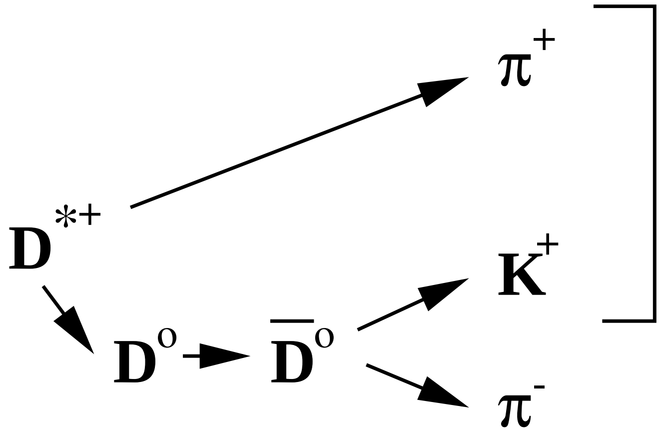
Signature of new physics

$$\mathbf{D}^o \rightleftarrows \boxed{\begin{array}{l}\text{SUSY,etc...}\\ \text{New Physics}\end{array}} \rightleftarrows \overline{\mathbf{D}}^o$$

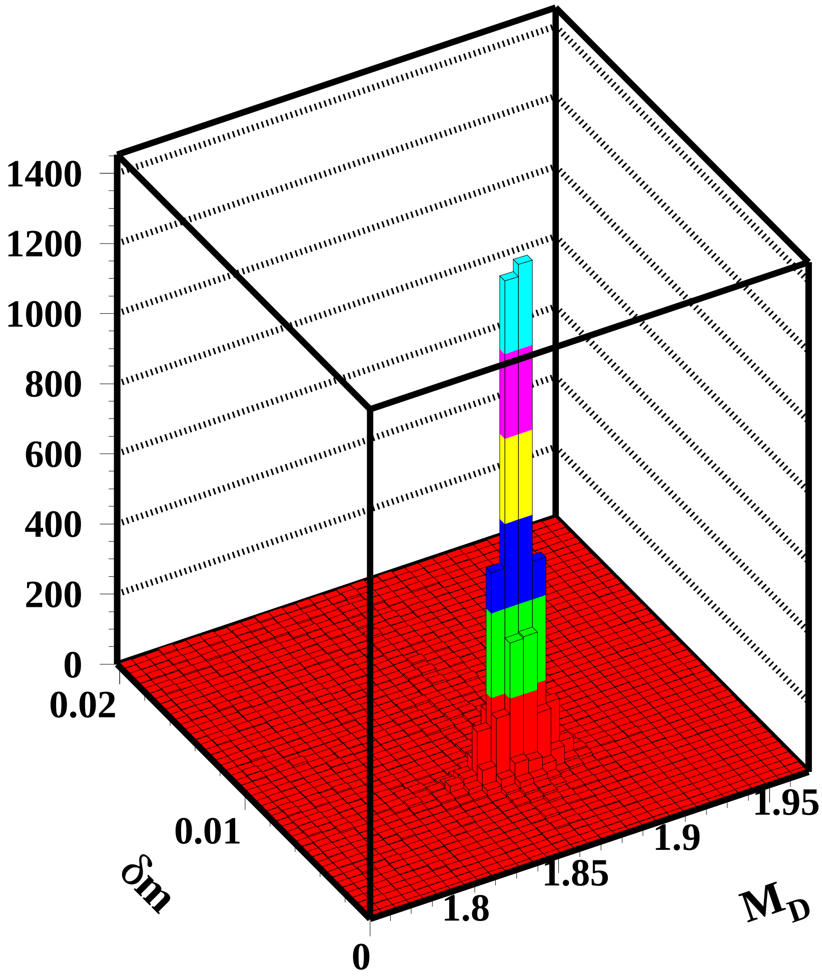
$$x = \frac{\Delta M}{\Gamma}$$

$$\mathrm{R}_{\mathrm{mixing}} = \frac{x^2+y^2}{2} \qquad \tan(\phi) = -2\frac{\Delta M}{\Delta\Gamma}$$

Experimental signature



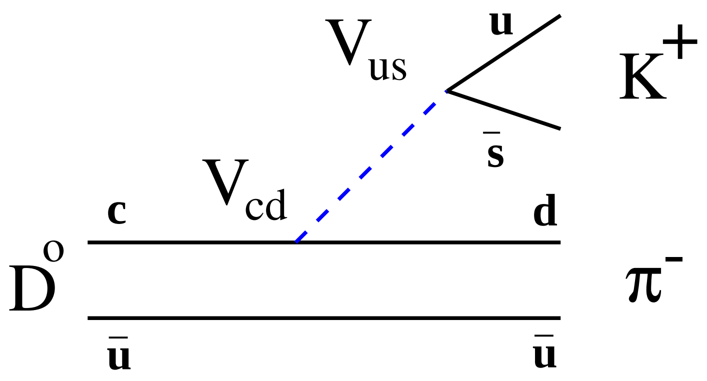
Wrong Sign
Mixing



- 3 charged tracks
- combine 2 to form D^o
- add slow pion to D^o to form D^{*+}

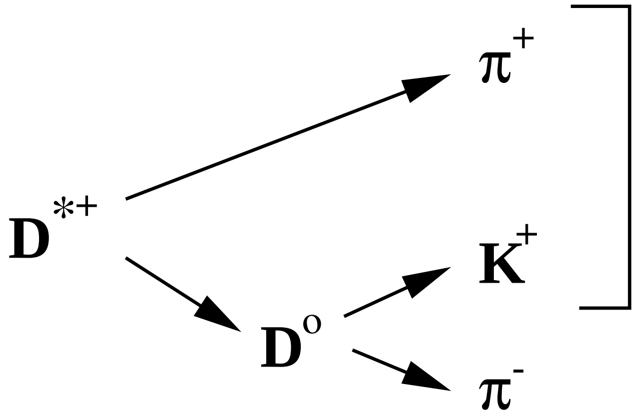
Additional Problem!

Doubly Cabbibo suppressed decays



$$\frac{\mathcal{B}\left(D^o \to \overline{f}\right)}{\mathcal{B}(D^o \to f)} \propto \tan^4 \theta_c$$

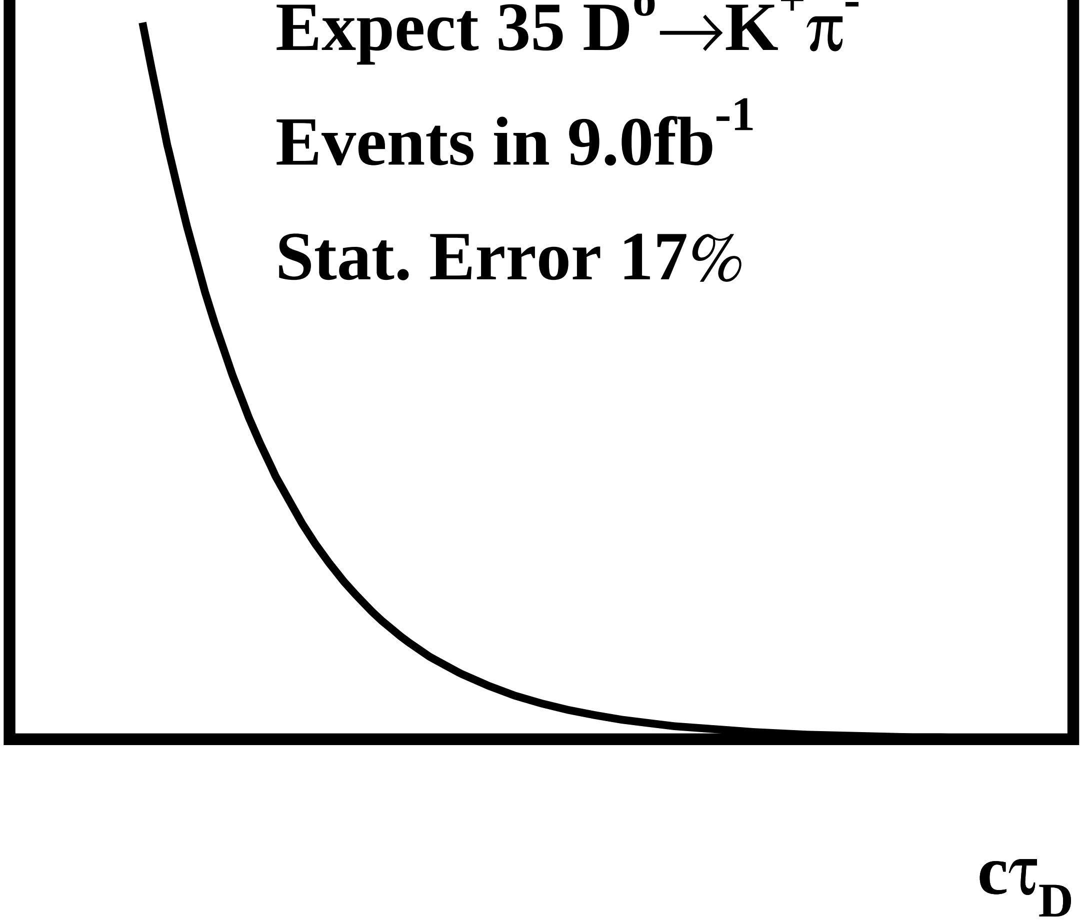
$$\mathcal{B}\left(D^o \to \overline{f}\right) >$$
$$\mathcal{B}\left(D^o \to \overline{D}^o \to \overline{f}\right)$$

