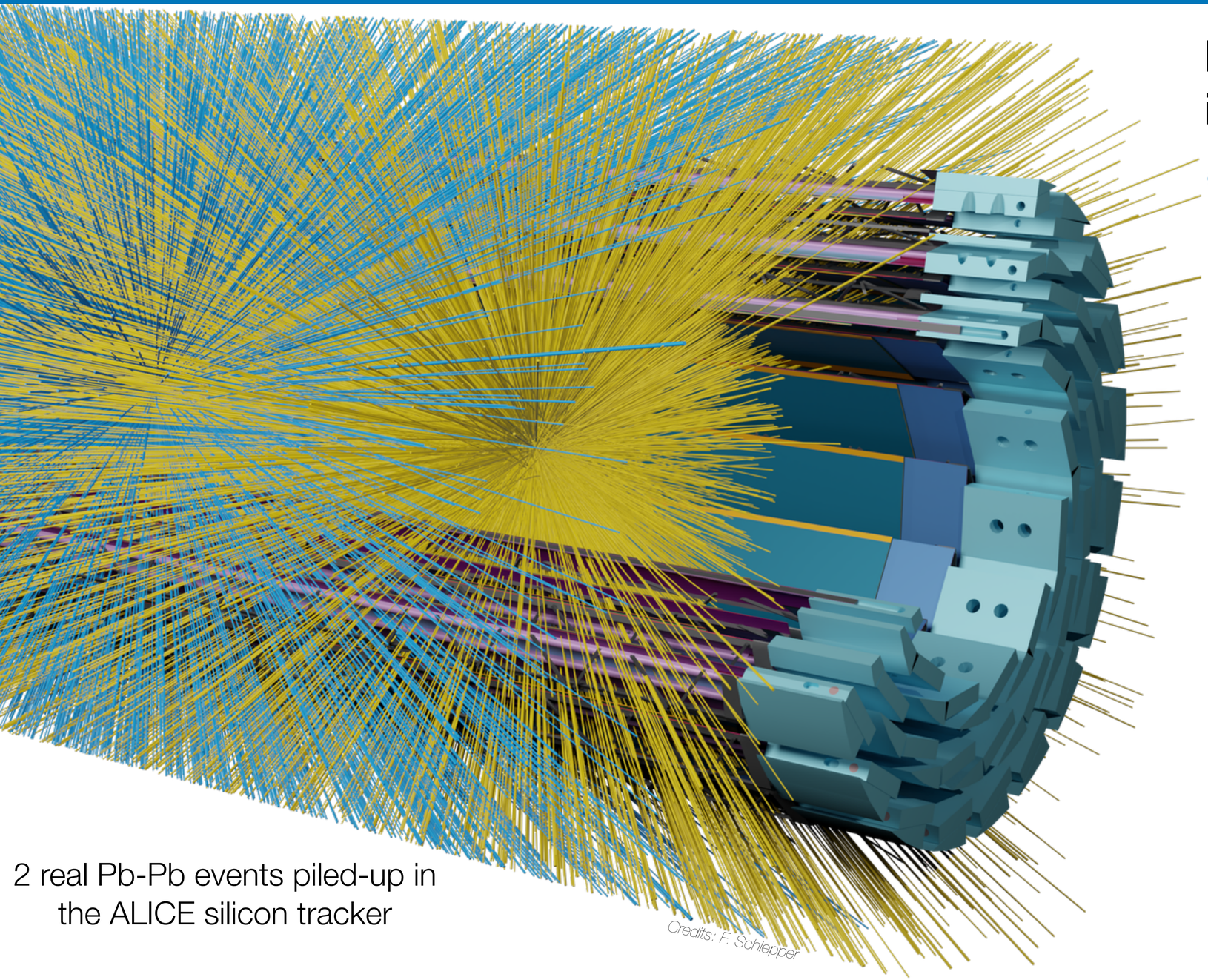
FLoMoTION

Flexible Low Momentum Tracking Ion-Ion collisions

Participating institutes: Austrian Academy of Sciences, CERN, INFN

Town Meeting, Hadron Physics in Horizon Europe - 2nd July 2025 - Nantes

The problem: high multiplicity + pile-up + low momentum

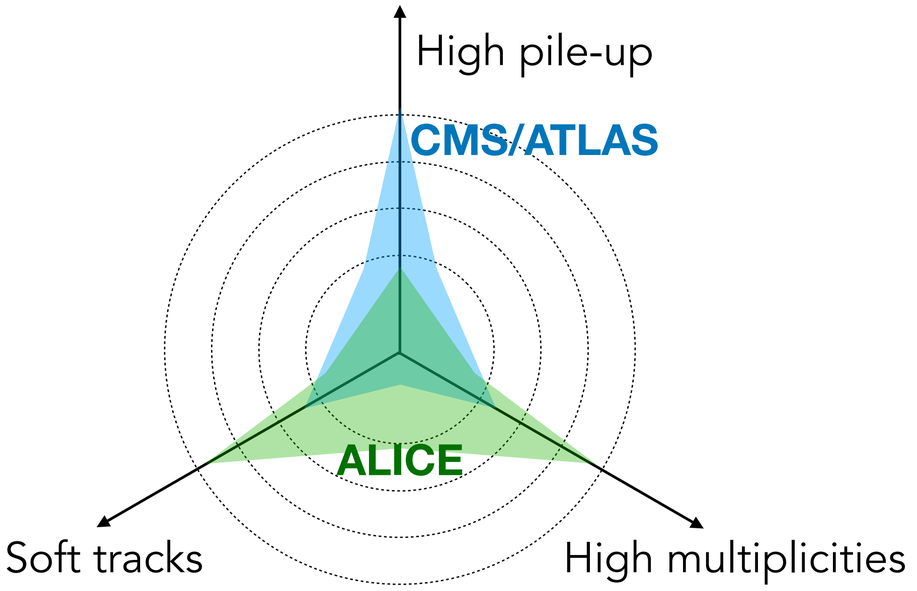


