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Background Measurements by using α and γ Detectors at the Center for Underground Physics in Korea

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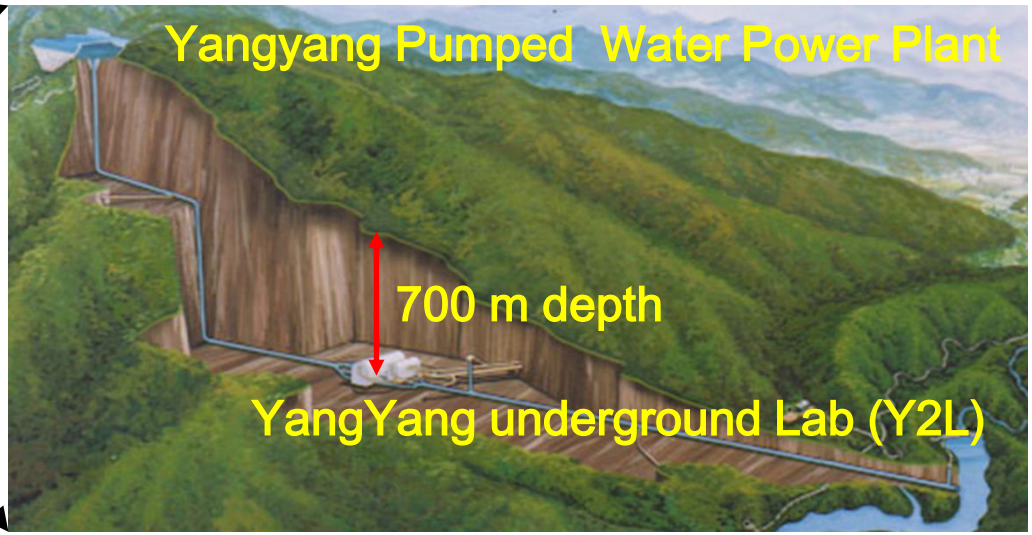
2015.09.09 (Wed.)

DARK MATTER A:
UNDERGROUND LABORATORIES session @ Agnelli

Center for Underground Physics (CUP)



- CUP has been conducting the following experiments in the Y2L.
  - KIMS-CsI/KIMS-NaI: WIMP search experiments
  - AMoRE: Neutrinoless double beta decay experiment

Why alpha (gamma) measurement?

- Major internal background from the NaI(Tl) is from Pb-210.
- Pb-210 needs to be less than 0.2 mBq/kg (currently 0.5 to 1.8 mBq/kg)
- Needs to measure the amount of Pb-210 in the NaI powder before the crystal growing.
- The Pb-210 decay produces 5.31 MeV alpha and 46 keV γ.
- Other detector materials and components need to be screened for low background.

Counter types: α particle detectors

1. ZnS:Ag sheet + PMT

   - EJ-440 ZnS:Ag sheet tested.
   - A prototype counter design prepared.
   - EJ-444 (ZnS:Ag + Plastic Scintillator) to be tested.

2. UltraLo-1800 (XIA) (Commercial Ionization chamber with Argon gas)

   - Delivered to the Y2L in May and is running now stably with samples.
   - Ultra low background (~10^{-4} count/hr/cm^2) copper disk being delivered to confirm the counter capability.

Counter types: 46 keV γ detectors

1. Well type Ge detector
   - A 110 cc well type Ge detector is being ordered from Ortec.
   - The design is being finalized for the production.

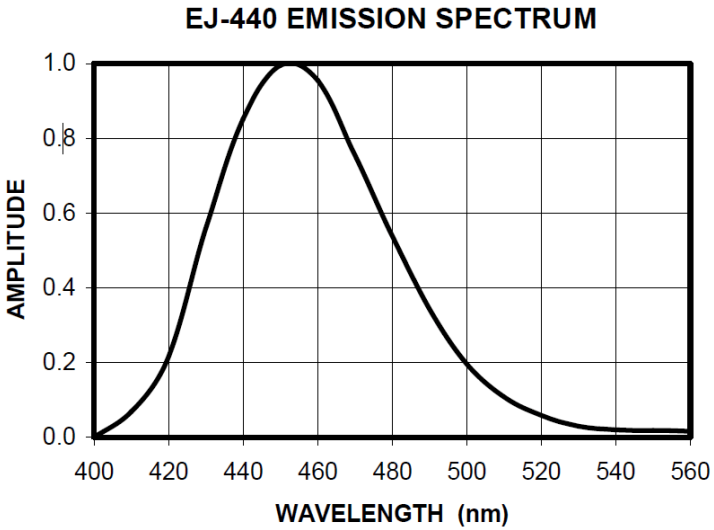
2. Other candidates being considered
   - CsI(Tl) crystal detector (thin and wide CsI(Tl) crystal)
   - Silicon sensor.

ZnS:Ag sheet (EJ-440)

Physical and Scintillation Constants

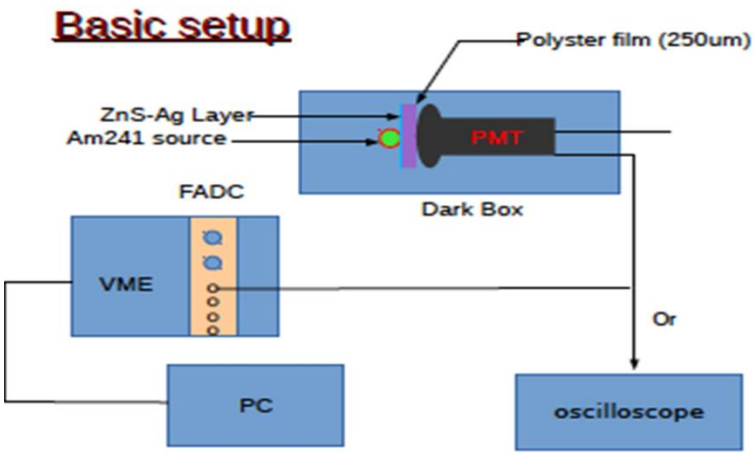
- Light Output, % Anthracene 300
- Wavelength of Max. Emission, nm 450
- Decay time, ns 200
- Phosphor Density, mg/cm^2 3.25
- Phosphor Density range, mg/cm^2 ± 0.25
- Thickness of Polyester Film, mm 0.25
- Density of polyester film, mg/cm^2 36
- Chemical Compatibility: The adhesive is soluble in common alcohols and other organic solvents. It is insoluble in water.

