On-Beam Commissioning of SALER: STJ-Based Recoil Spectroscopy at FRIB

CPAD, University of Washington: 10/21/26

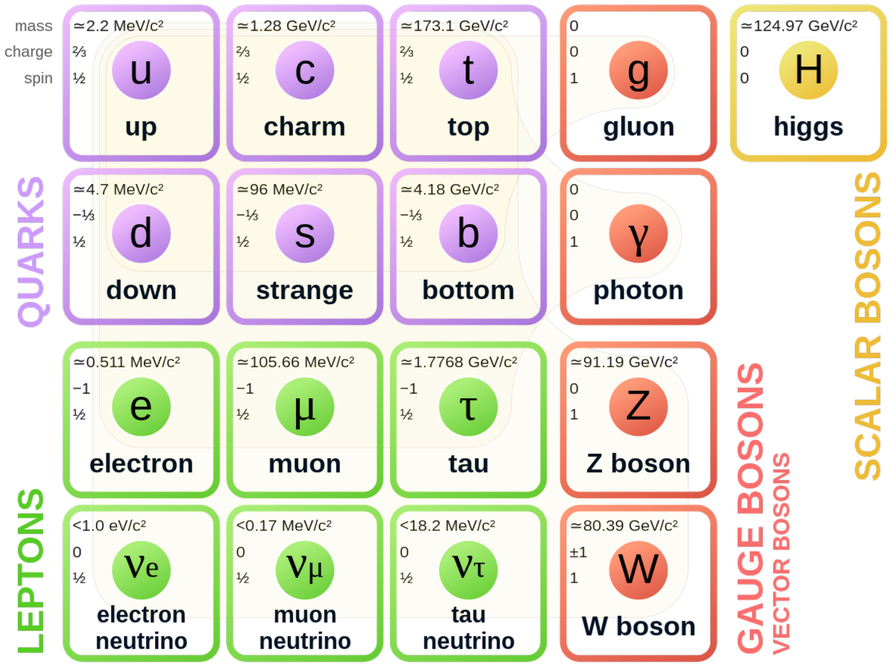
Glenn Richardson
richargl@frib.msu.edu





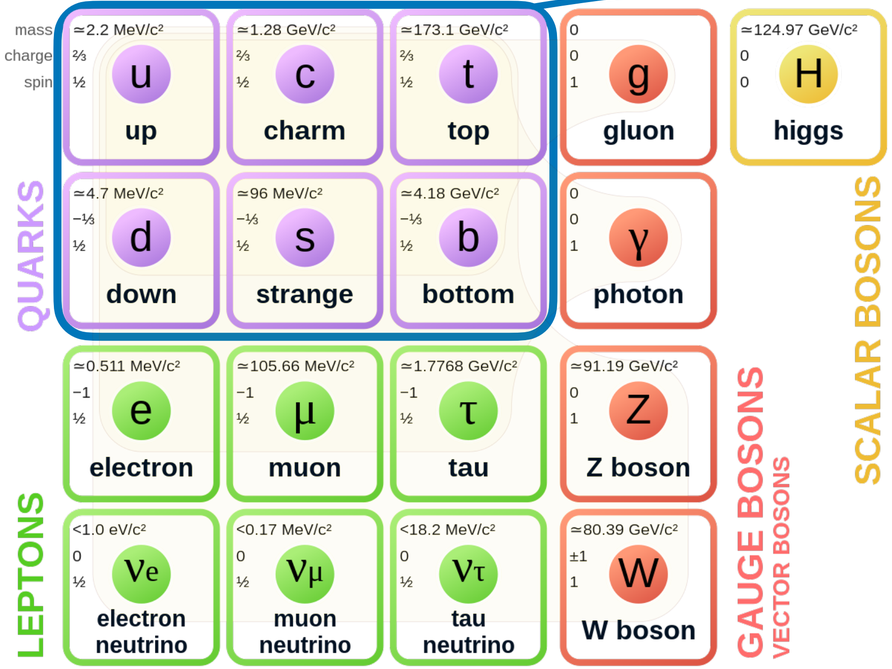
BSM Physics with SALER

- Precision studies of weak interactions offer avenue for BSM physics



BSM Physics with SALER

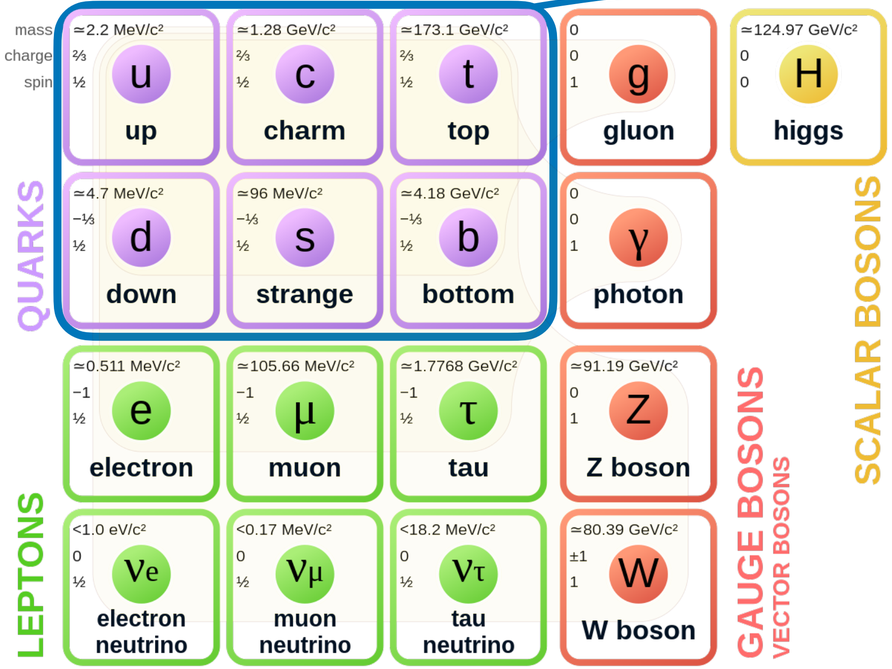
- Precision studies of weak interactions offer avenue for BSM physics
- Quark weak interactions described by “Unitary” CKM matrix



$$\begin{bmatrix} d' \\ s' \\ b' \end{bmatrix} = \begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} \begin{bmatrix} d \\ s \\ b \end{bmatrix}$$

BSM Physics with SALER

- Precision studies of weak interactions offer avenue for BSM physics
- Quark weak interactions described by “Unitary” CKM matrix
  - 2.4σ tension

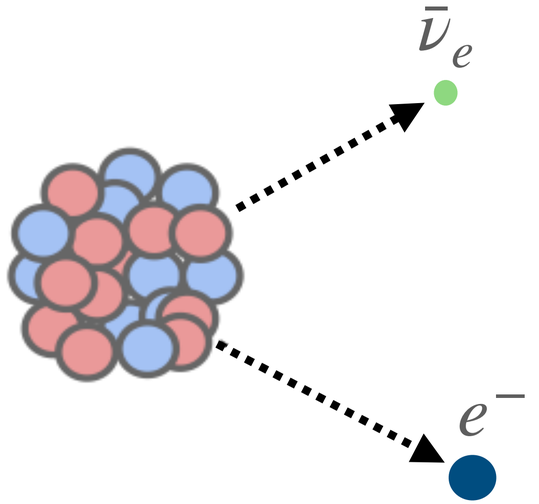


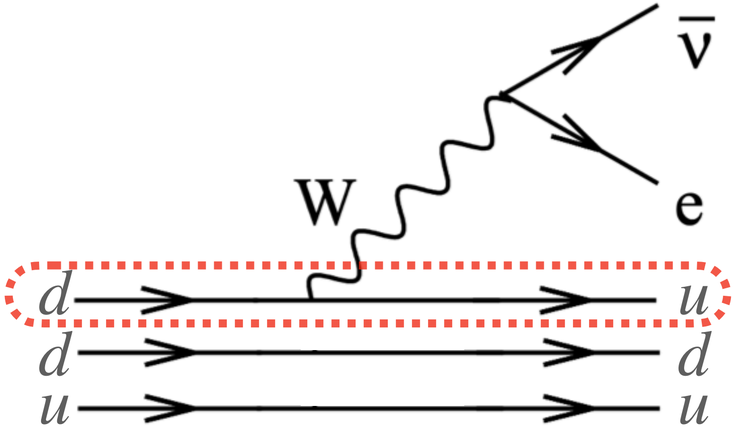
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$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9983(6_{stat.})(4_{sys.})$$

Testing V_{ud} With β-decay

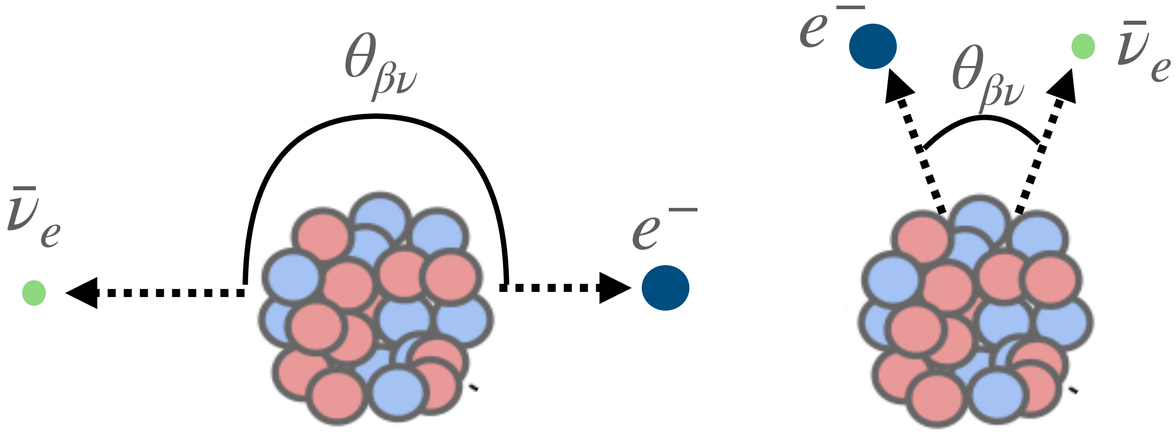
- Conversion of $d \rightarrow u$
  - Strong test of V_{ud}





Testing V_{ud} With β-decay

- Conversion of $d \rightarrow u$
  - Strong test of V_{ud}
- Want to measure $\bar{\nu}_e$ - e^- angular correlation

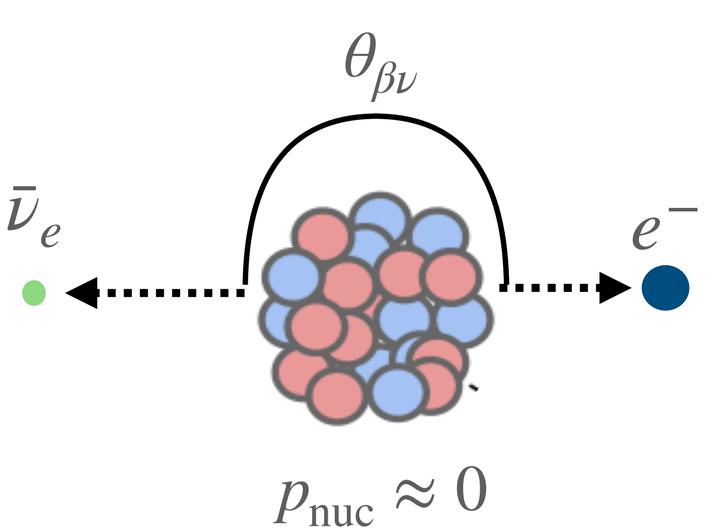


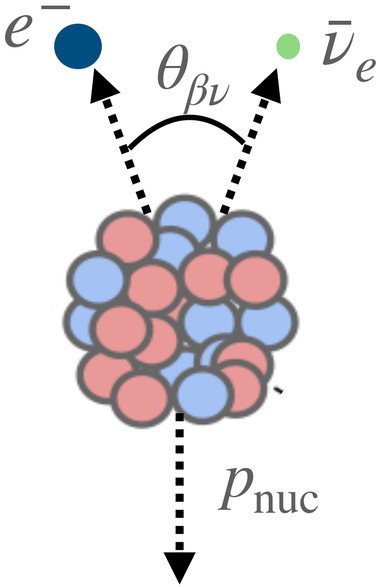
$$\mathcal{F}t\ [1 + \frac{f_A}{f_V}\rho^2] = \frac{K}{G_F^2 V_{ud}^2 g_v^2 (1 + \Delta_R^V)}$$

$$\alpha_{\beta\nu} \approx \frac{1 - \rho^2/3}{1 + \rho^2}$$

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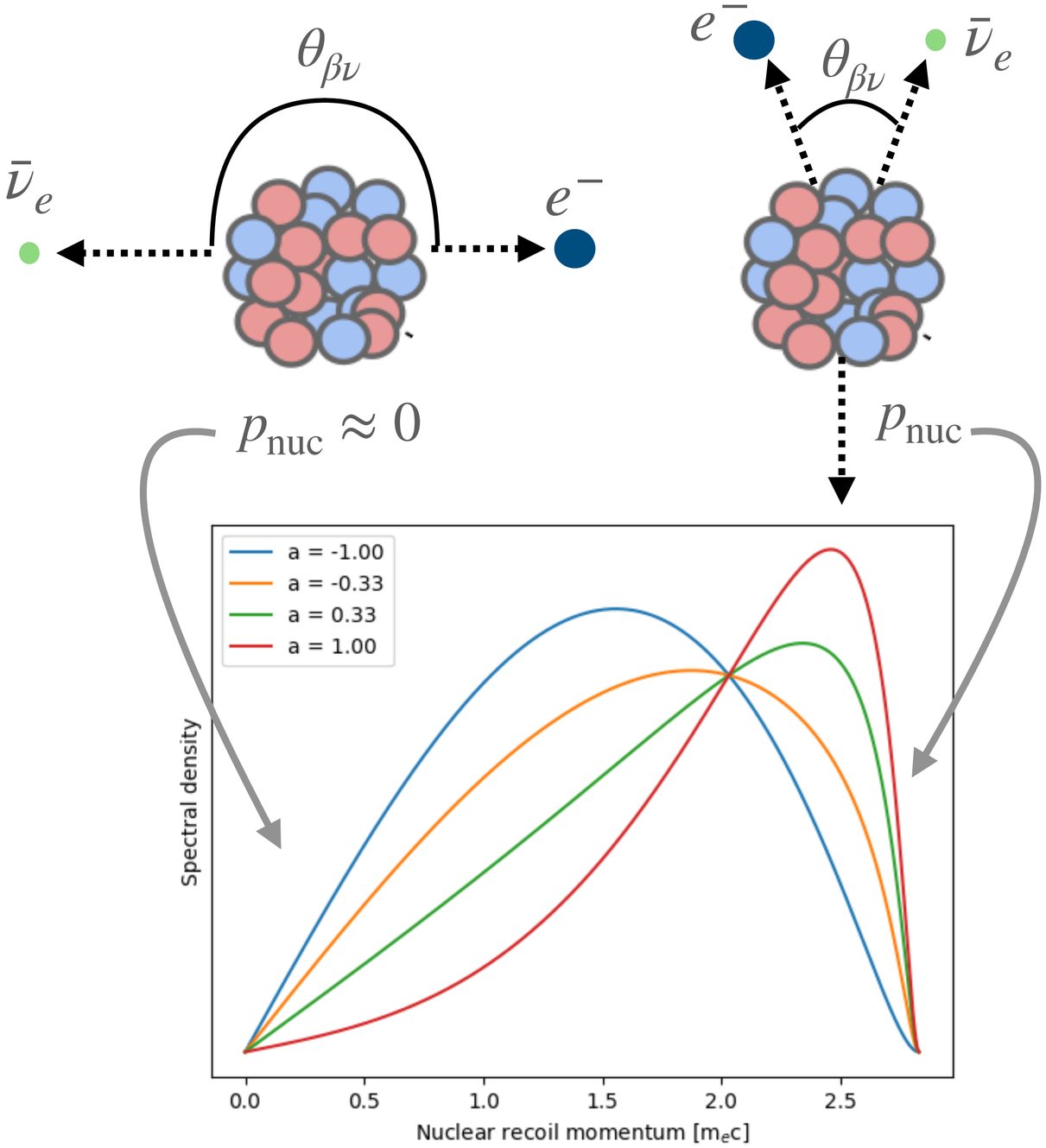
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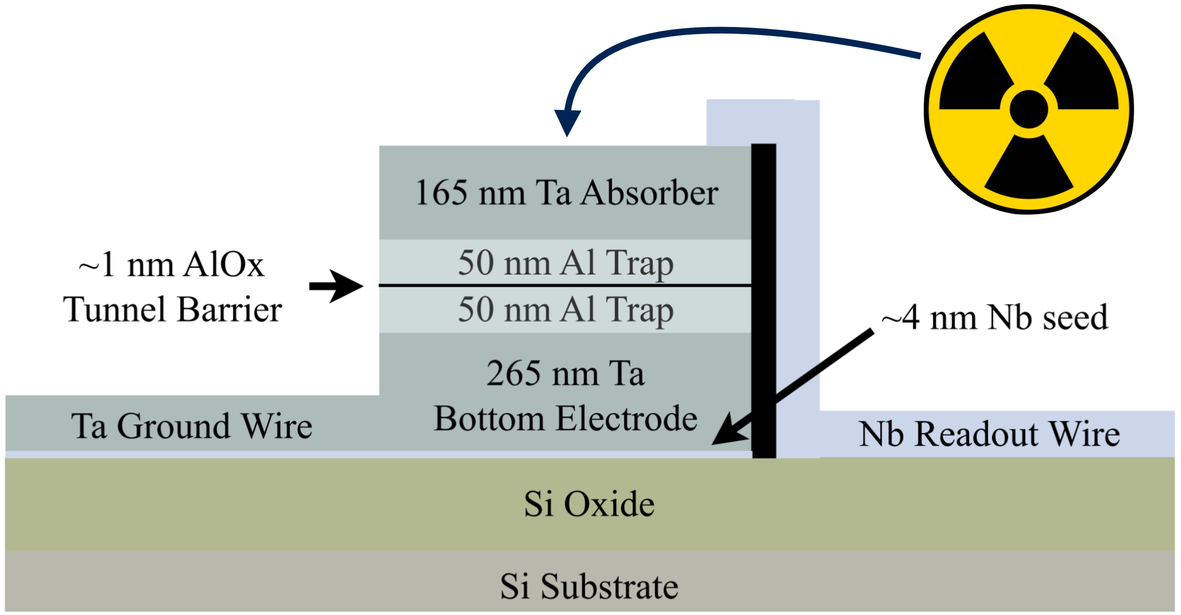
What is SALER?

