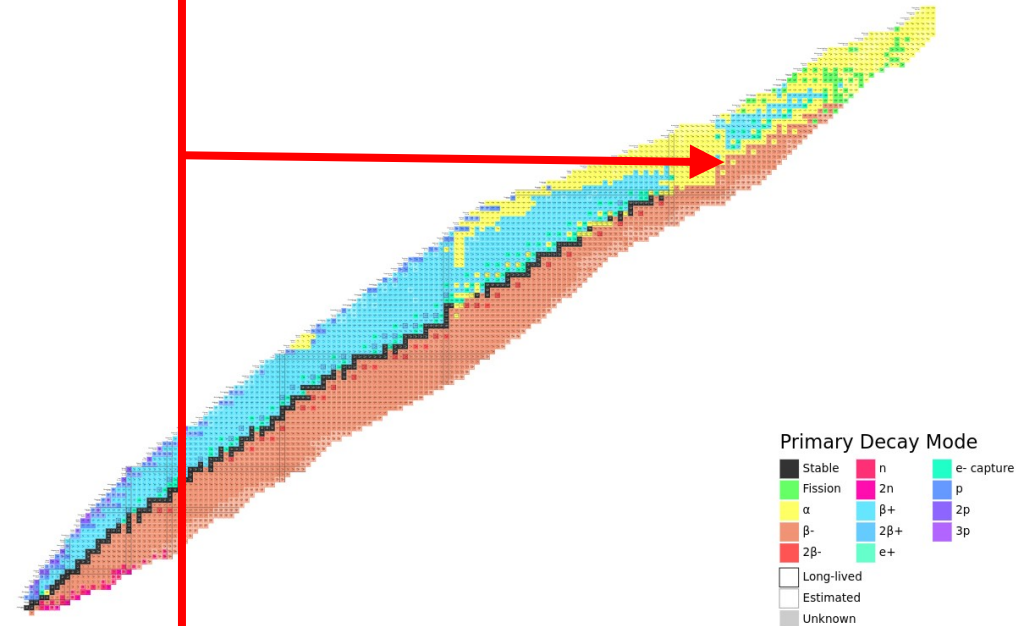
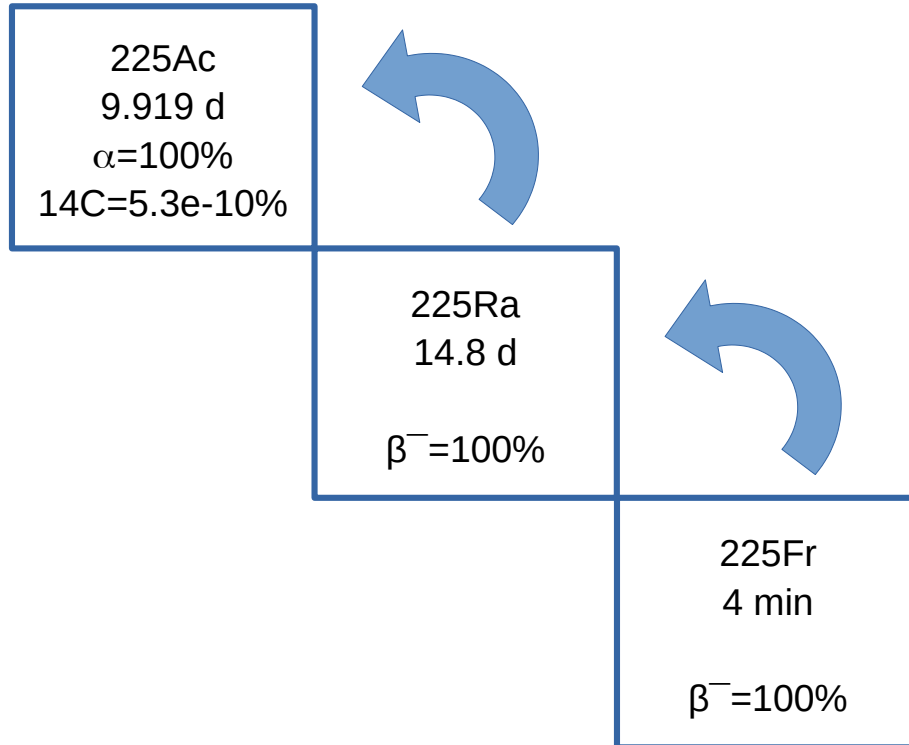


Beta Decay spectroscopy of ^{225}Fr \rightarrow ^{225}Ra

Abdulrahman Alshammari

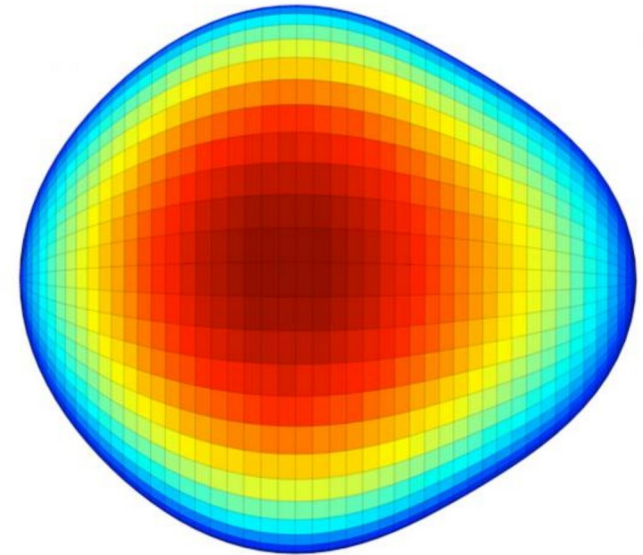
STFC Nuclear Physics Summer School 2024

225Fr decay chain



Motivation

- Nuclear structure:
 - Studying the octupole deformed shape (pear shaped, heavy, neutron rich nuclei).
 - ^{225}Ra is ideal for measuring EDM because its octupole deformation enhances the EDM by 100x, compared to ^{199}Hg .
 - Measuring EDM helps understand:
 - Charge distribution.
 - Violation of symmetry (Parity P and time-reversal T).
 - Reveal new physics beyond standard model.
- Measuring excited states of the even-odd ^{225}Ra .



The pear shape of the ^{224}Ra nucleus
<http://cds.cern.ch/record/2709309/?ln=en>

PHYSICAL REVIEW C **94**, 025501 (2016)

Improved limit on the ^{225}Ra electric dipole moment

Michael Bishof,^{1,*} Richard H. Parker,^{1,2,†} Kevin G. Bailey,¹ John P. Greene,¹ Roy J. Holt,¹ Mukut R. Kalita,^{1,3,‡}
 Wolfgang Korsch,³ Nathan D. Lemke,^{1,§} Zheng-Tian Lu,^{1,2,||} Peter Mueller,¹ Thomas P. O'Connor,¹
 Jaideep T. Singh,⁴ and Matthew R. Dietrich¹

Motivation

- Nuclear structure:
 - ^{225}Ra is ideal to measure electric dipole moment EDM.

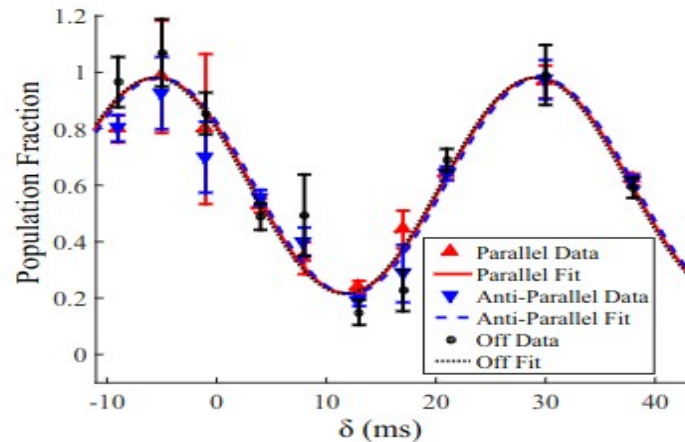


FIG. 6. Nuclear spin-precession data for three E-field conditions: E field parallel to B field, E field antiparallel to B field, and E field off. The plot shows population fraction in the bright state versus δ , where $\Delta T_{2,4} = 20000 + \delta$ ms. Lines represent a simultaneous fit of all the data to Eqs. (1) using a χ^2 minimization fitting program.

