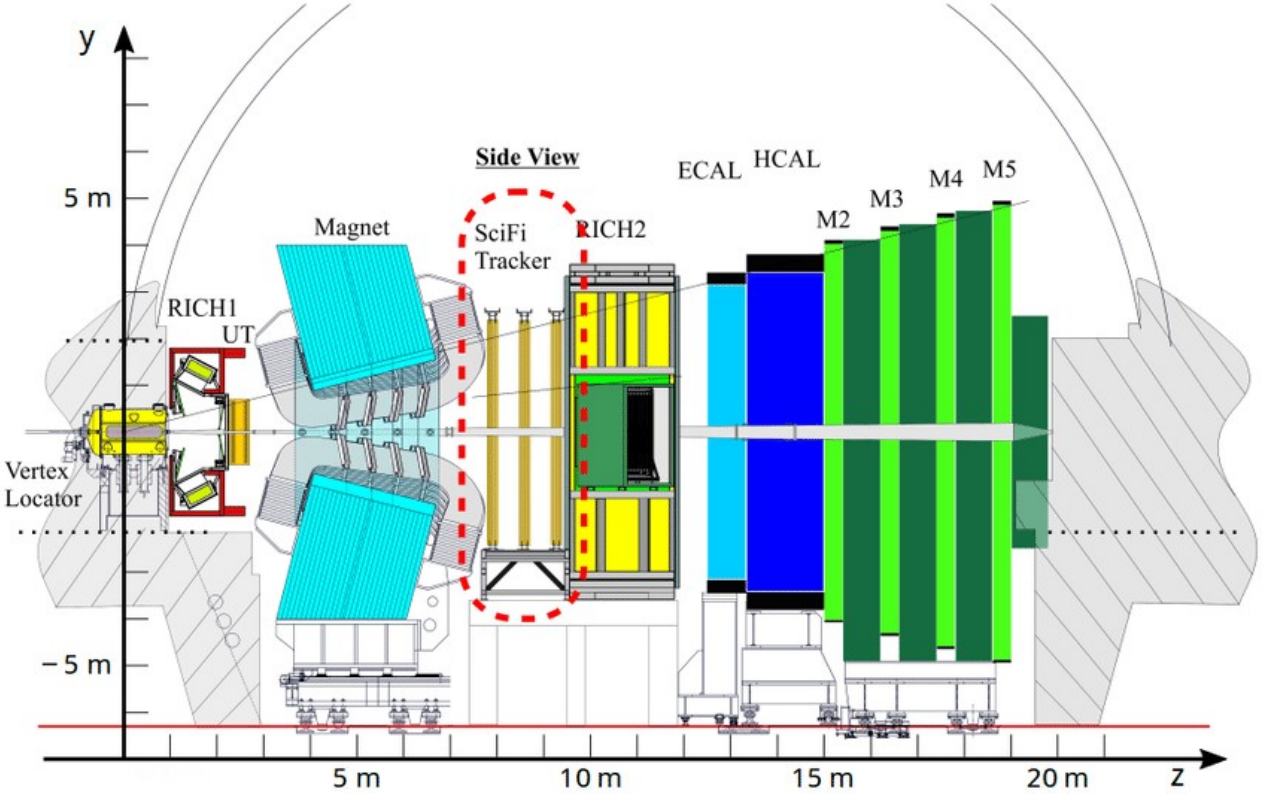
The Hybrid Seeding at LHCb

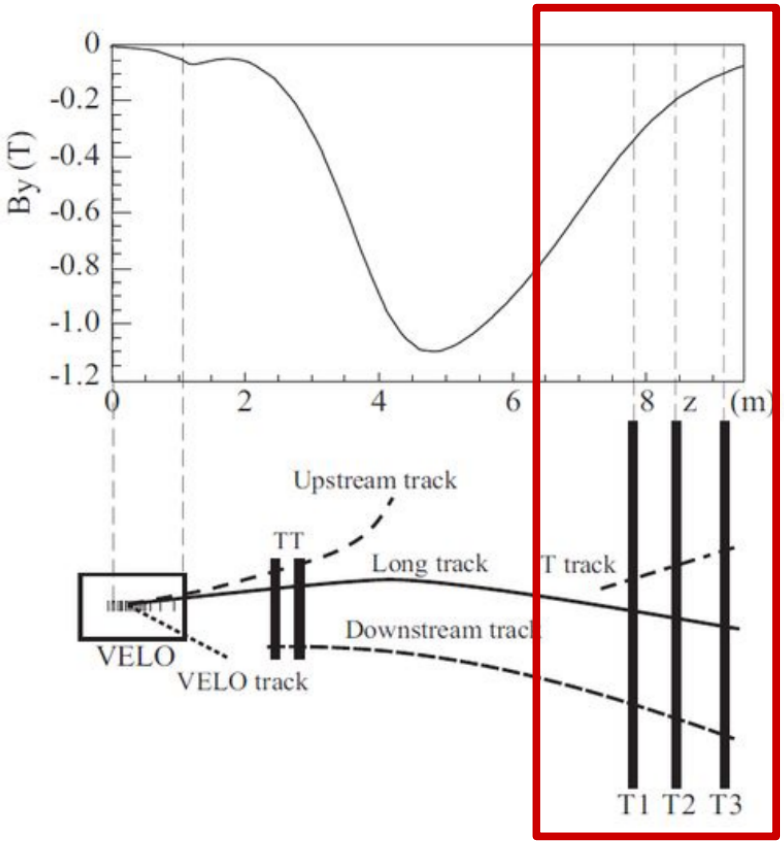
Louis Henry, on behalf of the LHCb-RTA project
Connecting the dots , 20/04/2020

European Research Council
Established by the European Commission

The hybrid seeding at LHCb

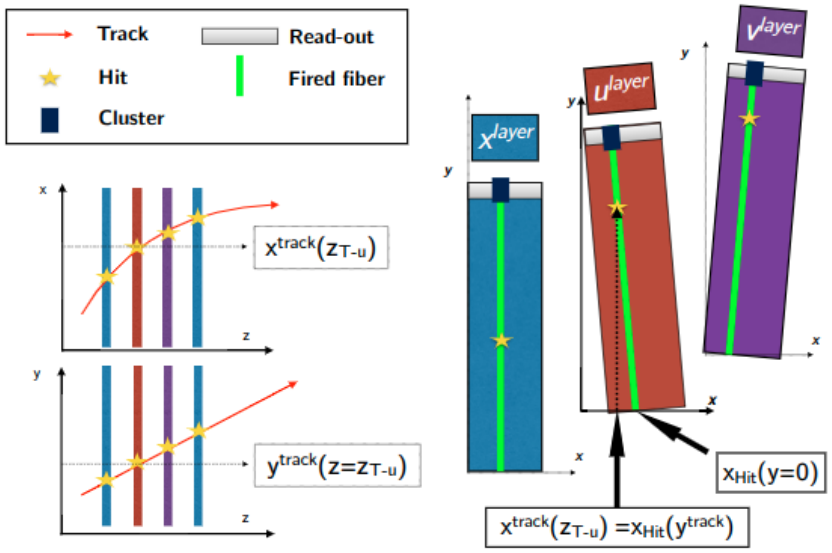
- LHCb is a detector along the LHC, specialised in the study of beauty and charm hadrons [JINST 3 (2008) S08005]
- The hybrid seeding is the **stand-alone reconstruction algorithm of the forward tracker (a.k.a SciFi), part of the tracker TDR.**
