University of Zurich[UZH]

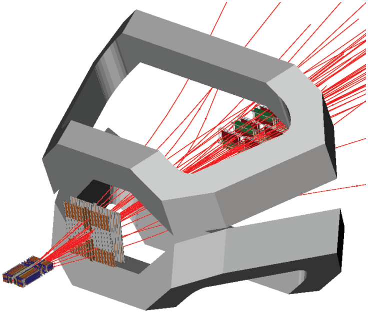
Measuring $B \to \mu\mu K^*$ at LHCb

PhD Seminar, ETH Zurich, 29. - 30. August 2011

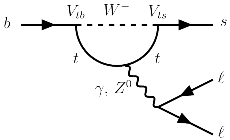
Michel De Cian

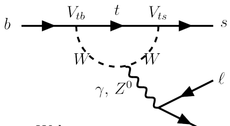
Outline

- Introduction
- The nitty-gritty stuff
- Conclusion



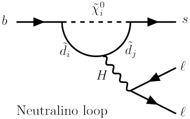
A Thing of Beauty is a Joy for ever



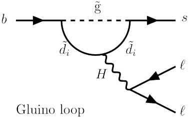


t–W loop

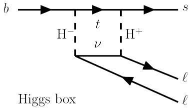
- $B \to \mu\mu K^*$ very rare in the SM, $\mathcal{B} \sim 10^{-6}$.
- Involves a $b \to s$ transition which is forbidden on tree level.
- Only possible with a penguin, new physics can enter at the same level as SM.
- Decay sensitive to many extensions of the SM:



Neutralino loop

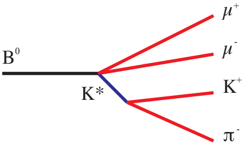


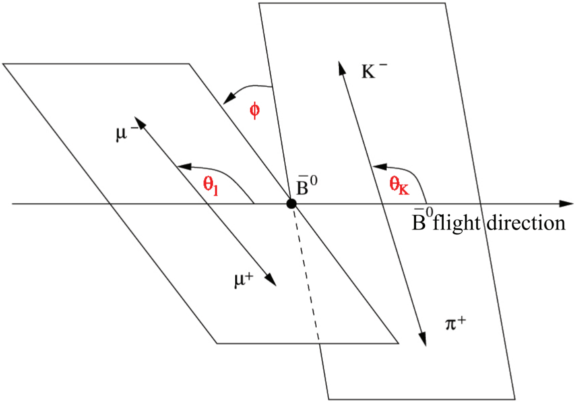
Gluino loop



Higgs box

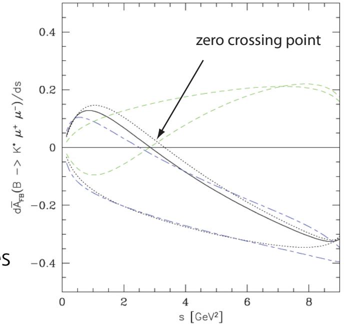
Angular distribution





- Three restframes: B restframe, DiMuon restframe, K^* restframe.
- Will only consider Θ_l and Θ_k in this analysis.

A_{FB}, F_L AND ALL THAT



- Different contributions from new physics processes give rise to different shapes of certain variables.
- Low theory error: A_{FB}, F_L, $d\Gamma/dq^2$
- Determine: $A_{FB} = \frac{N(\Theta_l < \frac{\pi}{2}) - N(\Theta_l > \frac{\pi}{2})}{N(\Theta_l < \frac{\pi}{2}) + N(\Theta_l > \frac{\pi}{2})}$ as a function of q^2 (counting experiment).
- Do a full fit to the Θ_l and Θ_k distributions:

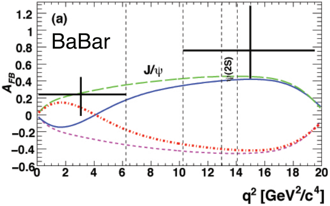
$$\frac{d\Gamma}{d\Theta_l dq^2} = \Gamma \cdot (\frac{3}{4} F_L \sin^2 \Theta_l + A_{FB} \cos \Theta_l + \frac{3}{8}(1 - F_L)(1 + \cos^2 \Theta_l))$$

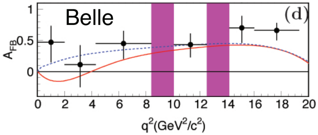
and

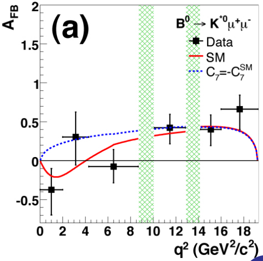
$$\frac{d\Gamma}{d\Theta_k dq^2} = \Gamma \cdot (\frac{3}{2} F_L \cos^2 \Theta_k + \frac{3}{4}(1 - F_L)(1 - \cos^2 \Theta_k))$$

- Shape as well as zero-crossing point is important.

