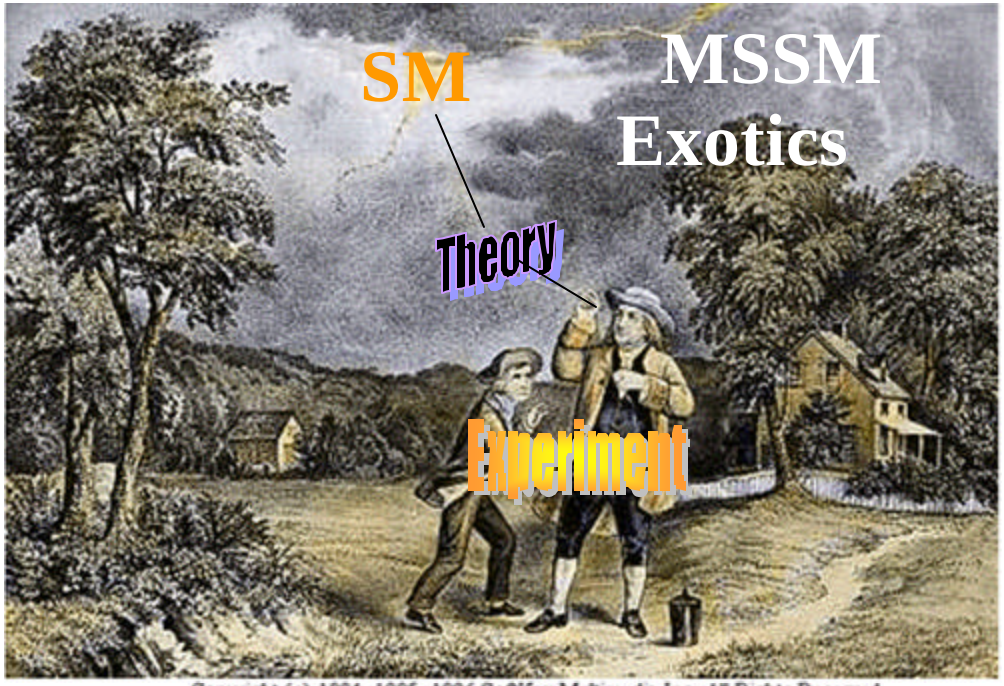
Rare Charm Decays

Recent Results from FOCUS (+Theory)



Will E. Johns

(for the FOCUS collaboration)

Recent Results from FOCUS

Concentrate on Background Effects

In the Confidence Limit Calculation

Background Fluctuations

- Treat like a nuisance parameter?
- Include as a systematic?
- Include in likelihood: Rolke-Lopez

[hep-ph0005187 v2]

Probability of finding a signal rate m and a background rate ***b*** given ***x*** events in a signal region and ***y*** events in background sidebands. Where t is the ratio of the number of background events(using MC!) in the sideband regions to the signal region:

$$P_{\mu,b}(x,y) = \frac{(\mu+b)^x e^{-(\mu+b)}}{x!} \frac{(\tau b)^x e^{-(\tau b)}}{y!}$$

And it's not just my P.O.V. …

A reminder during

"Journeys of an Accidental Statistician"

[Gary Feldman, *Fermilab conference on CL*, March 2000]
from the 1998 PDG [*Euro. Phys. J.* **C3**(1998)]:

"…we suggest that… a measure of sensitivity should be reported whenever expected background is larger or comparable to the number of observed counts."

In the Event Selection Too!

Optimizing a cut grid in the presence of background can still bias

- You can easily choose a downward fluctuation in the background and produce (you hope) an over-conservative limit.

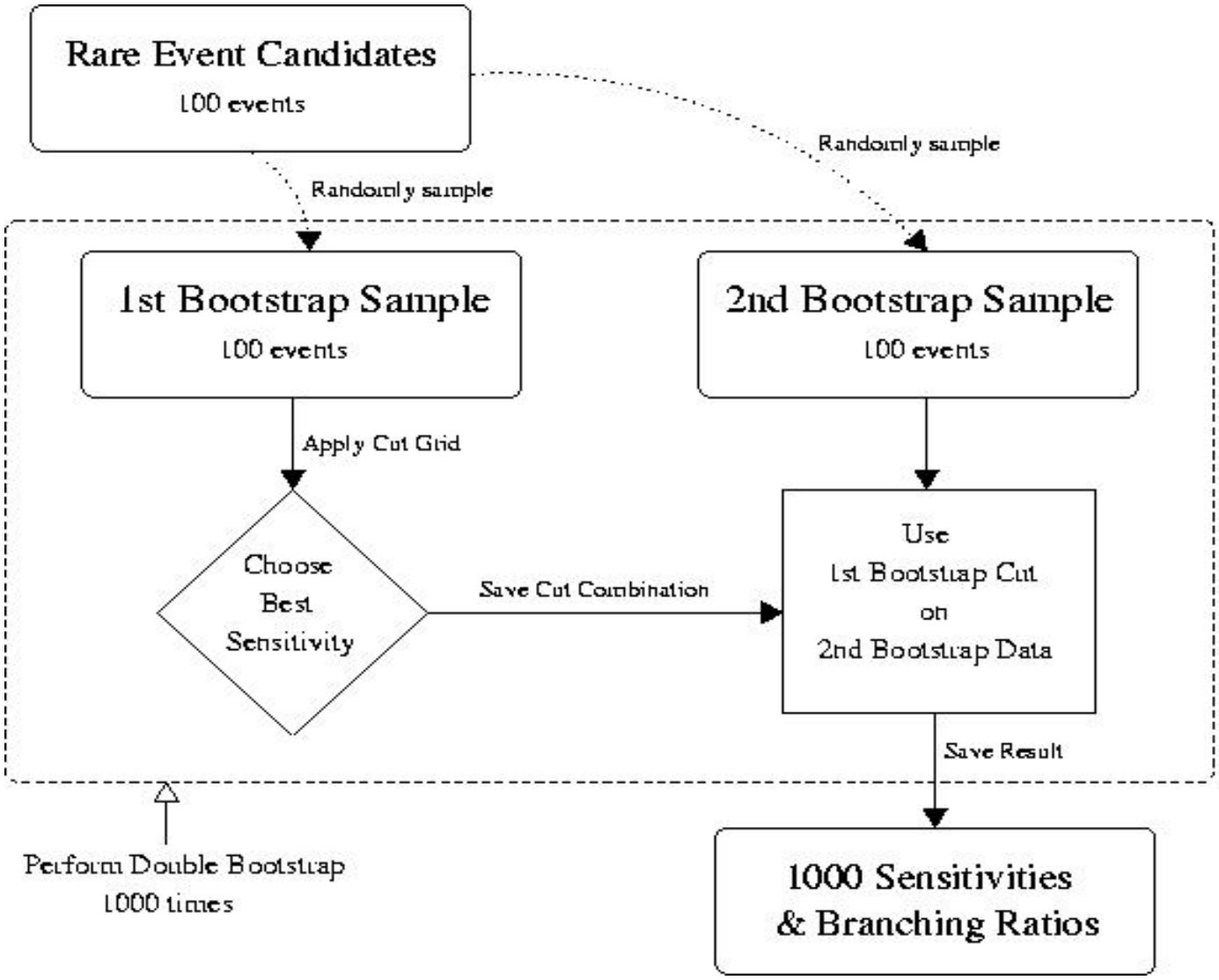
Approach: BOOTSTRAP (two ways)

