Analysis of the Semileptonic Decay

$$D^0 \to \overline{K^0}\pi^-\mu^+\nu_\mu$$

from

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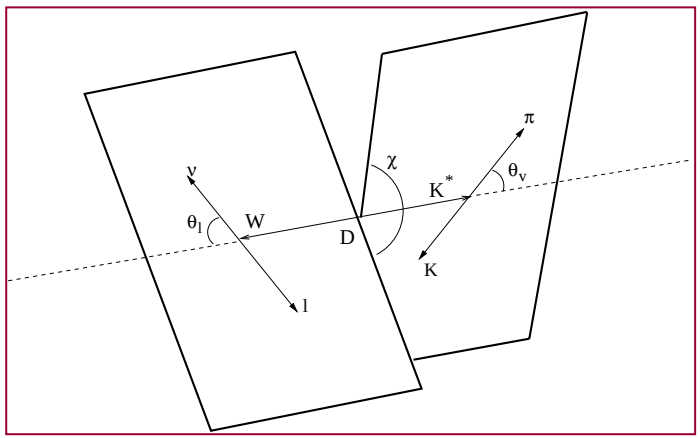
Outline

- **Event Selection**
- **Form Factor Ratios**
- **Kπ S-Wave Component**
- **Branching Ratio** $\dfrac{\Gamma(D^0 \to K^{*-}(892)\mu^+\nu_\mu)}{\Gamma(D^0 \to \overline{K^0}\pi^-\pi^+)}$

The Decay Amplitude

$$\frac{d\Gamma}{d\cos\theta_\nu d\sin\theta_l d\chi dq^2 dm_{k\pi}} \propto \left| \begin{array}{l} (1+\cos\theta_l)\sin\theta_\nu e^{i\chi} B_{K^*} H_+ \\ -(1-\cos\theta_l)\sin\theta_\nu e^{-i\chi} B_{K^*} H_- \\ -2\sin\theta_l(\cos\theta_l B_{K^*} + Ae^{i\delta})H_0 \end{array} \right|^2 + \frac{m_l^2}{q^2} \left| \begin{array}{l} \sin\theta_l \sin\theta_\nu B_{K^*}(e^{i\chi}H_+ + e^{-i\chi}H_-) \\ +2\cos\theta_l(\cos\theta_\nu B_{K^*} + Ae^{i\delta})H_0 \\ +2(\cos\theta_l B_{K^*} + Ae^{i\delta})H_t \end{array} \right|^2$$

Includes the Kπ S-wave component $Ae^{i\delta}$ that was measured by FOCUS in the decay $D^+ \to K^-\pi^+\mu^+\nu_\mu$ (Phys. Lett. B535, 2002, 43).



$$H_\pm(q^2) = (m_D + m_{K\pi})A_1(q^2) \mp 2\frac{m_D K}{m_D + m_{K\pi}} V(q^2)$$

