CORNELL UNIVERSITY LEPP
LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

Semileptonic decays at CLEO-c
HQL10, Frascati, Oct. 2010

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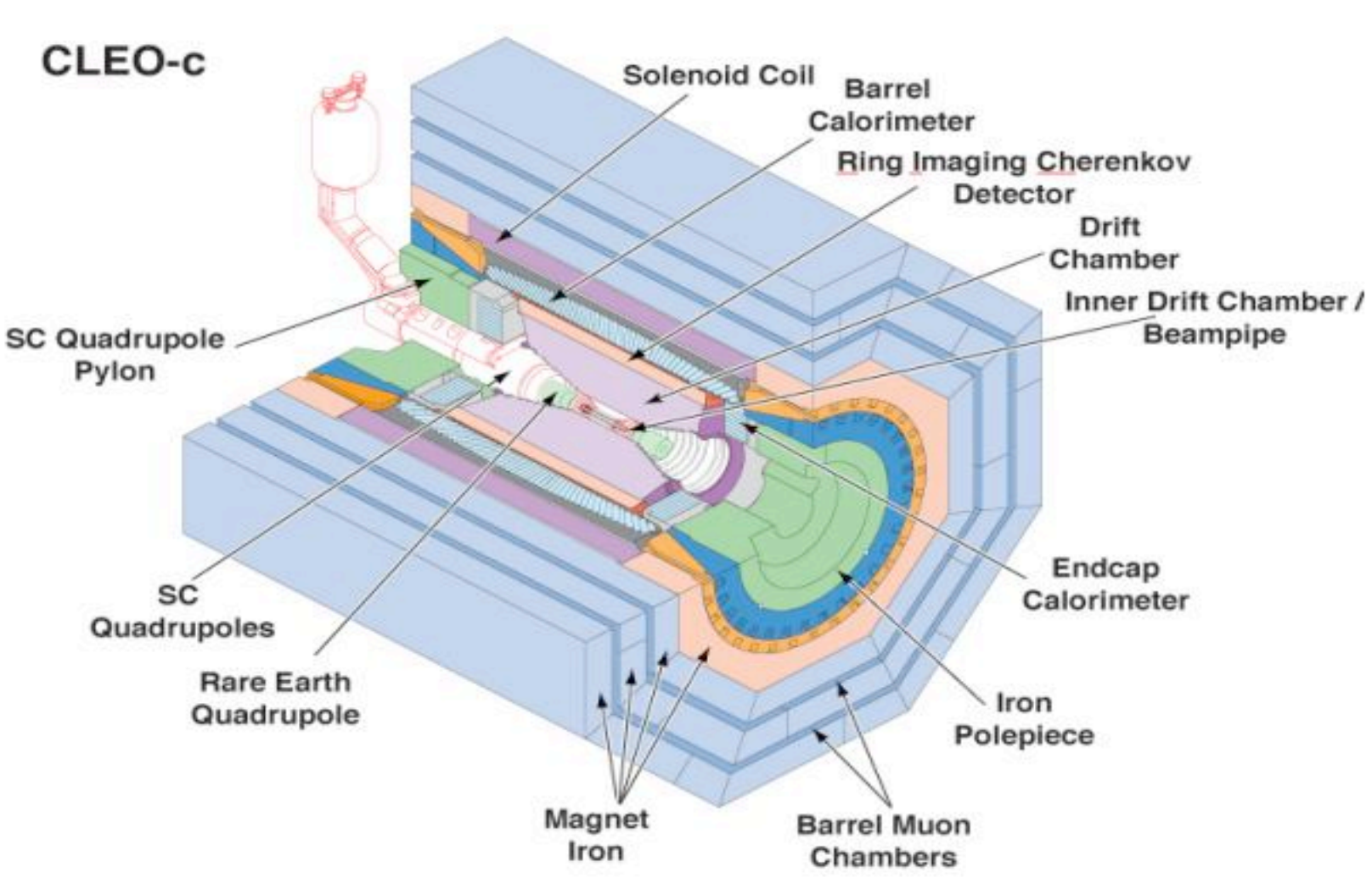
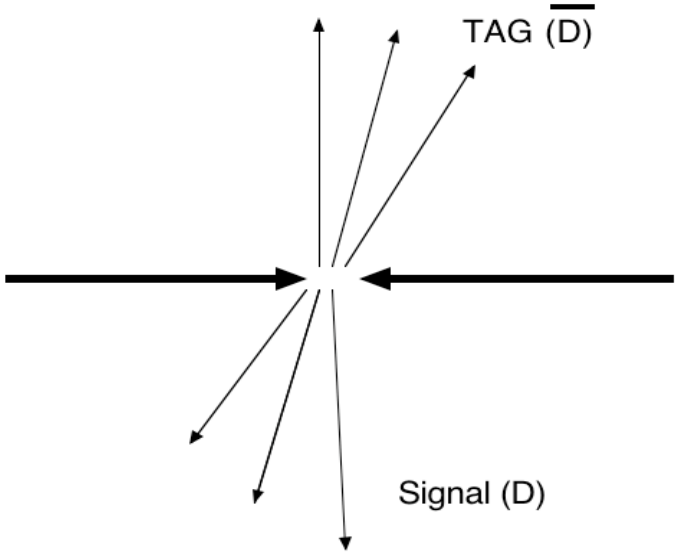
WHERE DISCOVERIES BEGIN

CLEO-c detector

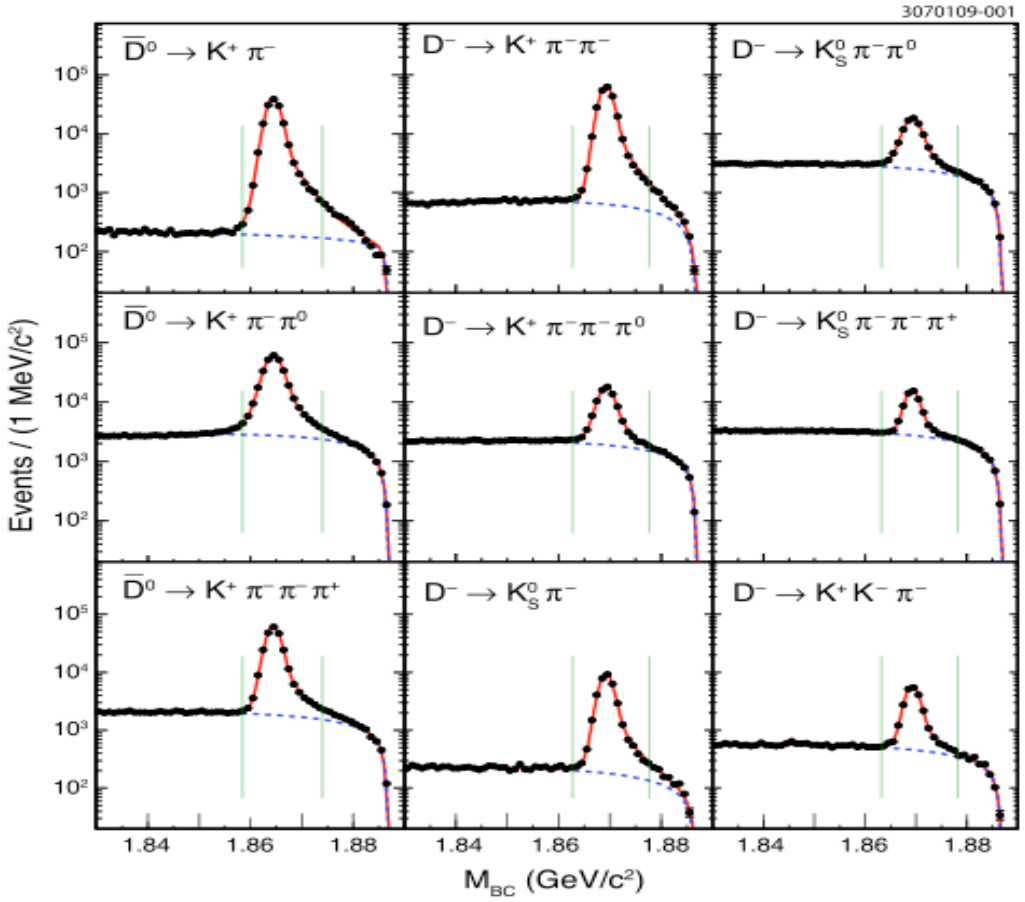
- similar to other detectors but lighter (no SVD, gaseous RICH)
- better neutrals and electrons
- muons are below threshold at CESR-c energies



