FOCUS Semileptonic and Rare Decays (a retrospective)

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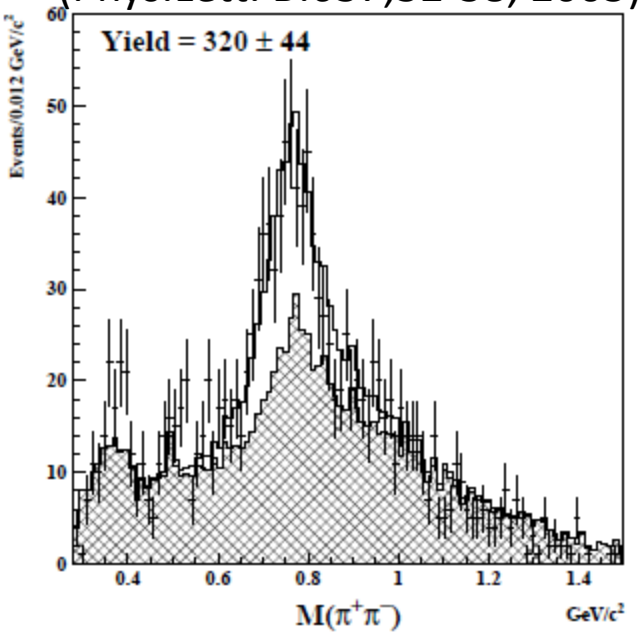
CHARM2010

Fixed Target Semileptonics (a stepping stone process)

- Typically, kinematics can not be closed (no energy constraint) and though statistics can be sizable, backgrounds can be large compared to e^+e^- experiments, like CLEO-C (or BES-III)…

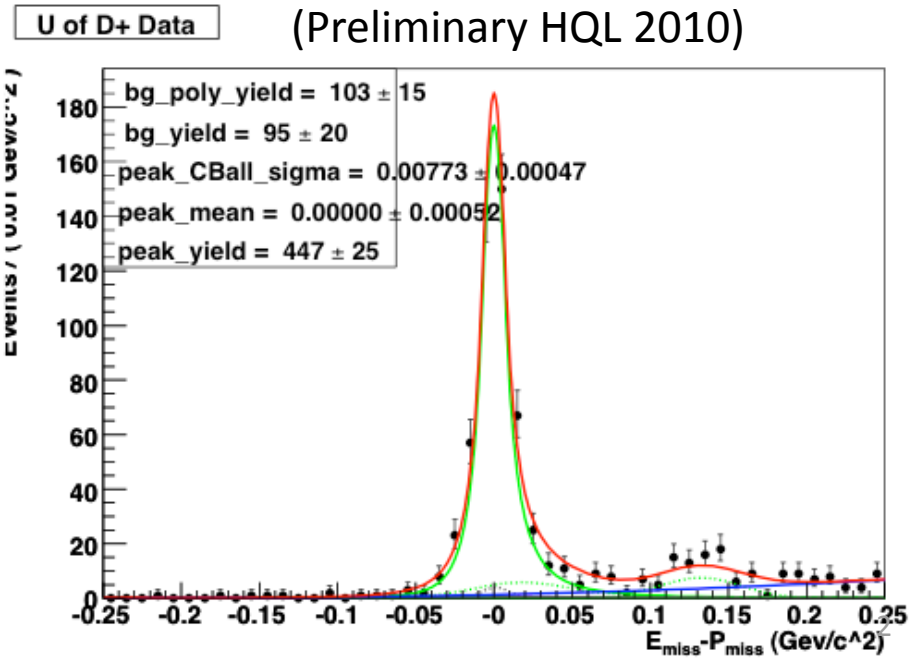
FOCUS $D^+ \to \rho \mu^+ \nu$

(Phys.Lett. B:637,32-38, 2005)



CLEO-c $D^+ \to \rho e^+ \nu$

(Preliminary HQL 2010)



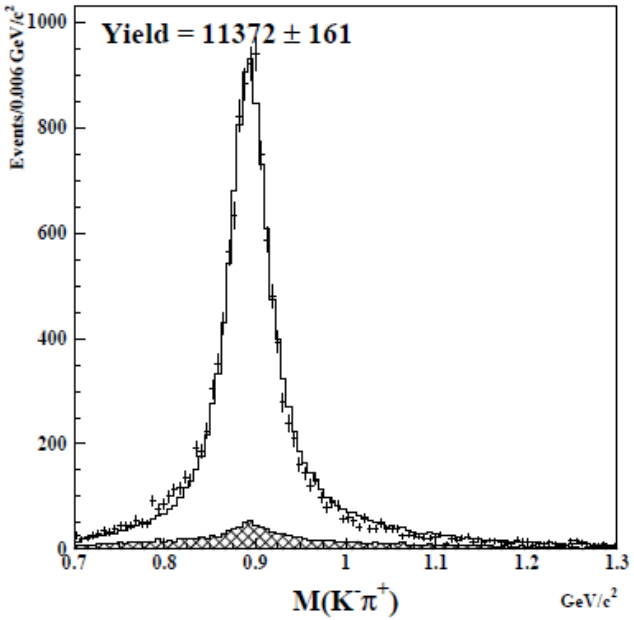
Fixed Target Semileptonics

- …But factorizable if you can measure or estimate the backgrounds
  - And

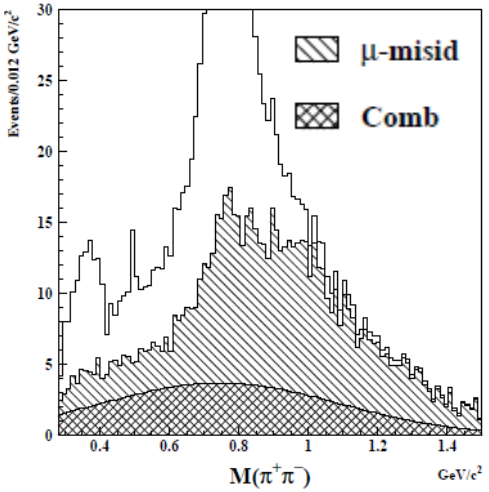
$$D^+ \to (K^-\pi^+)\,\mu^+\nu$$

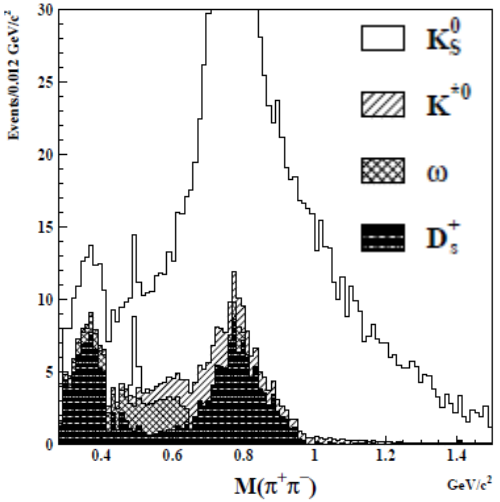
Is the Key to it all

FOCUS $D^+ \to (K^-\pi^+)\,\mu^+\nu$



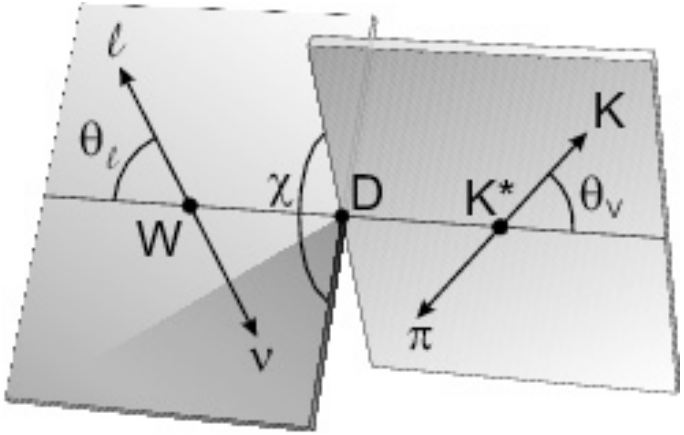
FOCUS $D^+ \to \rho\,\mu^+\nu$ (All Phys.Lett. B:637,32-38)



