Argonne NATIONAL LABORATORY

INSTALLATION AND COMMISSIONING OF THE ATLAS RADIOACTIVE ION SEPARATOR

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U.S. DEPARTMENT OF ENERGY

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HIAT2018 14th International Conference on Heavy Ion Accelerator Technology

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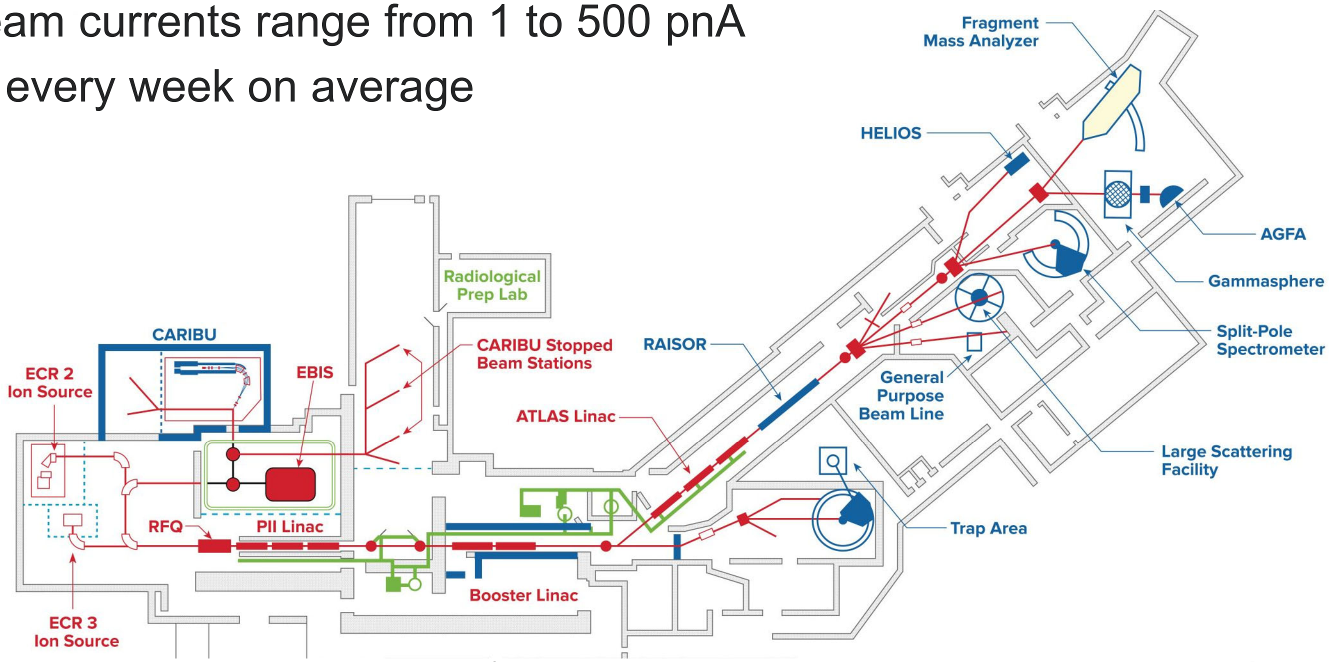
MOTIVATION AND BACKGROUND

OVERVIEW

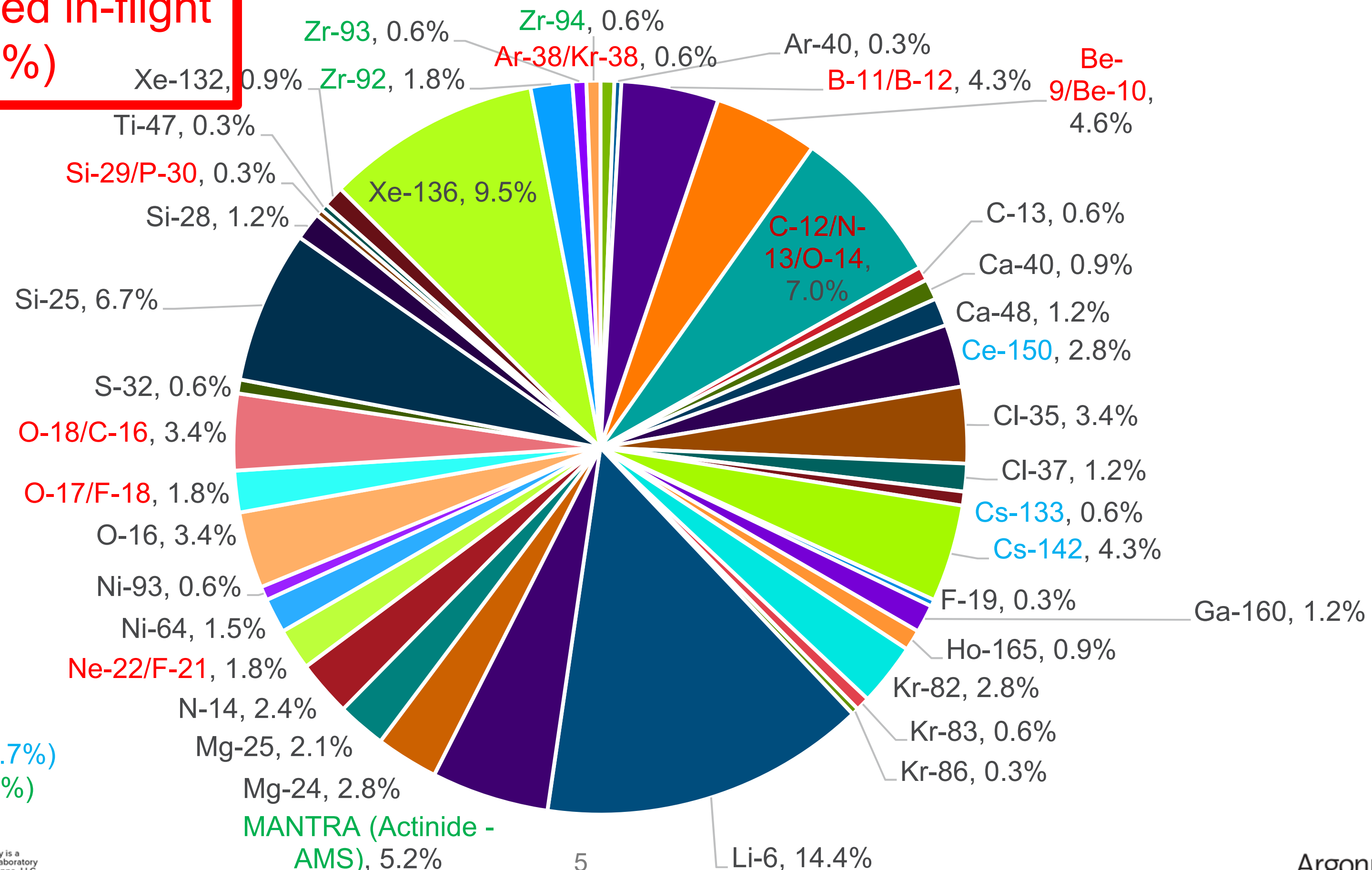
- ATLAS is a DOE National User Facility for stable, low energy, ion beams with a focus on nuclear physics research
- 3 accelerator sections, 50 SRF resonators providing an effective of ~52MV,
- Typical stable beam currents range from 1 to 500 pnA
- New experiment every week on average



Beam Species for Fiscal Year 2017

(percentage of beam hours scheduled)

RIBS produced in-flight (23.8%)



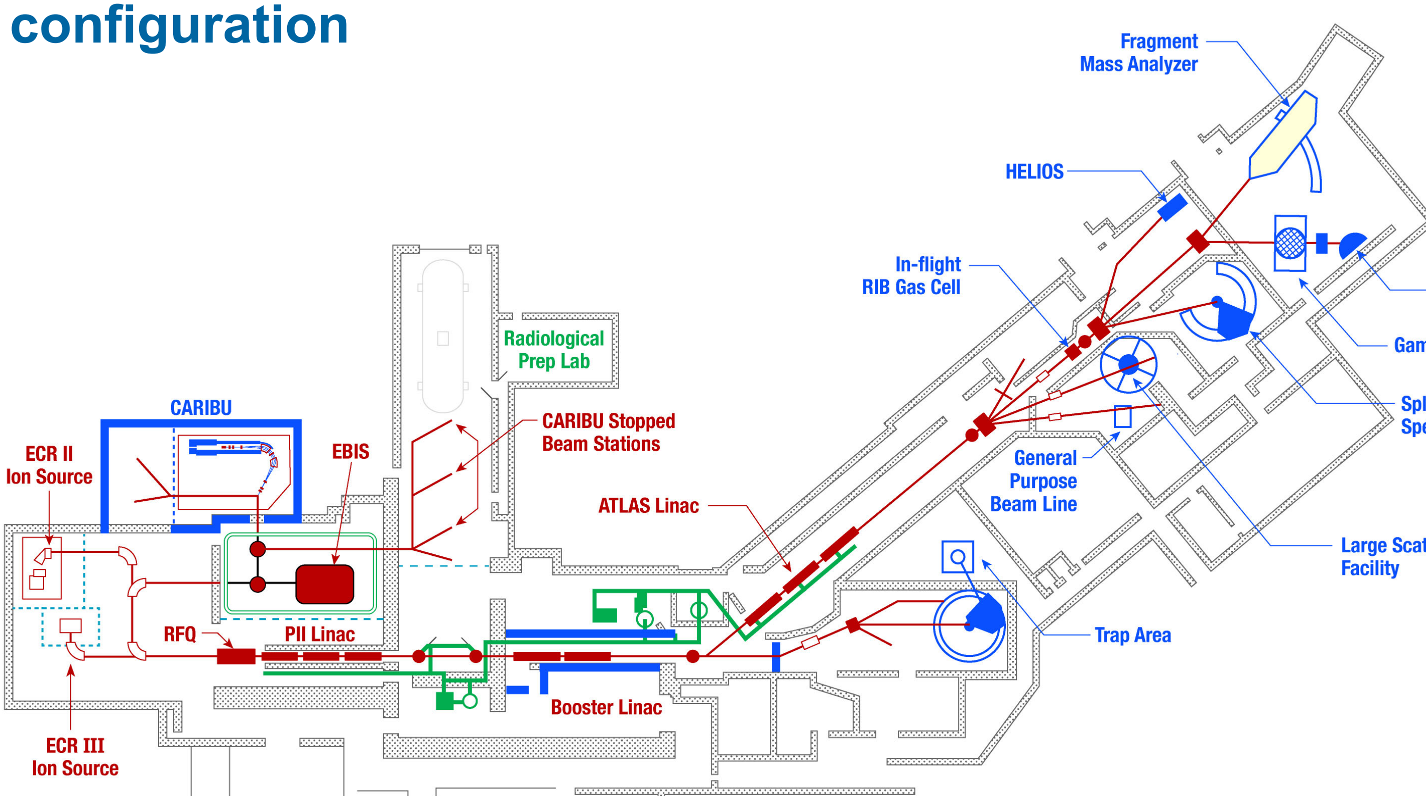
*MANTRA
Kr-78
Th-232
Th-233
U-235
U-238
Np-237
Np-238
Np-239
Pu-239
Pu-240
Pu-242
Pu-243
Pu-244
Pu-245
Pu-246
Pu-248
Pu-249

39+* unique ion species delivered in FY2017

RIBS from CARIBU (7.7%)
AMS experiments (8.2%)

IN-FLIGHT PROGRAM AT ATLAS

Former configuration



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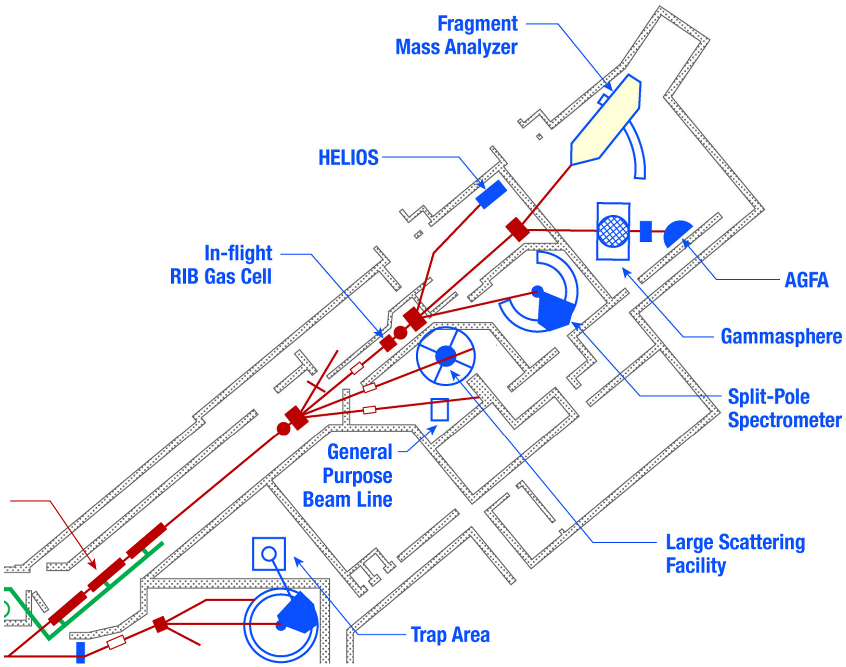

