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Grant Number 257070150 and 25610054

R&D towards spherical LXe TPC

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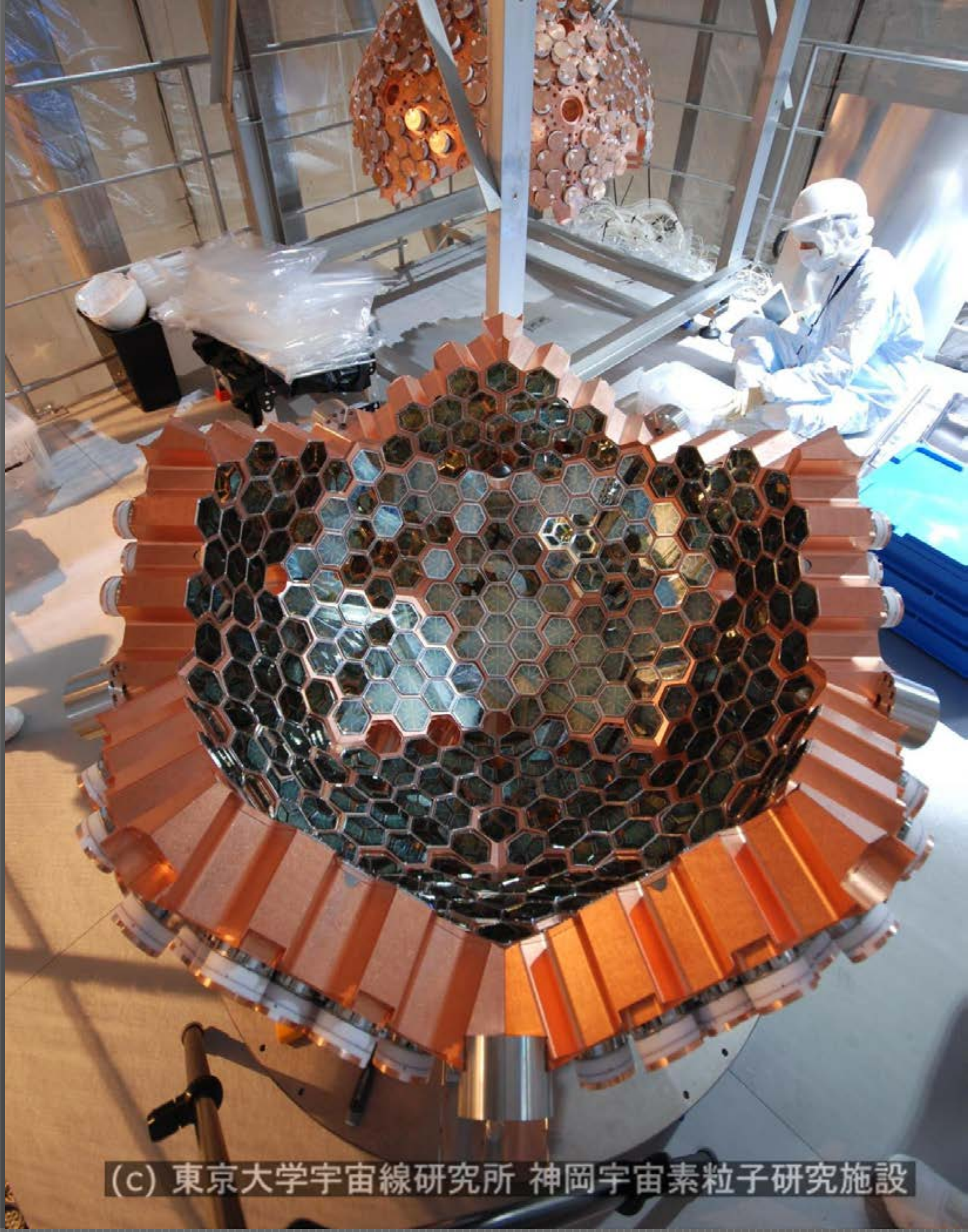
Irfu, CEA Saclay

8th symposium on large TPCs for low-energy rare event detection, Paris, Dec. 5 2016

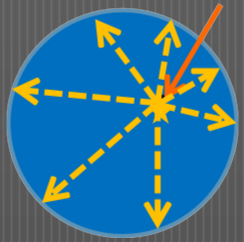
Motivation

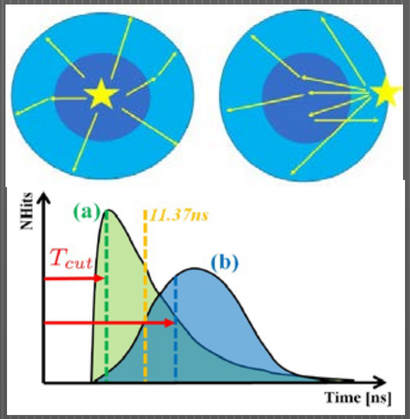
- XMASS
  - LXe spherical detector



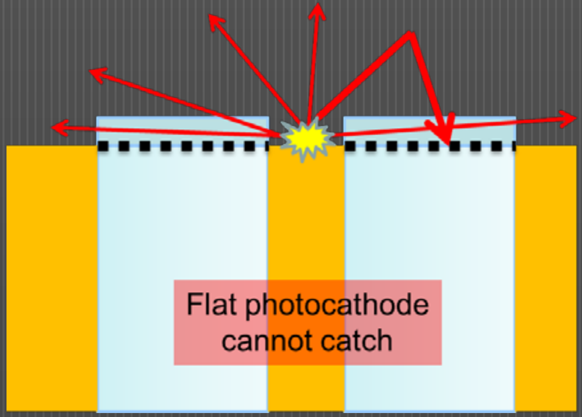
Surface background problem in low energy region

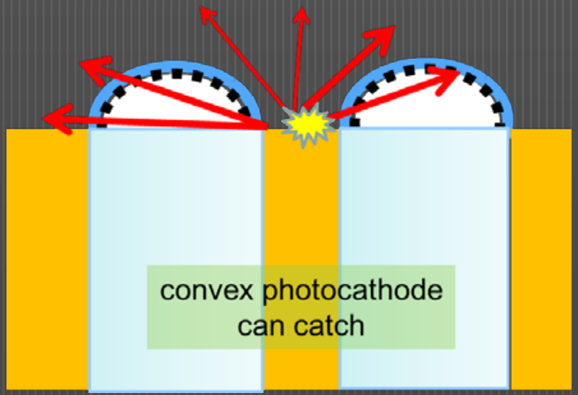
- Software vertex reconstruction with Q & T information of scintillation light may fail when the number of photoelectron is limited.
  - Especially surface BG events would be mis-reconstructed in the fiducial volume.
- Improvement of the hardware is indispensable.
  - New PMTs for XMASS 1.5





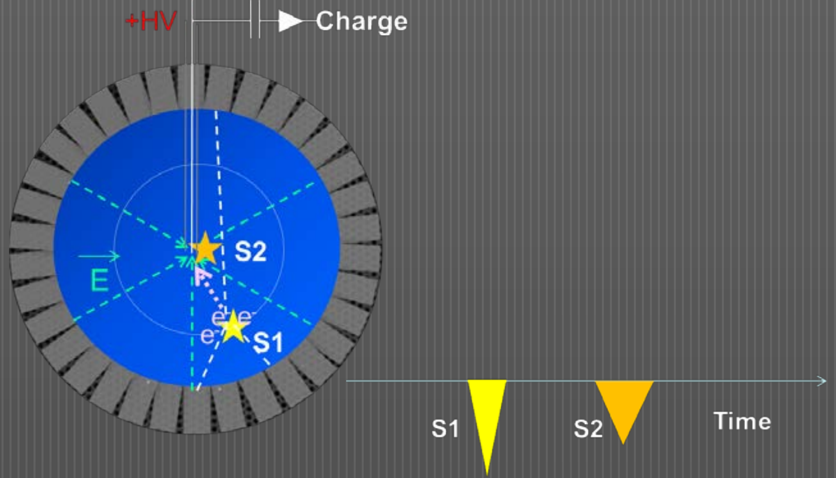
Q reconstruction and T cuts



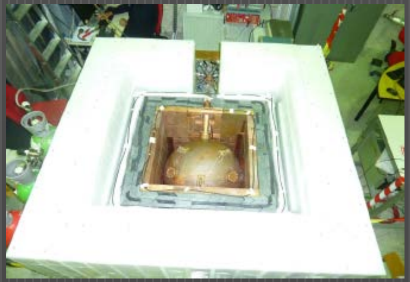


TPC hardware vertex reconstruction

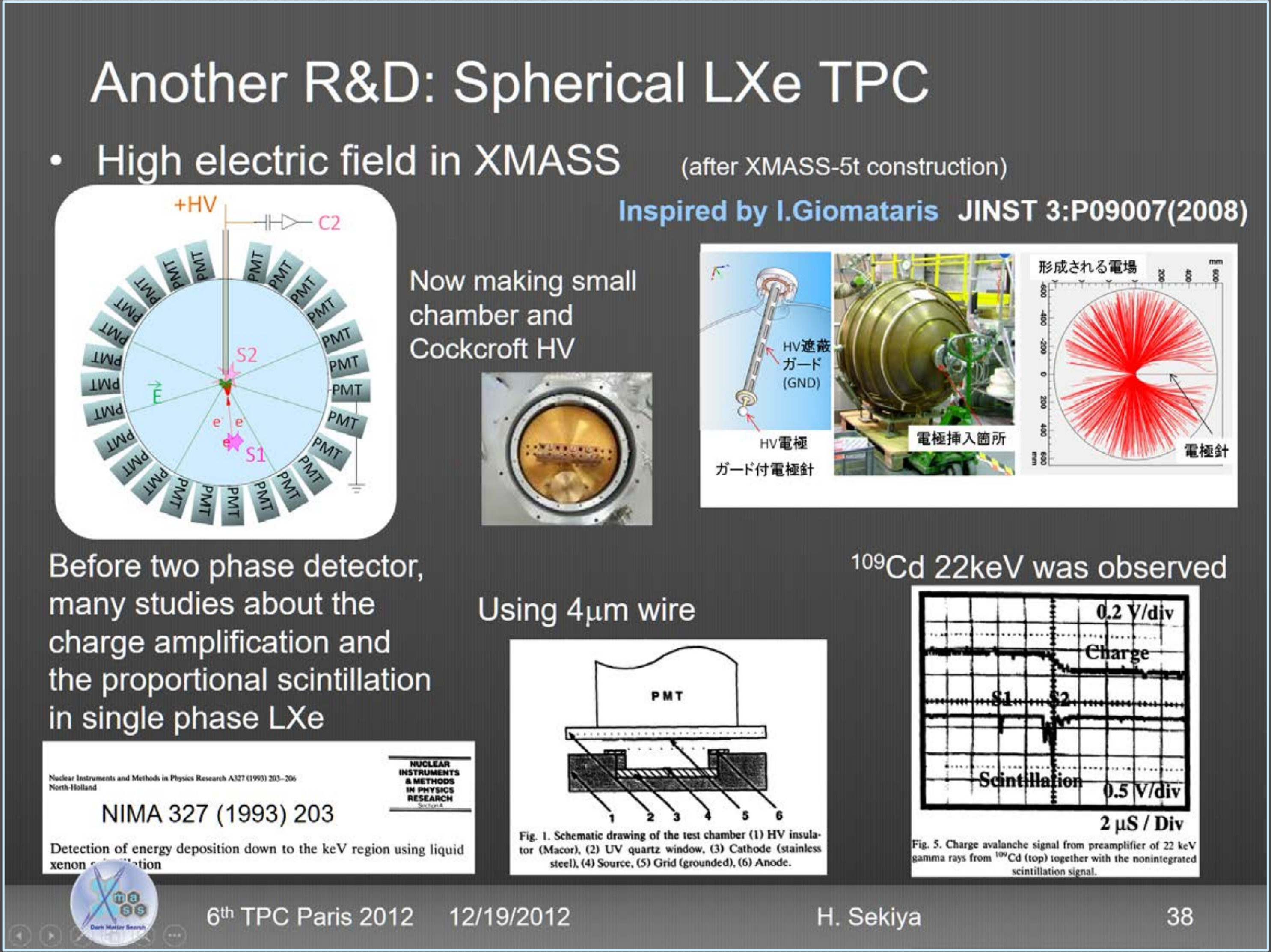
- Single phase TPC



– Liquid NEWS?



