LHCb detector status and commissioning

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Abstract. The LHCb detector status and commissioning is presented.

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INTRODUCTION

LHCb is the Large Hadron Collider experiment for precise measurement of CP violation and rare decays of beauty particles. The two other LHCb talks will be presented later this week [1]. Therefore I will present only a short introduction to the physics of LHCb before describing its detector and commissioning.

Excellent results have been obtained by the BELLE, BABAR, CDF and D0 Collaborations on beauty physics. These measurements gave coherent results as it can be seen in the combination obtained by the CKMfitter group [2] and presented on Fig. 1. So far, there are no indications for New Physics (NP). However the effects of different NP models have been predicted by many theorists and their non-observation results in strong constraints on the parameters of these models.

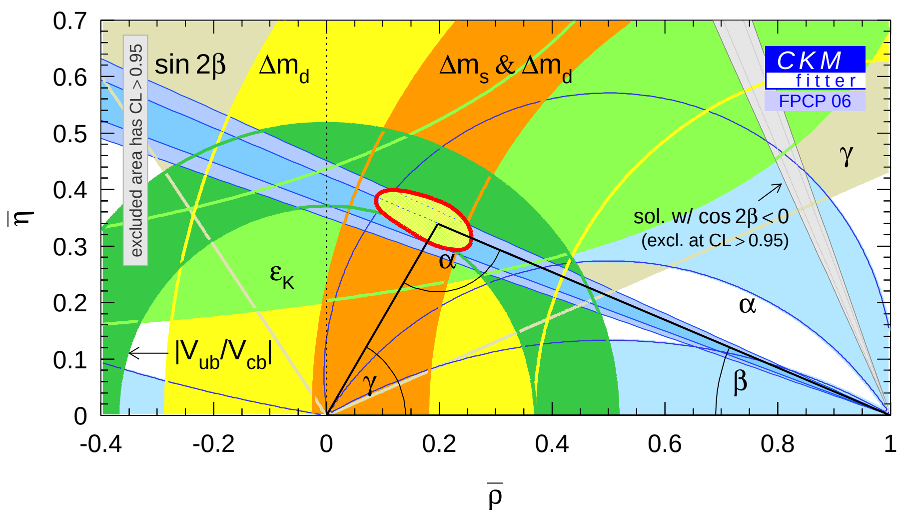
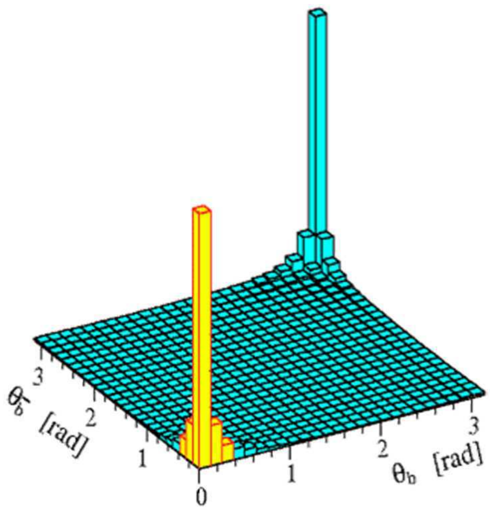


FIGURE 1. Combination of measurements obtained by the CKMfitter group.

The three angles of CKM triangle are measured with the precision presented in the Table. The γ angle is still not measured with significant precision. LHCb with 2 fb^{-1}, which is nominal one year luminosity of LHCb, will measure many parameters used in the CKMfitter compilation with higher precision and, therefore, will give more constraints on NP. Particularly, the three angles of CKM triangle will be measured with precision given in the Table. The measurement of γ will reach a precision of 5°. This angle will be measured in channels like ($B_s \rightarrow D_s K$) where the measurements are not effected by the NP contribution and in channels where they are ($B \rightarrow \pi\pi$, $B_s \rightarrow KK$, $B \rightarrow DK^*$). Therefore LHCb will be able to determine contribution of NP to these measurements. Fig. 3 shows how CKMfitter group compilation could look like using LHCb measurements with 2 fb^{-1}.



