

# Analysis of $D^+ \rightarrow \rho^0 \mu^+ \nu$ in FOCUS

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## Abstract

I will present preliminary results on the analysis of the semileptonic branching ratio

$$\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)}$$
 using data collected by FOCUS.

□ Semileptonic decays provide an excellent environment to study **hadronic currents** since:

○ SL process can be factorized into:

1. **Leptonic Current**
2. **Hadronic Current**

$$\mathcal{M}(P_{Q\bar{q}} \rightarrow X_{q'\bar{q}} l \nu) = -i \frac{G_F}{\sqrt{2}} V_{q'Q} L^\mu H_\mu$$

□ Heavy Quark symmetry relates the Form Factors of the decay  $c \rightarrow d W^+$  to those of the decay  $b \rightarrow u$  leading to more accurate model-independent determination of  $|V_{ub}|$

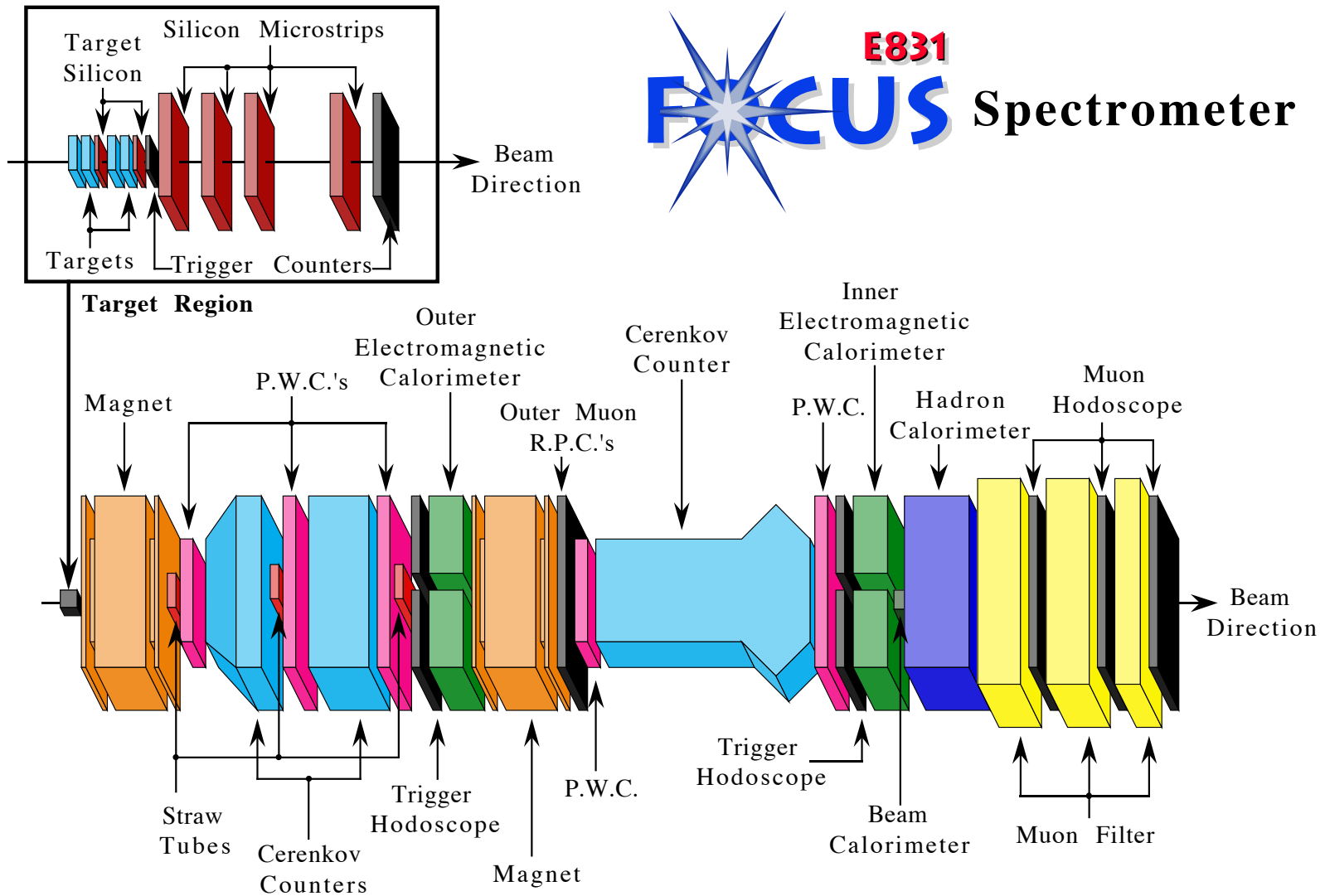
□ Experimental world average for  $\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)}$  and theoretical predictions differ by  **$2\sigma$**

○  $\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)} = 0.061 \pm 0.014$  (PDG average)

○  $\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)} = 0.030$  (Jaus model)

□ Previous measurements of  $\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)}$  have **large statistical errors**

FOCUS is a fixed target experiment that collected data at Fermilab from 1996 to 1997. Over one million charm particles were fully reconstructed.



