Readiness of the LHCb experiment for first data

Adriano Lai
INFN – Cagliari
On behalf of the LHCb collaboration

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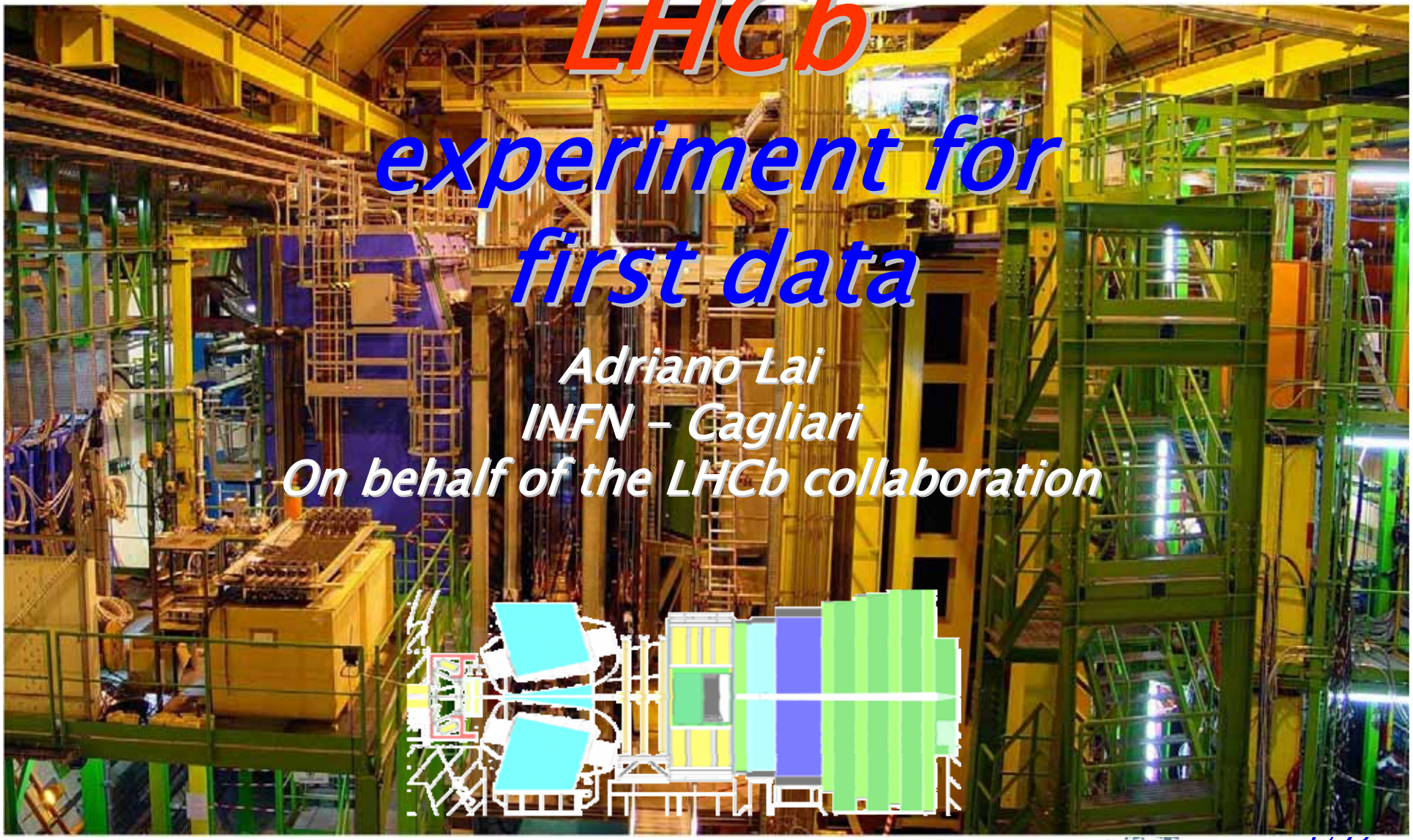

Talk outline

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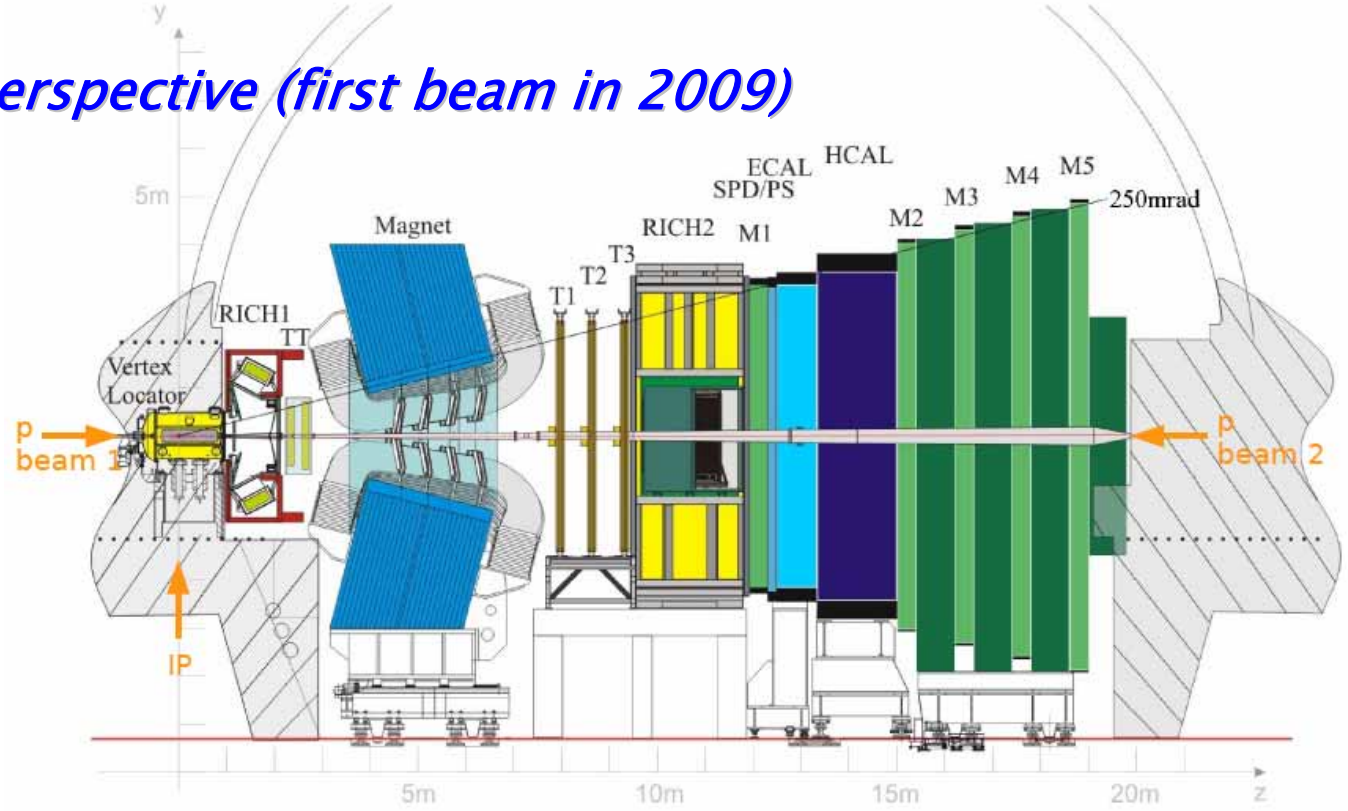
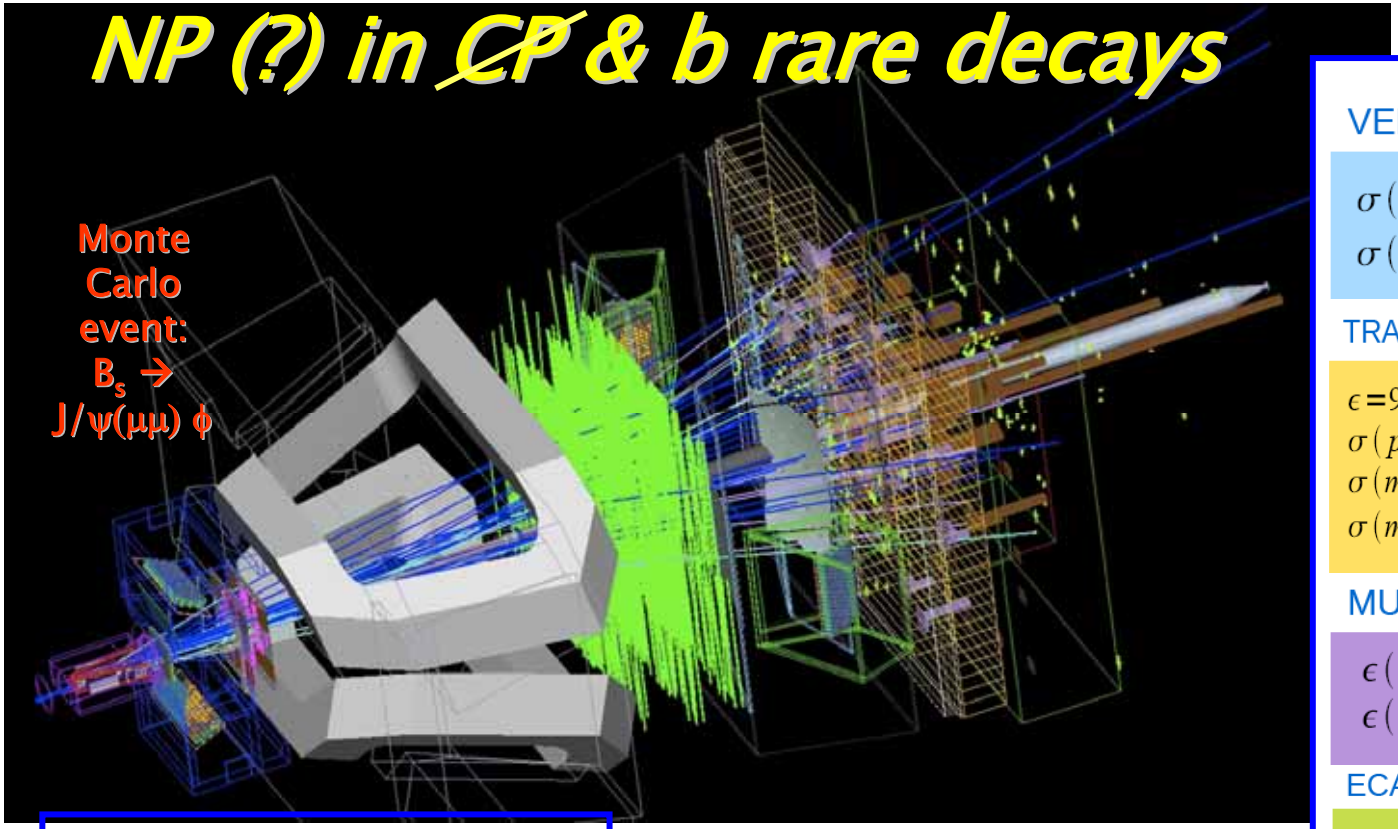
- *Introduction*
- *Some results from experiment commissioning in the last year*
- *Present Activities*
- *Short term perspective (first beam in 2009)*
- *Conclusions*



