CODEXb: status and plans

COmpact Detector for EXotics at LHCb

[1708.09395]

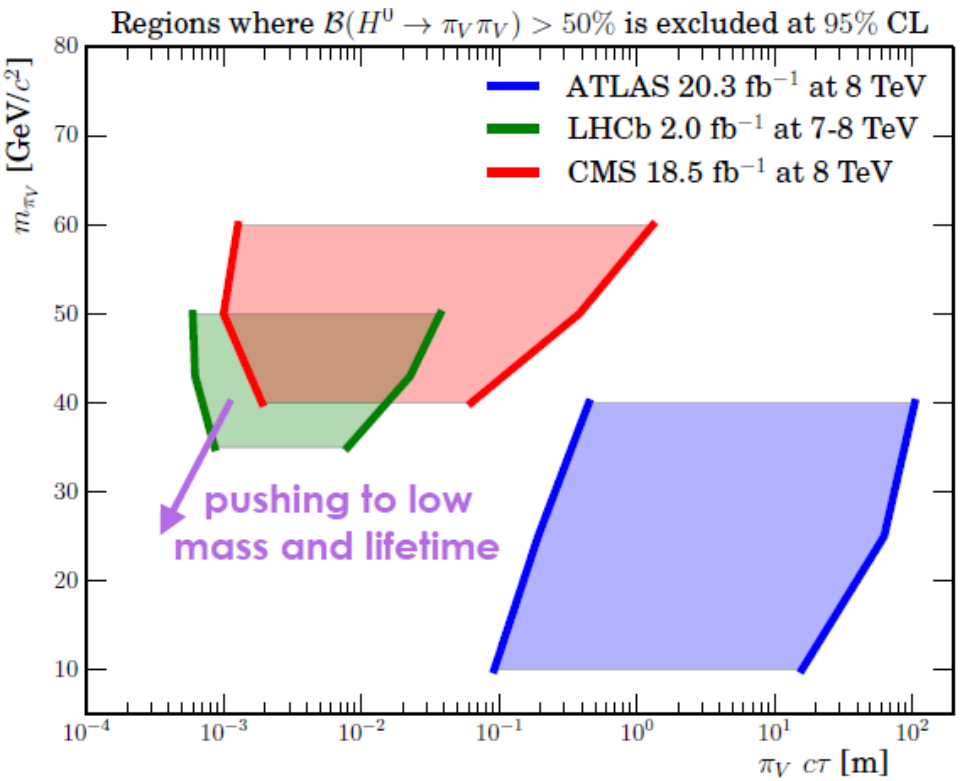
Biplab Dey

on behalf of the CODEX-*b* WG

Physics Beyond Colliders Workshop, CERN

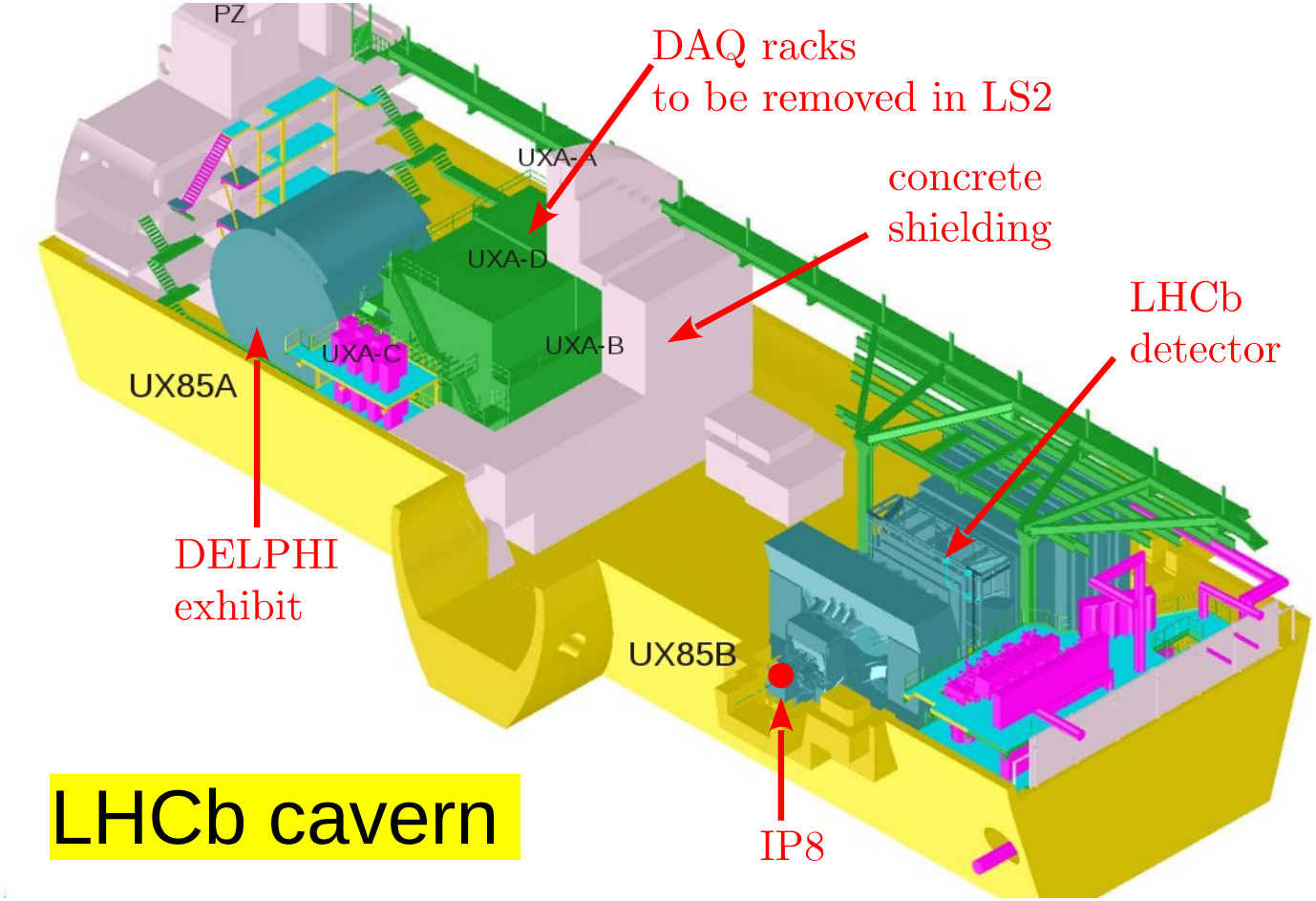
LHCb perspective

- Complementarity between ATLAS/CMS and LHCb: luminosity, acceptance, triggers, lifetime reach.



