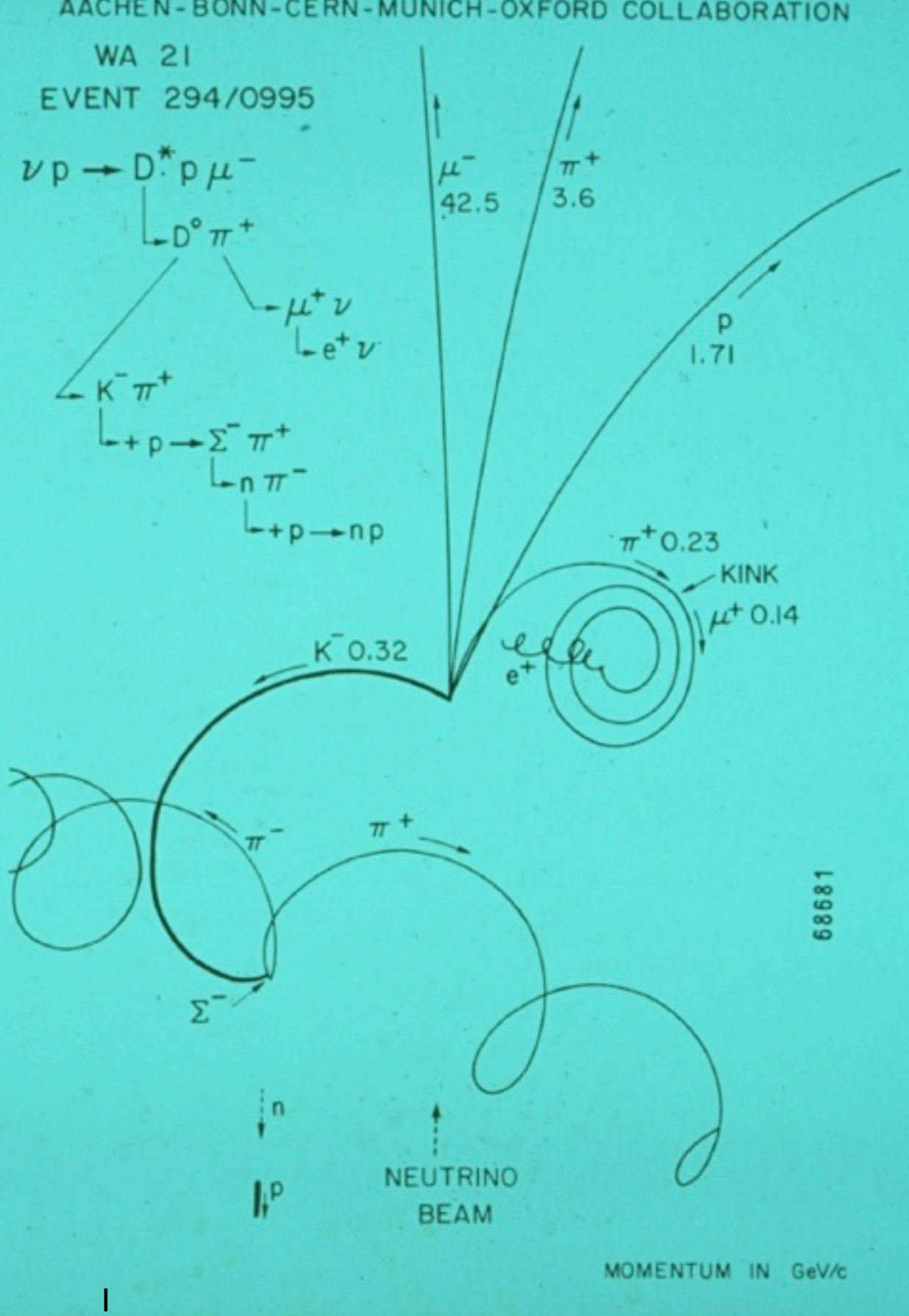
Tracking

Eugenio Paoloni



Argomenti Della Presentazione

- Il gruppo del tracking e la sua missione
- Algoritmi di identificazione e fit delle tracce
  - CDC: global track finder, local track finder.
  - VXD
  - CDC + VXD merging
  - Kalman fit
  - QA

Membri Del Gruppo

- Conveners del gruppo
  - Martin Heck, E.P.
- VXD & PXD:
  - Peter Kvasnicka, Peter Kodys, Rudi Früwirth, Jakob Lettenbichler, Manfred Valentan, Martin Ritter, Isabelle Ripp-Baudot
- CDC:
  - Viktor Trusov, Oliver Frost
- Cross-detector:
  - Giulia Casarosa, Benjamin Oberhof, Myroslav Stefaniuk
- Kalman Fit:
  - Tobias Schlüter, Johannes Rauch
- Analysis Data Model:
  - Markus Prim
- QA:
  - Micheal Ziegler, Simon Wehle

Road Map Presented At The 7th BPAC

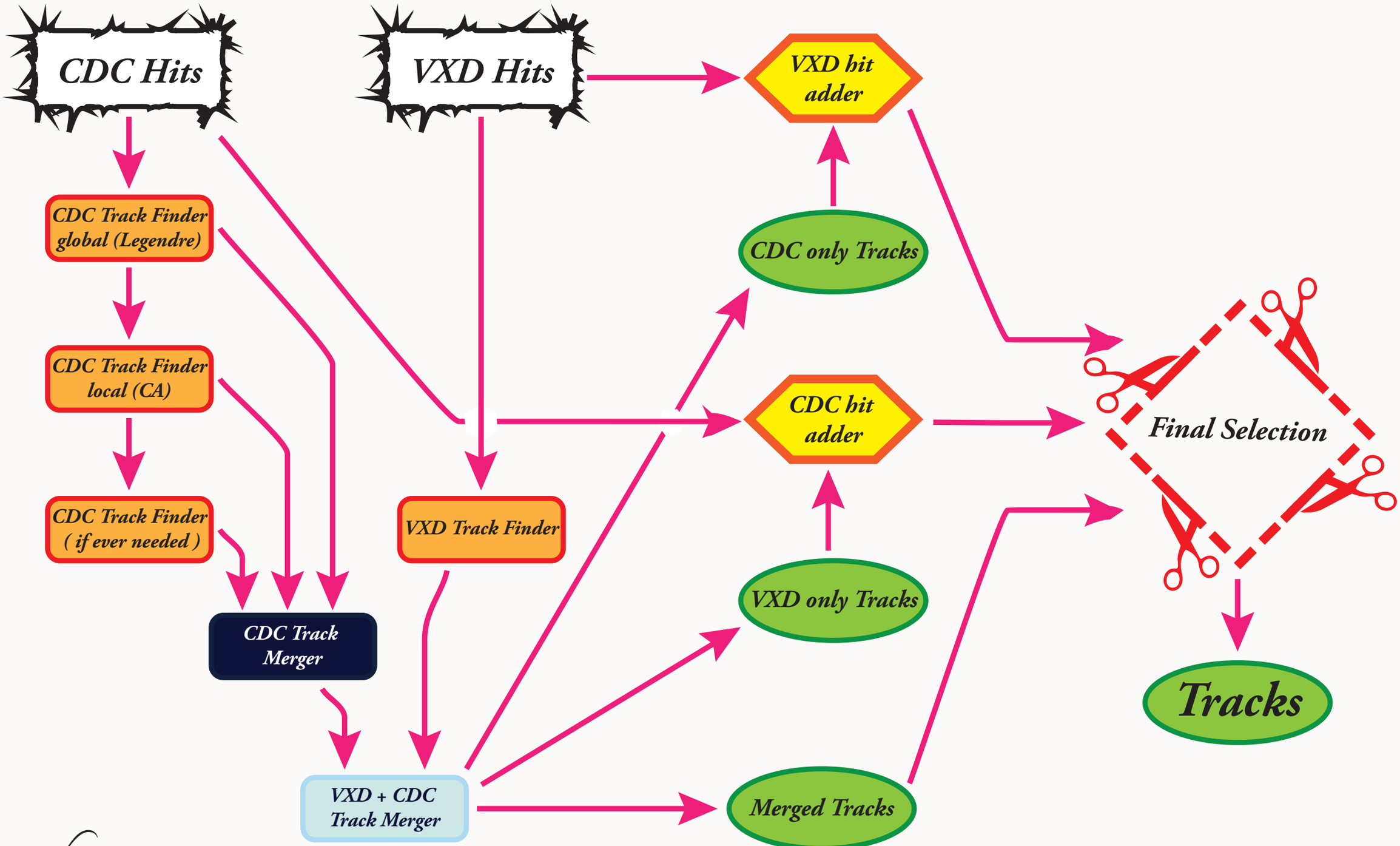
Now

- ~March: CDC Track extrapolation to VXD → Anticipated to Feb.
  → **MC campaign in April 14**
- ~September: CDC Finder functionality
  → **Physics Trigger development**
- ~Spring 15: Low-Level Speed optimization for all track finders;
  Full VXD TF functionality, including making use of hits due to curling tracks (currently ignored);
  Cross detector searches;
  Killer module to remove likely fake or double-found tracks;
  → **cosmics with CDC, TOP, ECL,... in May 15**
- ~Spring 16: Studies of methods to determine systematics on trackfinding effieciency, fake rates, etc. (**should be done before Data Taking**)
- After data-taking begins:
  Validation MC ←→ Data
  Final Pattern Reco including hits from Cluster Rescue (tuning depends on background)
  Material budget determination
  → **High Quality Analysis**