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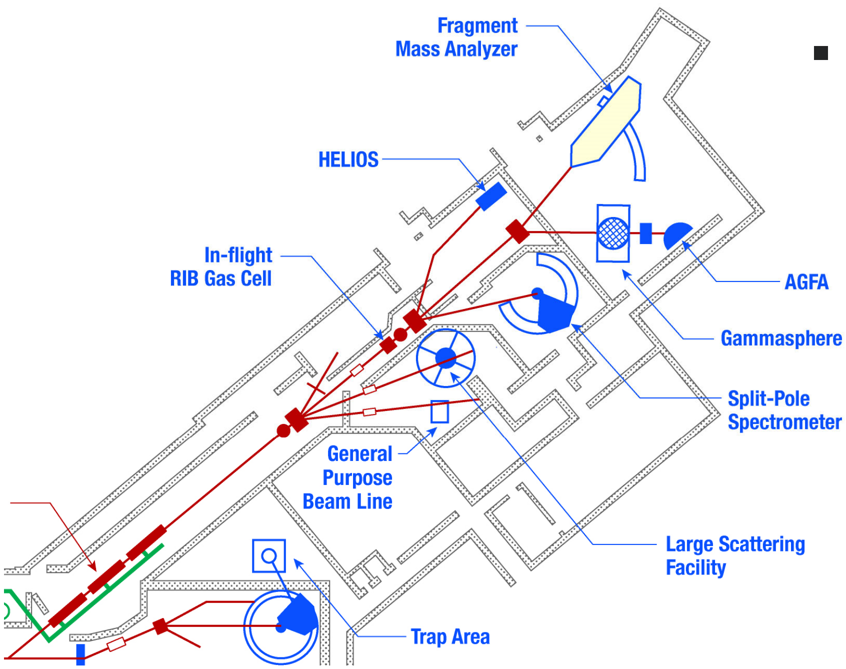
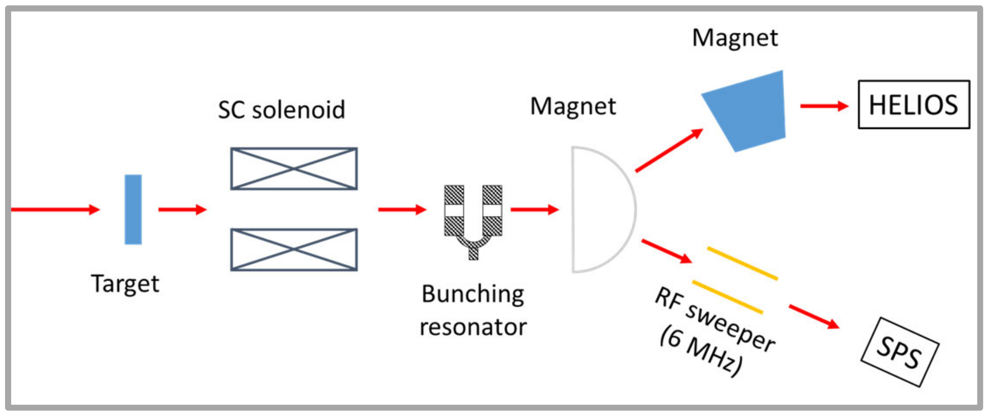


- Program established in 1996
- Designed for SPS
- Also worked for HELIOS



IN-FLIGHT PROGRAM AT ATLAS

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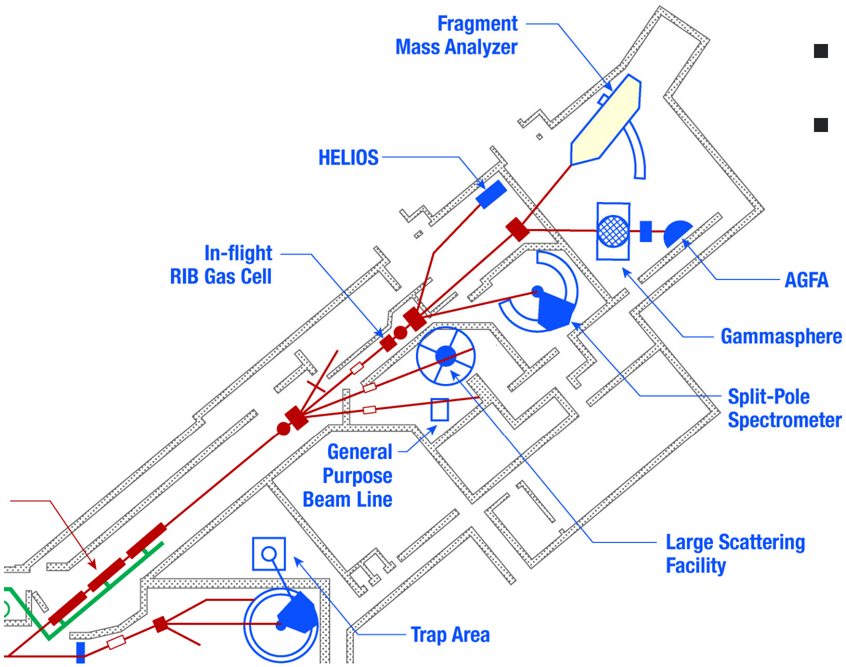
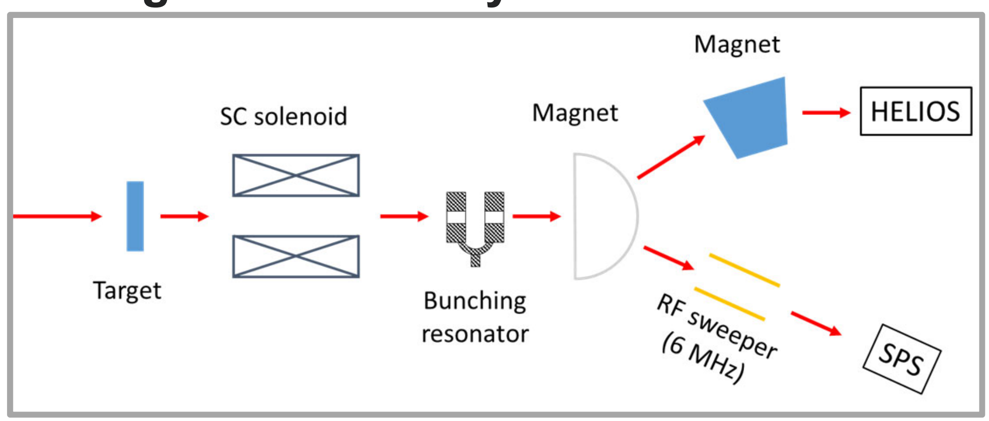


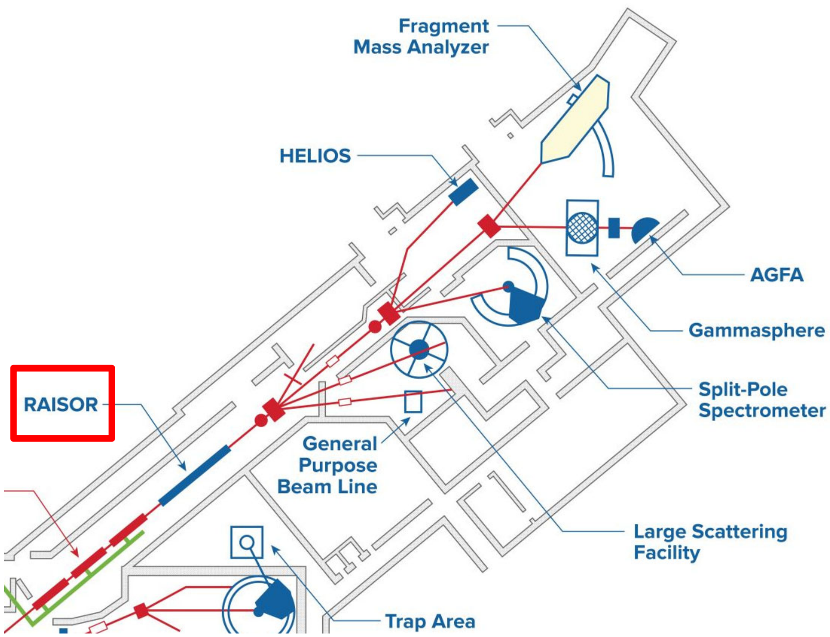
U.S. DEPARTMENT OF ENERGY — Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

- Program established in 1996
- Designed for SPS
- Also worked for HELIOS
- **Limitations**
  - **No dedicated beam dump**
  - **No dedicated focal plane**
  - **Target accessibility**



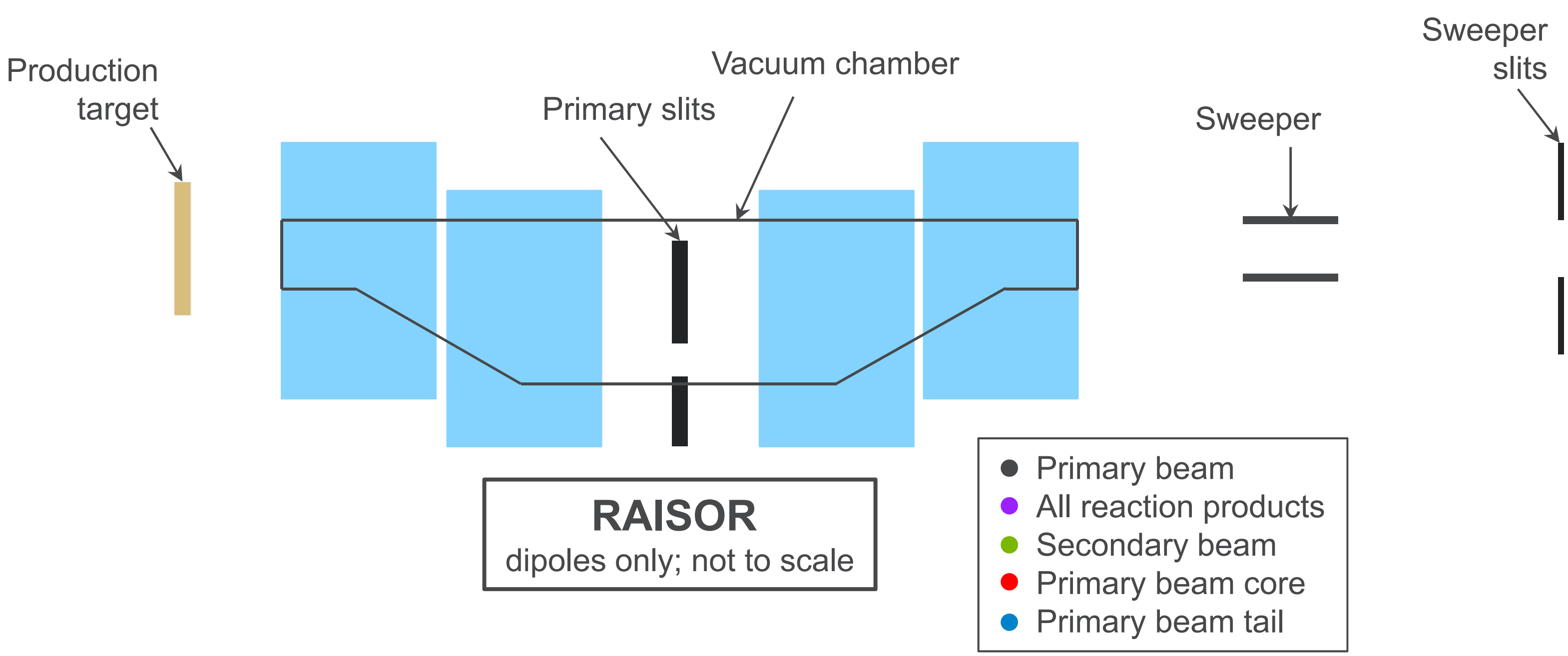
SOLUTION – RAISOR/AIRIS

RadioActive Ion SeparatOR/Argonne In-flight Radioactive Ion Separator



- Dedicated beam dump
  - Control primary beam power
  - Easier radiation shielding
- Focal plane with selection slits
- All ATLAS high energy targets accessible

