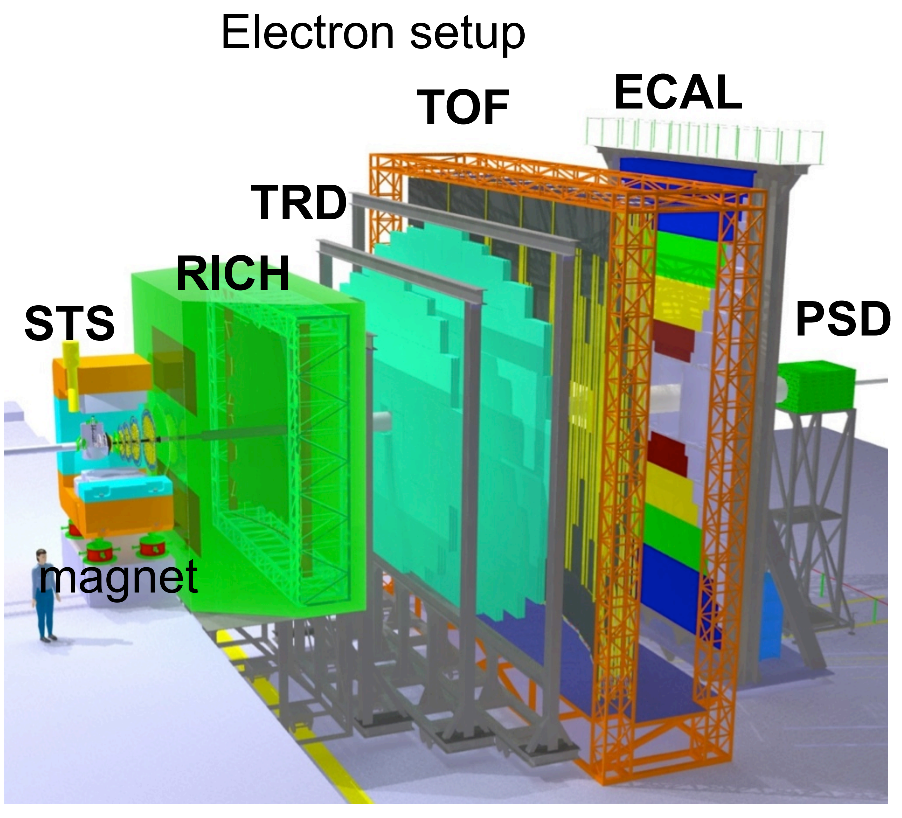
Selected event reconstruction algorithms for the CBM experiment at FAIR.

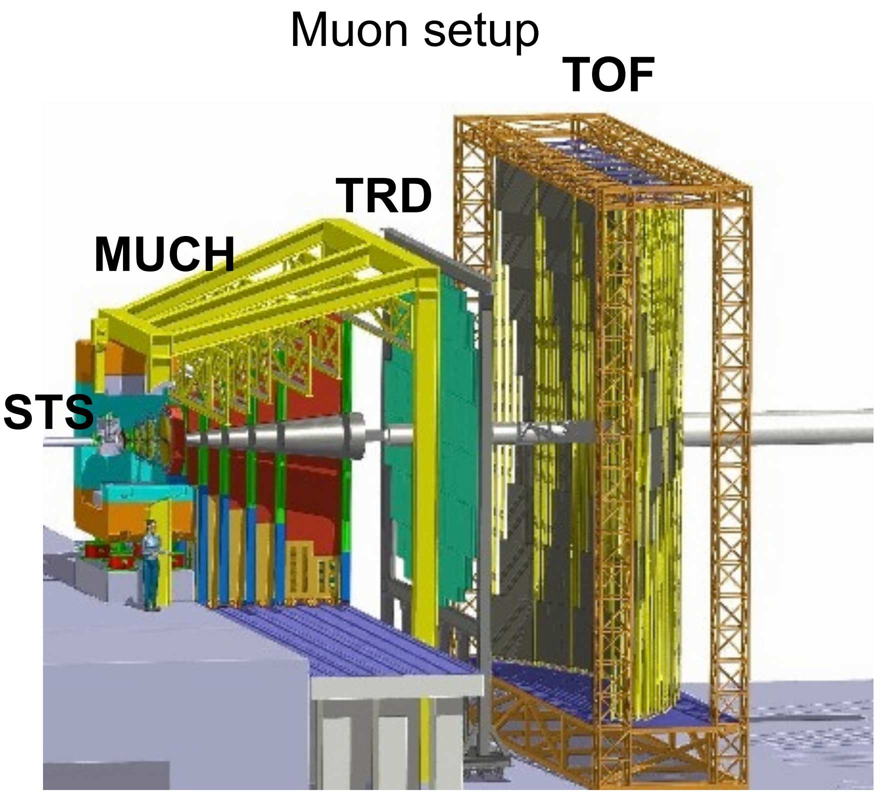
S. Lebedev[1,3], A. Lebedev[2,3], C. Hoehne[1] and G. Ososkov[3]
[1]Giessen University, [2]Frankfurt University, [3]LIT JINR

supported by BMBF and HIC for FAIR

The CBM experiment: "electron" and "muon" setups

CBM will provide hadron and lepton identification in large acceptance, good momentum and secondary vertex resolution