The competition

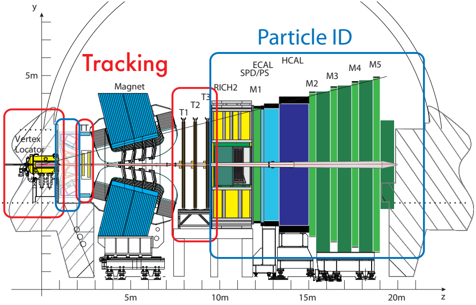






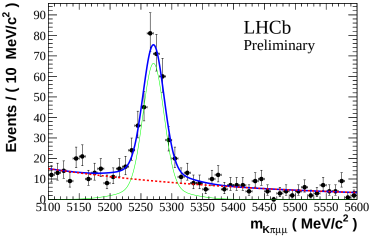
- BaBar: 60 $B \to \ell\ell K^*$ events in $384 \cdot 10^6 B\bar{B}$. [PRD79:031102, 2009]
- Belle: 230 $B \to \ell\ell K^*$ events in $657 \cdot 10^6 B\bar{B}$. [PRL103:171801, 2009]
- CDF: 164 $B \to \mu\mu K^*$ events in $6.8\,\text{fb}^{-1}$. [FERMILAB-PUB-11-364-PPD]
- ... Mind the sign convention ...
- An optimist would say,
  the SM is slightly disfavoured.

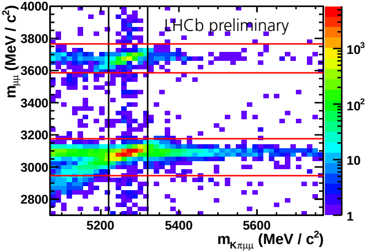
The LHCb analysis



- Want to look for $B \to \mu\mu K^*(\to K\pi)$.
- Need good muon identification down to low p_T.
- Particle ID for hadrons (RICH1 & 2, Calorimeters) helps to reduce combinatorics and peaking background.
- Used $\approx$ 309 pb^{-1} of data from 2011 for the analysis, 2010 data ($\approx$ 37 pb^{-1}) used for calibration.

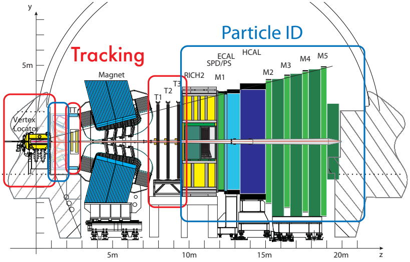
Selection of $B \to \mu\mu K^*$





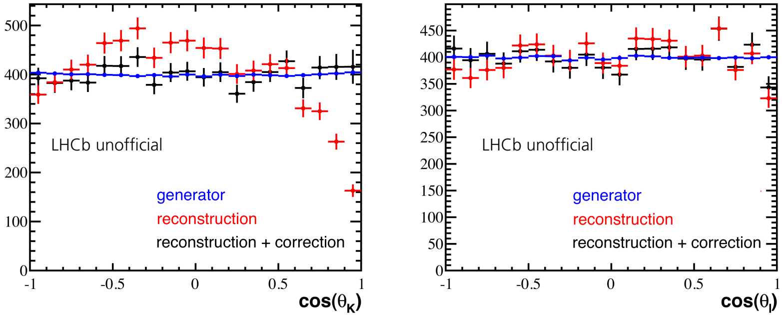
- Cut based preselection, Boosted Decision Tree selection.
- BDT trained with:
  - $B \to J/\Psi K^*$ (2010 data) for signal
  - $B \to \mu\mu K^*$ (2010 data), upper sideband for background.
- Pollution from $B \to J/\Psi K^*$ / $B \to \Psi(2S)K^*$:
  Cut out J/Ψ and $\Psi(2S)$ in the dimuon invariant mass.
- Peaking backgrounds can be a concern:
  - For example $B \to J/\Psi K^*$, where $\mu \to \pi$ and $\pi \to \mu$. Reconstruct the decay with different mass hypotheses and veto it.

