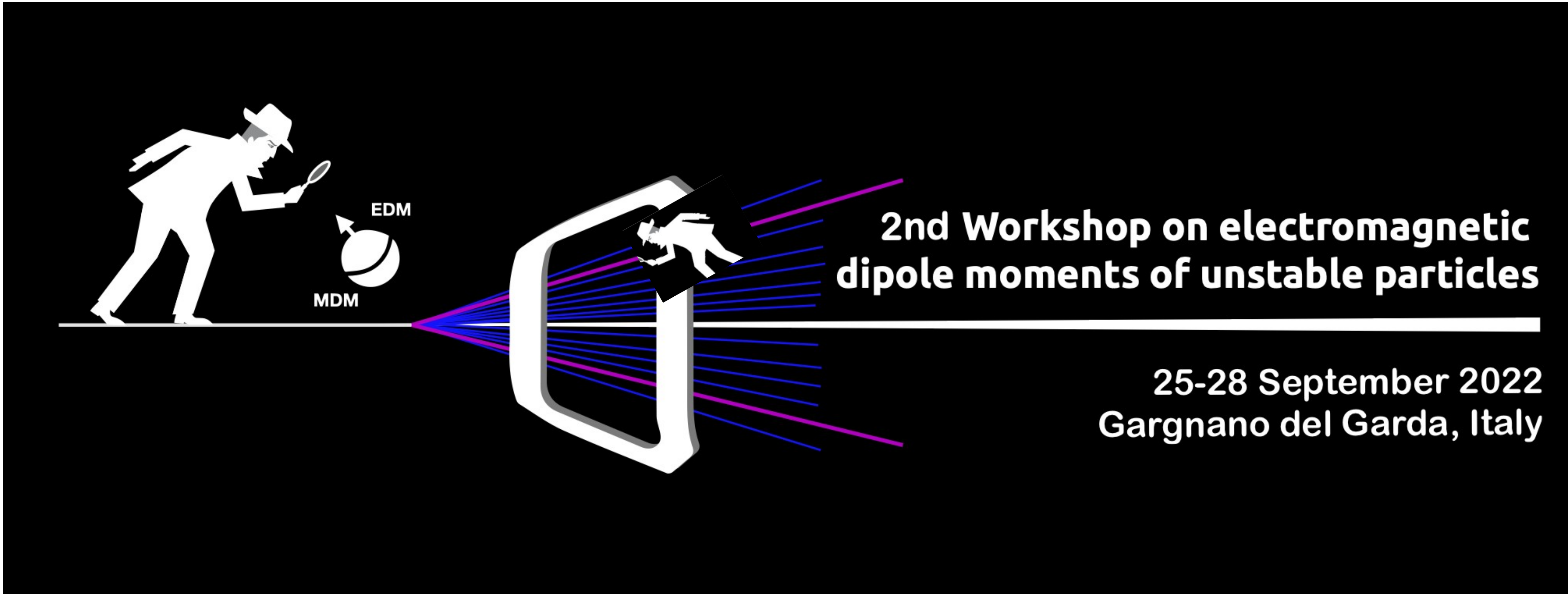
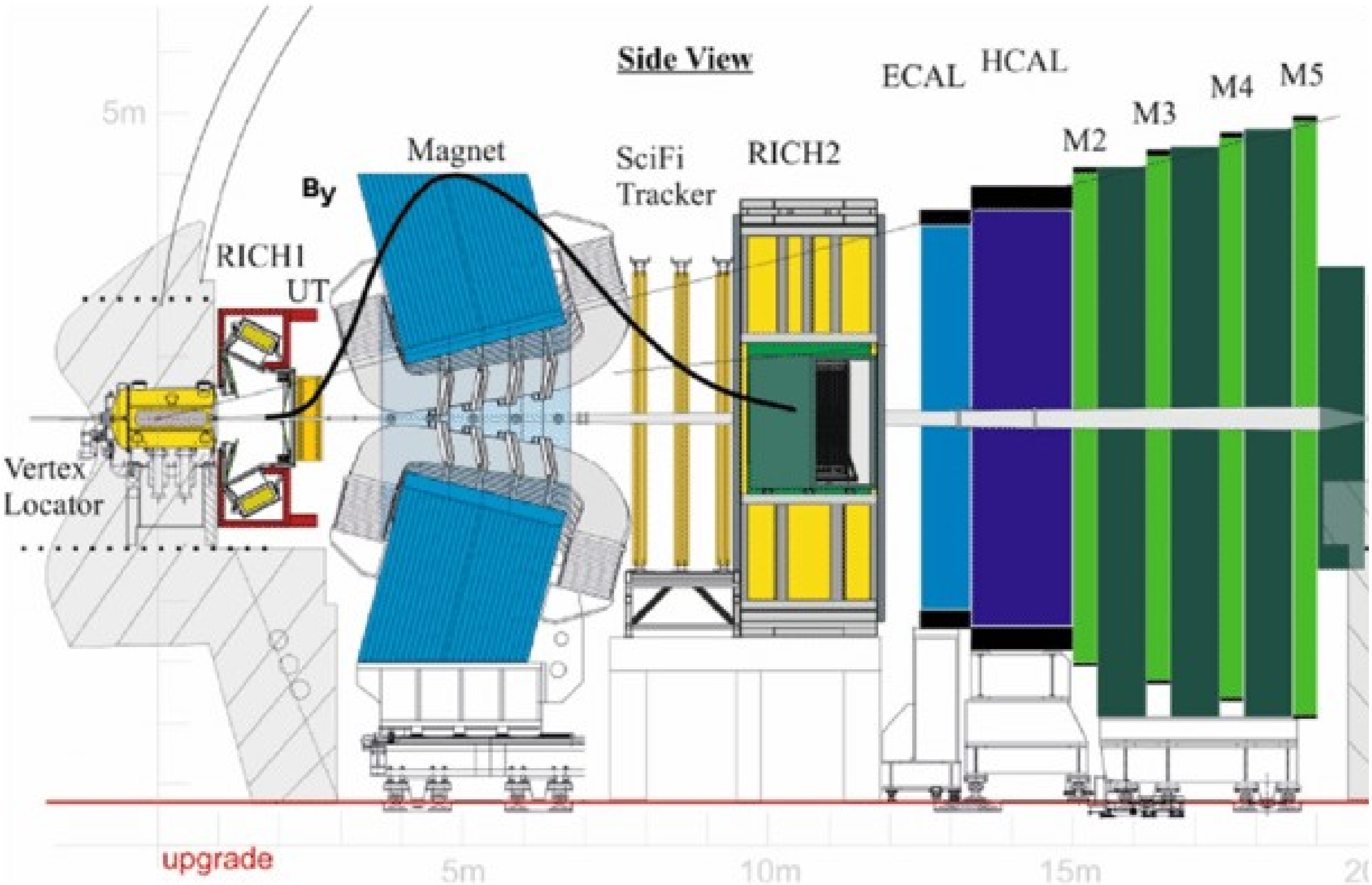