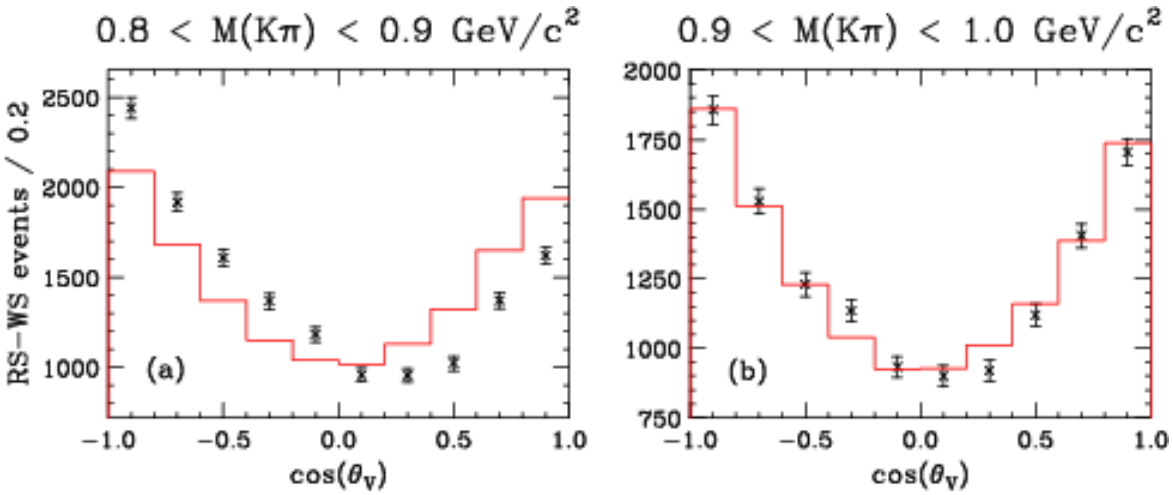


- Cabibbo-favored
- Important background in other modes
- Very little excited mode feed-down
- FOCUS Cerenkov separates K/pi/e well
- Long lifetime = large vertex separation
- In principle, well understood decay but
  - FOCUS found a surprise…

FOCUS saw discrepancies in the data



Phys.Lett.B535:43-51, 2002



$$D^+ \to \overline{K}^{*0} \mu^+ \nu$$

(Did NOT obey)

$$\frac{d^5\Gamma}{dm_{k\pi}dq^2 d\cos\theta_V d\cos\theta_\ell d\chi} \propto \left\{ \left| \begin{array}{c} \sin\theta_V (1+\cos\theta_\ell) e^{i\chi} B_{K^{*0}} H_+(q^2) \\ -\sin\theta_V (1-\cos\theta_\ell) e^{-i\chi} B_{K^{*0}} H_-(q^2) \\ -2\cos\theta_V \sin\theta_\ell B_{K^{*0}} H_0(q^2) \end{array} \right|^2 \right\}$$

Neutrino is left handed

V products spinless

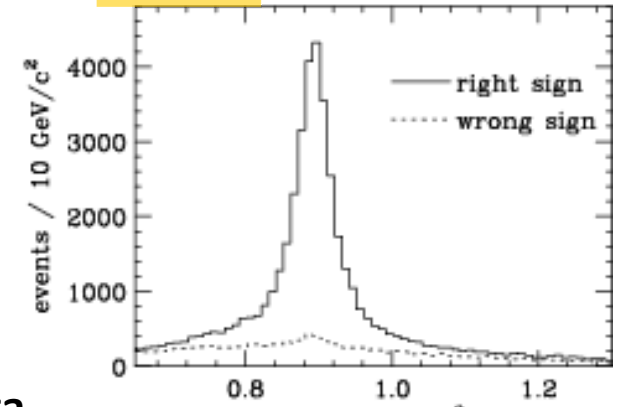
$$\frac{d^2\Gamma}{d\cos\theta_V d\cos\theta_\ell} \propto \{(1+\cos\theta_\ell)^2 \Gamma_+ + (1-\cos\theta_\ell)^2 \Gamma_-\} \sin^2\theta_V + 4\sin^2\theta_\ell \cos^2\theta_V \Gamma_0$$

Prefers W spin along muon,e

Prefer L_Z=0

FOCUS added a new term, things got better

With a Clean $K\pi\mu\nu$ signal

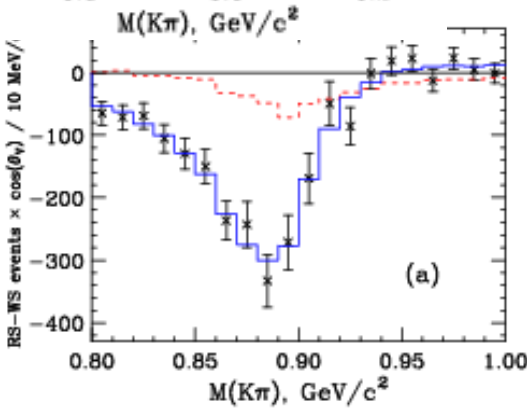


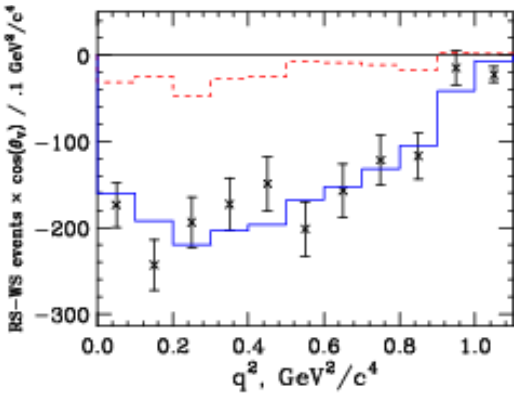
$$\frac{d^5\Gamma}{dm_{k\pi}dq^2 d\cos\theta_V d\cos\theta_\ell d\chi} \propto$$

$$\left\{ \left| \begin{array}{l} (1+\cos\theta_\ell)\sin\theta_V e^{i\chi} B_{K^{*0}} H_+(q^2) \\ -(1-\cos\theta_\ell)\sin\theta_V e^{-i\chi} B_{K^{*0}} H_-(q^2) \\ -2\sin\theta_\ell(\cos\theta_V B_{K^{*0}} + Ae^{i\delta}) H_0(q^2) \end{array} \right|^2 \right\}$$

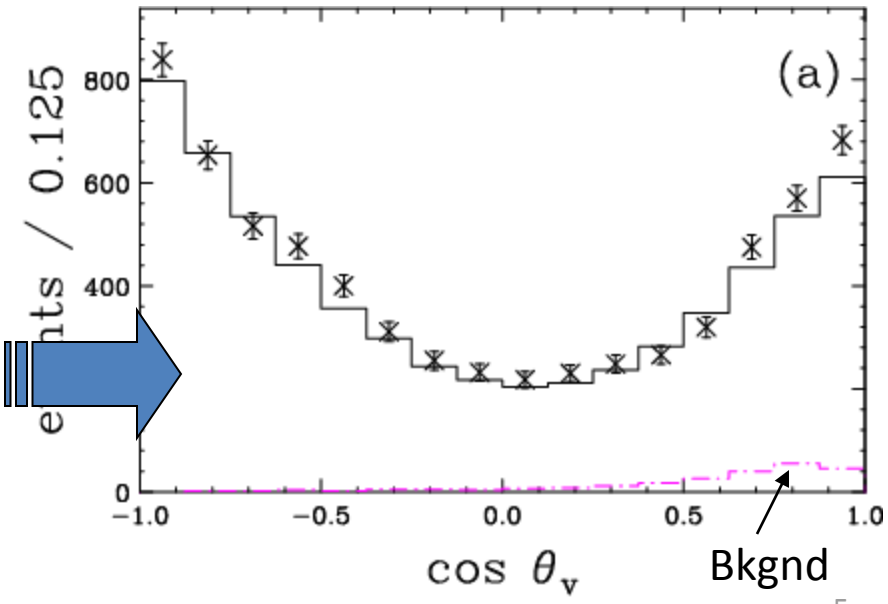
L=0 ansatz

The data (error bars) preferred the L=0 ansatz (solid) over no extra term (dashed)





And the distributions were ready for fitting



FOCUS BR Measurements

$$\frac{\Gamma(D^+ \to \overline{K}^{*0}\mu^+\nu)}{\Gamma(D^+ \to K^-\pi^+\pi^+)}, \frac{\Gamma(D_S^+ \to \phi\mu^+\nu)}{\Gamma(D_S^+ \to \phi\pi^+)}$$

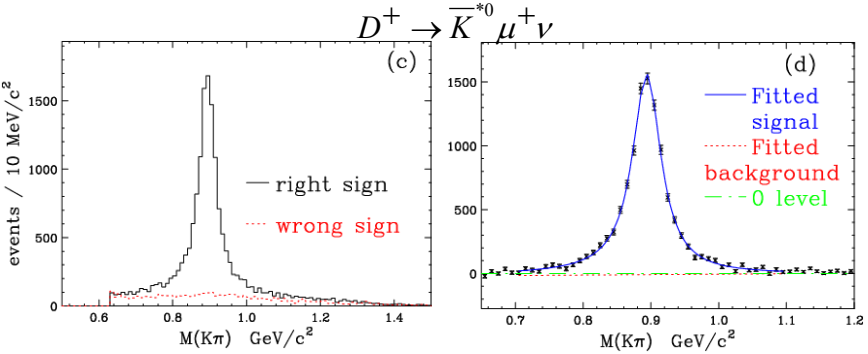
ISO2 – No unused tracks consistent with charm vertex (CL < 0.1%)