√s=3770 MeV: exclusive $e^+e^- \rightarrow D\bar{D}$, 818 pb^{-1}
($5.4X10^6$ DD events, $6.6X10^5$ D^0 tags, $4.8X10^5$ D^+ tags)



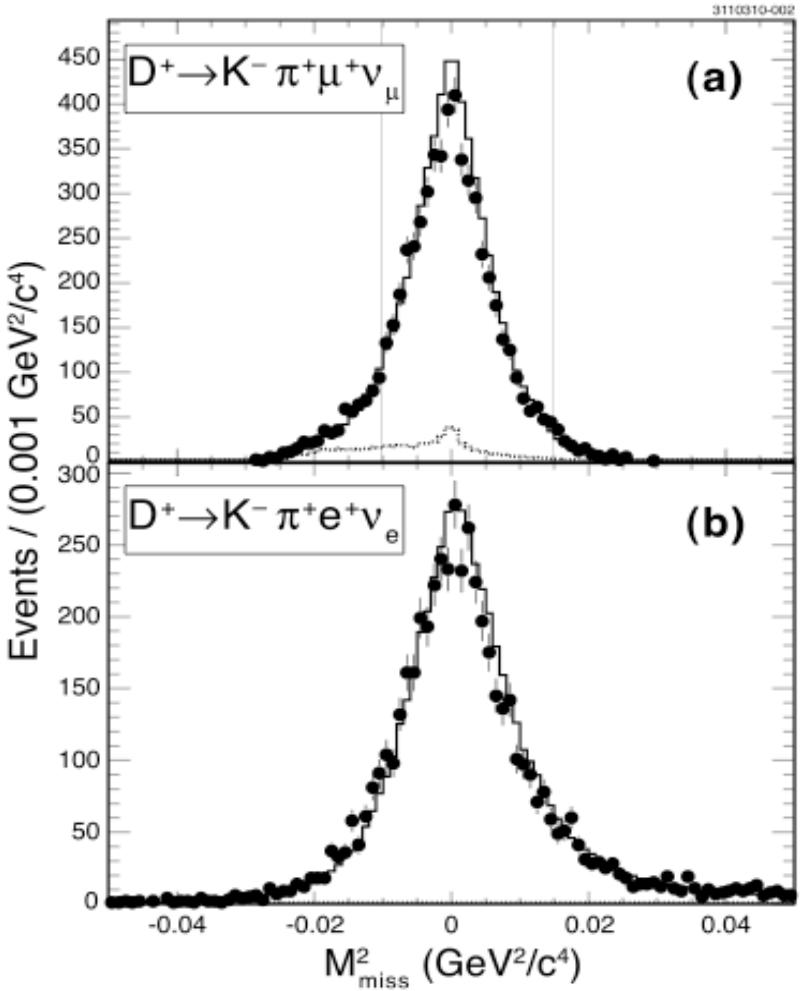
Tag signal-to-noise (log scale)



$\sqrt{s}$=3770 MeV: exclusive $e^+e^- \rightarrow$DD contd.

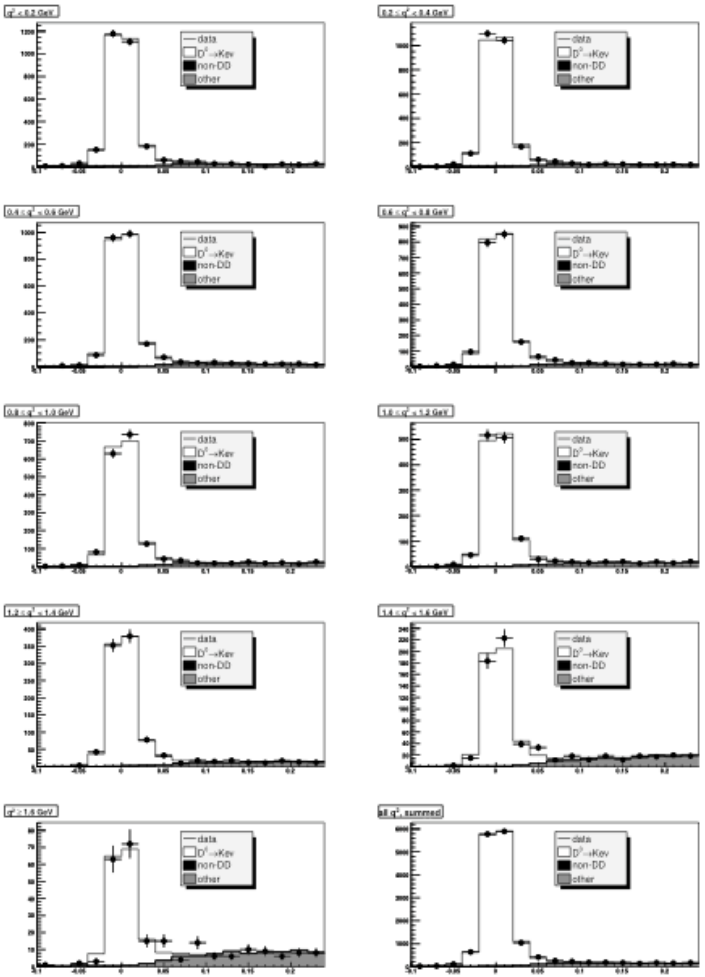
- 2 kinematic tag constraints (E_{beam}, M_D)
- $B=N_{sig}/(N_{tag}\varepsilon)$, luminosity info not used.
- Neutrino resolution characterized as either $U=E_{miss}-p_{miss}$ or $MM^2=E_{miss}^2-p_{miss}^2$

