Track Seeding in the sPHENIX Experiment

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Abstract

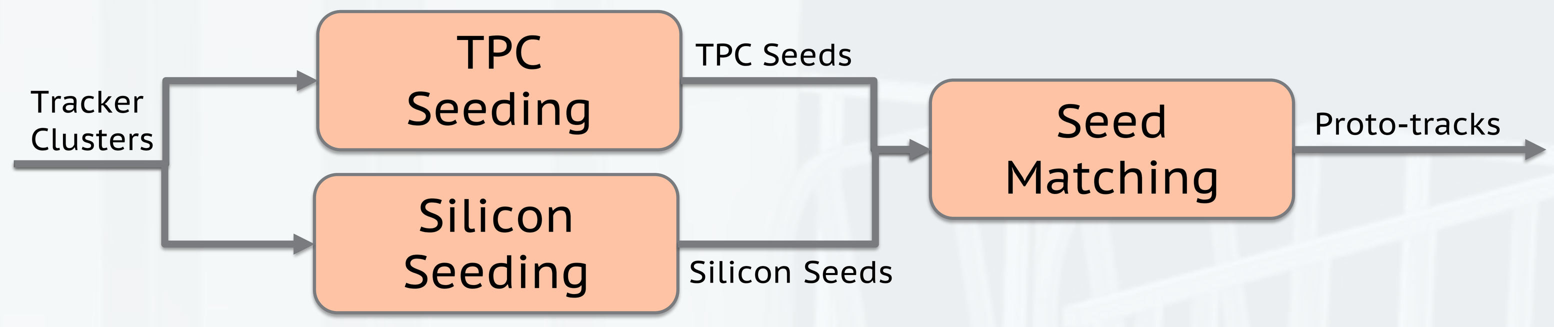
The tracking reconstruction procedure for the sPHENIX experiment combines data from the silicon pixel detector, silicon strip detector, time projection chamber, and micromegas-based modules to produce tracks that trace a particle's path through 57 total sensor layers. After clustering is completed, the track seeding modules identify chains of clusters that correspond to valid tracks, lengthen these cluster chains by including additional clusters on the same path, and perform a preliminary fit that serves as an initial estimate for later modules. Two separate seeding modules are involved in this process: a cellular-automaton seeding algorithm based on the ALICE time projection chamber (TPC) seeding algorithm is used for the sPHENIX time projection chamber, while a seeding algorithm provided by the A Common Tracking Software (ACTS) package forms the basis of the sPHENIX silicon detector seeding module. In this poster, we describe the structure and performance of the modules used in sPHENIX track seeding, using the results from the first primary data taking period.

Track Seeding Overview

An sPHENIX track seed contains:

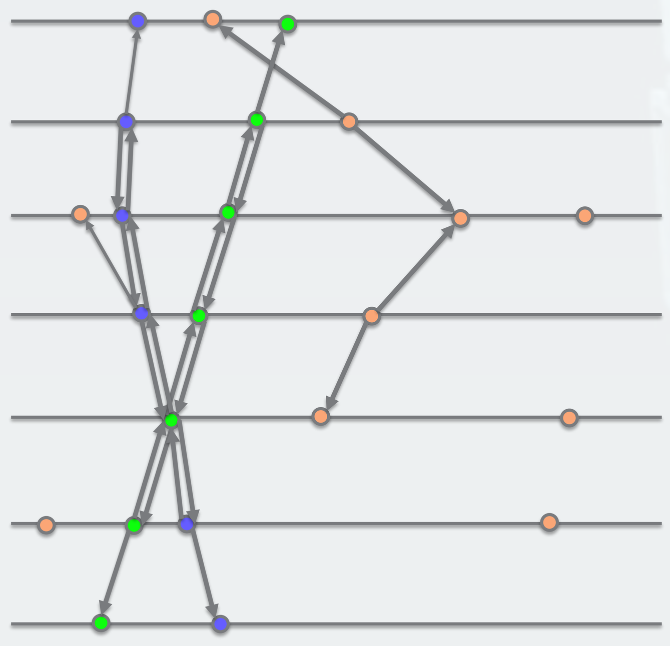
1) A **cluster chain** (clusters are obtained from previous clustering step)
2) A **momentum estimate** (calculated via circle-fit in (x,y) and linear fit in (r,z) to cluster chain).

