$D^0 \to \overline{D}^0$

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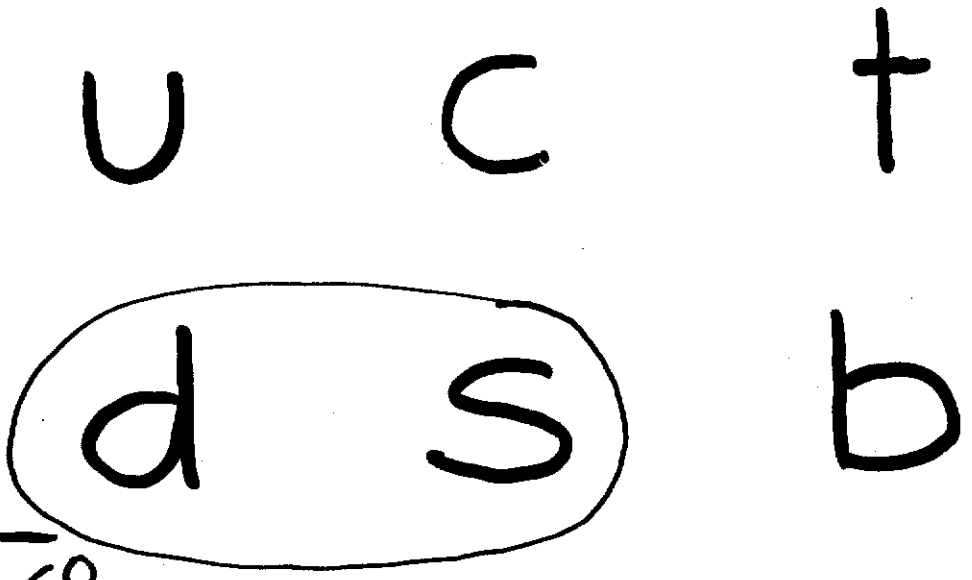
UCSB/CLEO
NuFact '00
May 25, 2000

