Status of the LHCb experiment

Andrei Golutvin (Imperial & ITEP & CERN)
On behalf of the LHCb collaboration

Outline:

- *Introduction*
- *Detector Subsystems*
- *Experimental Area*
- *Commissioning*
- *Cost and funding issues*
- *Collaboration matters*

LHCb is ready for data taking

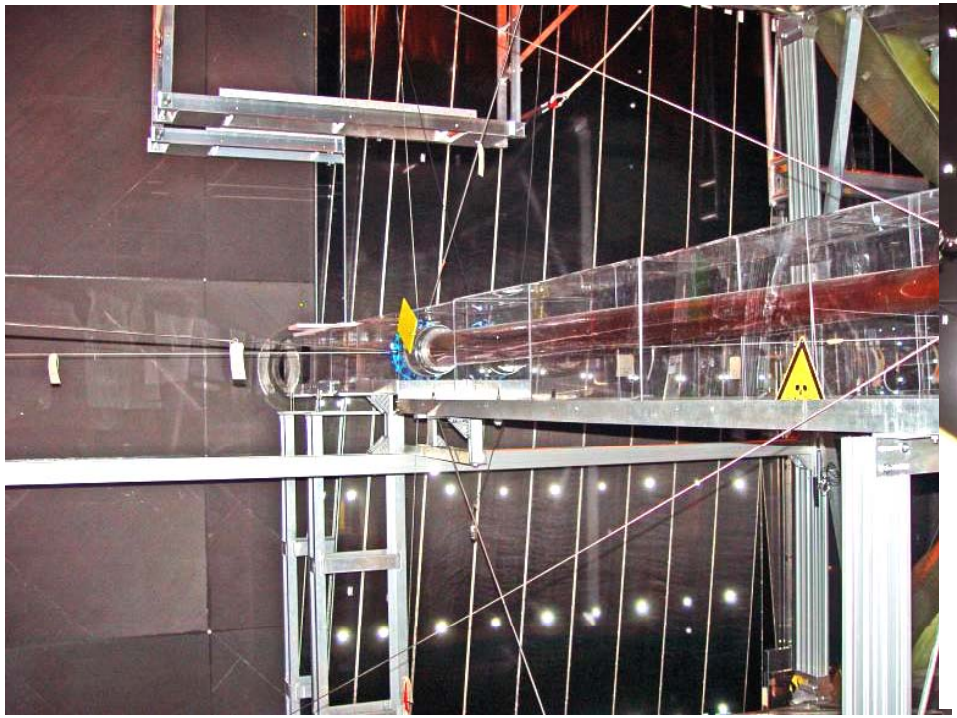
- *For all sub-detectors >95% channels are working*
- *Calo and Muon L0 is fully operational and heavily used during commissioning*
- *On line was fully operational for 2008 needs (currently readout at up to 70 kHz)*
  Completion of the installation is planned for spring 2009 to optimize cost performance
- ***LHCb had run shifts (24 hours/7 days) since middle of August to September***

Beam Pipe (CERN)

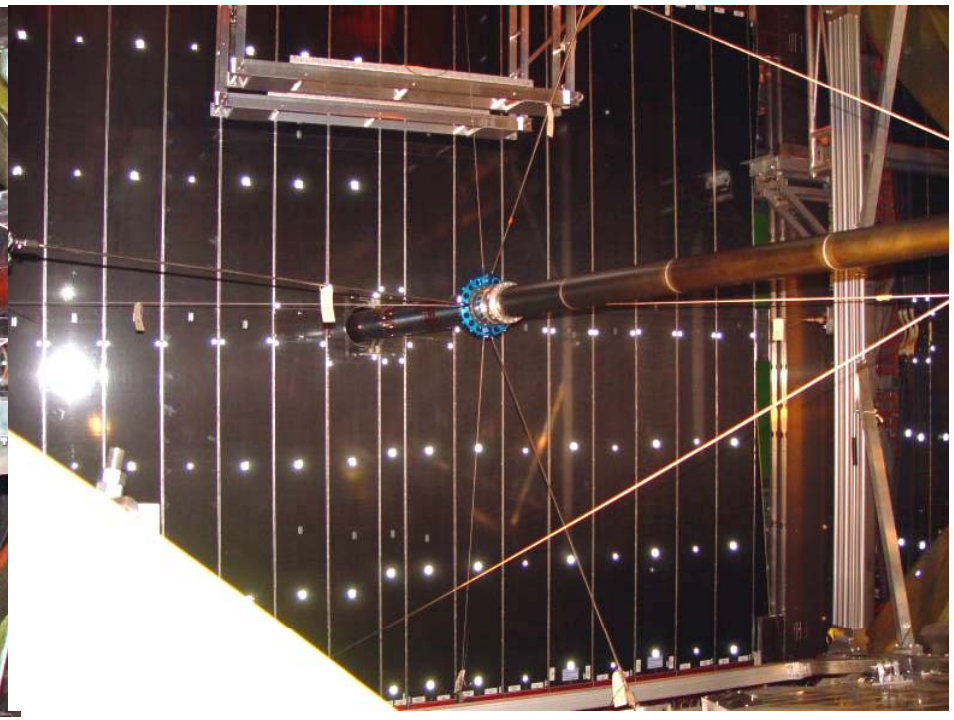
23 m long beam pipe consisting of 3 Be and 1 stainless steel sections

- *Installation and commissioning completed in summer 2007*
- *The beam pipe was under vacuum since June (till November) 2008*

