PARAMETER ESTIMATIONS OF THE CHERENKOV RADIATION RINGS IN THE RICH DETECTOR FOR THE CBM EXPERIMENT

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Since the elliptic model of Cherenkov radiation rings in the RICH detector of the CBM experiment was recently accepted supplementary to the previous circular one [1], an ellipse fitting algorithm based on the Kepler equation of ellipse with the following MINUIT minimization has been elaborated [1]. To avoid the time-consuming MINUIT application, we proposed a new direct ellipse fitting algorithm based on the Taubin method [2]. Here we describe and fulfil a comparative study of both algorithms. It is important to stress that the Taubin method is non-iterative and, therefore, is much faster than the Minuit Fitter. Besides, it is statistically more accurate. After detailed testing on the great statistics of simulated data, a corresponding software implementing the Taubin-based algorithm is also included in the CBM Framework and used as a default method.

Motivation

The CBM RICH detector is intended for electron identification. It is carried out by evaluating parameters of the Cherenkov radiation rings registered by the RICH photodetector. Due to optical distortions the shape of the Cherenkov rings on a photodetector plane differs from the ideal circle and can be approximated by an ellipse (Fig. 1).

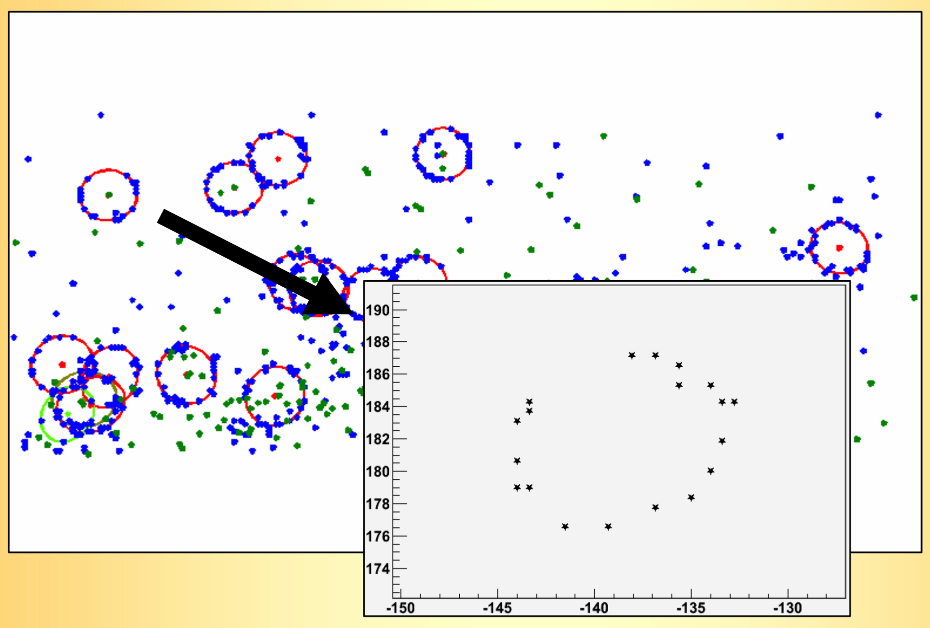
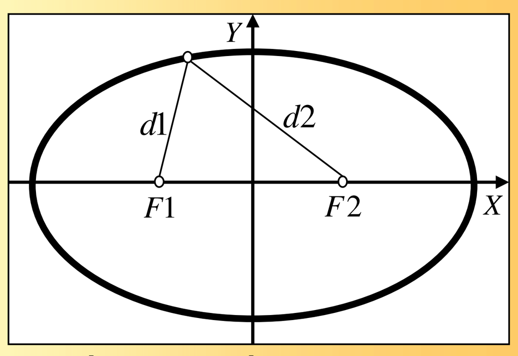


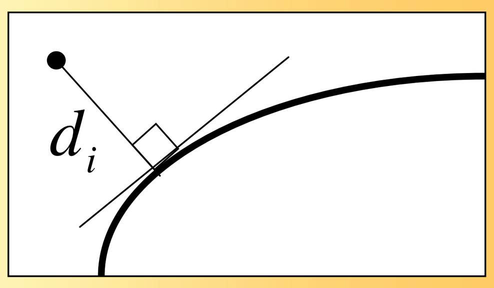
Fig. 1. *View of a typical RICH event on the photodetector plane*

The extremely high reaction rates (up to 10 MHz), events with large track multiplicity (about 800 charged particles per central Au + Au collision in the CBM) require correspondingly fast algorithms of data analysis, in particular, a fast and robust algorithm for ellipse fitting to measured points.