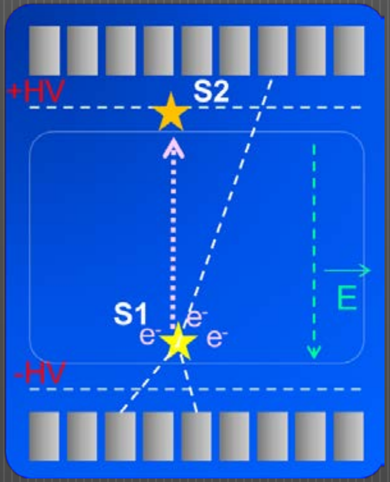
Taken from Ioannis's 7th TPC Paris

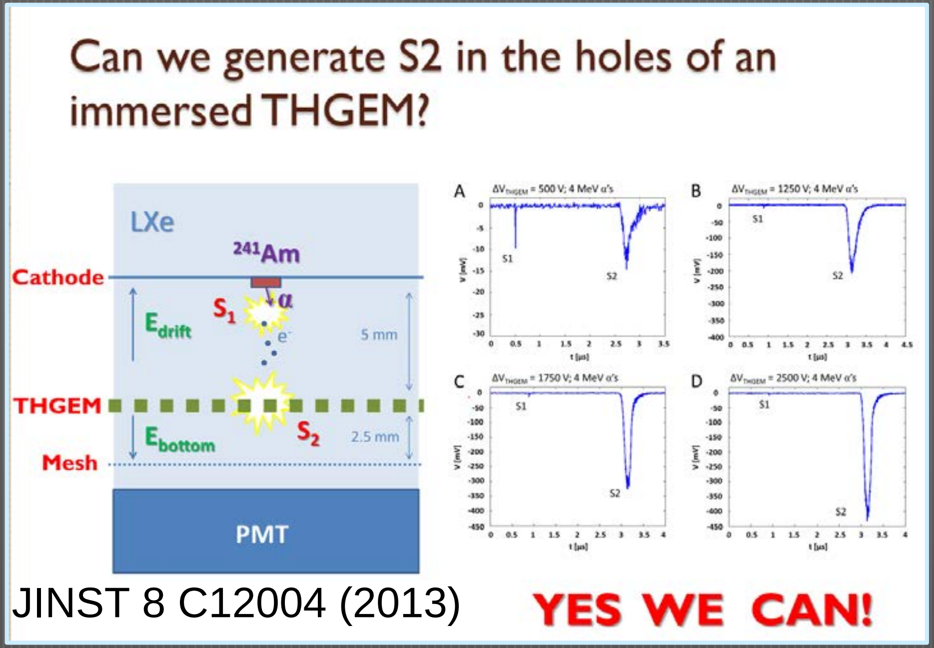


L. Arazi and A. Breskin et al.

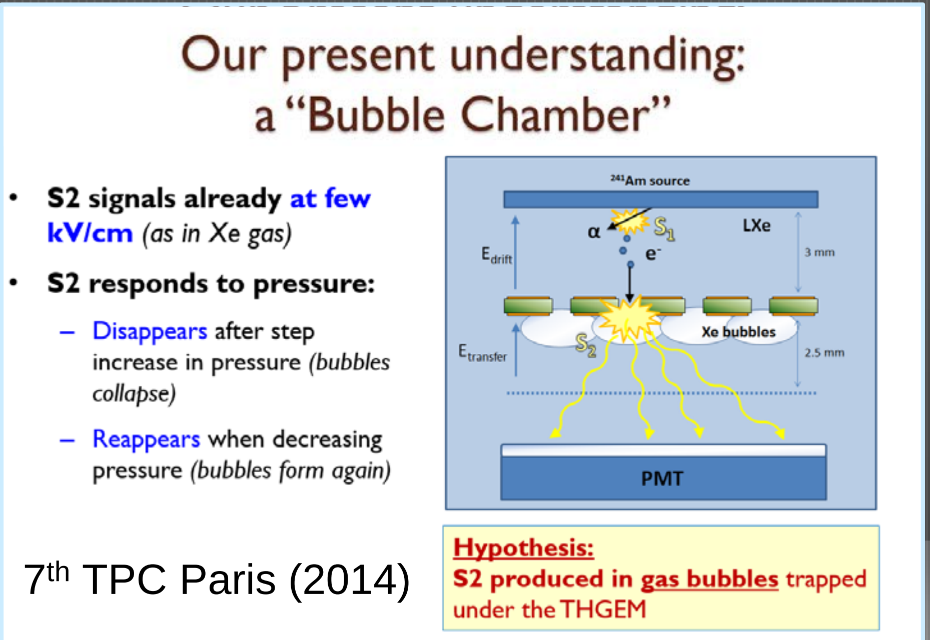
S2 in Liquid?

- Spherical shape is not good for first tests.
- Needle electrode is not the first thing to be test in Liquid.
- MPGD?   THGEM?
- Glass GEM! It's not cracked in LN2!





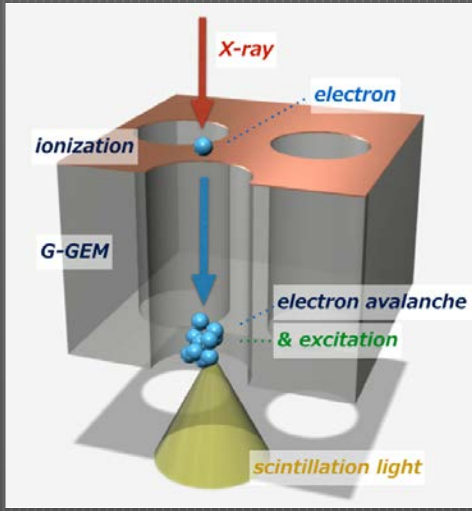
JINST 8 C12004 (2013)

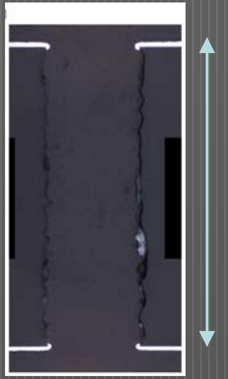


7^{th} TPC Paris (2014)

The Glass GEM

- Photo-sensitive glass substrate: PEG3





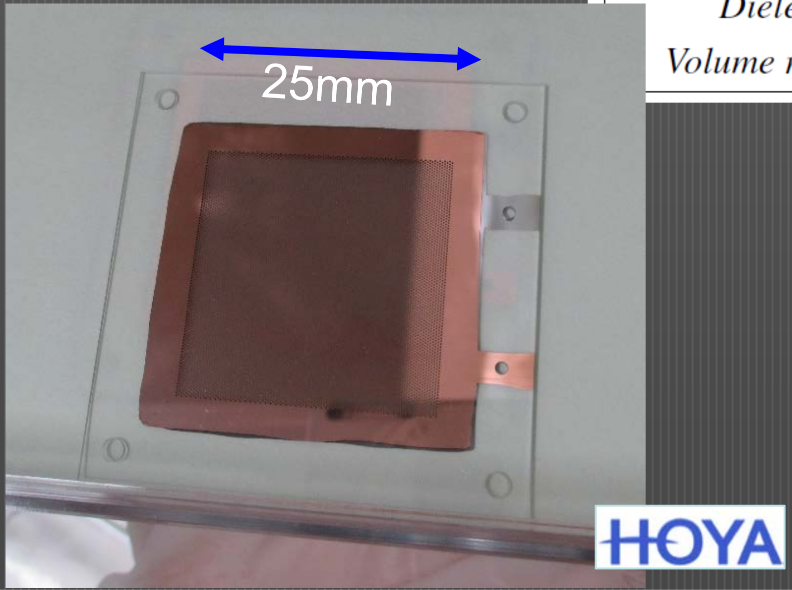
680µm

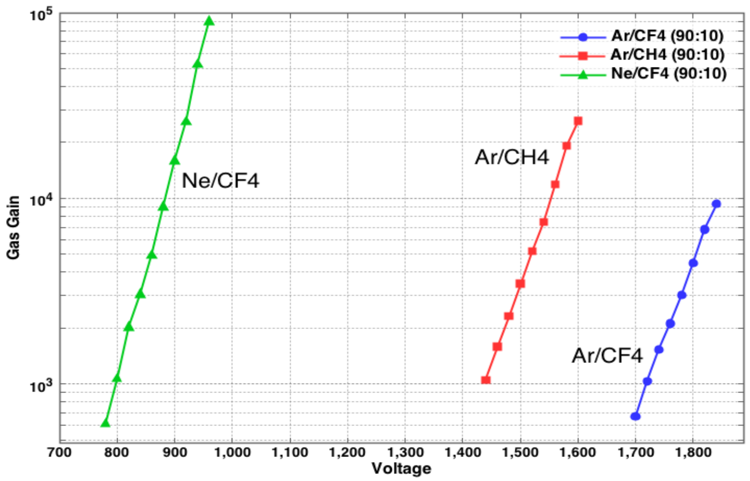
T. Fujiwara et al., JINST 9 P11007 (2014)

Type of GEM	*Glass GEM*	*CERN GEM*
Hole diameter	170 µm	50 µm
Pitch	280 µm	150 µm
Thickness	680 µm	50 µm
Insulator	Glass	Polyimide

Material	*PEG3*	*Polyimide*
Thermal conductivity @25°C (W/m K)	0.795	0.3 (@20°C)
Young's modulus (GPa)	79.7	18.6
Dielectric const. @1 GHz	6.28	3.55
Volume resistivity @25°C (Ω cm)	8.5×10^{12}	$\sim 10^{18}$

