# NASA Space Radiation Laboratory Workshop Summary

Trevor Olsen
Jessica Gasparik

12 May 2026
2026 RHIC/AGS Annual Users' Meeting & RHIC Science Symposium

Brookhaven National Laboratory
U.S. DEPARTMENT OF ENERGY

@BrookhavenLab

**Workshop: Nasa Space Radiation Laboratory- SUSC Bldg. 101. Conference Room 121- 122**

**Session** | **Conveners:** Trevor Olsen (Brookhaven National Laboratory), Jessica Gasparik (Brookhaven National Lab)

**Description**

2nd Morning session

9:00 - 9:10 AM **Introduction NSRL, Research Topics, Speakers**

**Speaker**
Jessica Gasparik (Brookhaven National Lab)

9:10 - 9:50 AM
**Drug Adjuncts that mitigate the Molecular and Cellular impacts of Galactic Cosmic Radiation**

**Speaker**
Dr Robert Schwartz (Sanford I. Weill Medical College of Cornell University)

9:50 - 10:30 AM
**HEARTS and HEARTS++, the present and future of radiation effects testing with very-high-energy, heavy ion beams**

**Speaker**
Andreas Waets (CERN)

10:30 - 11:10 AM **Machine Learning Assisted Tuning and Diagnostics of NSRL Beams**

**Speaker**
Eiad Hamwi (BNL)

11:10 - 11:55 AM
**Nuclear Data Measurements in Support of NASA Planetary Science Missions**

**Speaker**
Patrick Peplowski (Johns Hopkins Applied Physics Laboratory)

11:55 AM - 12:00 PM **Close-out**

NSRL's *first* participation in RHIC/AGS Users' Meeting

Showcasing four speakers from across the facility's multi-disciplinary user community

Radiobiology – Robert Schwartz, M.D.

Electronics Testing – Andreas Waets

ML & Accelerator Physics – Eiad Hamwi

Nuclear Data Measurements – Patrick Peplowski

# Introduction to NSRL

# NASA's Terrestrial Analog for Space Radiation Studies

As NASA sets its eyes **towards Mars**, understanding the **risks and uncertainties from** the **space radiation environment** is crucial:

"In space, astronauts are exposed to ionizing radiation that is quantitatively and qualitatively different from terrestrial radiation. This environment includes protons and high-Z, high-energy ions together with secondary radiation, including neutrons and recoil nuclei that are produced by nuclear reactions in spacecraft materials or tissue."

- *Risk of Radiation Carcinogenesis (2016)*
*NASA HRP Space Radiation Element*


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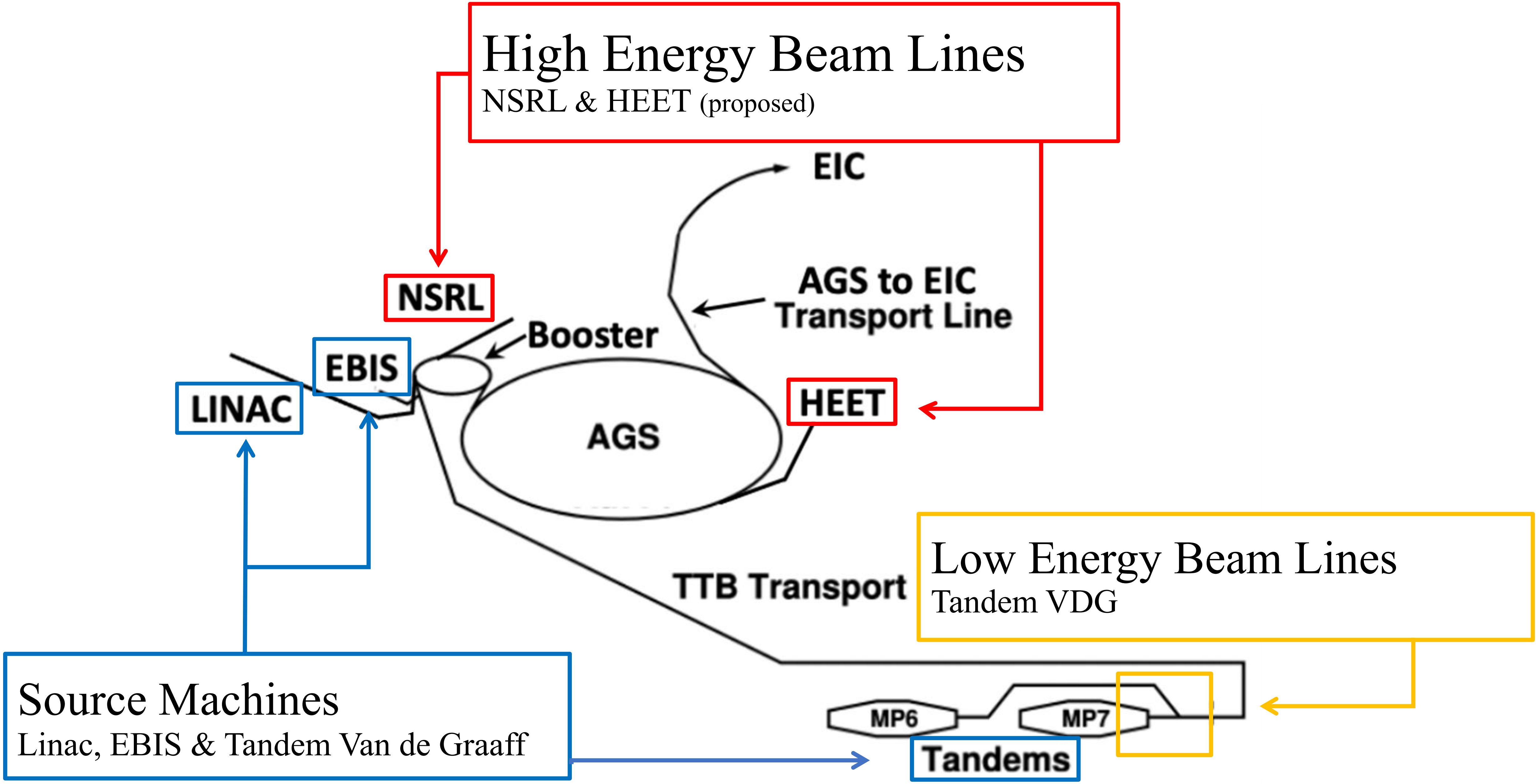

High Energy Beam Lines
NSRL & HEET (proposed)
EIC
AGS to EIC Transport Line
NSRL
Booster
EBIS
LINAC
AGS
HEET
TTB Transport
Low Energy Beam Lines
Tandem VDG
Source Machines
Linac, EBIS & Tandem Van de Graaff
MP6
MP7
Tandems