2 real Pb-Pb events piled-up in the ALICE silicon tracker

Credits: F. Schlepper

Reconstructing particle trajectories is a task as old as particle physics

- We now pushed in 3 directions



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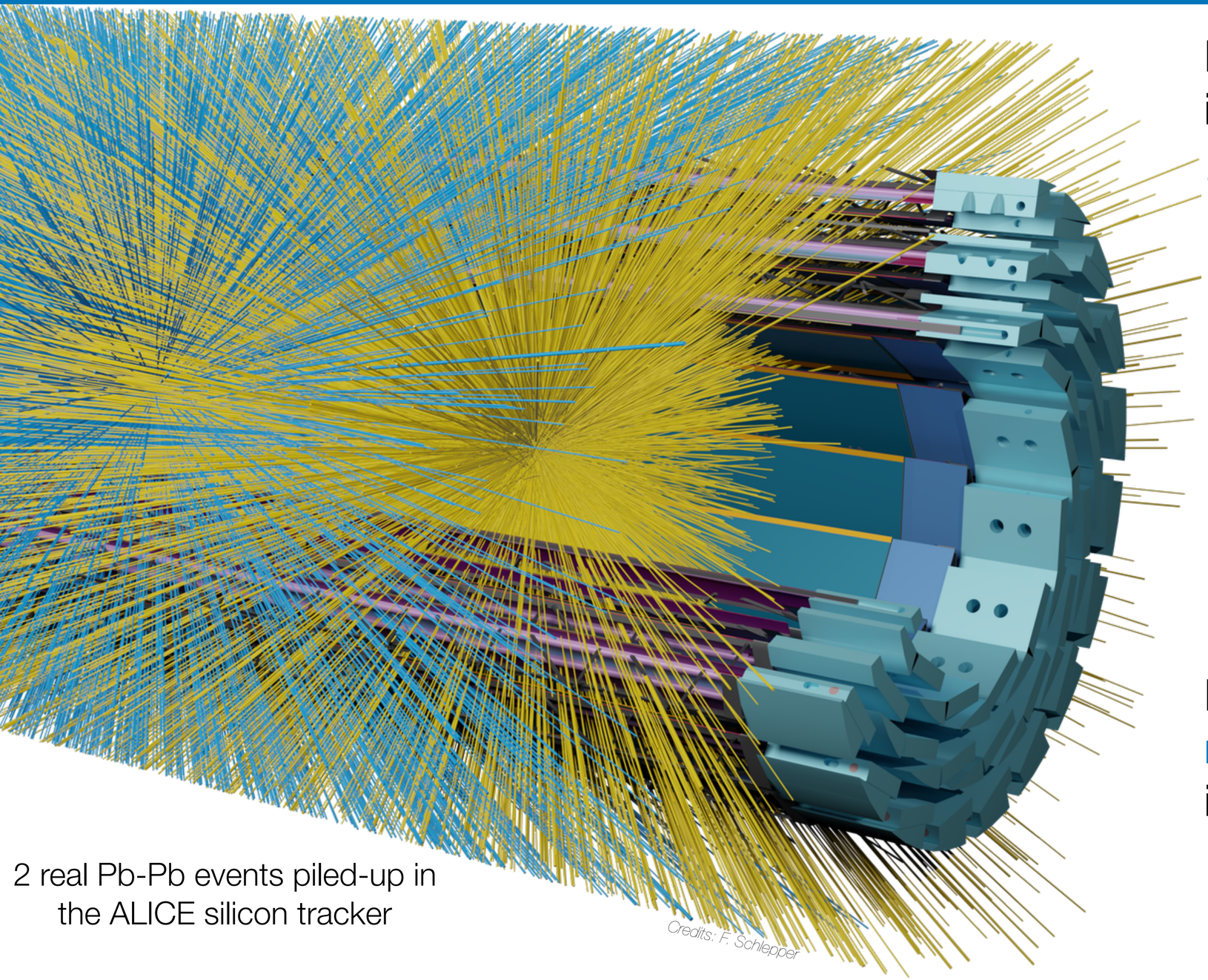

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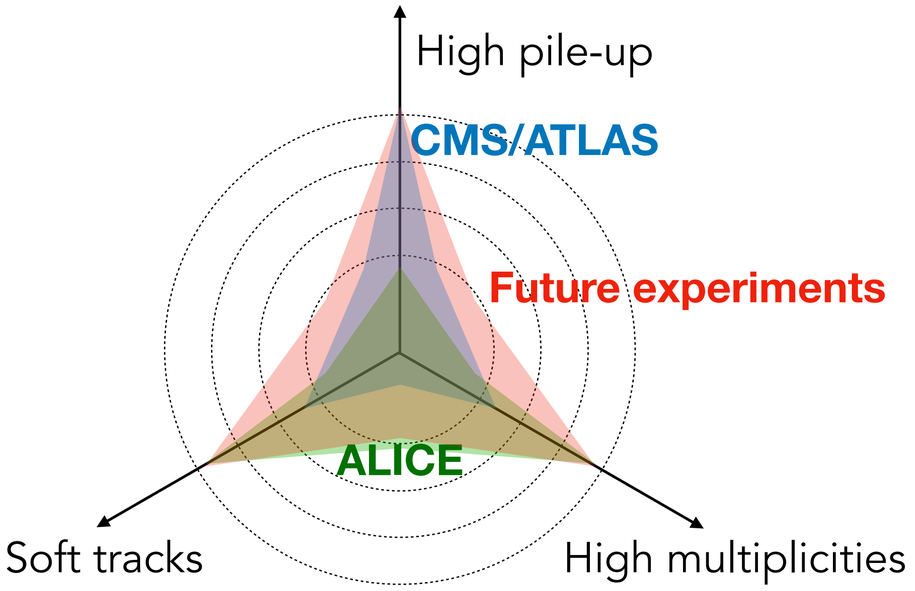

