B Beam Physics with the BaBar Detector

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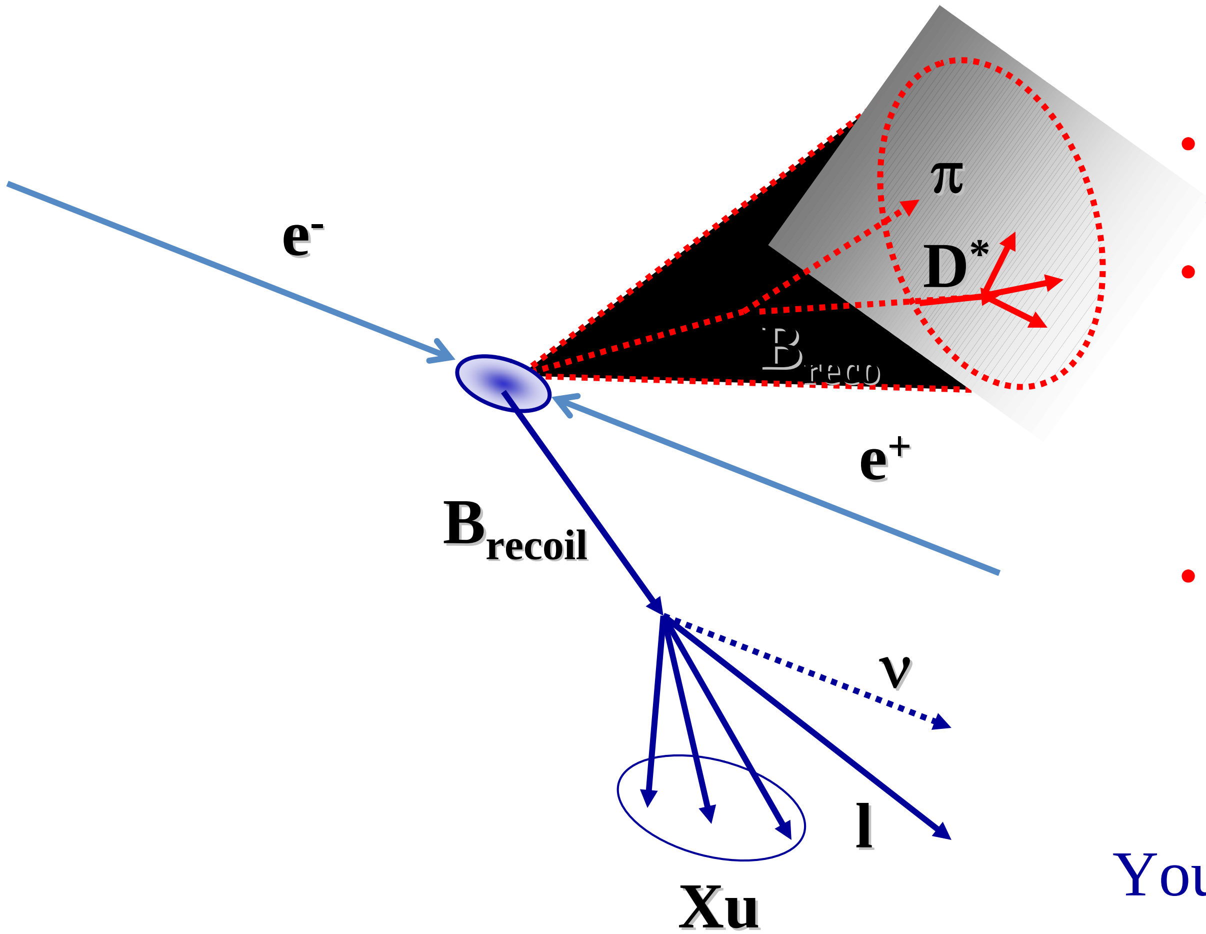
What is the B Beam Physics?

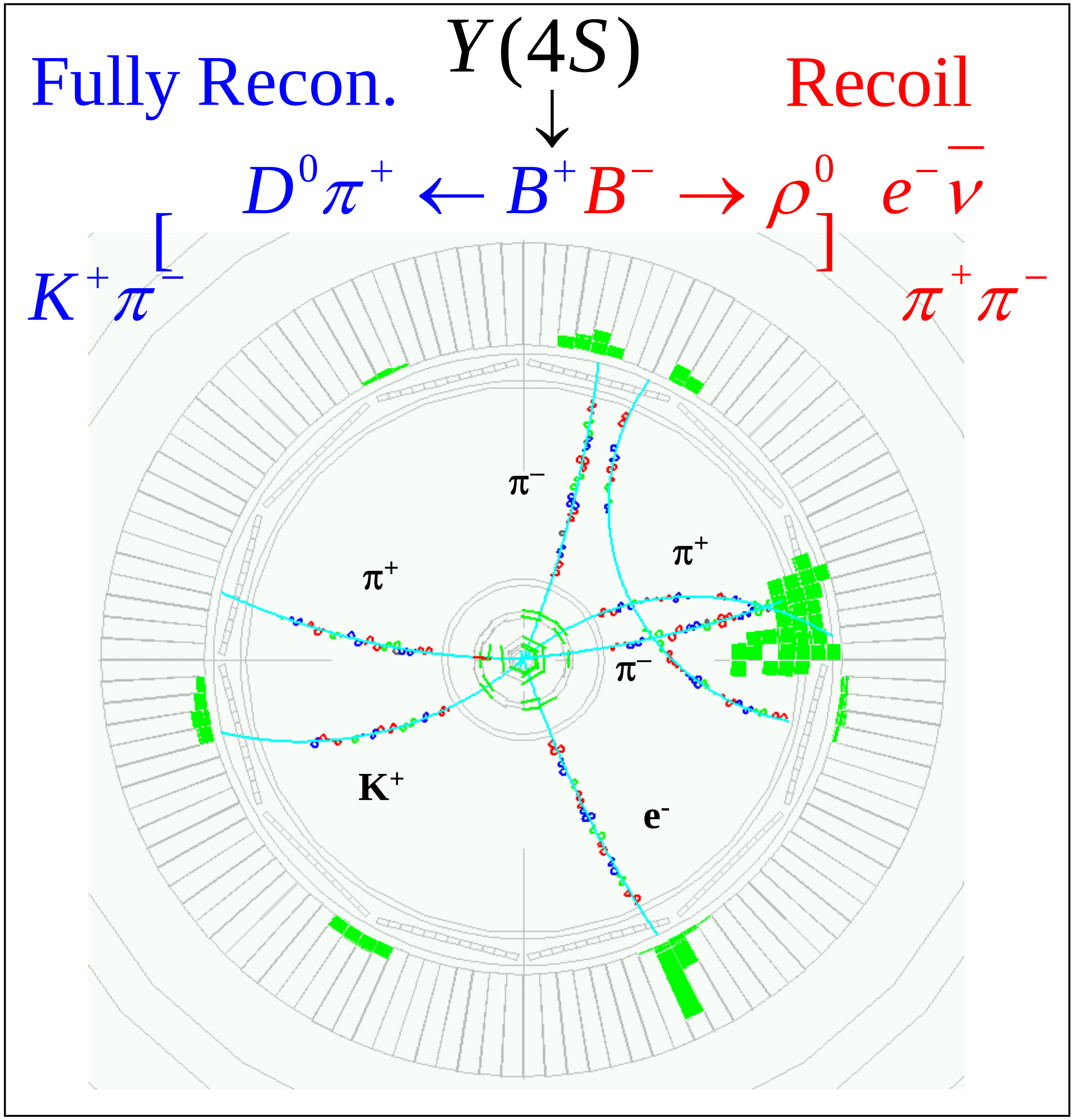


- Reconstruct one of the two Bs ...
- …and do it with “high” efficiency

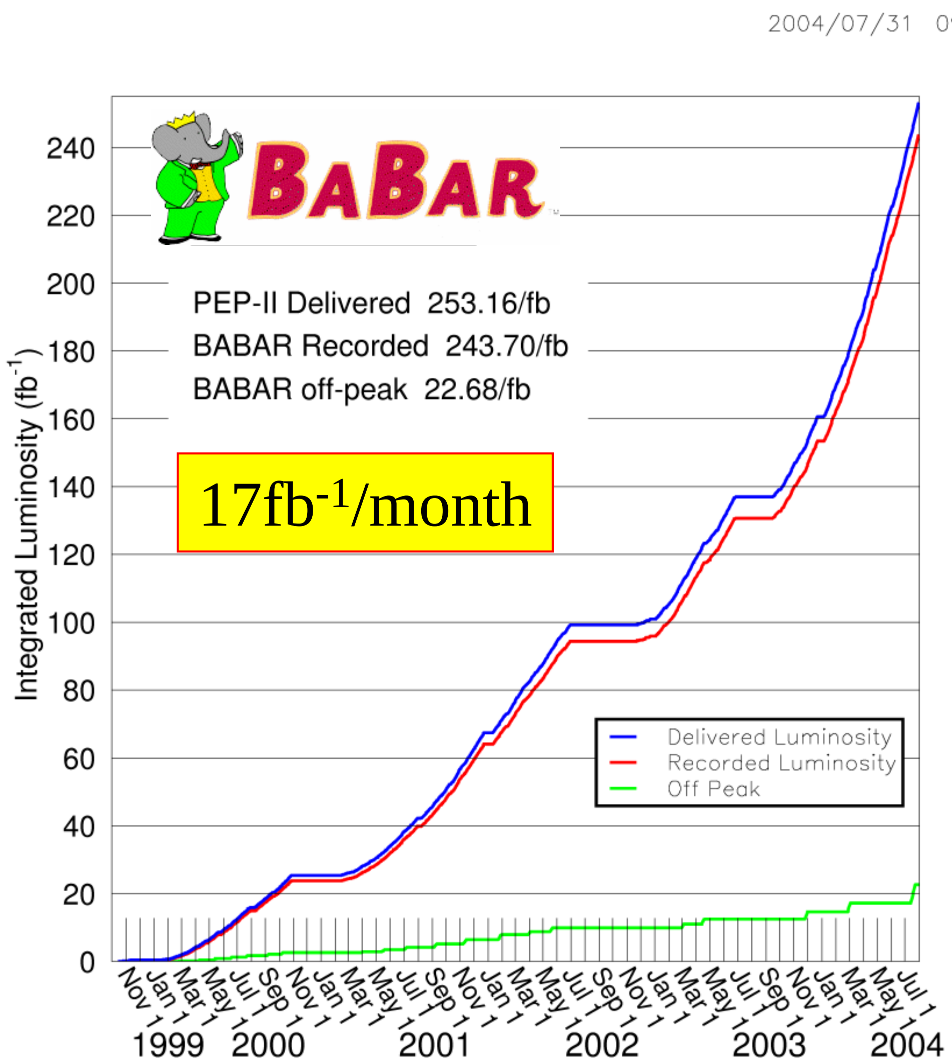
- The remainder of the event is the other B

You have a single B beam!!

Event Display



PEP II

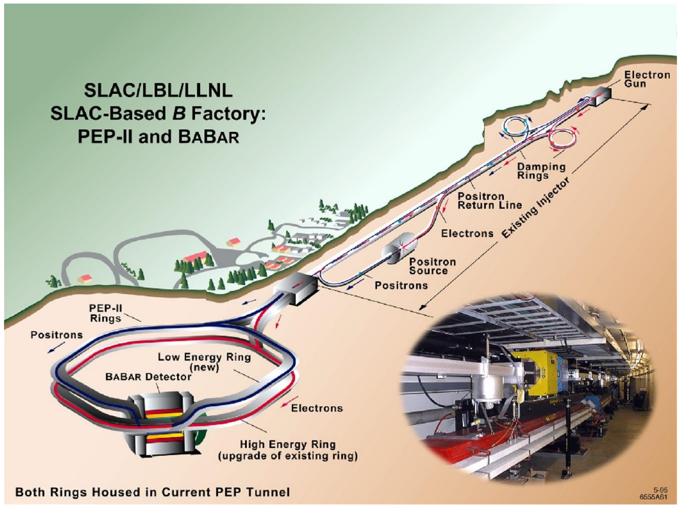


PEP-II peak luminosity:

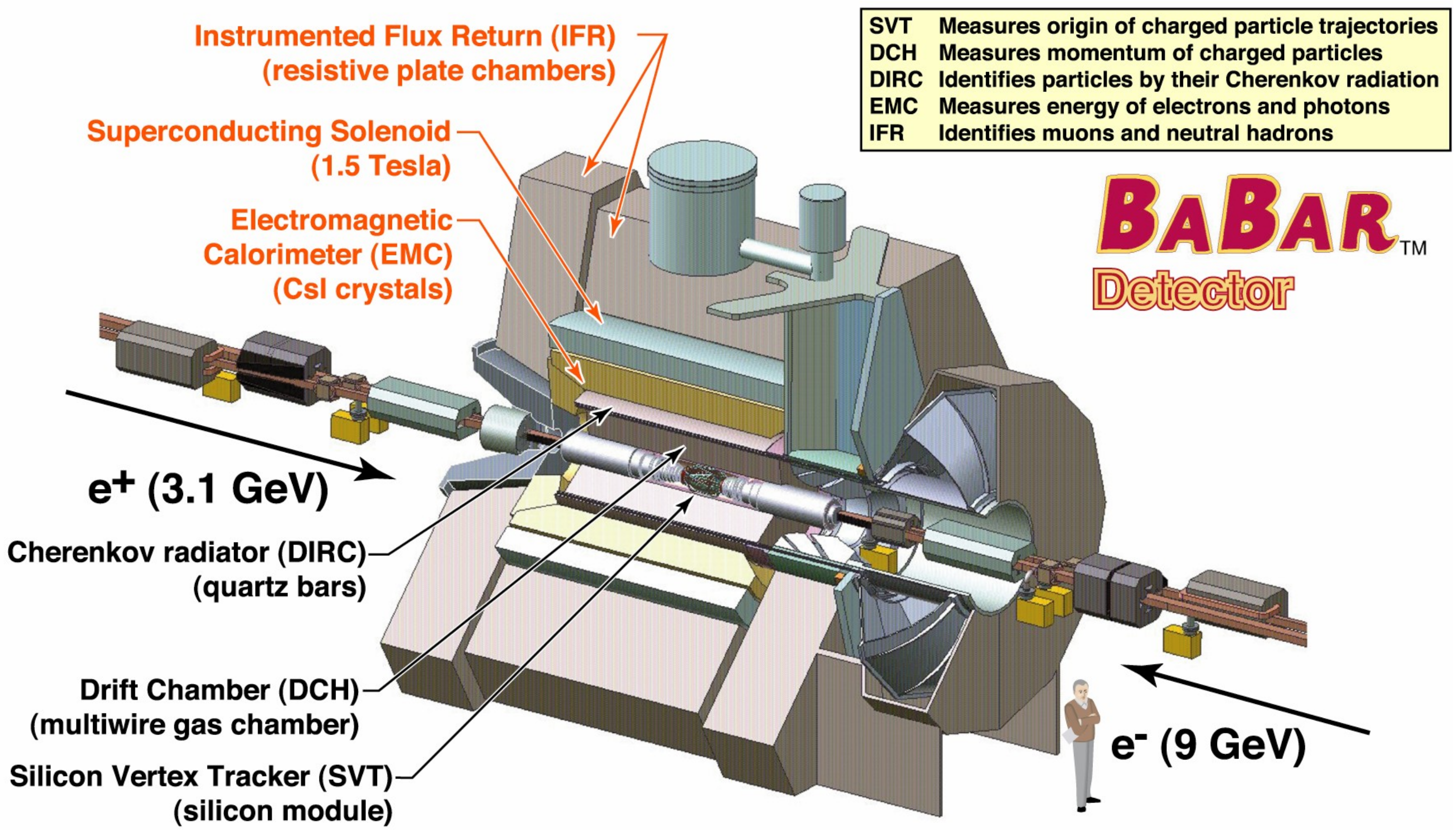
$9.2 \times 10^{33} cm^{-2}s^{-1}$

(exceeded design goal 3.0×10^{33})

PEP-II delivered	**253 fb^{-1}**
BaBar recorded	**244 fb^{-1}**



BaBar Detector



SVT: 97% efficiency, 15 μm z hit resolution (inner layers, perp. tracks)

SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \times p_T\ +\ 0.45\ \%$

DIRC: K-π separation 4.2 σ @ 3.0 GeV/c → 2.5 σ @ 4.0 GeV/c

EMC: $\sigma_E/E = 2.3\ \% \cdot E^{-1/4} \oplus 1.9\ \%$

Fully Hadronic Tags

Breco Tags

Aim is to collect as many as possible fully reconstructed B mesons in order to study the property of the recoil.

Reconstruct $B \to D(*)\, n\pi\, mK\, pK_s\, q\pi^0$ but the intermediate resonances are not requested. This is the so-called SemiExclusive Reconstruction.

- Two steps:
  - Reconstruction of the D meson in hadrons
  - Reconstruction of the B meson in hadrons
- the signal box is defined using two variables:

$$m_{ES} = \sqrt{E^{*2}_{beam} - p^{*2}_{B}}$$

→ *Resolution from beam energy*

$$\Delta E = E^{*}_{B} - E^{*}_{beam}$$

→ *Sensitive to E measurement*

- Iterative method.
- Finally ~1100 modes → ordered by purity.
- In events with multiple candidates, the best one is selected by:
  - Looking at the best ΔE within the same mode
  - Looking at the best purity if different modes

How Many B Mesons

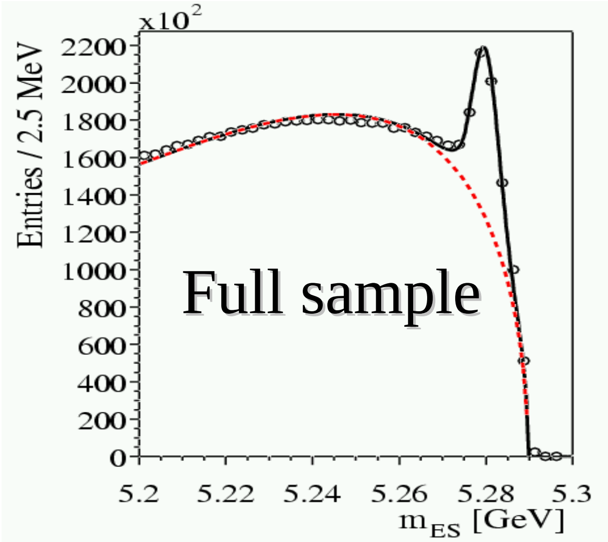
The final efficiency is ~0.4% (per bb_{bar} pair)

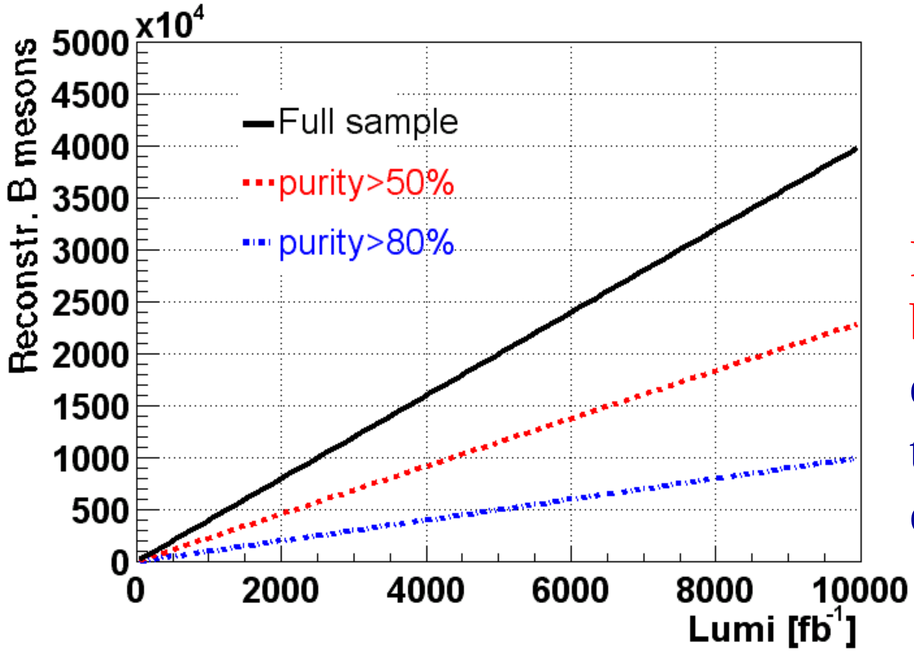
$\Rightarrow$ ~4000 B/fb^{-1}

$\Rightarrow$ 1500 B^0/fb^{-1}

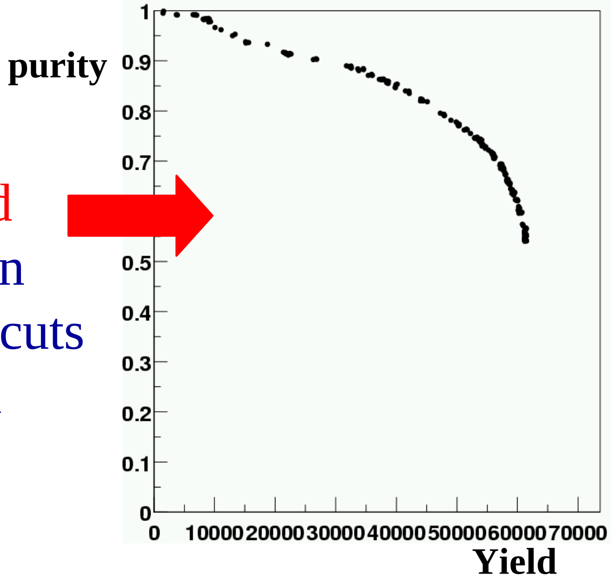
$\Rightarrow$ 2500 B^+/fb^{-1}

(~30% purity)





