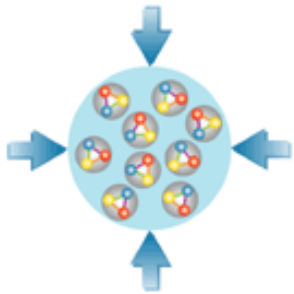


Fast Ring Recognition Algorithm for the RICH detector of the CBM Experiment at FAIR

Semen Lebedev

GSI, Darmstadt, Germany and LIT JINR, Dubna, Russia

Claudia Hoehne

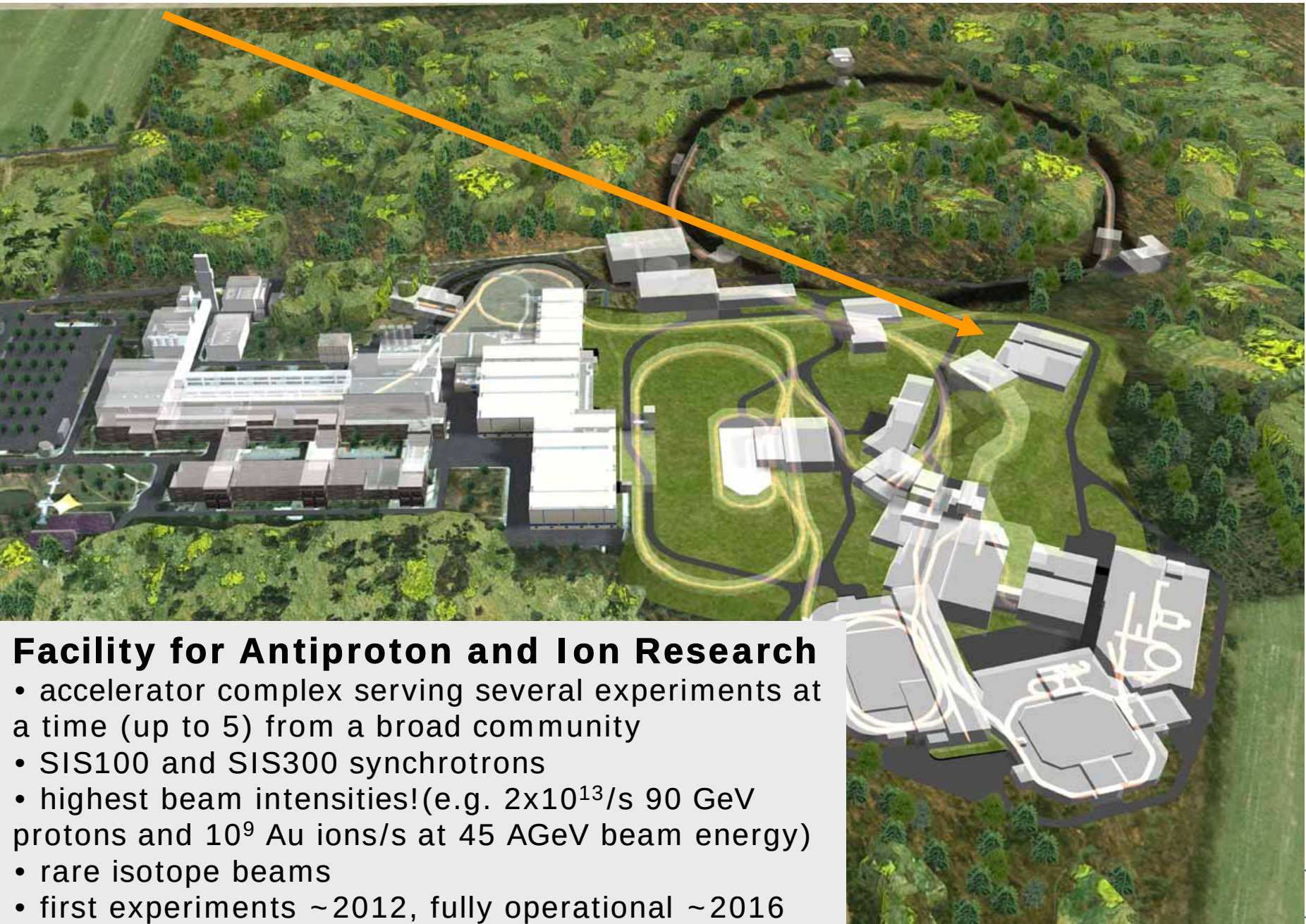
GSI, Darmstadt, Germany

Gennady Ososkov

LIT JINR, Dubna, Russia

S.Lebedev@gsi.de

CBM at FAIR



Facility for Antiproton and Ion Research

- accelerator complex serving several experiments at a time (up to 5) from a broad community
- SIS100 and SIS300 synchrotrons
- highest beam intensities!(e.g. $2x10^{13}$/s 90 GeV protons and 10^9 Au ions/s at 45 AGeV beam energy)
- rare isotope beams
- first experiments ~2012, fully operational ~2016

CBM experiment

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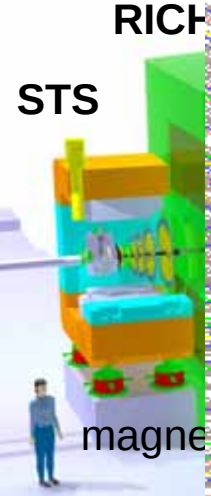

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About 1000 charged particles in central Au+Au collision at a beam energy of 25 AGeV in the CBM acceptance.

