Measurement of the ratio of branching fractions $Br(B \to K^*\gamma)/Br(Bs \to \varphi\gamma)$

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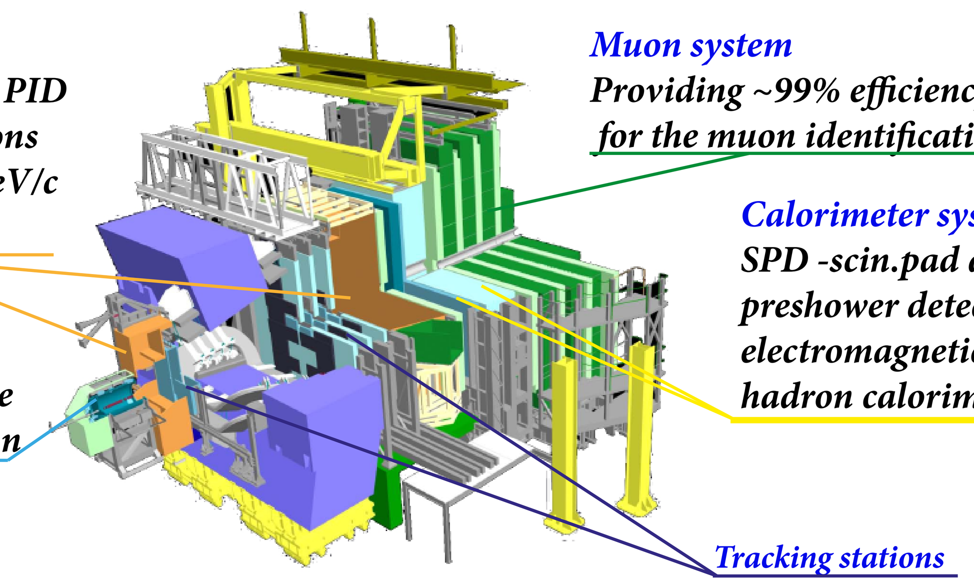
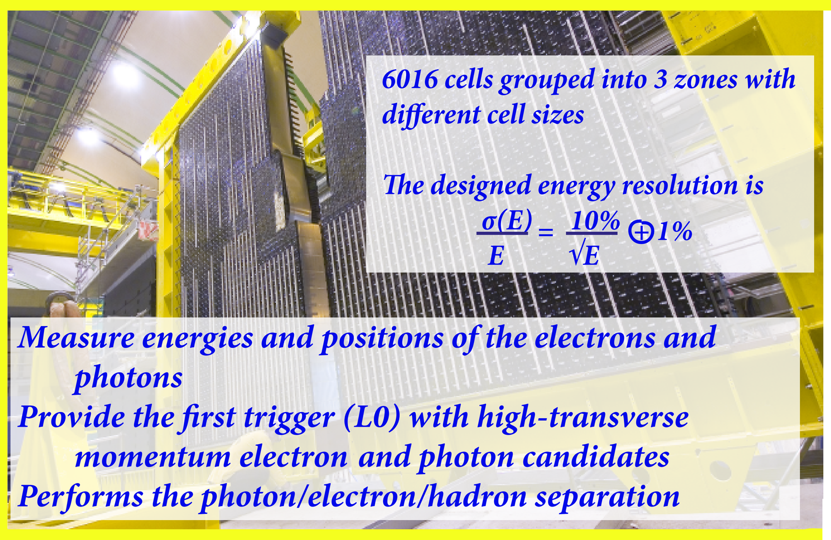
The LHCb detector



LHCb detector is a single arm forward spectrometer covering 300 mrad solid angle, which in terms of rapidity is $1.9 < \eta < 4.9$. The acceptance for the B-mesons is estimated to be ~300 μbarn.

A perfect calibration of the Electromagnetic Calorimeter (ECAL) is extremely important for the studies of the radiative decays. Monte-Carlo simulation shows that the 3% miscalibration of the ECAL leads to almost 20% increase in the B-meson mass resolution

Electromagnetic calorimeter calibration



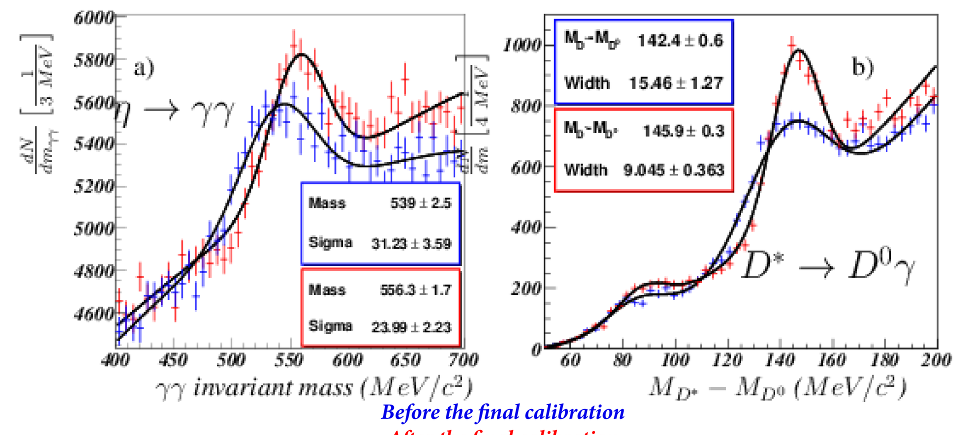
Energy resolution of each module has been determined at the test beam.

