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Developments for spherical single phase LXe TPCs

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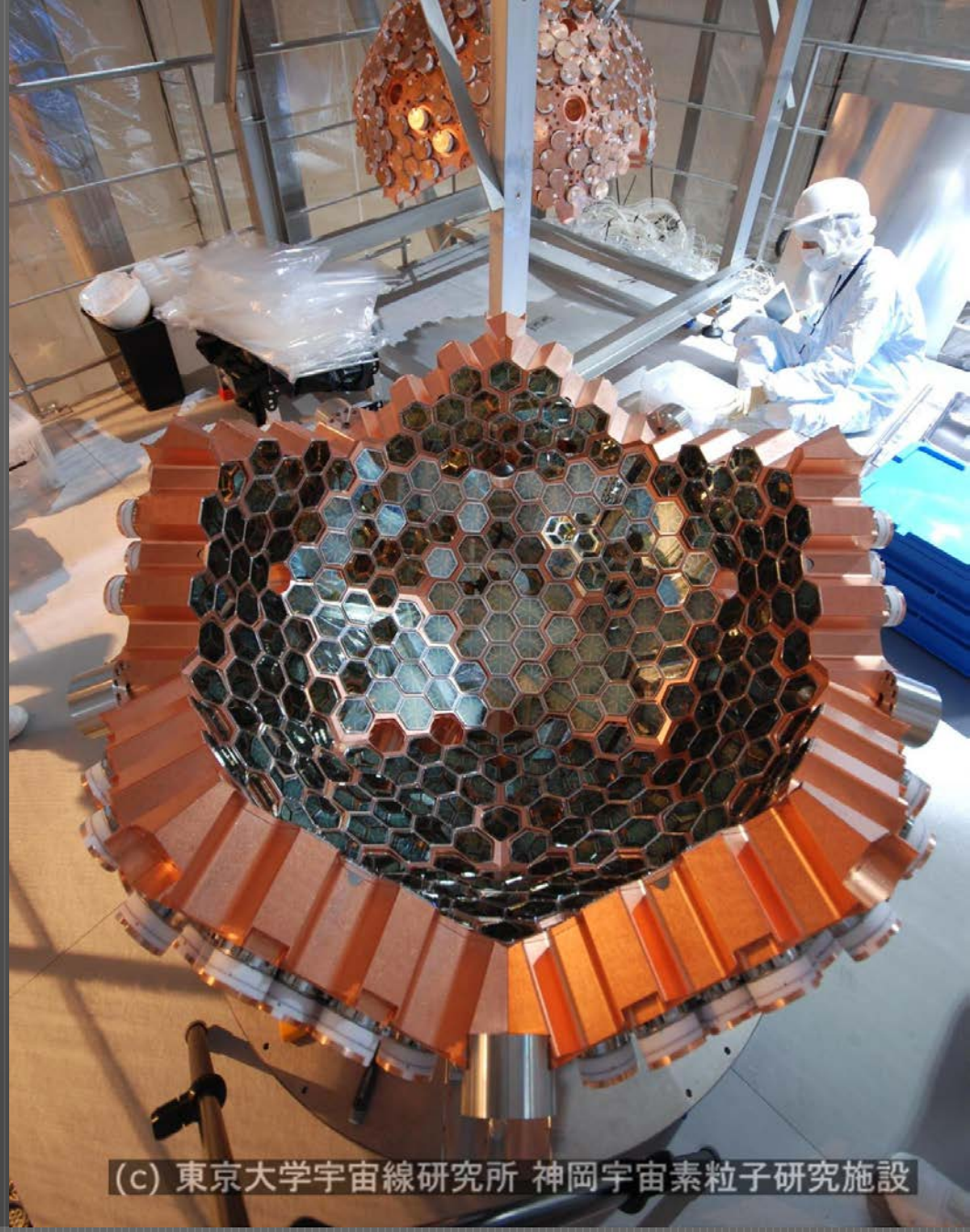
9th symposium on large TPCs for low-energy rare event detection, Paris, Dec. 14 2016

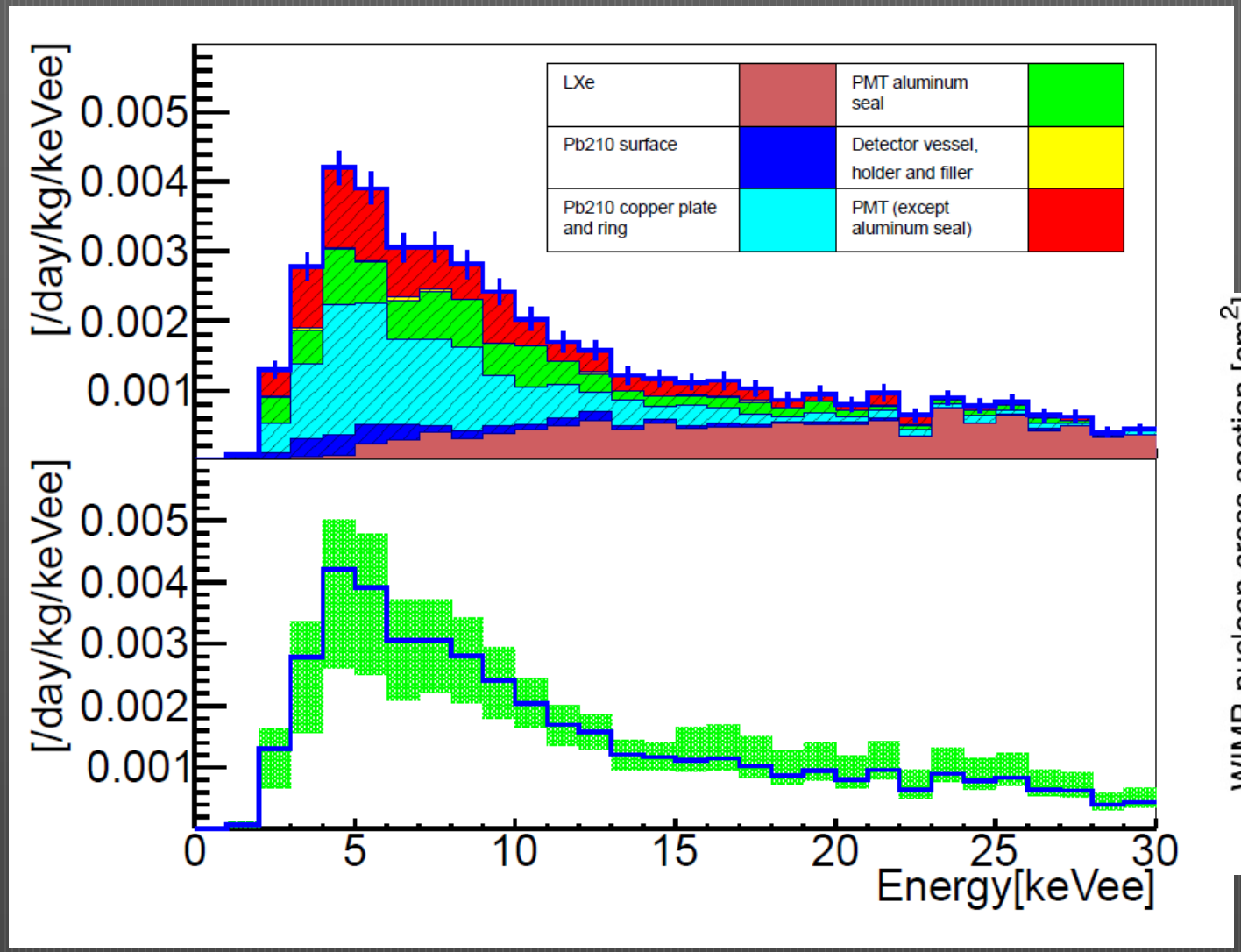
Motivation

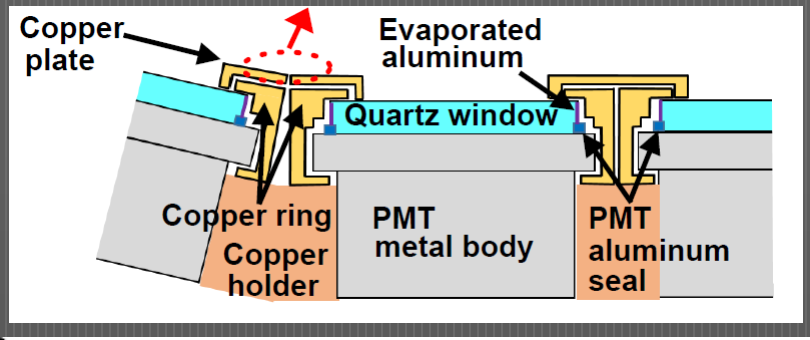
- XMASS
  - LXe spherical detector

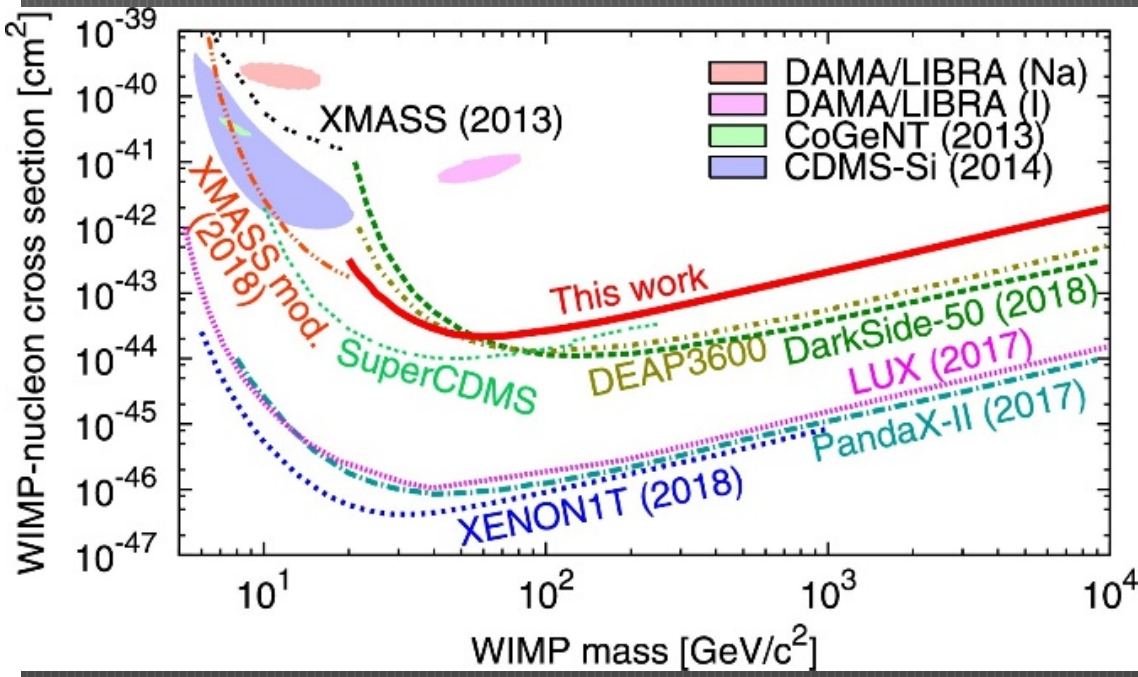


doi.org/10.1016/j.physletb.2018.10.070

Final XMASS results

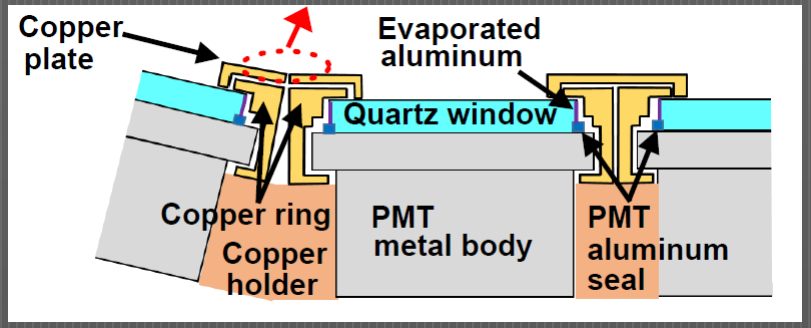


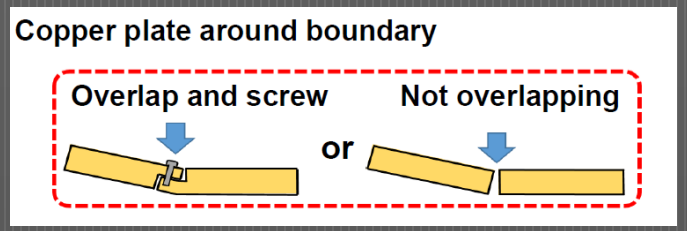


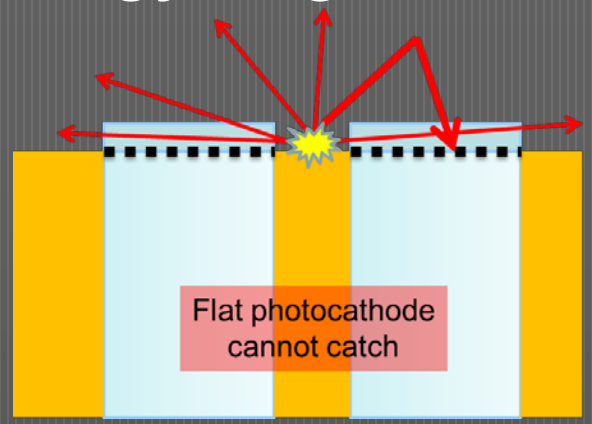


- To survey below 10^{-47}cm^2 region
  - This is not the way…

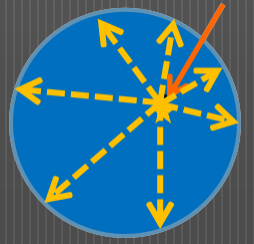
Surface background problem in low energy region

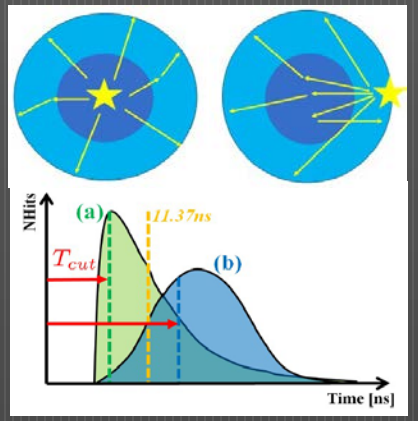






- Software vertex reconstruction with Q & T information of scintillation light may fail when the number of photoelectron is limited.
  - Especially surface BG events would be mis-reconstructed in the fiducial volume.
- Improvement of the hardware is indispensable.

