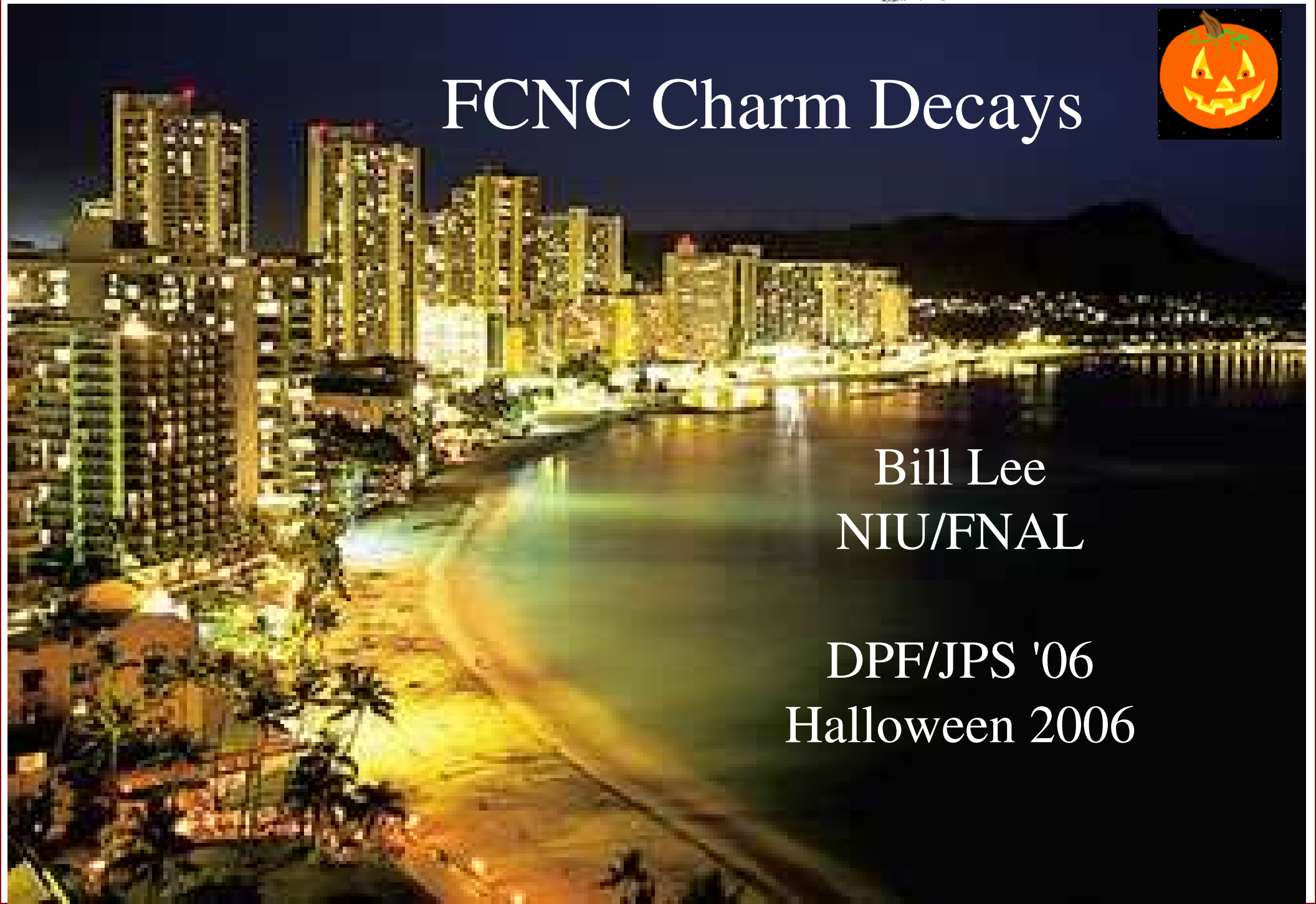


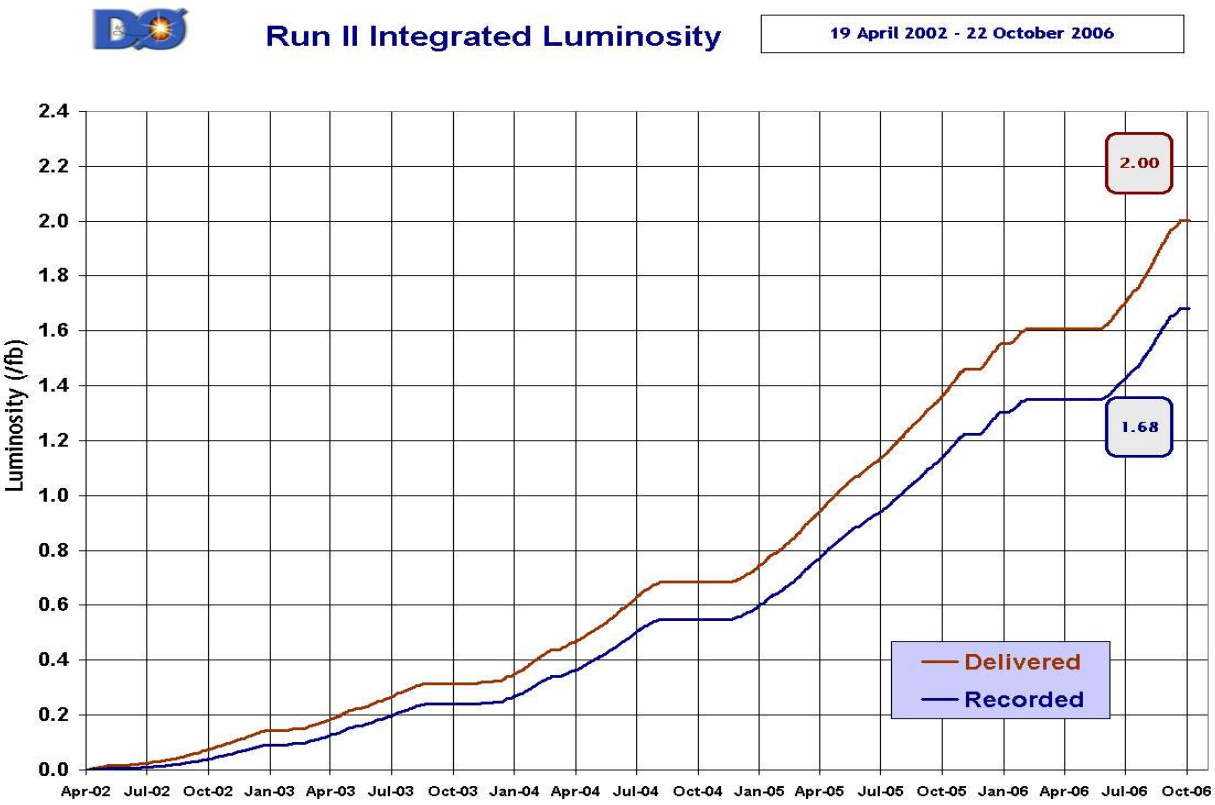
FCNC Charm Decays

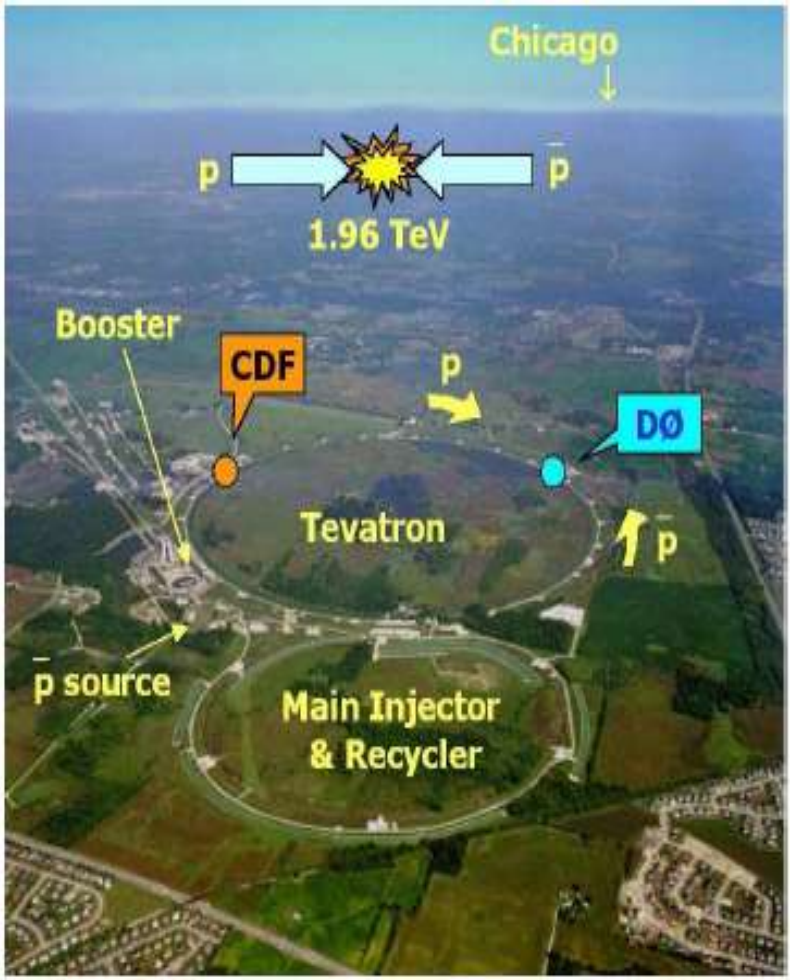
Bill Lee
NIU/FNAL

DPF/JPS '06
Halloween 2006

Tevatron

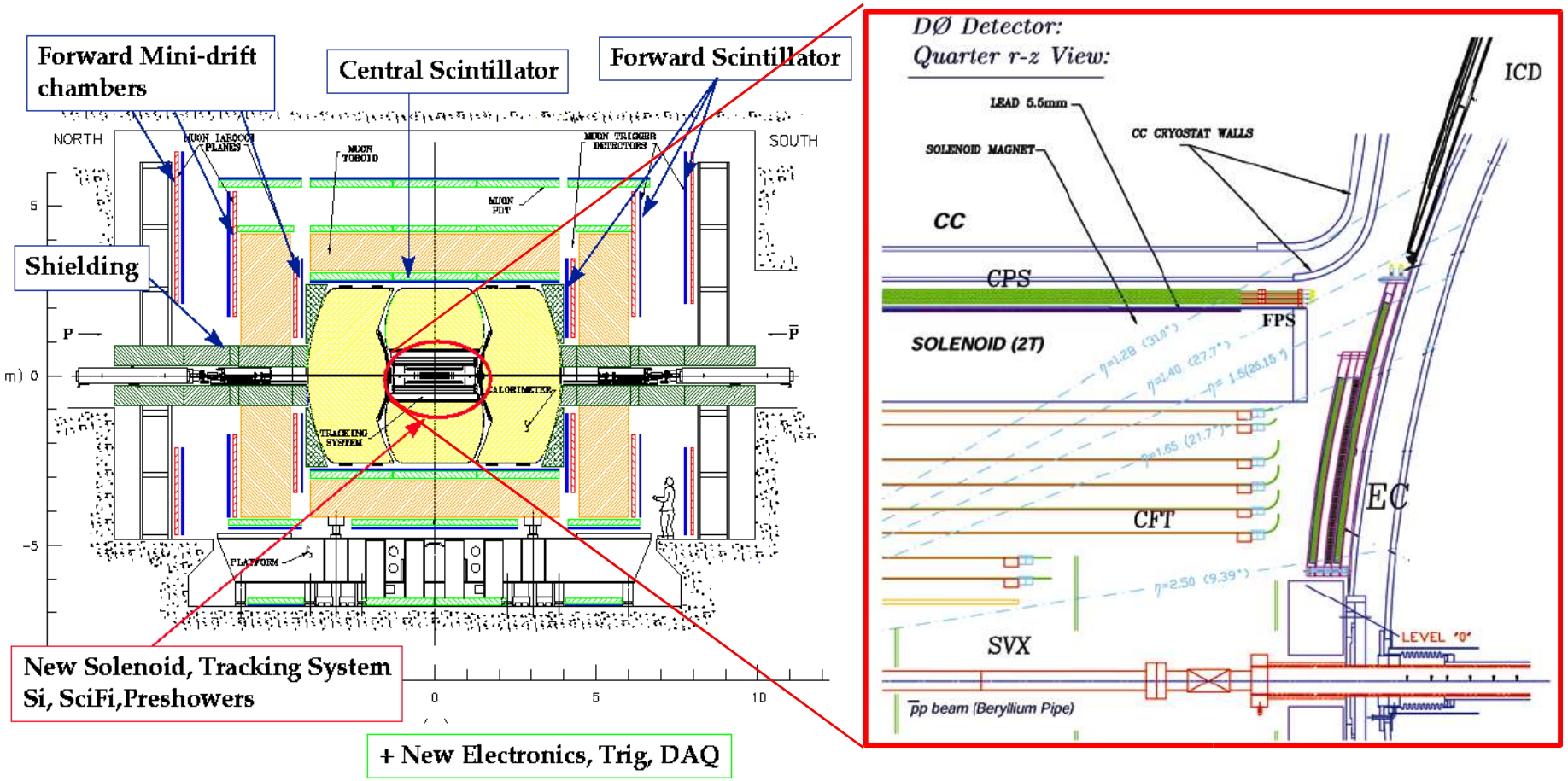
- The Tevatron is a $\sqrt{s}$=1.96 TeV $p\bar{p}$ collider.
- Since the last shutdown the Tevatron has set many DØ luminosity records including:
  - Instantaneous L = 2.2 E32/cm^2/s
  - Daily integrated L = 6.2 pb^{-1}
  - Weekly integrated L = 32 pb^{-1}