The photoelectron multipliers gains are determined with the help of LED system installed in the calorimeter.

Energy flow method, based on the idea that the distribution of the transverse energy over the surface of the calorimeter should be a smooth function of coordinates, allows to achieve 4% level in cell intercalibration.

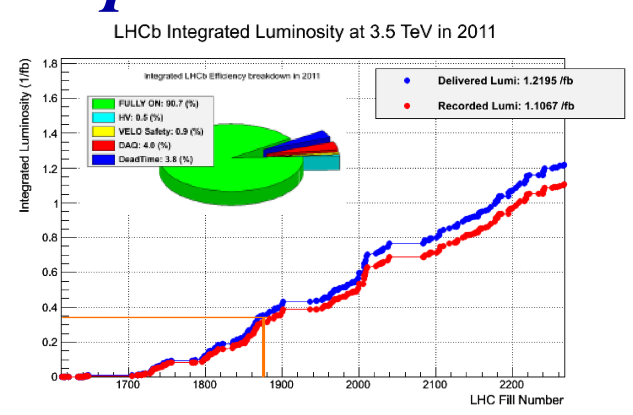
For the final calibration the «Mass distribution fit» method is used. It is based on the measurement of a well known value, namely the mass of a resolved π^0 in its decay into two photons and aims to achieve less than 2% fine calibration accuracy.

The whole calibration chain helps to improve the resolution for many particles in their decays with photons in the final states.



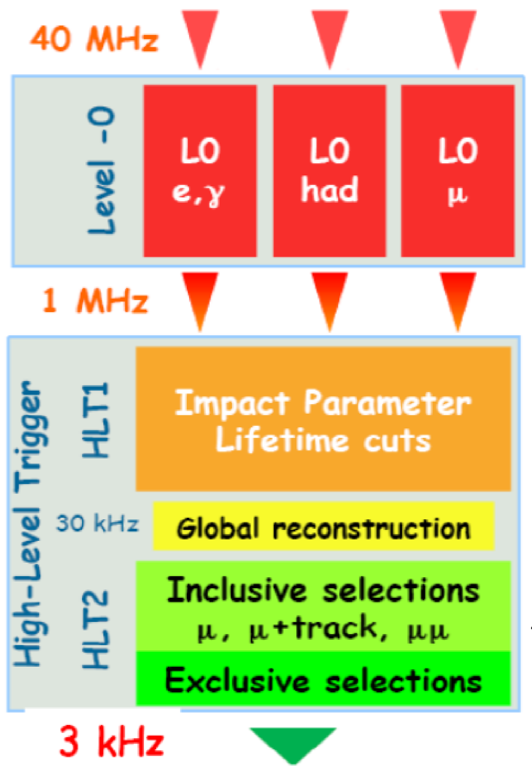
Before the final calibration
After the final calibration

Operation in 2011



LHCb has started to take data at the center of mass energy of $\sqrt{s}$ = 7 TeV since 2010. Current results are shown with the 340 pb^{-1} of data taken in 2011.

Trigger selection

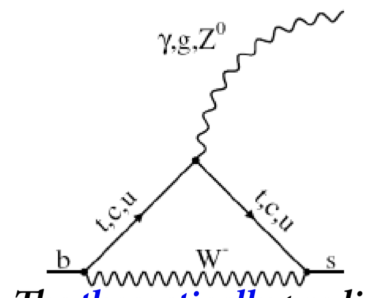


Radiative decays are triggered by purely hardware L0 trigger as containing a high transverse momentum photon candidate.

Further in the first step of the HLT an additional information from T-stations is used to select events with a high momentum kaon or pion candidate.

HLT2 having access to the information from most of the detectors, contains two dedicated exclusive selection lines for $Bs \to \varphi\gamma$ and $B \to K^*\gamma$ decays.

Radiative decays



Rare radiative decays of the B-mesons may provide a good test for the Standard Model (SM). Being forbidden at tree level, such processes may only occur due to loop diagrams involving FCNC and thus become very sensitive to the impact of non-standard particles. And accuracy of the theoretical predictions for such decays makes them attractive from the experimental point of view.