- Best Limit**s**, Optimizing Sensitivity (Dual)
- Best Limit, Optimizing Cuts w/Sensitivity (as a check on the Dual Bootstrap)

(Bootstrap = Sample with replacement)

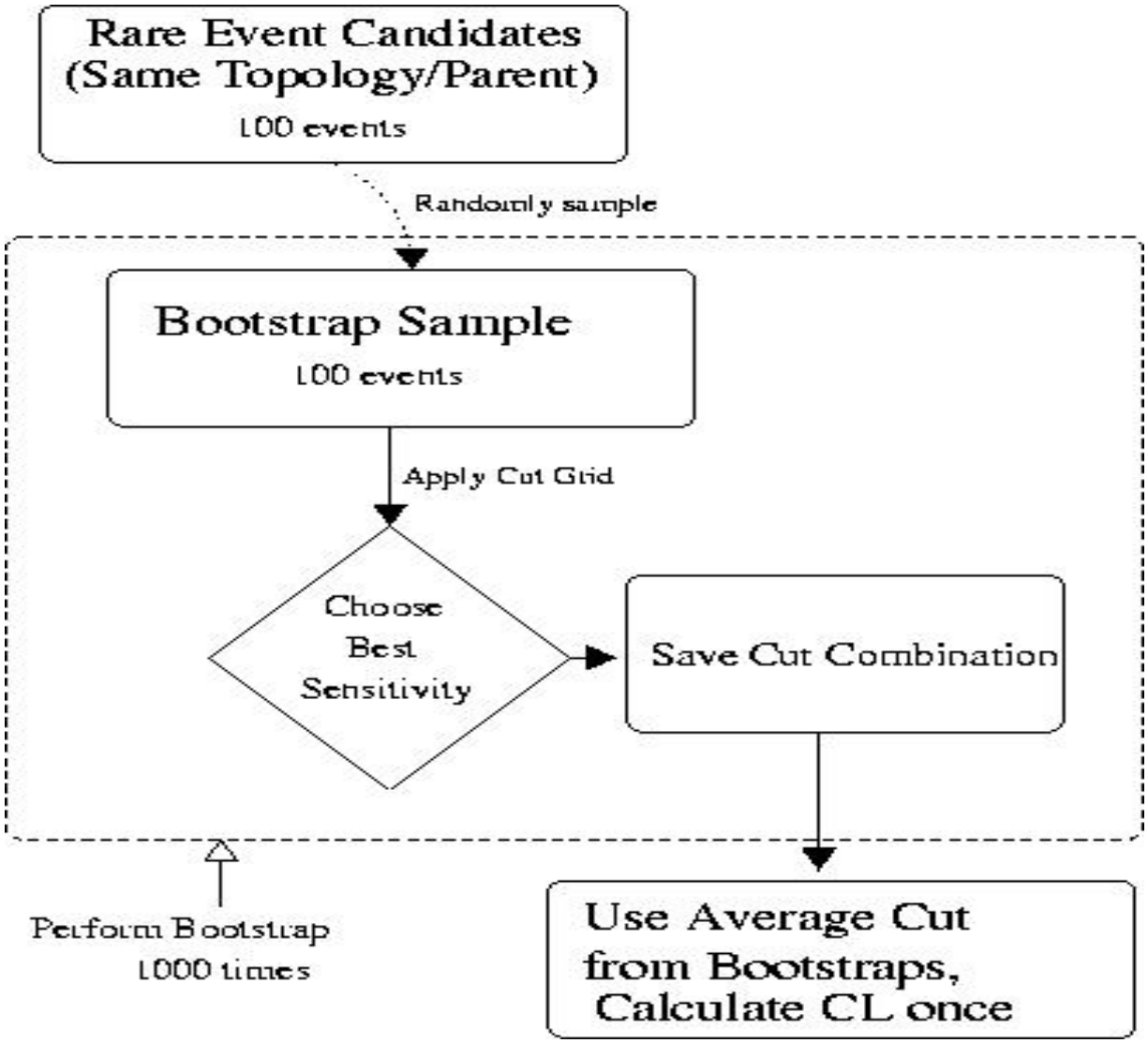
Dual Bootstrap

(NIM article in draft from Rolke-Lopez)