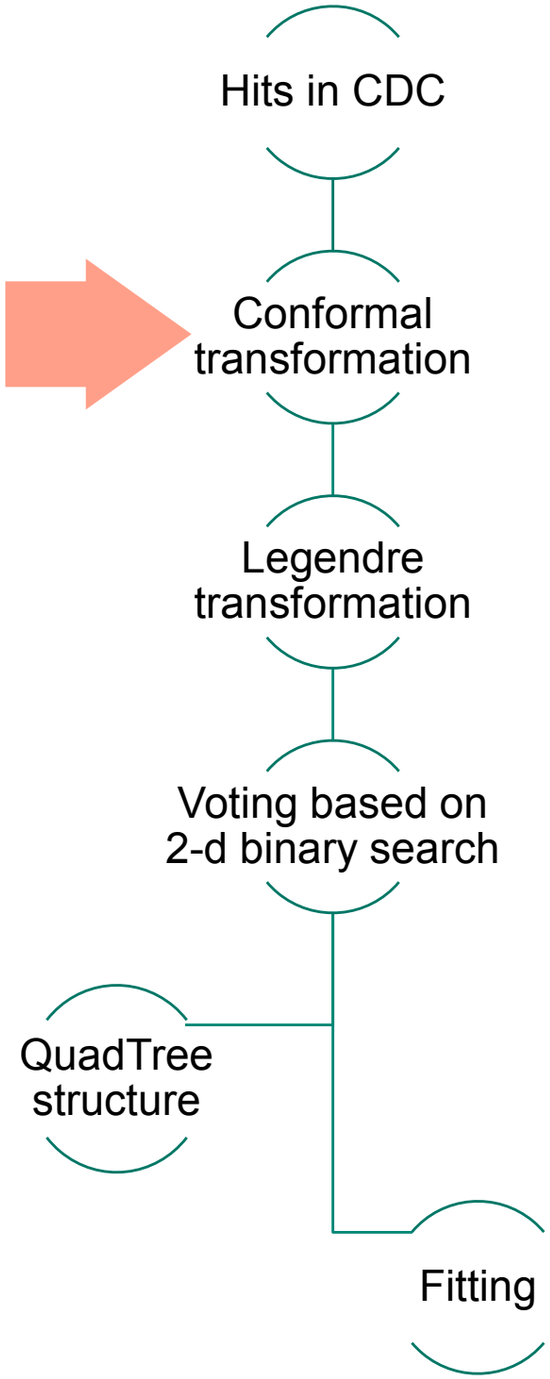
Missione Del Gruppo

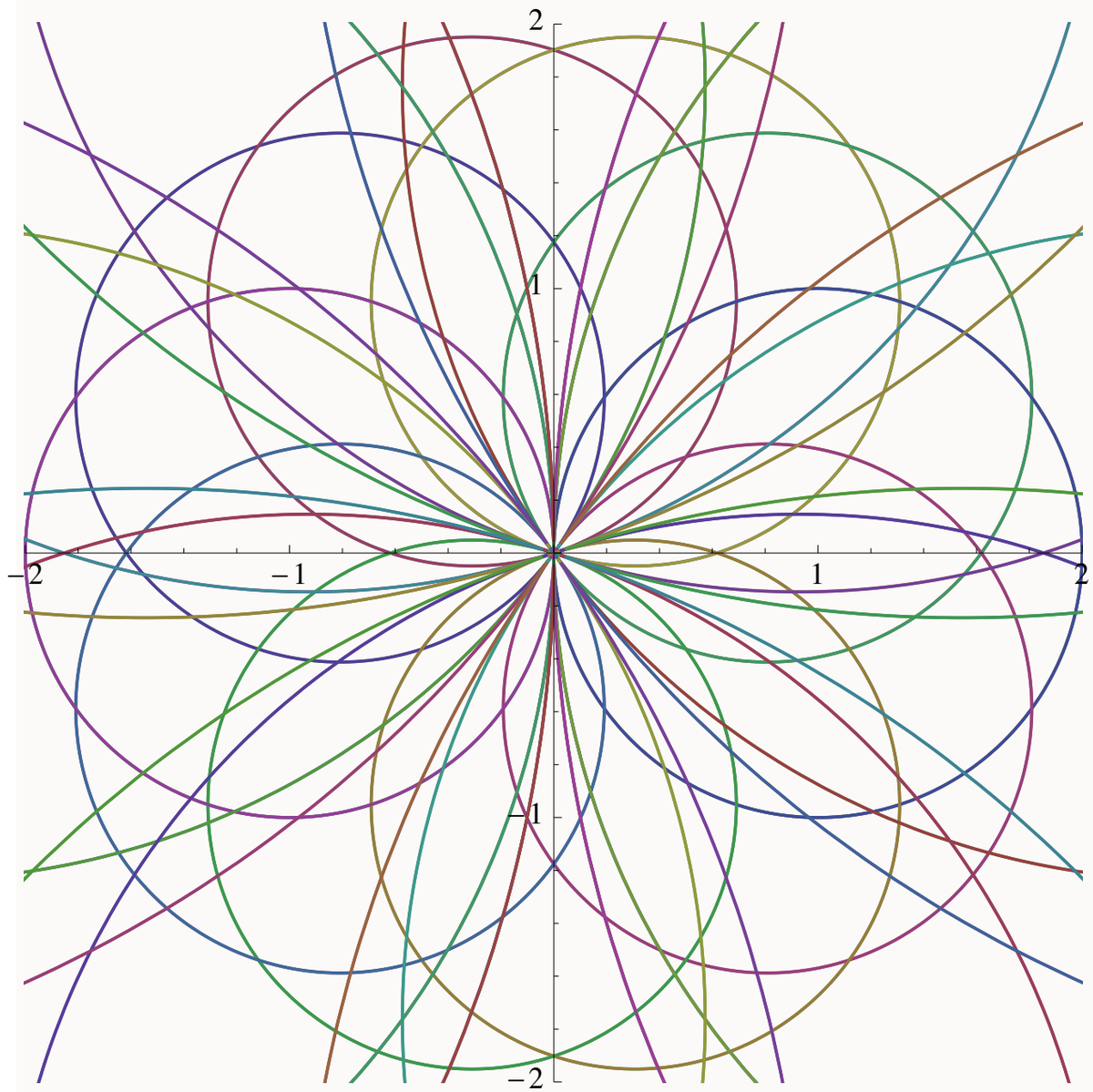
- Sviluppare e mantenere in funzione gli algoritmi per:
  - identificare gli hit prodotti da una stessa particella (pattern recognition),
  - connettere i puntini (per così dire) e determinare la traiettoria della particella.
- On-line durante la presa dati (sulla farm dell' High Level Trigger):
  - trigger, identificazione delle Regions Of Interests (ROI) sul PXD
- Off-line (ricostruzione completa degli eventi):
  - momento e posizione delle particelle nei pressi dell'IP,
  - estrapolazione delle traiettorie delle particelle dei rivelatori esterni necessaria per l'identificazione delle particelle.