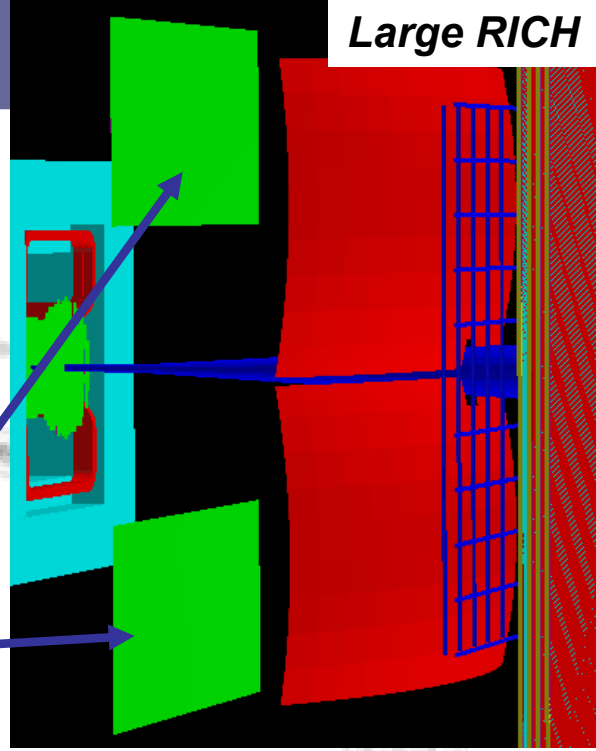
CBM RICH detector (I)

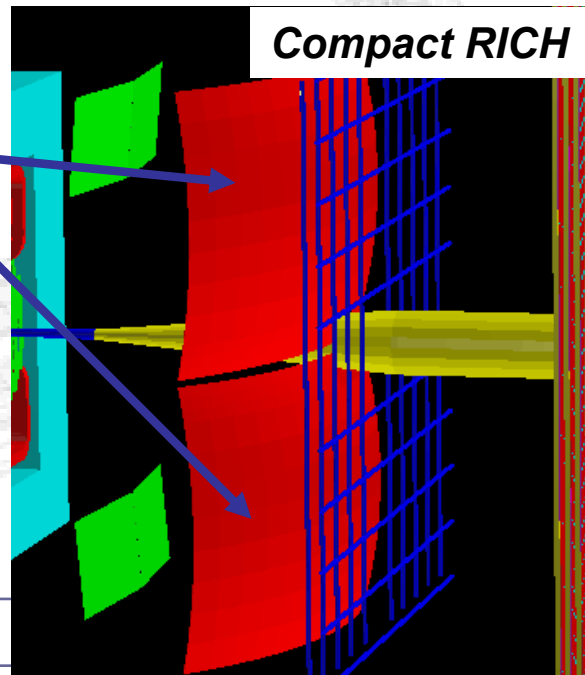
RICH in CBM will serve for electron identification for momenta up to 10 GeV/c -> study vector mesons and J/Ψ

Two different options of RICH (Large and Compact) are under discussions

RICH characteristics:

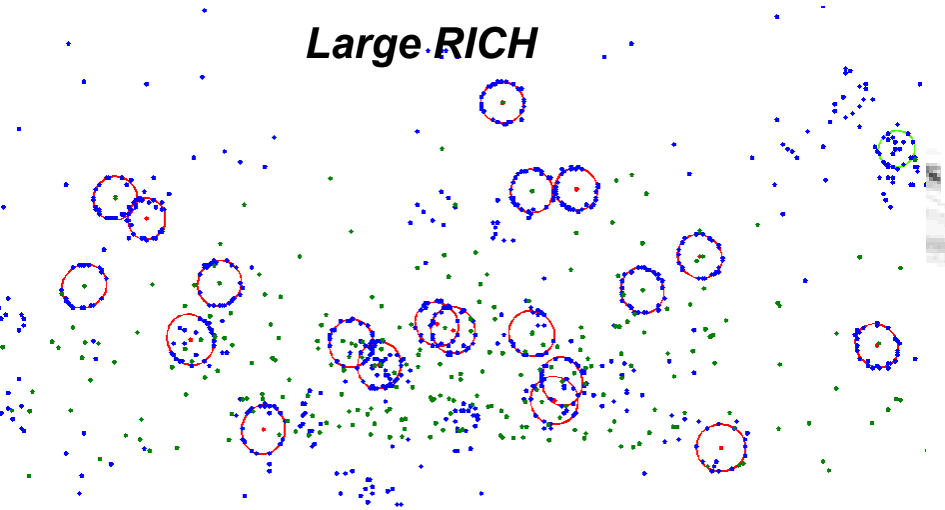
- ***radiator :***
  - ***N_2 length 2.5 m (large RICH)***
  - ***CO_2 length 1.5 m (compact RICH)***
- ***glass mirror of 6 mm thickness and aluminum support structure:***
  - ***mirror radius: 4.5m (Large) and 3m (Compact)***
  - ***size: 22 m^2 (Large) and 11.8 m^2 (Compact)***
- ***photodetector Hamamatsu H8500 MAPMT:***
  - ***9 m^2 -> 200k channels (large RICH)***
  - ***2.4 m^2 -> 55k channels (compact RICH)***
- ***about 20 hits/ electron ring***



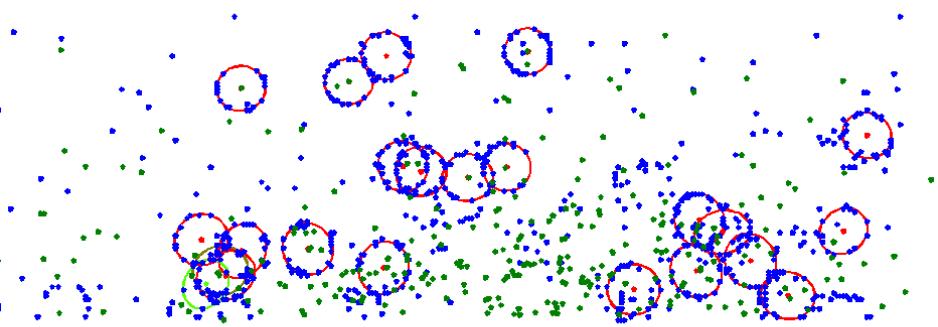


CBM RICH detector (II)