What is SALER?

- Superconducting Array for Low Energy Radiation (SALER)

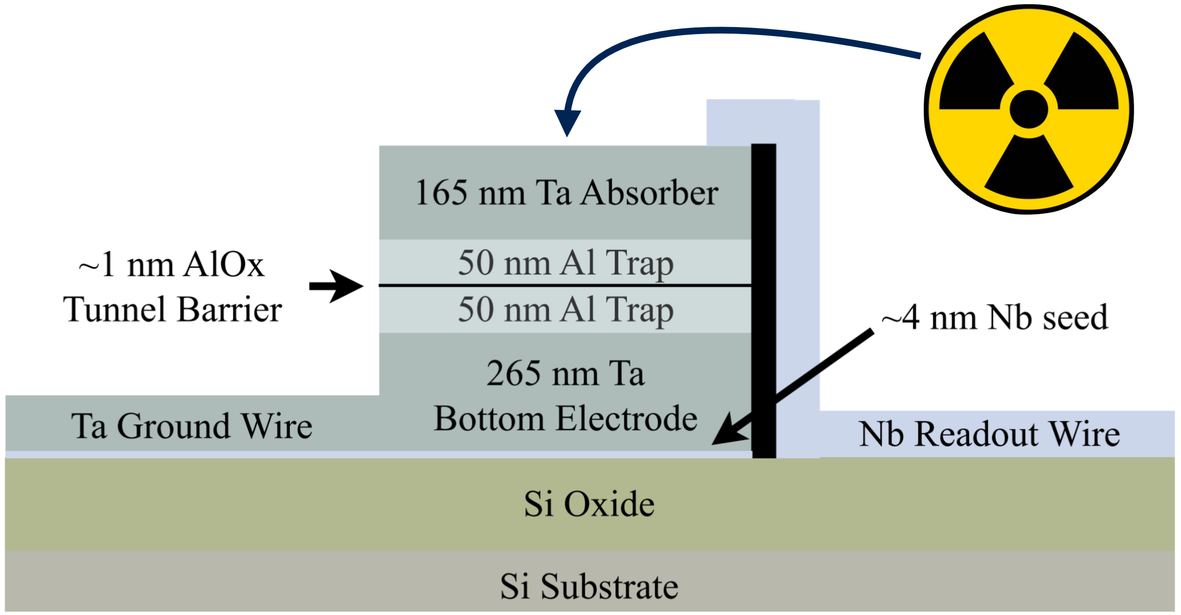
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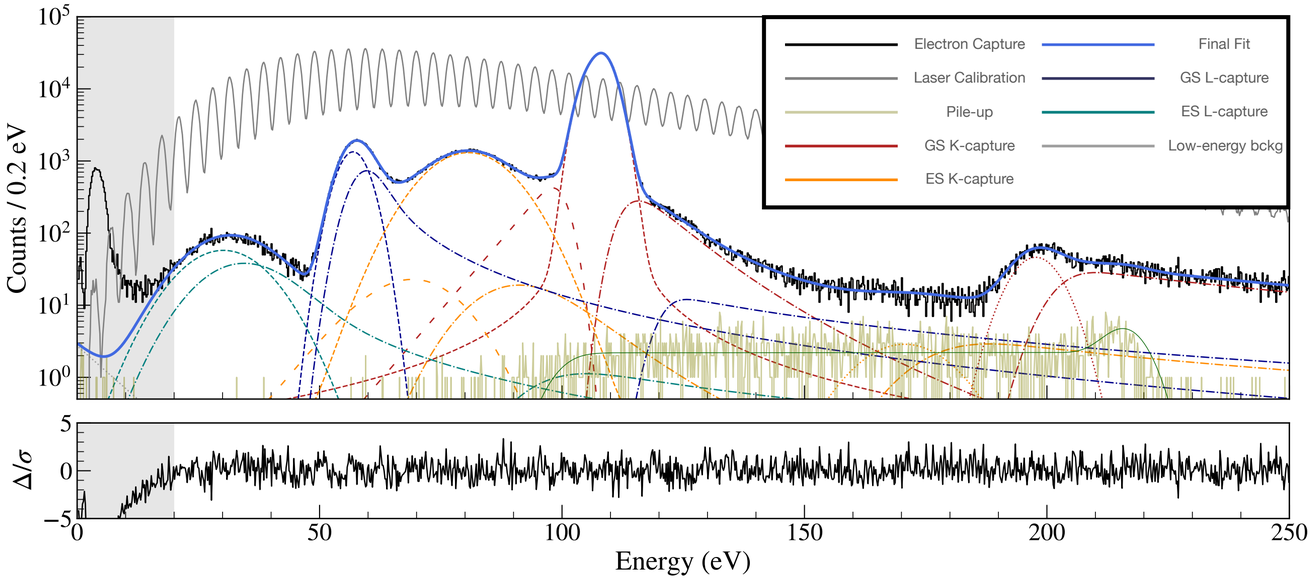
- Superconducting Array for Low Energy Radiation (SALER)
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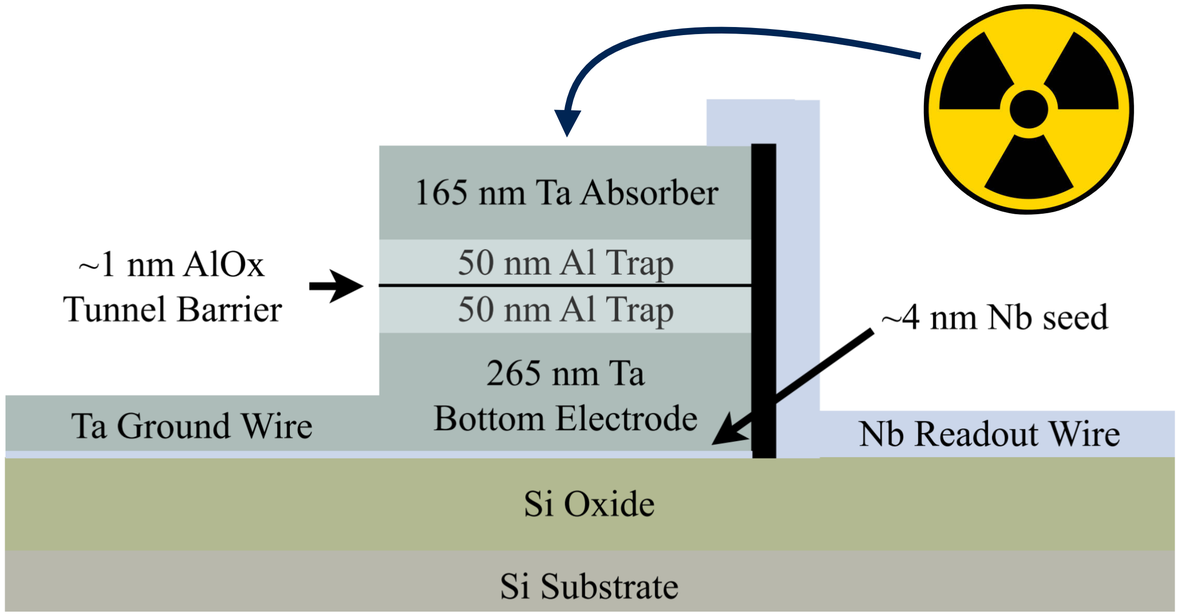


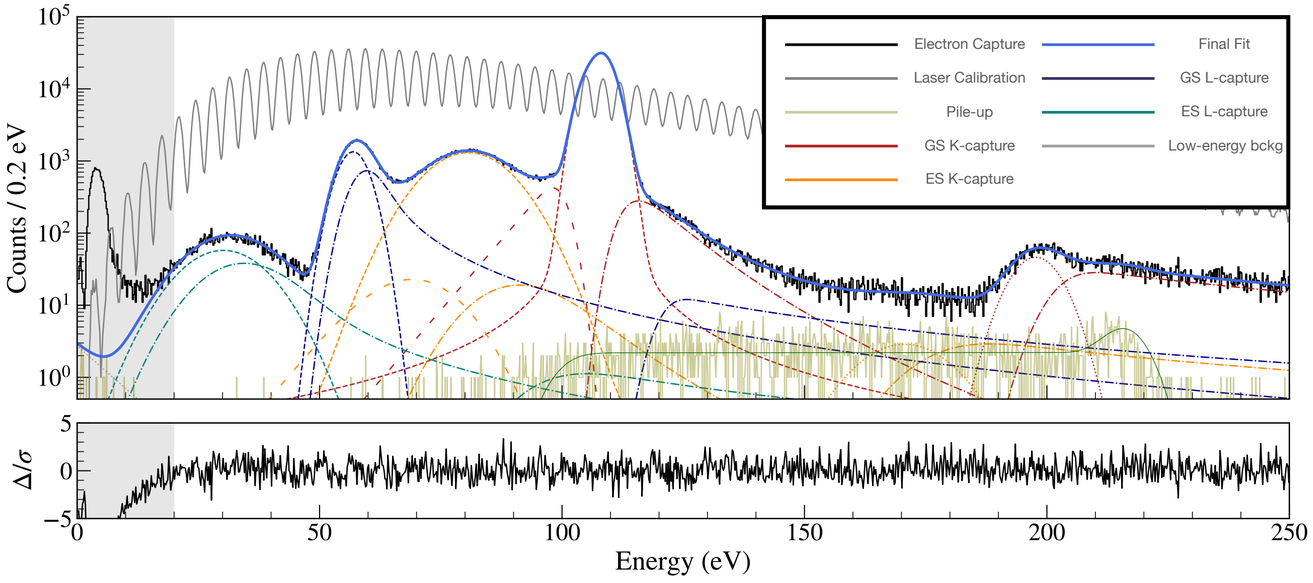


- STJ implantation pioneered by BeEST experiment
  - *Phys.Rev.D* 111 (2025) 5, 052010
- Implantation→Delivery→Measurement

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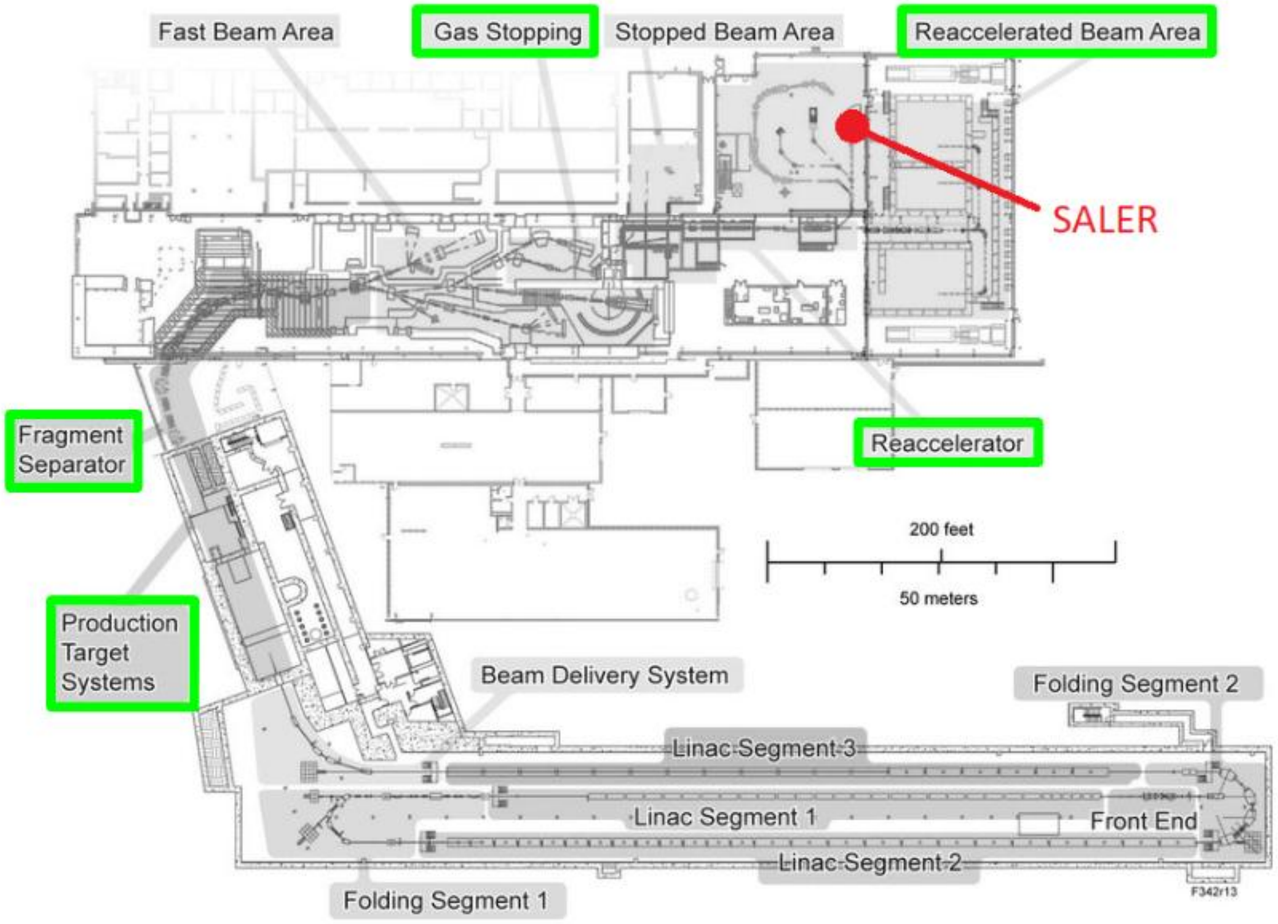




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- Implantation→Delivery→Measurement
  - $\tau_{\text{isotope}} \gg \tau_{\text{Fedex}}$