At first, an ellipse fitting algorithm based on Kepler ellipse equation (1) has been developed in the CBM framework. Due to strong non-linearity of the corresponding minimization problem, the MINUIT program has to be applied. Further we denote this algorithm as MF (Minuit Fitter)

$$d_1 + d_2 = 2a. \quad \textbf{(1)}$$



To avoid the time-consuming MINUIT Application, we proposed a new direct ellipse fitting algorithm based on Taubin method, which uses a linear approximation of the orthogonal distance between $\boldsymbol{i}$-th measured point and ellipse (2). We call it TF (Taubin Fitter)

$$d_i = \frac{\left\| P(x_i, y_i, \boldsymbol{\Theta}) \right\|}{\left\| \nabla P(x_i, y_i, \boldsymbol{\Theta}) \right\|} + O(d_i^2), \quad \textbf{(2)}$$

where $P(x,y) = A \cdot x^2 + B \cdot xy + C \cdot y^2 + D \cdot x + E \cdot y + F.$

Comparative analysis

In order to show the advantages of the Taubin method for data analysis in the RICH detector, we present the results of a comparative analysis of these algorithms.

First, for this comparison a representative set of points distributed along ellipses was simulated with different rotation angles of ellipse axes and various numbers of points. Each point was simulated with normally distributed errors in X and Y coordinates: $\boldsymbol{N}(0,\sigma)$ with σ**=0.3**. The results are shown in Fig.2 and Fig. 3.

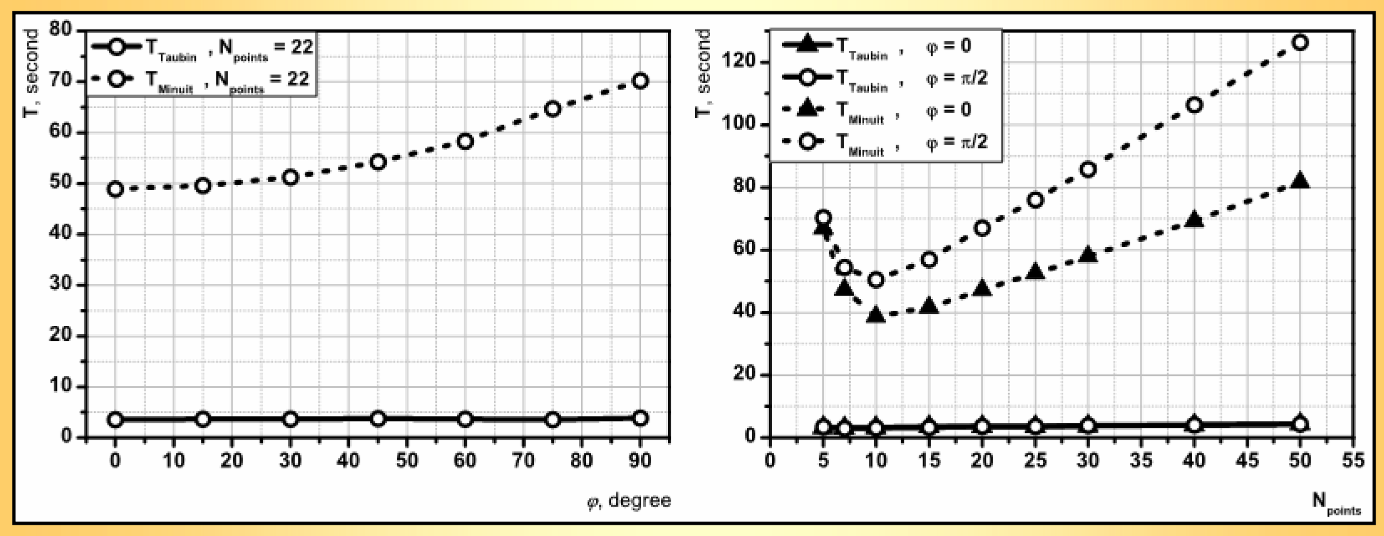


Fig. 2. *Calculation time for 10^5 ellipses vs. ellipse rotation angle (left) and number of points (right)*