$P^\circ \to \overline{P}^\circ$: fruitful systems

u c t

d s b

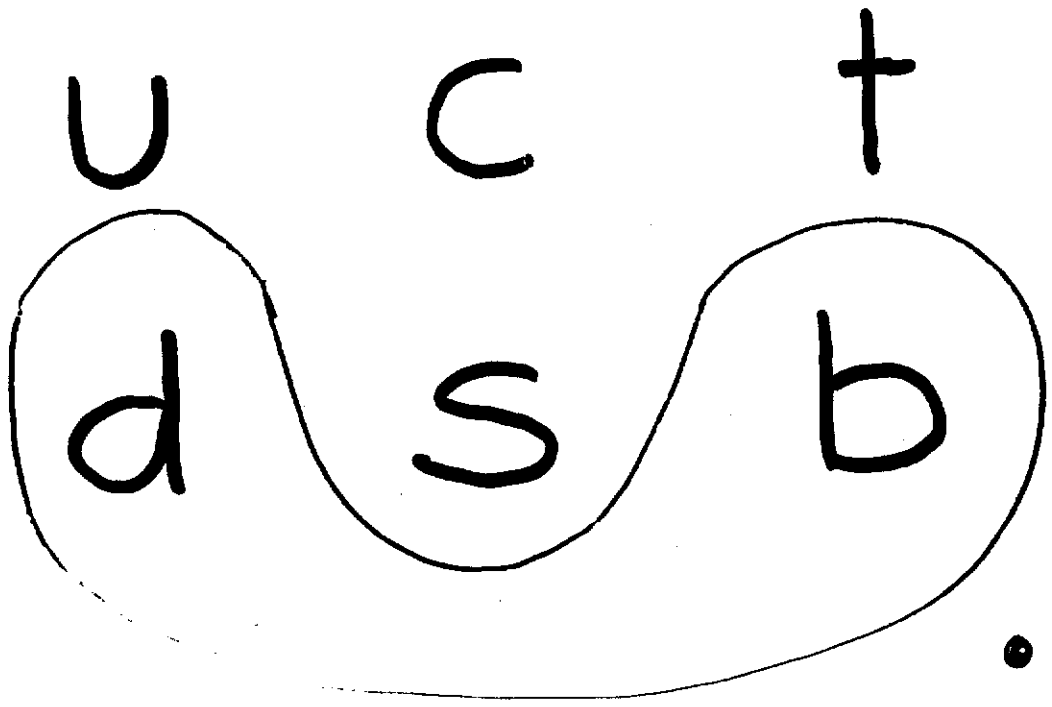
$P^0 \to P^0$: fruitful systems



$K^0 \to \bar{K}^0$

- $\exists$ charm
- $m_c \lesssim$ few GeV
- $\not{CP}$, $\exists$ top

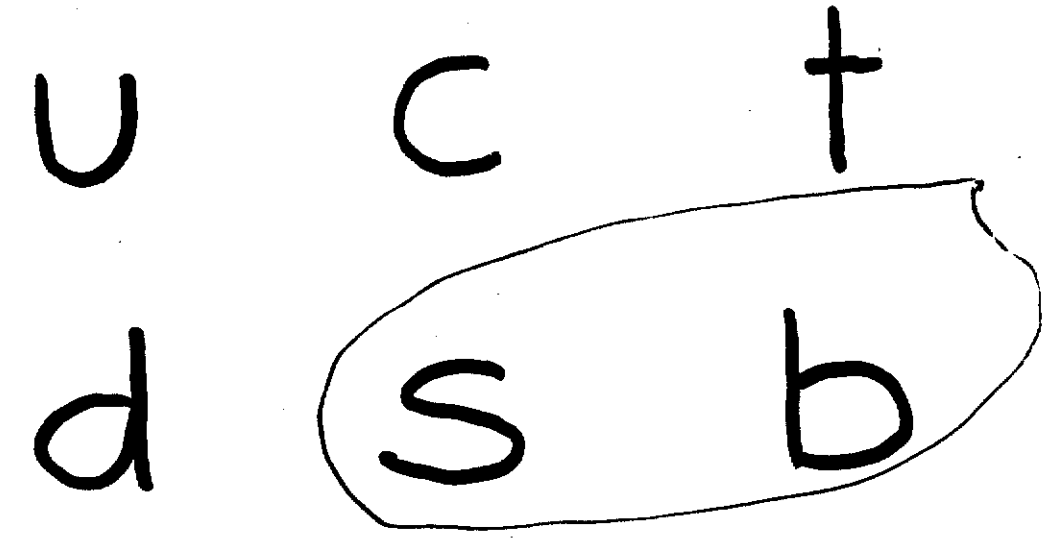
$P^0 \to P^0$: fruitful systems



$B_d^0 \to \bar{B}_d^0$

- $m_t \gtrsim 100$ GeV
- $\not{CP}$ part of standard model

$P^0 \to P^0$: fruitful systems

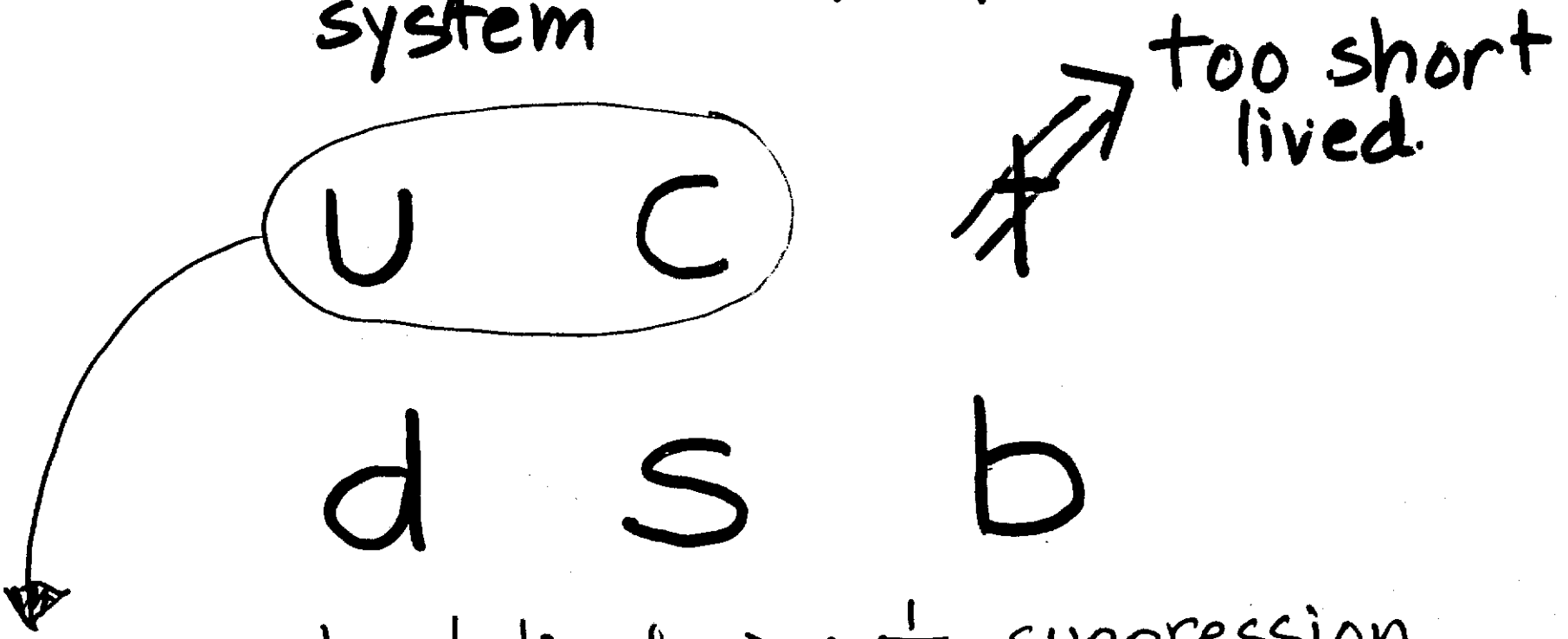


$B_s^0 \to \overline{B}_s^0$

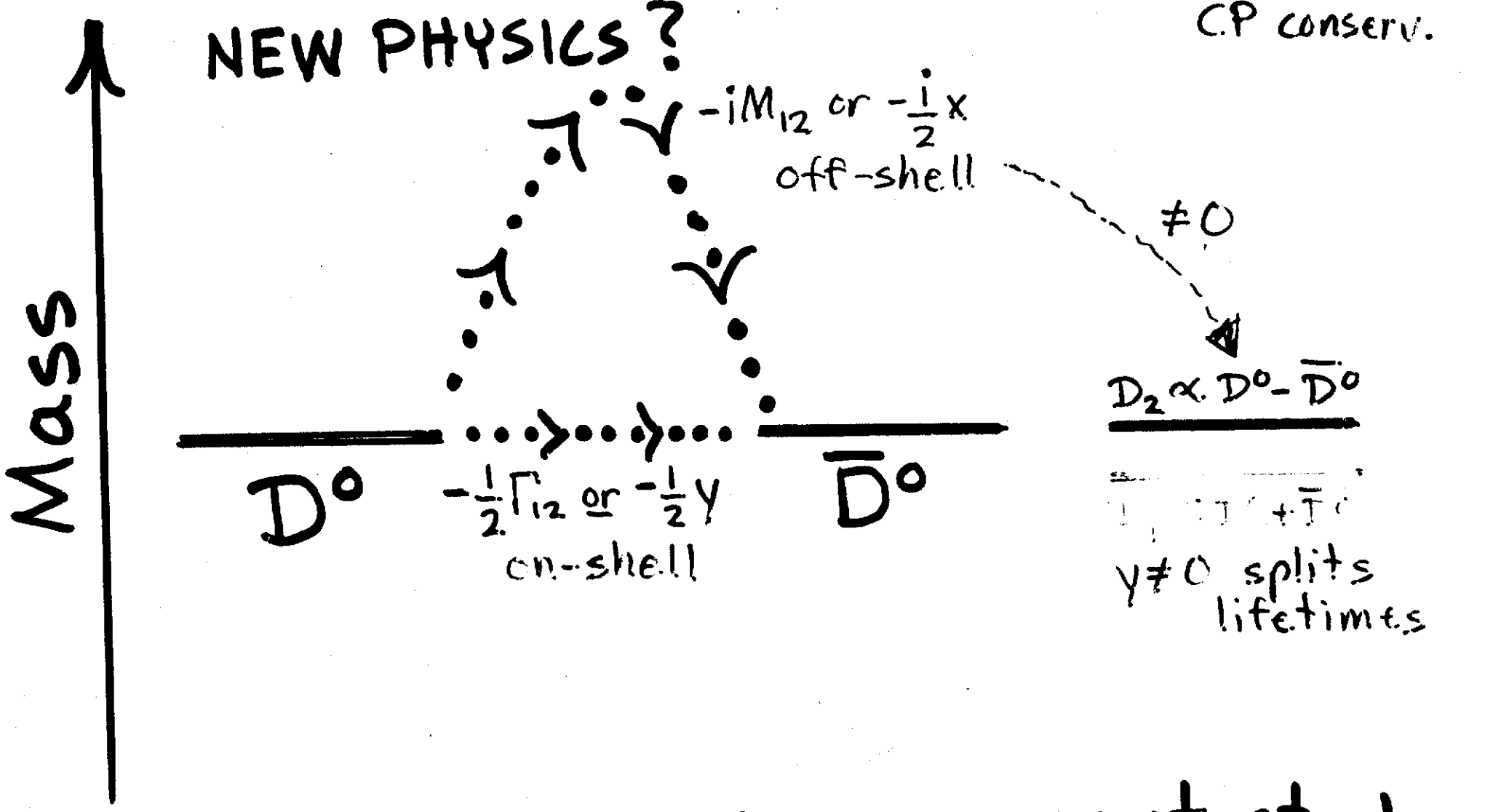
- large, so far lower lim.
- $|V_{ts}/V_{td}|$

$P^0 \to \overline{P}^0$: fruitful systems

$D^0 \to \overline{D}^0$: only viable up-type system



- CF → short lived → $\sim \frac{1}{20}$ suppression
- standard model → $|V_{cb}| \sim \frac{1}{20}$, $m_s \sim m_d \sim \Lambda_{QCD}$ further (accidental) suppression
- **WINDOW TO VIEW NEW PHYSICS**

