

CHARACTERISTICS OF AVAILABLE AND EXPECTED IN-FLIGHT BEAMS WITH RAISOR

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OUTLINE OF THE PRESENTATION

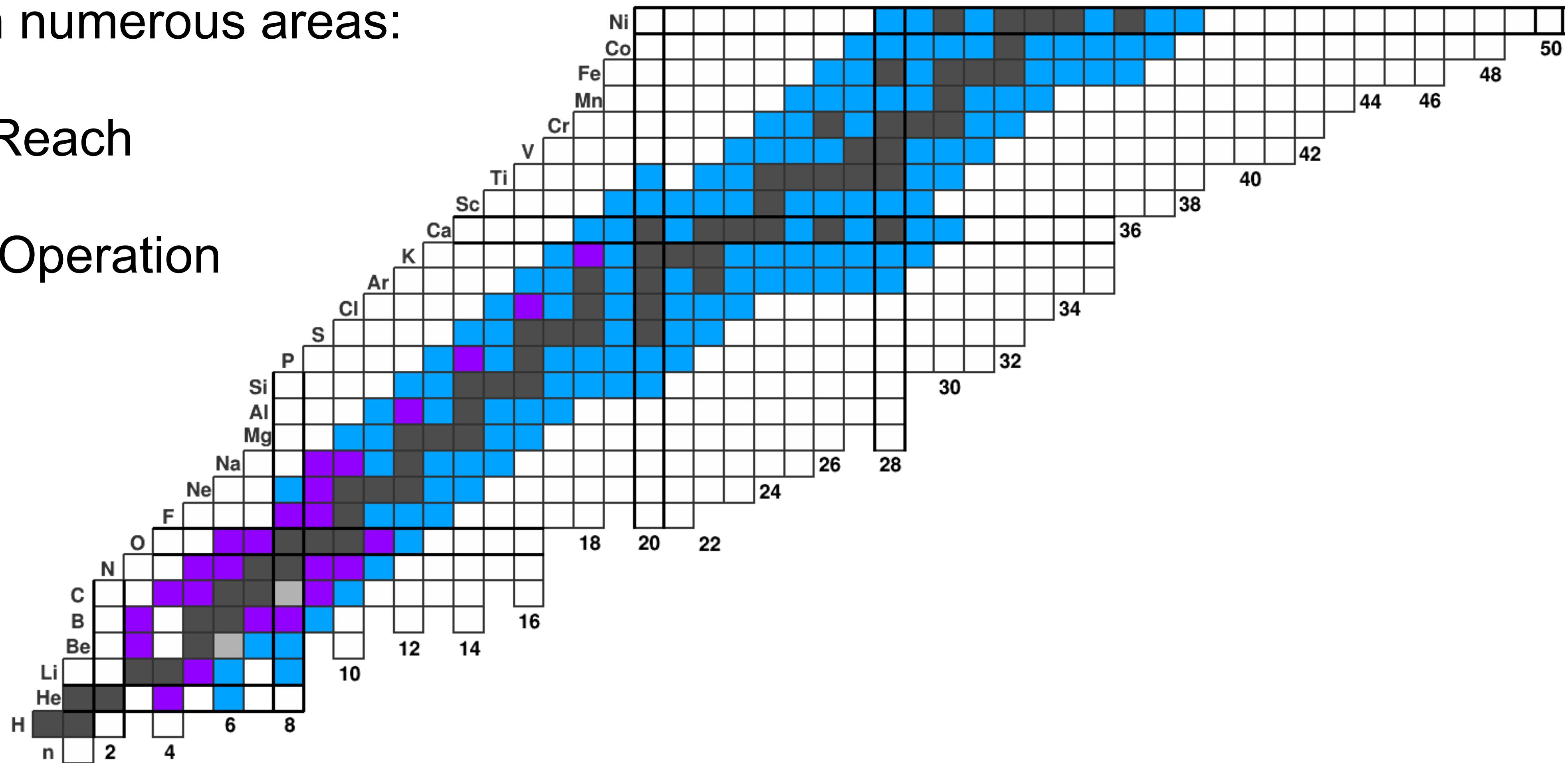
- RAISOR PRACTICALS - NAME, DESIGN, IMPLEMENTATION, PROCEDURAL
- RECENT RESULTS AND ACHIEVEMENTS
- FUTURE DIRECTIONS - HOW TO INCLUDE INPUT

UPGRADING THE ATLAS IN-FLIGHT CAPABILITIES

Leverage past experience & successes

Improvement in numerous areas:

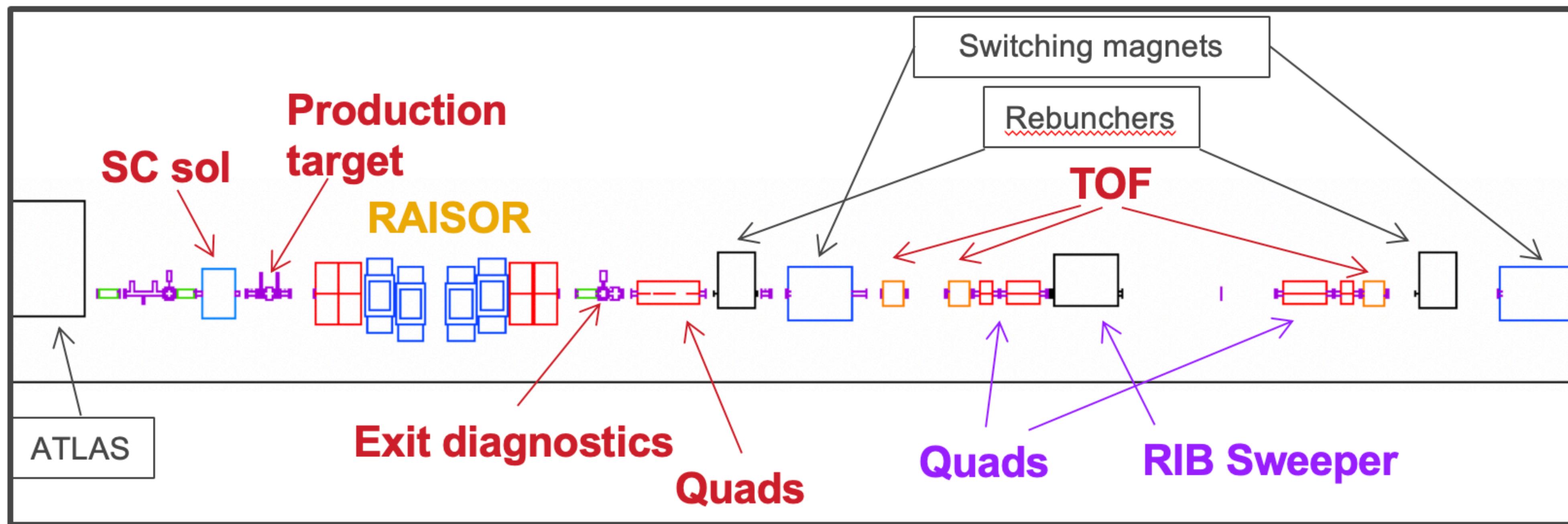
- Intensity
- Selectivity & Reach
- Accessibility
- Integration & Operation



RAISOR LAYOUT AND FEATURES

Multiple key design features considered

- Achromatic magnetic chicane
 - Momentum selection & stopping of primary beam current
- RF Sweeper / rebunchers
 - Further beam purification through velocity selection
- Upstream of all high-energy experimental areas

