Rare Decays at LHCb

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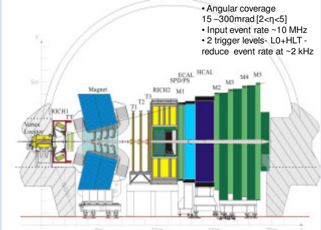
LHCb Detector



Single-arm spectrometer composed of Vertex Locator, Tracking System, RICH detectors, Calorimeter System (Preshower, ECAL, HCAL) and Muon system to explore the strongly forward peaked bb production at the LHC

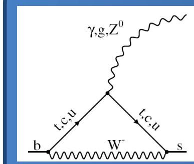
LHCb is designed to analyse CP violation and rare decays of B-mesons and b-baryons, to improve the Standard Model determinations on CKM parameters and to explore the full potential of physics beyond the Standard Model

If new physics manifests itself, studying CP asymmetries in B-meson decays may help to explain why the universe is predominately made of matter rather than antimatter.

In this regard, LHCb combines:
§ Good decay time resolution - to resolve B_s oscillations
§ Mass resolution - to efficiently suppress background
§ Excellent particle identification - for K-π separation
§ Efficient trigger - for many B-decay topologies.

Up to now, with more than 90% efficiency of data taking and at a measured cross-section of $\sigma_{bb\sim}$ = 284 x10^6 pb, LHCb recorded ~37 pb^{-1} in 2010 and ~50 pb^{-1} in 2011 at √s=7 TeV

Radiative Decays at LHCb



LHCb will seek to test the SM and confirm or constrain many of the NP models by making precision measurements on the radiative decays of B-mesons.

Radiative B decays provide a powerful tool in engaging a search for new physics. Theoretically, they are described through one-loop processes which can very well hide new physics (NP). Deviations from the SM predictions on the decay rates, CP and isospin asymmetries or angular distributions, are a clear proof on the existence of NP, therefore precise measurements on these observables are mandatory.

The polarization of emitted photons in radiative decays is particularly interesting as the $\bar{B}_s(B_s)$ meson decays predominantly into a left (right)-handed photon.

One way is to study the time evolution of $B_s^0 \to \phi^{CP}\gamma$ decays, where ϕ^{CP} is a CP-eigenstate. The time dependent decay width can be parameterized as:

$$\Gamma_{B\to\Phi^{CP}\gamma}(t) \sim \cosh\frac{\Delta\Gamma\, t}{2} - \mathcal{A}^{\Delta}\sinh\frac{\Delta\Gamma\, t}{2} + \mathcal{C}\cos\Delta m\, t - \mathcal{S}\sin\Delta m\, t$$

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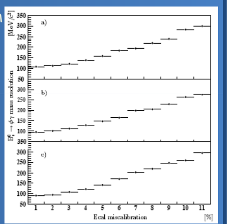
In SM: $\mathcal{C}$ =0, thus the measurement of $\mathcal{A}^{\Delta}$ and $\mathcal{S}$ directly determines the "wrongly"-polarized photon fraction

For the B_s system, $\Delta\Gamma_s$ non-negligible => $\mathcal{A}^{\Delta} \approx \sin 2\psi$ where $\tan\psi \equiv \left|\frac{\mathcal{A}(\bar{B}_s \to \Phi^{CP}\gamma_R)}{\mathcal{A}(\bar{B}_s \to \Phi^{CP}\gamma_L)}\right|$

§ Two benchmark radiative decays are $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$
§ $B_d \to K^*\gamma$ decay mode, measured first by CLEO and update by Babar and Belle is precisely known, (43.3±1.5)x10^{-6}. Its measurement at LHCb is crucial for the calorimeter calibration
§ $B_s \to \phi\gamma$ decay has been observed by Belle, with a $\mathcal{B}(B_s \to \phi\gamma)$=57$^{+22}_{-19}$x10^{-6}

Calorimeter calibration

Radiative decay studies require important prerequisites:
- Calorimeter calibration
- Implementation of the High Level Trigger (HLT)
- π^0/γ separation at high transverse energy
- Determination of proper time acceptance function from



Based on MC studies, already with 2 fb^{-1} recorded by LHCb in nominal conditions of operation ($\mathcal{L}=2\times10^{32}$ $cm^{-2}s^{-1}$) the following studies should be possible:

○ **The photon polarization in $B_s \to \phi\gamma$ with a precision of 0.22**

○ **The direct CP asymmetry in $B_d \to K^*\gamma$ with a precision of 1%**

MC Studies: 3% miscalibration of ECAL = 20% increase in signal width ≈ an effective 20% increase of the combinatorial background in the signal region (Figure)

$B_d \to K^*\gamma$ signal peak contains information about ECAL miscalibration:

- ***Position*** - global miscalibration factor for energetic photons
- ***Width*** - channel to channel calorimeter miscalibration

Using cosmic and early 2010 data, the calorimeter has been calibrated at the 2% level

The calibration procedure involved three stages:
1- calibration at the ~10% level using cosmic rays (during detector commissioning, 2007-2008)
2 - calibration at the 4-5% level using an 'energy flow' method to level out the channel response
3 - calibration at the 2% level using an iterative procedure based on a large π^0 sample
- This technique does not rely on information from the other subdetectors (is tracking independent) and is based on the direct relation between the energy shift of the photon and the shift of the visible position of π^0 peak.
- 2 & 3 are to be done regularly

LHCb performance

The efficient selection of events with B-mesons is acquired through a ***high performance trigger***.
Based on particles with large transverse momentum and displaced secondary vertices the LHCb trigger system will select the small fraction of interesting events (from the large number of *bb* and other *pp* inelastic events) which will be written to storage for further offline analysis.

The reduction in the output rate of events is achieved as follows:
Level-0 (L0) - high pT hardware trigger designed to reduce the LHC beam crossing rate of 40 MHz to 1MHz.
High Level Trigger (HLT) - software algorithms reducing the rate of accepted events from 1 MHz to 200 kHz.
HLT1 - confirms the decisions made by L0, it combines more accurate p_T determinations with information from the tracking system and VELO.
HLT2 - events that passed HLT1 are fully reconstructed and inclusive signatures of B-hadron decays are searched
Radiative decays will be triggered mainly due to the presence of a high energy photon.

Data Collection
37.5 pb^{-1} 2010 Data and 50.5 pb^{-1} 2011 Data at √s=7 TeV

Table 1

2010 data, $\mathcal{L}_{int}$	L0γ cut
4 pb^{-1}	2.4-2.8 GeV
5.4 pb^{-1}	4.4 GeV
28.6 pb^{-1}	3.2 GeV

For 2010 data all trigger lines had (Table 1):
relaxed cuts in the first few pb^{-1}
very hard cuts in 5.4 pb^{-1}
'intermediate' cuts in 28.6 pb^{-1}

$B_d \to K^*\gamma$ and $B_s \to \phi\gamma$ Mass Peaks

As the kinematic description of $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$ decays is very similar, a common selection is envisaged.

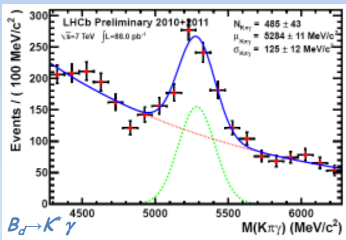
• First, the separation of pions from kaons is engaged. A cut on the significance of the track impact parameter eliminates the tracks from primary interactions. A vertex fit on such selected tracks is applied to form K*(ϕ) candidates.

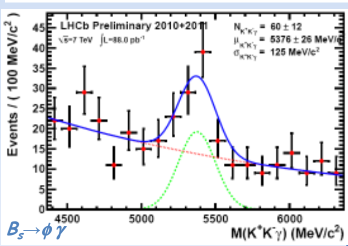
• A K*(ϕ) candidate is then combined with a photon. A constrain on the transverse energy of the photon (E_T>2.5 GeV), removes low energy photons.

• The primary vertex with minimum B impact parameter is chosen as B production vertex.

• Combinatorial background is suppressed by constraining the angle between the B momentum vector and B flight direction (distance between production and decay vertex). K*(ϕ) are produced with different polarizations for signal and background, this property is exploited to suppress correlated background from decays with π^0 in final states.

• Significant reduction of the background level is accomplished through additional cuts (B transverse momentum, track multiplicity)





With 88 pb^{-1} of integrated luminosity we collected:
(6.1±0.7) $B_d \to K^*\gamma$ candidates /pb^{-1}
(0.6±0.2) $B_s \to \phi\gamma$ candidates/pb^{-1}

By the end of June we expect to collect ≥200 pb^{-1} worth of data and ~1 fb^{-1} by the end of 2011.
Based on the 2010/2011 preliminary results, we expect to collect a sample of ~ 6k $B_d \to K^*\gamma$ events and 600 $B_s \to \phi\gamma$ events by the end of 2011.

Conclusions

With >~37pb^{-1} of recorded data in 2010 and >~50pb^{-1} in 2011, at more than 90% efficiency, LHCb performance is exquisite

With limited statistics from 2010 data, the calorimeter has been calibrated to a level of 2%

Additional 2011 provided visible improvement in triggering

It is expected that by the end of 2011, with a luminosity of ~1 fb-1, LHCb will set a new record over the B factories in collected data

By the end of 2011 we expect to collect significant statistics both for $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$ which will allow the determination of the ratio of $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$ branching fractions