Dipole Magnet Optimization for LEBT

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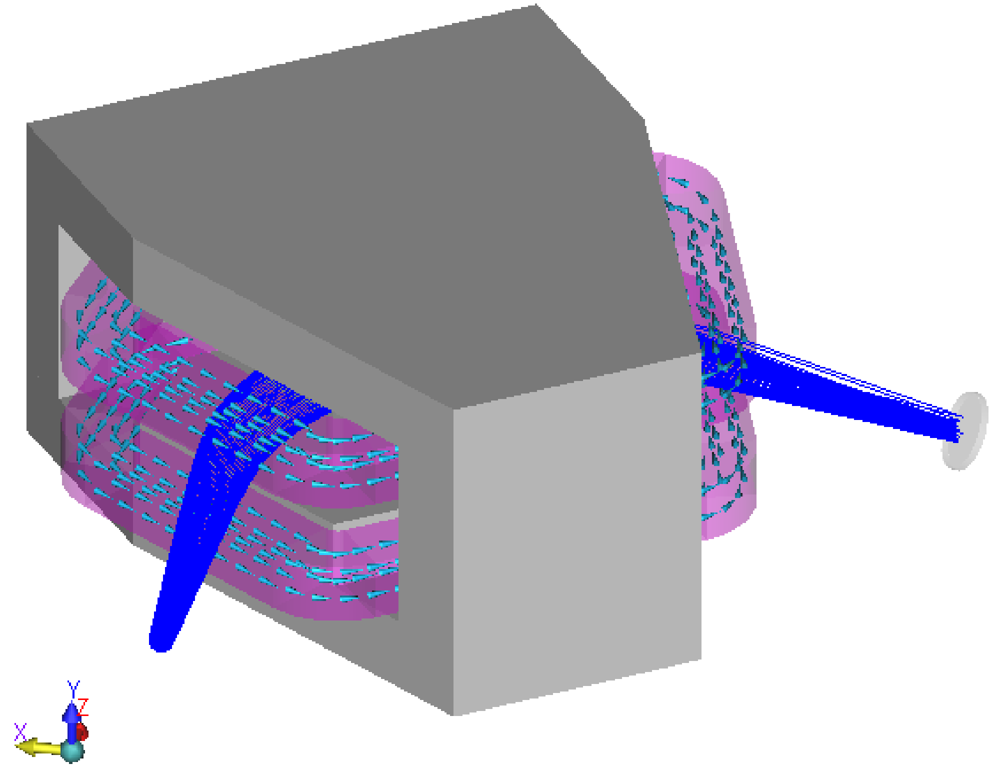
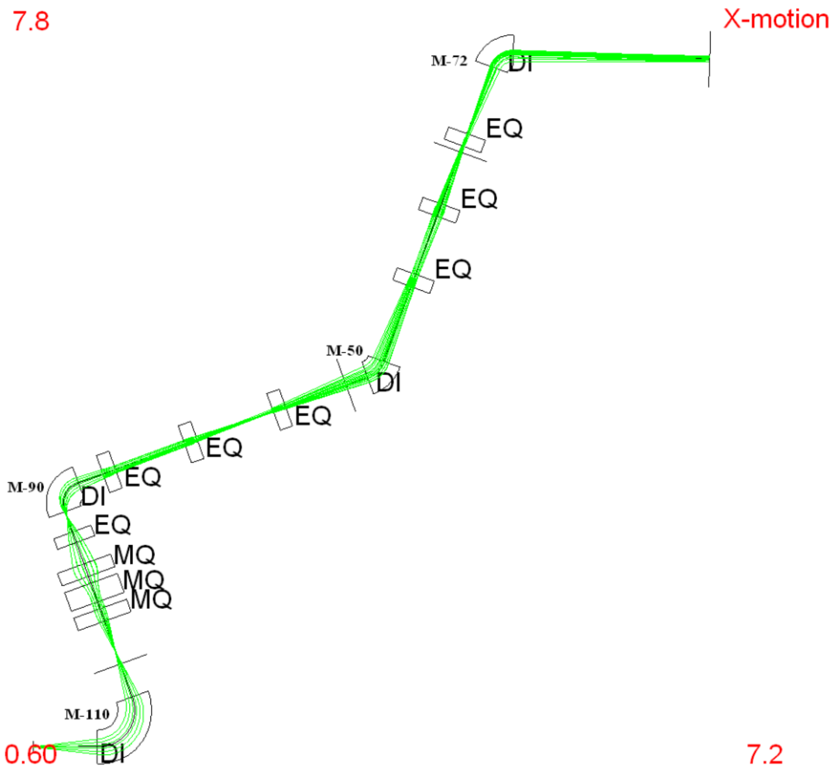


Outline

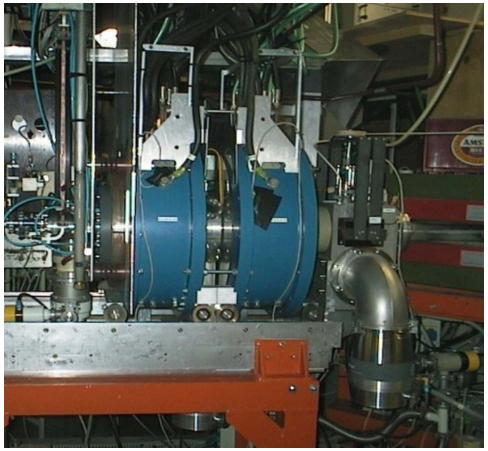
- Motivation
- Simulation of Ion beam extraction and transportation
- Beam profile and emittance measurements
- Dipole optimization
- Conclusion

