CATLIFE (Complementary Arm for Target LIke FragmEnts): Detector for Target like fragments at VAMOS++

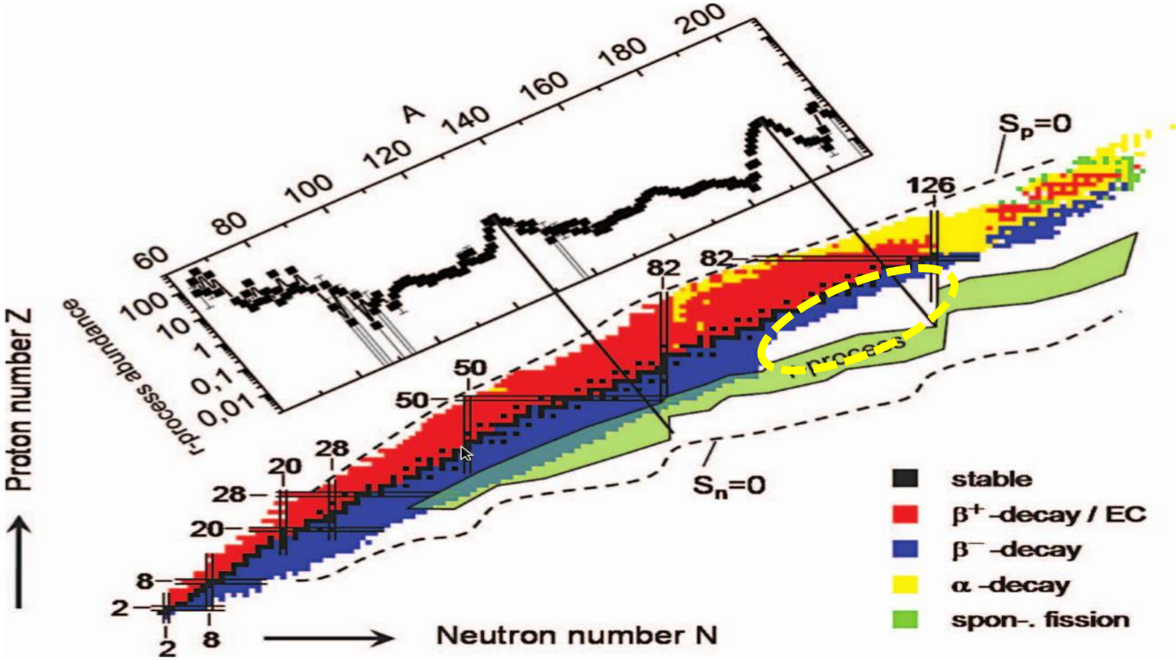
Yonghyun Son

Department of Physics and Astronomy, SNU

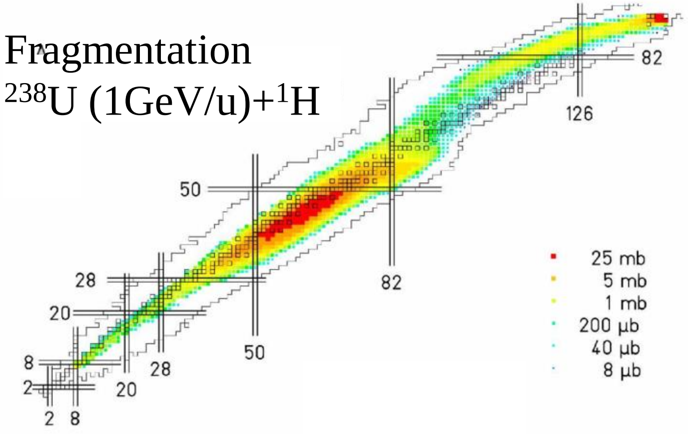
Center for Exotic Nuclear Studies, IBS

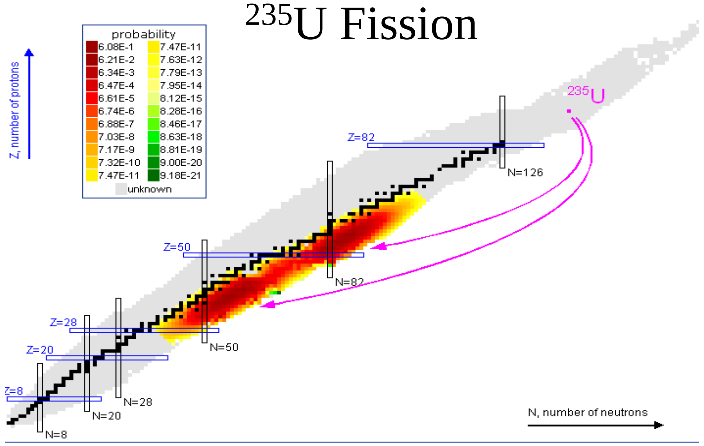
Contents

Motivation of Experiment



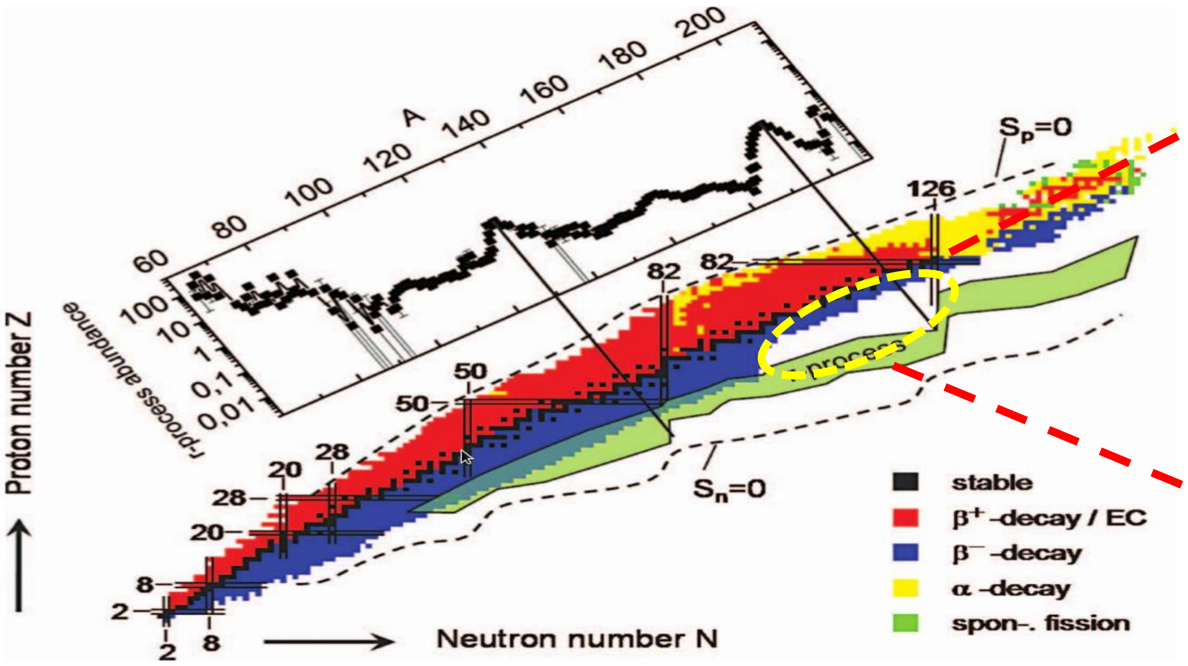
Reiner Krucken, Contemporary Physics Vol. 52, No. 2(2011) 101–120



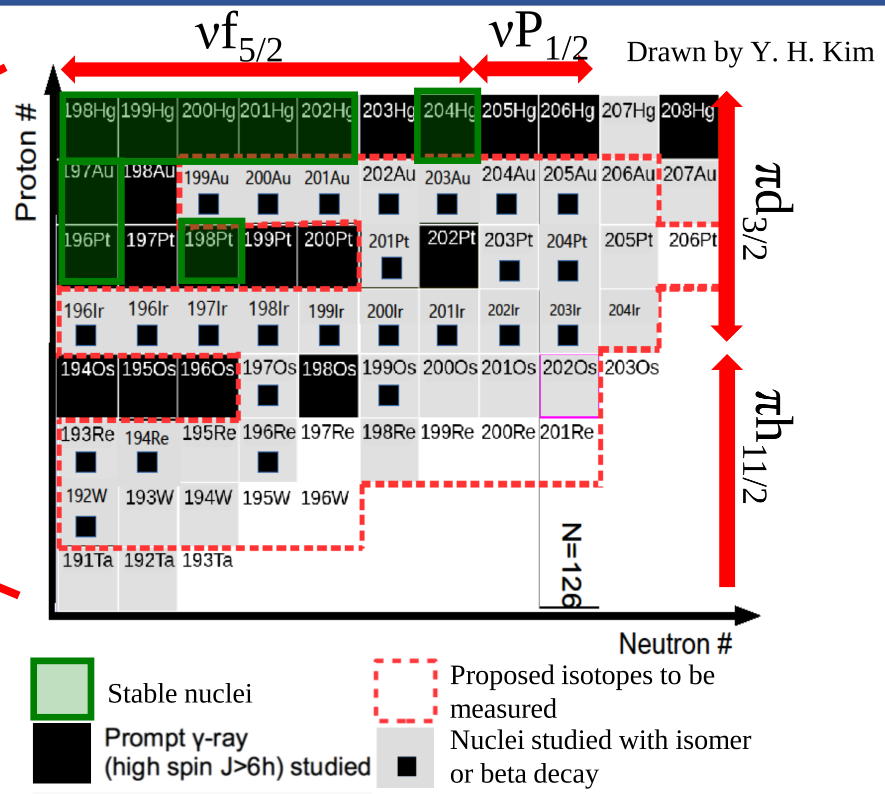


- “Blank spot” below ^{208}Pb : Relevant to nuclear-astrophysical r-process
- Evolution of nuclear structure N=126 shell closure neutron rich nuclei
- Difficult to access by conventional methods (fragmentation, fission)
- Using Multi-nucleon transfer reaction of 7MeV/u ^{136}Xe beam on ^{198}Pt target to access near N=126 neutron rich nuclei

Motivation of Experiment



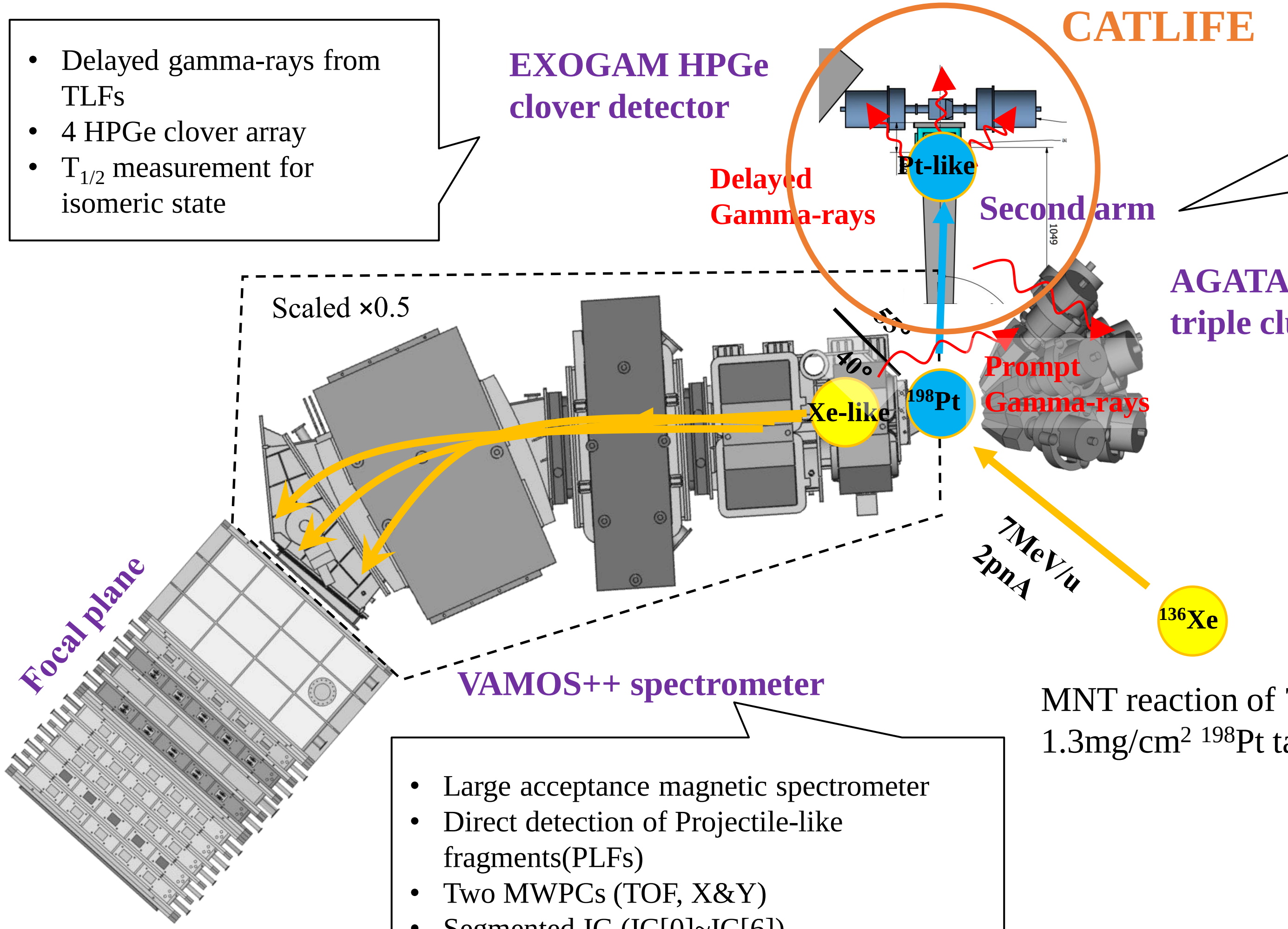
Reiner Krucken, Contemporary Physics Vol. 52, No. 2(2011) 101–120



