Semileptonic B decays at *BABAR*

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representing *BABAR* collaboration

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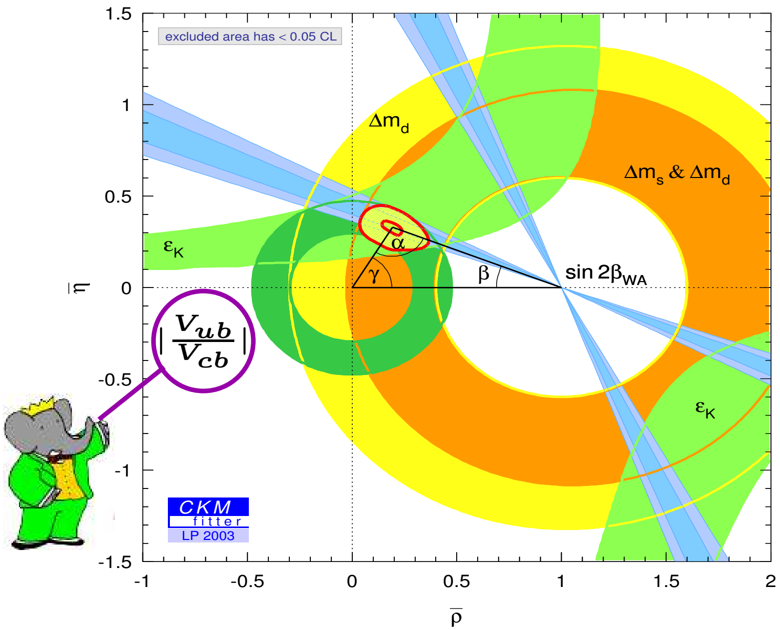
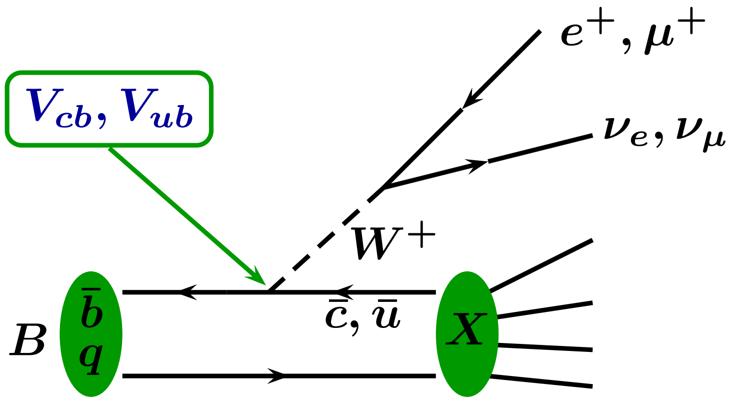
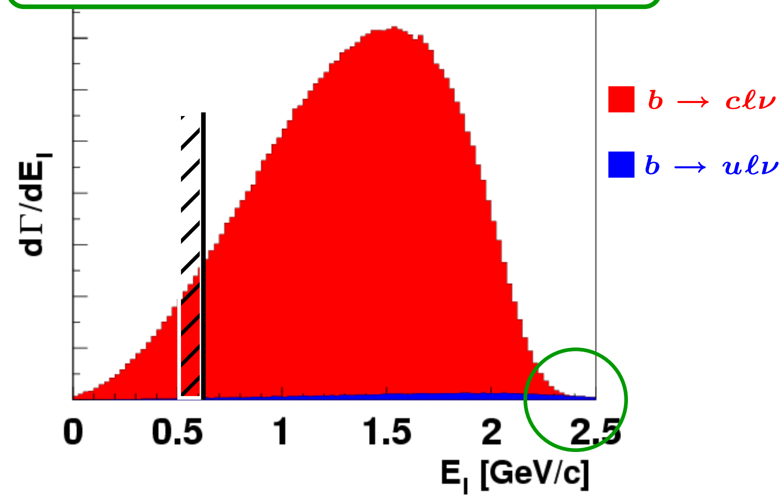


- $|V_{cb}|$
  - Lepton energy moments
  - Hadron mass moments
  - OPE fit
- $|V_{ub}|$
  - $\mathcal{B}(B \to X_u \ell\nu)$
  - $B^{\pm} \to \pi^0 \ell\nu$, "$\rho^0$"$\ell\nu$, $\omega\ell\nu$
- Search for physics beyond SM: $\tau \to \ell\ell\ell$

Les Rencontres de Physique de la Vallée d'Aoste

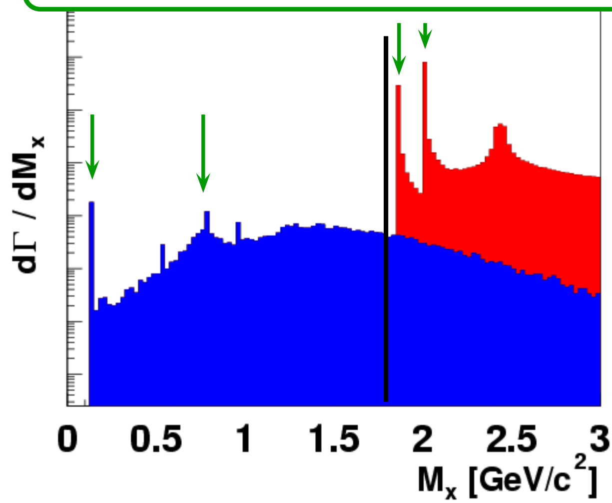


Lepton energy spectrum



- $|V_{cb}| \simeq 0.04$, $\mathcal{B}(B \to X_c \ell \nu) \simeq 10\%$
  - via incl. $\mathcal{B}(B \to X_c \ell \nu)$
  - via incl. E_ℓ, M_{X_c} spectra ← this talk
  - via excl. $\mathcal{B}(B \to D^{(*)} \ell \nu)$

Hadron mass spectrum



- $|V_{ub}| \simeq 0.004$, $\mathcal{B}(B \to X_u \ell \nu) \simeq 0.2\%$
  - via incl. lepton spectrum end point
  - via incl. M_{X_u} spectrum ← this talk
  - via excl. $\mathcal{B}(B \to \rho(\pi) \ell \nu)$

Operator Product Expansion (power series in α_s and $1/m_b$) calculates inclusive rate and moments of the E_ℓ, M_X distributions:

Theoretical uncertainty is 1.5%

Rate :

$$\Gamma_{c\ell\nu} = \frac{G_F^2 m_b^5}{192\pi^3} |V_{cb}|^2 (1 + A_{ew}) A_{pert} A_{nonpert} \cong |V_{cb}|^2 f_{OPE}(a_i)$$

up to α_s^2 and $1/m_b^3$ → 6 parameters

Moments: (E_ℓ, M_X)