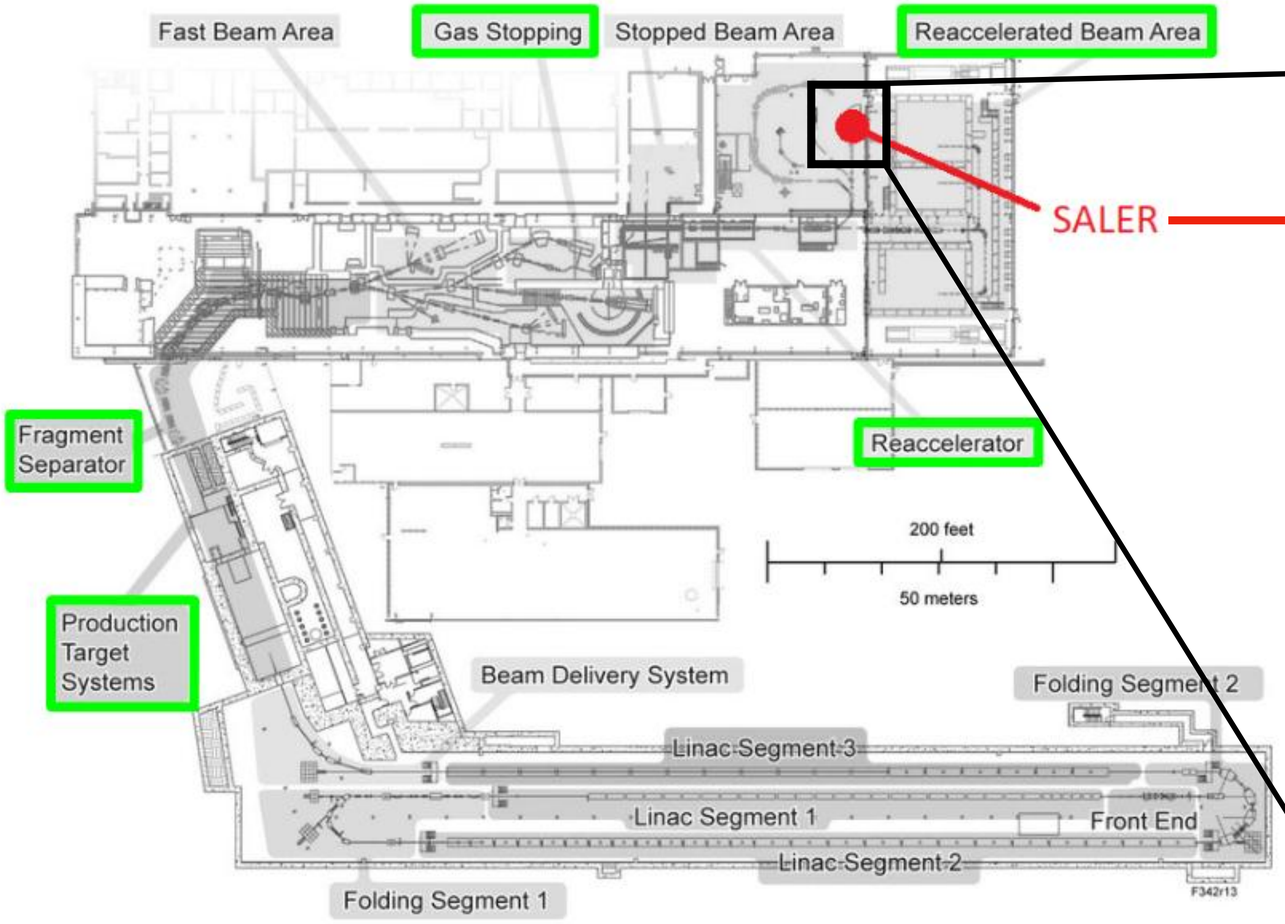
SALER @ FRIB

FRIB Facility



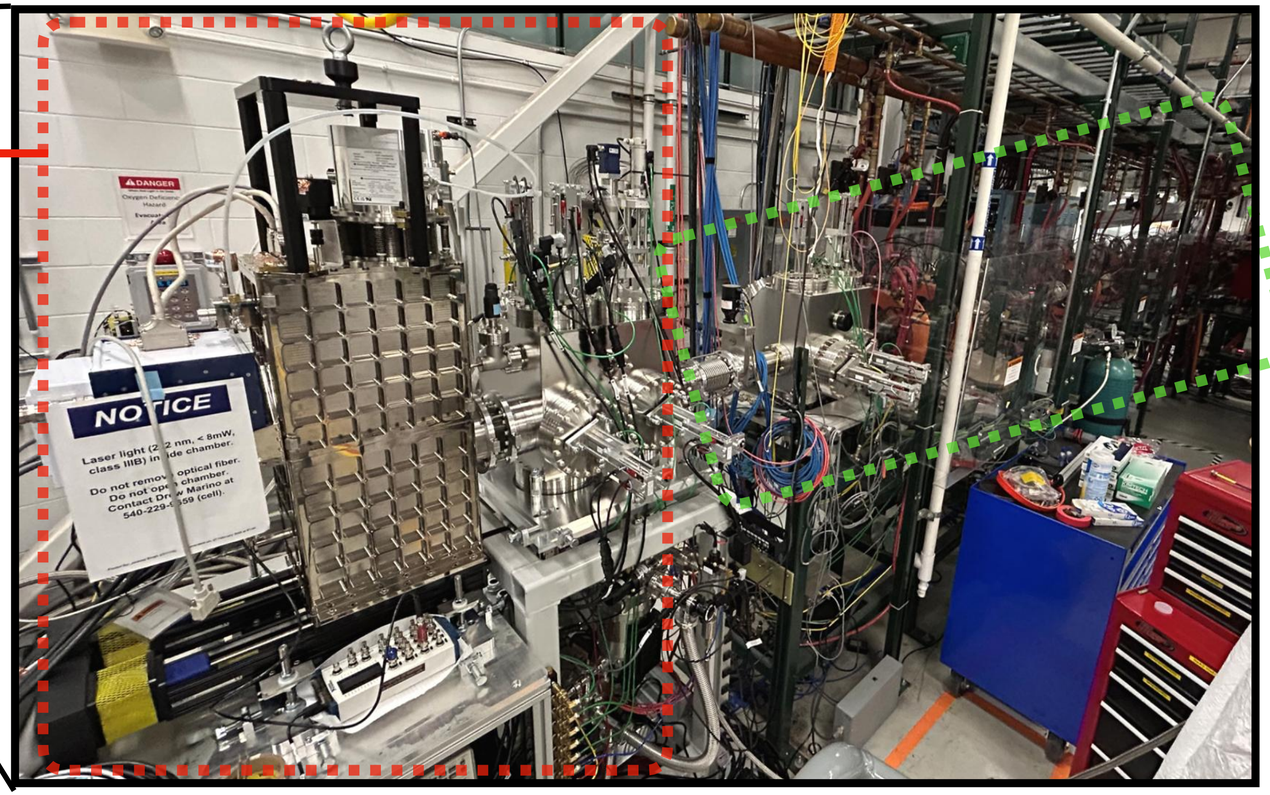
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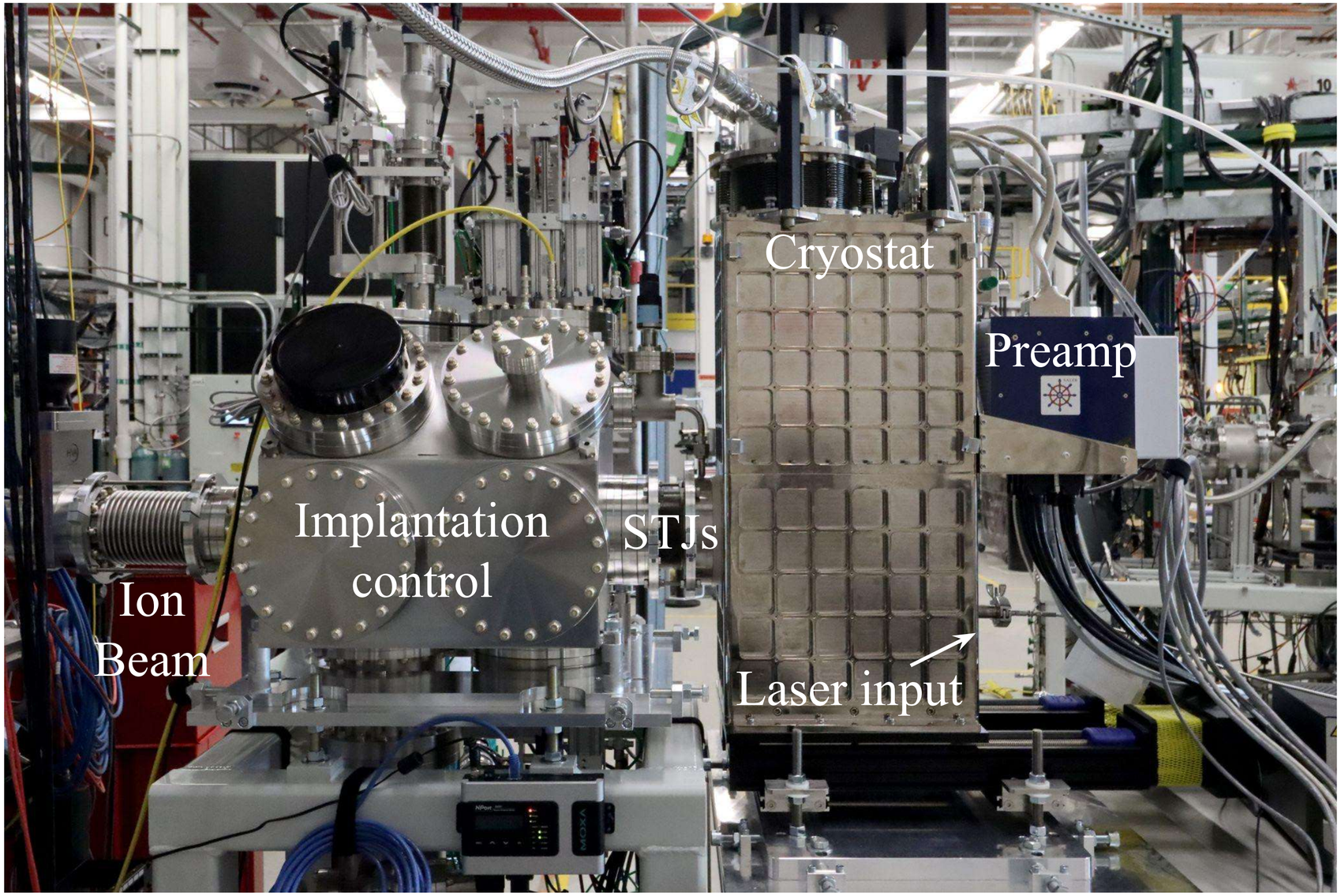


SALER

FRIB Beam Line

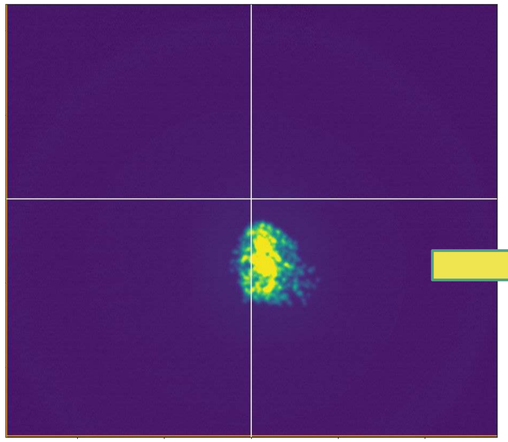


SALER System

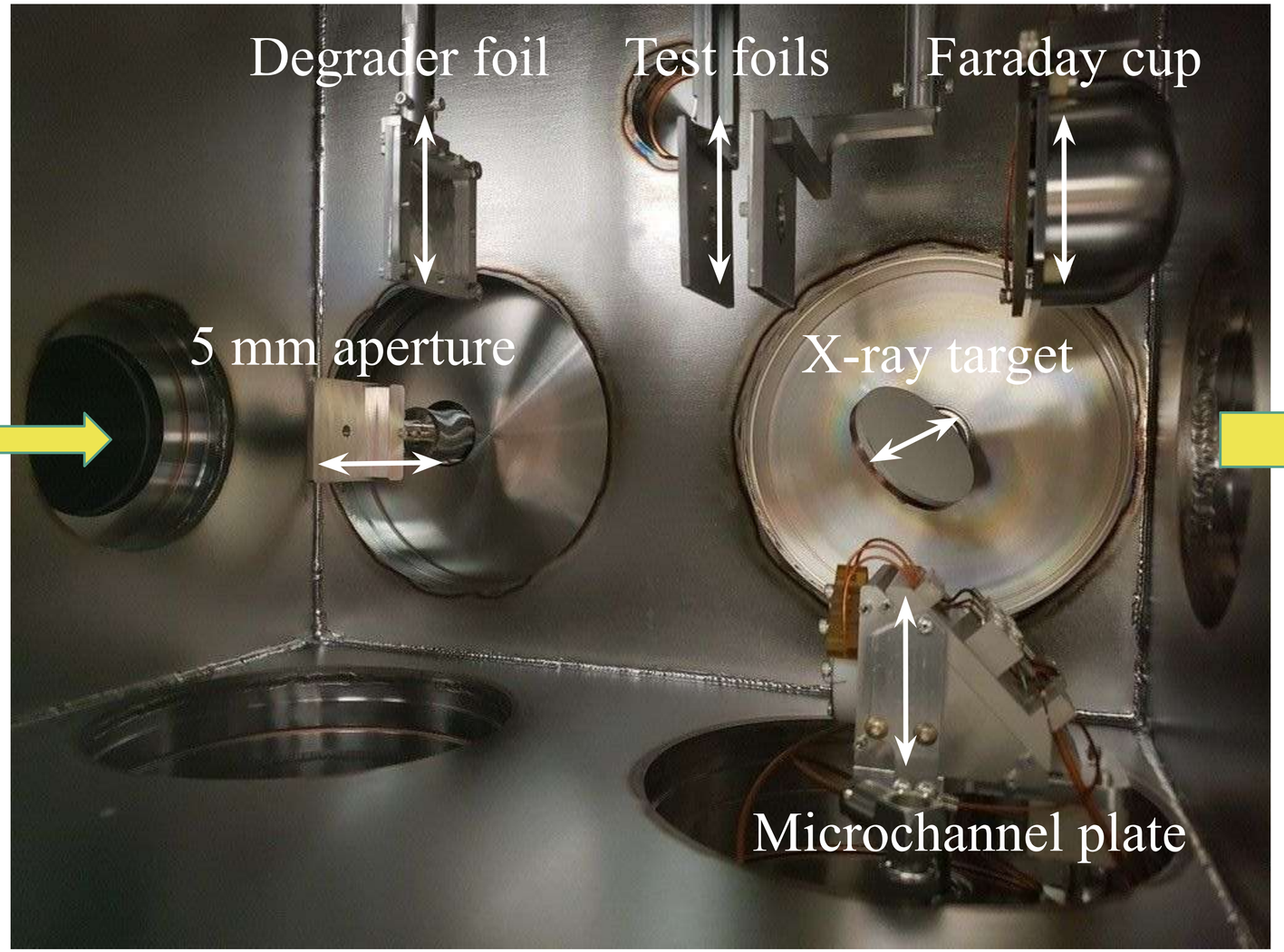


Implantation Control

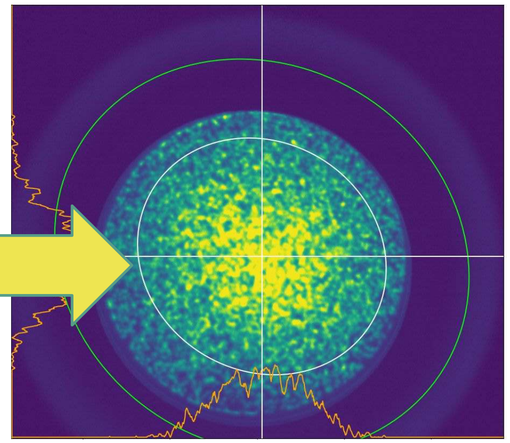
From FRIB
(~1 MeV / nucleon)