TABLE

CKM angle	Current value and precision	LHCb 2fb^{-1}
β	$21.7^{\circ}{}^{+1.3}_{-1.2}$	$\pm 0.5^{\circ}$
α	$100^{\circ}{}^{+15}_{-9}$	$\pm 10^{\circ}$
γ	$63^{\circ}{}^{+35}_{-25}$	$\pm 5^{\circ}$

FIGURE 2. (left) Angular distribution of $b\bar{b}$ pair production at the LHC; **TABLE** (right) Current precision of measurements of the three CKM angles and the estimated precision using LHCb measurements with 2 fb^{-1}.

The LHCb spectrometer will measure forward hadron production at the pp collider. At the LHC the $b\bar{b}$ pairs are produced mostly in the forward direction as shown in Fig. 2. As at the Tevatron, different b hadrons are produced: B_d, B_u, B_s, B_c, Λ_b, ... The $b\bar{b}$ cross-section is $\sim$500μb and 10^{12} $b\bar{b}$ pairs/year (10^7s) reach the LHCb spectrometer. The LHCb acceptance is more forward than the one of ATLAS/CMS and the observed $b\bar{b}$ cross-section is higher. The luminosity at the LHCb interaction point is intentionally limited to 2×10^{32} $\text{cm}^{-2}\text{s}^{-1}$ in order to observe one interaction per bunch crossing on average.

DETECTOR STATUS

For successful measurements of beauty physics the following detector requirements are needed:

- Good triggering, to select interesting events from huge background

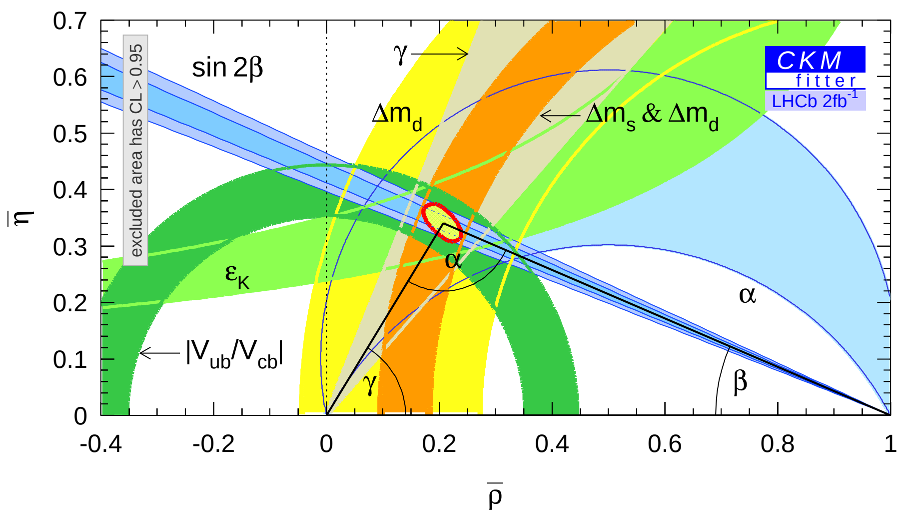


FIGURE 3. A possible CKMfitter combination using LHCb measurements with 2 fb^{-1}.

