Benjamin Audurier - 2nd IFT workshop - Chia, 5 sept. 2019

LHCb Overview and future upgrades in heavy-ion collisions

I. LHCb today
II. LHCb Upgrade I
III. LHCb Upgrade II

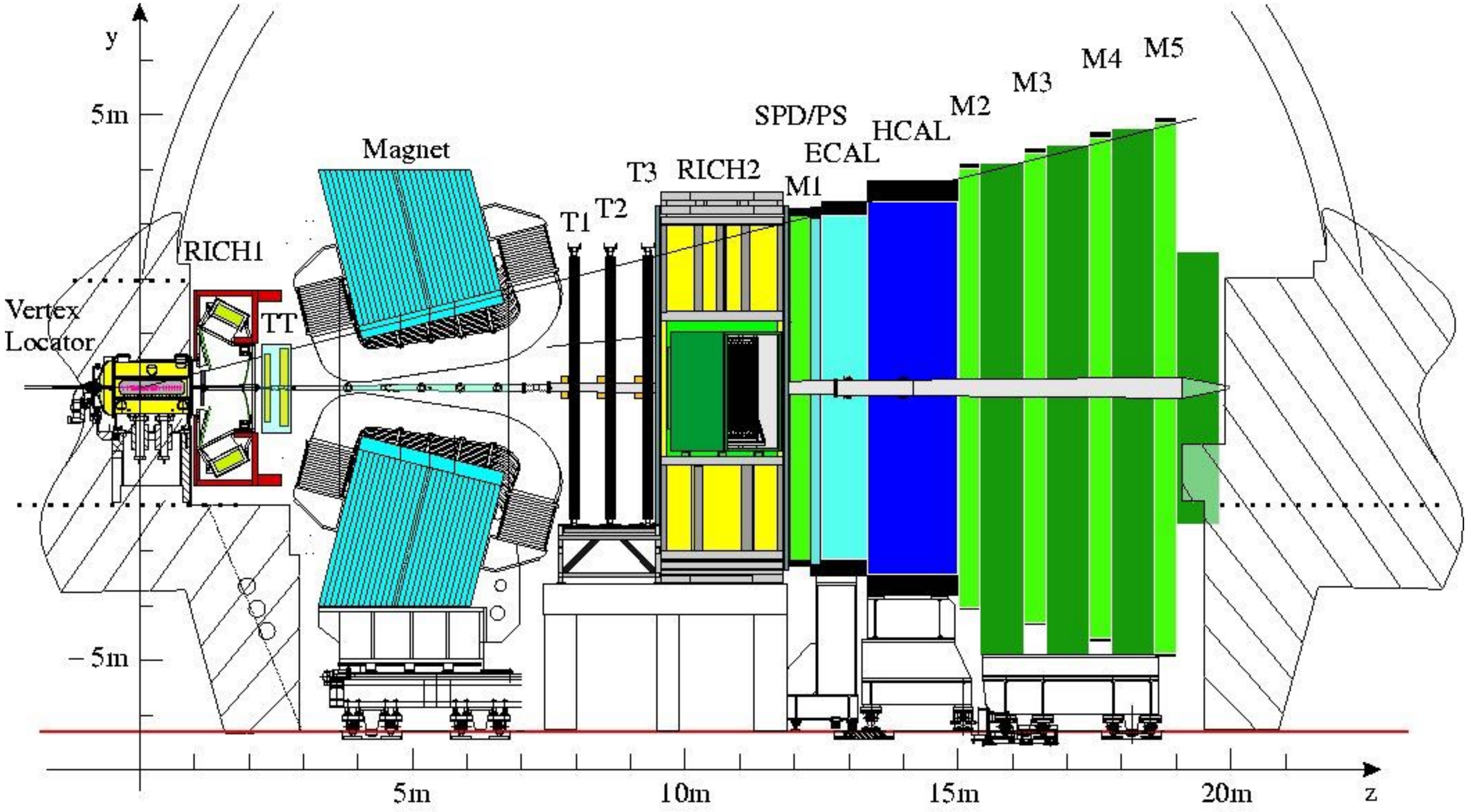
Grant funded by the Exploring Matter ERC Consolidator grant number 647 390

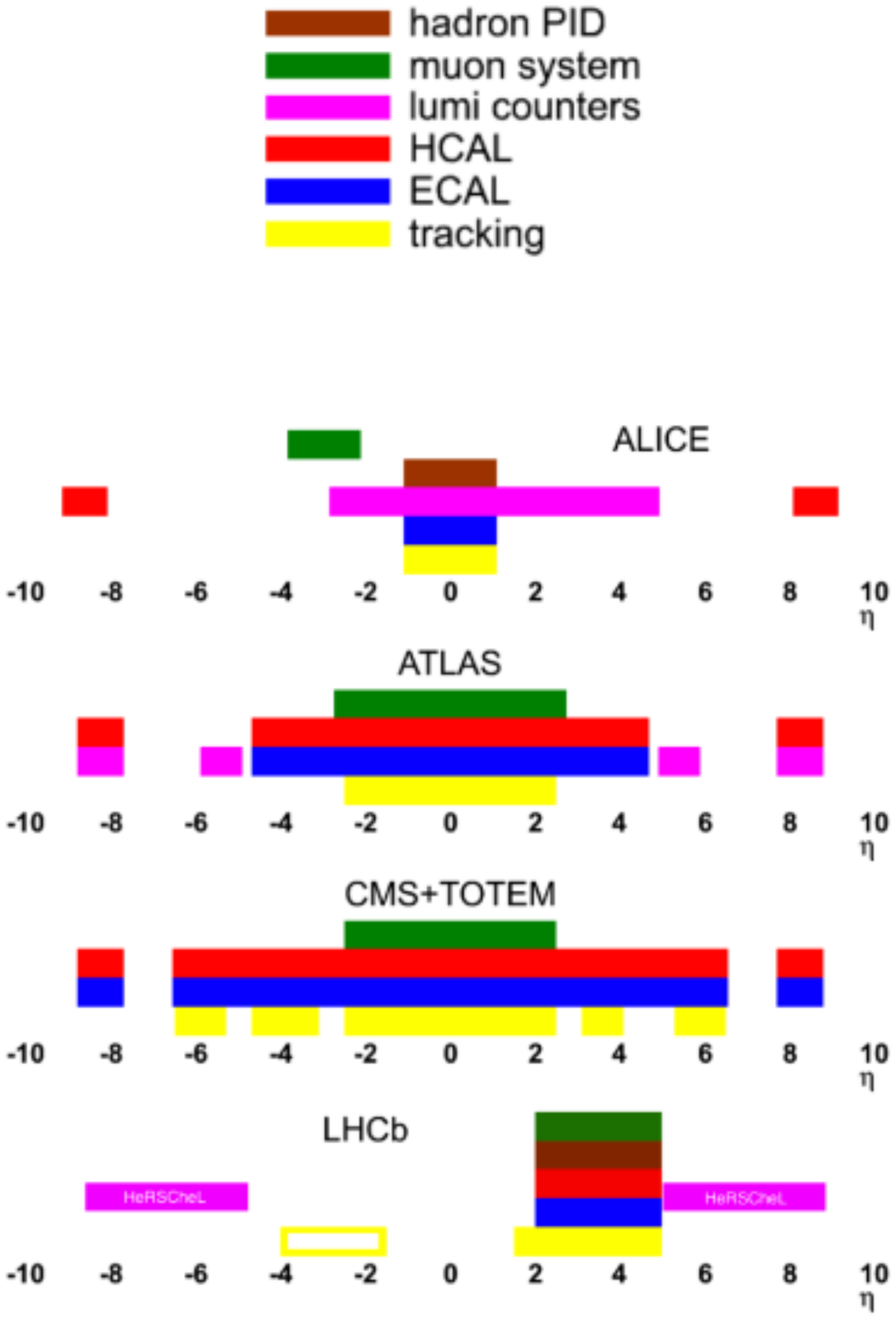
LHCb today (technically yesterday)

The LHCb detector

10.1142/S0217751X15300227

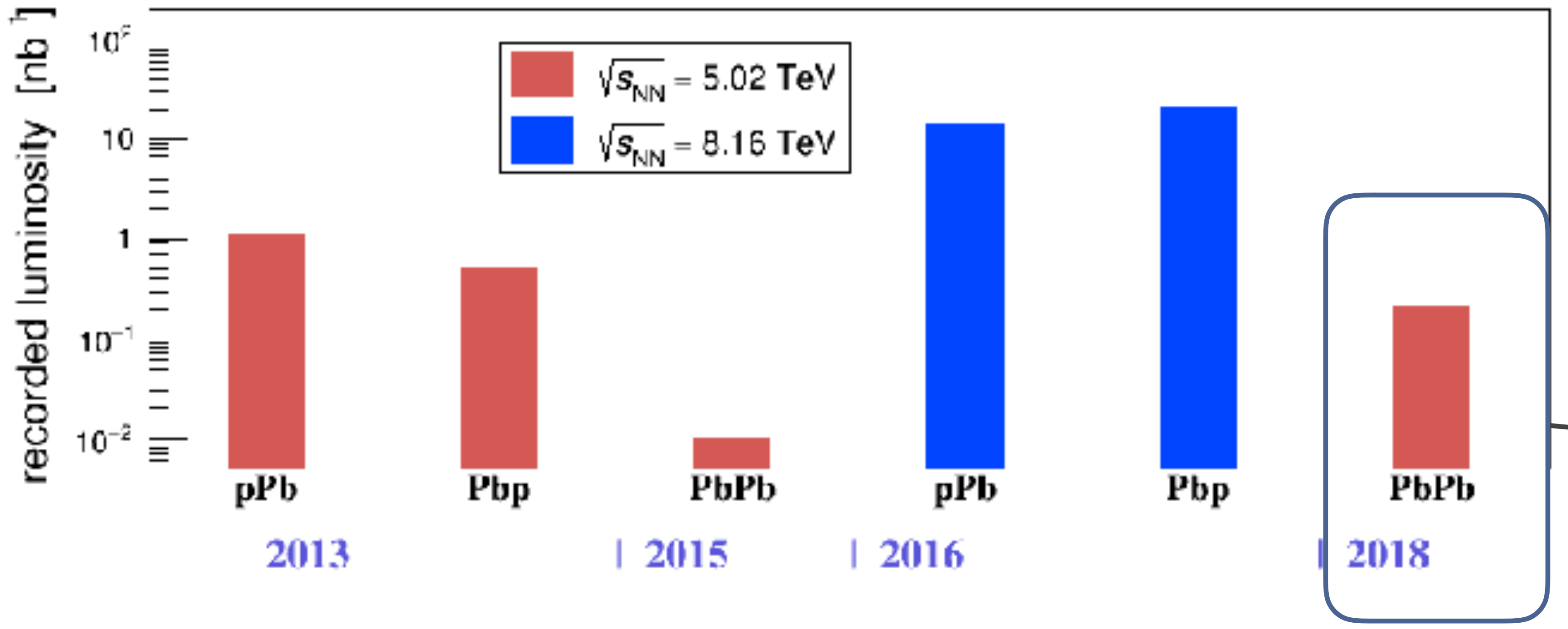
LHCb : **single arm spectrometer fully instrumented** in pseudo-rapidity range **$2 < \eta < 5$**