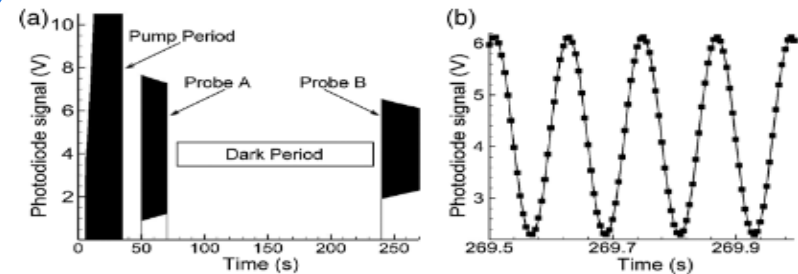


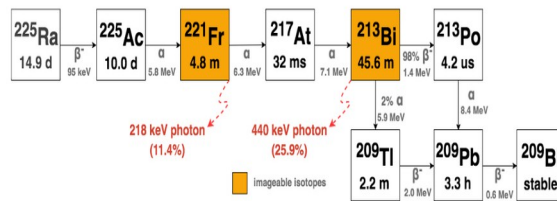
FIG. 2. The signal obtained from a single photodiode for one pump-probe cycle. (a) A complete view of the signal. During optical pumping, the transmission through the cell increases, quickly saturating the detector. The laser power is reduced during the probe periods A and B, which are analyzed to extract the phase difference accumulated between cells during the dark period. Individual Larmor oscillations are too rapid to be visible at this scale, but the exponential decay of the signal envelope can be seen. (b) An expanded view of the final 500 ms of the data train. The raw data points are connected by straight line segments to guide the eye; no fit is shown.

Motivation

225Ra decays into the rarest drug on earth 225Ac

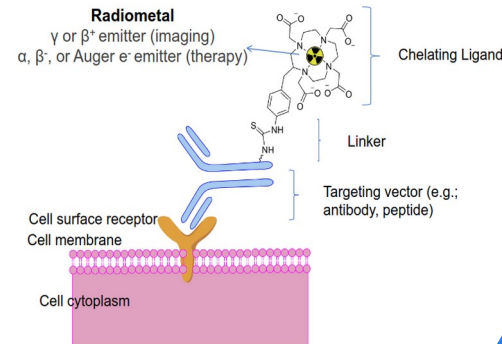
Targeted Alpha-Therapy with Actinium-225 (²²⁵Ac)

Actinium-225 (²²⁵Ac) has a relatively long half-life ($t_{1/2} = 10$ d) followed by four fast alpha decays



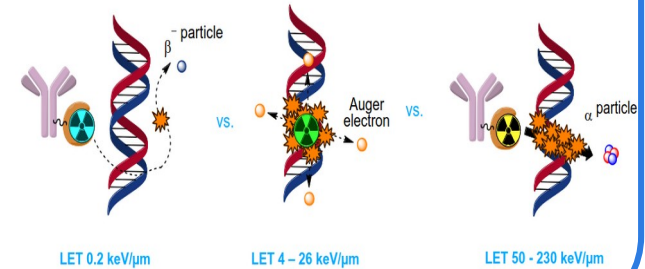
Some Biology :)

Nuclear Medicine with Radiometals



Targeted Alpha-Therapy

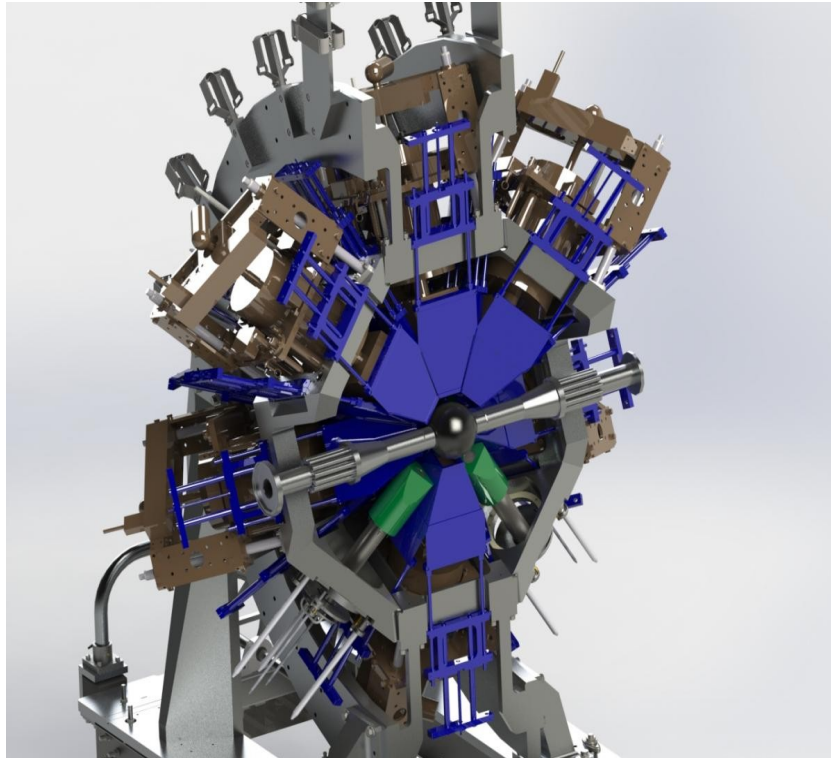
α -particles have high LET (~100 keV/ μ m) and typical range in tissue of 50 – 100 μ m (< 10 cell diameters)



Production and purification of ²²⁵Ra and ²²⁵Ac at TRIUMF's Isotope Separation On-line (ISOL) facility and subsequent radiolabeling studies with α -emitter ²²⁵Ac

https://indico.cern.ch/event/776181/contributions/3347130/attachments/1855365/3047190/C_Ramogi_da_Oral_Presentation_CAP_2019_for_PDF.pdf