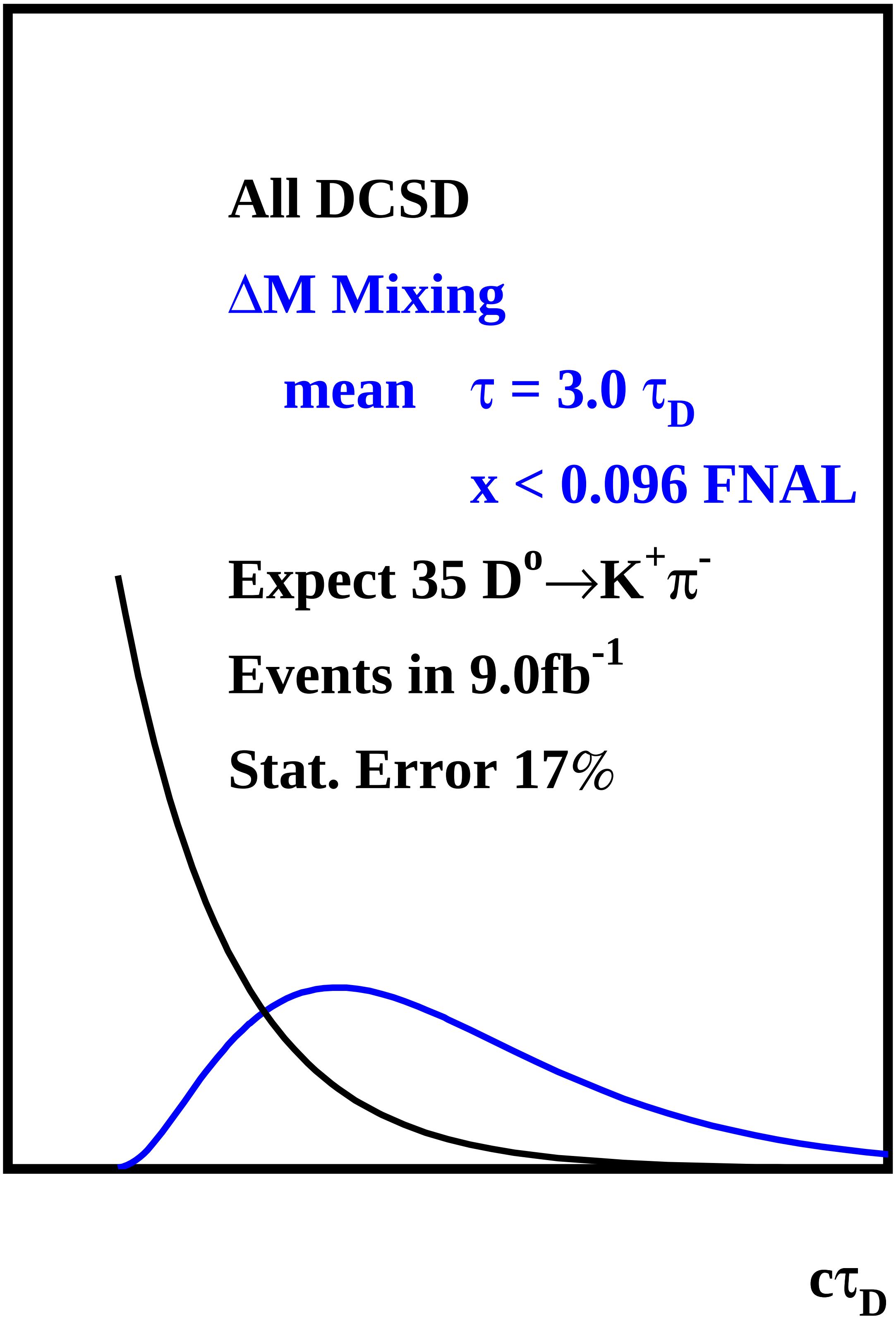


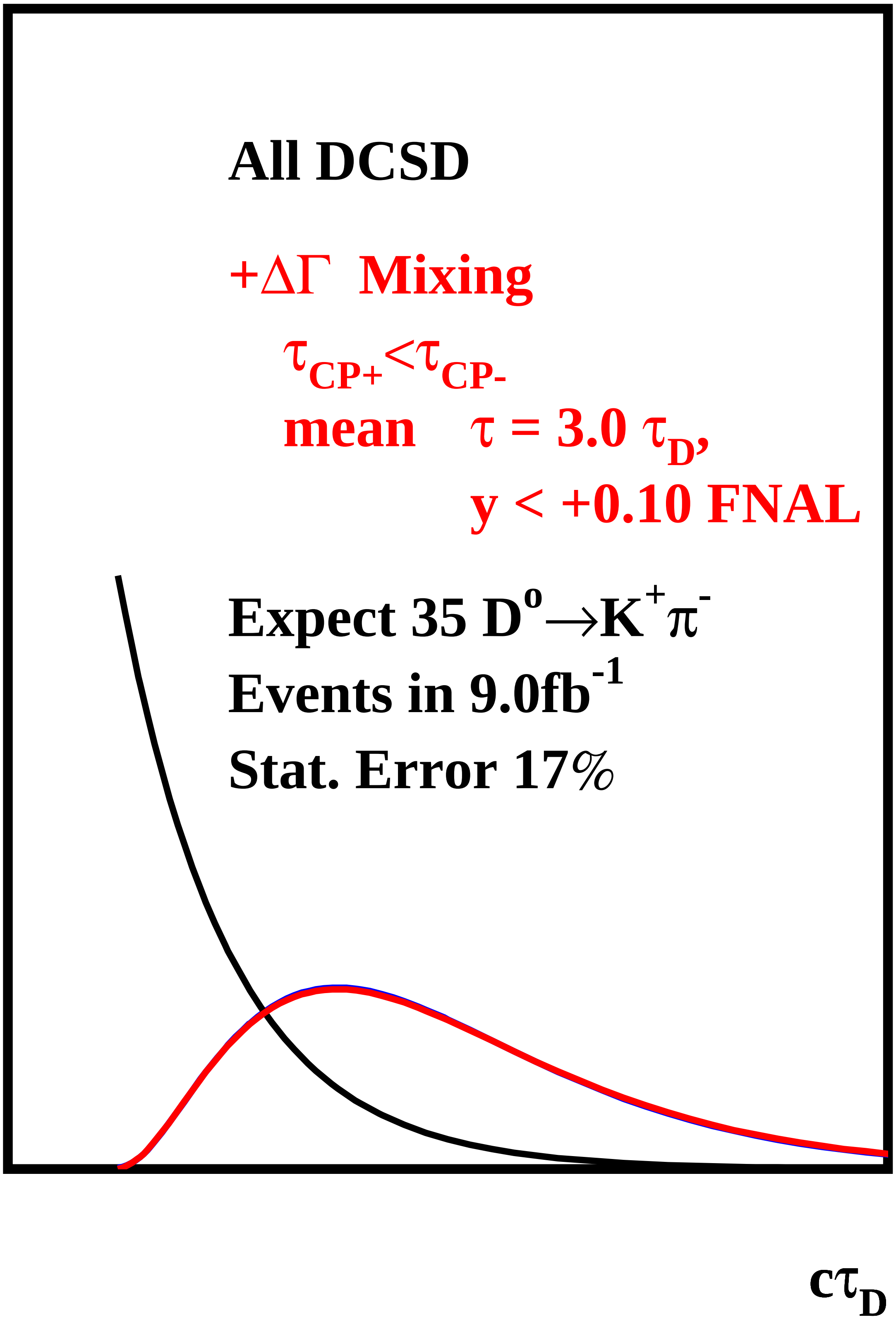
Wrong Sign
DCSD Decay

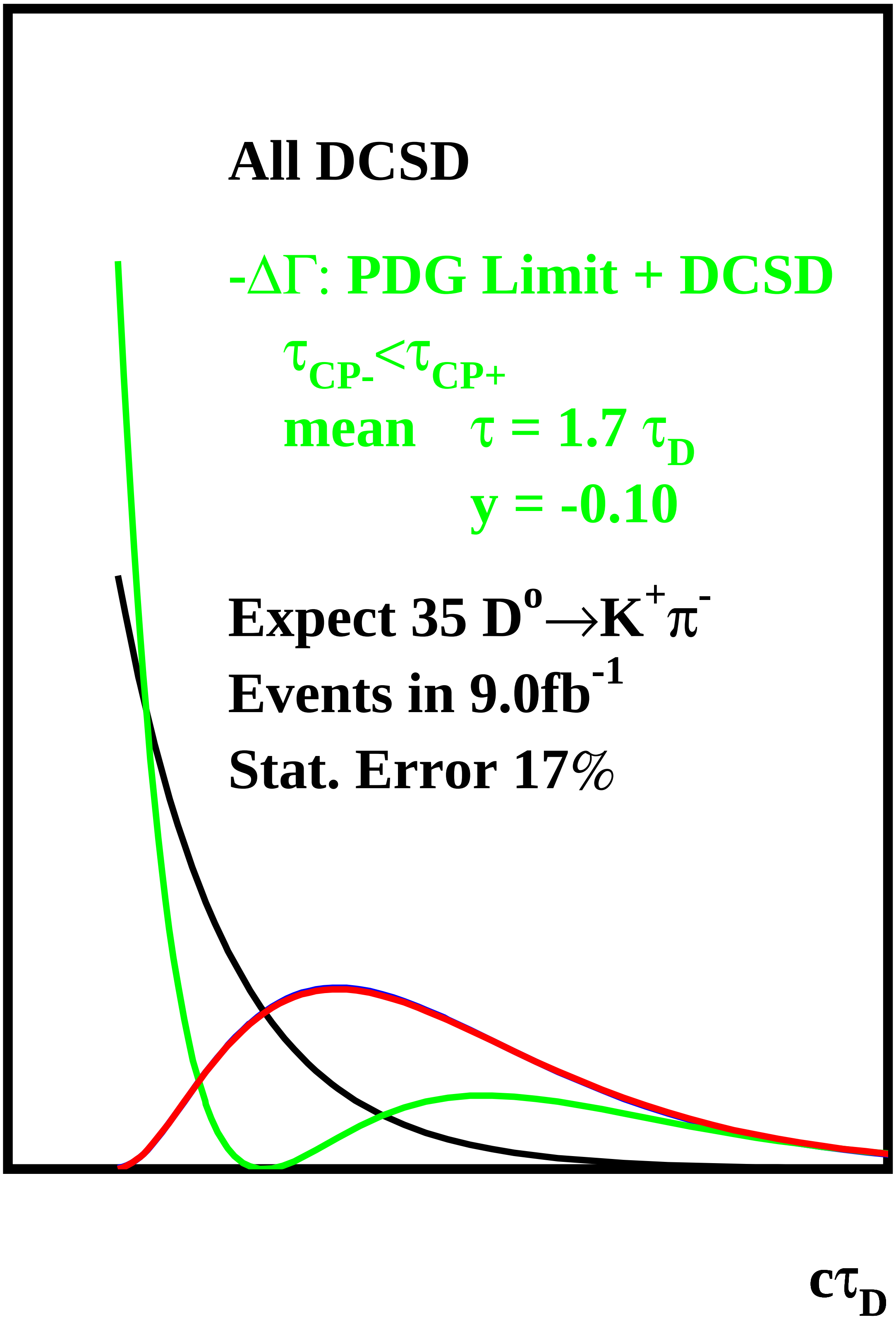
Mixing and DCSD have the same signature
How do we separate $\Delta\Gamma$,ΔM and DCSD?

All DCSD




All DCSD
ΔM Mixing
mean $\tau = 3.0\ \tau_D$
$x < 0.096$ FNAL
Expect 35 $D^o \rightarrow K^+\pi^-$
Events in $9.0 fb^{-1}$
Stat. Error 17%
$c\tau_D$

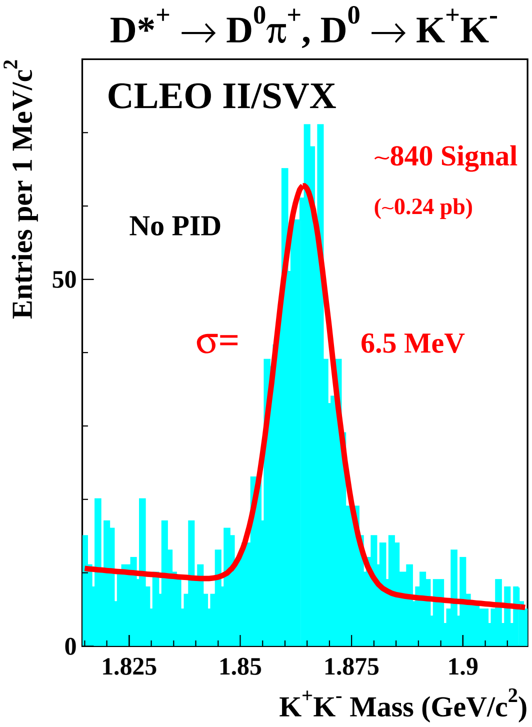