Acceptance correction (I)



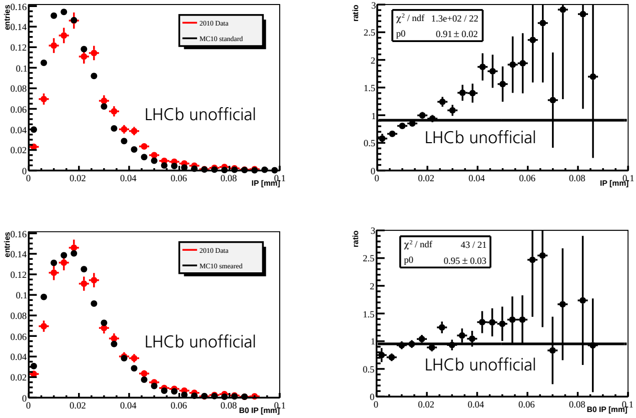
- We want to fit the distributions of $\cos\theta_l$ and $\cos\theta_k$ to extract physics variables. We need to be sure the distribution only reflects physics quantities and no other effect.
- Unfortunately, this is not case: Detector geometry and reconstruction effects distort these distributions (e.g. muon needs 3 GeV to reach the muon stations).

Acceptance correction (II)



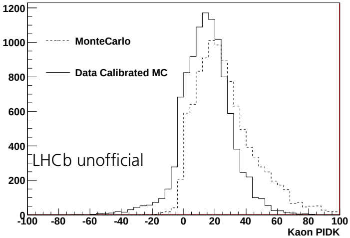
- Do event-by-event correction:
    - Generate phase-space MC, plot distributions.
    - Reconstruct and select the events, plot distributions.
    - Determine weight-factor and reweight events to get back to the MC distribution.

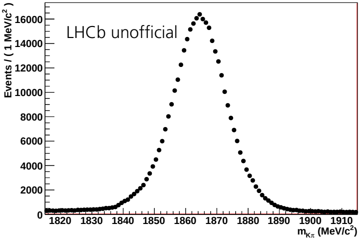
MC ↔ Data disagreements (I)



- Certain variables don't agree well on data and on MC.
- Impact parameter resolution worse on data than on MC, will influence selection. "Smear" impact parameter on MC to fake resolution on data.

MC ↔ Data disagreements (II)

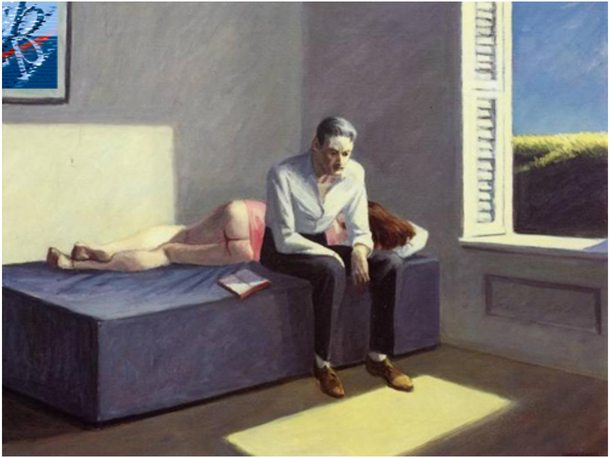




- Distributions of particle identification variables don't agree, but are input to selection / acceptance correction: Need to put the data-distributions into the MC.
- $\rightarrow$ Determine PID on data with a tag-and-probe method:
  - For μ: Use $B \rightarrow J/\Psi(\rightarrow \mu\mu)K$ (and avoid trigger bias).
  - For π, K: Use $D^0(\rightarrow K\pi)$

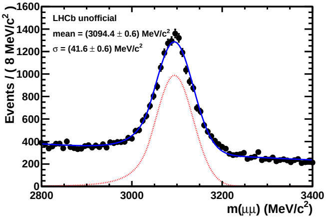
Tracking efficiency

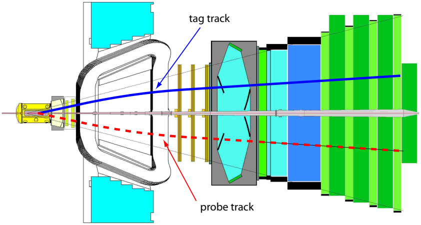
- Efficiency to reconstruct a track may be different in MC and data as well.
- It's not totally straightforward to measure the tracking efficiency in LHCb.
- Therefore...



