Semileptonic Decays: Recoil Technique

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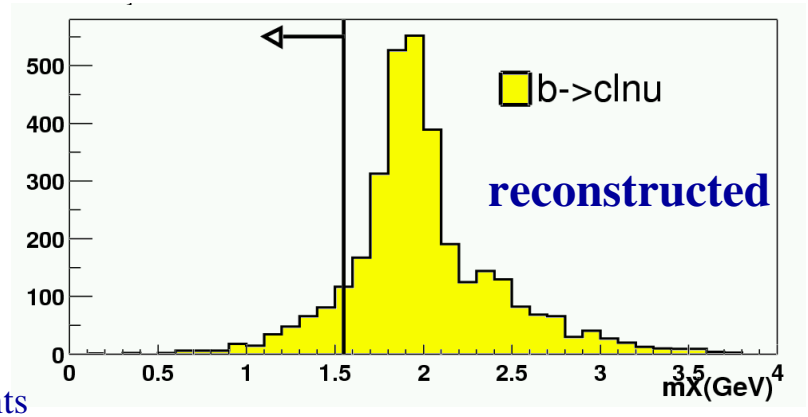
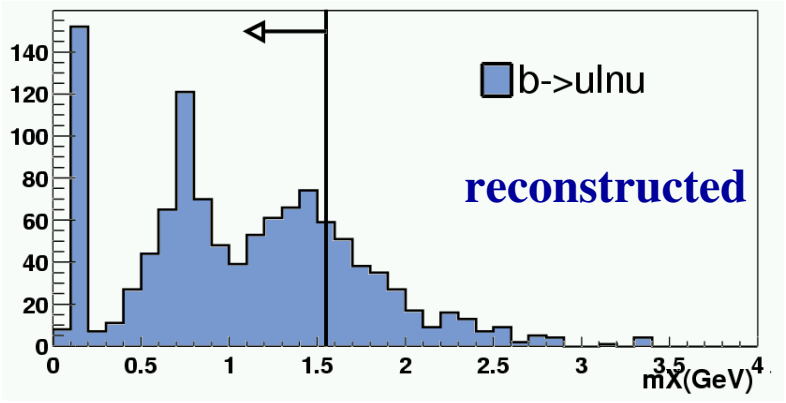
Inclusive V_{ub} Analysis

- Fully reconstruct one B
- B_{recoil} selection and reconstruction of the X system $B \rightarrow X_u l \nu$:
  - **One and only one lepton** with p*> 1 GeV/c
  - **Correlation between lepton charge and B_{reco} flavor** (B^0 mixing is corrected)
  - **Cut on the missing mass:** $M_{miss}^2 < 0.5 GeV^2$,
  - **charge conservation:** $Q_{tot}=0$
  - **Partially reconstructed neutrino** to reject $B^0 \rightarrow D^* l \nu$ events
  - **kinematic fit (2-C):** improve hadronic mass resolution
- Separate $B \rightarrow X_u l \nu$ in signal enriched and depleted:
  - ***signal enriched:*** veto on $K^{\pm}$ and K_S
    - **used to perform the measurement**
  - ***signal depleted :*** one or more $K^{\pm}$ or K_S in the event
    - **used as control sample**
- Systematics reduced by measuring

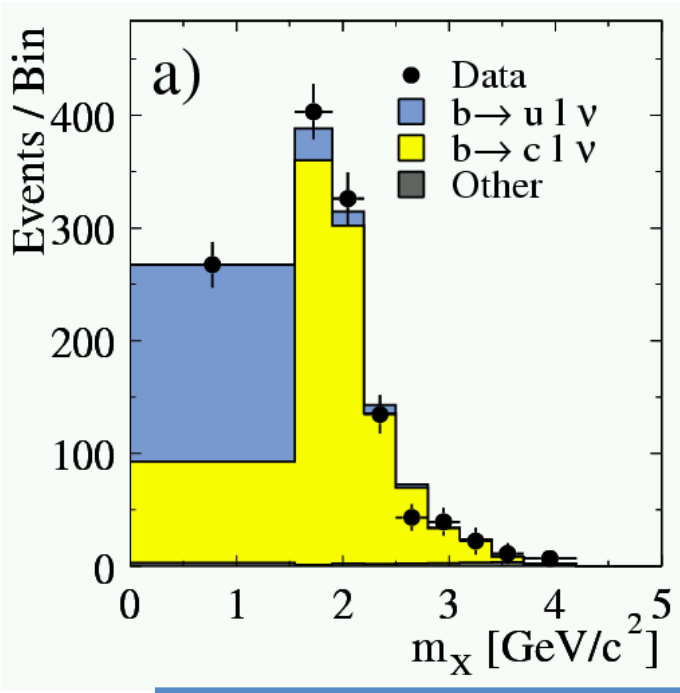
$$R_{u/sl}=B(B \rightarrow X_u l \nu)/B(B \rightarrow X l \nu)$$



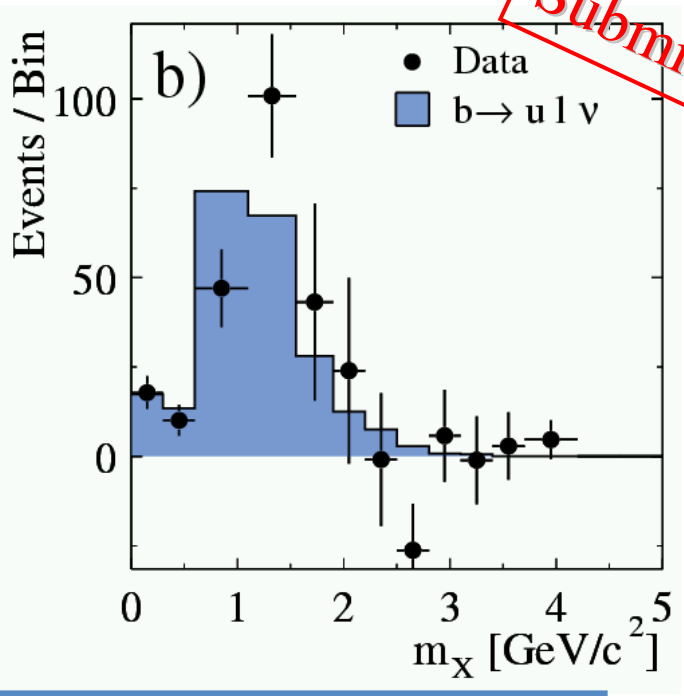


Inclusive V_{ub} Analysis

Fit to the mX distribution



Subtracted spectrum



Submitted to PRL

$$B(\overline{B} \to X_u l\overline{\nu}) = (2.24 \pm 0.27_{stat} \pm 0.26_{syst} \pm 0.39_{thsyst\_mx}) \cdot 10^{-3}$$

$$\frac{B(B^+ \to X_u l\overline{\nu})}{B(B^+ \to X l\overline{\nu})} \frac{B(\overline{B^0} \to X l\overline{\nu})}{B(\overline{B^0} \to X_u l\overline{\nu})} = 0.72 \pm 0.18_{stat} \pm 0.19_{syst}$$

$$|V_{ub}| = (4.62 \pm 0.27_{stat} \pm 0.26_{syst} \pm 0.39_{thsyst\_mx;B\to V_{ub}}) \cdot 10^{-3}$$