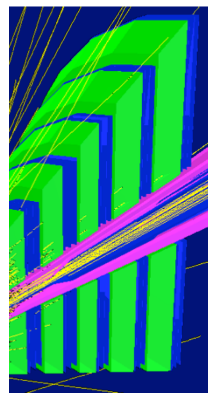
electron ID: RICH & TRD

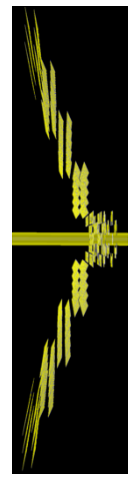
muon ID: MUon Chamber

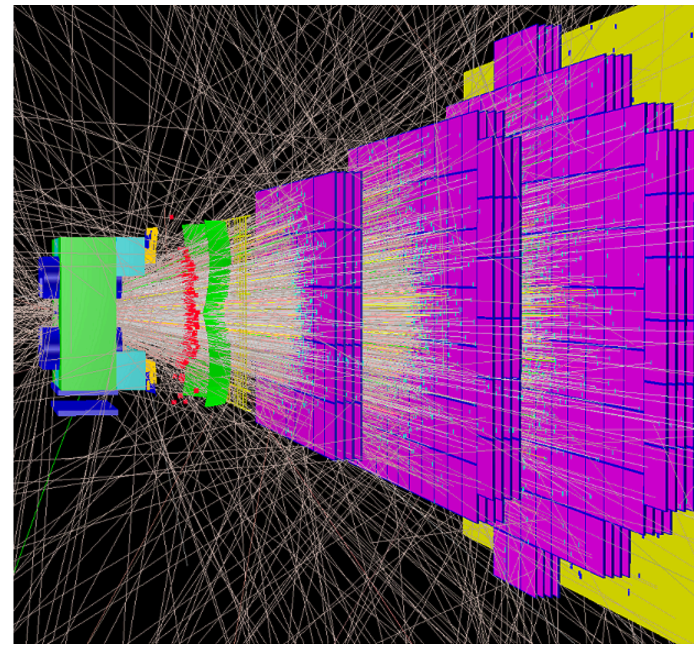
Challenges for event reconstruction

Peculiarities for CBM:

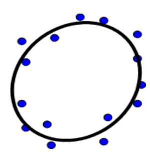
- **Large track and ring densities and multiplicities**
  - up to 1000 charged particles per reaction in +/- 25°
- **High reaction rate**
  - up to 10 MHz
- **Track reconstruction**
  - large material budget
  - complex detector structure,
    overlapping sensors, dead zones
- **Ring reconstruction**
  - Different number of hits in rings (5 – 35)
  - Elliptic shape of the rings (B/A = 0.9)







Central Au+Au collision at 25 AGeV (UrQMD + GEANT3)