Il Flusso Dei Dati

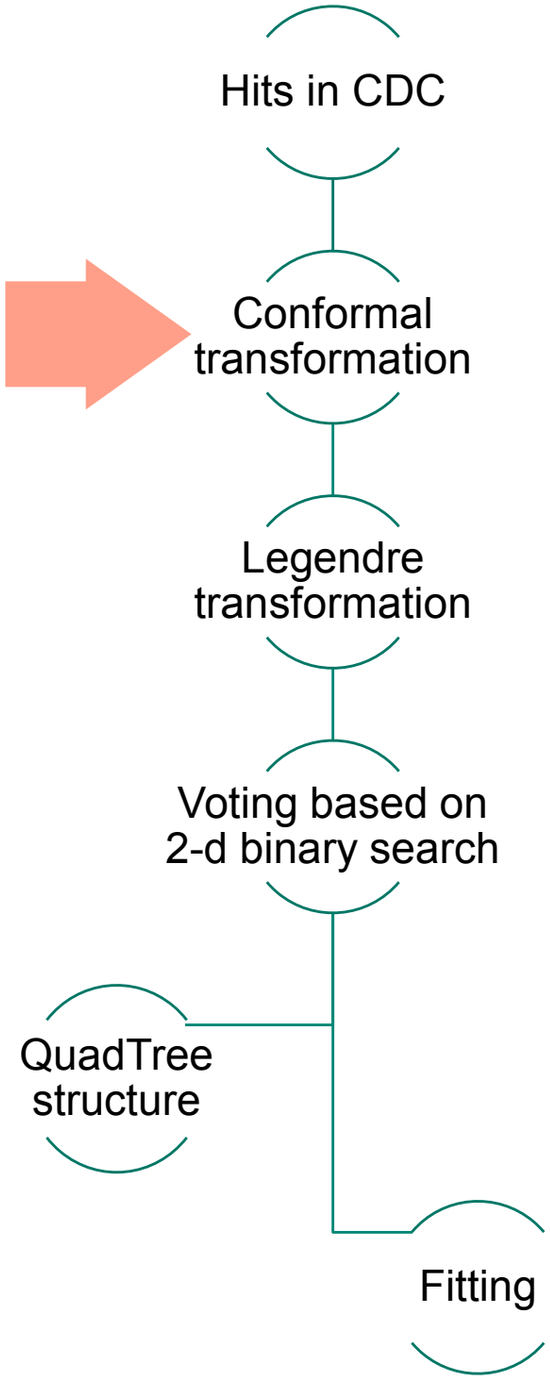


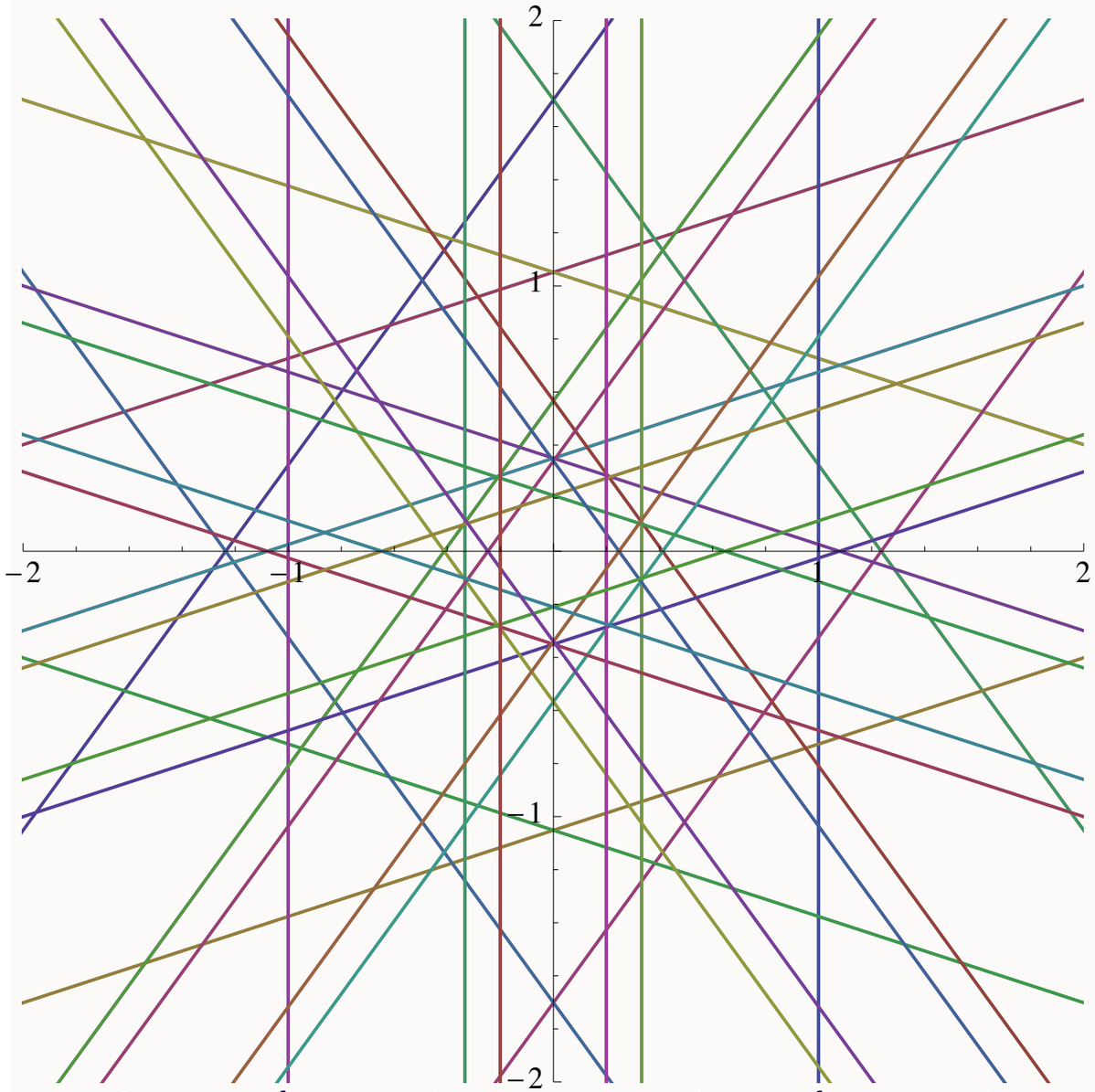
Legendre Track Finder





Legendre Track Finder



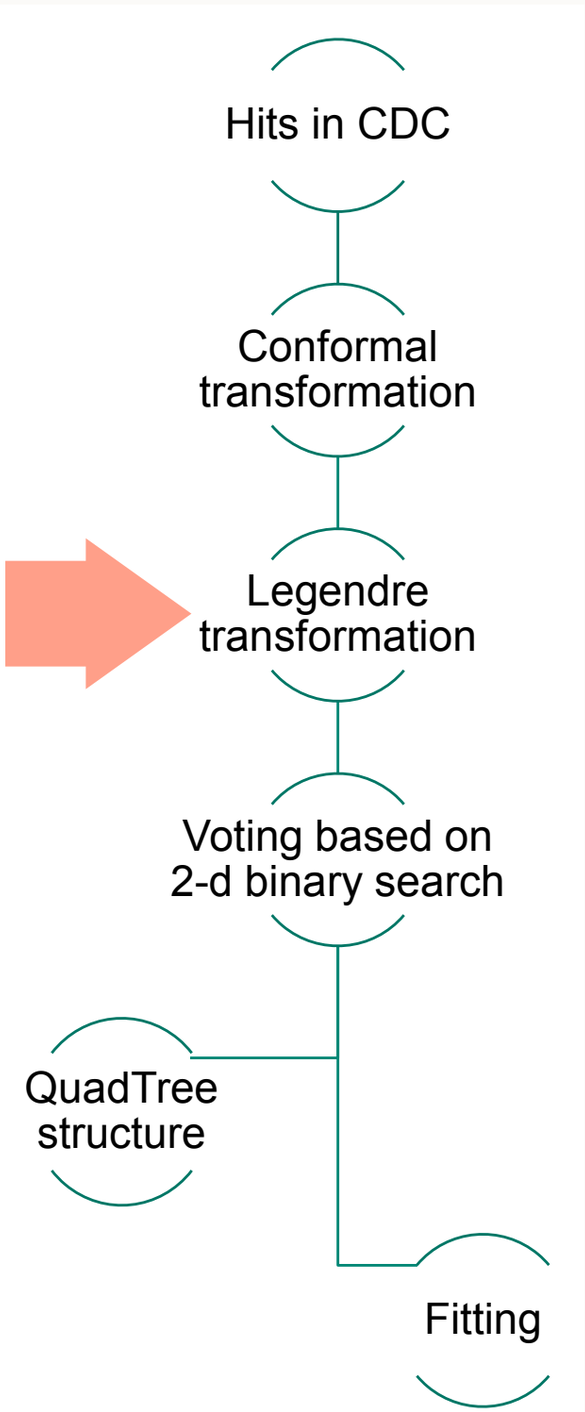


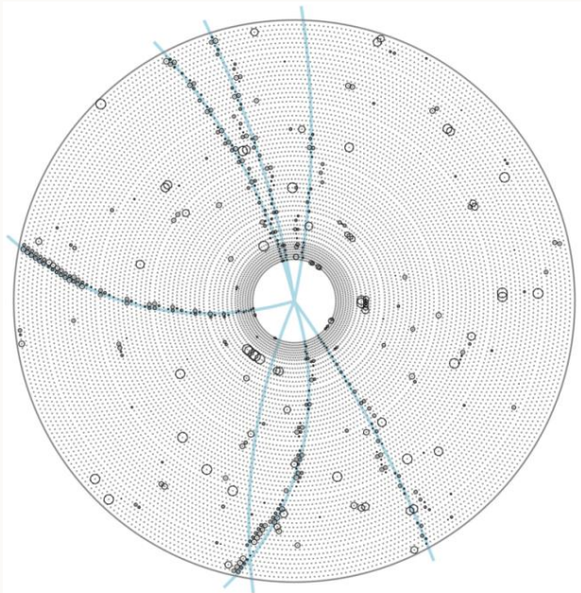
$$x' = \frac{2x}{x^2 + y^2}$$

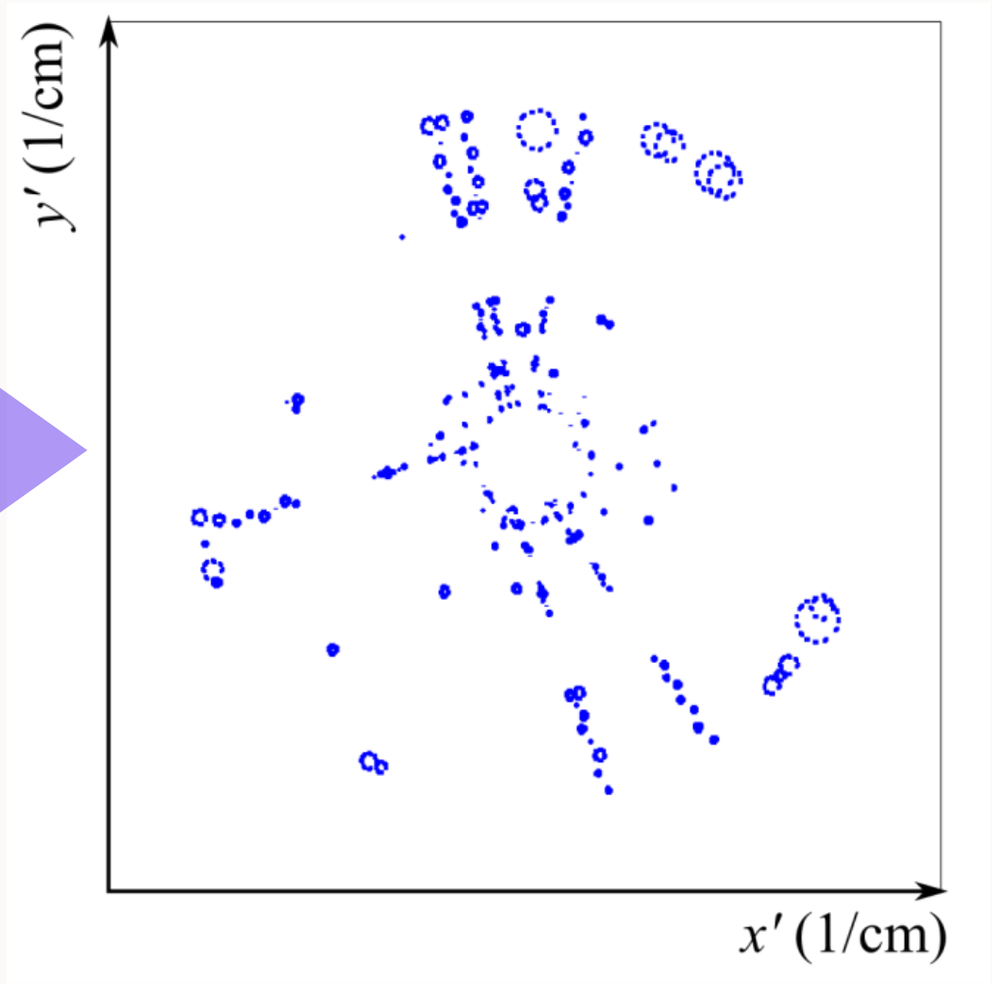
$$y' = \frac{2y}{x^2 + y^2}$$

La trasformazione porta circonferenze in circonferenze. In particolare circonferenze per l'origine in circonferenze degeneri.

Trasformazione Di Legendre

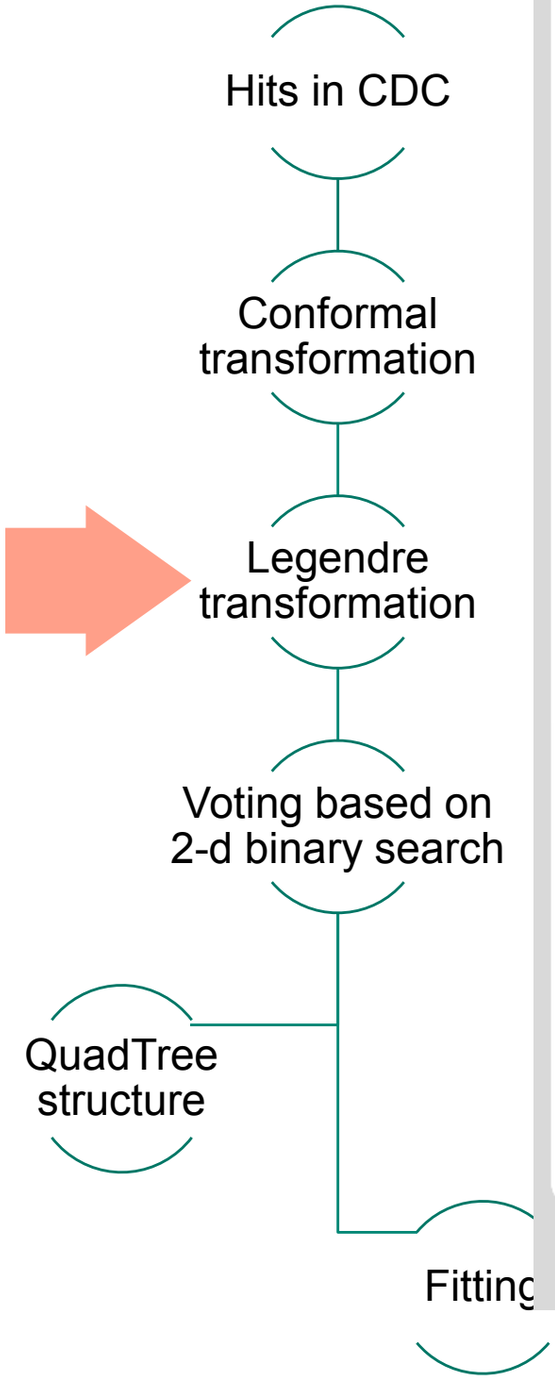






La trasformazione porta circonferenze in circonferenze.
In particolare le isocrone (in prima approssimazione circolari).

Trasformazione Di Legendre

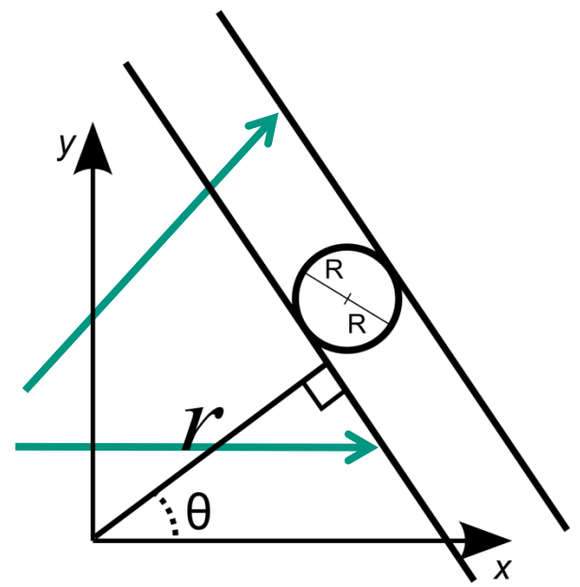


Transformation into Legendre space

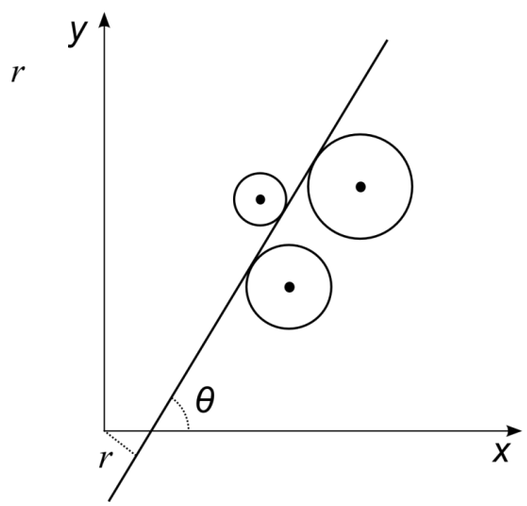
- The method is based on applying Legendre transformation to each drift circle in conformal space
- Legendre transformation of the circle can be written in next form:

$$f(x) \overset{\mathcal{L}}{\leftrightarrow} \begin{cases} r = x_0 \cos\theta + y_0 \sin\theta + R & \text{for concave} \\ r = x_0 \cos\theta + y_0 \sin\theta - R & \text{for convex} \end{cases}$$

