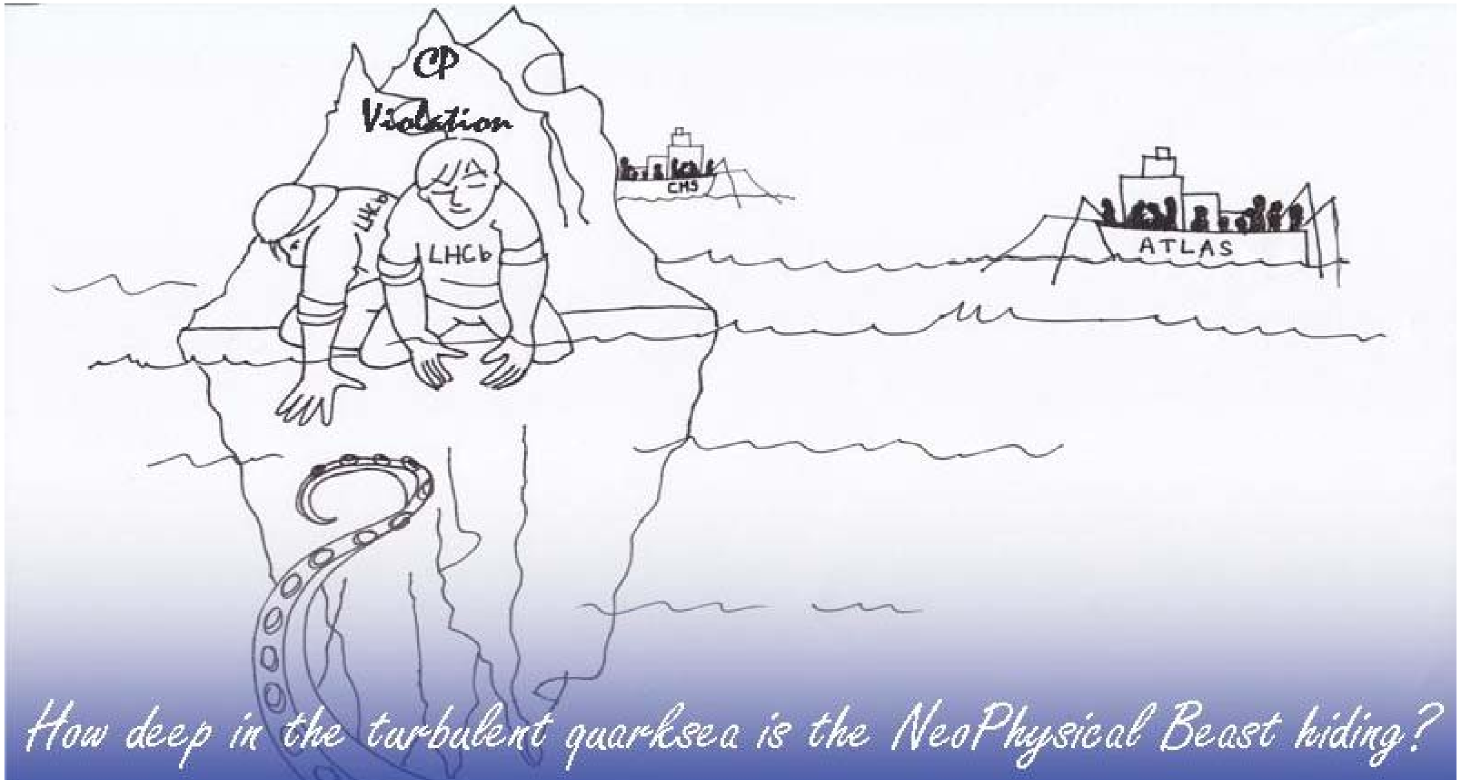
LHCb Readiness for Physics

Richard Jacobsson, CERN
on behalf of the LHCb Collaboration

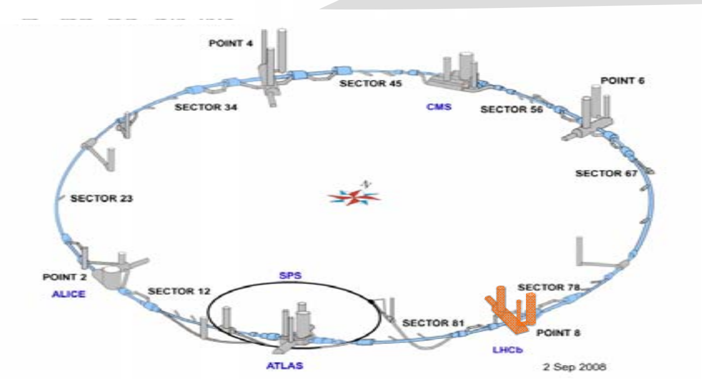


LHCb Physics Program described in Marie-Noelle Minard's talk on Thursday

I cover the key ingredients to exploit the physics potential

F.M. & R.J., CERN

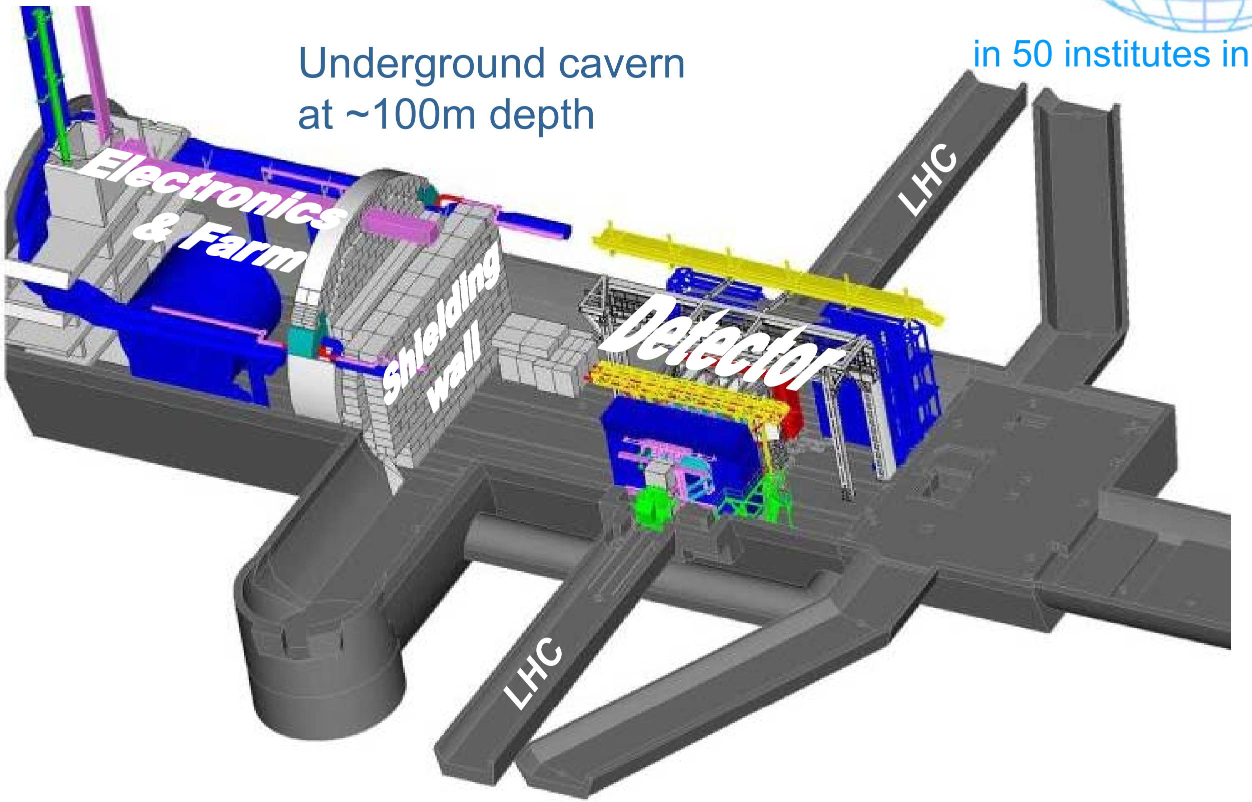
Place in the World



700 people

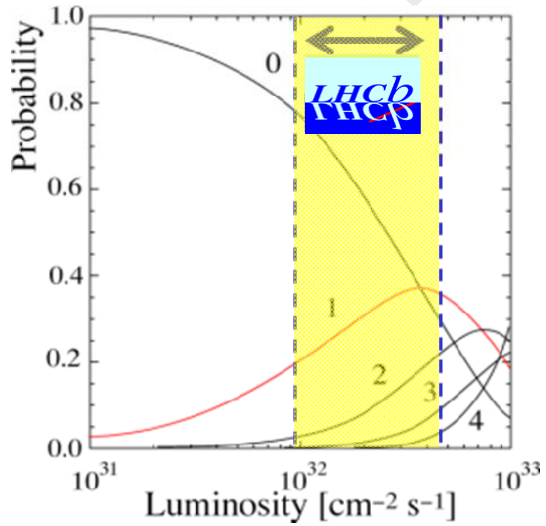
in 50 institutes in 16 countries

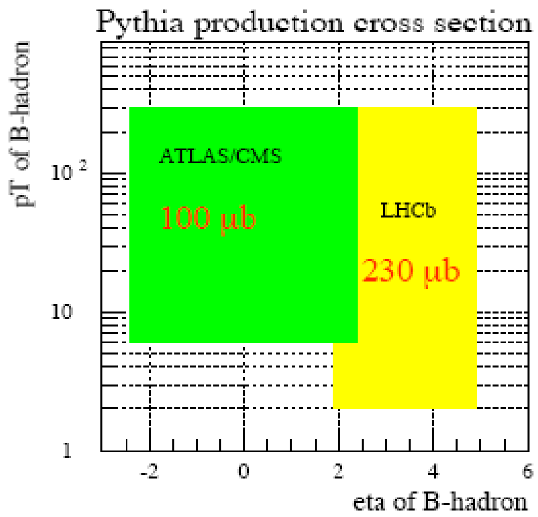
Underground cavern
at ~100m depth



LHCb Environment at LHC

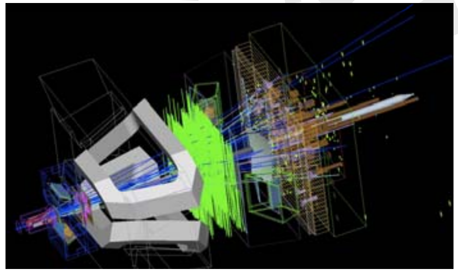
- High statistics:
  - LHCb interaction point $\mathcal{L}$ ~ 2 x 10^{32} cm^{-2} s^{-1} (1/50 GPDs)
    - LHCb design luminosity from start
    - Optimize single pp-interactions
    - 10 MHz visible interaction
  - $\int L$=2 fb^{-1}/year (10^7 seconds of LHC physics)
  - High bb cross-section σ_{bb}(14TeV) ~ 500 μb
  - 100 kHz bb-rate
  - Access to all b-hadrons $B^{\pm}$, B^0, B_d, B_u, B_s, B_c, b-baryons
  - ~ 10^{12} bb / year at LHCb IP
  - 1 day equivalent to 100 B-factory days
- Challenge of an hadronic precision experiment
  - Multiplicity per rapidity unity = 30
  - Background from high inelastic cross section of 80 mb
  - Branching ratios for B-meson decays relevant for LHCb physics