MM2 distribution. Solid dots: data
Solid line: MC, dashed line: background



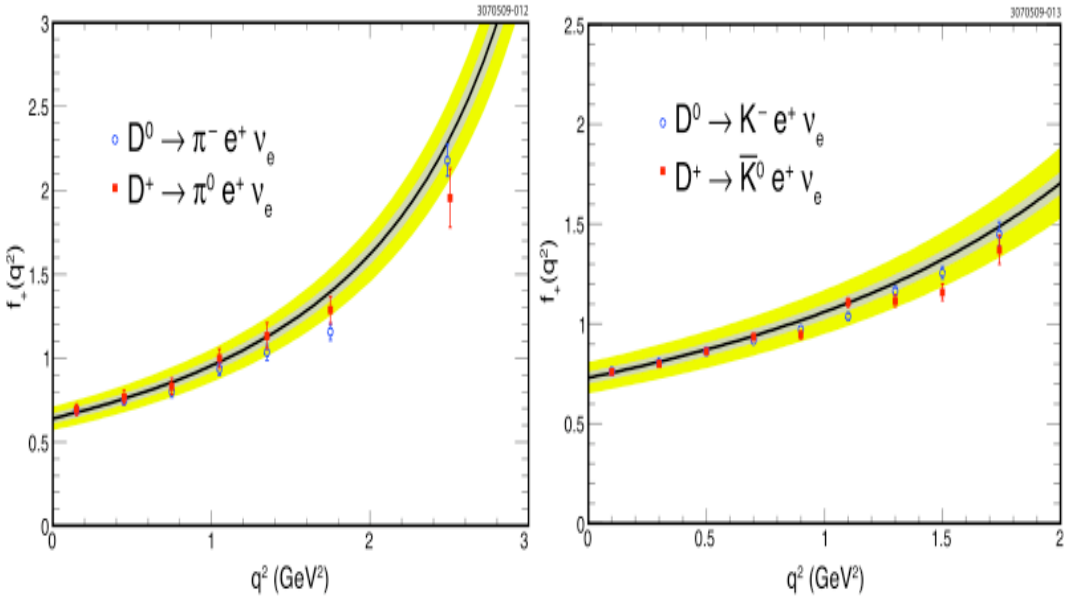
D→ (π,K)eυ, PRD 80: 32005, 2009

U signal from $D^0 \to K^- e\nu$ channel, 10 q^2 bins (points=DATA, histogram=MC)

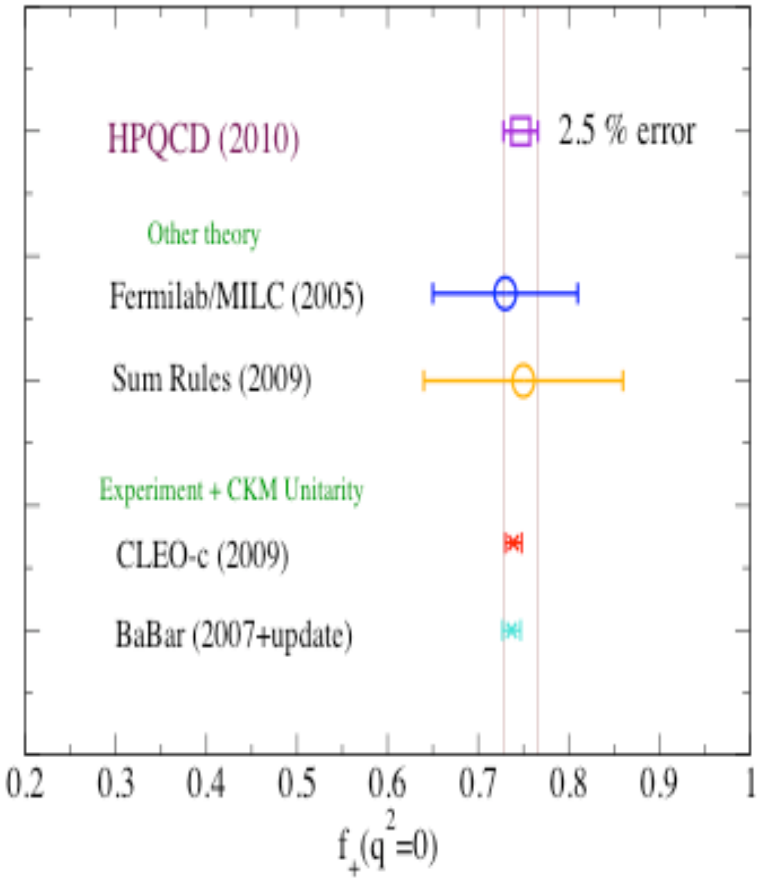


$$\frac{d\Gamma(D \to Pe\nu)}{dq^2} = X \frac{G_F^2 \left|V_{cd(s)}\right|^2}{24\pi^3} p^3 \left|f_+\left(q^2\right)\right|^2,$$

Form factor: CLEO data vs LQCD (yellow band)



D→ (π,K)eυ, comparison with high precision Lattice QCD (arXiv 1008.4562)



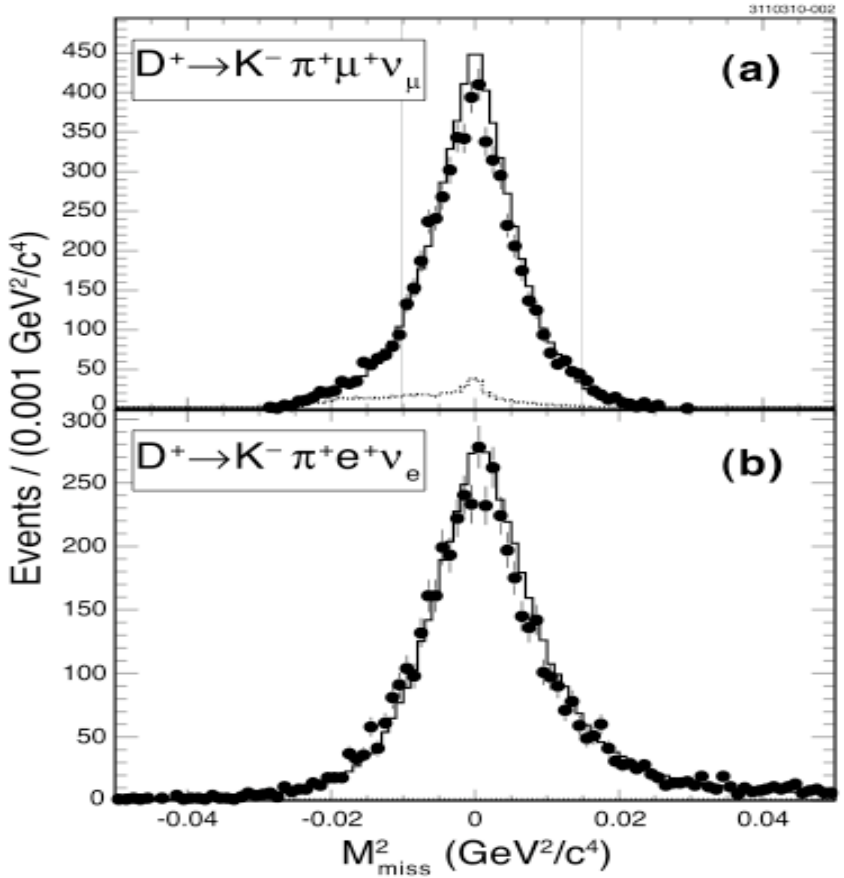
Extraction of CKM elements, assuming $f_+(q^2=0)=0.747\pm0.11\pm0.15$

$$|V_{cd}| = 0.234 \pm 0.007 \pm 0.002 \pm 0.025$$

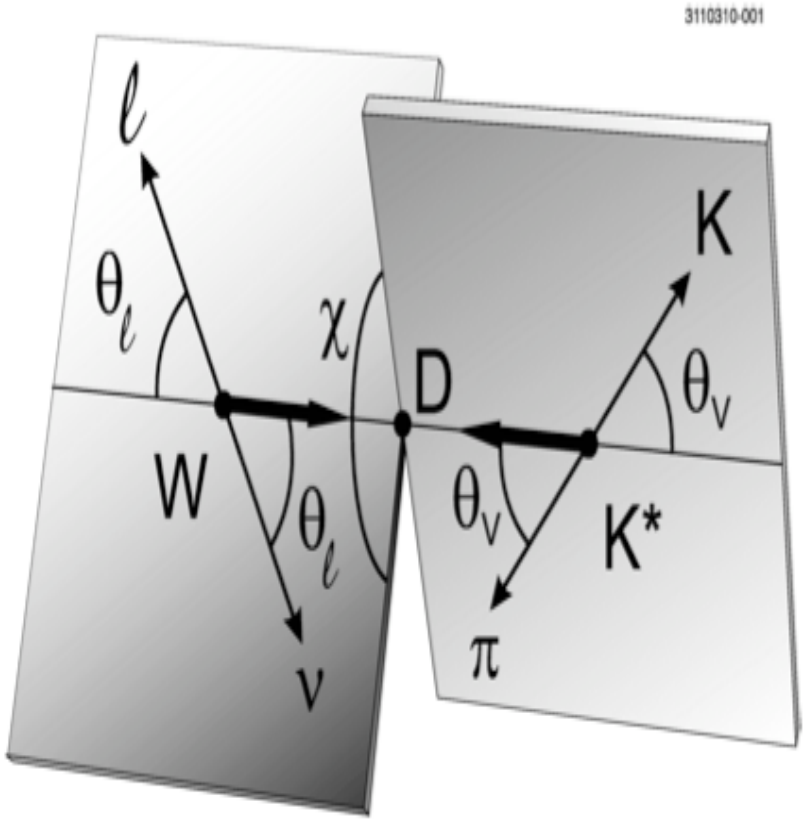
$$|V_{cs}| = 0.985 \pm 0.009 \pm 0.006 \pm 0.103,$$