DØ has just recently passed the 2 fb^{-1} mark, recording ~85% of delivered luminosity.

The DØ Run II Detector

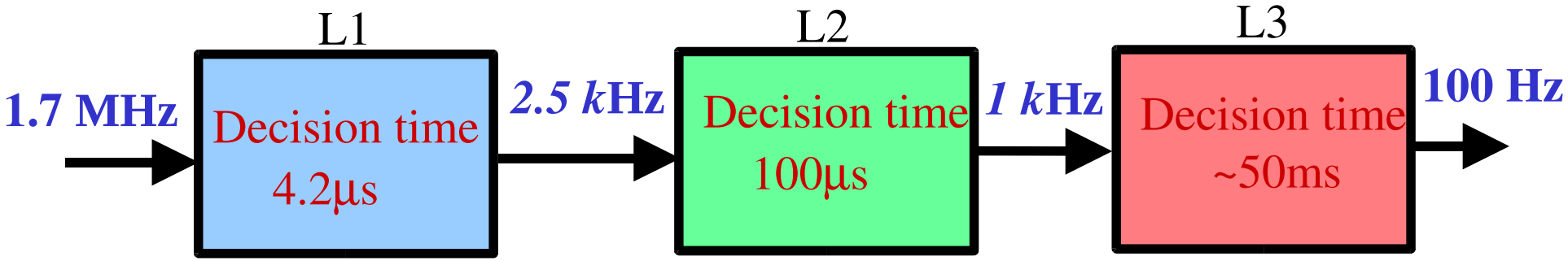


The DØ detector is a multipurpose detector with excellent muon and tracking coverage out to $|\eta|=2$. In addition, with the recent shutdown, DØ has added an additional inner layer of silicon and upgraded the track trigger to reduce fakes.

The D0 Trigger System

But data acquisition rate is limited to 100 Hz

⇒ 3 Level Trigger System



- **Hardware based**
- **Simple Signatures in up to a pair of Sub-Detectors**

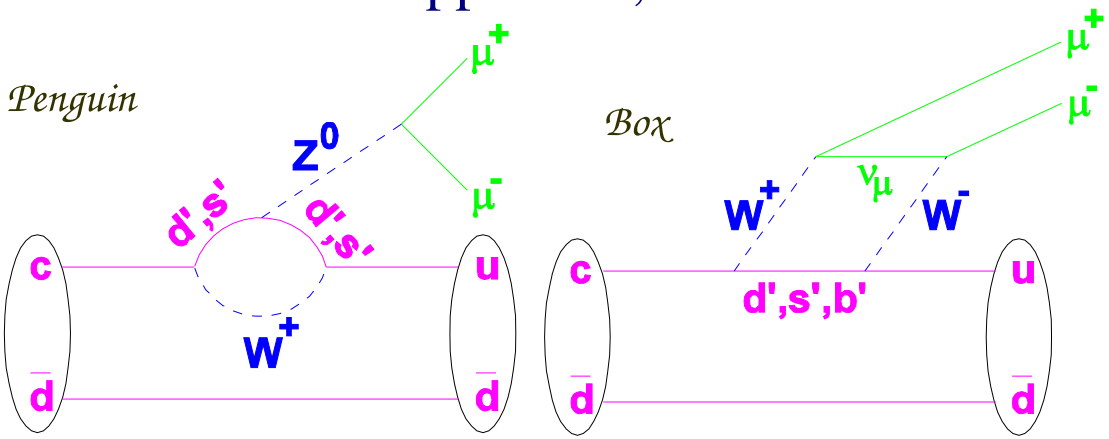
- **Software and Firmware based**
- **Physics Objects e,μ,jets, tracks**

