LHCb VErtex LOcator Upgrade

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LHCb experiment

- Goal: Study of the beauty quark
- Physics: Flavour physics CP and in B mesons
  - Matter - antimatter asymmetry
  - New Physics
- Detection in the forward direction —> Low p_T particles

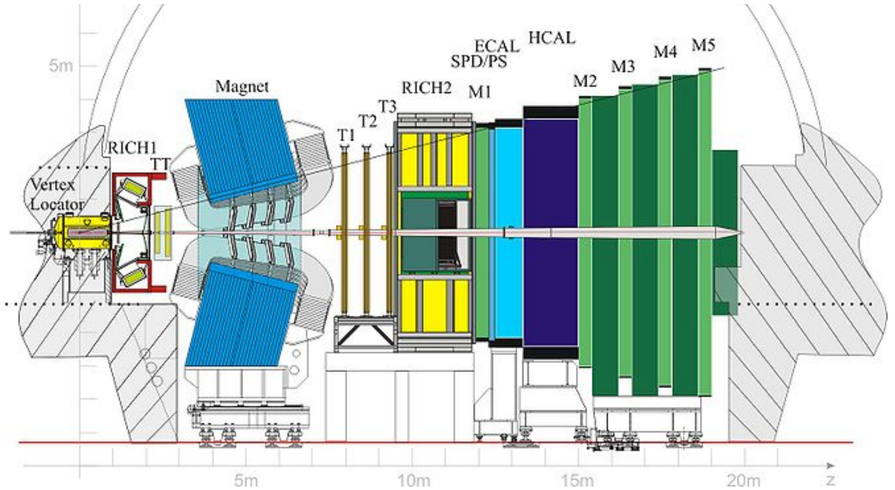


Figure 1: The basic layout of the LHCb detector. The interaction point is on the left [4].

VErtex LOcator (VELO)

Goal of the VELO

- Determining the IP to distinguish between prompt and non-prompt interactions
  - Improve Impact Parameter (IP) resolution
  - Software trigger op de IP

- Impact parameter: Distance between the primary pp collision and a secundair decay of a particle

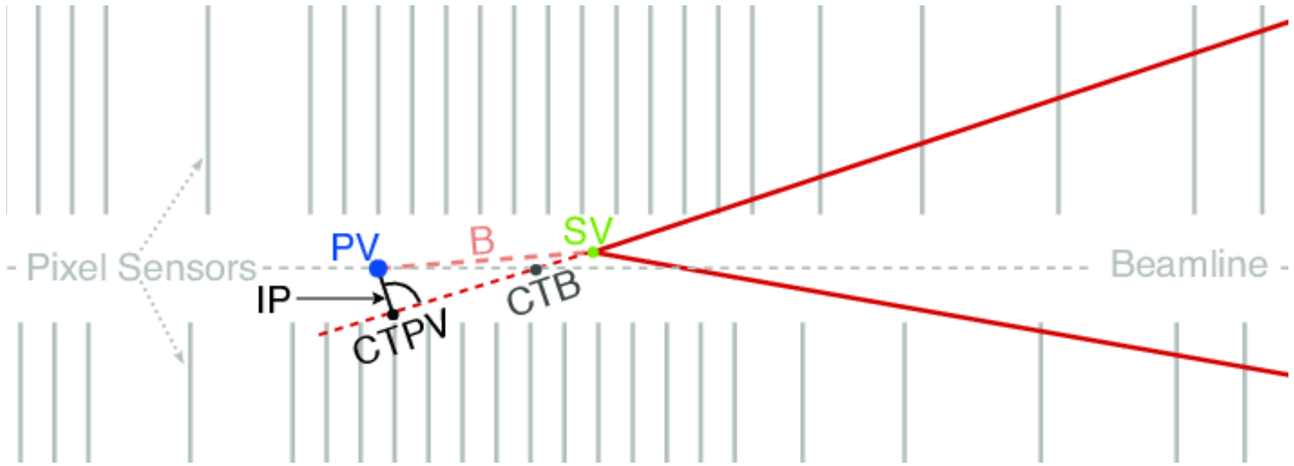


Figure 2: Sketch of B meson coming from the primary vertex (PV) and decaying inside the LHCb Vertex Locator into two daughter particles at the secondary vertex (SV) [5].

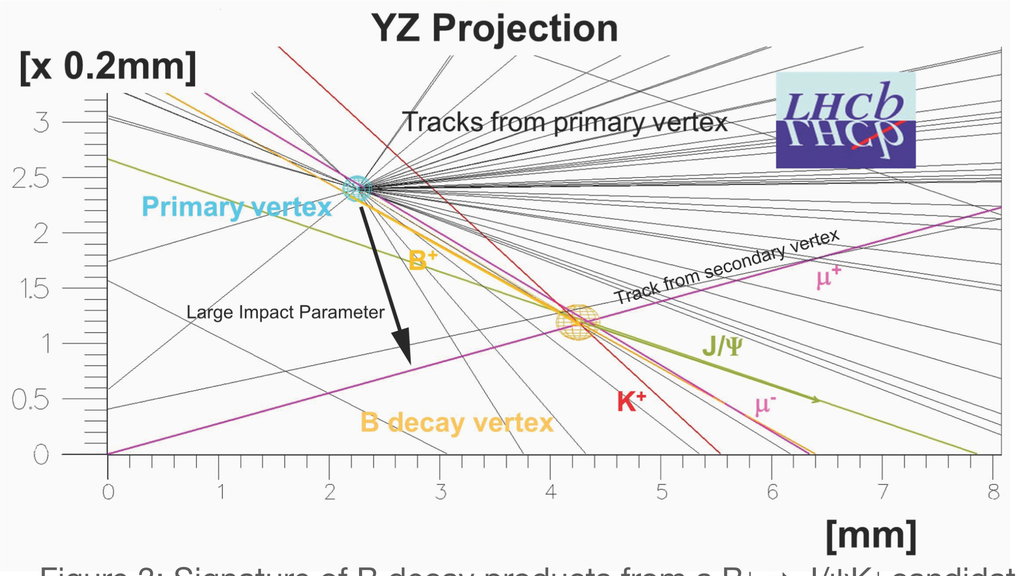
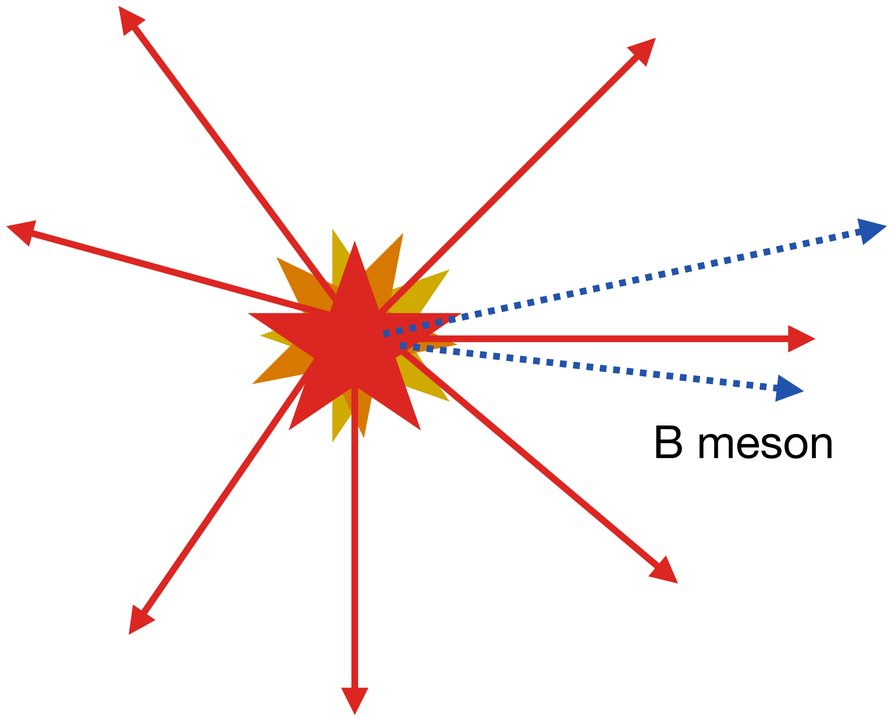


Figure 3: Signature of B decay products from a $B^+ \rightarrow J/\psi K^+$ candidate event in LHCb data [3].