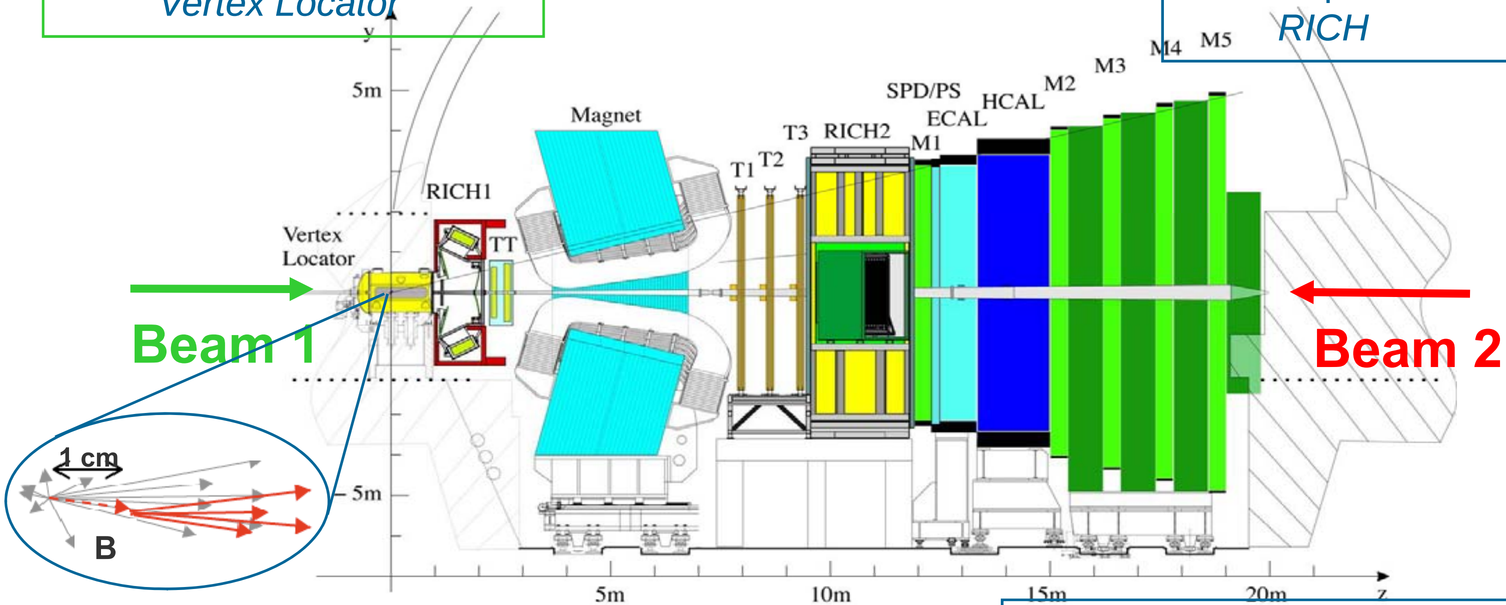
LHCb Detector at LHC

- Single-arm forward spectrometer
  - Acceptance 10-250 mrad (V) / 10-300 mrad (H) → $1.6 < \eta < 4.9$
  - Effective σ_{bb}(14 TeV) in LHCb acceptance ~230 μb



Good decay time resolution
Vertex Locator

Efficient particle identification
RICH



Good mass resolution
Tracker and Magnet

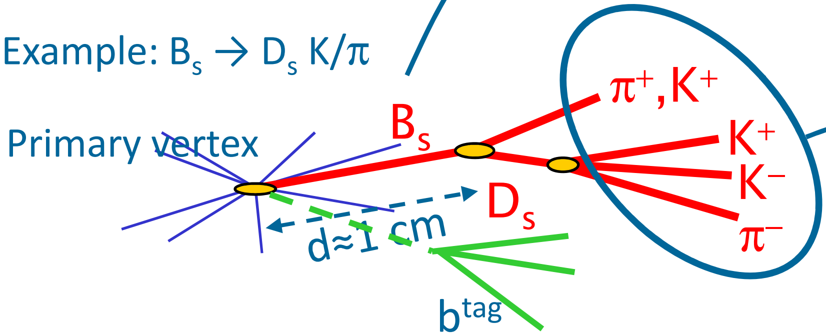
Efficient trigger for many B decay topologies
Muon system, ECAL+Preshower , HCAL, Vertex Locator

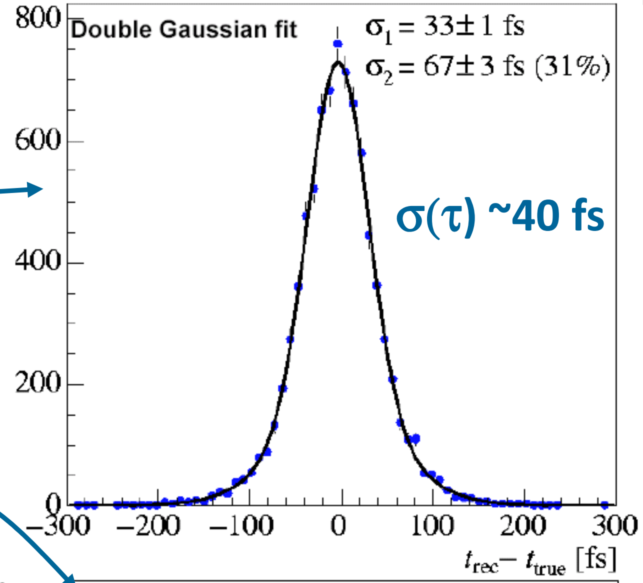
- Vertex Locator is a movable device
  - 35 mm from beam out of physics / 5mm from beam in physics