# NSRL Beam Capabilities

## Projectiles Options

**Protons, Deuterons, $H_2$**

**18 heavy ions between $2 \leq Z \leq 83$**

Uncharacterized neutron beam possible through deuteron breakup

## Beam Energy

**50 – 2500 MeV for protons**

**50 – 1500 MeV/n for heavy ions $Z \leq 26$ (Iron)**

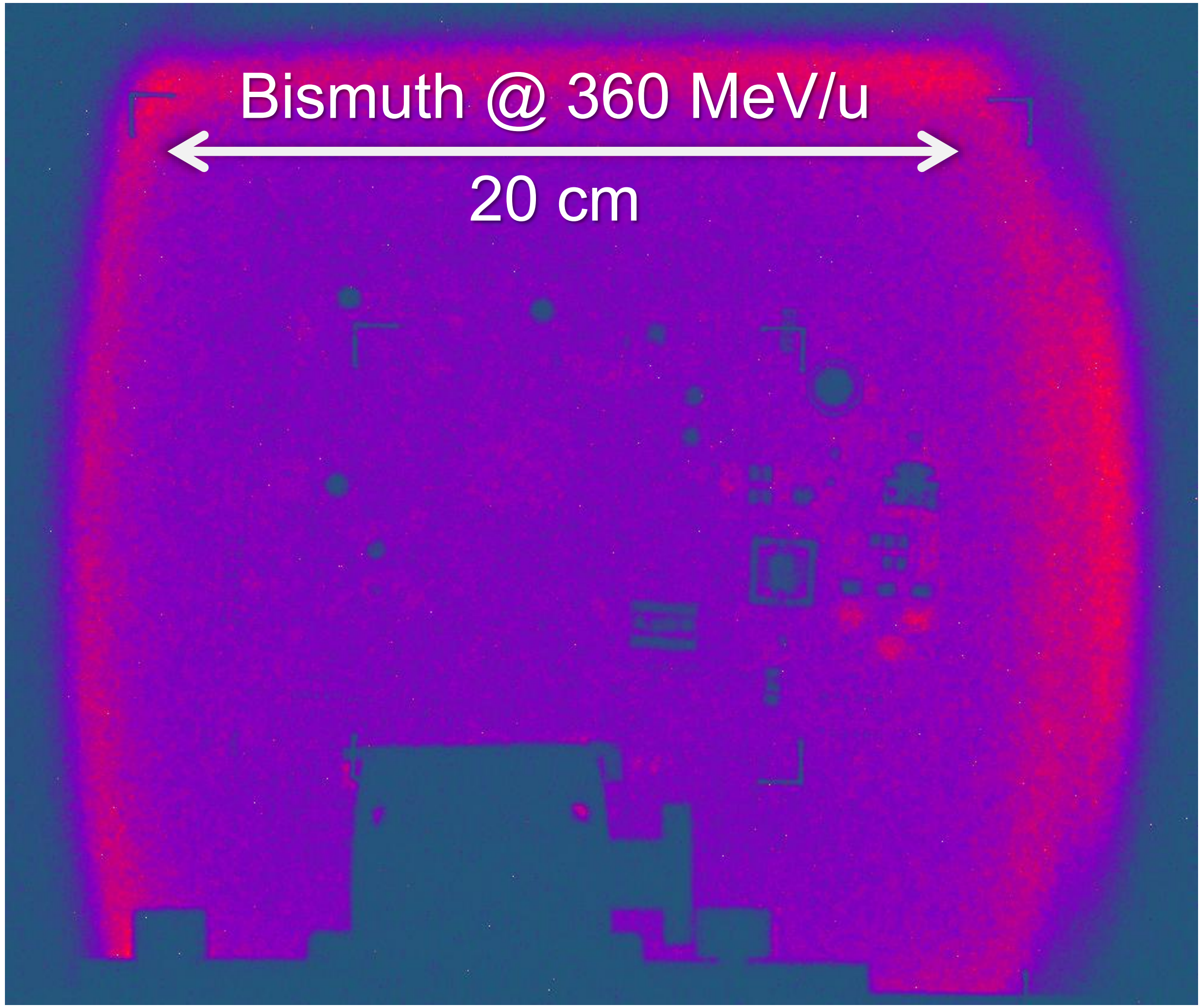
Reduced peak energy for Z > Fe… 380 MeV/n for Bi

Stopping beams, 10 MeV and below possible using polyethylene degrader

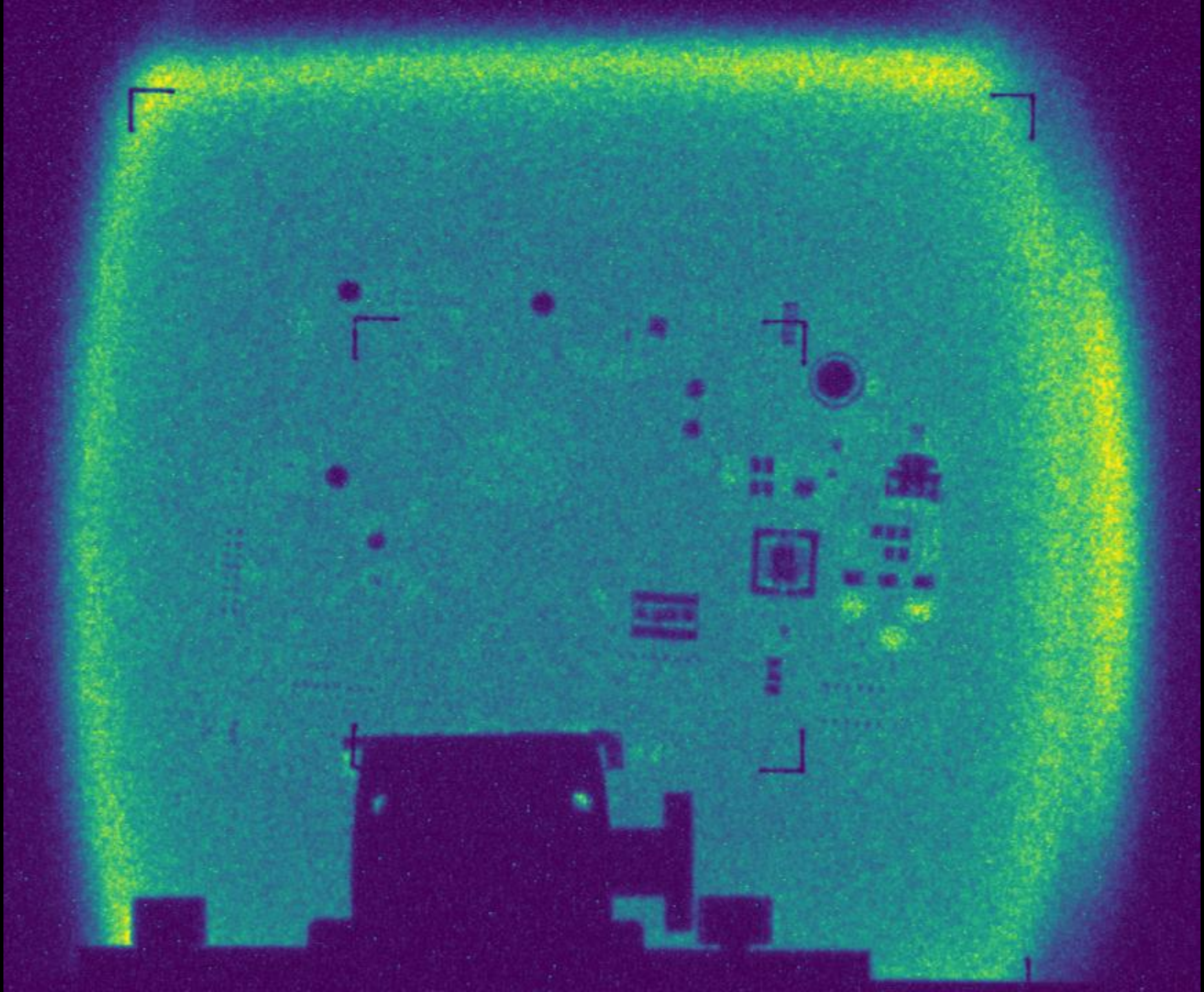
## Flux *(spills ~400 ms)*

1000 to $2 \times 10^{11}$ protons per spill

10 to $2 \times 10^{9}$ Fe ions per spill

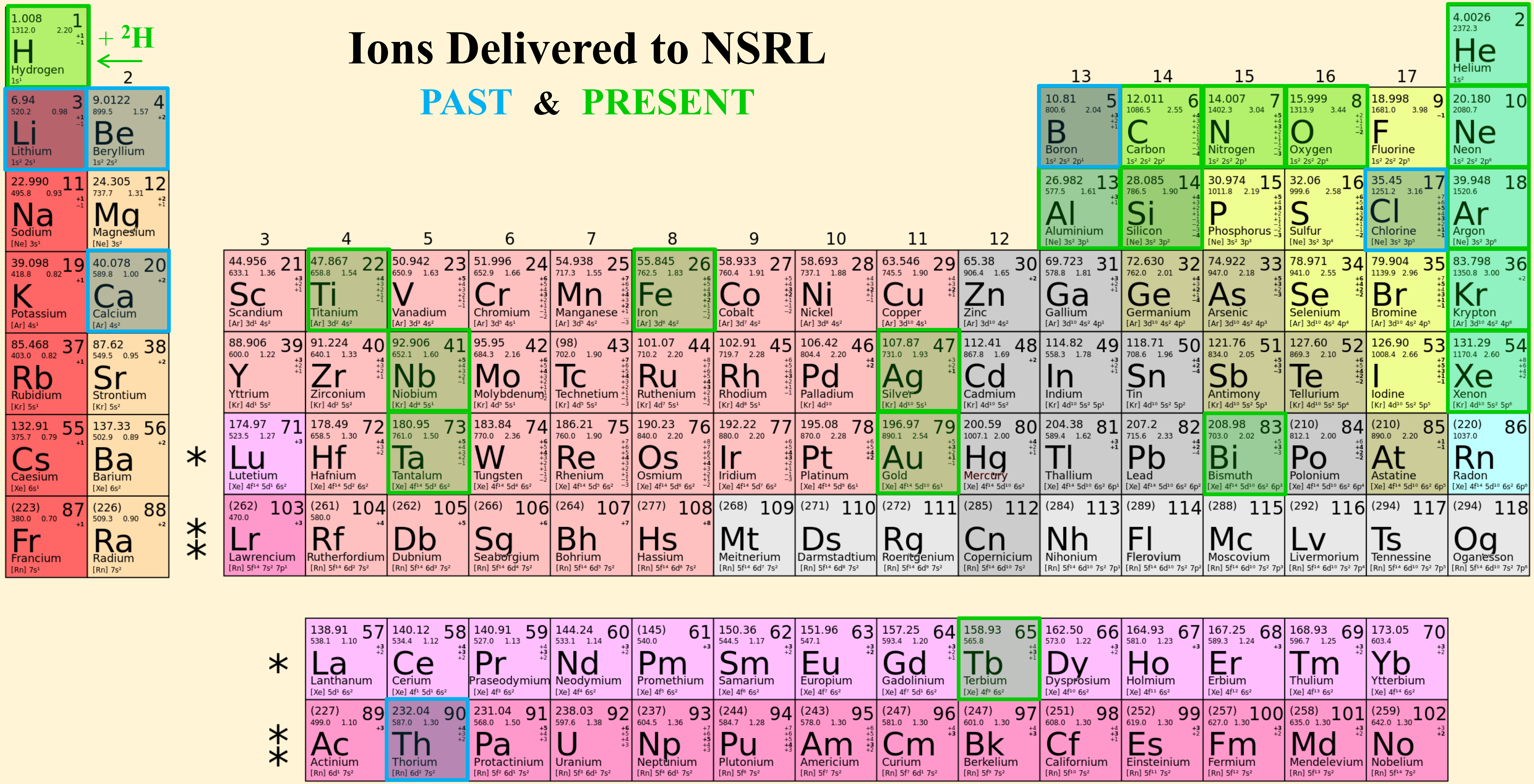



Adapted from M. Sivertz
"Snowmass Workshop on Calibration and Test Beams"