OPERATING PRINCIPLE



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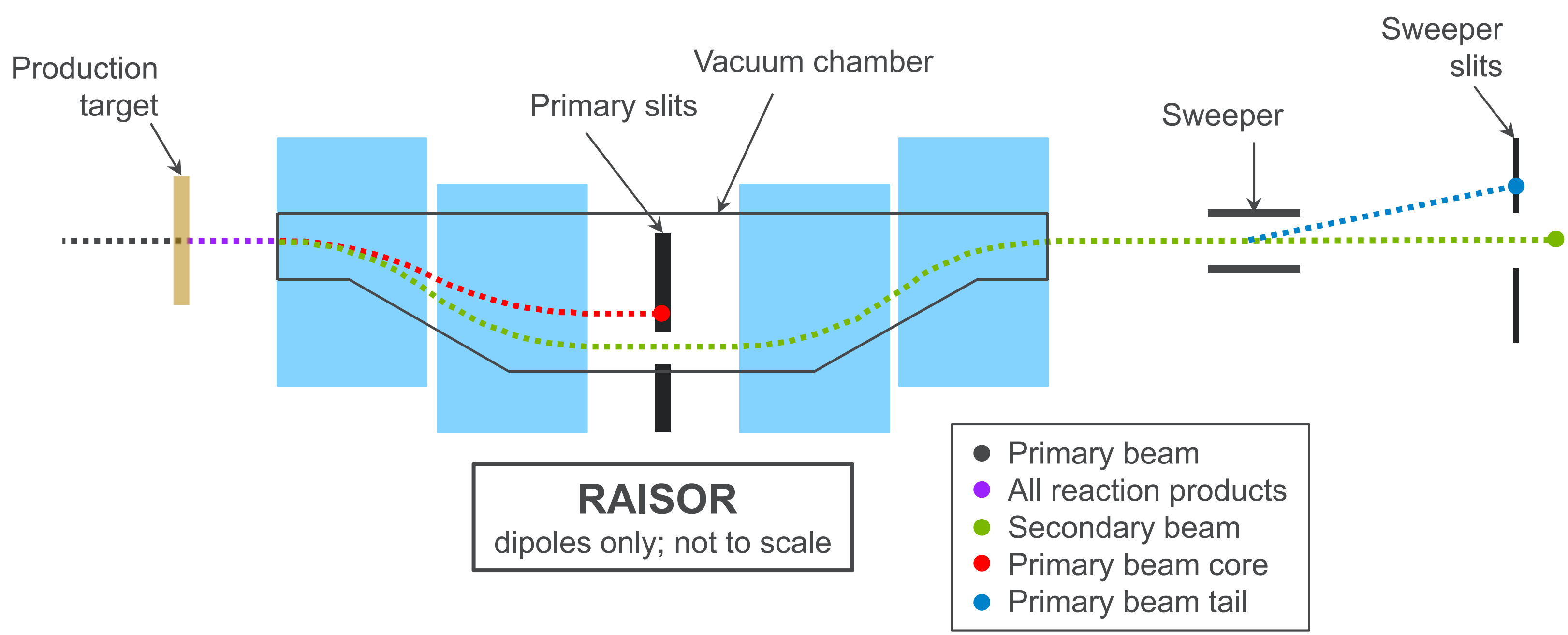
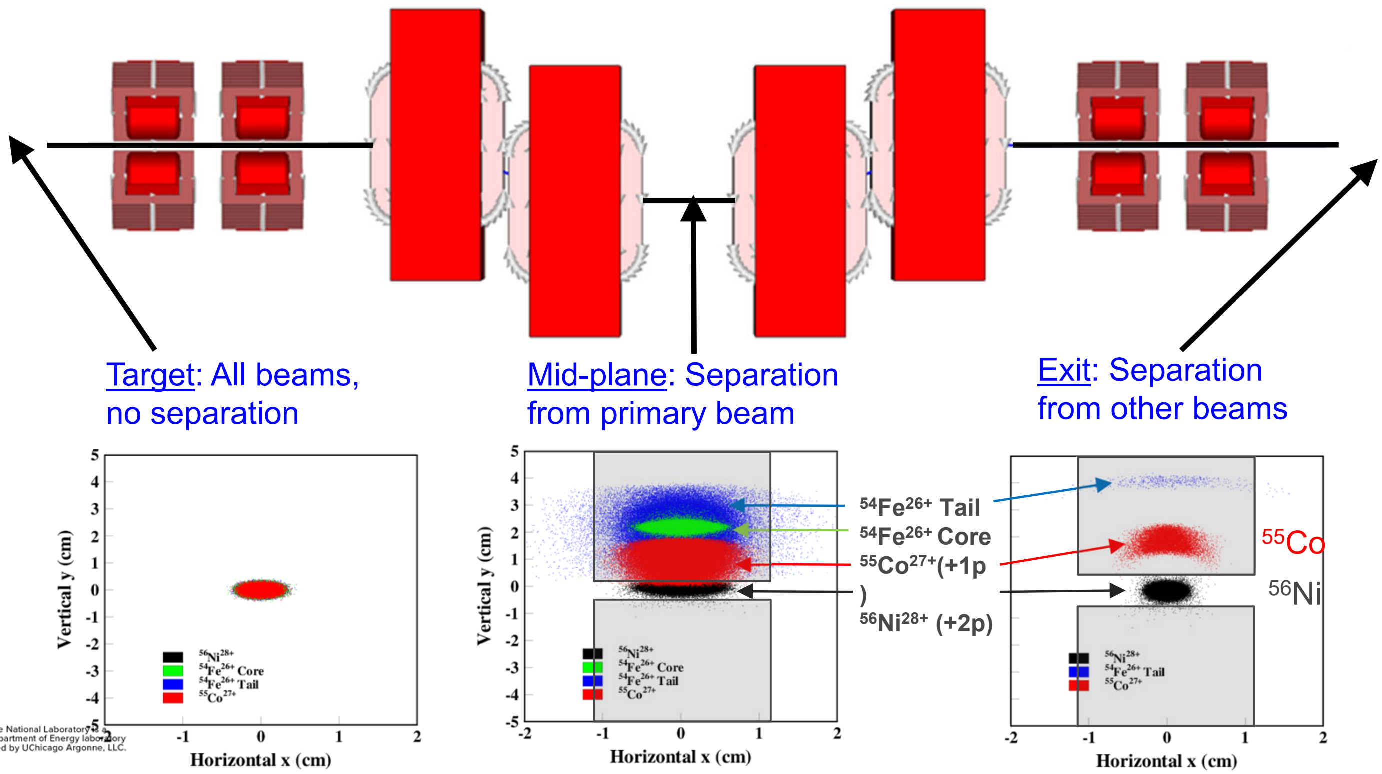


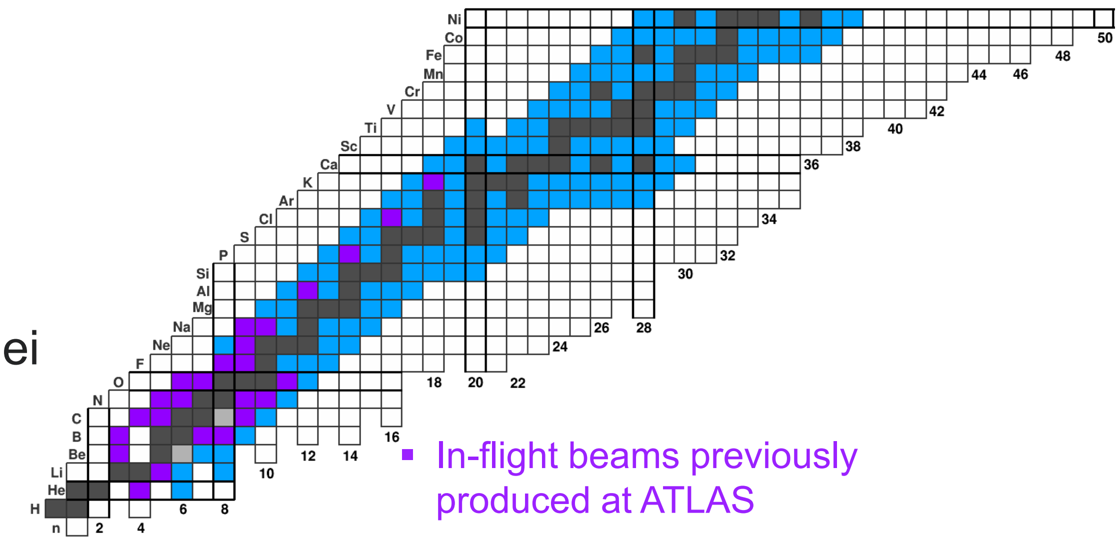
SIMULATED RAISOR PERFORMANCE

$^{56}Ni^{28+}$ produced from ^{54}Fe (^{12}C, ^{10}Be) at 10 MeV/u



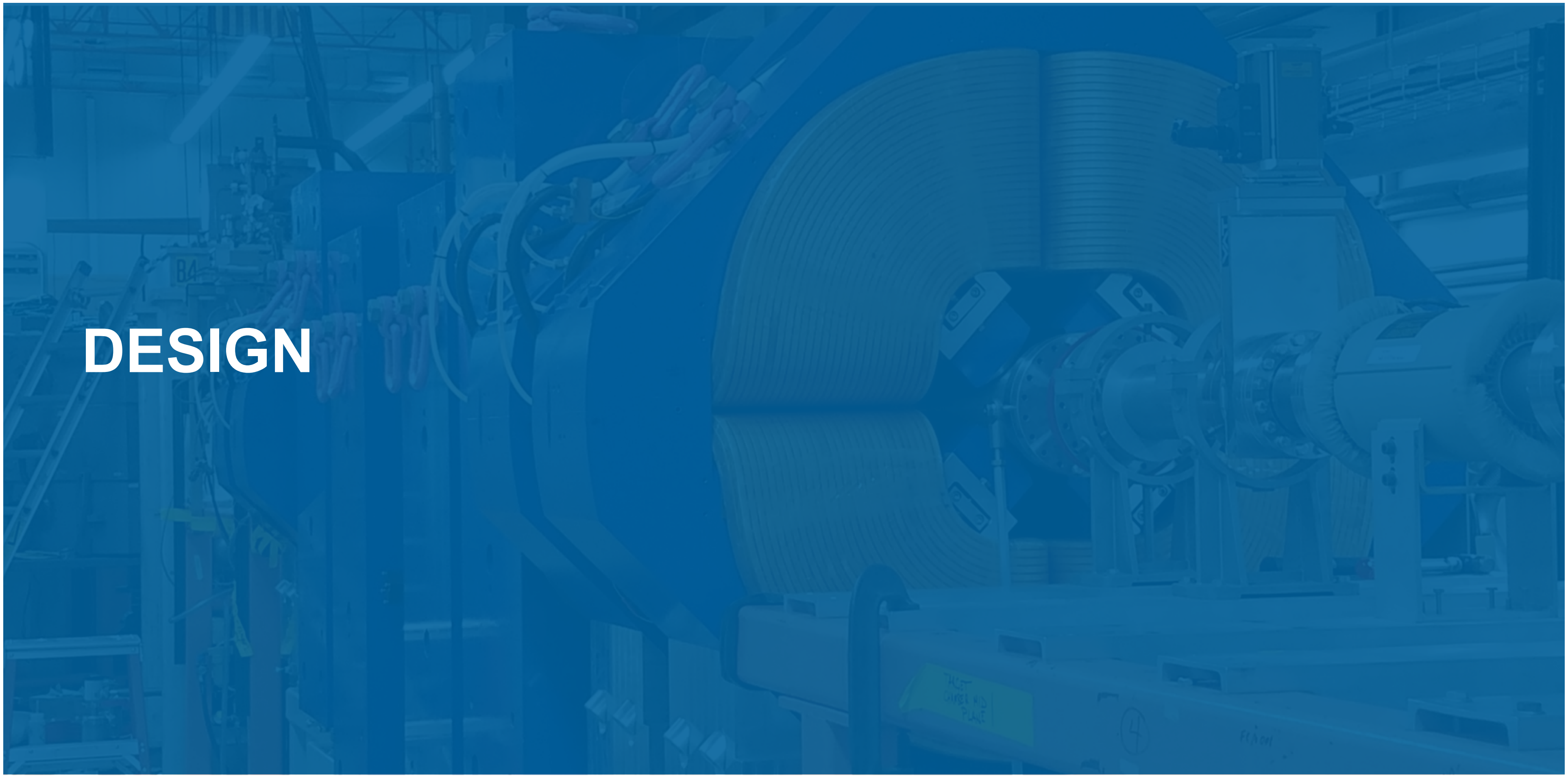
RAISOR PHYSICS MOTIVATION

- RAISOR will enable higher production intensities which will expand access to the chart of the nuclides
  - Further from stability
  - Higher mass
- Physics
  - Nuclear astrophysics
  - Single-particle structure
  - Pairing strength in nuclei
  - Collective properties of nuclei
  - Nuclear reactions
  - Fundamental symmetries



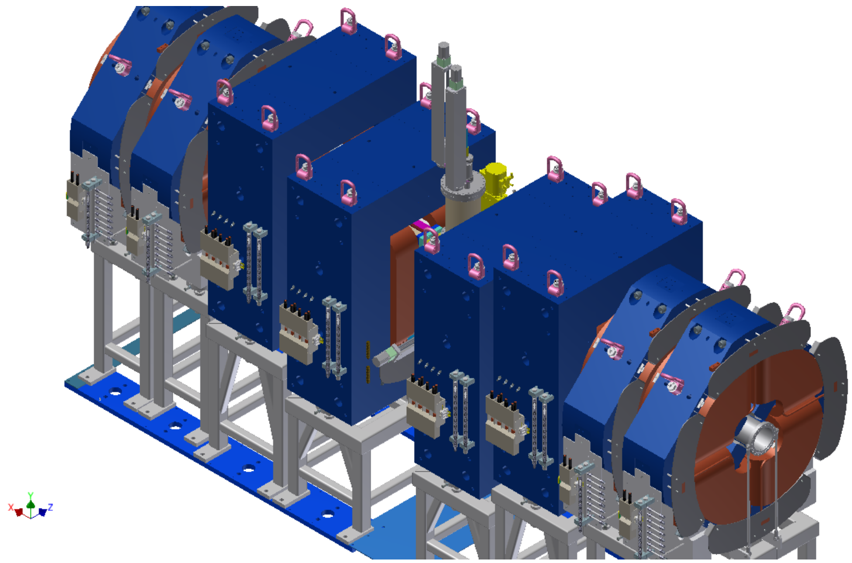
- In-flight beams previously produced at ATLAS
- Estimated secondary beams with $>10^3$ pps with RAISOR

DESIGN



PROJECT SCOPE

- Magnets
- Vacuum chamber
- Re-position RIB sweeper
- Mid-plane instrumentation
- Power supplies
- Utilities (power and water) distribution
- Beamline reconfiguration
- Diagnostics



