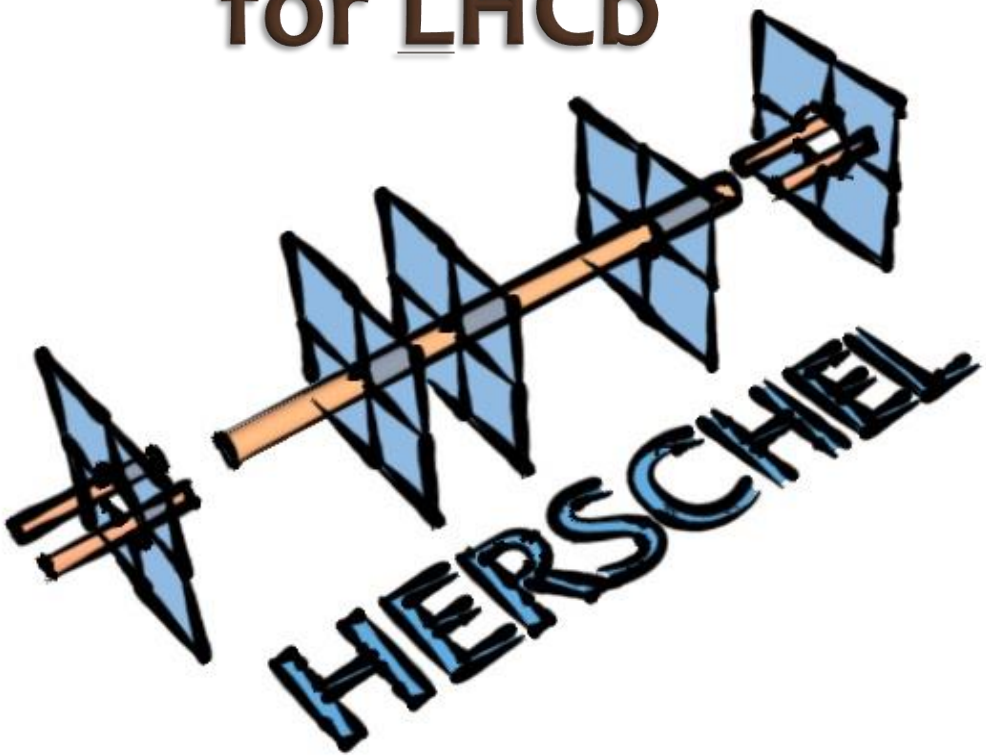
The High Rapidity Shower Counters for LHCb



Kazu Akiba – CERN/UFRJ-Brazil

On behalf of the Herschel team:

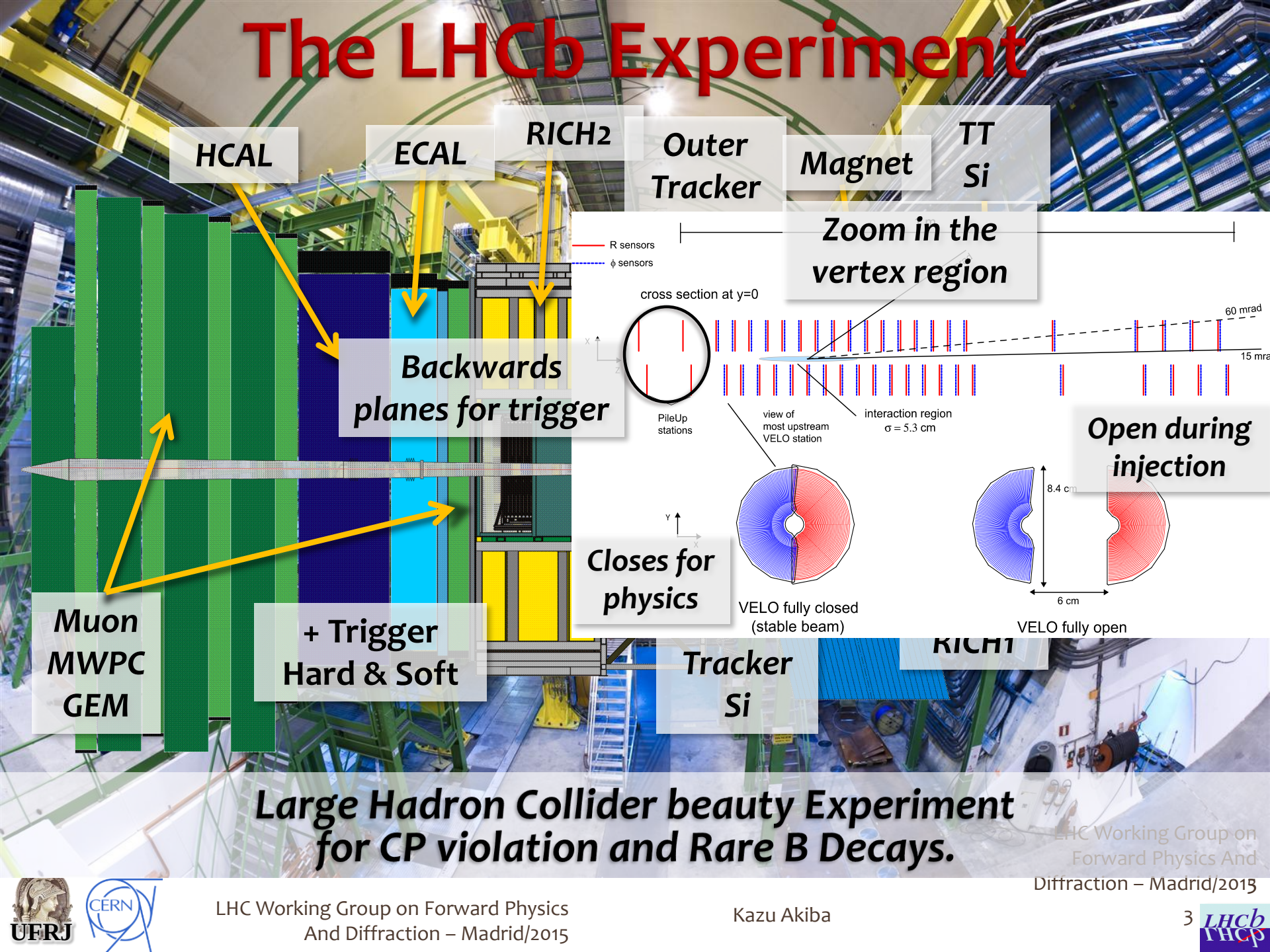
V. Coco , P. Collins , P. Dziurdzia , R. Dumps , R. Dzhelyadin, R. Jacobsson, C. Joram, D. Lacarrere
R. McNulty , L. Roy , H. Schindler , S. Stevenson , C. Thomas , G. Wilkinson

UFRJ CERN LHCb

Outline

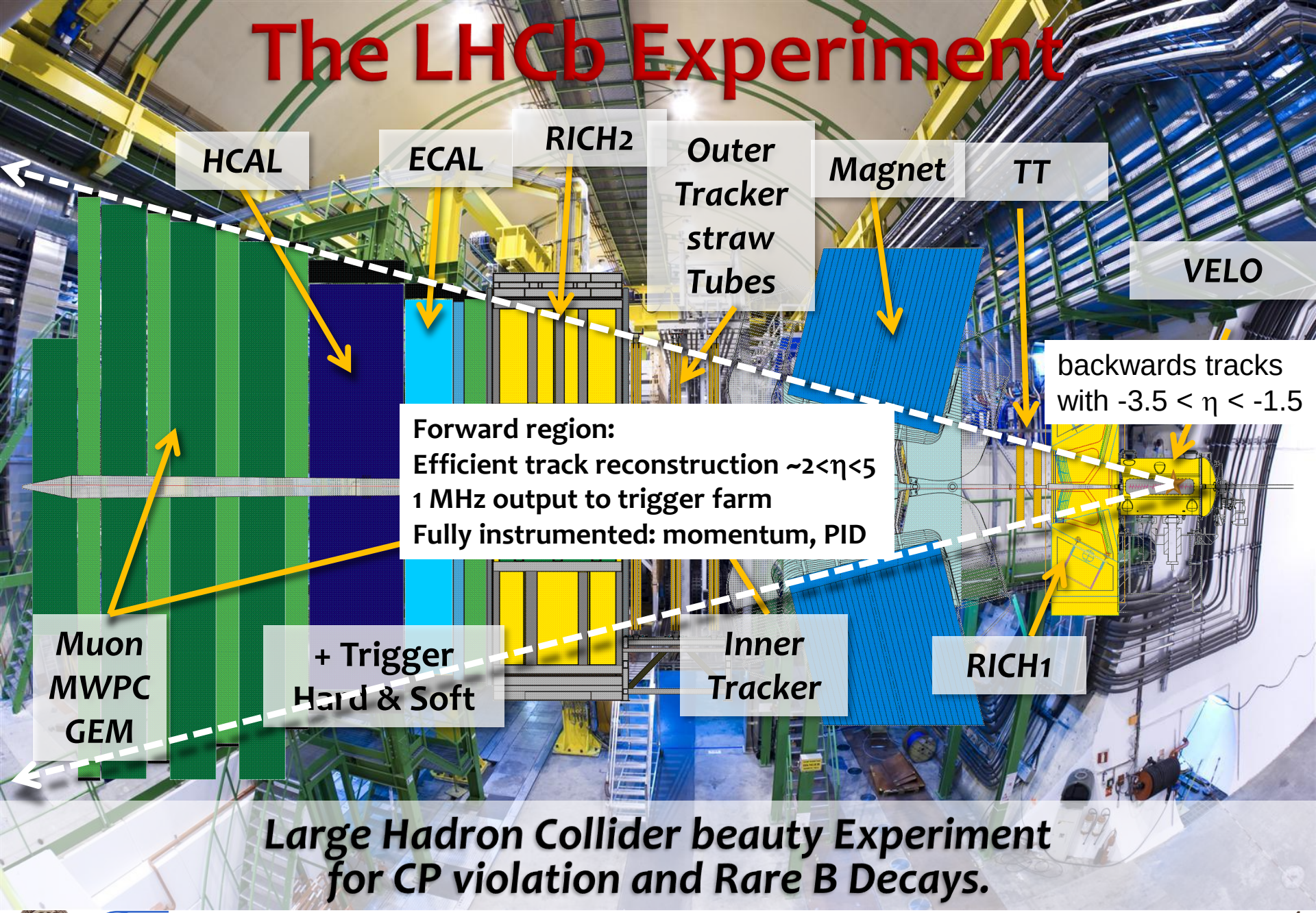
- LHCb Detector and CEP
  - Physics results by D. Johnson on Friday.
- Motivation to extend LHCb coverage
  - CEP physics and beyond
- The Herschel Project
  - Detector Design
  - First results
- Status and Prospects