Therefore, a track seeding module must mainly **assemble cluster chains** that, with **high efficiency**, reflect the true tracks of particles of interest, in a **high-occupancy environment** while **minimizing demand on time and memory** as much as possible.

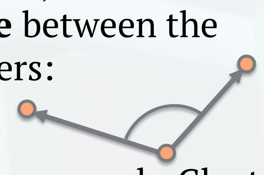


TPC Cellular Automaton (CA)-based Track Seeding

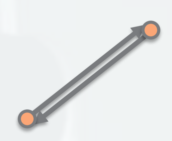
CA Seeding



Form a directed graph on the clusters, with connections between clusters in neighboring layers (within a search window) if the **breaking angle** between the clusters:



is large enough. Cluster chains are formed **only** for sets of clusters connected in **both** directions:

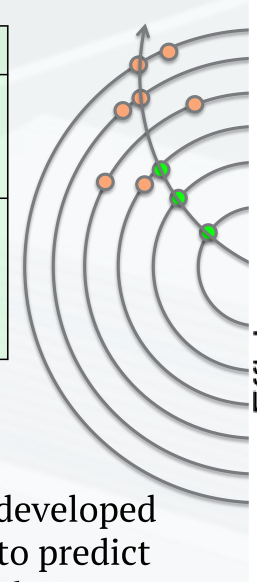


Typical Parameters	
Search window max. Δϕ	0.05 rad
Search window max. Δz	1.5 cm
Min. clusters per seed	3
Max. cos(triplet breaking angle)	-0.95
Max. cluster-by-cluster dz/dr variation	0.5
Max. cluster-by-cluster d^2phi/dr^2 variation	0.005

Cluster-by-cluster variation cuts are applied while following the cluster chains, to filter out seeds unlikely to be true tracks.