Future ion-ion experiments: high rate to look for rare probes decaying into soft tracks

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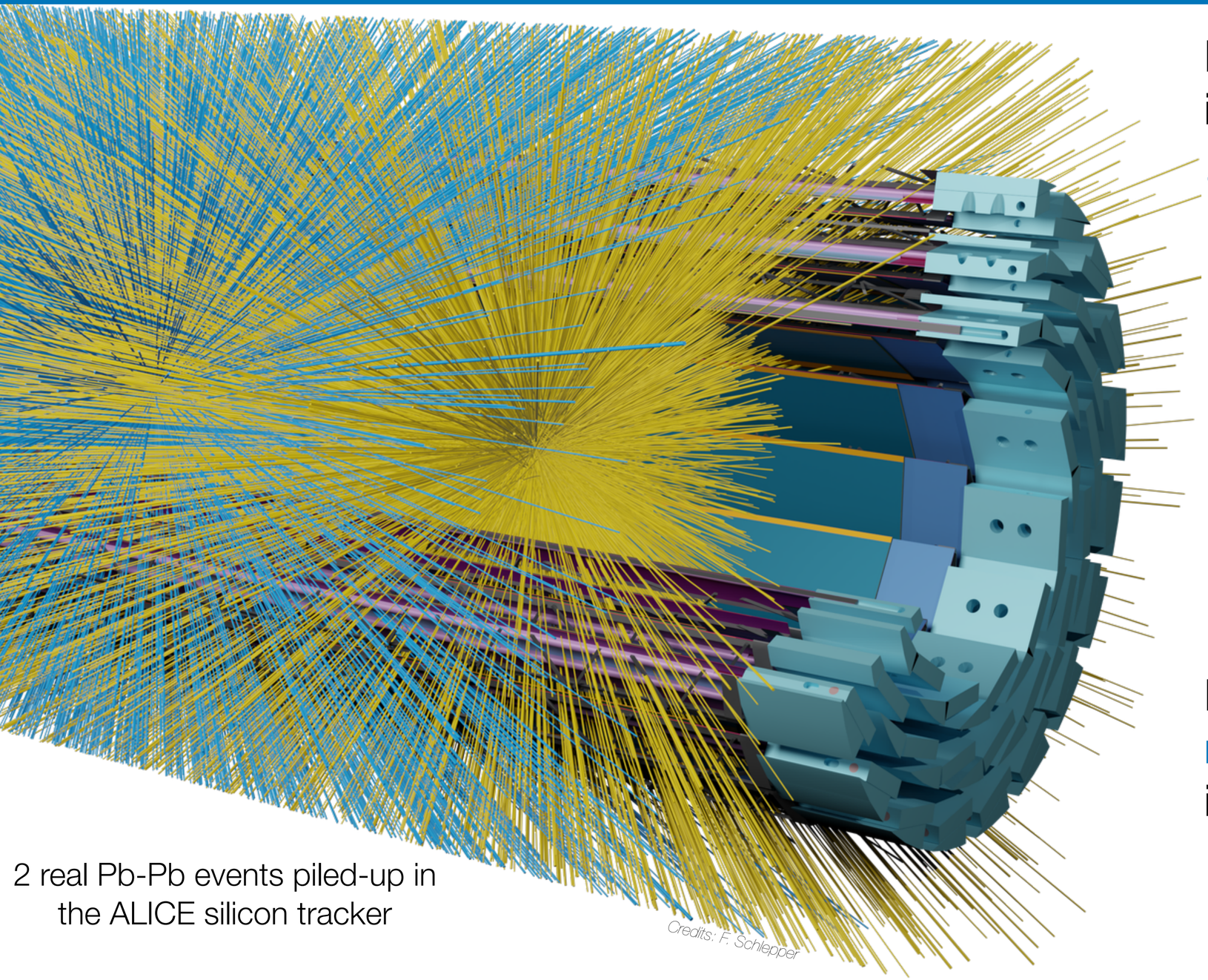

