High Precision CP violation Physics at LHCb

Scientific part of the proposal submitted to
the Swiss National Science Foundation by

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Contents

PART II: Scientific Information

1 Summary

LHCb [1] is an experiment designed for precise measurements of CP violation and rare B decays, exploiting the very large $b\bar{b}$ production cross section at the LHC collider at CERN. LHCb's main physics aims are to elucidate the flavour structure in the quark sector, and hopefully observe signals from New Physics (see Section 2.5).

LHCb is expected to be ready to record LHC's first collisions in 2008, and deploy its full physics program as soon as the LHC reaches a luminosity of 2×10^{32} cm^{-2}s^{-1} (Section 2.4). A working group has recently been set up within LHCb to study the possibility to upgrade the detector after an integrated luminosity of about 10 fb^{-1} in view of running at $\sim$ 10 times higher instantaneous luminosities.

Our particle physics group in Lausanne, now at EPFL's Laboratory for High-Energy Physics (LPHE), has worked on LHCb since the beginning of the project in 1995 and plays important roles in the leadership of the experiment (Section 3).

By the end of March 2008, we expect to have fulfilled our main construction responsibilities:

- Development and construction of the common readout boards "TELL1" and of the electronics for LHCb's silicon vertex detector "VELO" (Section 2.2.1).
- Development and construction of the silicon "Inner Tracker" detector (Section 2.2.2), in collaboration with other institutes (in particular University of Zurich) involved in LHCb's Silicon Tracker project.

In addition, we have participated in the following activities: development of trigger algorithms, R&D for the hardware implementation of the software trigger, general software developments, optimization of physics performance, and preparation for physics analysis (Section 2.2.3). The various aspects of the LHCb experiment are described in Technical Design Reports [2–12] and public LHCb notes [13]. Many presentations were given in conferences (see [14] for a list of recent LPHE contributions). The final design of the TELL1 board was published in a journal paper [15]. The LHCb collaboration is currently writing a publication describing the constructed LHCb detector and all its sub-detectors [16].

Our objectives for the forthcoming 2-year funding period 2008–2010 are the following:

- Commissioning of the hardware devices under our responsibility (TELL1 boards and firmware, VELO power supplies and readout chain, and all aspects of the Inner Tracker), without and with LHC beams, such as to render them fully operational as soon as possible (Sections 2.3.1a and 2.3.2).
- Calibration, performance monitoring and software alignment of the Inner Tracker (Section 2.3.2).
- Participation in the first data analysis and physics measurements (Section 2.3.3).
- In addition, considering our possible future involvement in the LHCb upgrade (and also in preparation for our next experiment), we plan to engage in new R&D activities for an upgraded TELL1 board (Section 2.3.1b) and in the area of fibre tracking (Section 2.3.4).

We ask SNSF to support the above-mentioned LHCb activities at LPHE through salaries as well as consumables and travel expenses. We also request funds from SNSF for equipment money to start the fibre tracking R&D and the work on a new version of TELL1. Funding for capital investment in the LHCb detector and for maintenance and operations is asked for in separate requests [17, 18].

2 Research plan

2.1 State of research in the field

The PEP-II machine at SLAC (USA) and the KEKB machine at KEK (Japan), the two asymmetric "B factories" (e^+e^- colliders producing boosted Υ(4S) resonances) are both performing above their design parameters and have reached peak luminosities of 1.2 and 1.7×10^{34} cm^{-2}s^{-1} (world record) respectively. The two detectors, BaBar at SLAC and Belle at KEK, are taking data efficiently. By Summer 2007, the BaBar and Belle collaborations had analyzed data samples corresponding to 431 and 657 million $B\bar{B}$ pairs, respectively.

In 2001 these two experiments established the existence of mixing-induced CP violation by observing the time-dependence of B^0 meson decays to a few specific CP eigenstates of the type $b \to c\bar{c}s$ (dominated by a single weak phase), and obtained significant measurements of $\sin(2\beta)$, 2β being the weak CP-violating phase of the $B^0 - \bar{B}^0$ mixing amplitude. Since then they have extended their studies to many more channels and refined their analyses of time-dependent or time-integrated CP asymmetries, including for B^0 decays to non-CP final states and charged B mesons decays. In 2004, direct CP violation became firmly established in the $B^0 \to K^+\pi^-$ decay amplitudes (which is due in this case to the interference between tree and penguin diagrams), and later in other modes as well. However, the third type of CP violation, called indirect CP violation in mixing, is still unobserved in the B^0 system: the current experimental sensitivity is not yet good enough to observe the very small asymmetry predicted within the Standard Model.

In addition to a precise measurement of the angle β of the unitarity triangle of the CKM matrix (which is now known with an error of about 1 degree), BaBar and Belle started to measure the angles α and γ in various ways, although with limited precision, especially for γ. So far all measurements of CP violation as well as other observables in hadronic flavour physics are consistent within the Standard Model: the CKM picture appears to give a coherent view of CP violation. Global analyses of all available results [19] indicate that a possible New Physics amplitude in $B^0 - \bar{B}^0$ mixing is now very likely to have a phase within a few degrees of that of the Standard Model amplitude, although its magnitude could still be sizeable.

Flavour-changing neutral current transitions such as $b \to d$ and $b \to s$ may reveal New Physics effects with significant phases. An example of such transition on which the BaBar and Belle experiments have focused in the last few years is $b \to s\bar{s}s$ (in particular the $B^0 \to \phi K_{\mathrm{S}}$ decay) dominated by penguin loops. The value of $\sin(2\beta)$ measured with such modes is predicted to be equal (within some theory uncertainties) to that obtained with the $b \to c\bar{c}s$ modes, and a discrepancy would be an indication of New Physics. A first hint of an overall discrepancy was announced in Summer 2003, and then reinforced with increased statistics a year later (at which point it was claimed to be a 3.8σ effect), before getting less significant in subsequent years and even vanishing in Summer 2007 (see [20] for world averages and comparisons).

BaBar and Belle will continue to dominate the B-physics field in the near future, however the exploitation of these experiments is coming to an end: BaBar data-taking is scheduled to stop at the end of September 2008 (after an estimated 600 fb^{-1} of data is accumulated, 470 fb^{-1} so far), and Belle is planned to run until 1000 fb^{-1} of data is accumulated at the $\Upsilon(4S)$ (715 fb^{-1} so far), which is expected towards the end of 2008.

B_s^0 production is not accessible in Υ(4S) decays. This is the reason why the Belle experiment collected 23.6 fb^{-1} of data at the Υ(5S) resonance, mainly to investigate the feasibility of B_s^0 physics at a B factory. First interesting results, including the observation of the $B_s^0 \to \phi\gamma$ decay mode [21], have been presented.

However, several interesting results in B_s^0 physics now come from the CDF and D0 experiments, which have now each analyzed more than 2 fb^{-1} of data from Run II of the Tevatron ($p\bar{p}$ collisions at 2 TeV). CDF observed $B_s^0 - \bar{B}_s^0$ oscillations in 2006 [22], with an oscillation frequency (or mass difference Δm_s between the two mass eigenstates of the $B_s^0 - \bar{B}_s^0$ system) consistent with the Standard Model expectation. This now opens the door for time-dependent CP measurements with B_s^0 decays (e.g. with $B_s^0 \rightarrow J/\psi\phi$ decays which allow to access the $B_s^0 - \bar{B}_s^0$ mixing phase ϕ_s), although such measurements will in general be very challenging for CDF and D0; a value of $\phi_s = -0.70^{+0.47}_{-0.39}$ has been published by D0 [23], to be compared to the SM prediction of -0.036 ± 0.002 [19].