All DCSD
+ΔΓ Mixing
$\tau_{CP+} < \tau_{CP-}$
mean $\tau = 3.0\ \tau_D$,
$y < +0.10$ FNAL
Expect 35 $D^0 \rightarrow K^+\pi^-$
Events in $9.0 fb^{-1}$
Stat. Error 17%
$c\tau_D$

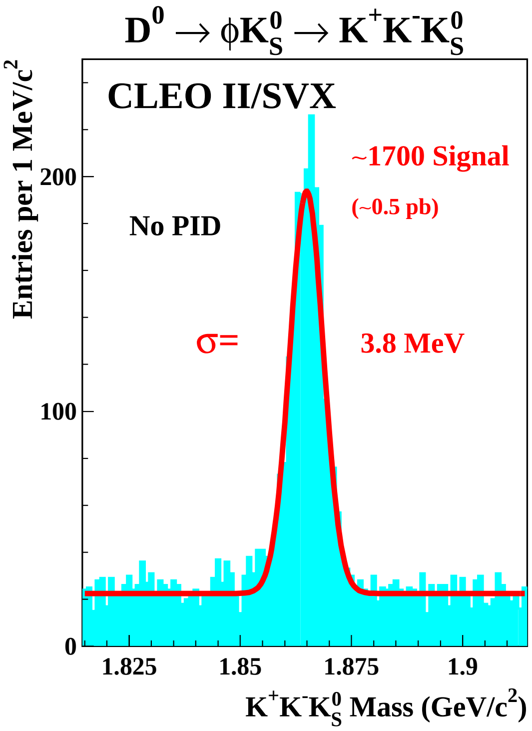

All DCSD
-ΔΓ: PDG Limit + DCSD
$\tau_{CP-} < \tau_{CP+}$
mean $\tau = 1.7\ \tau_D$
$y = -0.10$
Expect 35 $D^o \rightarrow K^+\pi^-$
Events in $9.0 fb^{-1}$
Stat. Error 17%
$c\tau_D$

