Outline

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

AECRIS

Cyclotron
AECRIS & Analyzing magnet

- RF heating: 14.1 GHz, (11-12.5 GHz)
- $B_{\text{inj}} = 2.1$ T, $B_{\text{min}} = 0.36$ T
- $B_{\text{ext}} = 1.1$ T, $B_{\text{rad}} = 0.86$ T
- Chamber length: 30 cm
- Chamber diameter: 7.6 cm
- Extraction aperture: 0.8 cm
- Typical analyzed beam currents for $\text{Ar}^{8+}$: 500 eµA, $\text{Ne}^{6+}$: 450 eµA and for $\text{O}^{6+}$: 650 eµA ($\text{O}^{6+}$)
- Total ext. beam cur. Upto: 4 mA
Analyzing magnet (M110)

- Double focusing
- Bending radius: 400 mm
- Bending angle: 110°
- Vertical gap: 67 mm
- Entrance pole face angle: 37°
- Exit pole face angle: 37°
• 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\textsuperscript{1+}) extraction from AECRIS

Spatial distribution at the plasma electrode

Ion trajectories through the extraction system

\[ +24 \text{ kV} \]

\[ -300 \text{ V} \]

GND


Beam profile and emittance behind the extraction system

Simulated (VT1)

Measured (VT1)

x & y 95% RMS Emitt : $65\pi$ mm mrad
Beam ($\text{He}^+$) 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 : $360 \pi$ mm mrad

Vertical emittance

95% RMS Emitt: $240 \pi$ mm mrad
Measured ion($\text{He}^+$) beam emittance

95% RMS Emitt : $390 \pi $ mm mrad

95% RMS Emitt: $320 \pi $ mm mrad
Pepper-pot simulation
Pepper-pot simulation

Pepper-pot Mask (x = 0)  

51 mm  

MCP
Pepper-pot simulation

Simulation

Measured

MCP

MCP
Initial co-ordinates for the aberration calculation
Effect of the second-order geometric aberration

VT1

VT2/VT1

x|yy

x′|yy

x|y′y′

x′|y′y′
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
Transport Simulation (1)

Vertical gap = 67 mm

VT1

VT2
Modified pole

Magnetic field at the mid-plane
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 show that the bending magnet with the second order correction improves the 4D phase-space distribution.
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Thanks for your Attention!