WGII – experimental aspects

Highlights and future priorities

Bob Kowalewski,
U. of Victoria

…on behalf of WGII
conveners and participants

Highlights

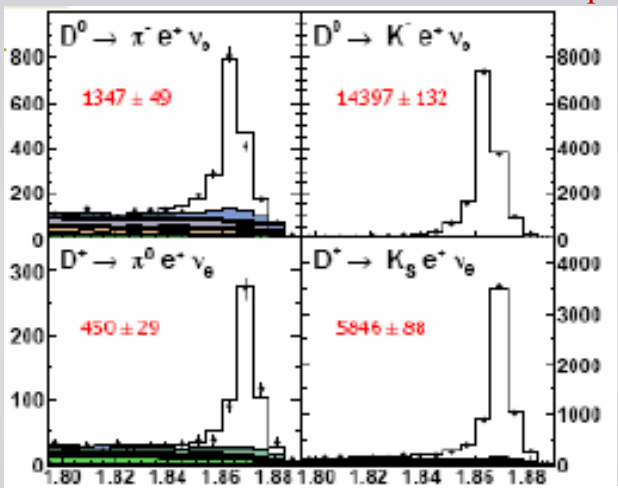
- Selected based on freshness and importance
- Charm semileptonic decays
- $|V_{cb}|$ exclusive: $B \to D^{(*)} \ell \nu$, HQET form factors
- $|V_{cb}|$ inclusive: moments, OPE, global fit
- $|V_{ub}|$ exclusive: $B \to \pi \ell \nu$, heavy-light form factors
- $|V_{ub}|$ inclusive: $B \to u \ell \nu$, OPE, resummation…

Semileptonic charm

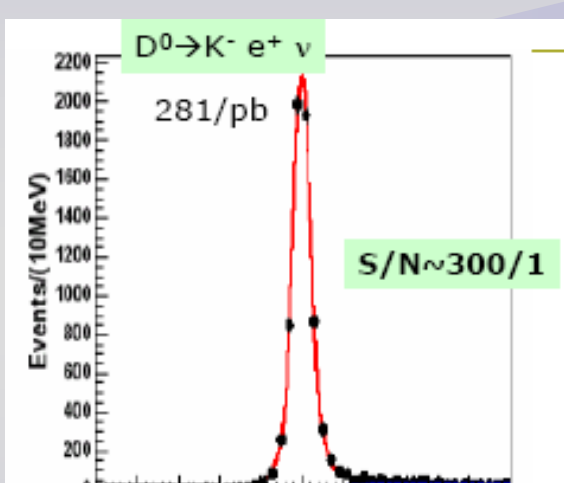
- New measurements improve $f^+(0)|V_{cq}|$
- 1-4% exp. error on $|V_{cq}|$ (LQCD error ~10% now)

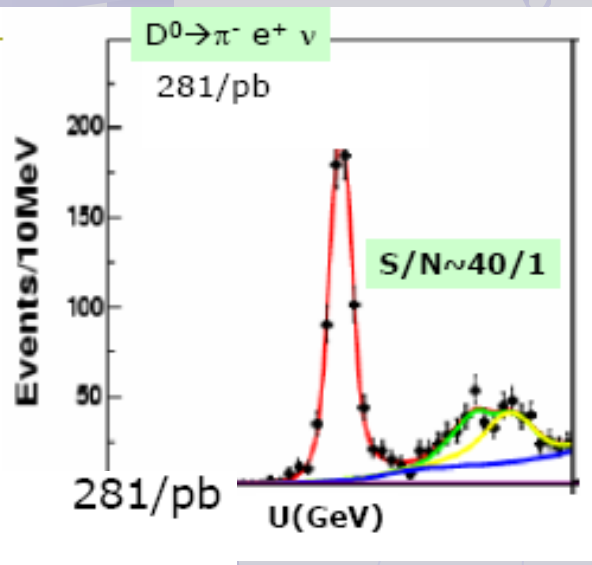
Charm Semileptonic Decays

Dan Cronin-Hennessy
Univ. of Minnesota



Branching Fractions





Form factors

	CLEO-c (tag)	CLEO-c (no-tag)	Average
$\pi^- e^+ \nu_e$	0.308(13)(4)	0.299(11)(8)	0.304(11)(5)
$\pi^0 e^+ \nu_e$	0.379(27)(23)	0.373(22)(13)	0.378(20)(12)
$K^- e^+ \nu_e$	3.60(5)(5)	3.56(3)(9)	3.60(3)(6)
$\bar{K}^0 e^+ \nu_e$	8.87(17)(21)	8.53(13)(23)	8.69(12)(19)

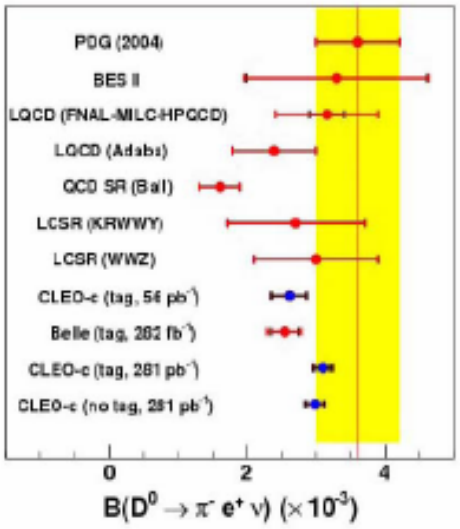
K: $f^+(0)V_{cs} = 0.744(7)(5)$
π: $f^+(0)V_{cd} = 0.143(5)(2)$

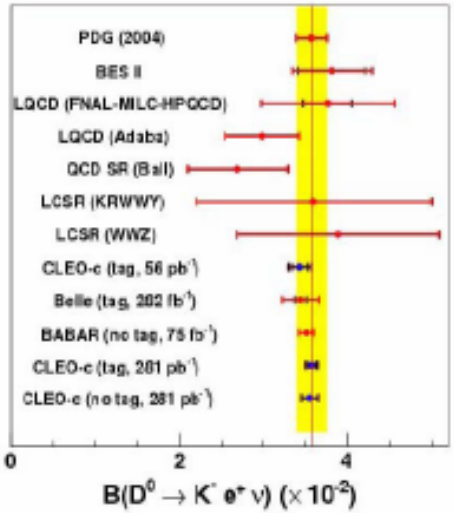
$$V_{cd} = 0.223 \pm 0.008 \pm 0.003 \pm 0.023$$
$$V_{cs} = 1.019 \pm 0.010 + 0.007 \pm 0.106$$