VErtex LOcator (VELO)

Goal of the VELO

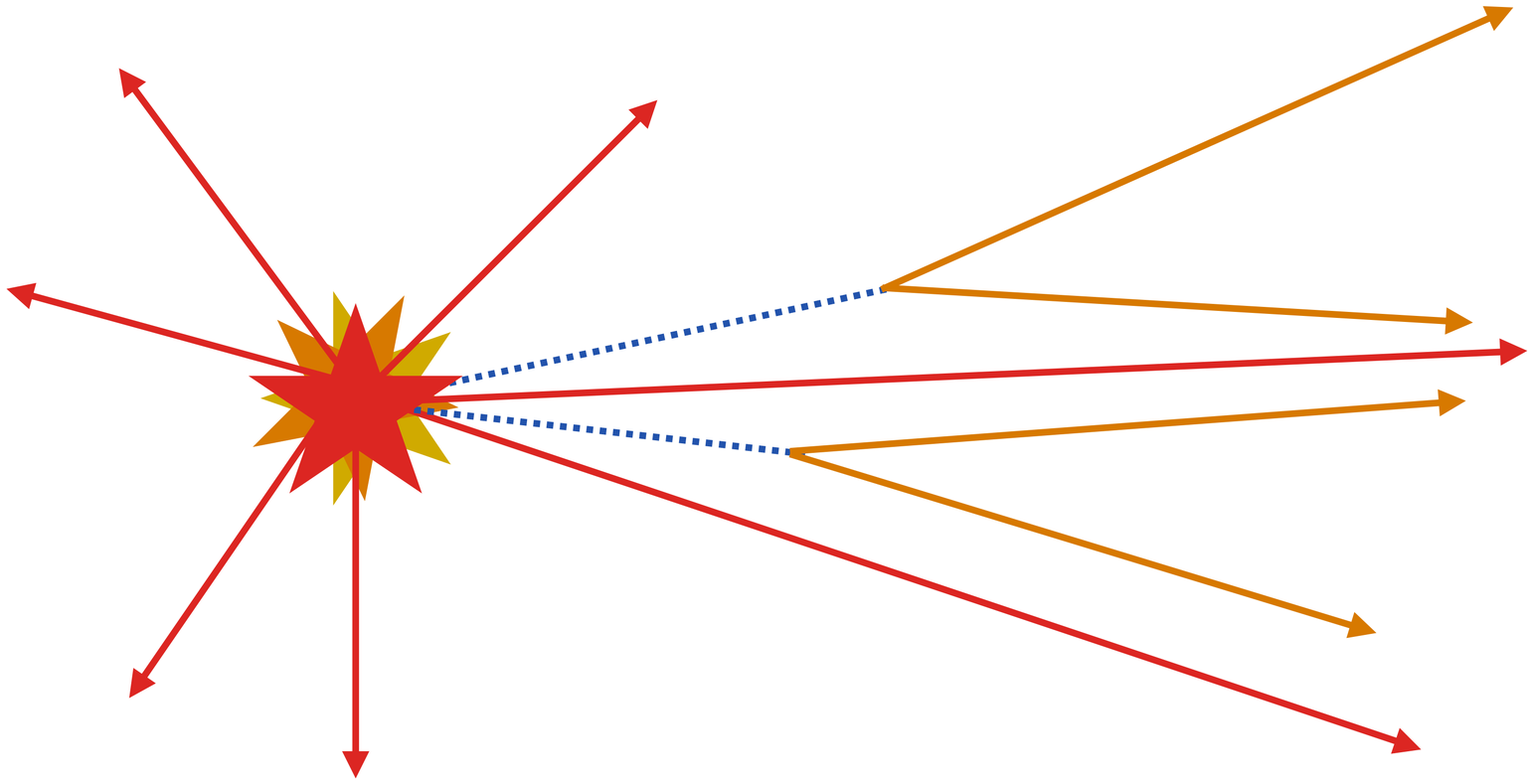
B mesons originated from collision



VErtex LOcator (VELO)

Goal of the VELO

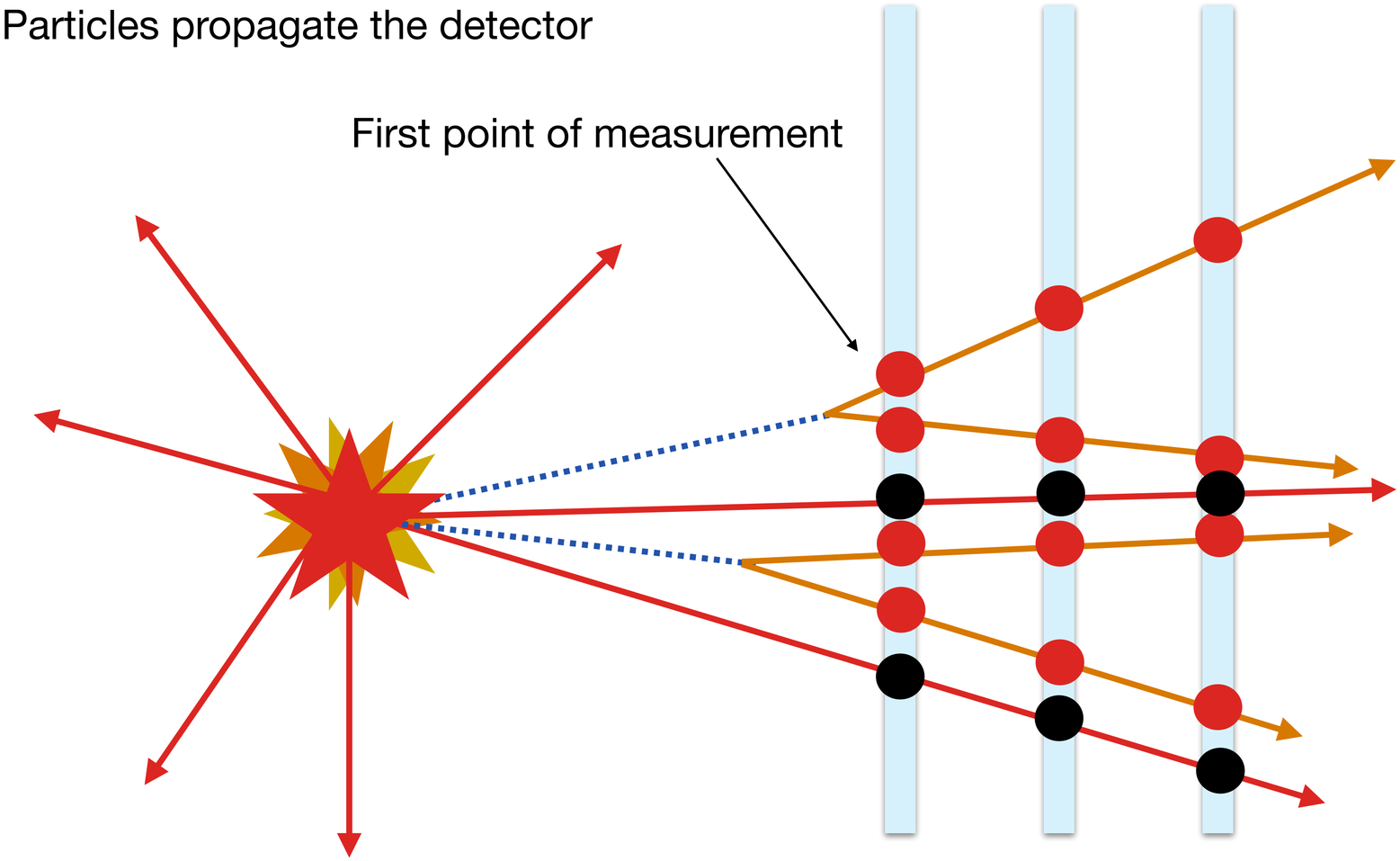
B mesons decay into daughter particles



VErtex LOcator (VELO)

Goal of the VELO

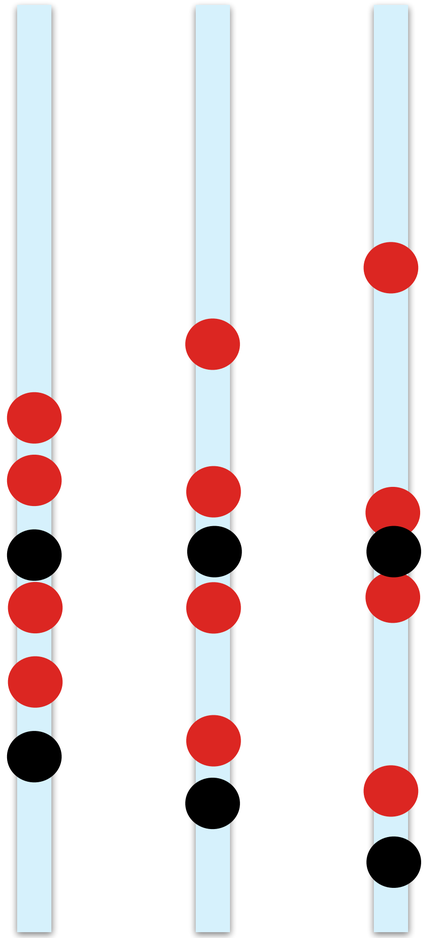
Particles propagate the detector



VErtex LOcator (VELO)