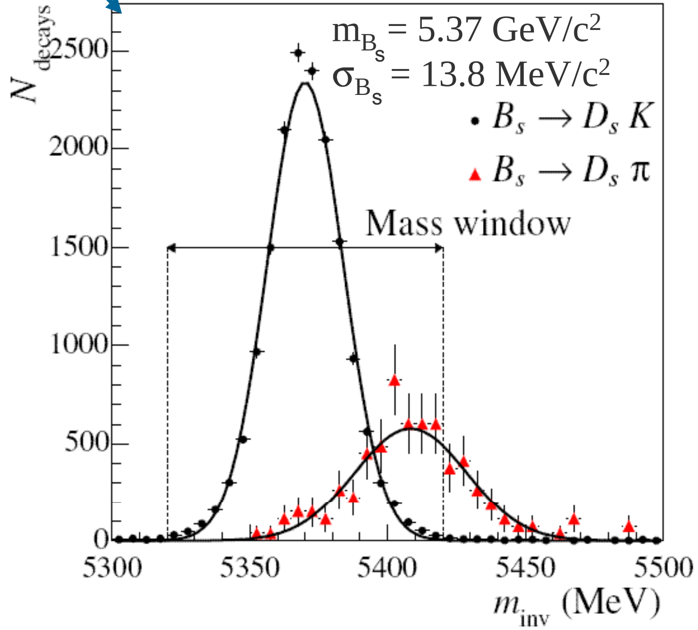
LHCb Expected Performance

- Decay time resolution ~40 fs

Example: $B_s \to D_s K/\pi$





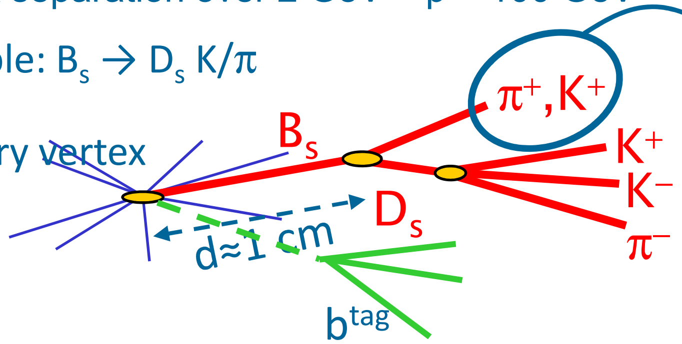


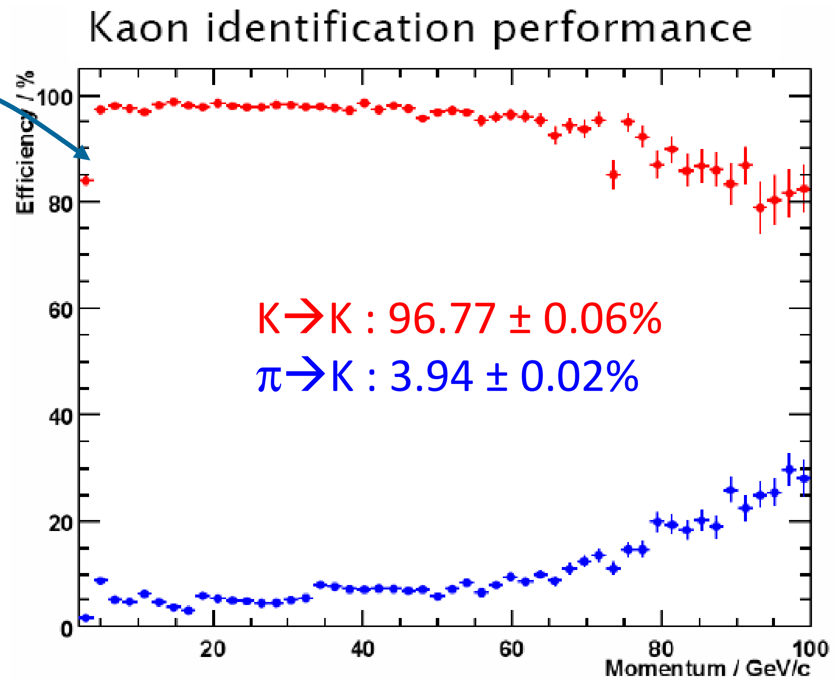
- Mass resolution 14 MeV

LHCb Anticipated Performance

- Particle identification
  - π/K separation over 2 GeV < p < 100 GeV

Example: $B_s \rightarrow D_s K/\pi$





- Energy resolution ECAL: $(9.4\pm0.2)\%/\sqrt{E} \oplus (0.83\pm0.02)\%$

- Energy resolution HCAL: $(69\pm5)\%/\sqrt{E} \oplus (9\pm2)\%$

LHCb Trigger

- Level-0 Hardware Trigger
  - Search for high-p_T μ, e, γ, hadron candidates

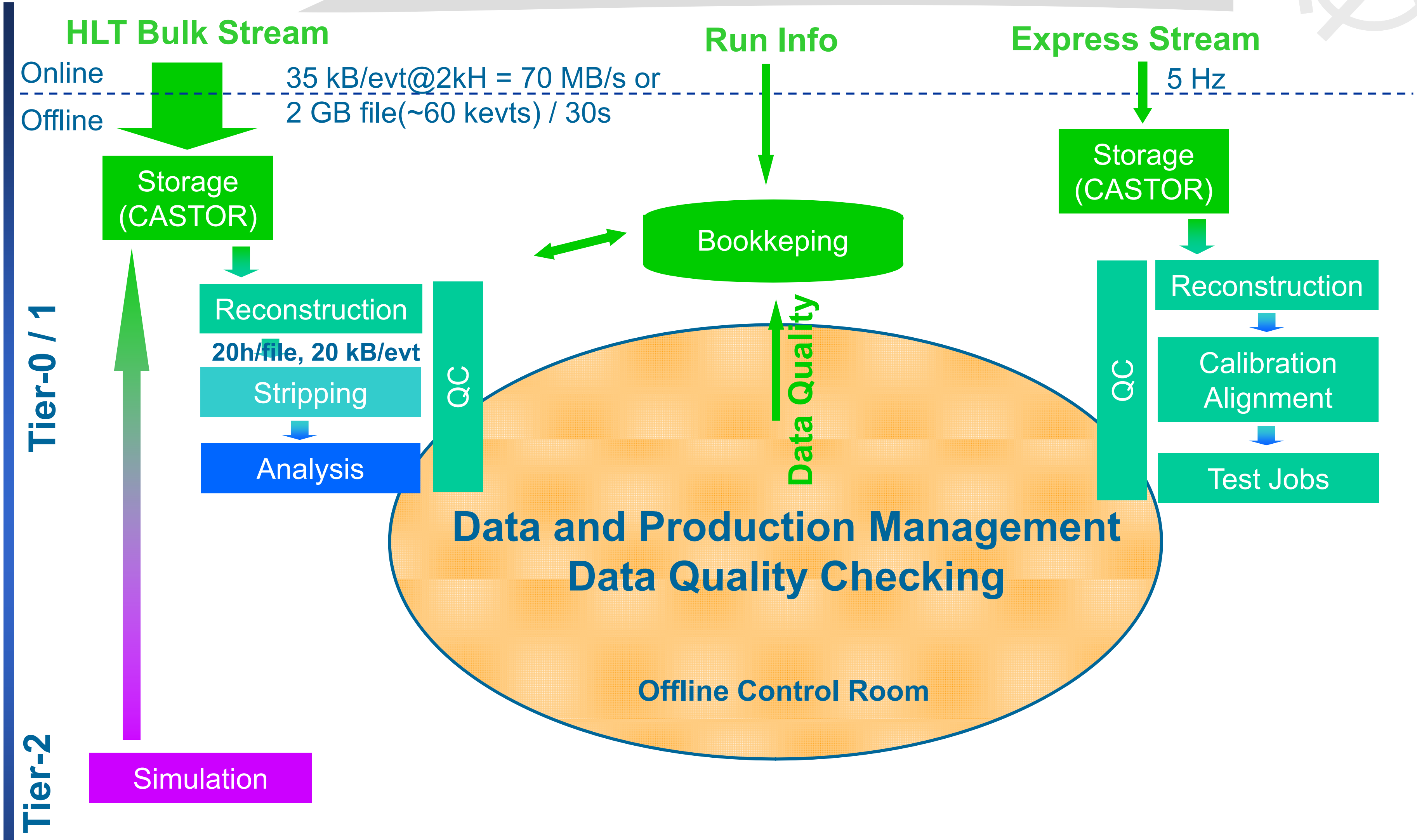
Trigger	had	μ	μμ	e±	γ	π^0
p_T> (GeV)	3.5	1.3	Σ>1.5	2.6	2.3	4.5

- High Level Trigger Farm with $\mathcal{O}$(1000) quadcores
  - HLT1: Confirm L0 candidate with more complete info, and add impact parameter and lifetime cuts
  - HLT2: global event reconstruction + selections

	ε(L0)	ε(HLT1)	ε(HLT2)
Electromagnetic	70 %	> 80 %	> 90 %
Hadronic	50 %		
Muon	90 %		

- L0 and HLT configured with Trigger Configuration Key distributed in the data to allow optimizing the trigger parameters in real-time

LHCb Data and Process Flow



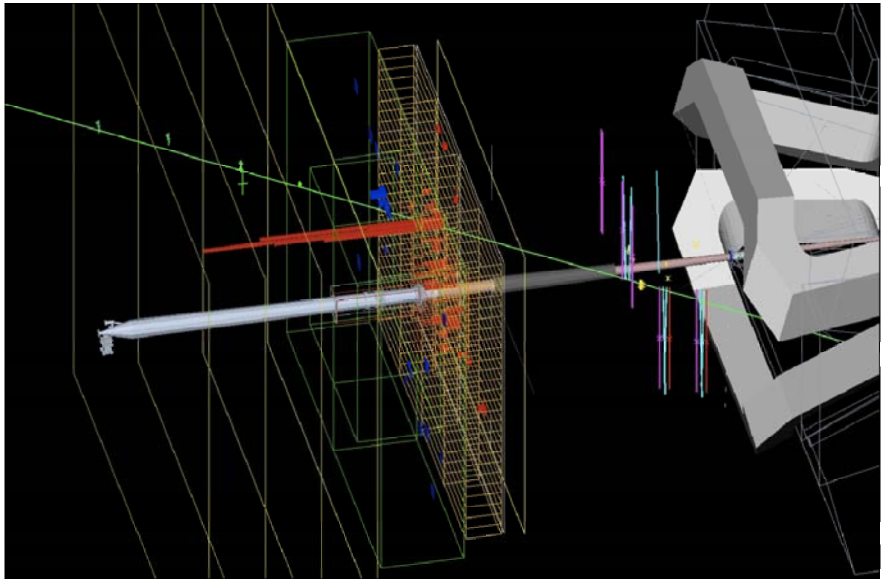
Commissioning LHCb

Two years of intense work 2006 – 2008

- Operating the detector AND people as a unit with common tools
  - Bring all components (sub-detectors and service systems) to operational state.
  - Define, implement and validate the tools and procedures needed to run the detector as a whole
  - Organise the activities to reach the ready state in time
- Understanding and calibrating the detector
  - Test pulses, radioactive sources
  - Cosmics
  - LHC injection tests
  - First days with beam
- Two shifters
  - Operating the whole detector from one console
  - Understandable high-level tools for diagnostics, alarms and data monitoring
  - Homogeneity in the system
  - Shifter training
  - On-call Experts for all sub-systems and sub-detectors
- Operational efficiency
  - Starting (<10min) and restarting (<1 min) rapidly and smoothly

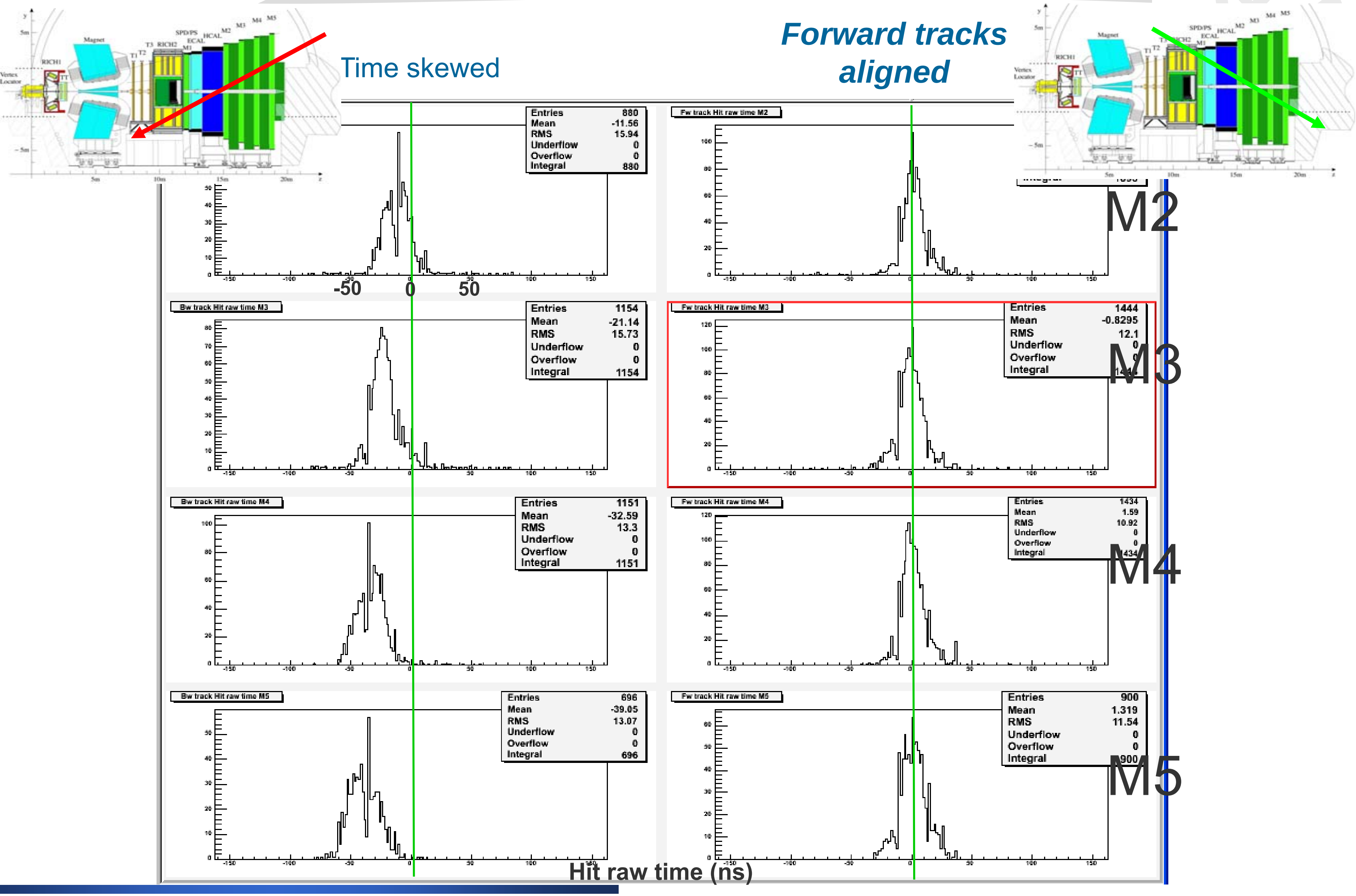
Commissioning with Cosmics

- Challenge: LHCb geometry is NOT well suited for cosmics…
  - "Horizontal" cosmics well below a Hz
  - Still 1.6x10^6 good events (July – September 2008) recorded for the large sub-detectors