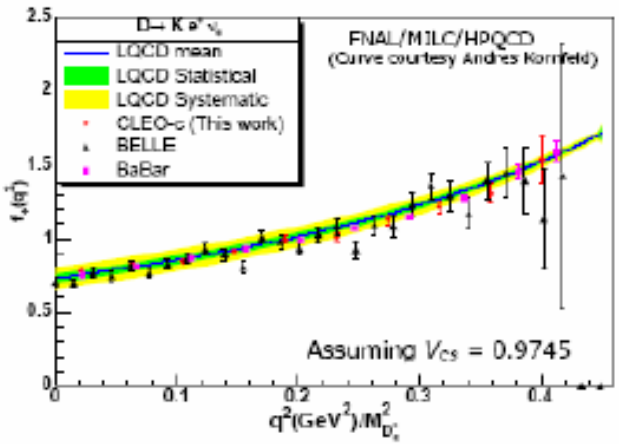
Nice summary from D. Cronin-Hennessy

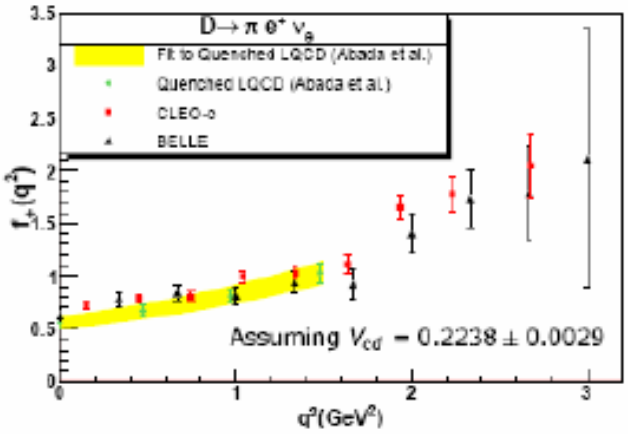
Summary Plots

The next level of precision has been reached with the analyses from BaBar, Belle and CLEO-c









Cronin-Hennessy, U of M

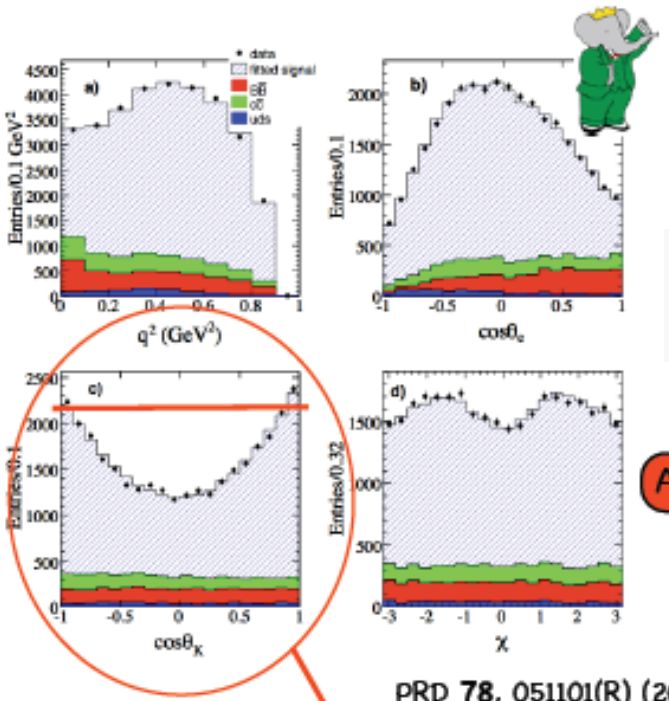
Modified pole model used as example:

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

New precision charm form factors: D_s

$D_s \rightarrow KKev$

Talk from R. Sacco,
Queen Mary, U. London



N_{sig} = 25341±178±488

r_V = 1.849±0.060±0.095

r_2 = 0.763±0.071±0.065

1.35±0.08

0.98±0.09

Quenched LQCD

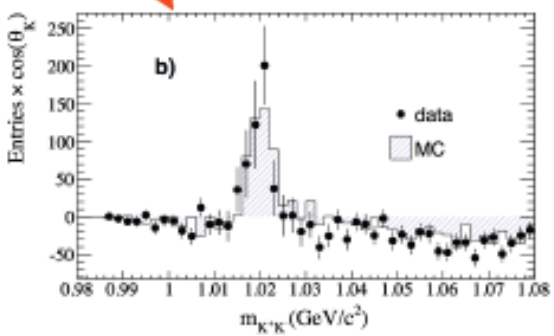
hep-lat/0109035

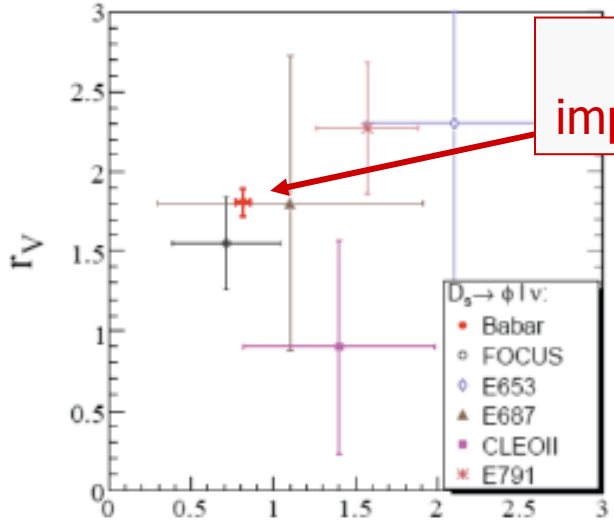
$m_A = 2.28^{+0.23}_{-0.18}\pm0.18$ GeV/c²

$A_1(0)$ = 0.607±0.011±0.019±0.018 GeV/c²

0.63±0.02

PRD **78**, 051101(R) (2008)





Big improvement!

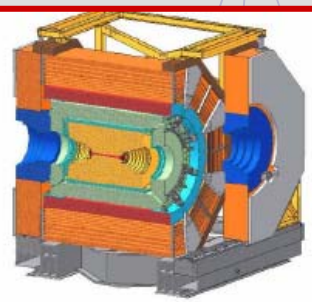
Future prospects in semileptonic charm

- More data to analyze in CLEO, B factories

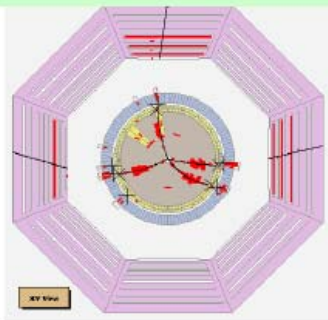
- **Future Improvements:**
  - BaBar, Belle and CLEO-c all have unanalyzed data. Unanalyzed data data varies from 9/10 to 2/3.
  - BaBar and CLEO-c analyses will gain more quickly since their approaches have larger relative statistical uncertainty.
  - Pion modes are statistics limited and will benefit greatly from the upcoming work. I would expect a measurement from BaBar for the $D^0 \rightarrow D^0 \rightarrow \pi\, e\, \nu$ soon.
  - The largest uncertainties of V_{cq} arise from theory.
    - With expected improvements from theory V_{cd} from semileptonic decay may may surpass V_{cd} from νN.

- New facility to exploit!