Excursion into tracking efficiencies

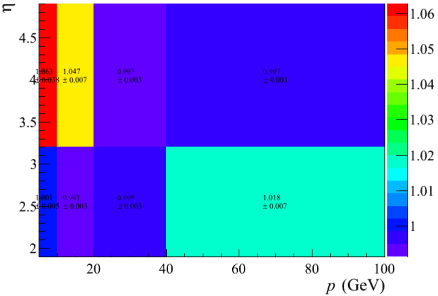
Tracking efficiency





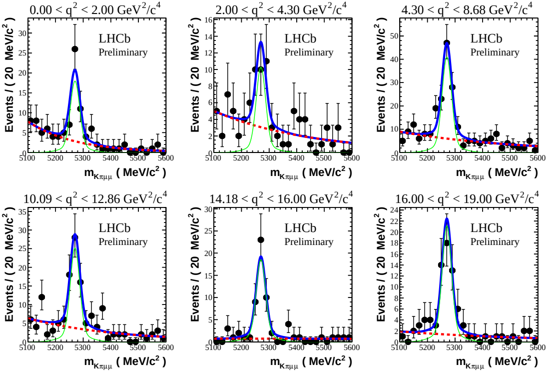
- Basic idea: Check the tracking detectors with a tracking detector.
- Tag track: Track with hits in Velo+T-stations.
- Construct probe track:
  - Either exclude subdetector and reconstruct track with the remaining ones.
  - Or (mis)use muons system (behaves like a tracking station with low resolution) or calorimeter.
- Combine tag & probe: Use peak / resonance to be sure hits belong to a particle and are not ghost hits.
- $\varepsilon = \frac{\text{\#probe tracks matched to reconstructed track}}{\text{\#probe tracks}}$

Composition in Red, Blue and Yellow
(a tribute to Piet Mondrian)



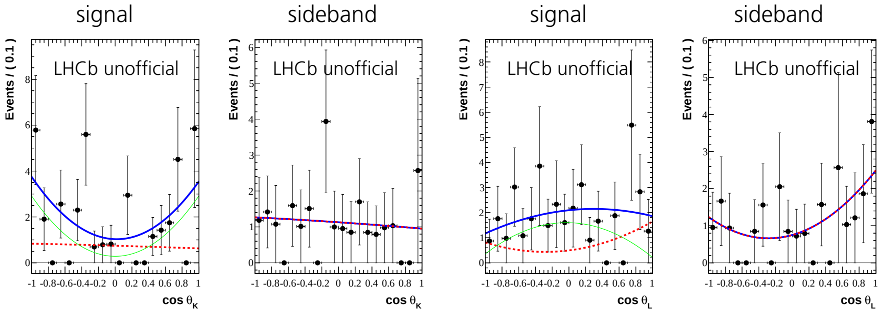
- Measure Velo efficiency (by excluding the Velo), T-station efficiency (by excluding the T-stations) and combine the efficiencies.
- Measure tracking efficiency in one go by constructing a track with hits in the muon- and the TT-stations as a probe.
- Do this on data and on MC, compute the ratio.

Fitting (I)



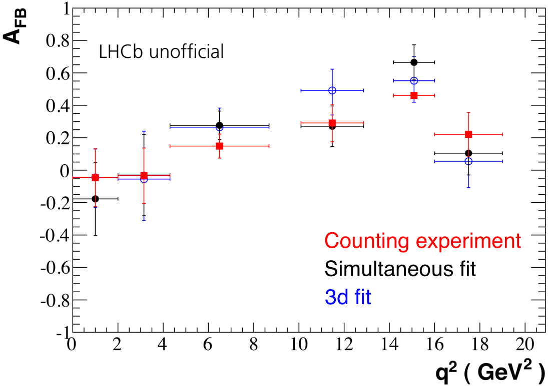
- Choose the same binning as Belle: Divide sample in 6 q^2 bins.
- Fit mass region with a double gaussian for the signal and an exponential for the background...
- ... and simultaneously fit $\cos\theta_l$ and $\cos\theta_k$ distributions for the signal region (± 50 MeV around peak) and the upper sideband ($5350 - 5600$ MeV).