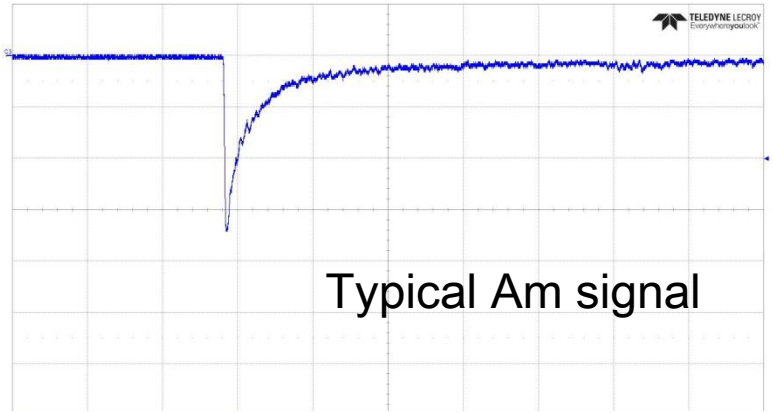
- Density ~ 4.09 g/cm^3

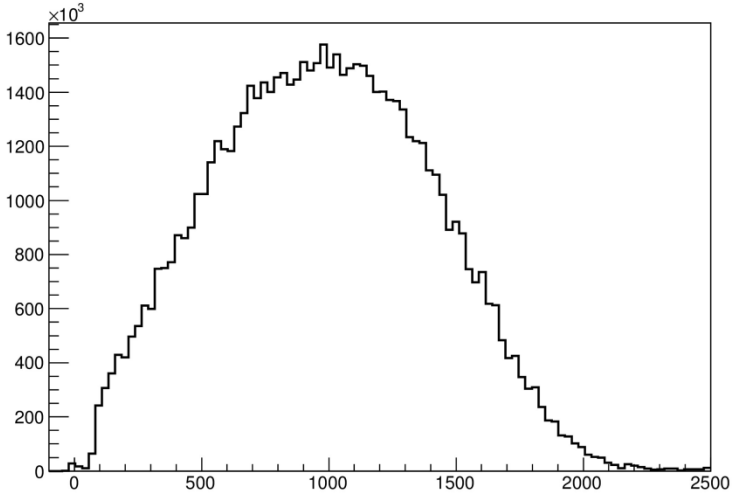


From ELJEN technology

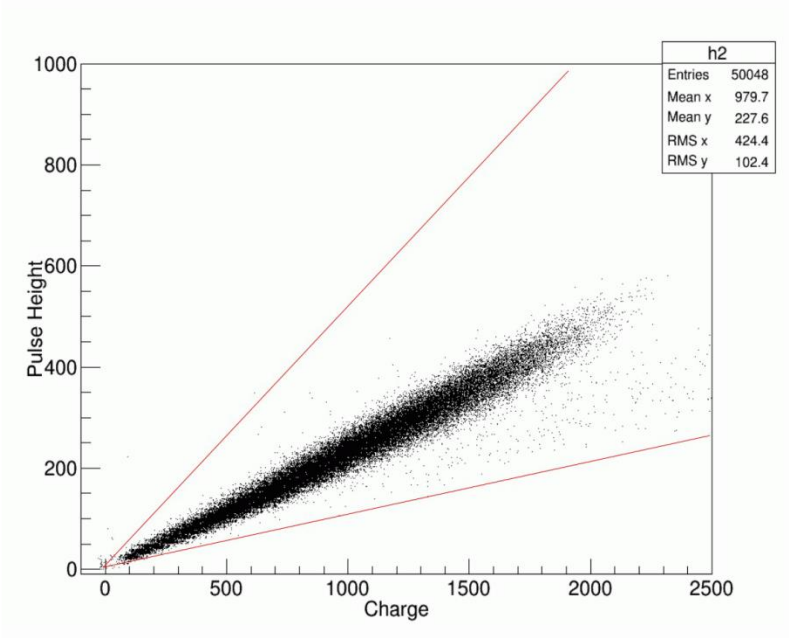
ZnS counter: Am-241 test



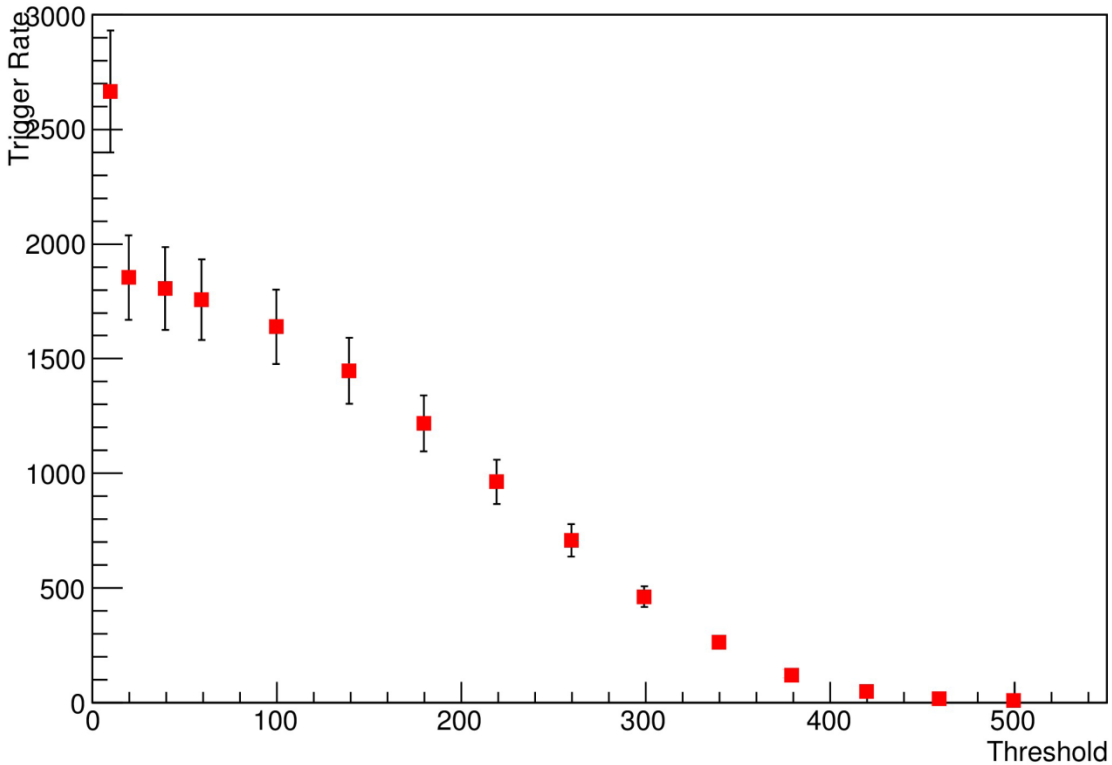


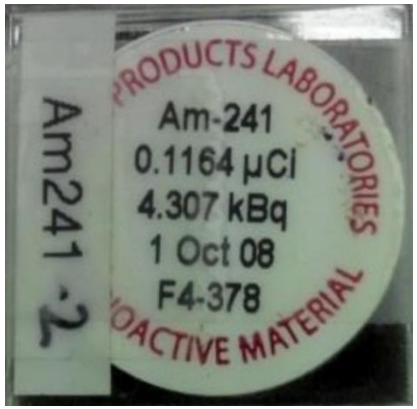


Charge

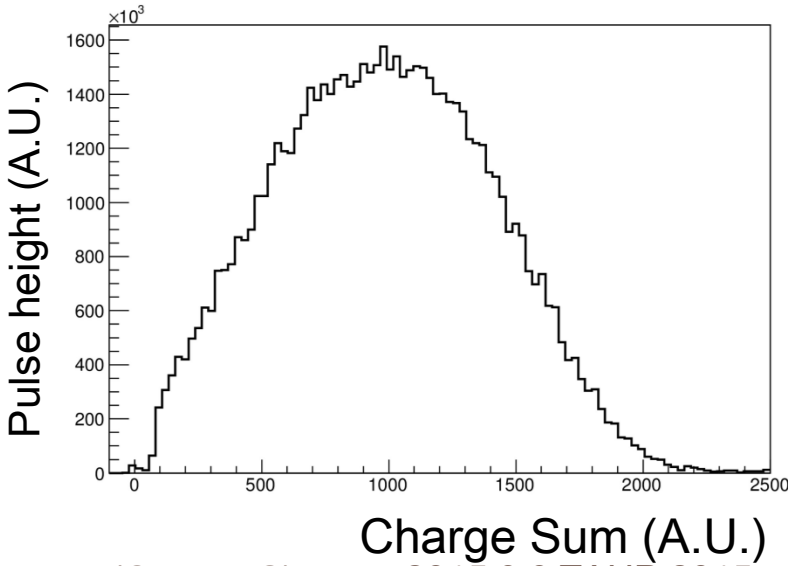


ZnS counter: Am-241 test (efficiency)





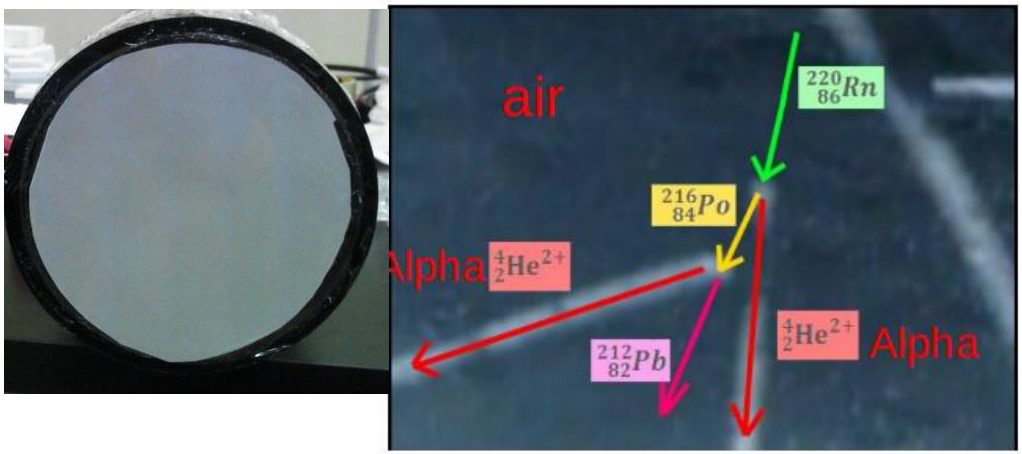
4307 Bq (10/1/2008)

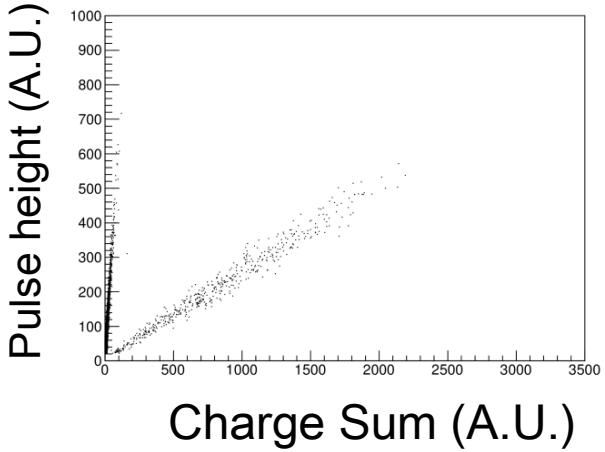


ZnS counter: Background test

Background data are taken for three different conditions.