- **BESIII has started data accumulation.**
- **Current running is at ψ'.**
- **Detector capabilities similar to CLEO-c.**
- **Early major start problems are solved.**
- **Luminosity at this early date is ~CESR-c.**
- **Expect 10 times CLEO-c at 3770 luminosity with one year of running.**



First hadronic event: July



D. Cronin-Hennessy, U of M

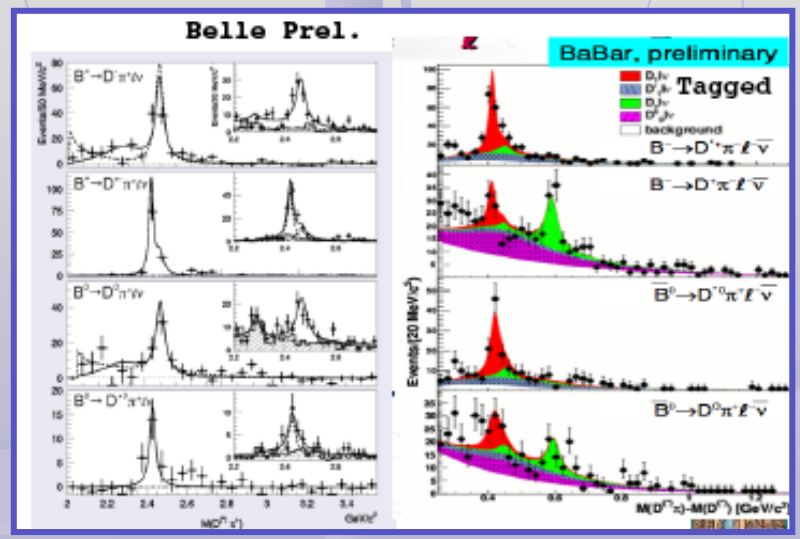
$|V_{cb}|$ from $B \to X_c \ell \nu$

- Old story: use HQET parameterization, fit slope, FF ratios and $|V_{cb}|$*FF(w=1)
- FF(1) from LQCD or LCSR

$\mathcal{G}(1)=1.074 \pm 0.018 \pm 0.016$
(M.Okamoto et al NPPS 140, 461 (2005))
$h_{\mathcal{A}}(1)=0.921 \pm 0.013 \pm 0.020$
(J.Laiho et al arXiv:0808.251 [hep-lat])

$|V_{cb}| * F.F.(w \to 1)$
$\rho_D^2, \rho_{D^*}^2$ (slopes of ff)
R_1, R_2 : form factor ratios (D*)

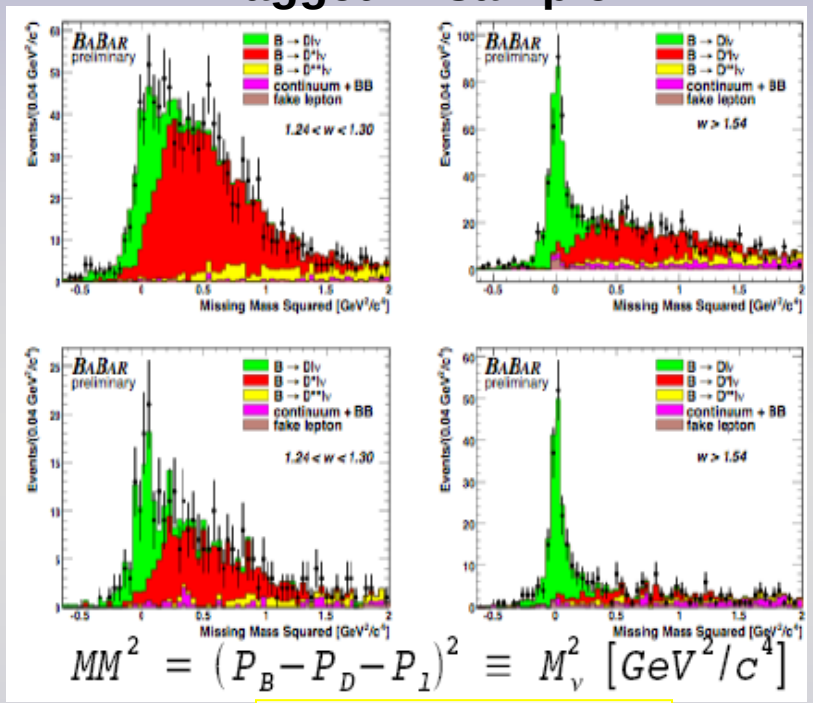
- NEW: improved precision on $B \to D^{**} \ell \nu$ and $B \to D^{(*)} \pi \ell \nu$ decays… but no time to discuss



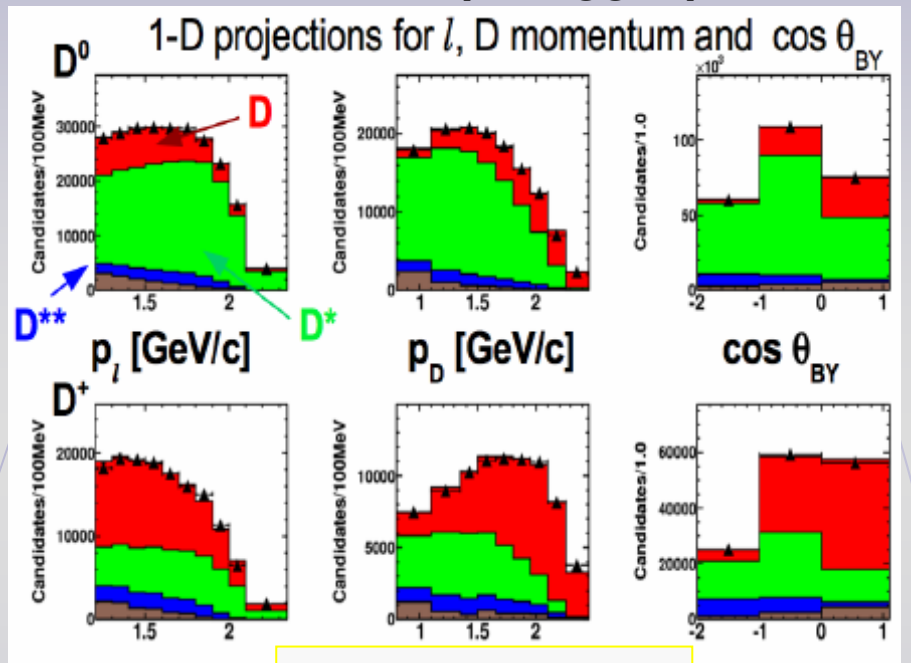
Belle : arXiv:0711.3252
BaBar: arXiv:0808.0528
BaBar: arXiv:0808.0333

Big improvement in B→Dℓν

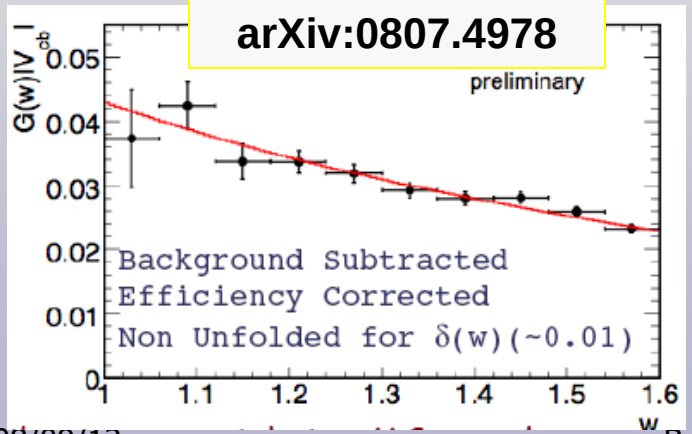
Tagged B sample



Global fit (untagged)



