Hades track reconstruction

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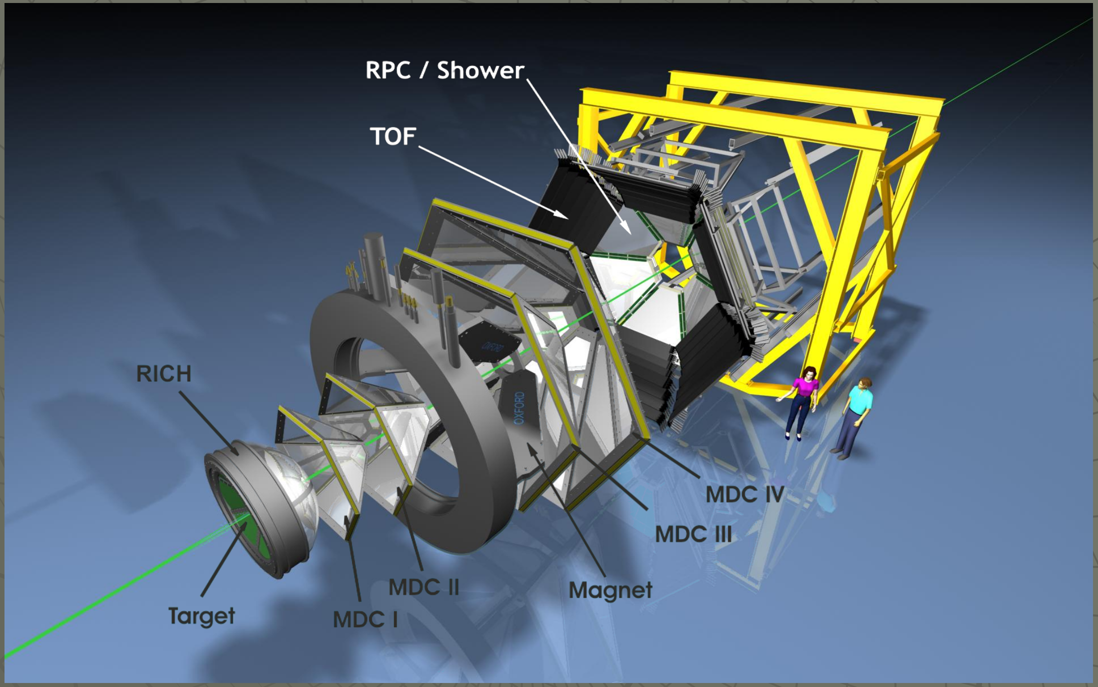
for the HADES collaboration

Outline

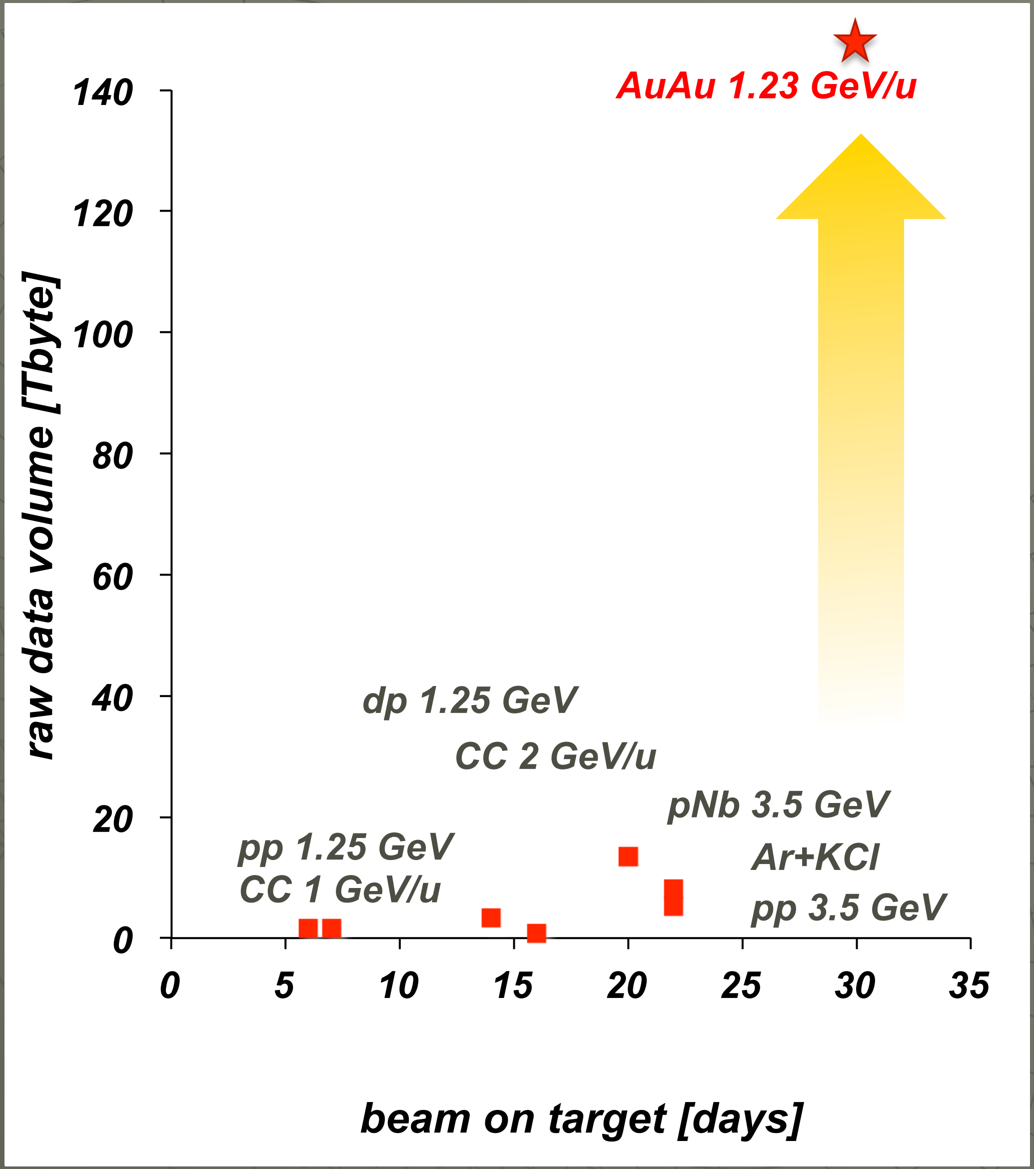
- The Hades spectrometer
- Track reconstruction
  - Candidate search
  - Segment fitter
  - Global vertex fit
  - Momentum reconstruction

The HADES spectrometer



- Ring imaging Cherenkov detector : hadron blind (30000 channels)
- Time of Flight walls: TOF/RPC (770+2150 channels)
- Shower detector for electron identification (17300 channels)
- 4 Planes of MDC for tracking of particles (26000 channels)
- Forward WALL (280 channels)
- START-VETO beam detectors

Au+Au at 1.23 GeV/u (beam time April – May ‘2012)



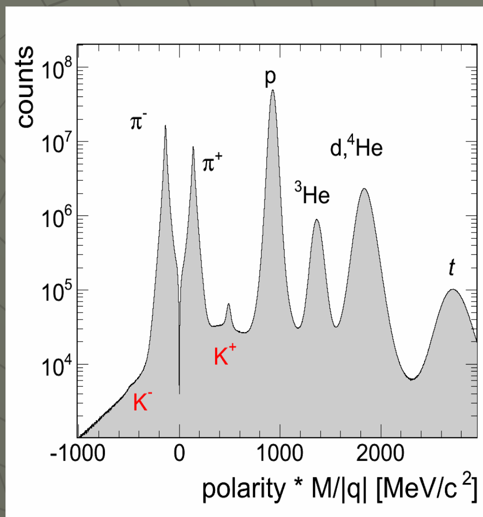
HADES DAQ:

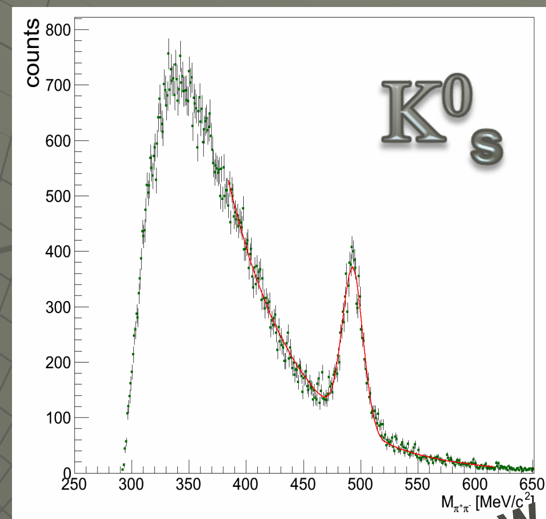
Versatile, FPGA board based system using dedicated add-on boards and data/trigger/slow-control transport via serial optical links (TRBnet)

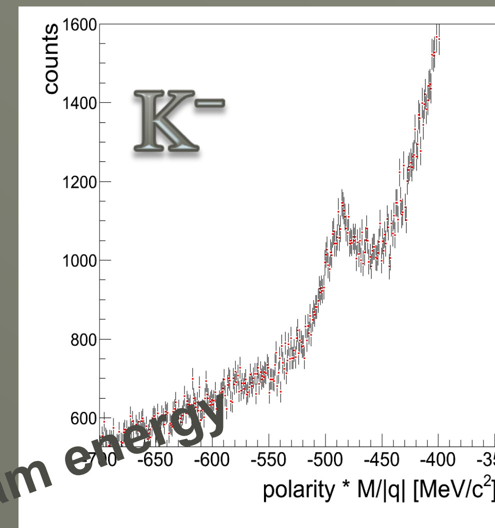
- 557 hours beam Au on Au target
- (1.2 - 1.5) x 10^6 ions per second
- 8 kHz trigger rate
- 200 Mbyte/s data rate
- 7.3 x 10^9 events
- 140 x 10^{12} Byte of data

Strangeness

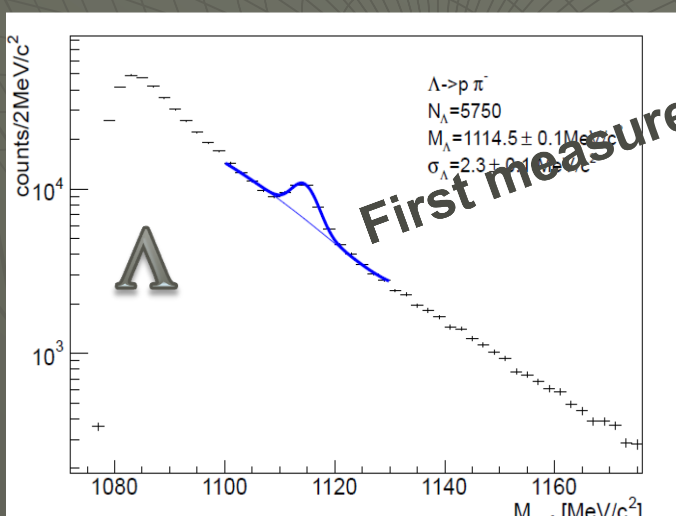
NN excess energy 0.44 GeV only!

