The SECAR Recoil Separator

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INSTITUTE FOR STRUCTURE AND NUCLEAR ASTROPHYSICS

JINA-CEE

UNIVERSITY OF NOTRE DAME

Large Multi-institutional Scientific Collaboration Ensures Active Scientific Program

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- **Current SECAR scientific collaboration: 60 members**

Argonne NATIONAL LABORATORY

CMU CENTRAL MICHIGAN UNIVERSITY

1804 OHIO UNIVERSITY

UMASS LOWELL

Washington University in St. Louis

LSU LOUISIANA STATE UNIVERSITY

MICHIGAN STATE UNIVERSITY

UCONN UNIVERSITY OF CONNECTICUT

JINA-CEE

SOUTH DAKOTA M SCHOOL OF MINES & TECHNOLOGY

THE UNIVERSITY OF TENNESSEE KNOXVILLE

OAK RIDGE National Laboratory

UNIVERSITY OF NOTRE DAME

Pacific Northwest NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY EST. 1943

INDIANA UNIVERSITY

ATM

SCHOOL OF MINES COLORADO 1874

McMaster University

NC STATE UNIVERSITY

Lawrence Livermore National Laboratory

Status

- SECAR is coupled to ReA3 to study p or α radiative capture reactions induced by unstable beam
- Gas Jet target JENSA fully commissioned and used in standalone mode
- Magnets and associated equipment are in place
- First commissioning in July 2018
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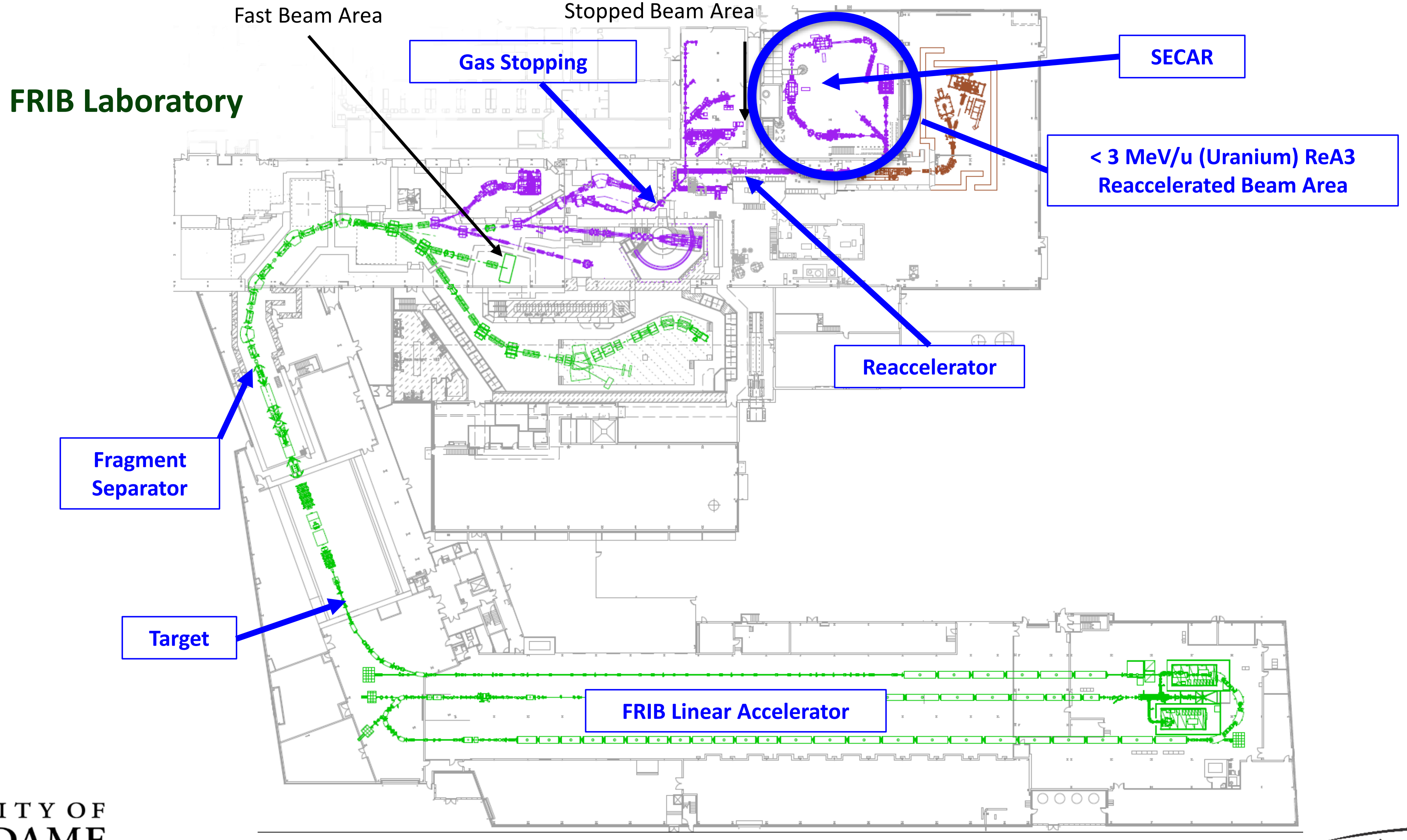
- Wien filter 2 acceptance at MSU start by March 2019

Determine composition of ejecta from

- Spectral lines
- Pre solar grains
- γ-rays?