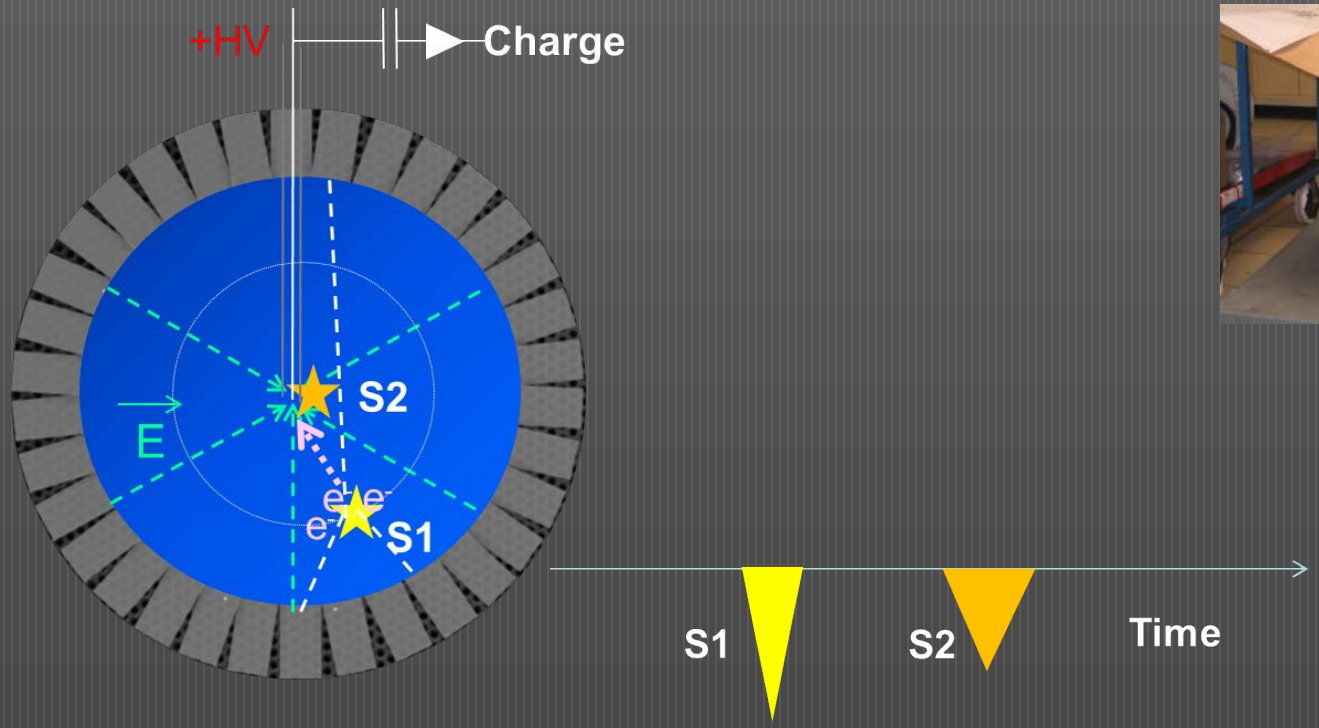




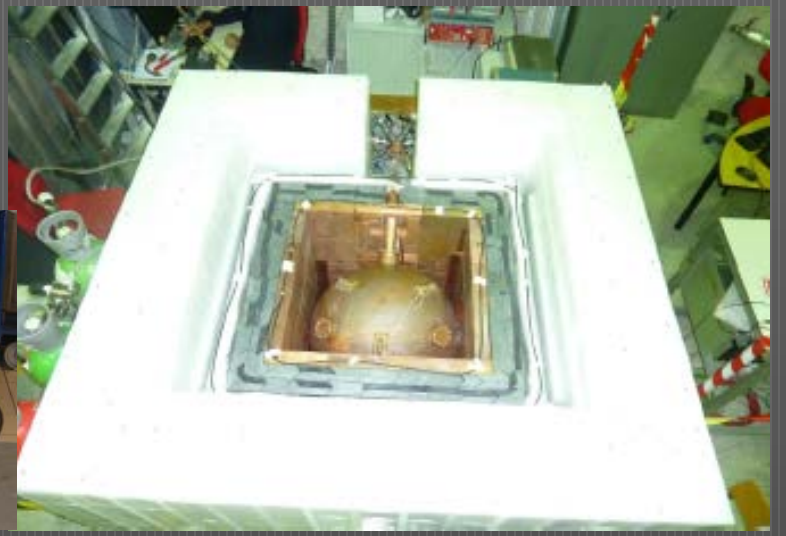
Q reconstruction and T cuts

TPC hardware vertex reconstruction

- Single phase TPC



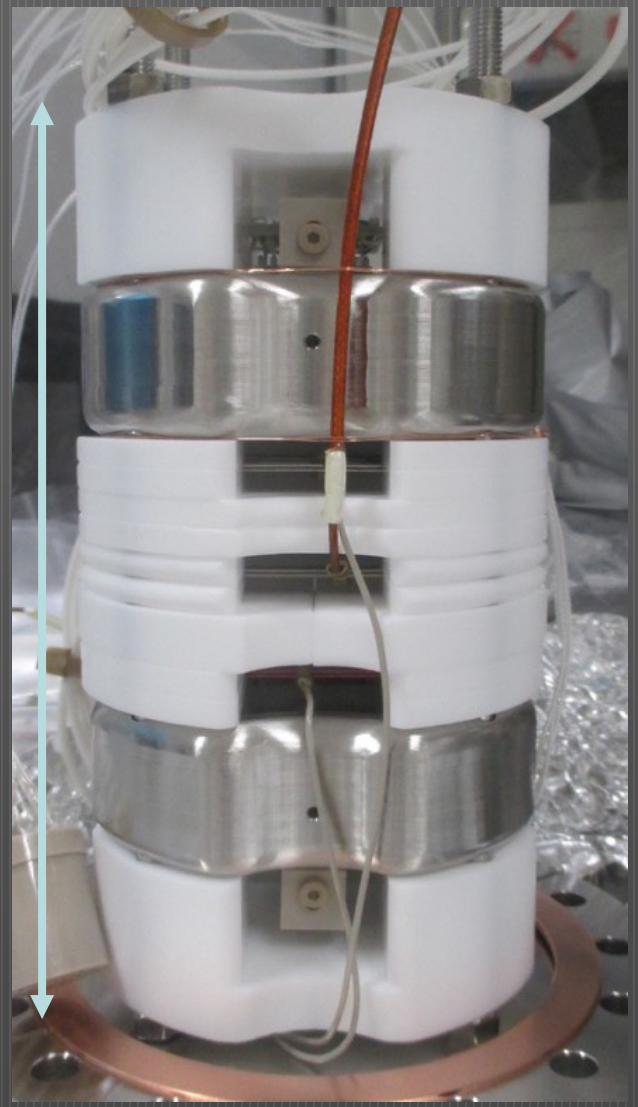
NEWS-G



Taken from Ioannis's 7th TPC Paris

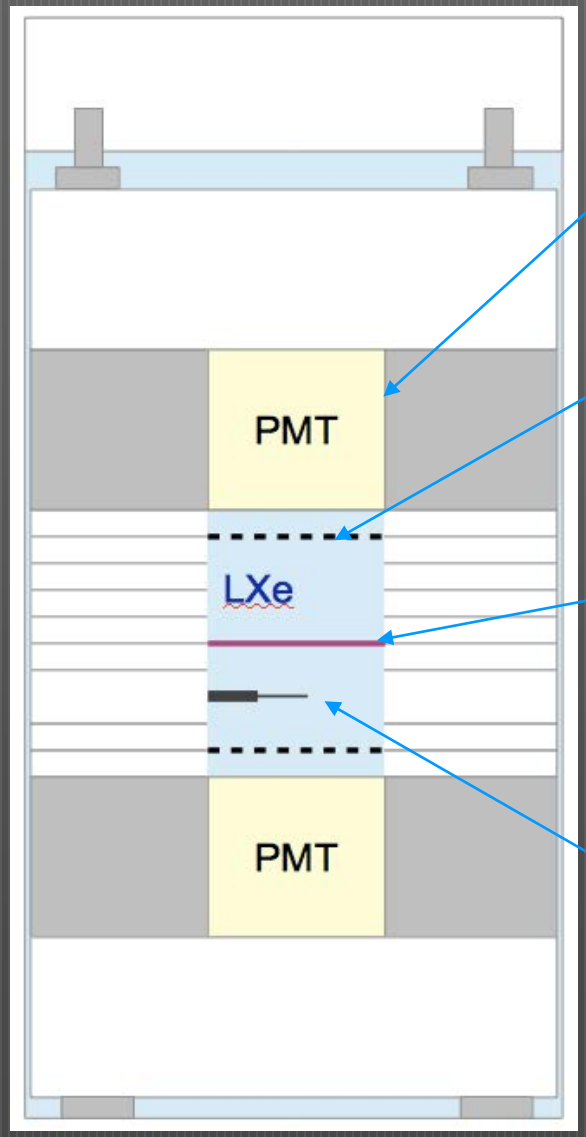
NEWS-L ?

2016 wire setup

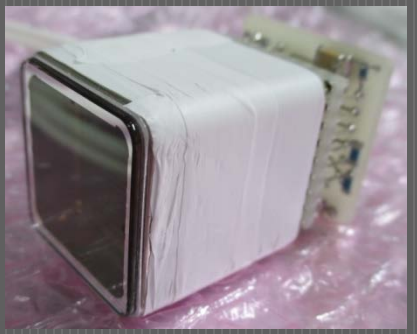


170mm

50mm



Hamamatsu
R8520-406
24mm□
+HV



GND wires

Au coated
10μm W wire

^{241}Am

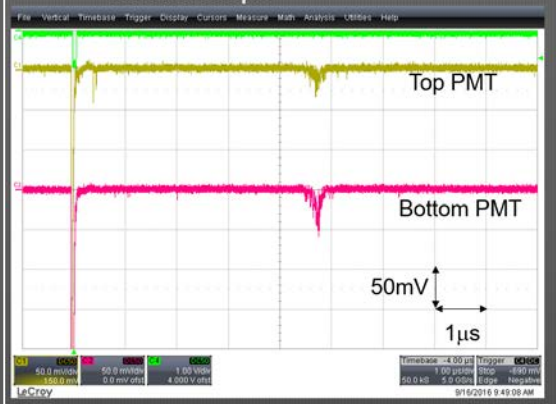
γ: 59.5, 26.3keV
X: 13.9keV
α: 5.49, 5.44,5.39MeV

In 2016 Paris TPC

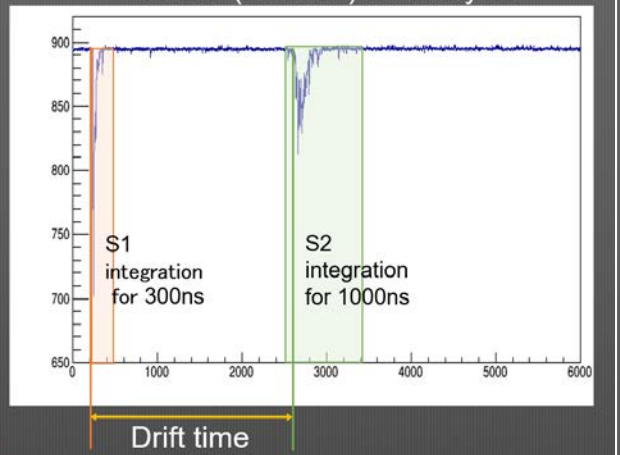
- S2 from ^{241}Am was observed.
  - Electron collection efficiency ~0.75%
  - Only from 5.5MeV α
  - No S2 from 59.5keV γ

S2 signal @ 4.5kV

- Oscilloscope



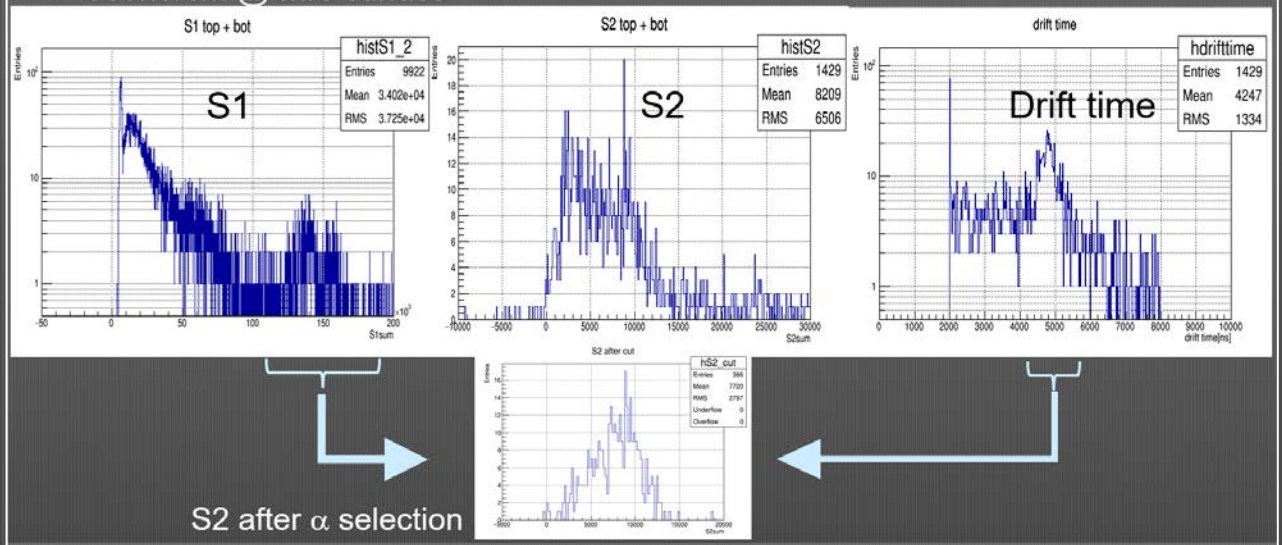
- FADC (DT5751) for analysis

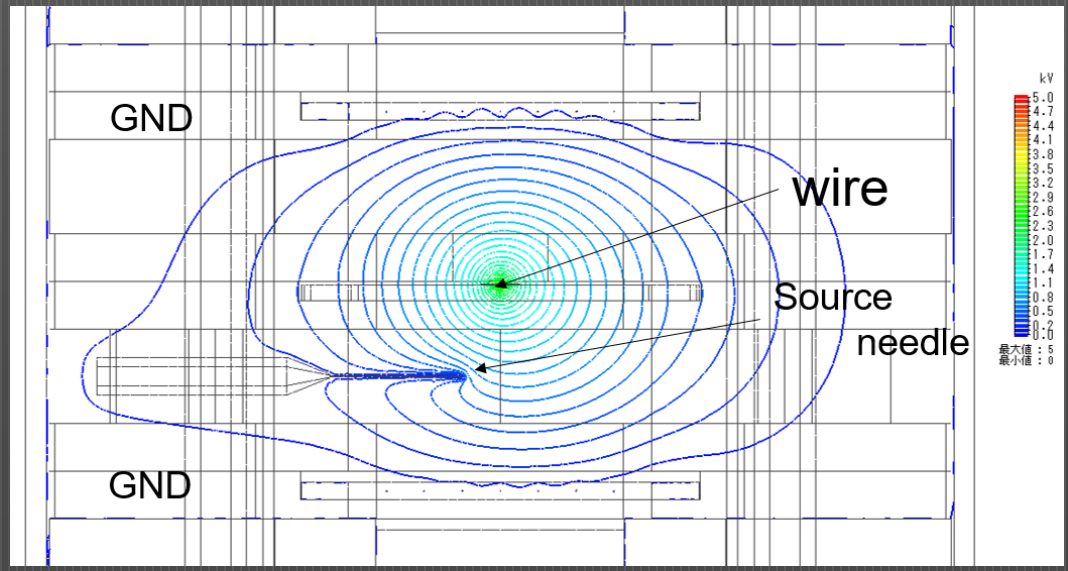


- E_{drift} ~ 1.6kV/cm → ~0.2-0.3cm/μs
- source-wire: 1cm → ~4-5μs

S1,S2 and drift time distributions@ wire 4.5kV

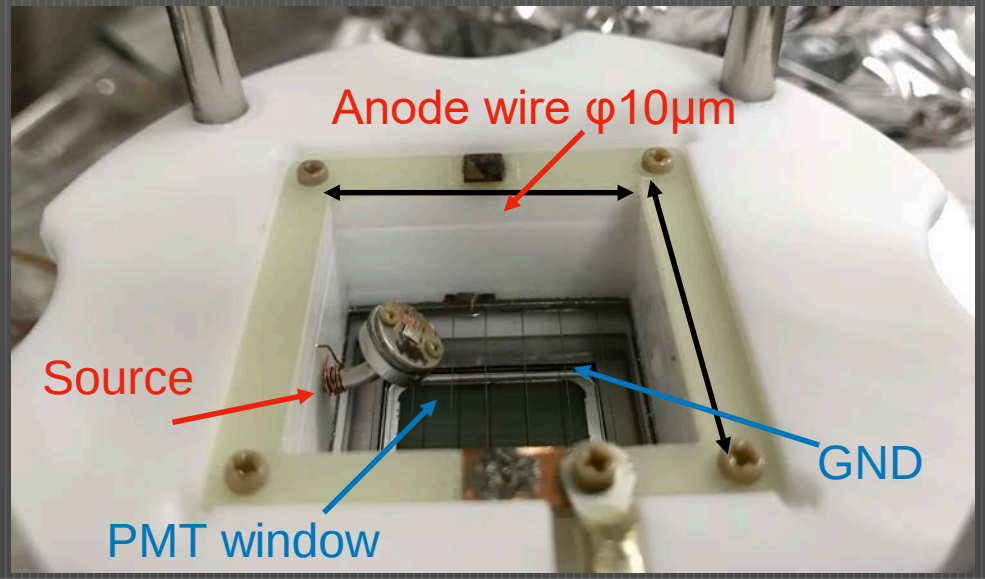
- 800kV/cm @ wire surface



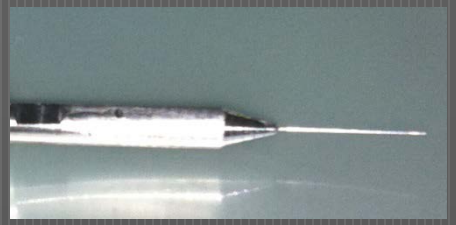


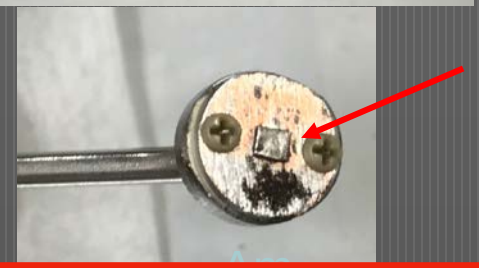
Improved 2018 setup

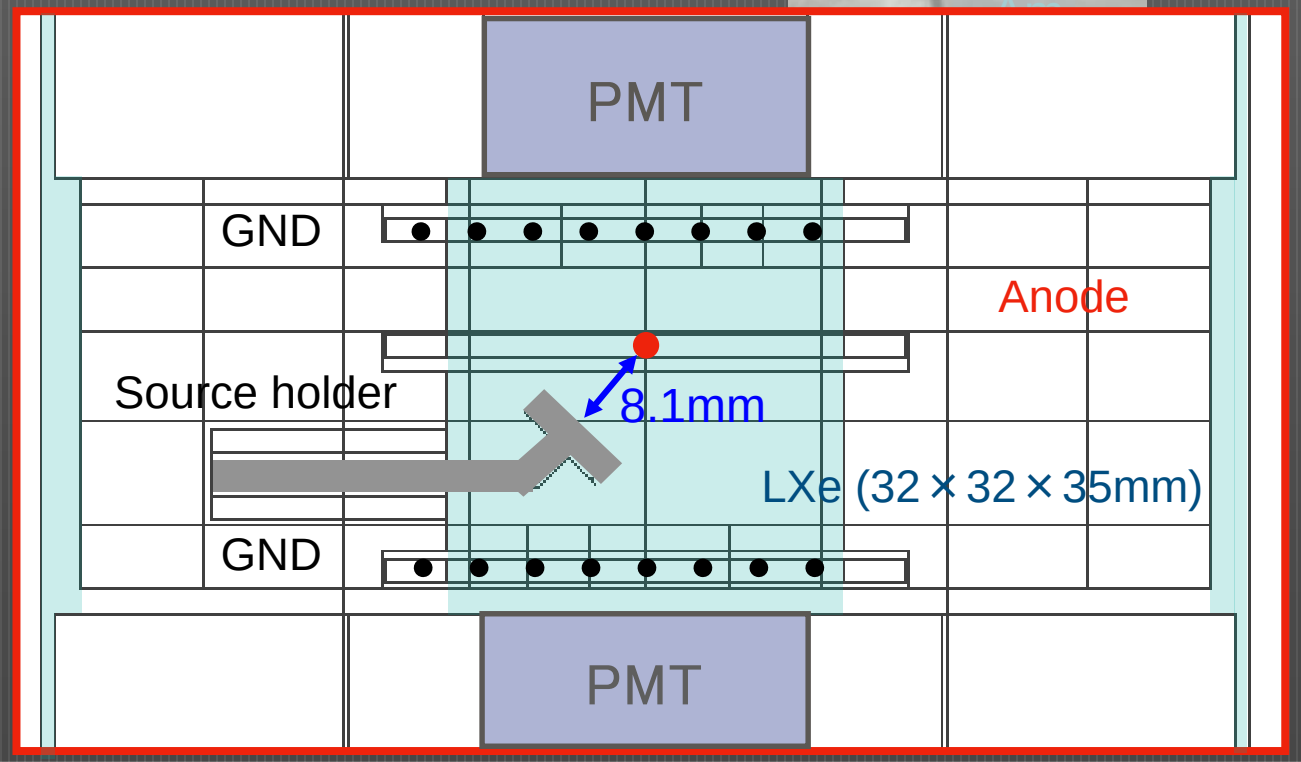
- Smaller dead region
  - Was non-negligible BG source



