Commissioning results of the 18GHz Superconducting Source for Ions- SUSI

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OUTLINE

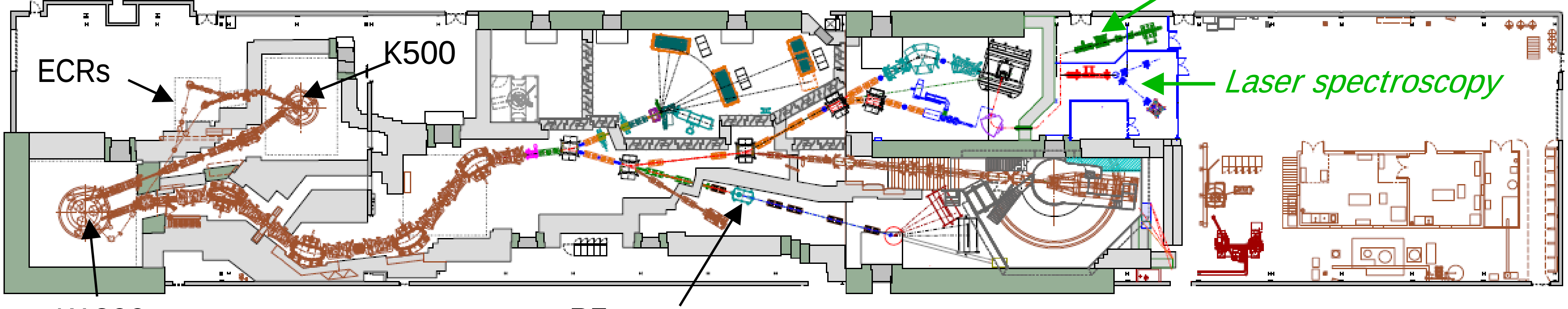
- Motivations to build SUSI
- SUSI Design and Construction
- Magnet Tests and Quenches
- Commissioning Results:

^{40}Ar: Ar^{11+} and Ar^{14+} ^{129}Xe: Xe^{20+} and Xe^{27+} ^{209}Bi: Bi^{28+} and Bi^{33}

- Beam Transport

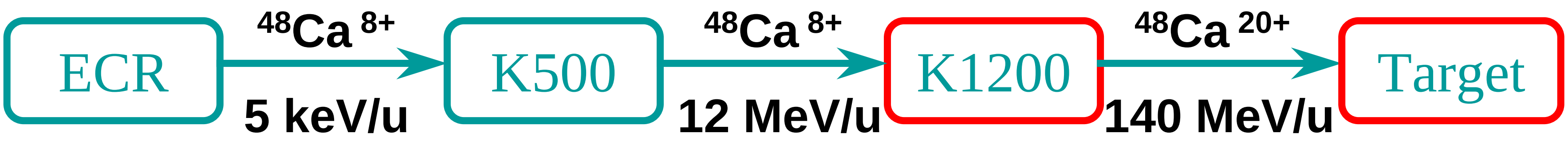
Rare isotope production by fast-beam fragmentation and in-flight separation

Forefront US user facility for rare isotope research and education in nuclear science, astro-nuclear physics and accelerator physics



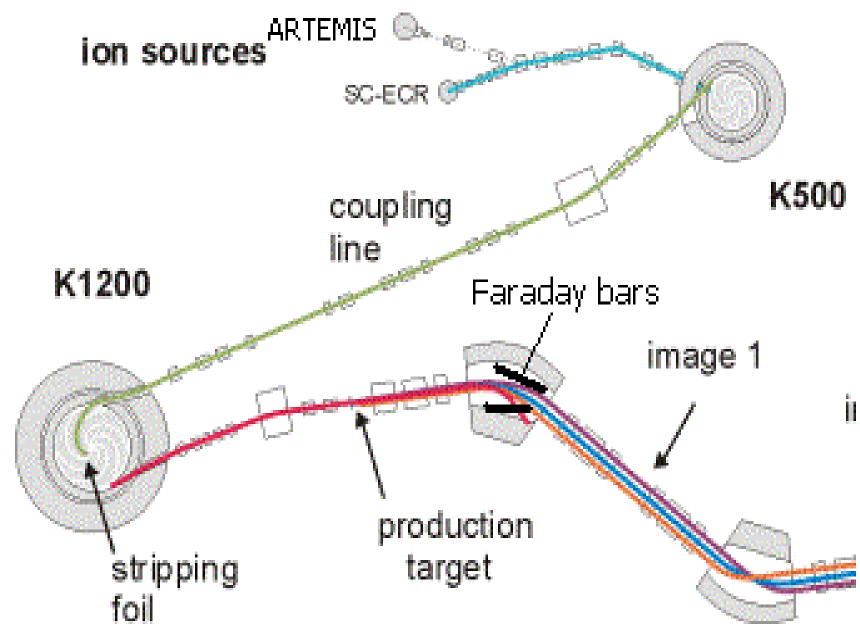
→ Fast, stopped, and re-accelerated beams

Coupled Cyclotron Facility - CCF

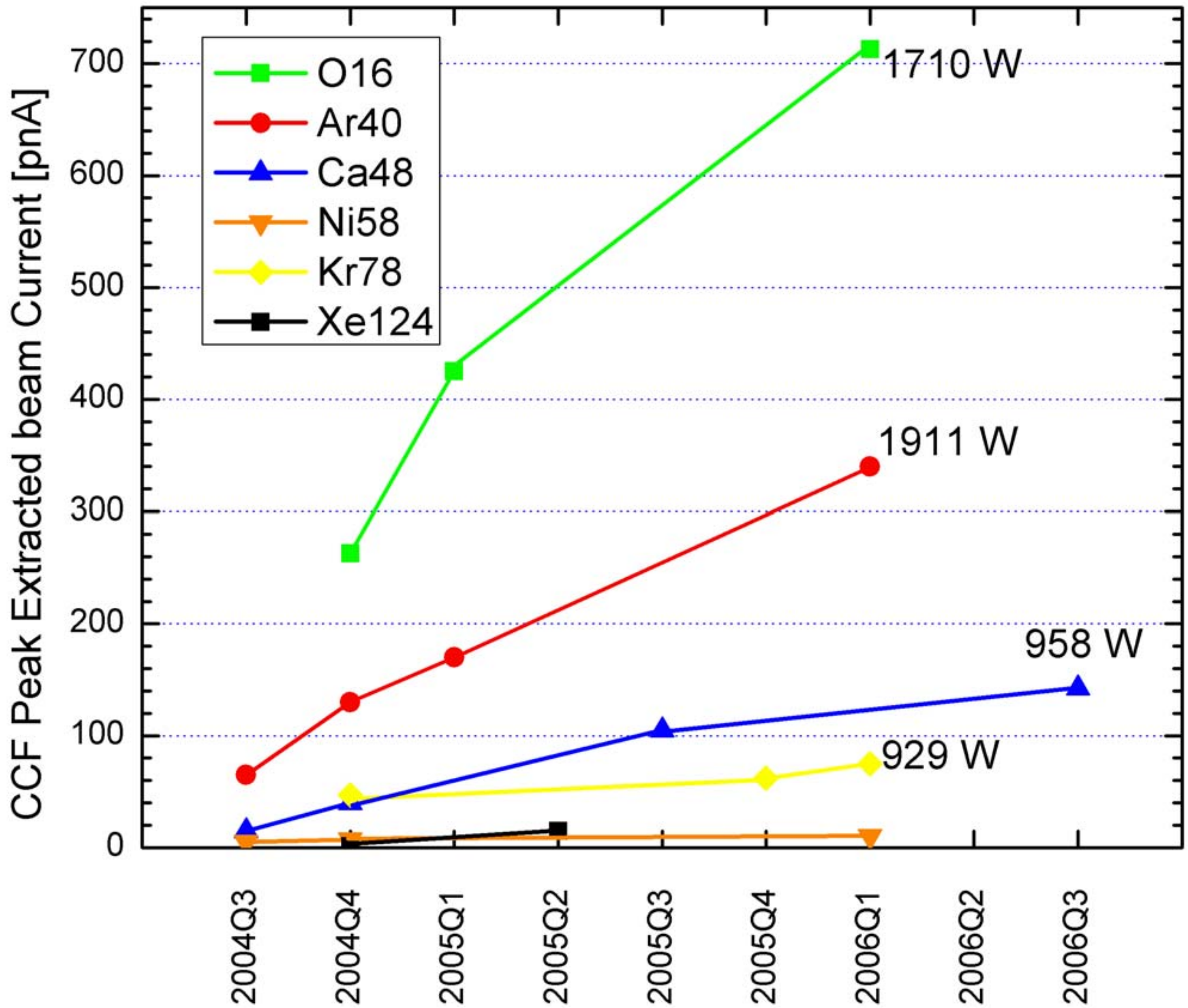


K 500 Injection

Ion	Charge State	Current (euA)
^{18}O	3+	35
^{40}Ar	7+	40
^{58}Ni	11+	8
^{76}Ge	12+	5
^{78}Kr	14+	15
^{48}Ca	8+	10
^{136}Xe	21+	11



Evolution of CCF Beam Intensities



NSCL Goal :Improve Primary Beam Power from CCF

- Improve ion beam intensity from Ion sources
- Improve beam matching into K500

- Minimize beam losses on deflectors
- Improve stripper foil lifetime

R&D effort:

- SuSI (3rd Generation Ion sources)
- Artemis-B
- Beam collimation
- Electrostatic focusing below ECR
- Beam chopper

SUSI Design and Construction

SuSI – Superconducting Source for Ions

- 3^{rd} Generation ion source with High B mode
  B_{inj}= 2.6 T, B_{ext}=1.5 T axial field
  B_r =1.5 T radial field