Goal of the VELO

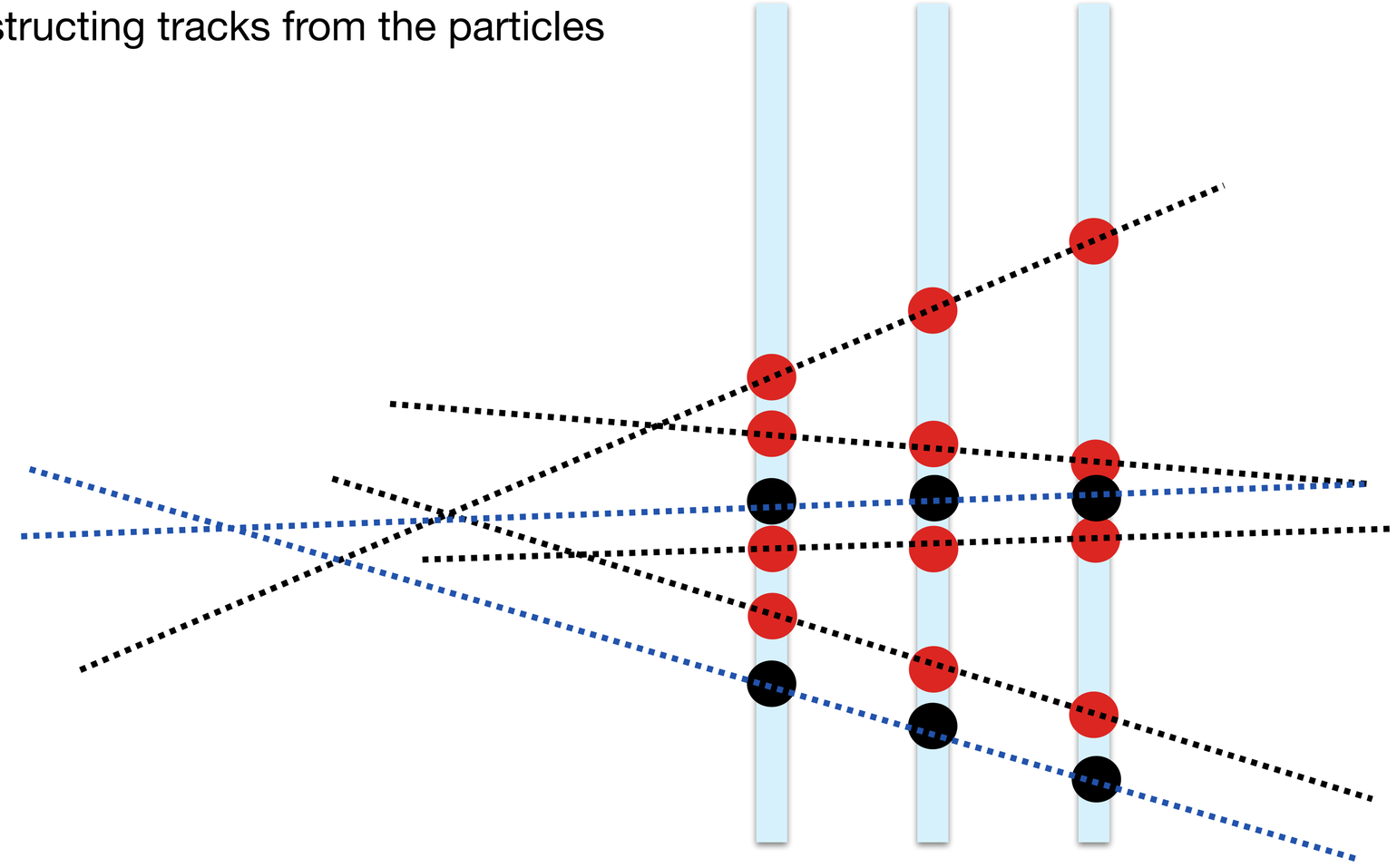
What the VELO measures:



VErtex LOcator (VELO)

Goal of the VELO

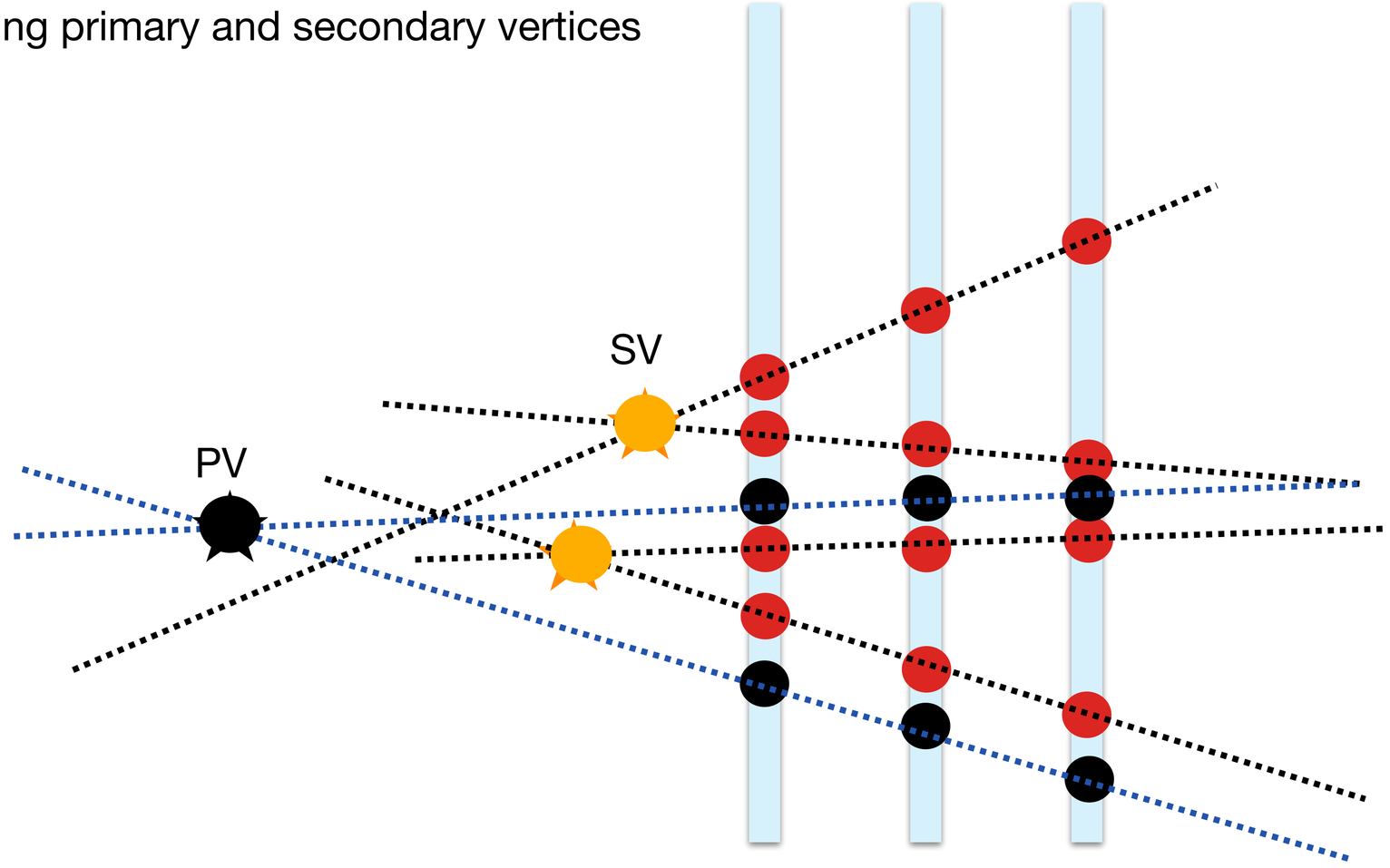
Reconstructing tracks from the particles



VErtex LOcator (VELO)

Goal of the VELO

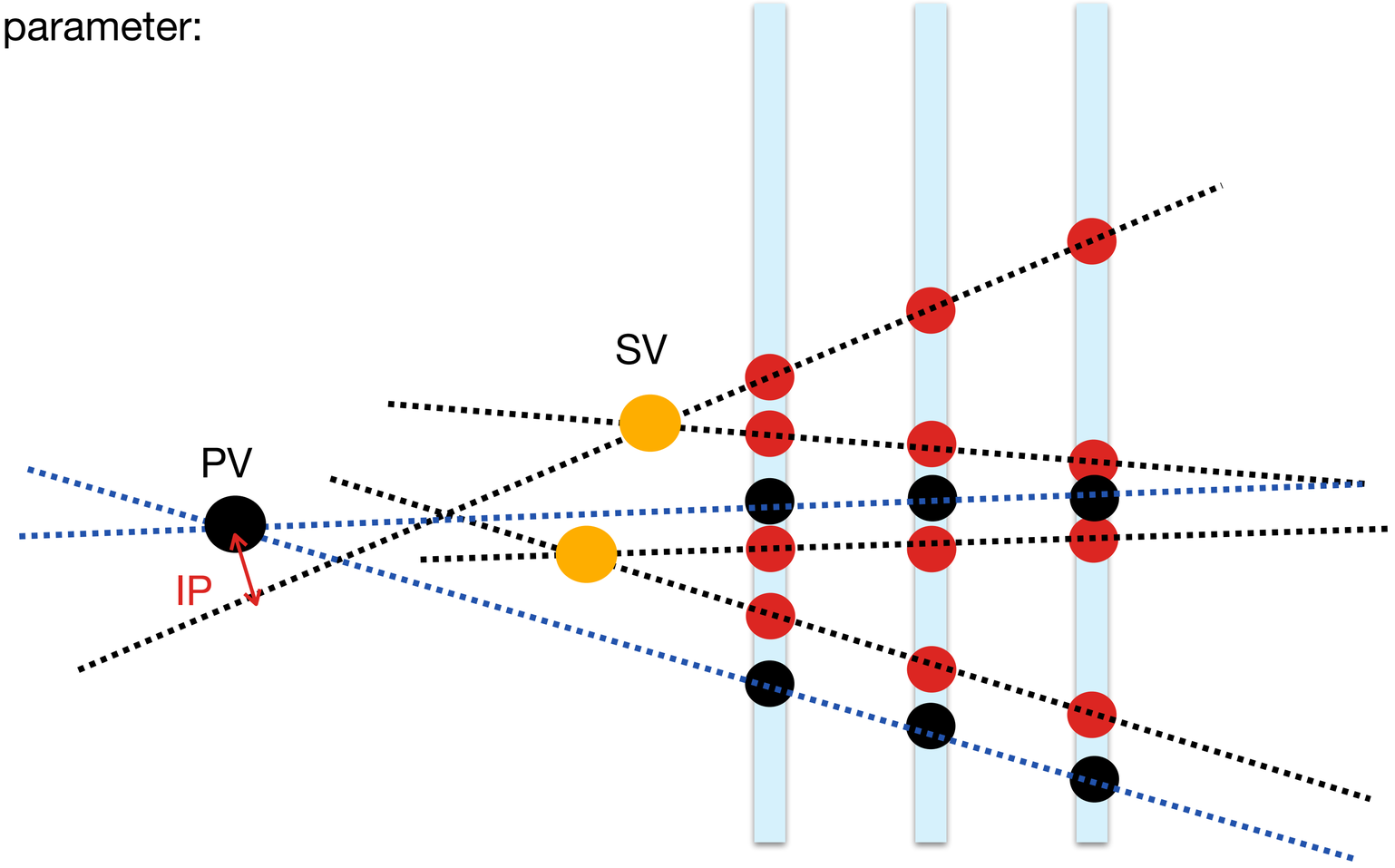
Identifying primary and secondary vertices