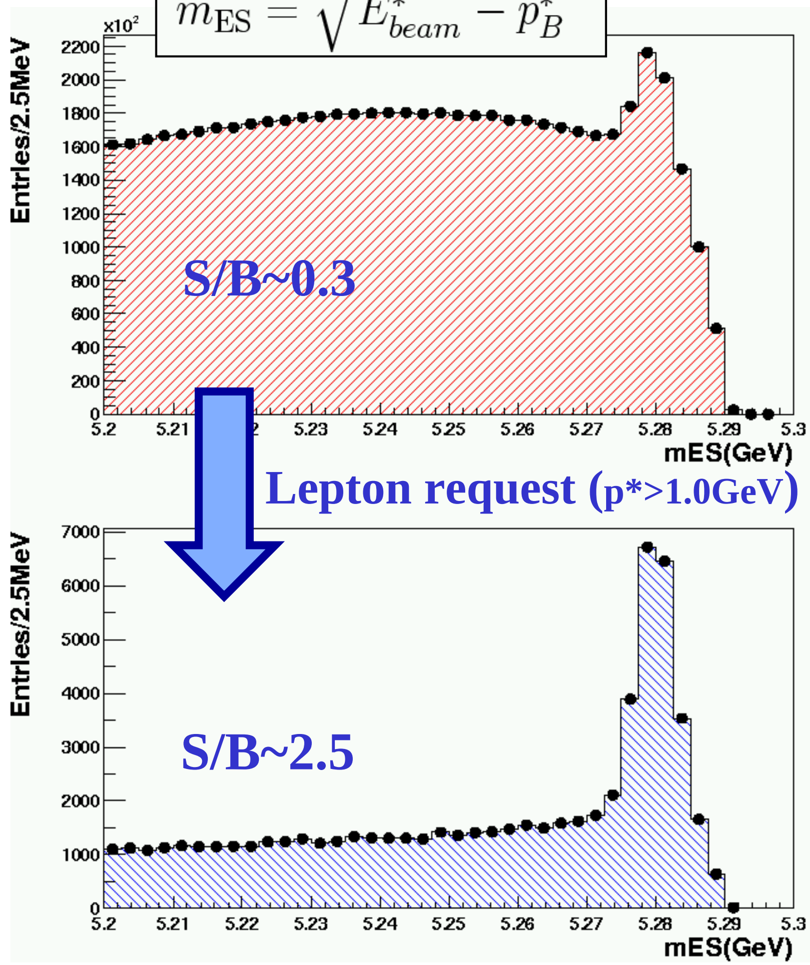
Purity can be optimized depending on the analysis cuts on the recoil

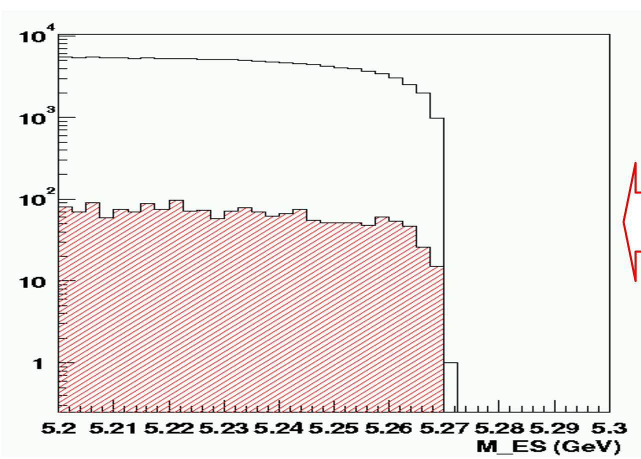


Effect of Cuts on the Recoil

Low purity could be an issue depending on the analysis.
Purity improves a lot once cuts on the recoil are applied. For instance continuum is removed by the presence of a high energy lepton.

$$m_{\mathrm{ES}} = \sqrt{E^{*2}_{beam} - p^{*2}_{B}}$$





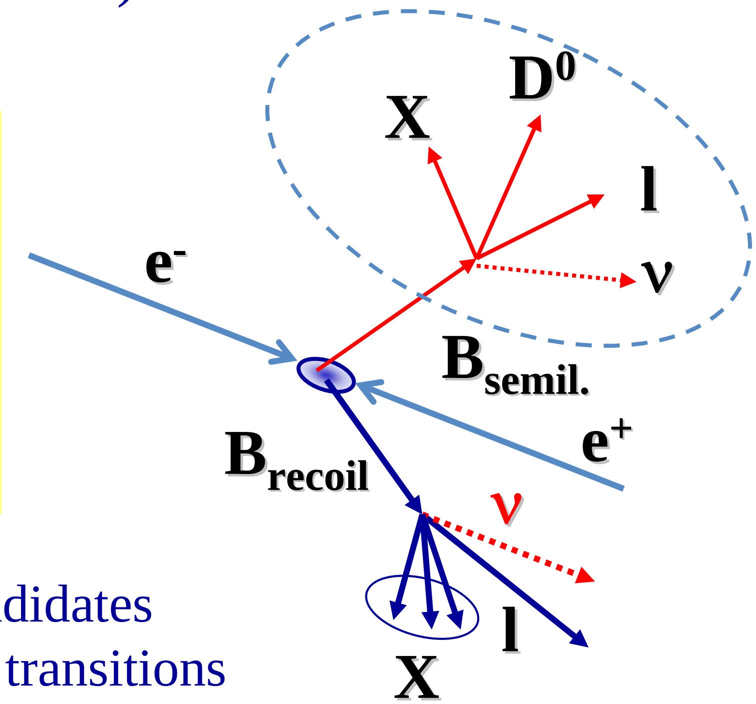
Continuum: before and after request lepton with p*>1.0GeV

Semileptonic Tags

Semil Tags

A different kind of tags can be obtained by using charm semileptonic B decays $B \rightarrow D\, l^- \nu\, X$, considering just the D meson and the lepton. Additional cuts are applied to remove background (for instance cosine of the angle between B and Dl system)

$B^- \rightarrow D^0\, l^-\, \nu\, X$
- → $K^- \pi^+$
- → $K^- \pi^+ \pi^0$
- → $K^- \pi^+ \pi^- \pi^+$
- → $K^0_s \pi^+ \pi^-$



Pro:
Higher stat.

Cons:
One missing neutrino
(compared with hadronic tags)

X^0 system: γ or π^0 only candidates from possible $D^{(*)0}\ \gamma\ D^0\ \gamma/\ \pi^0$ transitions

Partially Reco Tags

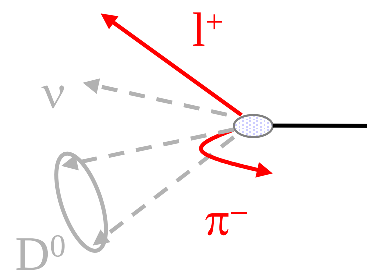
Partial Tags

$B \to D^* \, l \, \nu \, X$ decays are partially reconstructed

Using the soft π from the $D^* \to D^0 \, \pi_{soft}$

Selected by the following variables:

- Some preselection cuts on shape and multiplicity
- lepton mom. (p^*>1.3GeV)
- soft pion mom. (50MeV<p_π <200MeV)
- lepton-π Vtx probability

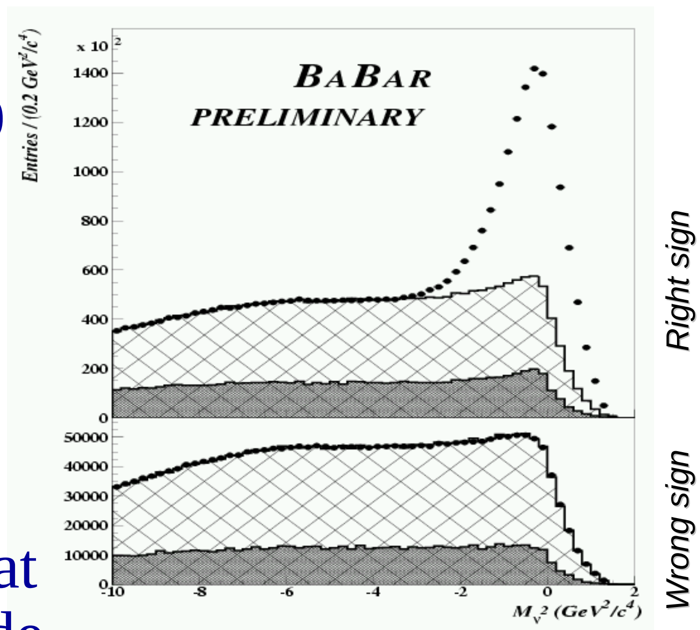


Signal yield is extracted via M_ν^2 (mis. mass squared)

D^* is assumed to be collinear with the soft π

Then:

$$E_D^* = \frac{E_{\pi_s} M_{D^*}}{M_\pi} \quad \Rightarrow \quad M_\nu^2 = (p_{B^0} - p_l - p_{D^*})^2$$



Pro:

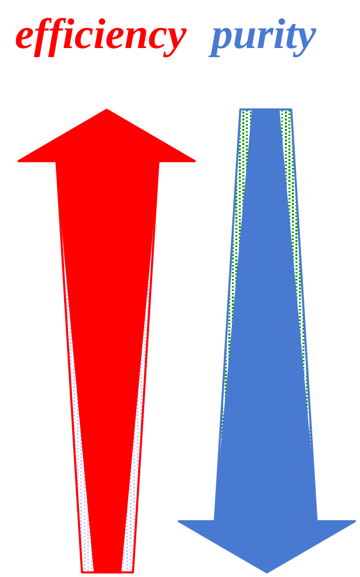
Even higher stat.

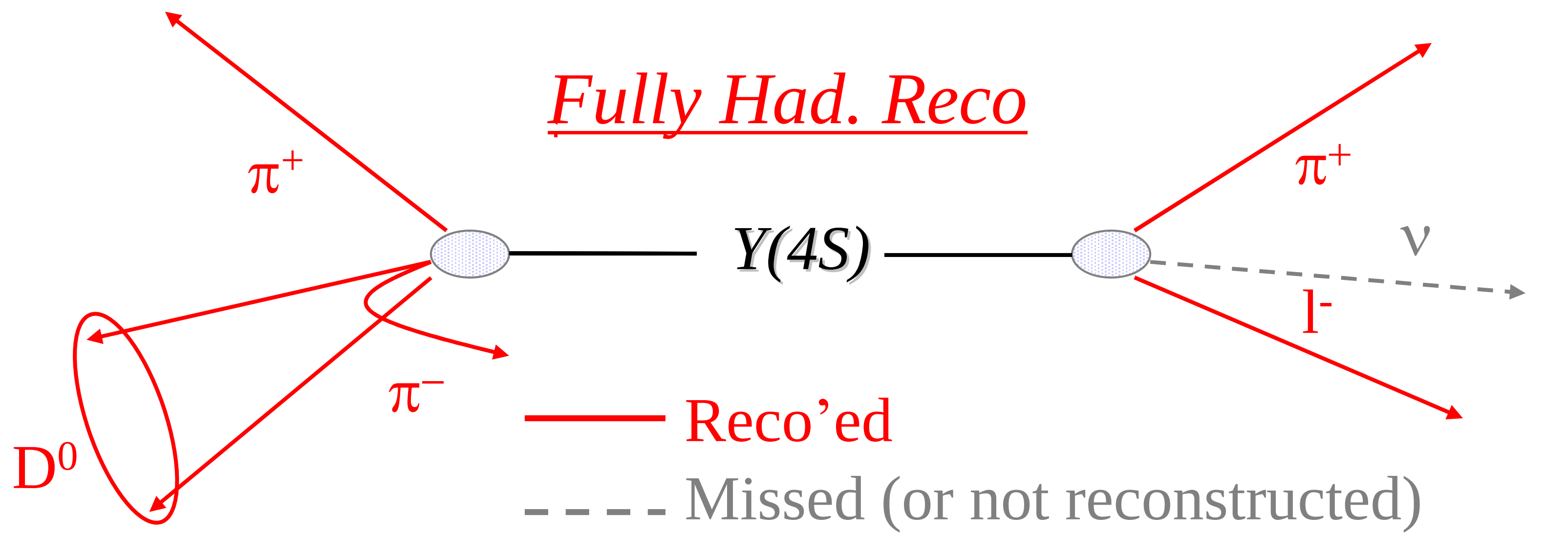
Cons:

Missing ν and mesons that can contaminate recoil side

Summary on Experimental Techniques

	Method	*tag side*
Untagged	No recoil	$(nh^{\pm}, m\gamma)$
Partial Tags	Recoil of partially reconstructed D*lν	π_{soft} l $(D^0 \nu X)$
Semil Tags	Recoil of B→D(*)lnX	$D^{(*)}$ l (νX)
Breco Tags	Recoil of fully recon. B→D(*)X	$D^{(*)}$ X





RECENT RESULTS

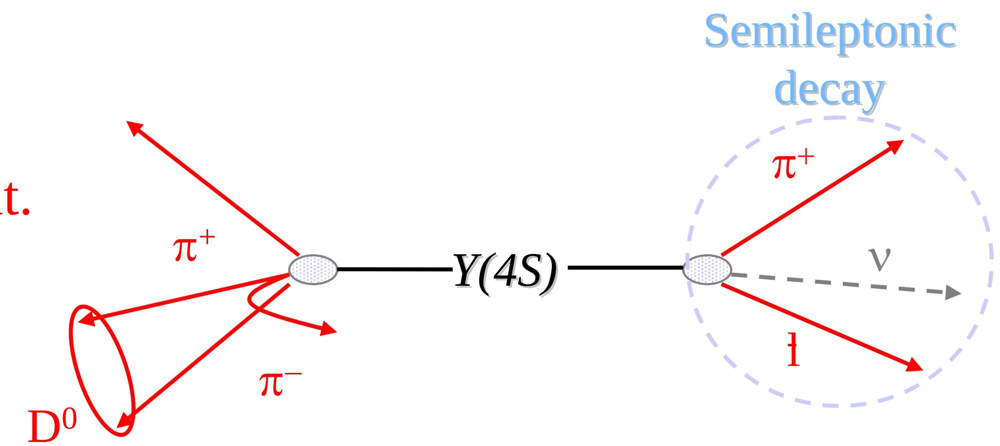
Recoil in Semileptonic Decays

$B \to Xl\nu$

Only one missing neutrino in the event.

$\Rightarrow$ system is overconstrained, we can

use kinematic fits



Typical cuts:

- One and only one lepton with p*> 1 GeV/c
- Correlation between lepton charge and B_{reco} flavor
- Cut on the missing mass: $M_{miss}^2 < 0.5 GeV^2$
- charge conservation: $Q_{tot}=0$
- Partially reconstructed neutrino to reject $B^0 \to D^* l \nu$ events

It is possible to reconstruct directly X mass in

$B \to Xl\nu$ $\Rightarrow$ resolution in m(X) ~ 300MeV

Possible measurements:

- **inclusive $B \to Xl\nu$ (V_{cb})**
- **inclusive $B \to X_u l\nu$ (V_{ub})**
- **exclusive $B \to (\pi,\rho,..)l\nu$ (V_{ub})**
- **exclusive $B \to D^{(*,**)}l\nu$**
- **exclusive $B \to D^{(*)}\tau\nu$**

Published or preliminary
Future

Incl. Semileptonic: HQE Expansions

- Heavy Quark Expansions, tool to correct for QCD effects
  - Expansion in terms of $1/m_b$ and $\alpha_s(m_b)$
  - Separate short- and long-distance effects at $\mu \sim 1$ GeV
    - Perturbative corrections calculable from $m_b\ m_c\ \alpha_s(m_b)$
    - Non-perturbative parameters cannot be calculated
- We choose calculation by Gambino & Uraltsev **hep-ph/0401063 & 0403166**
  - Kinetic mass scheme to $O(1/m_b^3)$
  - E_ℓ moments $O(\alpha_s^2)$
  - m_X moments $O(\alpha_s)$
- 8 parameters to be fitted

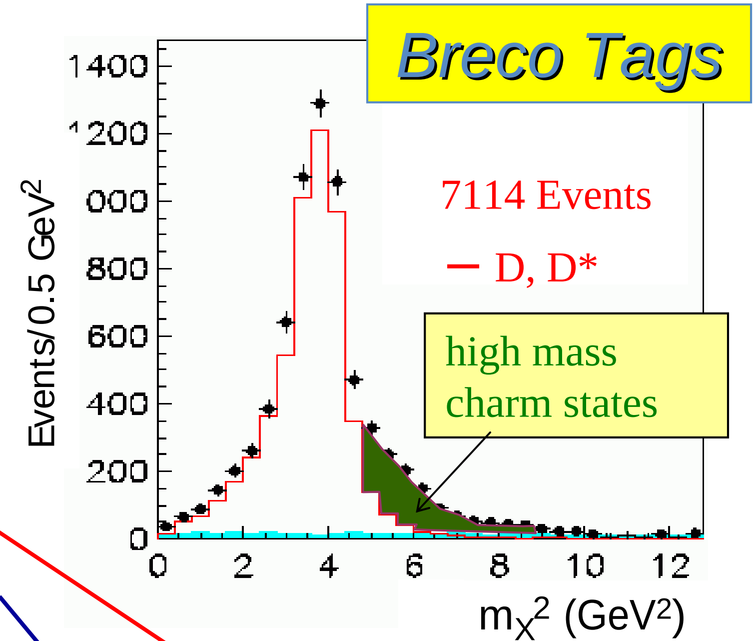
$|V_{cb}|$ m_b m_c $\mathcal{B}(B \to X_c l \nu)$ μ_π^2 μ_G^2 ρ_D^3 ρ_{LS}^3

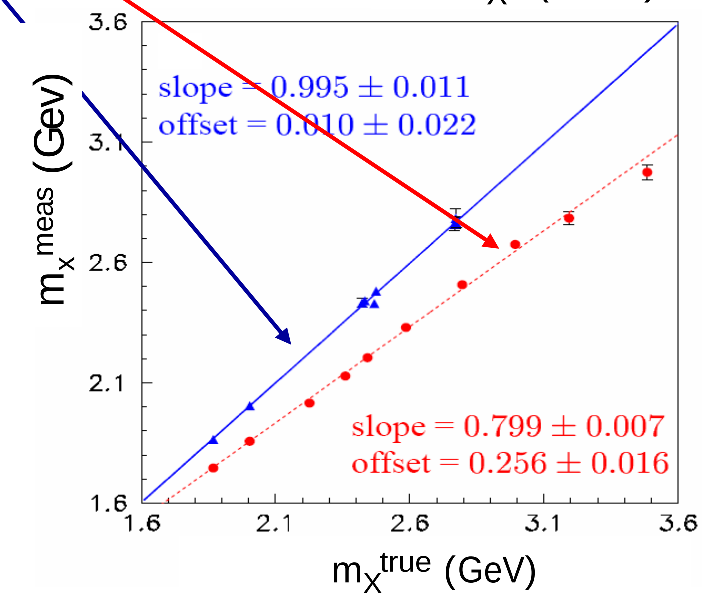
- μ_π^2: kinetic; μ_G^2: chromomagnetic — $O(1/m_b^2)$
- ρ_{LS}^3: spin-orbit; ρ_D^3: Darwin — $O(1/m_b^3)$

We measure moments of the mass of the X system as a function of minimum lepton energy E_l

Mass Moments in $B \rightarrow Xl\nu$ (V_{cb})