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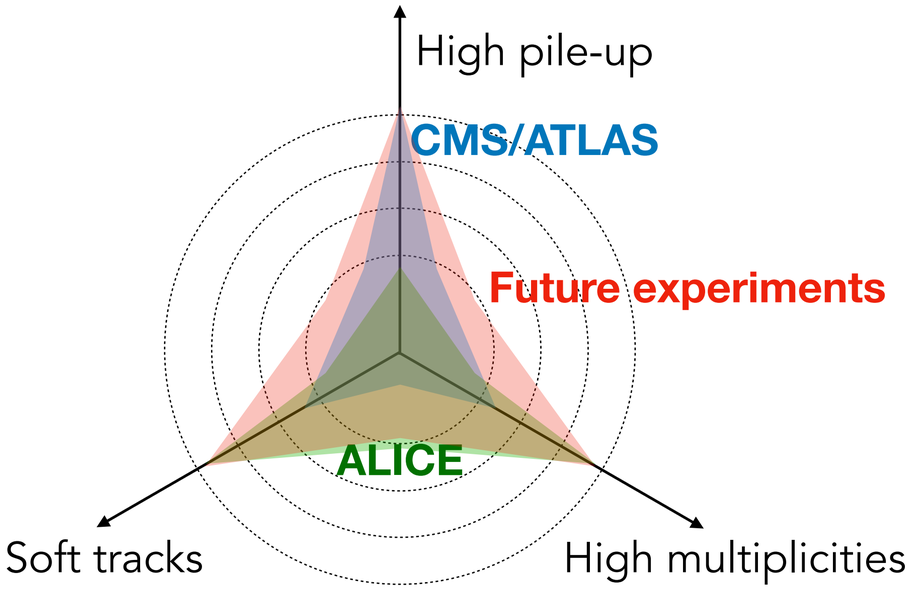
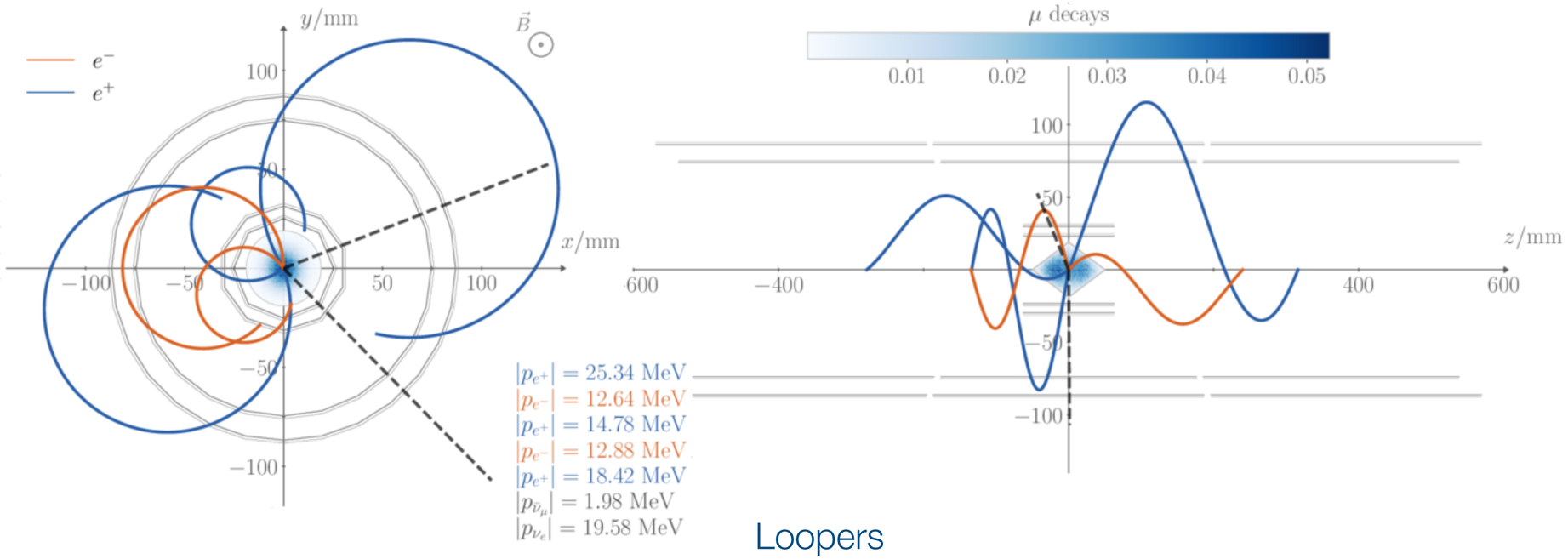


Future ion-ion experiments: high rate to look for rare probes decaying into soft tracks

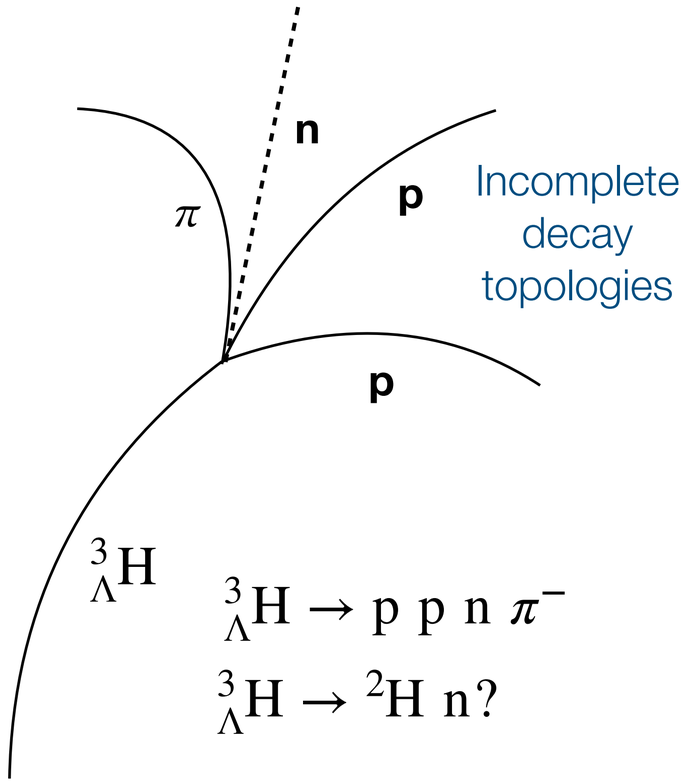
We need to develop new detector agnostic methods

