The $B_d \to K^{*0}\mu^+\mu^-$ decay at LHCb

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LPNHE (Paris 6), France

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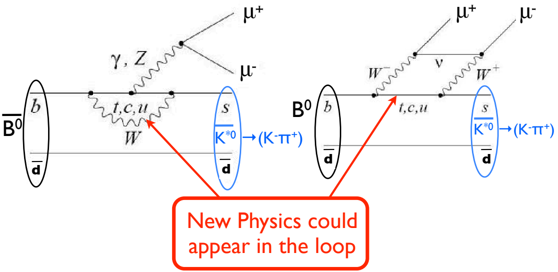
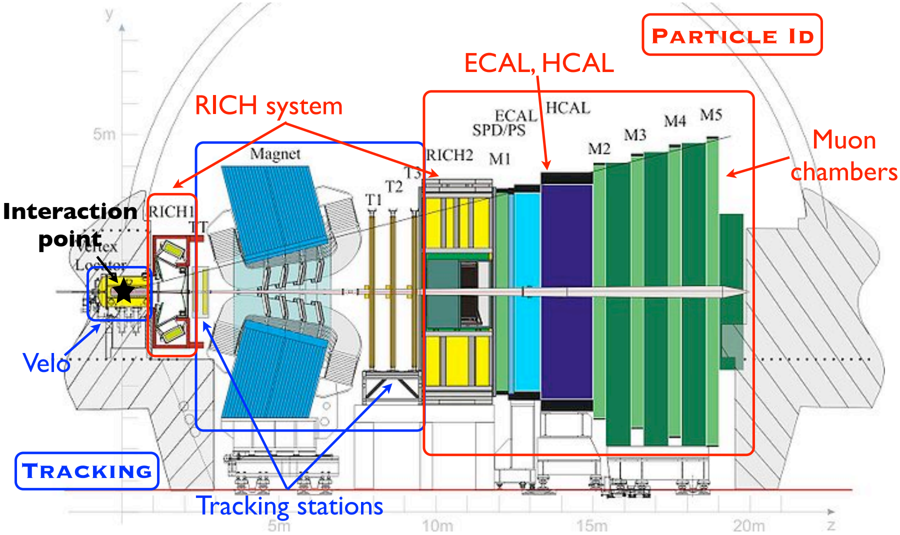
FCNC process



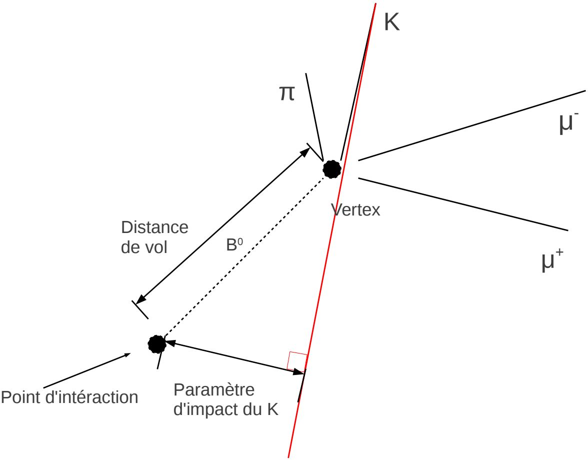
- In the rare process, as $B^0 \to K^{*0}(\to K\pi)\mu^+\mu^-$ decay, new physics particle can enter in the loop and modify Standard Model (SM) amplitudes.

- The interest of having a 4-body decay process is to have many angular observables, asymmetries which are sensitive to NP.
- The Branching Ratio (BR) in Standard Model (SM) of this 4-body decay is: $\approx 10^{-6}$