$D^+ \to K\pi l\upsilon$ PRD 81: 112001, 2010

MM2 signal distribution



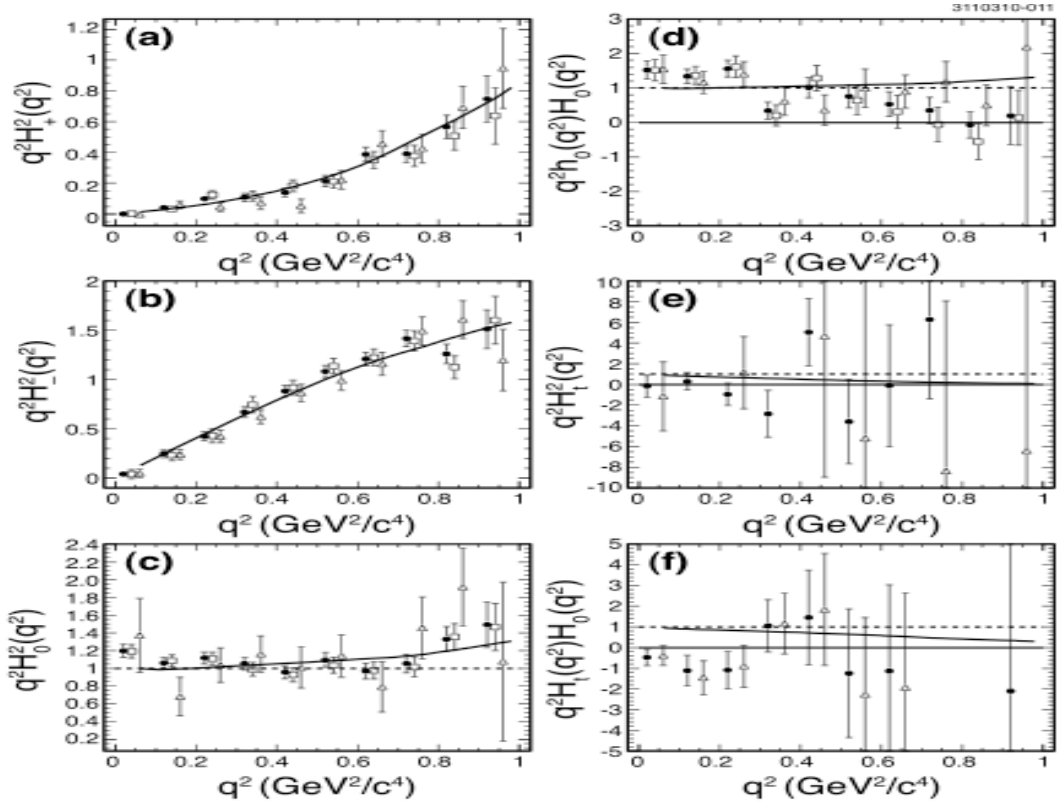
P→V transitions much more complex due to internal angular variables.



$D^+ \to K\pi l\upsilon$ contd.

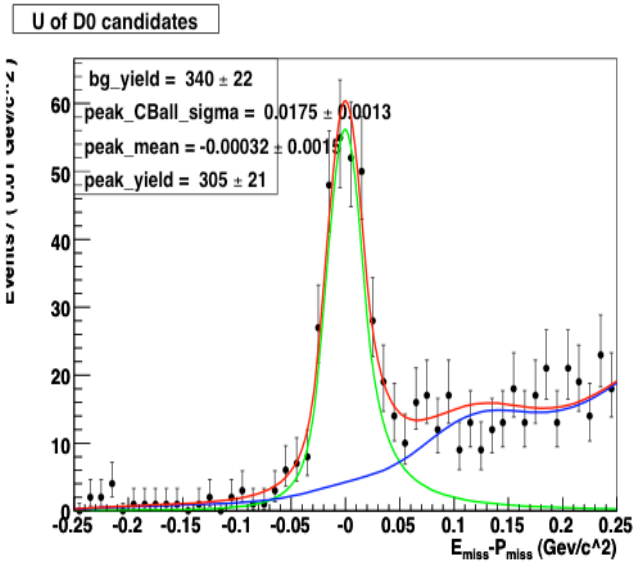
$$\int |\mathcal{A}|^2 d\chi = \frac{q^2 - m_\ell^2}{8} \left\{ \begin{array}{l} ((1+\cos\theta_\ell)\sin\theta_V)^2 |H_+(q^2)|^2 |\beta|^2 \\ +((1-\cos\theta_\ell)\sin\theta_V)^2 |H_-(q^2)|^2 |\beta|^2 \\ +(2\sin\theta_\ell\cos\theta_V)^2 |H_0(q^2)|^2 |\beta|^2 \\ +8\,\underline{\sin^2\theta_\ell \cos\theta_V H_0(q^2) h_0(q^2) \mathrm{Re}\{A e^{-i\delta}\beta\}} \end{array} \right\}$$

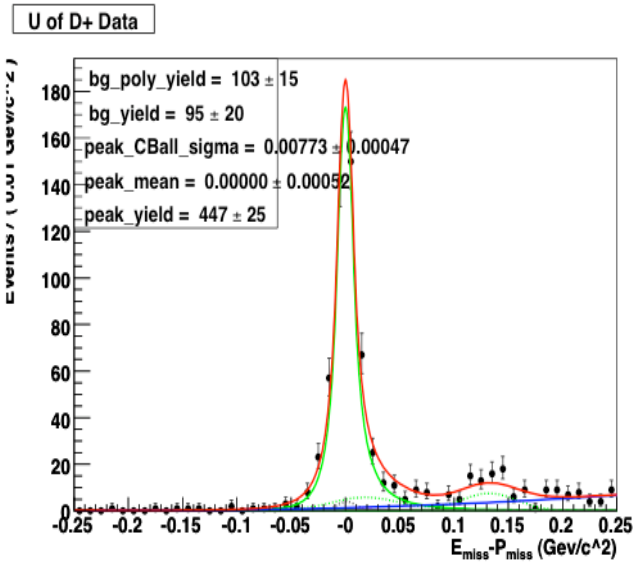
$$+ \frac{|\beta|^2}{8}(q^2 - m_\ell^2)\frac{m_\ell^2}{q^2} \left\{ \begin{array}{l} (\sin\theta_\ell \sin\theta_V)^2 |H_+(q^2)|^2 + (\sin\theta_\ell \sin\theta_V)^2 |H_-(q^2)|^2 \\ +(2\cos\theta_\ell\cos\theta_V)^2 |H_0(q^2)|^2 \\ +(2\cos\theta_V)^2 |H_t(q^2)|^2 + 8\cos\theta_\ell \cos^2\theta_V H_0(q^2) H_t(q^2) \end{array} \right\}$$



- B(D→K*0eυ)= (5.52±0.07± 0.13)%
- B(D→K*0μυ)=(5.27±0.07±0.14)%
- B_μ/B_e=(94.64±1.95±1.03) %
- $H_t(q^2)$ measurements inconsistent with LQCD models.
- No d- or f-wave evidence

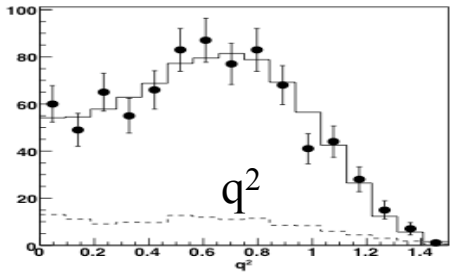
D→ρeυ, preliminary.