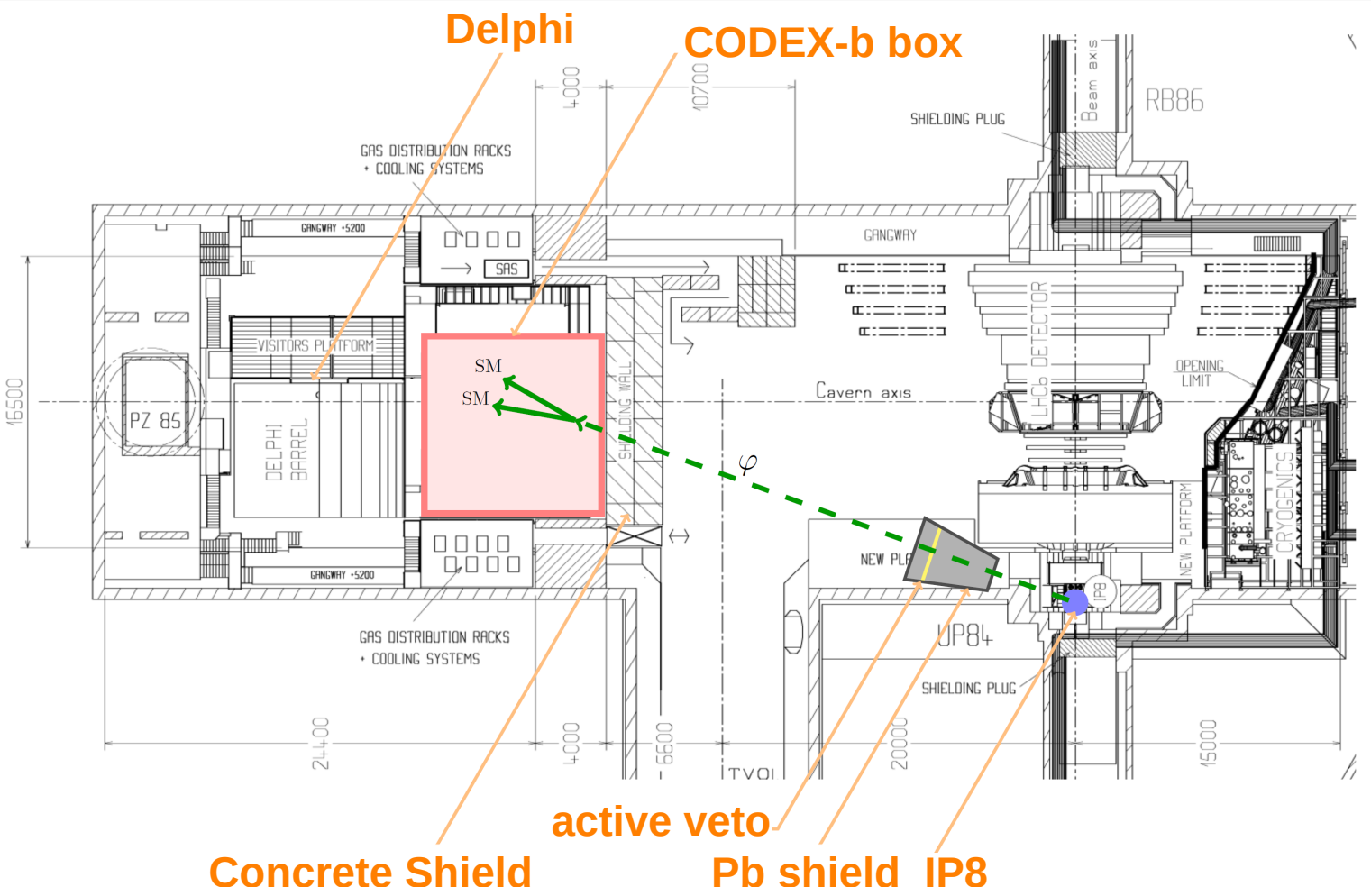
- Our best tracks originate inside the VeLo ($L \sim 20$cm). Longer lifetimes are challenging. CODEX-b to extend to much larger $c\tau$.

CODEX-b: proposal at Point 8



- DAQ racks in UXA-D move to surface for Run 3. Space available.
- Shielded, underground, $10 \times 10 \times 10$ m box, around 25 m from IP.
- Instrument with tracking layers $\Rightarrow$ CODEX-b

CODEX-b: another view



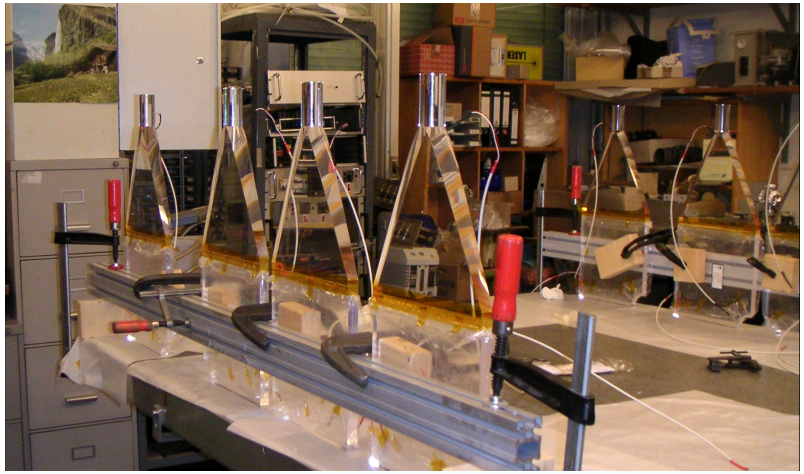
- If DELPHI is removed, access to even 20 × 10 × 10 m box.
- Angular acceptance ∼ 1%.