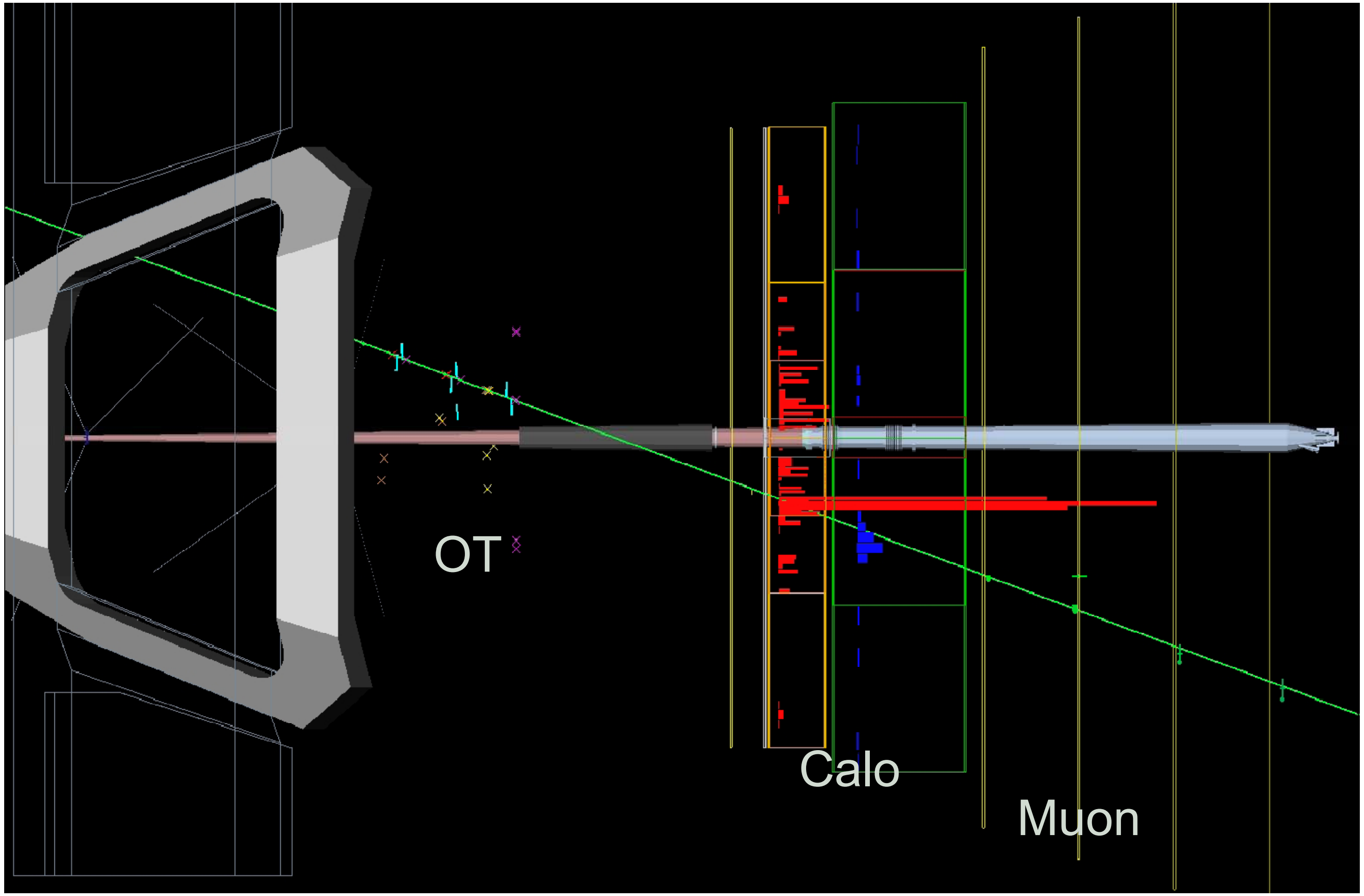
- Alignment in time and space with readout of consecutive "crossings" for a single trigger
  - Triggering by ECAL and HCAL calorimeters with a high gain to see MIP
  - Muon trigger without spatial correlation (no pointing geometry) constraint
    - The basic building blocks of the L0 trigger were commissioned this way at the end of 2007.
  - Readout of consecutive events also allows measuring the leakage in preceding and following clock cycles and optimizing signal over spill-over

Cosmic Alignment of Muon Stations



Cosmics for the Tracking Detectors

- Triggering by the Calorimeters and the Muon detector
  - Easy for Outer Tracker (OT), similar surface as the Calorimeter
  - Marginal for Inner Tracker (small), Trigger Tracker (too far), Vertex Locator (small and far...)



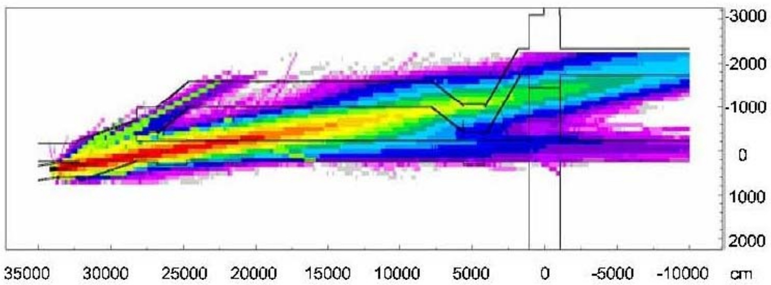
A First Glimpse of LHC Protons

LHCb@LHC Sector Tests

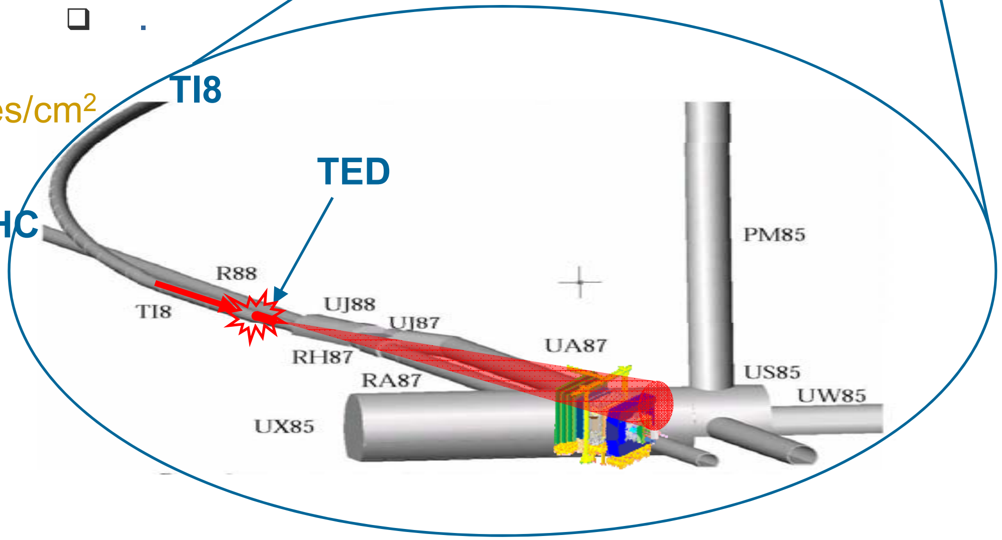
- Beam 2 dumped on injection line beam stopper (TED)
  - 4m tungsten, copper, aluminium, graphite rod in a 1m diameter iron casing
  - 340m before LHCb along beam 2
  - 8 mrad horisontally and 12 mrad vertically from LHCb beam axis

→

  - Wrong direction for LHCb
  - Centre of shower in upper right quadrant
  - High flux, centre of shower $\mathcal{O}(10)$ particles/cm^2
  - Vertex Locator $\mathcal{O}(0.1)$ particles/cm^2