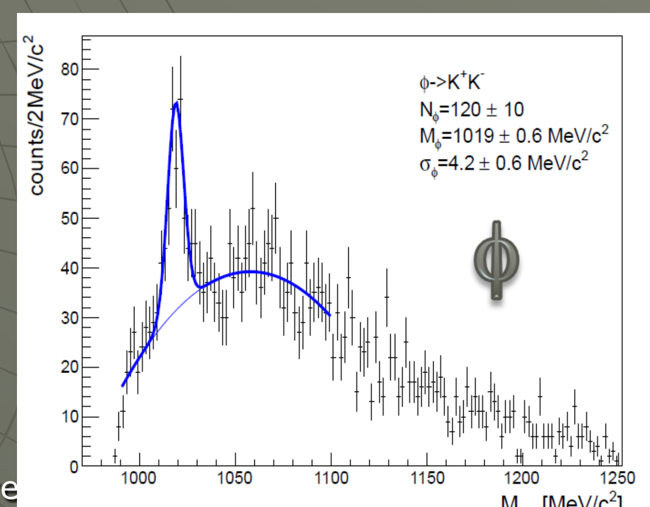




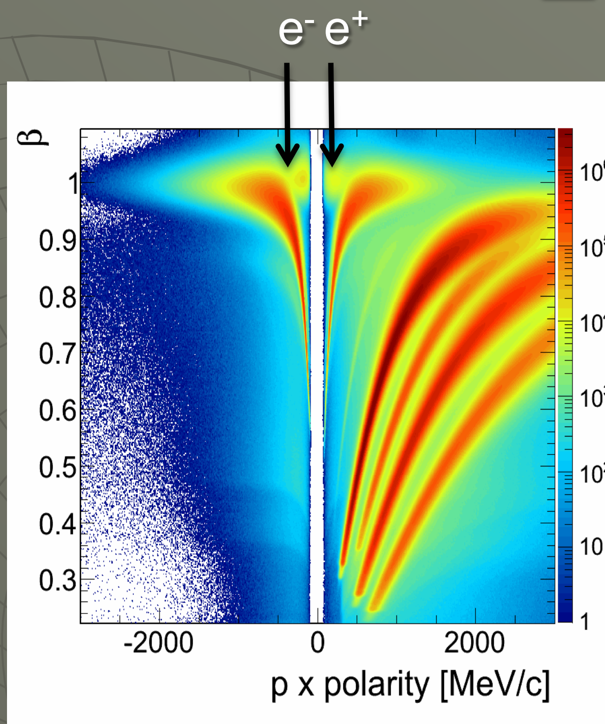


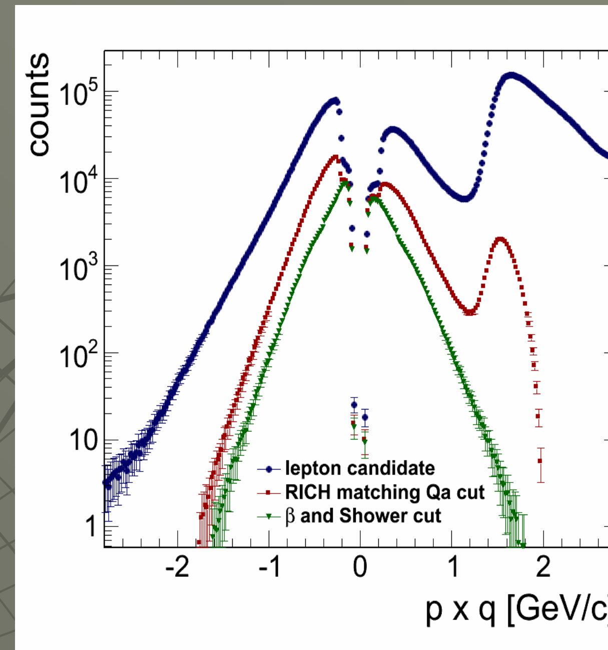
First measurement at such low beam energy



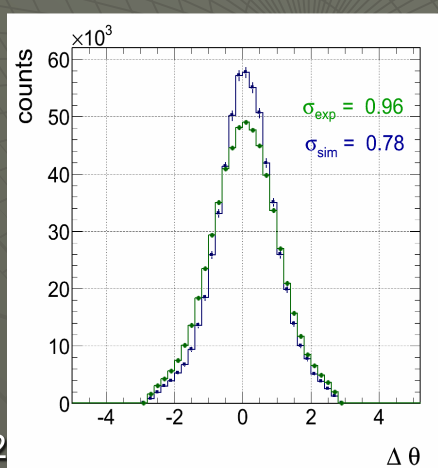


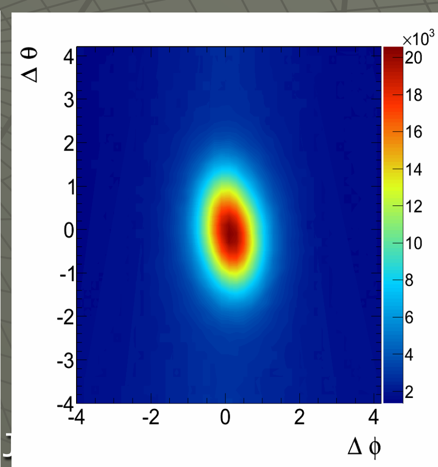
Leptons

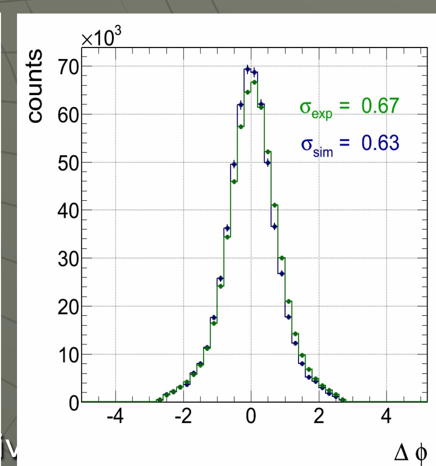




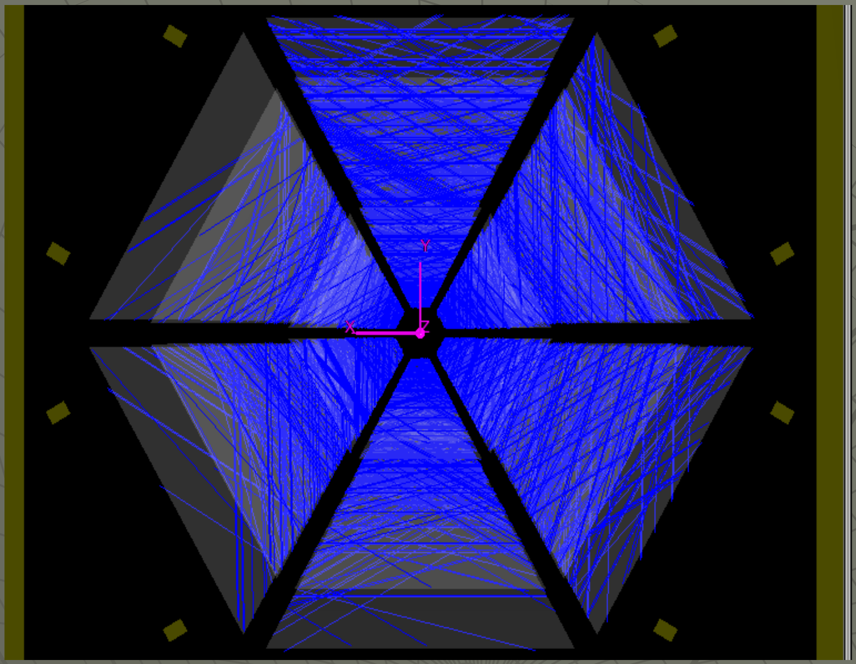
RICH – MDC spatial correlations

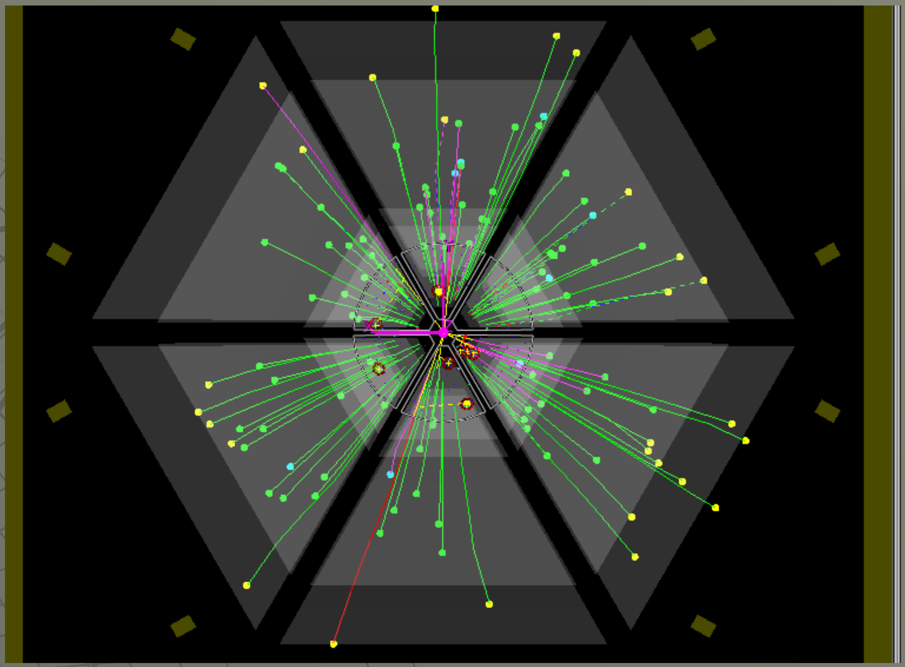






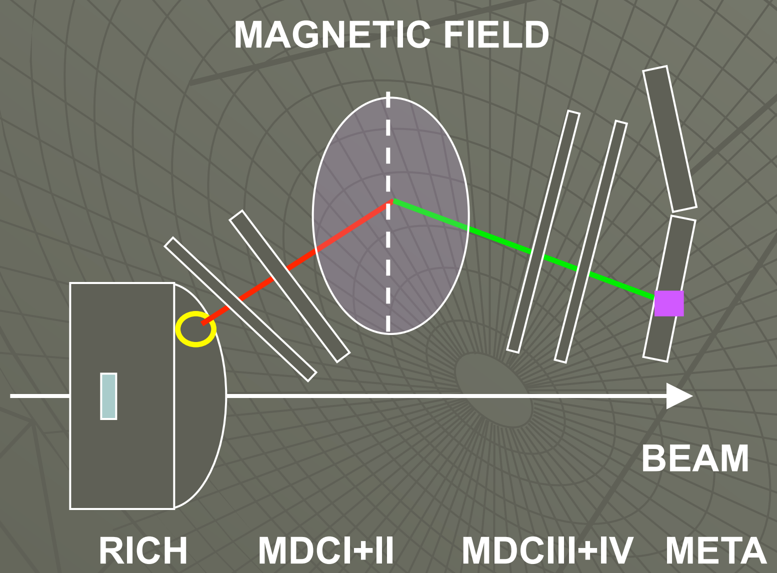
The Challenge





- Au+Au @ 1.23 AGeV, central collisions
- up to 140 (primary) charged particles in acceptance
- Double hit probability < 30% for MDCs
- Tracking issue: wires introduce long range correlations between particle tracks

Scheme of tracking



Correlation of detector information:

- The track segments of **inner** and **outer** MDCs are matched on Cluster level
- **Outer segments** are matched with **META hits**
- **Inner segments** are matched to **RICH hits**

Full particle track:

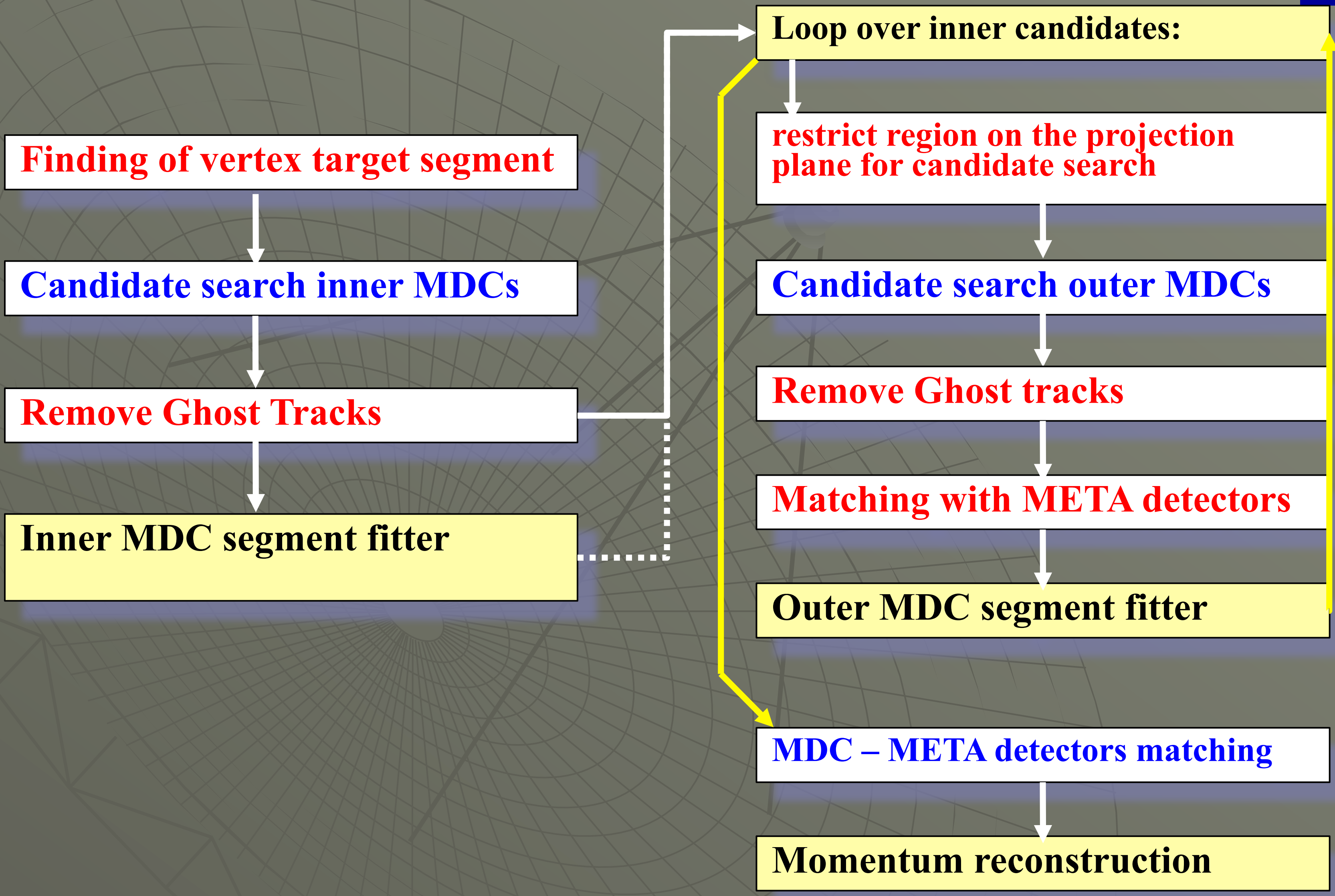
- Momentum reconstruction of full track
- Select and sort of tracks by quality and reject double hits

Final PID:

- User defined

Candidate search

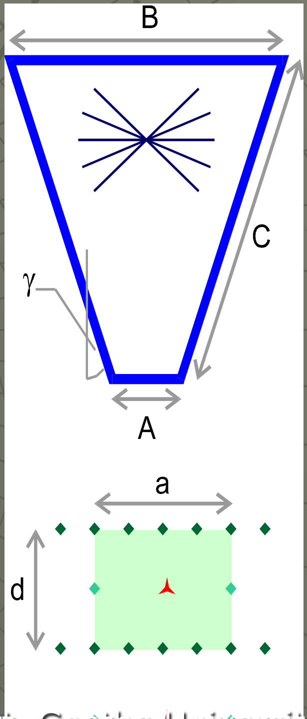
Real life: Current Scheme of the Candidate Search

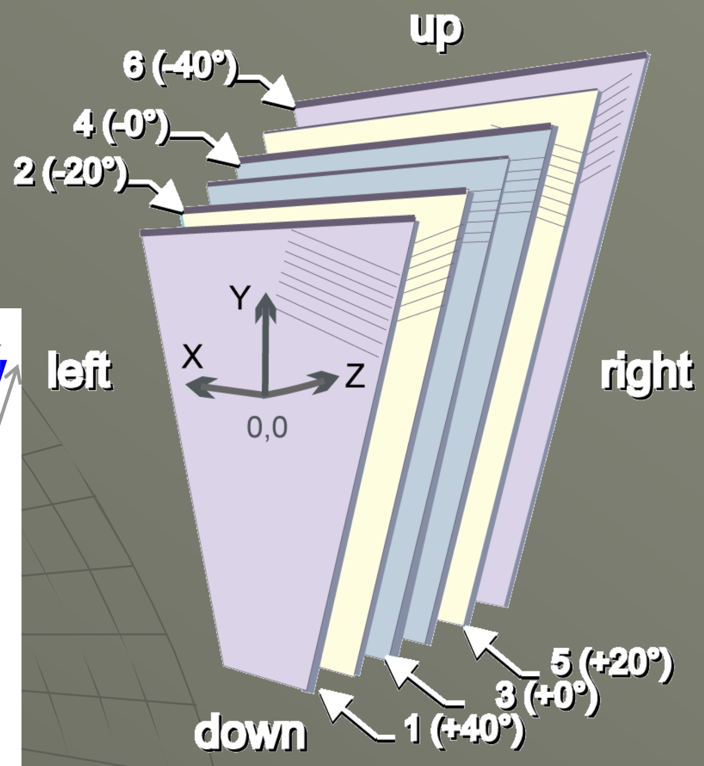


Geometry of the Tracking System

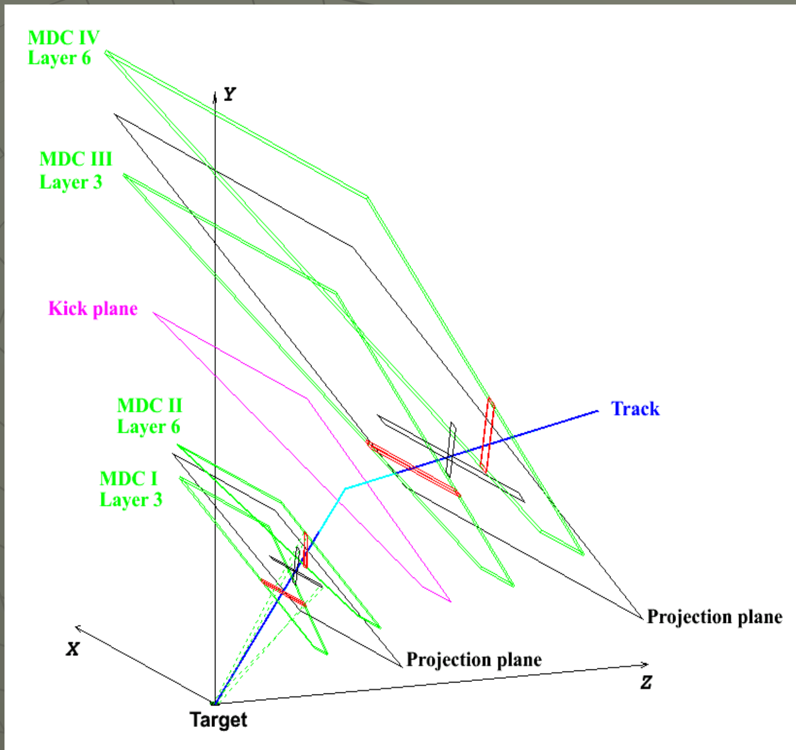
	A [mm]	B [mm]	C [mm]	a [mm]	γ [degree]	R [mm]	d [mm]
I	139,21	767,38	839,19	5	21,98	543,83	5
II	205,00	905,00	1049,27	6	19,49	705,19	5
III	310,43	1804,80	2139,05	12	20,44	1347,69	8
IV	345,46	2224,05	2689,04	14	20,44	1641,68	10

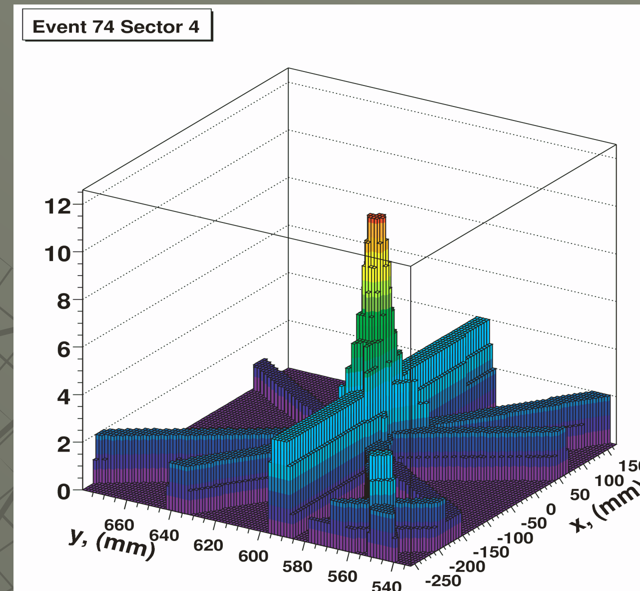
- 24 conceptually identical modules
  in 4 different geometries
- 6 drift cell layers in each module
  - orientation optimised with respect to
    resolution in direction of the kick angle
- ≈ 190 cells per layer
  - sufficient granularity (max multiplicity = 0.6 hits/cm along y)
- 26.200 cells in total





Principal of the Candidate Search





	σ_x [mu]	σ_y [mu]
Inner segment	560	170
Outer segment	1450	460

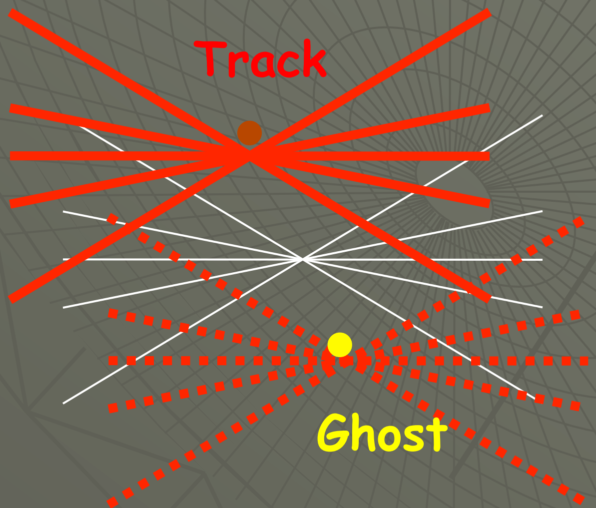
- Reduce a track in 3D to a spike on the projections plane
- Inner MDCs: use target segment for projection of drift cell volumes
- Outer MDCs: use hit point of inner segment on the kick plane for projection of the drift cell volumes

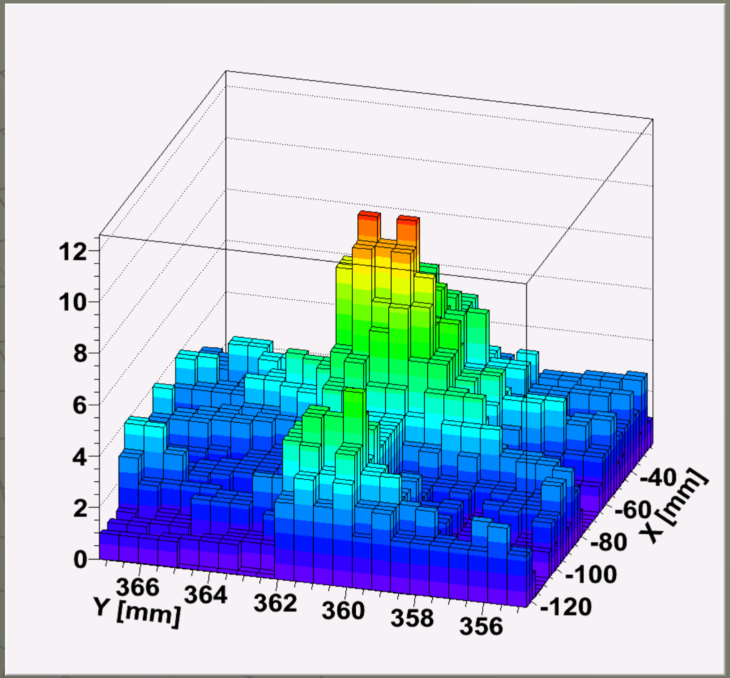
Inner MDCs: Removing of Ghost Tracks

Ghost cluster signatures:

- smaller average spike amplitude
- smaller average number of unique wires (contributing to this cluster only)
- larger average number of wires participating in real clusters
- smaller average cluster size (number of bins on the top of spike)

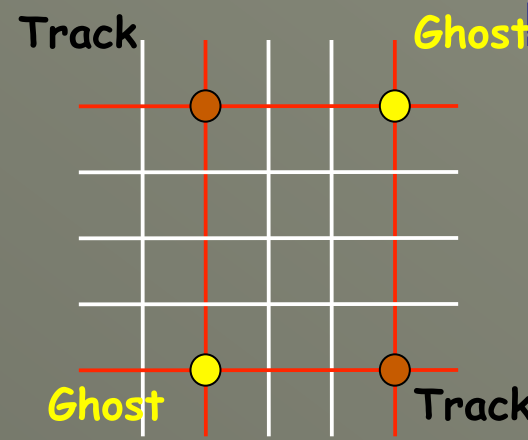
1. Find and remove of clusters which have practically **identical set** of wires

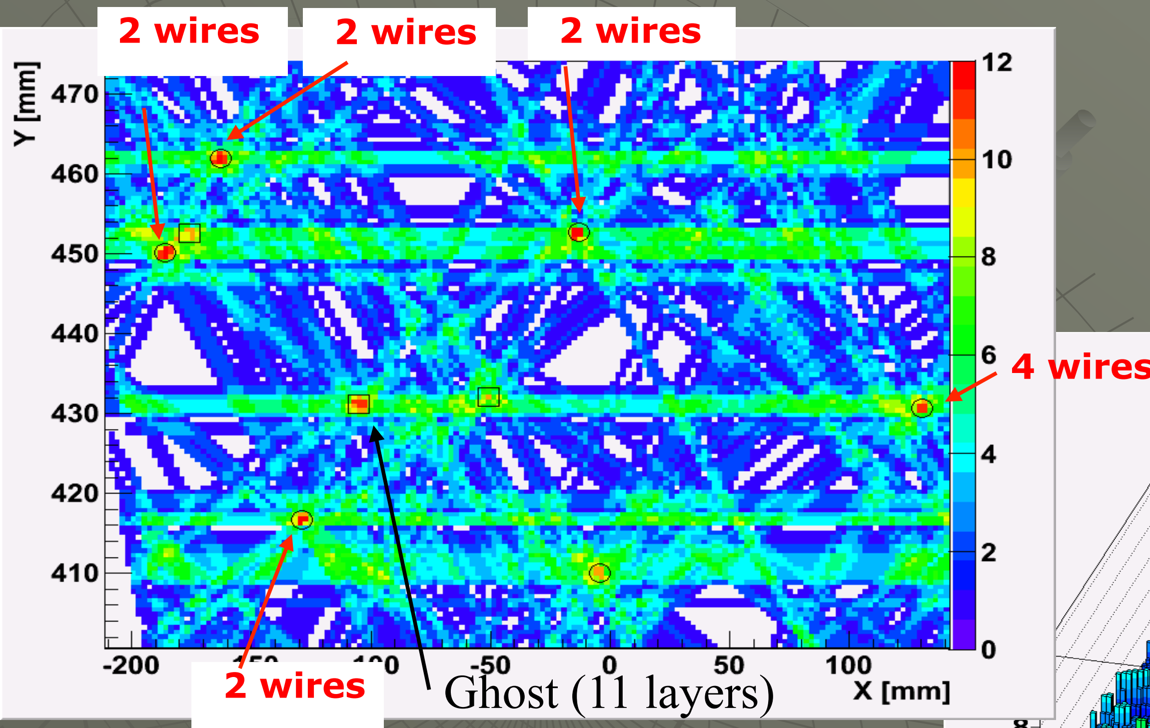


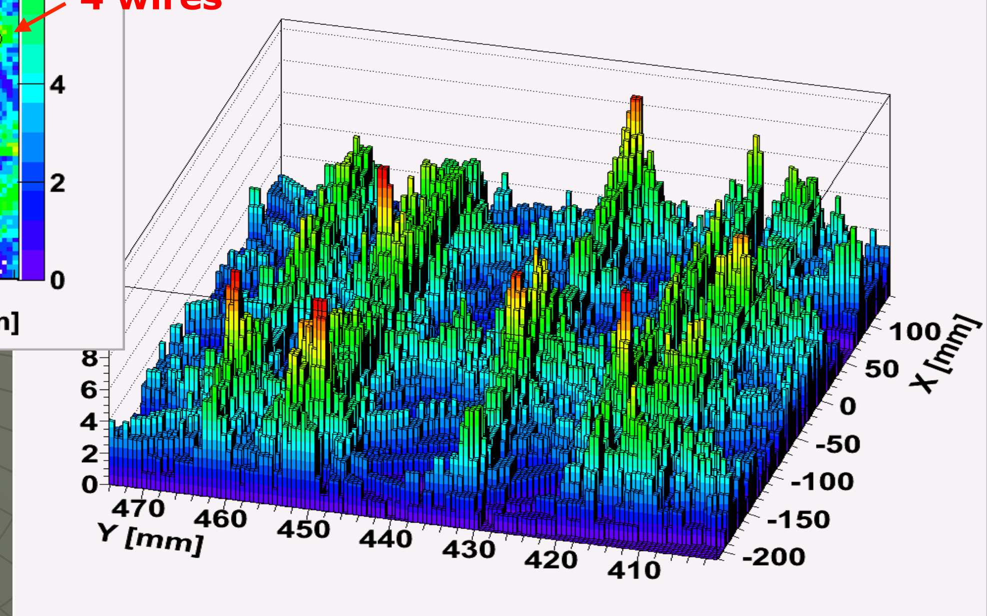


Inner MDCs: Removing of Ghost tracks

2. Removing of clusters **combined from different track** wires.
   Complex algorithm (~10 parameters)



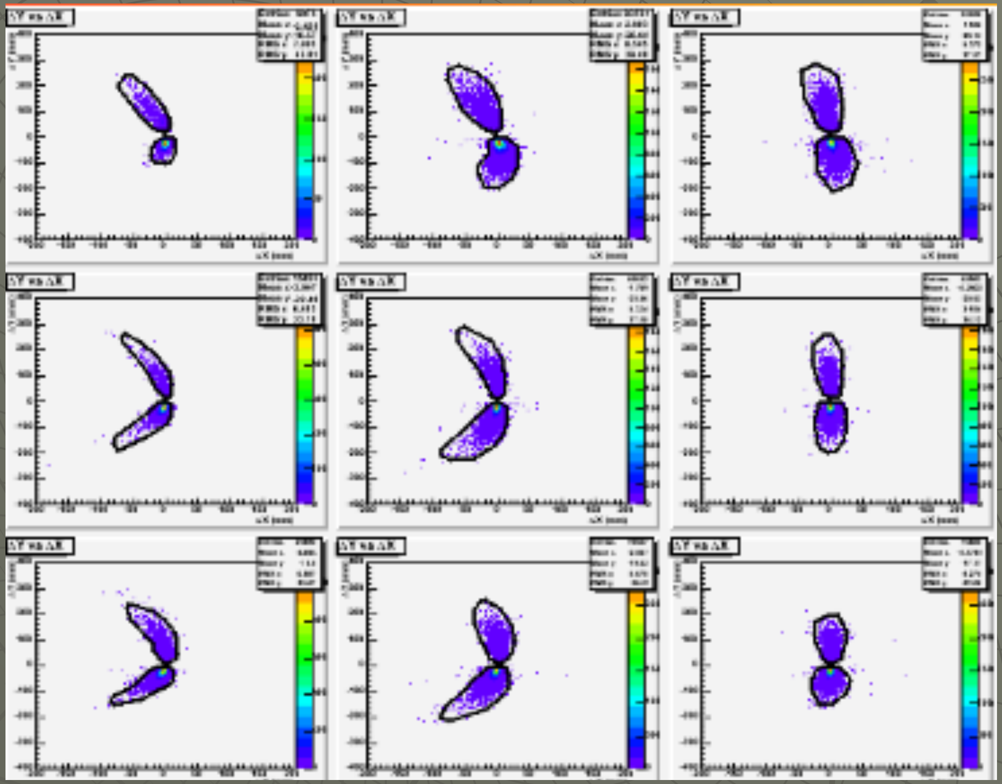




Outer MDCs : Reducing combinatory of possible candidates for one inner segment

Phi →

Theta ↓

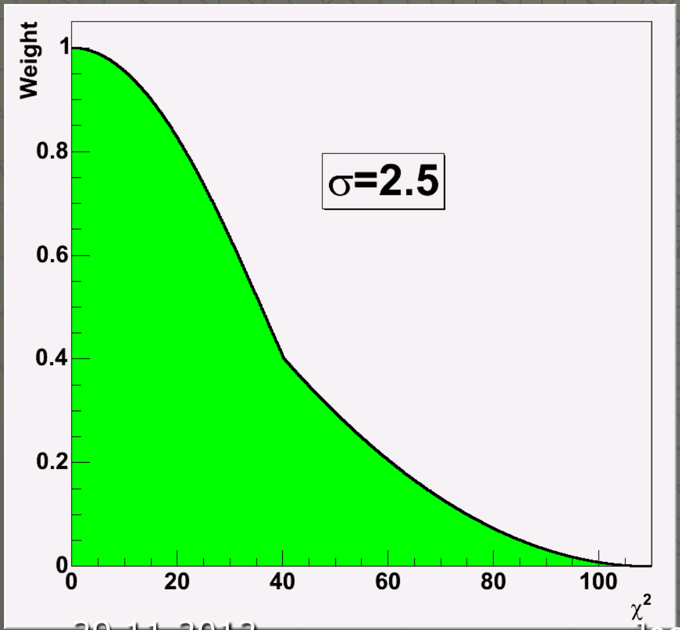


Strategy:

- restrict projections to range of physical tracks
- Cuts applied on the $\Delta x, \Delta y$ coordinates on the projection plane in front and behind the field region
- Purity:89%
- 0.26% lost tracks
- 87.2% removed ghosts tracks
- 6x6 bins in phi and theta

The Segment fitter

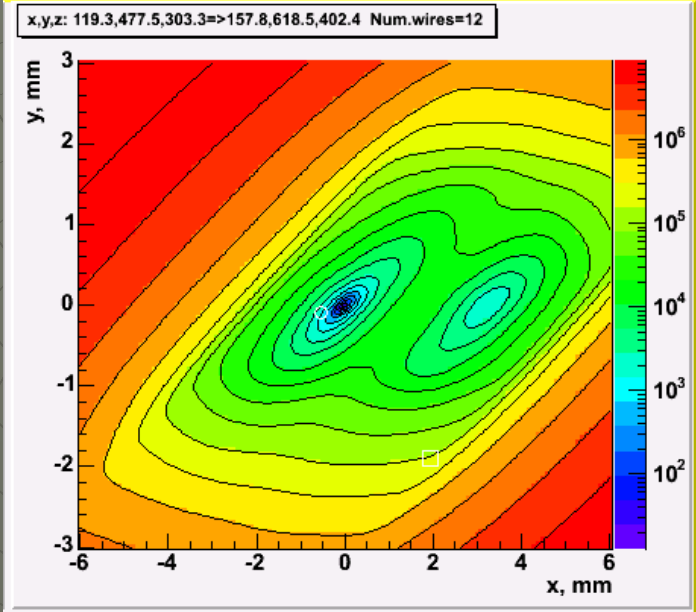
$$F = \sum_i \frac{(t^i_{drift} + t_{off} - t^i_{TDC})^2}{(\Delta^i_{TDC})^2} \cdot w_i$$