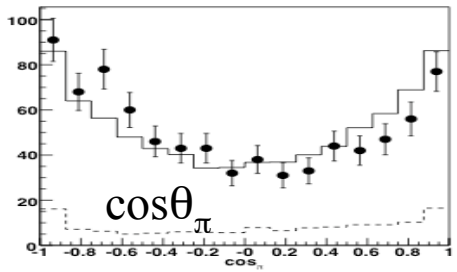


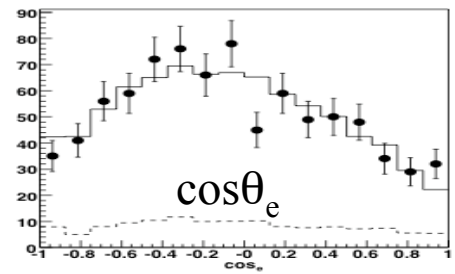


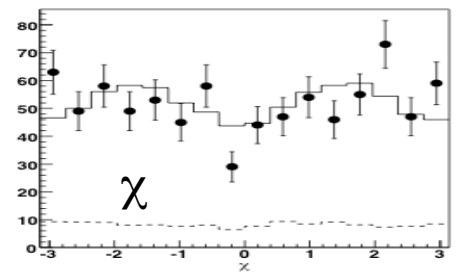
$$\frac{d\Gamma(B \to \rho l^+ \nu)/dq^2}{d\Gamma(B \to K^* l^+ l^-)/dq^2} \sim \frac{|V_{ub}|^2}{|V_{cb}|^2},$$

- $B(D^0 \to \rho e \upsilon) = (0.176 \pm 0.011 \pm 0.010)\%$
- $B(D^+ \to \rho e \upsilon) = (0.213 \pm 0.013 \pm 0.011)\%$
- $R_V = V(0)/A_0(0) = 1.48 \pm 0.15 \pm 0.03$
- $R_2 = A_2(0)/A_1(0) = 0.83 \pm 0.11 \pm 0.04$





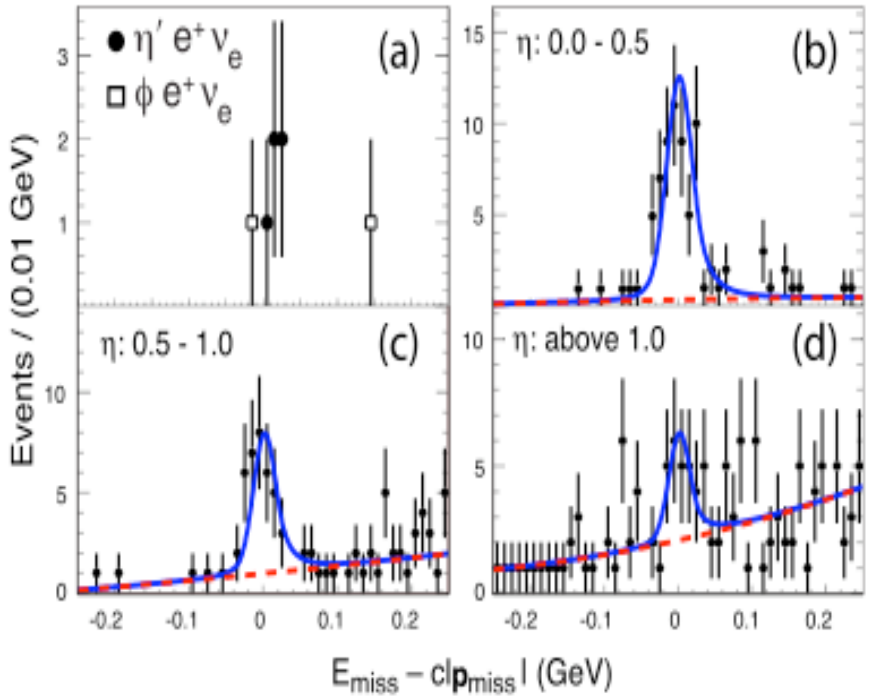




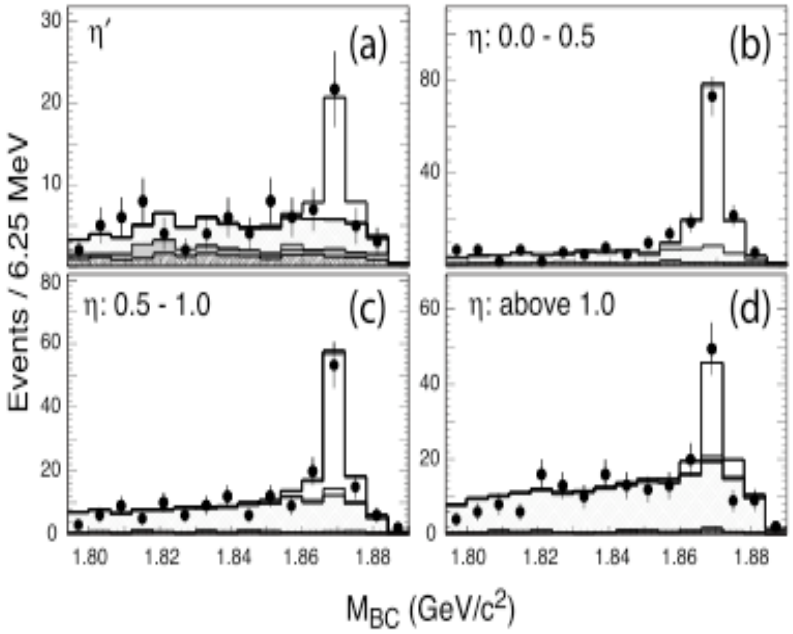
$D^+ \rightarrow (\eta, \eta', \phi) e \upsilon$, preliminary

$$\mathcal{B}(D^+ \to \eta e^+ \nu_e) = (11.4 \pm 0.9 \pm 0.4) \times 10^{-4},$$
$$\mathcal{B}(D^+ \to \eta' e^+ \nu_e) = (2.16 \pm 0.53 \pm 0.07) \times 10^{-4},$$
$$\mathcal{B}(D^+ \to \phi e^+ \nu_e) < 0.9 \times 10^{-4} \quad (90\%\ \text{C.L.})$$

