Event reconstruction of free-streaming data for the RICH detector in the CBM experiment

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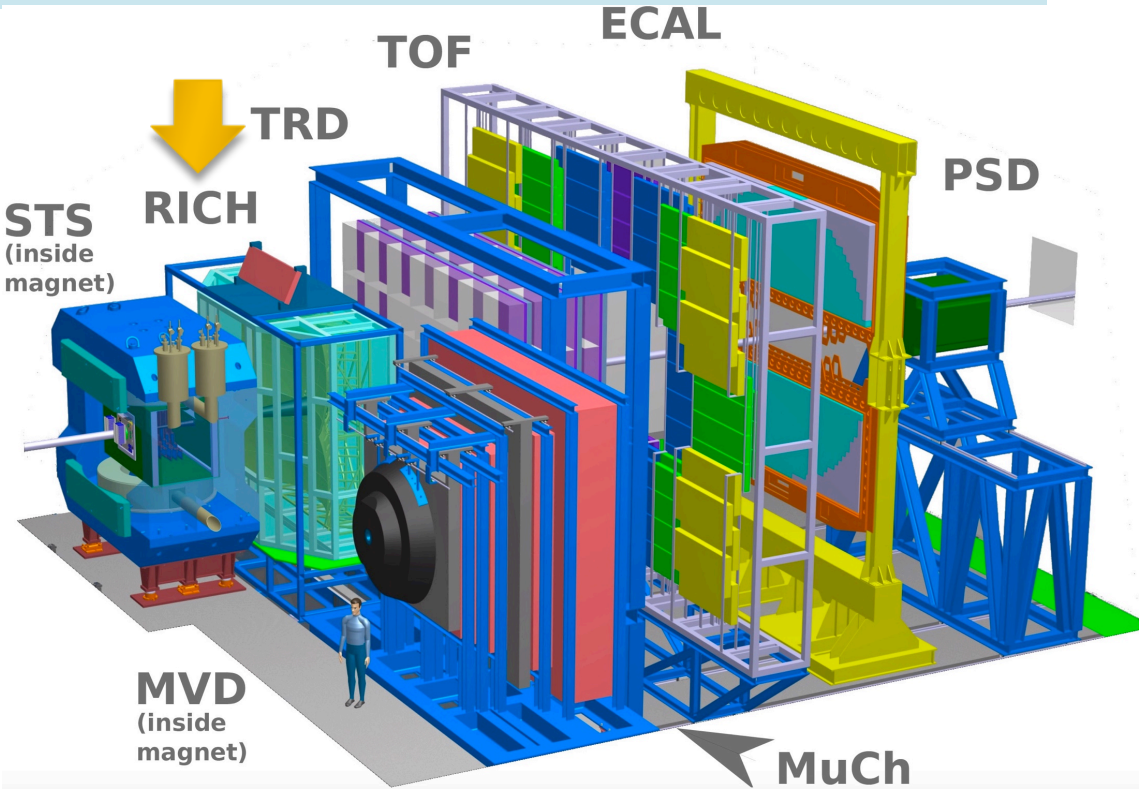
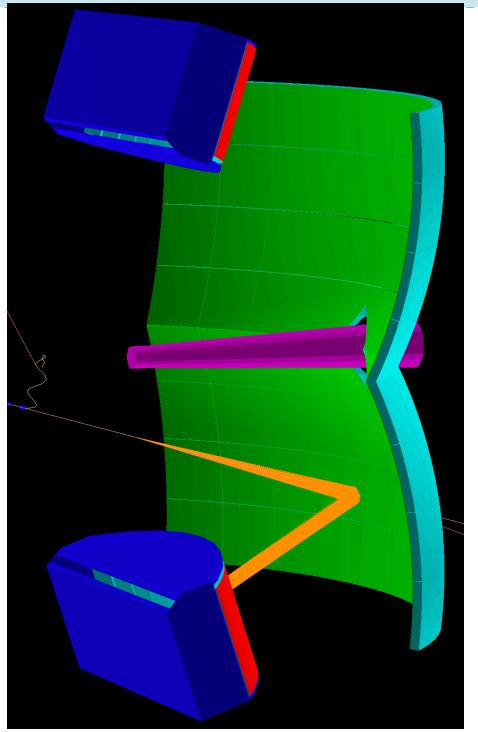
The Compressed Baryonic Matter (CBM) experiment

- Facility for Antiproton and Ion research (**FAIR**) at Darmstadt, Germany.
- **SIS100** synchrotron - protons up to 29 GeV, Au up to 11 AGeV.
- **CBM** is dedicated heavy ion experiment at FAIR.
- One key item of the CBM physics program is the precise measurement of **electromagnetic radiation** (low-mass vector mesons, J/ψ) via di-electrons.