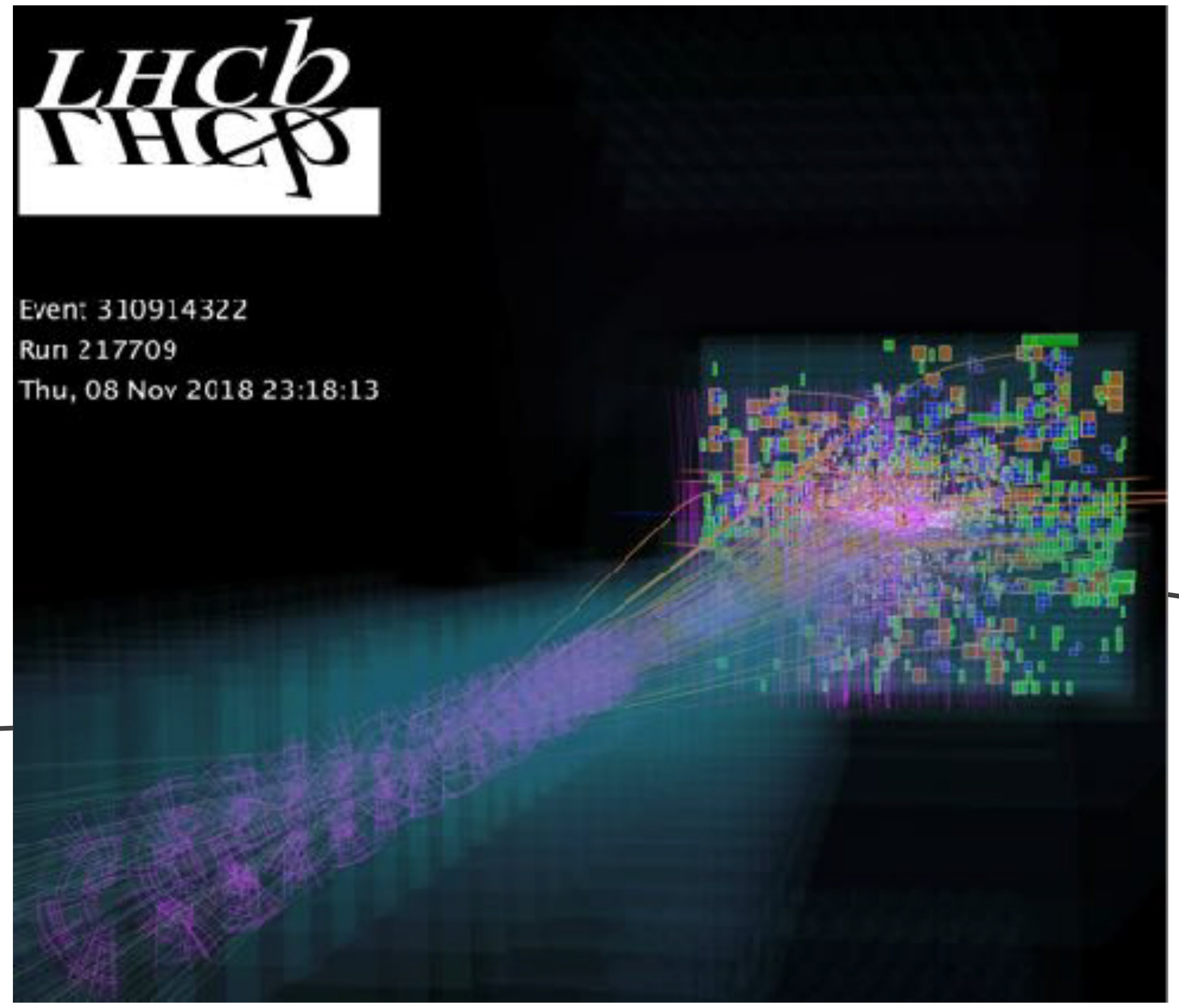




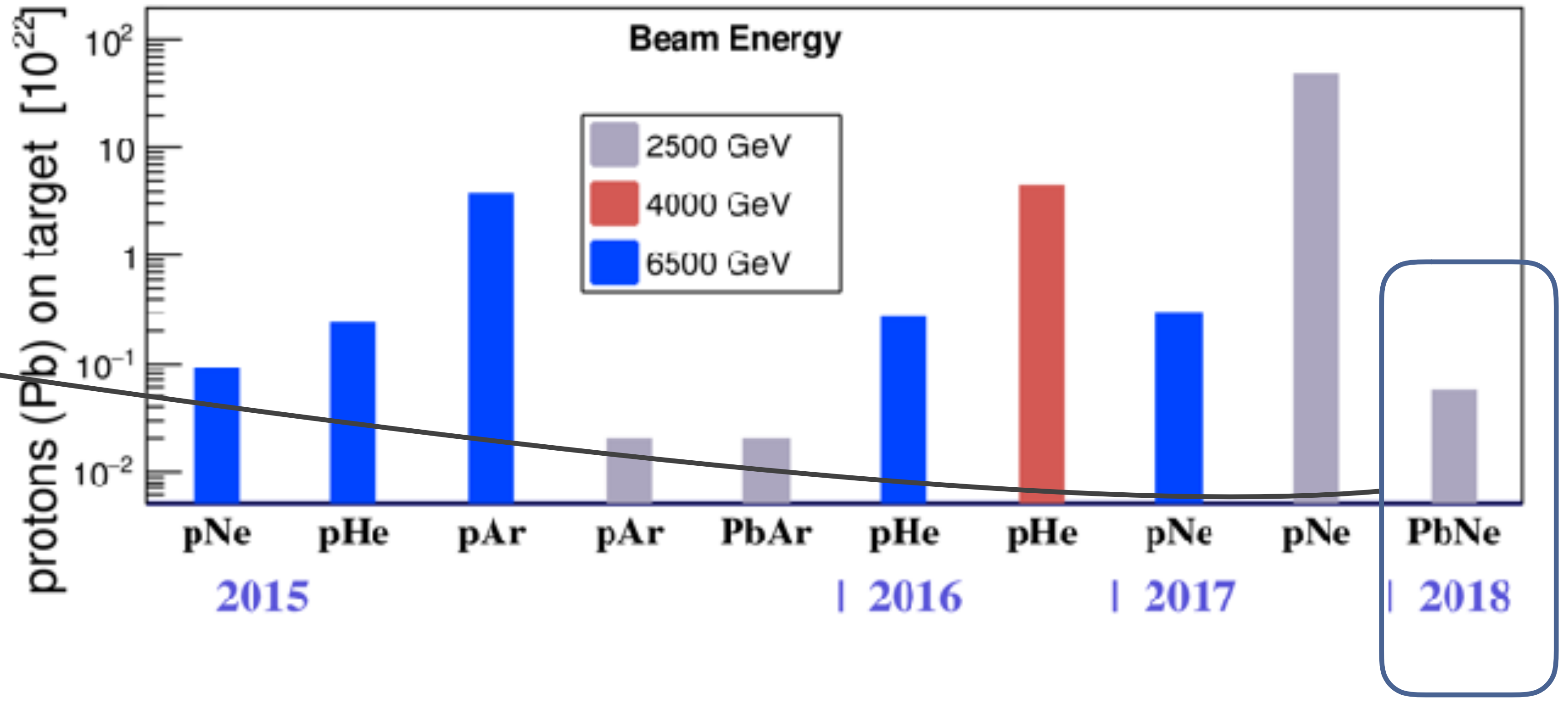
2018 data campaign

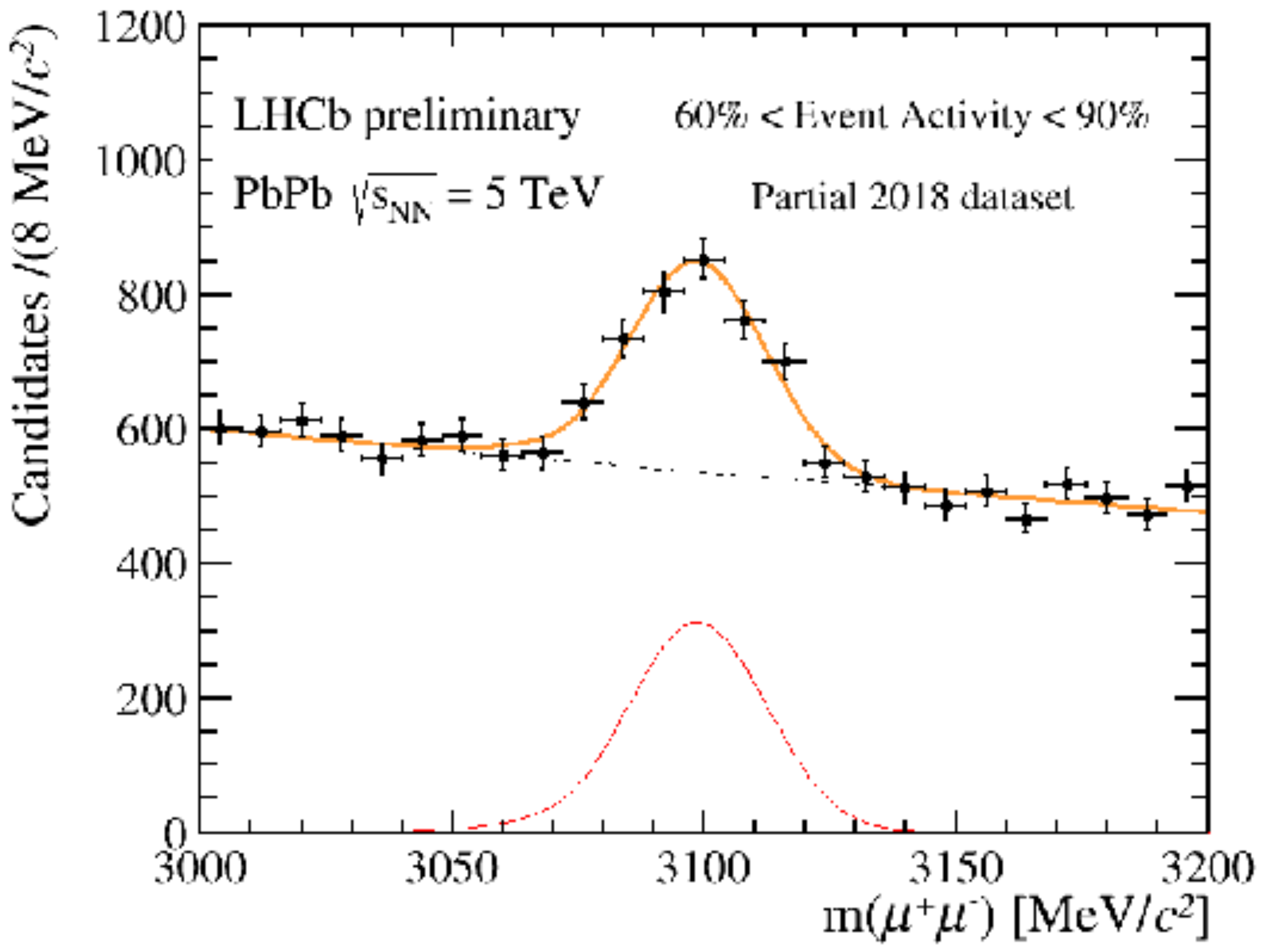
Collider mode samples



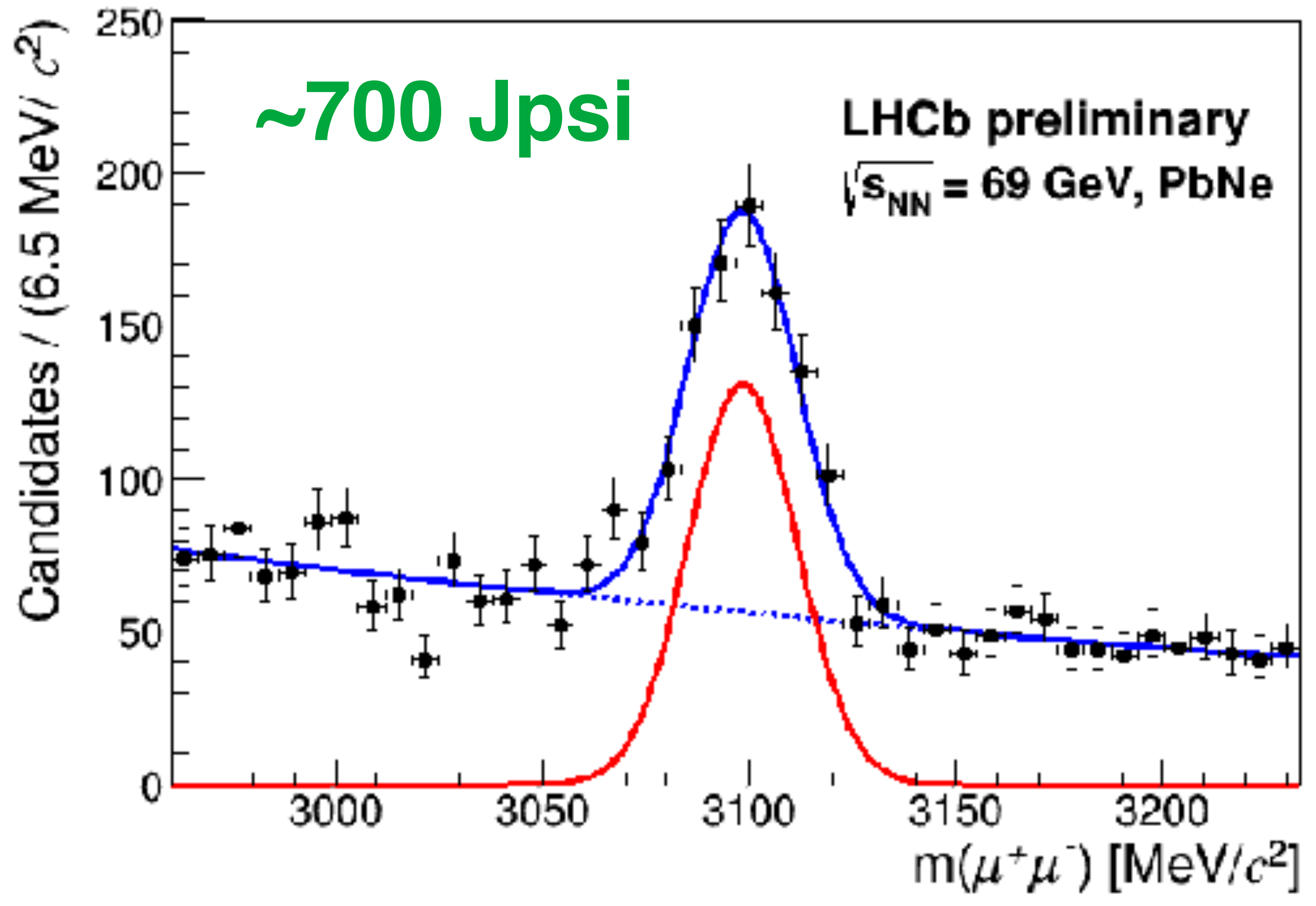


Fixed-target mode samples

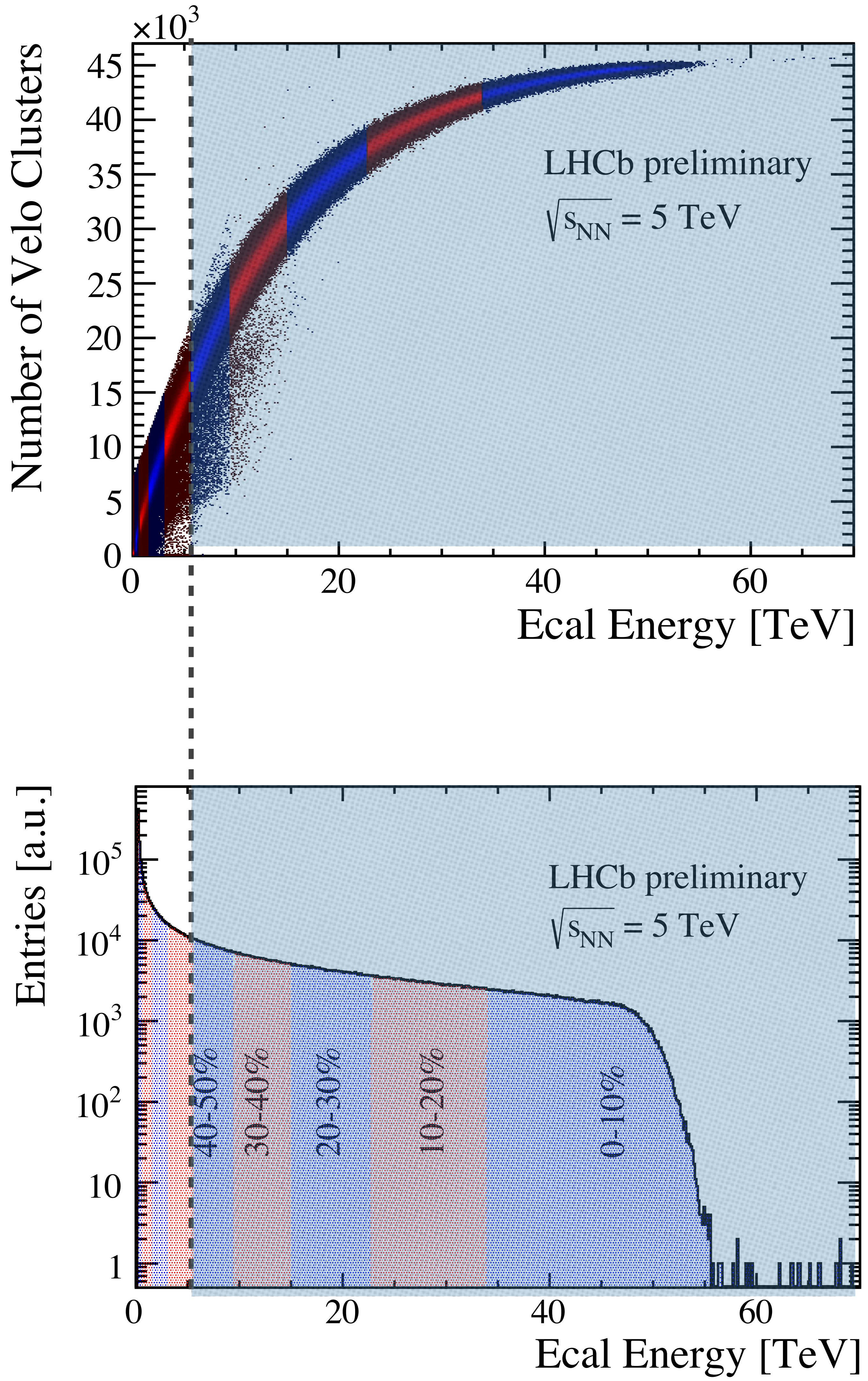




- Two new samples recorded last year:
  - PbPb : ~ 25 times 2015 luminosity.
  - PbNe : ~ 0.1 nb^{-1}