- Better ^{241}Am source
  - Was non-uniform
  - Was discharge source

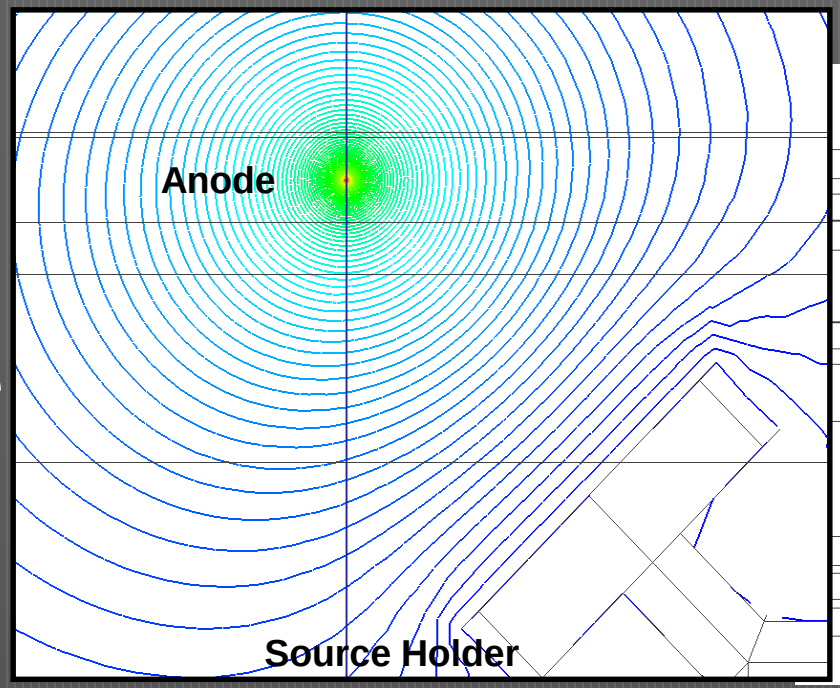




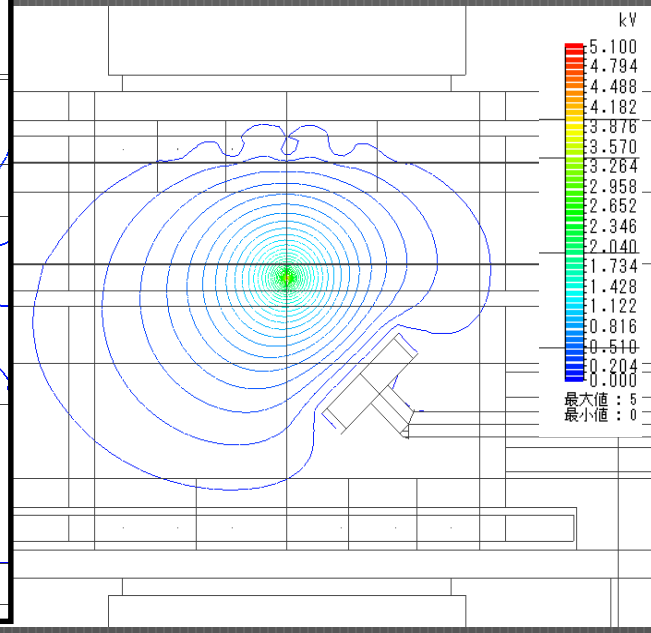


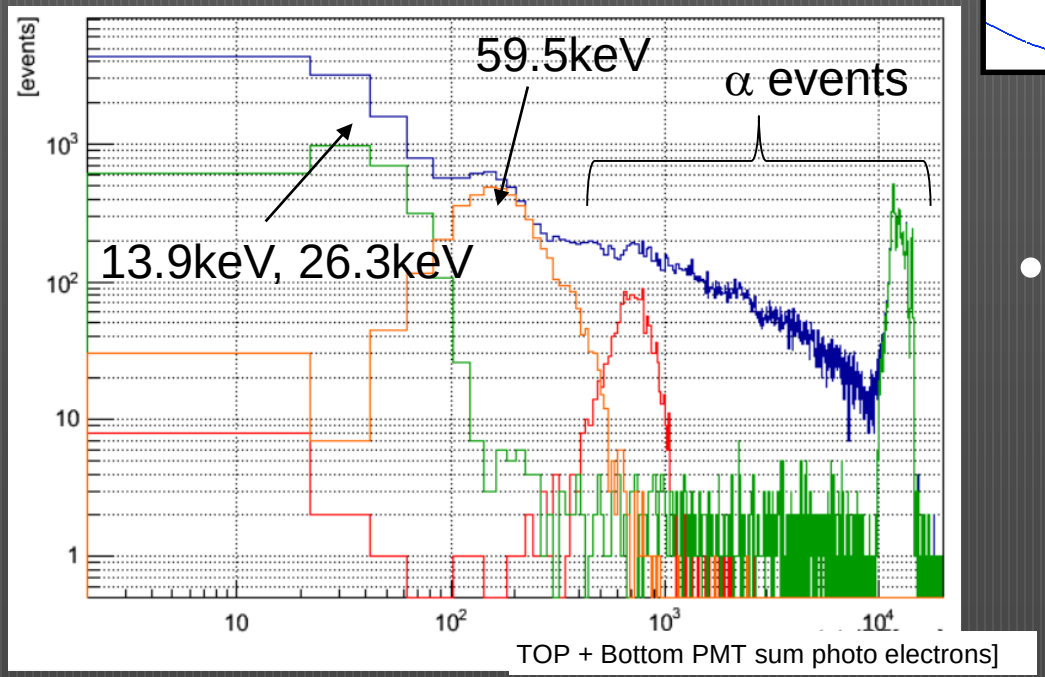
Simulations

- Electric field
  - More uniform between the source the anode wire



Anode 5kV



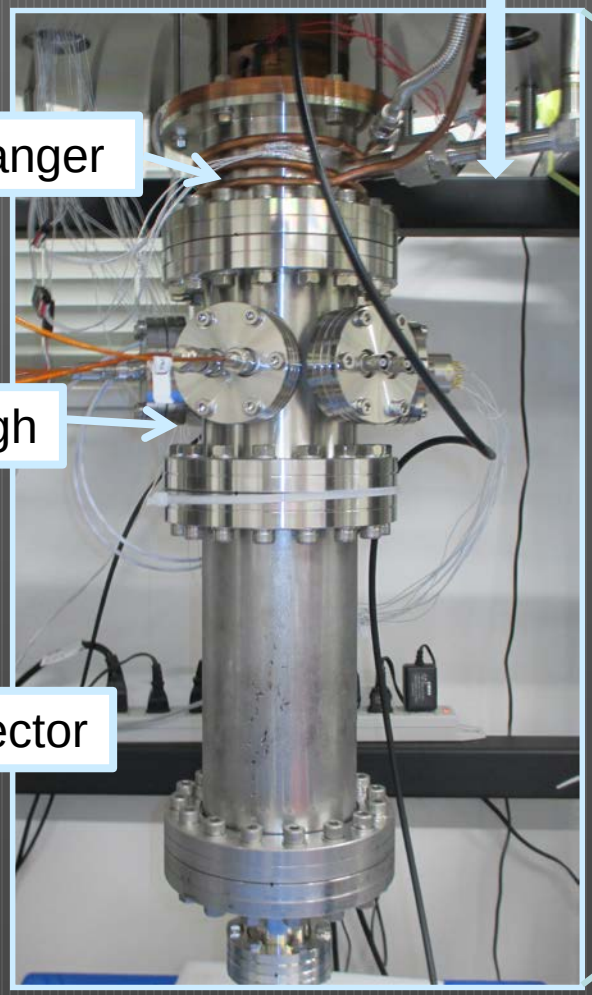


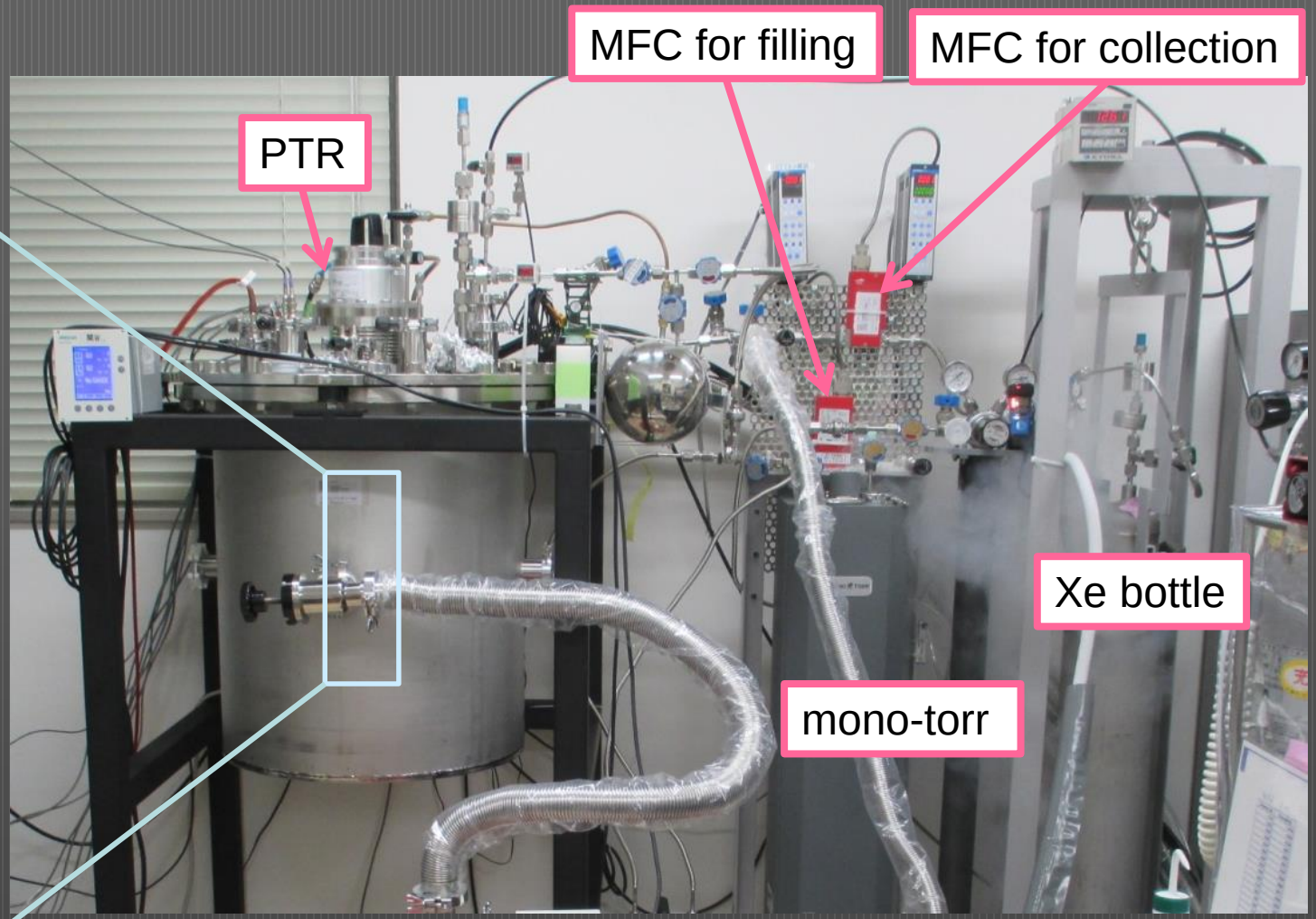
- S1 spectrum (Anode 0V)
  - Full light simulation w/ Geant4
  - 4 p.e./keV assumed
  - 13.9keV(X-ray) should be observed

Cryogenics

- 281.6L of Xe gas used

Inside of the outer chamber

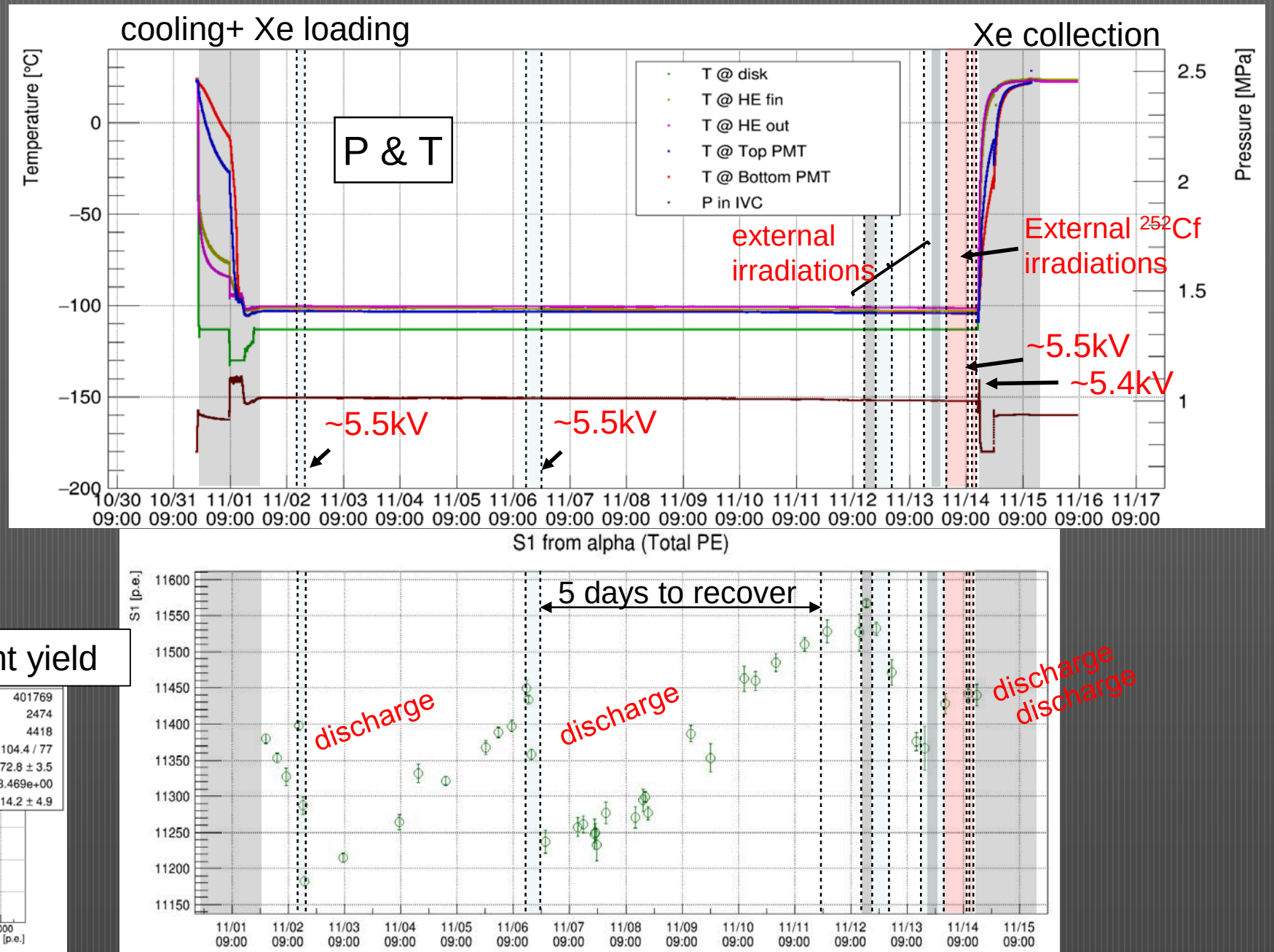




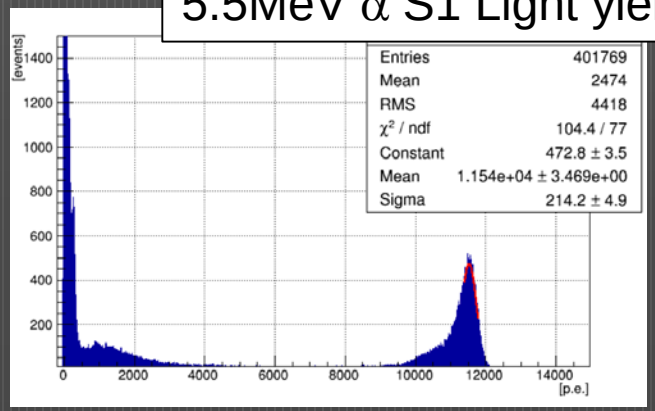
No gas nor liquid circulation

Xe conditions

- Oct 31-Nov14
- -102.4℃,0.049MPa
- Max anode 5.5kV
  - 750 kV/cm @wire
- LY dropped when discharged.