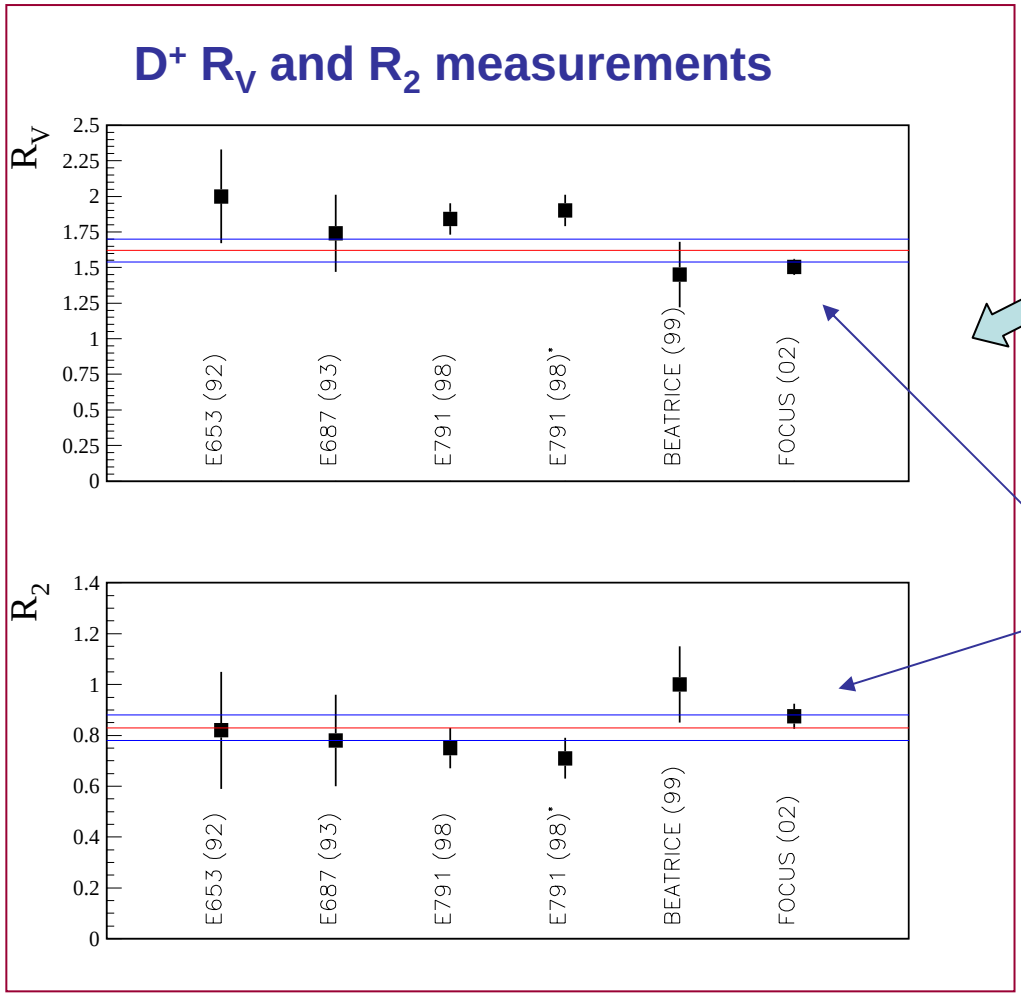
$$H_0(q^2) = \frac{1}{2m_{K\pi}\sqrt{q^2}}\left[(m_D^2 - m_{K\pi}^2 - q^2)(m_D + m_{K\pi})A_1(q^2) - 4\frac{m_D^2 K^2}{m_D + m_{K\pi}} A_2(q^2)\right]$$

$$H_t(q^2) = \frac{m_D K}{m_{K\pi}\sqrt{q^2}}\left[(m_D + m_{K\pi})A_1(q^2) - \frac{(m_D^2 - m_{K\pi}^2 - q^2)}{m_D + m_{K\pi}} A_2(q^2) + \frac{2q^2}{m_D + m_{K\pi}} A_3(q^2)\right]$$

We fit for the two form factor ratios: $\mathbf{R_V = V(0)/A_1(0)}$ and $\mathbf{R_2 = A_2(0)/A_1(0)}$