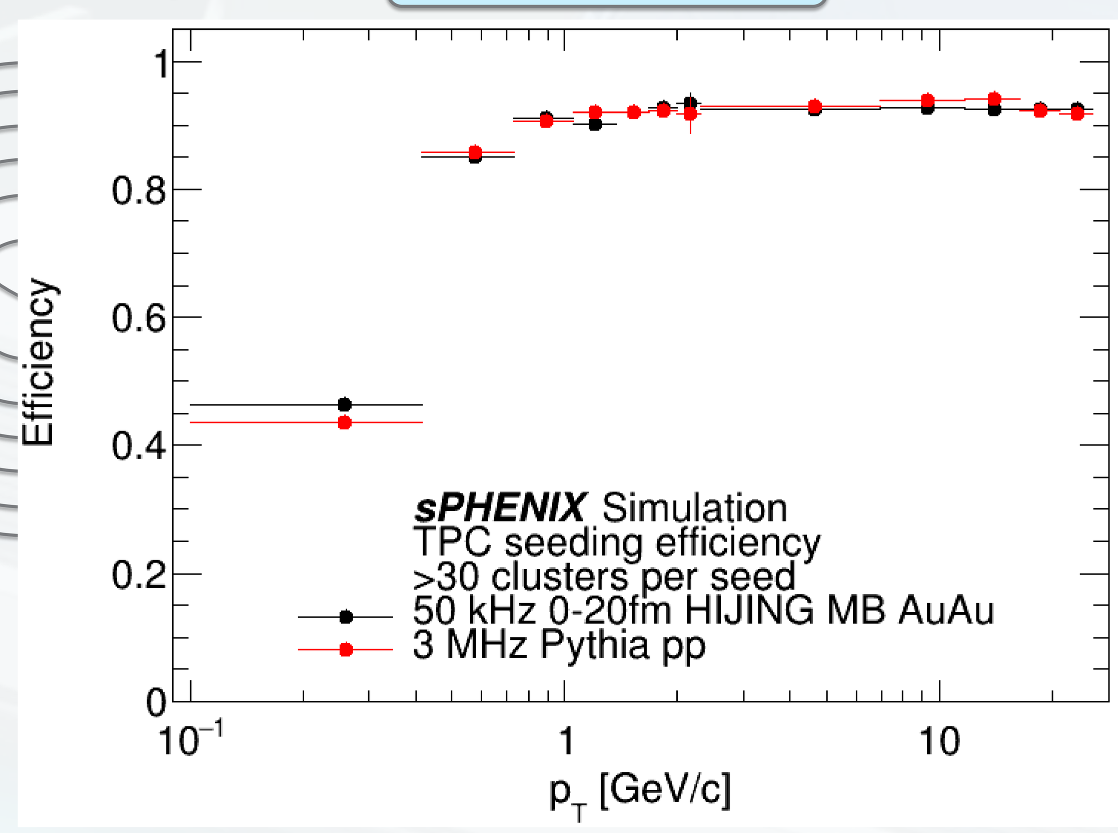
Seed Propagation

Typical Parameters	
Fixed cluster position error estimate	0.1 cm
Max. allowed deviation for cluster addition	5σ



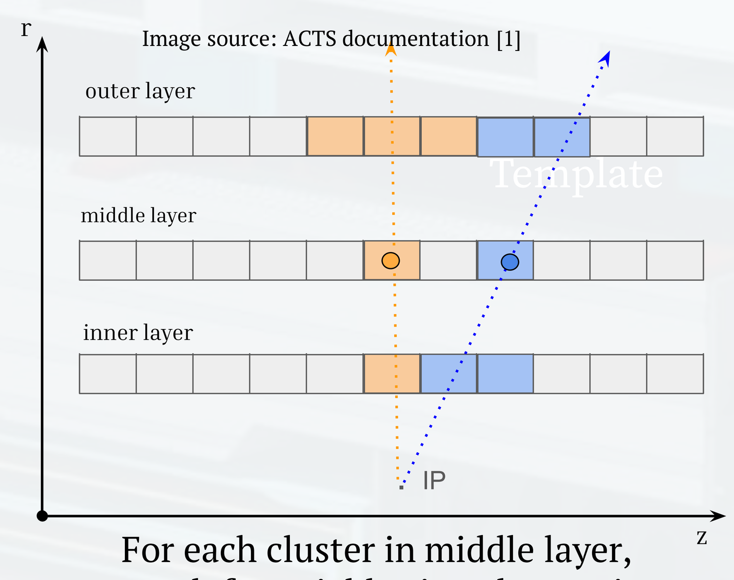
Apply a Kalman filter developed for the ALICE TPC [2] to predict the position of future clusters, and add clusters that fall within the proper search window.