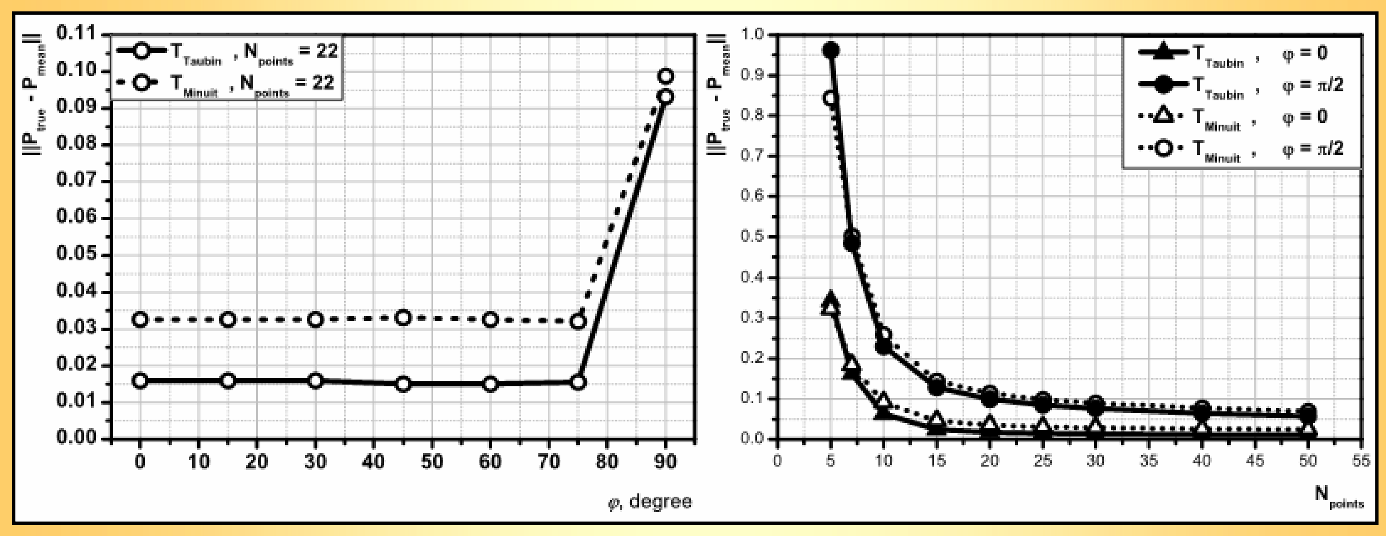


Fig. 3. *Euclid norm of mean errors of estimated parameters vs. ellipse rotation angle (left) and number of points (right)*

Secondly, for testing closer to the reality, 500 UrQMD events were simulated for Au+Au collisions at 25 *A*GeV with addition of 5e⁻ and 5e⁺ to each event. Then these events were reconstructed to check the RICH ring finding efficiency by both methods. The results are presented in Table 1 where the “fake” means a spurious ring, and the “clone” means a ring found more than one time.

Table. 1. *Ring finding efficiency*

Ring Finder with	Efficiency, %	Number of Fakes per event	Number of Clones per event
Minuit Fitter	90.33	6.75	0.42
Taubin Fitter	93.02	5.99	0.70

Results & Conclusion

- Taubin Fitter is 5~25 times faster than Minuit Fitter; moreover Taubin Fitter is practically independent of the number of points (see Fig. 2).
- Ring Finder shows a better efficiency with Taubin Fitter than with Minuit one (see Table 1).
- Taubin method is statistically more accurate than the method based on Minuit minimization (see Fig. 3).
- Taubin method is not iterative and does not need a starting value; this is important in data analysis with RICH.
- The cases when Taubin method gives non-ellipse solutions, are quite rare and can be handled by a special branch of the algorithm.

References

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