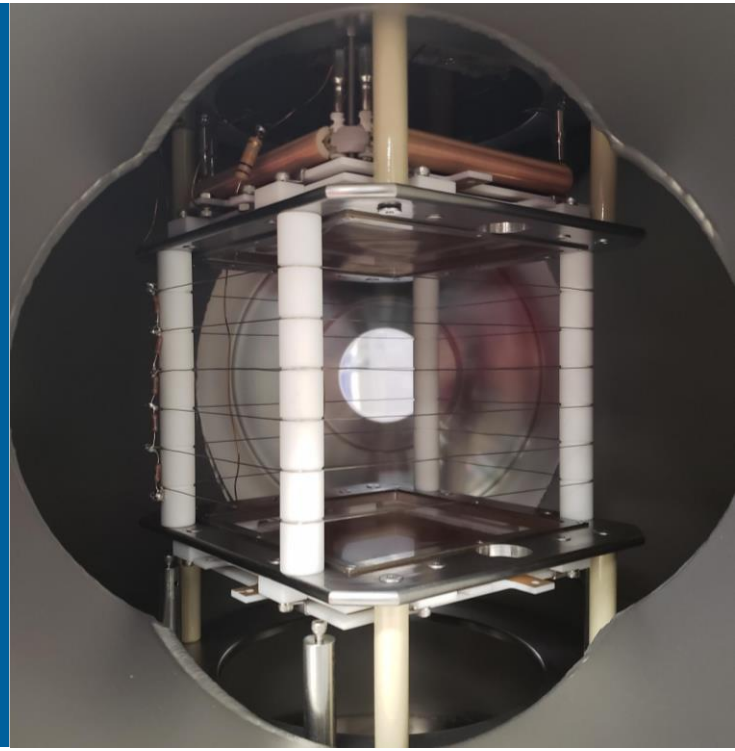
ARGONNE – AUGER-MEITNER RADIOISOTOPE MICROSCOPE (A-ARM)

AN INSTRUMENT FOR EXPERIMENTALLY MEASURING AUGER-MEITNER EMITTERS' ELECTRON MULTIPLICITIES AND ENERGY

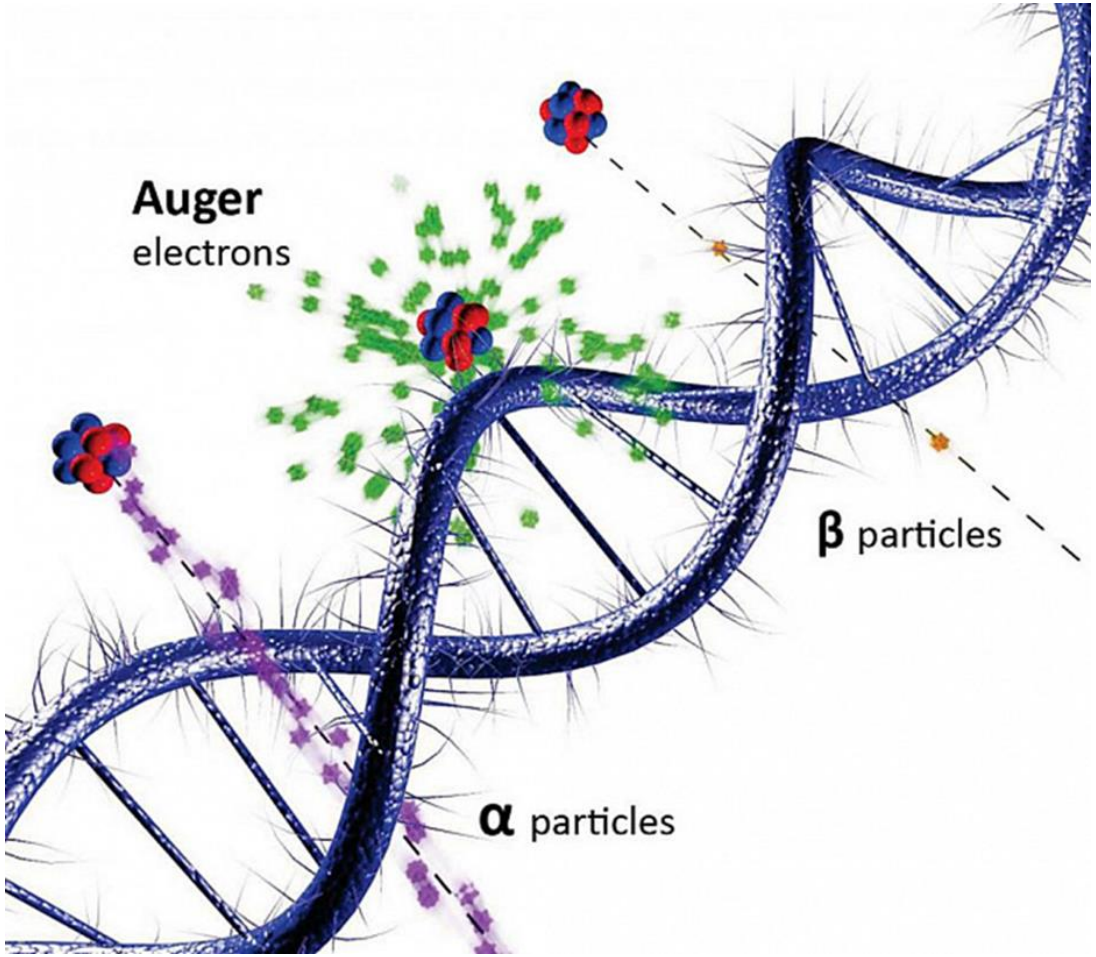


U.S. DEPARTMENT OF ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

RADIO-AUGERS APPLICATION TO MEDICINE

New measurements needed

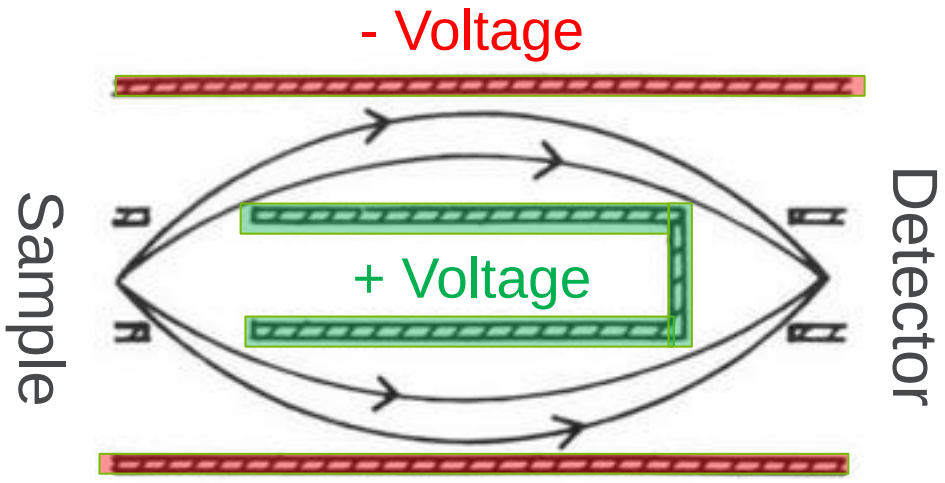
- The *very low energy* electrons are the most important. Less than 500 eV (Pomplun, 1990); the most important may be less than 18 eV! (Rezaee, 2014)
- Almost no measurements of the spectrum are available in this range, and none are available that provide *multiplicities!*
- Discrepancies seen between relative intensities and theory