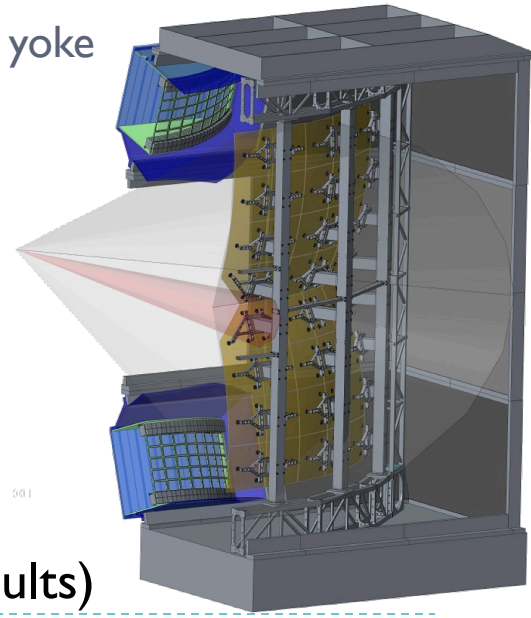


- **STS**: tracking, momentum measurement, **RICH+TRD**: electron ID, **TOF**: hadron ID **ECAL**: photons, **PSD**: event characterization.

Ring Imaging CHerenkov (RICH) detector



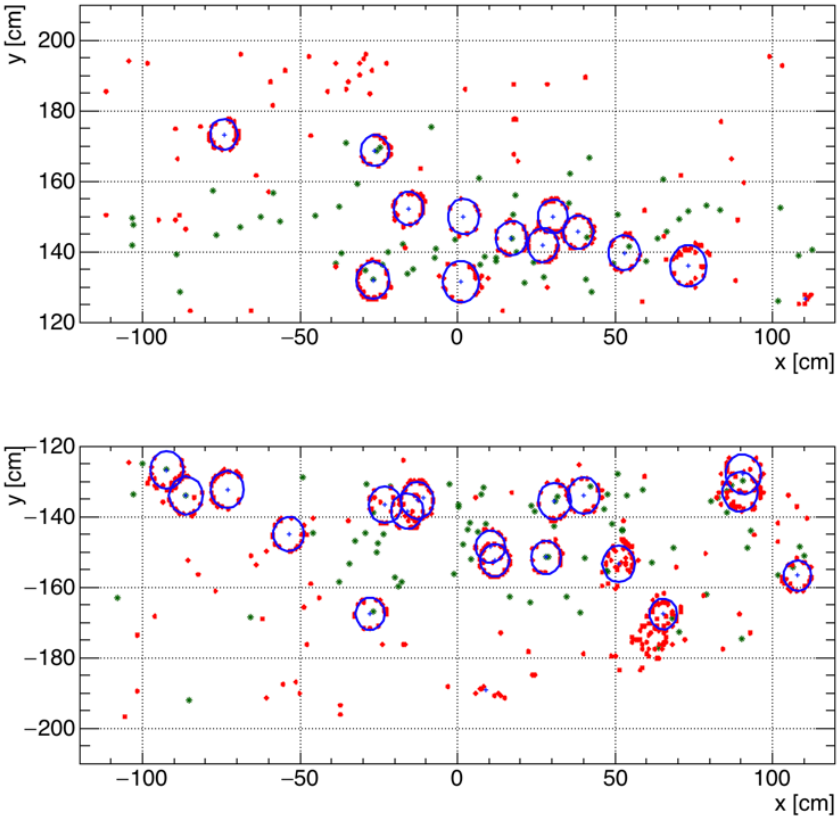
- **Electron identification** for p < 10 GeV/c
- CO_2 as radiator gas (1.7 m length, $p_{th,\pi}$= 4.65 GeV/c)
- Photondetector:
  - 2 MAPMT planes
  - Hamamatsu H12700 Multi-Anode PMTs
  - ~64000 channels
  - MAPMT planes shielded by magnet yoke