Large RICH

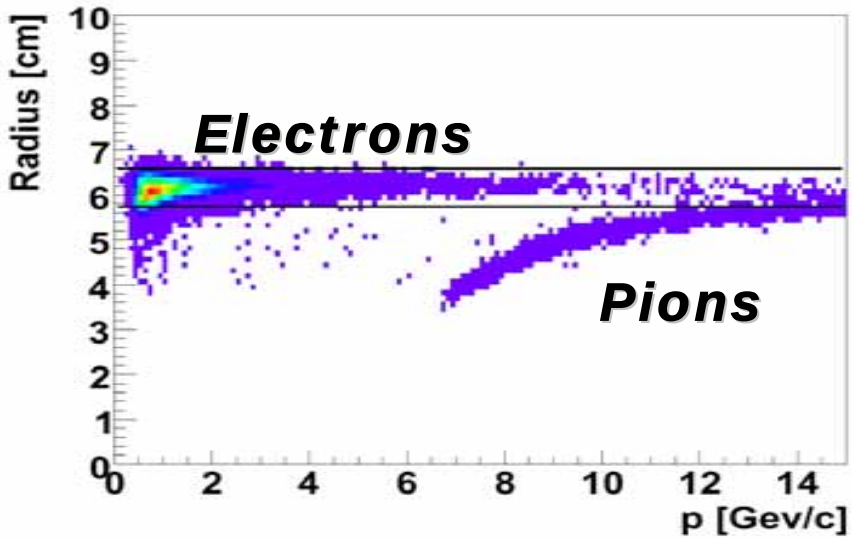


Compact RICH



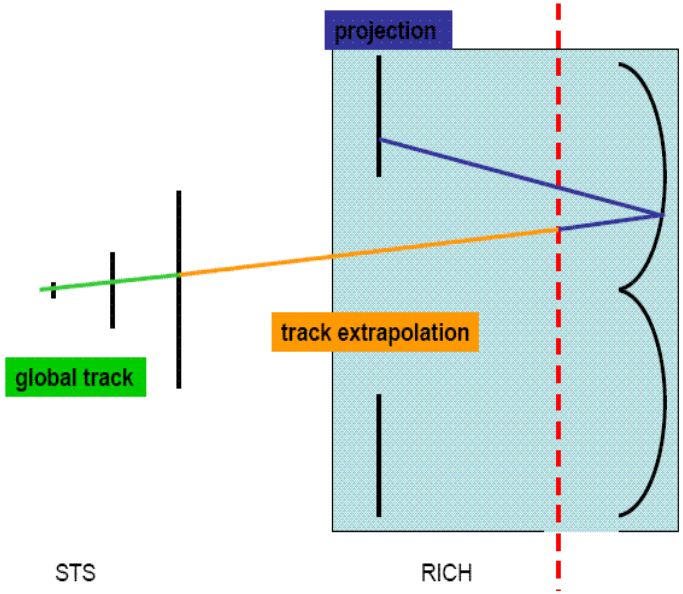
Part of typical event in the CBM RICH (Large and Compact). RICH hits (blue), found rings (red), track projections (green).

Typical reaction for CBM -> central Au+Au collisions at 25 AGeV beam energy Simulation: transport model UrQMD

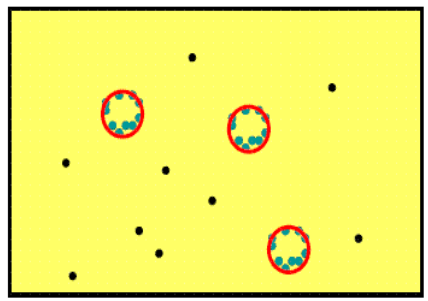


Radius versus momentum for reconstructed rings in central Au+Au collisions at 25 AGeV beam energy for UrQMD events (large RICH). A 3σ band around the mean radius is indicated by the solid lines.

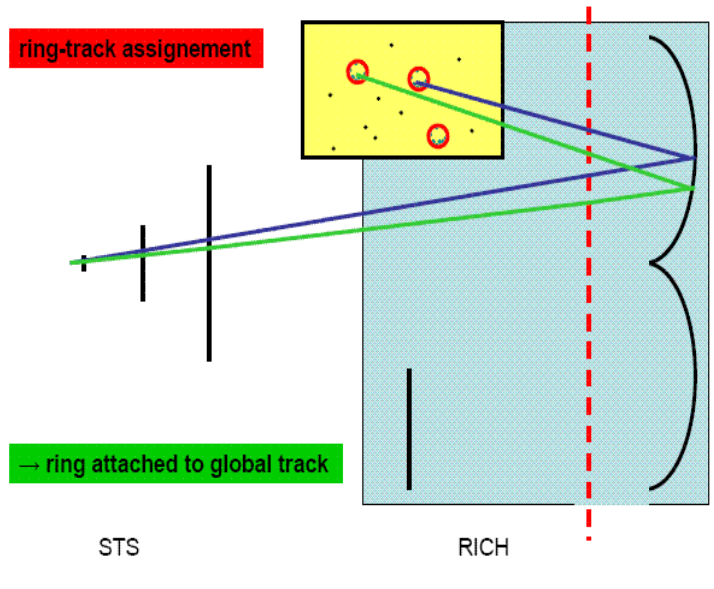
Reconstruction in the CBM RICH detector



Sketch of the STS and the RICH detector, track extrapolation and track projection onto the photodetector plane



sketch of RICH hits and found rings



ring-track matching

Main problems of ring recognition in CBM RICH:

- *high ring density (~100 rings per event, many secondary electrons);*
- *many overlapping rings;*
- *distortions and elliptic shape of the rings;*
- *measurement errors (the dimensions of sensitive pad are 0.6x0.6 cm and mean ring radius is ~6 cm).*
- *ring-track matching (high density of projected tracks)*

