LHCb VELO telescopes

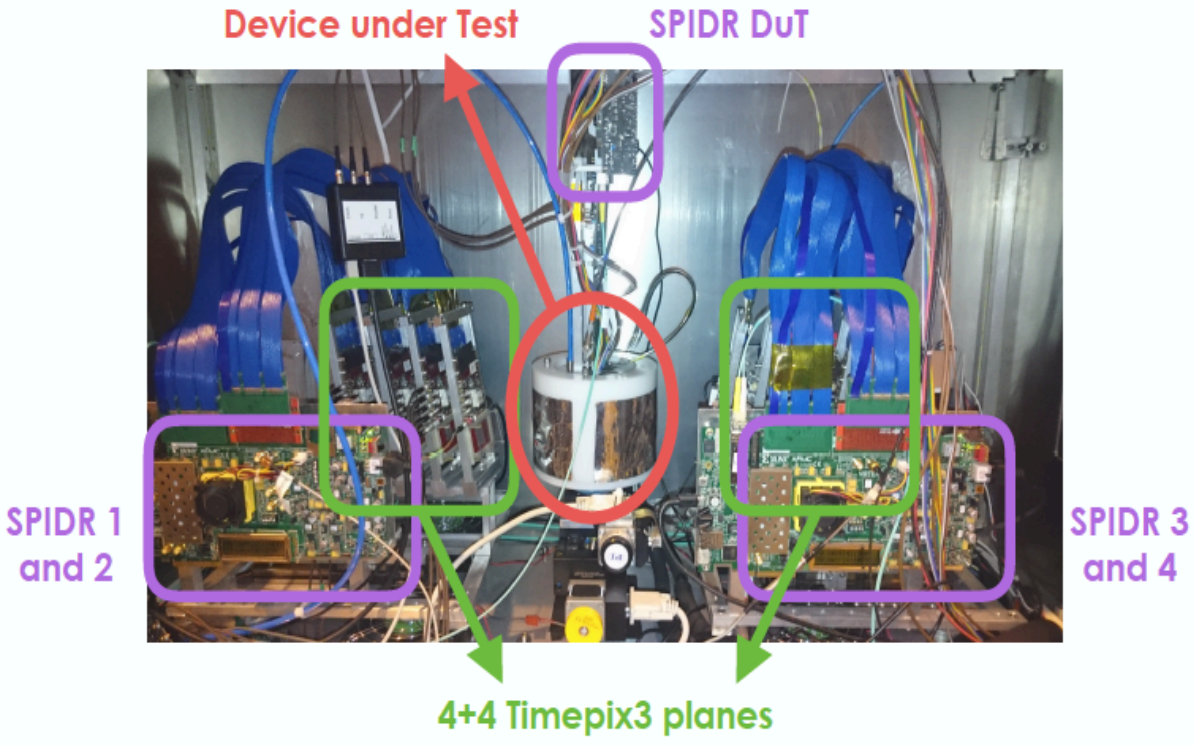
Martin van Beuzekom
on behalf of the LHCb VELO testbeam group
BTTB6
18 January 2018

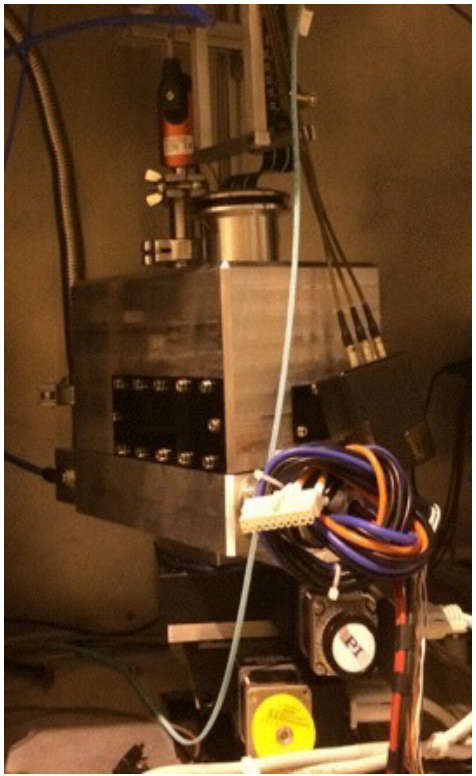
- Update Timepix3 telescope
- Some performance figures
- VeloPix mini telescope

LHCb

Nikhef

LHCb VELO timepix3 telescope at SPS



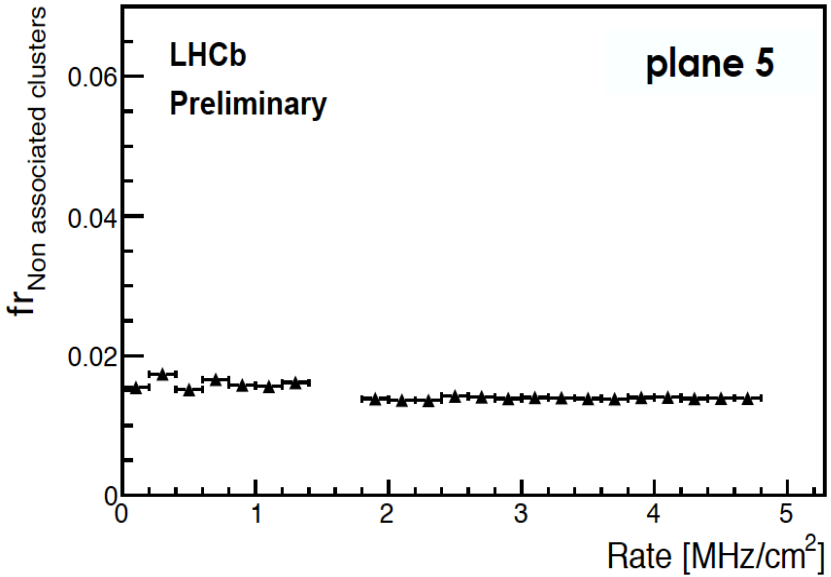


vacuum box for 1 kV sensors bias

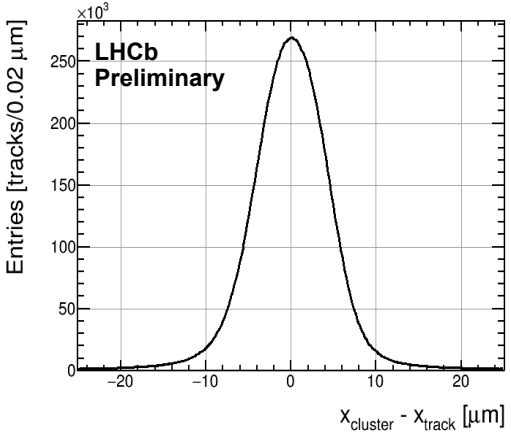
- Built for LHCb VELO upgrade sensor characterisation
- Each plane: 300 μm Silicon on 700 μm Timepix3, no PCB
- Simultaneous ToA and ToT measurement
- Data driven readout with SPIDR