- **Software based**
- **Simple versions of reconstruction algorithms**

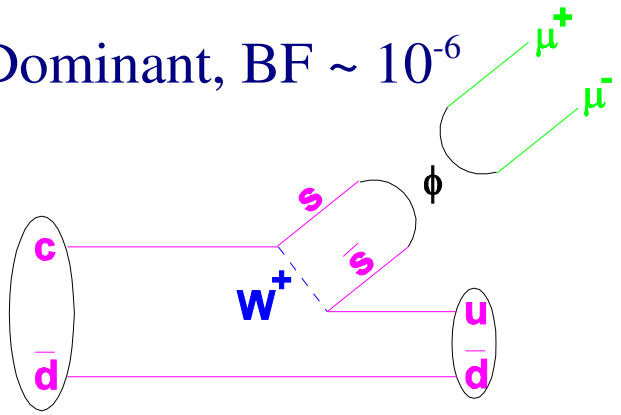
D and D_s FCNC Transitions

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

- Non-resonant decays
  - GIM suppressed, BF ~ 10^{-8}

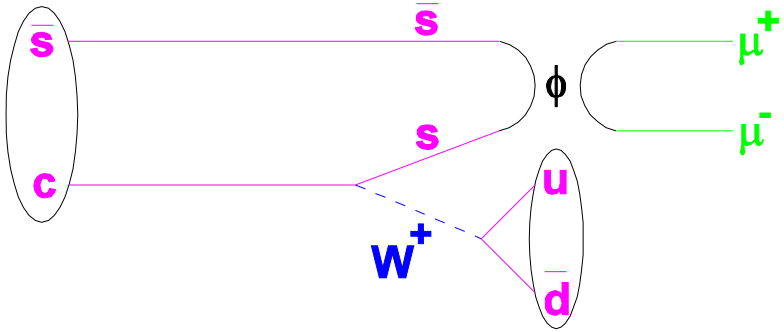


- Resonant decays
  - Dominant, BF ~ 10^{-6}



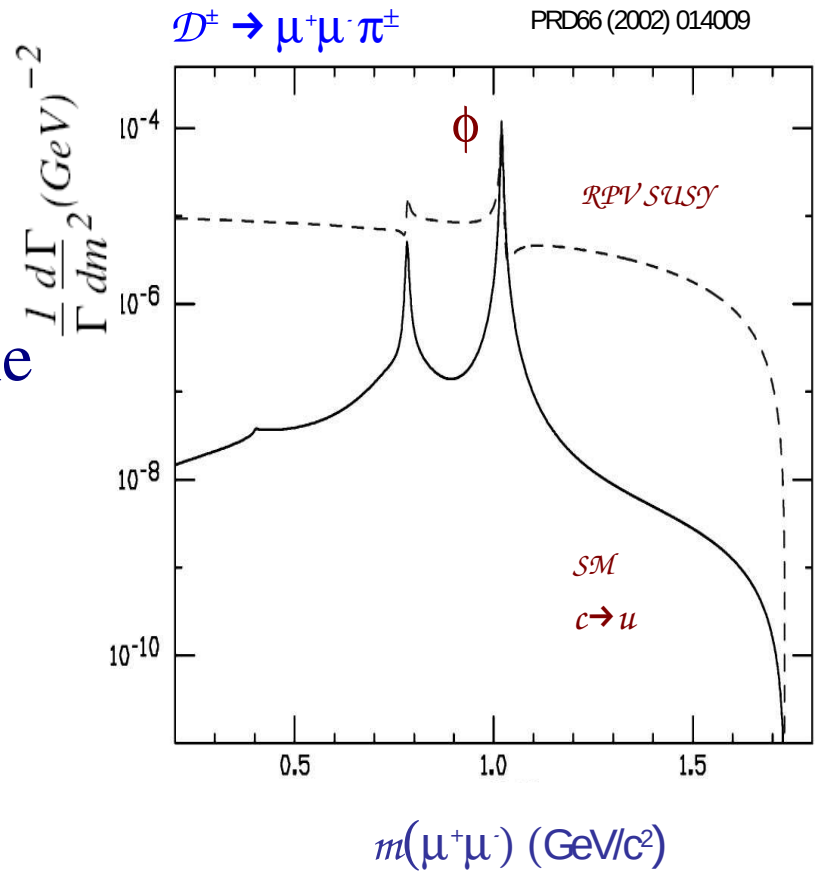
$D_s \to \mu^+\mu^-\pi$

- Non-resonant decays
  - penguin and box diagrams are absent
- Resonant decays
  - BF ~ 10^{-5}



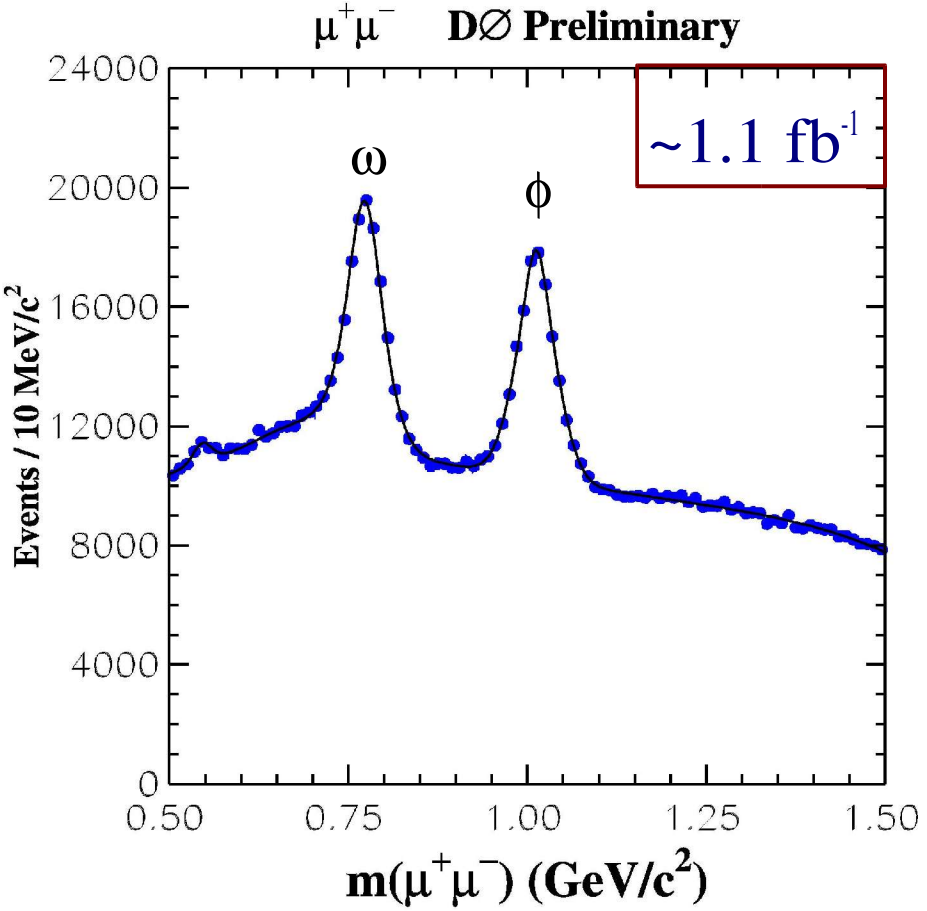
Why FCNC Charm?