3 cm



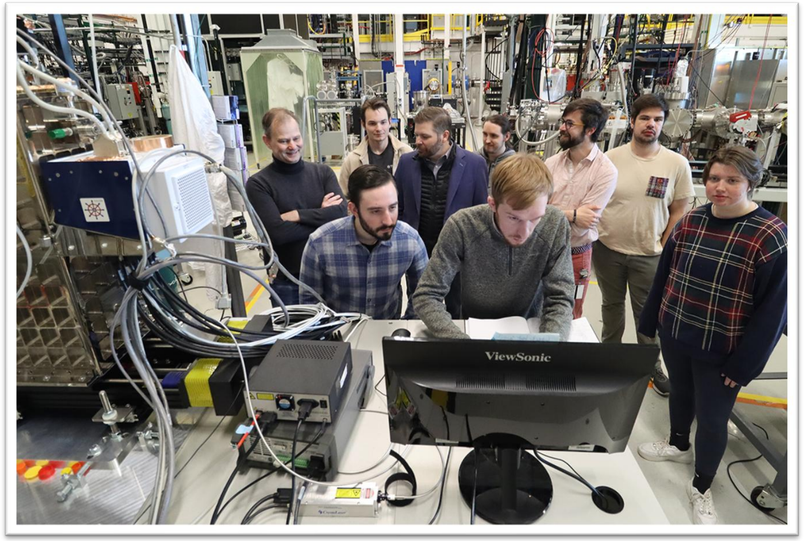
To SALER
(~100 keV / ion)



3 cm

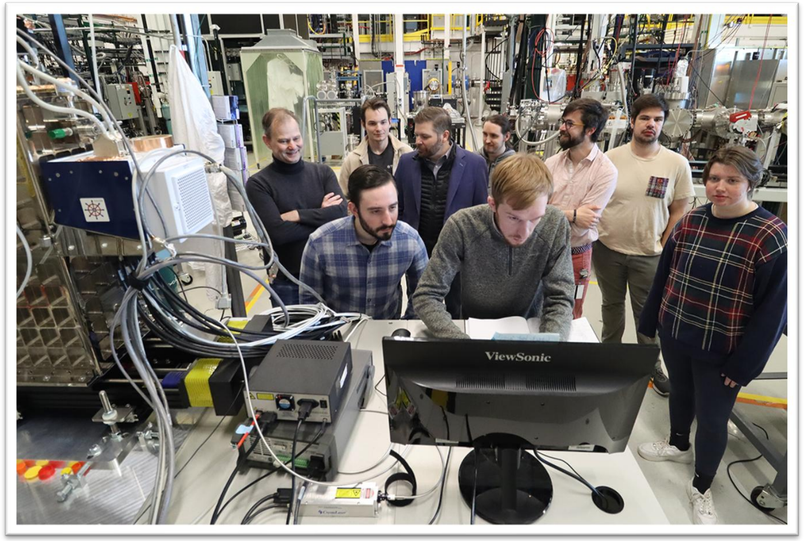
Online Commissioning

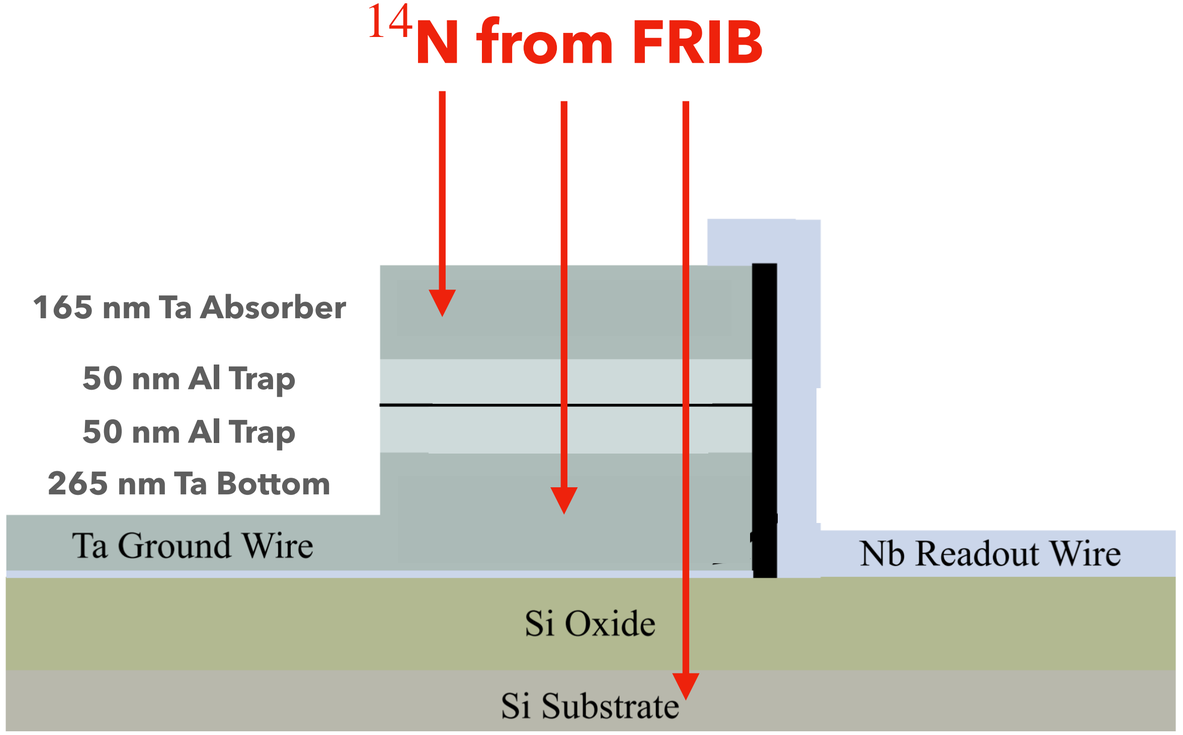
- Recently commissioned SALER with stable ^{14}N beam
  - NO radioactive decays
  - Measure implantation recoils



Online Commissioning

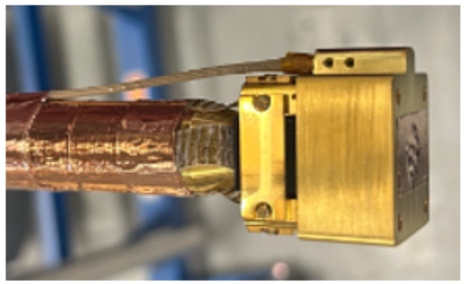
- Recently commissioned SALER with stable ^{14}N beam
  - NO radioactive decays
  - Measure implantation recoils
- Want to answer operational questions:
  - Can we implant into the STJ?
  - Can we control energy and implantation depth
  - What are the operational parameters

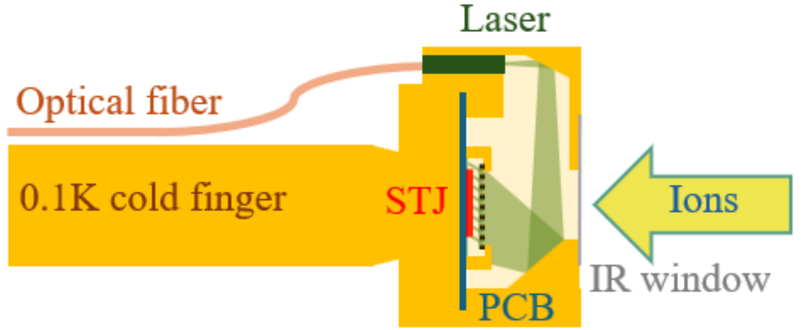


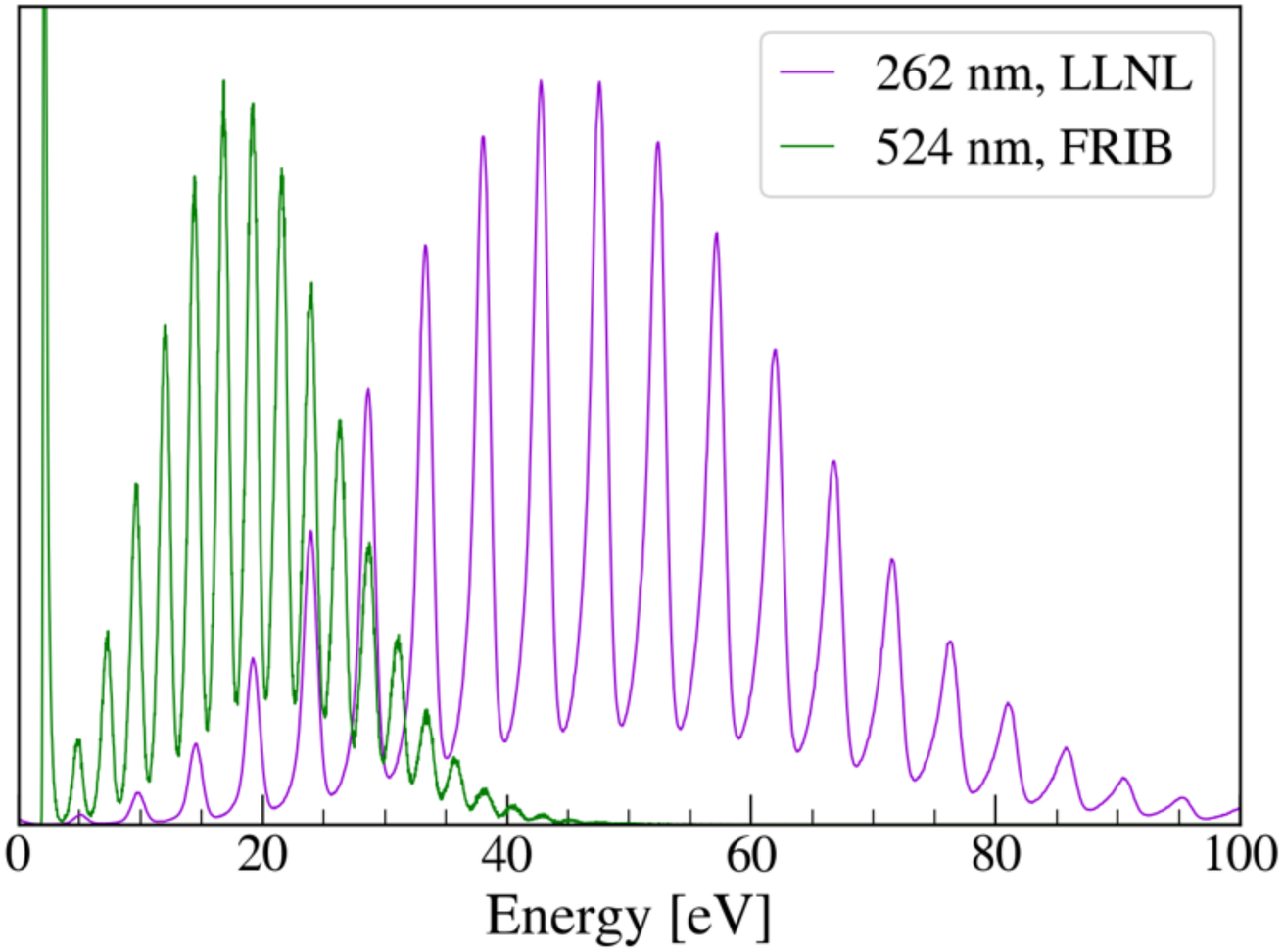


Laser Calibration

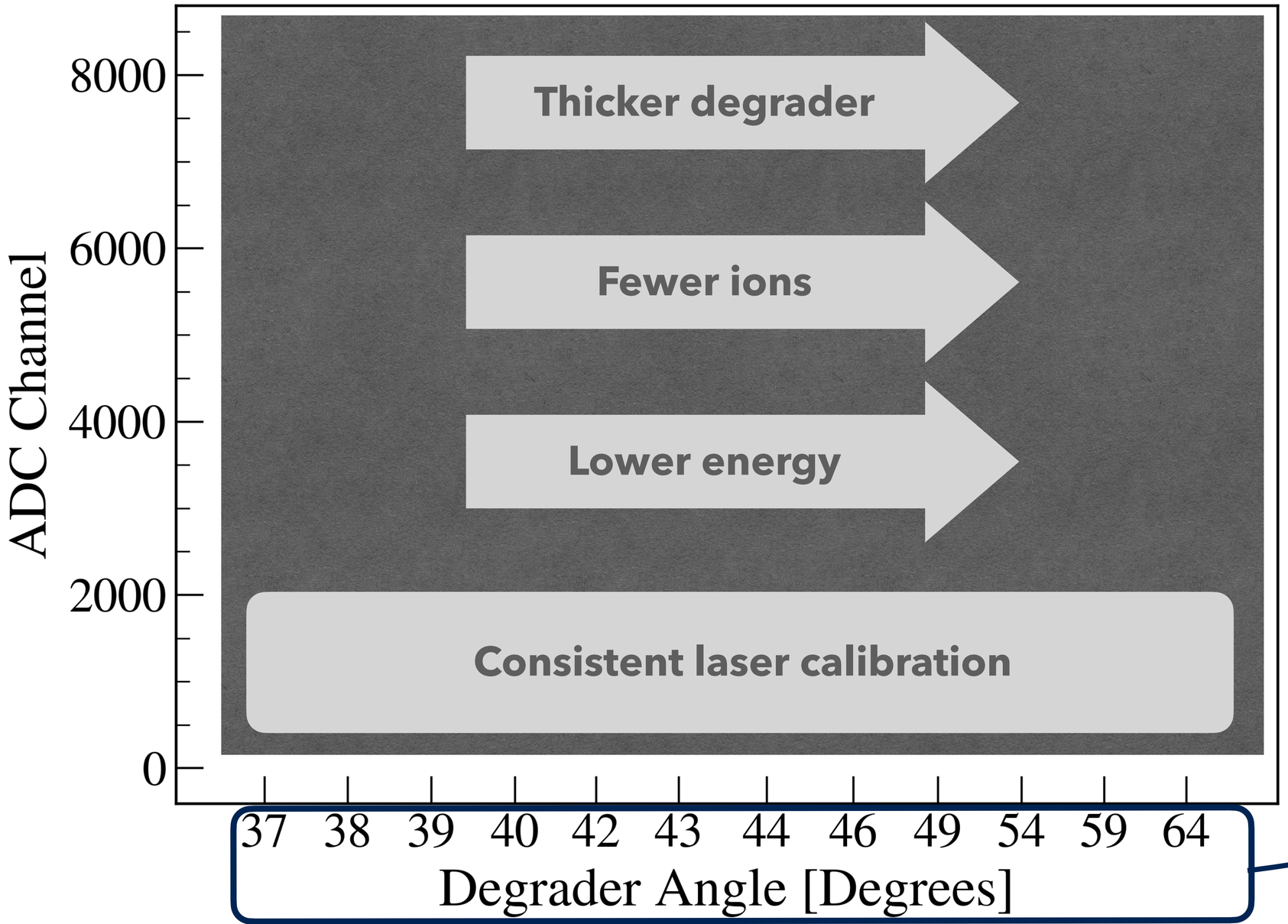
- Laser used for in-situ calibration
  - Pulsed nature allows alternating implantation and calibration
- Good agreement between LLNL testing and FRIB installation
- ~ 0.8 eV FWHM
  - SALER can operate in beamline