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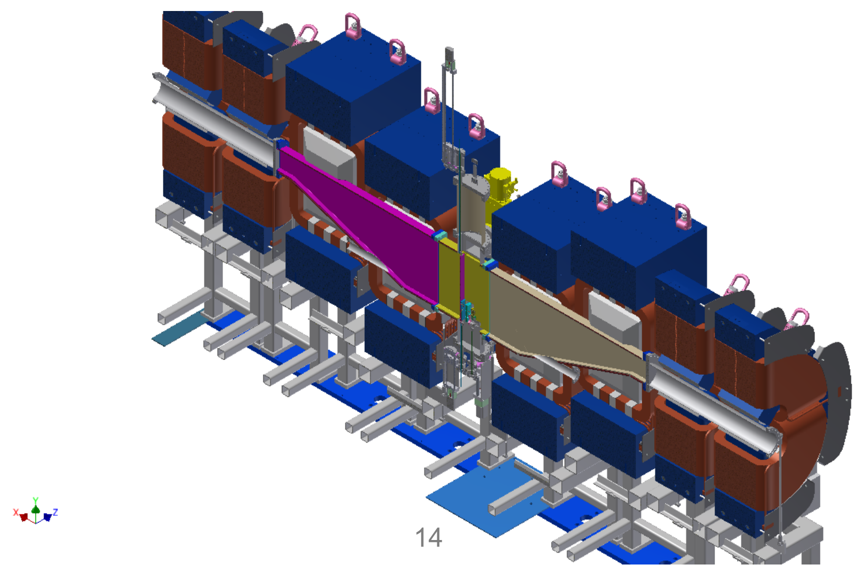

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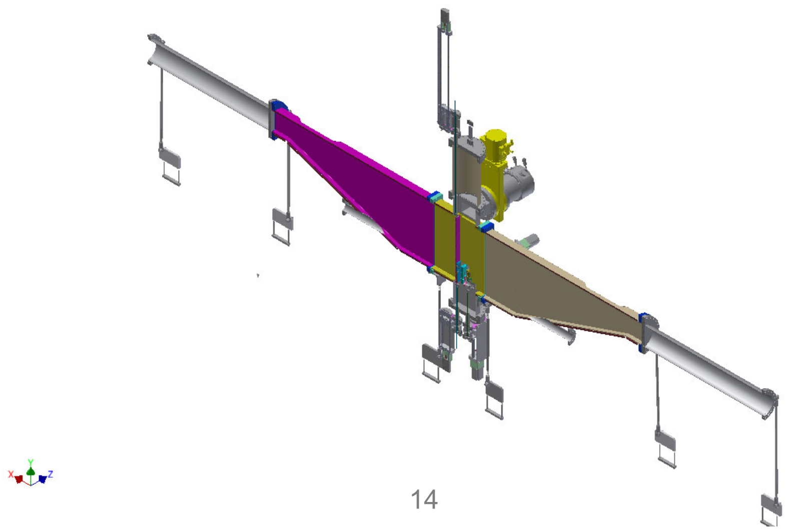

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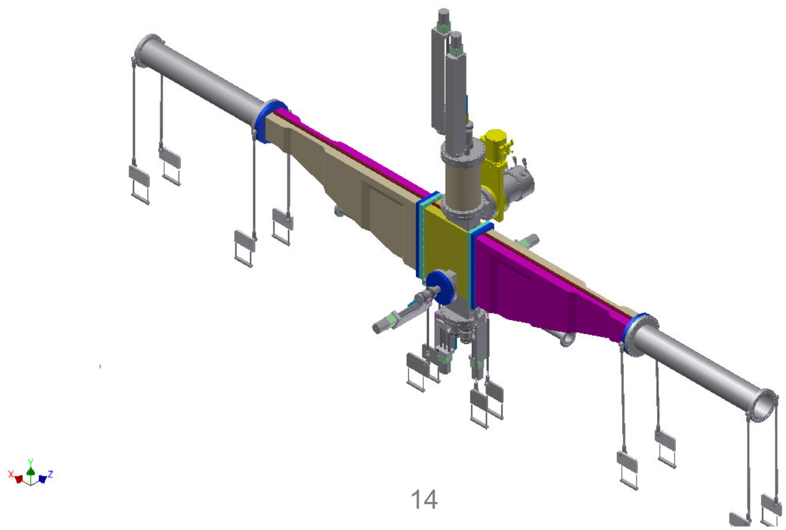
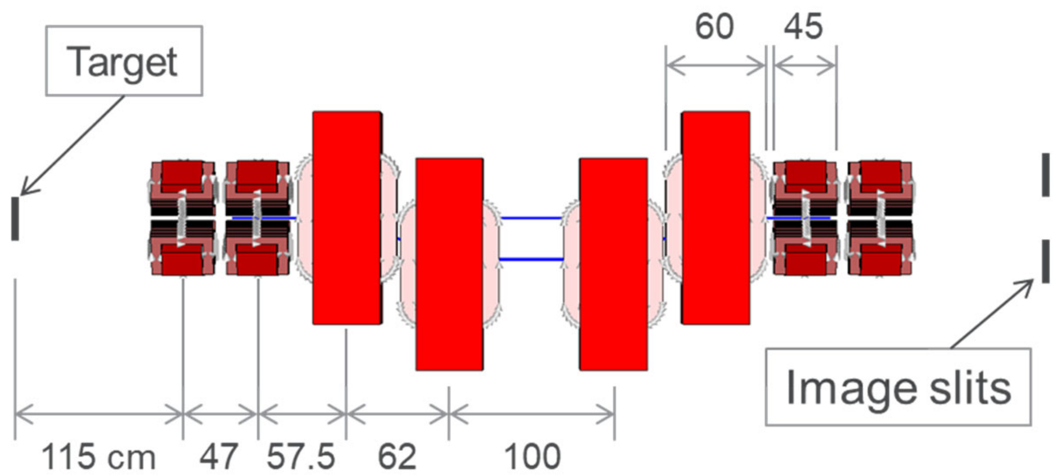
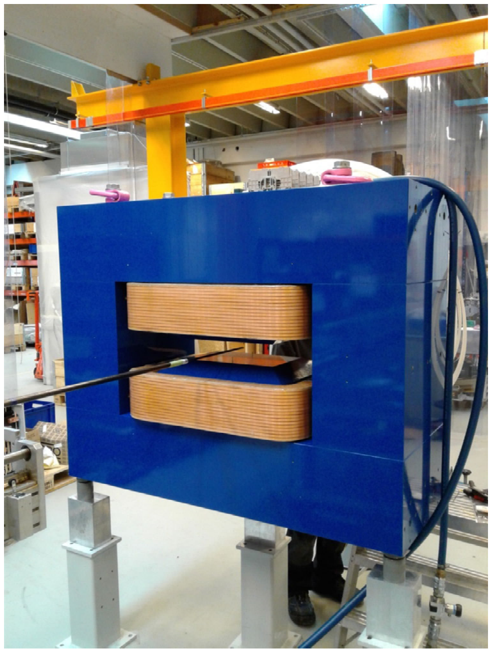


MAGNET DESIGN AND LAYOUT

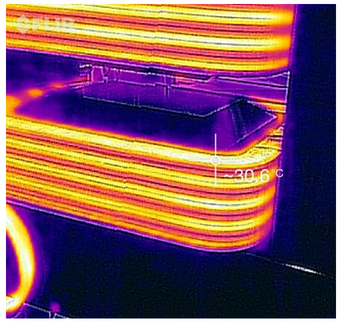
Total length	6.6 m
Angular acceptance	75 mrad
Dispersion at midplane	1.3 mm/%
Beam offset	30 ± 5 cm
Dipole gap	8 cm
Max dipole field	1.75 T
Dipole field integral	0.73 T-m
Dipole effective length	41.9 cm
Quadrupole aperture	16 cm
Quadrupole length	30 cm
Maximum pole tip field	1 T



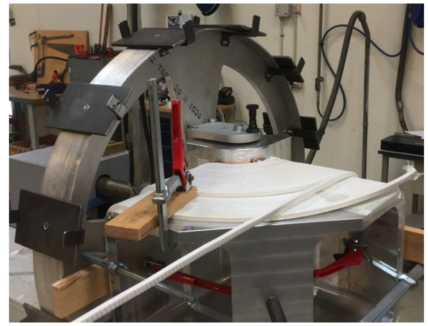
MAGNETS BY DANFYSIK (2016-17)



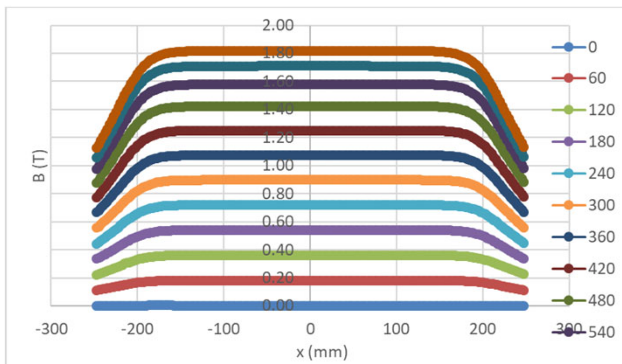
Dipole configured for mapping

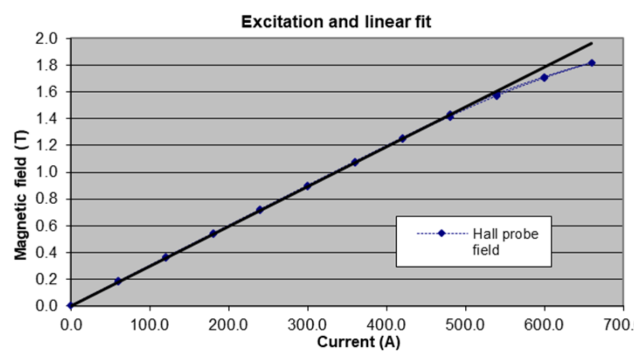


Coil cooling testing



Quad coil fabrication



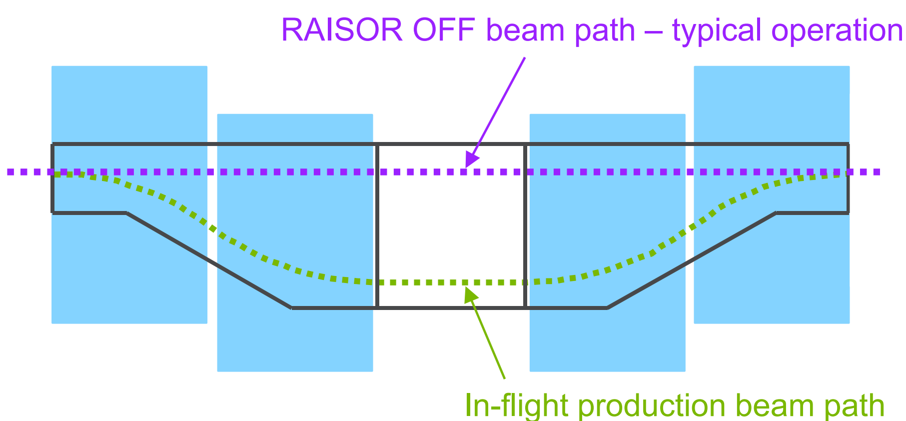


Excitation curves

DIPOLE VACUUM CHAMBERS

Design constraints

- Thin walled between dipole gap (8 cm) to maximize transmission
- Tall to accommodate RAISOR OFF and in-flight production beam paths
- Do not collapse under vacuum
- No internal supports to minimize scattering and preserve full range of operation



DIPOLE VACUUM CHAMBERS

Solutions

- Thin walls, 5 mm, between pole tips
- Externally reinforced (25 mm thick) between adjacent dipoles – deflection under vacuum <0.5 mm

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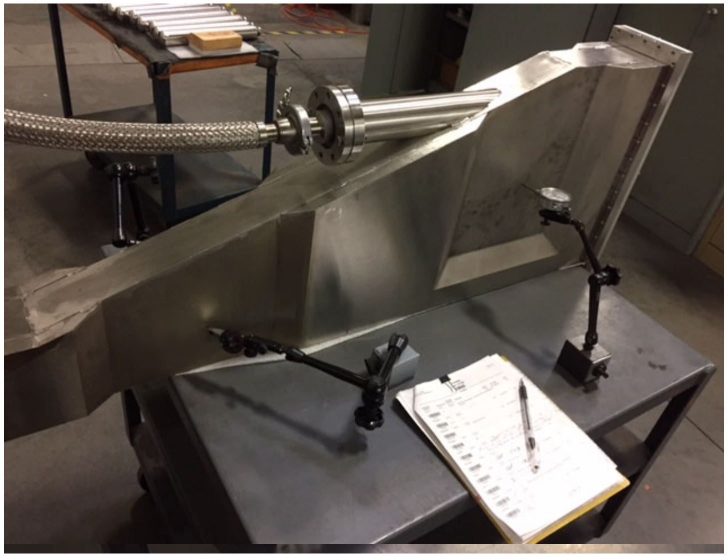
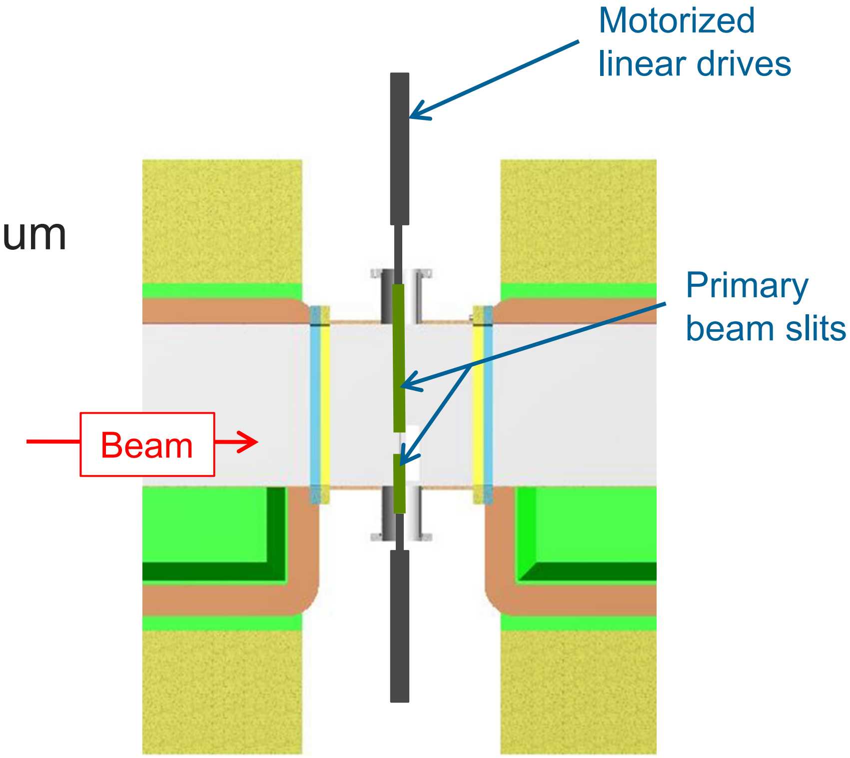