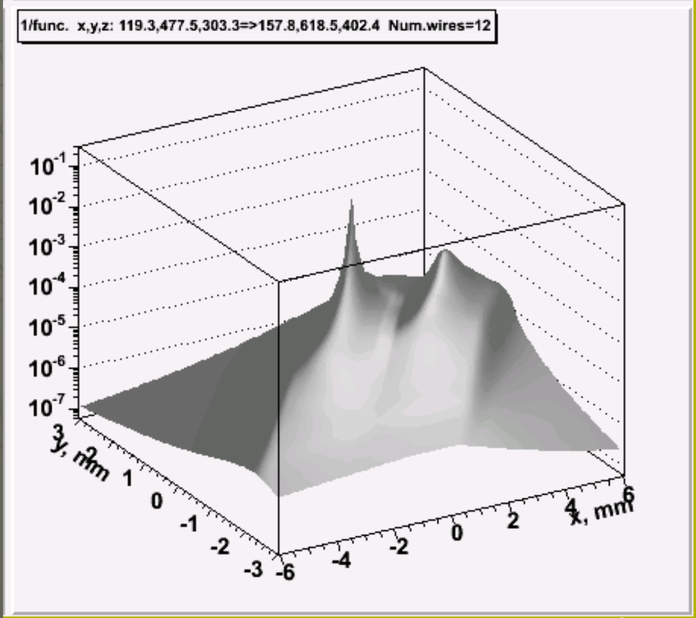


- Pre-fit procedure to find optimal start position for fit to avoid being trapped in local minima
- Straight line fit to wires of a pair of MDCs
- Distance of closest approach of the line to the wire is converted to drift time
- Drift time – distance correlation from GARFIELD calculations
- The functional is evaluated in time space
- Global offset parameter is used (time of flight etc…)
- Tukey weights used to minimize impact of wrong wires in the fit
- χ^2 minimization
- resolution better 150 mu

Fit has not reached minimum

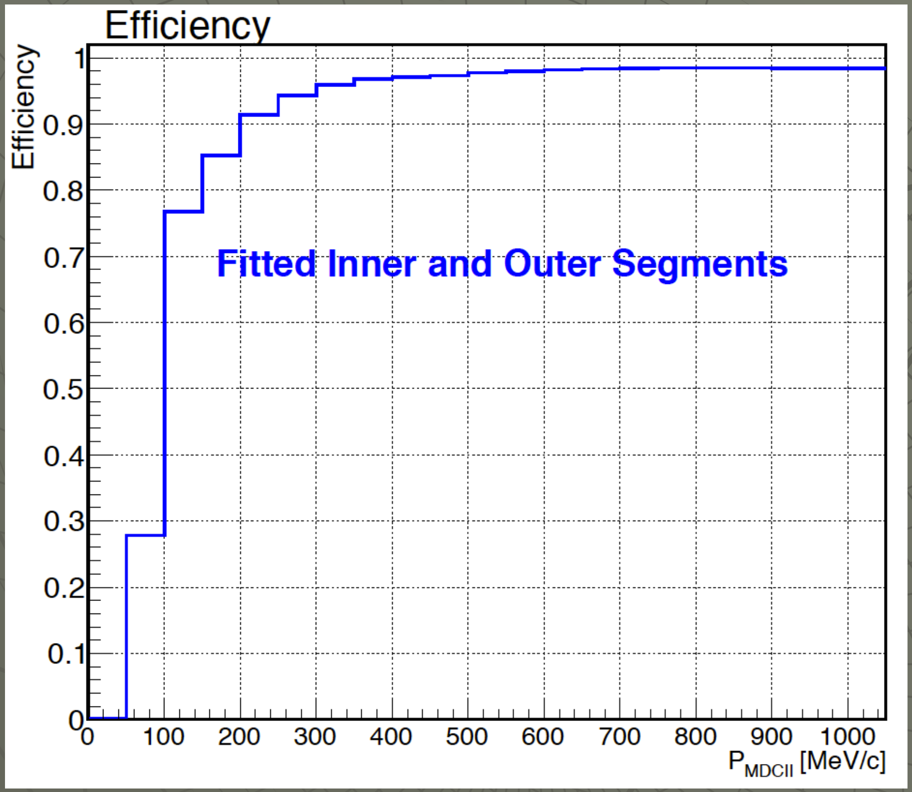
Avoiding local minima

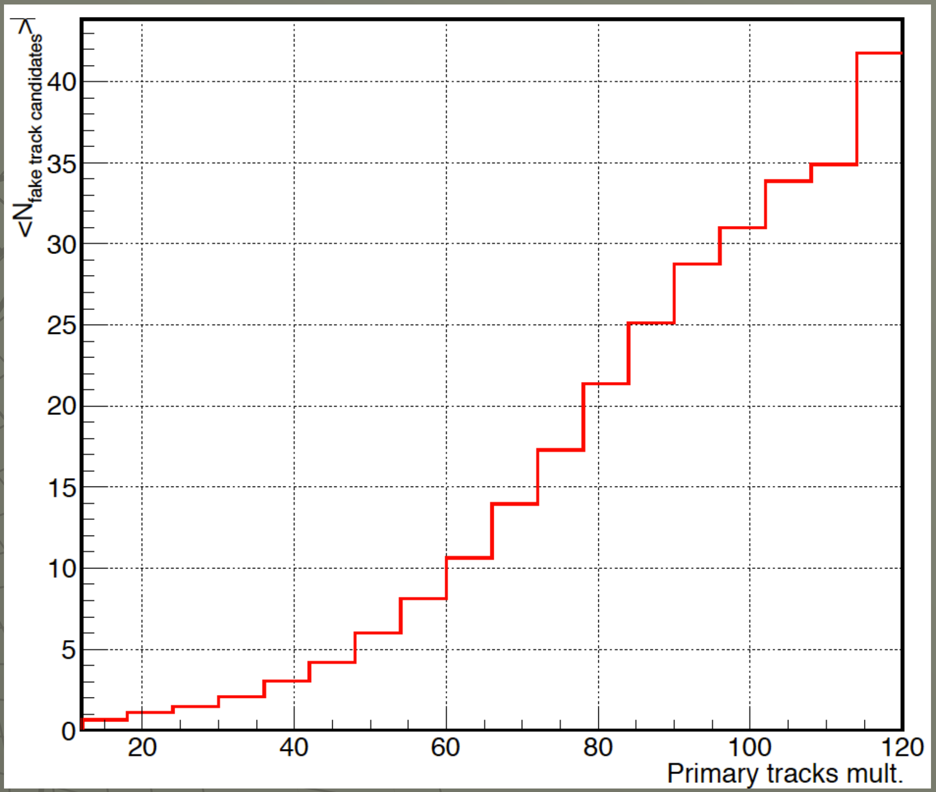




- standard gradient down hill fits can get easily trapped into a local minima
- due to wire orientation many local minima shows up
- Example: when starting with initial parameters pointing to the global vertex the probability is enhanced to find a local minima close to the starting value ➔ off-vertex tracks get systematically shifted
- Solution: run a pre fit to test possible combinations of wires for the best initial value

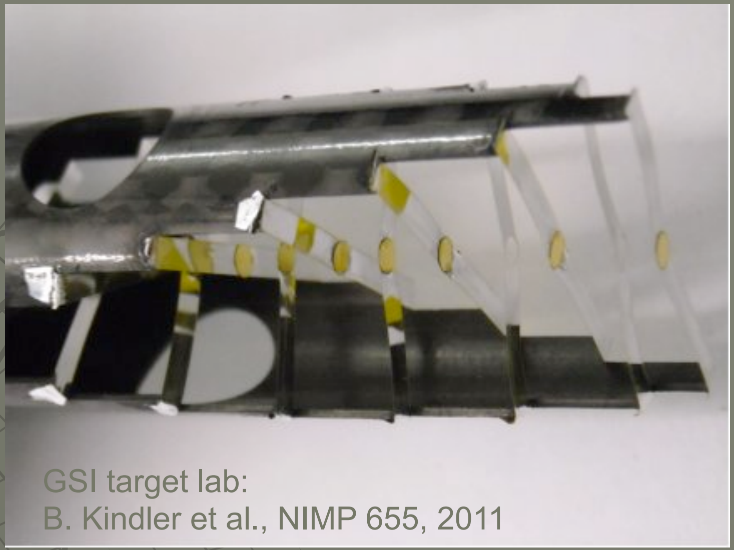
Candidate Search Efficiency

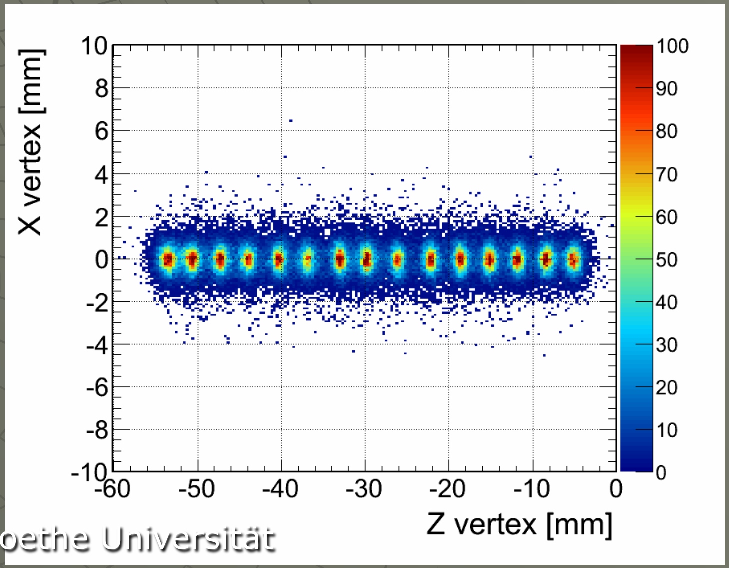




Global vertex reconstruction

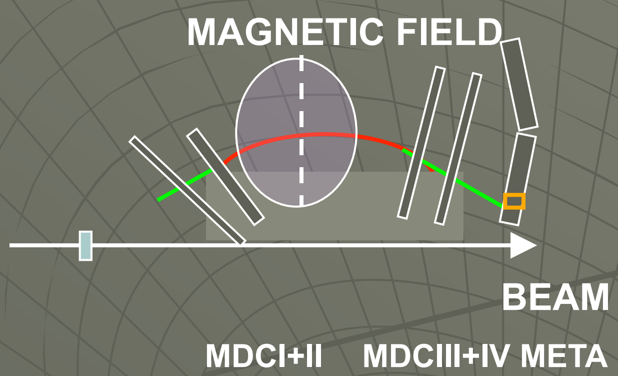
- First reconstructed during candidate search (no fit of drift times used)
- Second reconstruction based on fitted inner MDC segments: filtering + LSM fit (including Tukey weights)
- Third reconstruction based on fully reconstructed particles (same as segments)
- Resolution along z ~1 mm (depending on multiplicity)