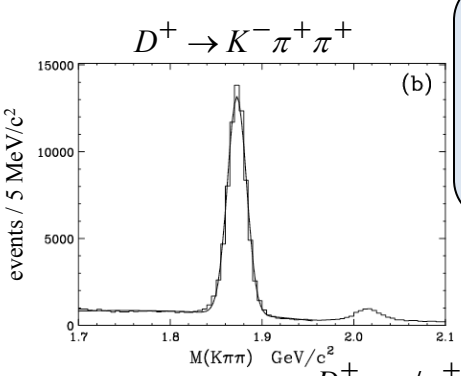
OoM – Charm vertex outside of target and silicon by $3\sigma_{Vertex}$

$M(K^-\pi^+\mu^+\{\nu\}) - M(K^-\mu^+\{\nu\}) > 0.18\,GeV/c^2$ (cuts $D^{*+} \to D^0\pi^+$)

$D^+ \to \overline{K}^{*0}\mu^+\nu$ Includes S-wave interference

Phys.Lett.B541:243-250, 2002





$$\frac{\Gamma(D^+ \to \overline{K}^{*0}\mu^+\nu)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} = 0.602 \pm 0.010(stat) \pm 0.021(sys)$$

0.56 ± 0.03 My estimate from PDG & PRD 81: 112001, 2010

Systematic errors :

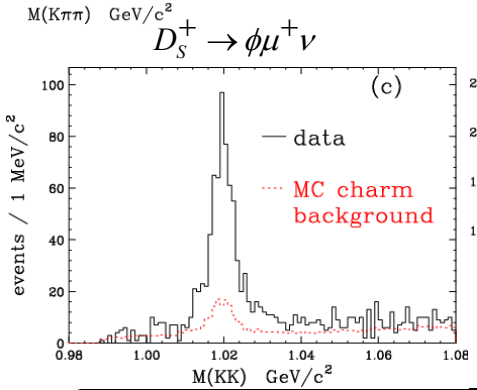
expressed as a fraction of σ_{stat}

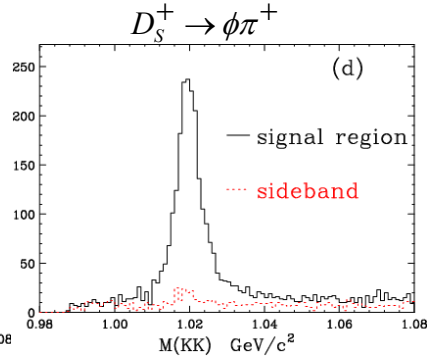
for D^+ (D_S^+) :

(add in if > 1)

- Vary Cuts $\Rightarrow$ 0.71, (1.06)
- Splitting Samples $\Rightarrow$ 1.57, (1.12)
- Vary fit (Bk, ff) $\Rightarrow$ 1.57, (0.94)

Total (quadrature) $\Rightarrow$ 2.2, (1.5)





$$\frac{\Gamma(D_S^+ \to \phi\mu^+\nu)}{\Gamma(D_S^+ \to \phi\pi^+)} = 0.54 \pm 0.033(stat) \pm 0.048(sys)$$

FOCUS Form Factors

$D^+ \to \overline{K}^{*0} \mu^+ \nu$

$$H_{\pm}(q^2) = (M_D + m_{K\pi}) A_1(q^2) \mp 2 \frac{M_D K}{M_D + m_{K\pi}} V(q^2) \qquad H_t(q^2) \text{ has } m_\mu^2 \text{ factor, set} = 0$$

Tried in fit, no sensitivity

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

$$A_i(q^2) = \frac{A_i(0)}{1 - q^2 / M_A^2}, (M_A = 2.5\ GeV/c^2) \qquad V(q^2) = \frac{V(0)}{1 - q^2 / M_V^2}, (M_V = 2.1\ GeV/c^2)$$

Fit to $r_v = \frac{V(0)}{A_1(0)} \qquad r_2 = \frac{A_2(0)}{A_1(0)}$ and S – wave parameters, A and δ

Technique: (common – vary generated parameters in Montecarlo by using agreement with reconstructed distributions and data)

Pioneered by D.M. Schmidt for E691 K*ev analysis: NIM A 328 (1993)

1st find S-wave with PDG r's,

3 bins in $\cos\theta_V$, 3 in $\cos\theta_\ell$, 3 in χ and 4 in $m_{K\pi}$

then fit for r's

S-wave term
Breaks symmetry

5 bins in $\cos\theta_V$, 5 in $\cos\theta_\ell$, 3 in $|\chi|$ and 3 in $q^2/q^2_{\max}$

S-wave term and r's essentially decouple

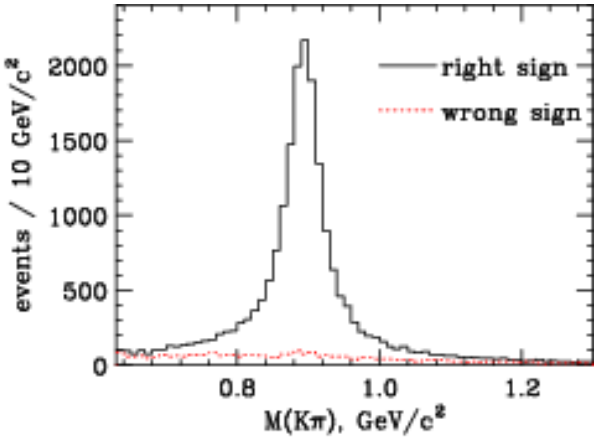
FOCUS Form Factors

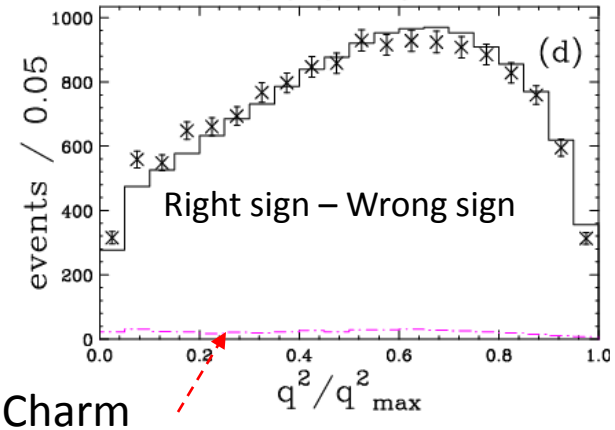
$$D^+ \to \overline{K}^{*0} \mu^+ \nu$$

Cuts similar to previous, some change to get uniform acceptance, one extra

OoM – Charm vertex outside of target and silicon by $1\sigma_{Vertex}$

Cut on $q^2 < 0.2$ GeV^2/c^2 ⟸ r's are flat, feeling m_μ? Goodness of fit issue





Charm Background

Systematic Checks

S-wave – varied cuts

35 fits – Sample Variance

Form Factor (3 sources)

1) Varied Cuts
2) Split sample

P_D, $D\overline{D}$, $m_{K\pi}$ $(0.9\,GeV/c^2)$

3) Vary MC input

Charm Backgrounds

$$-2 < \frac{A_3(0)}{A_1(0)} < 2$$

Results:

$$A = 0.330 \pm 0.022 \pm 0.015$$

$$\delta = 0.68 \pm 0.07 \pm 0.05$$

$$\pm(stat) \pm (sys)$$

$$r_V = 1.504 \pm 0.057 \pm 0.039$$

$$r2 = 0.875 \pm 0.049 \pm 0.064$$

Phys.Lett.B544:89-96, 2002

FOCUS Form Factors

$D^+ \to \overline{K}^{*0} \mu^+ \nu$

Non-Parametric test to look at single pole dominance ansatz (esp choice for s-wave)