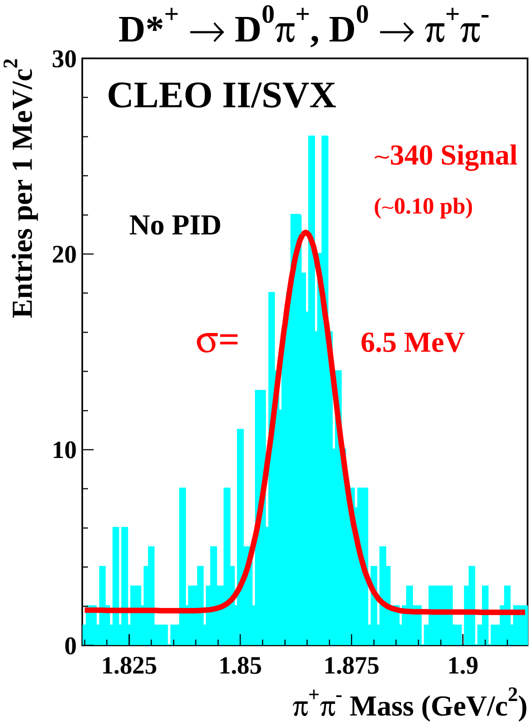
$\Delta\Gamma$ is straight-forward

CP odd

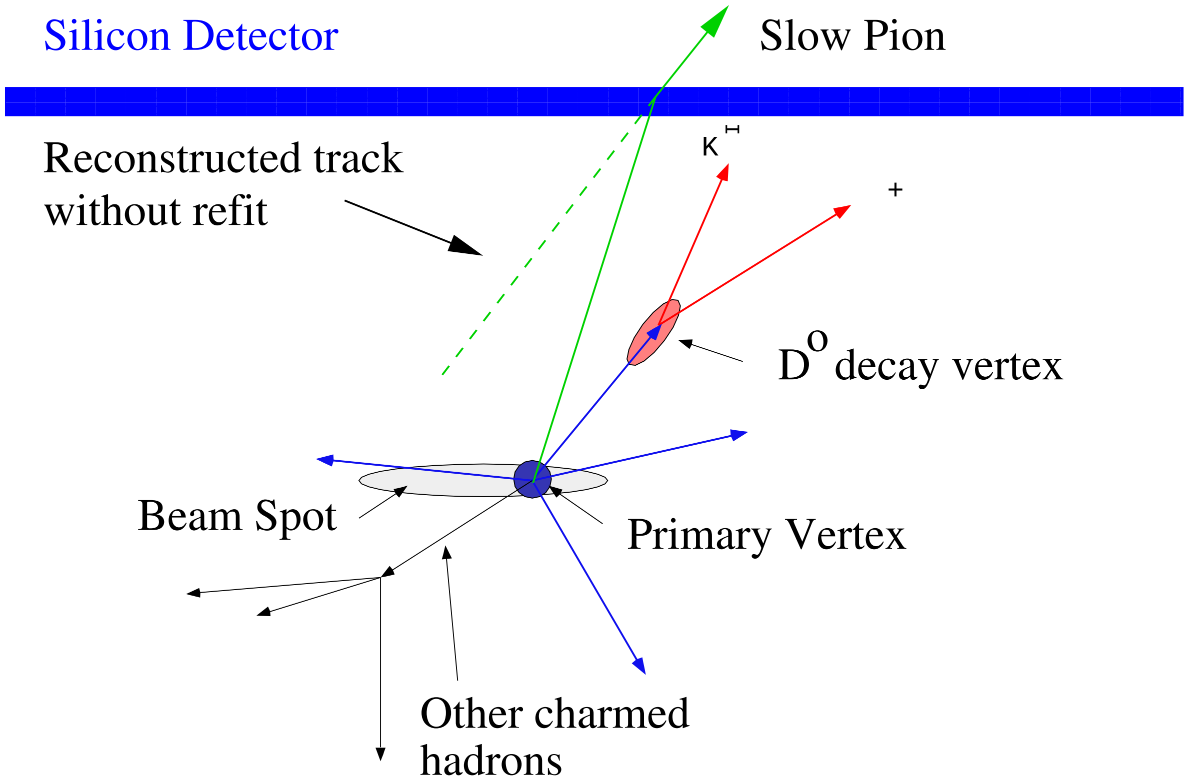
CP even

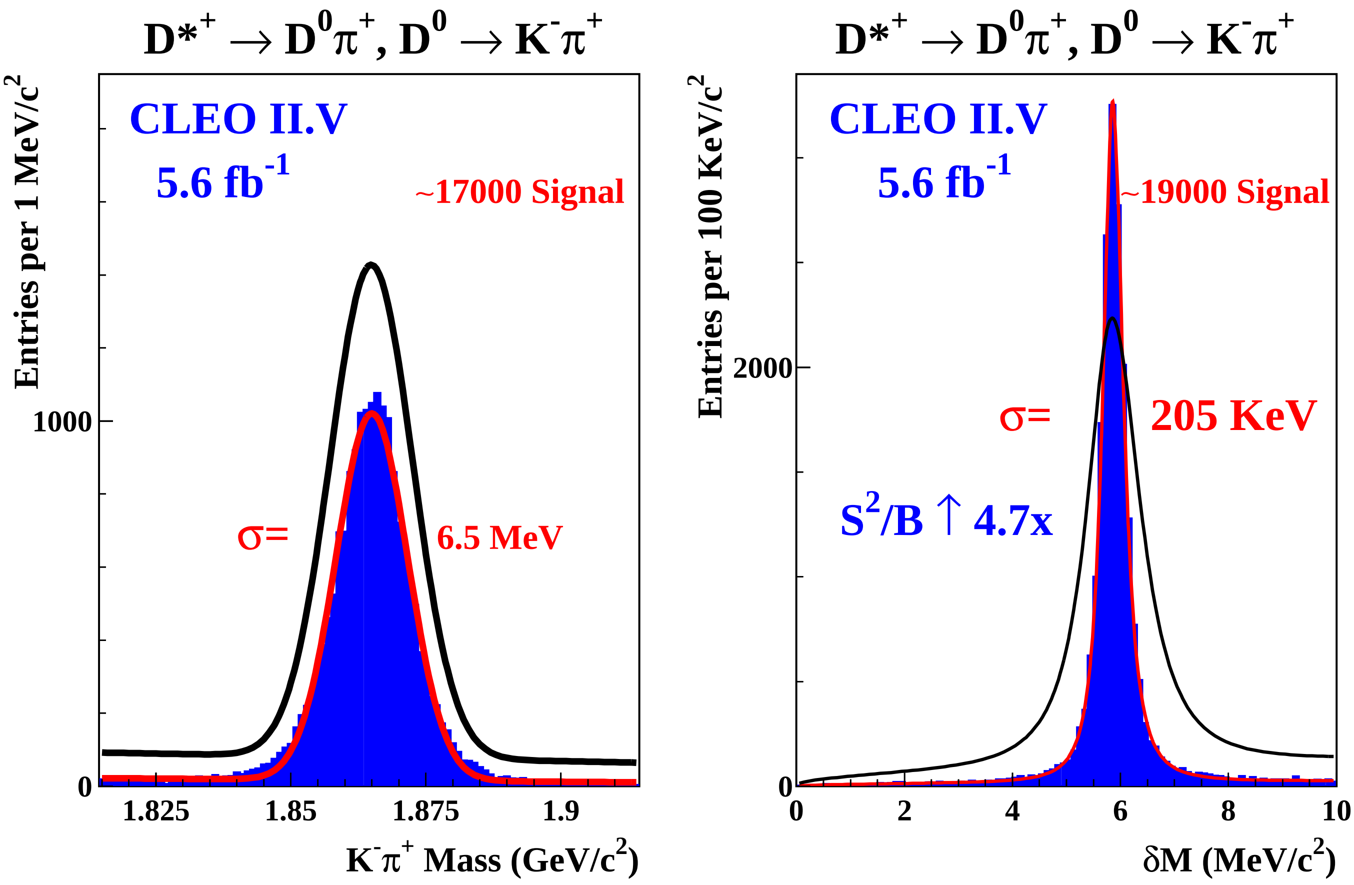




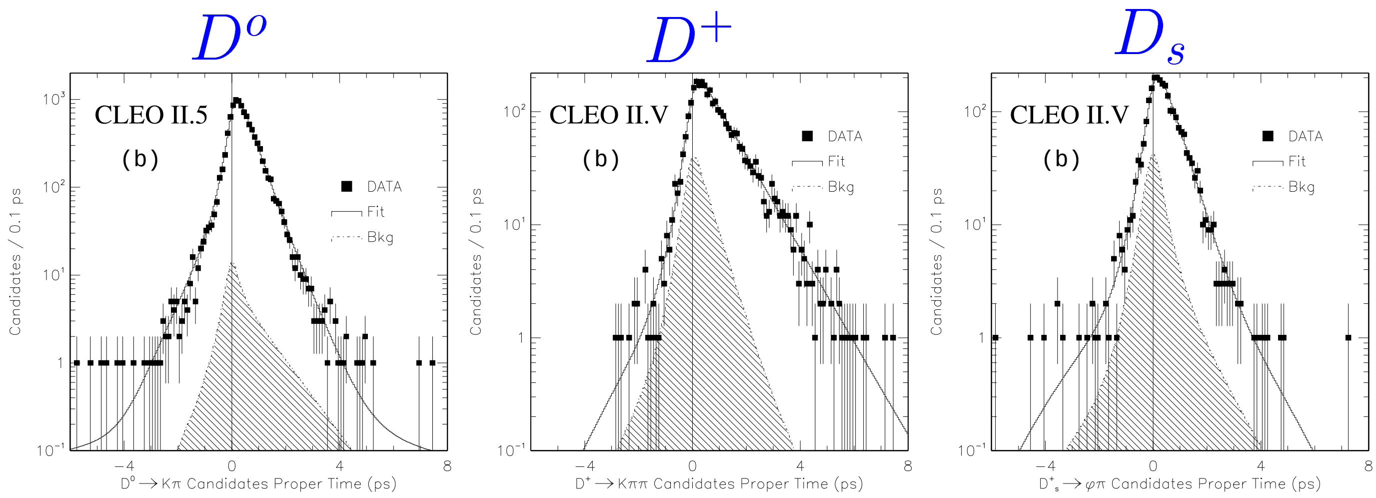


- Measure Γ in CP eigenstate decays
- Compute the difference in lifetimes
- E791 has done this analysis: (preliminary)
- $\Delta\Gamma/(2\Gamma) = -0.005 \pm 0.015$

