

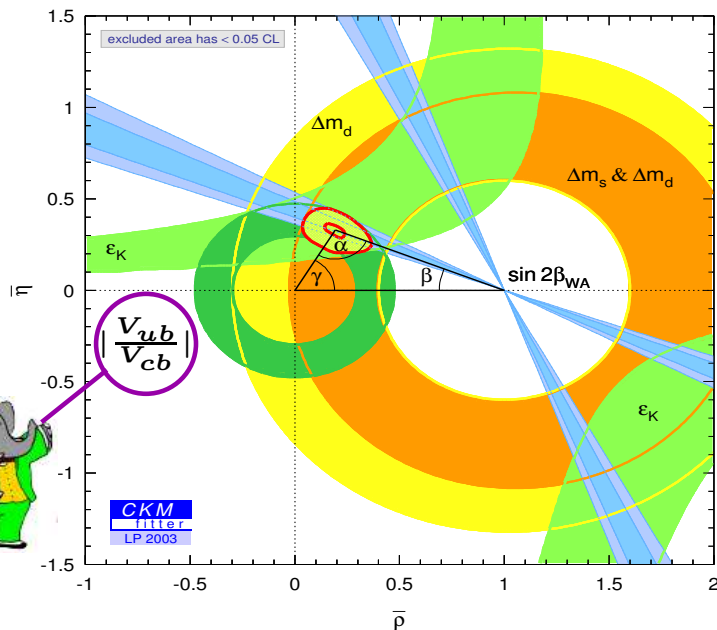


Semileptonic B decays at $BABAR$

Olga Igonkina (University of Oregon)

representing $BABAR$ collaboration

March 4, 2004

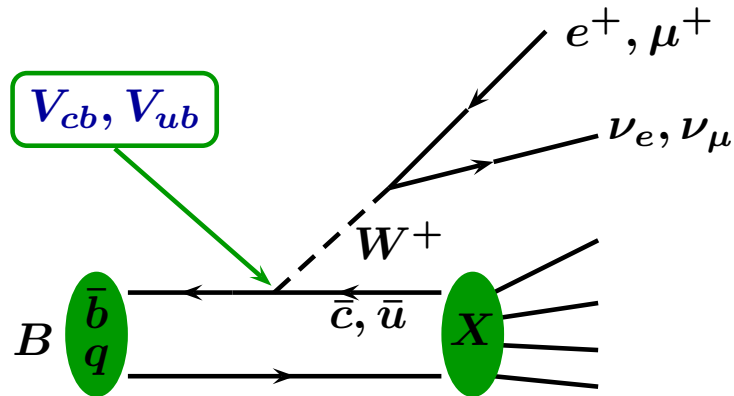


- $|V_{cb}|$
- Lepton energy moments
- Hadron mass moments
- OPE fit
- $|V_{ub}|$
- $\mathcal{B}(B \rightarrow X_u \ell \nu)$
- $B^\pm \rightarrow \pi^0 \ell \nu, \text{“}\rho^0\text{”} \ell \nu, \omega \ell \nu$
- Search for physics beyond SM: $\tau \rightarrow \ell \ell \ell$

Les Rencontres de Physique
de la Vallée d'Aoste



Measurements of $|V_{xb}|$ via $B \rightarrow X\ell\nu$



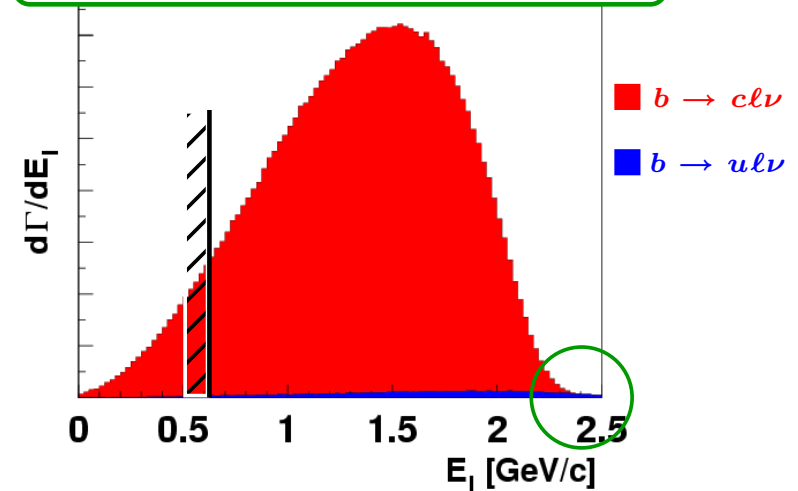
● $|V_{cb}| \simeq 0.04$, $\mathcal{B}(B \rightarrow X_c \ell \nu) \simeq 10\%$

- via incl. $\mathcal{B}(B \rightarrow X_c \ell \nu)$
- via incl. E_ℓ, M_{X_c} spectra
- via excl. $\mathcal{B}(B \rightarrow D^{(*)} \ell \nu)$

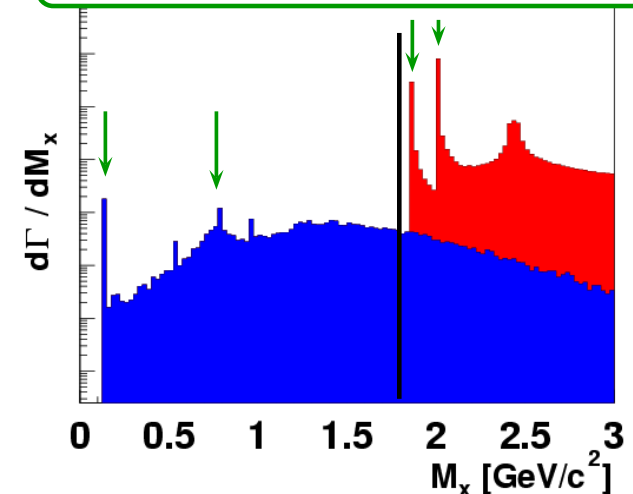
● $|V_{ub}| \simeq 0.004$, $\mathcal{B}(B \rightarrow X_u \ell \nu) \simeq 0.2\%$