Beam Pipe with protection and two OT stations closed



Beam Pipe protection removed



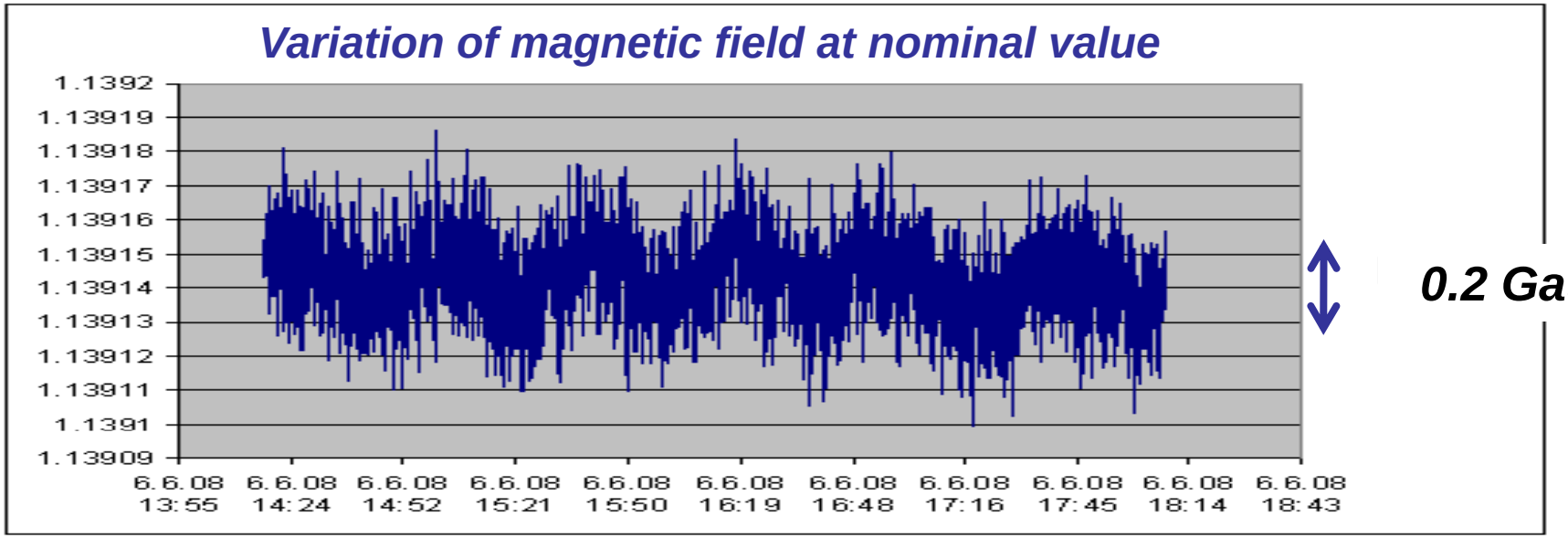
- *Identified leak fixed currently by varnishing. For long term a replacement of the third section has to be procured. Following discussions with potential manufacturers a tender for a replacement of UX85/3 Be beam pipe was launched*

Magnet (CF)

Warm dipole magnet with 4 Tm bending power along the beam axis

- *Measured stability of magnetic field is well within specifications*
  Symmetry of the B-field between two polarities was measured to be better than 10^{-4}, a special demagnetizing cycle for switching polarities is not necessary
- *The beam dump trigger, in case of magnet failure, has been tested together with the LHC operators*

Measured stability of the LHCb magnetic field (for both polarities)



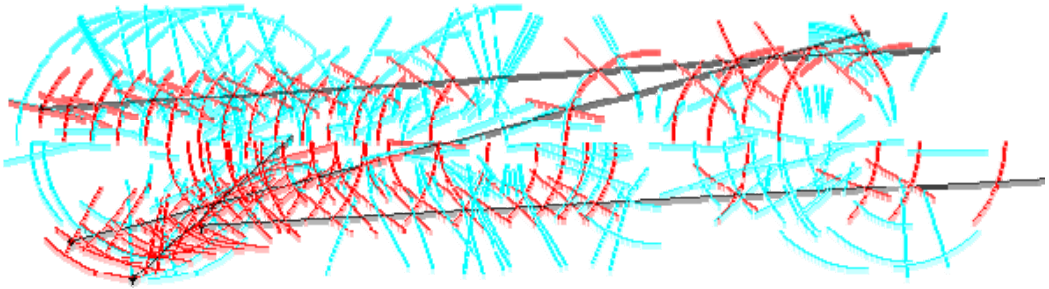
VErtex Locator (CH,DE,GB,NL)

2×21 pairs of Si sensors arranged in 2 halves; each pair consists of one sensor with R- and one sensor with φ-strips

- *Since last RRB:*
  - *Both VELO halves independently commissioned*
    - ✓ *Total system noise as expected*
  - *CO2 cooling system fully commissioned*
    - ✓ *Operated under full load at -25℃*
    - ✓ *Setting point was -5℃ for 2008 run*
      - *Minimizing effects of thermal cycling*
- *The HV and LV systems fully checked*

- *The VELO was able to record hits and reconstruct tracks during the beam synchronization tests in August 2008*

24th August
Run 30933 Event 8
Full detector powered



VELO Concerns

- *Low level leak in the RF foil*
- *TELL1 spares and hardware reliability*
- *Availability of LV spares*
- *Spare/Replacement VELO*
  - *modules under construction at Liverpool since 1 week*
  - *Production will be completed in April 2010*
  - *Discussion with VELO groups on building remaining mechanics to ease installation*

Outer Tracker – OT (CERN,CF,CN,DE,NL,PL)

Three stations with each 4 stereo layers of straw tubes 5 mm diameter and 5m length; 55k channels

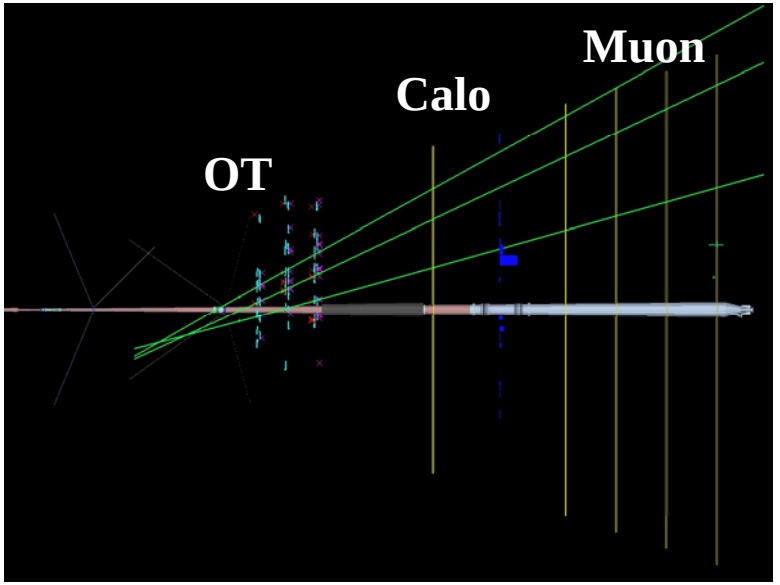
- *The detector installation completed before the 2008 LHC run including detector services such as gas, cooling and Detector Safety System (DSS)*