T track reconstruction

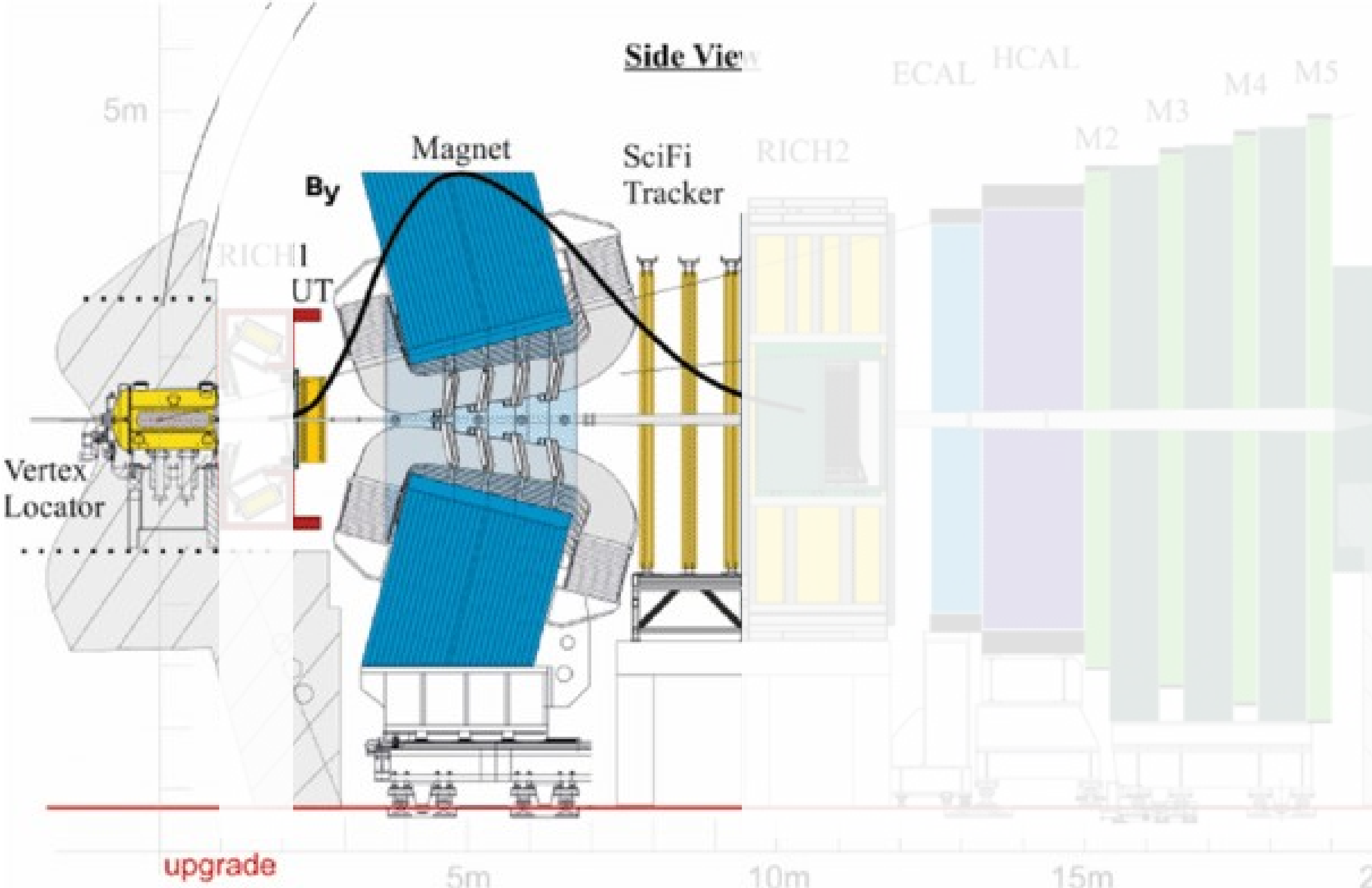
Among others: A. Hennequin, C. Agapopoulou, S. Aiola, L. Calefice, A. Oyanguren, B. Kishor Jashal, L. Pica, V. Svintozelskyi, L. Henry, R. Quagliani