NP (?) in ~~CP~~ & b rare decays



Potential

Effective σ_{bb}(14 TeV) in LHCb acceptance ~230 μb

$$\int_0^{LHC\_year} Ldt = 2\ \text{fb}^{-1}$$

270 x 10^9 B_d per year
70 x 10^9 B_s per year

All b-hadrons species produced

Challenges

Multiplicity per rapidity unity = 30

Background from high inelastic cross section of 80 mb

Branching ratios for B-meson decays relevant for LHCb physics O(10^{-3} -10^{-9})

Performance

VELO:

$\sigma(IP) \sim (14 + 35/p_T(\text{GeV}))$ μm
$\sigma(t) \sim (40-100)$ fs

TRACKING

$\epsilon = 95\%$ when $p > 5$ GeV and $1.9 < \eta < 4.9$
$\sigma(p)/p \sim 0.4\%$
$\sigma(m[B_s \rightarrow \mu\mu]) \sim 20$ MeV
$\sigma(m[K^*\mu\mu]) \sim 15$ MeV

MUON, RICH

$\epsilon(K) \sim 88\%$ for 3% π mis-id
$\epsilon(\mu) \sim 95\%$ for 5% π/K mis-id

ECAL

$\sigma(E)/E \sim (9.4/\sqrt{E(\text{GeV})} + 0.83) \times 10^{-2}$
$\sigma(m[B_s \rightarrow \phi\gamma]) \sim 90$ MeV

LEVEL–0 TRIGGER

$\epsilon(B_{d,s} \rightarrow J/\psi X) \sim 90\%$
$\epsilon(B_{d,s} \rightarrow hh) \sim 50\%$

LHCb trigger

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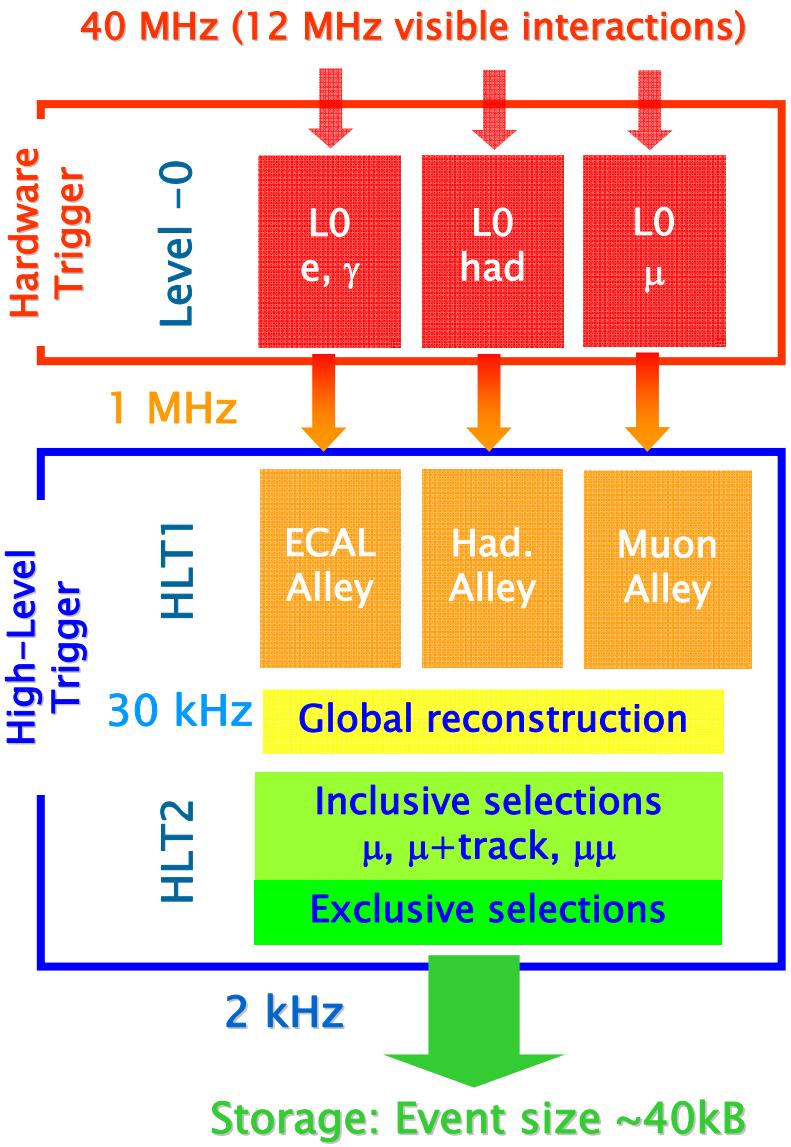

Level-0 Hardware Trigger

high-pT m, e, g, 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 *(C++ application)*

Event Filter Farm with up to 1000 16-core nodes

HLT1: Check L0 candidate with more complete info (tracking), add impact parameters and lifetime cuts

HLT2: global event reconstruction + selections.

	ε(L0)	ε(HLT)	ε(total)
Hadronic	50%	80%	40%
Electromagnetic	70 %	60%	40%
Muon	90%	80%	70%

ε corrected for acceptance and selection

"software" approach provides increasing processing power ~for free

Commissioning (2008)

COSMICS

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– Nominal Muon trigger configuration:

Coincidence of ≥ 1 hit for each muon station in projective geometry (from IP) ~ 0 Hz rate

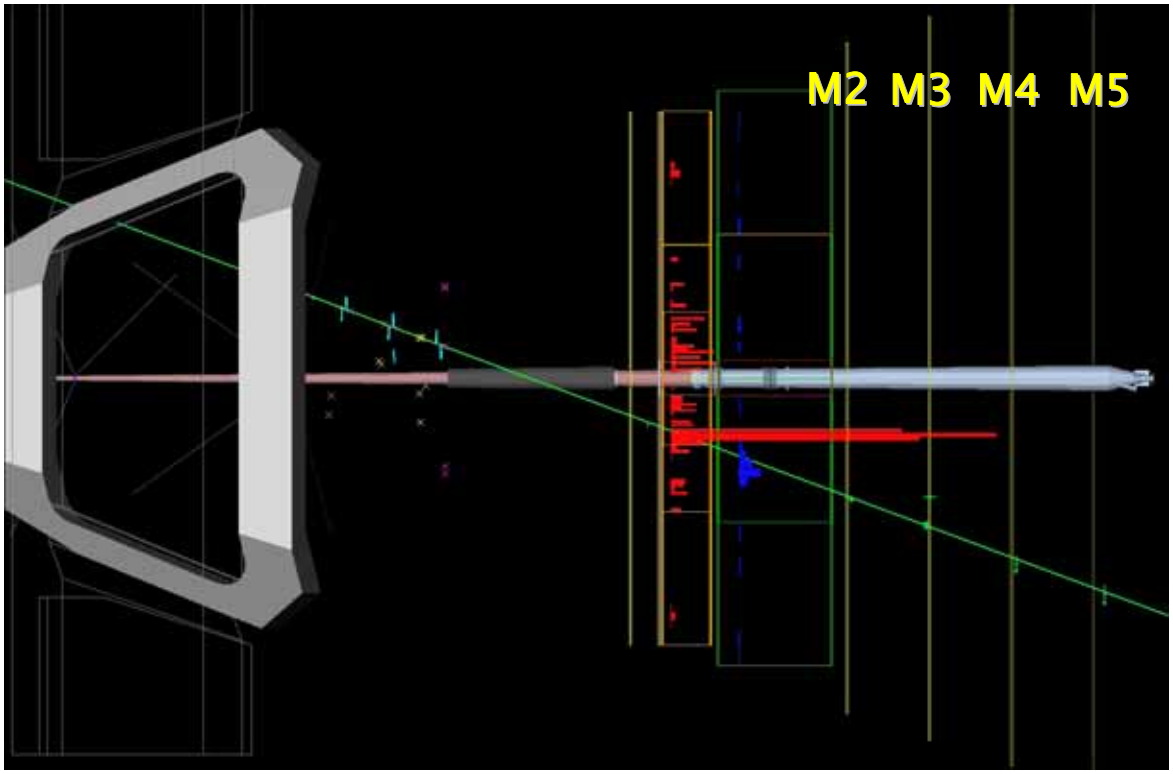
– Used Muon trigger config:

≥ 1 hit in station M3
→ 60 Hz rate
≥ 1 hit in stations (M4 & M5)
→ 4 Hz rate

– Calorimeter trigger:

ECAL & HCAL with high gain (MIP)
→ 10 Hz rate

"Wrong" detector geometry, but still well visible in large sub-detectors (Muon, Calo, Outer Tracker)



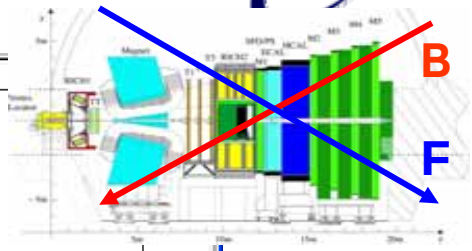
OR of Calorimeter and Muon triggers (in various combinations)

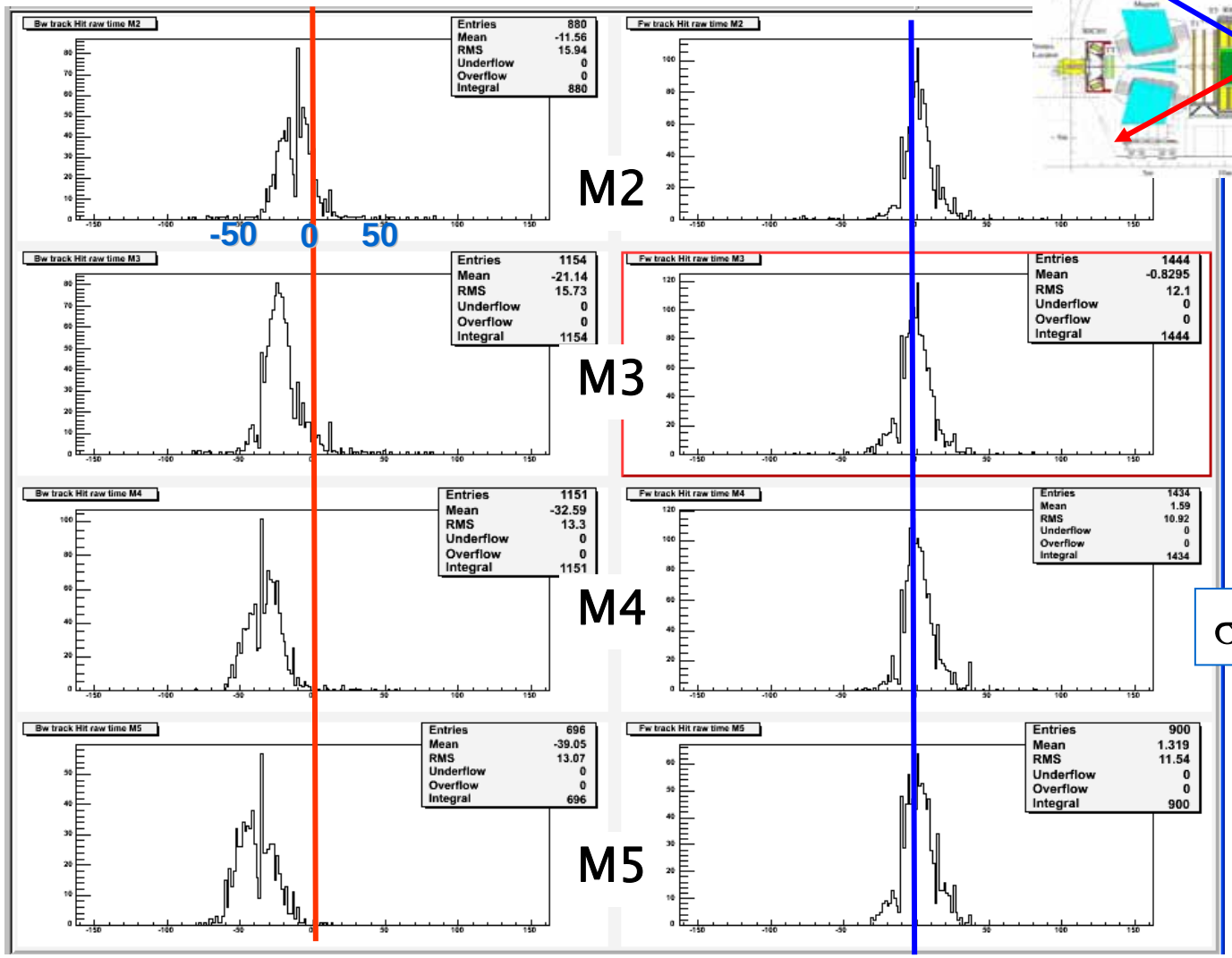
1.8 x 10^6 triggers acquired during Summer 2008

→ *Extensive commissioning of basic L0 building blocks*

First muon Alignment with cosmics

Backward tracks **Forward tracks**





Hit raw time (ns)

No analysis, no TOF corrections

σ ~11 ns

Alignment corrections loaded to be aligned on forward tracks

… After data analysis of events from cosmics

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Cleaning of tracks
(tracks with only 4 hits)

Detailed TOF
correction

Average on smaller
detector areas
(not enough statistics
on single channels)

station and region	time res
M2 R2	5.9 ± 1.6
M3 R2	6.5 ± 1.3
M4 R2	6.5 ± 1.4
M5 R2	5.8 ± 1.6
M2 R3	5.2 ± 0.5
M3 R3	5.0 ± 0.5
M4 R3	6.5 ± 0.4
M5 R3	6.5 ± 0.4
M2 R4	5.0 ± 0.1
M3 R4	4.9 ± 0.1
M4 R4	5.1 ± 0.1
M5 R4	5.6 ± 0.1

Low stat

5.3

5.7

6.0

6.0

Expectations from lab measurements

Muon detector Efficiency

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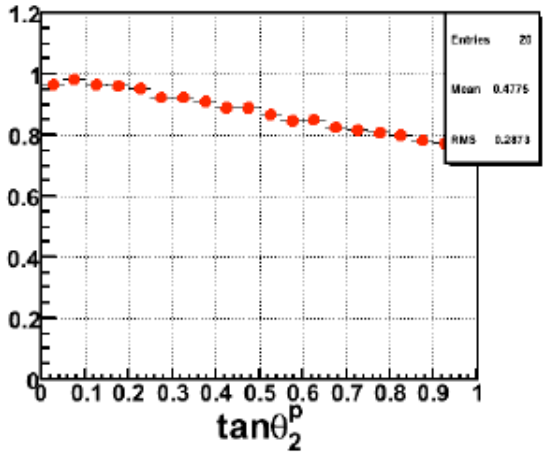
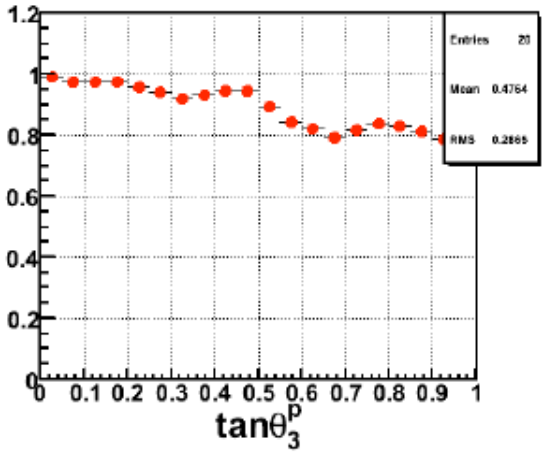
M2	M3	M4	M5
(84.8±0.1)%	(87.0±0.1)%	(89.8±0.1)%	(89.4±0.1)%