- via incl. lepton spectrum end point
- via incl. M_{X_u} spectrum
- via excl. $\mathcal{B}(B \rightarrow \rho(\pi) \ell \nu)$

Lepton energy spectrum



Hadron mass spectrum





Calculating $|V_{cb}|$ from inclusive $B \rightarrow X_c \ell \nu$

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

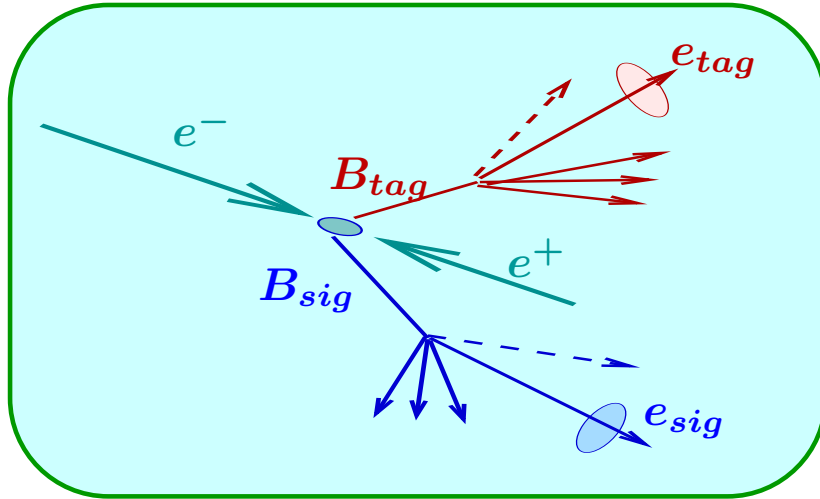
Cut on lepton energy

Calculations are performed in different mass schemes

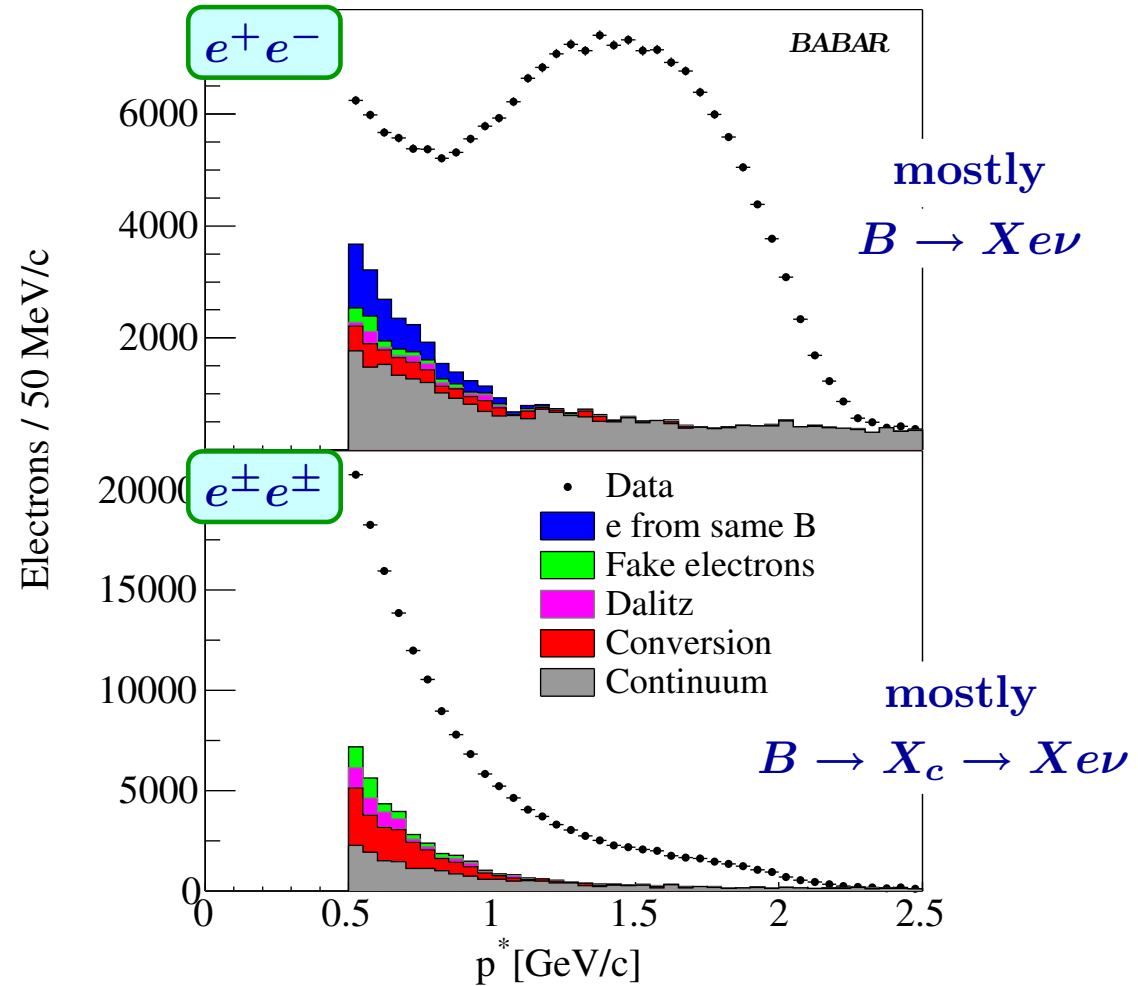
PRD67(2003)054012
NPB665(2003)367



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



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



$$N^{+-} = (1 - \chi) \cdot N_{B \rightarrow X_e \nu} + \chi \cdot N_{B \rightarrow X_c \rightarrow X_e \nu} + N_{bgr}^{+-}$$

