A CORRECTION SCHEME FOR THE HEXAPOLAR ERROR OF AN ION BEAM EXTRACTED FROM AN ECRIS

P. Spädtke, R. Lang, J. Mäder, F. Maimone, J. Roßbach, K. Tinschert, GSI Darmstadt

Outline

idea

simulation

video from the actual status

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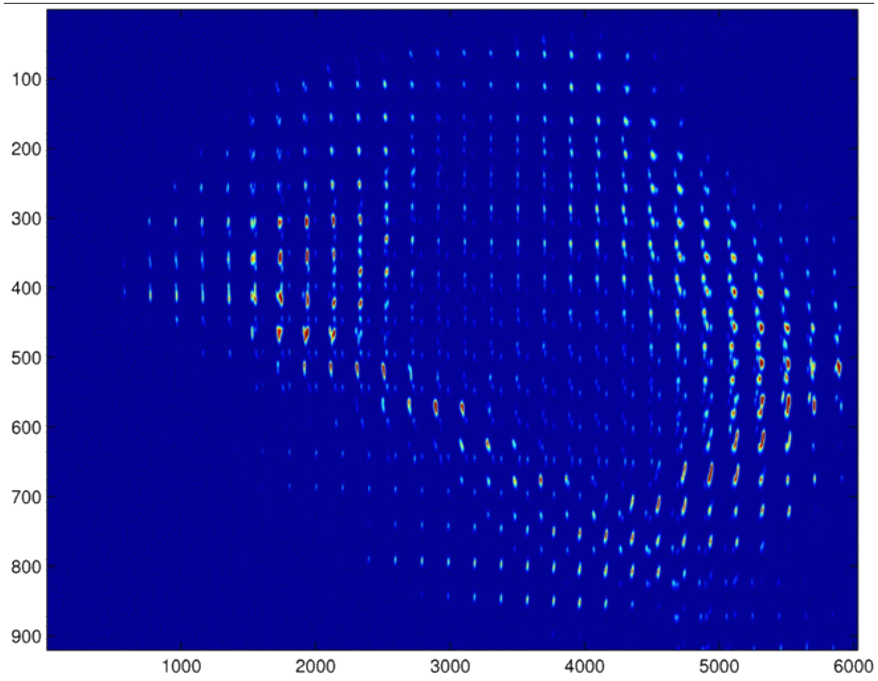
• **Ion beams generated by an ECRIS are suffering from the good confinement of this type of ion source.**



Single beam lets on a viewing target coming from an analyzed ion beam (one charge state only) defined by a pepper plate.

(→ collaboration KVI)

A structure on the beam is clearly visible.

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- **To increase the number of ions on target, either the number of extracted ions from the ion source has to be increased, OR, the emittance of the extracted ion beam has to be decreased.**

  Not always possible to increase intensity, sometimes even impossible…

- **The existence of aberrations increases the emittance. (clear!).**
- **Avoid sources of image errors (wise statement, but how??).**
- **Cure existing aberrations (if possible).**
- **Cut away useless beam. This is possible only, if the residual intensity is still high enough. At MSU this method is successful, the remaining ion beam still fits the requirement today.**

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There are two main reason for optical errors:

solenoid error: ions are generated at a location B≠0, therefore ∫Bds≠0.

according to

- **Partial beam decorrelation of sources providing ions out of axial magnetic fields, EPAC 1988, Rom, Italy. J. Reich, H. Beuscher, FA Jülich, R.K. Bhandari, Bhaba ARC, J.I.M. Botman, H.L. Hagedoorn, Eindhoven University**

- **J.I.M. Botman, H.L. Hagedoorn, Eindhoven University, J. Reich, FA Jülich, The beam emittance of cyclotrons with an axial injection system, EPAC 1988, Rom, Italy**

This error can be influenced by shifting the emittance from one transverse phase space virtually into the other transverse phase space, but this is only a different projection of the 4D phase space into real space.

hexapol error: $B \sim r^2$ → non linear → emittance growth!

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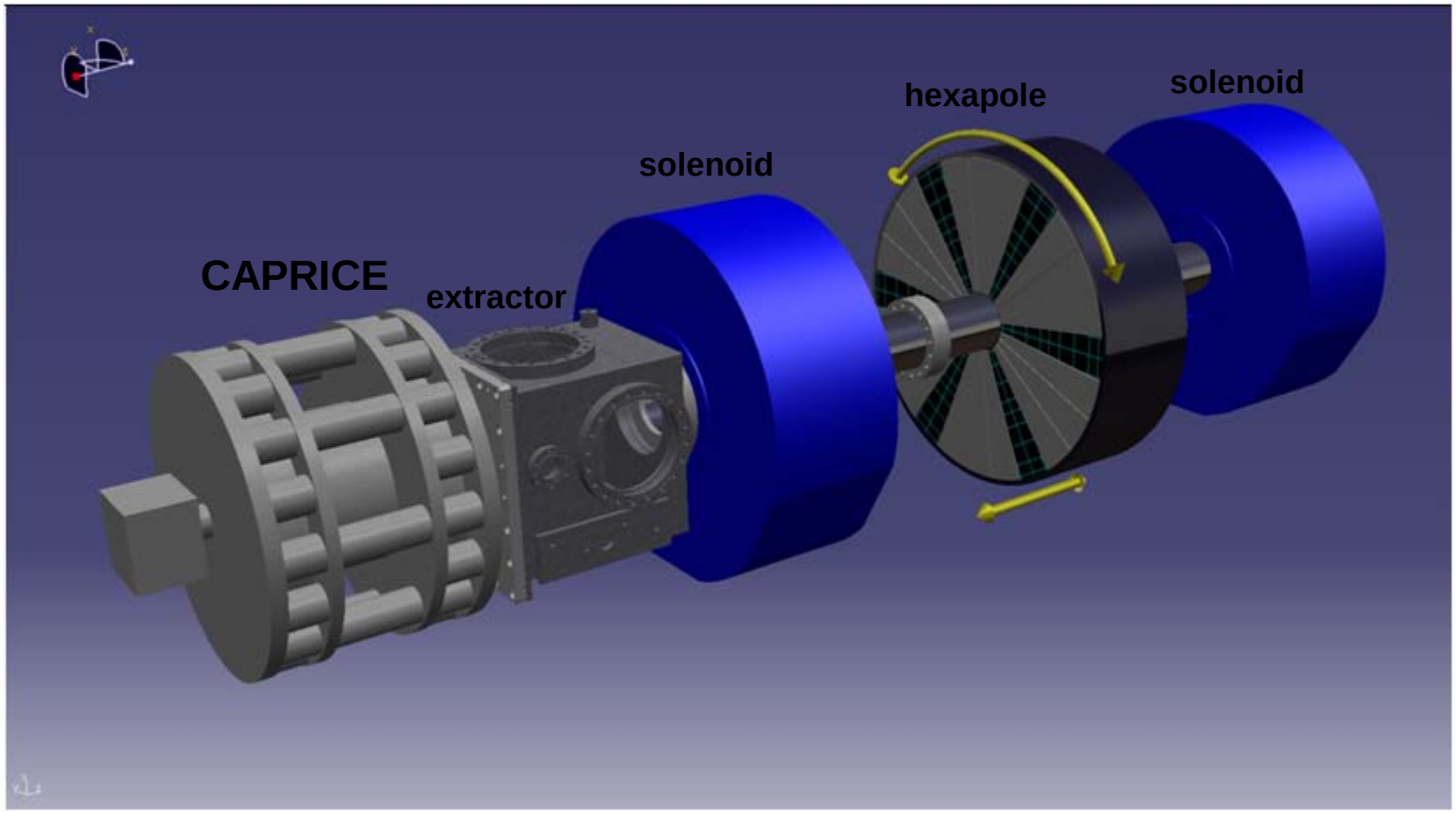

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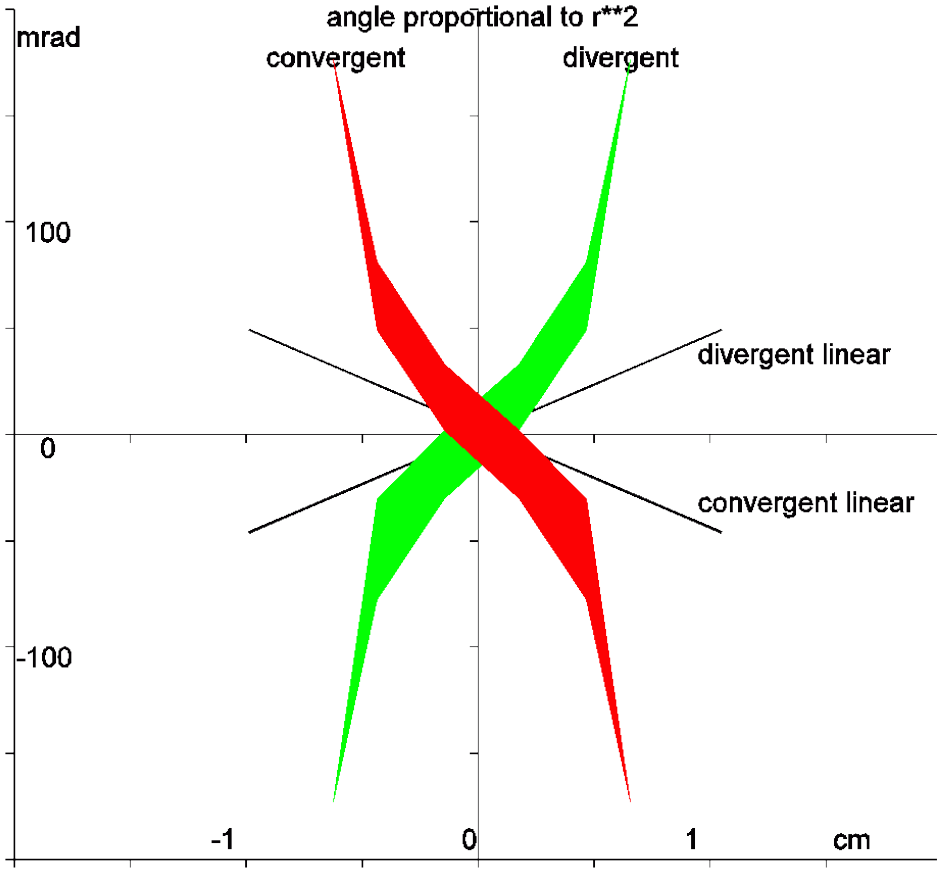

Goal: match the ion beam in such a way, that the following condition is true:

The ion beam has to have a profile with an angle r ~ r^2.

