Pseudo-scalar semileptonic analysis from FOCUS

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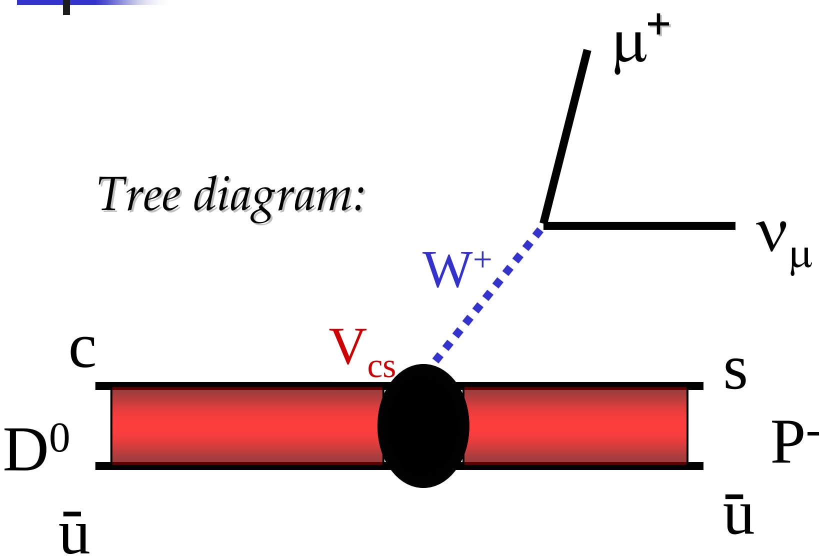
Outline

- Pseudo-scalar semileptonic decays: why are they interesting?
- $D^0 \to \pi^- \mu^+ \nu$ and $D^0 \to K^- \mu^+ \nu$ reconstruction in FOCUS.
- Parametric analysis:
  - Branching Ratio.
  - Pole Masses and $f^K_-(0)/f^K_+(0)$.
  - Form factor ratio $f^\pi_+(0)/f^K_+(0)$
- Non parametric analysis of $D^0 \to K^- \mu^+ \nu$ q^2-dependence.
- Conclusions.

Pseusoscalar semileptonic decays

Tree diagram:



$$H \propto \frac{G_F}{\sqrt{2}} J_H^{\mu} \overline{\psi}_l \gamma_\mu (1-\gamma_5)\psi_\nu$$

Hadronic current contains information about strong contibution.
Parametrization of hadronic current is simple:

$$J_H^{\mu} = f_+(q^2)(D+P)^{\mu} + f_-(q^2)(D-P)^{\mu}$$

The differential decay rate is:

$$\frac{d\Gamma\left(D \to P \ell \nu\right)}{dq^2} \propto \left| f_+(q^2) \right|^2 (A + B\eta + C\eta^2)$$

$$\eta = \frac{f_-(0)}{f_+(0)}$$

Measuring the q^2 dependence and the form factors in heavy to light quark transitions is critical to our understanding of QCD.

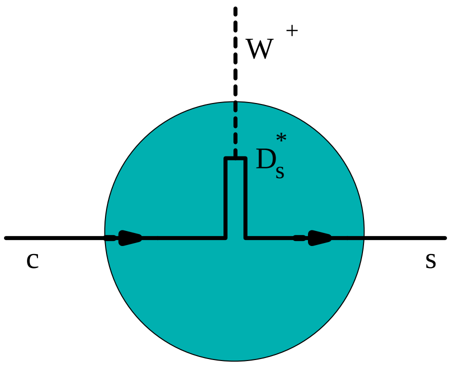
What do we measure?

- *$\pi\mu\nu$ to $K\mu\nu$ branching ratio*

- *pole masses*

$$f_{\pm}(q^2) = \frac{f_{\pm}(0)}{1 - \frac{q^2}{M^2}}$$

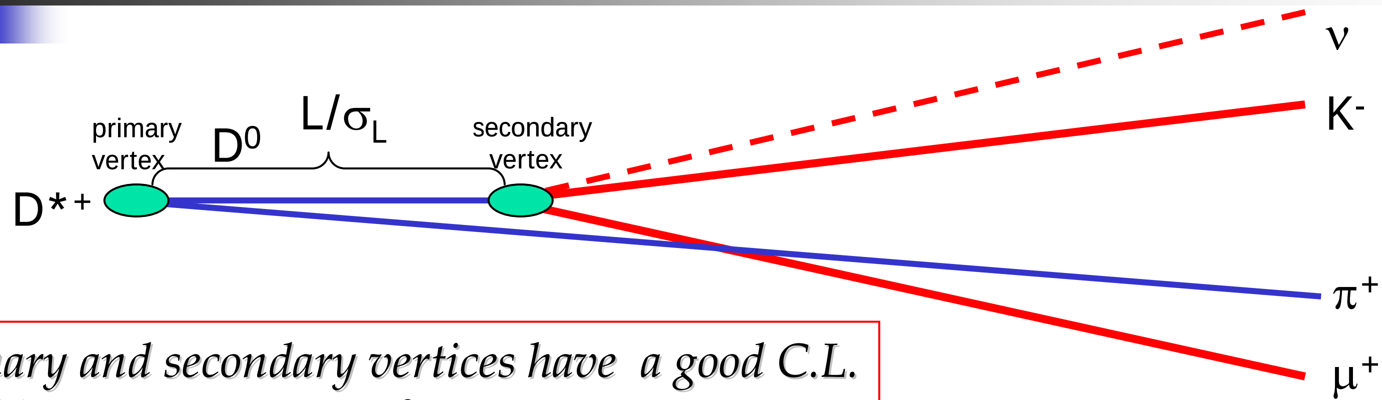
- *$f_-(0)/f_+(0)$: contributions from f_- are still not measured since they are proportional to the lepton mass squared.*



