LHCb Hardware Early Running Experience

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on behalf of the LHCb Collaboration

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LHCb

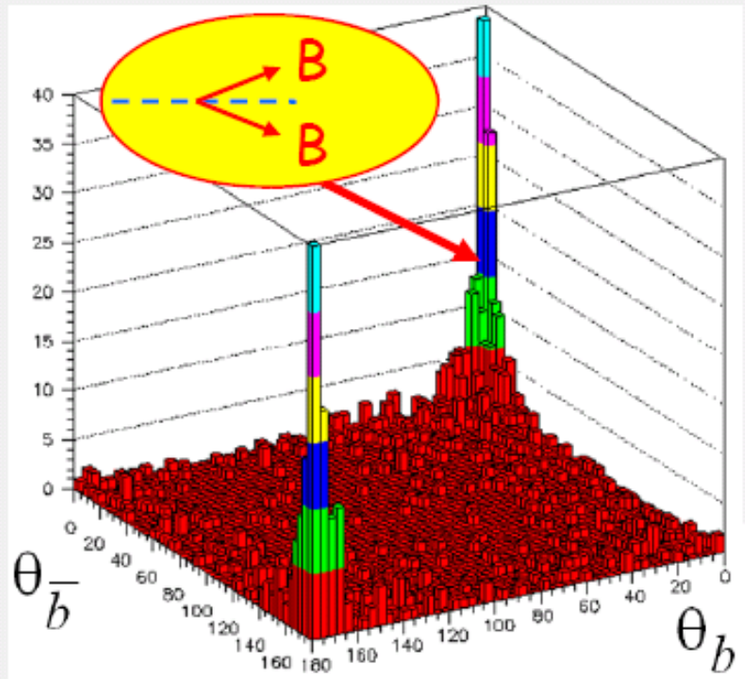
- LHCb is a flavour physics detector, designed to detect decays of b- and c-hadrons for the study of CP violation and rare decays.

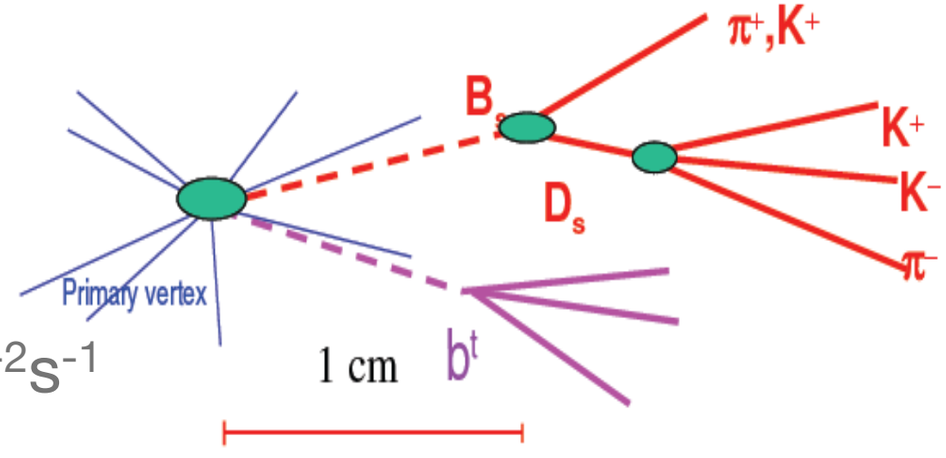
- Forward arm spectrometer as both b's primarily produced in the forward direction

- LHCb expected to operate in current config to 2015

- Open Detector - 10-300mrad

- Reach nominal luminosity in 2011 - $\mathcal{L}=2\text{x}10^{32}\text{cm}^{-2}\text{s}^{-1}$

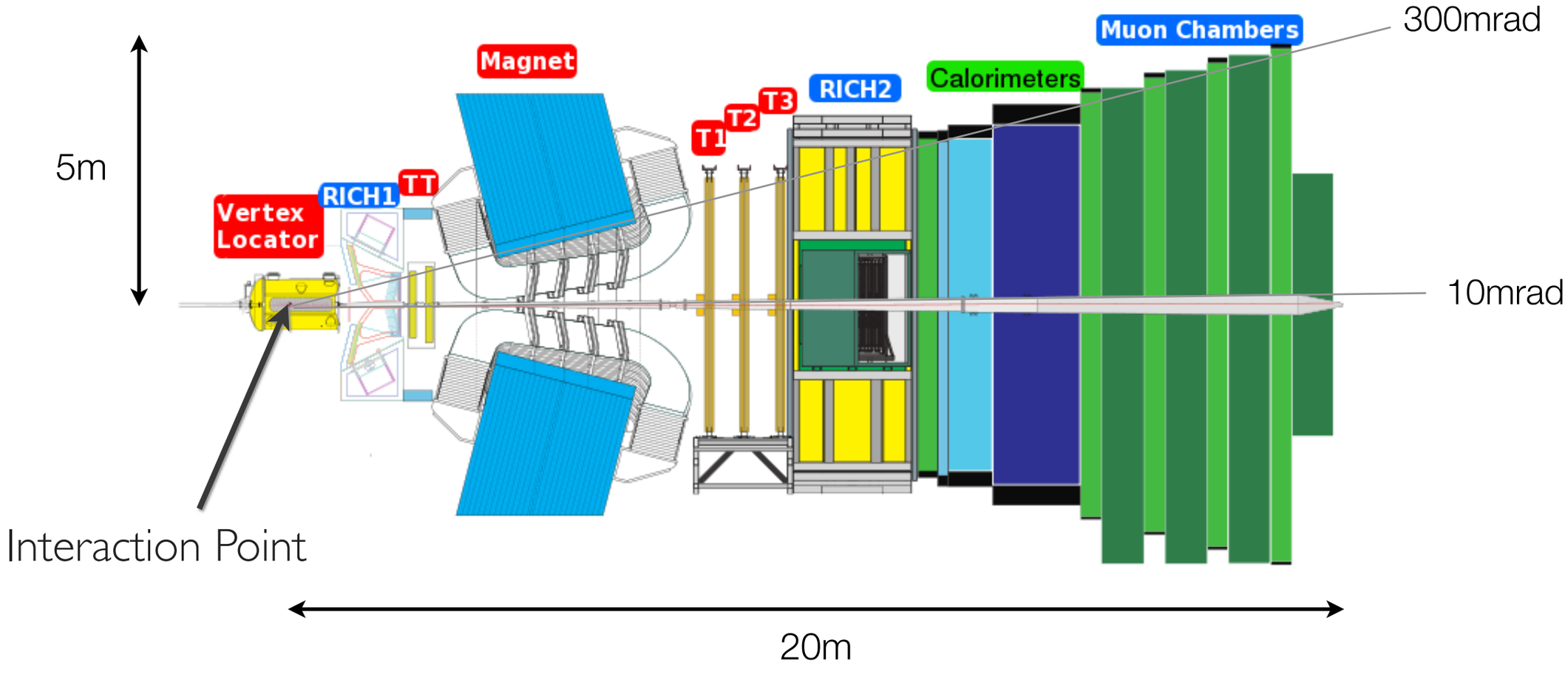




Precision | Instrument

LHCb

Momentum
Energy
Particle ID



LHCb

Momentum
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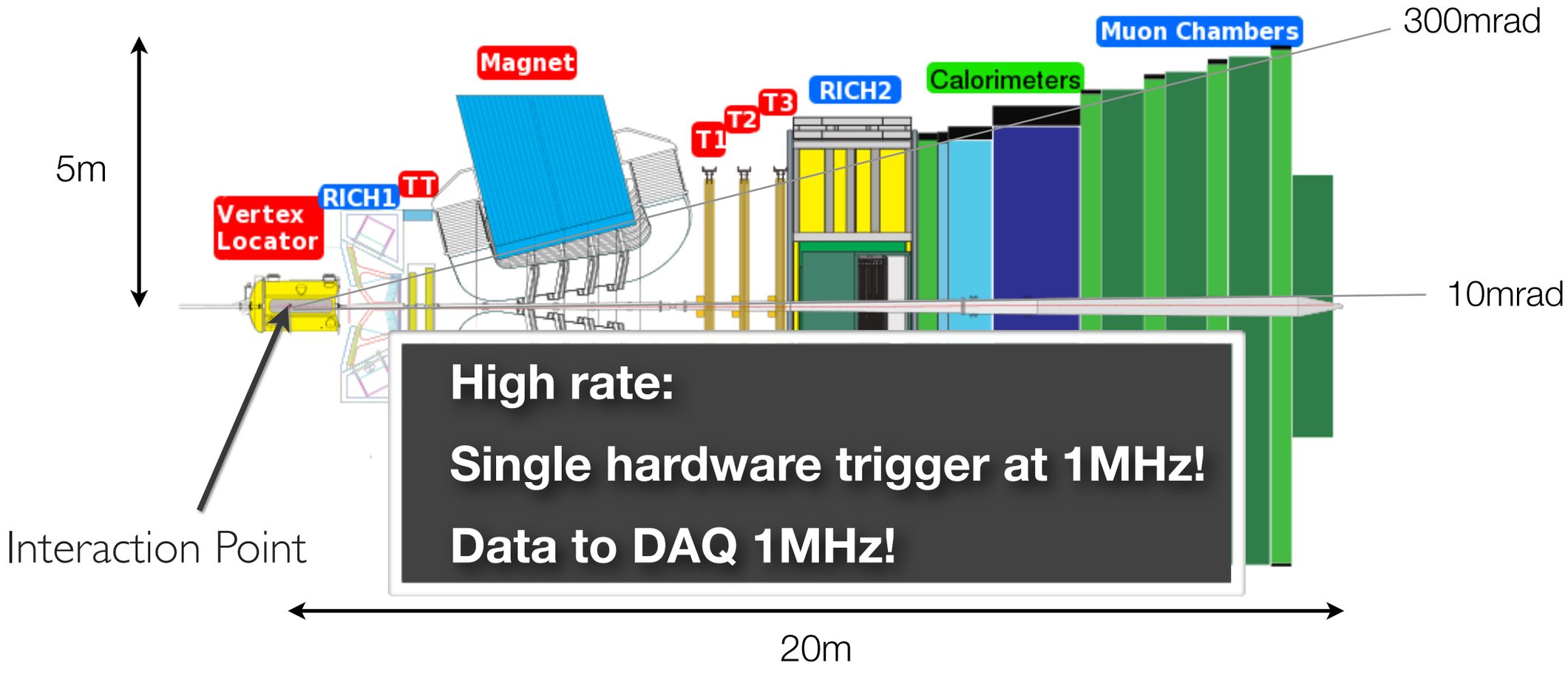
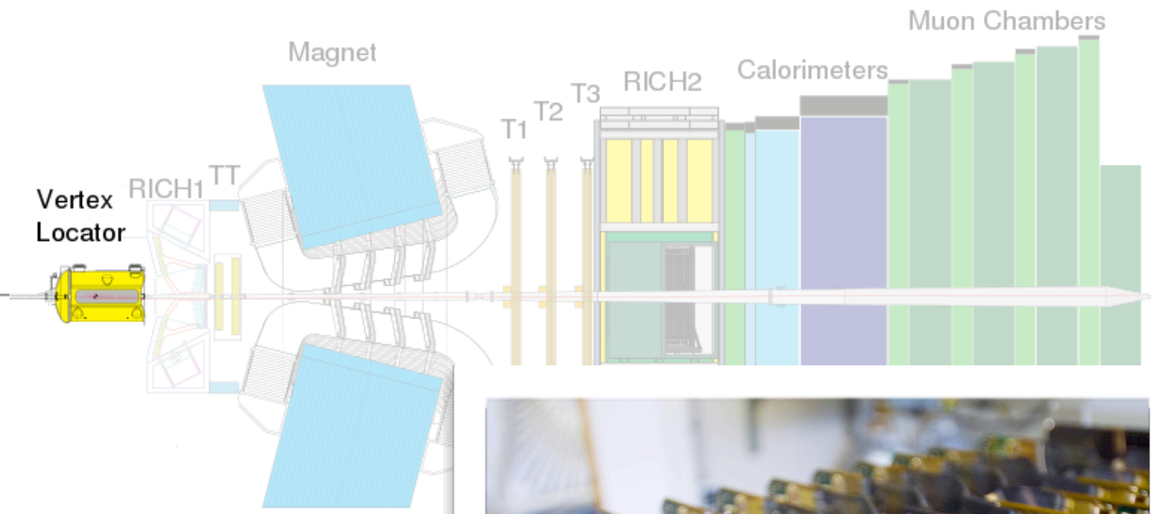
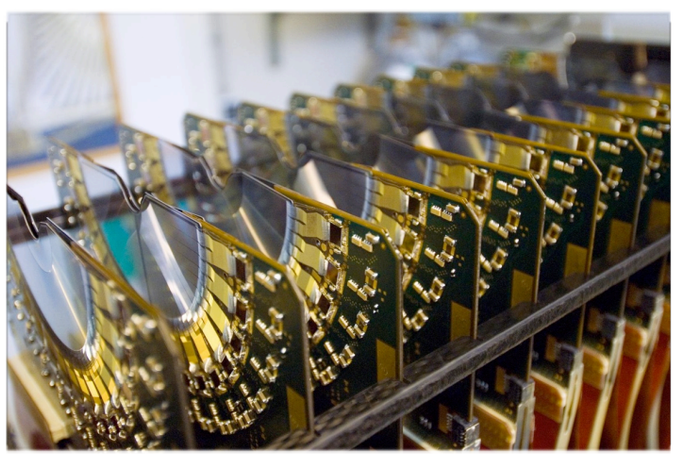