Expected Form Factor Values

No measurements for the D^0 yet

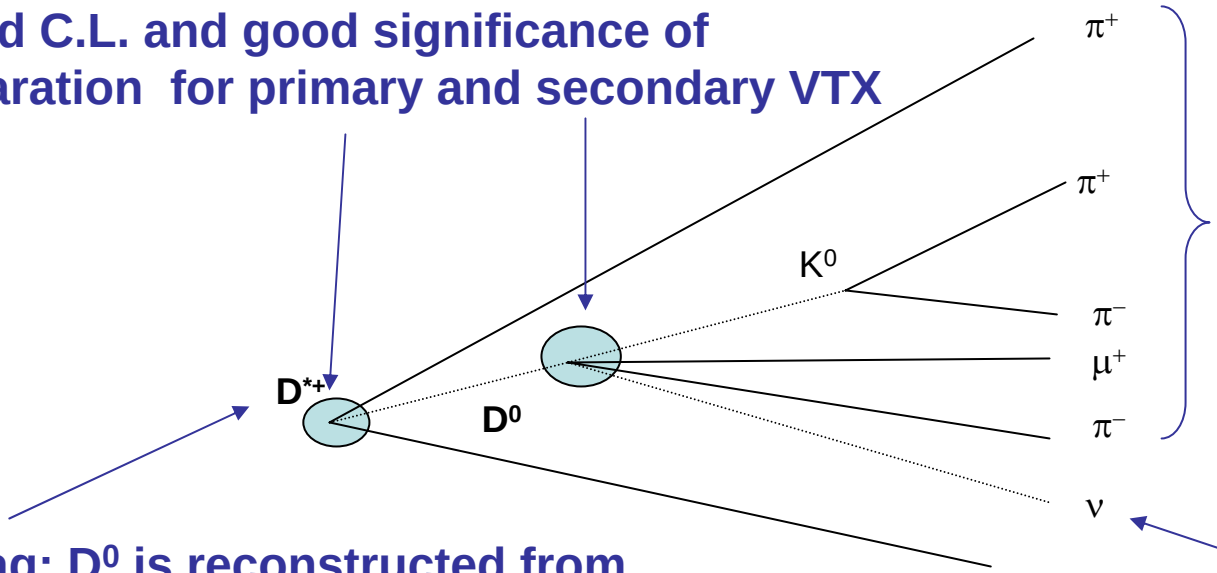


From isospin symmetry the D^0 F.F. should be the same as the D^+ F.F. Many measurements for the D^+ are available.

FOCUS is the first experiment that includes the effect of the S-wave component

Event Selection

Good C.L. and good significance of separation for primary and secondary VTX



Particle I.D. on muon and all the pions

D* tag: D^0 is reconstructed from the decay $D^{*+} \rightarrow D^0\pi^+$ and we look for signal in the mass difference distribution.

Missing neutrino energy: using the reconstructed primary and secondary vertices and E and P conservation, we calculate the best hypothesis for $q^2=(P_\nu+P_\mu)^2$

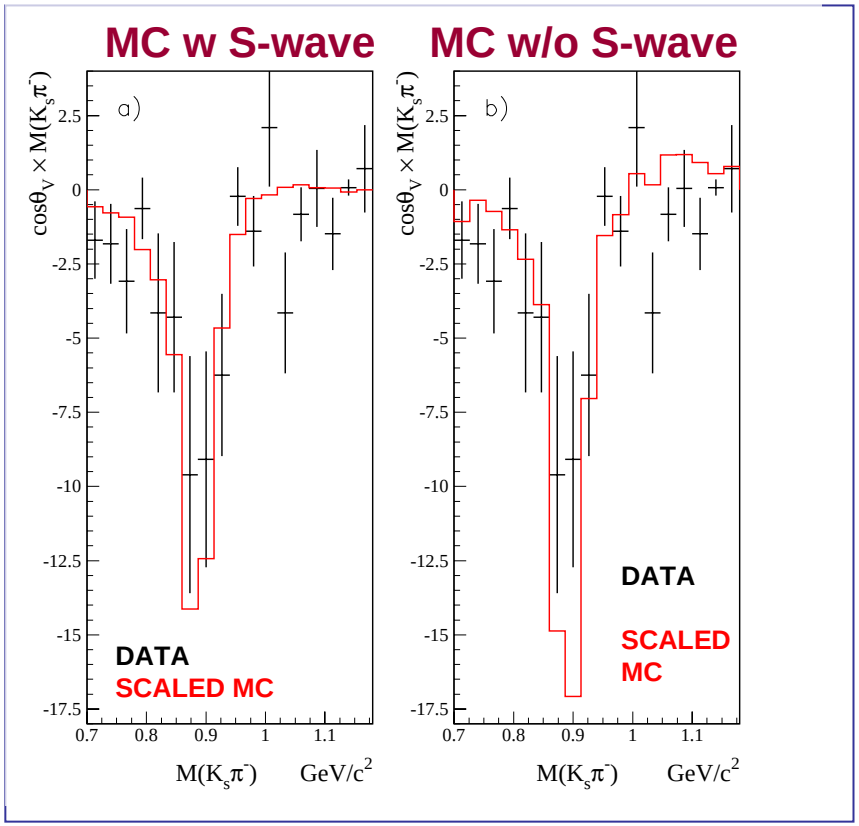
Mass requirements:

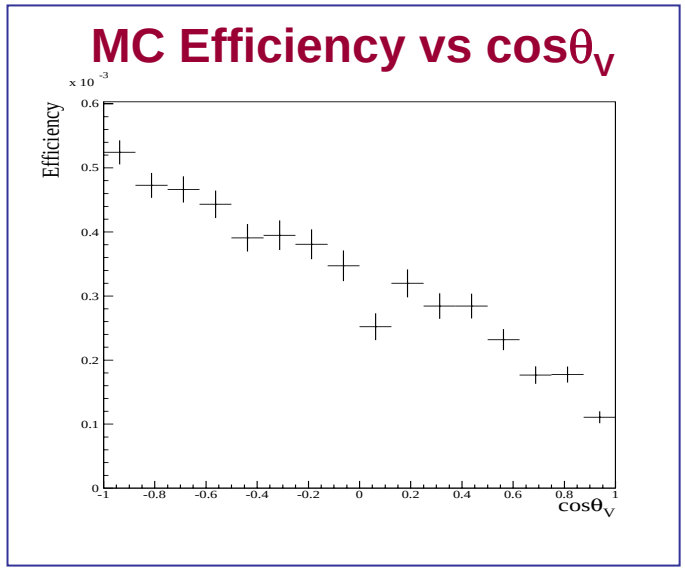
- **Recon. K_s mass within 3σ of nominal mass**
- **Recon. K* mass within 2Γ of nominal mass**
- **$M(K_s\pi^-\mu^+) < 1.8$ GeV/c^2**

The S-wave – K* Interference

$$Interference = 8\cos\theta_V \sin^2\theta_\ell A\Re(e^{i\delta}B_{K^*})H_0^2$$
$$-4(1+\cos\theta_\ell)\sin\theta_\ell \sin\theta_V A\Re(e^{i(\chi-\delta)}B_{K^*})H_+H_0$$
$$+4(1-\cos\theta_\ell)\sin\theta_\ell \sin\theta_V A\Re(e^{-i(\chi+\delta)}B_{K^*})H_-H_0$$

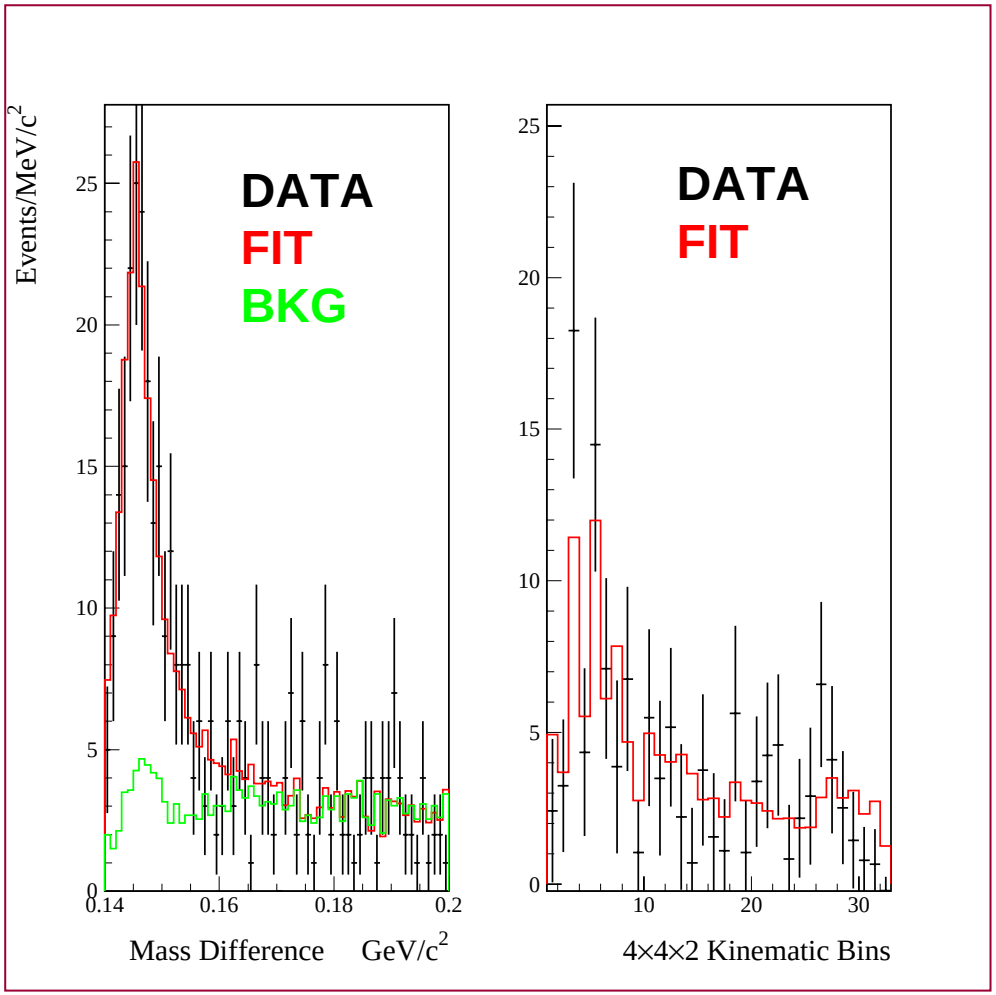
A term which is non-symmetric versus $\cos\theta_V$ appears due to the S-wave.