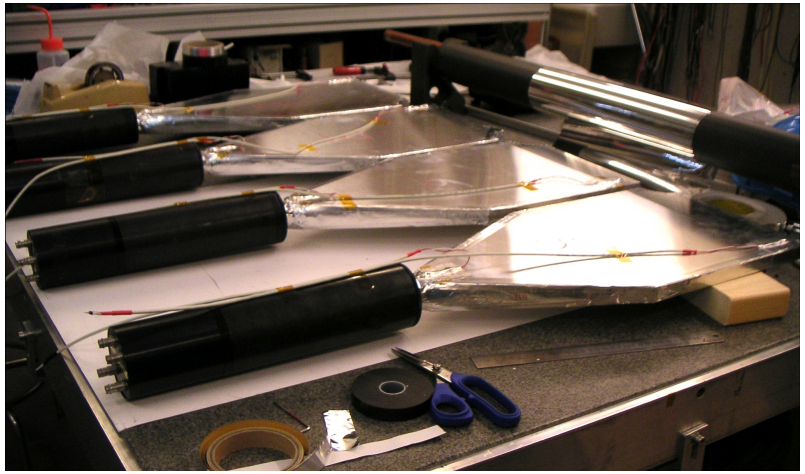
Background flux in UX85A cavern

- Understanding background rates critical for reach studies.
- Supervised a CERN summer student [Jongho Lee] to measure charged flux at different points in UX85A
- Used scintillators from Herschel detector in LHCb
- Very successful campaign: $\sim$ 50K triggers in 17 days
- Calibrate simulation employing these measurements

Herschel scintillators and setup

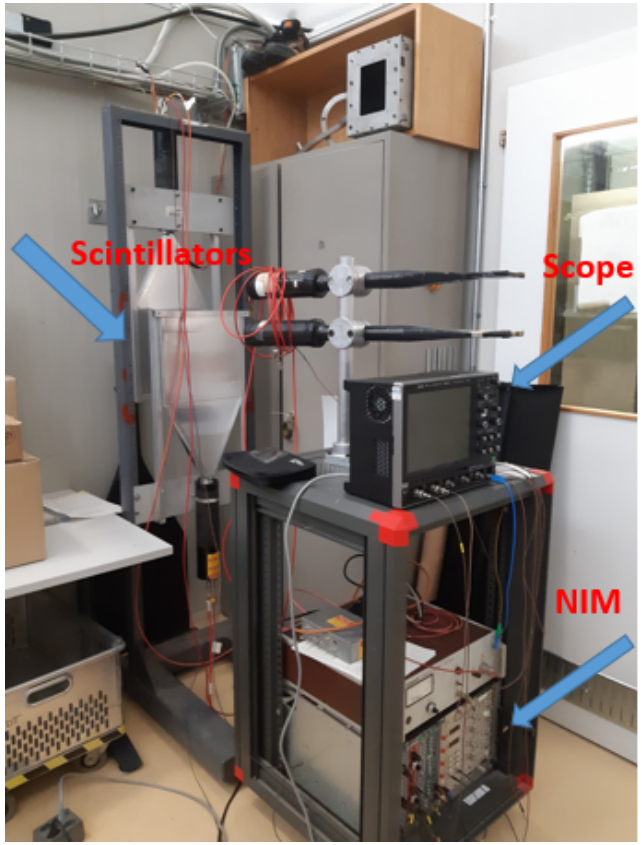
- Plastic scintillators w/ lightguides wrapped in Al foil, coupled to Hamamatsu R1828-01 PMT's
- 30×30 cm^2 area and 2 cm thickness.