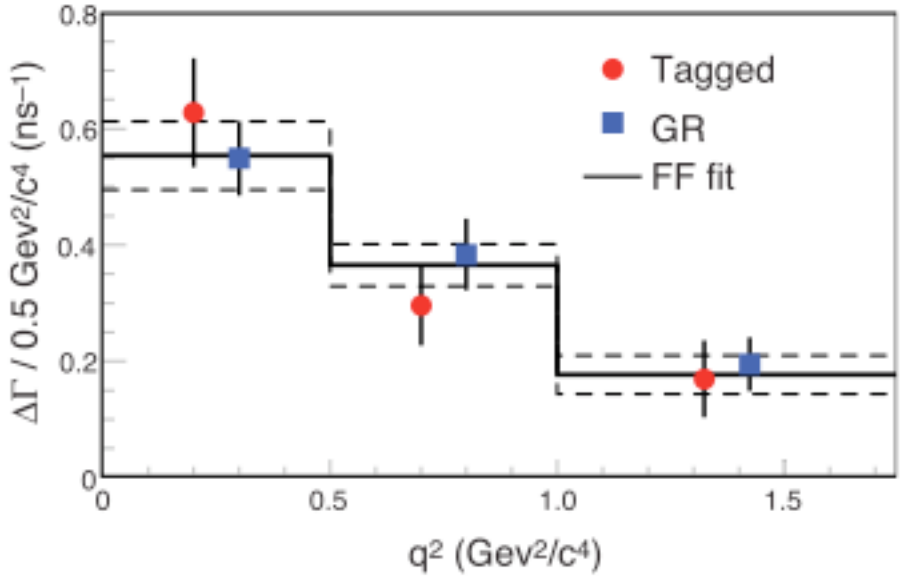
U distribution, Tagged analysis



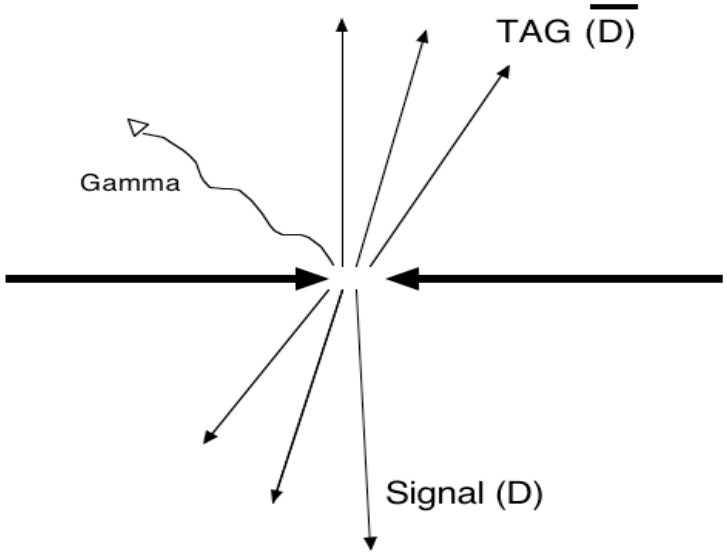
M_{BC}, General Reconstruction analysis



$D^+ \rightarrow \eta e \upsilon$ q^2 distribution, preliminary



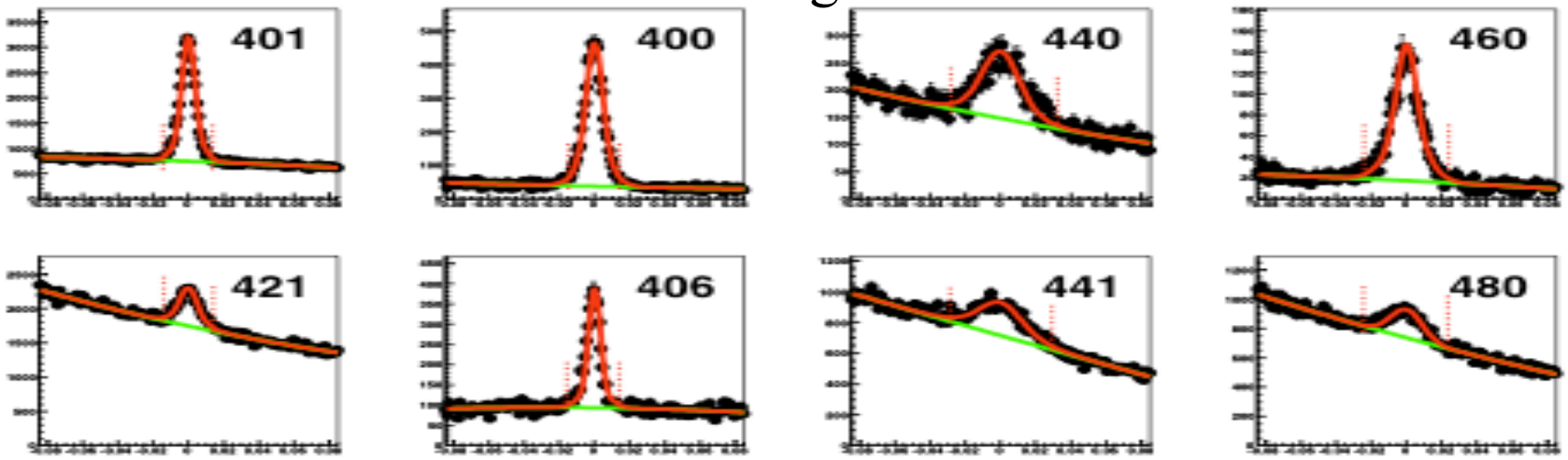
$\sqrt{s}$=4170 MeV: exclusive $e^+e^- \rightarrow D_s D_s \gamma$, 586 pb^{-1}



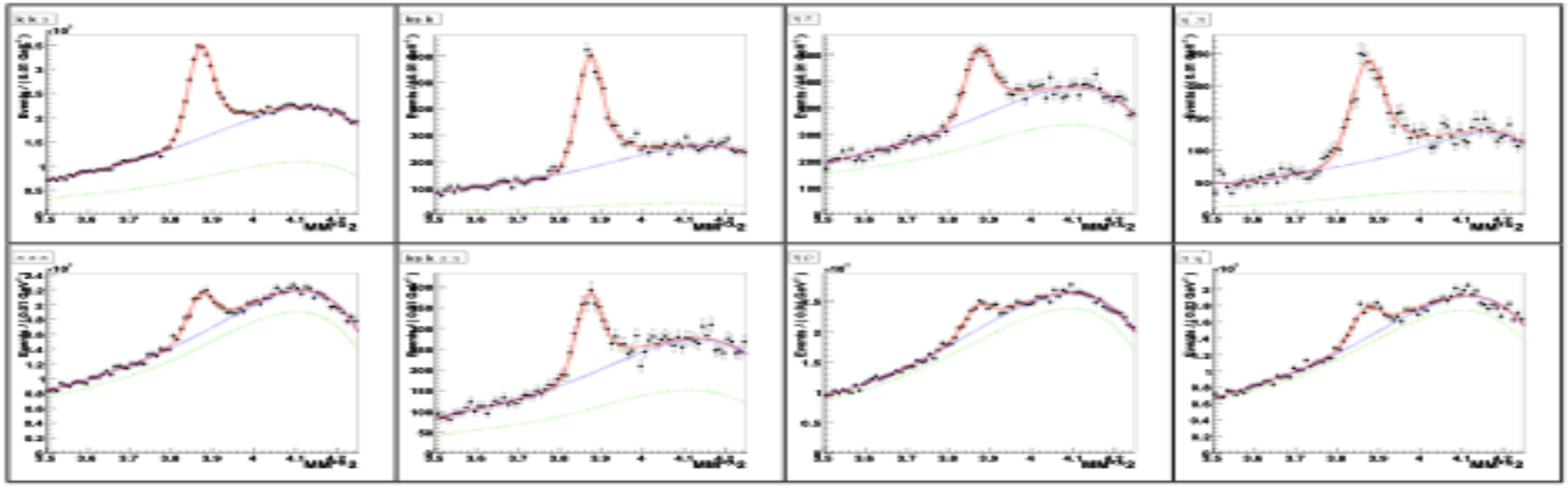
- $6X10^5$ events, $8X10^4$ D_s tags, $4.5X10^4$ $(D_s\gamma)$ tags
- Maximal D_s cross section dominated (95%) by excl. reaction $e^+e^- \rightarrow D_s D_s^*$
- $B(D_s^* \rightarrow D_s\gamma)$=95%
- 2 kinematic tag constraints, M_{Ds} and recoil $(D_s\gamma)$ mass
- More backgrounds due to D production, more neutral decays and annihilation tags (e.g., $D_s \rightarrow 3\pi$, $D_s \rightarrow \eta\rho$)

$\sqrt{s}$=4170 MeV: exclusive $e^+e^- \to D_s D_s \gamma$, contd.