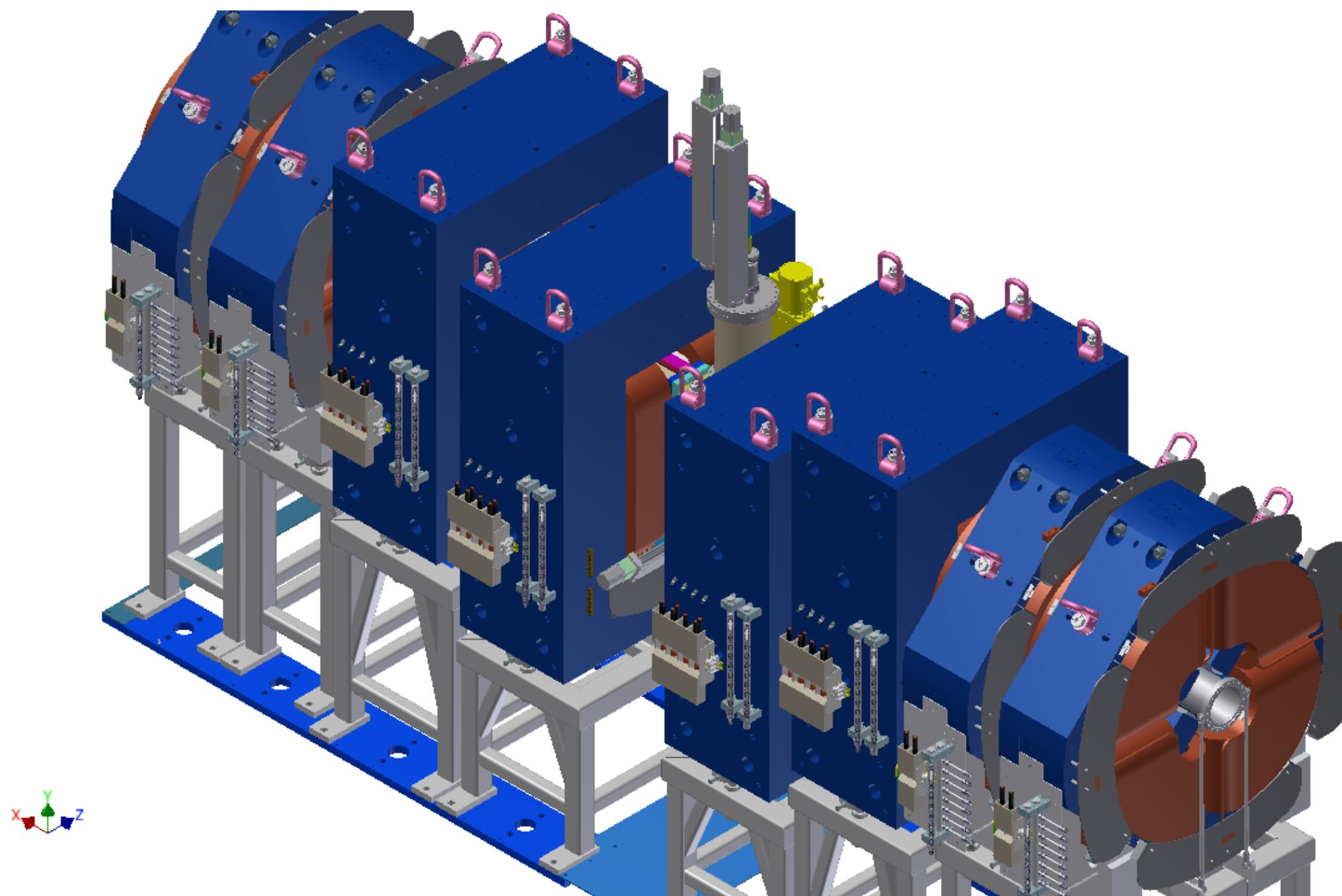


RAISOR LAYOUT AND FEATURES

Multiple key design features considered

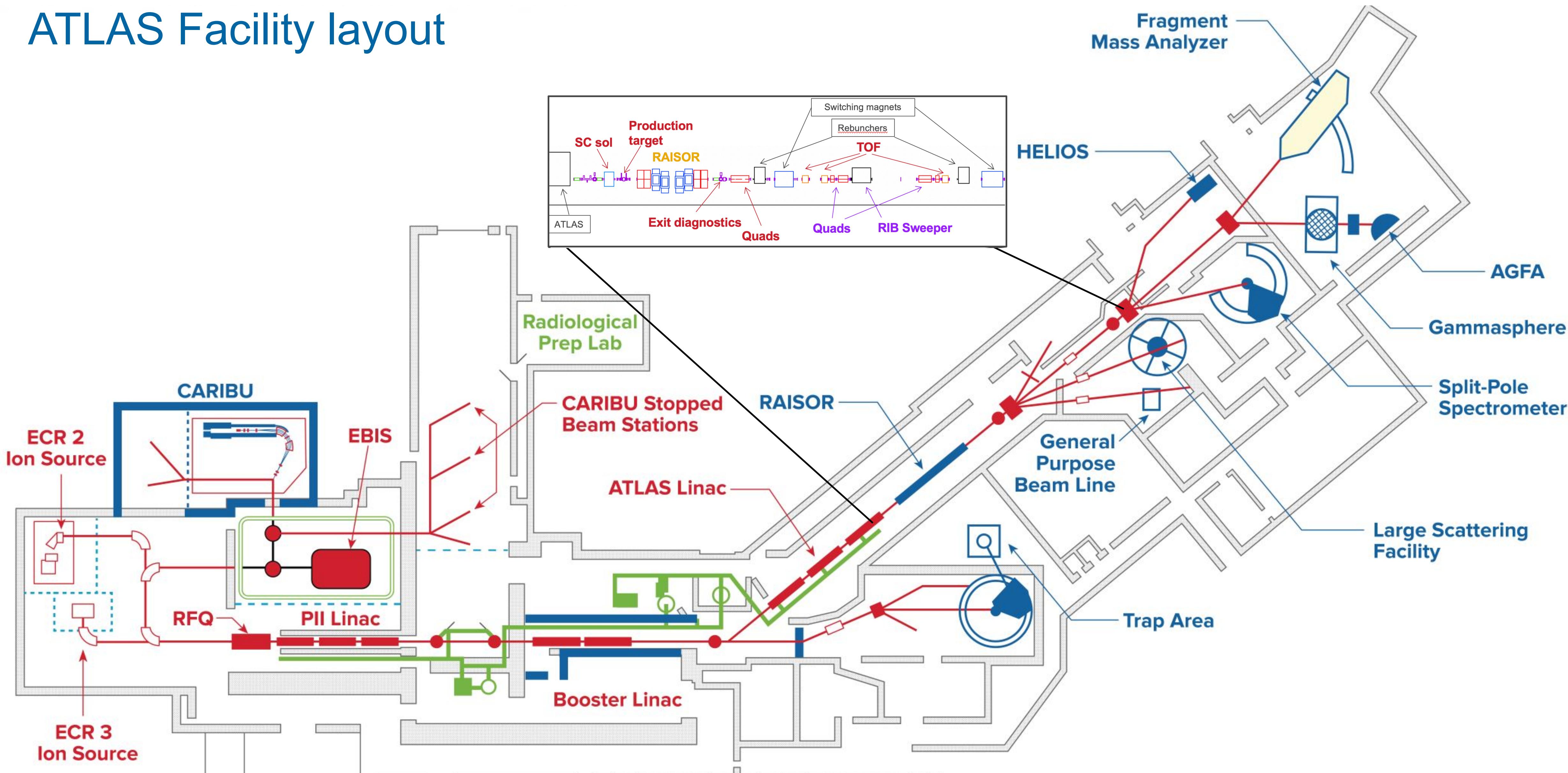
- Achromatic magnetic chicane
 - Momentum selection & stopping of primary beam current
- RF Sweeper / rebunchers
 - Further beam purification through velocity selection
- Upstream of all high-energy experimental areas

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



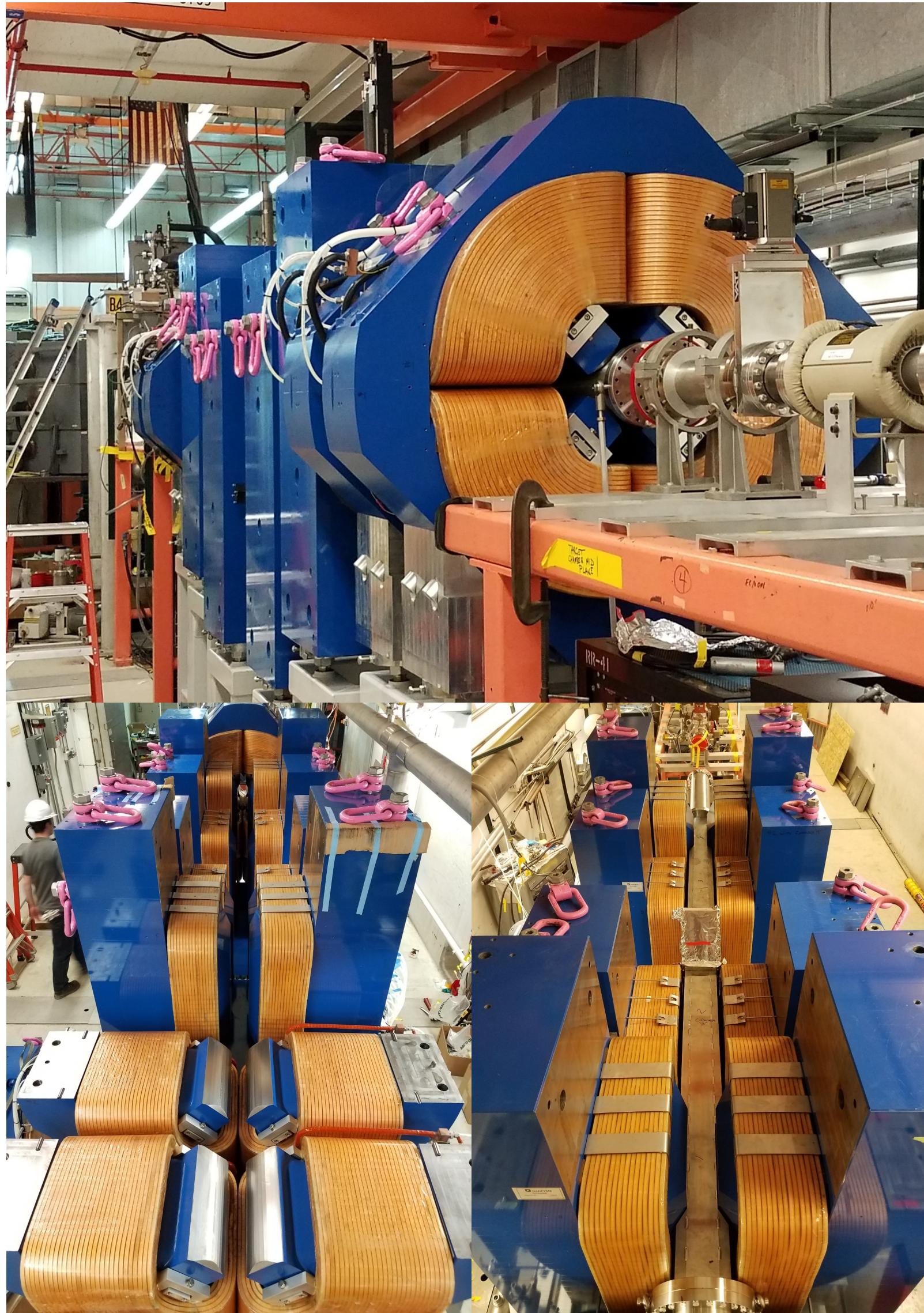
RAISOR LAYOUT AND FEATURES

ATLAS Facility layout

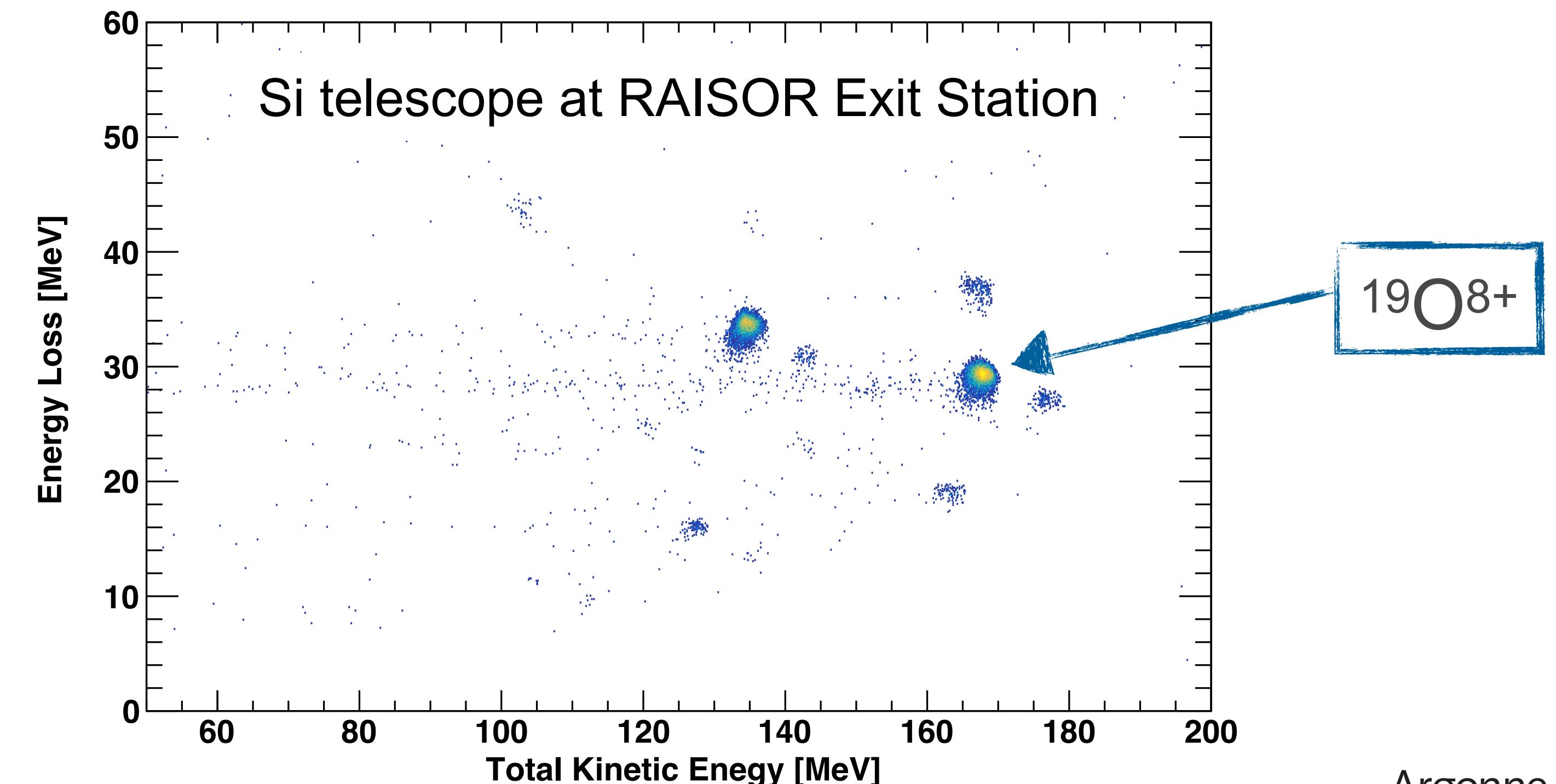


RAISOR COMMISSIONING AND OPERATING PRINCIPLES

AIRIS project complete fall 2018, RAISOR operating since Dec. 2018

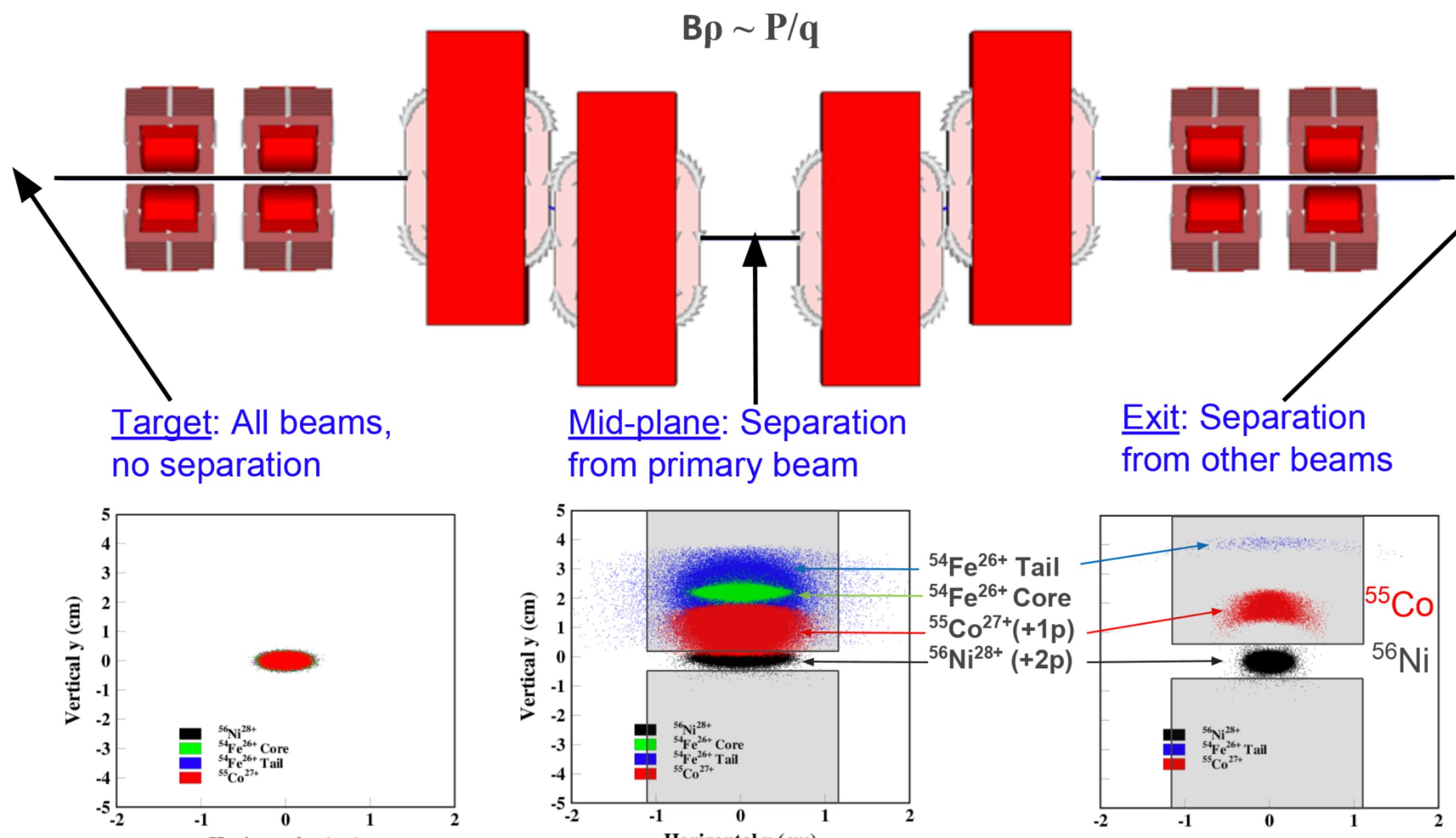


- 1) Stable beam passes through un-abated
- 2) Bending of stable beam
- 3) Production / delivery of an $^{19}\text{O}^{8+}$ secondary beam w/ proper characteristics