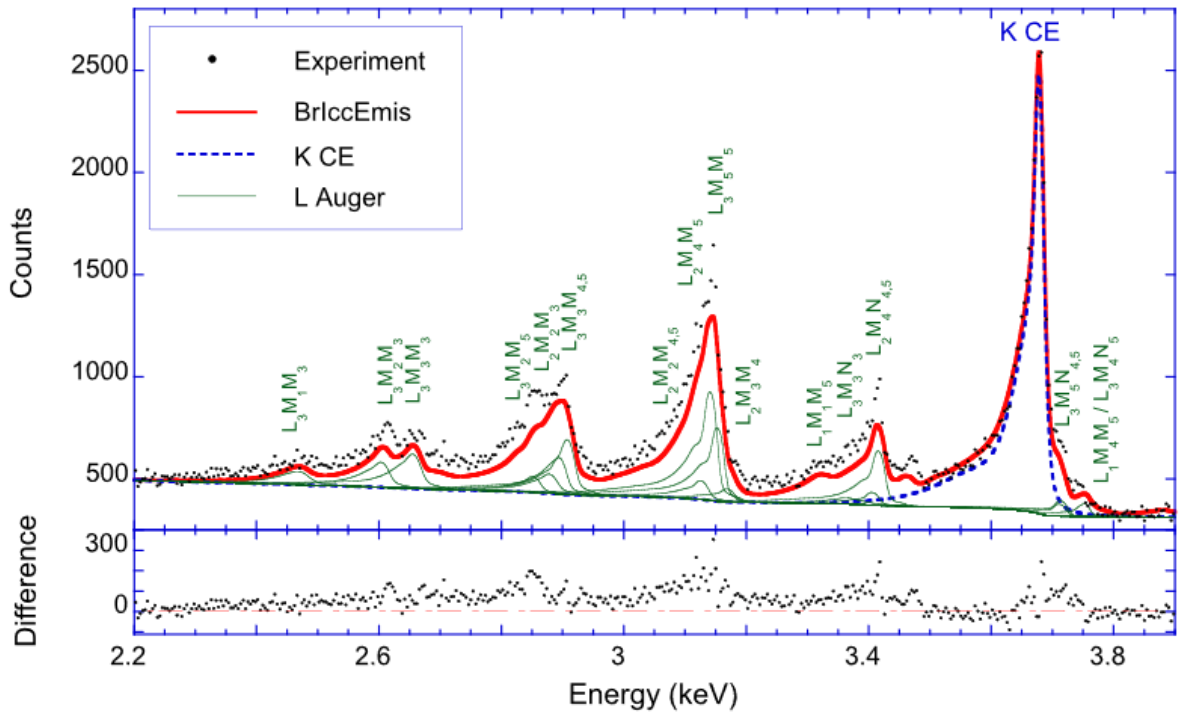


STATE OF THE ART

Strengths and Weaknesses

- A “Cylindrical Mirror Analyzer” uses an electric field and two slits act as bandpass filter
- Pro
  - Very high energy resolution
- Limitations
  - Requires small, dense samples
  - Great majority of electrons rejected during measurement
  - averaged spectra recorded (no multiplicity information)
  - Challenging to prepare thin samples
    - Only some species are accessible



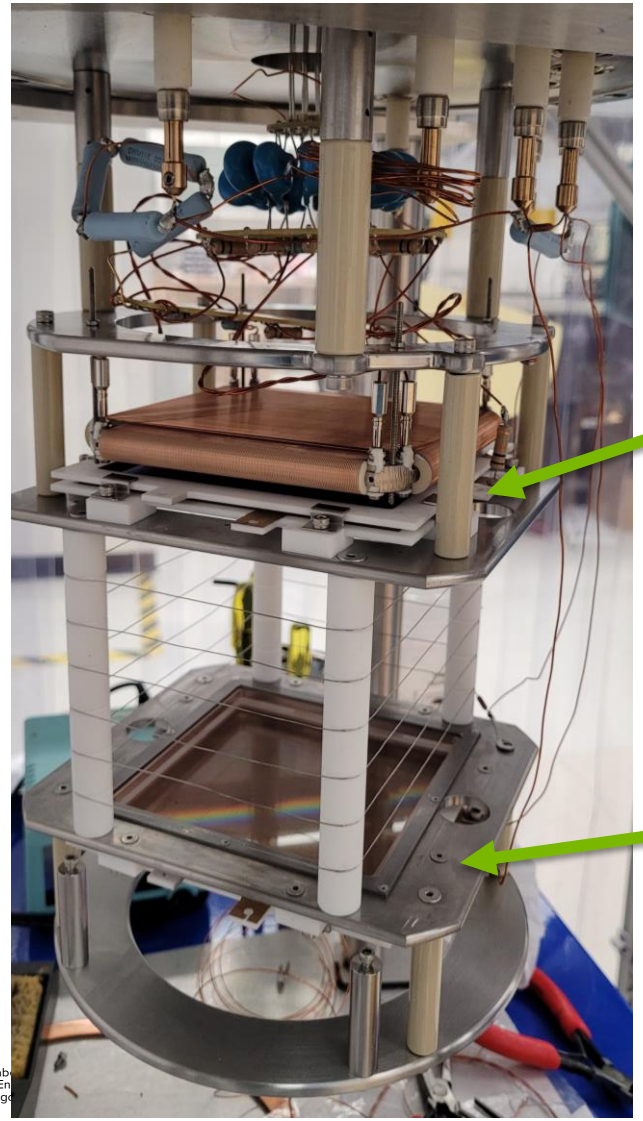


I-125 (Alotiby, 2018)

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

OUR APPROACH — USE GAS PHASE

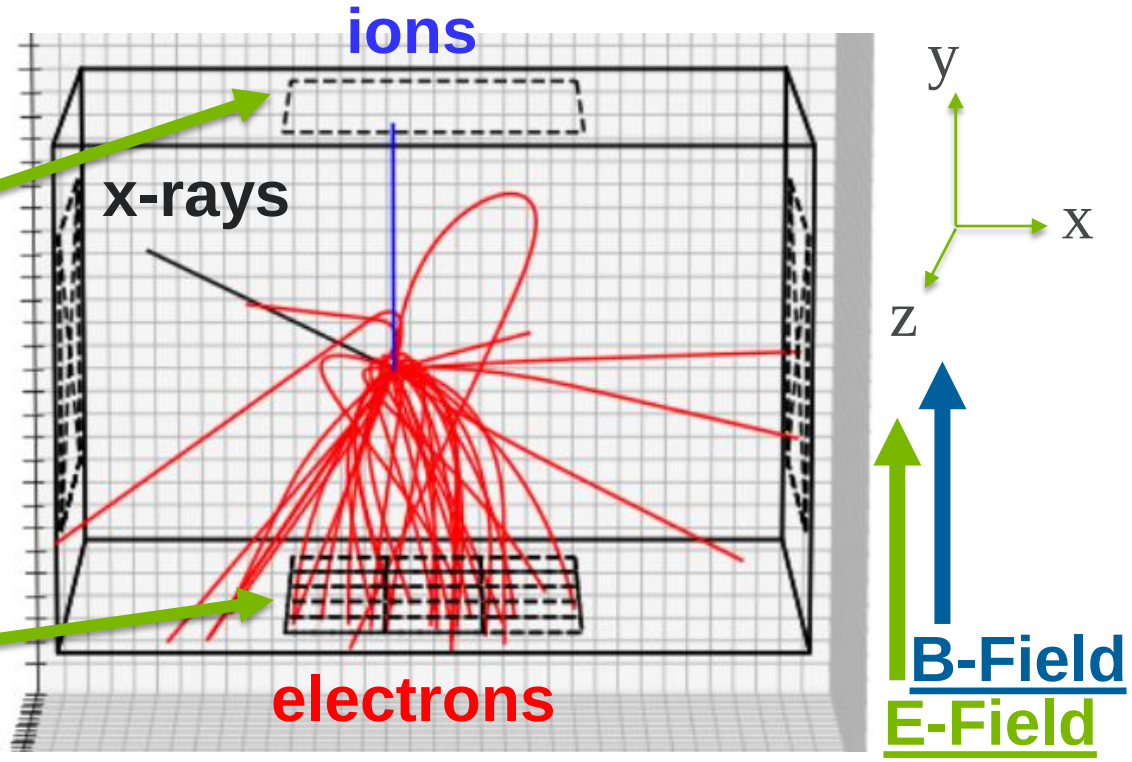
Ion, Auger-Meitner electron coincidence detection