Efficiency

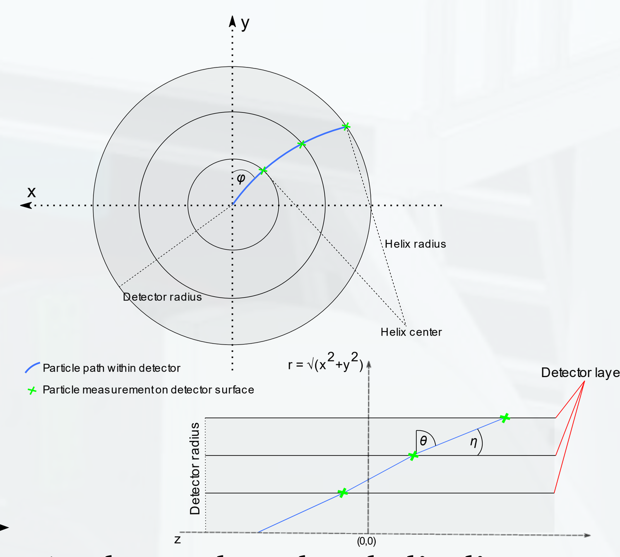


Silicon Track Seeding with ACTS

MVTX Triplet Seeding



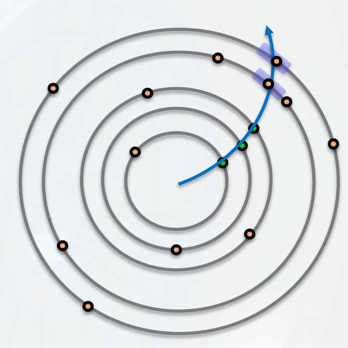
For each cluster in middle layer, search for neighboring clusters in top and bottom layer



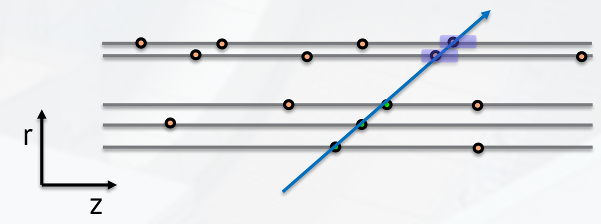
Apply cuts based on helix diameter, scattering corrections, DCA, seed multiplicity per cluster

Typical Parameters	
Min. p_T	100 MeV
Max. seeds per middle cluster	1
Search window max. Δr	15 mm
Max. impact parameter	20 mm
Max. transverse DCA	20 mm