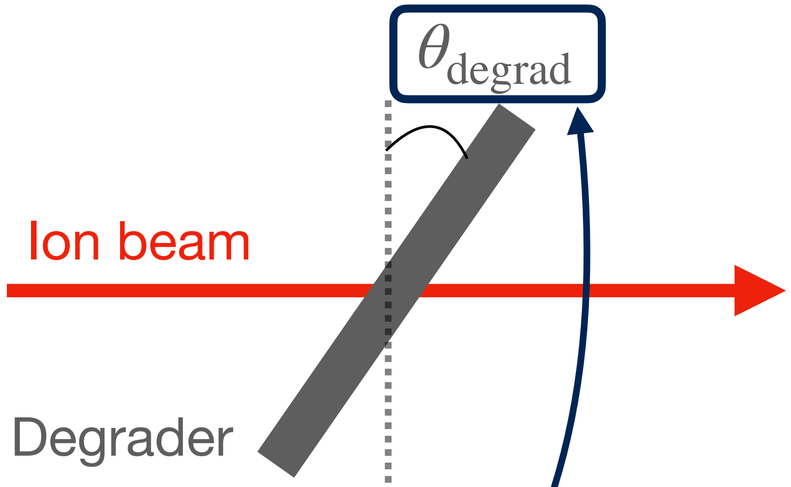




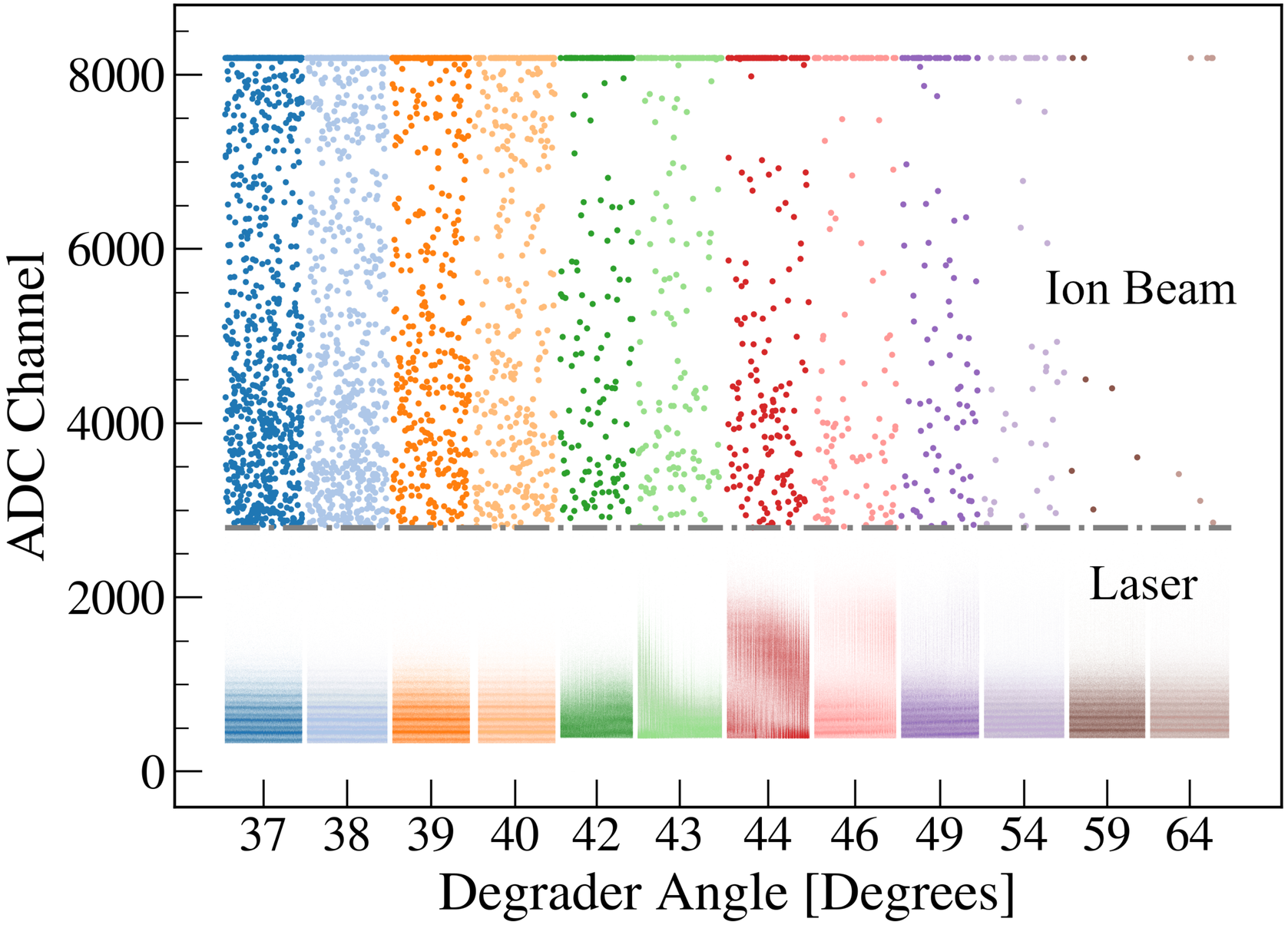


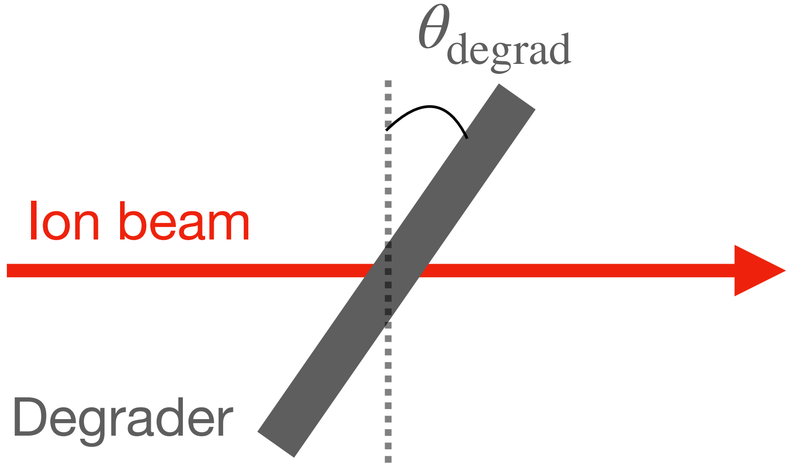
^{14}N Implantation



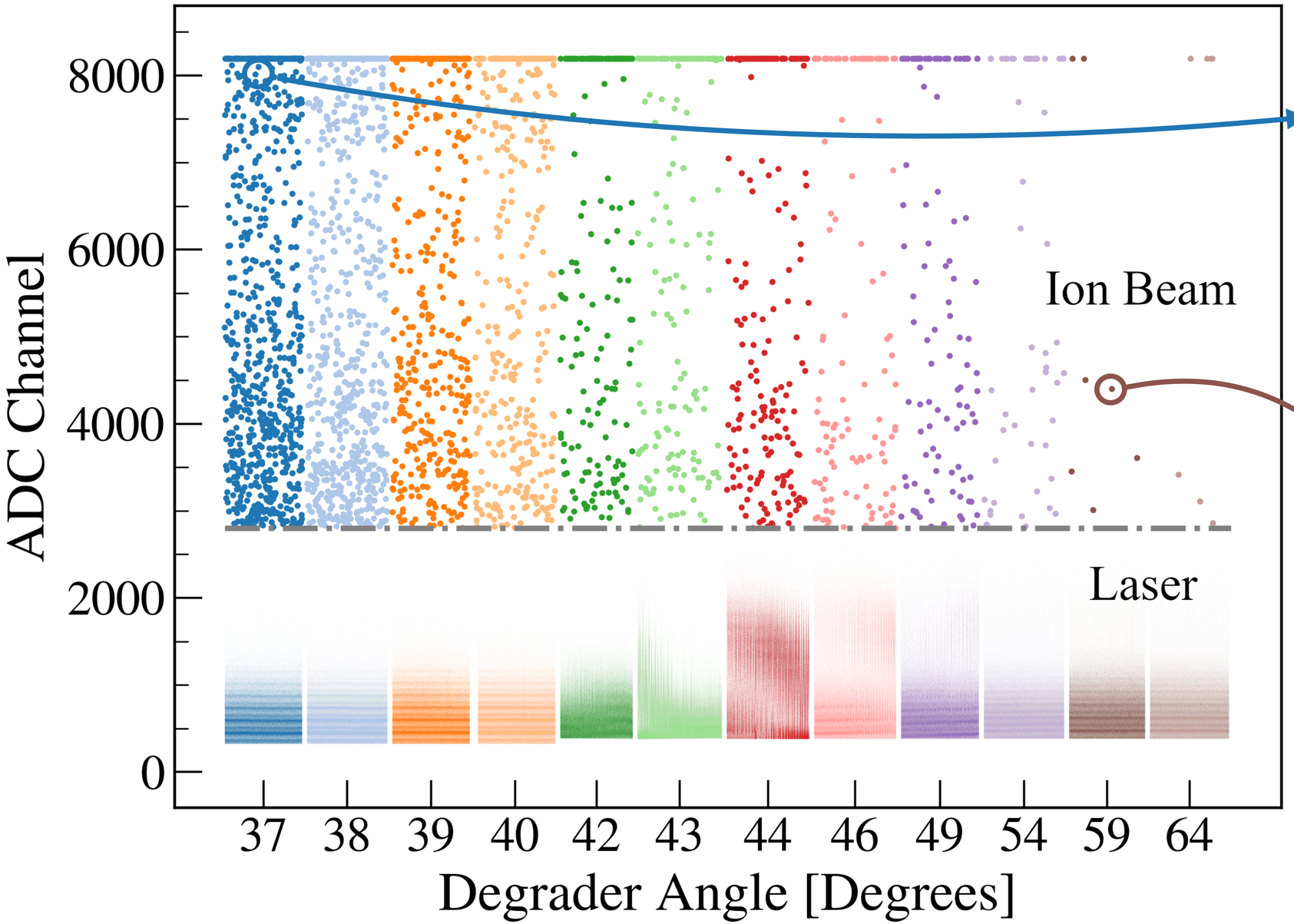


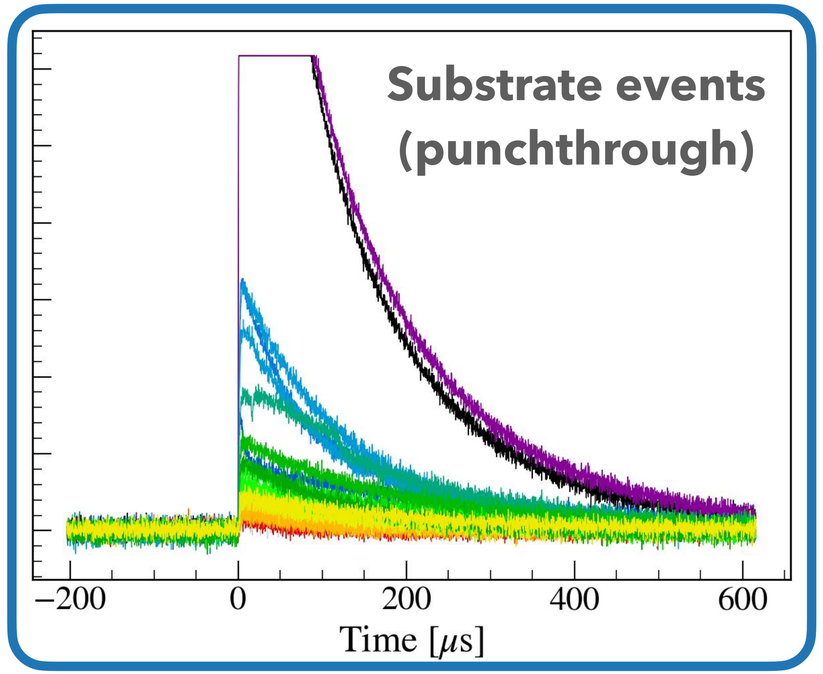
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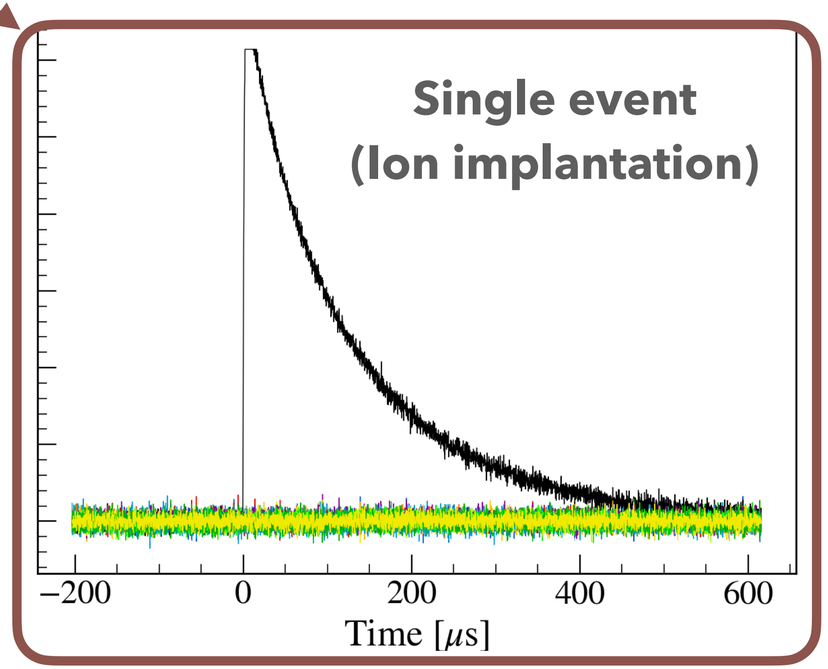




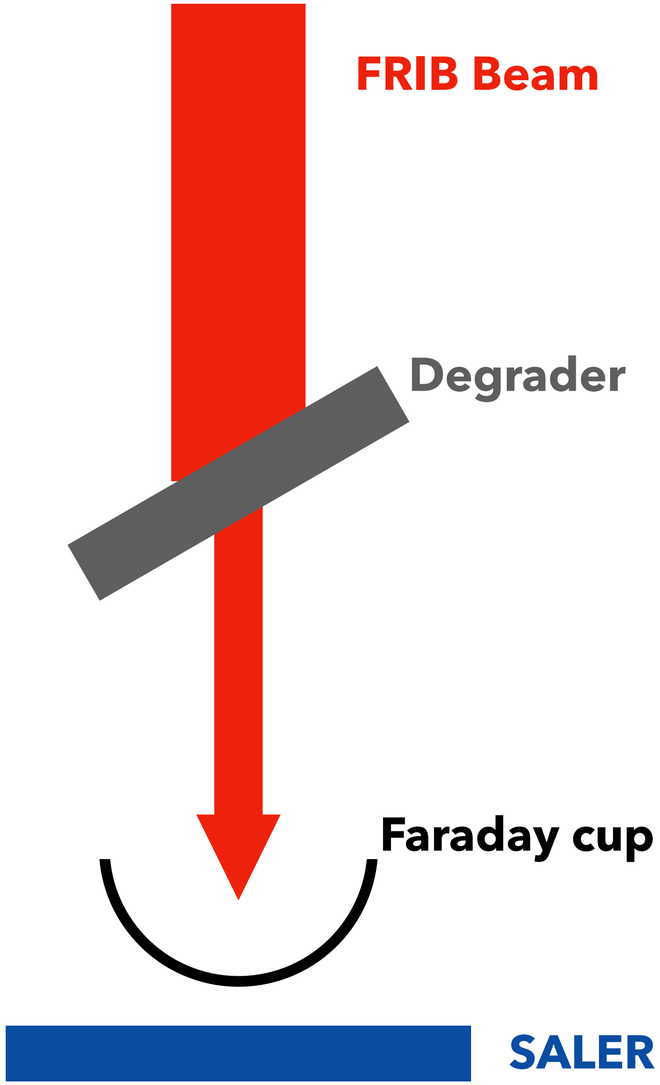
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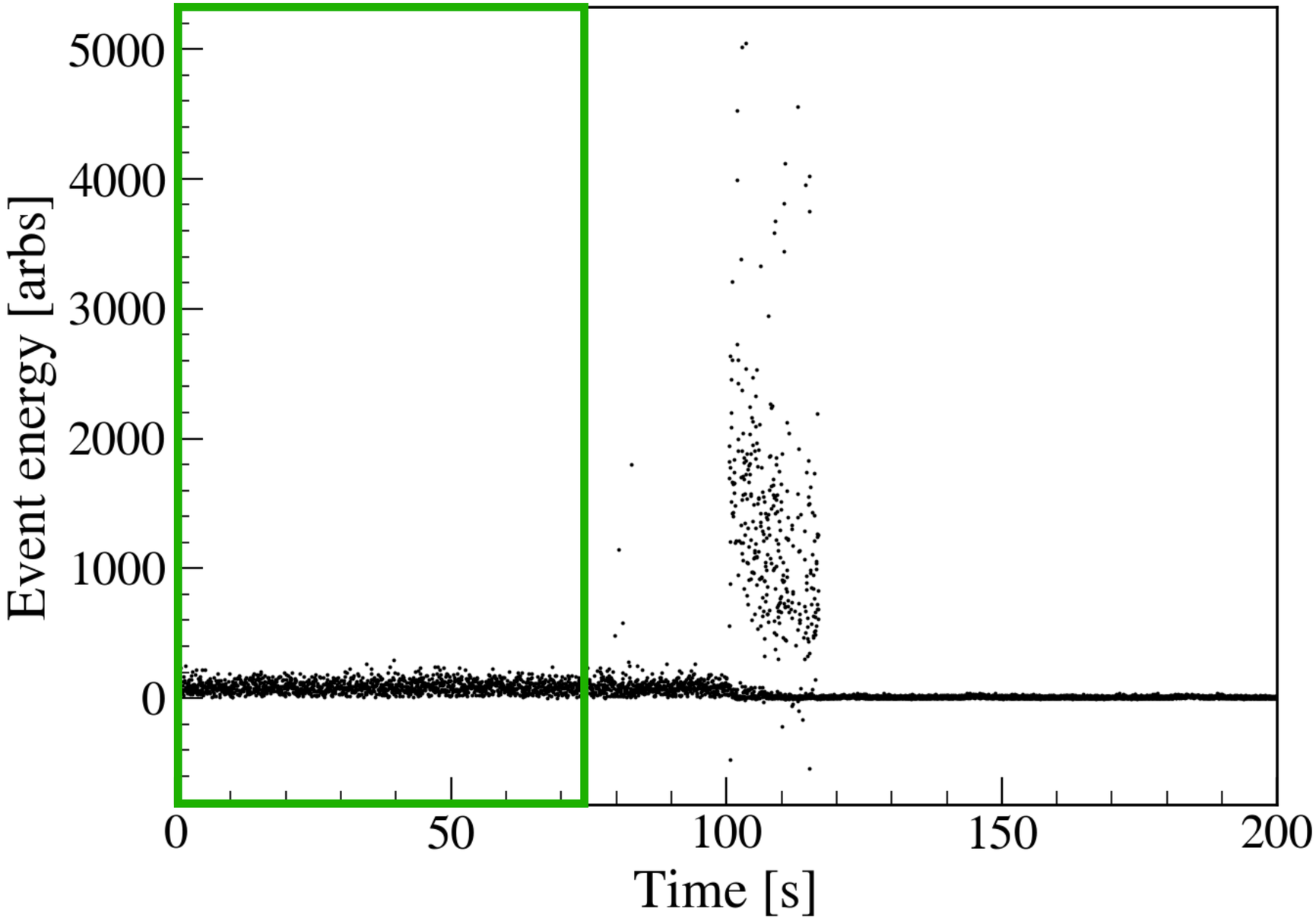