- Fully Superconducting Coils

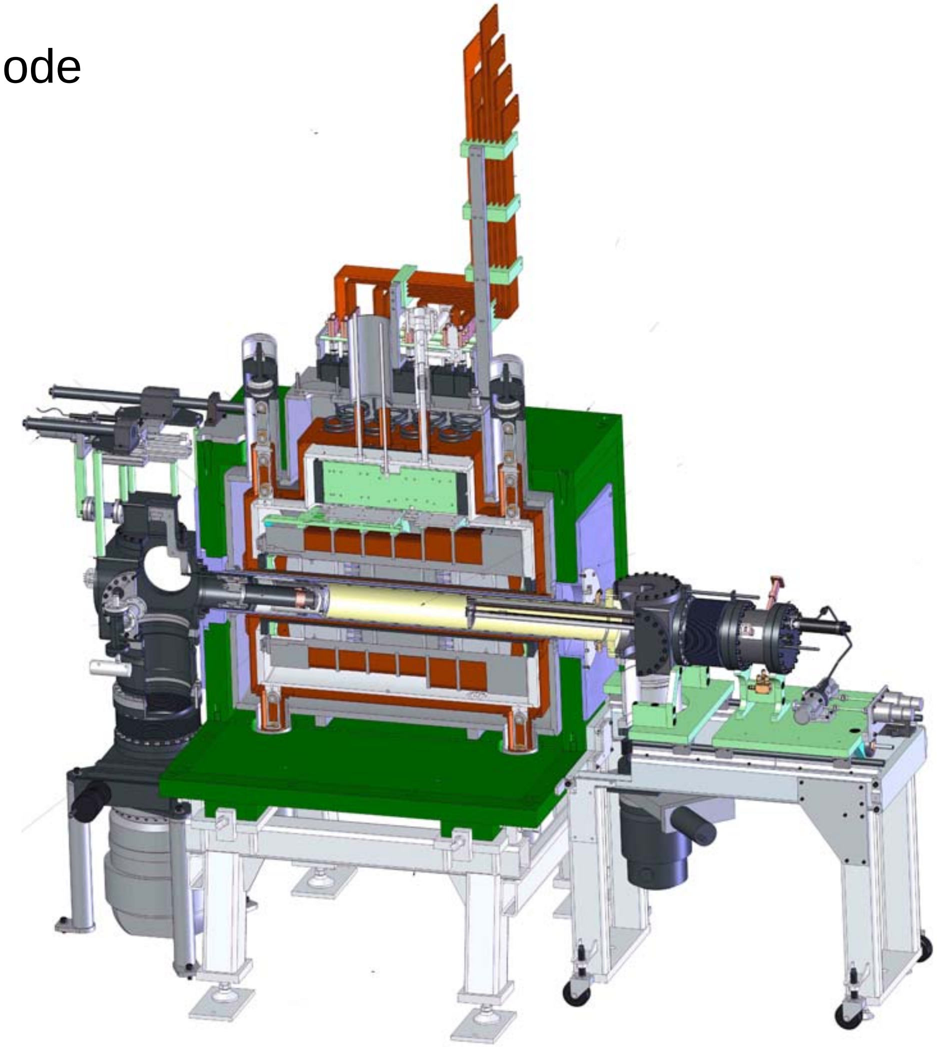
- Operating frequency:
18GHz (2kW) + 14.5 GHz (2kW)

- Plasma chamber diameter:
  100.8 mm (aluminum)

- Extraction voltage : up to 27kV (Cyclotron)

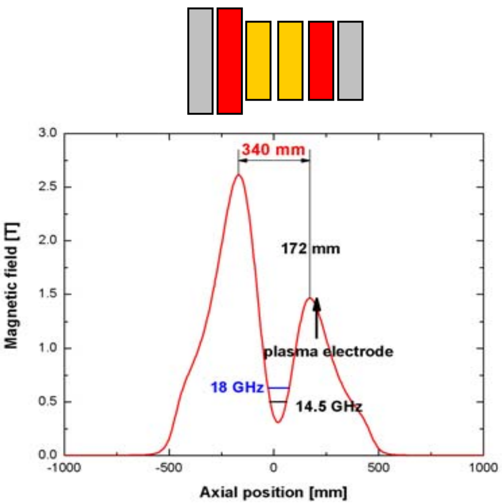
- Bias Disk

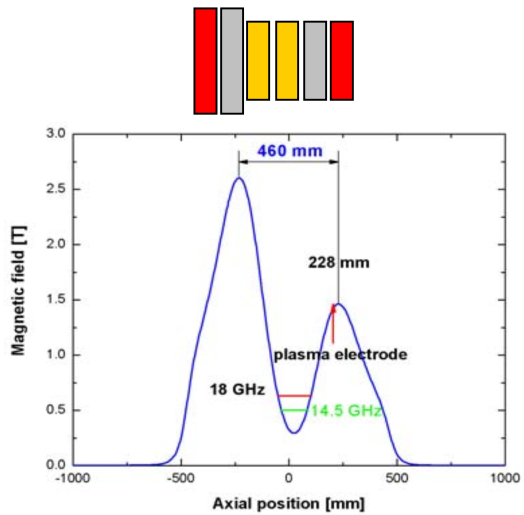
- 500l/s injection + 2000 l/s TP

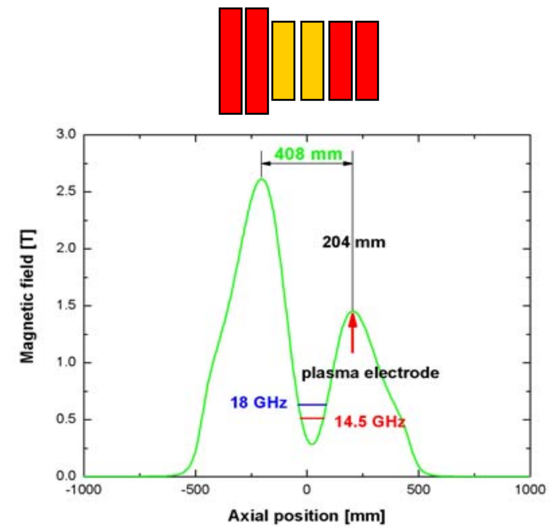


SuSI – Specific features

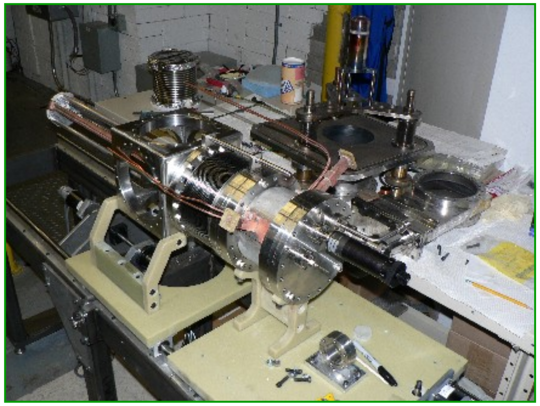
• "Flexible field"







- the relative distance between the resonant zone and plasma electrode can be varied
- the distance between the two magnetic maxima can be varied
- the "depth" of the magnetic minimum can be varied
- the position of the magnetic profile can be shifted

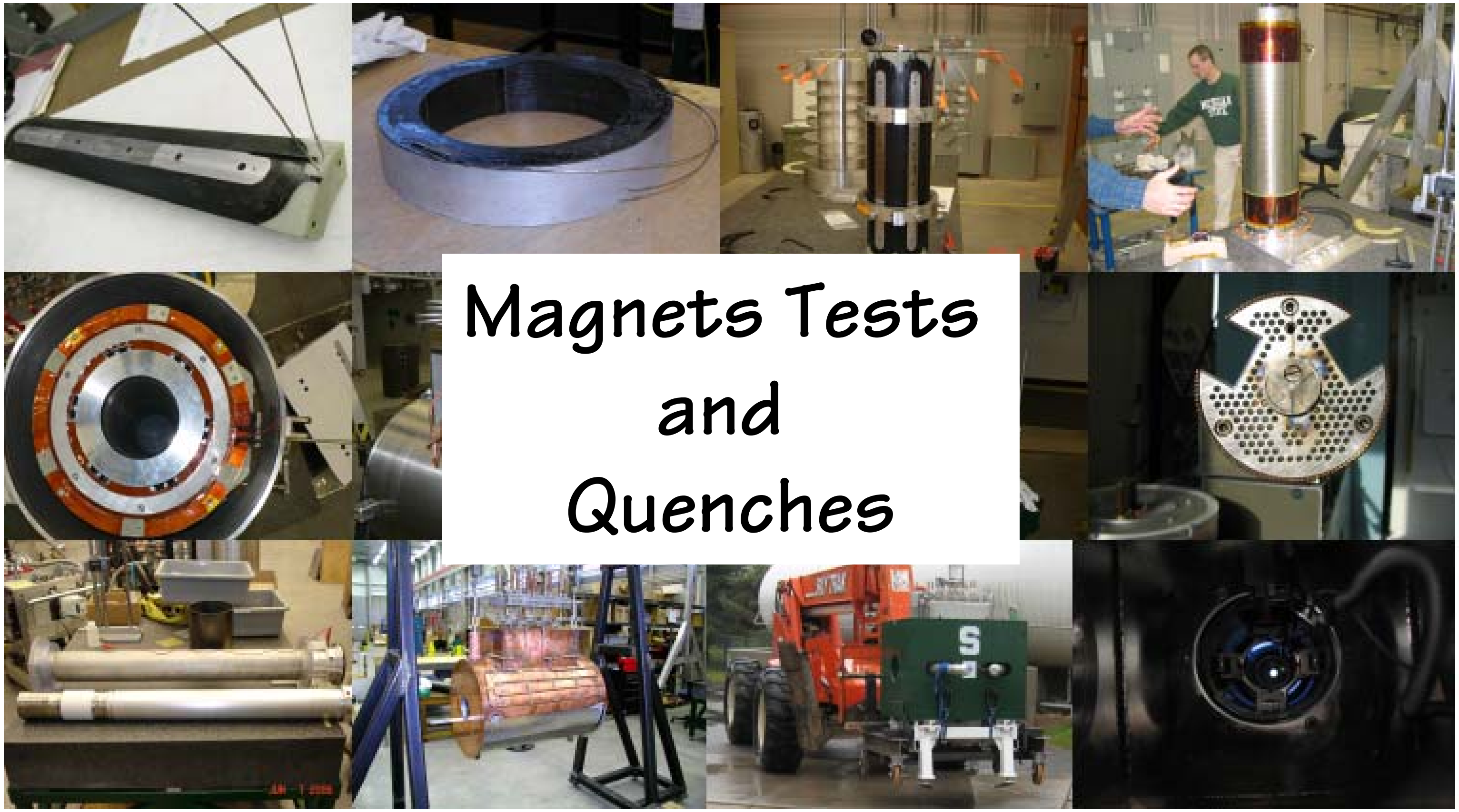


• Injection Assembly (Baffle) can be moved (i.e Plasma chamber volume can be changed)
• Biased disk position can be adjusted (relative to the baffle)