Propagation to INTT

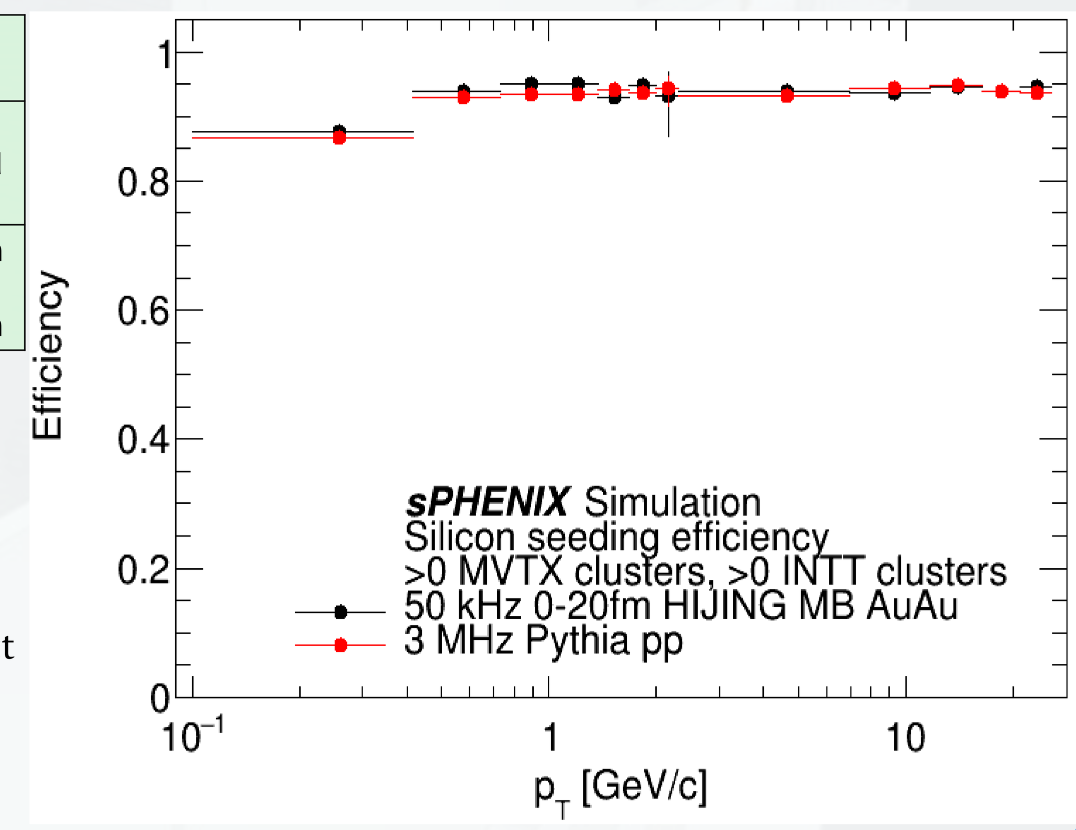


Typical Parameters	
Search window max. Δϕ	0.1 rad
INTT z strip width	16 mm / 20 mm



After assembling MVTX seed, project helix to INTT layers, add matching clusters to seed

Efficiency



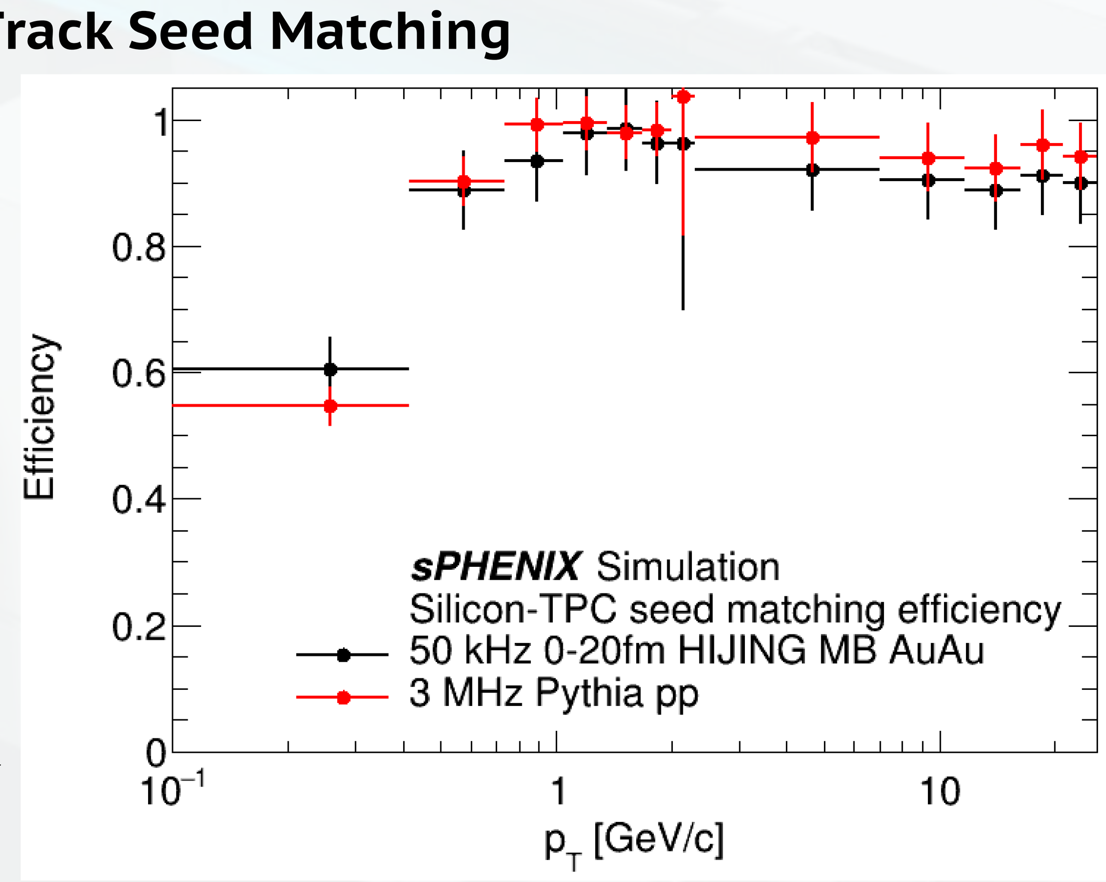
Track Seed Matching

Typical Parameters	
Search window max. Δη	0.005 (0.008 before TPC distortion correction)
Search window max. Δϕ	0.03 rad (0.04 rad before TPC distortion correction)

Searches for pairs of seeds (one silicon seed, one TPC seed) with similar enough (η, φ, z) in triggered (AuAu) events, or (η, φ) in extended-readout (pp) events. For each match, a track object containing both seeds is created.