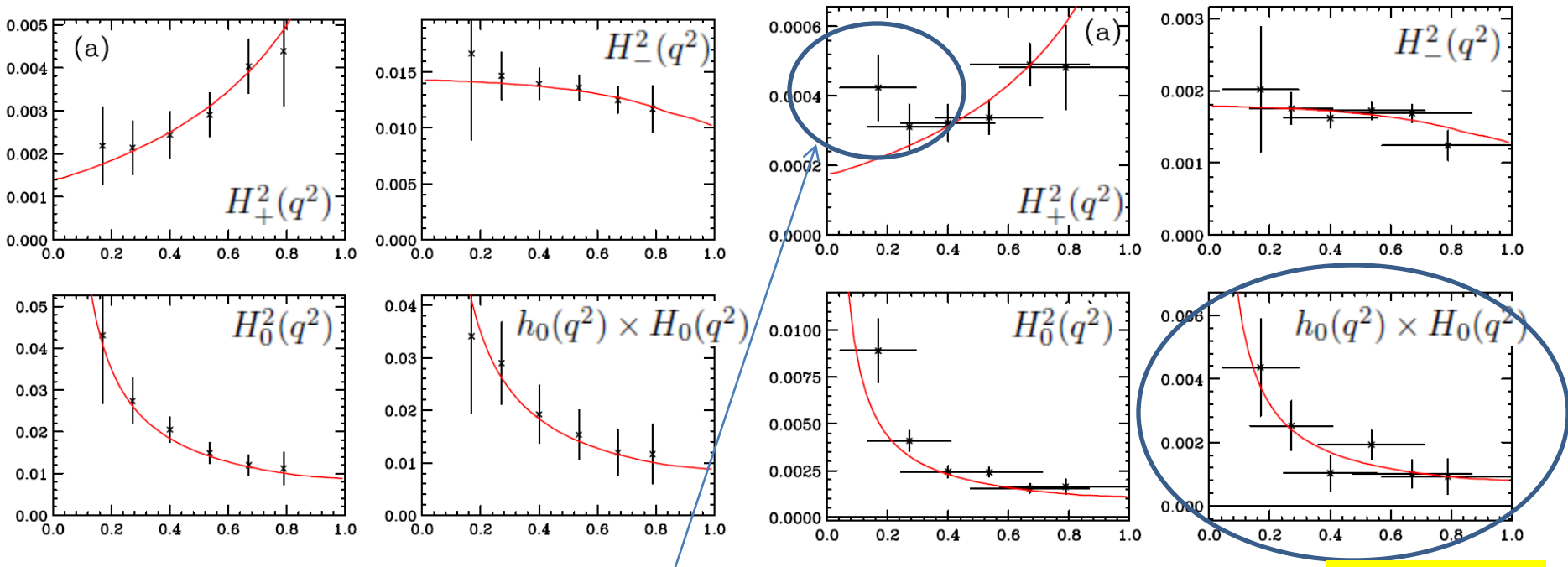
- Build up bin-wise transform of form factors
- Transform back from data to get projections, then fit using SPD model

$$\int |A|^2 \, d\chi = \frac{q^2 - m_\ell^2}{8} (\{(1+\cos\theta_\ell)^2 \, |BW|^2 |H_+(q^2)|^2 + (1-\cos\theta_\ell)^2 \, |BW|^2 |H_-(q^2)|^2\} \sin^2\theta_V$$

$$+ 2\sin^2\theta_\ell \cos^2\theta_V \, |BW|^2 \, H_0^2(q^2) + 8\sin^2\theta_\ell \cos\theta_V H_0(q^2) h_0(q^2) \mathrm{Re}\{A_S e^{-i\delta} BW\})$$

Monte Carlo

Data



Phys.Lett.B633:183-189, 2006

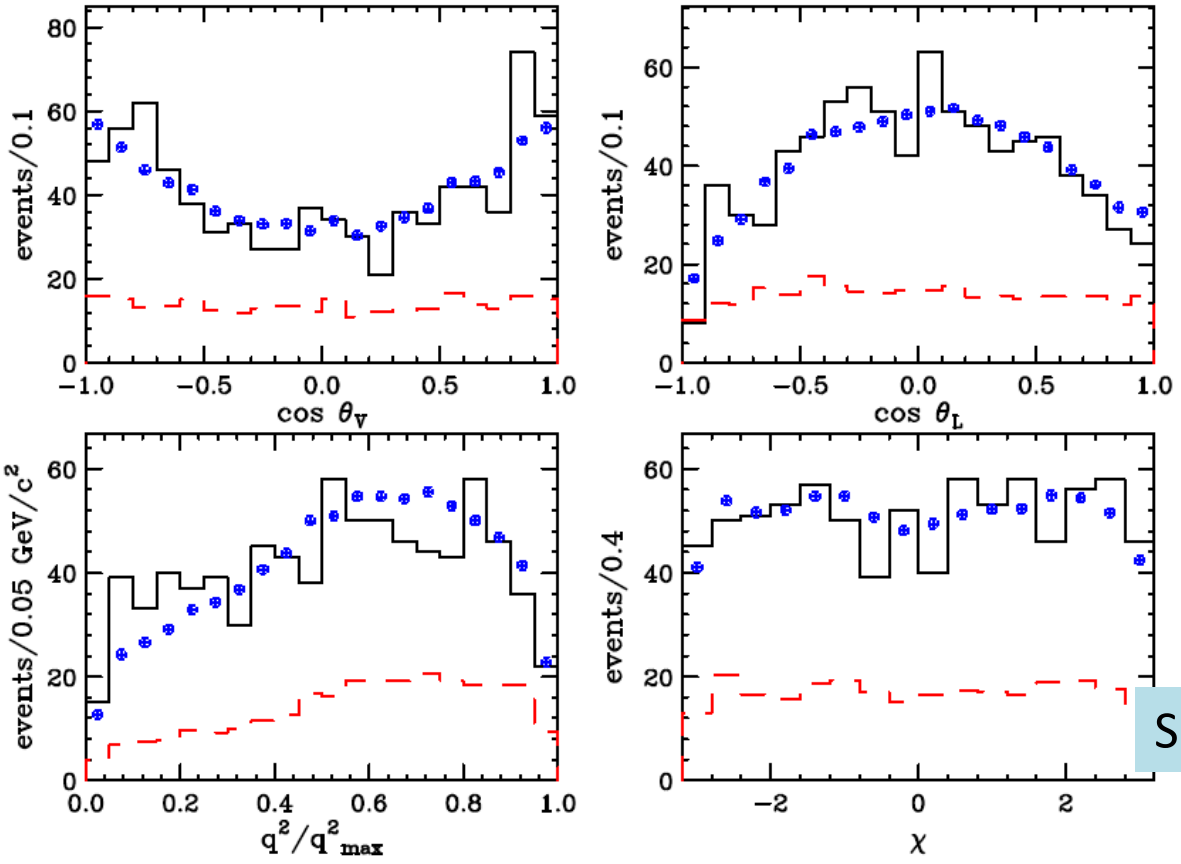
Looks good

Challenges at low q^2 persist even in the latest CLEO-c results

FOCUS Form Factors $D_S^+ \to \phi\mu^+\nu$

Similar to K* (should be similar via SU(3)), but S-wave not apparent here (< 5% at least)
-Data (Histogram) compared to fit + ccbar Bkgnd (dots) and just ccbar Bkgnd (dashed)

Phys.Lett.B586:183-190,2004



$$D^+ \to \overline{K}^{*0}\mu^+\nu$$

$$r_V = 1.504 \pm 0.057 \pm 0.039$$
$$r2 = 0.875 \pm 0.049 \pm 0.064$$
$$\pm(stat) \pm(sys)$$

$$D_S^+ \to \phi\mu^+\nu$$

$$r_V = 1.549 \pm 0.250 \pm 0.145$$
$$r2 = 0.713 \pm 0.202 \pm 0.266$$

Some variability due to cut choices

SU(3) analogy holds at these stats

Problem at higher stats?