ion time of flight ➔ ion charge ➔ e^- multiplicity

Ion MCP

e- MCP

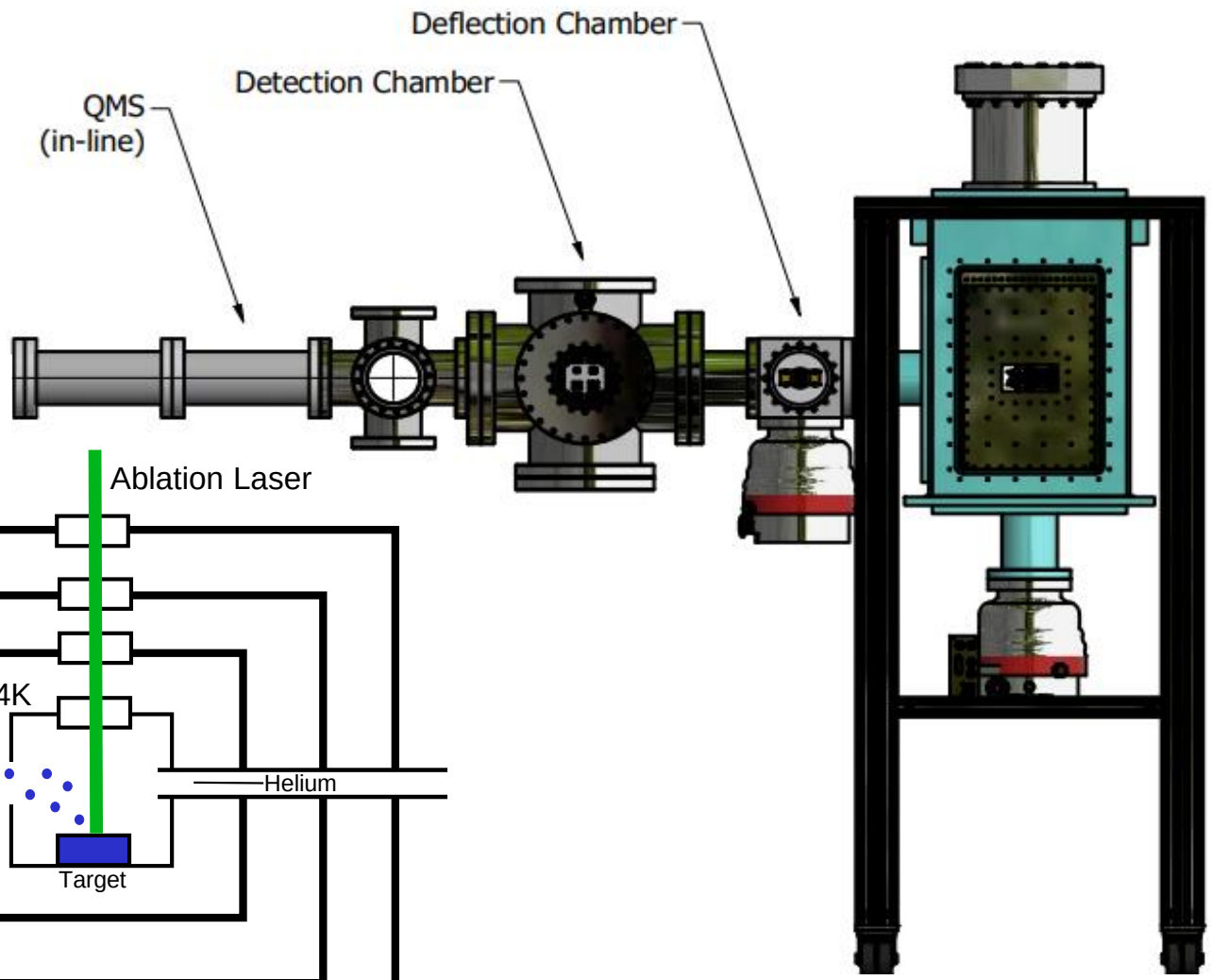


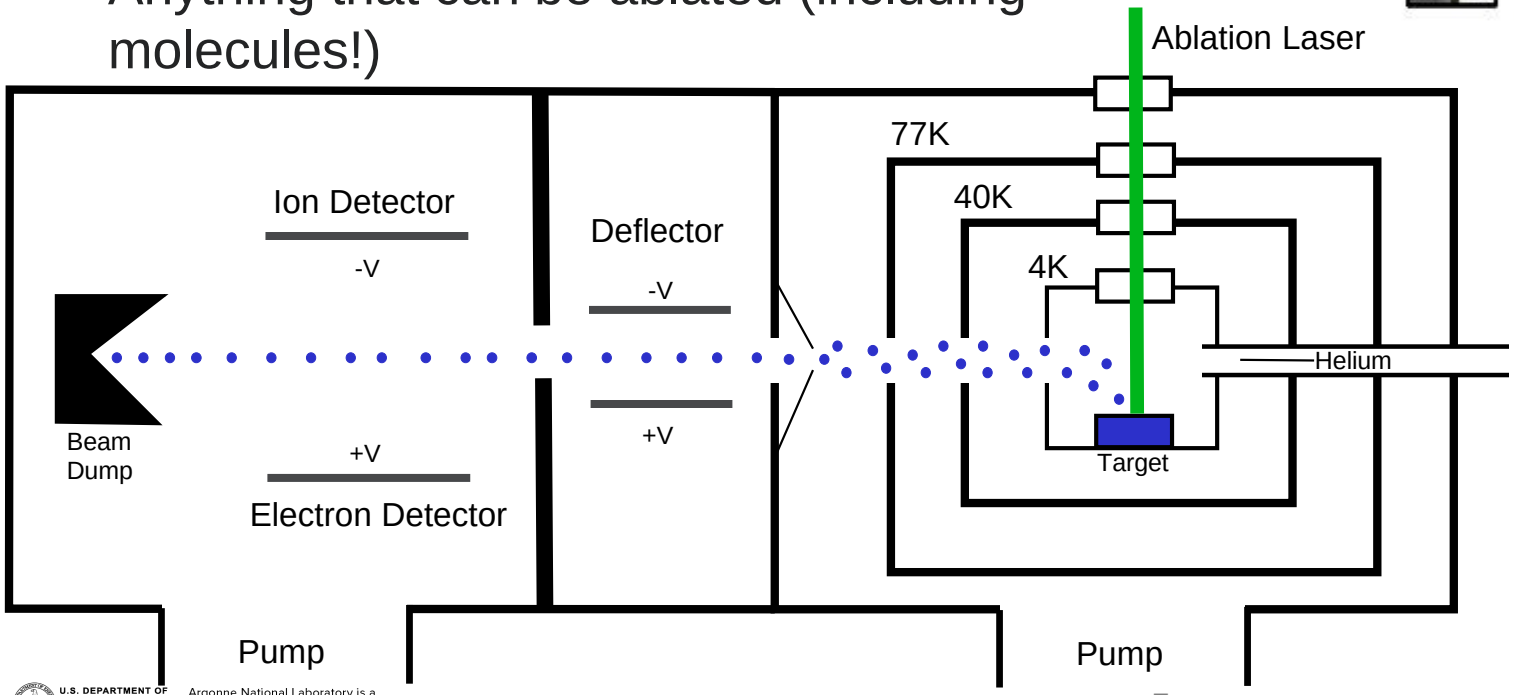
e^- time of flight + e^- position ➔ e^- energy

RADIOACTIVE SAMPLE DELIVERY

Cryogenic Buffer Gas Beam

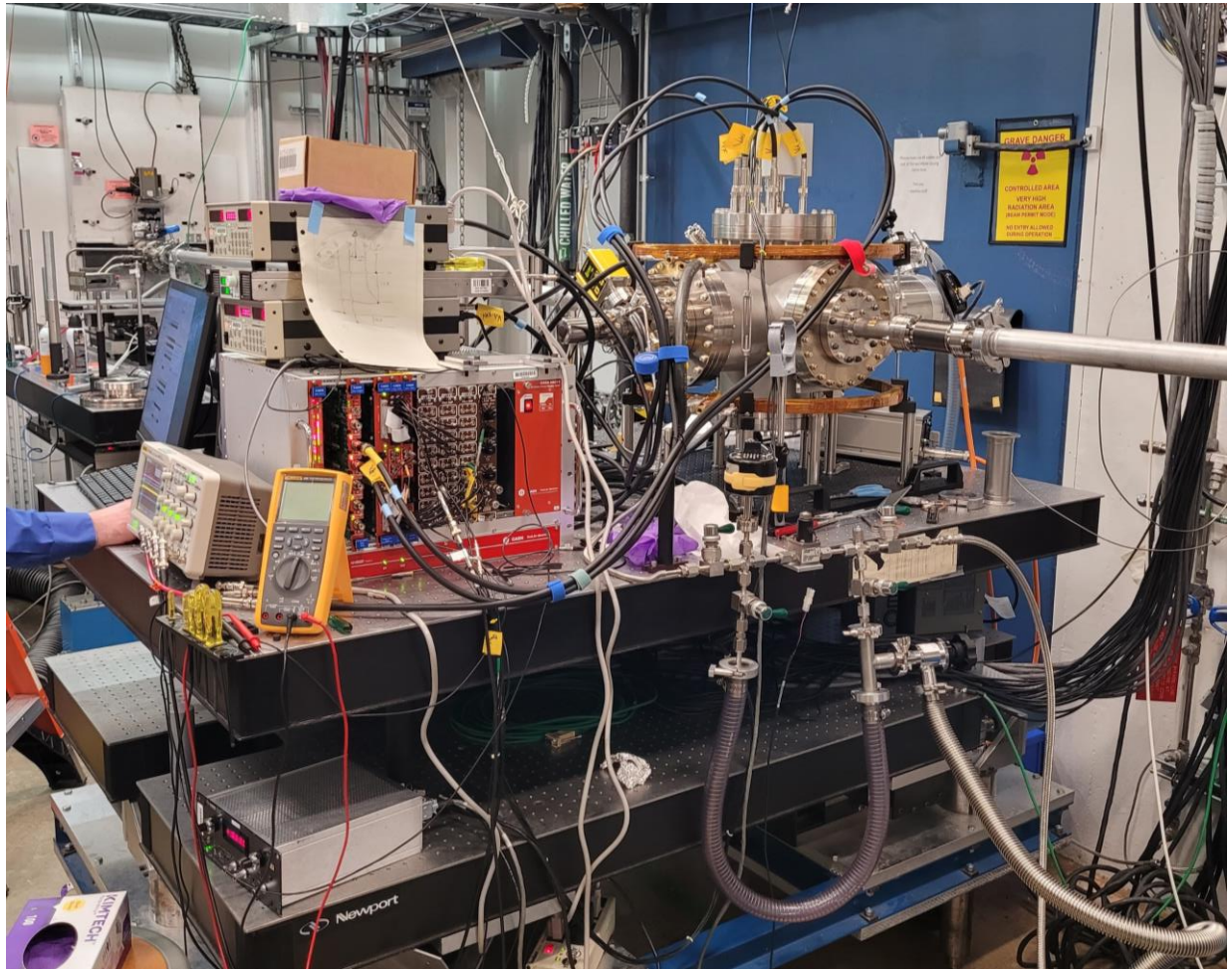
- ***Requirements*** —
  - Ablate ~10 to 100 mCi to detect order 1000 events
  - half life >~1 day
- ***General source*** —
  - Anything that can be ablated (including molecules!)