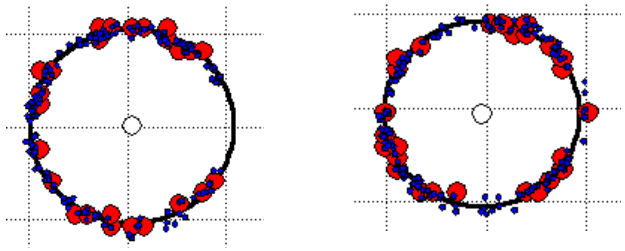


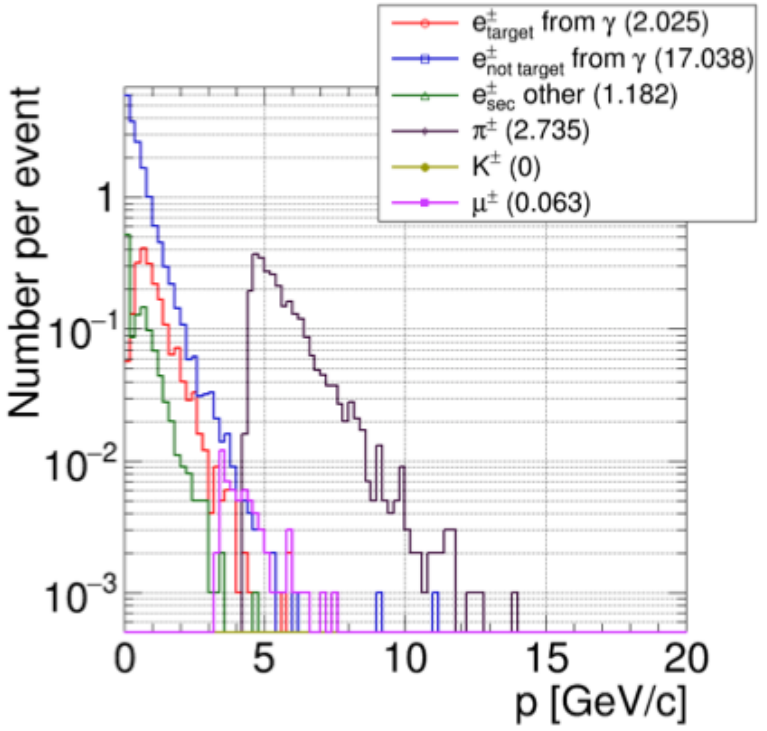
- Mirrors:
  - 2 large spherical mirrors (R = 3 m) as focusing optics
  - 80 mirror tiles (~40x40 cm^2)
- Required π suppression in RICH - 500, +TRD - 5000
- About 21 hits per electron ring (proven by beamtest results)

CBM-RICH event display, UrQMD central Au-Au at 8 AGeV

blue circles – reconstructed rings
red points – RICH hits including noise
green markers – track projections