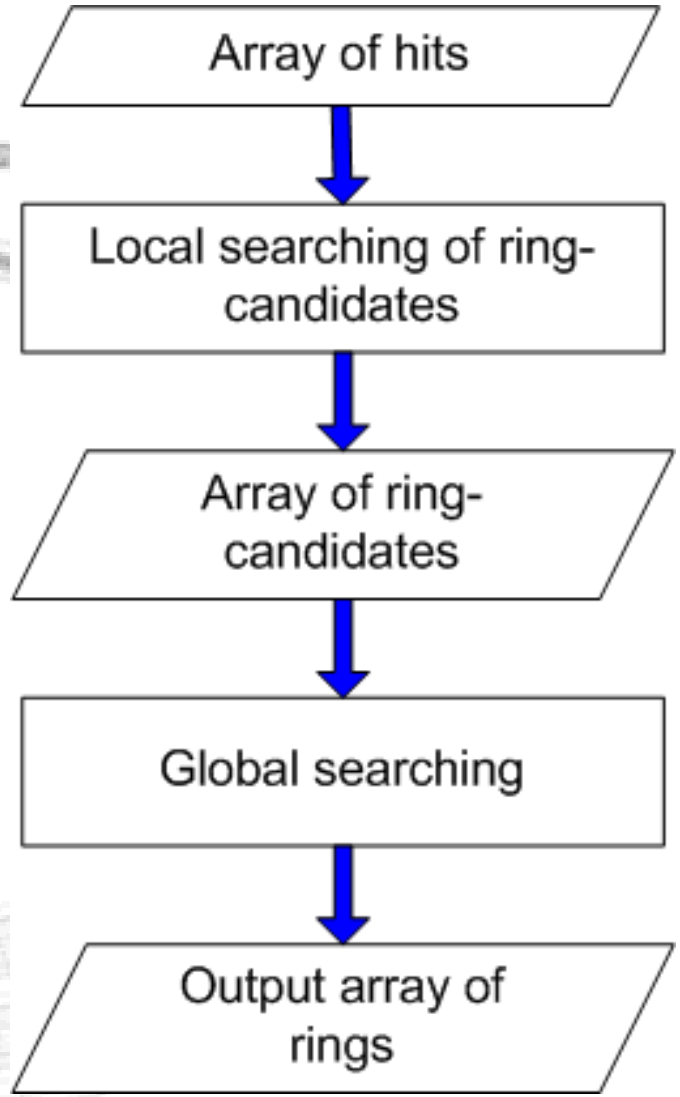
Ring recognition algorithm

Standalone ring finder.

Two steps:

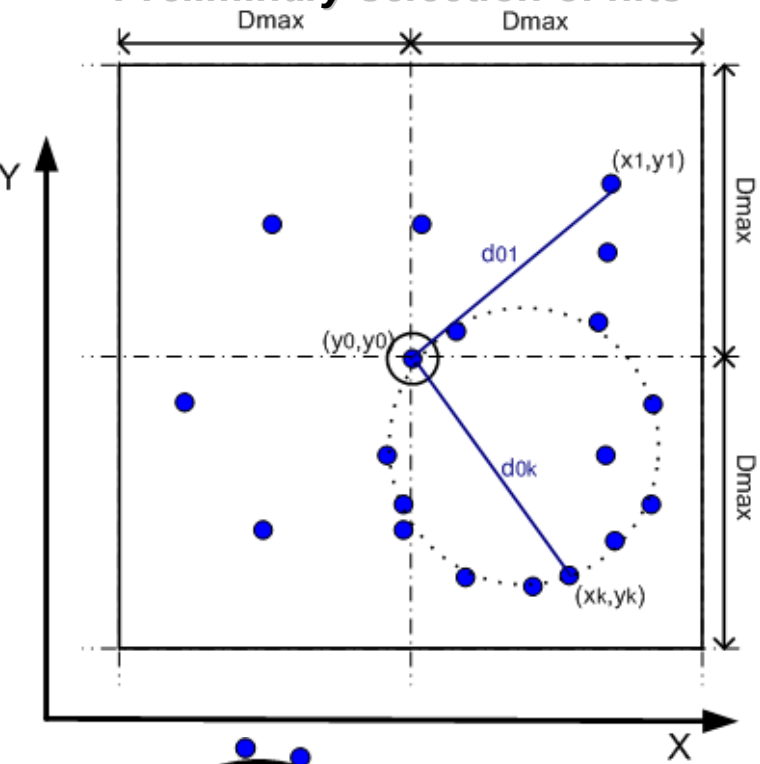
<u>Local search</u> of ring-candidates, based on local selection of hits and Hough Transform.

<u>Global search</u>. Filter: algorithm compares all ring-candidates and chooses only good rings, rejecting clone and fake rings.



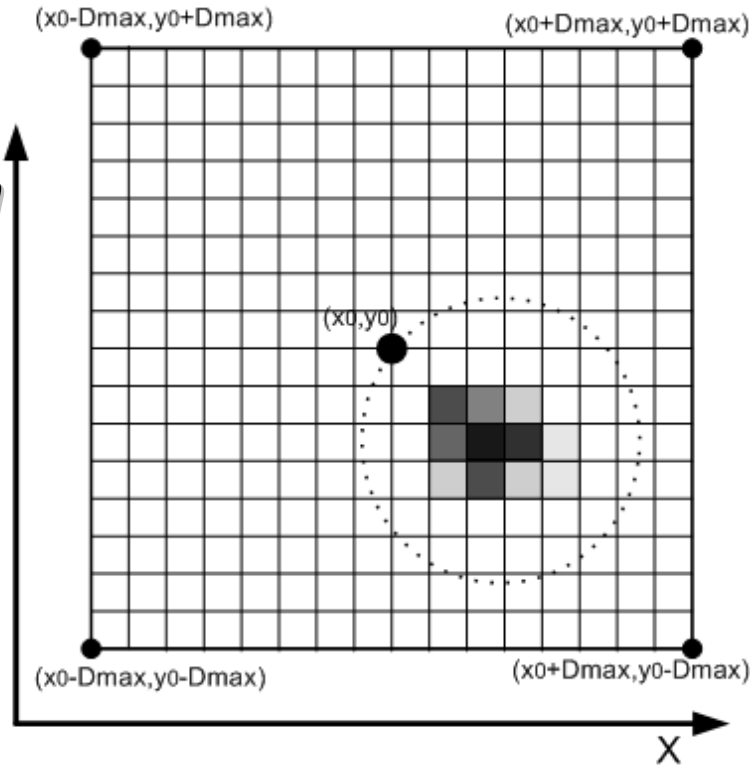
Ring recognition algorithm, local search