Gardagno del Garda, 28/09/2022

Introduction: the LHCb detector

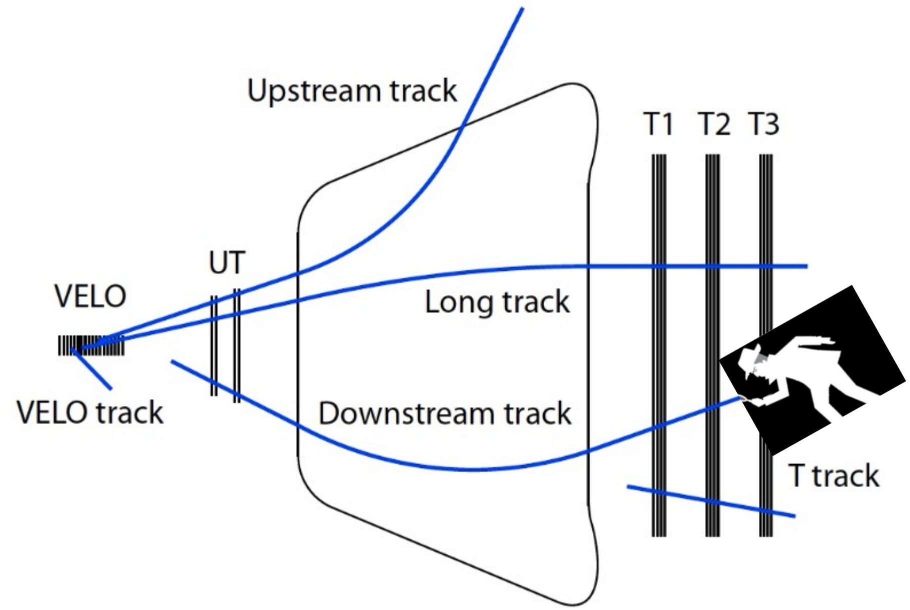


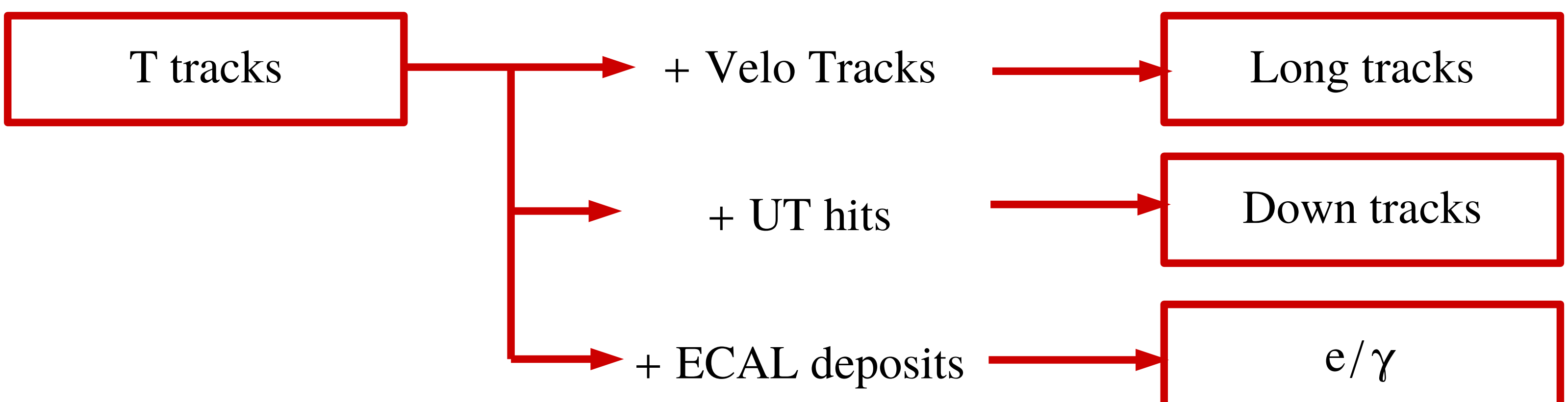
Introduction: the LHCb detector as a sequence of trackers



Introduction: the LHCb detector as a family of tracks

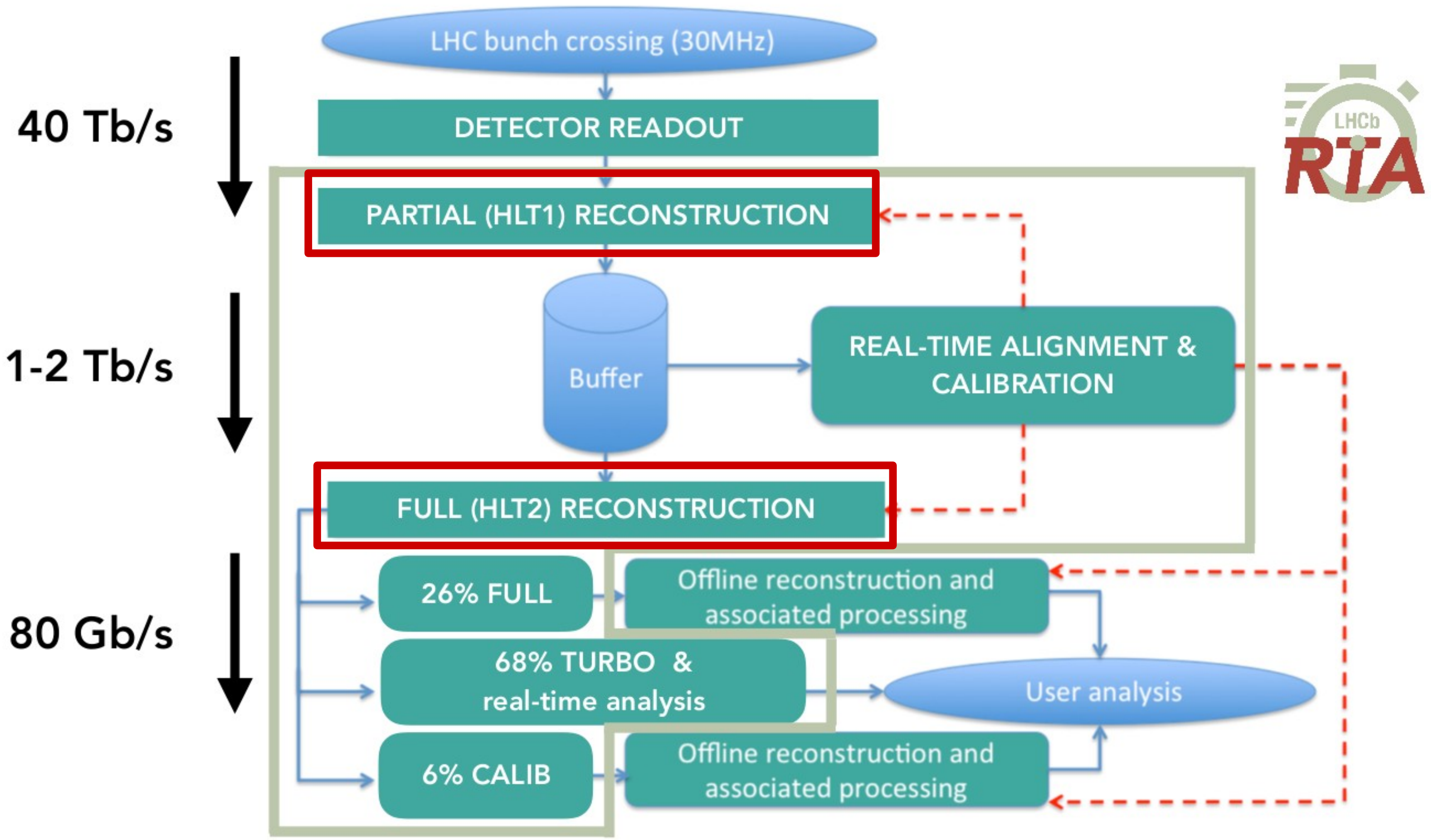
- VELO + SciFi (+UT): LONG.
  - Bread and butter for physics, best resolution.
- UT + SciFi: DOWN.
  - Useful if you are studying K_S and Λ. Do the same as LONG, just a bit worse.
- VELO: VELO.
  - Primary vertex determination
- VELO + UT : UPSTREAM.
  - Tend to be low-momentum ($p < 1$-1.5 GeV/c) tracks, deviated away by the magnet.
- **SciFi only: T-tracks:**
  - Secondaries, very-long-lived particles, unlucky K_S and Λ hadrons.