- Study for nuclear structure of neutron rich nuclei near N=126 shell closure
- How : Gamma-ray spectroscopy
- Many isomers exist in region of interest → Prompt and delayed gamma-ray spectroscopy is needed

Experimental Setup

- Delayed gamma-rays from TLFs
- 4 HPGe clover array
- $T_{1/2}$ measurement for isomeric state



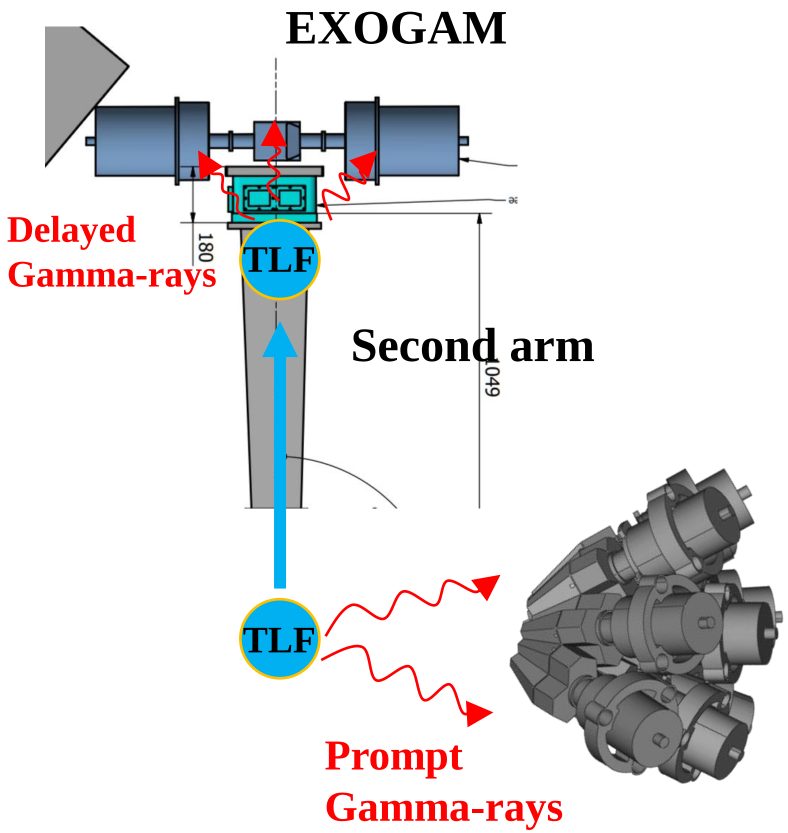
- Direct measurement of Target-like fragments (TLFs) velocity
- One MWPC (TOF, X&Y)

- Prompt gamma-rays form PLFs and TLFs
- 39 crystals with nominal configuration

- Large acceptance magnetic spectrometer
- Direct detection of Projectile-like fragments(PLFs)
- Two MWPCs (TOF, X&Y)
- Segmented IC (IC[0]~IC[6])
- Ion track reconstruction (Bρ, Path)

MNT reaction of 7MeV/u ^{136}Xe beam on 1.3mg/cm^2 ^{198}Pt target

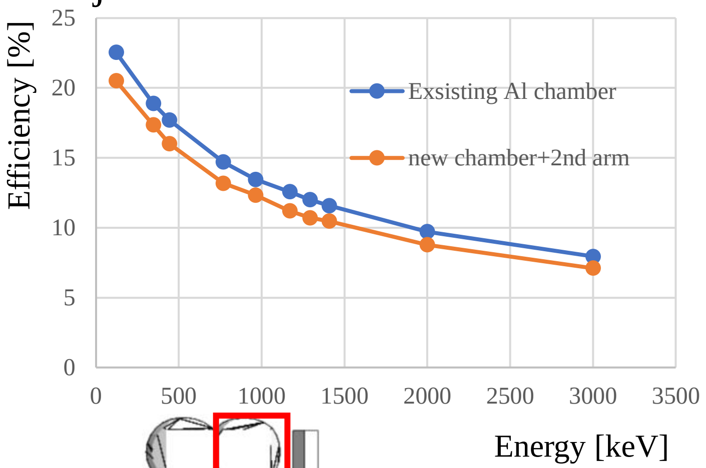
Experimental Setup : Necessity of the Second Arm



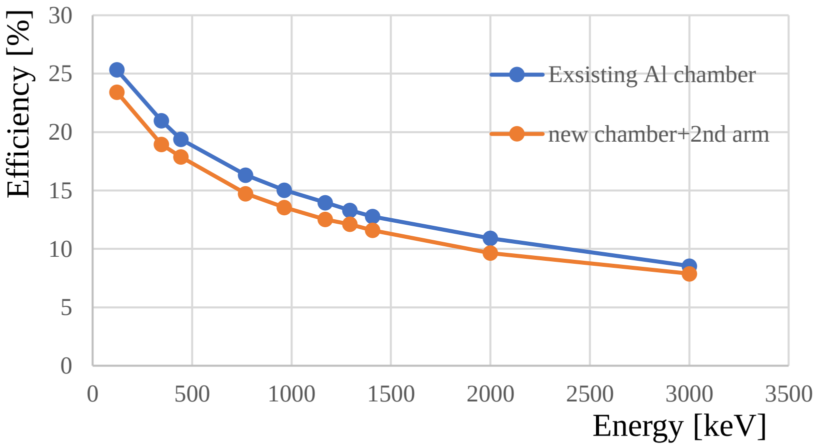
- Second arm : A new setup for TLF developed in SNU.
- PLFs are fully identified by VAMOS++ spectrometer.
- The nuclides of interested are on TLFs, difficult to identify directly, and many isomeric states in TLF nuclides exists.
- Additional setup for TLFs → **Second arm.**
- Velocity and TOF of TLFs are measured by second arm to calculate excitation energy and mass before neutron evaporation.
- Measurement can help TLFs identification and reaction mechanism study.
- GEANT4 Simulation verifying that we can use second arm for the experiment.

GEANT4 Simulation for CATLIFE

Projectile-like

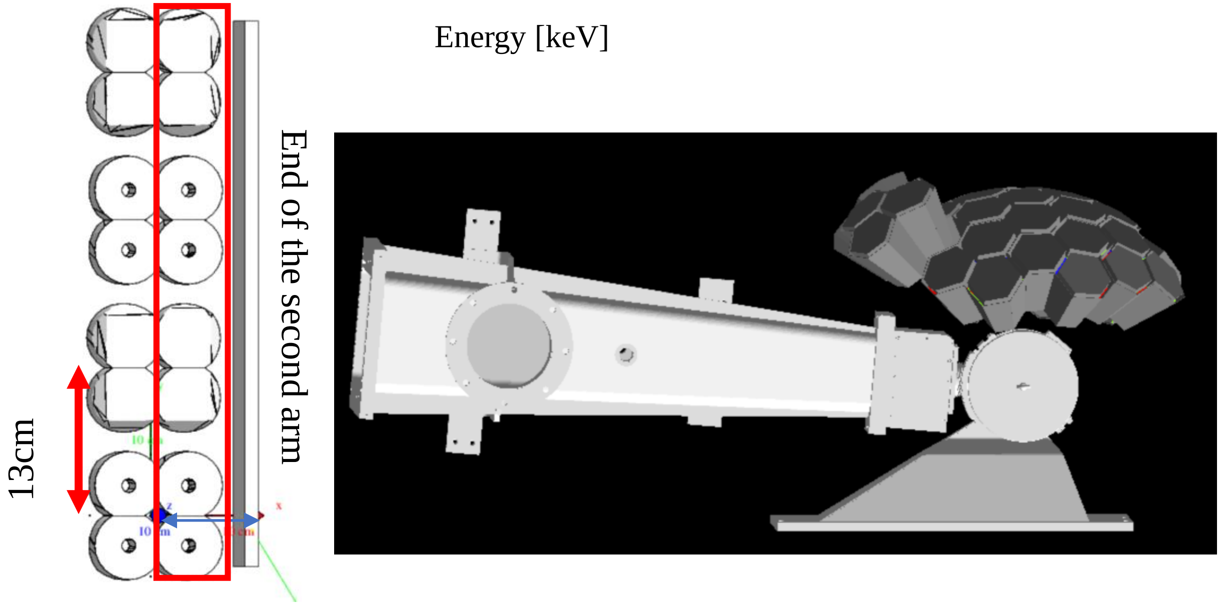


Target-like



For prompt gamma-ray, 4~7% loss in efficiency compared to original setup

→ Not crucial loss

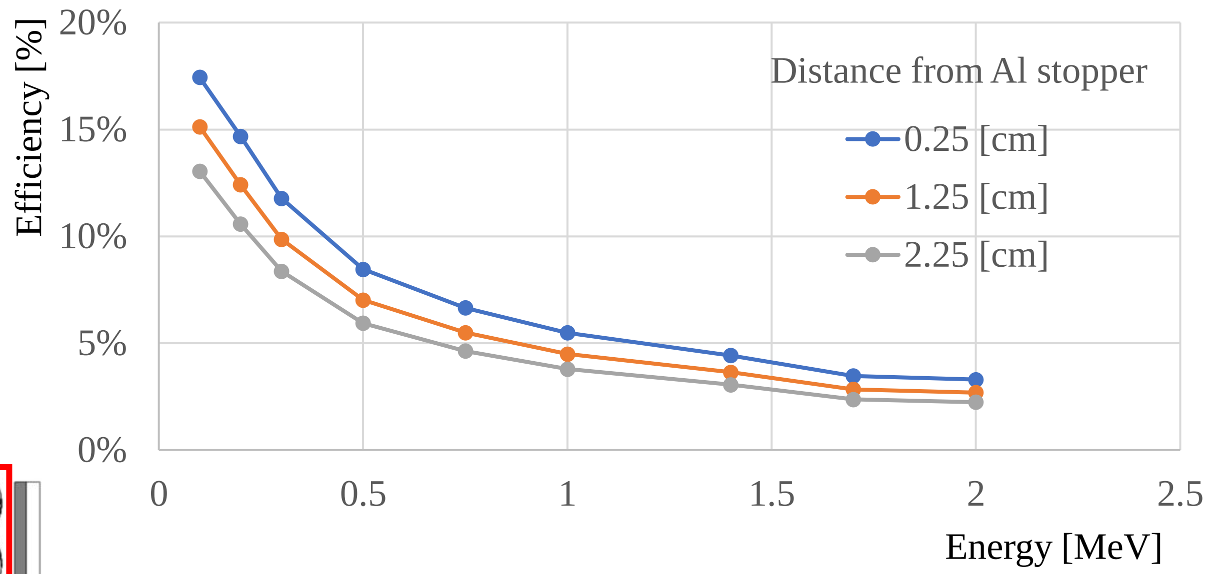


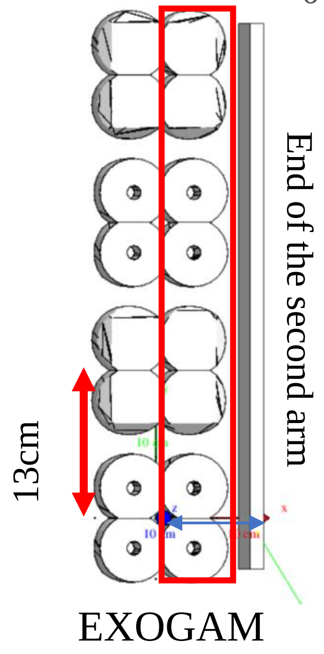
EXOGAM

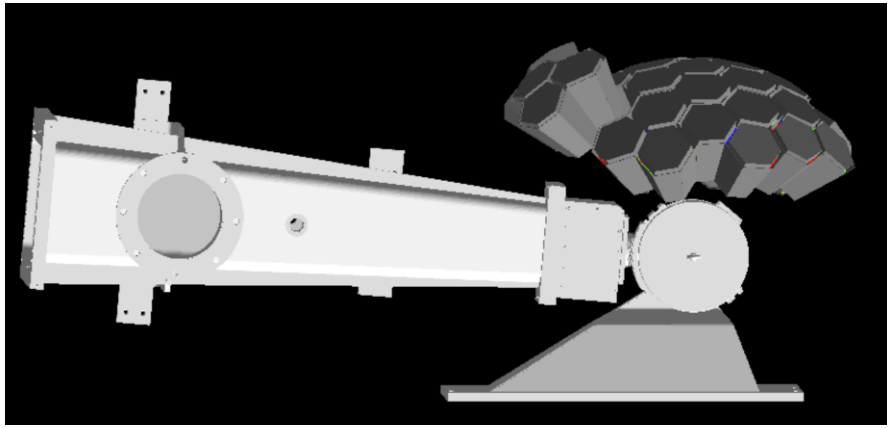
For delayed gamma-ray, sufficient efficiency for the experiment