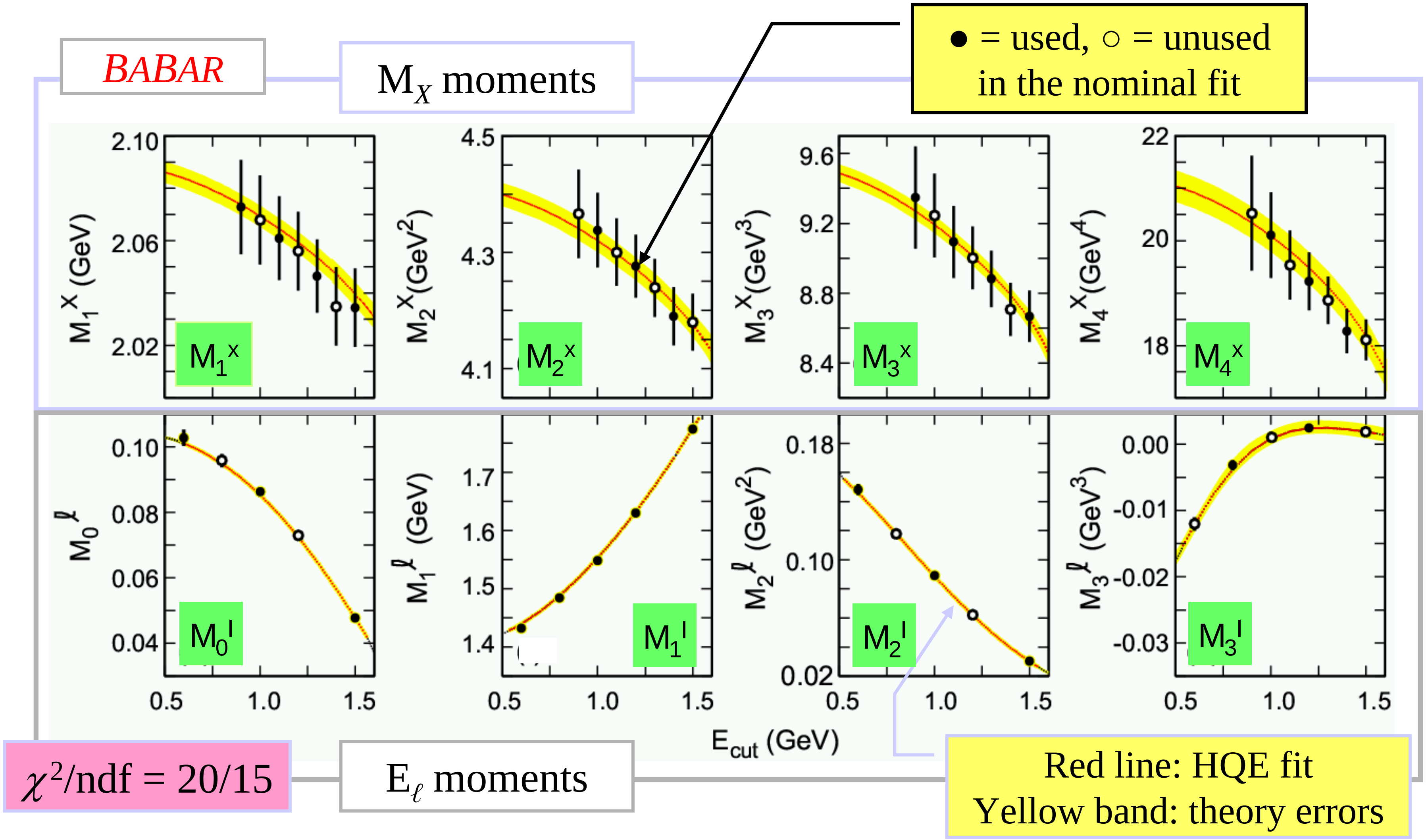
- To eliminate dependence of moments on uncertain BF and unknown masses of high mass charm mesons we calibrate m_x measurement
- Calibrate m_x based on MC simulation
  - *Linear relation between m_x^{meas} and m_X^{true}*
  - *Validate calibration with excl. $B \rightarrow D^{(*)} \ell \nu$*
- Moments corrected for detector effects and bkg





$$M_n^X = \frac{\int_{E>E_{cut}} m_X^n \, d\Gamma}{\int_{E_{cut}}^{\infty} d\Gamma}, (n = 1, 2, 3, 4)$$

Hadron mass moments


BABAR
M_X moments
● = used, ○ = unused
in the nominal fit
M1X
M2X
M3X
M4X
M0l
M1l
M2l
M3l
Ecut (GeV)
χ2/ndf = 20/15
Eℓ moments
Red line: HQE fit
Yellow band: theory errors

HQE Fit Results (kinetic mass scheme)

80fb^{-1}

Breco Tags

$$|V_{cb}| = (41.4 \pm 0.4_{\rm exp} \pm 0.4_{\rm HQE} \pm 0.6_{\rm th}) \times 10^{-3}$$

$$B_{cl\nu} = (10.61 \pm 0.16_{\rm exp} \pm 0.06_{\rm HQE})\%$$

$$m_b = (4.61 \pm 0.05_{\rm exp} \pm 0.04_{\rm HQE} \pm 0.02_{\alpha_s})\,{\rm GeV}$$

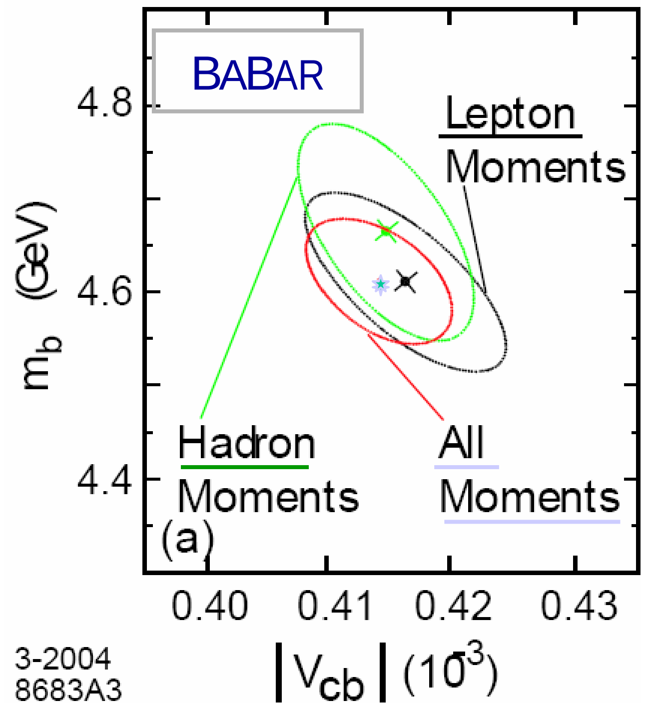
$$m_c = (1.18 \pm 0.07_{\rm exp} \pm 0.06_{\rm HQE} \pm 0.02_{\alpha_s})\,{\rm GeV}$$

$$\mu_\pi^2 = (0.45 \pm 0.04_{\rm exp} \pm 0.04_{\rm HQE} \pm 0.01_{\alpha_s})\,{\rm GeV}^2$$

$$\mu_G^2 = (0.27 \pm 0.06_{\rm exp} \pm 0.03_{\rm HQE} \pm 0.02_{\alpha_s})\,{\rm GeV}^2$$

$$\rho_D^3 = (0.20 \pm 0.02_{\rm exp} \pm 0.02_{\rm HQE} \pm 0.00_{\alpha_s})\,{\rm GeV}^3$$

$$\rho_{LS}^3 = (-0.09 \pm 0.04_{\rm exp} \pm 0.07_{\rm HQE} \pm 0.01_{\alpha_s})\,{\rm GeV}^3$$

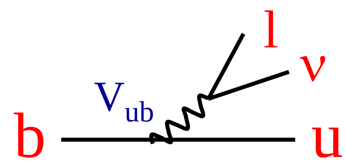


- Separate fits to hadron and lepton moments give consistent results
- Considerable improvement in precision for $|V_{cb}|$ (±2%) and B_{cln} (1.6%) and quark masses (factor of 6), as well as HQE parameters

Incl. V_{ub}: Theory and Uncertainties

Relevant issues

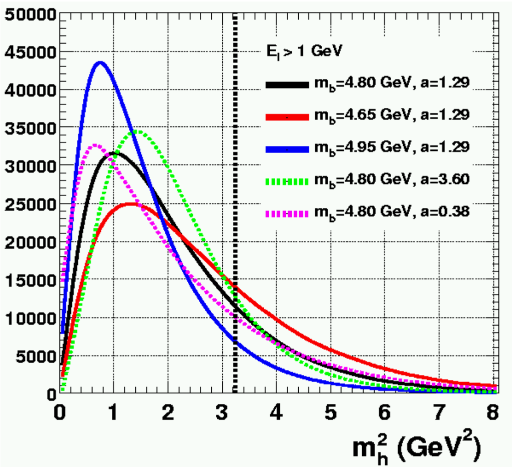
- hadronization effects and Fermi motion (b quark mass)
- non-perturbative parametrizations (Shape Function, SF) affected by large uncertainties.



Two approaches to extract $|V_{ub}|$ and estimate theo. systematics:

1. DeFazio-Neubert paper (*DFN*), tri-differential parametrization (E_e,m_X,q^2) to extrapolate.
   $|V_{ub}|$ extracted by

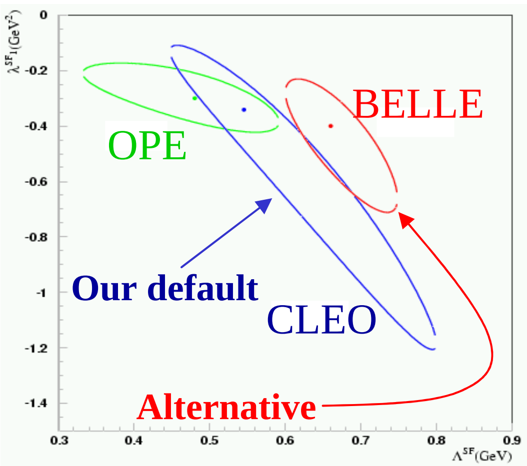
$$|V_{ub}| = 0.00424\sqrt{\frac{B(B \to X_u l\nu)}{0.002}\frac{1.61ps}{\tau_B}} \times (1 \pm 0.028_{OPE} \pm 0.039_{m_b})$$



2. q^2 vs m_X approach by Bauer et al. (*BLL*).
   partial BR with q^2 vs m_X cut. $|V_{ub}|$ is extracted using

$$|V_{ub}| = \sqrt{\frac{192\pi^3}{\tau_B G_F^2 m_b^5}\frac{\Delta B(B \to X_u l\nu; m_X < 1.7GeV/c^2, q^2 > 8GeV^2/c^4)}{G}}$$

   Dependence on SF (here in G) is much reduced.



Theo. uncertainties on non-perturbative effects are evaluated using λ^{SF} and Λ^{SF} ellipse from $b \to s\gamma$ from CLEO. Belle ellipse as an alternative.

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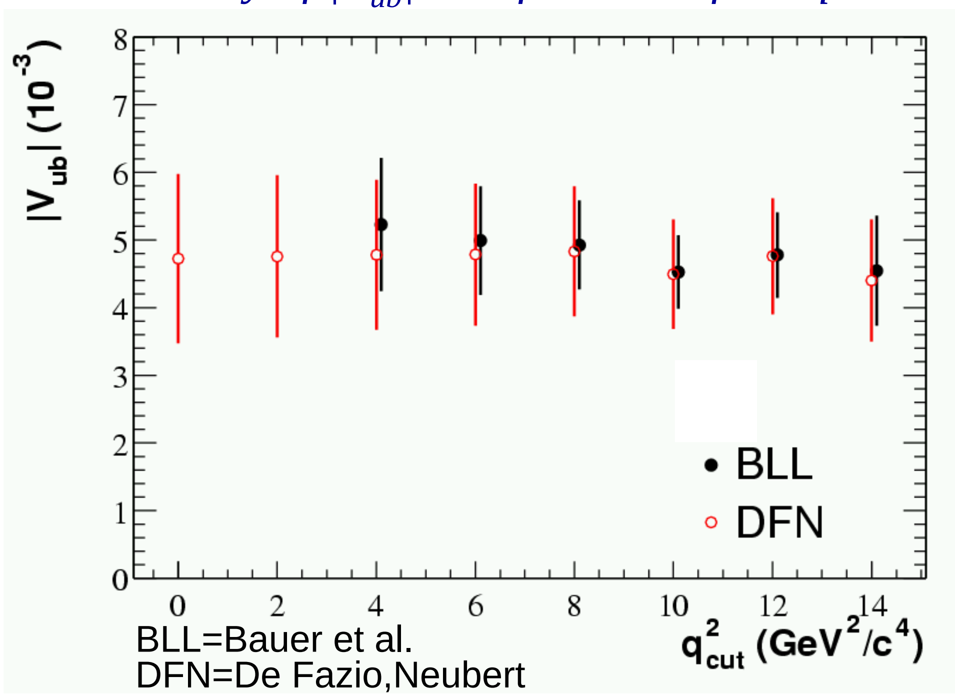
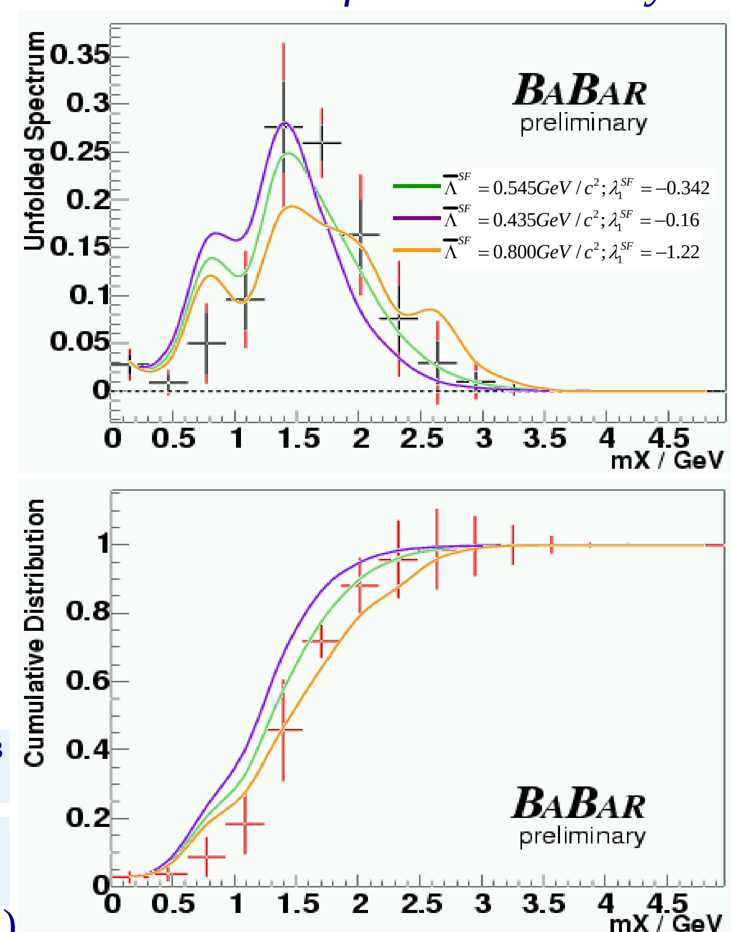
Breco Tags

Stability of $|V_{ub}|$ as a function of the q^2 cut



Unfolded m_X spectrum and cumulative distribution for $b \to u l \nu$ decays



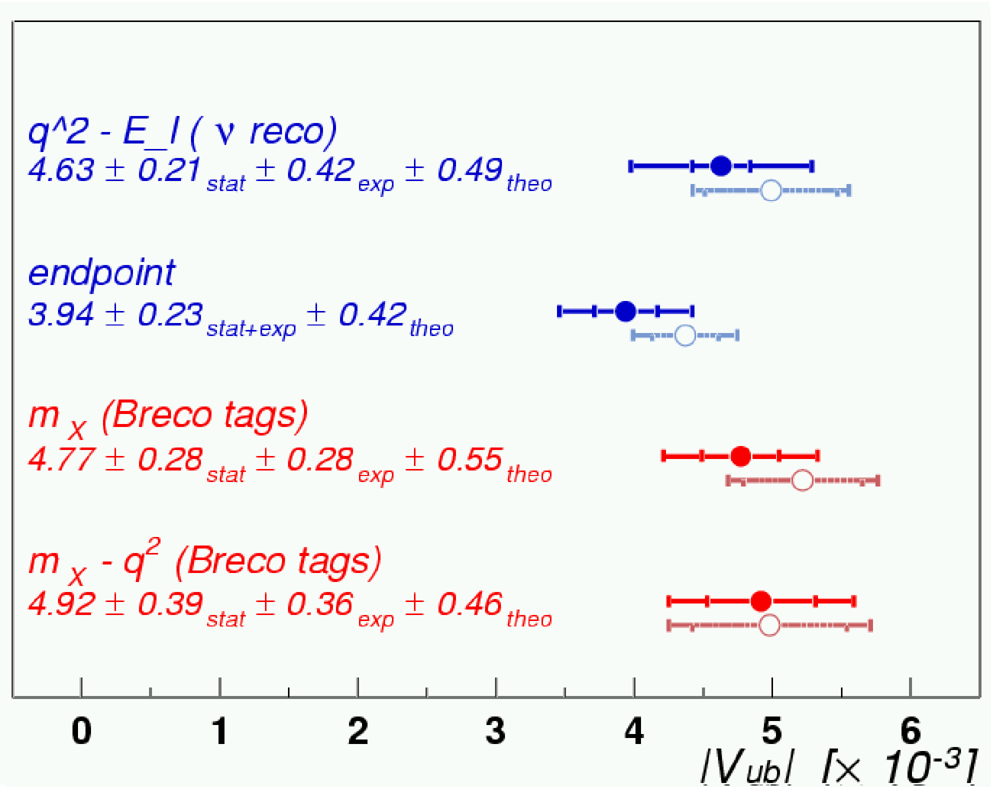
$$\Delta B(B \to X_u l \nu) = (0.88 \pm 0.14_{stat} \pm 0.13_{exp\ syst} \pm 0.02_{(m_b, a)\ syst}) \times 10^{-3}$$

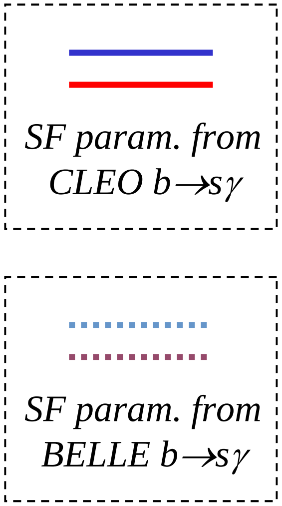
$$|V_{ub}| = (4.92 \pm 0.39_{stat} \pm 0.36_{exp\ syst} \pm 0.46_{theo\ syst}) \times 10^{-3}$$

(using BLL)

V_{ub} Summary

We measured $|V_{ub}|$ with different experimental inclusive techniques:





- Dominant error from modellization of non-perturbative effects (Shape Function, SF).
- We measured the unfolded m_X distribution. In future $b\to ul\nu$ decays can be used to put constraints on SF parameters.
- FUTURE: use $b\to ul\nu$ $m(X)$ moments to extract V_{ub} and non-perturbative params.

Excl. V_{ub}: Theory and Uncertainties

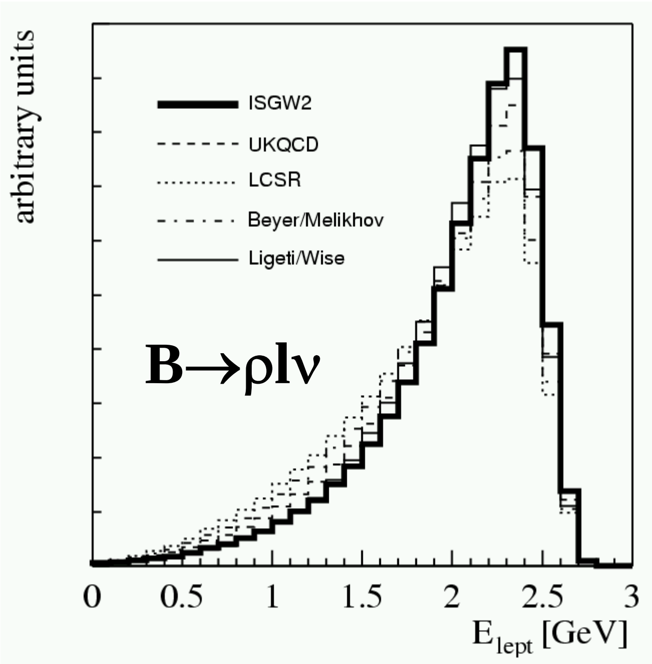
- primary challenge is calculation of the form factors (containing hadronization effects and non-pert. contributions)
- large uncertainties both extrapolation to full phase space and determination of $|V_{ub}|$
- different theoretical models predict different q^2 distributions.
- discriminate among models by a precise measurement of differential BRs.

The differential branching ratio can be related to $|V_{ub}|$ by the following relation

$$\frac{dB(B^0 \rightarrow \pi^- l^+ \nu)}{dq^2 d(\cos\theta_{Wl})} = |V_{ub}|^2 \tau_{B^0} \frac{G_F^2 k_\pi^3}{32\pi^3} \sin^2\theta_{Wl} \left| f(q^2) \right|^2$$

The bigger the integrated region the smaller the uncertainty on $|V_{ub}|$

Recoil approach reduces the extrapolation errors since we can use looser cuts! (less background)



Exclusive V_{ub}

Partial Tags

Breco Tags

- Partial Tags: measurement in bins of q^2(0-8-16GeV^2/c^4)
  Signal yields are extracted by fitting M_ν^2 (ν mass squared):

$$B(B^0 \to \pi^- l^+ \nu) = (1.46 \pm 0.27_{stat} \pm 0.28_{syst}) \times 10^{-4}$$

- Breco Tags: 9 $B \to X_u l \nu$ modes: X_u=$\pi^+,\pi^0,\rho^+,\rho^0,\omega,\eta,\eta',a_0^0, a_0^+$
  Approach similar to the inclusive analysis but resonances are exclusively and fully reconstructed on recoil.