- *$f^{\pi}_+(0)/f^{K}_+(0)$: test of SU(3) symmetry breaking.*

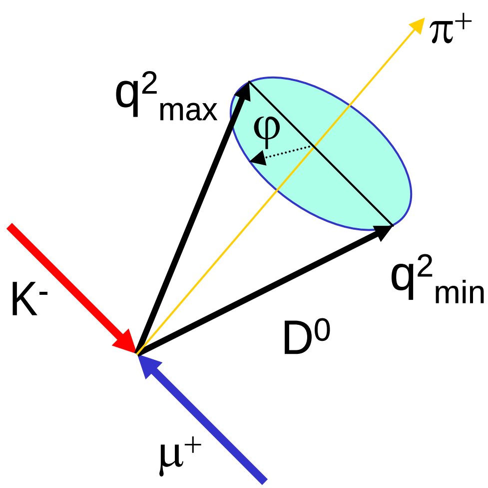
- *non parametric q^2 dependence: a model independent measurement would allow us to discriminate between different models.*

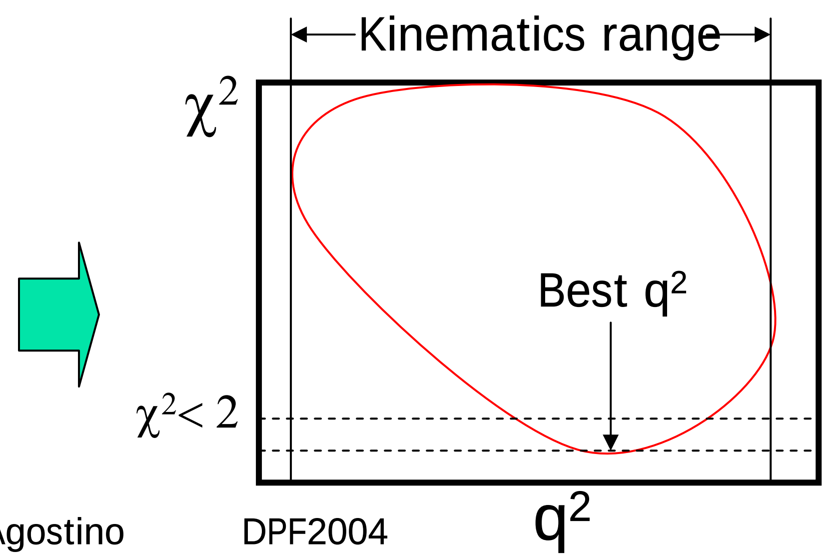
Semileptonic decay reconstruction



- *primary and secondary vertices have a good C.L.*
- *Visible mass > 1.0 GeV/c²*
- *$L/\sigma_L > 6$*
- *Cerenkov ID on K (π) and soft pion*

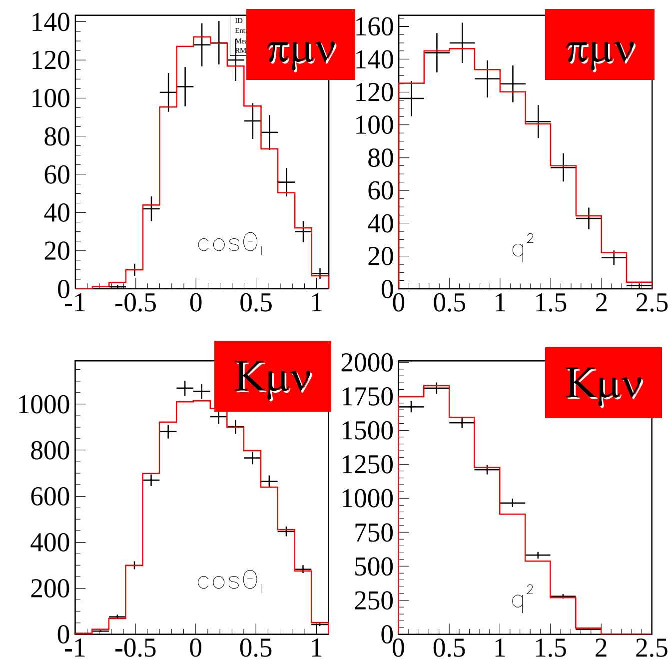
neutrino closure:



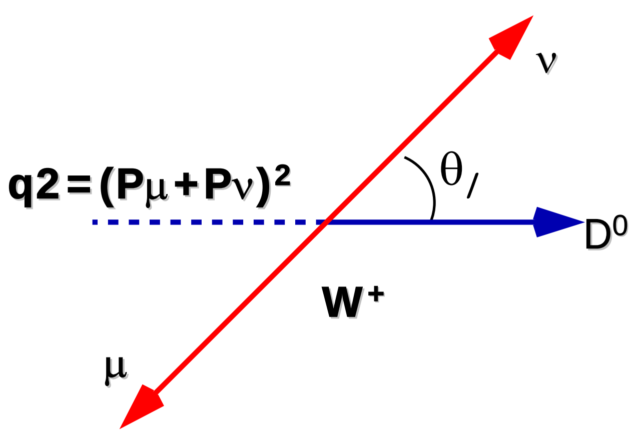


Fitting technique

The fitting procedure consists of a fit to the Kμν sample and the subsequent use of this information to determine πμν background.