## FOCUS main goals

1. High precision studies of Charm Semileptonic decays
2. Studies of Doubly Cabibbo suppressed decays
3. Search for CP violation, Rare and Forbidden decays
4. Charm Baryon spectroscopy
5. Lifetime measurements

## Some semileptonic modes studied so far are

1.  $D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu$
2.  $D_s^+ \rightarrow \phi \mu^+ \nu$
3.  $D^+ \rightarrow \overline{K}^0 \mu^+ \nu$
4. Other modes will be presented at this conference.

$$D^+ \rightarrow \rho^0 \mu^+ \nu$$

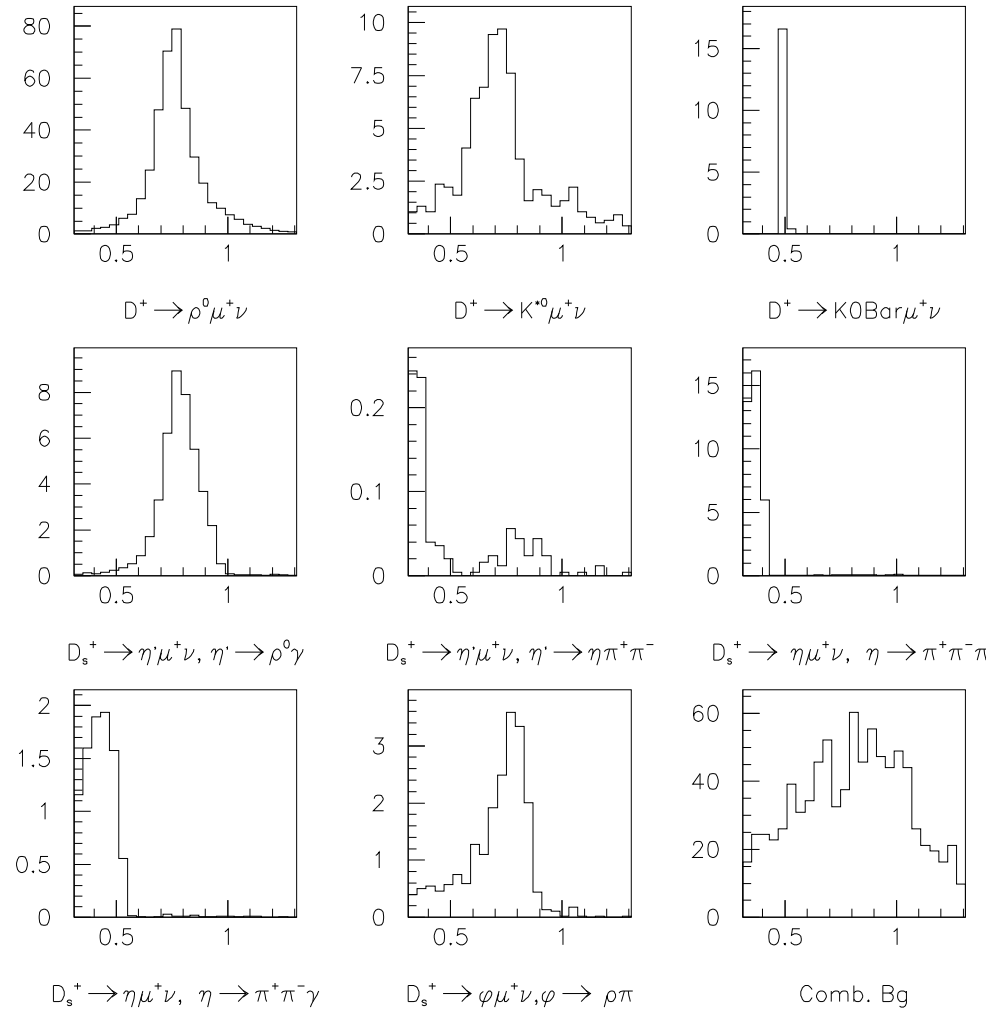
☐ Charm Semimuonic decays with two pions in the final state

1.  $D^+ \rightarrow \rho^0(\pi^+\pi^-)\mu^+\nu$
2.  $K/\pi$  misid from  $D^+ \rightarrow \overline{K}^{*0}\mu^+\nu$
3.  $D^+ \rightarrow \overline{K}^0\mu^+\nu$
4.  $D_s^+ \rightarrow \eta'(\rho^0\gamma)\mu^+\nu$
5.  $D_s^+ \rightarrow \eta'(\pi^+\pi^-\eta)\mu^+\nu$
6.  $D_s^+ \rightarrow \eta(\pi^+\pi^-\pi^0)\mu^+\nu$
7.  $D_s^+ \rightarrow \eta(\pi^+\pi^-\gamma)\mu^+\nu$
8.  $D_s^+ \rightarrow \phi(\rho\pi)\mu^+\nu$

