An unbinned method to measure FBA of the $B_d \to K^* \mu^+ \mu^-$ decay on LHCb

F. Marinho

Annual Meeting of the High Energy Particle Physics Group - 31 March - 2 April 2008 - Lancaster - 2008

Outline

- **Introduction**

  Rare B Decays

  Why $B_d \to K^* \mu^+ \mu^-$?

- **Forward-Backward Asymmetry**
- **Unbinned Method**
- **Results**

Rare Decays

LHCb Physics:
CP violation measurements in the *b* sector and search for rare B decays

Flavor Changing Neutral Current processes are good to test SM and to look for New Physics

- **These decays occur via box or penguin diagrams in the SM**
- **New Physics can possibly be seen at the same level of SM**
- **Allow indirect search of new particles**

$b \to sl^+l^-$:

$B_d \to K^*\mu^+\mu^-$, $B^+ \to K^+\mu^+\mu^-$, $B_d \to K^*e^+e^-$, $B^+ \to K^+e^+e^-$
(Branching ratio, angular distributions)

$b \to s\gamma$:

$B \to K^*\gamma$, $B_s \to \Phi\gamma$ (CP violation)

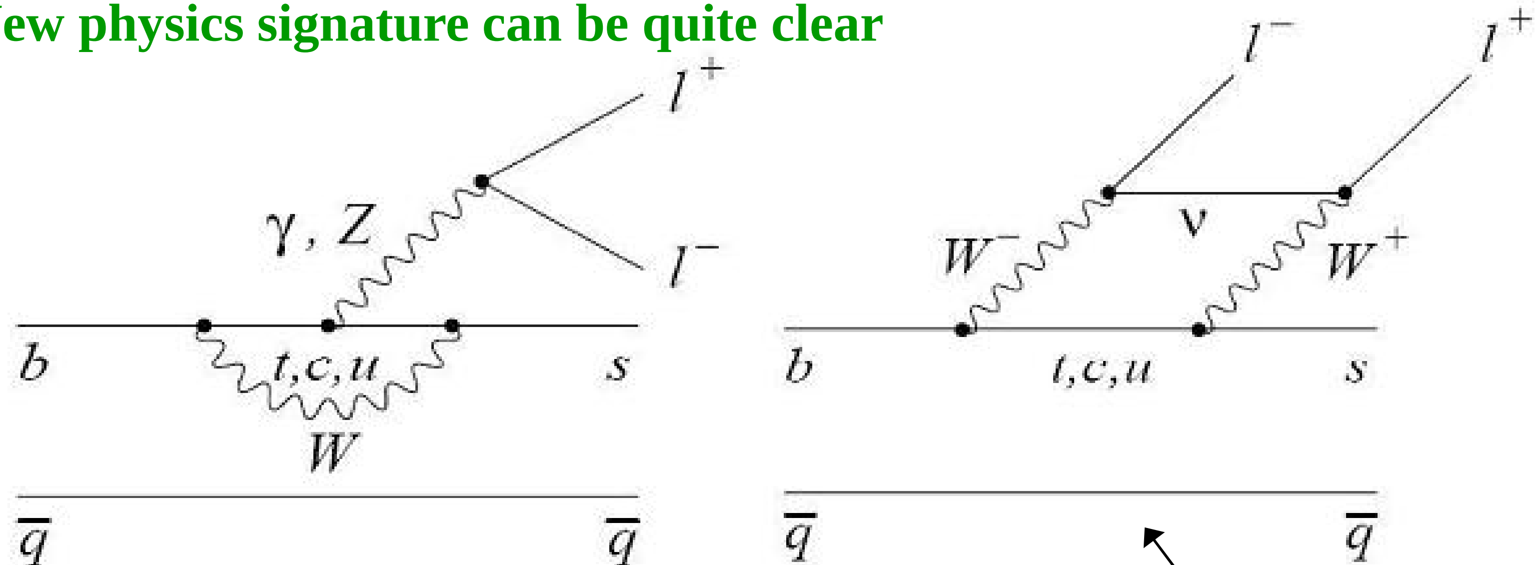
$B_s \to \mu^+\mu^-$ (Branching ratio)