- *Fit to the D*-D mass difference to find the amount of combinatoric background.*
- *Cut on the mass difference to suppress combinatoric and peaking background.*
- *Fit to $\cos\theta_l$ and q^2 to measure branching ratio, pole masses and the ratio $f_-(0)/f_+(0)$.*



$$F = -2\ln(\pi\mu\nu) + \chi_1^2 \qquad \chi_1^2 = (BR_{(\rho^-/K^{*-})} - 0.080)^2/(0.01)^2$$

$$F = -2\ln(K\mu\nu) + \chi_2^2 \qquad \chi_2^2 = (BR_{(K^*/K)} - 0.63)^2/(0.05)^2$$

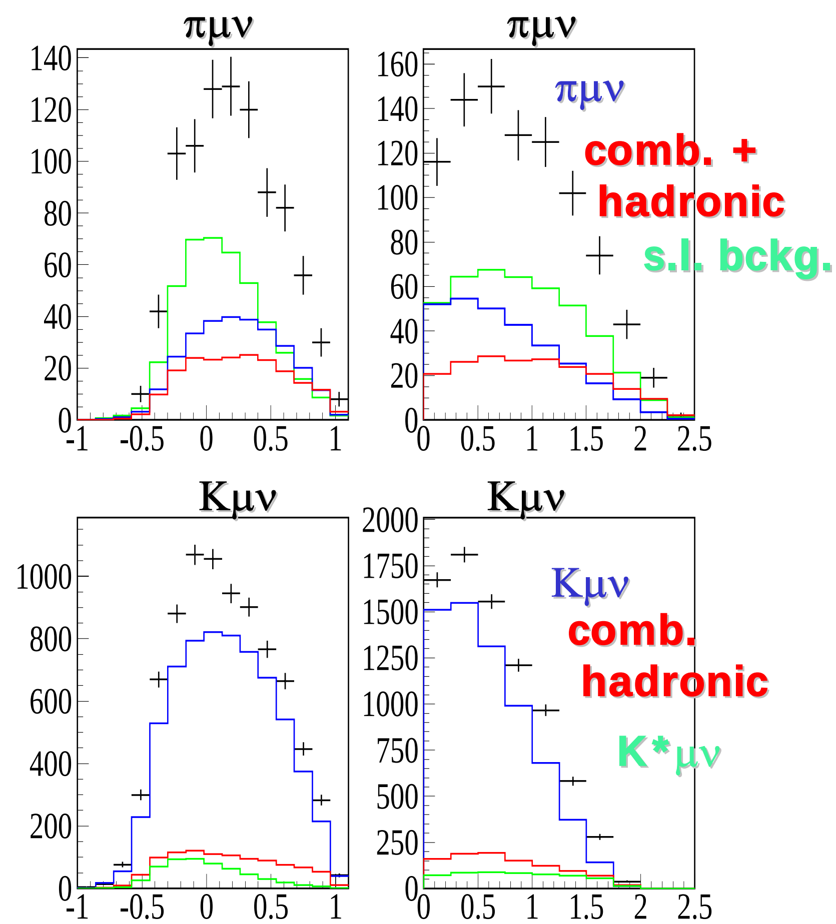
Weighting procedure

To measure pole masses and form factors we apply an event by event weighting:

$$Weight = \frac{I(m')/Norm.(m')}{I(m^0)/Norm(m^0)}$$

where $$I \propto \left|f_+(q^2)\right|^2 g\left(\frac{f_-(0)}{f_+(0)}\right)$$

$\pi\mu\nu$ and $K\mu\nu$ shapes and efficiencies change during the fitting process.

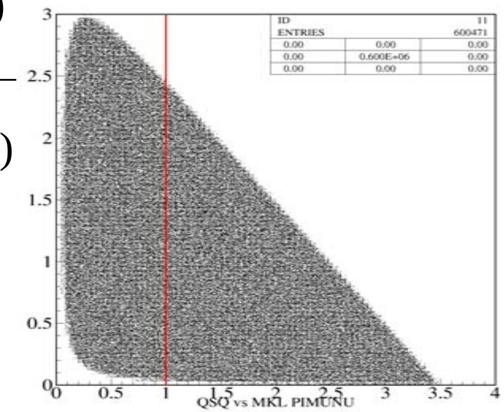


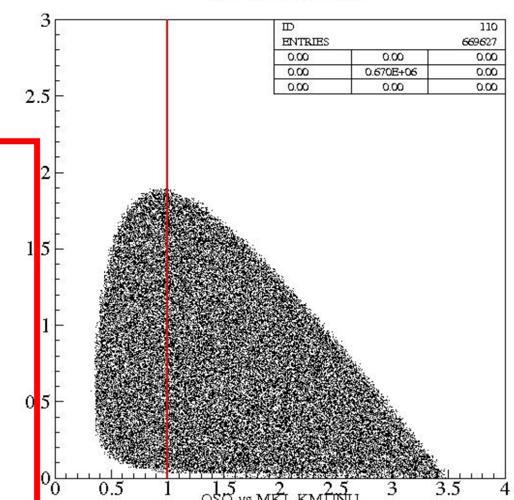
	Yield	B.R.(%)	Pole mass	$\frac{f_-^K(0)}{f_+^K(0)}$
$\pi\mu\nu$	288 ± 29	7.4 ± 0.8	$1.89^{+0.28}_{-0.14}$	
$K\mu\nu$	6572 ± 92	100.	$1.92^{+0.05}_{-0.04}$	$-1.69^{+1.8}_{-1.5}$