- Newly designed 25mm x 25mm G-GEM →
  – Available up to 300mm x 300mm

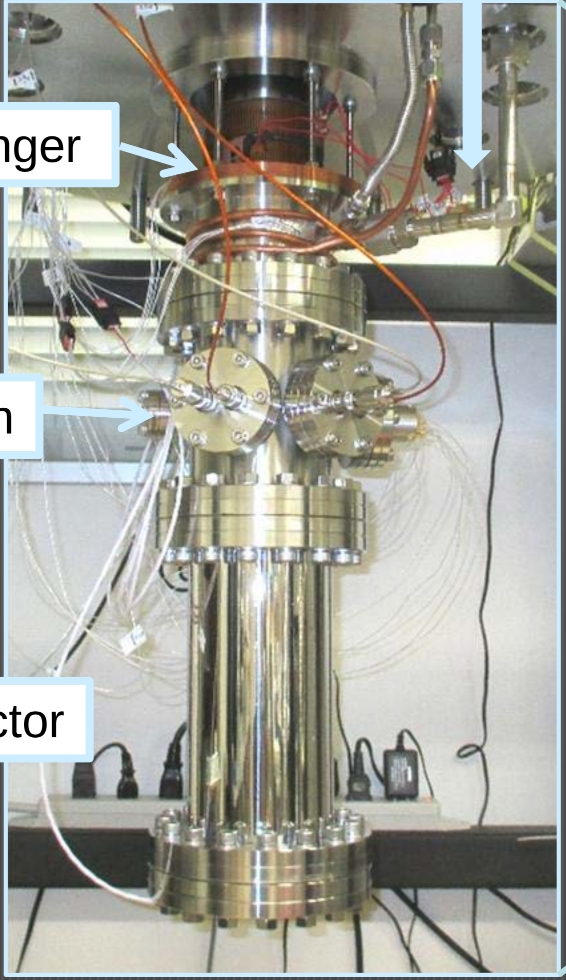


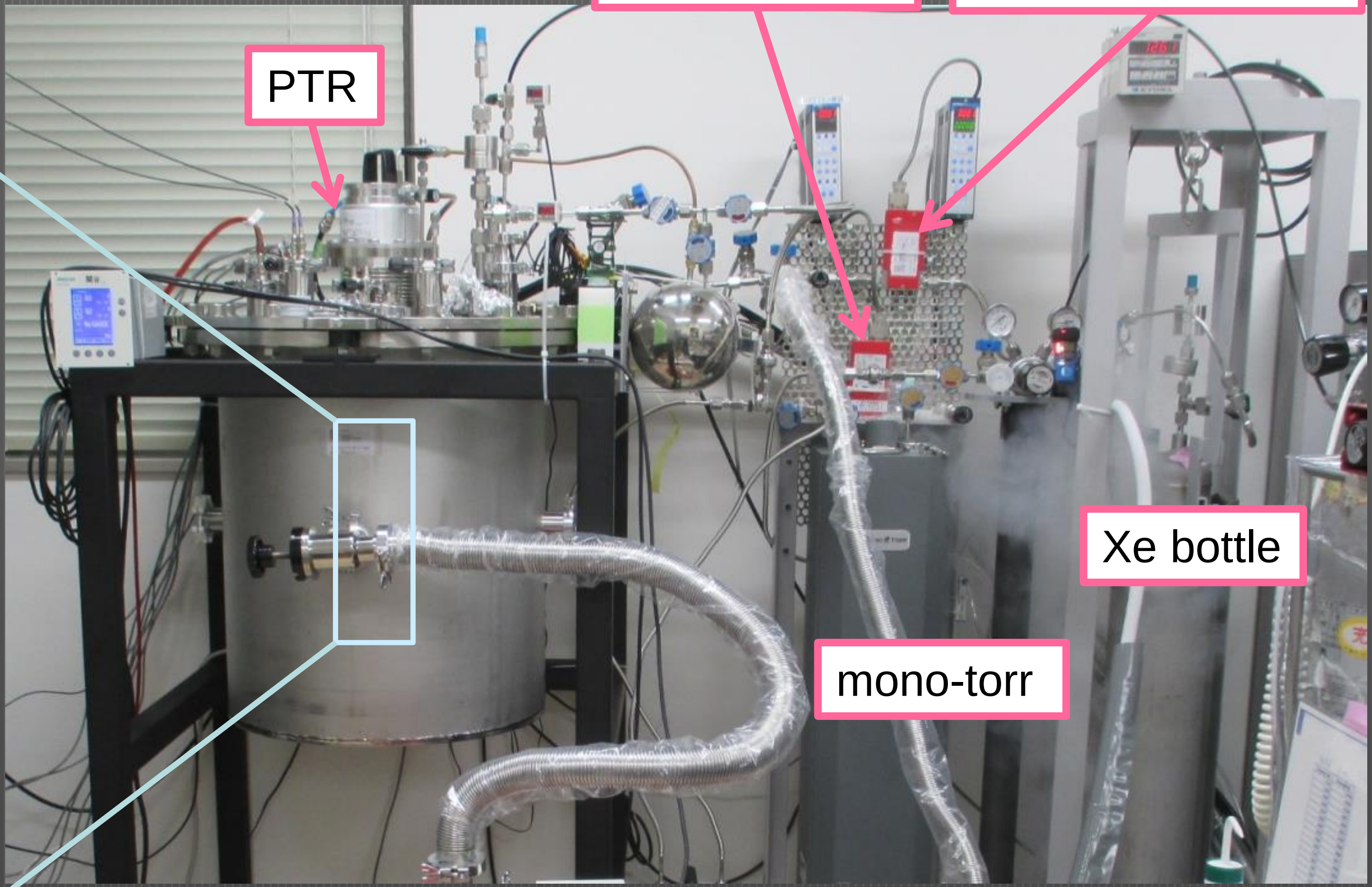


Cryogenics

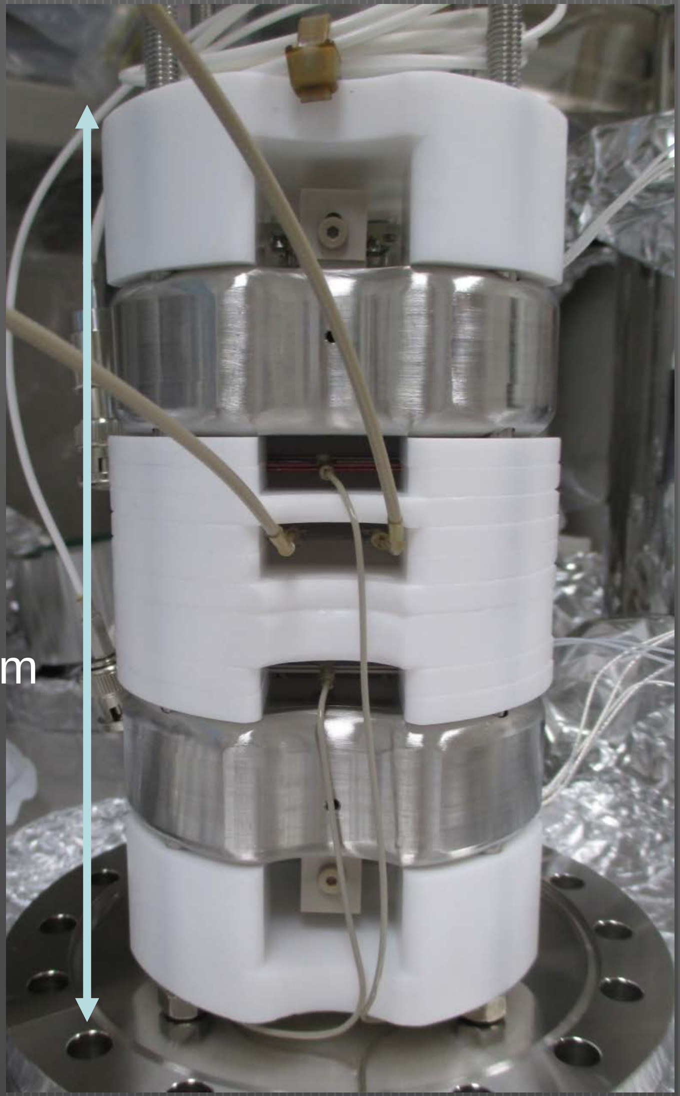
LXe operated at
Temperature -101.9^{o}C
Pressure 0.045MPa(G)