- *All FE and TELL1 boards installed and operational*
- *All HV and LV systems operational*

- *Detector positioned and surveyed. Preliminary results from tracking using cosmic events show the detector alignment is in according to the nominal values within ±1 mm*

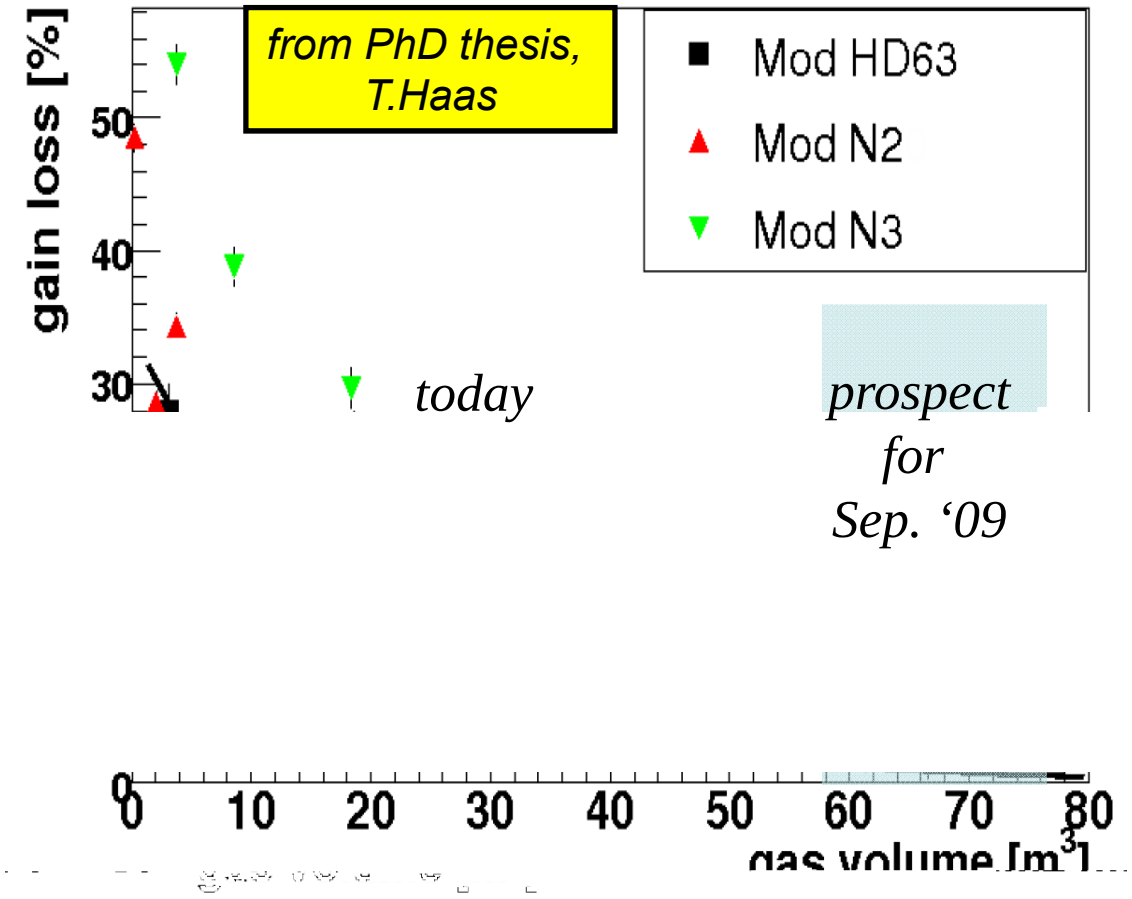
- *OT readout time aligned using LHC beam induced events*

- *LHC beam induced tracks reconstructed on September 10*



Gain Loss Prevention

Effects of Gas Flushing



Assuming constant gas flow of 0.8V/h

Heating modules during flushing also helps

- *Warming up in situ will be completed during winter shutdown*
- *HV training will be tested in situ*
- *New insight from laboratory studies: in addition to the out-gassing products, that deposit on the anode wires, ozone radicals are produced as well that have a cleaning effect on the deposit → no gain loss downstream of the irradiation area wrt gas flow*

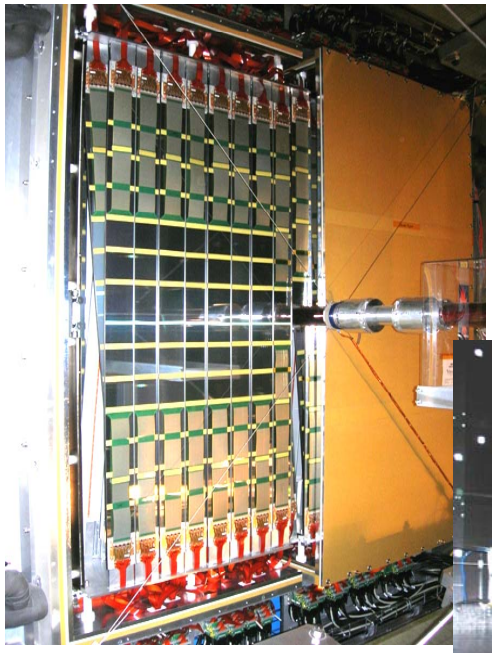
ST: Trigger Tracker & Inner Tracker

(CERN,CH,DE,ES,UA)

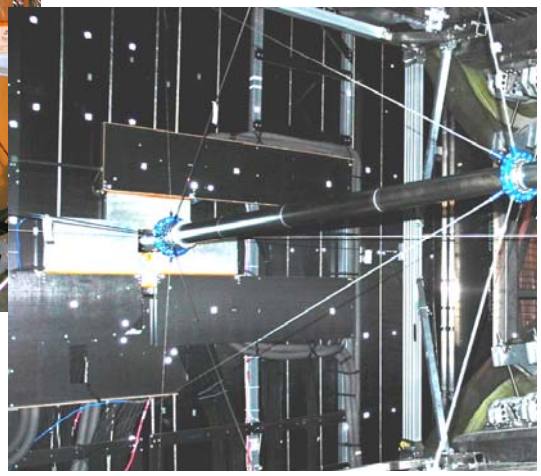
TT covers area of 1.4×1.2 m^2; 4 stereo layers with ladders consisting of 3 or 4 chained Si-sensors with strip pitch 183 micron; 143k channels
IT: 3 stations with 4 boxes each arranged around beam pipe; each box has 4 stereo layers x-u-v-x, modules with one or two chained Si-sensors; strip pitch 198 micron; 130k channels