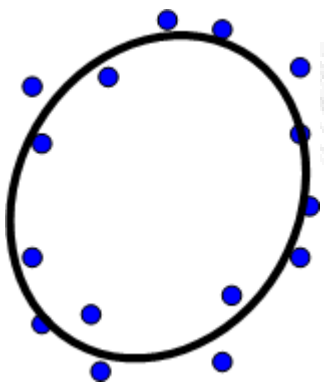
Preliminary selection of hits



Hough Transform

Histogram of ring centers





Ellipse fitter

Ring quality calculation

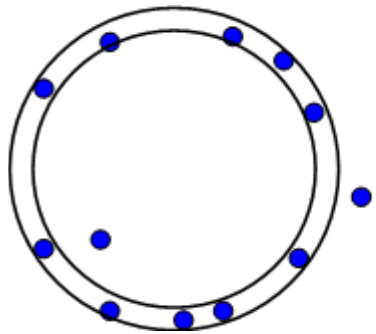
Remove hits of found ring *(only best matched hits)*

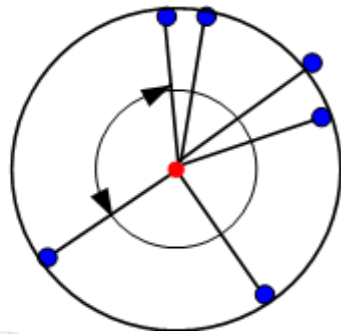
Ring array

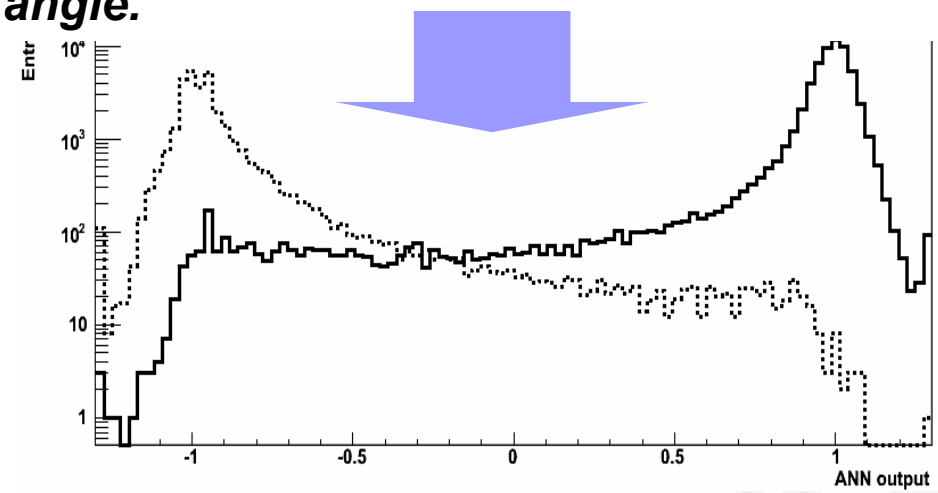
Rejection of fake ring candidates, ring quality calculation

Nine ring parameters selected for ring quality calculation:

- *number of hits in ring;*
- *chi-squared*
- *biggest angle between neighboring hits;*
- *number of hits in a small corridor around the ring;*
- *position of ring on photodetector plane;*
- *major and minor half axes of ellipse;*
- *rotation angle of the ellipse vs. azimuthal angle.*