- Inside of the chamber



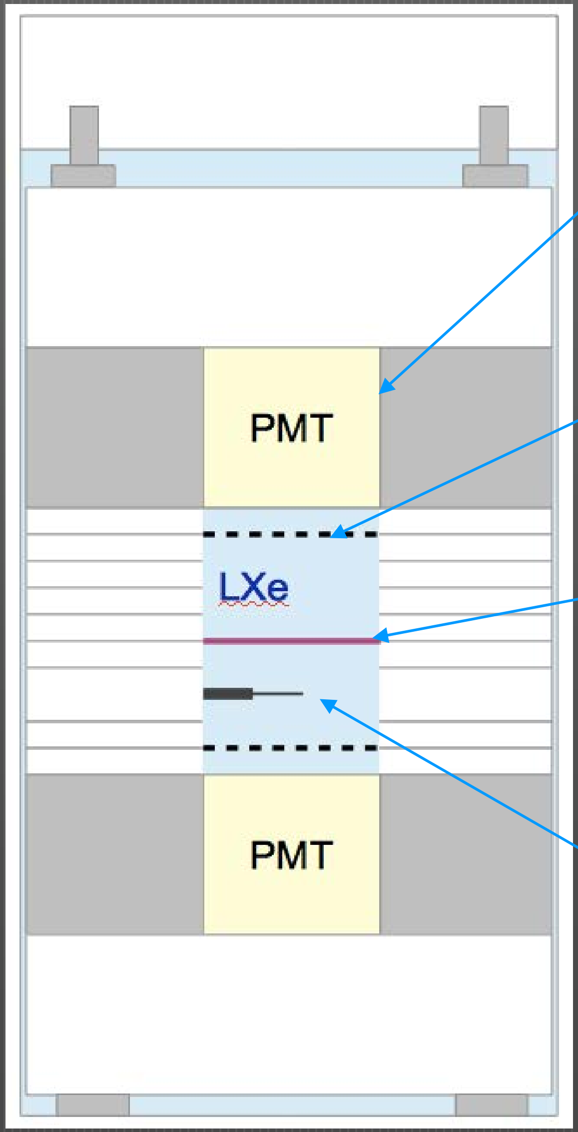


The glass GEM setup



170mm

50mm



Hamamatsu
R8520-406

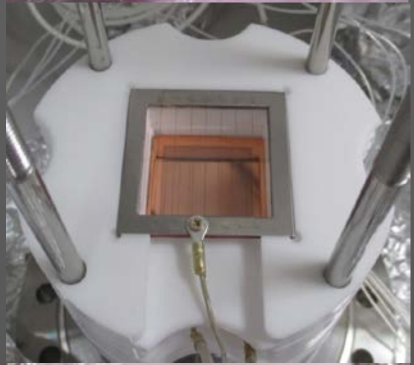
24mm□
+HV

GND wires

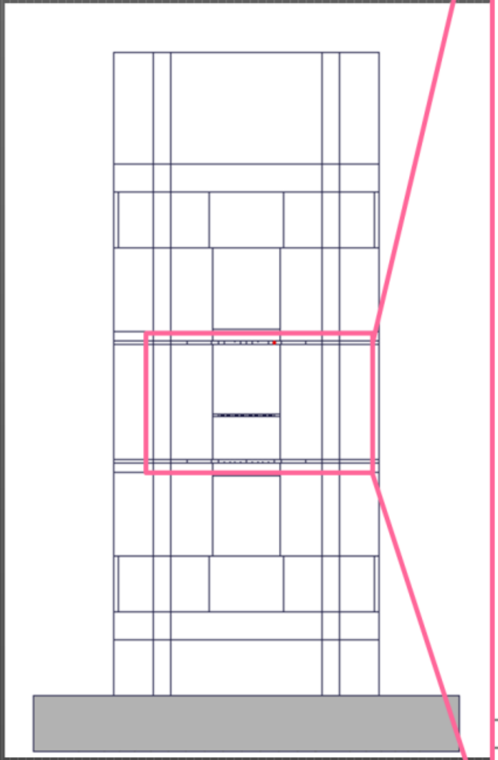
Glass GEM

^{241}Am

γ: 59.5, 26.4keV
X: 20.8, 17.8, 13.9keV
α: 5.49, 5.44MeV

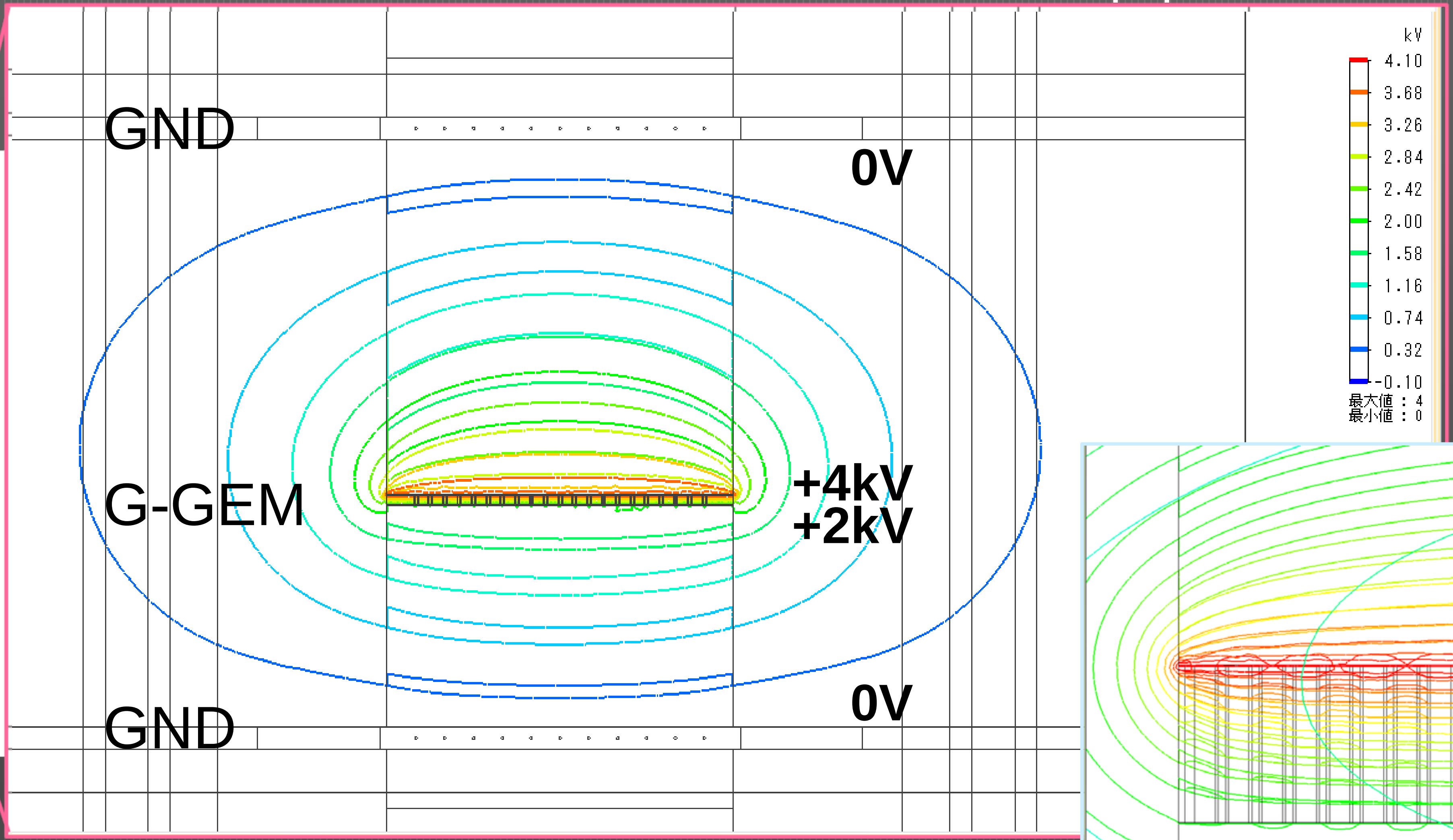


Expected electric field



Femtet®

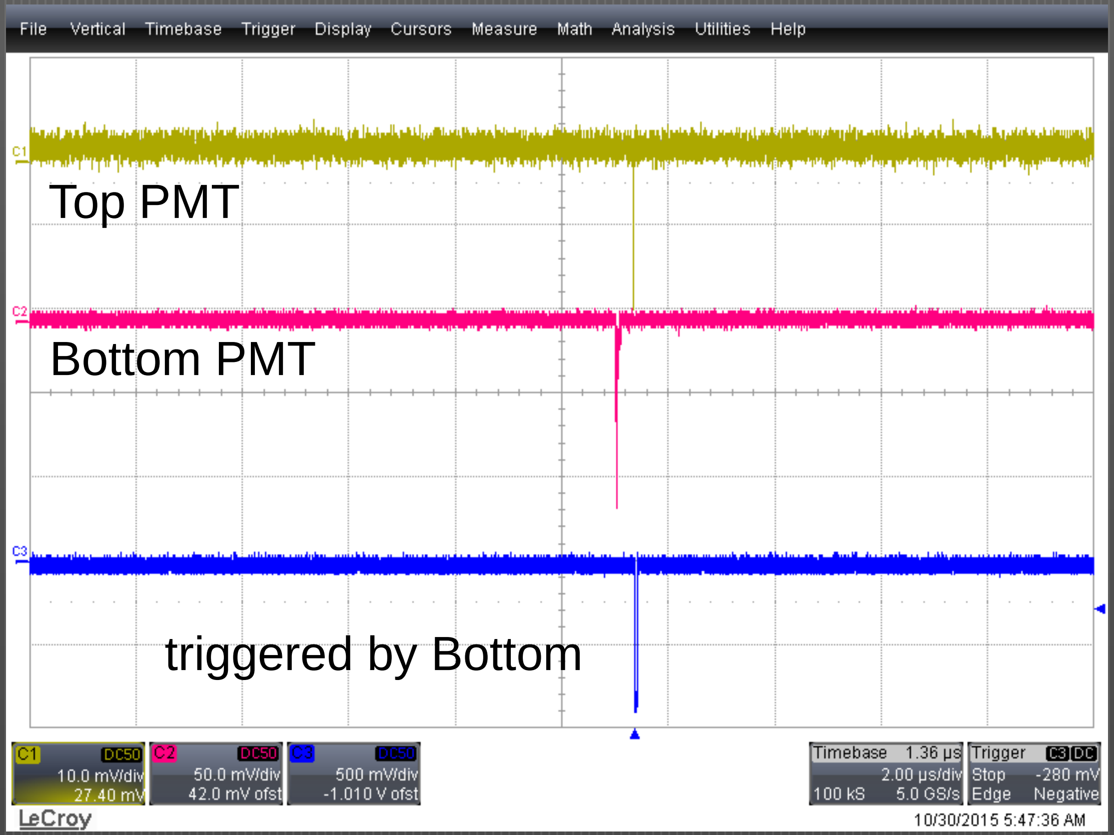
Equipotential line

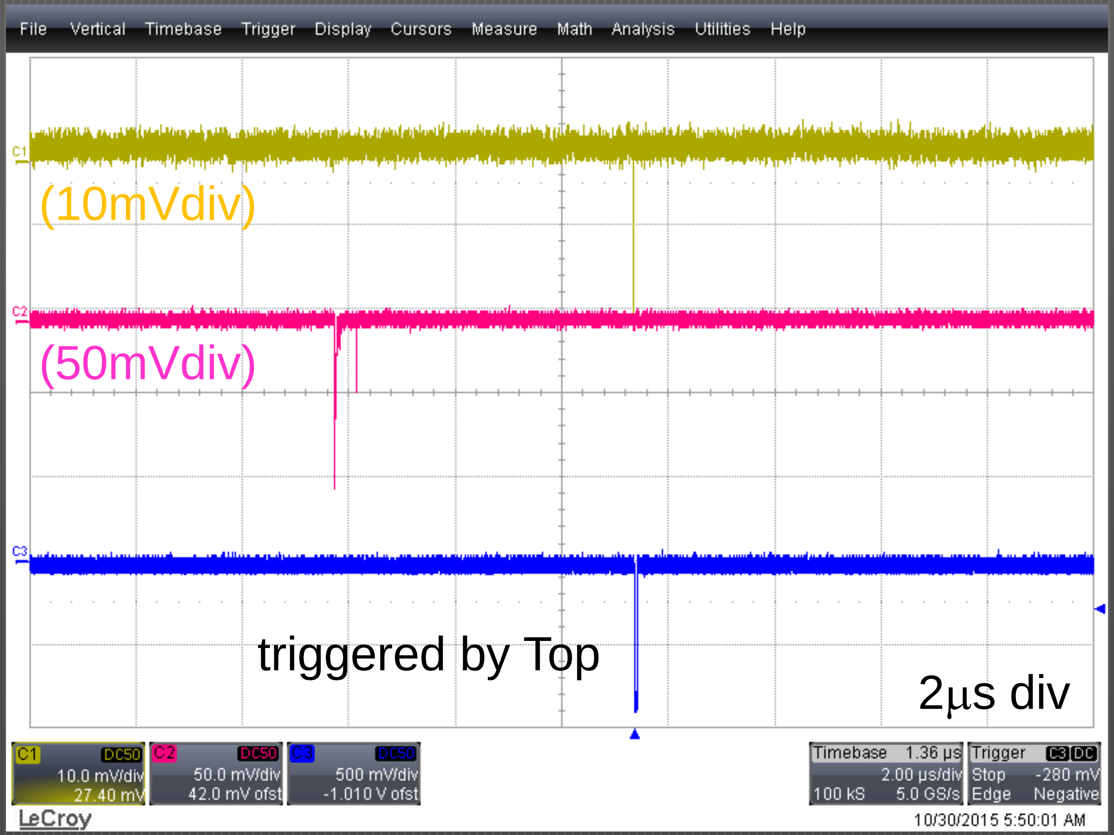


- Inside holes >30kV/cm should be formed

No S2 was observed….No bubble is produced by G-GEM

- $\Delta V_{G\text{-}GEM}$=2.5kV(drift:0.4kV/cm, G-GEM:38kV/cm)





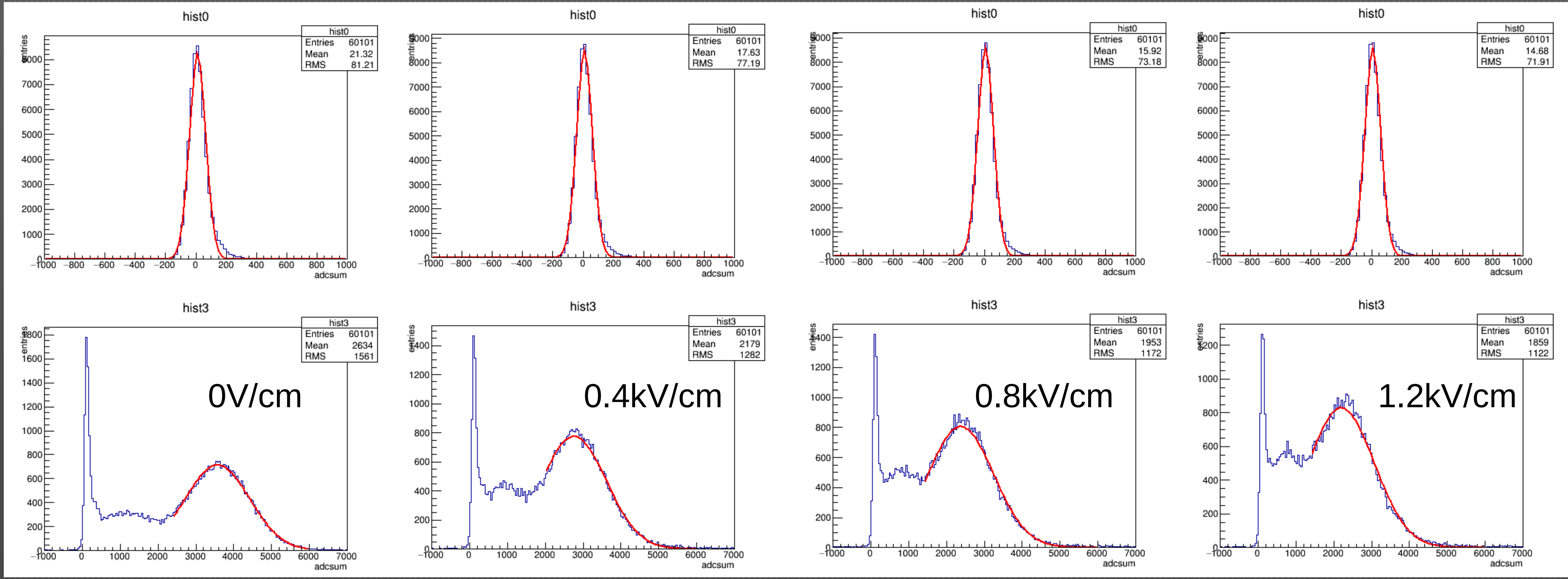
- Expected $\Delta T_{S2\text{-}S1}$ 4~5μsec

Electrons were really drifted

- Drift field-dependence of S1 59.5keV signals
  - Top PMT is almost “masked” by G-GEM, LY=7.9 p.e./keV@0V