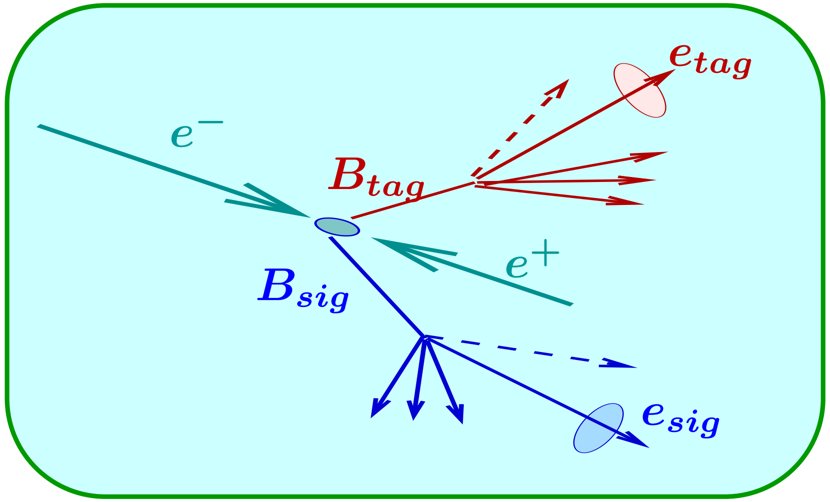
$$< X^n > (E_{cut}) = \left. \frac{\int (X - X^0)^n \frac{d\Gamma}{dX} dX}{\int \frac{d\Gamma}{dX} dX} \right|_{E_\ell > E_{cut}} \cong f'_{OPE}(a_i)$$

Cut on lepton energy

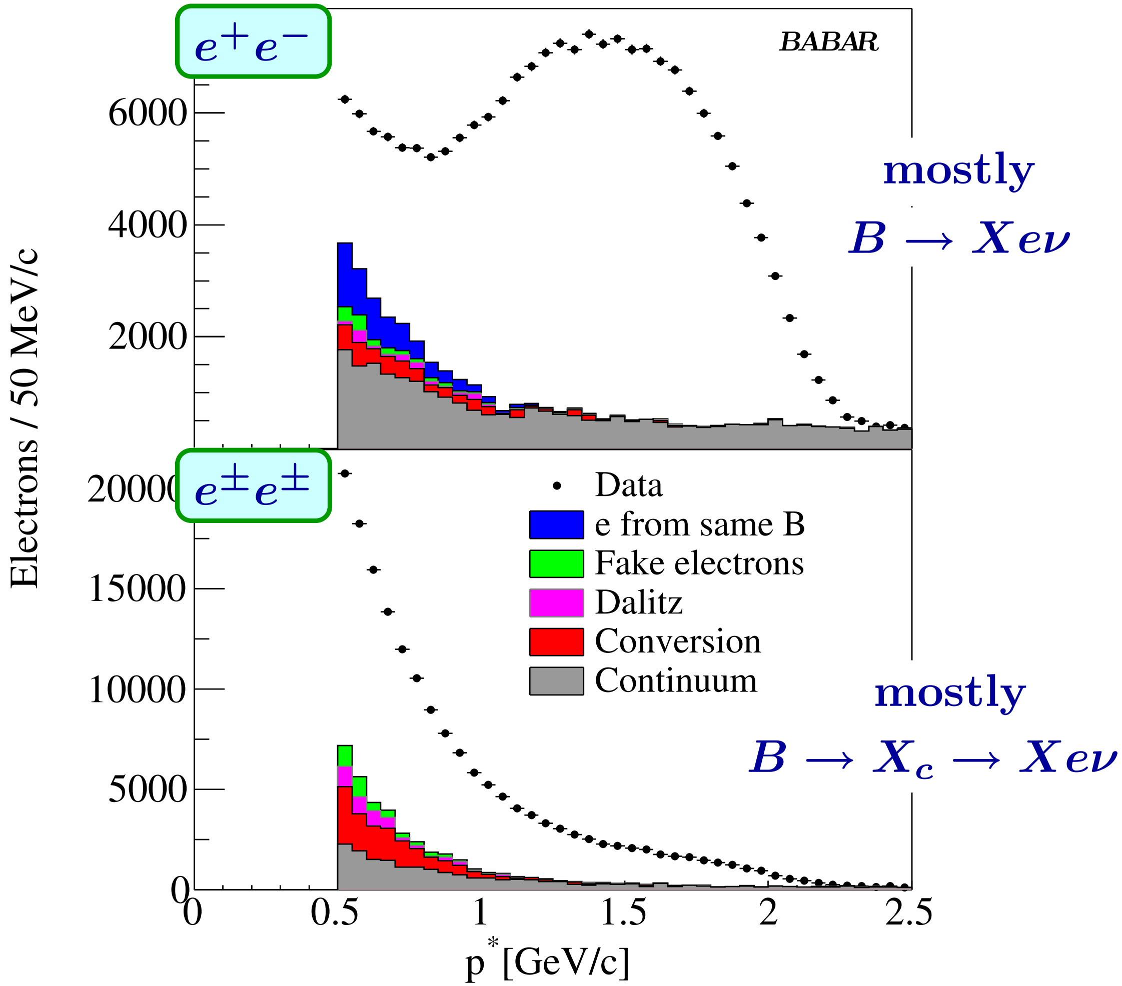
PRD67(2003)054012
NPB665(2003)367

Calculations are performed in different mass schemes

Inclusive $B \to X_c \ell \nu$: Electron Momentum Spectrum



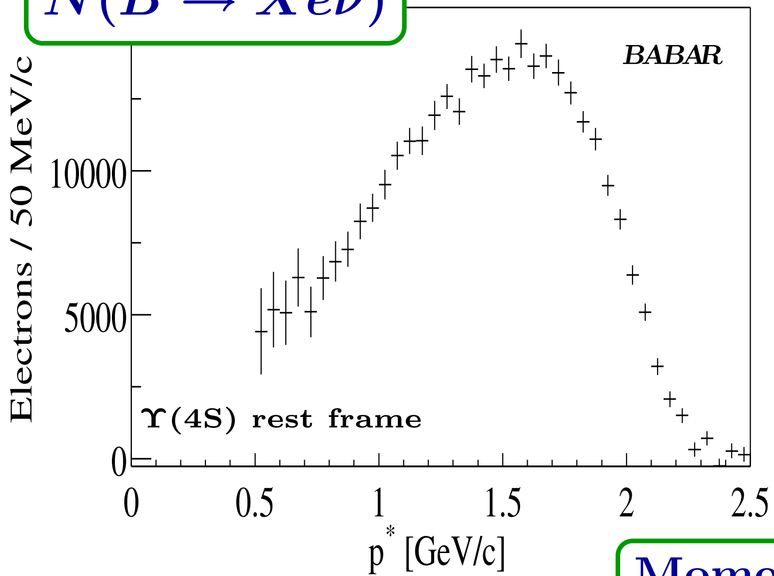
Selection of di-electron events
Statistics is large
Backgrounds are sizable
$e^{\pm}$ identification is important