VErtex LOcator (VELO)

Goal of the VELO

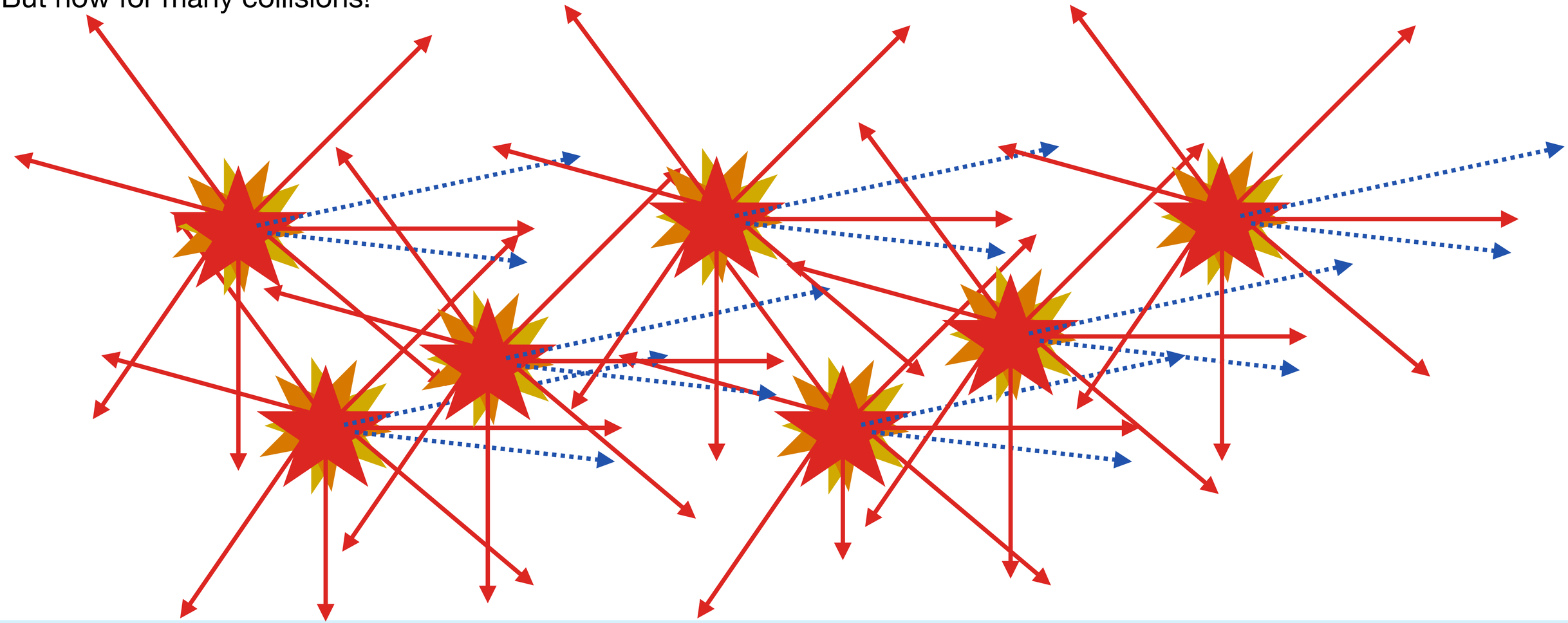
Impact parameter:



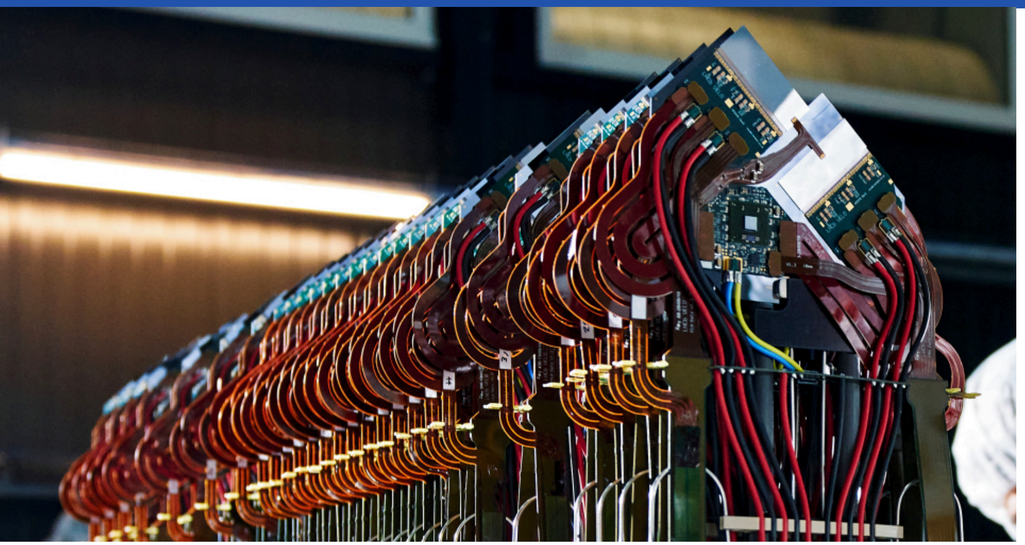
VErtex LOcator (VELO)

Goal of the VELO

But now for many collisions!



VErtex LOcator (VELO)



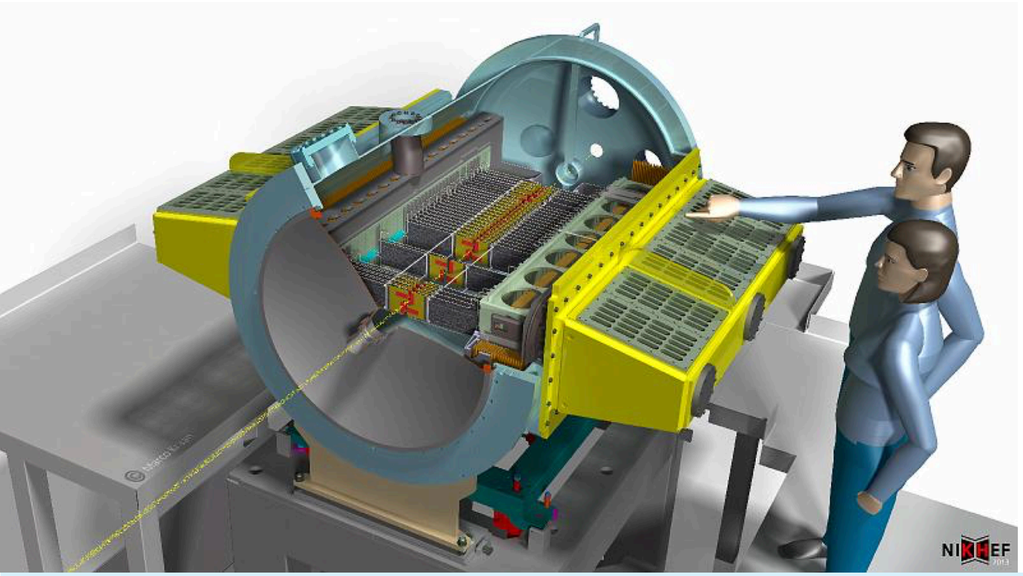


Figure 4: Artist's impression of the upgraded VELO once installed [3].

What is the VELO upgrade?

- The VELO is a silicon vertex detector
- Pixel sensors in stead of strips
- 26 stations over 1 m length
- 52 Modules

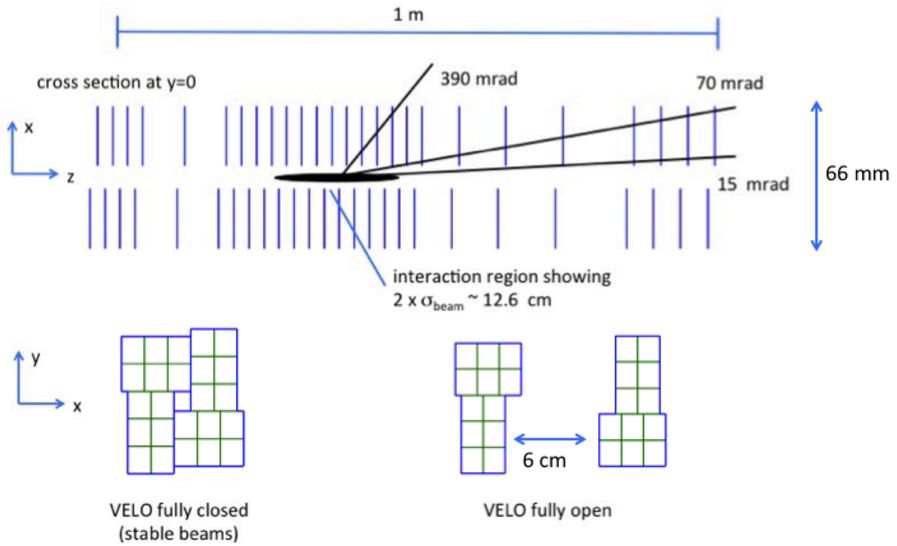


Figure 5: Schematic layout of the upgraded VELO [3].