The main discovery in the last year, however, is the evidence for $D^0 - \bar{D}^0$ mixing obtained simultaneously by Belle and BaBar [24] in Spring 2007. The D^0 meson was the last heavy-flavoured neutral system where this phenomenon has not yet been observed, because of its very small probability. In the Standard Model $D^0 - \bar{D}^0$ mixing is highly suppressed, and is therefore sensitive to New Physics contributions. The new B-factory results are consistent with each other and with the SM, but still leave significant room for New Physics to exist.

The next-generation experiments dedicated to b physics will include LHCb at CERN's LHC, and perhaps a few years later an upgraded Belle detector at a luminosity-upgraded KEKB machine. The full Belle/KEKB upgrade proposal [25] is not approved yet by the KEK laboratory, however good progress obtained recently with the operations of "crab cavities" in the current KEKB machine is encouraging. There is also another recent proposal for a completely new Super-B factory [26] that would come into operation in the first half of the next decade with a peak luminosity in excess of 10^{36} cm^{-2}s^{-1}, but which needs a substantial accelerator R&D.

The installation of LHCb is well under way and will be completed such as to be ready to take data as soon as LHC comes into operation in 2008. However, the LHC operation schedule and efficiency are likely to be such that the yearly nominal integrated luminosity of 2 fb^{-1} will only be reached in 2009 or 2010. LHCb is expected to accumulate ~ 10 fb^{-1} of data; the possibility to upgrade the detector after that is being investigated [27].

2.2 Status of our research

The LHCb experiment consists of the following sub-systems (see Fig. 1):

- the vertex detector or VErtex LOcator (VELO) with 21 silicon stations, together with the pileup system needed to identify events with several primary interactions;
- the tracking system consisting of a 4 Tm dipole magnet, the Trigger Tracker (TT) in front of the magnet, and three tracking stations (T1, T2, T3) behind the magnet; the latter are each subdivided into two regions: the silicon Inner Tracker (IT) and the straw tubes Outer Tracker (OT); the TT and IT devices are referred together as the Silicon Tracker (ST);
- two Ring Imaging CHerenkov counters (RICH1 after the VELO and RICH2 after T3);
- the Scintillating Pad Detector (SPD) and the Preshower (PS);
- the electromagnetic (ECAL) and hadronic calorimeters (HCAL);
- the muon detector stations (M1 to M5);
- the trigger system consisting of hardware and software levels;
- the Experiment Control System (ECS).

After the Technical Proposal [1] in 1998, the LHCb collaboration has produced Technical Design Reports covering all the detector components of the experiment [2–12]. Since then, the trigger and DAQ scheme was simplified. A first hardware trigger level (Level-0 or L0), based on data from the pileup, calorimeter and muon systems, will reduce the 16 MHz rate of visible collisions to 1 MHz. After a positive L0 decision, a full detector readout will be performed and High-Level Trigger (HLT) algorithms will be run on a single CPU farm of ~ 1800 CPU nodes to select only ~ 2 kHz of events to be written to disk for subsequent offline analysis.

The updated cost of the experiment is 75.341 MCHF [28], very close to the initial estimate included in the LHCb Memorandum of Understanding [29]. The current overall funding shortfall of ~ 0.5 MCHF, which affects the event filter farm, can be coped with by starting data taking

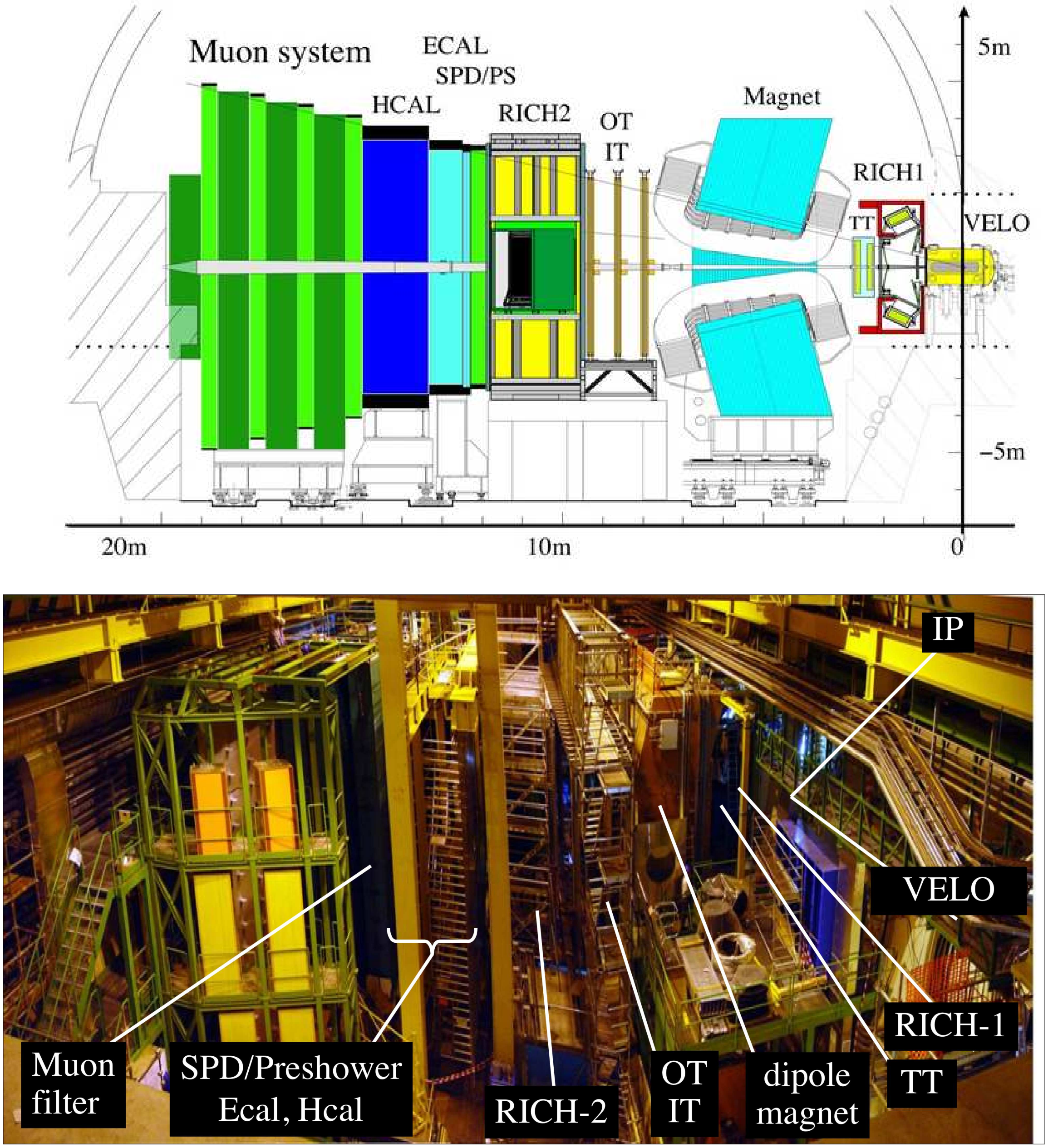

Figure 1: <u>*Top:*</u> *Schematic view of the LHCb apparatus, which will surround the LHC beam pipe, covering the forward angular region where b hadrons are produced with the largest probability. The proton beams will collide in the middle of the Vertex Locator (on the left of the figure).* <u>*Bottom:*</u> *Photograph of the cavern where the LHCb detector is being assembled. The interaction point IP and the VELO are hidden (on the right). The Inner Tracker (IT) is located behind the dipole magnet. This picture has been taken from the location of the concrete wall behind which the TELL1 readout boards are installed.*

Figure 2: *21 VELO modules (holding the half-disk silicon sensors) installed on their support and forming half of the VELO detector.*

in 2008 with a reduced CPU farm. The assembly and installation of the different sub-systems are progressing well according to a schedule aiming at a commissioned detector ready in time for the first LHC collisions in 2008.