SuSI – Construction Timeline

Coils winding completed	September 2005
Tested and trained Individuals coils	November 2005
Coil assembly (Hexapole + Solenoids)	early 2006
Coil assembly testing (Helium Dewar)	February 2006
Cryostat completed	September 2006
Yoke is installed	December 2006
Source is complete and moved to development Lab	January 2007
First Plasma Ignited	March 2007
Quenches problems and commissioning	

Magnets Tests and Quenches



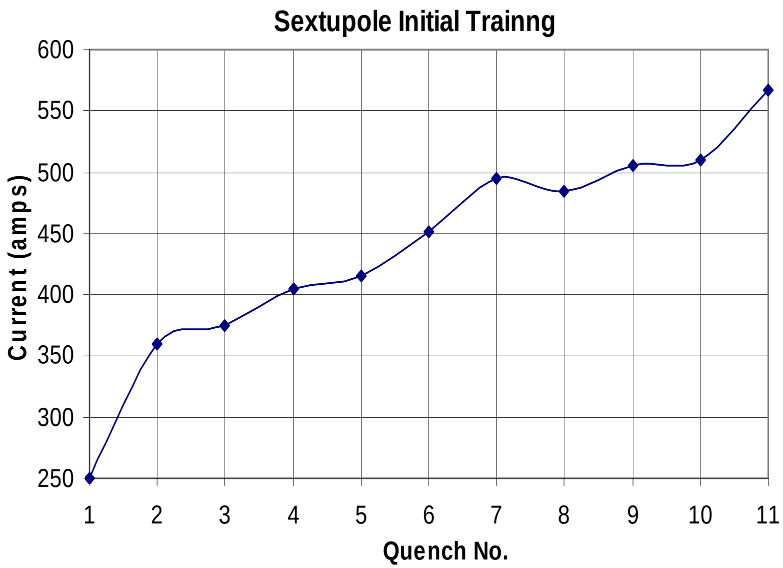
Single coil Testing

- Coils were taken to currents above what their maximum operating currents would be .
  - 2 small solenoids taken to 445 A, 1 large to 485 A, no quenches
  - Sextupoles trained to 720 A requiring 5-7 quenches, initial quench varied from 300A – 500A, all sextupole coils tested

Design values for 18GHz: 210A small(extraction) solenoids; 290A Large Solenoid(Injection); 370A (Hexapole)

Full Magnet Assembly Testing…

- 1st dewar test had sextupole on 1 600A power supply and 2 outer solenoids in series on another a 400 A power supply.
  - –Sextupole assembly trained from 250A to 567 A with 10 quenches. Then taken to 550 A and back to 0 without quench.
  - –Solenoids taken to 400 A after 1 quench at 365 A. Bruker supply blew a capacitor shortly thereafter. It was replaced with another Alpha.
  - – Sextupole again taken to 550 A alone without quench.



…….and it Quenched

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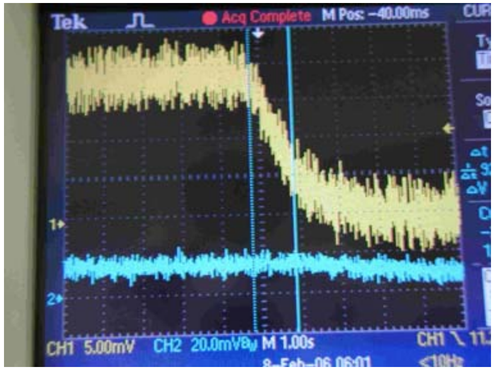
Trying to ramp up the field of the Solenoid and of the sextupole in <u>sequence</u> always resulted in a quench (While ramping)

- Solenoids energized first:
  - Solenoids at 400 A ↘ Sextupole quenches around 100 A.
  - Solenoids at 120 A ↘ Sextupole quenches around 260 A
  - Solenoids below 100A ↗ Sextupole goes to 500 A (no quench)

- Sextupole energized first, each done multiple times.
  - Sextupole at 400 A ↘ Quenches when solenoids reached about 150 A
  - Sextupole at 350 A ↘ Quenches when solenoids reached about 180 A



Shunt voltages monitored on scope to see where quench initiated. Sextupole shown to be quenching first even though the solenoids are being ramped.

Quenches Observations and training

- Ramp rates did not influence behavior

- Training sextupole alone higher with quenches at 600, 621, and 653 A did not improve behavior.

  Improve lead restraint in dewar did not improve behavior

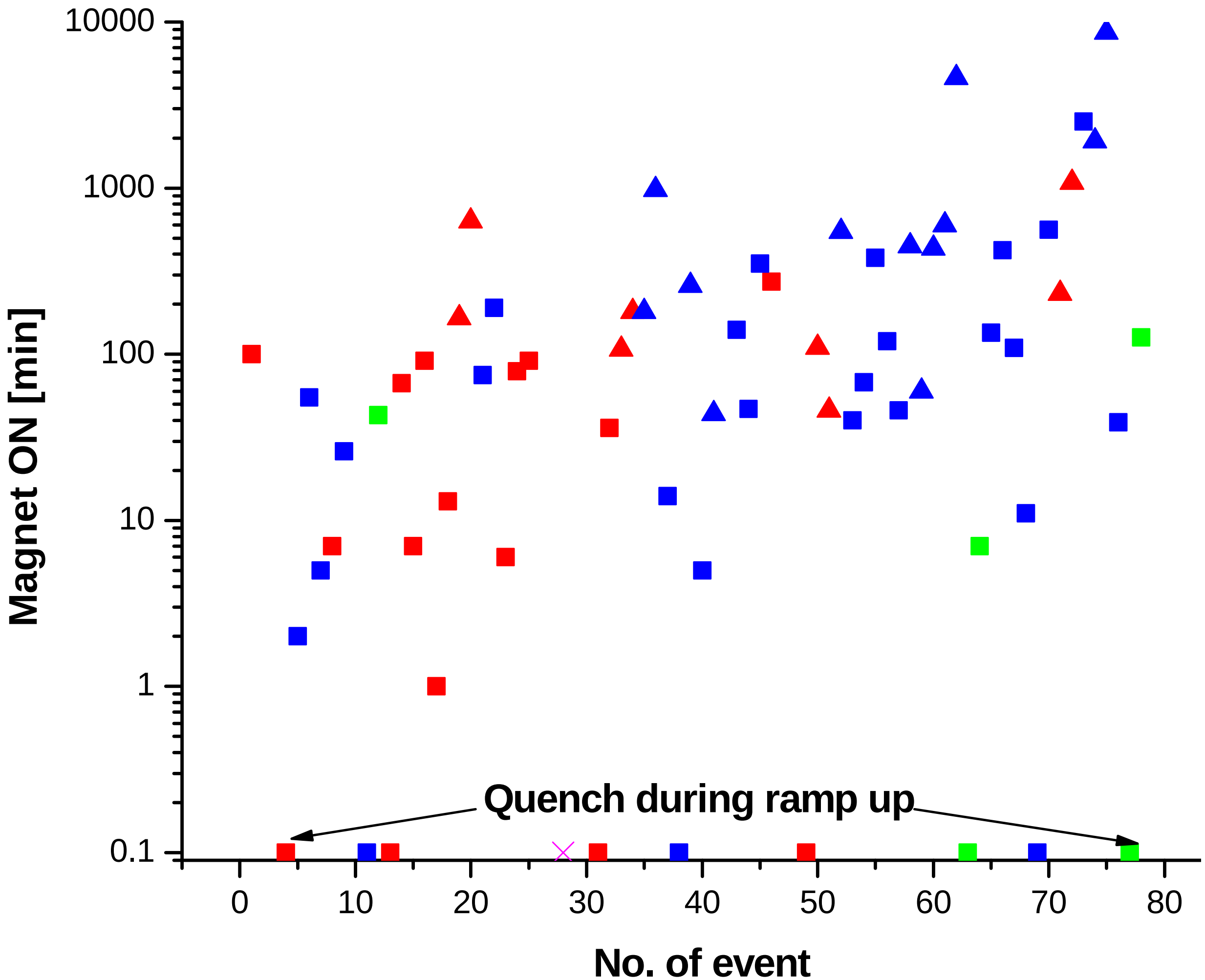
- Solenoids and sextupole ***energized evenly together*** gave best results.
  - Reached 240 A each on first try.
  - Trained to 390 A each in 3 quenches.
  - Ramped to 390 A each, then increased sextupole only to quench at 409 A.