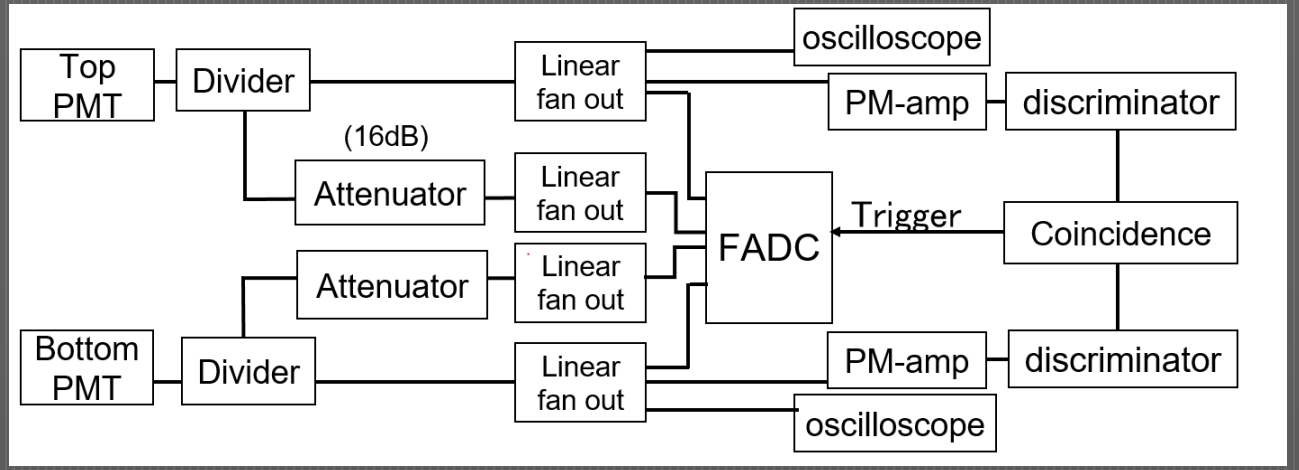


5.5MeV α S1 Light yield

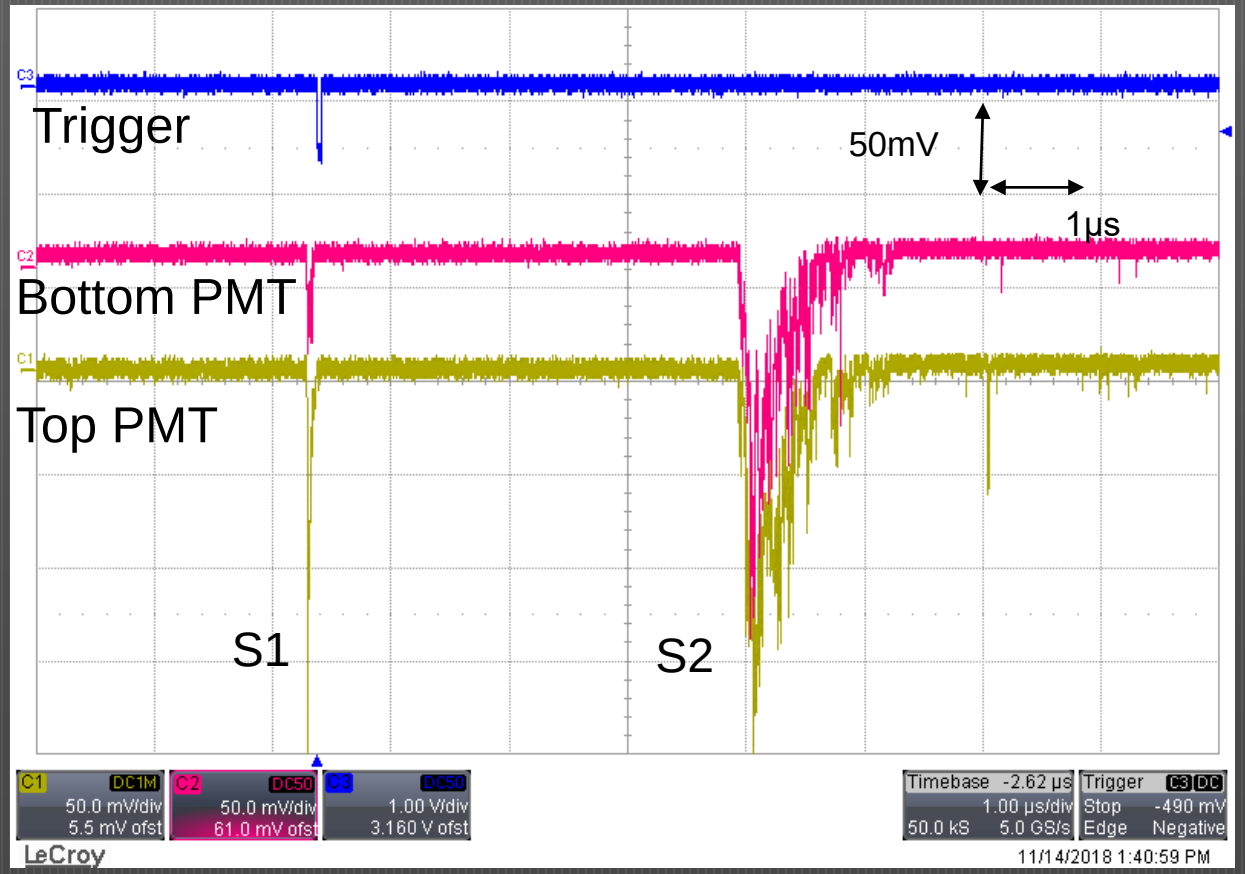


DAQ and Analysis

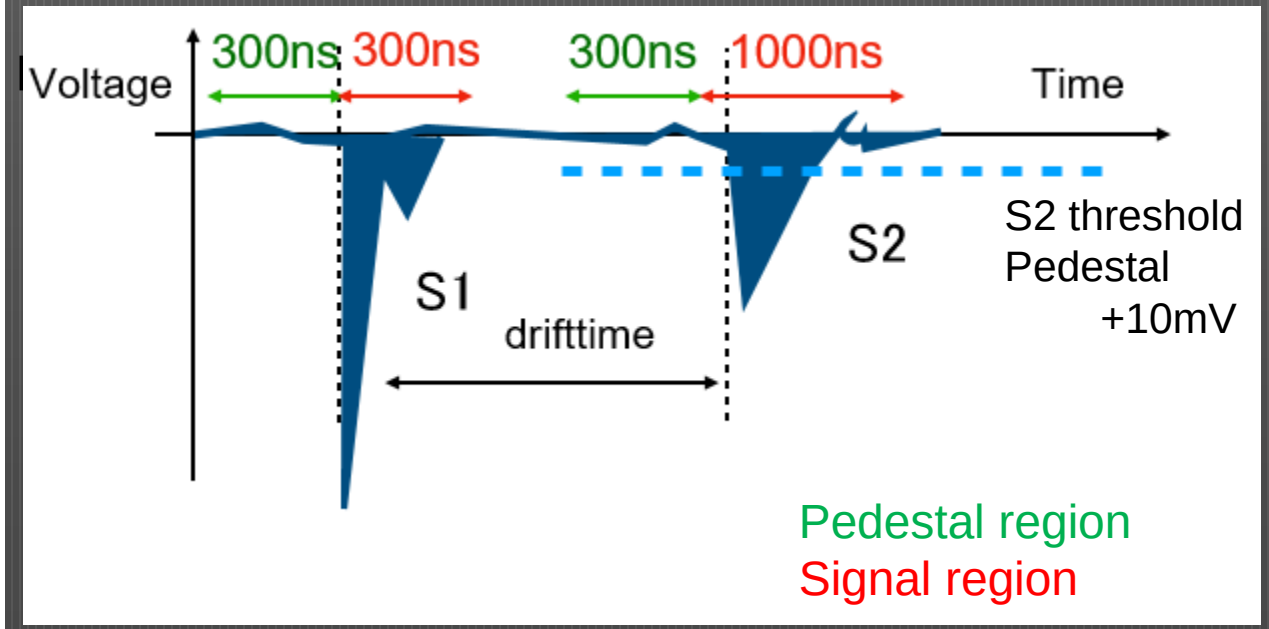
- Attenuator for wide dynamic range
  - To record both 5.5 MeV /α and 13.9 keV/X with a FADC