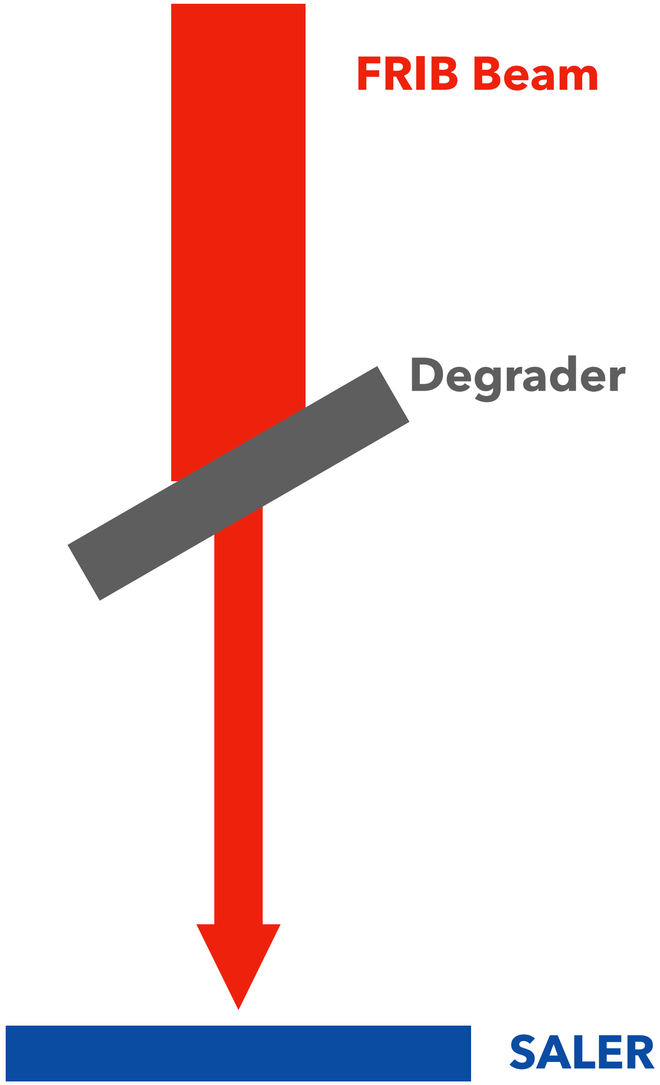


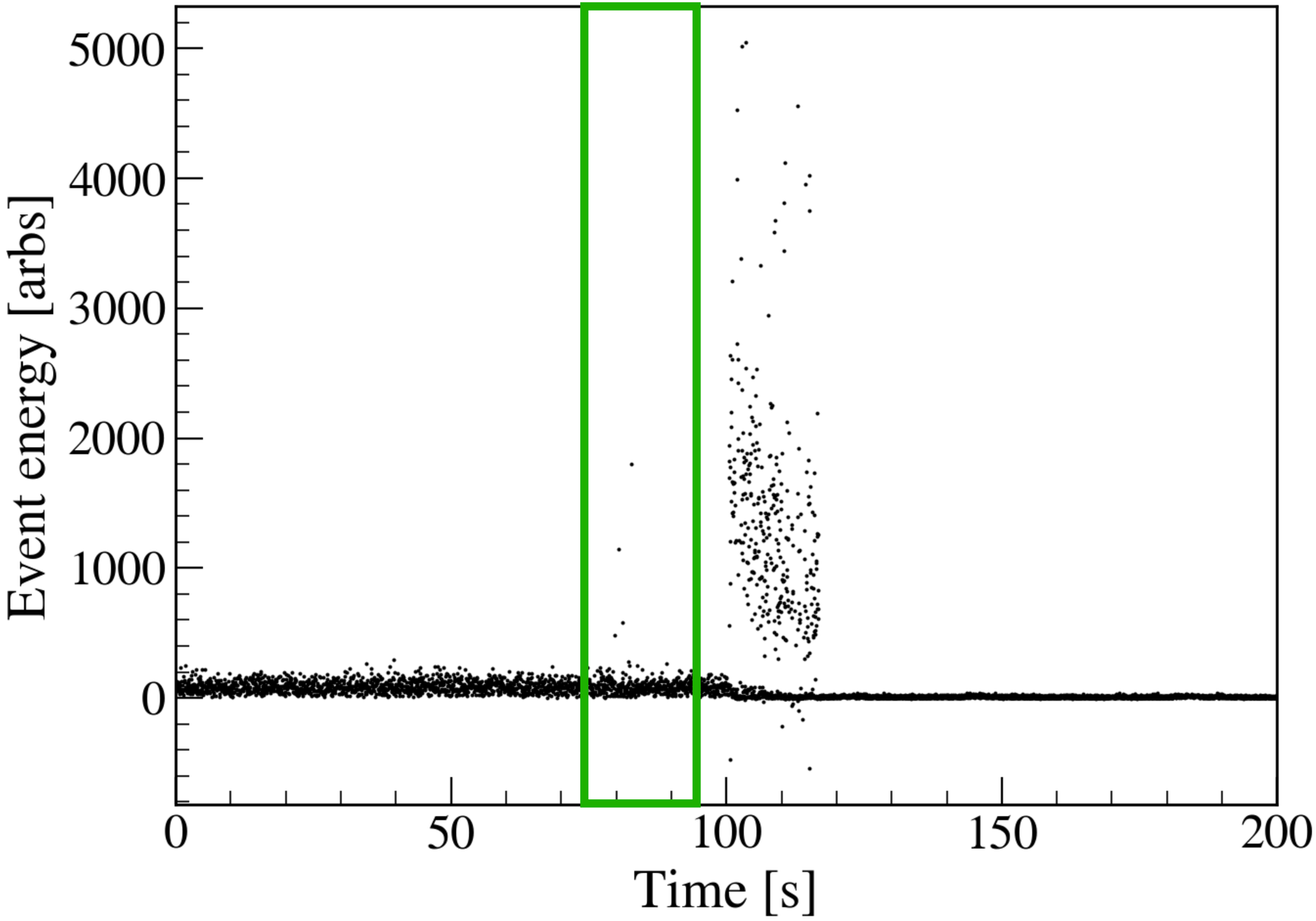
Blasting


FRIB Beam
Degrader
Faraday cup
SALER

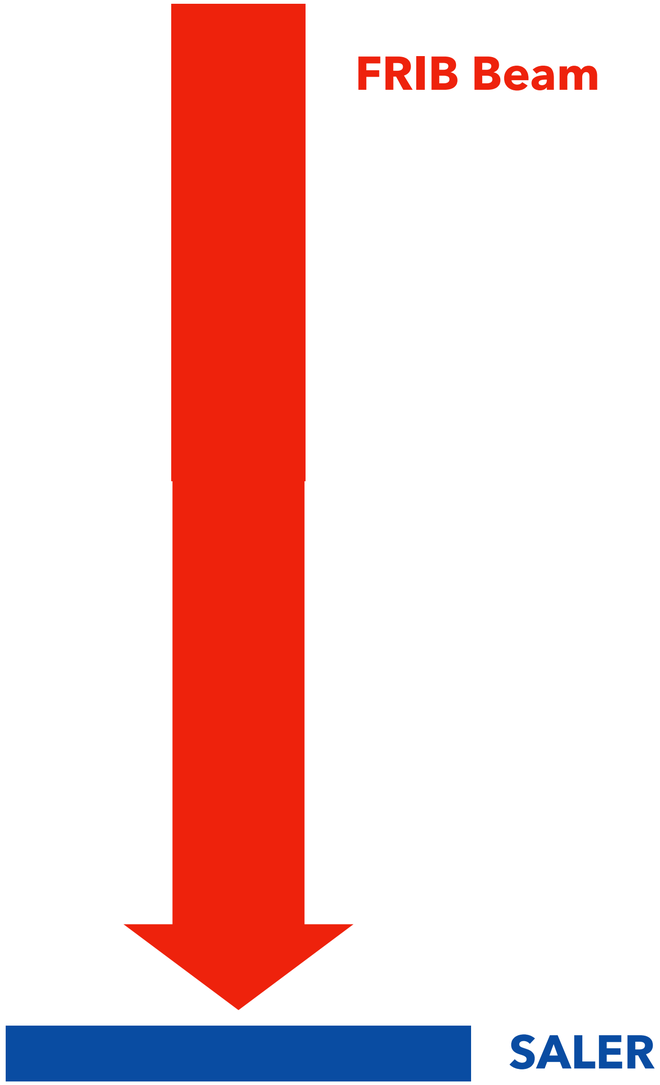

Event energy [arbs]
5000
4000
3000
2000
1000
0
0
50
100
150
200
Time [s]

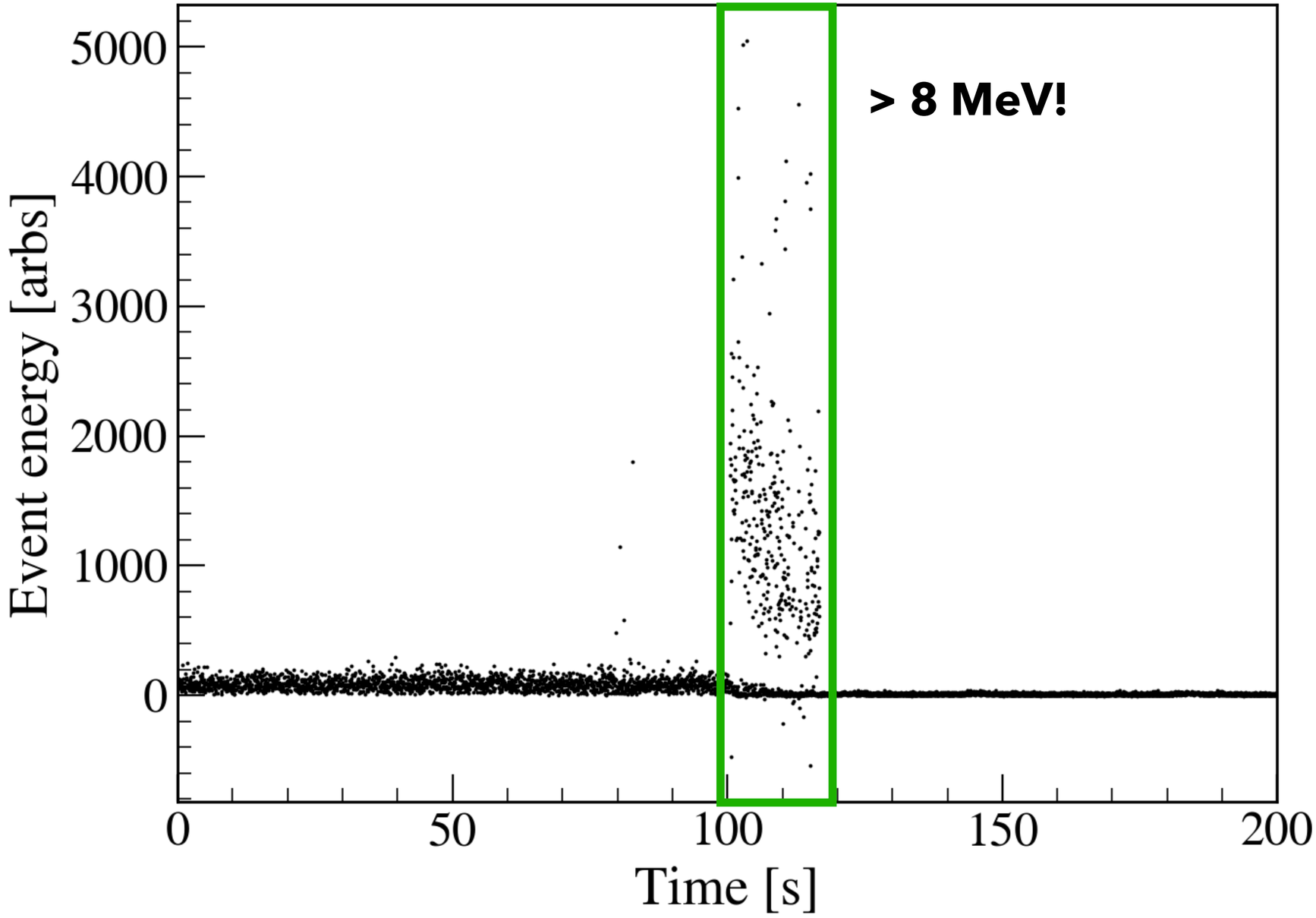
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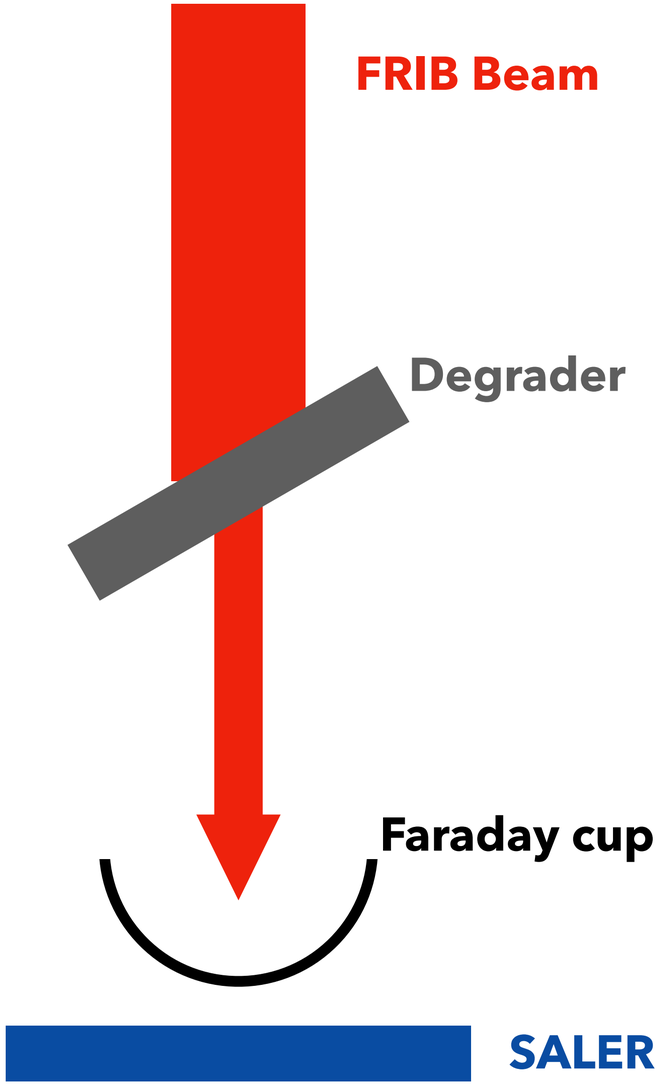