→ Second arm is available for the experiment

GEANT4 Simulation for CATLIFE







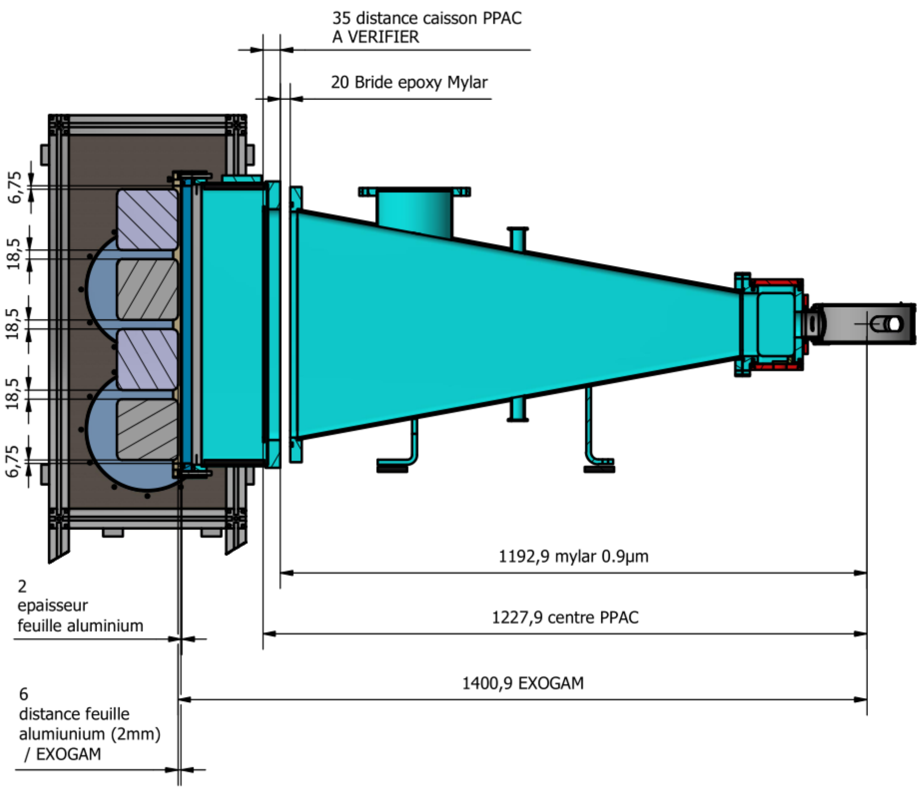
For prompt gamma-ray, 4~7% loss in efficiency compared to original setup

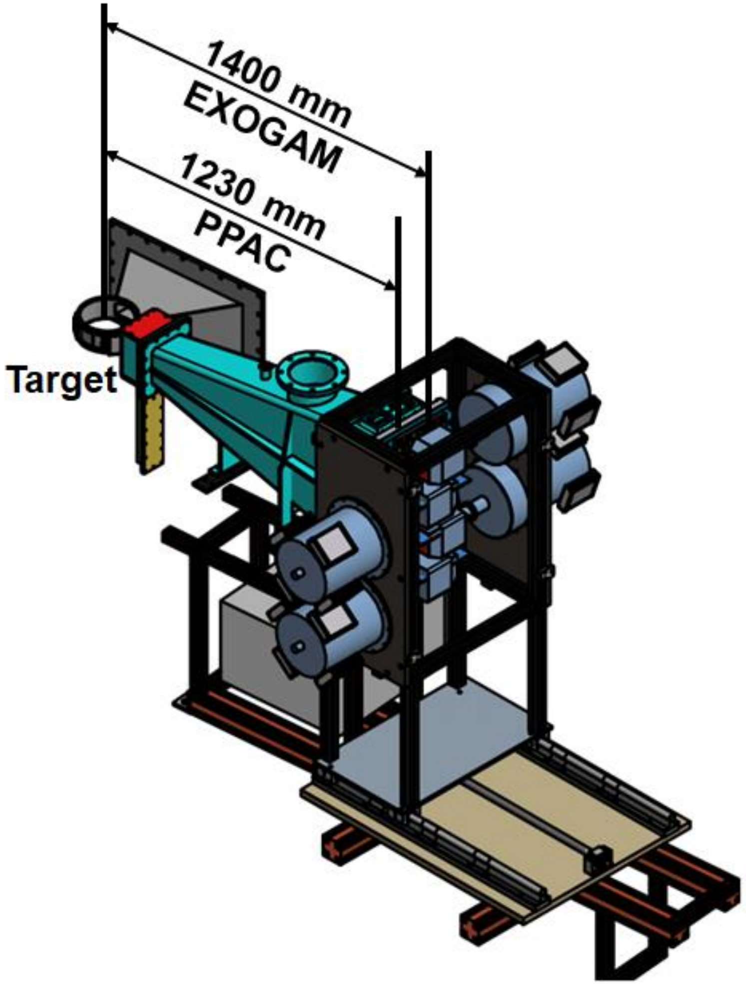
→ Not crucial loss

For delayed gamma-ray, sufficient efficiency for the experiment

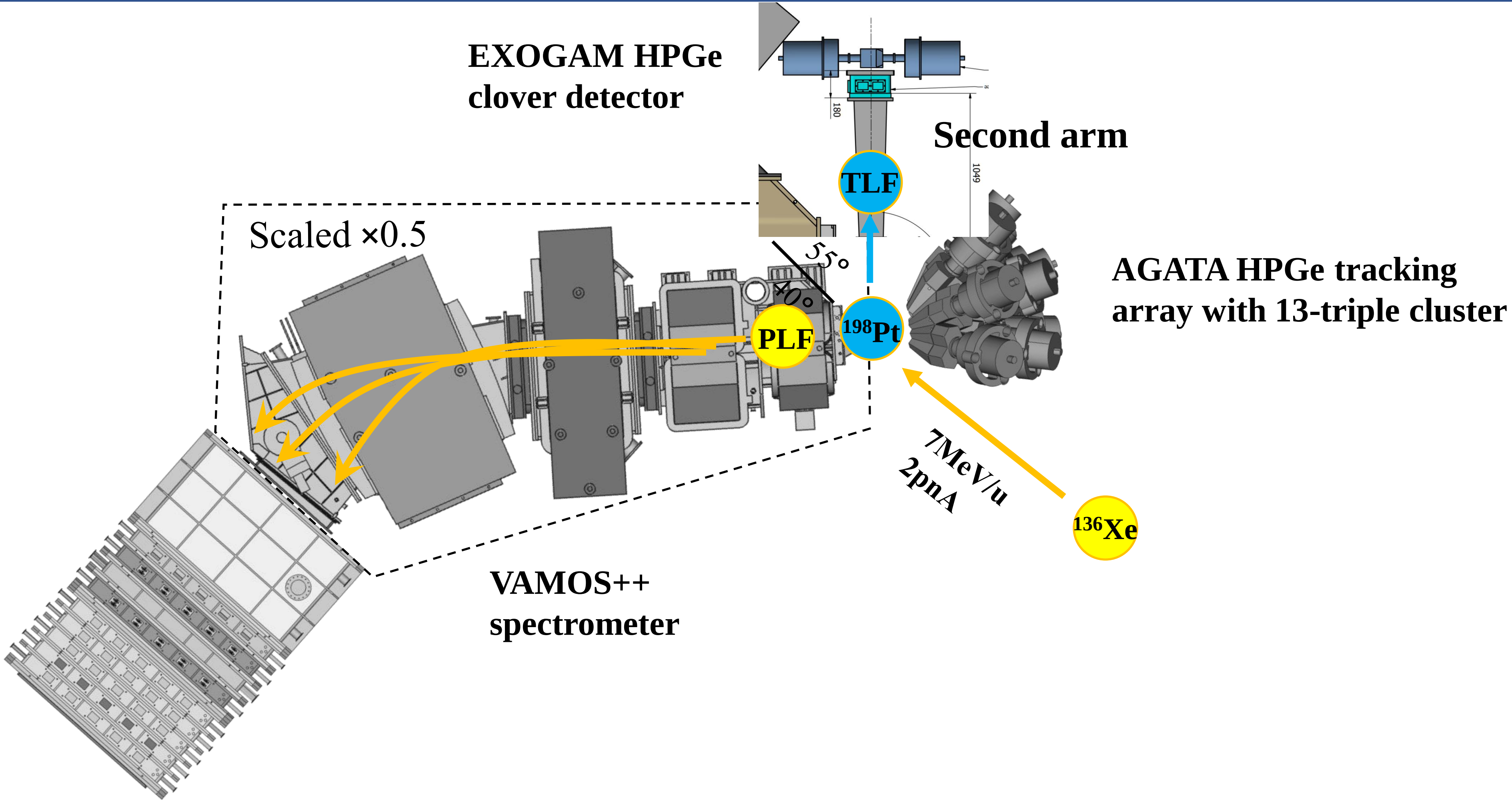
→ Second arm is available for the experiment