Whether convergent or divergent does not matter.

In such a case a hexapol correction can be used to straighten the emittance figure.

The correction should be as short as possible, to avoid different radii for the ion trajectories within the hexapole

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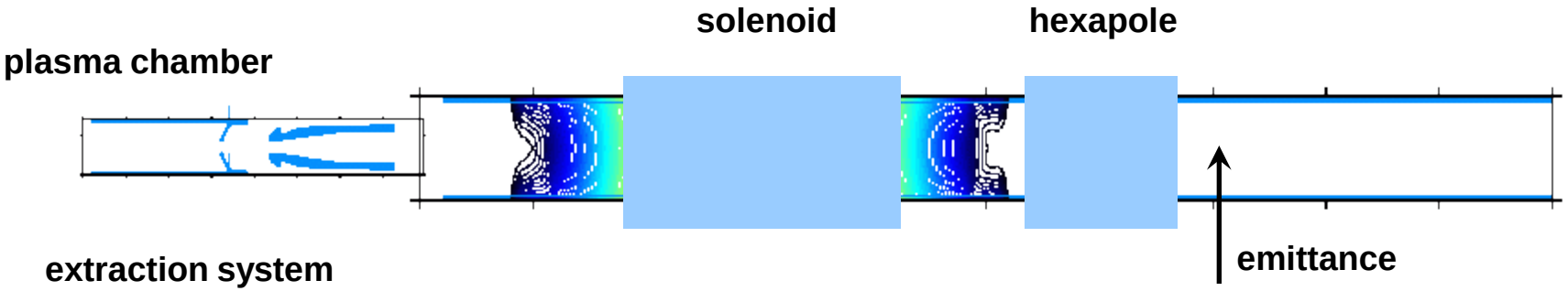

Boundary conditions for the simulation:

Simulation of extraction region including the plasma chamber for correct starting conditions of trajectories.

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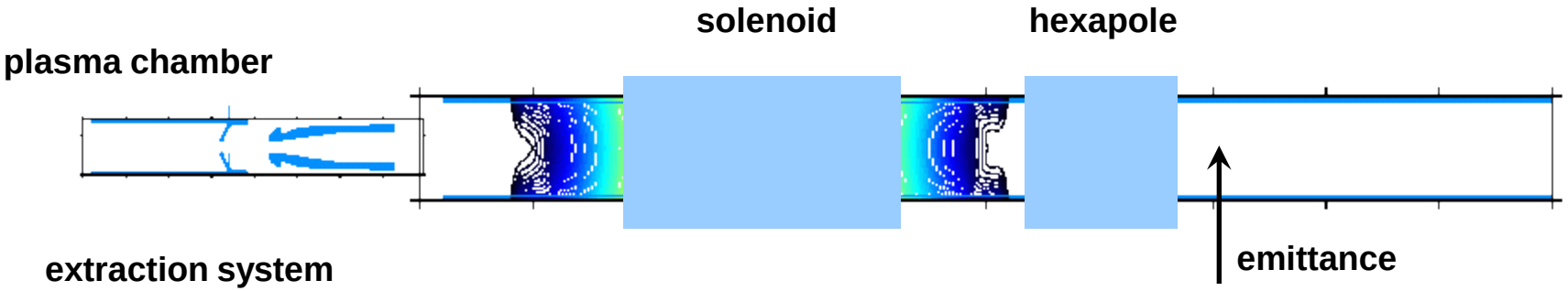

Boundary conditions for the simulation:

The starting position is at the location of weakest plasma confinement.

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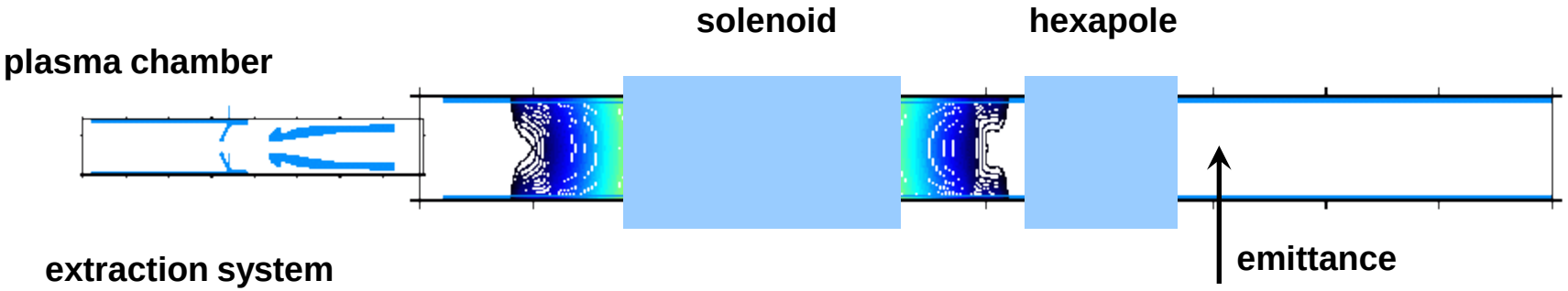

Boundary conditions for the simulation:

The full charge state spectrum has been assumed to produce a correct solution of Poisson's equation within the extraction system.

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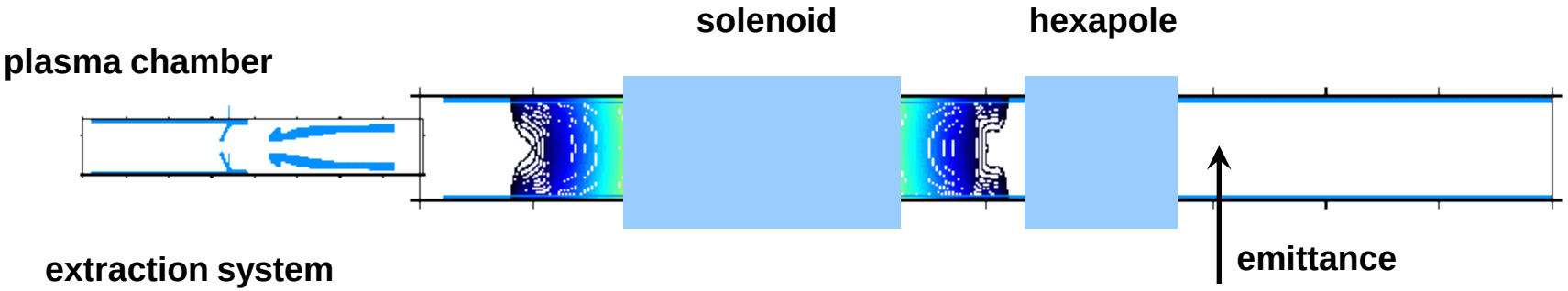

Boundary conditions for the simulation:

The electron density close to the plasma potential has been solved analytically.

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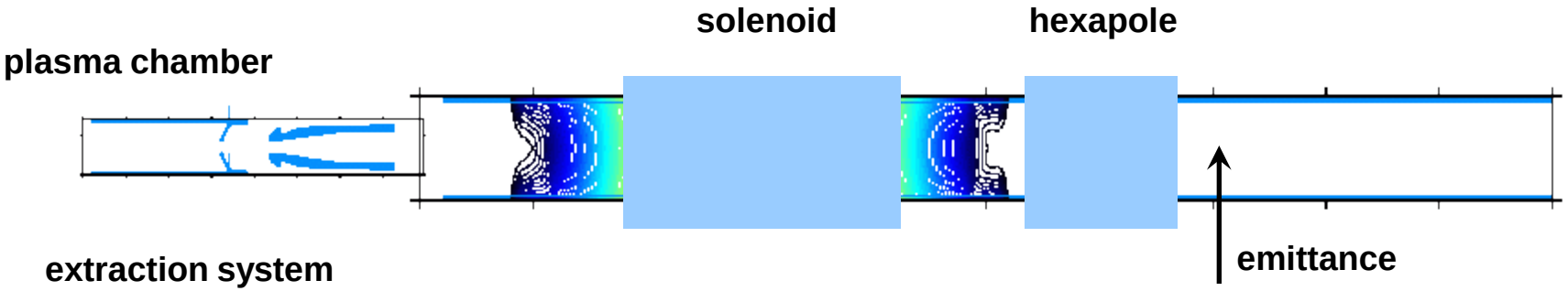

Boundary conditions for the simulation:

Plasma potential, particle density, and electron temperature have to be defined by the user.