Sub-detectors

Vertex | Locator

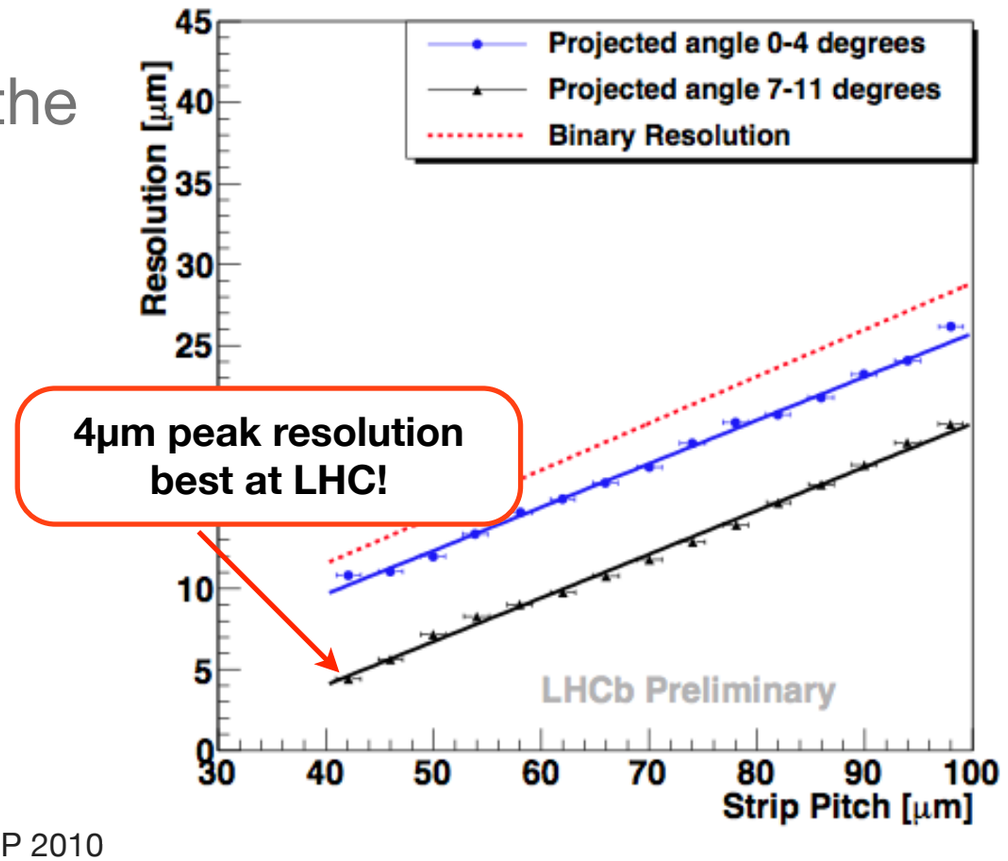
Vertex Locator





- Primary tracking and vertexing detector - R and ϕ sensors
- n^+-in-n silicon
- S/N ~ 20
- CO_2 cooling

- An aluminium foil (300μm thick) separates the 42 VELO modules from the LHC vacuum
- Retractable halves - 8mm from beam!
- Rad. Hard - Innermost region 1.3×10^{14} n_{eq}/cm^2/year

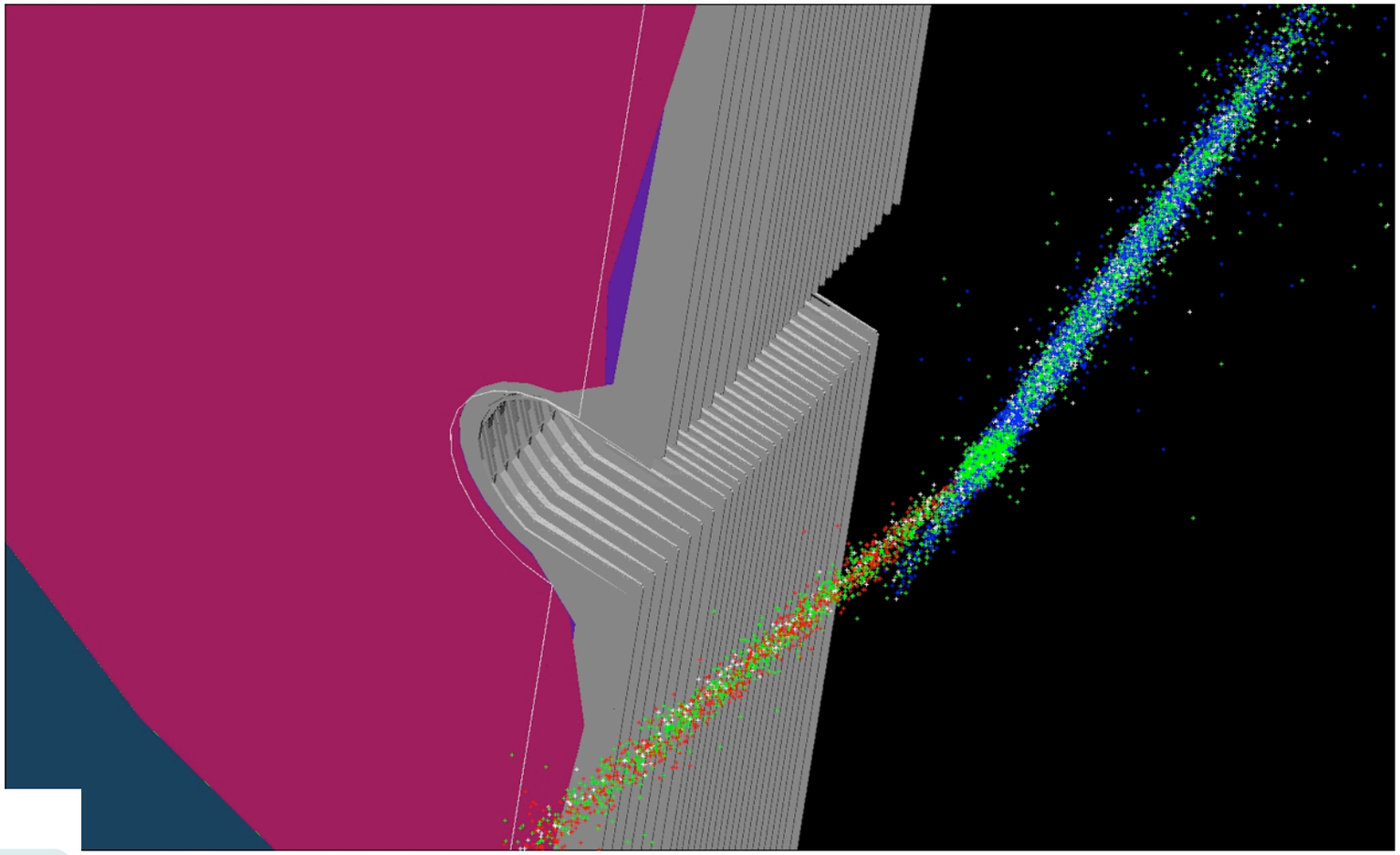


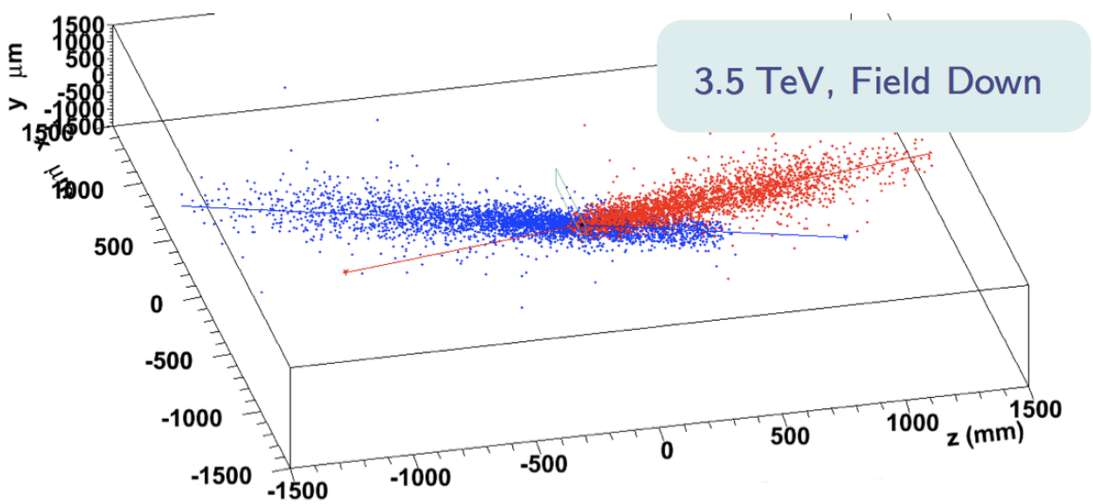
VELO - LHC

- Provide essential feedback to LHC

- Look at beam gas events - determine crossing angle

- determine absolute luminosity

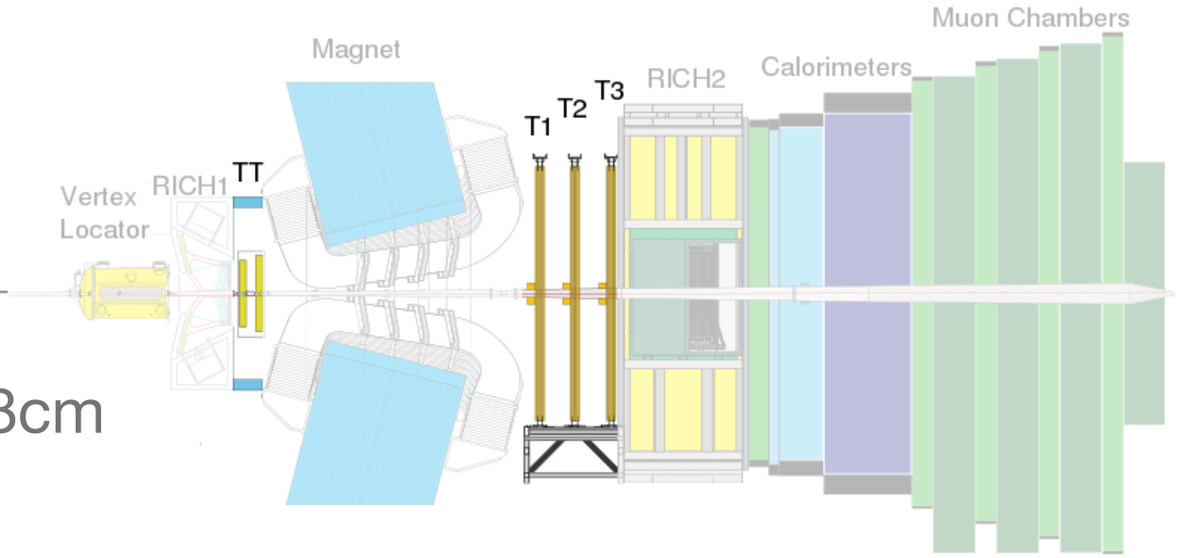




- extract beam shapes and monitor stability of beam using VELO

video

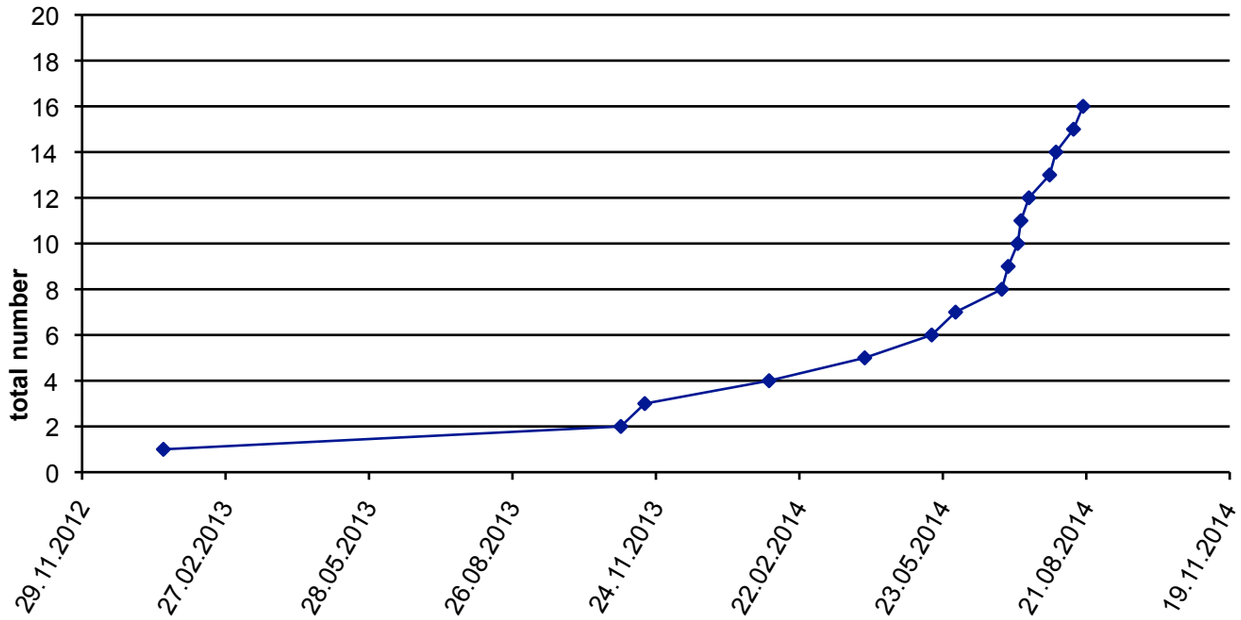
Silicon Tracker



- p-in-n - "*long strips*" 9cm, 11cm, 22cm, 38cm
- Strip pitch 183μm, 198μm
- Resolution 65μm
- S/N good
- noise rate 10^{-5}
- Winter technical stop
  - replace hybrids with broken bonds, service boxes, modules