MID-PLANE INSTRUMENTATION

- Primary beam slits
  - 1 kW each
  - Water cooled
  - Ta brazed to Cu
  - Top slit covers full area from vacuum chamber wall to offset position



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- Primary beam slits
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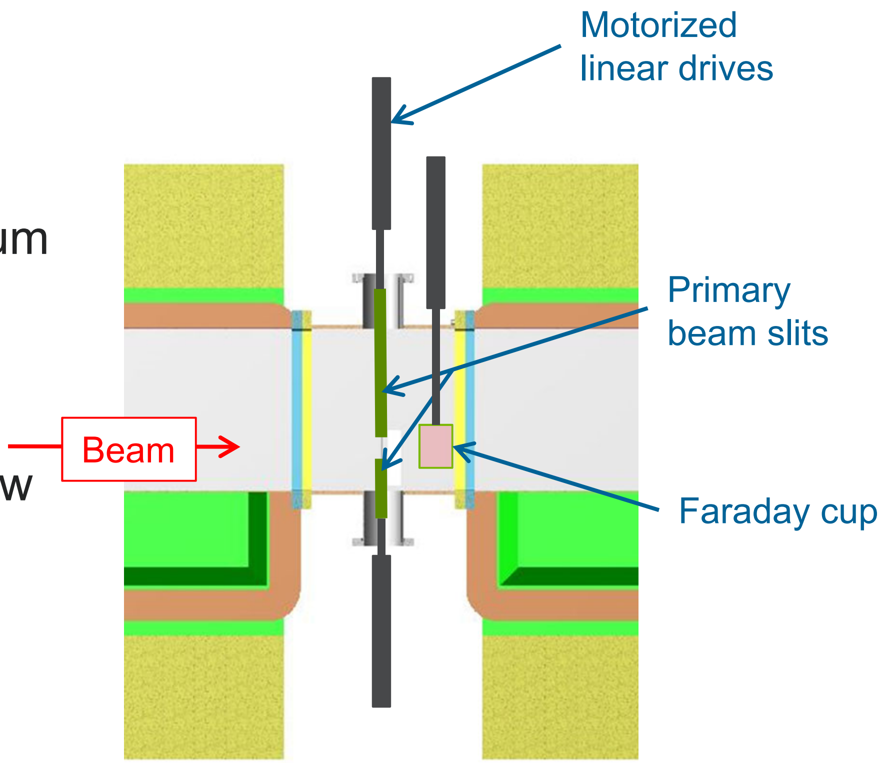
- Diagnostics
  - 1 kW Faraday cup
  - Plans for a beam viewer from below



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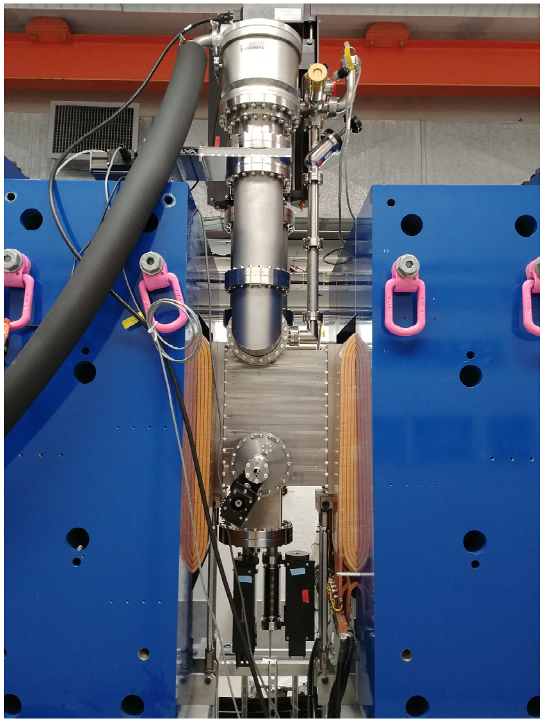
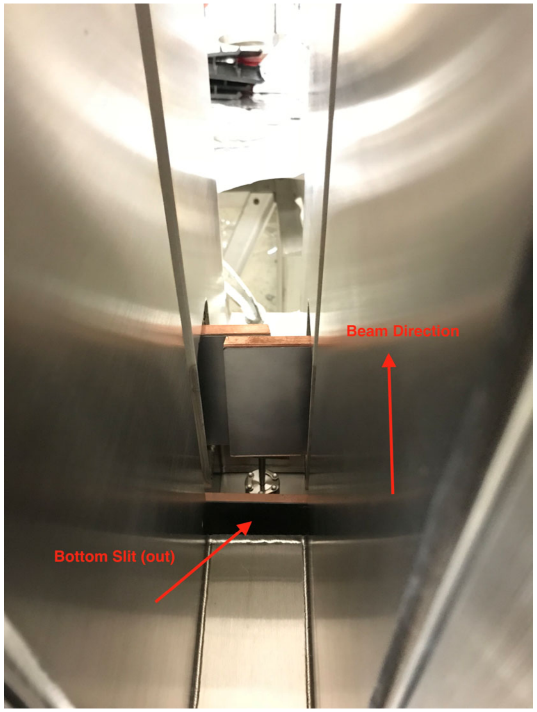
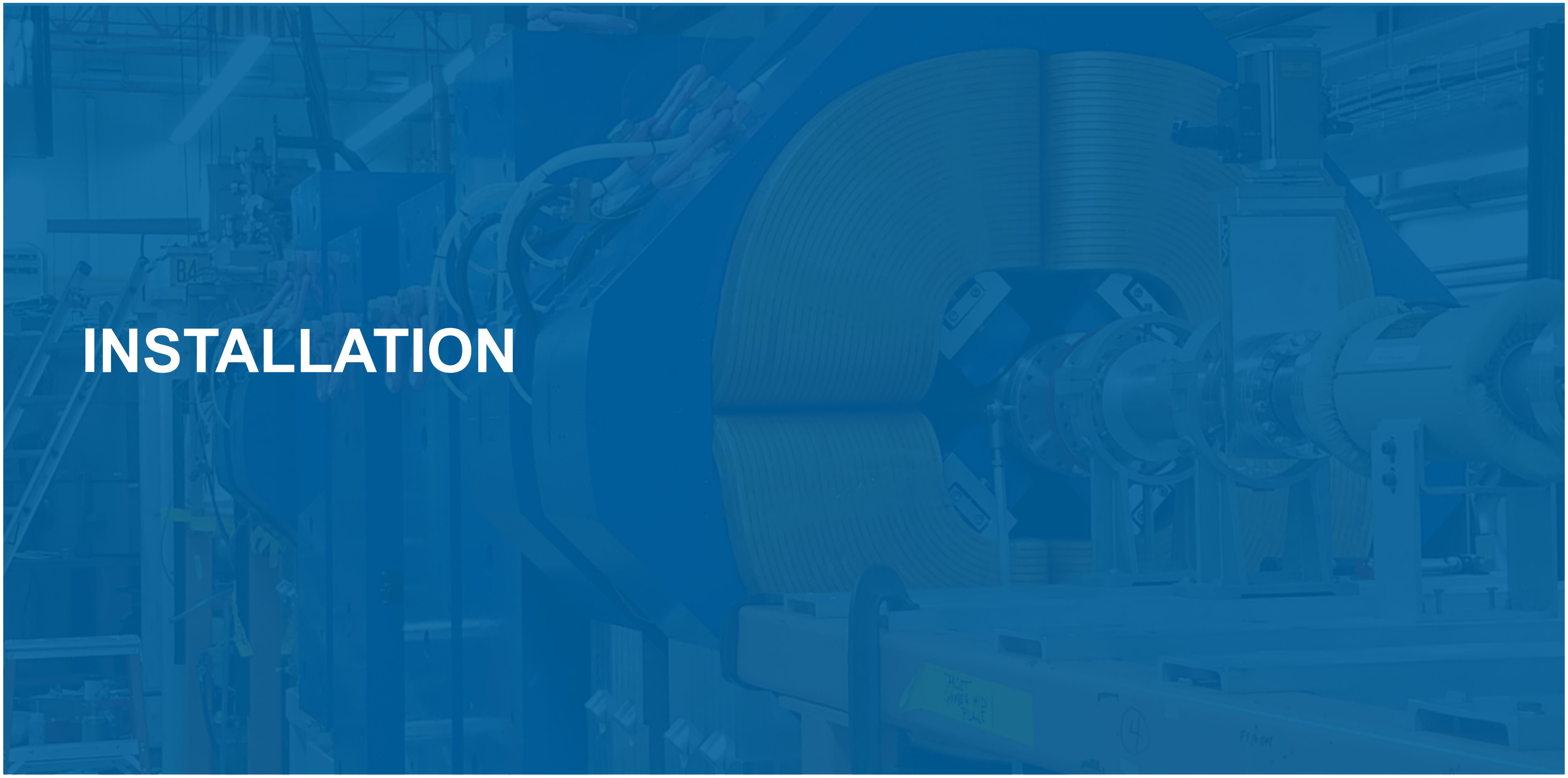




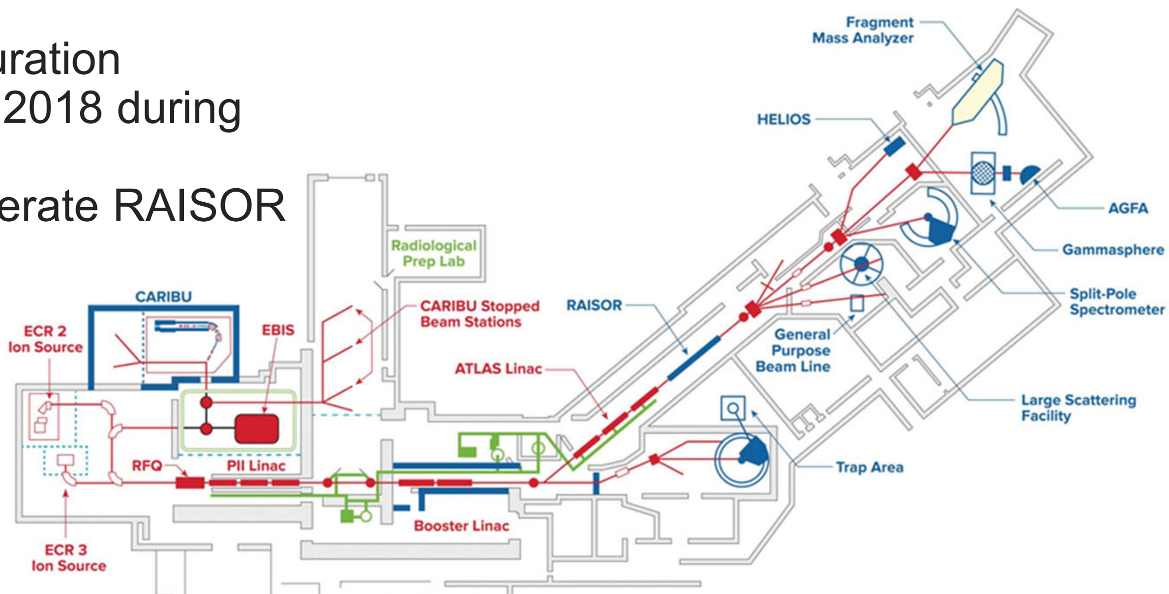


INSTALLATION

PHASED INSTALLATION

Risk management while running a user facility

- Phase 1: Magnet installation
  - January and February 2018
  - Typical annual downtime
- Phase 2: Beamline reconfiguration
  - 1.5 weeks in April – May 2018 during low energy experiments
  - Equipment needed to operate RAISOR



