LHC-B EXPERIMENT AT LHC, CERN

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A Letter-of-Intent to study the physics of b-quarks at LHC (CERN) was presented by LHC-B Collaboration in August, 1995 [1]. The new pp 14 TeV Large Hadron Collider (LHC), at CERN, provides an excellent opportunity for the B-physics research due to a high rate of $b\bar{b}$ production : expected $b\bar{b}$ cross section of 500 μbarn and $L = 1.5 \times 10^{32}$ cm^{-2} s^{-1} lead to 10^{12} $b\bar{b}$ pairs per year.

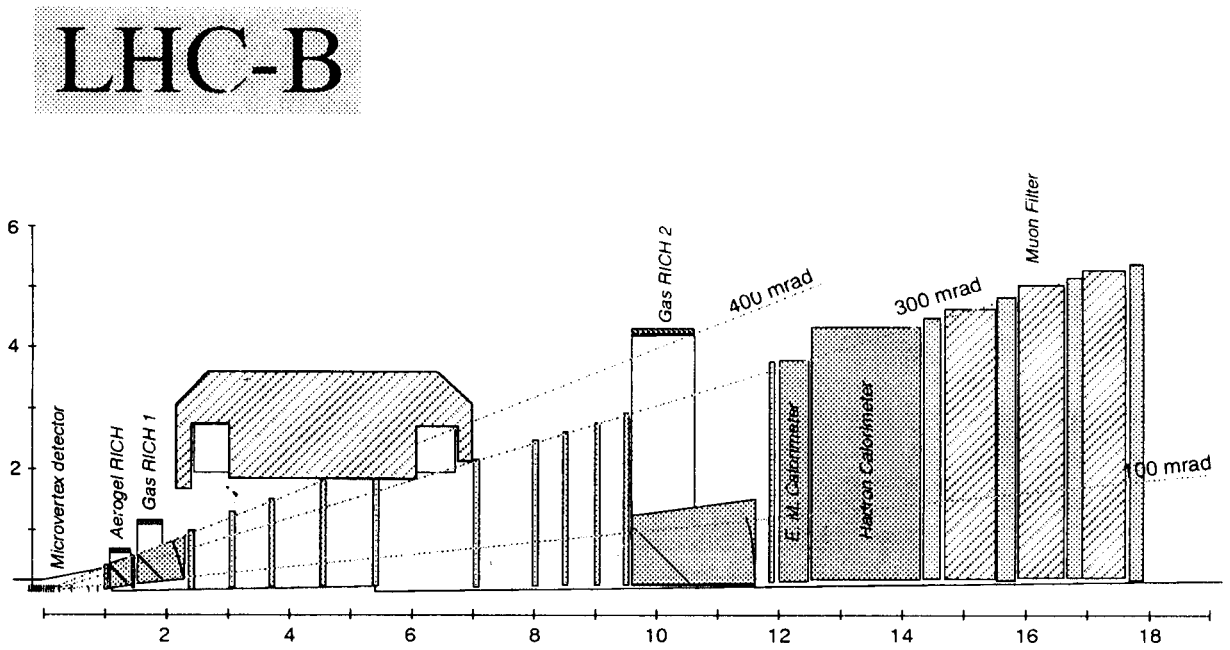

Fig.1. Side View of LHC-B layout (scales in meters). It consists of the following subdetectors (starting from the interaction point): silicon microvertex detector installed inside the collider vacuum pipe in the centre of the interaction region; RICH with arroge radiator; high angle gas RICH; tracking system containing 13 stations; dipole magnet(B = 3.6 T·m) ; low angle gas RICH; electromagnetic calorimeter; hadron calorimeter; muon system