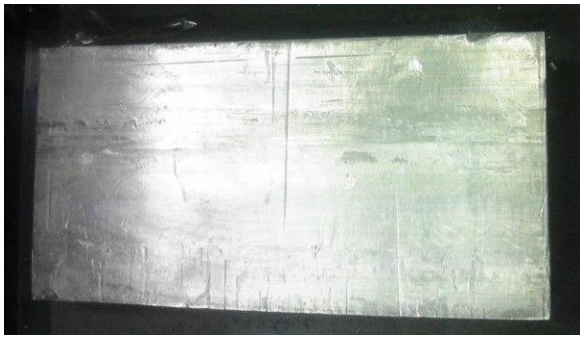
- Air contact with ZnS sheet (Atmospheric Radon effect test). Radon in Air is the main source of natural background alpha.
- Air tight (no air contact with ZnS sheet by using a mylar wrap)
- After a ultrasonic cleaning the ZnS sheet with DI water and air tight





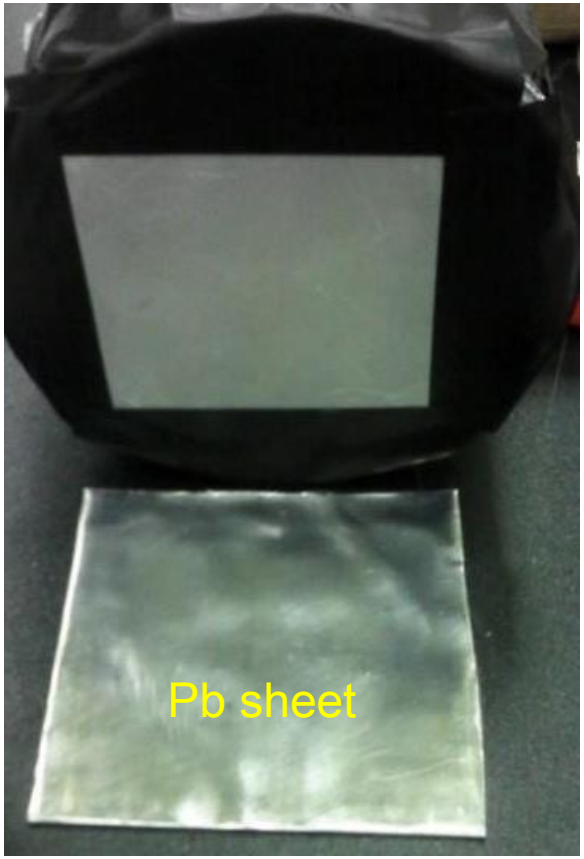
Air Tight	Ultrasonic clean	Alpha rate (/cm2/hr)
No	No	0.0584 ± 0.0101
Yes	No	0.0078 ± 0.0020
Yes	Yes	0.0044 ± 0.0011

ZnS counter: Pb block/sheet tests

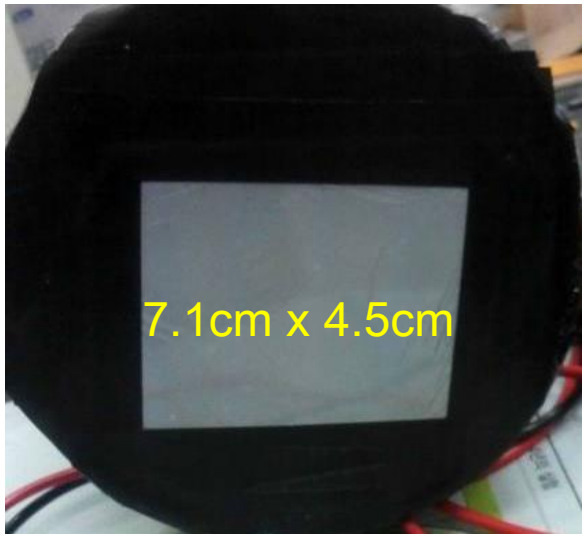


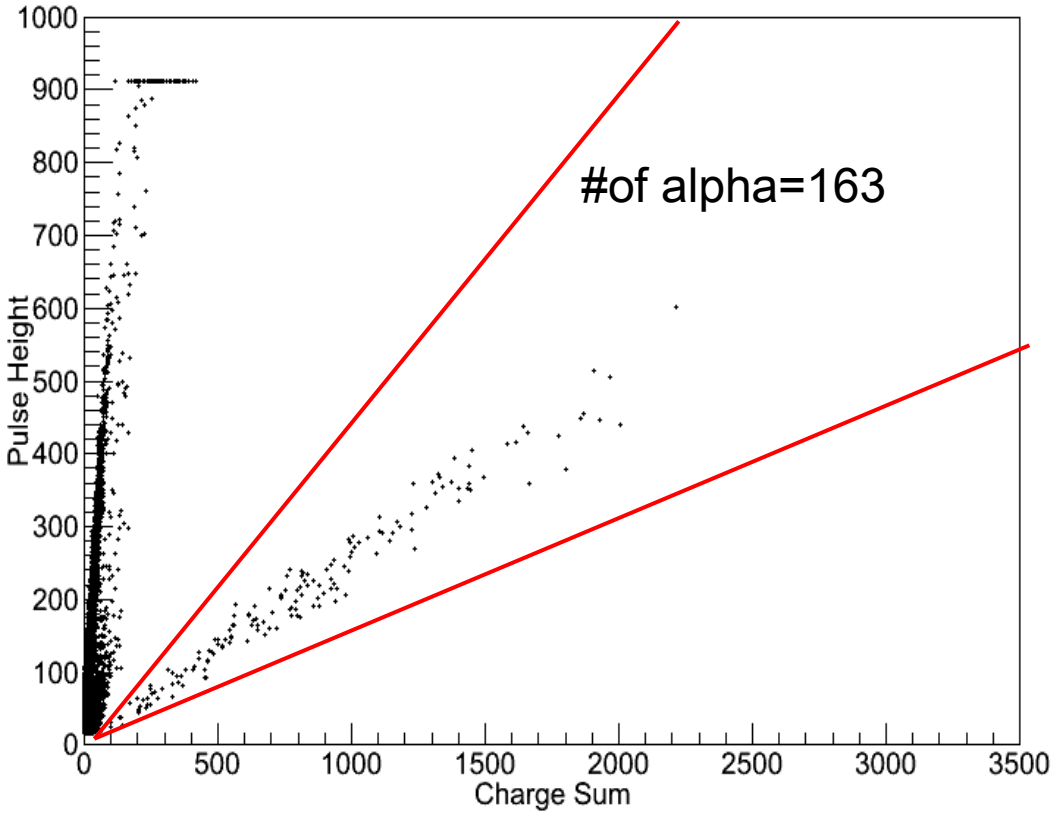
Pb block: 10 cm x 20 cm x 5 cm

Sample	Activity (/cm^2/hr)
Pb Block	2.578 ± 0.270
Pb sheet(Alcohol clean)	8.370 ± 0.249
Pb sheet(Acid and Alcohol cleaning	9.890 ± 0.142