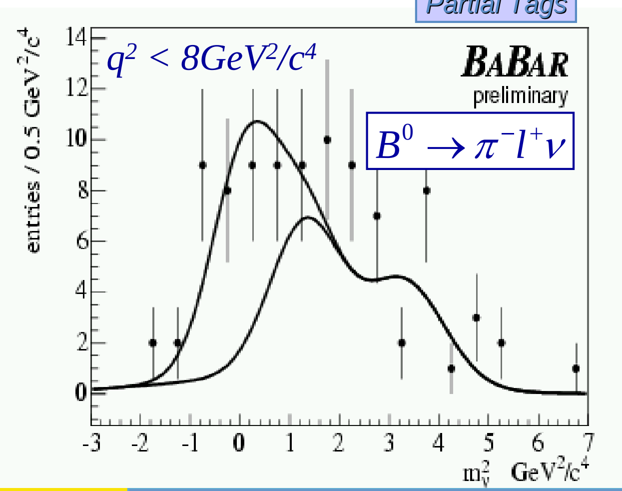
$$B(B^0 \to \pi^- l^+ \nu) = (1.08 \pm 0.28_{stat} \pm 0.16_{syst}) \times 10^{-4}$$

$$B(B^0 \to \rho^- l^+ \nu) = (2.57 \pm 0.52_{stat} \pm 0.59_{syst}) \times 10^{-4}$$

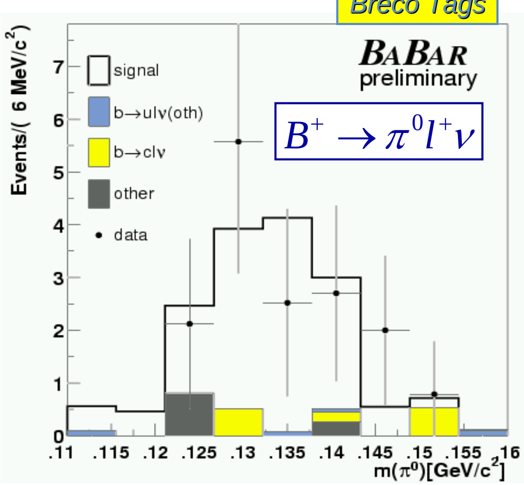
(upper limits for η,η',a_0^0, a_0^+, results in backup slides)

80fb^{-1}

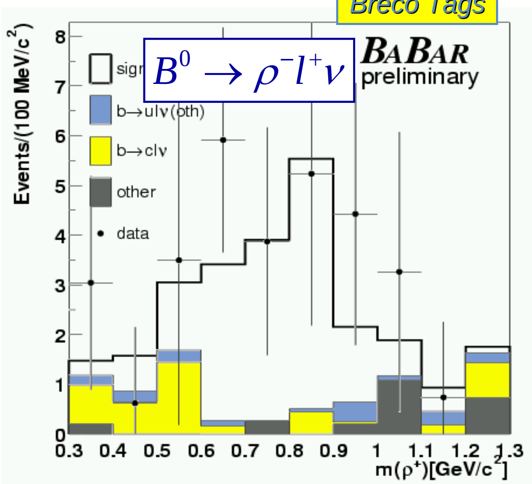
Partial Tags



Breco Tags

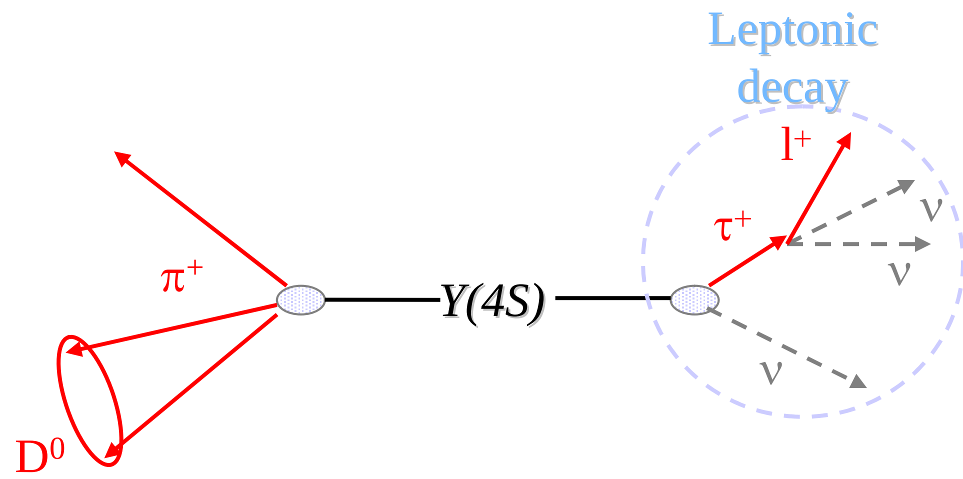


Breco Tags



Recoil in Leptonic Decays (and hνν)

B→τν,νν,Kνν



Recoil is useful in the leptonic decays with <u>many neutrinos</u> but we cannot use kinematic constraints anymore

Typical cuts:

require the recoil to have

- exact charged-particle content expected for signal
- number and total energy E_{extra} of neutrals observed less than an analysis-dependent threshold
- tagging efficiencies can be checked by "double-tagging"
- apply anti-continuum shape cuts

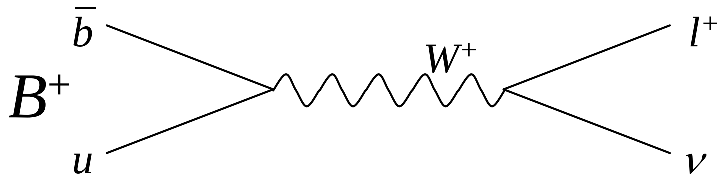
Measurements:

- **B→τν**
- **B→νν**
- **B→Kνν**
- **B→ττ**

Published or preliminary
Future

Leptonic B decays to $\tau^+ \nu$, $\nu\,\nu$

- Leptonic decays of heavy-quark mesons provide a laboratory
  - **For testing straightfoward SM predictions:**



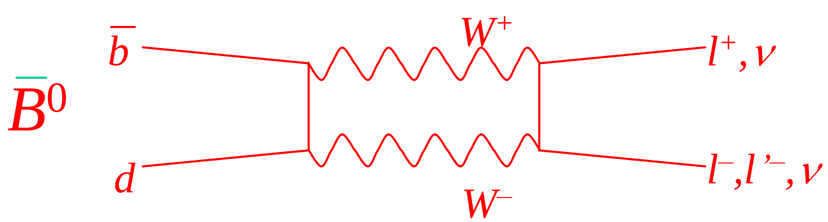
$$\mathcal{B}(B^+ \to l^+\nu) = \frac{G_F^2 |V_{ub}|^2}{8\pi} f_B^2 \tau_B m_B m_l^2 \left[1 - \frac{m_l^2}{m_B^2}\right]^2$$

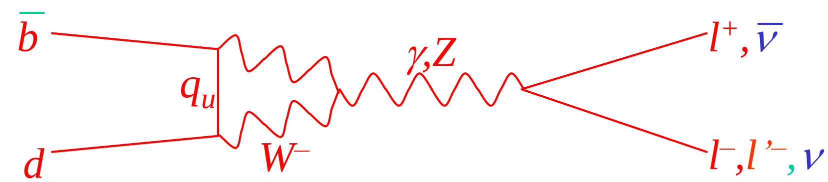
Note helicity suppression

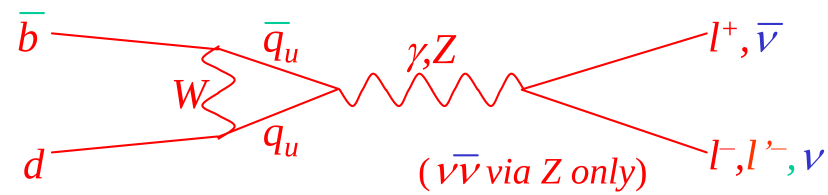
Calculable in Lattice QCD

In SM: $B(B^+ \to \tau^+ \nu_\tau) \sim (9.3 \pm 3.9)\times 10^{-5}$ (PDG'04 V_{ub}, f_B)
(pred.) $B(B^+ \to \mu^+ \nu_\mu) \sim (4.2 \pm 1.8)\times 10^{-7}$

  - **For searching for non-SM effects** in highly suppressed processes. Some new-physics in loops (e.g., SUSY) can enhance these by orders of magnitude.







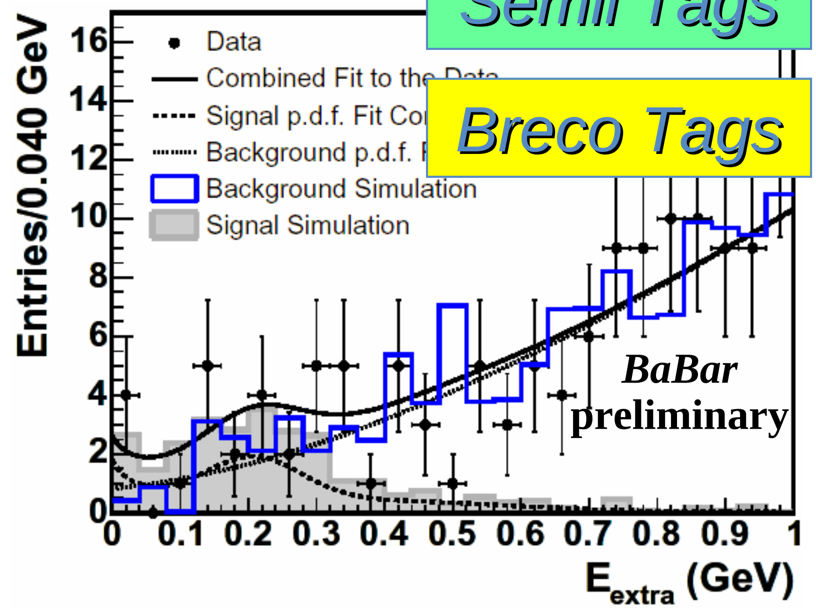
In SM: $B(B^0 \to \mu^+\mu^-) \sim 8\times 10^{-11}$
(pred.) $B(B^0 \to \nu\,\bar{\nu}) \sim$ zero

$B^+ \rightarrow \tau^+ \nu_\tau$ analysis I

- Semileptonic tags: ML fit to E_{extra}
  - Consider $\tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau$ and $\mu^+ \nu_\mu \bar{\nu}_\tau$
  - Signal: 14.8 ± 6.3 events
    Background: 115.2 ± 11.8 events
  - Significance as a signal: 2.3σ (stat. only)
  - Limit (CLs method, incl. syst.):
    $B(B^+ \rightarrow \tau^+ \nu_\tau) < 6.7\times10^{-4}$ (90%CL)

Semil Tags

Breco Tags



- Hadronic tags: event counts
  - $\tau^+ \rightarrow \pi^+ \bar{\nu}_\tau, \pi^+\pi^0 \bar{\nu}_\tau, \pi^+\pi^-\pi^+ \bar{\nu}_\tau, e^+ \nu_e \bar{\nu}_\tau, \mu^+ \nu_\mu \bar{\nu}_\tau$
  - Signal in kin./E_{extra} regions:
    15 events
    Background:
    17.2 ± 2.1(stat) ± 1.3 (syst) events
  - Limit (L-ratio w/ null hypothesis):
    $B(B^+ \rightarrow \tau^+ \nu_\tau) < 4.2\times10^{-4}$ (90%CL)

selection	τ branching fraction $\mathcal{B}(\%)$	eff'c'y given tag $\varepsilon_i(\%)$	backgr'nd estimate b_i	N_{obs} n_i
$e\nu\nu$	17.84 ± 0.06	3.4 ± 0.1	$0.7 \pm 0.4 \pm 0.1$	2
$\mu\nu\nu$	17.37 ± 0.06	1.9 ± 0.1	$0.9 \pm 0.5 \pm 0.1$	0
$\pi\nu$	11.06 ± 0.11	2.6 ± 0.1	$1.3 \pm 0.6 \pm 0.2$	2
$\pi^-\pi^+\pi^-\nu$	9.52 ± 0.10	0.6 ± 0.1	$4.3 \pm 1.0 \pm 0.3$	4
$\pi^-\pi^0\nu$	25.41 ± 0.14	2.0 ± 0.1	$10.0 \pm 1.6 \pm 1.3$	7
all	81.20 ± 0.22	10.5 ± 0.2	$17.2 \pm 2.1 \pm 1.3$	15

- Combined limit: $B(B^+ \rightarrow \tau^+ \nu_\tau) < 4.2\times10^{-4}$ (90%CL)

BB pairs used: $(88.9\pm1.0)\times10^6$

$B^+ \to \tau^+ \nu_\tau$ analysis II – $D^*l^-\nu$ tags

Semil Tags

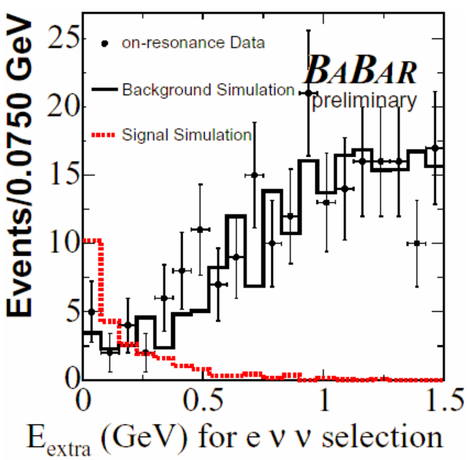
- Refinement of semileptonic part of analysis I
  - Tighten tag selection to require clean *D**
- Consider $\pi^+\bar{\nu}_\tau$, $\pi^+\pi^0\bar{\nu}_\tau$, $\pi^+\pi^-\pi^+\bar{\nu}_\tau$, $e^+\nu_e\bar{\nu}_\tau$, and $\mu^+\nu_\mu\bar{\nu}_\tau$
  - Mode-dependent kinematic selections
- Determine signals by counting events in E_{extra} regions

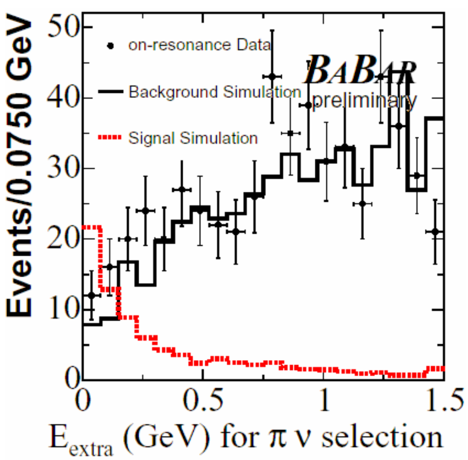
Using $(124.1\pm1.4)\times10^6$ *BB* pairs

Mode	$e^+\nu_e\bar{\nu}_\tau$	$\mu^+\nu_\mu\bar{\nu}_\tau$	$\pi^+\bar{\nu}_\tau$	$\pi^+\pi^0\bar{\nu}_\tau$	$\pi^+\pi^-\pi^+\bar{\nu}_\tau$
BG incl. systematics	15.2±3.1	8.1±2.1	55.3 ±7.4	29.8 ±5.1	25.1 ±3.4
Observed	13	10	72	30	26

Validations
- Signal efficiency, E_{extra}:
  - Double tags
- Backgrounds:
  - Control samples with extra tracks

(Signal MC scaled to $BF=10^{-3}$)





Result:
$B(B^+ \to \tau^+ \nu_\tau) < 4.3\times10^{-4}$ (90%CL)

Combined with hadronic tags:
(independent, 88.9M BB)
$B(B^+ \to \tau^+ \nu_\tau) < 3.3\times10^{-4}$ (90%CL)

Also recall (PRL 92, 221803, '04)
BaBar $B(B^+ \to \mu^+ \nu_\mu) < 6.6\times10^{-6}$

$B^0 \to$ invisible ($\nu\,\nu$), $\nu\,\nu\gamma$ analysis

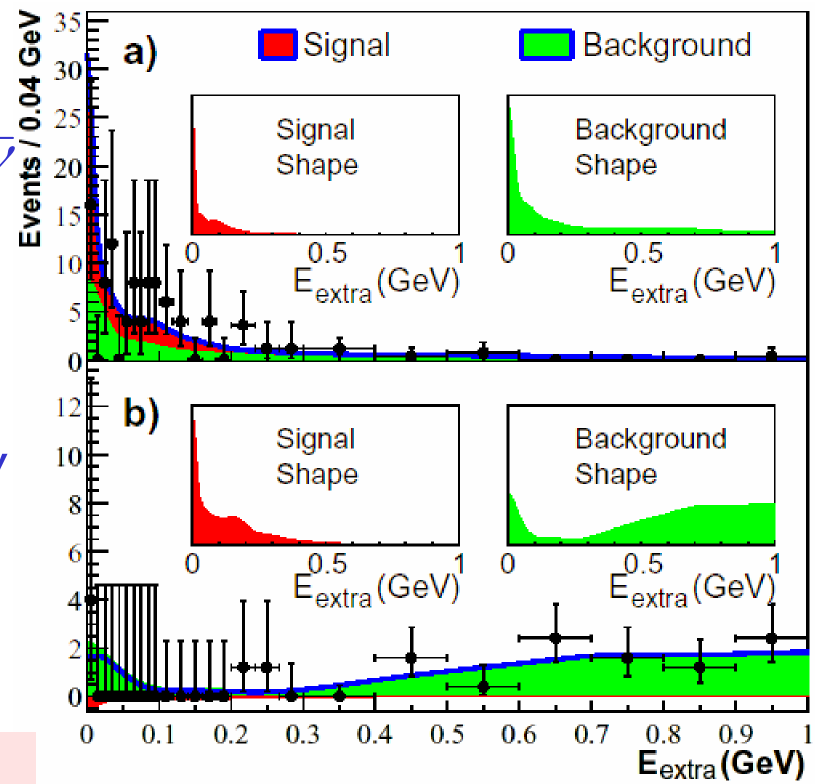
Semil Tags

- Semileptonic tags only: $B^0 \to D^{(*)+} l^- \bar{\nu}$ $(D^{*+} \to D^0 \pi^+)$
- Require "nothing" in recoil: no charged tracks, limited neutrals
- Signal obtained from ML fit to E_{extra} (KEYS shapes from MC):
  - $\nu\,\nu$:
    - Signal: 17 ± 9, background 19^{+10}_{-8} events
  - $\nu\,\nu\gamma$:
    - Signal: $-1.1^{+2.4}_{-1.9}$, background 28^{+6}_{-5}
- Upper limits:
  - Systematics for $\nu\,\nu$ ($\nu\,\nu\gamma$):
    - Additive: 7.4 (4.3) events
    - Multiplicative: 10.9% (11.1%)
  - Frequentist limit-setting procedure
    - Systematics taken as Gaussian

$B\bar{B}$ pairs used: $(88.5\pm1.0)\times10^6$

$\nu\,\bar{\nu}$

$\nu\,\bar{\nu}\gamma$



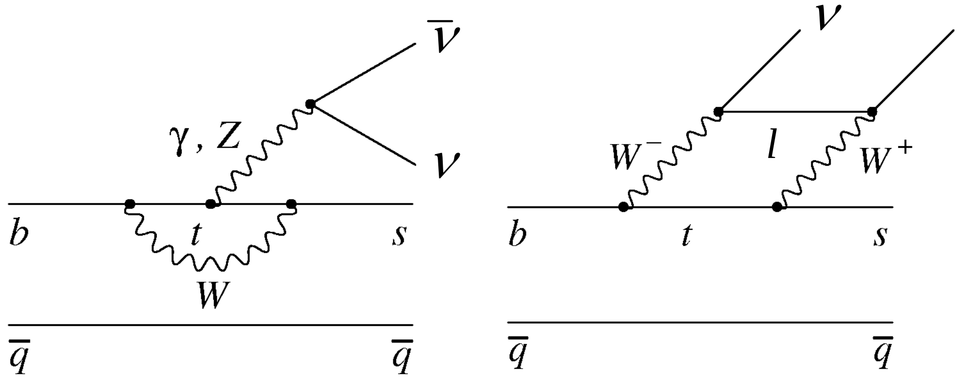
B($B^0 \to$ invisible) < 22 $\times 10^{-5}$ (90%CL)

B($B^0 \to \nu\,\bar{\nu}\gamma$) < 4.7 $\times 10^{-5}$ (90%CL)*

*Depends on constituent quark model for Dalitz plot shape (Lu & Zhang, Phys. Lett. B 381, 349 (1996))

B decays to $K/\pi^+ \nu \nu$

- Motivation
  - The flavor-changing neutral current decays $B \to K/\pi^+ \bar{\nu}\nu$ occur in the Standard Model via one-loop radiative penguin and box diagrams:



  - SM expectation: B($B^+ \to K^+ \bar{\nu}\nu$) ~ ($3.8^{+1.2}_{-0.6}$) × 10^{-6}, B($B^+ \to \pi^+ \bar{\nu}\nu$) ~ 2.8 × 10^{-7}

  - Their analysis is theoretically very clean; observation of these processes would be complementary to the observation of $B \to K^{(*)} l^+ l^-$ and will help in understanding the basic Standard Model physics of such diagrams.
  - These also present another opportunity for the observation of new-physics effects in the loops.

