Semileptonic Physics: Summary

by Will JOHNS (Vanderbilt University)

Review of the CLEO-c semileptonic results
by Giovanni BONVICINI (Wayne State University)

Studies of exclusive semileptonic B decays and extraction of |V_{ub}| at BaBar
by Paul TARAS (Universite de Montreal)

D, Ds Leptonic decays and form factors
by Marko STARIC (J. Stefan Institute, Ljubljana, Slovenia)

Studies of semileptonic decays with the LHCb detector
by Rob LAMBERT (CERN)

Finally! I'm glad somebody did it!

- I've have been using $\frac{\Gamma(D^+ \to (K^-\pi^+)\mu^+\nu)}{\Gamma(D^+ \to (K^-\pi^+)e^+\nu)} = 0.952$

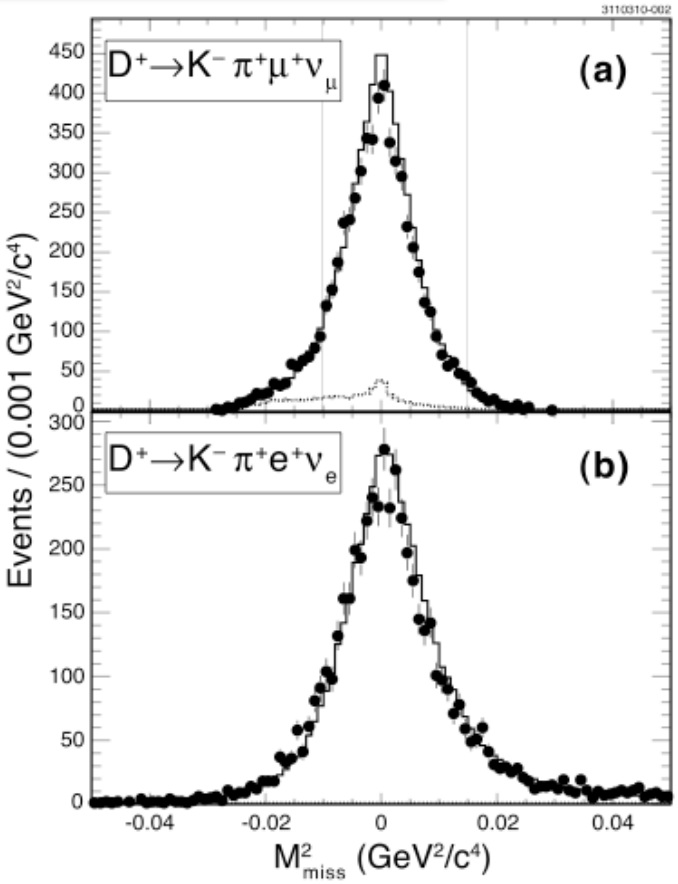
And CLEO (PRD 81: 112001, 2010) measures

  - $B\mu/Be = (94.64 \pm 1.95 \pm 1.03)\ \%$

- & heard this mode is tough to do in LQCD (loops+++?)

And CLEO finds Form Factors w/$H_t(q^2)$ inconsistent w/LQCD

- & find no evidence of *f* or *d* Wave in $M(K^-\pi^+)$



This is exciting to me since

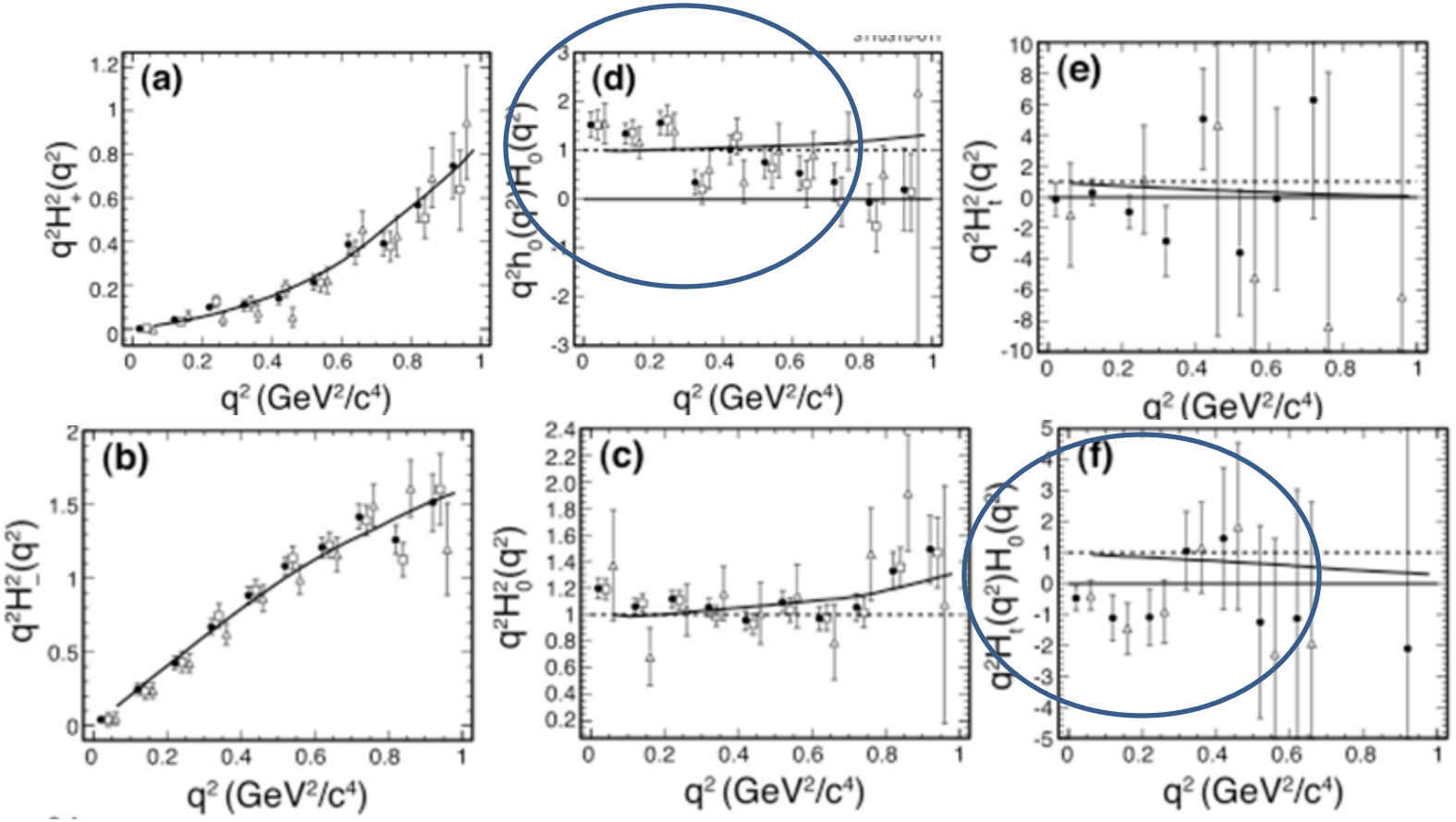
- The H_t form factors less suppressed at lower q^2

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

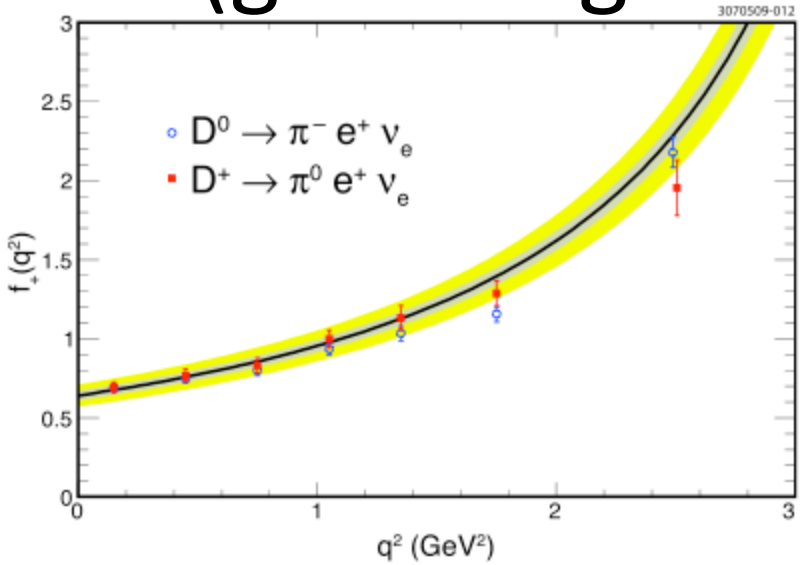
$$+ \frac{|\beta|^2}{8}(q^2 - m_\ell^2)\frac{m_\ell^2}{q^2} \left\{ \begin{array}{l} (\sin\theta_\ell\sin\theta_V)^2 |H_+(q^2)|^2 + (\sin\theta_\ell\sin\theta_V)^2 |H_-(q^2)|^2 \\ +(2\cos\theta_\ell\cos\theta_V)^2 |H_0(q^2)|^2 \\ +(2\cos\theta_V)^2 |H_t(q^2)|^2 + 8\cos\theta_\ell\cos^2\theta_V H_0(q^2)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

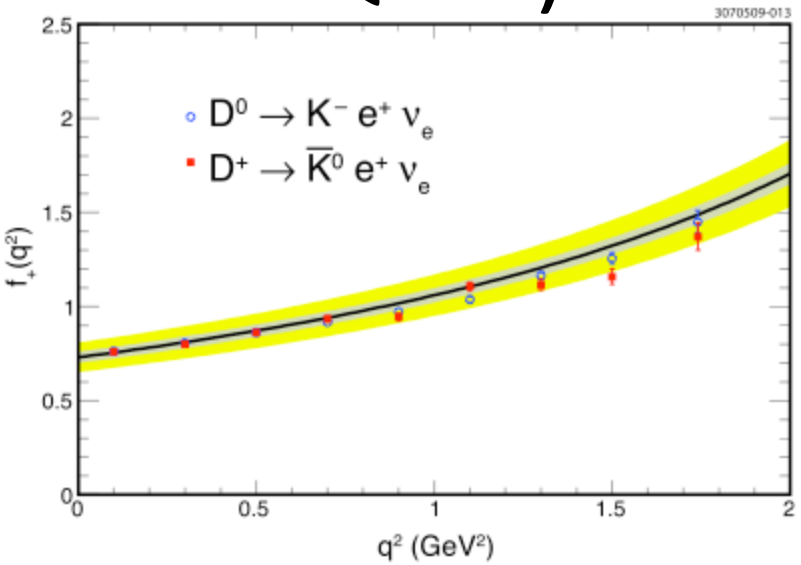
B(D→K*^{0}eυ)= (5.52±0.07± 0.13)%
B(D→K*^{0}μυ)=(5.27±0.07±0.14)%

And there's something interesting going on near low q^2



D→ (π,K)eυ, PRD 80: 32005, 2009 (get along well with LQCD!)