The EPFL group has contributed to the hardware R&D effort for the VELO, the Inner Tracker and HLT trigger. We have taken responsibilities in the development of trigger algorithms and in the assessment of the physics performance of the experiment. We are responsible for the construction and commissioning of the Trigger ELectronics and L1 boards (TELL1), for the VELO data transmission and low-voltage power supply systems, and, within the Silicon Tracker project, for the construction and commissioning of the Inner Tracker.

2.2.1 Readout electronics

[A. Bay (in charge), G. Haefeli (technical coordinator for TELL1), R. Frei, L. Locatelli, J. Borel, C. Potterat]

a) TELL1 boards

All needed 350 TELL1 boards have been produced with an excellent yield of about 97%. The boards for all subdetectors have been installed in the pit, and we are now focusing on the commissioning. A common firmware framework has been set up and an initial version distributed to the collaboration in 2006. About ten updates with increased functionality and additional subdetector designs have been released since.

b) VELO transmission line and power supplies

During the year 2006–2007 the VELO modules have been mounted in their supporting frames (Fig. 2) and they are now undergoing electronic tests and metrology measurements. In November 2007 they will be installed in the vacuum vessel, which has already been tested successfully. The electronics we have developed for the analogue transmission of the signals from the VELO hybrids to the TELL1 readout boards in the counting barracks is ready for commissioning, and all cables are in place. We have already performed a test on a full chain in the LHCb pit, which has given excellent results. All cables of the power supply systems (for low voltage and detector bias) have been installed, too. One third of the power modules have been received from the supplier (CAEN), while the rest is expected before the end of 2007.

In 2006 we did two tests in beams with several VELO modules. We have used the data for a comprehensive study of the signal quality, in particular of the cross talk between channels [30].

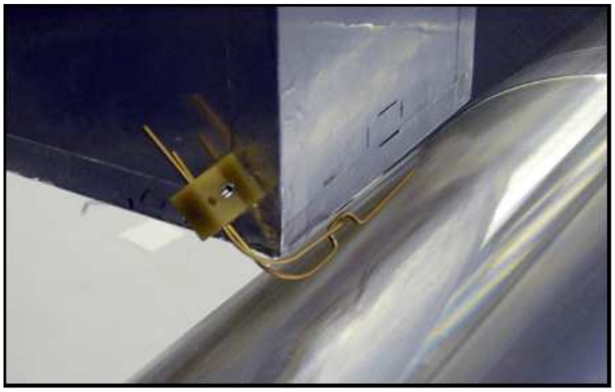

Figure 3: *Setup used for the development of the "beam pipe approach monitoring system" with two switches glued on a detector box (on the left) and a dummy beam pipe (on the right).*

This phenomenon can originate in the sensors (between adjacent diodes, and also in the complex topology of the double-metalization carrying the signals from the diodes to the hybrid), in the hybrids, and in the analogue line from the detector to the counting room. We have developed a software package to optimize the parameters of the filters removing the cross talk; these filters will be implemented in the TELL1 firmware.

2.2.2 Inner Tracker

[M.-T. Tran (in charge), J. van Hunen and F. Blanc (technical coordinators), O. Schneider, A. Bay, P. Fauland, A. Hicheur, R. Frei, J.-P. Hertig, M.-O. Bettler, G. Conti, N. Gueissaz, M. Knecht, L. Nicolas, A. Perrin, K. Vervink]

The Inner Tracker (IT) detector, described in the corresponding Technical Design Report [9], is part of the LHCb Silicon Tracker [31]. Its construction and integration in the experiment, and standalone commissioning will be finished within a few months.

a) Modules and detector boxes

All needed IT ladders (i.e. the modules consisting of one or two silicon sensors glued on a carbon fibre support together with the front-end electronics), including 15% of spares, have been assembled, bonded, submitted to ageing tests, and qualified to be used in the experiment.

We are currently installing these modules in their detector boxes. Each of these tight insulating boxes will host 4 vertical layers of 7 modules, attached on either side of two cooling rods. Out of the 12 boxes needed to form the 3 Inner Tracker stations, 5 are already assembled, of which 3 have undergone high voltage tests.

All boxes will be tested in the lab (high voltage, signal readout, temperature and humidity sensors, temperature switch) prior to their installation in the experiment. For this purpose, we will use the whole final readout chain, which will operate with the TELL1 boards and the LHCb software framework. These tests will allow us to verify the functionality of the whole detector chain. This task has just started, as we have to adapt the slow control PVSS [32] to our general DAQ. In the future PVSS will ensure the control of the entire readout. An in situ commissioning of each detector box using PVSS will be done.

Each detector box will be equipped with the so-called "beam pipe approach monitoring system", which will give an alarm if the detector box comes too close to the beam pipe. The design and production of this system is now completed; it relies on two switches made of gold-plated tungsten wires as shown in Fig. 3. The fine-tuning of the wires (e.g. switching position) is ongoing and the commissioning will be done shortly.