Reconstruction of complex topologies

JHEP 10 (2023) 006



Loopers



Incomplete decay topologies

Typical approach: find tracks first, combine them later to reconstruct both loopers and decays

- High multiplicity environments: high rate of fake hit attachments
  - Reduced efficiency and precision (momentum/mass shifts)

Reconstruction of complex topologies

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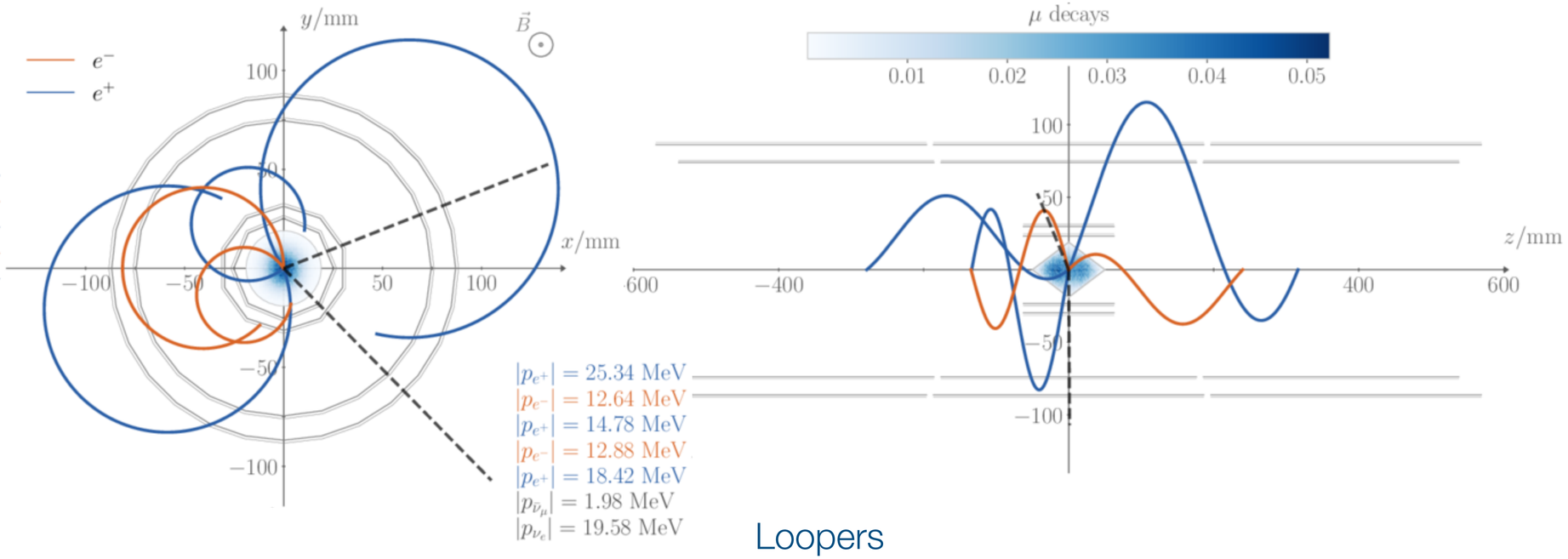

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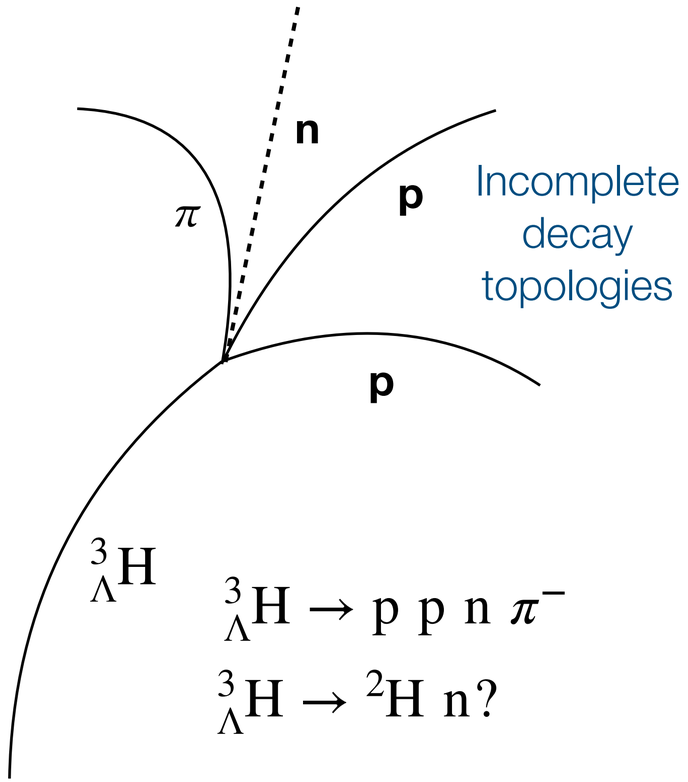