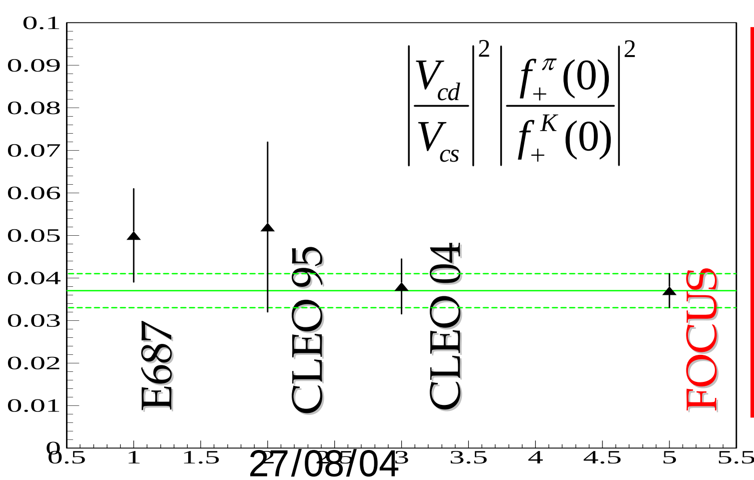
Extracting $f_+^{\pi}(0) / f_+^{K}(0)$

$$\frac{Y(\pi\mu\nu)}{Y(K\mu\nu)} = \left|\frac{f_+^{\pi\mu\nu}(0)}{f_+^{K\mu\nu}(0)}\right|^2 \left|\frac{V_{cd}}{V_{cs}}\right|^2 \frac{\int_{E_{l\min}}^{E_{lMax}} dE_l \int_{q^2_{\min}(E_l)}^{q^2_{Max}(E_l)} dq^2 \frac{f_+^{\pi\mu\nu}(q^2)}{f_+^{\pi\mu\nu}(0)} (A+B\eta+C\eta^2)\varepsilon^{\pi\mu\nu}(q^2)}{\int_{E_{l\min}}^{E_{lMax}} dE_l \int_{q^2_{\min}(E_l)}^{q^2_{Max}(E_l)} dq^2 \frac{f_+^{K\mu\nu}(q^2)}{f_+^{K\mu\nu}(0)} (A+B\eta+C\eta^2)\varepsilon^{K\mu\nu}(q^2)}$$

- Yields from the fit
- Efficiency as a function of q^2.
- $|V_{cd}/V_{cs}|^2 = 0.051$
- Compute a numerical integration on the Dalitz.







$$\left|\frac{V_{cd}}{V_{cs}}\right|^2 \left|\frac{f_+^{\pi}(0)}{f_+^{K}(0)}\right|^2 = 0.037 \pm 0.04$$

$$\frac{f_+^{\pi}(0)}{f_+^{K}(0)} = 0.85 \pm 0.04(stat.)$$

Systematic studies and results

- *Fit fluctuated data to test for biases and errors.*
- *Fit fluctuated fit function to test goodness of fit.*
- *Cut variations to verify Monte Carlo simulation.*
- *High statistics D^+ and D^0 decays used to test K to pi misidentification rate.*
- *Fit variations and alternative fitting procedure.*
- *Variations on the amount of backgrounds.*
- *Test on weak constraints increasing the input error by a factor of 10.*

$$\frac{\Gamma(\pi^- \mu^+ \nu)}{\Gamma(K^- \mu^+ \nu)} = 0.074 \pm 0.008(stat.) \pm 0.006(sys.)$$

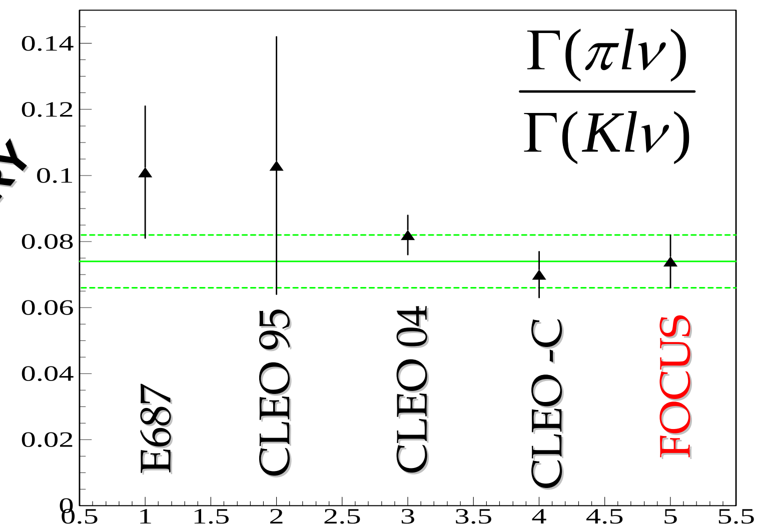
$$M_\pi = 1.89^{+0.28}_{-0.14}(stat.) \pm 0.07(sys.)$$