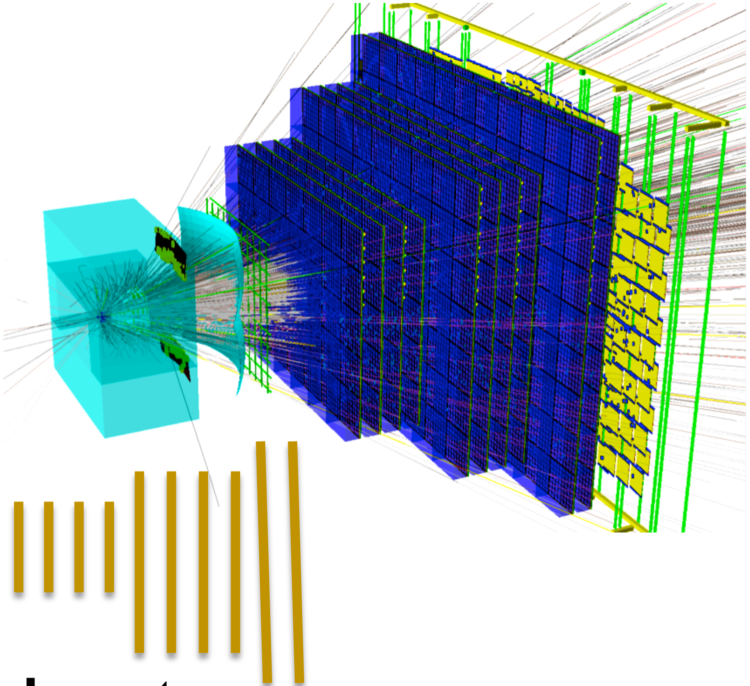


→ **fast reconstruction algorithms are essential**

radical speedup: optimization and parallelism

TRD and MUCH detectors

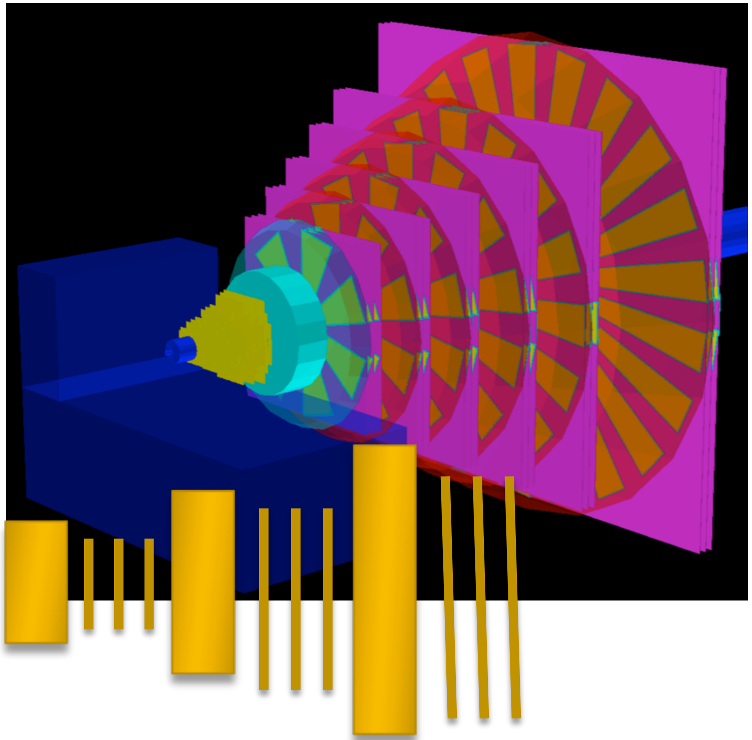
TRD: **Tracking and electron identification**



Layout:

- 10 layers starting at 5 m from the target.
- Rectangular pads, resolution: 300-500 μm across and 3-30 mm along the pad.

MUCH: **Muon identification**

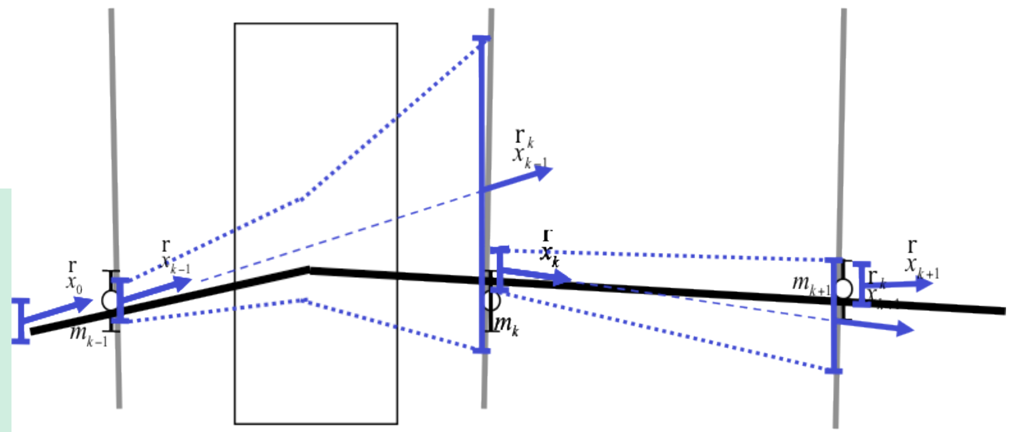


Layout:

- 18 GEM stations.
- First absorber 60 cm C + 5 Fe absorbers 20-20-25-35-100 cm.

Track reconstruction in TRD and MUCH

- Two main steps:
  - Tracking
  - Global track selection



Tracking is based on

- Track following
- Initial track seeds from STS
- Kalman Filter
- Validation gate
- Hit-to-track association techniques: nearest neighbor and branching
- Missing hits

Global track selection

- aim: remove clone and ghost tracks
- tracks are sorted by their quality, obtained by chi-square and track length
- Check for shared hits

Track propagation

- Inhomogeneous magnetic field: solution of the equation of motion with the 4th order Runge-Kutta method
- Large material budget: Energy loss (ionization: Bethe-Bloch, bremsstrahlung: Bethe-Heitler); Multiple scattering (Gaussian approximation)