which presents tangents to the circle

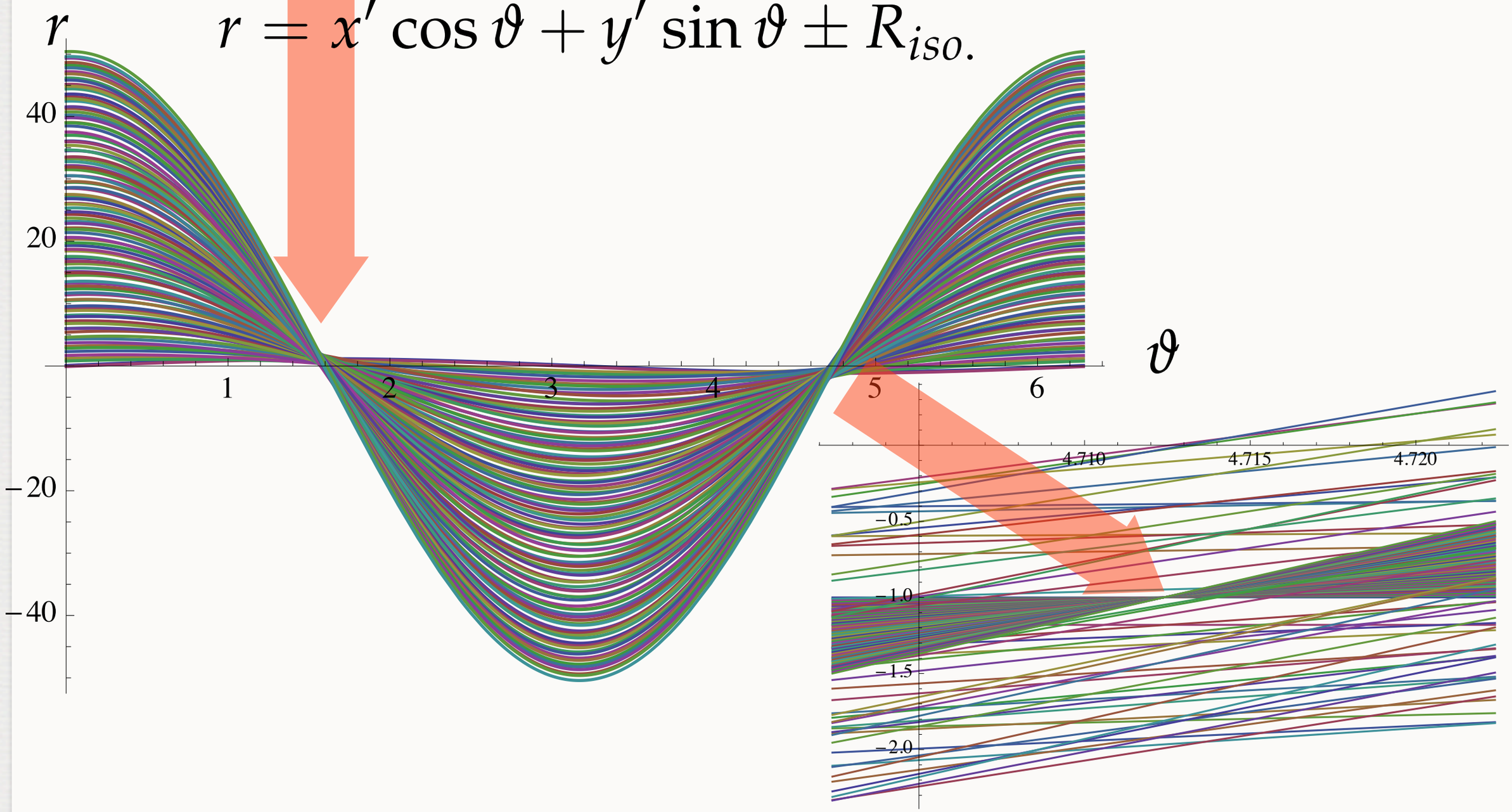


- Representation of the circle in the r, θ Legendre transformation space

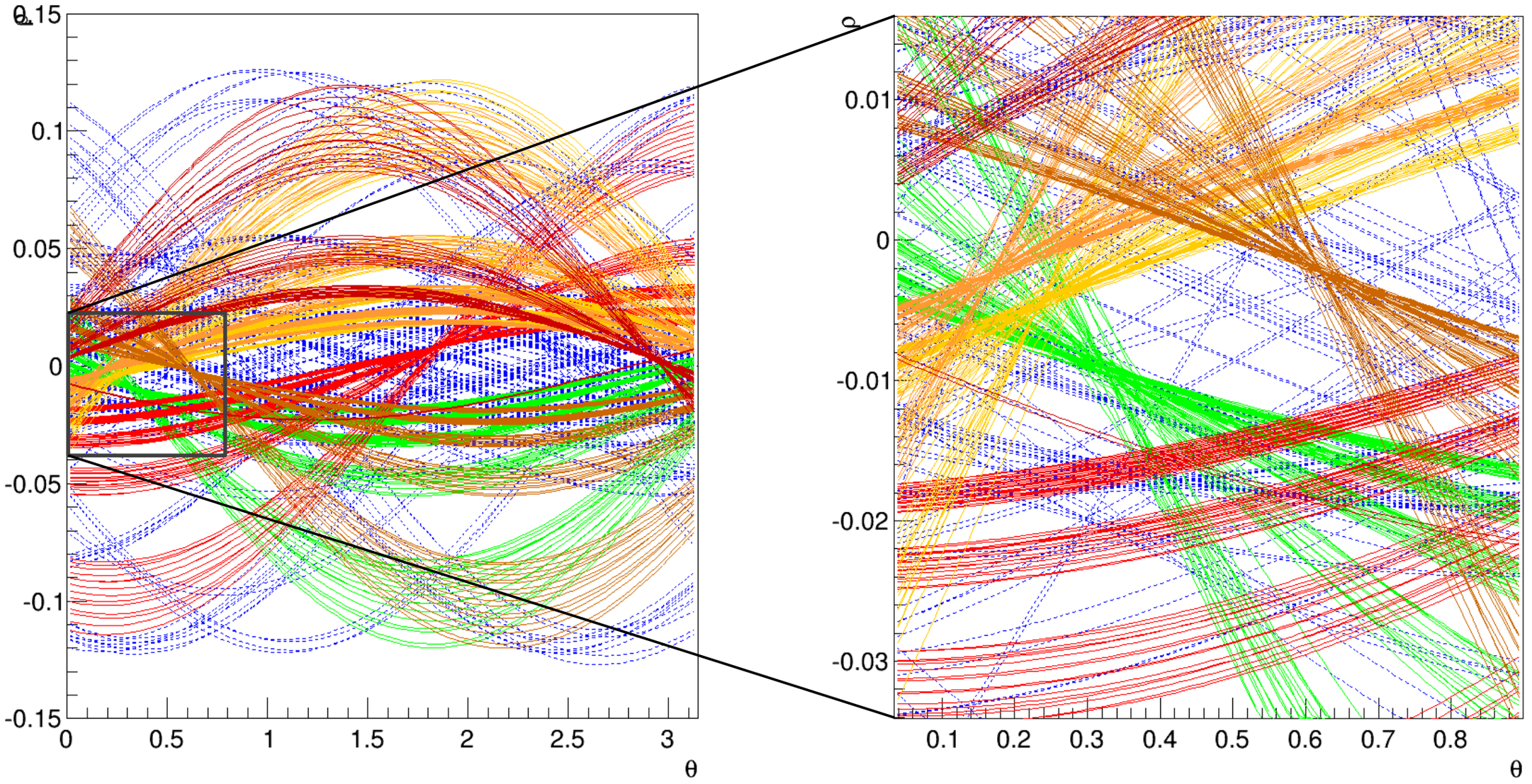


Provare Per Credere

$$r = x' \cos\vartheta + y' \sin\vartheta \pm R_{iso.}$$

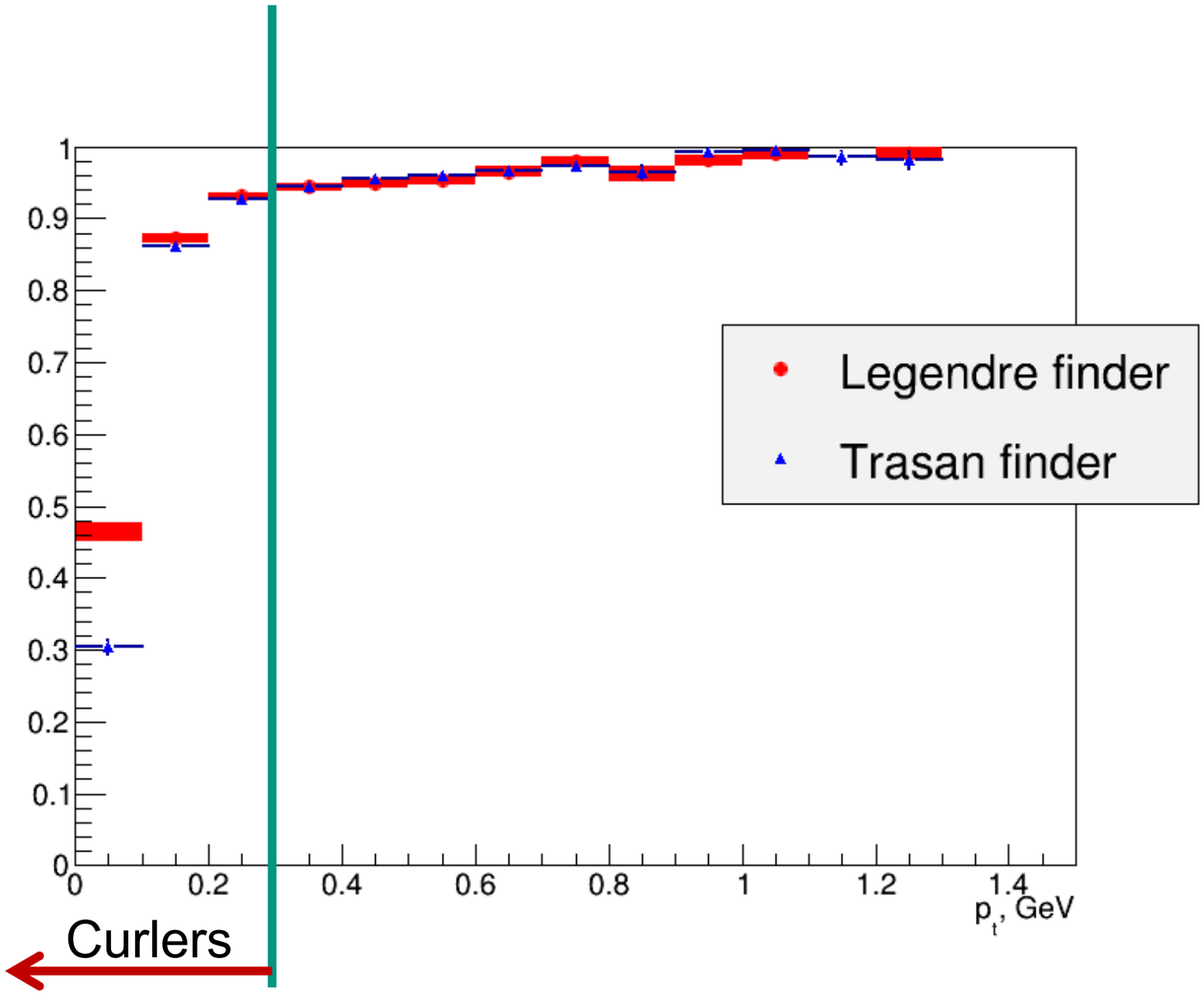


Sinograms of simulated event



Efficiency

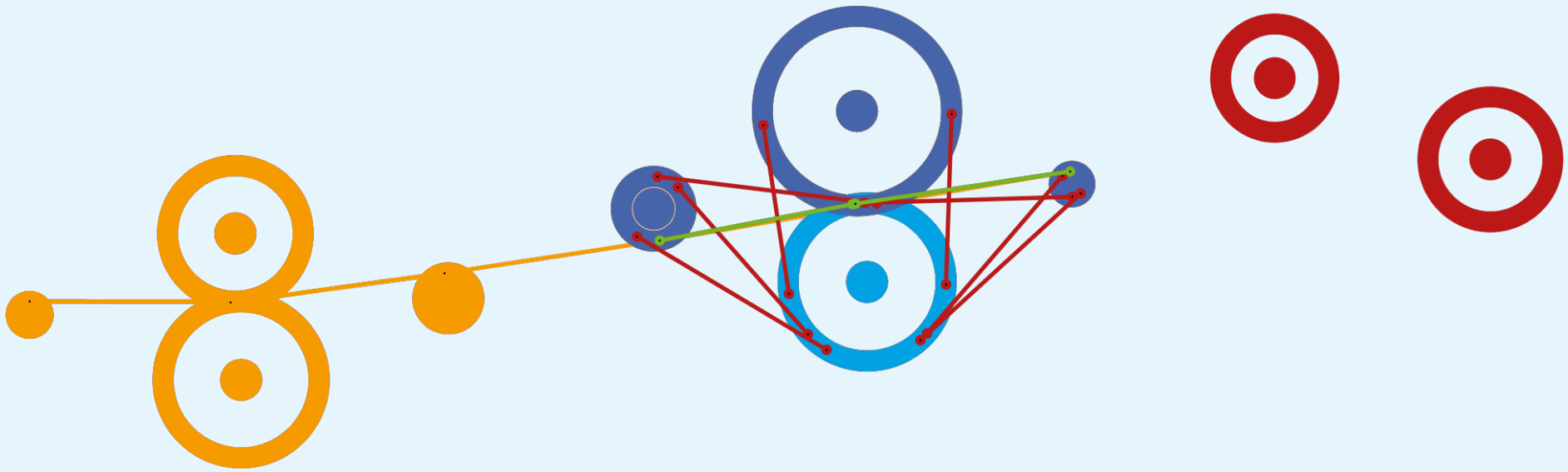
- Trasan vs Legendre finder efficiency (based on pre-generated sample of generic $B\overline{B}$ decays)



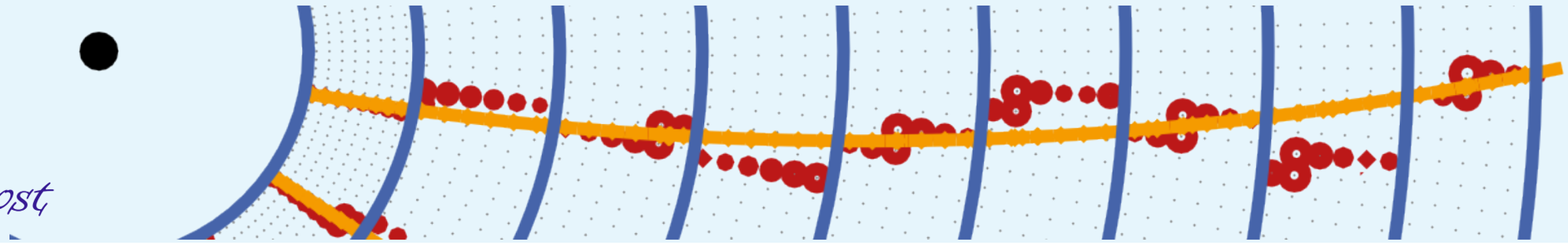
Local Track Finding

Bottom-up - A two stage process

Combine hits to segments limited by the superlayer bounds



Combine segments to tracks



Impasse Inaspettata...

Achievable cut quality for axial segment pair connections

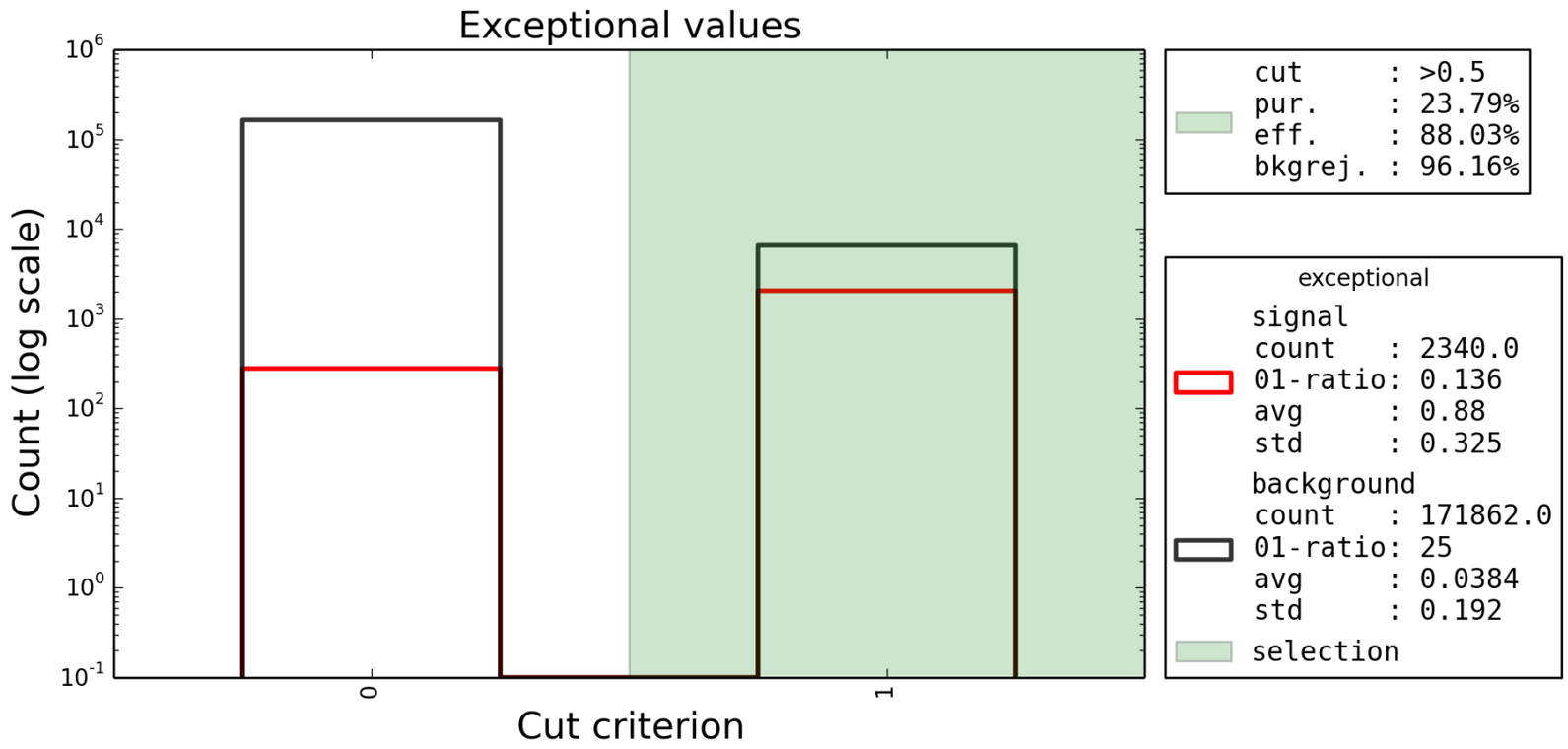
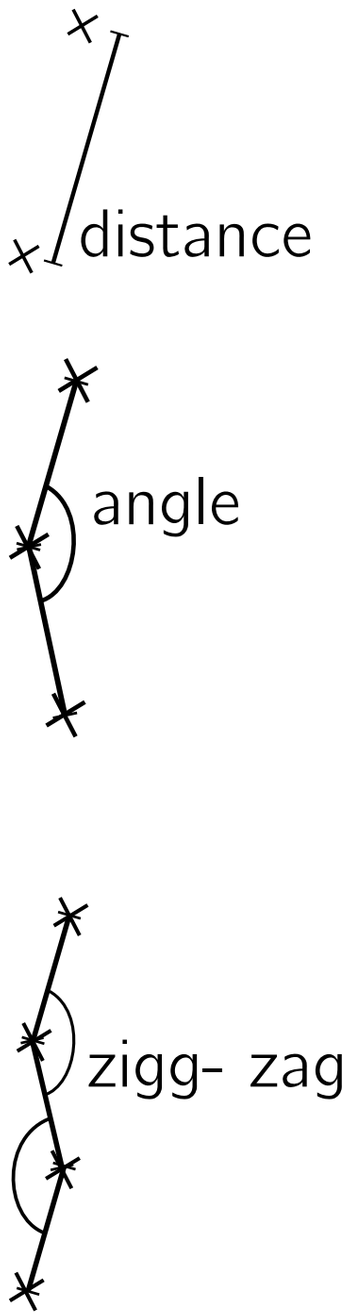


Figure: Cut using combination of parameter estimates - no error estimates calculated

Approach for reducing combinatorics



Schematic view of the low momentum track finder in Belle II

Unsorted hits from tracks, background, ghost coming from an event

O L *Sector setup - 1-hit filter*
filters by set of compatible sectors, allows momentum dependent setups

O L *Segment finder - 2-hit filter*
filters by distance, min&max, including virtual Segment

O L *2+1 hit filter*
High occupancy bypass (HOB)

O L *Neighbour finder - 3-hit filter*
filters by angle and Δ-distance min&max, pT

O L *3+1 hit filter*
HOB

L *Cellular Automaton*
evolving states, includes TC-collector

O L *Post 4-hit filter*
filters by zigZag, ΔpT, ...