- For every rare SM process there is a "beyond the SM" theory in which it is enhanced.
- Strict limits have been set experimentally from b → s and s → d in the down sector.
  - There is still room to have effects in the up sector.
    - RPV SUSY
      - Burdman et.al. PRD66, 014009
    - Littlest Higgs Models
      - Fajfer et.al. PRD73, 054026

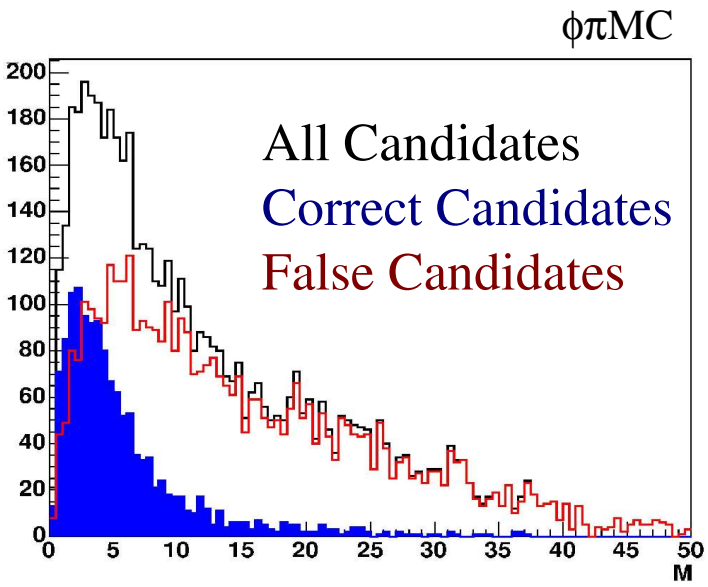


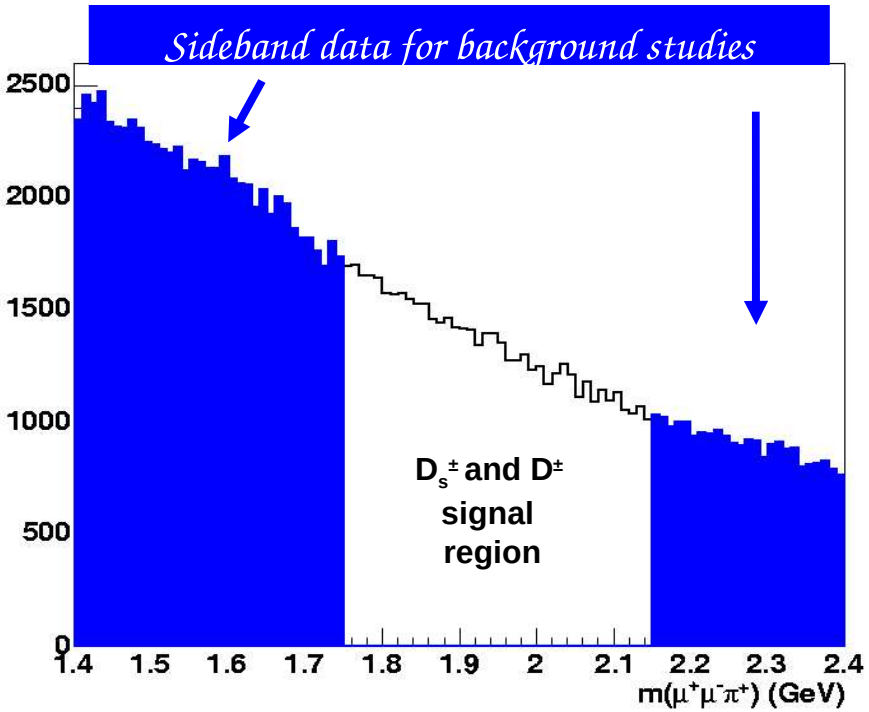
$c \to u\, \mu^+ \mu^-$ Analysis Strategy

- First search for long distance components $D \to \pi V$, $V \to \mu^+\mu^-$
- Golden Mode
  - $D_s \to \phi\, \pi$
  - (no penguin or box diagrams)
- Then search for excess in the continuum region
  - $D^+ \to \pi^+\mu^+\mu^-$ with $m(\mu\mu)$!= ϕ