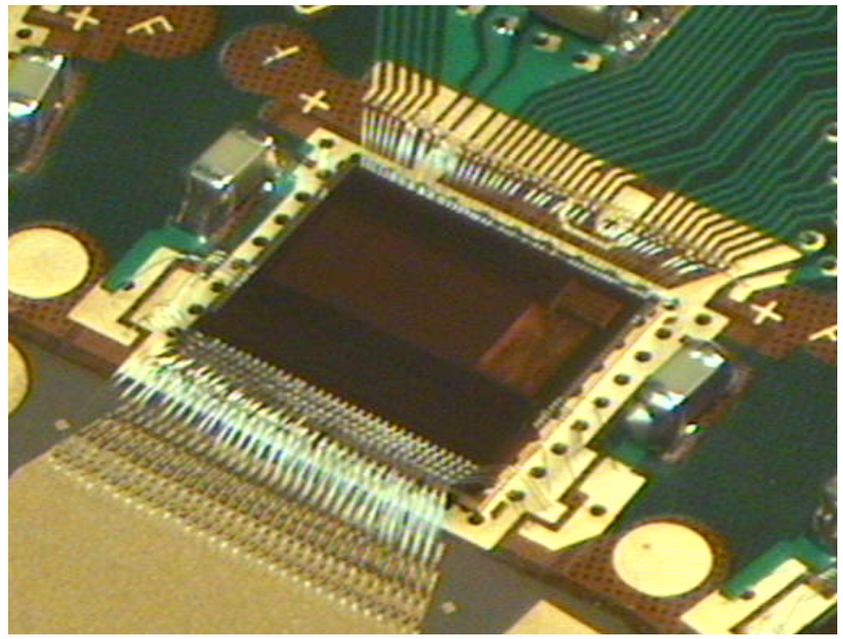
VCSEL - Front-end optical transmitter

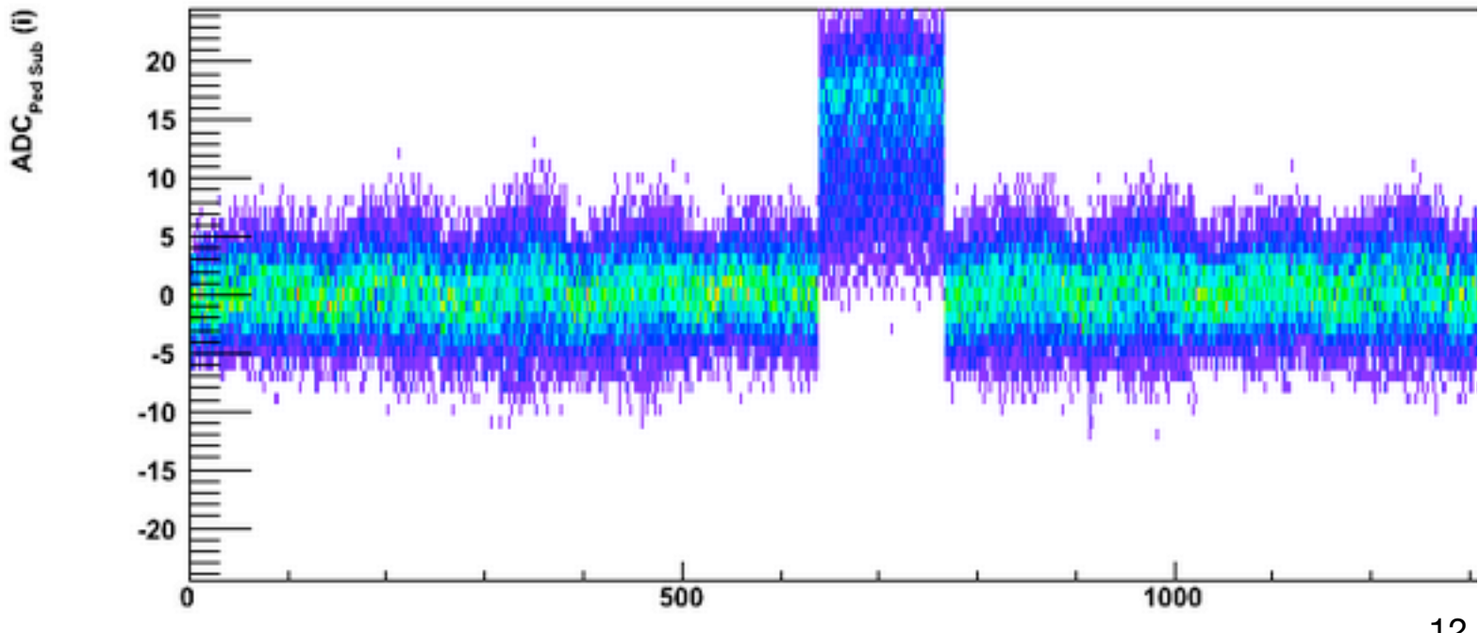
- Biggest cause of inefficiency in ST
- See discussion in Optical WG
- Dying VCSELs
  - 2 /month - reason unknown - testing with manufacturer
  - also seen in other subdetectors
- replacing during technical stops
- easier than ATLAS/CMS due to open detector



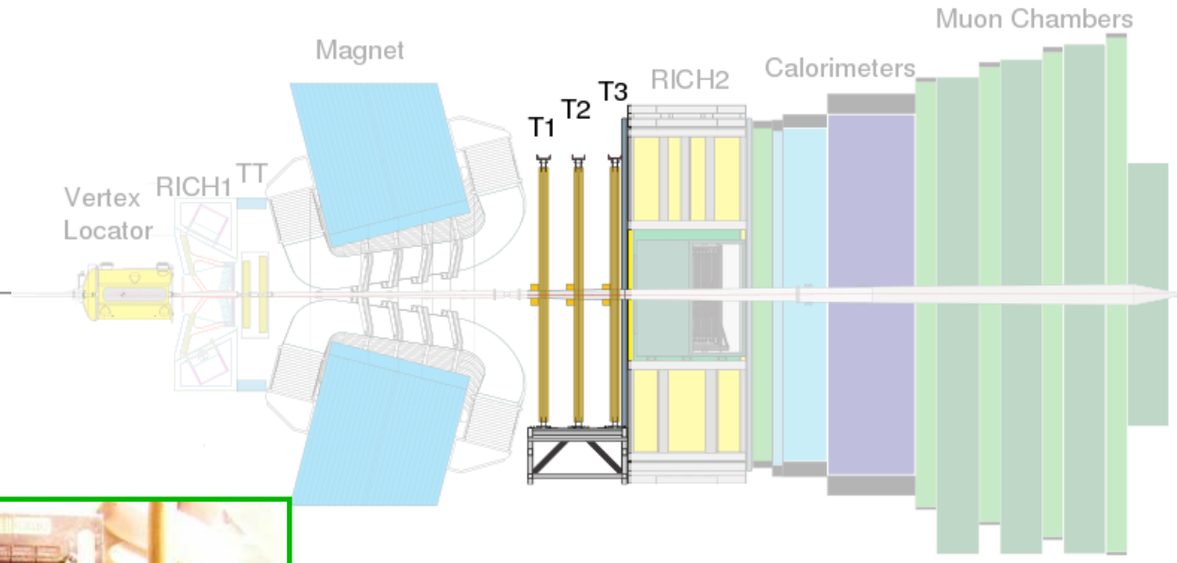
Beetle chip - Front-end ASIC

- Common to silicon detectors - VELO & ST
- Samples at 40MHz
- Analogue output and transmission to counting room
  - 60m copper cables with no loss of S/N
- Pedestal shift - On some chips pedestal is rate dependent - usually a step function with cut off ~10kHz
  - Solution - tune pedestals to rate
- Beetle derandomiser needs better emulation at high rate

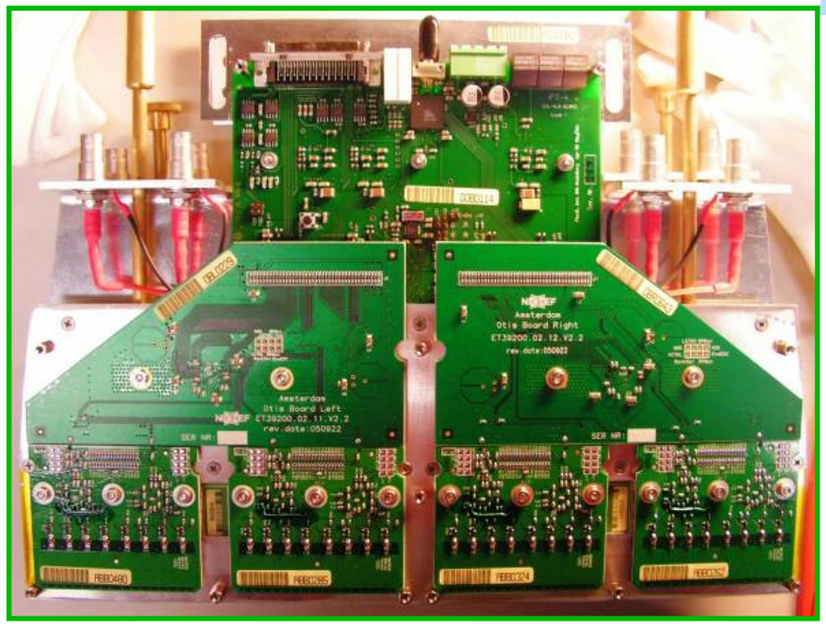




Outer Tracker



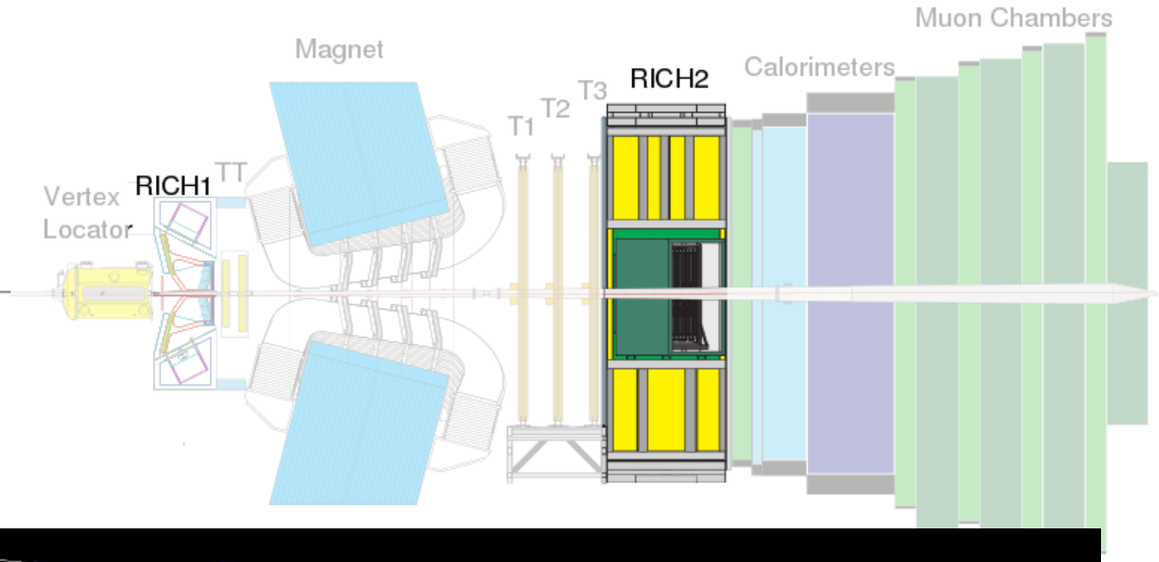
- Straw tracker surrounding part of ST
- <50ns drift time
- OTIS FE Time-to-Digital Converter ASIC performing well