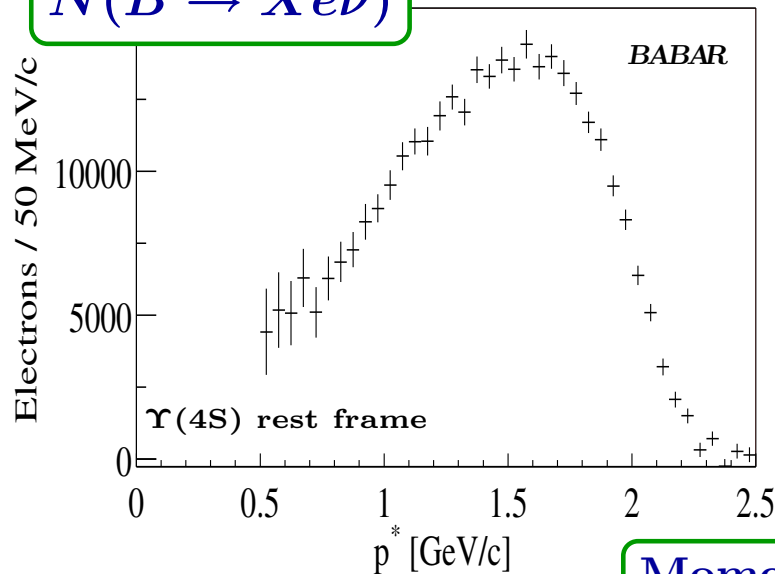
$$N^{\pm\pm} = \chi \cdot N_{B \rightarrow X_e \nu} + (1 - \chi) \cdot N_{B \rightarrow X_c \rightarrow X_e \nu} + N_{bgr}^{\pm\pm}$$

where χ is mixing parameter multiplied with fraction of neutral B



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

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

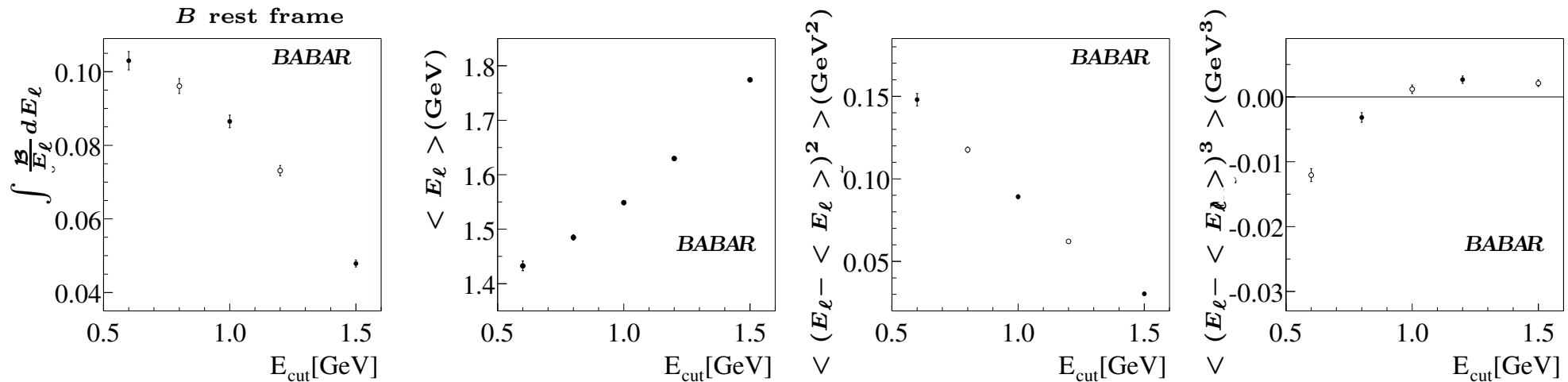


$$\int \mathcal{L} dt = 47.4 \text{ fb}^{-1}$$

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

Submitted to PRL

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



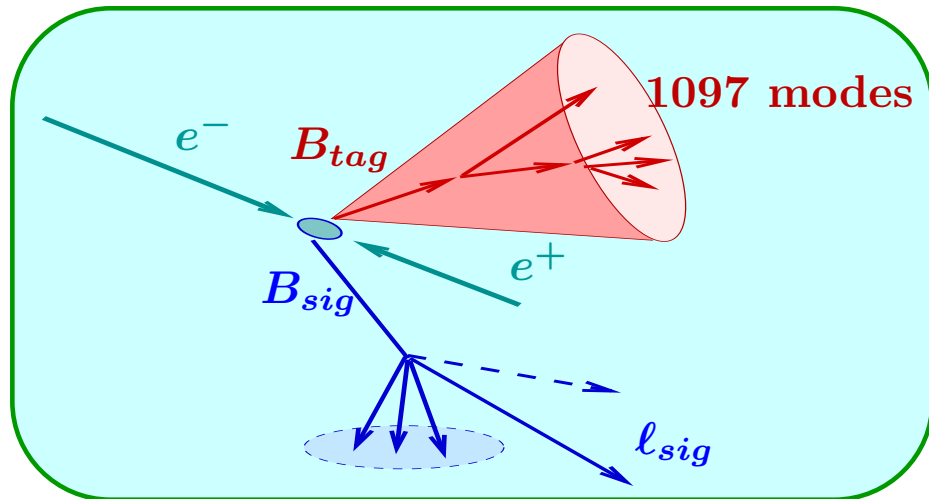
Submitted to PRL

corrected for efficiency and radiation.

points are highly correlated.