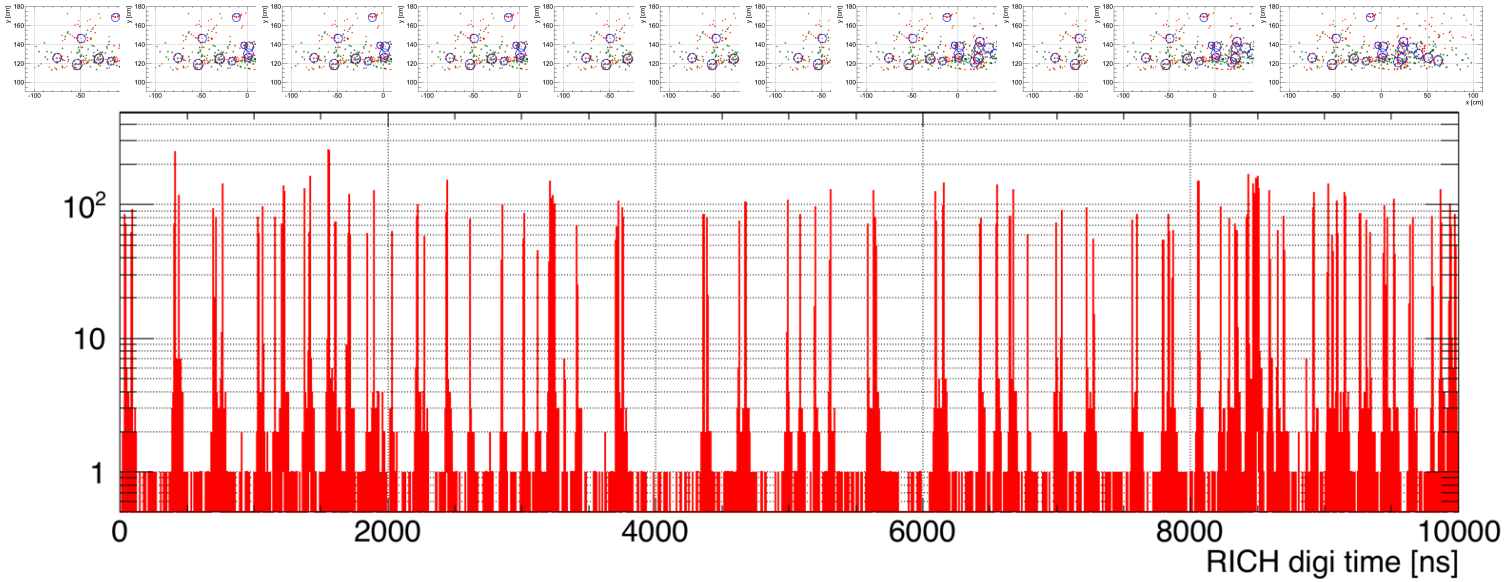




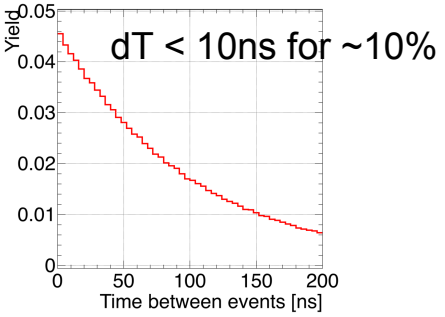
- Around 30 rings per event for central Au-Au at 8 AGeV

Free streaming data

10 MHz interaction rate, Au-Au mbias at 8AGeV
Part of time slice with ~100 events

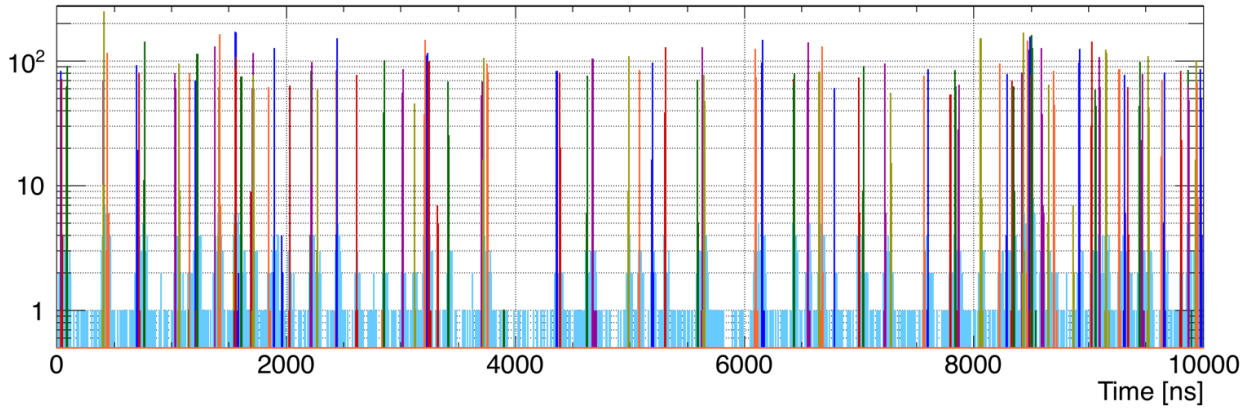


- CBM experiment will work in a triggerless mode.
- Free streaming data, no hardware trigger.
- Continuous time-slices instead of individual collisions.

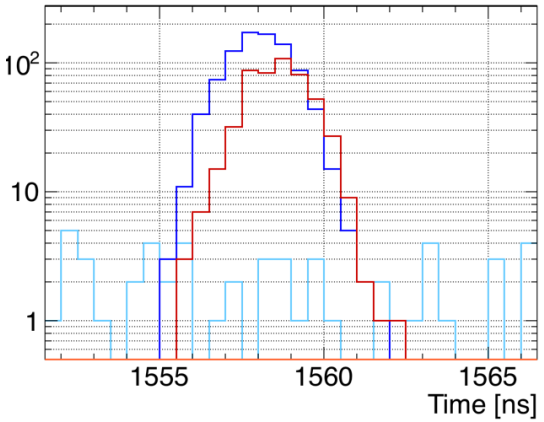


Detector response

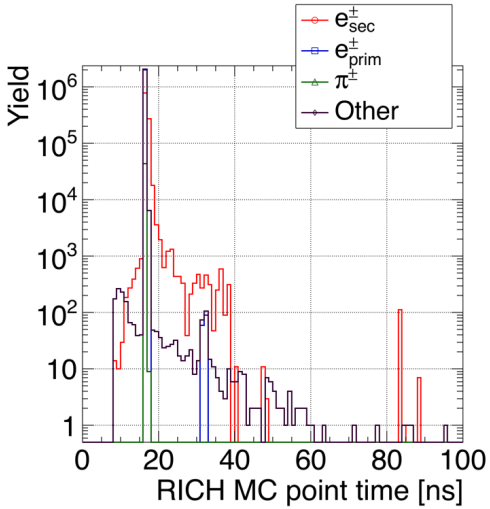
Different colors corresponds to different events