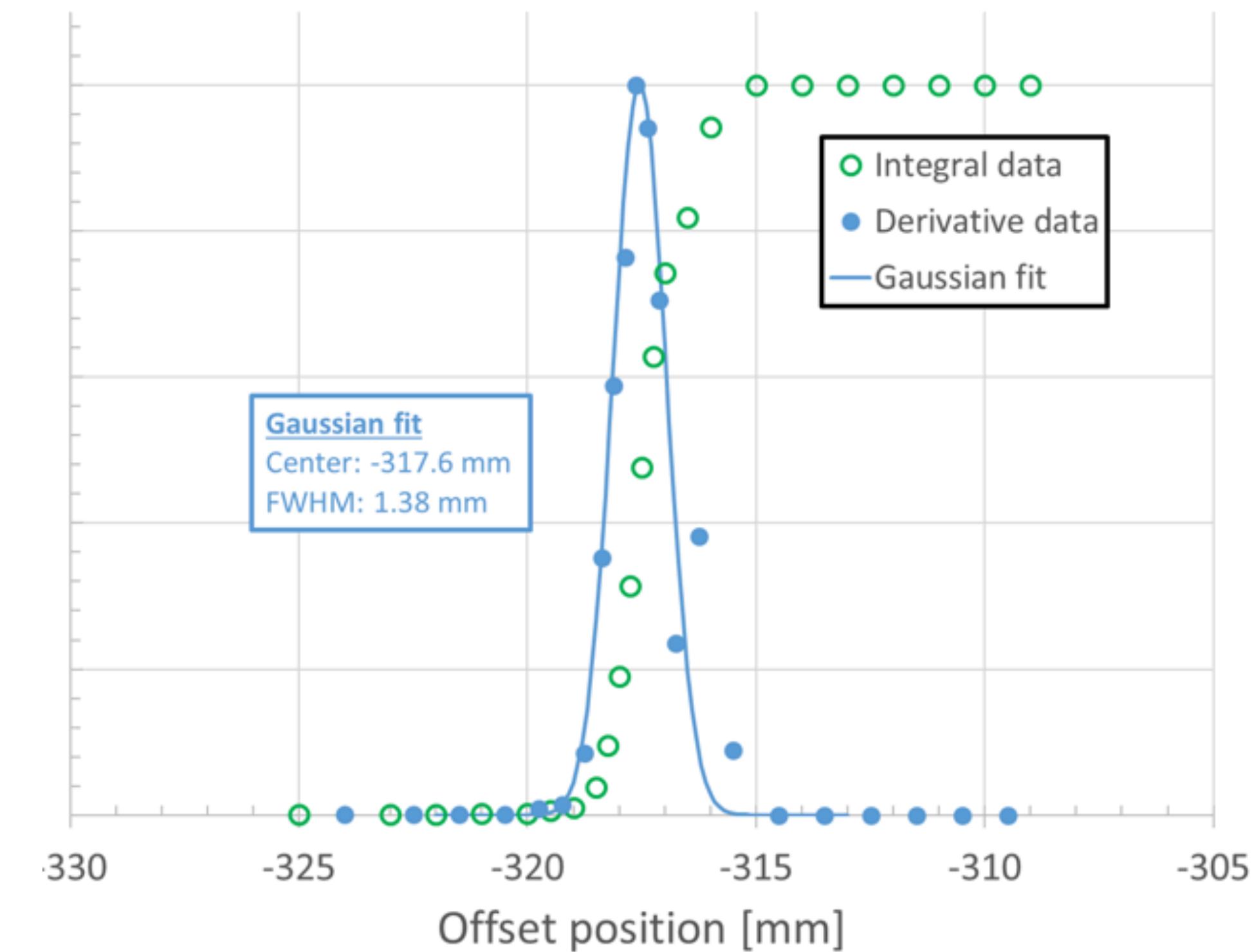


OPERATING PRINCIPLES

Scan beam at the mid plane, vertical slits block primary beam



$^{18}\text{O}^{8+}$ dispersive plane beam scan at the midplane



OPERATING PRINCIPLES

Use of the RF Sweeper to further clean the secondary beams

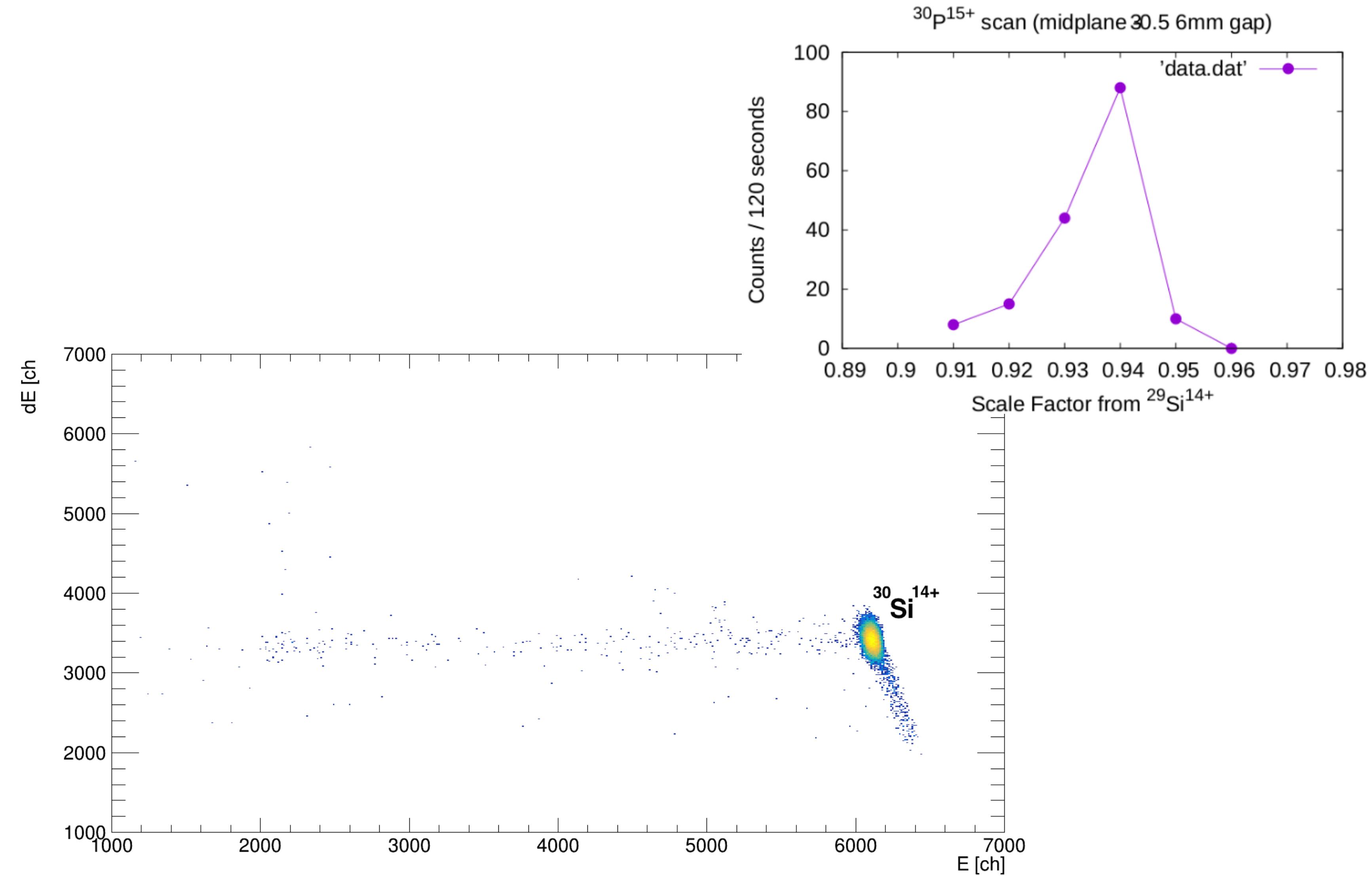
$^{18}\text{O}^{8+}$ beam at RAISOR focal plane

$^{18}\text{O}^{8+}$ beam after RF Sweeper

RF Sweeper Parameters		
Electrode length	1	m
Frequency	6.0625	MHz
Maximum Voltage	70	kV