LHC-B fully exploits advantages of the forward geometry (Fig.1) which allows to detect efficiently all B–decay tracks together with a tagging particle from the accompanying $\bar{b}$ due to a strong angular correlation in the $b\bar{b}$ pair production . A large average momentum of B–particles and, hence, the decay distance up to 7 mm favours high accuracy in the life time measurement. The use of a high precision Silicon MicroVertex Detector results in an estimated error in the proper life time measurement of about $(3-5)\%$. The tracking system consisting of 13 stations with a resolution in the bending plane of the dipole magnet less than 100 μm per station provides good momentum measurement for charged particles. The

reconstructed B-meson mass resolution is in the range of approximately $(3-10)$ MeV for different decay modes. An essential component of the LHC-B apparatus is an efficient particle identification capability due to the aerogel and gas RICH counters. They allow to distinguish between π's and K's in a wide momentum range in the whole detector aperture. This helps to suppress combinatorial and misidentification backgrounds during reconstruction of the B-decay. The electromagnetic and hadron calorimeters are used for high-p_t electron and hadron triggers. The electromagnetic calorimeter is also capable to identify electrons in the full energy range. For this purpose it is equipped with preshower detectors constructed from two layers of scintillating tiles with 1 cm thick lead converter between them. The muon system serves for the purpose of the muon identification as well as provides the high-p_t muon trigger.

Physics in LHC-B

The main physics goal is a high precision measurement of the CKM matrix parameters which is a crucial test of the Standard Model. These parameters are usually discussed in terms of so called "Unitarity triangle" (Fig.2). The triangle is determined by η and ρ parameters of the CKM matrix in the parametrization of Wolfenstein [2]. The "CP-reach"

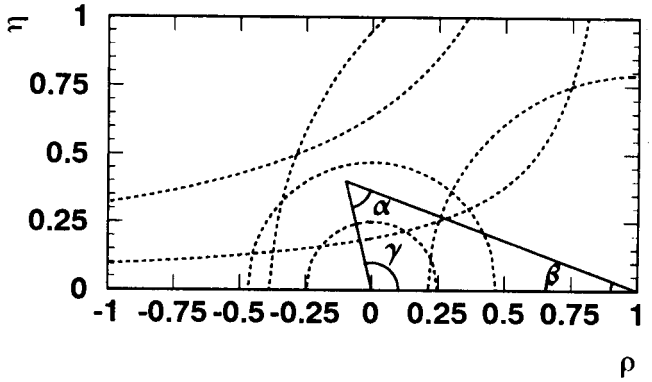

Fig.2. Limits of 1σ on the CKM parameters ρ and η for $m_t = 174$ GeV. The annular region centered in the origin is the region allowed by the measurements of $|V_{ub}/V_{cb}|$. The annular region centered in the point (1,0) is that allowed by measurements of B_s — $\overline{B}_s$ mixing. The approximately hyperbolic band is the region allowed by the measurements of the CP-violation parameter ϵ in the kaon decays

of the LHC-B experiment depends on the precision to which the inner angles α, β and γ of the triangle can be measured. Various channels of the B-meson decays will be exploited to extract these angles. This will allow to study carefully all the sources of the background as well as to reduce systematic errors. The estimated "CP-reach" potential of the LHC-B experiment is characterized by the numbers in the Table . B_s - $\overline{B}_s$ mixing measurements allow to determine mixing parameter x_s up to x_s=55.

"*CP*-reach" of LHC-B for angles α, β and γ for one year of running with the luminosity $L = 1.5 \times 10^{32}$ cm^{-2} s^{-1} compared with other B-experiments [3]. It should be noted that BaBar numbers are the summary over all modes available for the measurement. All errors are statistical only

Param.	Decay mode	LHC-B	ATLAS	HERA-B	BaBar
$\delta \sin(2\alpha)$	$B_d \to \pi^+\pi^-$	≤ 0.03	≤ 0.08		≤ 0.059
$\delta \sin(2\beta)$	$B_d \to J/\psi K^o_s$	≤ 0.017	≤ 0.028	≤ 0.11	≤ 0.085
$\delta\gamma$	$B_s \to D^{\mp}_s K^{\pm}$	$\leq 3.7^o$			
$\delta \sin(2\gamma)$	$B_d \to \bar{D}^0 K^*$	≤ 0.14			

However, the physics in LHC-B is not limited to just measurements of the *CP*–violation parameters. Among other interesting topics one can mention rare B–decays, spectroscopy of heavy flavour particles (B_d, B_s, B_c, D_s^- and D mesons, charm- and beauty-flavoured baryons, $c\bar{c}$- and $b\bar{b}$-onium states), search for *CP*–violation and oscillations in D–decays, τ -lepton physics, diffraction phenomena (pomeron physics), and many others.