Introduction: LHCb as a succession of triggers

- Collision rate and event size are unmanageable without a fast selection = trigger.
- Strategy has changed quite a bit between Run 2 and Run 3, will focus here on Run 3.

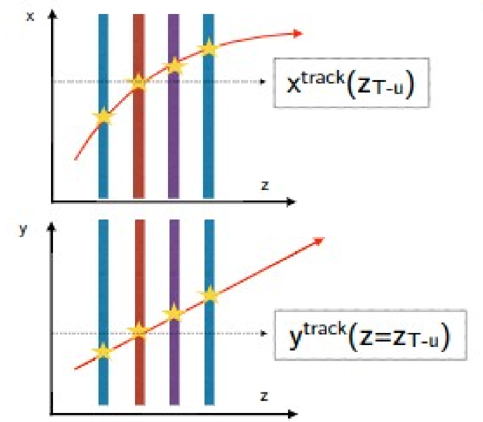


- Gist is:
  - HLT1: needs to be **fast**. Any decay with no dedicated reconstruction will **lose efficiency**.
  - HLT2: needs to be **complete**. Any decay with no full reconstruction will be **lost**.

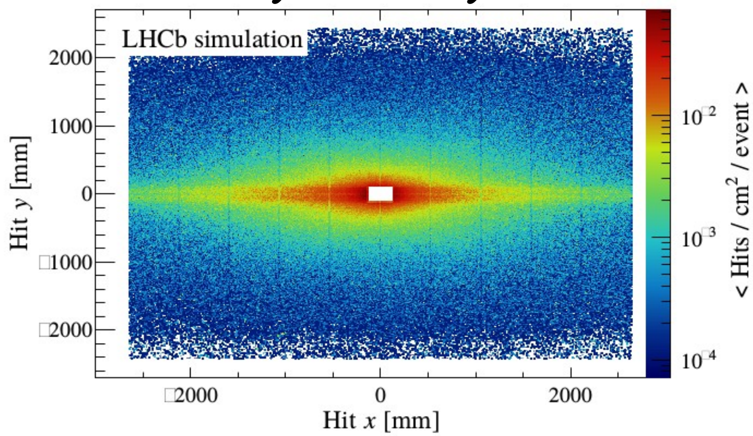
T track reconstruction at HLT2 level (Run 3)

Hybrid seeding: overall strategy

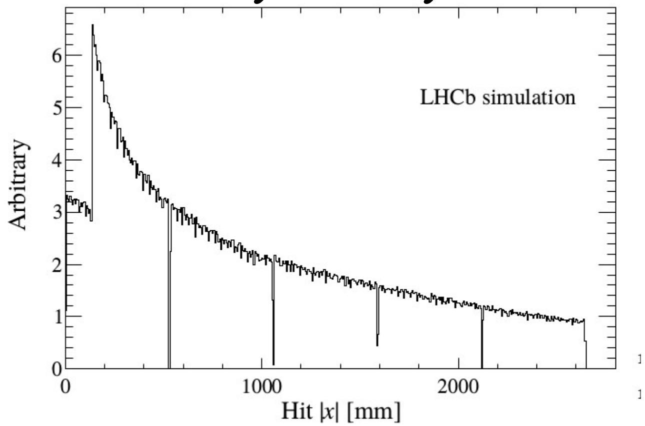
- SciFi: three stations arranged in a x-u-v-x geometry, u and v being layers titled by a +/- 5° stereo angle.
  - Easier to get x coordinate than y coordinate.
  - But ~only residual B_y field → simpler y trajectory (**line**).
- 2.5m long fibres → only give one coordinate, not two.