Data Selection

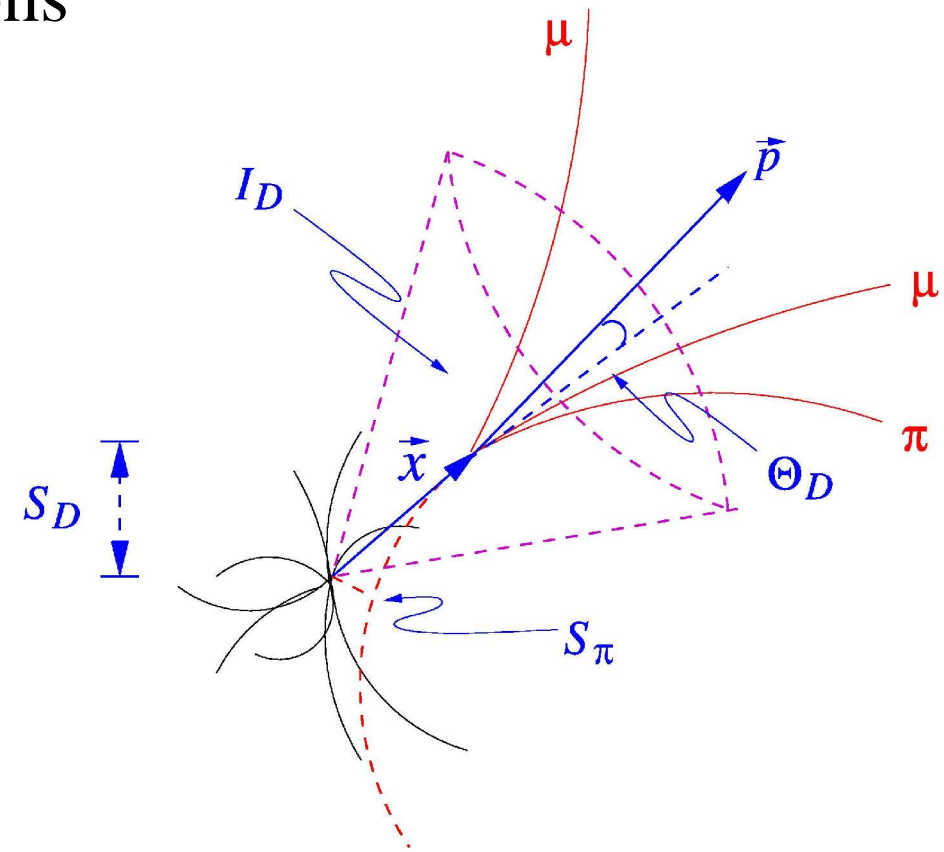




- Trigger on dimuon
- Add a track
  - in the same jet as the dimuon pair
  - from the same vertex as the dimuon.
- D selection
  - $\mu^+\mu^-$ and π form a good vertex
  - $1.3 < m(\mu^+\mu^-\pi) < 2.5$ GeV/c^2
  - $p(\mu^+\mu^-\pi)$ in the SV-PV direction
- Large track multiplicity leads to several D candidates per event.
  - Select the best track based on track p_T , D vertex χ^2, and distance between track and dimuon system.
    - $M = \chi^2_{vtx} + \kappa_\pi^2 + \Delta R_\pi^2$

