ITk 2nd-layer timing information for 4D-Tracking/Trigger

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Self-Introduction

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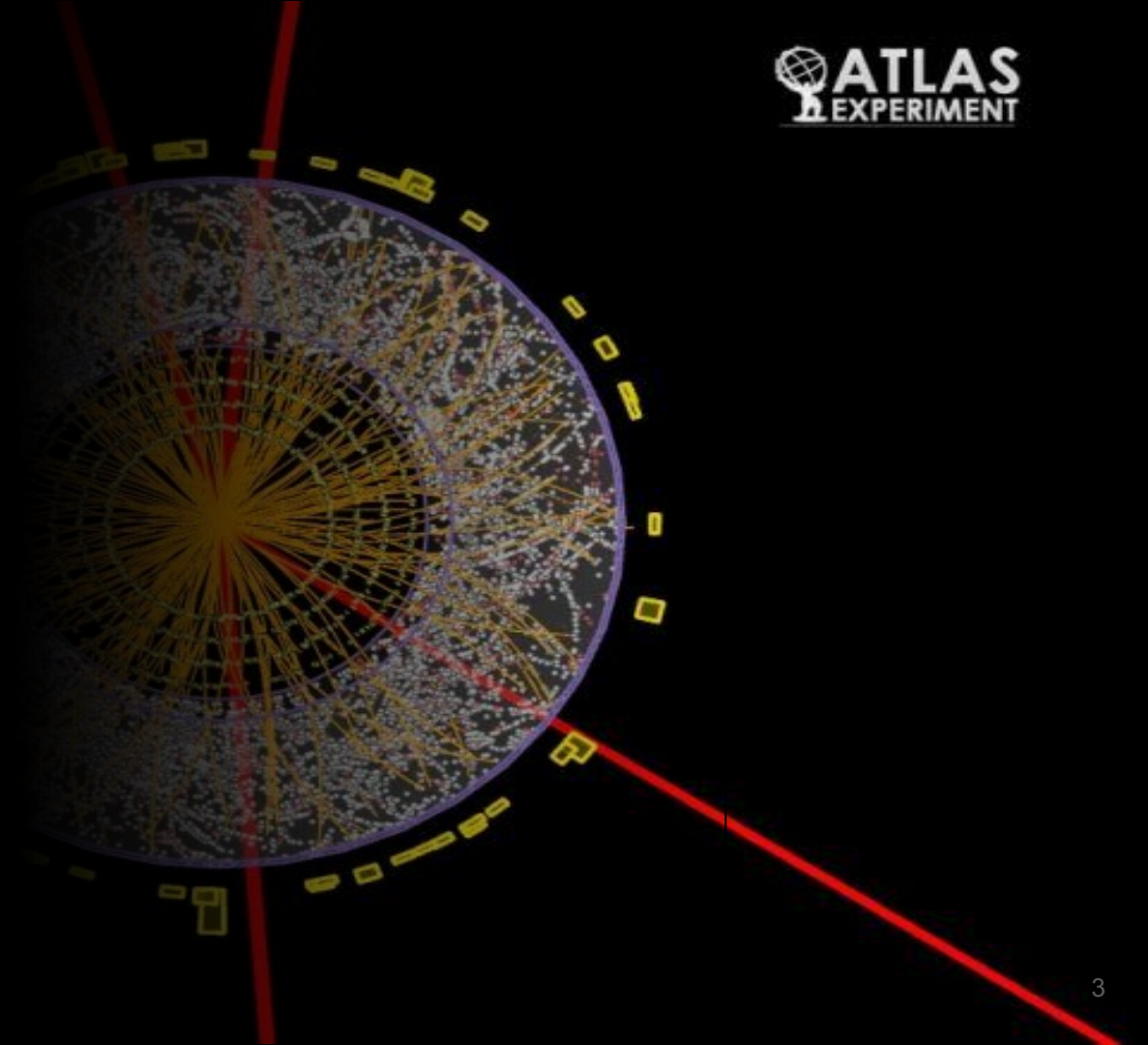
Introduction