Status in PbPb collisions



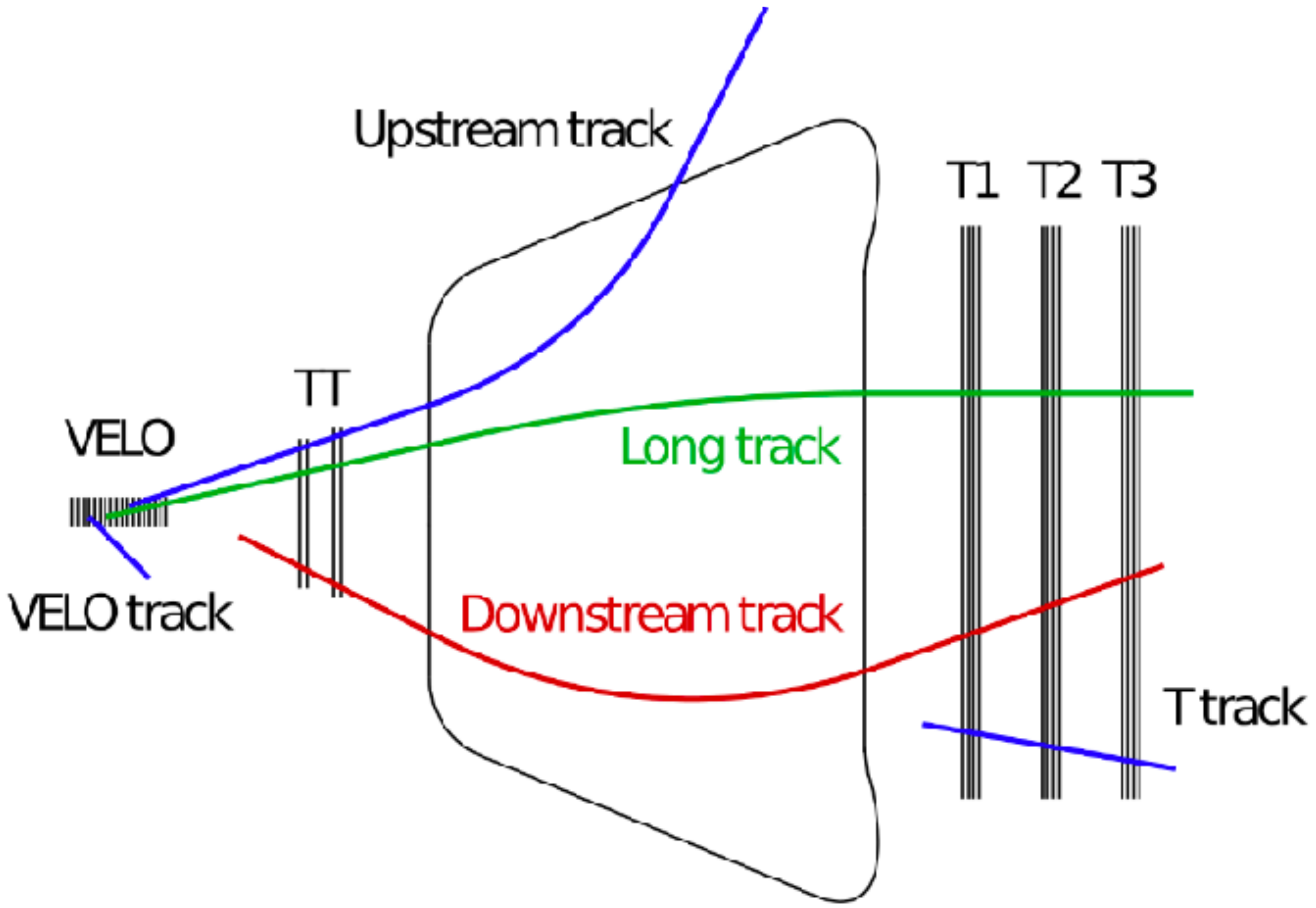
[redacted]

- VELO saturates in central collisions :
  - Centrality estimated with the calorimeter.
  - Current tracking algorithm efficient up to ~50%.
  - **Physics studies limited to ~50% less central events.**

Tracking in LHCb

- Many types of tracks in LHCb, the most important ones are
  - ➡ Long tracks.
  - ➡ Downstream tracks
- Tracking steps :
  - ➡ Finding a track : Forward Tracking algorithm.
    - Combine VELO seeds with hits in the T-stations
    - Match VELO tracks and seeds from T-stations
  - ➡ Fitting a track : Kalman filter.

The LHCb tracks



Tracking in PbPb

[redacted]

Tracking algorithm tuned for pp

- Velo Tracks killed in high-occupancy regimes
- Long Tracks reconstruction drops before that !

Examples on J/ψ reconstruction efficiencies :

[redacted]

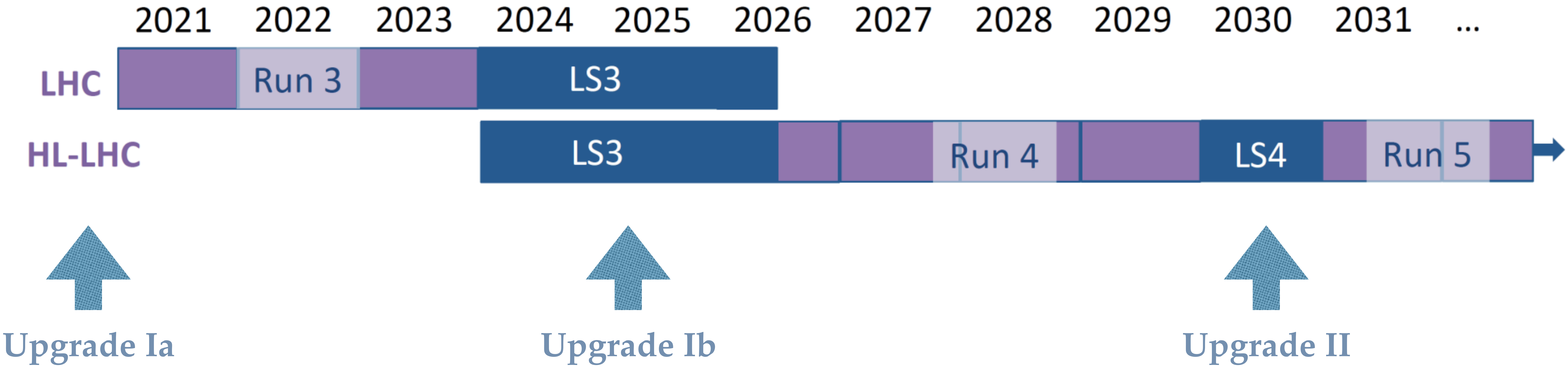
eCal Energy (MeV)

Publication since QM 2018

Reference	Subject
JHEP11 (2018) 194	Υ in pPb 8 TeV
JHEP02 (2019) 102	Λ_c in pPb 5 TeV
PRD99 (2019) 052011	Open beauty in pPb 8 TeV
PRL121 (2018) 222001	Antiproton in pHe 110 GeV
PRL122 (2019) 132002	Charm in pHe 87 GeV and pAr 110 GeV
LHCB-PUB-2018-015	Prospects for fixed target
LHCB-CONF-2018-005	Projection for pPb analyses in Run 3/4

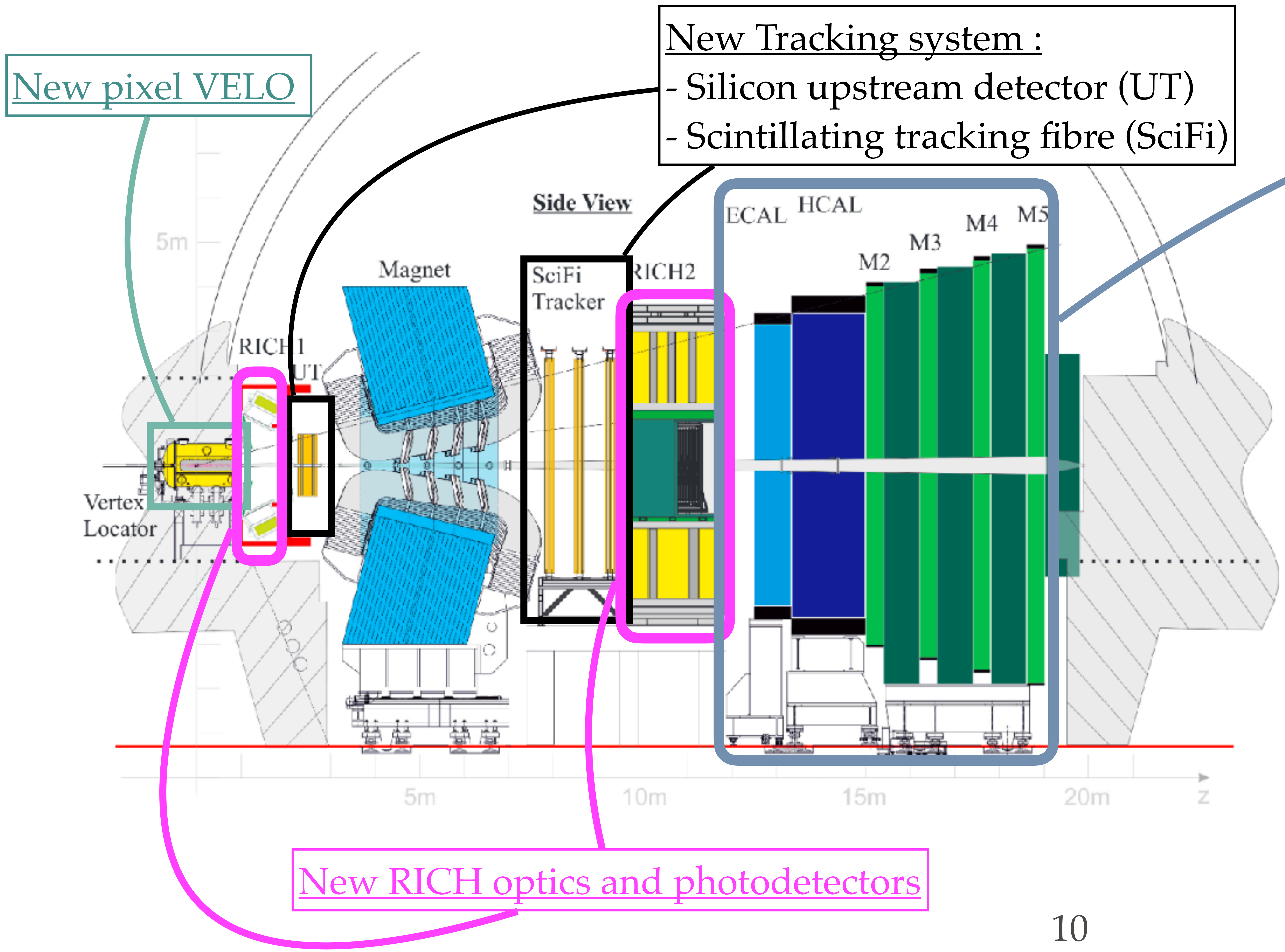
- **Good grasp** on **fixed-target** and **p-Pb** data samples.
- Many other results to come (see other LHCb talk during the workshop !).
- **Main difficulties** : tracking in high-occupancy regime.

LHCb Upgrade I



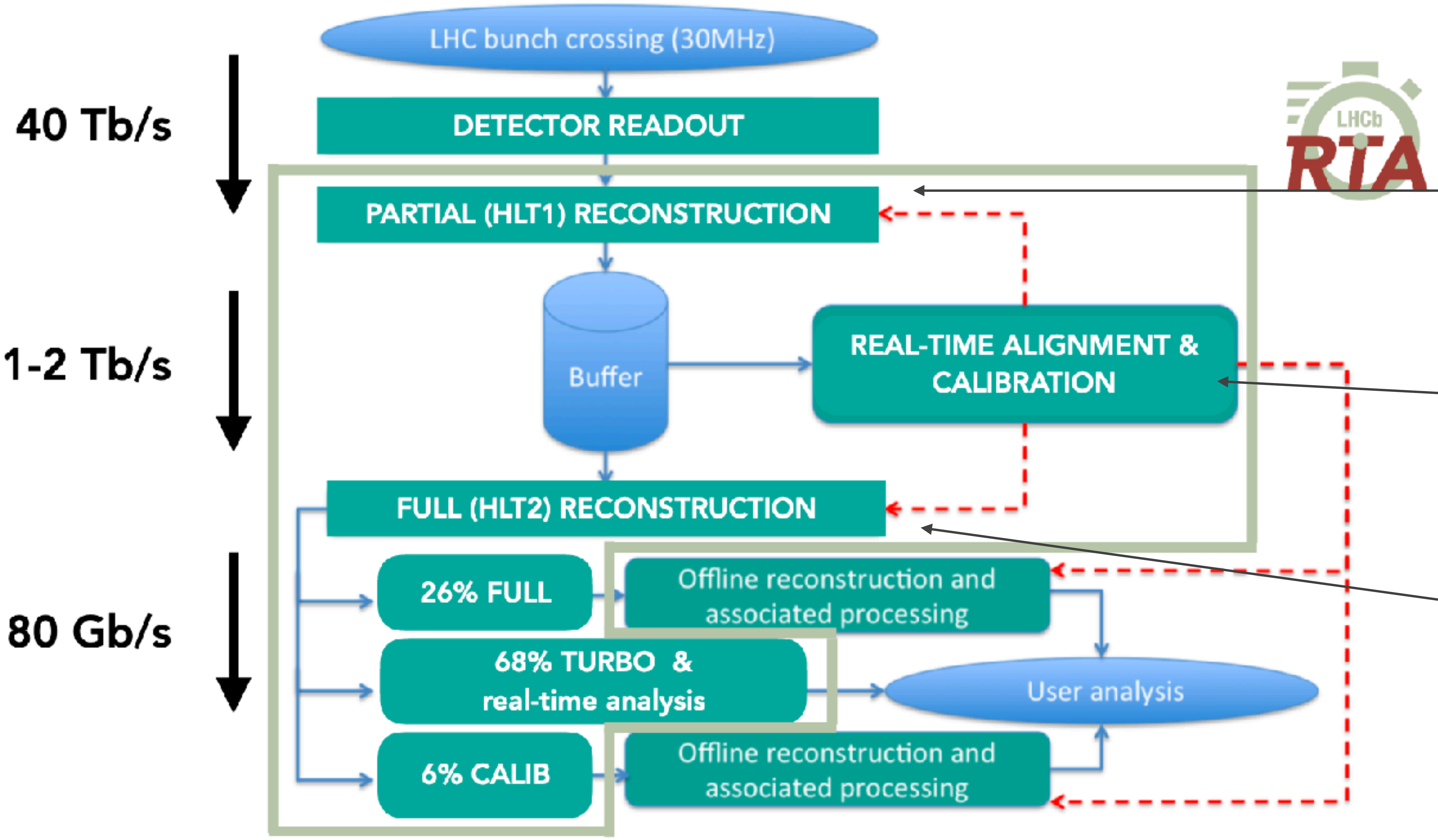
Requirements for Run 3 - Run 4

[CERN-LHCC-2012-007]



- Upgrade based on pp collision requirements :
  - ➡ Collision rate at 40 MHz.
  - ➡ Pile-up factor μ ≈ 5
- Full **software trigger.**
  - ➡ Remove L0 triggers.
  - ➡ Read out the full detector at 40 MHz.
  - ➡ Replace the entire tracking system.