BaBar (e), PRD 81: 112001, 2010

r_V=1.807 ± 0.046 ± 0.065

r_2-=0.816 ± 0.036 ± 0.030

March towards $D^0 \to K^- \mu^+ \nu$

- With the K* analisysis done, we were ready to tackle the neutral D pseuoscalar decays
  - The dream was to compare to LQCD, E687
  - K* feed-down important to know
- Problem! We didn't agree with CLEO result:

Phys. Rev. Lett. 89, 222001, 2002

$$\frac{D^+ \to \overline{K}^{*0} e^+ \nu}{D^+ \to \overline{K}^0 e^+ \nu} = 0.99 \pm 0.16$$

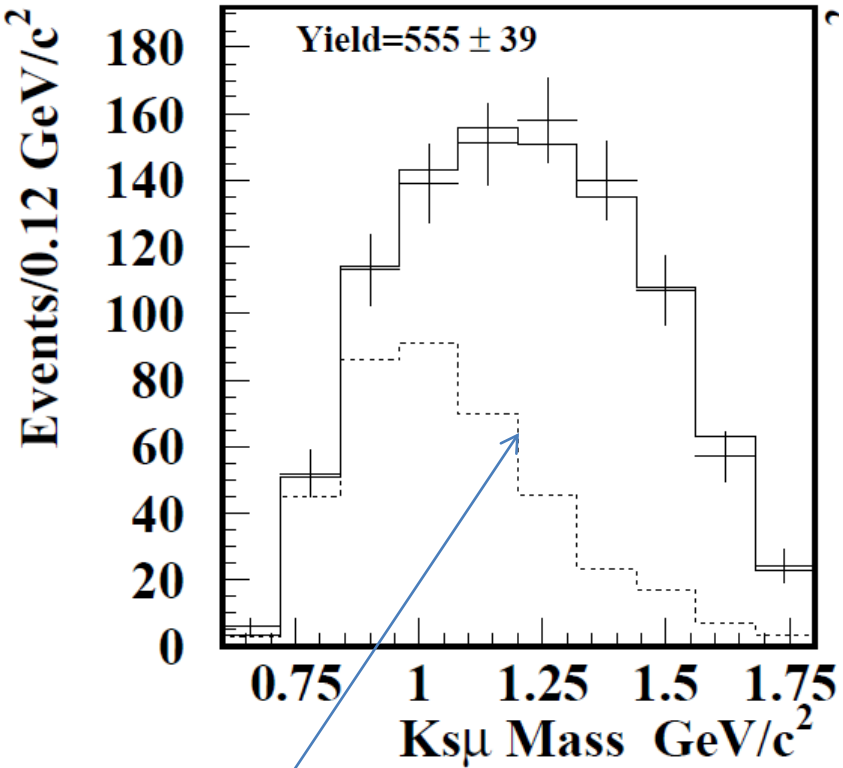
Previous (E687 muon) result compared D^0 and D^+ : 0.62 ± 0.11 (Phys. Lett. B 364, 127, 1995)

- Problem! PDG results (incl. 2003 partial update) looked very interesting (diff at 99% CL)

$$\Gamma(\mathrm{D}^+ \to \overline{\mathrm{K}}^0 \mathrm{e}^+ \upsilon) - \Gamma(\mathrm{D}^0 \to \mathrm{K}^- \mathrm{e}^+ \upsilon) = -25 \pm 9.7\ \mathrm{ns}^{-1}$$

- So we decided to measure $\dfrac{D^+ \to \overline{K}^{*0} \mu^+ \nu}{D^+ \to \overline{K}^0 \mu^+ \nu}$

March towards $D^0 \to K^- \mu^+ \nu$



Background, including K* etc.

- Compare

$$\frac{D^+ \to K\pi\,\mu^+\nu}{D^+ \to \overline{K}^0\mu^+\nu} = \frac{1/2}{1/3}\frac{\#K^-\pi^+\,\mu^+(Fit)}{\#K_S^0\mu^+(Fit)}\frac{\varepsilon(K_S^0\mu^+\upsilon)}{\varepsilon(K^-\pi^+\,\mu^+\upsilon)}$$

- K_S reconstructed only in the microvertex $(K_S \to \pi^+\pi^-)$
- Can include S-wave $(K^-\pi^+)$
- Result makes sense:

$$\frac{\Gamma(D^+ \to \overline{K}^{*0}\mu^+\nu)}{\Gamma(D^+ \to \overline{K}^0\mu^+\nu)} = 0.594 \pm 0.043 \pm 0.033$$

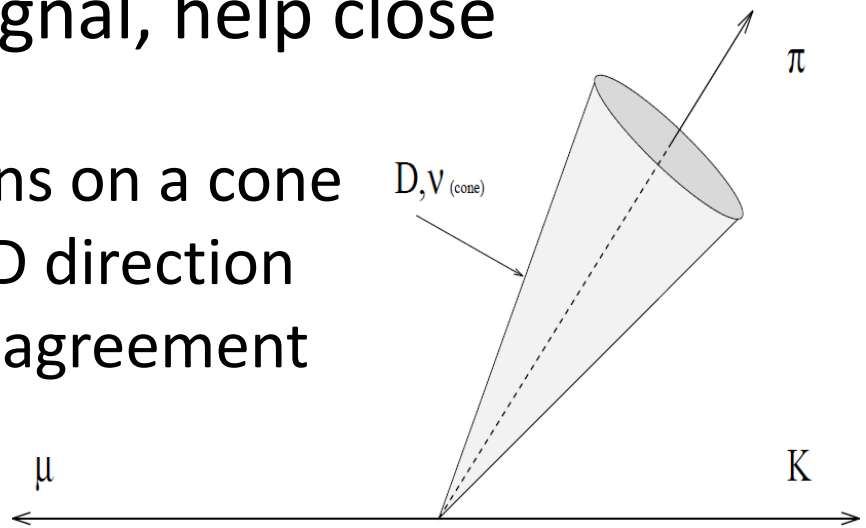
Phys.Lett.B598:33-41,2004

And there is better agreement between D^0 and D^+

$$\Gamma(D^+ \to \overline{K}^0\mu^+\upsilon) - \Gamma(D^0 \to K^-\mu^+\upsilon) = 11 \pm 11\,\mathrm{ns}^{-1}$$

FOCUS Form Factors

- Use D* tag to get cleaner signal, help close kinematics
  - In $K\mu$ CM frame D, ν solutions on a cone
  - Boost cone to lab, compare D direction
  - Choose best χ^2, cut on CL of agreement



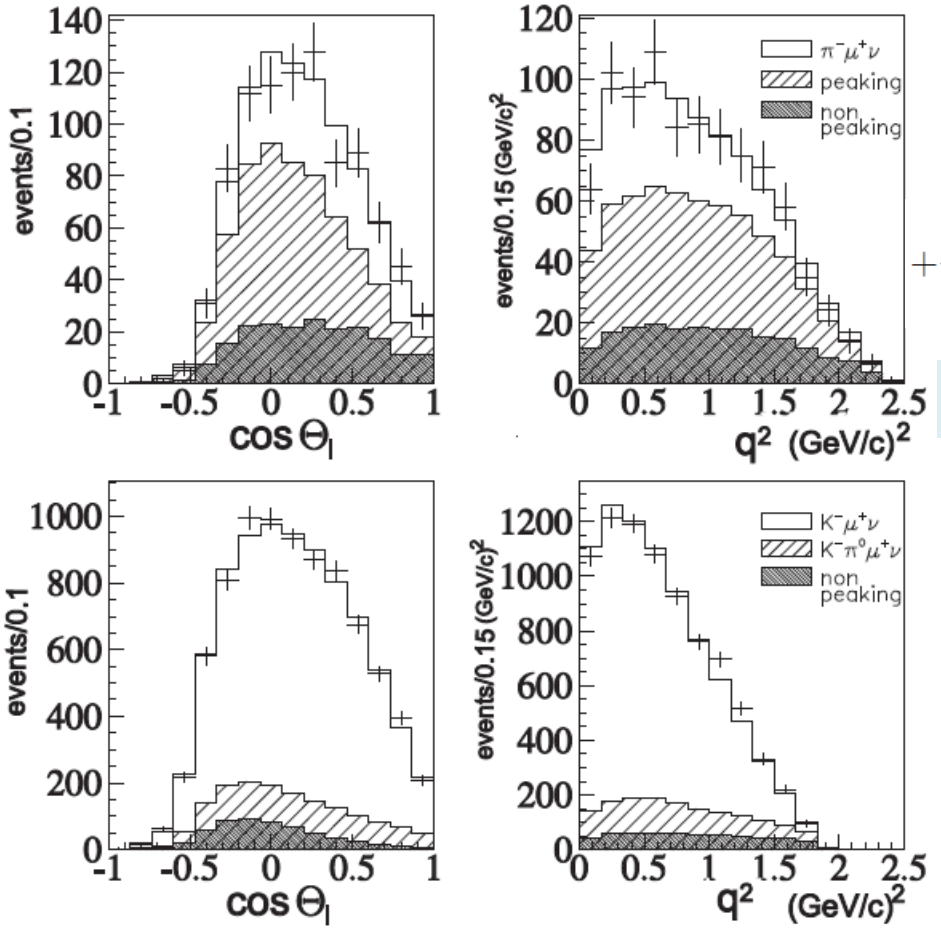
(picture from speakers thesis…very dusty)

- Two techniques for fitting
  - Non-parametric deconvolution (remember K*?)
    - Only for $D^0 \to K^- \mu^+ \nu$
  - Discrete transform
    - Fit only to parameterized function $D^0 \to K^- \mu^+ \nu$ & $\pi^- \mu^+ \nu$
    - Use for BR too