High-Luminosity LHC



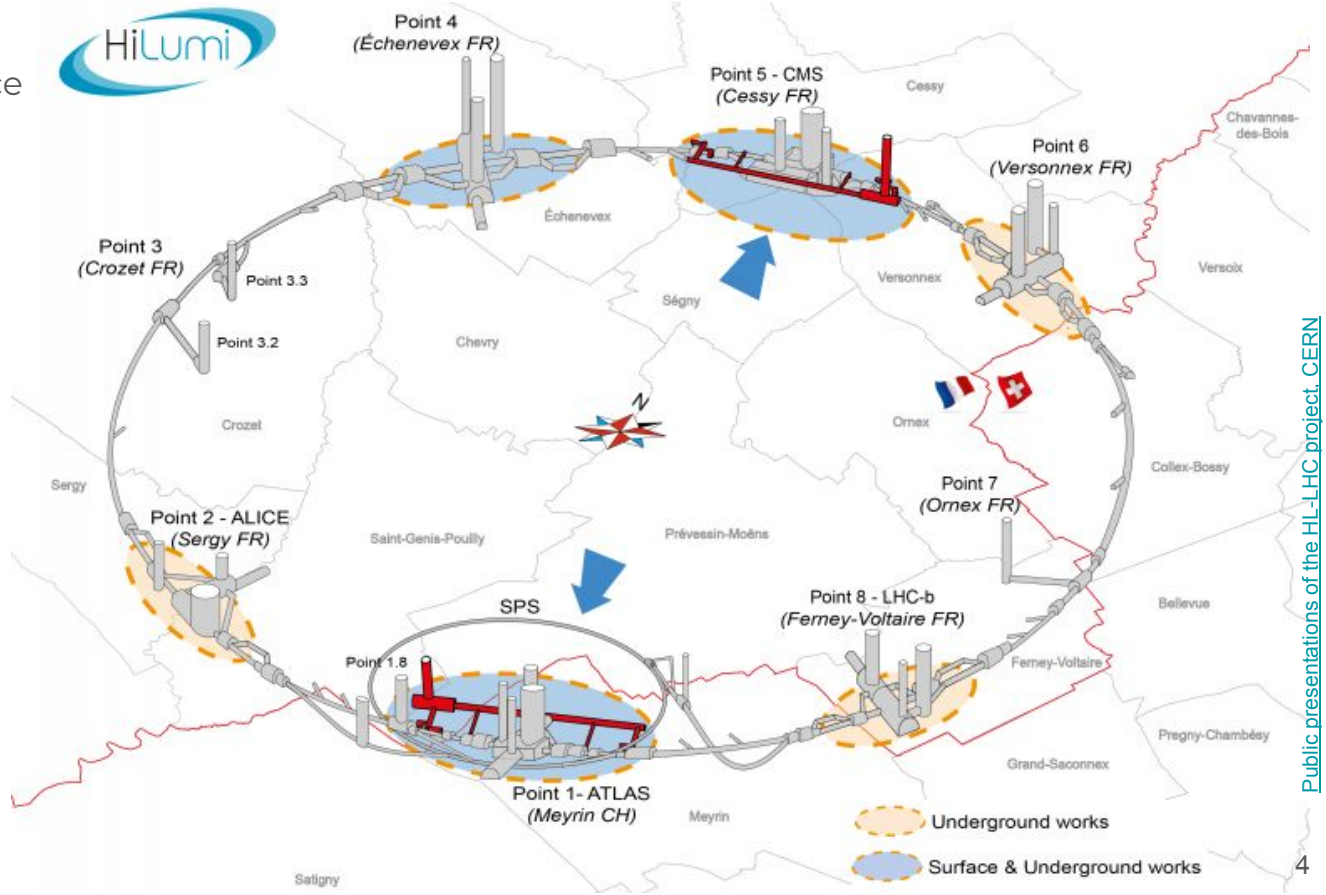
High Luminosity - Large Hadron Collider

Instantaneous luminosity : Number of collisions per surface unit over a given period.

HL-LHC : Scheduled to start in June 2030, with instantaneous luminosity of 5-7.5·10^{34} $cm^{-2}s^{-1}$ (current is 2·10^{34} $cm^{-2}s^{-1}$)

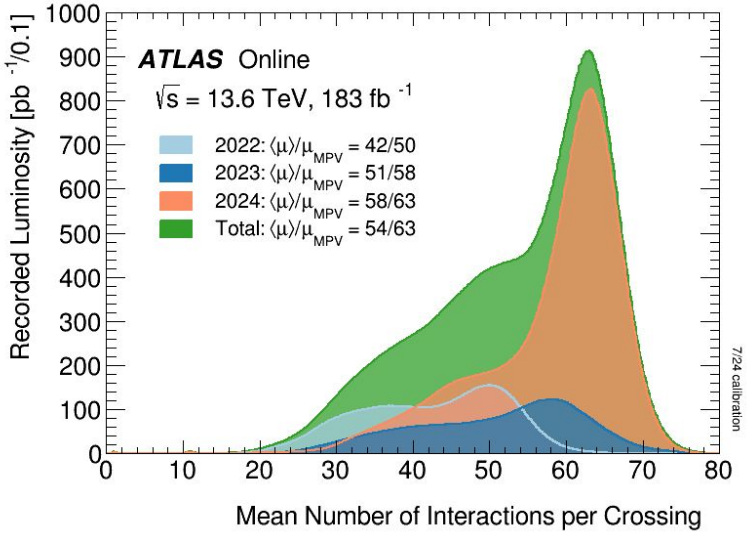
HL-LHC : will produce at least 15 million Higgs bosons per year compared to 3 millions in 2017.