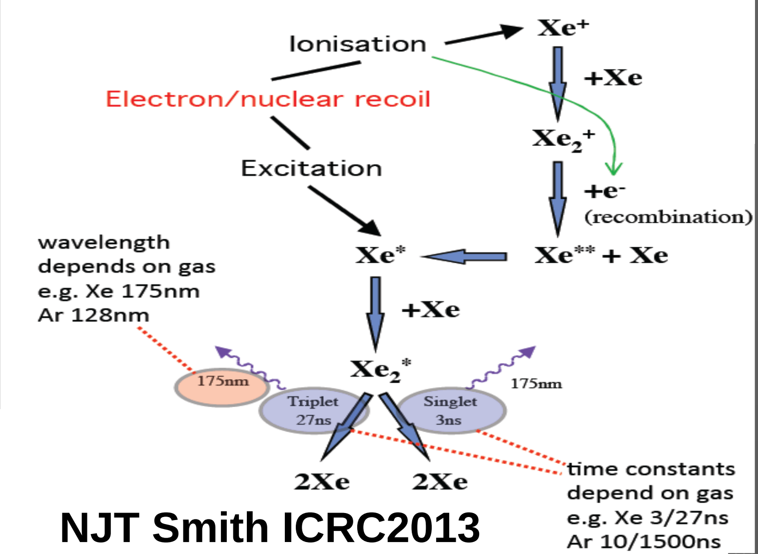
Top PMT

Bottom PMT

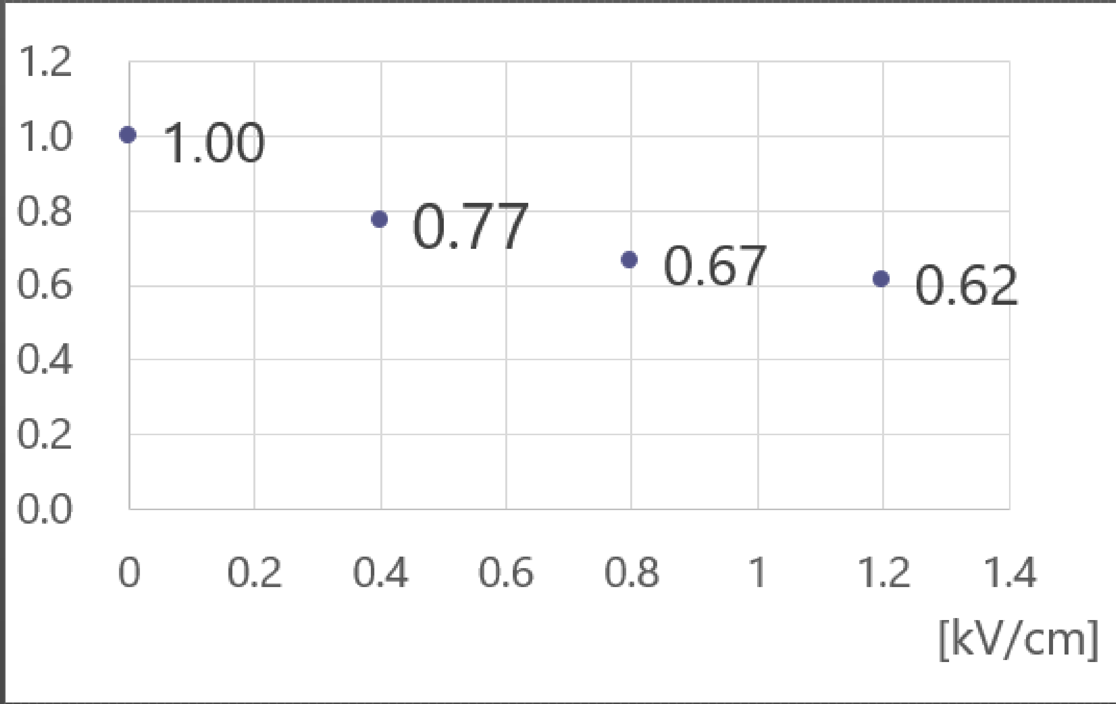


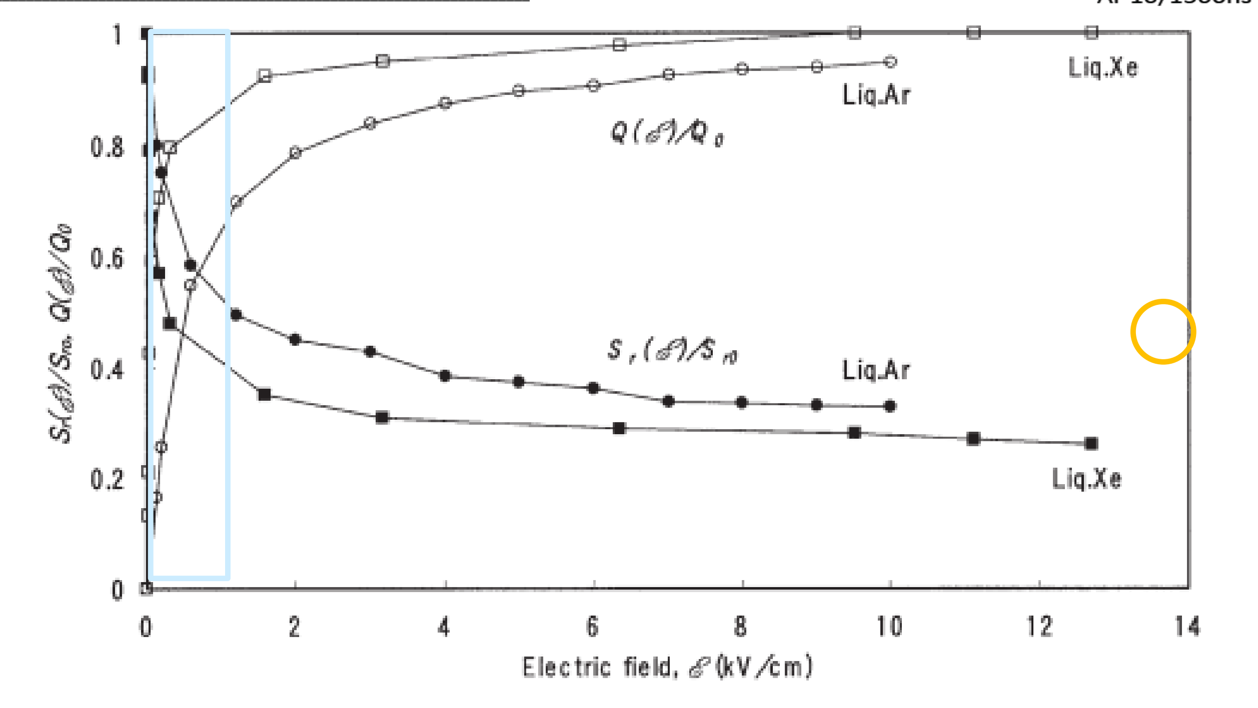
S1 light yield as a function of the field

- Suppression of the recombination was confirmed



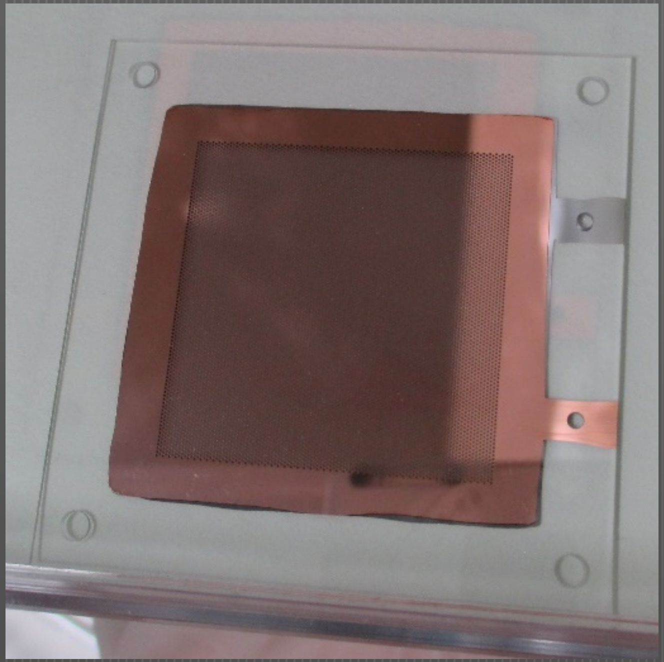
NJT Smith ICRC2013





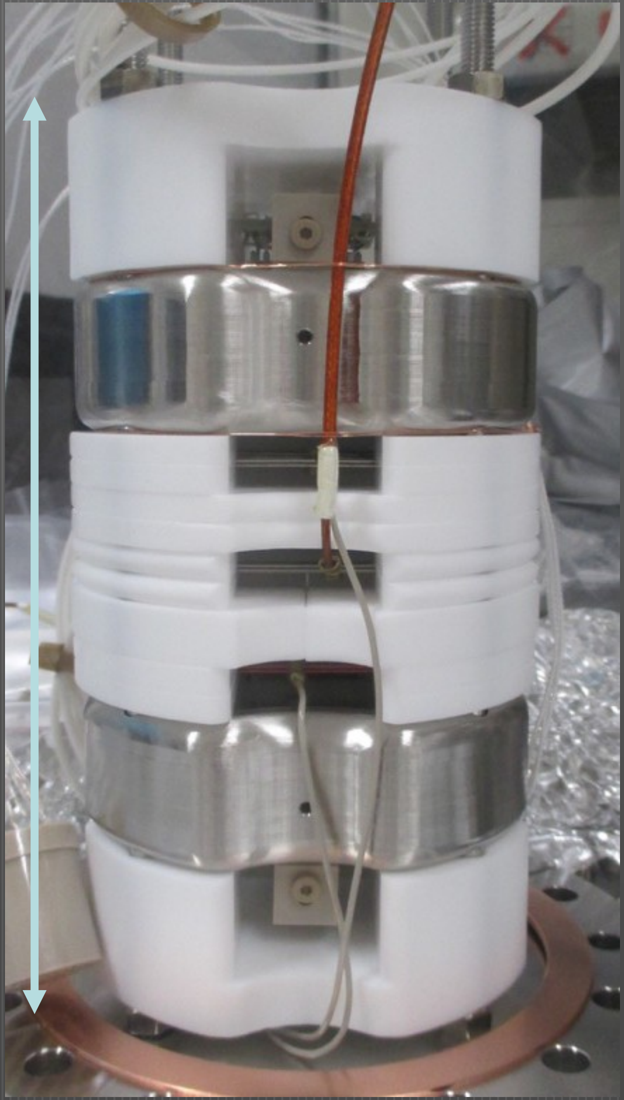
T. Doke et al.,Jpn. J. Appl. Phys. Vol. 41 (2002) pp. 1538–1545

Should take a step back to “wire”



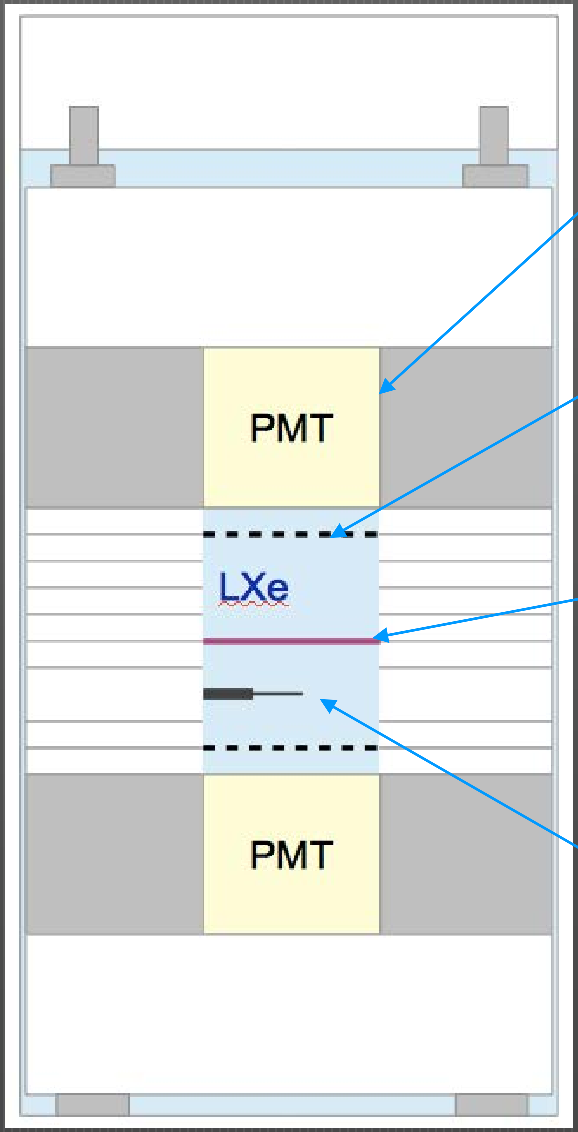
- Au plated 10μmϕ W wire soldered on an epoxy board