Finally:

- It was possible to ramp solenoids to 390A and then take the sextupole up to 585 A

… it's not over for the Quenches…

The coil system was found to quench after having reached the desired field values



Coils system now within ion source cryostat

Red – 14.5 GHz fields
Blue – 18 GHz fields
Green – 24 GHz fields

- Quench (all systems)
Δ - ramped down (all systems)

Quench Updates

•The last Quench after the source had reach the field values was observed on November 2nd 2007! (Field had been up for 8mn)

• The source was run for more than 250 Hours since August without any Quenches

•4 out 6 Solenoids were used over a wide range of currents (Mid1 and 2, Extraction1 and 2. Also the Hexapole can be adjusted over a wide range (~100A) without any problem.

• A Magnetic field equivalent to run a 24GHz microwave was run for 24h and then ramp down without quench!

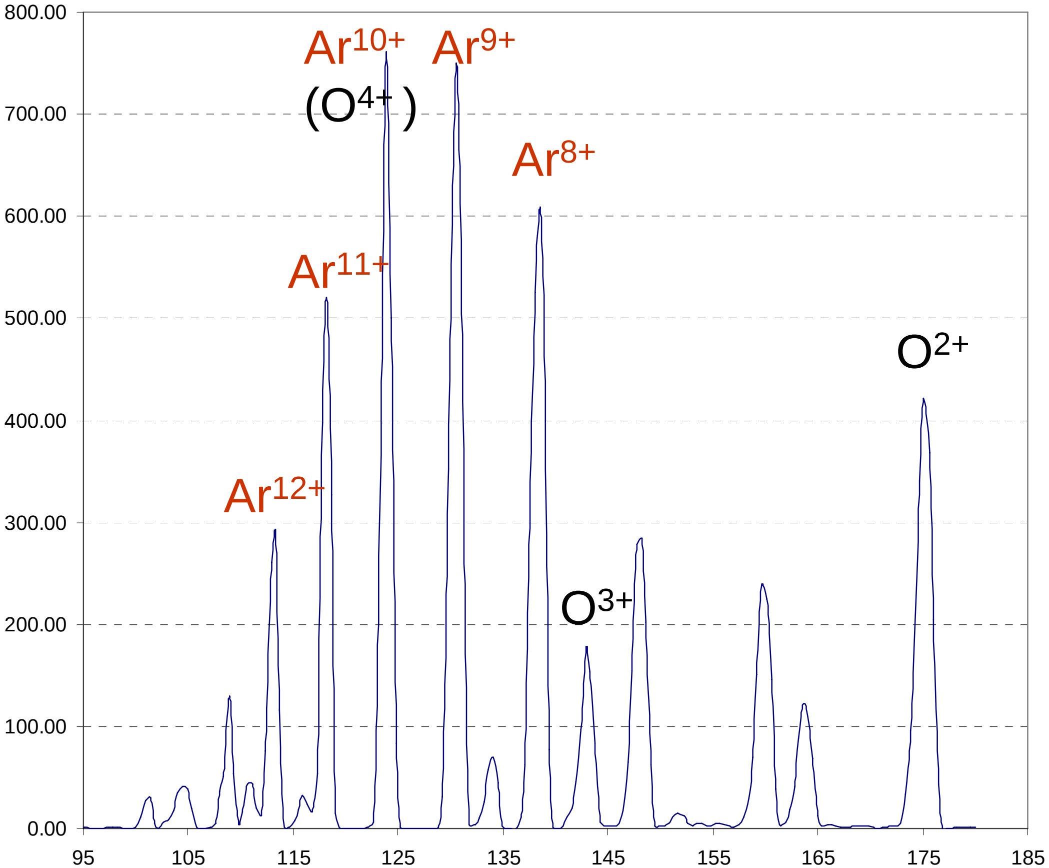
Commissioning Results with SUSI

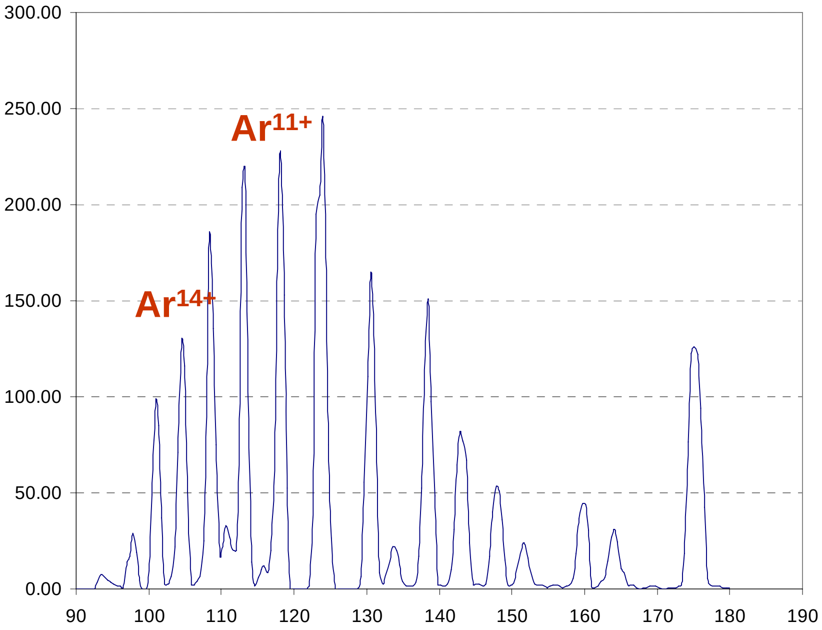
^{40}Ar: Ar^{11+} and Ar^{14+}

^{129}Xe: Xe^{20+} and Xe^{27+}

^{209}Bi: Bi^{28+} and Bi^{33+}

Commissioning Results from SUSI : ^{40}Ar



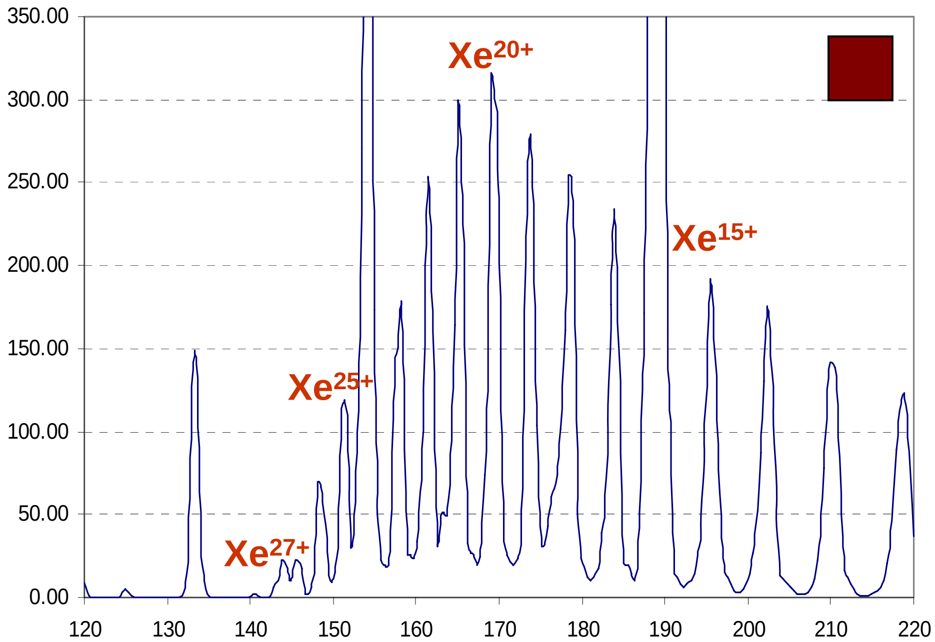


Ar^{14+} :145euA

Ar^{11+} :550euA

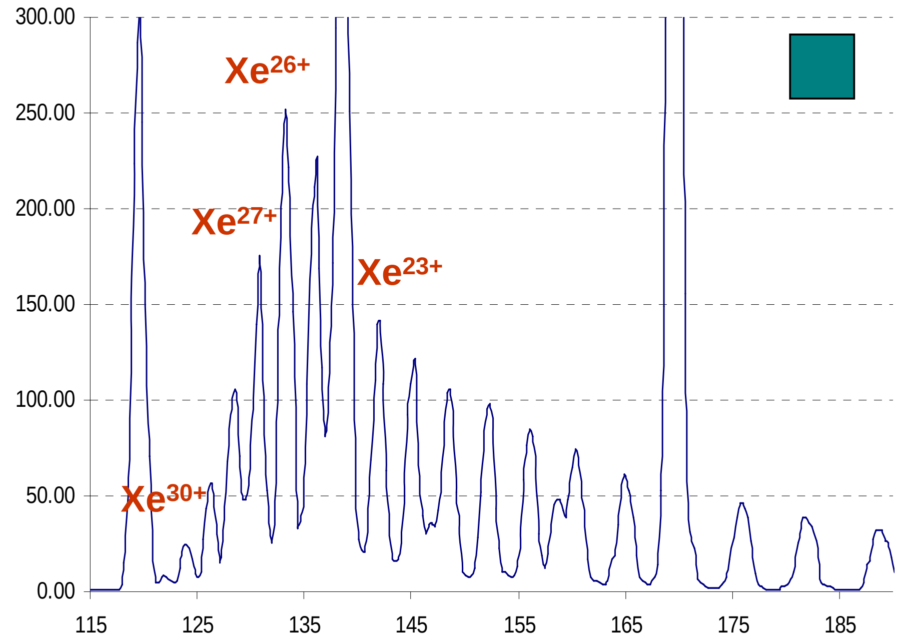
Pw= 1.5kW (18GHz)
Pw= 300W (14.5GHz)