Anode 5kV

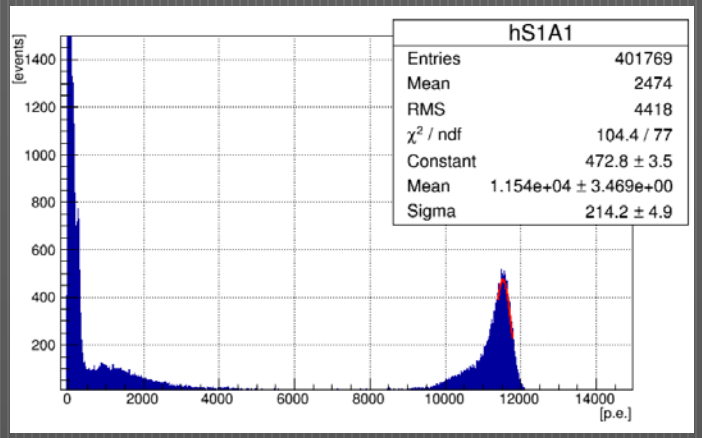


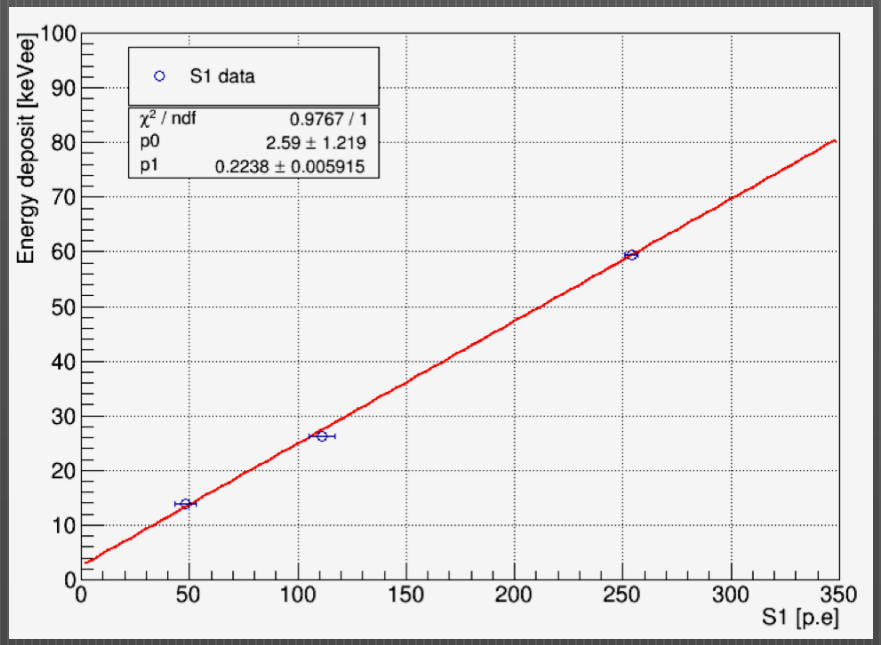
S1/S2 peak calculations

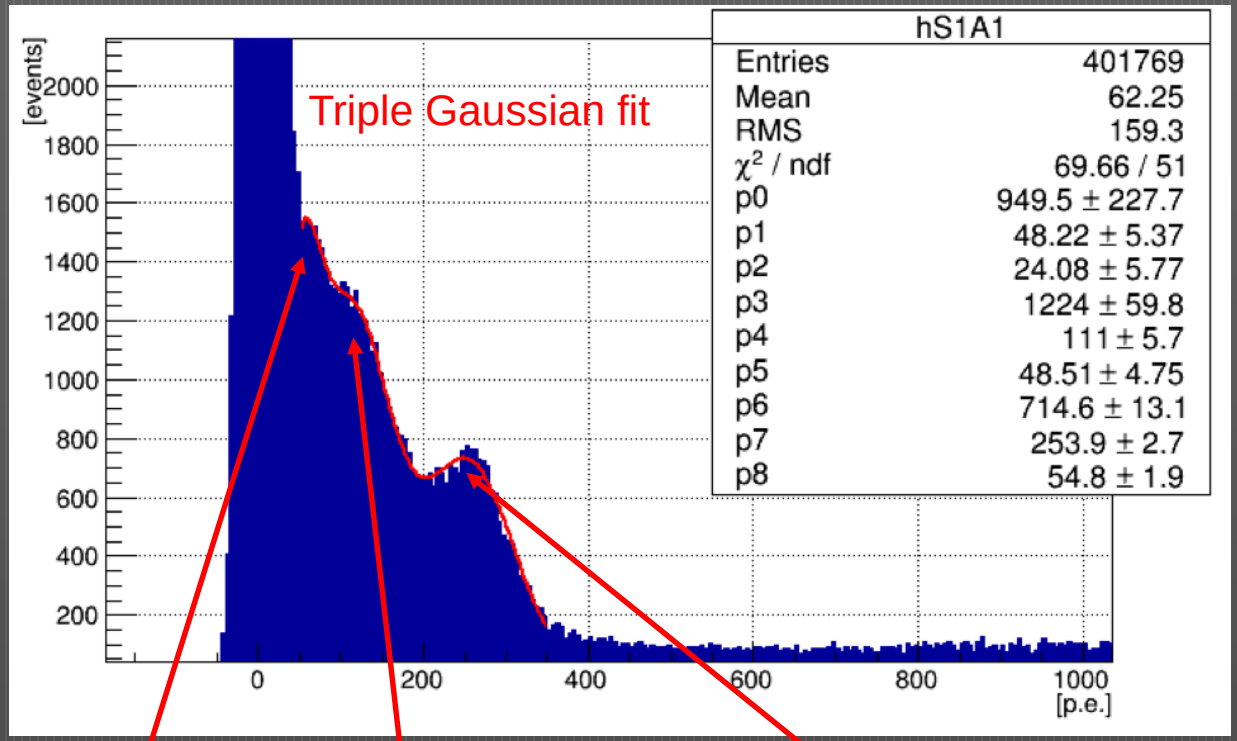


Low energy S1 spectrum @0V

- Wide range data







48 ± 5 p.e.
13.9 keV

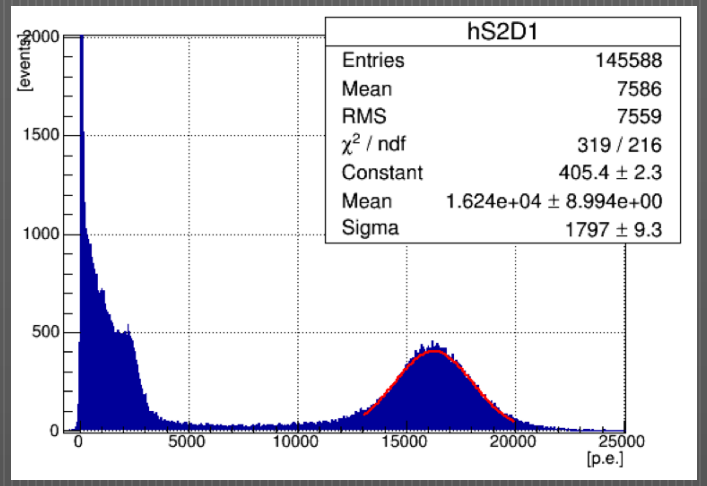
111 ±6 p.e.
26.3 keV

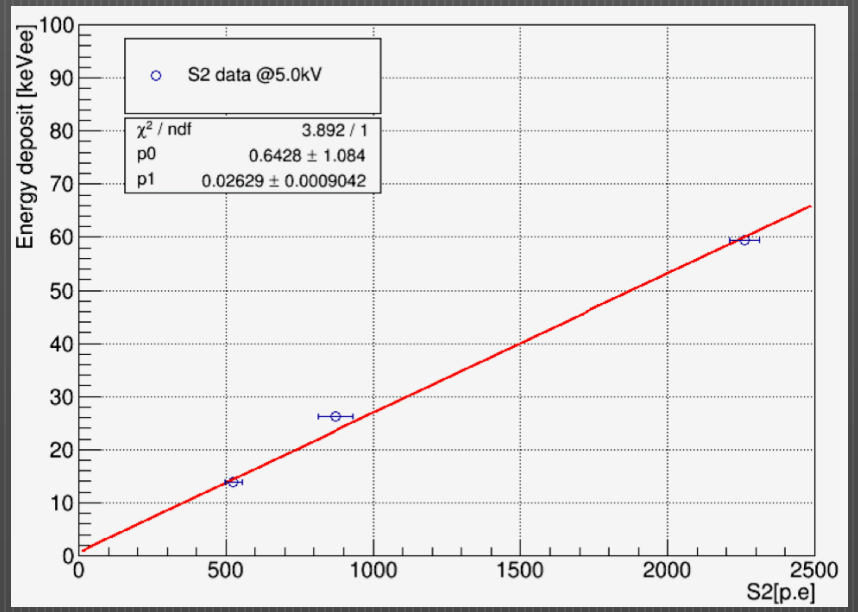
254 ± 3 p.e.
59.5 keV

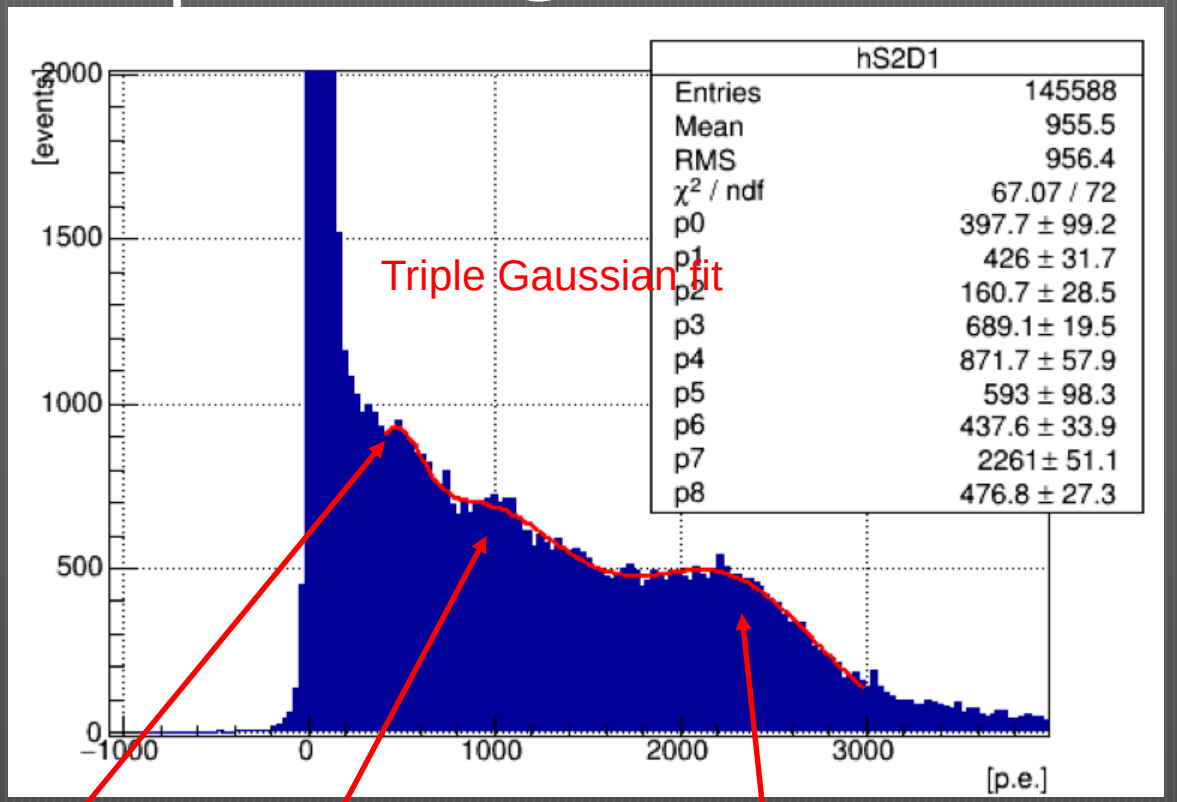
S1(@0kV): 4.2 p.e./keV

Low energy S2 spectrum @5kV

- Wide range data







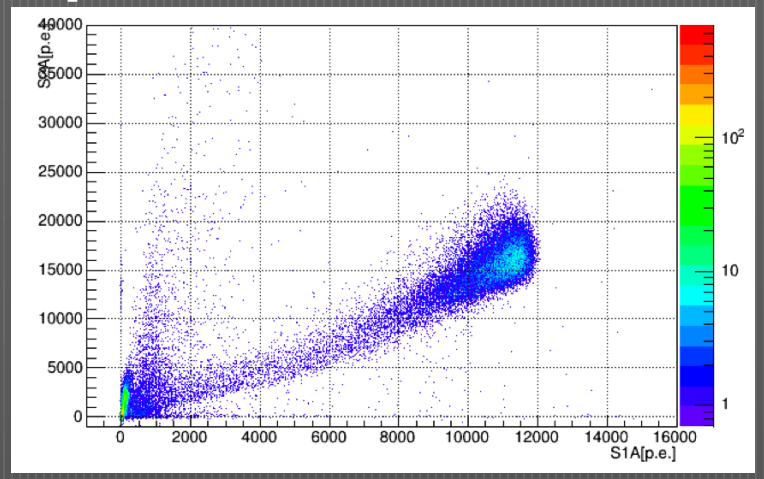
426 ± 31 p.e.
13.9 keV

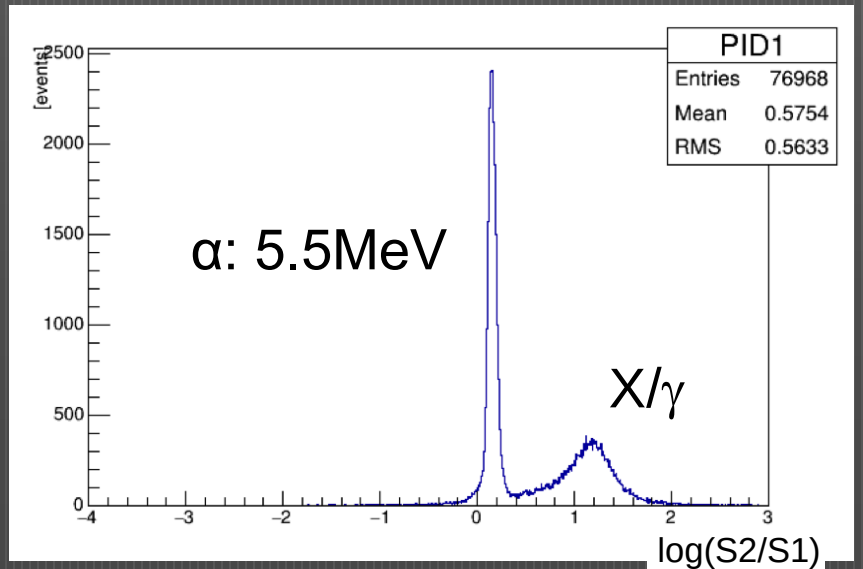
872 ±58 p.e.
26.3 keV

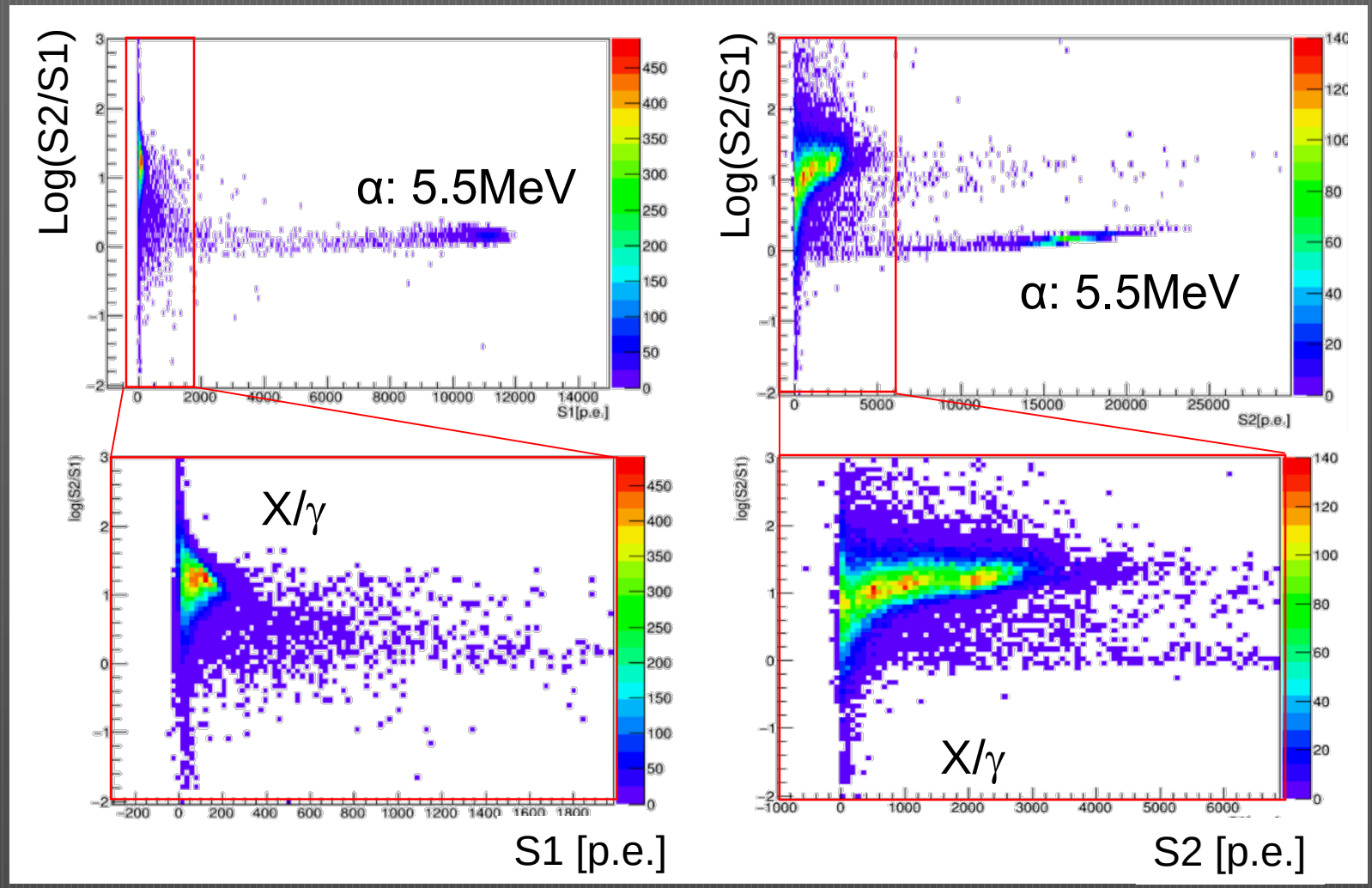
2261 ± 51 p.e.
59.5 keV

S2(@5kV): 39 p.e./keV

S1 vs S2 @ 5kV

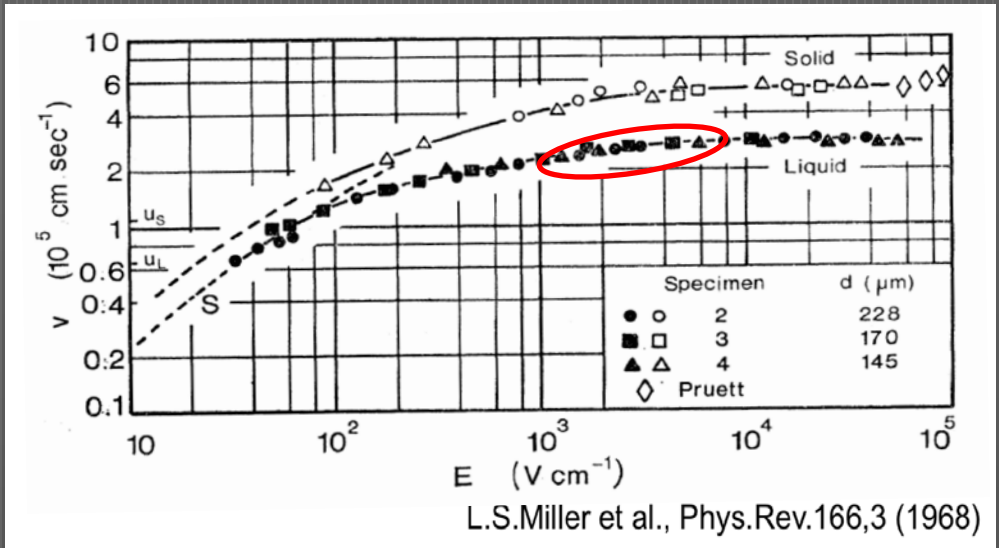




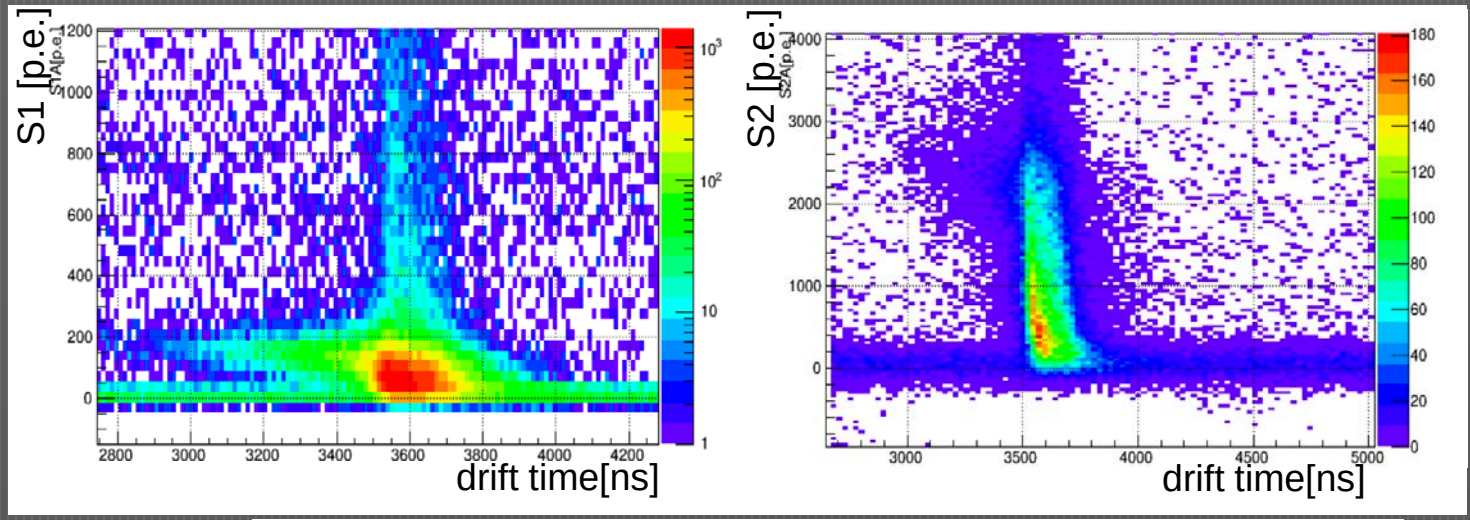


- αs and γs are clearly separated
  - Down to ~10keVee??