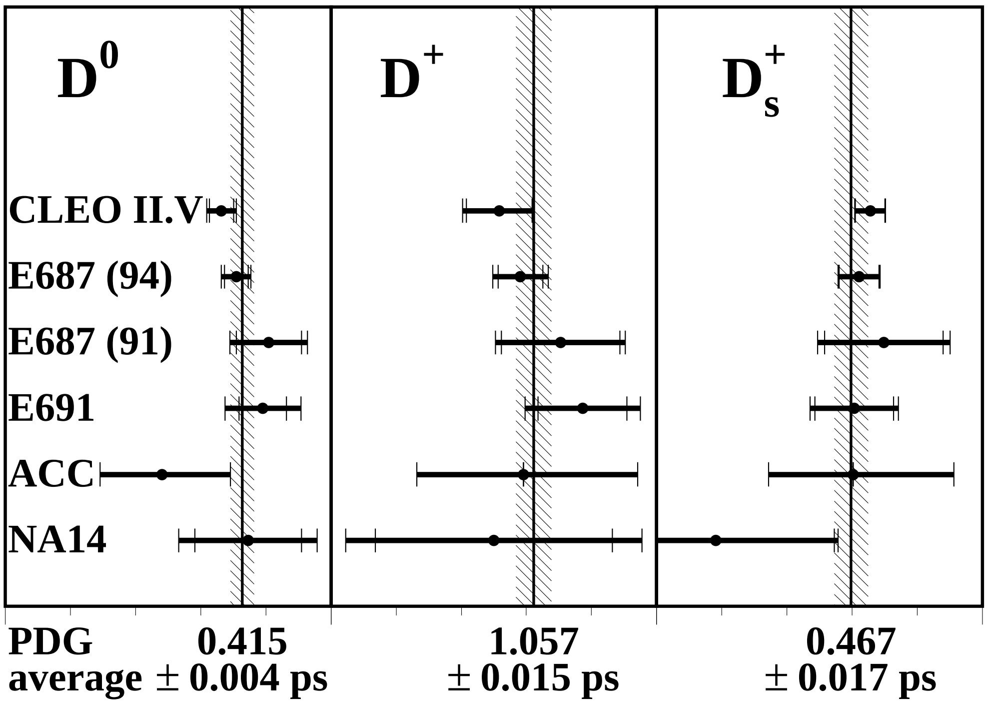

Silicon Detector
Slow Pion
Reconstructed track
without refit
K
+
D0 decay vertex
Beam Spot
Primary Vertex
Other charmed
hadrons


D*+ → D0π+, D0 → K-π+
CLEO II.V
5.6 fb-1
~17000 Signal
σ=
6.5 MeV
Entries per 1 MeV/c2
1000
0
1.825
1.85
1.875
1.9
K-π+ Mass (GeV/c2)
D*+ → D0π+, D0 → K-π+
CLEO II.V
5.6 fb-1
~19000 Signal
σ=
205 KeV
S2/B ↑ 4.7x
Entries per 100 KeV/c2
2000
0
0
2
4
6
8
10
δM (MeV/c2)

Lifetime Measurements (preliminary)



Using 3.7 fb^{-1} of CLEO II.V data:

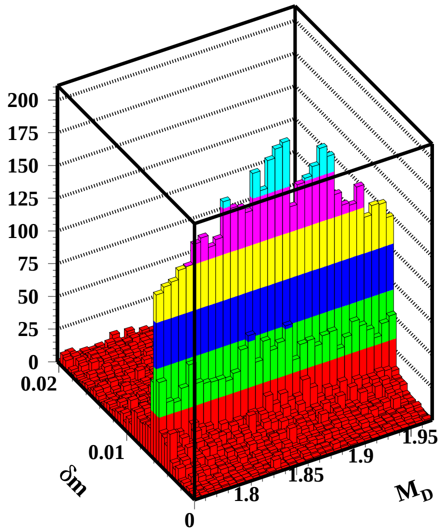


Presented by Sören Prell

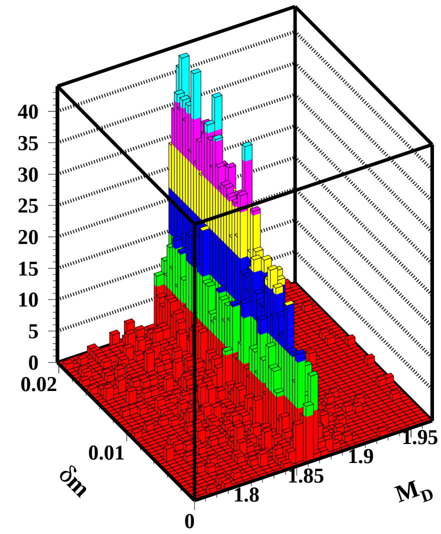
9:00 AM Thursday, Session 3C

Backgrounds

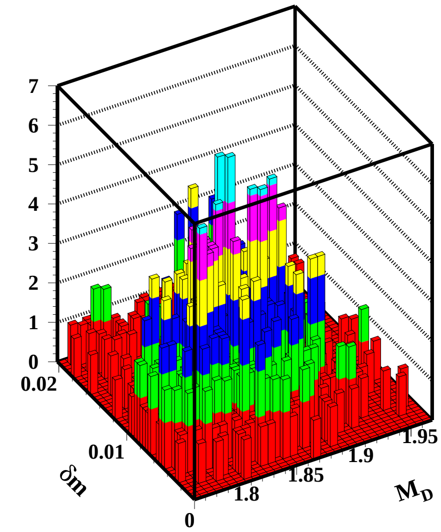
Right sign decay
$D^{*+} \rightarrow D^o\pi^+; D^o \rightarrow K^-\pi^+$
Mis-identify $K \leftrightarrow \pi$
Suppress with PID and Mass flip



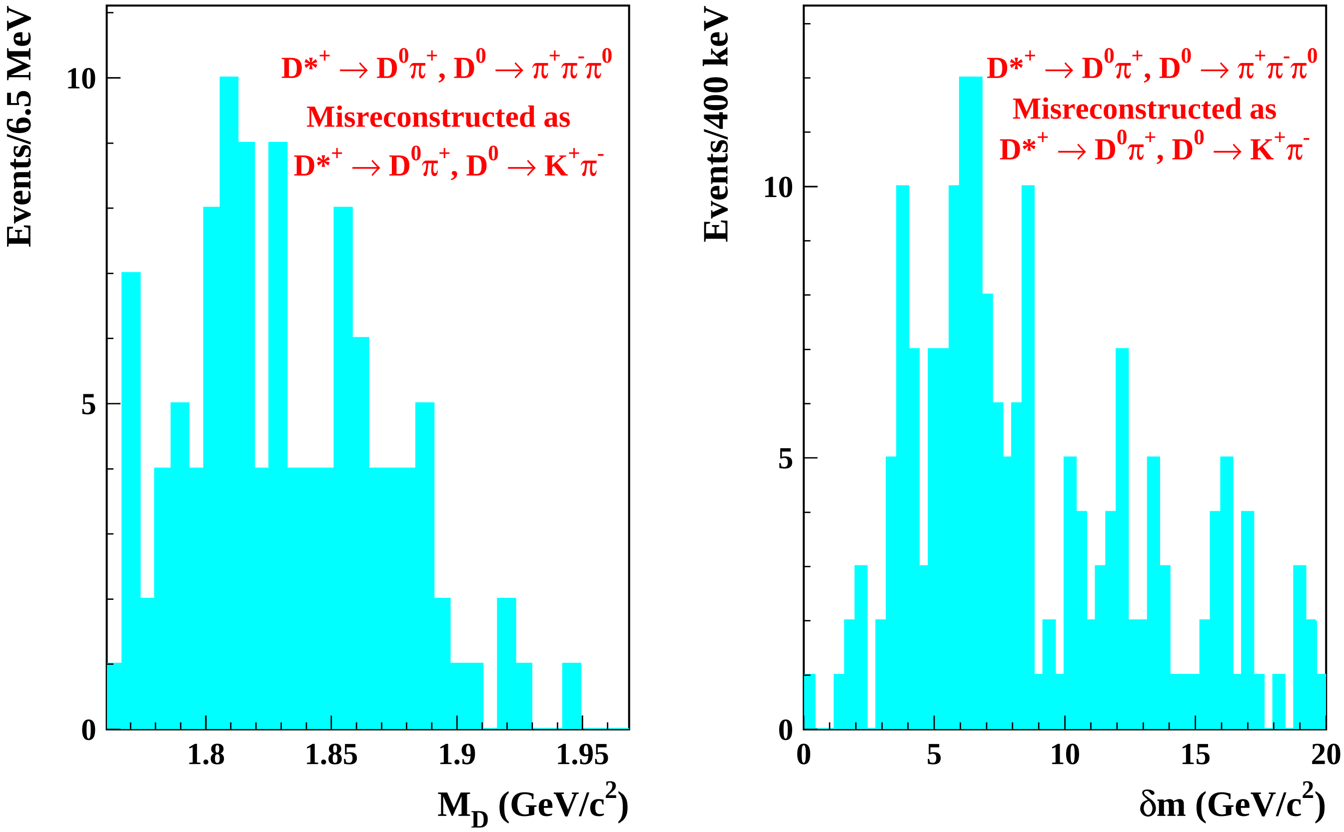
Real $D^o \rightarrow K^-\pi^+$ decay
Random slow pion
Extract from fit



Real $D^{*+} \rightarrow D^o\pi^+$ decay
$D^o \rightarrow \pi^-\pi^+\pi^0$
Lose the π^0 and mis-ID one of the π's
Suppress with PID

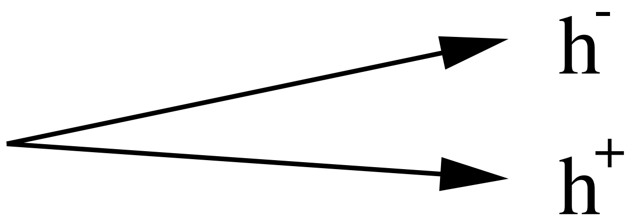


M_{D^o} and δM for $\pi^+\pi^-\pi^0$



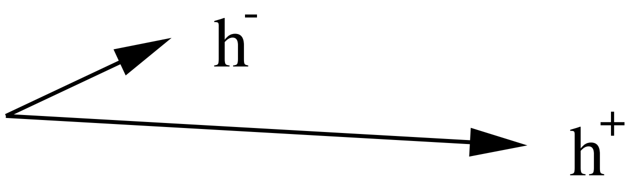
- This background peaks broadly in δM and lives around the D^o mass.
- It is dangerous but our good resolution allows us to deal with it.