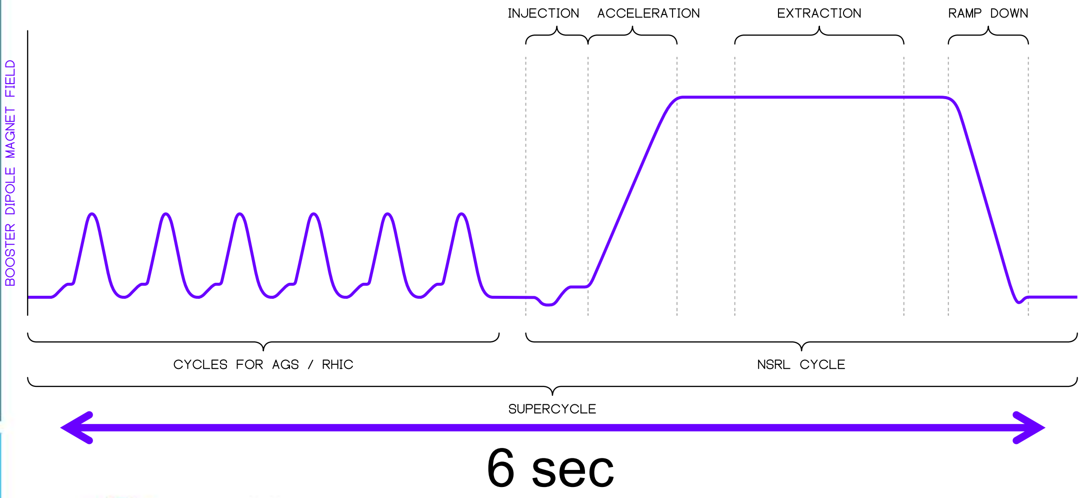
# Ions Delivered to NSRL

## PAST & PRESENT

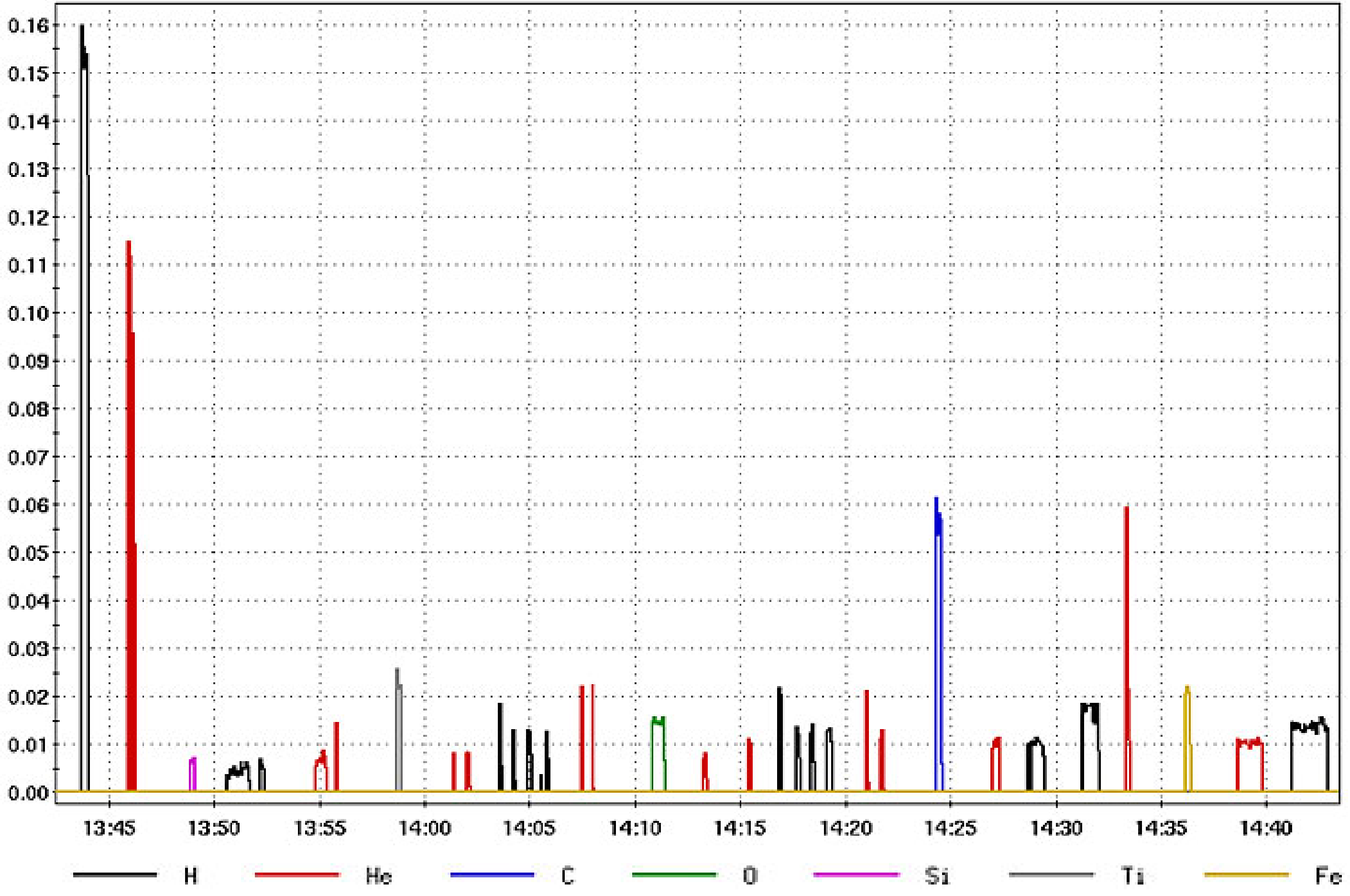


# Rapid Beam Switching via Laser Ion Source + EBIS

*Pulse-to-Pulse Modulation* for pre-injector systems allows for fast ion switches & simultaneous use of RHIC/EIC and NSRL




NASAs “GCR Sim”: 7 different ions in 33 beams within 1h

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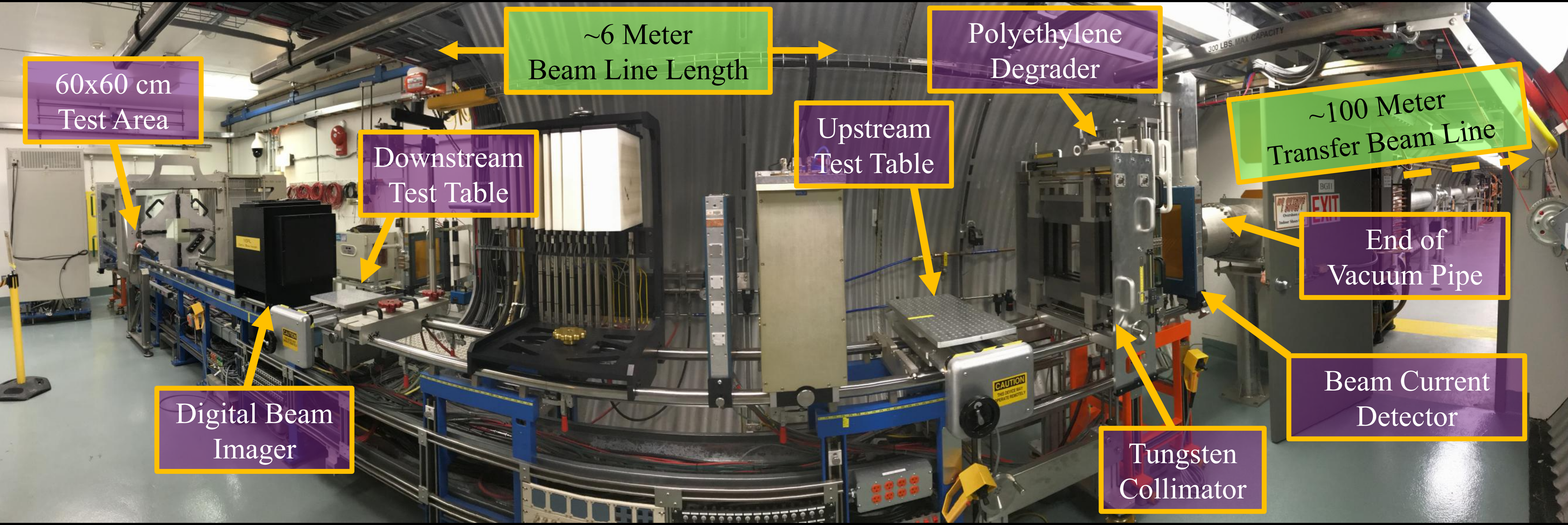
# NSRL Target Room