TOOLS FOR IDENTIFICATION / DELIVERY OF IN-FLIGHT BEAMS

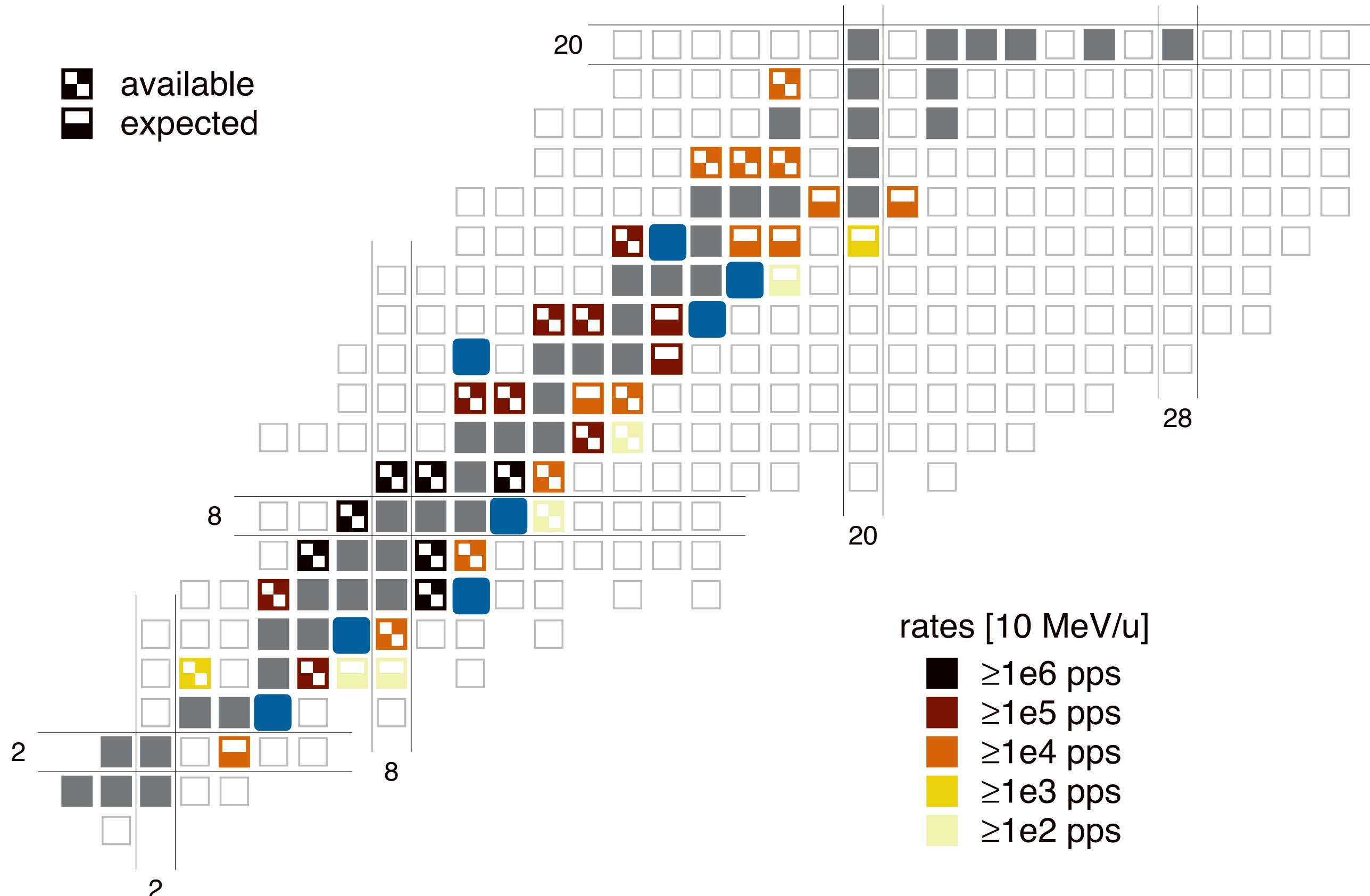
Development & implementation of tools



IN-FLIGHT BEAMS PRODUCED IN CY19

Eight beams & six completed experiments ranging from Li to P

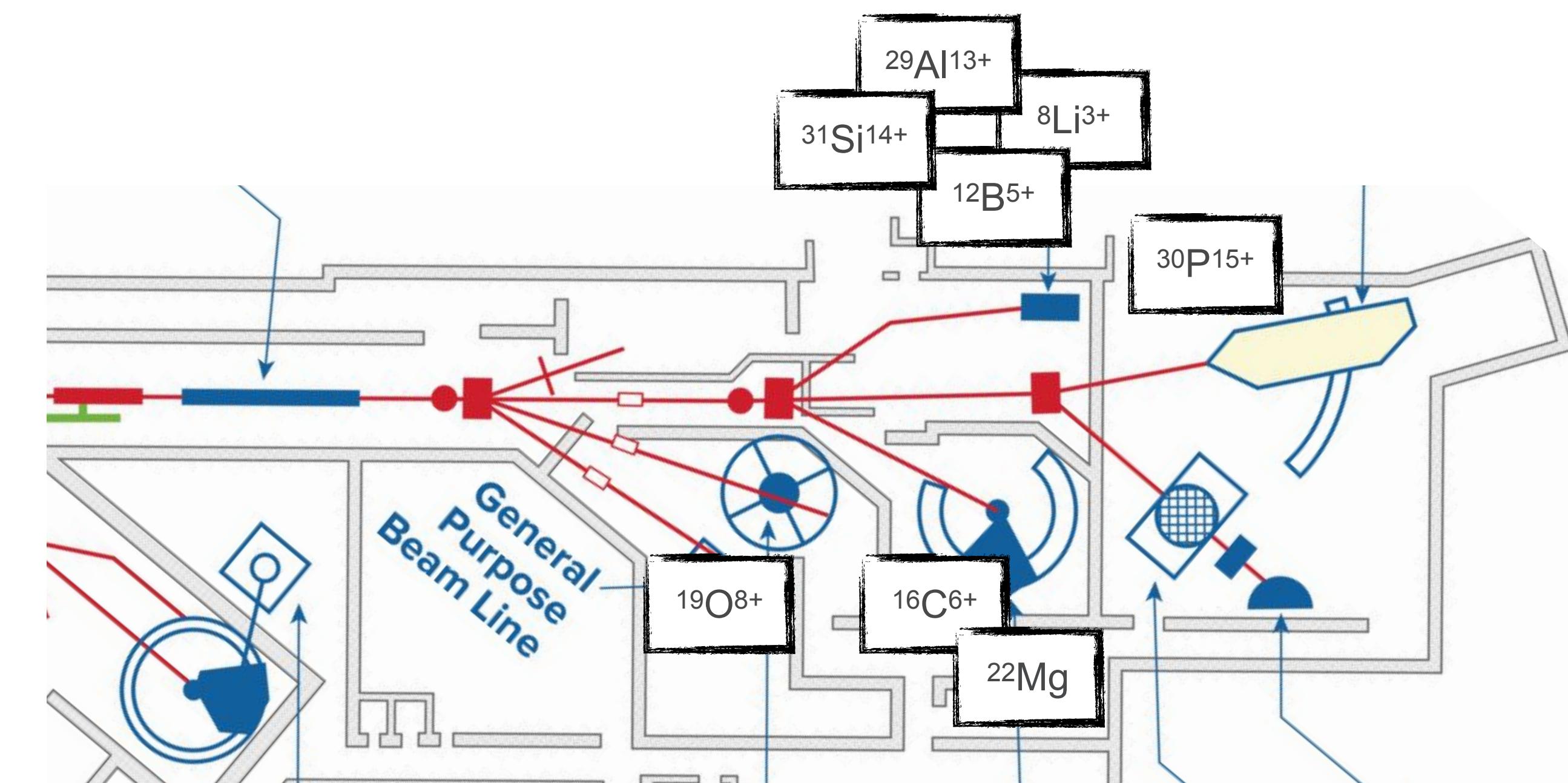
- $^{19}\text{O}^{8+}$ - commissioning measurement at ATSCAT
- $^{16}\text{C}^{6+}$ - Fusion cross sections @ MUSIC [LSU (Hood) / ANL]
- $^{30}\text{P}^{15+}$ - $^{30}\text{P}(\text{d},\text{p})$ with GODDESS [ORNL (Pain)]
- $^{12}\text{B}^{5+}$ - $^{12}\text{B}(\text{t},\text{p})$ @ HELIOS - UCONN (Wuosmaa)
- $^8\text{Li}^{3+}$ - $^8\text{Li}(\text{t},\text{p})$ @ HELIOS - UCONN (Wuosmaa)
- $^{31}\text{Si}^{14+}$ - $^{31}\text{Si}(\text{d},\text{p})$ @ HELIOS - LSU/ANL (Wilson)
- ^{22}Mg - Development of a ^{22}Mg beam at $\sim 50 - 60$ MeV @ MUSIC - ANL (Avila)
- $^{29}\text{Al}^{13+}$ - $^{29}\text{Al}(\text{d},\text{p})$ @ HELIOS - Manchester (Sharp)



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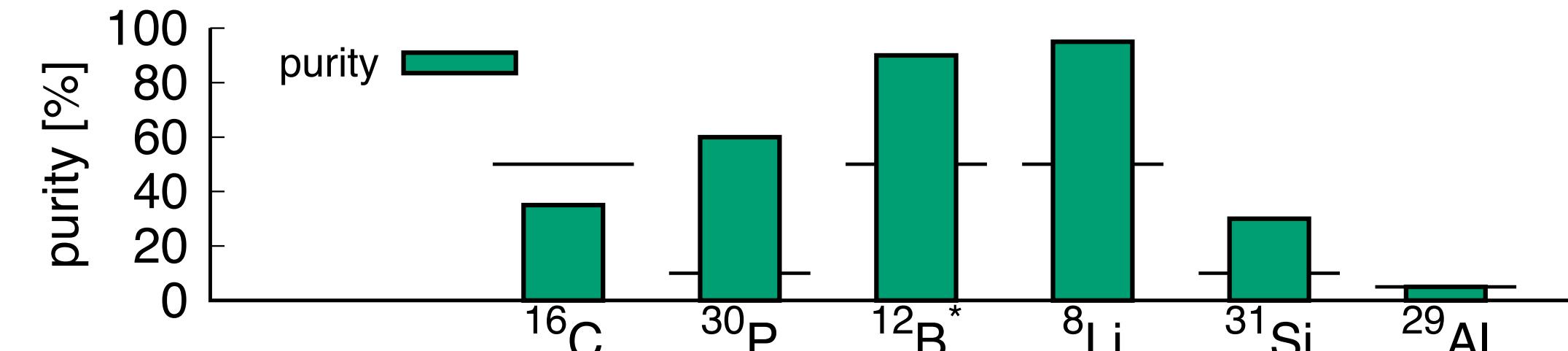
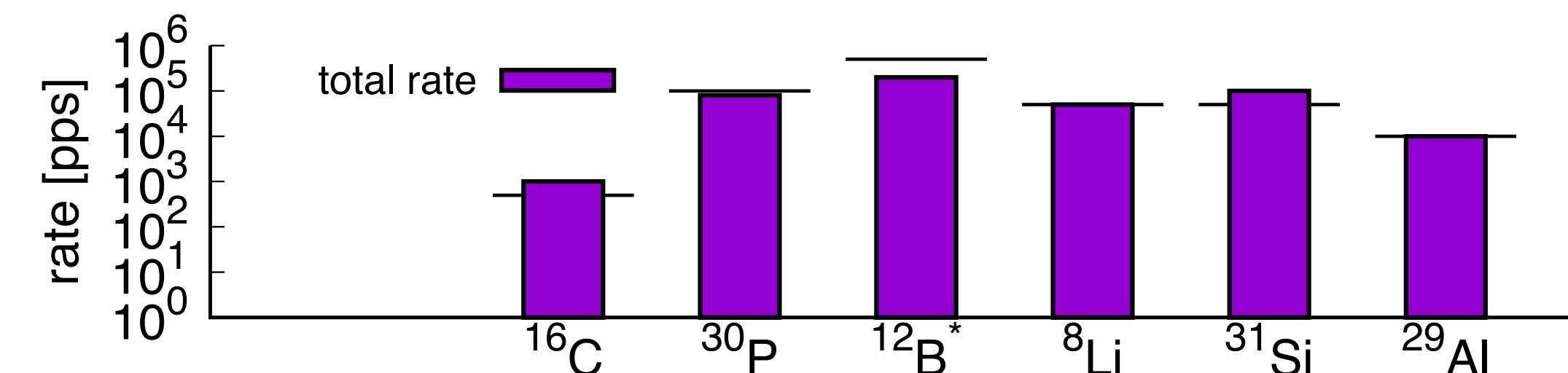
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- ^{22}Mg - Development of a ^{22}Mg beam at ~50 - 60 MeV @ MUSIC - ANL (Avila)
- $^{29}\text{Al}^{13+}$ - $^{29}\text{Al}(\text{d},\text{p})$ @ HELIOS - Manchester (Sharp)