The LHCb Experiment



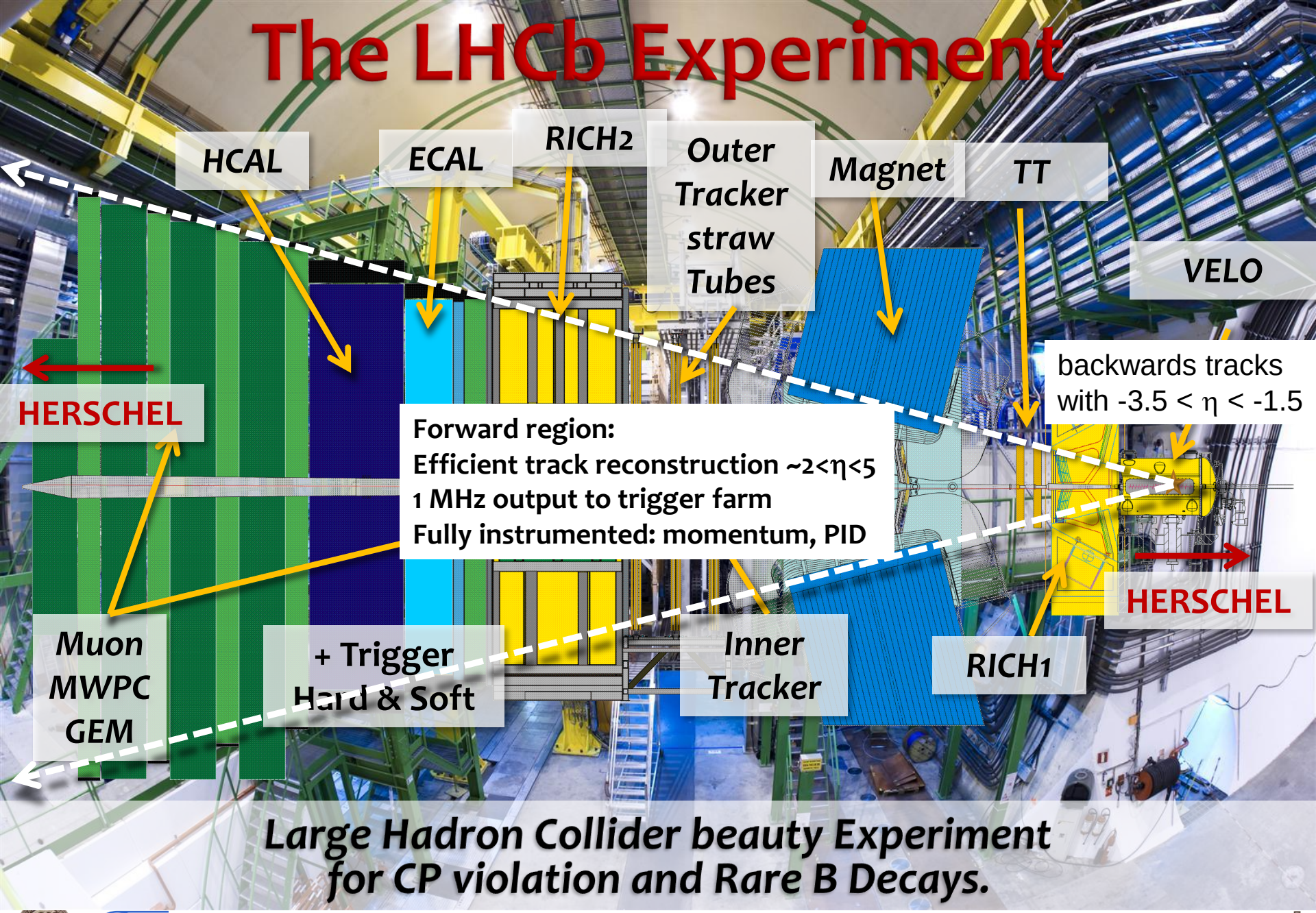
Large Hadron Collider beauty Experiment for CP violation and Rare B Decays.

The LHCb Experiment



Large Hadron Collider beauty Experiment for CP violation and Rare B Decays.

The LHCb Experiment



Large Hadron Collider beauty Experiment for CP violation and Rare B Decays.

CEP@LHCb

- LHCb very well suited to studies of CEP production

- Access to high rapidities
  - $2 < \eta < 5$ acceptance for forward tracking;
  - good complementarity with ATLAS/CMS
  - Some sensitivity to backwards tracks with $-3.5 < \eta < -1.5$

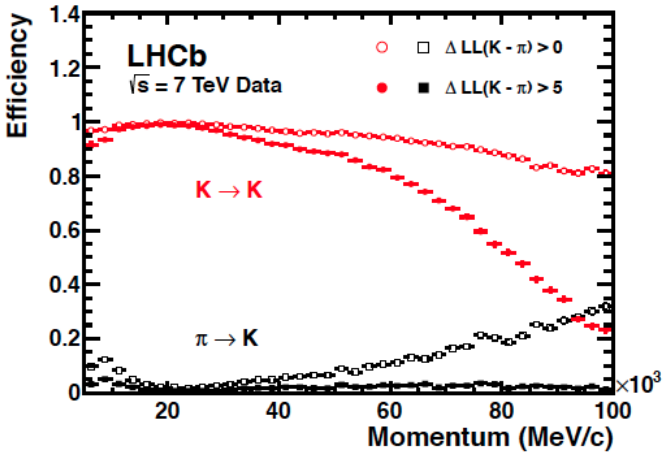
- Relatively low pileup
  - Analysis greatly simplified by using single interaction events

- Trigger
  - First level trigger output rate of 1 MHz
  - muon/calo + some VELO information available
  - Flexibility available at second level trigger with full event information

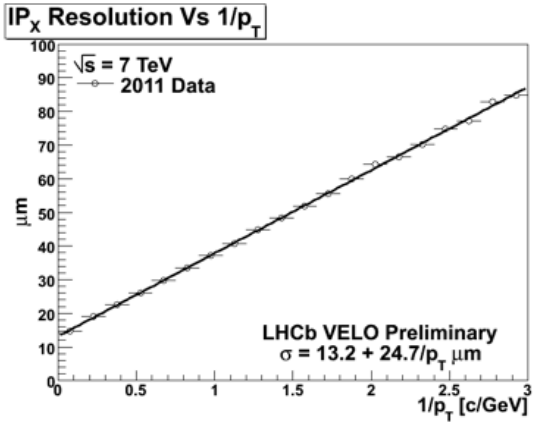
- Excellent particle ID
  - Possibility to distinguish CEP decays to K,p,μ,π final states

- Sensitivity to low p and low p_T particles
  - both at trigger stage, and for precise reconstruction