Experimental Setup : CATLIFE

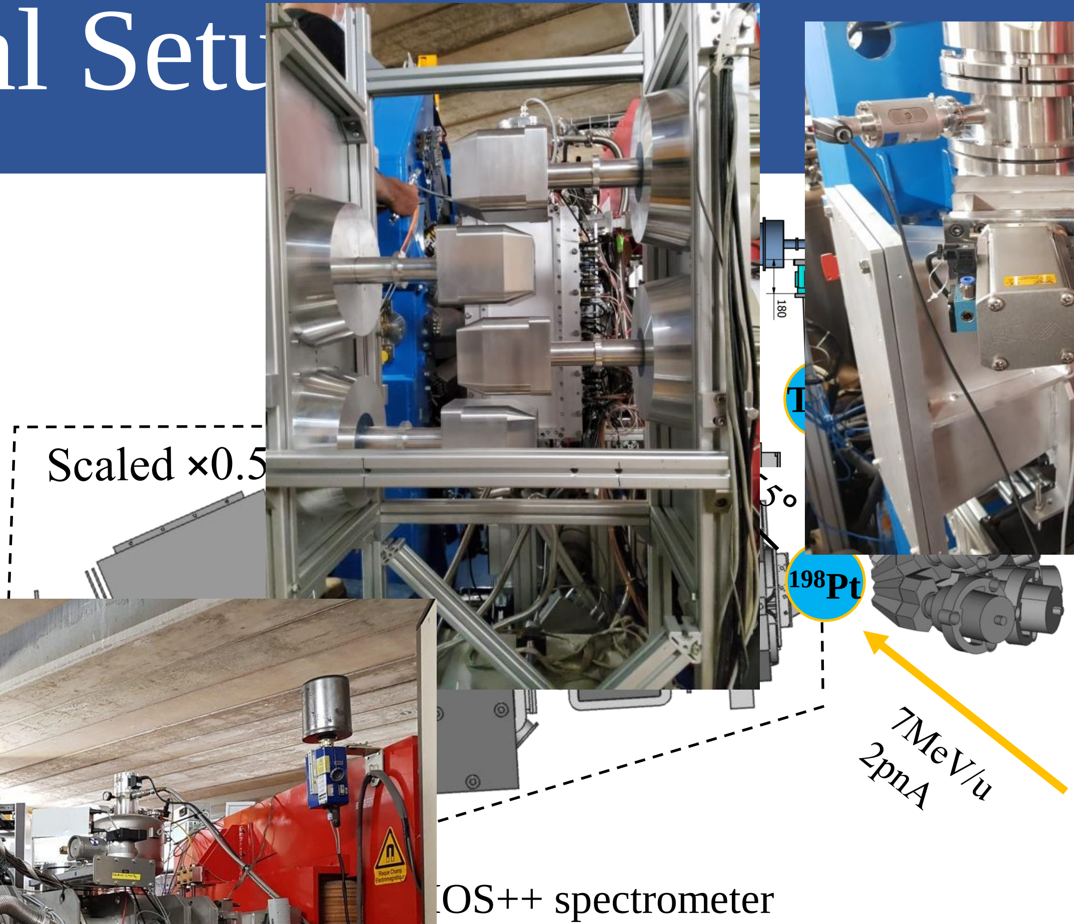


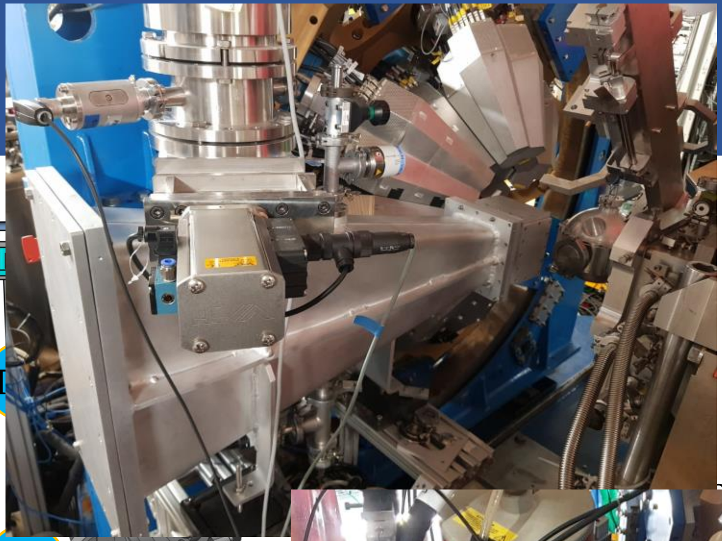


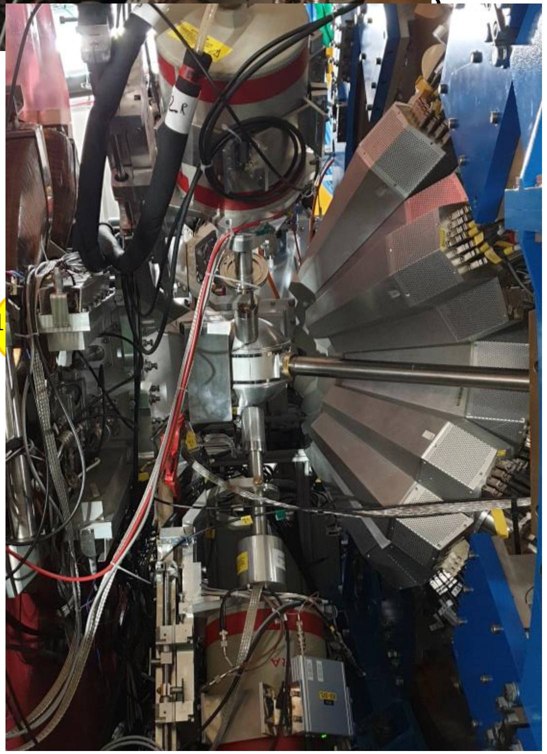
Experimental Setup

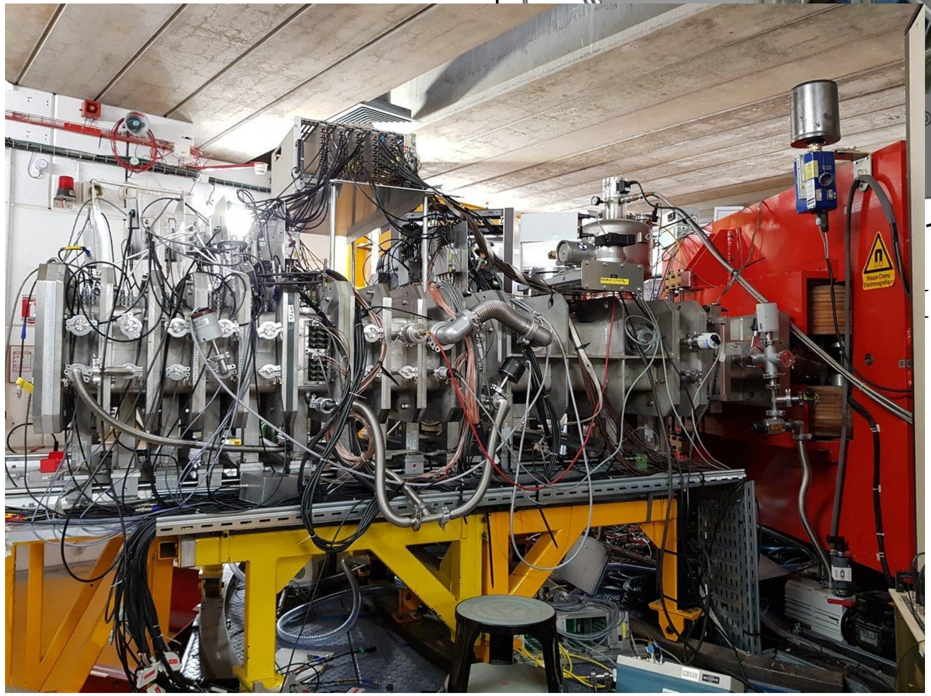


Experimental Setu

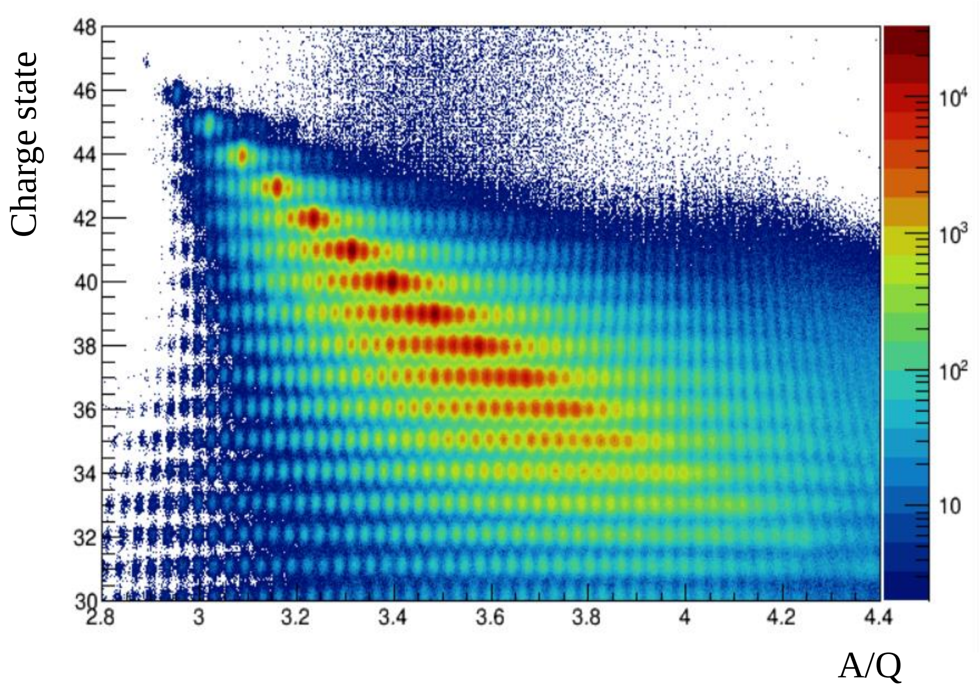


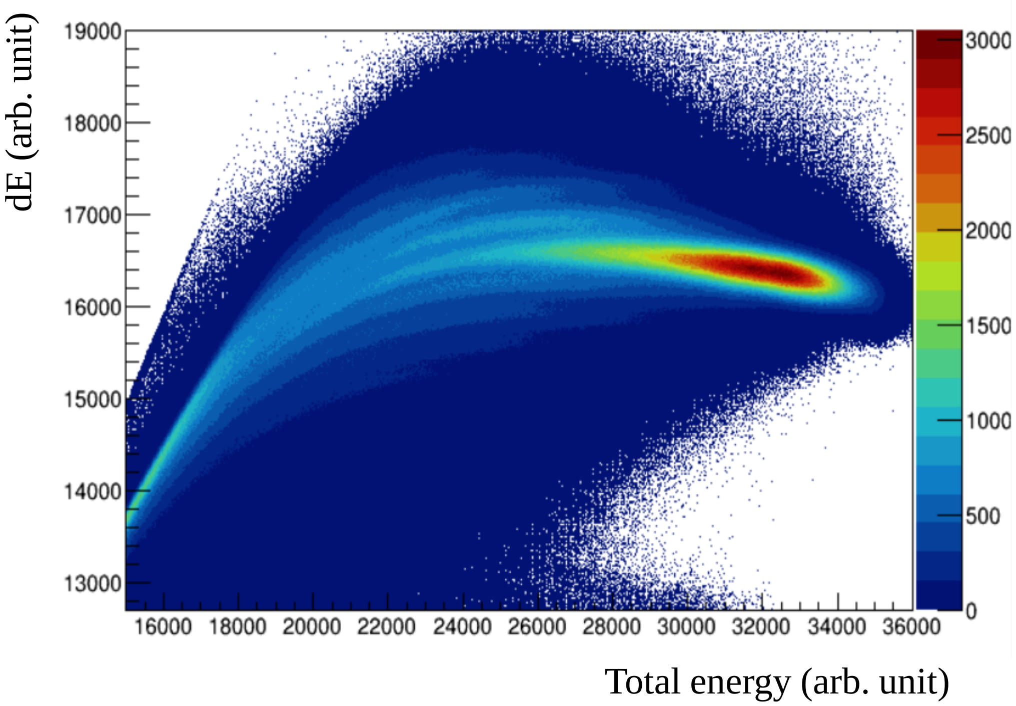






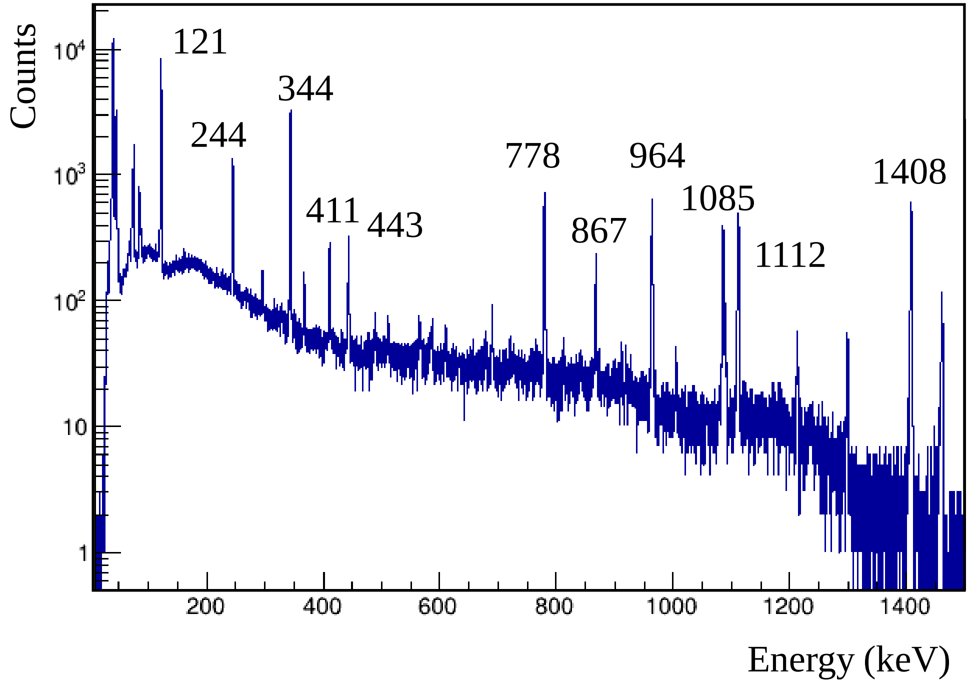
Experimental Result : Ion Distribution





- Projectile-like fragments are well identified for preliminary result (Q/ΔQ ~ 80, M/ ΔM ~ 210)
- Charge states and mass numbers are identified using machine learning (Y.Cho)

Experimental Result : Energy Calibration & Time Correction



- High precision gamma-ray spectroscopy is necessary → Precise calibration is essential!
- Initial calibration with ^{152}Eu source : Third order calibration $E_{cal} = c_0+c_1x+c_2x^2+c_3x^3$.
- **Problem : Gain change over time** due to electronics
- Another problem : Initial calibration does not fit well at high energy region.
- Cannot use ^{152}Eu source calibration for online data → Use online data for calibration.