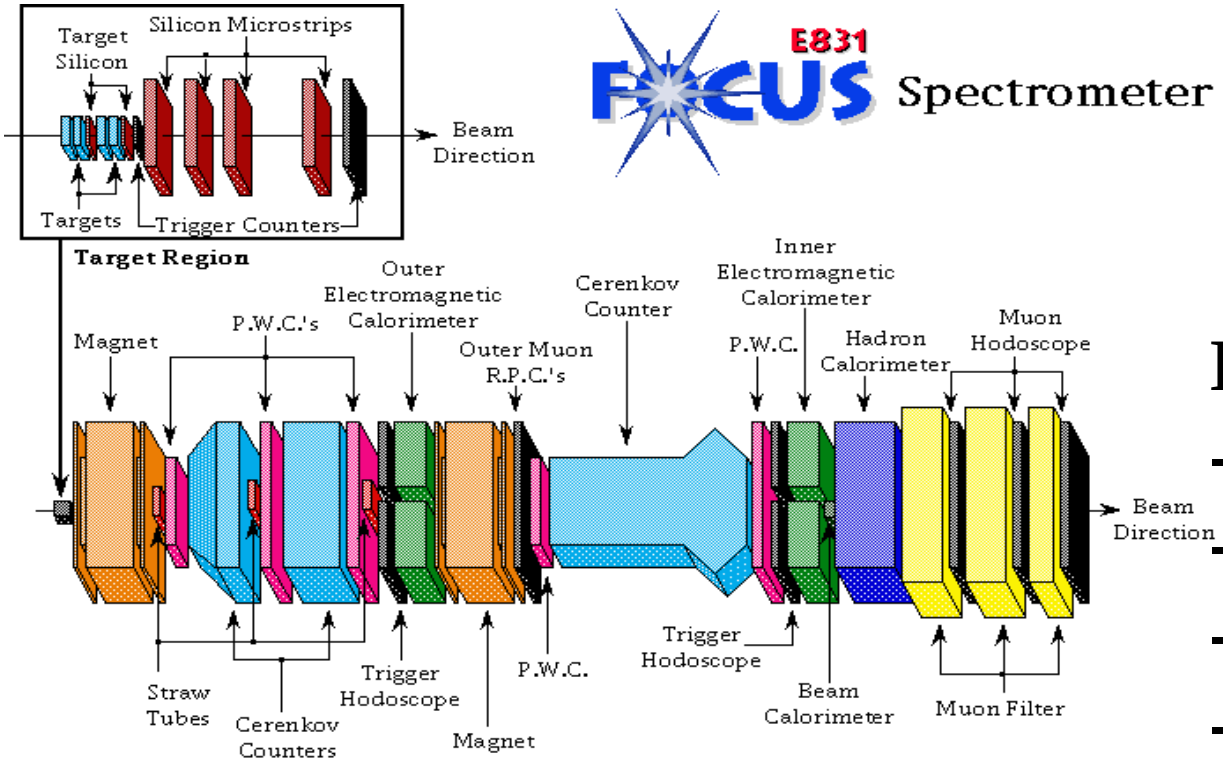


Cut Bootstrap

(Developed by Dan Engh for his thesis)



Data from 96-97 run of FOCUS



E831 FOCUS Spectrometer

Over 1,000,000 Reco'd. Charm

Excellent:
-Vertex Resolution
-Particle ID
-Momentum Res.
-Lots of Pubs…

FOCUS Detector References:

- **[NIM A320(1992) 519]**
- **[NIM A329(1993) 62]**
- **[hep-ex/0108011]**
- **[hep-ex/0109028]**
- **[hep-ex/0204023]**

Collaborating Institutions

University of California, Davis

CBPF (Brazil)

CINVESTAV (Mexico)

University of Colorado, Boulder

Fermi National Accelerator Laboratory

Laboratori Nazionali di Frascatti dell'INFN (Italy)

University of Illinois, Urbana

Indiana University, Bloomington

Korea University, Seoul

INFN and University of Milano (Italy)

University of North Carolina, Asheville

INFN and University of Pavia (Italy)

University of Puerto Rico, Mayaguez

University of South Carolina, Columbia

University of Tennessee, Knoxville

Vanderbilt University

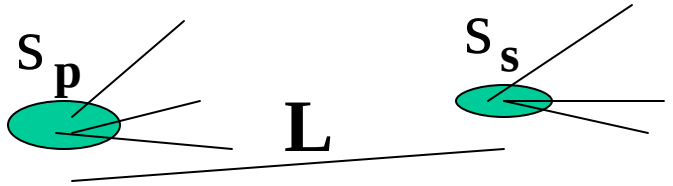
University of Wisconsin, Madison

~ 100 Physicists

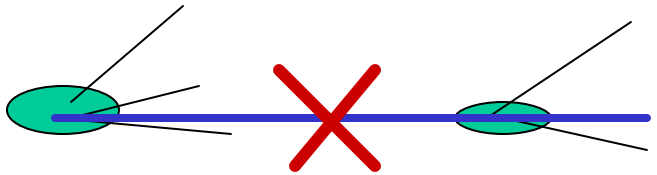
Look at decays with 2 or more muons

Cut Grid, based on vertexing, Particle ID

L/s – vary from >5-21



ISO1 – CL DK's in prim
(vary <0.1 –0.001)



DCL – CL of DK vertex (>1 -- 4%)

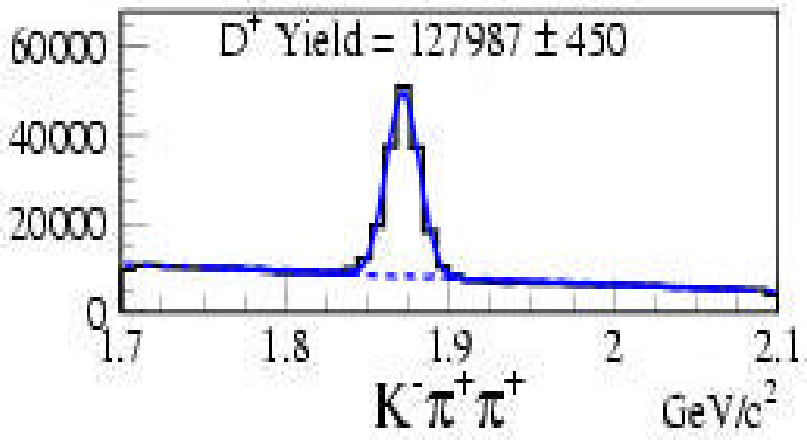
MuCL – CL for Muon ID (>1 – 10%)