The theoretically predicted branching fractions have the same value of $(4.3 \pm 1.4) \times 10^{-5}$ for both decays.

	$B \to K^*\gamma$	$Bs \to \varphi\gamma$
BaBar ($\times 10^{-5}$)	$4.47 \pm 0.10 \pm 0.16$	
Belle ($\times 10^{-5}$)	$4.01 \pm 0.21 \pm 0.17$	$5.7^{+1.8+1.2}_{-1.5-1.1}$
CLEO ($\times 10^{-5}$)	$4.55^{+1.8+1.2}_{-1.5-1.1} \pm 0.34$	

These decays have already been observed by Belle (both $B \to K^*\gamma$ and $Bs \to \varphi\gamma$ decays), BaBar and CLEO ($B \to K^*\gamma$ only) collaborations, which found a good agreement between the measured branching fractions of these decays and the SM predictions.

The effects of the New Physics may nevertheless be discovered through

For example, with 2 fb^{-1} of data LHCb expects to be able to measure the direct CP-asymmetry in the $B \to K^*\gamma$ decay. And the measurement of the photon polarization in the $Bs \to \varphi\gamma$ decay, which may be sensitive to the Left-Right Symmetric Model or unconstrained MSSM, is marked as one of the key measurements of the LHCb experiment. In the SM, the photons emitted in the $b \to s$ transitions should be predominantly right-handed and any excess of the «wrong»-polarized photons is consiedered as the evidence of the New Physics.

Experimentally, the photon polarization may be accessed through the time dependend CP-violation parameters:

$$\Gamma_{B^0_{(s)} \to \Phi^{CP}\gamma}(t) = |A|^2 e^{-\Gamma_{(s)}t}\left(\cosh\frac{\Delta\Gamma_{(s)}t}{2} - \mathcal{A}^{\Delta}\sinh\frac{\Delta\Gamma_{(s)}t}{2} + \mathcal{C}\cos\Delta m_{(s)}t - \mathcal{S}\sin\Delta m_{(s)}t\right)$$

and in the SM $\mathcal{A}^{\Delta} \approx \sin 2\psi \cos\varphi_{(s)}$, where $\tan\psi \equiv \left|\frac{\mathcal{A}(\bar{B}_{(s)} \to \Phi^{CP}\gamma_R)}{\mathcal{A}(\bar{B}_{(s)} \to \Phi^{CP}\gamma_L)}\right|$.

In order to reduce the systematic errors on the measured ratio of branching fractions, the selections for two decays were made as close to each other as possible, thus making use of the common topology, kinematics and photon efficiency of the decays.

Event selection

Vector meson selection

Two opposite-charged tracks of a good quality (track fit $\chi2 < 5$) are used to form a vector meson (K^* or φ).

Each of the tracks is identified to be a kaon or a pion with the help of logarithmic likelihood technique based on the information from different detector subsystems.

Both tracks are required not to point to the primary vertex (track impact parameter $\chi2 > 25$) and have a significant transverse momentum in excess of 500 MeV/c.

An unconstrained vertex fit is applied to the common vertex of the two tracks and the quality of this fit is also used as the selection criterion (vertex fit $\chi2 < 9$).

Mass of such a candidate should not be too far from the known PDG value ($\Delta m(K^*) < 55$ MeV/c², $\Delta m(\varphi) < 10$ MeV/c²).

Photon selection

Photon is reconstructed as an energy cluster in the electromagnetic calorimeter, having no matching track. Additional information from the SPD and Prs detectors is used for the photon identification.

The transverse energy of the photons is required to exceed 2600 MeV/c.

A contribution from the merged neutral pions is rejected with the help of the special photon/pion separation tool based on the shape of the shower in the ECAL.