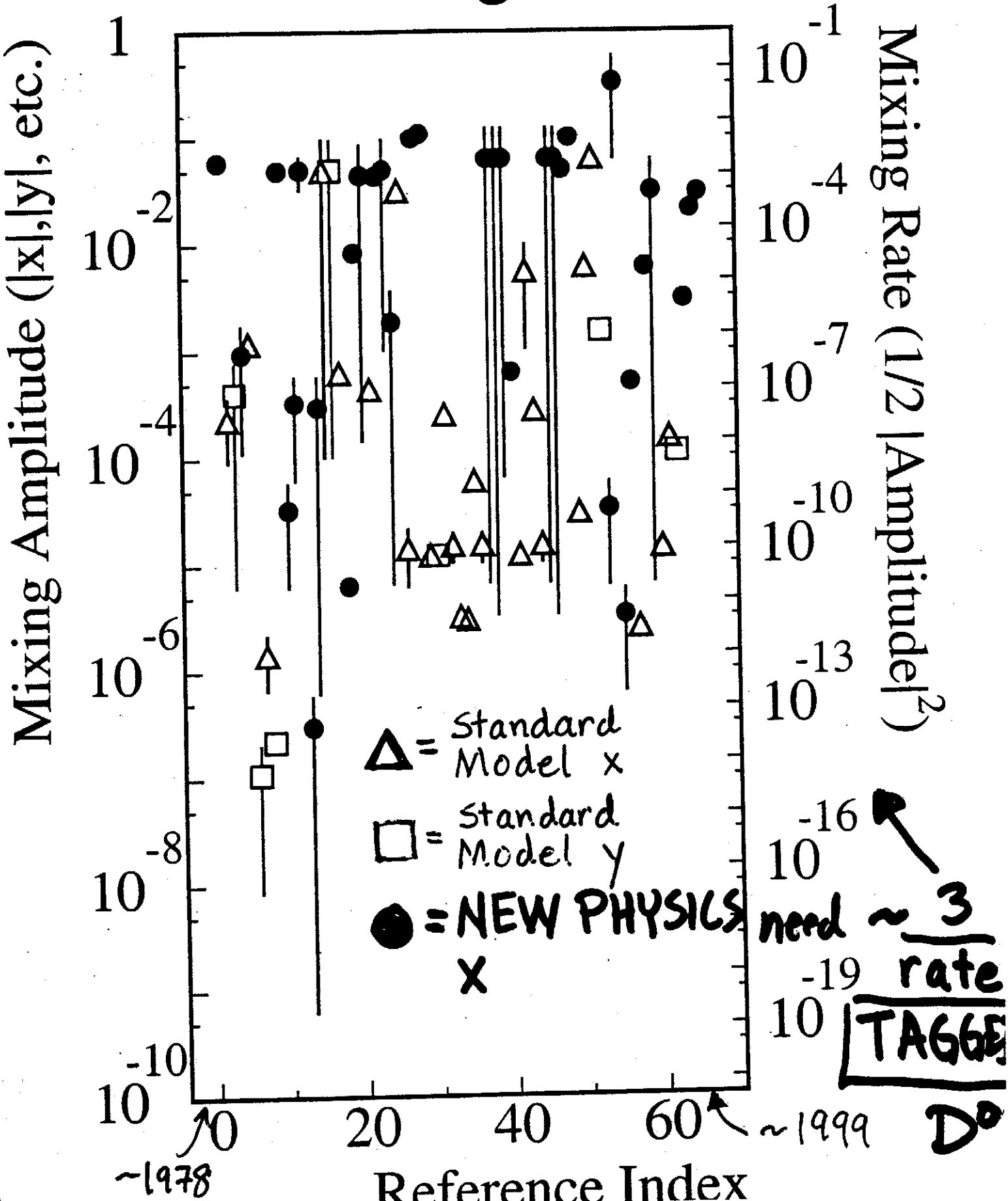


$$i\frac{\partial}{\partial t}\left\{e^{+}\begin{bmatrix} D^0 \\ \bar{D}^0 \end{bmatrix}\right\} = -\frac{1}{2}\begin{bmatrix} 0 & ix+y \\ ix+y & 0 \end{bmatrix}\begin{bmatrix} \quad \\ \quad \end{bmatrix} \Rightarrow$$

must study time evolution to distinguish NEW PHYSICS

y factory ... vertex?

D^0-$\overline{D^0}$ Mixing Predictions



III WORKSHOP ON PHYSICS AND DETECTORS FOR DAΦNE
FRASCATI, NOVEMBER 16TH-19TH, 1999
CONFERENCE PROCEEDINGS, PP. 000-000

CP VIOLATION AND RARE DECAYS

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6.9 New Limits on Charm Mixing

Because the standard-model contributions to D^0 - $\bar{D}^0$ mixing and to CP violation in D decays are so minute, there are many opportunities to observe new physics. [S1, S2] The large number of fully reconstructed charmed mesons available in CLEO, the LEP experiments, and Fermilab fixed-target experiments make possible incisive searches, reviewed here by Jeff Appel. [S0] We can now contemplate experiments to reconstruct 10^8 charms, and it is worth thinking about how to pursue those opportunities. In particular, with Fermilab's 800-GeV fixed-target program at an end, we need to consider how to exploit dedicated B experiments for charm. A novel possibility, recently noticed, is that a 4-kg-year exposure at a neutrino factory could lead to a tagged sample of a million semileptonic D decays.

$X \sim \left[\frac{2.3}{10^6}\right]^{1/2}$

started CLEO II SVX 1991

$\sim 0.3\%$ .... TAG QUALITY

not (just) #D^0 is limitation

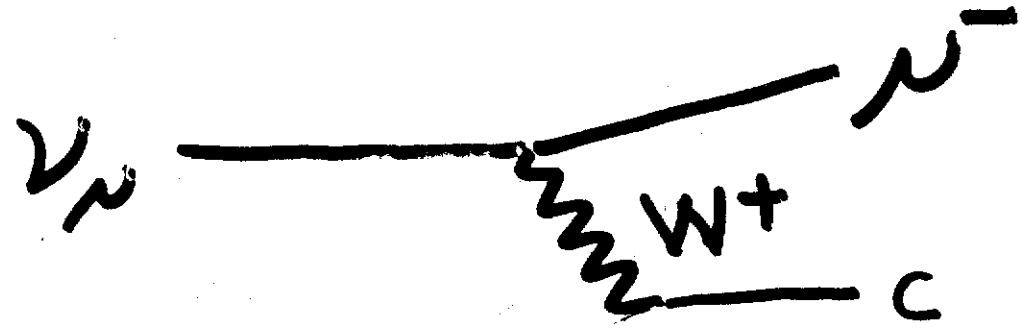
CHALLENGE : TAG

not # D's

Mistag Rates : $D^{*+} \to \pi_s^+ D^0$

random π_s $\bar{D}^0 \to$

CLEOII.V
$\sim 10^{-3}$
no missing $\vec{P}$
$\sim 3 \cdot 10^{-2}$ $K \ell \nu$



CCFR : $1.4 \cdot 10^{-2}$
10^6 tags : $x \sim 2\%$
mistag $\propto E_\nu^2$ (?)
@30 GeV $x \sim 0.7\%$

Is mistag rate trustable?
$\Rightarrow$ v. solid @ e^+e^-

A. Bodek 1992 SSI

Mistag Rate

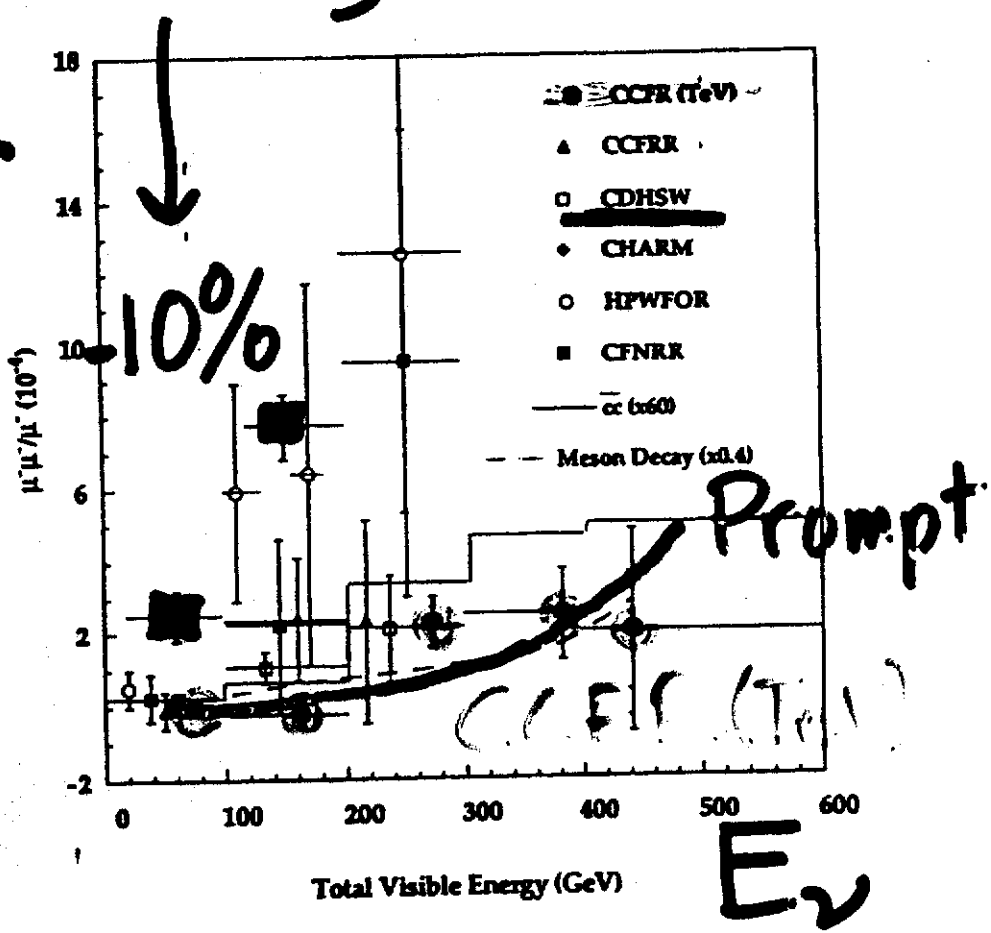


Figure 5: The prompt same-sign dimuon rates relative to the charged-current rate compared to previous experiments. The CCFR TeV points and the histogram representing the 90% C.L. upper limit are from this experiment. The dashed line represents the energy dependence of the meson-decay background rate, decreased by 0.4 to match the level of the same-sign dimuon data excess. The solid line represents the rate due to $c\bar{c}$ gluon bremsstrahlung increased by a factor of 60 to equal the level of the same sign excess.