# Session Highlights

## Robert Schwartz, M.D. (Weill Medical College of Cornell), Radiobiology

***Unfortunately, no slides available***
***Here is my attempt to summarize***

Experimental evaluation of simulated microgravity and space radiation exposure in mice with countermeasure drug (Kaempferol, flavonoid compound found in foods)

**Does countermeasure provide medically observable protection for astronauts?**

*Yes,* it was reported that organ function and oxidative stress was improved in countermeasure-treated group compared to control group

While study is performed in mice, some up-regulated and down-regulated expressed genes are shared in human genetics with slight differences

Further investigation at NSRL is planned

# Andreas Waets (CERN), Microelectronics Testing

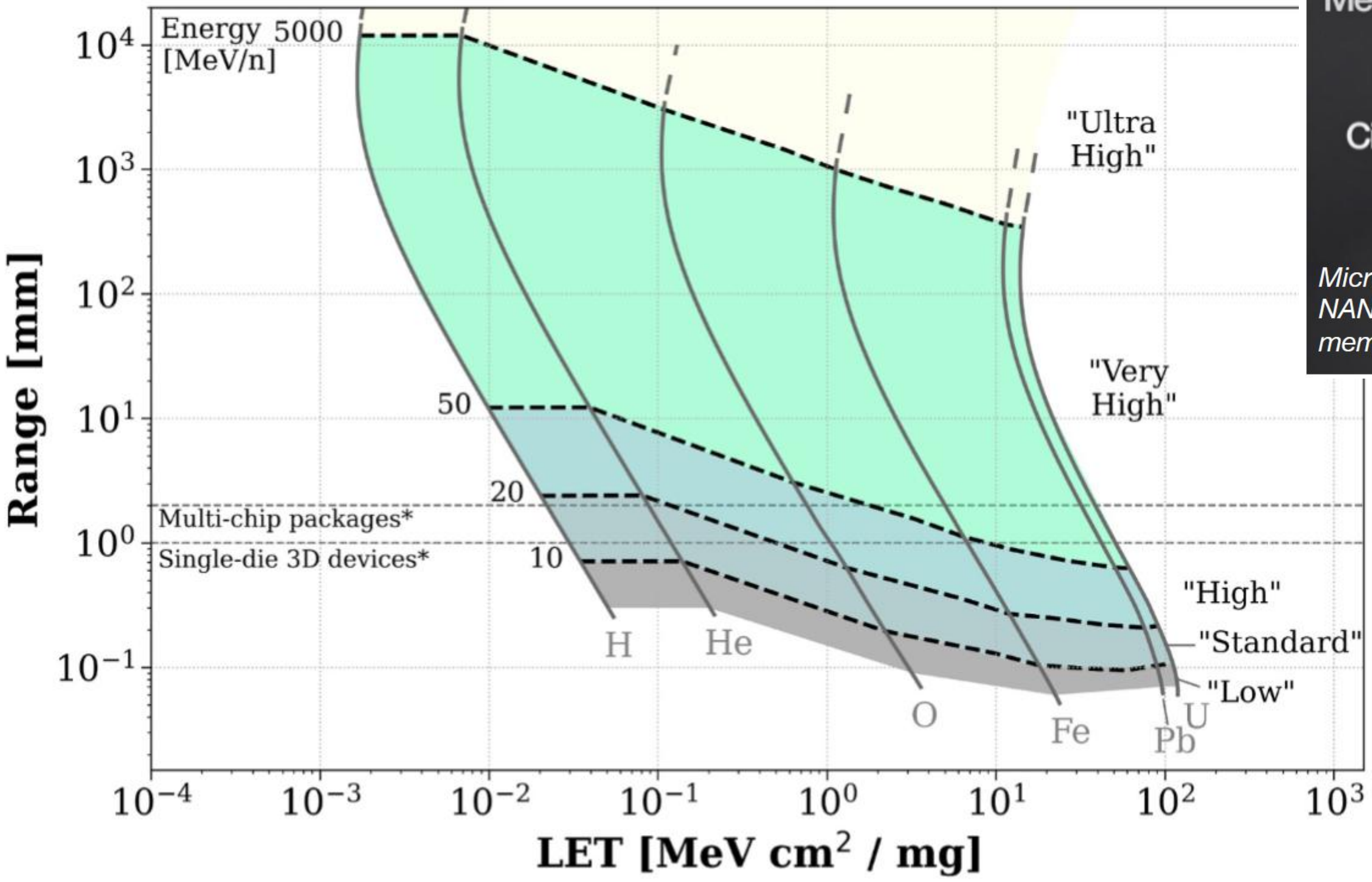
CERN | HEARTS

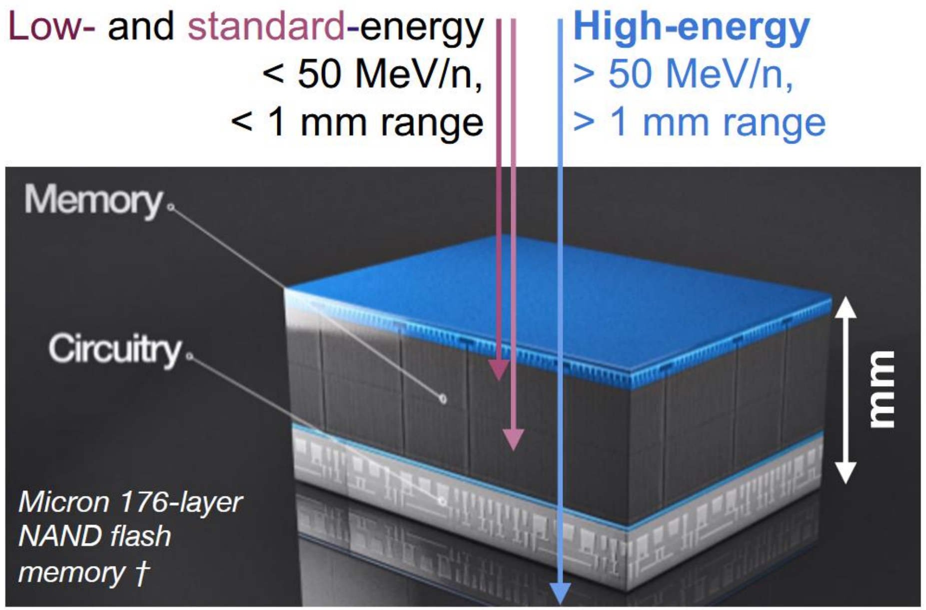
# HEARTS and HEARTS++, the present and future of radiation effects testing with very-high-energy, heavy ion beams in Europe.