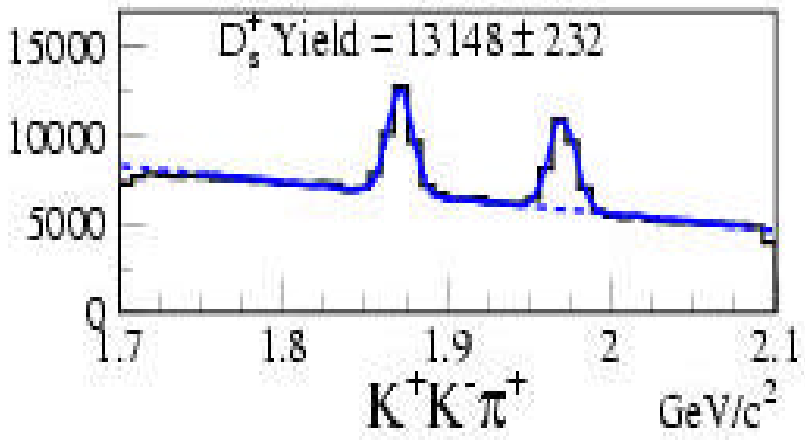
Cut on m P, (bigger MCS, more h-m at low P)

Vary Cerenkov cuts for p's and K's
(likelihood differences)

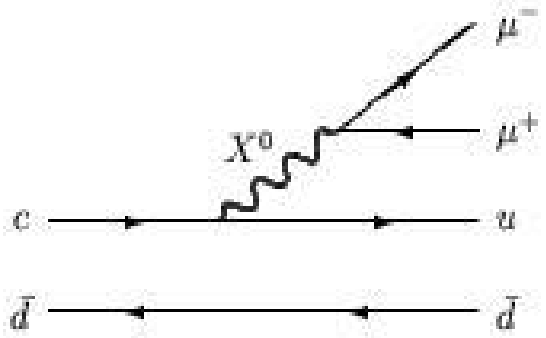
Normalize Rare modes to Golden/Silver modes

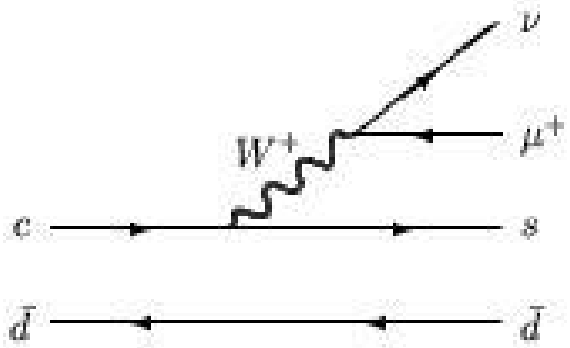
$D^+ \Rightarrow K^-p^+p^-$ **(loosest cuts)** **$D_s^+ \Rightarrow K^+K^-p^+$**