The $B_d \to K^* \mu^+ \mu^-$ Decay

- Rare FCNC with predicted BR = $(1.19 \pm 0.39) \times 10^{-6}$ (NNLO)

Already measured at B factories - BR = $(1.22{+0.38}{-0.32}) \times 10^{-6}$

- Interesting place to confirm SM and to look beyond
- New physics signature can be quite clear



- Forbidden at tree level
- Penguin and Box diagrams

Assortment of measurables whose dependence on $\mu^+\mu^-$ mass can reveal new physics

- Angular distributions: Forward-Backward asymmetry and its zero point
- Wilson coefficients (A_{10}/A_7 and A_9/A_7)

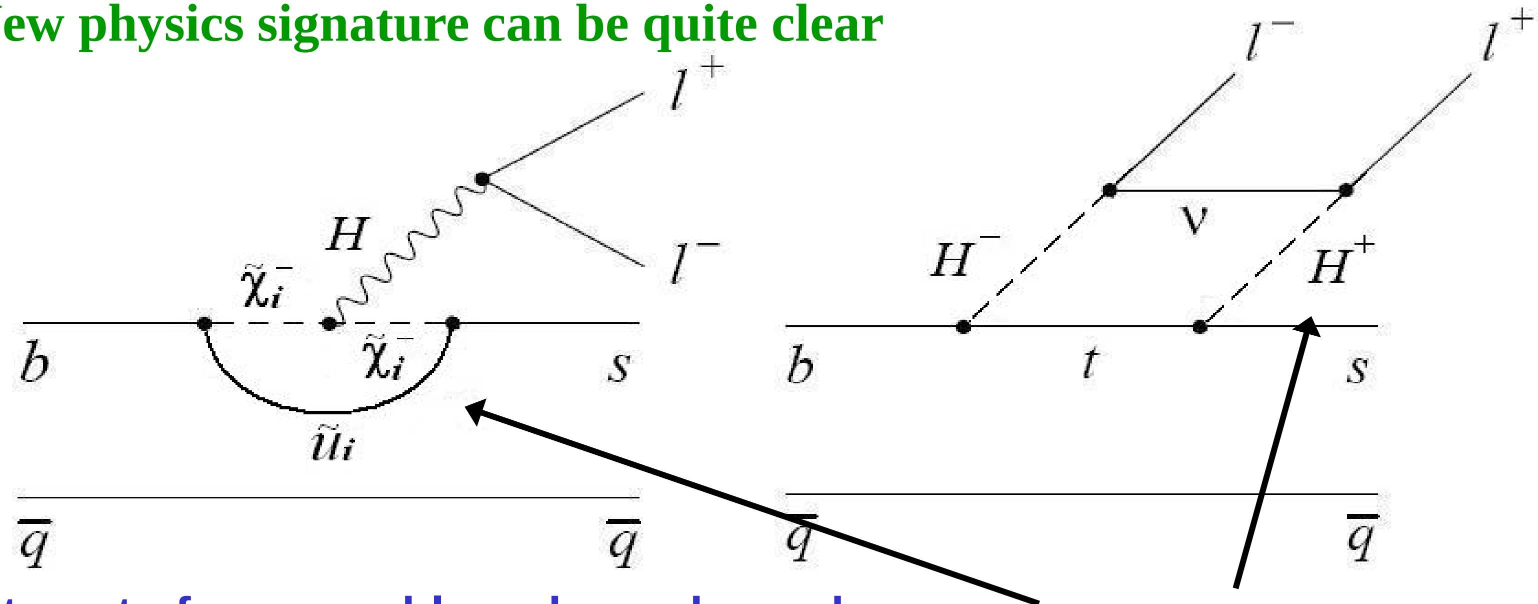
LHCb competitive with Babar and Belle after few weeks of data taking (~$0.07 fb^{-1}$)

The $B_d \to K^* \mu^+ \mu^-$ Decay

- **Rare FCNC with predicted BR = (1.19±0.39) x 10^{-6} (NNLO)**

Already measured at B factories - BR = (1.22+0.38-0.32) x 10^{-6}

- **Interesting place to confirm SM and to look beyond**
- **New physics signature can be quite clear**