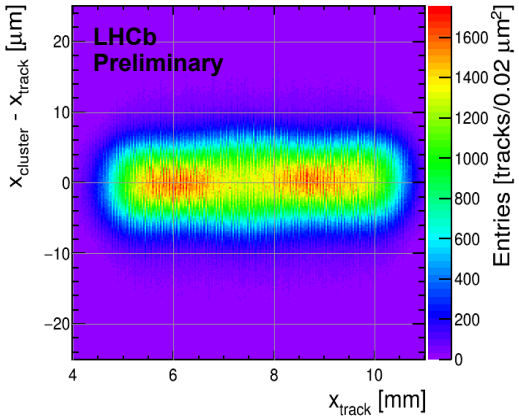
Telescope introduction II

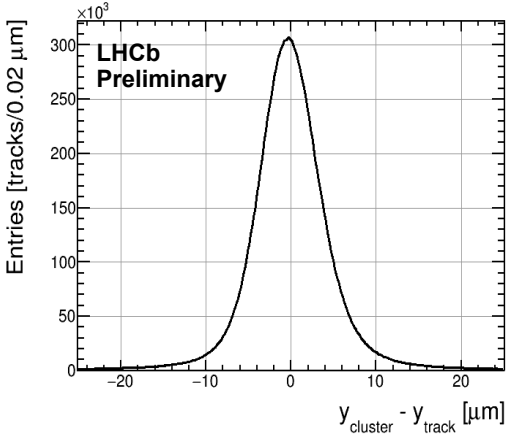
- High tracking rate, ~10 Mtracks/cm^2/s by design
- Tested up to 5 Mtracks/cm^2/s without loss of performance
- Four TDC inputs with 260 ps bins to ease integration of DUTs
- Analysis with Kepler (Gaudi based) reconstruction framework
- Telescope used by many LHCb and non-LHCb groups

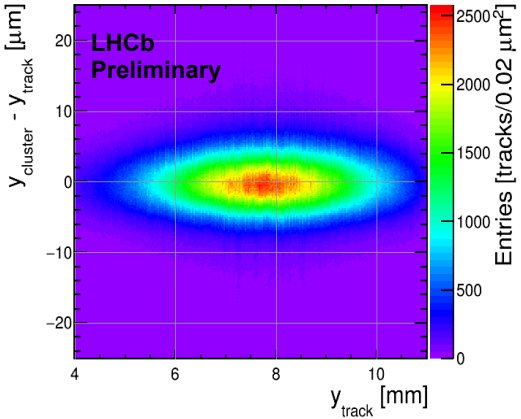


Performance: Spatial resolution



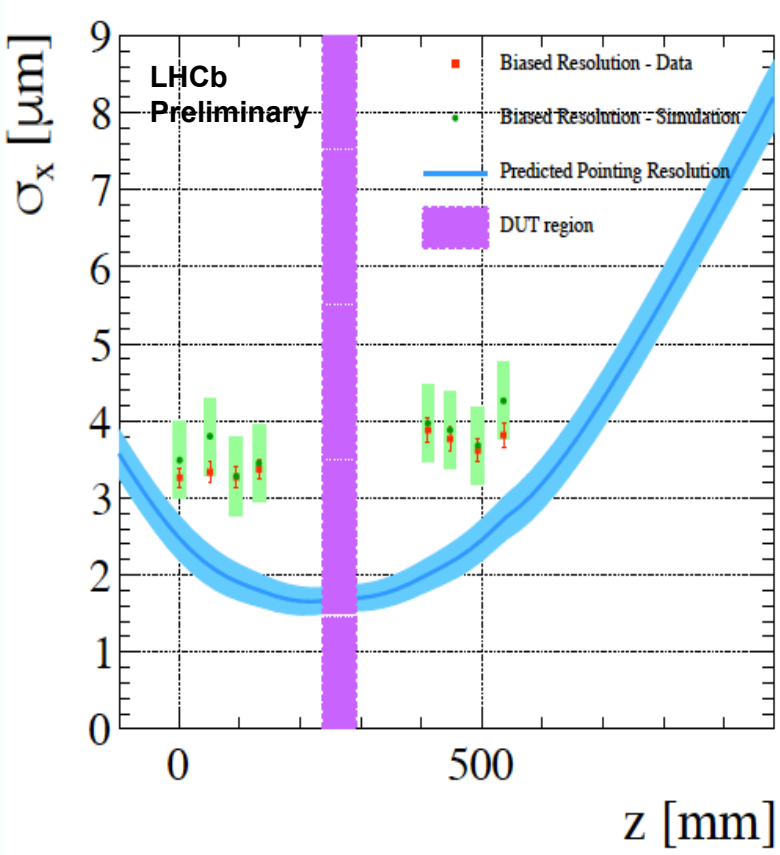


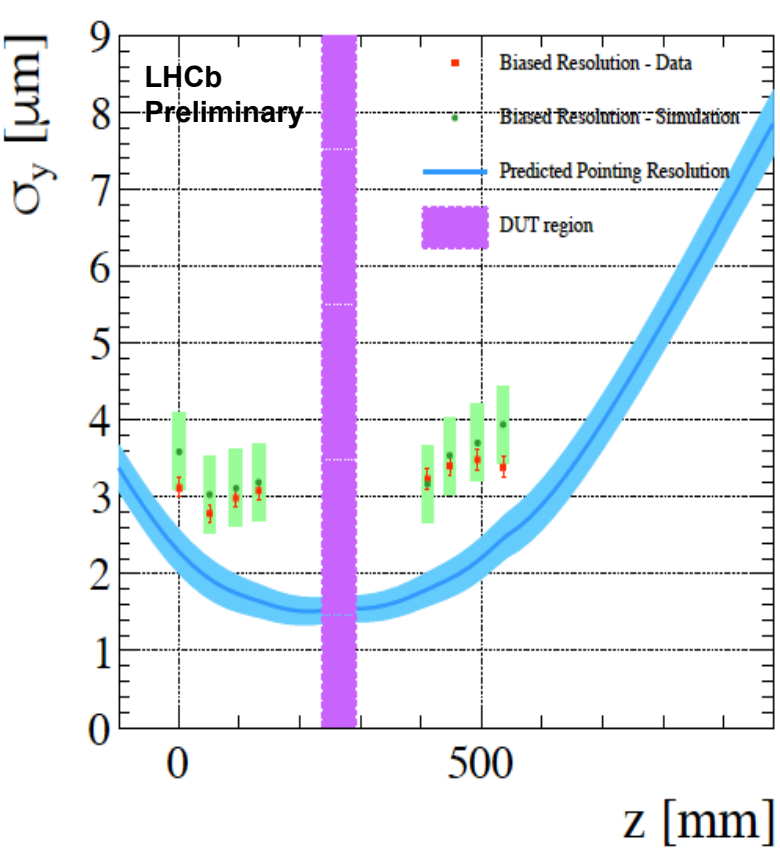




- Pixel dimensions 55 x 55 μm^2
- Detector planes at 9° angles (yaw, pitch) for optimal resolution
- (biased) Resolution 3 – 4 μm
- No significant contribution from (mis)alignment