Experimental Result : Energy Calibration & Time Correction

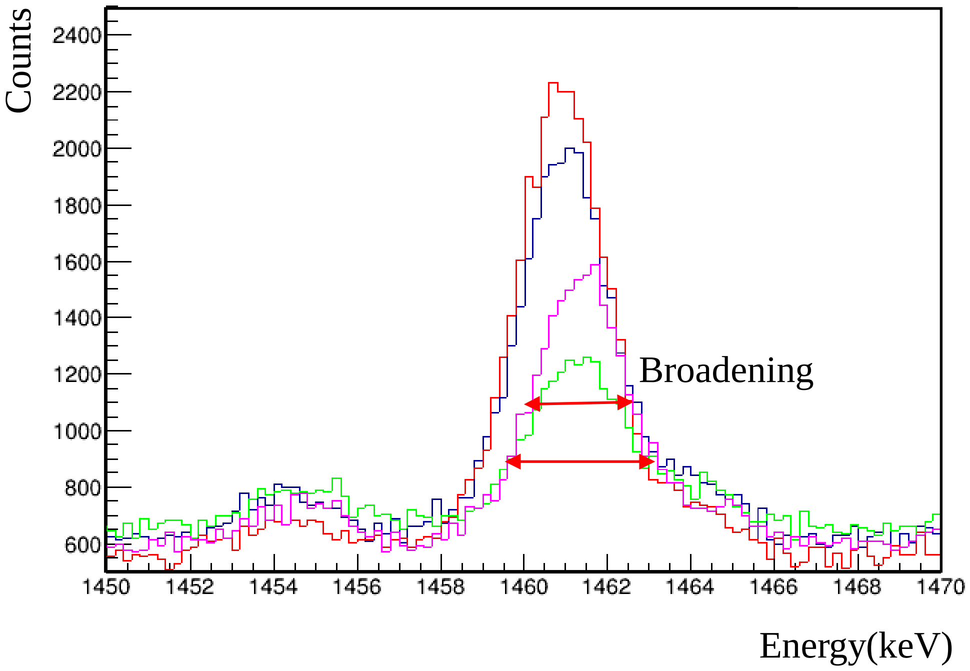
Clover #1	FWHM of 1408 keV peak (keV)
Crystal 00	2.42
Crystal 01	2.51
Crystal 02	2.46
Crystal 03	2.65

Clover #3	FWHM of 1408 keV peak (keV)
Crystal 08	2.42
Crystal 09	2.64
Crystal 10	2.53
Crystal 11	2.44

Clover #2	FWHM of 1408 keV peak (keV)
Crystal 04	3.38
Crystal 05	2.82
Crystal 06	2.64
Crystal 07	2.76

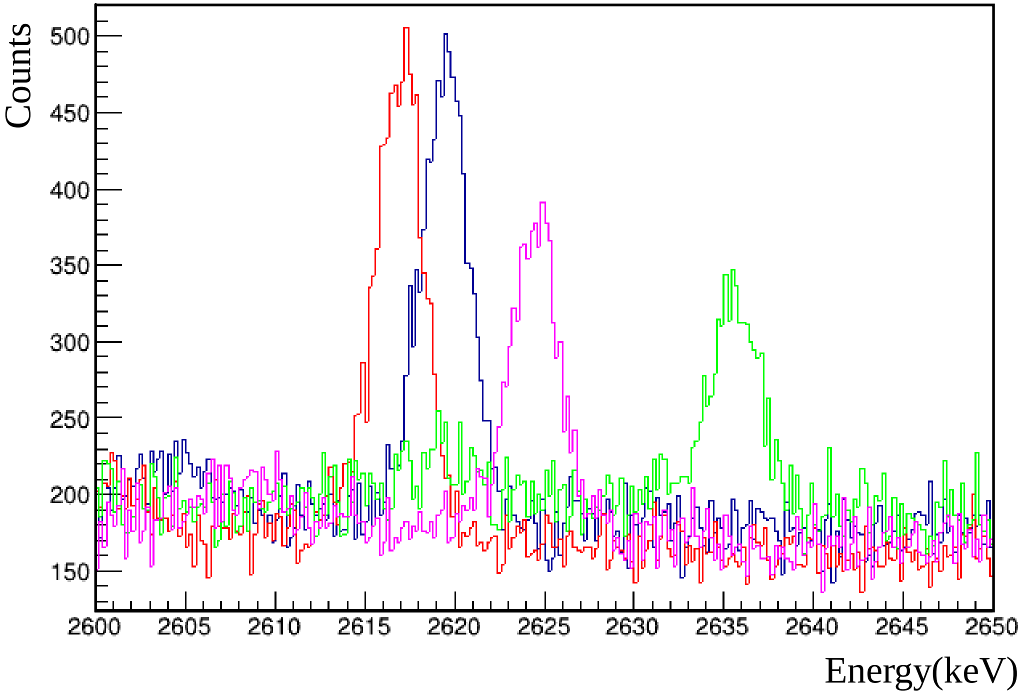
Clover #4	FWHM of 1408 keV peak (keV)
Crystal 12	2.31
Crystal 13	2.86
Crystal 14	2.26
Crystal 15	2.31

Experimental Result : Energy Calibration & Time Correction



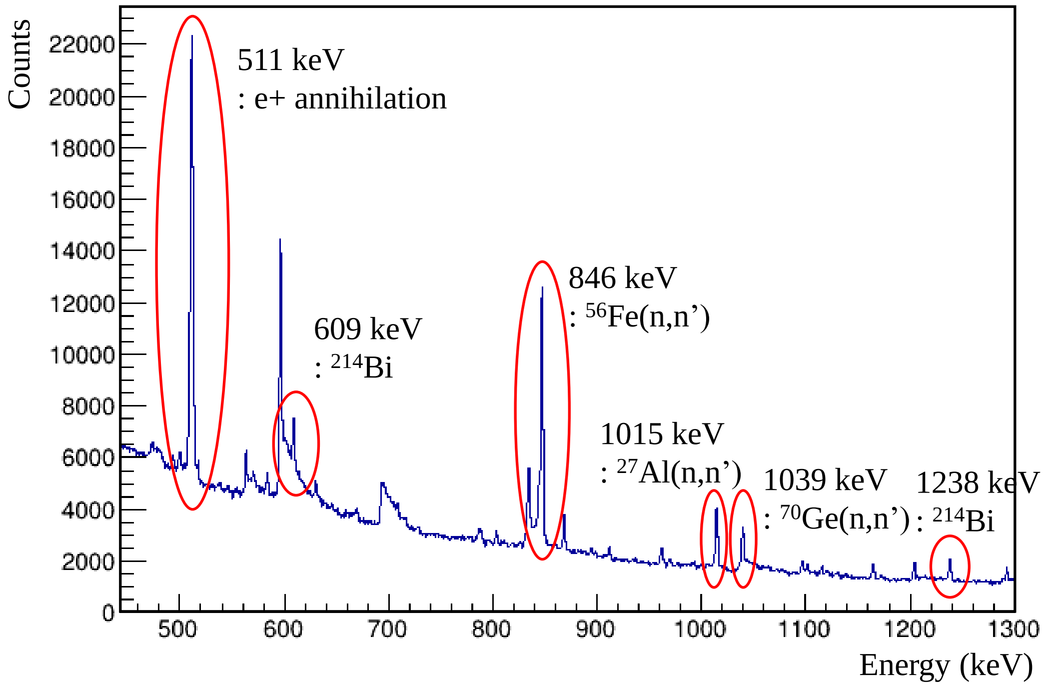
- High precision gamma-ray spectroscopy is necessary → Precise calibration is essential!
- Initial calibration with ^{152}Eu source : Third order calibration $E_{cal} = c_0+c_1x+c_2x^2+c_3x^3$.
- **Problem : Gain change over time** due to electronics
- Another problem : Initial calibration does not fit well at high energy region.
- Cannot use ^{152}Eu source calibration for online data → Use online data for calibration.

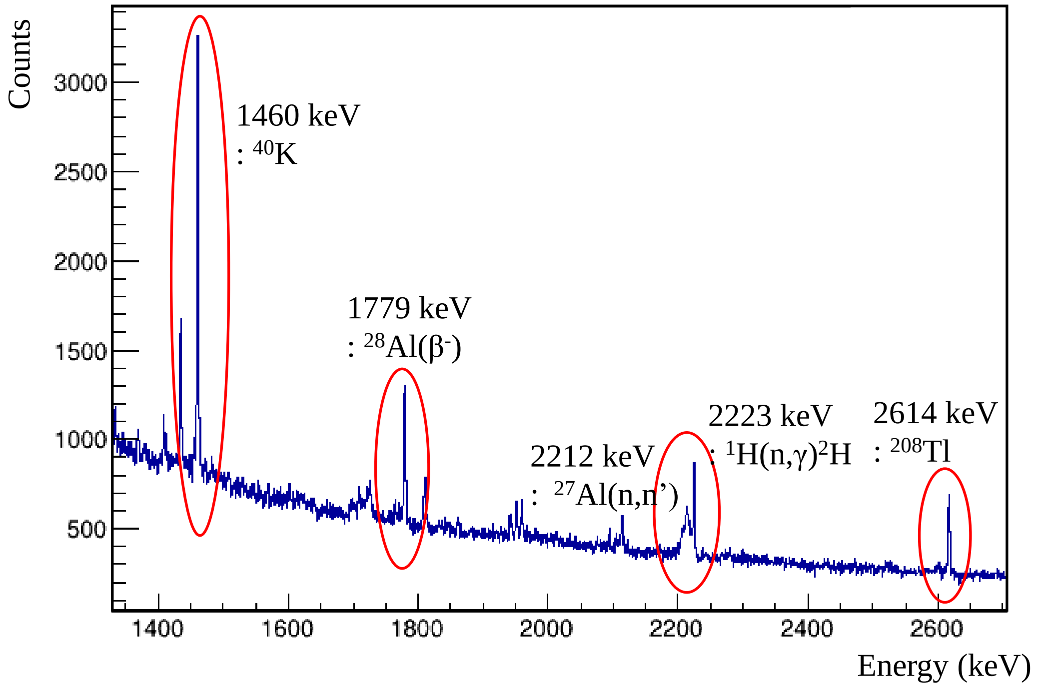
Experimental Result : Energy Calibration & Time Correction



- High precision gamma-ray spectroscopy is necessary → Precise calibration is essential!
- Initial calibration with ^{152}Eu source : Third order calibration $E_{cal} = c_0+c_1x+c_2x^2+c_3x^3$.
- **Problem : Gain change over time** due to electronics
- Another problem : Initial calibration does not fit well at high energy region.
- Cannot use ^{152}Eu source calibration for online data → Use online data for calibration.

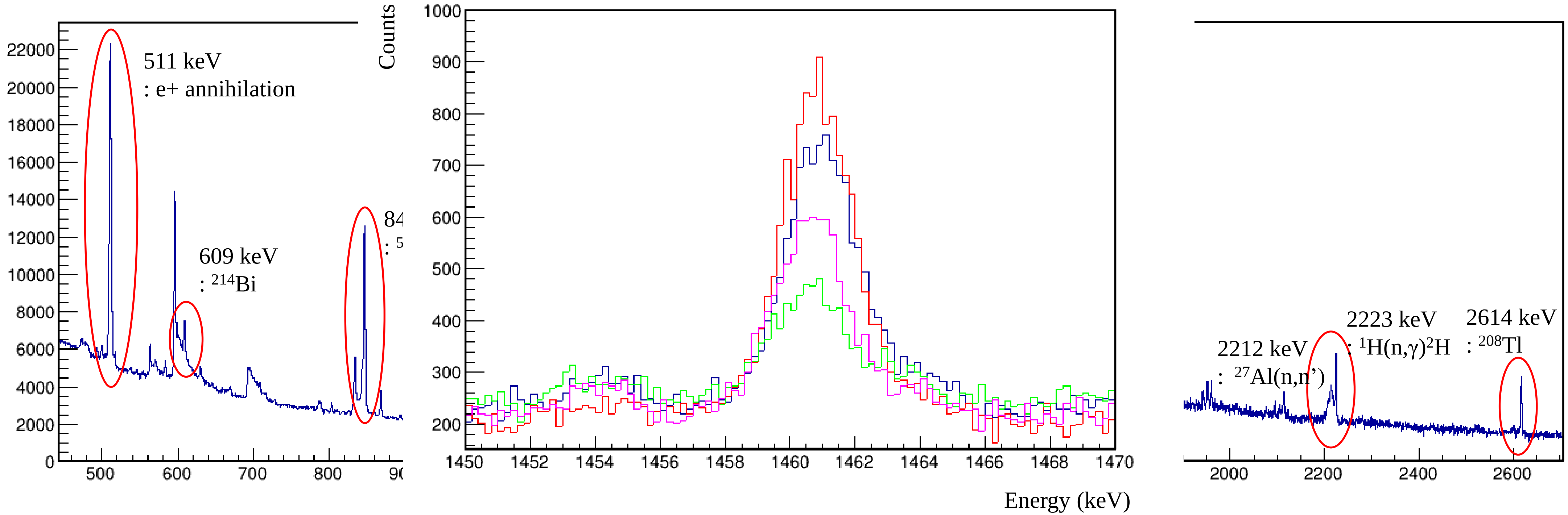
Experimental Result : Energy Calibration & Time Correction





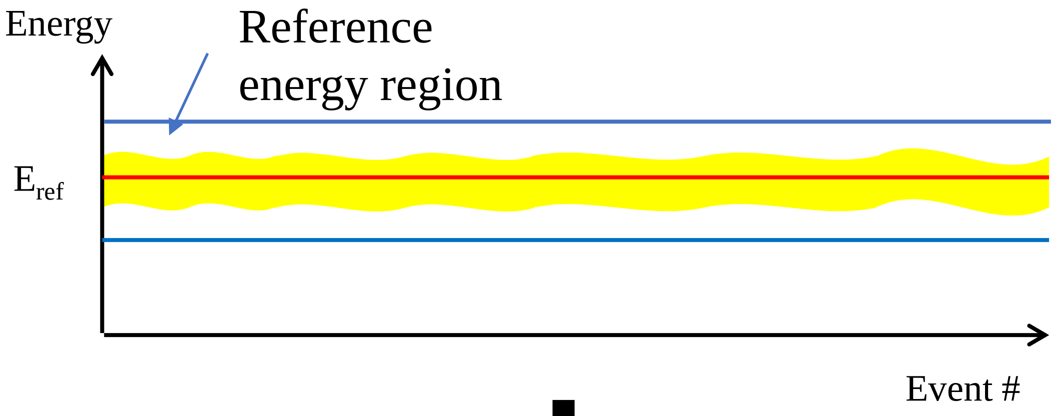
- With online data, applying initial calibration (^{152}Eu source calibration) and find the peaks in histogram.
- Compare it with the energies of known background peaks.
- Calibrating again with these peaks : $E_{cal} = c_0+c_1x+c_2x^2+c_3x^3$