VErtex LOcator (VELO)

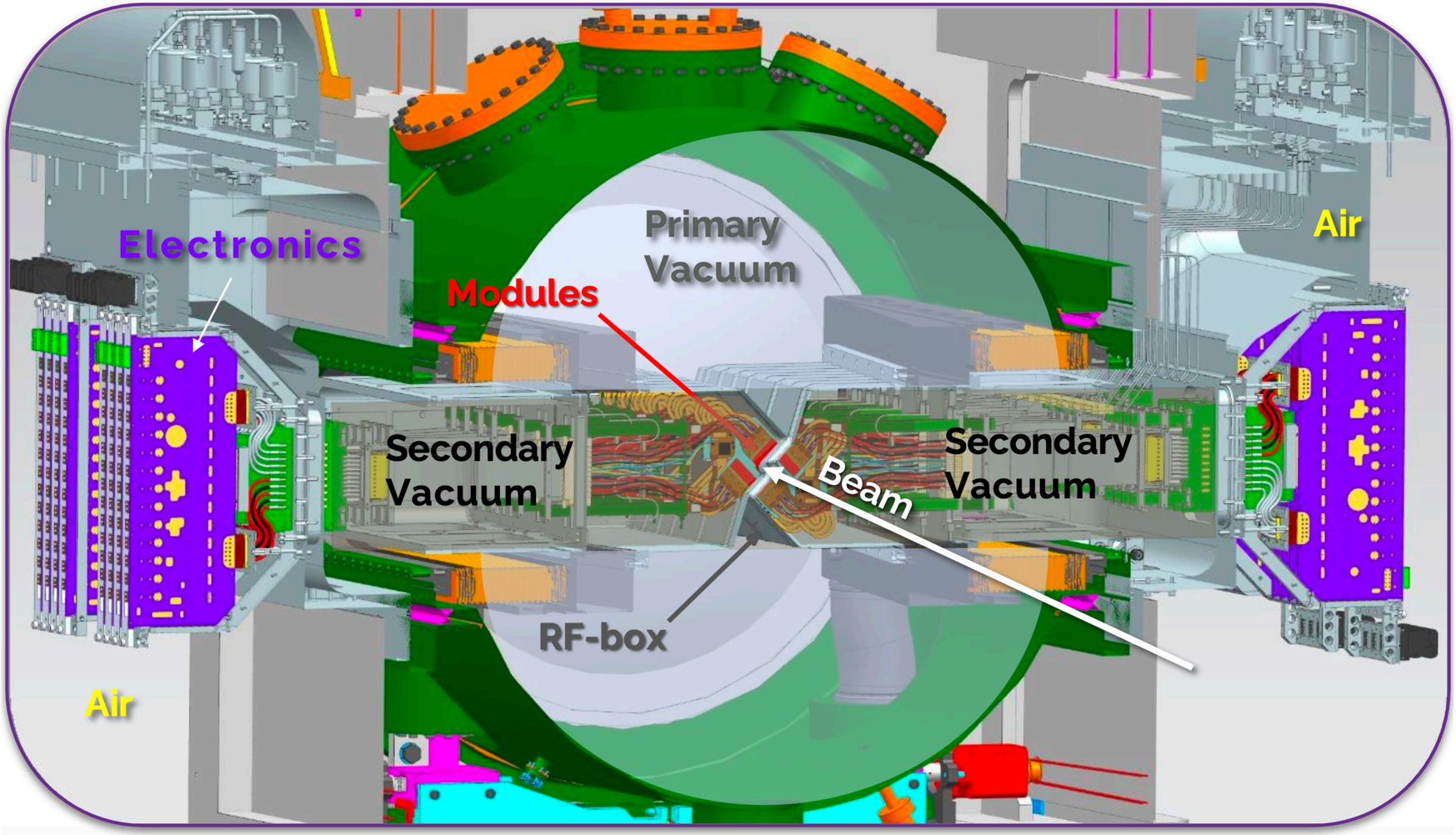
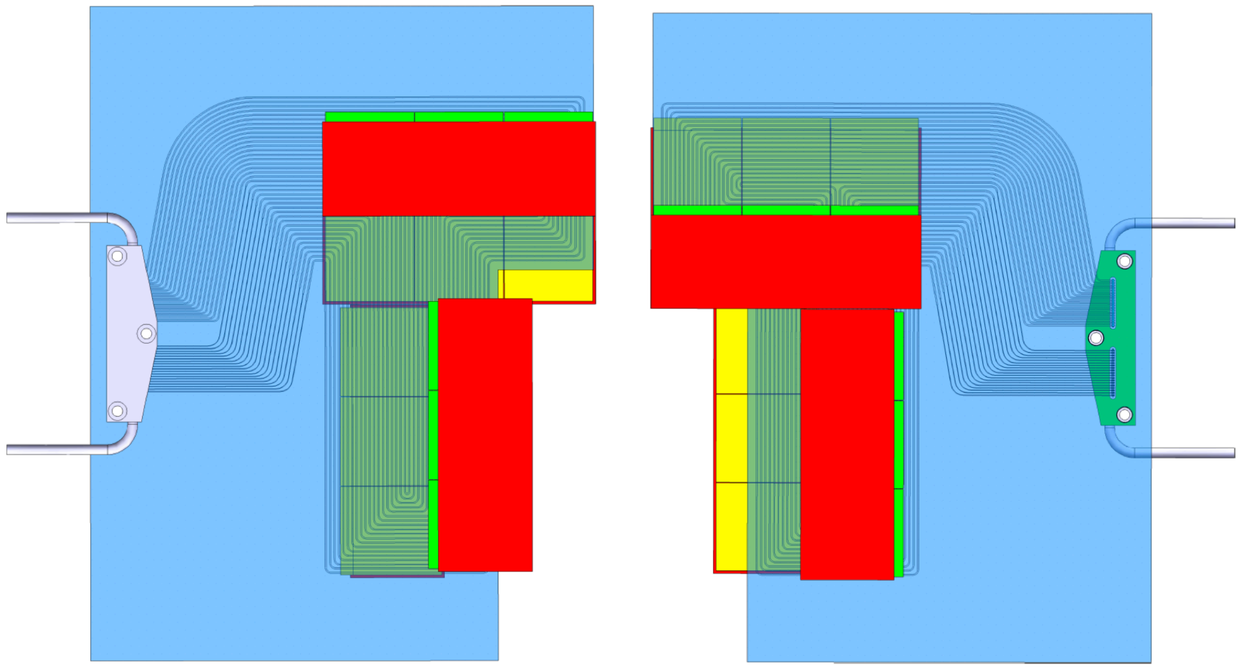


Figure 6: Schematic layout of the VELO upgrade [6].

Secundair vacuum

- The VELO is placed in a secondair vacuum
  - Separated from the beam vacuum by RF foil
    - VERY THIN! ~aluminum foil