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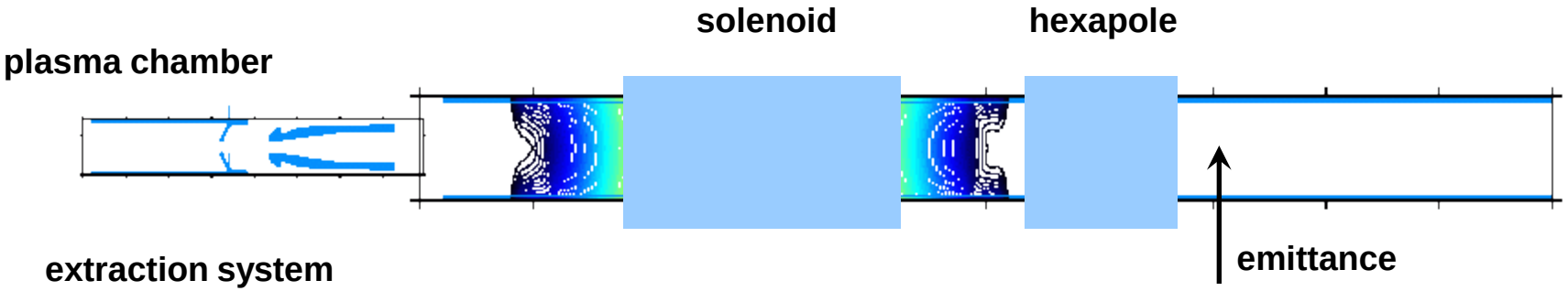

Boundary conditions for the simulation:

The space charge of the drifting ion beam is assumed to be compensated by electrons. These electrons are generated by collisions of primary ions with residual gas atoms and will be trapped in the space charge potential, whereas the secondary ions are repelled from this potential. This implies to avoid the usage of electrostatic lenses.

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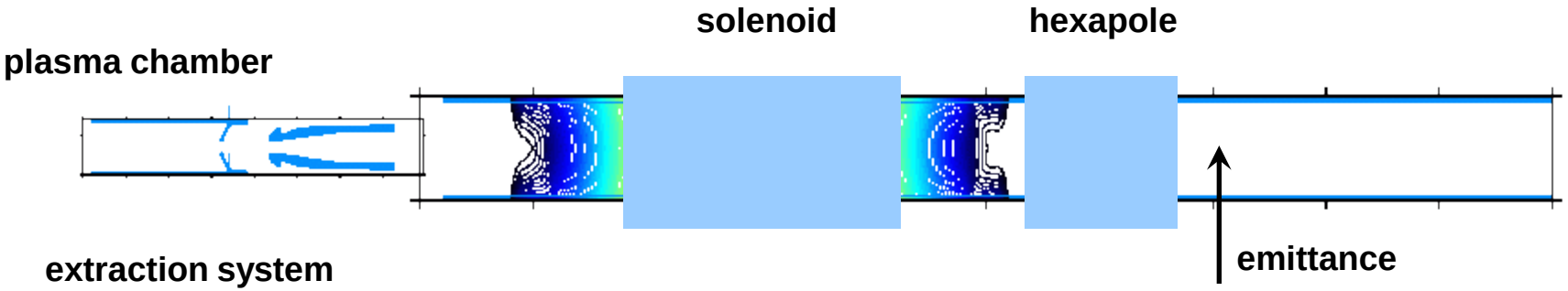

Boundary conditions for the simulation:

Only one charge state has been saved (and used) for further transport simulation in a second section of simulation: here Ar3+.

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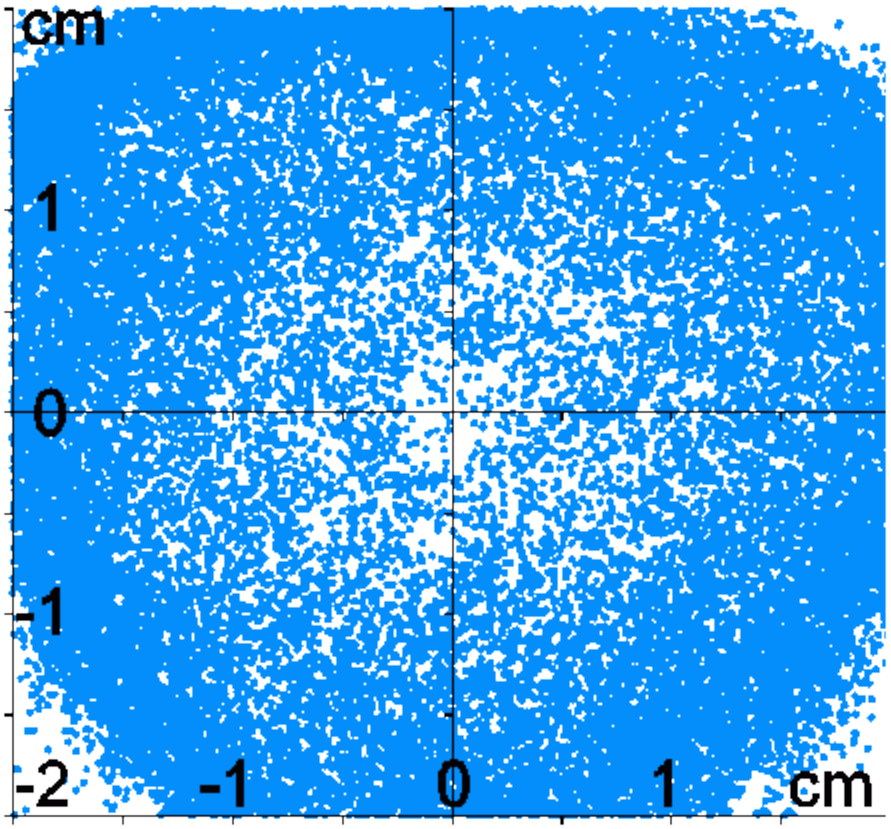
Simulation using the particles extracted from the ion source:

Increasing focusing strength



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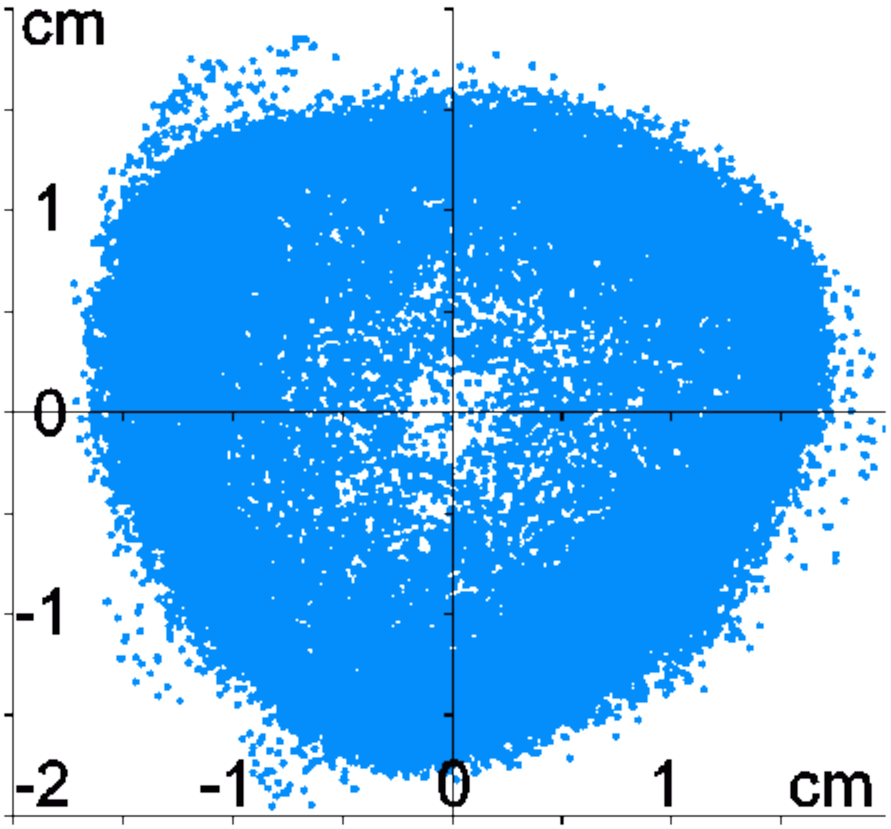

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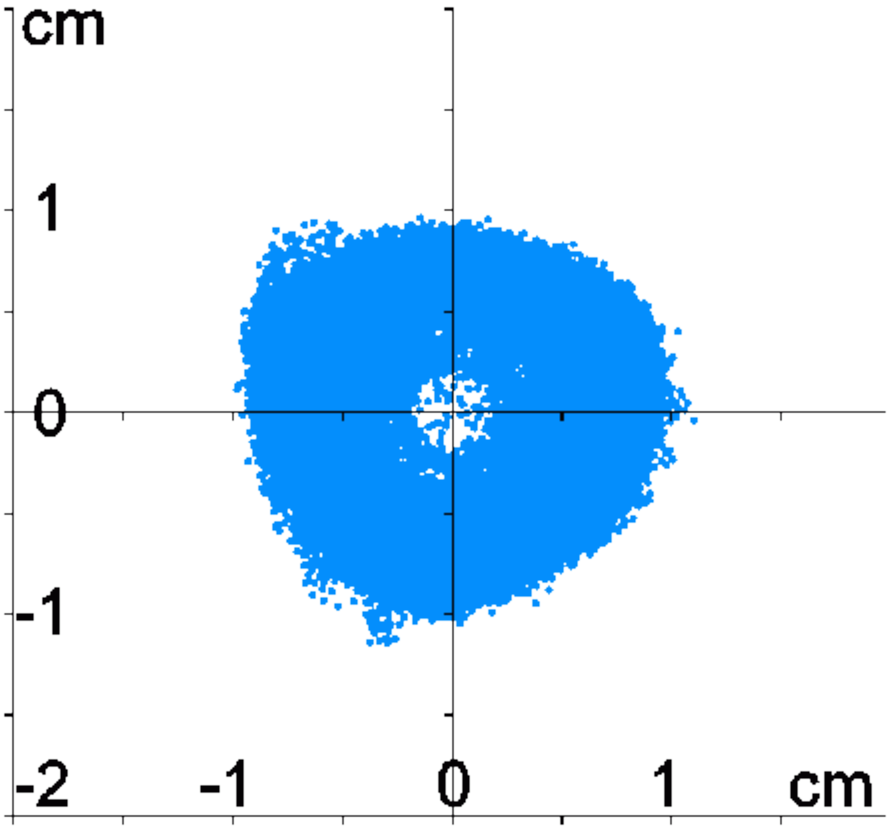