Tools

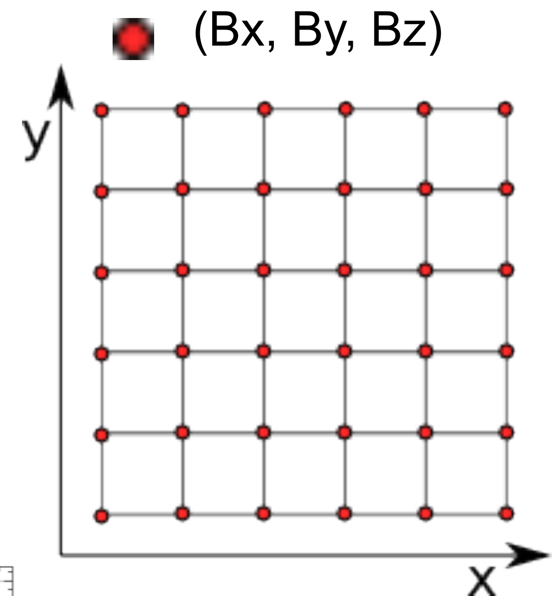
- TGeoManager
- Full magnetic field map

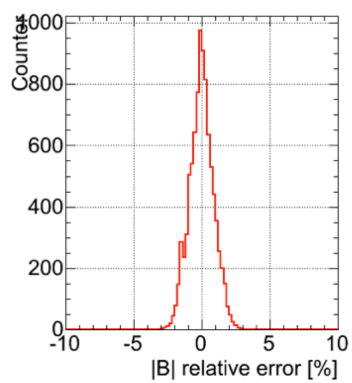
Track reconstruction Discussion

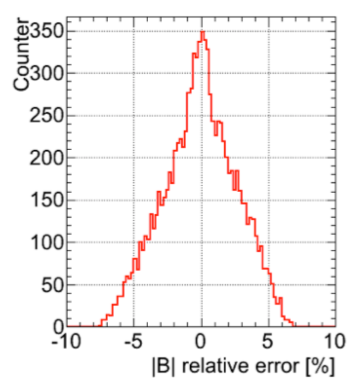
- Disadvantage:
  - Relatively slow calculation time
  - Hard to implement SIMD version
- Advantage:
  - General tracking algorithm. Can be used for different geometries and different experiment setups without modifications.
- How to improve calculation time:
  - Simplification of geometry -> fast access to material budget.
  - Approximation of magnetic field.

Optimization of the tracking algorithm. Magnetic field approximation.

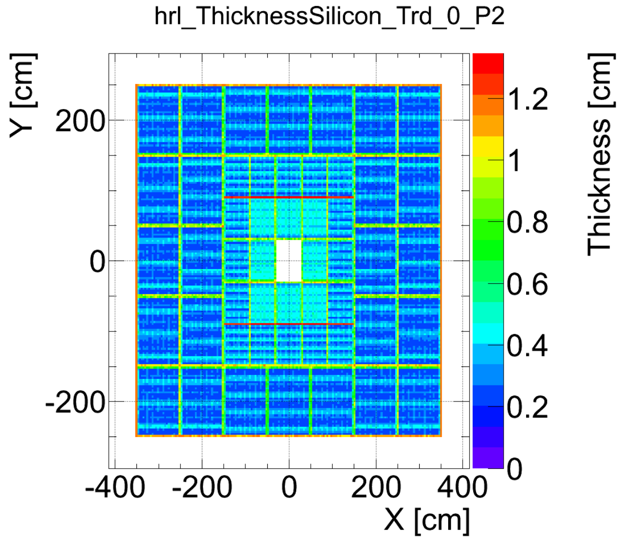
- Track propagation
- Two approaches:
  - OLD: polynomial approximation
    - bad quality for Z > 2m due to B-field fluctuations.
  - NEW: Field approximated as grid slice in (X,Y)
    - High accuracy
    - Low memory consumption
    - It's fast
    - No SIMD access







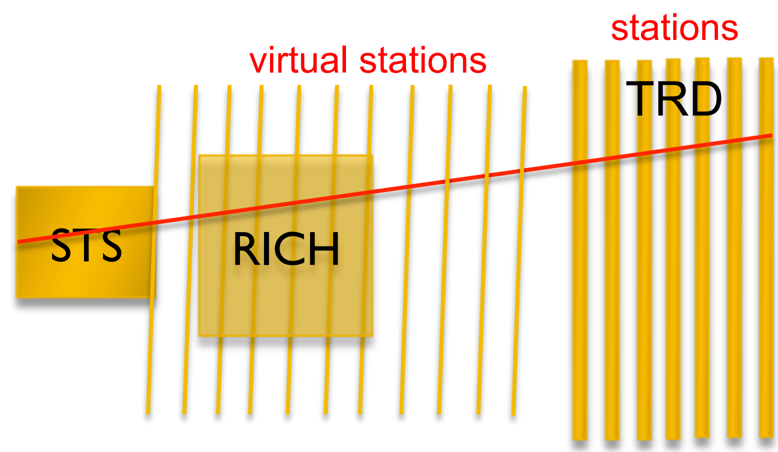
Optimization of the tracking algorithm. Geometry representation in tracking



Material approximation in silicon equivalent

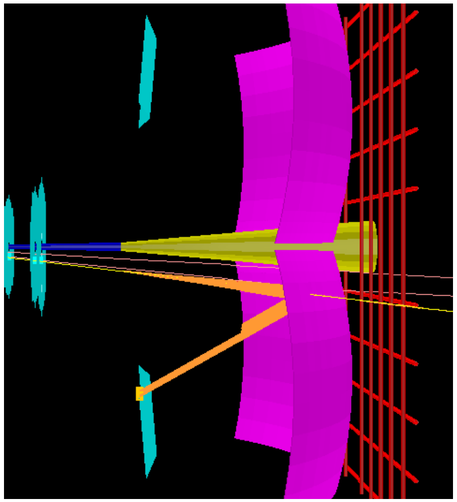
<u>Detector geometry:</u>

- stations: material + field + hits
- virtual stations: material + field



- Standard implementation of tracking uses full B-field map and TGeoManager and much better optimized for different geometry setups.
- For a better optimization one needs to optimize algorithm for a certain detector geometry.