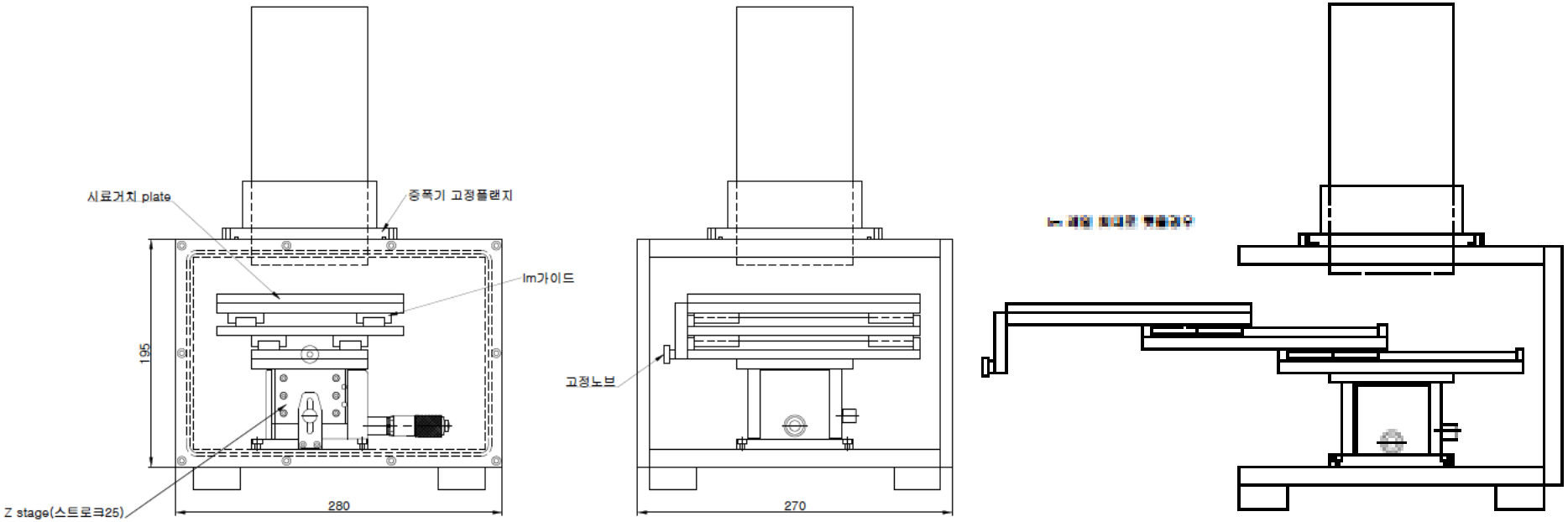
ZnS counter: Goslar lead





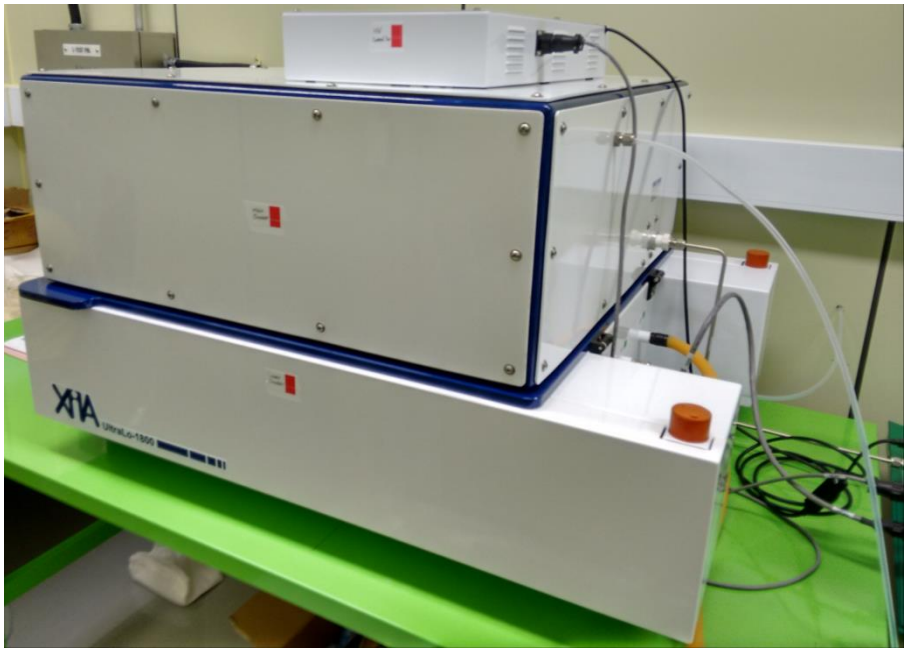
Alpha rate is 0.64 ± 0.12 /cm^2/hr

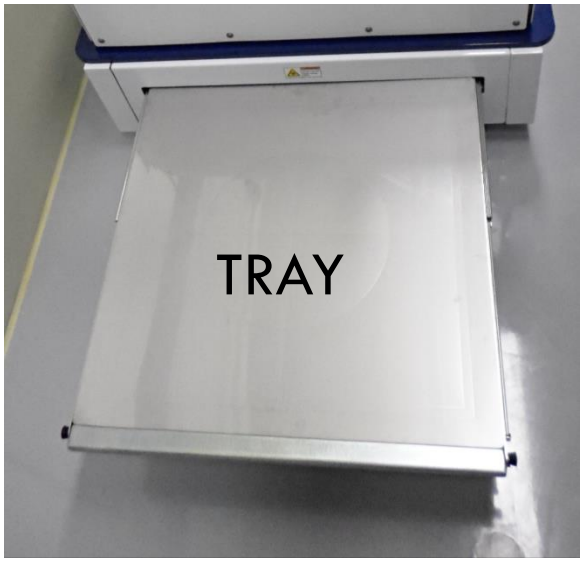
ZnS counter: Prototype design



XIA UltraLo-1800 counter

- Ionization chamber with Argon gas and no window.
- Test sample size: <1800 cm^2 area and <8 mm height.
- Can separate real signals from the tray from the backgrounds inside the chamber.
- Delivered to the Y2L on May 6th and now in full operation.





UltraLo-1800: Specification

Performance category	Specification
Required counting time for measurement of ULA (0.001) sample1	(50%) 6 hrs, (25%) 24hrs, (12.5%) 90 hrs -- (measurement accuracy) time
Required counting time for measurement of LA (0.01) sample1	(50%) 30 min, (25%) 2.5 hrs, (12.5%) 9 hrs -- (measurement accuracy) time
Typical counter efficiency	> 90% of 2π
Energy resolution (230Th source) < 6% FWHM (at 4.6 MeV)	< 6% FWHM (at 4.6 MeV)
Energy sensitivity range	1-10 MeV
Sample sizes	(typical min - max) 300mm wafer (707cm2) - 1800cm2

1 – Sample assumed to be 300mm wafer (count times drop by factor of 2.5 when using max sample area)

UltraLo-1800: Schematic

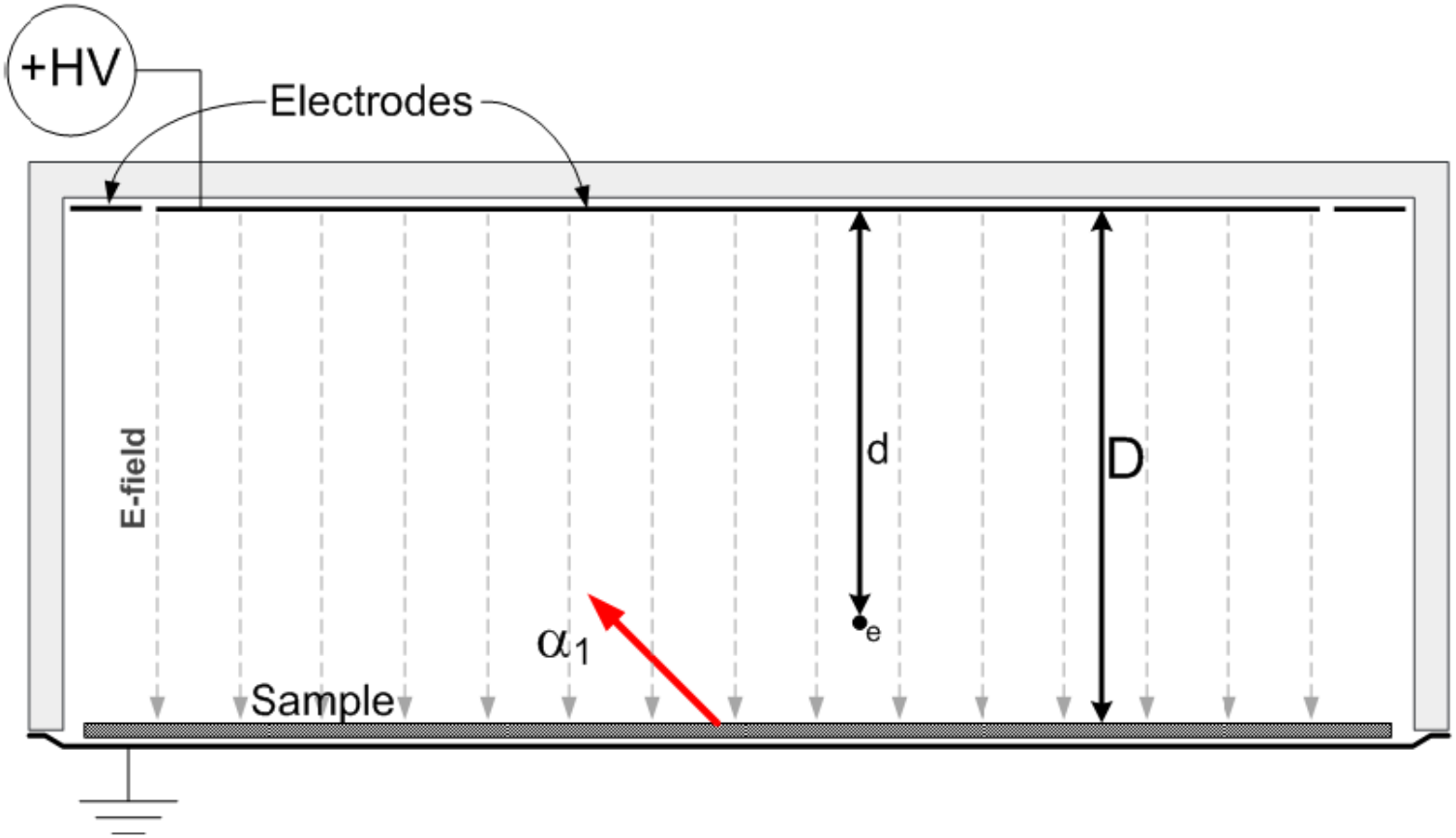


Figure II-2: Schematic overview of the important parts of the UltraLo-1800's active volume.