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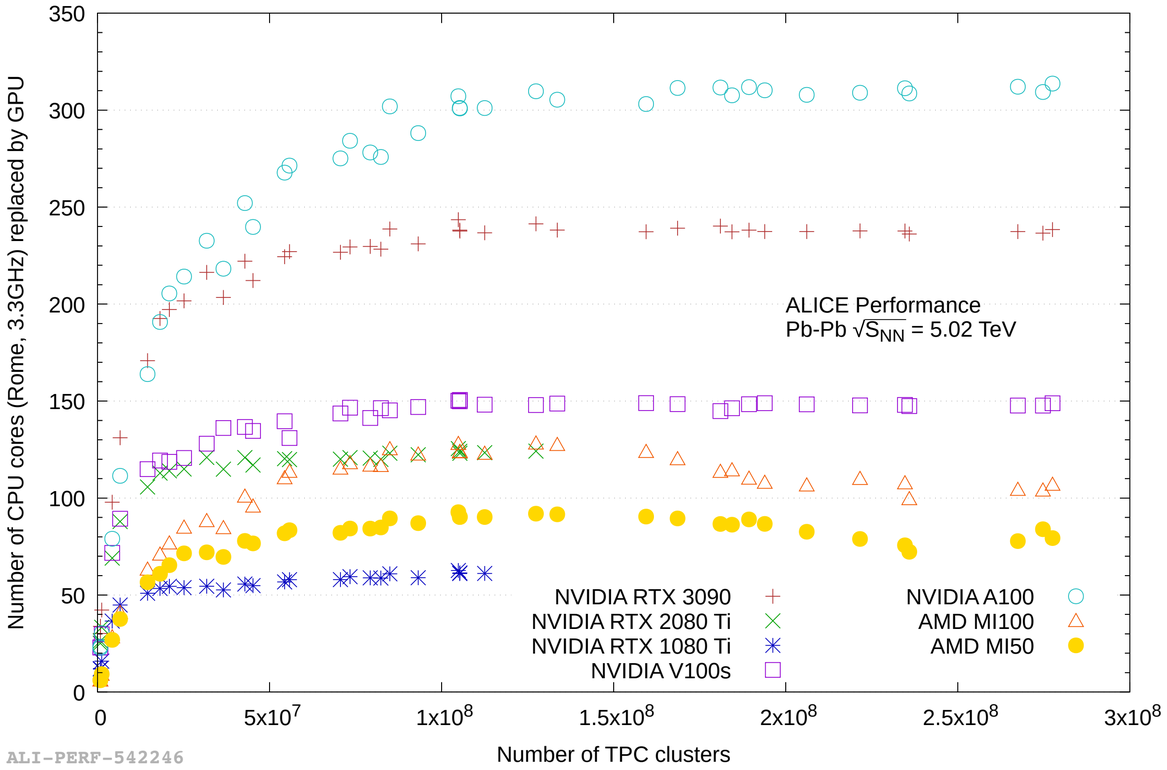
Aim to implement a fully integrated framework to reconstruct both tracks and complex topologies

Need for speed (and power efficiency): GPU processing



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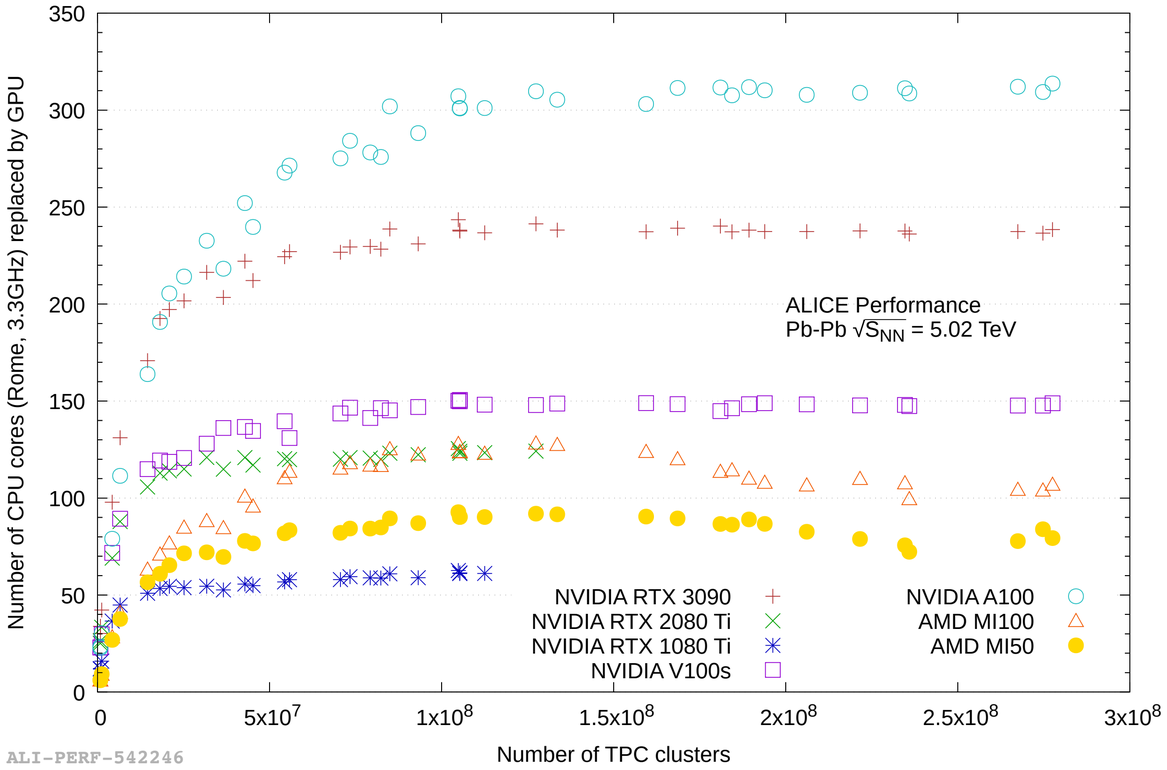