Inclusive V_{ub} Analysis: Perspectives

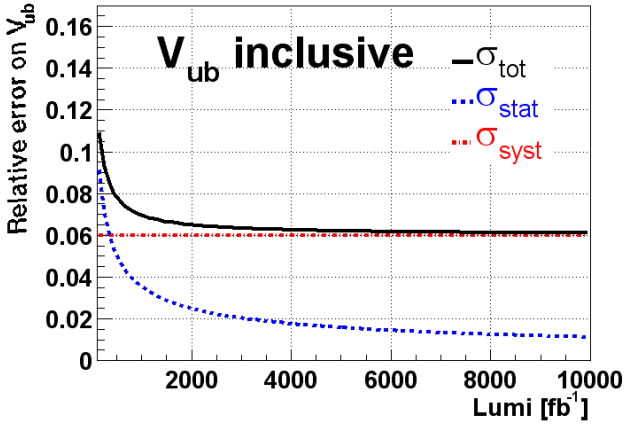
This analysis (as it is now) will be limited by sistematics pretty soon (200-300 fb^{-1})

But it can be upgraded, for instance:

- q^2 vs M_X approach (see Bauer et al. *hep-ph/0111387*)
- combination of variables for a shape function independent approach (see Ciuchini et al. *ph/0204140*)

This methods have lower efficiencies and then require higher statistics

Assuming a theo. error of 5% and an experimental syst. error of 3% on V_{ub} we get:



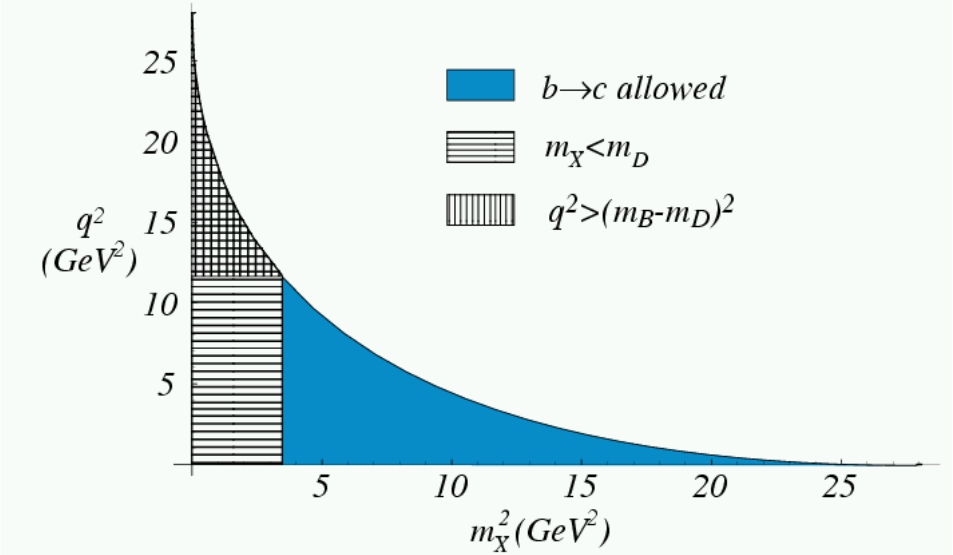
Questions:

are we able to keep experimental systematics under control with higher luminosity?

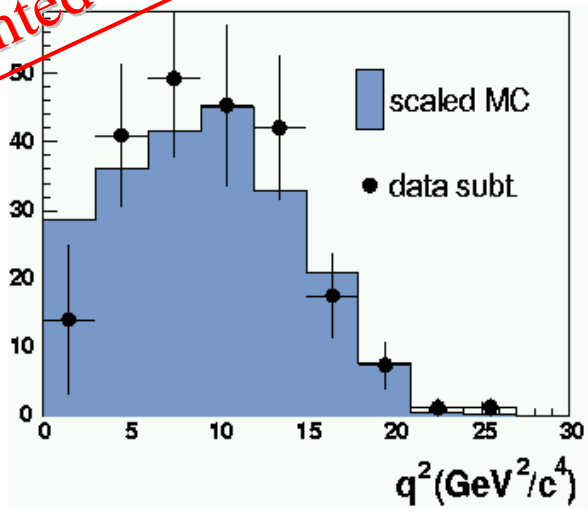
Can we go below 5% for theo. systematics?

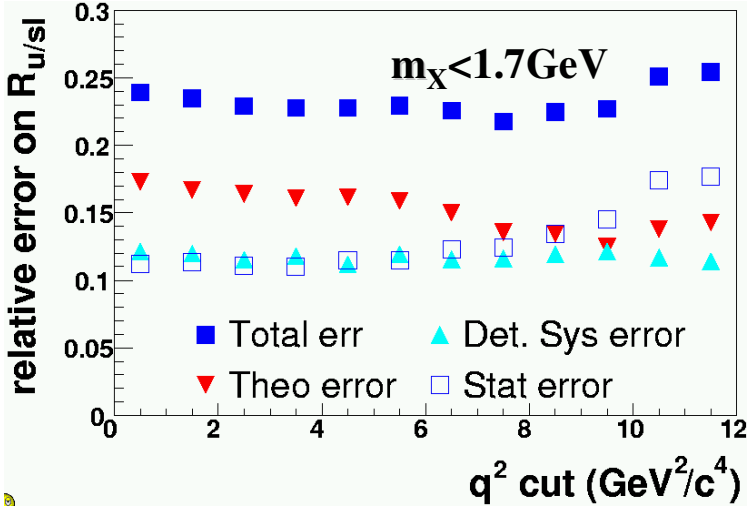
Future for Incl. V_{ub} : q^2 vs mX analysis

A combination of cuts on q^2 and mX reduces the theoretical error (Bauer et al. hep-ph/0111387) excluding regions of phase space with singularities and decreasing extrapolation error



Presented at LP03





~35% gain in theo. error

Future for Incl. V_{ub} : other approaches

- Try combination of variables. Ciuchini et al. ph/0204140

$$\left|\frac{V_{ub}}{V_{cb}}\right|^2 \simeq C(\alpha_s)\frac{\frac{dBR_{sl,u}}{d\xi}}{\left.\frac{dBR_{rd}}{dx}\right|_{x=\xi} - h(\xi;\alpha_s)}$$

This approach (that uses b→ulν and b→sγ) in not dependent on shape function. Since resonances in $b \to s\gamma$ have to be removed, efficiency will go down by >50%. In 500fb^{-1} it can be performed.