APS COMMISSIONING RUN!

Goal: Test detection concept, characterize instrument

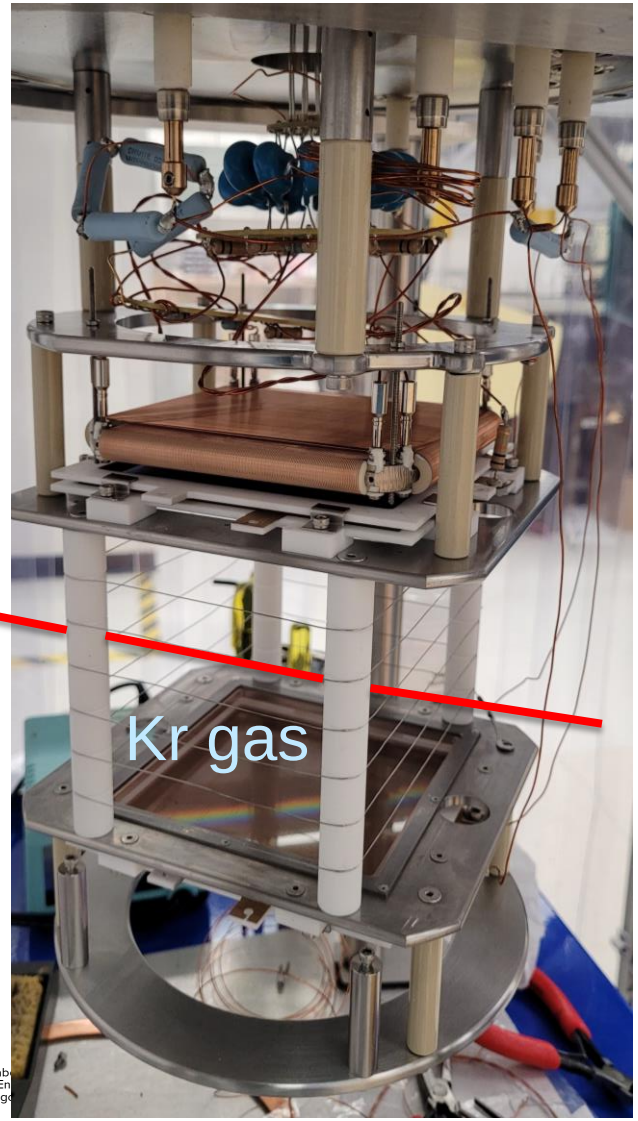


Advanced Photon Source (APS) at Argonne used to induce Auger cascade

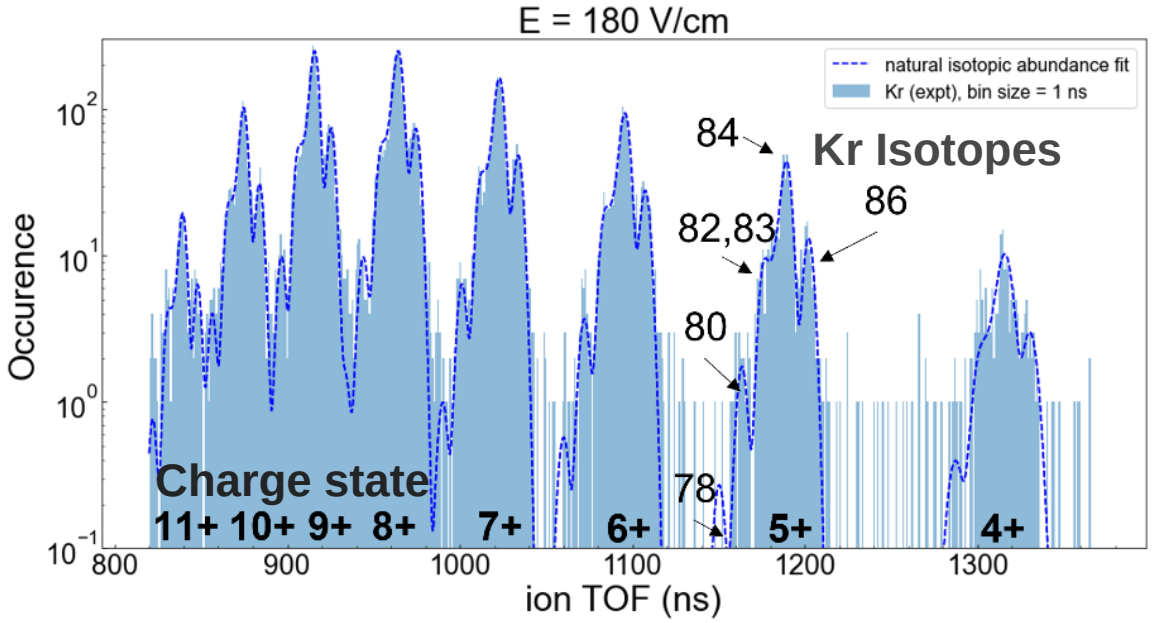
APS X-RAY SOURCE

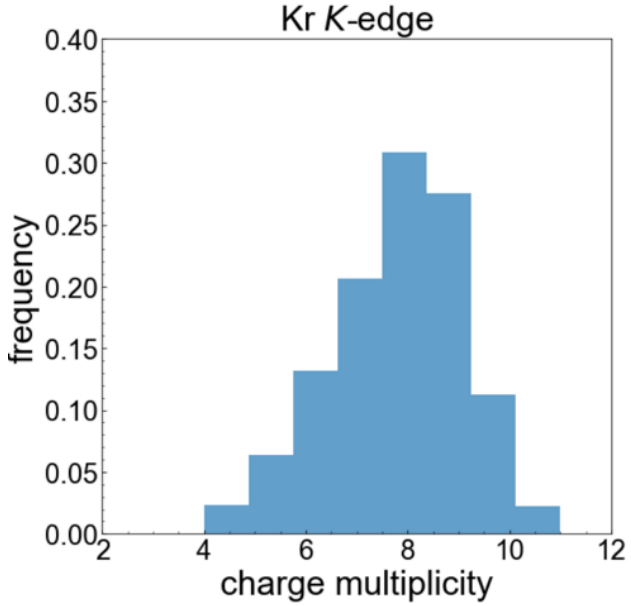
Exciting krypton K-edge

X-ray path



Krypton Ion Time of Flight



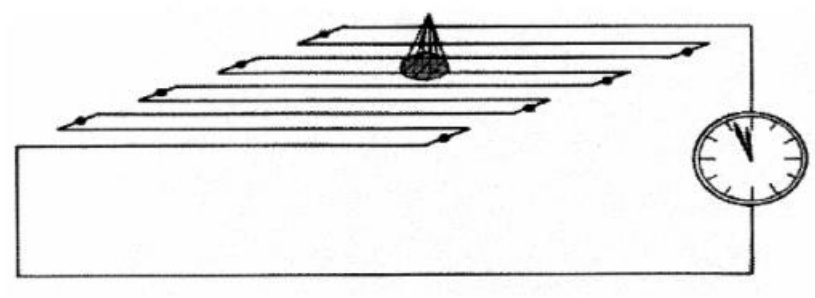


Mass resolving power: 150

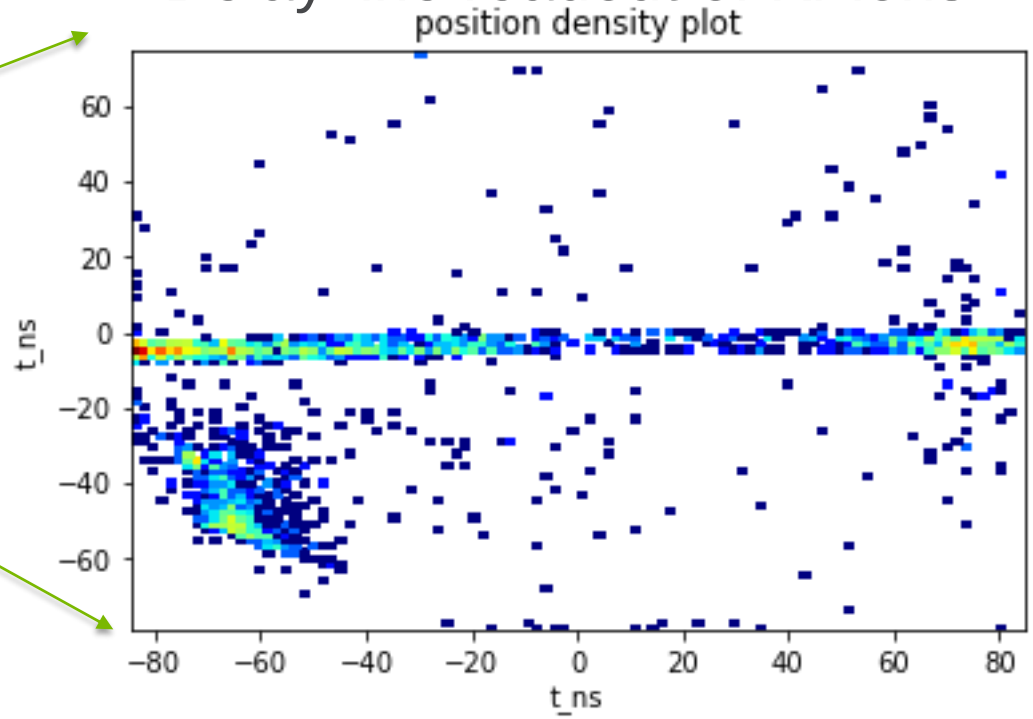
U.S. DEPARTMENT OF ENERGY
Argonne National Lab
U.S. Department of En
managed by UChicago
Argonne NATIONAL LABORATORY