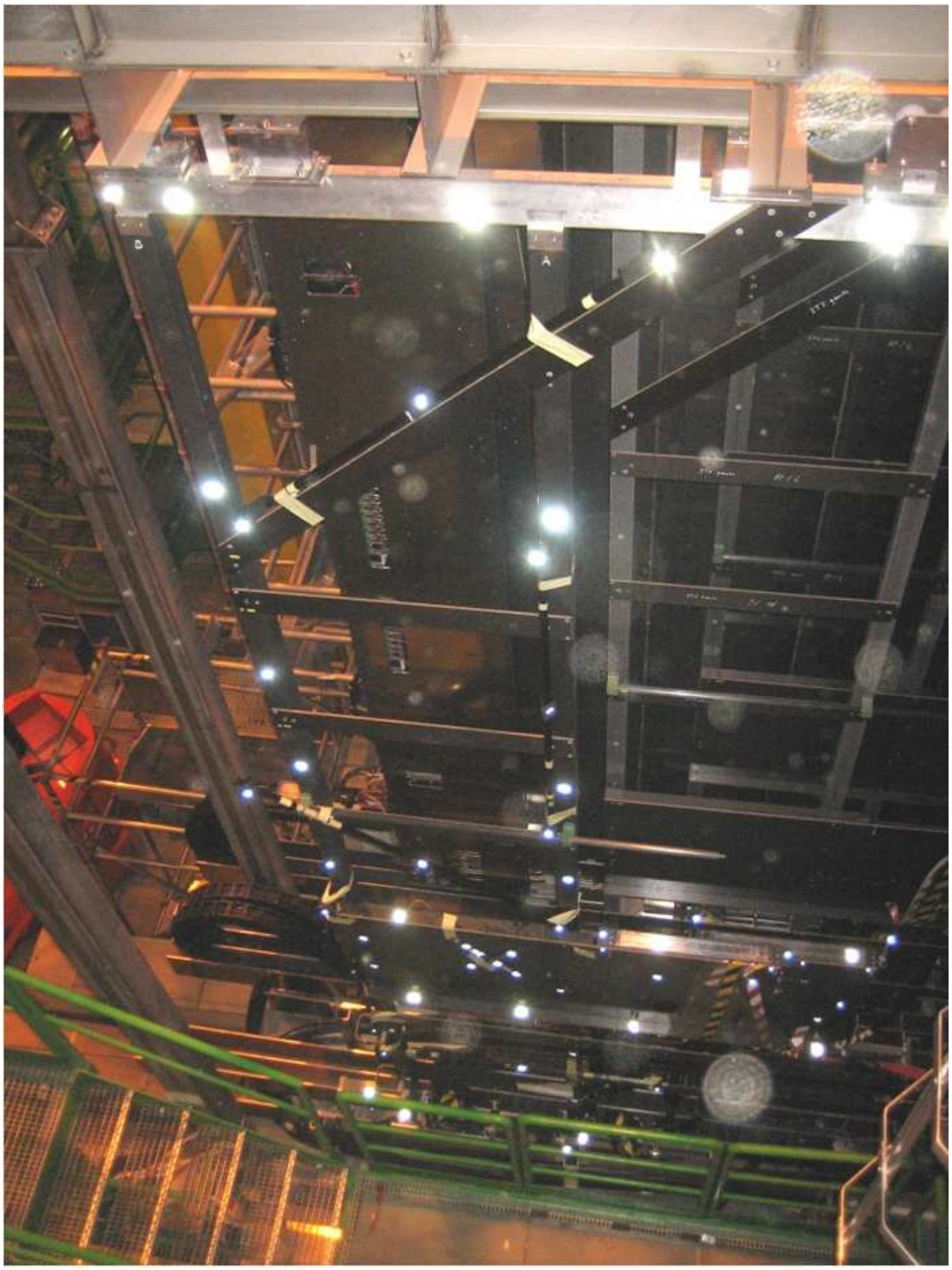

Figure 4: *Support frames of three half-stations of the Inner Tracker installed in the pit (behind each other). Reflecting targets used for the photogrammetry can be seen on the first support frame (IT1).*

b) Support frames and supplies

The three carbon fibre support frames (see Fig. 4) have been slided in during Spring 2007. The high- and low-voltage supply lines for the detector front-end, the signal cables as well as the cooling pipes have been installed in the cable chains attached to the bottom of these frames. The cable chains needed to be reinforced in order not to crush the insulation of the cooling pipes. Some other practical modifications of the original design had to be made during the mounting of the support frames.

The pipes bringing the C_6F_{14} coolant to the detector boxes and the ones bringing cool water to the service boxes have been drawn. Leak tests for these pipes have started.

Figure 5: *IT detector survey using two theodolites. On the left, four layers of silicon sensors attached to a box cover are hanging on a revolving frame on which targets have been placed.*

c) Survey of the support frames and of the sensors inside the boxes

Several attempts have been made to survey the position of the support frames with respect to the LHCb coordinate system (Fig. 4). However, after opening and closing the stations, we were not able to obtain reproducible positions of the support frames. This is due to the large size and small weight of these structures, as well as the strength of the HV and LV supply lines. Recently we have rigidified the positioning beams. A new survey using this new structure must be done soon.

The positions of the sensors inside a detector box will be known only via the position of the targets placed on the box cover. The relative positions and angles of the sensors with respect to these targets therefore need to be measured prior to closing the detector box. The measurements have been done in our "clean tent" using two theodolites and a dedicated frame (Fig. 5). Only small displacements of the sensors (below 1.5 mm) have been noticed, which are due to the vertical positioning of the cooling rod with respect to the box cover. The angles of the silicon sensors relative to their nominal positions in the box have also been determined for three detector boxes. Typical rotation angles of 5 mrad have been found around the horizontal axis parallel to the box, whereas rotation angles of 1 mrad at most have been found around the vertical axis or the "beam" axis.

d) Commissioning of the Inner Tracker

The commissioning plan for the Inner Tracker is rather tight:

- by the end of October 2007, we should be able to read out half a station in the pit;
- by the end of December 2007, we should have a first half station fully commissioned;
- by the end of January 2008, all three stations should be ready for global commissioning within LHCb.

In order to reach these goals, work must be done in parallel as much as possible.

2.2.3 Trigger and offline software, physics performance studies

[O. Schneider (physics coordinator), A. Bay, T. Schietinger, J. van Hunen, A. Hicheur, S. Villa, J. Borel, L. Fernández, S. Jimenez-Otero, F. Legger, L. Locatelli, L. Nicolas, N. Zwahlen]

Our recent contributions to the trigger and offline software development can be summarized as follows:

- Trigger algorithms: The first prototype of exclusive b-hadron selections for the High-Level Trigger has been finalized [33, 34]. In addition, two new algorithms have been designed, studied and implemented in the context of the effort to re-design the trigger software following the 2005 decision to go for a full detector readout at 1 MHz: an algorithm to match VELO tracks to HCAL objects having fired the Level-0 trigger [35], and a new di-electron trigger [36].
- T-station alignment with tracks: Following a first study of the Inner Tracker alignment [37] used as input to the global LHCb alignment strategy [38], we are now working on the alignment software framework for the Outer Tracker and Inner Tracker [39], taking responsibility for the solving algorithm and for the selections of tracks to be used for alignment [40]. First versions of the corresponding software tools have been delivered to the collaboration [41].
- Magnetic-field map: We have analyzed the measurements of the LHCb dipole field performed in December 2005 and compared them to design values from simulations. The preparation of a realistic B-field map to be used in the reconstruction of the real data and in future Monte Carlo simulations is well advanced [42].

We have finalized all our physics performance studies based on the 2004–2005 Monte Carlo samples, getting ready to analyze the 2007 Monte Carlo samples with the latest reconstruction software:

- B_s^0 mixing parameters: $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^\mp K^\pm$ selections have been developed [43], the former being used to update the statistical sensitivity to Δm_s [34]. The sensitivity to the phase ϕ_s has been assessed using the $B_s^0 \to J/\psi\eta$ [44], $B_s^0 \to J/\psi\eta'$ [45], $B_s^0 \to \eta_c\phi$ [34] and $B_s^0 \to J/\psi\phi$ [34] decays. The combined uncertainty is now expected to be $\sigma(\phi_s) = 0.022$ with 2 fb^{-1} of data, which is 2–3 times better than the 2003 estimate [10] and opens the possibility to measure ϕ_s down to its small Standard Model expected value of $-2\beta_s \sim -0.04$ with 10 fb^{-1} of data [34]. We have presented this important conclusion in several conferences [46–50].
- Polarized Λ_b radiative decays: Decay amplitudes and angular distributions of polarized $\Lambda_b \to \Lambda(X)\gamma$ decays were calculated and studied in view of probing the polarization of the emitted photon [51–53], and corresponding sensitivity studies have been performed using fully simulated $\Lambda_b \to \Lambda(1115)\gamma$ and $\Lambda_b \to \Lambda(1670)\gamma$ decays [53–55].
- Higgs boson physics: The results of an updated study of the possibility to detect a light Standard Model Higgs boson decaying to $b\bar{b}$ and produced in association with a W or Z boson has been written up [56]. A prospective study for the search of supersymmetric Higgs decays through displaced vertexes is encouraging [57] and will be pursued.

New large Monte Carlo samples have been simulated in 2006–2007 by the LHCb collaboration, using a new version of the detector geometry and reconstruction programs. The analysis of these samples is just starting. We are involved in the following physics studies: checks and maintenance of the selection of $B_s^0 \to D_s^- \pi^+$ events, study of the main systematics associated with the measurement of Δm_s, reconstruction and selection of $B_s^0 \to J/\psi\phi$ events where $J/\psi \to e^+e^-$, and selection of $B_s^0 \to J/\psi(\mu^+\mu^-)K_S^0$ events.

2.3 Detailed research plan

During the first year of the forthcoming period, we will concentrate on the commissioning of the TELL1 board, VELO readout chain, and Inner Tracker, both without and with LHC beams. The LHC schedule no longer foresees a low-energy "pilot run" at the end of 2007, but a startup in mid-2008 with the goal of reaching high energy as soon as possible; however, significant luminosity is not expected before the 2009 run (see Section 2.4 for more details on the LHC schedule). The 2008 run should be used as much as possible to debug, calibrate and align the detector. During the second year covered by this request, we plan to carry out first physics measurements, using the data collected in 2009 with a stably-operating detector.