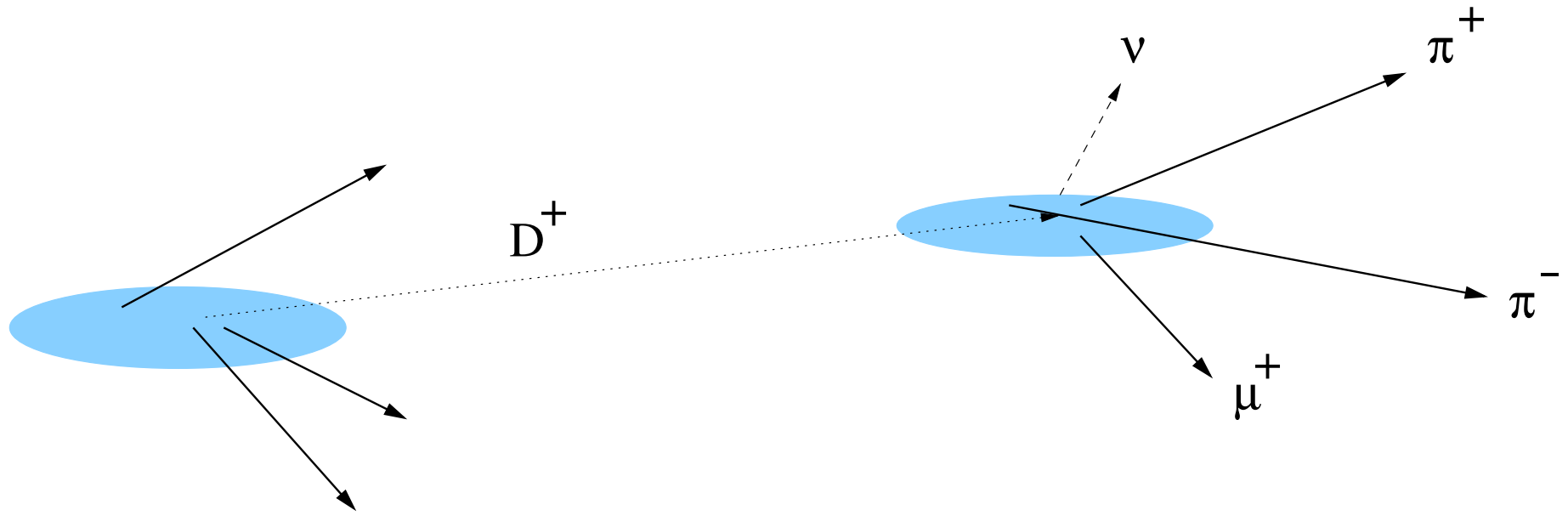
☐ Muon mis-id

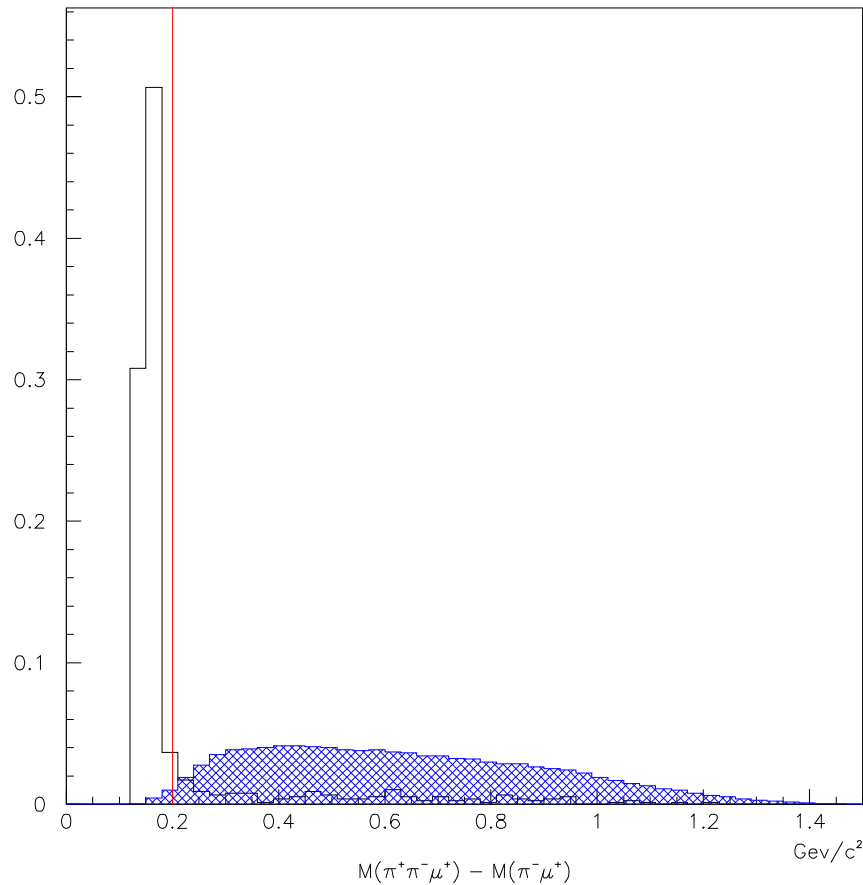
☐ Combinatoric Background

## $\pi^+\pi^-$ Invariant Mass



- ❑ Look for 2 opposite sign pions forming a good vertex with a muon ( $CL_{sec} > 1\%$ )
- ❑ No other tracks compatible with coming from the secondary vertex ( $iso2 < 1\%$ )
- ❑ Significant detachment of the primary and secondary vertex ( $L/\sigma_L > 20$ )
- ❑ Secondary must be  $2\sigma$  out of the target material
- ❑ Pionicity  $> 3$  for pion with OPPOSITE charge to the muon
- ❑ Pionicity  $> 1$  for pion with SAME charge as the muon
- ❑  $1.2 < M(\pi^+ \pi^- \mu^+) < 1.8$  and  $M(\pi^- \pi^+ \mu^+) - M(\pi^- \mu^+) > 0.20$