RICH Particle ID performance

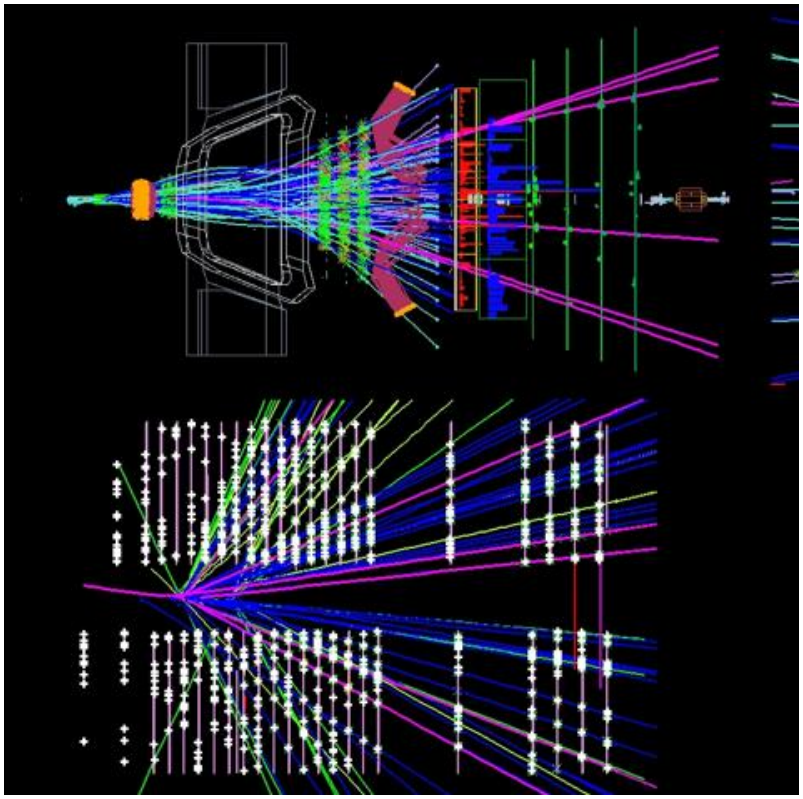


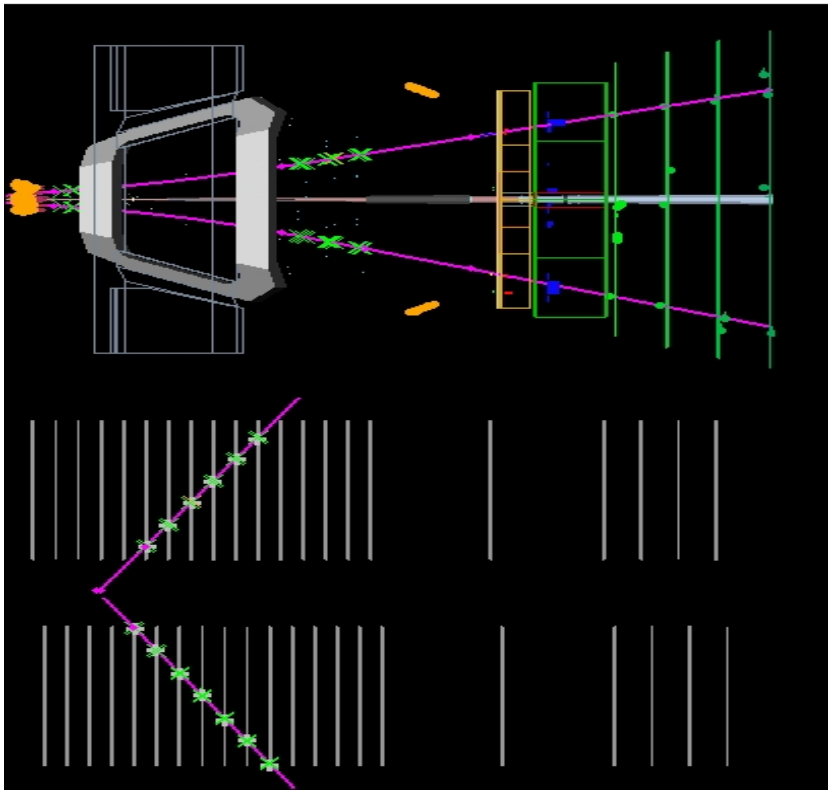
VELO impact parameter resolution



CEP Trigger at LHCb

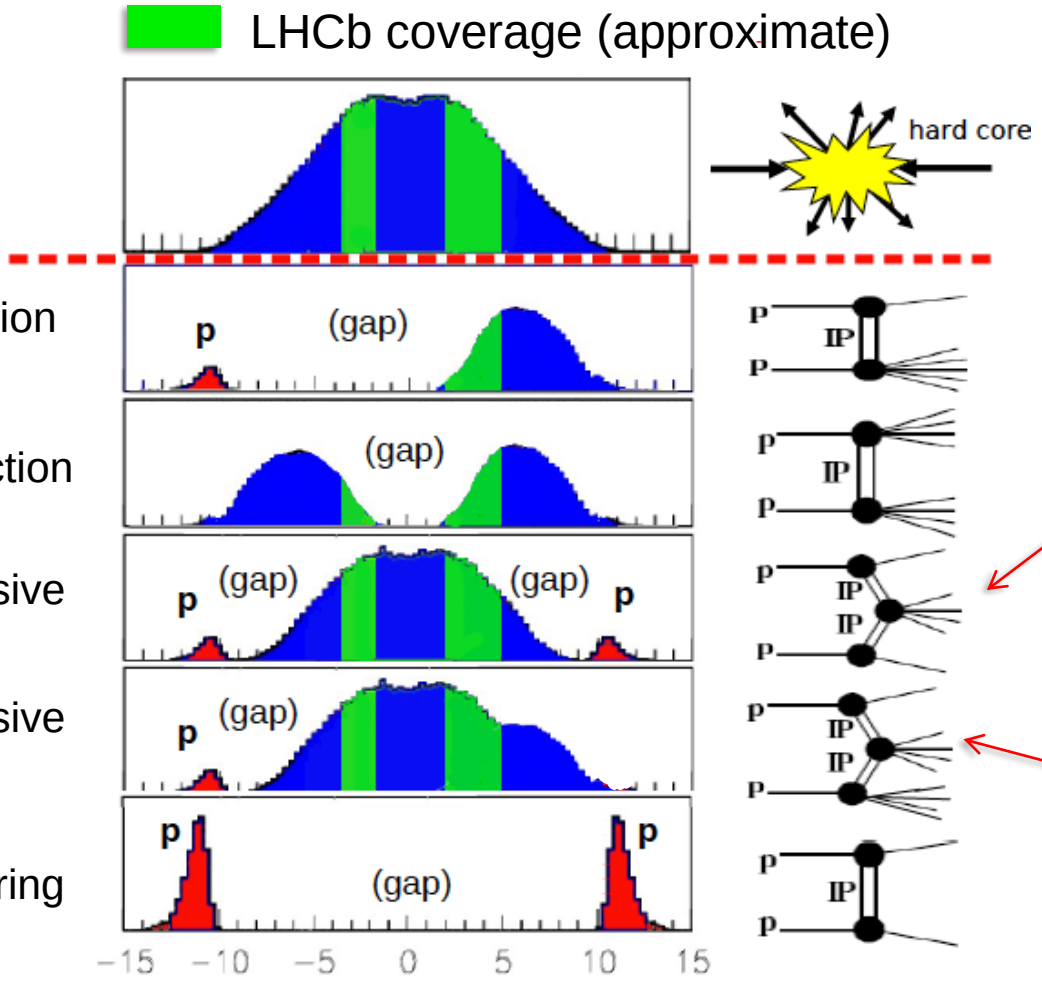
Typical events: Many tracks + high Pt objects
Picked up with high efficiency by standard LHCb triggers





CEP events
No other activity in event; low P_T
Dedicated high efficiency trigger (e.g. for muons)
Level 0: 1μ (p_T>400 MeV) or 2μ (p_T> 80 MeV)
+ low multiplicity calorimeter signature
High Level Trigger: di-μ candidate with p_T<900MeV

CEP Events and Backgrounds



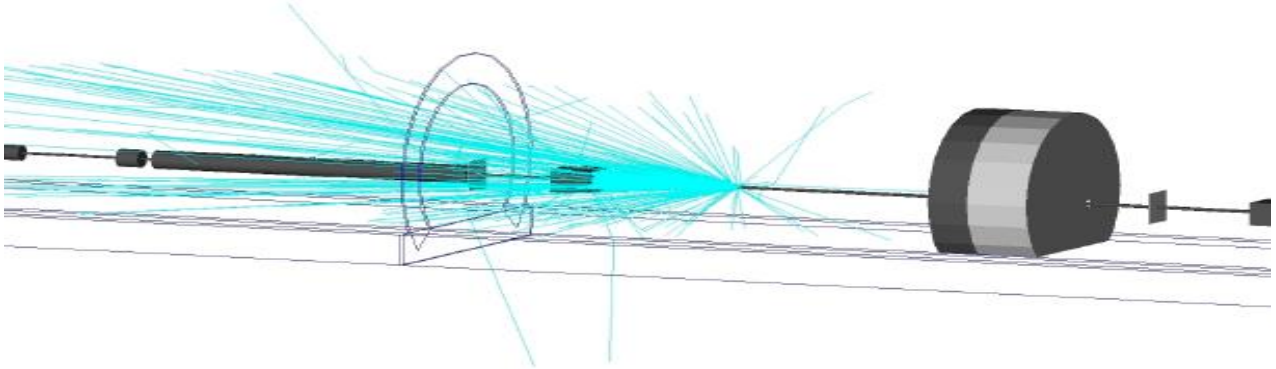
CEP events:
Trigger on and reconstruct a handful of particles (muons, hadrons, photons..)

CEP backgrounds:
reject events with additional particles, usually very forward

After D. d'Enterria arxiv 0806.0883 and http://cern.ch/dde

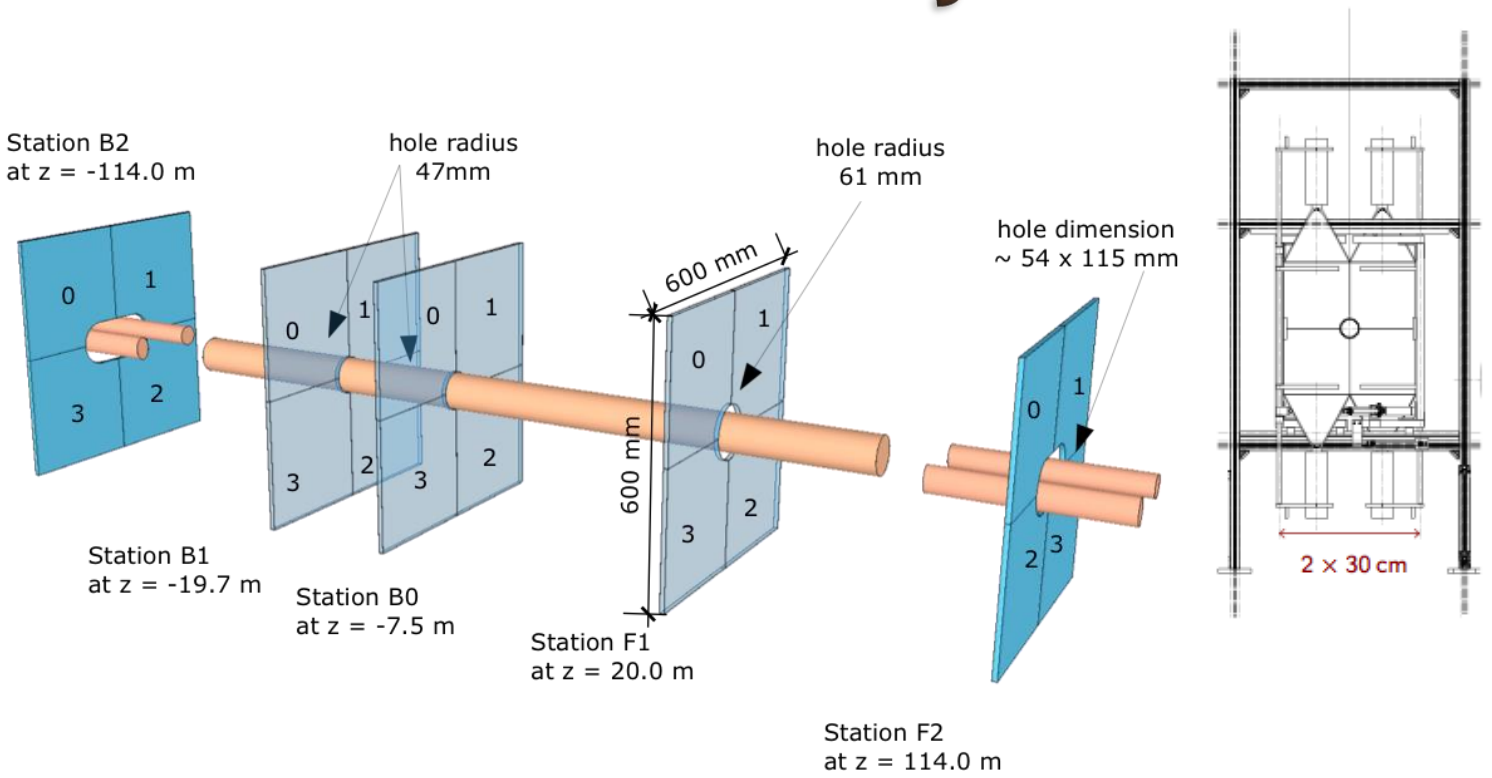
Eliminating Backgrounds

- Idea of Herschel is to install scintillators in the tunnel where the beam pipe is accessible
  - Detect showers from high rapidity particles interacting with beam pipe elements