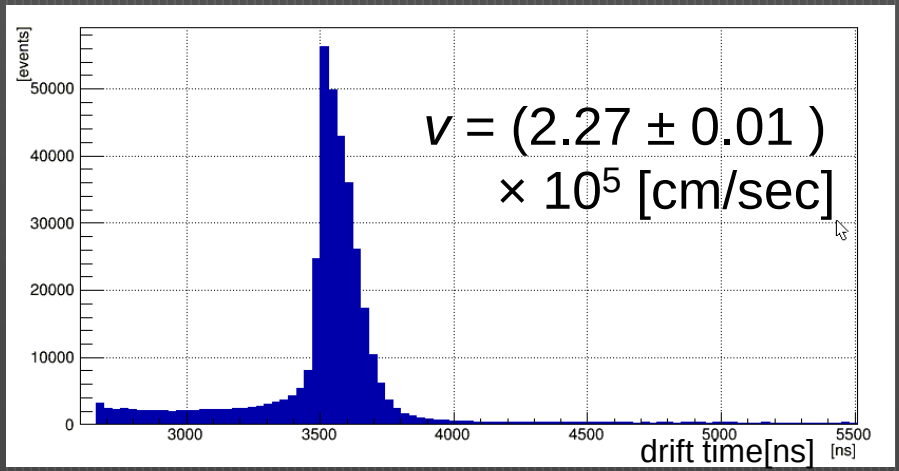
Drift velocity

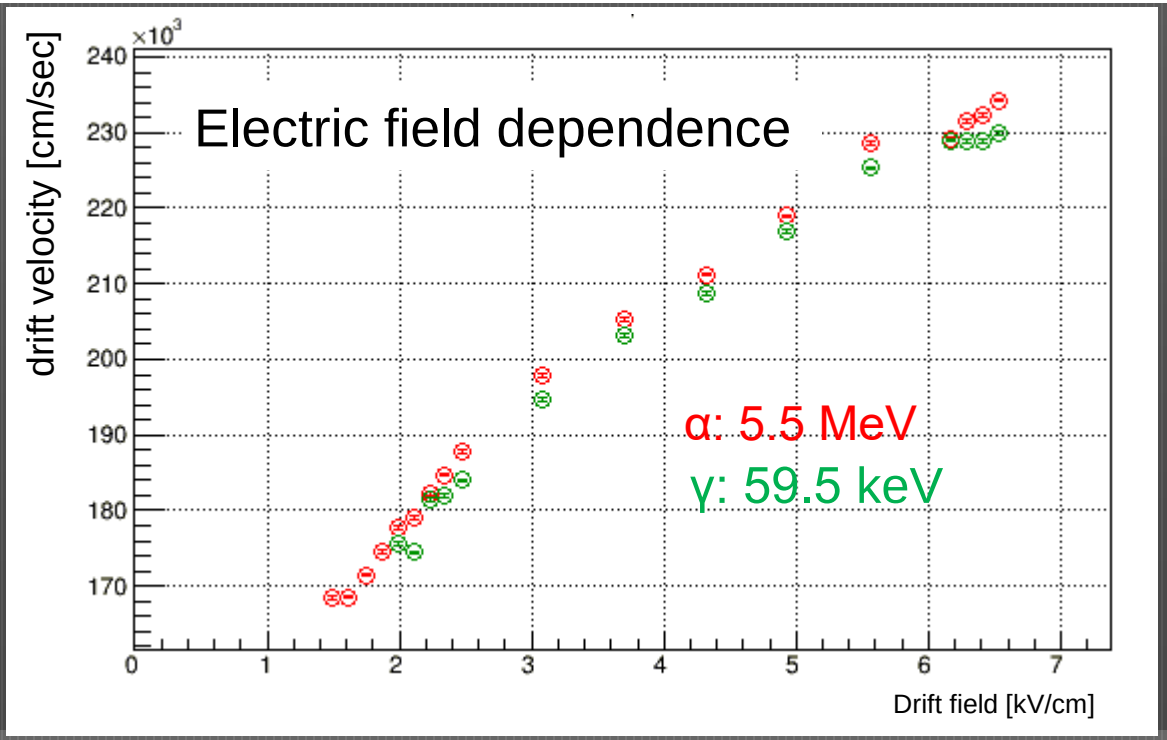


Raw events in low energy region @5kV



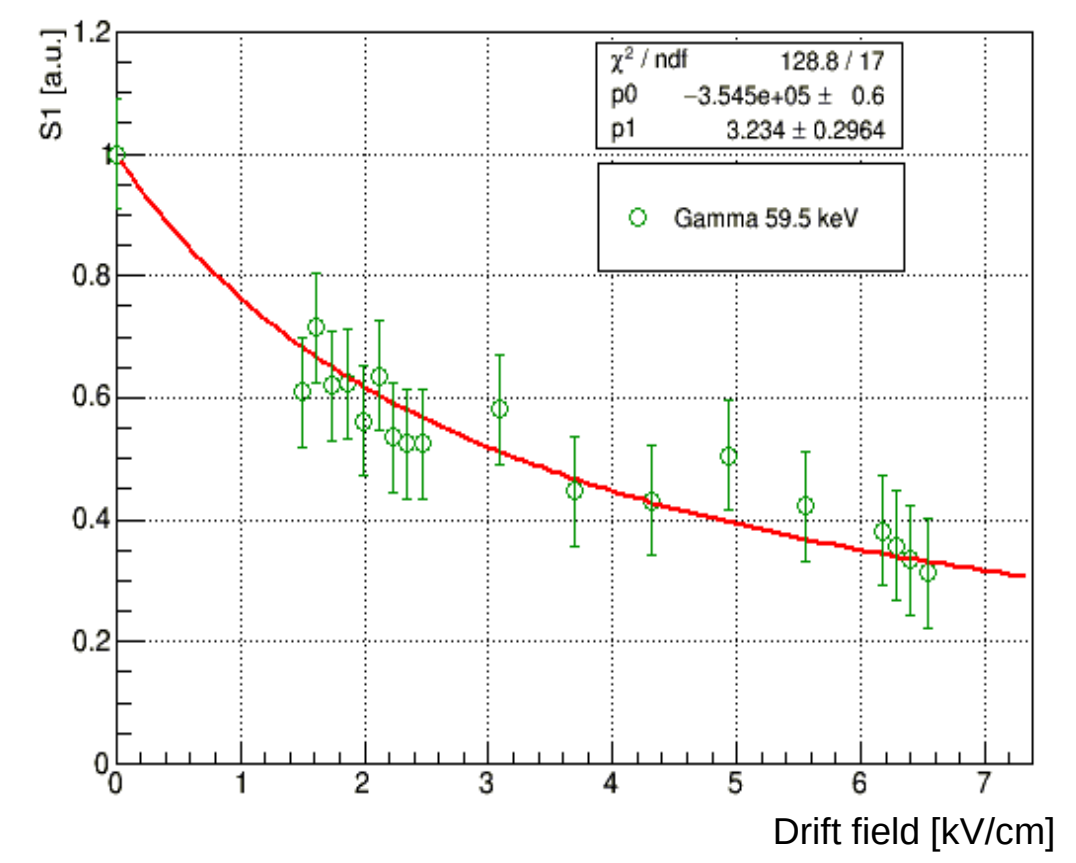
1D drift time distribution @5kV





S1: Drift field dependence

- Relative S1 amplitude



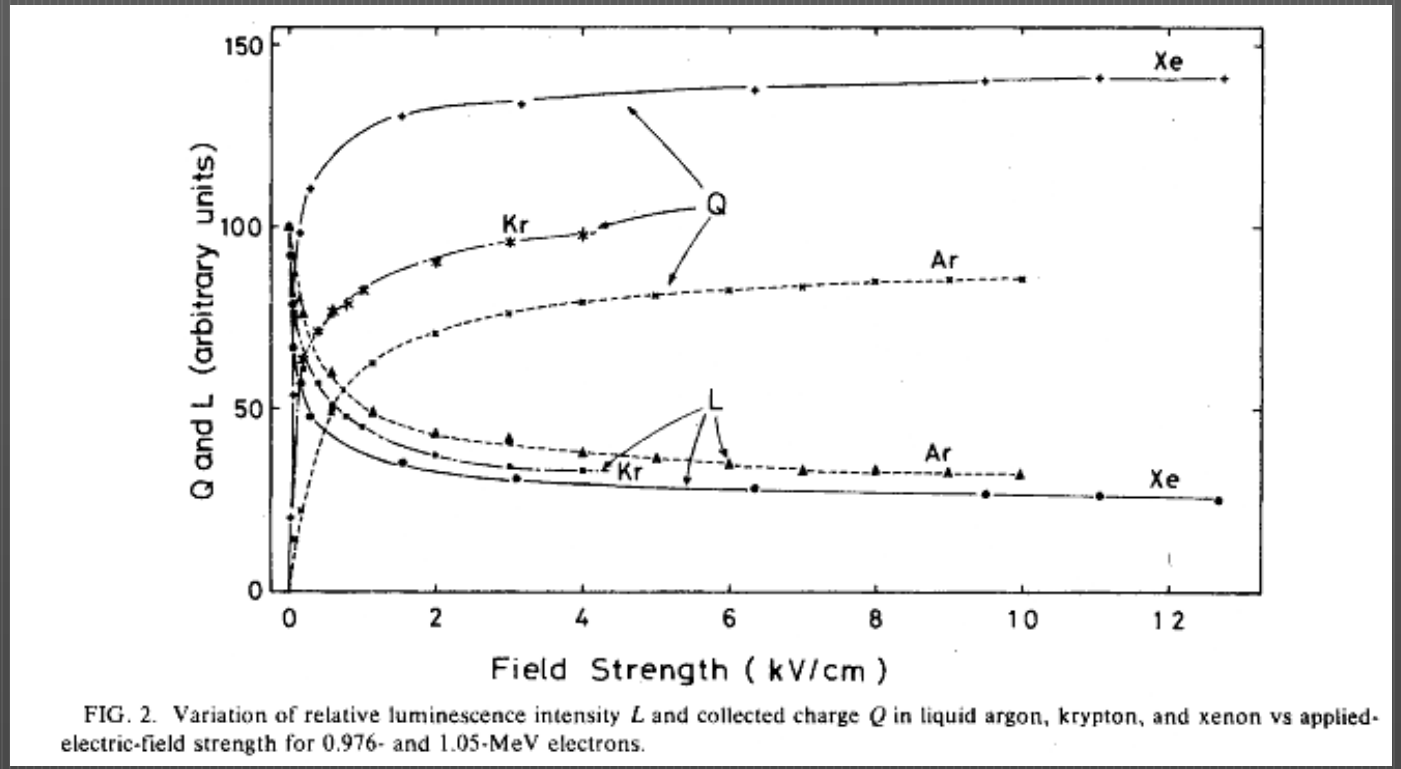


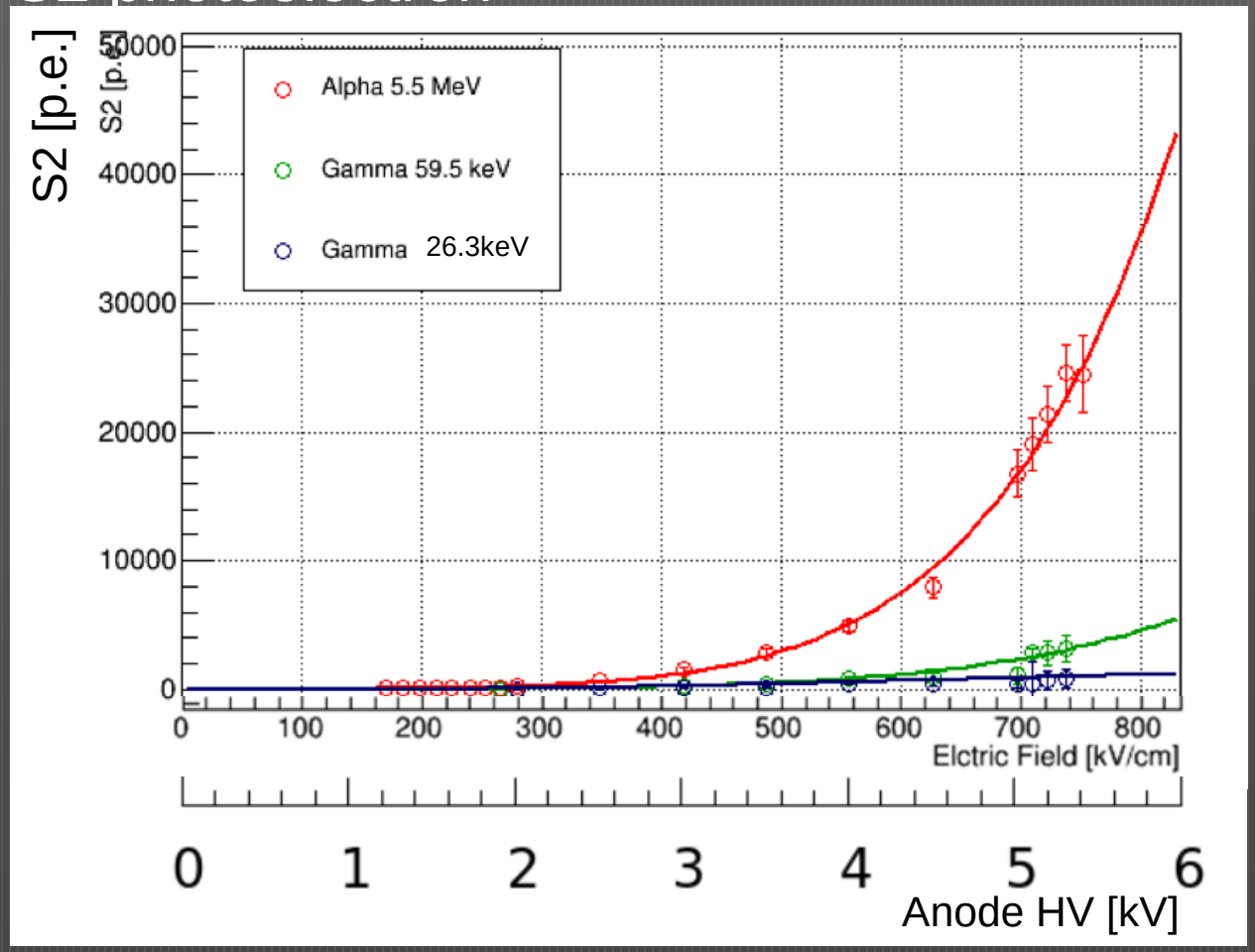
FIG. 2. Variation of relative luminescence intensity L and collected charge Q in liquid argon, krypton, and xenon vs applied-electric-field strength for 0.976- and 1.05-MeV electrons.