$\sigma_{theo}(V_{ub}) \sim 5\%$

- Can we measure m_b directly on our data-sample?

Kowalewski et al. (ex/0205038) say that we can, using $< E_W - | p_W |>$

With the current data-sample (80fb^{-1}) $\sigma(m_b) \sim 120MeV$

$\Rightarrow$ in 500fb^{-1} $\sigma(m_b) \sim 50MeV \Rightarrow \sigma_{theo}(V_{ub}) \sim 6\%$

Incl. V_{ub} :questions

- With 10 ab^{-1} we will have >10000 $b\to u l\nu$ selected events

  we can measure the full kinematics (modulo a cut on the invariant mass of the hadronic system) with high resolution.

  Which information can we get from this?

- We can perform measurements for B^0 and B^+ separately.

  How much can we learn from this?

- Suppose we are able to measure m_b and a (Λ and $\lambda 1$) directly from the $b\to u l\nu$ mX distribution with very small errors.

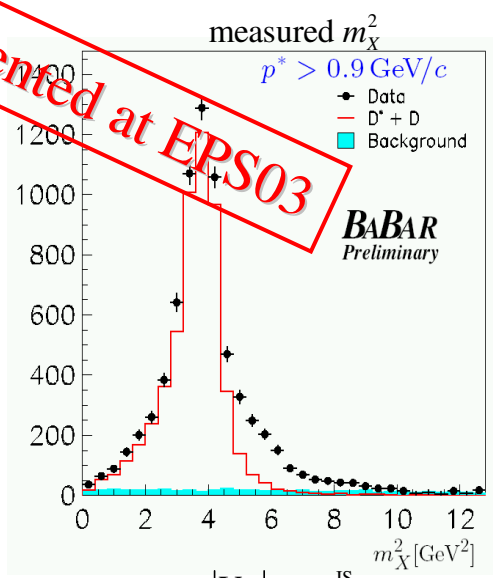
  Which is the remaining error? Shape function and duality? Can they be reduced?

Inclusive Analyses: V_{cb}

Goal is to measure the $\langle m_X^2 \rangle$ for different cuts on the momentum of the lepton and then extract (λ_1, $\overline{\Lambda}$)

- Direct measurement of the hadronic mass using the recoil of fully reconstructed B mesons
- Kinematic fit to improve the resolution on $\langle m_X^2 \rangle$
- Measured mass corrected by using a model indipendent calibration curve from MonteCarlo

Presented at EPS03

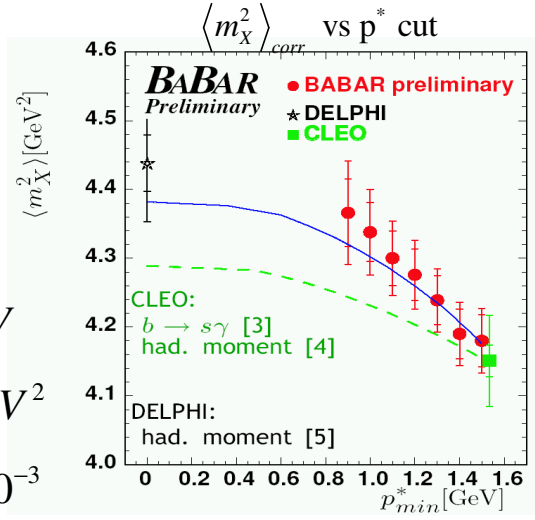


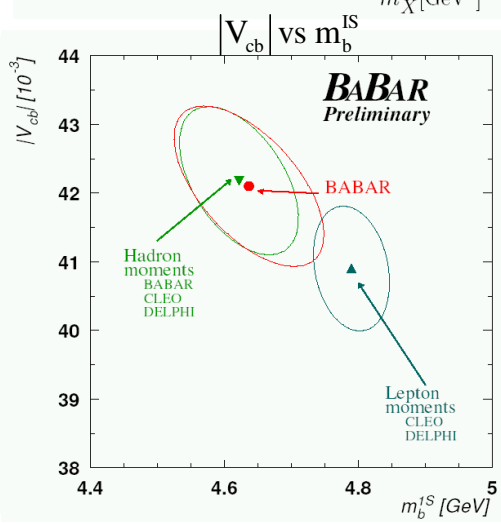
Fitting the mass moments: (hep-ex/0307046)

$$\begin{cases} \overline{\Lambda}^{\overline{MS}} = (0.53 \pm 0.09_{\mathrm{exp}})\,GeV \\ \lambda_1^{\overline{MS}} = (-0.36 \pm 0.09_{\mathrm{exp}})\,GeV^2 \end{cases}$$