The wire setup

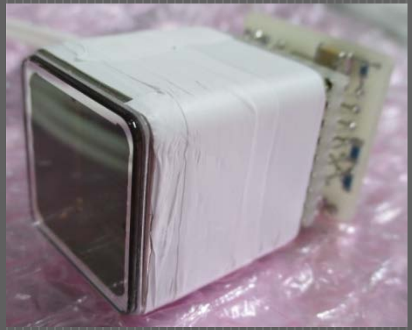


170mm

50mm



Hamamatsu
R8520-406
24mm□
+HV



GND wires

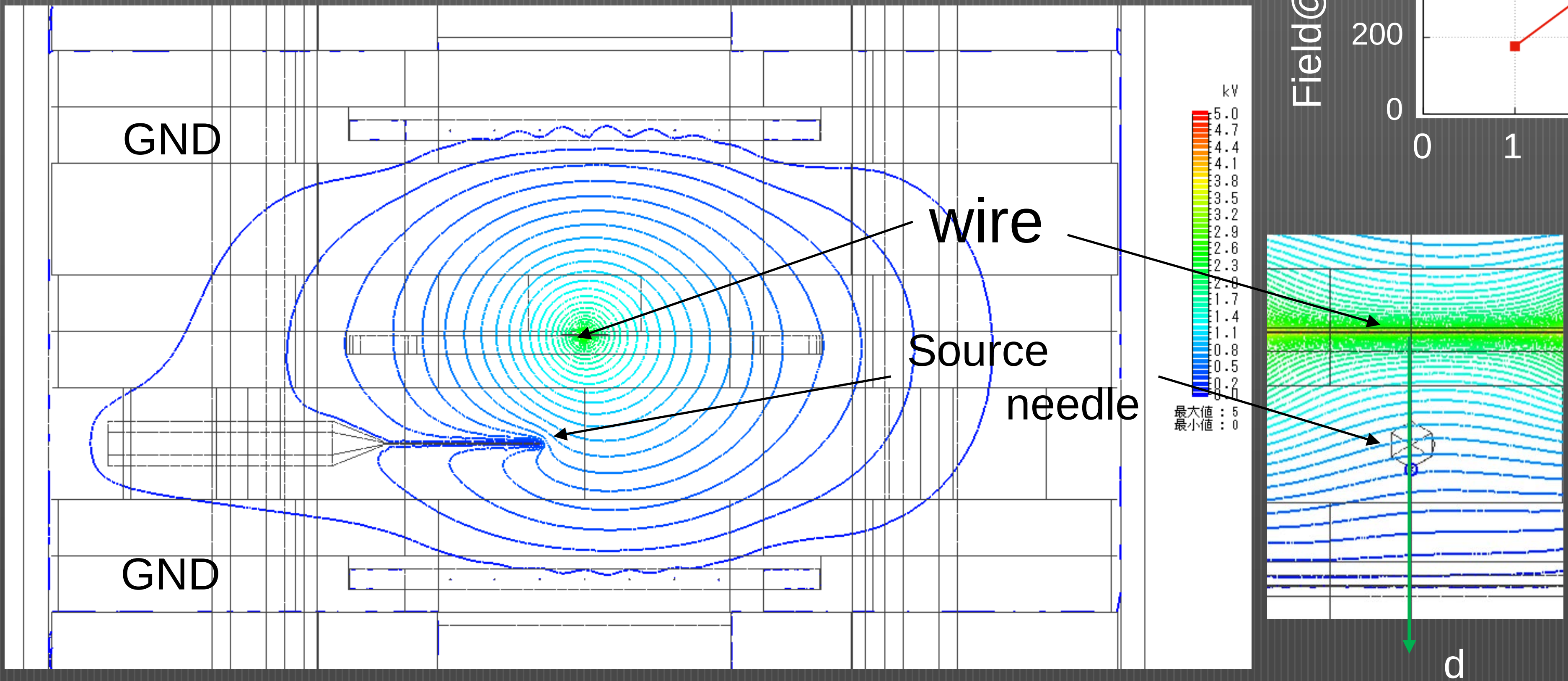
Au coated
10μm W wire

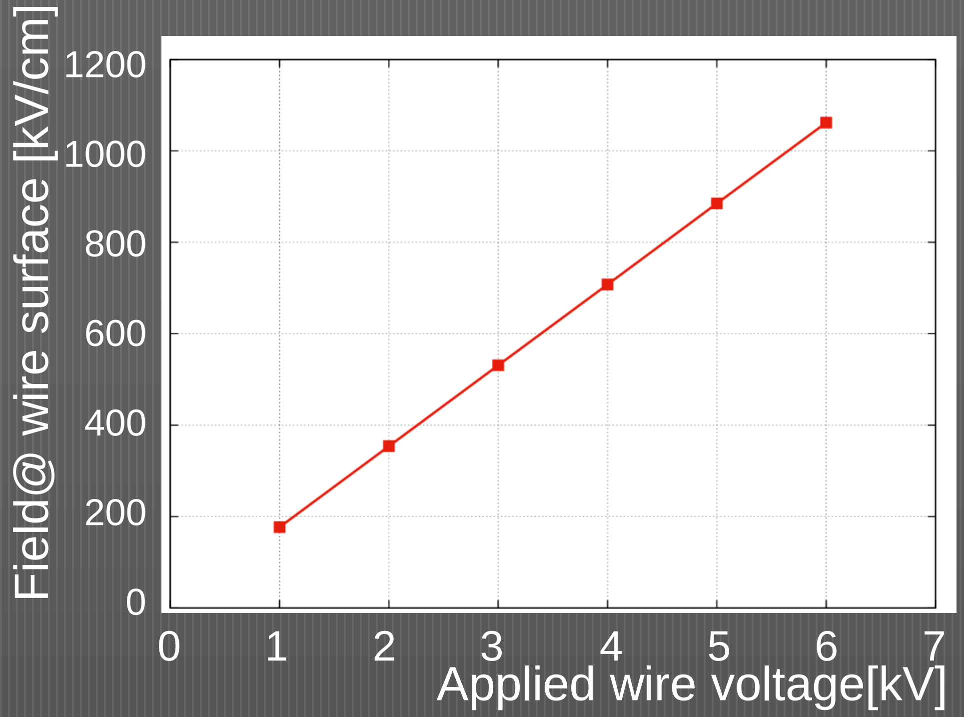
^{241}Am

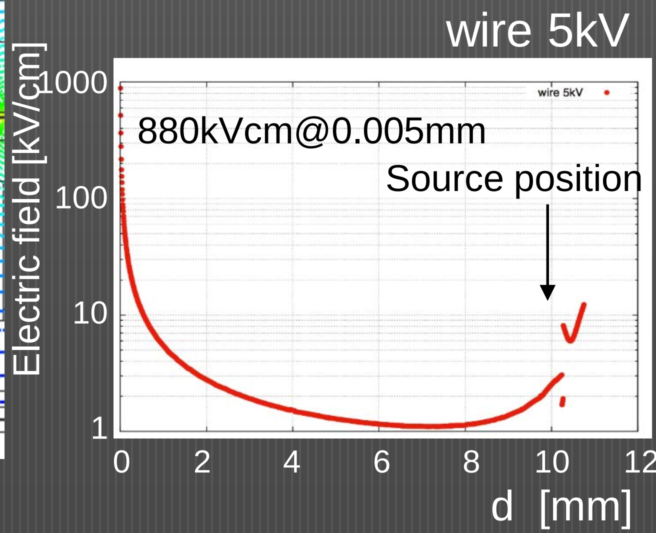
γ: 59.5, 26.4keV
X: 20.8, 17.8, 13.9keV
α: 5.49, 5.44MeV