  - Needs to runs inside the HLT2 trigger (total throughput needed ~ kHz/node).





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).

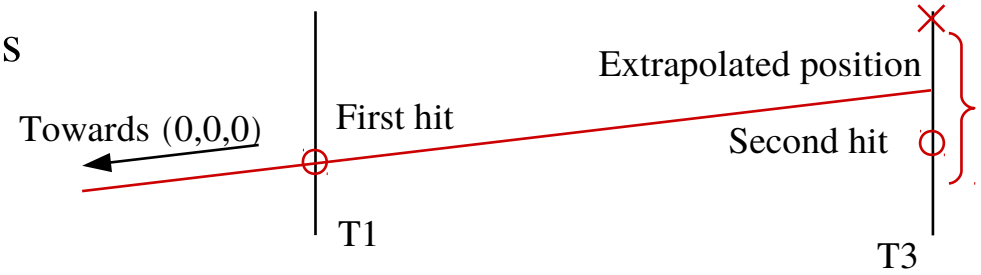


- Combinatorics too large to tackle all at once → **iterative strategy**: go for high-momentum first (~straight lines), cleanup the environment progressively.
- Each iteration starts with different pair of layers in T1 & T3.
  - Covers for hit inefficiency → modest theoretical cap on efficiencies.
- Final recovery step allows to ease hypothesis of tracks coming from (0,0,0) → better on displaced vertices.