Goal : record about 3000-4000 fb^{-1} until 2040 (more than 10 times the Run 3 integrated luminosity)

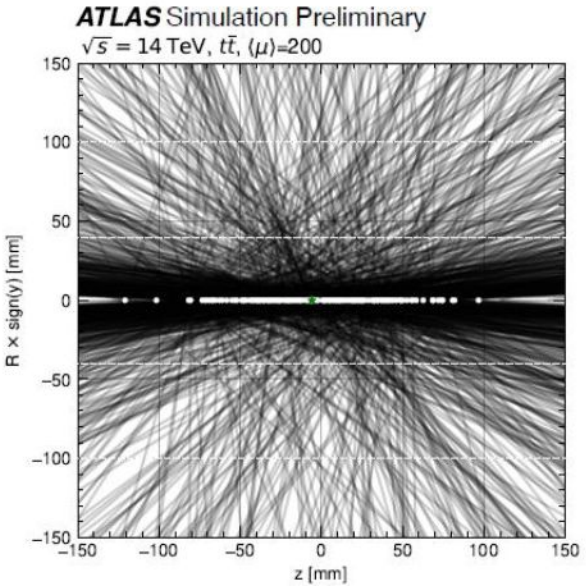


Challenges for the HL-LHC

Pile-up : More than one near-simultaneous collision happening at each beam-crossing. The **most energetic** collision is called **main vertex**, the secondary vertices are called **pile-up** events.



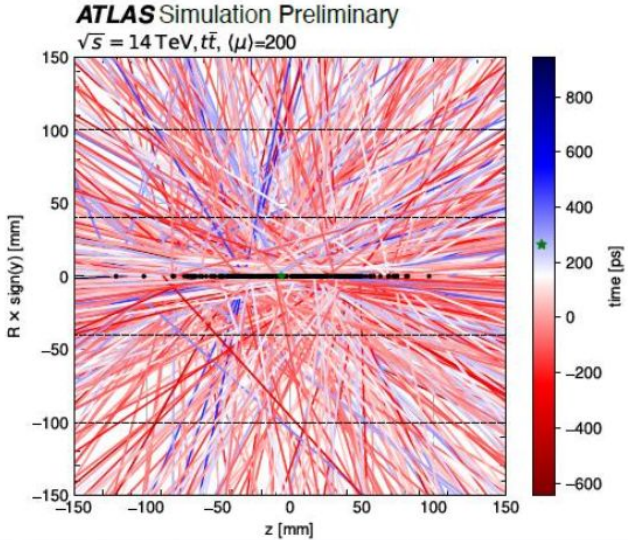
Higher luminosity : Additional proton-proton interactions (more secondary vertices)
From ~63 in Run 3 up to 150-200 at HL-LHC

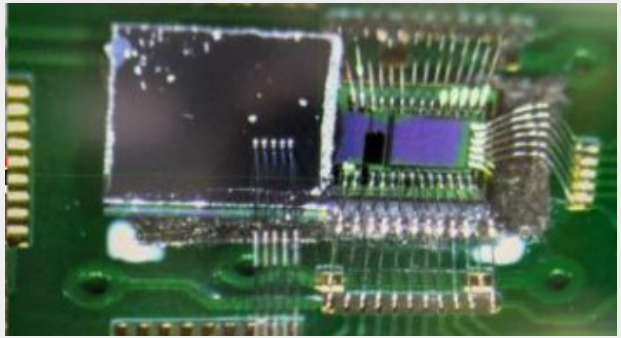


LGAD Timing-measurement

Idea : Implementing timing on the 2nd layer of the inner detector.
Goal : Time resolution down to 30ps
(1 cm at light speed)

Timing information is used to reduce the number of points considered for track-reconstruction