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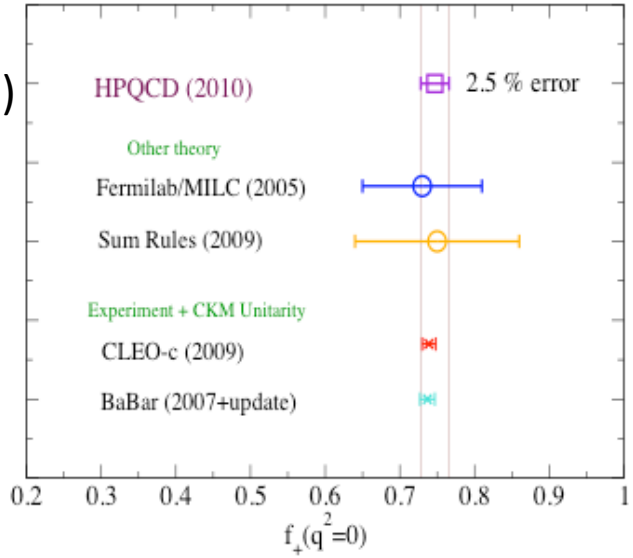
(arXiv 1008.4562)



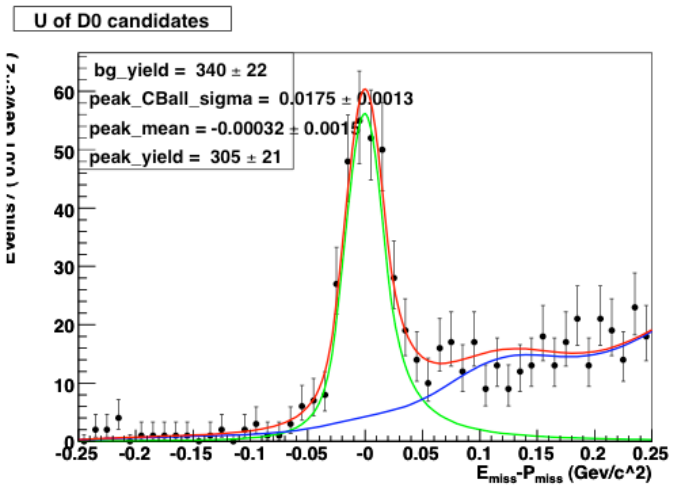
Extraction of CKM elements, assuming f+(q2=0)=0.747±0.11±0.15

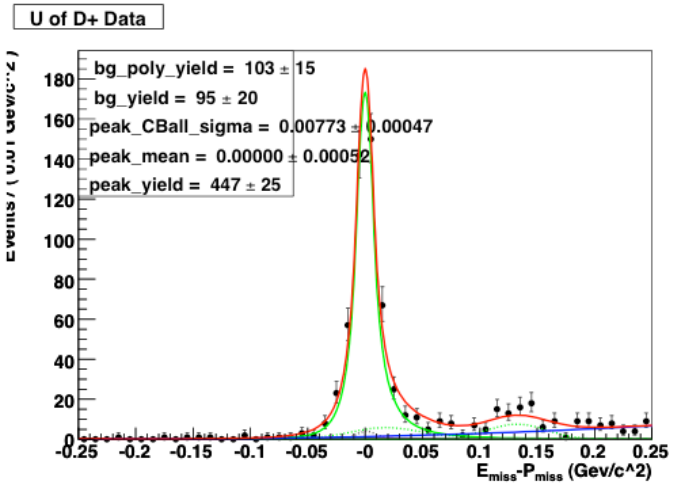
$$|V_{cd}| = 0.234 \pm 0.007 \pm 0.002 \pm 0.025$$

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

Several Previews as well

- D→ρeυ, preliminary (This is super clean to me!)



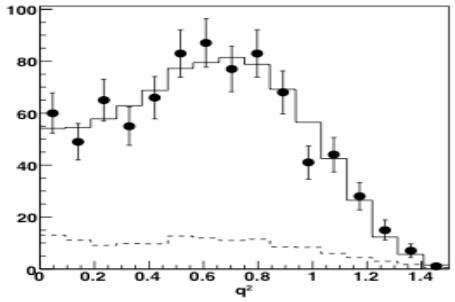


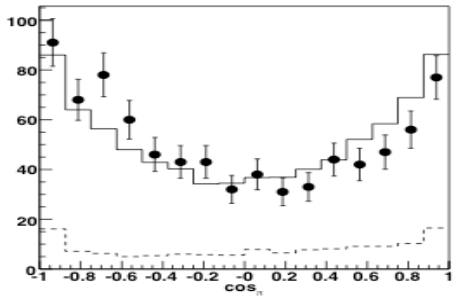
$B(D^0 \to \rho e \upsilon) = (0.176 \pm 0.011 \pm 0.010)\%$

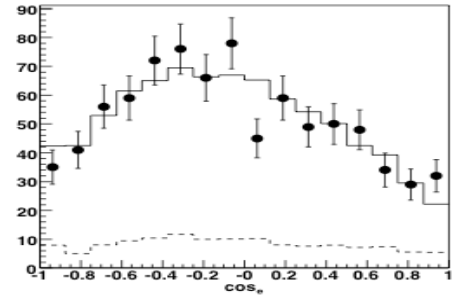
$B(D^+ \to \rho e \upsilon) = (0.213 \pm 0.013 \pm 0.011)\%$

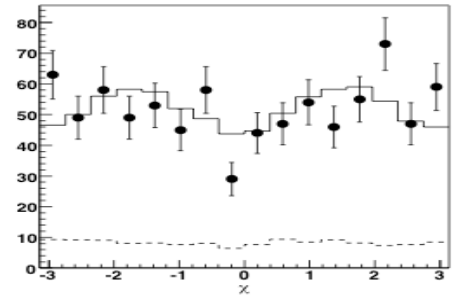
$RV = V(0)/A0(0) = 1.48 \pm 0.15 \pm 0.03$

$R2 = A2(0)/A1(0) = 0.83 \pm 0.11 \pm 0.04$







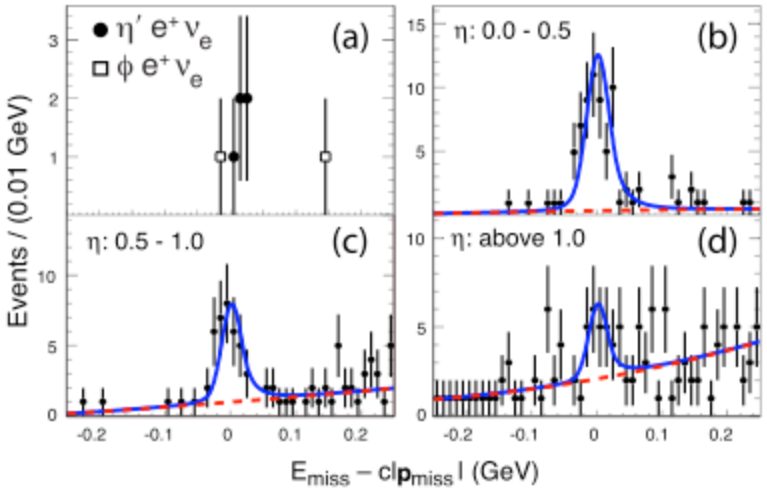


Previews continued

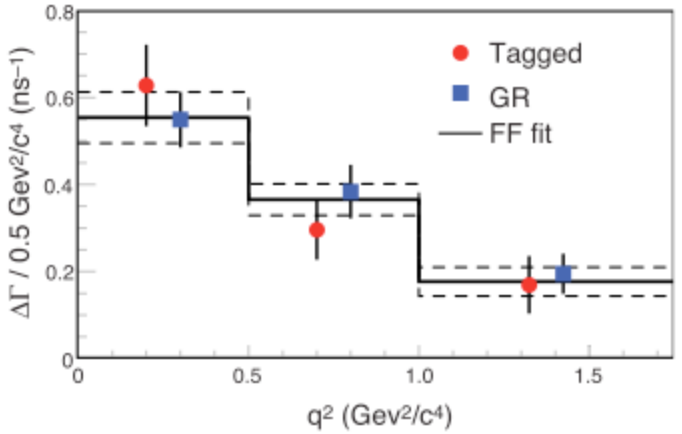
- $D^+ \rightarrow (\eta, \eta', \phi) e \upsilon$, preliminary

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

U distribution, tagged analysis

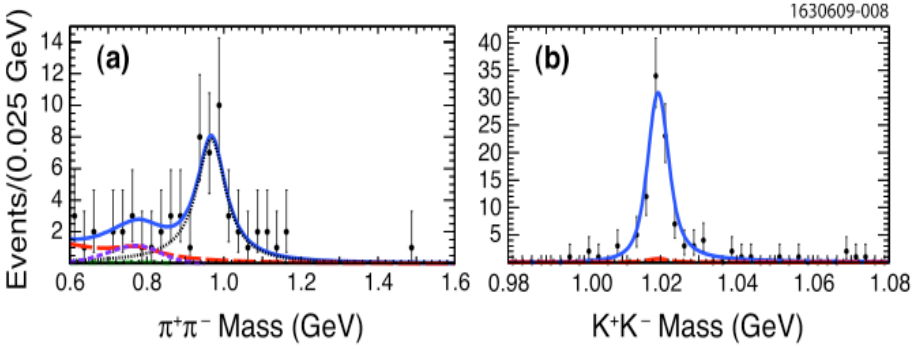


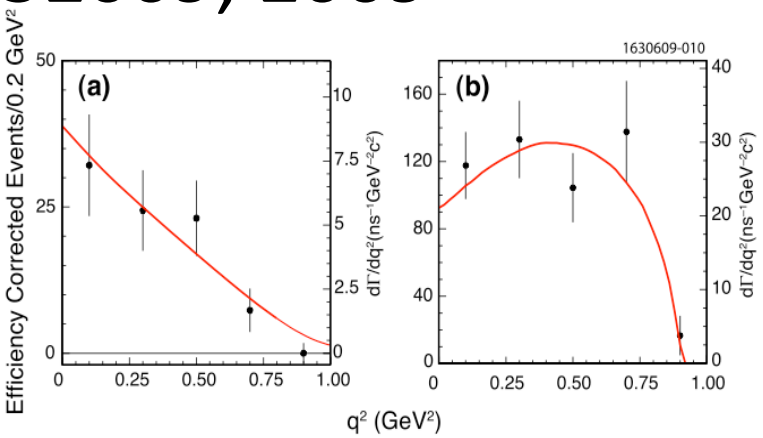
$D^+ \rightarrow \eta e \upsilon$ q2 distribution, preliminary