Unlike Sign (normalization)

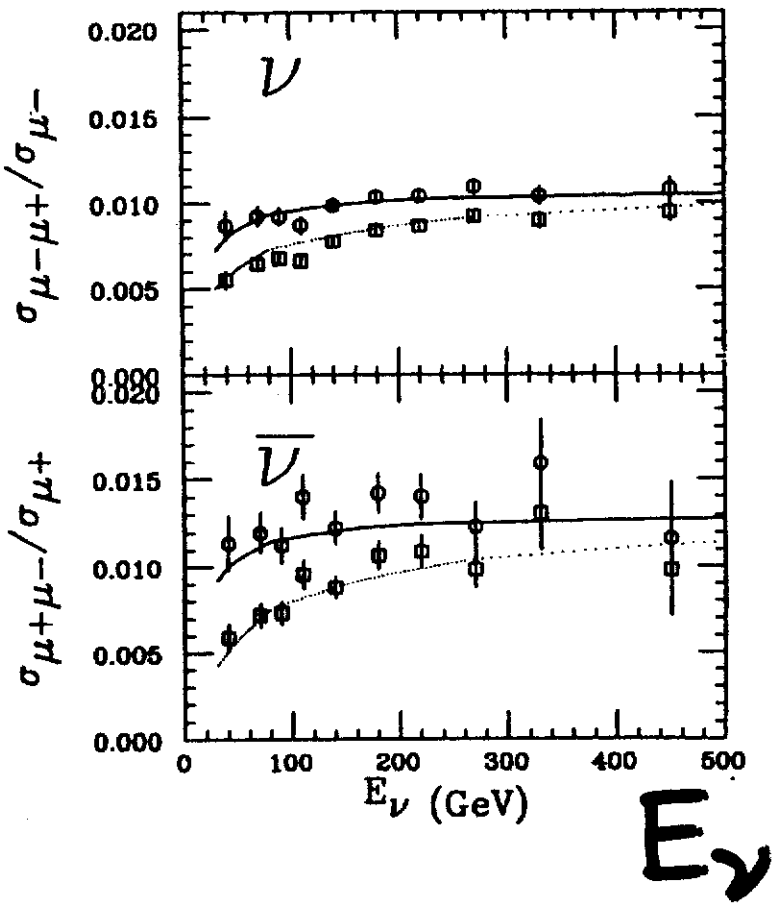
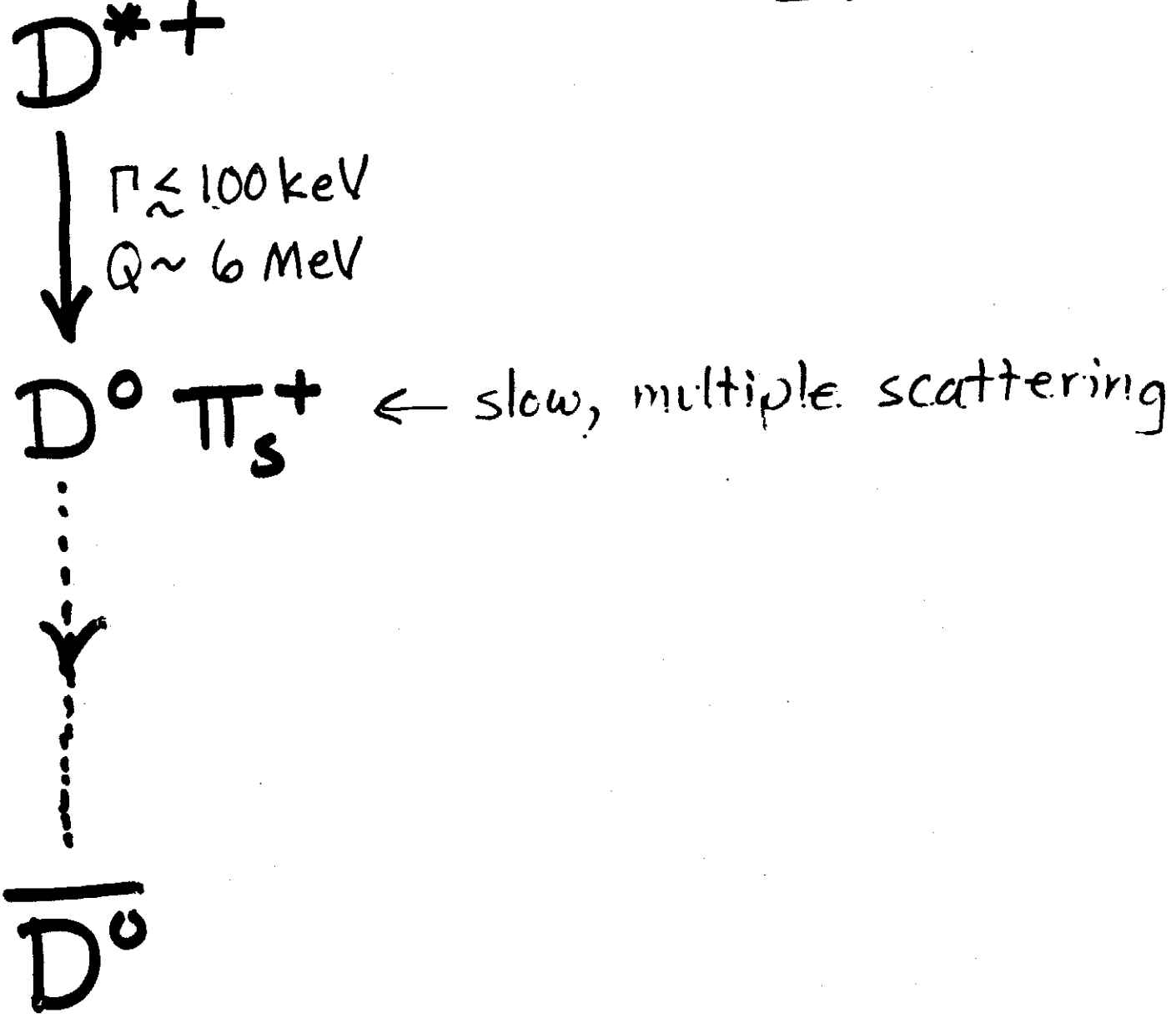
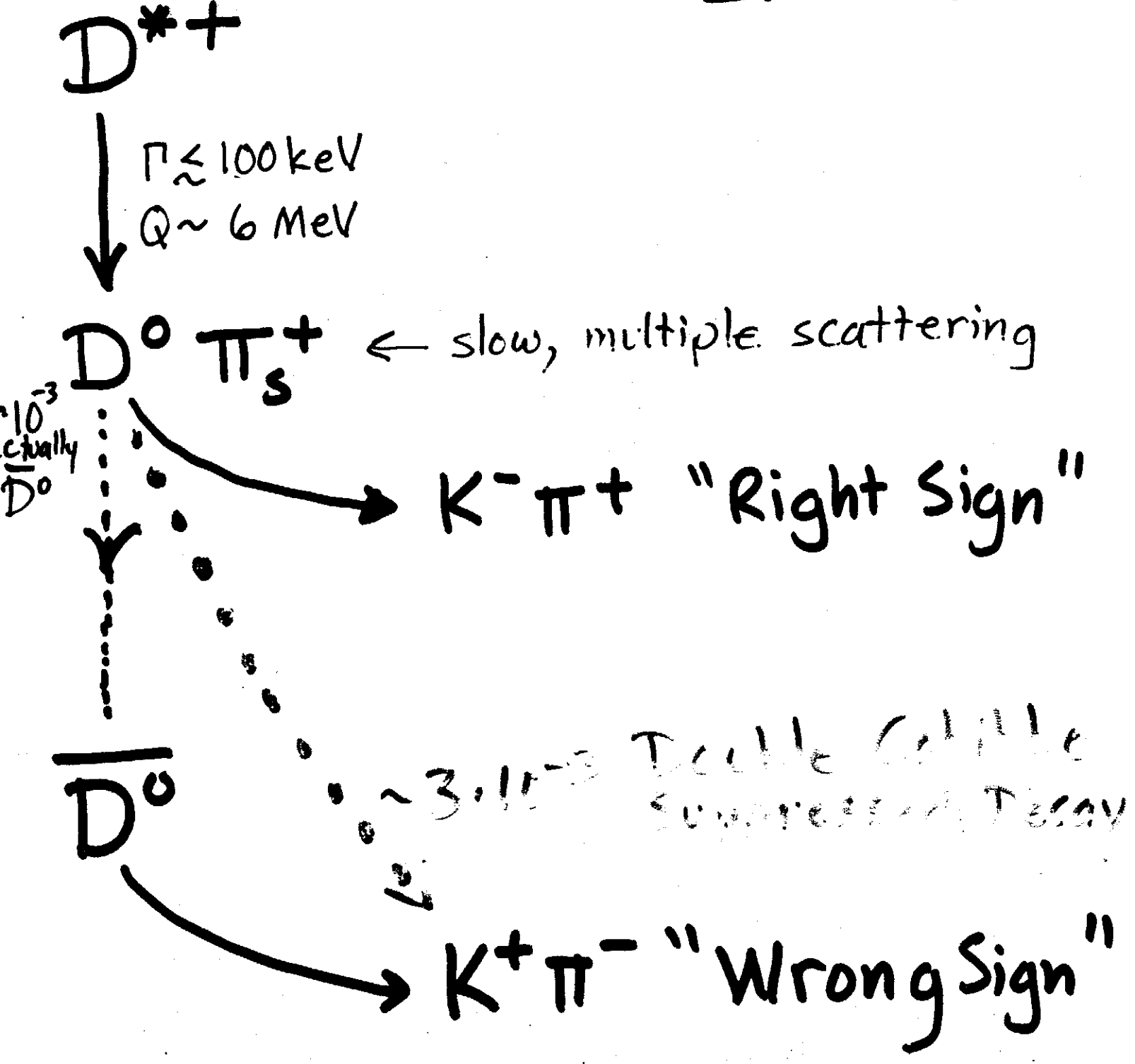