~ 42 mm projected range for an 5.5 MeV alpha particle in Argon gas

UltraLo-1800: Separation for different alpha locations

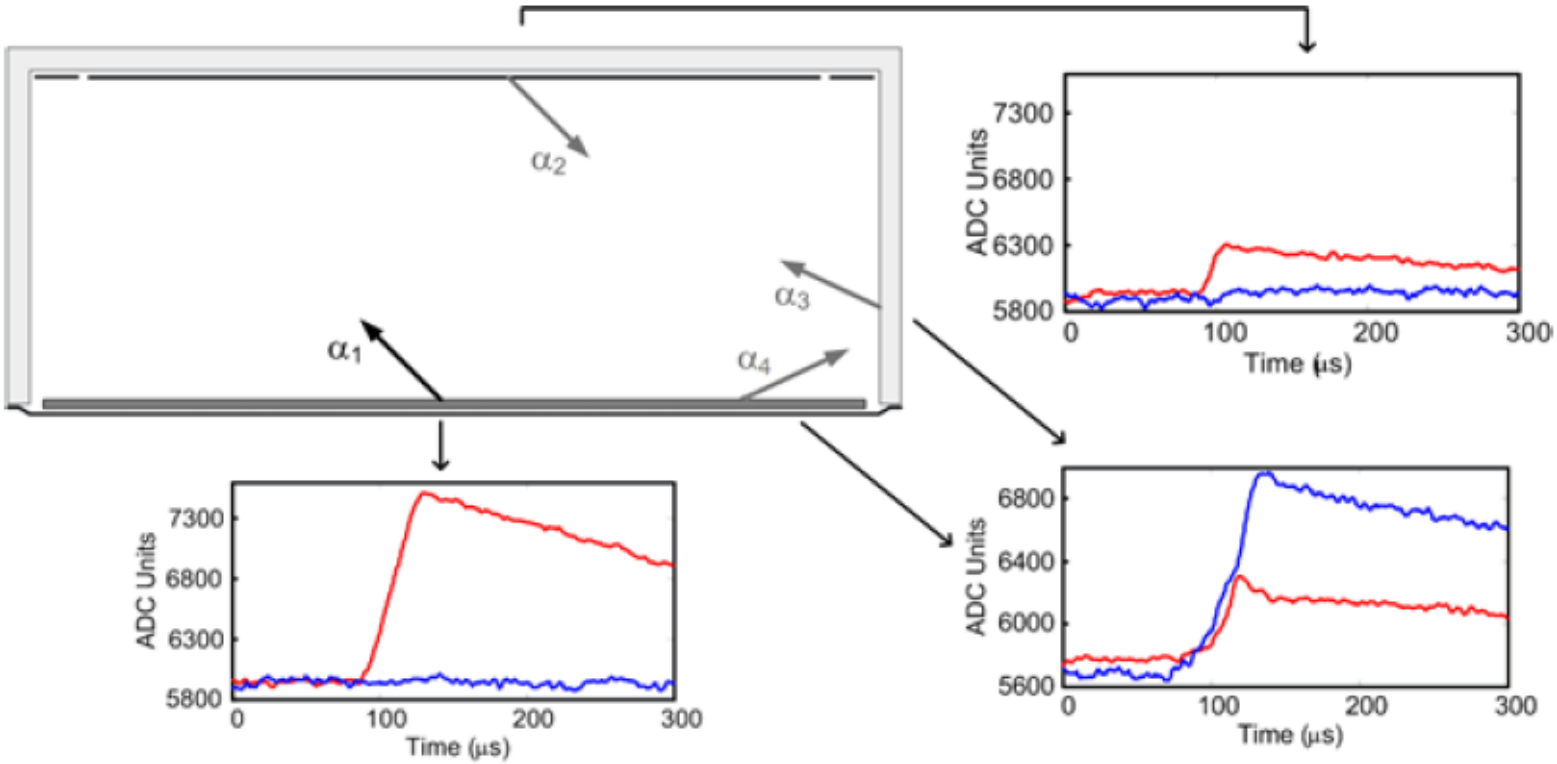
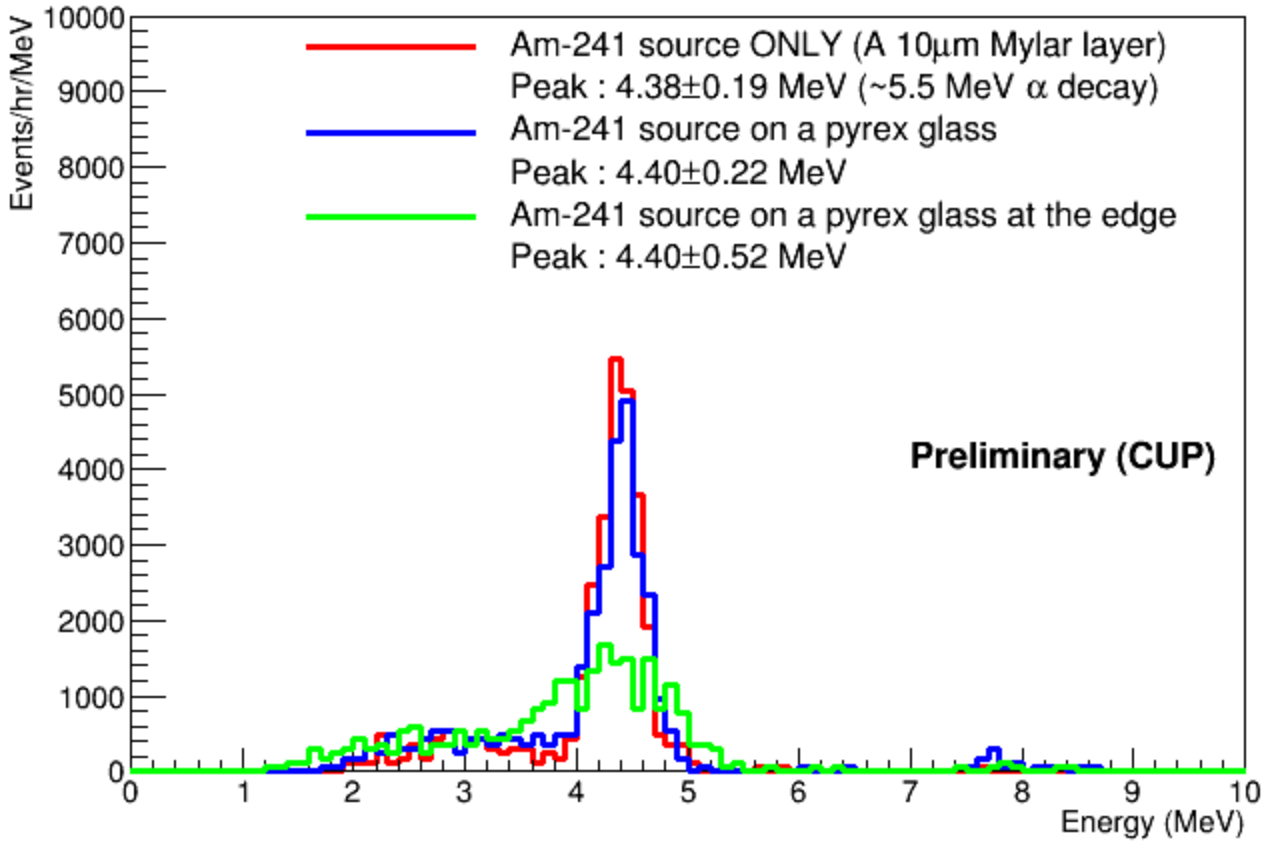


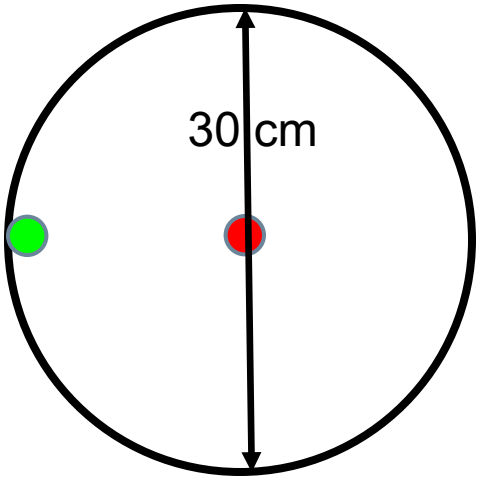
Figure II-6: Alphas originating from various locations in the counter and their resulting pulses. α_1 shows a sample alpha, α_2 shows a ceiling emission, and α_3 shows a sidewall emission, and α_4 shows a sample alpha that travels under the guard. The anode pulse is shown in red, the guard in blue.