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

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



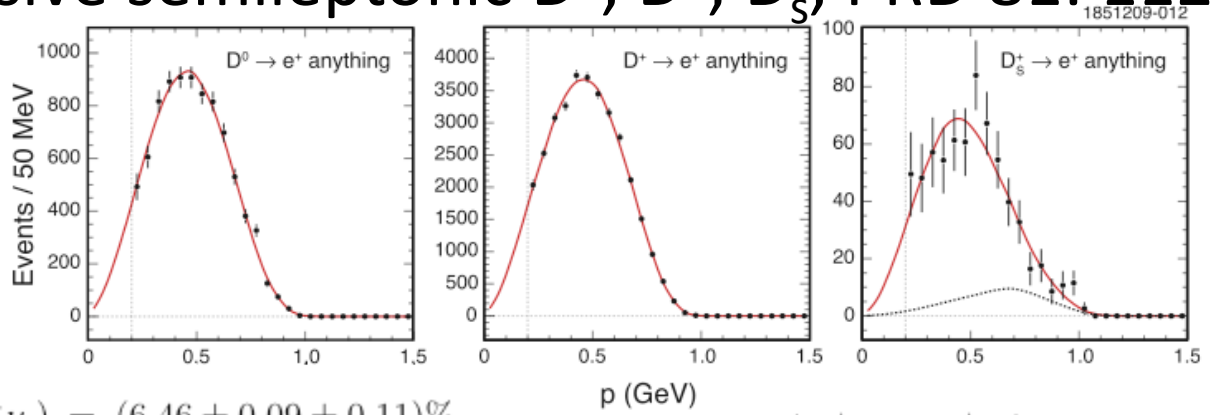


$M(f_0)=(977\pm10\pm1)$ MeV

$\Gamma(f_0)=(91\pm10\pm3)$ MeV (Sizeable Rate has implications for B_s decays)

$B(D_s \to f_0 e\upsilon)= (0.20\pm0.03\pm0.01)\%$

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



$$\mathcal{B}(D^0 \to Xe^+\nu_e) = (6.46 \pm 0.09 \pm 0.11)\%,$$
$$\mathcal{B}(D^+ \to Xe^+\nu_e) = (16.13 \pm 0.10 \pm 0.29)\%,$$
$$\mathcal{B}(D_s^+ \to Xe^+\nu_e) = (6.52 \pm 0.39 \pm 0.15)\%,$$

$$\frac{\Gamma(D^+ \to Xe^+\nu_e)}{\Gamma(D^0 \to Xe^+\nu_e)} = 0.985 \pm 0.015 \pm 0.024$$
$$\frac{\Gamma(D_s^+ \to Xe^+\nu_e)}{\Gamma(D^0 \to Xe^+\nu_e)} = 0.828 \pm 0.051 \pm 0.025.$$

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Studies of exclusive semileptonic *B decays and extraction of $|V_{ub}|$ at BaBar*

- Measure $|V_{ub}|$ with 2 different analyses:

- In the π-η analysis, study 3 decay modes and measure $q^2 = (P_B - P_{meson})^2$

$$B^0 \to \pi^- \ell^+ \nu \qquad B^+ \to \eta \ell^+ \nu \qquad B^+ \to \eta' \ell^+ \nu$$

- In the π-ρ analysis, study 4 decay modes and measure $q^2 = (P_\ell + P_\nu)^2$

$$B^0 \to \pi^- \ell^+ \nu \quad B^+ \to \pi^0 \ell^+ \nu \quad B^0 \to \rho^- \ell^+ \nu \quad B^+ \to \rho^0 \ell^+ \nu$$

- Motivation

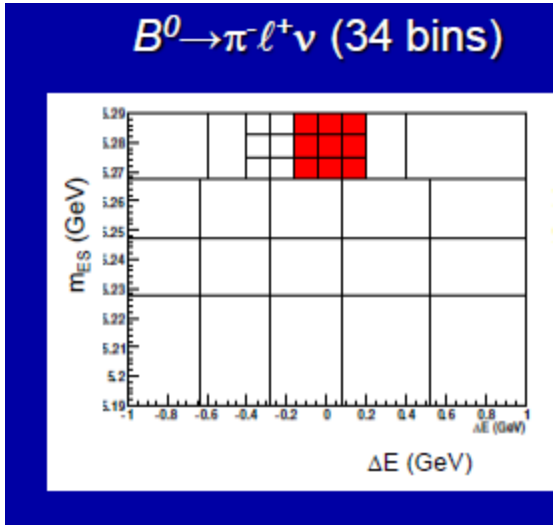
$|V_{ub}|$ results presented at FPCP2010 (Bob Kowaleski)

$B \to \pi \ell \nu : (2.95 \pm 0.31) \times 10^{-3}$ (exclusive)

$B \to u \ell \nu : (4.27 \pm 0.38) \times 10^{-3}$ (inclusive)

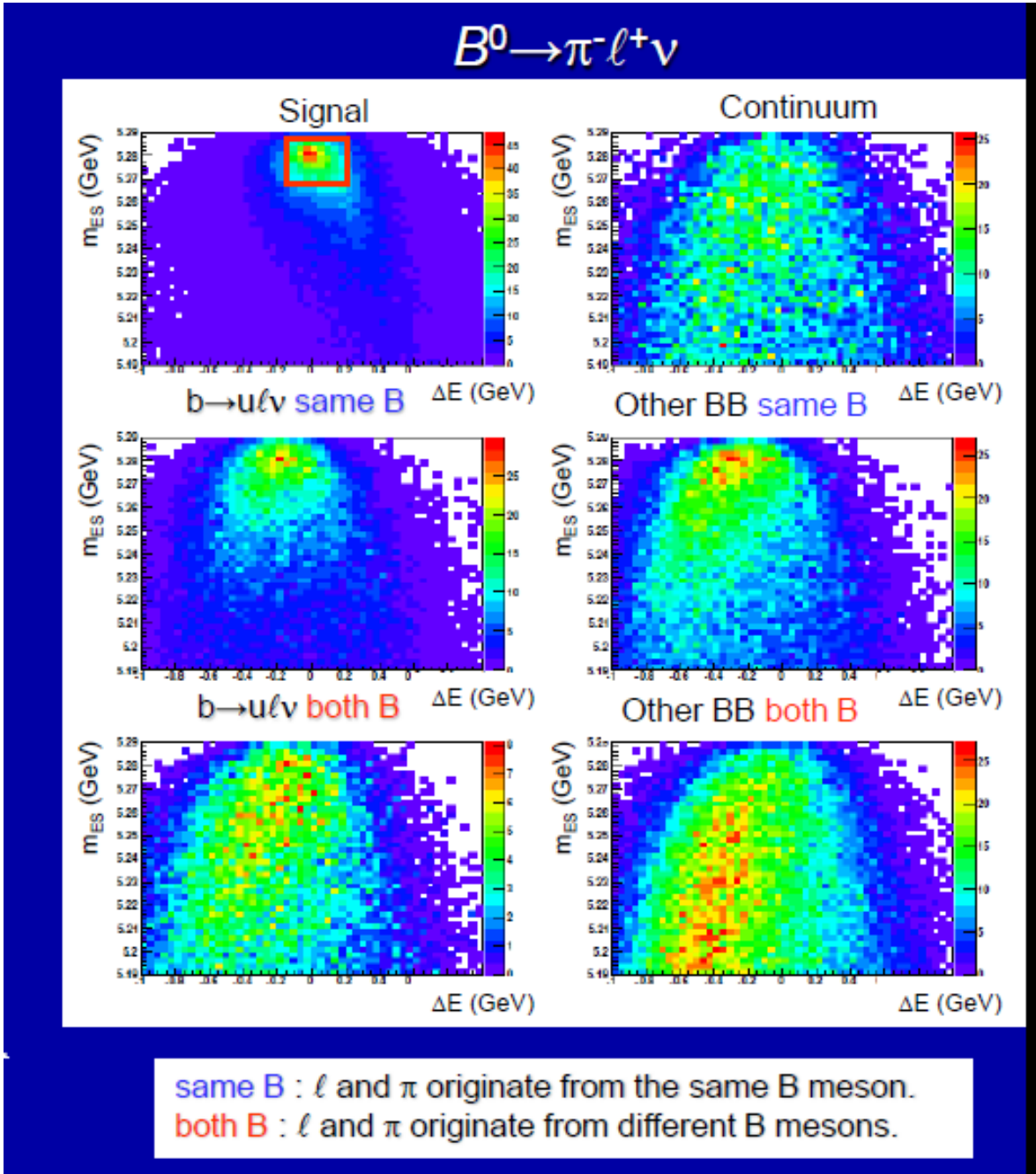
Should we take this difference of 2.7 σ seriously?

Use 2 dimension MC for contributions/shapes (no need for Bkgnd fctns)



Fit distributions, but split in bins of q^2.

Use yield estimates in bins of q^2 and compare form factors!