- *All modules + service boxes installed*
- *Detector surveyed with magnet on*
- *Detector cooled to operating T = 0^o C*
- *Currently 99% of TT and 97% of IT channels commissioned and operational*
- *Remaining faults are mostly due to individual malfunctioning components In the Service Boxes close to the detectors; will be fixed in the coming weeks*

TT



IT

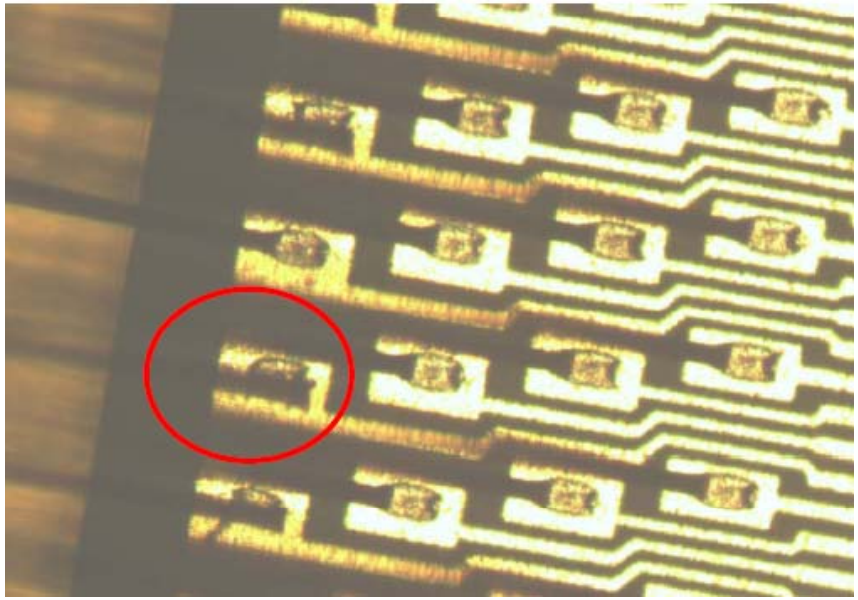


Silicon Tracker

- *Both TT and IT participated successfully in global commissioning*
- *Time alignment within a few ns and initial spatial alignment using LHC synchronization tests*

Concerns:

A number of wire bonds have broken on 6 out of 280 TT FE readout hybrids
Production of further spares is being prepared (for the case if this spreads to other hybrids)



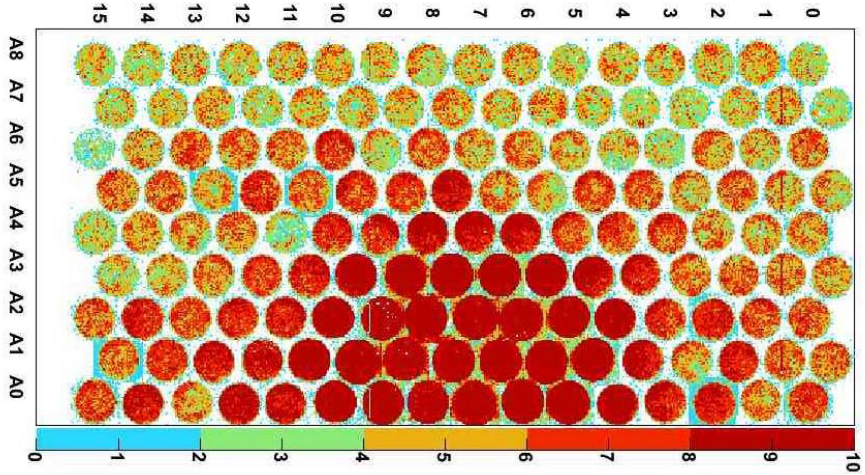
RICH (CERN,CF,GB,IT)

RICH1 and RICH2 with 3 radiators covers momentum range 2-100 GeV; RICH1: 5cm aerogel with n=1.03 & 4m³ C4F10 with n=1.0014; RICH2: 100m³ CF4 with n=1.0005; ~500 HPD to readout

- *Both RICH detectors are complete and routinely taking laser-pulsed and cosmic data.*
- *Internal timing of RICH system has been determined using pulsed laser light (<1 ns) piped onto HPDs by optical fibre. Coarse time alignment to the rest of LHCb has been achieved using LHC beam dumped onto the beam stopper (TED). Photon hits were observed with first circulating beams on Sept.10*

Hits in one HPD plane of RICH2
(30 events from Beam 1 on collimator)

Fine alignment still to be done



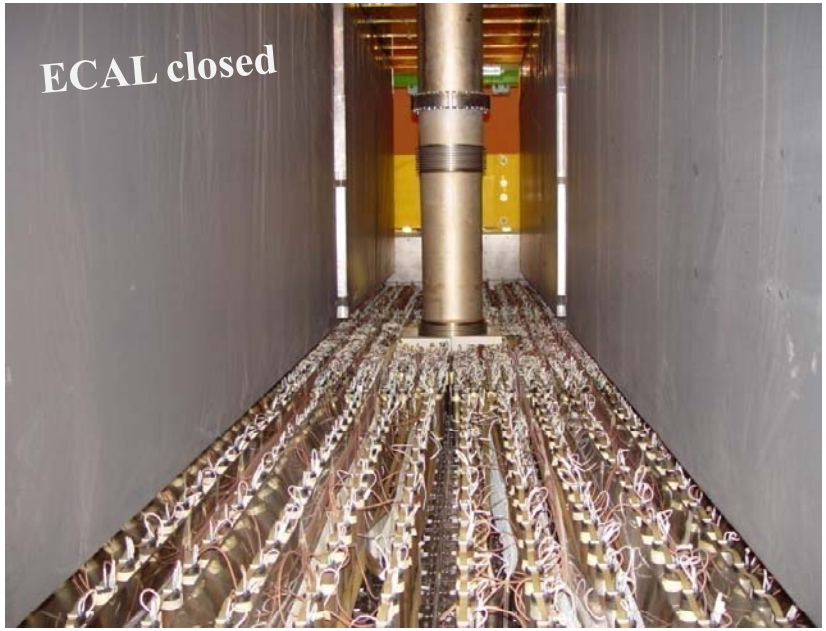
- *RICH calibration procedures are well advanced and waiting for final verification with collisions*