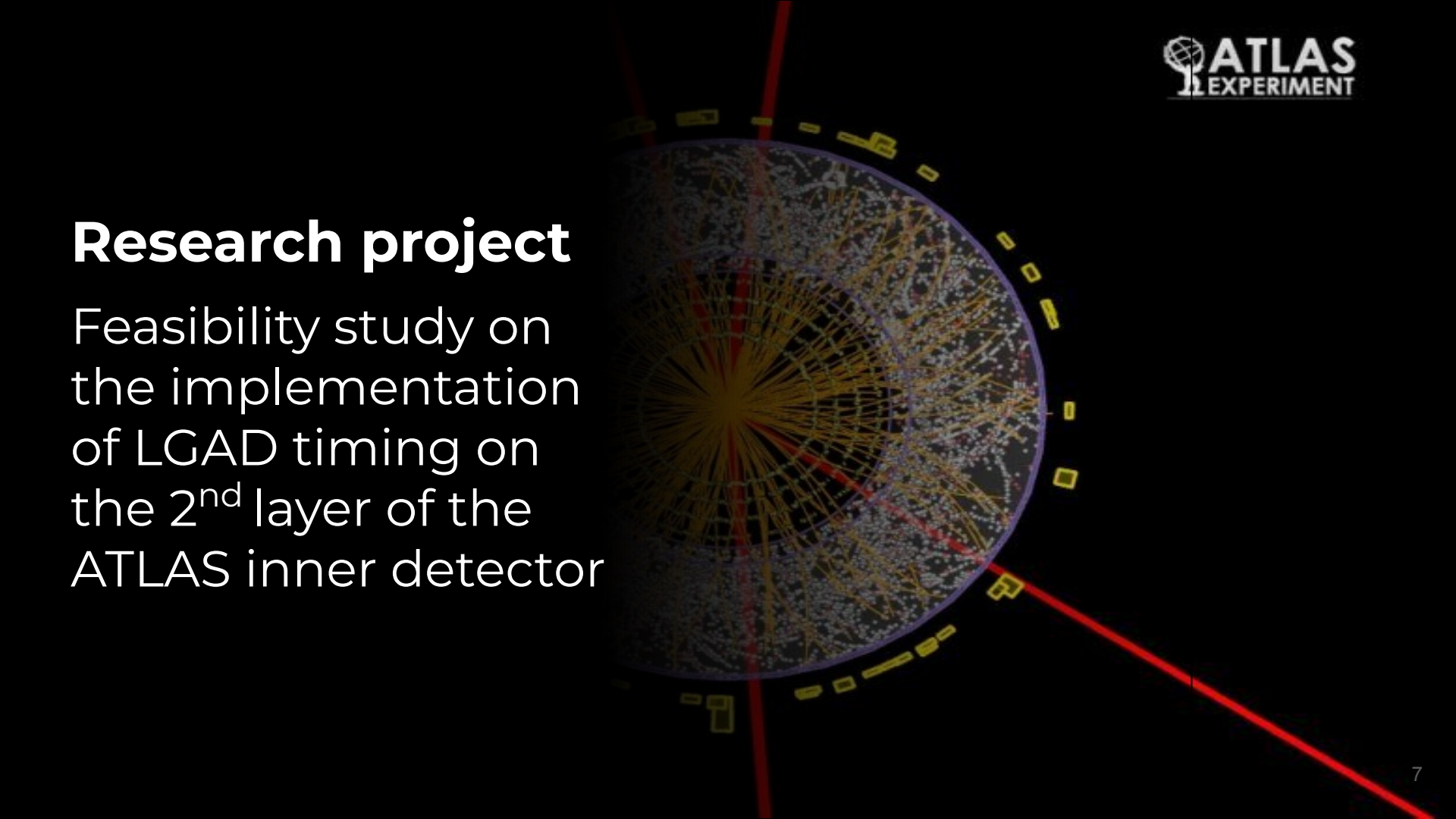




Flip-Chipped LGAD sensor

LGAD : Low-Gain Avalanche Detector

Prototypes under development in the ATLAS clean rooms in the N-Hall with timing resolution down to 20 ps possible for very thin sensors



Research project

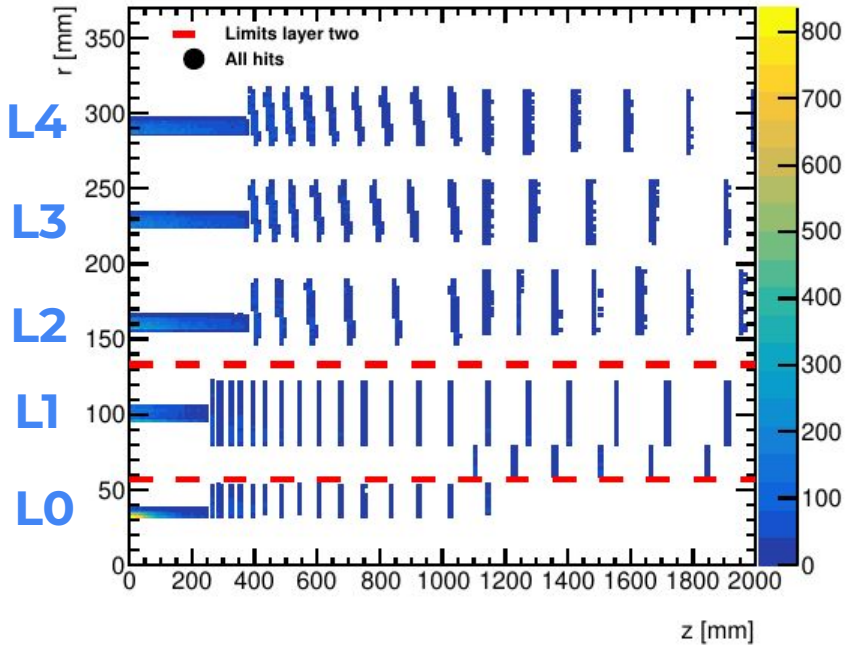
Feasibility study on the implementation of LGAD timing on the 2nd layer of the ATLAS inner detector