Tag mass

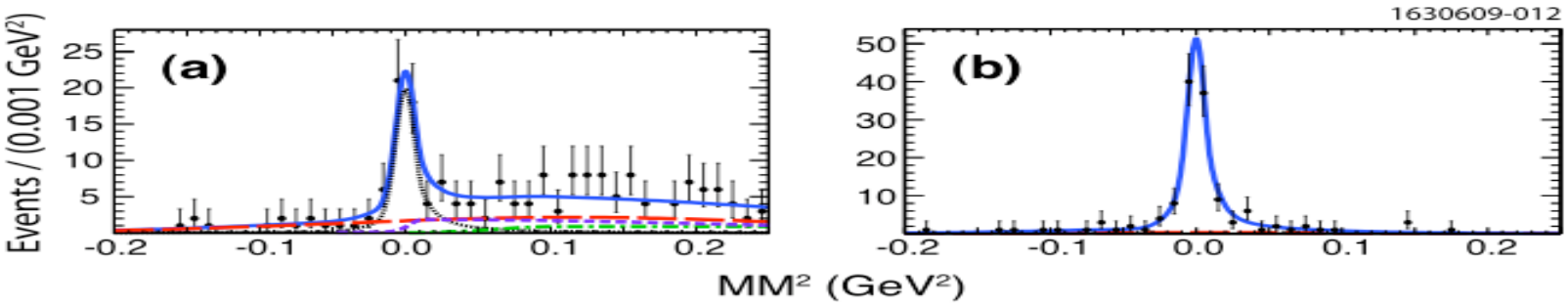


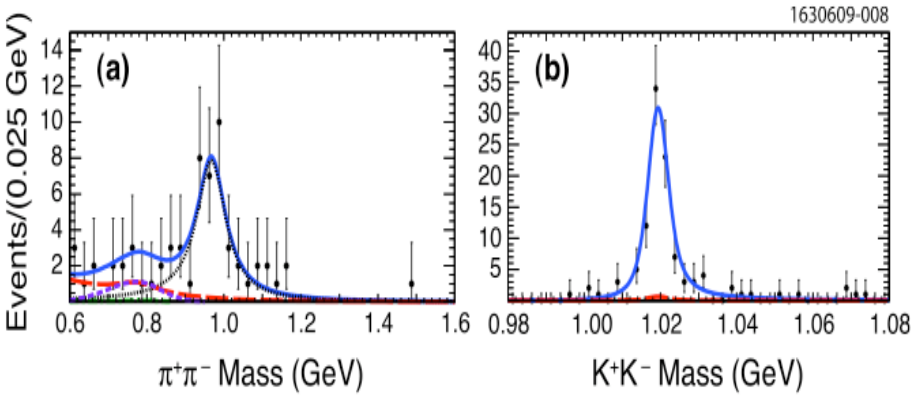
Recoil Mass

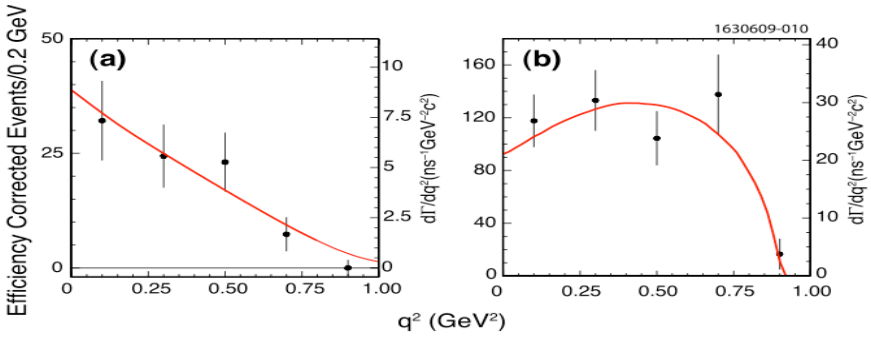


$D_s \to f_0 e\upsilon$, PRD 80: 52009, 2009

Simultaneous analysis for ($\pi^+\pi^- e\upsilon$) (a) and ($K^+K^- e\upsilon$) (b)