New Physics

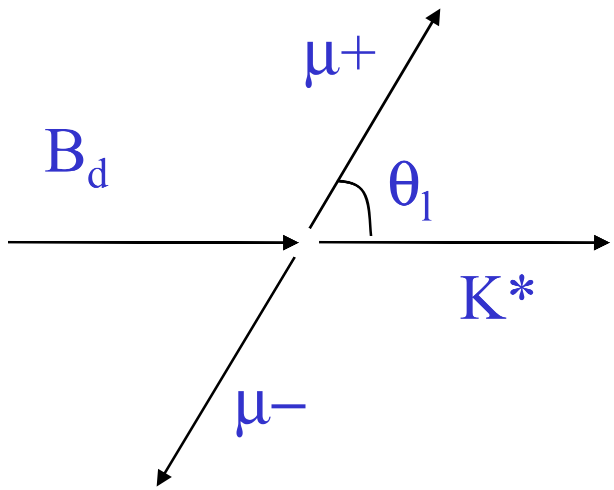
Assortment of measurables whose dependence on $\mu^+\mu^-$ mass can reveal new physics

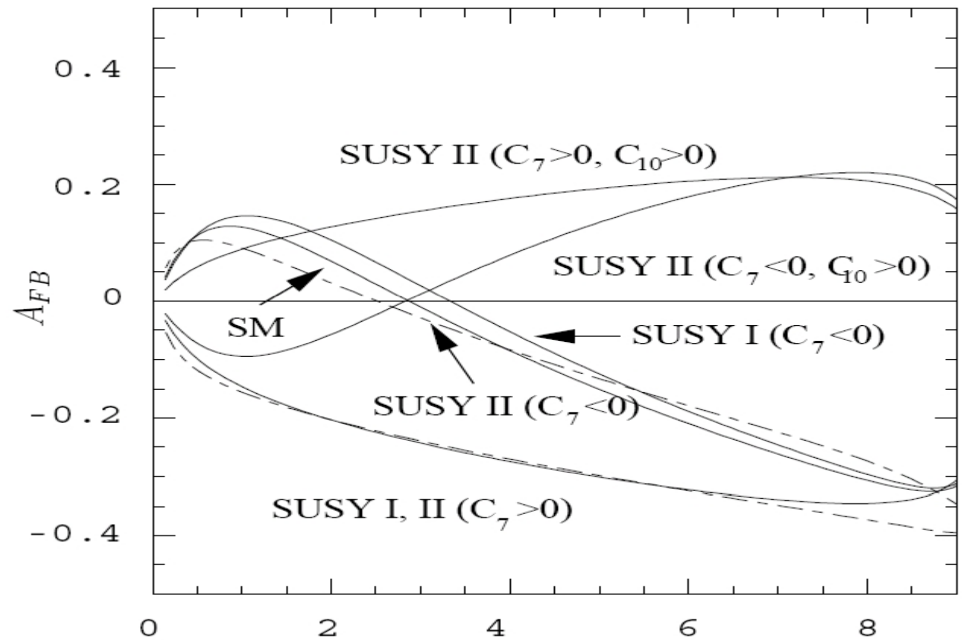
- Angular distributions: Forward-Backward asymmetry and its zero point

- Wilson coefficients (A_{10}/A_7 and A_9/A_7)

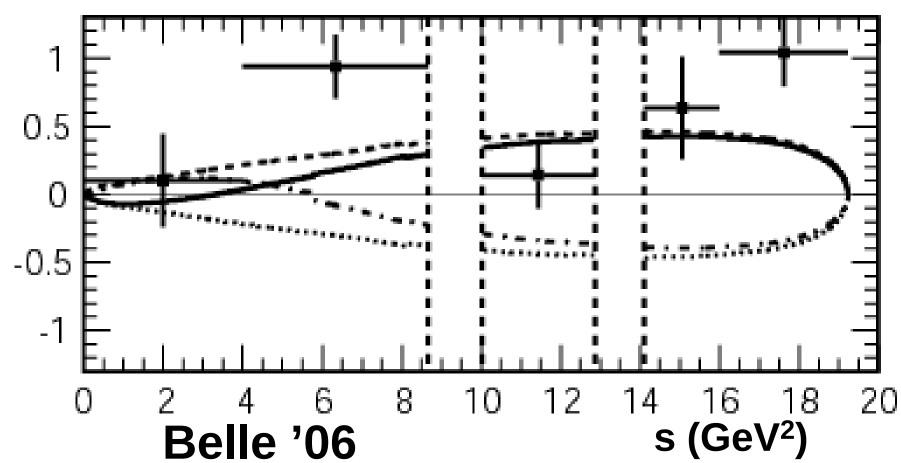
Forward Backward Asymmetry

Counting events according to the angle between the positive lepton and the B meson on the dimuon rest frame.