Figure 6: Opposite-sign dimuon rates versus E_ν for ν_μ (top) and $\bar{\nu}_\mu$ (bottom) data. Rates corrected for acceptance, smearing, and kinematic cuts are indicated by squares. Those corrected for slow rescaling with $m_c = 1.31$ are given by circles. The curves indicate the slow rescaling model prediction with $m_c = 1.31\ GeV/c^2$ (dotted) and $m_c = 0.0\ GeV/c^2$ (dashed).

CLEO II.V 2000



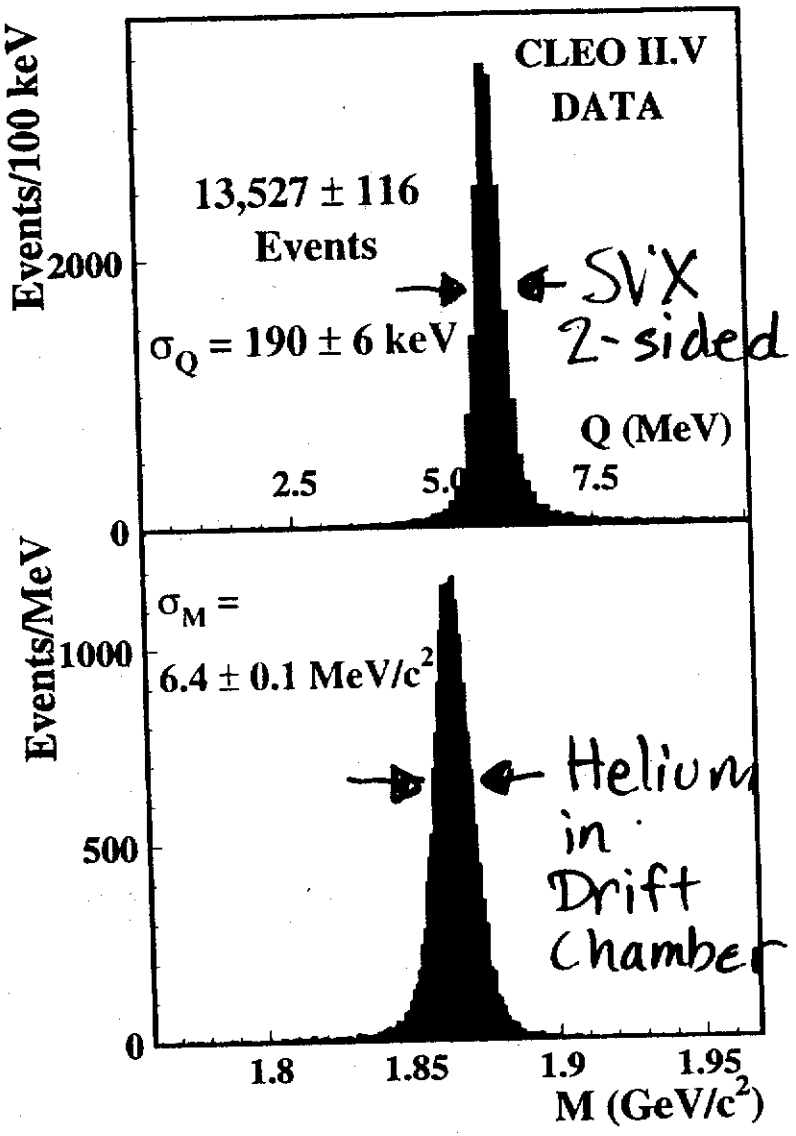
CLEO II.V 2000



TIME EVOLUTION SORTS OUT 3 ROUTES: x, y, DCSD

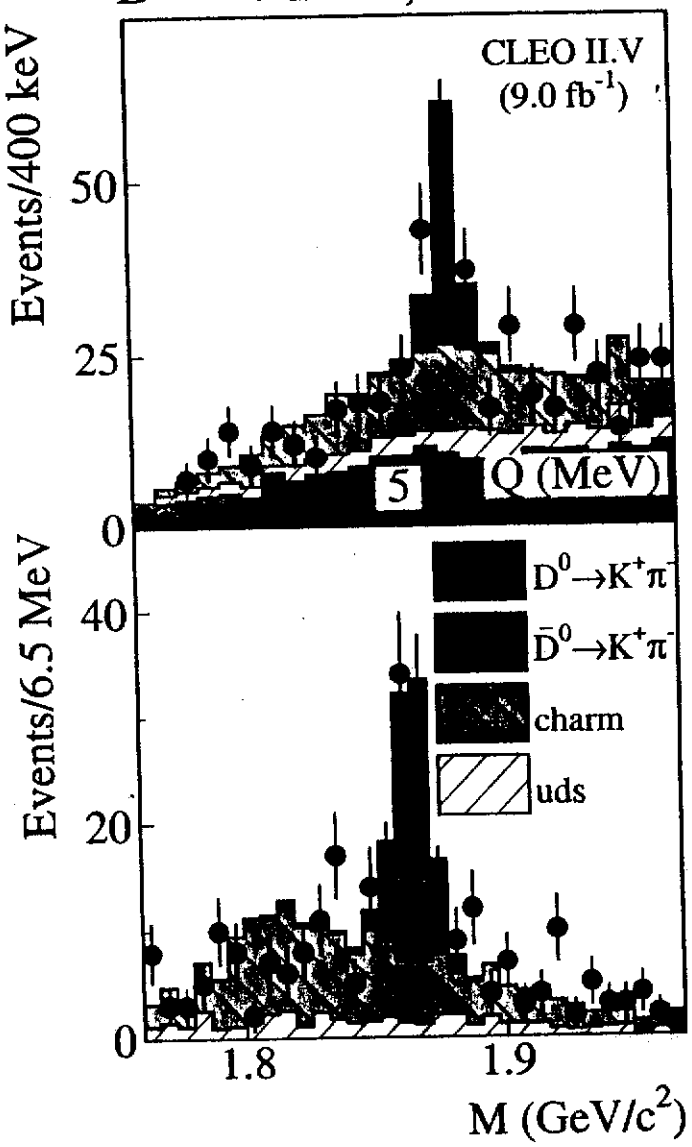
Right Sign

$D^{*+} \to D^0\pi^+, D^0 \to K^-\pi^+$



Wrong Sign

$D^{*+} \to D^0\pi^+, D^0 \to K^+\pi^-$



Wrong Sign
Mistag
↑
determined
in Q
sidebands

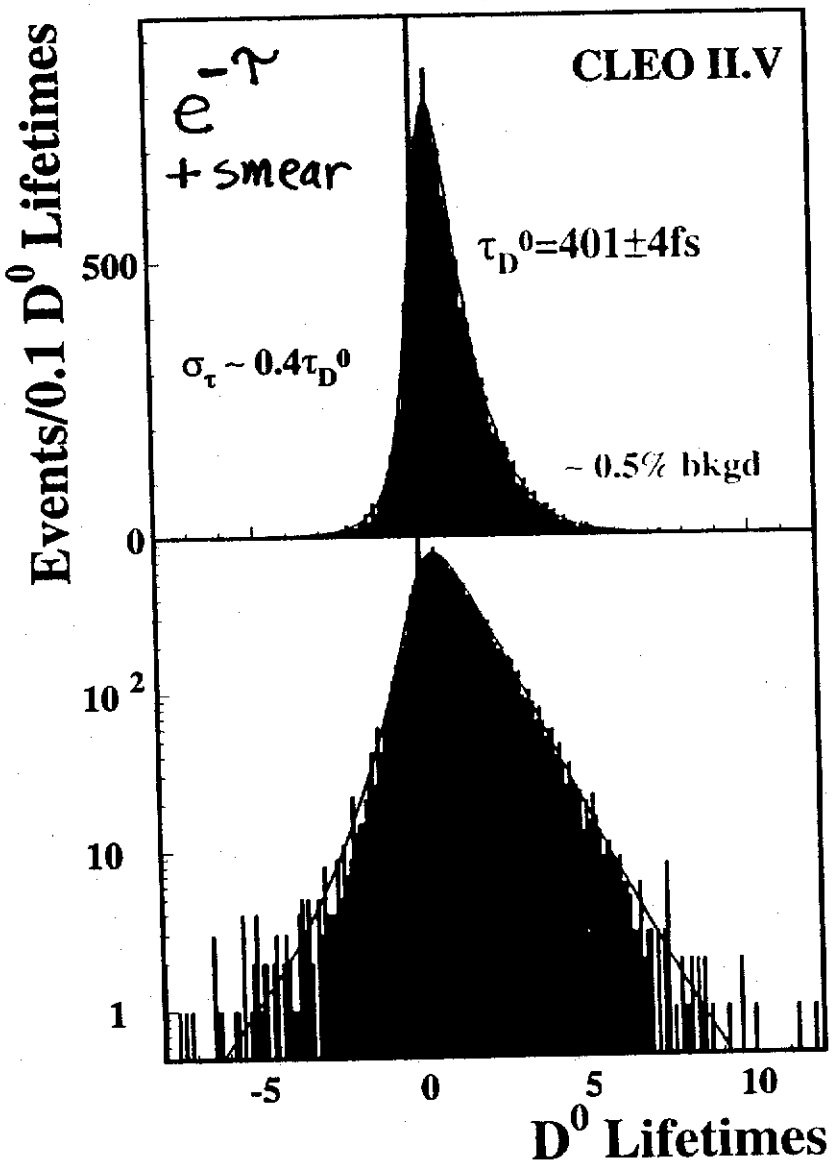
Not at fundamental limiting (detector) resolutions

$$R = \frac{WS}{RS} = (0.332^{+0.063}_{-0.065} \pm 0.04$$

TIME EVOLUTION:

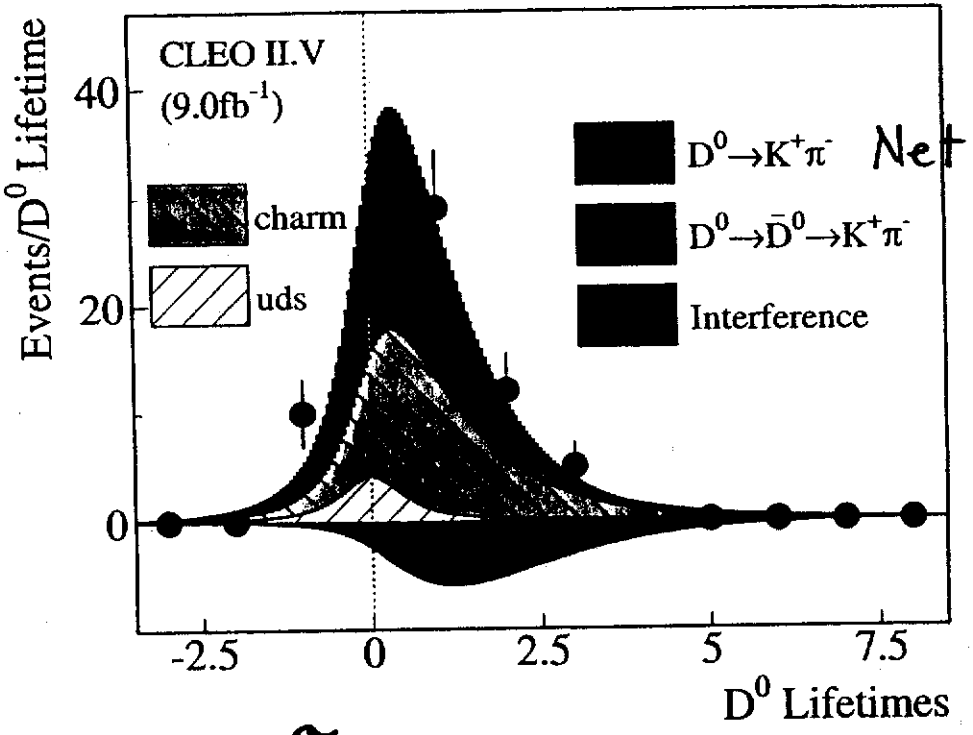
Right Sign

$D^{*+} \to D^0\pi^+, D^0 \to K^-\pi^+$



WRONG SIGN

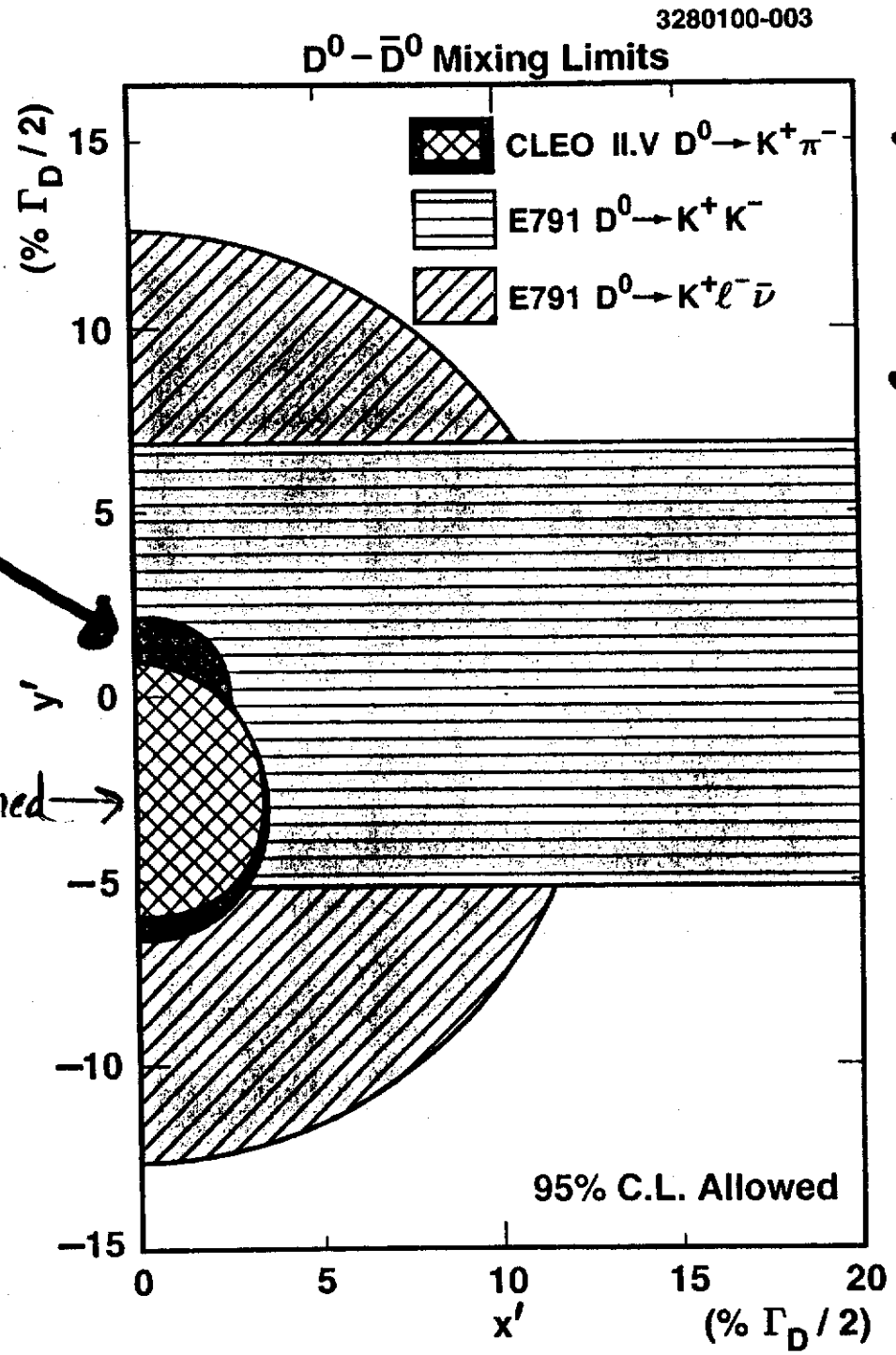
$D^{*+} \to D^0\pi^+, D^0 \to K^+\pi^-$



$$WS(\tau) = e^{-\tau}\left(R_{DCSD} + \sqrt{R_{DCSD}}\,y'\tau + \tfrac{1}{4}(x'^2 + y'^2)\tau^2\right)$$