UltraLo-1800 counter: Am-241 calibration

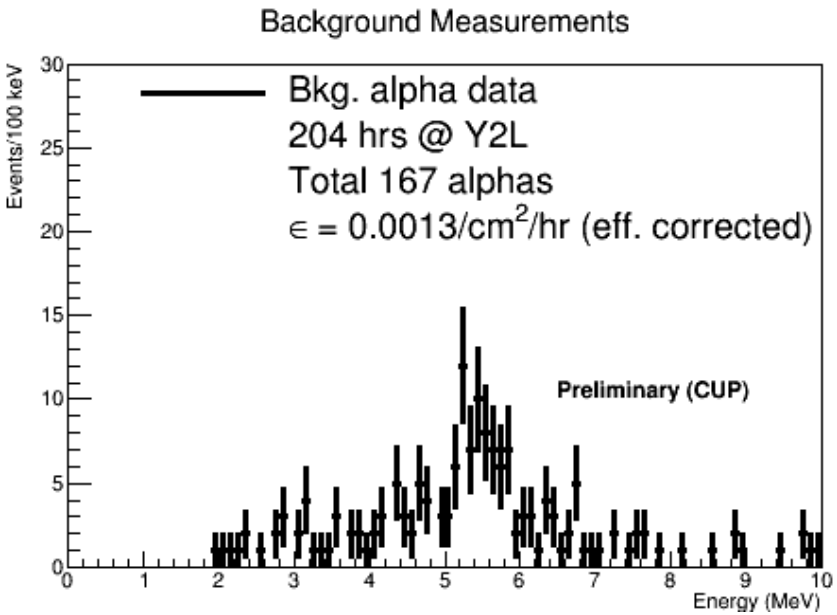


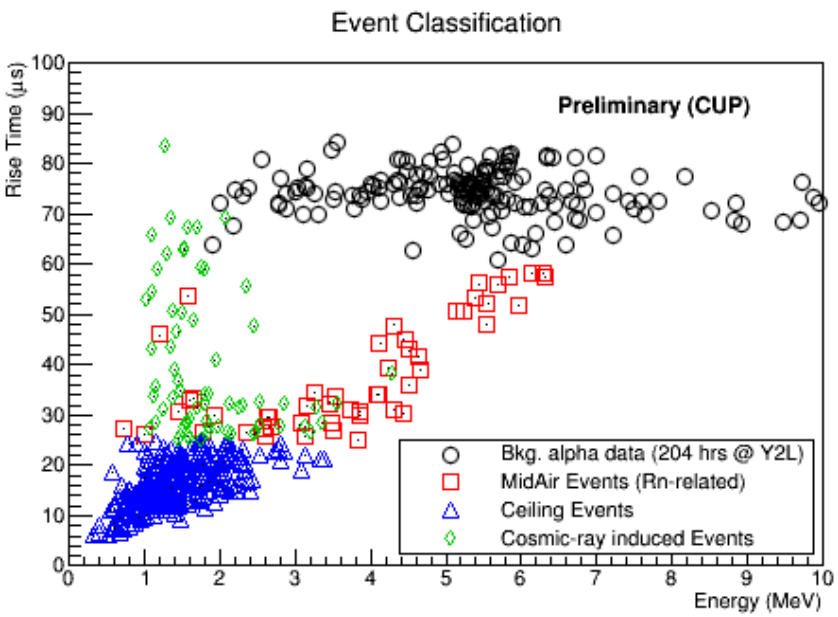
- Am source with a pin hole on Al. foil and 10 μm plastic wrap (~ 1 mm air gap)

Source positions



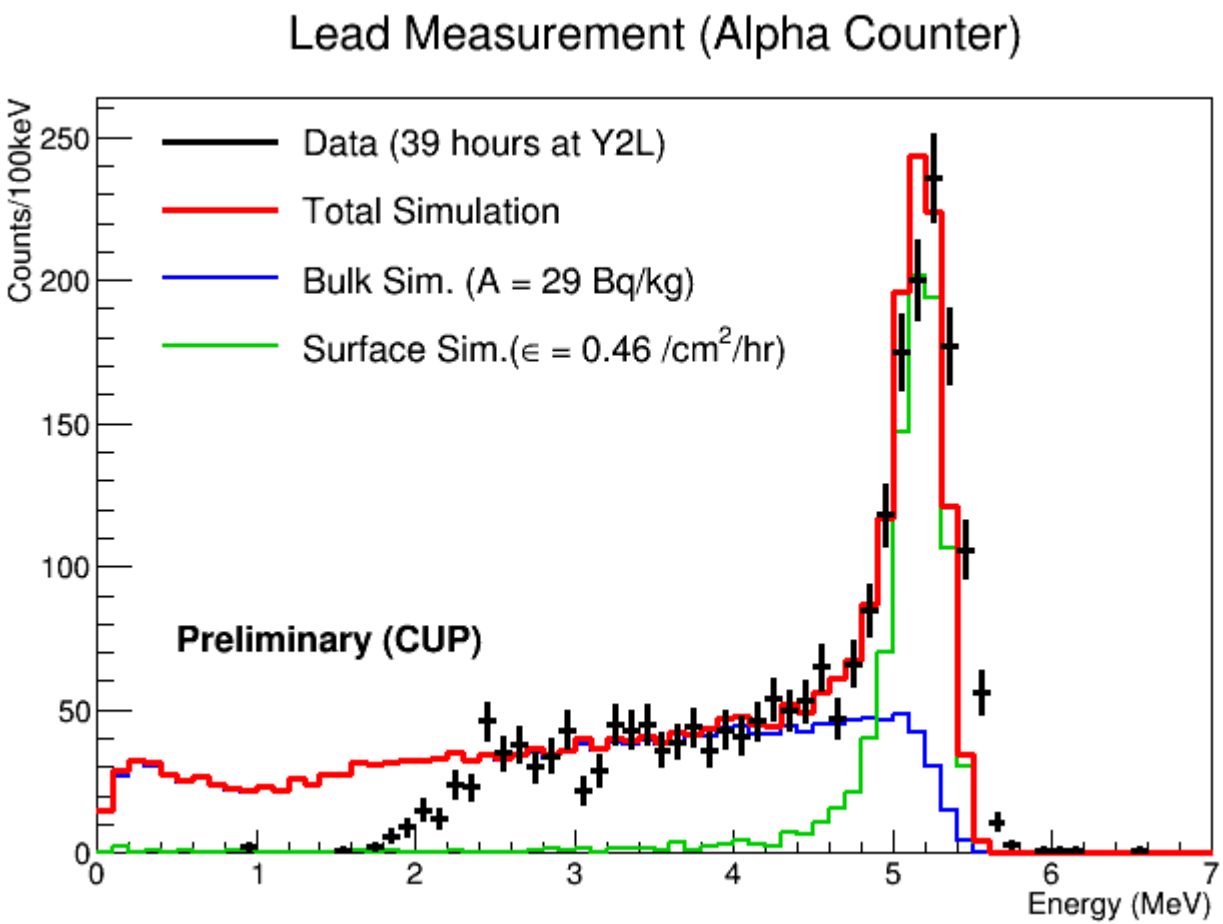
UltraLo-1800 counter: Tray Background

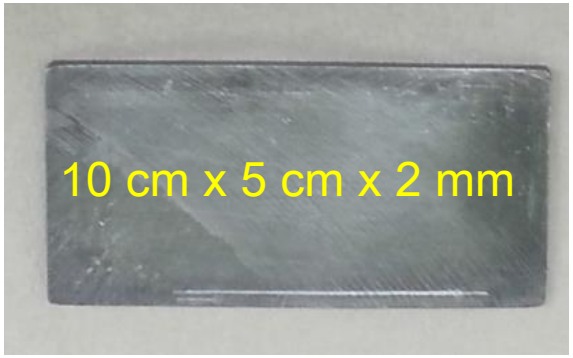




- Tray background of 0.0013 count/cm^2/hr is consistent with the specification.
- Ultra Low background Cu disk (10^{-4} level) to be tested very soon.