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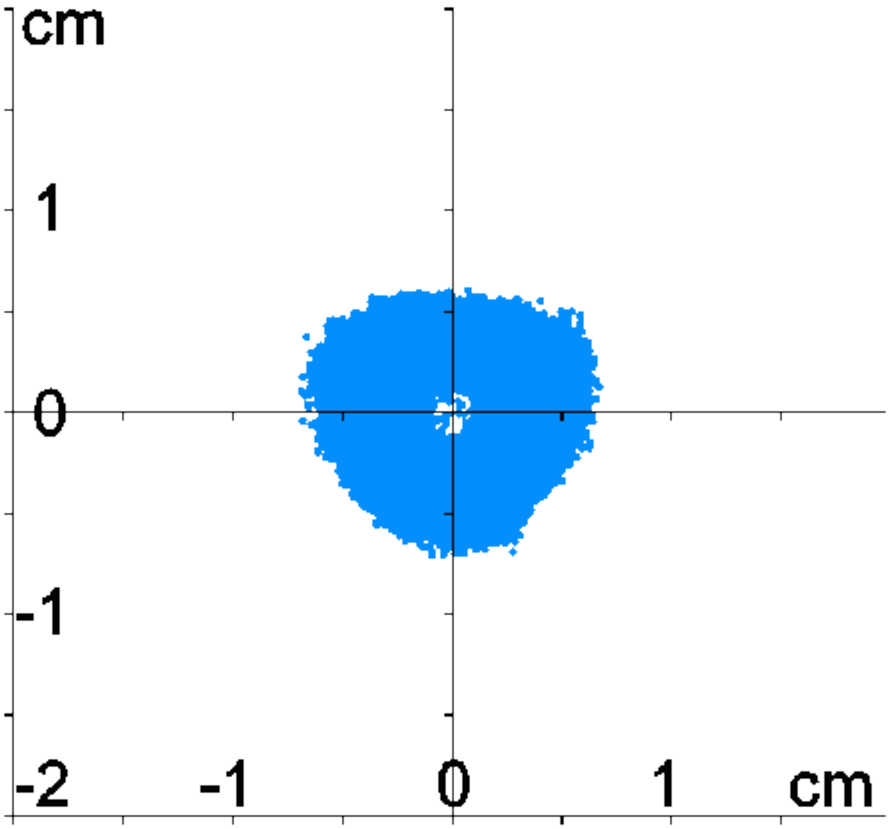

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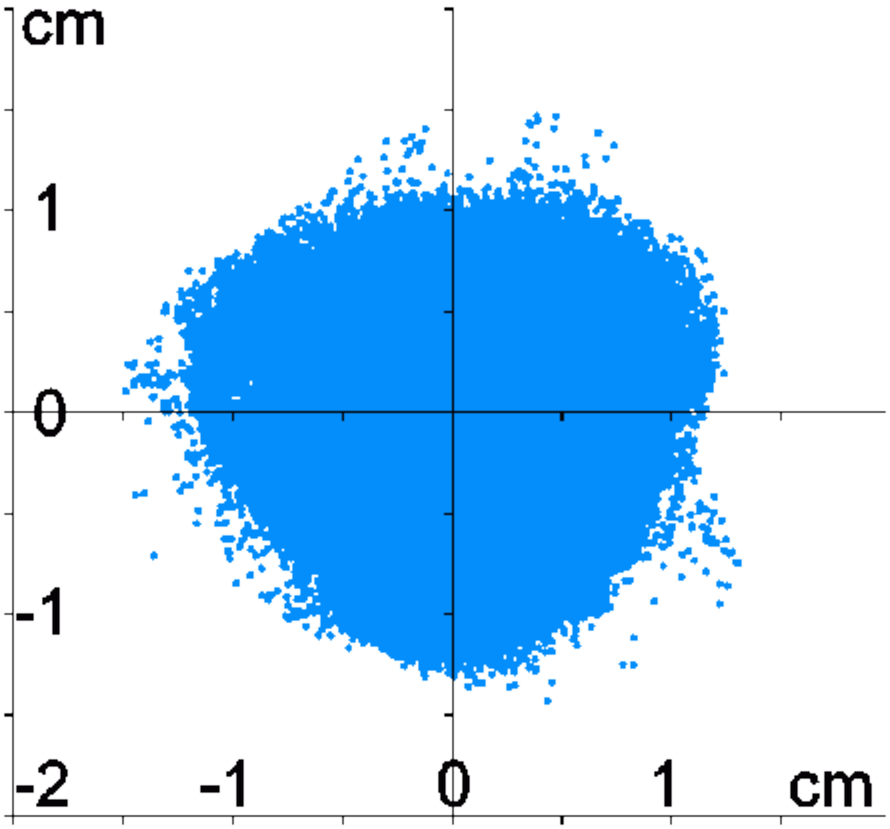

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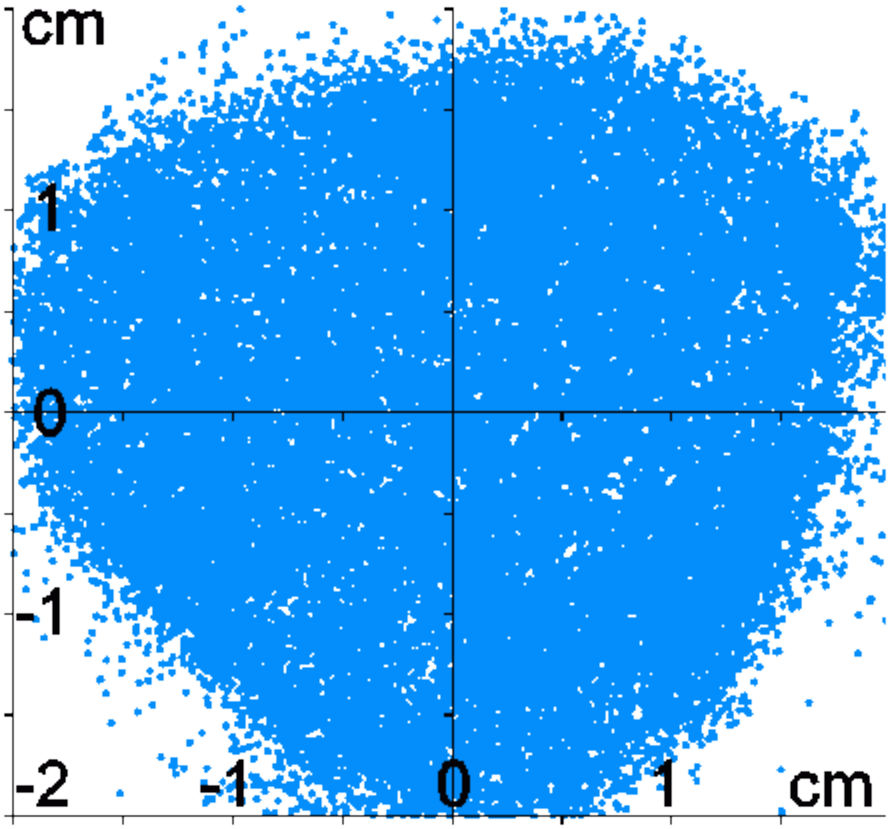

Diagnostic:

The emittance in 3d-programs is defined in a comparable way to the experimental device using a slit and a grid to measure the emittance.

To increase the information from these measurements, a more resolved data analysis has to be performed.

This is true for simulation as well!

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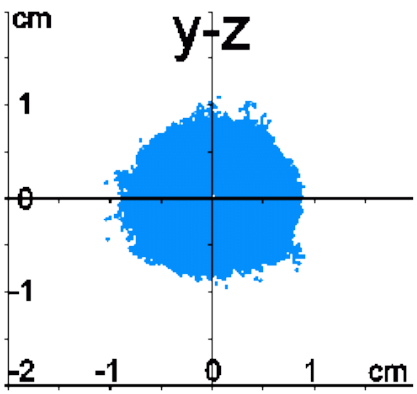