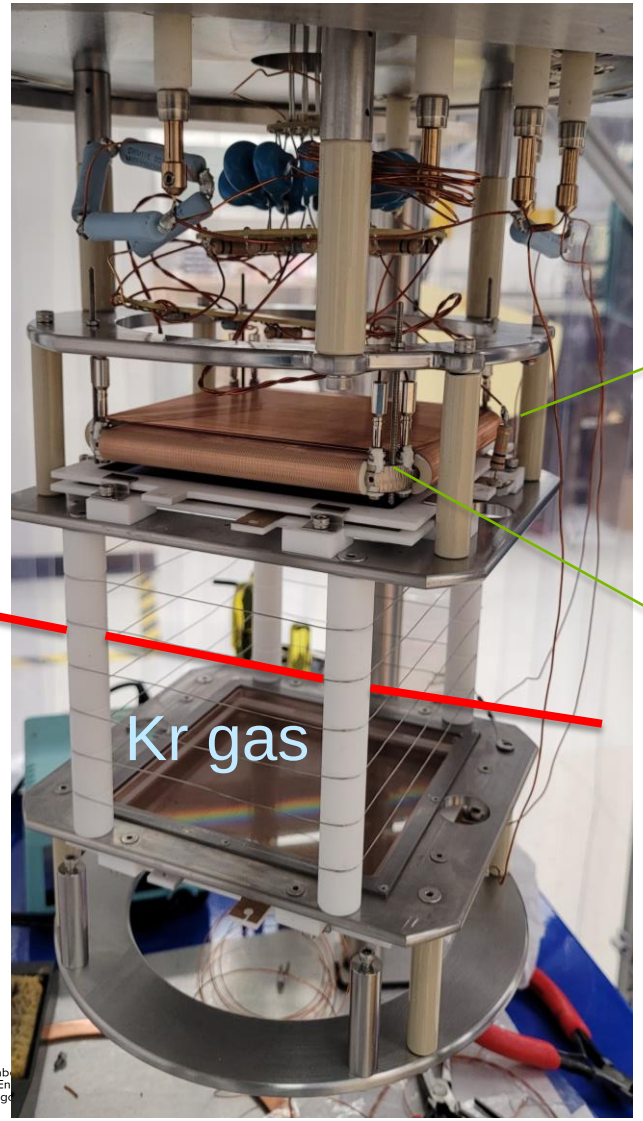
APS X-RAY SOURCE

Exciting krypton K-edge



Delay line readout of Kr ions





X-ray path

Ion MCP

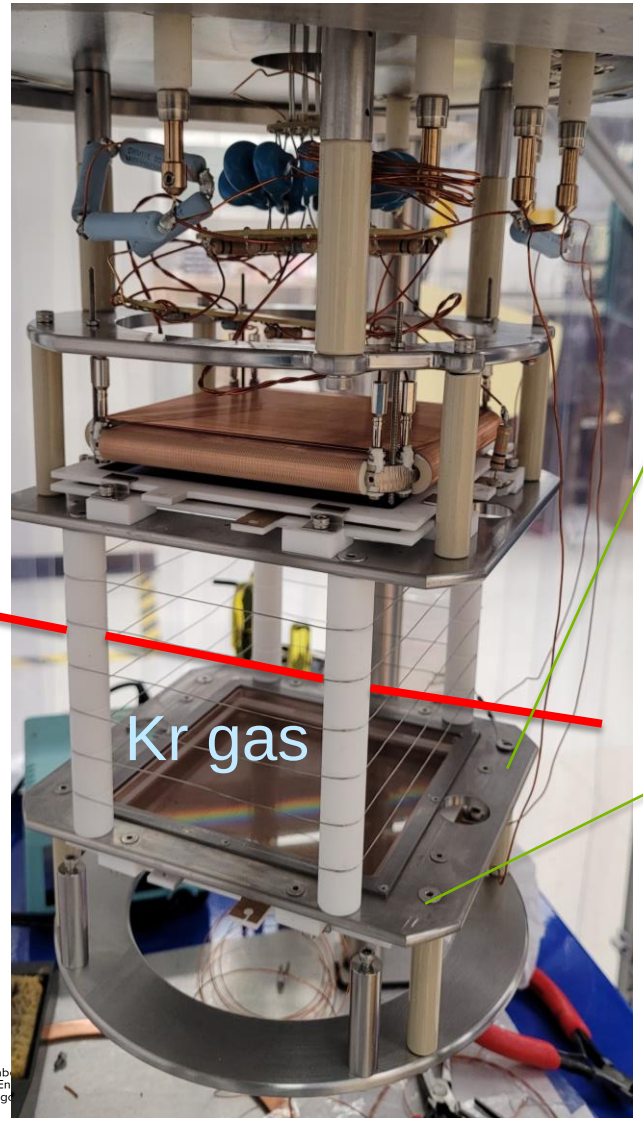
e- MCP

Low rate of ions enables precise spatial detection using delay line technique! May enable extension to molecules.

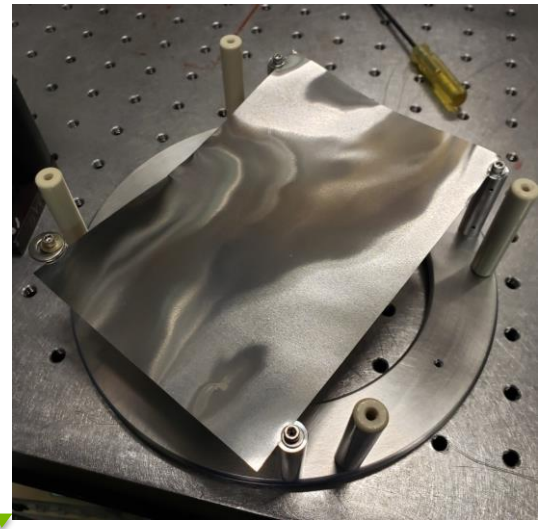
APS X-RAY SOURCE

Exciting krypton K-edge – detecting electrons

X-ray path

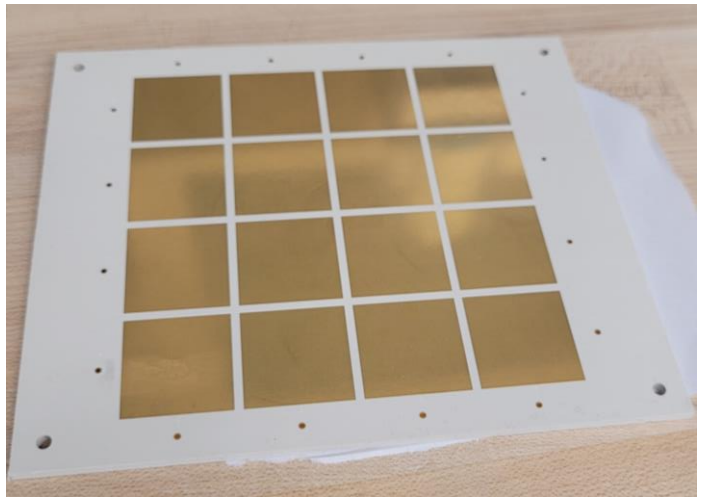


Electron detection collector plate



-1 electron maximum
-*Very poor* spatial resolution
-No time of flights
-Was available