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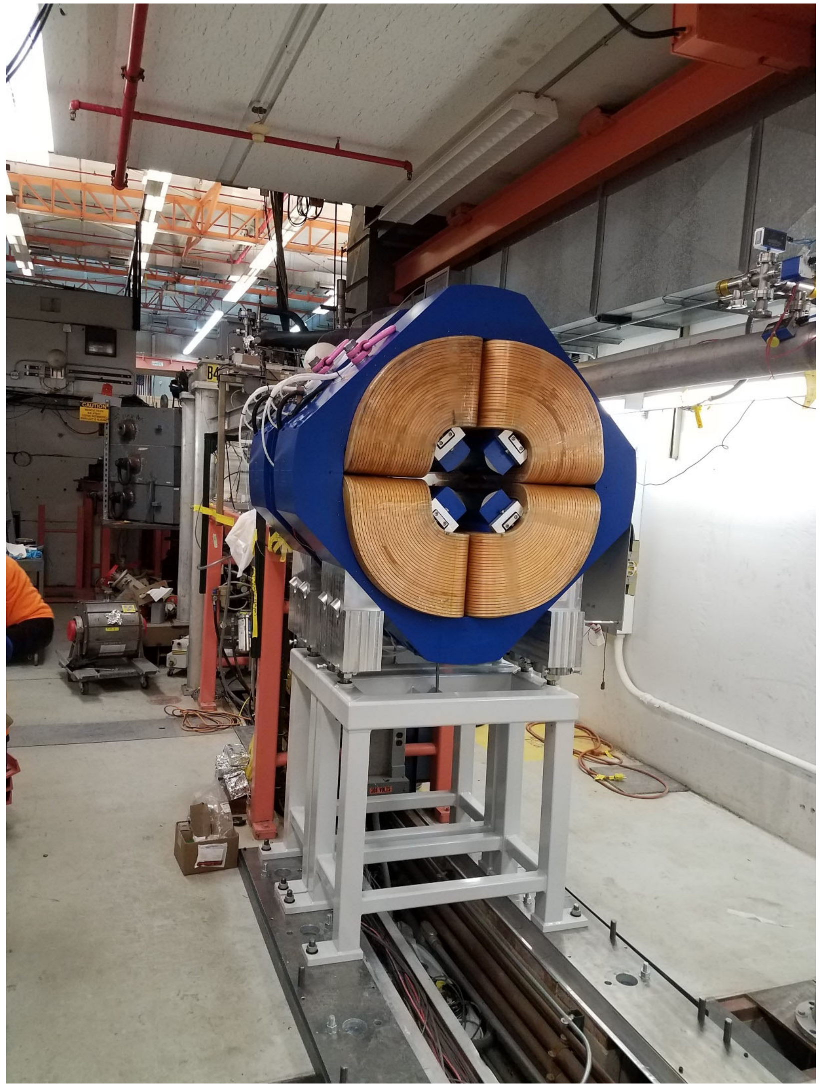
  - Equipment needed to operate RAISOR
- Phase 3: Optimized performance
  - January 2019
  - RF sweeper relocation
  - Shorter downstream focusing lattice for higher efficiency transport to experiments