What you think you see



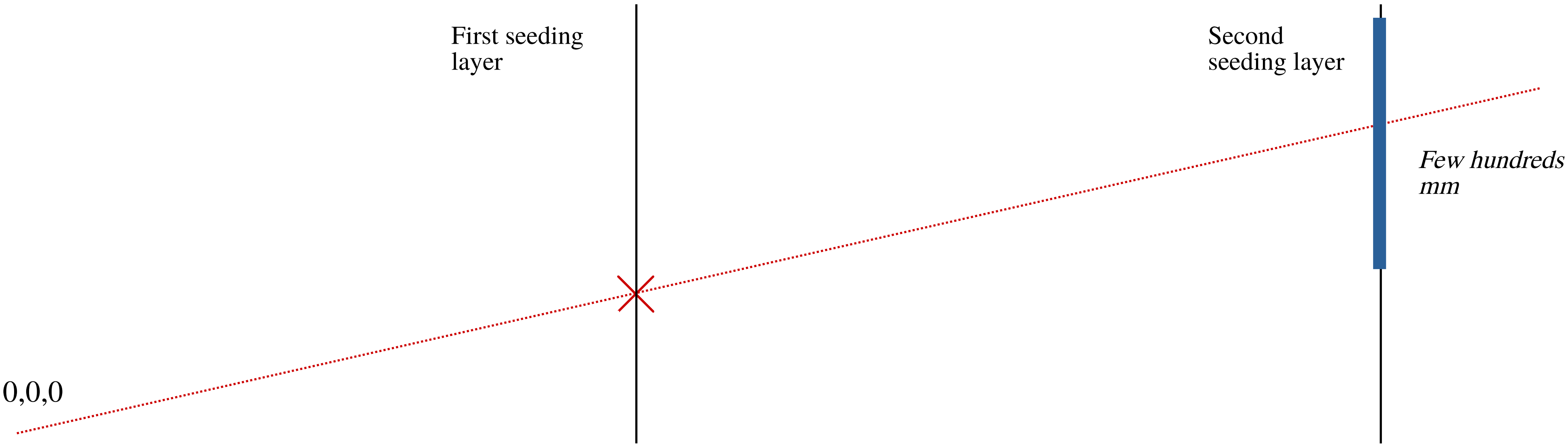
What you really see



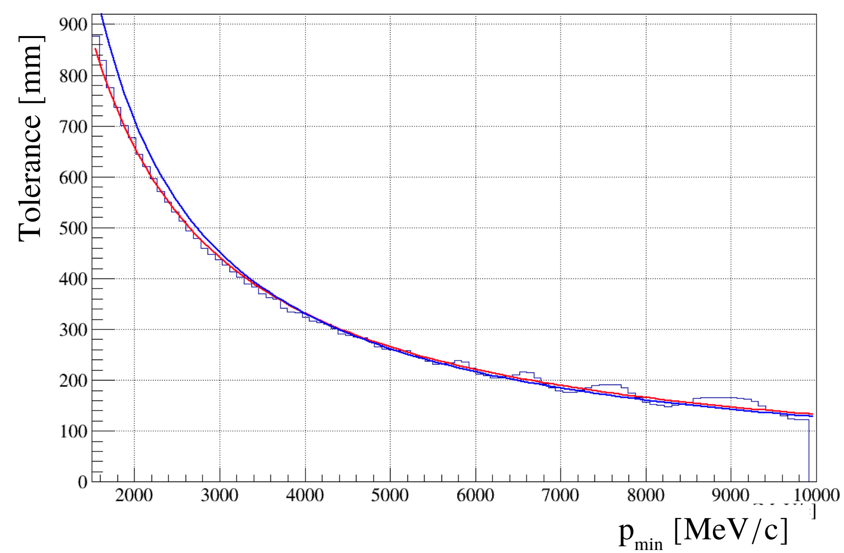
- Combinatorics too large to tackle all at once → **iterative strategy**: go for high-momentum first (~straight lines), cleanup the environment progressively.
- Each iteration starts with different pair of layers in T1 & T3.