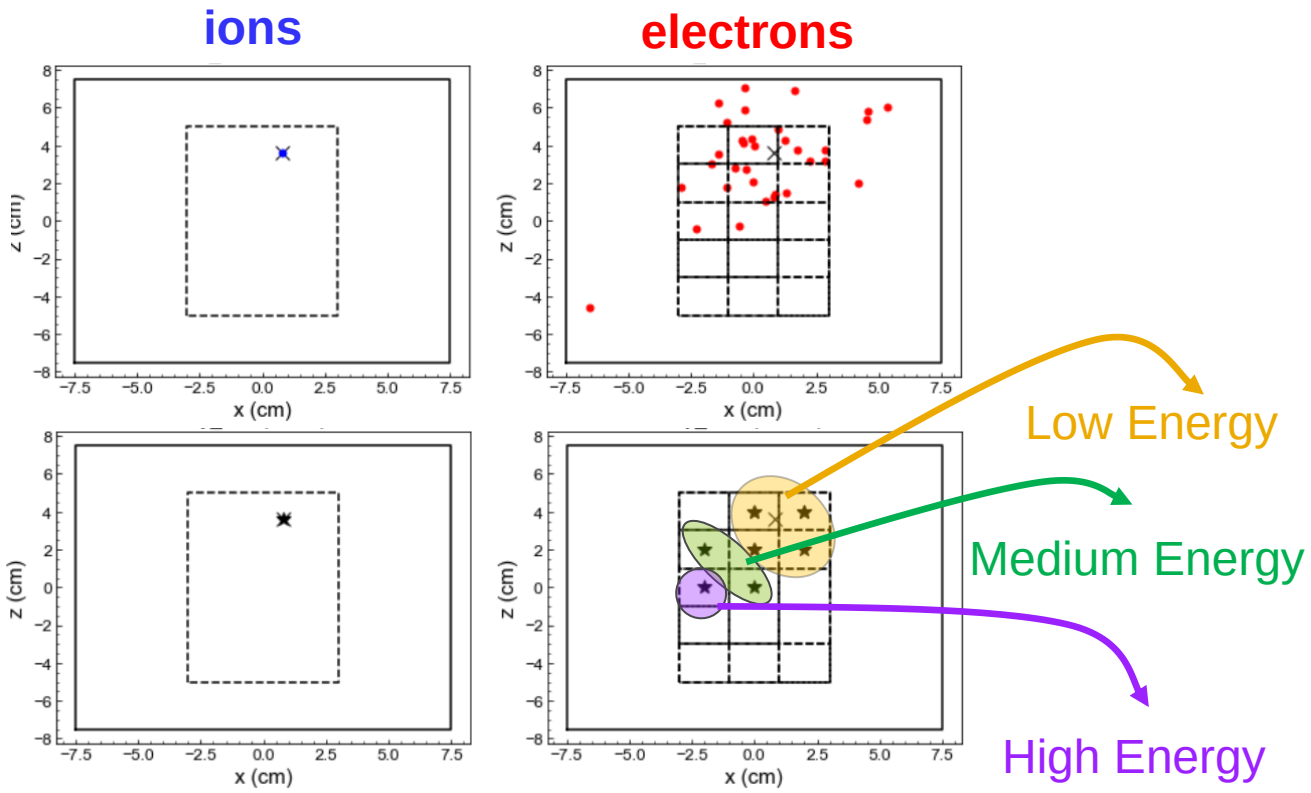
Electron detection collector pads

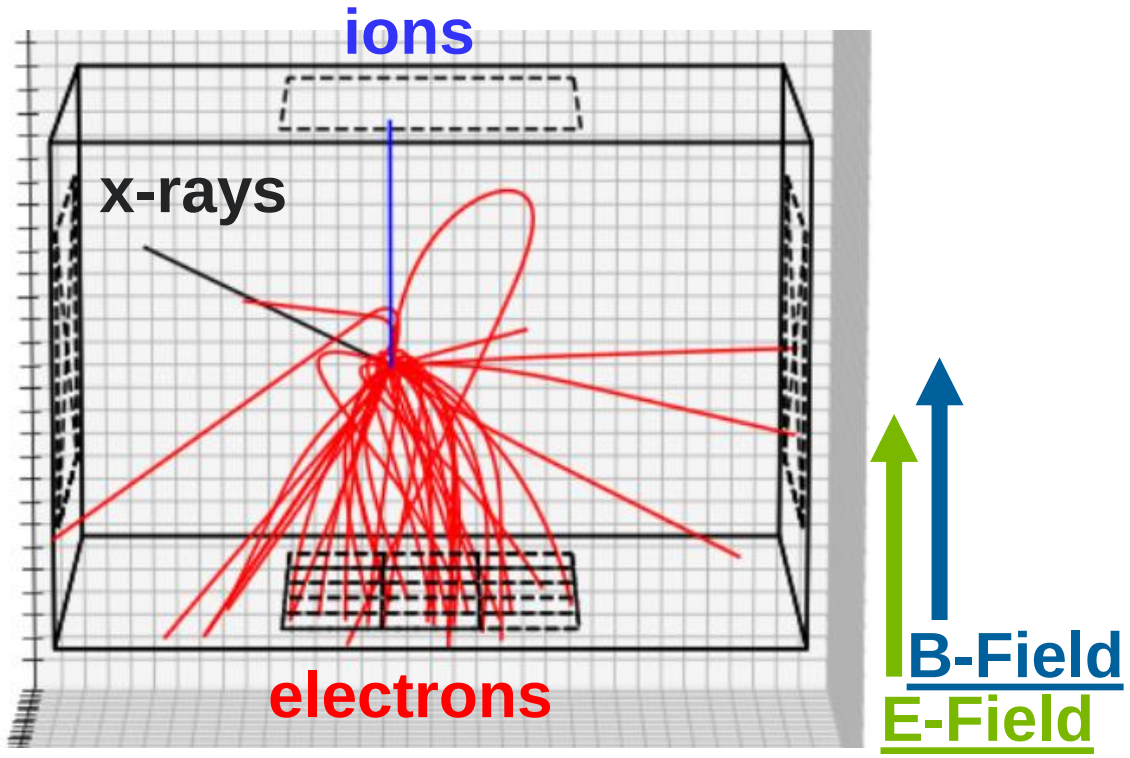


-16 electron maximum
-Delayed by COVID

EXTRACTING ELECTRON INFORMATION

Relative time of flight + displacement ➔ Energy binning



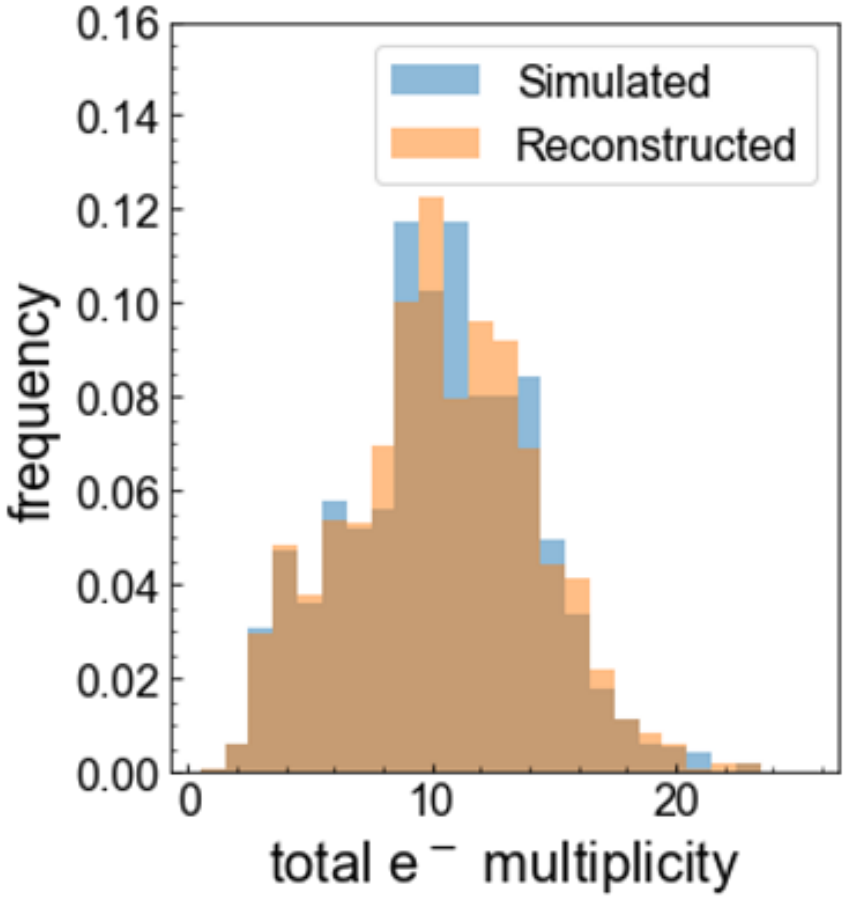


Pads enable energy binning into biologically relevant energy regimes

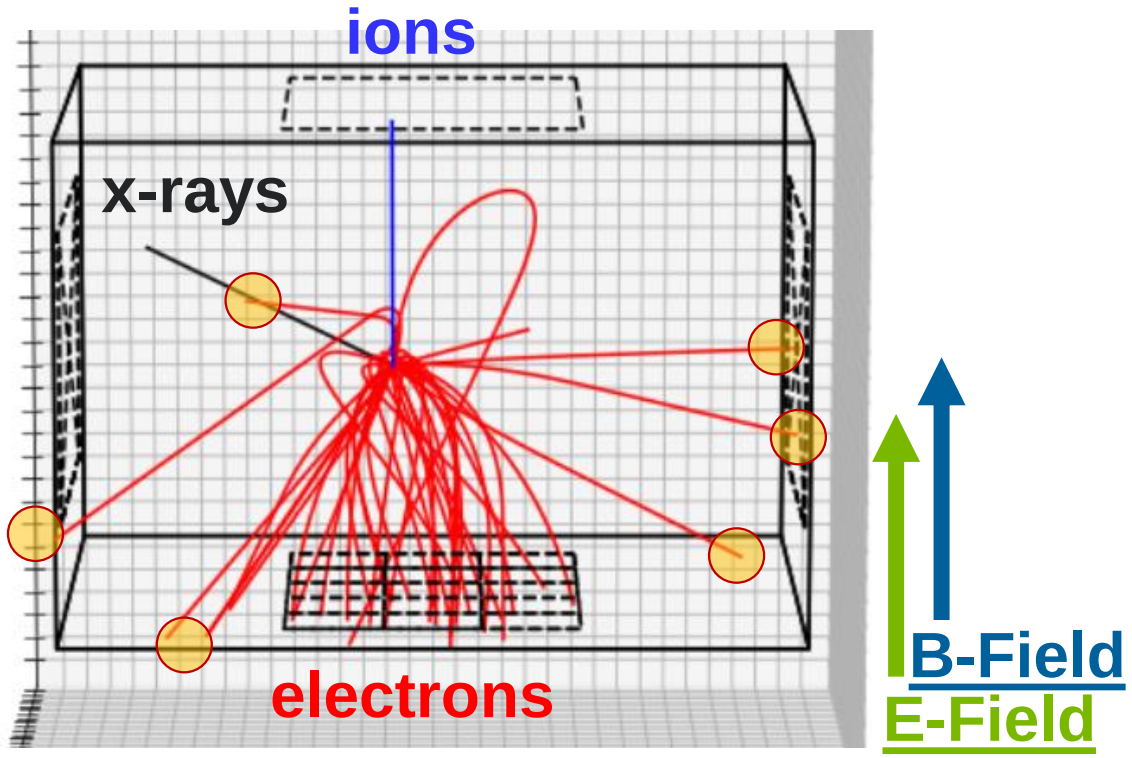