T. Doke et al.,Jpn. J. Appl. Phys. Vol. 41 (2002) pp. 1538–1545

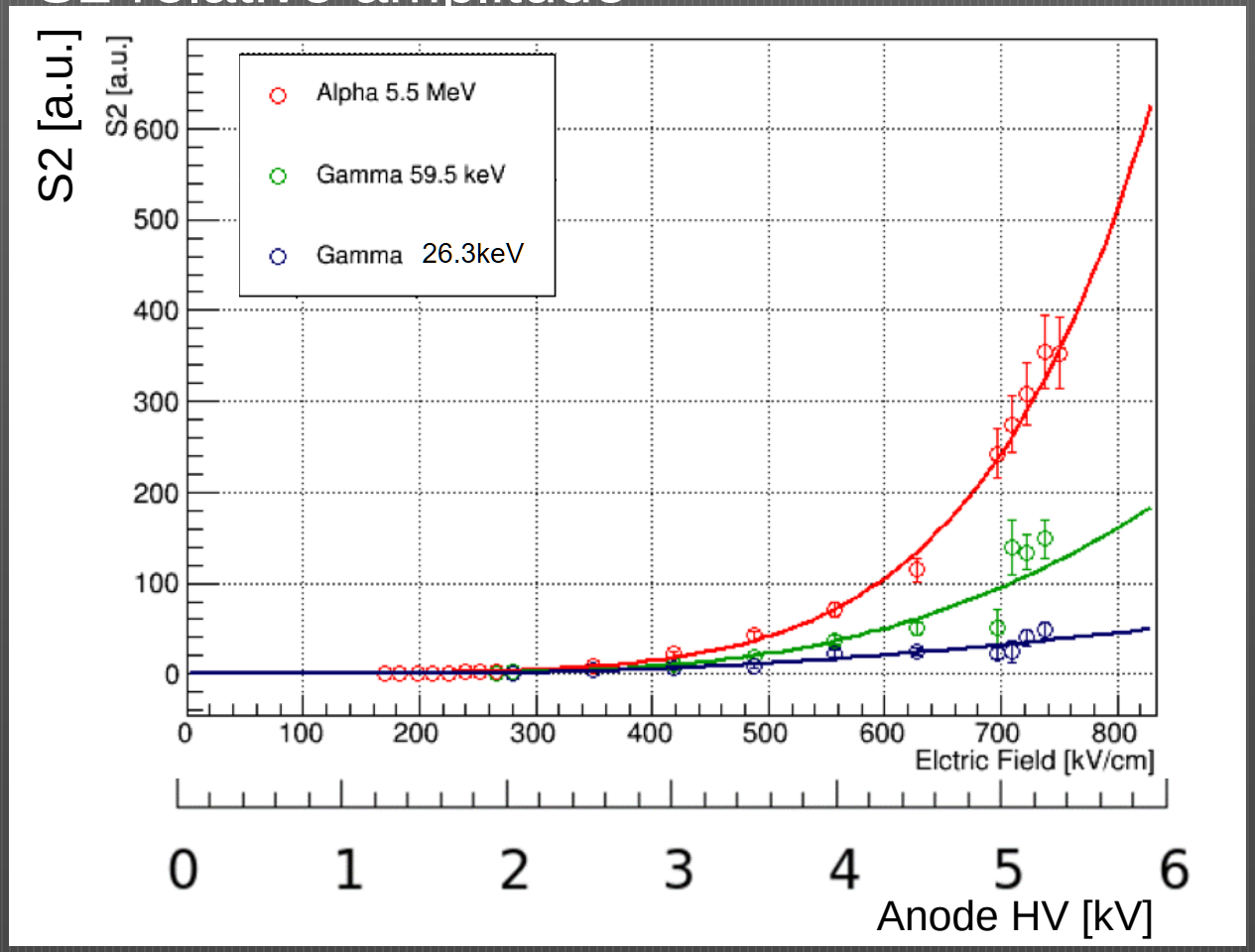
S2: Anode HV/ Field dependence

- First results for low energy gamma
- Threshold ~350kV/cm

S2 photoelectron

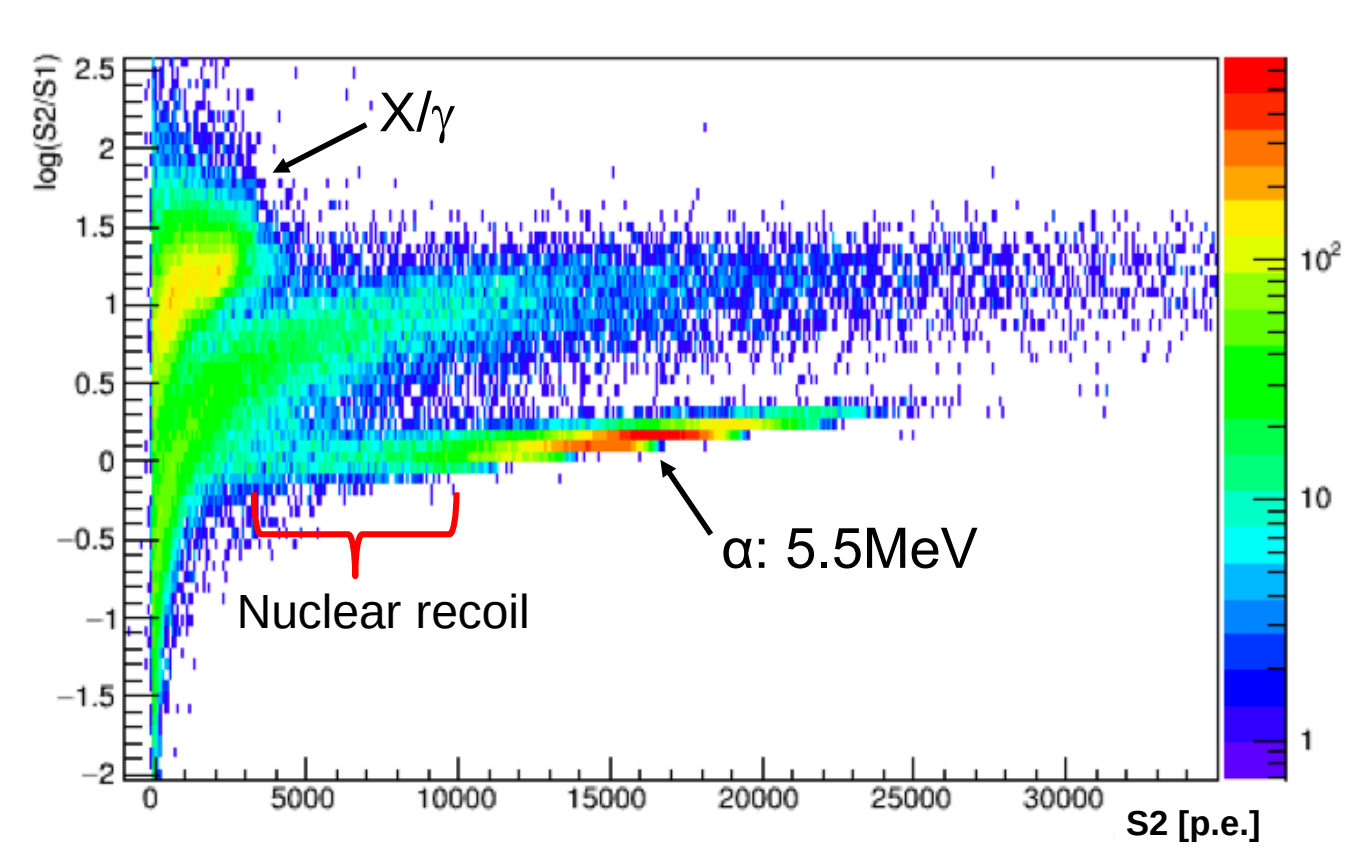


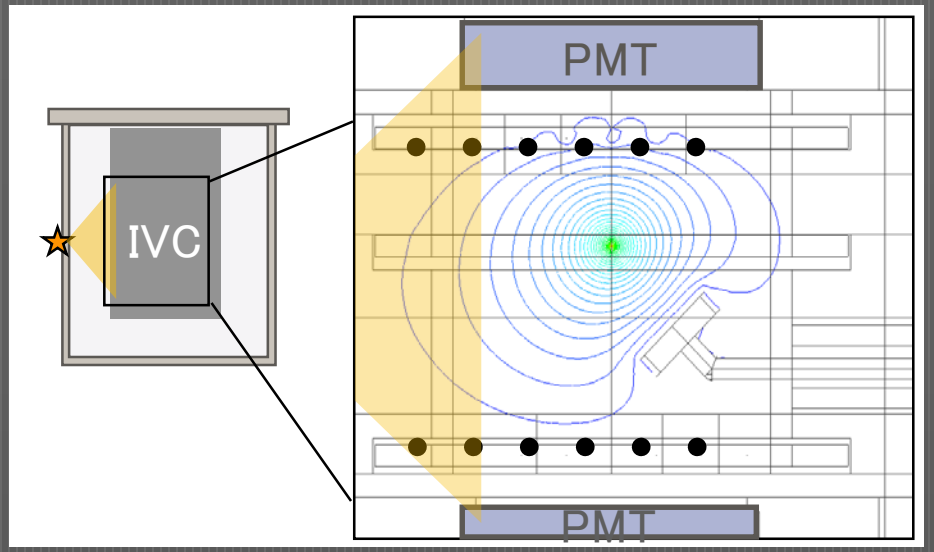
S2 relative amplitude



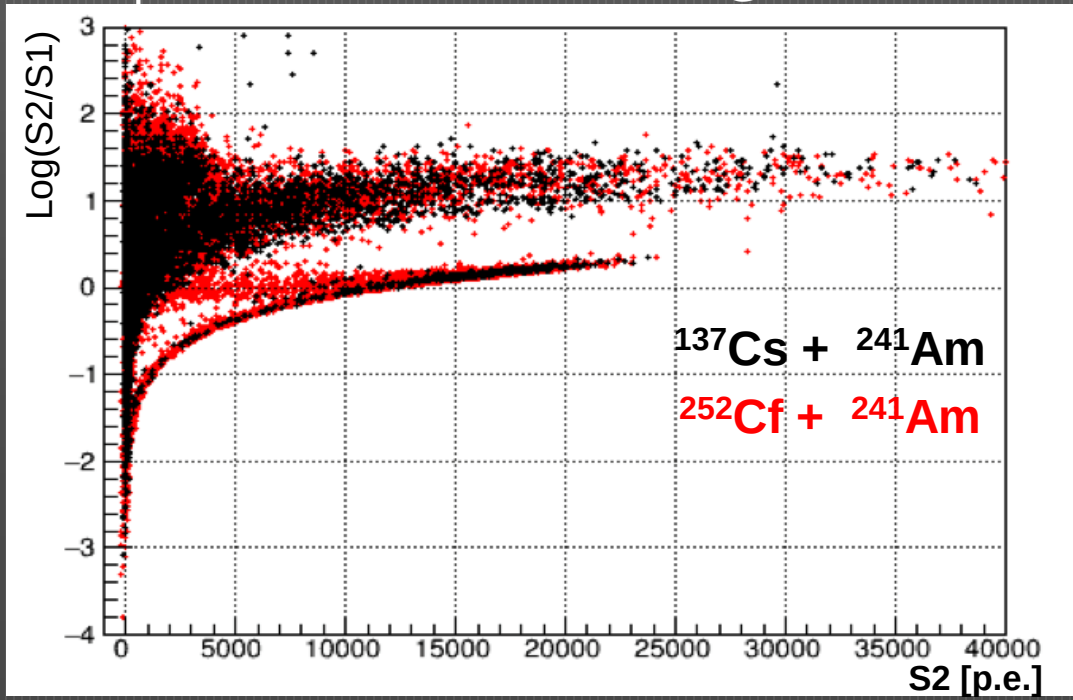
Nuclear recoils by ^{252}Cf external irradiation

^{252}Cf + ^{241}Am @5kV



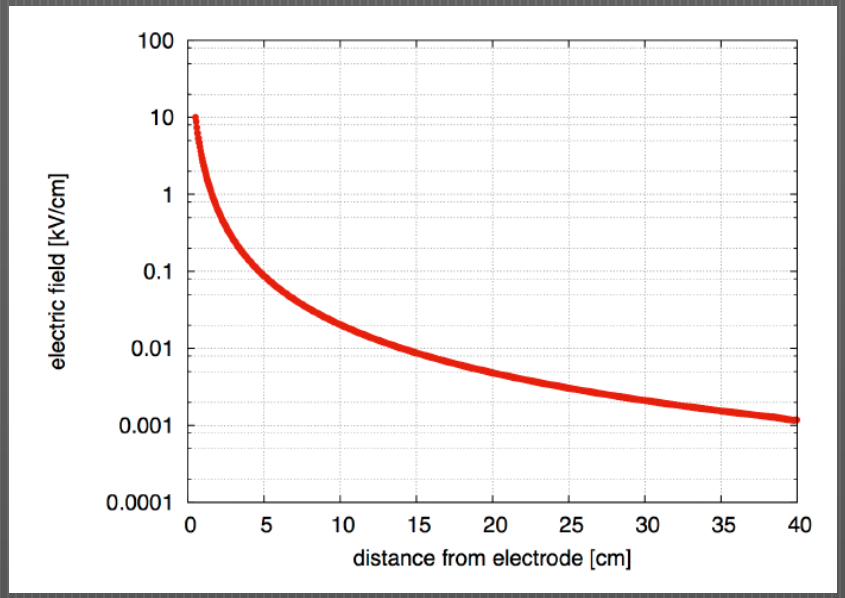


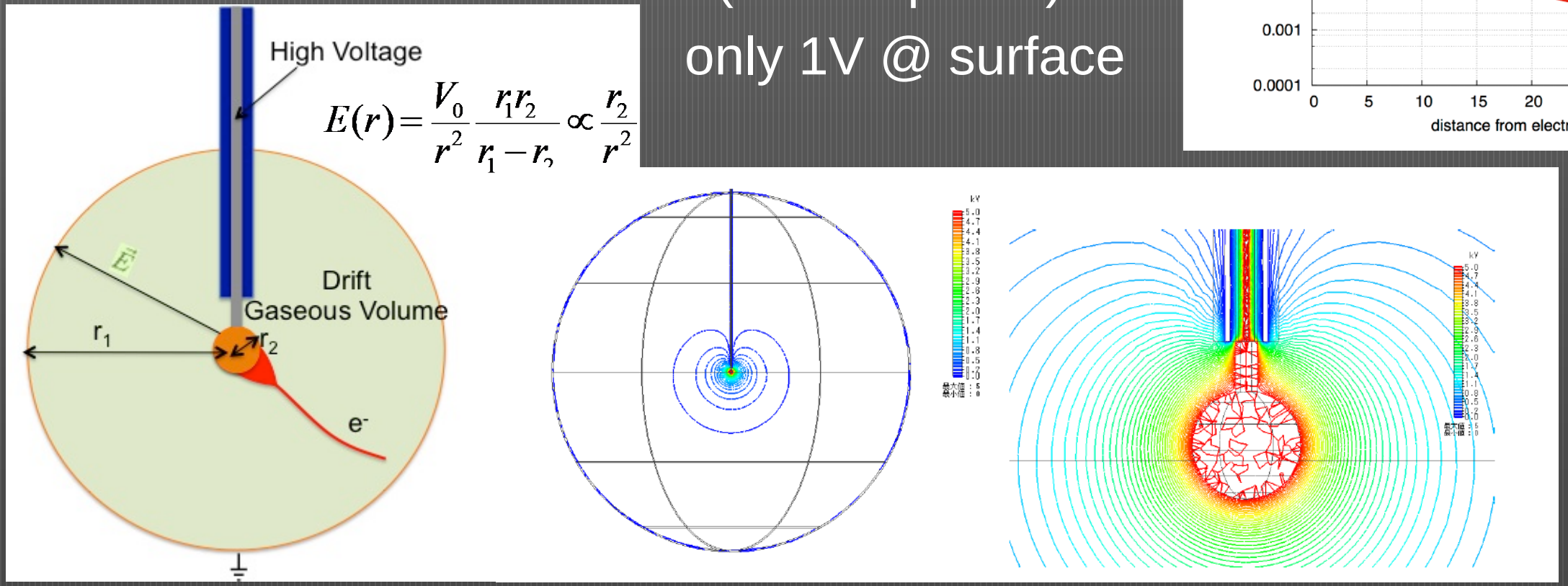
Comparison with ^{137}Cs + ^{241}Am @5kV



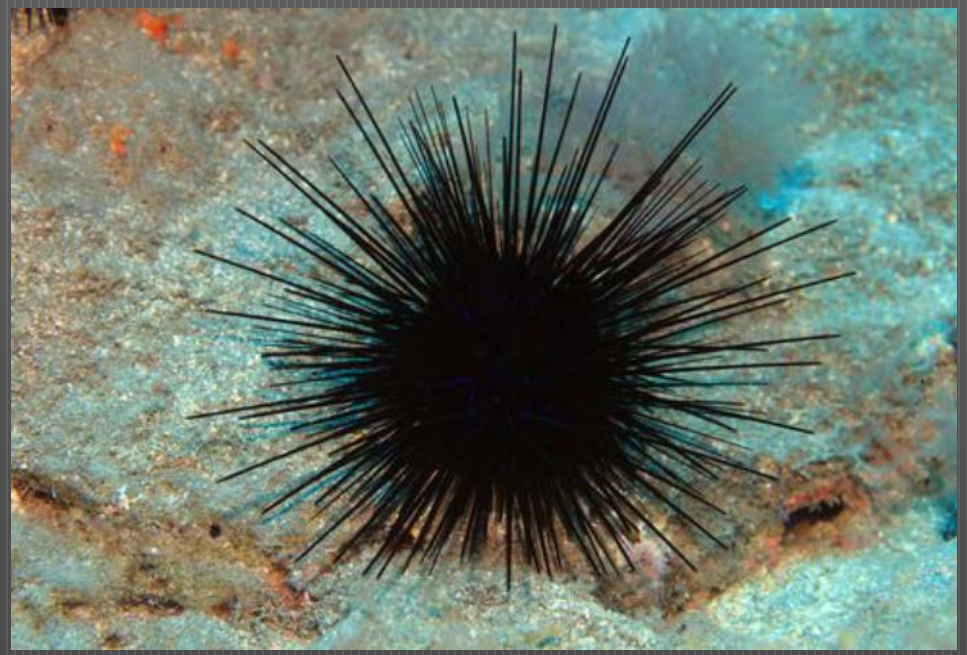
Towards spherical detector

- The issue: too low voltage @ surface
  - Simulation: 5kV 5mm ball in XMASS (80cm sphere)
    only 1V @ surface