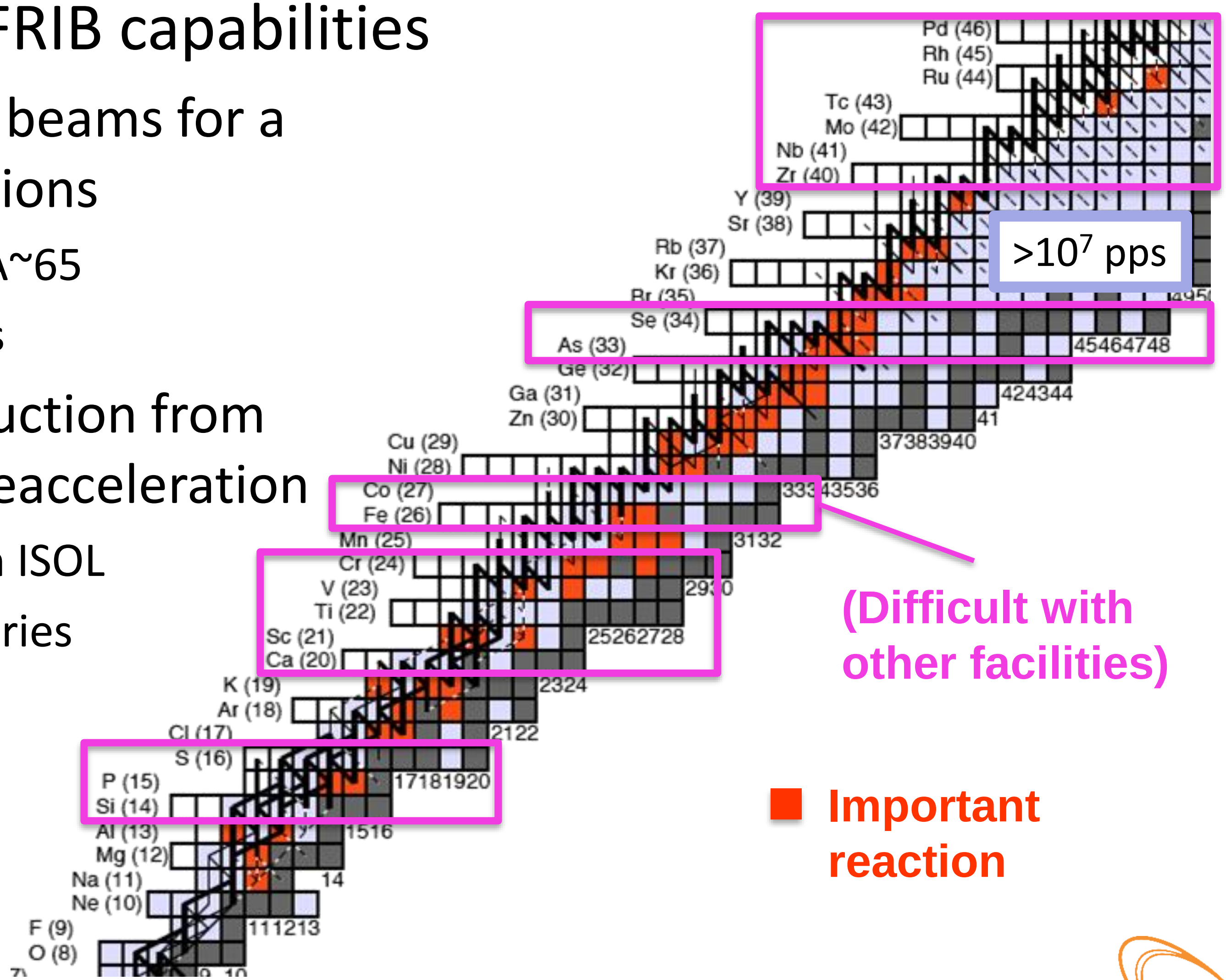
From H. Schatz

SECAR Fully Integrated into FRIB
Enables Direct Measurements of Astrophysical Rates