EXTRACTING ELECTRON INFORMATION

Ion analysis *informs* electron analysis (Bayesian inference)

Pt 191 Simulation



High energy e- *less likely* to be detected

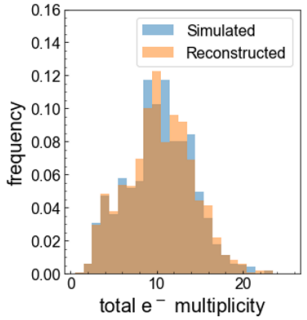


Low energy e- *more likely* to be detected

SIMULATION-SINGLE EVENT RECONSTRUCTION

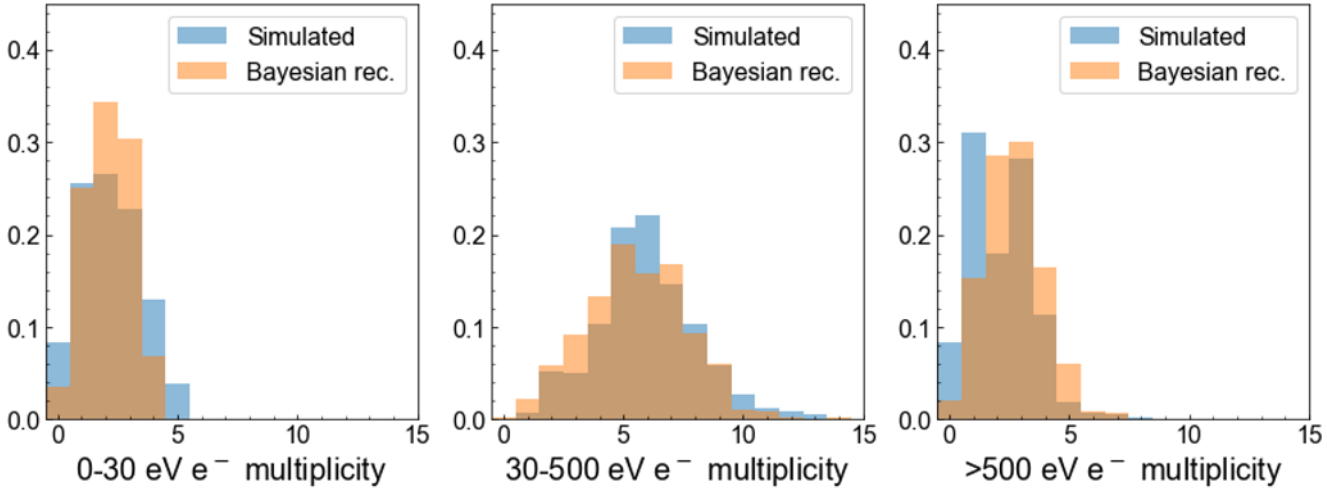
Ion analysis *informs* electron analysis (Bayesian inference)