UltraLo-1800: Goslar lead

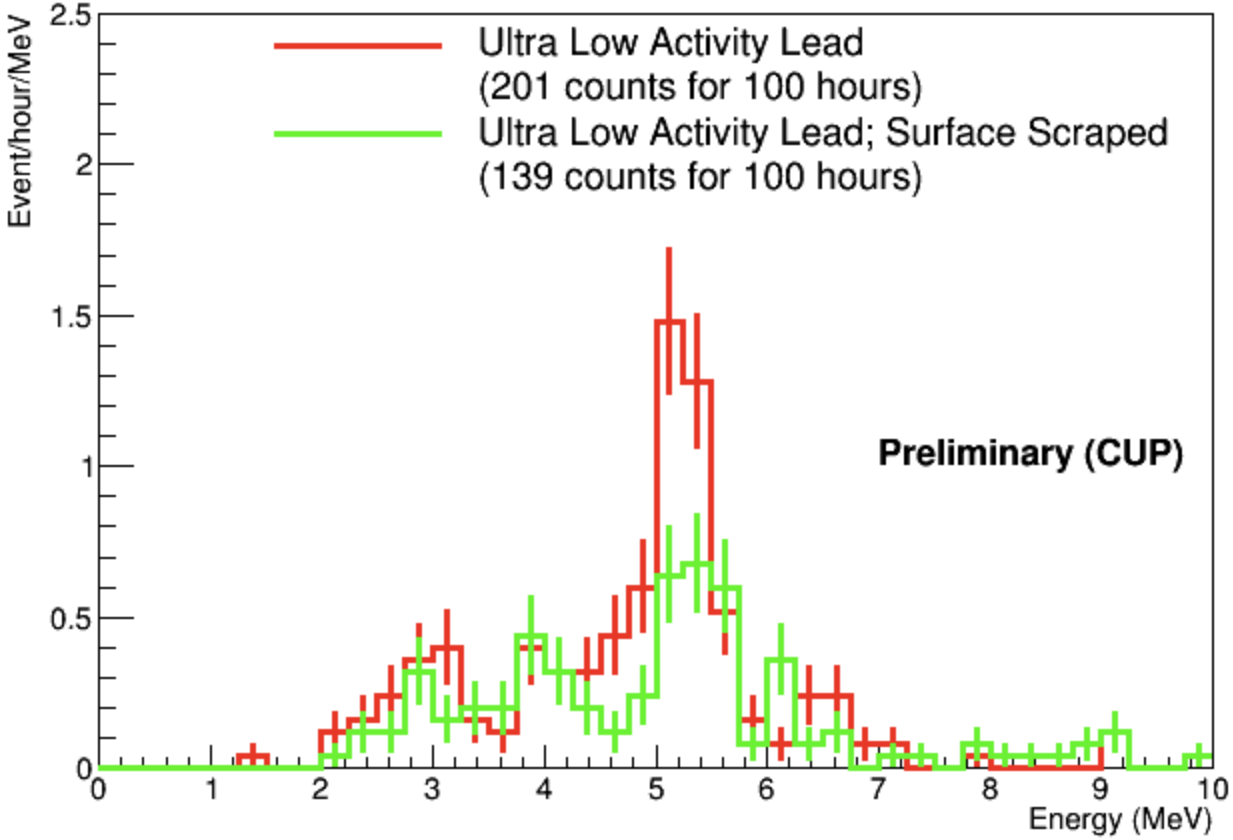




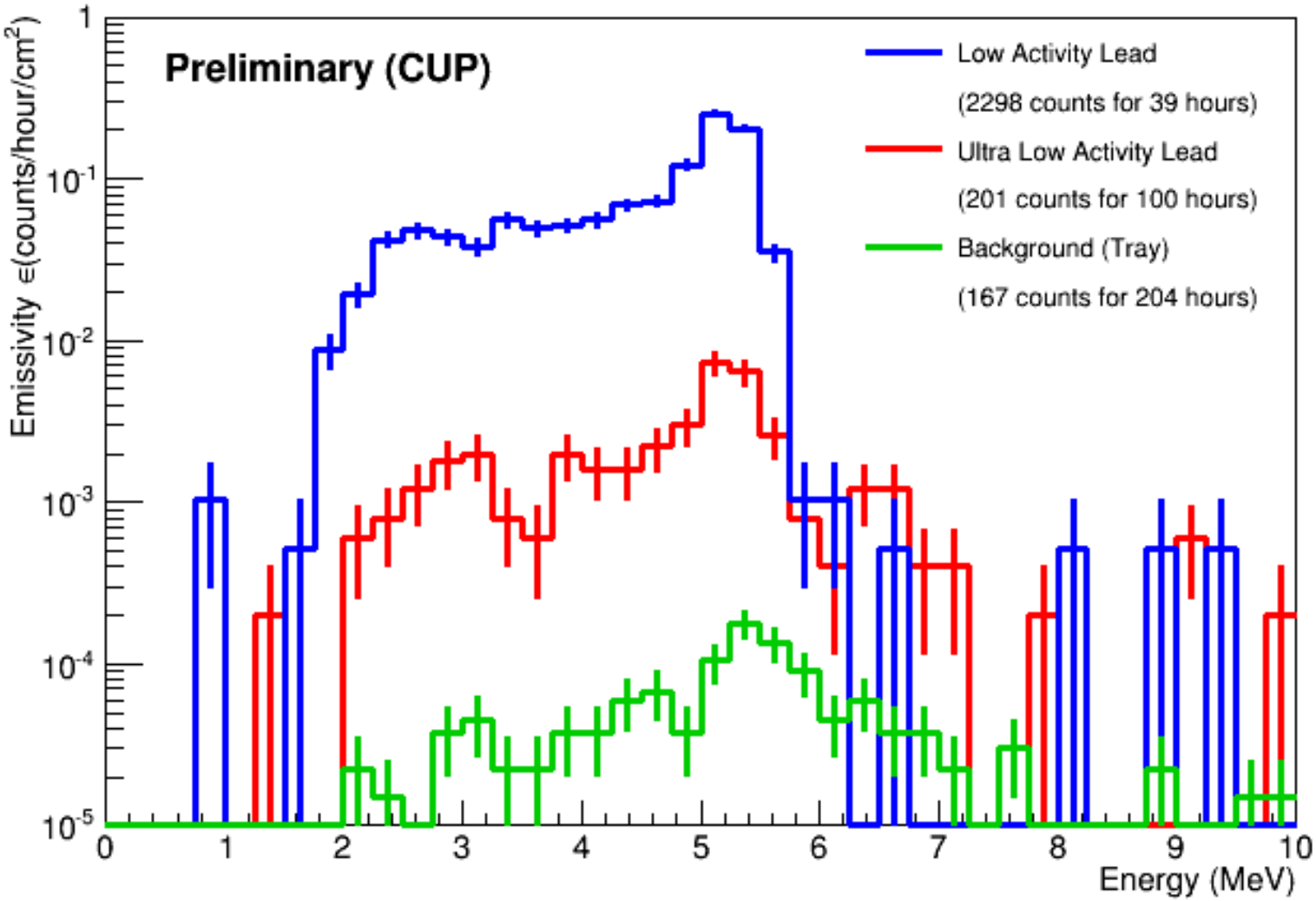
- 0.64 /cm^2/hr in ZnS test
- 5.5 MeV alpha particles in Pb can escape up to 15.7 μm (SRIM) depth.