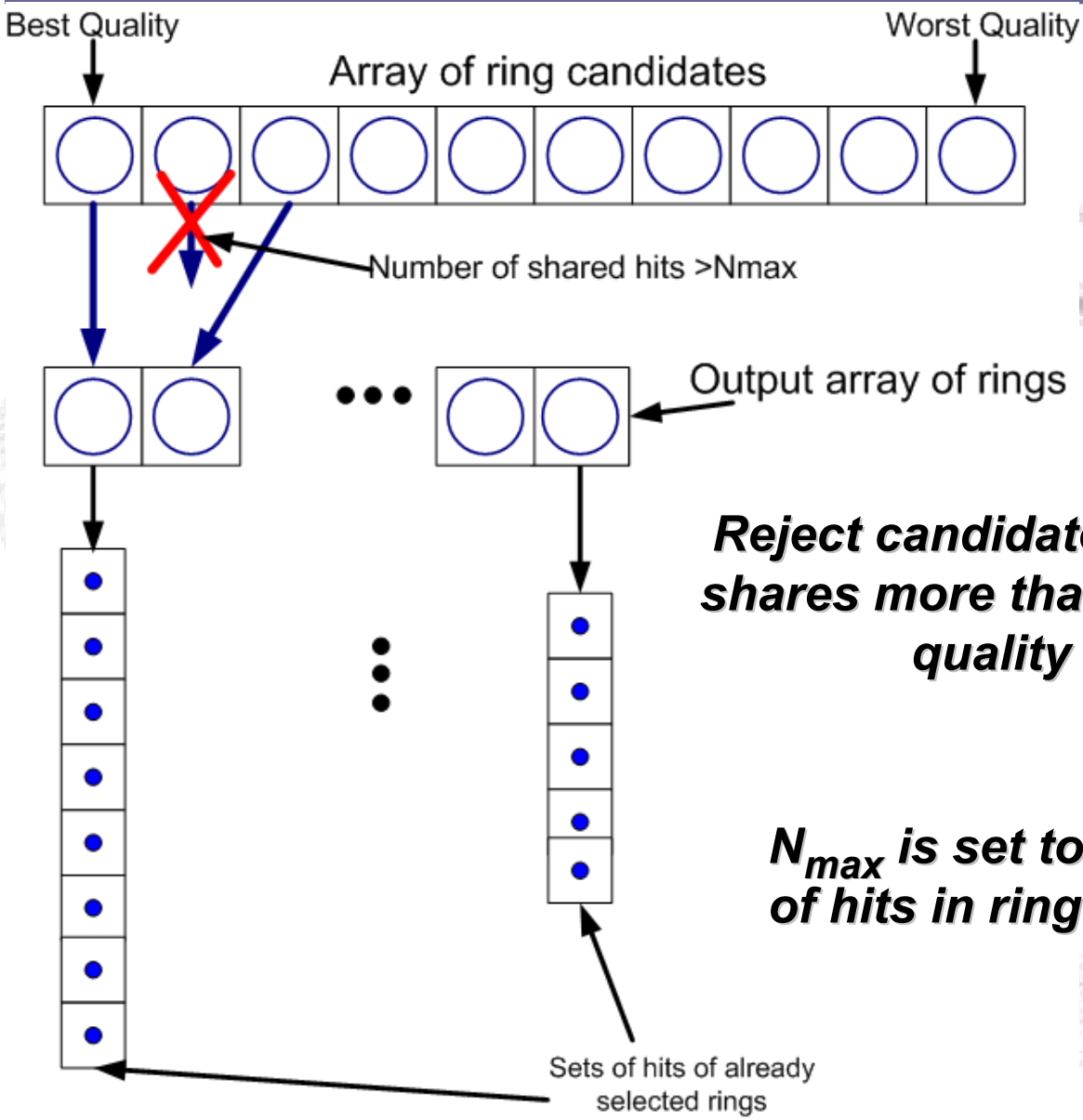




ANN output value for correctly found (solid line) and fake (dashed line) rings

- *ANN derives ring quality from these parameters.*
- *The ANN output provides a ring quality parameter or probability, whether ring-candidate was found correctly or not.*

Ring recognition algorithm, global search



Reject candidate with worse quality if it shares more than N_{max} hits with a better quality ring candidate.

N_{max} is set to 30% of the total number of hits in ring

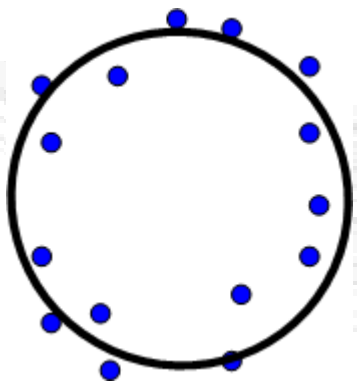
RICH ring fitting methods

Circle fitting

- usage in ring finding algorithm
- program realization of the COP (Chernov-Ososkov-Pratt), based on the minimization of the functional

$$\bar{M}(a,b,R) = \sum_{i=1}^{n} \left[\left((x_i - a)^2 + (y_i - b)^2 - R^2 \right)^2 / 4 * R^2 \right]$$

- Newton method for nonlinear equations with one variable is used
- 3-4 iterations
- algorithm is very robust to the initial parameters



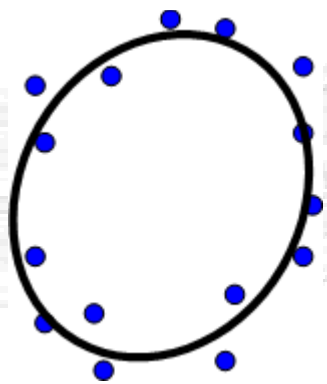
Ref: Comp Ph Com Volume 33, Issue 4, 1984, 329-333

Ellipse fitting

- Rings in the photodetector plane have a slight elliptic shape
- general, as conic section

$$P(\mathbf{X}) = Ax^2 + Bxy + Cy^2 + Dx + Ey + F$$

- Taubin method is used
- Minimize P(x) by A,B,C,D,E,F, but measuring deviations along normals to the curve.
- non-linearity is avoided by Tailor expansion
- non-iterative very fast direct algorithm
- no need of starting parameter values



Mean B/A for CBM RICH rings = 0.9

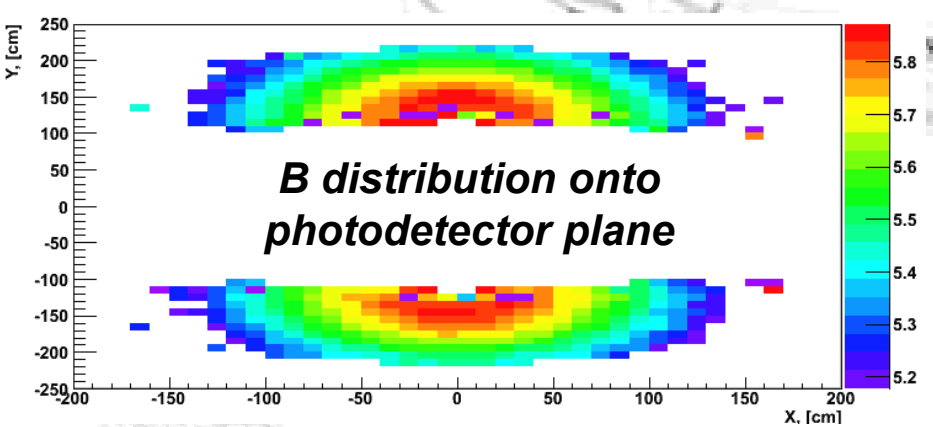
Ref: N. Chernov J Math Im Vi, 27 (2007), 231-239.

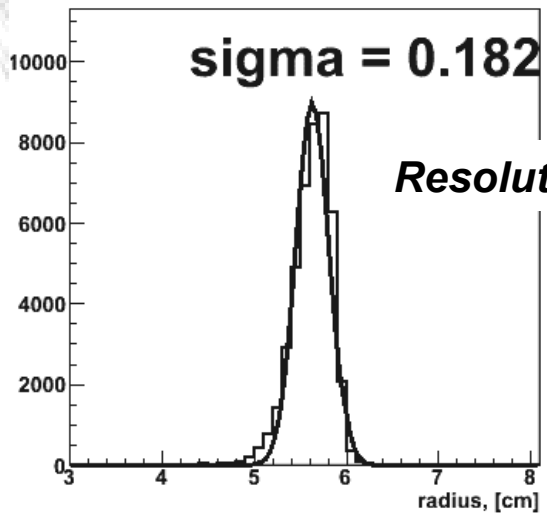
Thanks to A.Ayriyan (JINR, Dubna) and N. Chernov (USA)

Ring parameter correction

Example for minor half axis of ellipse (B)