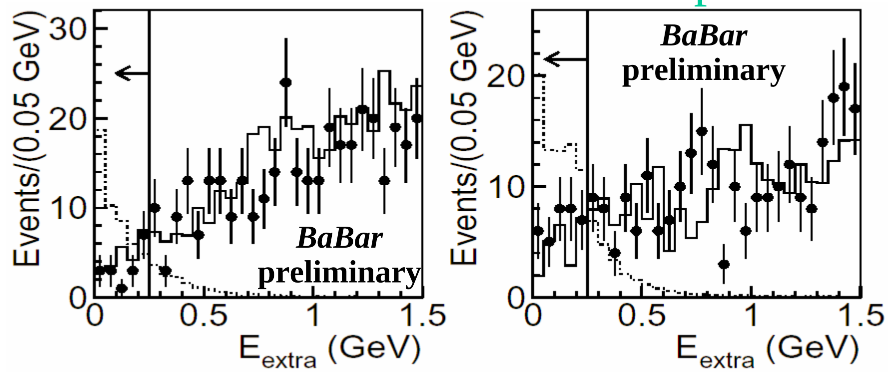
$B^+ \to K/\pi^+ \nu \nu$ analysis

- Uses tags of both types
  - Signal obtained from E_{extra}/p_K region

Tags	Hadronic	Semileptonic
Background events (incl. systematics)	3.9±1.1	3.4±1.2 (non-peaking)
Signal events	3	6
Efficiency (%)	0.055±0.005	0.115±0.009
Limit (90%CL) on $B(B^+ \to K^+ \nu\bar{\nu})$	6.2×10^{-5}	7.0×10^{-5}

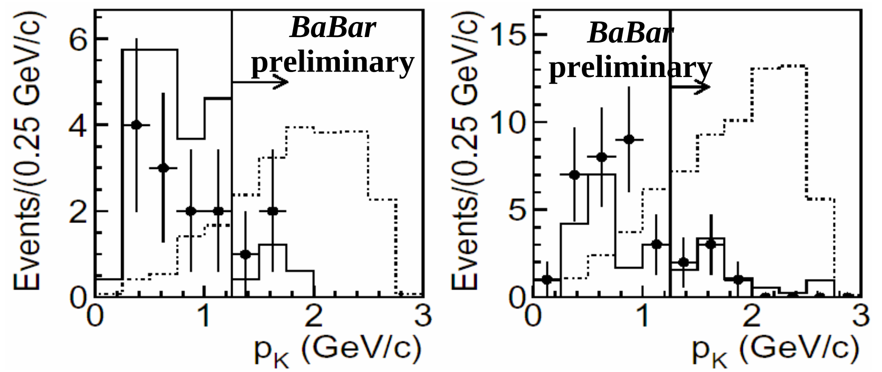
Breco Tags | Semil Tags

E_{extra} | hadronic | semileptonic



Points: data; solid: background MC; dashed: signal MC (arbitrary scale)

p_K



- Combined limit:

  $B(B^+ \to K^+ \nu\bar{\nu}) < 5.2\times10^{-5}$ (90%CL)

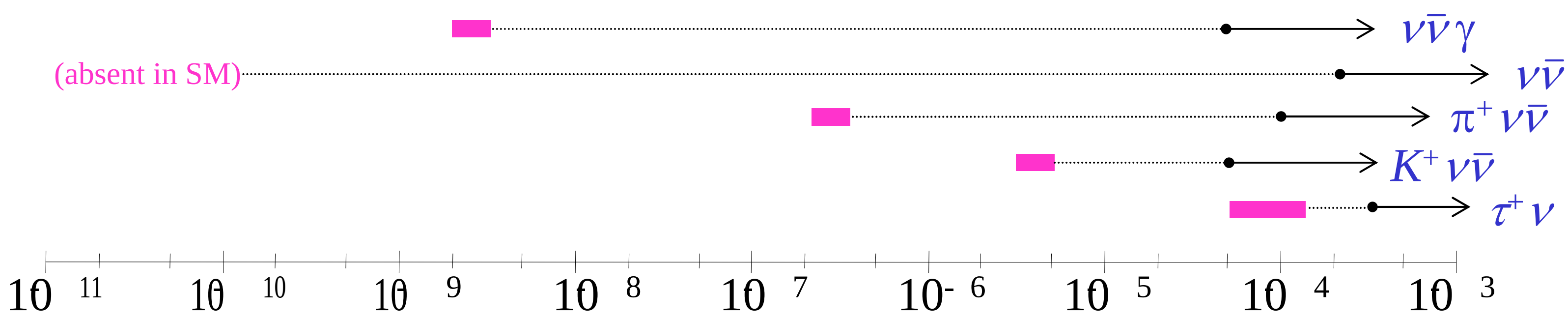
- Also possible to set limit on $B^+ \to \pi^+ \nu\nu$
  - Change PID requirement; use only hadronic analysis: $B(B^+ \to \pi^+ \nu\bar{\nu}) < 1.0 \times10^{-4}$ (90%CL)

$B\bar{B}$ pairs used: $(88.9\pm1.0)\times10^6$

Summary of Leptonic Decays (and hνν)

- Upper limits on branching fractions of several rare leptonic and/or FCNC decays of *B* mesons useful as …
  - checks of basic predictions for weak decays of heavy-quark mesons (e.g., f_B), and
  - probes for new physics beyond the Standard Model

- These decays have not yet come into sight

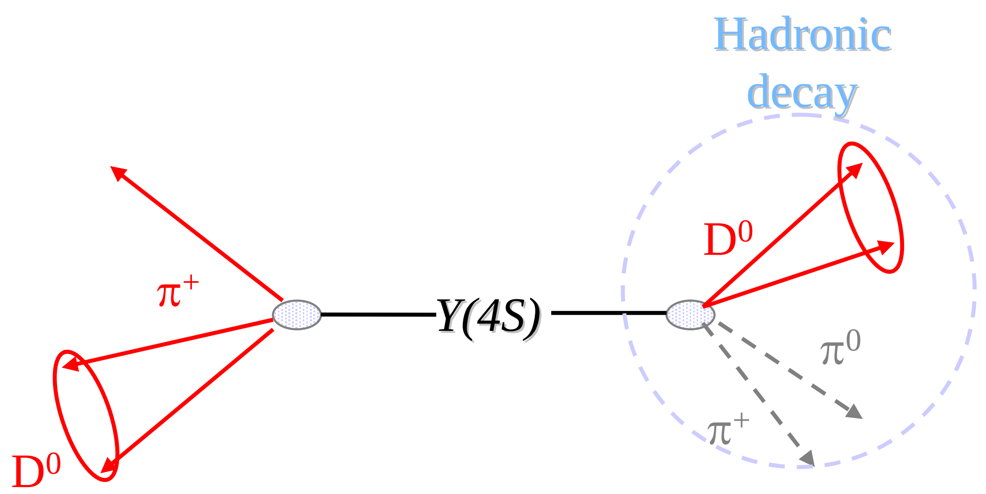


but some are now within an order of magnitude or less of the SM expectations…

- Some of these will very likely be observed in few years from now…

Recoil in Hadronic Decays

B→DX



In principle no neutrinos in the event.
Full event reconstruction could be done but
too low efficiencies.
Inclusive approach used instead.

Typical approach:

- *reconstruct exclusively a meson*
  - charmed ($D^{0/\pm(*)}$ or $D_s^{(*)}$)
  - charged pion or kaon
- Measure the inclusive BR (i.e. BR(B→DX)) by normalizing to the total number of fully reconstructed tags

…. or …..

- Study inclusively the missing mass of the event (measuring BRs, checking for new resonances)

Measurements:

- **$B\to D^{0/\pm}X$, $B\to D_sX$**
- **$B\to D^{0/\pm(*,**)}\,\pi/K$**
- **$B\to D^{0/\pm(*)}X$, $B\to D_s^{(*)}X$:**

study of missing mass

Published or preliminary
Future

Inclusive charm

Hadronization models (Heavy Quark Expansion) predict average charm multiplicity in *B* decays, **$n_c \approx 1.2$-1.3**

[Bagan et al. PLB351(1995)
Buchalla and Dunietz, PLB364(1995)
Neubert and Sachrajda, Nucl.Phys.B483(1997)]

We define:

- *Flavor* ***correlated charm*** production from dominant $b \to c$ transition

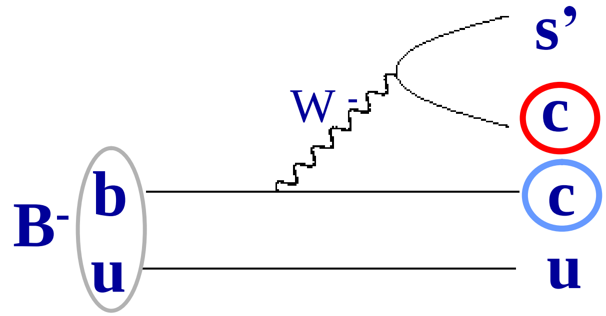
$$X_c = D^+, D^0, D_s^+, \Lambda_c^+, \Xi_c, (c\bar{c})$$

$$N_c = \sum_{X_c} \mathcal{B}(B^- \to X_c X)$$

- *Flavor* ***anti-correlated charm*** production from $W^- \to c\bar{s}'$ decay

$$\bar{X}_c = D^-, \bar{D}^0, D_s^-, \bar{\Lambda}_c^-, (c\bar{c})$$

$$N_{\bar{c}} = \sum_{\bar{X}_c} \mathcal{B}(B^- \to \bar{X}_c X)$$



$$n_c = N_c + N_{\bar{c}}$$ [charge-conjugation implied everywhere]

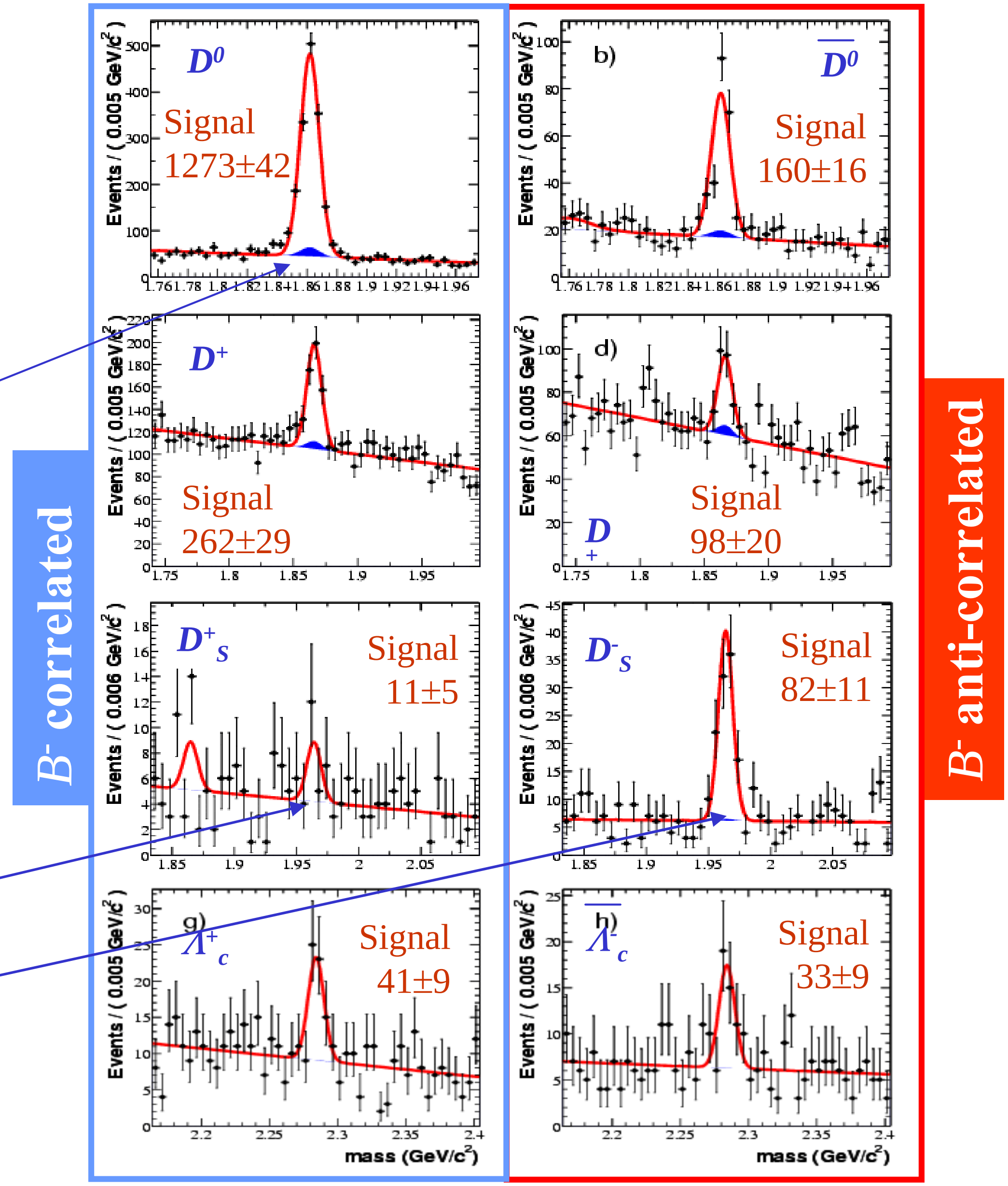
Inclusive Charm

Breco Tags

Data sample: 89 million B pairs

Linear bkg:
combinatorics
Blue-shaded areas:
true charm particles from background of misreconstructed ***B***

- Significant production of correlated D^0 and D^+
- D_s correlated production small. Anti-correlated dominant.



Inclusive Charm: Results

- using

$$\mathcal{B}(B^- \to \Xi_c X) = \mathcal{B}(B^- \to \Lambda_c^- X) - \mathcal{B}(B^- \to \Lambda_c^+ \Lambda_c^- K) \cong \mathcal{B}(B^- \to \Lambda_c^- X)$$

- neglecting $\mathcal{B}(B^- \to \Xi_c X)$
- using $\mathcal{B}(B^- \to (c\bar{c}) X) = (2.3 \pm 0.3)$ %

We get

B^-

$$N_c^- = 0.983 \pm 0.030 \pm 0.046^{+0.028}_{-0.023}$$
$$\bar{N}_c^- = 0.330 \pm 0.022 \pm 0.020^{+0.051}_{-0.031}$$
$$n_c^- = 1.313 \pm 0.037 \pm 0.062^{+0.063}_{-0.042}$$

B^0

$$N_c^0 = 1.039 \pm 0.051 \pm 0.049^{+0.039}_{-0.031}$$
$$\bar{N}_c^0 = 0.237 \pm 0.036 \pm 0.012^{+0.039}_{-0.024}$$
$$n_c^0 = 1.276 \pm 0.062 \pm 0.058^{+0.066}_{-0.046}$$

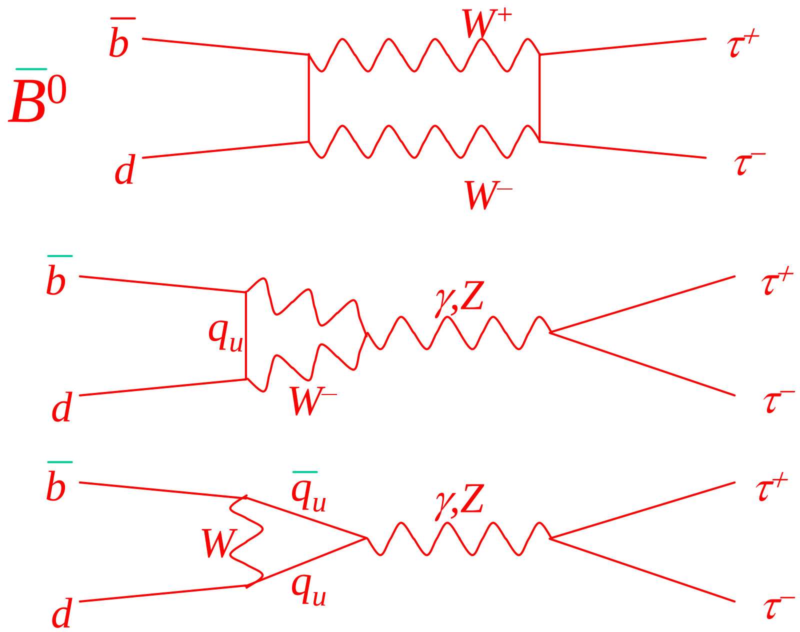
X_c	correlated $\mathcal{B}(B^- \to X_c X)$ %	anti-correlated $\mathcal{B}(B^- \to \bar{X}_c X)$ %
D^0	$79.3 \pm 2.5 \pm 4.0^{+2.0}_{-1.9}$	$9.8 \pm 0.9 \pm 0.5^{+0.3}_{-0.3}$
D^+	$9.8 \pm 1.2 \pm 1.2^{+0.8}_{-0.7}$	$3.8 \pm 0.9 \pm 0.4^{+0.3}_{-0.3}$
D^+_s	$0.5 \pm 0.6 \pm 0.2^{+0.2}_{-0.1}$ <2.2 at 90% CL	$14.3 \pm 1.6 \pm 1.5^{+4.9}_{-3.0}$
Λ^+_c	$3.5 \pm 0.8 \pm 0.3^{+1.3}_{-0.8}$	$2.9 \pm 0.8 \pm 0.3^{+1.1}_{-0.6}$

X_c	correlated $\mathcal{B}(B^0 \to X_c X)$ %	anti-correlated $\mathcal{B}(B^0 \to \bar{X}_c X)$ %
D^0	$51.1 \pm 3.1 \pm 2.5^{+1.3}_{-1.3}$	$6.3 \pm 1.9 \pm 0.5^{+0.2}_{-0.2}$
D^+	$39.7 \pm 3.0 \pm 2.8^{+2.8}_{-2.5}$	$2.3 \pm 1.8 \pm 0.3^{+0.2}_{-0.2}$ < 5.1 at 90% CL
D^+_s	$3.9 \pm 1.7 \pm 0.4^{+1.3}_{-0.8}$ < 8.7 at 90% CL	$10.9 \pm 2.1 \pm 0.8^{+3.8}_{-2.3}$
Λ^+_c	$4.9 \pm 1.7 \pm 0.4^{+1.8}_{-1.0}$	$2.0 \pm 1.2 \pm 0.2^{+0.7}_{-0.4}$ <3.9 at 90%CL

- No evidence of $B^- \to \Lambda_c^+ \Lambda_c^- K$
- First measurement of D^+_s correlated
- Sizeable Λ_c production

FUTURE

$B \to \tau\tau$



SM prediction:

$$B(B^0 \to \tau^+\tau^-) \sim 3\times10^{-8}$$

…but…

Potential enhancements up to 10^2 due to new physics

No published experimental UL

Very difficult measurement

- ~2/3 of the $B^0 \to \tau^+\tau^-$ events contain at least one K_L
- Many neutrinos, large missing mass

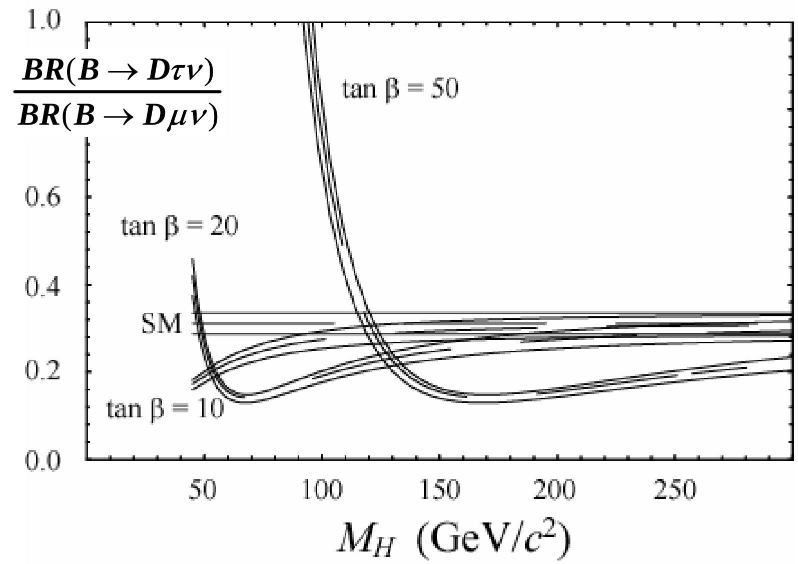
This measurement is possible only on the recoil