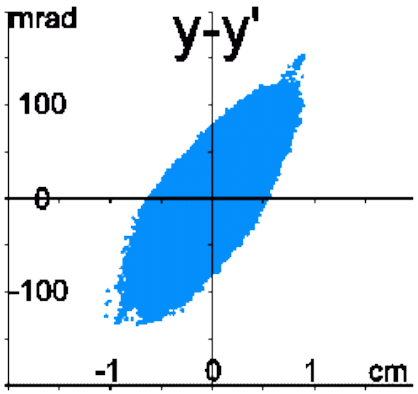

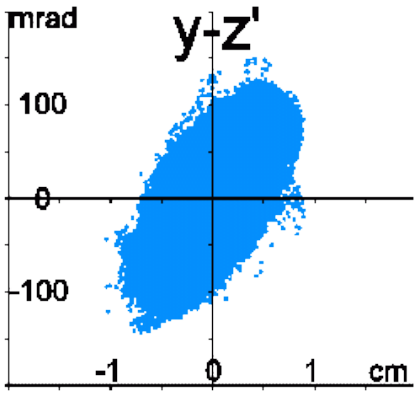

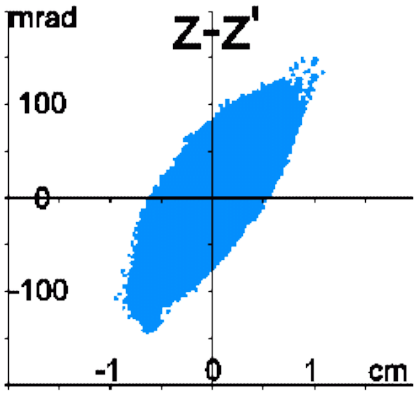

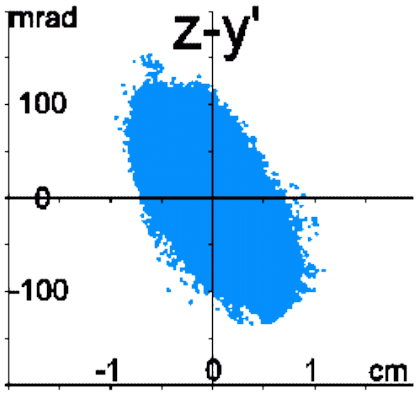

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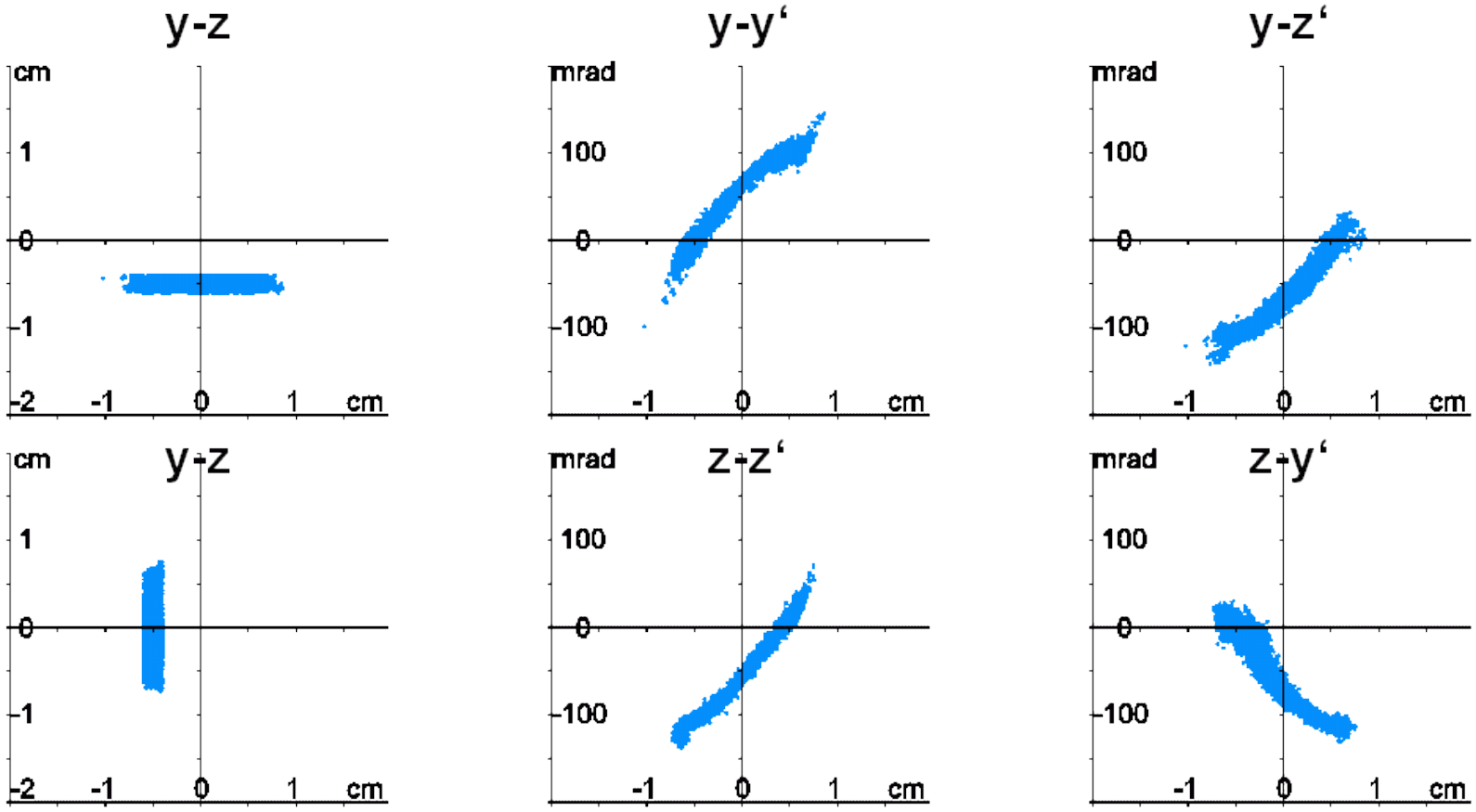

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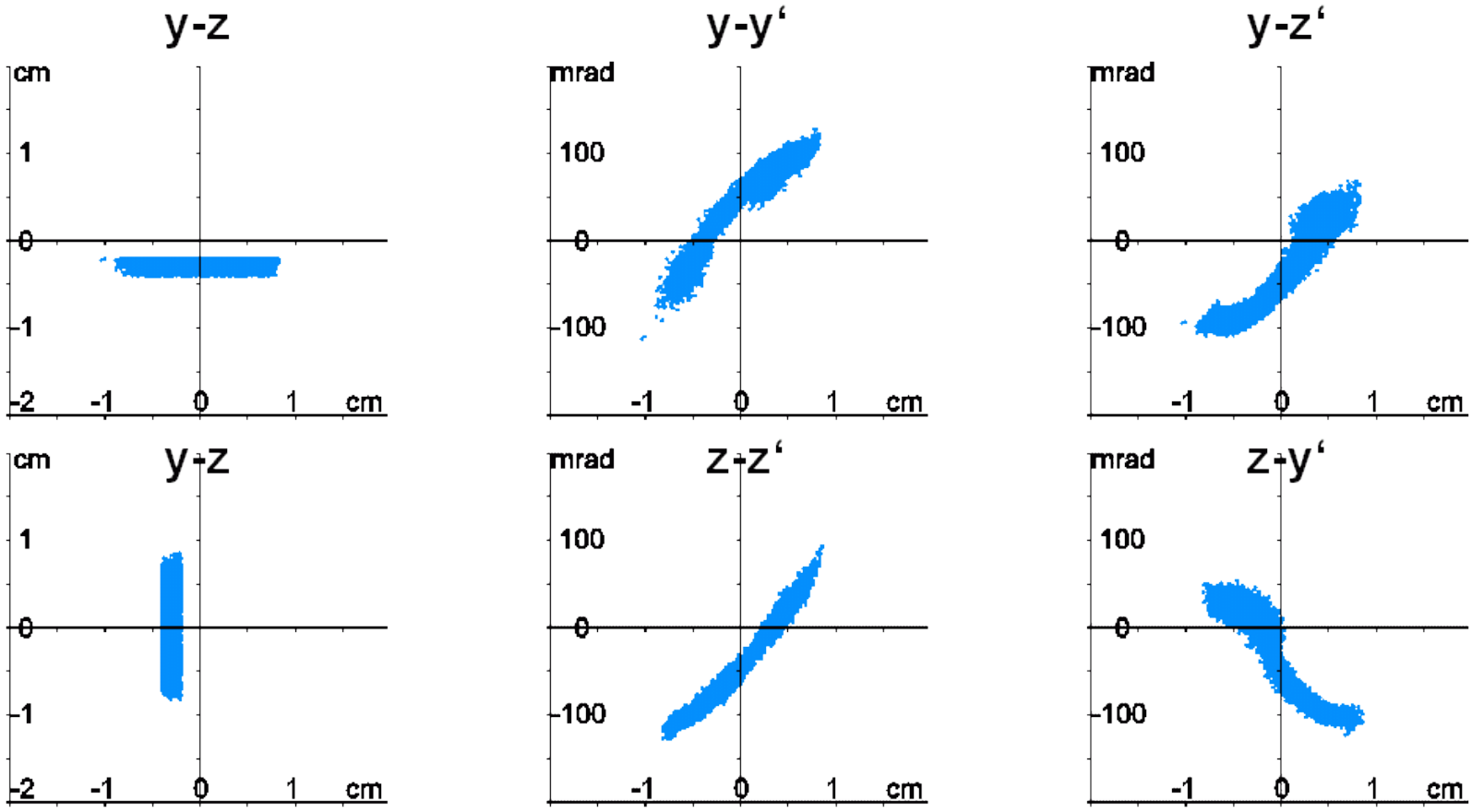

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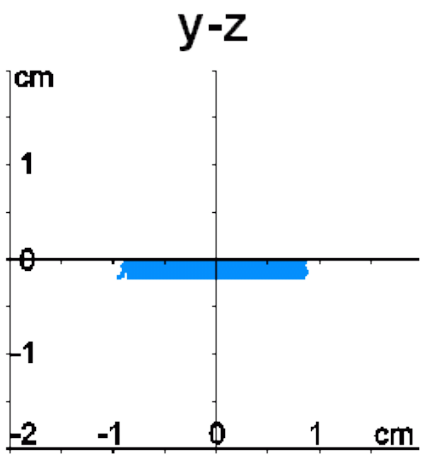