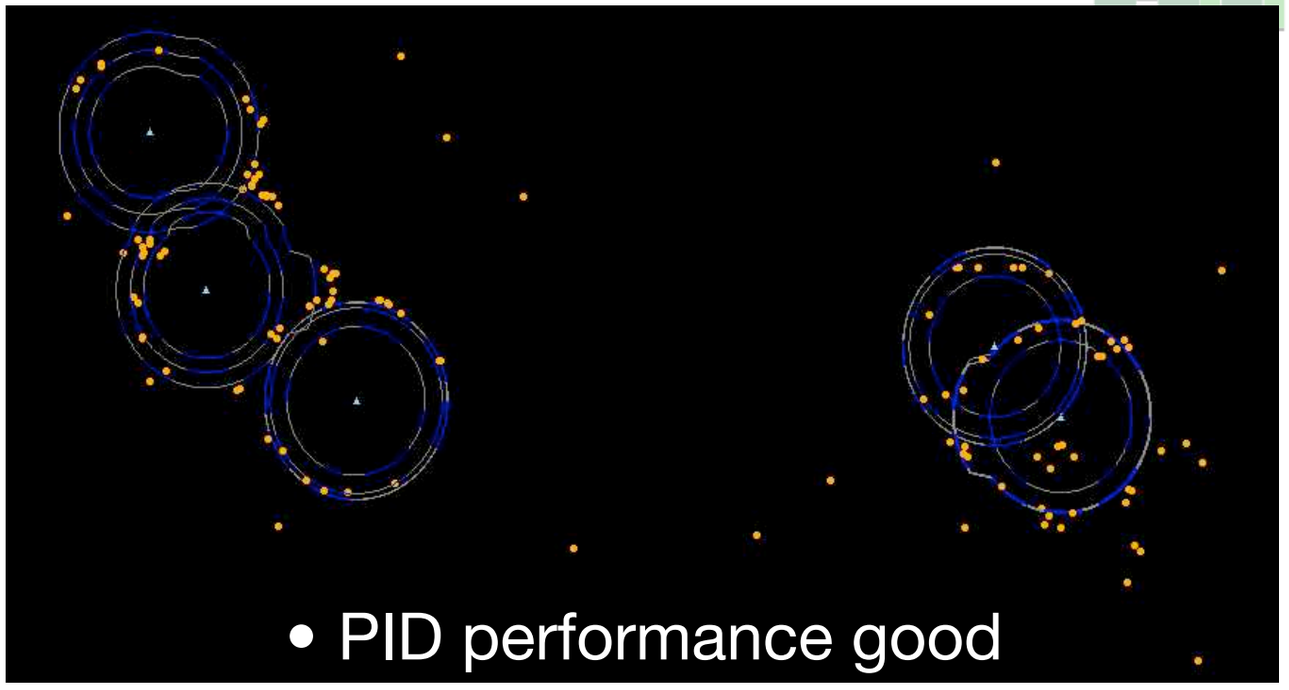
- Repairs
  - ~20 FE boxes exchanged
  - adding Cu shields to front-end boxes in winter stop for noise reduction

RICH detector

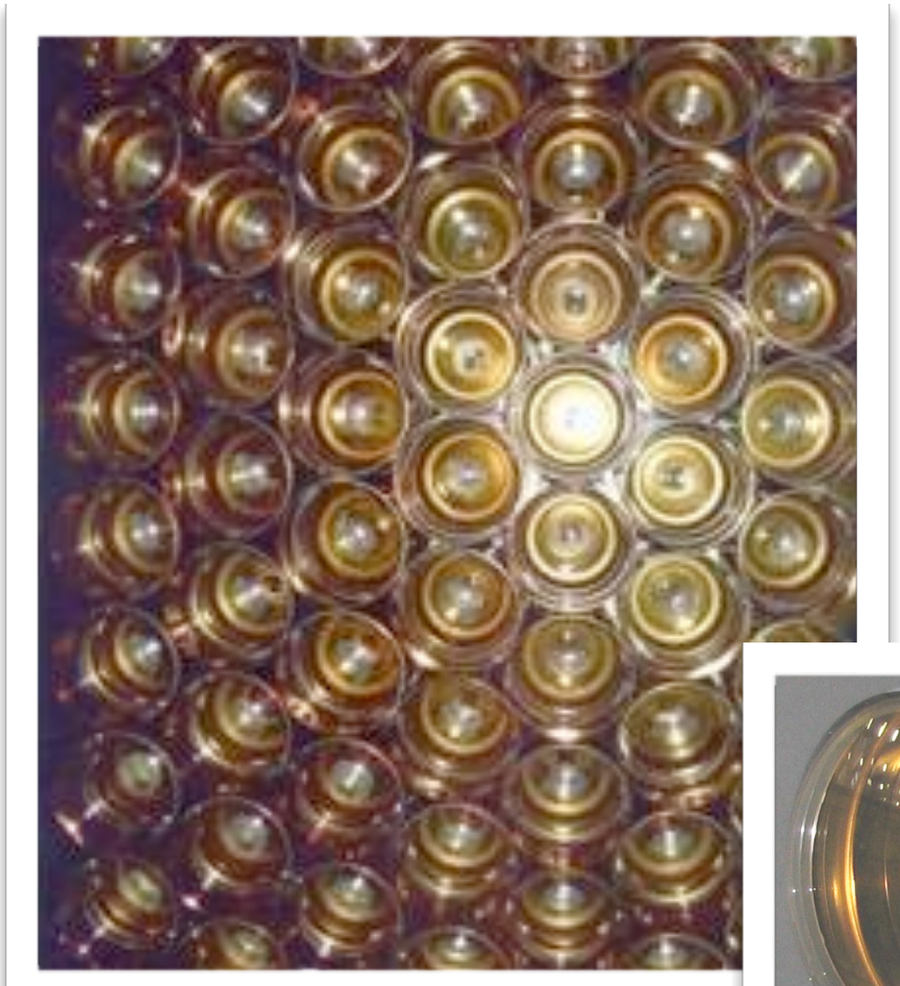
- Cerenkov detector



- Separation of K,π,p



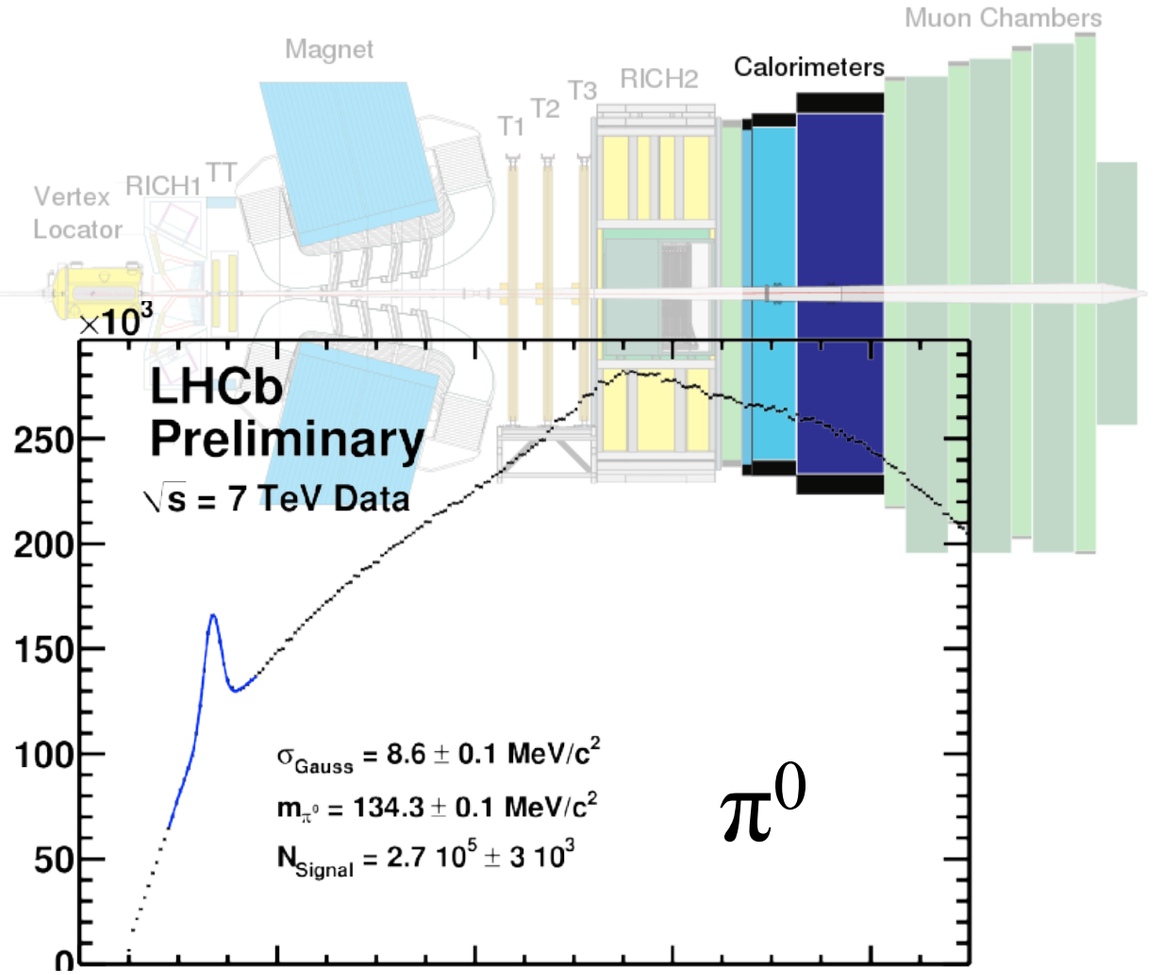
- PID performance good

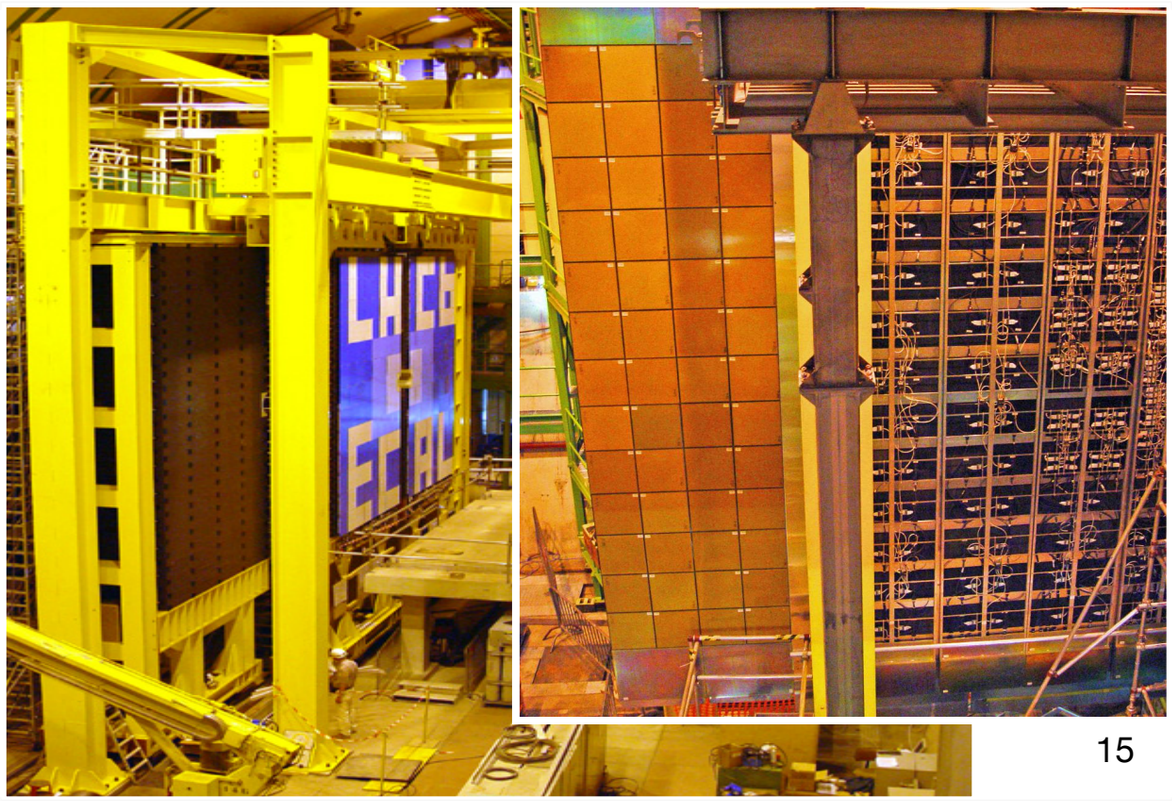


- Hybrid Photon Detectors - 20kV
  - Noise-less - can detect single photons
  - Pixel chip - design error introduces small dead time at high rate

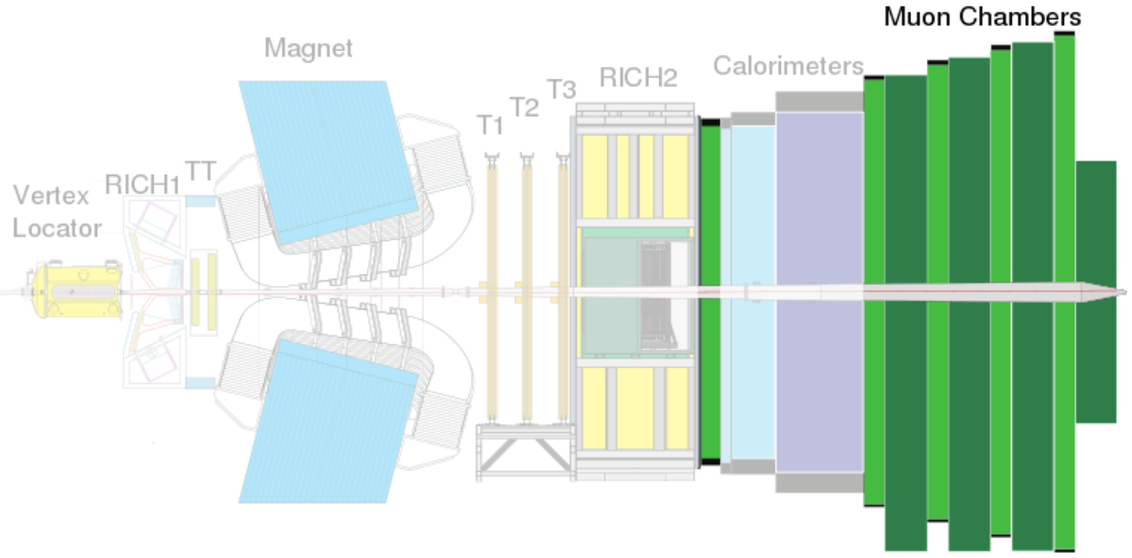
Calorimeters

- SPD/PS, ECAL, HCAL
- Sampling calorimeters - Interleaved scintillator and absorber
- Each Calo scintillator tile read out via MAPMT pixel photomultiplier
- *System very stable*
- HV modifications required - noise improved