Andreas Waets
on behalf of the HEARTS and HEARTS++ project teams

May 12th, 2026
RHIC/AGS AUM

# Andreas Waets (CERN), Microelectronics Testing



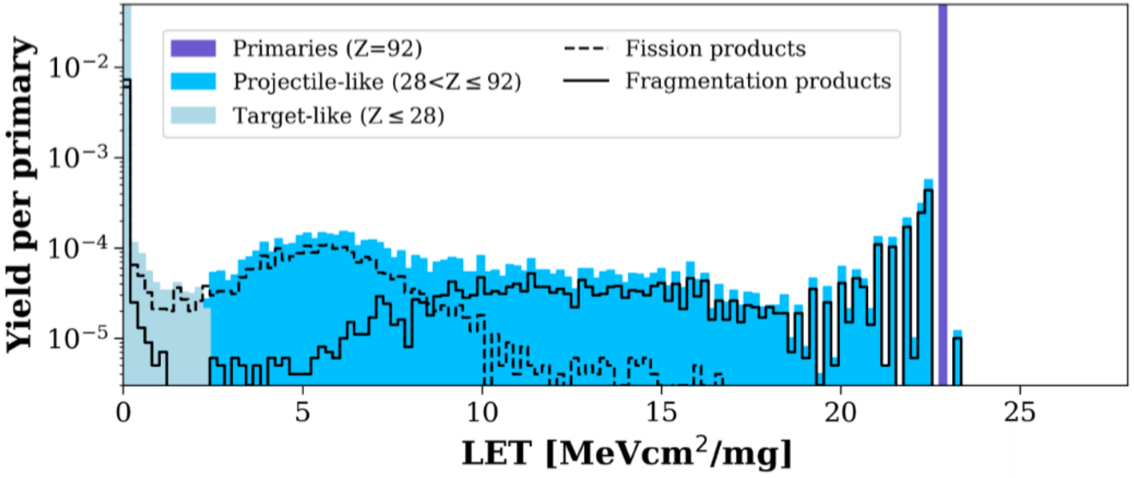

**Standard energy**:
< 50 MeV/n & < 1mm range

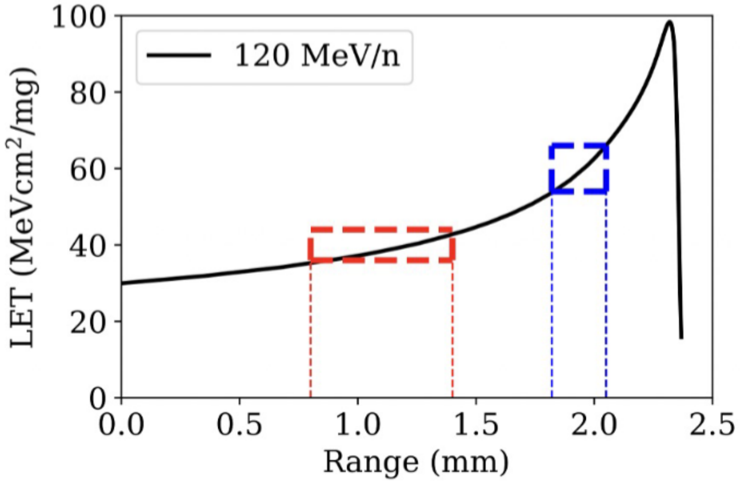
**Very high energy**:
50 - 5000 MeV/n & > 1mm range

Particularly **interesting for SEE testing** due to their **combination of high LET and high penetration range**

- avoid testing in vacuum and delidding of parts,
- reach all sub-layers of a device under test (state-of-the-art microelectronics with complex / 3D architectures),
- ensure the LET can be as constant as possible across the device.

# Andreas Waets (CERN), Microelectronics Testing



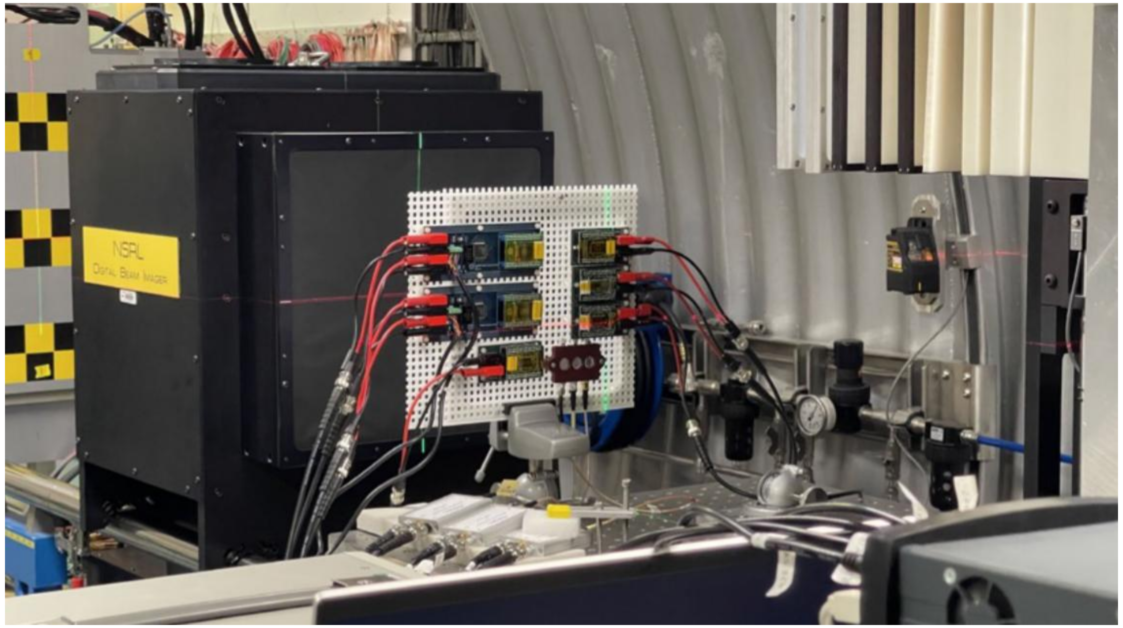




SEE σ

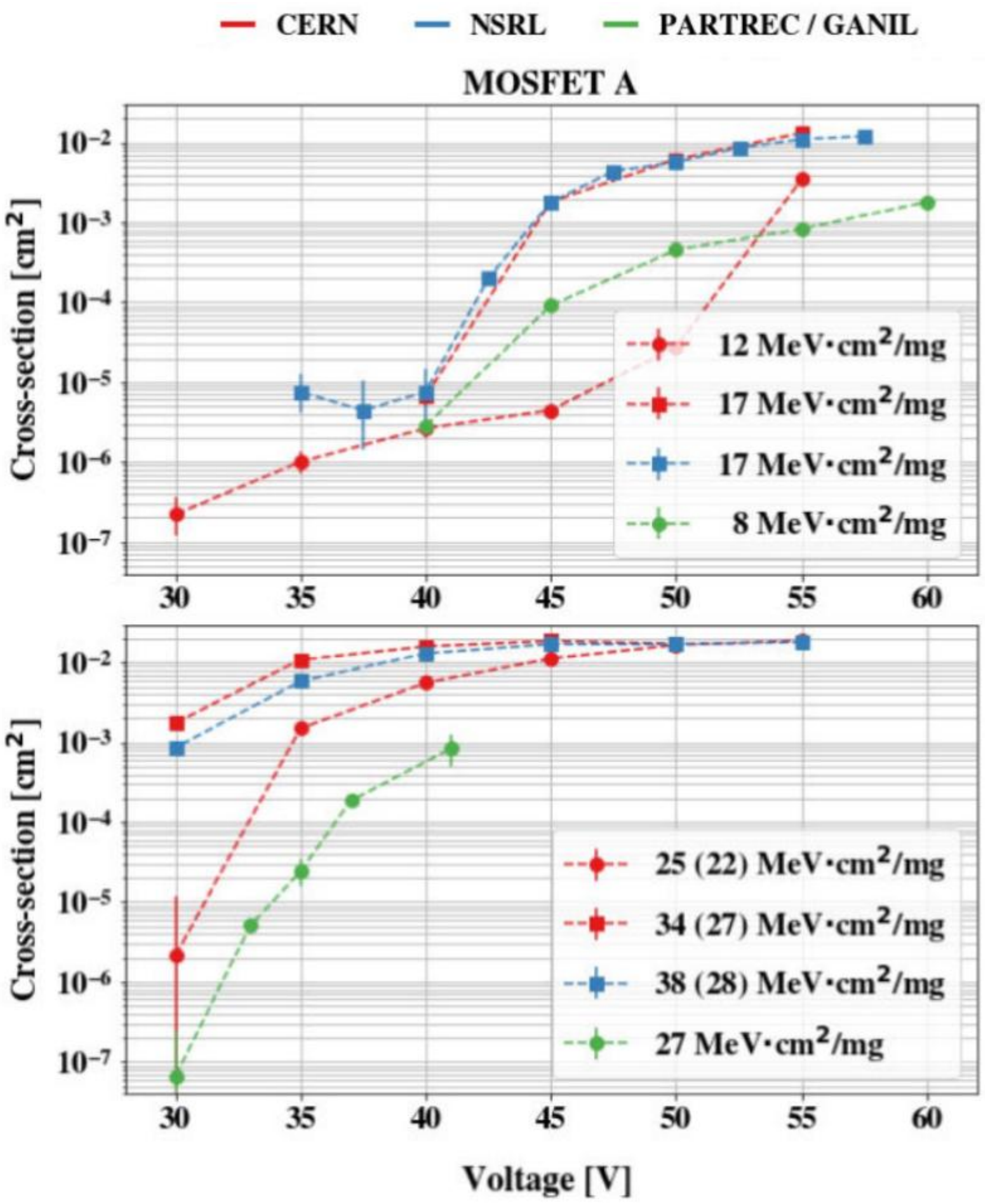
| | VHE, heavy ion beams | Modern microelectronics | |
|---|---|---|---|
| LET | Beam **fragmentation** through inelastic interactions (spallation, fission) | (Unknown) material budget inside device-under-test (DUT), **uncertainty on LET** close to the Bragg peak | **Energy deposition (LET) distribution** |
| Fluence | **Flux attenuation of** primary particles (secondary particle population due to fragmentation) | **Range distribution** due to straggling, uncertainty on particle range and if SV inside DUT can be reached) | Range distribution, **primary fluence attenuation** |