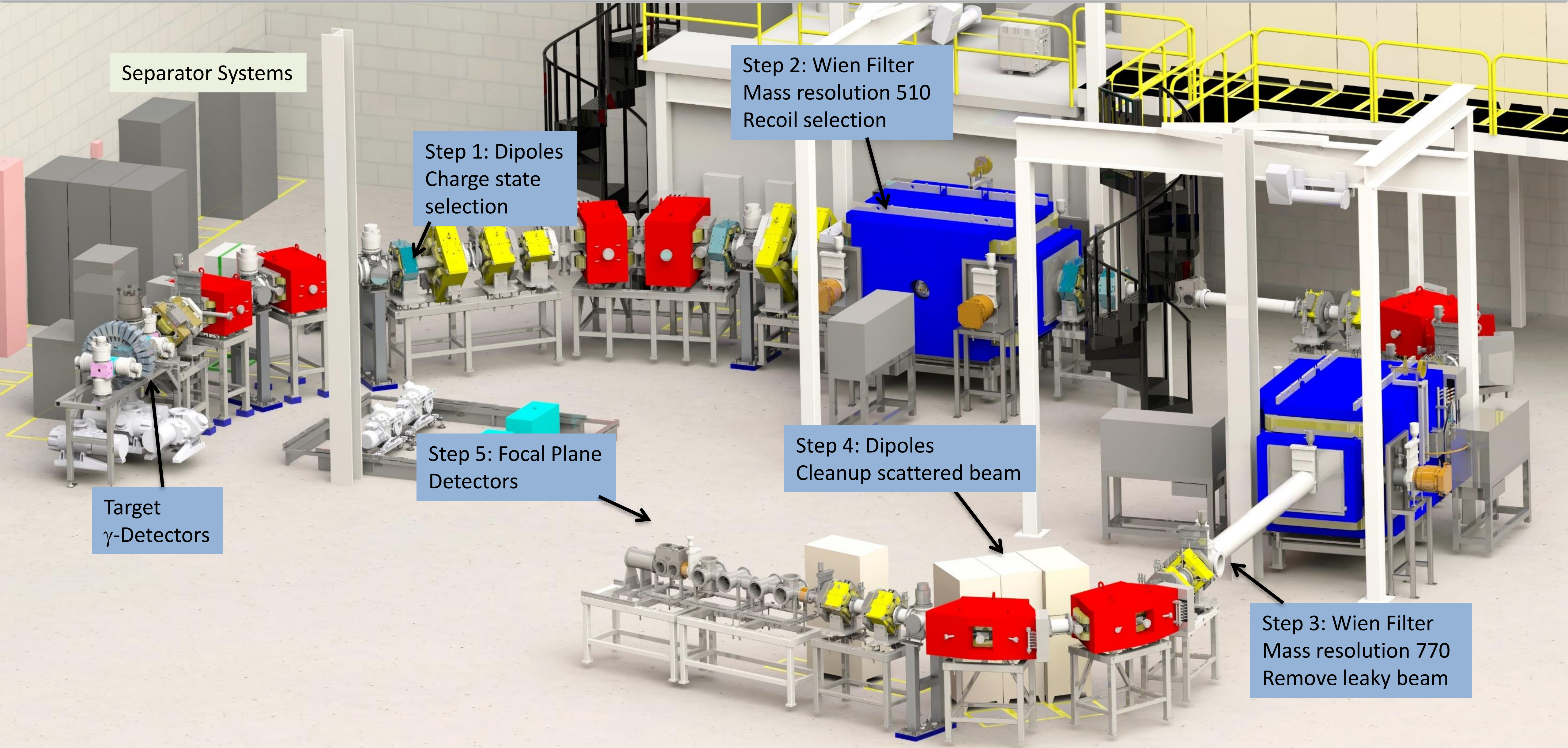


SECAR Takes
Advantage of Unique FRIB Capabilities

- SECAR is matched to unique FRIB capabilities
  - Intense low energy radioactive beams for a broad range of important reactions
    - Along the rp-process path up to A~65
    - Intensity range 10^7 pps – 10^{11} pps
  - Unique radioactive beam production from fragmentation, stopping, and reacceleration
    - Beams that are not available with ISOL
    - Flexibility to react to new discoveries