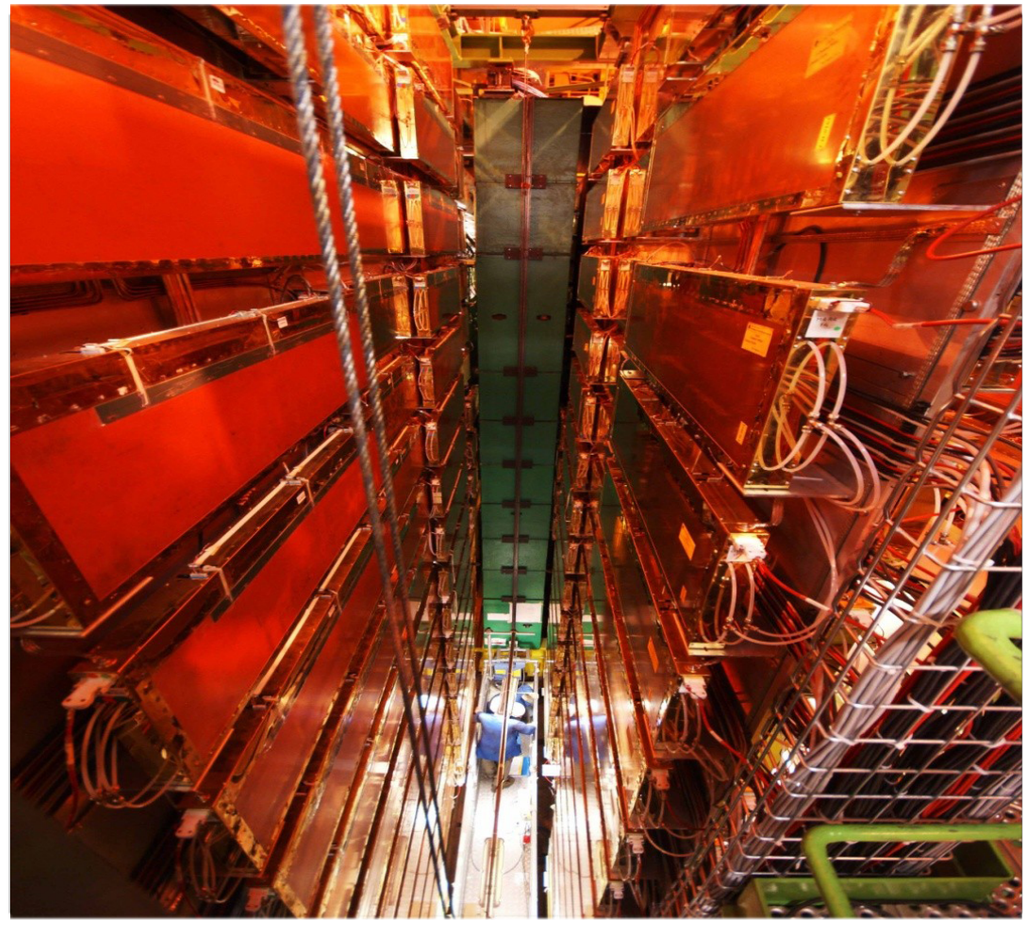




Muon Chambers

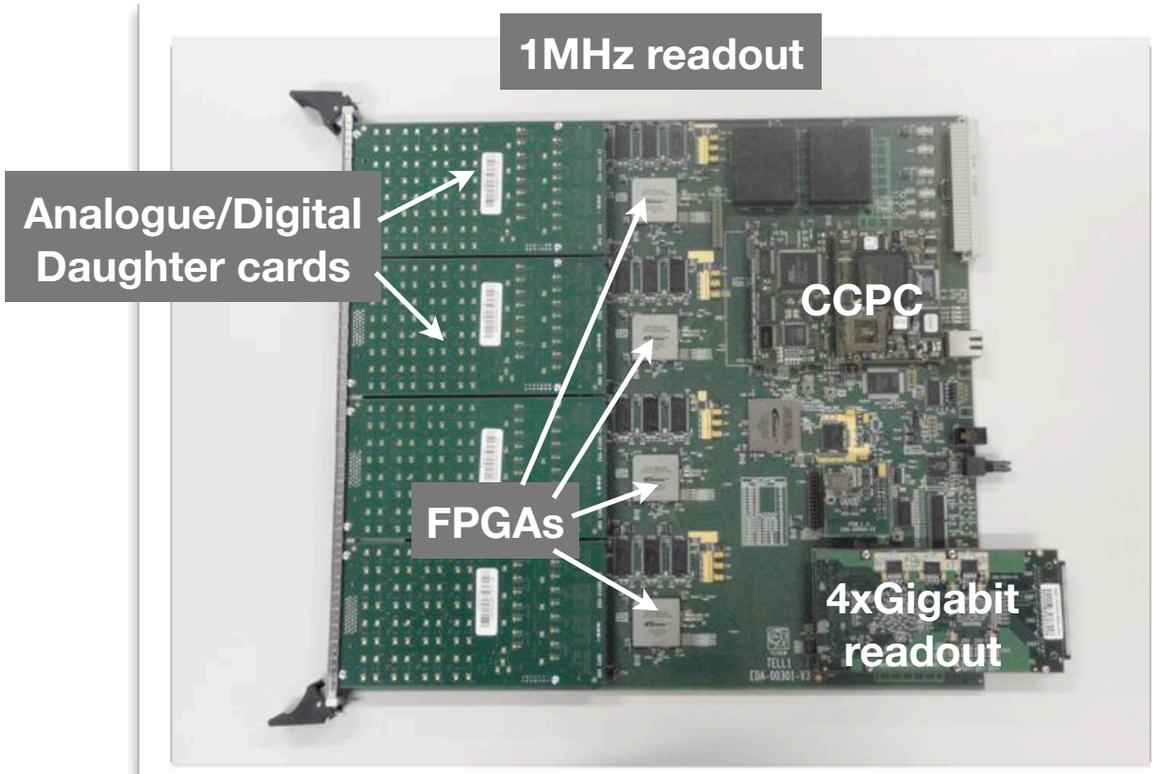


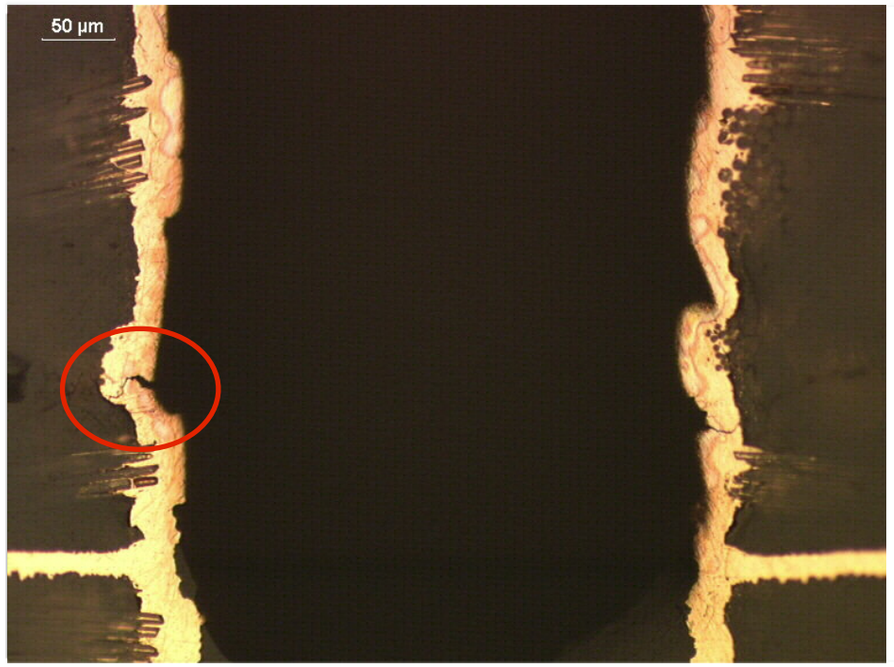
- Multiwire Proportional Chambers, except M1R1 - triple GEM
- HV power supplies
  - resistor on daughter boards faulty, had to replace on 2500 boards
  - high infant mortality, ~25% had to be repaired/ replaced by manufacturer
  - much more stable with recent replacements and repair
- CARIOCA (amp, shaper) & DIALOG (logic)- no problems
- SYNC (TDC) - minor mis-timing bug - tightened time window -> OK.



TELL1 - Common readout board for LHCb

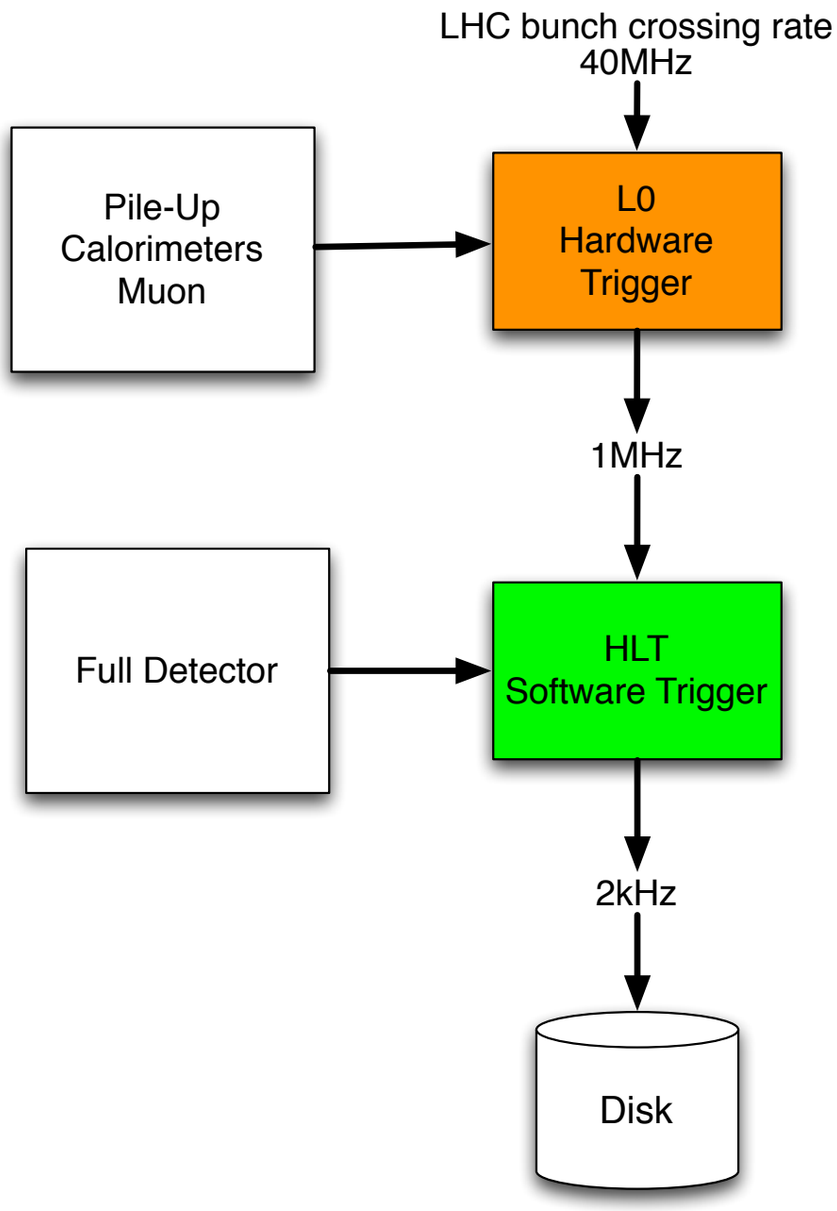
- Failing TELL1s
  - 10/292 this year, very little in last few months
  - often during powercuts
- Tell1 replacements
  - *Not plug and play*
- Firmware on FPGAs
  - enables same board to be used by different sub-detectors
  - Lots of testing/emulation needed before firmware upgrade qualified
  - *requires a lot of support from subdetector*
- Tell1 high rate issues - resolved in new firmware