Kalman filter
Calculates QI's

Circle fit
HOB for Kalman

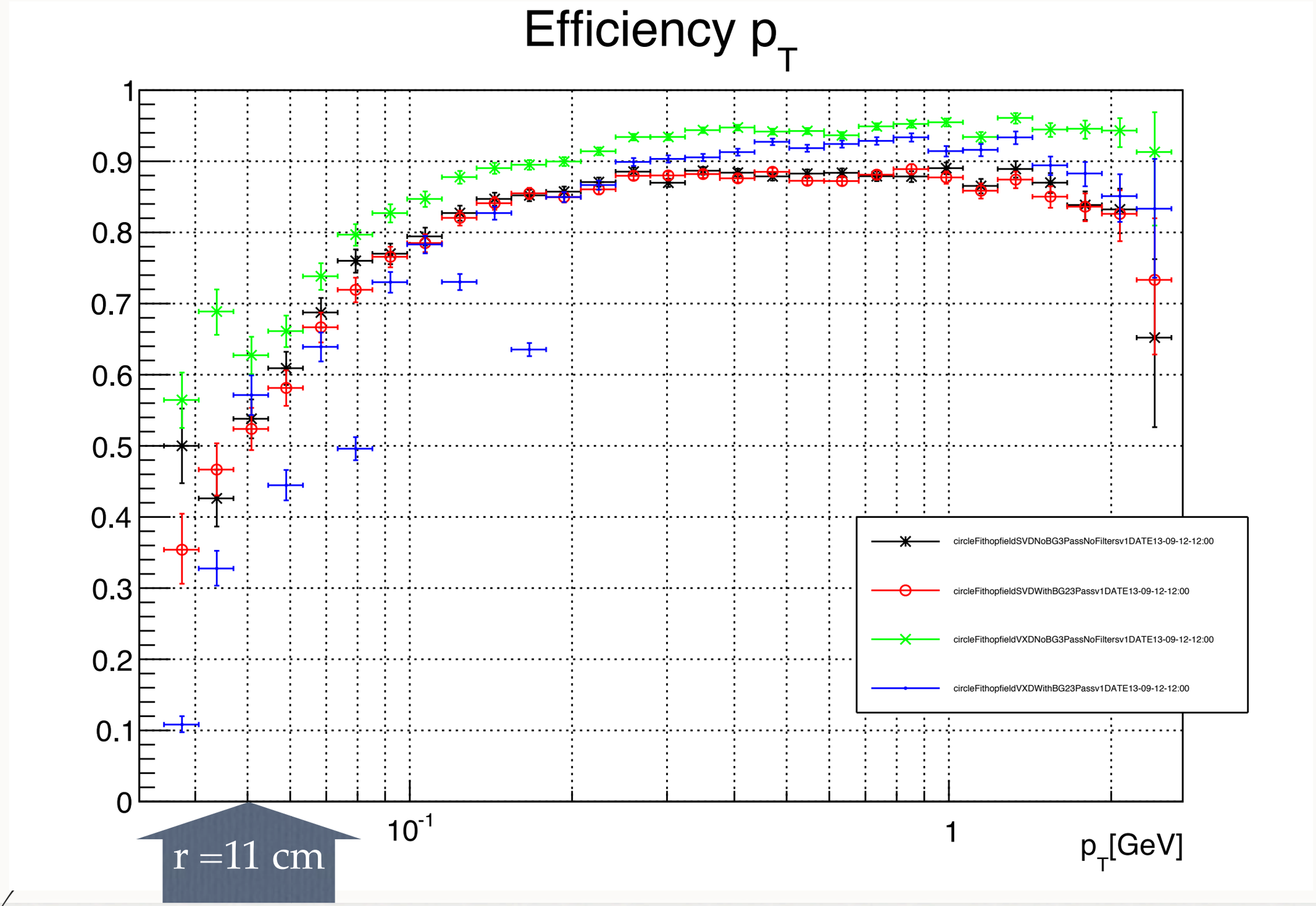
Greedy algorithm
HOB for Hopfield

Hopfield Network
uses QI's to find best subset among overlapping TC's

Clean TC's

- ***Black arrows*** *represent a schematic interpretation of the possible number of combinations of hits at that point*
- ***Red arrows*** *represent high occupancy bypass strategies*
- ***Filters*** *marked with an* ***O*** *use external information generated by simulation*
- ***Steps*** *marked with an* ***L*** *cycle through several passes*

Efficienza Del VXDTF



Pregi E Difetti Del VXDTF

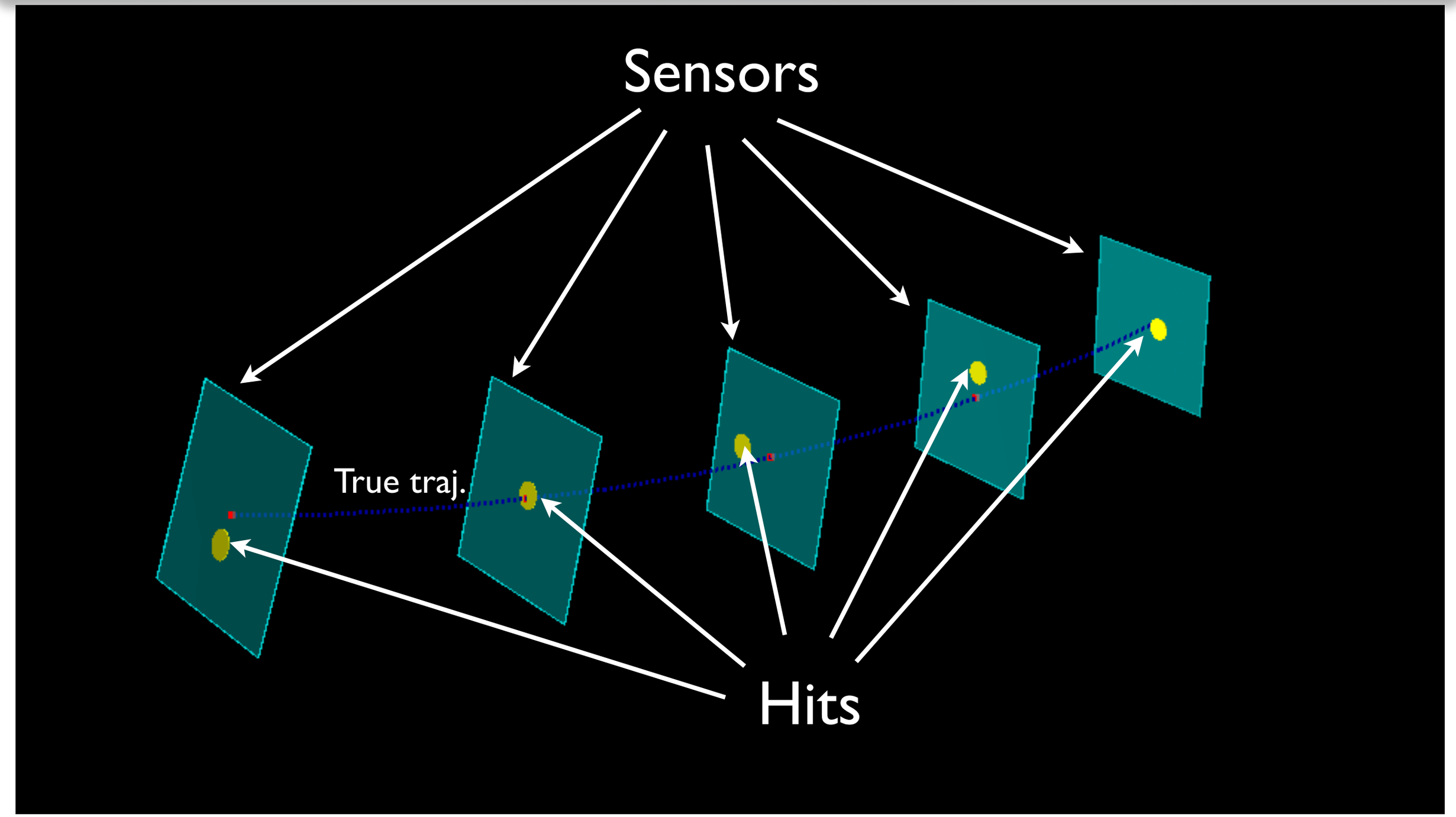
- Il codice si è comportato egregiamente durante il test-beam a Desy.
- Ha prestazioni degne di rispetto (specie in termini di velocità).
- Ma… ha oramai varcato la soglia del non ritorno dal punto di vista della mantenibilità.
  - Non dà risultati completamente ripetibili (spiacevoli differenze dell'ordine del per mille).
  - Ha poche classi, ma con metodi lunghi un migliaio di righe.
  - Non è scontato che il dottorando che lo sta sviluppando rimanga in Belle-II.
  - Migrazione (assistita) del codice in corso d'opera.

Unire i Puntini

Ovvero GenFit

Genfit Display - Visualizing a Track-Fit

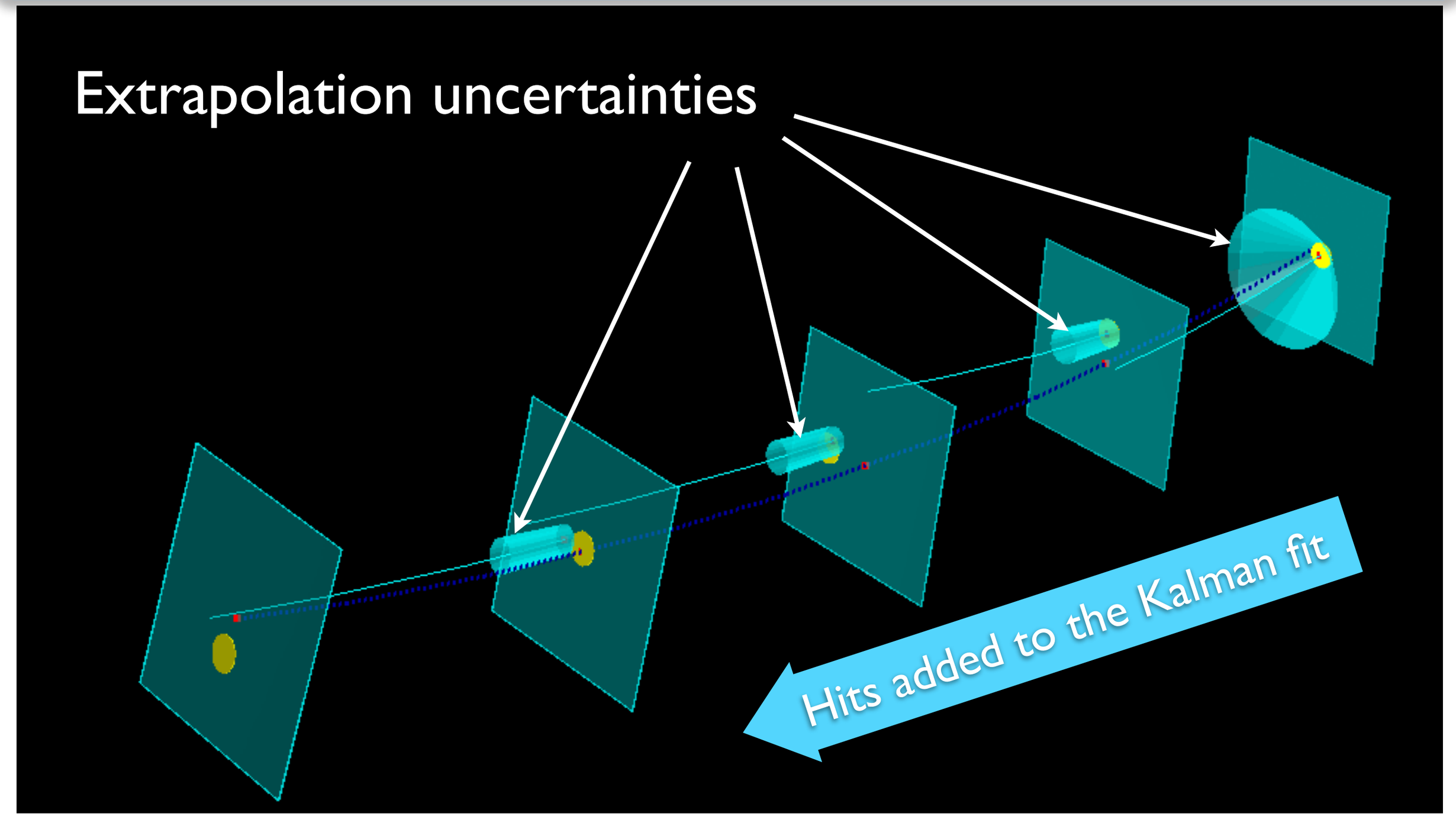
Technische Universität München



Reference track.