Motivation

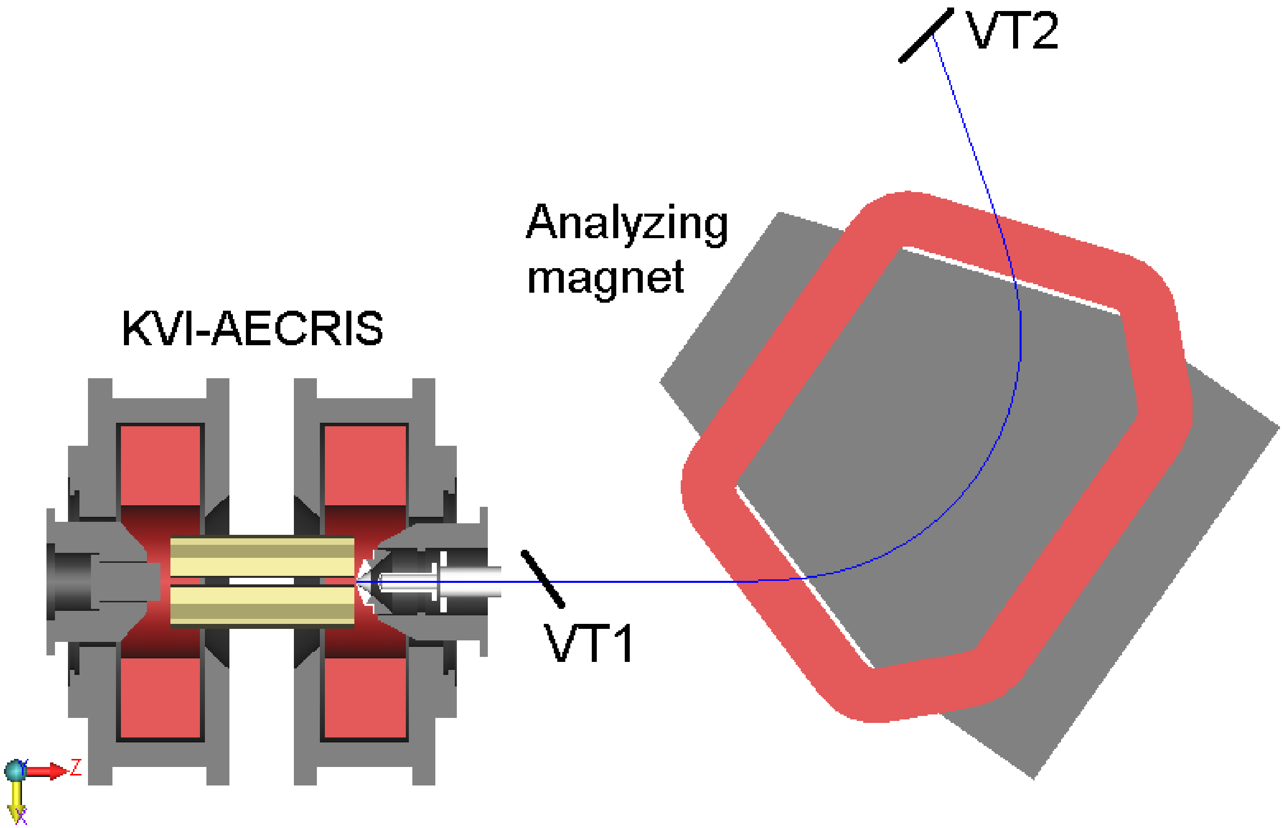
Cyclotron



AECRIS

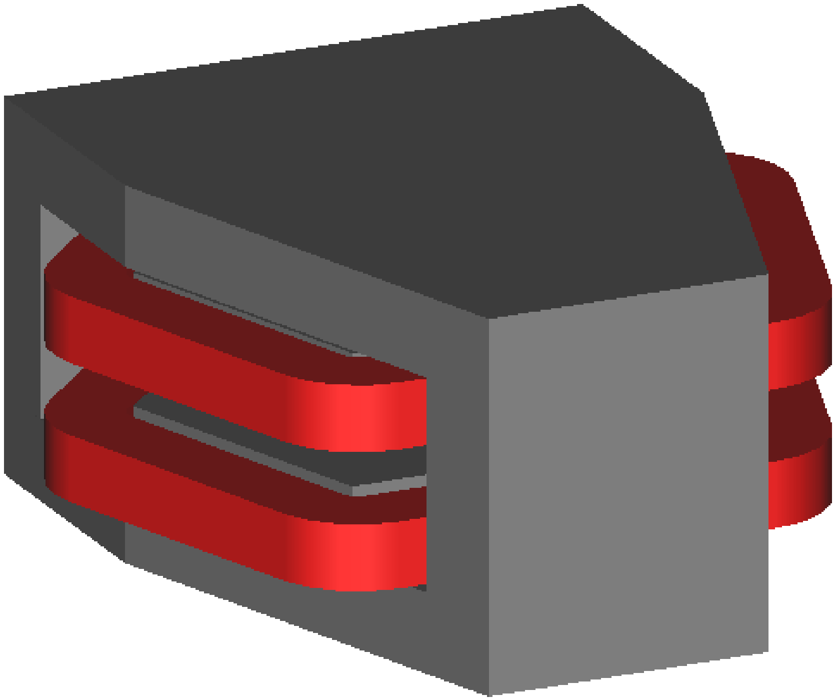


AECRIS & Analyzing magnet



- RF heating: 14.1 GHz, (11- 12.5 GHz)
- B_{inj} = 2.1 T, B_{min} = 0.36 T
- B_{ext} = 1.1 T, B_{rad} = 0.86 T
- Chamber length: 30 cm
- Chamber diameter: 7.6 cm
- Extraction aperture: 0.8 cm
- Typical analyzed beam currents for Ar^{8+} : 500 eμA , Ne^{6+} : 450 eμA and for O^{6+} : 650 eμA (O^{6+})
- Total ext. beam cur. Upto: 4 mA

Analyzing magnet (M110)



- Double focusing
- Bending radius: 400 mm
- Bending angle: 110^0
- Vertical gap: 67 mm
- Entrance pole face angle: 37^0
- Exit pole face angle: 37^0

Numerical tools used for the simulations

- PIC-MCC

  (Initial Phase-space distribution)

- GPT

  (Beam extraction and transport simulation including space charge effects)

- LORENTZ-3D

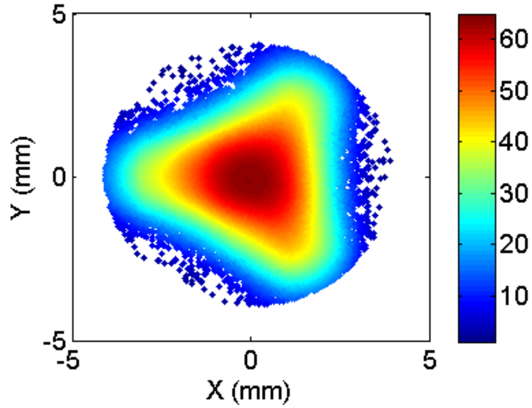
  (3D E/M-field calculation, Beam extraction and transport simulation)

- COSY-INFINITY

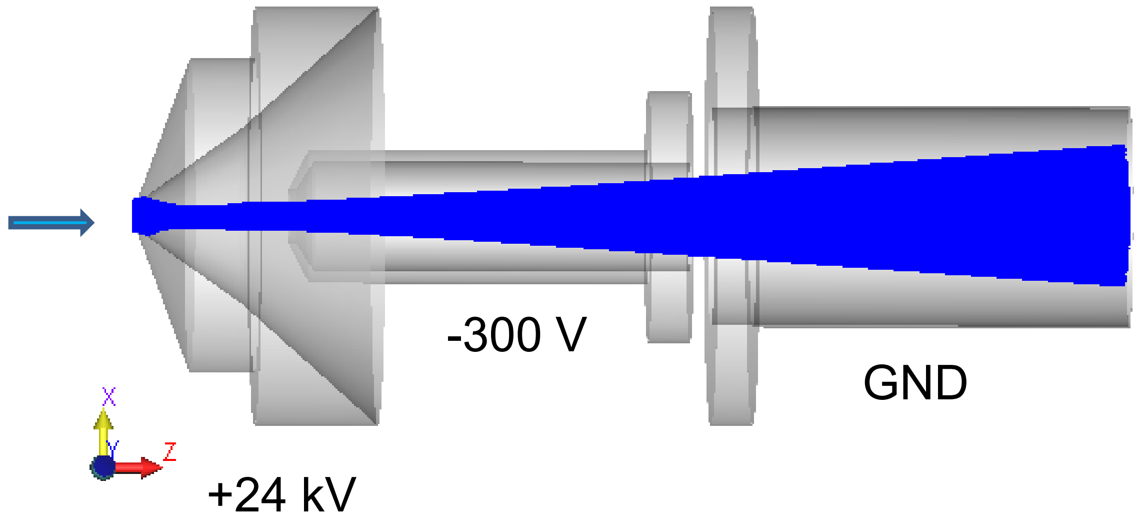
  (Beam envelope calculation)