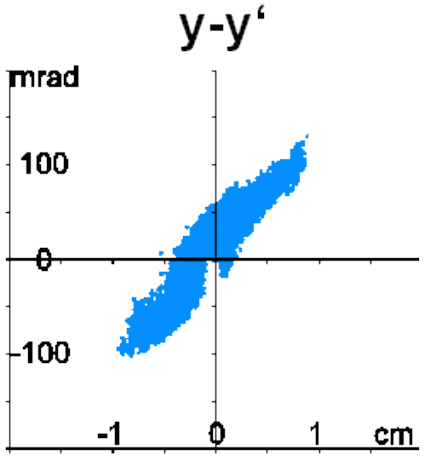

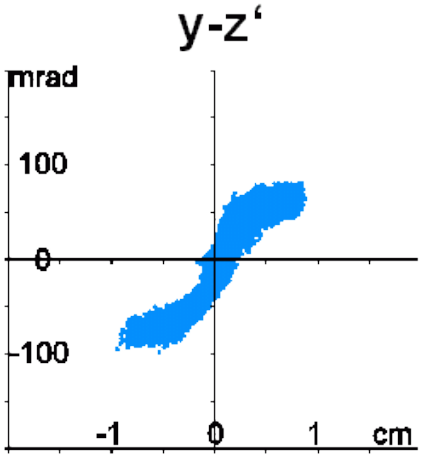

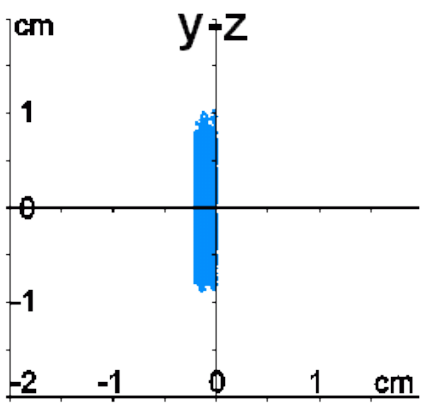

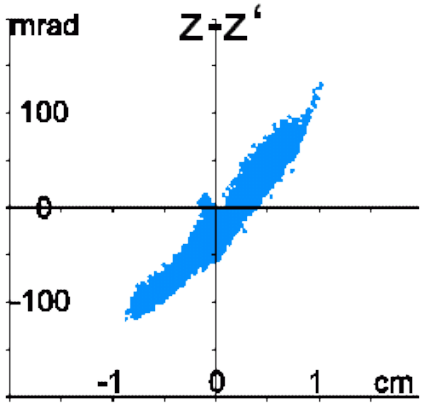

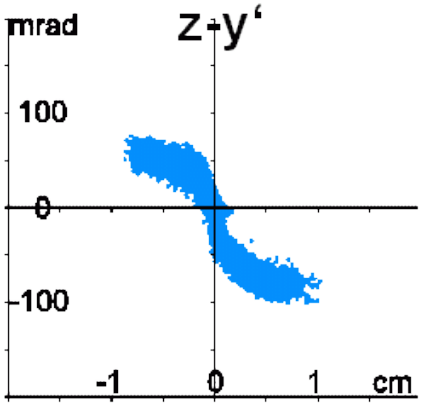

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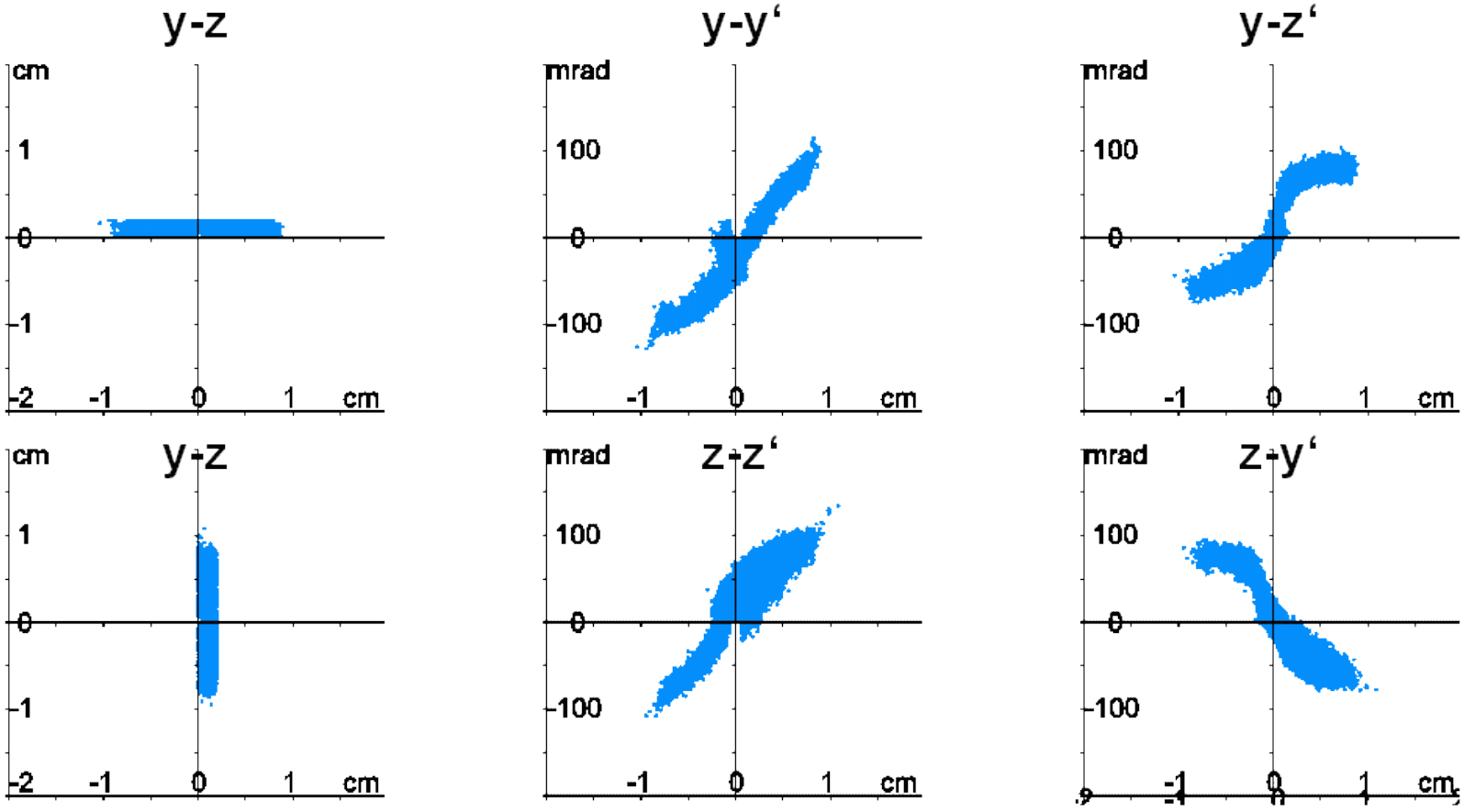

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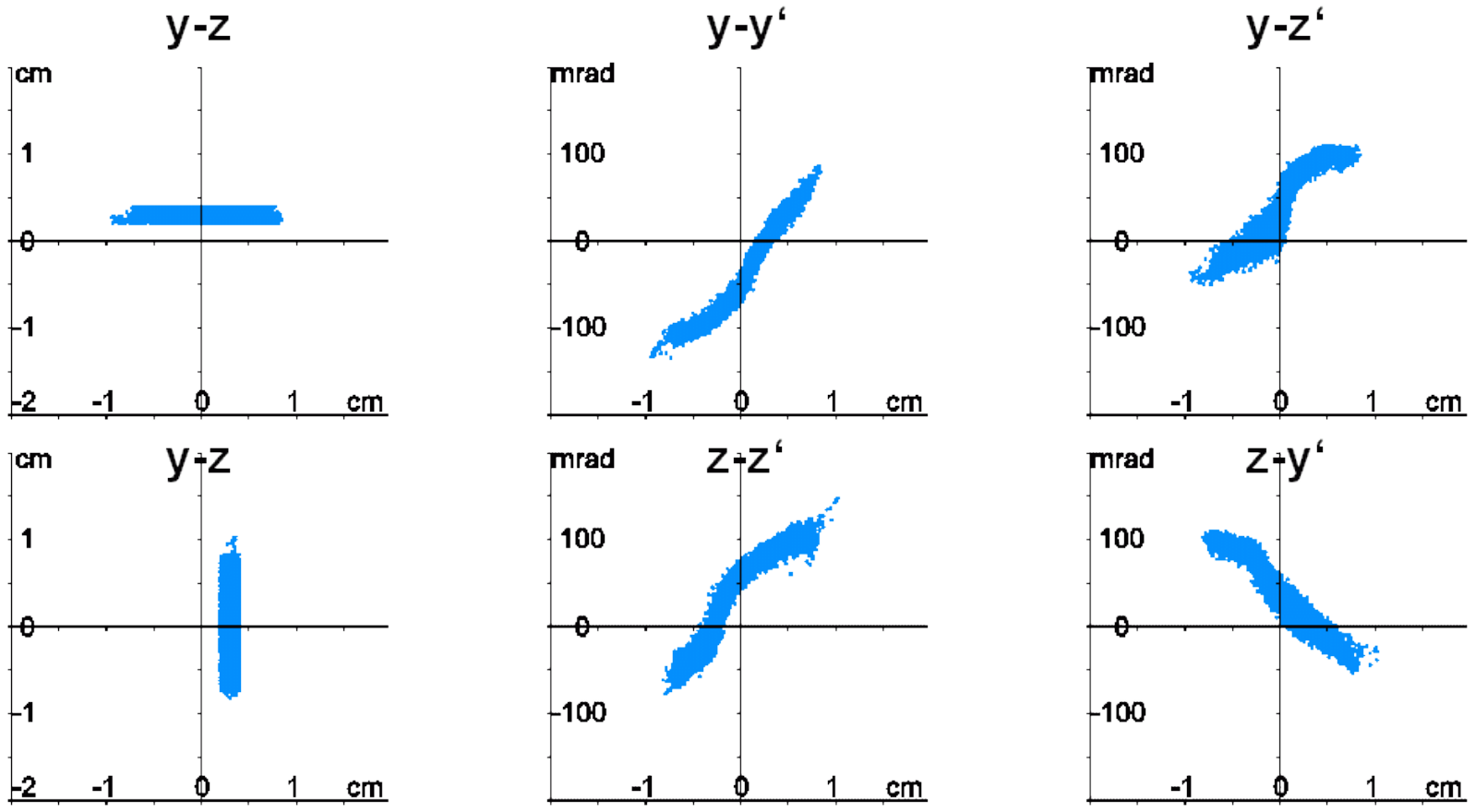