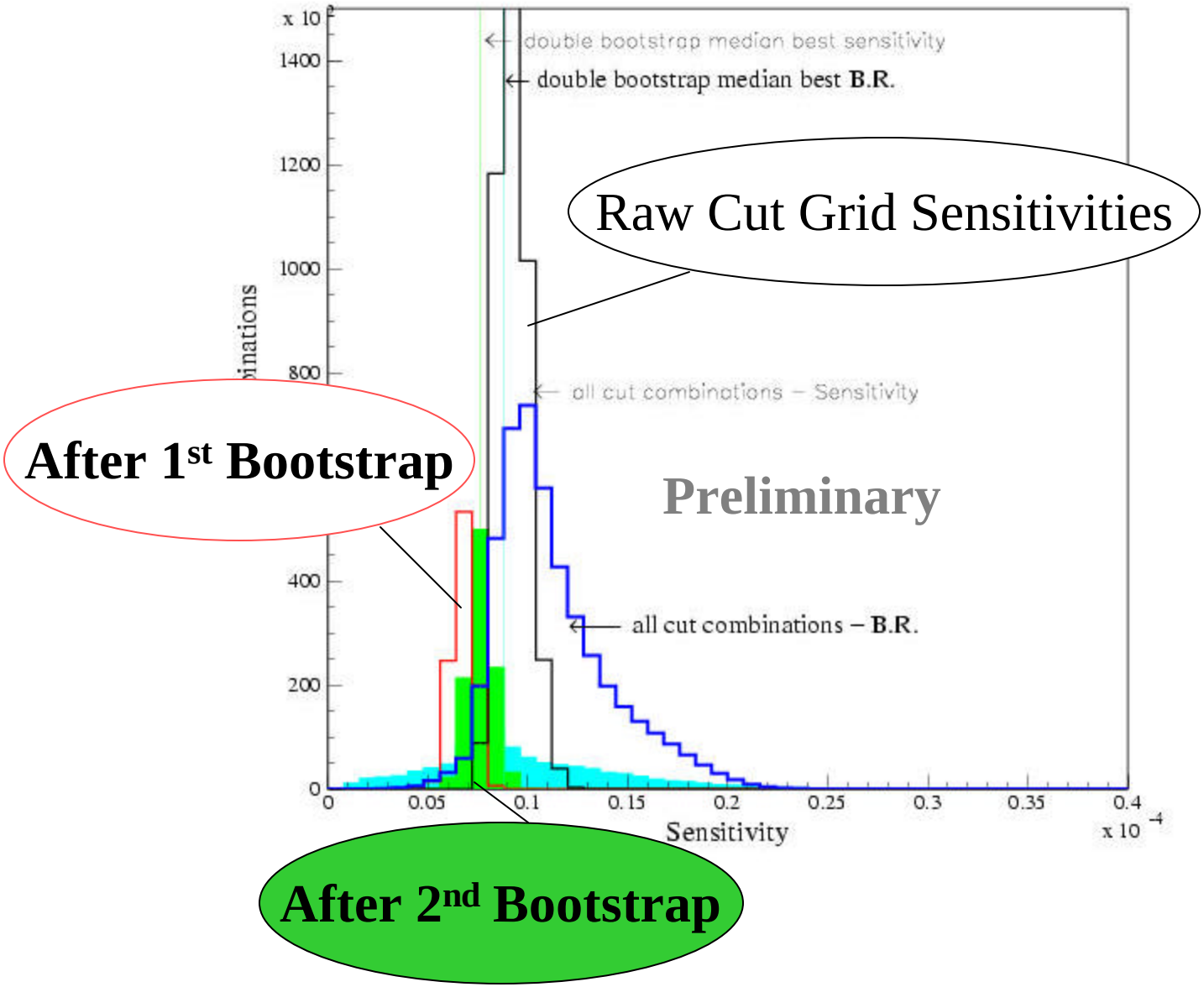
Goal





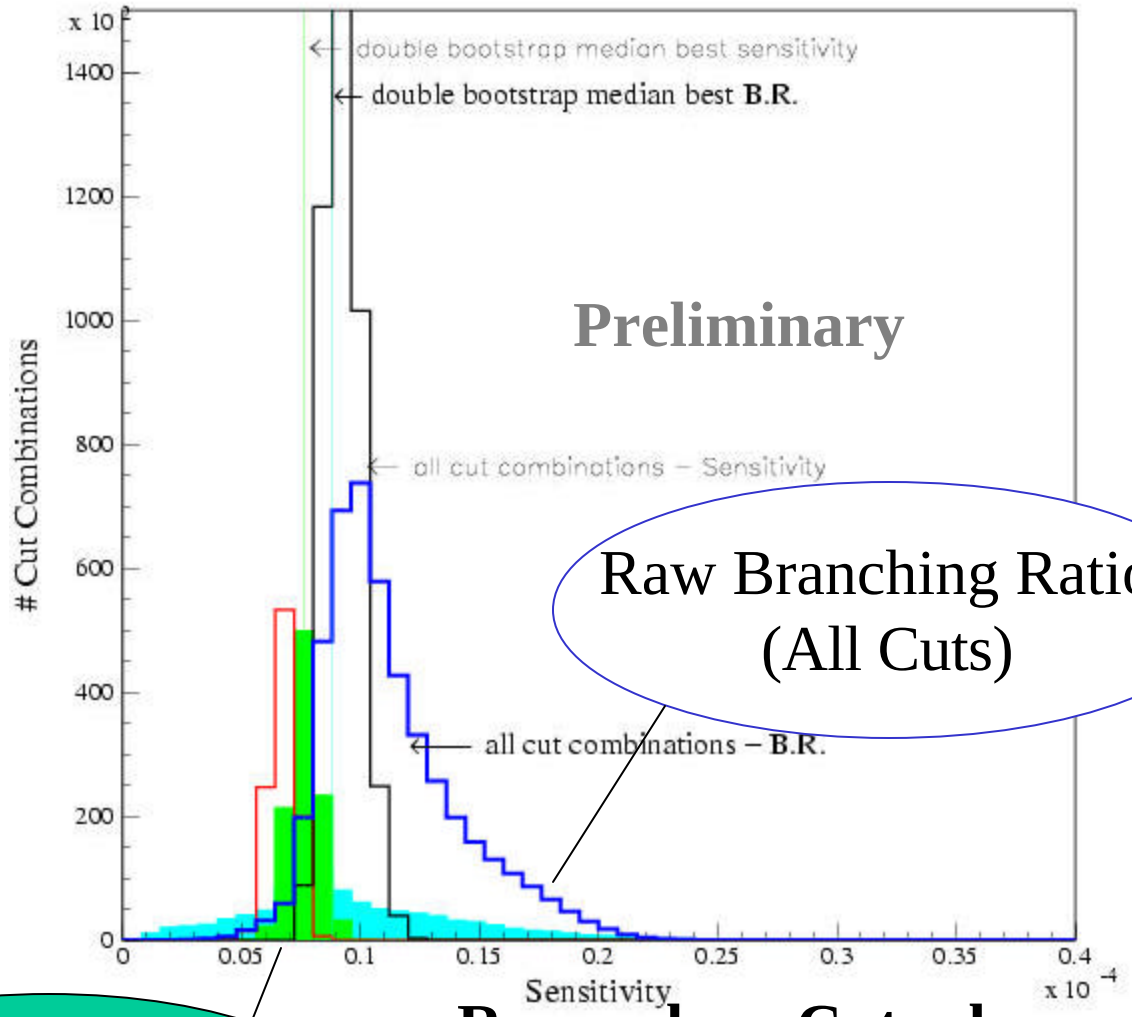
$$BR(D^+ \to \pi^+\mu^+\mu^-) \sim (\frac{M_W}{M_X})^4 BR(D^+ \to \overline{K}^o\mu^+\nu_\mu)$$