FOCUS Form Factors $D^0 \to K^- \mu^+ \nu$ & $\pi^- \mu^+ \nu$

Backgrounds are more challenging for the pion mode, similar to B->πlν in Babar/Belle

Projections to parameterized fit



$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{8\pi^3\, m_D} |V_{cs}|^2 \left|f_+(q^2)\right|^2 P_K \left(\frac{W_0 - E_K}{F_0}\right)^2$$

$$\left[\frac{1}{3} m_D P_K^2 + \frac{m_\mu^2}{8 m_D}(m_D^2 + m_K^2 + 2 m_D E_K)\right.$$

$$\left. + \frac{1}{3} m_\mu^2 \frac{P_K^2}{F_0} + \frac{1}{4} m_\mu^2 \frac{m_D^2 - m_K^2}{m_D} Re\left(\frac{f_-(q^2)}{f_+(q^2)}\right) + \frac{1}{4} m_\mu^2 F_0 \left|\frac{f_-(q^2)}{f_+(q^2)}\right|^2\right]$$

2 parameterizations (done before "z" method)

$$f_+(q^2) = \frac{f_+(0)}{1 - q^2/m_{\text{pole}}^2}$$

$$f_+(q^2) = \frac{f_+(0)}{(1 - q^2/m_{D^*}^2)\,(1 - \alpha\, q^2/m_{D^*}^2)}$$

Systematics : different event selections, alternative fit methods, & consistency of results between split samples

Phys.Lett. B607:233-242, 2005 &
Phys.Lett.B607:51-58, 2005

FOCUS Form Factors (&BR) $D^0 \to K^- \mu^+ \nu$ & $\pi^- \mu^+ \nu$

FOCUS

Phys.Lett. B607:233-242, 2005 &
Phys.Lett.B607:51-58, 2005

$$D^0 \to K^- \mu^+ \nu$$

$$m_{Pole} = 1.93 \pm 0.05 \pm 0.03\ \mathrm{GeV/c^2}$$

$$\alpha = 0.28 \pm 0.08 \pm 0.07$$

$$f_-^{(K)}(0)/f_+^{(K)}(0) = -1.7^{+1.5}_{-1.4} \pm 0.3$$

$$\pm(stat) \pm (sys)$$

CLEO-c

PRD 80, 32005 2009

$$m_{Pole} = 1.91 \pm 0.02 \pm 0.01\ \mathrm{GeV/c^2}$$

$$\alpha = 0.31 \pm 0.04 \pm 0.02$$

$$\pm(stat) \pm (sys)$$

$$D^0 \to \pi^- \mu^+ \nu$$

$$m_{Pole} = 1.91^{+0.30}_{-0.15} \pm 0.07\ \mathrm{GeV/c^2}$$

$$\frac{\Gamma(D^0 \to \pi^- \mu^+ \nu)}{\Gamma(D^0 \to K^- \mu^+ \nu)} = 0.074 \pm 0.008 \pm 0.007$$

$$\left|\frac{V_{cd}}{V_{cs}}\right|^2 \left|\frac{f_+^{\pi}(0)}{f_+^{K}(0)}\right|^2 = 0.037 \pm 0.004 \pm 0.004$$

$$m_{Pole} = 1.91 \pm 0.03 \pm 0.00\ \mathrm{GeV/c^2}$$

$$\frac{\Gamma(D^0 \to \pi^- e^+ \nu)}{\Gamma(D^0 \to K^- e^+ \nu)} = 0.082 \pm 0.003$$

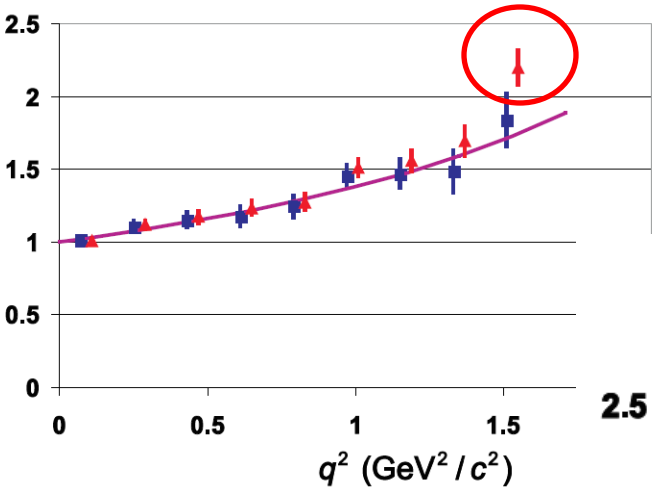
(My calculations from the CLEO – c Paper)

$$\left|\frac{V_{cd}}{V_{cs}}\right|^2 \left|\frac{f_+^{\pi}(0)}{f_+^{K}(0)}\right|^2 = 0.041 \pm 0.002$$

FOCUS Form Factors $D^0 \to K^- \mu^+ \nu \;\&\; \pi^- \mu^+ \nu$

Non-Parametric result, 1st running comparison to unquenched LQCD q^2

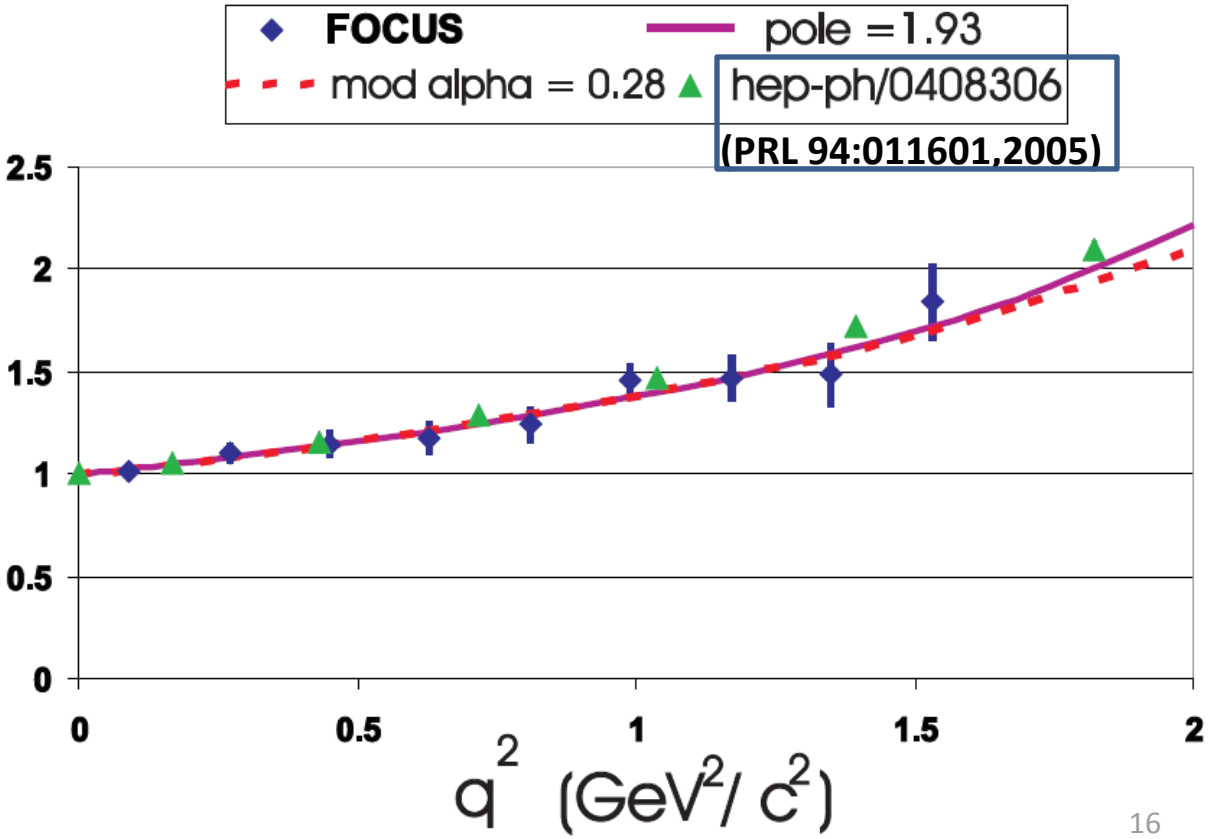
$f_+(q^2)$ Before Bkgnd Subtraction



Simple pole mass fit as a check to parametric

$$m_{Pole} = 1.93 \pm 0.05 \pm 0.03\ \mathrm{GeV/c^2}\ (parm)$$

$$m_{Pole} = 1.93 \pm 0.04 \pm 0.05\ \mathrm{GeV/c^2}\ (non-parm)$$



Good Agreement!!

Need more stats to weed out surprises!