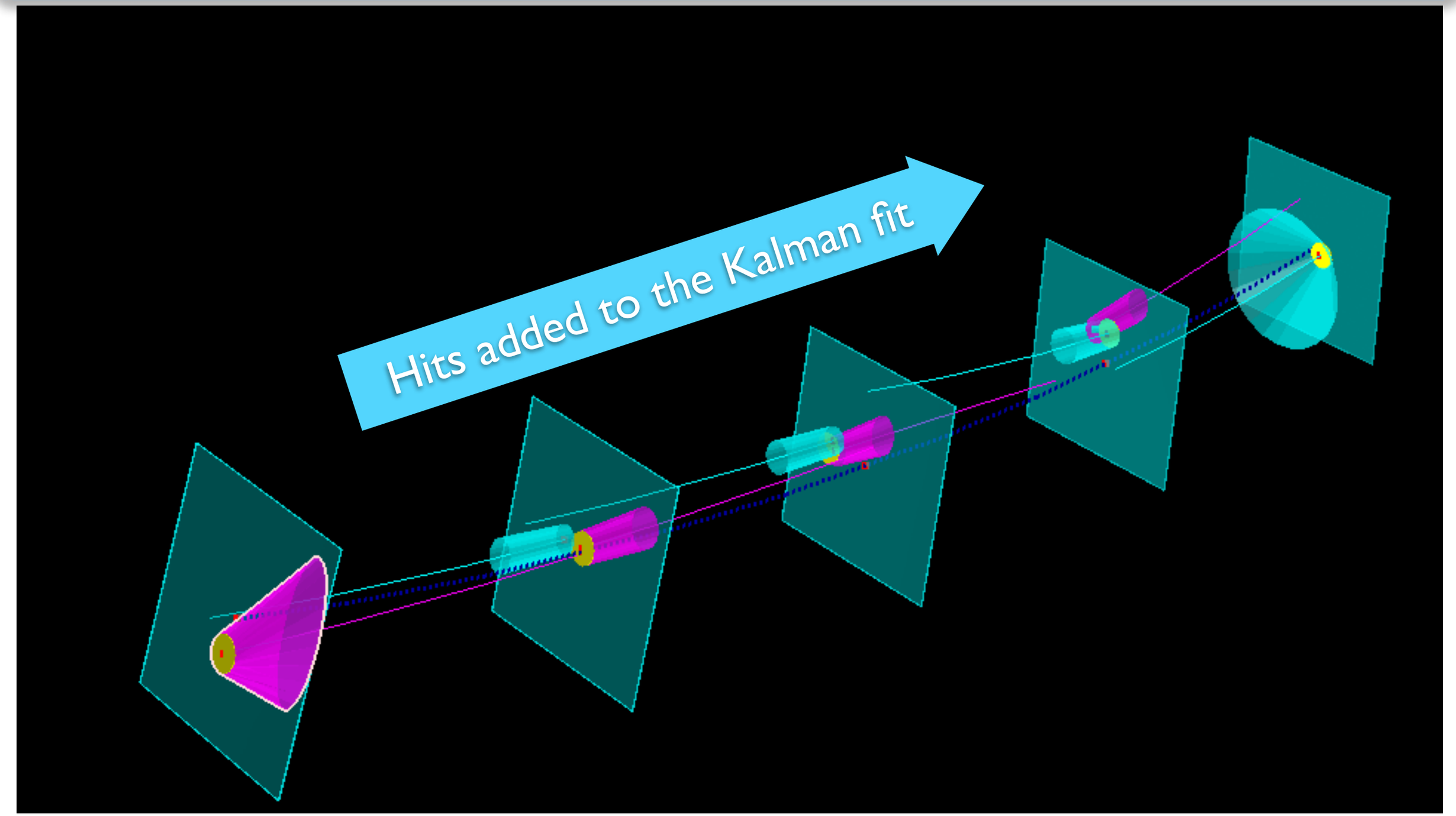
Genfit Display - Visualizing a Track-Fit

Technische Universität München



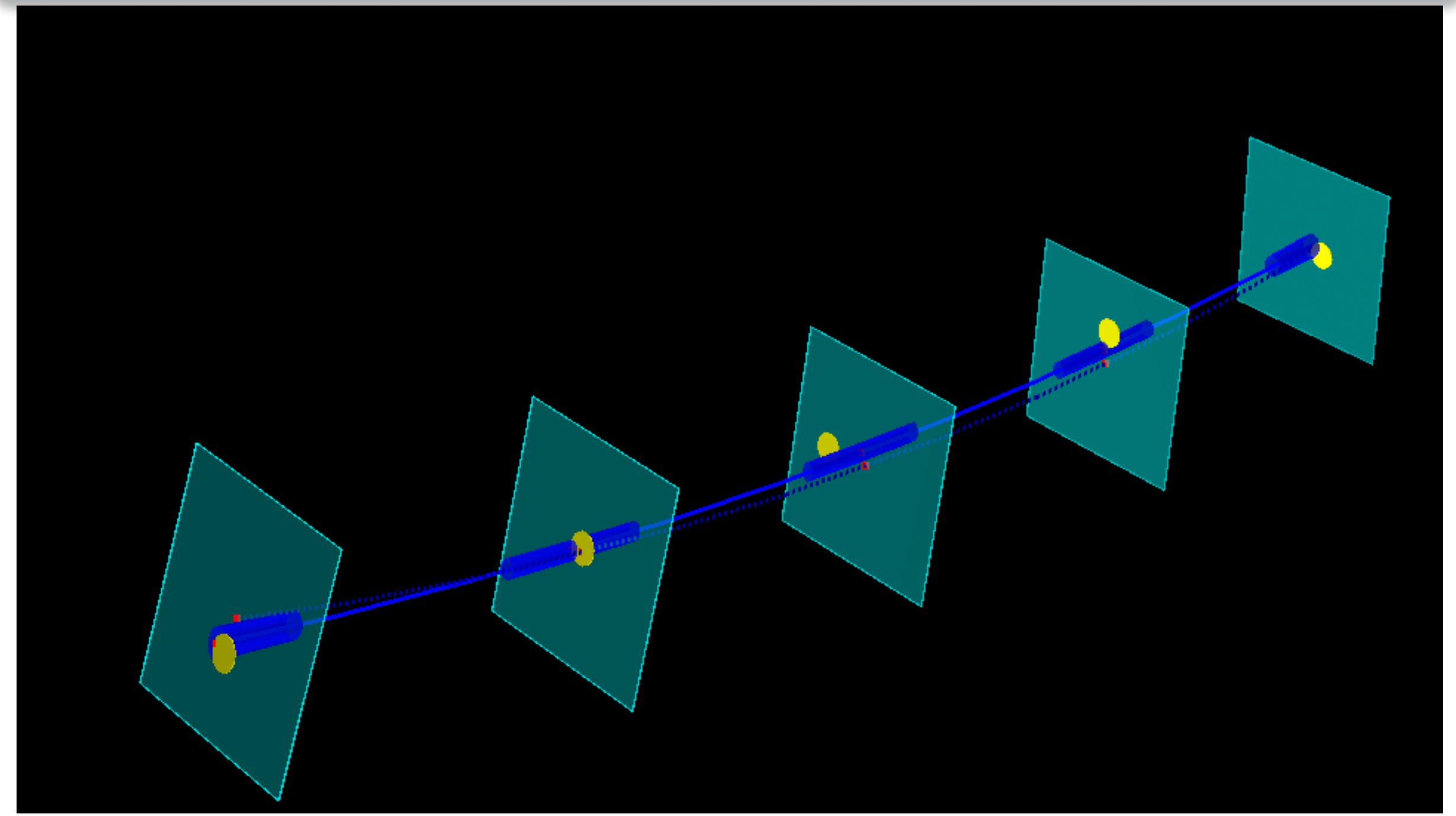
Forward fit.

Genfit Display - Visualizing a Track-Fit



Backward fit.

Genfit Display - Visualizing a Track-Fit



Smoothed track.

Track Merging (B. Oberhof)

VXDCDCTrackMerger algorithm

- *Tracks are extrapolated to CDC wall using StateOnPlane:*
  genfit::MeasuredStateOnPlane cdc_SoP=cdc_Track[i]->GetFittedState();
  cdc_SoP.extrapolateToCylinder(CDC_wall_radius, pos_seed, mom_seed);

- *Then we take 6D state vector and covariance matrix:*
  cdc_SoP.get6DStateCov(cdc_state, cdc_cov);

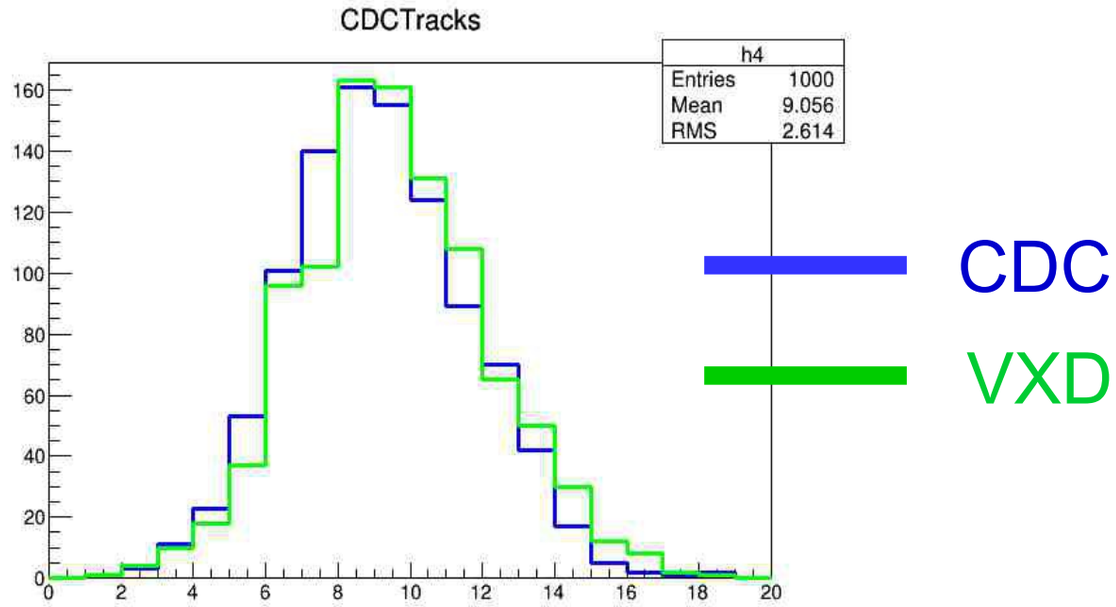
- *For every CDC track we loop over all VDX tracks and we calculate:*
  $X^2 = (cdc\_state - vxd\_state)\ (vxd\_cov + cdc\_cov)^{-1}\ (cdc\_state - vxd\_state)$

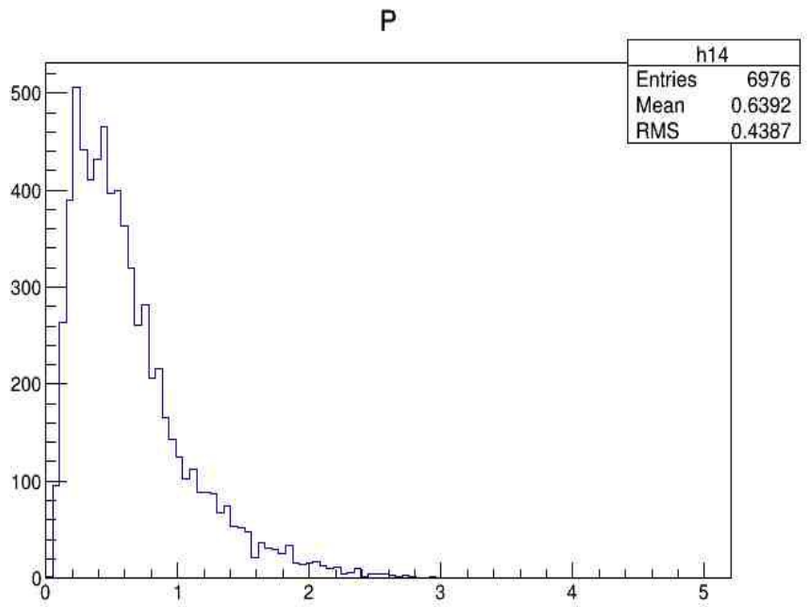
- *Only tracks with $X^2 < X^2_{max}$ are accepted (currently $X^2_{max}=100$, see plots later)*

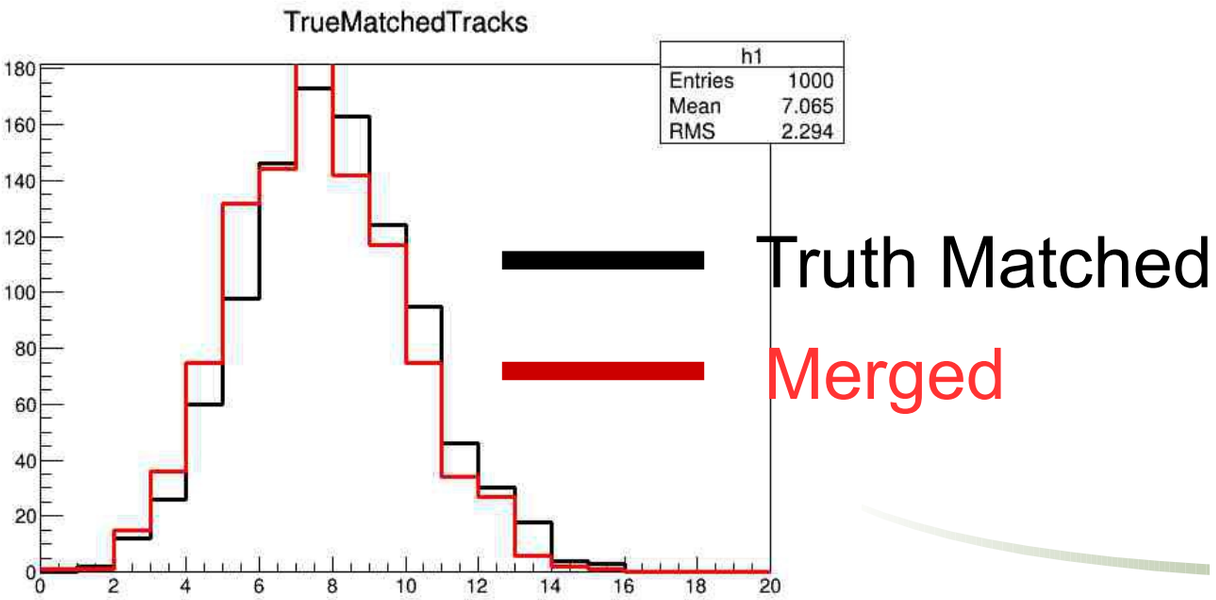
- *We match the two tracks with lowest X^2 and store their indexes in a:*
  RelationArray<CDCGFTrkidx, VXDGFTrkidx>