Not corrected for projectivity

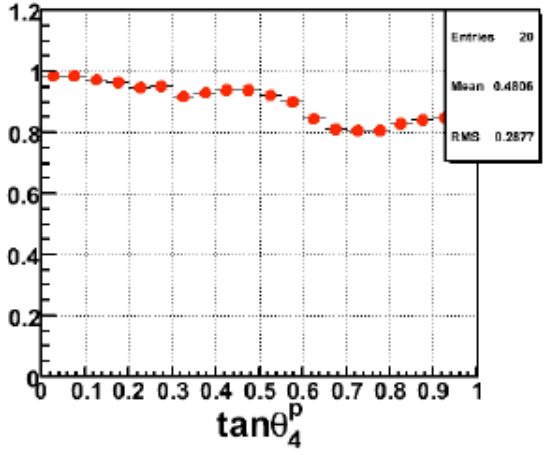
M2



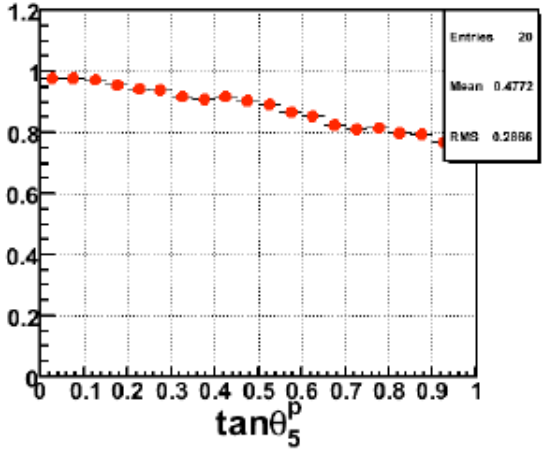
M3



M4



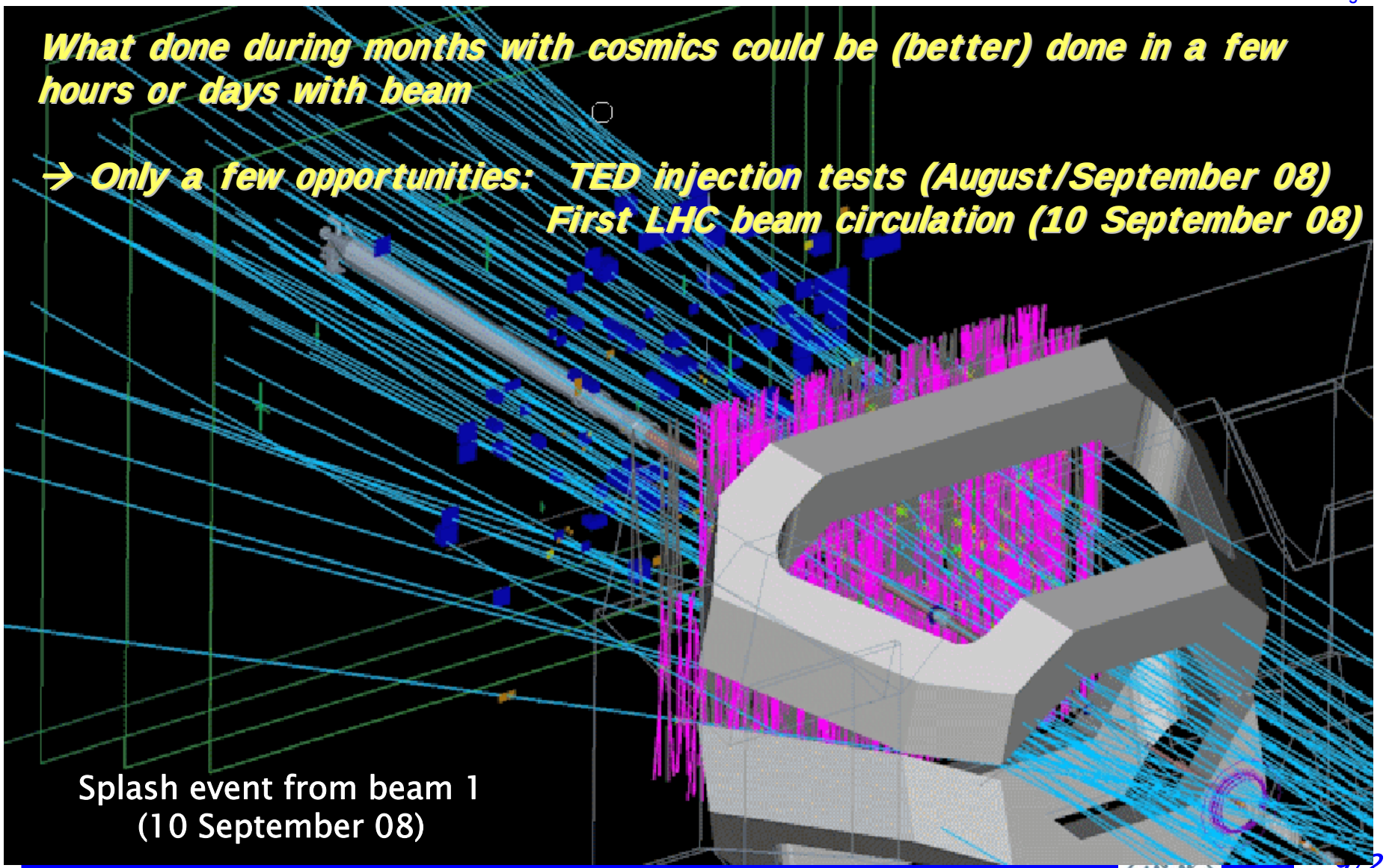
M5



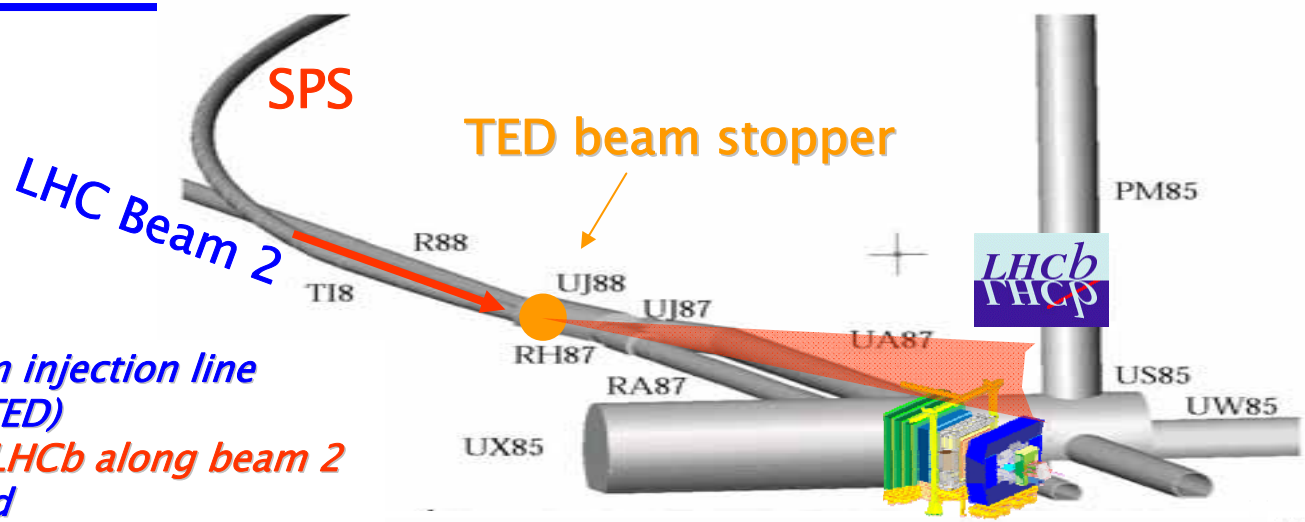
ε as a function of the track angle

Commissioning (2008)

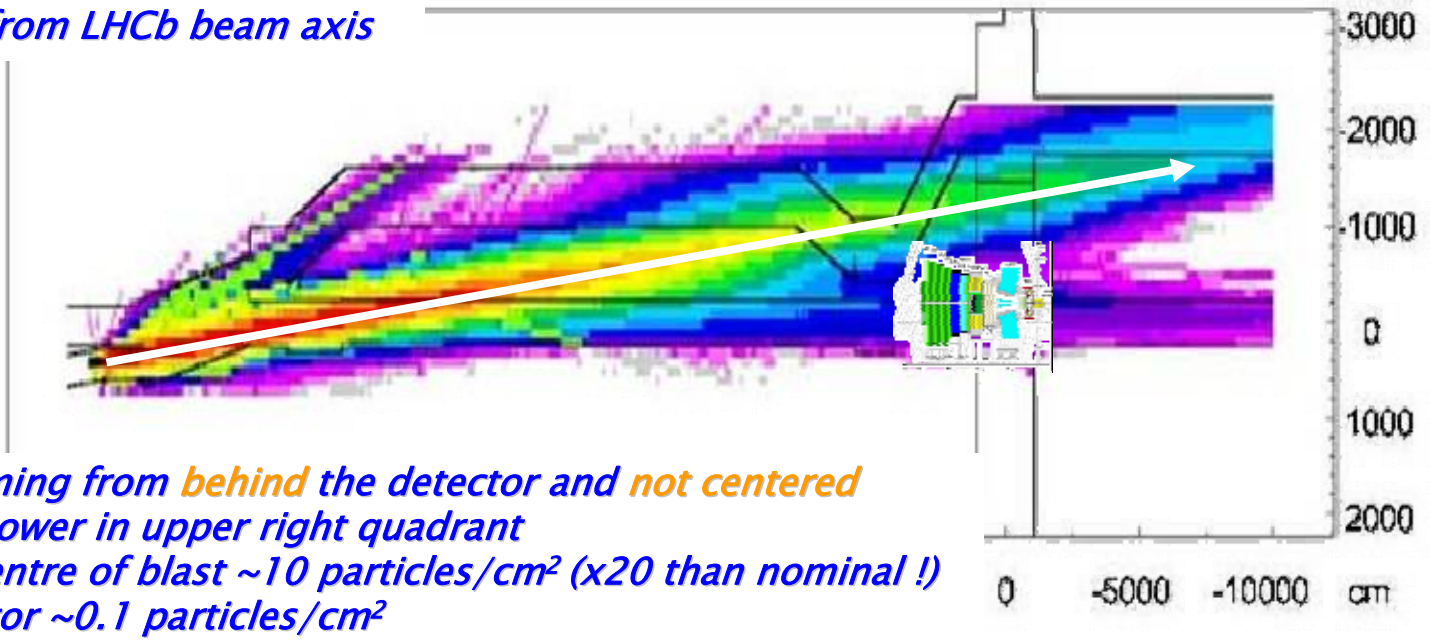
Particle blasts… the more messy the better…