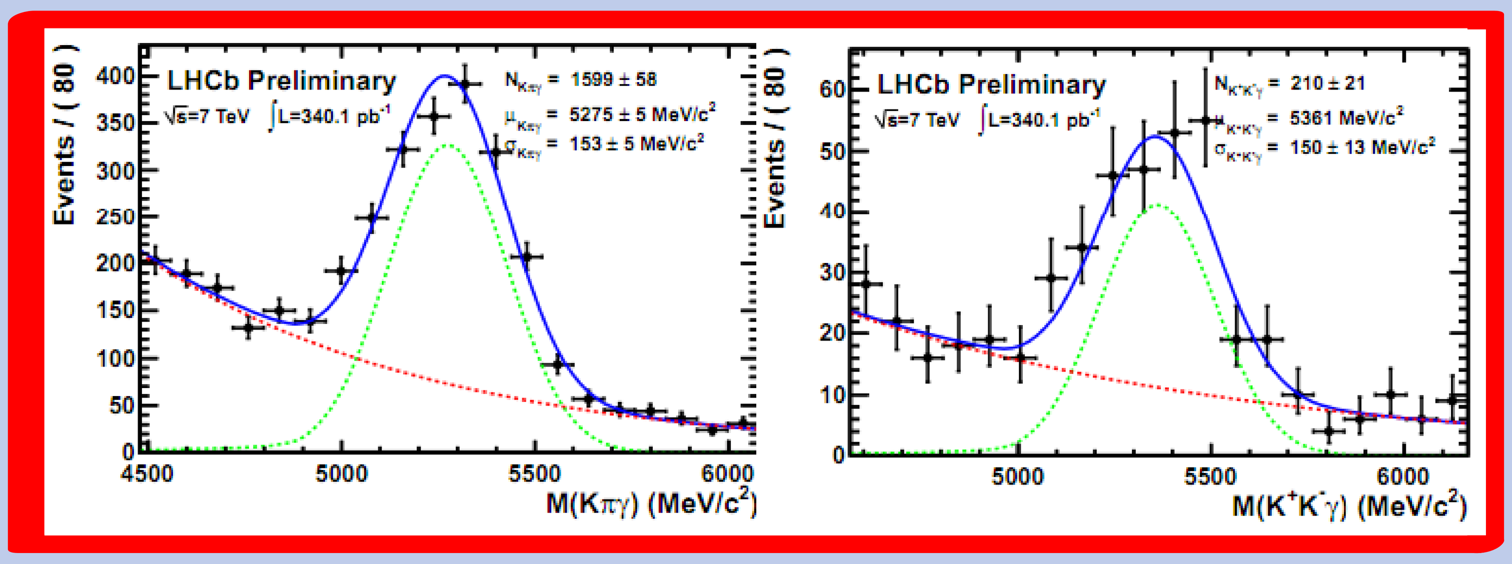
Build a B-candidate

High transverse momentum ($P_T(B)$>3 GeV/c)

Point to the primary vertex (impact parameter $\chi2 < 9$)

$B \to K^*\pi^0$ and $B \to \varphi\pi^0$ background is rejected by a cut on the cosine of the helicity angle ($|\cos\theta_{hel}| < 0.8$)

No additional track from the event can be added to the B decay vertex.



As the result of the selection the two rare radiative decays: $B \to K^*\gamma$ (left) and $Bs \to \varphi\gamma$ (right) were observed with the signal to background ratio in ±3σ region at the level of 1.7.

The number of the Bs → φγ events in the peak is currently the world's largest sample of Bs decays in this channel.

Measurement of the branching fraction ratio

$$\frac{\mathcal{B}(B^0 \to K^{*0}\gamma)}{\mathcal{B}(B^0_s \to \phi\gamma)} = \boxed{\frac{\mathcal{Y}_{B^0 \to K^{*0}\gamma}}{\mathcal{Y}_{B^0_s \to \phi\gamma}}}\boxed{\frac{\mathcal{B}(\phi \to K^+K^-)}{\mathcal{B}(K^* \to K^+\pi^-)}}\boxed{\frac{f_s}{f_d}}\boxed{\frac{\epsilon_{B^0_s \to \phi\gamma}}{\epsilon_{B^0 \to K^{*0}\gamma}}}$$

Signal yields
Extracted from the simultaneous fit of the two peaks with the mass difference fixed, after subtraction of the calculated peaking background contributions.
Crystal Ball + expontial are used as the fit

Branching fractions of the vector mesons
The known PDG values are used

Hadronization probabilities
Combined LHCb measurement:
$fs/fd = 0.267^{+0.021}_{-0.020}$

Efficiencies ratio
Is combined from the trigger, acceptance and reconstruction, and selection efficiencies. The first ones are estimated from the Monte-Carlo model of the decays. The selection efficiency without PID is also extracted from the Monte-Carlo and the PID efficiency is evaluated directly from the data with the help of calibration samples.

Conclusions

In 340 inv. pb of pp collisions at a centre of mass energy of $\sqrt{s}$ = 7 TeV the ratio of branching fractions between $B \to K^*\gamma$ and $Bs \to \varphi\gamma$ has been measured to be

$$\frac{\mathcal{B}(B^0 \to K^{*0}\gamma)}{\mathcal{B}(B^0_s \to \phi\gamma)} = 1.52 \pm 0.14(\text{stat}) \pm 0.10(\text{syst}) \pm 0.12(f_s/f_d)$$

Combining the ratio of branching fractions with the World Average measurement for the $B \to K^*\gamma$, a value for $Br(Bs \to \varphi\gamma)$ was obtained with an uncertainty twice smaller than the previous Belle measurement:

$$\mathcal{B}(B^0_s \to \phi\gamma) = (2.8 \pm 0.5) \times 10^{-5}$$

Both measurements are the most precise ones for the moment and both are compatible with the Standard Model predictions.

Looking forward to the new exciting measurements!