VELO Module



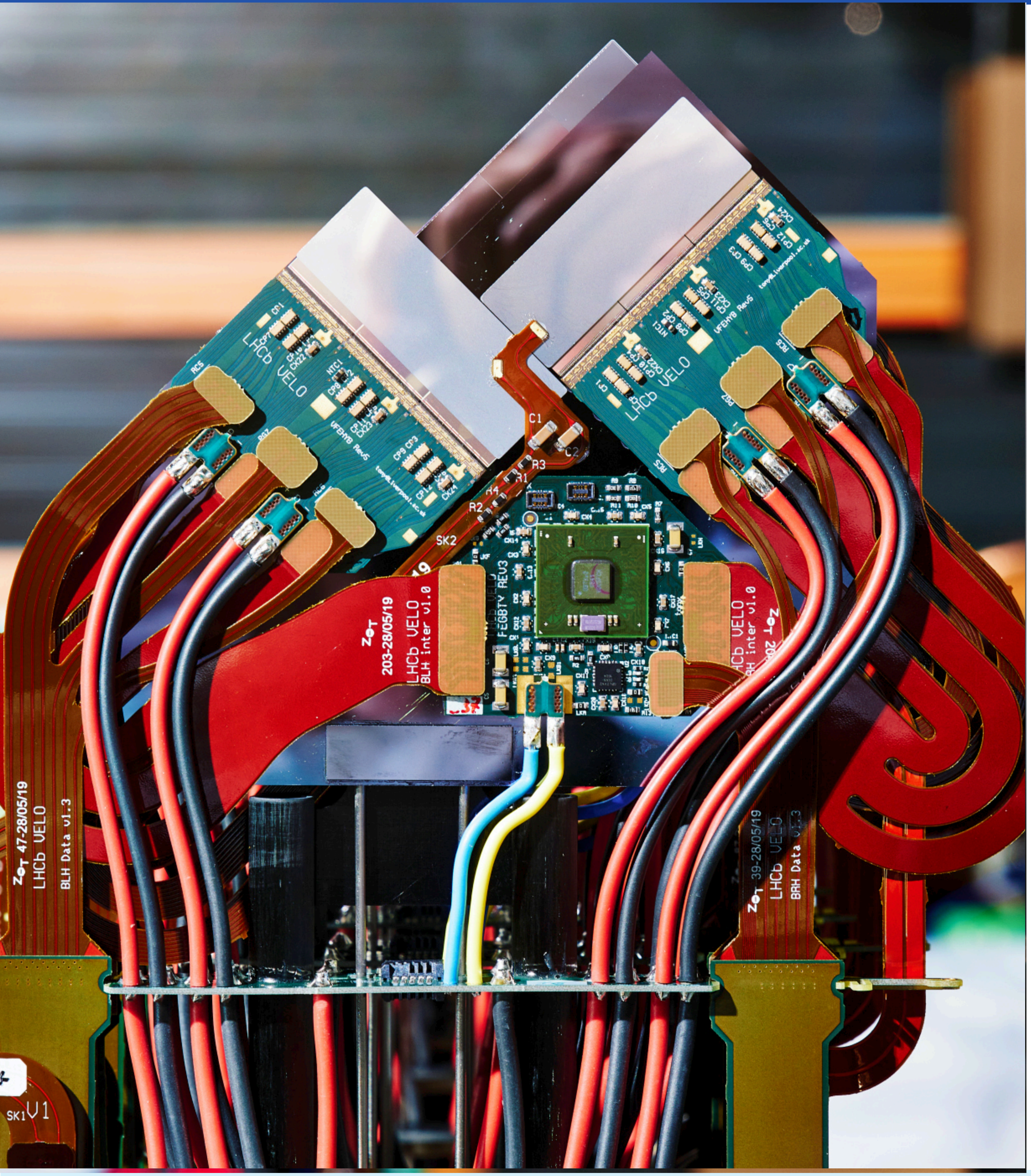
Front view Back view

Figure 7: Front and rear side of a module containing two 3 × 1 tiles on either side

Pixel sensors

- Each module has 4 sensors
- Each sensor is bump-bonded to three VeloPix ASICs —> this is a tile
- Four tiles form an “L” shape, two sensors on each side of the module

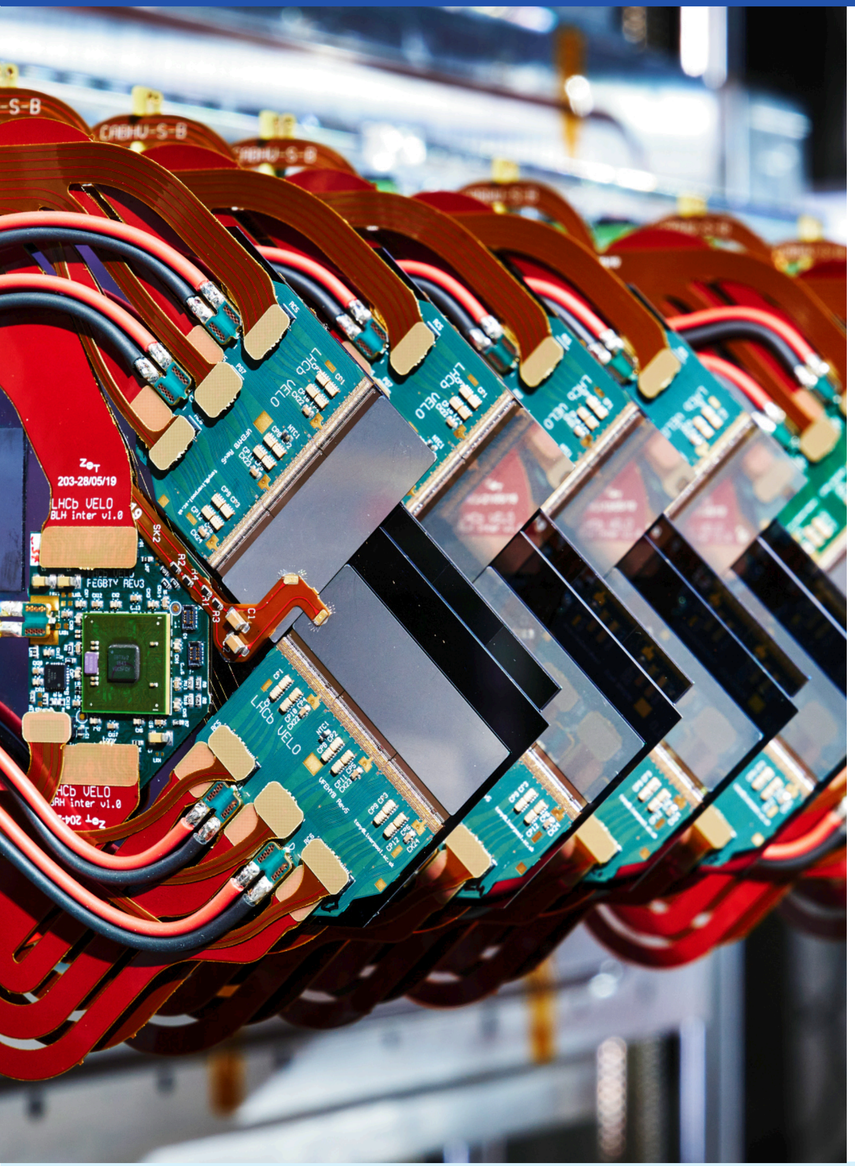
VELO Module



Pixel sensors

- New VeloPix ASIC for readout
- 55 µm x 55 µm pixels
- High granularity —> good position resolution

Impact parameter resolution



Detector quantities to improve the IP resolution

$$\sigma_{\mathrm{IP}}^2 = \frac{r_1^2}{{p_{\mathrm{T}}}^2}\left(0.0136\ \mathrm{GeV}/c\ \sqrt{\frac{x}{X_0}}\left(1+0.038\ \ln\left(\frac{x}{X_0}\right)\right)\right)^2 + \frac{\Delta_{02}^2\sigma_1^2+\Delta_{01}^2\sigma_2^2}{\Delta_{12}^2}$$

- Position resolution
- Material budget
- Distance of interaction point and first measured point

Impact parameter resolution

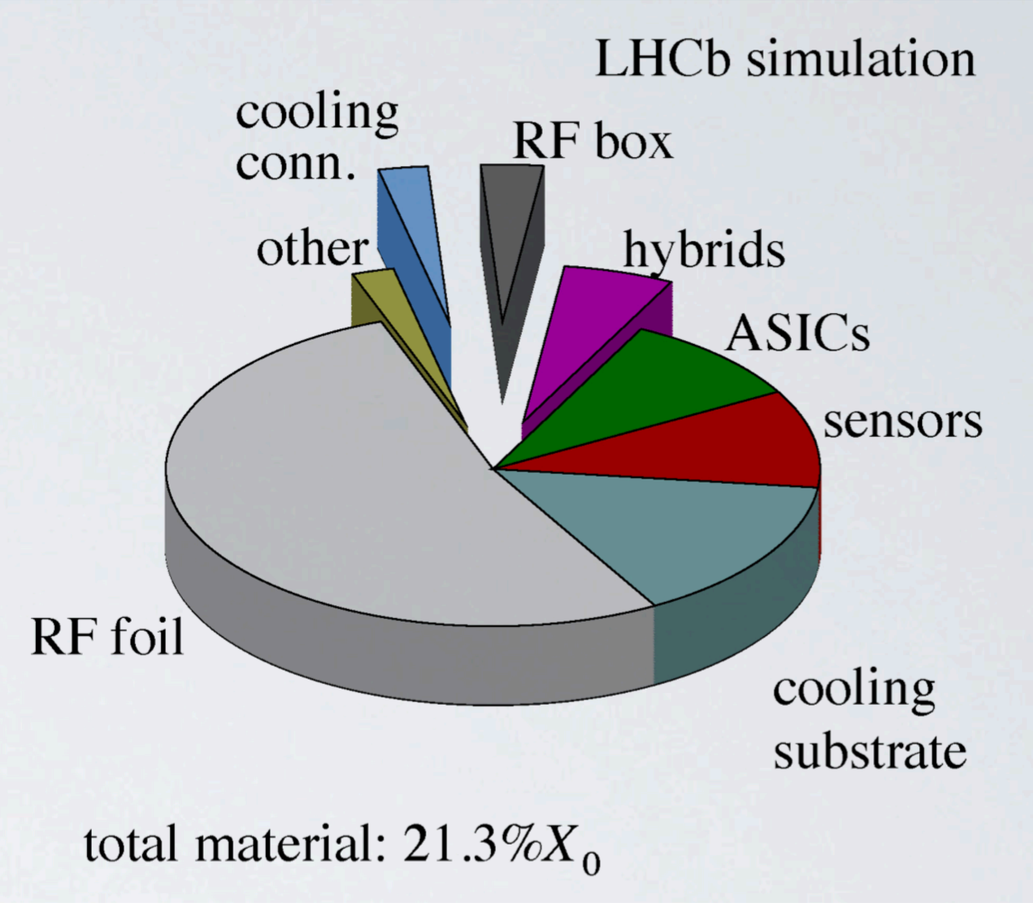


Figure 8: breakdown of the total material of the VELO upgrade by component. The largest contribution comes from the RF foil [7].