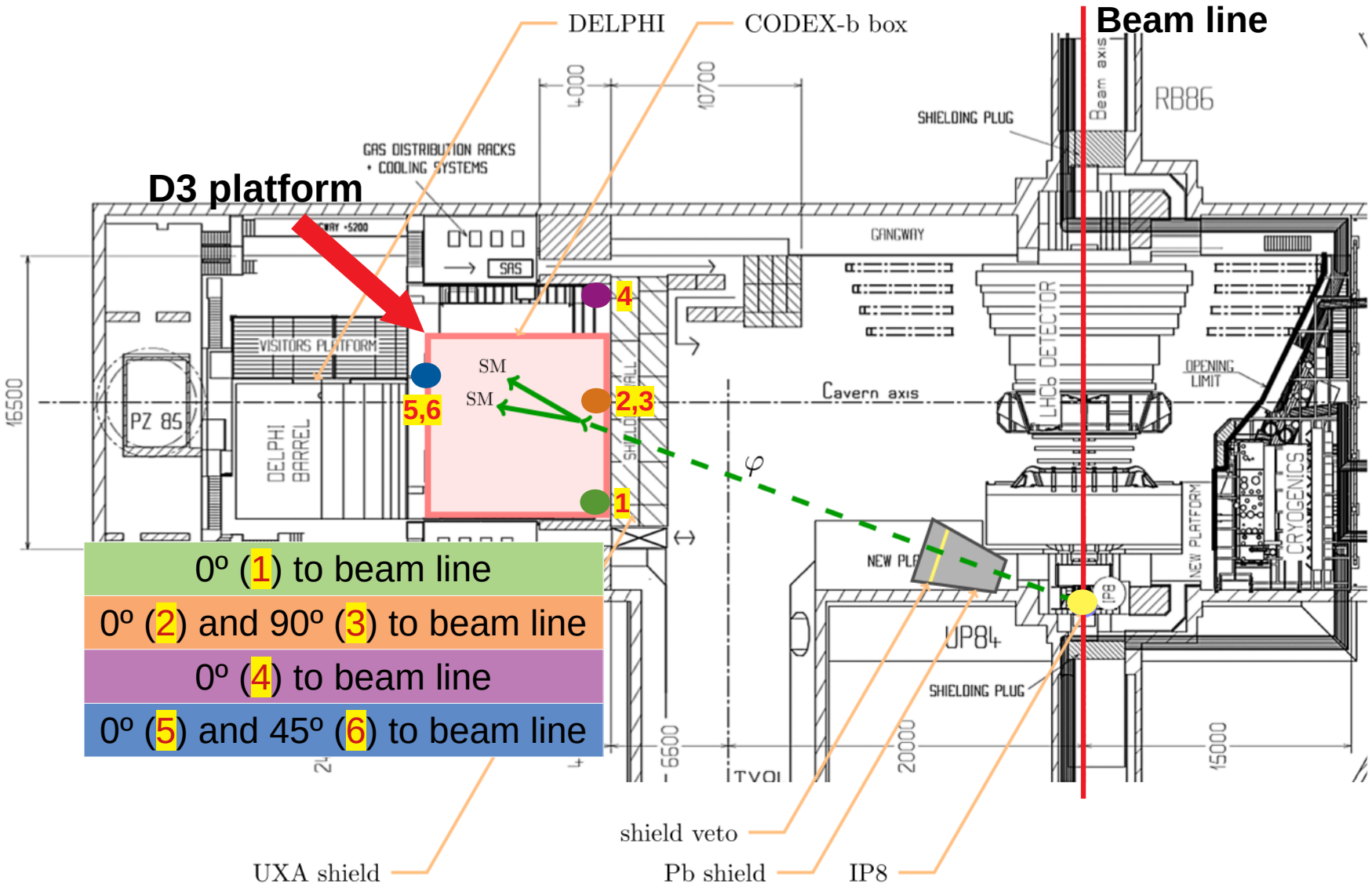
- Tested with cosmics on surface. $\sim$ 100% efficient for MIP's
- Can't measure energy deposit though.

Test bench assembly in VeloLab



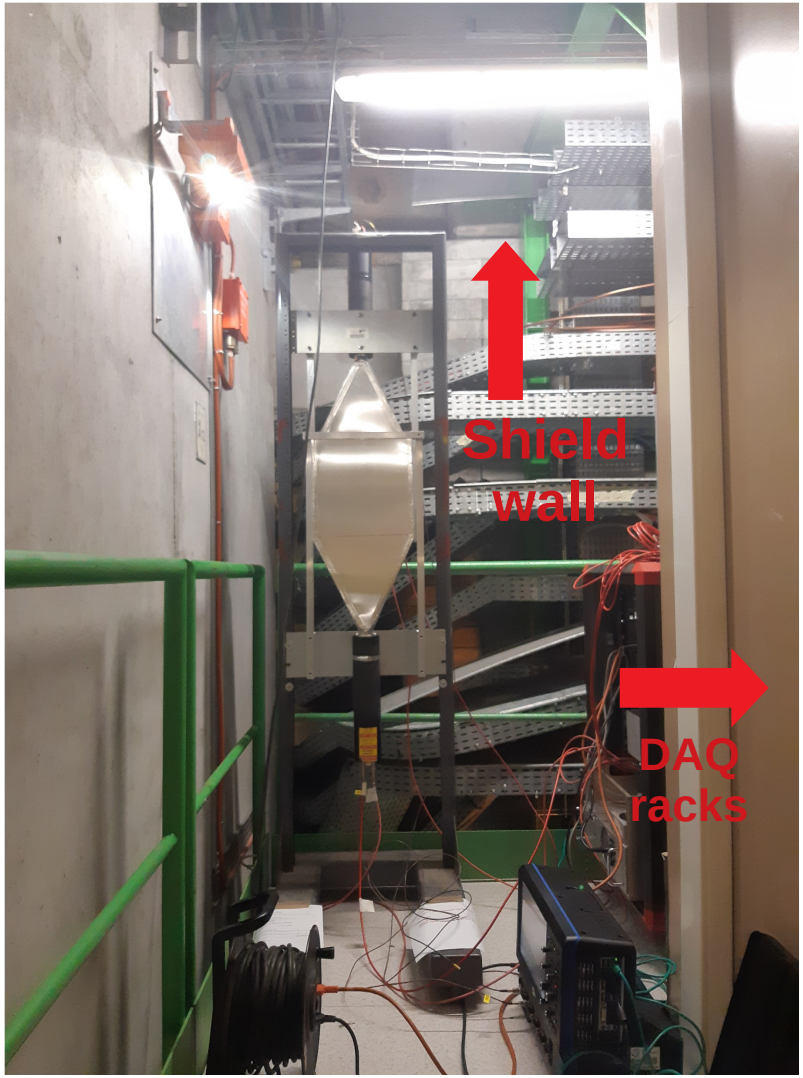
- Upright iron stand, scintillators horizontally separated by $\sim$ 11 cm.
- NIM crate + LeCroy WR scope for DAQ.
- Coincidence trigger in 5 ns window (no spillover effects)