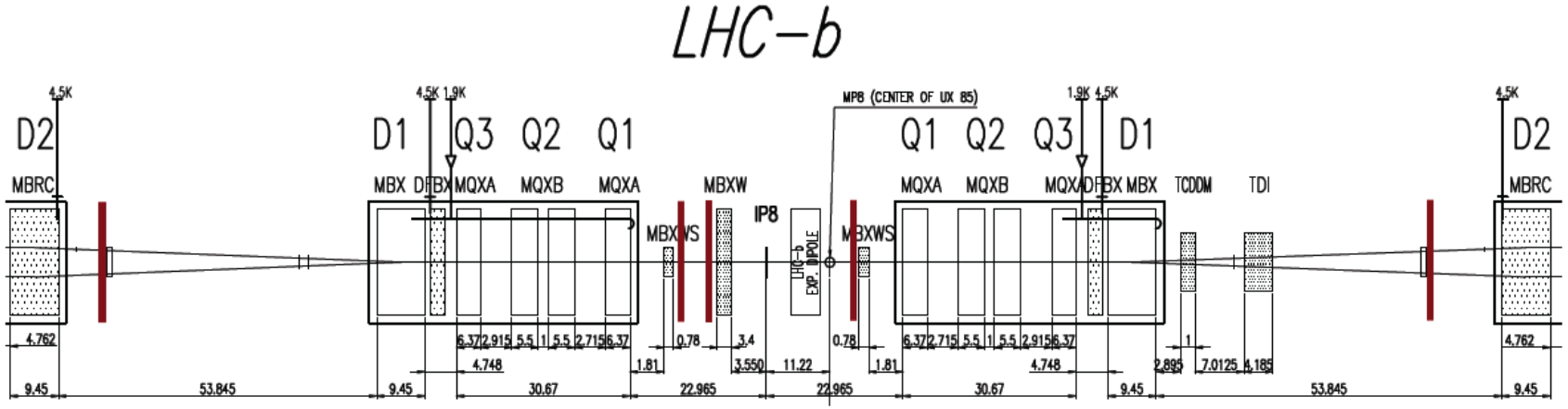
  - In addition **to enhancing Central Exclusive Physics**, it will also act as general rapidity gap detectors and will identify very forward showers in low mass diffractive excitation
  - LHCb readout also offers potential to incorporate signals into trigger **at L0 (40 MHz) trigger**
  - Other topics such luminosity measurement and understanding of machine backgrounds may also benefit from an improved LHCb hermeticity
- The irreducible backgrounds to the analyses are dominated by inelastic backgrounds: undetectable events where the proton breaks up in the forward direction

Detector Layout



Each station consist of 4 plastic scintillator plates, 20 mm thick, glued to “fishtail” light guides
Two different radii of inner cut-out depending on beam pipe layout

Position of Herschel Stations



B side

Left/Backwards/Upstream

① z ~ -7.5m (after MBXW)
② z ~ -19m (before MBXWS)
③ z ~ -114m (after BRAN)

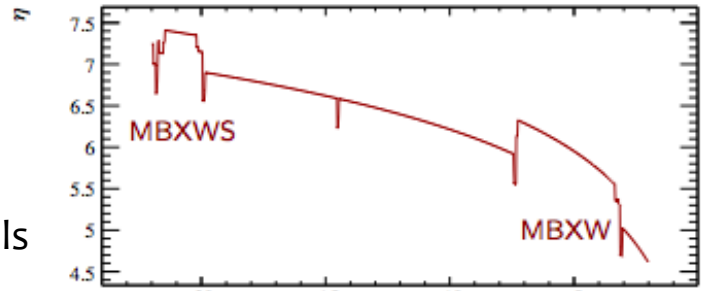
Right/Forwards/Downstream

① z ~ 20 m (close to MBXWS)
② z ~ 114m (after BRAN)

F side

Dictated by:

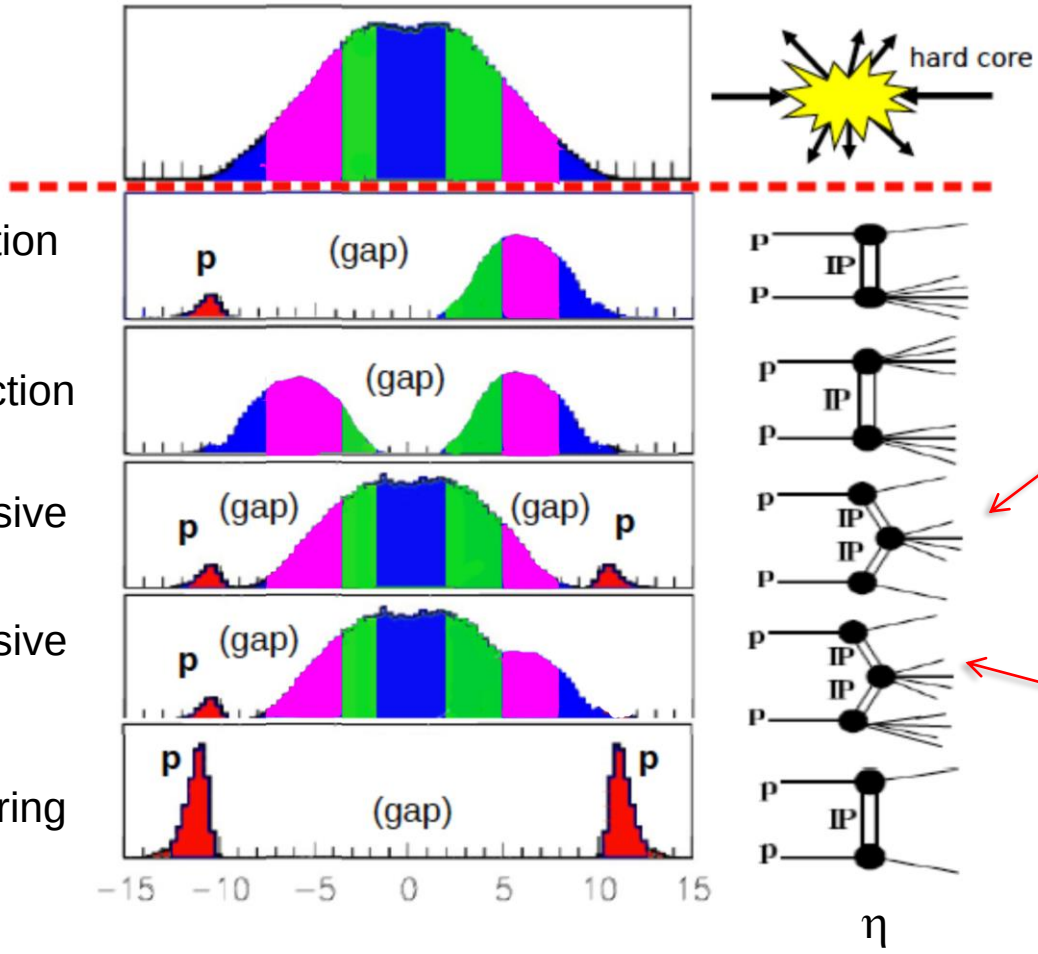
- Availability of free space
- Vicinity to aperture limiting machine elements
- Stations after BRAN give view of high rapidity neutrals



Pseudorapidity of a straight-line track from the IP crossing the aperture limitation at a given z.

CEP events and backgrounds

LHCb coverage (approximate) + Herschel extension

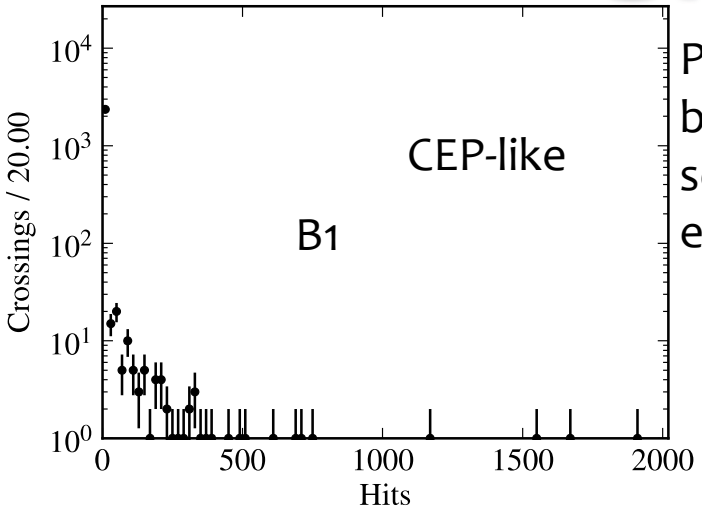


η ~ from 5 to 8

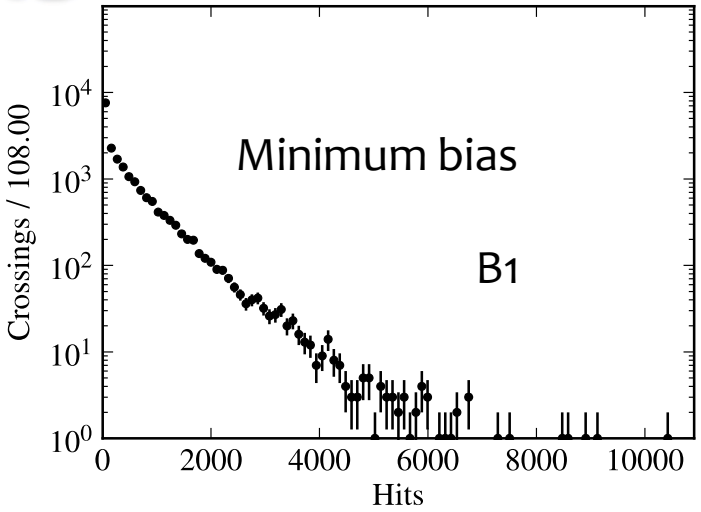
CEP events:
Trigger on and reconstruct a handful of particles (muons, hadrons, photons..)