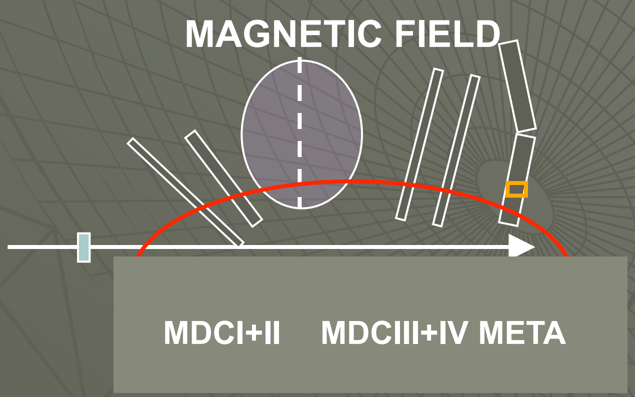


Momentum reconstruction

Momentum reconstruction



Spline

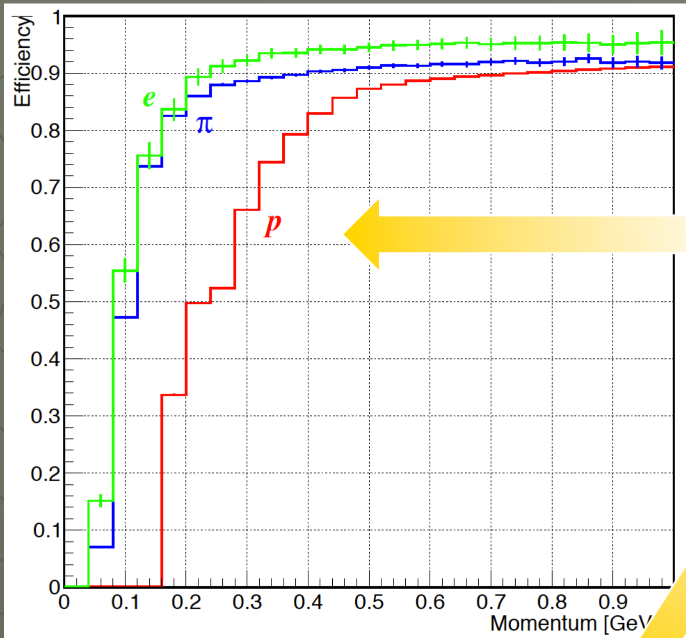


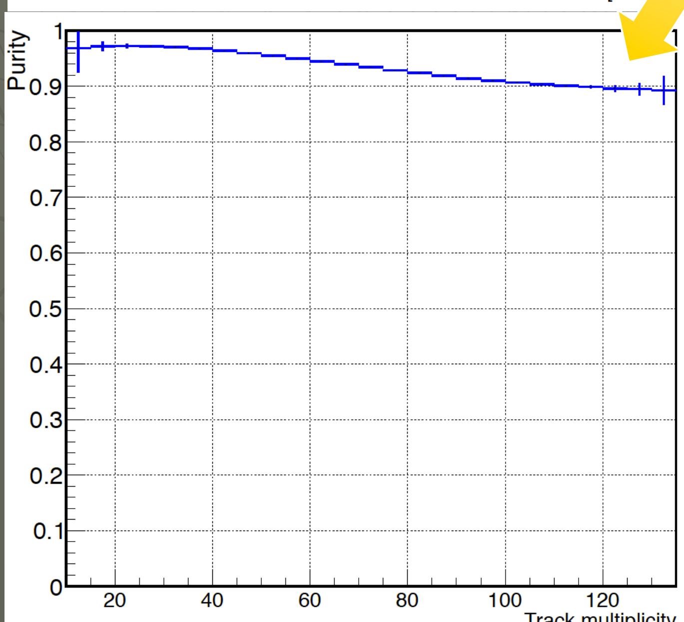
Runge Kutta

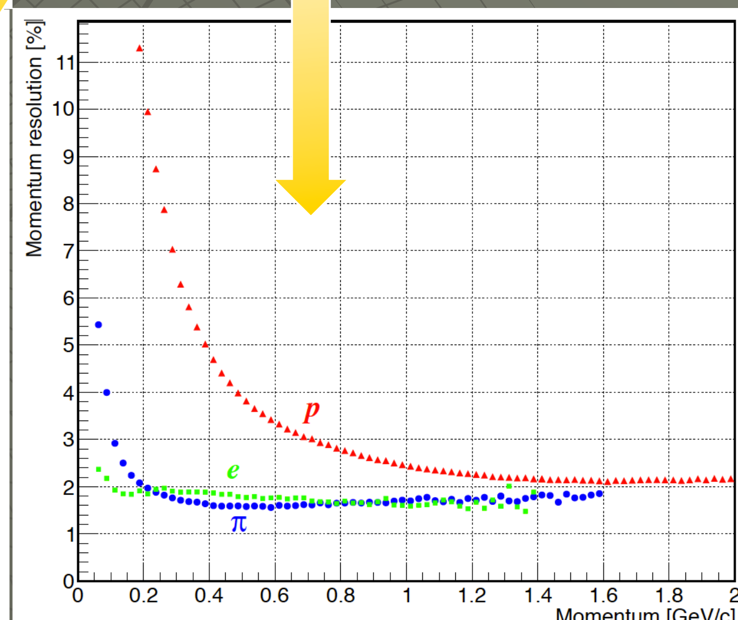
- **Spline :**
  - use 5th order spline to emulate a track in the field region
  - use inner and outer segments
  - the segment directions are not touched by the algorithm
  - good resolution, fast
- **Runge Kutta:**
  - 4th order, adaptive step size
  - propagates particle through magnetic field
  - uses inner and outer segments points
  - modifies the segments direction and position
  - improved resolution, computing intensive
- **Kalman :**
  - Uses MDC times measurements
  - Runge Kutta propagation
  - Input from Segments + Spline momentum
  - Forward propagation + smoothing
  - Deterministic Annealing Filter
  - Treatment of competing measurements
  - Improved resolution, computing intensive

Fitted segments + META matching + RK + Particle Sorter

Track Reconstruction Efficiency,
Purity,
Momentum Resolution



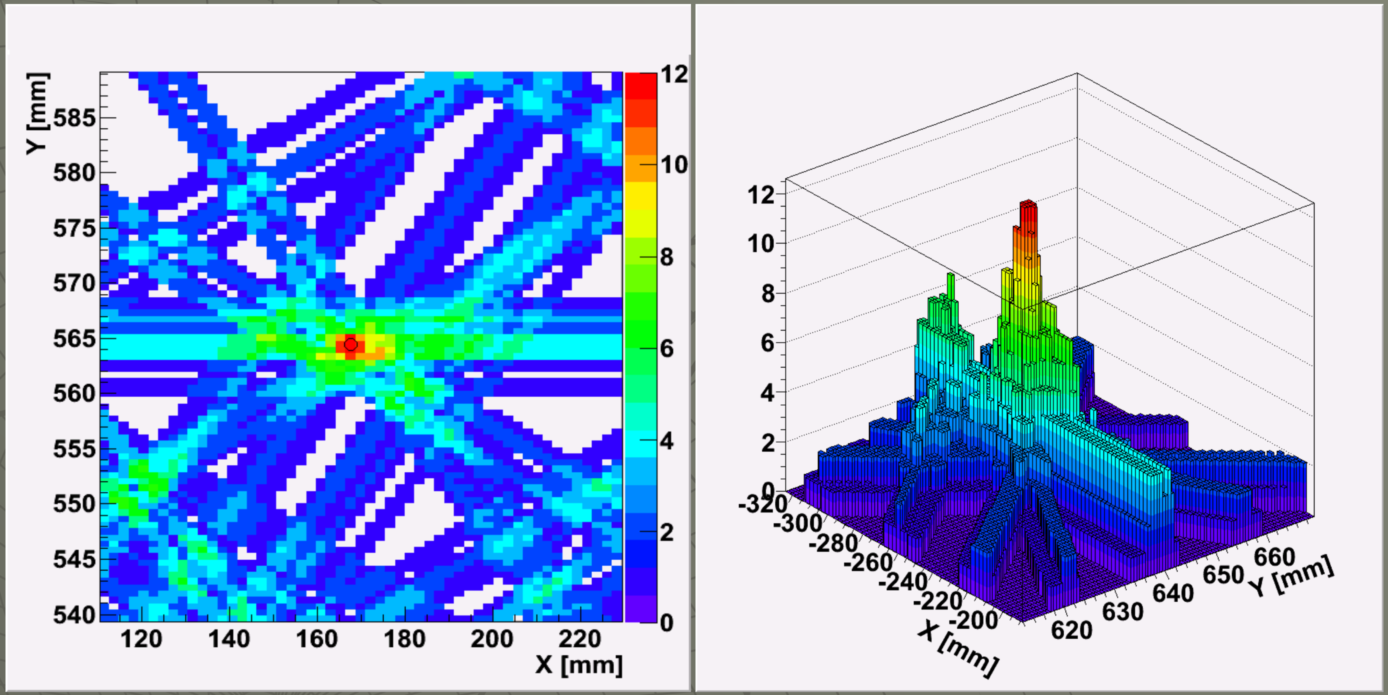




Thank you for your attention

Candidate Search

Inner MDC Cluster Finder



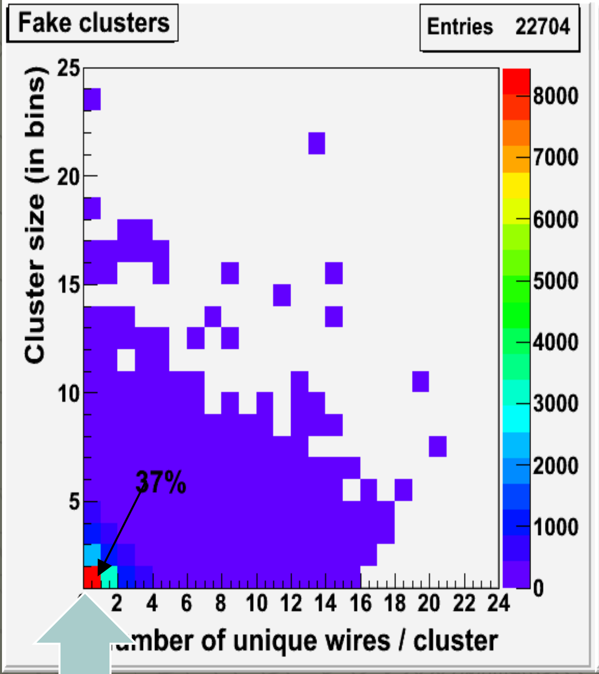
- Project plane size: ~400 x 1100 bins
- Level of candidate search: at least 9 layers must have fired wires
- Information for candidate parameters extracted on the top of spike

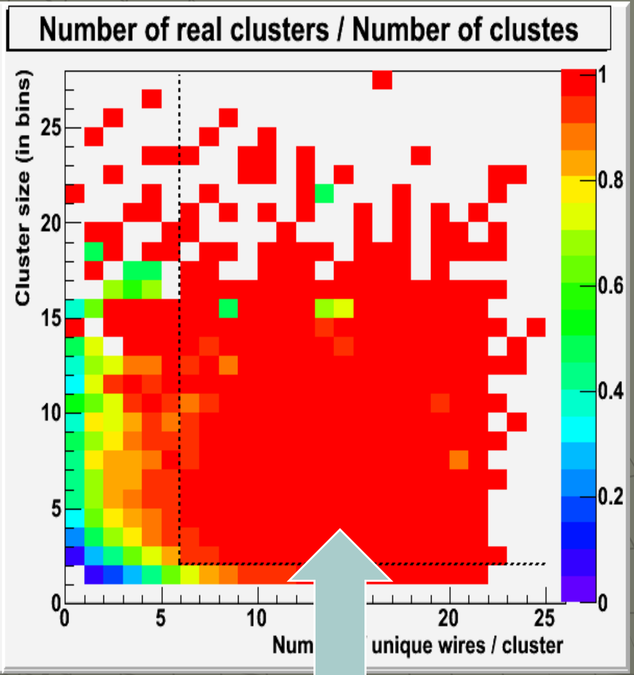
Removing of clusters *combined from different track* wires