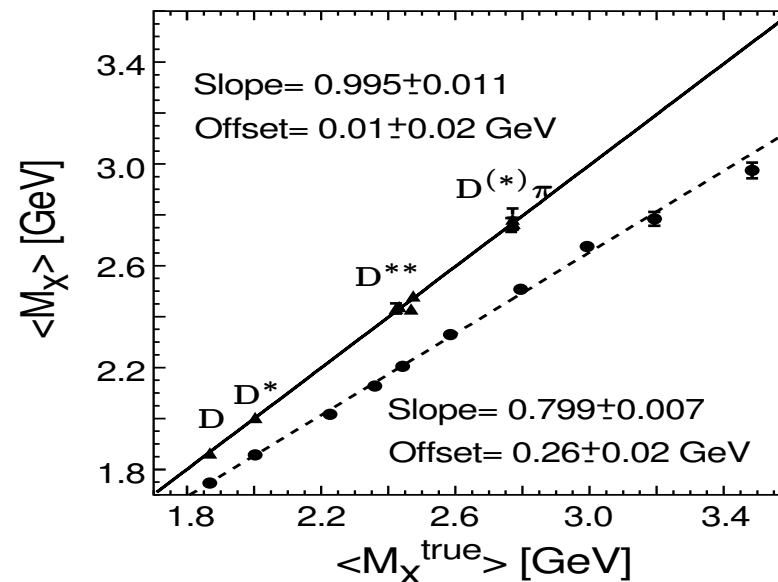
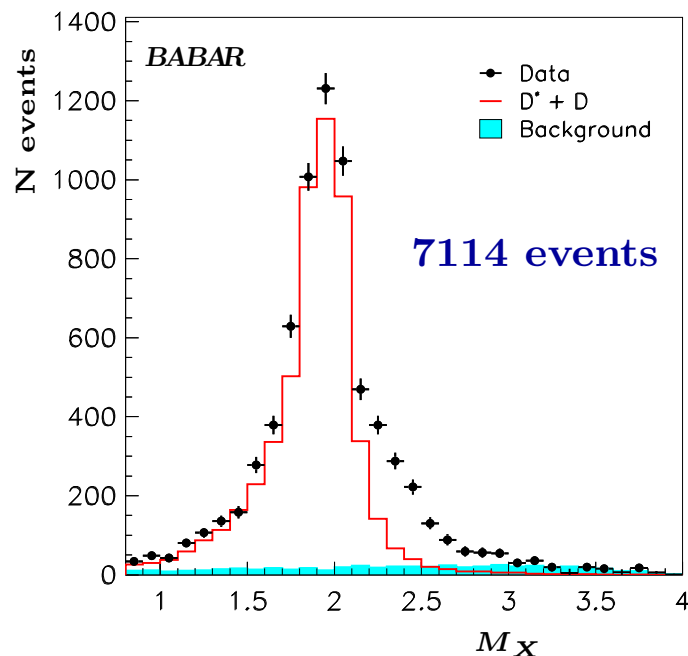
Inclusive $B \rightarrow X_c \ell \nu$: Hadron Mass Spectrum



Fully reconstructed tag B
No missing information
Backgrounds are small
Statistics is limited

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

Fit $\Upsilon(4S) \rightarrow B_{tag} X \ell \nu$ each event
Calibrate M_X on MC,
check on D^* data.



Before and after calibration



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

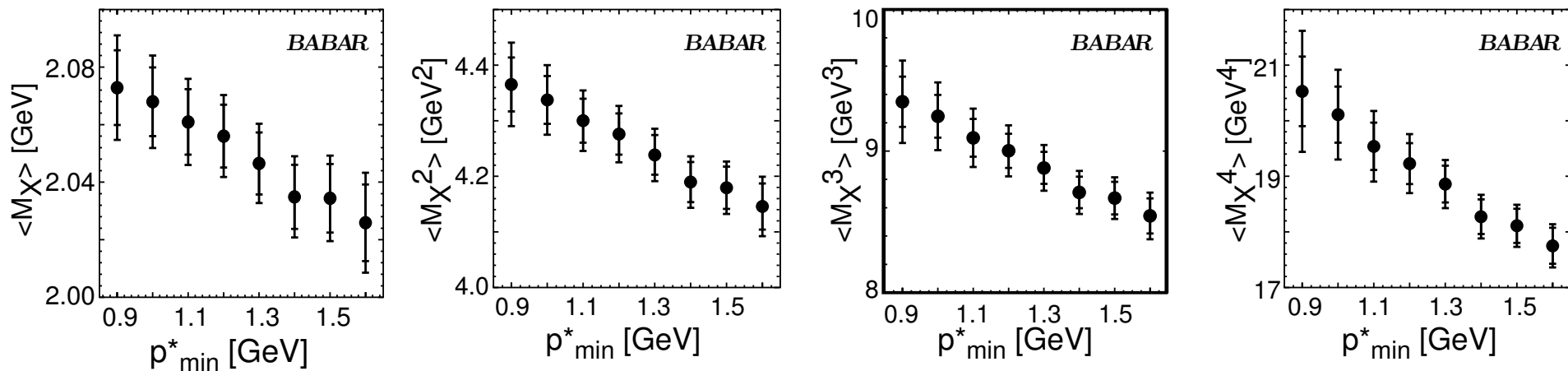


No dependence on the relative fractions and masses of various X_c !
Statistically independent of lepton energy moments measurement

Moments of $B \rightarrow X_c \ell \nu$ 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

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

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

Obtain parameters a_i from the fit with no constraints:

- leading order — ● $m_b(1\text{GeV})$ and $m_c(1\text{GeV})$ - b - and c -quark masses
- $1/m_b^2$ — ● $\mu_\pi^2(1\text{GeV})$ - *kinetic energy* of the b -quark in the B -meson
- $\mu_G^2(1\text{GeV})$ - hyperfine splitting
- $1/m_b^3$ — ● $\rho_D^3(1\text{GeV})$ - expectation value of Darwin operator
- $\rho_{LS}^3(1\text{GeV})$ - equivalent of the spin-orbital interaction in atoms

$\mathcal{B}_{B \rightarrow X_c \ell \nu}$ is extrapolation of $\langle E_\ell^0 \rangle$ to $E_{cut} = 0$