PNPI Contribution

The PNPI group took an active part in the preparation of the LoI document since the very beginning of the LHC-B Collaboration in summer 1994. A full GEANT based [4] simulation program was initiated at PNPI and adopted by the Collaboration as a main tool for the LHC-B performance studies.

An extensive study of particle flows through the setup was carried out. It was done for various scenarios of the detector layout, especially for different configurations of the beam pipe and magnetic field. This study set requirements for the tracking system since the problem of high occupancy is the main one for efficient track finding.

The most important component of the LHC-B experiment is efficient triggering. At assumed operating luminosity $L = 1.5 \times 10^{32}$ cm^{-2} s^{-1} there will be about 10 MHz interaction rate. The Level-1 trigger should provide output rate of just 230 kHz while retaining as many B–events as possible. The main Level-1 trigger types are high-p_t muon, electron, and hadron triggers. The hadron triggers are B-decay mode specific while the lepton triggers could be regarded as general purpose ones. Therefore, it was crucial for the experiment to demonstrate satisfactory performance of the lepton triggers. The PNPI group developed algorithms of both muon and electron triggers that were shown to satisfy Level-1 requirements and were feasible to implement in the hardware.

The PNPI group also took part in the analysis of the LHC-B physics performance. A detailed study of $B \to J/\psi X$ final states (where $X = K^o_s$, ϕ and K^*) was carried out. This study formed the basis for the estimations of the β angle determination quality.

The PNPI group proposed and actually started an R&D program on development of Micro Cathode Strip Chambers (MCSC) as an option for the inner part of the tracking system [5]. The MCSC use analogue signals which are induced on narrow cathode strips orthogonal to the anode wires. In order to get low occupancies, the distance between the cathode and the wires is only 0.6 mm and the width of the cathode strips is ≤ 1 mm. They will cover an area of 40×40 cm^2 around the beam pipe at each tracking station.

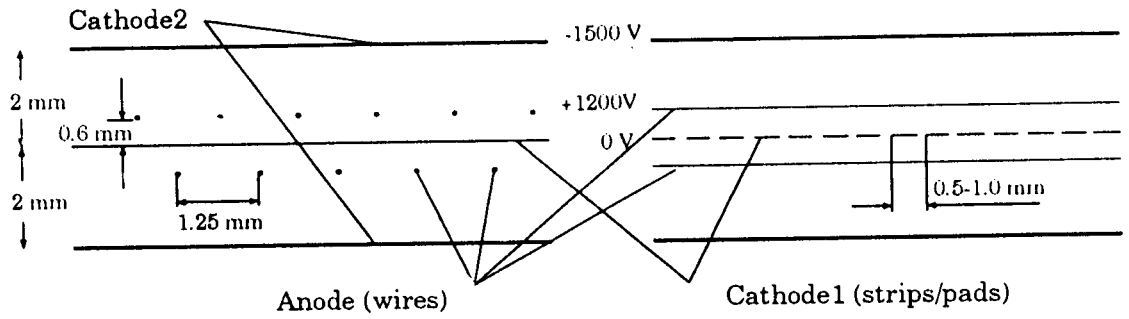

Fig.3. Schematic cross cut of MCSC

The geometry of the MCSC that we propose to use in this project is shown in Fig.3. An essential feature of the design is the back-to-back structure where the charge is induced on the cathode strips simultaneously from two anode planes. This yields a charge distribution along the anode wires which is symmetric around the crossing point of the track with the cathode strips plane. Therefore, the track inclination and the Lorentz shift of the electron drifting in a magnetic field do not produce any systematic shifts in the measured coordinates but lead only to a small increase in the signal width.

Recently several MCSCs have been designed at PNPI for the E781 experiment at FNAL. These chambers have geometry and charge integration time close to those proposed for the LHC-B.

The Cathode Strip Chambers (CSC) were proposed by the PNPI group as an option for the Muon System. An extensive R&D program on developing the CSC technology is currently underway [6]. The PNPI is actively participating in it

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