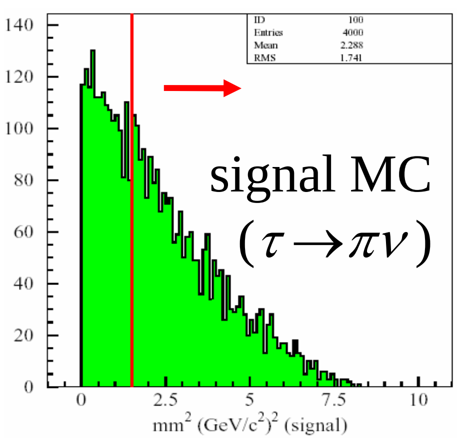
B→Dτν

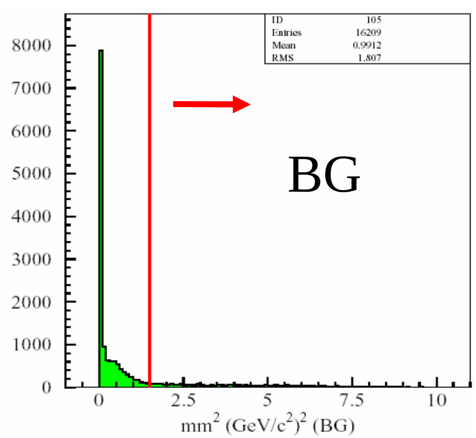
- Channel sensitive to new Physics

- 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:

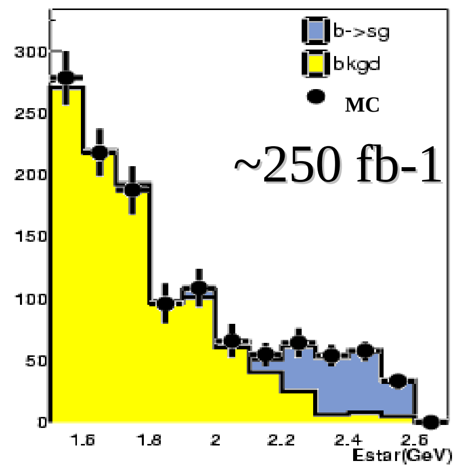
$D^0 \to K^-\pi^+$	4%
$\to K^-\pi^+\pi^0$	13%
$\to K^-\pi^+\pi^+\pi^-$	7%
$\to K^-\pi^+\pi^+\pi^-\pi^0$	4%
$\to K_S\pi^0$	1%
$\to K_S\pi^+\pi^-$	2%
$\to K_S\pi^+\pi^-\pi^0$	4%
Total	**35%**

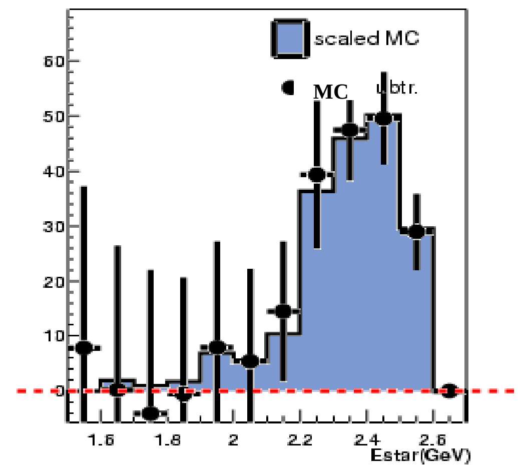
$\tau^- \to \pi^-\nu_\tau$	11%
$\to \rho^-\nu_\tau$	25%
Total	**36%**

Perspectives on $B \rightarrow X_s \gamma$

Breco Tags

An interesting application is in measuring $b \rightarrow s\gamma$ branching ratio and photon spectrum. It presents many advantages with respect to the fully inclusive approach:





1) Continuum is subtracted by fitting mes in the reconstructed side
2) Exact boost in the recoiling B meson rest frame → no smearing due to the B meson momentum in the Y(4S) frame
3) Perfect tagging. You can distinguish between B^0-B^0_{bar} and B^+-B^-
4) You could in principle separate and measure dγ contribution

Assuming an efficiency of 50% in the recoil:

$N_{events}/fb^{-1} = 3 \cdot 10^{-4} * 4 \cdot 10^{3}/fb^{-1} * 0.5 = 0.6/fb^{-1}$ ⇒ **600ev. in $1 \cdot ab^{-1}$**

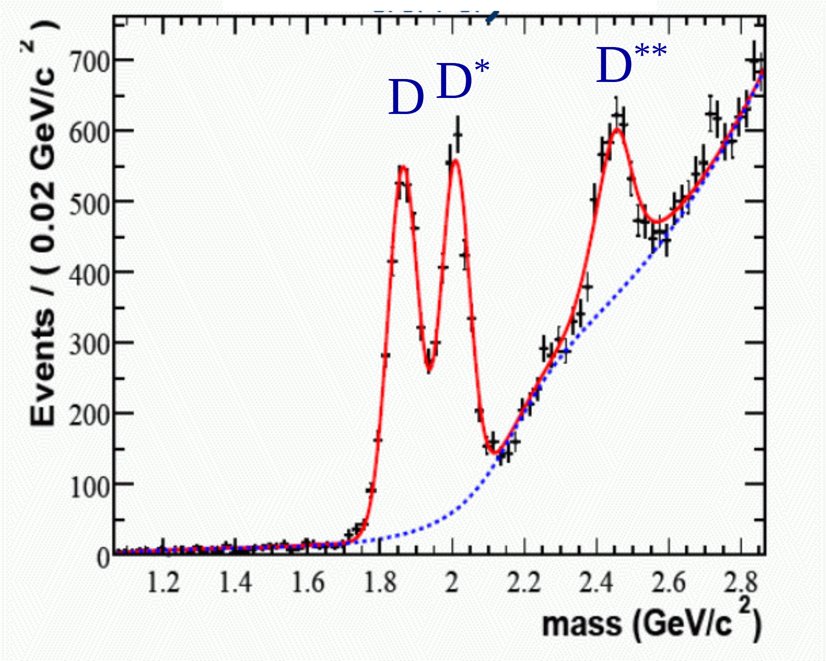
B.R. NBreco. Eff..

Study of X mass recoiling to a π/K

Breco Tags

- Pick up a track on the recoil
- Reconstruct the missing mass as difference from the Y(4s)

  (P(X)=P(Y(4S)-P(Breco)-P(π))
- Extract BRs for $B \to D, D^*, D^{**}\pi$



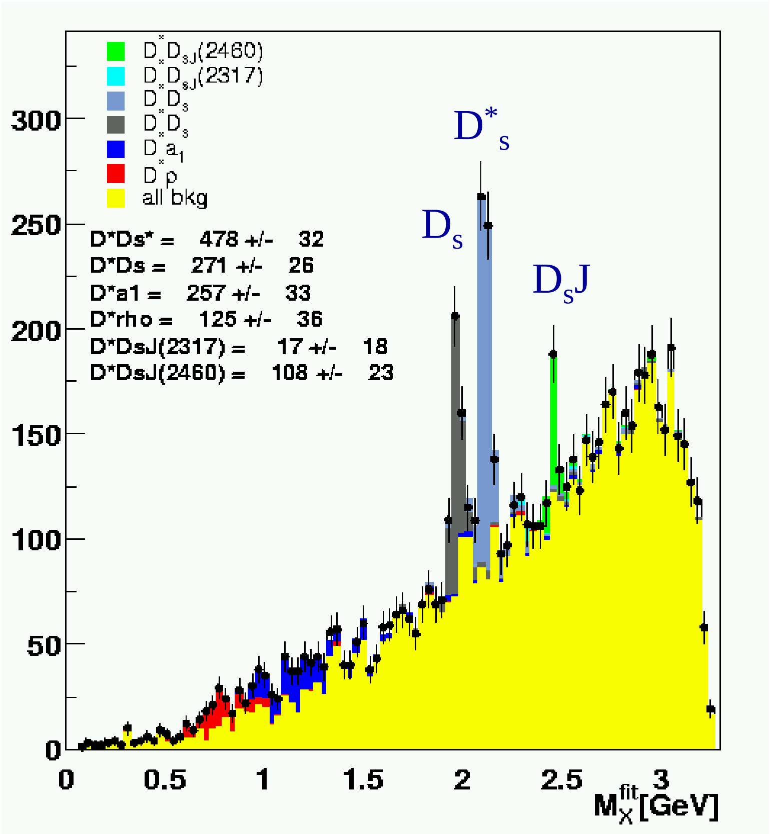
Advantages

- *Clean way to study and measure the decays to excited states ($B \to D^{**}\pi$)*
- *Small systematics (no intermediate BRs)*
- *Possibility to study ratio of BRs with negligible systematic uncertainties*

Study of X mass recoiling to a $D^{+/0(*)}$

Breco Tags

- Exclusively reconstruct charmed meson
- Reconstruct the missing mass as difference from the Y(4s)
  (P(X)=P(Y(4S))-P(Breco)-P(D))
- Apply kinematic fit to improve the resolution of Mx
- Extract BRs for $B \to D^{\pm,0(*)} D_s, D_s^*, D_sJ$



Advantages

- *Small systematics (no intermediate BRs)*
- *$B \to D^{\pm,0(*)} D_sJ$ with no assumption on D_sJ BRs*
- *Possibility to study ratio of BRs with negligible systematic uncertainties*
- *Check for possible new resonances*

CP analyses?

Time dependent CP analyses? Lots of advantages:

1. Very nice vertexing (usual is $70\mu m \otimes 180\mu m \rightarrow 70\mu m \otimes 70\mu m$)
   breco tagging breco breco
2. Almost perfect tagging
3. B^0-B^+ separation
4. You can have an inclusive reconstruction on the recoil side

Possible examples:

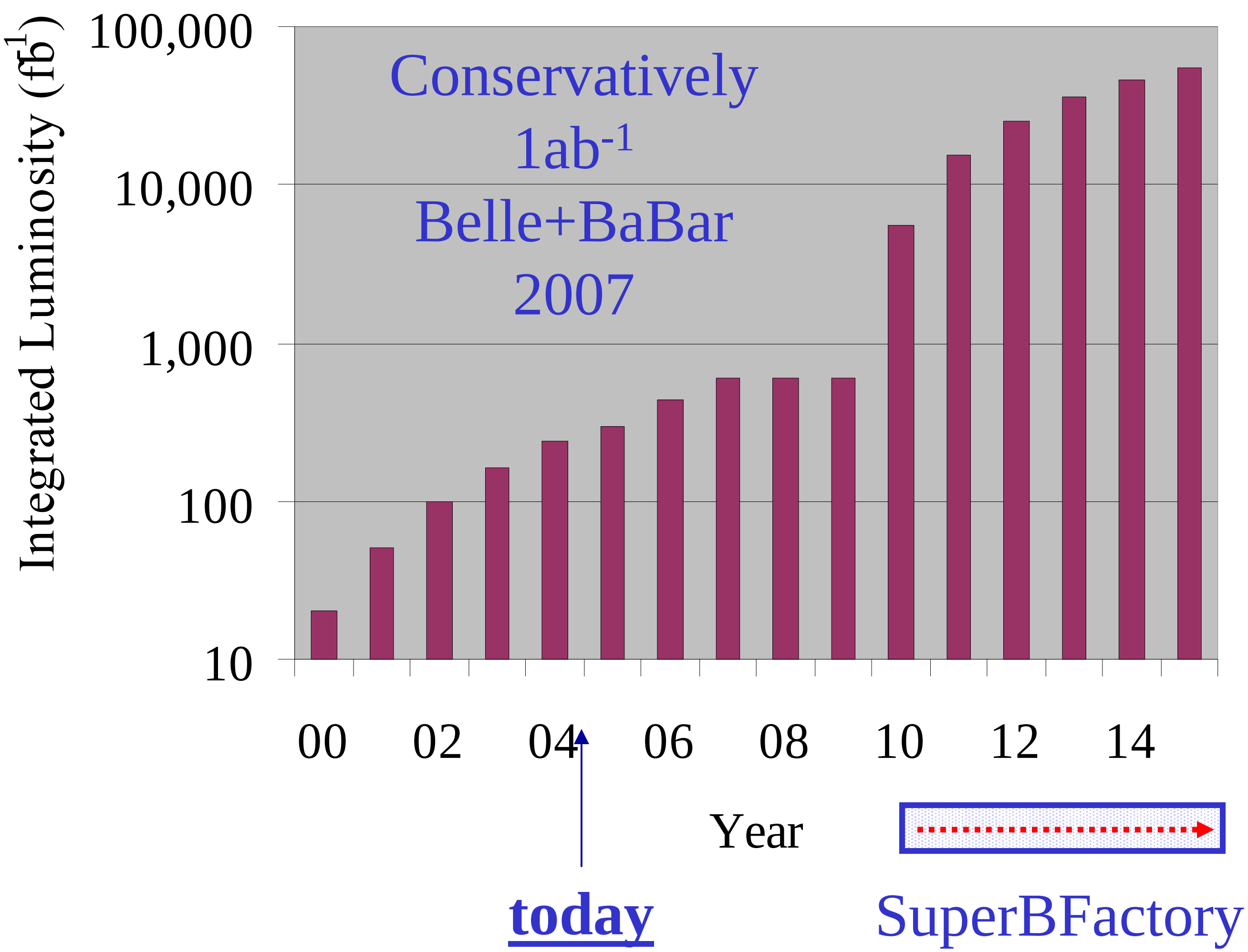
- $B^0 \rightarrow X_S\gamma$????

Direct CP:

Possible example: $B^+ \rightarrow D^0K^+$????

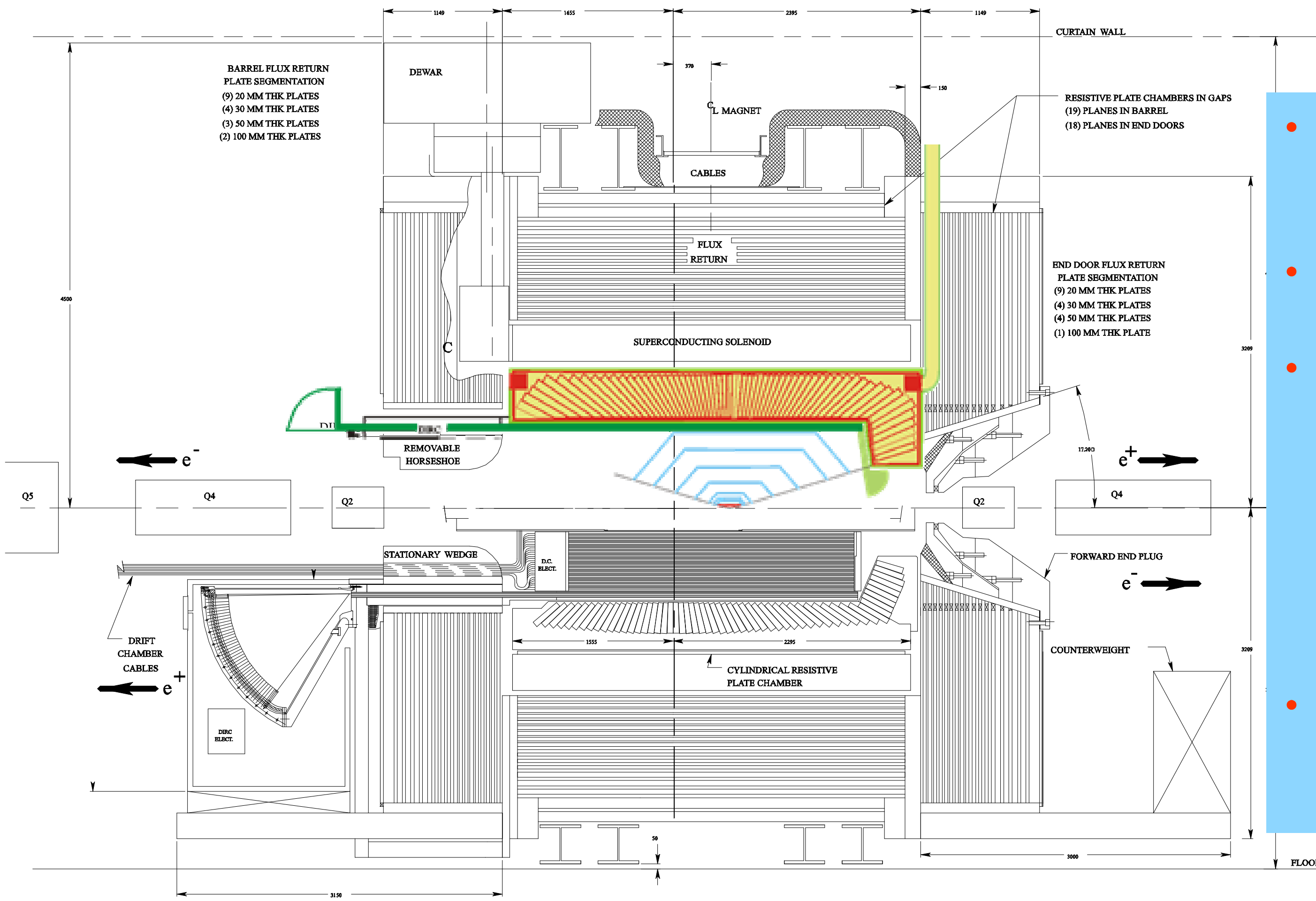
└→ reconstructed inclusively to enlarge stat.

Which luminosity in the next years?



SuperB Detector Proposal

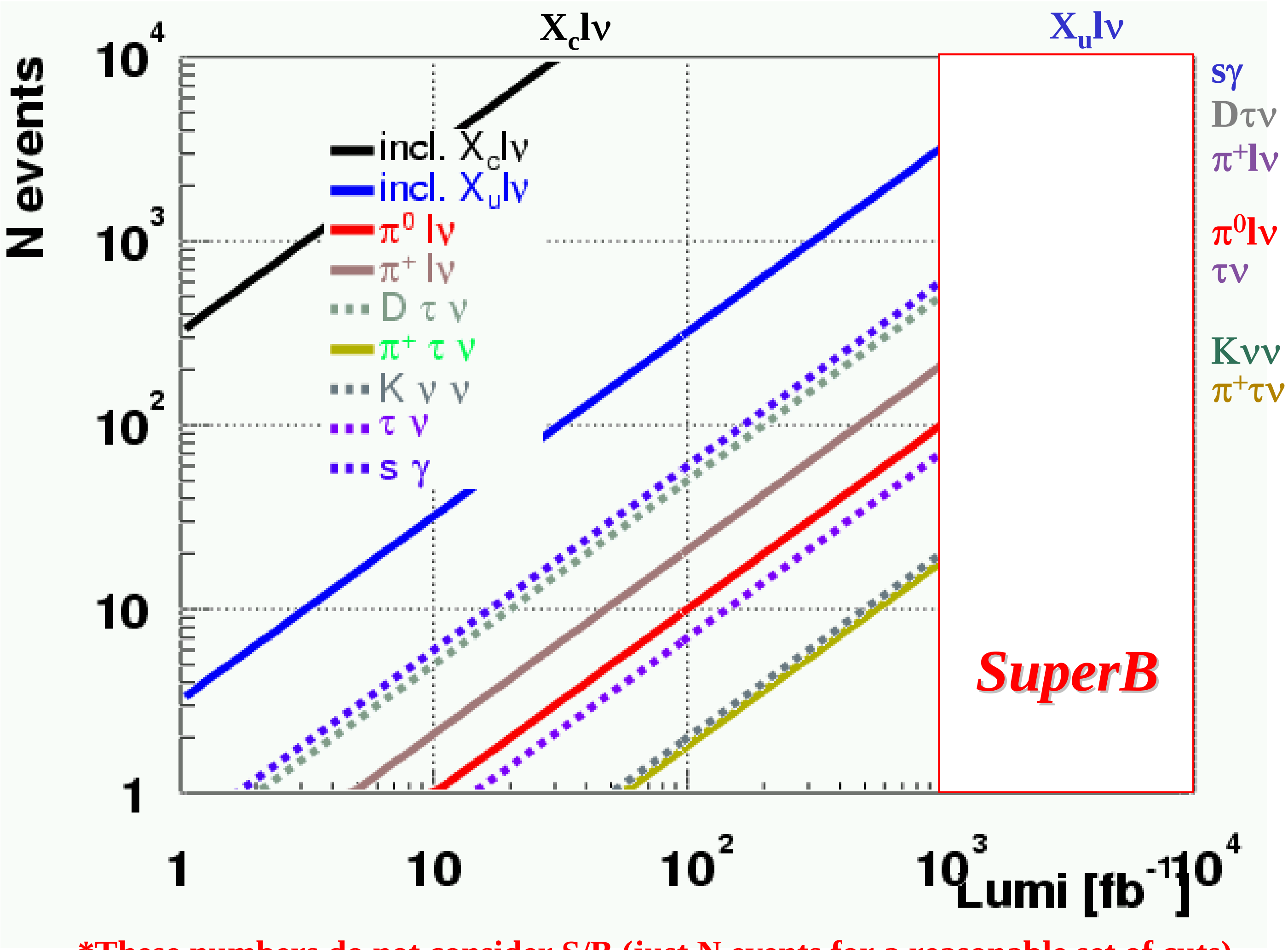
- Possible upgrade of BaBar detector:



- IFR upgraded (ongoing)
- New EMC – liquid Xe
- New tracker
  - Two inner pixel layers
  - Seven(?) thin double-sided Si-strip arch layers
- New DIRC(s) with compact readout

Emphasis on high segmentation, fast integration time, radiation hardness

Summary on Sensitivity



***These numbers do not consider S/B (just N events for a reasonable set of cuts)**
****Some of them use more than one type of tags. If not, they could be improved**

Conclusions

- Recoil approach provides the best environment to perform analyses in different fields:
  - Semileptonic Decays: inclusive and exclusive V_{ub}/V_{cb}, $D\tau\nu$, …
  - Leptonic Decays: $\tau\nu$, $\nu\nu$, $\tau\tau$, $K/\pi\nu\nu$, …
  - Hadronic Decays: inclusive charm production, study of missing mass in $B\rightarrow DX$ decays
- BaBar published already many new results using this method (6 publications and lots of preliminary results).
  ~all statistically limited
- This method will be crucial in future when larger statistics will be collected by BaBar and in particular if a SuperBFactory will be built.