Mass Flip



$$P_+ = P_-$$

$$M_{K^-\pi^+} = M_{K^+\pi^-}$$

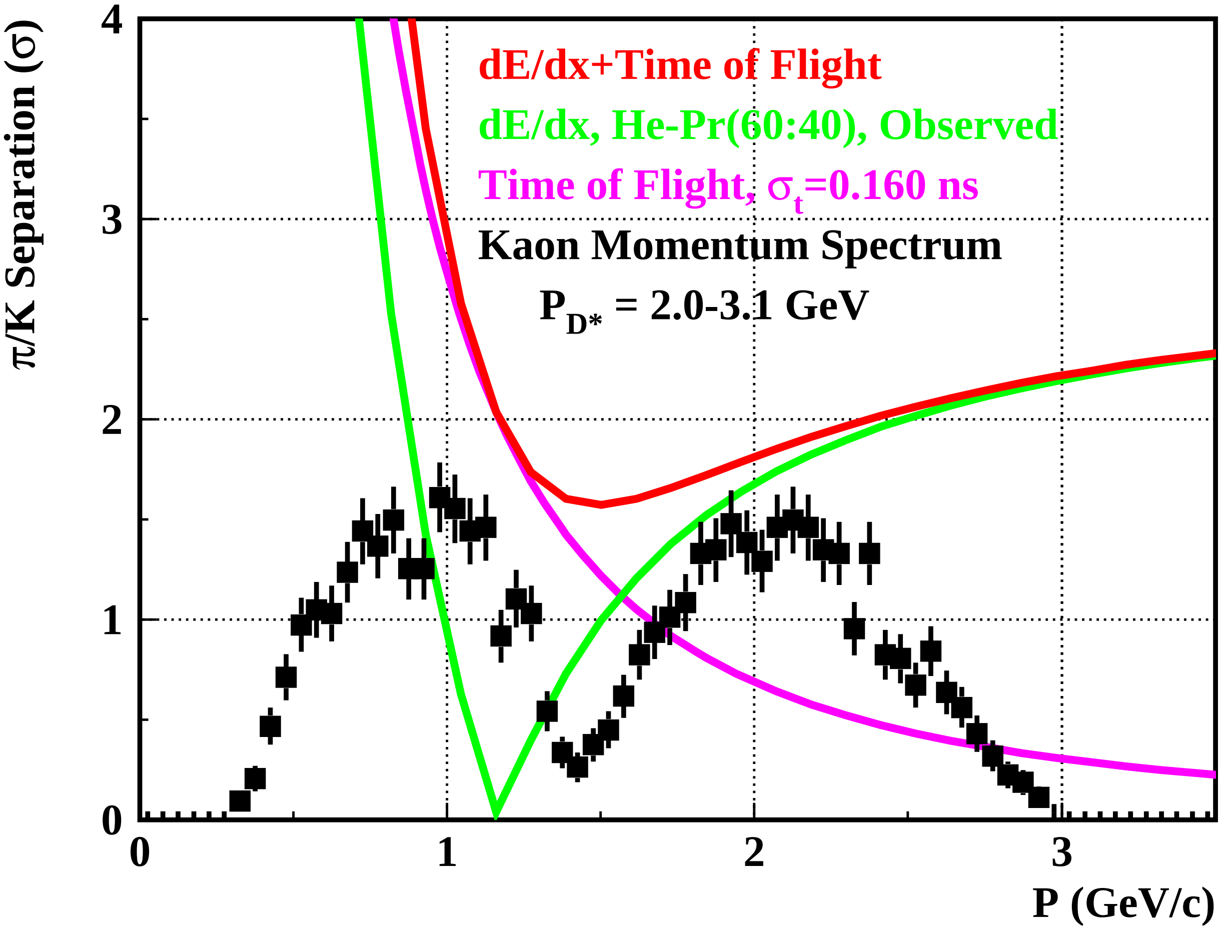


$$P_+ > P_-$$

$$M_{K^-\pi^+} > M_{K^+\pi^-}$$

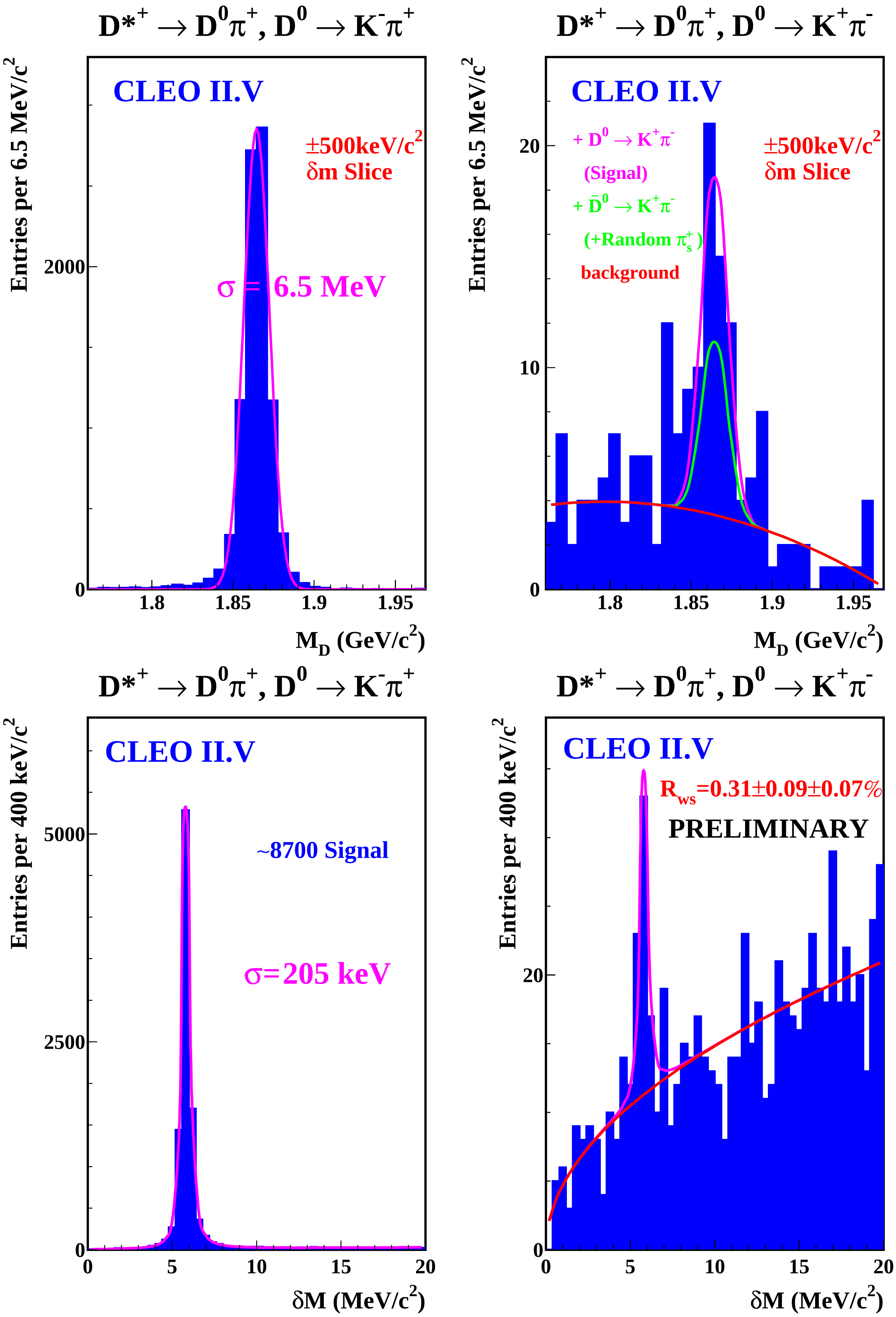
- require different kaon assignments to have diffent $M_{K\pi}$
- suppresses misidentified right sign decays