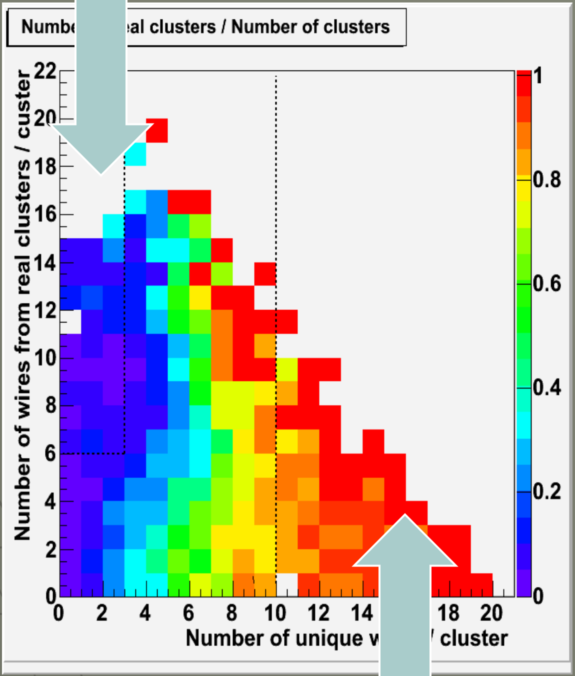
Cluster amplitude (Acluster) = 12

Remove

Acluster = 11





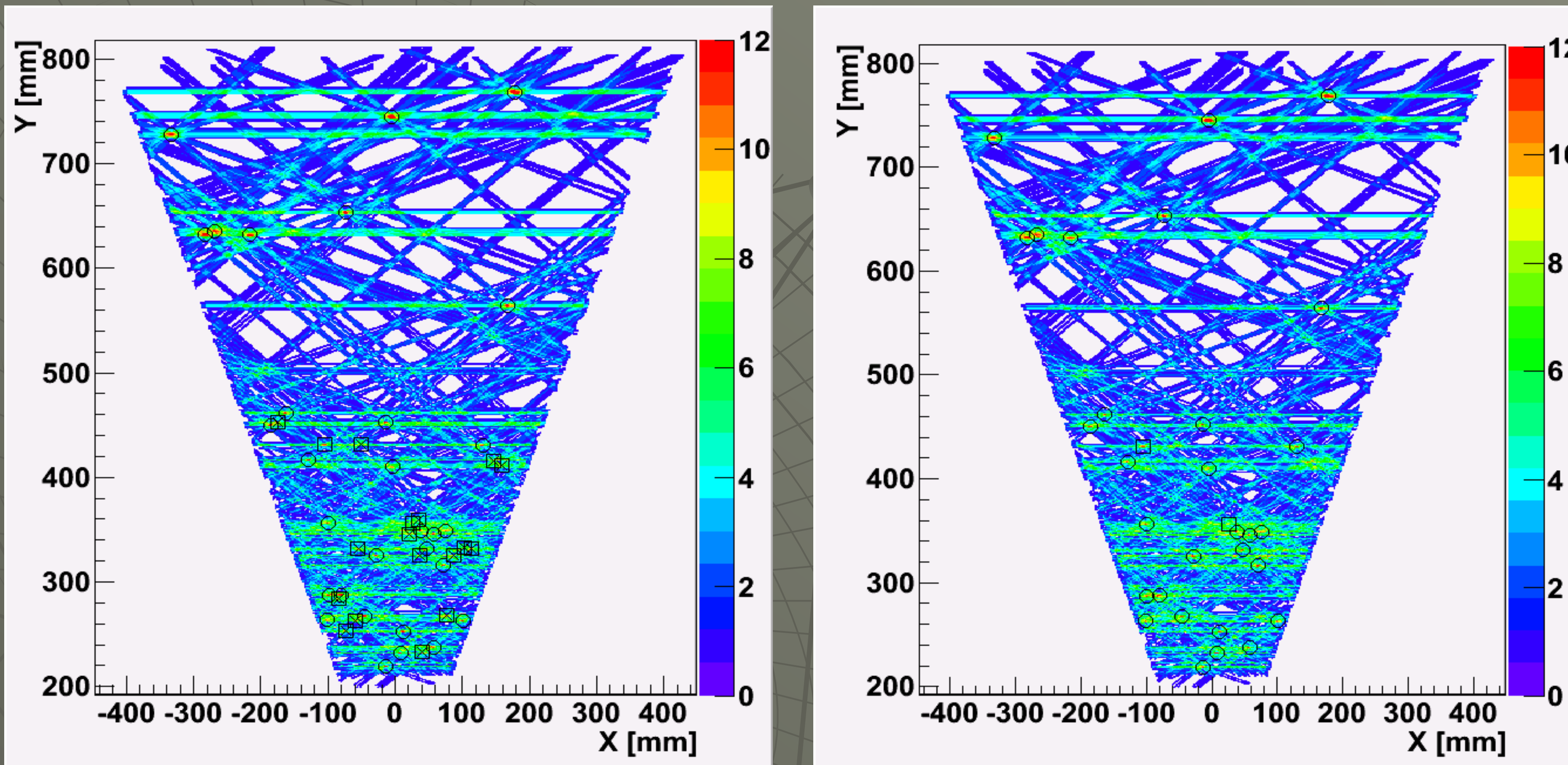


Remove clusters from this bin **Mark these clusters as "real"**

Mark as "real"

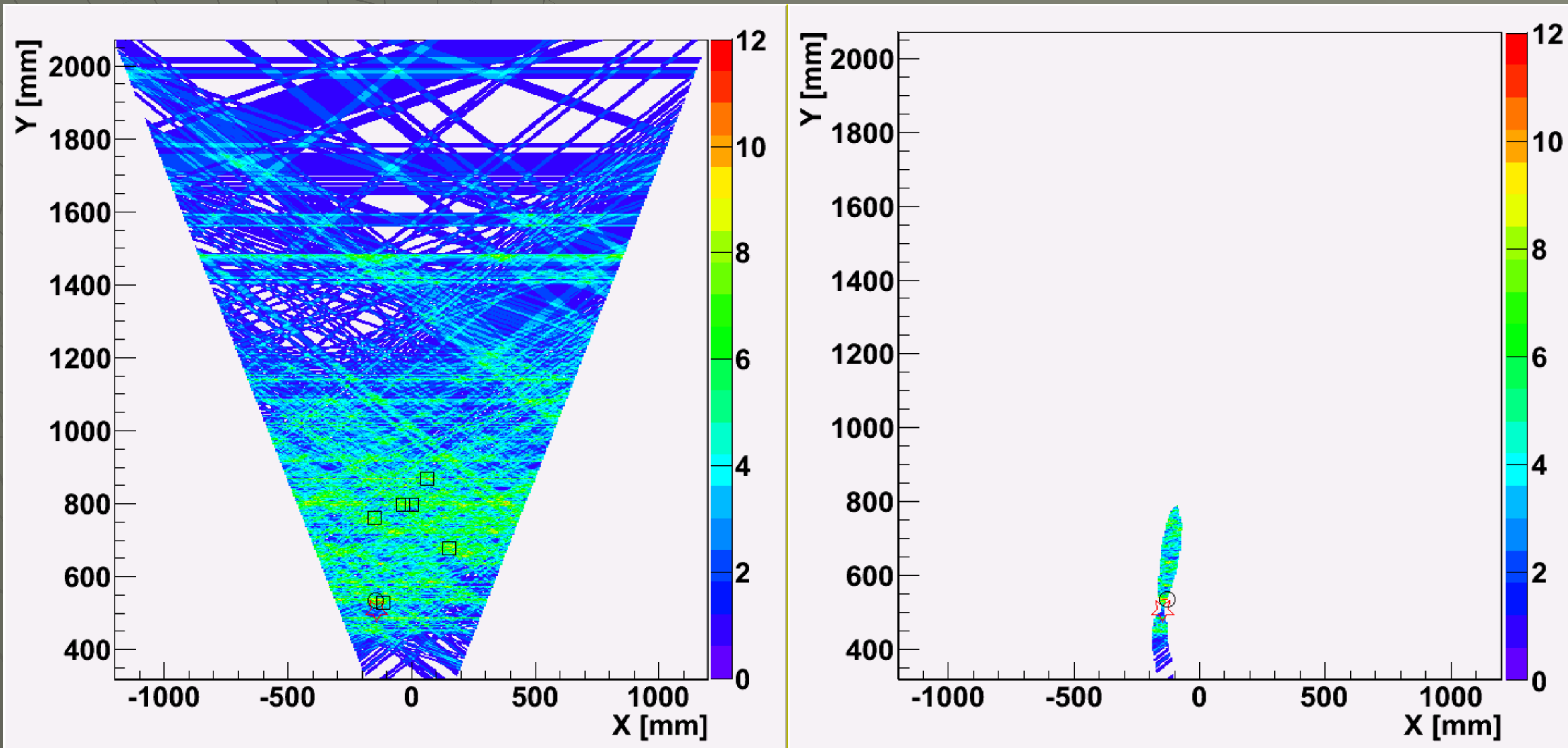
***Acluster* = 10 ...**

Inner MDCs: Removing of Ghost Tracks



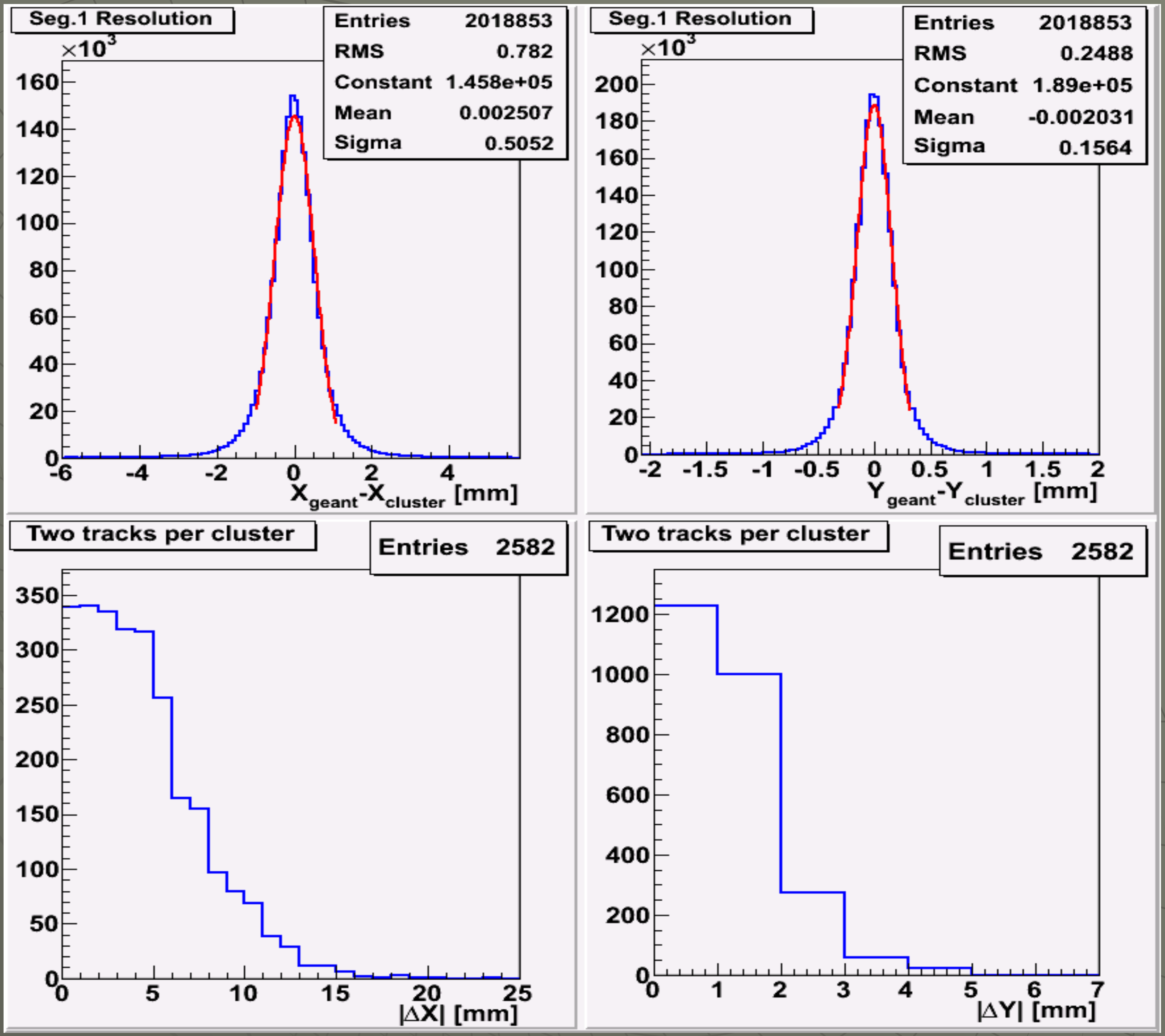
○ - track cluster
□ - ghost cluster

Outer MDC: Track Kick Cut



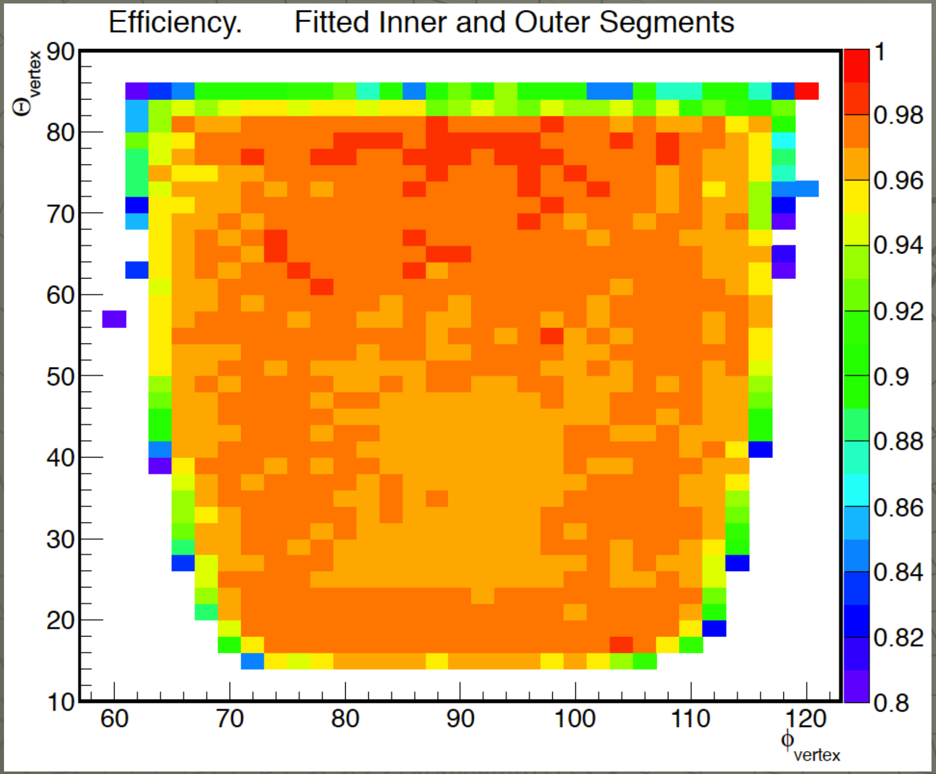
- inner cluster cross
○ - track cluster
□ - ghost cluster