$D^+ \Rightarrow p^+m^+m^-$ Dual Bootstrap Results



$D^+ \Rightarrow p^+m^+m^-$

Dual Bootstrap Results

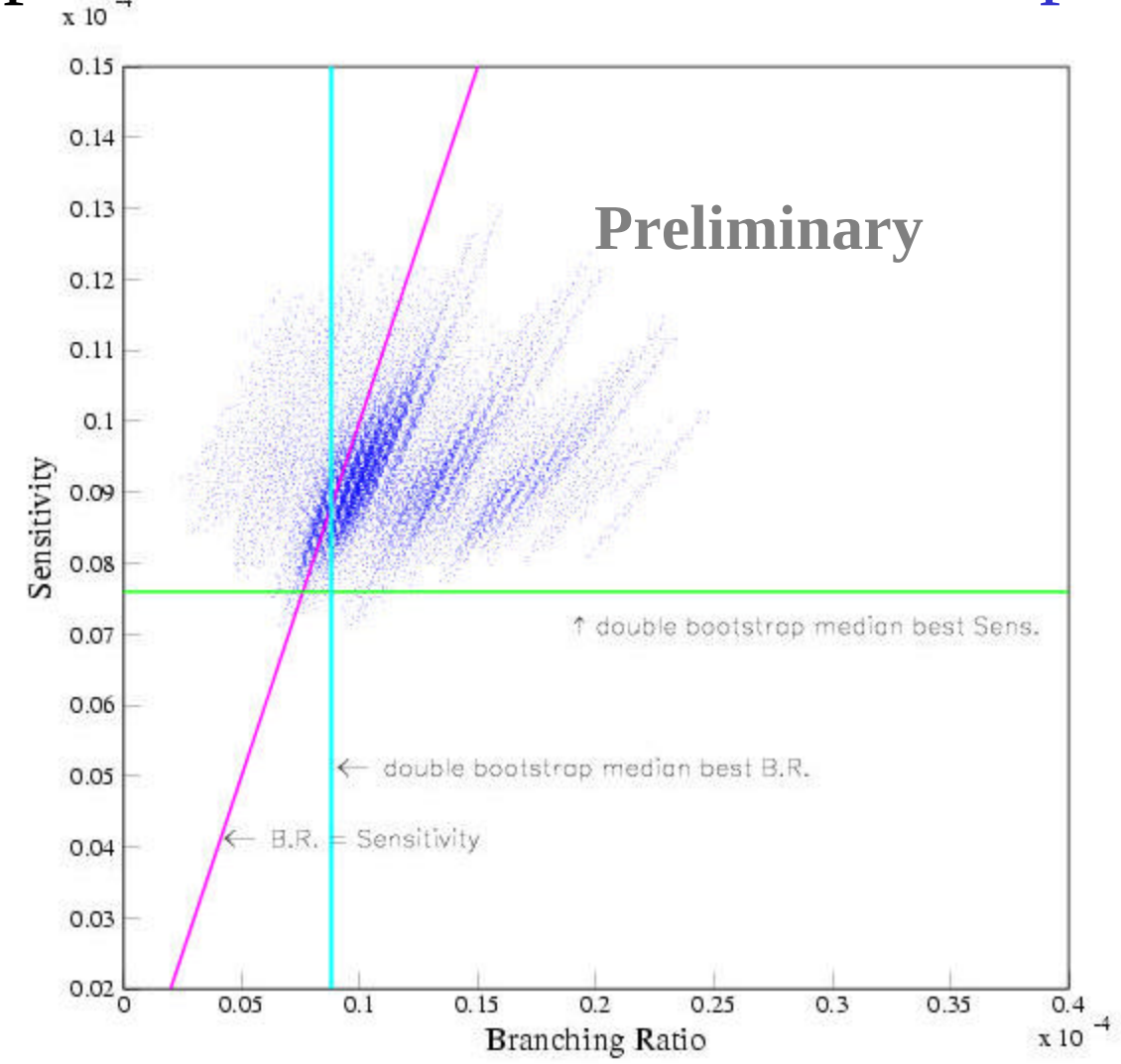


Raw Branching Ratios (All Cuts)

2nd Bootstrap Branching ratios

Remember: Cuts chosen by optimizing Sensitivity (Box Closed) in the 1st Bootstrap

