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Measurement of the partial Branching Fraction for $\overline{B} \rightarrow X_u \ell \overline{\upsilon}$ and determination of $|V_{ub}|$ at BaBar

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Outline

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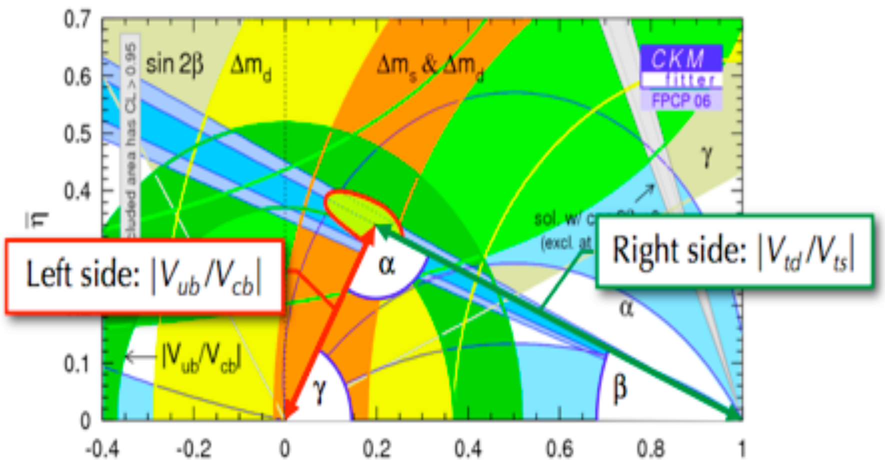
Motivations

- CKM Matrix:
  - Gives insight into Quark flavour mixing
  - and elements $|V_{ub}|$ and $|V_{td}|$ are important in the study of CP Violation in the SM
  - $|V_{ub}|$ because of its magnitude is not currently measured with great precision

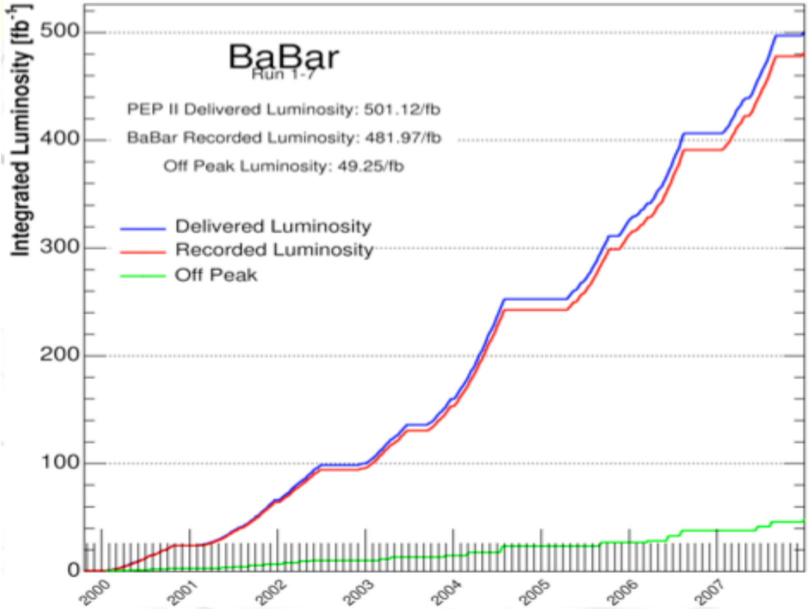
$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} = \begin{bmatrix} 0.97383 & 0.2272 & 0.00396 \\ 0.2271 & 0.97296 & 0.04221 \\ 0.00814 & 0.04161 & 0.999100 \end{bmatrix}.$$