SEE σ

# Andreas Waets (CERN), Microelectronics Testing




| | Observed effect in very-high-energy vs. standard-energy ion beams | Explanation |
|---|---|---|
| **SEU** | Higher cross section in SRAMS for highly degraded beams | Confirmation of the role of the beam fragments, particularly when large cumulative beam degrader thicknesses are used. |
| **SEL** | Higher cross section in sub-threshold region for SRAMS | Cannot be justified by fragments but potentially by inelastic collisions with W atoms present in some SRAMs. |
| **SEB** | Different SEB cross section for one MOSFET device | Decapsulation, lower on-resistance, further research needed. |



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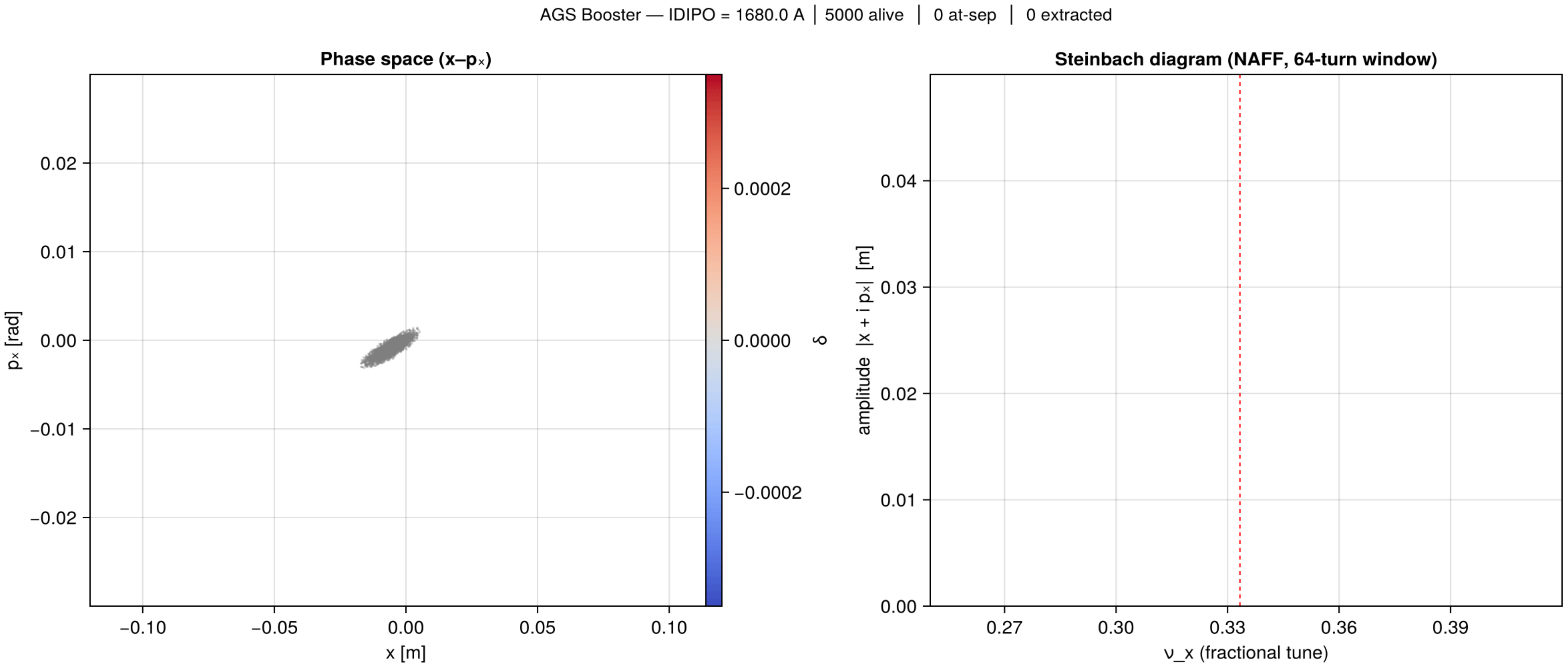
# Machine Learning Assisted Tuning and Diagnostics of NSRL Beams

E. Hamwi, K. Brown, L. Hajdu, G. Hoffstaetter, W. Lin, M. McCarthy, T. Olsen

EIC–BeamAI collaboration

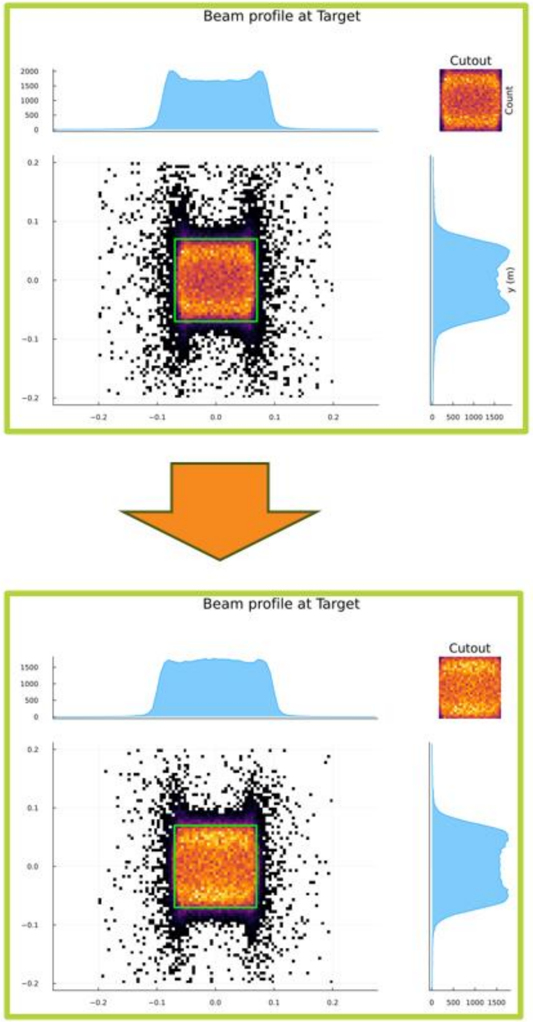
Electron-Ion Collider

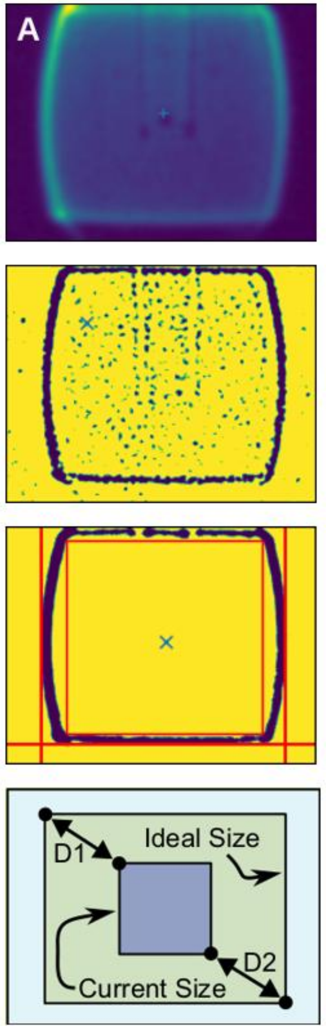
# SciBmad slow extraction sim. from the AGS booster