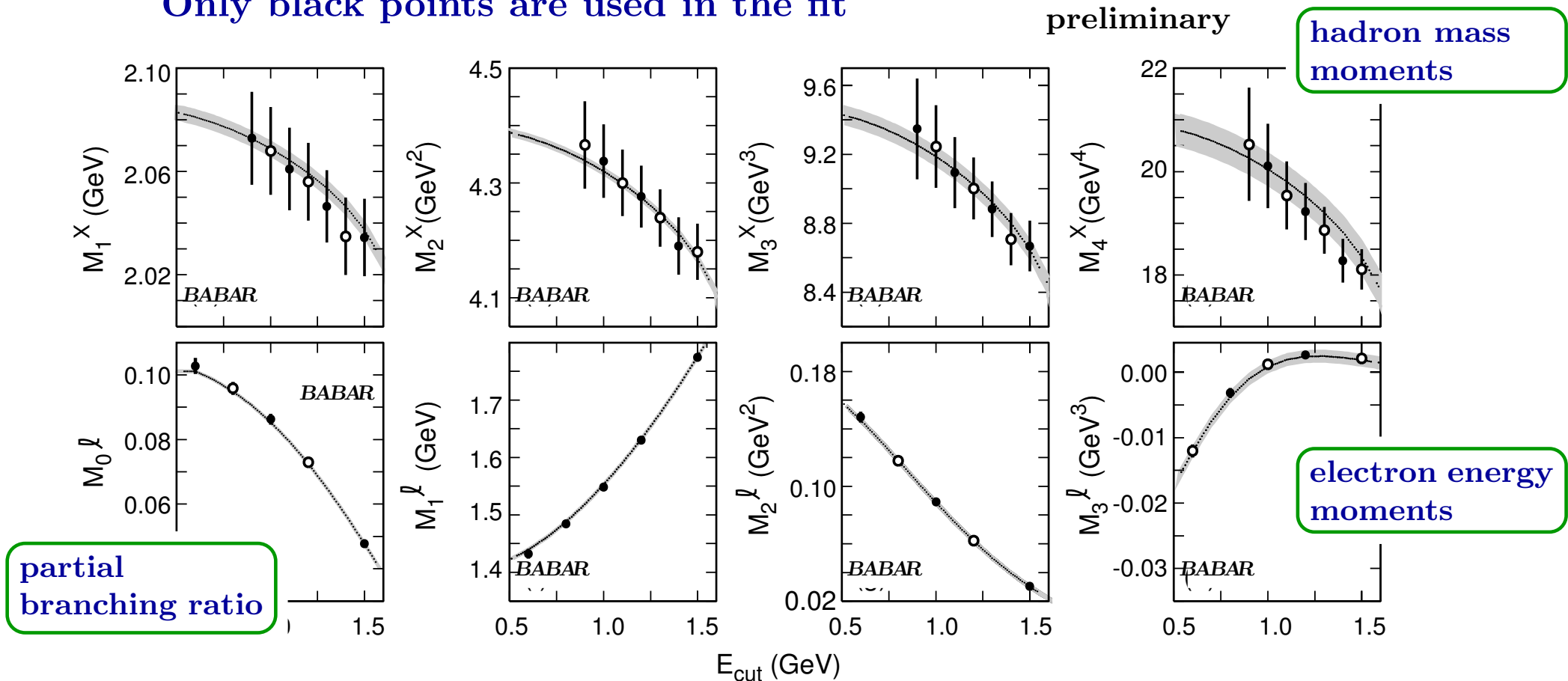


Simultaneous fit of E_ℓ and M_X moments



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



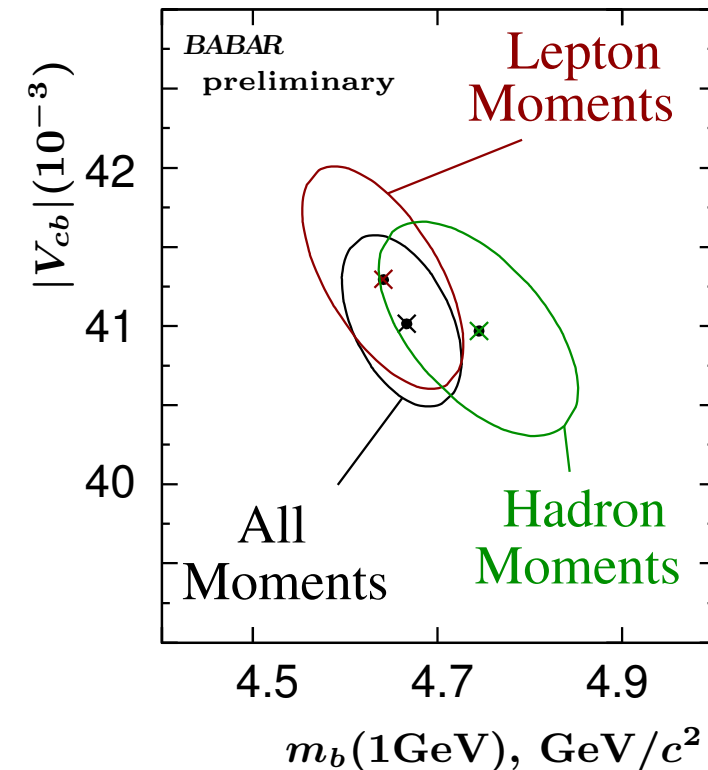
Bands correspond to the theoretical uncertainties



- Different theoretical accuracy for moments:
 $\langle M_X^n \rangle$ miss part of E_{cut} -dependent perturbative corrections
- Experimental uncertainty for $\langle M_X^n \rangle$ is larger than for $\langle E_\ell^n \rangle$
- 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

Constrained fit:

$\Delta\chi^2 = 1$ ellipses



$\langle M_X \rangle$ are fitted with $\langle E_\ell^0 \rangle$



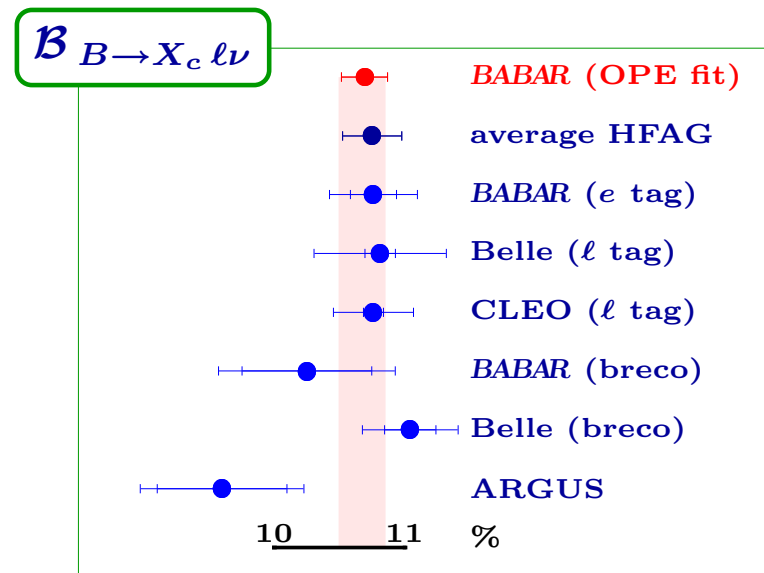
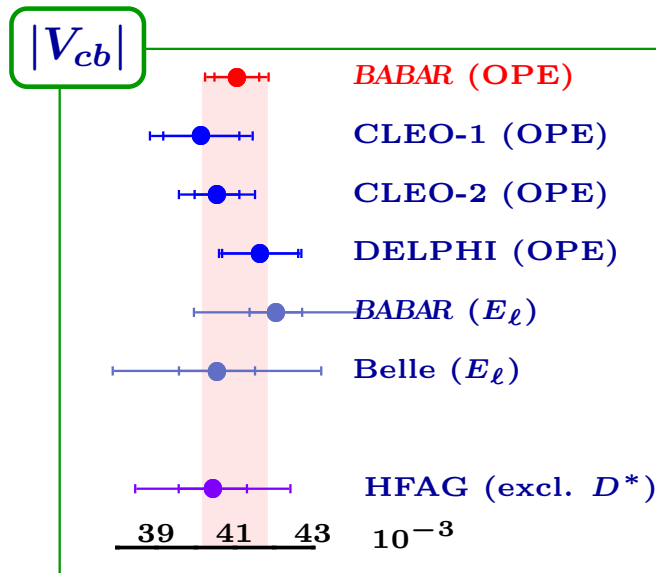
preliminary

$$\begin{aligned}|V_{cb}| &= (41.25 \pm 0.45_{exp} \pm 0.41_{OPE} \pm 0.62_{th}) 10^{-3} \\ \mathcal{B}_{B \rightarrow X_c \ell \nu} &= (10.62 \pm 0.16_{exp} \pm 0.06_{OPE})\% \\ m_b(1\text{GeV}) &= (4.65 \pm 0.05_{exp} \pm 0.04_{OPE})\text{GeV} \\ (m_b - m_c)(1\text{GeV}) &= (3.43 \pm 0.02_{exp} \pm 0.02_{OPE})\text{GeV}\end{aligned}$$

independent of scheme

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

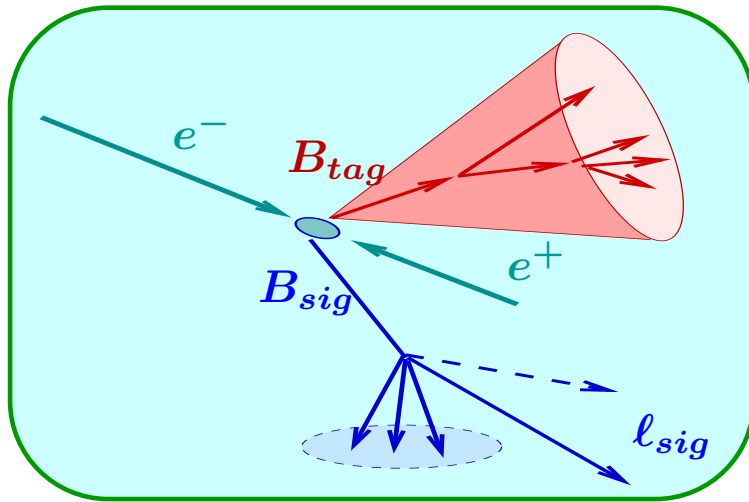
$$m_c(1\text{GeV}) = (1.22 \pm 0.09) \text{ GeV}$$



Different OPE schemes



Inclusive $B \rightarrow X_u \ell \nu$, low M_X spectrum



Fully reconstructed tag B .

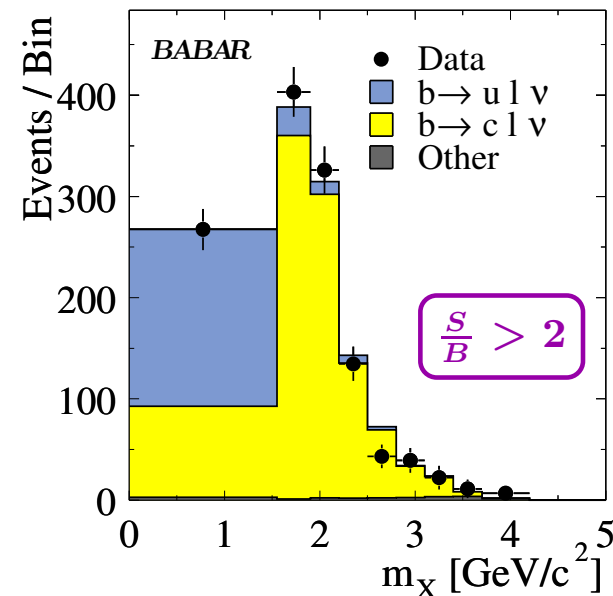
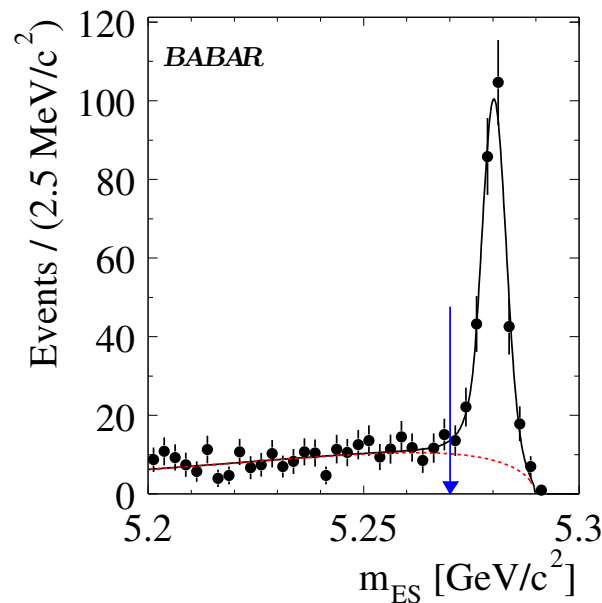
Suppress $B \rightarrow X_c \ell \nu$ on signal side.