$$\mathrm{FBA} = \frac{\mathrm{Forward}_{\mathrm{evts}}\left(m_{\mu\mu}^2\right) - \mathrm{Backward}_{\mathrm{evts}}\left(m_{\mu\mu}^2\right)}{\mathrm{Total}_{\mathrm{evts}}\left(m_{\mu\mu}^2\right)}$$



Kernel density estimation

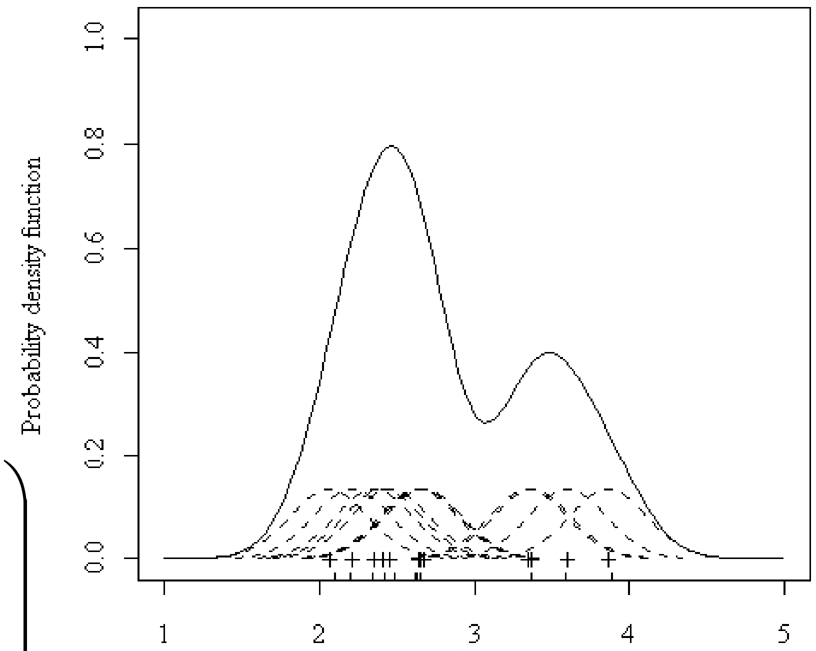
How to estimate accurately the density function of an observable (*dimuon mass, FBA,…*) ?

⇒ **Kernel density (*aka unbinned*) method converges fast providing a continuous curve**

⇒ **Probability density function *f* obtained using a Gaussian kernel:**

$$f\left(m_{\mu\mu}^2\right)=\frac{1}{N\sqrt{2\pi}h_{m_{\mu\mu}^2}}\sum_{i=0}^{N}\exp\left(-\frac{1}{2}\left(\frac{m_{\mu\mu}^2-m_{\mu\mu}^{2\ i}}{h_{m_{\mu\mu}^2}}\right)^2\right)$$

Sum over events (sum) — **Smoothness** (h)



Density estimation using **kernel functions** (*gaussians*)

All events contribute to the distribution estimate with more or less weight.