The model that includes the S-wave is used (and the model w/o S-wave is included in the systematic studies)

Form Factor Ratios



- **ΔM distribution is fit with mode specific MC for signal and MC without mode for background**
- **$\cos\theta_l$ X $\cos\theta_V$ X q^2 background subtracted distribution is fit with efficiency corrected decay amplitude shape**

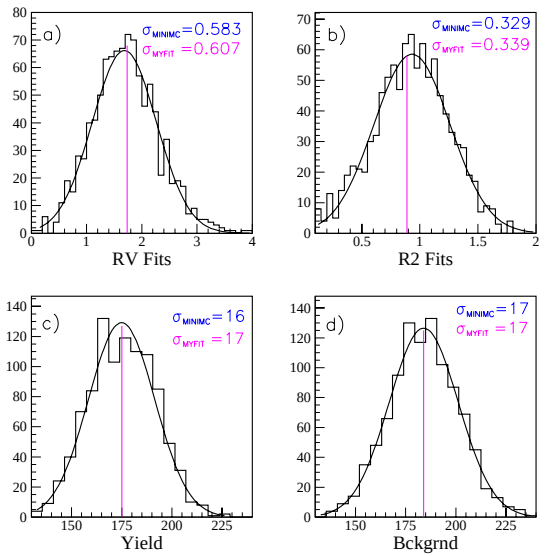
$$RV = 1.733 \pm 0.607$$

$$R2 = 0.890 \pm 0.339$$