LHCb trigger in run II and Turbo



Partial event reconstruction

- Data preparation for tracking
- Track reconstruction
- Efficient event selection to reduce the rate to between 500 - 1000 kHz

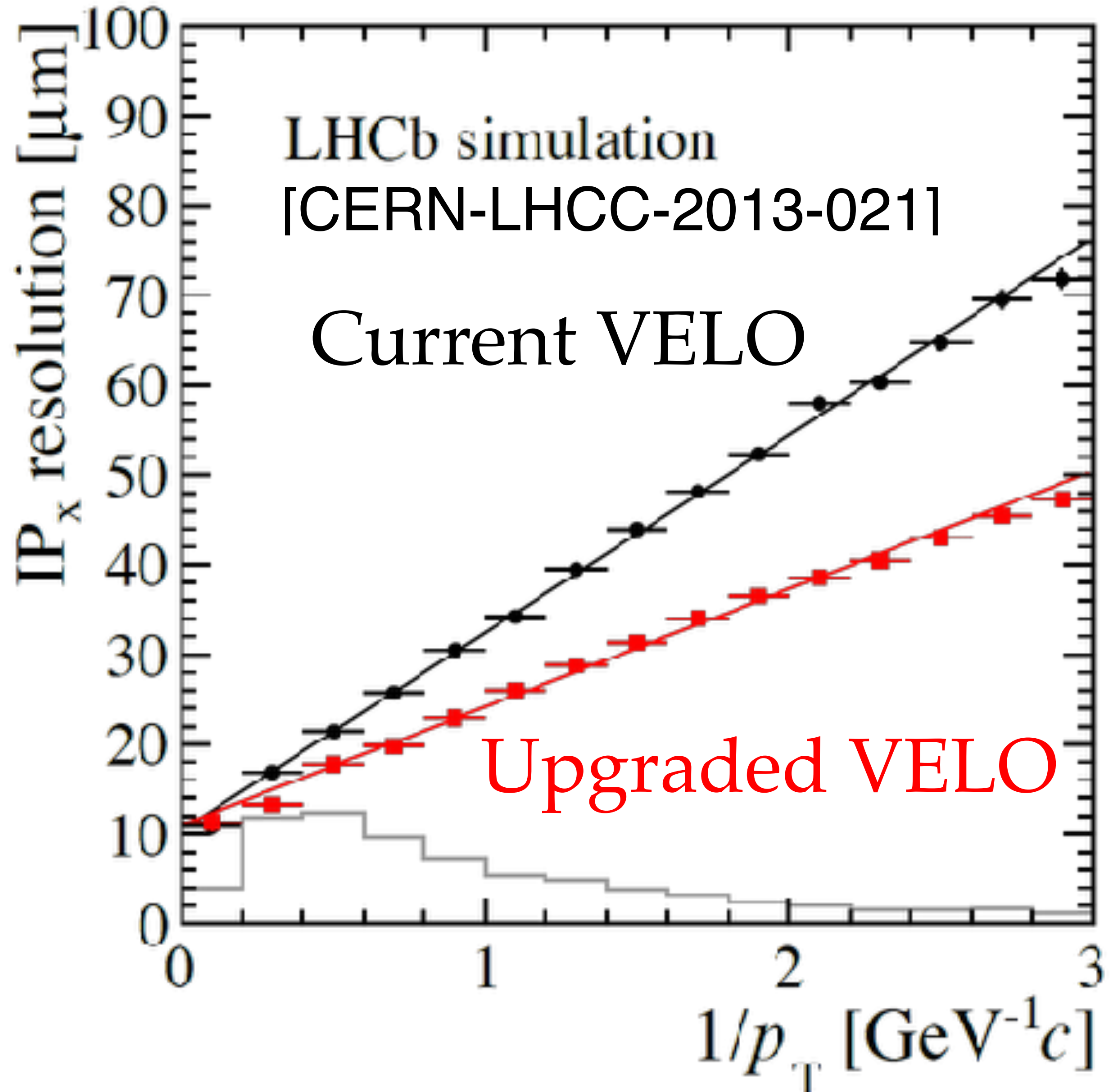
Re use the Run II strategy

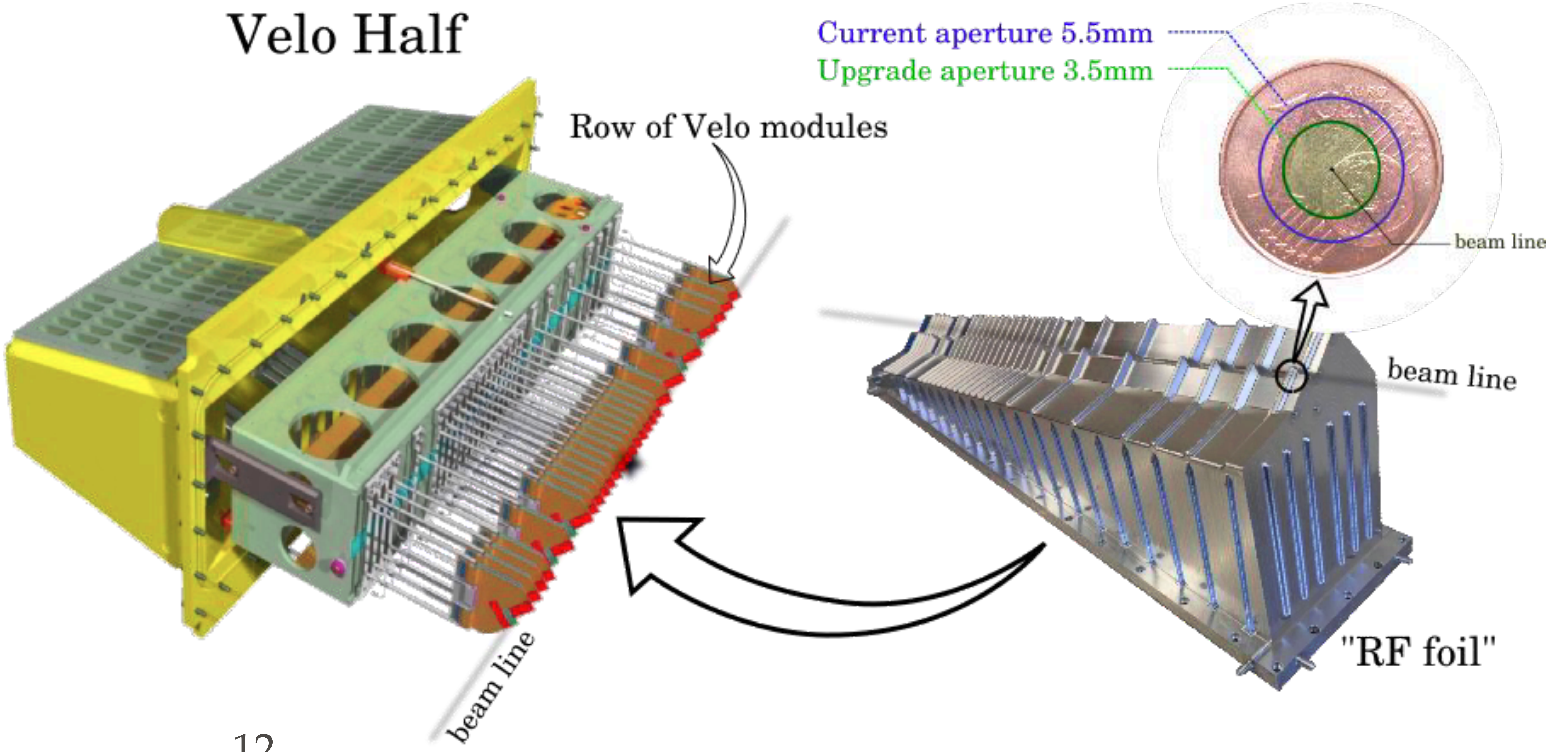
Full event reconstruction

- Best tracking performance, add PID information
- Best hadron trigger
- Offline quality selections
- Physics analysis on output of the trigger

Tracking system: Vertex Locator (VELO)

- Silicon pixel detector, **41 M 55 x 55 μm² pixels.**
- Closest pixels at 5.1 mm from the beam line.
- Aluminium foil to protect the Velo without interfering with the beam.
- Sensors to be kept < -20°C
- **Total data rate** : 2.8 Tb/s

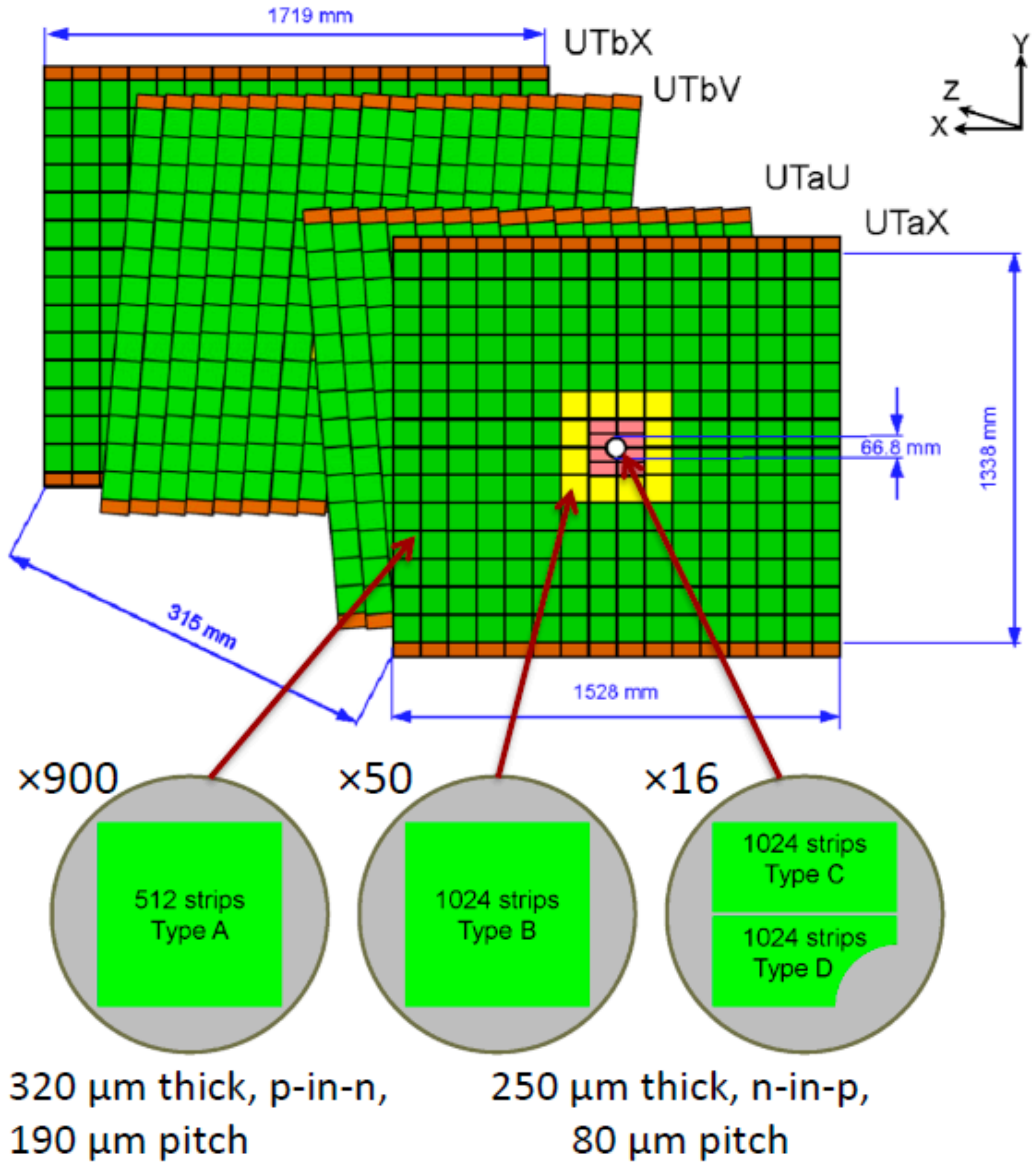




Tracking system: Upstream Tracker (UT)