Experimental Result : Energy Calibration & Time Correction



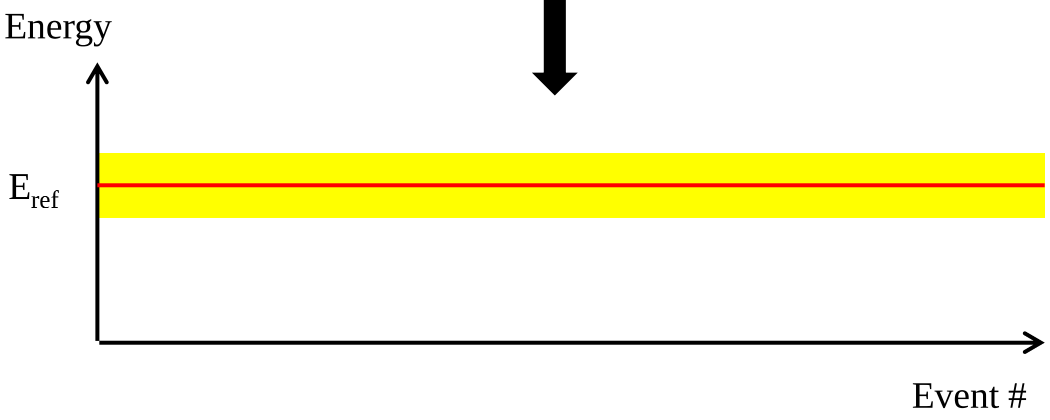
- With online data, applying initial calibration (^{152}Eu source calibration) and find the peaks in histogram.
- Compare it with the energies of known background peaks.
- Calibrating again with these peaks : $E_{cal} = c_0+c_1x+c_2x^2+c_3x^3$

Experimental Result : Energy Calibration & Time Correction



$b[i] = (1\text{-}w)\cdot b[i\text{-}1] + w\cdot E_{ref}/E_{cal}$

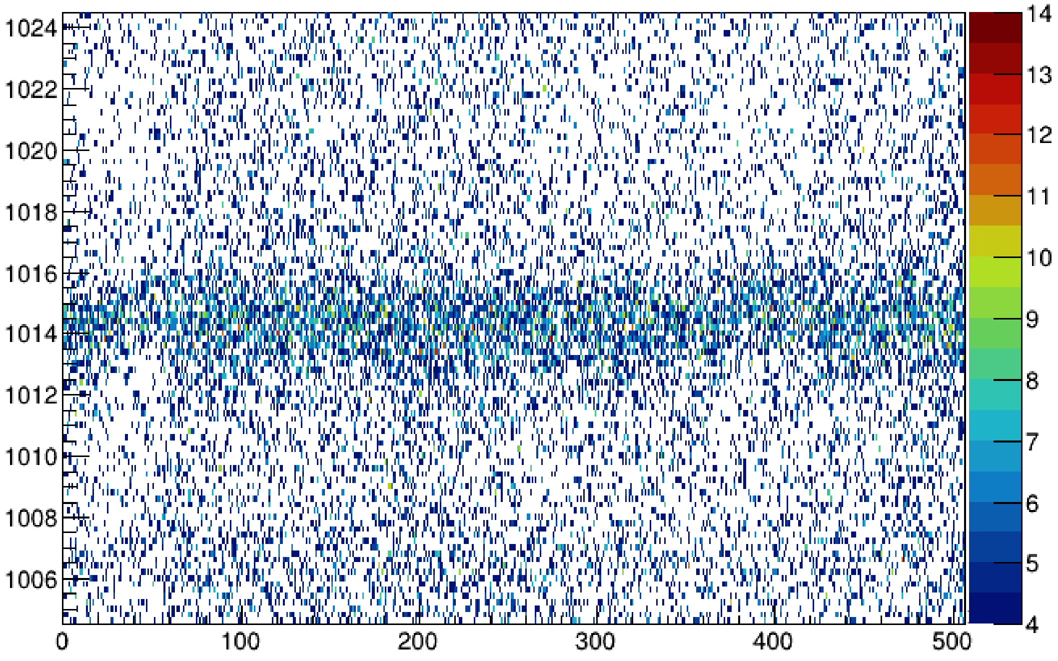
$E_{corr} = E_{cal}\cdot b[i]$



- To adjust influence of time, we must correct the calibration by the time.
- Assume that gain changes continuously over time, and the change can be corrected linearly.
- Event by event correction using events around the reference energy.
- Set relative initial gain as $b[0] = 1$
- If events counts near E_{ref}, change gain slowly using weight w, $b[i] = (1\text{-}w)\cdot b[i\text{-}1]+w\cdot E_{ref}/E_{cal}$ and apply gain for correction.

Experimental Result : Energy Calibration & Time Correction

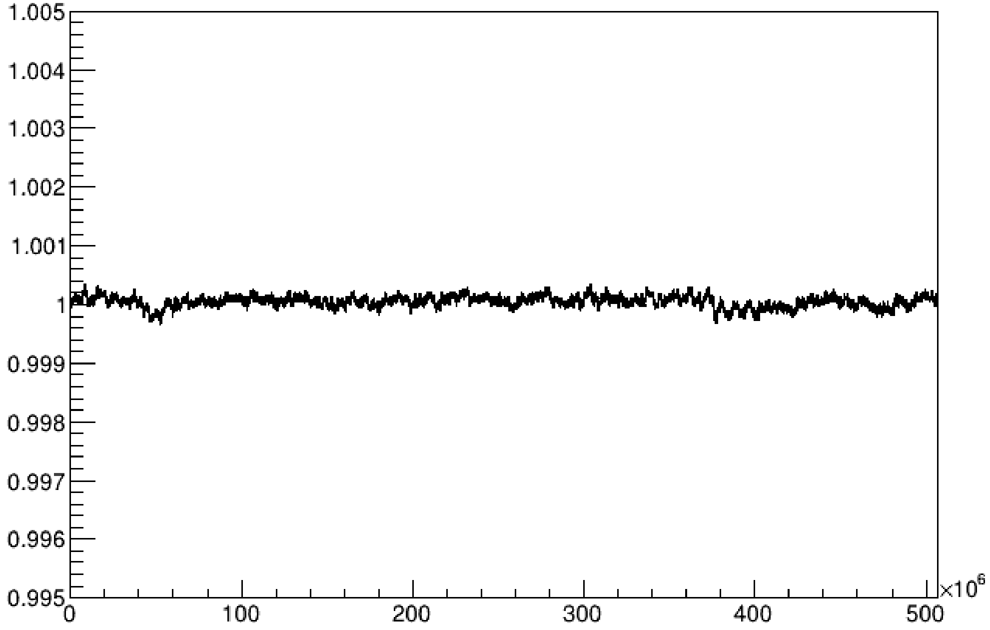
Energy (keV)