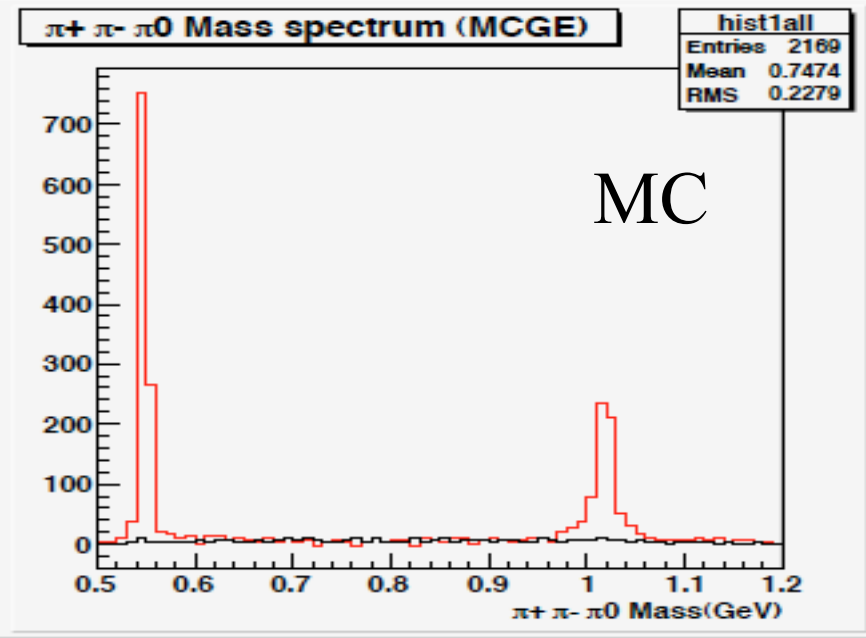


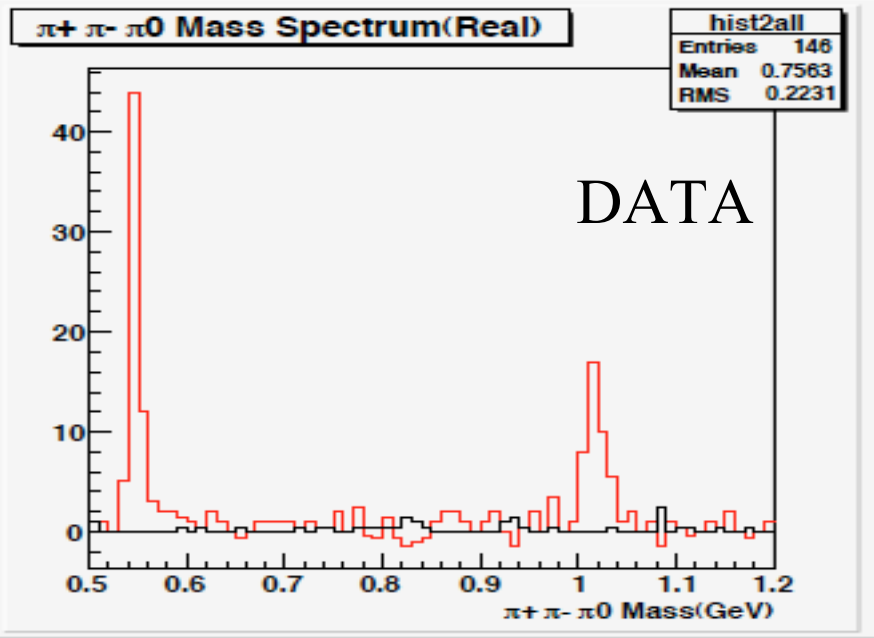


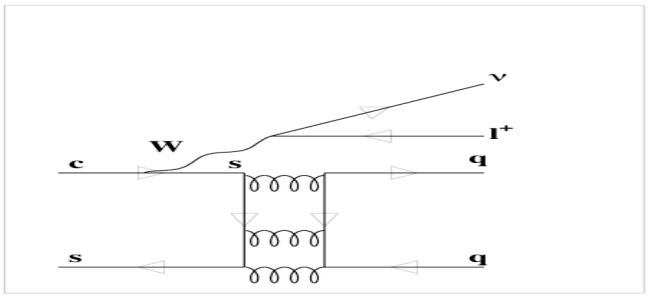
Interest: B_s physics input.
Golden $B_s \to \psi\phi$ is
not a CP-eigenstate, while
$B_s \to \psi f_0$ is. Measurement shows exp.
Sizeable rate.

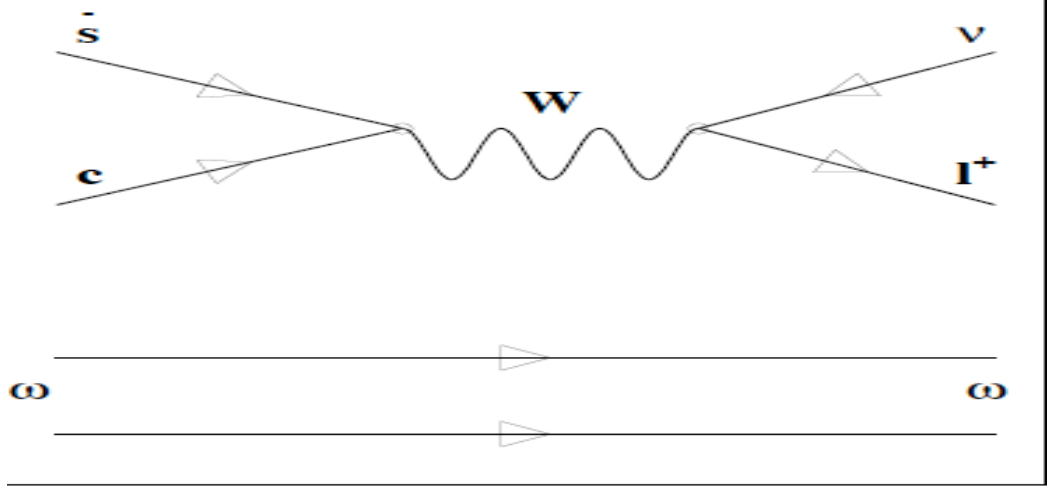
$M(f_0)=(977\pm10\pm1)$ MeV
$\Gamma(f_0)=(91\pm10\pm3)$ MeV
$B(D_s \to f_0 e\upsilon)= (0.20\pm0.03\pm0.01)\%$

$D_s \rightarrow \omega e \upsilon$,prelim. (B<0.23% 95% C.L.)

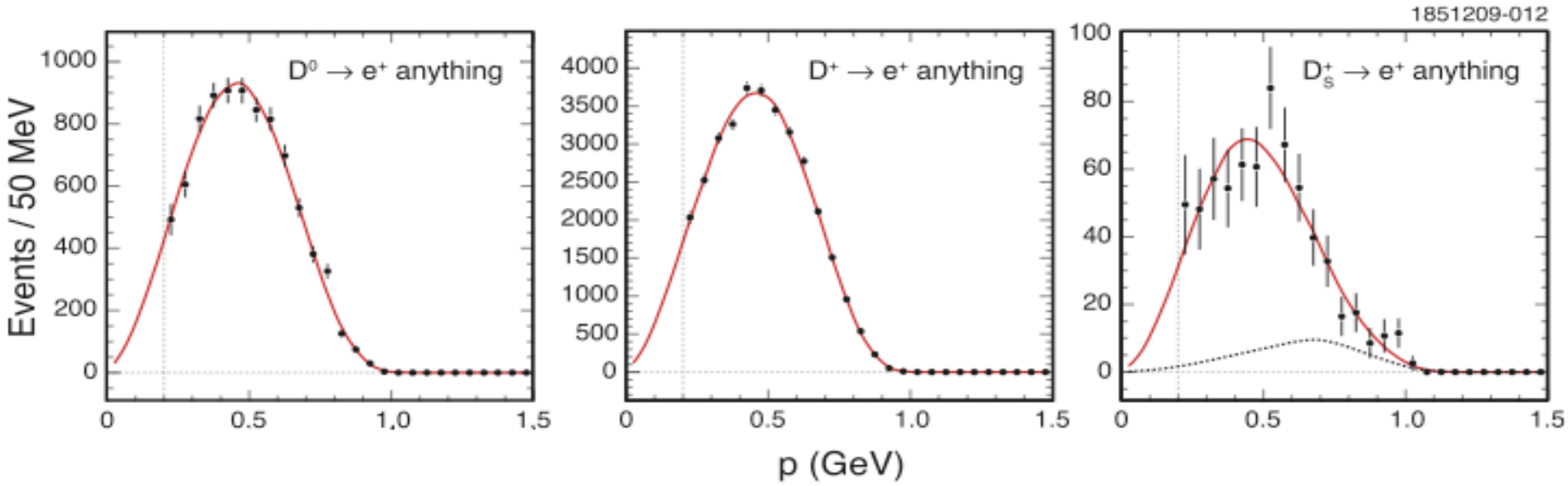








Inclusive semileptonic D^+, D^0, D_s, PRD 81: 112001, 2010



$$\mathcal{B}(D^0 \to Xe^+\nu_e) = (6.46 \pm 0.09 \pm 0.11)\%,$$
$$\mathcal{B}(D^+ \to Xe^+\nu_e) = (16.13 \pm 0.10 \pm 0.29)\%,$$
$$\frac{\Gamma(D^+ \to Xe^+\nu_e)}{\Gamma(D^0 \to Xe^+\nu_e)} = 0.985 \pm 0.015 \pm 0.024$$

$$\mathcal{B}(D_s^+ \to Xe^+\nu_e) = (6.52 \pm 0.39 \pm 0.15)\%,$$
$$\frac{\Gamma(D_s^+ \to Xe^+\nu_e)}{\Gamma(D^0 \to Xe^+\nu_e)} = 0.828 \pm 0.051 \pm 0.025.$$

Summary

- Numerous precision and new measurements of charmed meson decays, due to excellent neutral and electron detection and exclusive reactions
- High quality (2.5%) comparisons with High Precision Lattice QCD
- High quality form factor, and CKM matrix elements, measurements, for $D^+ \to (K, K^*, \pi, \rho) e \upsilon$.
- First observation of $D^+ \to \eta' e \upsilon$ and $D_s \to f_0 e \upsilon$
- First measurement of form factor for $D^+ \to \eta e \upsilon$