Ion beam(He^{1+}) extraction from AECRIS

Spatial distribution at the plasma electrode



Ion trajectories through the extraction system

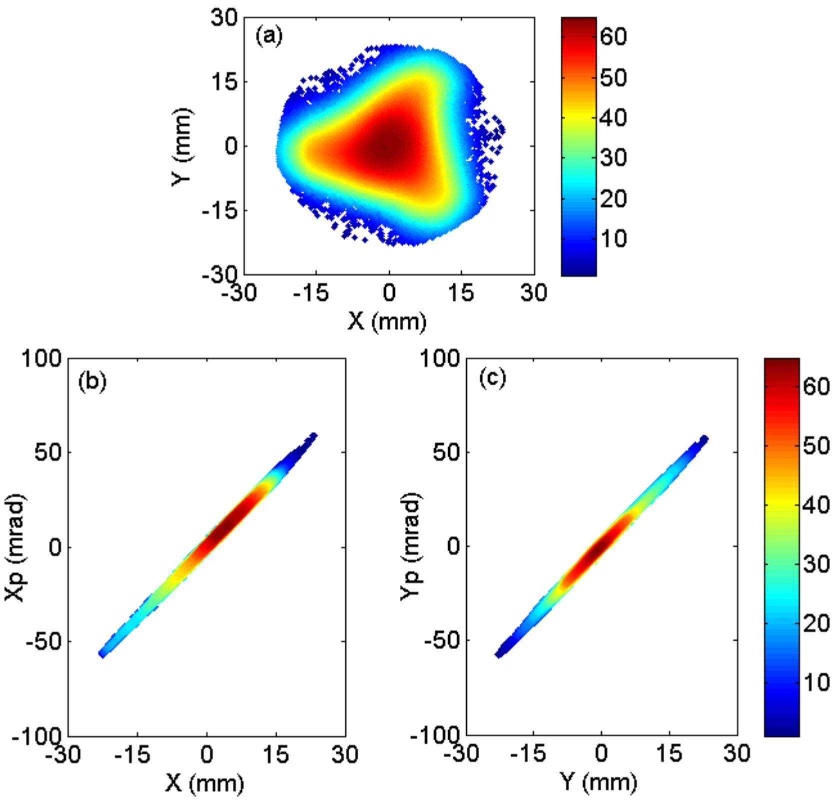


V. Mironov and J.P.M. Beijers, Phys. Rev. ST Accel. Beams **12**, 073501 (2009)

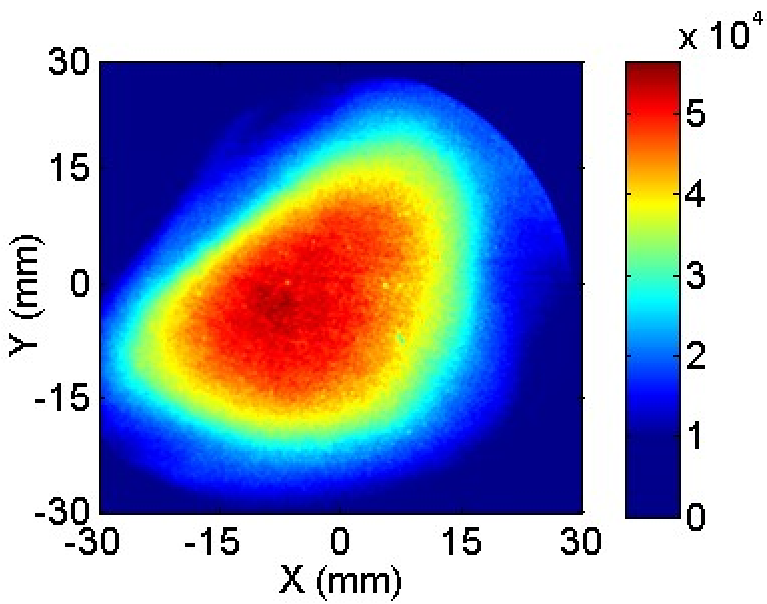
S. Saminathan et.al., Rev. Sci. Instrum **81**, 02B706(2010).

Beam profile and emittance behind the extraction system

Simulated (VT1)



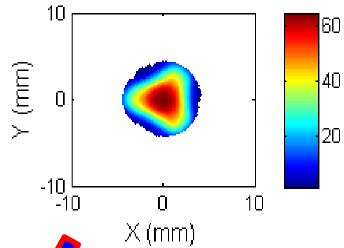
Measured (VT1)



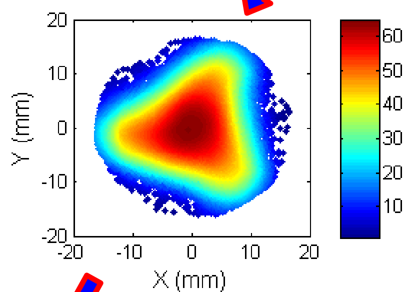
x & y 95% RMS Emitt : 65 π mm mrad

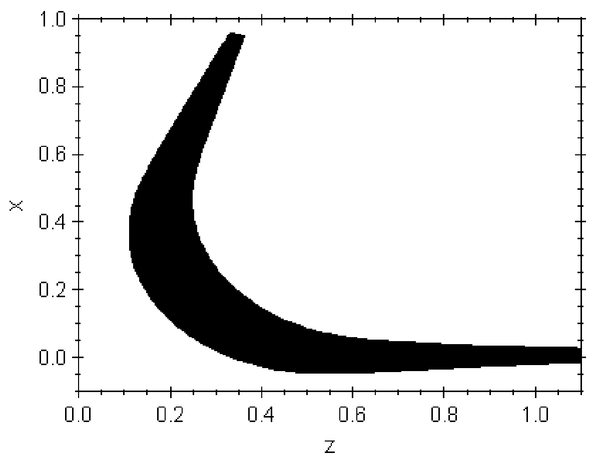
Beam (He^+) Transport Through Analyzing Magnet

Plasma electrode

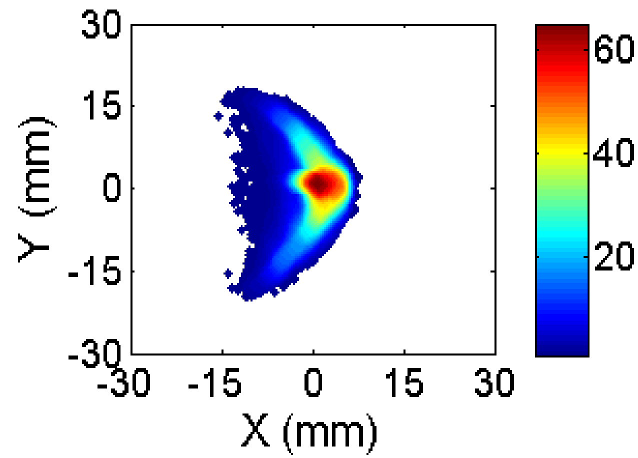


Ground electrode



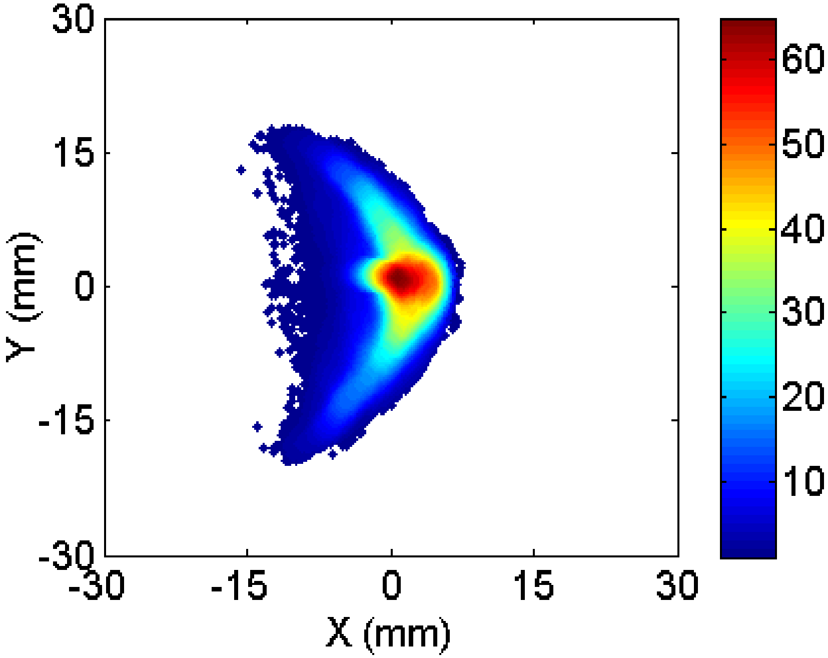


M-110

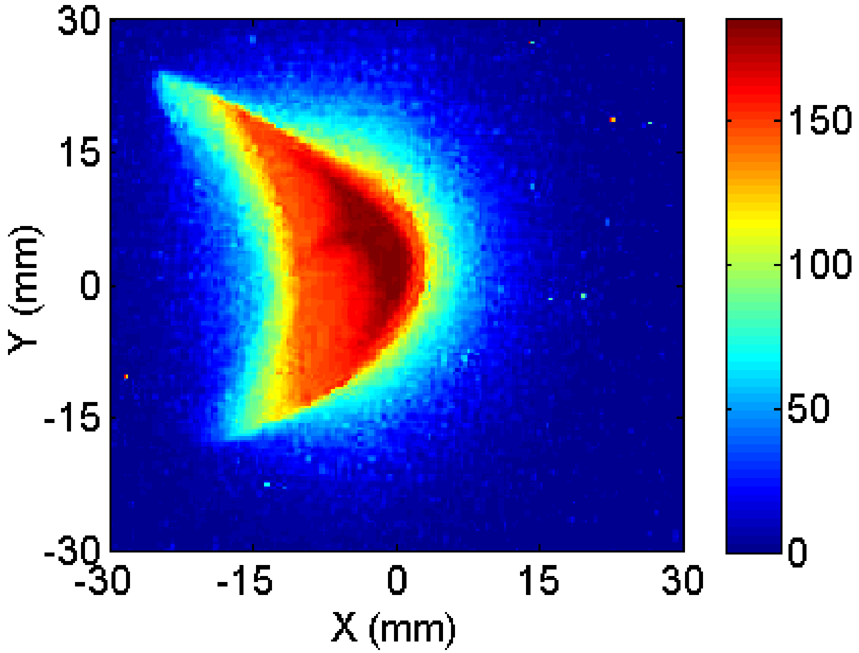


Ion beam profile behind the analyzing magnet

Simulated (VT2)