Performance: Pointing resolution

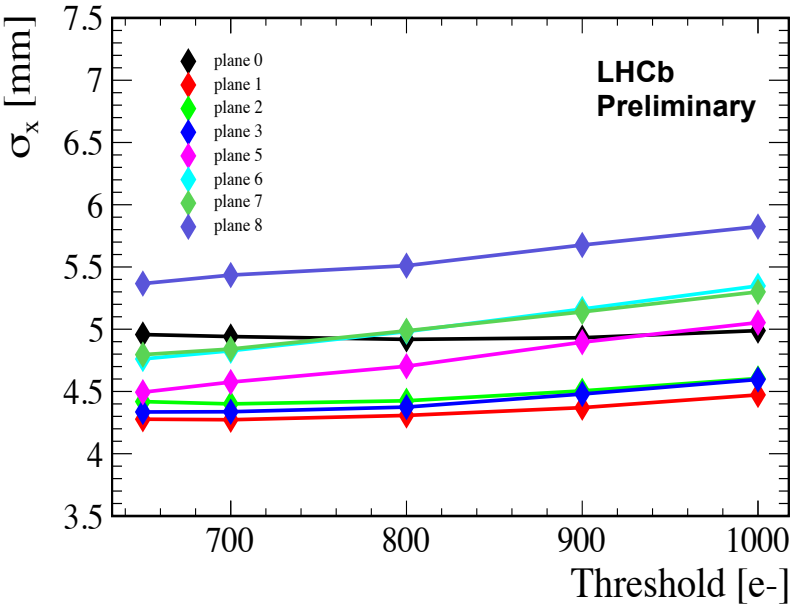


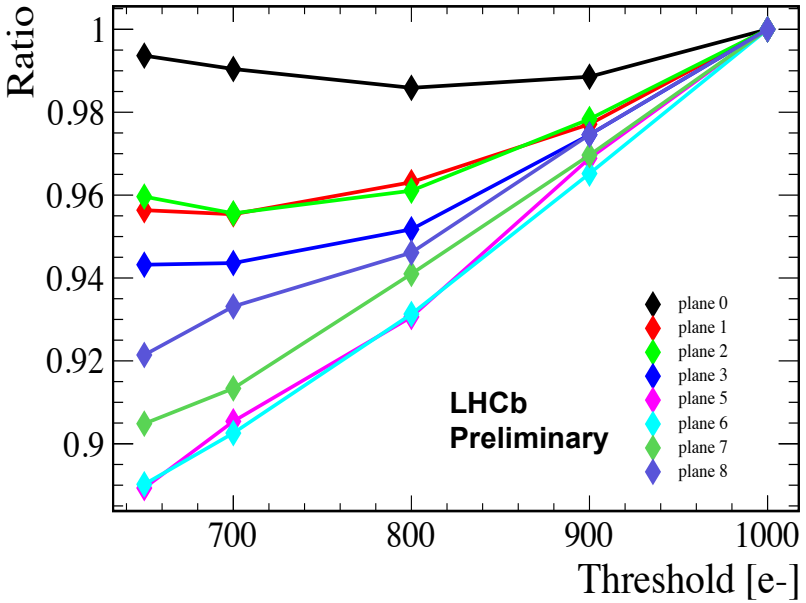


Pointing resolution near DUT: x=~1.67 μm & y=~1.57 μm

Some improvement possible: lower threshold

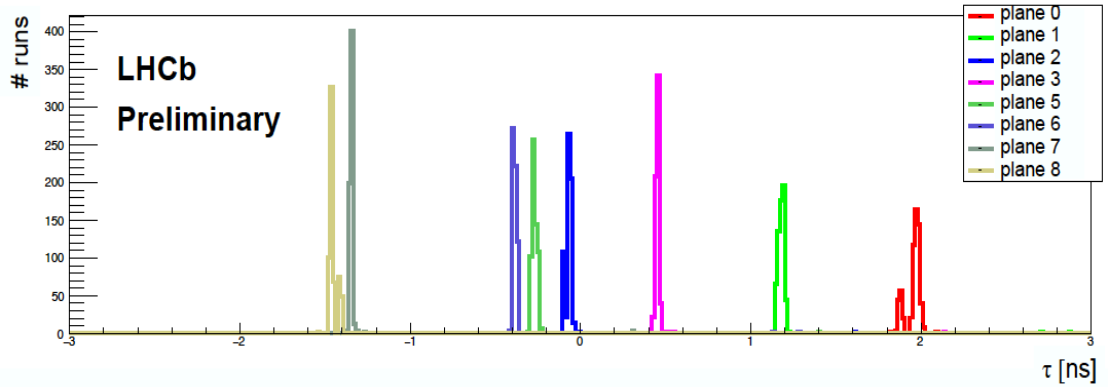
- Default threshold 1000 e-
- Lower threshold gives up to 10% resolution improvement
  - due to slightly larger cluster size
- Some extra noise for very low thresholds