Phys.Lett.B607:67-77, 2005

FOCUS Form Factors (&BR)

$D^0 \to K^{*-}\mu^+\nu$

- Like the D+ (should via SU(3)), S-wave too!
- Reconstruct $K^{*-} \to (K_S^0 \to \pi^+\pi^-)\pi^-$
- Combined fit ΔM (60 bins)

$\cos\theta_V \times \cos\theta_\ell \times q^2$ (4 x 4 x 2 Bins)

  - Cut on ΔM for 32 bin fit
    - Constrain signal, bkgnd same

-Uses "cone closure" too

recall $D^+ \to \overline{K}^{*0}\mu^+\nu$

$r_V = 1.504 \pm 0.057 \pm 0.039$

$r2 = 0.875 \pm 0.049 \pm 0.064$

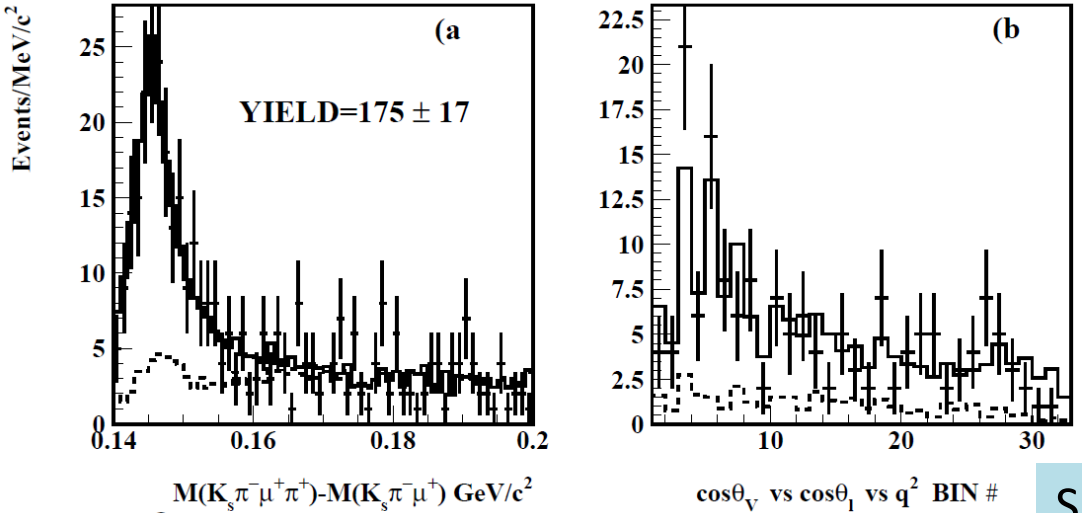
$A_S = 0.330 \pm 0.022 \pm 0.015\ (/GeV)$

$D^0 \to K^{*-}\mu^+\nu$

$r_V = 1.706 \pm 0.667 \pm 0.342$

$r2 = 0.912 \pm 0.370 \pm 0.104$

$A_S = 0.347 \pm 0.222 \pm 0.053\ (/GeV)$



Systematics : different event selections, alternative fit methods, consistency of results between split samples, varying input parameters

SU(3) analogy holds at these stats too

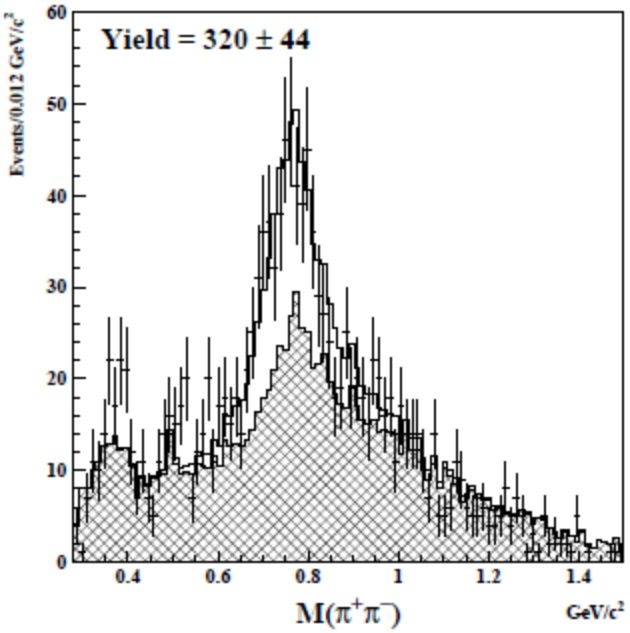
$$\frac{\Gamma(D^0 \to K^*(892)^-\mu^+\nu)}{\Gamma(D^0 \to \overline{K}^0\pi^-\pi^+)} = 0.337 \pm 0.034 \pm 0.013$$

Corrected PDG fit to e mode: 0.35 +/- 0.03

FOCUS last Semileptonic BR

$$\frac{D^+ \to \rho\mu^+\nu}{D^+ \to \overline{K}^{*0}\mu^+\nu}$$

Phys.Lett. B:637,32-38, 2005



Remember this one from the beginning?

Tour de-force in the Background Est
Did w/constraints and w/o (many)

Decay Mode	Total Yield	Yield in signal region
$D^+ \to \rho^0\mu^+\nu$	320 ± 44	282
$D^+ \to K^-\pi^+\mu^+\nu$	68 [a]	44
$D^+ \to K^0_S\mu^+\nu$	7 ± 6	0
D_s^+ modes total	179 ± 40	101
$D^+ \to \omega\mu^+\nu$	51 ± 22	10
Muon Mis-Id	550 ± 44	263
Combinatoric	233 ± 50	99

Systematics : different event selections, alternative fit methods, consistency of results between split samples, varying input parameters

$$\frac{D^+ \to \rho\mu^+\nu}{D^+ \to \overline{K}^{*0}\mu^+\nu} = 0.041 \pm 0.006 \pm 0.004$$

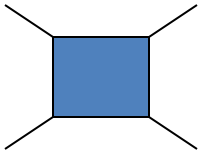
PDG fit to e mode: 0.039 +/- 0.007

My estimate from CLEO-c e modes from HQL2010 & PRD 81:112001, 2010 = 0.042 +/- 0.003

Rare Charm Decays

Potential FCNC Decays are Suppressed

Box Diagrams are Smallish for Charm



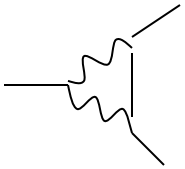
No Top Quuark in the loop

Short Distance

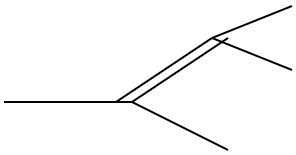
10^{-19} $\Longleftrightarrow$ $BR(D^o \to \mu^+\mu^-)$

10^{-8} $\Longleftrightarrow$ $BR(D^+ \to \pi^+\mu^+\mu^-)$

Long Distance



10^{-13} $\Longleftrightarrow$ $BR(D^o \to \mu^+\mu^-)$



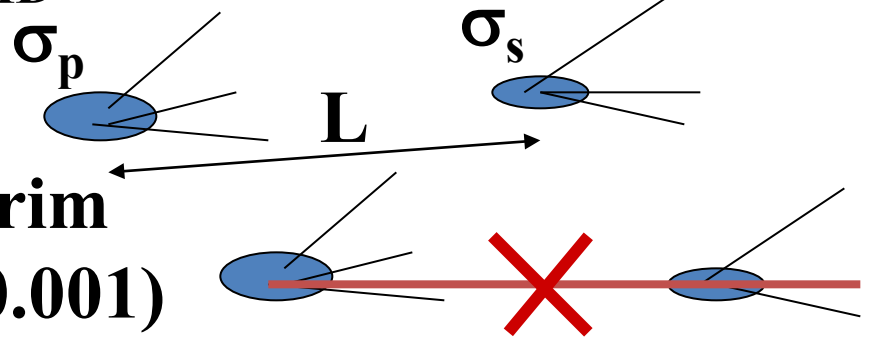
10^{-6} $\Longleftrightarrow$ $BR(D^+ \to \pi^+\mu^+\mu^-)$