$$N^{+-} = (1-\chi) \cdot N_{B \to X e\nu} + \chi \cdot N_{B \to X_c \to X e\nu} + N^{+-}_{bgr}$$
$$N^{\pm\pm} = \chi \cdot N_{B \to X e\nu} + (1-\chi) \cdot N_{B \to X_c \to X e\nu} + N^{\pm\pm}_{bgr}$$

where χ is mixing parameter multiplied with fraction of neutral B

$N(B \to X e \nu)$

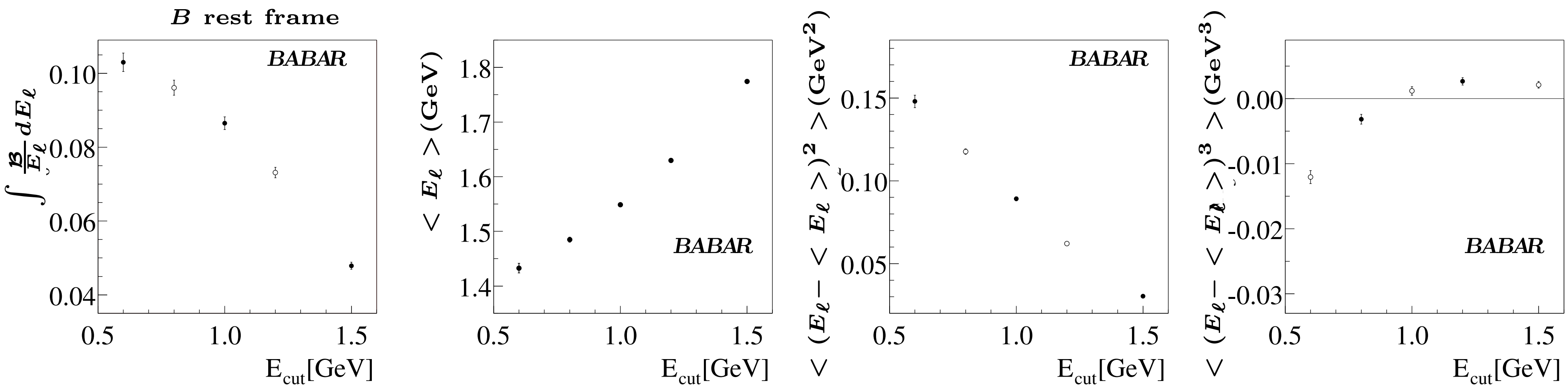


$\int \mathcal{L} dt = 47.4\ \text{fb}^{-1}$

$Br(B \to X e \nu(\gamma))|_{E_{cut} > 0.6\ GeV} =$
$(10.36 \pm 0.06_{stat} \pm 0.23_{sys})\%$

Submitted to PRL

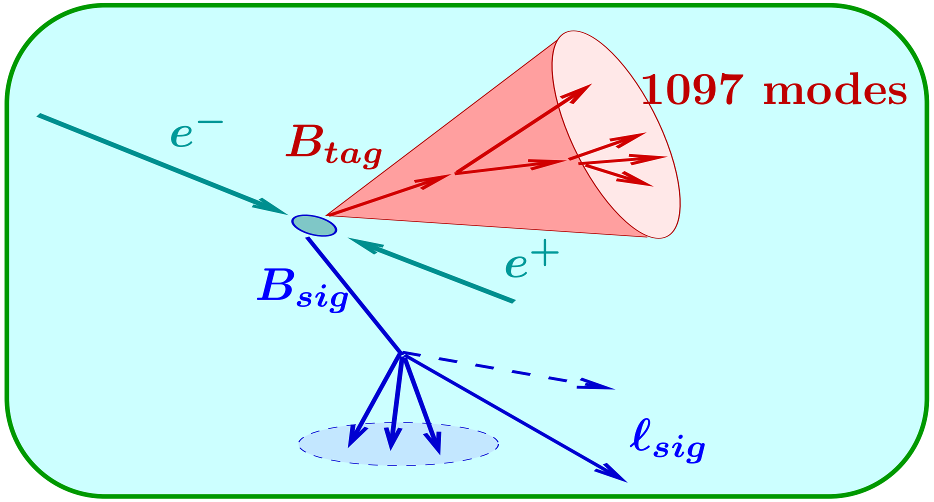
Moments of $B \to X_c \ell \nu$ lepton spectrum as function of E_{cut}



Submitted to PRL

corrected for efficiency and radiation.

points are highly correlated.