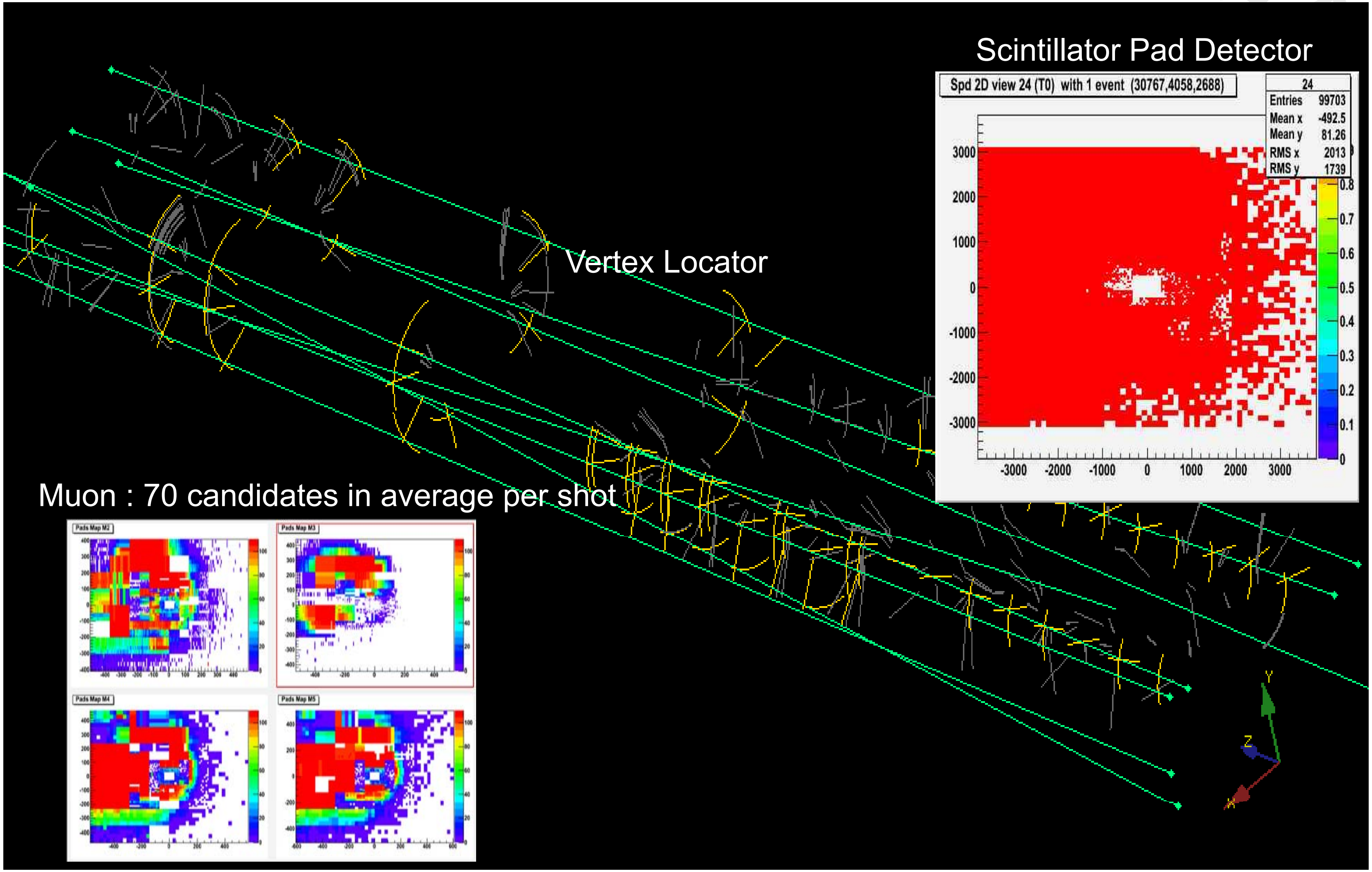
- .



A First Glimpse of LHC Protons

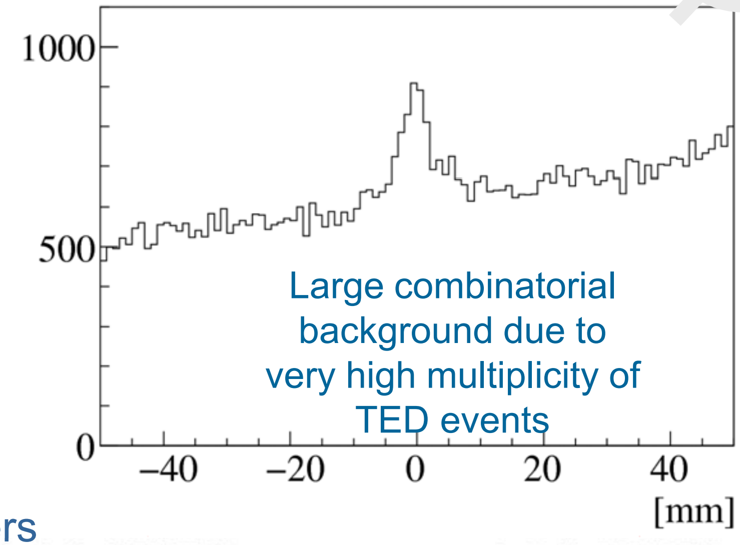
- Very useful for alignment in space and time
  - Internal and cross-detector
  - Triggering by Scintillator Pad Detector multiplicity and readout of consecutive crossings
- LHC Sector Test on August 24th, 5x10^{9} p per shot every 48s
  - Vertex Locator, Calorimeters, Muon
  - about 700 VELO tracks
- LHC Sector Test on September 5th and 6th, 2x10^{9} p every 48s
  - Lower track density
  - Multiplicity Vertex Locator: 5.3 → 2.6,
  - Vertex Locator, Inner Tracker, Trigger Tracker, Calorimeters, Muon
  - about 700 VELO tracks

A First Glimpse of LHC Protons

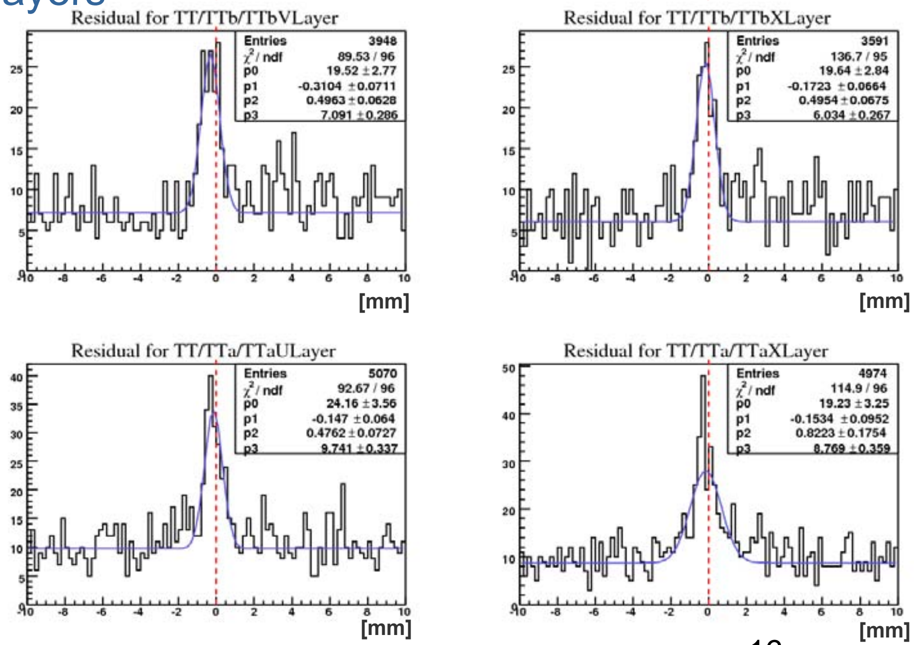


TED Space Alignment

- Extrapolation of Vertex Locator tracks to IT (7m)

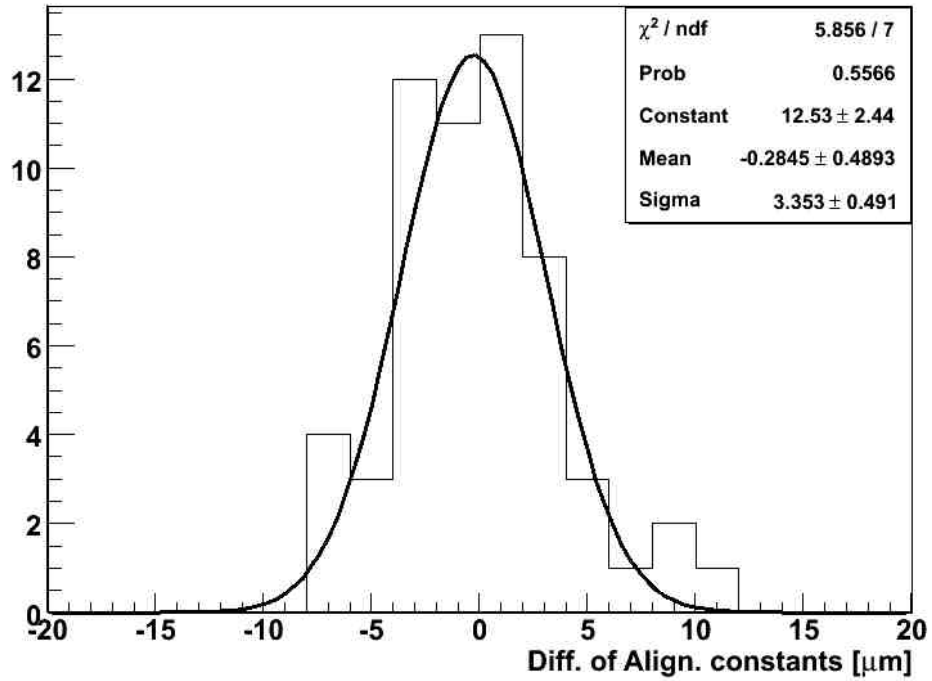


- Extrapolation of Vertex Locator tracks to TT layers
  - Within 300 μm of expected

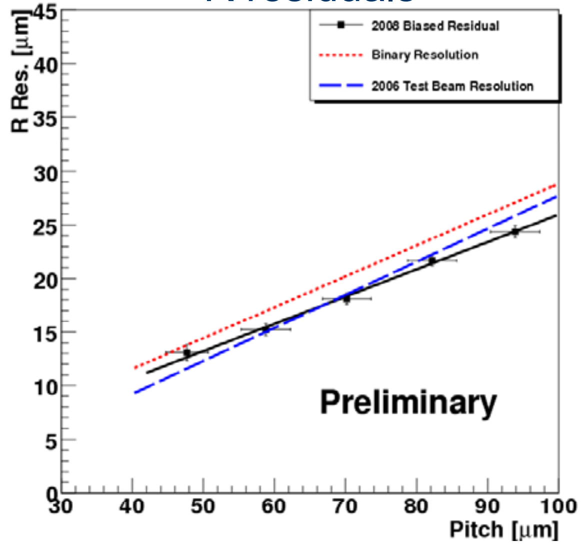


VELO Space Alignment with TED

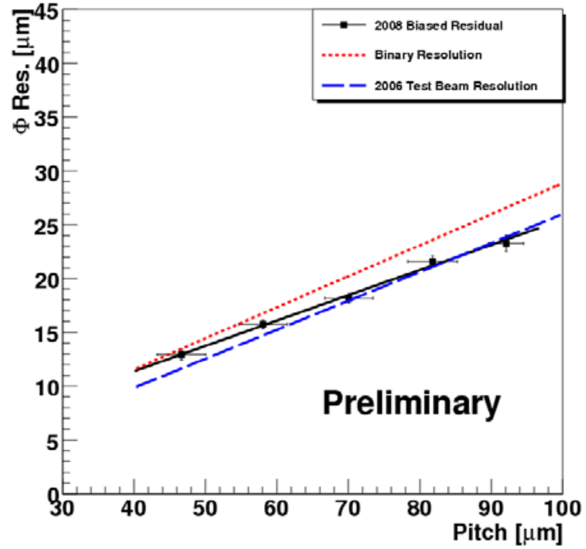
- The detector displacement from metrology usually is less than 10 μm
- Module alignment precision is about 3.4 μm for X and Y translation and 200 μrad for Z rotation