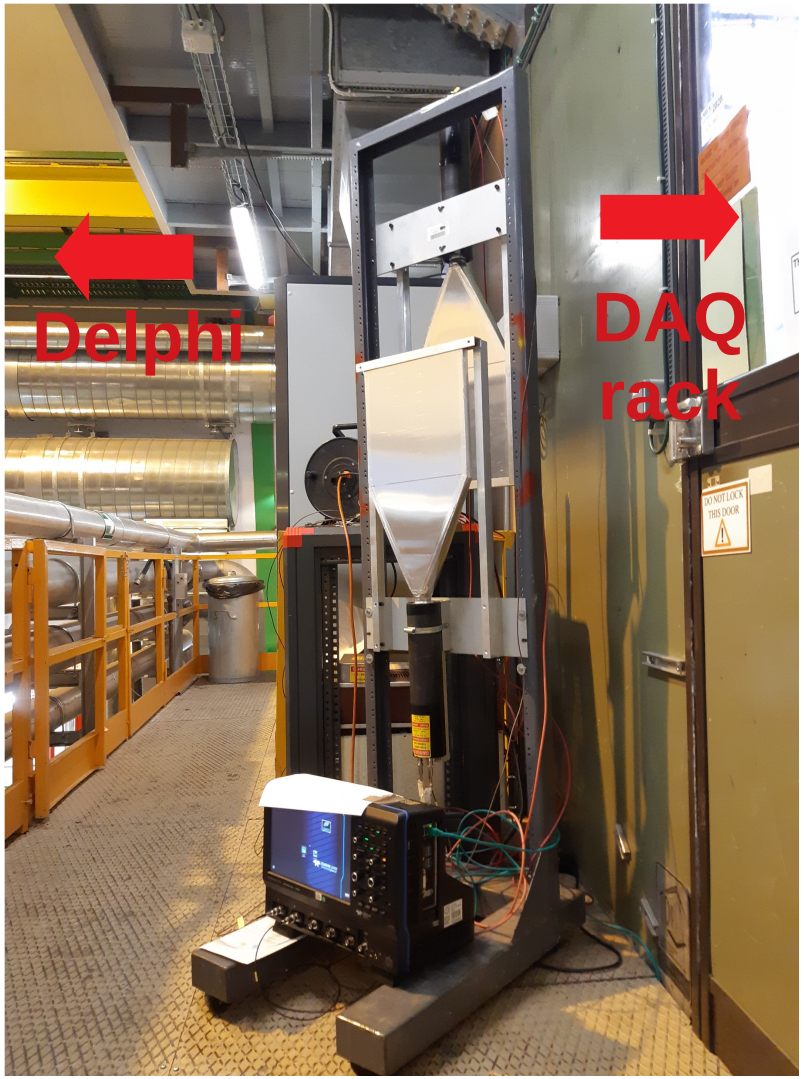
Four measurement positions on D3 platform



Equipment setup on D3

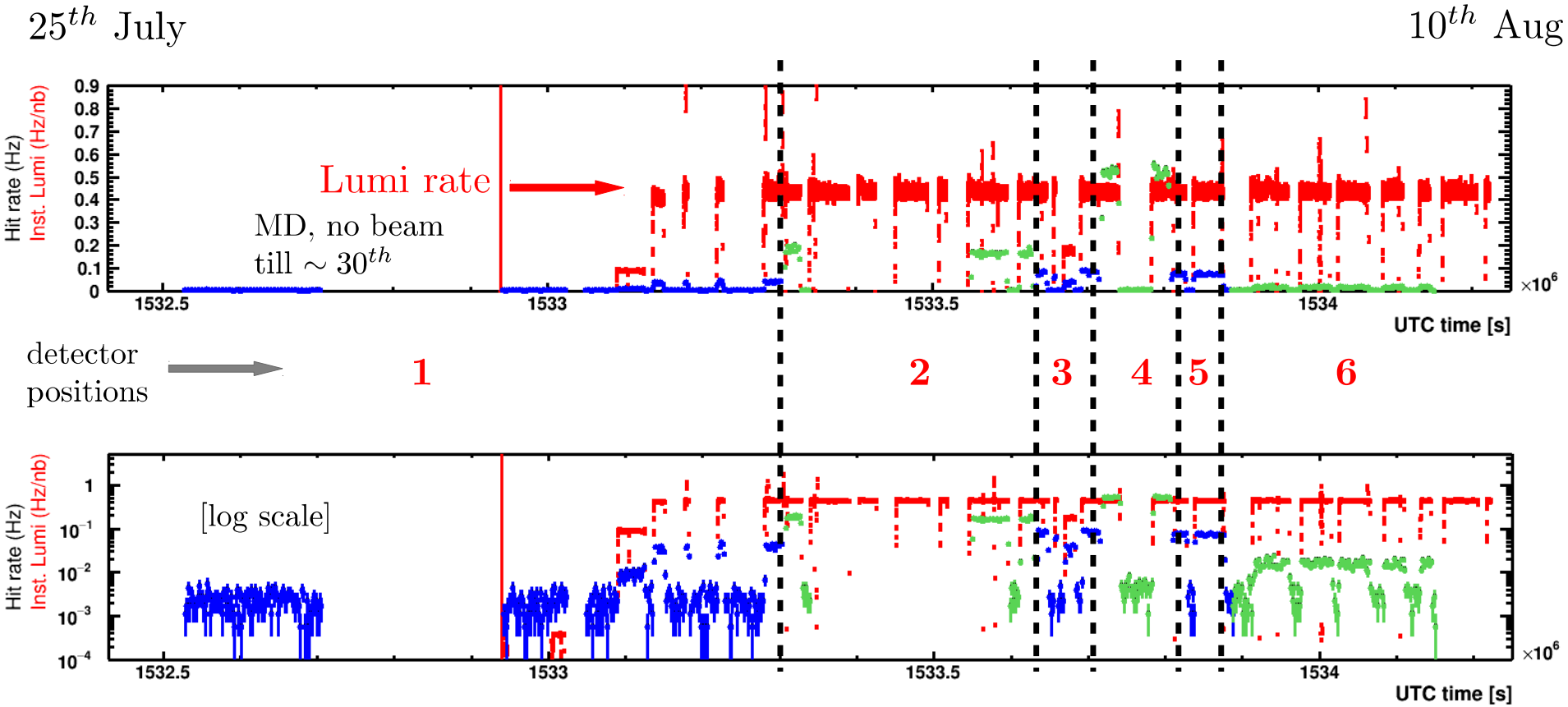
Equipment setup on D3 (cntd.)