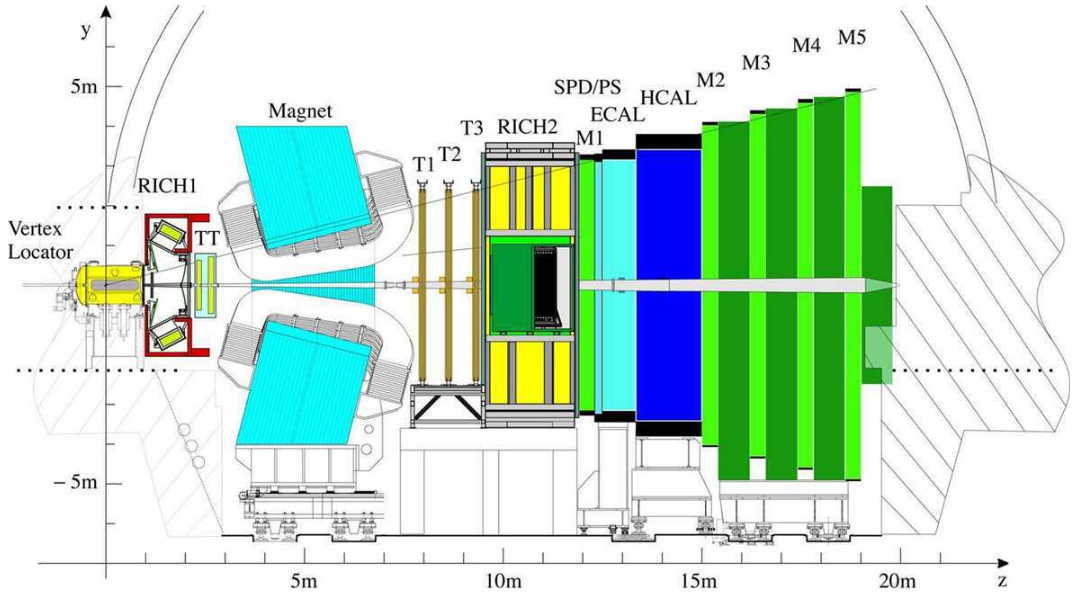


FIGURE 4. The LHCb detector.

- Good vertexing, to measure decay points and reduce backgrounds
- Good tracking, to reconstruct tracks and measure well their momenta
- Good particle identification, to prevent decay products of one decay mode becoming the background to another mode where kinematical separation is not sufficient
- High speed DAQ coupled to large computing resources for data processing

The LHCb detector is presented in Fig. 4. The protons collide inside the Vertex Locator. Products of interaction are identified by two RICH detectors located on two sides of the Magnet. The second RICH detector is followed by the calorimeter detectors and moun spectrometer. The tracks are measured by Trigger Tracker (TT) chambers and Tracking (T) stations located before and after the Magnet. There is no material inside the Magnet.

Importance of material absence inside the Magnet is best seen on the example of electrons, particles which would be mostly affected by its presence. In LHCb electrons radiate photons either before or after the Magnet as shown in Fig. 5 (left). The clusters from the photons emitted by the electrons after the Magnet are merged with those from electrons. Electrons are identified by comparing energy measured in the electromagnetic calorimeter ECAL with track momentum measured in the magnetic field. The position of clusters from photons radiated by electrons before the Magnet is precisely known by extrapolating the direction of the corresponding electron tracks. $J/\psi \to e^+e^-$ reconstruction is obtained by adding radiated photons to electrons and is shown in Fig. 5 (right).

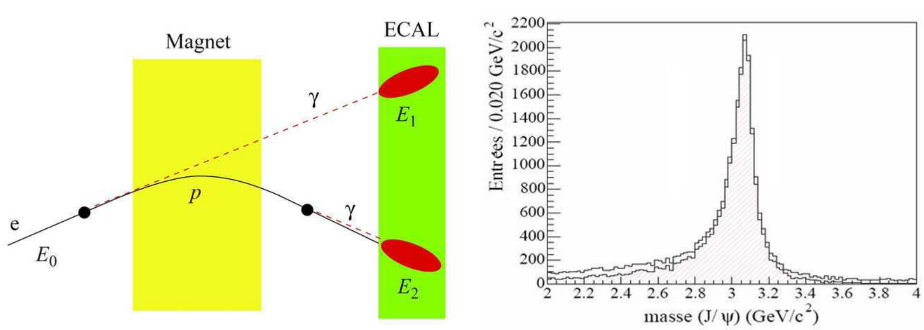


FIGURE 5. Photon radiation by electrons in LHCb (left) and the J/ψ reconstruction after adding radiated photons to electrons (right).