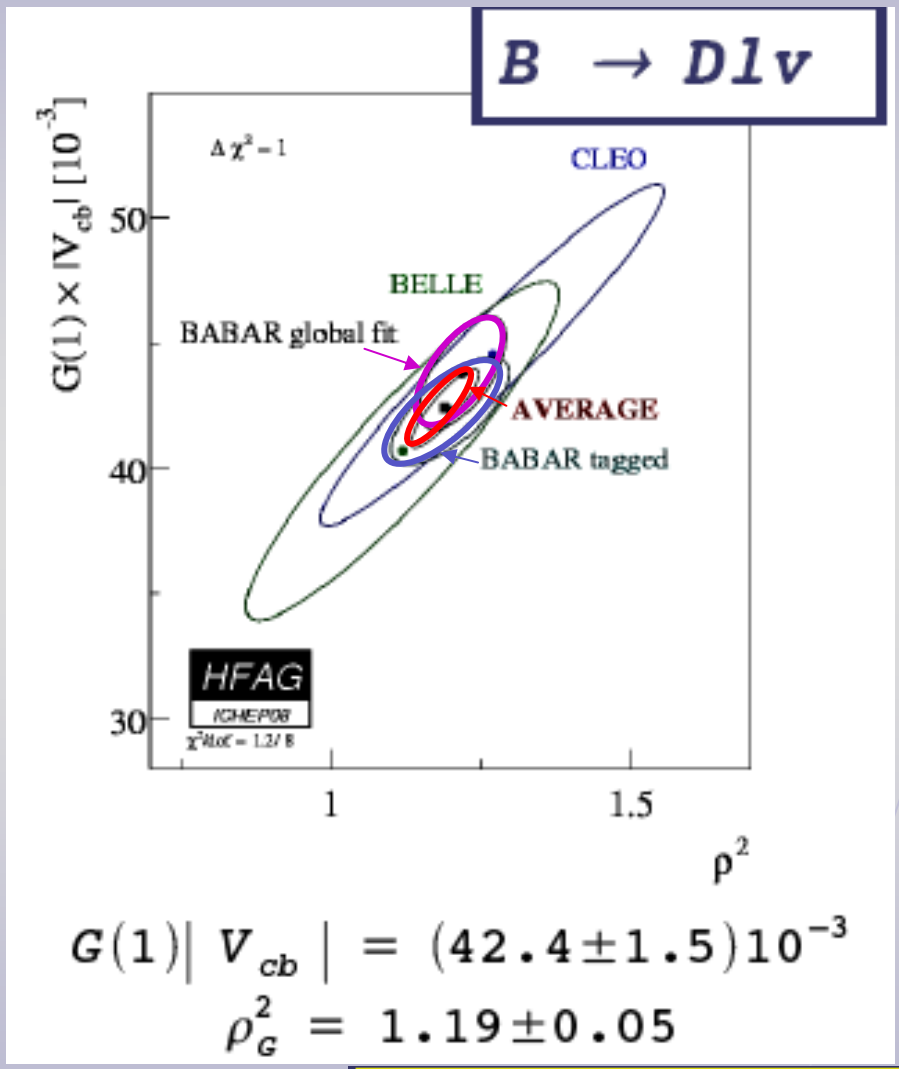
arXiv:0809.0828



arXiv:0807.4978

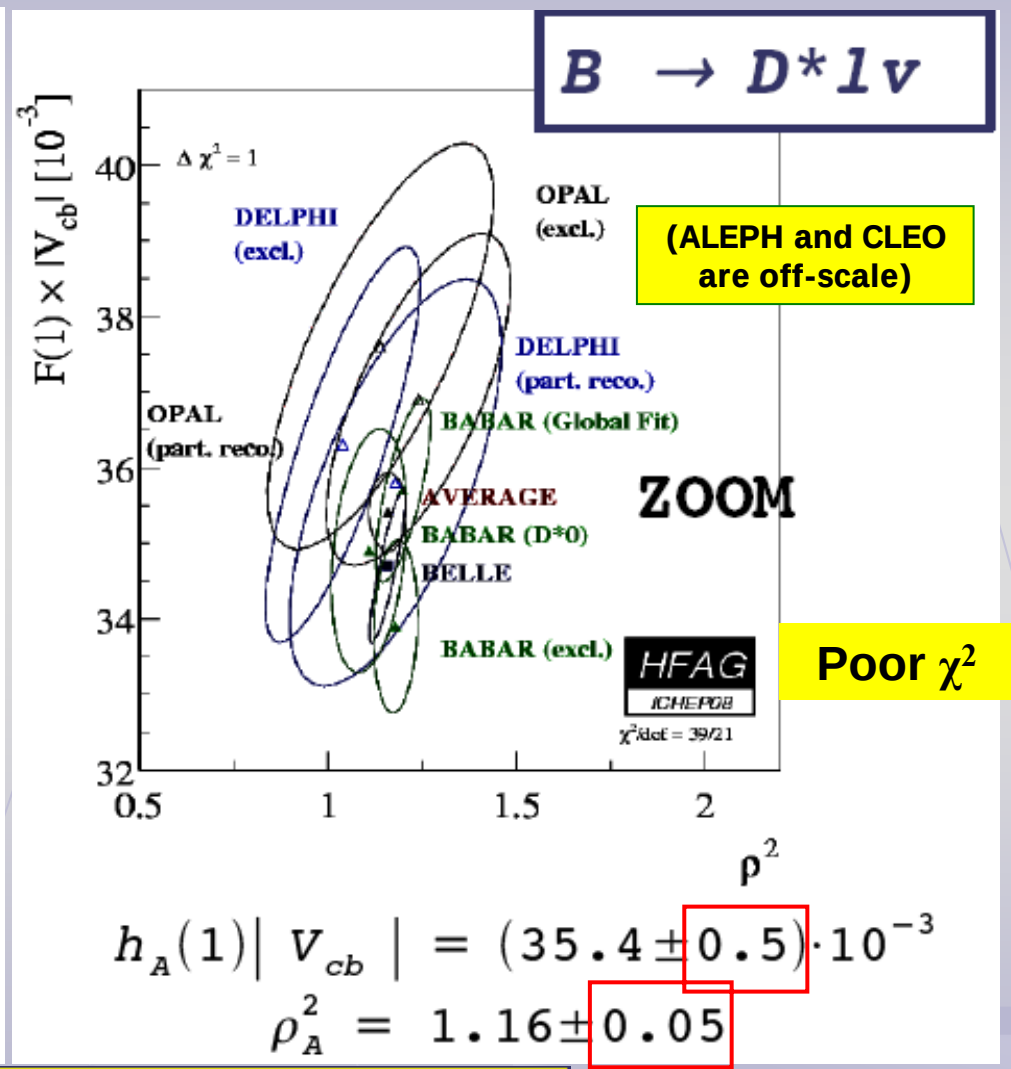
- New tagged and untagged preliminary measurements of Dℓν from BaBar
- Complementary methods; largely independent (also for D*ℓν)

Updated $D^{(*)}\ell\nu$ averages



$$G(1)\left|V_{cb}\right| = (42.4 \pm 1.5)10^{-3}$$

$$\rho_G^2 = 1.19 \pm 0.05$$



(ALEPH and CLEO are off-scale)