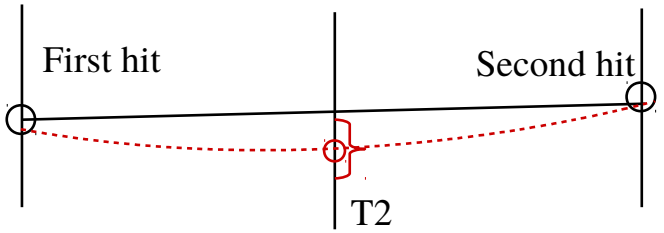
Hybrid seeding: XZ search

Principle of the search:

- Starts with doublet search in T1 & T3, windows depending on minimum p, taking charge asymmetry in consideration.



- For each doublet, already a charge-momentum estimation → narrower windows to look for 3rd hit in T2 station, taking bending into account.



- 3 hits + cubic correction estimated on MC → track model. We look for remaining hits.
  - Tracks that have at least 5 out of 6 possible hits and satisfactory χ^2 are kept.

Speeding-up the code

- Hits read with increasing x → cache position of current tolerance window to only move few hits at each step.
- Parabola-solving can be avoided by pre-calculating functions of z layers.
- Early stopping, efficient look-around search, avoid branchments.
- Unrolled loops when looking for 3rd hit in first or second T2-x layer.

Hybrid seeding: confirming tracks with U/V hits

- At that stage, XZ segments are dominated by ghosts → need for U/V combination.
- XZ segment provides us with x(z) equation, so hits in U/V layers can be translated into y coordinate, and thus to t_y.
  - Real tracks have ~ constant t_y if no scattering and come from close to the origin.
- Solution: discretised Hough cluster search in bins of $t_y = y/z$.