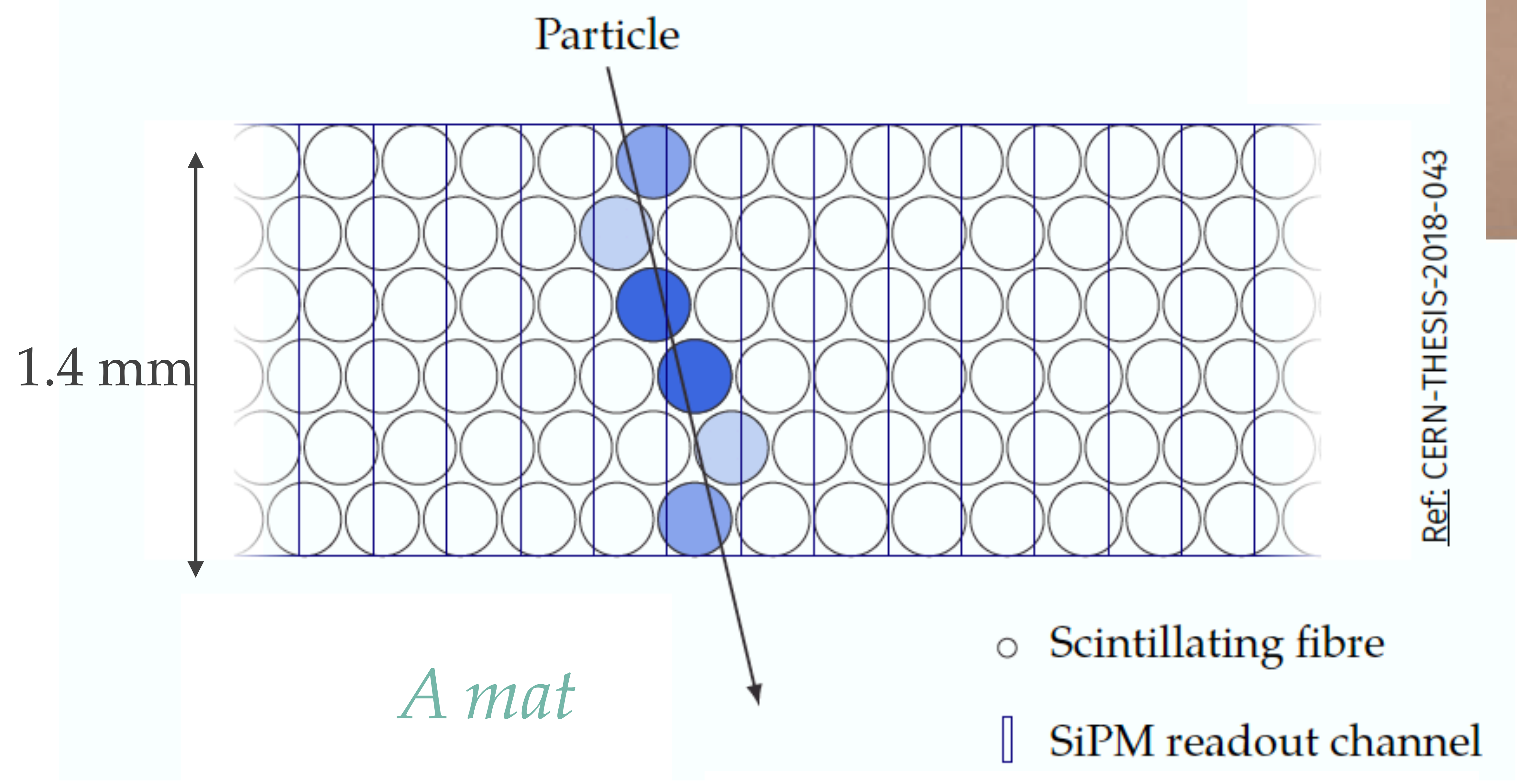
- 4 stations with x-u-v-x layers of silicon micro strip detectors.
  - Sensors with 512 or 1024 strips (4 different types).
  - 68 staves / 968 sensors.
- **Replace the TT system.**

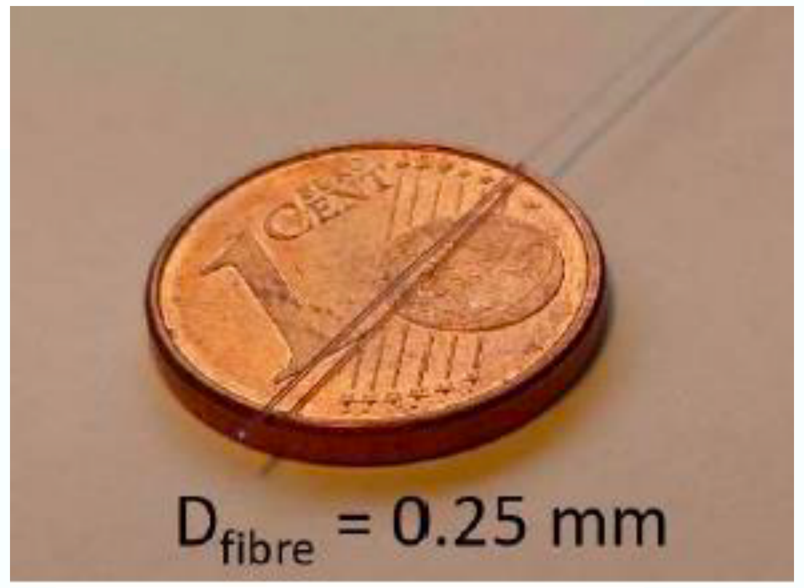
[redacted]

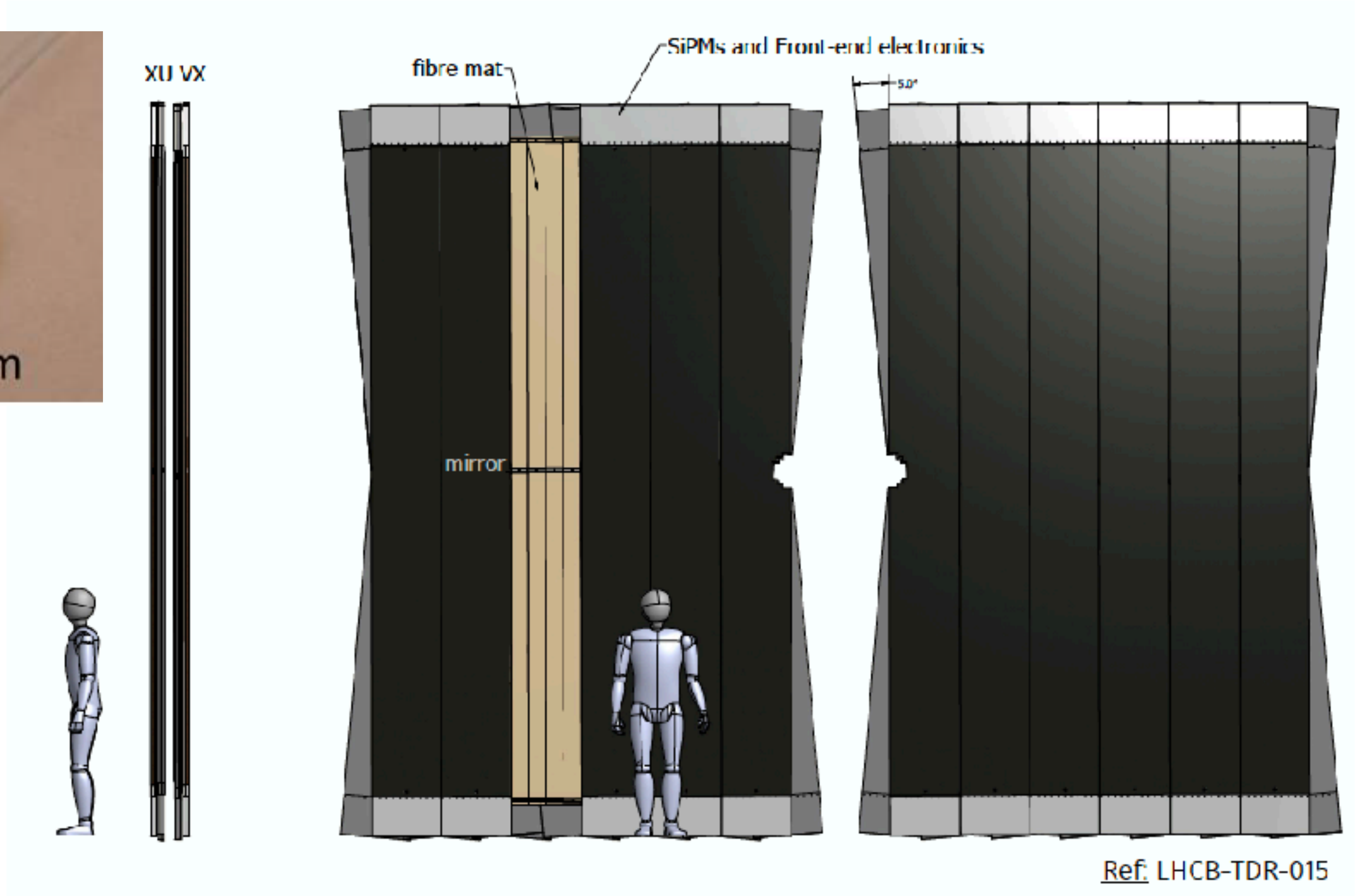


Tracking system: Scintillating fibre tracker (SciFi)

- ~10000 km of scintillating fibres arranged in 6 layers with silicon photo-multipliers (SiPM) readout.
  - 3 stations.
  - 4 detection layers per station arranges in x-u-v-x configuration per stations.
  - 10 modules of 2x4 mats.