Performance: Time resolution

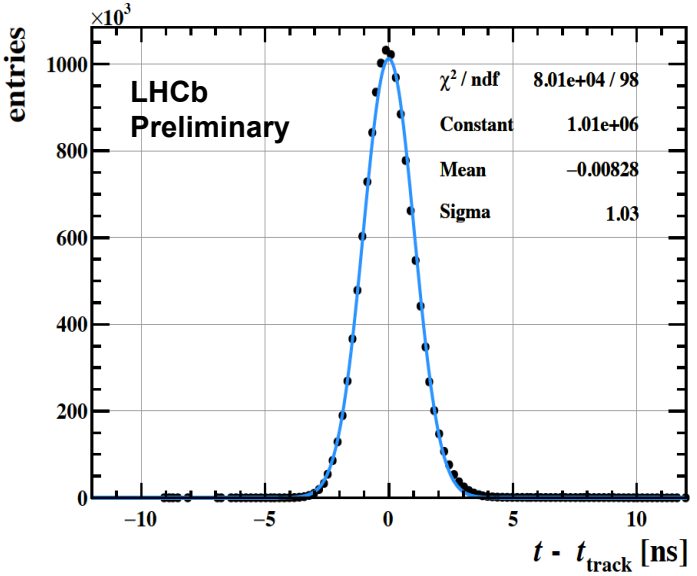
mean of biased track time residual



- Timing stable from run to run
- Offset determined per run

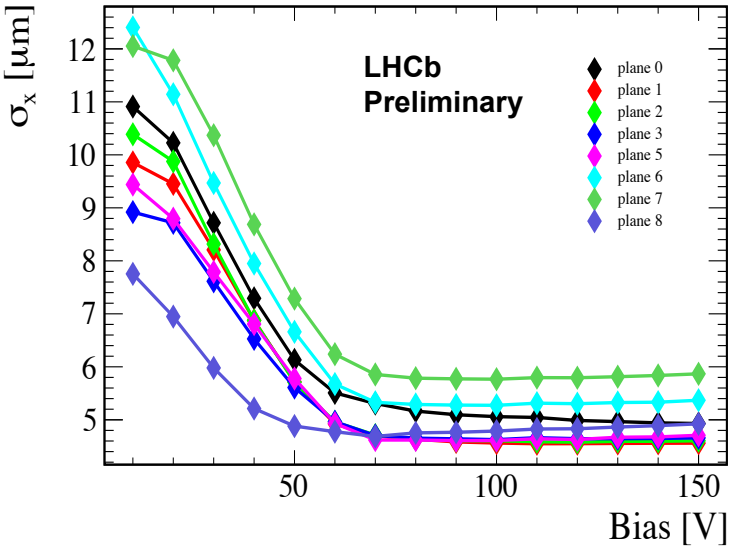
- Time resolution per plane σ_{int} = ~1 ns
  - worse than expected (1.56 ns / $\sqrt{12}$)
  - due to residual timewalk and charge collection time
- Telescope time resolution $\sigma_{tel} = \sigma_{int} / \sqrt{8} = 0.35$ ns
  - too optimistic?, residuals might be correlated
- Dedicated study required, some data available

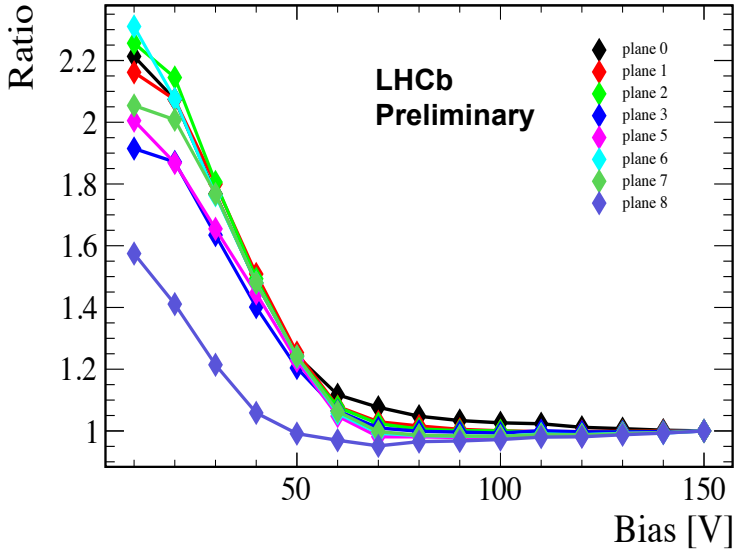
biased track time residual



Resolution versus bias voltage

- Charge collection, hence timing will improve with higher bias voltage
- However, we do not want to compromise spatial resolution
- Seems that spatial resolution barely changes from 100 to 150 V bias
- Improvement on time resolution not yet determined

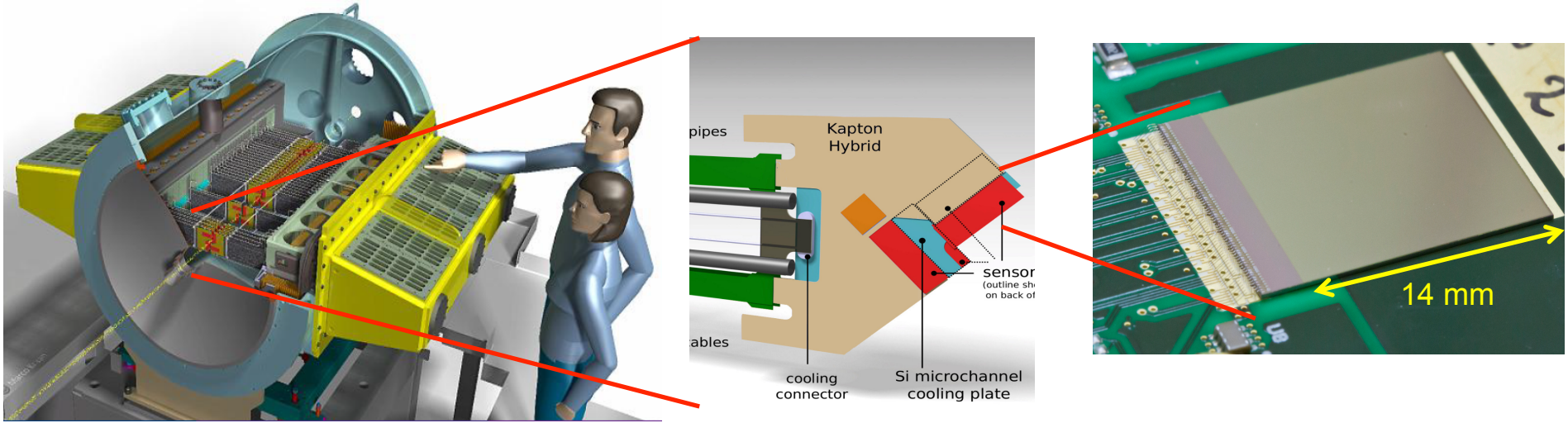




VeloPix

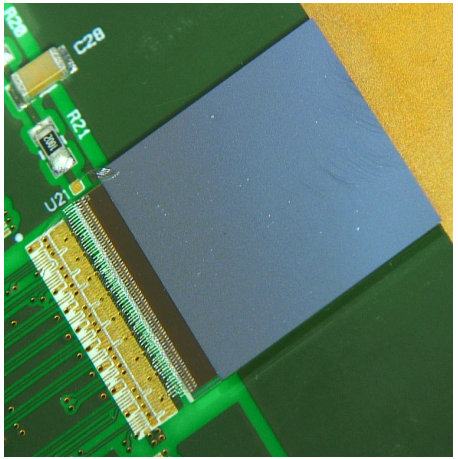
Reminder: LHCb VeloPix

- Derived from Timepix3, tailored to LHCb Vertex Locator
- Binary readout, radiation hard
- No trigger, read out all data, AND high luminosity -> huge data rates (20 Gbit/s/chip)
- First chip version fully functional but had some flaws -> version used in mini-telescope
- Issues solved for 2nd version of VeloPix, final qualification ongoing