The CBM RICH detector

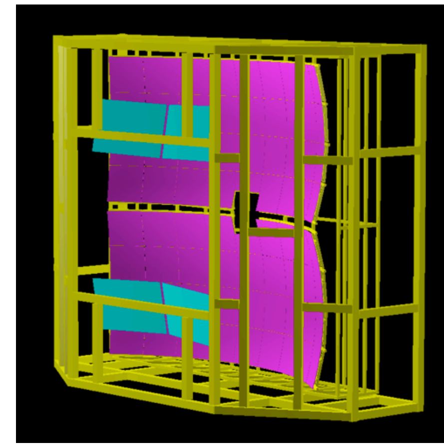


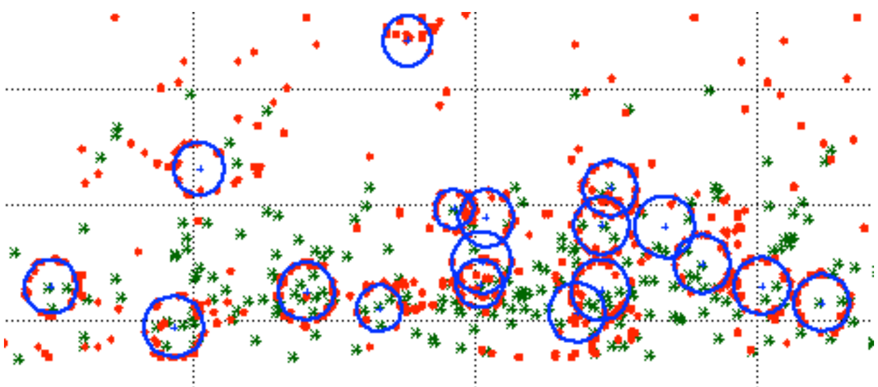
RICH: electron identification by Cherenkov radiation

RICH characteristics:

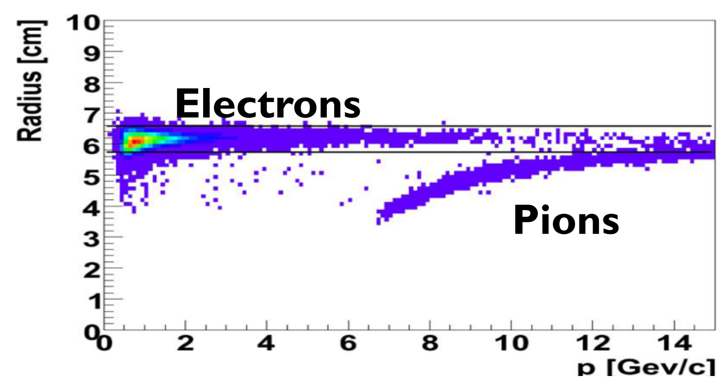
- **radiator:** CO_2 length 1.7 m; $P_{th,\pi}$ =4.65 GeV/c
- **glass mirror of 6 mm thickness:**
  3m radius; 11.8 m^2 size
- **photodetector Hamamatsu H8500 MAPMT:**
  2.4 m^2 -> 55k channels

Mean number of hits per electron ring is 22.



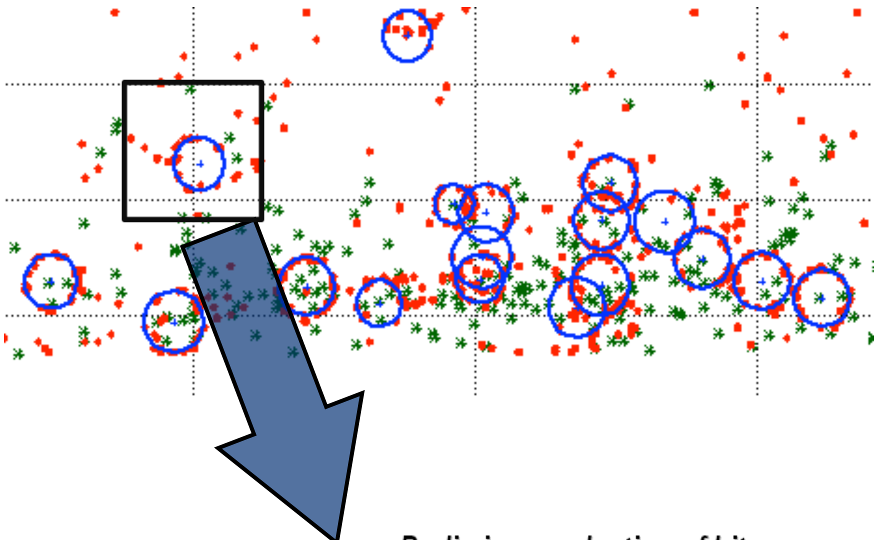


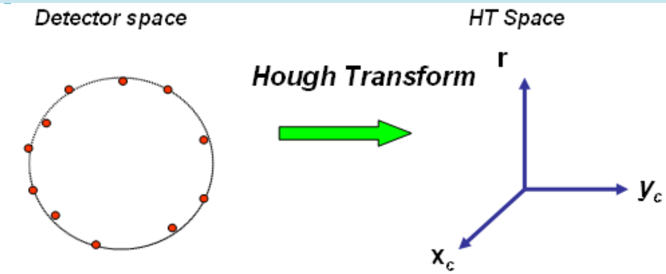
RICH hits (blue), found rings (red), track projections (green).