Pt 191 Simulation

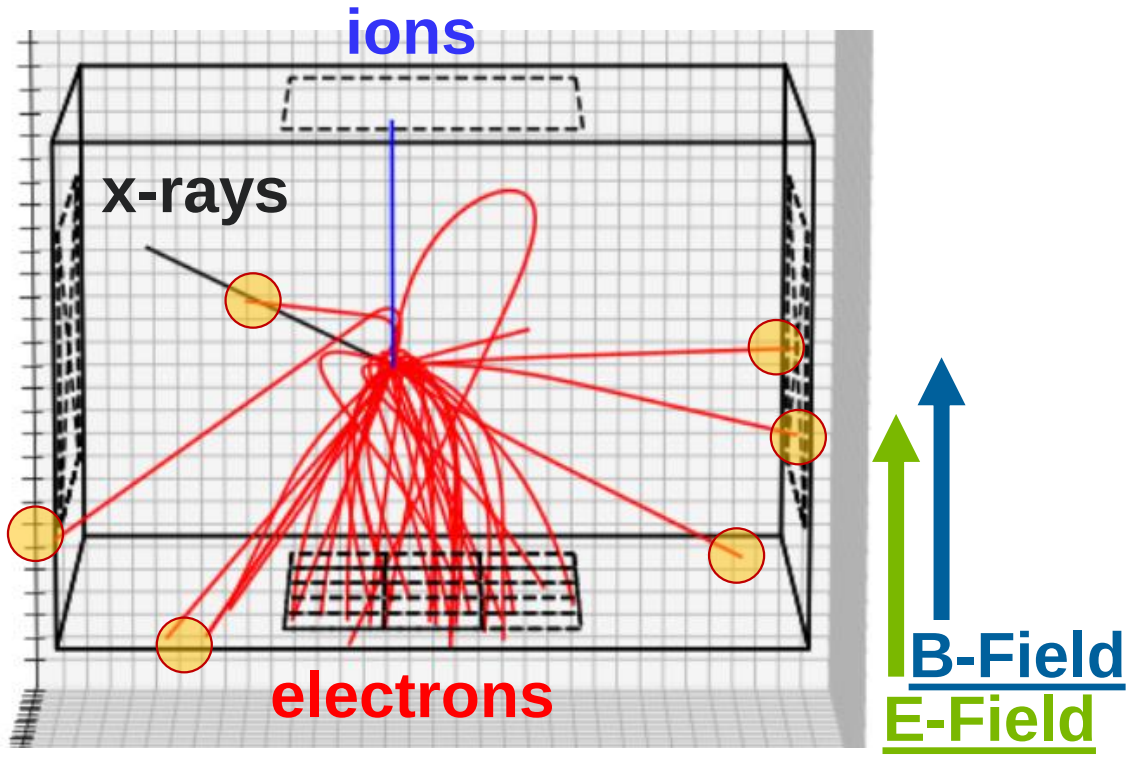


Extract multiplicity information for each energy bin

Detailed multiplicity of ^{191}Pt



High energy e⁻ *less likely* to be detected

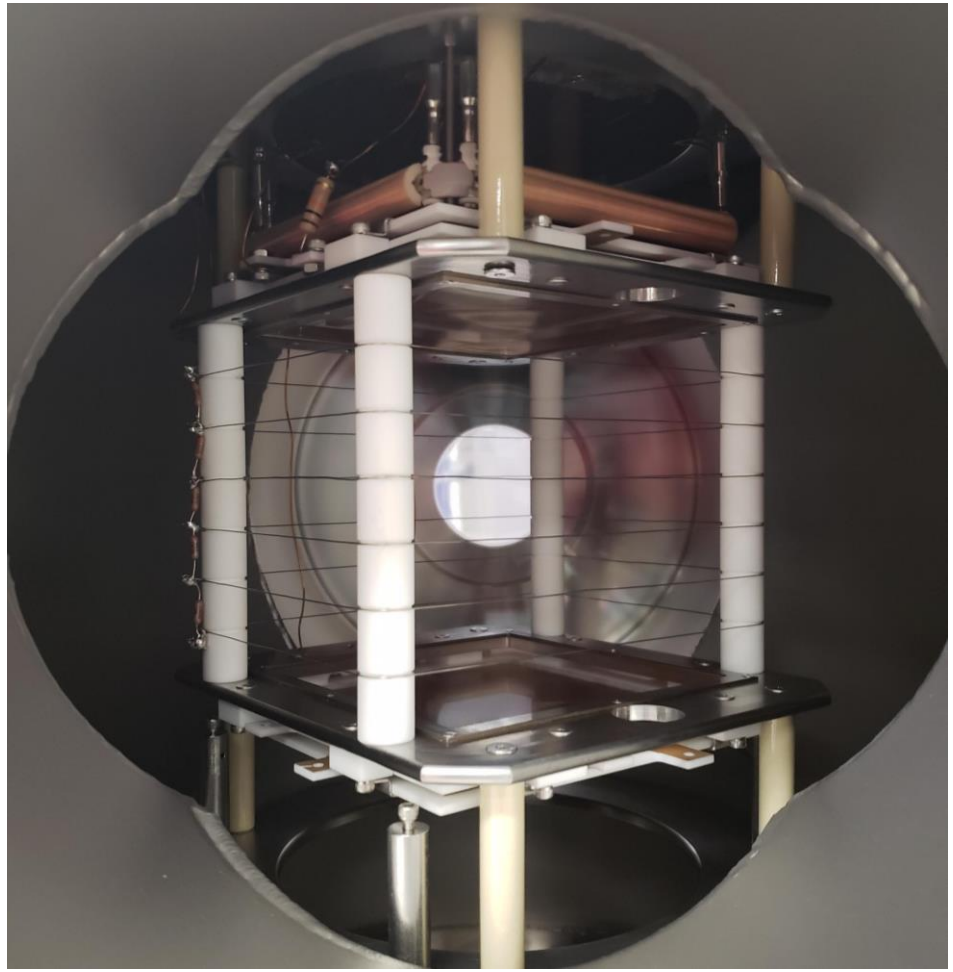


Low energy e⁻ *more likely* to be detected

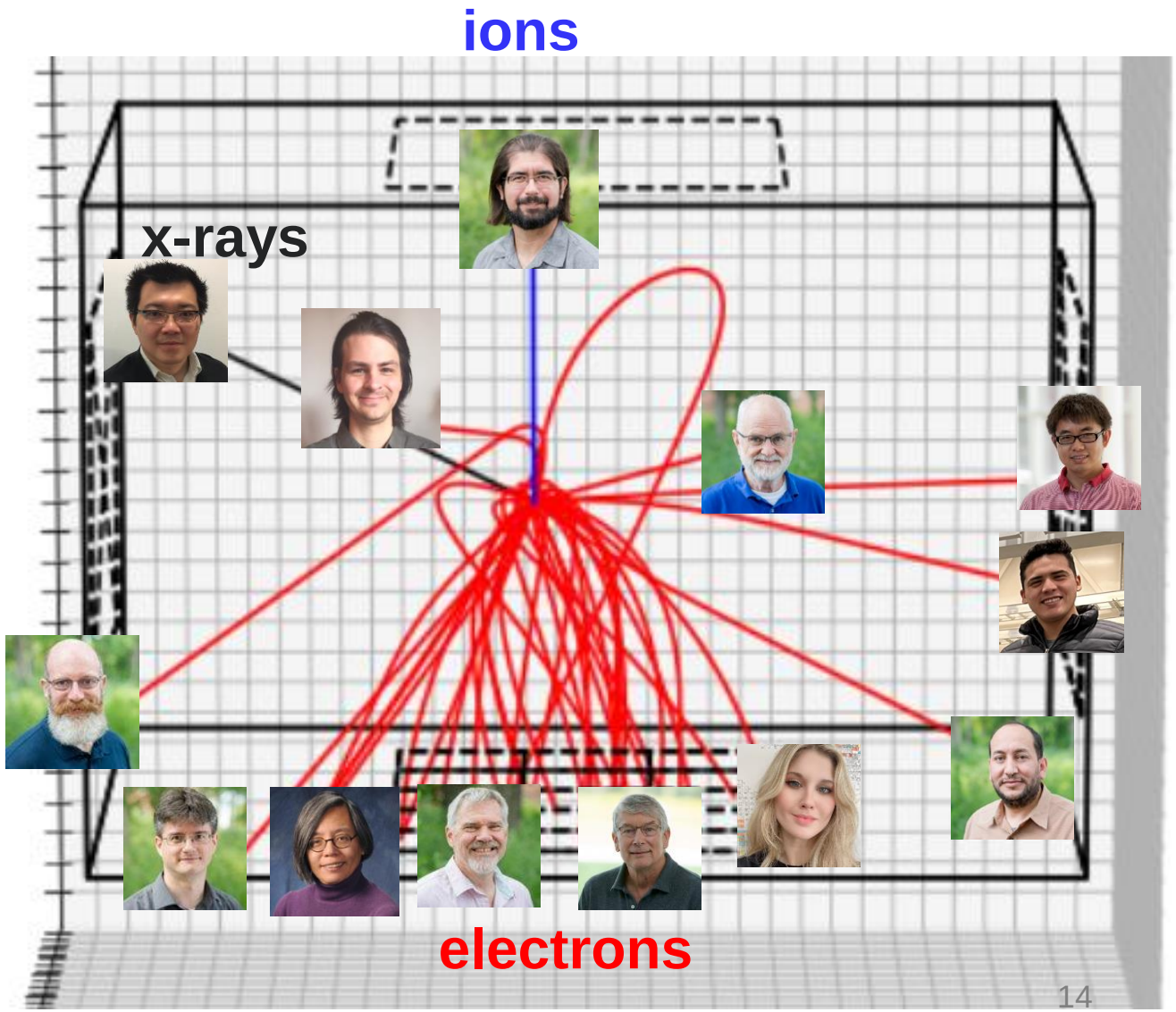
OUTLOOK

Instrument behaving within bounds of expectations so far!

- Proof of principle established at first APS run
- Test electron MCP pads and “detailed multiplicity” analysis at next APS run in late March
- Exploring limits of data extraction (e.g. molecules) through simulation and next tests at APS
- Currently assembling radioactive beam source in parallel



ACKNOWLEDGEMENTS



The A-ARM team!

- Kevin Bailey
- Matthew Dietrich
- Alejandro Hernandez
- Phay Ho
- Peter Mueller
- Brahim Mustapha
- Jerry Nolen
- Tom O'Connor
- Amy Renne
- Stephen Southworth
- Patrick Stollenwerk
- Junqi Xie
- Linda Young

Funding: Argonne LDRD

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

THANK YOU!