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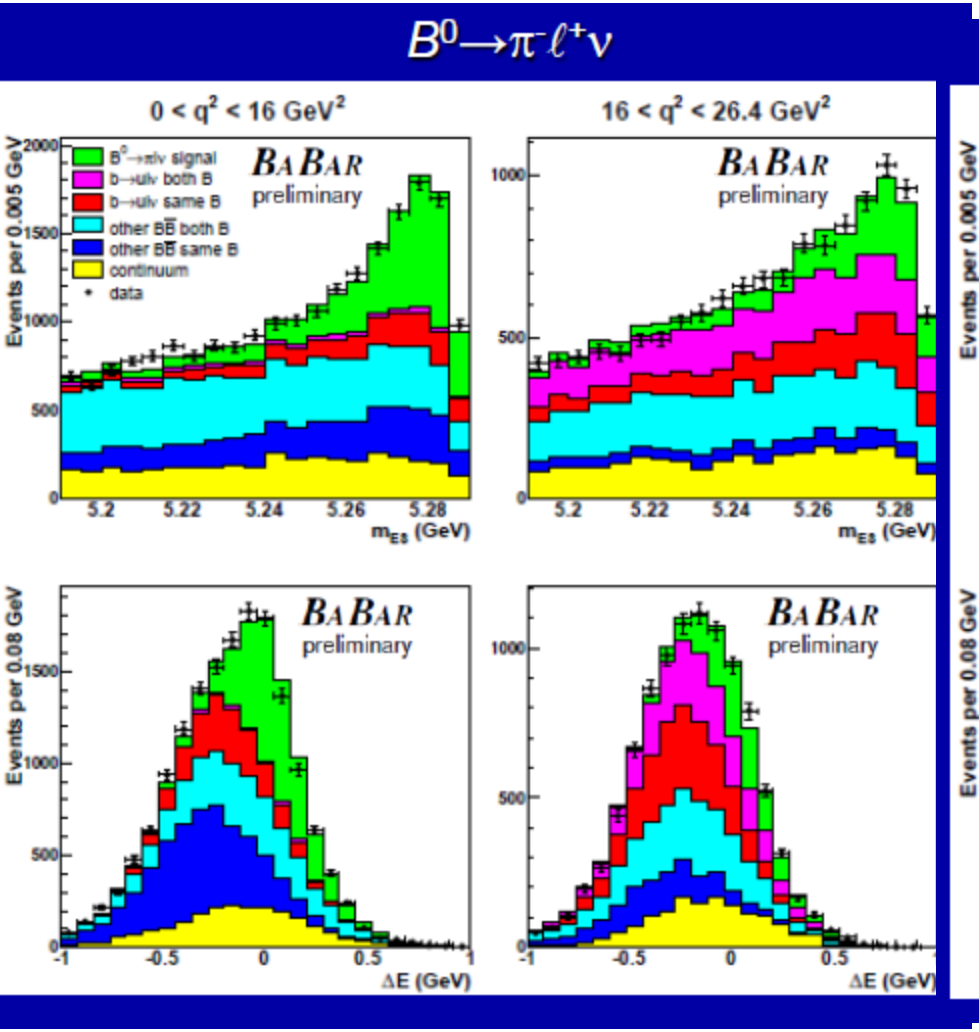
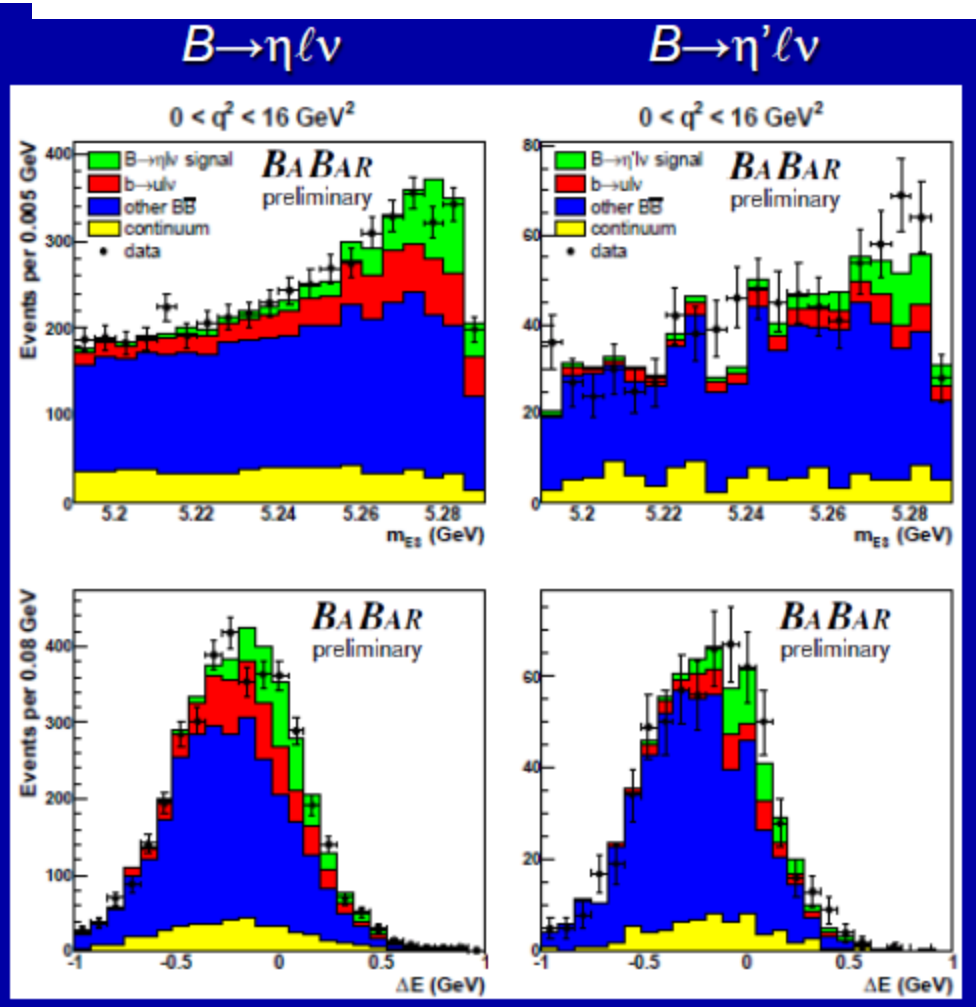
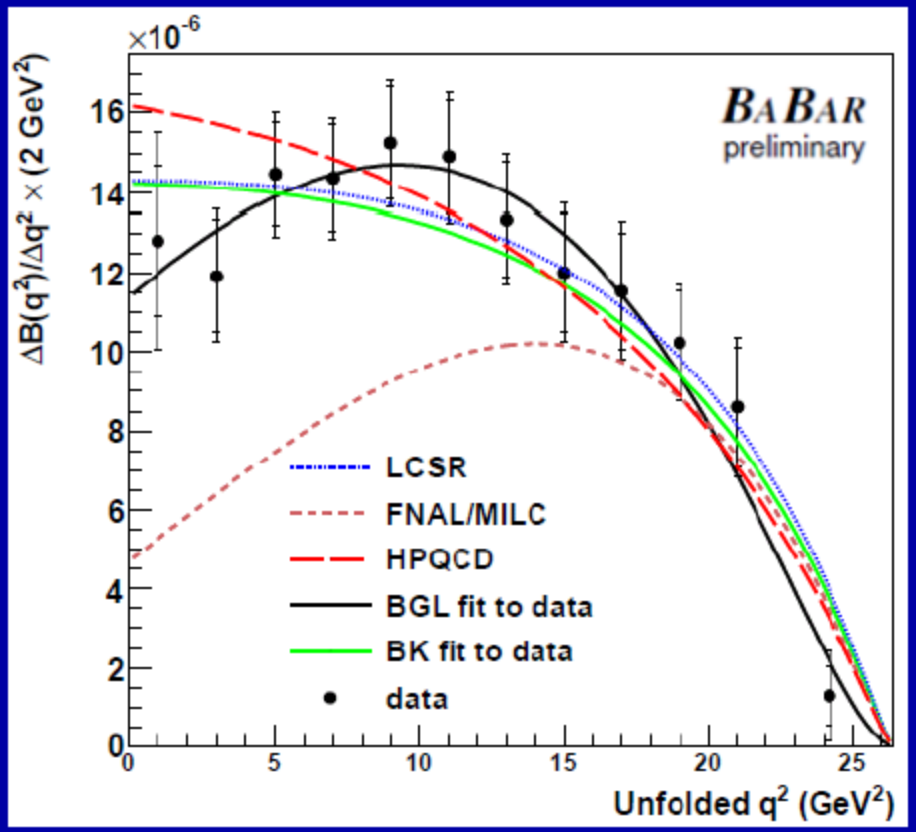
Projections of fit as a check





The end product!

$B^0 \to \pi^- \ell^+ \nu$



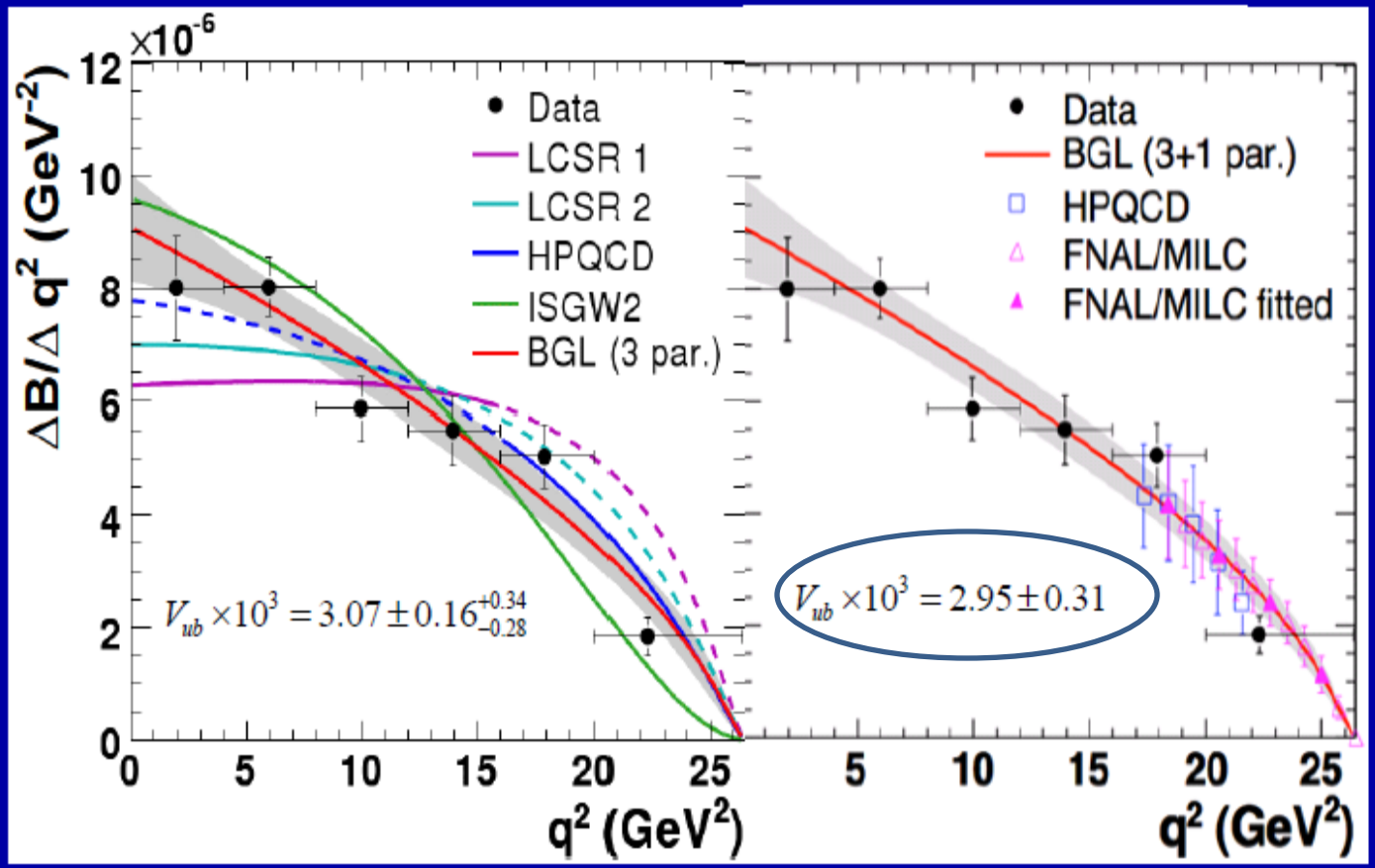
Function Ref.	Fit Parameter	$\pi^- \ell^+ \nu$ value	χ^2/ndf	Prob.
BK	α_{BK}	0.51 ± 0.04	10.5/10	39.6%
BGL	a_1/a_0	-1.58 ± 0.13	19.3/10	3.7%
BGL	a_1/a_0	-0.64 ± 0.30	3.8/9	92.2%
	a_2/a_0	-6.8 ± 1.8		