$$M_K = 1.92^{+0.05}_{-0.04}(stat.) \pm 0.03(sys.)$$

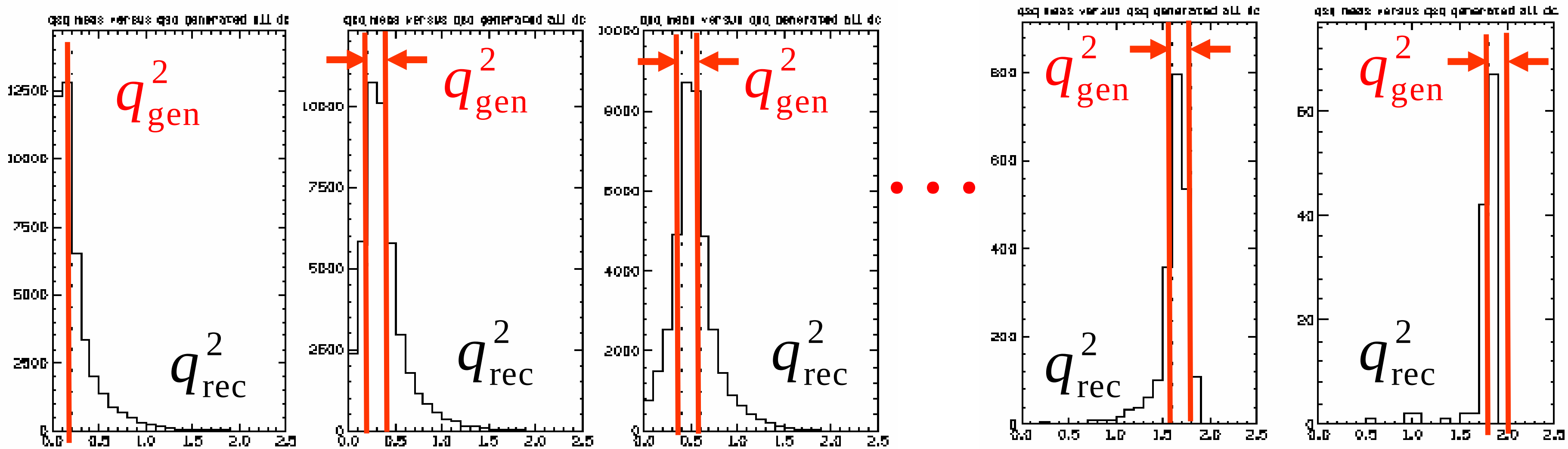
$$\frac{f_-^K(0)}{f_+^K(0)} = -1.69^{+1.8}_{-1.5}(stat.) \pm 0.3(sys.)$$

$$\frac{f_+^\pi(0)}{f_+^K(0)} = 0.85 \pm 0.04(stat.) \pm 0.04(sys.)$$

PRELIMINARY



Correcting for smearing in FOCUS

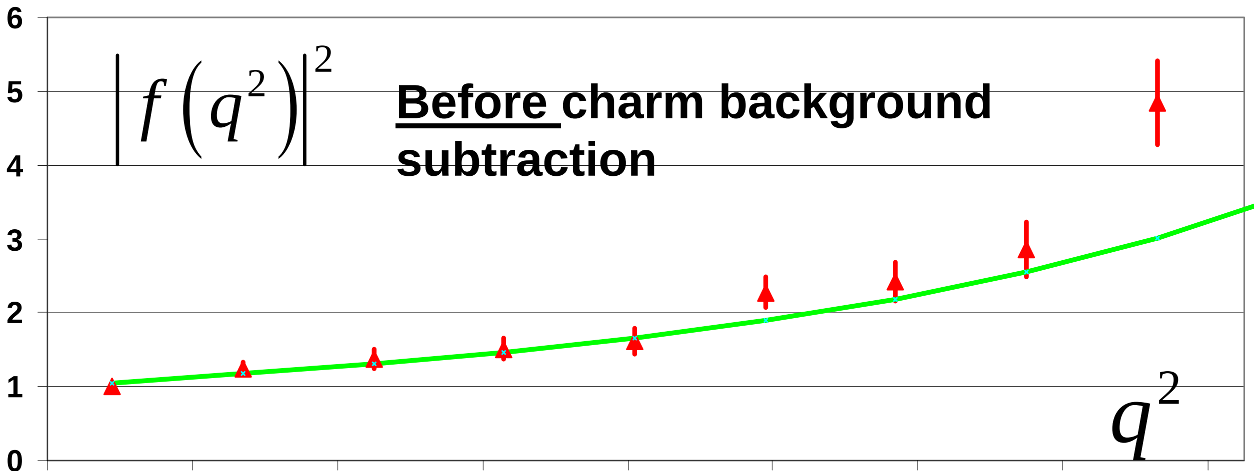


A deconvolution matrix is constructed from the number of events generated in the i-th q^2 bin that end up reconstructed in the j-th q^2 bin. This matrix is then used to correct data for resolution and efficiency