Feasibility study on the implementation of LGAD timing on the 2nd layer of the ATLAS inner detector

Concretely : Numerical simulation an HL-event with a main vertex producing a **single muon** and **150 pile-up** vertices producing pions.

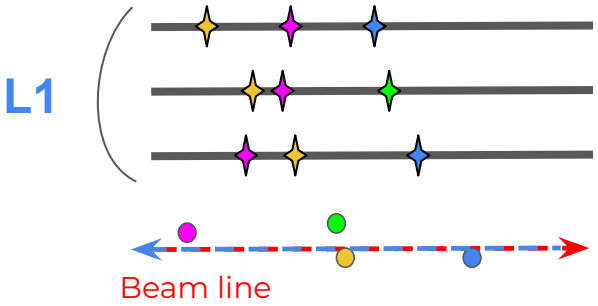
Goal : Reconstruct particles tracks in the inner detector and their origin vertices using 4D-tracking (x, y, z, **t**)

New information !



Reconstructing tracks

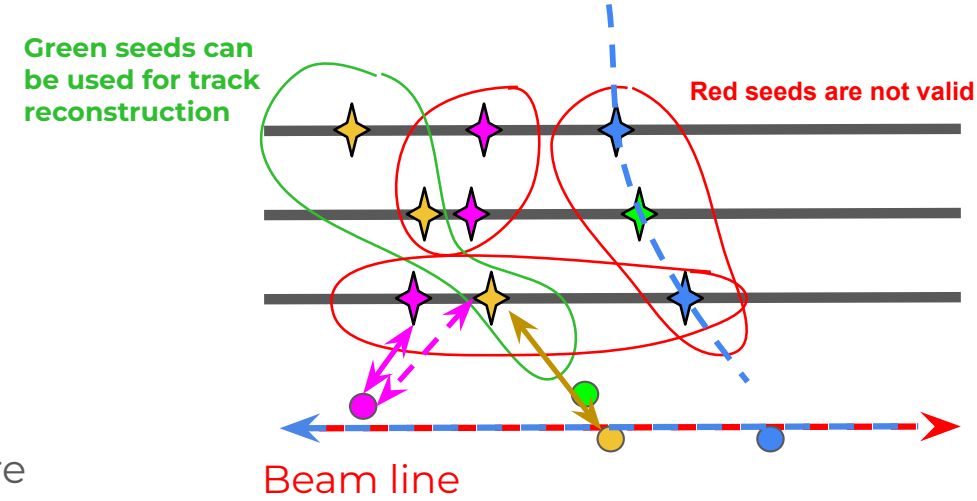
Simplified model : toy hits on L1 layer (with timing measurement) with particles coming from 4 different vertices



- Vertex 1 : t1
- Vertex 2 : t2
- Vertex 3 : t3
- Vertex 1 : t1

The vertices are not simultaneous !

Seeding algorithm : approximating local curvature of the trajectory of a particle by taking a **triple of three hits (seed)** in the inner detector



The only **valid seeds** are those with three hits coming from the same vertex.

Correlation study

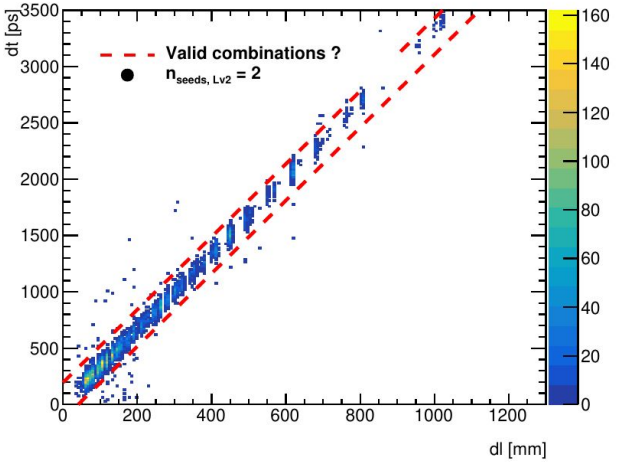
We take only seeds (a_i, b_i, c_i) with at least **two hits on the second layer**, meaning 4D-position in space : $a_i = (x_i, y_i, z_i, t_i)$ and $c_i = (x'_i, y'_i, z'_i, t'_i)$.
For these two seeds we compute the following :