QCD calculations agree with data in their ranges of validity

arXiv:1010.0987, submitted to Phys. Rev. D

Charged and neutral agree, so…

Fit to expt data only



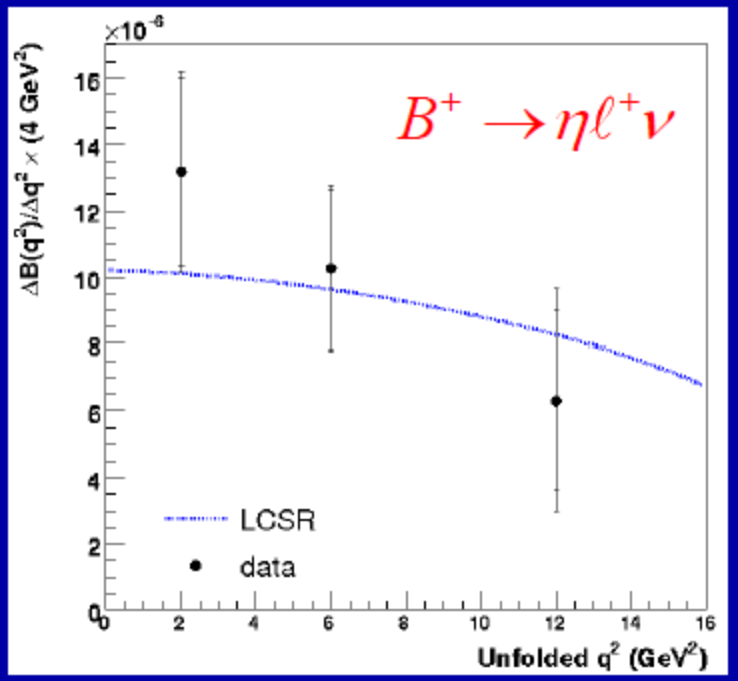
Fit to expt data & theor values

Parametrization	χ^2/ndf	Prob(χ^2/ndf)	Fit parameters
BK	6.8/4	0.148	$\alpha_{BK} = +0.310 \pm 0.085$
BGL (2 par.)	6.6/4	0.156	$a_1/a_0 = -0.94 \pm 0.20$
BGL (3 par.)	6.3/3	0.100	$a_1/a_0 = -0.82 \pm 0.29$
			$a_2/a_0 = -1.14 \pm 1.81$

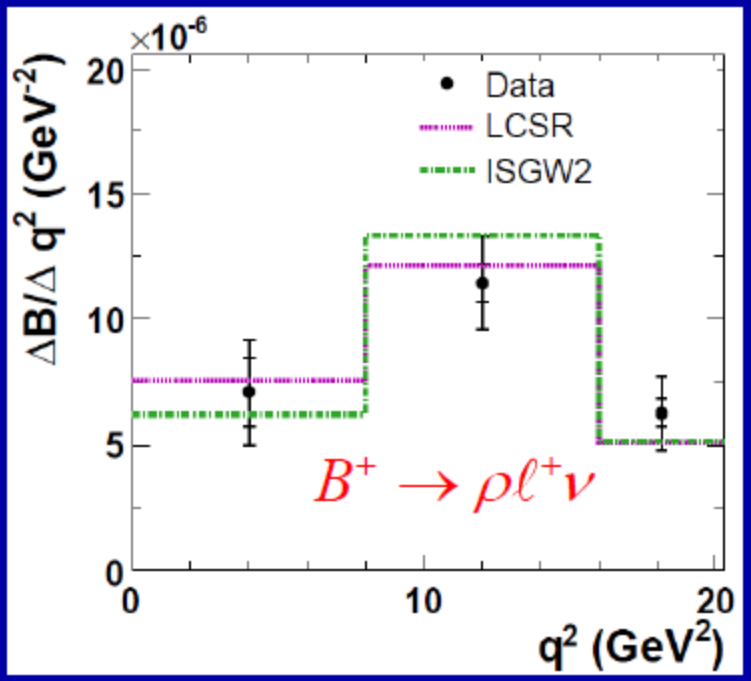
arXiv:1005.3288, accepted by Phys. Rev. D

Lesser players

π-η analysis



π-ρ analysis



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Is 2.7 sigma to be taken seriously?

For me, difficult to say. Wait for the combined data from pi/rho and pi/eta analyses?

Branching fractions :

π-η analysis

$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu) = (1.42 \pm 0.05_{stat} \pm 0.08_{syst}) \times 10^{-4}$$
$$\mathcal{B}(B^+ \to \eta \ell^+ \nu) = (3.61 \pm 0.45_{stat} \pm 0.44_{syst}) \times 10^{-5}$$
$$\mathcal{B}(B^+ \to \eta' \ell^+ \nu) = (2.43 \pm 0.80_{stat} \pm 0.34_{syst}) \times 10^{-5}$$

$$\mathcal{B}(B^+ \to \eta' \ell^+ \nu)/\mathcal{B}(B^+ \to \eta \ell^+ \nu) = 0.67 \pm 0.24_{stat} \pm 0.11_{syst}$$

π-ρ analysis

$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu) = (1.41 \pm 0.05 \pm 0.07) \times 10^{-4}$$
$$\mathcal{B}(B^0 \to \rho^- \ell^+ \nu) = (1.75 \pm 0.15 \pm 0.27) \times 10^{-4}$$

Inclusive value of $|V_{ub}|$

$|V_{ub}| = (4.27 \pm 0.38) \times 10^{-3}$

|Vub| :

π-η analysis

	q^2 (GeV^2)	$\Delta\zeta$ (ps^{-1})	$\|V_{ub}\|$ (10^{-3})
HPQCD	> 16	2.07 ± 0.57	$3.24 \pm 0.13 \pm 0.16\ ^{+0.57}_{-0.37}$
FNAL	> 16	$2.21\ ^{+0.47}_{-0.42}$	$3.14 \pm 0.12 \pm 0.16\ ^{+0.35}_{-0.29}$
LCSR	< 12	$4.00\ ^{+1.01}_{-0.93}$	$3.70 \pm 0.07 \pm 0.09\ ^{+0.54}_{-0.39}$

$$|V_{ub} f_+(0)| = (8.6 \pm 0.3_{stat} \pm 0.3_{syst}) \times 10^{-4}$$

π-ρ analysis

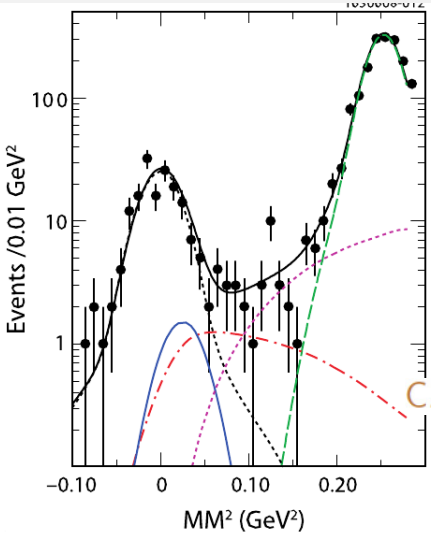
$3.21 \pm 0.17^{+0.55}_{-0.36}$
(2.95 ± 0.31)
$3.78 \pm 0.13^{+0.55}_{-0.40}$

$(10.8 \pm 0.6) \times 10^{-4}$

- All three QCD calculations of the form factor for $B \to \pi \ell \nu$ decays are consistent with data and yield values of |Vub| consistent with the value of |Vub| measured in inclusive semileptonic decays

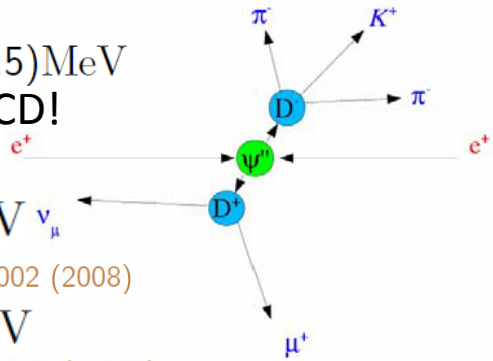
D^+,D^s leptonic decay mini-review +

CLEO-c: $D^+ \to \mu^+\nu$ (818 pb^{-1})



$f_{D^+} = (207.6 \pm 9.3 \pm 2.5)\mathrm{MeV}$

Agrees well with LQCD!