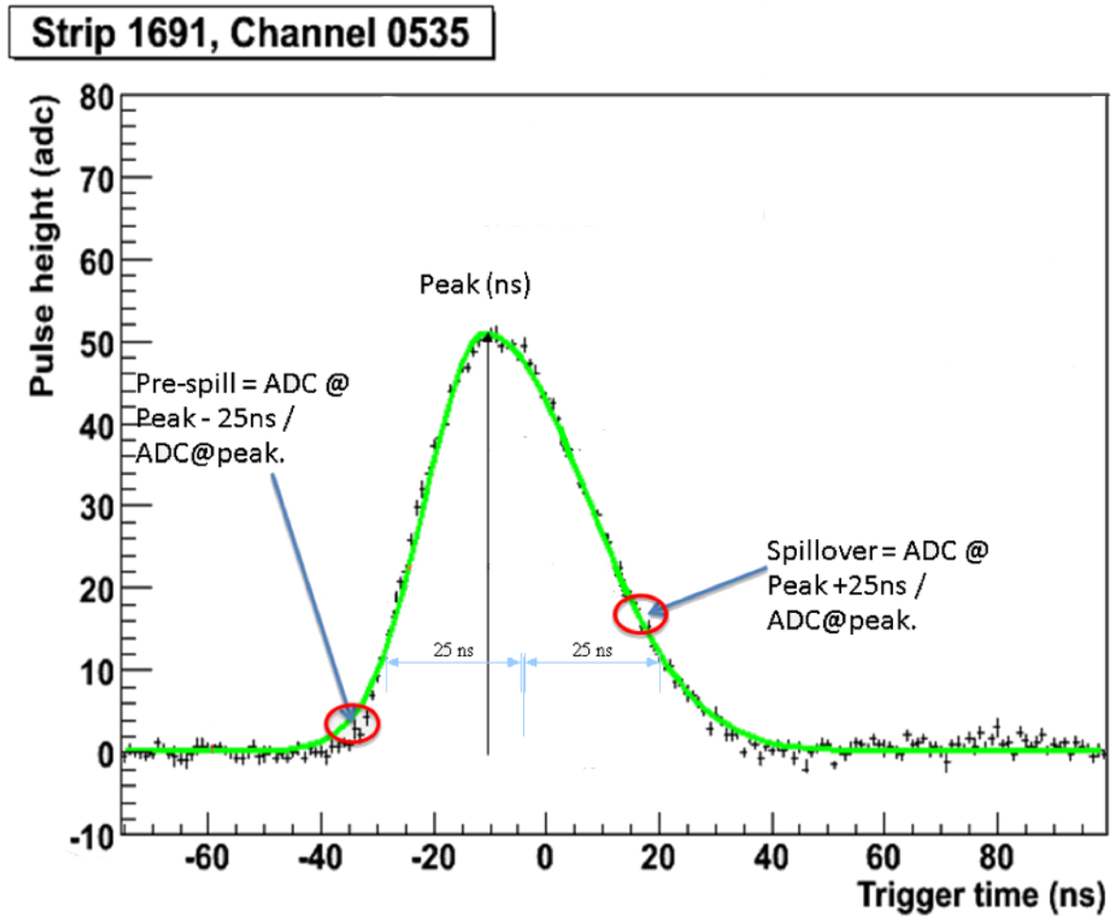
Trigger

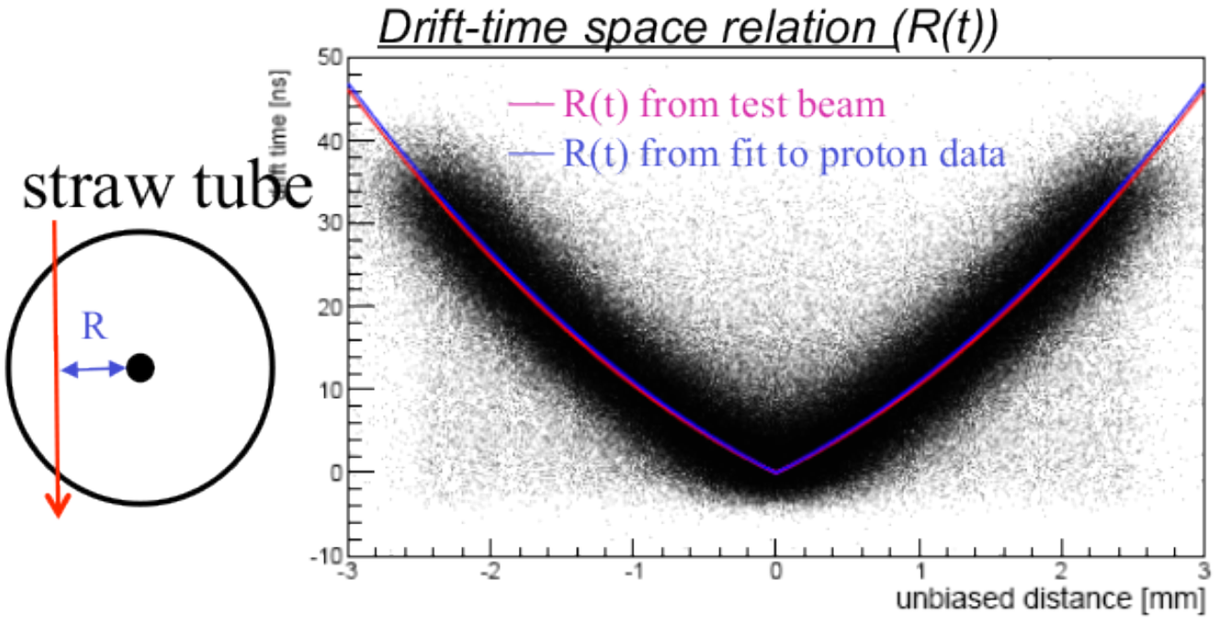
- L0 Hardware trigger uses 1.6GHz high speed opto-links
  - L0 Decision Unit - no problems
- HLT Farm
  - 550 servers, 4 core, 1GB ram/core = 1/3 of final configuration (staged)
  - Upgrade expected soon



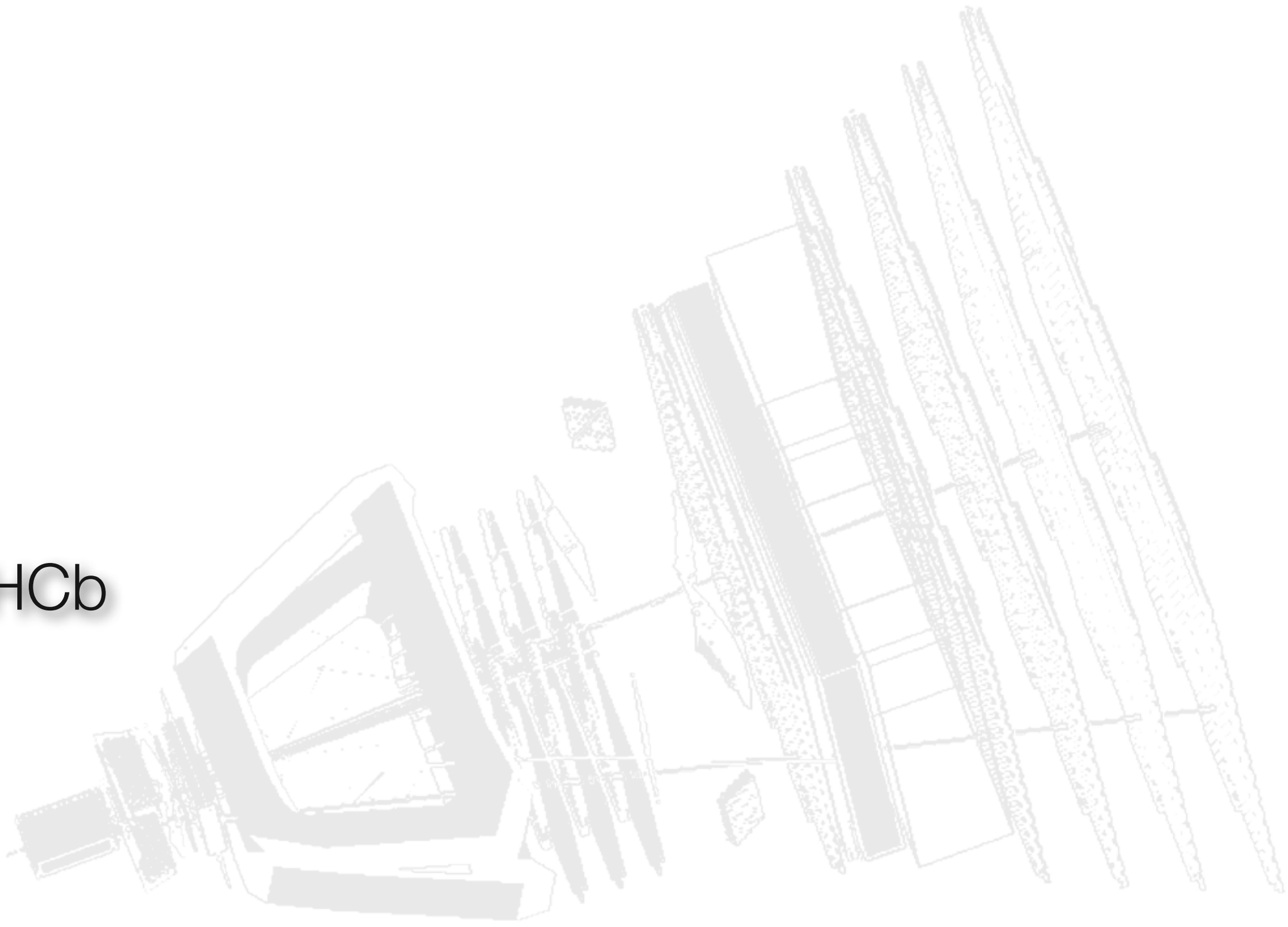
Timing

- Global LHCb timing
  - Calorimeter timed to beam crossing (0.75ns)
- Other subdetectors time to calorimeter
- VELO - all links timed to 1ns
  - Equalise pre-spill/spillover
- OT good to ~2ns





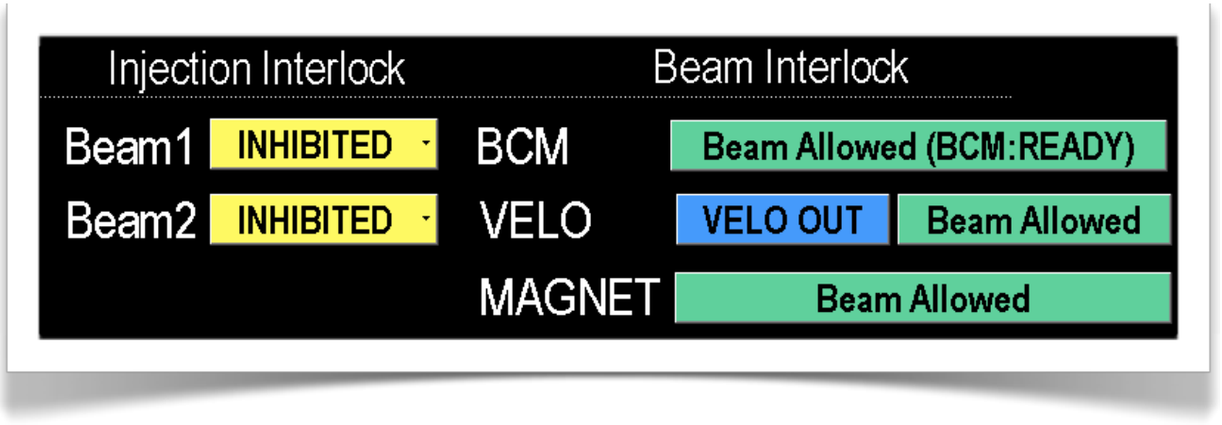
LHCb



General LHCb Improvements

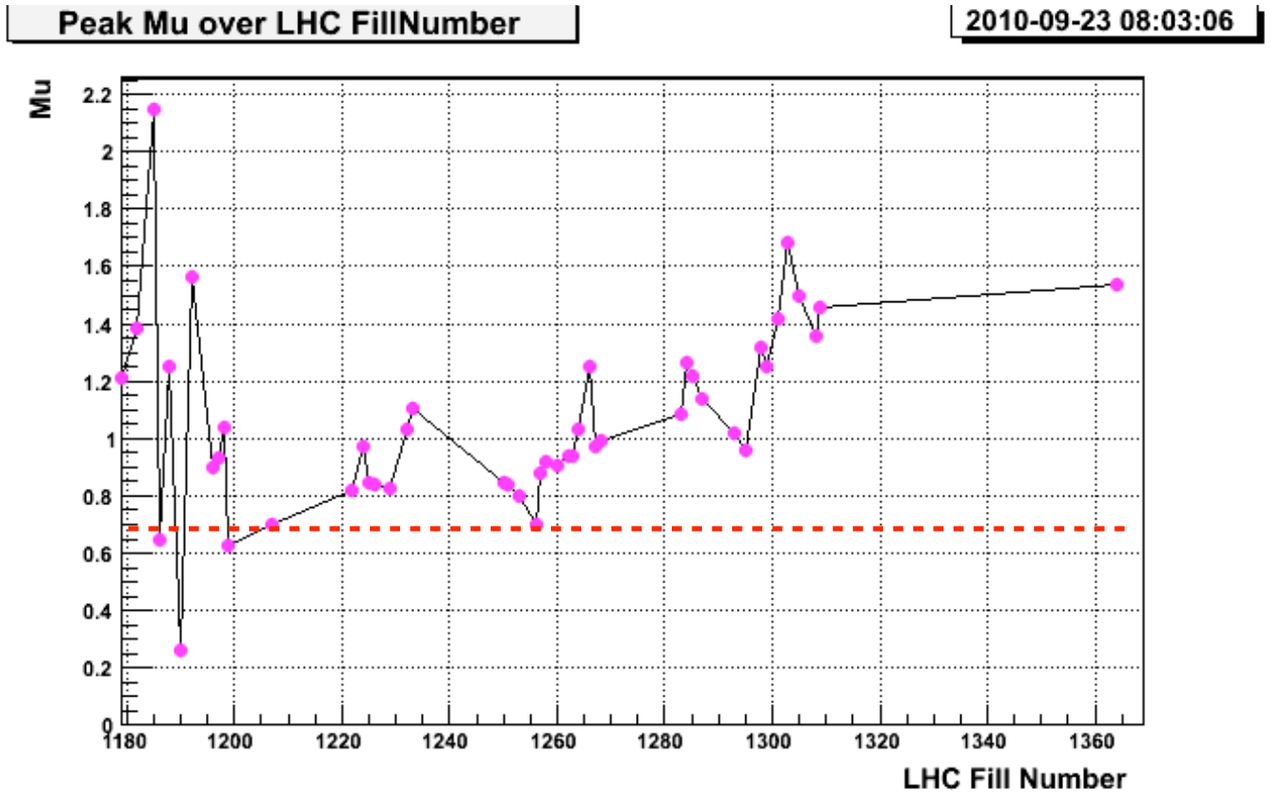
- Work on reducing down-time during beam
  - automatic recovery of failing DAQ systems
  - exclude/include trigger farms on the fly during data taking
  - problems in monitoring/calibration do not halt running
  - fewer problems running at high rate (100-200kHz L0)
- Some things can't be prevented
  - Thunderstorms, general powercuts, network outages - recovery time ~6 hours
  - Learned much from recent test power-cuts - faster in future
- Interface with LHC
  - High level of automation, interlocking
  - Shifter required for confirmation
  - VELO critical - most sensitive part of LHCb