TED runs



Beam 2 dump on injection line beam stopper (TED)
- *340m before LHCb along beam 2*
- *8 mrad H and*
- *12 mrad V from LHCb beam axis*



Particles coming from behind the detector and not centered
Centre of shower in upper right quadrant
High flux, centre of blast ~10 particles/cm² (x20 than nominal !)
Vertex Locator ~0.1 particles/cm²

TED runs (2)

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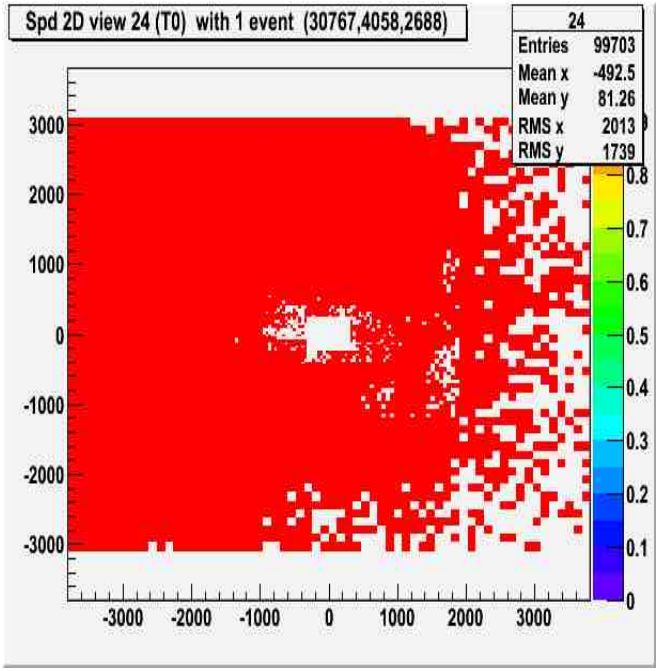
Trigger by Scintillator Pad Detector (SPD) multiplicity.

Readout of consecutive triggers centered on the triggered event (Time Alignment Events)

SPD



2 usable LHC injection tests:

August 22nd, 5x10⁹ p per shot (every 48s)
Muon, Calo, VELO
700 tracks in VELO

September 5th and 6th, lower flux 2x10⁹ p per shot
Muon, Calo, VELO, IT, TT
700 tracks in VELO

Useful tests to verify space and time alignment within single sub-detectors and among sub-detectors
First opportunity of "good" statistics in small area detectors (VeLo, TT)

Pictures from TED runs

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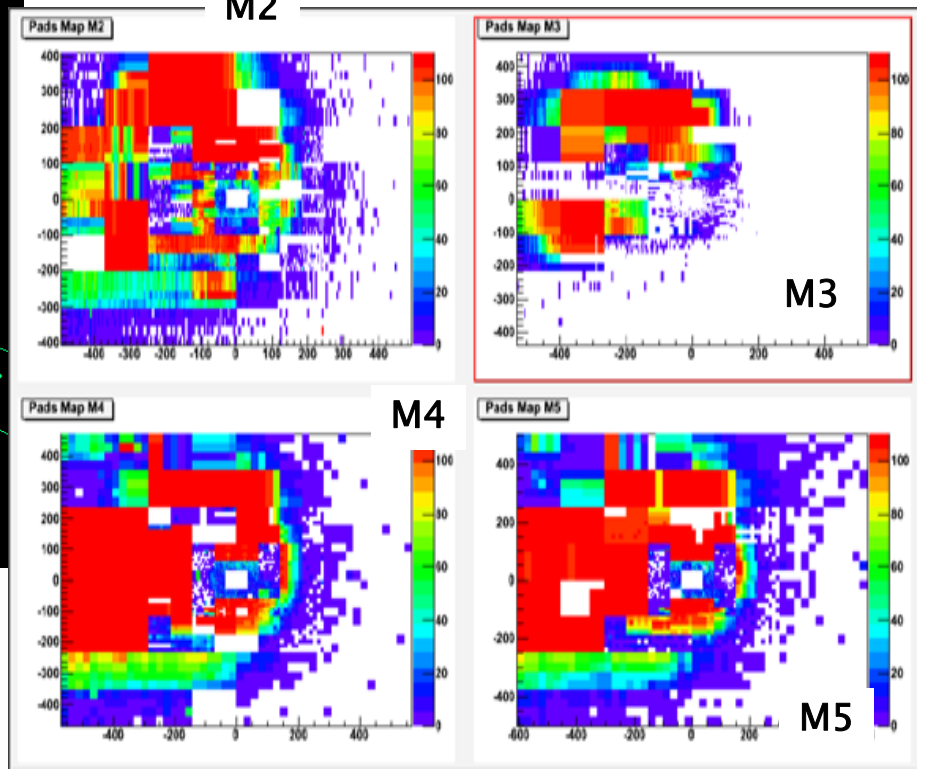
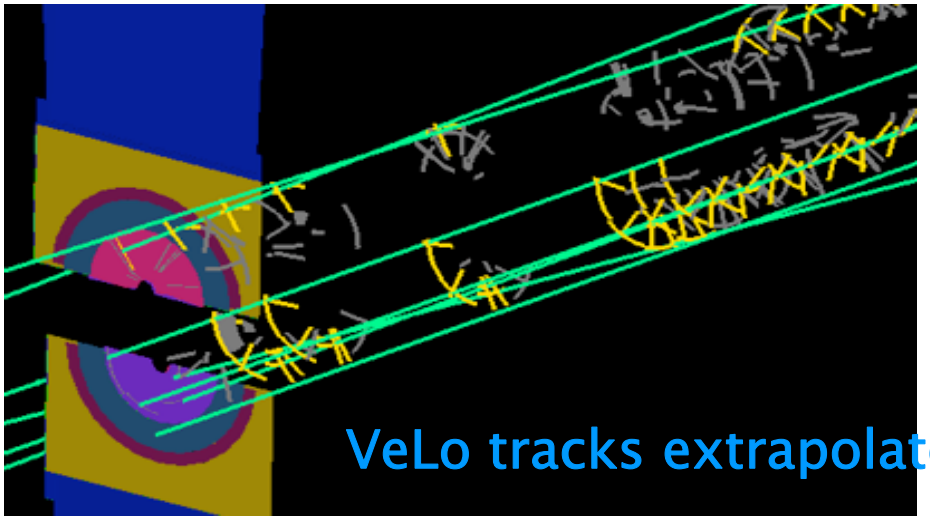


Muon
~70 candidates per shot



TED runs and Alignments : highlights from space domain

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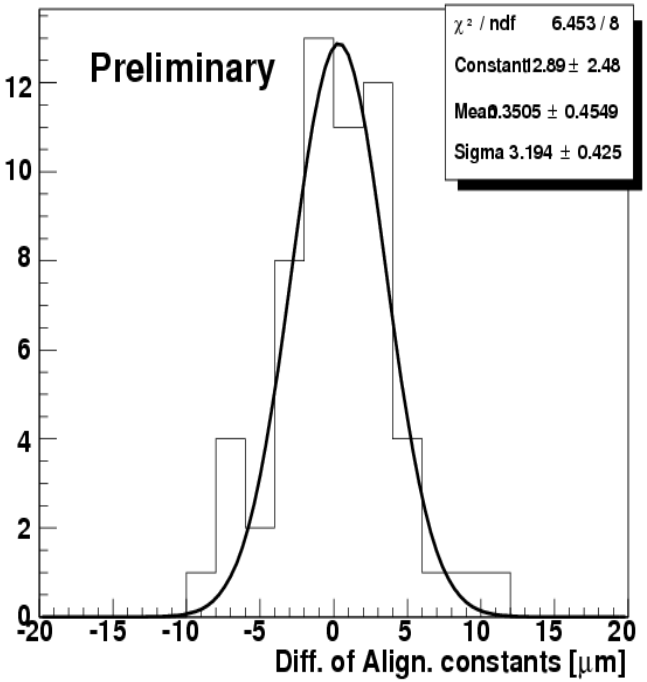
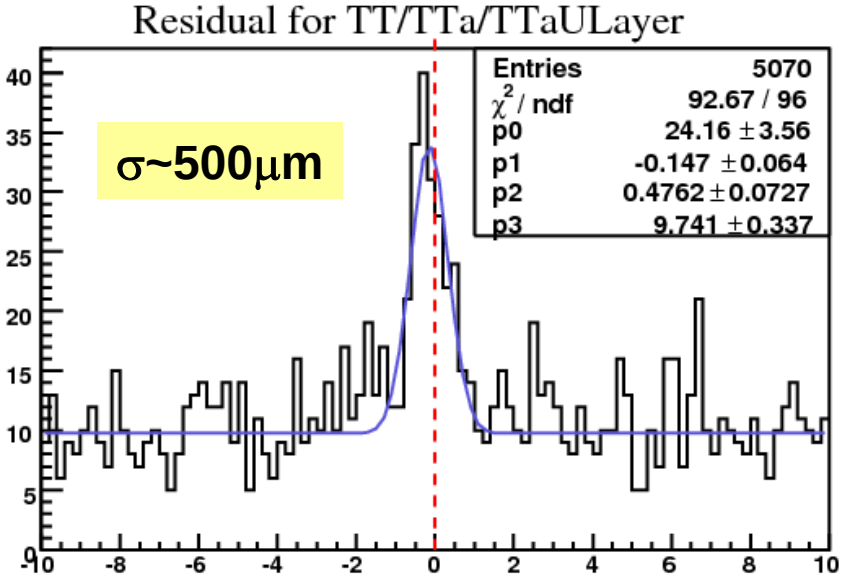