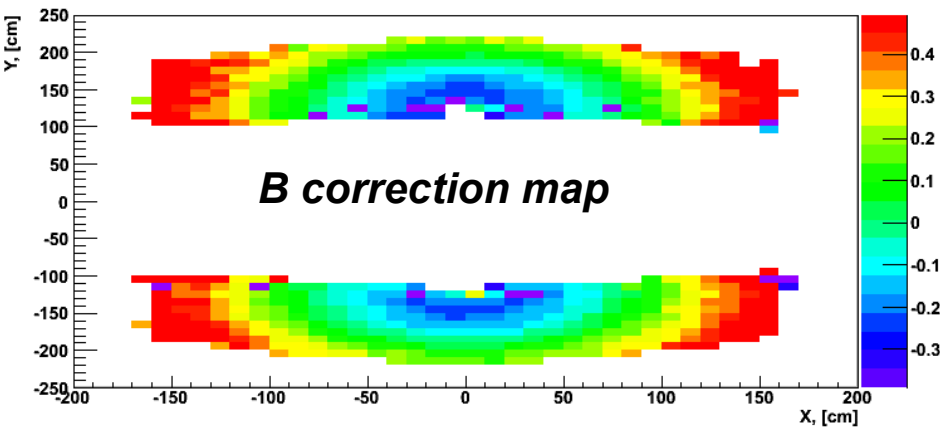
Why?

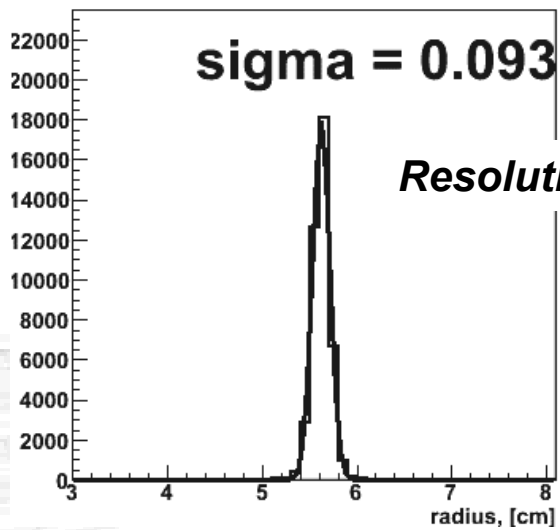




B distribution BEFORE correction

How?