Particle ID

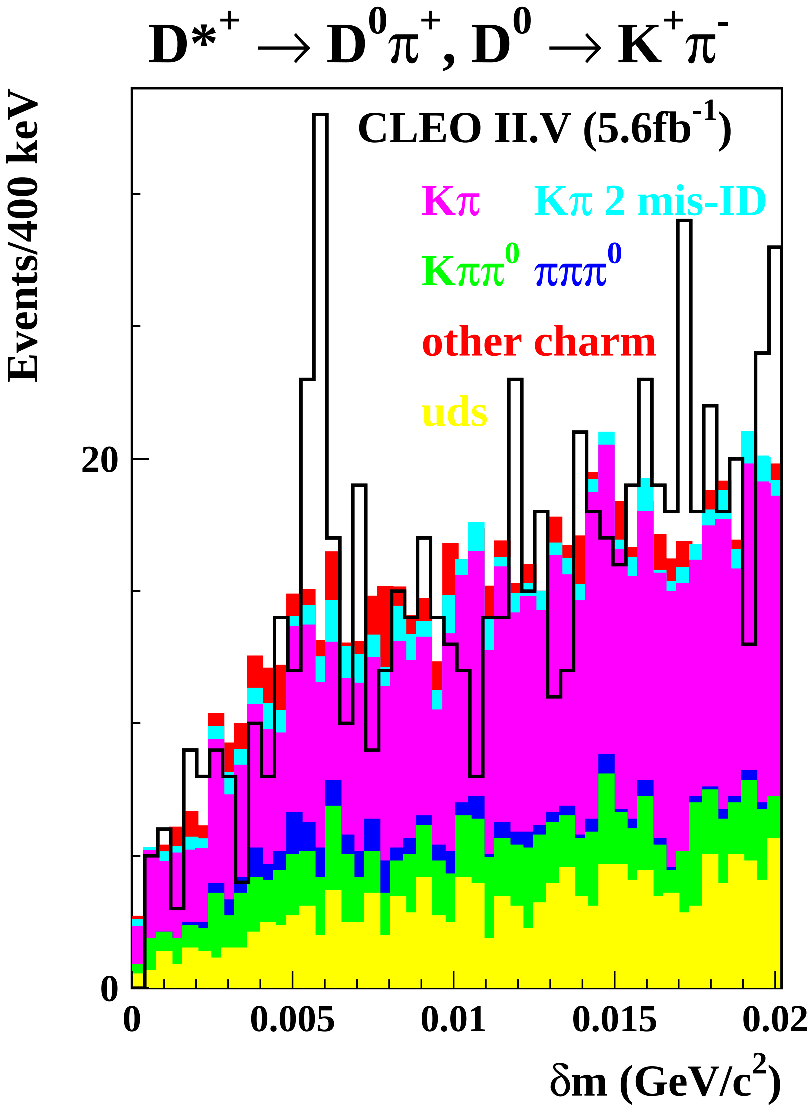


- We use both Time of Flight and DE/DX to identify particle species
- At crossover, where DEDX π/K separation is zero, the Time of Flight adds information.
- π/K separation is never worse than 1.5σ
- The mass flip cut selects events that fall outside the poor region