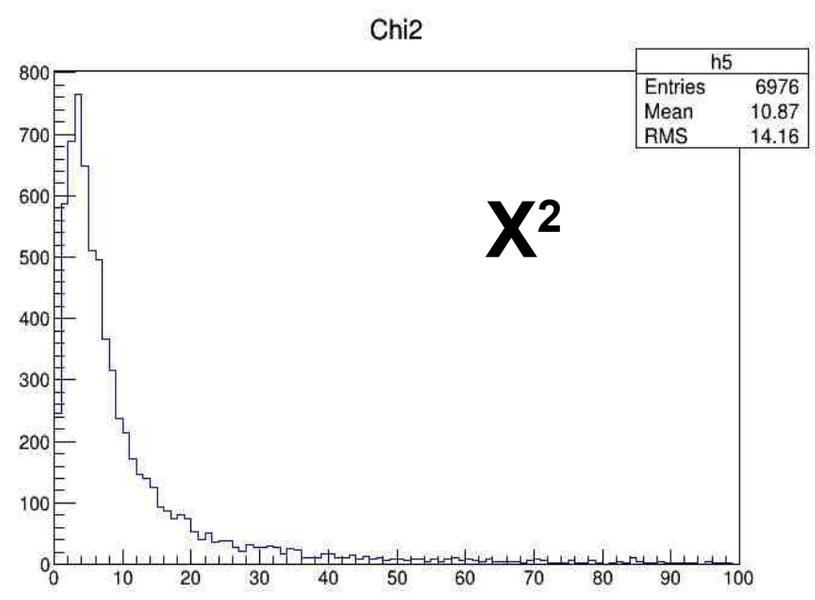
Simulation with EvtGen

- *For a more realistic test we used EvtGenInput generator*
- *1000 evts with default generator setting*



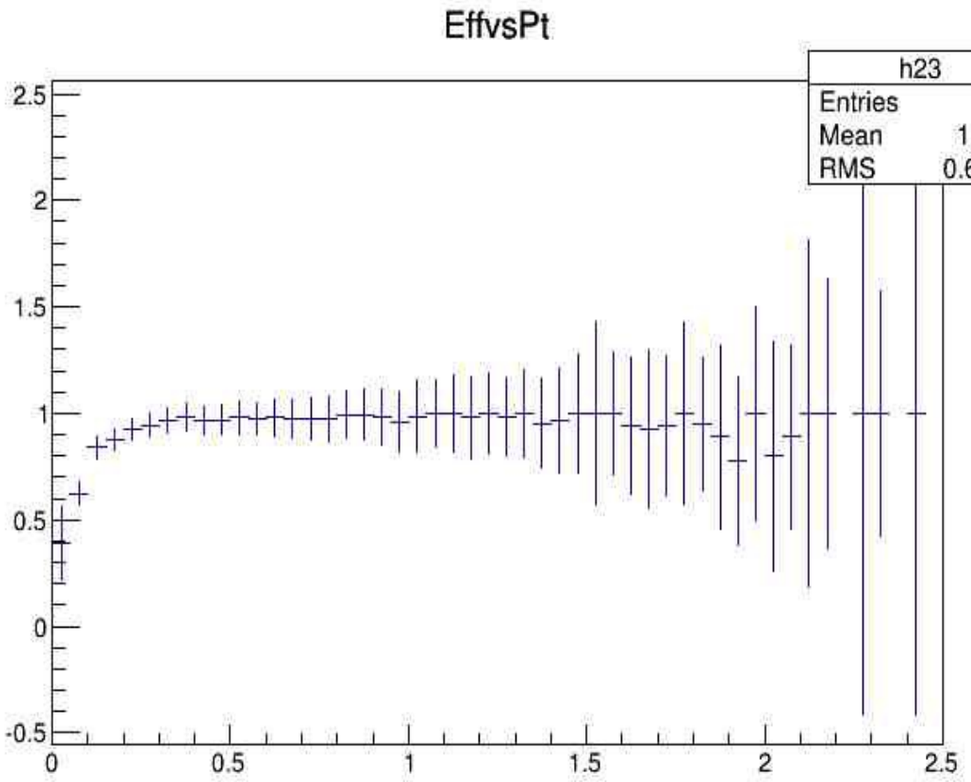


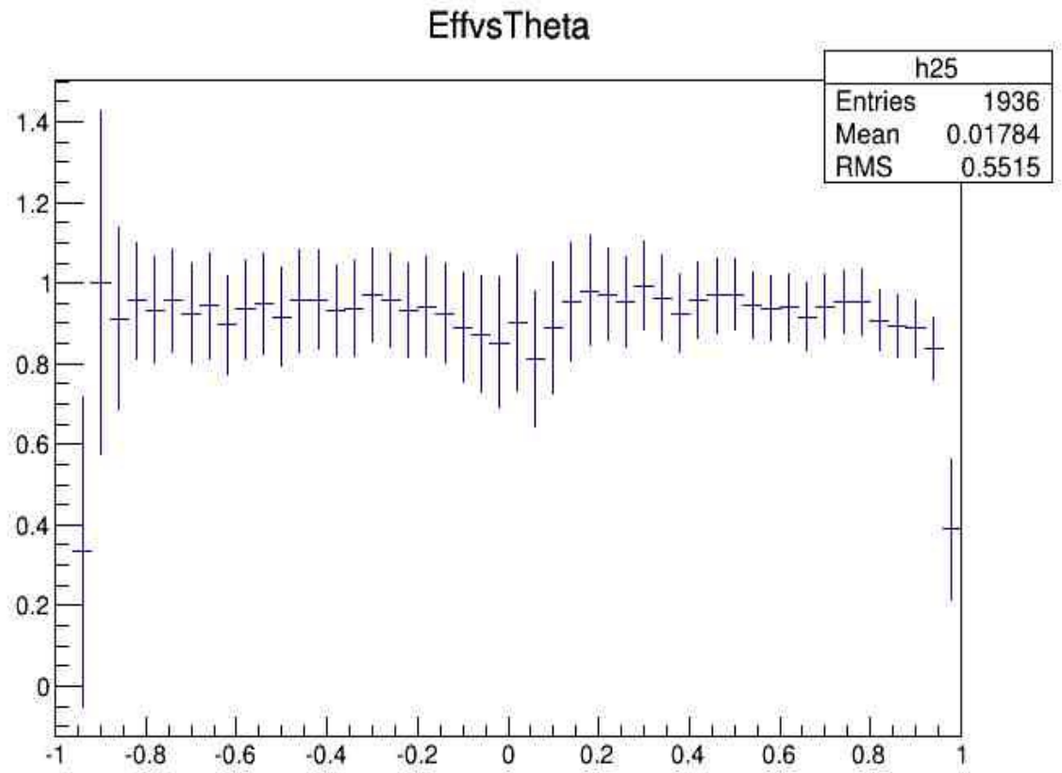




Risultati Con EvtGen

- *Efficiency (correctly merged/truly matched): 93.2%*
- *Purity (correctly merged/merged): 98.9%*





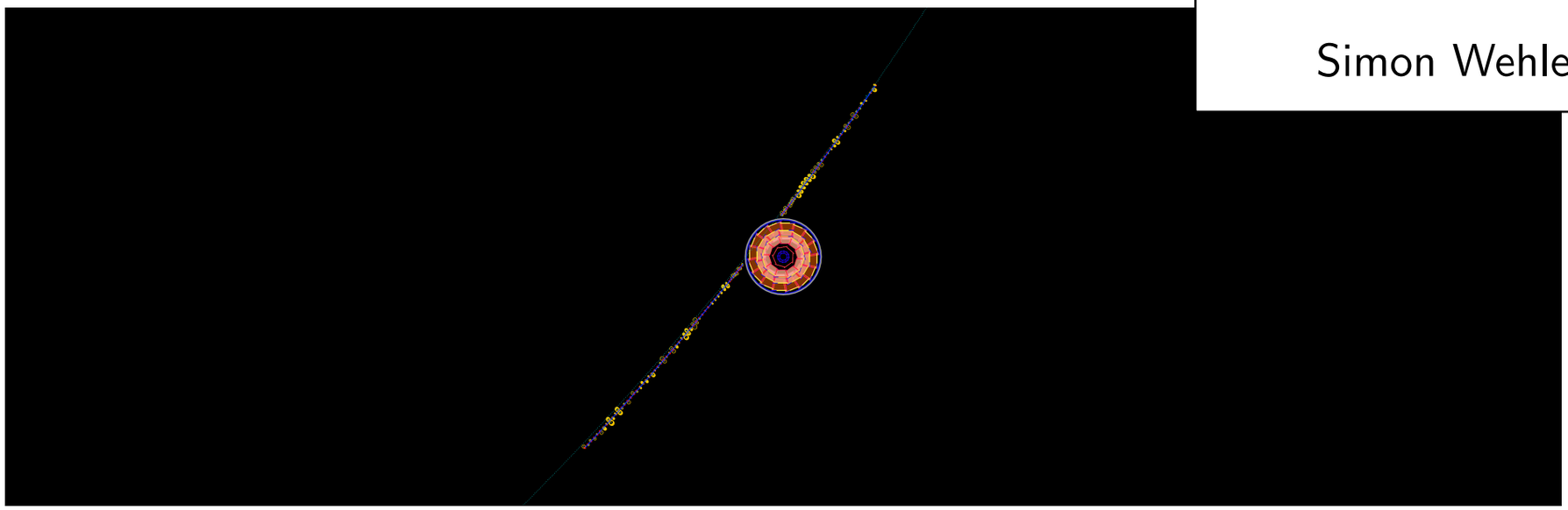
- *Efficiency drop for $p_T < 300$ MeV, confirms muon result*
- *Significant drop in the forward region, some minima around $\vartheta = 0$*

Helix parameter correlation

Alignment Validation

F2F Tracking Meeting in Pisa

Simon Wehle, DESY

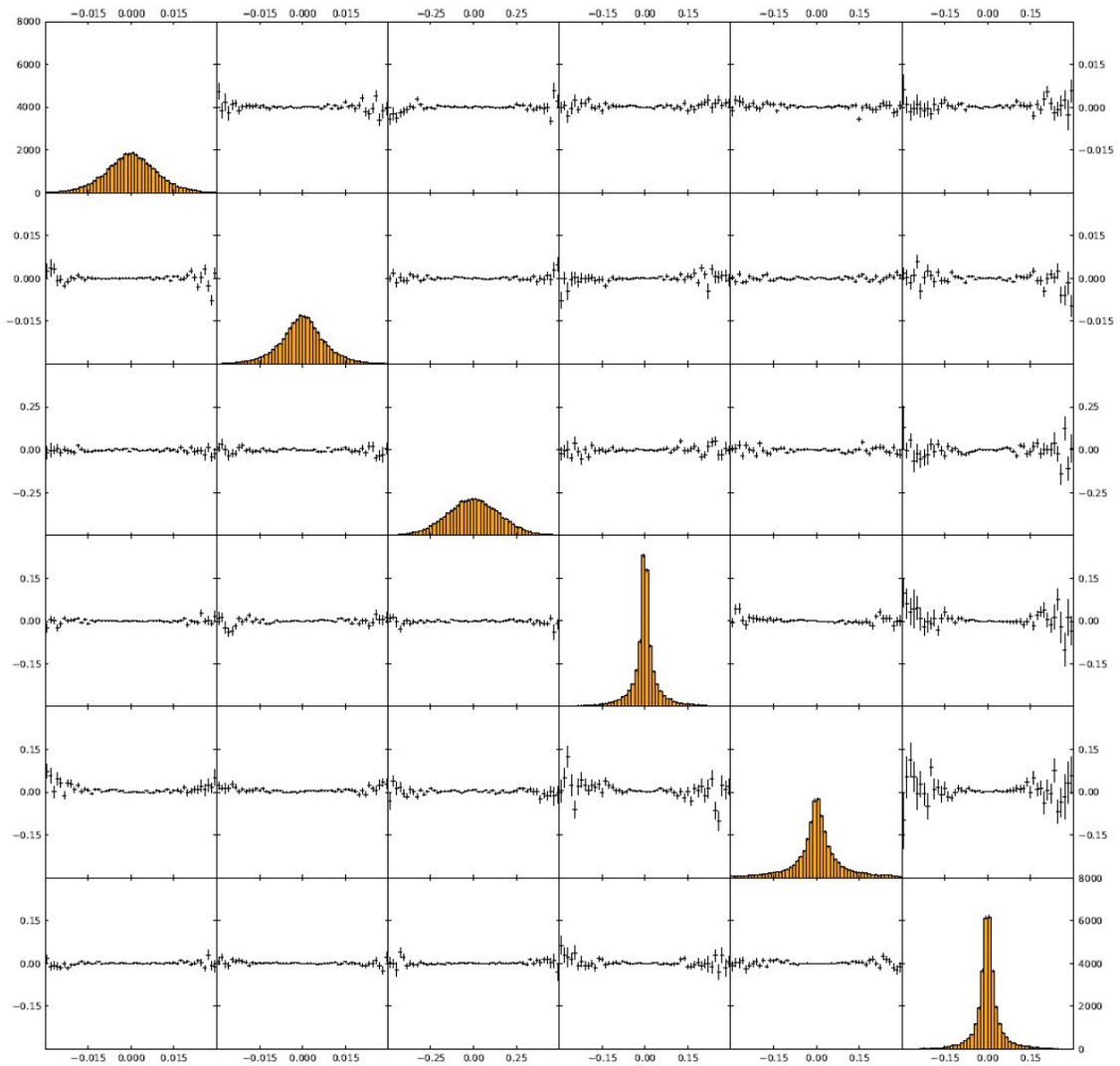


- Fit one cosmic track as two tracks from IP region
- Look at differences in helix parameter (e.g. $\Delta z_0, \Delta\omega$)
- Look at correlations between helix parameters (should be uncorrelated)