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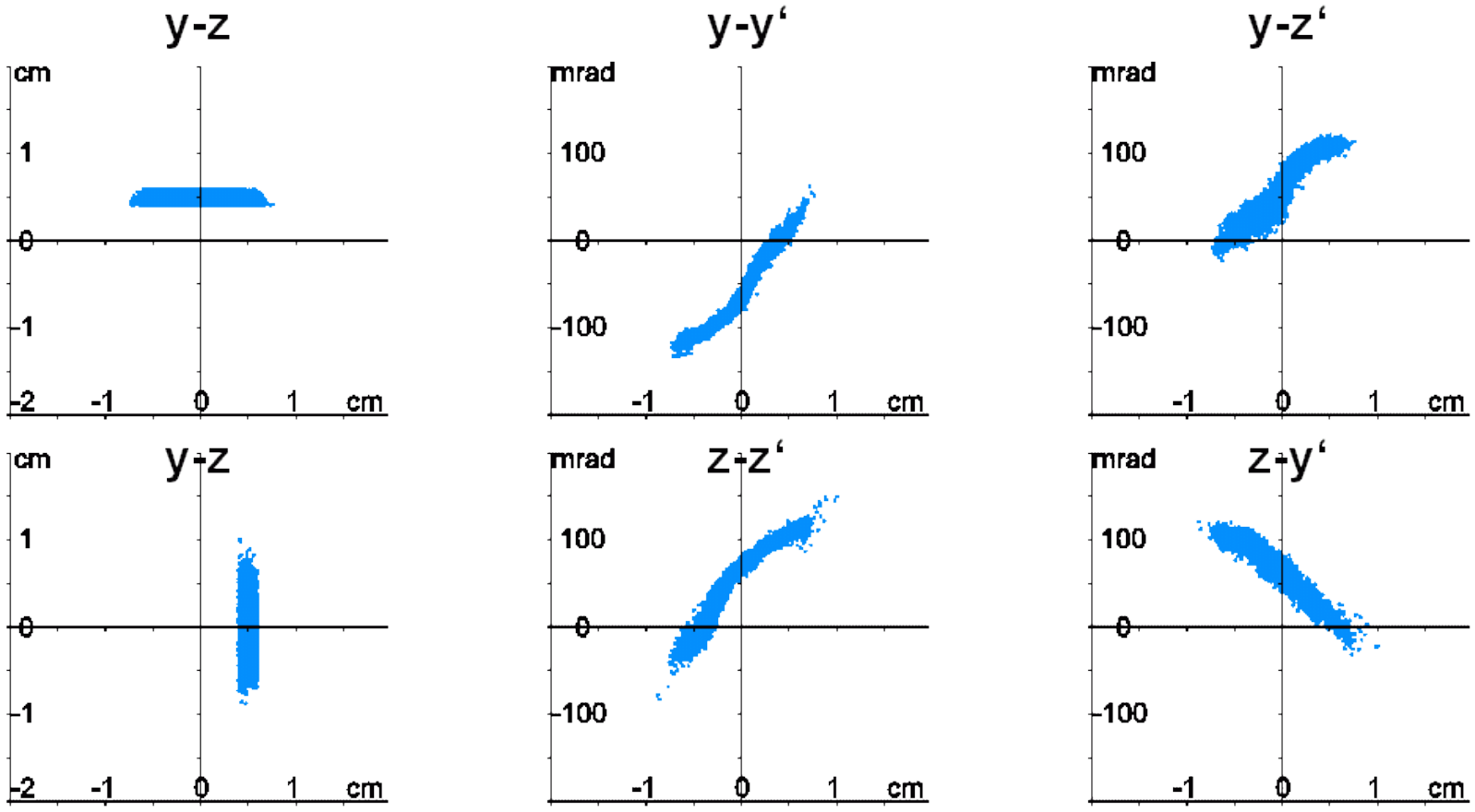

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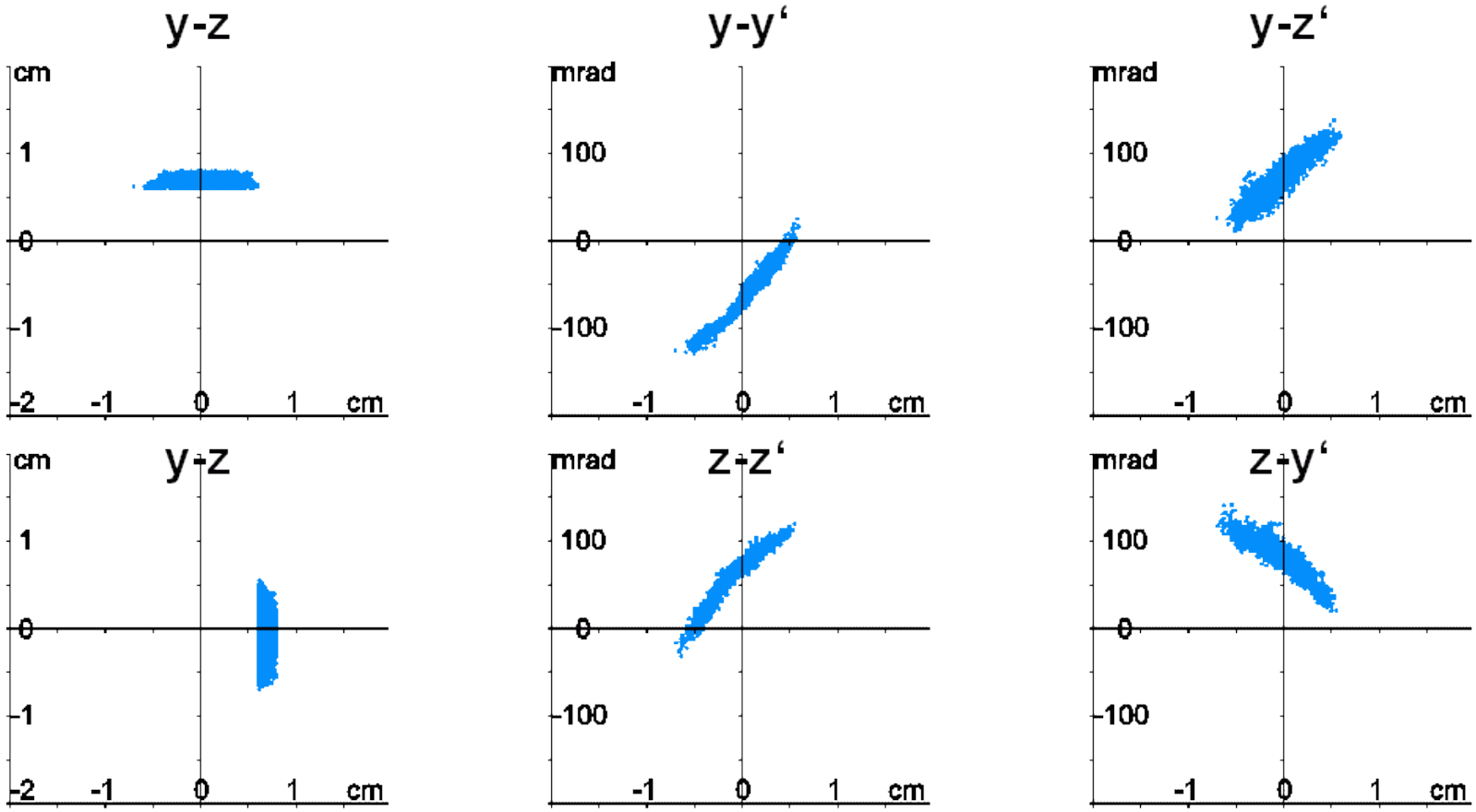
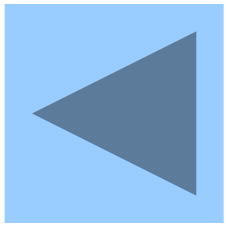
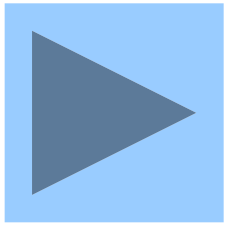


Again?



Enough!



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Experiment at the test bench EIS

→ hope you have seen the poster on Tuesday:

F. Maimone, K. Tinschert, P. Spädtke, J. Mäder, J. Roßbach, R. Lang, GSI Darmstadt, L. Celona, INFN-LNS Catania, Microwave frequency dependence of the properties of the ion beam extracted from a CAPRICE type ECRIS.

- **observable: profile on viewing target behind the analyzing dipole**
- **frequency for plasma heating is changed from 12.5GHz to 16.5GHz. The originally used 14.5GHz klystron has been replaced with a tunable TWT. The frequency is changed in 200kHz steps with 20ms time duration for each step. All other parameters of the ion source and the beam line has been kept constant.**
- **result from the beam optics view: There is a strong influence of the frequency on the extracted beam. However, the global shape seems to be defined by the magnetic field; the electric field inside the plasma (!) seems to deliver plasma to the extraction --- or not!**
- **Consequence: if the visible structures are generated already within the plasma, collisions did not destroy these structures → collisions are not important for the path of the trajectories.**