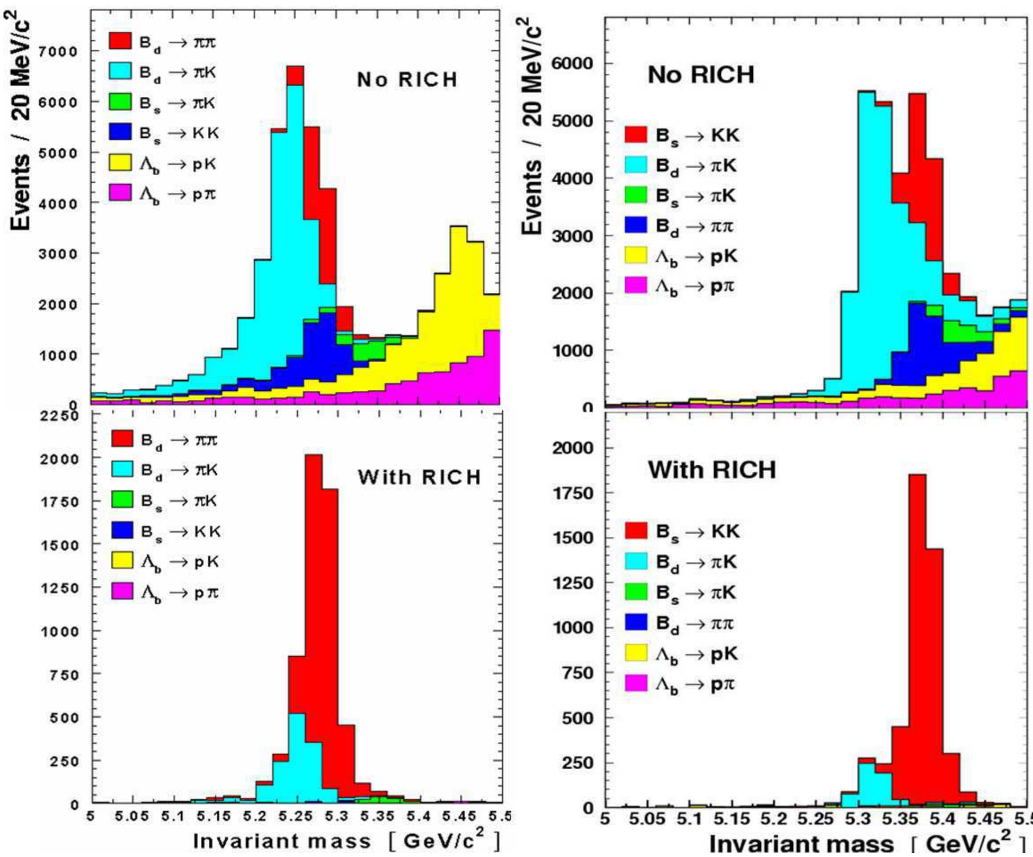


FIGURE 6. $B_d \rightarrow \pi\pi$ and $B_s \rightarrow$KK selection with and without RICH identification.

Vertexing and tracking is assured by 21 Vertex Locator silicon stations and by TT and T chamber stations. The track density is high, therefore TT station and inner part (IT) of T stations is made in silicon technology, the outer part (OT) is made in straw tube technology. The excellent track reconstruction efficiency >95%, momentum resolution Δ p/p $\sim$ 0.4%, impact parameter resolution $\sim 20\mu$m and proper time resolution $\sim$ 40 fs are obtained. The fraction of false tracks "invented" by the reconstruction program is low $\sim$ 4%.

The particles are identified by two RICH detectors. RICH1 identifies low momentum tracks. using two radiators, Aerogel and C_4F_{10}. CF_4 allows to identify high momentum tracks in RICH2. The kaons are identified with 88% efficiency and a corresponding misidentification rate of pions as kaons is 3%. There is better than 3σ separation between pions and kaons with momenta between 3 and 80 GeV.

The importance of good particle identification in b physics is shown in an example of $B_s \rightarrow$ KK and $B_d \rightarrow \pi\pi$ selection presented in Fig. 6. Without RICH identification the two selections are strongly contaminated by background. The RICH detectors allow a very clean selection of these two decays. This is a unique feature at hadron colliders.

The Hardware Trigger is reducing the 40 MHz bunch crossing rate into 1 MHz rate transmitted to the software trigger. High p_T electrons, photons and hadrons measured by the Calorimetry and high p_T muons and muon pairs measured by the Muon Spectrometer are selected. Multiple interactions are rejected by the Pile-up system located near the Vertex Locator.

The Software Trigger is using the data sent from different subdetectors through the Readout Network to CPU processors. Full detector information is therefore available at 1 MHz. The hardware trigger is confirmed or not and then more information is used step-by-step and uninteresting events are rejected. Ultimately, data are stored at a rate of 2 kHz.

Fig. 7 shows the LHCb detector construction status in spring 2006. The interaction point is located inside the LHC tunnel on the right hand side of the Figure. The particles produced at the interaction traverse then, from the right to the left hand side, the RICH1 and the Magnet. The three tracking chamber stations will be installed in the empty

FIGURE 7. LHCb detector in spring 2006.

space after the Magnet. RICH2 detector is already installed followed by the Calorimeter detectors. ECAL and HCAL detectors are already in place as well as the thin wall of lead converter. On both sides of the lead the thin scintillator pad SPD and PRS detectors will be installed in order to measure the beginning of shower development and distinguish between e's and γ's. The ECAL and the HCAL detectors are placed on the chariots and can be open and closed in any possible configuration. The SPD, PRS and lead wall are fixed from above and similarly can be opened and closed in any possible configuration. The muon detector wall is seen on the left hand side of Fig. 7.