CEP backgrounds:
reject events with additional particles, usually very forward

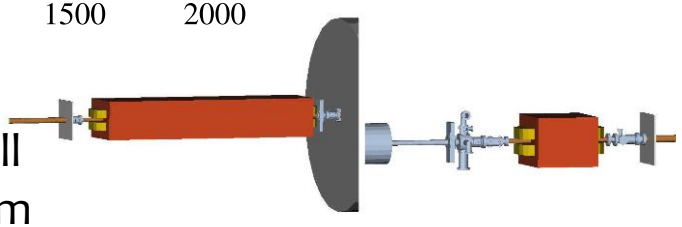
Simulations



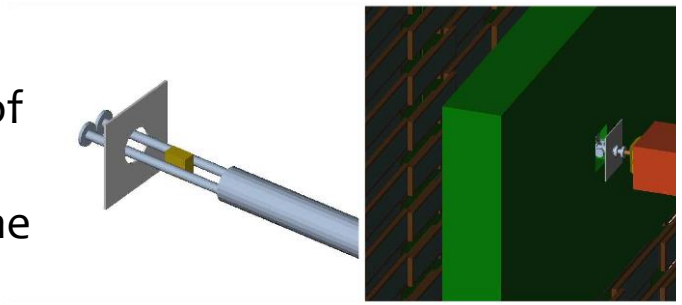
Particles from CEP-like background can still be seen and used to reject events.

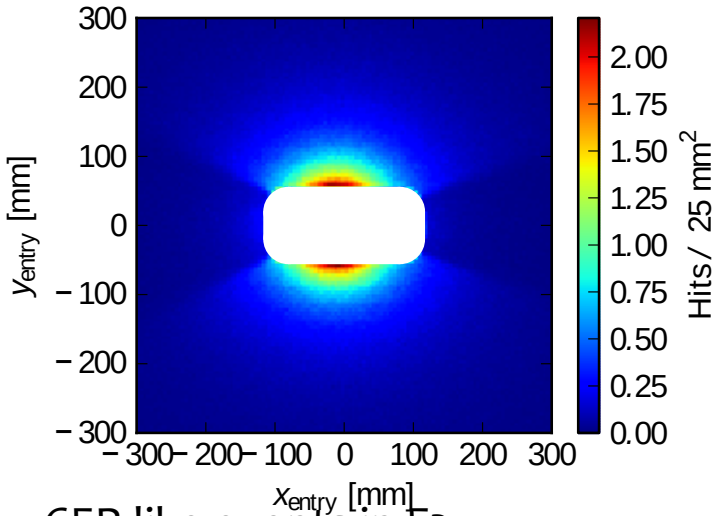


Beam elements and Magnetic fields are well described up to +/-120 m



Additional integration of few final elements of the beam line and proper treatment of the intact protons are under development

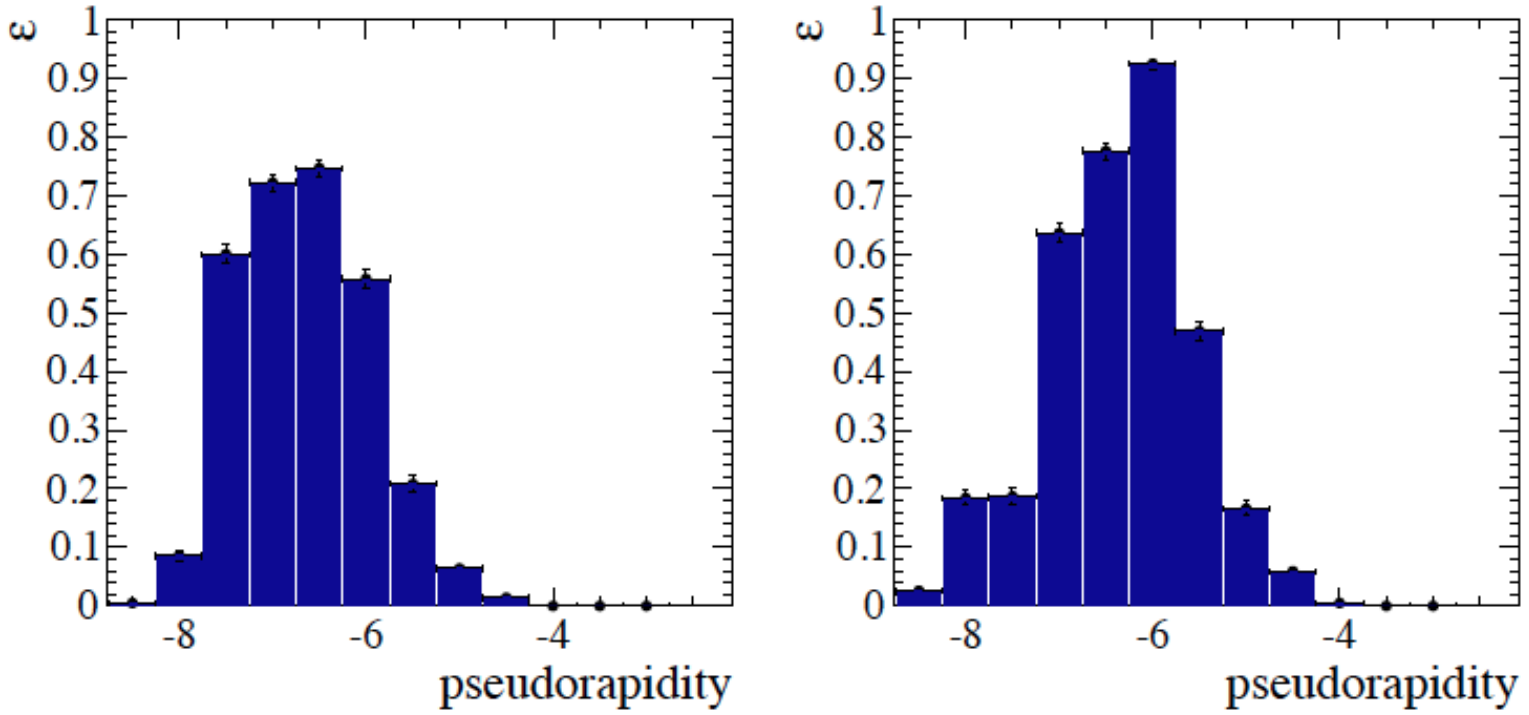




CEP-like events in F2

Simulation – Efficiencies

Checked with particle gun, down to very low p_T values

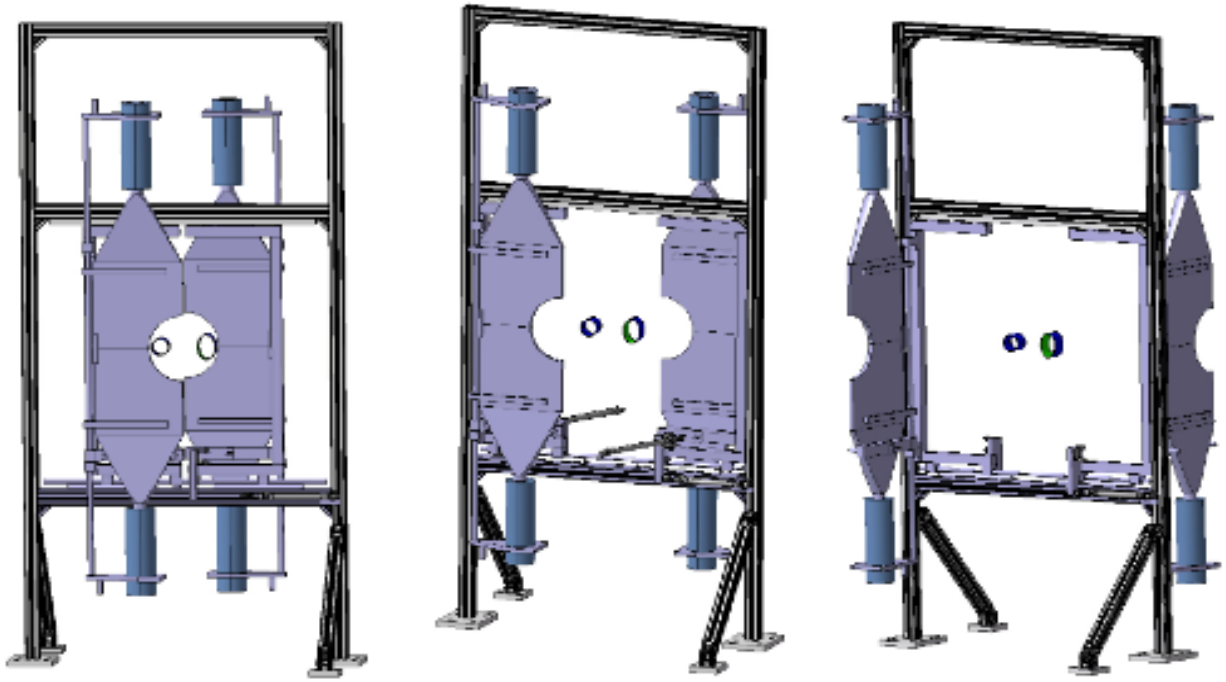


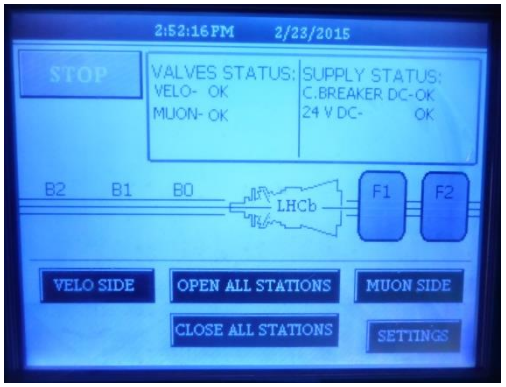
Efficiency to detect 5 or more hits extends beyond nominal pseudorapidity coverage, due to showering

Detector Construction

Detectors were constructed and mounted at CERN,
They have integrated LEDs in two regions to monitor radiation damage.
After construction they were tested and pre-calibrated with cosmic rays.

Station support structures





- Support frame of station at +20 m is attached to shielding wall between muon system and LHC tunnel
- Supports for other stations are bolted to tunnel floor
- Pneumatic motion system to retract scintillators from high fluence region if data taking is not possible for extended time periods

PMT + Base

PMT performance requirements:

Cope with a huge flux of photons

- Even with a reduced gain anode currents will be very high
- Large range in gain still needed for commissioning

Distinguish small CEP signals above the minimum ionising (and other) background

25 ns running – which gives huge CEP yields – places additional constraints on pulse speed

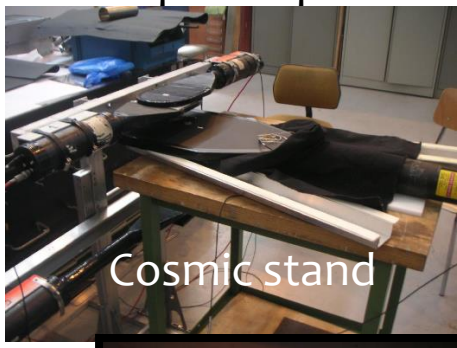
PMT choice: HPK R1828-01 2" diameter.