$D^+ \Rightarrow p^+m^+m^-$ Dual Bootstrap Results

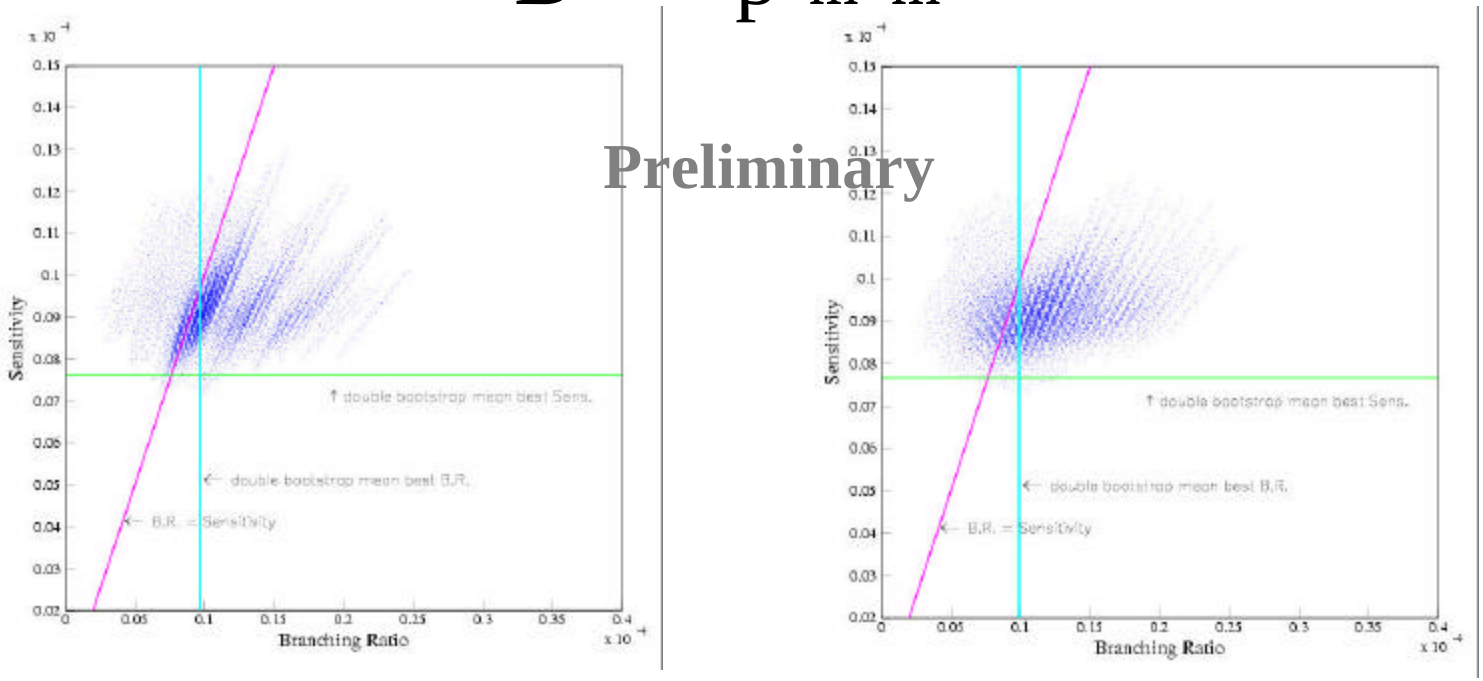


Sensitivity vs. Branching Ratio (as promised…)

And in case you're curious…

Rolke-Lopez compare to Unified (Feldman-Cousins)

$D^+ \Rightarrow p^+m^+m^-$



(sorry, using mean values here…)

Why Bother? (SM calcs are SO low…)

MSSM R-Parity Violating Terms Boost Rates

(Burdman, Golowich, Hewett, Pakvasa) [hep-ph/0112235 v2]

-Look for new Physics!- (Away from poles!)

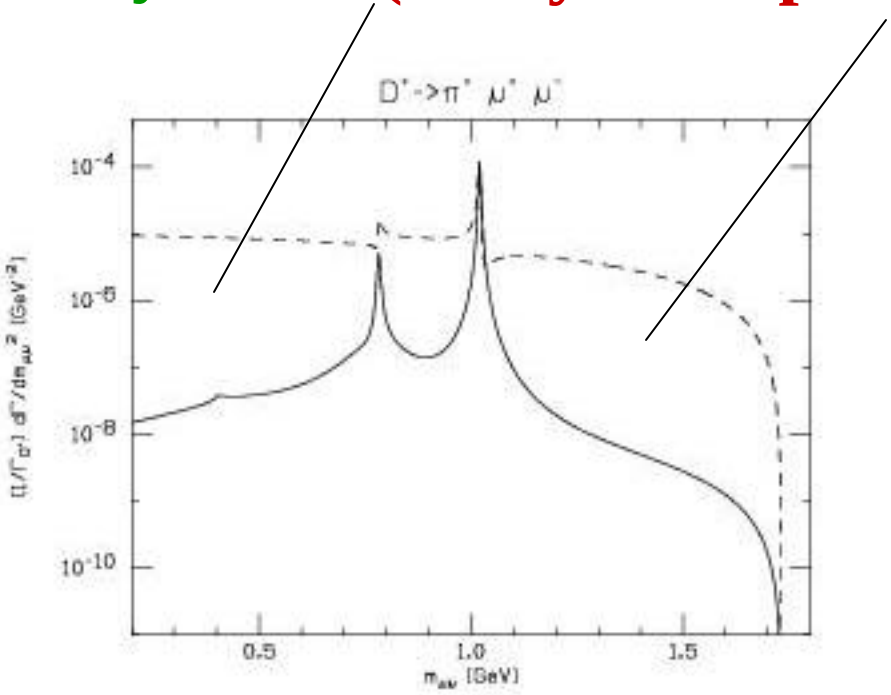
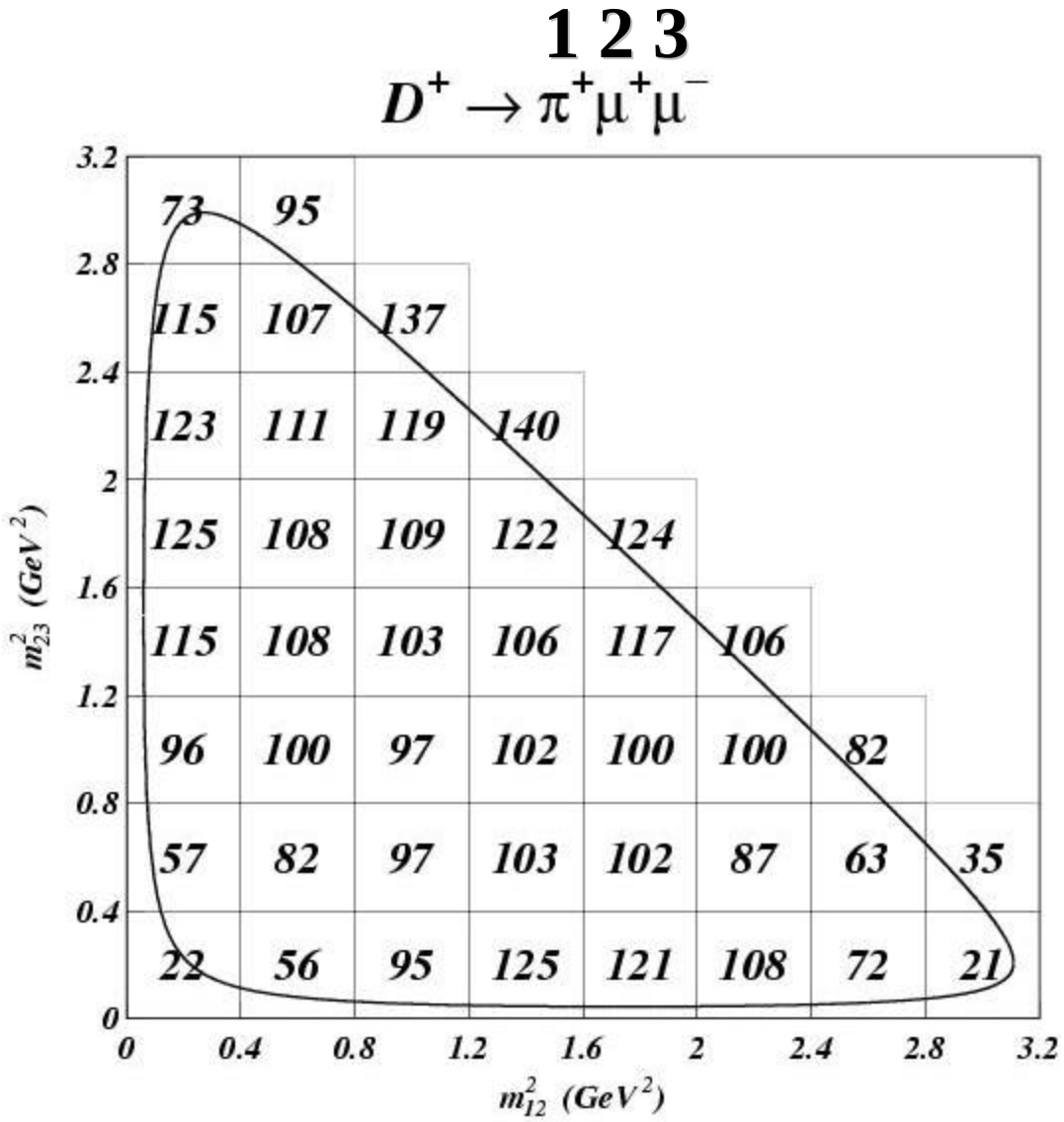