Global snapshot of the data

- Measurement campaign spanning 17 days in July-Aug. 52036 triggers.
- 6 positions/configurations on D3 marked in blue and green, alternatingly:



Detailed features: background rate w/o beam

- Ambient background hit rate between fills or in MD, without beam.

Position	Description	Hit rate [mHz]
P1	shield, right corner, $\parallel$ to beam	1.99 ± 0.07
P2	shield, center, $\parallel$ to beam	2.76 ± 0.03
P3	shield, center, $\perp$ to beam	2.26 ± 0.03
P4	shield, left corner, $\parallel$ to beam	3.11 ± 0.03
P5	shield + D3 racks, center, $\parallel$ to beam	1.95 ± 0.03
P6	shield + D3 racks, center, 45° to beam	2.22 ± 0.02

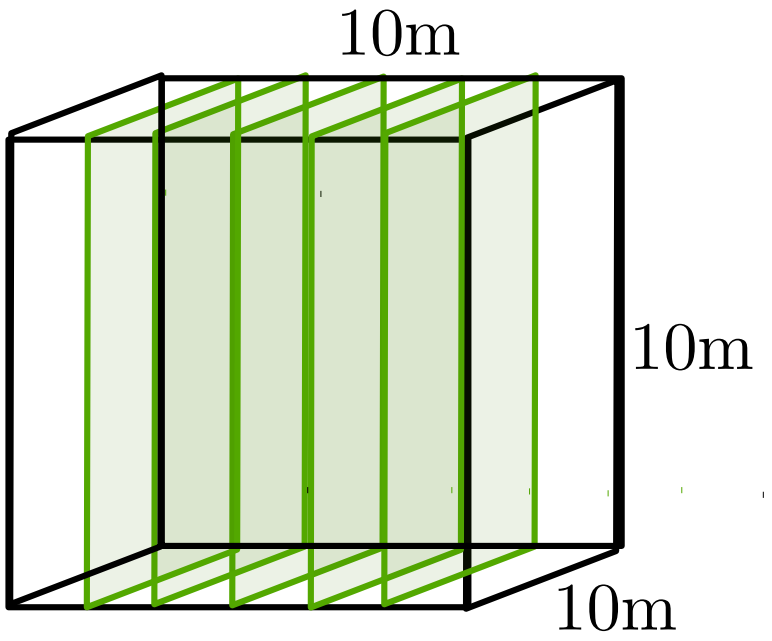
- Pretty consistent, ~ 2 mHz, across all positions and essentially negligible

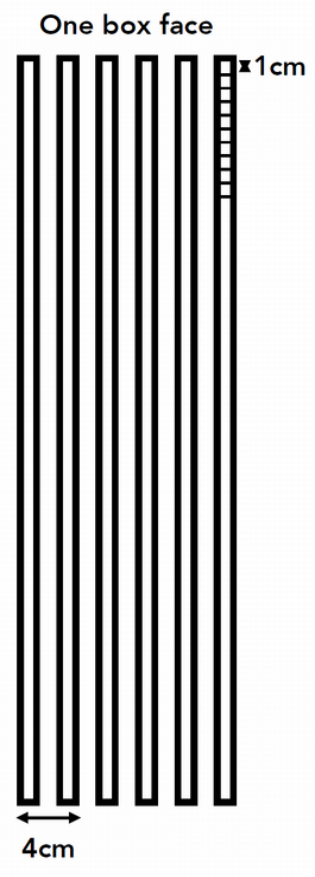
Specific features rate during stable beam

Position	Description	Hit rate [mHz]
P1	shield, right corner, $\parallel$ to beam	38.99 ± 0.99
P2	shield, center, $\parallel$ to beam	167.10 ± 1.43
P3	shield, center, $\perp$ to beam	82.81 ± 1.55
P4	shield, left corner, $\parallel$ to beam	517.45 ± 3.52
P5	shield + D3 racks, center, $\parallel$ to beam	73.58 ± 1.18
P6	shield + D3 racks, center, 45° to beam	15.71 ± 0.33

- Maximal rate at P4, $\sim$ 0.5 Hz during beam. Calibrate simulation.
- Clear η dependence: $P1 \Rightarrow P2 \Rightarrow P4$. Rate higher at higher η
- The D3 racks definitely add some shielding as well (hard to simulate).