R residuals

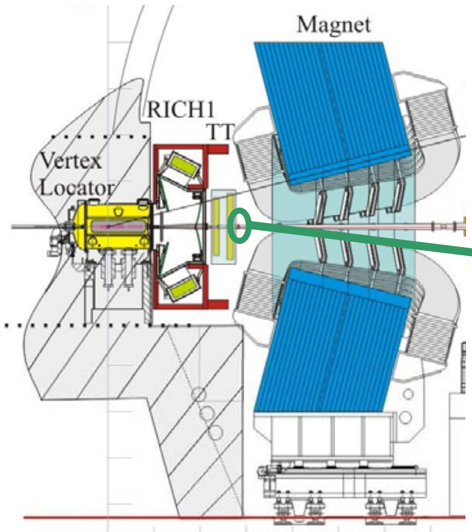


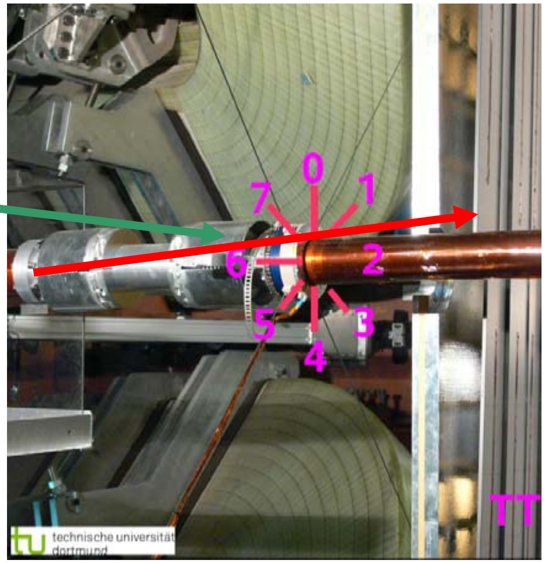
Φ residuals

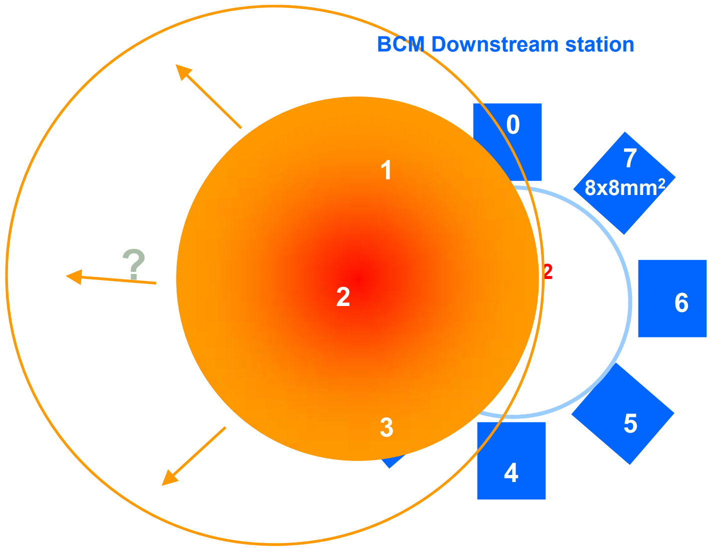


Commissioning Beam Condition Monitor

- LHCb Beam Condition Monitor consists of two stations of CVD diamond sensors
  - Protect experiment against beam losses
  - Difficult to commission properly but we were "lucky"….
- LHCb BCM pulled 'beam dump' three times during LHC Sector Tests
  - Loss appeared as a concentrated shower at ~9 o'clock in BCM as seen along Beam 2
    - Hypothesis: Compatible with little or no injection kick and TDI open at top
    - 7400 nA seen in sensor 2
    - 36 pA/mips ➔ >10^5 particles per sensor ➔ >10^7 particles assuming an area of 10x10cm^2
    - Injection beam absorber slit (TDI) in the wrong position during dumping