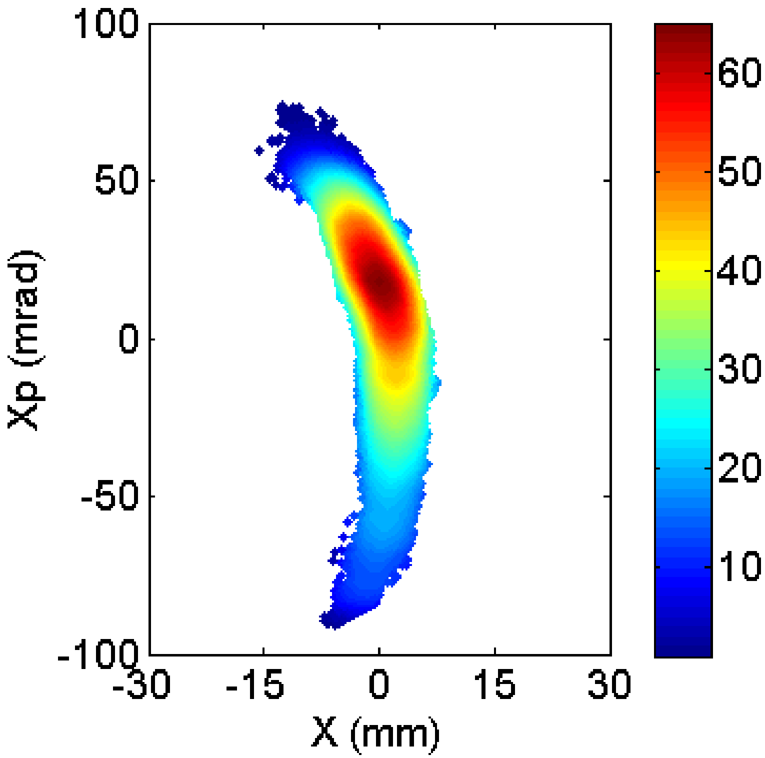


Measured (VT2)



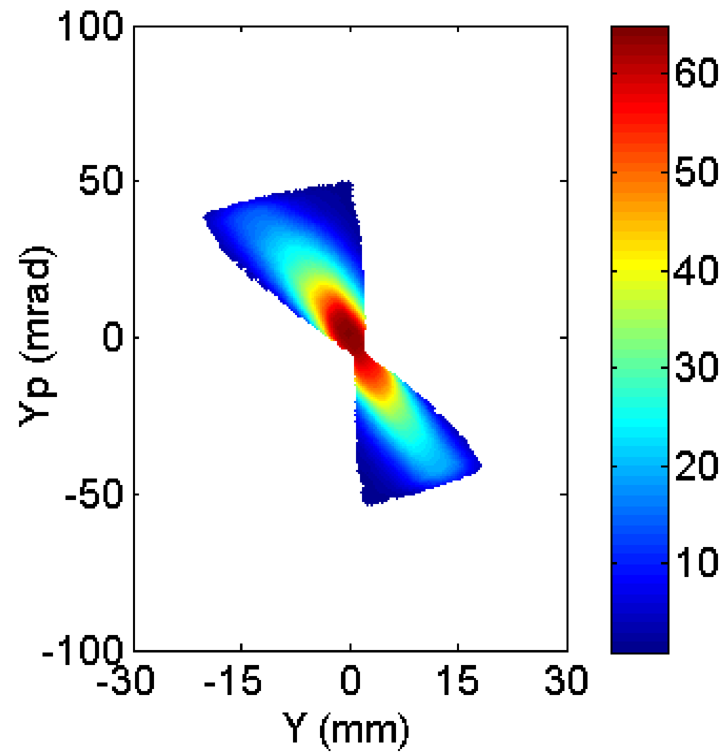
Simulated beam emittance behind the analyzing magnet