Computer Physics Communications, 2020, 107713

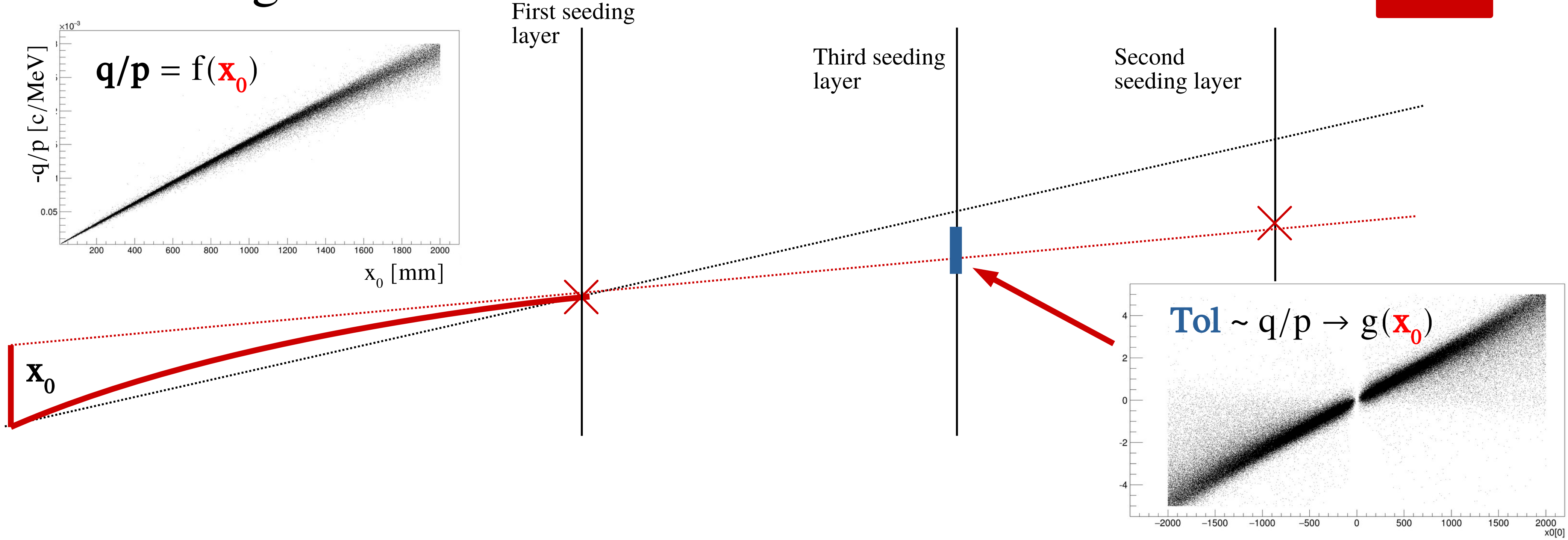
XZ tracking: one hit, one opportunity



- For all hits in the first layer, **draw a line from (0,0,0)**: this is the trajectory of an infinite momentum particle coming from the luminous region.
- But we are not looking for infinite momentum particles → **tolerance** around the projected position.
- Right: evolution of the tolerance needed as a function of the minimum momentum considered.
  - **Blue**: theoretical curve, **Red**: fit on MC.

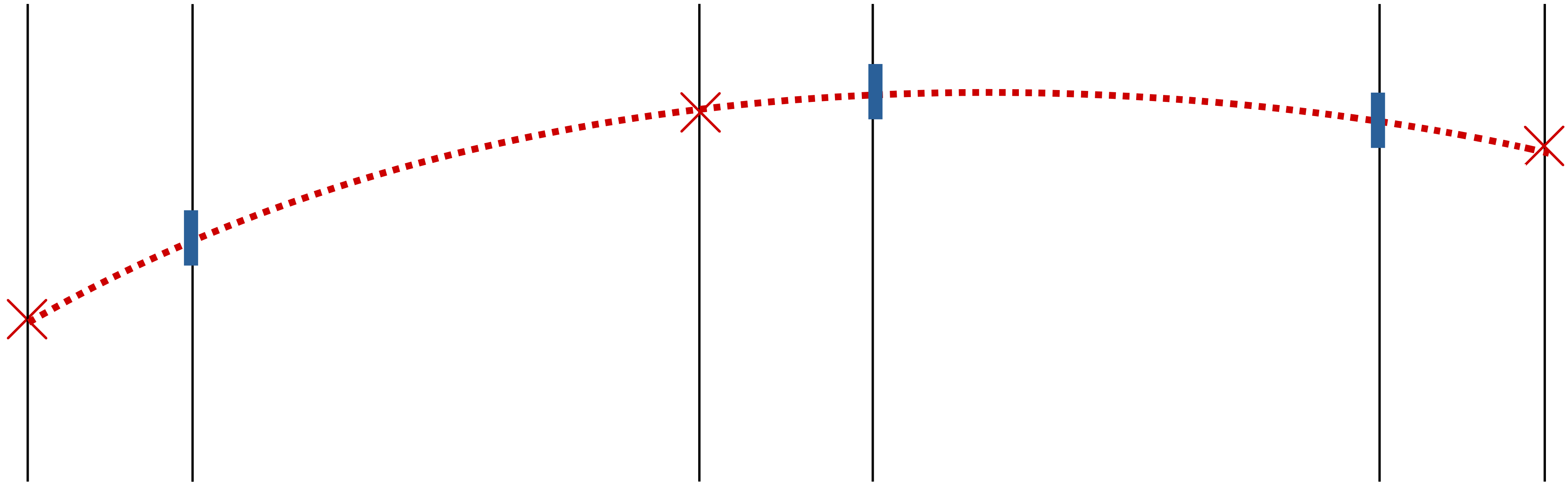


XZ tracking: two is a crowd



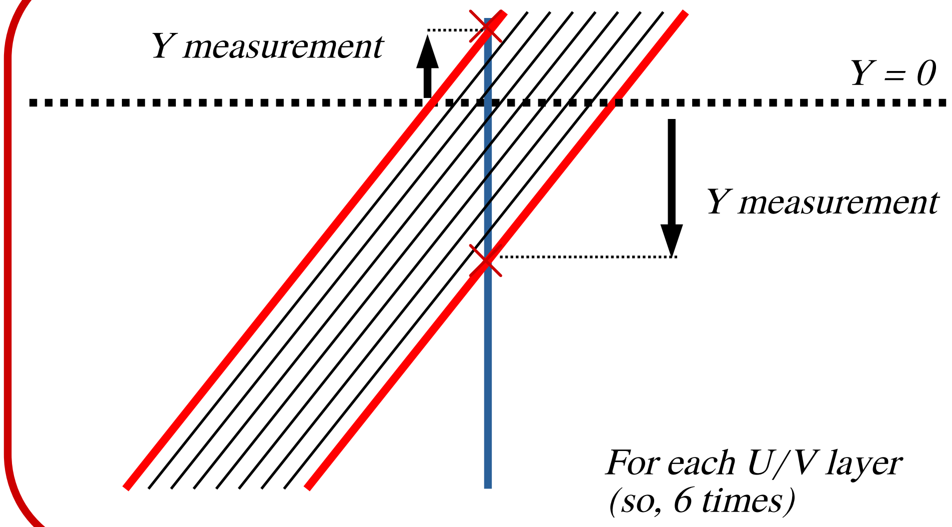
- Not infinite momentum is equivalent to saying that the second hit is not on the line between the first hit and (0,0,0), which is equivalent to $\mathbf{x_0}$ **!= 0**.
- X_0 is in fact a **momentum measurement**, by the displacement in the magnetic field of the magnet (left plot).
- There is still some field in the SciFi → this momentum measurement helps refine a **tolerance window** in a middle layer (middle plot))
- Two-hit window was hundreds of mm wide, this one is few mms.