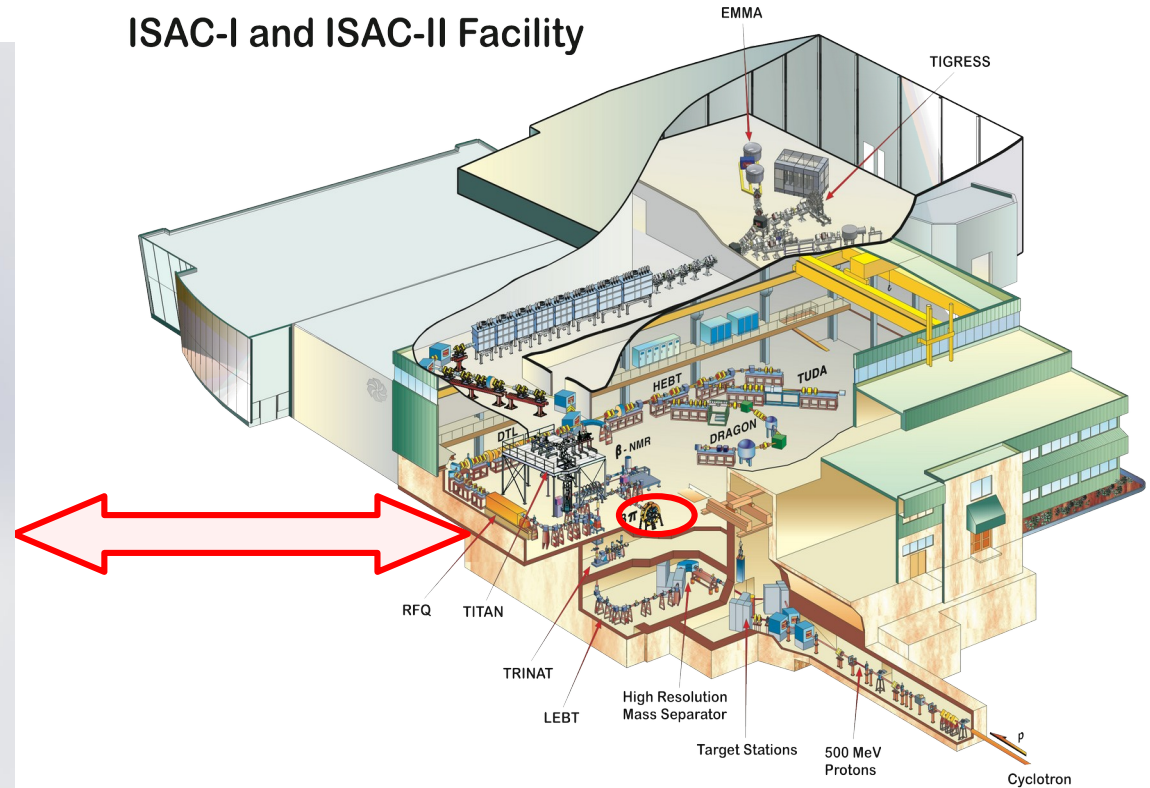
The Facility



GRIFFIN

<https://www.physics.uoguelph.ca/griffin>

ISAC-I and ISAC-II Facility

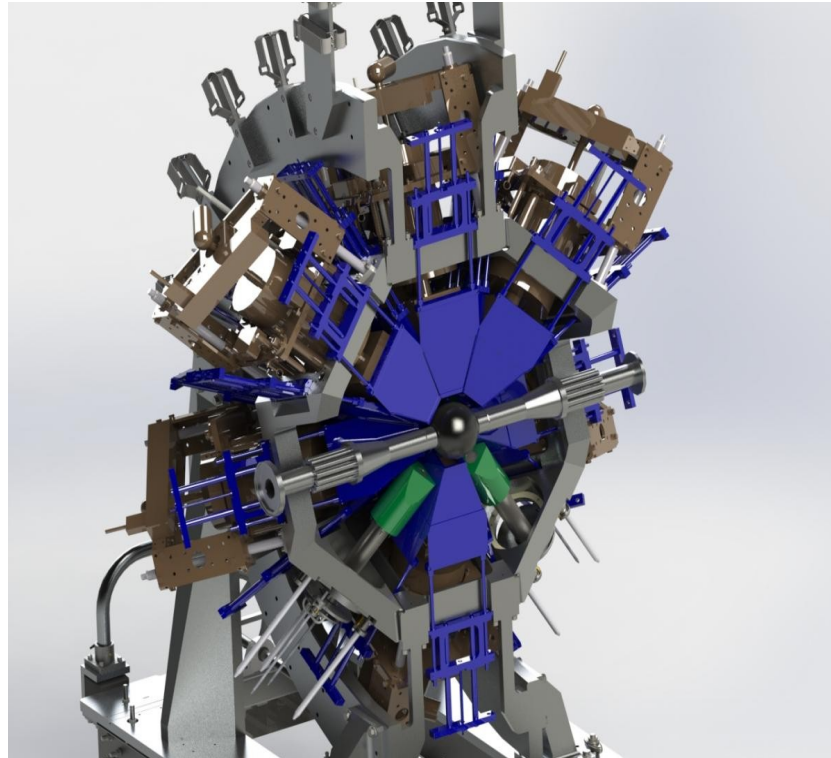


The ISAC I experimental hall

<https://discoverourlab.triumf.ca/tour-our-lab/isac-1/>

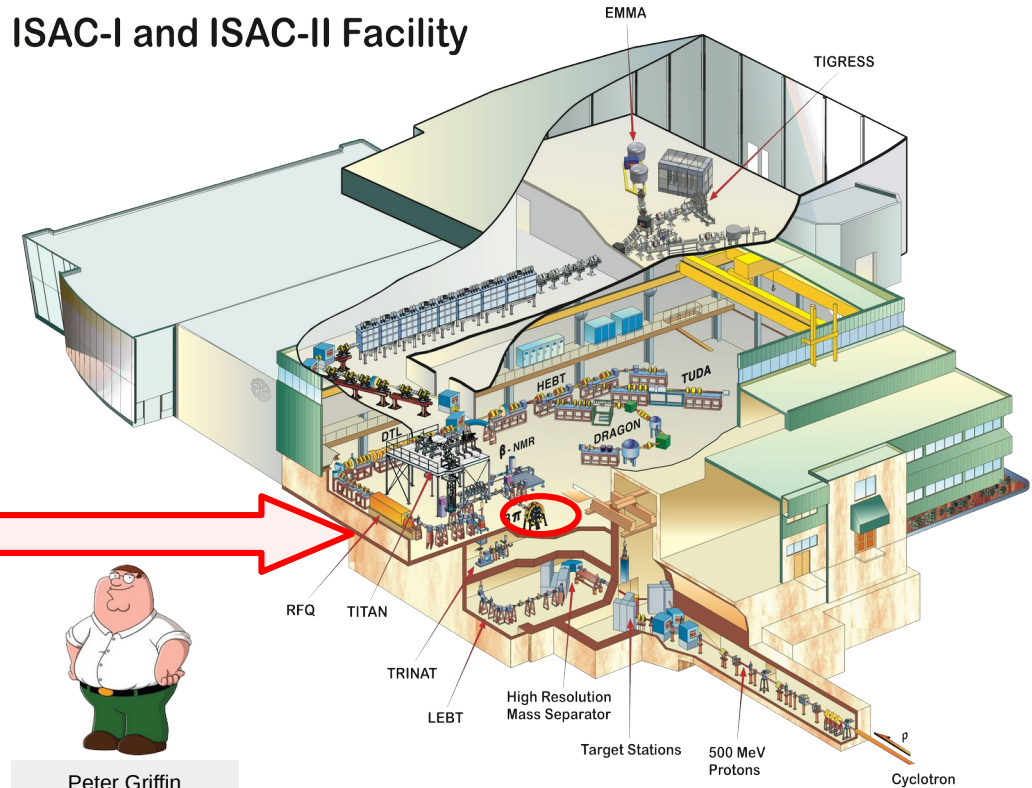
The Facility

ISAC-I and ISAC-II Facility



GRIFIN

<https://www.physics.uoguelph.ca/griffin>



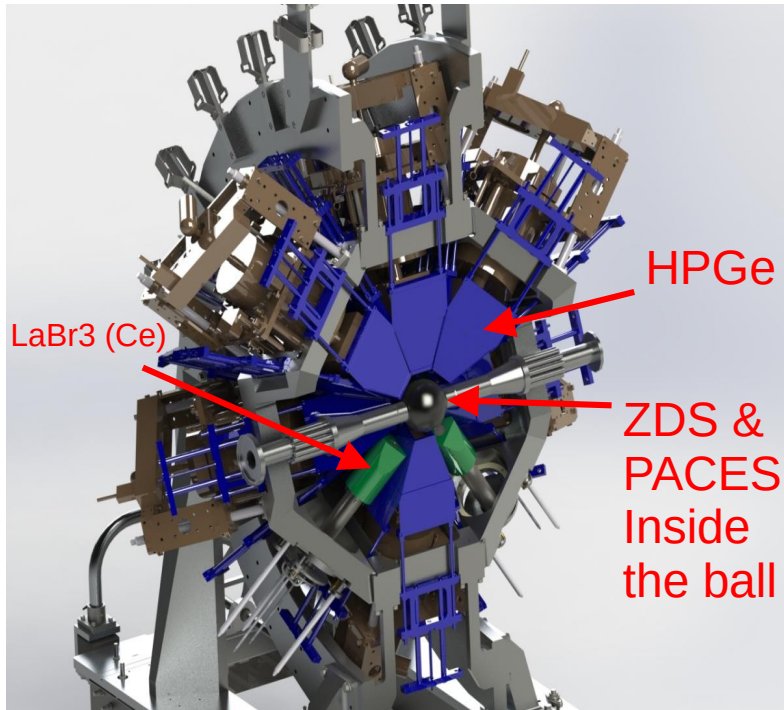
Peter Griffin
GRIFIN
same name but a
different job