VELO alignment:

Module alignment precision is about 3.4 μm for X and Y translation and 200 μrad for Z rotation



Relative alignment VELO-TT (~1.5m apart)

- Expected *uncertainty* in VELO-TT extrapolation: 300μm
- Hit residuals observed in TT: 500μm
- Offsets: 150-300μm

September, 10th 2008

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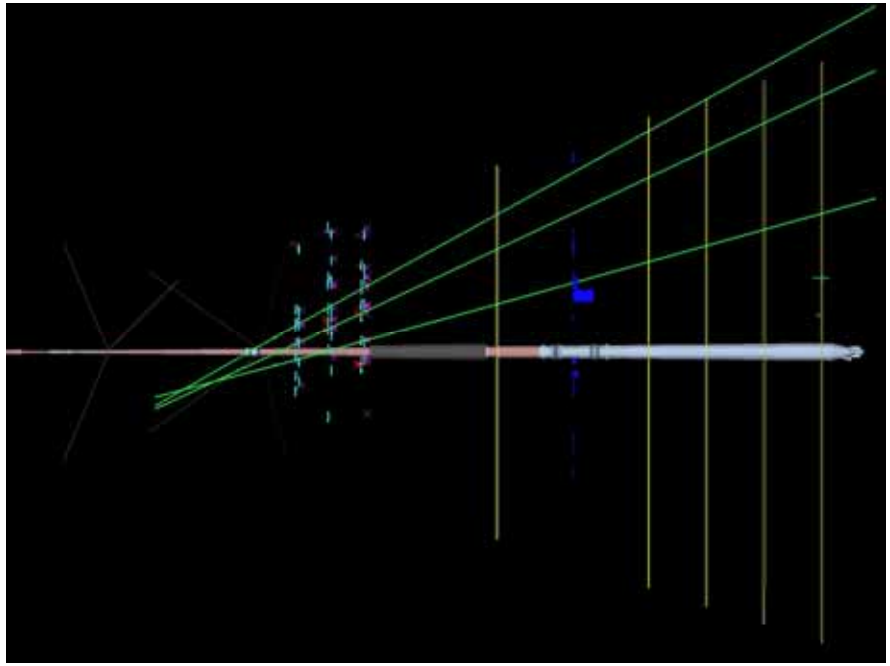

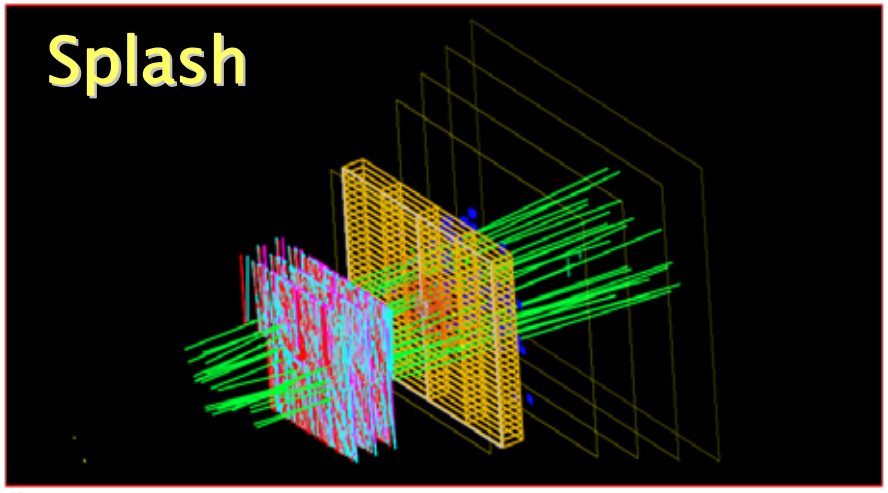

1st circulating beams (no collisions yet)
Beam 1 in the right direction:
Looking for halo and splash events

Important testbench for:

- ***Alignments***
- ***Experiment operation (smooth and quick on/off of the system)***

Exciting yet too short

- ***Very good response of Control and DAQ Systems***
- ***Use of "physics" Muon trigger (4-fold coincidences)***

Beam 1 on RICH2

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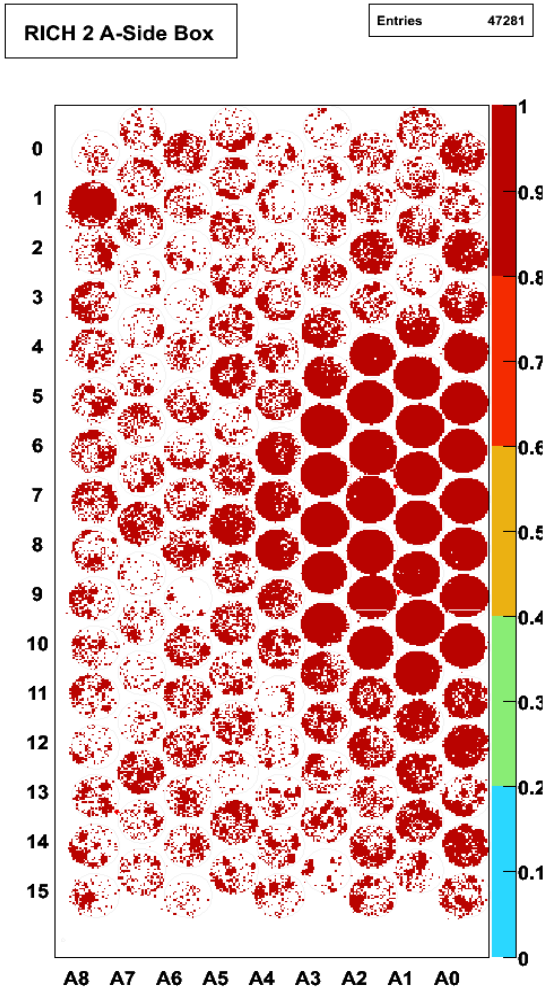
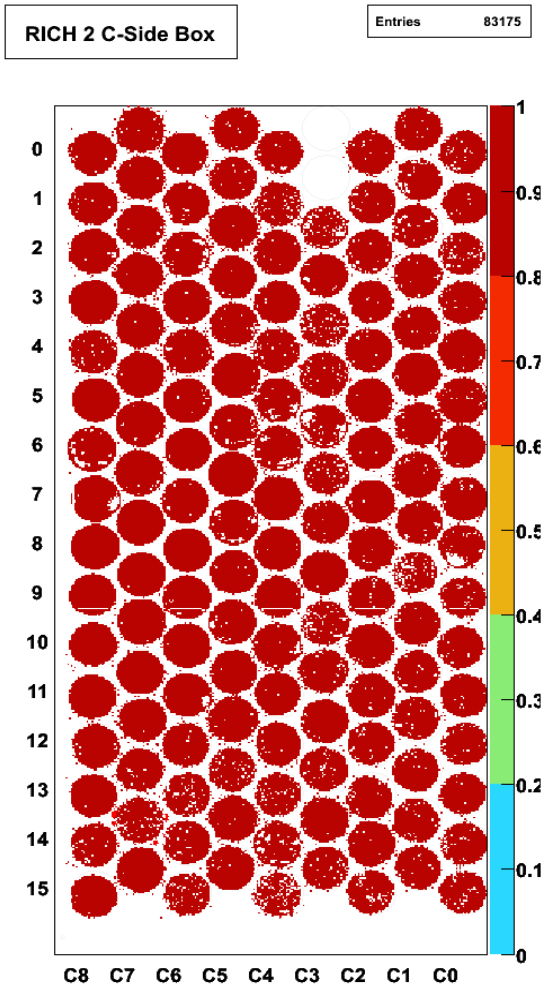


One event in RICH2 during the beam1 on collimator runs on September 10th.