Poor χ^2

$$h_A(1)\left|V_{cb}\right| = (35.4 \pm 0.5)\cdot 10^{-3}$$

$$\rho_A^2 = 1.16 \pm 0.05$$

$|V_{cb}| = (39.7 \pm 1.4_{exp} \pm 0.9_{theo}) \times 10^{-3}$ (D)

$|V_{cb}| = (38.1 \pm 0.6_{exp} \pm 0.9_{theo}) \times 10^{-3}$ (D*)

Still some puzzles

☹ New results from both D^{*0} and D^{*+} will increase the BR deficit

PDG 2008

Decay Mode	Branching Fraction
$B^- \to \ell^- \bar{\nu}_\ell$ + anything	10.99 ± 0.28 %
$B^- \to D^0 \ell^- \bar{\nu}_\ell$	2.27 ± 0.11 %
$B^- \to D^{*0} \ell^- \bar{\nu}_\ell$	6.07 ± 0.29 %
$B^- \to D^+ \pi^- \ell^- \bar{\nu}_\ell$	0.42 ± 0.05 %
$B^- \to D^* \pi^- \ell^- \bar{\nu}_\ell$	0.61 ± 0.05 %
$B^- \to D^{(*)} n\pi \ell^- \bar{\nu}_\ell$	$\simeq$??
$B^- \to D^{(*)0}(\pi) \ell^- \bar{\nu}_\ell$	9.9 ± 0.3 %

$B(D^{*0}l\nu)=(5.4\pm0.2)\%$

BABAR prel.(not included)

Decay Mode	Branching Fraction
$\bar{B}^0 \to \ell^- \bar{\nu}_\ell$ + anything	10.33 ± 0.28 %
$\bar{B}^0 \to D^+ \ell^- \bar{\nu}_\ell$	2.17 ± 0.12 %
$\bar{B}^0 \to D^{*+} \ell^- \bar{\nu}_\ell$	5.16 ± 0.11 %
$\bar{B}^0 \to D^0 \pi^+ \ell^- \bar{\nu}_\ell$	0.43 ± 0.06 %
$\bar{B}^0 \to D^{*0} \pi^+ \ell^- \bar{\nu}_\ell$	0.49 ± 0.08 %
$\bar{B}^0 \to D^{(*)} n\pi \ell^- \bar{\nu}_\ell$	$\simeq$??
$\bar{B}^0 \to D^{(*)}(\pi) \ell^- \bar{\nu}_\ell$	8.7 ± 0.2 %

$B(D^{*+}l\nu)=(4.4\pm0.3)\%$

Belle prel.(not included)

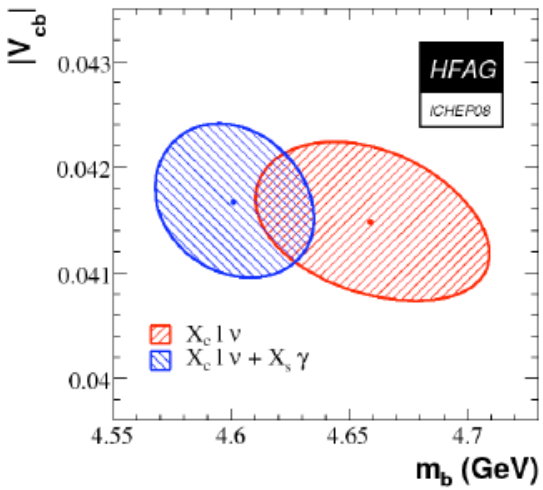
☹ A problem in "traditional" B-fact. measurements of Br(B^0 -> D^{*+} lν) ?

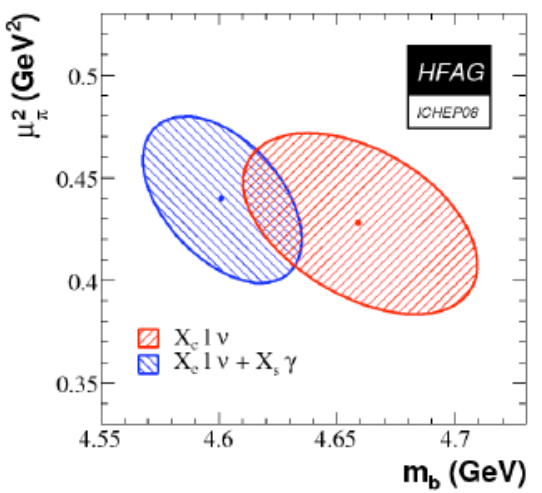
BABAR PRD77,32002,08	4.7±0.4
Belle ICHEP 08	4.4±0.3
PDG 2008	5.2±0.1
Rescaled B+ PDG2008	5.7±0.1
Rescaled B+ BABAR PRL100, 231803 (2008)	5.2±0.4

Emphasizes importance of the $D\ell\nu$ measurements

$|V_{cb}|$ from global fit to moments

- Calculate and measure moments of E_e and M_X^2 spectra in $b \to c\ell\nu$ decays and E_γ in $b \to s\gamma$ decays
- Use ~60 moments, fit for 7 parameters
- Should $b \to s\gamma$ be included? Maybe, but quantifying theory uncertainty requires more work





Input	$\|V_{cb}\|$ (10^{-3})	m_b (GeV)	μ^2_π (GeV^2)	χ^2/ndf
All moments	41.67+/-0.43(fit)+/-0.08(τ_B)+/-0.58(th)	4.601+/-0.034	0.440+/-0.040	29.7/57
$X_c l\nu$ only	41.48+/-0.47(fit)+/-0.08(τ_B)+/-0.58(th)	4.659+/-0.049	0.428+/-0.044	24.1/46

Recent progress, outlook

- Renewed attention on theoretical correlation matrix.
  - Under study; first look suggests this might be the source of anomalously low $\chi^2/\mathrm{d.f.}$ (~30/60)
  - ~no impact on m_b, but lowers $|V_{cb}|$ by ~1 sigma
- New moment measurements from Belle ($b \to s\gamma$) and BaBar (M_X moments in $b \to c\ell\nu$)
- Interest in including threshold determinations of m_b and/or m_c, once the errors on these are agreed upon
- $|V_{cb}|$ from inclusive/exclusive are converging

Exclusive $|V_{ub}|$

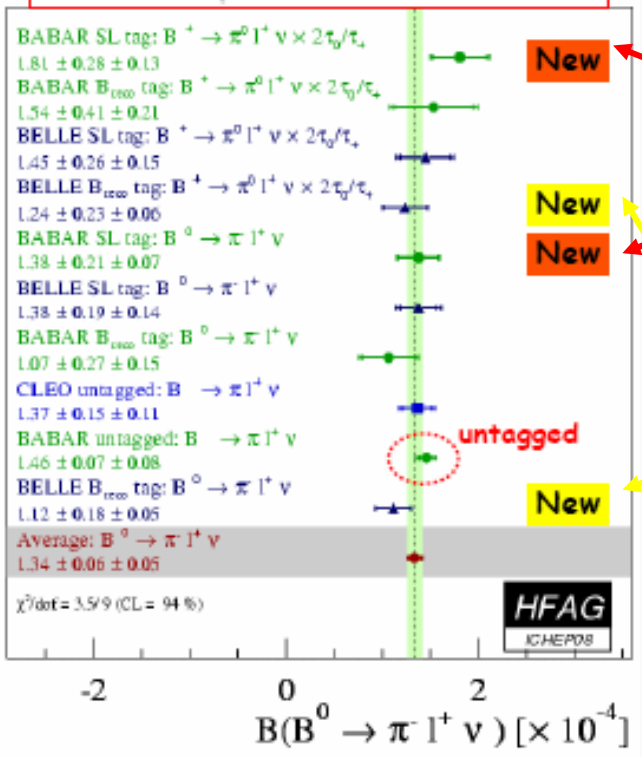
Main interest: B→$\pi\ell\nu$

Jochen Dingfelder
(University of Freiburg)