T1U	1	...	1	0
...	...	...	...	
T3V	0	...	1	1
Total	3	...	**5**	2

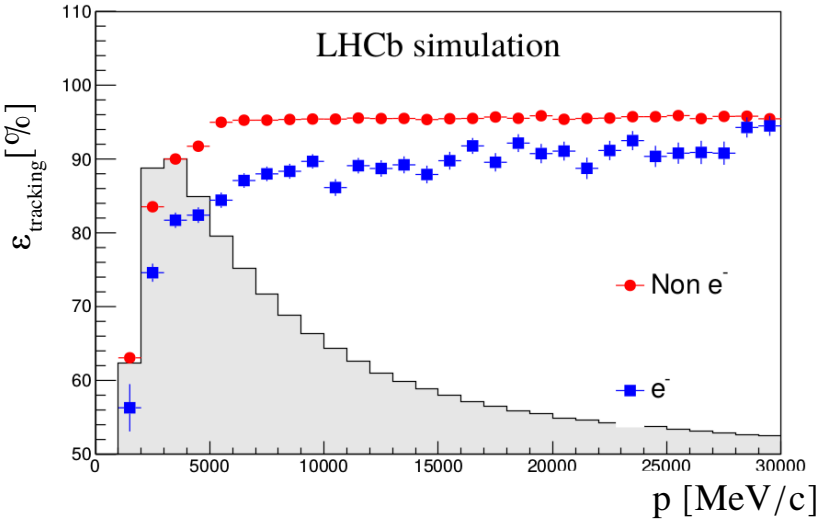
+ mapping between bins & hits

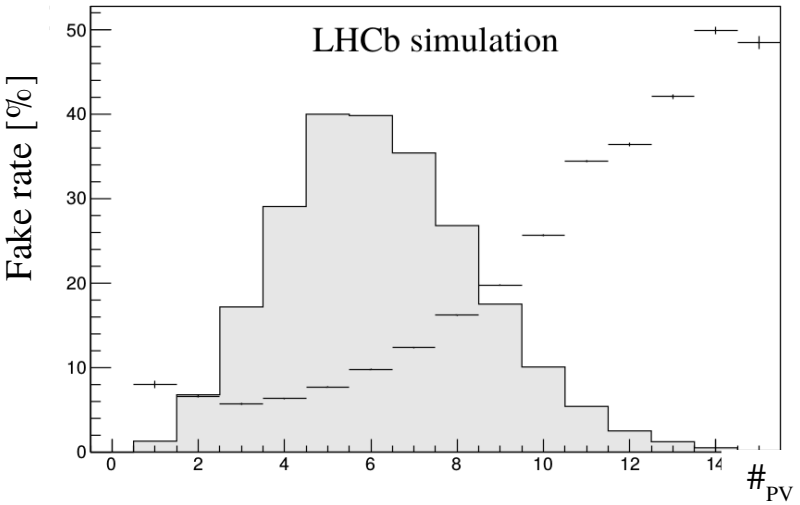
  - Does not need sorting or hit addition/removal.
  - In-built possibly to alleviate hypothesis that track comes from (0,0,0).

- If Hough cluster corresponding to XZ segment found:
  - Add U/V hits to the track.
  - Perform a full fit and reject candidates with large χ^2.
  - Create LHCb track object.

Hybrid seeding performance

Physics performance:

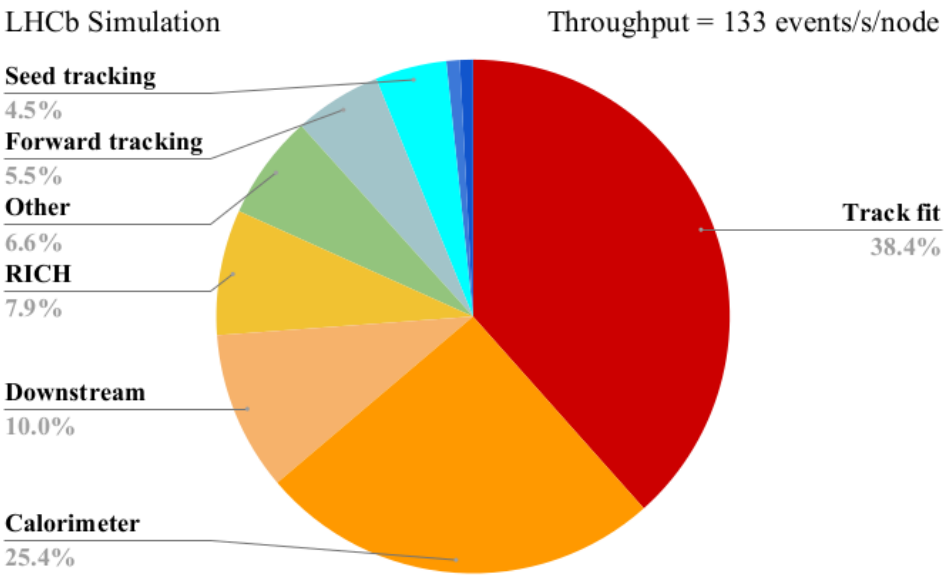




- Efficiency on non-e⁻ tracks goes up to ~95% at p > 7 GeV/c; fake rate kept under 10% on average.

Timing:

- Currently, seeding is < 5% than total HLT2.
- Among expected improvements:
  - Change to structure-of-array inputs.
  - Vectorisation of (parts of) the algorithm.



Conclusion

- The hybrid seeding is a fast and efficient reconstruction algorithm, only using hits in one LHCb subdetector.

- T tracks produced by the hybrid seeding are used in several ways in current LHCb software:
  - Extended with UT hits → allow to reconstruct "downstream" tracks, which allow to reconstruct more long-lived particles (K_S mesons, Λ baryons).
  - Matched with Velo tracks → complementary way to construct Long tracks besides Forward tracking.
  - Matching with electromagnetic clusters: could help e/γ discrimination.

- Proposals to use T tracks as physics inputs by themselves:
  - Would increase lifetime range of searches for long-lived particles: possible decay length would go from ~2m (UT) to 8m (first SciFi station).
  - Measurement of the Λ baryon electromagnetic dipole moments (part of SELDOM project [URL]).