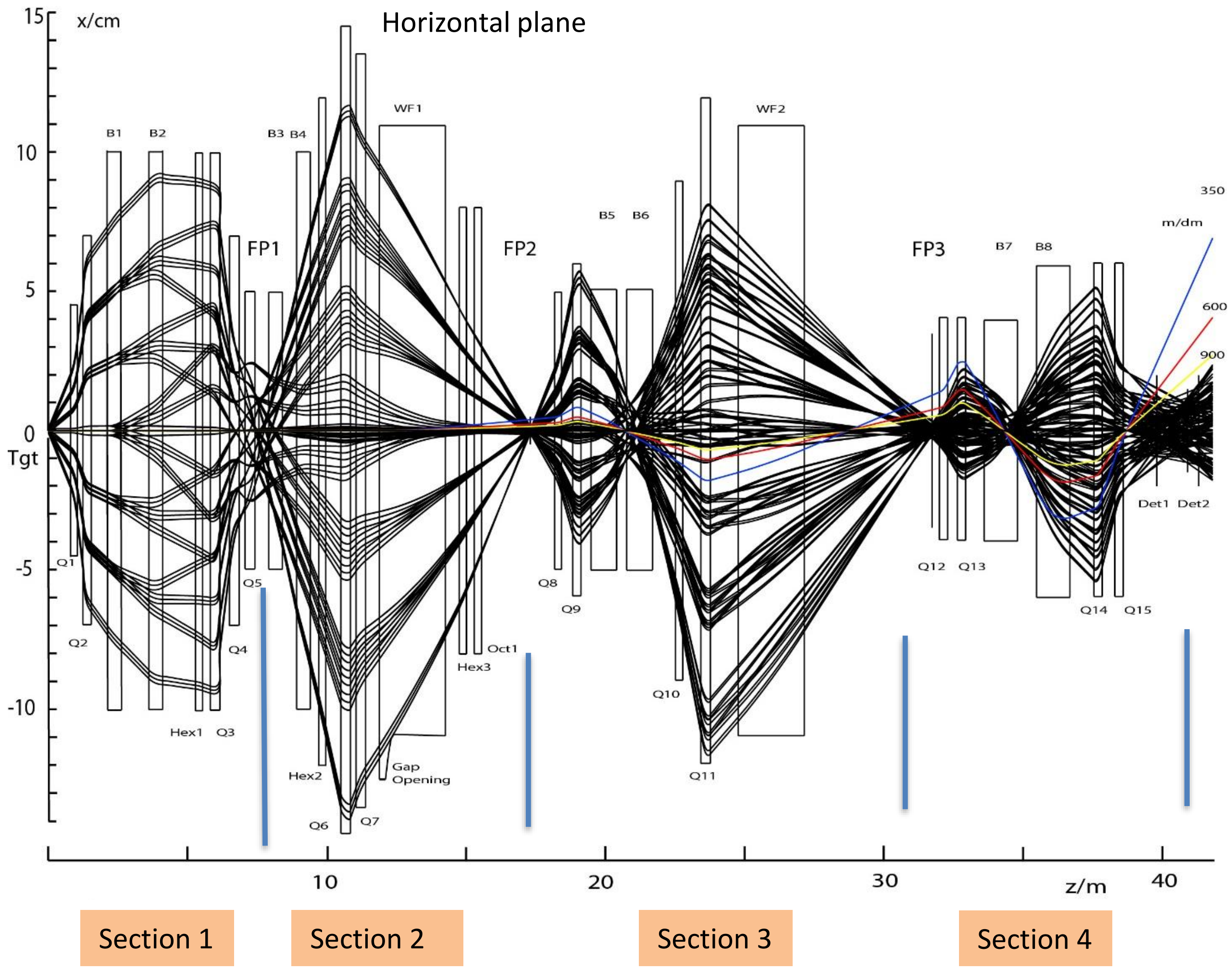


Technical Solution



Ion Optics Optimized

SECAR



- Section 1: Charge Selection
- Section 2: Mass separation
  - Mass Resolv. Power R_m = 747
  - **Mass Resolution R_{HO} = 510**
  - Achromatic focus
- Section 3: Second stage of mass separation
  - Mass Resolv. Power Rm =1283
  - **Mass Resolution = 770**
  - Disp. R16=0, focus R12 = 0
- Section 4: Momentum dispersion

Angular acceptance: +/-25mrad
Energy Acceptance: +/-3.1%

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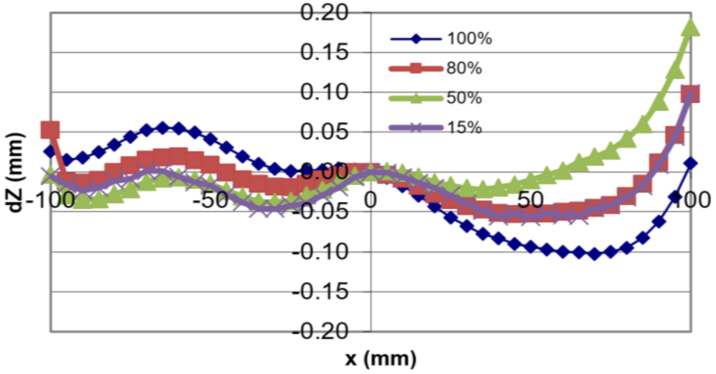
I S N A P