https://en.wikipedia.org/wiki/Peter_Griffin

The ISAC I experimental hall

<https://discoverourlab.triumf.ca/tour-our-lab/isac-1/>

Beam production and GRIFFIN Detectors

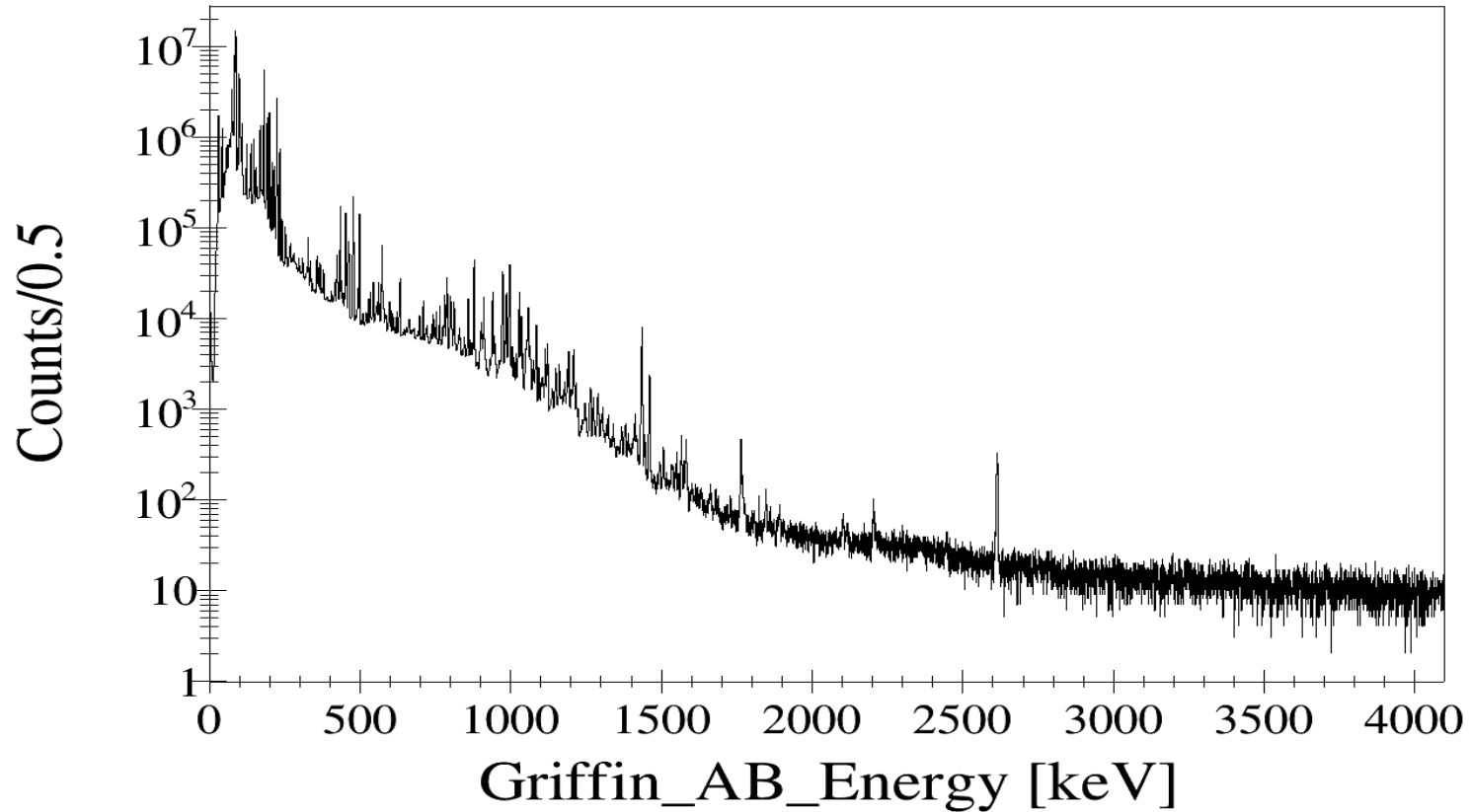


- **Beam:**
 - A low energy radioactive ion beam ^{225}Fr produced by ISAC-I from UCx target using hot surface ion source.
 - Beam energy ~ 20 to 40 keV. Max 10^6 pps of ^{225}Fr .
- **(GRIFFIN):**
- **Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei**
 - **HPGe clover:** 15 out of 16 detectors are used, one is removed give space for the PACES liquid nitrogen supply
 - **ZDS:** Zero degree Scintillator to detect β particles in-vacuum.
 - **PACES:** The Pentagonal Array of Conversion Electron Spectrometers [Si(Li)] detectors for internal conversion electron
 - **LaBr3 (Ce):** Cerium-doped lanthanum bromide scintillators for fast-coincidence-timing
 - **DAQ:** The data acquisition system
 - **moving tape system:** 12.7 mm Mylar tape used to implant the beam on, and moved behind lead shield to the tape box