Search window is p_T-dependent; lower-p_T seeds have significantly wider (2x, 4x, 6x wider) windows.

Also applies the INTT crossing measurement to the silicon seed in general, and assigns a crossing number to the TPC seed based on the silicon information.



If no silicon seed is found for a TPC seed, a track object is made anyway, containing only the TPC seed. This is useful for K_s and conversions, both of which may not produce any hits in the silicon detectors.

Without an associated silicon seed, the TPC-only track object has an unknown absolute z position; in triggered data-taking, this is resolved by assuming the seed originated at the triggered crossing.

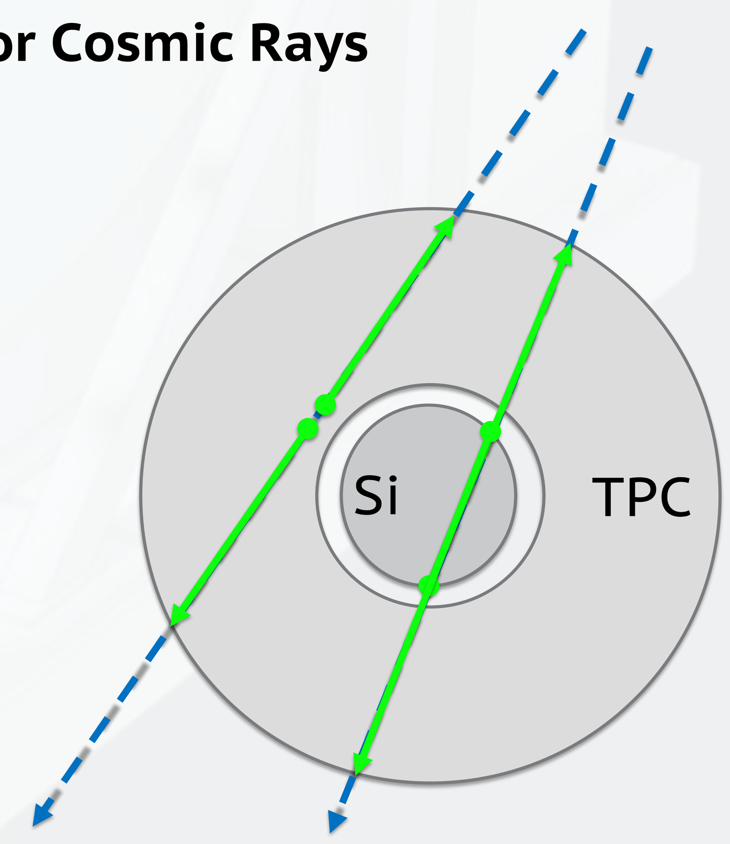
Track Seeding for Cosmic Rays

The same CA seeding module is used for cosmic ray reconstruction in the TPC, but with much wider search windows.

One consequence: cosmic ray track gets split into two TPC seeds (one incoming, one outgoing).

Typical Parameters	
Search window max. Δϕ	1 rad
Search window max. Δz	50 cm

The silicon seed is generated by propagating the TPC seed into the silicon detectors, using a fitted helix approximation, and finding nearby clusters.



References and Acknowledgements

[1] Ai, X., Allaire, C., Calace, N. et al. A Common Tracking Software Project. Comput Softw Big Sci 6, 8 (2022). https://doi.org/10.1007/s41781-021-00078-8

[2] Alice O2 Group. Alice O2 Software. Github repository. https://doi.org/10.5281/zenodo.1493334

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