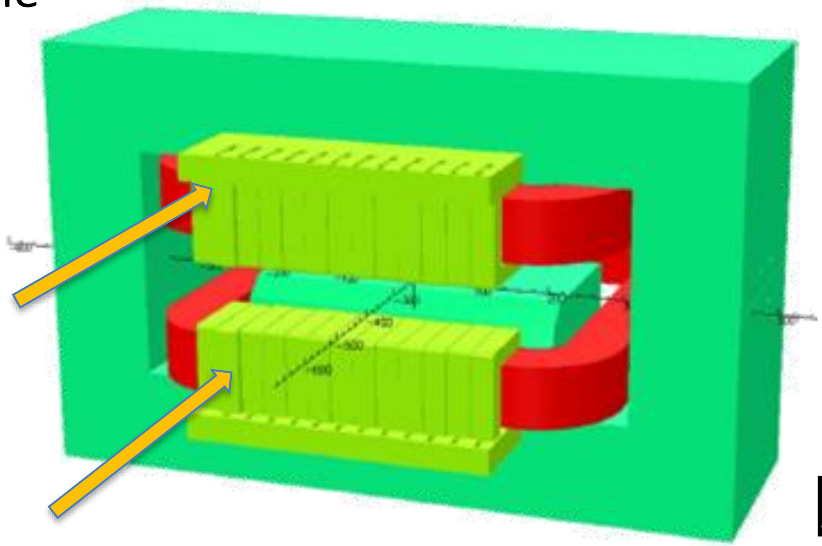
All Magnets are Delivered and Installed

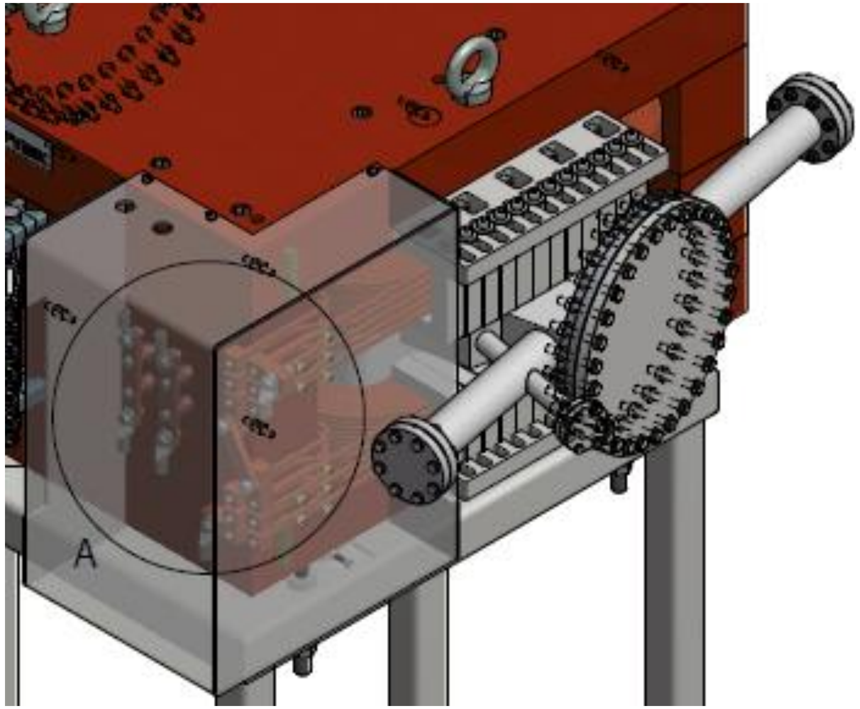



- 8 Dipole magnets with embedded higher order corrections
- 14 Quads + 1 with hexapole
- 3 hexapoles and 1 octupole