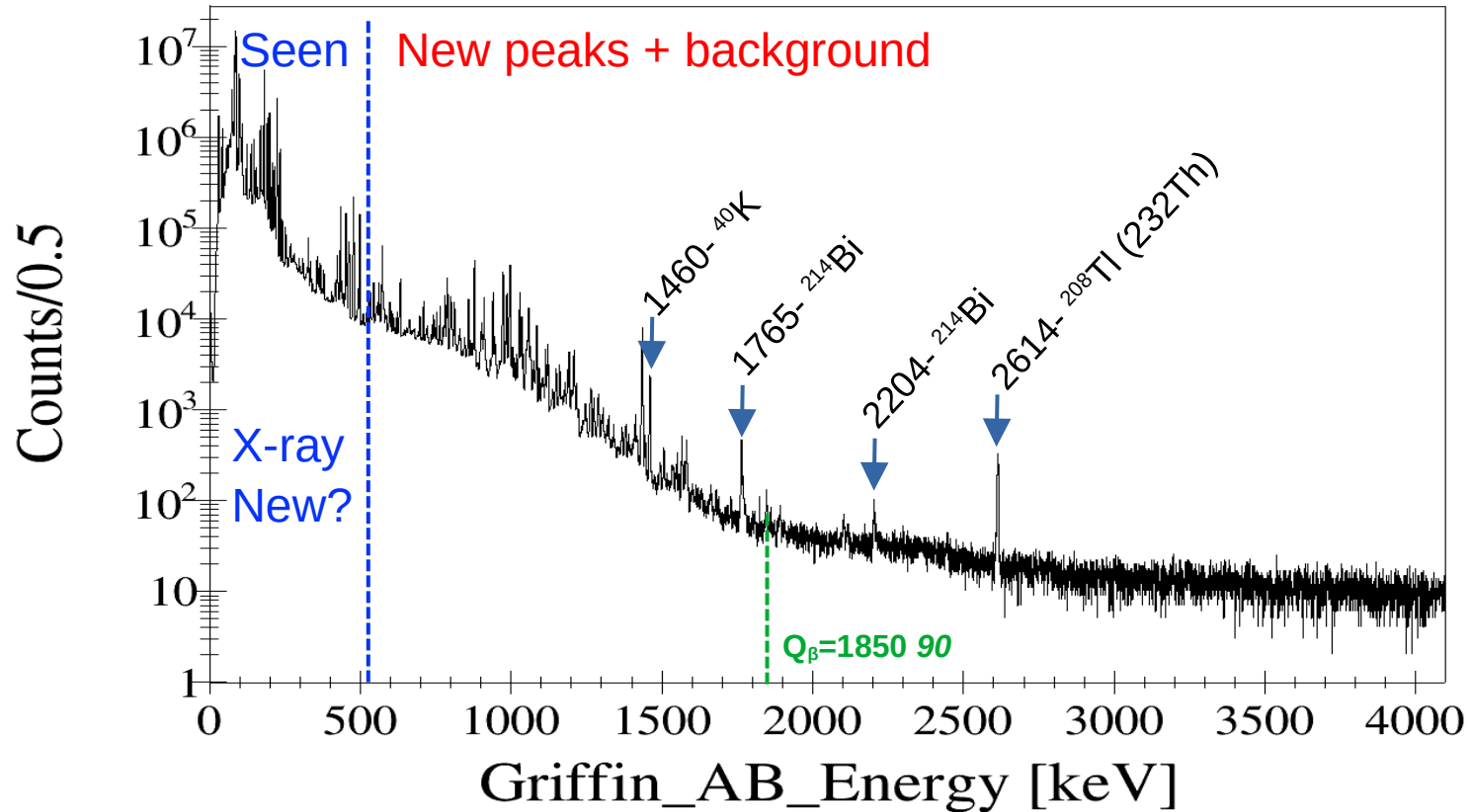
GRIFFIN

<https://www.physics.uoguelph.ca/griffin>

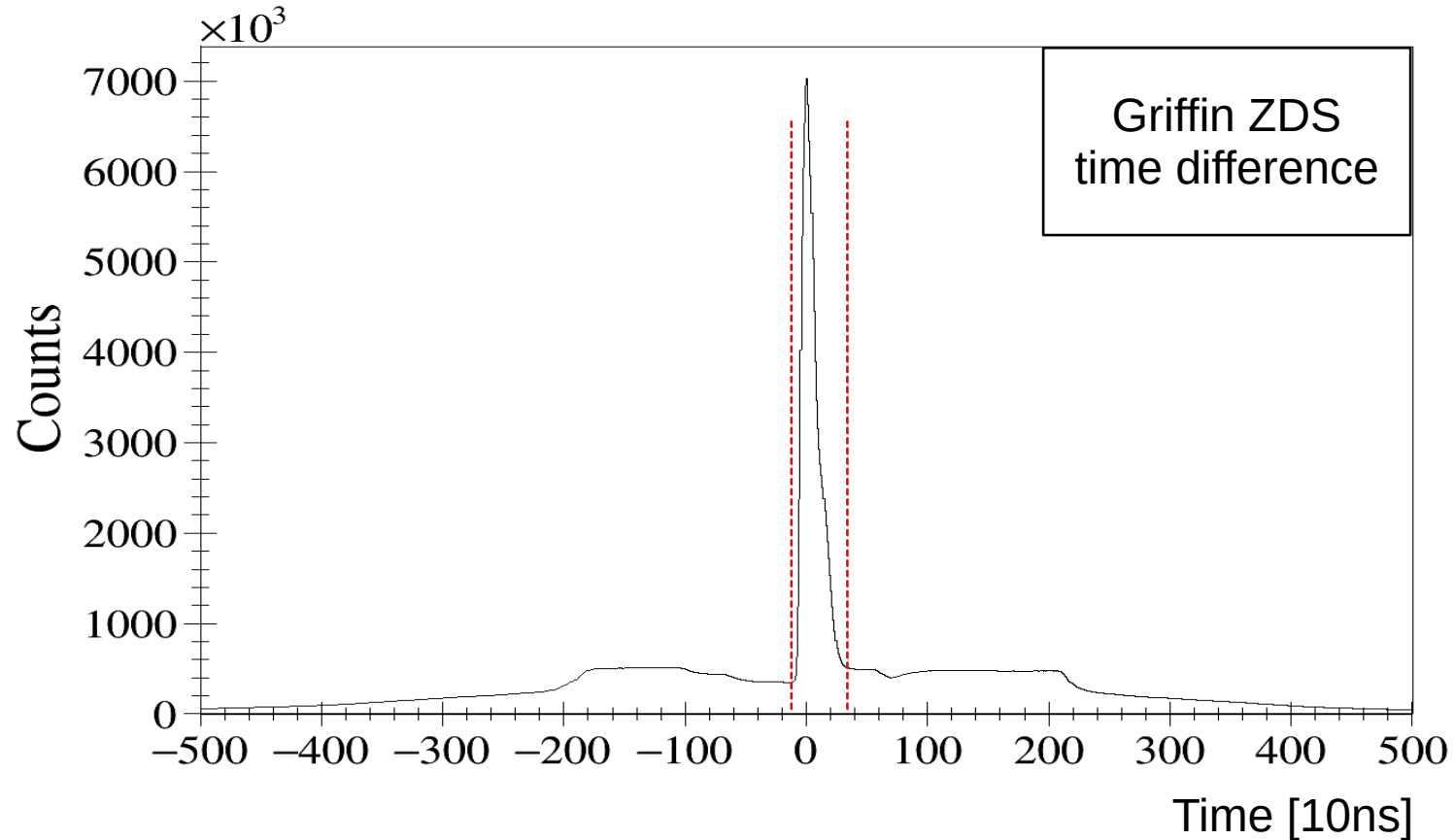
Data analysis



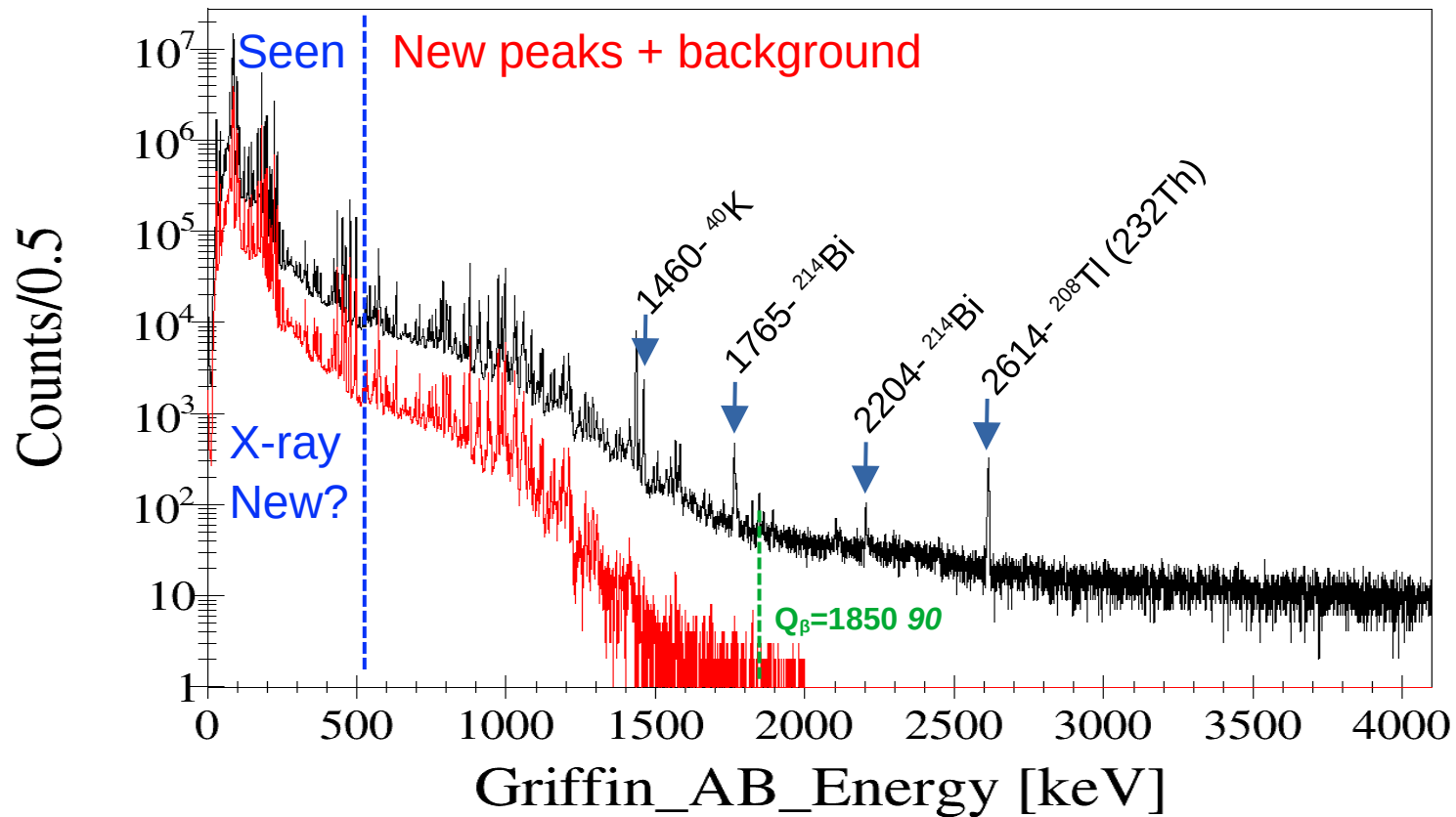
Data analysis



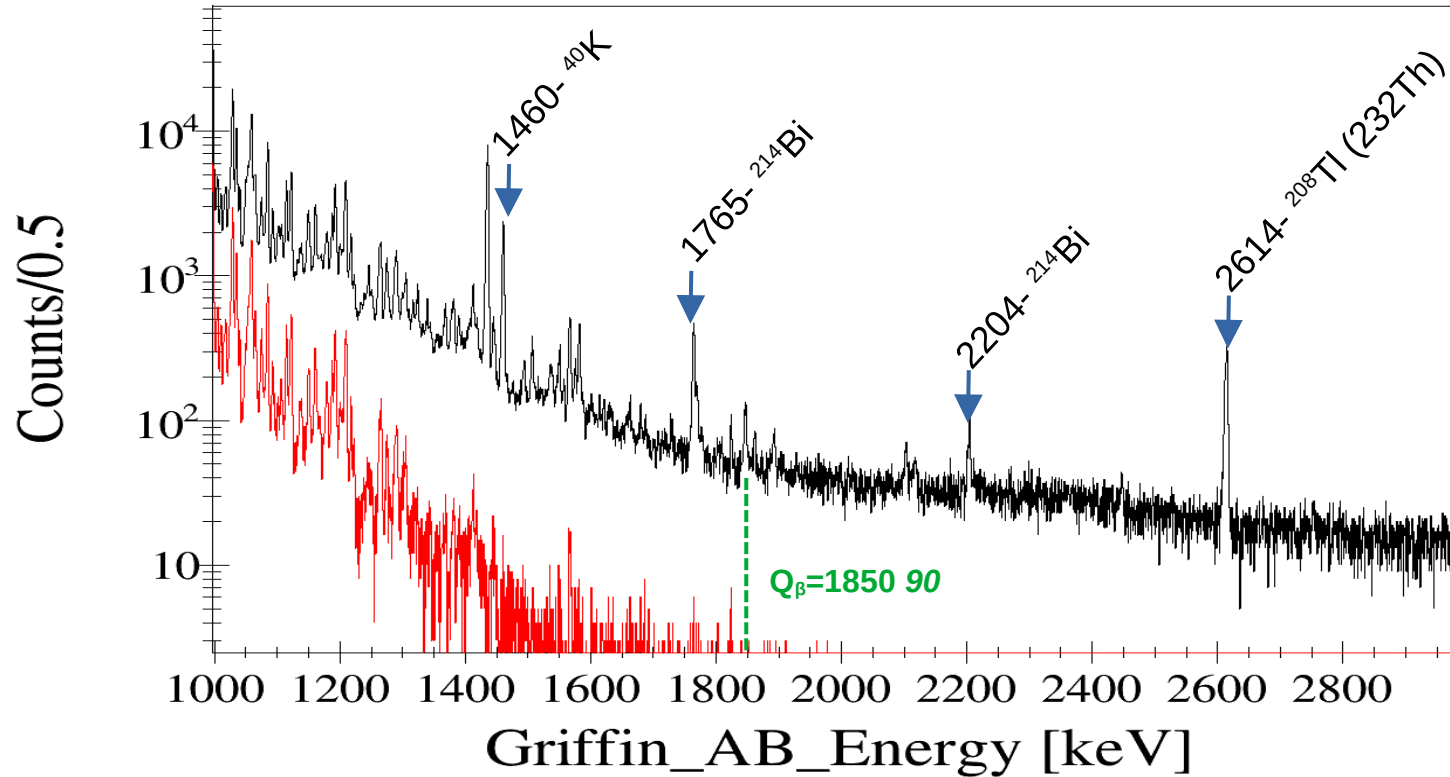
Data analysis