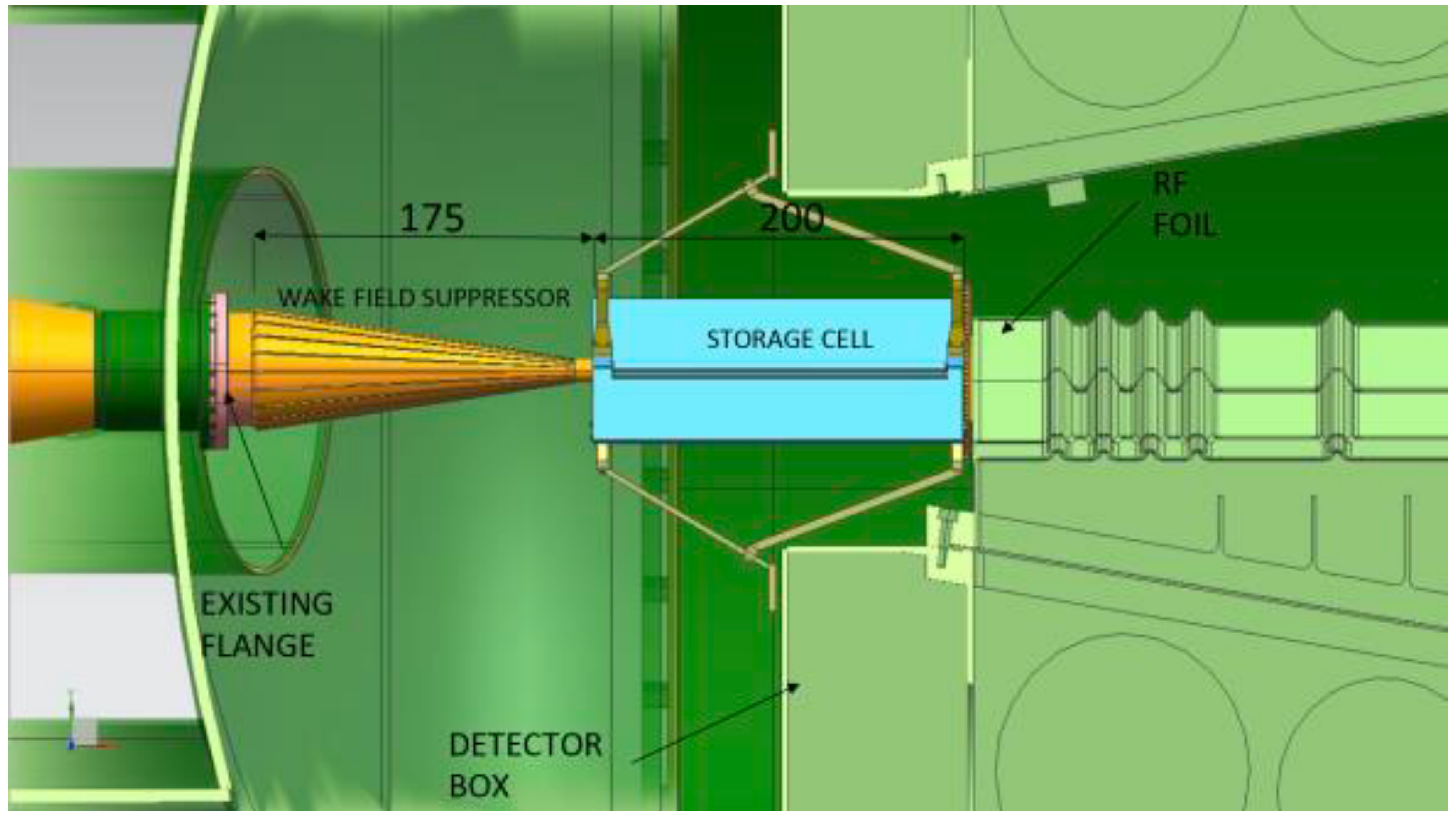


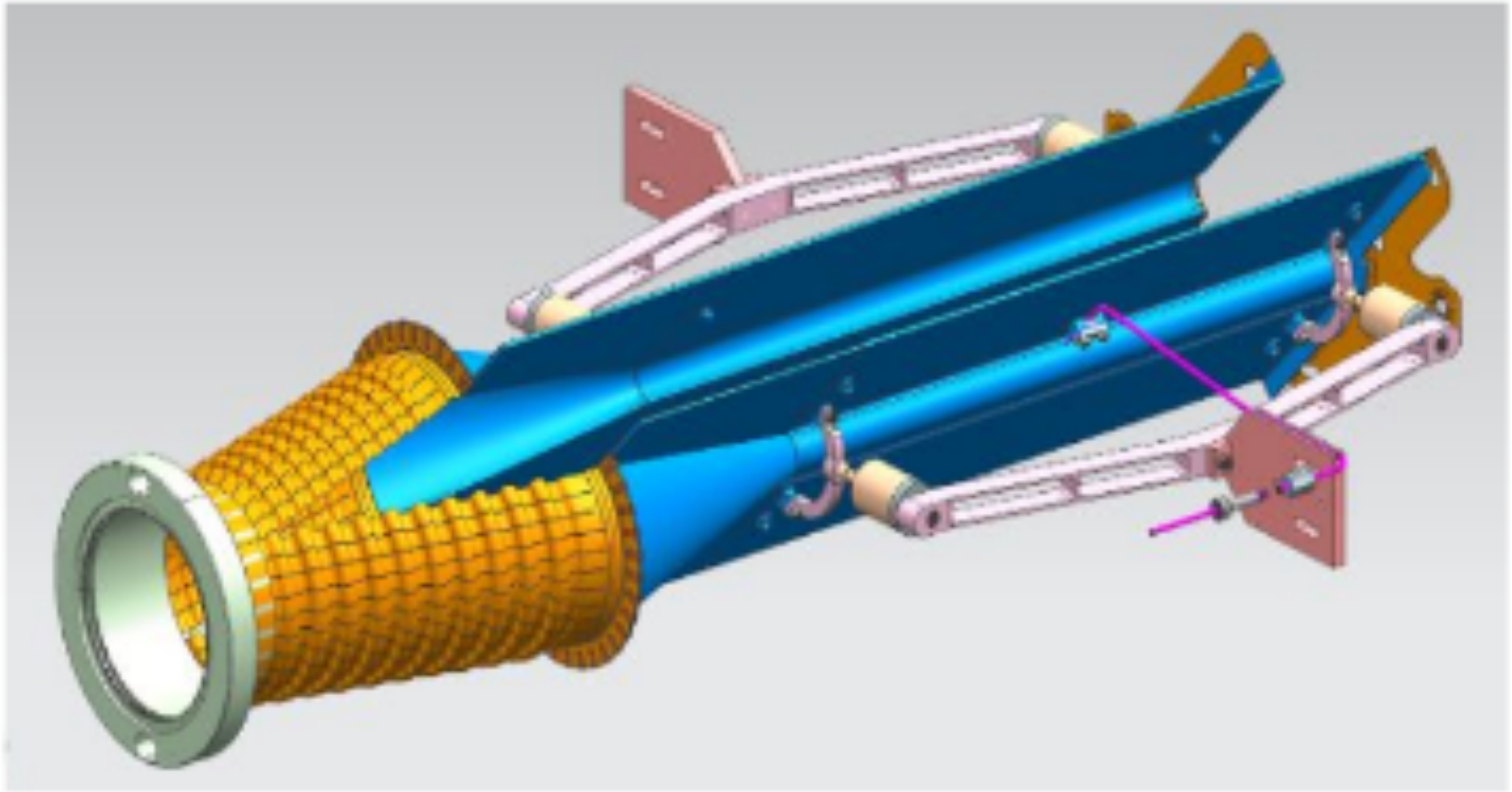




LHCb fixed target program evolution

- SMOG 2 (TDR) : Standalone gas confinement cell covering z ϵ [-500;-300] mm :
  - ➡ more gas targets and much higher luminosity.
  - ➡ simultaneous pp-pSMOG data-taking.
  - ➡ would allow many nice early measurements.





SMOG2 cell

Run 3 - Run 4 scenarios

Year	Systems, $\sqrt{s_{NN}}$	Time	L_{int}
2021	Pb–Pb 5.5 TeV	3 weeks	2.3 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2022	Pb–Pb 5.5 TeV	5 weeks	3.9 nb^{-1}
	O–O, p–O	1 week	500 μb^{-1} and 200 μb^{-1}
2023	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2027	Pb–Pb 5.5 TeV	5 weeks	3.8 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2028	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2029	Pb–Pb 5.5 TeV	4 weeks	3 nb^{-1}
Run-5	Intermediate AA	11 weeks	e.g. Ar–Ar 3–9 pb^{-1} (optimal species to be defined)
	pp reference	1 week	

- Scenarios taken from the Yellow report. **CERN-LPCC-2018-07**

Projection in PbPb Run 3 - Run 4

No saturation up to (at least) ~30% centrality

Projection in PbPb Run 3 - Run 4

Long tracks reconstructed up to (at least) ~30%

Projection in PbPb Run 3 - Run 4

[redacted]

No saturation of SciFi up to (at least) ~30%

J/ψ reconstructed up to (at least) ~30%

LHCb Upgrade II

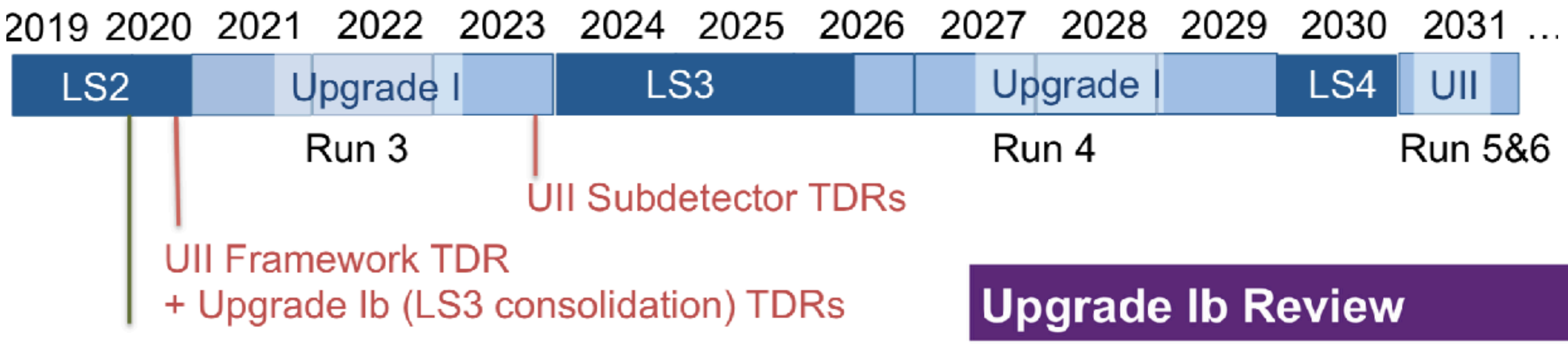
EoI : CERN-LHCC-2017-003
Physics case : CERN-LHCC-2018-027

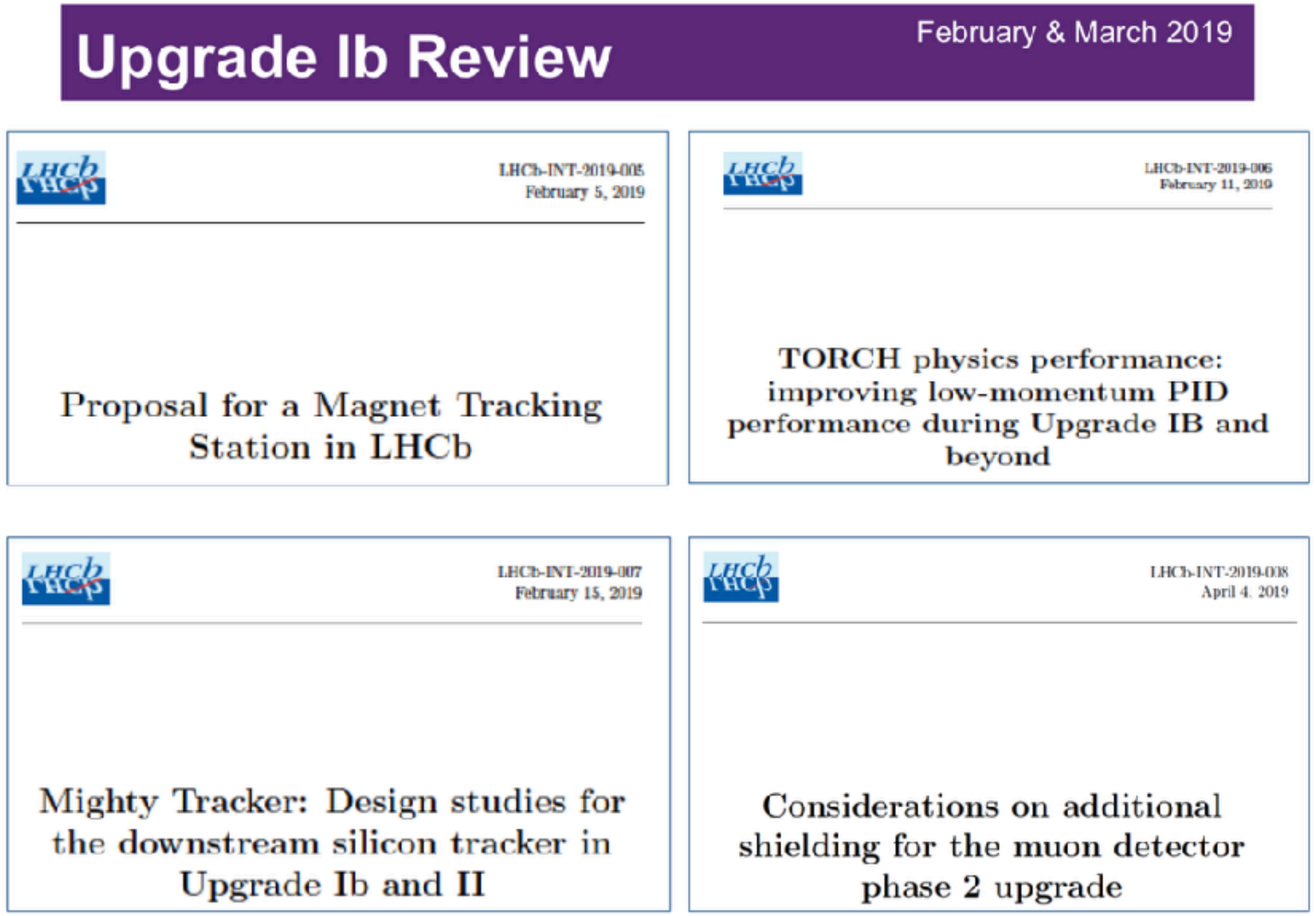
Upgrade I:
- 2×10^{33} cm^{-2} s^{-1}
- **Pile-up = 5**

→

Upgrade II:
- 1.5×10^{34} cm^{-2} s^{-1}
- **Pile-up = 42**

Phase II in a nutshell

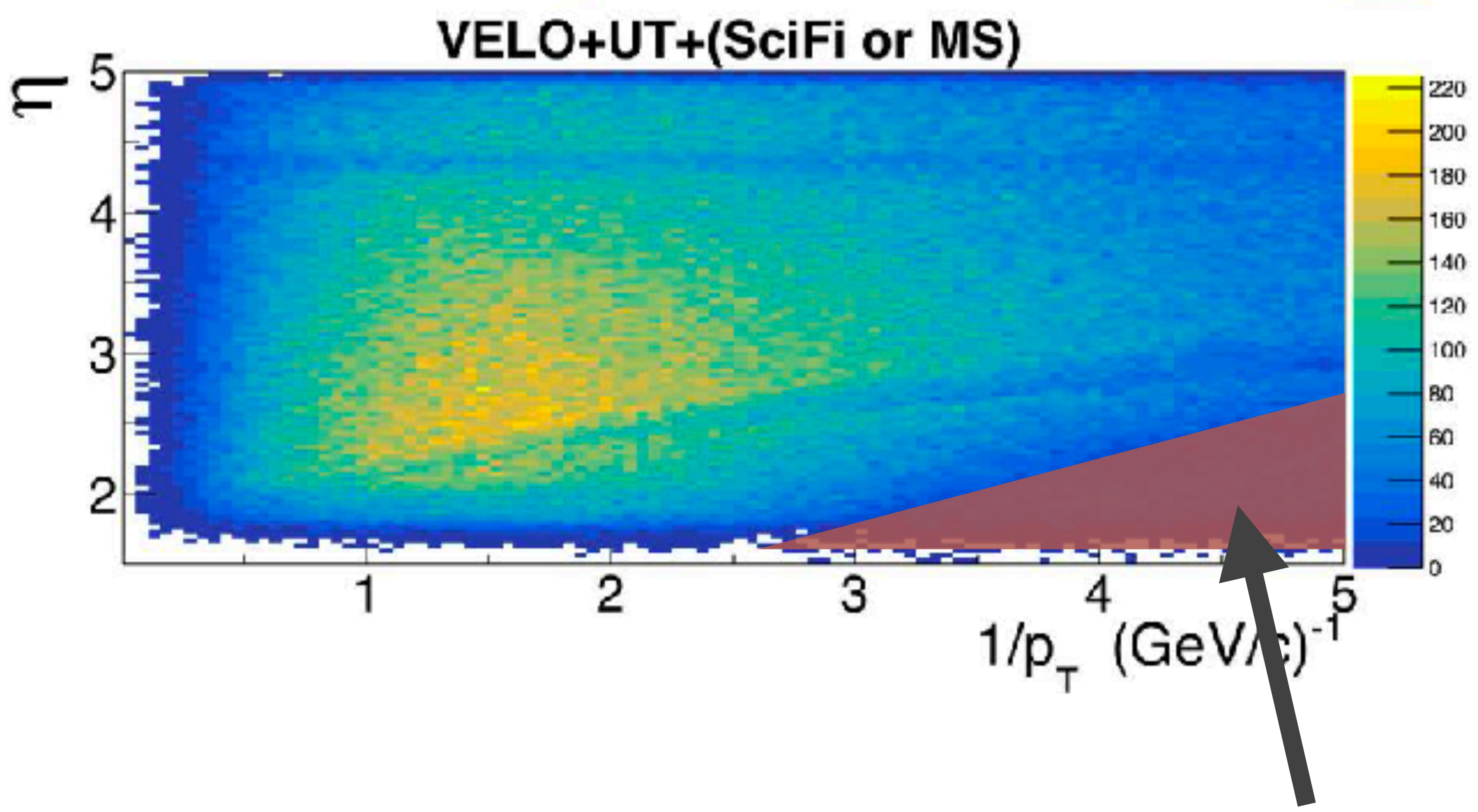




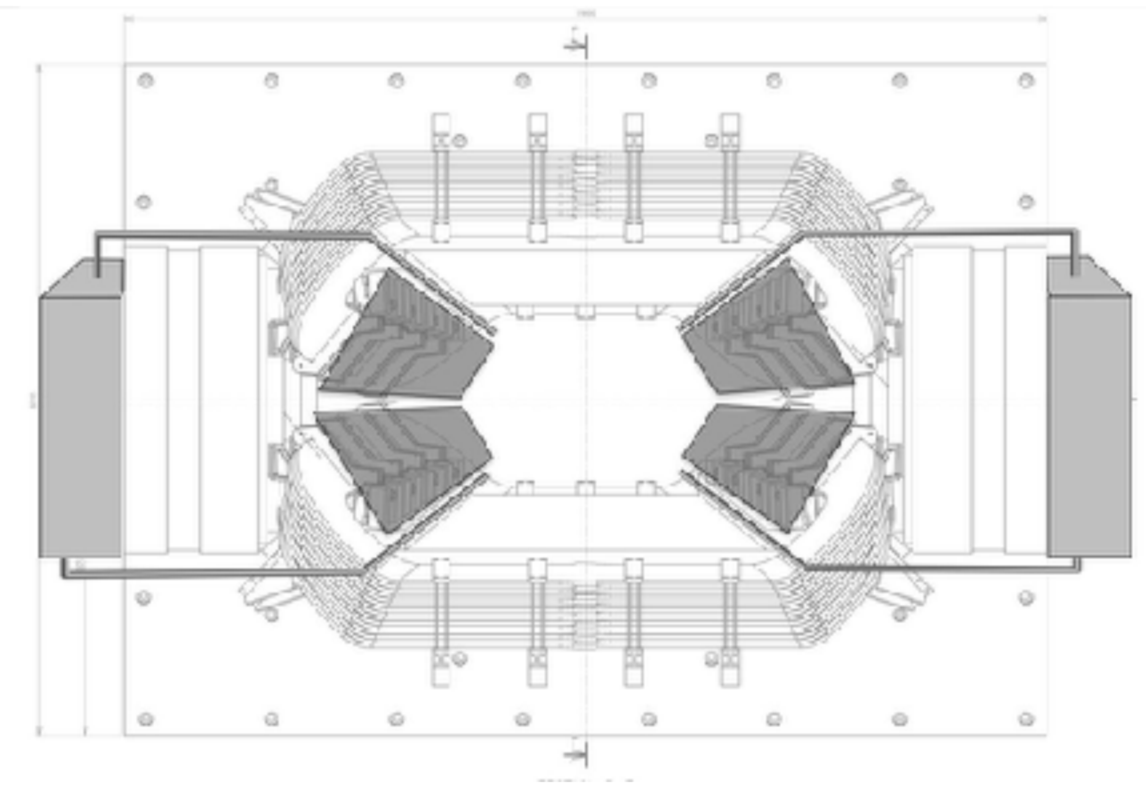
- Sub detectors considering timing :
  - Before the magnet :
    - VELO, RICH1
  - After the magnet :
    - TORCH, RICH2, ECAL