Measured deviation from the specified field boundary







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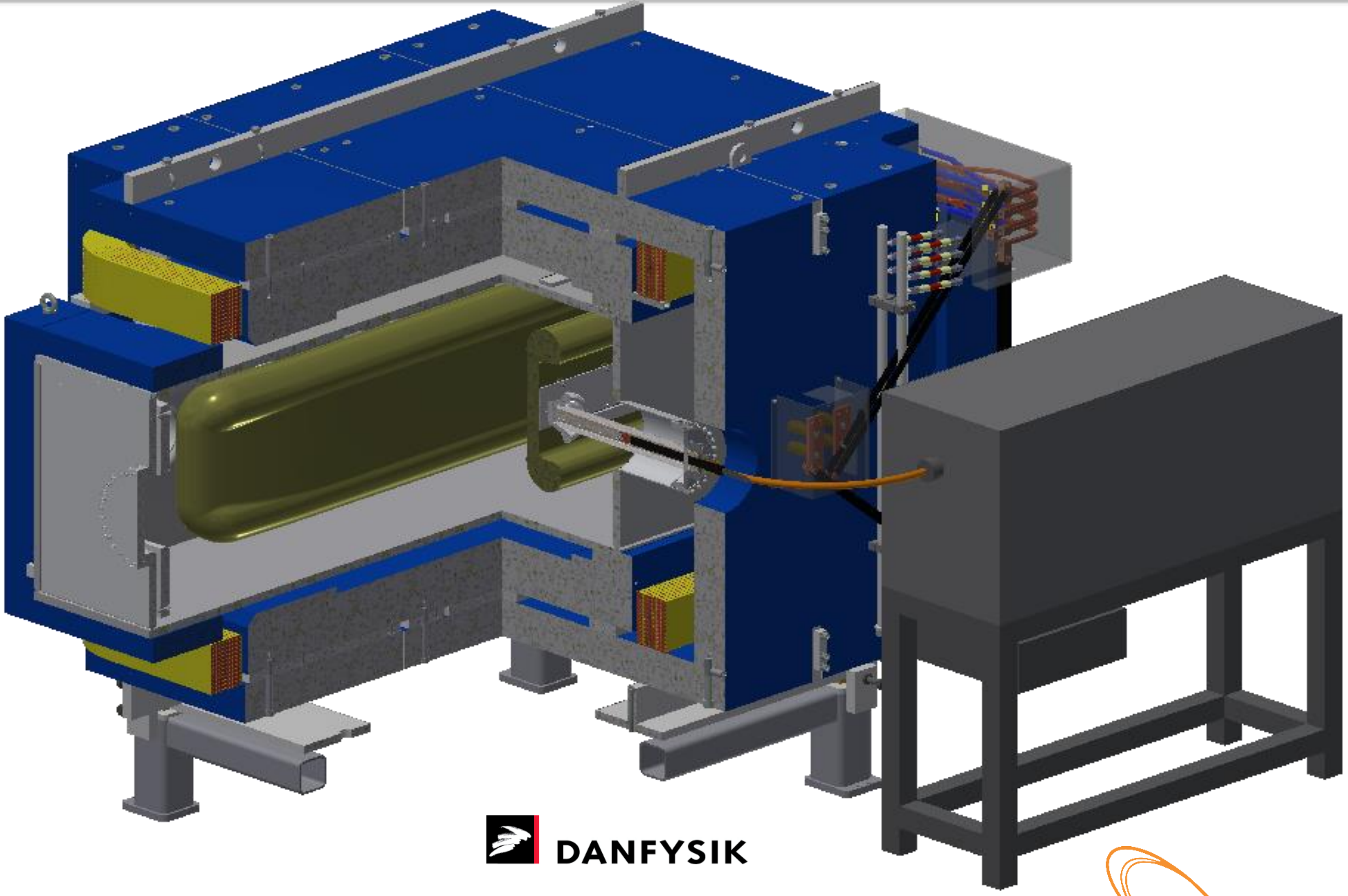
ISNAP

Wien Filters: E&M Fields Shape and Ratio

- EFL = 2.36m
- Operation Fields:
  - E=+/-250kV
  - B=0.12T
- Good field region:
  - 11cm (H)x7cm(V)
- Common mirror plate
- E-field defines EFL
  - Moveable magnetic field clamp to match B field length to E (Range +/-1.25 cm)



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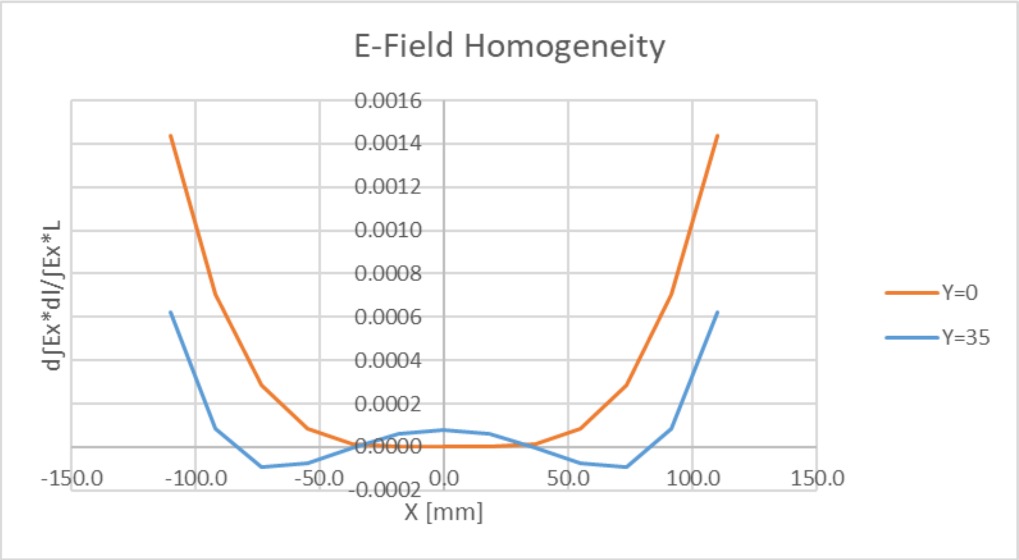
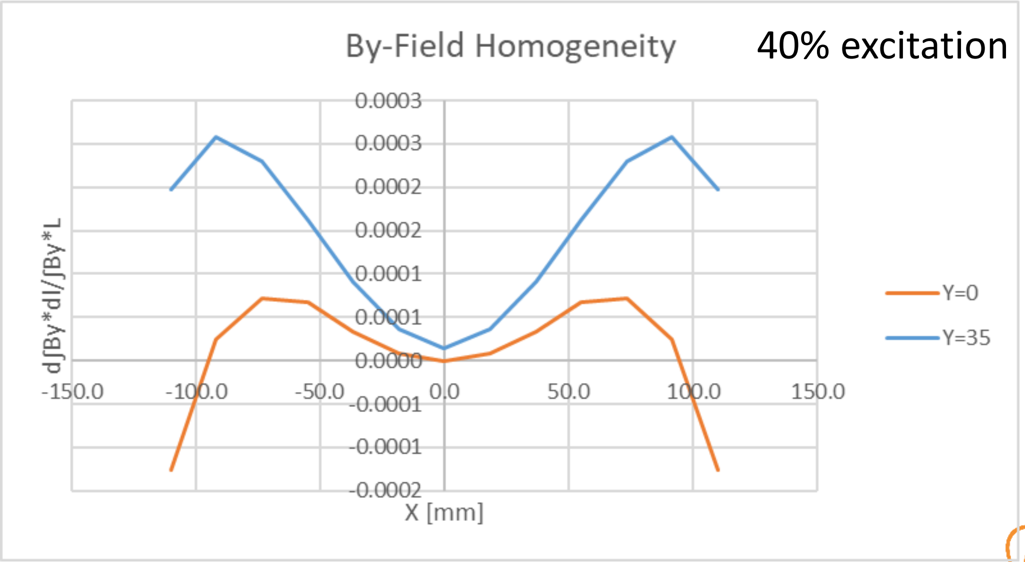
Wien Filter Transversal Homogeneity