and using $\Gamma_{sl} = (4.37 \pm 0.18) \cdot 10^{-11}\,MeV$

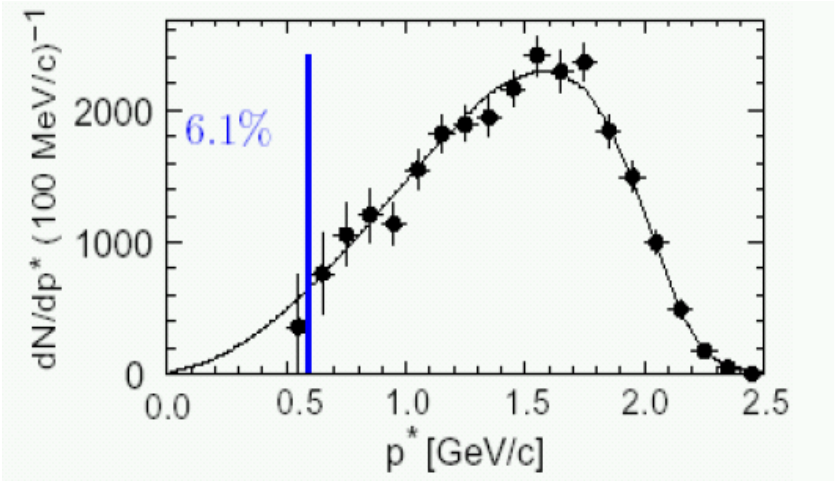
$$\begin{cases} m_b^{IS} = (4.64 \pm 0.09_{\mathrm{exp}} \pm 0.06_{pert.} \pm 0.07_{1/m_B^3})\,GeV \\ \lambda_1^{IS} = (-0.26 \pm 0.06_{\mathrm{exp}} \pm 0.04_{pert.} \pm 0.04_{1/m_B^3})\,GeV^2 \\ |V_{cb}| = (42.10 \pm 1.04_{\mathrm{exp}} \pm 0.52_{pert.} \pm 0.50_{1/m_B^3}) \cdot 10^{-3} \end{cases}$$





Other Inclusive Analyses

- Measurement of the lepton spectrum, ratio BR($B^0 \to X l \nu$)/BR($B^+ \to X l \nu$) and V_{cb}



Questions:

•Do we need 100 times the present statistics to do these ones?
We will be limited by systematics very soon

•Which kind of high precicsion tests can we perform? (we are talking about millions of semileptonic events in the recoil….)

Future for Inclusive Measurements

Two main concerns:

- If we don't push down the theoretical systematics larger data samples will be useless
- How can higher luminosities affect the experimental systematics uncertainties?

BTW recoil technique allows us to measure:

- Kinematic variables with high resolution (with the possibility to unfold them)
- Inclusive quantities for different multiplicities

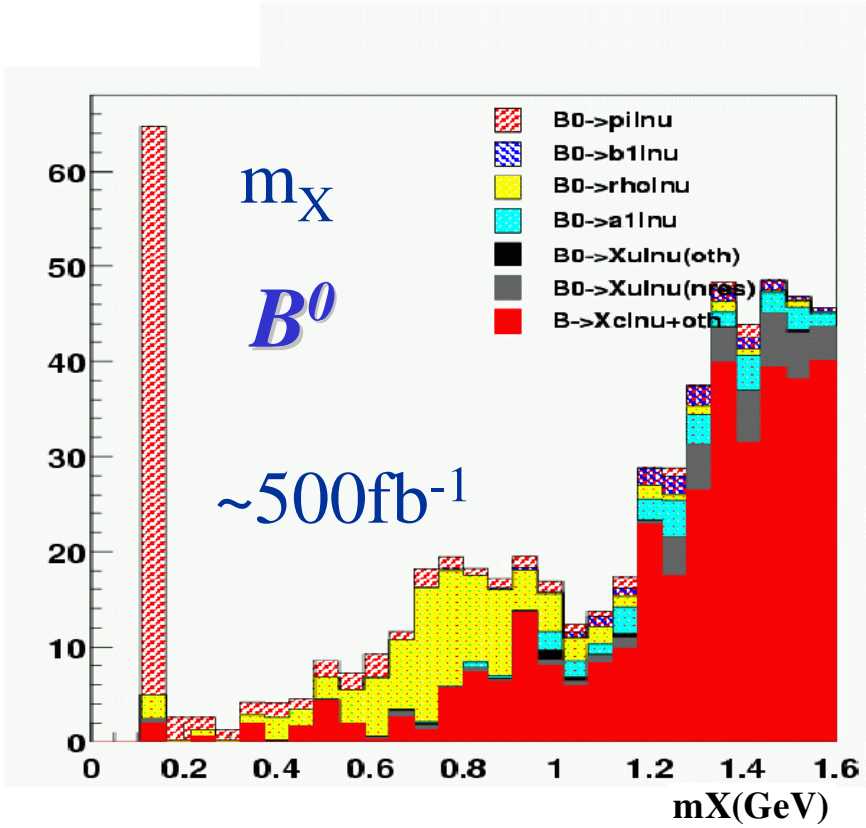
Question: Are we sure that we cannot use this information better?

Exclusive Charmless Decays

Recoil is the ideal environment to measure charmless exclusive decays:

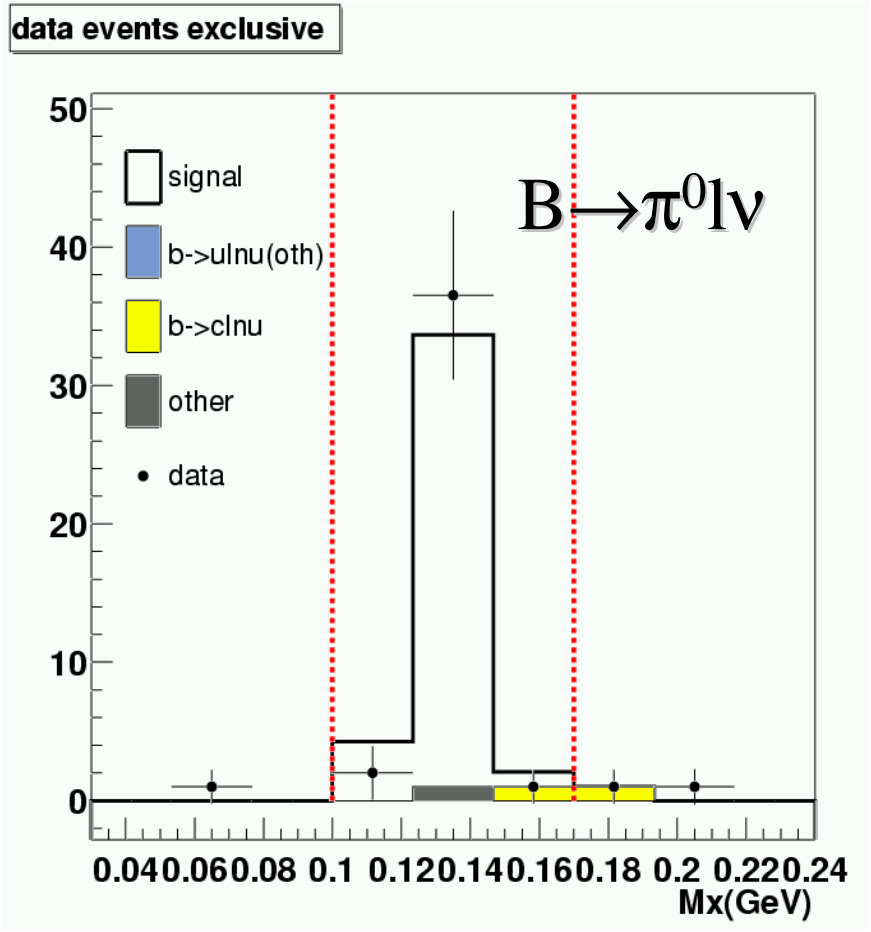
- No kinematic cuts (basically full phase space is used)
- No dependence from FF
- Crossfeed highly reduced.
- No continuum