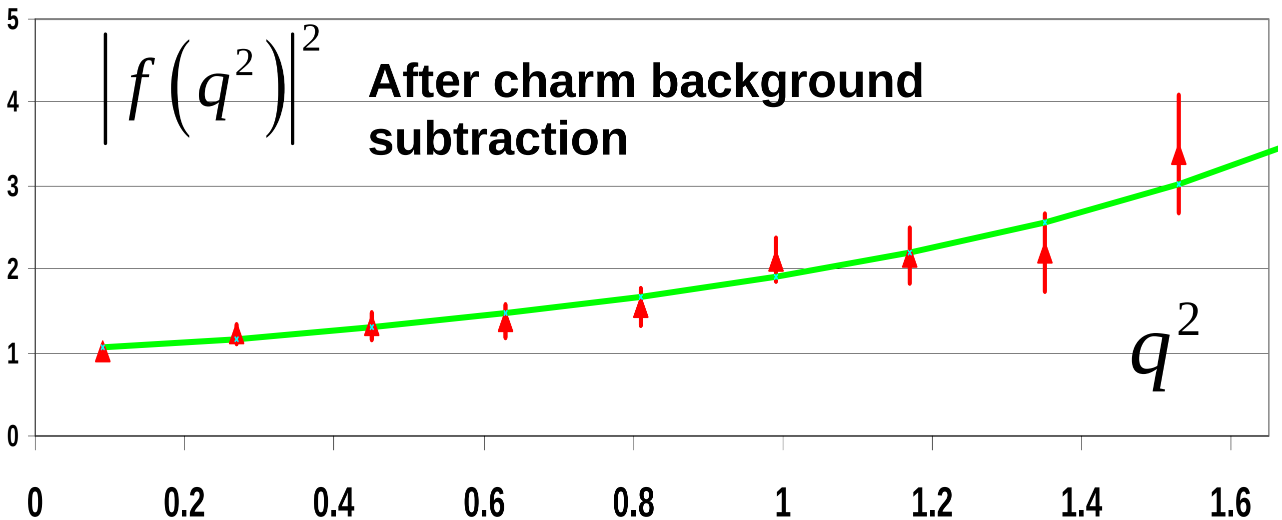
$$\begin{pmatrix} N^{G1}_{M1}/\tilde{f}_1^2 & N^{G2}_{M1}/\tilde{f}_2^2 & N^{G3}_{M1}/\tilde{f}_3^2 \\ N^{G1}_{M2}/\tilde{f}_1^2 & N^{G2}_{M2}/\tilde{f}_2^2 & N^{G3}_{M2}/\tilde{f}_3^2 \\ N^{G1}_{M3}/\tilde{f}_1^2 & N^{G2}_{M3}/\tilde{f}_2^2 & N^{G3}_{M3}/\tilde{f}_3^2 \end{pmatrix}^{-1} \begin{pmatrix} \tilde{M}_1 \\ \tilde{M}_2 \\ \tilde{M}_3 \end{pmatrix} = \begin{pmatrix} f^2\left(q_1^2\right) \\ f^2\left(q_2^2\right) \\ f^2\left(q_3^2\right) \end{pmatrix}$$

We actually use a 10 × 10 matrix

Correcting for charm backgrounds



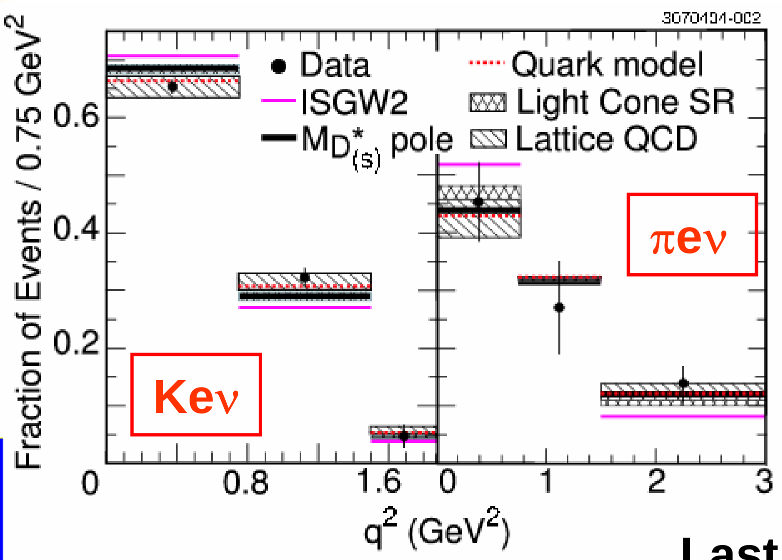
Interestingly enough the backgrounds seem to be primarily at high q^2