Get $N_{B \rightarrow X \ell \nu}$ from m_{ES} in each M_X bin

Fit M_X to get $N_{B \rightarrow X_u \ell \nu}$

(Use wide bin for $M_X < 1.55 \text{ GeV}/c^2$ to minimize MC systematics)

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





Inclusive measurement of V_{ub}



Accepted by PRL

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

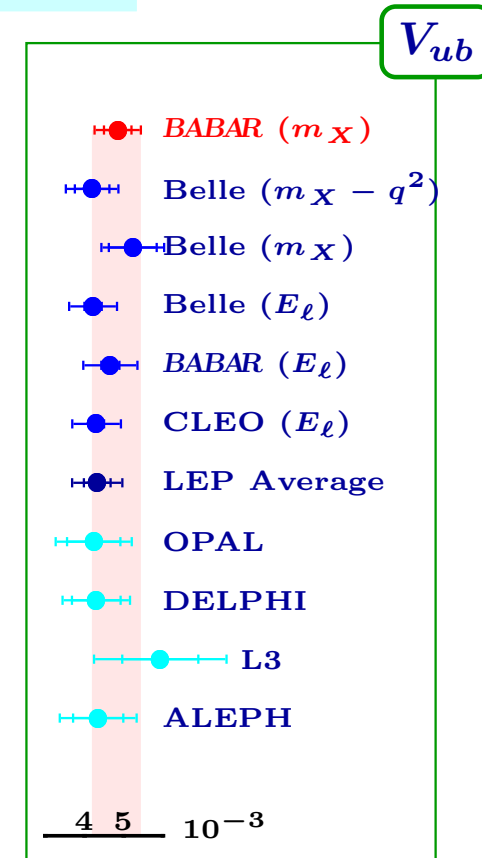
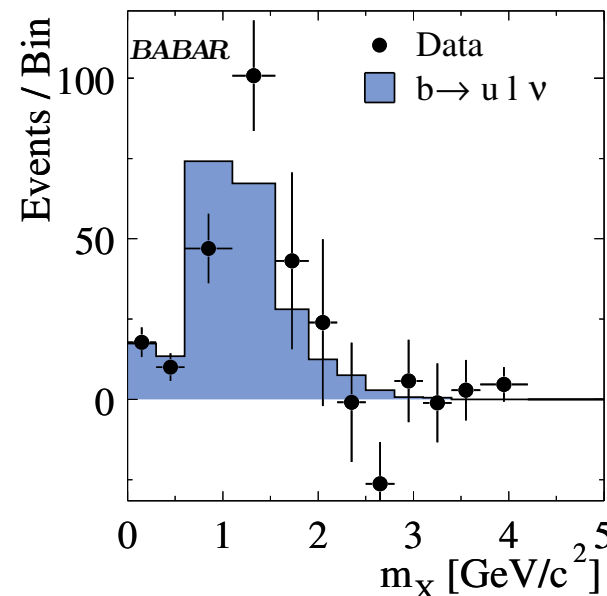
$$\frac{\mathcal{B}(B \rightarrow X_u \ell \nu)}{\mathcal{B}(B \rightarrow X \ell \nu)} = (2.06 \pm 0.25_{stat} \pm 0.23_{sys} \pm 0.36_{th}) 10^{-2}$$
$$\mathcal{B}(B \rightarrow X_u \ell \nu) = (2.24 \pm 0.27_{stat} \pm 0.26_{sys} \pm 0.39_{th}) 10^{-3}$$

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

(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



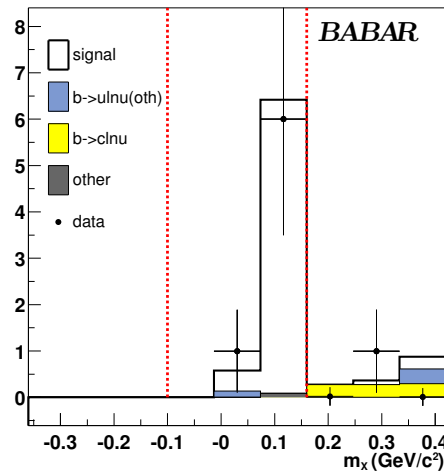


Exclusive $B \rightarrow X_u \ell \nu$ channels

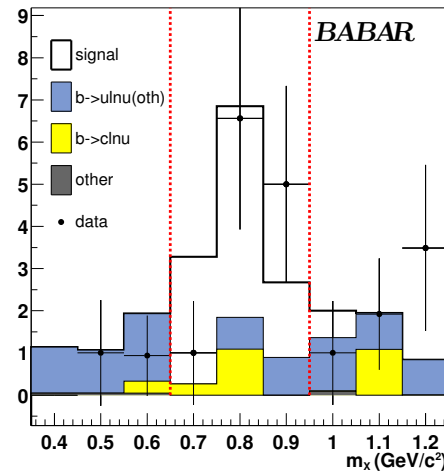


Exclusive decays $B \rightarrow X_u \ell \nu$ are identified in the same sample ($\int \mathcal{L} dt = 82 \text{ fb}^{-1}$):