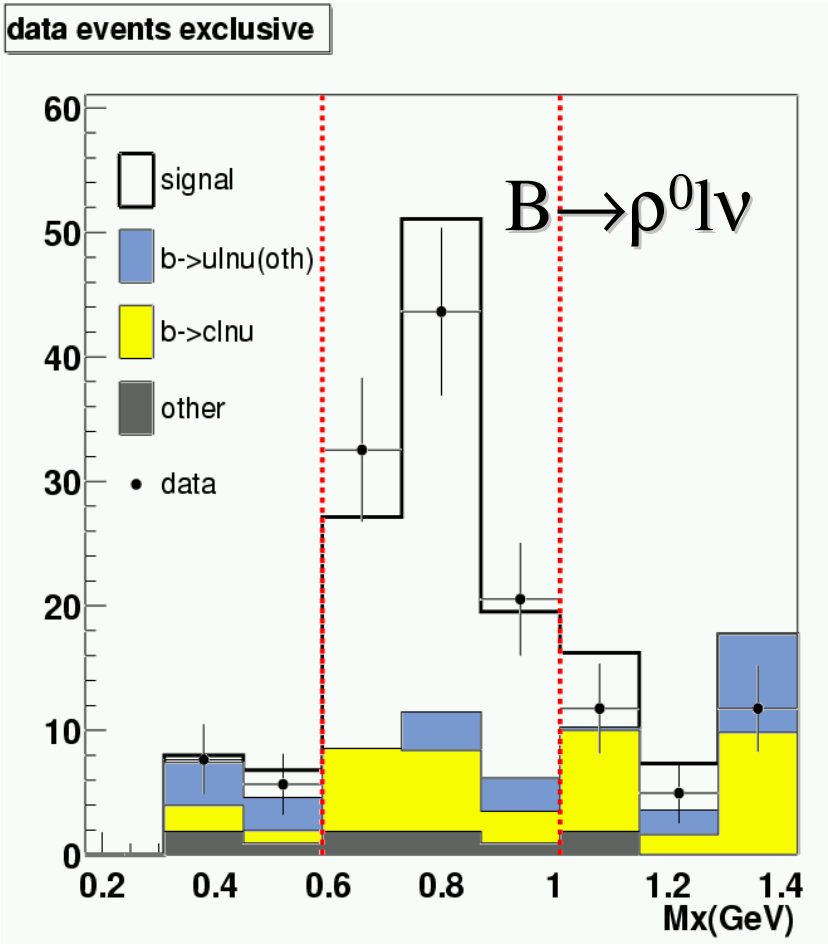
Just applying the cuts of the inclusive V_{ub} analysis you can get (no dedicated cuts to separate different modes)



Exclusive Charmless Decays

These were the MC studies (for 500fb^{-1}) in May…





Exclusive Charmless Decays

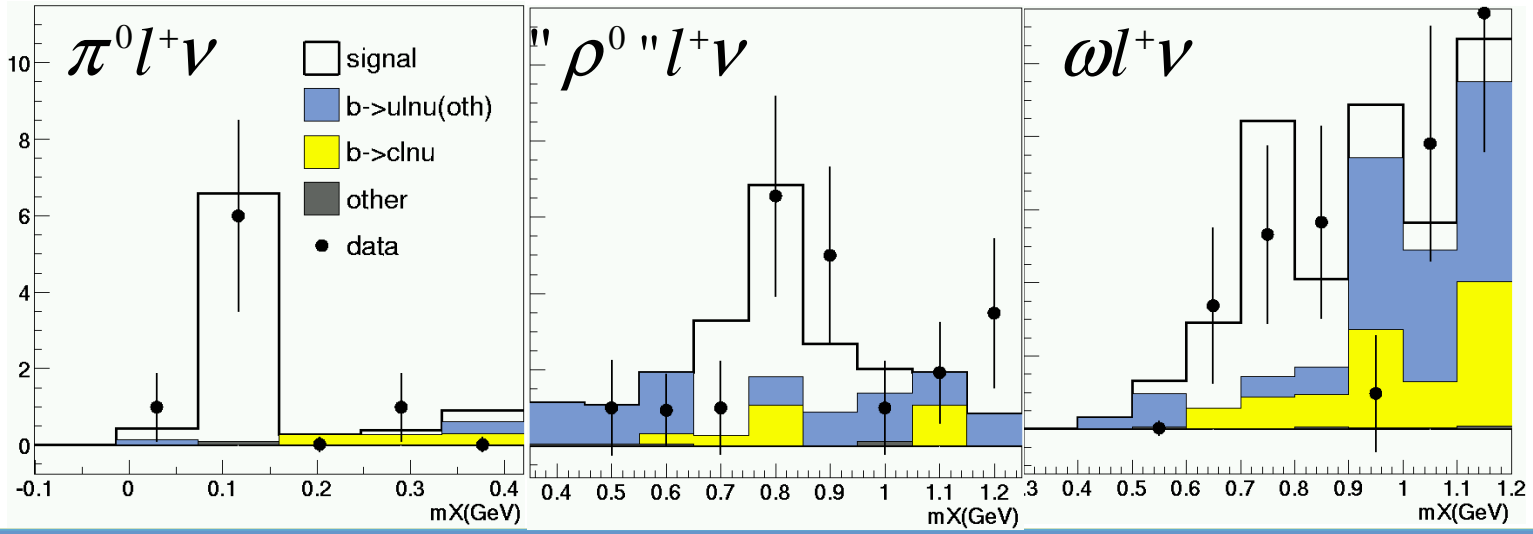
…and these are the results (for 82fb^{-1})…

$$\begin{cases} \mathcal{B}(B^+ \to \pi^0 l^+ \nu) = (0.78 \pm 0.32_{stat} \pm 0.13_{syst}) \cdot 10^{-4} \\ \mathcal{B}(B^+ \to "\rho^0" l^+ \nu) = (0.99 \pm 0.37_{stat} \pm 0.19_{syst}) \cdot 10^{-4} \\ \mathcal{B}(B^+ \to \omega l^+ \nu) = (2.20 \pm 0.92_{stat} \pm 0.57_{syst}) \cdot 10^{-4} \end{cases}$$