Murad Qasaimeh et al, arXiv:1906.11879

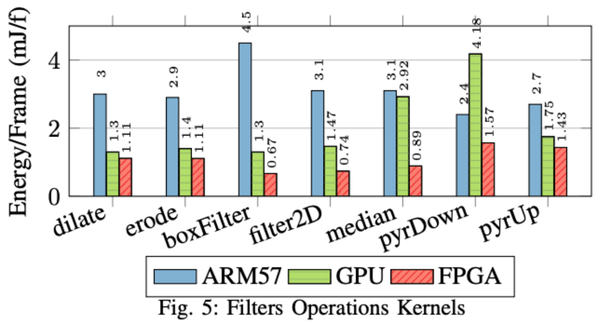

Fig. 5: Filters Operations Kernels

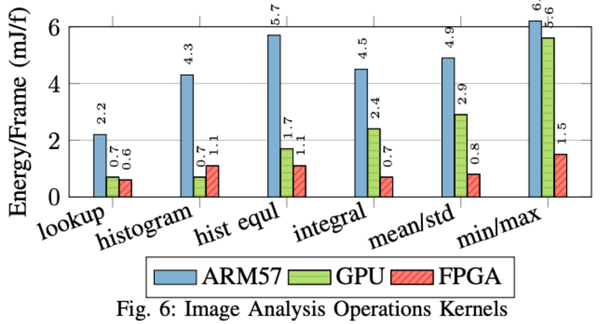

Fig. 6: Image Analysis Operations Kernels

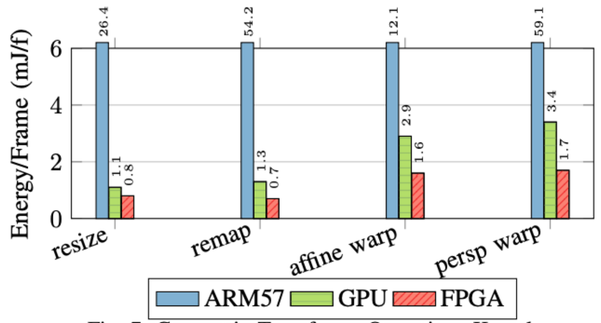

Fig. 7: Geometric Transforms Operations Kernels

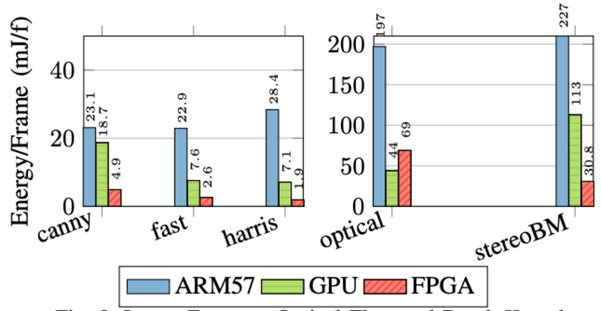

Fig. 8: Image Features, Optical Flow and Depth Kernels

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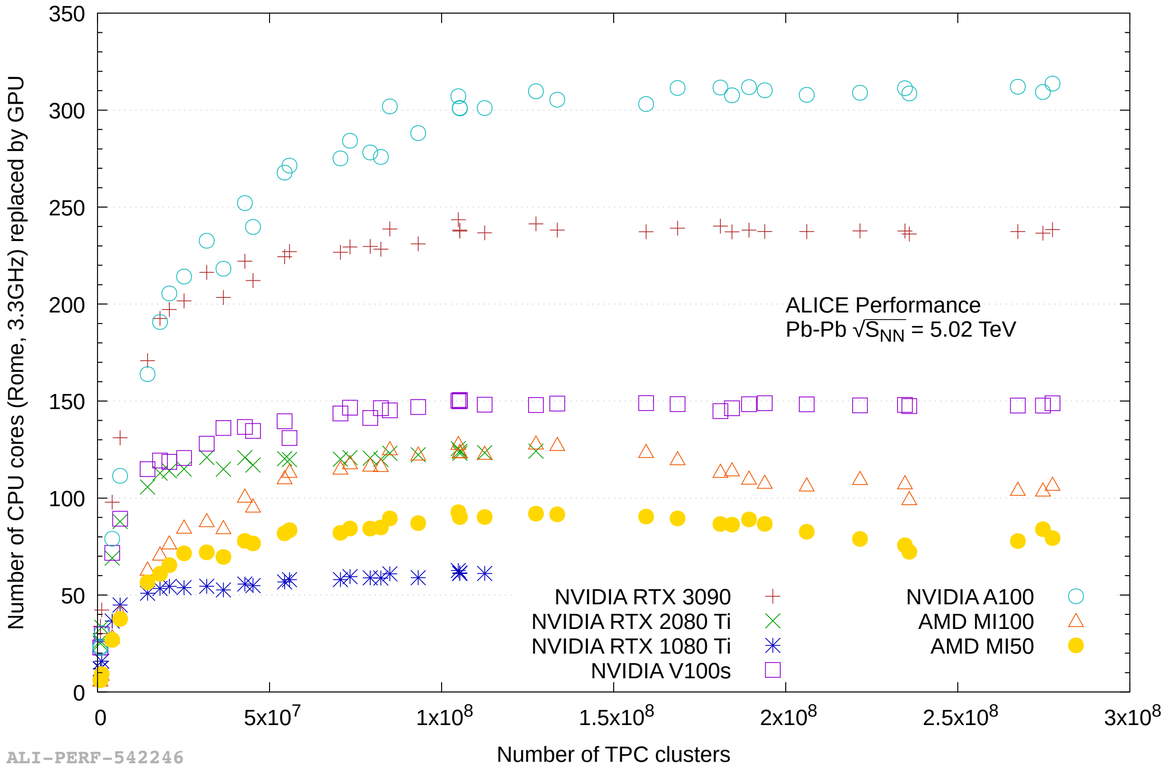