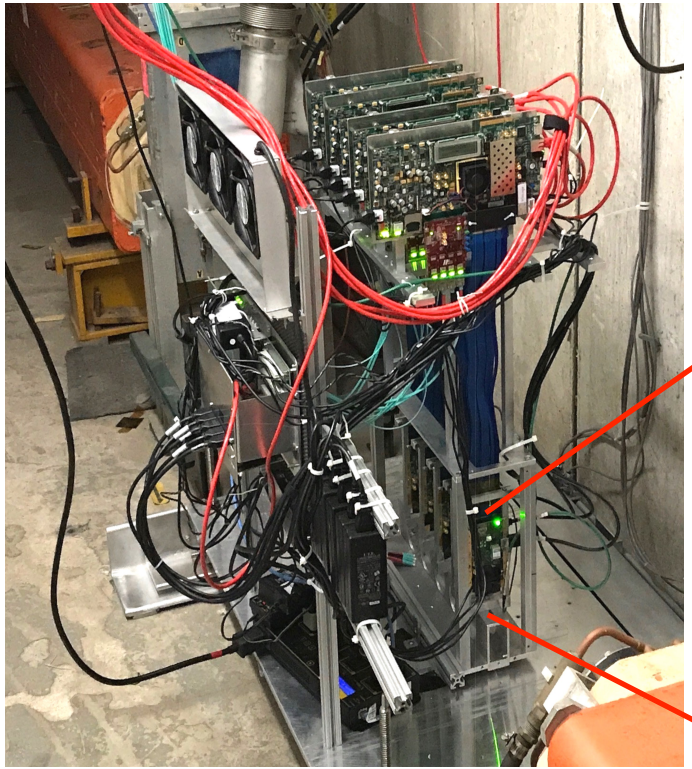
Comparison VeloPix and Timepix3

	Timepix3 (2013)	VeloPix (2016)
Pixel arrangement	256 x 256	
Pixel size	55 x 55 μm²	
Peak hit rate	80 Mhits/s/ASIC	800 Mhits/s/ASIC 50 khits/s/pixel
Readout type	Continuous, trigger-less, TOT	Continuous, trigger-less, binary
Timing resolution/range	1.5625 ns, 18 bits	25 ns, 9 bits
Power consumption	<1.5 W	< 2 W
Radiation hardness		400 Mrad, SEU tolerant
Sensor type	e- and h+ collection	e- collection
Max. data rate	5.12 Gbps	20.48 Gbps
Technology	130 nm CMOS	

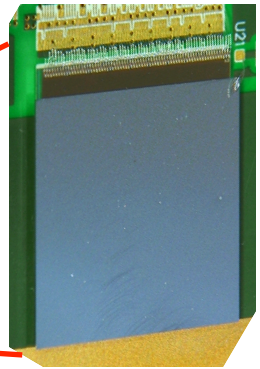


VeloPix mini telescope

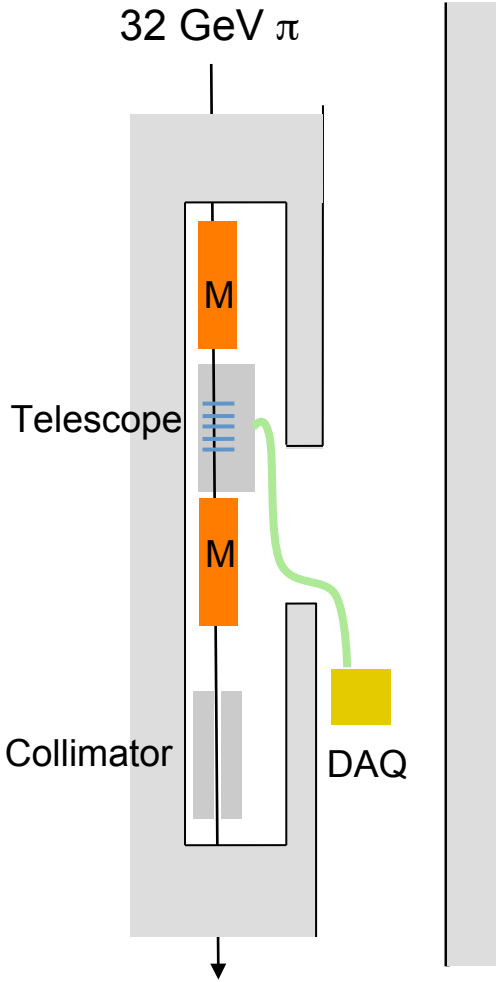
- Most VeloPix functions tested in lab and with Timepix3 telescope
- Except high rate performance

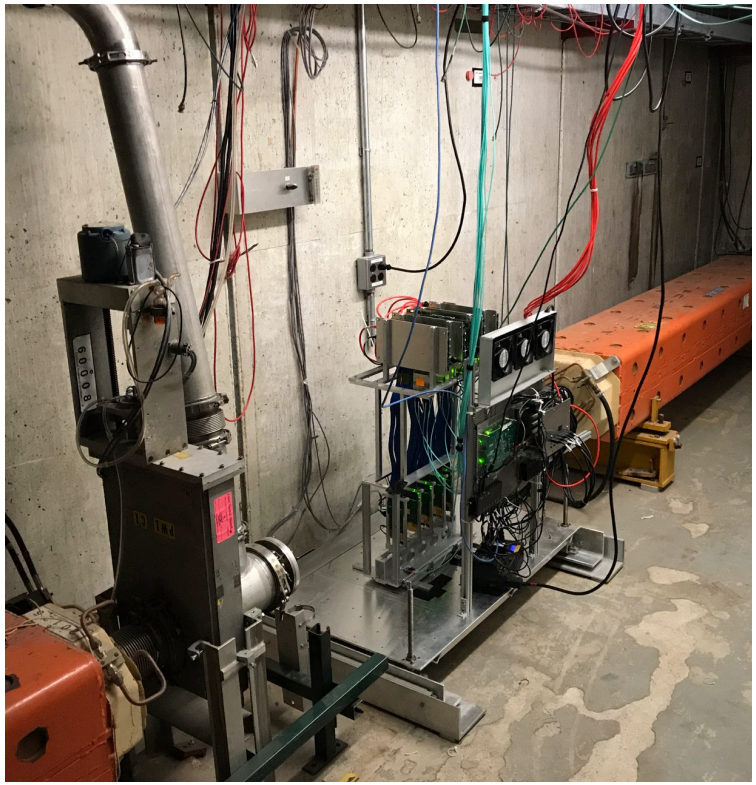


- Built a 5 layer (mini) telescope
- Reusing Timepix3 telescope HW
- Tested in High Rate area at Fermilab