2.3.1 Readout electronics

a) VELO and TELL1 commissioning and maintenance

The major activity in 2008 will be the commissioning of all the sub-systems. Full scale debugging of the TELL1 firmware has started now with all the boards installed in the pit. The baseline code for all subdetectors has become stable enough, so that we are able to read out the whole LHCb. However, further work is still needed to implement subdetector-specific algorithms, such as zero suppression, in particular for the VELO.

Other TELL1-connected activities at LPHE will be:

- the preparation of "bit-perfect" software models for the emulation of the VELO and ST TELL1 algorithms. This is needed for the evaluation and validation of the complex calculations running in the firmware of each board. In particular the common noise correction algorithm and zero suppression needs to be adapted to the experimental situation, only known during real data taking;
- the preparation of the VELO and ST detector calibration and performance monitoring programs, and
- the preparation of a slow control and monitoring system based on the commercial PVSS framework. For this, we have already produced over 100 interactive graphical panels, among which some are common to all subsystems and about 30 are specific to the VELO and ST subsystems.

A first version of the latter two items will be ready by mid-2008. We are of course committed to provide support and maintenance for the hardware and software developed or built by the LPHE group.

b) LHCb upgrade and new TELL1 with 10 times higher data rate (TELL10)

The upgrade of the LHCb experiment, if decided, will strongly rely on a new powerful DAQ system. CERN has launched the GBT (Gigabit Bidirectional Trigger and Data Link) project to ensure the availability of a low power, radiation hard data link system for the upgrade of the LHC experiments [58]. It combines data acquisition (DAQ), fast control (TTC) and slow control (ECS) on a single bidirectional optical fibre. With this link a new high performance readout board for LHCb is required, which acts as a driver for the GBT TTC and ECS part and provides at least 10 times higher data acquisition bandwidth. Such a board, called TELL10 (= TELL1 × 10), must take advantage of the latest FPGA technologies such as fast serial interconnects, 10-Gigabit link technology and fast embedded control interfaces [59]. Having already developed the TELL1, we will naturally be in charge of such a project, which also will allow to acquire useful know-how for future experiments.

We plan to start the studies in 2009 and have a first prototype in 2010.

2.3.2 Inner Tracker

Together with the rest of the IT group, and with the help of various experts in the collaboration (on DAQ, software, reconstruction, ...), we will bring and maintain the IT in operation for physics data taking. This work will include calibration, monitoring, alignment, and maintenance.

a) Calibration and monitoring

Calibration and monitoring will be performed using the controls and software tools described in Section 2.3.1a). The shape of signal pulses will be determined, such as to optimize the settings of the front-end chip. Once beam is available, this can be done using real tracks traversing the detector, rather than injected charge pulses. Pedestals and noise levels will be regularly measured and checked for each channel, both in raw and common-mode noise subtraction modes. These measurements, together with results from track reconstruction when available, will be used to determine the parameters (thresholds, ...) to be used in the TELL1 boards during data-taking.

Relevant parameters needed for the offline reconstruction (such as the list of dead channels) will be monitored and stored in the LHCb database.

b) Alignment

The data obtained in the survey process will be analyzed and stored in the LHCb database; they will be used as the starting point for the precise software alignment using tracks from beam-gas or pp interactions. Data will be recorded without and with the LHCb dipole magnetic field. Without B field, tracks are expected to have a larger number of hits, but their momentum (hence multiple scattering) will be unknown; track linking between the T stations and the VELO will be easier. The software alignment of the T stations should be attempted in both cases. Comparison of the results will allow to debug the procedures and tackle possible problems.

c) Maintenance

During the first significant shutdown of the LHC machine (possibly in winter 2008–2009), we plan to change the layout for the routing of the cables bringing the signals from the central top detector boxes to the service boxes outside the acceptance. This will improve the material distribution in the acceptance of the Outer Tracker. Cables will need to be replaced, and the partitioning in the service boxes redefined.

The monitoring of the performance of the sensors as they get irradiated in the LHCb environment will be an important aspect of the maintenance of the detector. Although there is no immediate worry for the radiation damage on the sensors, a beam accident cannot be excluded and particular attention must be brought in the mid- or long-term to the inner-most long ladders: in case of significant degradation they will need to be exchanged with spares or ladders located in the outer part of the box. Such operation can only be done during a machine shutdown.

2.3.3 Preparation for physics analysis and first physics analysis

Our laboratory is planning to be heavily involved in LHCb physics analyses. However, given the new LHC schedule, physics results from the 2008 run are uncertain, and only relatively low statistics measurements are expected to be possible with the data collected in 2009. Our strategy until early 2010 is therefore to focus on a few aspects of LHCb's core physics program (B physics), where we know a significant contribution should be possible with the 2009 data, while taking also the time to investigate two other fields of high physics interest (direct search for Higgs bosons and search for new physics with τ leptons), which are not yet well established in the LHCb physics program.

a) B physics

Our main focus within the B physics program of LHCb will be the search for a New Physics phase in B_s^0 mixing [34]. We expect already a very interesting measurement of the mixing phase ϕ_s based on $B_s^0 \to J/\psi\phi$ decays collected in the 2008–2009 data, even if the integrated luminosity turns out to be as low as (a fraction of) 1 fb^{-1}. However, this is a complex measurement, requiring all aspects of the experiment to be under control and calling for a team effort (both at LPHE and within LHCb). On the way to ϕ_s, we plan to perform (or contribute to) several other measurements:

- study of the inclusive $J/\psi \to \mu^+\mu^-$ production and measurement of the fraction of J/ψ from b-hadron decays (as a function of p_T); $b\bar{b}$ production cross-section measurement;
- reconstruction of exclusive $B \to J/\psi X$ decays, proper time resolution studies and lifetime measurements;
- study of $B_s^0 \to J/\psi\phi$ time and angular distributions;
- measurement of Δm_s with $B_s^0 \to D_s^-\pi^+$ decays, and calibration of flavour tagging;
- measurement of CP violation in $B_s^0 \to J/\psi\phi$ decays.

The study of the first items in this list can in principle start with the 2008 data already, after the detector is calibrated and aligned. Indeed Monte Carlo studies indicate that we expect ~ 470 $B^0 \to J/\psi K^{*0}$, ~ 65 $B_s^0 \to J/\psi\phi$, and ~ 70 $B_s^0 \to D_s^-\pi^+$ reconstructed signal events per 0.001 fb^{-1} [34, 43, 60].

For the longer term, the use of $B_s^0 \to D_s^{\mp}K^{\pm}$ decays for the measurement of the CKM angle γ [61] is also of interest to us, as it will be a natural extension of the experimental techniques needed for the $B_s^0 \to D_s^-\pi^+$ and $B_s^0 \to J/\psi\phi$ analyses.

We are also planning to perform, by the end of 2008, a feasibility study to extract γ from $B_{s,d}^0 \to J/\psi K_S^0$ decays using a method based on U-spin symmetry [62]. Such technique might be applicable with very large data samples, e.g. in case of an upgrade of the LHCb detector to run at higher luminosities.

