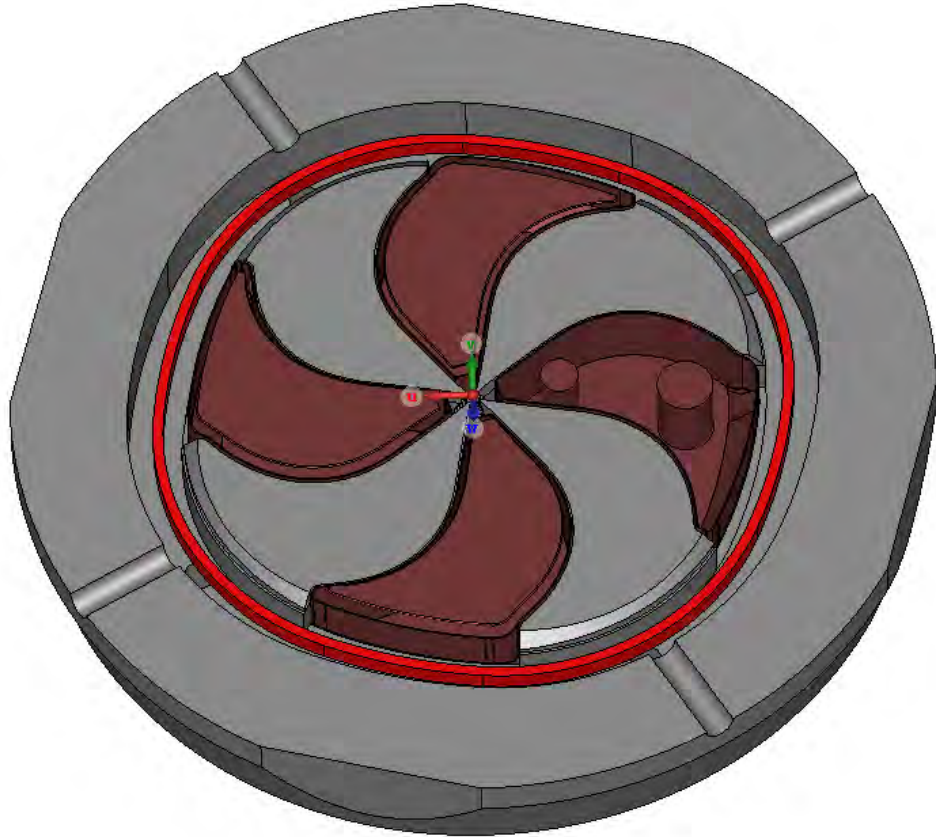# CORD (Closed ORbit Dynamics): A new field map evaluation tool for cyclotron particle dynamics

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SC230 isochronous cyclotron

SC230 – compact isochronous cyclotron for proton therapy and biomedical research, being developed at JINR.

Designing a new cyclotron requires accurate and fast field map evaluation software.

The motivation for making a new code for finding equilibrium orbits comes from the need to get the maximum amount of information on the field maps without time-consuming beam tracking.

Iterative scheme for finding equilibrium orbits

Our software is based on the CYCLOPS[1] algorithm - a classic algorithm that was written in 1959 by M.M. Gordon, which is one of the most reliable and widely used.

Original CYCLOPS:

- For a fixed orbital energy T the corresponding values of the radius r and the radial momentum p_r are obtained.

- Initial values are extrapolated at every step of T.

CORD:

- For a fixed radius r the corresponding values of the radial momentum p_r and energy T are obtained.

- Initial values are calculated once → parallel calculation is possible.

A similar approach has been published by C. Baumgarten[2] , but we made our own implementation of the algorithm in Matlab.

[1] *Gordon M.M.*, Computation of closed orbits and basic focusing properties for sector-focused cyclotrons and the design of «cyclops». Part. Accel. 1984, *16*, pp. 39-62.

[2] *Baumgarten C.*, Cyclotron closed orbits on a radial grid //Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. – 2011. – V. 647. – №. 1. – pp. 31-33.