Horizontal emittance



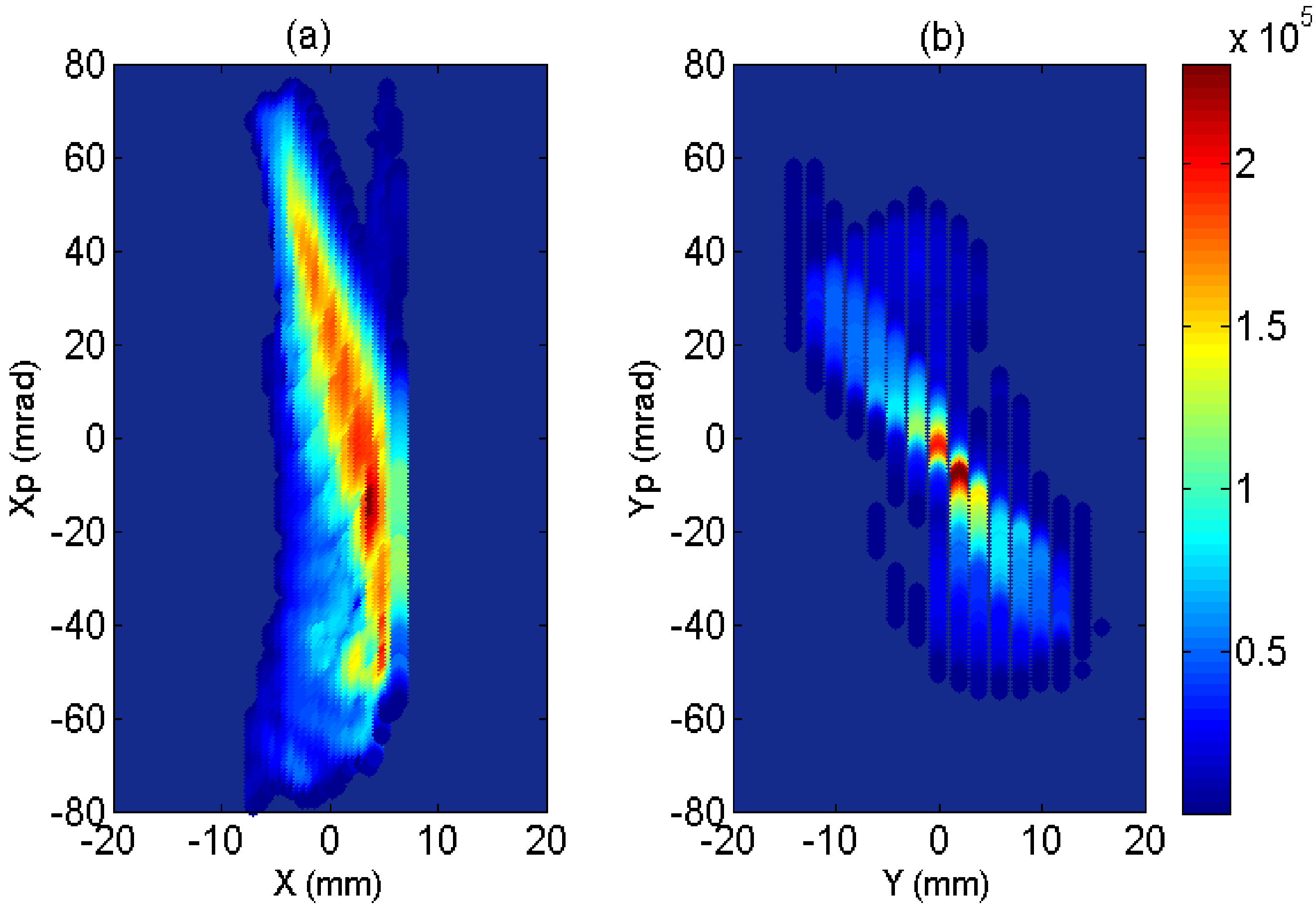
95% RMS Emitt : 360 π mm mrad

Vertical emittance



95% RMS Emitt: 240 π mm mrad

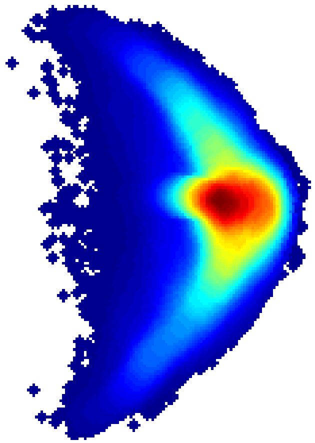
Measured ion(He^+) beam emittance



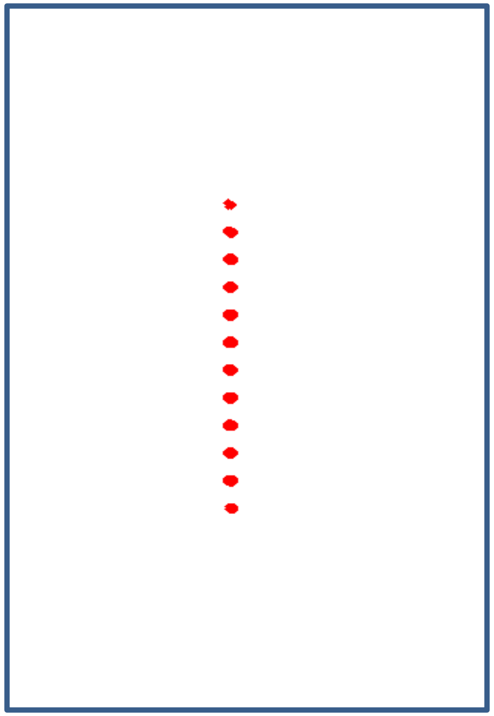
95% RMS Emitt :390 π mm mrad

95% RMS Emitt: 320 π mm mrad

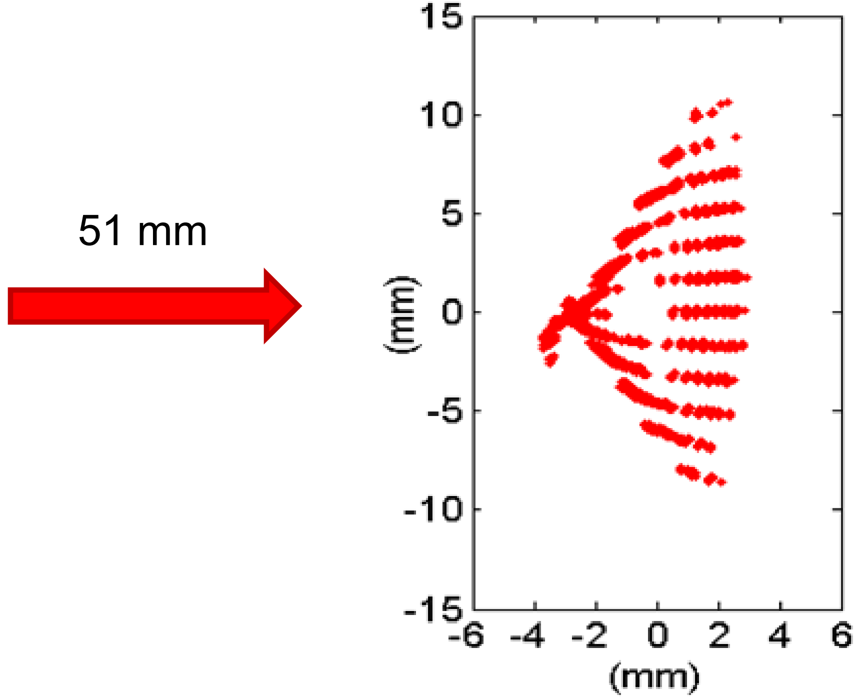
Pepper-pot simulation



Pepper-pot simulation



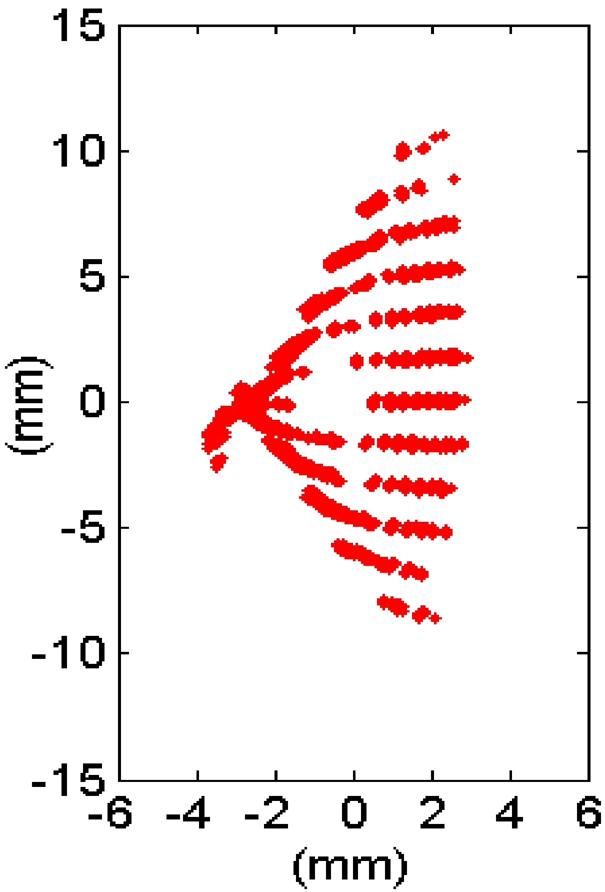
Pepper-pot
Mask (x = 0)