B → πℓν total branching fraction

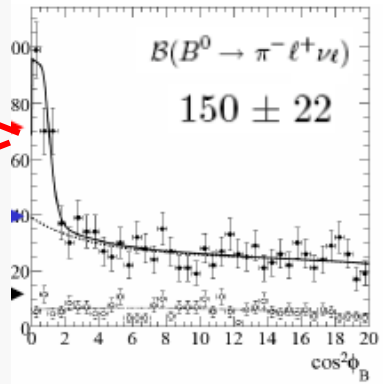
stat: 5% syst: 4%

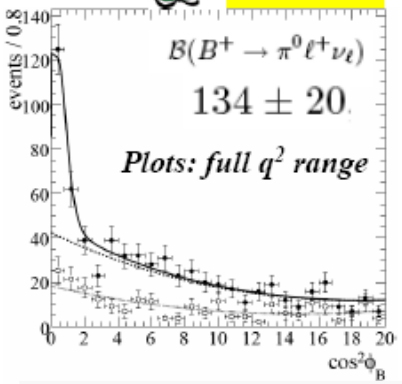
$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu_\ell) = (1.34 \pm 0.06 \pm 0.05) \times 10^{-4}$



0805.2408

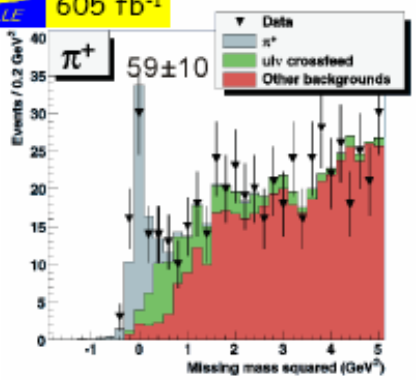
348 fb^{-1}

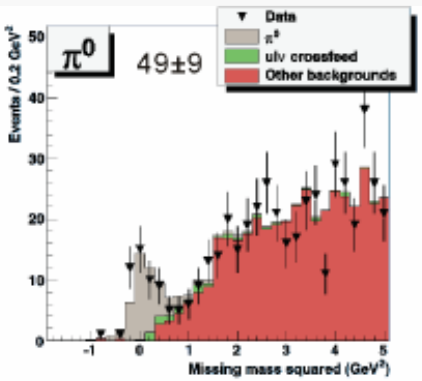




Presented at ICHEP08

605 fb^{-1}



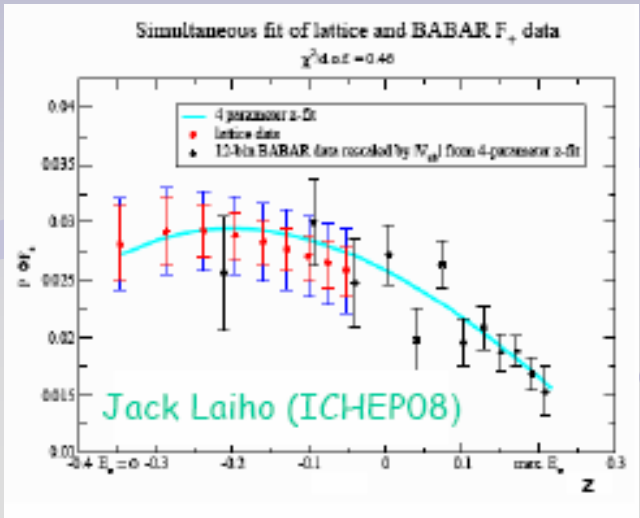


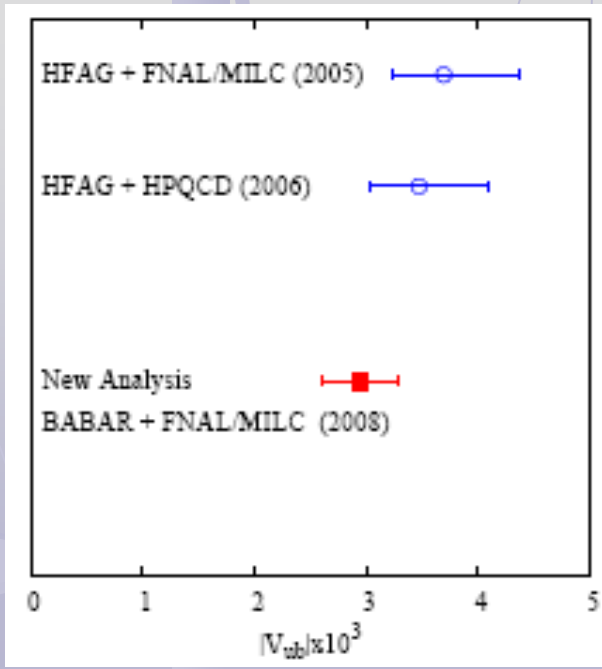
σ(V_{ub}) from expt: 3%

Determination of $|V_{ub}|$

- Most accurate BF($B \to \pi \ell \nu$) and best q^2 spectrum still come from untagged BaBar measurement
- Fits to $\Delta BF(q^2)$ and lattice points can be used to constrain FF shape, extract $|V_{ub}|$
- New preliminary FNAL/MILC calculation of $f_+(q^2)$ gives much lower $|V_{ub}|$; if confirmed this would re-introduce a tension with the inclusive $|V_{ub}|$ determination

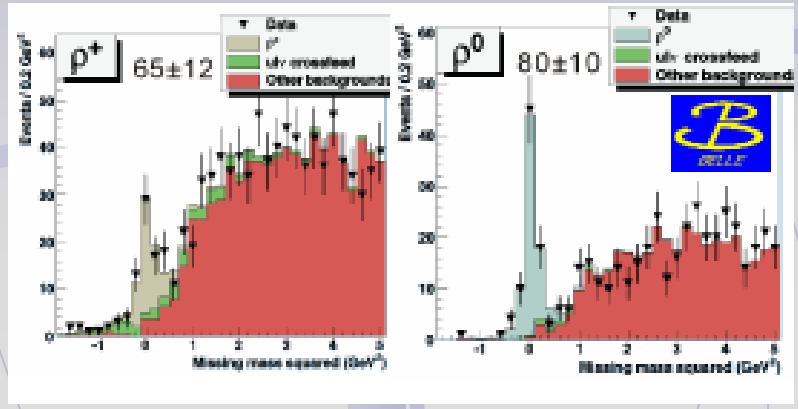
$2.94 \pm 0.35 \times 10^{-3}$ (Preliminary)
(Van de Water at LAT08)