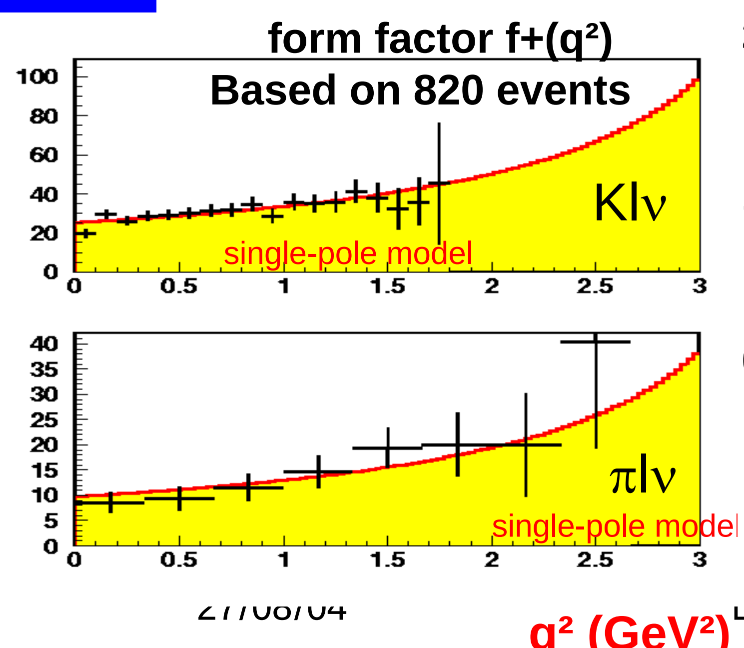


After subtracting known charm backgrounds $f_+(q^2)$ is an excellent match to a pole form with **m_{pole}= 1.92 GeV**

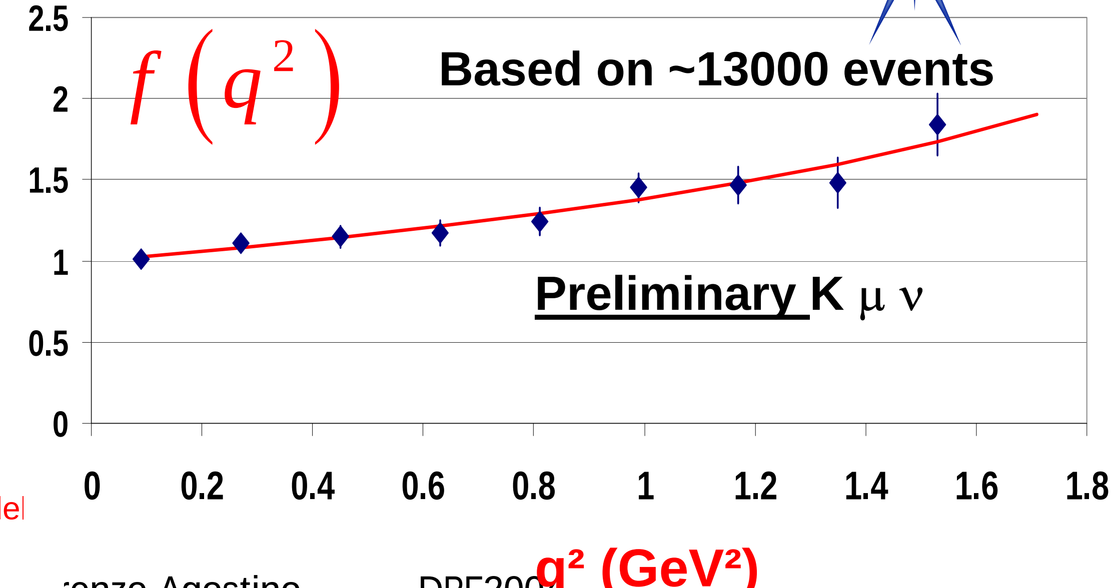
How do we compare on $f_+(q^2)$?