Rare Decay Results from FOCUS

Look for 3 bodies with 2 muons

$$D^+_{(S)} \to (\pi, K)^{\pm} \mu^{\mp} \mu^{+}$$

Cut Grid, based on vertexing, Particle ID



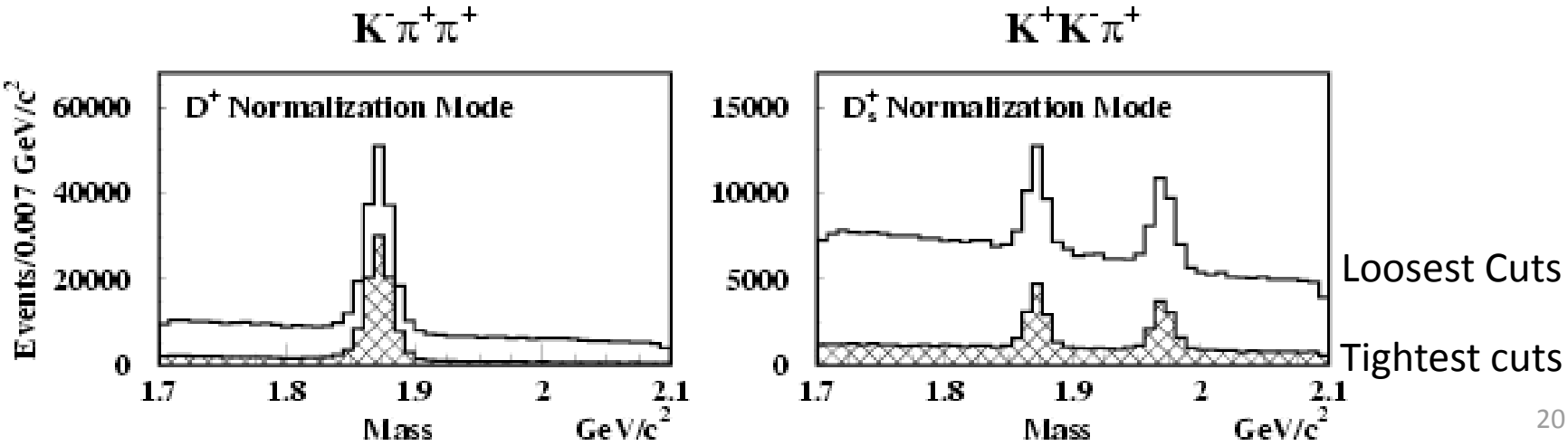
L/σ – vary from >5-21

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%)

Cuts on P(μ) for μ's, Cerenkov for π's and K's



Rare Decay Results from FOCUS

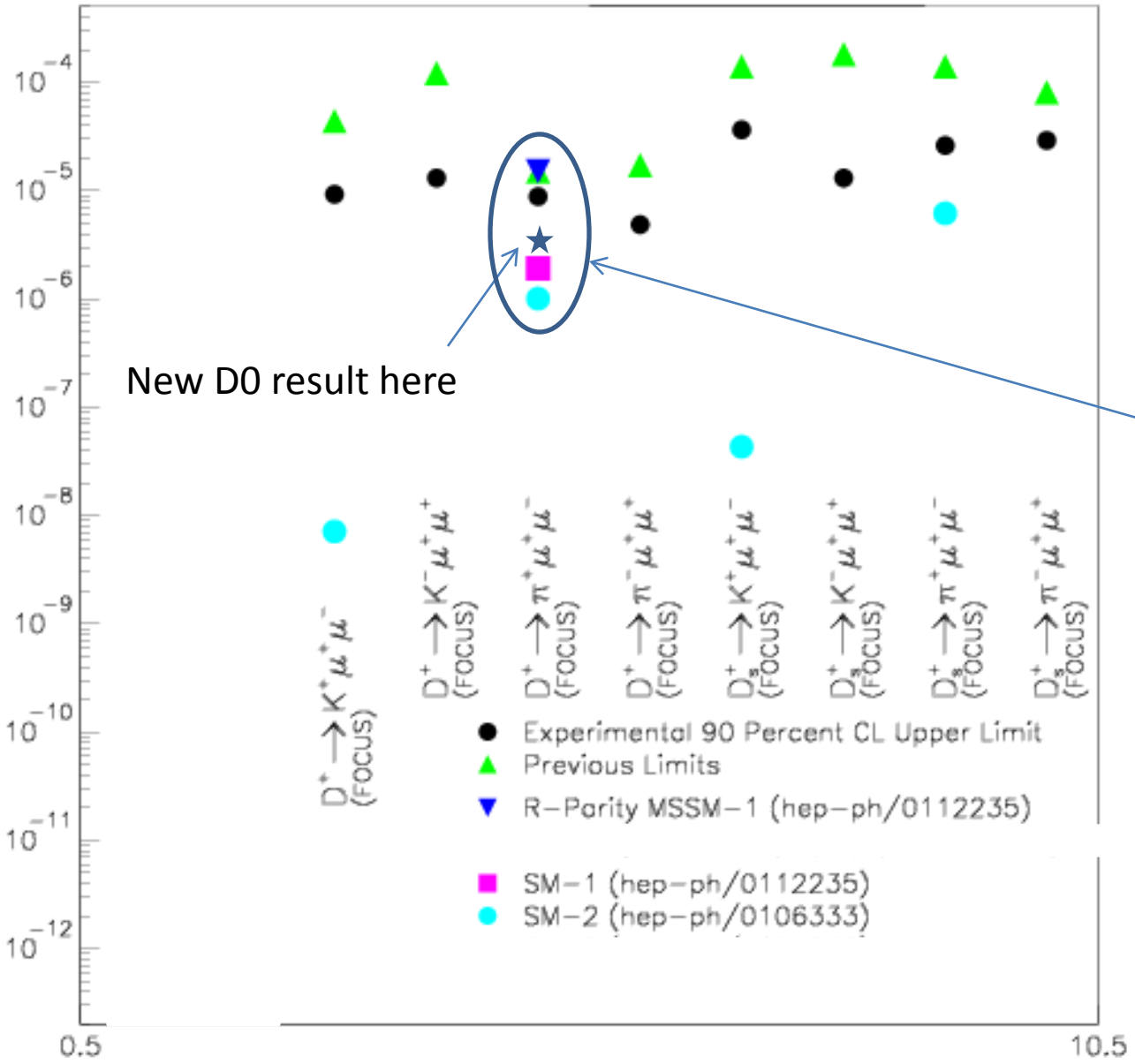
$$D^+_{(S)} \to (\pi, K)^{\pm} \mu^{\mp} \mu^{+}$$

Decay Mode	Dual Bootstrap	Sensitivity	Sys. Error	Result W/sys	Single Cut(w/sys)	Previous (E791)
$D^+ \Rightarrow K^+\mu^+\mu^-$	9.1×10^{-6}	7.5×10^{-6}	7.5%	9.2×10^{-6}	12×10^{-6}	44×10^{-6}
$D^+ \Rightarrow K^-\mu^+\mu^+$	13×10^{-6}	4.8×10^{-6}	7.5%	13×10^{-6}	12×10^{-6}	120×10^{-6}
$D^+ \Rightarrow \pi^+\mu^+\mu^-$	8.8×10^{-6}	7.6×10^{-6}	7.5%	8.8×10^{-6}	7.4×10^{-6}	15×10^{-6}
$D^+ \Rightarrow \pi^-\mu^+\mu^+$	4.9×10^{-6}	5.6×10^{-6}	7.5%	4.8×10^{-6}	5.2×10^{-6}	17×10^{-6}
$D_s^+ \Rightarrow K^+\mu^+\mu^-$	3.3×10^{-5}	3.3×10^{-5}	27.5%	3.6×10^{-5}	3.8×10^{-5}	1.4×10^{-4}
$D_s^+ \Rightarrow K^-\mu^+\mu^+$	1.3×10^{-5}	2.1×10^{-5}	27.5%	1.3×10^{-5}	2.0×10^{-5}	1.8×10^{-4}
$D_s^+ \Rightarrow \pi^+\mu^+\mu^-$	2.4×10^{-5}	3.1×10^{-5}	27.5%	2.6×10^{-5}	1.8×10^{-5}	1.4×10^{-4}
$D_s^+ \Rightarrow \pi^-\mu^+\mu^+$	2.6×10^{-5}	2.3×10^{-5}	27.5%	2.9×10^{-5}	2.2×10^{-5}	0.8×10^{-4}

(E687)

Dominated by PDG rate to normalizing mode

Situation almost the same as in 2003



New D0 result

$$\Gamma(D^+ \to \pi^+\mu^+\mu^-)/\Gamma_{Tot}$$

$$< 3.9\times10^{-6}\ (90\%\ CL)$$

PRL:100 101801, 2008

In fact, D0 see's the phi
And excludes the region

FOCUS Round-UP

- We had some pioneering results
  - S-wave in the K* mode
  - Running comparison to LQCD
  - Non-parametric and cone-closure techniques
  - Remember that our results built up over time as we learned more about the realities of the higher statistics environment
- Our results seem to have held up well
  - There's still an opportunity to improve many FOCUS results, 13 years after data taking ended
- Apologies to others experiments I left out
  - (And for not mentioning the K* width measurement)
  - And experiments that never got a chance to run…