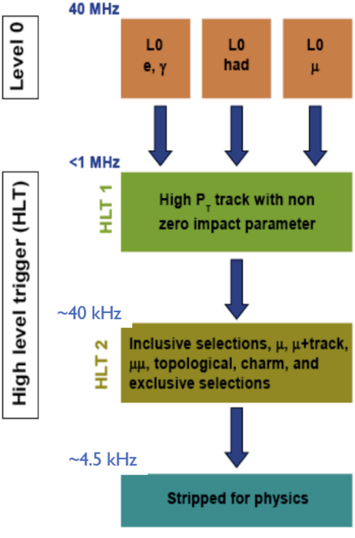
The LHCb experiment



The decay


K
π
μ-
Vertex
Distance
de vol
B0
μ+
Point d'intéraction
Paramètre
d'impact du K

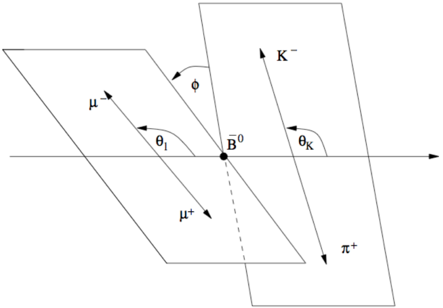
The Trigger



- High Level Triggers (HLT) is the last level of trigger of LHCb and it's a full software trigger.
- It's specific to different decay channel.
- It's divide in two steps:
  - HLT1:
    - at least 2 tracks in the detector, with a large momentum and transverse momentum,
    - one of the particle has a large Impact Parameter (IP) w.r.t the Primary Vertex (PV)
    - More cuts are availlable for decays involving muons.
  - HLT2:
    - searches for secondary vertices,
    - cut on decay length and invariant mass

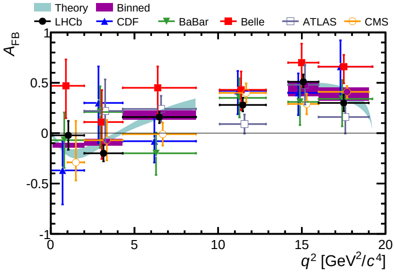
The decay rate

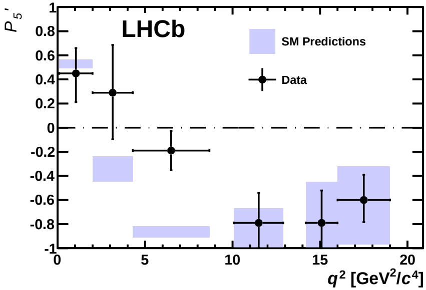
- The decay rate of the four body final state after combining B and $\bar{\mathrm{B}}$ decays is described by the equation below
- The observables F_{L} and S_i are function of Wilson coefficients and form factors.



$$\frac{1}{\Gamma}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi}=\frac{9}{32\pi}\Big[\frac{3}{4}(1-F_{\mathrm{L}})\sin^2\theta_K+F_{\mathrm{L}}\cos^2\theta_K+\frac{1}{4}(1-F_{\mathrm{L}})\sin^2\theta_K\cos2\theta_\ell$$
$$-F_{\mathrm{L}}\cos^2\theta_K\cos2\theta_\ell+S_3\sin^2\theta_K\sin^2\theta_\ell\cos2\phi$$
$$+S_4\sin2\theta_K\sin2\theta_\ell\cos\phi+S_5\sin2\theta_K\sin\theta_\ell\cos\phi$$
$$+S_6\sin^2\theta_K\cos\theta_\ell+S_7\sin2\theta_K\sin\theta_\ell\sin\phi$$
$$+S_8\sin2\theta_K\sin2\theta_\ell\sin\phi+S_9\sin^2\theta_K\sin^2\theta_\ell\sin2\phi\Big]$$

The observables





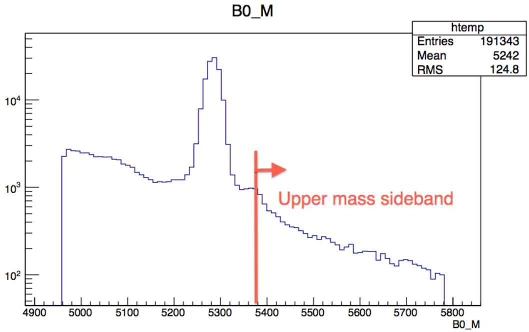
- $A_{FB} = \frac{3}{4} S_6$, is the forward-backward asymmetry
- $P_5' \approx S_5$

The selection of the events

$3fb^{-1}$ of data has been recorded by LHCb in 2011+2012

The offline event selection consist in a set of loose cut requirements:

- the particle identification of the final state particle
- the flight distance of the B mesons.

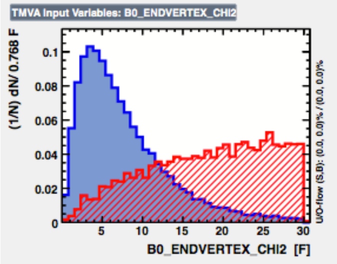


- Most of the event come from the $J/\psi \to \mu^+\mu^-$ resonance
- combinatorial background: random combination of the 4 final-state particle.