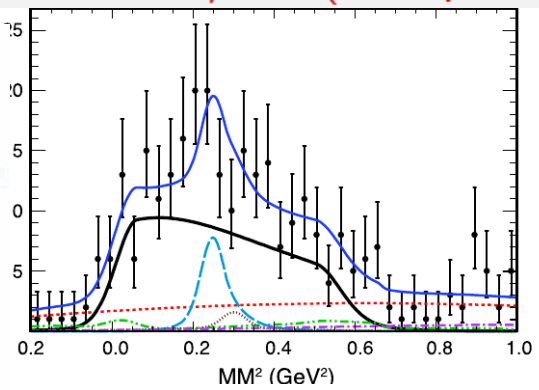
$f_{D^+} = (207 \pm 4)\mathrm{MeV}$

E. Follana et al., PRL 100, 062002 (2008)

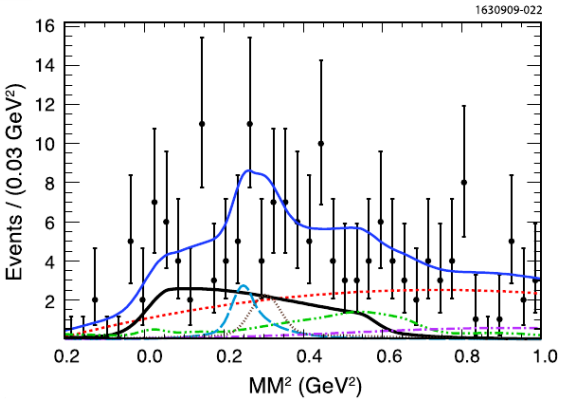
$f_{D^+} = (207 \pm 11)\mathrm{MeV}$

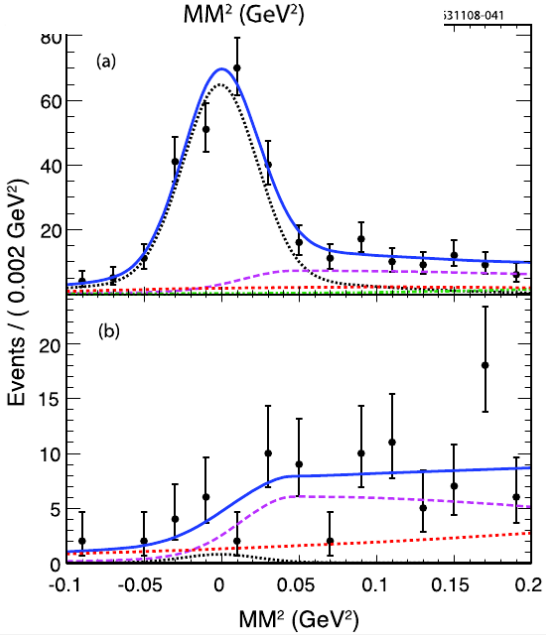
C. Aubin et al., PRL 95, 122002 (2005)

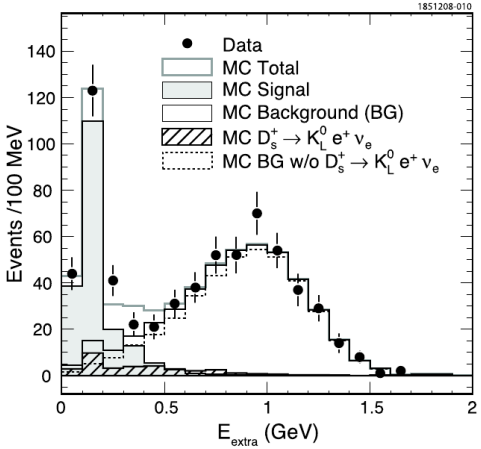
CLEO-c: $D_s^+ \to \tau^+\nu$, $\tau^+ \to \rho^+\nu$ (600 pb^{-1})



CLEO-c: $D_s^+ \to \tau^+\nu$, $\tau^+ \to e^+\nu\nu$ (600 pb^{-1})





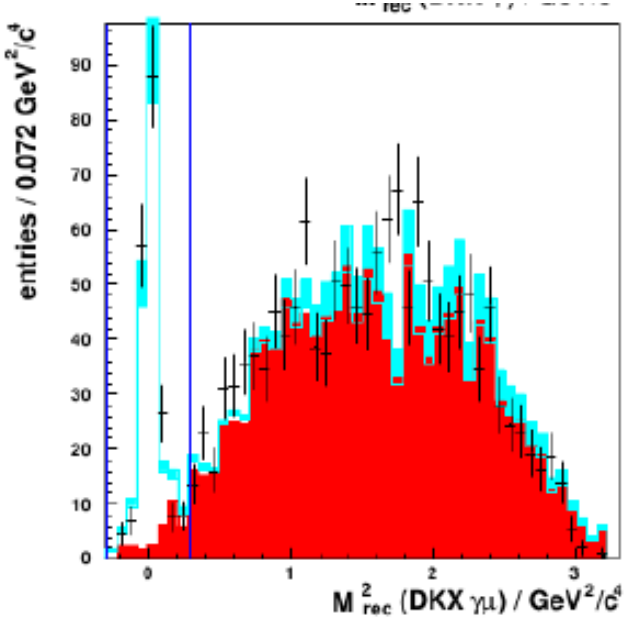


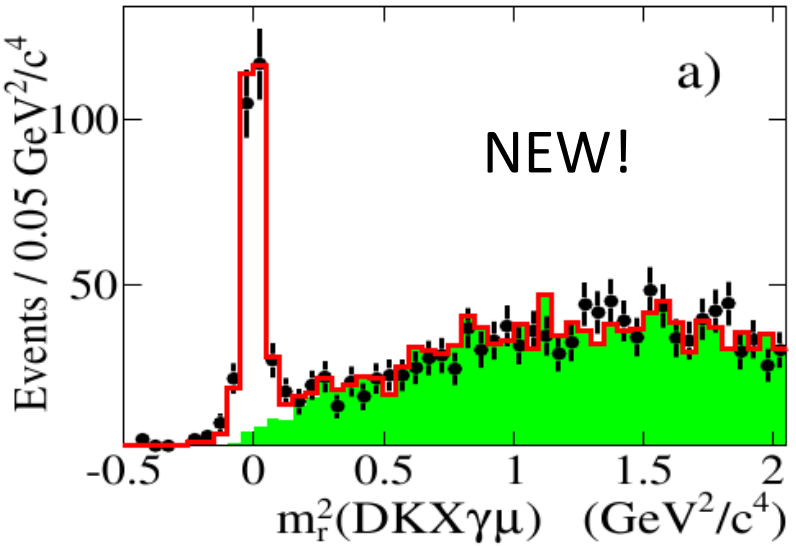
Very impressed with the cleanliness for the electronic tau mode for all the experiments

CLEO-c: $D_s^+ \to \mu^+\nu$ & $D_s^+ \to \tau^+\nu(\to \pi^+\nu\nu)$ (600 pb^{-1})

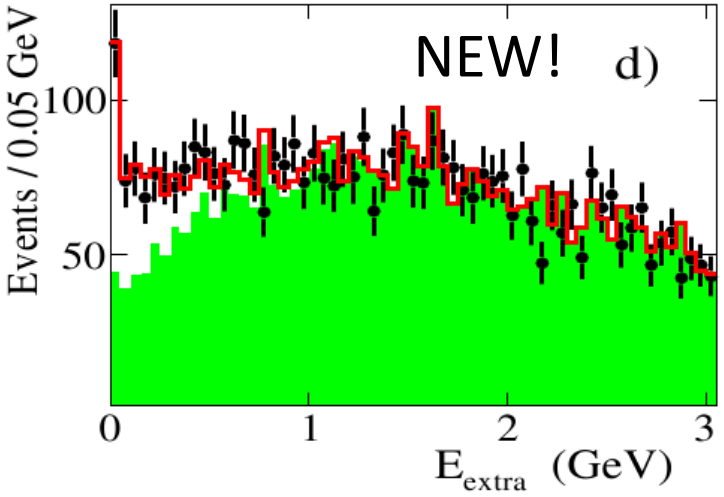
D^+,D^s leptonic decay mini-review +

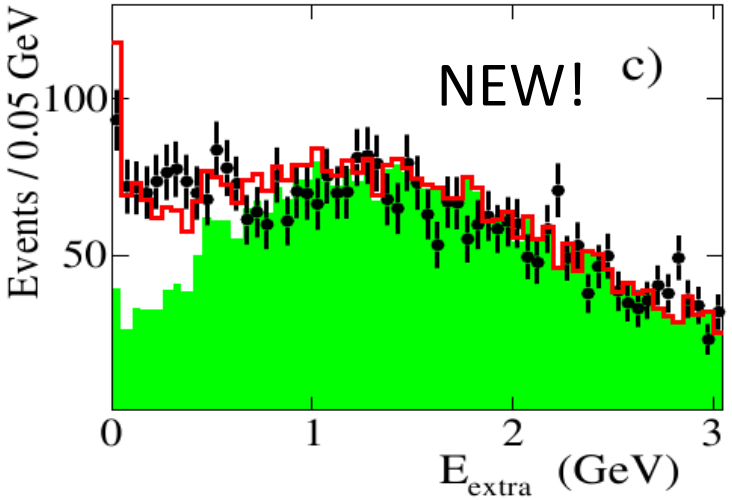
Belle: $D_s^+ \to \mu^+\nu$ (548 fb^{-1})





BaBar: $D_s^+ \to \mu^+\nu$ & $D_s^+ \to \tau^+\nu$ (521 fb^{-1})





D^s leptonic decay mini-review +

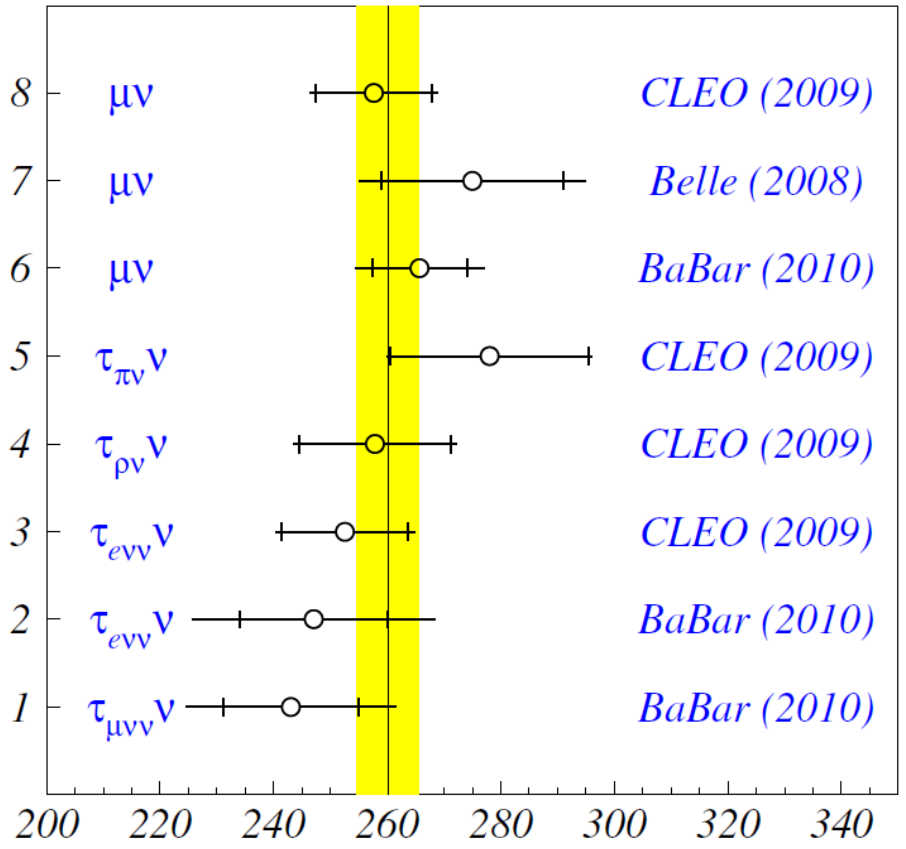
Most precise unquenched Lattice QCD calculations (by HPQCD):