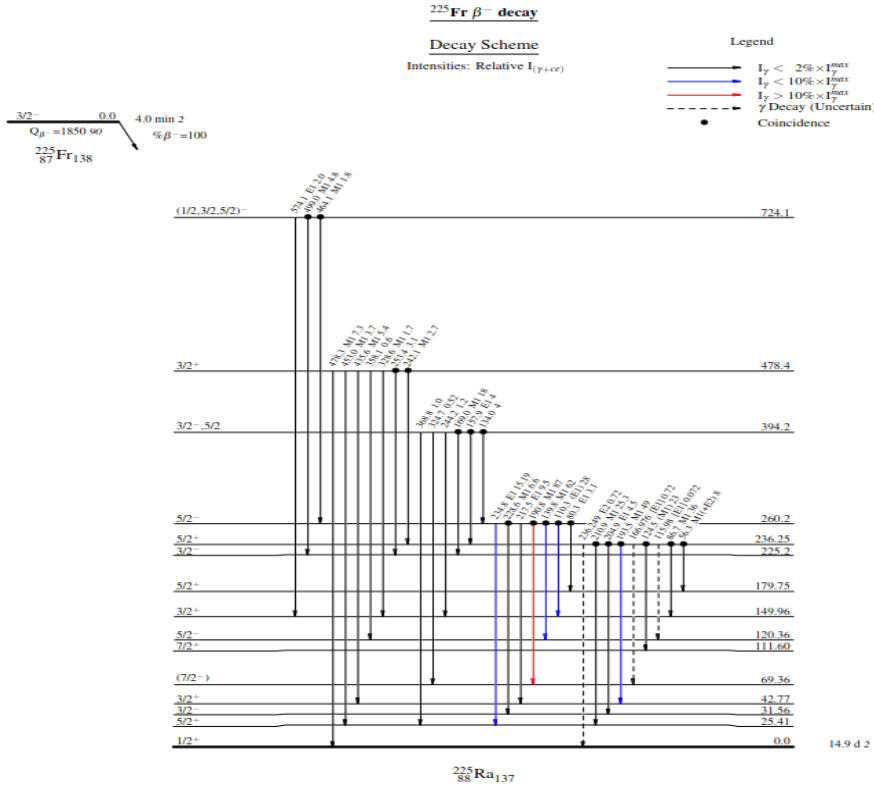
Data analysis



Data analysis

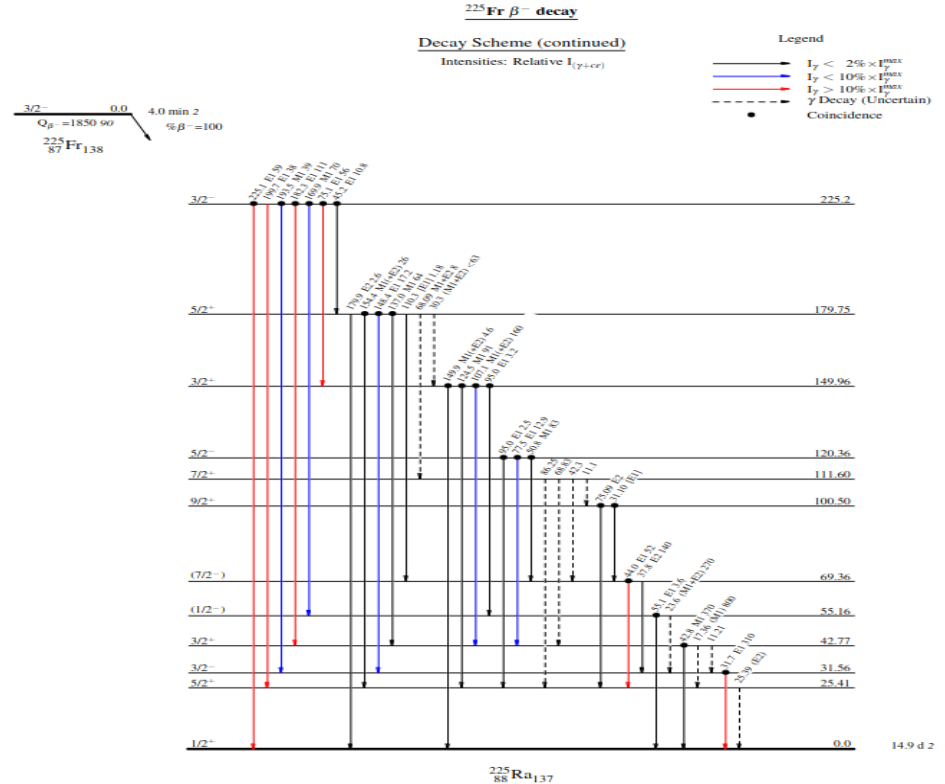


Data analysis – ^{225}Fr level scheme



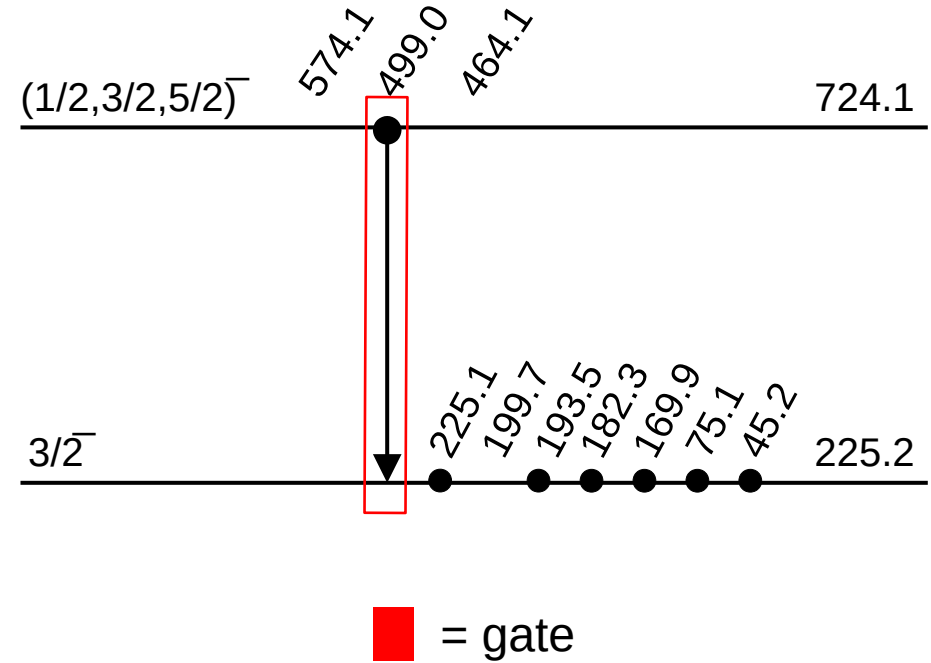
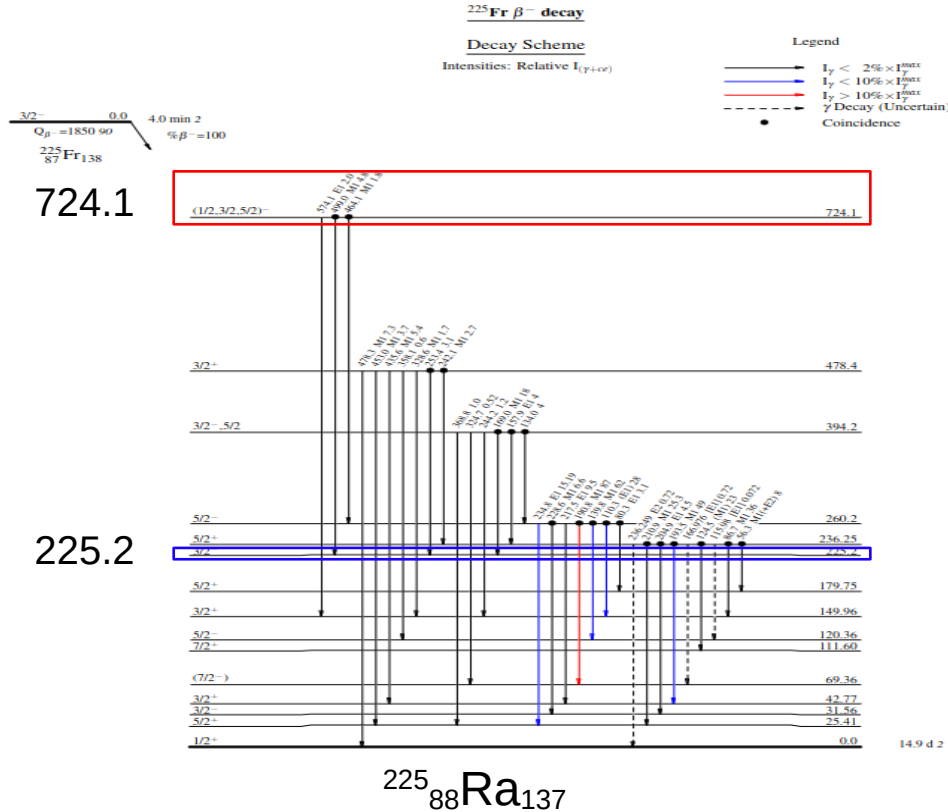
Level scheme pt 1