- Because of the unitarity condition we get 'the' unitarity triangle

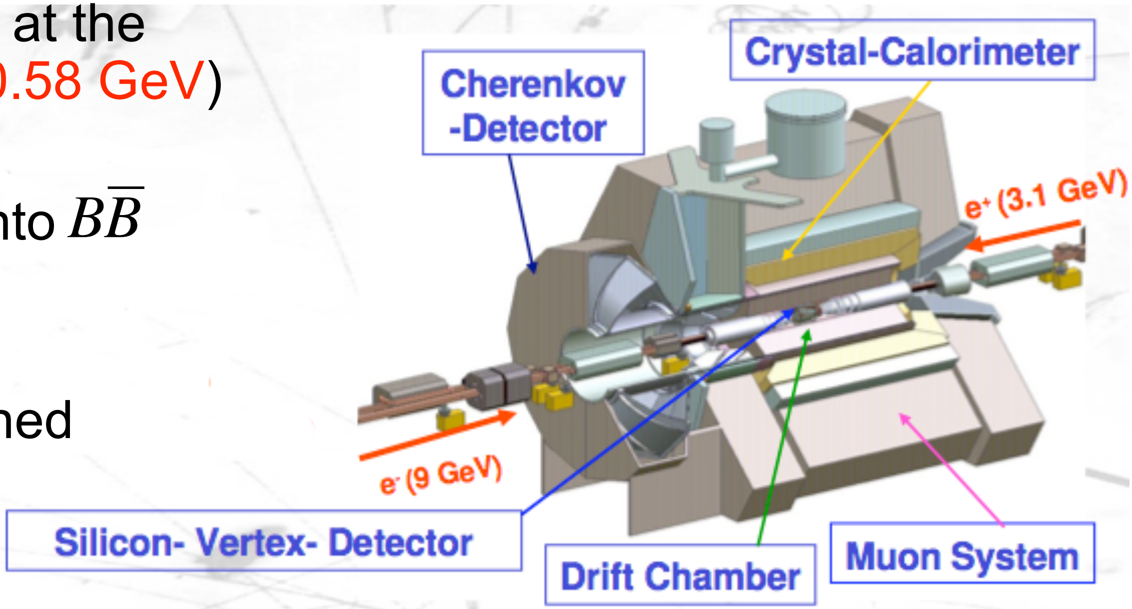


- Goal is to 'over-constrain' the triangle
- New physics (if triangle does not close) ?
- My analysis will be the measurement of $|V_{ub}|$ (left side)

Brief overview of BaBar



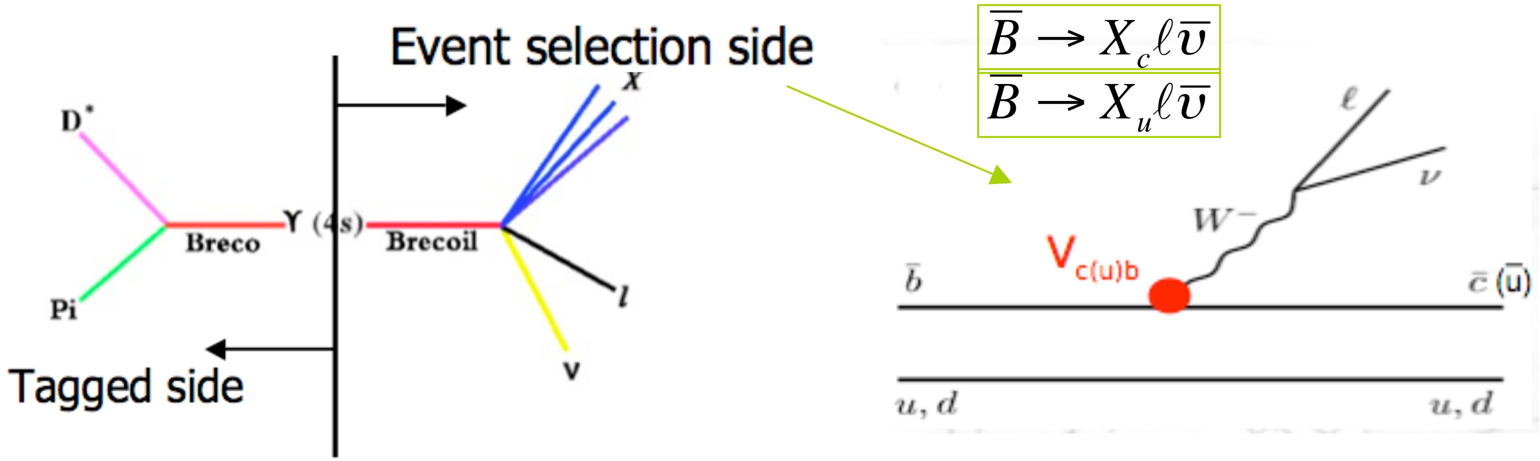
- We collide e^+ and e^- at the Y(4s) resonance (10.58 GeV)
- Y(4s) then decays into $B\overline{B}$
- Data taking at Y(4s) resonance has finished
  - 430 /fb of $B\overline{B}$
  - 45 /fb of 'off-peak'