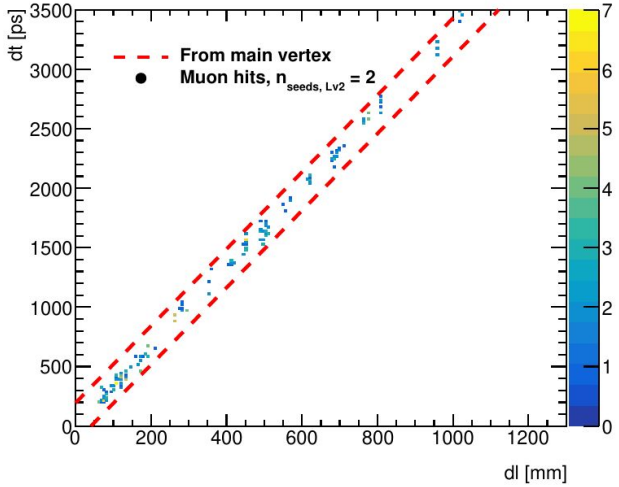
$$dl = \sqrt{(x_a - x_c)^2 + (y_a - y_c)^2 + (z_a - z_c)^2}$$

and $\quad dt = |t_a - t_c|$

We expect to get a proportional relationship between the distance *dl* [mm] between the hits a_i-c_i, and the time interval *dt* [ps] between these hits.

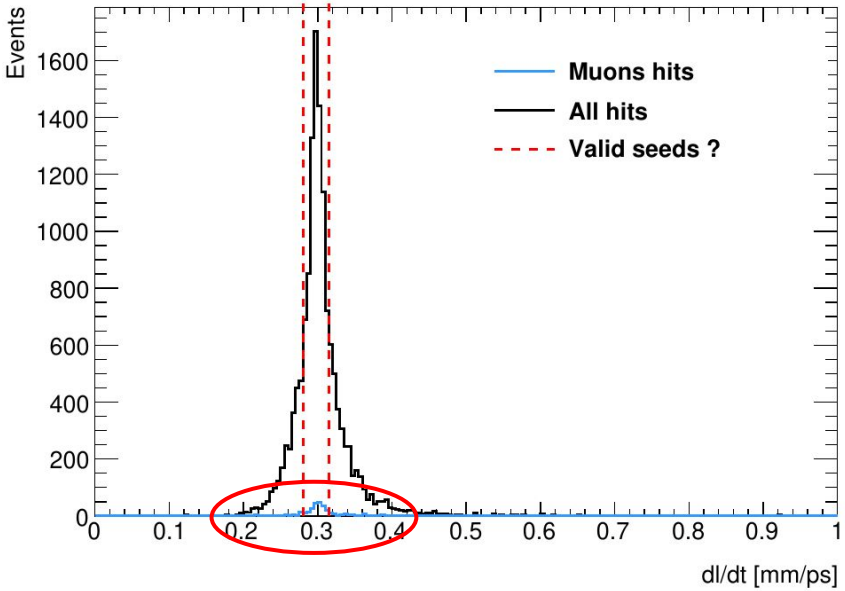
We try to exclude all **wrong combinations** by **removing outliers**.