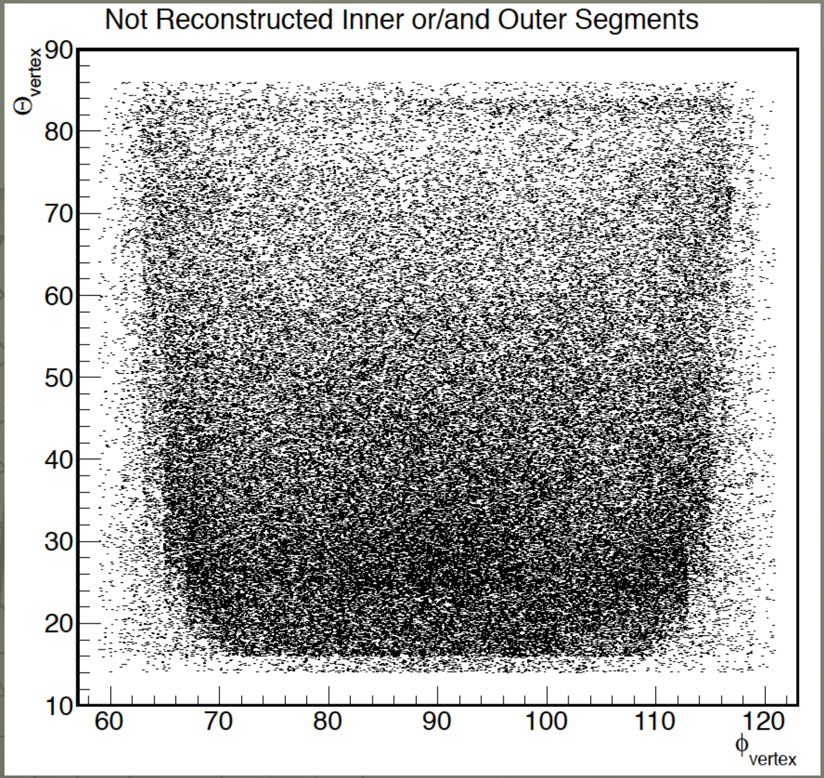
Inner MDC Candidate Search: Resolution



- σ_x = 500 micron
- σ_y = 160 micron
- No segment fit

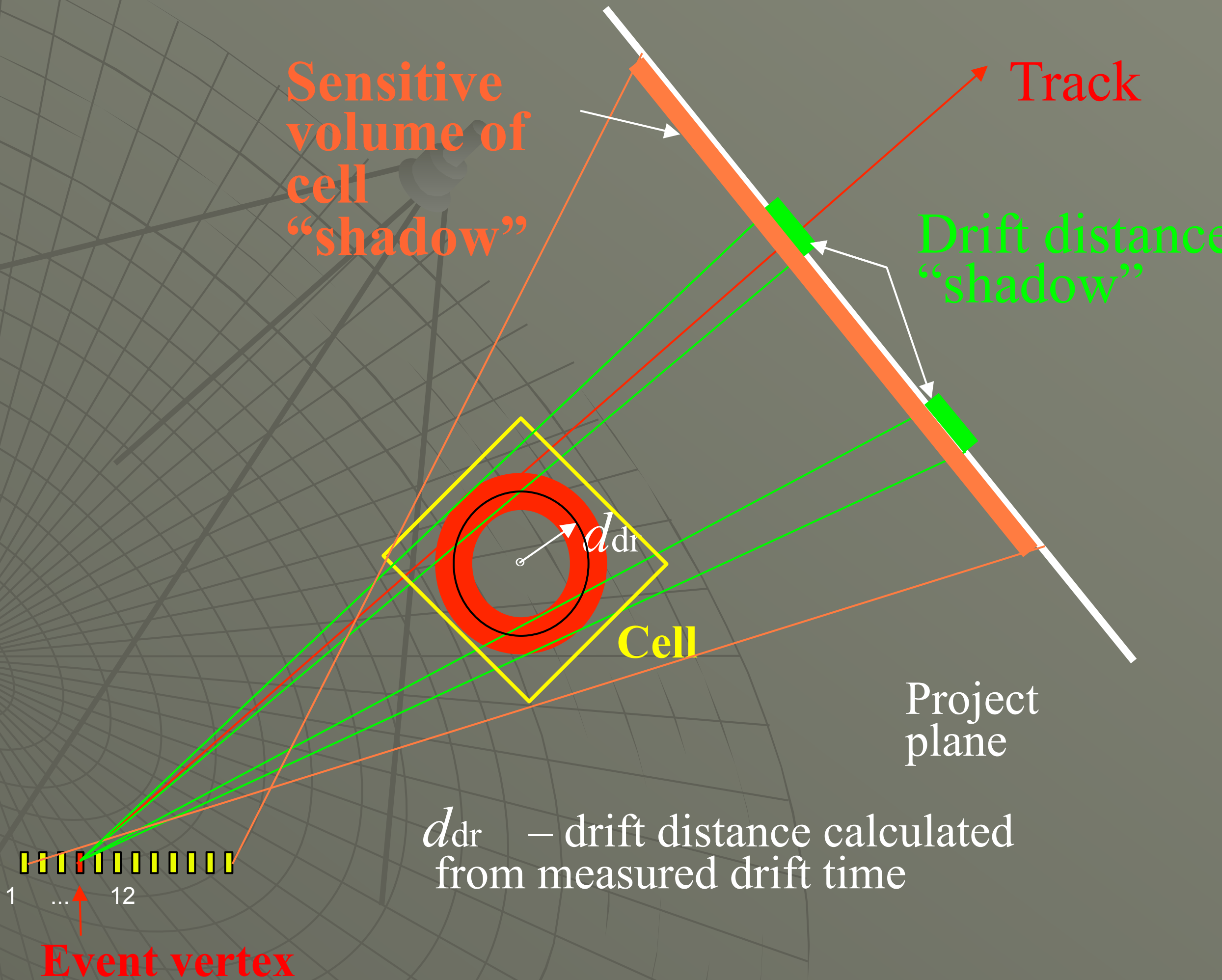
Candidate Search Efficiency





Scheme of using Drift Time in the Candidate Search

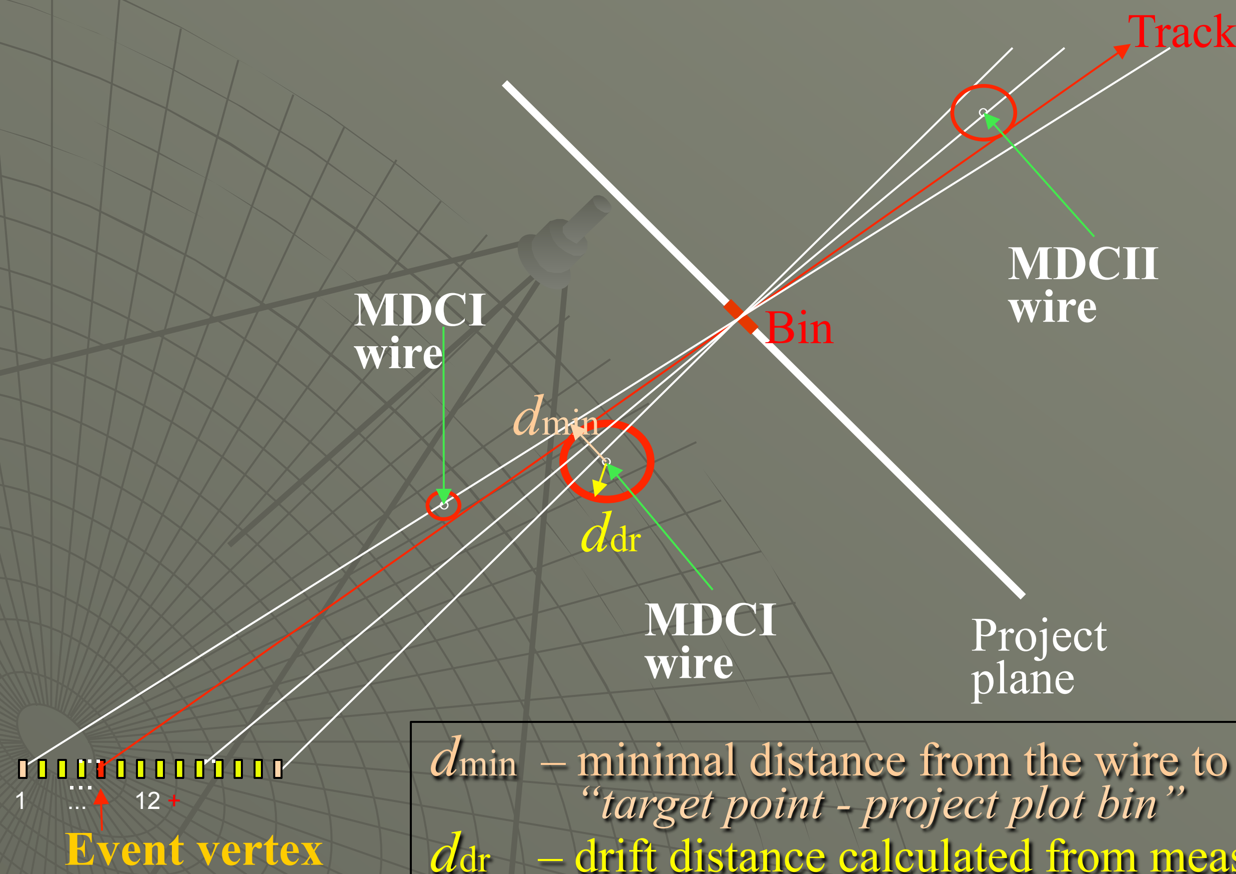
- Using the drift time to shrink the projected drift cell volume increases the contrast of the candidate search
- Increasing the number of bins on the projection plane improves further but increases the number of ghost tracks too



d_{dr} – drift distance calculated from measured drift time

Finding of Target Segment of the Event Vertex

- **Strategy:** try to find the target segment to shrink down the projection volumes and improved the initial values for tracking



d_{min} – minimal distance from the wire to the line *"target point - project plot bin"*

d_{dr} – drift distance calculated from measured drift time

Cut: $|d_{dr} - d_{min}| < \Delta d_{cut}$

Finding of Target Segment of the Event Vertex

- Apply threshold to the distributions to filter
- Find Target segment by best projection of all wires simultaneously
- Smooth distributions to find maximum with best precision
- After vertex fit all 12 target segments well separated