Calorimeters

(CERN,CF,ES,FR,RO,RU,UA)

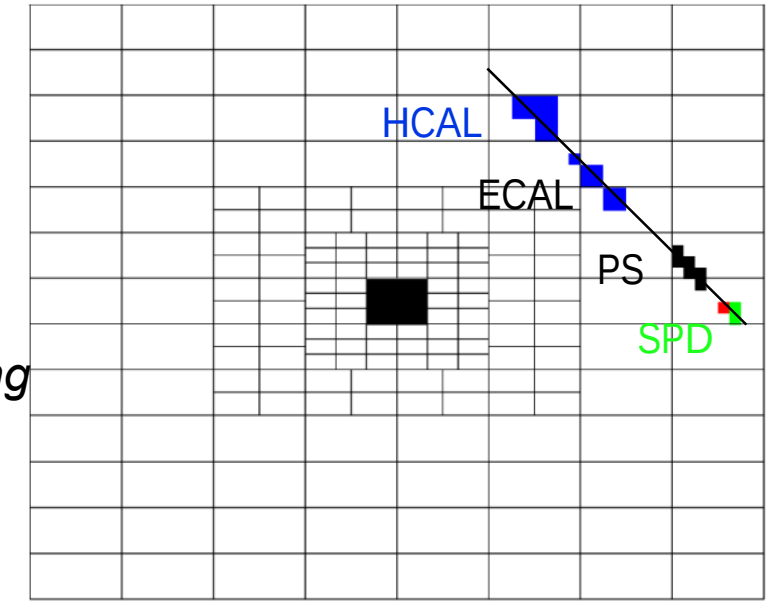
PS/SPD: 12k scint. tiles readout by WLS; ECAL: 6k shashlik cells; HCAL: TILE Calo, 1.5k channels

- *System is complete*
- *Stability of the PMT gain being monitored using LED system*
- *HCAL calibration with Cesium source has been used for the gain calibration*



Calorimeters

- *Intensive use of ECAL & HCAL for cosmic triggers since June 2008*
- *Operate ECAL/HCAL at 10^5 gain at ~10Hz/half detector rate*
- *HCAL – ECAL – PS – SPD commissioned using cosmics. Time alignment ~3ns achieved*



Improvements:

In order to reduce noise to a negligible level and improve the PMT stability, the modification of the ECAL Cockroft-Walton HV system will be undertaken during this 2008/2009 shutdown

Muon (CERN,CF,IT,RU)

Arranged in 5 SuperLayers; M1 consists of 12 double triple GEM chambers and 264 MWPC's; M2-M5 consists of 1104 MWPCs

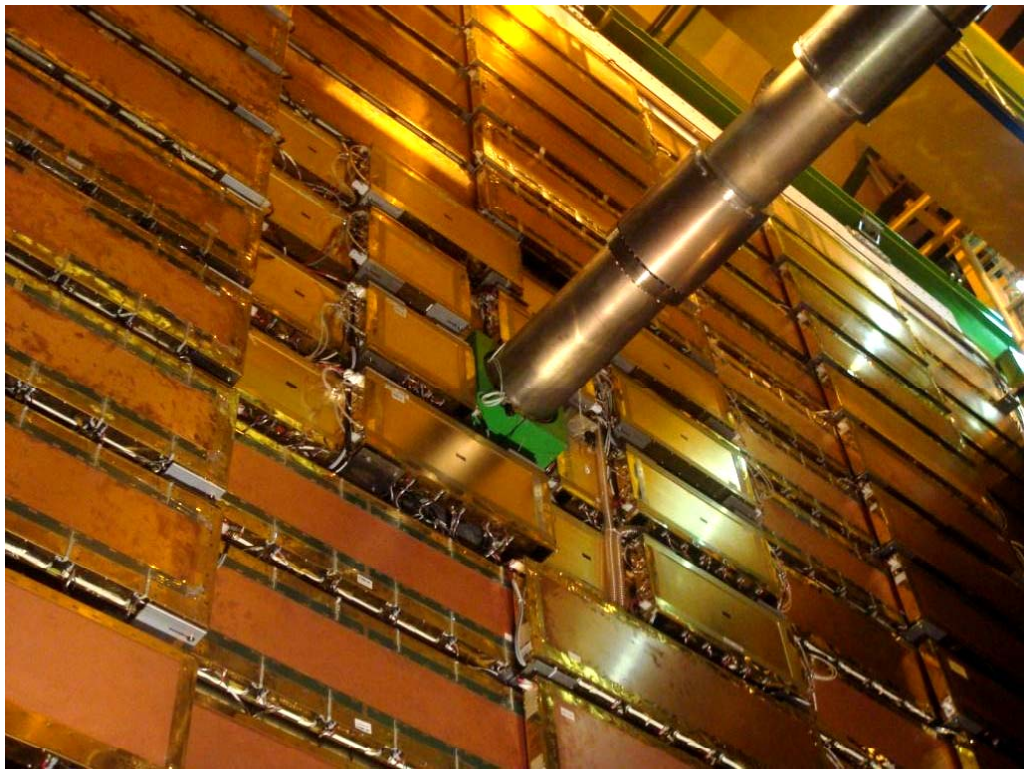
- *Installation of M2-M5 stations successfully completed*

- *System is fully tested and surveyed. All chambers are within ±1 (2) mm of their nominal position in x(y) direction*