Commissioning Results from SUSI : ^{129}Xe



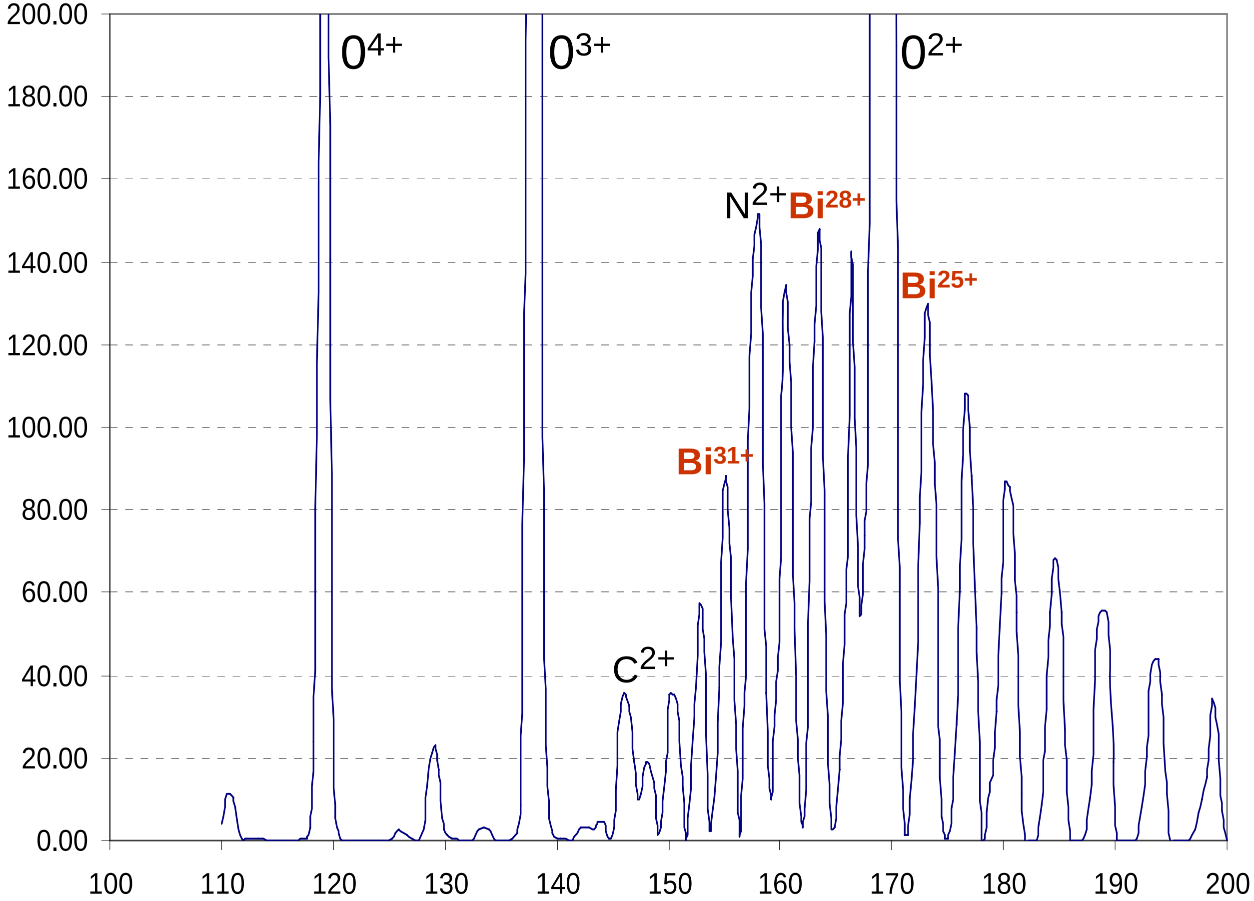
^{129}Xe : optimized on Xe^{20+} :335euA
1.7kW 18GHz
300W 14.5GHz

^{129}Xe : optimized on Xe^{27+} :180euA
1.8kW 18GHz
500W 14.5GHz



Commissioning Results from SUSI : ^{209}Bi

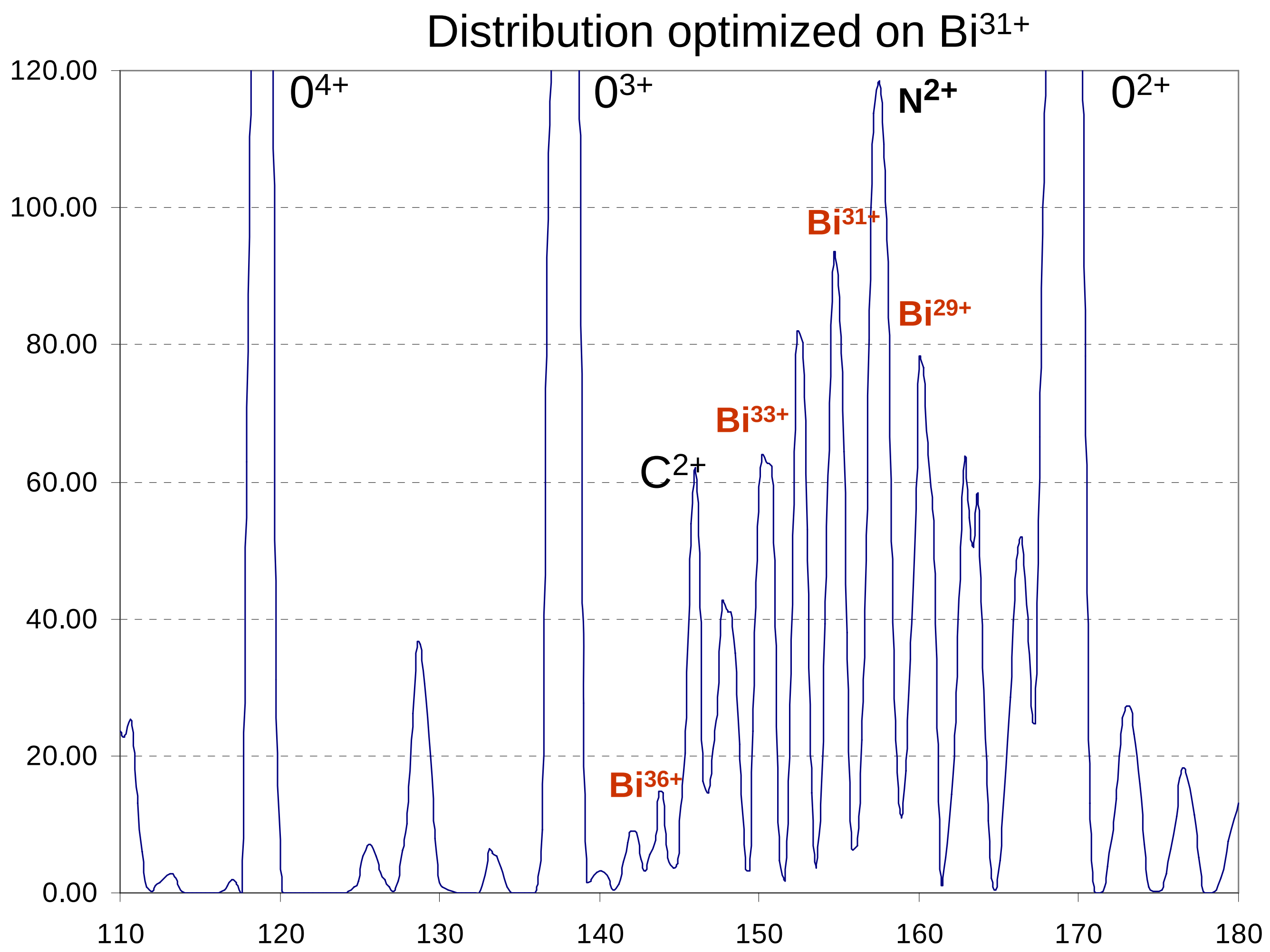
Distribution optimized on Bi^{28+} ~150euA



1.4kW (18GHz) + 300W (14.5GHz)

Commissioning Results from SUSI : ^{209}Bi

1.7kW (18GHz) + 300W (14.5GHz)