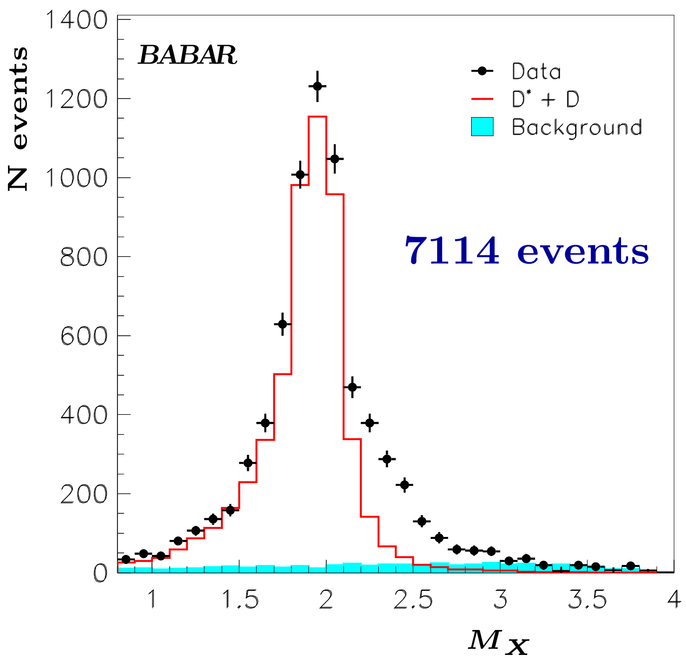
Fully reconstructed tag B

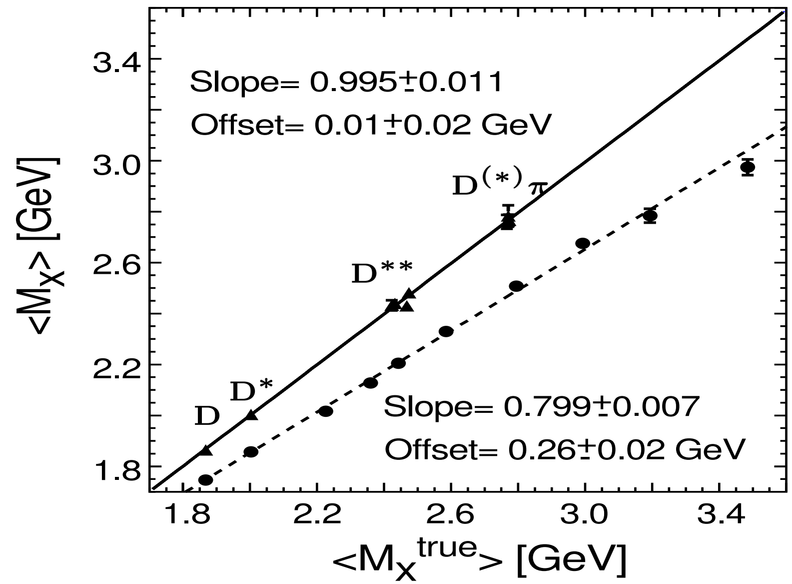
- No missing information
- Backgrounds are small
- Statistics is limited

Signal side: $B \to X_c e \nu$, $B \to X_c \mu \nu$

Fit $\Upsilon(4S) \to B_{tag} X \ell \nu$ each event

Calibrate M_X on MC,
check on D^* data.





Before and after calibration

Inclusive $B \to X_c \ell\nu$: Hadron Mass Spectrum

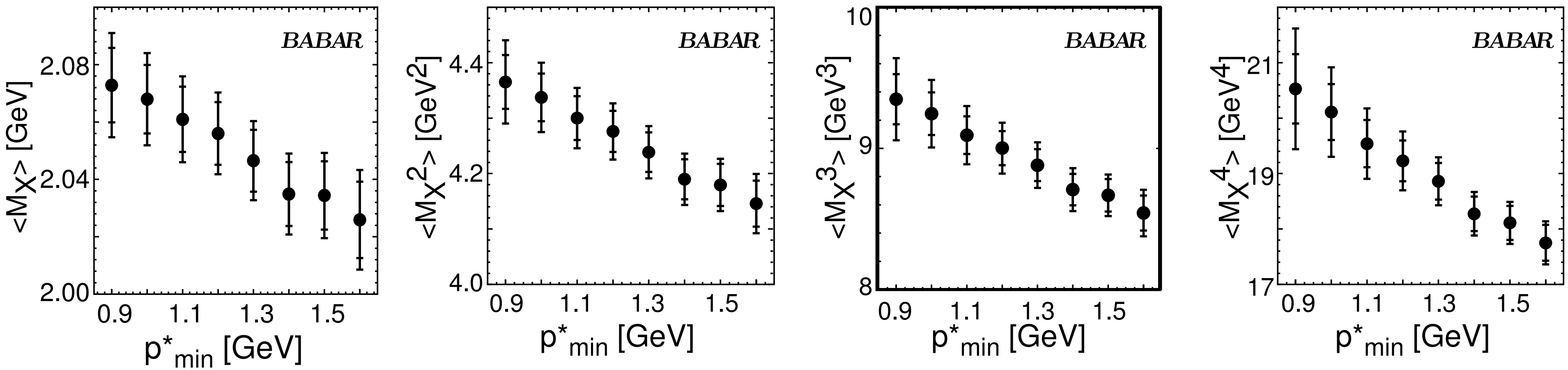
No dependence on the relative fractions and masses of various X_c!

Statistically independent of lepton energy moments measurement

Moments of $B \to X_c \ell\nu$ hadron mass spectrum as function of E_{cut}

$\int \mathcal{L}dt = 82\ \text{fb}^{-1}$

Submitted to PRL (including all tables)



corrected for efficiency and radiation

points are highly correlated.

Taylor expansion

$$|V_{cb}| = \sqrt{\frac{\mathcal{B}_{B\to X_c \ell\nu}}{\tau_B}} \cdot [C_0 + \sum C_i \cdot (a_i - a_0)]$$

$$< X^n > (E_{cut}) = C'_0 + \sum C'_i \cdot (a_i - a_0)$$

Obtain parameters a_i from the fit with no constraints:

- leading order — m_b(1GeV) and m_c(1GeV) - b- and c-quark masses
- $1/m_b^2$ < μ_π^2(1GeV) - *kinetic energy* of the b-quark in the B-meson
- μ_G^2(1GeV) - hyperfine splitting
- $1/m_b^3$ < ρ_D^3(1GeV) - expectation value of Darwin operator
- ρ_{LS}^3(1GeV) - equivalent of the spin-orbital interaction in atoms