SUMMARY OF BEAMS PRODUCED / DELIVERED

Eight beams & six completed experiments ranging from Li to P

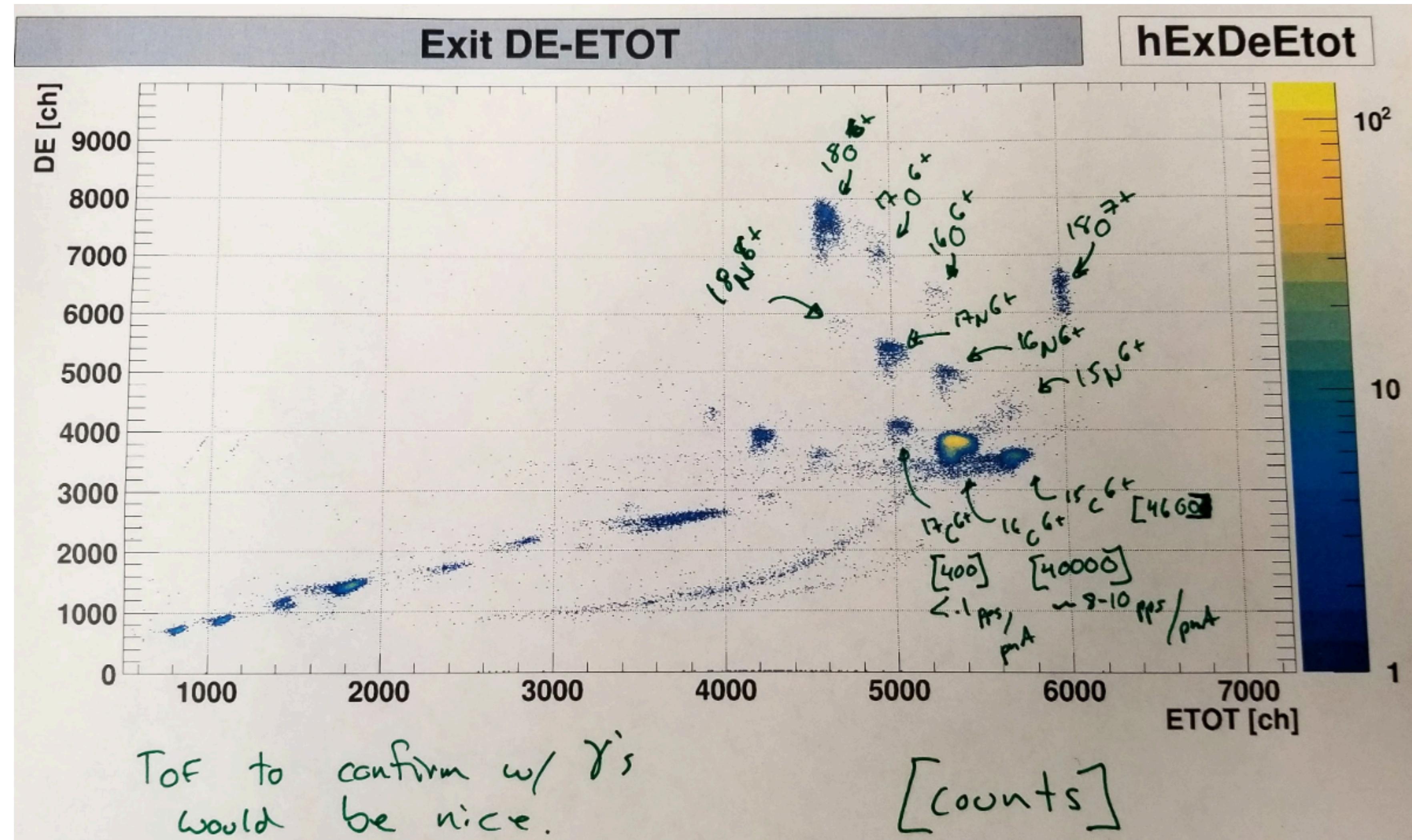
Beam	Energy [MeV/u]	Rate [pps]	Purity [%]	Reaction	Primary beam intensity [pnA]	Target	Spot size [fwhm]
$^{19}\text{O}^{8+}$	8.8	2E+05	60	$^{18}\text{O}(\text{d},\text{p})$	50	Warm D ₂ gas	<6 mm
$^{16}\text{C}^{6+}$	14.0	1E+03	35	$^{18}\text{O}(\text{Be}^9, -2\text{p})$	150	12 mg/cm ² Be	<7 mm
$^{30}\text{P}^{15+}$	8.3	8E+04	60	$^{29}\text{Si}(\text{d},\text{n})$	40	Cold D ₂ gas	~5 mm
$^{12}\text{B}^{5+}$	7.2	2E+05	90	$^{11}\text{B}(\text{d},\text{p})$	200	Cold D ₂ gas	<8 mm
$^8\text{Li}^{3+}$	9.2	5E+04	95	$^7\text{Li}(\text{d},\text{p})$	150	Cold D ₂ gas	< 8 mm
$^{31}\text{Si}^{14+}$	10.0	1E+05	30	$^{30}\text{Si}(\text{d},\text{p})$	20	Cold D ₂ gas	< 8 mm
$^{22}\text{Mg}^{11+}$	2.7	1E+03*	-	$^{20}\text{Ne}(\text{He}^3, \text{n})$	100*	Warm ^3He gas	-
$^{29}\text{Al}^{13+}$	10.7	1.5E+04	5	$^{30}\text{Si}(\text{Be}^9, -1\text{p})$	120	4 mg/cm ² Be	< 8 mm



CHARACTERISTICS OF BEAMS PRODUCED BY RAISER

Eight beams & six completed experiments ranging from Li to P

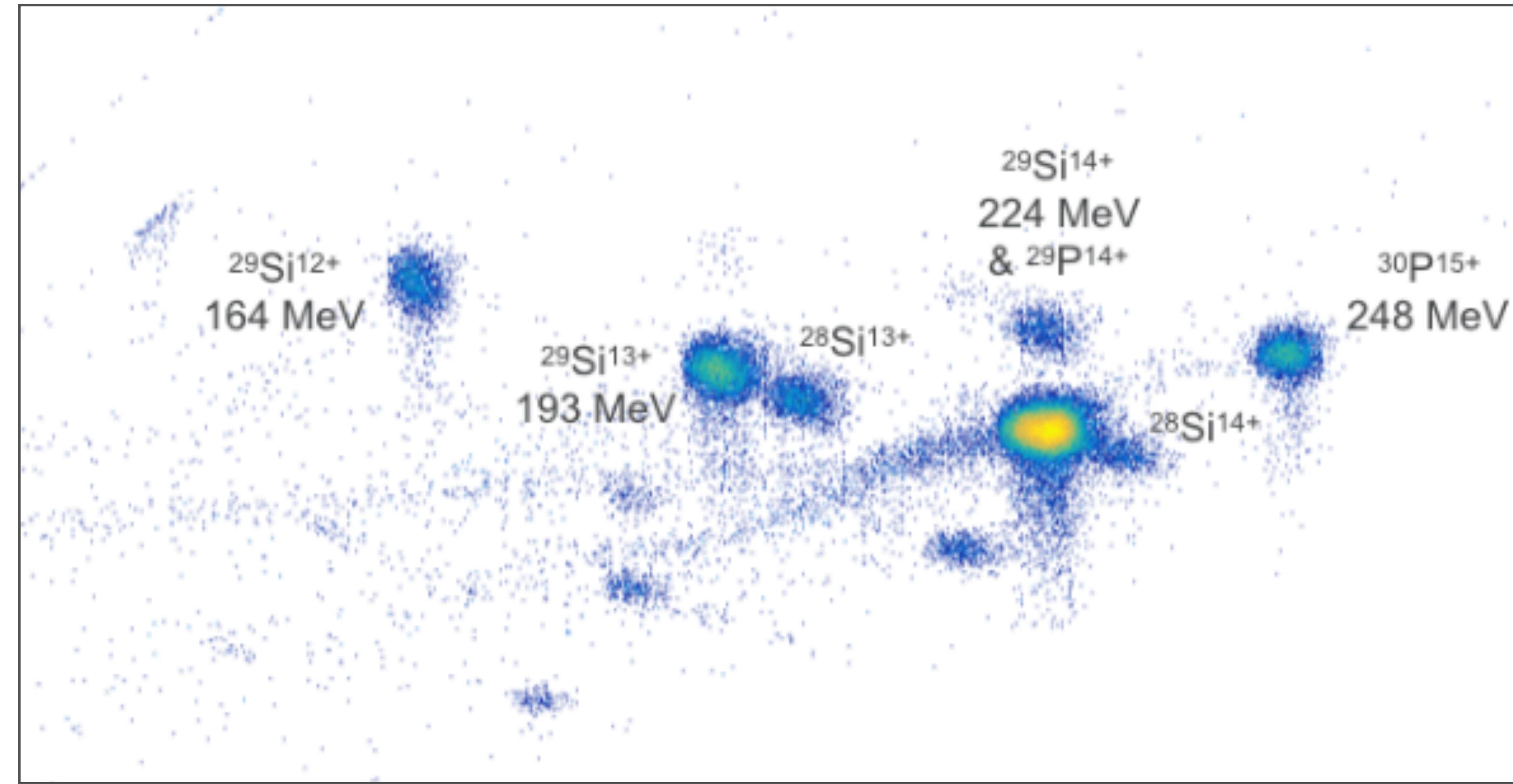
- 16C6+
-



CHARACTERISTICS OF BEAMS PRODUCED BY RAISER

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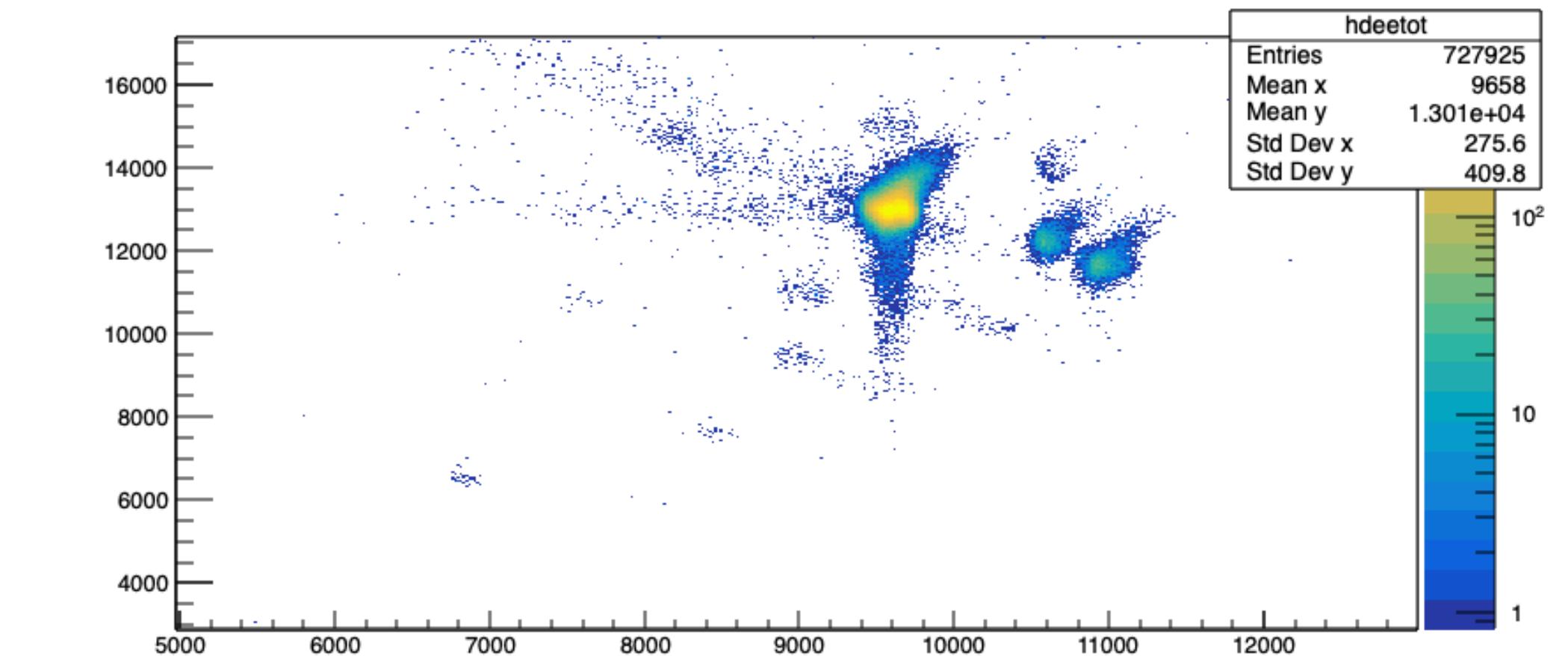
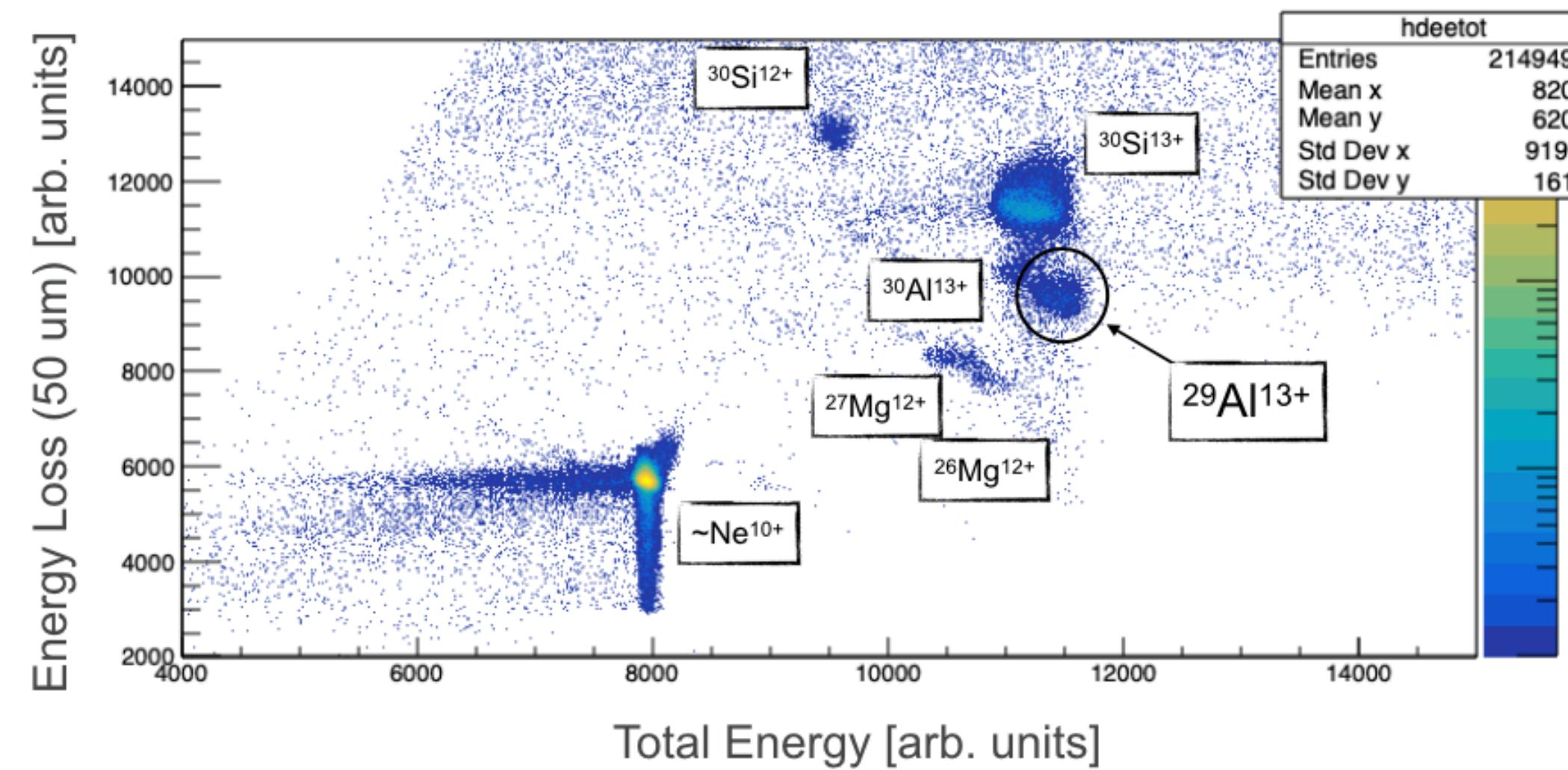
- 30P15+