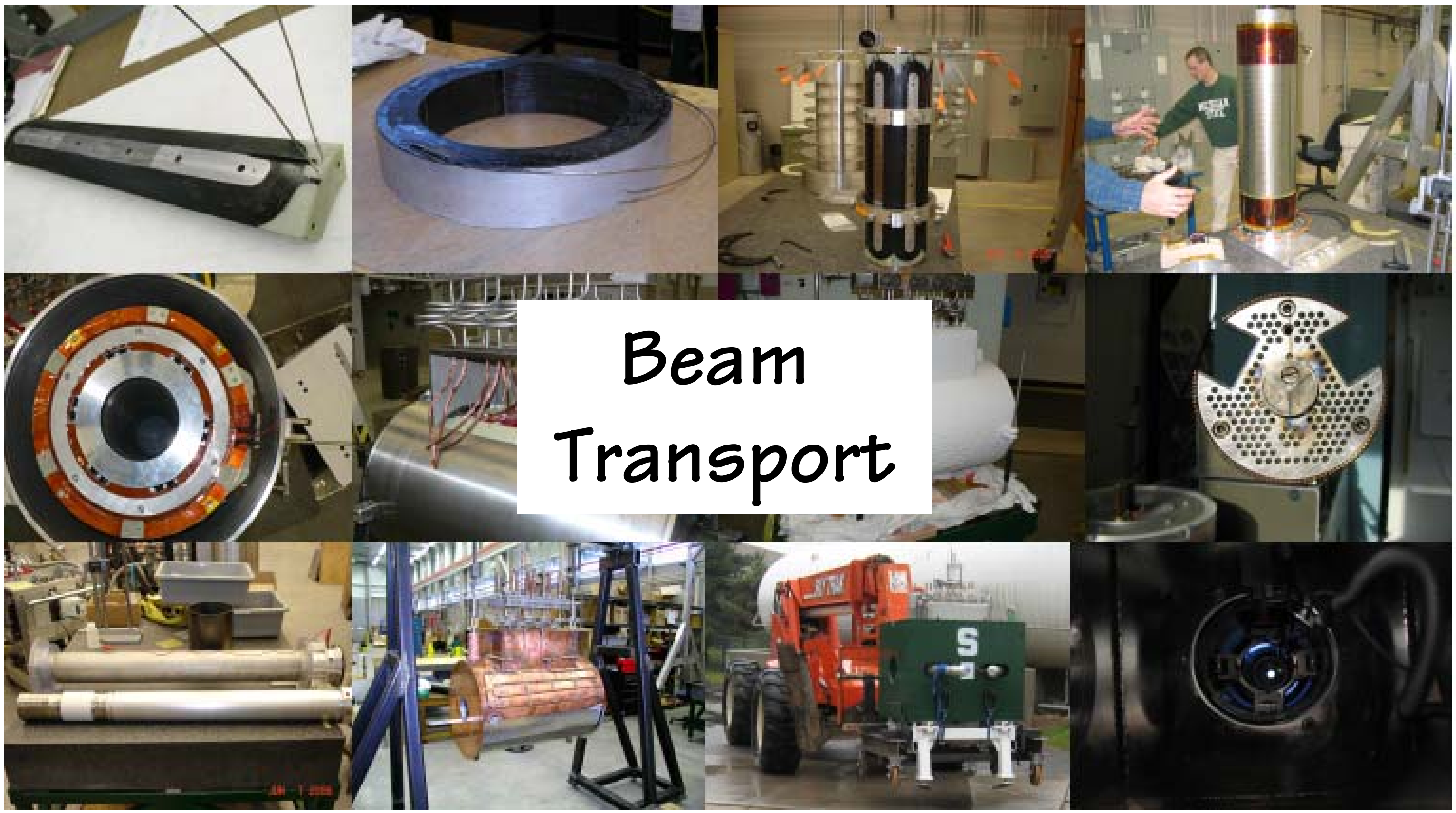
About 20euA Bi^{36+} and 65euA of Bi^{33+}

Plastic insulation issue

While using the source at higher power (1kW) , the HV insulation acrylic tube failed

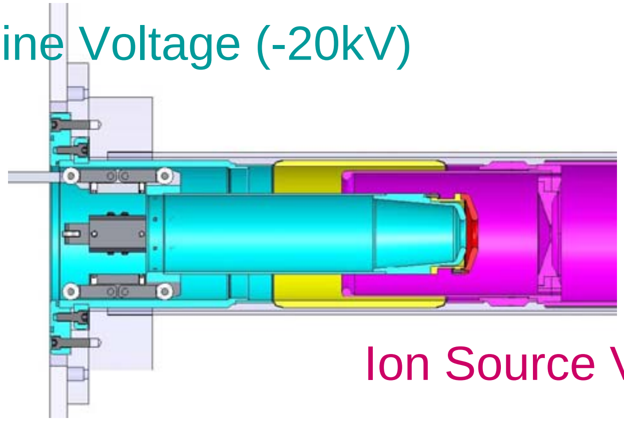
Caused by X-rays triggered by too high sextupole setting?

Beam Transport

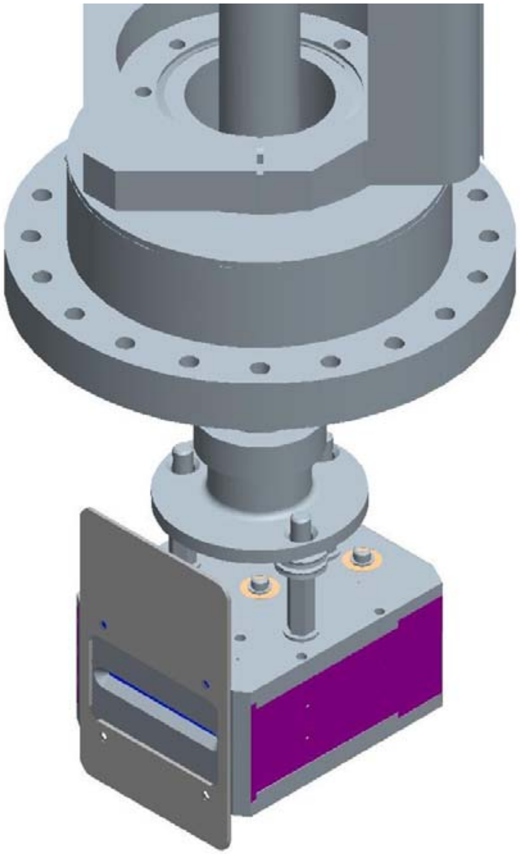


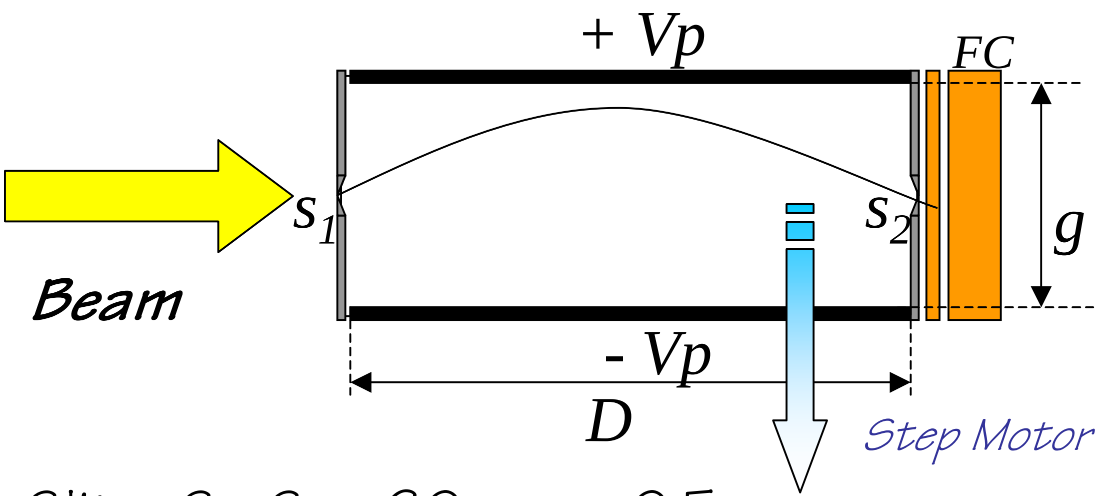
SUSI Beam Transport

- Accel-Decel system
- Adjustable puller position
- Beamline following the ion source can be biased up to –20kV



NSCL Allison Emittance scanner (2D)





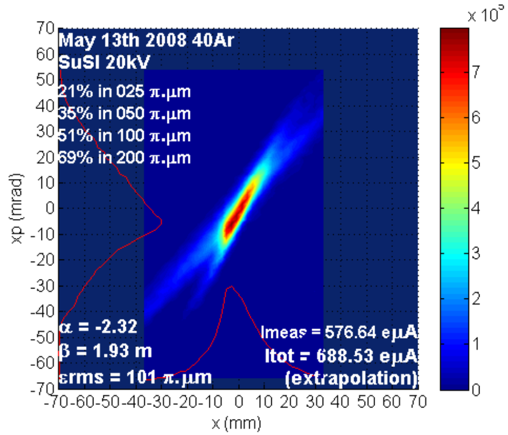
Slits: S_1=S_2= 60 mm x 0.5 mm
g=12mm ; D= 7.5 cm ;

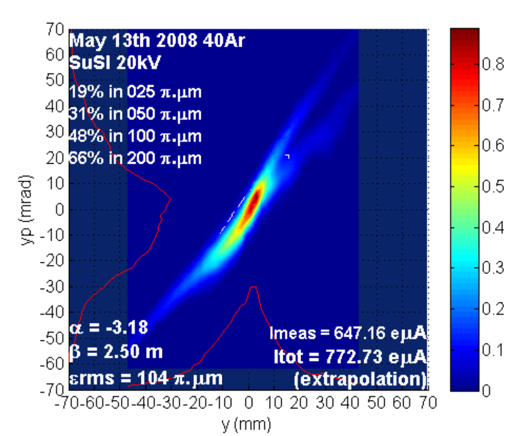
Δx_{int} = s= 0.5 mm
$\Delta x'_{int}$=+/- s/D= +/-6.7 mrad
x'_{Max}= 2g/D ≅ 300 mrad

Emittance measurement after ion source

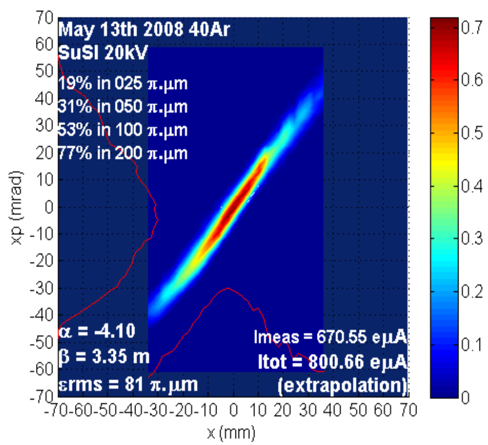
- Allison ES positioned right after extraction cube (X and Y)