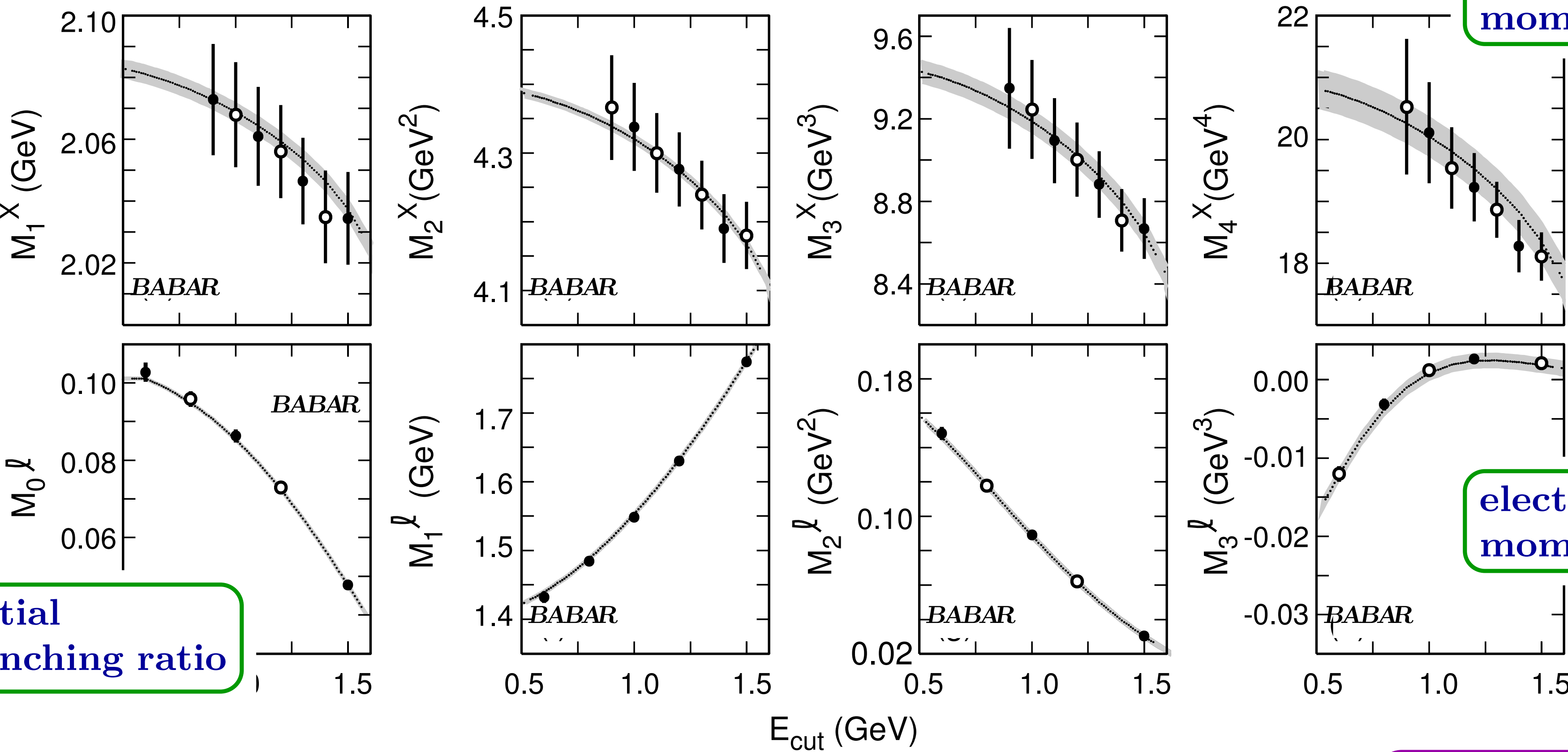
$B_{B\to X_c \ell\nu}$ is extrapolation of $< E_\ell^0 >$ to $E_{cut} = 0$

Calculations are taken from Gambino and Uraltsev hep-ph/0401063.

Simultaneous fit of electron energy moments and hadron mass.
Only black points are used in the fit

preliminary

hadron mass moments



electron energy moments

partial branching ratio

Bands correspond to the theoretical uncertainties

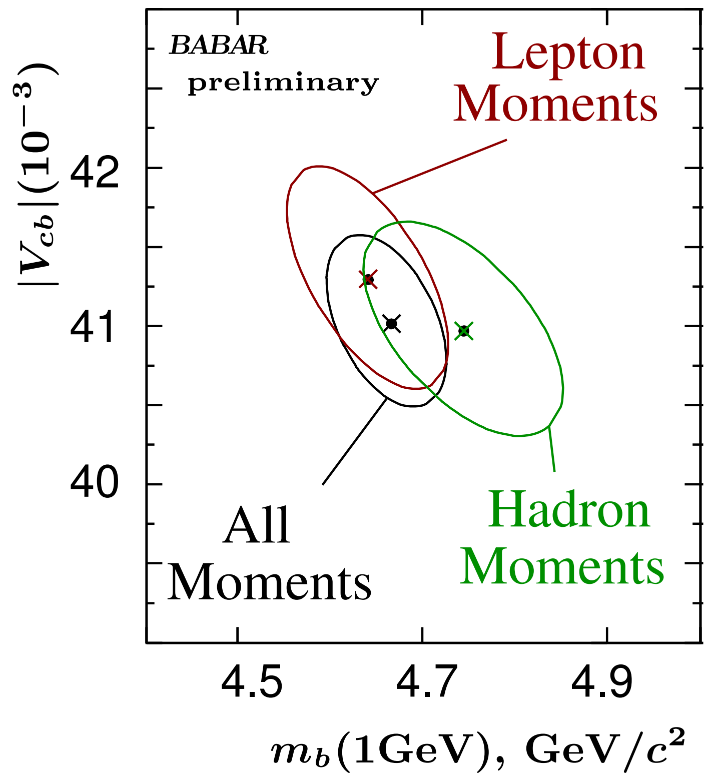
Fit quality: $\frac{\chi^2}{ndof} = \frac{14.8}{20}$

Fit E_ℓ and M_X moments separately

Constrained fit:

$\Delta\chi^2 = 1$ ellipses

- Different theoretical accuracy for moments:
  $< M_X^n >$ miss part of E_{cut}-dependent perturbative corrections
- Experimental uncertainty for $< M_X^n >$ is larger than for $< E_\ell^n >$
- The variation of α_s have very small impact on result
- The separate fit of moments (with constrained μ_G^2 and ρ_{LS}^3) are in very good agreement



$< M_X >$ are fitted with $< E_\ell^0 >$

preliminary

$$|V_{cb}| = (41.25 \pm 0.45_{exp} \pm 0.41_{OPE} \pm 0.62_{th})\, 10^{-3}$$

$$\mathcal{B}_{B \to X_c \ell \nu} = (10.62 \pm 0.16_{exp} \pm 0.06_{OPE})\%$$

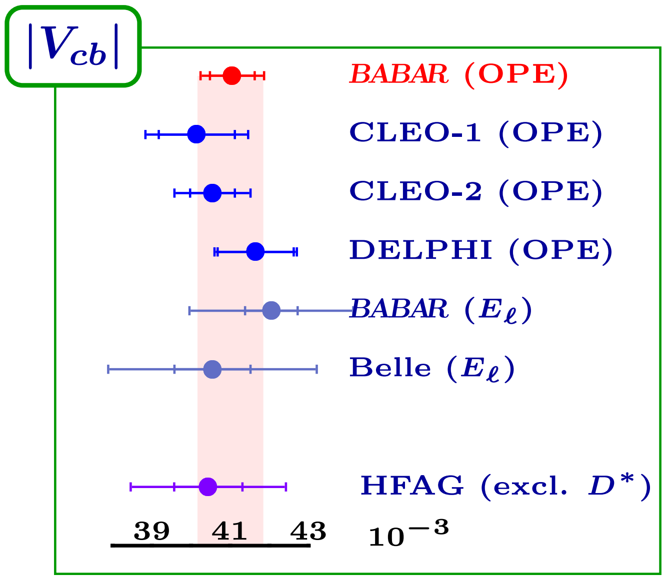
$$m_b(1\mathrm{GeV}) = (4.65 \pm 0.05_{exp} \pm 0.04_{OPE})\mathrm{GeV}$$