Finally, we intend to pursue the study of radiative Λ_b decays [53–55], with the goal to observe for the first time such decays in the 2008–2009 data.

b) Direct Higgs searches

We would like to continue the study of the possibility to observe a light SM-like Higgs boson ($115\ \text{GeV}/c^2 < m_H < 135\ \text{GeV}/c^2$) produced in association with a W or Z boson and decaying to a $b\bar{b}$ pair of quarks [56, 63]. The corresponding experimental signature, consisting of two b jets and an isolated lepton (from the gauge boson decay), has already been searched for at the Tevatron [64], but is considered to be very difficult to use at ATLAS and CMS. LHCb appears to be in a complementary situation: higher cross section than at Tevatron and excellent b-jet tagging capabilities, but low luminosity and limited solid angle coverage. Nevertheless about 30% of the Higgs bosons produced at LHC are emitted inside the LHCb acceptance ($1.8 < \eta < 4.9$). From our Monte Carlo study we obtain a signal significance $S/\sqrt{B} \sim 0.26\sigma$ per 2 fb^{-1}, where σ is the signal cross section in pb. Assuming the SM prediction of 2–3 pb, we obtain a significance of at most 2 after 20 fb^{-1}, i.e. 10 years of running. This performance is limited by our ability to reject $t\bar{t}$ background, due to lack of acceptance. We have shown that this can be significantly improved by instrumenting the rapidity range from 0.8 to 1.8 with a veto detector. We therefore intend to study in detail the possibility to add such a (calorimetric) device, for instance around RICH1, to improve our $t\bar{t}$ rejection and hence sensitivity to a light SM Higgs. Another problem is the poor energy resolution for large p_T electrons in the ECAL, due to saturation of each channel at a transverse energy of about 10 GeV; we will put some effort to overcome this situation. As soon as LHC starts, we will also determine the real background level.

In a certain SUSY model with R-parity violation and non-unified gaugino masses [65,66], the light Higgs decay $h^0 \to \tilde{\chi}^0\tilde{\chi}^0$ produces at least two b jets and several displaced vertices, which should be easily recognized thanks to the excellent vertex resolution of the LHCb detector. A significant fraction of such events might be produced in the LHCb acceptance and would pass the trigger. Based on our preliminary study [57] assuming $m_{h^0} = 115$ GeV/c^2, $m_{\tilde{\chi}^0} = 50$ GeV/c^2, an h production cross section of $\simeq 90$ pb as predicted by PYTHIA, and BR$(h^0 \to \tilde{\chi}^0\tilde{\chi}^0) \sim 0.7-0.9$, we expect $\sim 10^3$ reconstructed and selected signal events with less than 7% background.

First versions of some of the algorithms needed for such analyses (e.g. jet reconstruction, as well as b-jet tagging following a method based on displaced vertices [63]) have already been implemented in the LHCb framework. We will further develop our analysis for the search of the SUSY Higgs and neutralinos, including HLT code, and look for a signal in the first data.

c) New Physics searches with τ leptons

Many extensions of the Standard Model predict lepton flavour violation. This could result in neutrino-less τ decay such as $\tau^+ \to \ell^+\gamma$ and $\tau^+ \to \ell^+\ell^-\ell^+$ ($\ell = e, \mu$). The three-lepton final state could be reconstructed in a hadronic environment if it contains at least one muon.

Although a large number of τ leptons will be produced at LHC, the LHCb experiment has not yet studied in detail its τ physics potential. An early and isolated study [67] concluded that the sensitivity for the $\tau \to 3\mu$ mode is of the order of 10^{-7} with 2 fb^{-1} of data, similar to the current B factory limits [68]. We think it is worth revisiting this conclusion in the light of the improved understanding of the final detector performance and trigger capabilities.

We intend to start this investigation using simulated events, and get a Monte Carlo sensitivity estimate by the end of 2008. First, the kinematics of τ leptons and their decay products will be studied for $D_s \to \tau X$ decays, $b \to \tau\nu X$ decays and prompt τ production. Since the transverse momentum distribution of muons from τ decays is soft, the Level-0 trigger may need to be retuned. Then, offline selections of $\tau \to 3\mu$, $\tau \to 2\mu e$ and possibly $\tau \to \mu 2e$ decays need to be developed and backgrounds understood. Finally, these selections will be implemented in the High-Level trigger and the overall trigger chain tuned in view of the 2009 run.

In order to obtain reliable trigger and reconstruction efficiencies, a method must be developed to check the τ production kinematics in the data, using standard τ decays as control channels. This method will be applied in 2009, as soon as data becomes available. By the end of 2009, we should have a realistic estimate of the sensitivities for lepton flavour violating τ decays.

Using a similar methodology, we also intend to investigate exclusive $B \to \tau\nu X$ decays, which are sensitive to a virtual charged Higgs.

2.3.4 Fiber tracking R&D

Original design requirements for the LHCb detector include the ability to operate with an instantaneous luminosity as high as $\sim 5 \times 10^{32}$ cm^{-2}s^{-1} for a limited period, while the assumed average running luminosity is $\sim 2 \times 10^{32}$ cm^{-2}s^{-1}. For the accumulated radiation doses, all the subsystem components should operate up to an integrated luminosity of 20 fb^{-1}, except the VELO sensors which need replacements after 6 fb^{-1}, since they operate at less than 1 cm from the beams where the particle density is exceedingly high.

Assuming LHC will provide full physics production runs from 2009, the LHCb experiment would collect ~ 10 fb^{-1} of data by the end of 2013, which should be sufficient to achieve the original goals of the experiment. After this, an order of magnitude increase in the working luminosity would be required in order to improve the measurements to an interesting level. LHC can deliver the luminosity without problem, noting its design luminosity of 10^{34} cm^{-2}s^{-1}. However, the LHCb trigger, readout electronics and several detector components have to be replaced in order to cope with the much higher event rate, particle density and radiation doses.

One of the problems will be the occupancy of the Outer Tracker near the boundary with the Inner Tracker. The current straw technology used for the Outer Tracker has a limited prospect for improvement. Possible solutions are to increase the coverage of the Inner Tracker, which uses micro-strip silicon sensors, or to replace the Outer Tracker and in the Inner Tracker with a single higher-granularity detector without division between the inner and outer parts. For the second option, the LPHE group is considering a scintillating-fibre tracker read out by Silicon Photomultipliers (SiPM). A scintillating-fibre tracker with 200 μm fibres can easily achieve the required resolution and granularity to keep the occupancy below the few percent level, even in the region where the current Inner Tracker operates. The usage of multi-channel SiPM could allow the coverage of a large surface of 12 m^2 per layer needed for the entire tracker.

R&D on using single-channel SiPM have been already actively pursued by the linear collider community for the calorimeters. Application of scintillating fibres read out by multi-channel SiPM is an extremely promising field for a large scale precision tracking for future detectors. Therefore, LPHE would like to set up a R&D programme along this line.

As first step, we plan to compare different SiPM's. For this purpose, we are already discussing with Hamamatsu Photonics, Japan, to develop prototypes. Other devices are available from Italy, which we plan to test as well. For this purpose, we would like to develop a DAQ board allowing the readout of SiPM's with a PC via an USB interface. The most crucial part is to try different ways of optical coupling to the scintillating fibres and test detection efficiencies for different SiPM's. As second step, we should build a scintillating-fibre tracker demonstrator for evaluation by the LHCb collaboration. In addition we might consider to use such device in a small experiment. A high resolution compact tracker requiring little electric power is an ideal device for a space or high altitude balloon experiment. One possible experiment could be the Positron Electron Balloon Spectrometer (PEBS) [69], whose primary purpose is a precision measurement of the positron and electron cosmic ray flux in the energy range from 1 to 100 GeV.

The know-how acquired would be useful for a future participation in a ILC/CLIC project.

2.4 Project timetable

We give here some more information about the overall status and the expected timetable of the LHCb project for the next couple of years. This is of course very tightly coupled to the LHC machine timetable, which recently accumulated some delays for technical reasons.