Three (!) brand new results from CLEO, BELLE, and FOCUS on $f_+(q^2)$

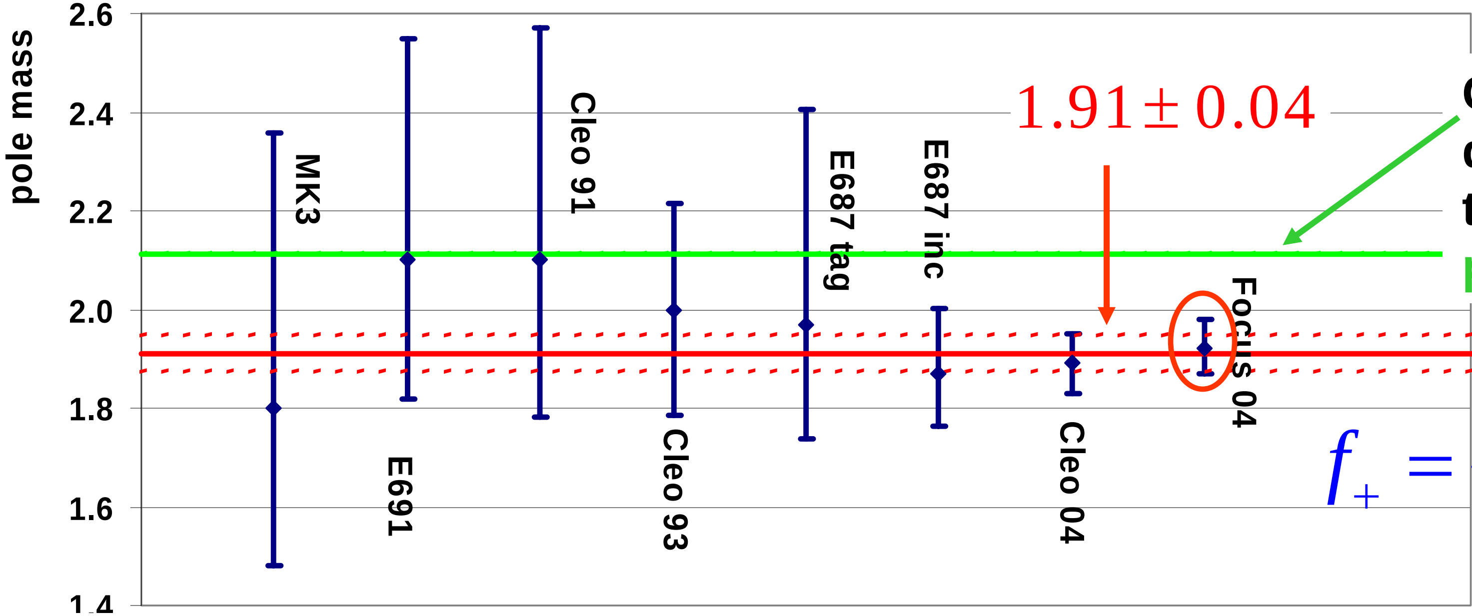




Last but not least….

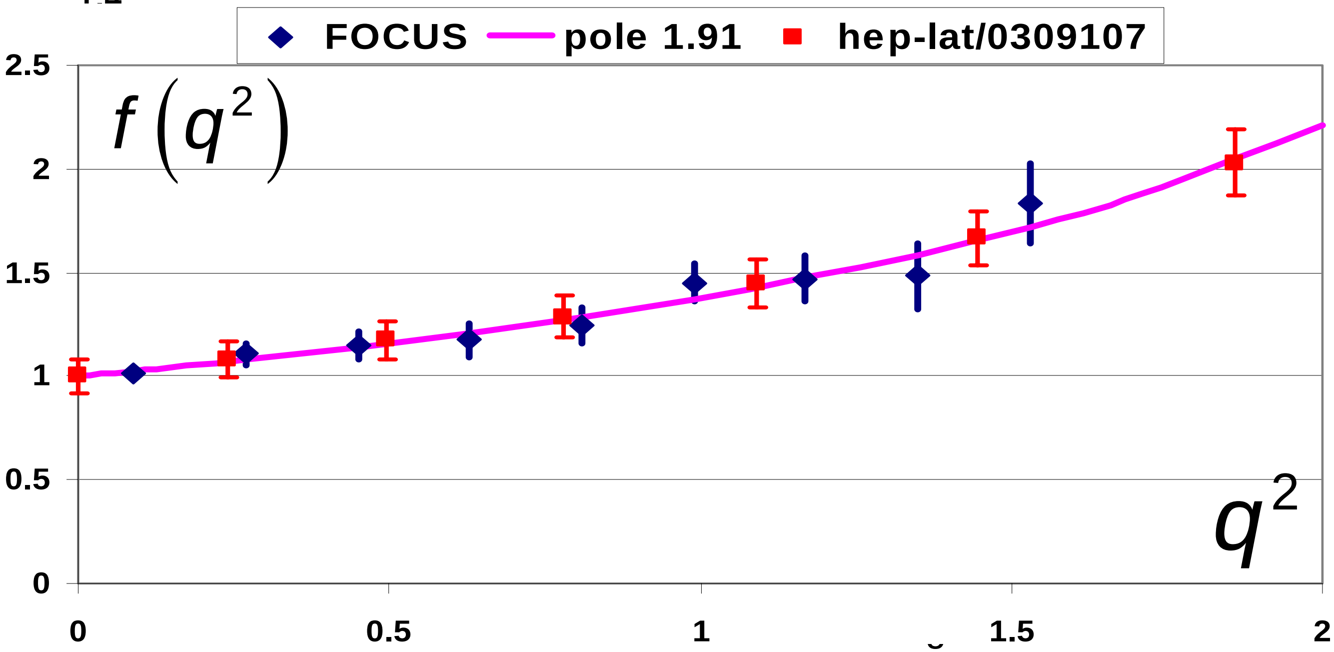


Pole mass fits and LQCD calculations



Clearly the data does not favor the simple Ds* pole

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



Agreement with LQCD unquenched calculation is also very impressive!

This calculation predicts *$f_+^\pi(0)/f_+^K(0)$=0.85 in great agreement with the FOCUS result.*

Conclusions

- *We presented new results on D^0 pseudoscalar semileptonic decays from FOCUS. We measured the pole masses for both $\pi\mu\upsilon$ and $K\mu\upsilon$, the form factor ratio $f_-^K(0)/f_+^K(0)$ as well as the ratio $f_+^\pi(0)/f_+^K(0)$.*
- *The pole masses are lower than the predicted values at the D^* or D_s^* masses.*
- *We have the best measurement of $f_+^\pi(0)/f_+^K(0)$ which is consistent with the predictions from SU(3) symmetry breaking and lattice QCD.*
- *The $\pi\mu\upsilon$ to $K\mu\upsilon$ branching ratio is consistent with recent results from CLEO.*
- *Finally we presented a non-parametric analysis of the q^2 dependence for $D^0 \to K\mu\upsilon$ which shows excellent agreement with the results obtained with the parametric analysis and Lattice QCD.*