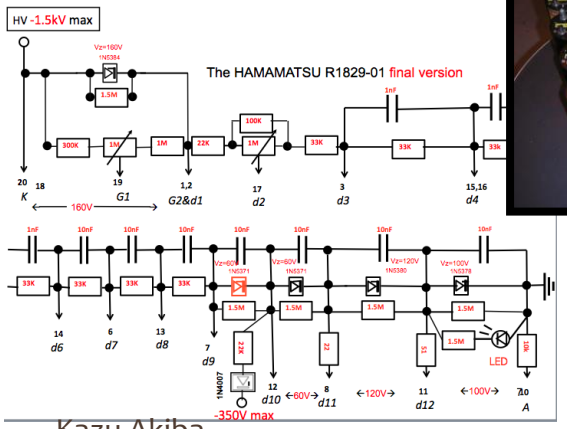
- Maximum anode average current up to 200 uA
- Fast signal response 1.3 ns rise time
- Large gain adjustment

Divider – in house design

- must drain 2-4 mA -> extra bias current
- zener diodes to stabilise operation

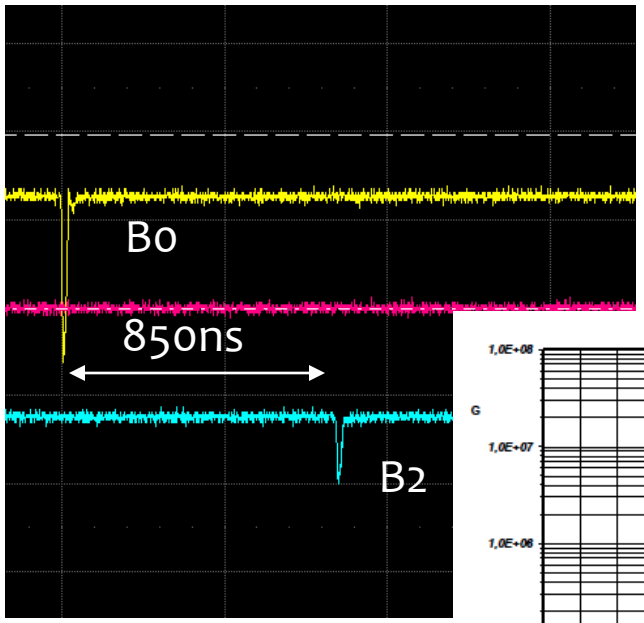
(Previous LHCb experience for Beam Loss Scintillators)



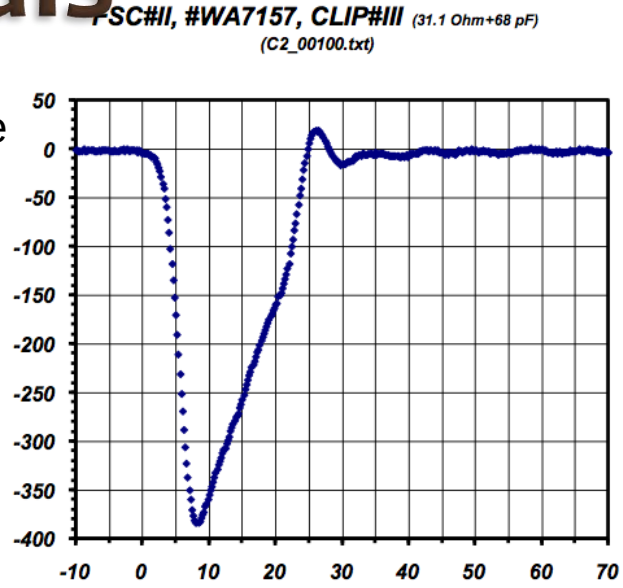


circuit

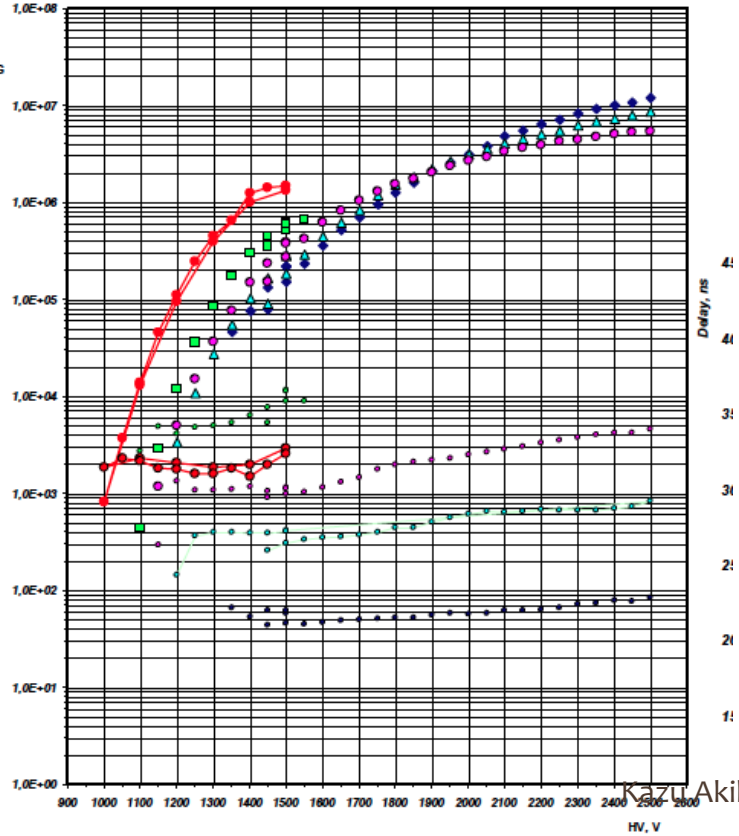
Photon signals

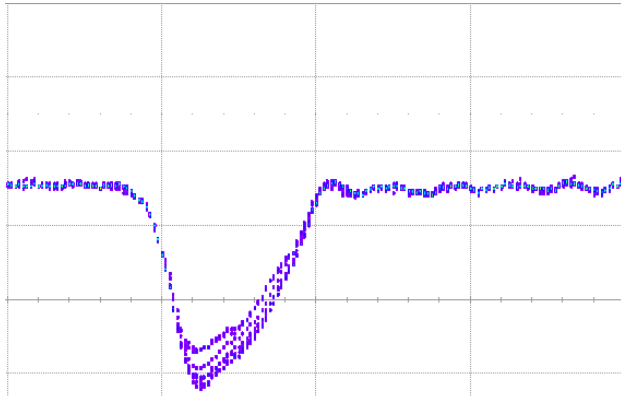


Cosmic stand results indicate light yield of ~200 p.e.



Individual gain of
Each detector measured
With the cosmic
Stand setup

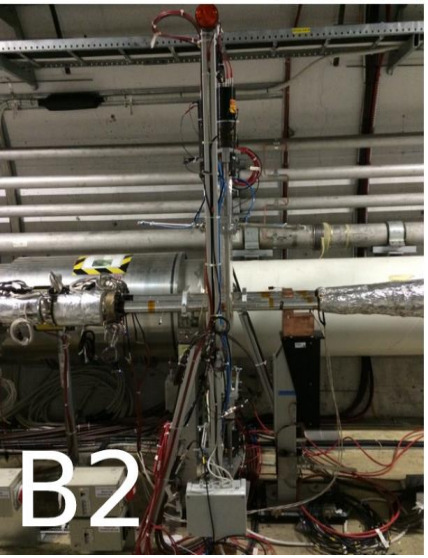


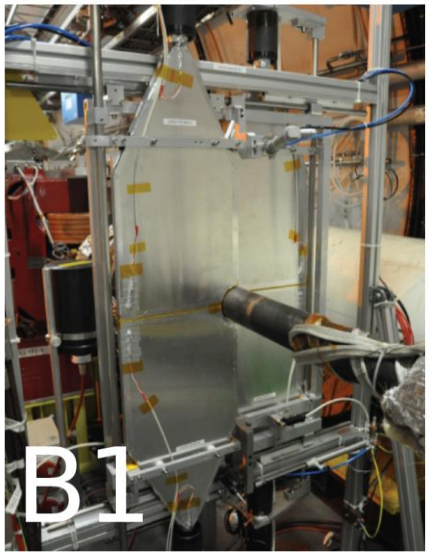


Data taken with installed setup shows the predicted behaviour

Installation

-114m -19.7m -7.5m





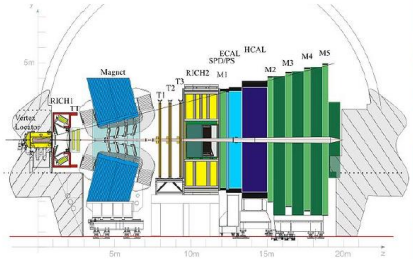
Detectors installed since December.

All cabling installed.