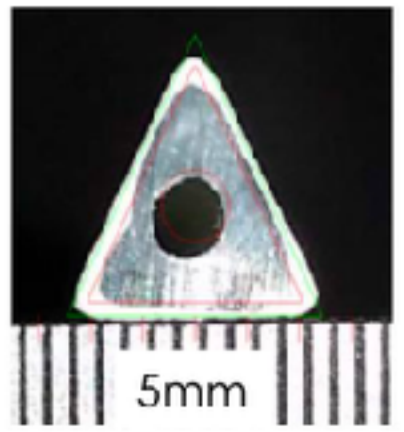
Magnet Tracking Station

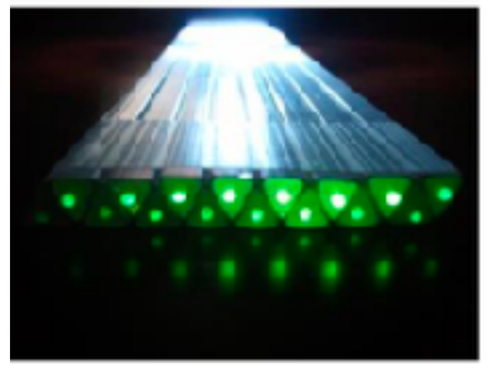
- Proposal for tracking station inside the magnet.
  - ➡ Increase coverage of upstream tracks.
  - ➡ Physics motivations : access to converted photons.
- Technology:
  - ➡ Triangular Extruded Scintillating Bars (same as D0)
  - ➡ SiPM arrays adapted to SciFi/PACIFIC readout.
  - ➡ Ongoing R&D in LANL.
- **Proposing the installation of a small prototype** inside the magnet during LSIII.

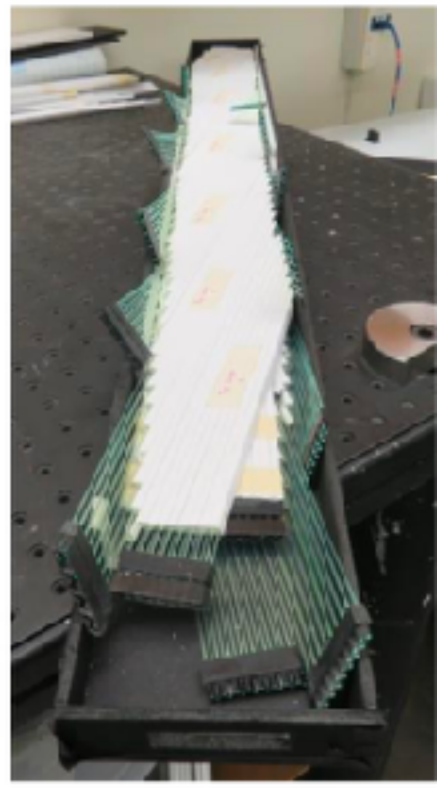


Extended acceptance





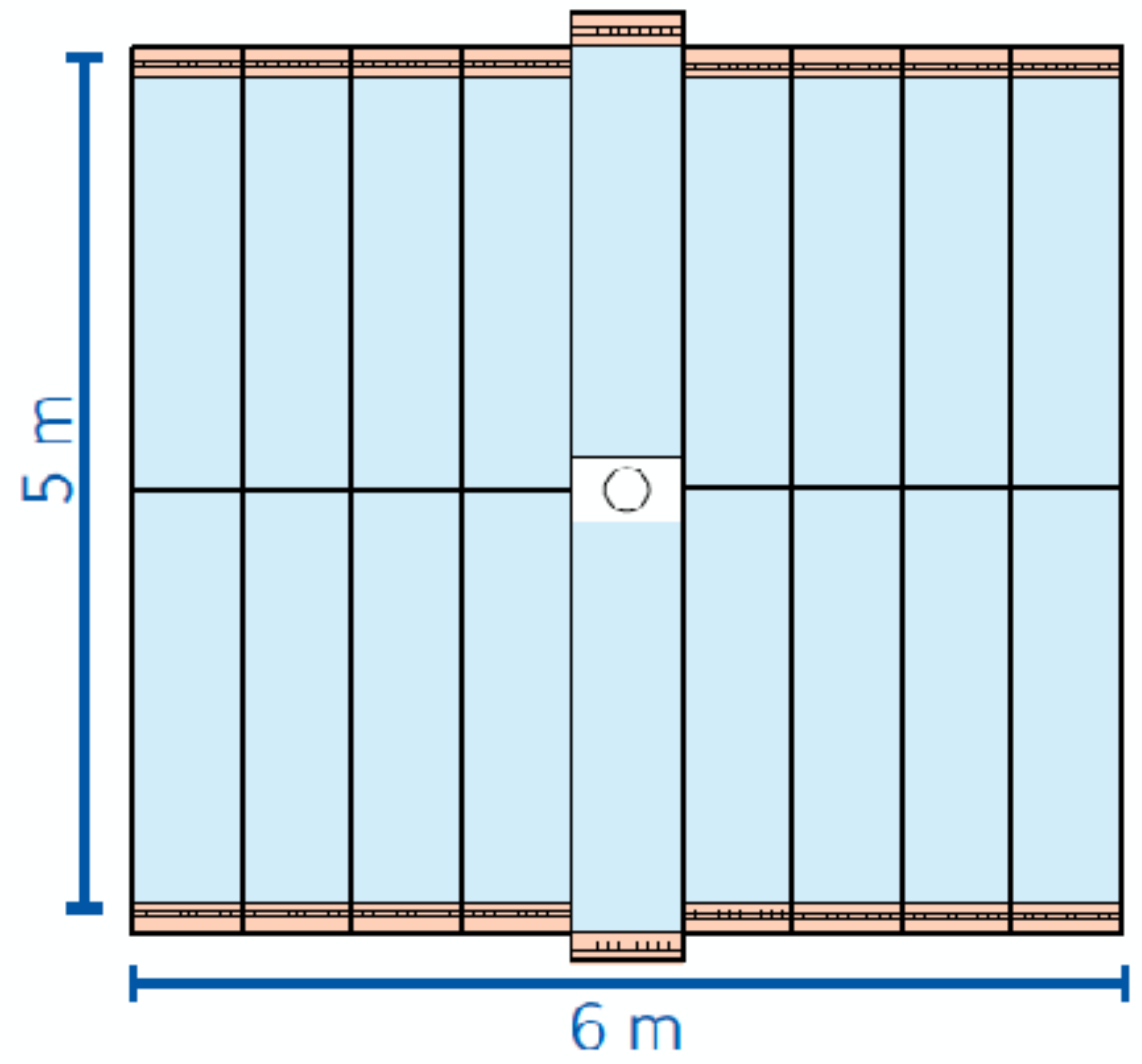


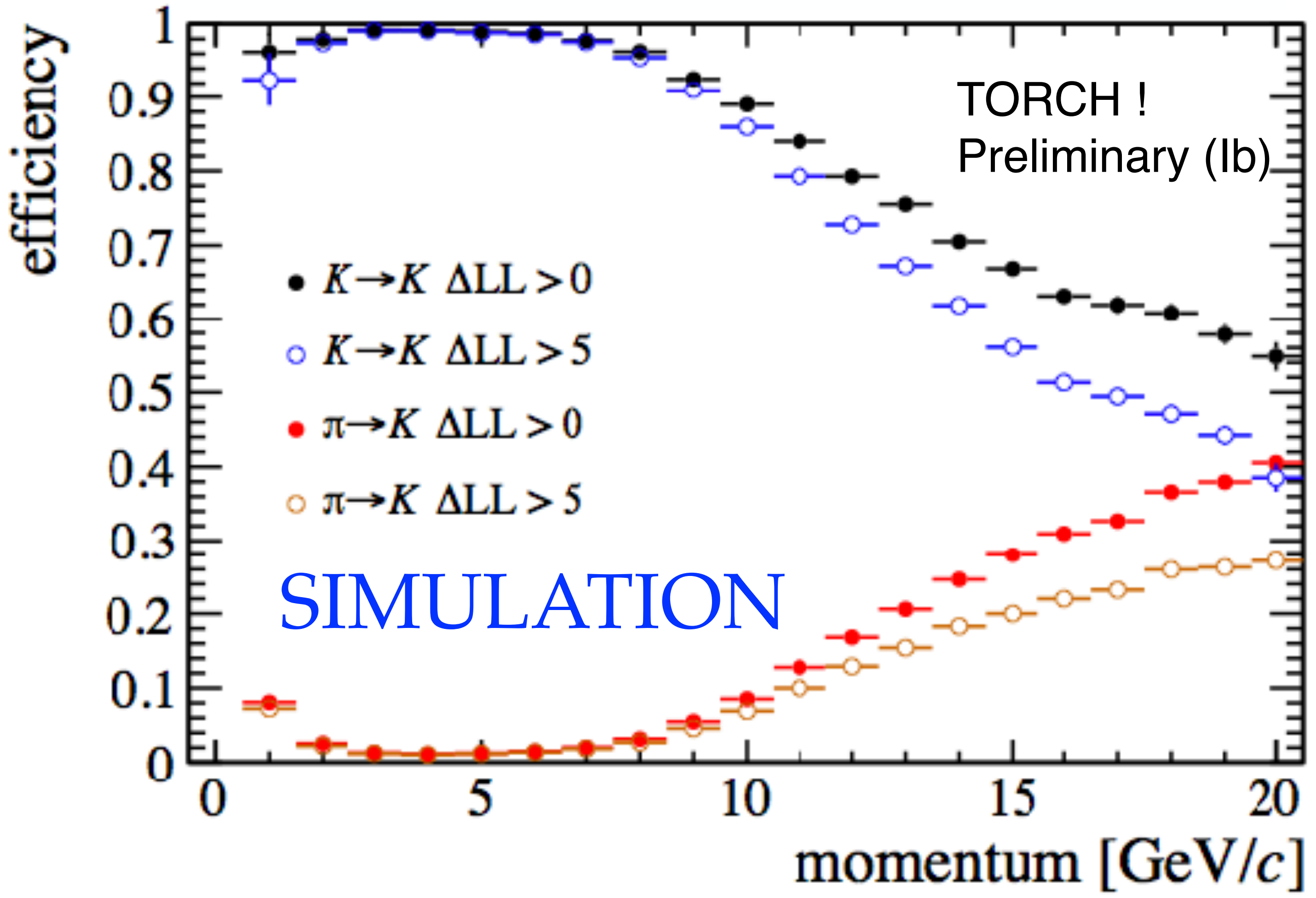


LHCb-INT-2019-006

TORCH - Low momentum PID

- TORCH is a large area time of flight detector that is designed to provide PID in the GeV/c momentum range
  - Considered for use in Upgrade Ib.
  - Exploit prompt production of Cherenkov light in a quartz radiator plate to provide a fast timing signal.
  - Aim for a resolution of 10-15 ps per track
  - A large-scale prototype has been developed.
  - Test-beam ongoing
  - **Good separation between between π/K/p is possible in 2-10 GeV/c range.**