- $f_{D_s^+} = 241 \pm 3$ MeV E. Follana et al., PRL 100, 062002 (2008)
- $f_{D_s^+} = 248.0 \pm 2.5$ MeV C.T.H. Davies et al., arXiv:1008.4018 (2010)

Naive average CLEO+Belle+BaBar:
$f_{D_s^+} = (260.1 \pm 5.4)$ MeV
HFAG average (for FPCP10 - latest BaBar results not included):
$f_{D_s^+} = (254.6 \pm 5.9)$ MeV

- New HPQCD result in good agreement with recent HFAG average
- Agreement including Babar in "Naïve" average agrees also

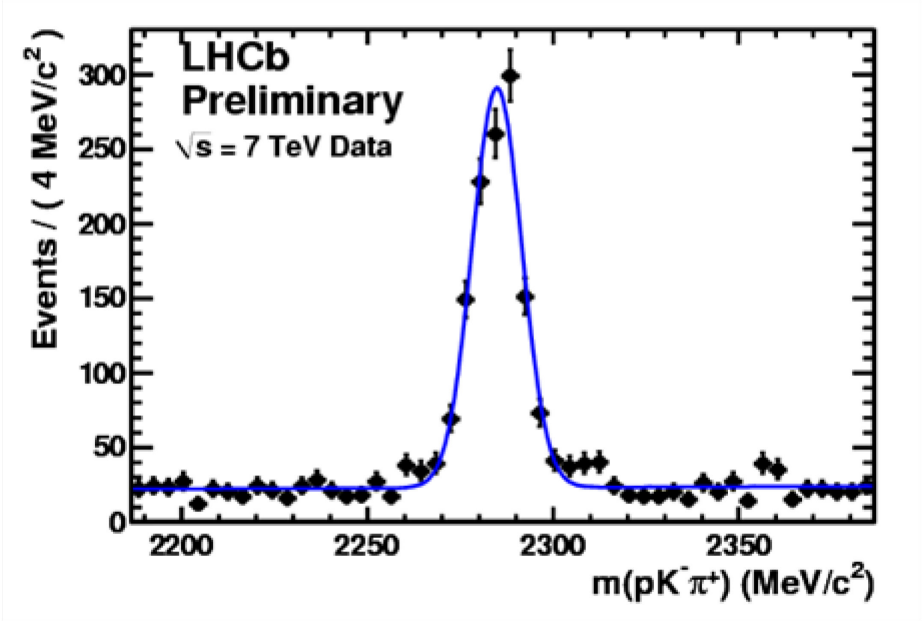
(& if anything, I would expect the HFAG to get a little lower with the BaBar result)



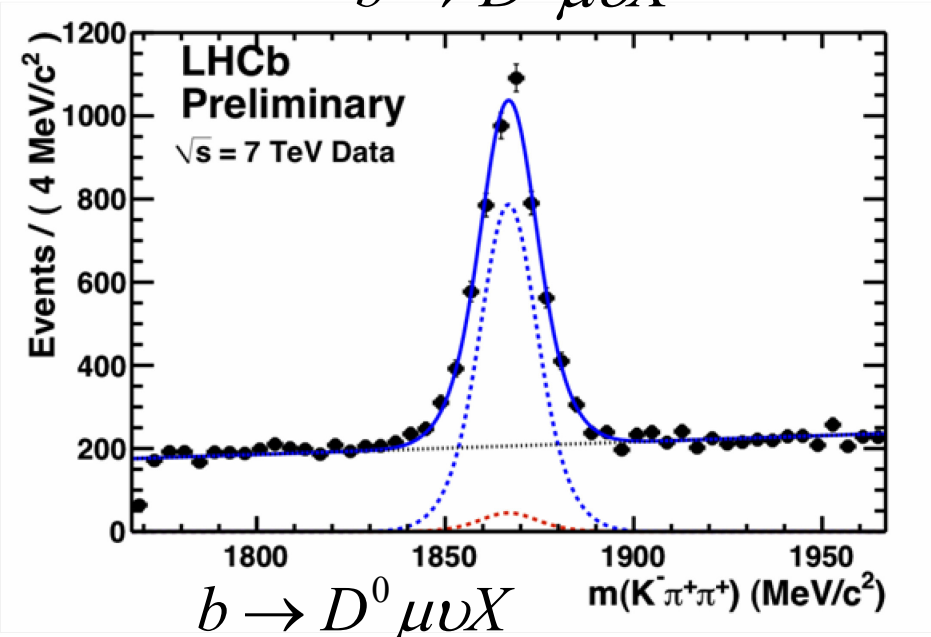
From: Studies of semileptonic decays with the LHCb detector Rob LAMBERT

LHCb Glimpses

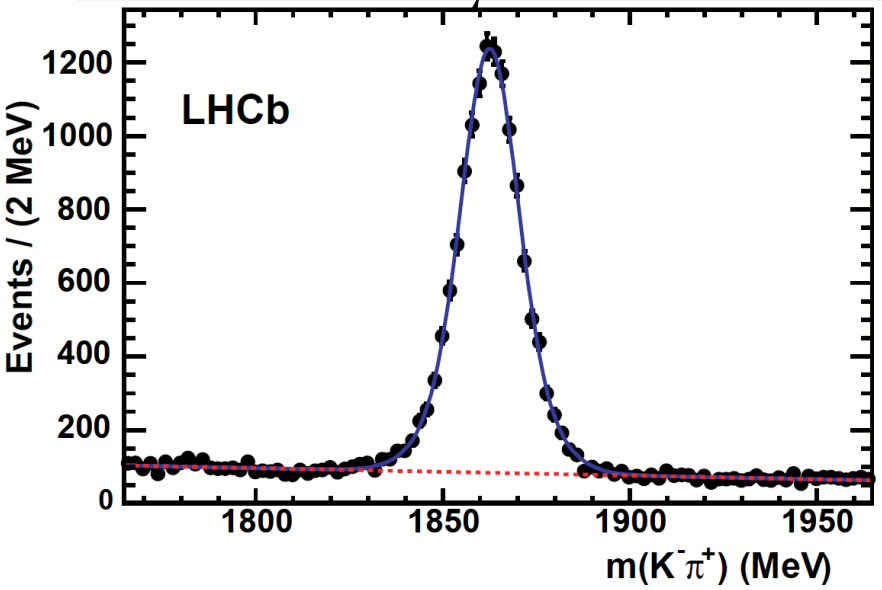
$\Lambda_b \to \Lambda_c \mu \upsilon X$



$b \to D^+ \mu \upsilon X$



$b \to D^0 \mu \upsilon X$



To me, these signals are clean and a great validation of the hadron collider forward B physics concept.
(Comments at talk: signals could be dirtier!)

Towards |Vub|, Start with |Vcb|

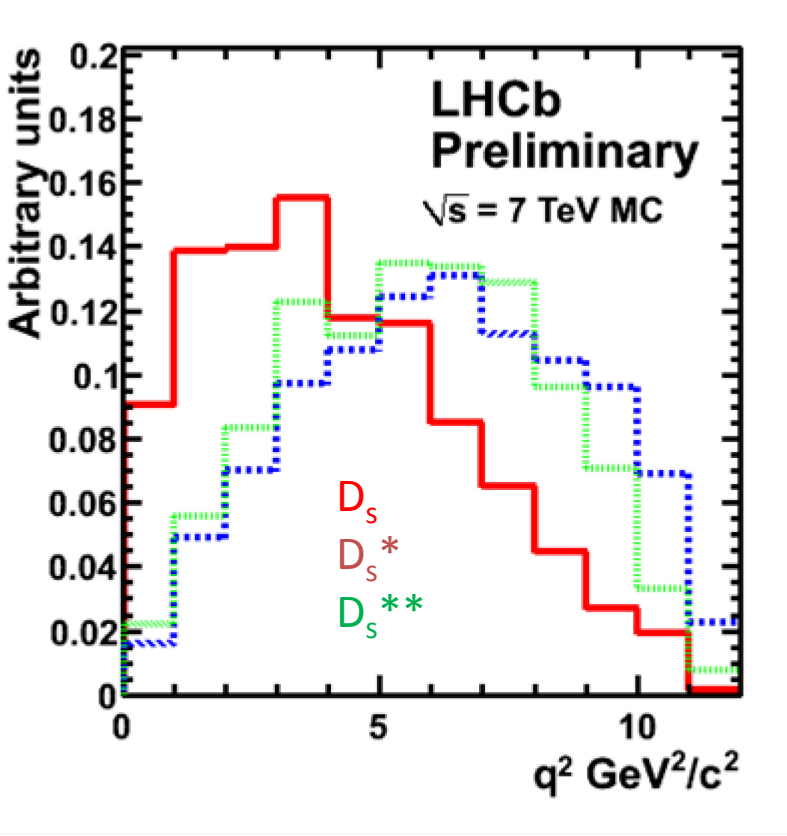
- Investigate excited D_s
- D/D*/D**, ~2.5:~6:~1
- 0.8 pb^{-1} examined
- Looks Good!