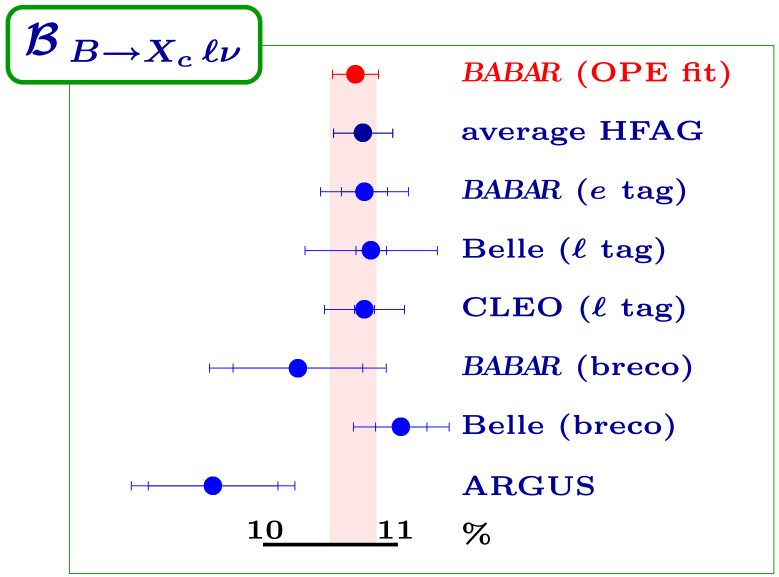
$$(m_b - m_c)(1\mathrm{GeV}) = (3.43 \pm 0.02_{exp} \pm 0.02_{OPE})\mathrm{GeV}$$

independent of scheme

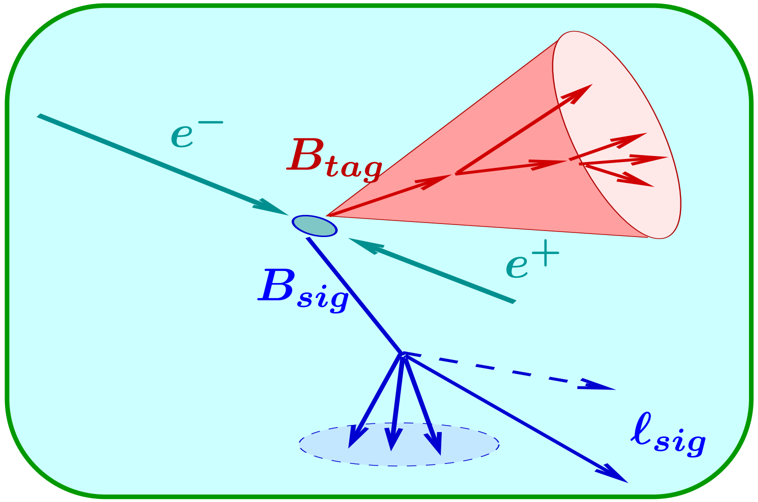
$$\bar{m}_b(\bar{m}_b) = (4.26 \pm 0.05)\ \mathrm{GeV}$$

$$m_c(1\mathrm{GeV}) = (1.22 \pm 0.09)\ \mathrm{GeV}$$



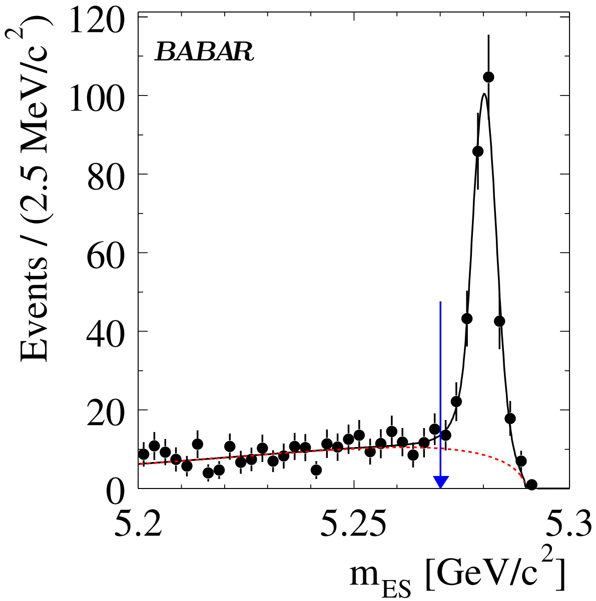


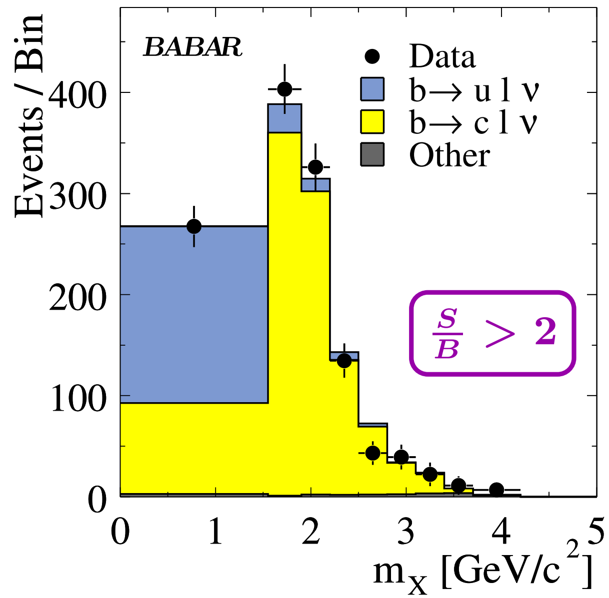
Different OPE schemes



Fully reconstructed tag B.
Suppress $B \to X_c \ell\nu$ on signal side.
Get $N_{B\to X\ell\nu}$ from m_{ES} in each M_X bin
Fit M_X to get $N_{B\to X_u \ell\nu}$
(Use wide bin for $M_X < 1.55\mathrm{GeV}/c^2$ to minimize MC systematics)