"ρ^0" is defined as $\pi^+\pi^-$ in the mass window $0.65 < m_{\pi^+\pi^-} < 0.95$ GeV

Presented at LP03

Projection of the results on the m_X variable

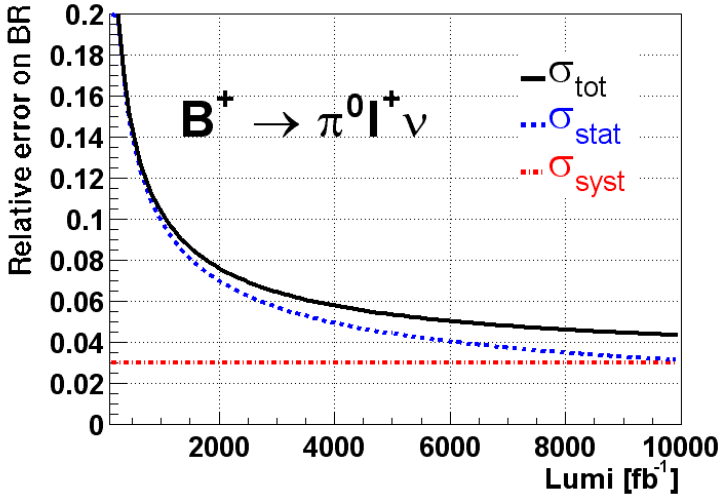


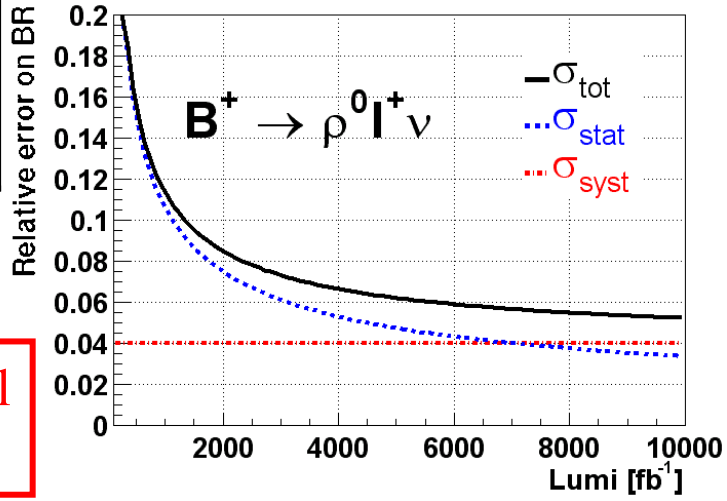
Excl. Charmless Decays: Perspectives

BR measurement	S/B	σ(tot)500fb^{-1}	σ(tot)10ab^{-1}
$B\to\pi^0 l\nu$	>10	~14%	~4%
$B\to\rho^0 l\nu$	~4	~15%	~5%
$B\to\omega l\nu$	~2.5	~16%	~6%
$B\to\pi^+ l\nu$	>10	~11%	~3%
$B\to\rho^+ l\nu$	~2	~15%	~6%

*Here I assumed negligible systematics from FF and a rough estimate of experimental syst. error

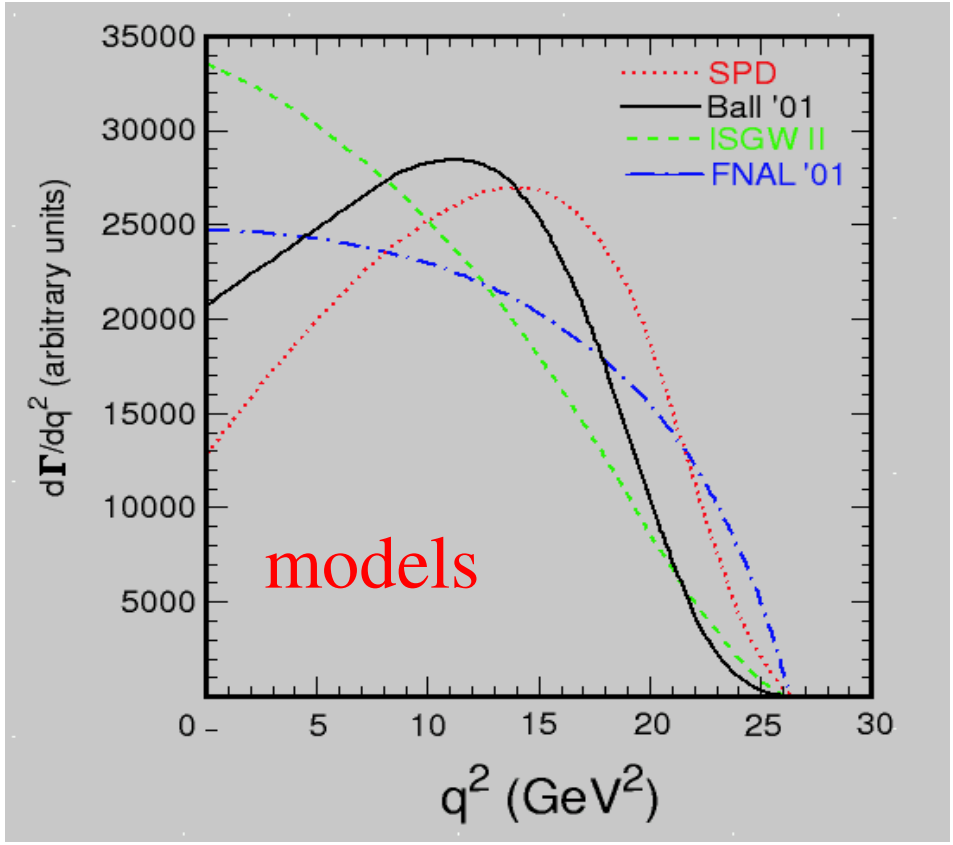
They can still be improved by performing an actual "exclusive" analysis on the recoil