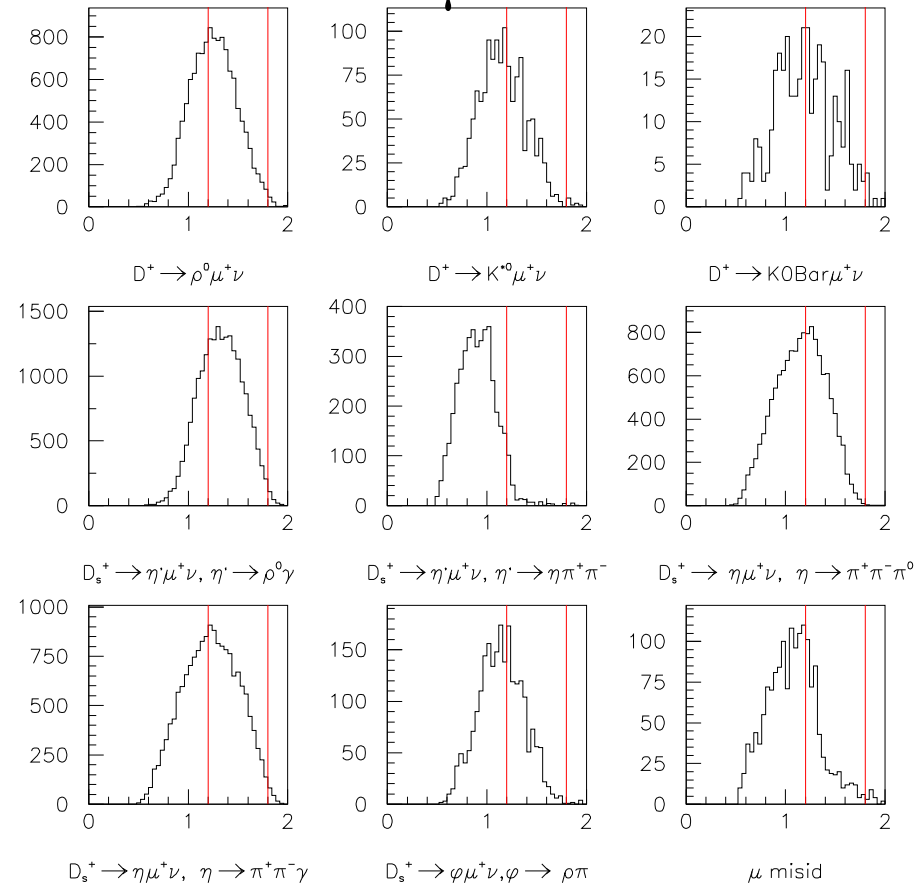


## Mass difference cut

Remove BG from decay chain

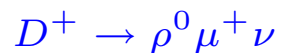


## $\pi^+\pi^-\mu^+$ Mass

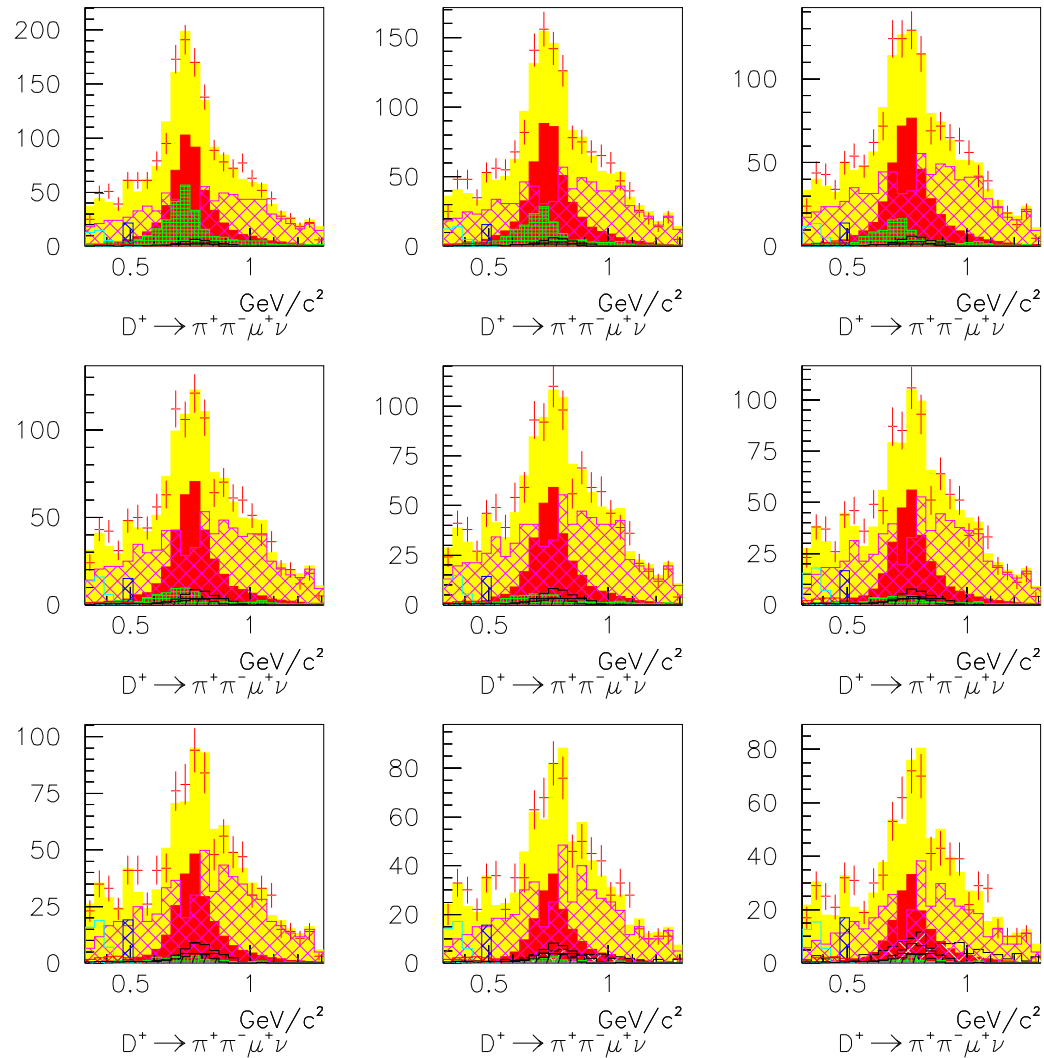


## Visible mass cut

Allows for the missing energy of the neutrino while suppressing events with too much missing energy (e.g., additional pions)



- Tightening the identification cut on the pion with opposite sign to the muon suppresses the  $\overline{K}^{*0}$  background (green hatched histogram)



Fit Invariant mass  $M(\pi^+ \pi^-)$ :