BACKUP SLIDES

Incl. V_{ub}: m_X vs. q^2

Breco Tags

Extension of the already published result (PRL92,071802).

- Recoil selection and reconstruction of X system:
  - One and only one lepton with p*> 1 GeV/c
  - Correlation between lepton charge and B_{reco} flavor
  - Cut on the missing mass: $M_{miss}^2 < 0.5\text{GeV}^2$,
  - charge conservation: $Q_{tot}=0$
  - Partially reconstructed neutrino to reject $B^0 \to D^* l \nu$ events
  - kinematic fit (2-C): improve hadronic mass resolution
  - Kaon veto

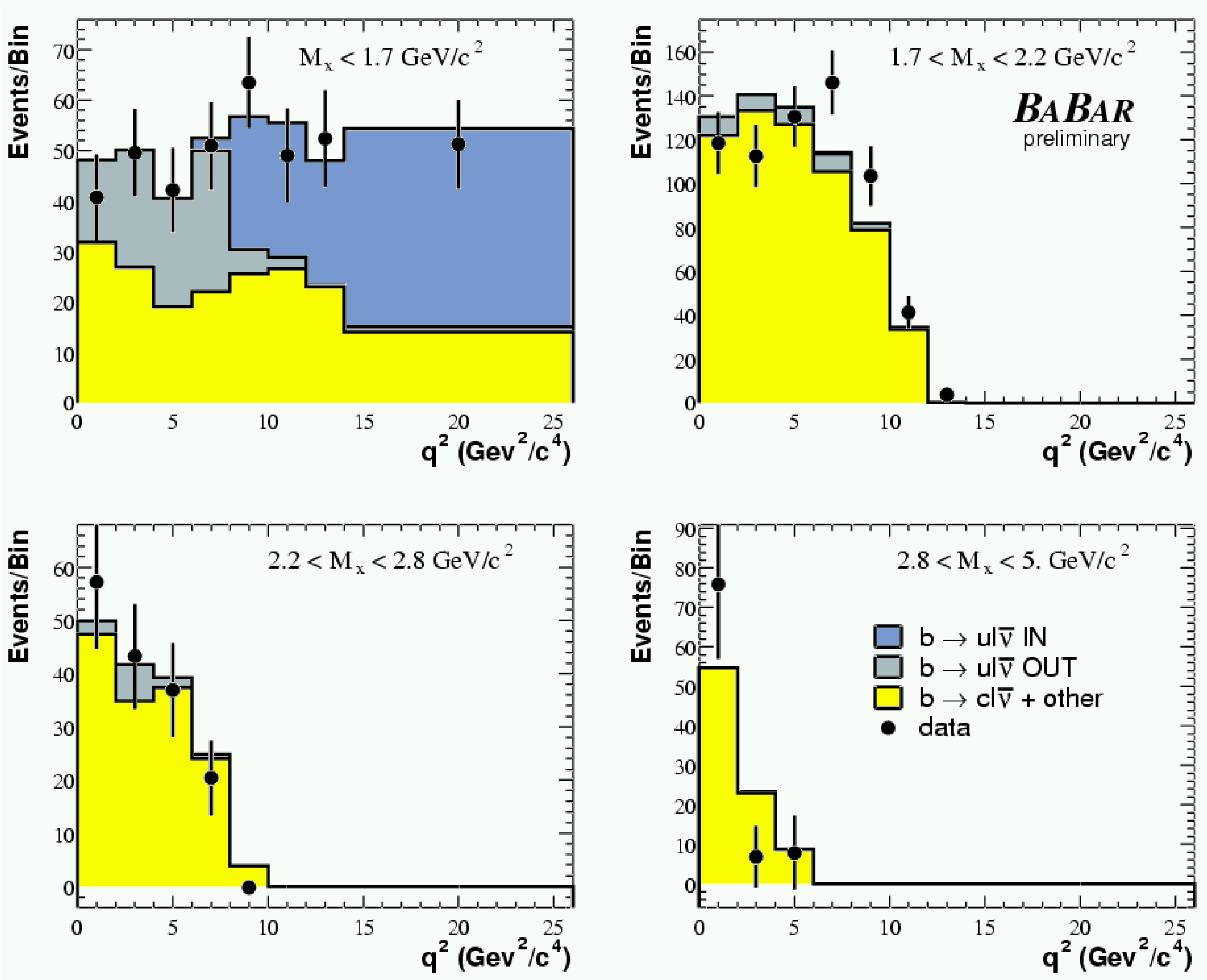
- Systematics due to lepton ID and tag normalization reduced by measuring a ratio of BRs $R_{u/sl} = \frac{B(B \to X_u l\nu)}{B(B \to X l\nu)}$

- m_X <1.7GeV and q^2>8GeV^2 using the approach by Bauer et al. Dependence on shape function parameters is much reduced

This approach and sample have been also used to unfold the m_X spectrum.

Inclusive: m_X and m_X vs. q^2

Breco Tags



Inclusive: Unfold Had. Mass Spectrum

Breco Tags

80fb^{-1}

m_X spectrum can be converted in a universal variable by unfolding detector and selection effects.

relationship between measured and true spectra is:

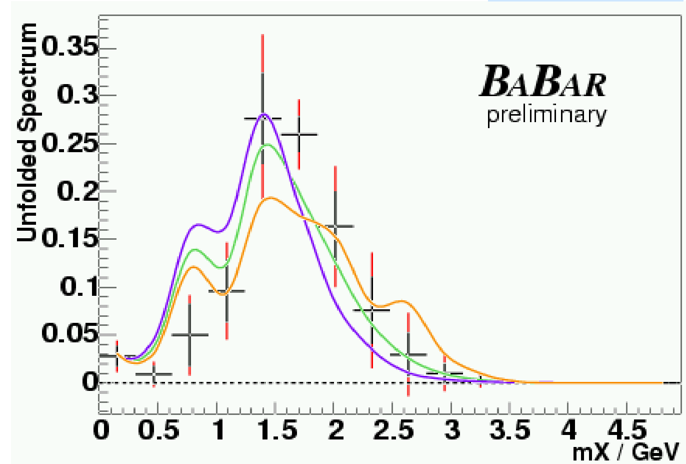
$\vec{x}_{meas} = \mathbf{A}\,\vec{x}_{true}$ where $\mathbf{A}$ is the detector response matrix, in general is non-invertible.

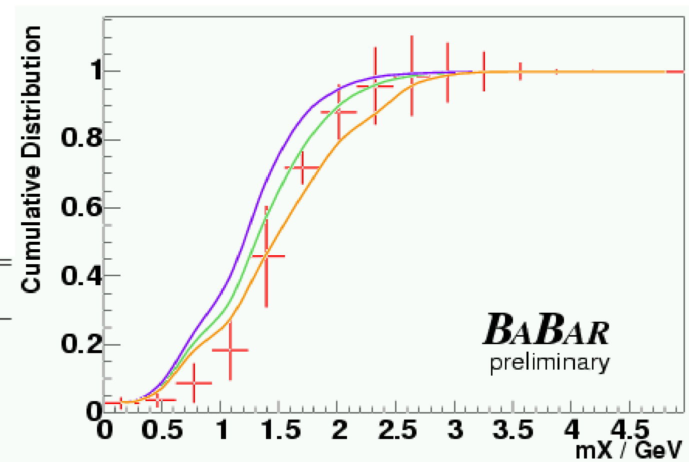
Unfolding method is based on procedure specified in hep-ph/9509307.

Systematics effects are properly taken into account.

First and second moment of the $b \to u l \nu$ m_X distribution are extacted:

	$M_{X,0}$ (GeV/c^2)	$\mathcal{M}$	$\sigma(\mathcal{M})$	Correlation	$\sigma_{\rm stat}$	$\sigma_{\rm det}$	$\sigma_{\rm sig}$	$\sqrt{\sigma^2_{\rm bkg} + \sigma^2_{\rm breco}}$
$\mathcal{M}_1$	1.86	1.363	0.089		0.063	0.023	0.018	0.039
$\mathcal{M}_2'$	1.86	0.143	0.037	−0.824	0.027	0.010	0.006	0.015
$\mathcal{M}_1$	5	1.602	0.244		0.150	0.075	0.061	0.142
$\mathcal{M}_2'$	5	0.271	0.095	0.782	0.048	0.036	0.022	0.069





Exclusive: $B \to (\pi,\rho,\omega,\eta,a_0)\, l\nu$

Breco Tags

9 $B \to X_u l \nu$ modes are studied:

$X_u = \pi^+, \pi^0, \rho^+, \rho^0, \omega, \eta, \eta', a_0^0, a_0^+$

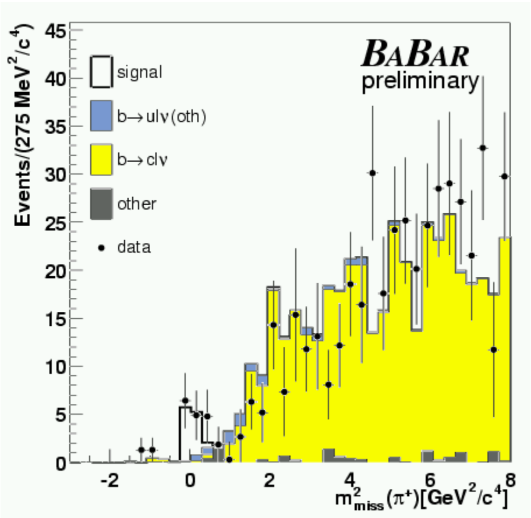
Resonances are exclusively reconstructed on the recoil.

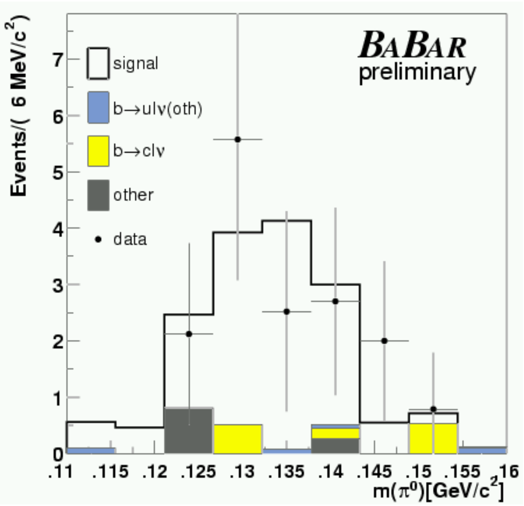
Similar cuts as for the inclusive m_X analysis, such as p*>1GeV and miss. mass squared of the event.

Further per mode cuts to reject $b \to c$ and crossfeed background are used

$80 fb^{-1}$

	Mass(MeV)	Width(MeV)	Decay modes
$\pi^{\pm} l\nu$	139.57	-	-
$\pi^0 l\nu$	134.98	-	$\gamma\gamma$
$\rho^{\pm} l\nu$	775	150	$\pi^0\pi^{\pm}$
$\rho^0 l\nu$	775	150	$\pi^-\pi^+$
$\omega l\nu$	782.6	8.5	$\pi^-\pi^+\pi^0$ (89%)
$\eta l\nu$	547.8	-	$\gamma\gamma$ (39.4%) $\pi\pi^+\pi^0$(22.6%) $\pi^0\pi^0\pi^0$(32.5%)
$\eta' l\nu$	957.8	-	$\rho^0\gamma$(29.5%) $\eta\pi^-\pi^+$ (44.3%)
$a_0^{\pm} l\nu$	985	50 100	$\eta\pi^{\pm}$ (~all)
$a_0^0 l\nu$	985	50 100	$\eta\pi^0$ (~all)





Exclusive: B→ (π,ρ,ω,η,a_0) lν

Breco Tags

Similar approach to the inclusive analysis but resonances are exclusively and fully reconstructed on recoil.

We measure:

$$B(B^0 \to \pi^- l^+ \nu) = (1.08 \pm 0.28_{stat} \pm 0.16_{syst}) \times 10^{-4}$$

$$B(B^0 \to \rho^- l^+ \nu) = (2.57 \pm 0.52_{stat} \pm 0.59_{syst}) \times 10^{-4}$$

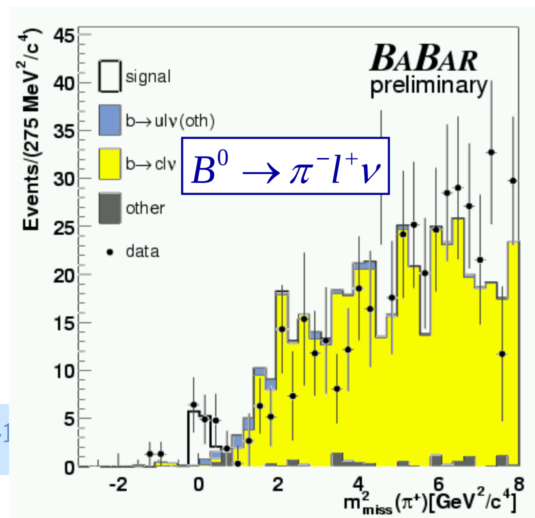
$$B(B^+ \to \eta l \nu) < 1.2 \times 10^{-4} (90\% CL)$$
$$B(B^+ \to \eta' l \nu) < 4.5 \times 10^{-4} (90\% CL)$$
$$B(B^+ \to a_0^0 l \nu) B(a_0^0 \to \eta \pi^0) < 5.3 \times 10^{-4} (90\% CL)$$
$$B(B^+ \to a_0^+ l \nu) B(a_0^+ \to \eta \pi^+) < 3.3 \times 10^{-4} (90\% CL)$$

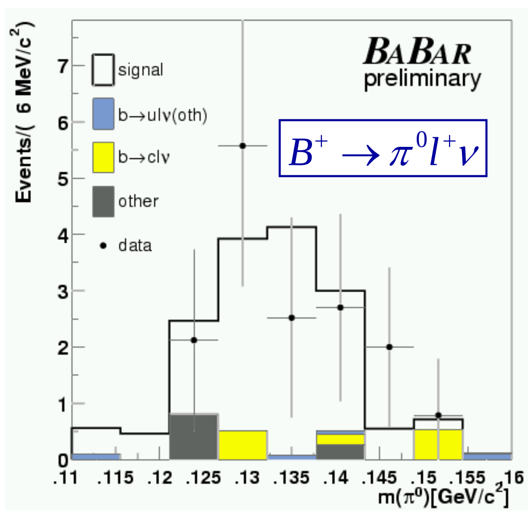
These two results make use of:

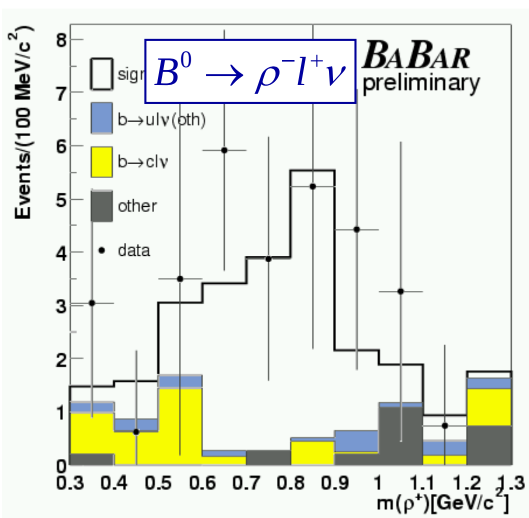
$$\begin{cases} B(B^0 \to \pi^- l^+ \nu) = 2B(B^+ \to \pi^0 l^+ \nu) \\ B(B^0 \to \rho^- l^+ \nu) = 2B(B^+ \to \rho^0 l^+ \nu) \\ B(B^+ \to \rho^0 l^+ \nu) = B(B^+ \to \omega l^+ \nu) \end{cases}$$

Systematics are dominated by MC statistics.
Large systematics due to non-resonant contribution in B → ρlν.
Theoretical systematics are small (~ 4-7%)

80fb^{-1}

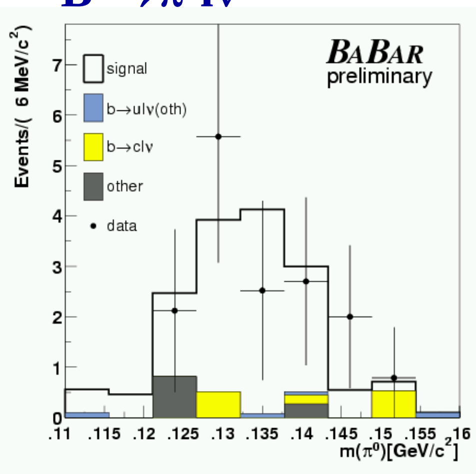




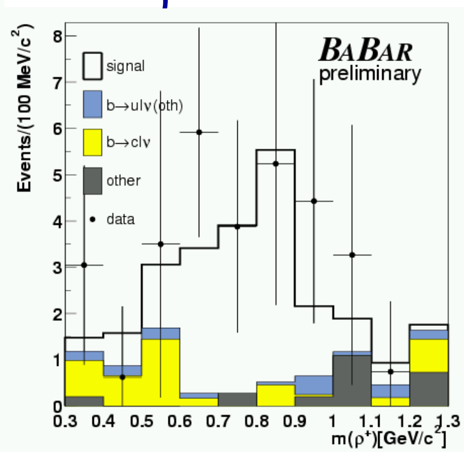


Results (80fb^{-1})

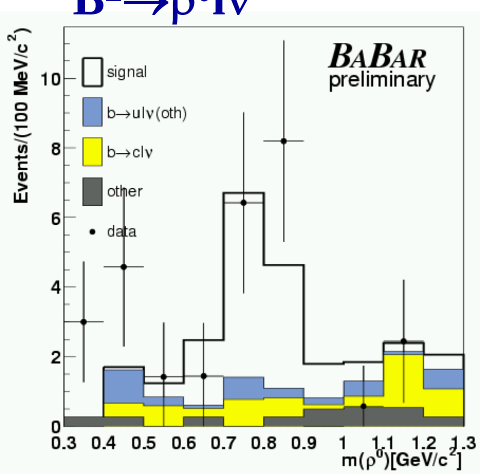
$B^{\pm}\rightarrow\pi^{0}l\nu$



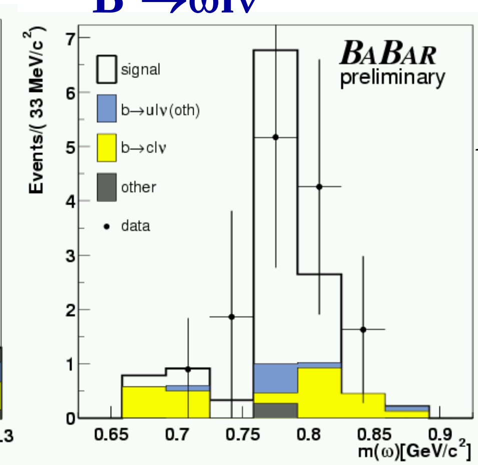
$B^{0}\rightarrow\rho^{\pm}l\nu$



$B^{\pm}\rightarrow\rho^{0}l\nu$



$B^{0}\rightarrow\omega l\nu$



$$B(B^0 \rightarrow \pi^+ l\nu) = (0.89 \pm 0.34_{stat} \pm 0.12_{syst}) \times 10^{-4}$$

$$B(B^+ \rightarrow \pi^0 l\nu) = (0.91 \pm 0.28_{stat} \pm 0.14_{syst}) \times 10^{-4}$$

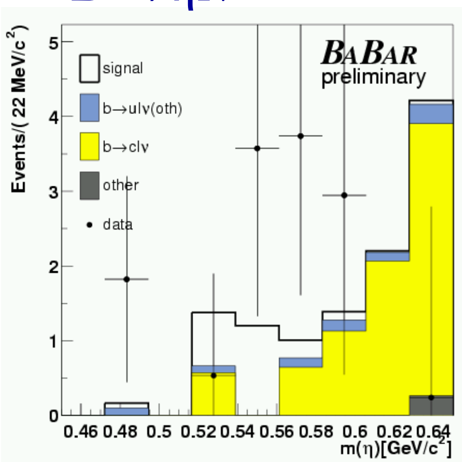
$$B(B^0 \rightarrow \rho^+ l\nu) = (3.5 \pm 1.1_{stat} \pm 0.7_{syst}) \times 10^{-4}$$

$$B(B^+ \rightarrow "\rho^0" l\nu) = (1.04 \pm 0.39_{stat} \pm 0.16_{syst}) \times 10^{-4}$$