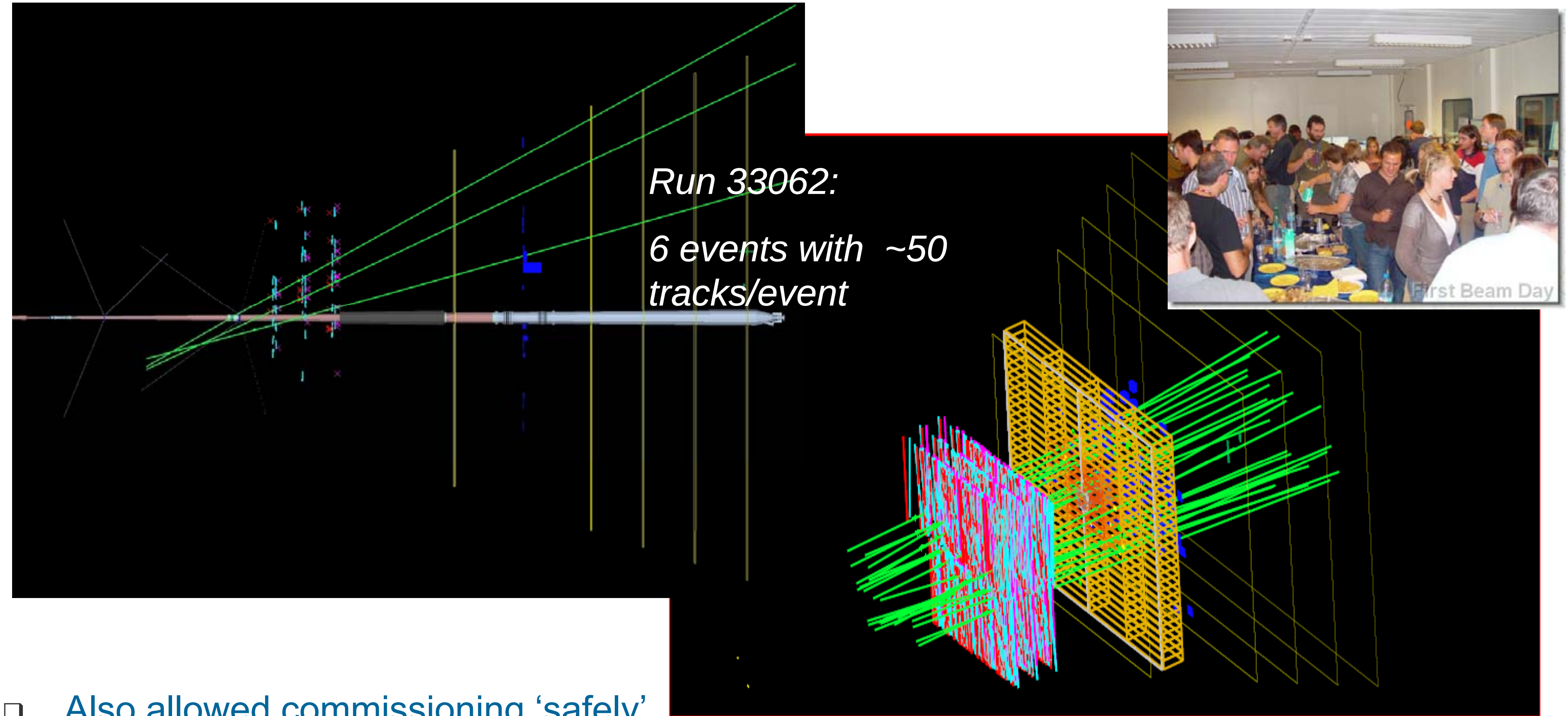




Experience with First Beam

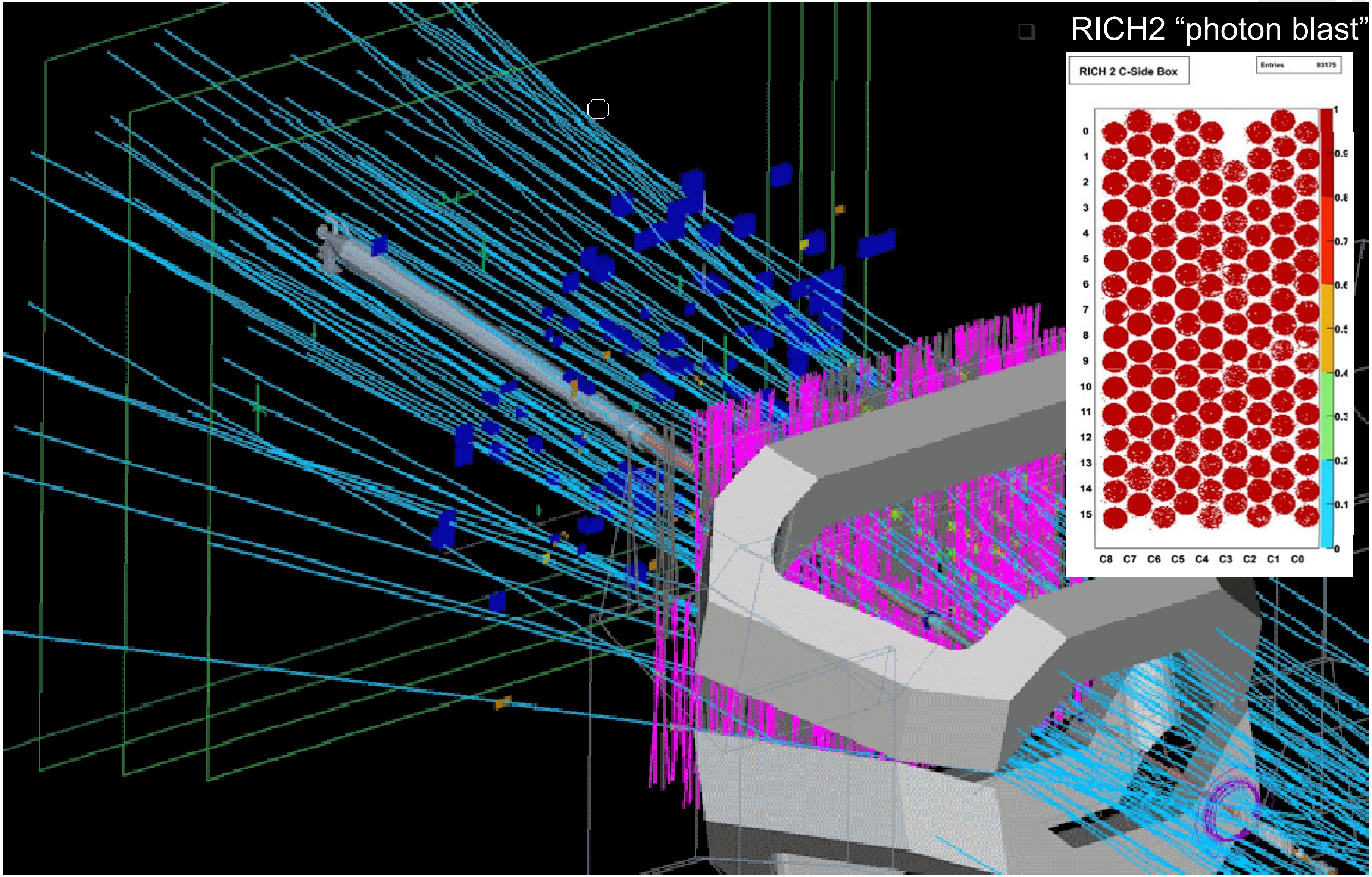
LHC Media Day - September 10

- An all too short honeymoon with LHC…
- Contrary to what we wish for the future, the splashes were Highly Desired Events!



- Also allowed commissioning ‘safely’
  - Software and hardware communication interfaces with LHC
  - Monitoring of LHC instrumentation and beam conditions

Experience with 150 Joules



2008-2009 Shutdown Activities

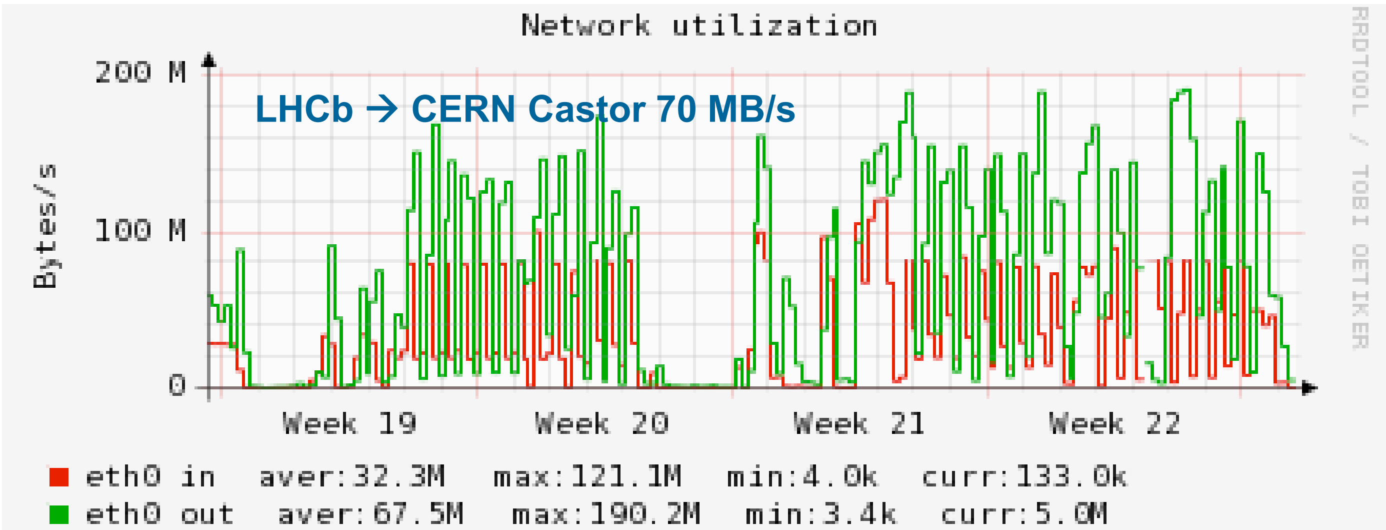
General maintenance, and improvements and repairs which early commissioning identified:

- HPD replacements in RICH
- Modification of the ECAL HV system
- Readout boards aging viases

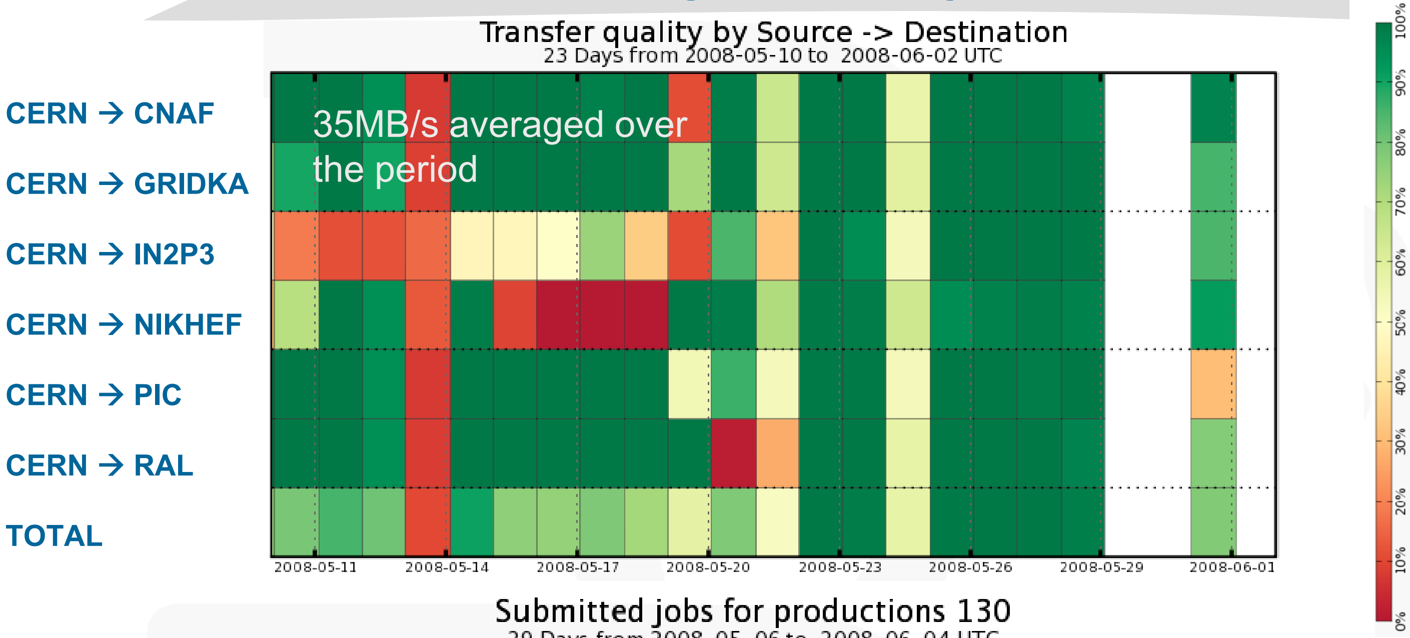
- Data storage for a 2 kHz output rate ready
- Installation of full–size readout network for a 1 MHz readout
- Adding 350 farm computing nodes to the current 200 in place
  - Sufficient bandwidth for a full 1 MHz readout
  - Farm nodes for computing power will be added as needed but infrastructure for up to 2000 in place
- Commissioning 1 MHz readout in April and onwards
- Installation of last Muon station(M1) in between RICH and the Calorimeters
- Improving
  - HV control
  - Data Monitoring
  - Automatizing global control
- Full Experiment System Test (online and offline)

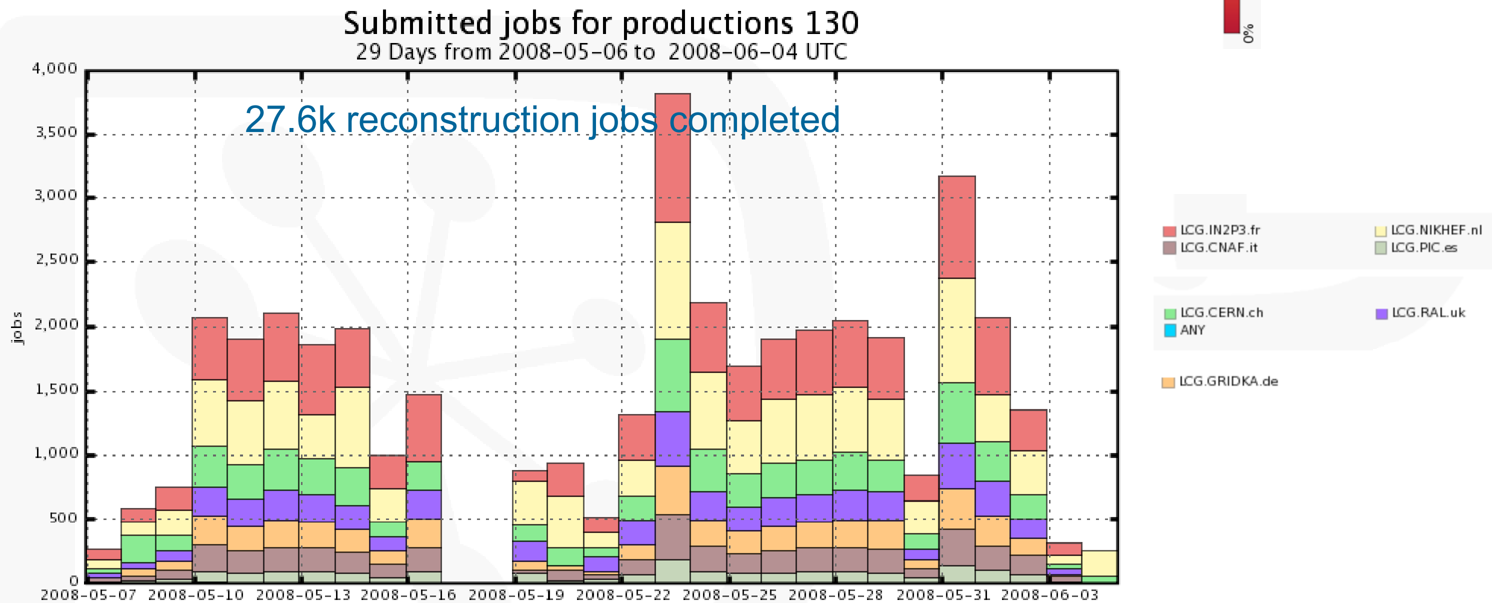
Exercising the System

- Common Computing Readiness Challenge 08 (CCRC'08) validated
  - Raw data upload: Online → Tier0 storage (CERN Castor)
    - Use Distributed Infrastructure with Remote Agent Control (DIRAC) transfer framework
  - Raw data distribution to Tier1s
    - CNAF, GridKa, IN2P3, NIKHEF, PIC, RAL
  - Data reconstruction at Tier0+1
    - Production of RDST, stored locally, and data access
  - Stripping of reconstructed data
    - Distribution of streamed DSTs to Tier1s centres