Fitting (II)



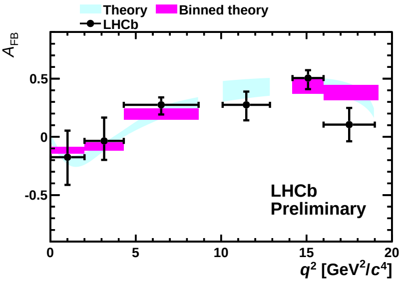
- Showing: $2\,\text{GeV} < q^2 < 4.3\,\text{GeV}$
- Very much dominated by low statistics.

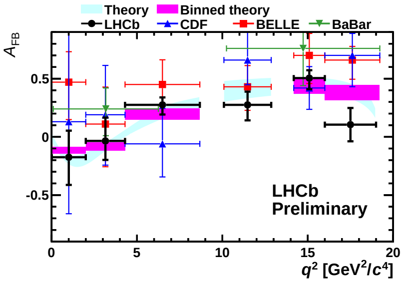
COUNTING



- Instead of fitting, can also just count #forward and #backward events in a q^2 bin.
- Was done as a crosscheck for the extraction of the parameters from the fit.
- Good agreement.

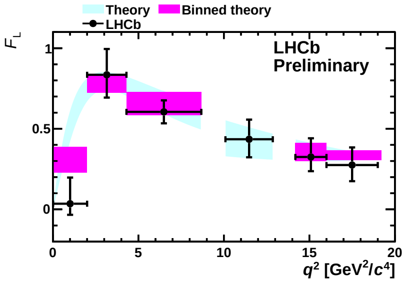
A_{FB}



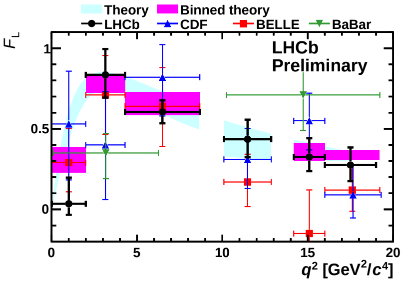


- In good agreement with prediction from SM.
- Compatible within the errors with the measurements from CDF, Belle and BaBar.
- More statistics will clearly be beneficial.

F_L

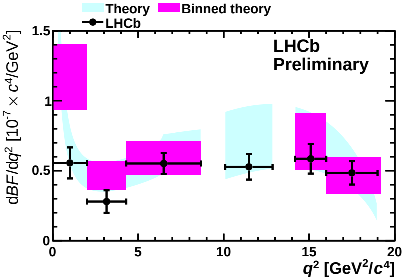


Theory
Binned theory
LHCb
LHCb Preliminary
F_L
q² [GeV²/c⁴]

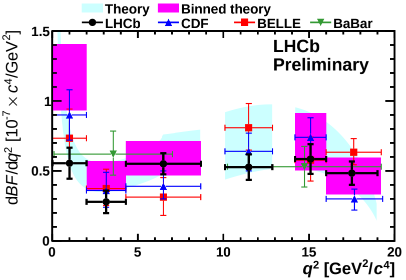


Theory
Binned theory
LHCb
CDF
BELLE
BaBar
LHCb Preliminary
F_L
q² [GeV²/c⁴]

$d\Gamma/dq^2$



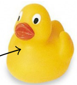
Theory
Binned theory
LHCb
LHCb
Preliminary
dBF/dq² [10⁻⁷ × c⁴/GeV²]
q² [GeV²/c⁴]



Theory
Binned theory
LHCb
CDF
BELLE
BaBar
LHCb
Preliminary
dBF/dq² [10⁻⁷ × c⁴/GeV²]
q² [GeV²/c⁴]

Conclusion

- LHCb has made the most precise measurements of A_{FB}, F_L and the differential crosssection in the decay $B \to \mu\mu K^*$.
- Errors are statistically dominated, looking forward to more data.
- No signs of new physics...



Die Ente bleibt draussen!