Detector	Efficiency
VELO	99.3
ST	99.1
OT	>99.9
RICH	96.3
CALO	>99.9
MUON	99.8

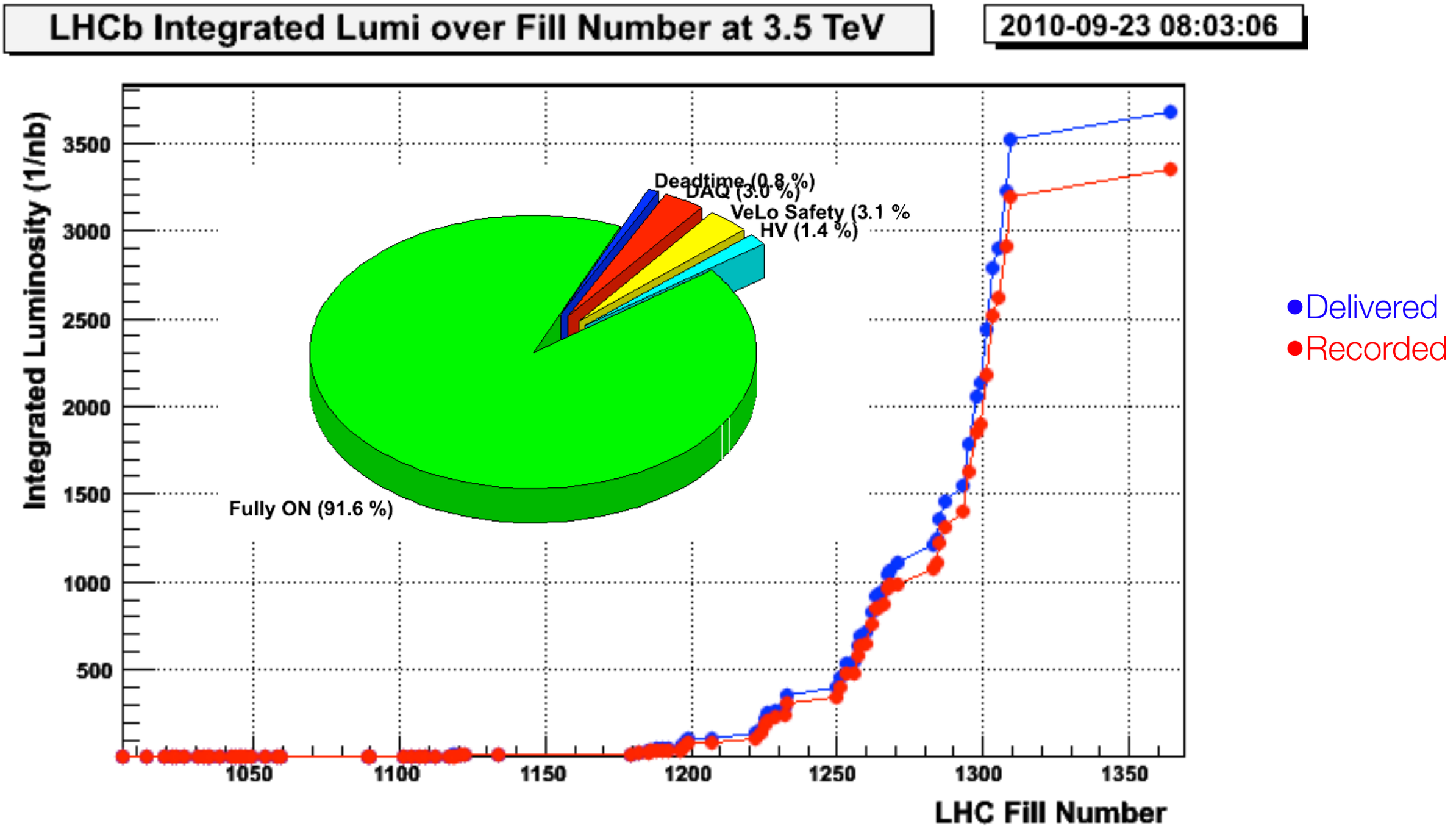


LHCb Increasing Data rate/size

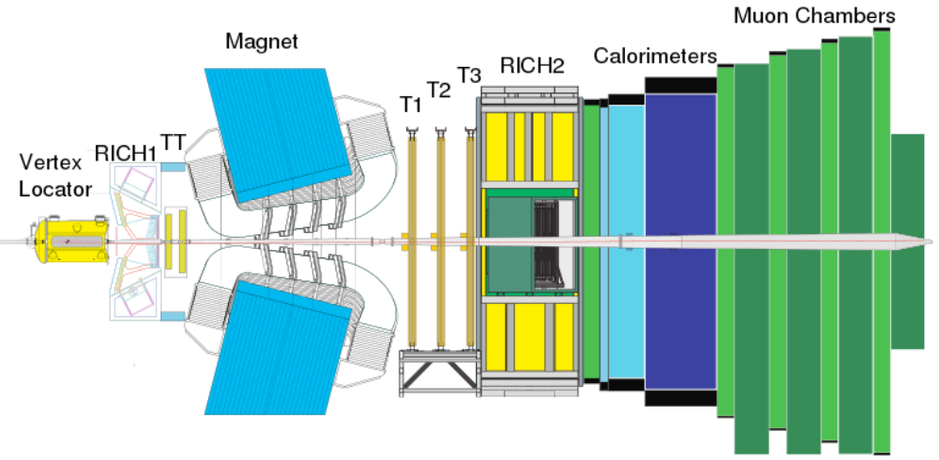
- Multiple Interactions - 1.5 per bunch crossing - designed for 0.7
  - high occupancies, large event size (85kB vs 35kB), storage backpressure
  - identifies bottlenecks
- At higher luminosity
  - need new trigger config as data rate goes up
  - *harsher cuts at L0 trigger*
  - *harsher cuts in HLT*
- Current running scenario closer to upgrade design
  - Adapted firmware/software to cope with large event sizes