XZ tracking: habemus parabola



- Now we can drop any reference to the origin: we have the trajectory in the SciFi: looking for the 3 remaining hits with a ~ 1mm tolerance.
- Track is then fitted, and we apply quality criteria.
- At this stage, we have ‘XZ’ segments. Lots of them are ghosts, and they have no y information.

Adding U/V hits: Hough cluster



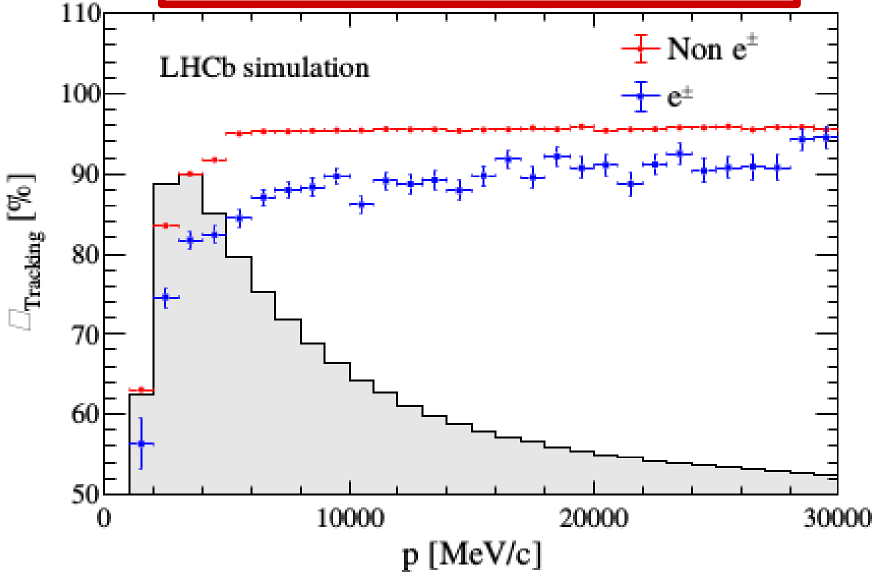
Hough cluster search

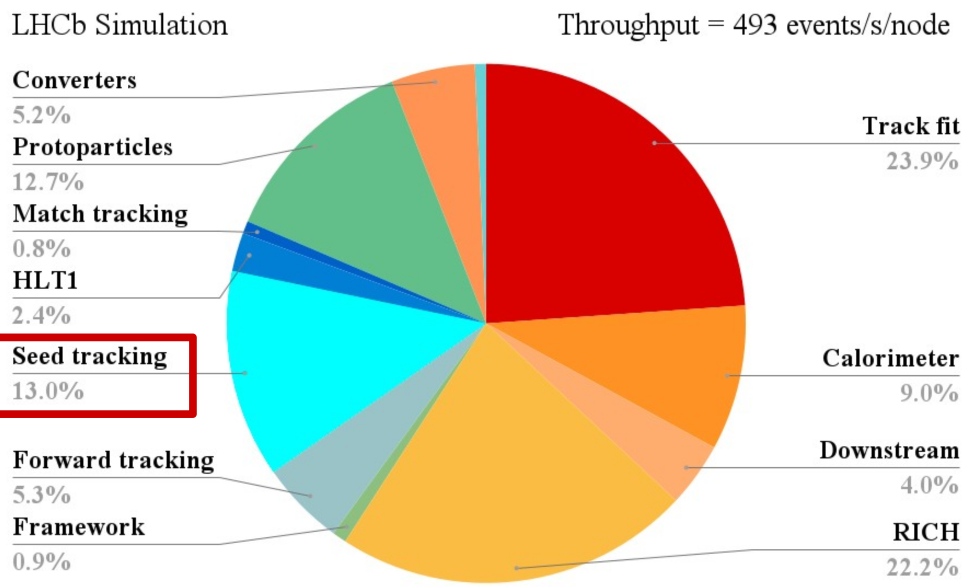
	Binned values of $y/z = t_y$			
Lay1	1	...	1	0
...	...	...	...	
Lay6	0	...	1	1
Total	3	...	5	2

- From the fit to the XZ track, we have a **x(z)** equation → positions in every tilted layer.
- For each tilted layer, collect compatible hits and convert them to a y measurement.
- Two hypotheses:
  - Trajectory inside the SciFi is a line: $y(z) = a + t_y * z$
  - Tracks come from the origin following a line: $y(z) = t_y * z \rightarrow y/z = \text{constant}$.
- We bin the t_y values measured and look for accumulated values: **Hough cluster**.
- Then fit the track and apply quality criteria → done!

Performances

Computer Physics Communications, 2020, 107713



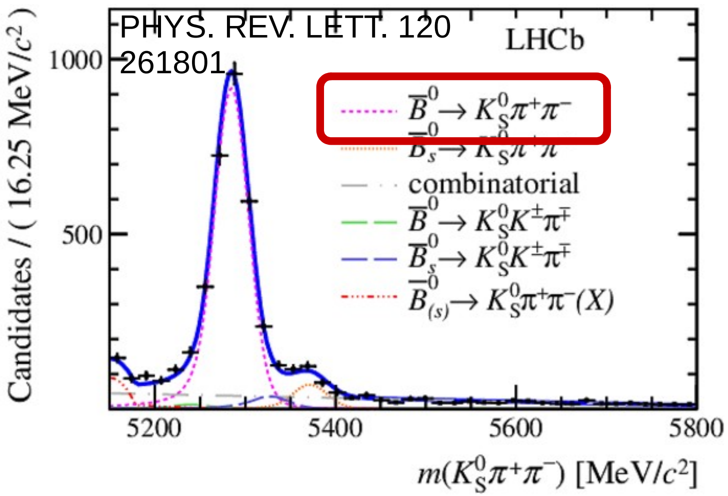


- Efficiency on tracks from decays far away from the origin is still rather good (> 80%)
  - No official figure, unfortunately.
- Fast enough to run 'first', to clean the SciFi environment for other algorithms to use the remaining hits.