MCP

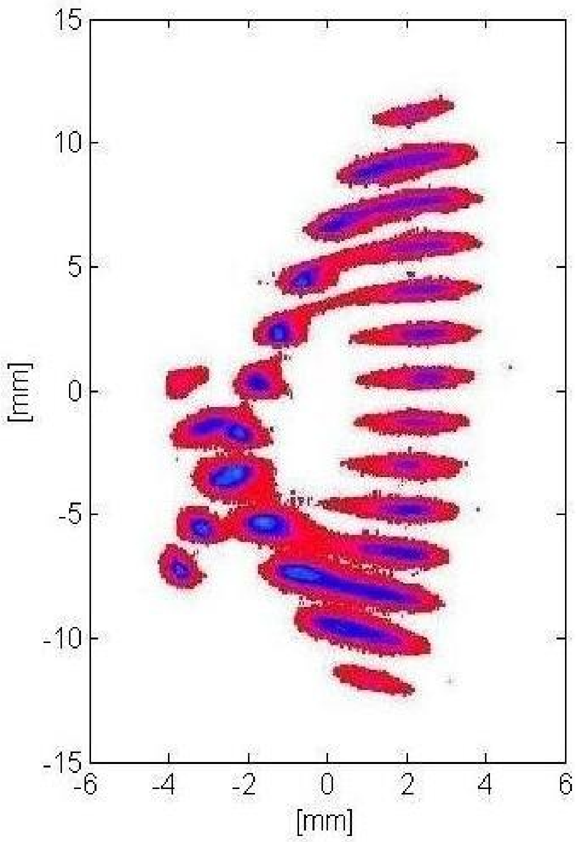
Pepper-pot simulation

Simulation



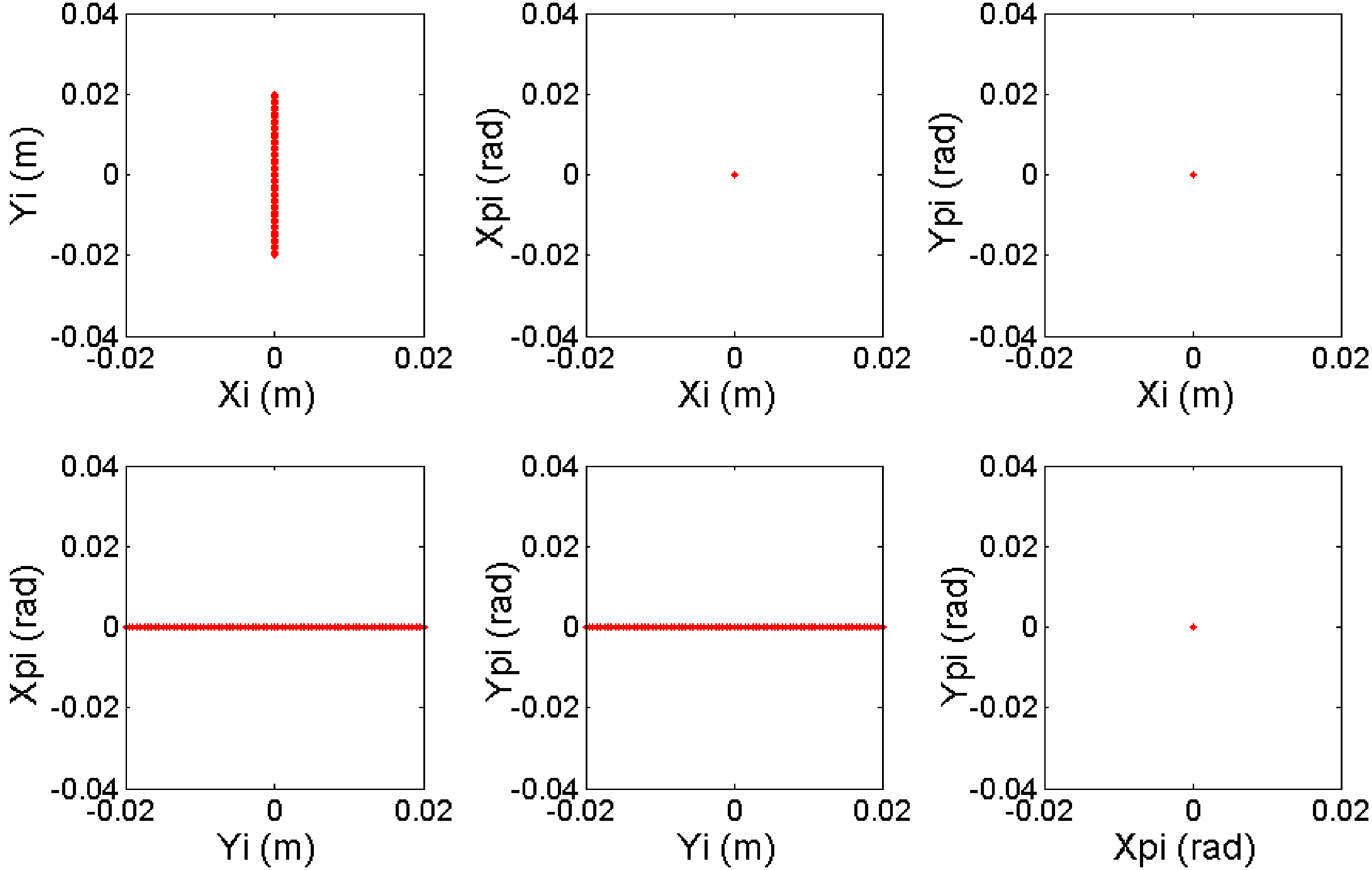
MCP

Measured

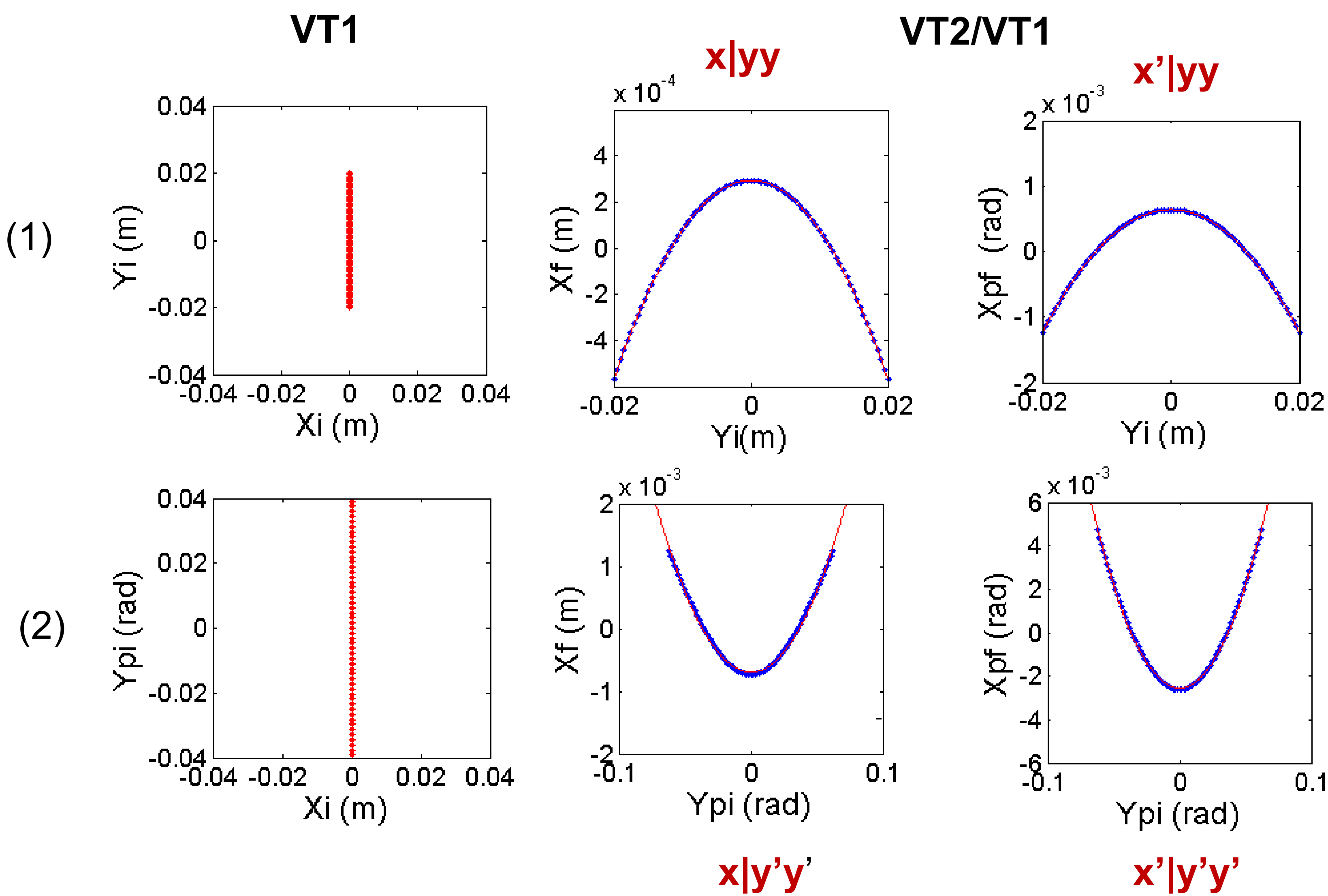


MCP

Initial co-ordinates for the aberration calculation



Effect of the second-order geometric aberration



Methods to correct the image aberrations

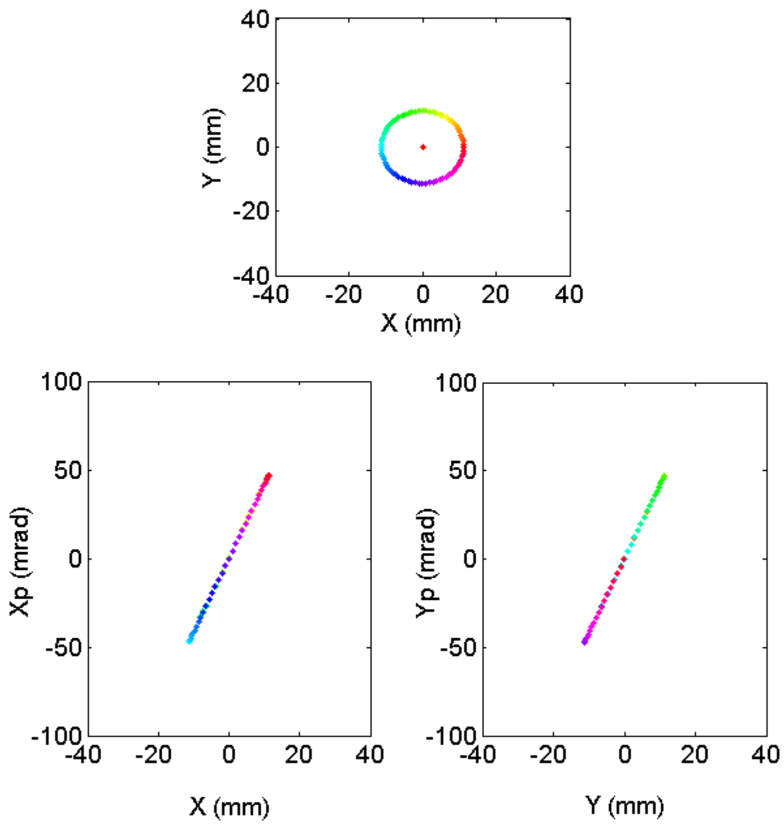
- By placing a correction element(Multipole) between an object and an image of an optical system. Disadvantage: Availability of space in the beam line.

- The required magnetic flux distribution can be achieved by using a specially designed pole shape. Disadvantage : Fine tuning of the multipole field.

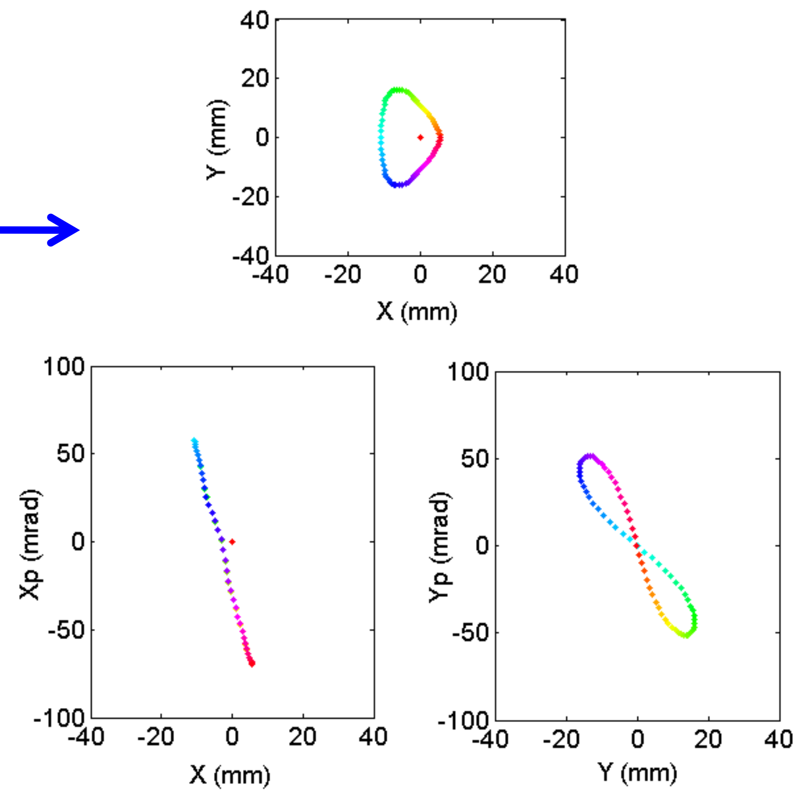
- Generating the required flux distribution by a superposition of thin multipole coils (etched electronic circuit boards) with the main poles of the magnet.