Formed electric field

- 5kV → 880kV/cm@ wire surface

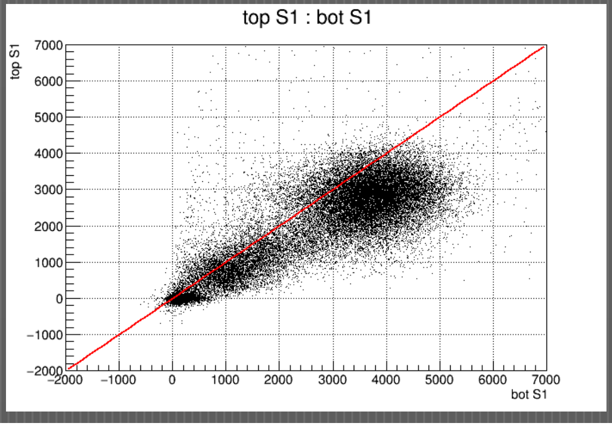




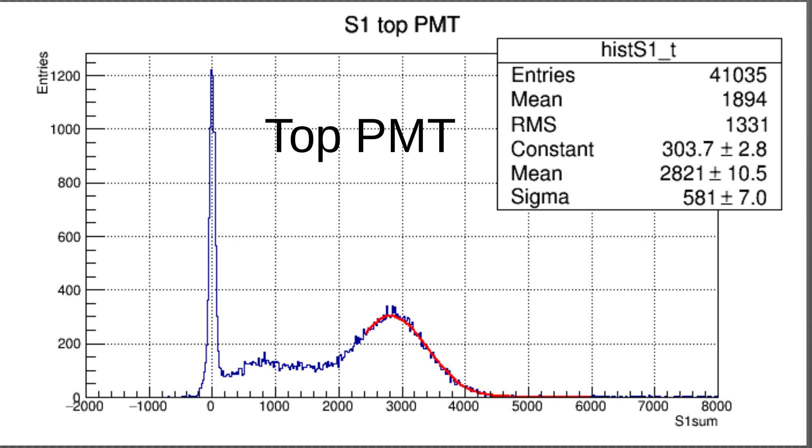


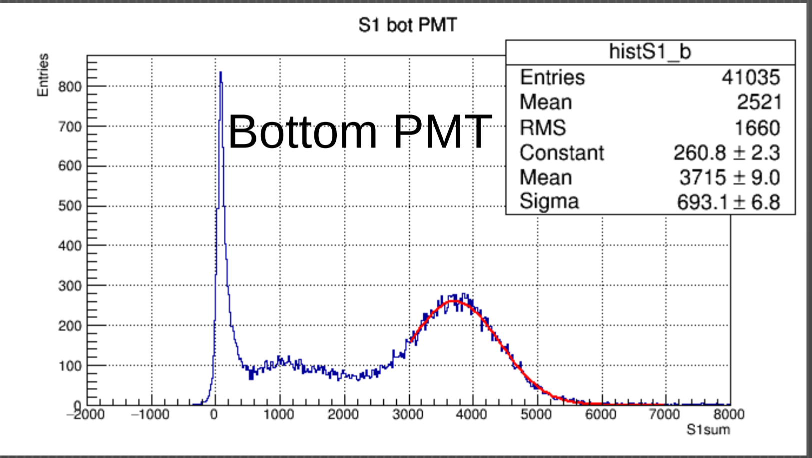
S1 59.5keV signal @0V

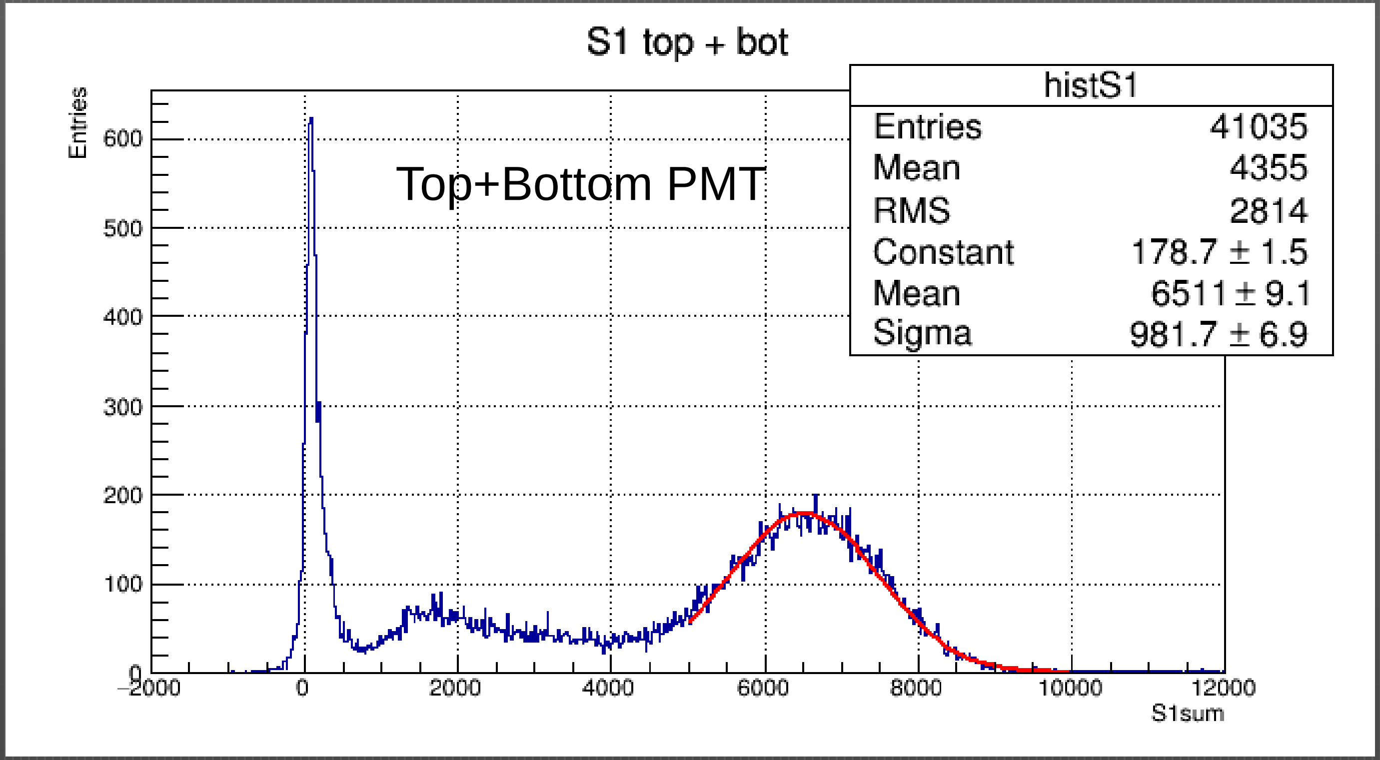
Top



bottom



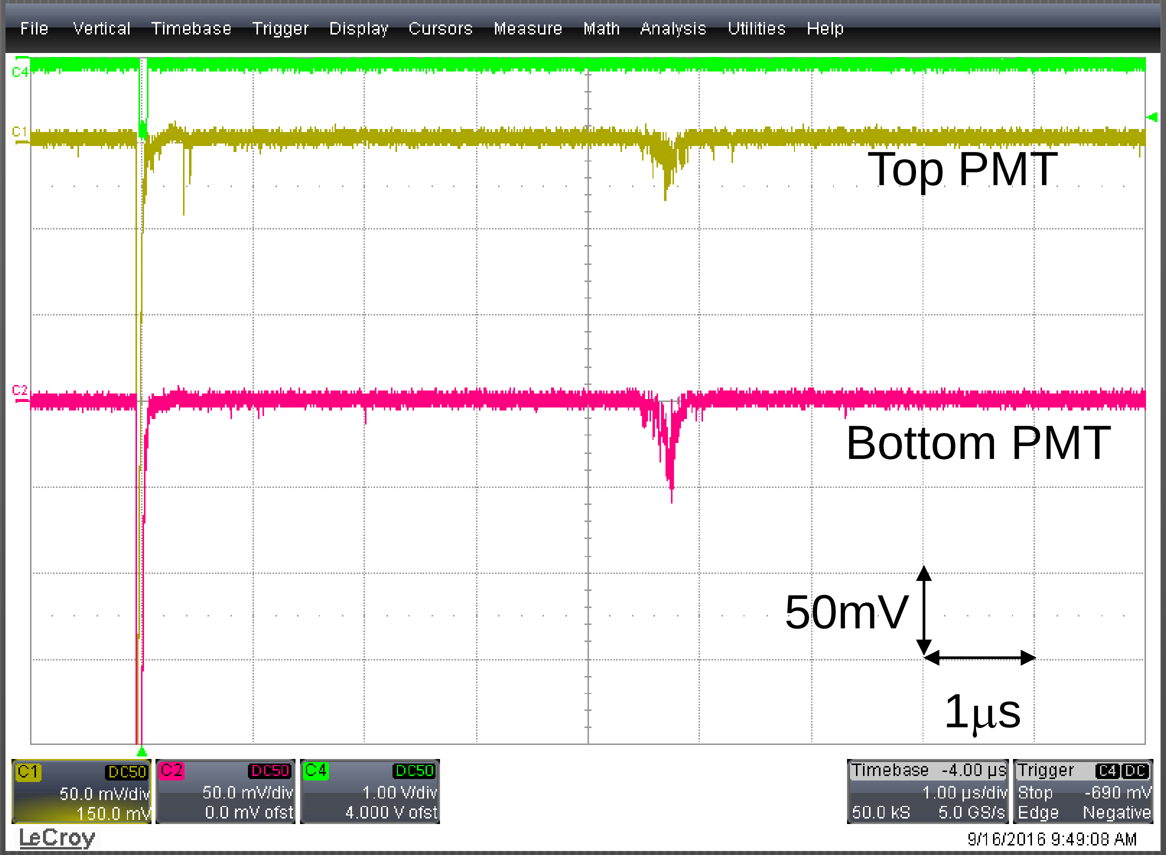




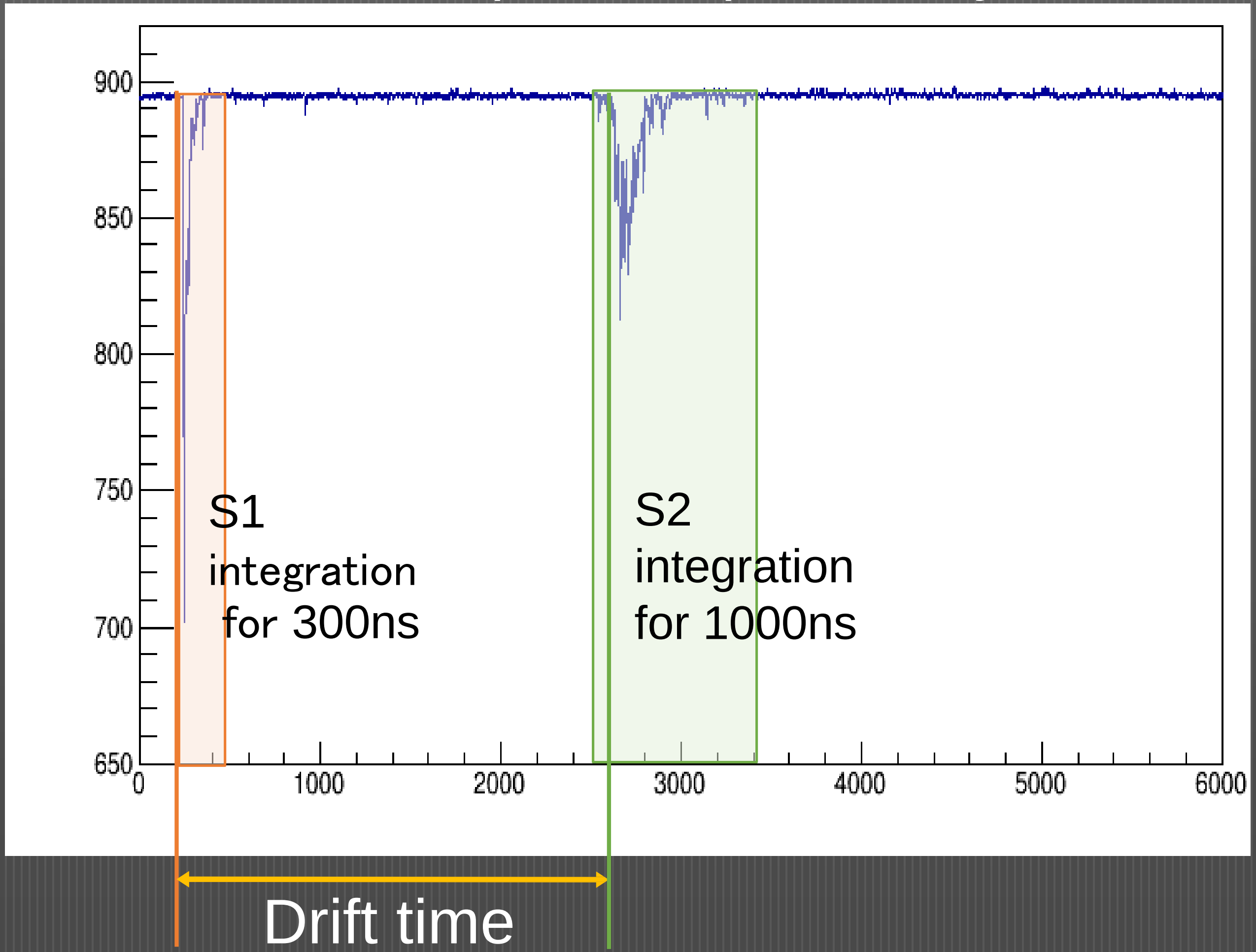
- LY= 13.7 p.e./keV

S2 signal @ 4.5kV

- Oscilloscope



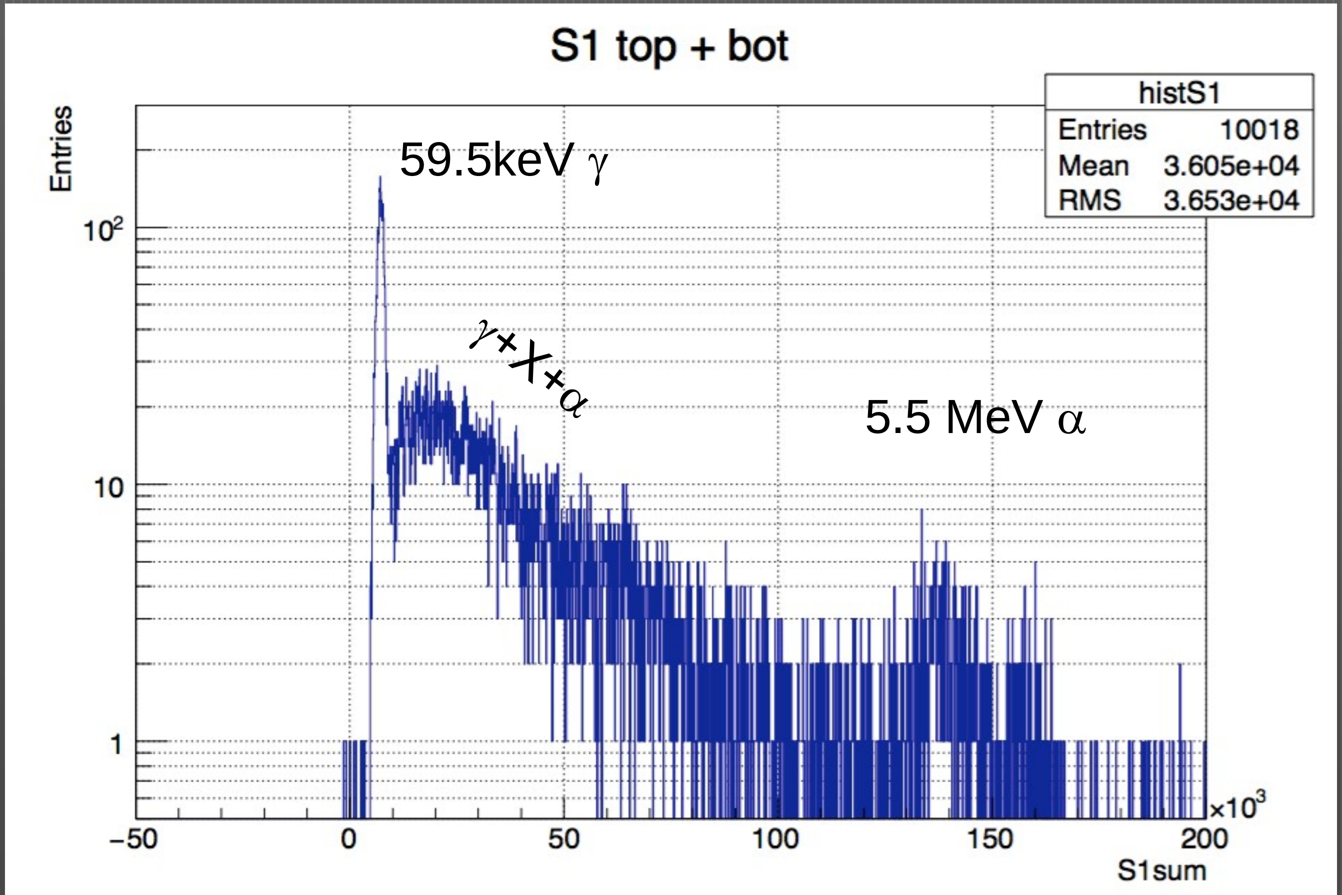
- FADC (DT5751) for analysis