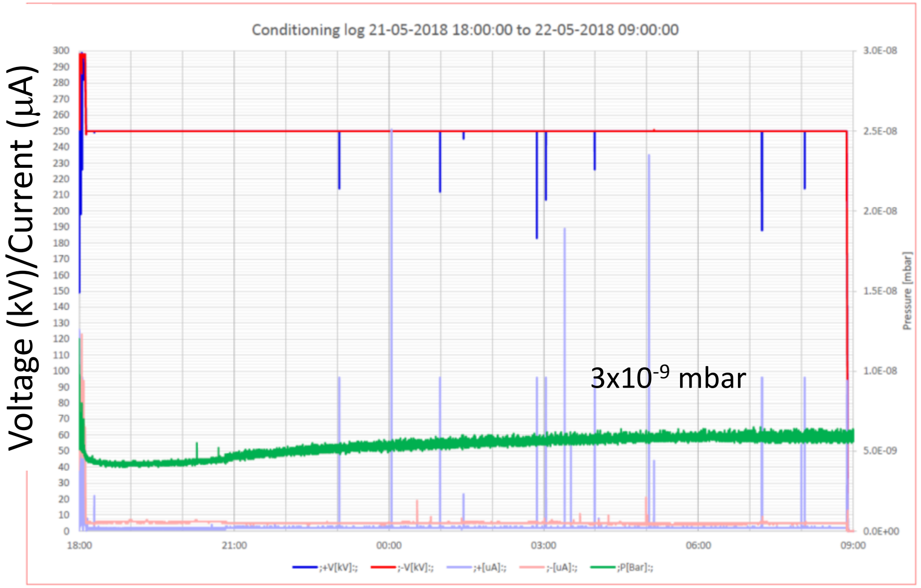
- Integrated Field*dz compared to the center line
  - Calculated for E-field
  - Calculated for B-field and compared to measurement
    - Probe position sensitivity limited
  - integrated in ion optics calculation