A multivariate analysis

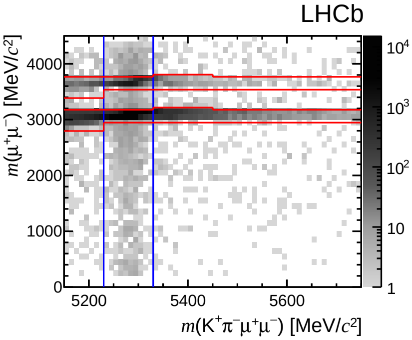
Then a multivariate(MVA) offline selection is used to reduce the combinatorial background.

- The previous MVA was trained using 26 inputs variables like the flight distance of the B mesons, or the transverse momentum of the K^{*0}.
- The $B^0 \to K^{*0} J/\psi$ candidates was used as proxy for the signal and the upper mass sideband of $B^0 \to K^{*0}\mu^+\mu^-$ events as a background sample.



The analysis strategy

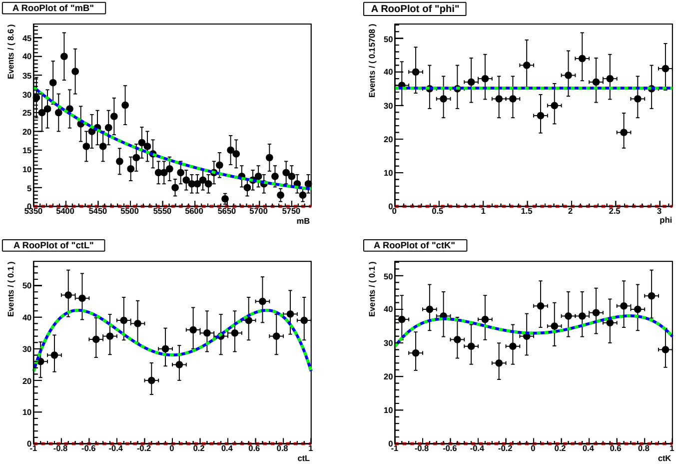
The analysis is done in six bins of q^2 and the region $1 < q^2 < 6$ GeV^2



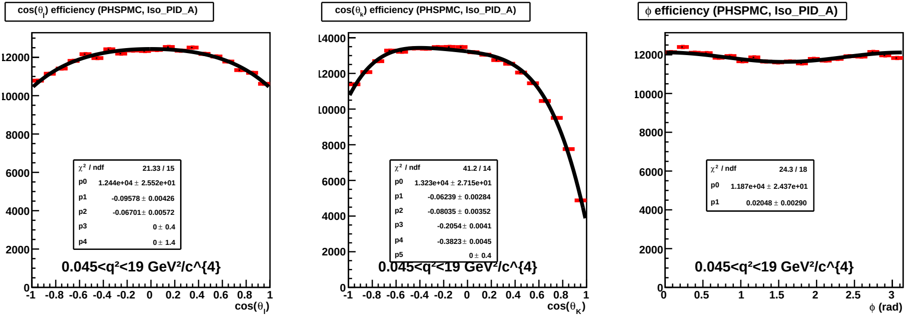
- Vetoed the region of dimuon corresponding to the charmonium resonances: $J/\psi(1S)$ and $\psi(2S)$
- Vetoed some other peaking background to a negligible level.

Angular distribution

In order to extract the observable we need to parametrize the angular distribution of the background.



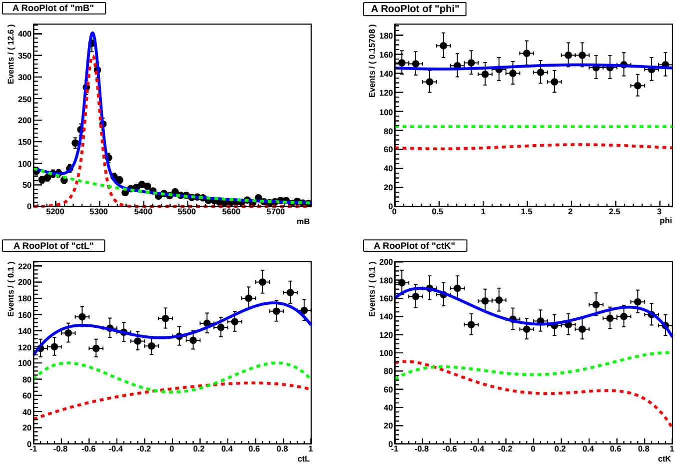
Acceptances



- The acceptance of the detector should be taken account to extract the angular distribution coming from the decay.
- The asymmetry in $\cos(\theta_K)$ is due to the difference of masses between the kaon and the pion.