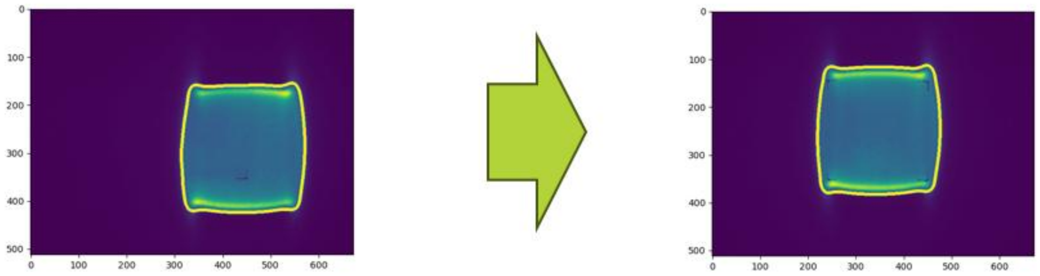
Eiad Hamwi (BNL), ML/AI Accl. Phys

# Bayesian optimization for target



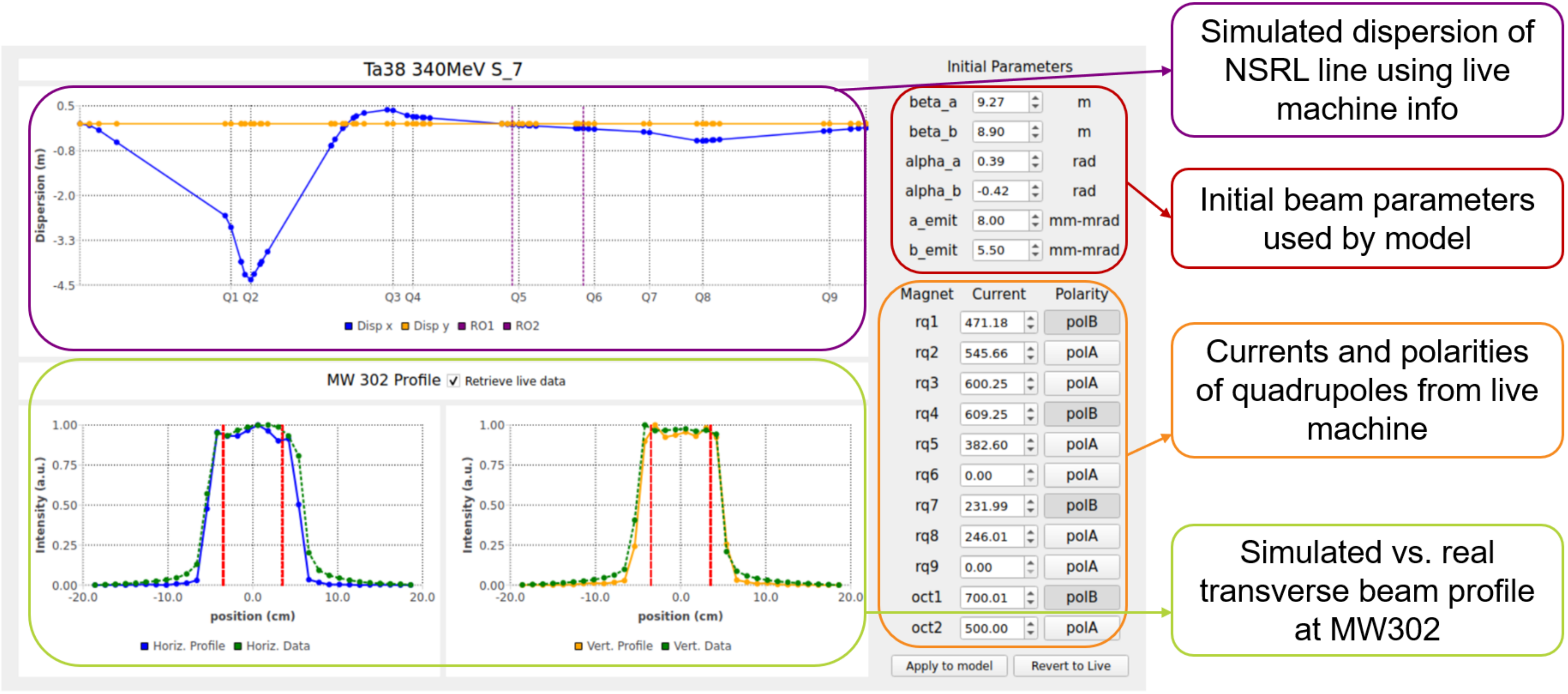







Eiad Hamwi (BNL), ML/AI Accl. Phys

# Digital Twin for the NSRL line



JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

# Nuclear Data Measurements in Support of NASA Planetary Science Missions

## NSRL as a tool for fundamental science research

Patrick Peplowski
Johns Hopkins Applied Physics Laboratory

2026 RHIC/AGS Annual Users' Meeting & RHIC Science Symposium
May 12 2026

# Cross Section Measurements at NSRL

- Activated Foil Technique
  - Short, intense irradiation
  - On- and off-site measurements of activated foils
- Data Analysis
  - Spectral Analysis
  - Radionuclide identification
  - Determine initial activation
  - Correct for detector response
  - Calculate cross section and systematic uncertainties.
- Validate Analysis
- Interpret Results

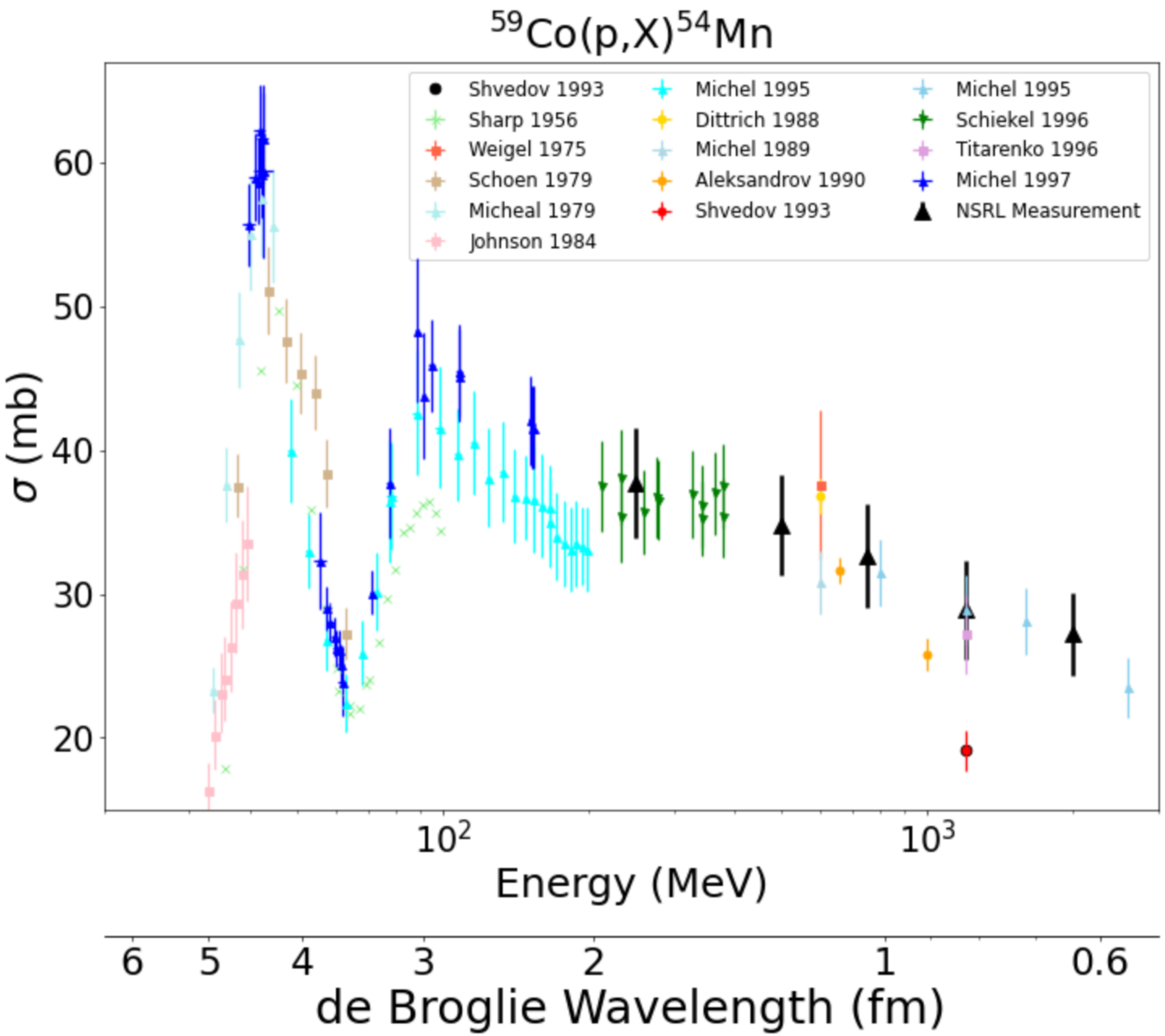
80 separate cross section measurements were produced from just ~10 minutes of NSRL beam time