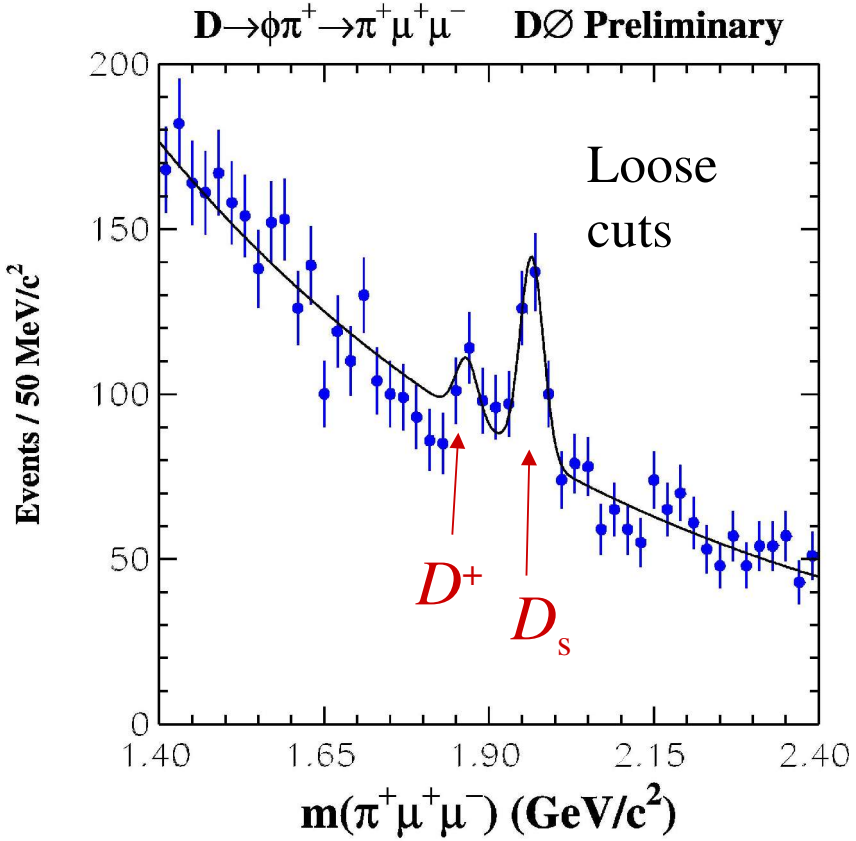
Background Supression

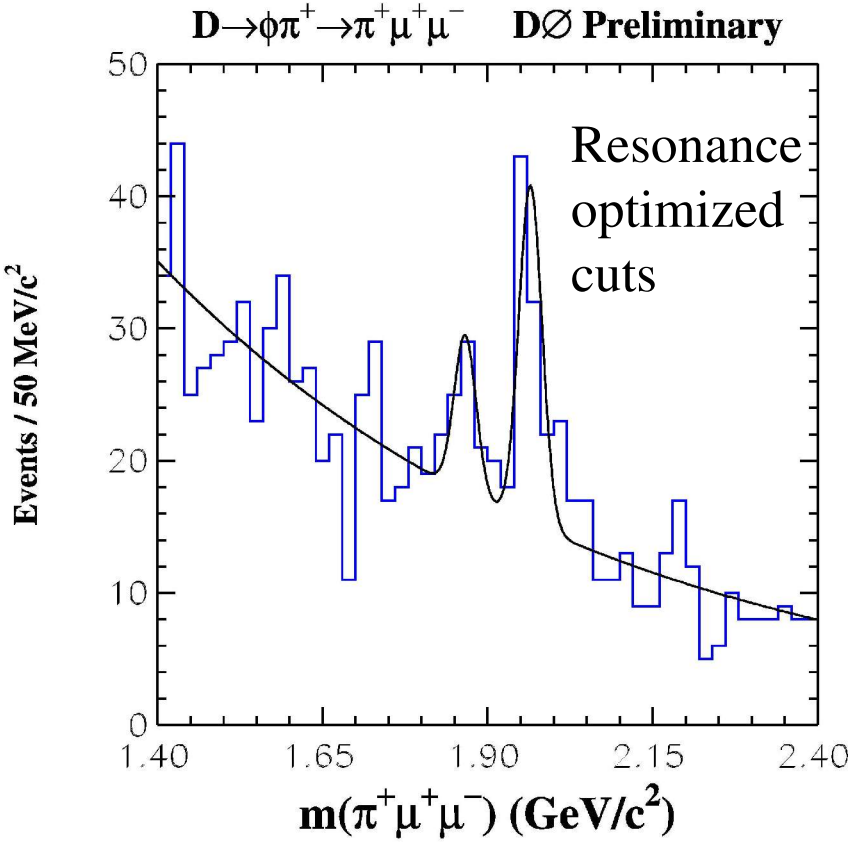
- Use variables that take advantage of long lifetimes of heavy hadrons
  - Isolation: $I_D = p(D)/\sum p_{\text{cone}}$
    - $R = (\Delta\eta^2 + \Delta\phi^2)^{1/2} < 1.0$
  - Transverse flight length significance: S_D
  - Collinearity angle: Θ_D
  - Pion impact parameter significance: S_π
- Variables are tuned separately for D and D_s due to the differing lifetimes



$D \to \pi \phi \to \pi \mu^+ \mu^-$

$0.96 < m(\mu^+ \mu^-) < 1.06$ GeV/c^2





$n(D_s) = 133 \pm 25$

$n(D^+) = 37 \pm 19$

$n(D^+) = 26 \pm 9$

$n(D_s) = 65 \pm 11$

Extracting the Resonant Branching Fraction

$$\frac{n\left(D^+\right)}{n\left(D_s\right)}=\frac{f^+_{c\to D}}{f^s_{c\to D}}\times\frac{f^s_p}{f^+_p}\times\frac{\epsilon^+}{\epsilon^s}\times\frac{\mathrm{BF}\left(D^+\to\phi\pi^+\to\pi^+\mu^+\mu^-\right)}{\mathrm{BF}\left(D^+_s\to\phi\pi^+\right)\times\mathrm{BF}\left(\phi\to\mu^+\mu^-\right)}$$

$f_{c\to D}$: Fraction produced in fragmentation

f_p: Prompt fraction

ε: Reconstruction efficiency

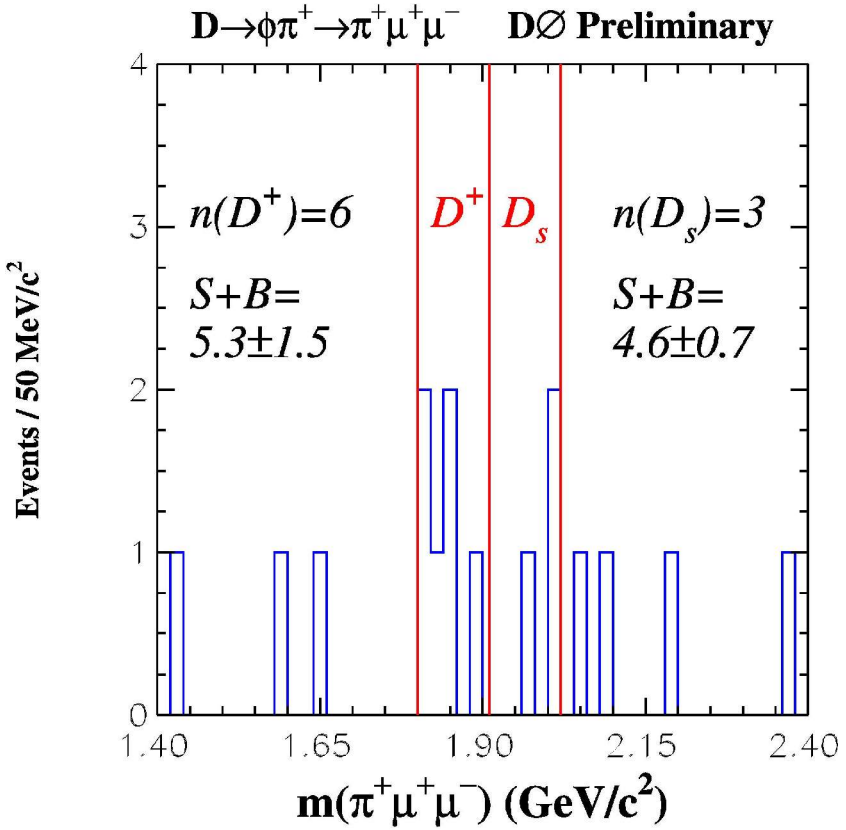
$$\frac{\mathrm{BF}\left(D^+\to\phi\pi^+\to\pi^+\mu^+\mu^-\right)}{\mathrm{BF}\left(D^+_s\to\phi\pi^+\right)\times\mathrm{BF}\left(\phi\to\mu^+\mu^-\right)}=0.17\pm0.07\pm0.05$$

$$\mathrm{BF}\left(D^+\to\phi\pi^+\to\pi^+\mu^+\mu^-\right)=\left(1.75\pm0.7\pm0.5\right)\times10^{-6}$$

SM: 1.77×10^{-6} CLEO-c ($\phi\to ee$): $\left(2.7^{+3.6}_{-1.8}\pm0.2\right)\times10^{-6}$