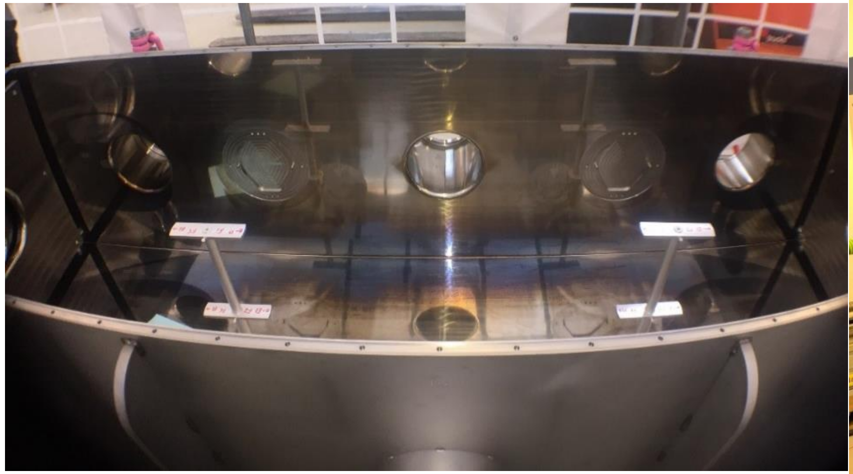


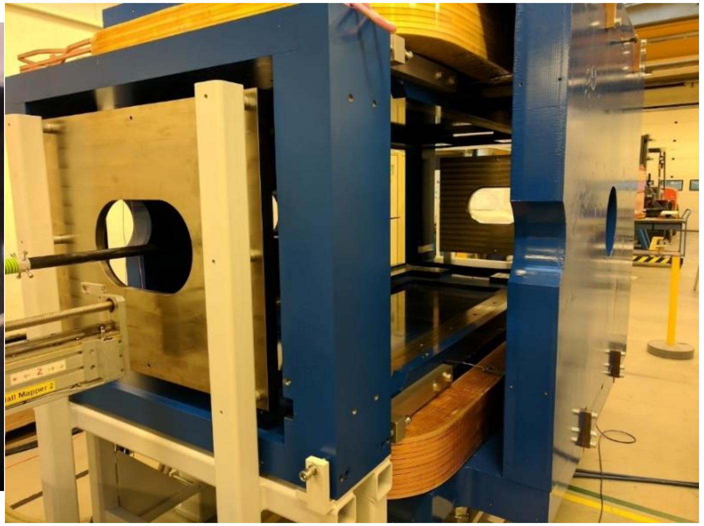


Wien Filter 1 Factory Acceptance

- Factory conditioning demonstrated +/-270kV
  - Full magnetic field (0.12T)
  - Stable (1 spark/hour) at +/-250 kV
- Shipped to MSU this week



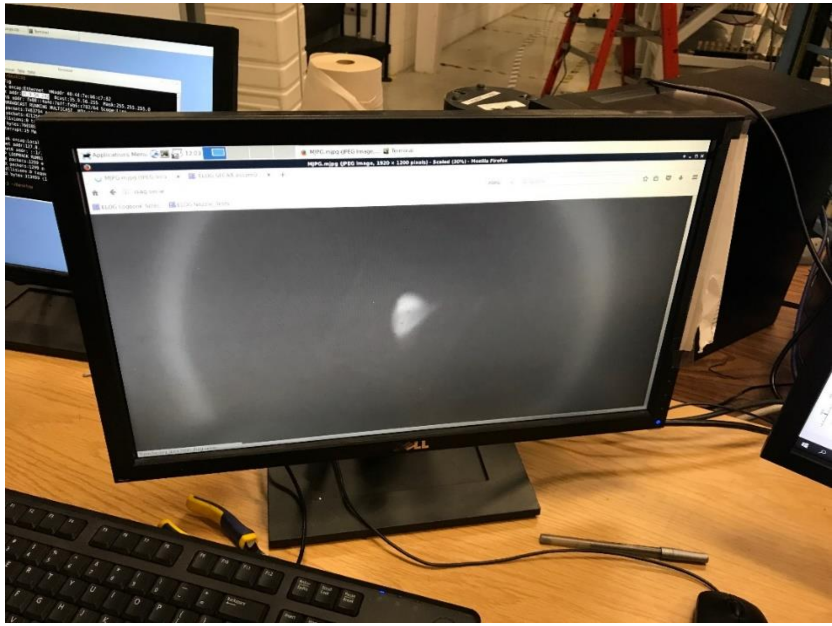




	+kV
	-kV
	+μA
	-μA
	mbar

First Commissioning Beam

- H_2^+ from ReA3 stable ion source
- Beam tune to first focal point
  – Dispersion measured comparable to calculations
- Beam tuned to SECAR from ReA3
  – With help of Matt Amthor



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Experimental test of an online ion-optics optimizer

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Charge State of Recoil

- The efficiency of a SECAR experiment is:
  - $\epsilon =$ **Charge State Fraction** * Transmission * Detection Efficiency
- Nuclear reaction can take place anywhere in the gas target
  - Part of the product will NOT cross enough material to reach charge state equilibrium
  - Solution by various group: Post stripper and measurements
  - Charge state model are failing to predict charge state in gas at low energy (~0.2-3 MeV/u)
    - ETACHA requires modification for gas
    - RISP/Seoul National University ETACHA4E (extended)

SECAR Design and Construction Team

Hendrik Schatz (project manager, MSU)

Michael Smith (deputy project manager, ORNL)

Georg Berg (project physicist, UND)

Aftab Hussein (project engineer, MSU)

Fernando Montes (deputy project physicist, infrastructure, installation, commissioning , MSU)

Manoel Couder (separator system, UND)

Jeff Blackmon (experimental system, LSU)

Kelly Chipps (jet gas target, gamma detection, ORNL)

Uwe Greiffe (extended gas target, CSM)