Event overlaps in time

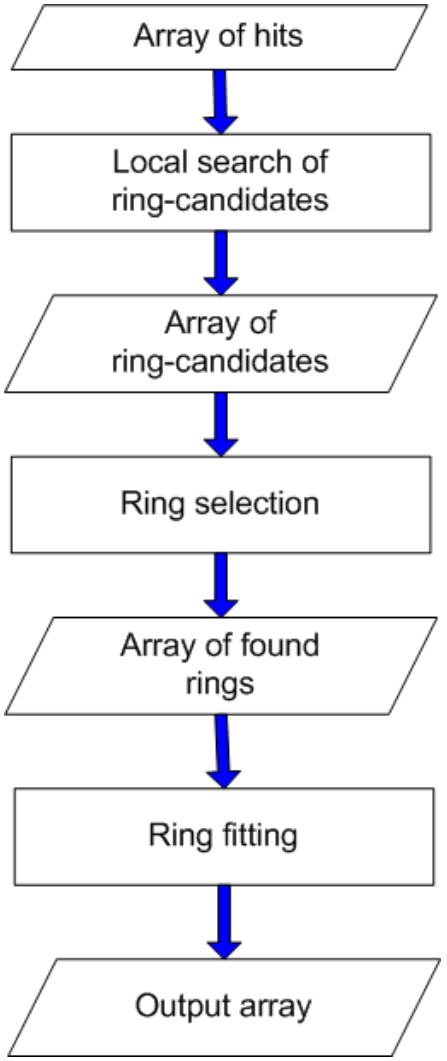


- Realistic detector simulation:
  - Real Quantum Efficiency measurements
  - Noise and cross-talk hits
  - Event correlated noise scaled with event multiplicity
- Digitizer parameters:
  - PMT pixel dark rate: 1kHz
  - Time resolution: 1 ns
  - Pixel dead time: 50 ns

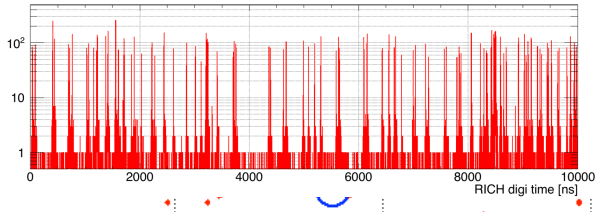


Ring reconstruction algorithm

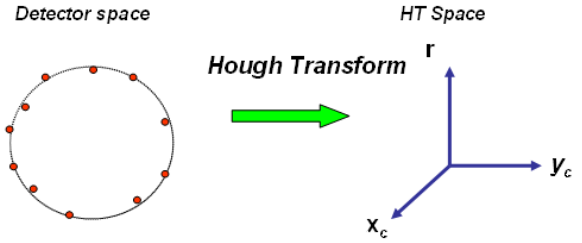
- Ring finder
  - Array of hits (X,Y and time measurements)
  - No track information
- Algorithm consists of 3 steps:
  - Ring-candidate finding
    - Hough Transform
  - Ring selection
    - compares all ring-candidates and chooses only good rings while rejecting ghost and clone rings
  - Ring fitting
    - Ellipse fitter based on Taubin method



Hough Transform for the ring-candidate reconstruction

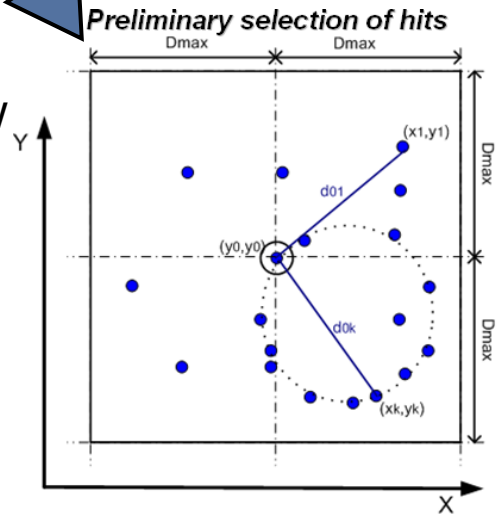


Preselection of hits in 3D (X, Y, time)