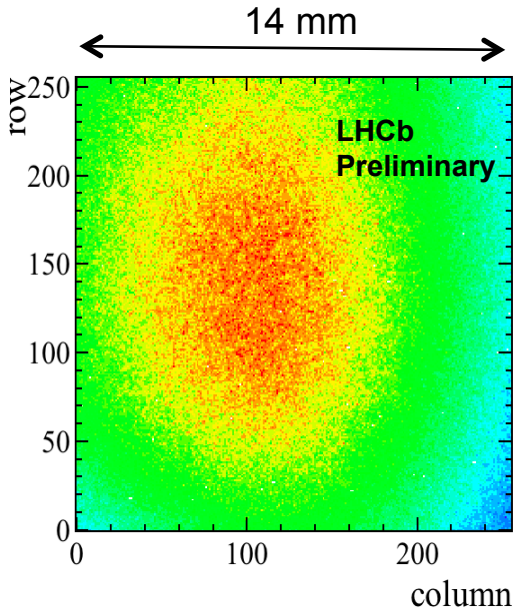
High rate test area at Fermilab (M03)

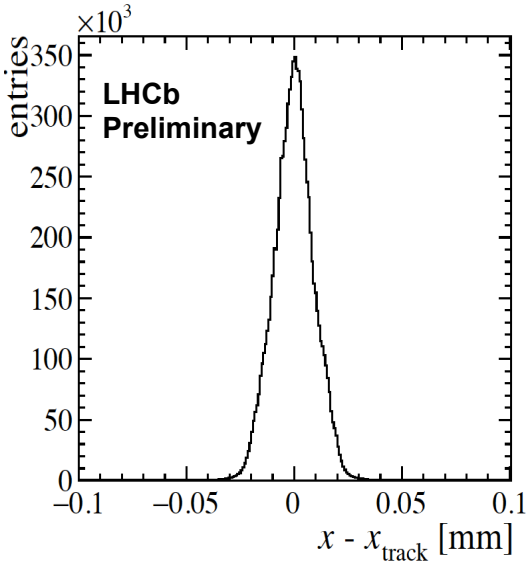




A look at the data

- First attempt to run telescope, many last minute fixes …
- Step wise increase of beam rate to > 200 Mtracks/cm^2/s
- One spill of 4.2 seconds gives about 40 Gbytes on disk
- Analysis with modified version Kepler framework
- First results look OK, but still need to analyse highest rate runs in detail



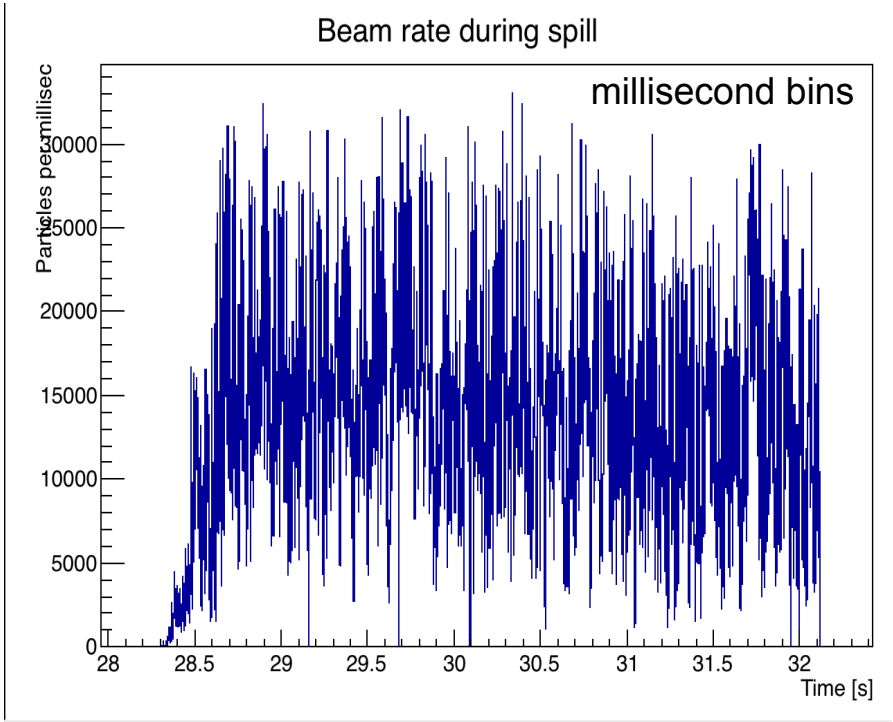


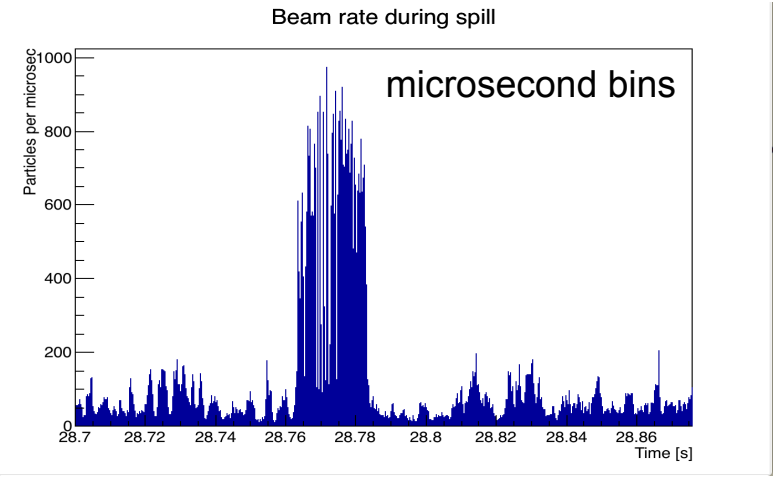
residuals ~ 10 um
(as expected)

first VeloPix tracks!