Material budget

- To reduce multiple scattering
- Biggest contribution is the RF foil

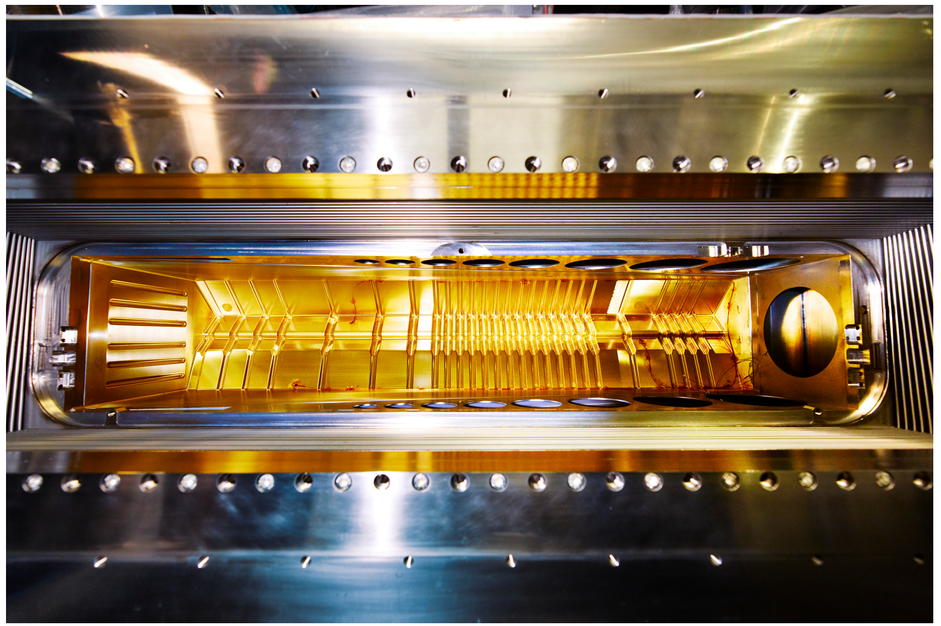


Figure 9: Picture of the RF foil [2]

Impact parameter resolution

First measurement point

- Improving IP resolution —> first detection point as close as possible to the interaction point
- 5 mm from beam pipe
- Movement mechanism —> two retractable halves

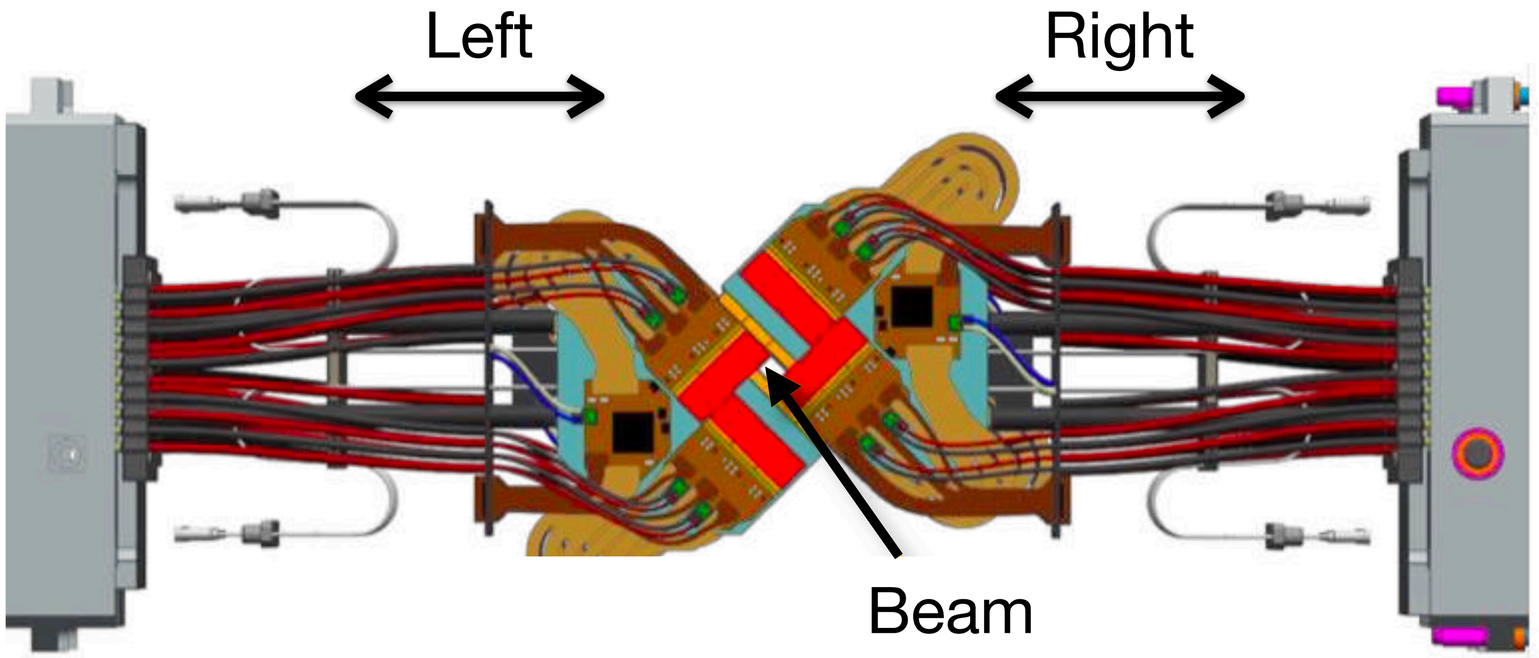
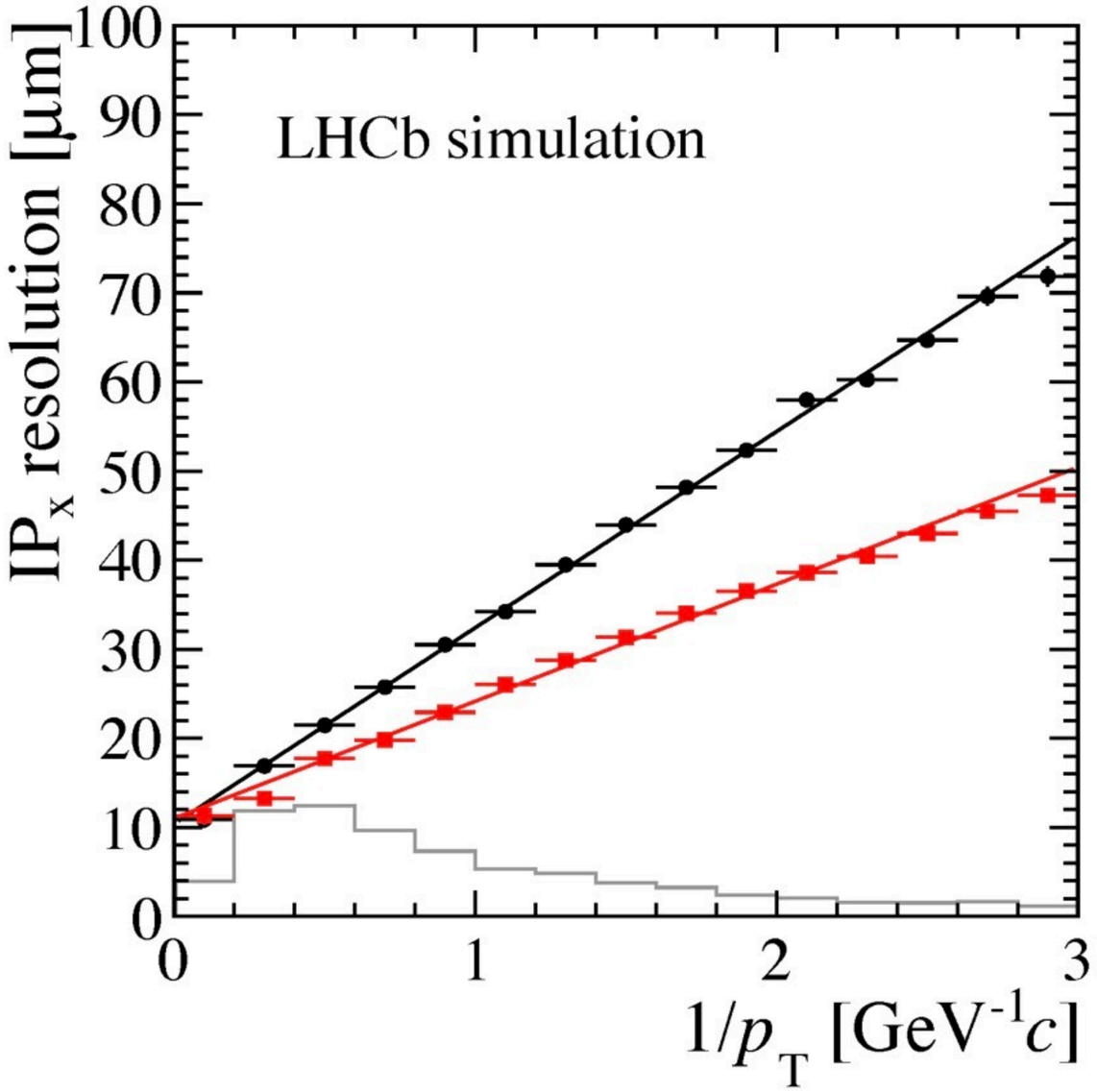


Figure 10: Two retractable halves of the VELO [7].