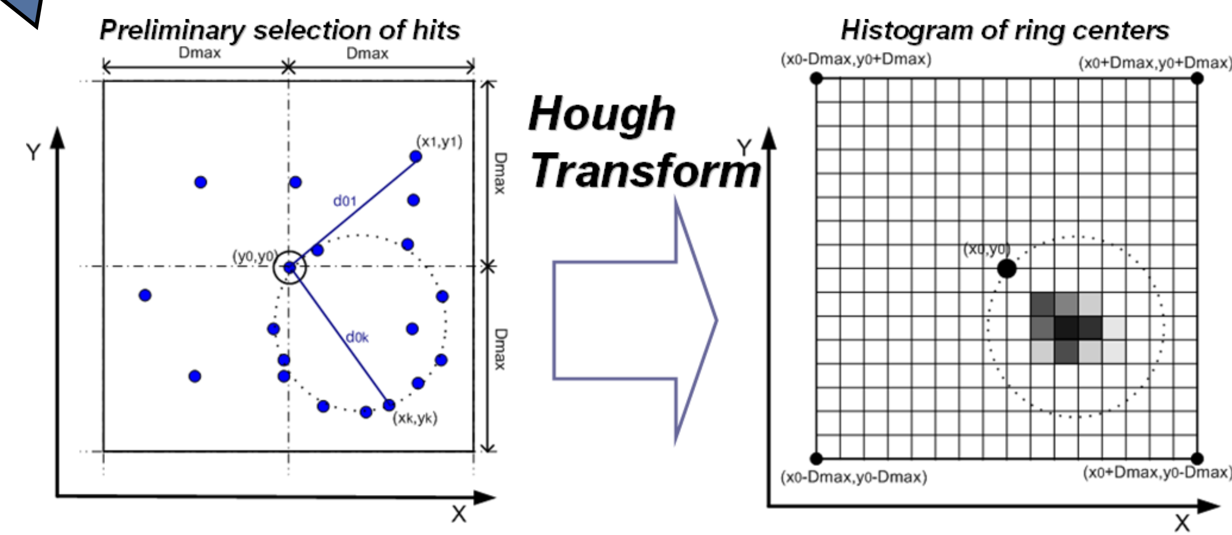
Radius vs. momentum for reconstructed rings.

Hough Transform for the ring reconstruction



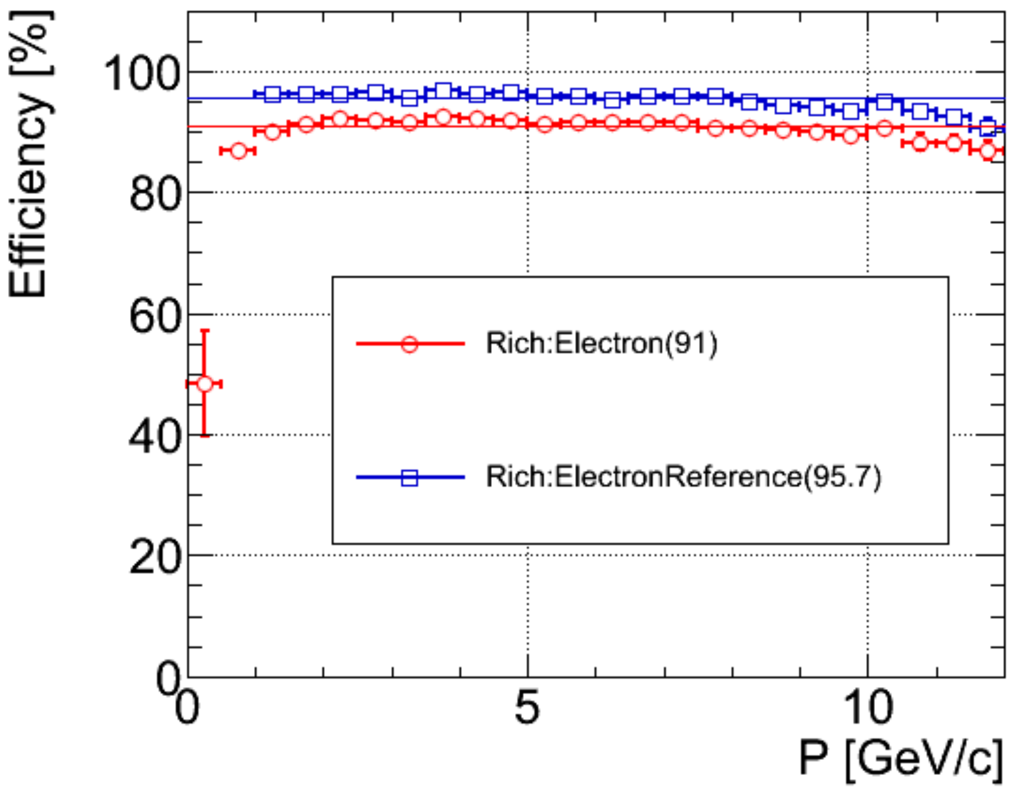


Hough Transform:
large combinatorics => slow
Localized Hough Transform:
much less combinatorics => fast



Reconstruction performance in RICH

Simulation: UrQMD events at 25 AGeV Au-Au collisions + **omega meson ->e+e-** embedded in each event.



