Experimental Comparison of Electrostatic and Magnetic Solenoid Focusing of Low Energy Heavy Ion Beams at the NSCL/MSU

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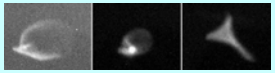
Abstract

Experience at the National Superconducting Cyclotron Laboratory has shown the first focusing element after the electron cyclotron resonance ion source (ECRIS), before the beam is analyzed by a magnetic dipole, to be critical to subsequent beam transport and matching. Until 2004, both ion sources at the NSCL used a solenoid as this first focusing element. Observation of hollow beam formation led to further analysis and the decision to replace the solenoid with an electrostatic quadrupole triplet on a test basis [1]. Substantial increases in net cyclotron output were achieved, leading us to adopt electrostatic quadrupole focusing as the permanent configuration. In addition, a sextupole magnet was installed in this beam line. Motivations for these changes and results of operating experience are discussed.

Focusing Solenoid

Calculated Analyzed Beam w/Solenoid

Reducing Helium Support Gas decreases the ring size.



Beam line is scaled to select 48Ca+8, then 4He+1 and finally 4He+2 (Left to Right). The calcium is defocused by both helium charge states. The ring for the 4He+1 case is smaller because only the 2+ helium is short-focused. The 4He+2 beam is itself the highest Q/A beam component, so there is no overfocusing by the solenoid and the source is properly imaged.

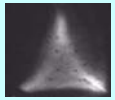
ECRIS
es. DOUBLET
es. OCTUPOLE
es. DOUBLET
SEXTUPOLE

ECRIS SOLENOID

ECRIS
es. TRIPLET
SEXTUPOLE

Electrostatic Triplet

Calculated Analyzed Beam w/Electrostatic Quad Triplet



View Plate Image now reflects beam formation

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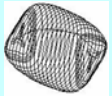
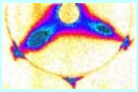


Beam is Born in a Sextupole Field

+



X-Ray Image implies spacially distributed beam formation [Biri]

Triplet + Sextupole

Sextupole off

Sextupole on Rotation Bad

Sextupole on but too weak

Less Rigid Beam (protons) allow full correction but only at a point

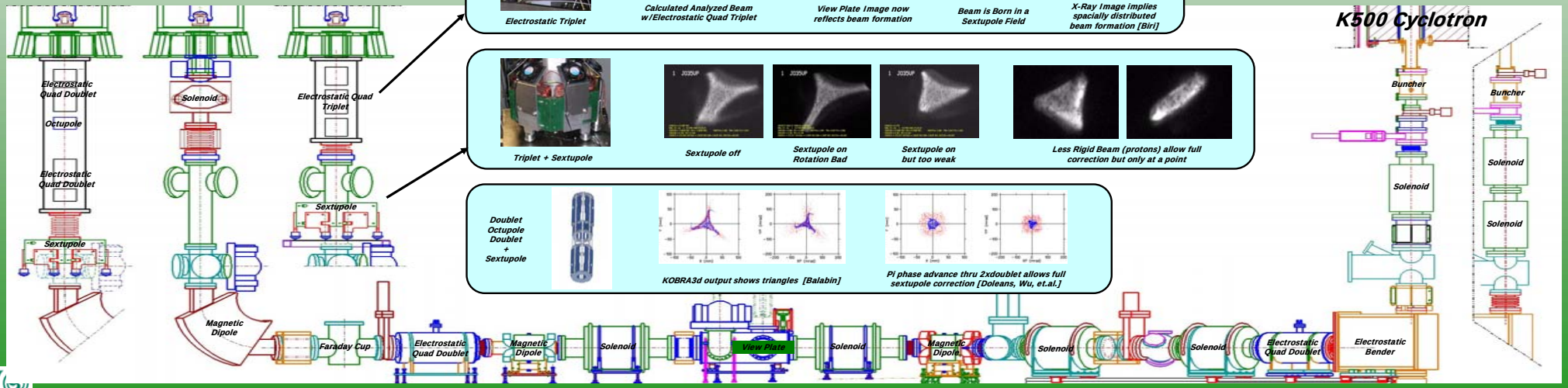
Doublet
Octupole
Doublet
+
Sextupole

KOBRA3d output shows triangles [Balabin]

Pi phase advance thru 2xdoublet allows full sextupole correction [Doleans, Wu, et.al.]

Gains of Electrostatic over Magnetic Focusing (~ x2)

	^{16}O	^{36}Ar	^{40}Ar	^{40}Ca	^{78}Kr	^{124}Xe
ICS Beam (Analyzed)	3.8	2.0	2.8	1.1	1.2	1.4
K500 In	1.8	4.6	2.6	1.6	1.3	1.4
K500 Out	1.3	2.4	1.9	1.8	1.5	1.5
K1200 Out	1.8	1.9	1.9	1.5	1.8	2.8



INJECTION LINE LAYOUT

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