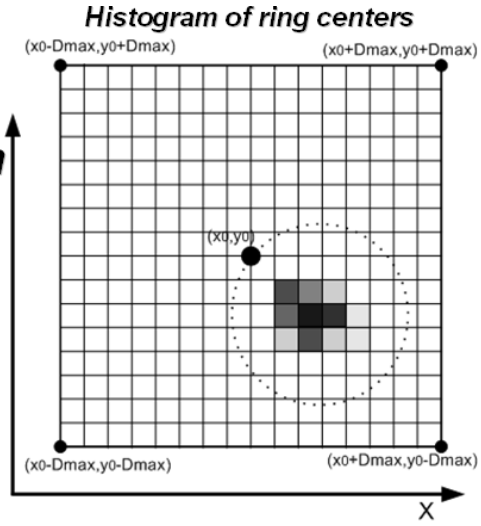


Hough Transform:
large combinatorics => slow
Localized Hough Transform:
much less combinatorics => fast

Time window ±3σ

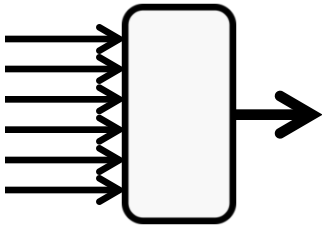


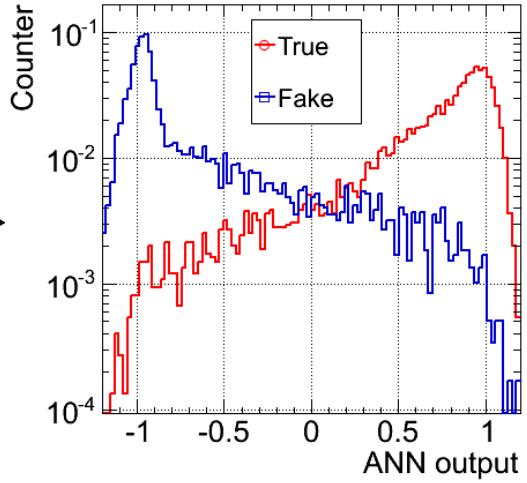
Hough Transform

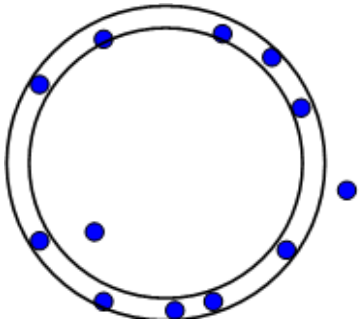


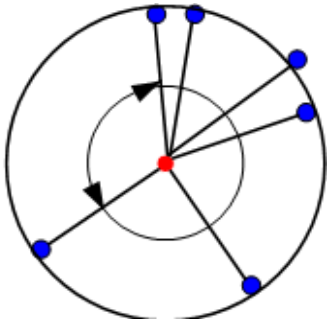
Selection of ring-candidates
Ring quality

- Ring quality parameters:
  - number of hits in ring;
  - chi-squared;
  - number of hits in a small corridor around the ring;
  - biggest angle between neighboring hits;
  - position of ring on photodetector plane;
  - radius