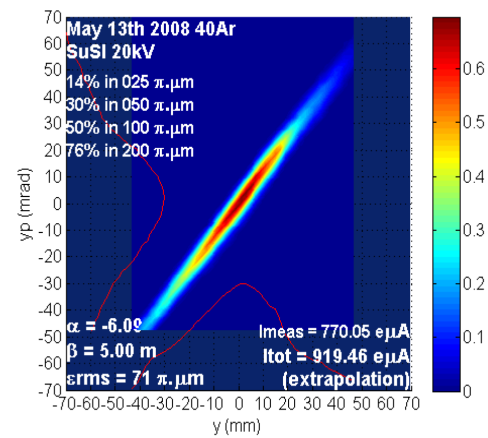
25mm Gap





55mm Gap





- Changing extraction field (Solenoid) or BD did not impact ES distribution

SUSI Bending Magnet Test

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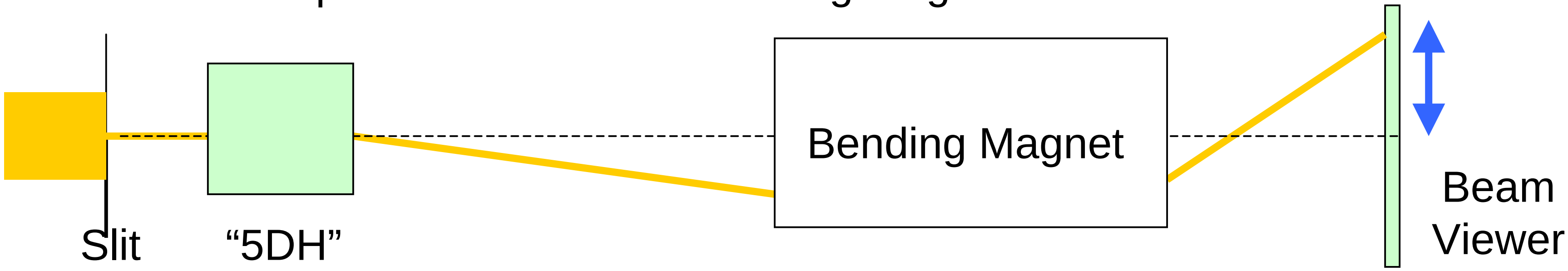
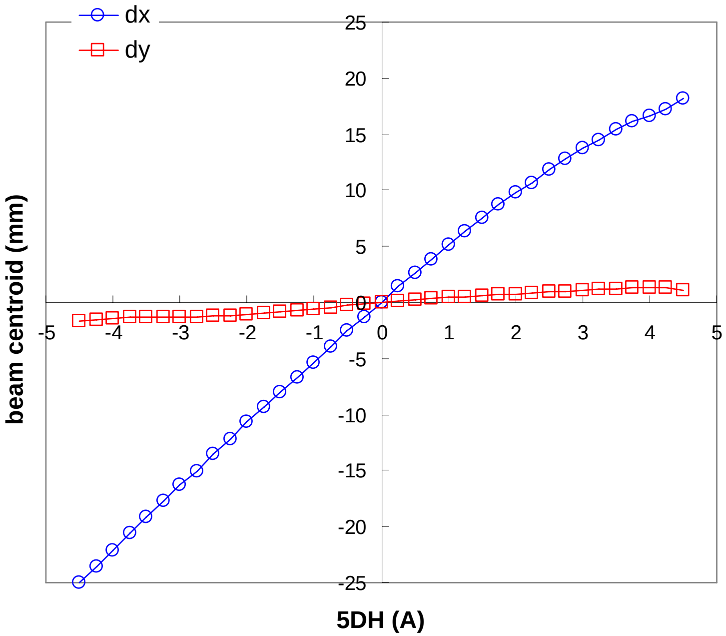
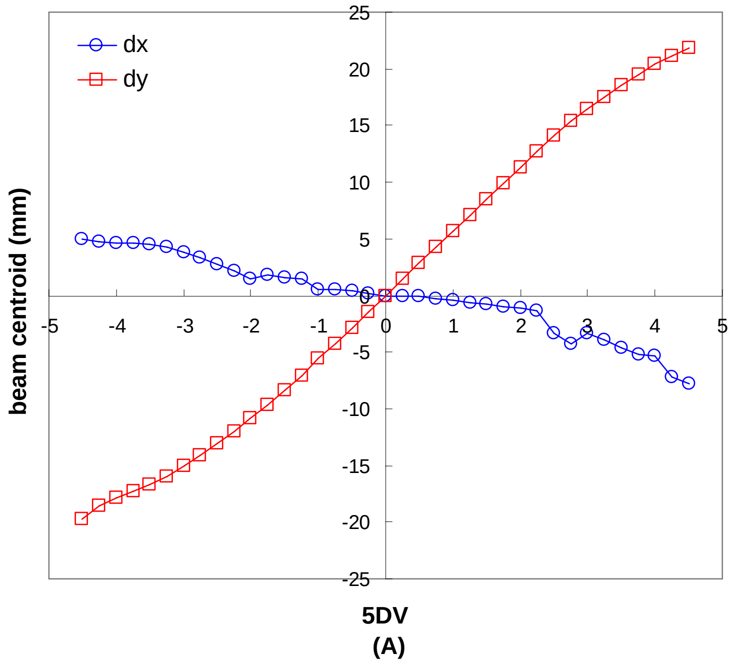
- Test with a "pencil beam" and a steering magnet