ZENAR
MILWAUKEE
CAP. 5 TON SN. 5705
EXIT




CAUTION
STAND CLEAR


18 X 12
Lifting Gear Hire
EXIT
HERCULES
HYSTER


18X12
Lifting Gear Hire
10 TON


4750

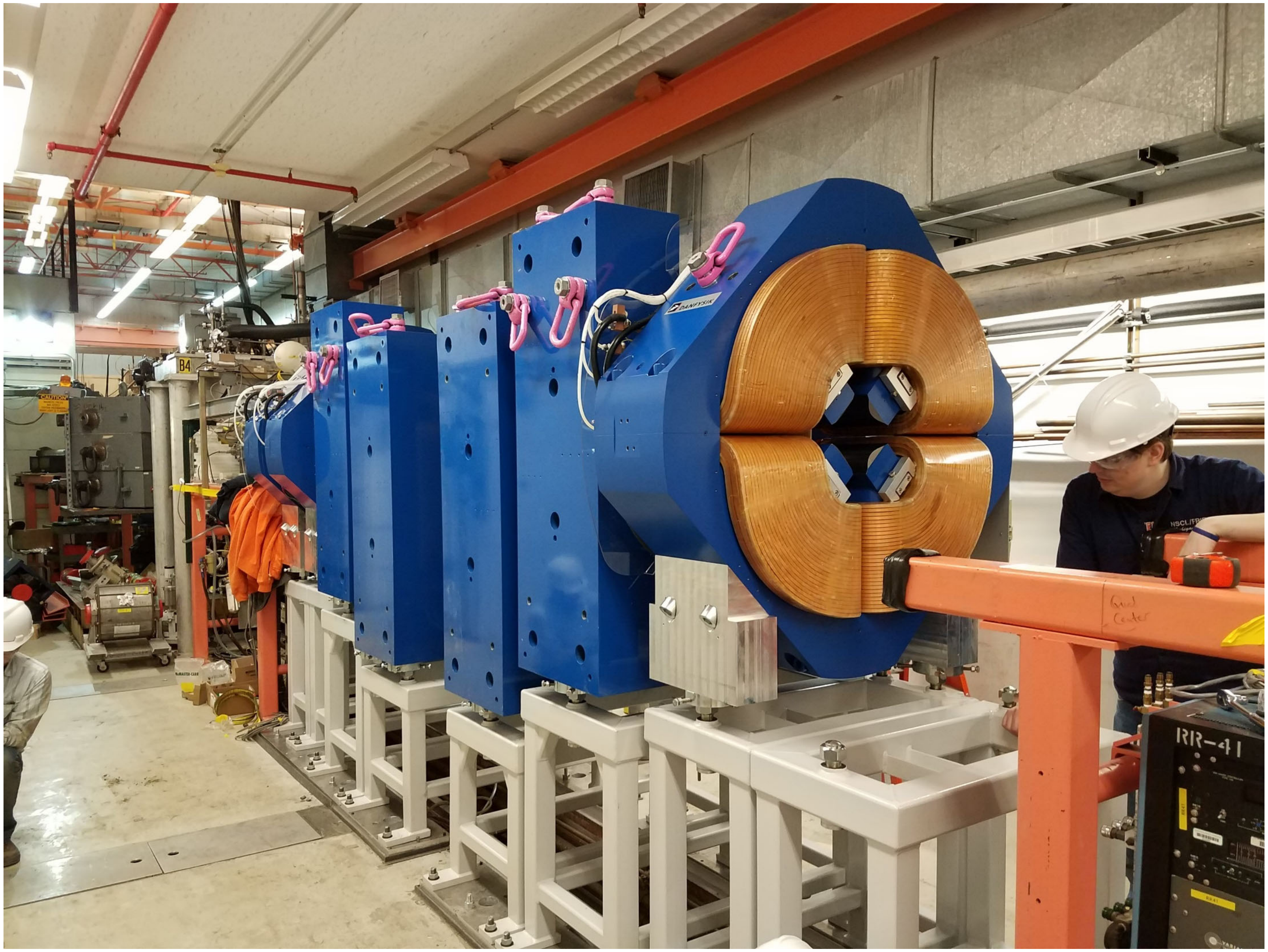

EXIT
B4


Gear Hire
EXIT
ARGONNE
DRIVING & RIGGING
10 TON

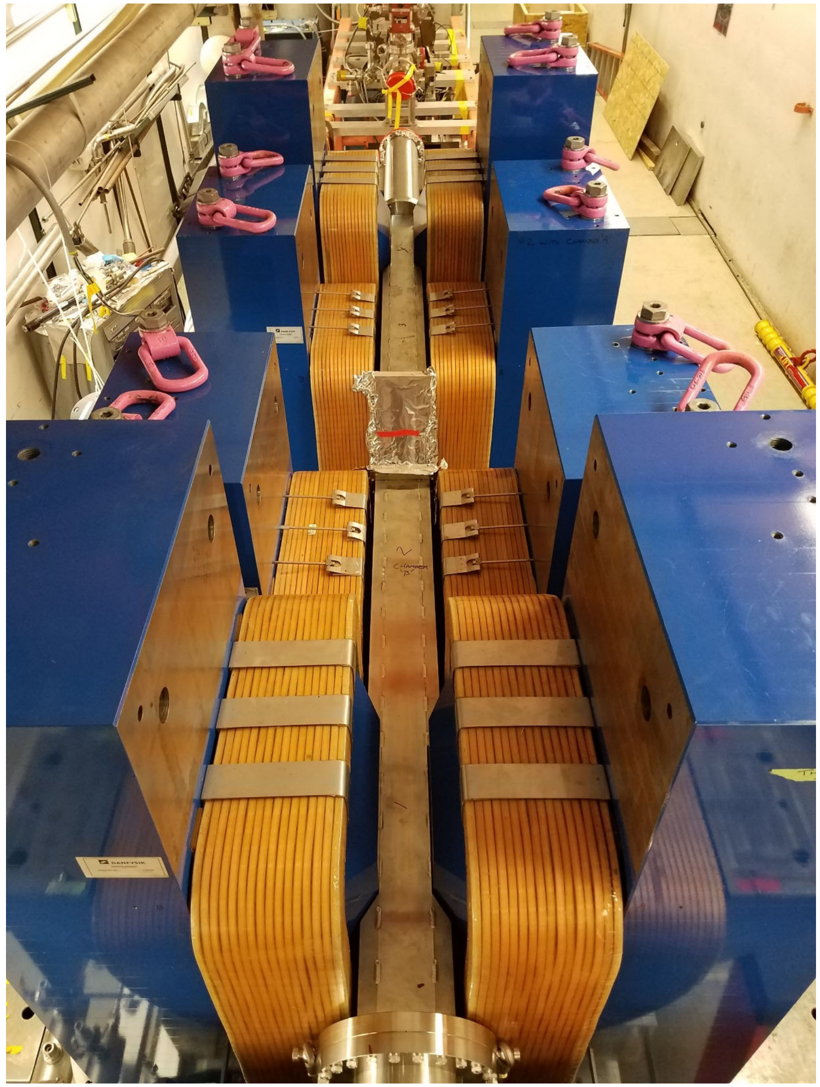

10 TON

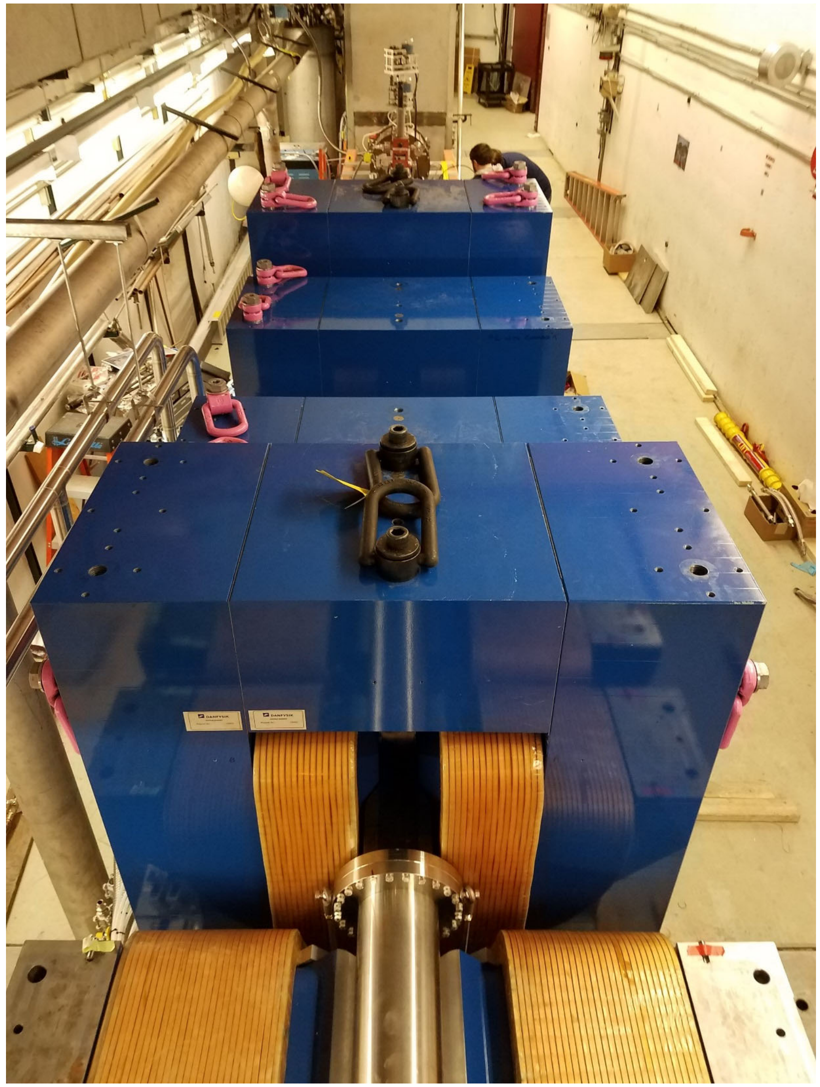

VERSA-LIFT

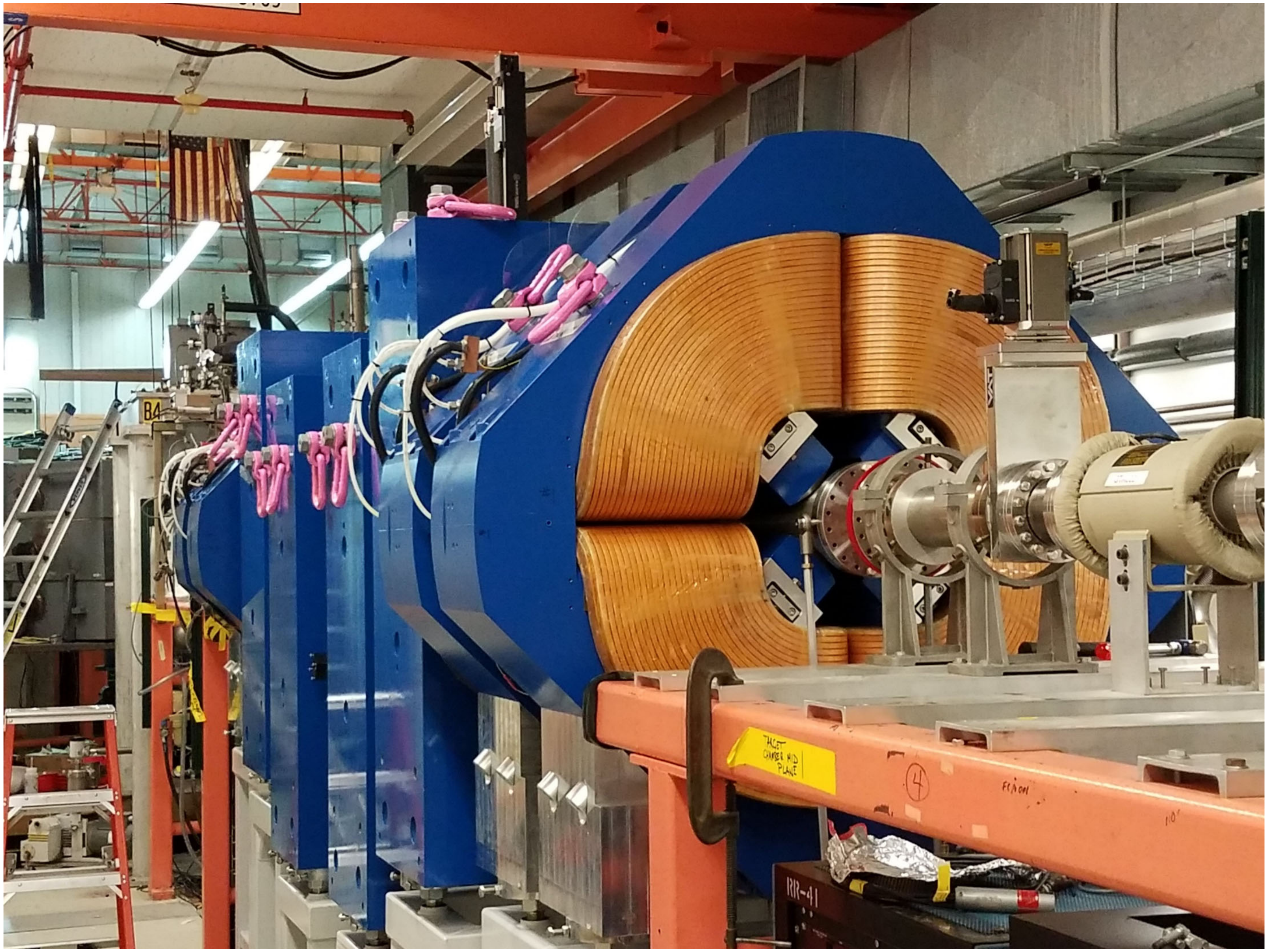

EXIT
B4


B4
RR-41


MILWAUKEE
CAP. 5 TON SN. 5705
B4
DANFYSIK
DANFYSIK

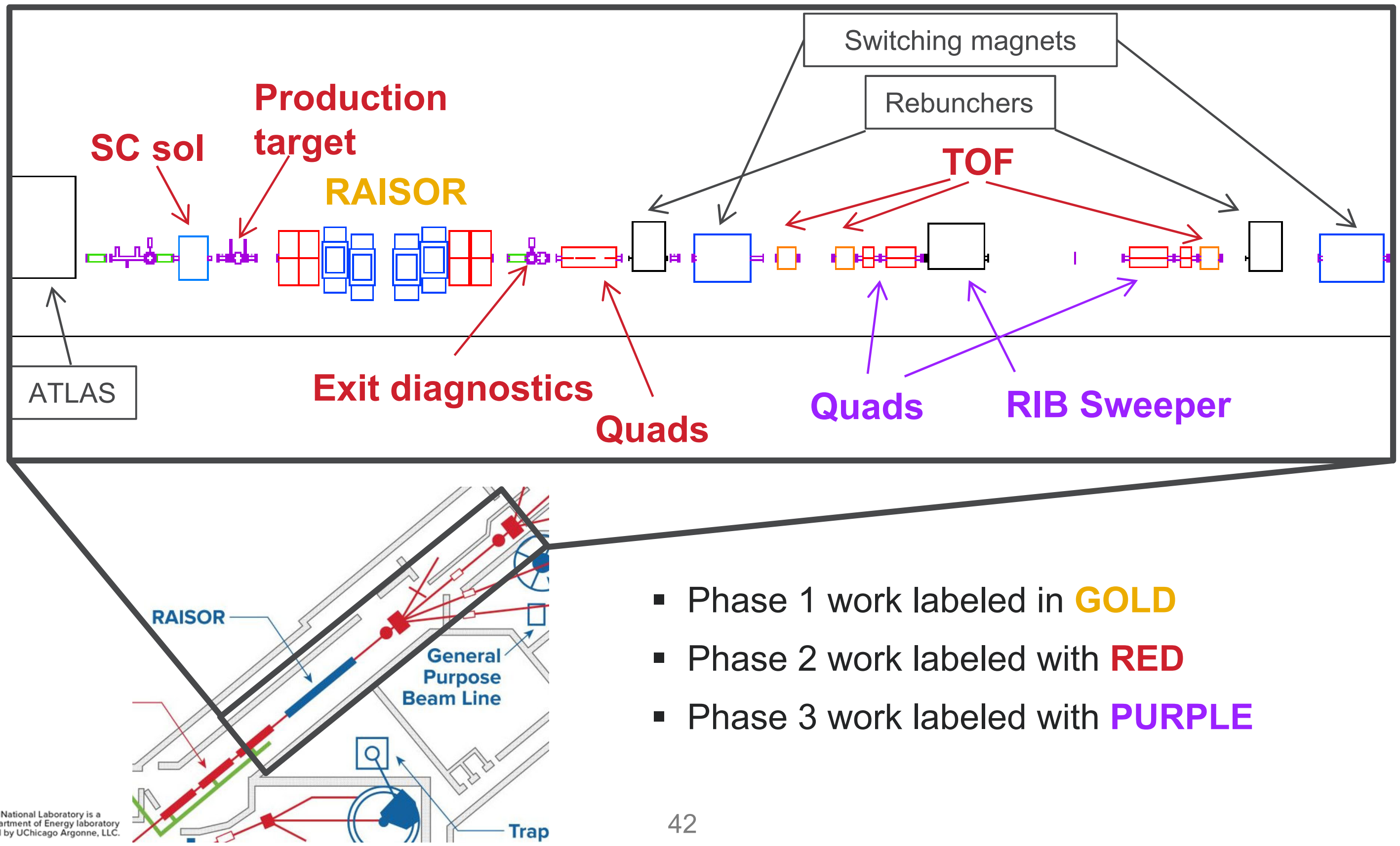






TARGET CHAMBER MID PLANE
B4
RR-41
4

RAISOR FULL BEAMLINE RECONFIGURATION



- Phase 1 work labeled in **GOLD**
- Phase 2 work labeled with **RED**
- Phase 3 work labeled with **PURPLE**

COMMISSIONING

COMMISSIONING

Goals and timeline

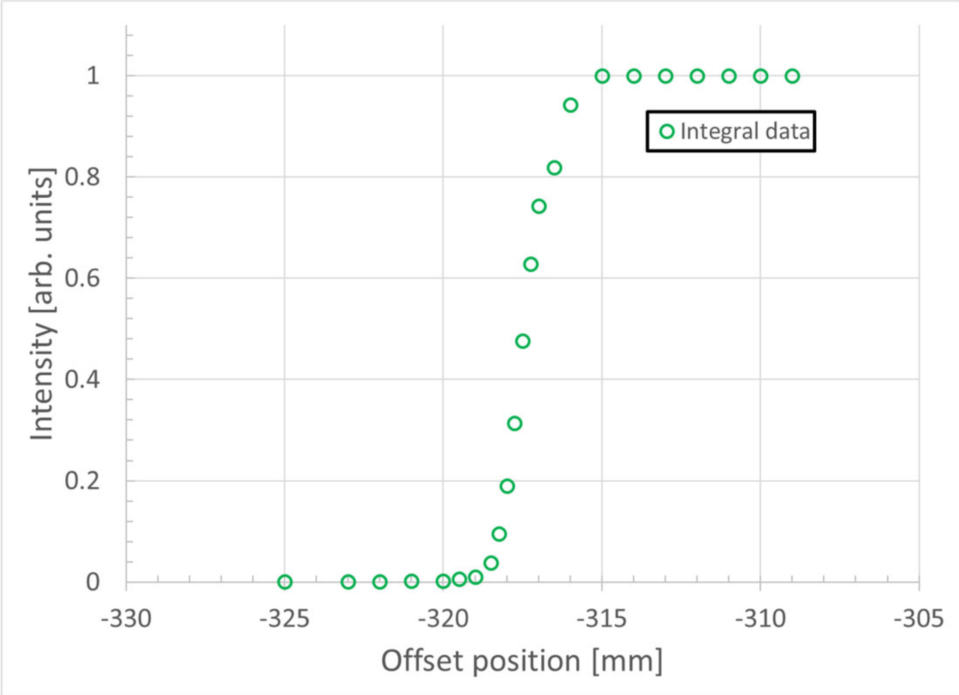
- Use of quadrupoles only to transport beam straight through RAISOR – March 2018
- Primary beam deflected through chicane and transported to target – July 2018
- Secondary beam production tests
  - ^{19}O – July 2018
  - ^{16}C, ^{17}N, ^{20}O – October 2018

CONFIGURATION STEPS

- Identify the nominal trajectory
  - Eventual path of **primary** has to intercept a midplane slit not the vacuum chamber
- Measure TOF beam energy with and without target in place → target thickness
- Tune stable primary beam through chicane to exit
- Scale all magnets for secondary beam based on measured target thickness and reaction kinematics simulations (LISE++)

PRIMARY BEAM TUNING AT THE MIDPLANE

Basic slit scan



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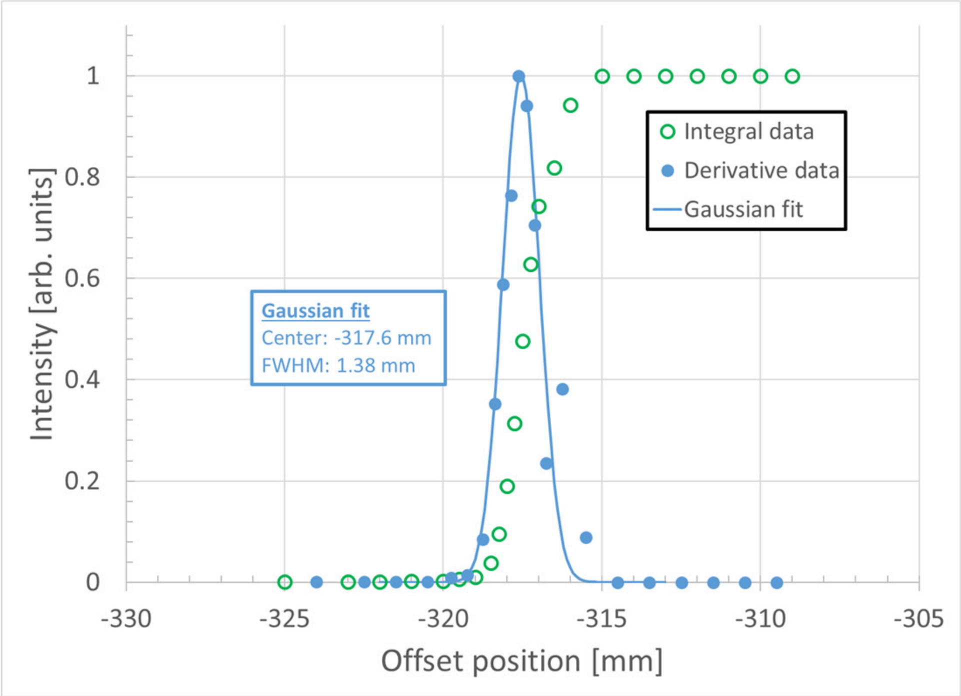