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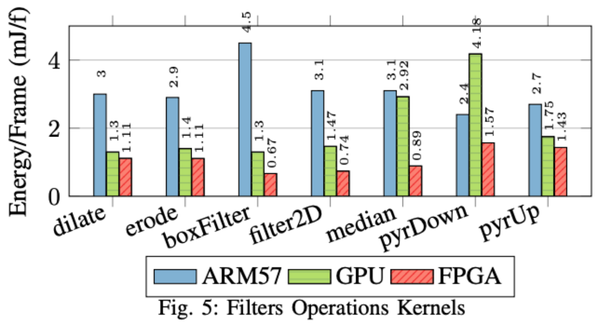

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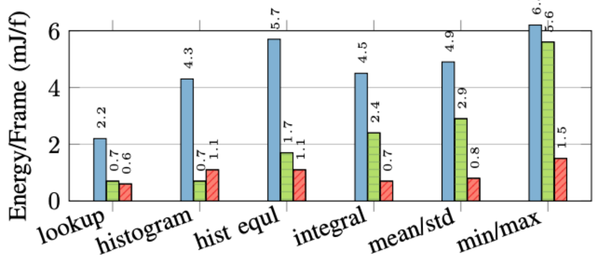

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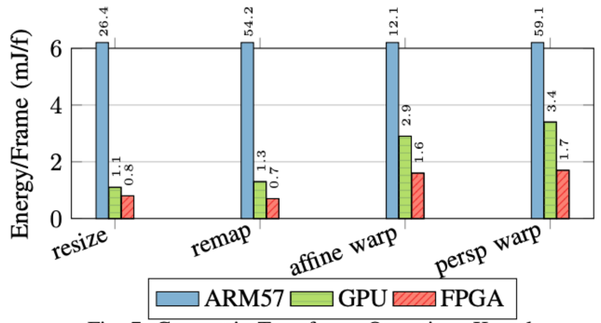

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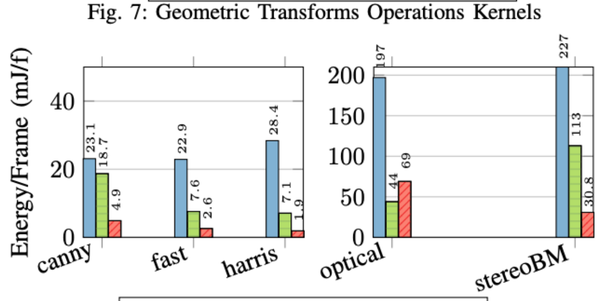

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Any modern tracking/reconstruction code should be able to leverage GPU resources

FLOMOTION objectives

The project aims to close the gap between the currently available tools and the needs of the community when designing (and running!) new ion-ion experiments

- Tracking of low p_T particles in high multiplicity and high pile-up environments
- Reconstruction of complex topologies
- Inclusion of PID in the tracking process

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Building and improving on currently available frameworks

Key4hep a:ts KFParticle

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The project can be structured in three work packages:

1. *Performance-oriented design for high multiplicity and low momentum tracking*
2. *Reconstruction of complex topologies*
3. *Particle-ID aware tracking*

Work programme and financial request

Work package 1 deliverables:

1. General purpose reconstruction code for low p_T tracks in high. mult. and high pile-up
2. GPU (HIP/CUDA/OneAPI) porting of the code

Work package 2 deliverables:

1. Looper topology reconstruction in ion-ion
2. Generic decay topology reconstruction integration with tracking

Work package 3 deliverables:

1. Integration of PID (dE/dx, TOF, TRD) measurement in tracking with momentum refitting
2. Explore the use of trajectory modification to identify particles

Activities of the project are in synergy with current developments at the participating institutes (Austrian Academy of Sciences, CERN, INFN)

- Kick-off workshop to start the activities, tutorials meetings, closing workshop
- 2 PhD students + 1 postdoc to be part of the development of the software framework across the work packages

Financial request

Two PhD students	150 000 €
One 2-year postdocs	100 000 €
Workshops and trainings	35 000 €
Indirect costs	115 000 €
Travel support*	50 000 €
Total requested budget	**450 000 €**

*approximately 20 infrastructure accesses per year (e.g. CERN) are foreseen

Infrastructure usage

ALICE EPN farm. Credits ALICE Collaboration

The development of high performance solutions to tracking will require leveraging new accesses to heterogeneous computing resources

- At CERN: ALICE Event Processing Node farm (350 servers, each equipped with eight AMD GPUs)
  - From July 2026 (LHC long shutdown): room for projects to efficiently use such resources
- Other facilities available also at INFN CNAF and in Vienna

All the developed code and tooling (e.g. containers) for both the project itself and the access to the infrastructure will be made available on dedicated hosting platforms available at CERN