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4000
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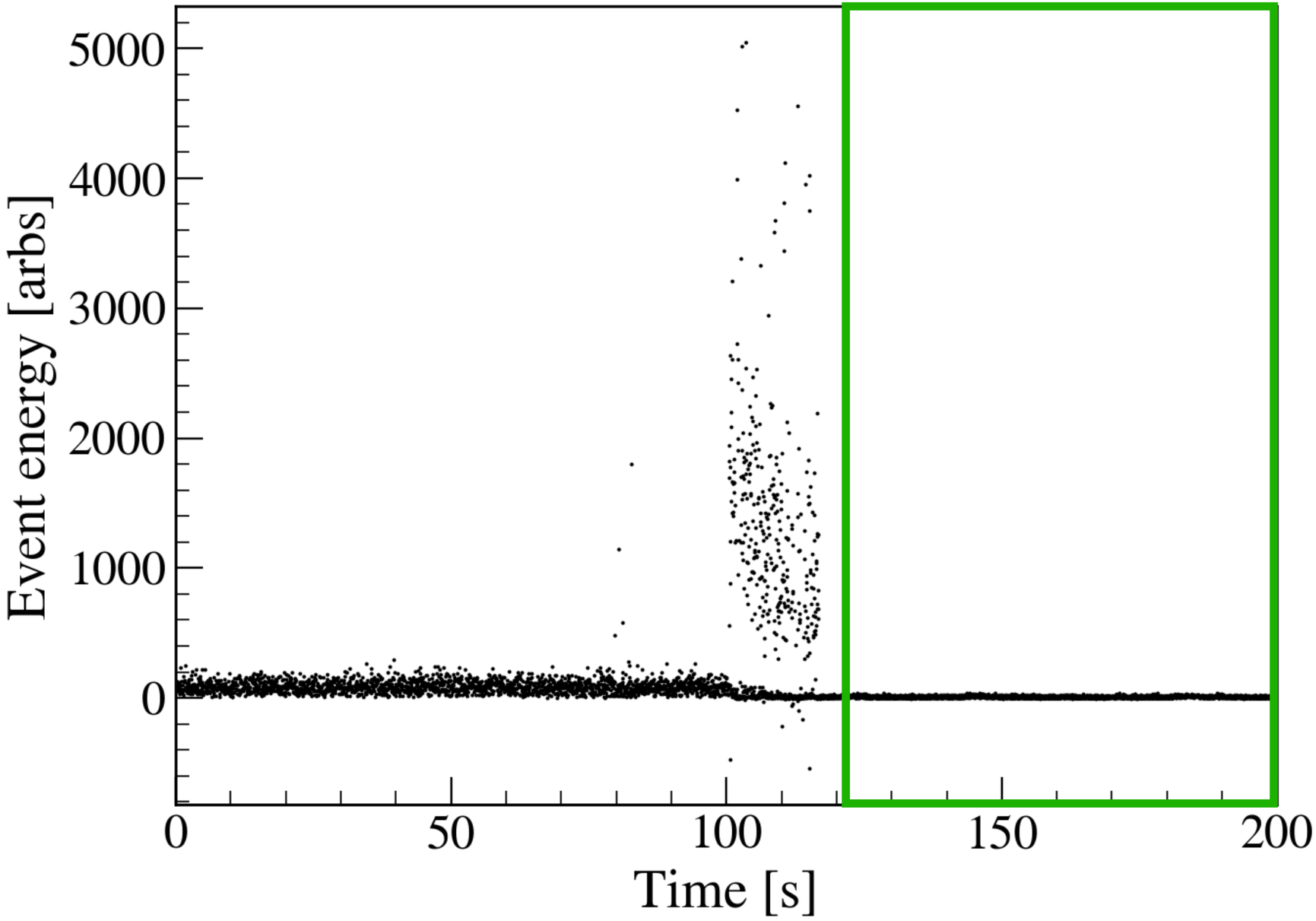
Blasting


FRIB Beam
SALER


> 8 MeV!
Event energy [arbs]
5000
4000
3000
2000
1000
0
0
50
100
150
200
Time [s]

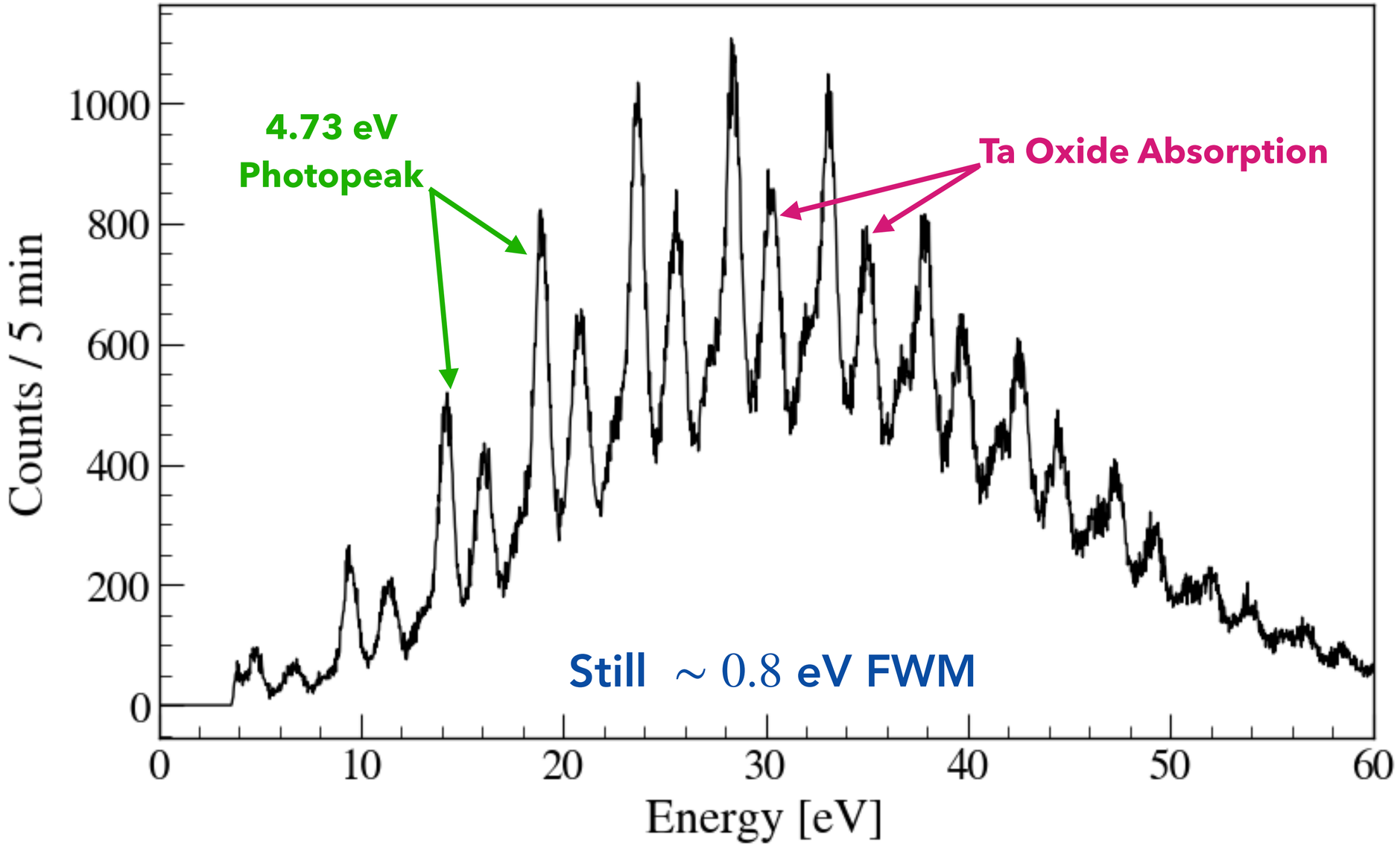
Blasting


FRIB Beam
Degrader
Faraday cup
SALER


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100
150
200
Time [s]

One Fridge Cycle Later …

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Upcoming SALER Work

- ^{25}Al beam time approved for early 2027
  - β^+ isotope for V_{ud} measurement
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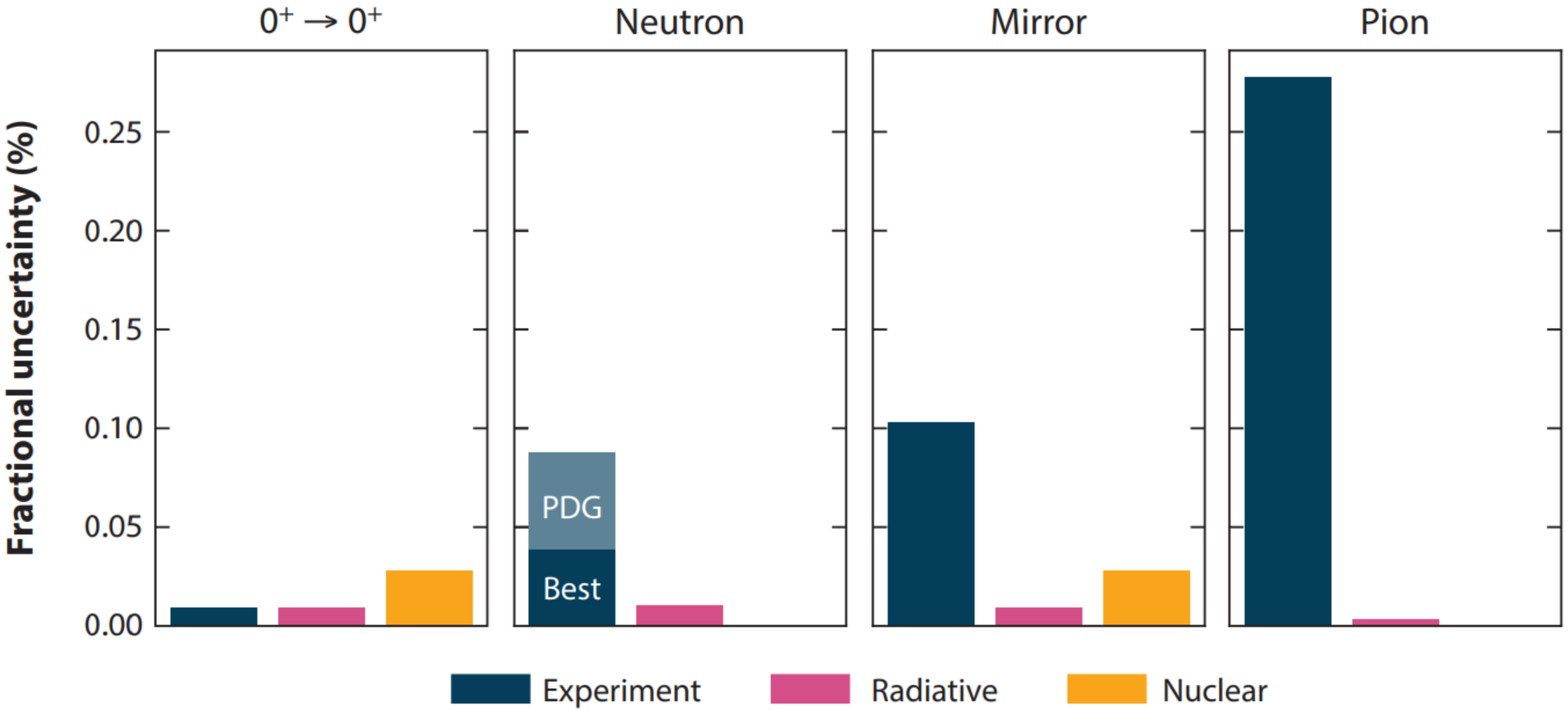
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- Other potential future projects: More V_{ud} isotopes (Mirror and Superallowed), STJ quenching factor, and other implanted detector types

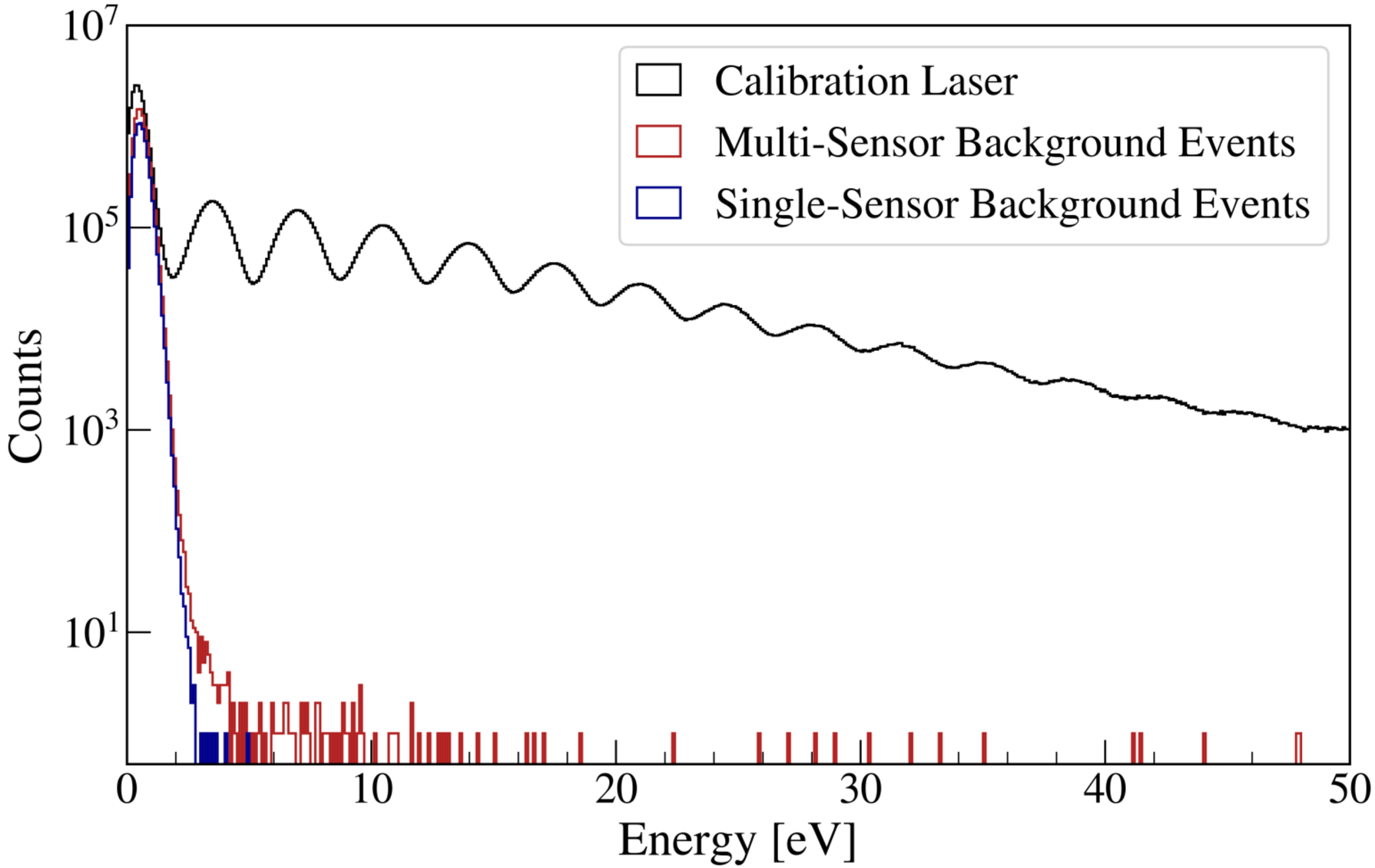


Thank You!