Event number

Before time correction

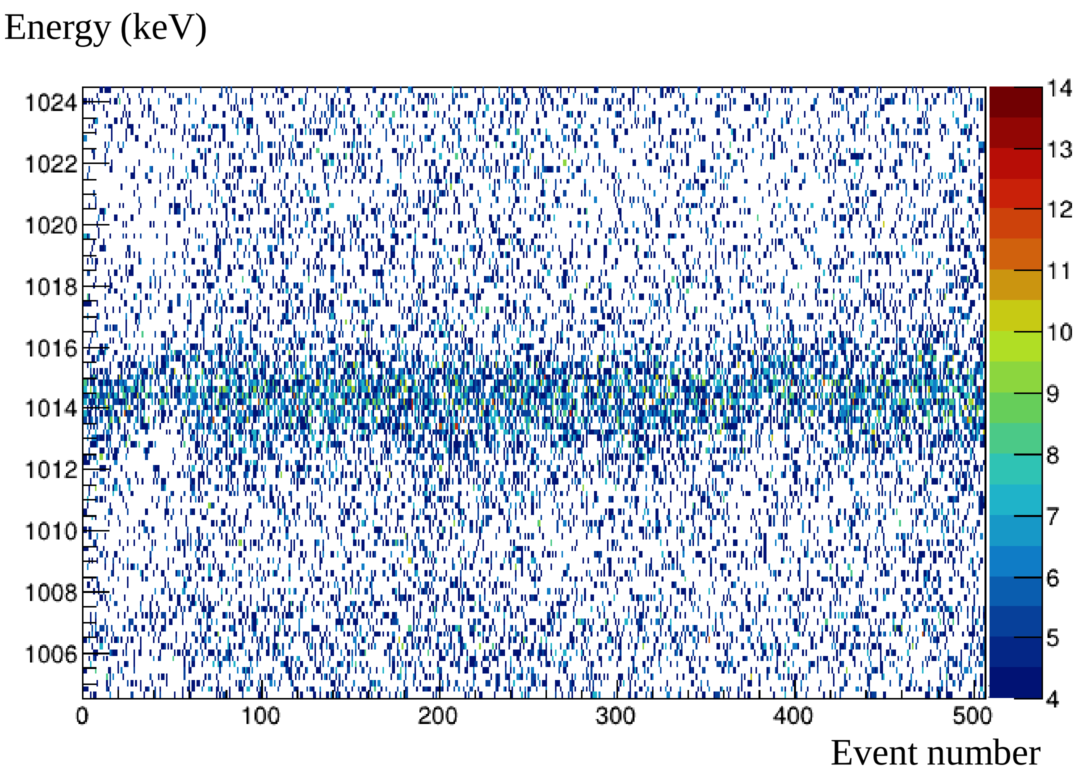
FWHM of 1014.5 keV peak : 2.42



Event number

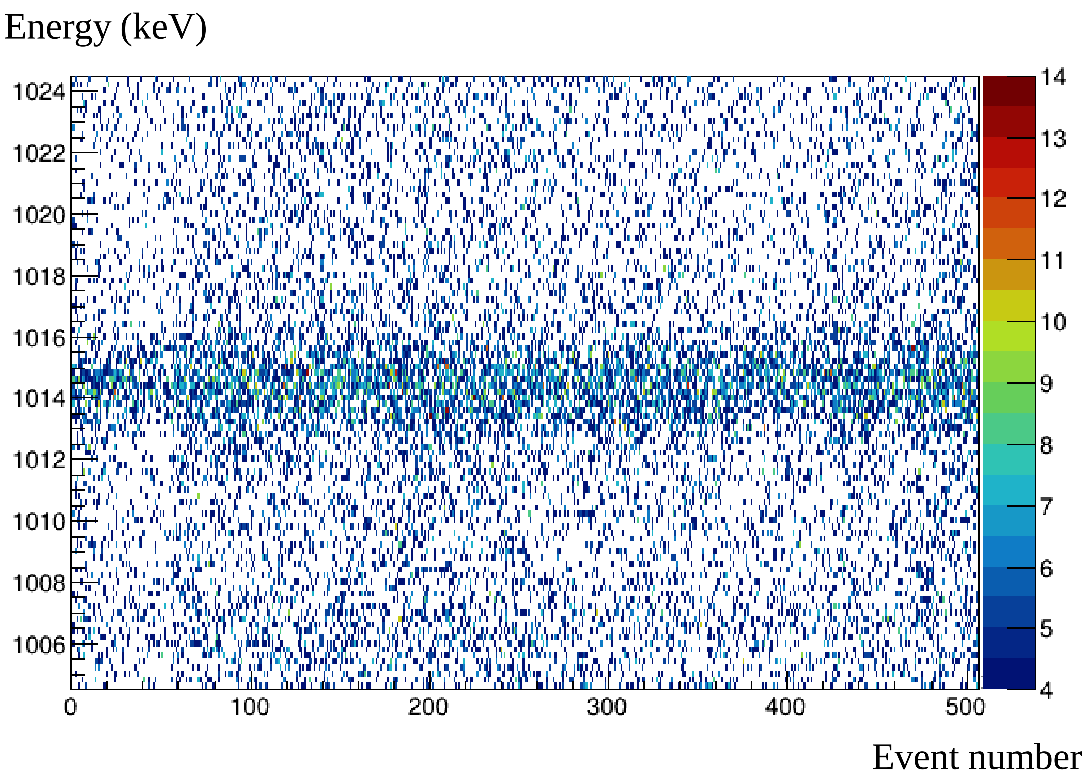
Changing gain value

Experimental Result : Energy Calibration & Time Correction



Before time correction

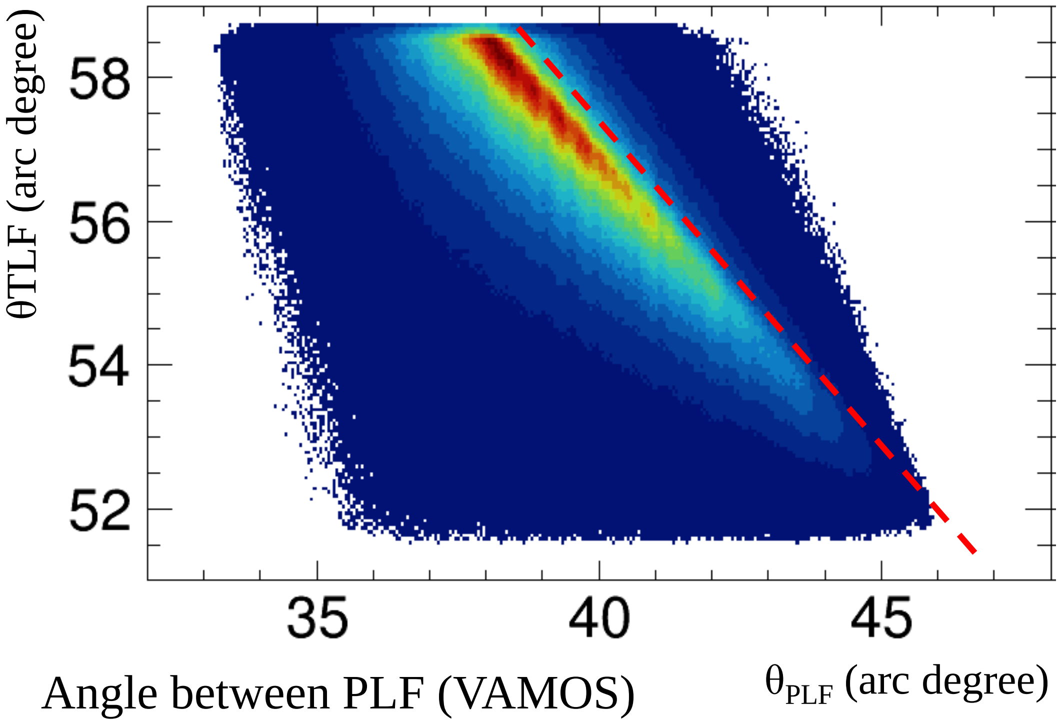
FWHM of 1014.5 keV peak : 2.42



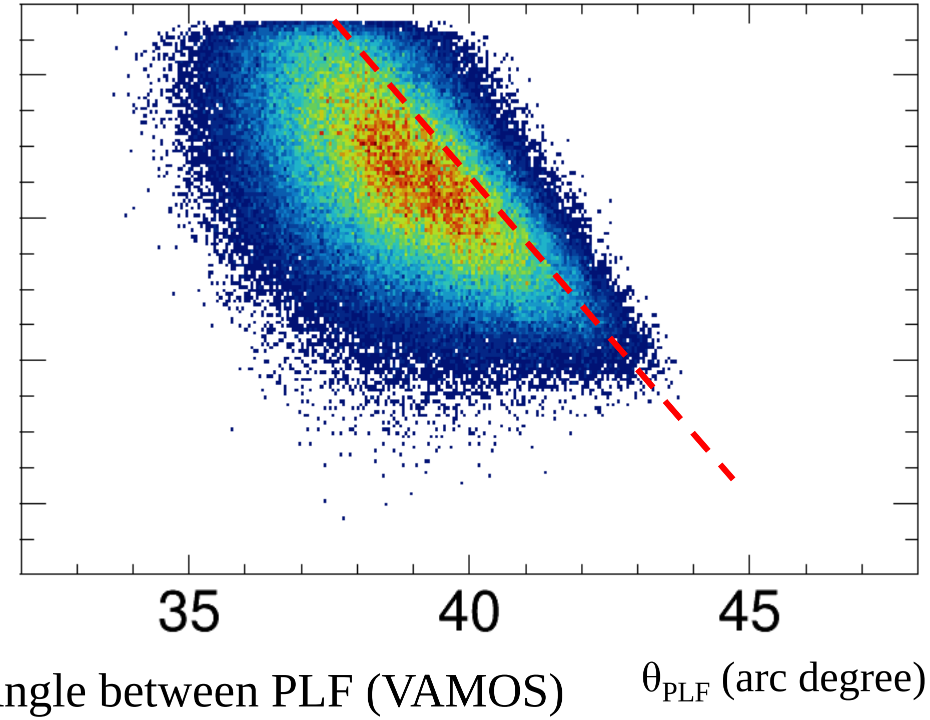
After time correction

FWHM of 1014.5 keV peak : 2.38

Experimental Result : Angular Correlation



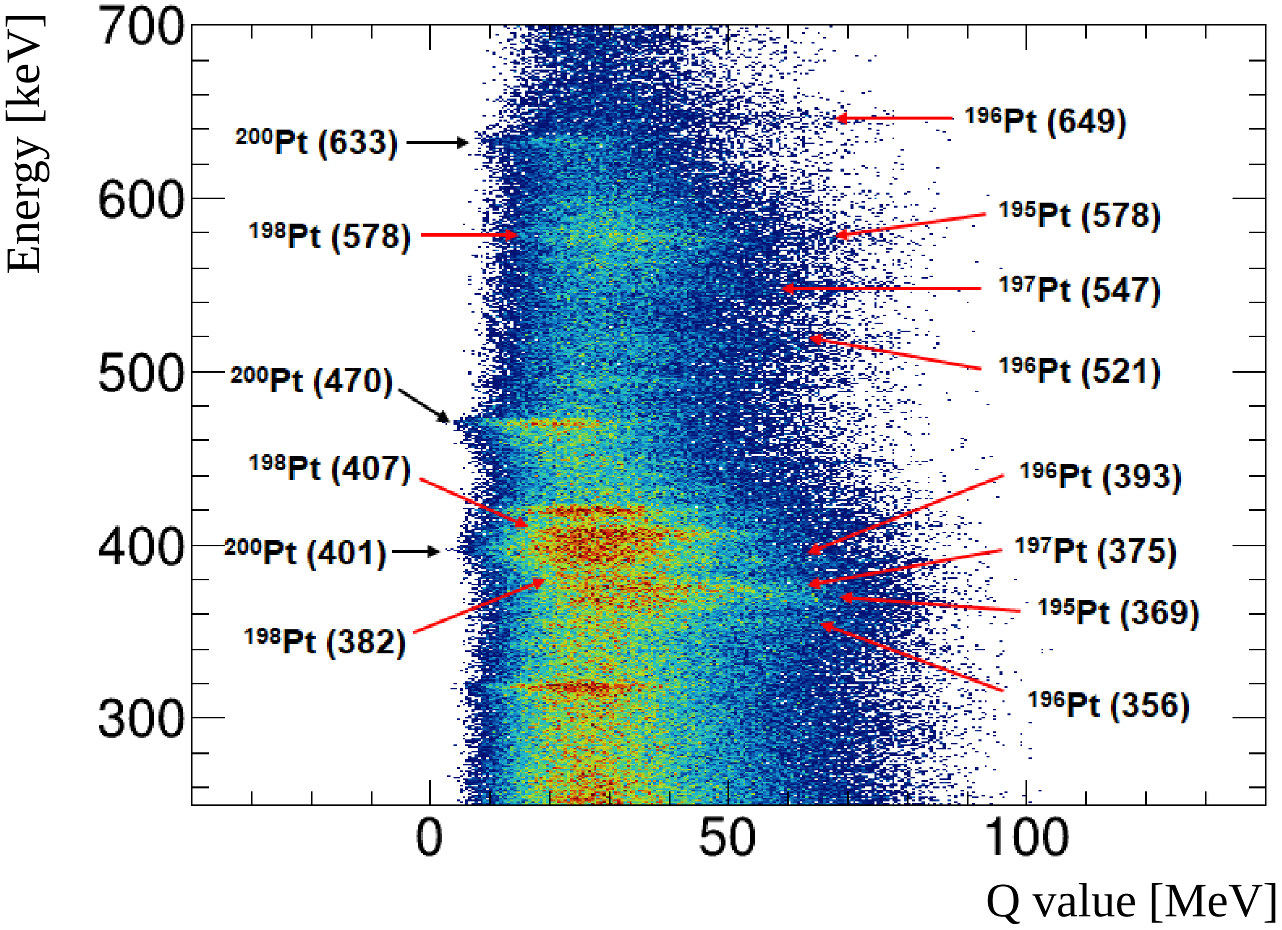
Angle between PLF (VAMOS) vs TLF (CATLIFE) for ^{134}Xe



Angle between PLF (VAMOS) vs TLF (CATLIFE) for ^{138}Ba

- Clear angular correlation between PLF and TLF

Experimental Result : Angular Correlation



Prompt γ-ray energy vs Q-value of TLFs corresponding to ^{134}Xe as PLF

- The Q value was obtained from the measured velocities of both PLF (VAMOS++) and TLF (CATLIFE) assuming that the reaction occurred at the center of target.
- A clear effect of neutron evaporation as a function of the Q value can be seen.
- The deduction of the A distribution of the TLF before evaporation using the measured velocity is in progress.

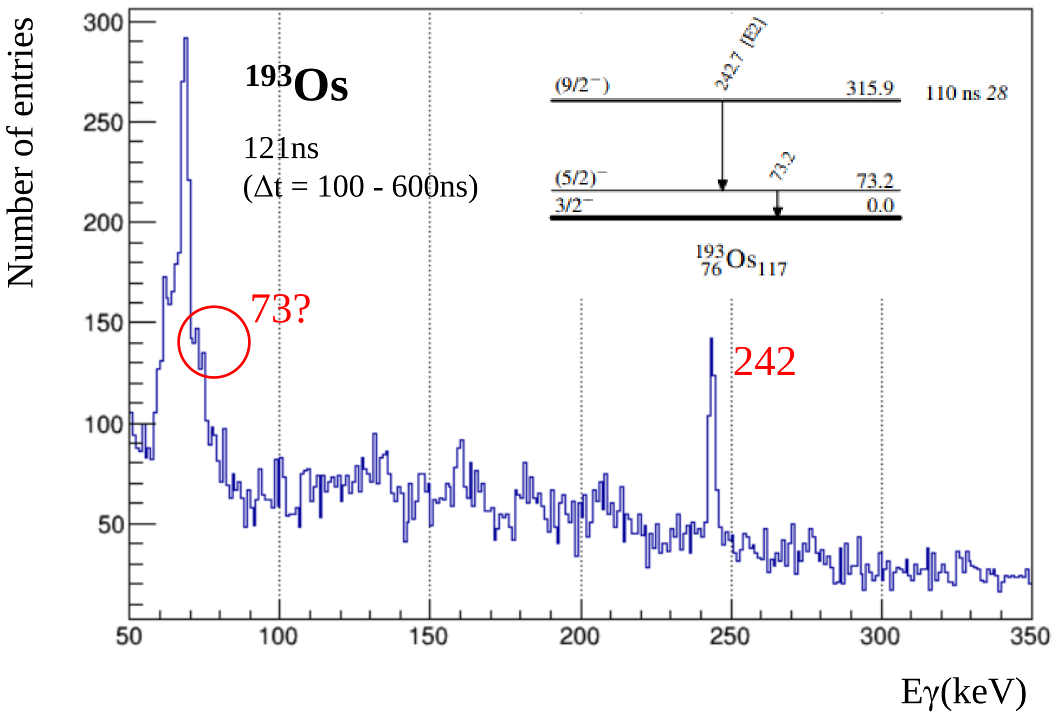
CENS CENTER FOR EXOTIC NUCLEAR STUDIES 서 울 대 학 교 SEOUL NATIONAL UNIVERSITY

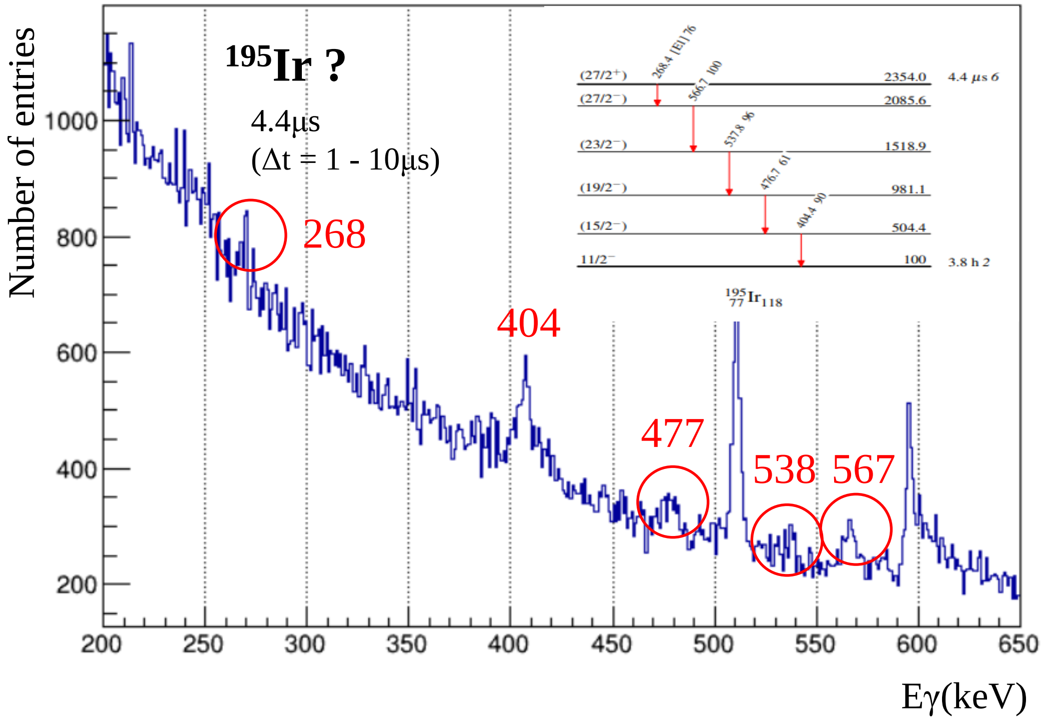
Experimental Result : Isomer Results Less Exotic Side

$T_{1/2}$(>0.1μs)	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205
74 (W)	0.36μs														
75 (Re)	77μs	85μs	65μs	45μs		3.6μs									
76 (Os)			**0.13μs**				0.08μs								
77 (Ir)					**4.4μs**			0.07μs				3.4μs	0.8μs		
78 (Pt)												141μs	0.64μs	0.15μs / 5.5μs / 55μs	
79 (Au)											**5.6μs**		140μs	**2.1μs**	0.16μs
80 (Hg)													21.9μs		5.9μs

- The time window for delayed γ-ray is 0.1μs to 100μs

Experimental Result : Isomer Results Less Exotic Side





- Delayed γ-rays from the decay of isomeric states of TLFs stopped at the end of the second arm, detected by EXOGAM.
- Peaks from **^{193}Os** decay scheme was observed at 3n evaporation channel, and **^{195}Ir** suspected peaks at 2n evaporation channel.