Algorithm	Time/ev [ms]
Initial	**800**
Fast	**45**

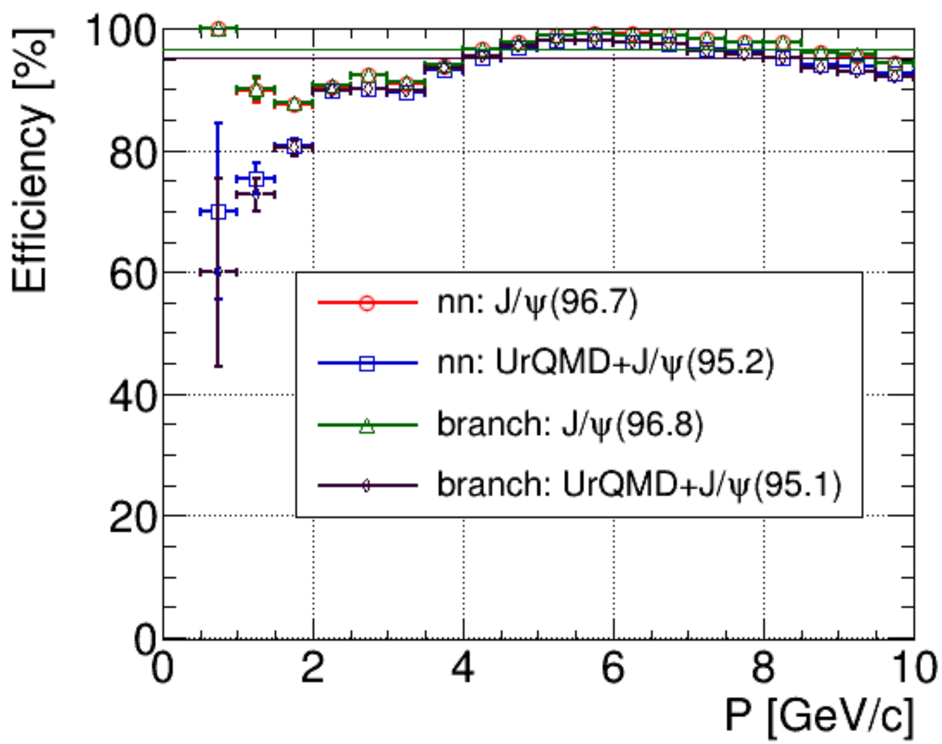
- Speedup factor 17.7.
- Reconstruction efficiency is more than 90%.

RICH acceptance: rings with >= 7 hits. Ref: >= 15 hits.

Track reconstruction performance in MUCH

MUCH acceptance: tracks with >= 7 hits.

Simulation: UrQMD events at 25 AGeV Au-Au collisions
J/psi meson ->mu+mu-

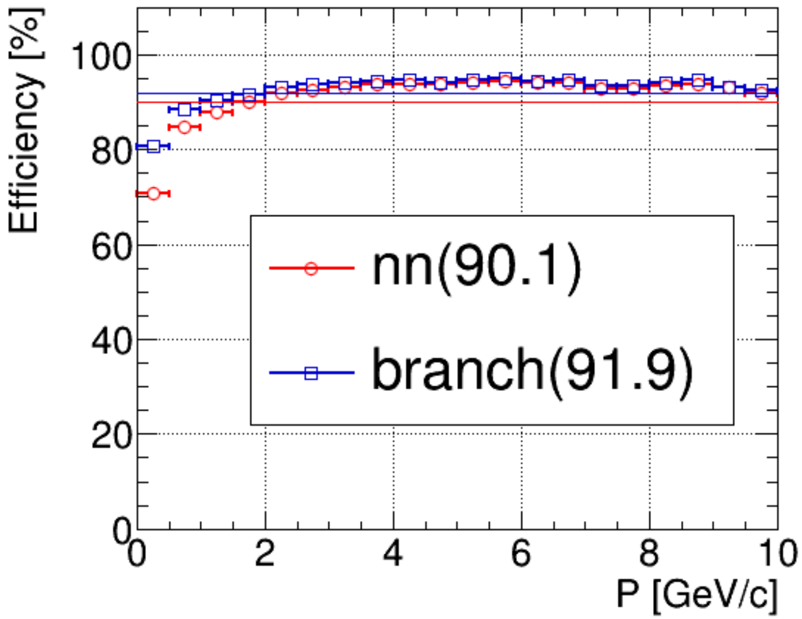


- Both tracking approaches show the same performance

Track reconstruction performance in TRD

TRD acceptance: TRD tracks with >= 8 hits.