The originally planned low-energy "pilot run" foreseen at the end of 2007 has been cancelled. According to the latest official machine schedule, beam commissioning should start in May 2008. The first physics run, at low luminosity but high energy, should start towards the end of July 2008 and extend until the end of 2008 in three stages: operation with low number of bunches (1, 43, 156), operation with 75 ns bunch spacing, and then 25 ns bunch spacing. According to machine experts, this schedule is already excluded and an additional delay of at least 2 months is unavoidable. We can therefore expect that the 2008 run will only deliver a very small integrated luminosity to LHCb, and it is clear that this will not be enough for any substantial physics program. However, these data will be extremely useful to calibrate and align the detector, so as to be ready for smooth data taking for the 2009 physics run, which should reach the nominal luminosity of 2×10^{32} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in LHCb as soon as possible.

Delays in the construction and installation of the LHCb detector have also occurred. The commissioning of several sub-detectors has already started, while some other sub-detectors, such as the Inner Tracker are still being installed. Global commissioning is starting now with parts of certain sub-detectors (such as RICH and colorimeters). According to the latest general planning of the experiment, all sub-detectors should be completely ready for global commissioning by March 2008, with the exception of the first muon station which will join at the end of April 2008. Due to its geometry and orientation in space, LHCb will not be able to take cosmic-ray data as usefully as a central detector. However some global commissioning activity with cosmic rays is foreseen for the muon system, calorimeter system and Outer Tracker, in order to time-align these systems, detect mis-cabling and exercise track reconstruction. The rate of interesting “horizontal” comic rays, i.e. with a slope of at most 30 degrees, has been estimated to be around 0.3 Hz.

The first useful tracks traversing the entire detector will arise from beam-gas collisions as soon as a LHC beam will be circulated clockwise in the LHC. These tracks will be exploited as much as possible to time-align the detector as a whole before the first *pp* collisions. A few days (at most) of collisions at injection energy ($\sqrt{s} = 900$ GeV) is possible and under discussion. The LHCb dipole magnet will most probably be off (at low energy it is not possible to have the full current in the magnet and close the VELO detector at the same time). Operations at high energy will be attempted as soon as possible. During the first stage of the 2008 run, collisions will occur in LHCb only once displaced bunches are injected in one ring (e.g. 4 displaced bunches in 43-bunch mode, or 16 displaced bunches in 156-bunch mode). The luminosity is expected to be very low, between 10^{27} cm^{-2}s^{-1} and 10^{31} cm^{-2}s^{-1} at most. In the next stages (75 ns or 25 ns bunch spacing), a beam crossing angle is needed at the interaction point. The details of the scenarios put forward by the machine specialists are still uncertain and likely to change.

During the 2008 data-taking period, a simplified trigger will be used; the last stages of the HLT trigger will be run and tested, but will not be applied (until needed). A full stable trigger will be aimed at from the beginning of the 2009 run, which will hopefully yield a significant (if not major) fraction of the nominal annual luminosity of 2 fb^{-1} and enable LHCb to deploy its physics program.

2.5 Significance of the planned research

CP violation, i.e. the fact that there is no perfect symmetry between matter and anti-matter, was first observed in 1964 in an experiment with neutral K mesons. However, the fundamental origin of CP violation is still to be understood. The theoretical description of this phenomenon is related to the generation of mass by the Higgs mechanism of the Standard Model (SM), which results in a set of parameters, grouped in a matrix called the Cabibbo-Kobayashi-Maskawa (CKM) matrix and describing the flavour structure in the quark sector. The detailed study of the magnitudes and phases of the CKM elements, and in particular the ones related to the third generation of quarks, is a powerful test of the SM. So far, all experimental results are compatible with the SM.

However, the SM cannot be the ultimate theory: it has two many free parameters (masses and mixing angles). The pattern of these parameters must be governed by a hidden mechanism yet to be discovered, and so the SM is believed to be a low-energy effective theory of a more fundamental theory at a higher energy scale, possibly in the TeV region. This New Physics would imply new symmetries, particles, dynamics, and flavour structure, generating CP violation beyond the SM. It is also well known that such New Physics and new sources of CP violation could be of crucial help in explaining the cosmological baryogenesis and, in the end, the fact that matter completely dominates over anti-matter in our Universe.

Before 2009 several experiments, both at B factories and at the Tevatron, will perform CP violation measurements in the b-quark sector. We can expect that direct measurements of $\sin(2\beta)$ (where β is an angle depending on the free parameters of the CKM matrix) using B^0 decays to CP eigenstates of the type $b \to c\bar{c}s$ will have a combined uncertainty of ~ 0.02. However the other two angles of the CKM unitarity triangle will not be known so well. The relatively low statistics measurements with decays like $B^0 \to \pi^+\pi^-$ or $B^0 \to \pi^+\pi^-\pi^0$, together with the theoretical uncertainty associated with these decays, will only yield a determination of the angle α with rather limited accuracy. Similarly, measurements of the third angle γ will not

Decay mode(s)	Measured physics parameter	Expected statistical precision	Comment	Ref.
$B^0 \to J/\psi K^0_S$	$\sin(\phi_d)$	± 0.020	$\phi_d = 2\beta$ in SM	[60]
$B^0_s \to D^-_s \pi^+$	Δm_s	± 0.007 ps^{-1}	$> 5\sigma$ observation with just 0.25 fb^{-1}	[61]
$B^0_s \to J/\psi\phi$, $J/\psi\eta$,	ϕ_s	± 0.022	$\phi_s = -2\chi = -0.036 \pm 0.002$ in SM	[34]
$\eta_c\phi$, $D^+_s D^-_s$				
$B^0_s \to \phi\phi$	$\phi_{\rm NP}$	± 0.11	New Physics phase $\phi_{\rm NP}$	[70]
$B^0 \to D K^{*0}$	angle γ	$\pm 9^\circ$	Insensitive to New Physics in loops	[71]
$B^+ \to D K^+$	angle γ	$\pm 5 - 13^\circ$	$\sigma(\gamma)$ depends on strong phases $\delta_D^{K\pi}$, $\delta_D^{K3\pi}$	[72]
$B^0_s \to D^\mp_s K^\pm$	angle γ	$\pm 10^\circ$	Insensitive to New Physics in loops	[61]
$B^0 \to \pi^+\pi^-\pi^0$	angle α	$< \pm 10^\circ$	Sensitive to New Physics	[73]
$B^0 \to \pi^+\pi^-$,	angle γ	$\pm 2 - 9^\circ$	$\sigma(\gamma)$ depends on penguin/tree ratio,	[74]
$B^0_s \to K^+K^-$			method assumes U-spin symmetry	
$B^0 \to K^{*0}\mu^+\mu^-$	$C_7^{\rm eff}/C_9^{\rm eff}$	$\pm 11\%$ (rel)	Zero of forward-backward asymmetry	[75]
			sensitive to New Physics	
$B_s \to \mu^+\mu^-$	BR		Sensitive to New Physics,	[76]
			exclude New Physics with just 0.5 fb^{-1}	
$D^{*+} \to D^0(\phi^- K^+)\pi^+$	x'^2	1.4×10^{-4}	$D^0 - \bar{D}^0$ mixing,	[77]
	y'	1.9×10^{-3}	sensitive to New Physics	

Table 1: *Examples of measurements possible with 2 fb^{-1} of LHCb data (corresponding to 10^7 s of data-taking at a luminosity of 2×10^{32} cm^{-2}s^{-1}), assuming Standard Model (SM) B^0_s mixing parameters, $\gamma \sim 60^\circ$ and no significant strong-phase differences in the tree diagrams for the $B^0_s \to D^\mp_s K^\pm$ and $B^0 \to D_{CP}K^{*0}$ decays. The LHCb experiment is expected to collect at least 10 fb^{-1} (assuming no upgrade).*

reach a sufficient precision to make a significant test of the CKM picture.