Figure 12: The dilepton mass distribution for $D^+ \to \pi^+\mu^+\mu^-$ normalized to Γ_{D^+}. The solid line shows the sum of the short and the long distance SM contributions. The dashed line includes the allowed R-parity violating contribution from Supersymmetry (see text for details).

Acceptance is important!



Monte Carlo relative efficiencies for events generated flat across the dalitz surface

All other modes, nearly final (still preliminary) FOCUS results

(Many thanks to Dan Engh for all his work!)

Decay Mode	**Dual Bootstrap**	**Sys. Error**	**Result W/sys**	**Sensitivity W/sys**	**Single Cut(w/sys)**	**Previous (E791)**
$D^+ \Rightarrow K^+\pi^+\pi^-$	9.1×10^{-6}	7.5%	9.2×10^{-6}	7.5×10^{-6}	11.8×10^{-6}	4.4×10^{-5}
$D^+ \Rightarrow K^-\pi^+\pi^+$	1.3×10^{-5}	7.5%	1.3×10^{-5}	4.8×10^{-6}	1.2×10^{-5}	12×10^{-5}
$D^+ \Rightarrow p^+\pi^+\pi^-$	8.8×10^{-6}	7.5%	8.8×10^{-6}	7.6×10^{-6}	7.5×10^{-6}	1.5×10^{-5}
$D^+ \Rightarrow p^-\pi^+\pi^+$	4.9×10^{-6}	7.5%	4.8×10^{-6}	5.6×10^{-6}	5.2×10^{-6}	1.7×10^{-5}
$D_s^+ \Rightarrow K^+\pi^+\pi^-$	3.3×10^{-5}	27.5%	3.6×10^{-5}	3.3×10^{-5}	3.8×10^{-5}	1.4×10^{-4}
$D_s^+ \Rightarrow K^-\pi^+\pi^+$	1.3×10^{-5}	27.5%	1.3×10^{-5}	2.1×10^{-5}	2.0×10^{-5}	1.8×10^{-4}
$D_s^+ \Rightarrow p^+\pi^+\pi^-$	2.4×10^{-5}	27.5%	2.6×10^{-5}	3.1×10^{-5}	1.8×10^{-5}	1.4×10^{-4}
$D_s^+ \Rightarrow p^-\pi^+\pi^+$	2.6×10^{-5}	27.5%	2.9×10^{-5}	2.3×10^{-5}	2.2×10^{-5}	0.8×10^{-4}

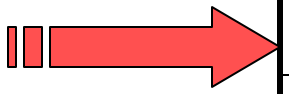
(E687)

Dominated by PDG rate to normalizing mode

All other modes, nearly final (still preliminary) FOCUS results

Compared to recent Theory

Sets New Limit!



Decay Fraction	**Result W/sys**	**MSSM R-Parity**	**SM-1**	**SM-2**
$D^+ \Rightarrow K^+\mu^+\mu^-$	9.2×10^{-6}			7.1×10^{-9}
$D^+ \Rightarrow K^-\mu^+\mu^+$	1.3×10^{-5}			
$D^+ \Rightarrow p^+\mu^+\mu^-$	8.8×10^{-6}	1.5×10^{-5}	1.9×10^{-6}	1.0×10^{-6}
$D^+ \Rightarrow p^-\mu^+\mu^+$	4.8×10^{-6}			
$D_s^+ \Rightarrow K^+\mu^+\mu^-$	3.6×10^{-5}			4.3×10^{-8}
$D_s^+ \Rightarrow K^-\mu^+\mu^+$	1.3×10^{-5}			
$D_s^+ \Rightarrow p^+\mu^+\mu^-$	2.6×10^{-5}			6.1×10^{-6}
$D_s^+ \Rightarrow p^-\mu^+\mu^+$	2.9×10^{-5}			

[hep-ph/0112235 v2]

[hep-ph/0106333 v1]

Not quite ready for prime time from FOCUS

Preliminary!

FOCUS Sensitivity: 1.2×10^{-6}

$\mathbf{D^0 \Rightarrow \mu^+\mu^-}$

PDG:$<4.1 \times 10^{-6}$

(Hugo Hernandez UPR)

Theory

R-Parity MSSM: 3.5×10^{-6}

SM1: 3.0×10^{-13}

Expect $\mathbf{D^+ \Rightarrow \mu^+\mu^+\mu^-}$ **soon**

(from Dan Engh too)

Wrap-Up

- FOCUS results will set new limits (x10 in some cases)
- New Limit on R-Parity Violating MSSM
- Bootstrapping gives you more info when calculating limits
- More results coming soon from FOCUS
- Room for x10 stats before SM kicks in