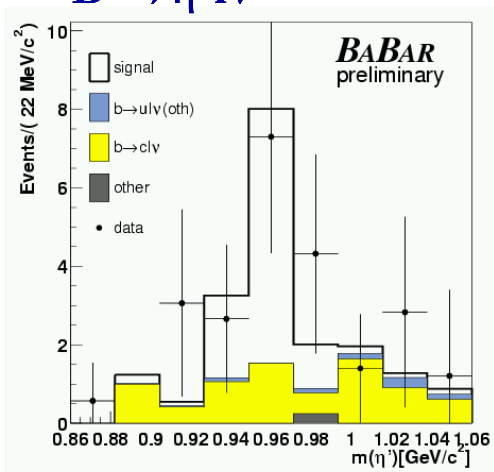
$$B(B^+ \rightarrow \omega l\nu) = (1.26 \pm 0.55_{stat} \pm 0.24_{syst}) \times 10^{-4}$$

Results (80fb^{-1})

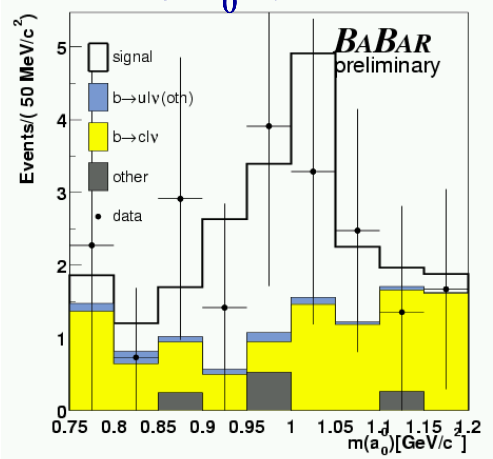
$B^{\pm}\to\eta l\nu$



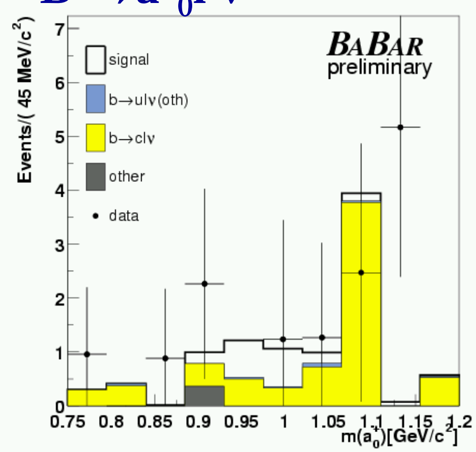
$B^{\pm}\to\eta' l\nu$



$B^{\pm}\to a^0_0 l\,\nu$



$B^0\to a^{\pm}_0 l\,\nu$



$$B(B^+\to\eta l\nu)=(0.39\pm0.41_{stat}\pm0.22_{syst})\times10^{-4}$$

$$\Rightarrow\quad B(B^+\to\eta l\nu)<1.2\times10^{-4}(90\%CL)$$

$$B(B^+\to\eta' l\nu)=(2.7\pm1.2_{stat}\pm0.5_{syst})\times10^{-4}$$

$$\Rightarrow\quad B(B^+\to\eta' l\nu)<4.5\times10^{-4}(90\%CL)$$

$$B(B^+\to a_0^0 l\nu)B(a_0^0\to\eta\pi^0)=$$

$$(2.7\pm1.4_{stat}\pm0.9_{syst})\times10^{-4}$$

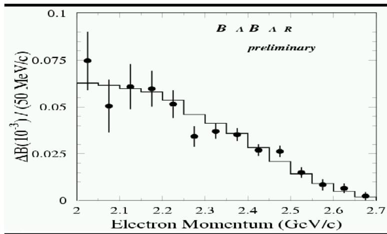
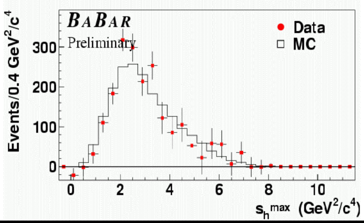
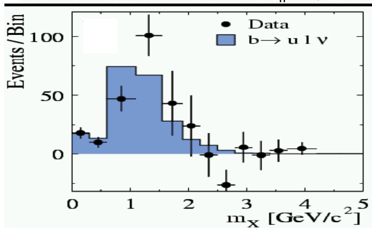
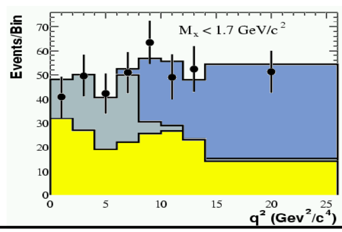
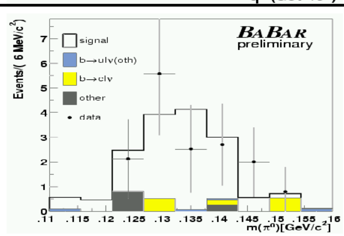
$$\Rightarrow\quad B(B^+\to a_0^0 l\nu)<5.3\times10^{-4}(90\%CL)$$

$$B(B^+\to a_0^+ l\nu)B(a_0^+\to\eta\pi^+)=$$

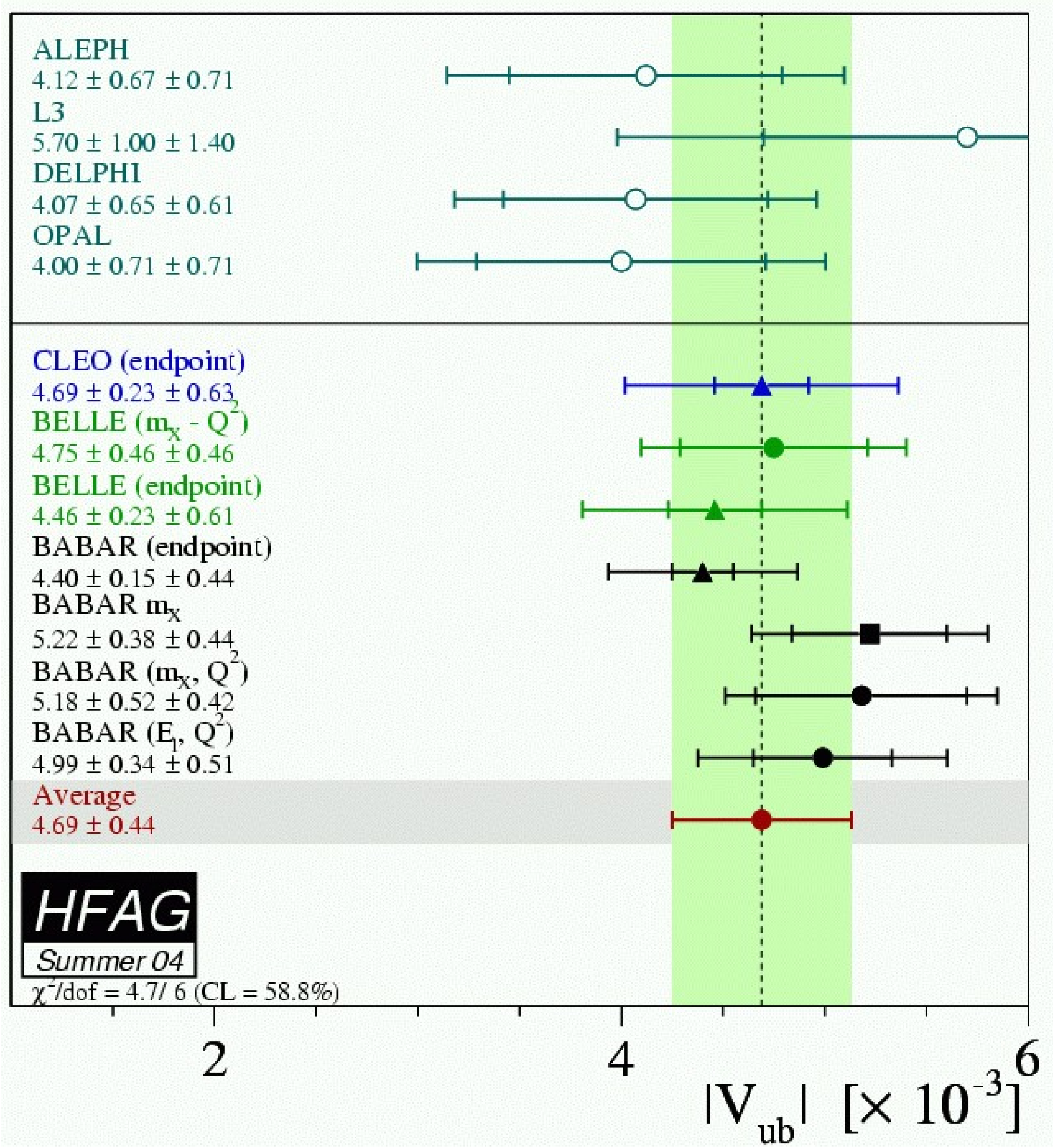
$$(0.7\pm1.6_{stat}\pm0.3_{syst})\times10^{-4}$$

$$\Rightarrow\quad B(B^+\to a_0^+ l\nu)<3.3\times10^{-4}(90\%CL)$$

V_{ub} measurements with BaBar

	method	S/B	Pros&Cons	$V_{ub}(x10^{-3})$
	*Untagged* *inclusive* Electron spectrum endpoint E_e>2.0GeV Total rate using f_u from CLEO	0.05→0.2	•High statistics •Duality valid for tight E_e cuts? •Bkg subtraction	$3.94 \pm 0.23_{exp} \pm 0.42_{theo}$
	*Untagged* *inclusive* E_e vs q^2 and neutrino reconstruction E_e>2.0GeV and s_h<3.5 GeV^2/c^4 Total rate using DeFazio-Neubert	~0.5	•High statistics •Lower syst. on shape functions •Bkg subtraction	$4.63 \pm 0.47_{exp}{}^{+0.62}_{-0.36 theo}$
	*Breco Tags* *inclusive* m_X analysis (1-D) m_X<1.55 GeV/c^2 Total rate using DeFazio-Neubert	~1.7	•Low background •High resolution •Low statistics •Shape func. syst.	$4.77 \pm 0.40_{exp}{}^{+0.69}_{-0.45 theo}$
	*Breco Tags* *inclusive* m_X vs q^2 analysis m_X<1.7 GeV/c^2 and q^2 >8.0 GeV^2/c^4 V_{ub} using Bauer et al.	~2	•Low background •Very small syst. on SF param. •Small statistics	$4.92 \pm 0.53_{exp} \pm 0.46_{theo}$
	*Partial Tags* *Breco Tags* *exclusive* Total rate using Form Factors calc.	1→20	•Very small bkg •~no cut on kinem •Small statistics	$(B(B^0 \to \pi^- l^+ \nu) = (1.22 \pm 0.26) \times 10^{-4})$

V_{ub} measurements



Conclusions for Exclusive Decays

We also developed novel methods to measure EXCL. CHARMLESS decays:

- Breco tags:

$$B(B^0 \to \pi^- l^+ \nu) = (1.08 \pm 0.28_{stat} \pm 0.16_{syst}) \times 10^{-4}$$
$$B(B^0 \to \rho^- l^+ \nu) = (2.57 \pm 0.52_{stat} \pm 0.59_{syst}) \times 10^{-4}$$

- Semil tags:

$$B(B^0 \to \pi^- l^+ \nu) = (1.46 \pm 0.27_{stat} \pm 0.28_{syst}) \times 10^{-4}$$

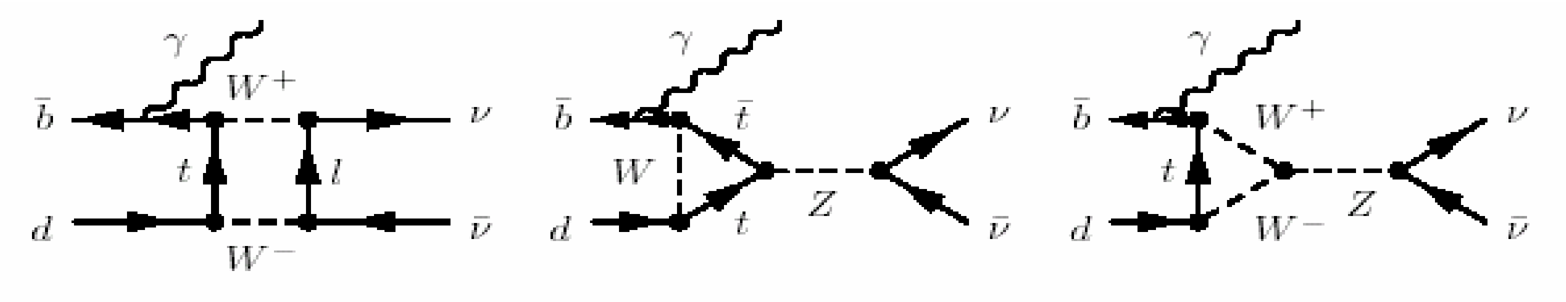
AVERAGE

$$B(B^0 \to \pi^- l^+ \nu) = (1.22 \pm 0.19_{stat} \pm 0.18_{syst}) \times 10^{-4}$$

B→νν: Motivations

- $B^0 \rightarrow$ invisible (+ gamma) is unmeasured, sensitive to new physics
  - Several new physics models predict a small but significantly nonzero branching fraction for $B^0 \rightarrow$ invisible
    - Dedes, Dreiner, & Richardson hep-ph/0106199
      (*SUSY model, attempt to explain* NuTeV *anomaly,* $\mathcal{B}(B^0 \rightarrow \text{invisible}) = O(10^{-6})$)
    - Agashe, Deshpande, & Wu hep-ph/0006122
      Agashe & Wu hep-ph/0010117
      Davoudiasl, Langacker, & Perelstien hep-ph/0201128
      (*Large extra dimensions,* $\mathcal{B}(B^0 \rightarrow \text{invisible}) = O(10^{-7})$)

- Diagrams (in SM):



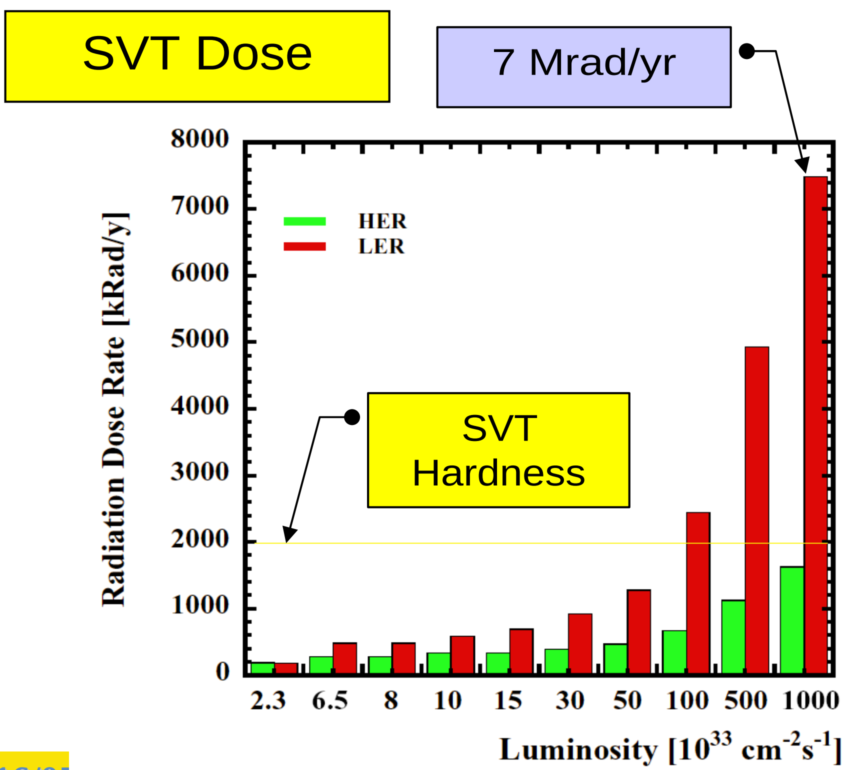
- Can be measured via reconstruction of tag-side B + "nothing else" – this analysis uses semileptonic tags.

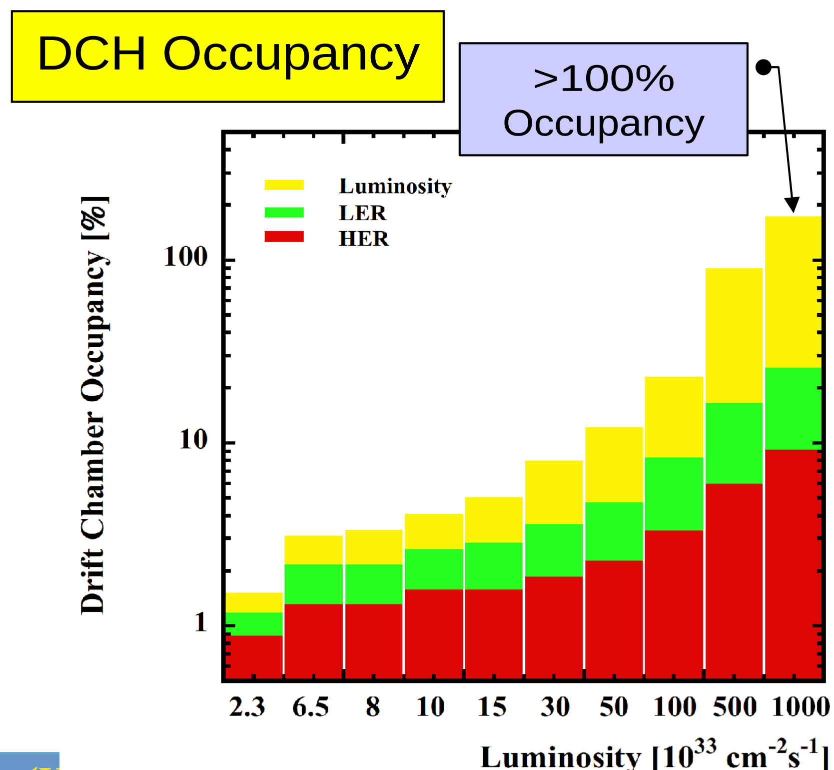
Beams in a SuperB

	Super B-Factory		B-Factory	
Beam	e+	e-	e-	e+
E(GeV)	8.0	3.5	9.0	3.1
#bunches	7000		800	
lifetime (min)	7	5	200	
Current (A)	10.3	23.5	1.0	1.8
β^*(mm)	x=15/y=1.5		x=450/y=10	
Emittance(nm)	x= 44/y=0.44		40/2.5	
Beam spot (μm)	x= 81/y=0.8		x= 147/y=5	
Tune shift	0.10		0.07	

- Reaching 10^{36} implies that a series of issues have to be faced:
  - ▶Higher beam currents, stronger focusing, *continuous injection*
  - ▶Increased background and higher rates for detector
    - Radiation damage
    - High occupancy

NEED NEW DETECTOR





Detector Issues

- Super BaBar detector designed to have sufficient granularity to deal with the high occupancy
  However, some issues need investigating
  - ▶tracking efficiency and fake tracks
  - ▶calorimeter resolution, fake photons, ability to veto pi0, etc
  - ▶particle ID performance
  - ▶etc

  ! *studies yet to be performed*
- Some *detector R&D is needed* for:
  - ▶thin (100 μm) Si detector and low-power electronics
  - ▶small-cell drift chamber in high radiation environment
  - ▶focusing DIRC with pixel PMT
  - ▶choice of EM calorimeter: liquid Xe vs. (fast) crystals
  - ▶technology for muon ID

Rough physics reaches

	BaBar+ Belle (2007)	SuperBaBar (/year)	SuperBelle (2010)	LHCb (/year)	BTeV (/year)
Lumi N_{bb}	$1ab^{-1}$ $2x10^9$	$10ab^{-1}$ $2x10^{10}$	$3ab^{-1}$ $6x10^9$	10^{12}	10^{11}
$\delta\sin2\alpha$ $(\pi\pi)$ $N(\pi\pi)\varepsilon_{eff}^{tag}$	0.07 900	0.025 9000	0.04 3000	1000	1500
$N(\pi0\pi0)$ $\delta C(\pi0\pi0)$ $\delta\alpha-\alpha_{eff}$	460 0.15 9^o	4600 0.05 3^o	1500 0.09 5^o	-	-
$\delta\sin2\alpha$ $(\pi\pi\pi)$	0.06	0.03	0.06		0.06
$\delta\gamma$($B_s\rightarrow KK$)	-	-	-	5^o	5^o
$\delta\gamma$ $(B_d\rightarrow DK)$	7^o	5^o	6^o	$7\text{-}8^o$	13^o
$\delta\gamma$ $(B_s\rightarrow DsK)$	-	-	-	14^o	8^o
$\delta\sin2\beta$ (ϕK_S)	0.2	0.07	0.1	0.2	0.12
$N(X_s ll)$	700	7k	3K	4K K*ll	4K K*ll
$\delta\sin2\chi$ $(J/\psi\eta,J/\Psi\phi)$	-	-	-	0.06	0.02

Approximate numbers that were used to stir the discussion ⟹