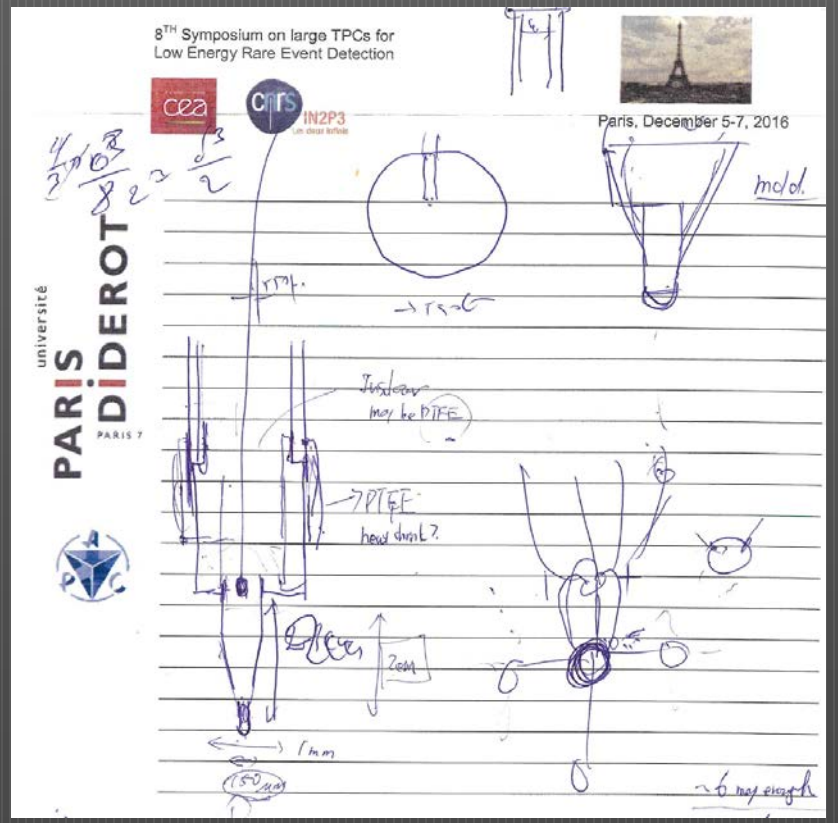


Multi ball or more Achinos-like electrode is necessary

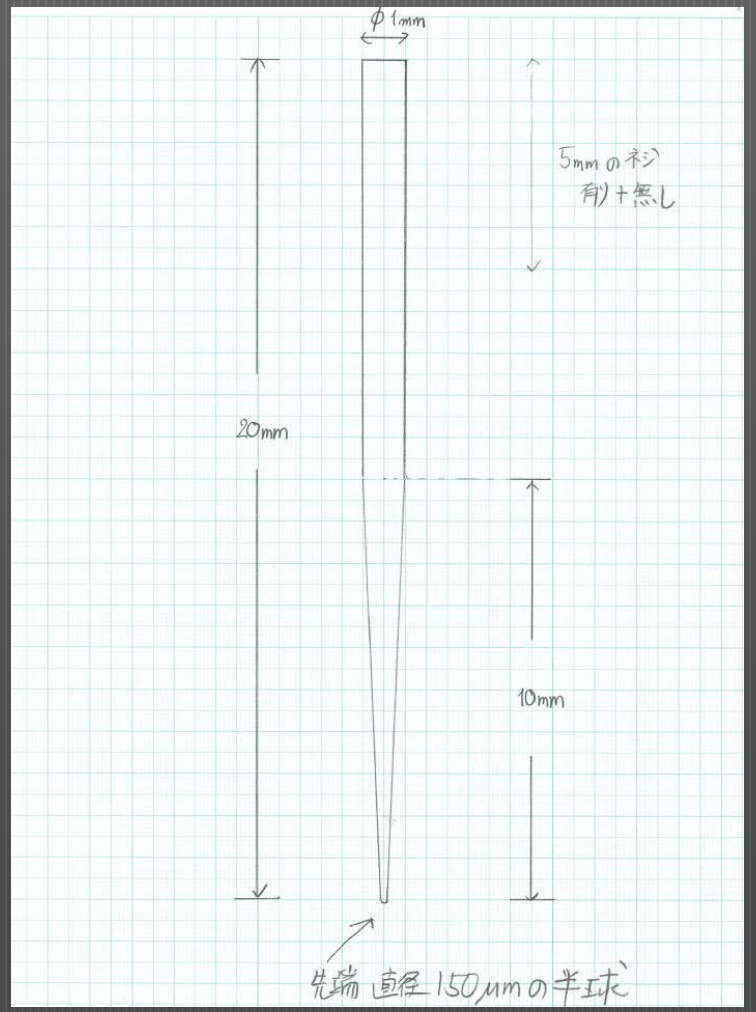


Development got started in Paris 2016

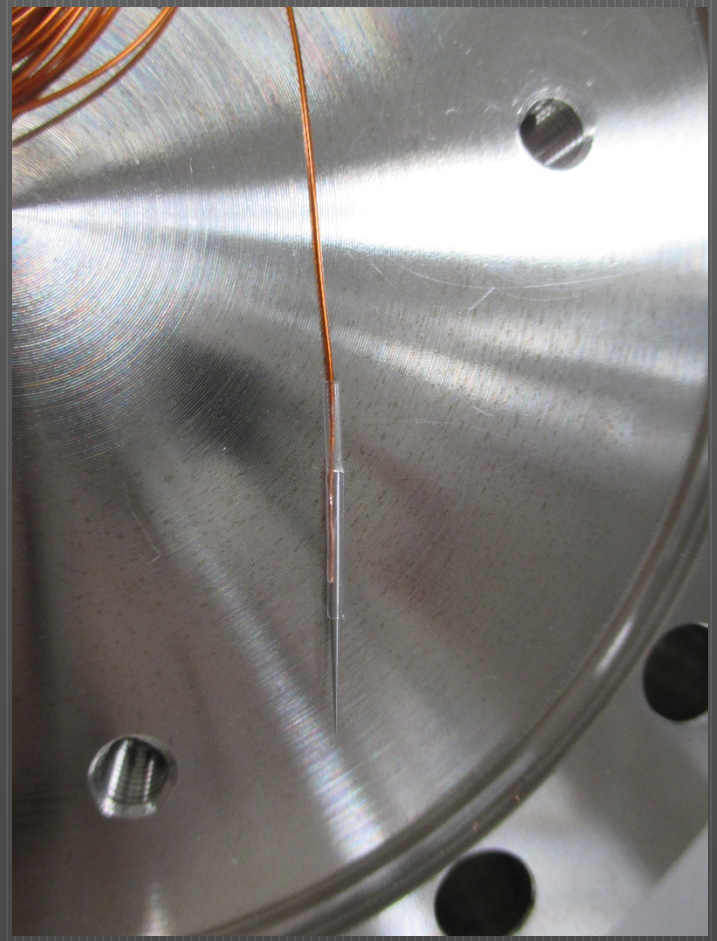
- 150μm half ball



2016 Dec.

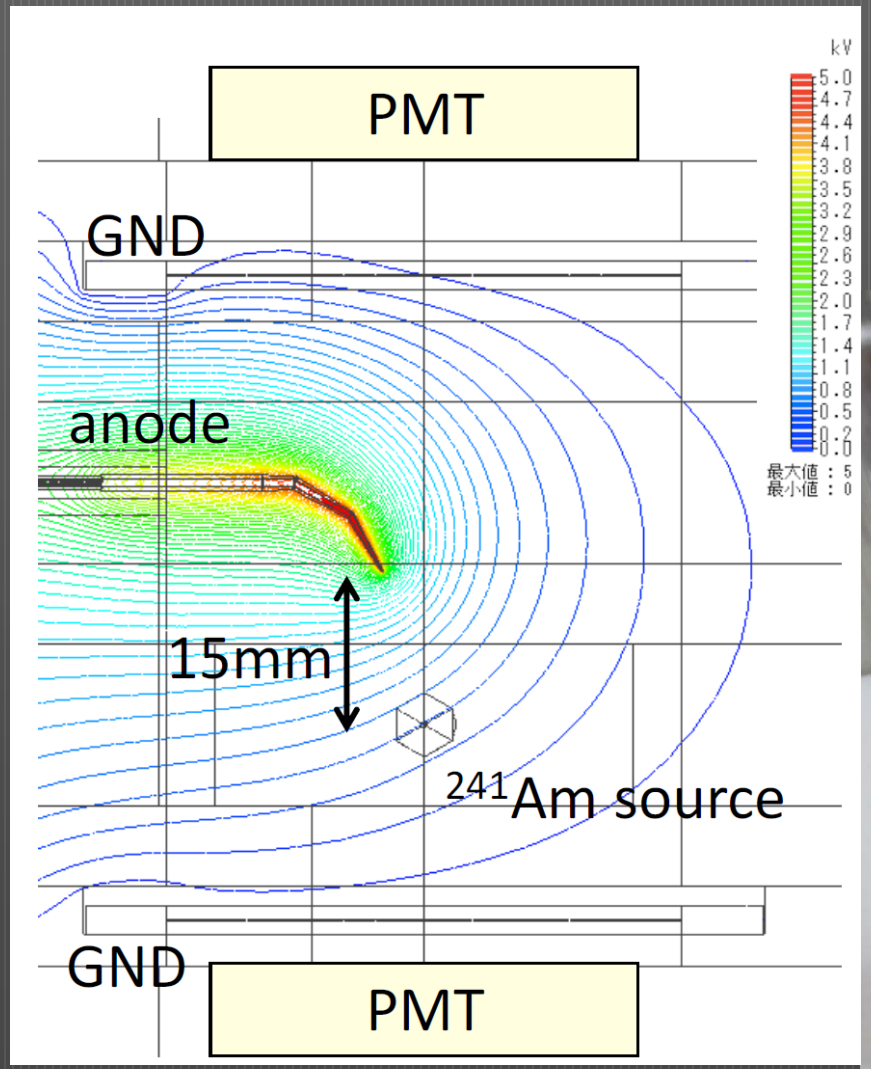


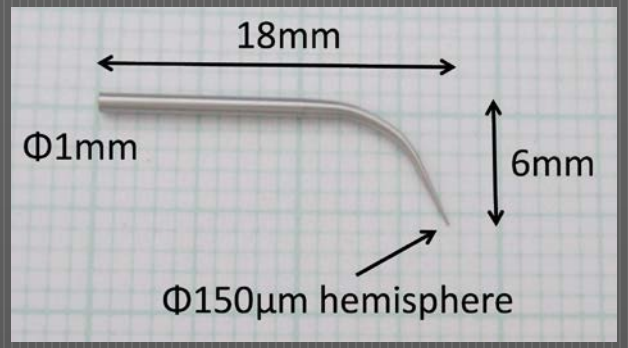
2017 Jan.

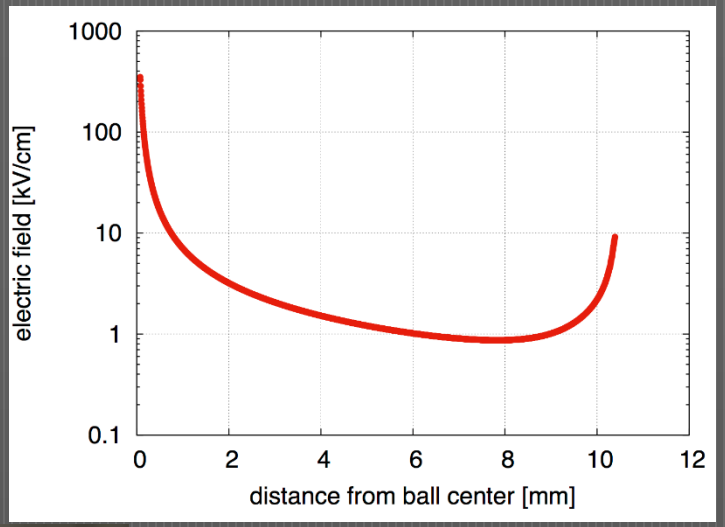


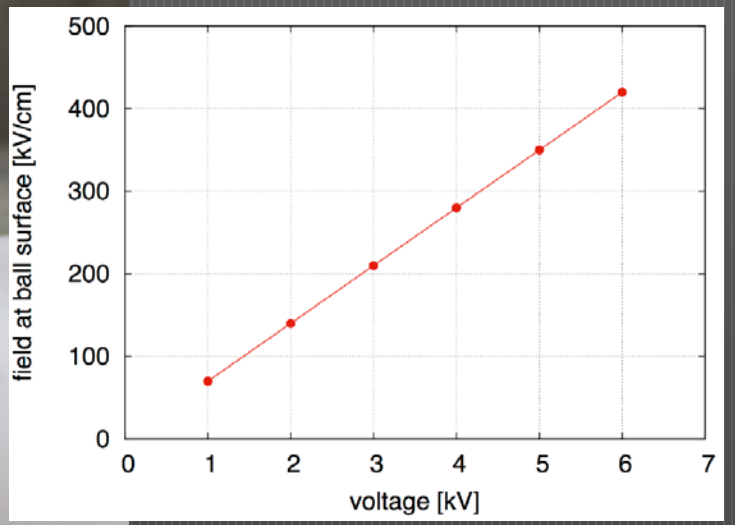
2017 Mar.

2017 Apr



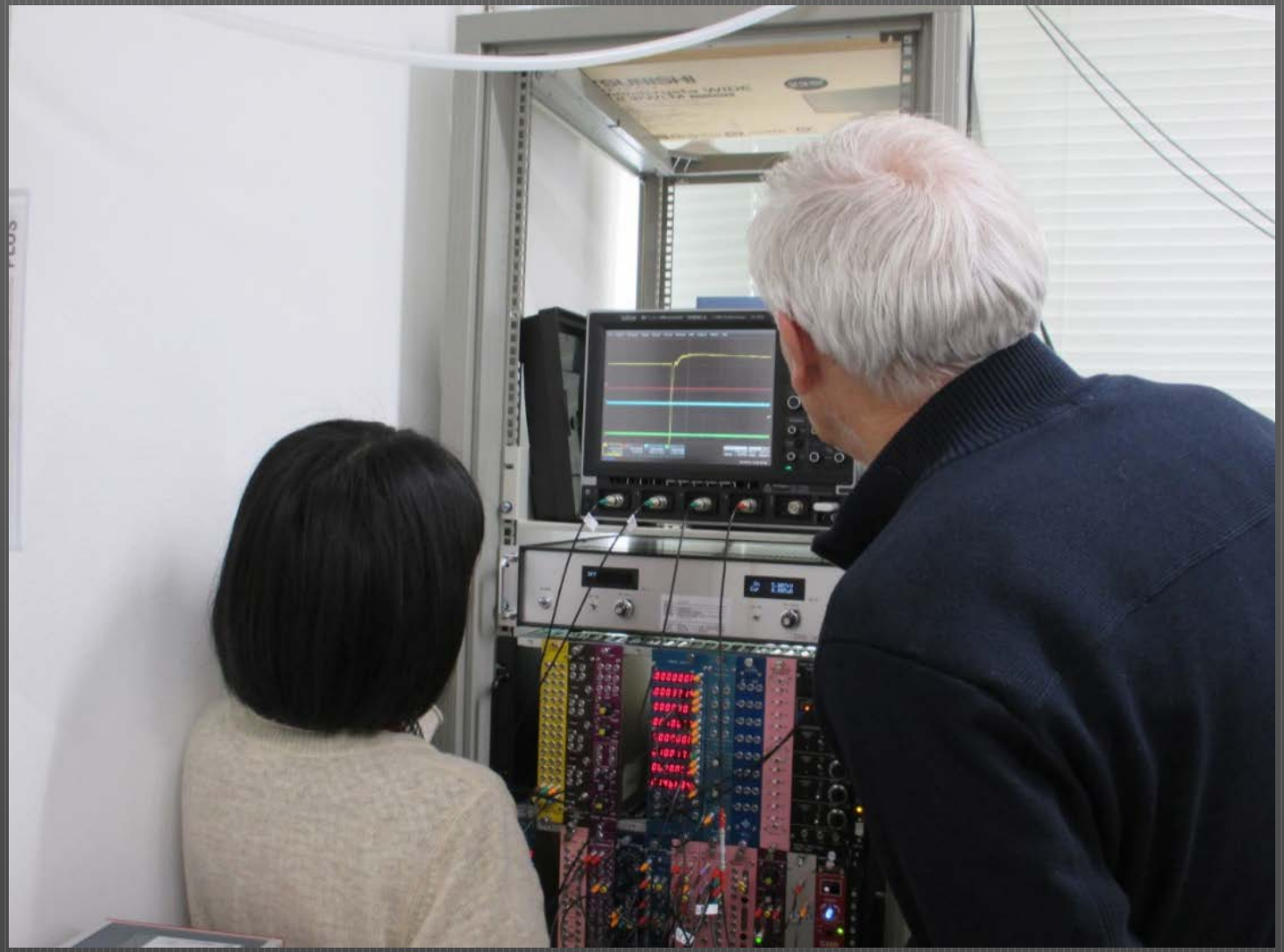






HV should be 6kV for to get 400kV/cm

2017 Apr.



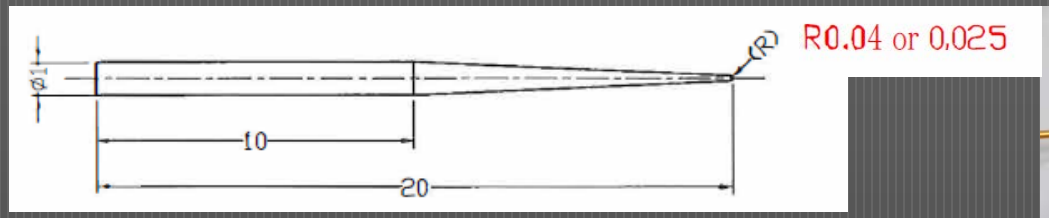
Discharge

@Feedthrogh
(PEEK)

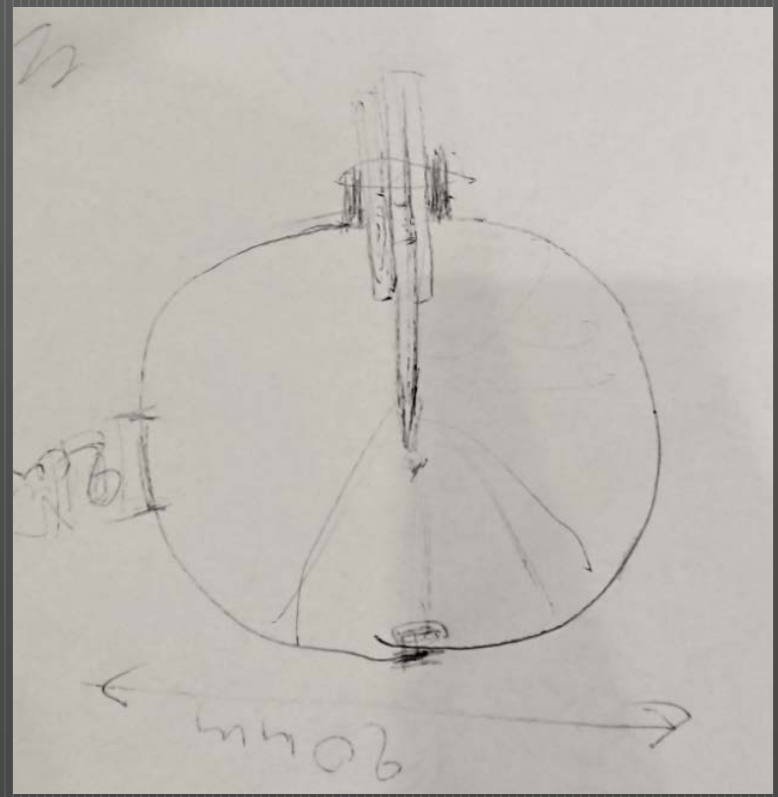
- Stable 6kV application was not achieved
- Electron collection efficiency extremely low
- Only S1 signals

Things are on-going

- The new source setup is already established.
- 80um and 50um “ball” electrode are ready.



- Spherical designs are underway
  - Tea strainer can be used as GND sphere



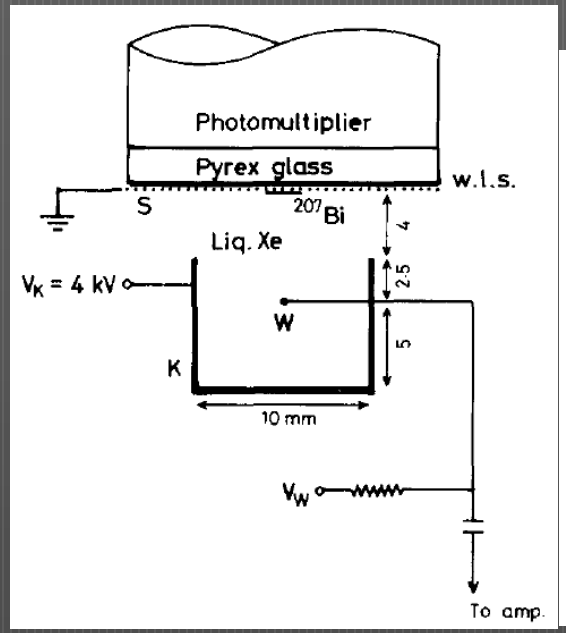
Summary

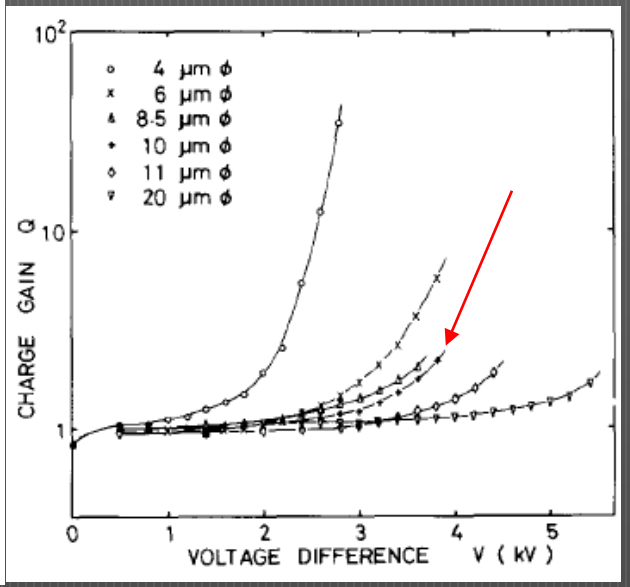
- LXe single phase detector has been tested.
- With a 10um wire, it was operated stably at 700kV/cm and S2 signals for 13.9keV X-ray was observed for the first time.
  - Demonstration of LXe single phase TPC @ ~10keV region!!
  - LY was only 4.2p.e./keV. There is room to improve!
- Single phase PID performance was also investigated.
- Design works are ongoing towards the 1st 10cm size prototype of spherical detector.

Extra slides

Previous works

- 1MeV β from ^{207}Bi
  - S2 threshold 410kV/cm
- 5.3MeV α from ^{210}Po
  - S2 threshold 412±10kV/cm





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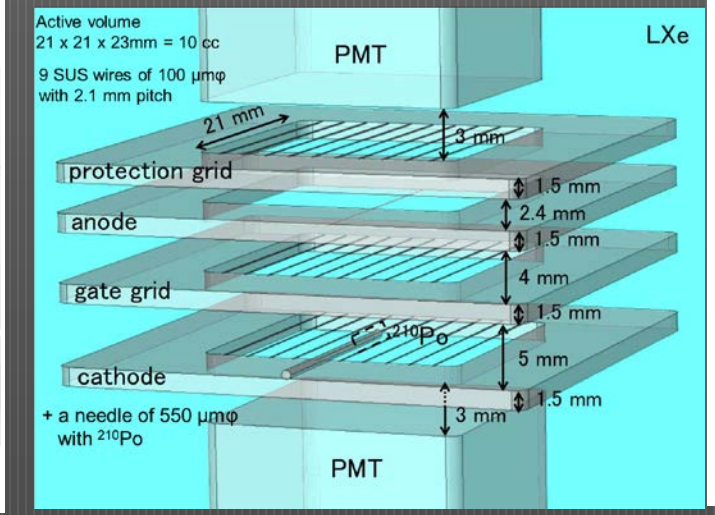

E. April et al. JINST 9(2014) P11012