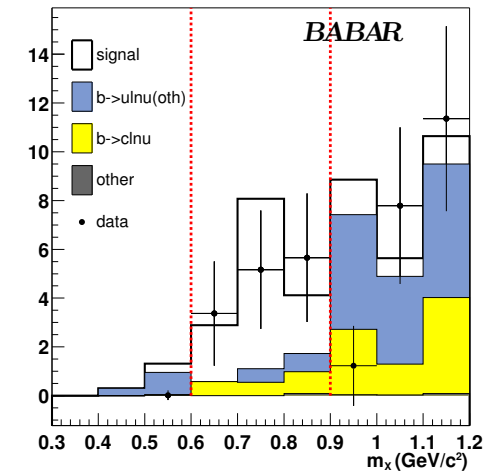
$$B^\pm \rightarrow \pi^0 \ell \nu$$



$$B^\pm \rightarrow \text{“}\rho^0\text{”} \ell \nu$$



$$B^\pm \rightarrow \omega \ell \nu$$



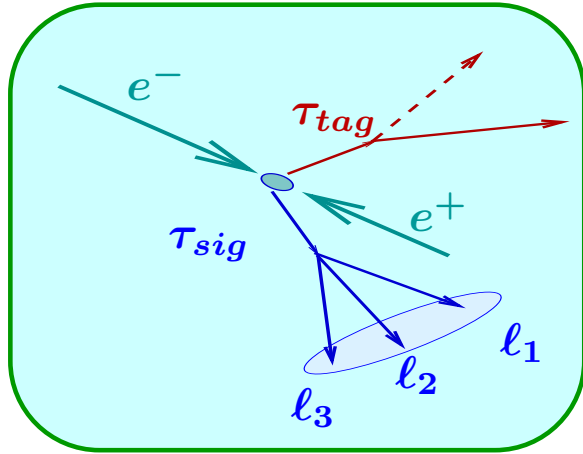
preliminary

$$\mathcal{B}(B^\pm \rightarrow \pi^0 \ell \nu) = (0.78 \pm 0.32_{stat} \pm 0.13_{sys}) 10^{-4}$$

$$\mathcal{B}(B^\pm \rightarrow \text{“}\rho^0\text{”} \ell \nu) = (0.99 \pm 0.37_{stat} \pm 0.19_{sys}) 10^{-4}$$

$$\mathcal{B}(B^\pm \rightarrow \omega \ell \nu) = (2.20 \pm 0.92_{stat} \pm 0.57_{sys}) 10^{-4}$$

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



1-3 topology events

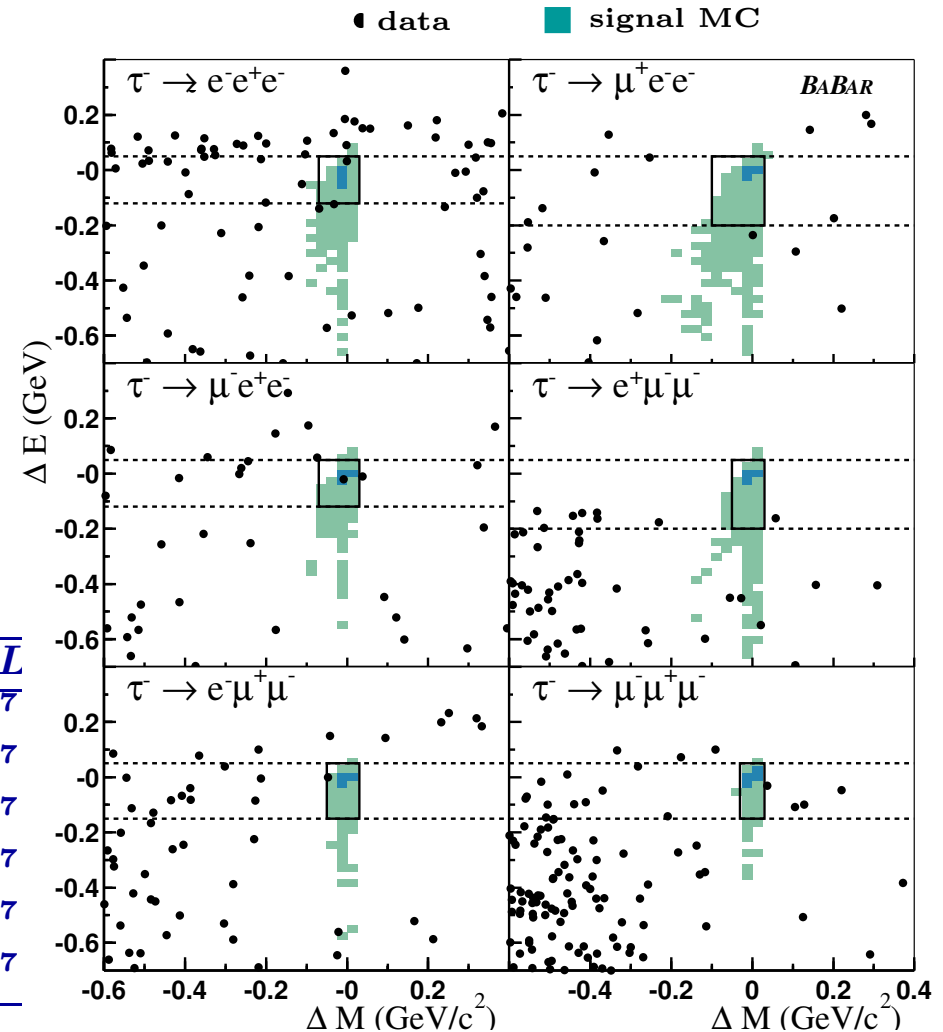
$$E(lll) = E_{cms}/2, m(lll) = m_{\tau}$$

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

Decay	N	N_{bgd}	$\mathcal{B}_{\text{UL}} @ 90\% CL$
$\tau^- \rightarrow e^- e^+ e^-$	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	$< 1.9 \times 10^{-7}$

Search for signal of non-SM physics:

Sensitive to SUSY, heavy sterile neutrino, etc



accepted by PRL



- 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:

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

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

and precise determination of m_b and m_c

- Measurement of $\mathcal{B}(B \rightarrow X_u \ell \nu) / \mathcal{B}(B \rightarrow X \ell \nu)$ 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

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

More results soon!