Simulation: UrQMD at 25 AGeV Au-Au collisions + **J/Psi->e+e-** embedded in each event.



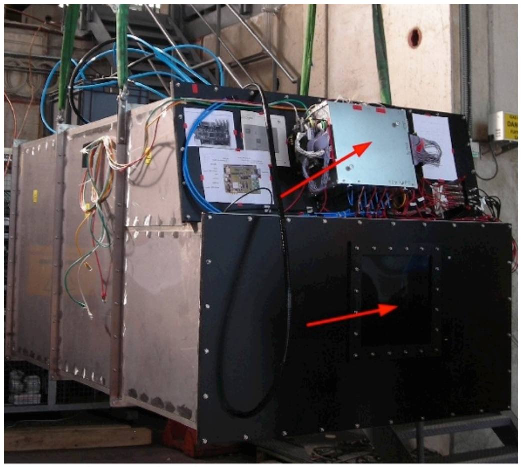
Algorithm	Time/ev [ms]
Branching std	**2500**
Nearest neighbor std	**1300**
Fast nearest neighbor	**90**

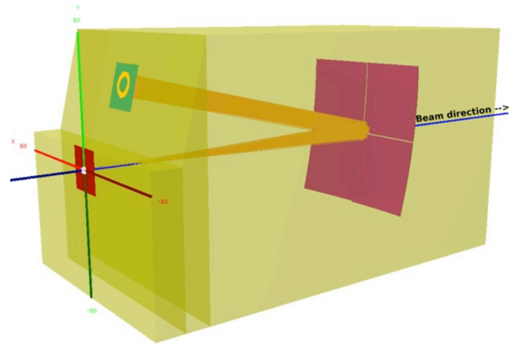
Preliminary!
Speedup factor 14.

- Branching tracking performance is slightly better in comparison to nearest neighbor approach, however NN algorithm is faster and easier to implement.

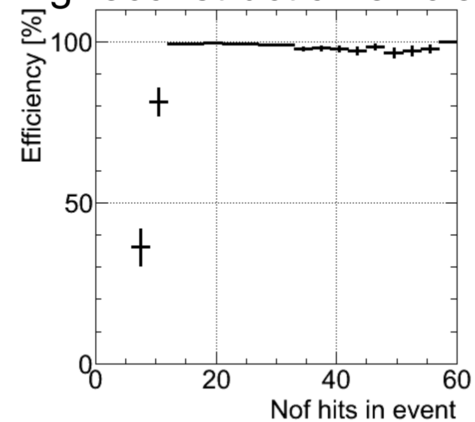
RICH prototype

RICH box

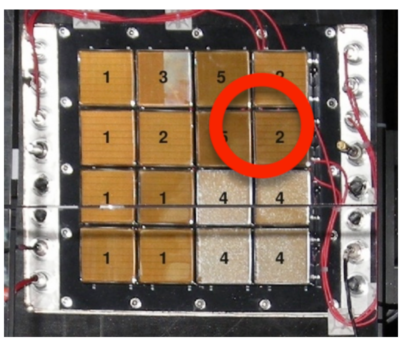




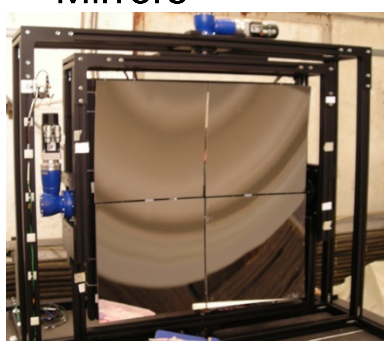
Ring reconstruction efficiency



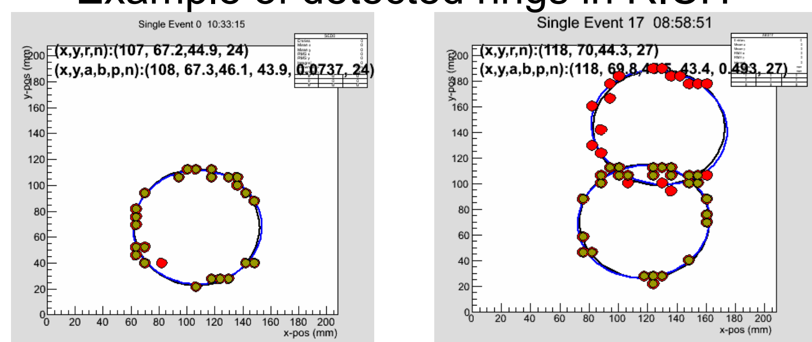
Photodetectors



Mirrors



Example of detected rings in RICH



- Full-size RICH prototype was successfully tested in CERN in 2011 and 2012.
- Developed algorithms were used for event reconstruction for RICH prototype.

Summary

- Event reconstruction algorithms in the RICH, TRD and MUCH detectors were presented.
- Although standard reconstruction algorithms are slower, but they are more general and do not depend strongly on geometry. Development of fast algorithms leads to implementation which strongly depends on a certain geometry.
- Ring reconstruction algorithm were used for data analysis for the CBM-RICH prototype.