Impact parameter resolution



Results

- IP resolution of VELO (black) versus the VELO upgrade (red)

Figure 11: The x resolution of the IP. The current VELO is shown with black circles and the upgrade VELO with red squares, $\sqrt{s}$ = 14 TeV. The resolutions in x and y are similar. Grey histogram shows the relative population of b-hadron daughter tracks in each $1/p_T$ bin [3].

Performance

Primary vertex location

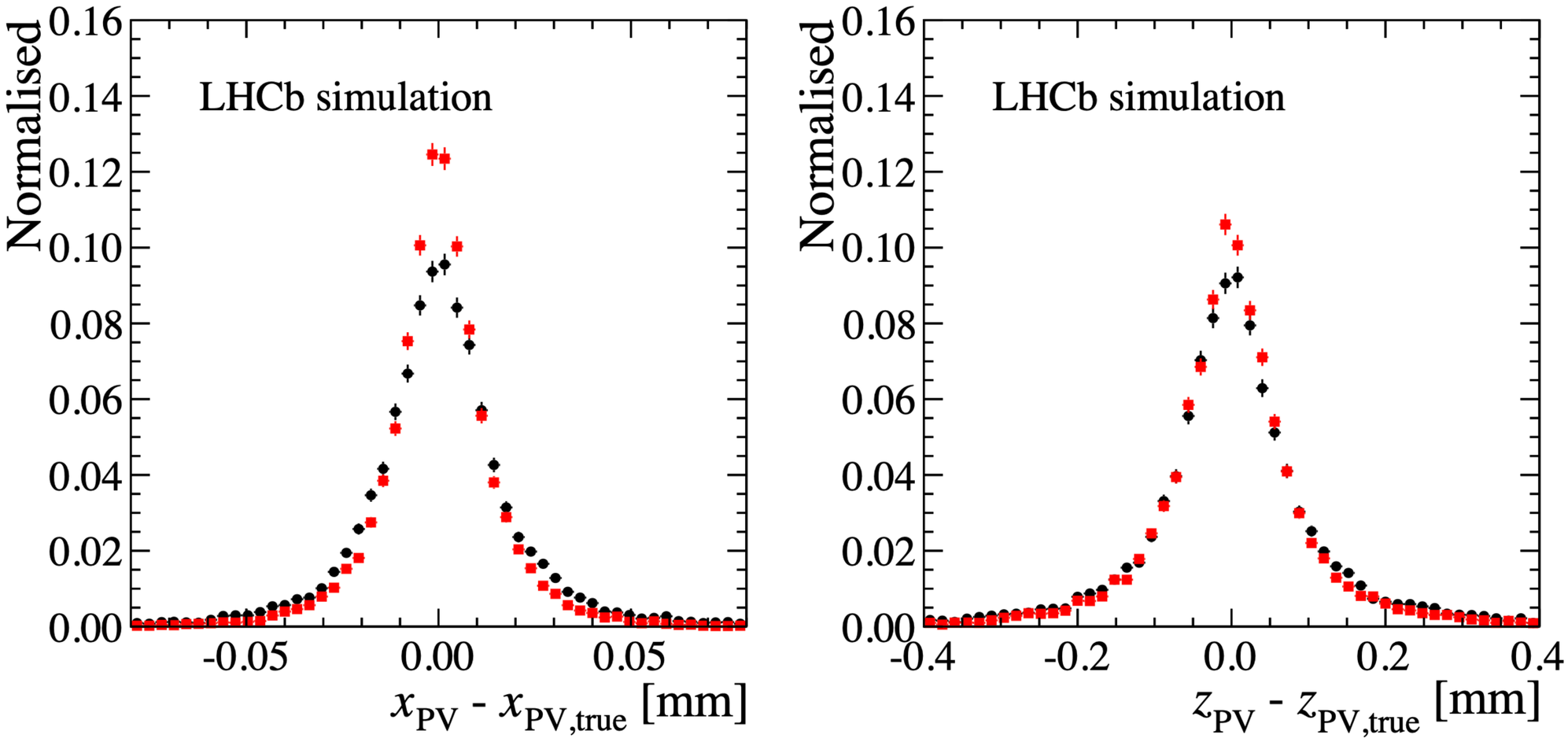
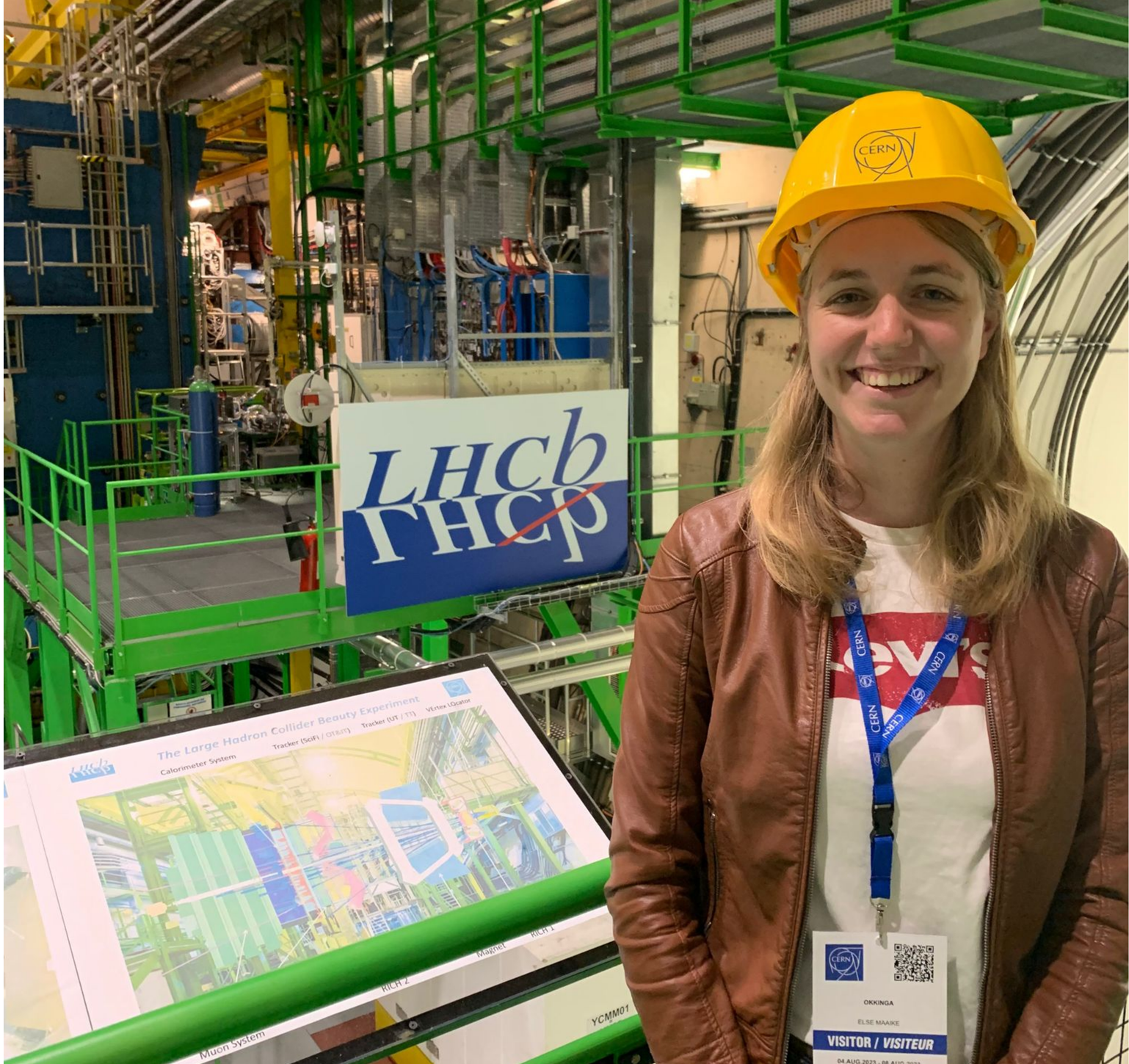


Figure 12: The difference between the true and reconstructed PV position in x and z is shown. The current VELO is shown with black circles and the upgrade VELO with red squares. The resolutions in x and y are similar [3].

Thank you!


LHCb
The Large Hadron Collider Beauty Experiment
Calorimeter System
Tracker (SciFi / OT&IT)
Tracker (UT / TT)
Vertex Locator
Muon System
Magnet
RICH 2
RICH 1
YCMM01
CERN
OKKINGA
ELSE MAAIKE
VISITOR / VISITEUR

References

- CERN photos:
  - [1] LHCb Upgrade 2018
    Beam test North Area in Prévessin (bldg 887) [online]: https://cds.cern.ch/record/2644707
  - [2] LHCb VELO in the clean room [online]: https://cds.cern.ch/record/2801027
- [3] TDR
- [4] LHCb prepares for a RICH harvest of rare beauty, *CERNCOURIER* [online]: https://cerncourier.com/a/lhcb-prepares-for-a-rich-harvest-of-rare-beauty/
- [5] New approaches for track reconstruction in LHCb's Vertex Locator - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Sketch-of-B-meson-coming-from-the-primary-vertex-PV-and-decaying-inside-the-LHCb-Vertex_fig2_335860361 [accessed 22 Mar, 2024]
- [6] The LHCb VELO detector: design, operation and first results, Efrén Rodríguez Rodríguez on behalf of the LHCb VELO group, 2023
- [7] The LHCb VELO Upgrade, Stefano de Capua on behalf of the LHCb VELO group, 2018 [online]: https://cds.cern.ch/record/2630580/files/decapua_VELOupgrade 07.07.pdf