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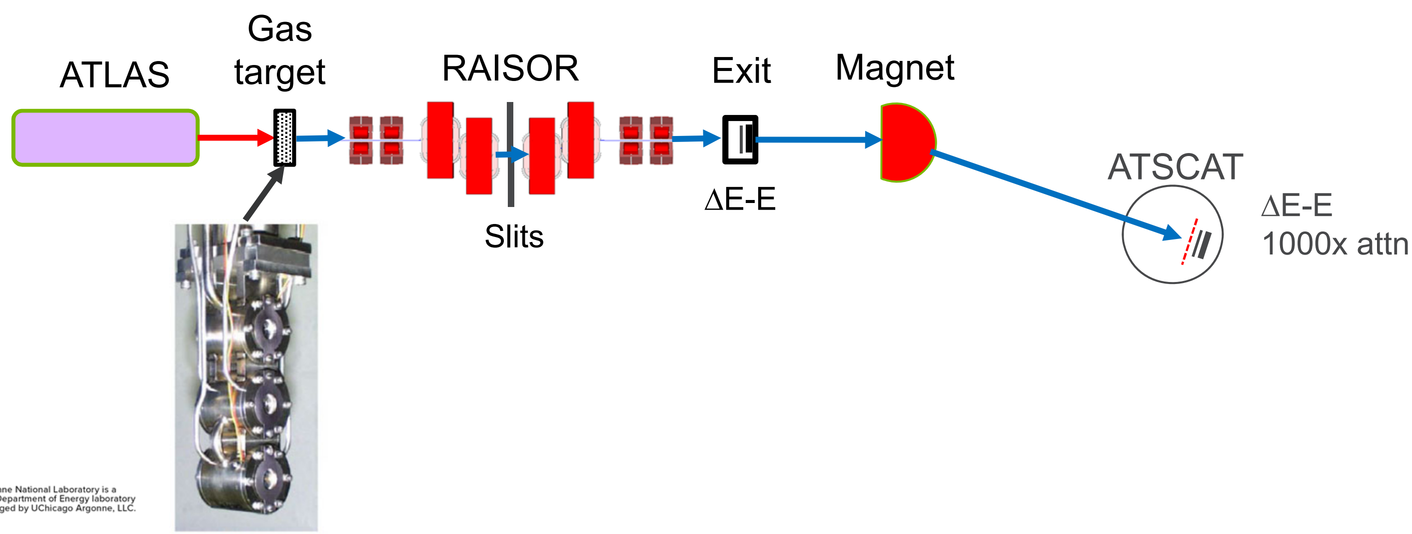
COMMISSIONING RUN

Secondary beam production

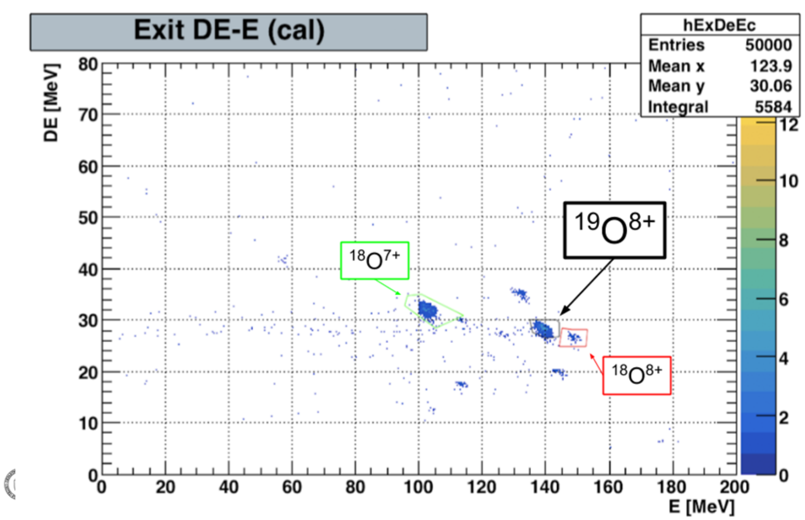
- Primary beam ^{18}O at 180 MeV
- Target: D_2 gas at 1.4 bar and 22 C (0.9 mg/cm^2)
- Secondary beam production goals: ^{19}O at 2×10^5 ions/s and 50% purity



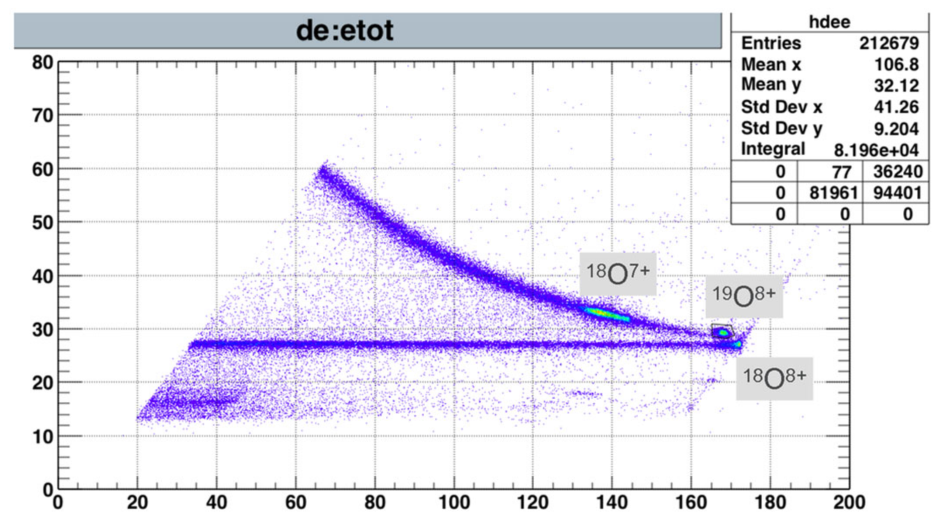
COMMISSIONING RESULTS

- $^{18}O^{5+}$ – 45 pnA
- $^{19}O^{8+}$ – 2x10^5 pps ✔
- Purity – 55% ✔

Low intensity identification

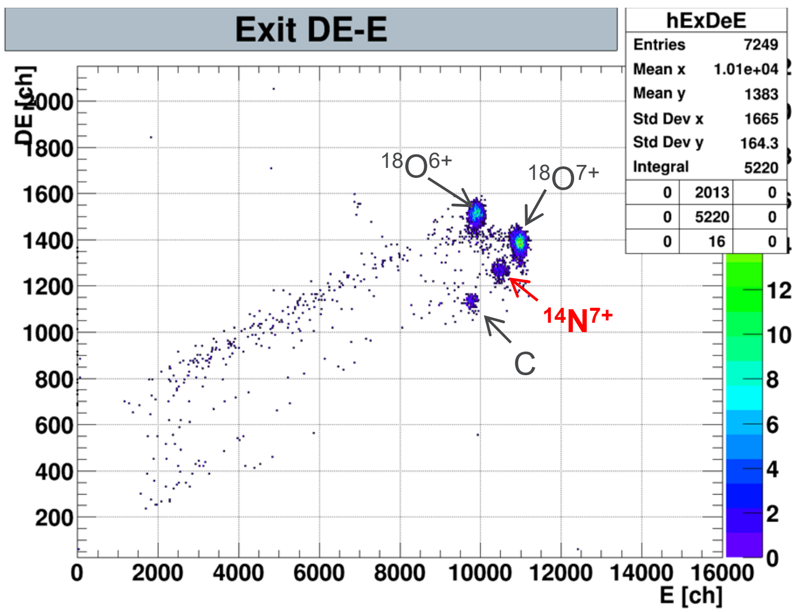


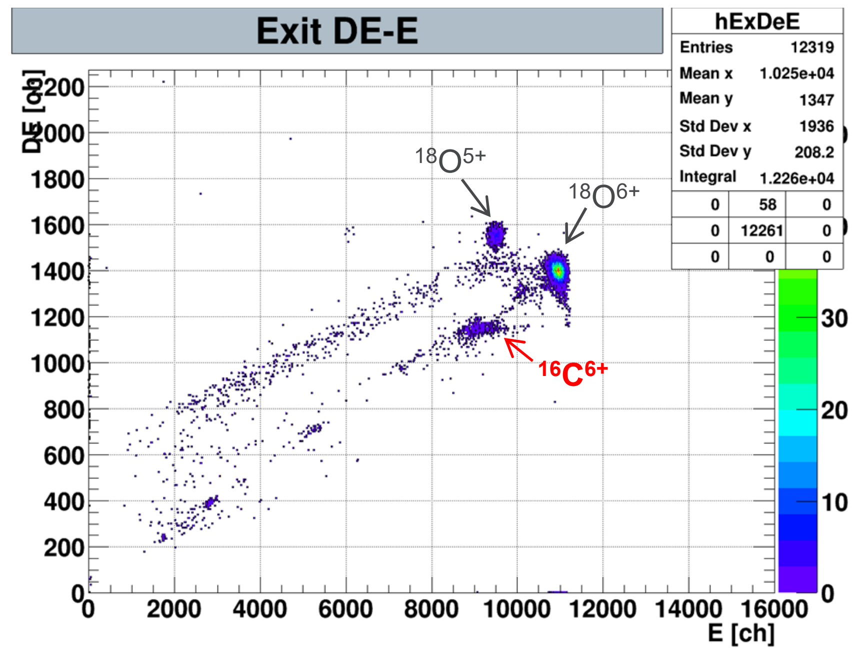
High intensity production



OTHER REACTIONS STUDIED

- ^{18}O [264 MeV] (^{9}Be,^{11}C) **^{16}C**
- ^{18}O [264 MeV] (^{9}Be,^{10}B) **^{17}N**
- ^{18}O [264 MeV] (^{18}O,^{16}O) **^{20}O**





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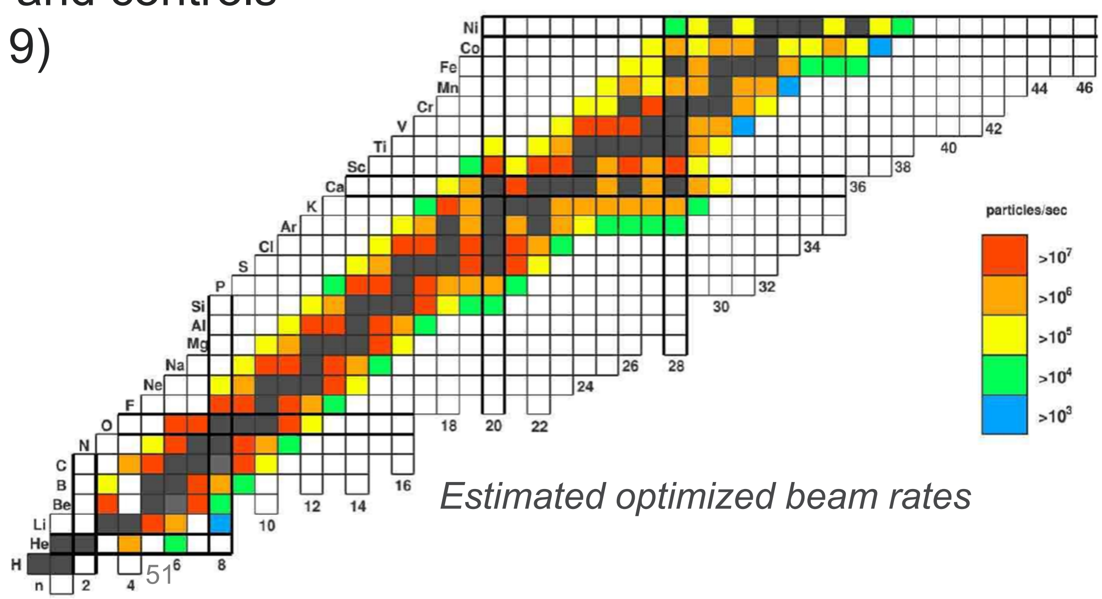
CLOSING REMARKS

- RAISOR is working as expected
- We are preparing for 2 physics experiments in spring 2019
- Future improvements
  - Improve tuning, diagnostics, and controls
  - Install phase 3 (January 2019)
    - High purity
    - High transport efficiency
  - Develop high power targets



Estimated optimized beam rates

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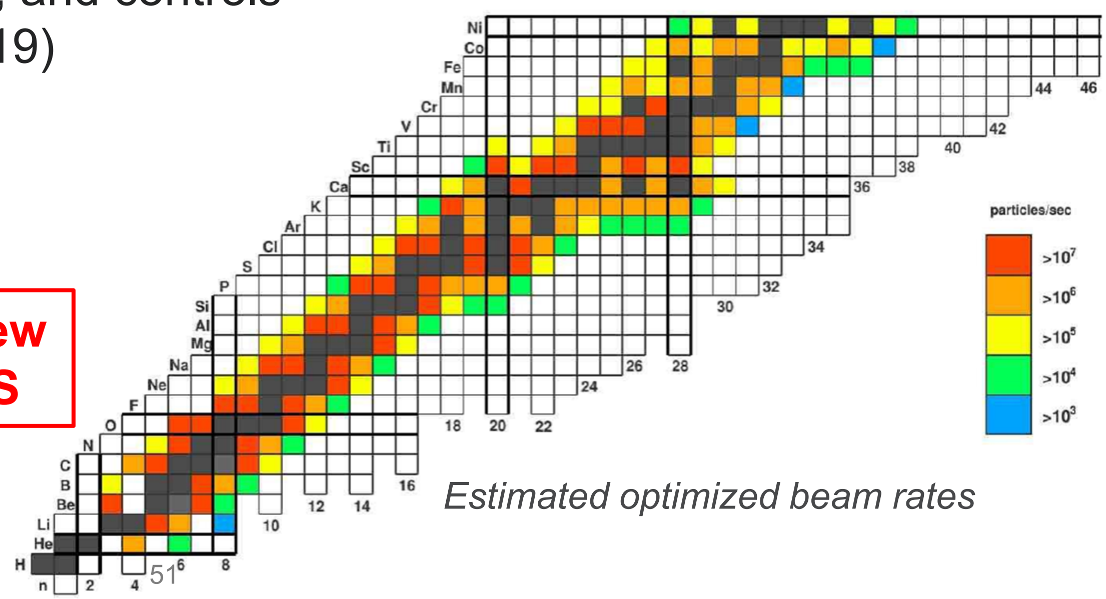
Develop and deliver exciting new radioactive ion beams at ATLAS



Estimated optimized beam rates


THANK YOU!