- *The gas system and HV system are tested.*

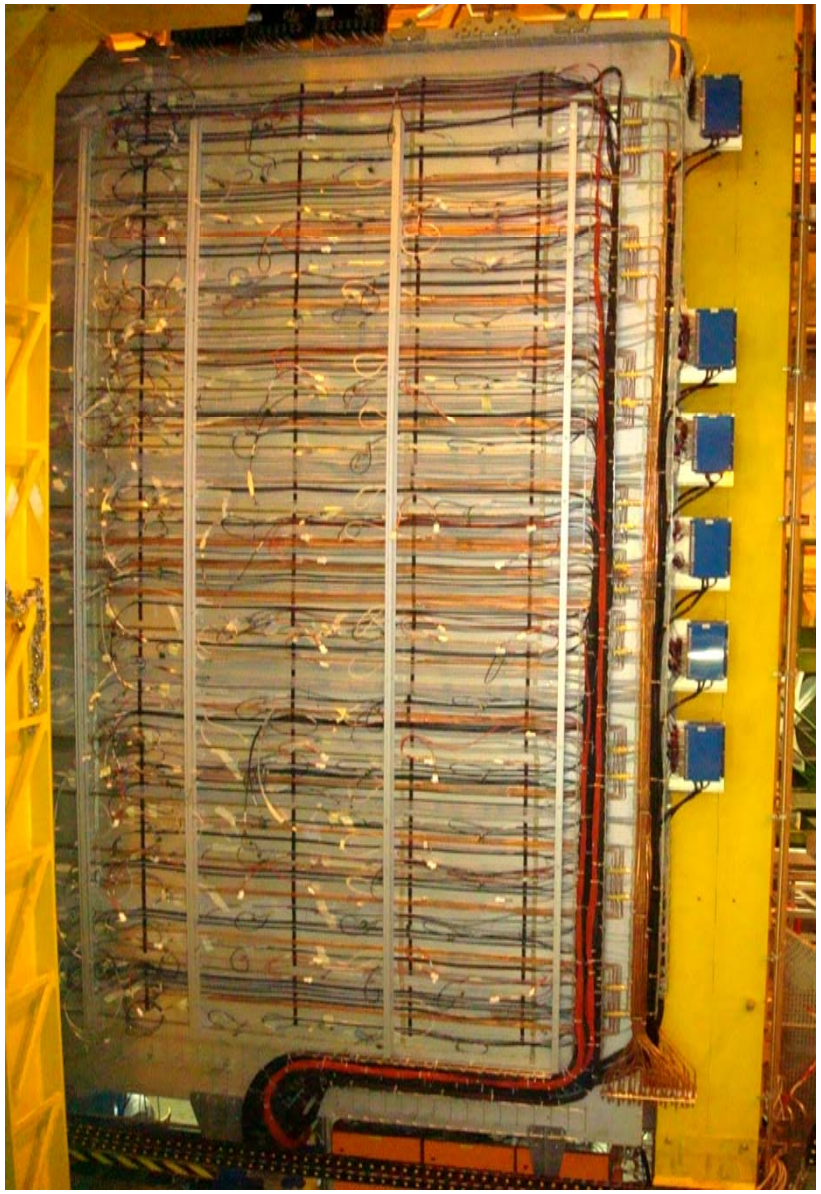
- *Readout timing is aligned and adjusted using cosmics and first machine beams*

- *Production of spare chambers is close to completion in PNPI and LNF. M1 will be completed during winter shutdown*



M1 status

- ✓ *Mechanics completed*
  - *Walls, chambers support rails, moving system, cable chains*
- ✓ *Work on services ongoing:*
  - *Gas piping: On wall piping completed*
    Flexibles being installed
  - *Cabling: >95% of cables installed*
- ✓ *The installation of chambers will start in December 2008.*



Trigger and Online

(CERN,CF,CH,DE,FR,ES,GB,IT,NL)

- *Commissioning of the L0 trigger was completed in October 2008*
  L0 selects routinely events with cosmics and beam induced data

- *The commissioning of the High Level Trigger (HLT) is progressing well using a version adapted for tests with cosmics and/or random L0 triggers. The hardware that was foreseen for 2008 is installed and operational: ~15% of network and HLT farm capacity, corresponding to 100 1U servers containing 16 computing cores each*

- *The system is regularly in use for all Sub-detector commissioning and global commissioning efforts*

- *Delivery of the rest of the HLT CPU farm is planned for mid February 2009 with subsequent installation and commissioning (has to match to the maintenance period of the cooling plant)*

Computing

- *Successful use of the track reconstruction program for data taken with cosmics, injection tests and LHC beams. Results were used to align the detectors and the first outcome looks promising.*

- *The MC simulation has been updated for the 2008 geometry. A large production for physics studies of the first data is being started now.*

- *LHCb has participated successfully in CCRC in May 2008. Transfer rates above nominal (70 MB) have been achieved. The main concern remains the file accessibility from jobs running on Tier1's.*

- *LHCb is preparing a Full Experiment System Test (FEST09) to start at the beginning of 2009. Simulated data will be injected into the HLT farm and follow the standard pass, including L0 simulation and HLT processing and selection → Full system test including alignment and calibration as well as first physics analysis studies*