Transport Simulation (2)

Vertical gap = 110 mm



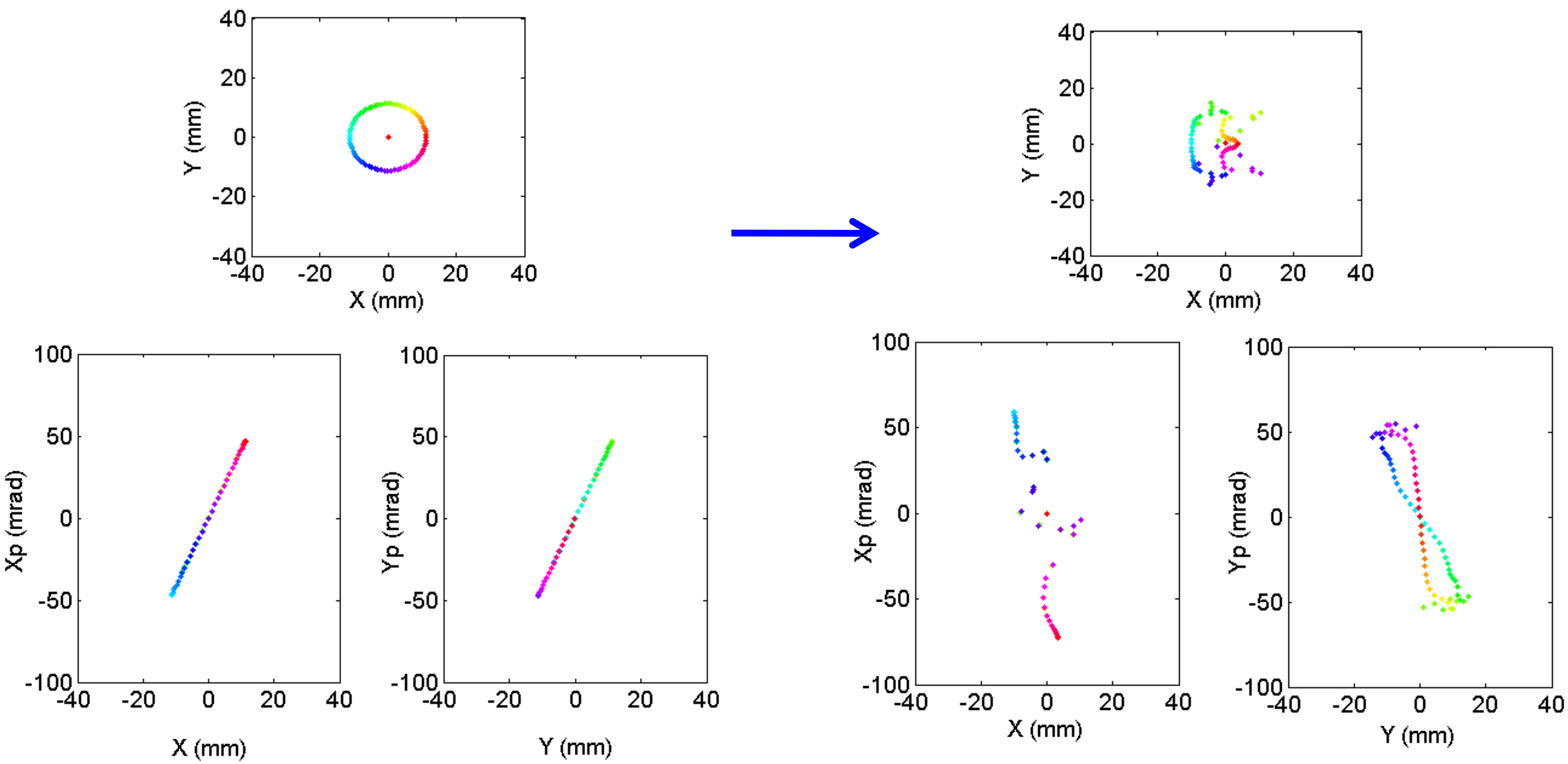
VT1



VT2

Transport Simulation (1)