Measure $\mathcal{B}(B \to X_u \ell\nu)/\mathcal{B}(B \to X\ell\nu)$





Accepted by PRL $\int \mathcal{L}dt = 82\ \text{fb}^{-1}$

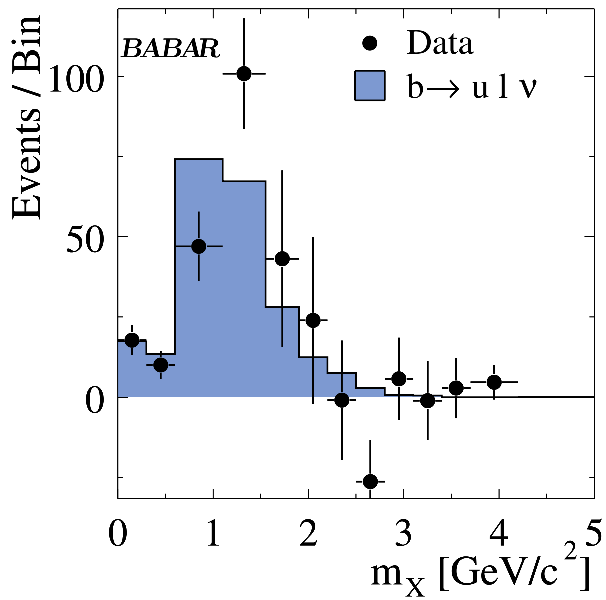
$$\frac{\mathcal{B}(B\to X_u \ell\nu)}{\mathcal{B}(B\to X\ell\nu)} = (2.06 \pm 0.25_{stat} \pm 0.23_{sys} \pm 0.36_{th})\,10^{-2}$$
$$\mathcal{B}(B\to X_u \ell\nu) = (2.24 \pm 0.27_{stat} \pm 0.26_{sys} \pm 0.39_{th})\,10^{-3}$$

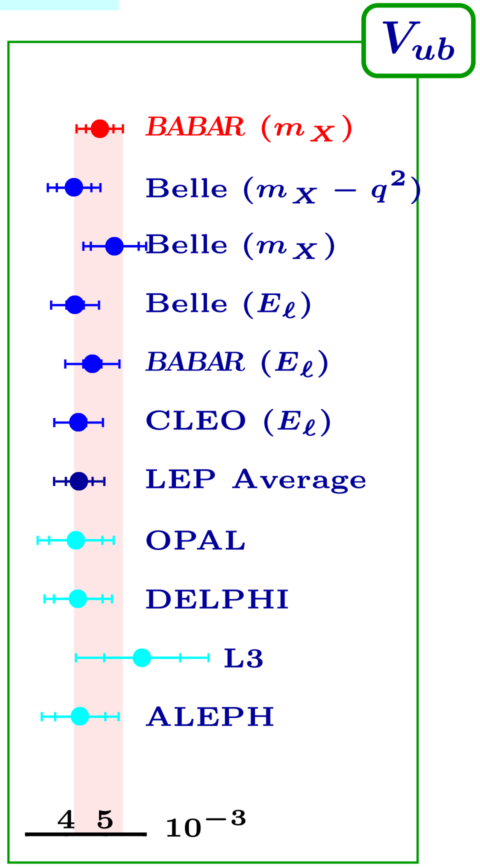
$$|V_{ub}| = 0.00445 \cdot \sqrt{\frac{\mathcal{B}(b\to u\ell\nu)}{0.002}\,\frac{1.55\text{ps}}{\tau_b}} \cdot (1 \pm 0.056_{th})$$

(calculations from 1999)

$$|V_{ub}| = (4.62 \pm 0.28_{stat} \pm 0.27_{sys} \pm 0.40_{MC} \pm 0.26_{th})\,10^{-3}$$

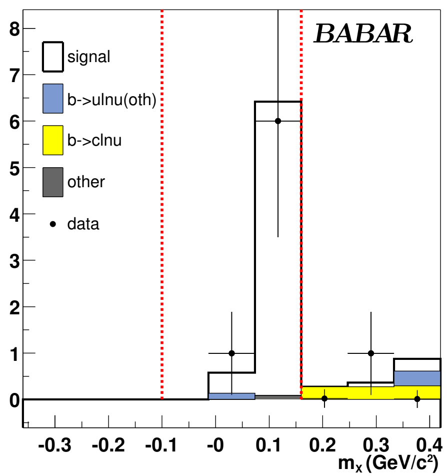
No cut on q^2 is applied. Shape function uncertainty is not fully understood



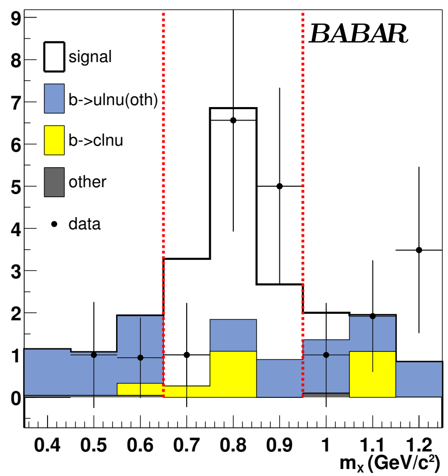


Exclusive decays $B \to X_u \ell\nu$ are identified in the same sample ($\int \mathcal{L}dt = 82\text{fb}^{-1}$):