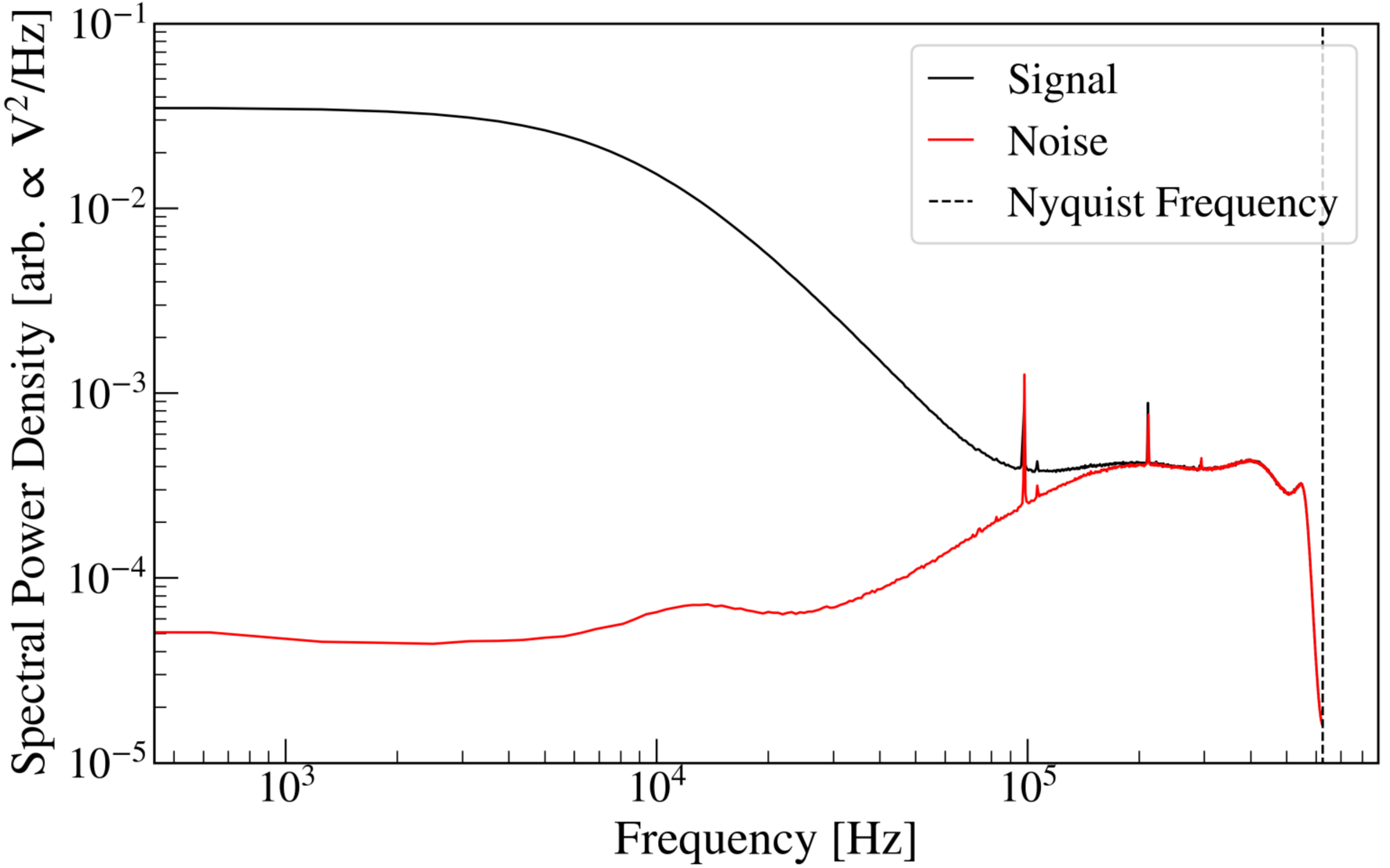
V_{ud} Measurement Techniques



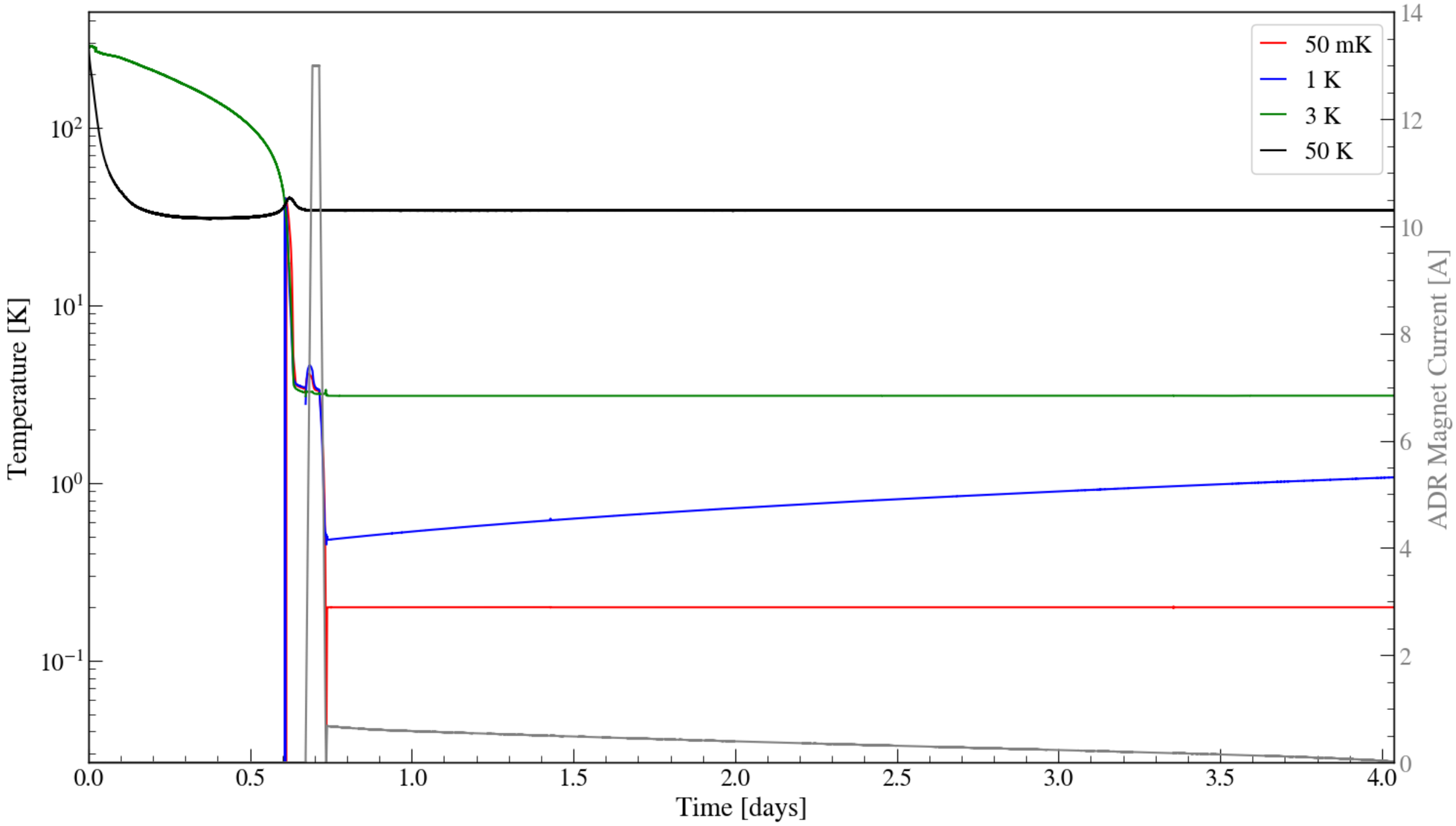
Backgrounds in STJ Arrays



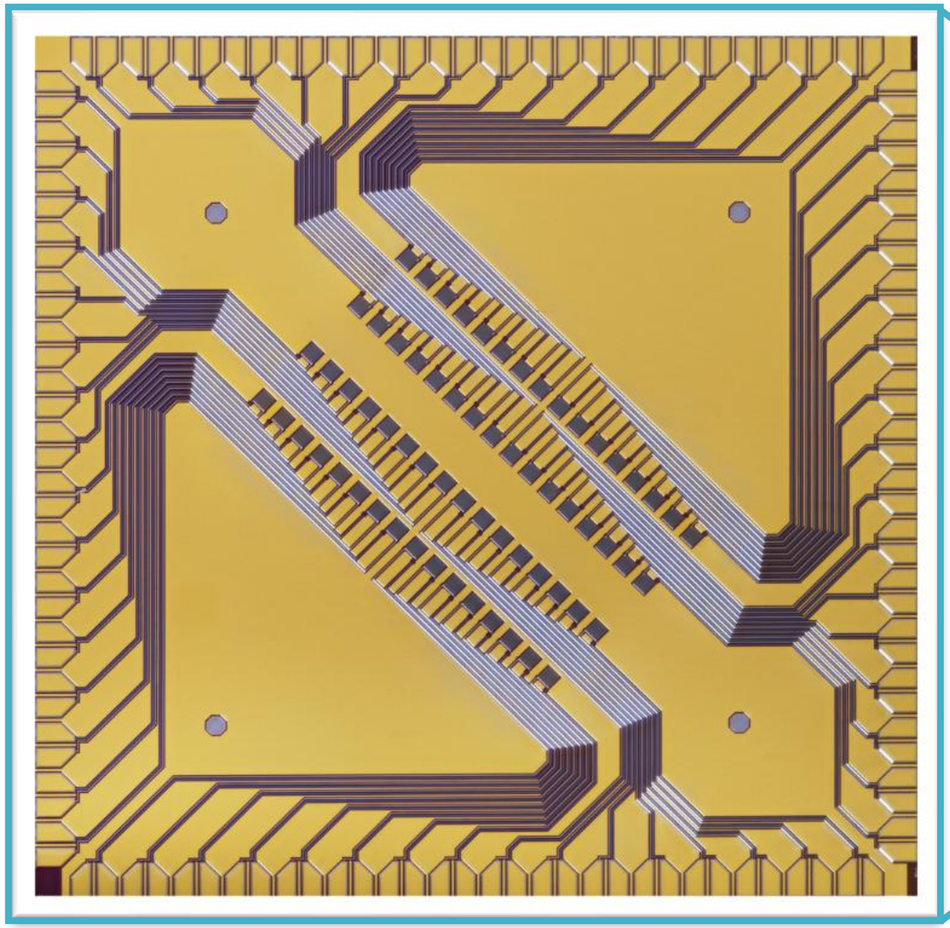
STJ Noise Profile

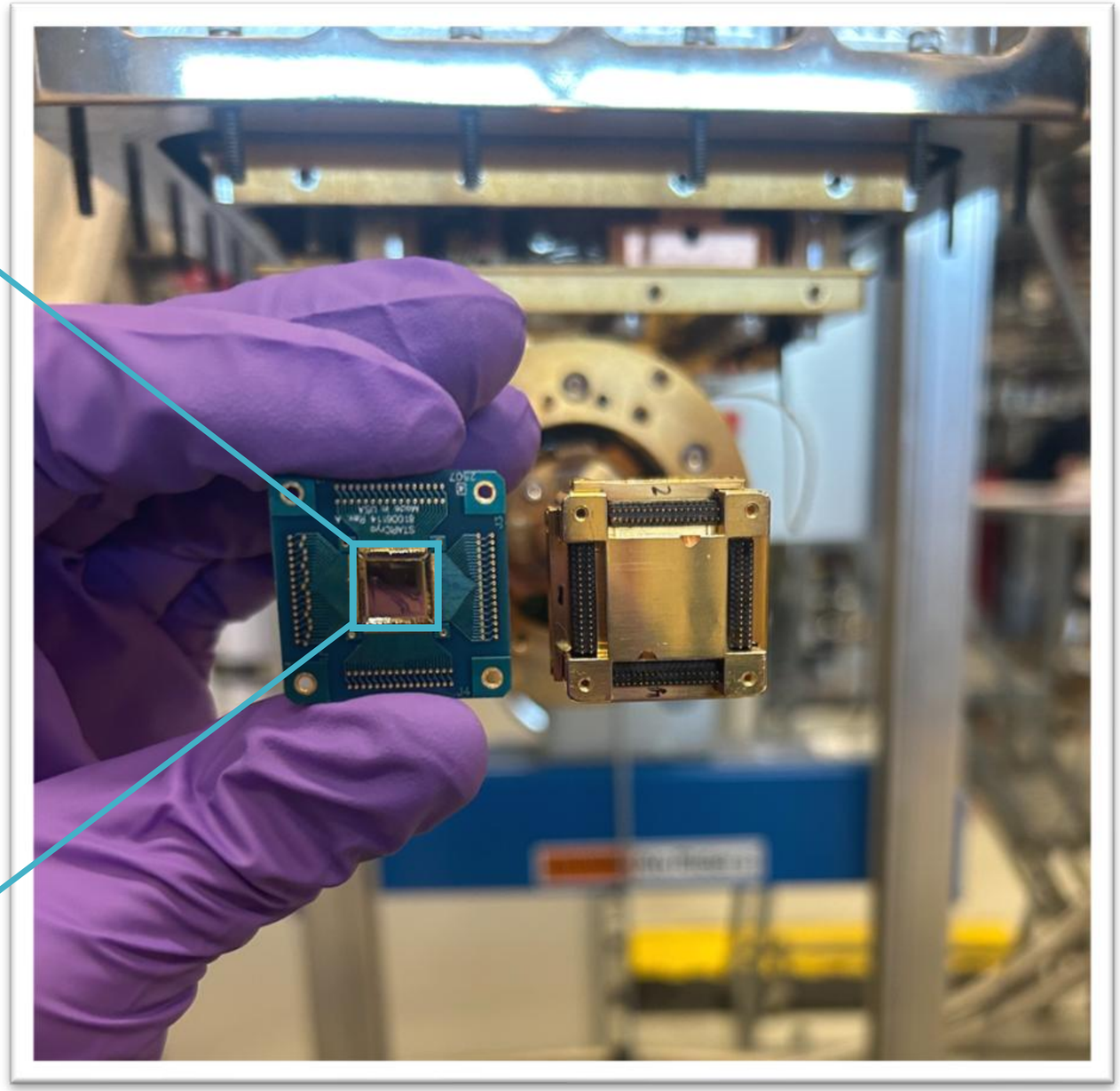


SALER Fridge

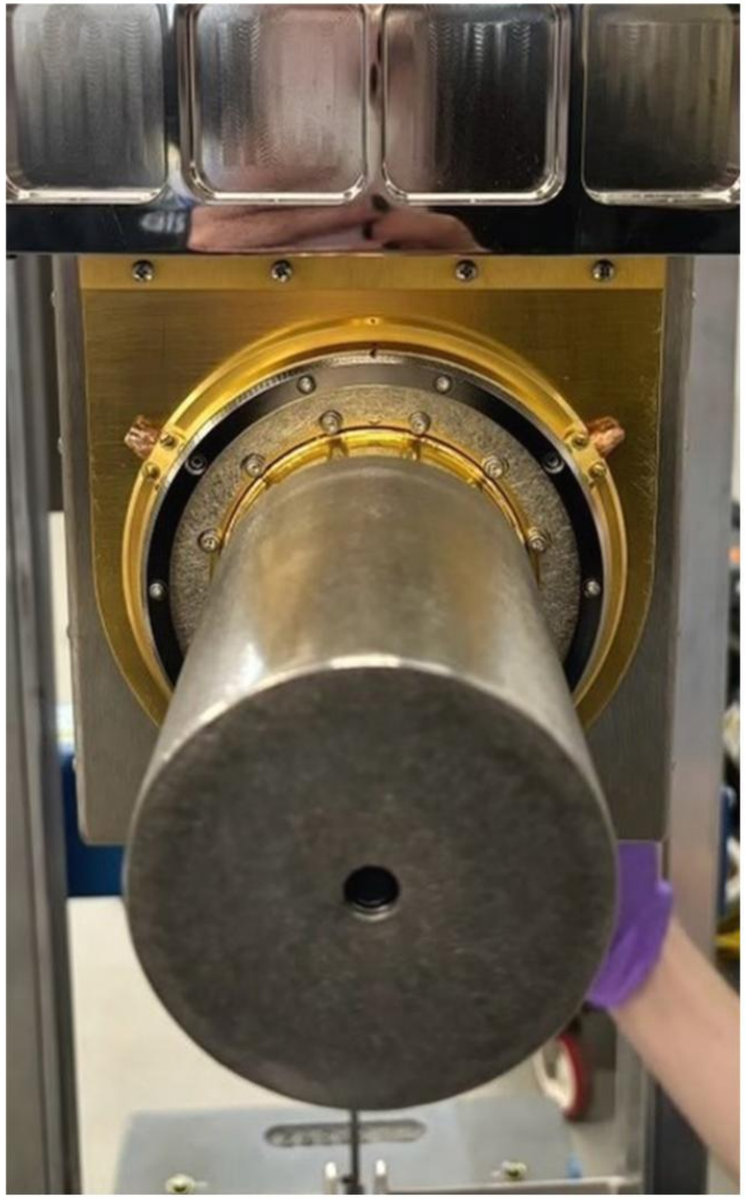


STJ Array





Ion Windows



Magnetic Shielding