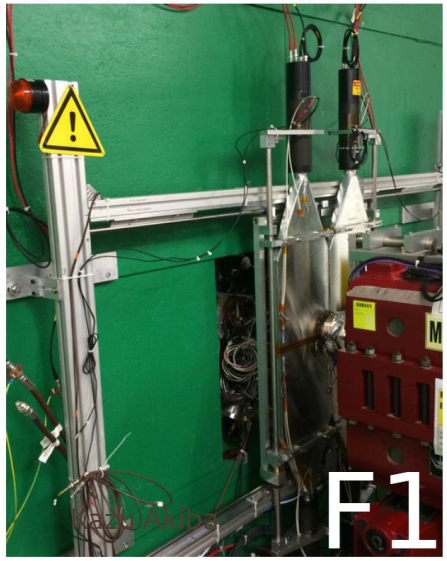
HV and LV systems installed

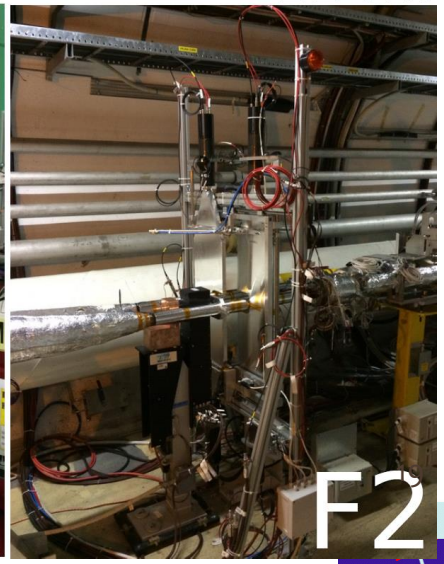
Final installation of Readout

20m 114m



LHC
P





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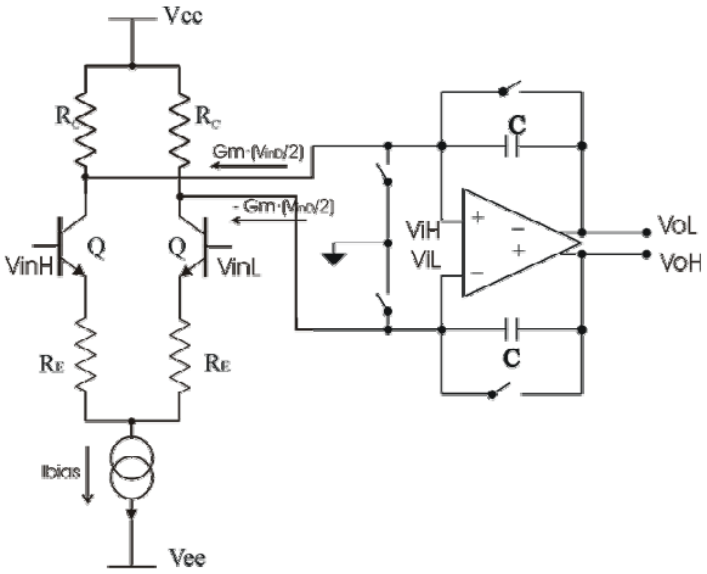
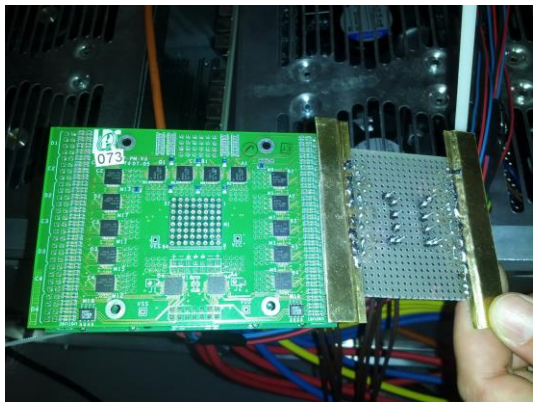
Electronics

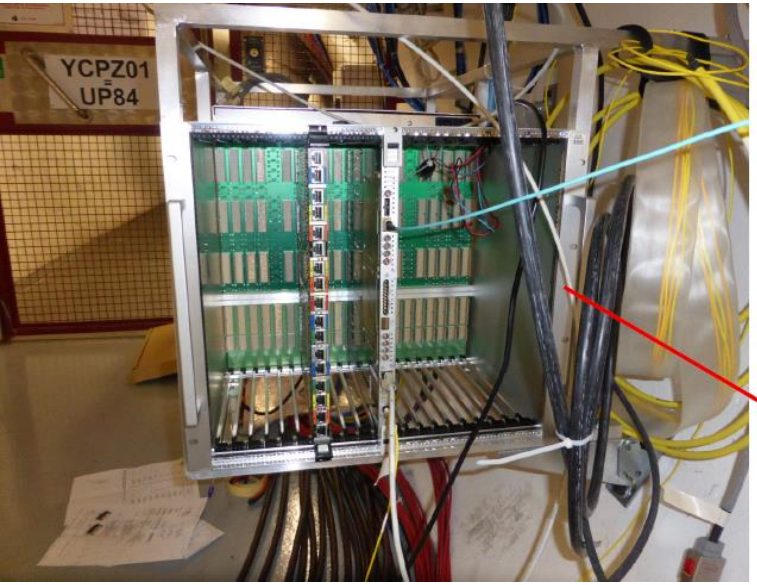
- Using existing electronics from LHCb – SPD-PS.
- 2 switching integrator circuits allow to take data at the very high signal rate ~30 MHz @ 25 ns.
- Front-end boards + selection board combine the information per side and can participate in L0 Trigger
- 20 channels in total: little increase in overall LHCb bandwidth

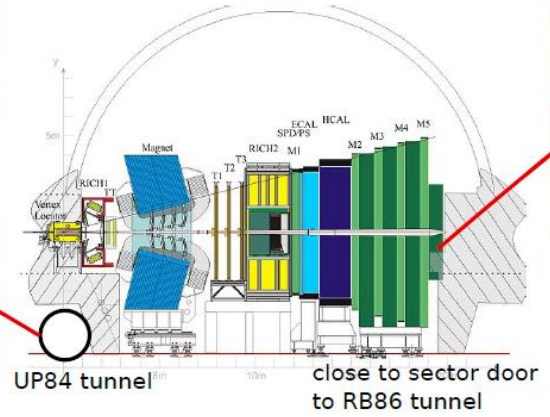


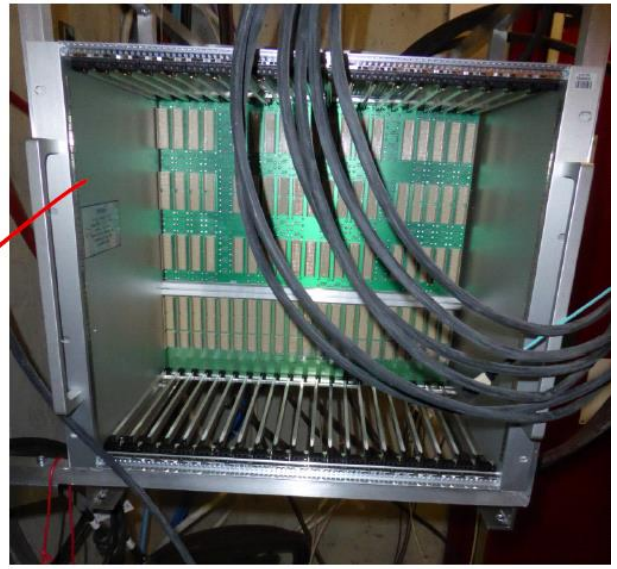


Very-Front end board

Commissioning

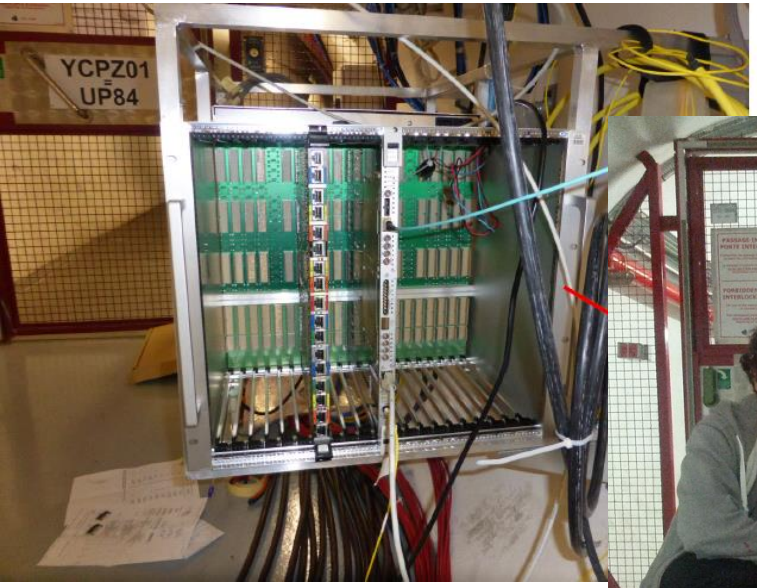


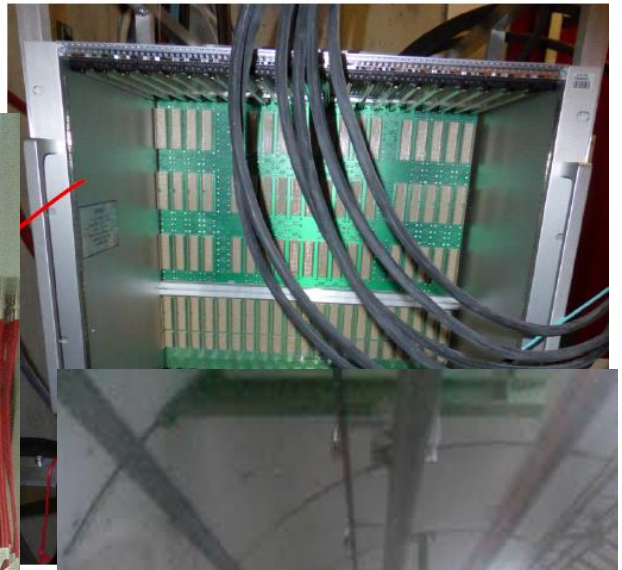


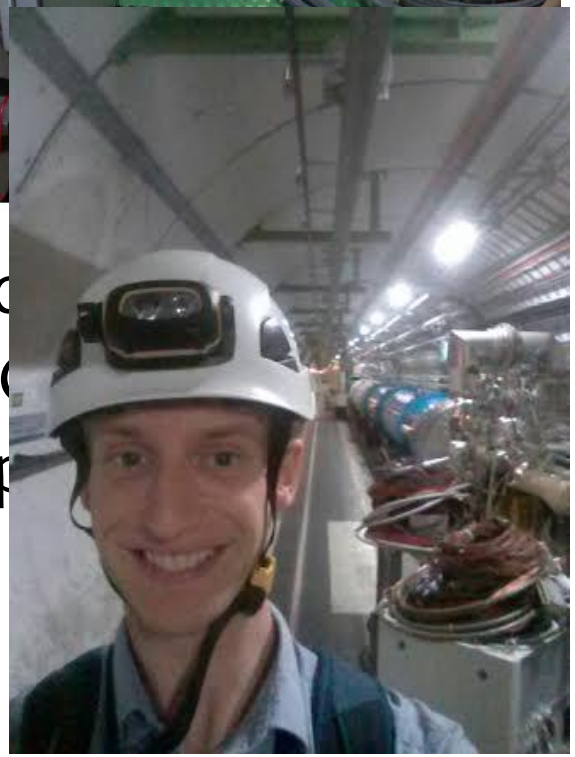


- Electronic crates installed and operational
- System already integrated into the LHCb detector
- Very-Front-End adaptor cards to be replaced for full speed