$$y' = y\cos\delta - x\sin\delta \qquad \delta = \text{a strong phase.}$$

3 Types of
~~CP~~
allowed



constrained →

ALLOWED CP

95% CL

$-5.8\% < y' < 1.0\%$

$|x'| < 2.9\%$

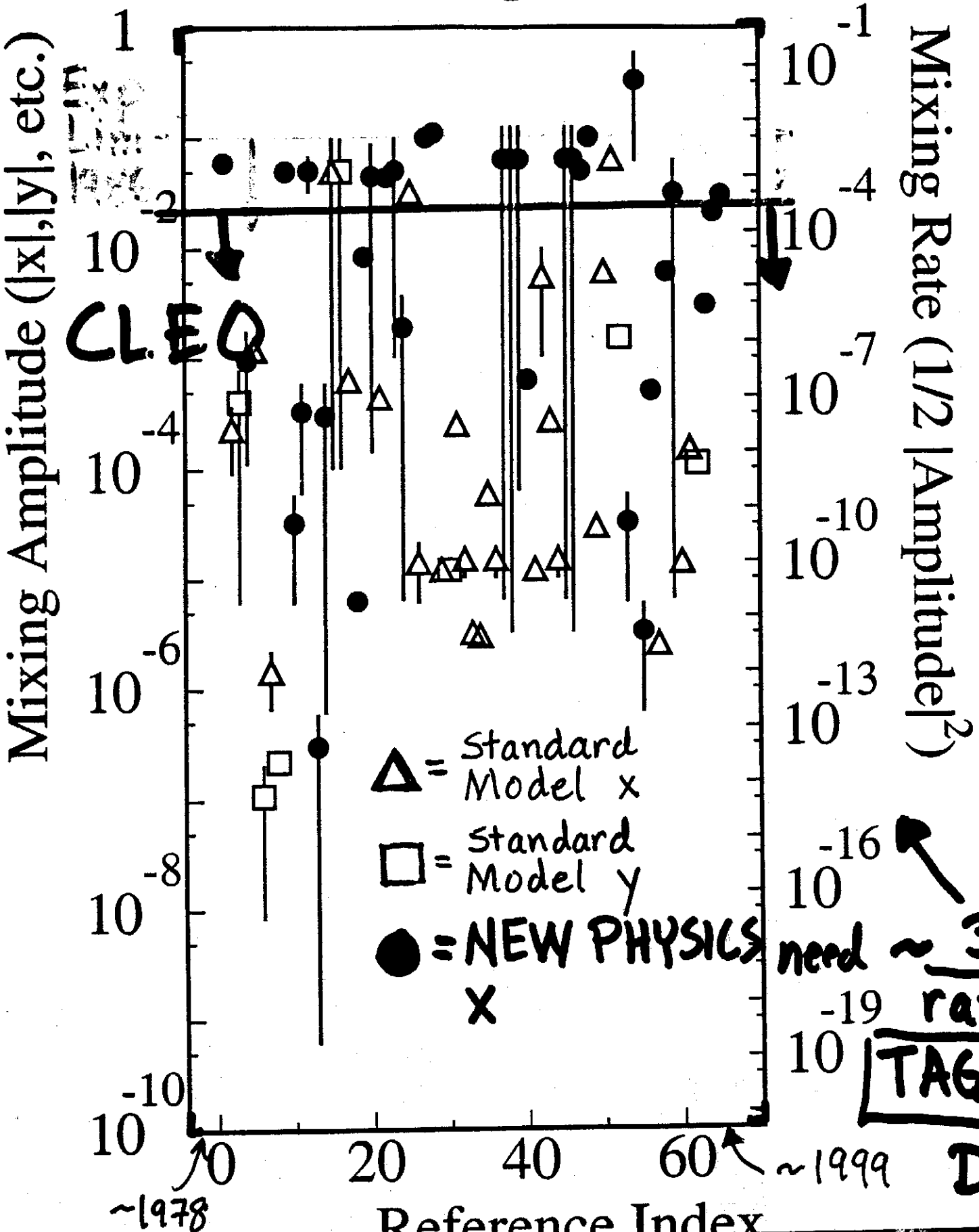
↑

9 1/fb

$K\pi\pi^0$

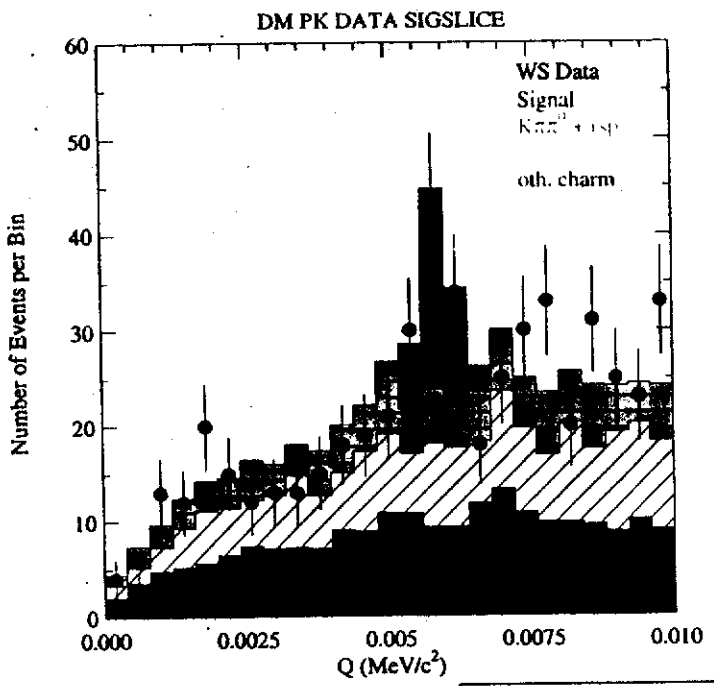
$K3\pi$ soon

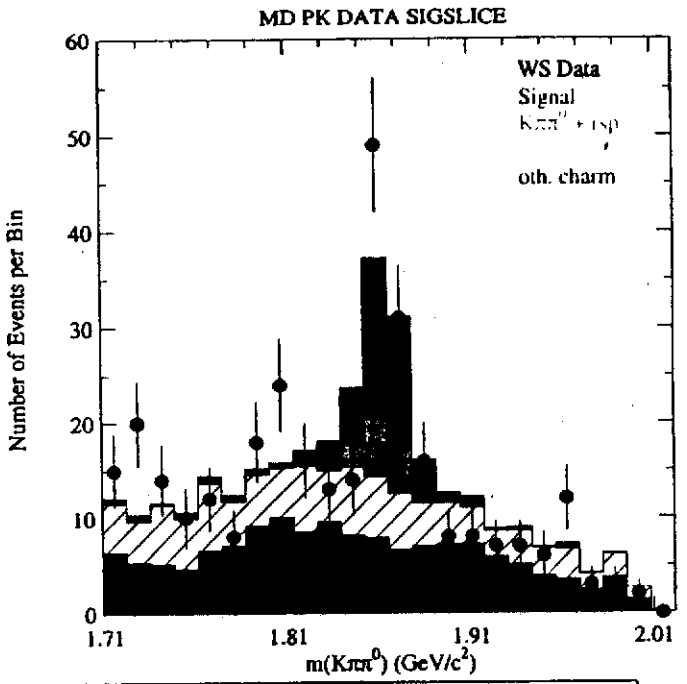
D^0-$\overline{D^0}$ Mixing Predictions



$D^0 \to K^+\pi^-\pi^0$ Channel

Alex Smith
Minnesota





Preliminary

$$N_{WS} = 39^{+10}_{-9}\ (\text{from fit}) \pm 7\ (\text{sys})$$

$$N_{RS} = 9045$$

4.9σ significance of signal

First observation of this decay!

Future (this technique)

- Background Limited by DCSD
  - win as $[\int \mathcal{L} dt]^{-1/4}$
  - $\simeq x' < \dfrac{0.7\%}{([\int \mathcal{L} dt]/1000\ fb^{-1})^{1/4}}$

$\Rightarrow$ similar to 10^6 ν's $\rightarrow \ell^- \ell^-$ @ 30 GeV

$\Rightarrow$ any way to get to $[\int \mathcal{L} dt]^{-1/2}$ (background-less?)