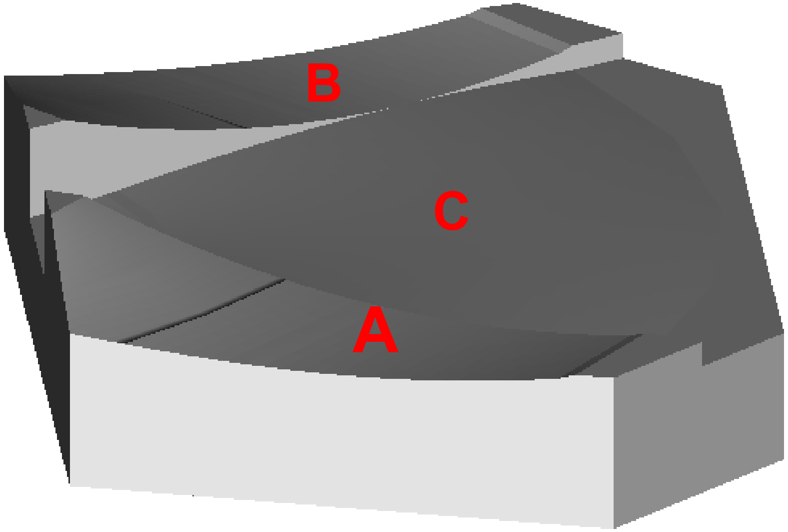
Vertical gap = 67 mm



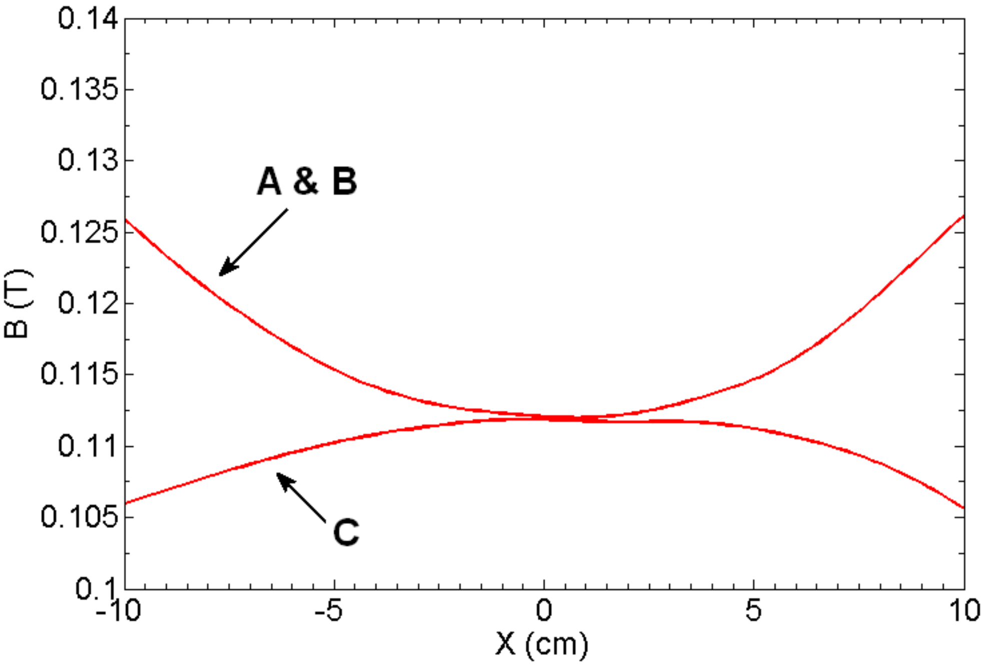
VT1

VT2

Modified pole

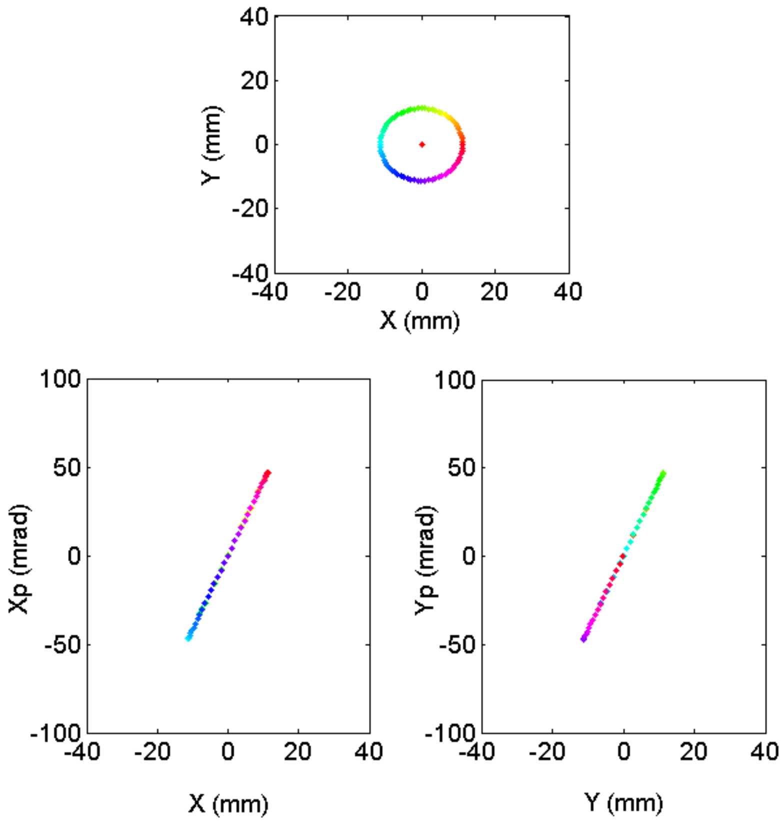


Magnetic field at the mid-plane

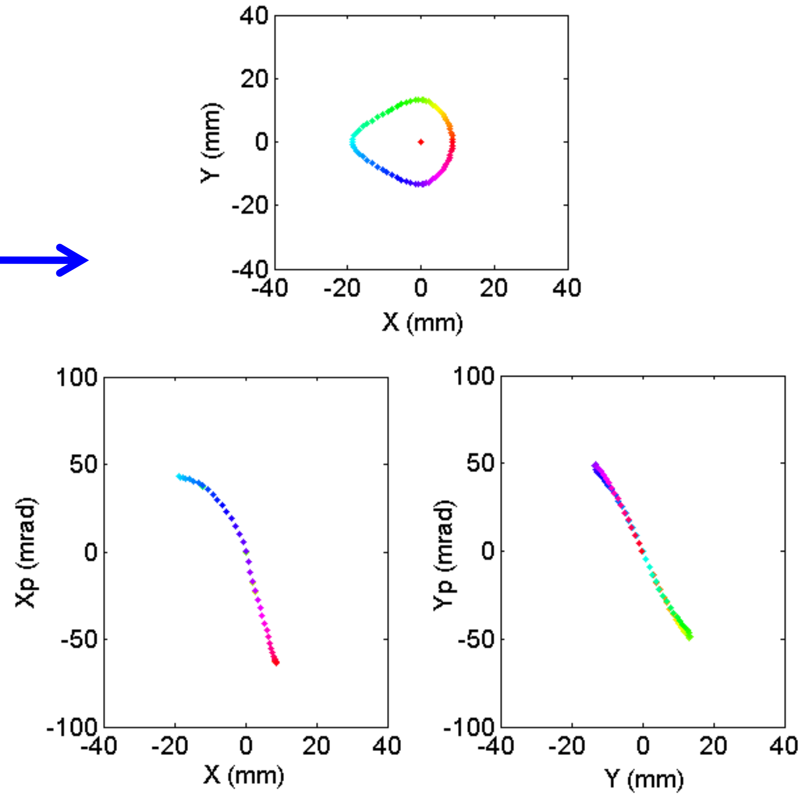


Transport Simulation (3)

Modified pole



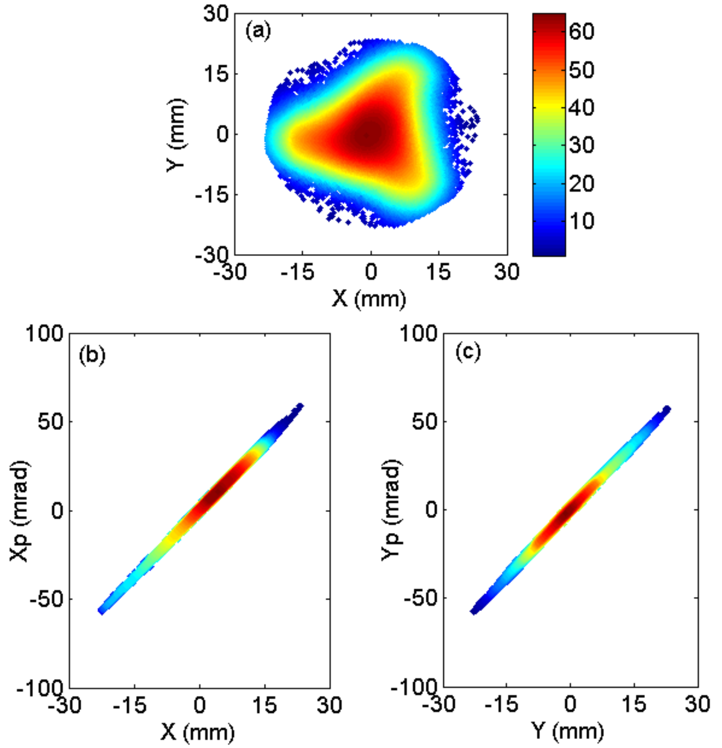
VT1



VT2

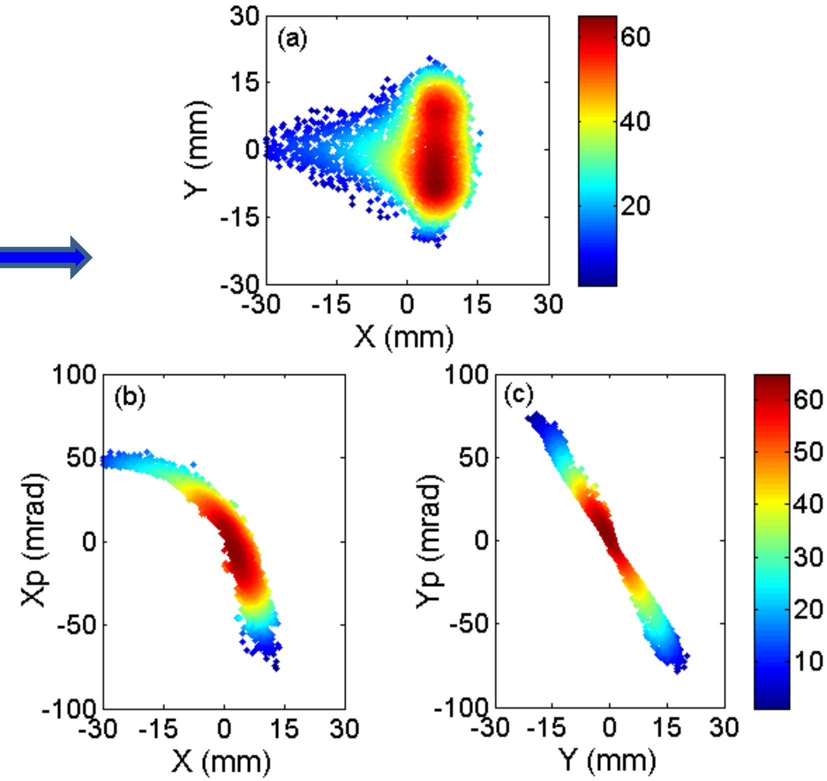
Ion beam transport through the modified dipole

Behind the Extraction system (VT1)



Emitt : 65 π mm mrad

Behind the Analyzing magnet (VT2)



Emitt : 190 π mm mrad

Emitt : 150 π mm mrad

Conclusions

- The experimental observations support the model assumptions
- Second order aberrations of the bending magnet strongly increase the effective beam emittance.
- Simulation results shows that the bending magnet with the second order correction improves the 4D phase-space distribution.

Our Team

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Jan Mulder

Sytze Brandenburg

Thanks for your Attention !