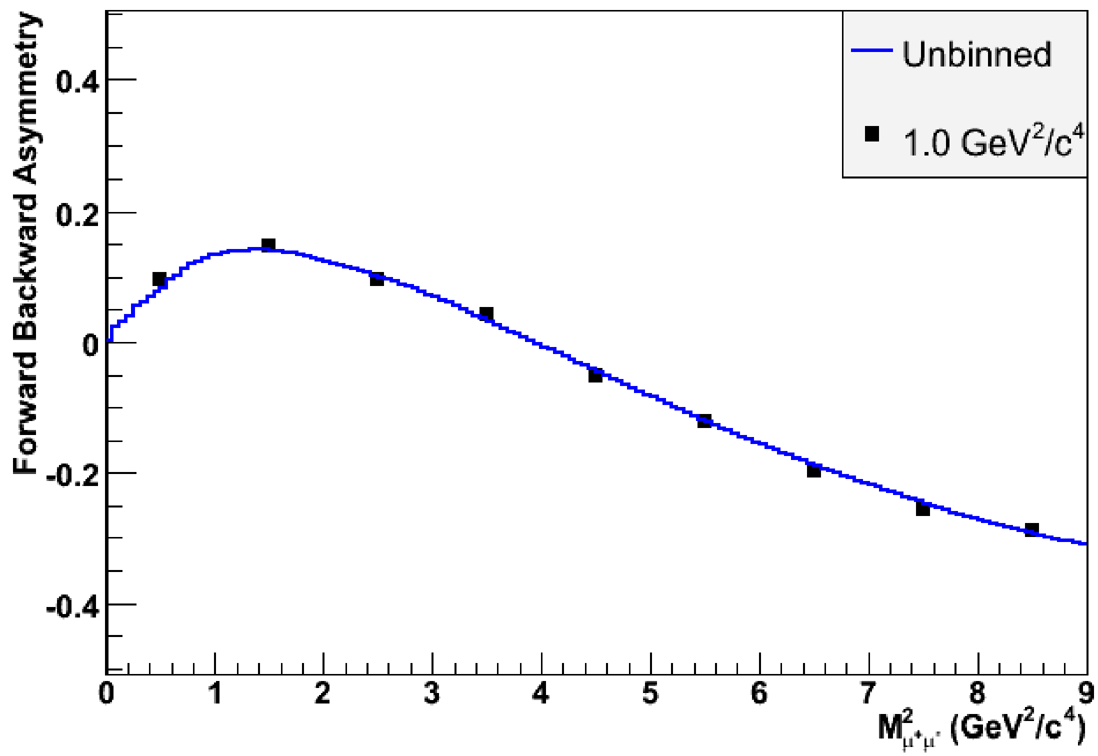
Forward-Backward asymmetry

Once the mass distribution for the forward and backward events is calculated one can rewrite the number of events and calculate the FBA as:

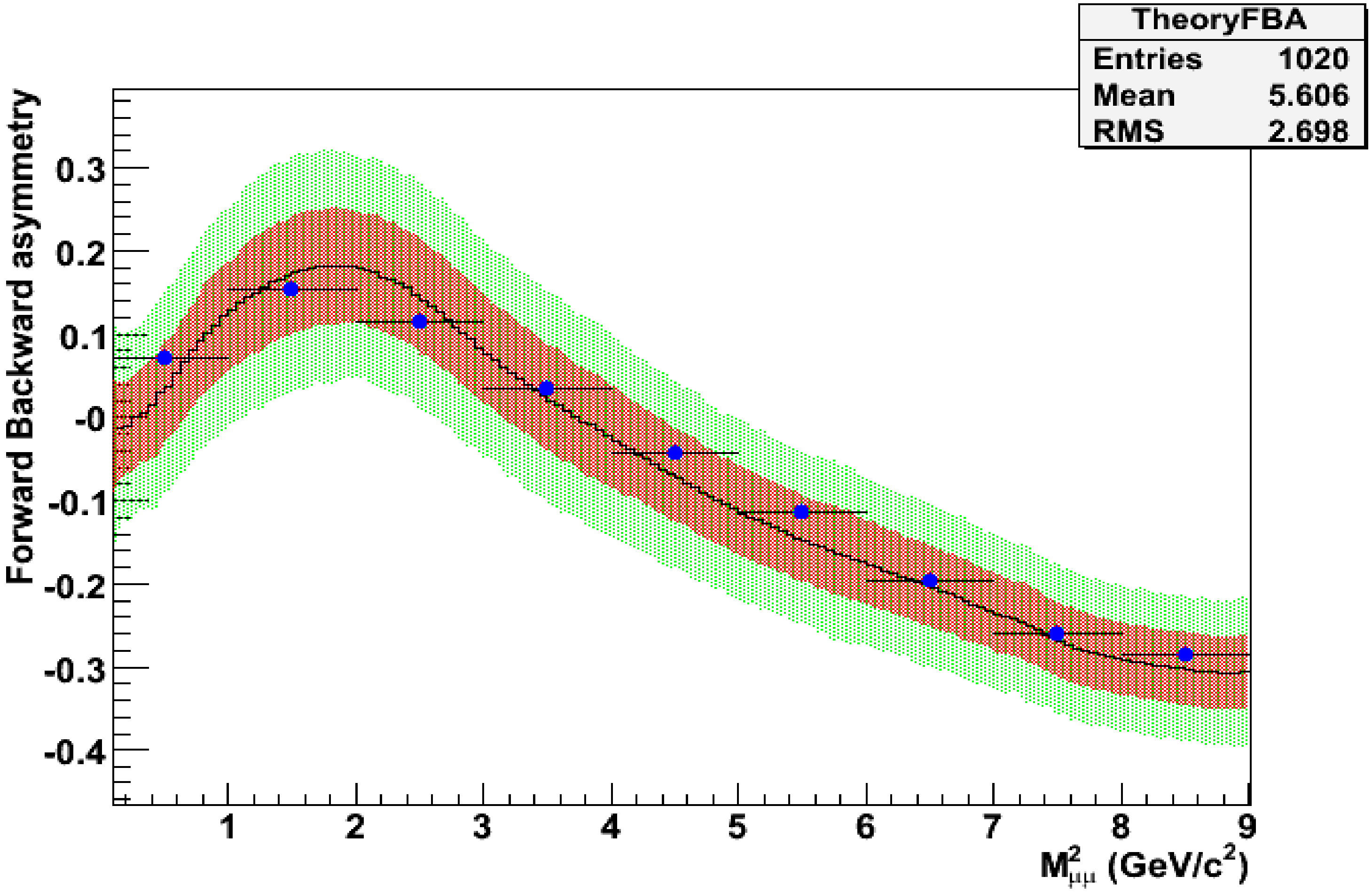
$$\mathrm{FBA}\left(m_{\mu\mu}^{2}\right)=\frac{\mathrm{Total}_{\mathrm{forward}}\mathrm{f}_{\mathrm{forward}}\left(m_{\mu\mu}^{2}\right)-\mathrm{Total}_{\mathrm{backward}}\mathrm{f}_{\mathrm{backward}}\left(m_{\mu\mu}^{2}\right)}{\mathrm{Total}_{\mathrm{forward}}\mathrm{f}_{\mathrm{forward}}\left(m_{\mu\mu}^{2}\right)+\mathrm{Total}_{\mathrm{backward}}\mathrm{f}_{\mathrm{backward}}\left(m_{\mu\mu}^{2}\right)}$$

Unbinned method converges to the correct FBA curve

Using 100 data sets each ~2fb^{-1}



Forward-Backward asymmetry



- FBA zero point directly extracted from curve
- Uncertainties calculated by sampling the dimuon mass distributions
- Uncertainty can be calculated from single data sample using jackknife method (being implemented)