$$\mathcal{L} = \prod_{i=1}^{\#bins} \frac{n_i^{s_i} e^{-n_i}}{s_i!}$$

$s_i$  = number of events in bin  $i$  of data histogram

$n_i$  = number of events in bin  $i$  of fit histogram

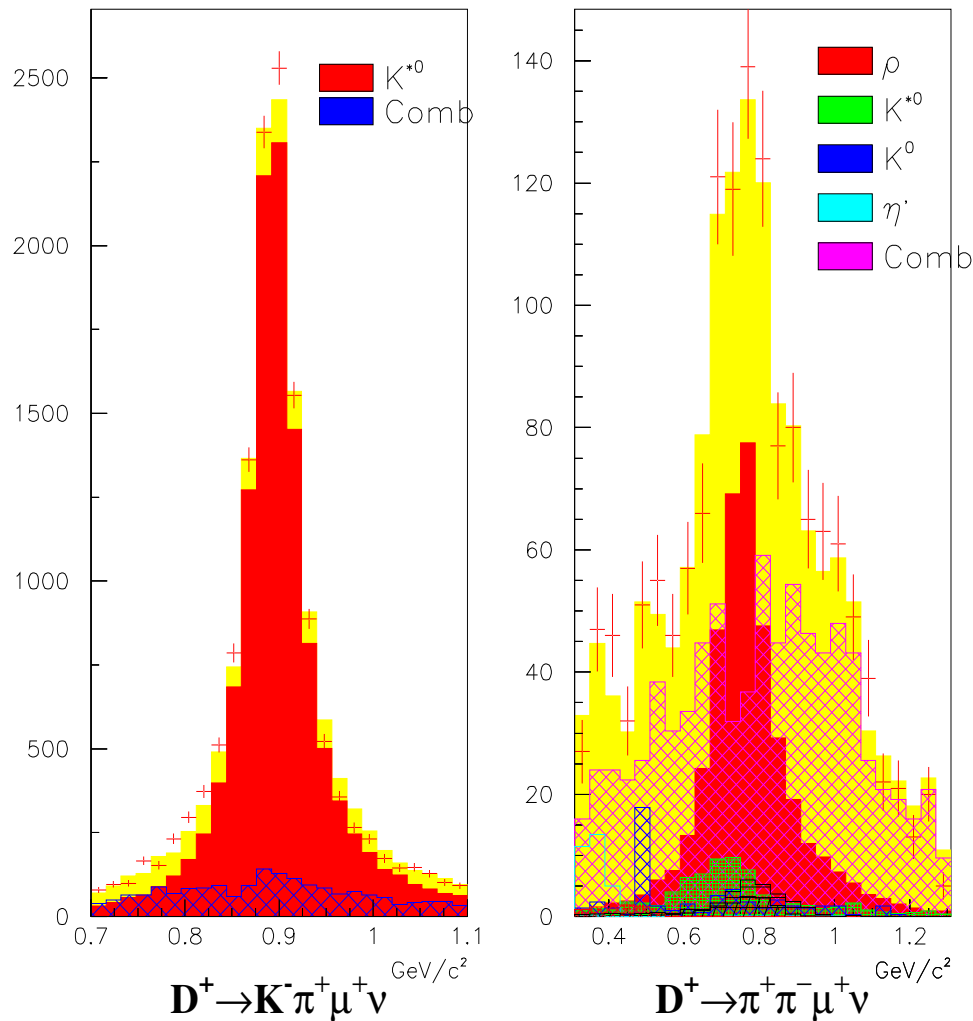
$$\begin{aligned} n_i = & Y_{\rho\mu\nu} S_1 + \frac{Y_{\overline{K}^{*0}\mu^+\nu}}{\epsilon(\overline{K}^{*0}\mu^+\nu)} \epsilon(\overline{K}^{*0}\mu^+\nu \rightarrow \rho\mu\nu) S_2 + \\ & Y_{D^+ \rightarrow \overline{K}^0 \mu^+ \nu} S_3 + \frac{Y_{D_s^+ \rightarrow \phi \mu^+ \nu}}{\epsilon(D_s^+ \rightarrow \phi \mu^+ \nu) BR(\phi \rightarrow KK)} BR(\phi \rightarrow \rho\pi) S_4 + \\ & \frac{Y_{D_s^+ \rightarrow \phi \mu^+ \nu}}{\epsilon(D_s^+ \rightarrow \phi \mu^+ \nu) BR(\phi \rightarrow KK)} \left\{ BR_{\eta'} \cdot \left[ BR(\eta' \rightarrow \rho\gamma) \epsilon(\eta' \rightarrow \rho\gamma) S_5 + \right. \right. \\ & \left. \left. BR(\eta' \rightarrow \eta\pi\pi) \epsilon(\eta' \rightarrow \eta\pi\pi) S_6 \right] + BR_\eta \cdot \left( BR(\eta \rightarrow \pi\pi\pi^0) \epsilon(\eta \rightarrow \pi\pi\pi^0) S_7 + \right. \right. \\ & \left. \left. BR(\eta \rightarrow \pi\pi\gamma) \epsilon(\eta \rightarrow \pi\pi\gamma) S_8 \right) \right\} + C S_9 + M S_{10} \end{aligned}$$

Where;  $BR_{\eta'} = \frac{BR(D_s^+ \rightarrow \eta' l \nu)}{BR(D_s^+ \rightarrow \phi l \nu)}$ ;  $BR_\eta = \frac{BR(D_s^+ \rightarrow \eta l \nu)}{BR(D_s^+ \rightarrow \phi l \nu)}$

Fit parameters, normalized Monte Carlo Shapes

The fit histogram is composed of the following:

1.  $D^+ \rightarrow \rho^0 \mu^+ \nu$  signal, with shape given by the Monte Carlo and the yield as a fit parameter.
2. Feed-through from  $D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu$ , ( $K/\pi$  misid) with shape given by Monte Carlo and the yield extracted from the  $D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu$  analysis using a Breit Wigner line shape.
3.  $D^+ \rightarrow \overline{K}^0 \mu^+ \nu$ , with shape given by Monte Carlo and yield determined as a fit parameter.
4. Various backgrounds from  $D_s^+ \rightarrow \eta' \mu \nu$  and  $D_s^+ \rightarrow \eta \mu \nu$ , with yields obtained from the  $D_s^+ \rightarrow \phi \mu^+ \nu$  efficiency corrected yield and the PDG values for  $\frac{BR(D_s^+ \rightarrow \eta' \mu \nu)}{BR(D_s^+ \rightarrow \phi \mu \nu)}$  and  $\frac{BR(D_s^+ \rightarrow \eta \mu \nu)}{BR(D_s^+ \rightarrow \phi \mu \nu)}$ , respectively.
5.  $D_s^+ \rightarrow \phi \mu^+ \nu$ ,  $\phi \rightarrow \rho \pi$ , with shape determined by Monte Carlo and yield obtained from  $D_s^+ \rightarrow \phi \mu^+ \nu$  efficiency corrected yield and the PDG value for  $BR(\phi \rightarrow \rho \pi)$ .
6. Combinatoric background
7. Muon Misid



- Whenever possible the same cuts have been applied to the  $D^+ \rightarrow \overline{K^{*0}} \mu^+ \nu$  sample to reduce systematic effects.
- This includes the correction due to the S-wave interference  $\eta'$  present in the  $D^+ \rightarrow K^- \pi^+ \mu^+ \nu$  observed by FOCUS.

$$\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K^{*0}} \mu^+ \nu)} = \frac{Y_\rho^{(data)}}{Y_{K^{*0}}^{(data)}} \times \frac{Y_{K^{*0}}^{(MC)}}{Y_\rho^{(MC)}} \times RelBR^{(MC)}$$

$$Y_\rho = 397 \pm 42$$

$$Y_{\overline{K^{*0}}} = 11811 \pm 151$$

$$\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K^{*0}} \mu^+ \nu)} = 0.0381 \pm 0.0041$$

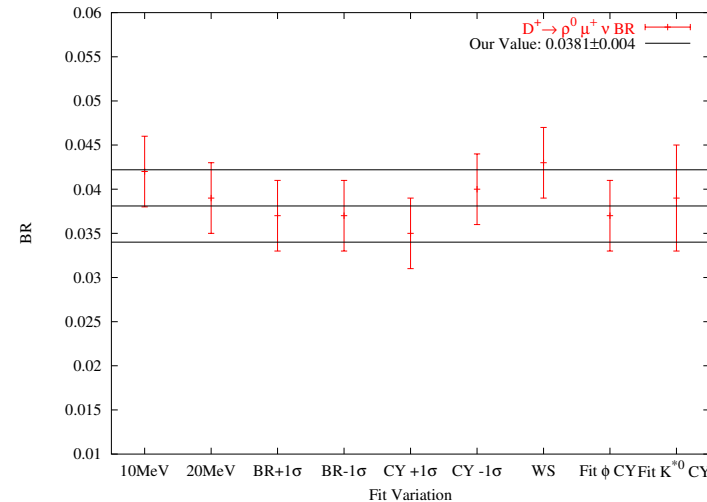
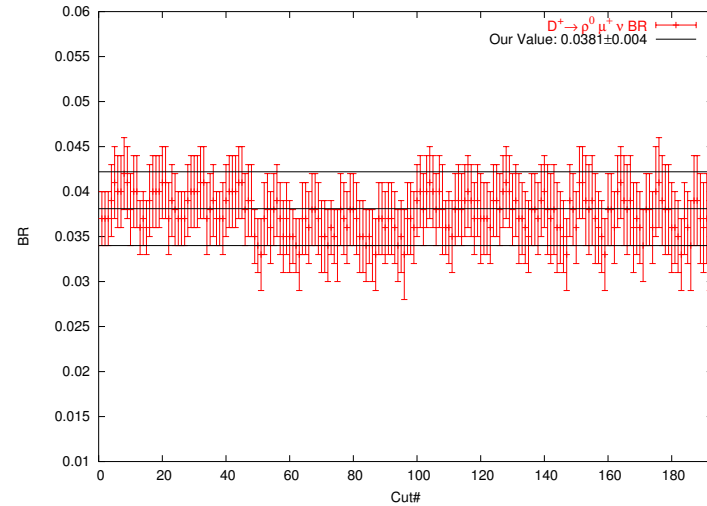
Systematic effects have been evaluated by:

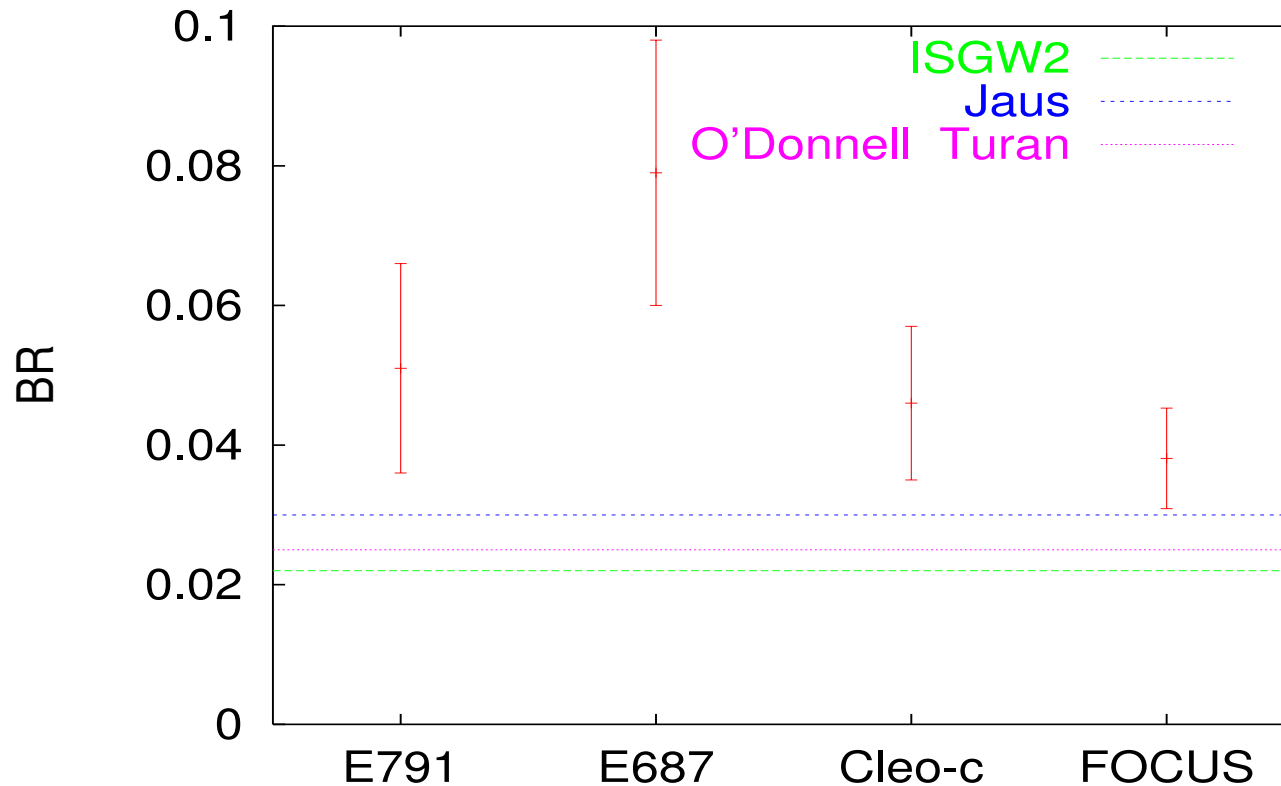
1. Changes in fitting technique

- Change binning scheme
- Change fit inputs (i.e., PDG BR's and efficiency corrected yields) by  $\pm 1\sigma$
- Allow parameters fixed in the fit to float freely

2. Changes in cut selection (192 cut sets)

Syst. Source	$\sigma_{syst}$
fit variants	0.0032
cut variations	0.0041
Total Syst.	0.0052





❑ **ISGW2** (1995): *Phys. Rev. D Vol 52 p2783* (BR=0.023)

❑ **Jaus**(1996): *Phys. Rev. D Vol 53 p1349* (BR=0.030)

❑ **O'Donnell & Turan**(1997): *Phys. Rev. D Vol 56 p295* (BR=0.025)

❑ CLEO-c result is from a data sample of 60  $pb^{-1}$ . *CLEO Conf 04-3* ( $D^0 \rightarrow \rho^- e^+ \nu$ )

$D^+ \rightarrow \rho^0 \mu^+ \nu$ yield	$397 \pm 42$
$\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)}$	$0.0381 \pm 0.0041 \pm 0.0052$
$\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)$	$(0.202 \pm 0.038) \times 10^{10} \text{ s}^{-1}$

- ❑ This preliminary result is now the most precise measurement of the branching ratio

$$\frac{\Gamma(D^+ \rightarrow \rho^0 \mu^+ \nu)}{\Gamma(D^+ \rightarrow \overline{K}^{*0} \mu^+ \nu)}$$

- ❑ Theoretical predictions are in agreement with our measured branching ratio and decay rate.
- ❑ We will work on fitting the kinematic variables to extract the form factor ratios of the decay.