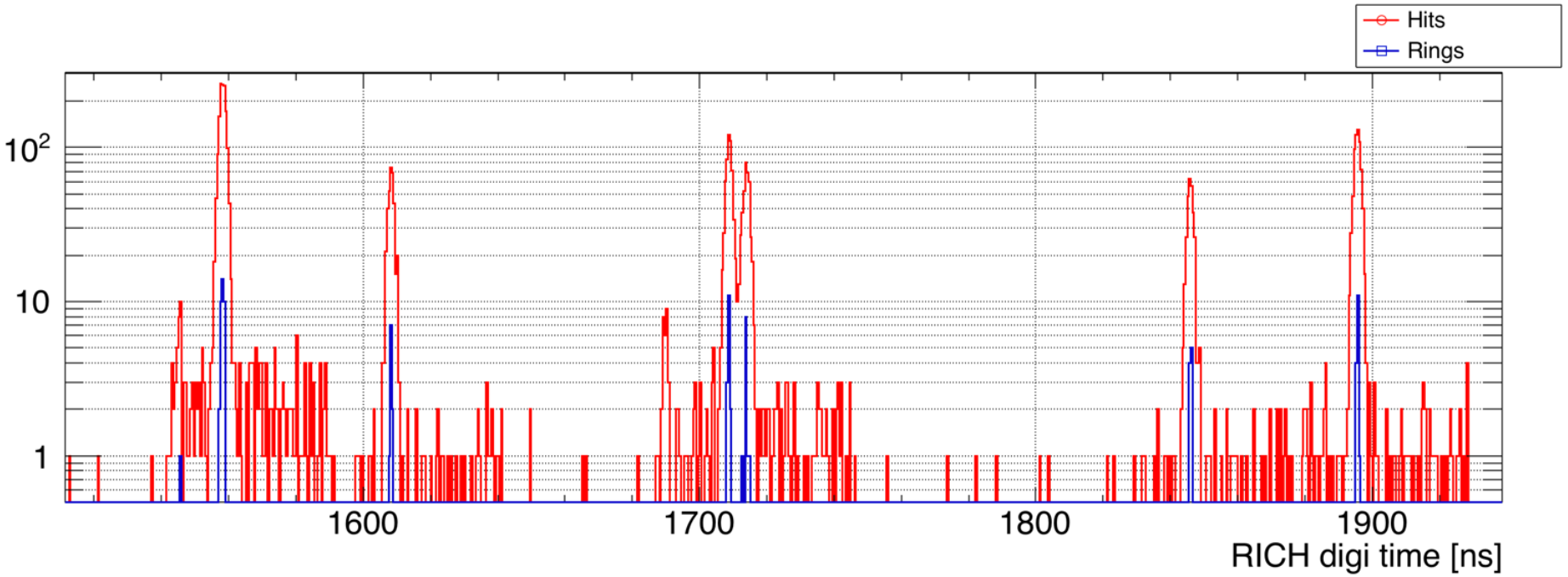






- **<u>Artificial Neural Network (ANN)</u>** derives ring quality from six parameters.
- Selection of good rings is based on ring quality and shared hits.
- Ring-candidates from the same time-slice (different events).
- If the candidate shares more than 25% of its hits with a better quality ring the candidate is rejected.

Ring reconstruction results



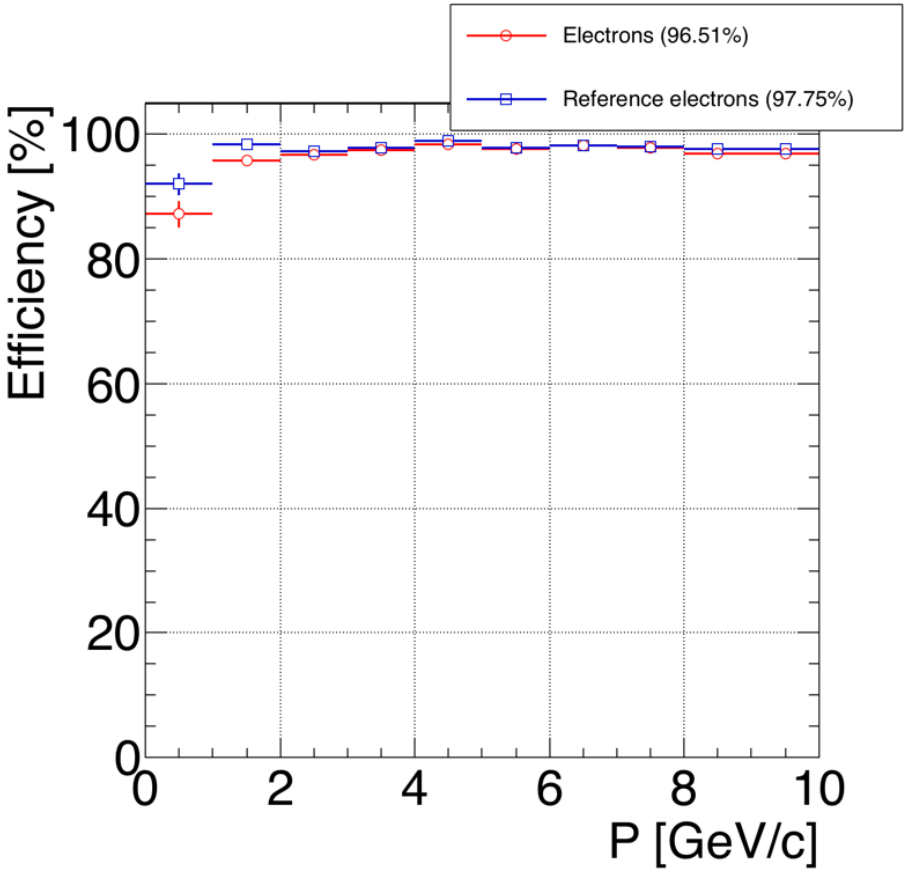
- Ring time = average time of all attached hits.
- Rings are nicely grouped into events -> reconstruction uses time information properly.