- LHCb, BTeV, CDF, HERA-B, CMS, DØ, Atlas, ν-factory

.... E_{D^0} unknown

.... $D^0 \to K l \nu$ hard

n.c DCSD background

- $e^+e^- \to \Upsilon(4s) \to \bar{B}^0 B^0$

highly constrained energy

$\bar{B}^0 \to \pi_f^- D^{*+}$

$D^{*+} \to \pi_s^+ D^0$

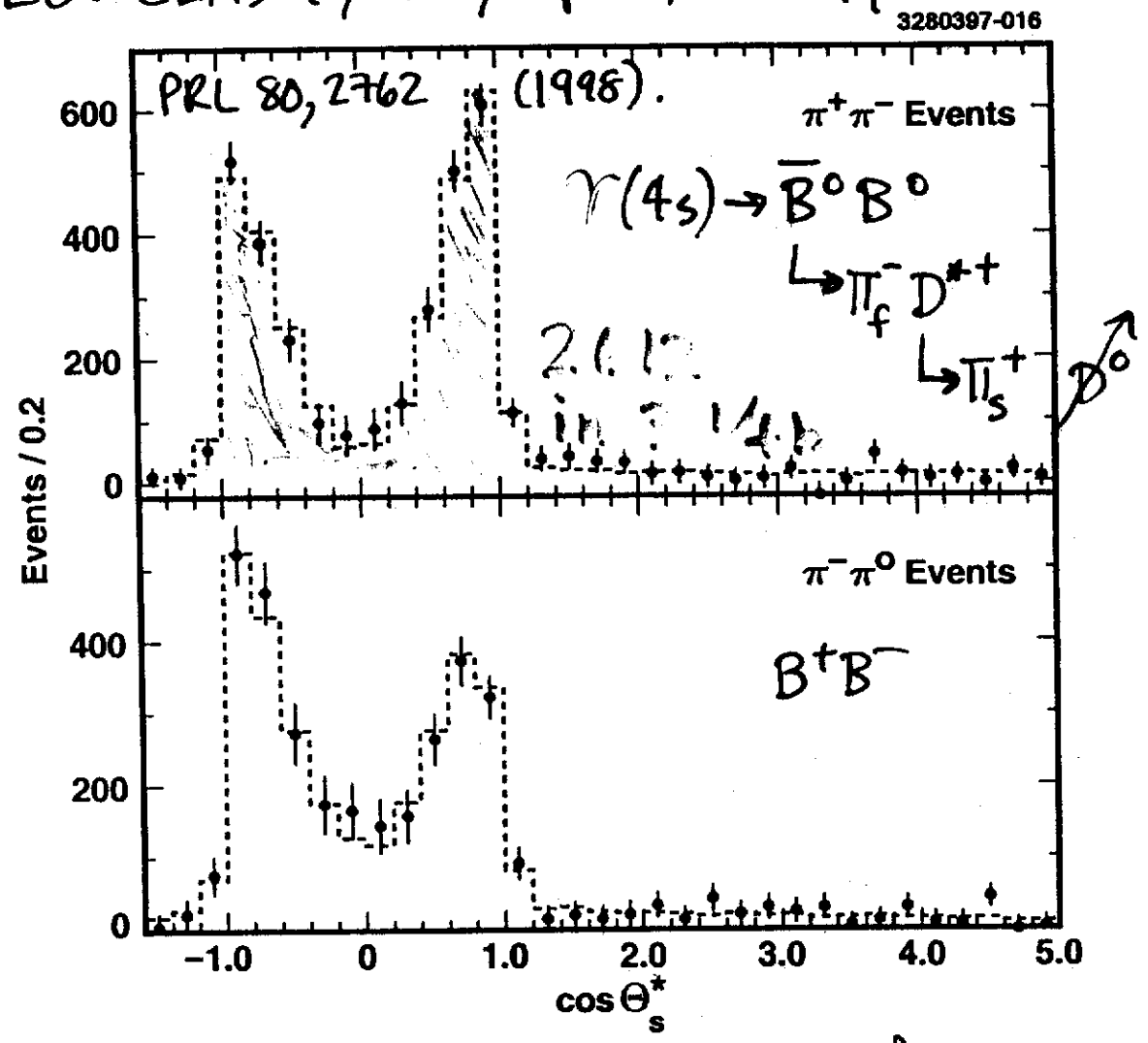
$D^0 \to K l \nu$

$\vec{P}_{D^0}$ known from a priori: • e^+e^- beams
• $\pi_f^- \pi_s^+$

to ~ mrad ~ 10's MeV

1 C

CLEO: CLNS 97/1485, hep-ex/9706019



D^{*+} decay angle

+ $D^{*+}\rho^-$

(CLNS 00/1668
hep-ex/0005013
subm PRL)

$\Rightarrow$ $1.4 \cdot 10^5$ tagged,
assumed bkgd-free.
$D^0 \to K\ell\nu$
in 1000 1/fb

$$|x| \lesssim \frac{0.7\%}{\left[\left(\int \mathcal{L}\,dt\right)/1000\ 1/\text{fb}\right]^{1/2}}$$

could be done NOW... at 10 1/fb

Conclude

Several (2 $\Upsilon(4s)$, 1 ν-fact) routes to

$|x| \lesssim 0.7\%$ in next decade.

At this level, D^0-$\bar{D}^0$ surpasses K^0-$\bar{K}^0$ as the highest FCNC hurdle.