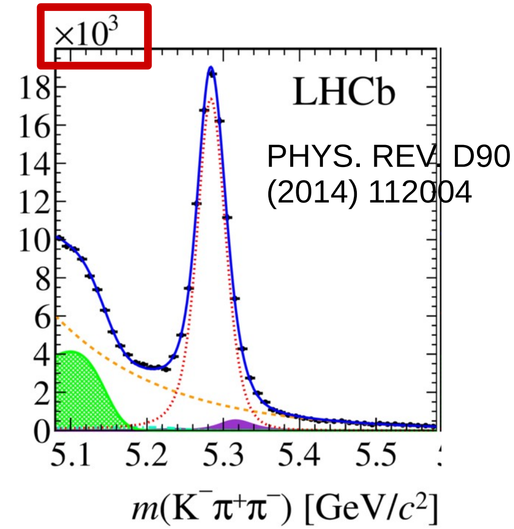
T track reconstruction at HLT1 level

Porting the seeding to HLT1: why and how?

- T tracks are ingredients to Long and Down tracks, and only way to access Down tracks.
  - Huge statistical price to pay when no HLT1 line → bottleneck for many analyses.



K_S reconstruction, vertexing, ***lack of HLT1***

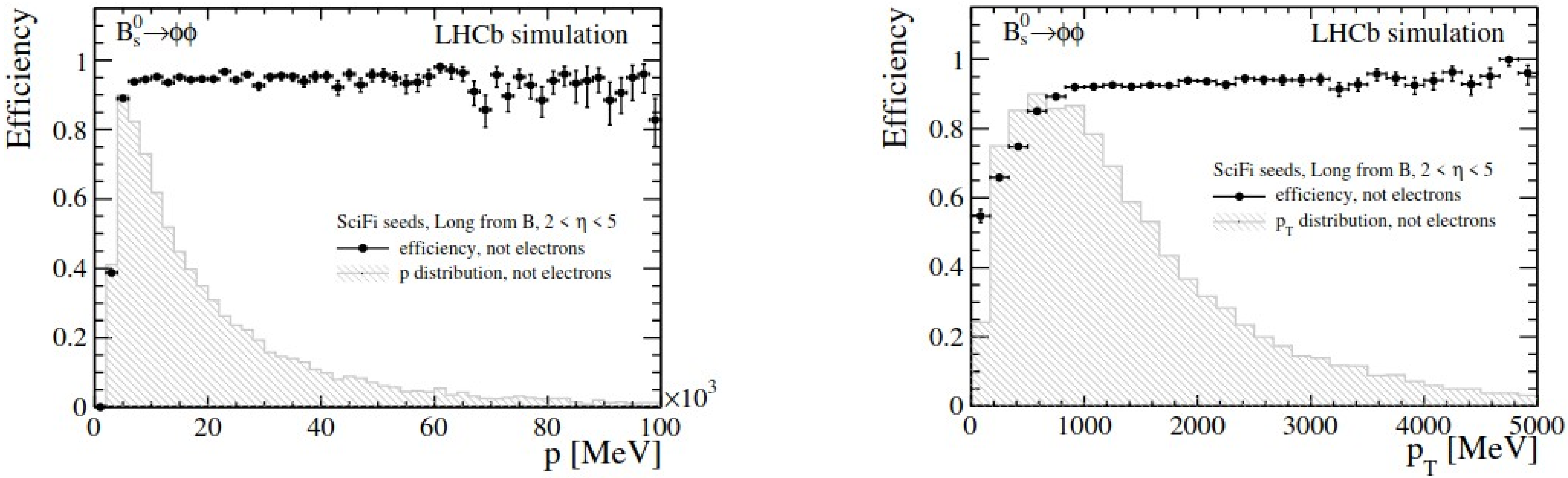


- Current Long track reconstruction in HLT1 has to cut low p_T tracks
  - Impact on charm, strange, soft physics.
- Switch to HLT1 mindset: bulk of the work is hard combinatorics → **perfect for GPUs**.
- Adapting an algorithm to GPUs is a bit more than changing the framework
  - Trade-offs e.g. number of variables in memory and number of calculations have to be considered.
- Take-away message for GPU developing: benchmark, benchmark, benchmark. You rarely know from first principles what is going to be better.

Choosing the parallel scheme

- **For XZ track reconstruction:**
  - Form triplets in a first parallel scheme → uses a lot of memory but is timing efficient.
  - For each triplet, promote them to full tracks.
- **For U/V hit addition:**
  - Parallelise only on XZ tracks.
  - Adapt the Hough clustering to a “xz-like approach”:
    - iterate over all possible hits in a first seeding layer.
    - If unsuccessful, do the same in a second seeding layer, to cover for inefficiencies.
- **Clone killing:**
  - Iterations are kept and produce lots of clones: most tracks are reconstructed twice.
  - Voting algorithm with O(n) algorithm employed to get rid of clones.

Performance of T track reconstruction in HLT1



- 'Saturation' value a bit lower for high momentum tracks (- 2-3%) → normal considering we cut a few corners.

- Large efficiency at low p_T → gain in soft, charm physics compared to other types of reconstruction.

Seeding in HLT1 expected to have a large impact on study of K_S, Λ, and maybe LLPs (see next presentations)

Conclusion

- T tracks are a key ingredient to the LHCb tracking strategy, but rarely used by themselves.

- Obtained through the Hybrid Seeding, which has been developed for HLT2 mindset (don't lose anything).
  - Fast and flexible, covers a lot of physics cases.

- Overhaul of the seeding and exploitation of GPU capabilities made it possible to add it to HLT1:
  - Expected increased statistics for LLPs, K_S, Λ.
  - Alternative path to Long-track reconstruction with much higher low-p_T efficiency.
  - Article being written.

- Exciting times ahead for T tracks: maybe we can use them for themselves?