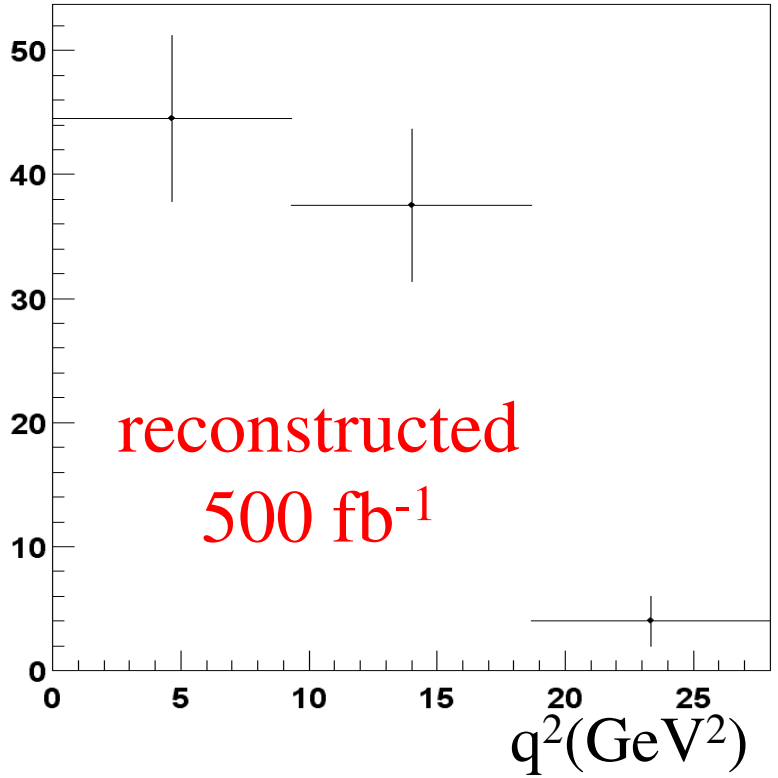




q^2 Spectrum

q^2 spectrum for $B^0 \to \pi^+ l^- \nu$





With higher stat. we can discriminate among models

Excl. V_{ub} :questions

- With the recoil approach we can get rid of the FF dependency on BR determination (no cut on kinematics)

  ... but FF error in V_{ub} determination is still there...

  Can we use this clean sample to reduce this error?

- Suppose I can measure many exclusive modes BRs (π^+ ,π^0 ,ρ^+ ,ρ^0 ,ω ,η, η') with small errors. Is there a smart way to combine them to reduce error on V_{ub}? Can we know form factors for all of them?

- In principle we could measure the non-resonant contribution spectrum (a1 and higher in mass) by difference. Is it interesting?

- This technique can be used to do inclusive and exclusive measurement of V_{ub} on the same sample and similar cuts at the same time. Can we use this information? (at the moment the two V_{ub} averages (exclusive and inclusive) show a bit of disagreement)

Exclusive Charm Decays

$B^0 \to D^* l \nu$:

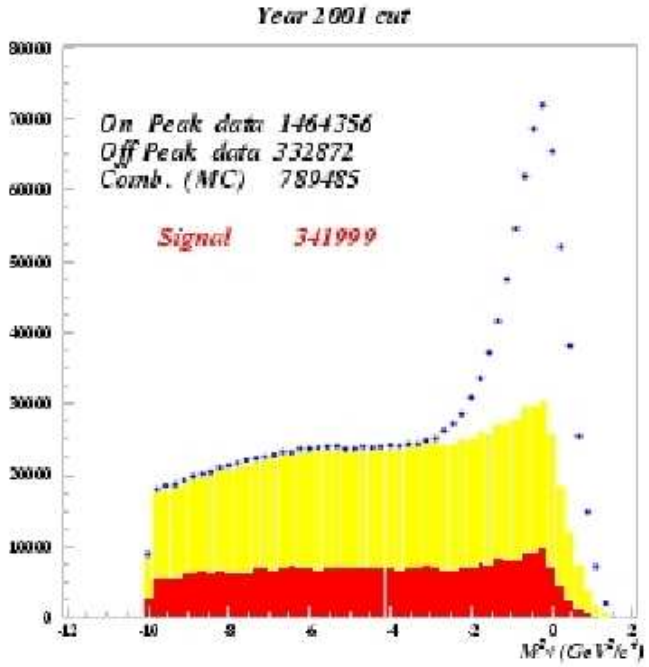
- Present measurement of this BR is limited by systematics
- This decay can be studied on the recoil using a partial reconstruction on the recoil. It means that you tag only the lepton and the soft π using the correlation between the soft π and the D*
- eff. = 0.55% for $B^0\bar{B}^0$ events

  $\Rightarrow$ on the recoil eff = (0.15 * 0.55)%

  $\Rightarrow$ ~7.5ev./fb^{-1}
- Many of the systematics can be reduced (f^0/f^+, BRs,D^{**}) $\Rightarrow \sigma_{syst}$ ~ 4%
- 500fb^{-1} should be enough

Purely exclusive mode on the recoil?

$\Rightarrow$ CLEO-C results are needed to reduce systematics due to BRs



Charm Decays: Higher Resonances

$B \to D^{**} l\nu$:

- Partial reconstruction+recoil can be used to measure also these channels, using soft pion (bkg events in $B^0 \to D^* l\nu$ become signal here) or you can tag a $D^{0,+} l\nu$ event
- Separated using $\cos(\theta_{BY})$ and, for instance, the presence of additional π_s with the right charge
- $\Rightarrow$ ~O(1)ev./fb^{-1} for D**lν

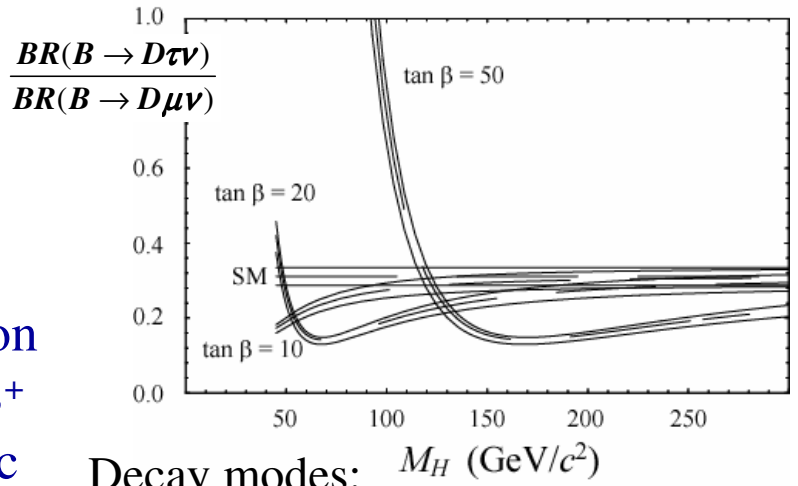
$B \to D(1,2) l\nu$:

- These channels can be studied with an purely exclusive approach
- Low level of background and charge conservation help

  $\Rightarrow$ higher luminosities should be useful for all these modes

Perspectives on B→Dτν

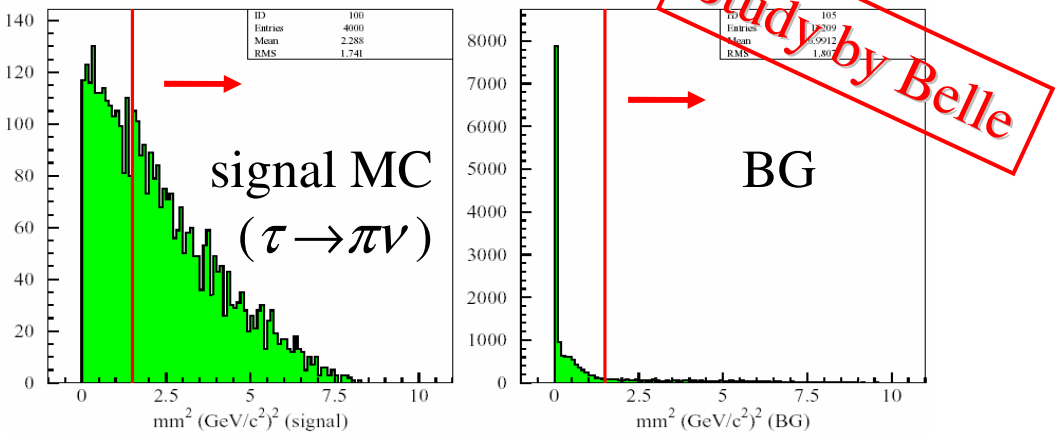
- Channel sensitive to new Physics
- Presence of large missing mass tags these events
- Lots of advantages in studying this channel on the recoil (nice miss. mass resolution, no B^0-B^+ crossfeed, direct reconstruction of the hadronic mass)



Decay modes:

$D^0 \to K^-\pi^+$	4%
$\to K^-\pi^+\pi^0$	13%
$\to K^-\pi^+\pi^+\pi^-$	7%
$\to K^-\pi^+\pi^+\pi^-\pi^0$	4%
$\to K_S\pi^0$	1%
$\to K_S\pi^+\pi^-$	2%
$\to K_S\pi^+\pi^-\pi^0$	4%
Total	35%

$\tau^- \to \pi^-\nu_\tau$	11%
$\to \rho^-\nu_\tau$	25%
Total	36%



Perspectives on B→Dτν

$B^- \to D^0 \tau^- \nu_\tau$ reconstruction efficiency

- Full-recon. efficiency is **not** included.
- Total efficiency = 6%

Study by Belle

Background estimation at 3 ab^{-1}

- Signal = 100±10, BG = 1700±40

(this is with hadronic reconstruction eff. = 0.1% in tag side)

But it could be highly improved:

- more τ modes
- more D decay modes
- higher breco efficiency (0.1%→0.4%)

$B \to X_u \tau \nu$?

Ok, we can do charm channels but…

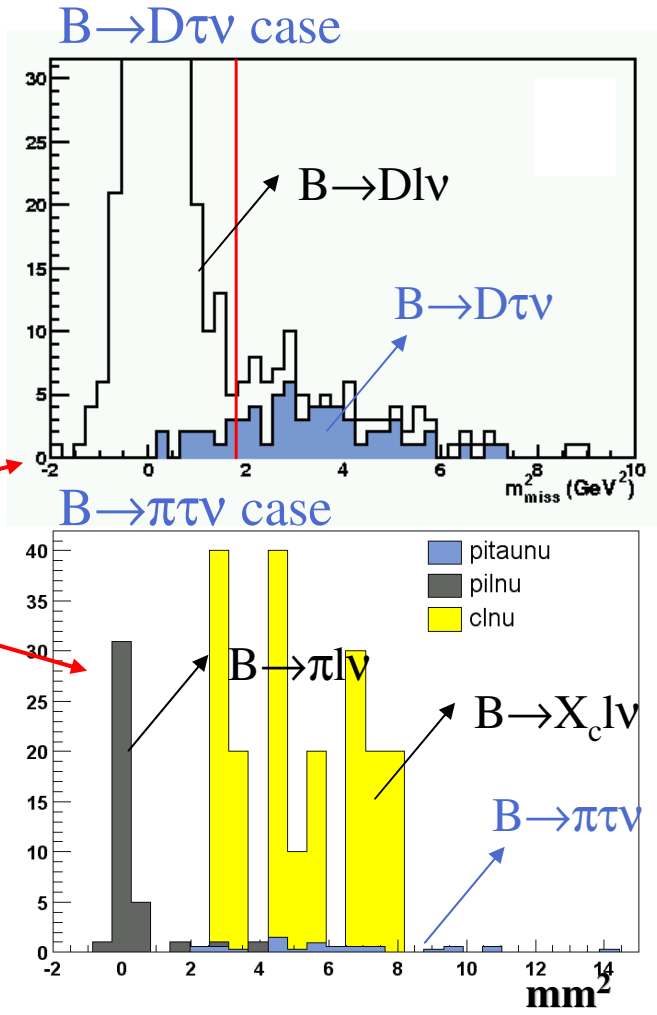
what about charmless ones?

$B \to X_u \tau \nu$

For instance let's take $B \to \pi \tau \nu$:

- $B \to \pi l \nu$ can separated by using missing mass (as for $D\tau\nu$)…

  … but you are in the $b \to c l \nu$ bkg region
- It looks very hard but perhaps possible
- Any theoretical interest in this?



Future for Exclusive Measurements

- Exclusive charmless decays look very promising.
- Many new approaches for exclusive charm decays but they could be systematically limited at the time of SuperBaBar.
- $B \rightarrow D\tau^{-}\nu_{\tau}$: feasible. It could be precisely measured with high luminosities
- $B \rightarrow X_u \tau\nu$?