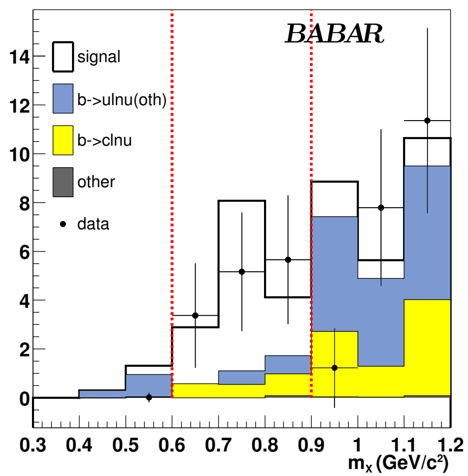
$B^{\pm} \to \pi^0 \ell\nu$



$B^{\pm} \to$ "ρ^0" $\ell\nu$



$B^{\pm} \to \omega \ell\nu$



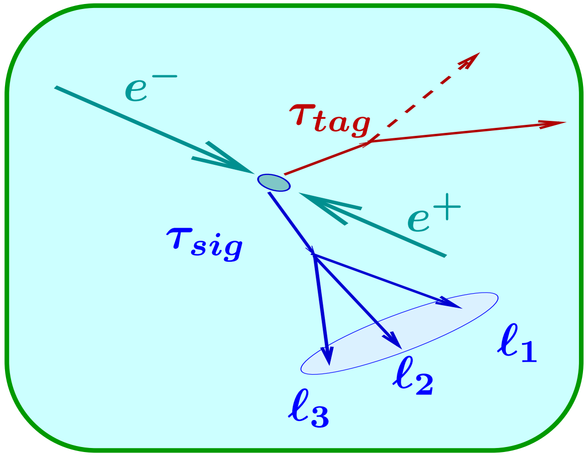
preliminary

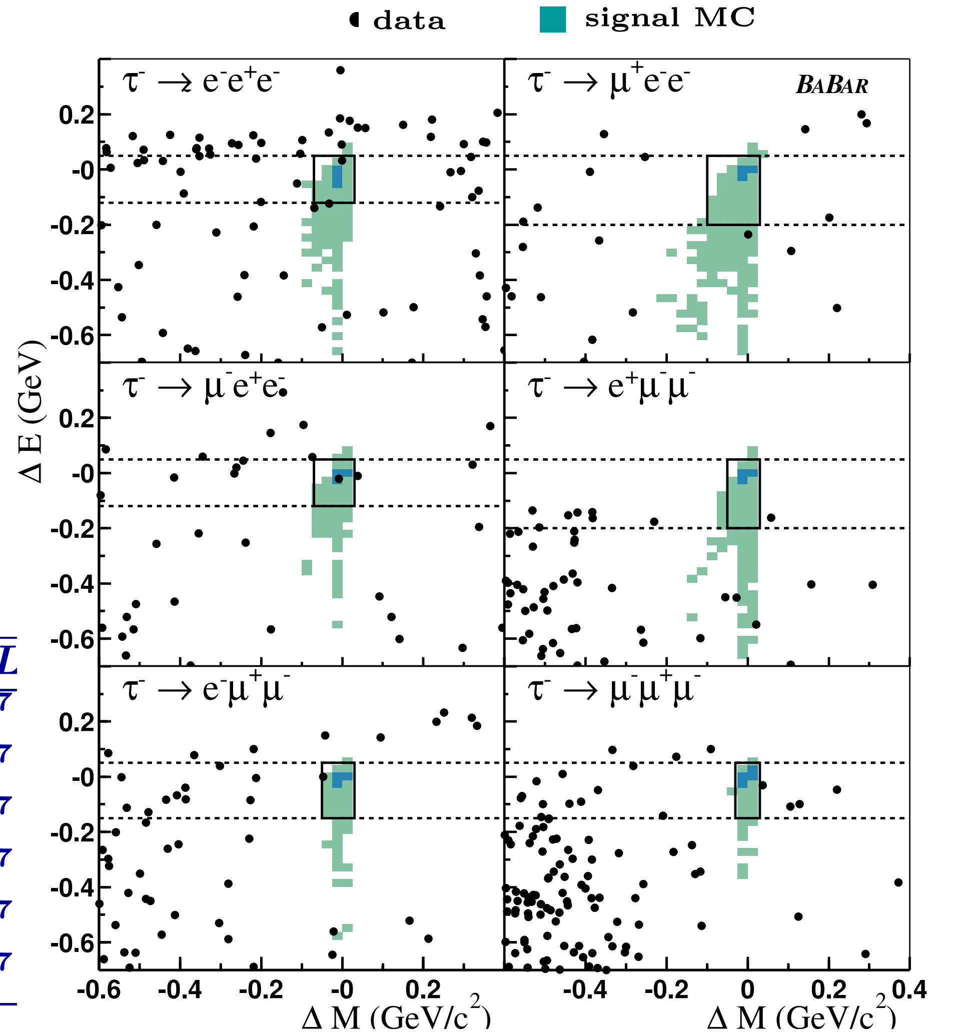
$$\mathcal{B}\,(B^{\pm} \to \pi^0 \ell\nu) = (0.78 \pm 0.32_{stat} \pm 0.13_{sys})10^{-4}$$
$$\mathcal{B}\,(B^{\pm} \to \text{``}\rho^0\text{''} \ell\nu) = (0.99 \pm 0.37_{stat} \pm 0.19_{sys})10^{-4}$$
$$\mathcal{B}\,(B^{\pm} \to \omega \ell\nu) = (2.20 \pm 0.92_{stat} \pm 0.57_{sys})10^{-4}$$

"ρ^0" is $\pi^+\pi^-$ with $0.65 < m_{\pi^+\pi^-} < 0.95$ GeV$/c^2$

Search for signal of non-SM physics:

Sensitive to SUSY, heavy sterile neutrino, etc





accepted by PRL

1-3 topology events

$E(\ell\ell\ell) = E_{cms}/2$, $m(\ell\ell\ell) = m_\tau$

$\int \mathcal{L}dt = 92\ \mathrm{fb}^{-1}$

Decay	N	$N_{\rm bgd}$	$\mathcal{B}_{\rm UL}$@90%CL
$\tau^- \rightarrow e^-e^+e^-$	1	1.51 ± 0.11	$< 2.0 \times 10^{-7}$
$\tau^- \rightarrow \mu^+e^-e^-$	0	0.37 ± 0.08	$< 1.1 \times 10^{-7}$
$\tau^- \rightarrow \mu^-e^+e^-$	1	0.62 ± 0.10	$< 2.7 \times 10^{-7}$
$\tau^- \rightarrow e^+\mu^-\mu^-$	0	0.21 ± 0.07	$< 1.3 \times 10^{-7}$
$\tau^- \rightarrow e^-\mu^+\mu^-$	1	0.39 ± 0.08	$< 3.3 \times 10^{-7}$
$\tau^- \rightarrow \mu^-\mu^+\mu^-$	0	0.31 ± 0.09	$< 1.9 \times 10^{-7}$

Summary

- New measurements of semileptonic B decays :
  - moments of lepton energy up to 3rd order as function of E_{cut}
  - moments of hadron mass up to 4th order as function of E_{cut}
  - which are used in most precise OPE fit with no external parameters and constrains:

    $|V_{cb}| = (41.25 \pm 0.45_{exp} \pm 0.41_{OPE} \pm 0.62_{th})\, 10^{-3}$

    $\mathcal{B}_{B \to X_c \ell\nu} = (10.62 \pm 0.16_{exp} \pm 0.06_{OPE})\%$

  and precise determination of m_b and m_c

- Measurement of $\mathcal{B}(B \to X_u \ell\nu)/\mathcal{B}(B \to X\ell\nu)$ on clean sample

  $|V_{ub}| = (4.62 \pm 0.28_{stat} \pm 0.27_{sys} \pm 0.40_{MC} \pm 0.26_{th})\, 10^{-3}$

- New results in τ physics : upper limits on the fraction of lepton flavor violation decays

  $\mathcal{B}_{\tau \to \ell\ell\ell} < 1 - 3 \cdot 10^{-7}$ at 90% CL

More results soon!