Equilibrium orbits
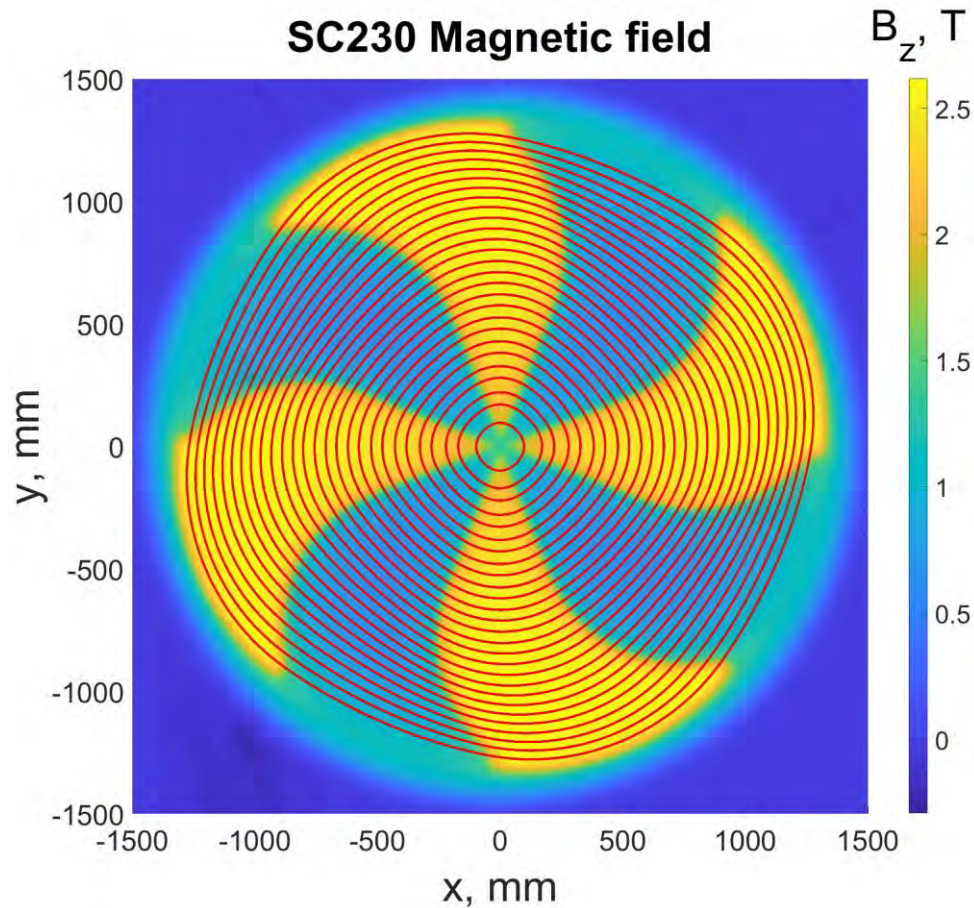
Closed orbits calculated using our method

The number of iterations is constant and can be set to provide the necessary precision.

To check if the orbits found by the procedure fit the precision requirements 3 parameters are calculated for every orbit:

ΔR – the difference between initial and final radius of the orbit,
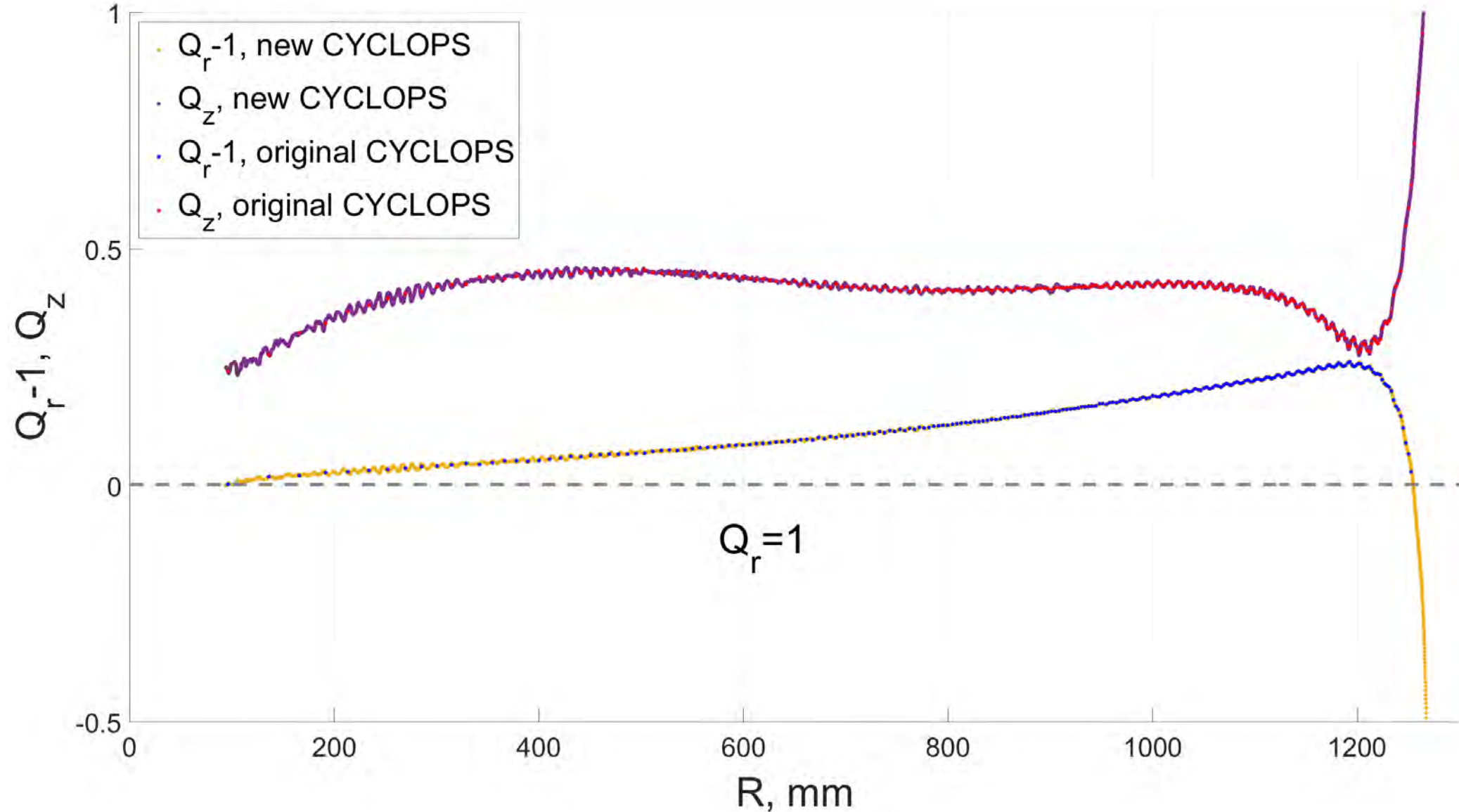
ΔP_r – the difference between initial and final radial momentum,

R_{center}/R – offset of the center of the orbit.

Values of the thresholds: $\Delta R = 10^{-3} m$, $\Delta P_r = 10^{-20} kg \cdot m/s$, $Rcenter/R = 0.1$.

Betatron frequencies

Conclusion

- The code for beam dynamics analysis was briefly presented. This code is called CORD – short for Closed ORbit Dynamics.

- CORD code was created in Matlab Live Editor as an Executable Notebook, which combines code, output, and formatted text. It is planned that in the near future CORD will be available for download on the JINR website.

- The CORD code was used in the design of the SC230 magnetic and accelerating systems and will be in demand at the stage of magnetic field formation for the analysis of the measured magnetic field maps.