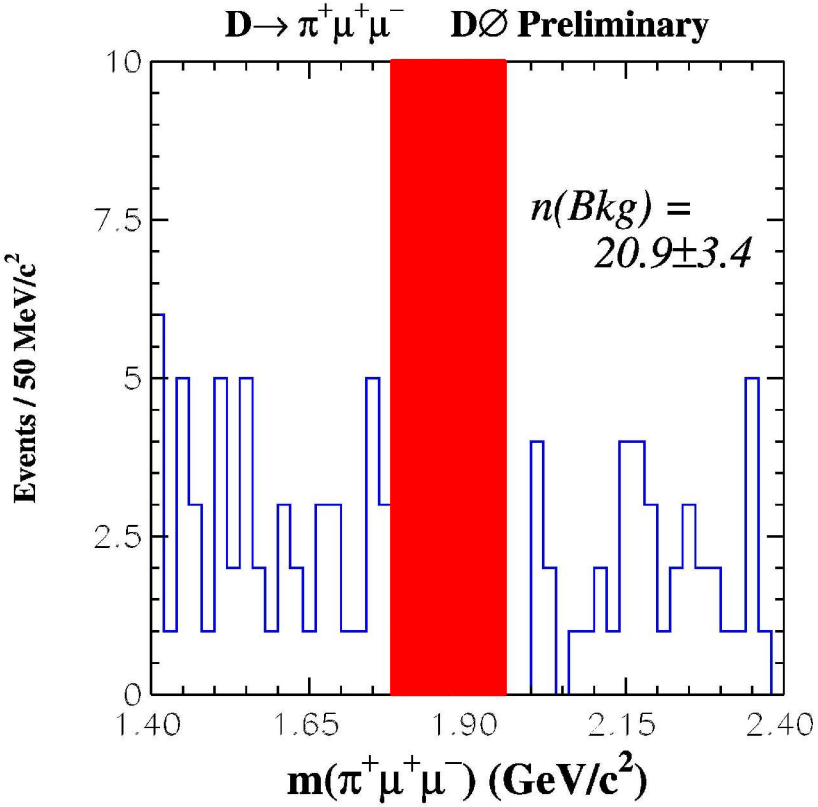
$D^+ \to \pi^+ \mu^+ \mu^-$

$0.96 < m(\mu\mu) < 1.06$ GeV/c2



$0.2 < m(\mu\mu) < 0.96$ GeV/c^2

$1.06 < m(\mu\mu) < 1.76$ GeV/c^2



Good agreement with expectations

Nonresonant $D^+ \to \pi^+ \mu^+ \mu^-$

Branching Fraction Limit

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

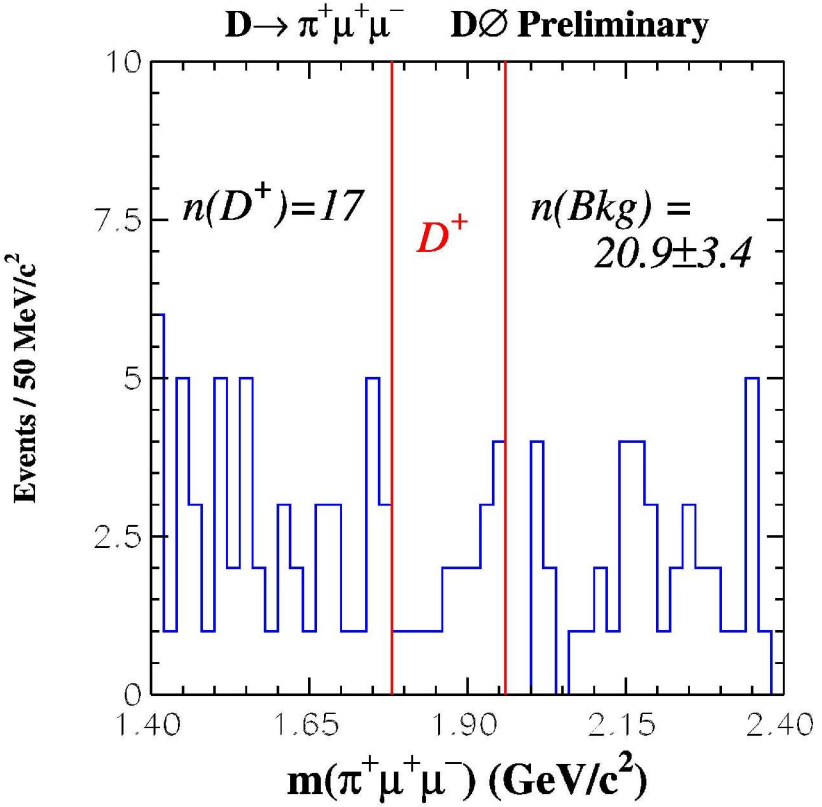
D0: $< 4.7 \times 10^{-6}$ @ 90% C.L

CLEO-c($\pi e^+ e^-$): $< 7.4 \times 10^{-6}$ @ 90%

FOCUS: $< 8.8 \times 10^{-6}$ @ 90%

$0.2 < m(\mu\mu) < 0.96$ GeV/c^2

$1.06 < m(\mu\mu) < 1.76$ GeV/c^2



Conclusions

- DØ clearly observes (>7σ) $D_s^+ \rightarrow \phi\pi^+$ and sees evidence (3.1σ) for $D^+ \rightarrow \phi\pi^+$.
- DØ has measured the branching fraction for $D^+ \rightarrow \pi^+ \phi \rightarrow \pi^+ \mu^+\mu^-$.
  - consistant with the product of the two branching fractions.
- DØ has searched for the continuum production of $D^+ \rightarrow \pi^+ \mu^+\mu^-$.
  - There is no evidence of signal in this channel.
  - Set the most stringent limit to date.
- FCNB charm decays are useful in setting limits on the effects of SUSY in the up quark sector.
- The Tevatron continues to deliver, expect DØ's 2 fb^{-1} data set in the not so distant future.