Prospects for improvement in exclusive $B \to X_u \ell \nu$

- Measure other hadronic final states to better quantify $\pi \ell \nu$ backgrounds at large q^2



Belle, ICHEP08

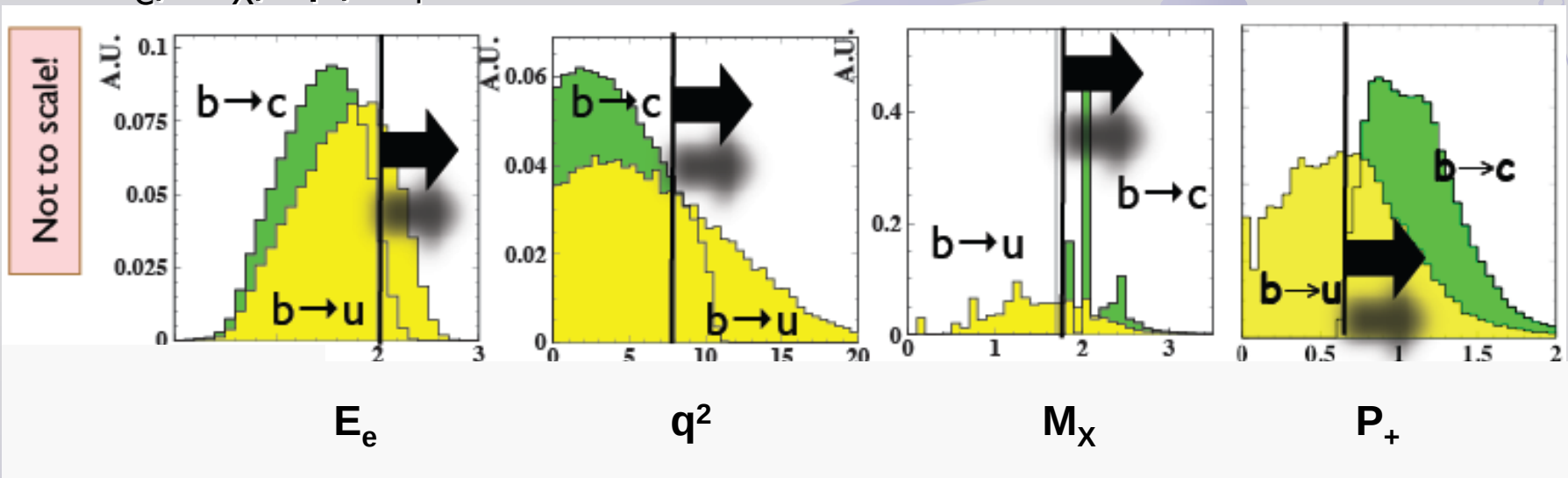
- Many current analyses do not use the full available statistics

Extrapolations of $B^0 \to \pi^+ \ell \nu$ measurements: Today → 1ab^{-1}

	N_{signal}	$\sigma_{BF,stat}$(%)	$\sigma_{BF,syst}$(%)	$\sigma_{BF,exp}$(%)	$\sigma_{Vub,\ exp}$(%)
Had. tag	59 → 100	16 → 12	4 → 3	17 → 12	9 → 6
SI. tag	150→ 430	15 → 9	5 → 4	16 → 10	8 → 5
Untagged	5k → 25k	5 → 2	5 → 5	7 → 5	3.5 → 2.5

Inclusive b→uℓν

- Experimental measurements of partial rates in regions of E_e, M_X, q^2, P_+…

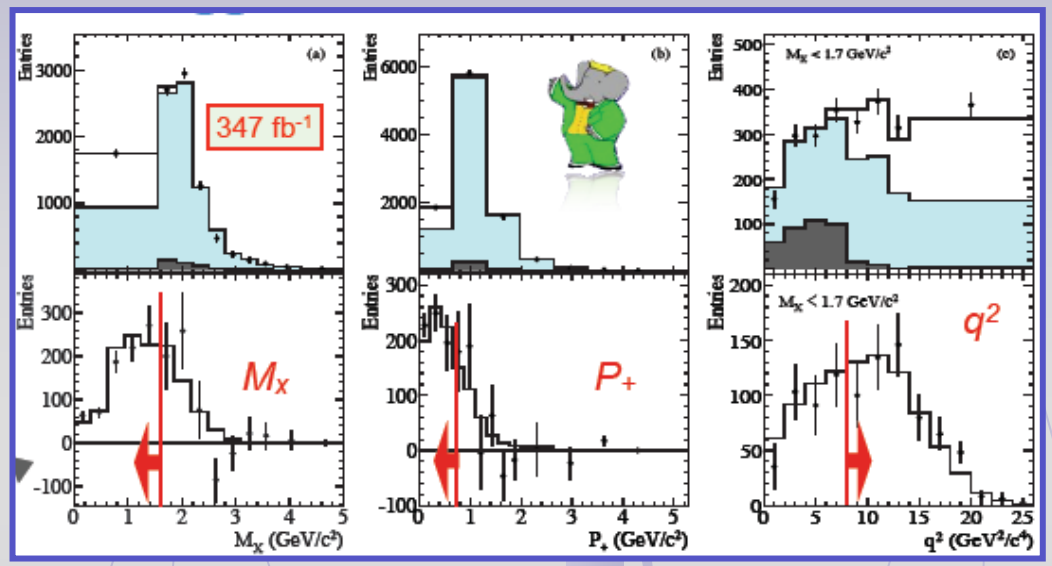


- Recall b→u rate ~ 2% of b→c rate

- New measurements…

$|V_{ub}|$ from inclusive $b \to u \ell \nu$

- New at ICHEP08: BaBar recoil analysis
  $\sigma_{Vub} \sim$ 8.5% (theory+m_b ~7%)
- New at CKM08: Belle multivariate (BDT) analysis, measures ~full $b \to u \ell \nu$ rate:
  $\sigma_{Vub} \sim$ 7% (theory+m_b ~4%)

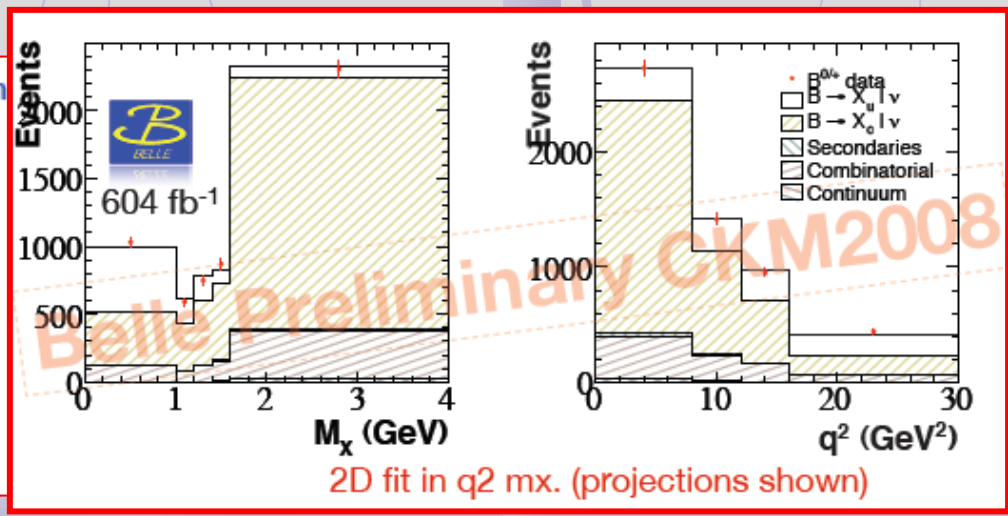


3. BDT cut with many input par's: M_{miss}^2, dZ, dr, Q_{total}, Qlepton Nlepton, Q(B), D* partial reco etc.....

4. Combinatorial estimated from MC, normalisation from sideband region. (same approach as Vcb moments analyses)

5. 2D fit to M_x, q^2 with backgrounds and signal floated to determine background yield.