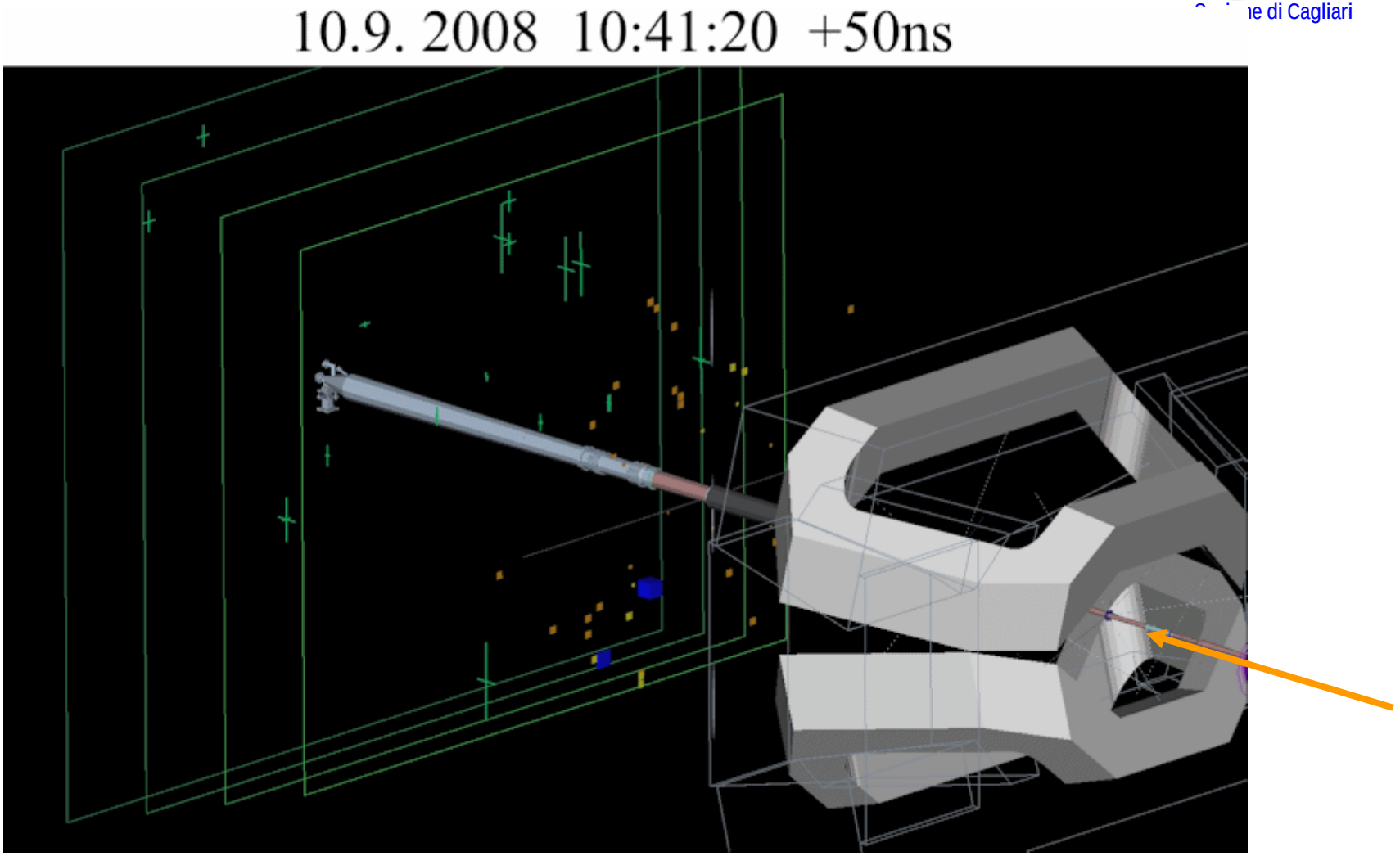
Photon blast, occupancy as high as 140k hits, out of roughly 200k pixels in the active area.

RICH1 stayed off during these runs (too close to the beam pipe).

Timing inside 25 ns window



First beam: Calo & Muon



5 consecutive time slots acquired per trigger

Tracks in the Outer Tracker

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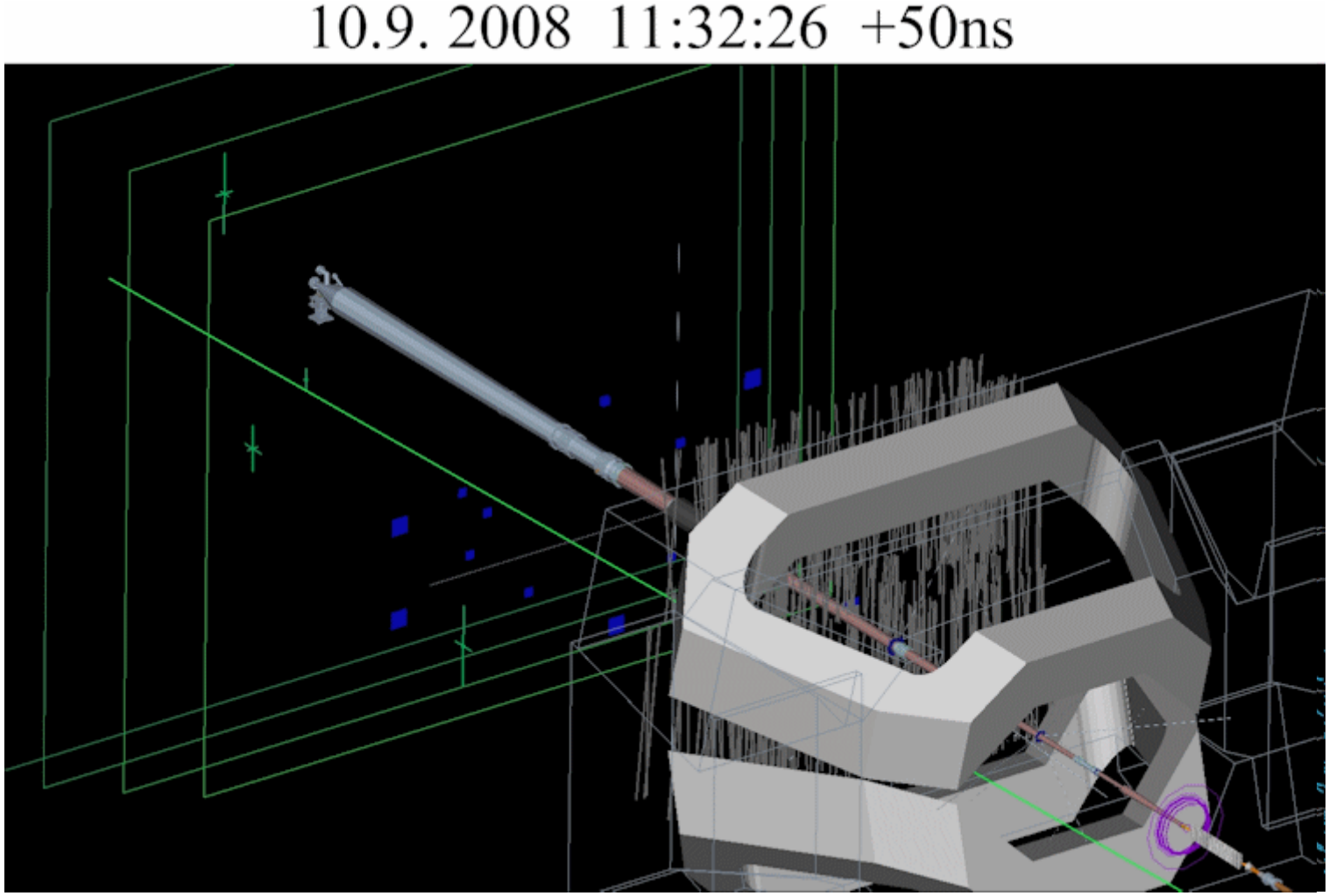

5 consecutive time slots acquired per trigger

Back-end tests

FEST (Full Experiment System Test)