CHARACTERISTICS OF BEAMS PRODUCED BY RAISER

Eight beams & six completed experiments ranging from Li to P

- 29Al13+ / 31Si14+



CHARACTERISTICS OF BEAMS PRODUCED BY RAISER

Eight beams & six completed experiments ranging from Li to P

- $^{22}\text{Mg}^{12+}$

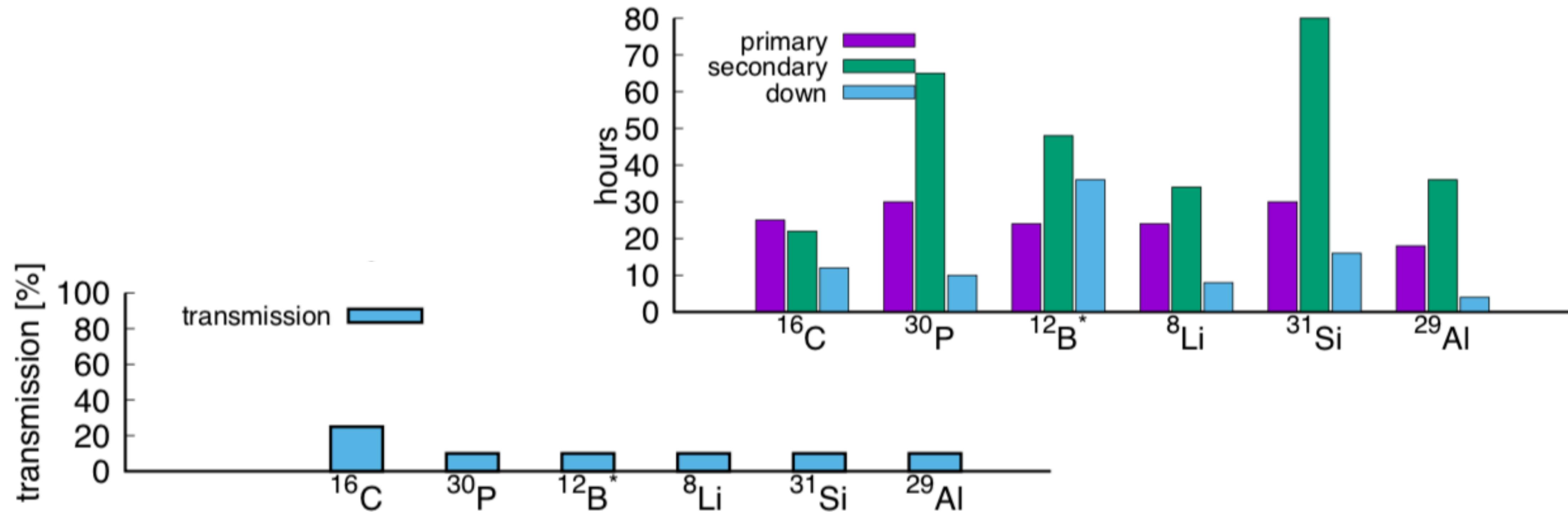
SUMMARIZING DELIVERED BEAMS

Calendar year 2019

INTO THE NEAR FUTURE

Text

- Increase the number of beams available & strive towards energies / purities demanded by the community
- Evaluate and address current limitations
 - Transmission, delivery times, targets, shielding



INTO THE DISTANT FUTURE

Text

- Text

PRACTICALITIES FOR IN-FLIGHT PROPOSALS

https://www.anl.gov/atlas/inflight-radioactive-beams

CAREERS NEWS EVENTS STAFF DIRECTORY

Argonne NATIONAL LABORATORY

RESEARCH

A searchable table of in-flight radioactive ion beams

Isotope + 1 - 25 / 120 < >

A
Z
N

Rate [pps]
50 2000000

Energy [MeV/u]
2 50

Purity [%]
2 50

Designation +

More actions... ▾

Isotope	Rate [pps]	Energy [MeV/u]	Purity [%]	Designation
6He	1.00E+04	10	5	Expected
6He	2.00E+04	14	5	Expected
8Li	5.00E+04	6	5	Expected
8Li	5.00E+04	10	10	Available
8Li	1.00E+04	14	10	Expected
7Be	1.00E+04	6	10	Expected
7Be	5.00E+03	10	20	Available
7Be	1.00E+03	14	20	Expected
10Be	1.00E+05	6	50	Available
10Be	1.00E+05	10	50	Available
10Be	2.00E+04	14	50	Expected
11Be	2.00E+02	10	50	Expected
11Be	1.00E+03	14	50	Expected
12Be	2.00E+02	10	50	Expected
12Be	1.00E+03	14	50	Expected
12B	2.00E+06	6	20	Available
12B	1.00E+06	10	50	Available
12B	2.00E+05	14	50	Available
13B	2.00E+04	10	20	Available
13B	5.00E+04	14	50	Available
11C	1.00E+06	6	10	Available
11C	5.00E+05	10	20	Available
11C	1.00E+05	14	20	Available
15C	2.00E+06	6	50	Available
15C	1.00E+06	10	50	Available

1 - 25 / 120 < >

ARGONNE TANDEM LINEAR ACCELERATOR SYSTEM

In-Flight (Radioactive) Beams

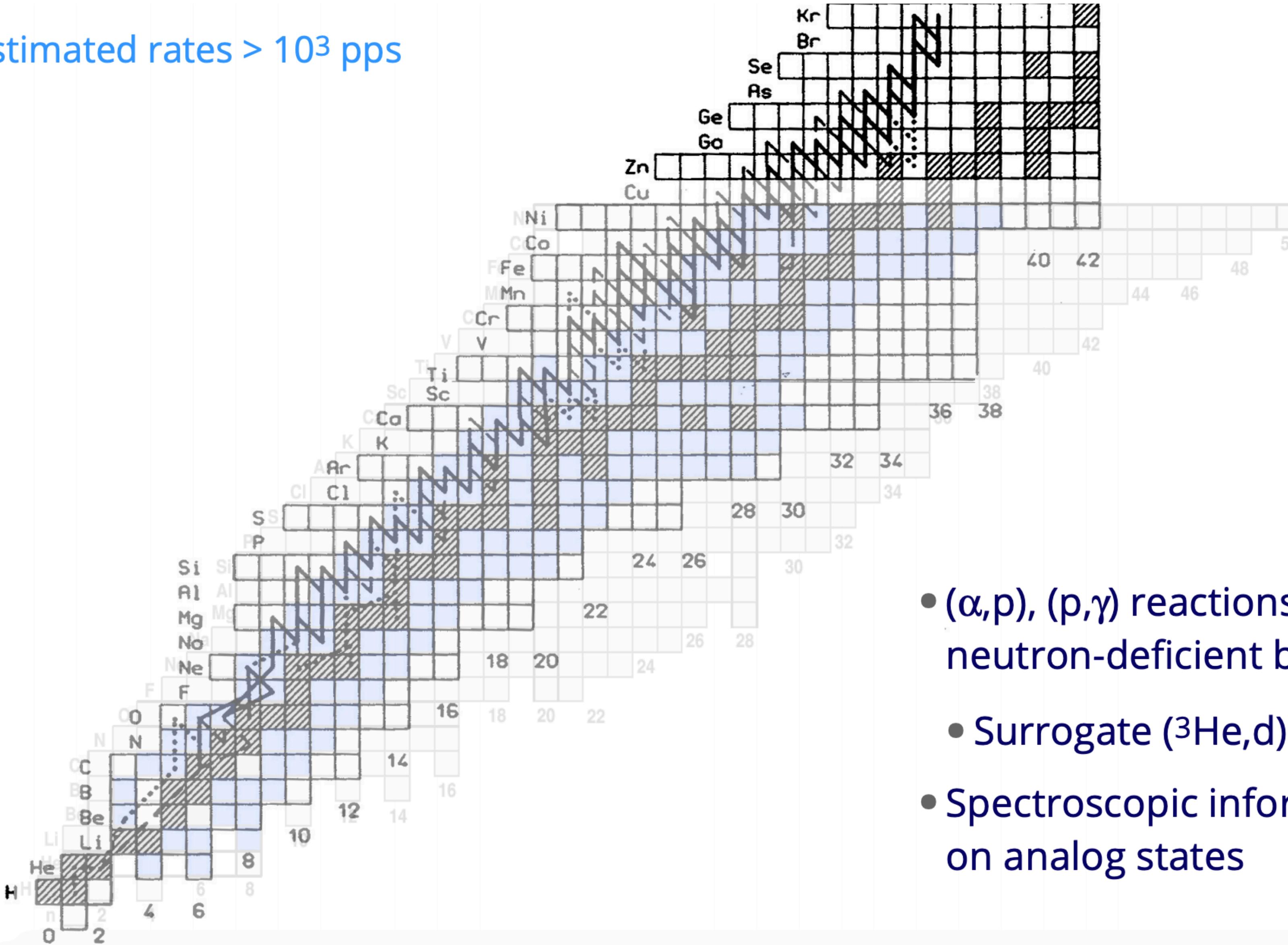
Beam Designations

- **Available** - schedule experiments w/ out developments
- **Expected** - development required before scheduling experiment
- **Absent from list** - development before experiment can be approved

NUCLEAR ASTROPHYSICS OPPORTUNITIES

Available isotopes with ultimate rates $>10^3$ pps

- Estimated rates $> 10^3$ pps



INPUT FOR FUTURE DIRECTION PLANNING

What are the priorities for the auto community

- Species, rates, purity, energies
- ...all the above?