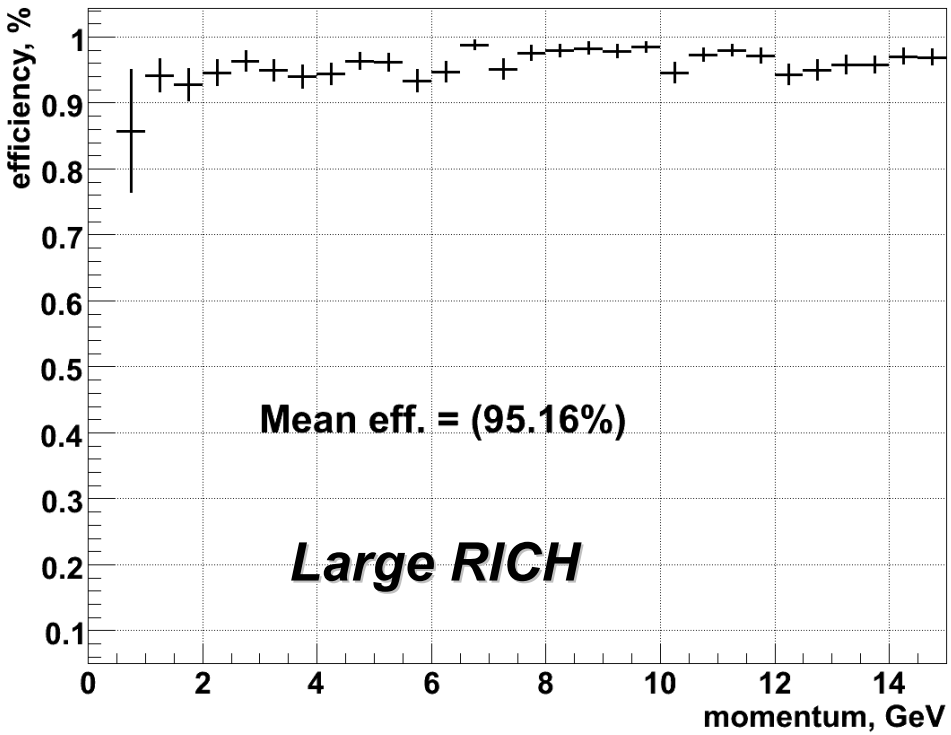


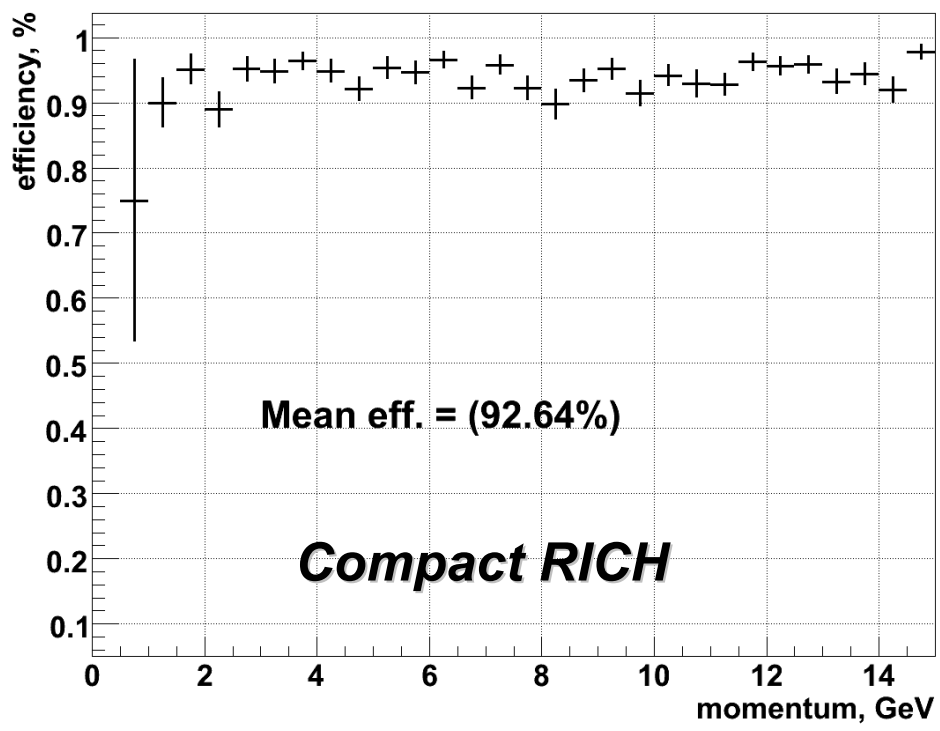


B distribution AFTER correction

Ring finding efficiency

Typical reaction for CBM -> central Au+Au collisions at 25 AGeV beam energy (UrQMD)



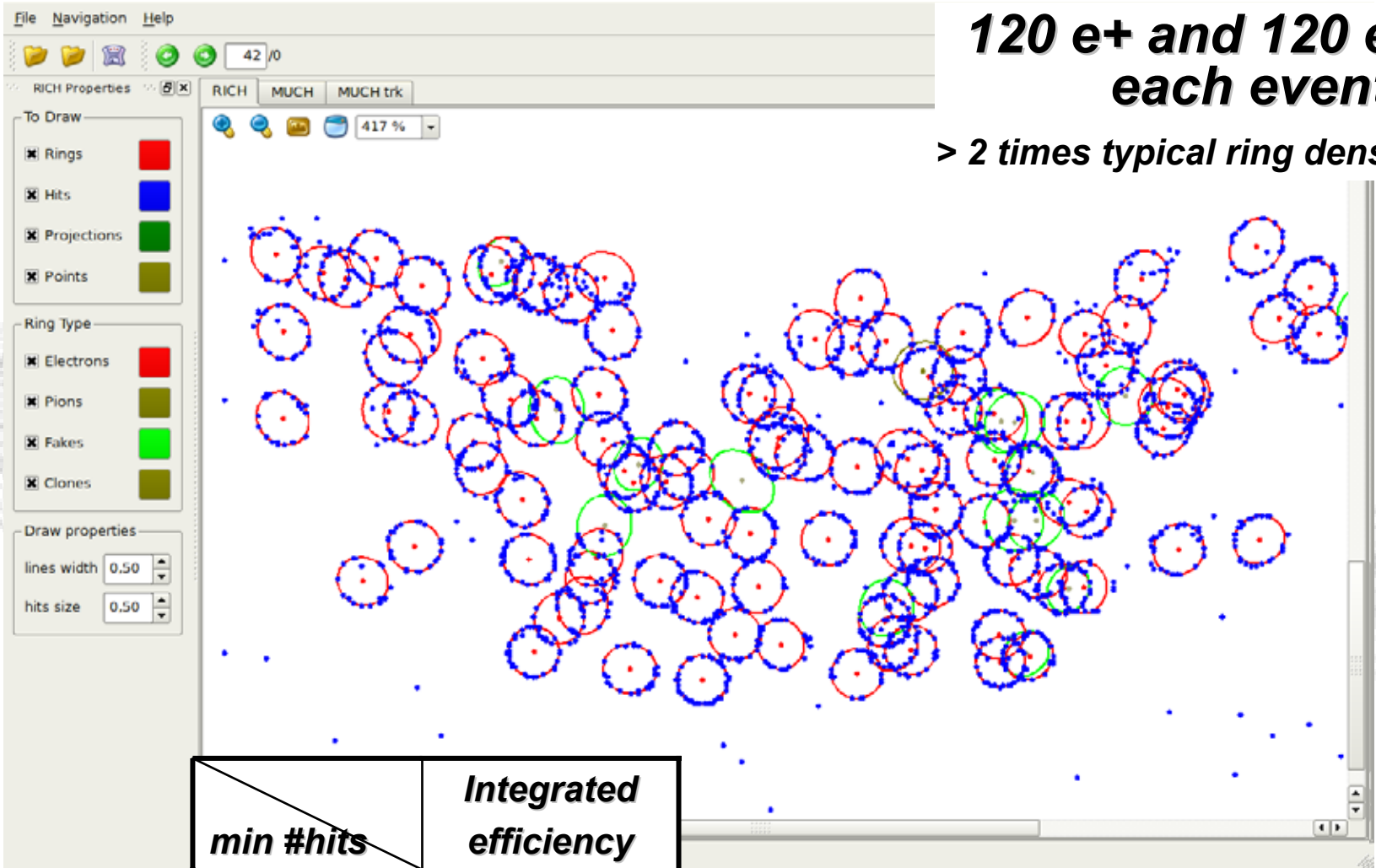


Efficiency for e+ and e- embedded in central Au+Au collisions at 25 AGeV beam energy

	Large	Compact
radiator gas and length	N_2 length 2.5 m	CO_2 length 1.5 m
photodetector size (No. of channels)	9 m^2 (200k)	2.4 m^2 (55k)

Accepted rings = rings with >= 5 hits

Test for ring finder



120 e+ and 120 e- in each event

> 2 times typical ring density

min #hits	*Integrated efficiency*
5	*91.07*
10	*92.71*
15	*95.28*

Mean number of hits per ring is 22

Summary

- ***Fast and efficient algorithm for ring recognition in CBM RICH was developed***
  - ***based on the HT method with local selection of hits.***
  - ***Fast and robust ellipse fitting algorithm has been implemented for precise estimation of ring parameters.***
  - ***A global ring search algorithm was developed to select good rings, while rejecting fake and clone rings.***
- ***Significant efforts were made to speed up the algorithm. Time of one event reconstruction in RICH (up to 100 rings) varies from***
  - ***82 ms on a Intel Pentium Core2 6400 2.13 GHz***
  - ***42 ms on a Intel Pentium Core2 P8400 2.26 GHz***
- ***Ring finding algorithm has shown a very good performance and robustness to high ring multiplicity environment.***