<https://www.nndc.bnl.gov>

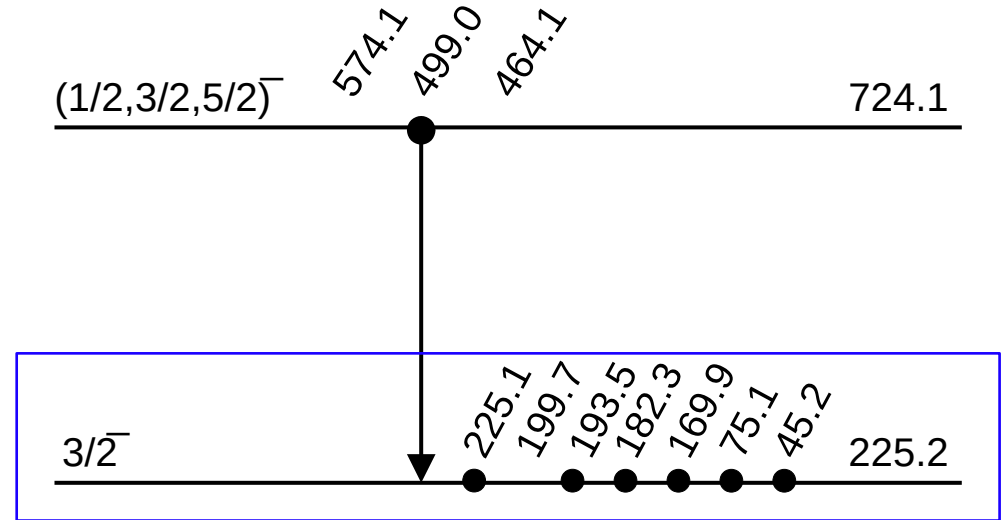
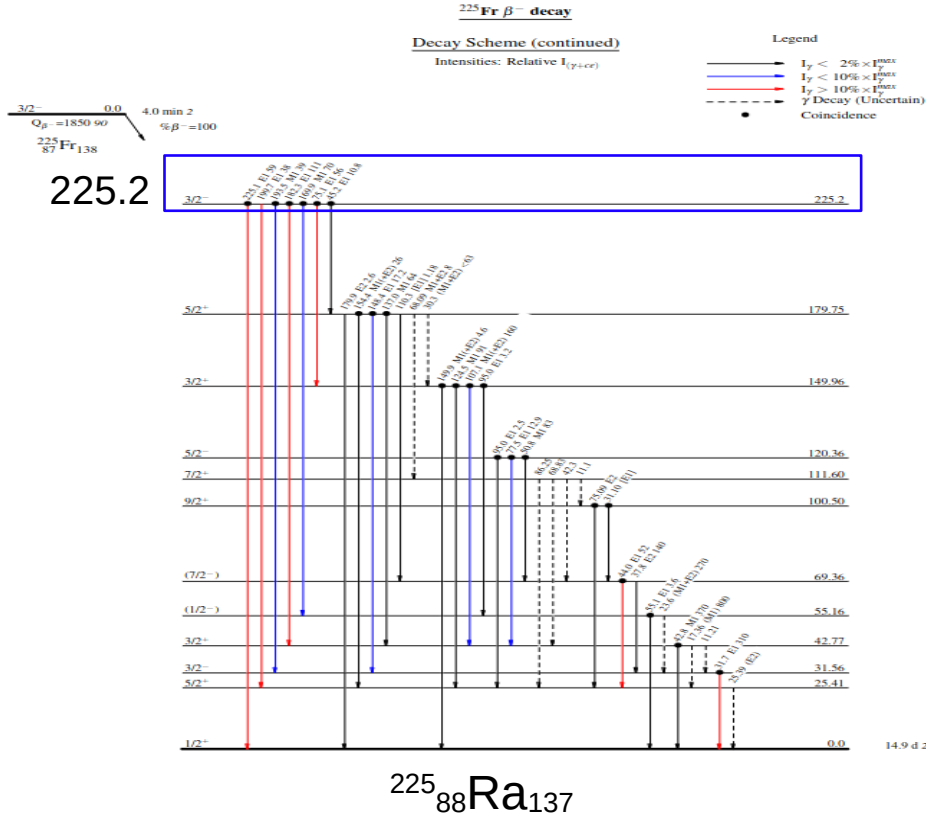