TITLE

Text

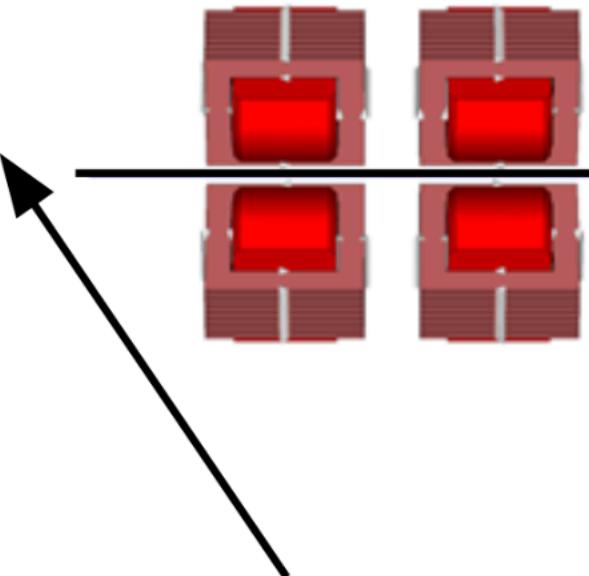
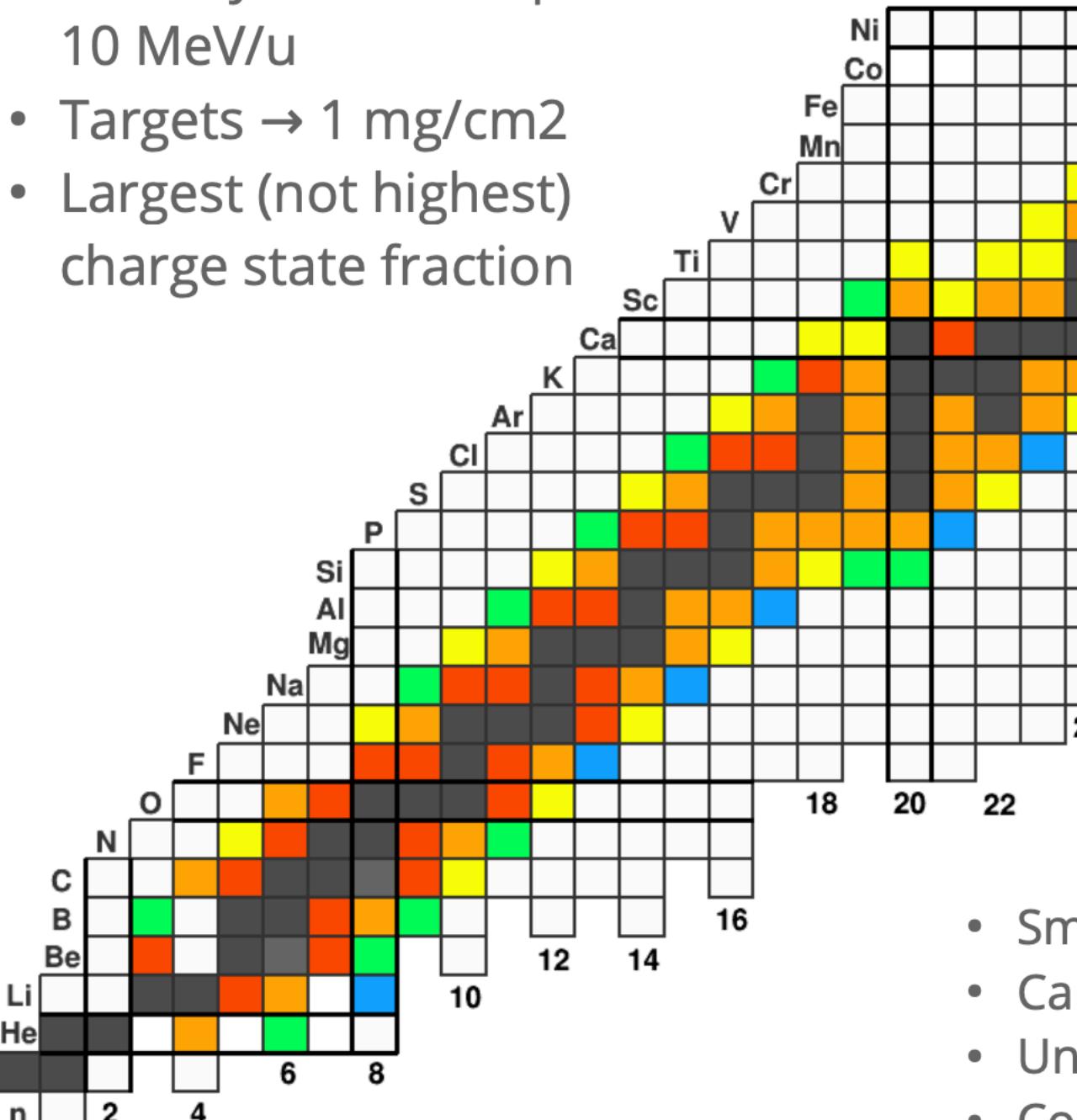
- Text

TITLE

Text

- Text

- Primary beam $\rightarrow 1 \text{ pA}$,
10 MeV/u
- Targets $\rightarrow 1 \text{ mg/cm}^2$
- Largest (not highest)
charge state fraction



Target: All beams, www.phy.anl.gov/airis/rates.html
no separation

- Dipole maximum $B\beta=1.75$

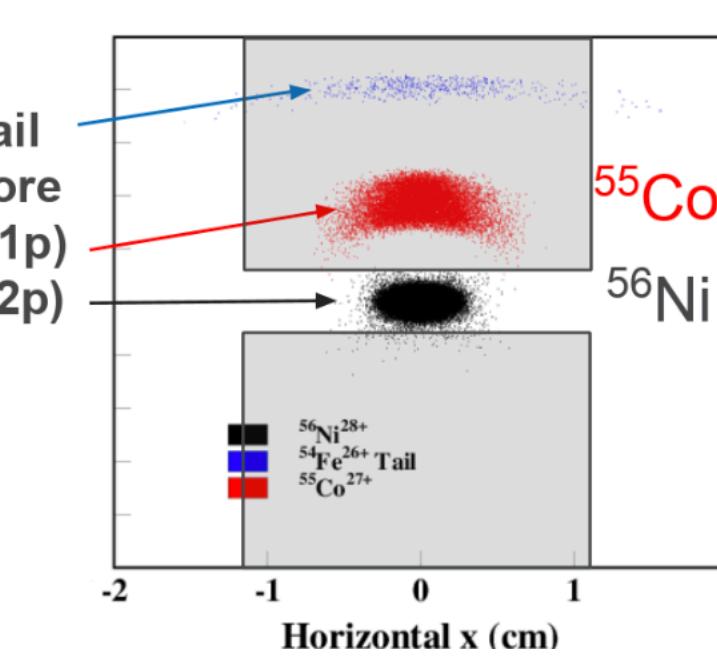
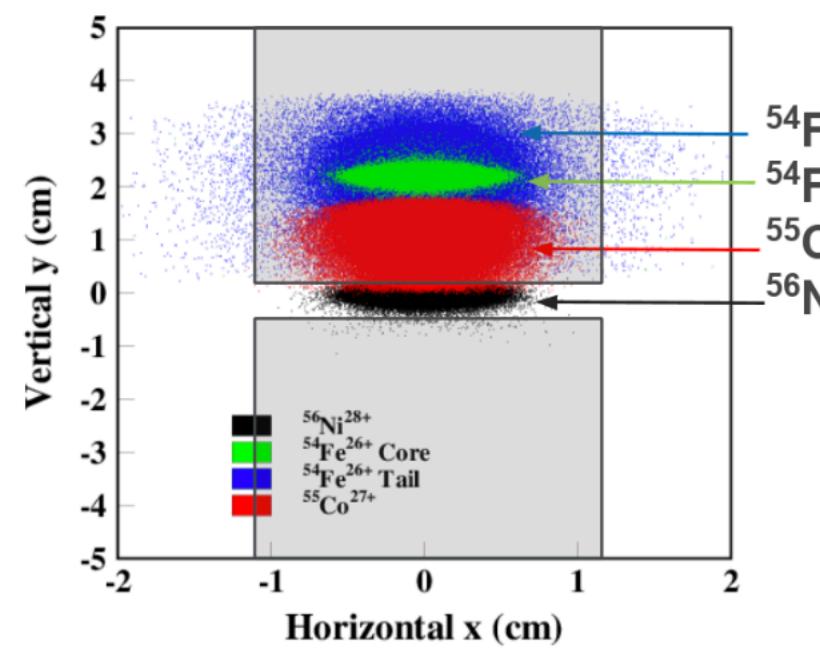
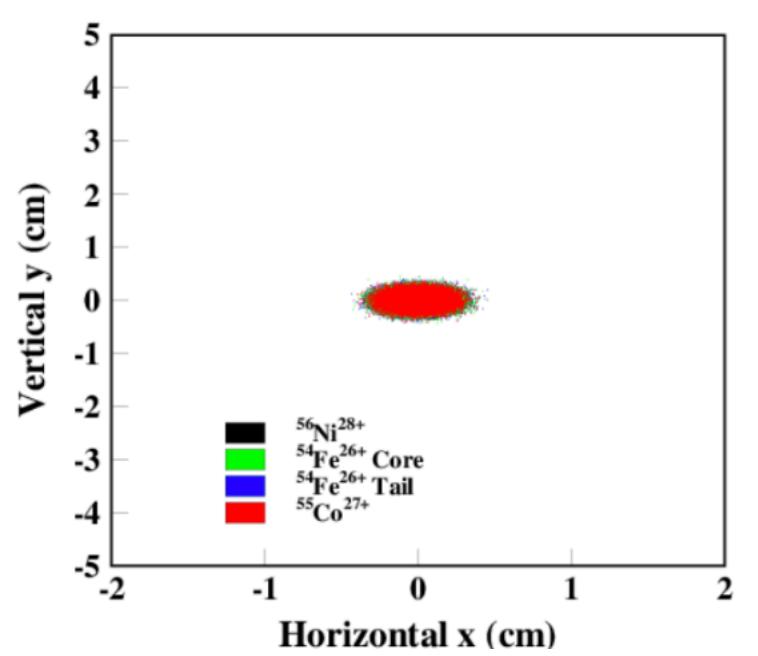
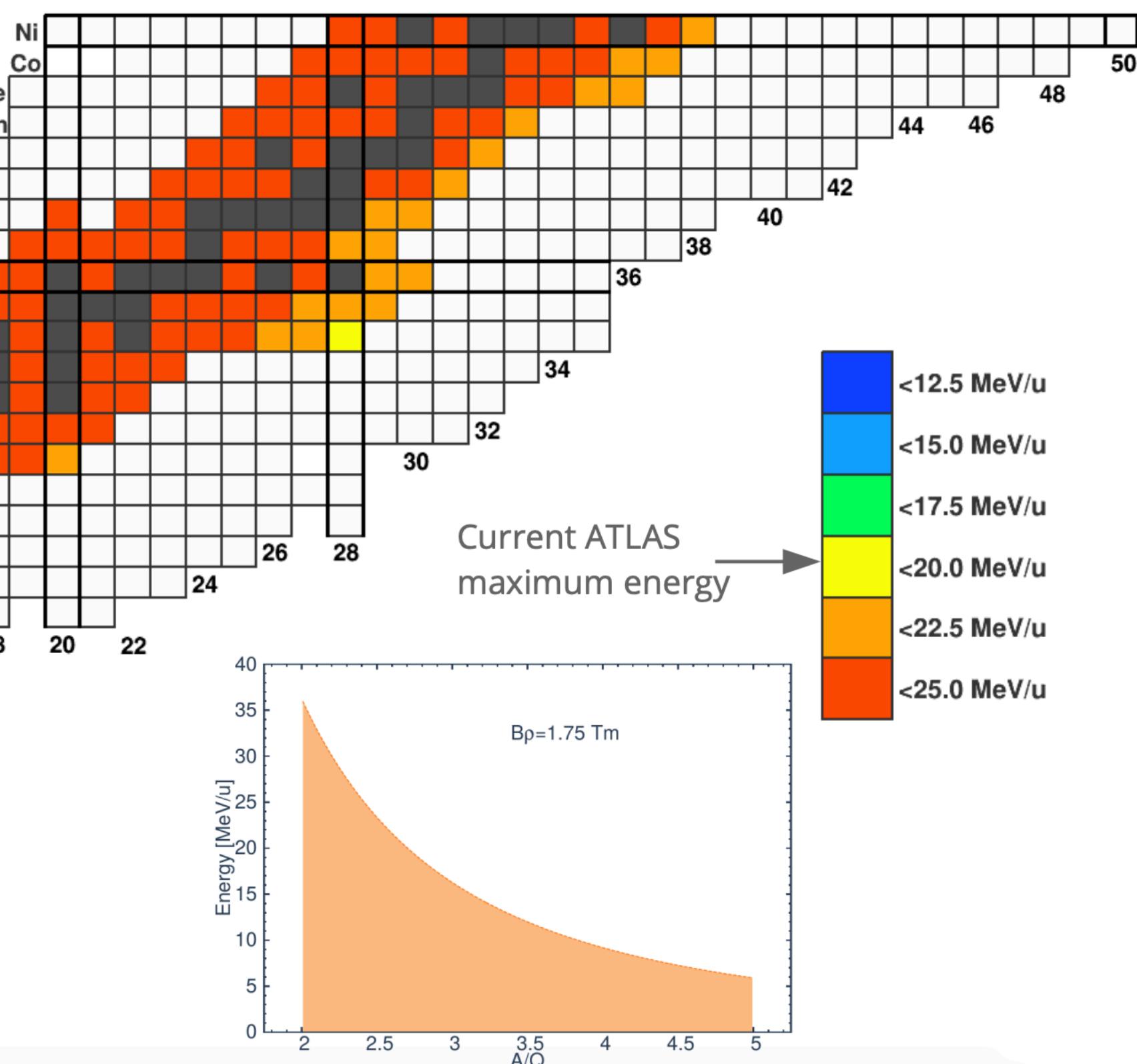
Tm

- Charge-state $\rightarrow q=Z$

- $q=Z-1$ ($Z>20$)