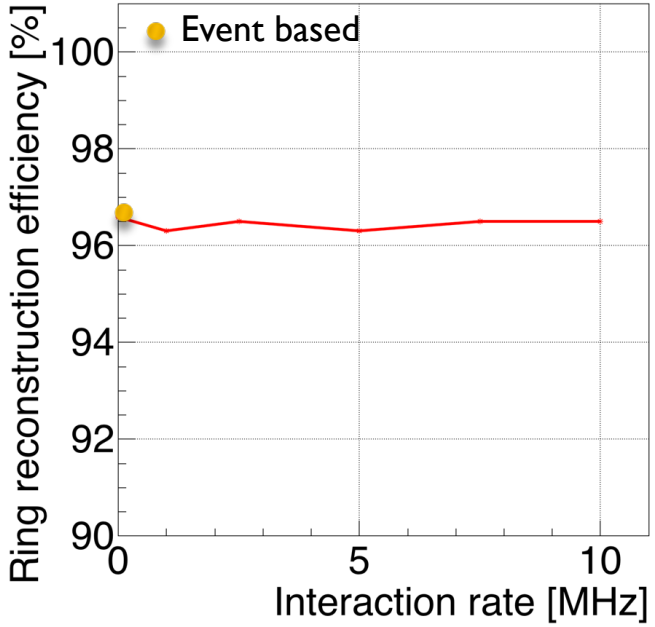
Ring reconstruction results
Au-Au mbias events at 8 AGeV

10 MHz interaction rate

Electron - primary $e^{+/-}$ with at least 7 hits,

ElectronReference - primary $e^{+/-}$ with at least 15 hits





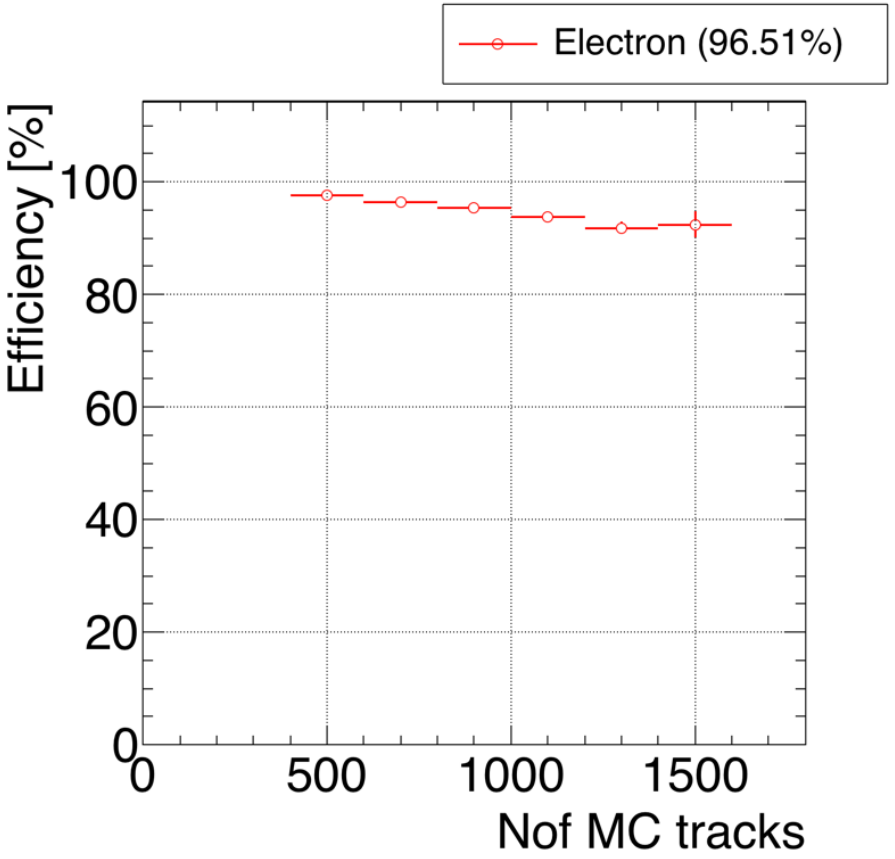
A ring is defined as **correctly found** if it has more than 60% of hits from one Monte-Carlo ring, otherwise a ring is defined as **ghost ring**.

Summary

- CBM will be one of the first heavy ion experiment which works in a triggerless mode.
- The simulation and reconstruction of the free streaming data in the CBM-RICH was successfully developed.
- The performance of time-based reconstruction is the same as event-based reconstruction.

- Backup

Ring reconstruction results
Au-Au mbias events at 8 AGeV, 10 MHz



- Ring reconstruction vs. event particle multiplicity