Summary

- Multi-nucleon transfer reaction is used to access near N=126 shell closure neutron rich nuclei.
- CATLIFE is loaded to identify Target-like fragments indirectly with its velocity and time of flight.
- Since gain of EXOGAM crystals change continuously over time, event by event correction is used to correct it.
- The Q value determined from velocity measurements in VAMOS++ and CATLIFE, illustrated the effect of neutron evaporation in the TLF, using an A, Z gated PLF prompt γ-ray spectrum.
- The isomeric transitions in ^{193}Os are observed at 3n evaporation channel.
- This result demonstrates the successful implementation of the new CATLIFE spectrometer.
- Ongoing analysis for A distribution before neutron evaporation and a further reduction of delayed γ-ray background will further improve the TLF identification and the corresponding delayed γ-ray spectroscopy.

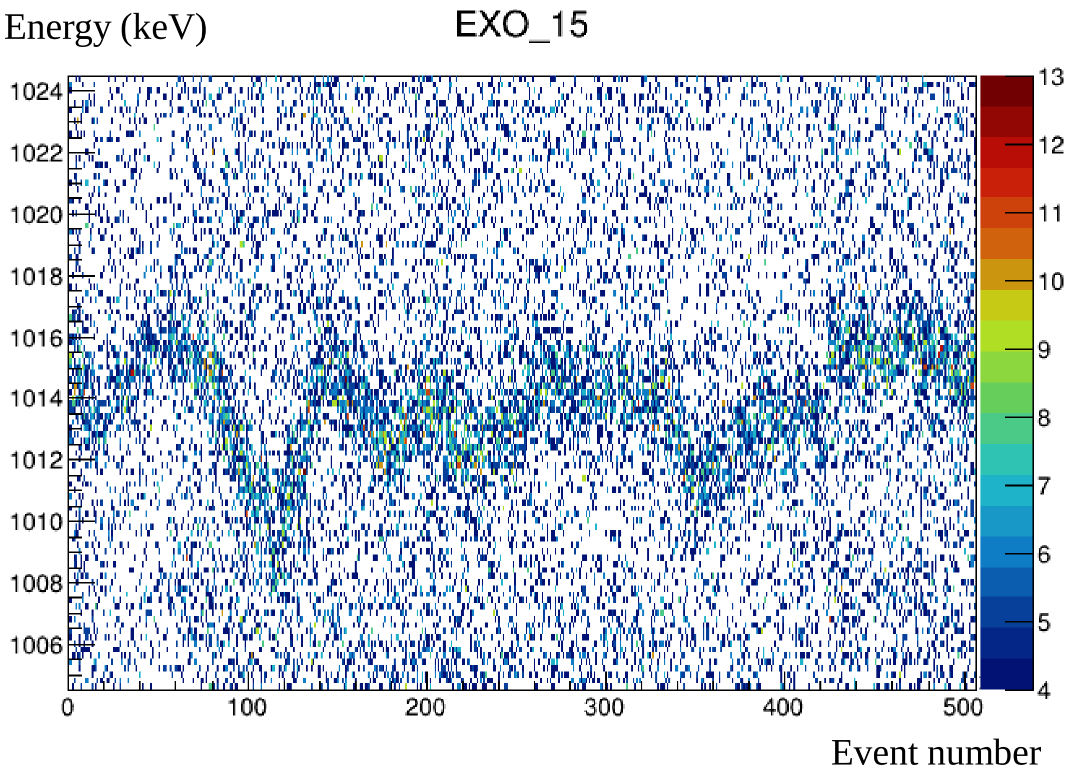
Thank you for your attention!

Backups

- GEAN4 Simulation conditions

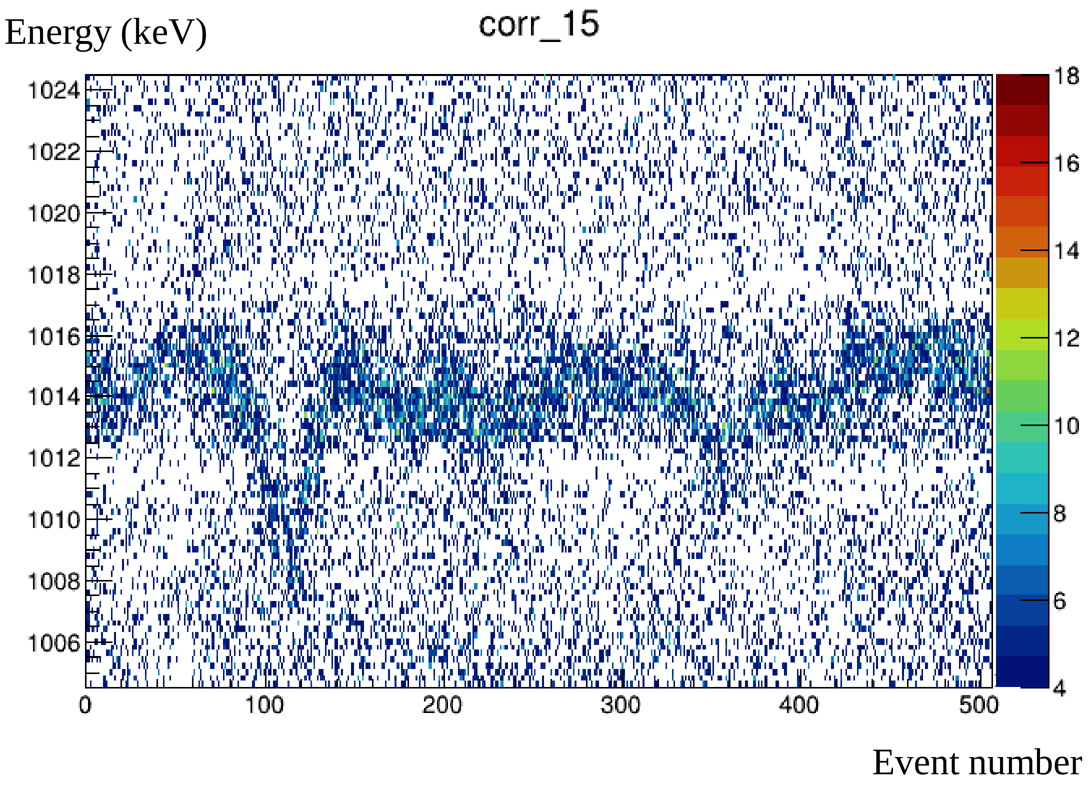
- Thickness of Al stopper is 6mm
- Ions implanted uniformly at stopper, isotopically emits gamma-ray
- Only front crystals are used
- Assuming Add-back between front crystal within same Clover

Backups



Before time correction

FWHM of 1014.5 keV peak : 3.98

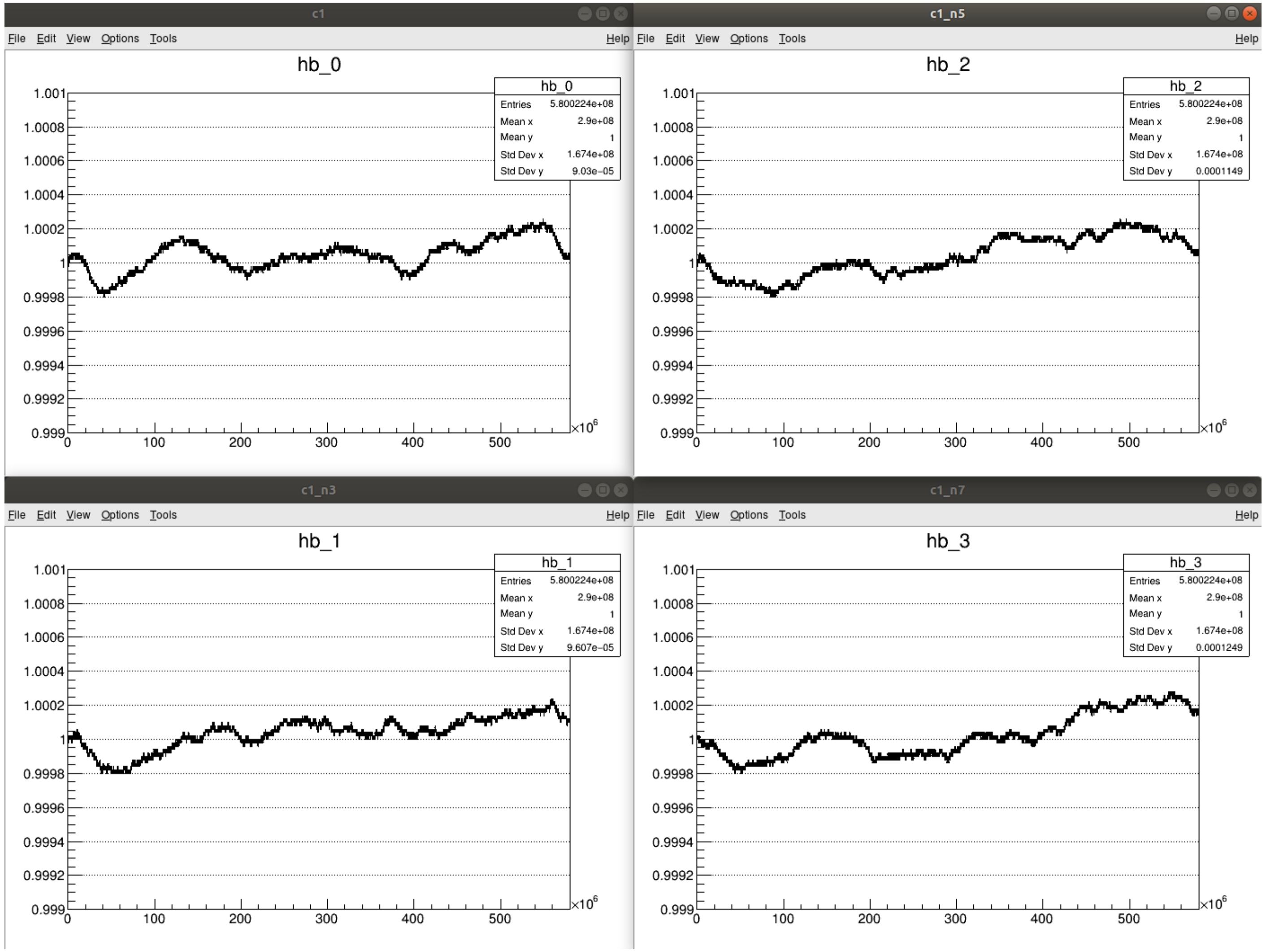


After time correction

Changing gain value

FWHM of 1014.5 keV peak : 2.97

Backups


c1
File Edit View Options Tools Help
hb_0
Entries 5.800224e+08
Mean x 2.9e+08
Mean y 1
Std Dev x 1.674e+08
Std Dev y 9.03e−05
c1_n5
File Edit View Options Tools Help
hb_2
Entries 5.800224e+08
Mean x 2.9e+08
Mean y 1
Std Dev x 1.674e+08
Std Dev y 0.0001149
c1_n3
File Edit View Options Tools Help
hb_1
Entries 5.800224e+08
Mean x 2.9e+08
Mean y 1
Std Dev x 1.674e+08
Std Dev y 9.607e−05
c1_n7
File Edit View Options Tools Help
hb_3
Entries 5.800224e+08
Mean x 2.9e+08
Mean y 1
Std Dev x 1.674e+08
Std Dev y 0.0001249
1.001
1.0008
1.0006
1.0004
1.0002
1
0.9998
0.9996
0.9994
0.9992
0.999
0
100
200
300
400
500
×10^6