Analysis Technique

Semi-leptonic decays

- To measure $|V_{ub}|$ we can use semi-leptonic decays of B mesons



- B_{reco} is fully reconstructed with hadronic tags

- We reconstruct one B_{reco} candidate in:
  - 0.3% of the $B^0\overline{B^0}$ events
  - 0.5% of the B^+B^- events

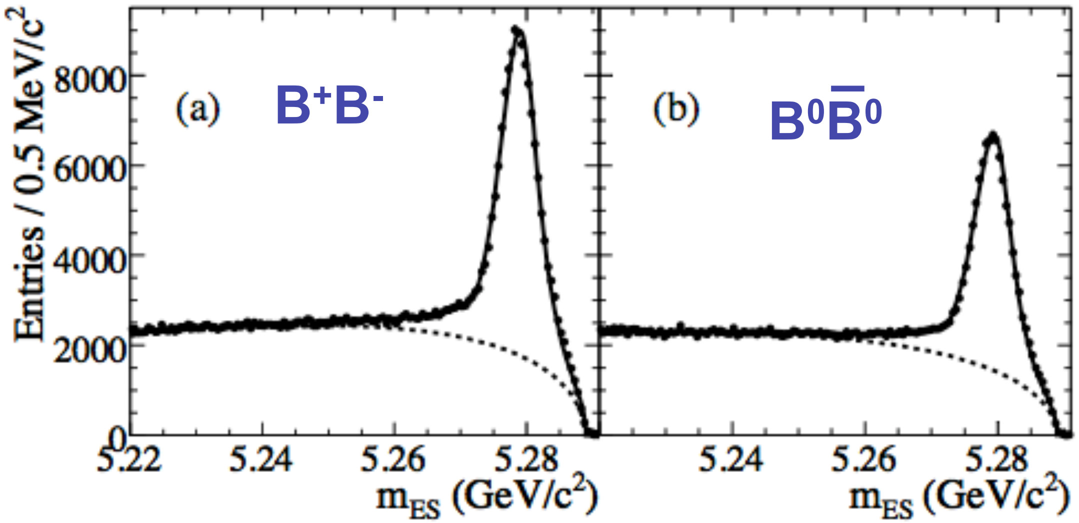
- B_{recoil} is the semi-leptonic side (look for an electron or a muon after tagging the B_{reco} side)

- For kinematic consistency of B_{reco}
  - Require the beam energy difference to be 0 within 2 standard deviations
  - Require the beam energy substituted mass (m_{ES}) to peak at mass of B (5.28 GeV)

$$m_{ES} = \sqrt{s/4 - \vec{p}_B^{\,2}} \qquad \Delta E = E_B - \sqrt{s}/2$$

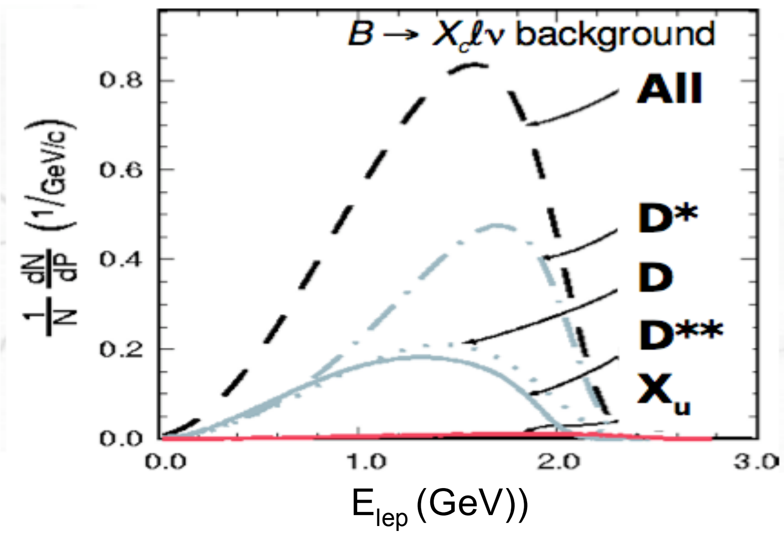
- Combinatorial and continuum* background is modeled by the same dashed line.
  - Continuum background is $e^+e^- \to q\bar{q}$ where $q = u,d,s,c$