Experimental Area

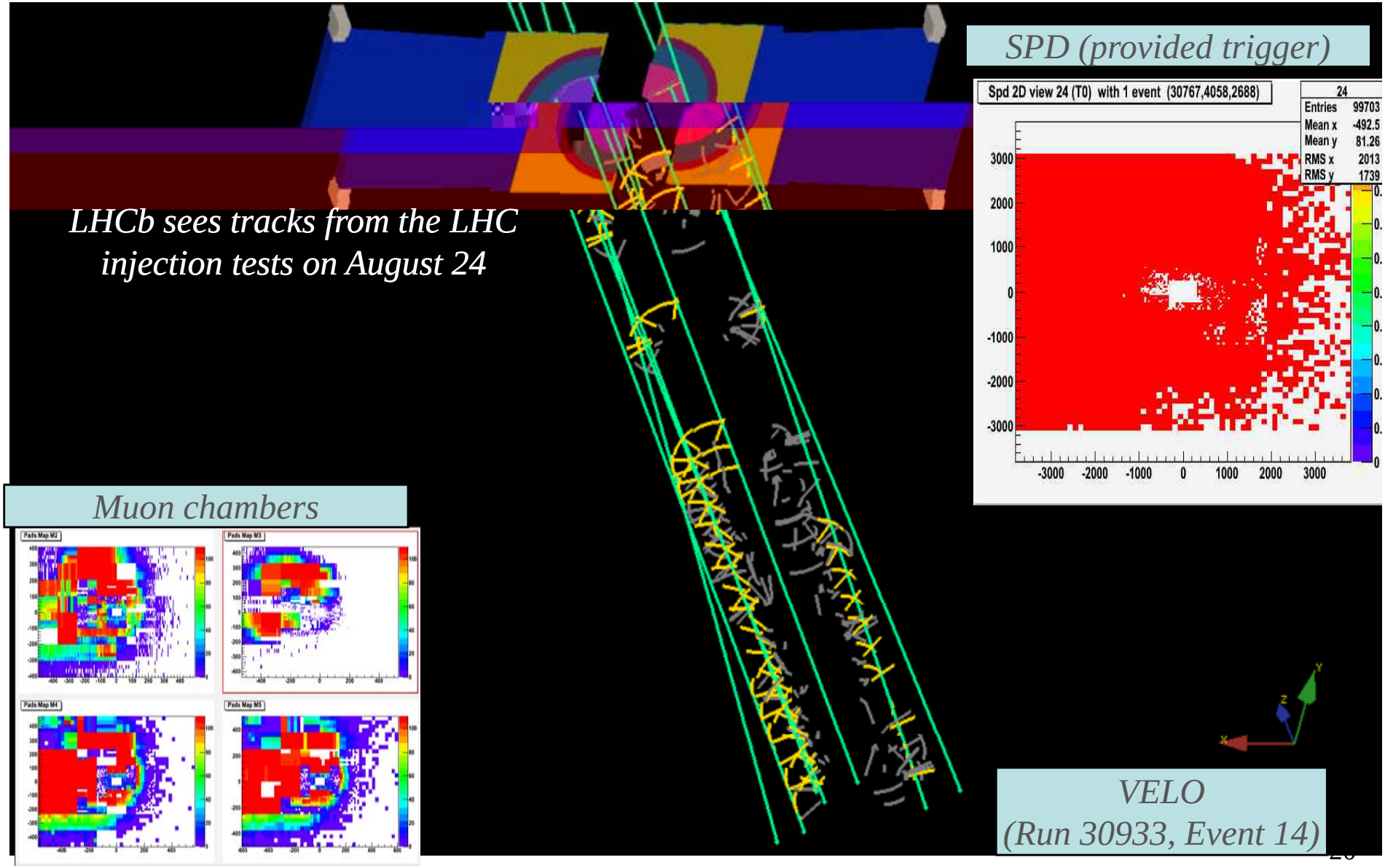
- *The installation of the radiation shielding wall and all detector services has been completed*
- *The beam and radiation monitoring system (Bean Condition Monitor, a metal foil radiation Monitoring System and Active radiation Monitors) has been installed to ensure protection & monitoring of the beam background conditions*

- LHCb BCM, being the main protective device of LHCb, "initiated" beam dump at three dumps on TDI 11:22, 12:10, 12:47 on August 23 during synchronization tests

We had fully operational detector in August/September

(with 24 hours shift coverage)

Muon originated from the beam stopper cross LHCb in the "wrong" direction



Global Commissioning

- *The muon and calorimeter triggers were used to get tracks and to perform initial alignment in time and space*

  - *VELO, TT, IT and OT were time aligned to a few nanoseconds*
    Calorimeters and Muon were time aligned using cosmics
    RICH was also time aligned (to ~15 ns)

  - *Initial spatial alignment indicated no major problem*
    Resolution in the expected range

- *Now we are back to the commissioning with cosmics, fixing identified problems and preparing for an efficient 2009 run.*
  Plan to restart global operations in April 2009

Physics: main objectives

Search for New Physics in CP-violation and Rare Decays

Key Measurements	Accuracy in 1 nominal year ($2\ fb^{-1}$)
❑ *In CP – violation*	
✓ ϕ_s	**0.023**
✓ γ *in trees*	4.5°
✓ γ *in loops*	10°
❑ *In Rare Decays*	
✓ $B \rightarrow K^* \mu\mu$	$\sigma(s0) = 0.5\ GeV^2$
✓ $B_s \rightarrow \mu\mu$	**3σ measurement down to SM prediction**
✓ *Polarization of photon in radiative penguin decays*	$\sigma(A\Delta) = 0.2$ (in $B_s \rightarrow \phi\gamma$)

Physics: main objectives

Search for New Physics in CP-violation and Rare Decays

Key Measurements	Sensitivity with 10 fb^{-1} (few years of data taking)
❑ *In CP – violation*	
✓ ϕ_s	**0.01**
✓ γ in trees	2-3°
✓ γ in loops	5°
❑ *In Rare Decays*	
✓ $B \rightarrow K^* \mu\mu$	$\sigma(s0) = 0.28\ GeV^2$
✓ $B_s \rightarrow \mu\mu$	**5σ measurement down to SM prediction**
✓ Polarization of photon in radiative penguin decays	$\sigma(A\Delta) = 0.09$ (in $B_s \rightarrow \phi\gamma$)

If NP is discovered by LHCb with 10 fb^{-1} the NP models should be studied
Plan for LHCb upgrade to collect ~100 fb^{-1}
There are many observables where we are not limited by theoretical uncertainties

Expected LHCb sensitivities for 100 fb^{-1}

Observable	Sensitivity
$S(B_s \to \phi\phi)$	$0.01 - 0.02$
$S(B_d \to \phi K_S^0)$	$0.025 - 0.035$
ϕ_s $(J/\psi\phi)$	0.003
$\sin(2\beta)$ $(J/\psi K_S^0)$	$0.003 - 0.010$
γ $(B \to D^{(*)}K^{(*)})$	$< 1^\circ$
γ $(B_s \to D_s K)$	$1 - 2^\circ$
$\mathcal{B}(B_s \to \mu^+\mu^-)$	$5 - 10\%$
$\mathcal{B}(B_d \to \mu^+\mu^-)$	3σ
$A_T^{(2)}$ $(B \to K^{*0}\mu^+\mu^-)$	$0.05 - 0.06$
$A_{\rm FB}(B \to K^{*0}\mu^+\mu^-)$ s_0	$0.07\,{\rm GeV}^2$
$S(B_s \to \phi\gamma)$	$0.016 - 0.025$
$A^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	$0.030 - 0.050$
charm x'^2	2×10^{-5}
mixing y'	2.8×10^{-4}
CP y_{CP}	1.5×10^{-4}