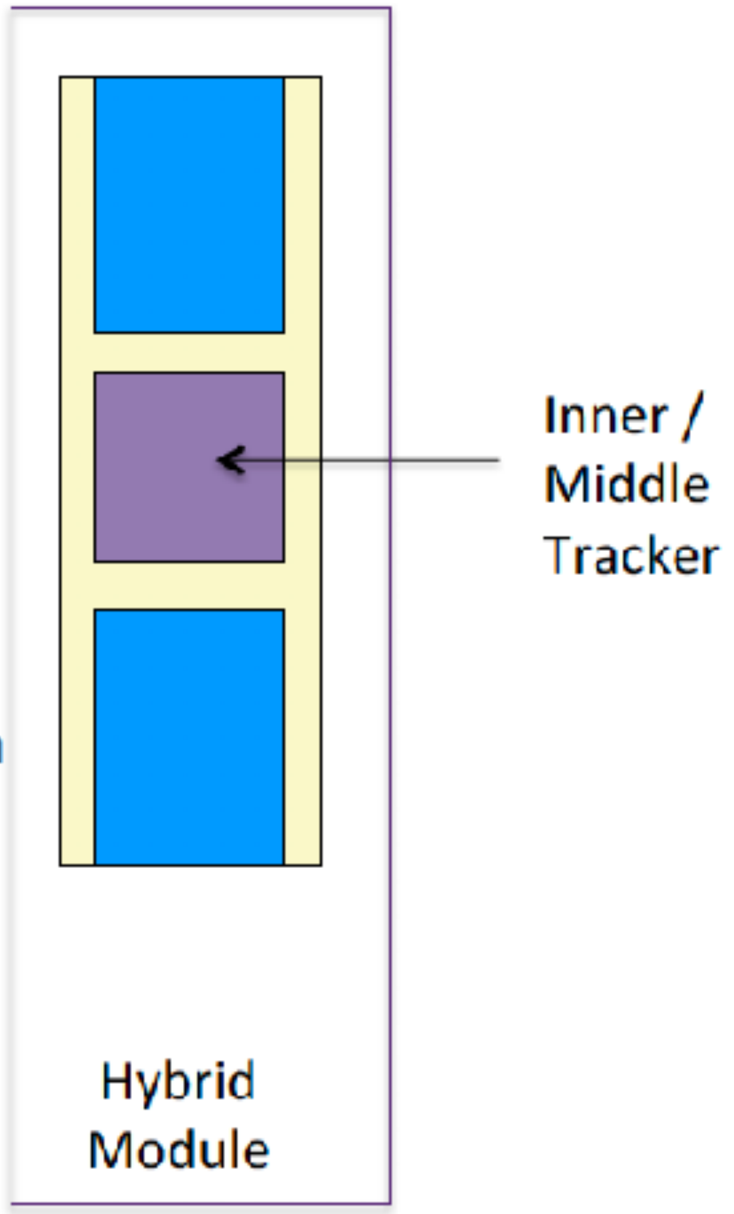


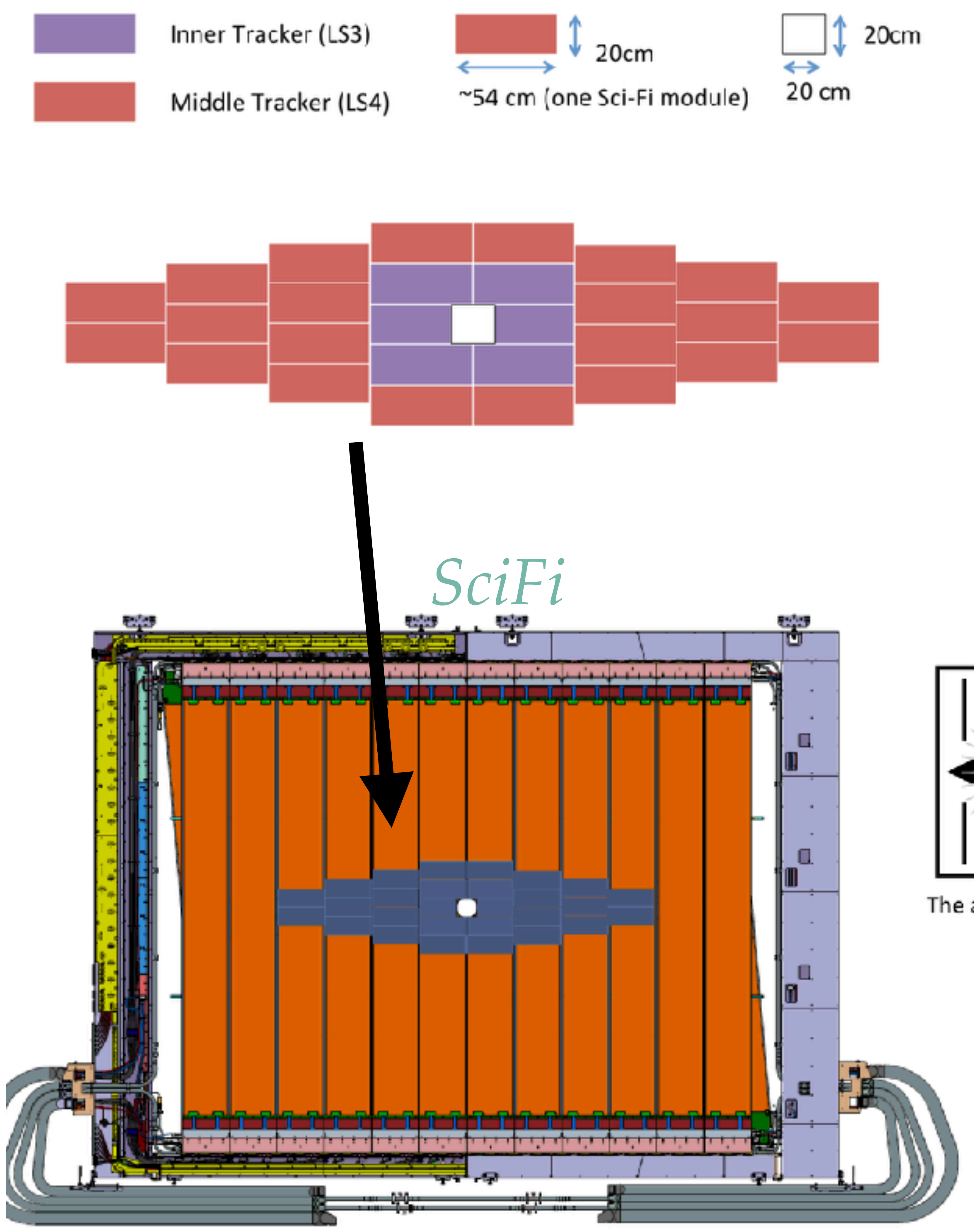
Half-scale demonstrator

Mighty Tracker

LHCb-INT-2019-007

- Mighty tracker : biggest silicon tracker built by LHCb.
    - Upgrade 1B: Inner Tracker + Scifi
        - Limited change to SciFi
        - DMAPs technology for silicon sensors.
    - Upgrade II: New mighty silicon tracker covering larger area
        - Rebuild of SciFi + reuse IT
- Hybrid technology detector, many challenges !
    - Cost -> design choice.
    - Cooling.
    - Mechanical challenges to build the hybrid module.
    - Read-out and electronics.
    - Hardware-based tracking in Run 5?

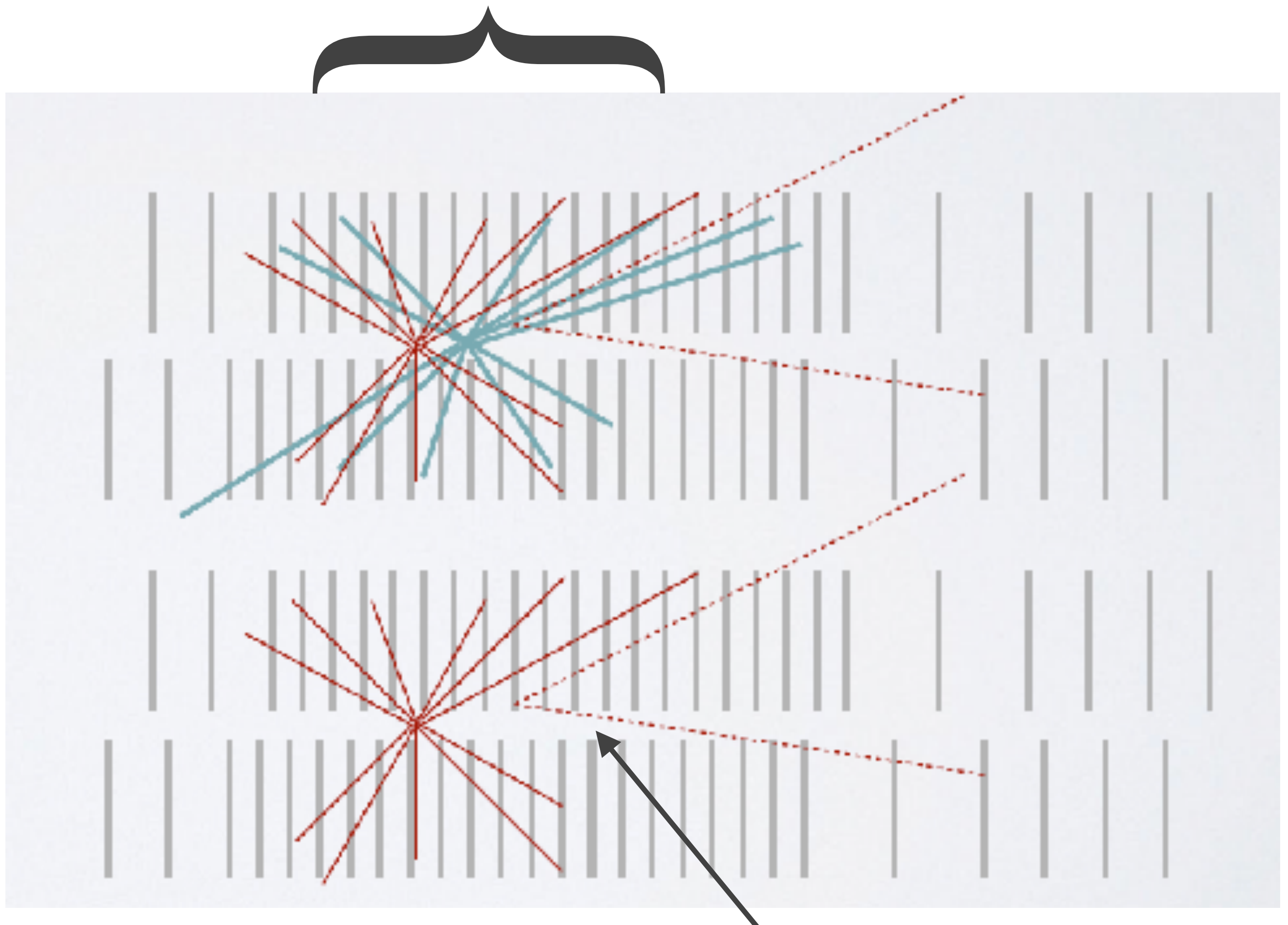




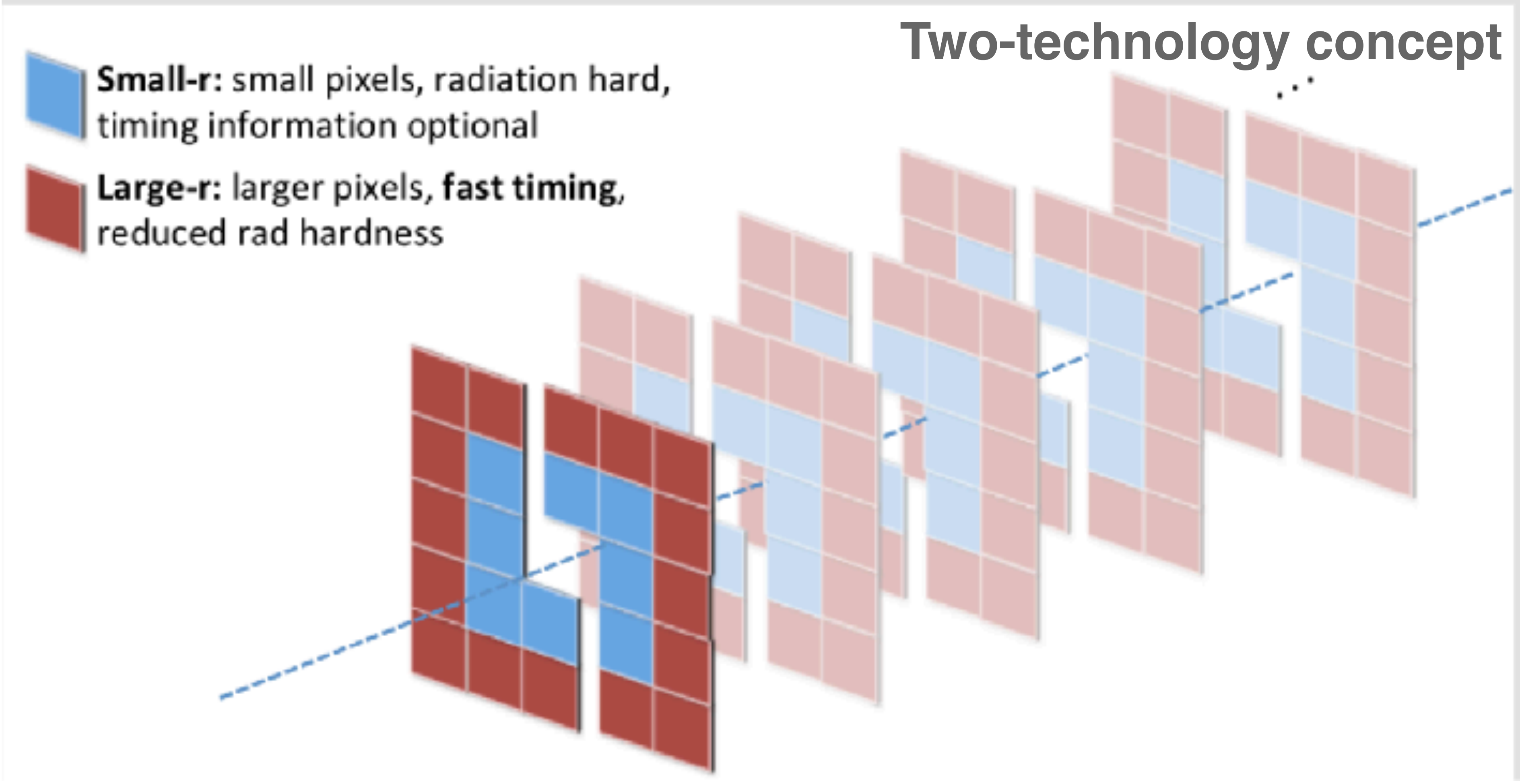
VELO

σ_z(lumi region) ≈ 45 mm
σ_t(lumi region) ≈ 190 ps

- Upgrade II VELO faces **significant mechanical challenges**
  - ➡ huge impact on the design and R&D.
- Track timing will be crucial
  - ➡ PV timing and associations, displaced track trigger etc.
  - ➡ Difficult question to address that will impact the design.
  - ➡ Other issues : cooling, radiations …



Typical B meson flight time ~15ps



Conclusion

- Lessons learned from run I - run II :
  - ➡ LHCb **fully performant** in **p-SMOG, p-A and (ultra-) peripheral AA collisions.**
  - ➡ Main limitations : **tracking**
- Expectations for LHCb upgrade I :
  - ➡ **New tracking detectors + algorithms** benefit all HI collisions !
  - ➡ LHCb **could reconstruct particles up to (at least) ~30% centrality** without specific tuning !
- LHCb Upgrade II (U2):
  - ➡ Physics case available.
  - ➡ **HI physics conditions (if any) covered by HL-LHC** requirements at LHCb.
  - ➡ **Bright future ahead for the IFT working group !**