- Sm^H
 - Cal
 - Un
 - CoI
- other reaction channels
- > 25% transported to experimental areas

from other beams

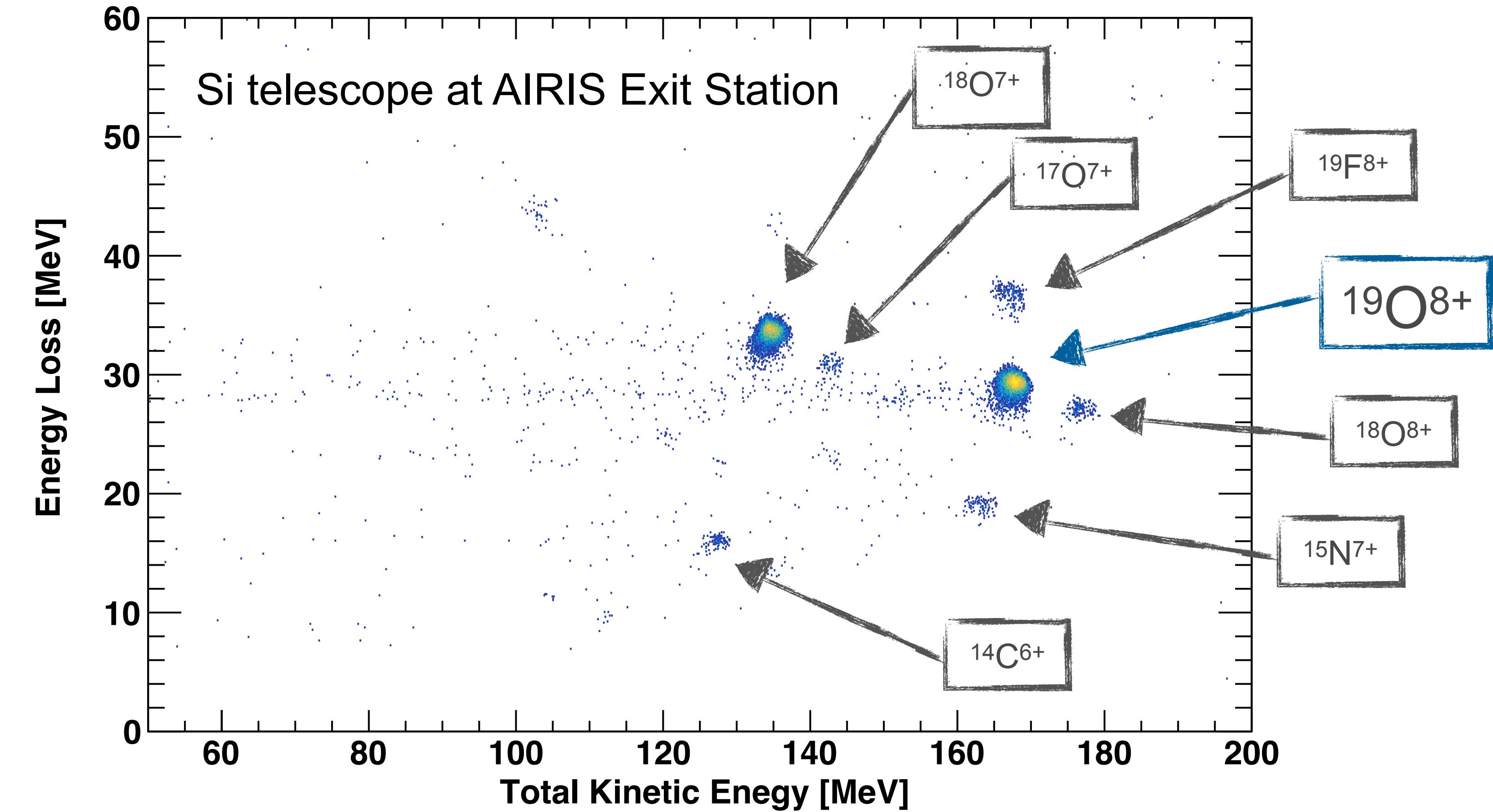


COMMISSIONING RESULTS

Achieved key performance parameters (KPPs) for ^{19}O beam production

^{19}O in-flight beam

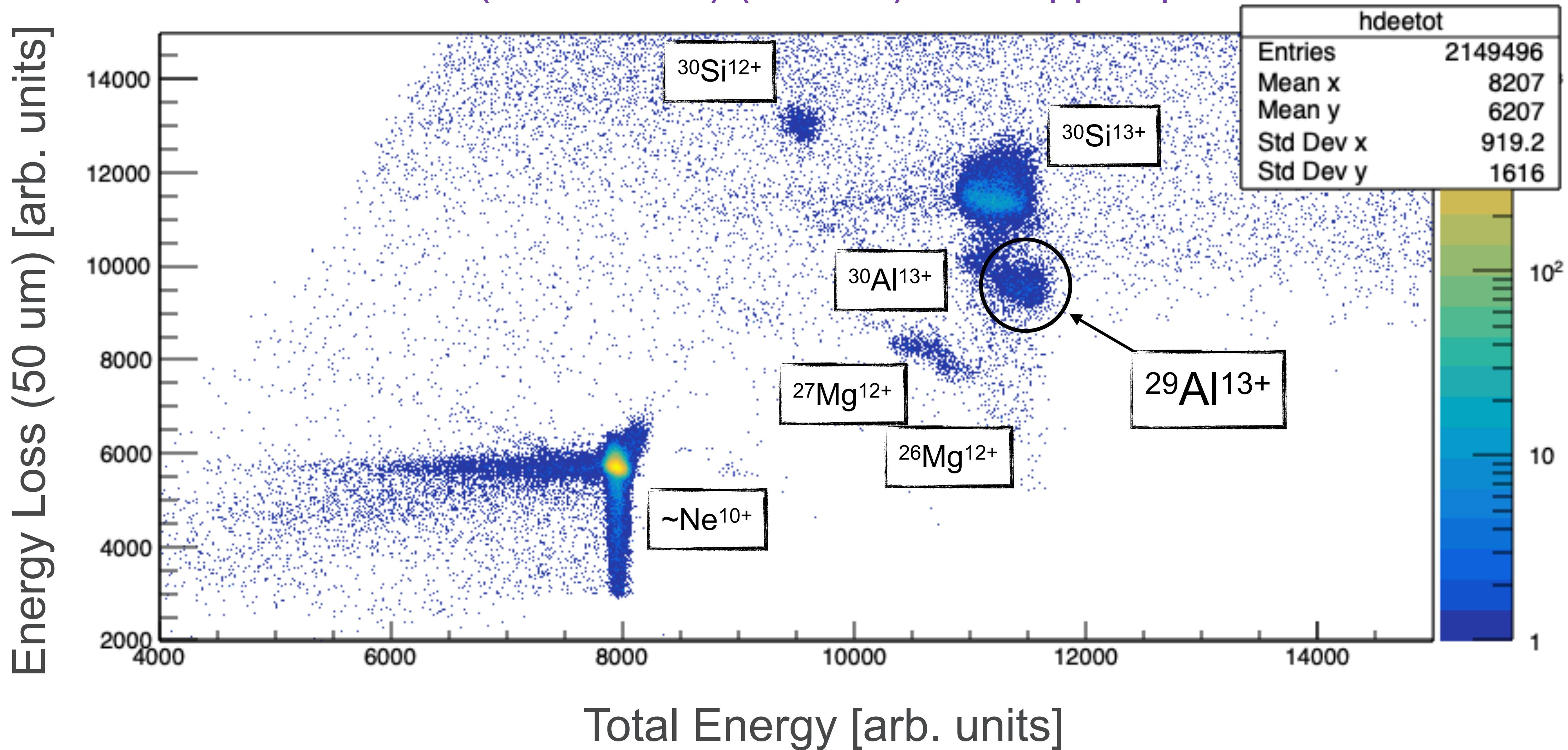
	KPP	Demonstrated
Energy [MeV]	>125	168(1)
Rate [10^5 pps]	>2	2.14(11)
Purity [%]	>50	62(4)



29AL, 31SI DEVEL RUN JUNE '19

29Al Setting (+5% scale, ~5mm slits [$\sim 2.5\%$ momentum acceptance])

$$\text{Rate} = (4000/4000)/(0.0022) = 450 \text{ pps / pnA} \rightarrow$$



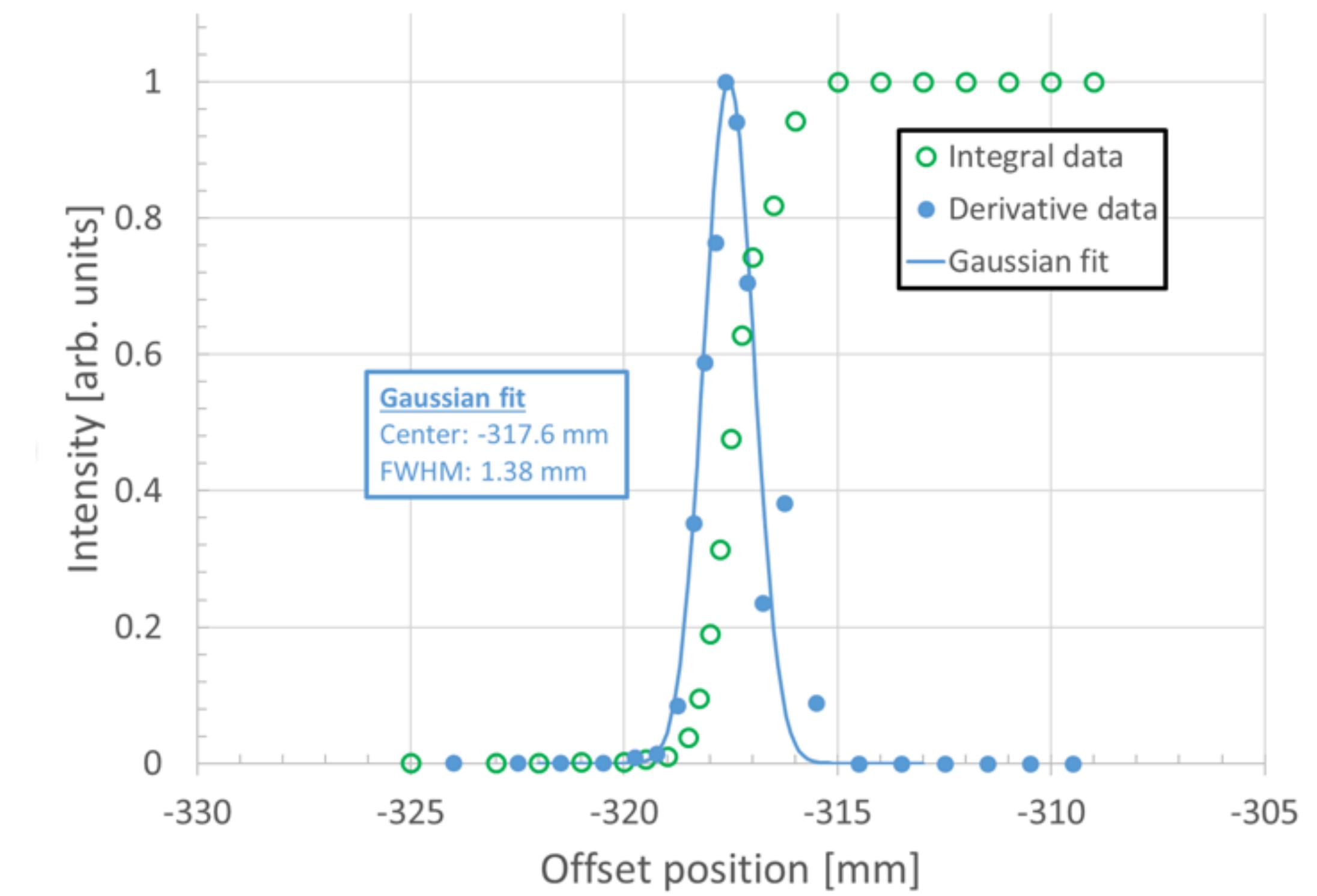
TOWARDS PRODUCTION OF THE IN-FLIGHT BEAM

Demonstrated transmission of the primary & degraded beams through AIRIS

- Primary beam transported through AIRIS at 0 cm midplane offset (March 2018)
- Primary $^{18}\text{O}^{5+}$ 180 MeV transported at a -32 cm midplane offset w/ >99% efficiency
- Degraded $^{18}\text{O}^{8+}$ at ~172 MeV transported at a -32 cm midplane offset w/ >95% efficiency
 - 2% & full open $\Delta\text{P}/\text{P}$ slit settings

NOTE: An A/q $\sim 36/10$ contaminant was identified in the primary beam coming from the ECR source. Detector signals from this contaminant were well separated from ^{18}O reactions & were not considered in the performance of AIRIS in terms of the purity results

$^{18}\text{O}^{8+}$ dispersive plane beam scan at the AIRIS midplane



ACKNOWLEDGEMENTS

- SCIENTIFIC RESEARCH STAFF
- ATLAS OPERATIONS
- TECHNICAL SUPPORT MEMBERS

DOE OFFICE OF SCIENCE NP