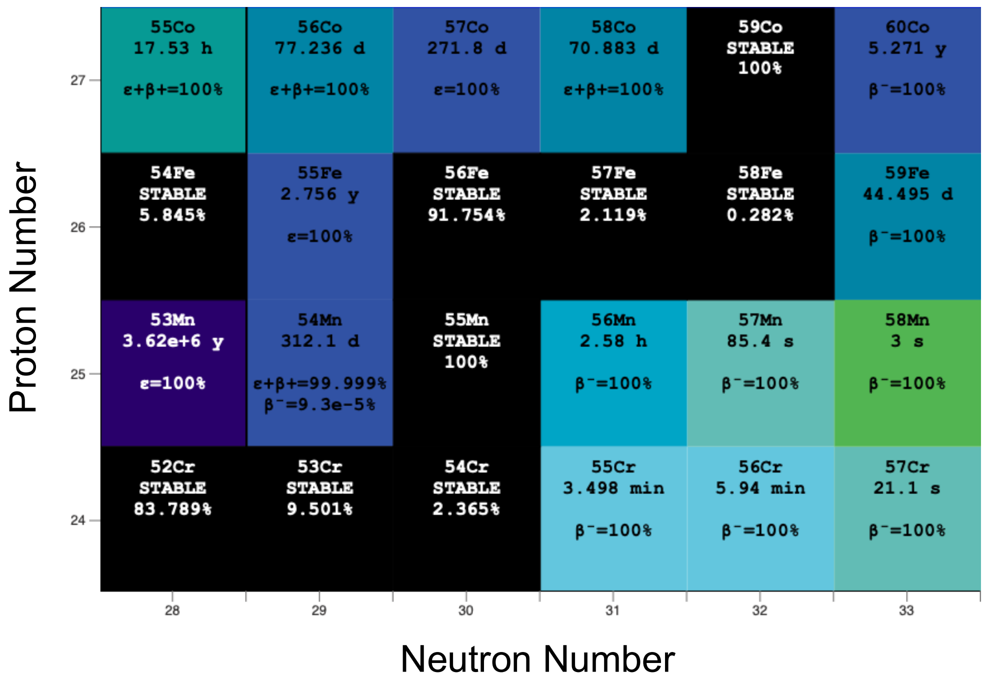
**Table 3.** Reaction cross sections derived from the activated target measurements

| Reaction | Type[∇] | Cross Section (mb) and statistical uncertainty | | | | |
|---|---|---|---|---|---|---|
| | | 250 MeV | 500 MeV | 750 MeV | 1200 MeV | 2000 MeV |
| $^{59}Co(p,pn)^{58}Co$ | I | 51.7±4.8 | 45.9±4.2 | 44.5±4.2 | 44.6±4.2 | 46.4±4.3 |
| $^{59}Co(p,p2n)^{57}Co$ | I | 38.2±4.1 | 26.2±2.7 | 24.5±2.8 | 24.0±2.4 | 24.2±2.9 |
| $^{59}Co(p,3p)^{57}Mn$ | I | 0.4±0.2 | 1.0±0.4 | 1.6±0.2 | 0.6±0.7 | 0.8±0.5 |
| $^{59}Co(p,p3n)^{56}Co$ | I | 9.4±1.2 | 6.9±0.9 | 5.3±0.8 | 5.3±0.9 | 3.6±0.6 |
| $^{59}Co(p,4p)^{56}Cr$ | I | 0.10±0.03 | 0.14±0.03 | 0.14±0.02 | 0.14±0.02 | 0.15±0.01 |
| $^{59}Co(p,X)^{56}Mn$ | C | 4.5±0.3 | 5.6±0.4 | 6.9±0.5 | 8.5±1.2 | 9.1±2.9 |
| $^{59}Co(p,5p)^{55}Co$ | I | 3.5±0.3 | 2.3±0.2 | 2.5±0.4 | 2.2±0.5 | 2.9±0.3 |
| $^{59}Co(p,3p3n)^{54}Mn$ | I | 37.7±3.8 | 34.8±3.5 | 32.6±3.6 | 28.9±3.4 | 27.2±2.9 |
| $^{59}Co(p,X)^{53}Fe$ | C | 1.9±0.1 | 1.4±0.1 | 1.3±0.1 | 0.9±0.1 | 0.8±0.1 |
| $^{59}Co(p,X)^{52}Mn$ | C | 8.9±1.7 | 6.6±1.5 | 6.0±1.7 | 6.2±1.8 | 3.3±0.6 |
| $^{59}Co(p,X)^{51}Cr$ | C | 28.2±3.5 | 31.1±3.8 | 23.7±5.1 | 23.2±3.7 | 17.6±3.7 |
| $^{59}Co(p,X)^{49}Cr$ | C | -- | -- | -- | 3.1±0.2 | 2.7±0.1 |
| $^{59}Co(p,X)^{48}V$ | C | 6.8±0.8 | 9.5±1.0 | 9.9±1.2 | 8.8±1.0 | 7.3±0.8 |
| $^{59}Co(p,X)^{47}Sc$ | C | 2.8±2.7 | 2.6±1.2 | 4.9±2.2 | 4.4±1.4 | 3.3±0.5 |
| $^{59}Co(p,X)^{46}Sc$ | C | 3.0±0.6 | 5.3±0.8 | 6.2±1.3 | 5.7±0.8 | 4.0±0.6 |
| $^{59}Co(p,X)^{44}Sc$ | C | -- | -- | 7.3±0.6 | 7.0±0.6 | 5.6±0.4 |
| $^{59}Co(p,X)^{44}Sc^{m}$ | C | 2.0±1.1 | 5.1±1.4 | 9.2±2.1 | 6.7±1.9 | 6.4±1.2 |

[∇] *"I" denotes an individual cross section measurement, "C" denotes a cumulative cross section measurement*

# Patrick Peplowski, Nuclear Data

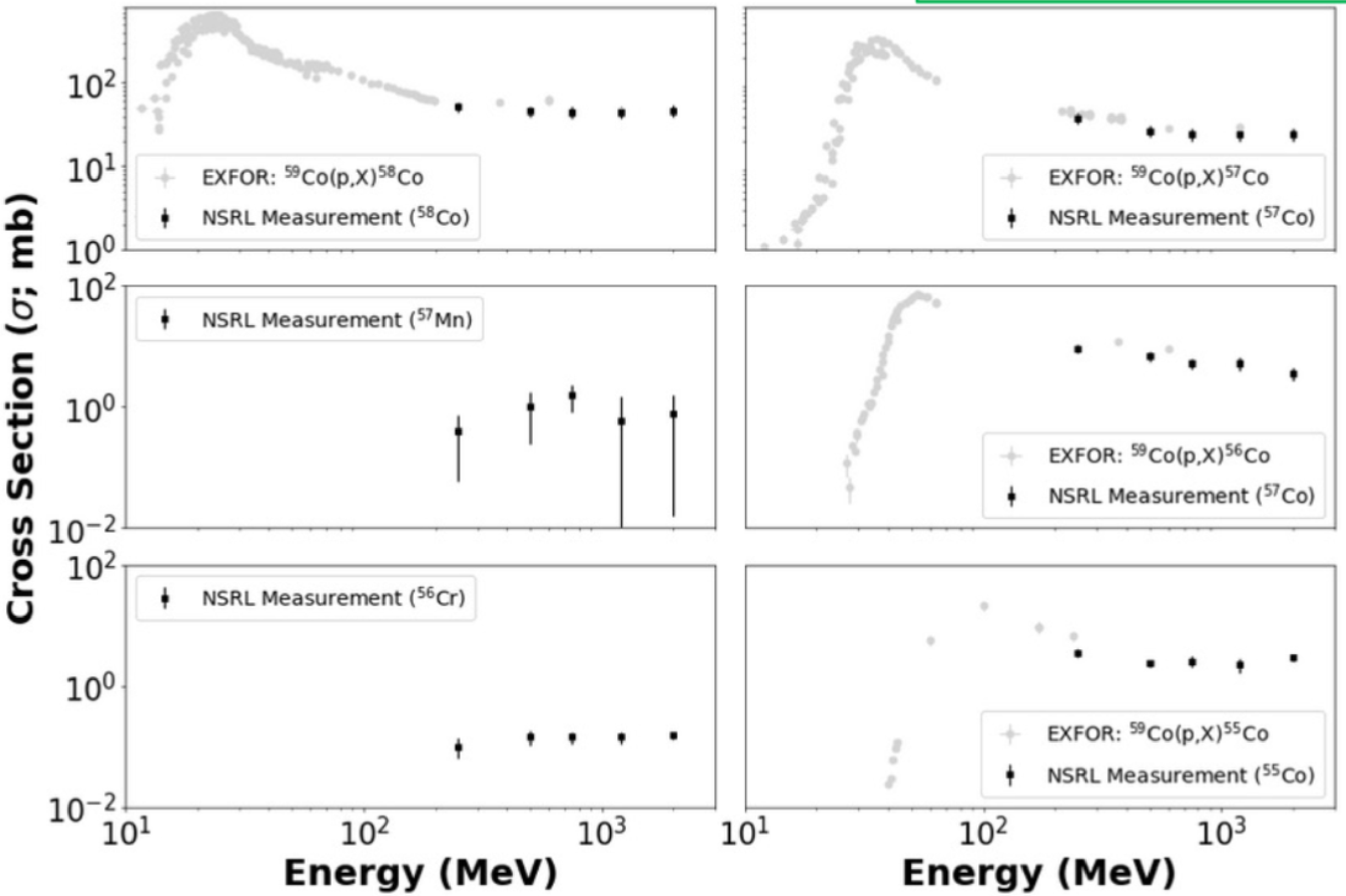



NSRL measurements were validated against published results from dedicated cross section measurements.

# Patrick Peplowski, Nuclear Data

NSRL measurements fill many gaps in the existing literature (from EXFOR)



NSRL is a multi-disciplinary, fixed target beam line hosting user experiments at the RHIC/EIC complex

We will operate for the foreseeable future as demand for high energy heavy ion beam continues to grow