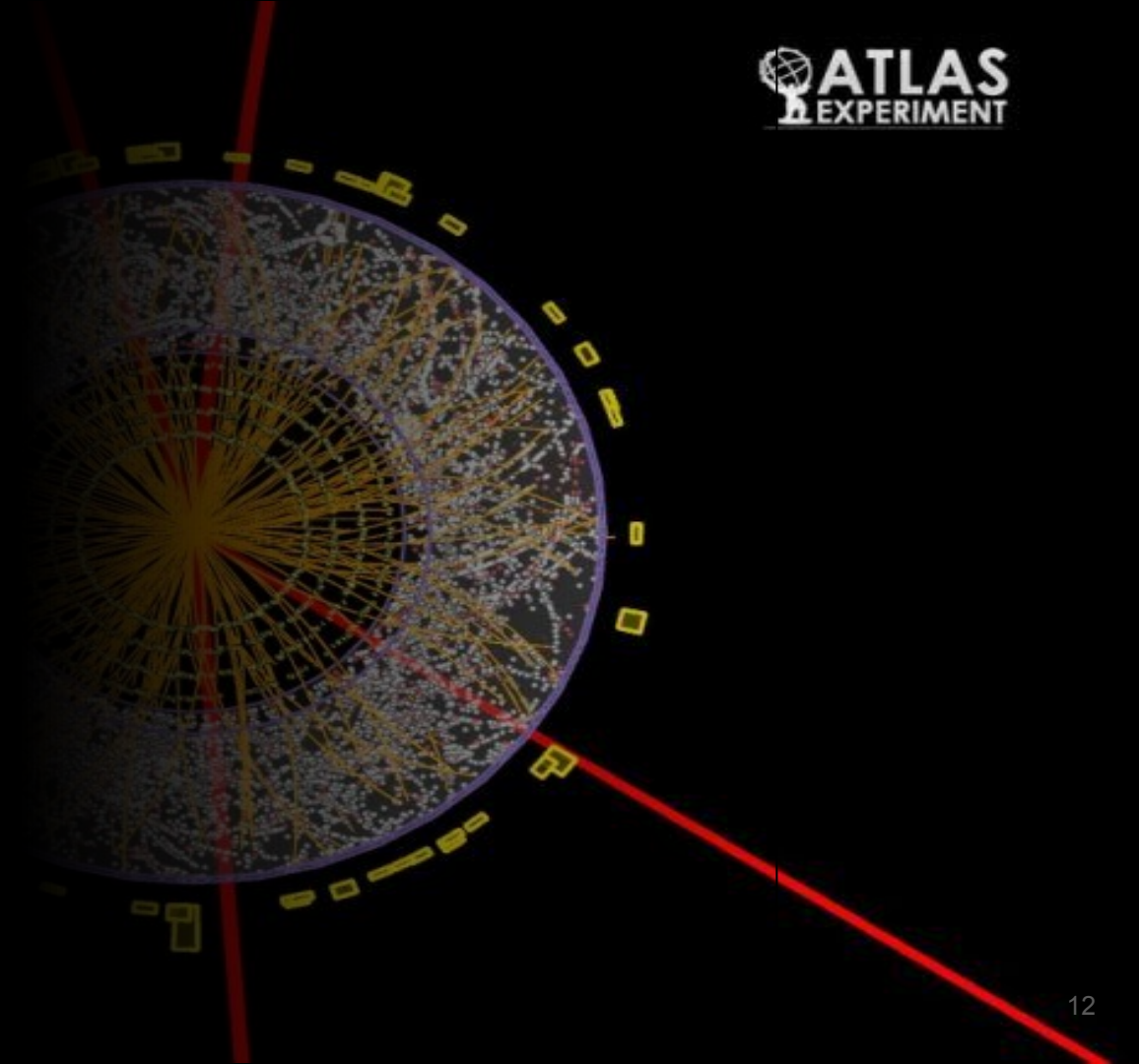
Conclusion

- With this procedure, we managed to **reduce the number of seeds** used for track reconstruction by ~38.7 %
- **Tracking** : The same procedure with timing will be used to remove tracks with **wrong combinations** of hits.



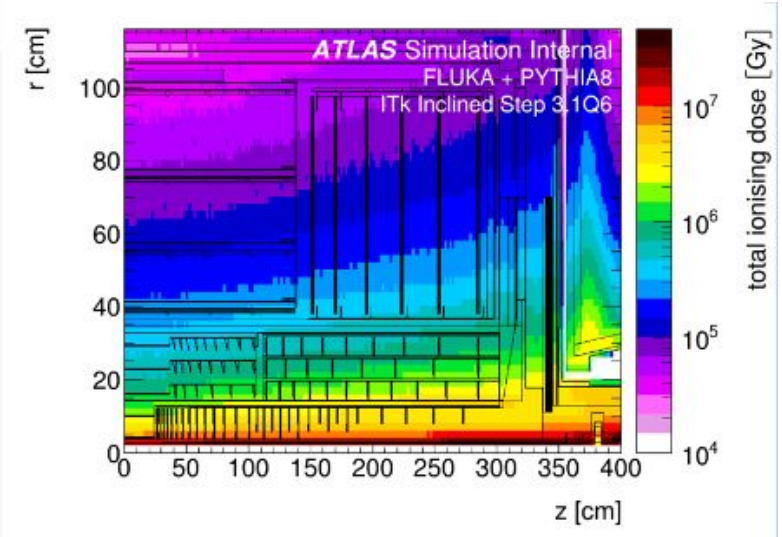
Thank you for your attention !