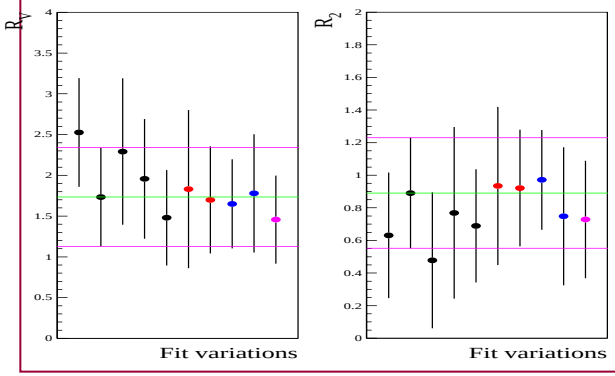
$$YIELD = 175 \pm 17$$

Systematic Studies

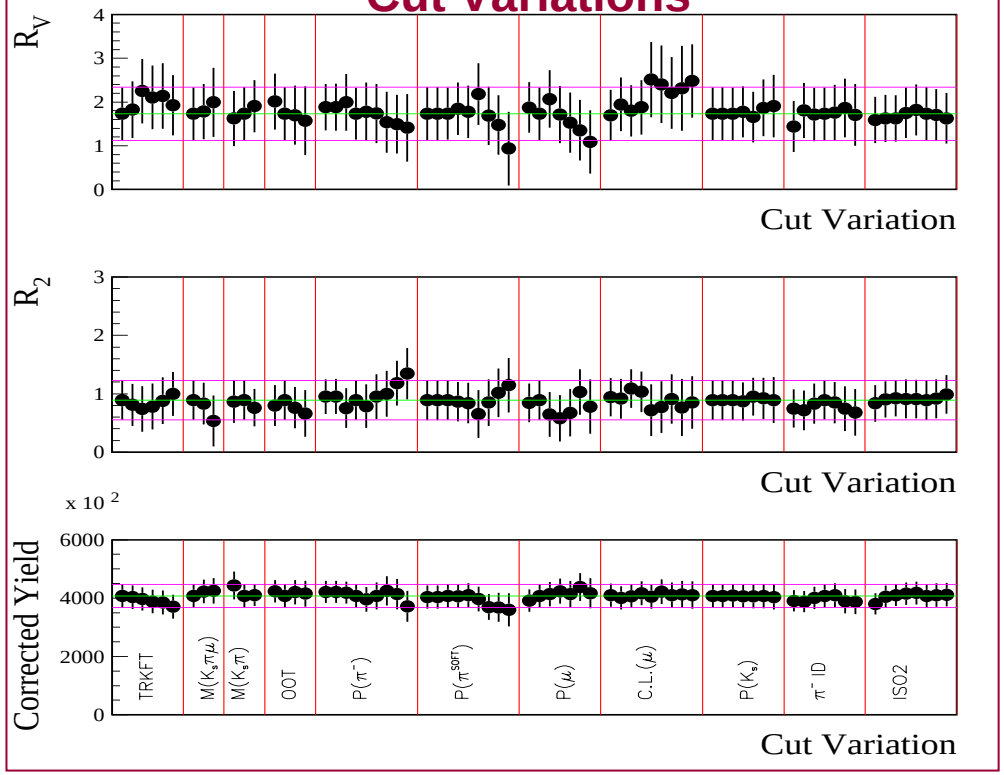
Toy MC



Fit Variations



Cut Variations

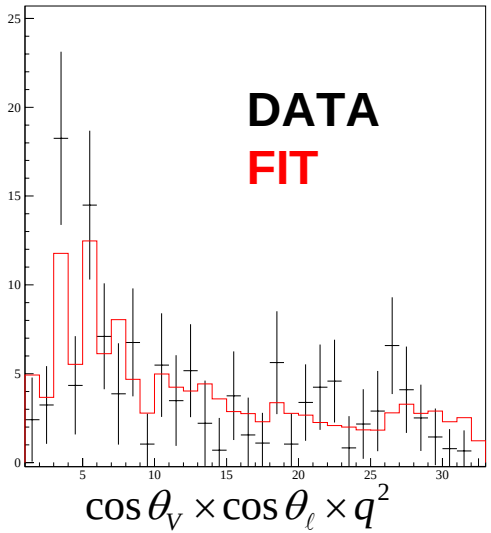


$$\sigma(sys)^{RV} = 0.350$$

$$\sigma(sys)^{R2} = 0.155$$

Preliminary!!

The Kπ S-Wave Parameters

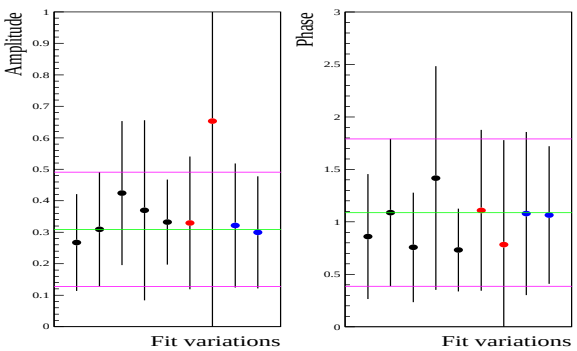


- **Fit performed like for the form factor ratios.**
- **R_V and R_2 are fixed to our measurement.**