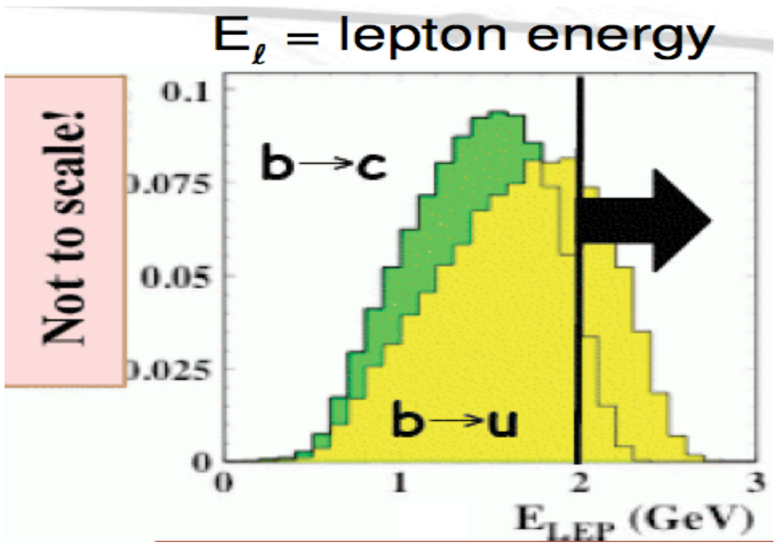
- Do a maximum likelihood fit on m_{ES} to extract signal.



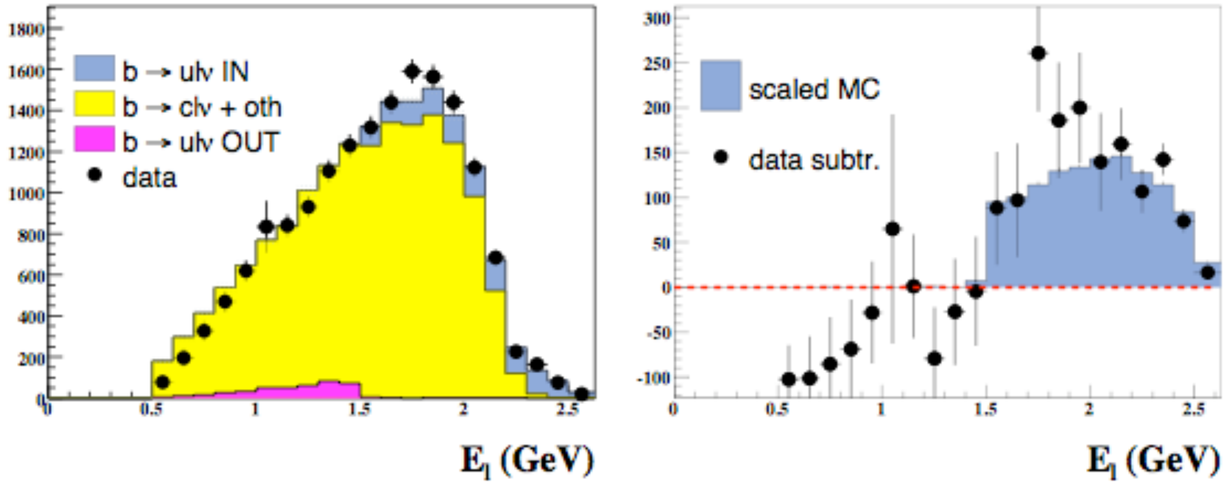
The ‘irreducible background’

- The main background contribution comes from $\overline{B} \rightarrow X_c \ell \overline{\upsilon}$ decays (50 times larger than the signal).
  - kinematically similar to signal (hard to separate)
- We select regions of phase space where the background is suppressed and measure a partial branching fraction
- I use the energy of the lepton (right) in the B rest frame (E_l) to do this
- Restricting the phase space in this way challenges the theory





Preliminary results



- What you see above is the various contributions after selection cuts, background subtraction and m_{ES} fit.
  - Dataset = 347.4 /fb (383 Million $B\overline{B}$ pairs)

- *Normalize MC and data by performing a χ^2 fit to data (1.9 for above plot)*

$$\Delta B\ (p \in 1.5 - 2.6\ GeV) =$$

0.0131 ± 0.002 (stat) ± 0.001 (MC stat)