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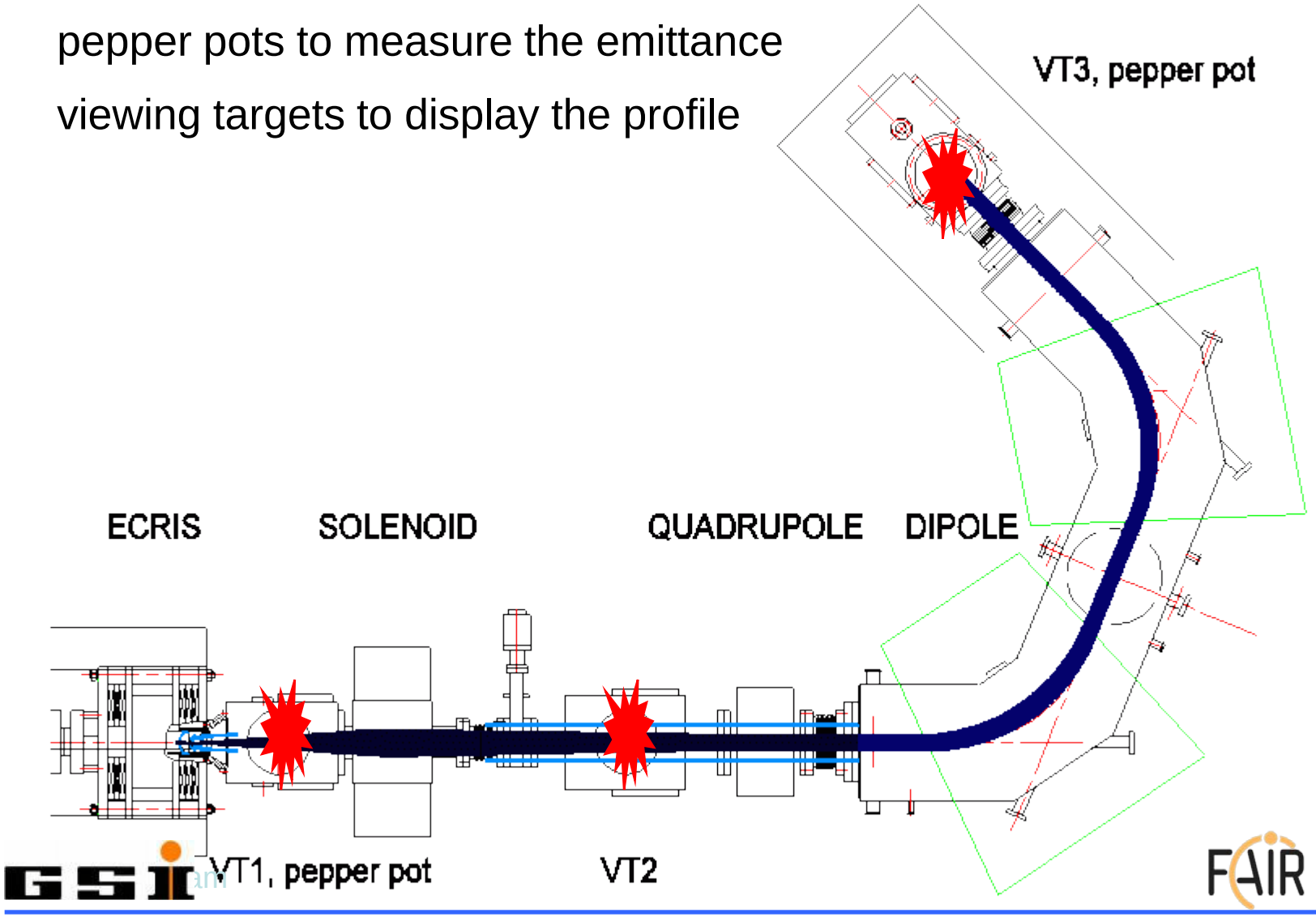
pepper pots to measure the emittance

viewing targets to display the profile



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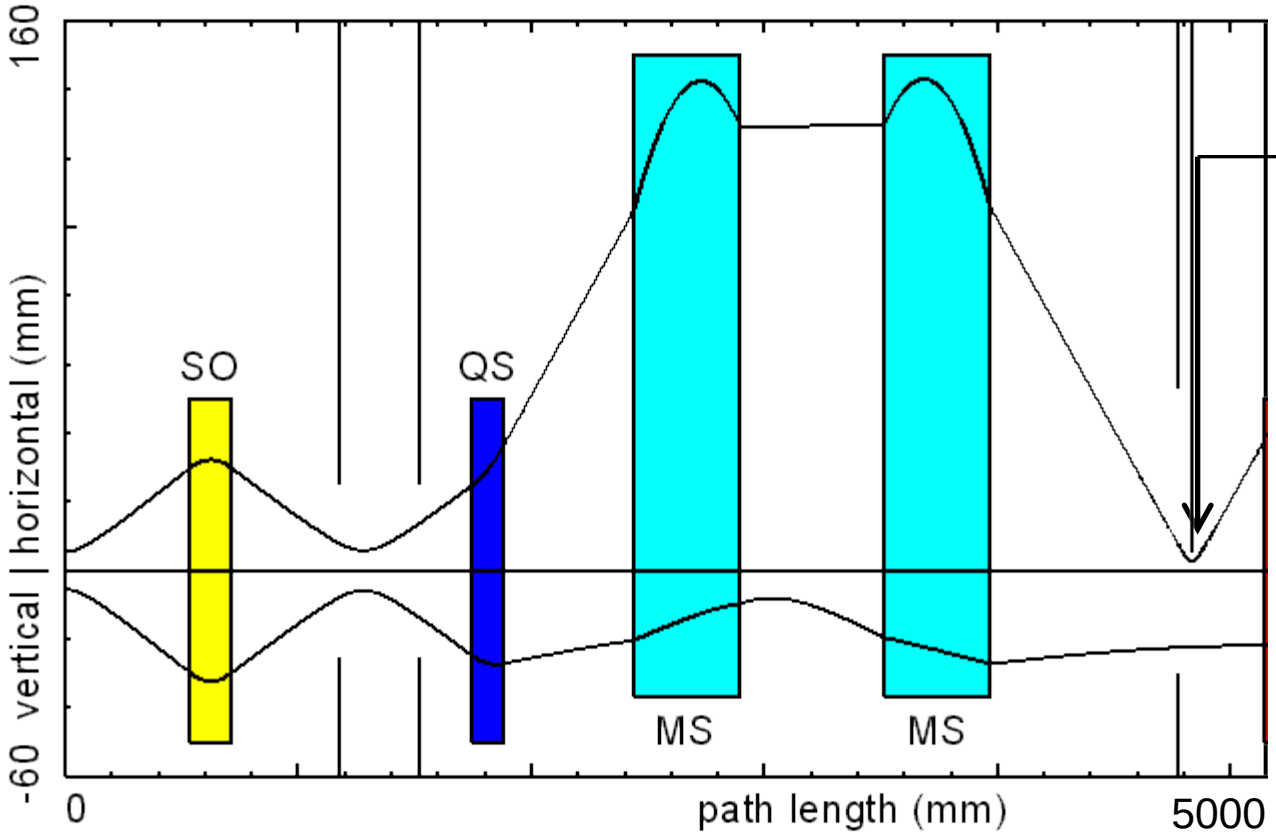

first order simulation of the beam line with MIRKO

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Ar^{8+} 15kV U_{ex} on VT3

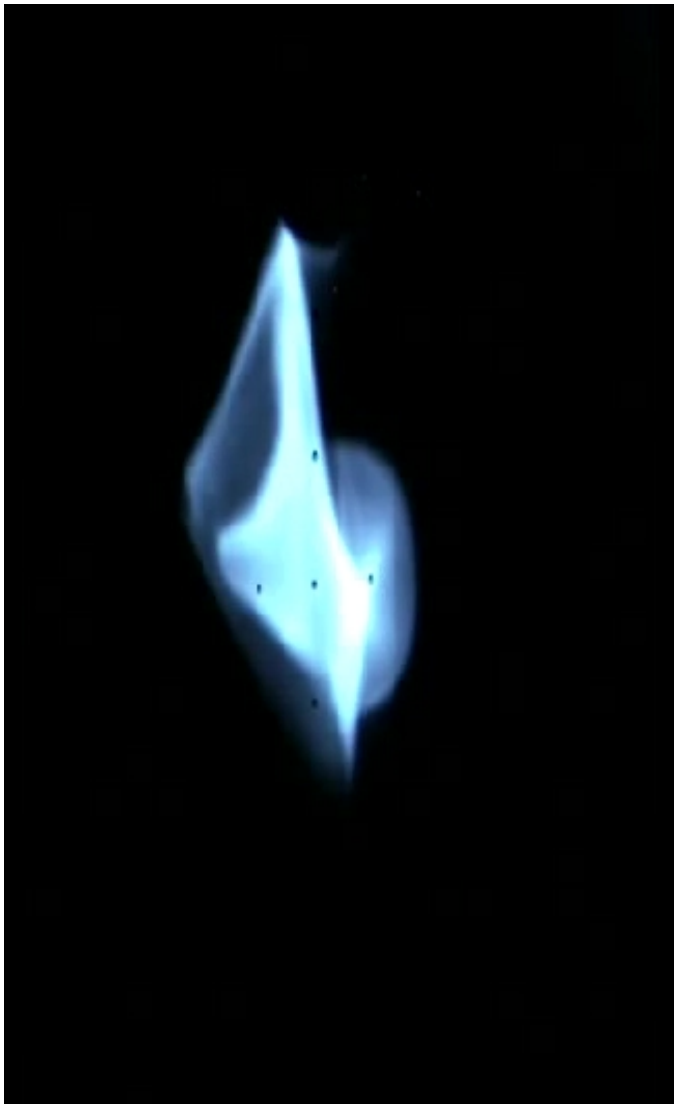
ramping the rf equal to the time displayed

16:37 → 12.5GHz

16:45 → 16.5GHz

extracted current not constant → TUPOT12!

I_{total} < 2.8 mA
I_{8+} < 200µA



Hypothesis:

May be we have seen B-surfaces inside the plasma chamber, from where ions can be extracted --- if plasma will be produced at correct places.

???

Facts:

The ion beam is transported by a solenoid, quadrupole singlet, dipole, and several drift sections. This defines the picture on the viewing target. This structures will not be present, if another type of ion source is used (MUCIS with He at the EIS test bench).

Our interpretation: these structure is already defined inside the plasma chamber.

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Some findings are not really new!

Conclusion in:

Partial beam decorrelation of sources providing ions out of axial magnetic fields

L.Reich, H.Beuscher, FA Jülich, R.K.Bhandari, Bhaba Atomic Research Center, J.I.M.Botman, H.L.Hagedoorn, Eindhoven University, The Netherlands, 1988.

… although the fringe field of the ECR source was included in the Turtle runs using an appropriate set of solenoids the program is not able to simulate the real ion optics coming from the plasma surface and the electric fields in the puller gap including space charge …

… so far it was evident that heavy and fluctuating changes … occured when the microwave power to the plasma was changed or a change in the gas flow led to different currents out of the source …