Minimal geometry for tracking

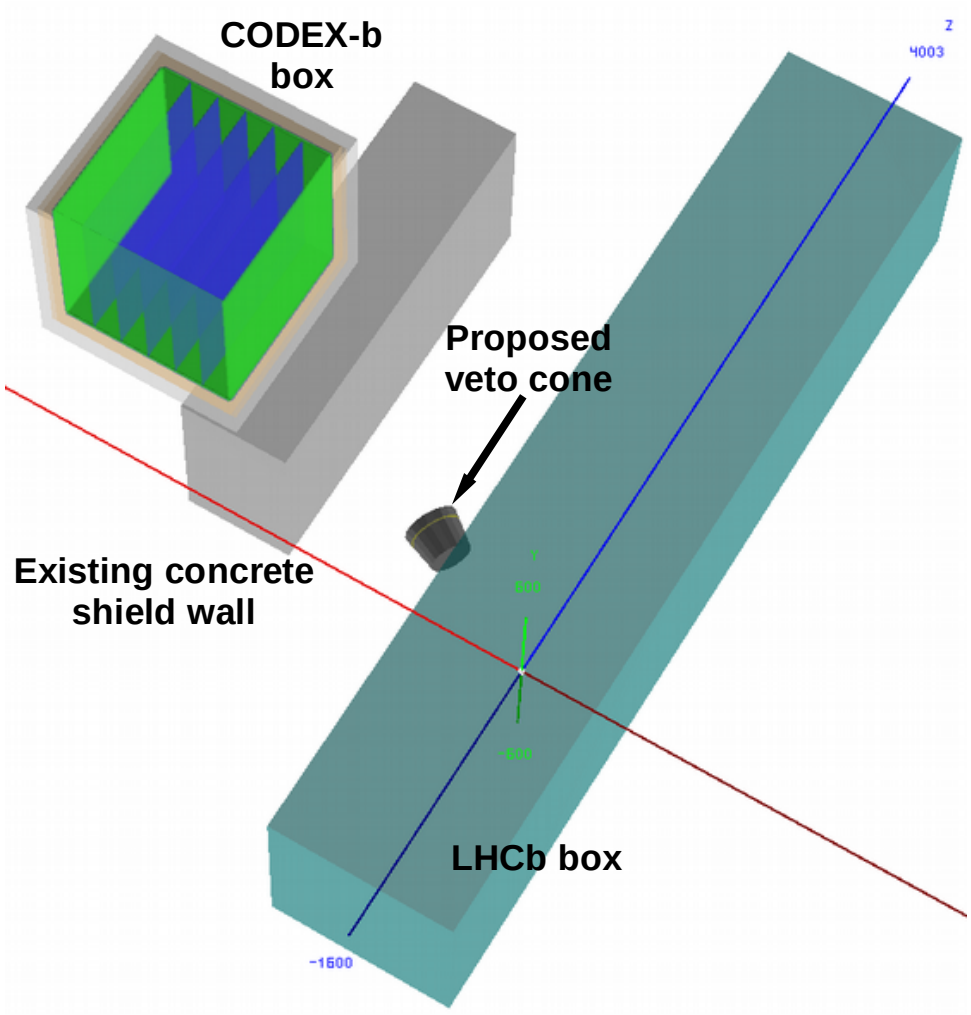




- Resistive plate chambers (RPC's)
- 6 RPC layers at 4 cm intervals on each box face with 1 cm granularity

- 5 equally spaced triplets along the depth to minimize distance between reconstructed vertex and 1st measurement. $\epsilon_{\text{tracking}} \sim \mathcal{O}(1)$.
- 50-100 ps timing from RPC's foreseen for mass reconstruction

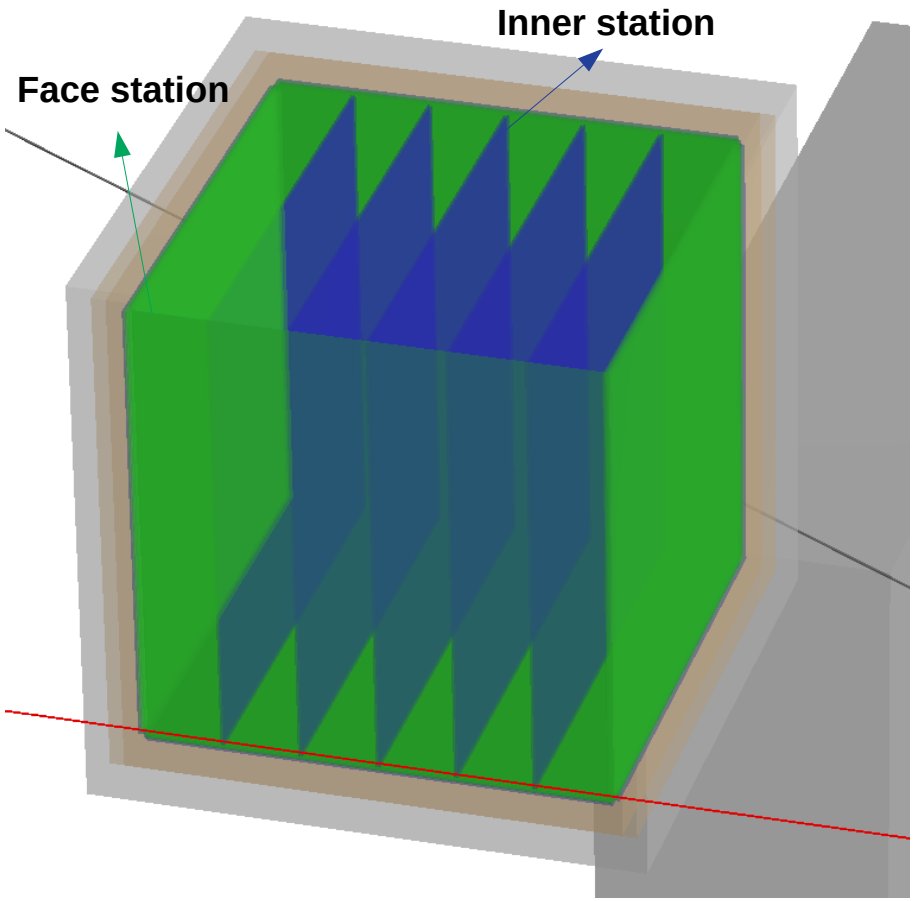
Detector geometry using DD4hep package



- Veto cone
  - Two Pb absorbers
  - Active Si shield layer
- Concrete shield wall
  - 3.2 m thickness
  - Block most particles from *pp* collisions
- CODEX-b box
  - Consists of two types of stations: inner and face.