Level scheme pt 2

Data analysis – ^{225}Fr level scheme

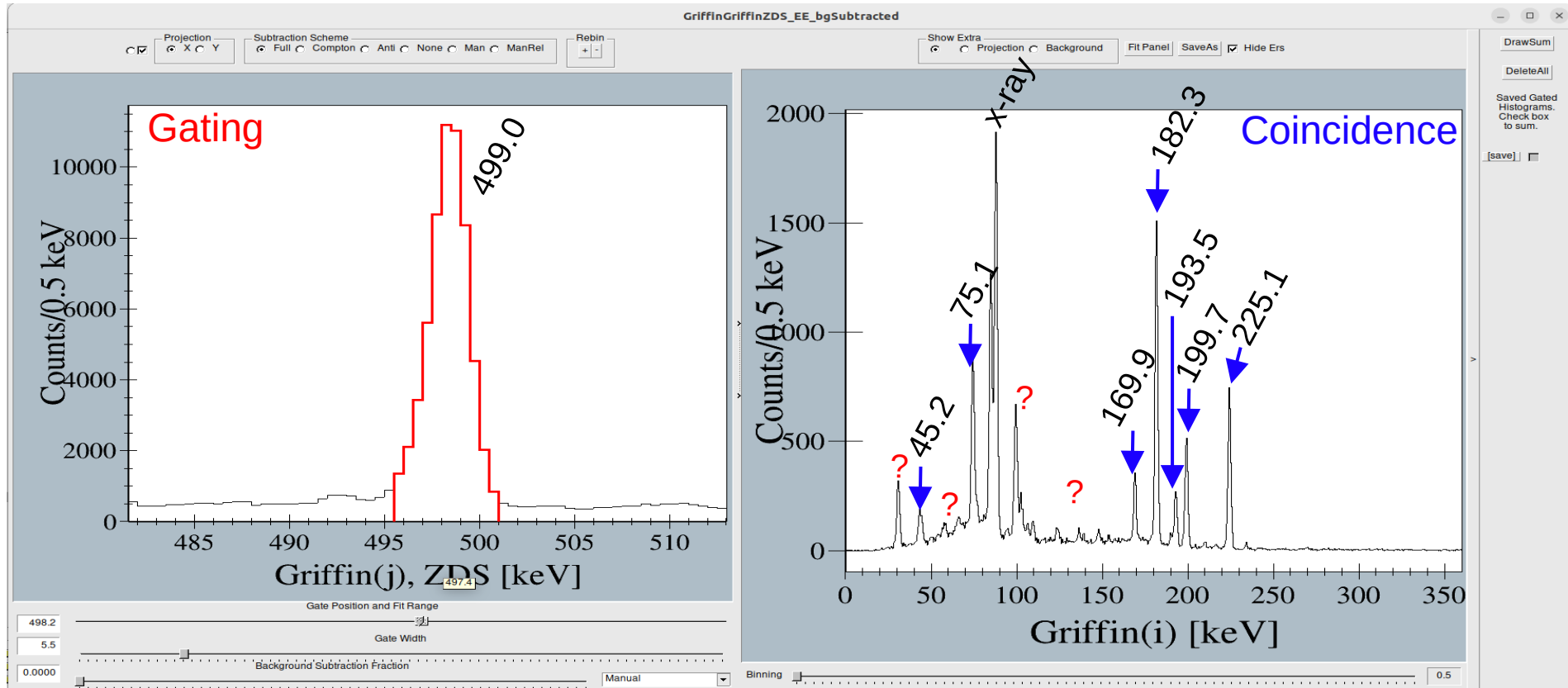


Data analysis – ^{225}Fr level scheme

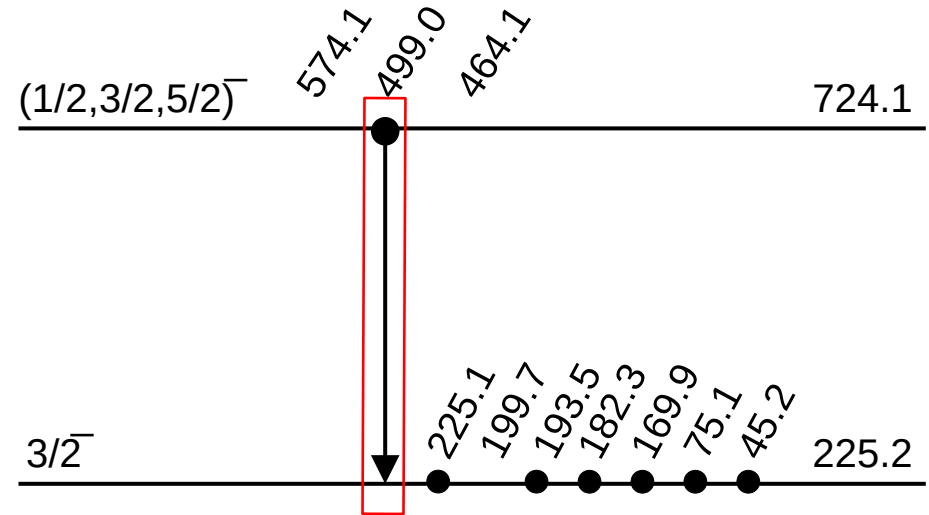
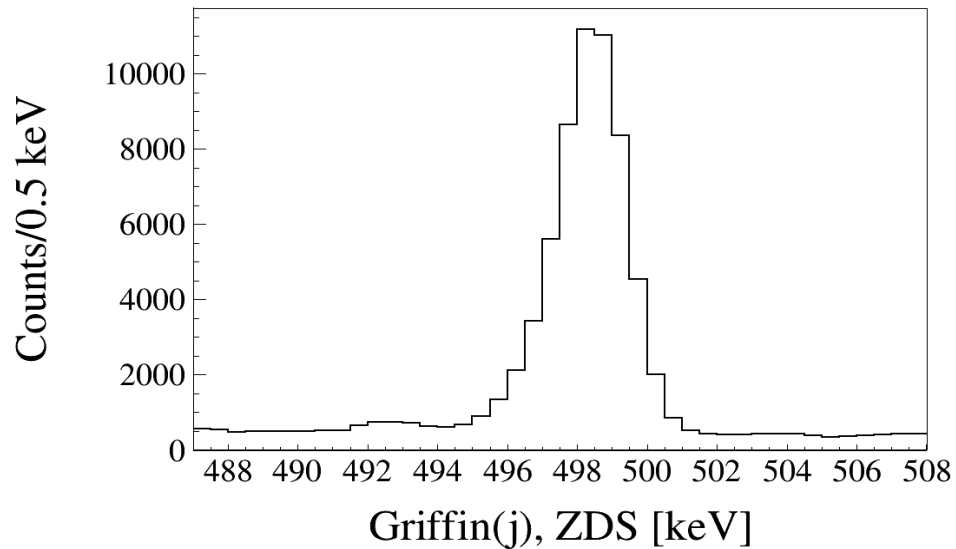


■ = Gamma in coincidence

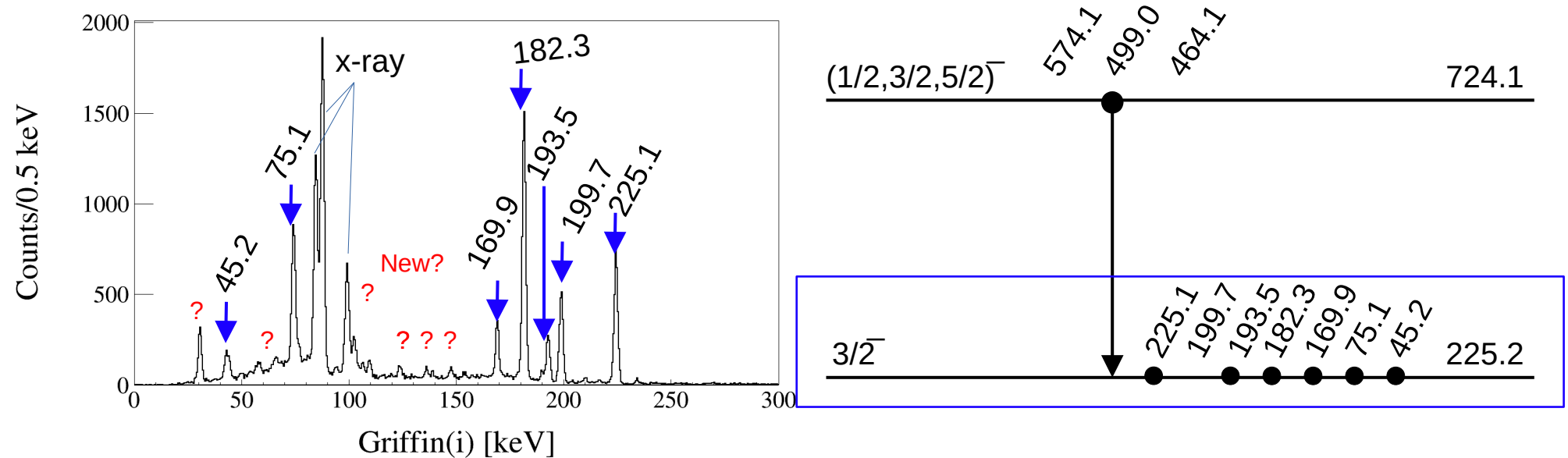
Data analysis – jroot software for gating and fitting



Data analysis – 499.0 keV gating



Data analysis – γ -rays in coincidence



X-Ray ^{225}Ra :

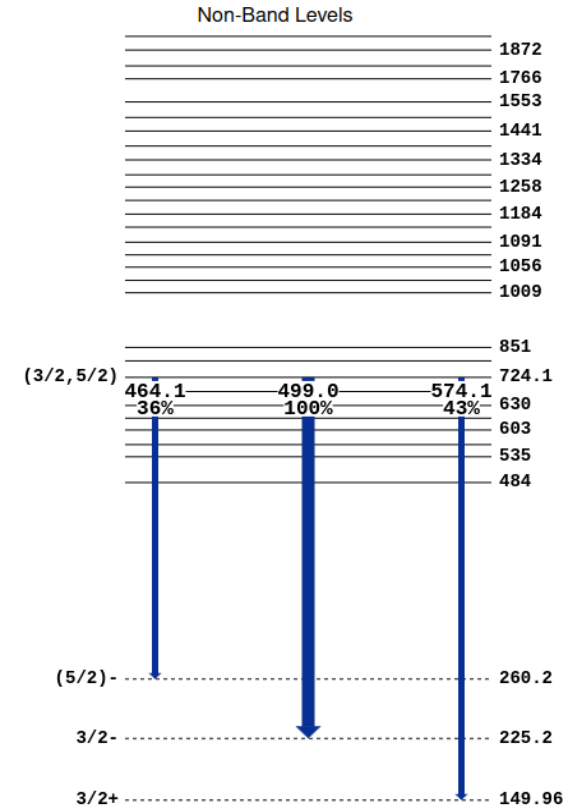
$K\alpha_1$: 88.470 keV

$K\alpha_2$: 85.430 keV

$K\beta_1$: 100.130 keV

Future work

- Continue data analysis.
- Find new peaks and (new transition).
- Find new energy level.
- Filling the decay scheme accordingly.
- Lifetimes from LaBr3 (Ce).
- Conversion electron from PACES.
- Angular correlation from Griffin.



Thank you :)