In fact, most (if not all) CP violation measurements in B decays will still be statistics-limited when the LHC machine turns on. This is also true for a number of CP-conserving observables, for example the dimuon mass spectrum and the forward-backward asymmetry in $B^0 \to K^{*0}\mu^+\mu^-$ decays, which are expected to be very sensitive to possible New Physics in the $b \to s$ loop transitions. Furthermore any measurement involving B^0_s mesons (including key observables for the investigation of possible new particles involved in the $b \to s$ flavour-changing neutral currents) cannot be performed at the $\Upsilon(4S)$ resonance, leaving this field for higher energy machines. The Tevatron experiments have started to explore this.

Because of the very large $b\bar{b}$ production cross section at the LHC ($\sim$ 0.5 mb) the LHCb experiment will record a lot more statistics than current experiments, for all types of b hadrons. With its good triggering efficiency, high proper-time resolution and powerful particle identification (which the multi-purpose experiments such as CDF, D0, ATLAS and CMS don't have), it will not only repeat with better precision the measurements performed at the B factories and the Tevatron, but also make several direct and clean determinations of all CKM angles, using also B^0_s-meson decays and channels with very low branching ratios. Examples of the precision reachable on several interesting observables are given in Table 1. This will constrain the unitarity triangle and check the consistency of the CKM picture beyond what is possible at the current B factories and at the Tevatron.

Perhaps most importantly, LHCb will be well placed to measure a few superb $b \to s$ observables with high sensitivity to New Physics: for example the forward-backward asymmetry in

$B^0 \to K^{*0}\mu^+\mu^-$ decays, the $B_s^0 - \bar{B}_s^0$ mixing phase, and the $B_s^0 \to \mu^+\mu^-$ branching ratio (see Table 1).

Such a systematic investigation will carry forward the study of CP violation and flavour physics beyond that of any other currently running experiment or programme. It should not only enable observations of deviations from the Standard Model predictions, but also eventually lead to the identification of the flavour structure of the underlying New Physics (observed either indirectly in loop processes or directly at LHC's energy frontier), and therefore to a deeper understanding of Nature and its symmetries at the electroweak scale or above.

3 Summary of information for the assessment of this request

In its letter of August 4, 2004, the Division 2 of SNSF informed us about the specific criteria that the Research Council would like to take into account when assessing annual funding requests for ongoing long-term projects, and asked us to provide answers to four different questions. Although the relevant information is already detailed or implied in various places of this document and our common requests to FORCE, we give below, in the form of an executive summary, our answers to these questions.

a) What are the strong points and the scientific contributions of your participation in the project ?

Strong points:

- Expertise in B physics and CP violation physics (former or present participation of the leading members of our group in the CPLEAR, CDF, ALEPH, L3 and Belle experiments).
- Expertise in building and commissioning silicon vertex detectors (SVX for CDF, SVD for L3).
- Expertise in DAQ electronics (analogue and digital).
- Well-trained technical staff and well-equipped infrastructure at our home institute (electronics and mechanics workshops).

Scientific contributions:

- The Lausanne group has played a leading role in the experiment from the very beginning, in particular for the definition and design of the project.
- Members of our group have made some key contributions to the approval of the project in its current form.
- Our group has successfully developed a readout board (TELL1) that was subsequently adopted by the rest of the experiment.

b) To which extent are you funded by third-party sources (schools, cantons, confederation, . . .) ?

Since 1998 our research group in Lausanne has been granted a total amount of 5.9 MCHF for the construction of the LHCb detector which can be split into the following categories according to the source of funding:

- 20% from ordinary budgets at the University of Lausanne and then at EPFL;
- 21% from extraordinary grants at the University of Lausanne;
- 9% from extraordinary grants at EPFL;
- 6% from SNSF;
- 44% from FORCE (FOnds pour la Recherche au CERN).

c) What is the weight of your group in the global project ?

We occupy the following managerial and responsibility positions within the global project:

- Prof. T. Nakada, spokesman of the LHCb collaboration since 1995;
- Prof. O. Schneider, LHCb physics coordinator since 2000;
- Prof. A. Bay, LHCb coordinator of the TELL1 electronics since 2003; co-convener of the “Jets” physics working group since 2005;
- Dr J. van Hunen, co-convener of the “Proper time and mixing” physics working group from 2005 to 2007.

In view of the above, our group bears considerable weight in the organization and leadership of the LHCb collaboration, which includes $\sim$ 700 members from 47 institutes in 14 different countries.

In addition, we are responsible for the development, construction and commissioning of the following LHCb components:

- the Trigger Electronics and L1 (TELL1) boards, which will be used for the readout of 93% of LHCb's electronics channels;
- the data transmission and powering of the Vertex Locator, which is a key system for the trigger, as well as for any time-dependent physics measurement;
- the Inner Tracker stations, which will cover the low pseudo-rapidity region where the density of tracks will be the highest, and therefore contribute very significantly to the geometrical acceptance of the LHCb spectrometer, especially for high-multiplicity b-hadron decays.

These systems are essential for the LHCb experiment, and therefore represent very important responsibilities.

Our weight in the project can be compared with the following fractions, which our group represents or assumes in LHCb:

- 7.9% of the detector investment (5.97 MCHF out of 75.34 MCHF);
- 3.5% of the collaboration members (according to author list);
- 2.8% of the Ph.D. physicists and engineers.

d) Were the goals fixed in the previous period reached, and is the project evolving according to the established schedule ?

Compared to the official schedule available a year ago, the startup of the LHC machine at high energy has been delayed by a few months. The LHCb experiment is still foreseen to be complete, commissioned and ready to take data when the LHC starts beam operation. For recent reports of the global status of the LHCb project (to the LHC committee or to the LHCb Resource Review Board), see:

`http://www.cern.ch/lhcb-doc/progress/progress.htm`

Our electronics project is on schedule, and the goals fixed in the previous period will be reached.

A significant delay (larger than the contingency available last year) has been accumulated in the Inner Tracker construction and installation, which is now expected to be completed at the end of 2007. Fortunately, this delay has no consequence because of the new situation with the machine schedule.

All our analyses of the 2004–2005 Monte Carlo data samples have been completed, with two of our PhD students submitting their theses in 2007. New studies on our 2006–2007 Monte Carlo have started, as foreseen. However, the LHCb collaboration experiences several problems with the deployment of its distributed computing model, resulting in delays with the processing of our large Monte Carlo samples. Many problems have been solved and it is expected that the stripped and re-processed samples will become available in time for completing the Monte Carlo physics studies before data-taking starts.

Availability of unpublished documents

Unpublished documents cited in this request (LHCb notes, LPHE notes, Master and Ph.D. theses, funding requests, ...) are made available electronically and can be accessed at `http://lphe.epfl.ch/fn`

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[13] LHCb public notes are available from the CERN document server:
`http://cdsweb.cern.ch/search.py/?c=LHCb+Notes`.

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— T. Nakada, “LHCb status and physics”, conference on Supersymmetry in 2010’s, Sapporo, Japan, June 2007.

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— G. Haefeli, “Enabling technologies for a new TELL DAQ interface module”, 1st LHCb Workshop on High Luminosity Upgrade, Edinburgh, UK, January 2007.

— O. Schneider, “LHCb expected physics performance with 10 fb^{-1}”, 1st LHCb Workshop on High Luminosity Upgrade, Edinburgh, UK, January 2007.

— T. Nakada, “CERN LHC Experiments and B Physics Programme”, 2nd International Workshop on B factories and New Measurements (BNM2006II), Nara, Japan, December 2006.

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