Commissioning

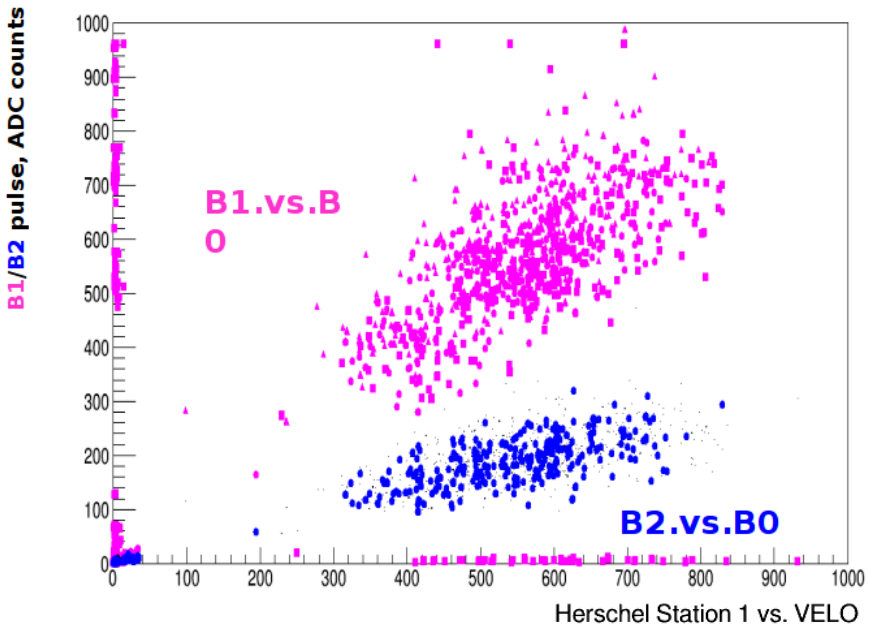




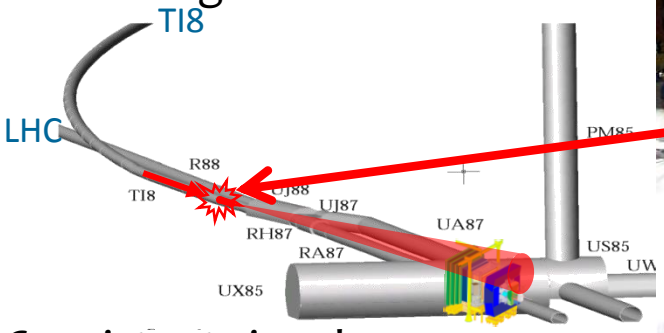


- Electronic crat ic
- System already HC
- Very-Front-End ep speed

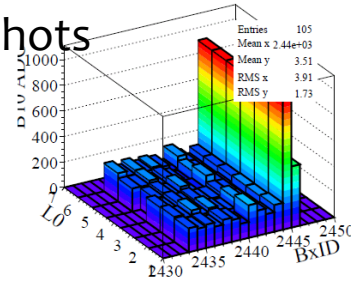
Sector tests: TED Run

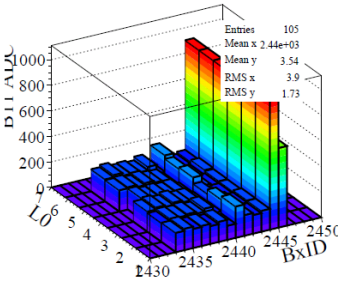


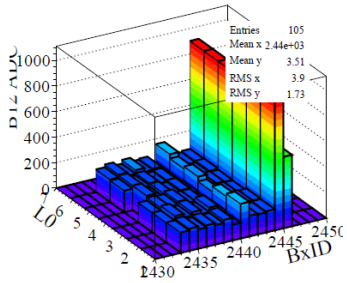
Correlation between stations
Shows that the detectors
are working well

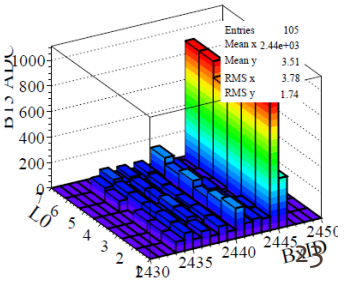


Consistent signal
On many TED shots

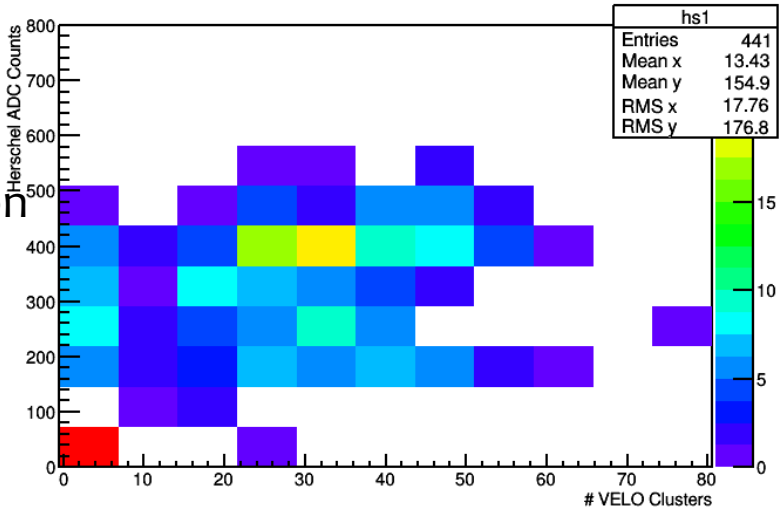








Clear correlation
with the VELO



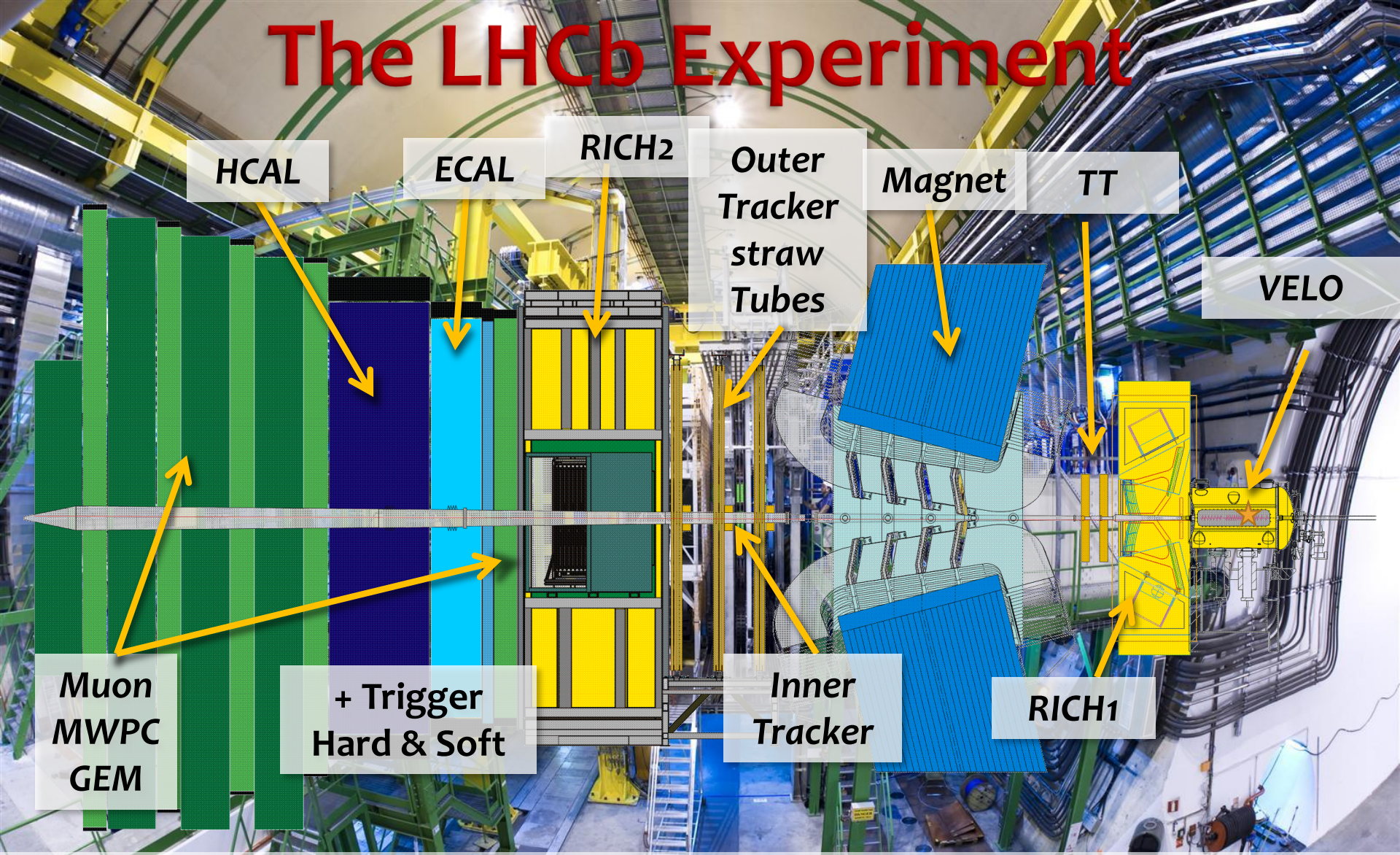
Current Status

- Finalize commissioning with beam
- Commission the LED system integrated to the LHCb readout
- Install trigger electronic system to integrate to central trigger (using existing LHCb boards)
  - Should be done by the LHC technical stop in June.
- Implement the required trigger logic in the front-end PGA chips.

Conclusions

- The Herschel project is almost ready!
  - Extend LHCb coverage with very forward scintillators in LHC tunnel upstream and downstream of experiment
  - Improve selection of and triggering on events with large rapidity gaps and interpretation of central exclusive and single diffractive analyses
- Will participate in the data taking of 2015
  - Integrated to LHCb
  - should acquire >5 fb^{-1} of data with low pileup of run II.
- Detector Installation is finished.
- Final commissioning of readout and trigger electronics

The LHCb Experiment



Large Hadron Collider beauty Experiment for CP violation and Rare B Decays.