Extraction of $|V_{ub}|$

- To extract $|V_{ub}|$ use Analytic Coupling model:

$$\boldsymbol{B[p \in (a,b)] = B_{SL}/(1+R_{c/u})W(a,b)}$$

  - a and b are the limits for the lepton energy (1.5 and 2.6)
  - $R_{c/u} = |V_{cb}|^2/|V_{ub}|^2 \, I(p) G(\alpha_S, p)$
    - ratio of semi-leptonic widths (contains what we want to extract, $|V_{ub}|$)
  - $B_{SL} = 0.1066 \pm 0.0020$
    - semileptonic branching ratio and we know it from experiment quite well
  - $W(a,b)$, $I(p)$ and $G(\alpha_S,p)$ are all theory functions

- Other models 'on the market' include both shape function and parton-related models

Conclusion and prospects

- Presented is a partial branching fraction of $\overline{B} \to X_u \ell \overline{\upsilon}$ using a dataset of 383 million $B\overline{B}$ pairs (347.4 /fb). Not final result!
- Current endpoint analyses go from around 2.0 - 2.6 GeV in the lepton energy, I plan to lower to around 1.6 -2.6 GeV. This will reduce theoretical errors
  - *Endpoint analysis here is taken from 1.5 - 2.6 GeV for default testing purposes*
- To do this accurately the irreducible background needs to be understood and suppressed a lot more than it is now. Charm tagger?
- Implementation of a $\overline{B} \to X_u \ell \overline{\upsilon}$ new MC generator will also be available (when I finish it!)
- Will also use a new model to calculate $|V_{ub}|$
- A further 80 /fb of data will be available for my full analysis

Backup

- Systematic errors are reduced by normalizing to the total number of semi-leptonic events. ($R_{u/sl}$)

$$\Delta R_{u/sl} = \Delta B(\overline{B} \rightarrow X_u \ell \overline{\upsilon}) / B(\overline{B} \rightarrow X \ell \overline{\upsilon})$$

- Major systematic errors from: m_{ES} fits, detector and MC statistics

Selection Criteria	N_{sl}^{meas}	N_{u}^{meas}
Breco candidate	per-purity mode	per-purity mode
minimum lepton momentum	$p^* > 1.0\mathrm{GeV}/c$	$p^* > 1.0\mathrm{GeV}/c$
# of Charged Leptons	$N_{lep} > 0$	$N_{lep} = 1$
Lepton Charge - B flavour [5]	$Q_{b(recoil)} Q_l > 0$	$Q_{b(recoil)} Q_l > 0$
Total charge/event		$Q_{tot} = 0$
Missing mass[2]		$M_{miss}^2 < 0.5\mathrm{GeV}^2$
Kaon Veto for signal enhancement		$N_{K^\pm} = 0$ and $N_{K_S} = 0$

PDG 2006

Decay Mode	Branching Fraction
$B^+ \rightarrow l^+ \nu_l$ + anything	10.9 $\pm$ 0.4 %
$B^+ \rightarrow \bar{D}^*(2007)^0 \ell^+ \nu_\ell$	(6.5 $\pm$ 0.5) %
$B^+ \rightarrow \bar{D}^0 \ell^+ \nu_\ell$	(2.15 $\pm$ 0.22) %
$B^+ \rightarrow \bar{D}_1(2420)^0 \ell^+ \nu_\ell$	(0.56 $\pm$ 0.16) %
$B^+ \rightarrow \bar{D}_2(2460)^0 \ell^+ \nu_\ell$	< 0.8% @90CL
$B^+ \rightarrow D^- \pi^+ \ell^+ \nu_\ell$	(0.53 $\pm$ 0.10) %
$B^+ \rightarrow D^{*+} \pi^+ \ell^+ \nu_\ell$	(0.64 $\pm$ 0.15) %
$B^+ \rightarrow \bar{D}^{(*)} n\pi \ell^+ \nu_\ell$	??

mES fits: The tagged side is of the type $B_{reco} \rightarrow \overline{D}^{(*)} Y^\pm$

$Y^\pm$ consists of hadrons with total charge ±1 ($K^\pm$, $\pi^\pm$)

We test signal purity with MC. Only modes with a purity of >20% are used

$$p_\upsilon = p_{\Upsilon(4S)} - p_{B_{reco}} - p_X - p_\ell$$