CODEXb box volume: details

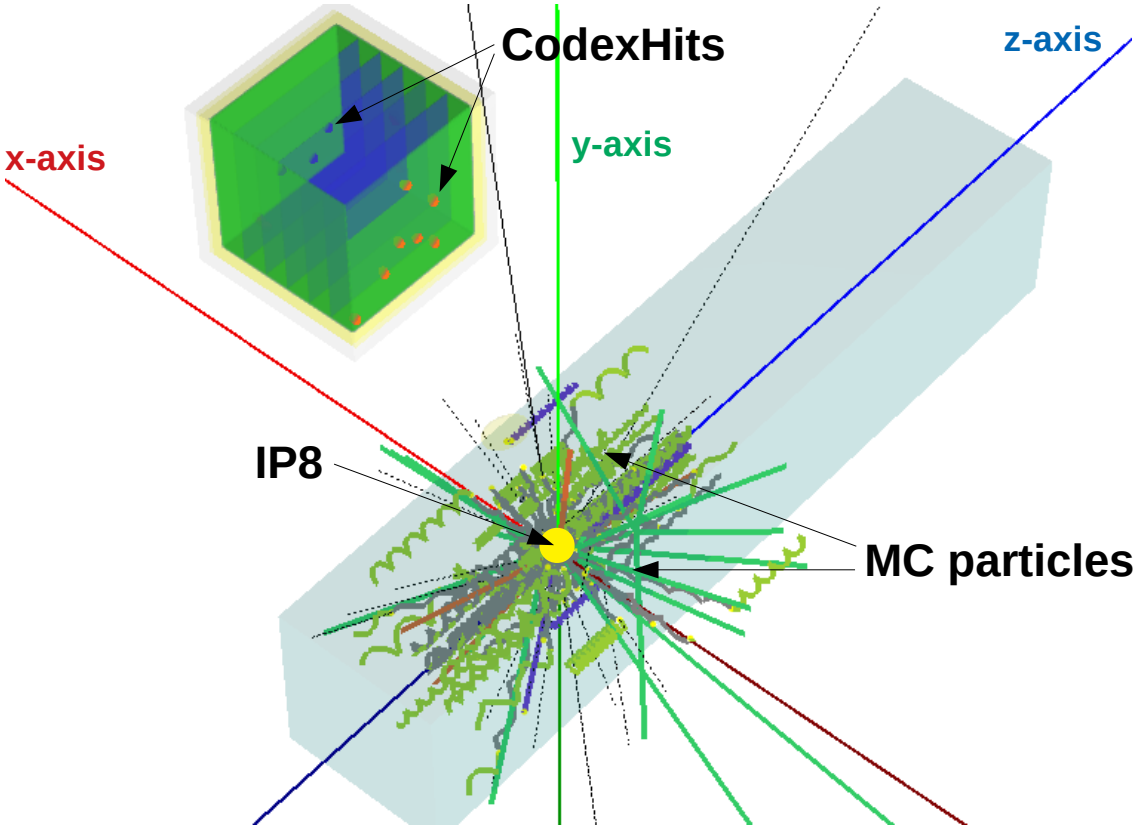
- Nominal geometry from 1708.09395. Replace RPC's by simple Silicon layers as sensitive element



- Inner station (x5)
  - Silicon tracker
  - 3 layers of 10 x 10 m^2 size and 2 cm thicknes
  - Inter-layer distance is 4 cm
- Face station (x6)
  - Silicon tracker
  - 6 layers of 10 x 10 m^2 size and 2 cm thickness
  - Inter-layer distance is 4 cm

Sample Minbias event

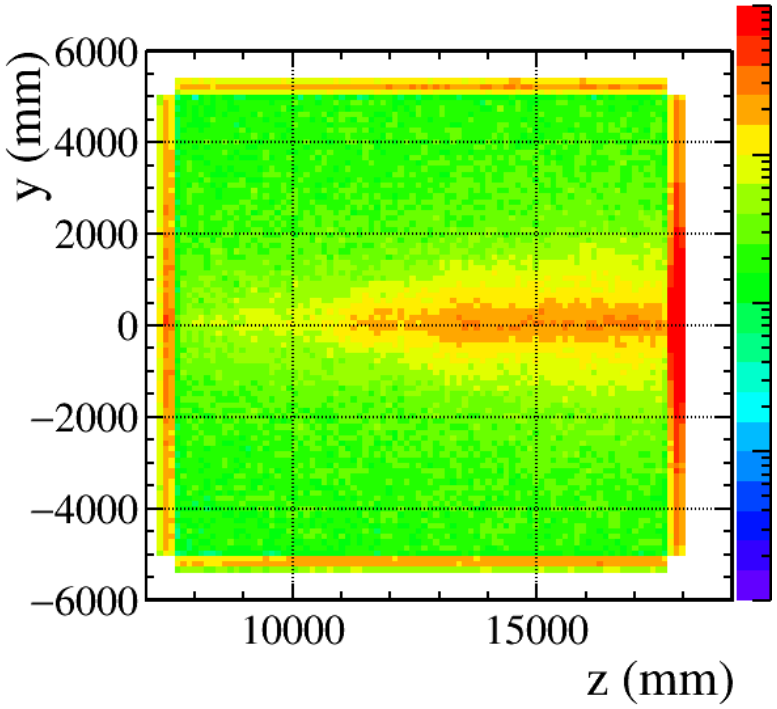
- 13 TeV minbias events with existing shield **removed**



- Simulation running on the grid within LHCb framework (Gauss).

η DEPENDENCE IN SIMULATION

- Simulation reproduces the higher activity seen in data.
- $P1 \Rightarrow P4$, at higher η (larger z) has higher hits.



- `MCHits` seen in all the layers.

Machine Induced Background (MIB) sources

- CODEX-b is essentially a zero background experiment
- Background induced by the LHC machine has to be considered carefully, especially during HL-LHC
- Relevant sources for IP8/LHCb: beam-gas interactions, IR7 Betatron Cleaning, IR3 momentum cleaning, IP1 ATLAS elastic enteractions
- `LbMIB`: tool within `Gauss` to simulate this background
- We do see MIB hits in CODEX-b volume. Can we veto them w/ tracking.

Summary and next steps

- Critical steps achieved since 2017 proposal paper
  - Background flux directly measured in cavern, for calibration
  - Include detector within the official LHCb simulation
  - Measurement simulation mature (final reults not today). Normalizations have to be done correctly.
- Next important steps
  - Tracking, including timing information on the hits.
  - Simplistic Si layers used. Move to realistic RPC's and/or Calorimeters
- LHCb Internal-Note for the measurement campaign being prepared

CODEX-B: WHO WE ARE

- Theory colleagues:
  S. Knapen, M. Papucci, D. Robinson, H. Ramani, J. Evans, ...
- LHCb physicists:
  J. Lee, V. Coco, B. Dey, R. Dumps, V. Gligorov, H. Schindler, P. Ilten, X. Vidal + many others...
- Support from LHCb computing and simulation:
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- Growing collaboration...you're very welcome to join!!!

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Thanks!