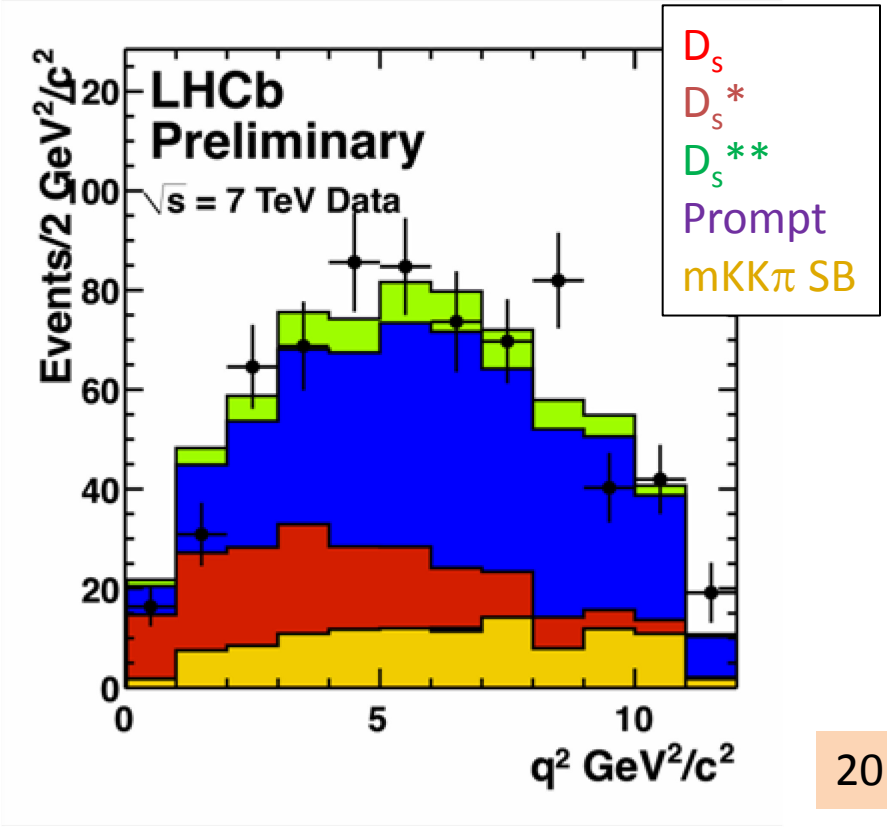
Theory predicts Γs(sl)~90% Ds+Ds*+DsJ

$$Br(B_s \to D_s e\nu_e) = (2.85 \pm 0.35)\%$$

$$Br(B_s \to D_s^* e\nu_e) = (7.09 \pm 0.88)\%$$

arXiv:1003.5576





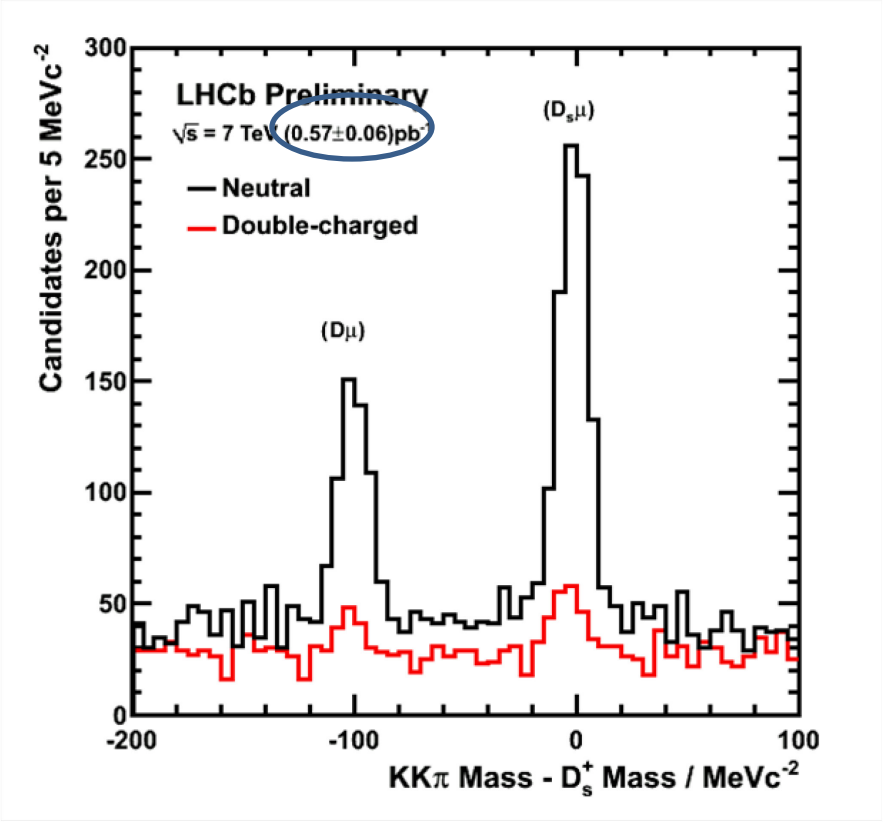
Prospects for a_{fs}

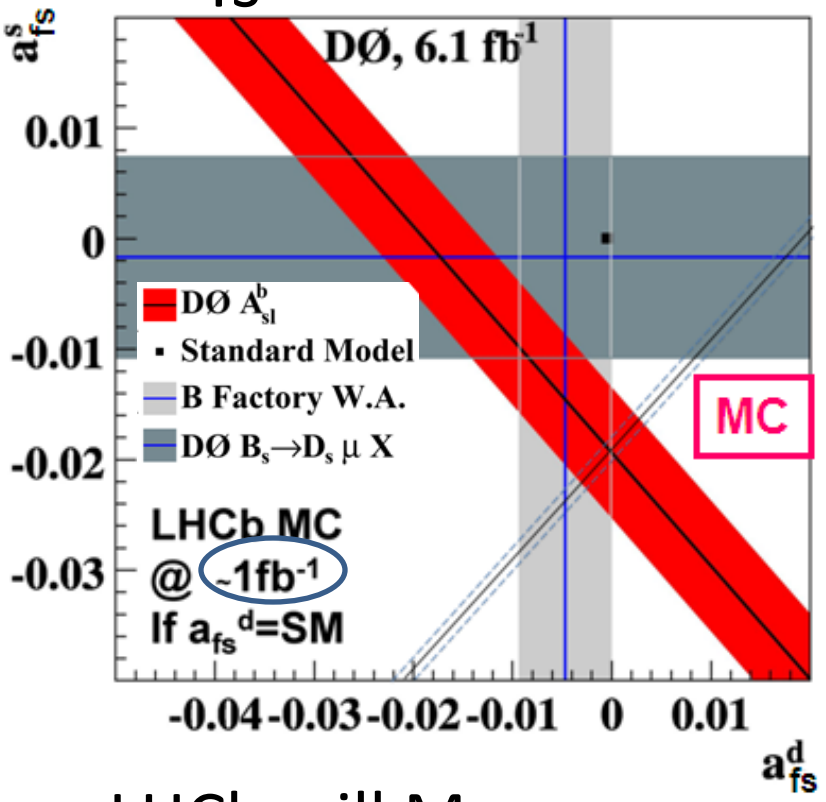
D0 Measures: (3.2 σ from SM!)

$$p\bar{p} \to \mu X \text{ vs. } p\bar{p} \to \mu\mu X$$

$$A^b \approx \frac{a^s_{fs} + a^d_{fs}}{2}$$

$$A^b = [-9.57 \pm 2.51(\text{stat}) \pm 1.46(\text{syst})] \times 10^{-3}$$





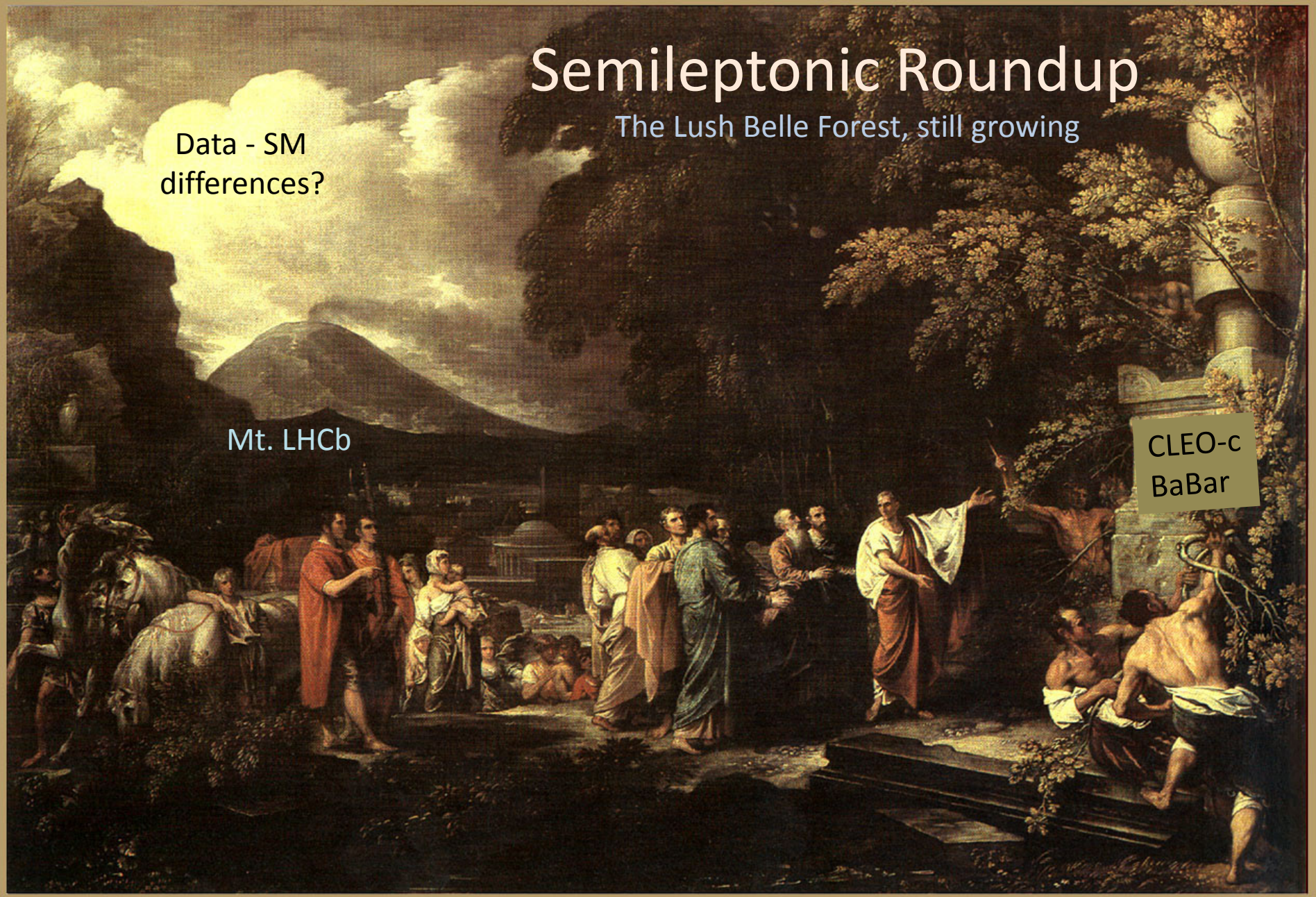
LHCb will Measure:

$$B_s \to D_s \mu \upsilon X \text{ vs. } B_d \to D \mu \upsilon X$$

$$\Delta A^{s,d}_{fs} = \frac{a^s_{fs} - a^d_{fs}}{2} \; SM = \left(+2.5^{+0.5}_{-0.6}\right) \times 10^{-4}$$

Semileptonic Roundup

The Lush Belle Forest, still growing



The Paintings of Benjamin West by Helmut von Erffa and Allen Staley, Yale University Press, New Haven & London, 1986