The current status and construction planning of the LHCb detector is given below:

- Magnetic field has been already successfully mapped.
- Tracking chambers: OT production is finished, IT and TT chambers are being produced, installation in the pit will end in Autumn 2006.
- Calorimetry: SPD and PRS detectors will be installed in Summer 2006.
- Vertex detector: vacuum tank is already installed, silicon modules are produced and tested now and will be installed in the pit on the beginning of 2007.
- Beam pipe is composed of three sections in beryllium and the last one in stainless steel, installation starts soon and will be completed at the end of 2006.
- RICH1: shielding is already in place, end of installation is planned for the beginning 2007.
- Muon system: muon filter is in place, muon chambers are being produced, installation has started already and will end at the beginning of 2007.
- Electronics: most of electronics will be installed at the pit in the Summer and Autumn 2006, the tests within subdetectors will continue till the end of 2006, when the global commissioning will start.

GLOBAL COMMISSIONING

The global commissioning without beam will be made in the first half of 2007. The control and safety will be commissioned, the DAQ and the electronic calibration procedures will be tested. The scalability of the system will be checked and improved when needed.

Circulated beam will be available in the Summer of 2007. This is important since LHCb is a forward detector and therefore cosmic rays (mostly vertical) are not very useful. On the other hand interactions of LHC beam with beam gas give useful tracks for time and position alignment.

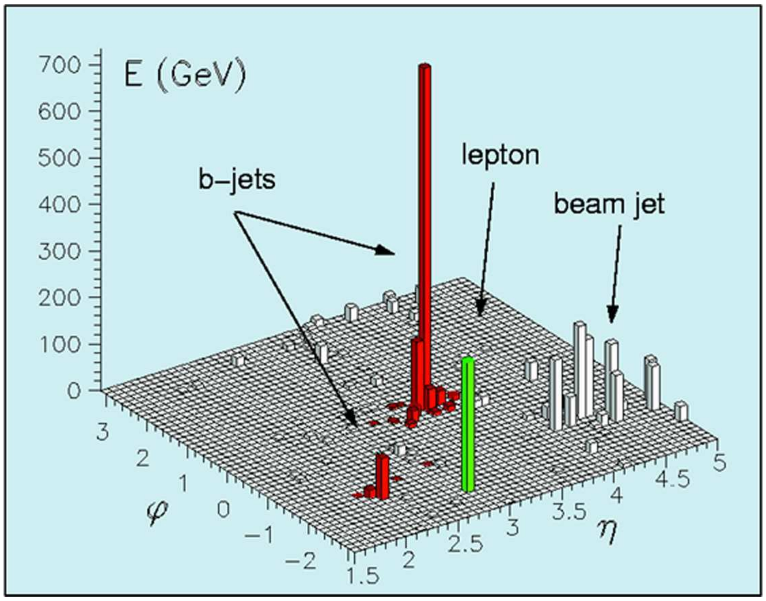


FIGURE 8. A possible signature of light Higgs event in LHCb.

During the pilot run the alignment will be measured without magnetic field and finally trigger setup and data taking will be made with magnetic field.

BONUS: LIGHT HIGGS SEARCH

At LHC a significant fraction ($\sim$ 30%) of the light Higgs bosons, currently being search for at the Tevatron, are emitted forward within the acceptance of the excellent LHCb spectrometer. LHCb has very good b-quark identification and its spectrometer will be very well calibrated with the large number of B meson peaks. The LHCb Collaboration is investigating a possibility of Higgs discovery by measuring Higgs decay into $b\bar{b}$ jets associated with high p_T lepton in order to reduce high $t\bar{t}$ production background. A typical light Higgs production event is shown in Fig. 8. The sensitivity to such light Higgs events is currently under study.

FINAL REMARKS

The LHCb detector construction and commissioning is progressing efficiently. It will be ready in 2007 to observe first collisions at LHC and soon after to get first physics results. More details can be found in [3] and [1].

I would like to thank the organizers of this Symposium for the excellent organization, many members of the LHCb collaboration for their help in preparation of this presentation and Stephane T'Jampens for CKMfitter plots.

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