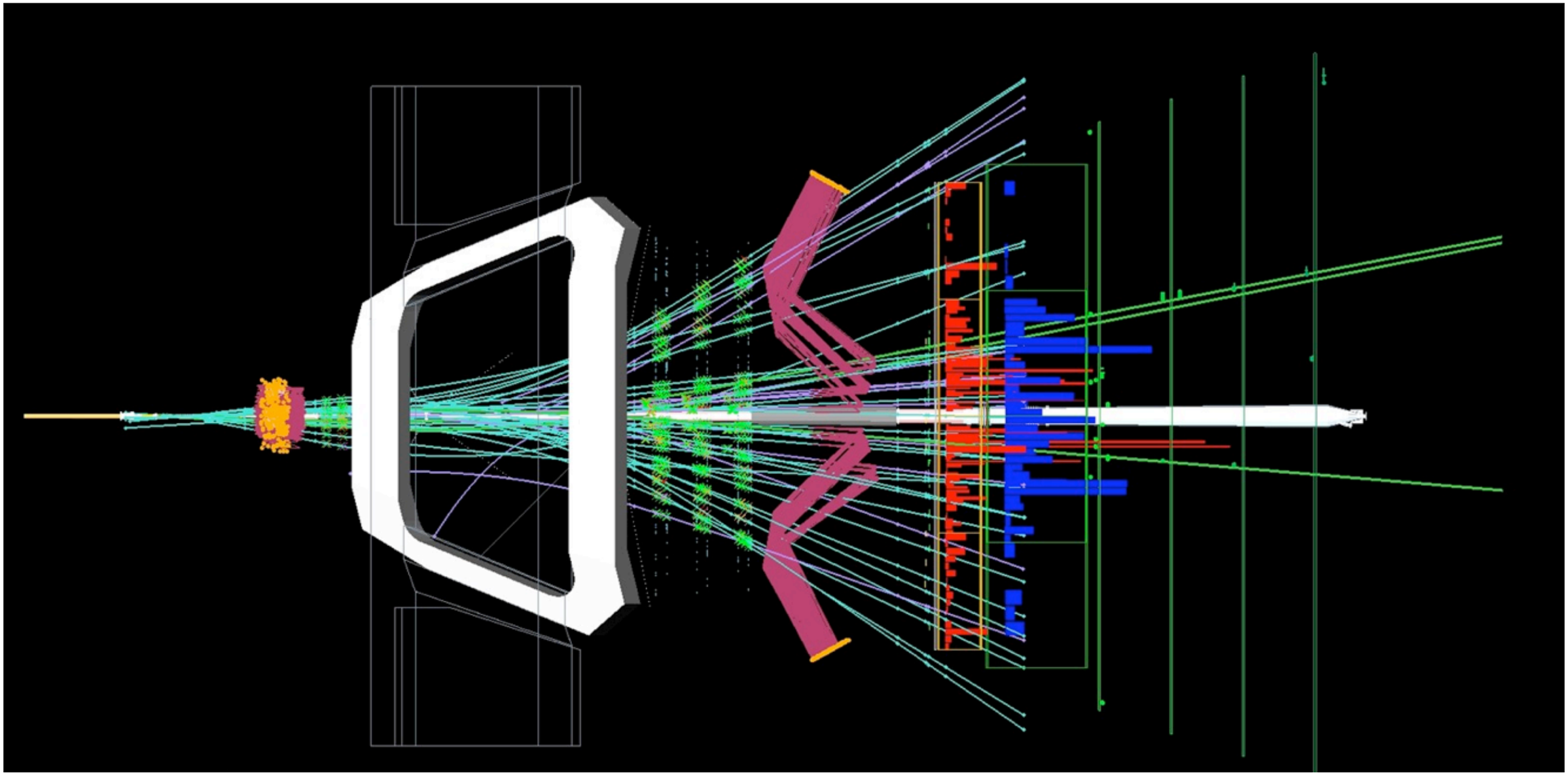


Luminosity Uptime



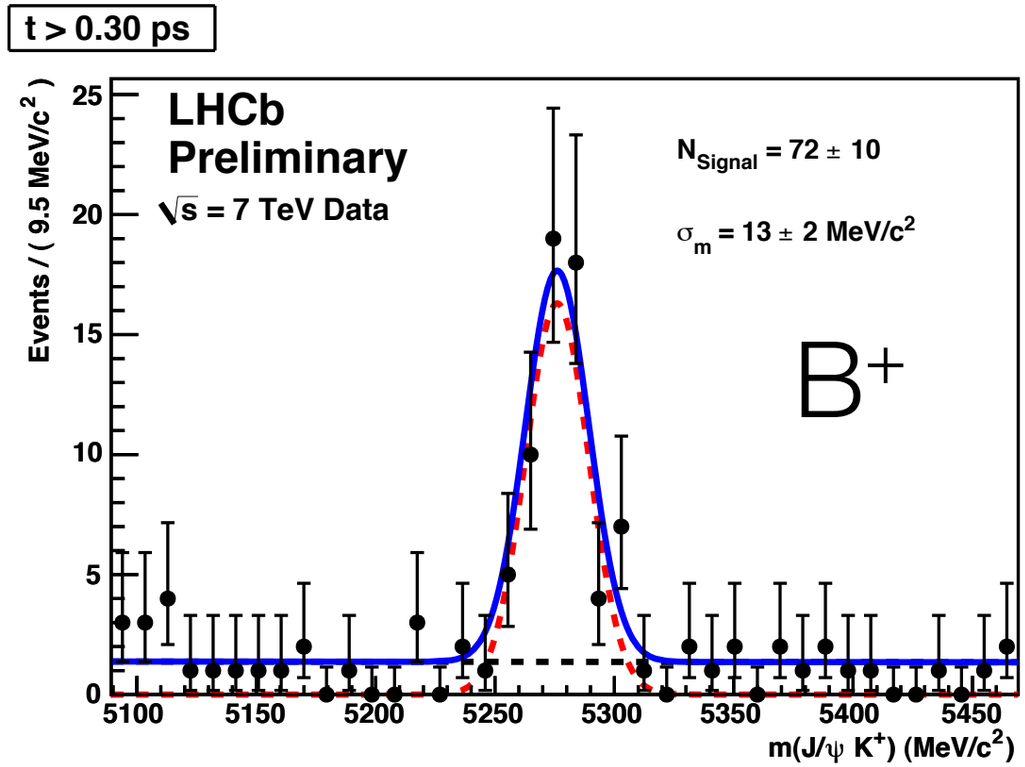
Result


Muon Chambers
Magnet
Calorimeters
RICH2
T3
T2
T1
TT
RICH1
Vertex
Locator



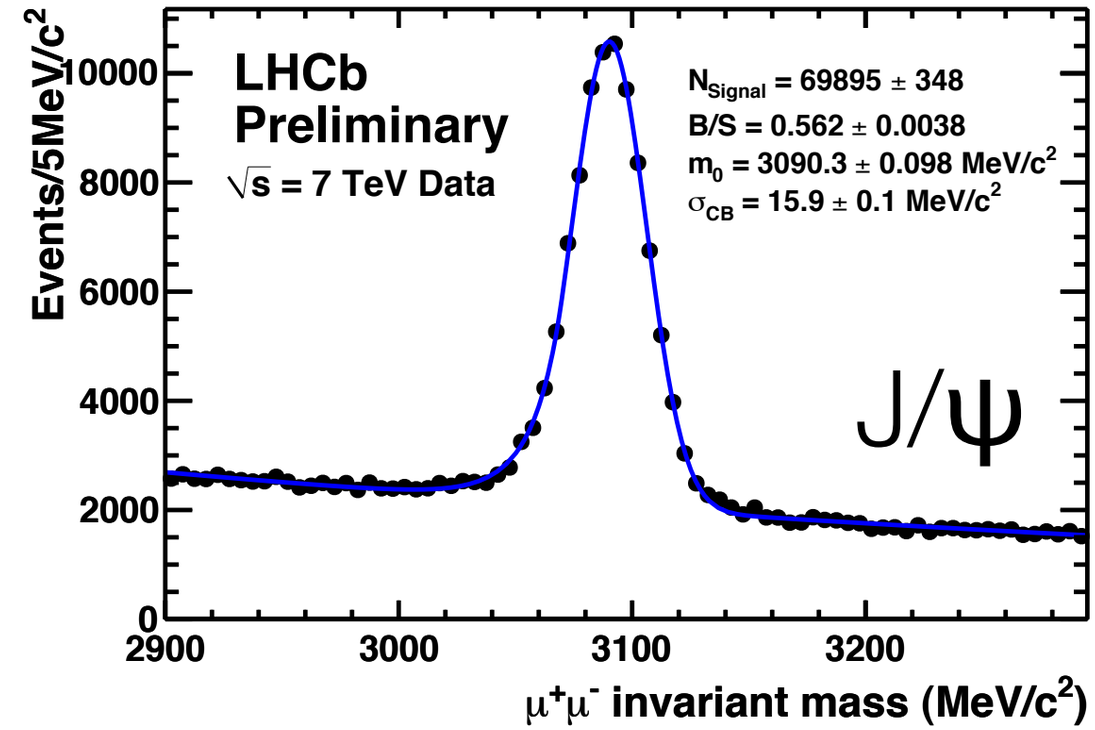
Conclusion

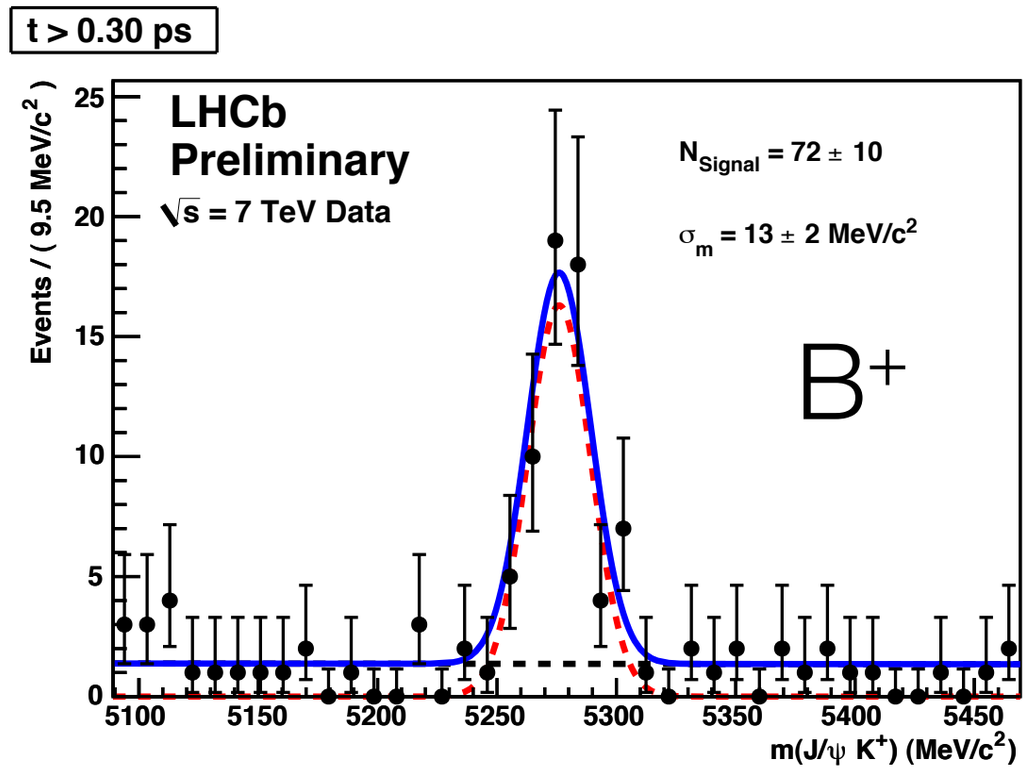
- LHCb showing excellent performance
- Over 91% uptime for *total* luminosity delivered this year.
  - Typically 97% in recent months
- Most subdetectors >99% working channels
  - others fixed/replaced in winter stop
- LHCb is a precision physics detector with unique capability
  - Will reach its physics potential next year
- Looking forward to fruitful years of physics to come.

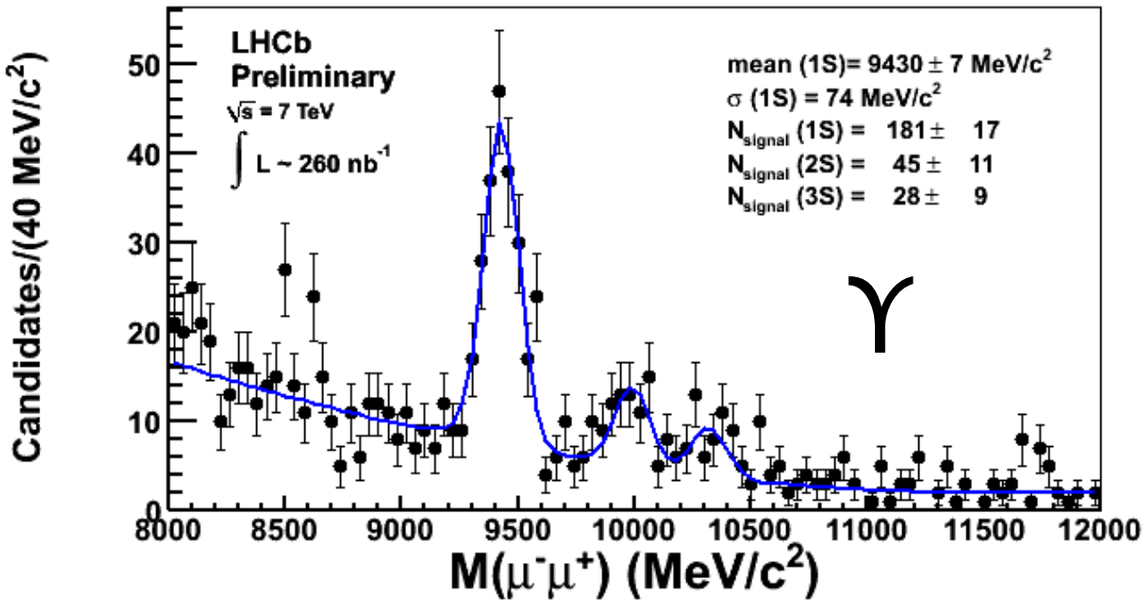


Backup

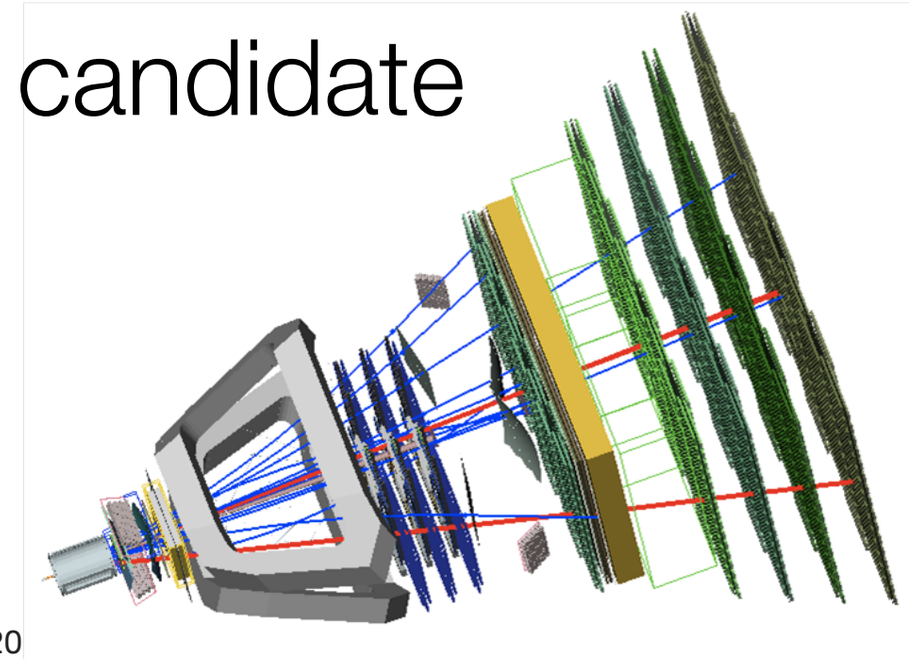
Results!



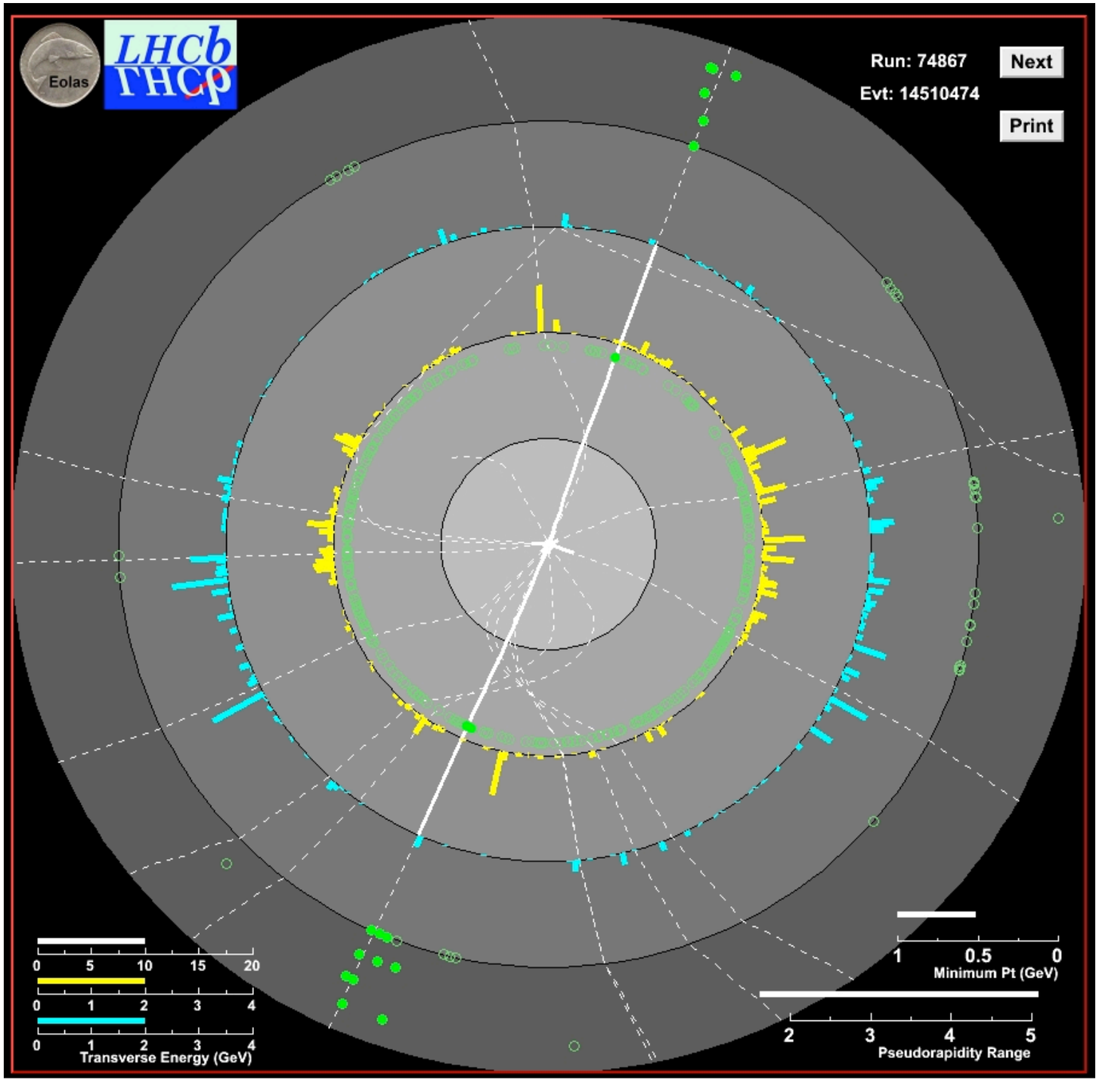




Z^0 candidate



Z^0 Candidate



Timing

Time after peak (ns)	Prespill %	Spillover %	S/N loss %
0	2.0	24.5	0
1	4.0	21.8	1.6
2	6.2	19.2	1.5
3	9.2	16.8	2.2
4	13.0	14.6	4.4
5	17.5	12.5	6.4
6	22.9	10.5	8.7