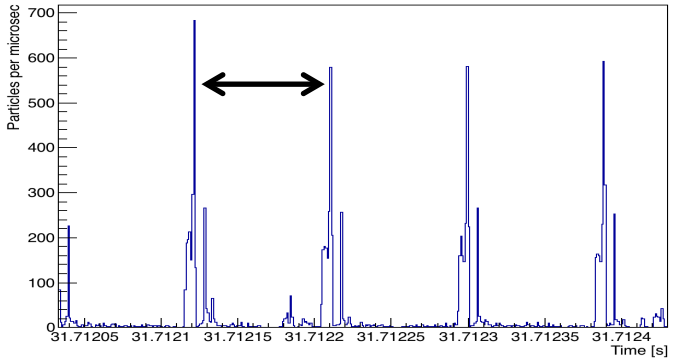
Beam rate

- Beam rate seems to fluctuate significantly, even at millisecond scale
- Average rates are misleading
- Some analysis challenges ahead





main injector cycle = 11.6 us: 7 batches, 1 filled

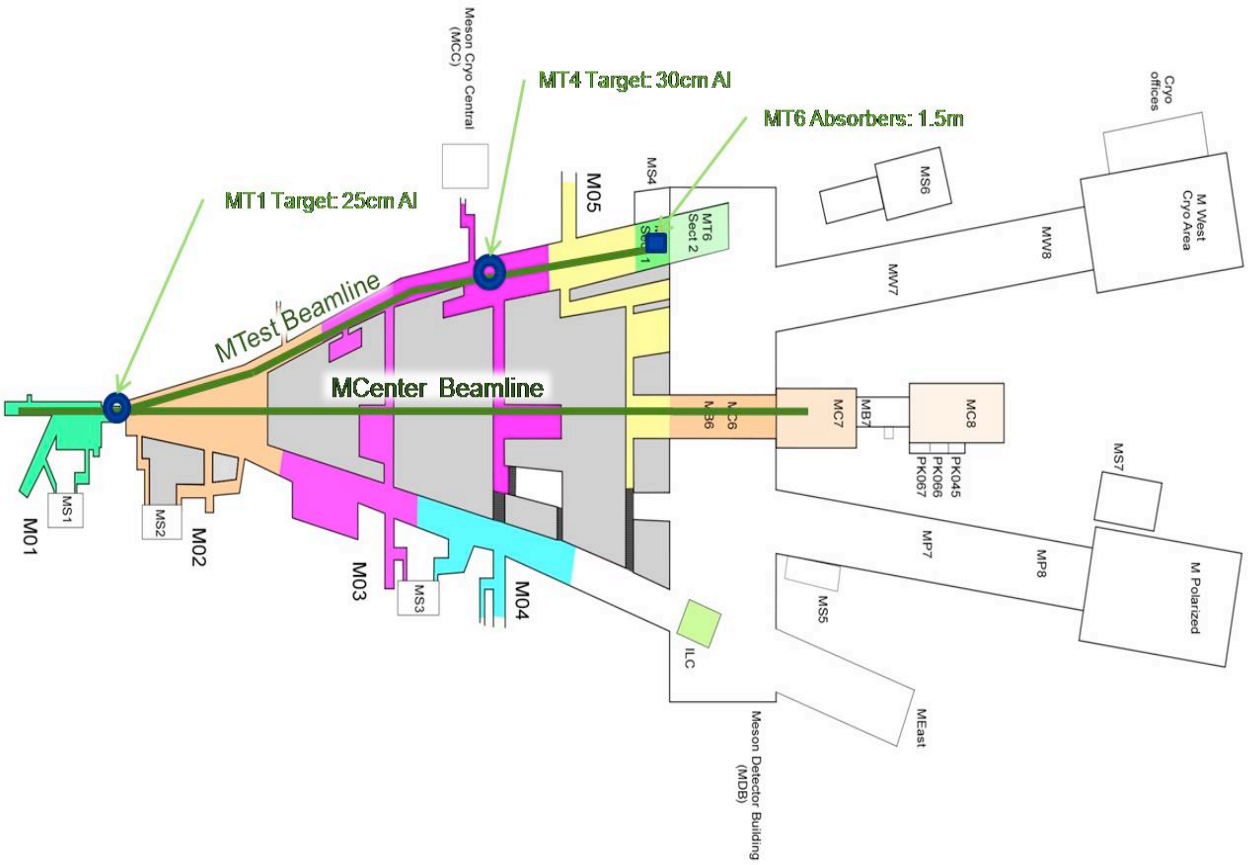


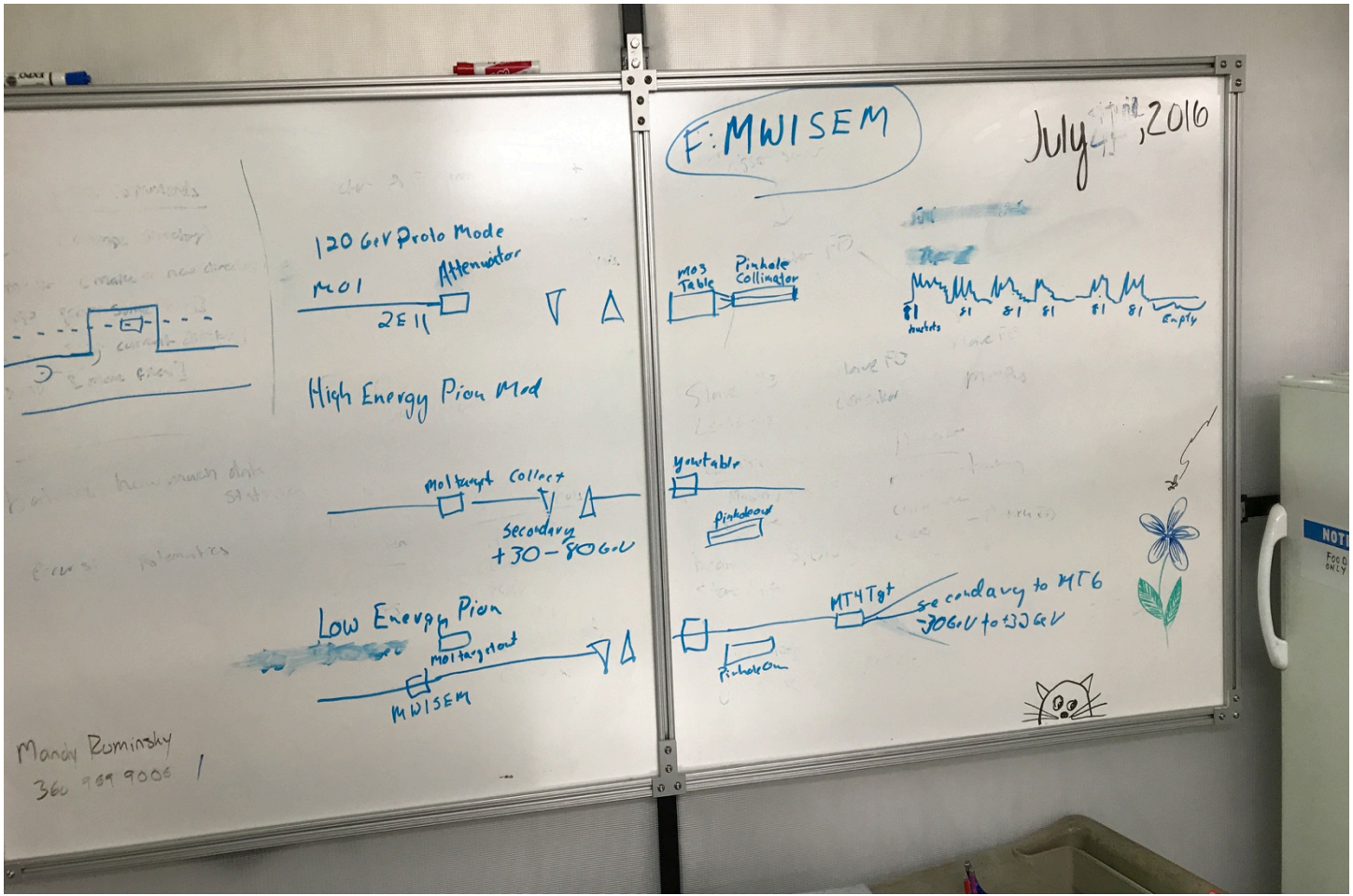
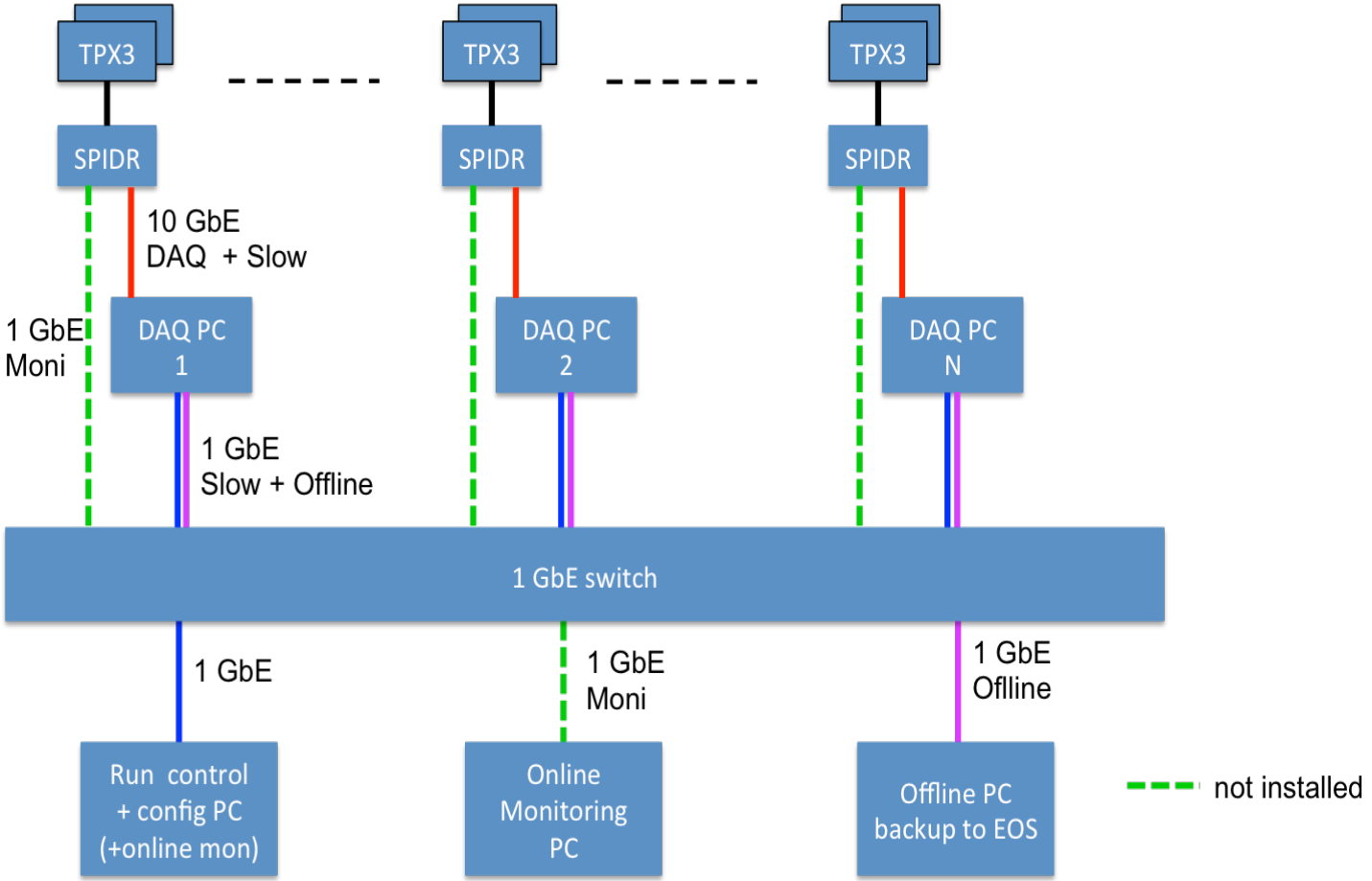
Summary

- LHCb Timepix3 telescope operated successfully > 3 years
  - Workhorse for LHCb VELO upgrade program
  - Also frequently used by other LHCb and non-LHCb groups
- Spatial resolution < 2 μm, time resolution < 1 ns, track rate > 5 Mtracks/cm^2/s
  - Minor improvements possible

- Built VeloPix mini-telescope to test VeloPix at high-rate at FNAL
  - Interesting and challenging 'exercise'
- Successfully acquired data with rates > 200 Mtracks/cm^2/s
- Results so far as expected; high rate data to be analysed in greater detail
  - Still on the agenda: timewalk measurement of VeloPix with Timepix3 telescope

Back up


Meson Cryo Central (MCC)
MT4 Target: 30cm Al
MT6 Absorbers: 1.5m
Cryo offices
MT1 Target: 25cm Al
MS4
M05
MS6
MT6 Sect 2
MT6 Sect 1
M West Cryo Area
MW8
MW7
MTest Beamline
MCenter Beamline
MC6
MB6
MC7
MB7
MC8
PK045
PK066
PK067
MS7
MP7
MP8
M Polarized
MS1
MS2
M01
M02
M03
MS3
M04
MS5
ILC
MEast
Meson Detector Building (MDB)


F: MWISEM
July 4, 2016
120 GeV Proto Mode
M01
Attenuator
2E11
High Energy Pion Mod
M03 Table
Pinhole Collimator
Empty
Collect
Secondary
+30-80GeV
Low Energy Pion
MWISEM
MT4Tgt
secondary to MT6
-30GeV to +30GeV
Mandy Rominsky

Timepix3 telescope networking