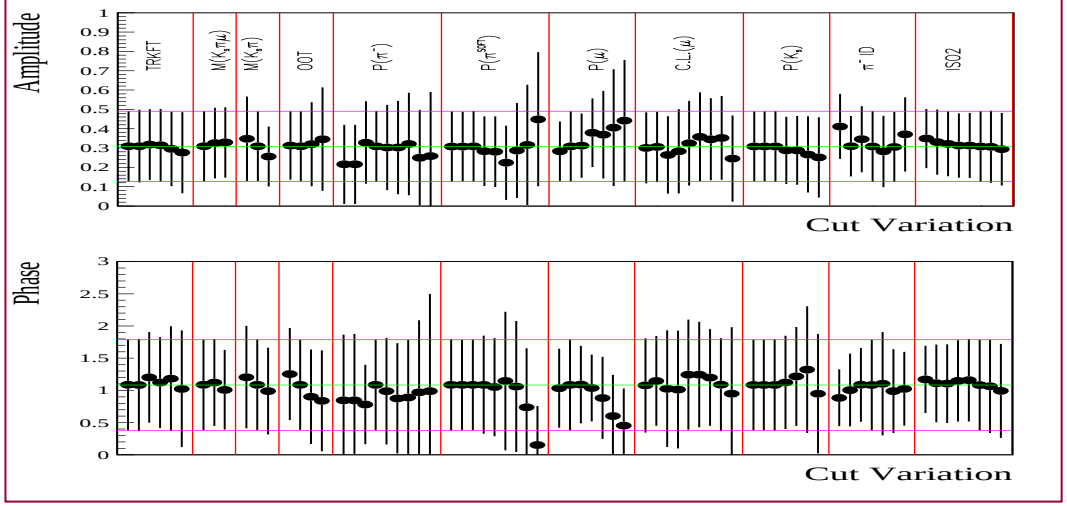
$$A = 0.310 \pm 0.182 \ GeV^{-1}$$

$$\delta = 1.09 \pm 0.70 \ rad$$

Fit Variations



Cut Variations

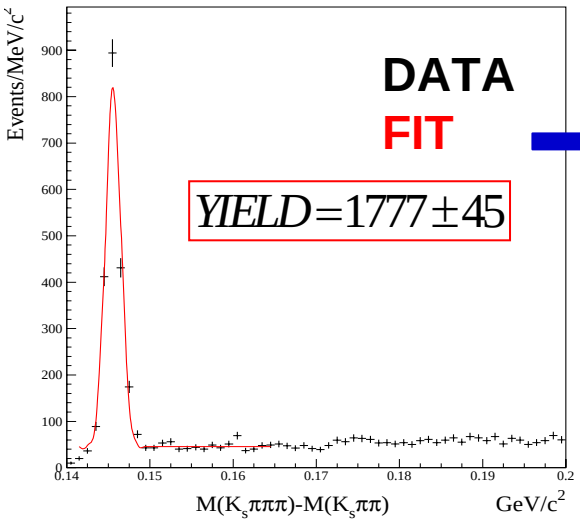


$$\sigma(sys)^A = 0.047 \ GeV^{-1}$$

$$\sigma(sys)^\delta = 0.22 \ rad$$

Preliminary!!

Branching Ratio $\frac{\Gamma(D^0 \to K^{*-}(892)\mu^+\nu_\mu)}{\Gamma(D^0 \to \overline{K^0}\pi^-\pi^+)}$

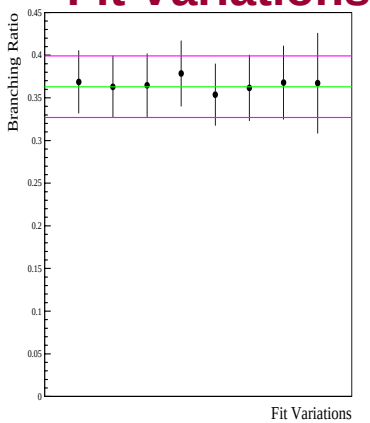


D*-D mass difference fit for the normalization mode (reconstructed as $K_s\pi^-\pi^+$ with identical cuts to the semileptonic mode where possible)

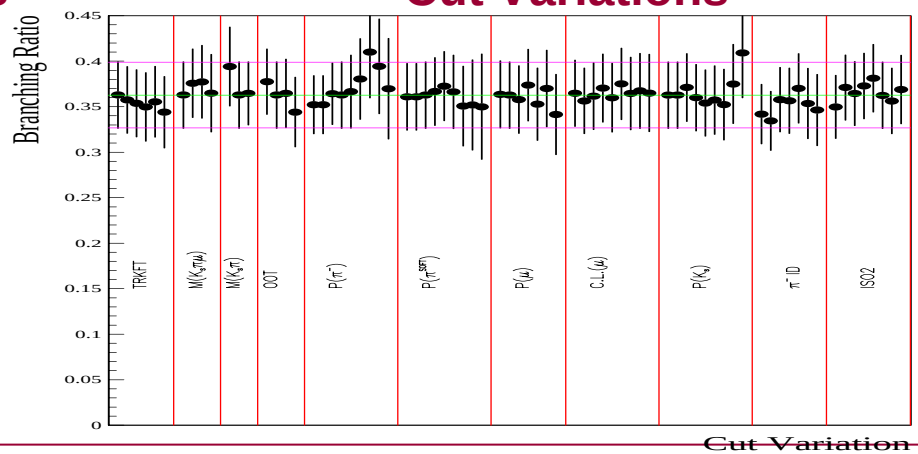
Accounting for the S-wave component in $\overline{K^0}\pi\mu\nu$ we find:

$$\frac{\Gamma(D^0 \to K^{*-}(892)\mu^+\nu_\mu)}{\Gamma(D^0 \to \overline{K^0}\pi^-\pi^+)} = 0.345 \pm 0.034$$