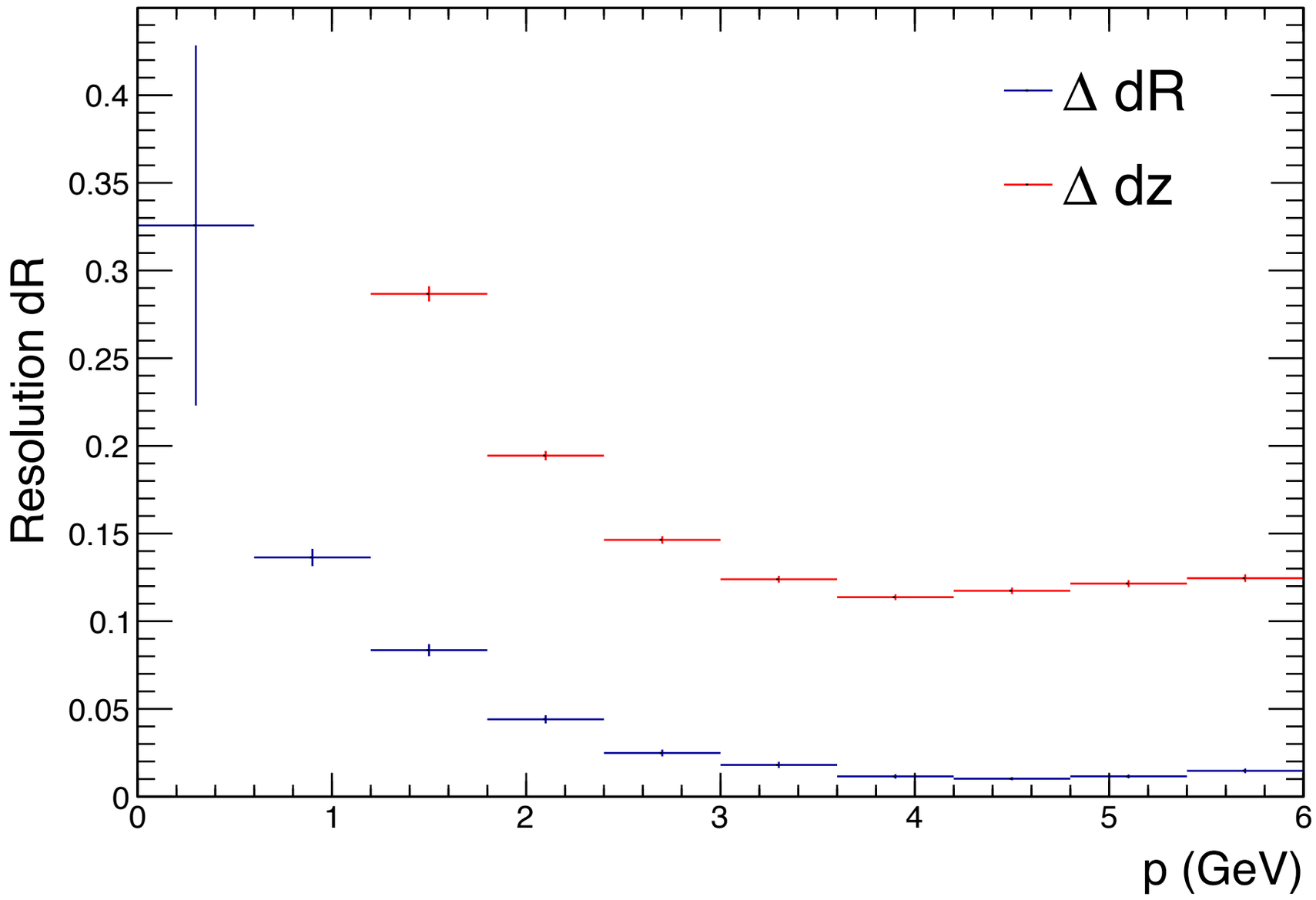
Test Sui Cosmici

Impact parameter correlation of one cosmic muon track

- Δx
- Δy
- Δz
- Δp_x
- Δp_y
- Δp_z



Cosmic track vertex resolution (CDC)



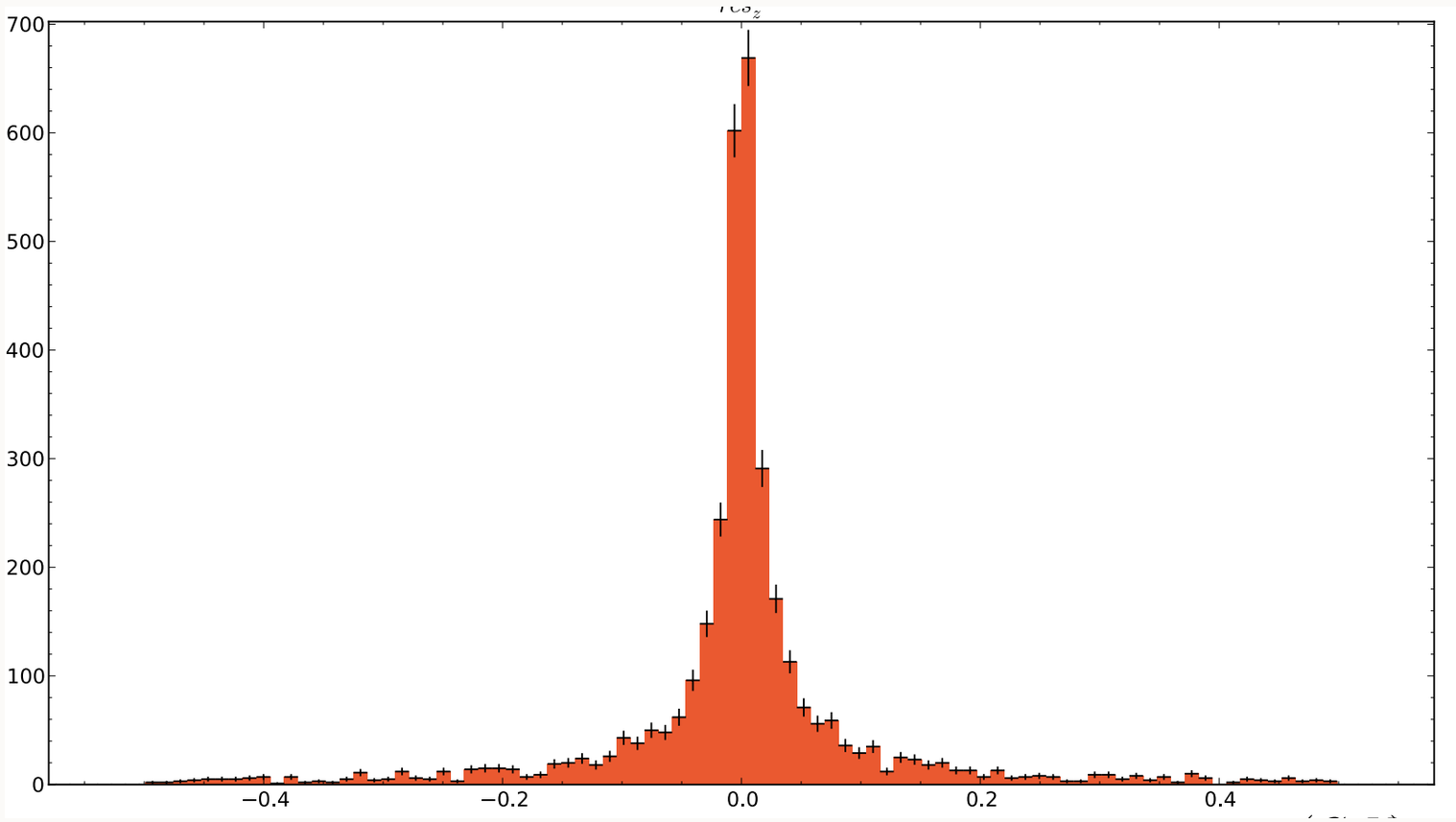
D^0 In $K3\pi$

The decay is reconstructed in the decay chain:

$$e^+e^- \to c\bar{c} \to XD^{*+},$$
$$D^{*+} \to pi^+_{\text{slow}} D^0,$$
$$D^0 \to K3\pi$$

Track quality requirements:

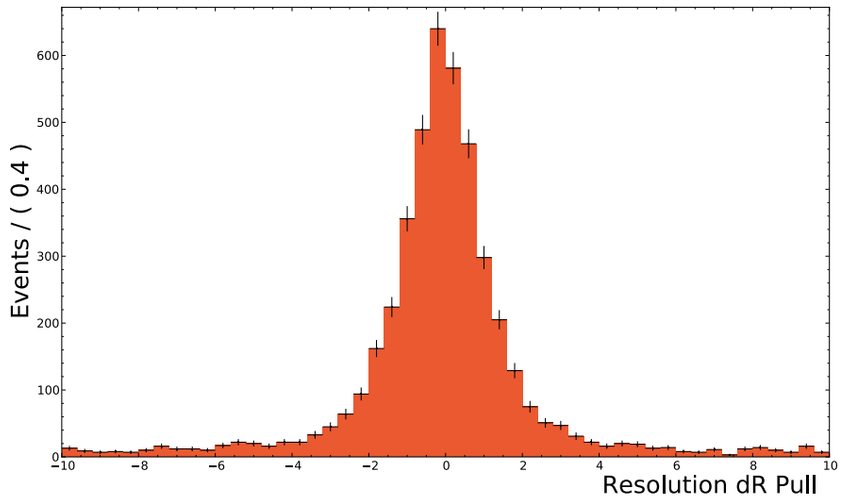
- # hits in SVD
- # firing wires in the CDC
- Transverse momentum $P_t > 70\text{MeV}/c$
- IP cuts

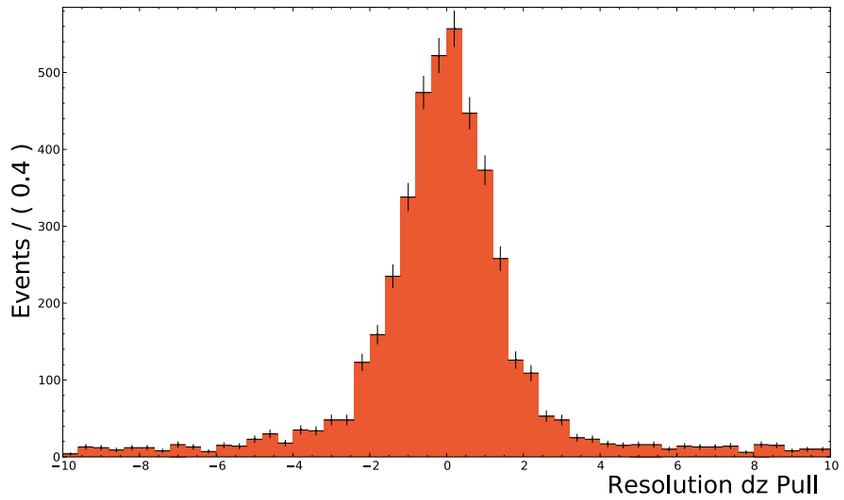


Vertex resolution x(cm)

D^0 In $K3\pi$

$D^0 \to K3\pi$ Vertex Resolution Pull





Pull

- Mean: -0.075 ± 0.019
- Sigma: 1.202 ± 0.021

Pull

- Mean: -0.013 ± 0.020
- Sigma: 1.283 ± 0.021

Attività Che Apriremo A Breve

- Leggi: Attività per cui richiederemo alla collaborazione tempo di persone. Apro una parentesi (:
  - Sì, ma in quale consesso vanno fatte queste richieste?
  - A chi rendono conto le istituzioni che si assumono incarichi che poi non onorano?
  - A chi, quale consesso devono riportare i convener?
- Chiudo la parentesi .)

Posizioni Che Vorrei Apriremo A Breve

- Contact persons con i rivelatori. Al momento il link è piuttosto fragile ed indefinito.
- Contact persons con i gruppi di fisica: gli sviluppatori del codice non hanno una visione sufficientemente ampia per percepire correttamente pregi e limiti dei loro algoritmi (Fatti esclusi i presenti, si intende).
  - Il gruppo inizia ad aver bisogno di qualcuno che guardi i risultati della ricostruzione con occhio critico e dica cosa è prioritario.
- Contact persons con il gruppo di simulazione del background.

Conclusioni

- Il codice fornisce buone prestazioni, ma ha bisogno di essere testato in maniera estensiva. Leggi:
  - persone volenterose anche con poca esperienza sono più che bene accette.
- Alcune parti risultano:
  - in via di migrazione (VXDTF)
  - in via di sviluppo o messa a punto (Local CDC track finder, Event Reconstruction Data Model, Track Final Selection),
  - ancora mancanti (Hit adder CDC ➔ VXD)

Thank You for Your Attention