$S_0 = 4.04 \pm 0.40$ GeV^2/c^4

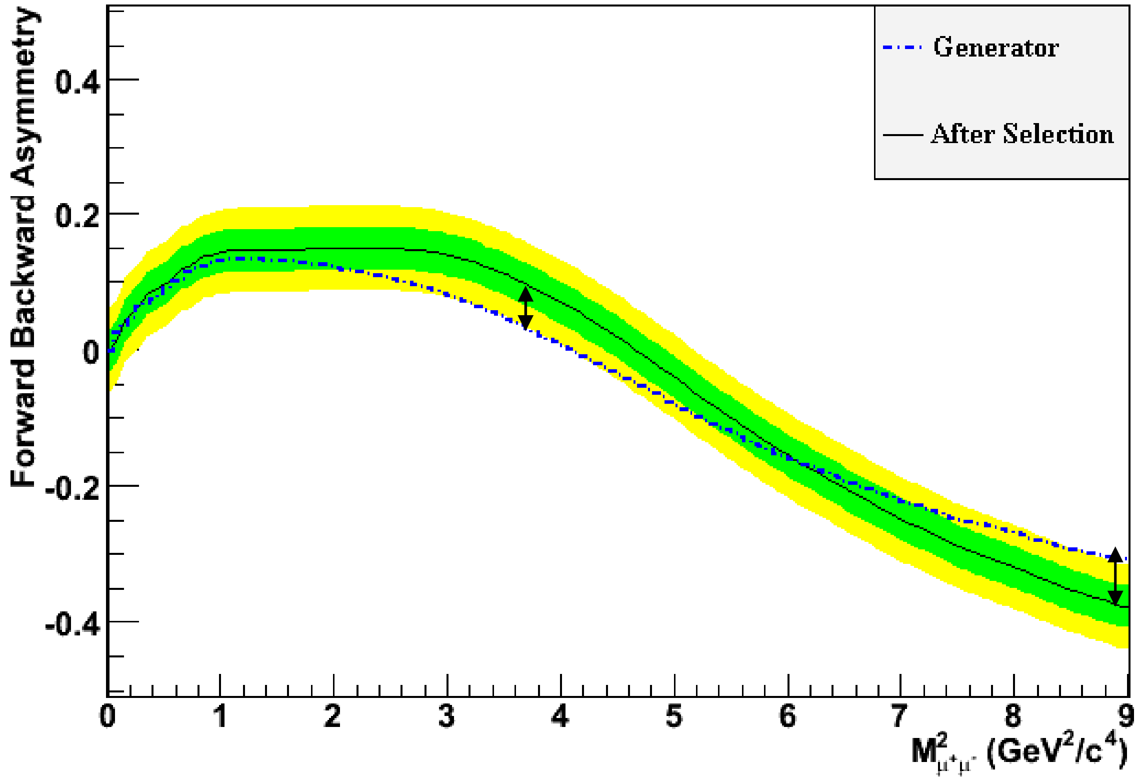
Compatible with binned method and our previous version with fit

J. Dickens, CERN-LHCb-2007-039

Acceptance Effects

Reconstruction and selection affect the Forward Backward Asymmetry

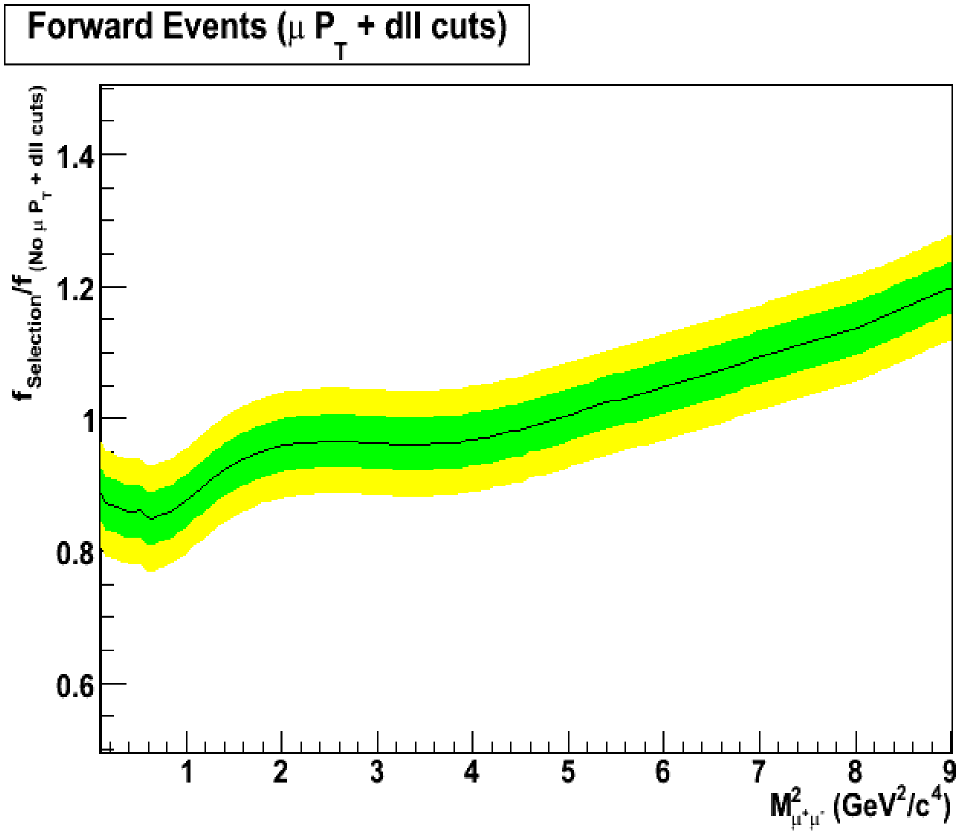
- **Evaluate FBA with detector simulation + selection**
- **~425k events - (about $8fb^{-1}$)**
- **No trigger simulation included**
- **Goal was to evaluate which selection cuts contribute to difference between curves**