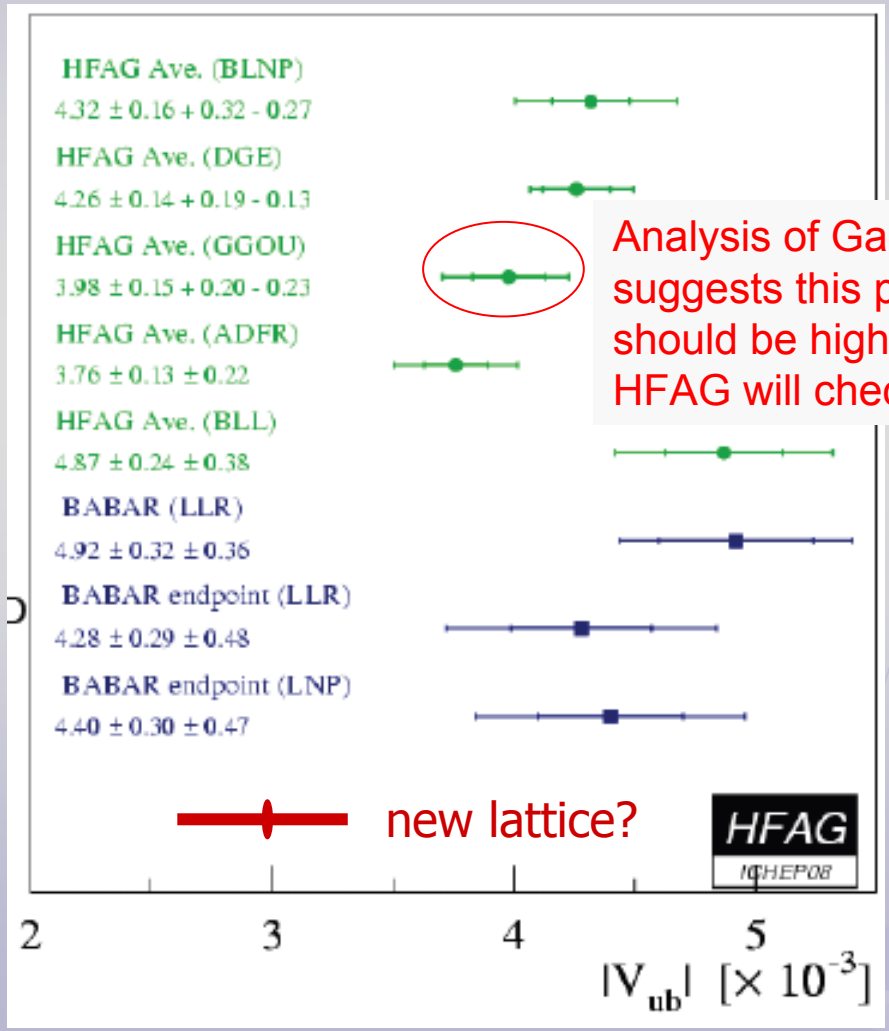
6. Measure absolute rate.

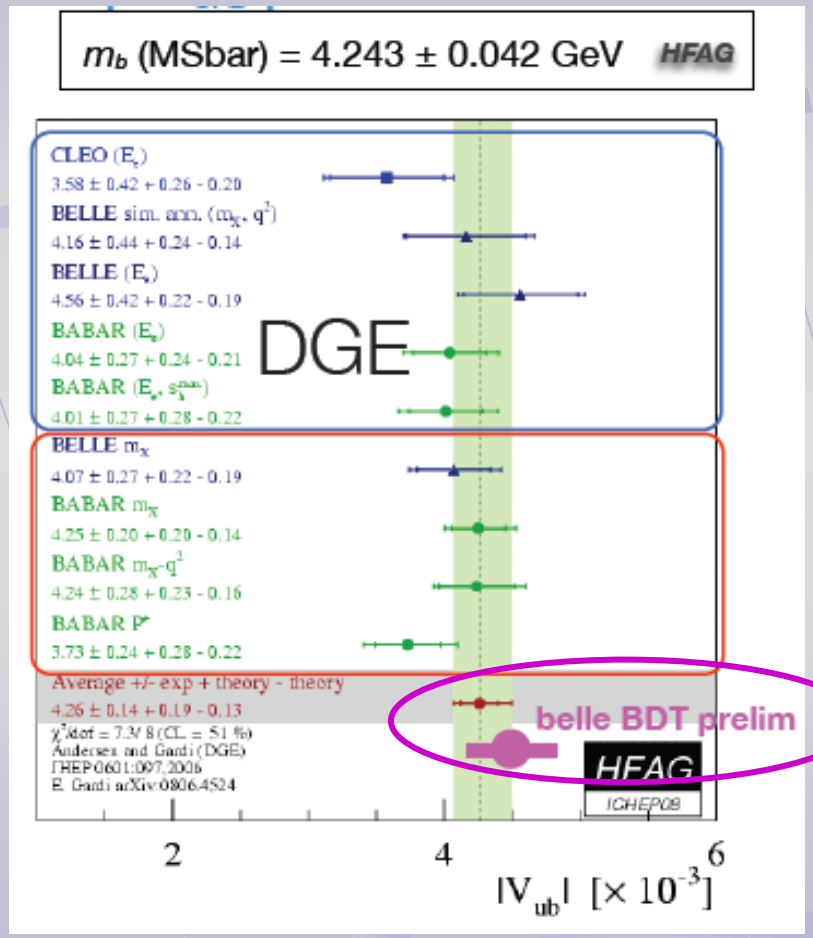


2D fit in q2 mx. (projections shown)

$|V_{ub}|$ from inclusive decays

Using m_b from $B \to X_c \ell \nu$ and $b \to s\gamma$





With latest measurement, inclusive $|V_{ub}|$ does not go down…

Priorities (excl. theory), outlook

- Sort out $B \to D^* \ell \nu$ measurements; Σ BF puzzle
- Further improve $B \to D \ell \nu$ (need Belle results)
- Further improve $B \to \pi \ell \nu$ at high q^2
- Incorporate latest theoretical advances into global fit to $b \to c \ell \nu$ and $b \to s \gamma$ moments
- Further improve full $b \to u \ell \nu$ rate (need BaBar results)
- Lots to do, manpower is decreasing ☹

- $|V_{ub}|$ inclusive/exclusive "tension" becoming significant