Also studying Lepton Flavour Violation in $\tau \to \mu\mu\mu$

Cost and Funding

No change since last RRB in April 2008

The overall cost remains unchanged with 75 MCHF
The LHCb experiment will be fully financed with the contribution of 200 kUSD from US-NSF on behalf of the Syracuse group for the CPU's in the pit (93 kUSD have been already paid; the remainder will be paid later this year)

VELO Replacement Modules

- *Production of spare modules has been launched in May*

  ~ 75% of hybrids fabricated (well within specs and expected yield)

  ~ 15% of the phi-sensors received and under tests. First bunch of r-sensors due for delivery in late October

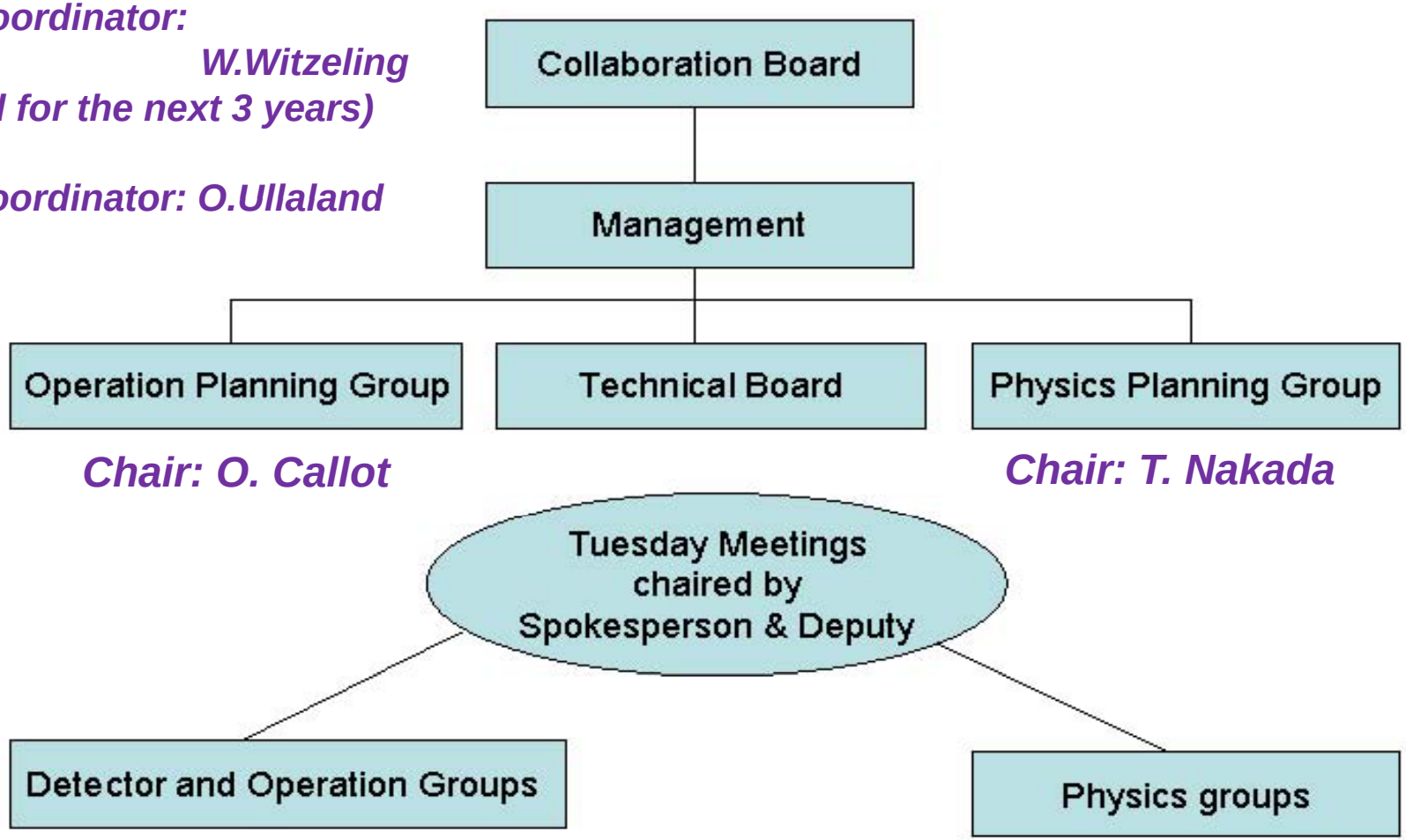
Collaboration Matters: LHCb organization

Management:

Spokesperson: ***A.Golutvin***
Deputy: ***A.Schopper***
Technical Coordinator:
W.Witzeling
(reappointed for the next 3 years)

Resource Coordinator: O.Ullaland

CB Chair: ***U. Straumann***
starting from November 1
Many thanks to Elie Aslanides



New group from the University of Bari, led by Prof. Antimo Palano, was accepted

Physics groups

CP-violation

Convener: Guy Wilkinson
Deputy: Marta Calvi
(with particular responsibility for tagging and proper time)

Coordinators of the key measurements:

ϕ_s *O. Leroy*

γ **in loops** *V. Vagnoni*

γ **in trees** *J. Libby*

Rare Decays

Convener: Ulrik Egede

Coordinators of the key measurements:

$B_s \rightarrow \mu\mu$ *F. Teubert*

$B \rightarrow K^*\mu\mu$ *M. Patel*

$B \rightarrow X\gamma$ *I. Belyaev*

Flavor Physics (very 1st measurements)

Convener: Olivier Schneider

Coordinators:

Soft QCD *M. Schmelling*
1st phys with min. bias

Quarkonium and B *P.Robbe*
1st phys. with J/ψ

EW physics *T. Shears*

Higgs and exotica *C. Matteuzzi*

Direct LUMI measurement *J. Panman*

Conclusion

- *A clear experimental signature of New Physics unlikely to be discovered at currently operating experiments*
  LHCb has many opportunities to discover NP in flavour sector within a few years of data taking (10 fb^{-1} sample); complementary to direct search by ATLAS & CMS
  Preparing the upgrade to collect 100fb^{-1} is very important to study NP models

- *LHCb was fully operational to start data taking in September 2008. First LHC beam induced data have been successfully taken and used for the time and space alignment*

- *Essential now to prepare for the effective start-up next year:*
  - *Complete M1 installation and commissioning*
  - *Upgrade DAQ system to its full capacity*
  - *A few other improvements for various subdetectors*