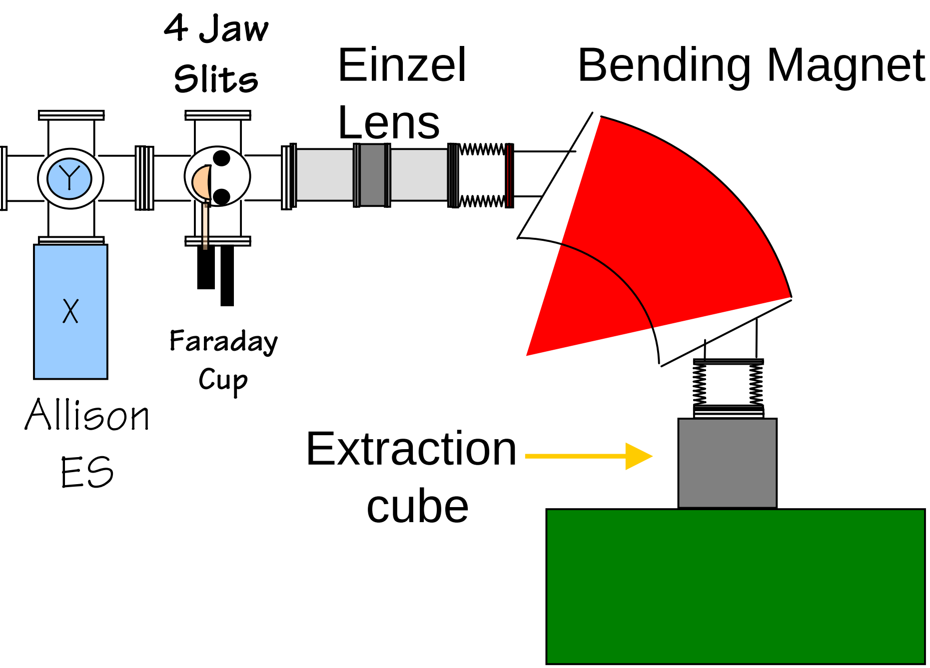


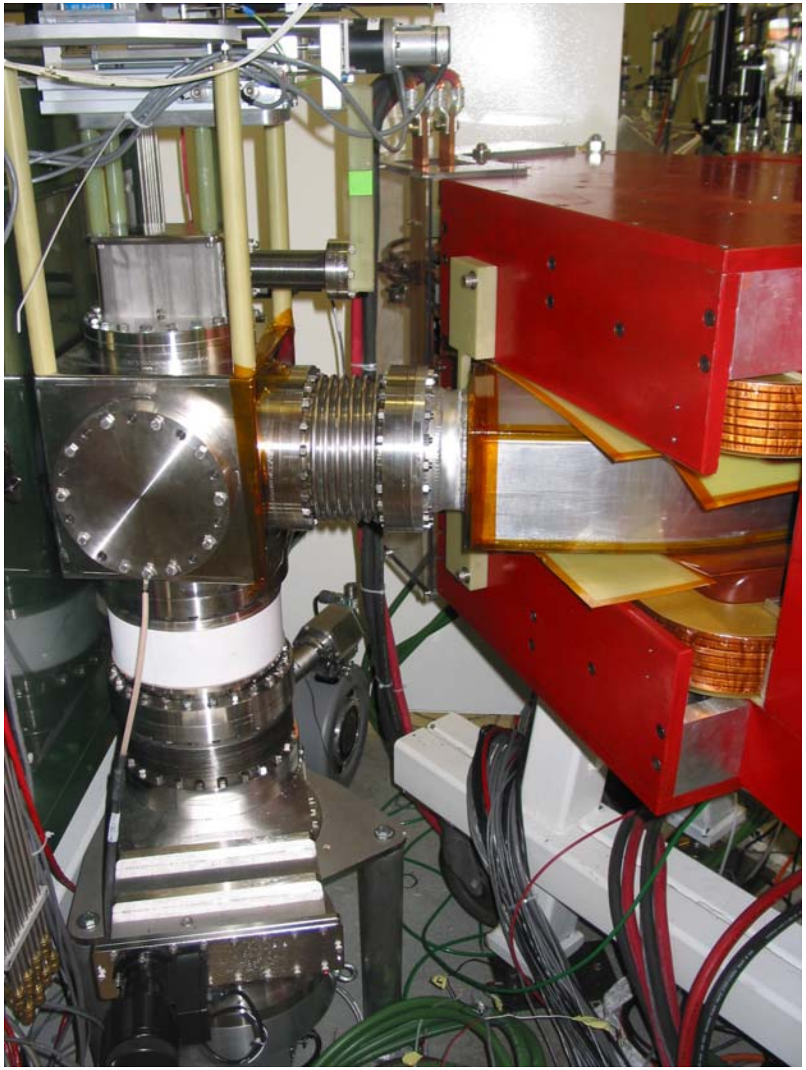


Beam transport without Focusing Element

1st case: Argon beam 1.5mA total extracted current. Source at 24kV

2nd case: Argon beam 4 mA total extracted current. Source at 24kV

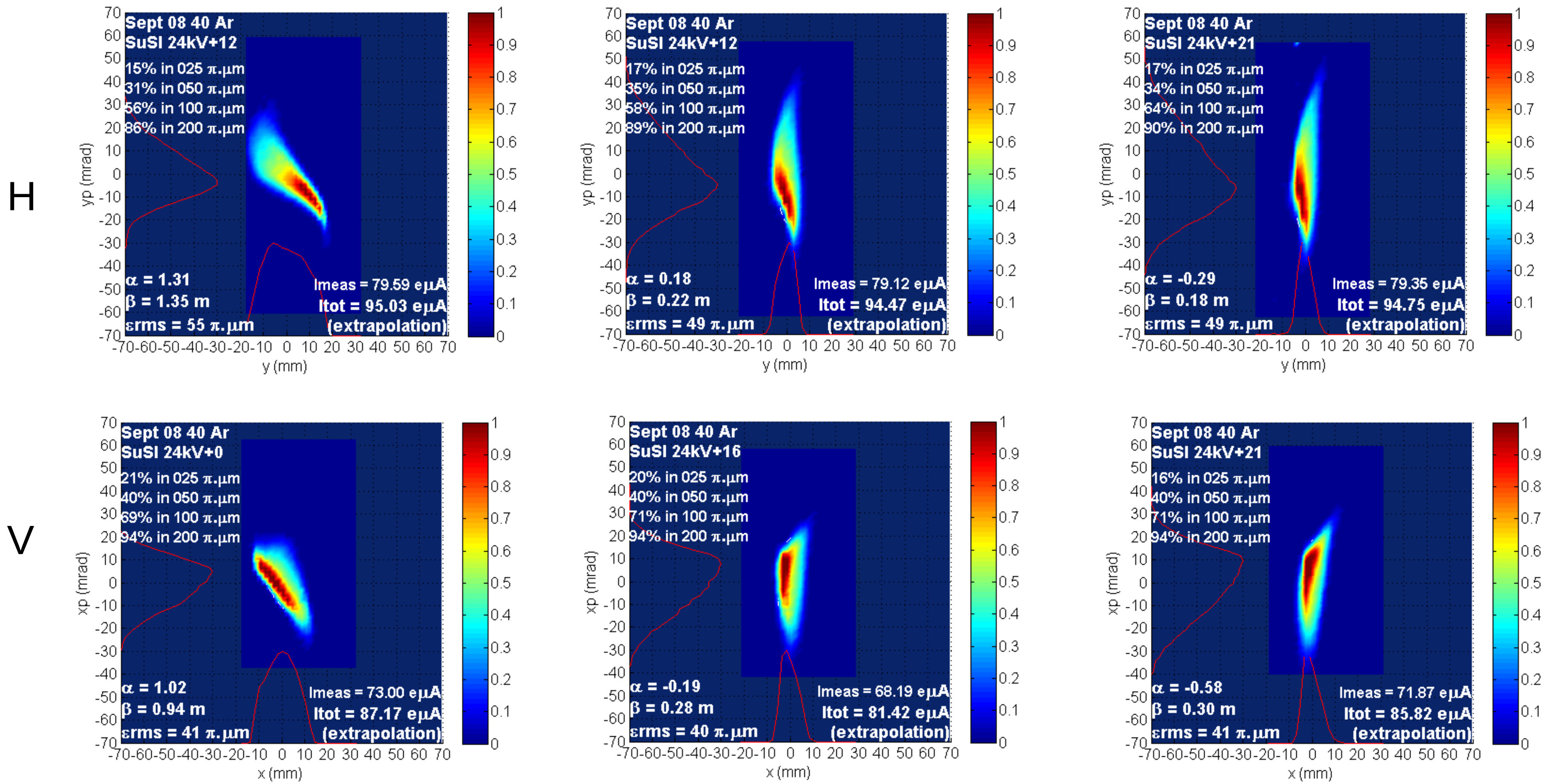




1st case: Argon beam 1.5mA total extracted current

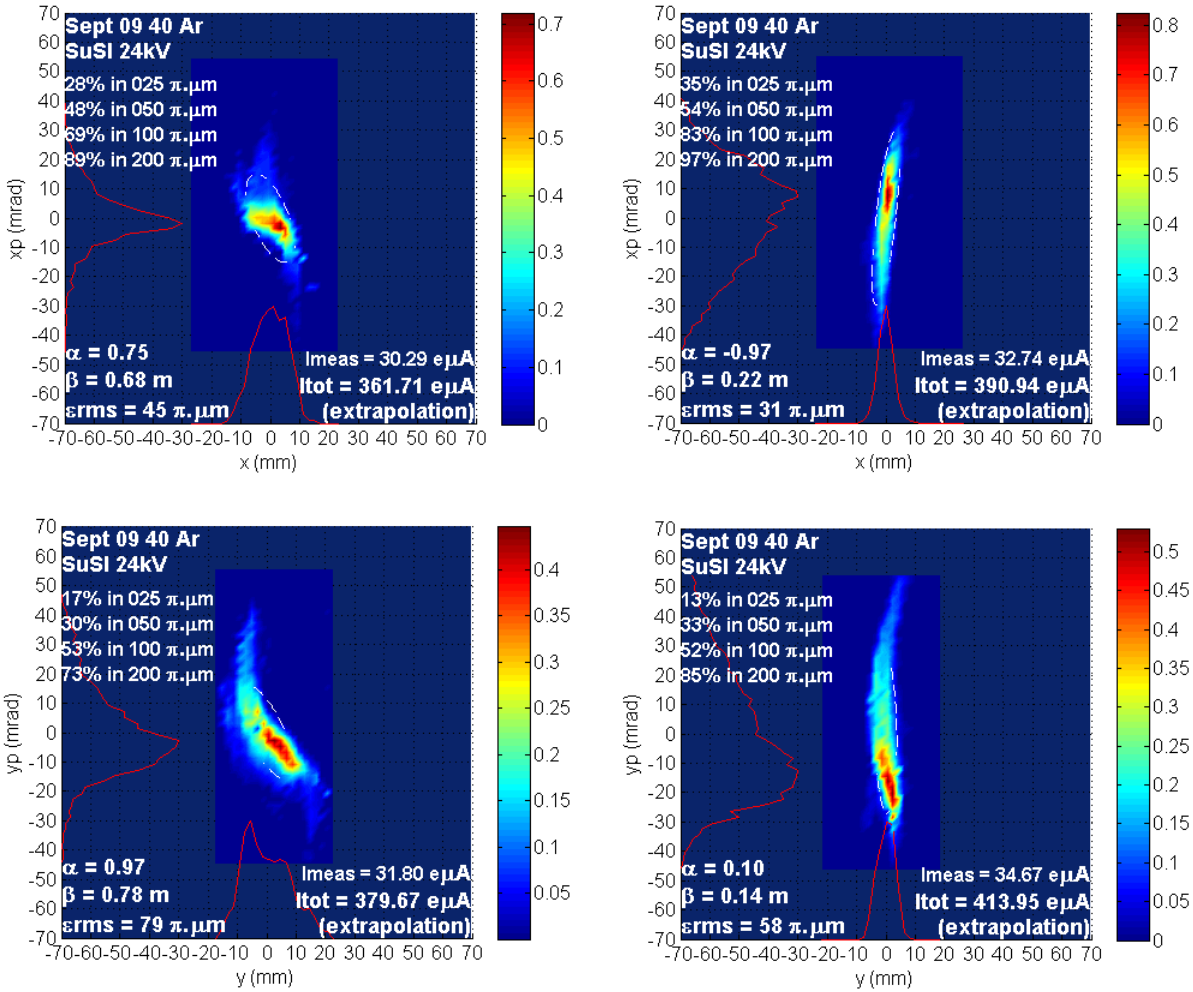
- Transmission about 85% without bias and reach about 95% with –20 kV on the beam line

Beamline at 0kV | Beamline at -11kV | Beamline at -21kV



2nd case: Argon beam 4 mA total extracted current.

Beamline at 0kV | Beamline at -21kV



- Measured transmission goes from 68 % at 24kV to 83 % at 45 kev/q energy
- Total extracted current went up 0.5 mA to reach 4.5 with the beam line biased
- Current in F-Cup went up from 400 euA to 500euA
- RMS emittance improved with the biased beam line

Conclusion I

- Good intensity have been demonstrated for Argon, Xenon and Bismuth
- Transmission with No focusing element/ biased beamline was measured to be 83 % with a 4mA beam.There seems to be some merit to bias the beam line
- More metallic beams will be produced soon: Calcium, Nickel and Uranium
- Systematic study of flexible field to improve extracted intensities and emittance
- Current limits to avoid quenches
- Potential upgrade by removing the 14GHz transmitter and replacing it with a 18GHz klystron to add more power (SECRAL)

Conclusion II

• SUSI will likely be moved to Operation and connected to the CCF during the coming FY

• Beam dynamics simulations to determine the best transport scheme including method to properly collimate the beam emittance

• A new Set of coils have been made and all material and parts to build a new coils assembly have been purchased. Pending decision to allocate resources to assemble this 2nd set.