UltraLo-1800: Ultra Low Activity Lead

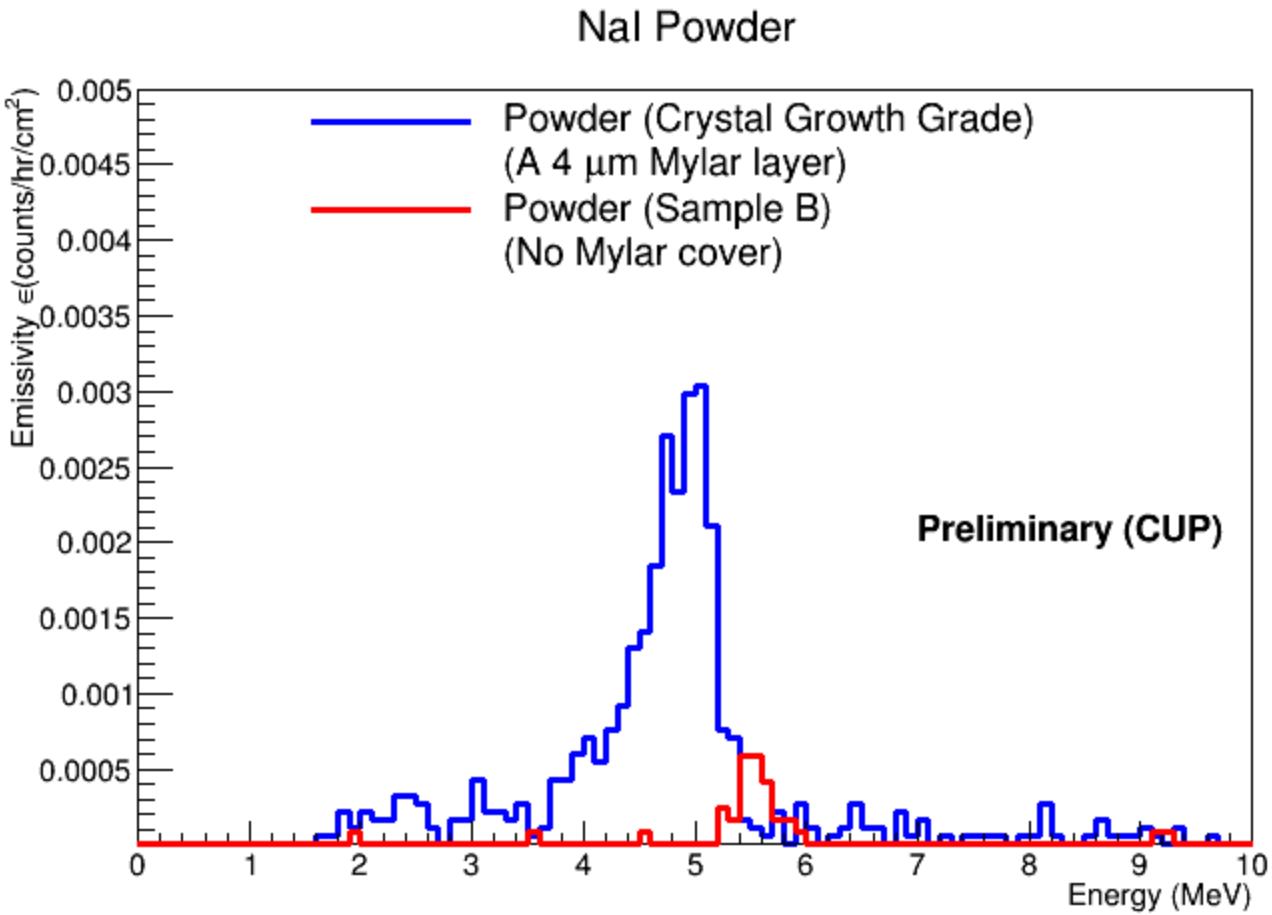
Lemer Pax T2FA 93 cm x 50 cm x 0.8 cm

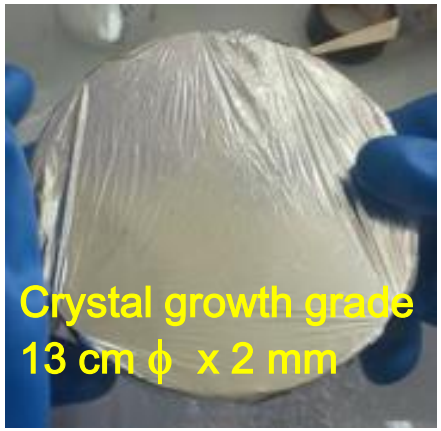


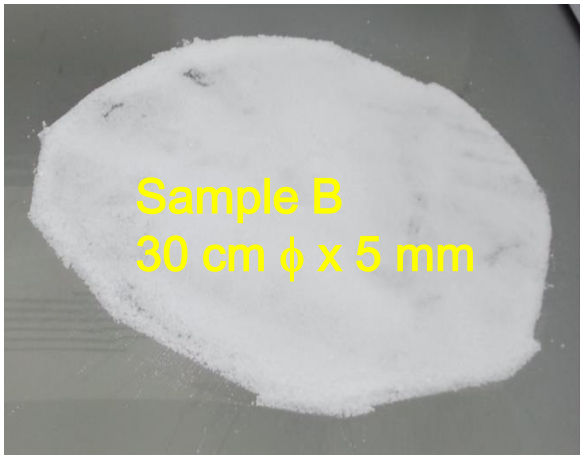
UltraLo-1800: Comparison of Leads



UltraLo-1800: NaI powder

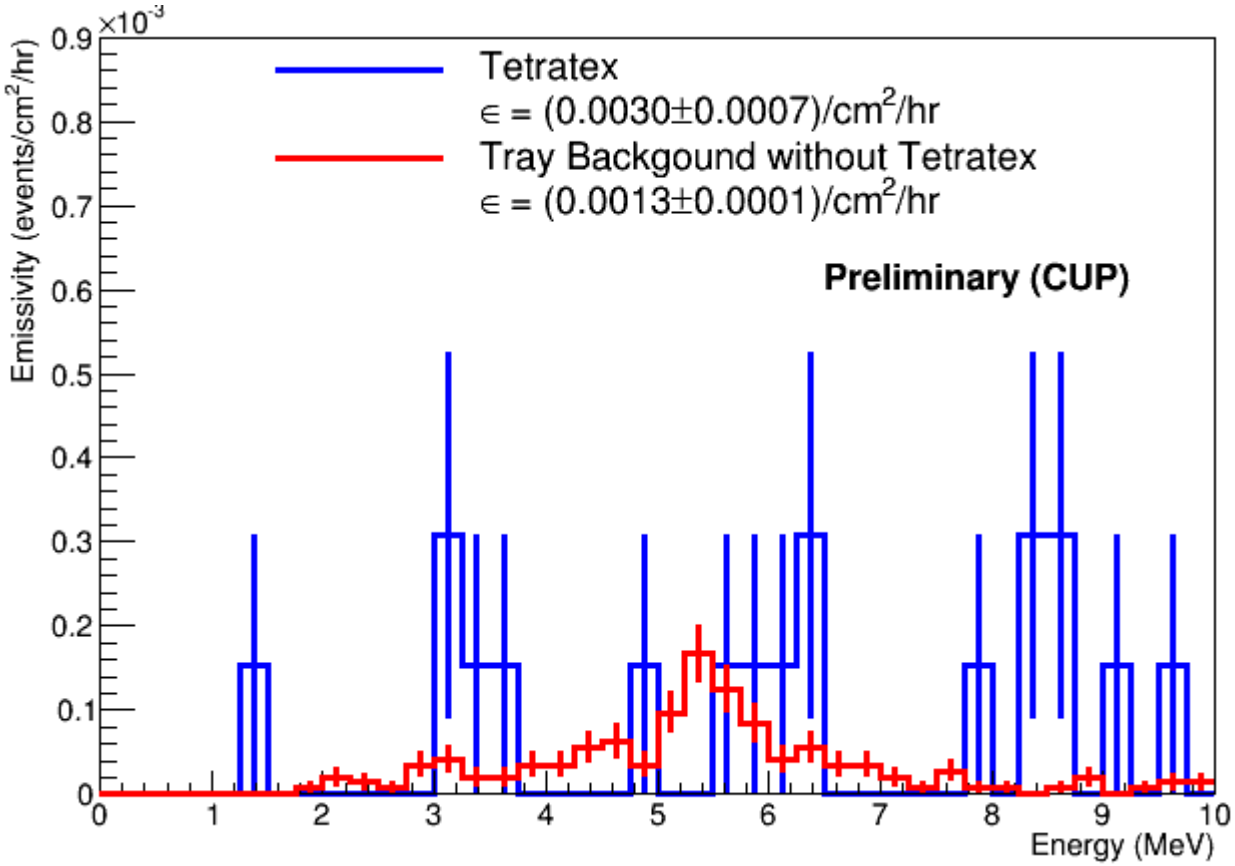






- 5.5 MeV alpha particles in NaI powder (ρ ~ 2 g/cm^3) can escape up to 55 μm (SRIM) depth.

UltraLo-1800: Tetratex (Teflon)



(256 μm thick, 707 cm^2)

- 5.5 MeV alpha particles in a Teflon (ρ = 2.2 g/cm^3) can escape up to 25.7 μm (SRIM) depth.
- 0.0028±0.0007 /hr/cm^2 (8 hours data).
- 0.0013±0.0001 /hr/cm^2 for the background.

Summary

- To reduce internal background from Pb-210 in the NaI powder, the Alpha/gamma measurement effort has started.
- ZnS sheet for alpha measurement has been tested for 4 months and proved to be useful for an easy counting of alpha particles with a background level of 0.004 count/cm^2/hr. A prototype is being designed.
- XIA UltraLo-1800 installed at Y2L and stable operation has been achieved with some number of samples tested.
- Well-type Ge detector for 46 GeV gamma measurement is being procured. Final purchase design is being discussed with the company.
- Simulation efforts are on-going with NaI, Pb, and ZnS with Am-241 source and Po-210.