Exercising the System

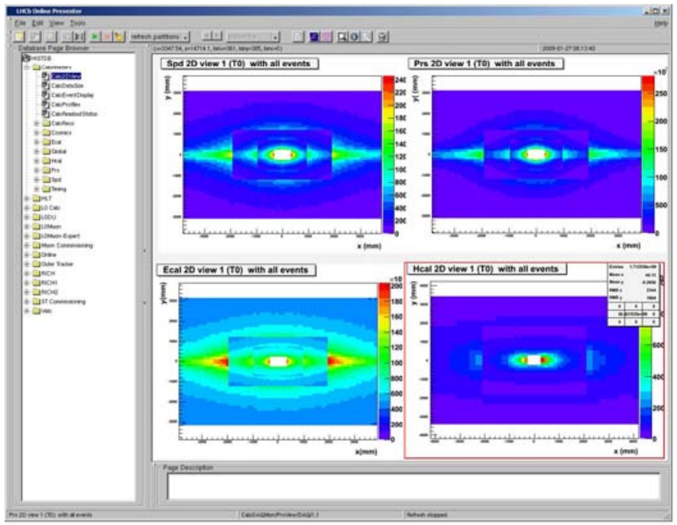




Back to Exercising the System

- Full Experiment System Test:
  - Be ready to receive, process and analyze 7 million events in the first hour of collisions
  - Replacing detector with injection of 10^8 minimum bias “accepted” MC events in Online system at HLT rate
    - 4 TeV beam, Velo closed, field, no spill-over, standard pile-up, 1 x 10^{32} with ~1100 bunch crossings in LHCb for 50ns running, crossing-angle
  - A data flow and processing challenge to test the data-flow AFTER the High Level Trigger
    - Data monitoring, high level trigger configuration, propagation of conditions and alignment constants, express stream, data transfer, run database, bookkeeping, reconstruction in Tier1, data quality checking and procedures, alignment, condition database releases,…

“Data” from last week



Operation and Focus 2009/2010

Our vision of possible operation for 2009/2010

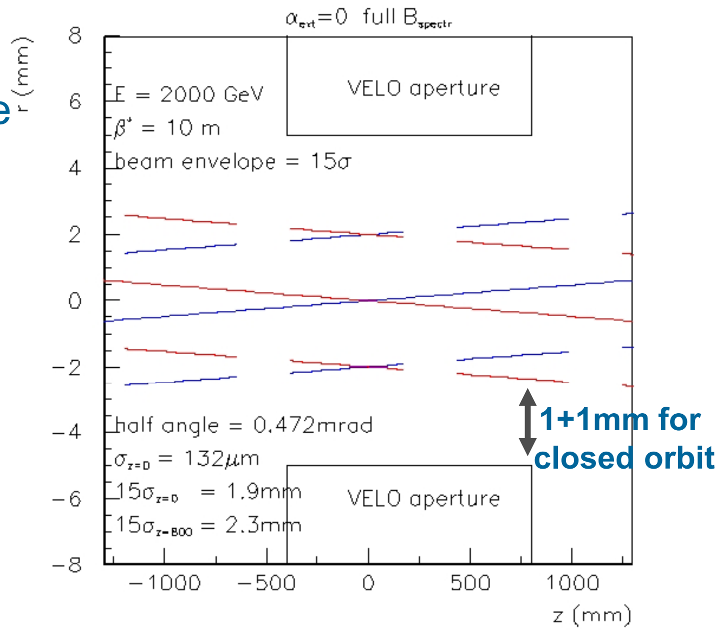
- Generally favouring long stable run as soon as possible after "technical runs"

- "TED runs" : LHC injections with beam on injection beam stopper (TED)
  - A few runs in the month before circulating beams
  - Checking space and time alignment
  - Study tracking

- 450 GeV collisions
  - VELO open, no LHCb B-field
  - Few shifts at 450 GeV to get final time and space alignment

- As soon as possible move to highest possible safe and stable energy
  - Commissioning of LHCb magnets
  - With LHCb B-field at nominal, VELO may only be closed with ≥2 TeV/beam

VELO safety@2 TeV/beam



Operation and Focus 2009/2010

- 68 colliding bunch pairs out of 156, no external crossing, ≥2 TeV/beam (4 TeV/beam) (Nominal 2622 colliding bunch pairs out of 2808 in 3564 possible buckets)
  - 9 x 10^{10} p/bunch, β^*=3m → $\mathcal{L}$ = ~2.3 x 10^{31}
  - Few weeks at 2.3 x 10^{31}, $\varepsilon_{op} = 20\%$ giving us the minimum need of 5 pb^{-1}

  - Goal is to have quickly access to ~10^8 minimum-bias and ~10^6 μμ-events
    - Calibrations
    - Track efficiencies, reconstruction performance, particle ID,….
    - Checking and tuning MC parameters,
    - Exercise fit machinery for analysis
    - Low-p_T physics

- As soon as possible move to a scheme that allows collecting ~0.5 fb^{-1} in the most efficient way to get first results on BR($B_s \rightarrow \mu^+\mu^-$) and ϕ_s
  - 0.3-0.5 fb^{-1} to improve on expected limit from Tevatron with 9 fb^{-1}

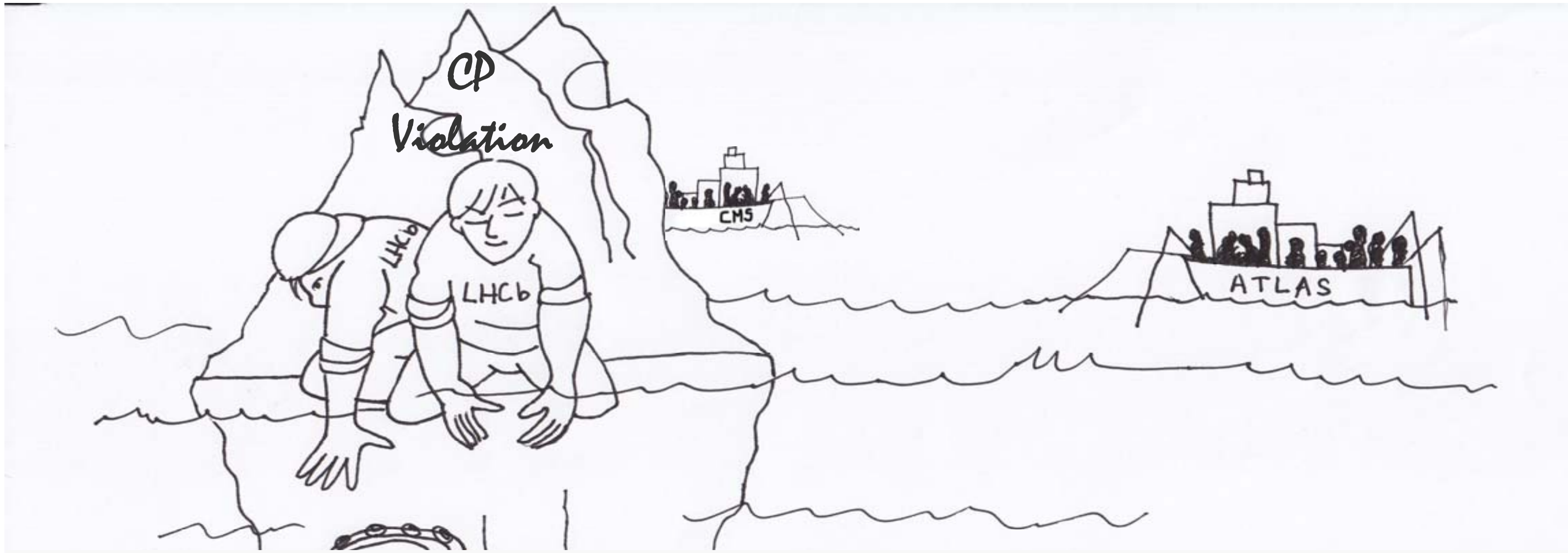
Operation and Focus 2009/2010

- 50ns bunch scheme: 1173 colliding bunch pairs out of 1333, 4(5) TeV/beam
  - 9 x 10^{10} p/bunch, β^*=10m → $\mathcal{L}$ = ~1.3 x 10^{32}
  - 150 days (5m) at 1.3 x 10^{32}, $\varepsilon_{op} = 30\%$ → ~0.5 fb^{-1}
  - Lot of things said about what we can do with a nominal year of 2 fb^{-1} but we will make-do with some very important key measurements with 0.5 fb^{-1} and lower energy (Marie-Noelle's talk).
    - ϕ_s in $B_s \to J/\psi\phi$
    - BR in $B_s \to \mu^+\mu^{+-}$
    - A_{FB} $B \to K^*\mu^+\mu^-$
  - Trigger strategy is being refined to give more importance to inclusive selections of key channels for the first measurements

Conclusions

- LHCb has become an operational experiment “waiting” for beam
- Highly motivated relatively small team
- We were ready in time
  - Cosmics gave a first working point
  - TED events end of August gave the first ever LHC-induced tracks
  - Time alignment and space alignment done at first level
  - Beam-collimator shots were obviously the high-light of 2008, “unfortunately”…
- Shutdown activities progressing well with preparation for 1 MHz readout and many improvements
  - Still many (too…) experts in the control room…necessary ones or not…
- Real-time full-chain tests from High Level Trigger to analysis pre-selection with MC data a very important tool to running in the system
- All in all I hope I have demonstrated that we are ready and merit some New Physics!

Fishing competition



How deep in the turbulent quarksea is the NeoPhysical Beast hiding?

F.M. & R.J., CERN