Right sign   Wrong sign



Fit Components

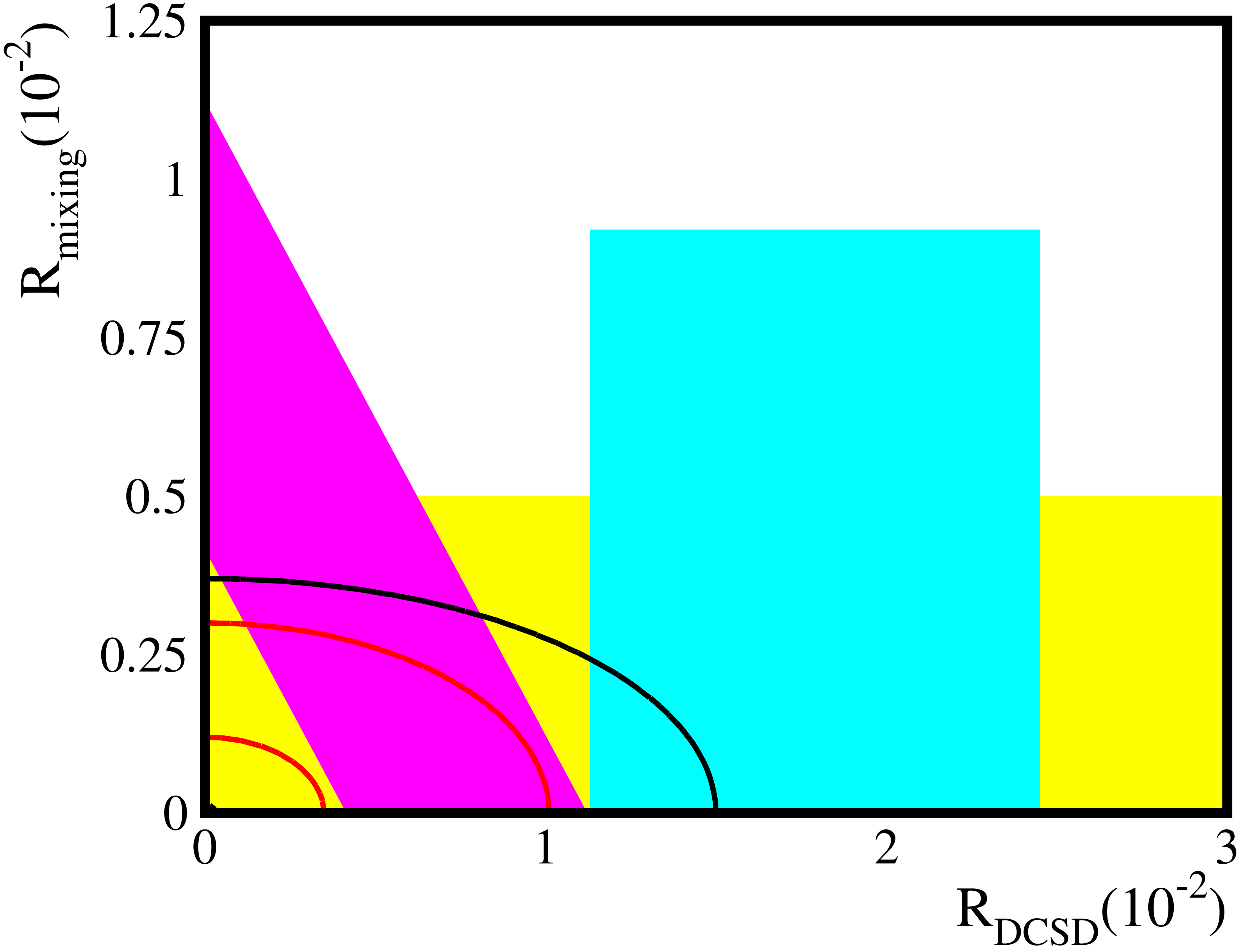


Systematic Error

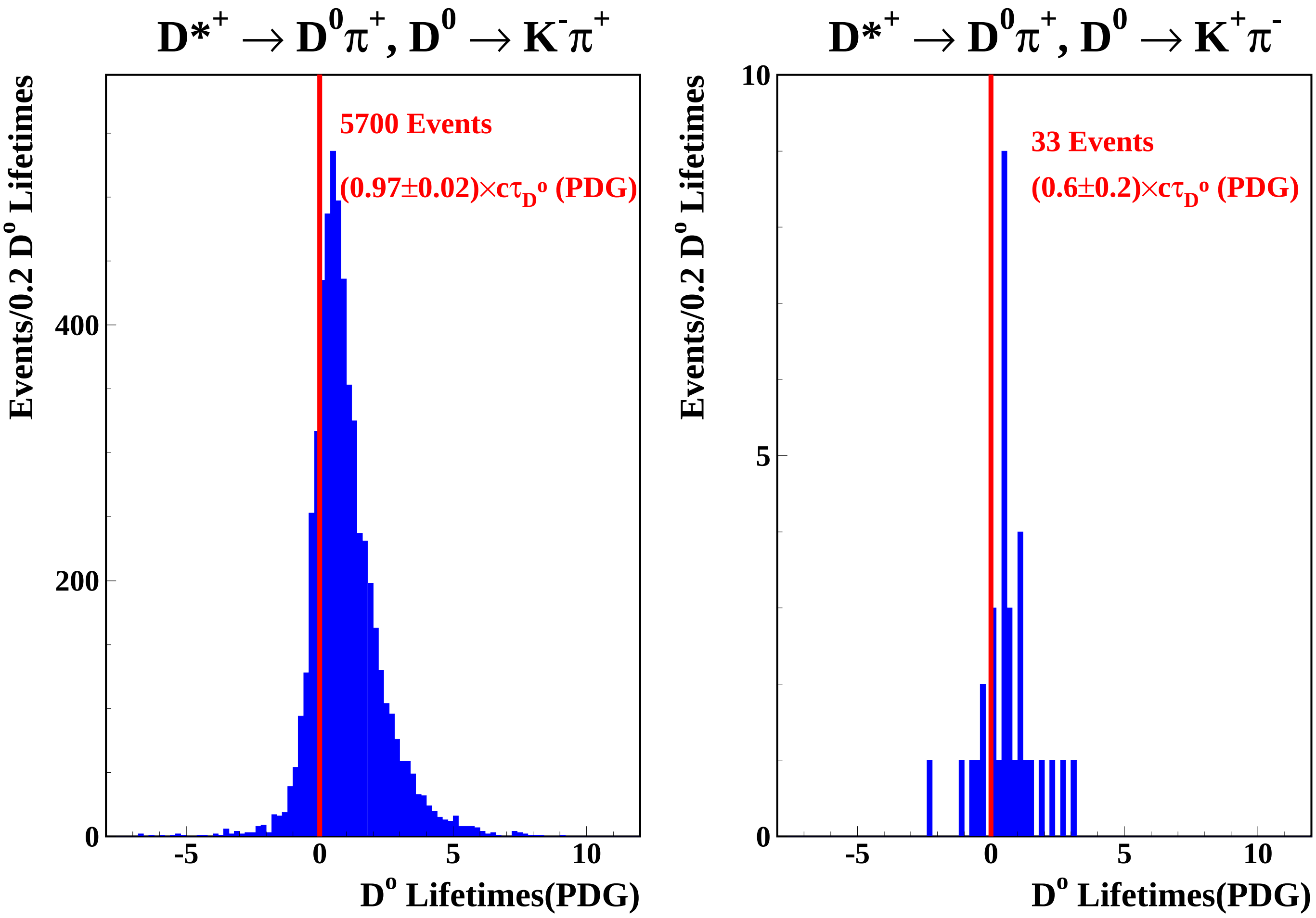
SOURCES
$P_{D^{*+}}$
Mass Flip
K dE/dx $(\mathcal{L}_K - \mathcal{L}_\pi)$
π dE/dx $(\mathcal{L}_\pi - \mathcal{L}_K)$
Prob_{D^0} vertex
$\text{Prob}_{\pi_{soft}}$ vertex
$\cos\theta_{\pi_{soft}}$
$M_{K\pi}$ fit range
Track Quality
Binning $M_{K\pi}$
Binning $M_{\delta m}$
Total ± 0.07

$$R_{\rm ws} = (0.31 \pm 0.09 \pm 0.07)\%$$

World D^0 Mixing: $\cos\phi=0$



"Back of the envelope" Lifetimes

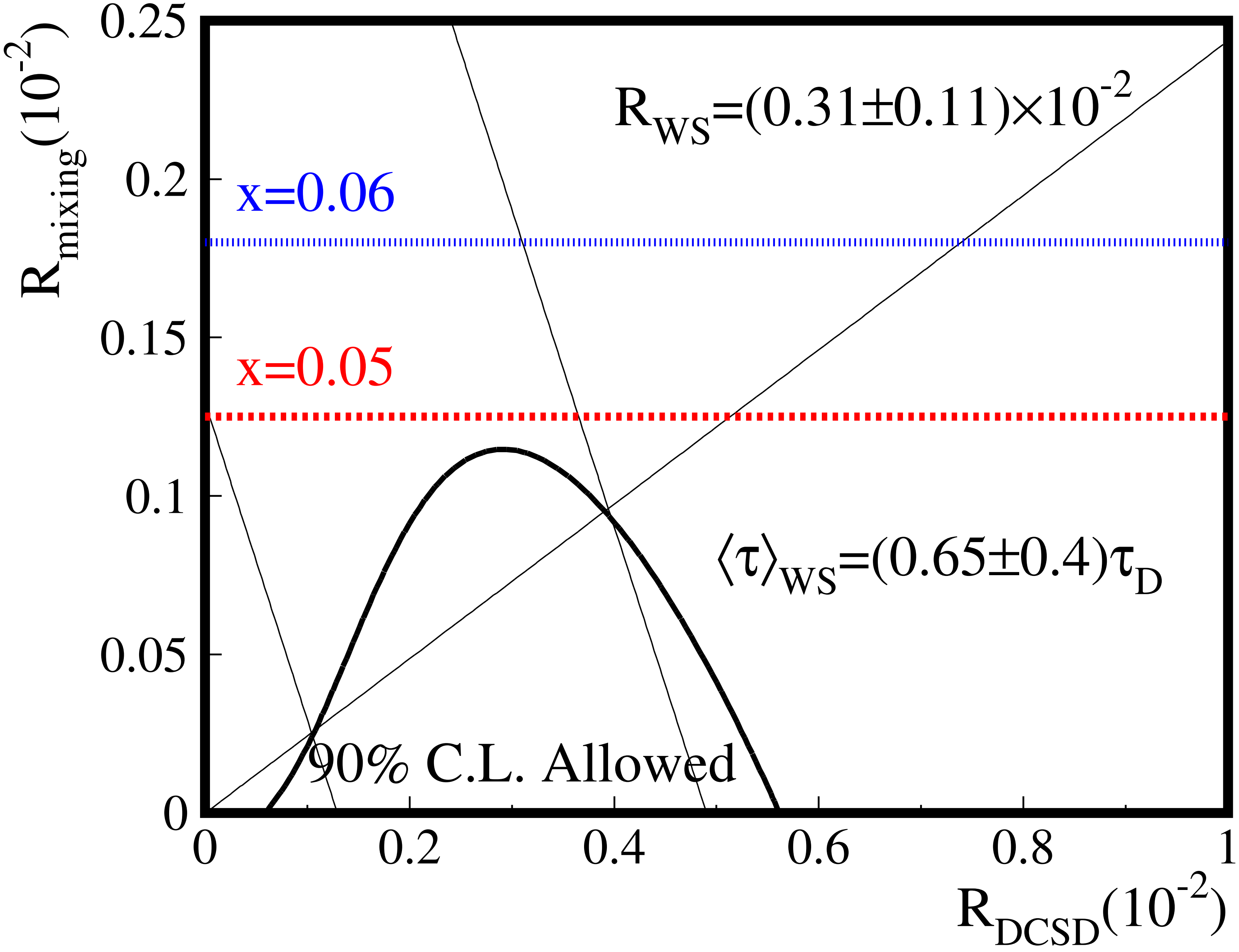


Mode	N_{fit}	τ (τ_{D^o})
Signal	17.3 ± 5.4	?
Real D^o	8.9 ± 0.8	1.0
Other	5.8 ± 0.0	0.0

Mode	τ (τ_{D^o})
DCSD	1.0
Mixing	3.0

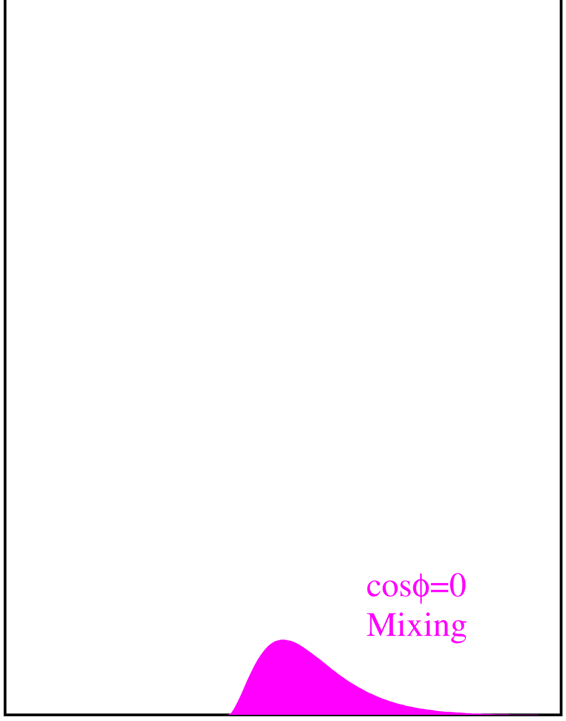
$$\tau_{\text{wrong sign}} = (0.65 \pm 0.33(\text{stat}) \pm 0.5(\text{syst})) \times \tau_{D^o}$$

CLEO II.V: D^0 Mixing, $\cos\phi=0$



Conclusion

- Prospects for the mixing analysis are good
  - Mass resolution,
  - Lifetime resolution,
  - Signal efficiency and background
  - are all good.
- Currently making best measurement of wrong sign rate
  $R_{\mathrm{ws}} = (0.31 \pm 0.09 \pm 0.07)\%$
  - Data size will almost double before data taking stops
  - Currently implementing a 2-d fit to control
    the backgrounds with structure.
  - $D^o \to K^+\pi^-\pi^0$, $K^+\pi^-\pi^+\pi^-$ and $\ell^-\nu$X will be added.
- "Back of the envelope" $c\tau$ calculation demonstrates our sensitivity to limit R_{mixing}
  - A full fit to the distribution will be implemented.


cosϕ=0
Mixing