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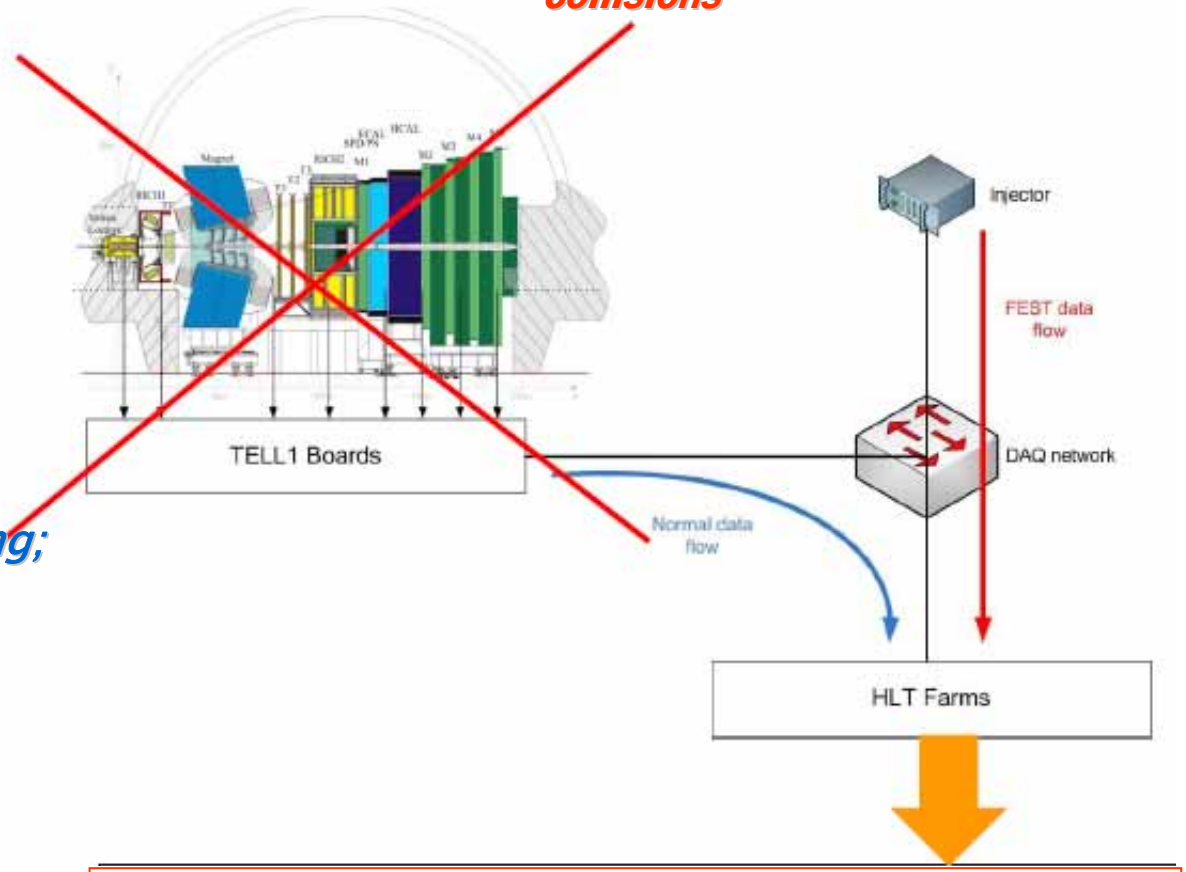
Raw-Monte Carlo events injected into the DAQ chain as if coming from the readout boards

(@2kHz "preselected events that will pass the HLT")

***AIM**: get prepared to receive, process and analyze 7 million events in the first hour of collisions*



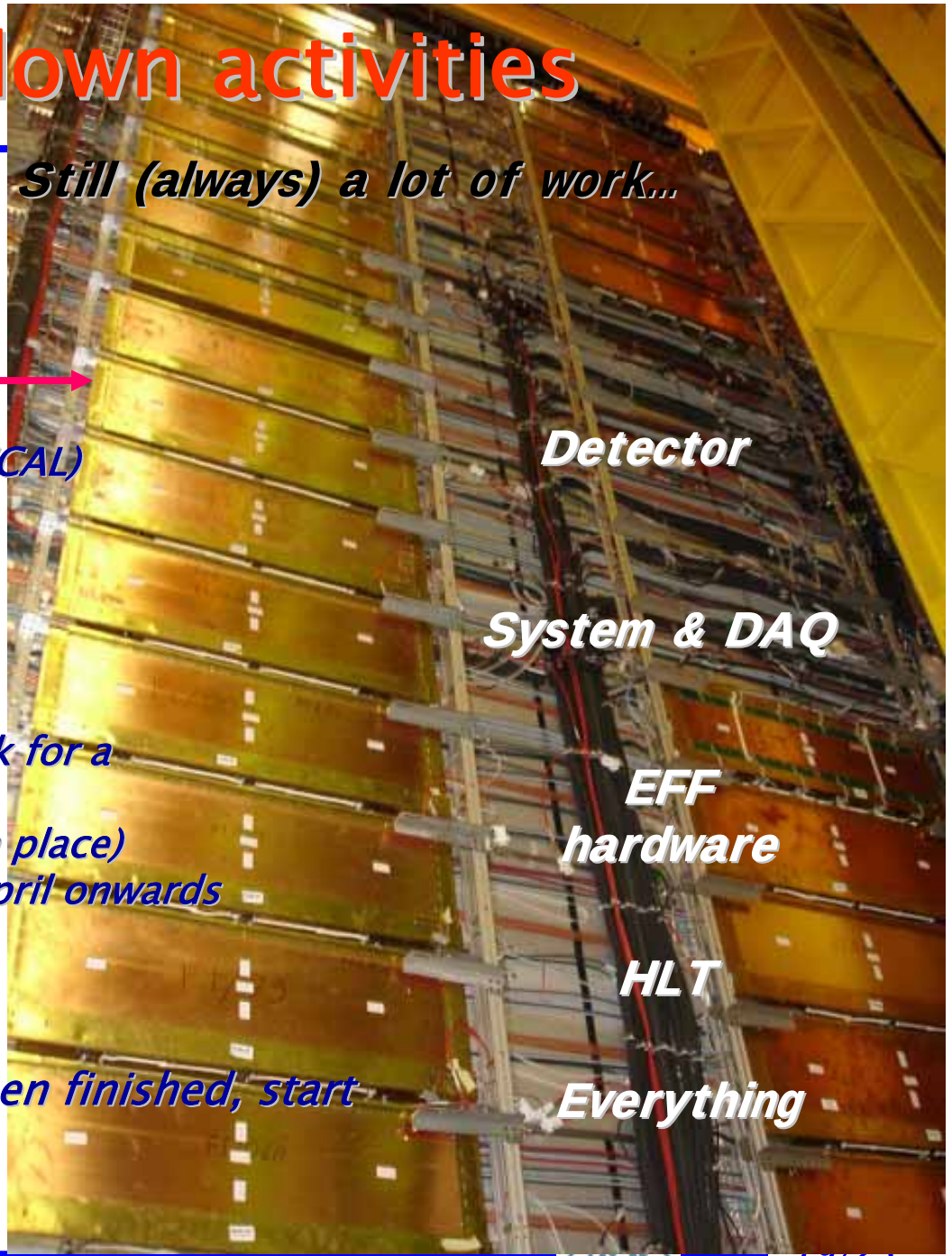
What we test:

- *Run control (the "injector" emulates a sub-detector);*
- *Data stream;*
- *Dynamic farm node balancing;*
- *Data monitoring;*
- *Data storage*
- *Interaction with the GRID*

1.9kHz achieved steadily (limited by MC injector)

Online and offline data monitoring and processing

2009 Shutdown activities



Still (always) a lot of work…

Main activities until next July:

M1 installation and commissioning → **Detector**
HPD replacement (RICH)
HV and readout boards modification (ECAL)
Fixing of defective channels (MUON)

Control System optimization → **System & DAQ**
FEST weeks

Installation of full-size readout network for a 1 MHz readout
(add 350 nodes to the 200 presently in place) → **EFF hardware**
Commissioning 1 MHz readout from April onwards

Reduce HLT output rate to 2 KHz → **HLT**

Debug, continue to debug and, when finished, start debugging again → **Everything**

LHC schedule 2009/10

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What we can expect/hope today:

TED runs (August)
450 Gev runs (September)

Preliminary phase
(~like planned one year before…)

October and beyond

450 GeV → 2 TeV	*Setting-up run*
2 TeV → 4 TeV, 5 pb^{-1} overall	*Technical run*
4 TeV 50 ns, 0.5(3) fb^{-1} overall	*Physics run*

LHCb plans 2009/10

Set-up and Technical phases: ramping from 450 GeV to 4 TeV

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68 colliding bunch pairs out of 156

9 x 10^{10} p/bunch, β^*=3m ➔ *L* ~2.3 x 10^{31} (target *L*)

Few weeks @ 2.3 x 10^{31}, ε_{op} = 20% ➔ 5 pb^{-1}

Up to 2 TeV (6-7 weeks ?):

1. *Refine time and space alignment reaching nominal conditions.*

2. *VELO open, no LHCb B-field*
(With LHCb B-field at nominal, VELO may only be closed with ≥2 TeV/beam)

≥2 TeV/beam (6-7 weeks ?):

1. *Operation of LHCb magnets*
2. *Closing of VELO*

LHCb plans 2009/10

Physics runs @ 4 TeV

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50ns bunch scheme: 1173 colliding bunch pairs out of 1333, 4(5?) TeV/beam

9×10^{10} p/bunch, $\beta^*=10$m ➔ $\mathcal{L} = \sim 1.3 \times 10^{32}$

200 days @ 1.3×10^{32}, $\varepsilon_{op} = 20/30\%$ ➔ **~0.3(5) fb^{-1}**

Nominal LHCb year should provide 2 fb^{-1} @ 7 TeV

...but significant measurements @ 0.3 fb^{-1} and lower energy are possible

$B_s \rightarrow J/\psi(\mu^+\mu^-)\,\phi$ — **$2\beta_s$ measurement competing or better than Tevatron result**

$B_s \rightarrow \mu^+\mu^-$ — **BR limit approaches SM value**

A_{FB} in $B_d \rightarrow K^*\mu^+\mu^-$ — **Statistics ~4 times better than present B-factories**

Trigger strategy is adapted to favor inclusive selections of key channels for the first measurements

Conclusion

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LHCb is eager to receive the first collisions (we need them!) to conclude commissioning and tune calibrations towards nominal conditions

The experiment is well advanced in preparing the reception of the first collisions at moderate luminosity as soon as the LHC will be able to deliver significant physics (DAQ, HLT and analysis)

Our (reacheable!) target is collecting and quickly exploiting 0.3 fb^{-1} of physics in the first "year" of run

THANK YOU !

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