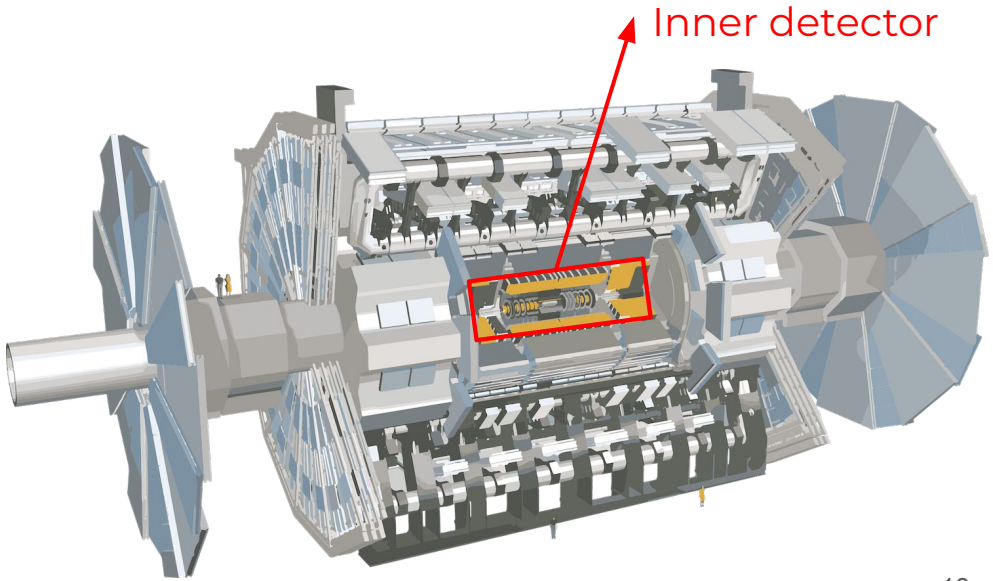
Additional materials



Challenges for the HL-LHC

Increase in radiation : motivation for the ATLAS inner tracker (ITk) upgrade. Implementing better forward coverage for particles with trajectory closer to the beam line (higher η).

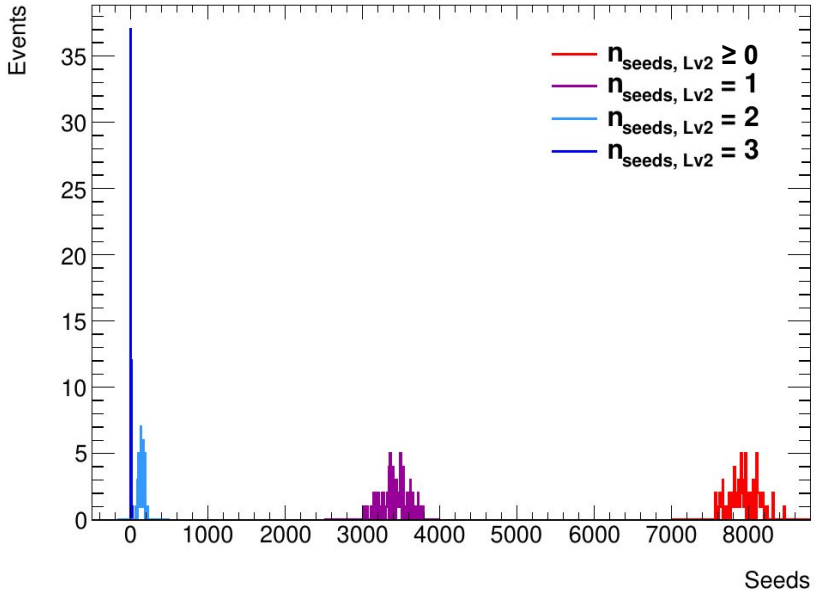


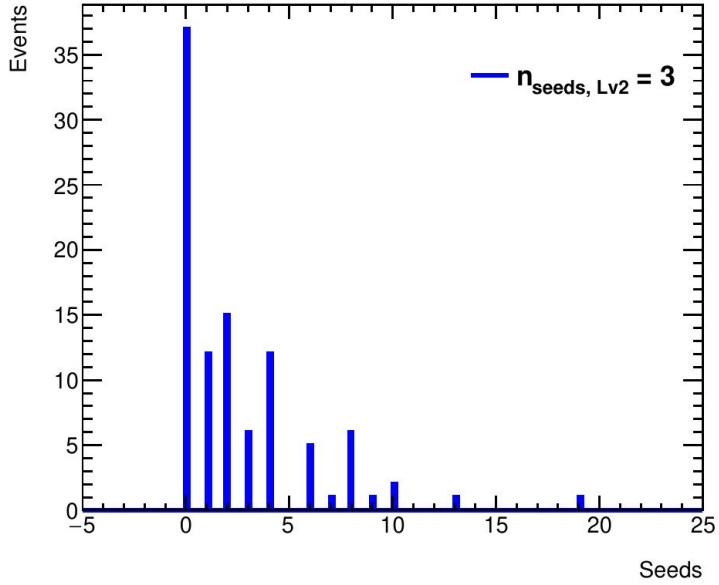


The ATLAS Detector

Seeds in the second layer

Distribution of the number of seeds for each event taking enforcing n = {1, 2, 3} seeds on the second layer





Seed pseudorapidity distribution

Comparing the pseudorapidity for different conditions on the number of seeds on the second layer