Fit Variations



Cut Variations



Preliminary!!

$$\sigma(sys)^{BR} = 0.008$$

Conclusions

We have presented preliminary results from FOCUS on:

- **the first measurement of the D^0 semileptonic form factor ratios**
- **the analysis of the $K\pi$ S-wave contribution with the first measurement of the amplitude and phase in the D^0 system**
- **the first measurement of the branching ratio** $\frac{\Gamma(D^0 \to K^{*-}(892)\mu^+\nu_\mu)}{\Gamma(D^0 \to \overline{K^0}\pi^-\pi^+)}$

$$RV = 1.733 \pm 0.607(stat) \pm 0.350(sys)$$

$$R2 = 0.890 \pm 0.339(stat) \pm 0.155(sys)$$

$$A = 0.310 \pm 0.182(stat) \pm 0.047(sys)\ \ GeV^{-1}$$

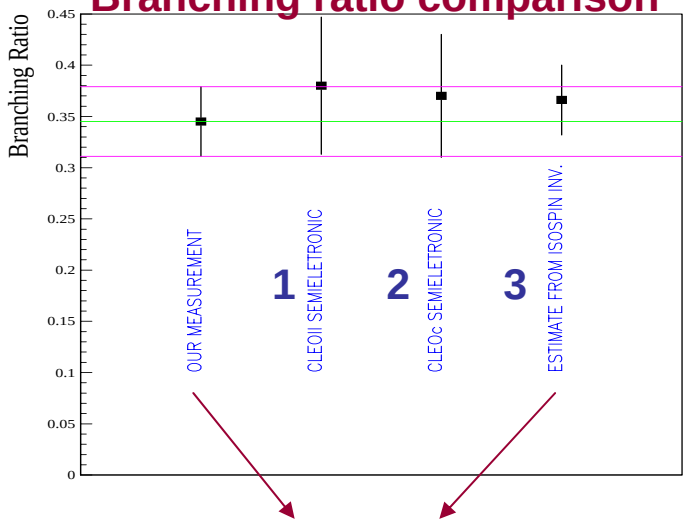
$$\delta = 1.09 \pm 0.70(stat) \pm 0.22(sys)\ \ rad$$

$$\frac{\Gamma(D^0 \to K^{*-}(892)\mu^+\nu_\mu)}{\Gamma(D^0 \to \overline{K^0}\pi^-\pi^+)} = 0.345 \pm 0.034(stat) \pm 0.008(sys)$$

Preliminary!!

Conclusions cont.

Branching ratio comparison



Include Kπ S-wave effects

1= $\dfrac{\Gamma(D^0 \to K^{*-}(892)e^+\nu_e)}{\Gamma(D^0 \to \overline{K^0}\pi^-\pi^+)}$ **from CLEO II**

2= $\dfrac{B(D^0 \to K^{*-}(892)e^+\nu_\mu)}{B(D^0 \to \overline{K^0}\pi^-\pi^+)}$ → **from CLEO c** / → **from PDG ave.**

3= $\dfrac{\Gamma(D^+ \to K^{*0}\mu^+\nu_\mu)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} \times \dfrac{\tau(D^0)}{\tau(D^+)} \times \dfrac{B(D^+ \to K^-\pi^+\pi^+)}{(D^0 \to \overline{K^0}\pi^-\pi^+)}$

↳ **from FOCUS, includes S-wave effects**

All the results are in excellent agreement when compared to the values for the isospin partner D^+ and the B.R. result for the semielectronic mode. Isospin symmetry works great.

R_V, R_2, A and δ comparison

	FOCUS D^0	FOCUS D^+
R_V	$1.733 \pm 0.607 \pm 0.350$	$1.504 \pm 0.057 \pm 0.039$
R_2	$0.890 \pm 0.339 \pm 0.155$	$0.875 \pm 0.049 \pm 0.064$
A (GeV^{-1})	$0.310 \pm 0.182 \pm 0.047$	$0.330 \pm 0.022 \pm 0.015$
δ (rad)	$1.09 \pm 0.70 \pm 0.22$	$0.68 \pm 0.07 \pm 0.05$