Angular distribution

Then we extract the angular distribution for the $B^0 \to K^{*0}\mu^+\mu^-$ signal to be able to fit the observables.

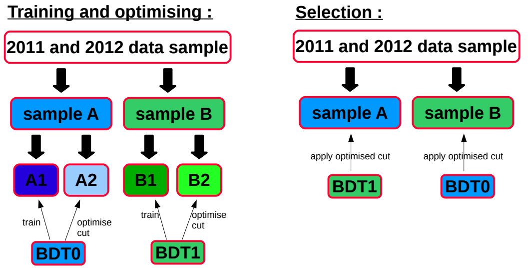


Improvements for the 2012 analysis

- changing the MVA strategy
- reduce the number of input variables on the MVA
- adding new variables in the MVA

New MVA strategy

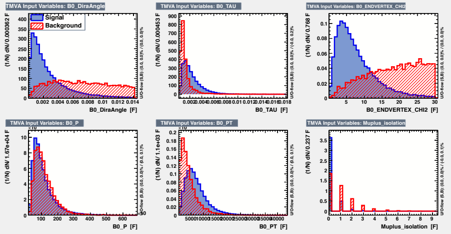
The "usual" way to use a MVA is to take a small part of your data, to train the MVA, then apply the answer of the MVA on the rest of your data and throw away the data use for the training.
But loose a part of your data may be an issue when you deal with a rare decay.

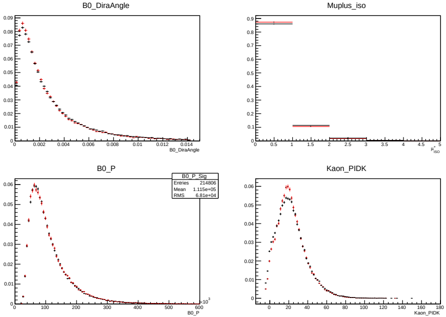


- The new strategy is to divide the data available in 2
- use on part to train the MVA
- and apply the MVA answer to the other part and vice versa

Inputs variables

Selection of variable with a good data-MC comparison and wih a good separation between Signal and Background.





In blue : The signal distribution

In red : The background distribution

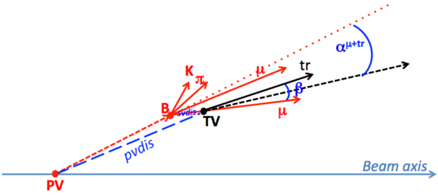
In black : The data distribution

In red : The MC distribution

Isolation variables

Introduction of the muon isolation variable from the $B_s \to \mu^+\mu^-$ analysis.

Number of tracks satisfying:

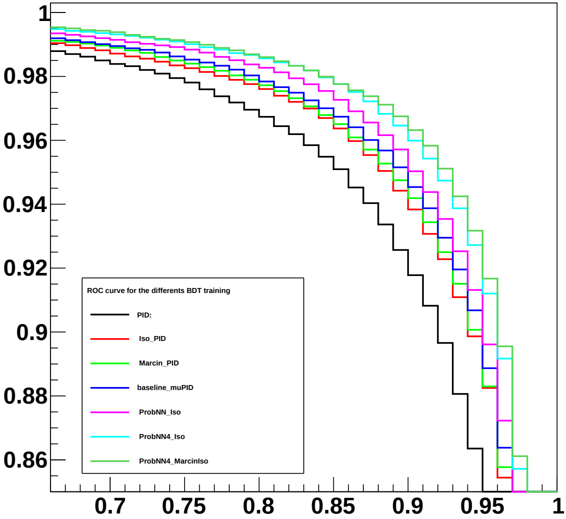


- Track impact parameter significance wrt the PV, ips > 3,
- svdis = [-0.15, 30],
- pvdis = [0.5, 40],
- $\beta < 0.27$,
- $fc = \frac{|\vec{P_\mu}+\vec{P_{tr}}|\cdot\alpha^{\mu+tr,PV}}{|\vec{P_\mu}+\vec{P_{tr}}|\cdot\alpha^{\mu+tr,PV}+P_{T\mu}+P_{Ttr}} < 0.6$;
- Doca (μ, tr) < 0.13,

$\Longrightarrow$ μ refer to one of the muon.

Results on MVA training

ROC curve: B sample



Conclusions

- Selection is finalized.
- Start the Branching ratio analysis for the winter conferences
- Stay tuned for the angular analysis and the update on the P_5' variable
- May be enough statistics to start the direct fit of the Wilson coefficients ...