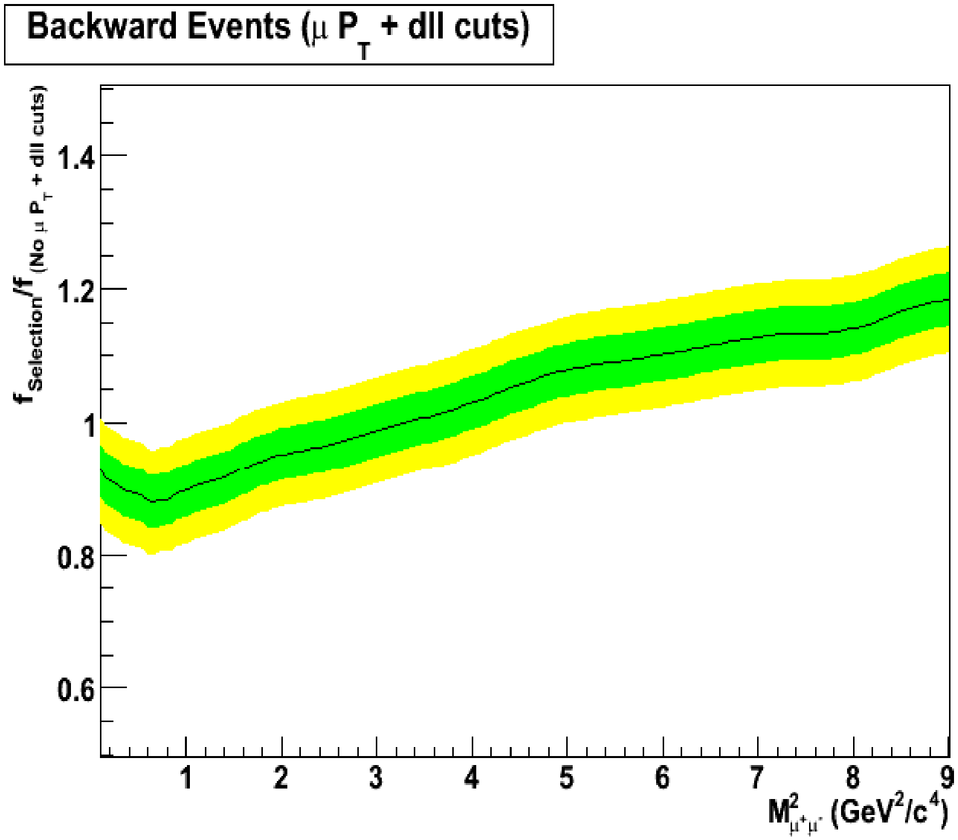


⇒ **The zero point difference is about 0.5 GeV^2/c^4**
⇒ **Maximum FBA amplitude difference 1.8-2.0σ ($8fb^{-1}$)**

Acceptance Effects

Mainly due to single μ cuts





⇒ Acceptance effect due to P_T and Particle identification

⇒ Strong the correlation between these two variables

⇒ The zero point becomes 0.25GeV^2/c^4 closer and the FBA amplitude difference ~1.1-1.8σ (8fb-1).

Summary and Perspectives of $B_d \rightarrow K^* \mu^+ \mu^-$ Analysis

- Unbinned method developed
- Simple method provides good convergence with low number of events
- The zero point sensitivity is ~4.0 ±0.4 GeV/c^2
- Reconstruction and selection affect Forward Backward Asymmetry
- Significant acceptance effects due to single muon cuts

  Possible calibration with $J/Psi \rightarrow \mu^+ \mu^-$ samples
- Studies on background subtraction are being carried out.