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

Mainly caused by 5.5MeV α, not by 59.5keV

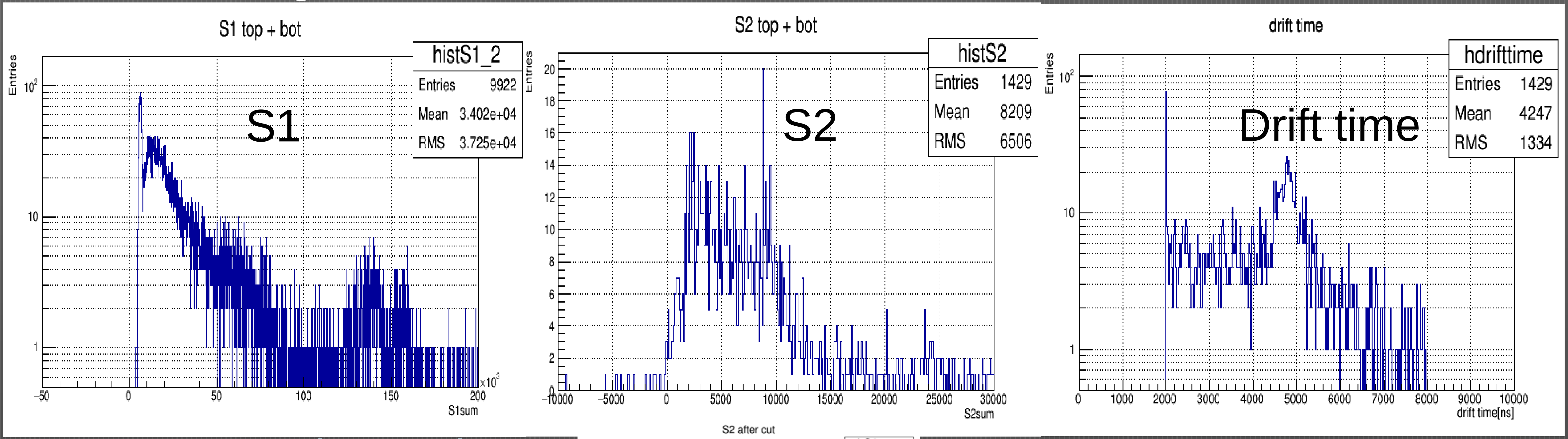
- S1 spectrum @0kV



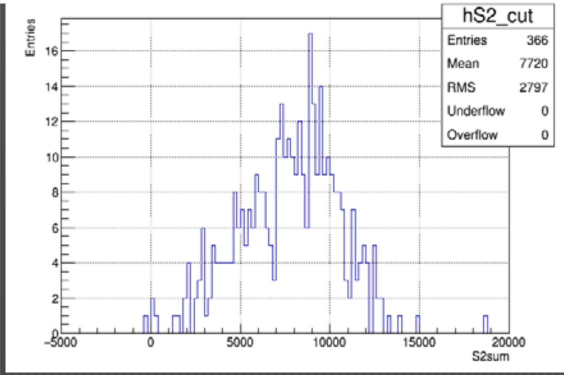
γ: 59.5, 26.4keV
X: 20.8, 17.8, 13.9keV
α: 5.49, 5.44MeV

S1,S2 and drift time distributions@ wire 4.5kV

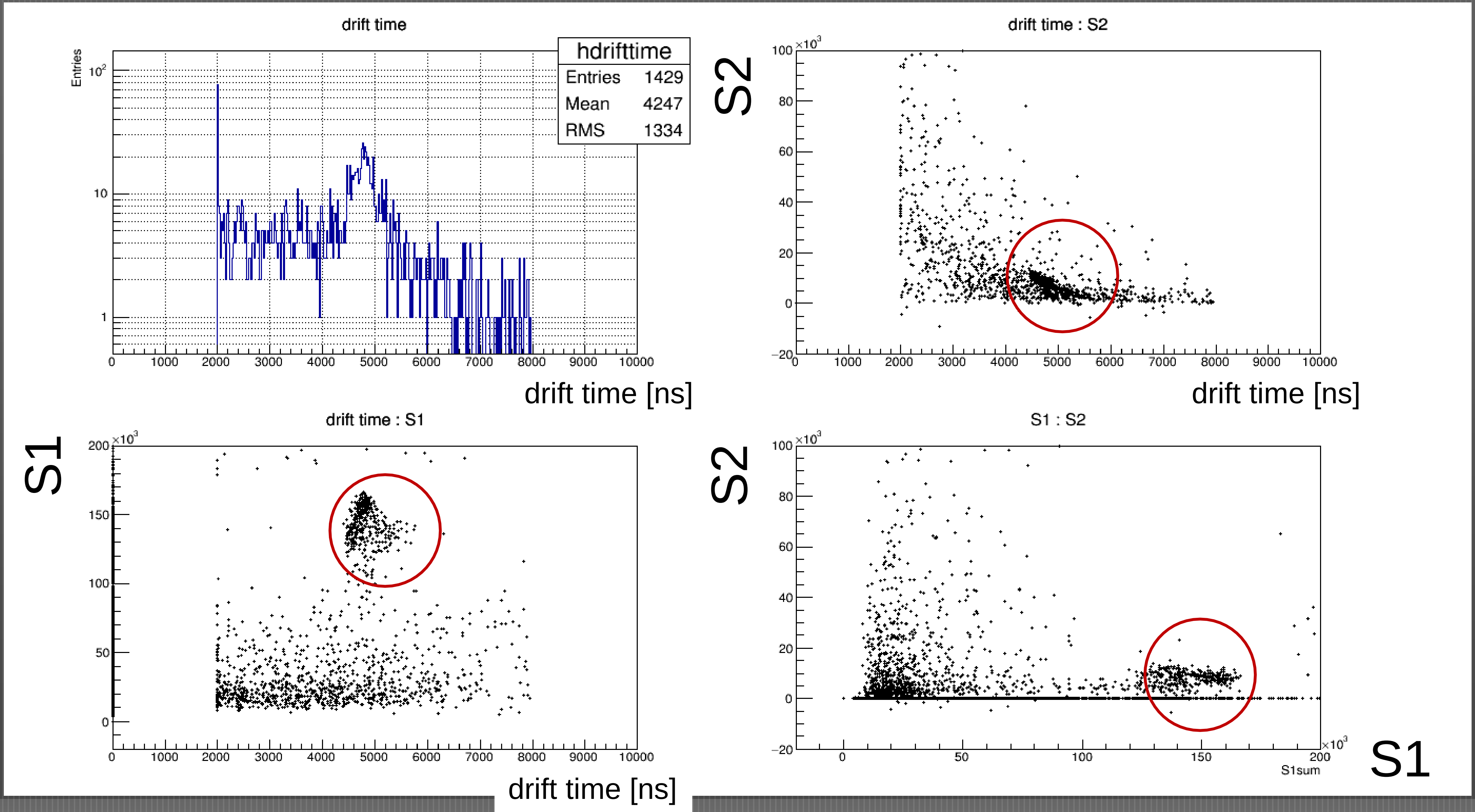
- 800kV/cm @ wire surface



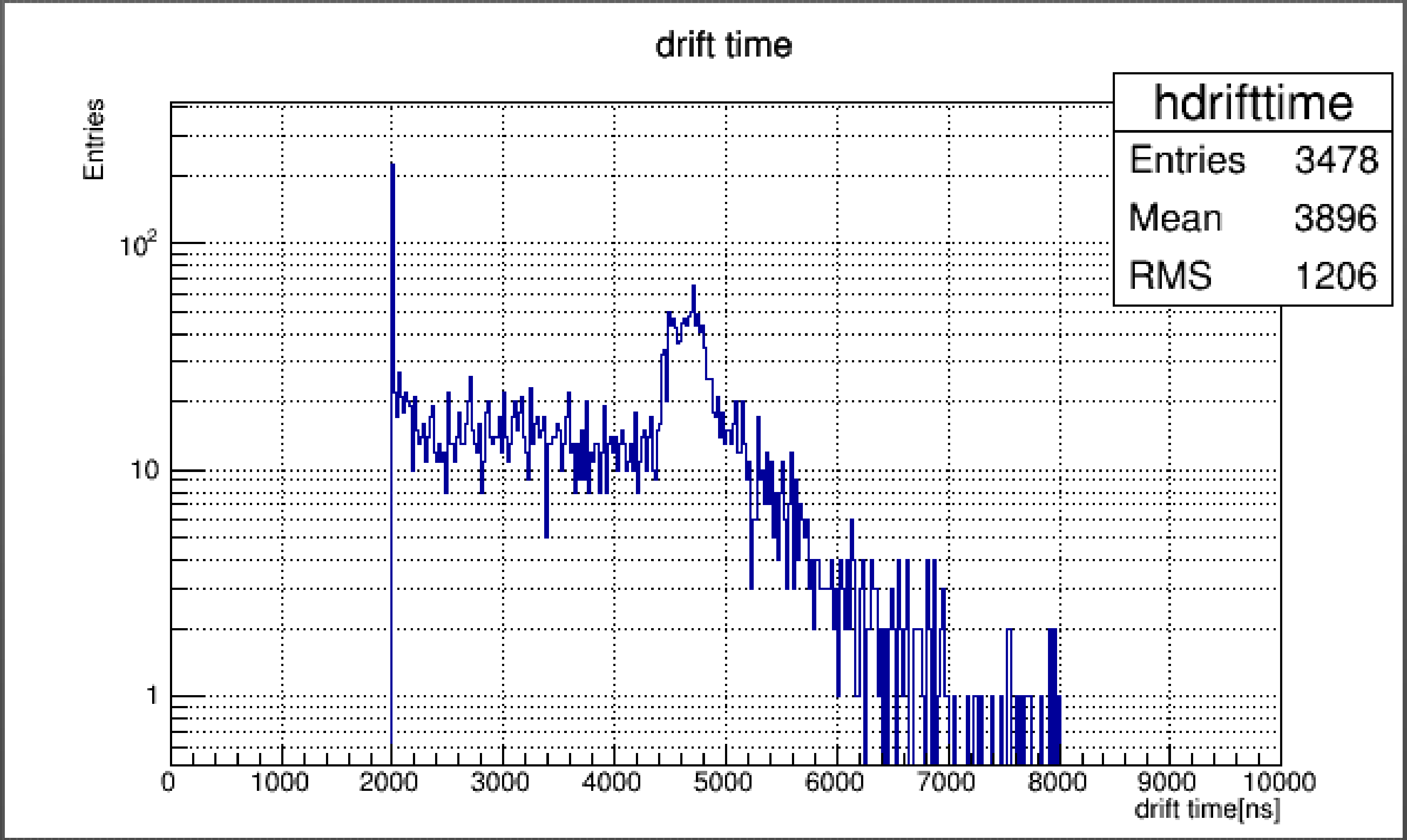
S2 after α selection



The clusters correspond to α the peak @4.5kV

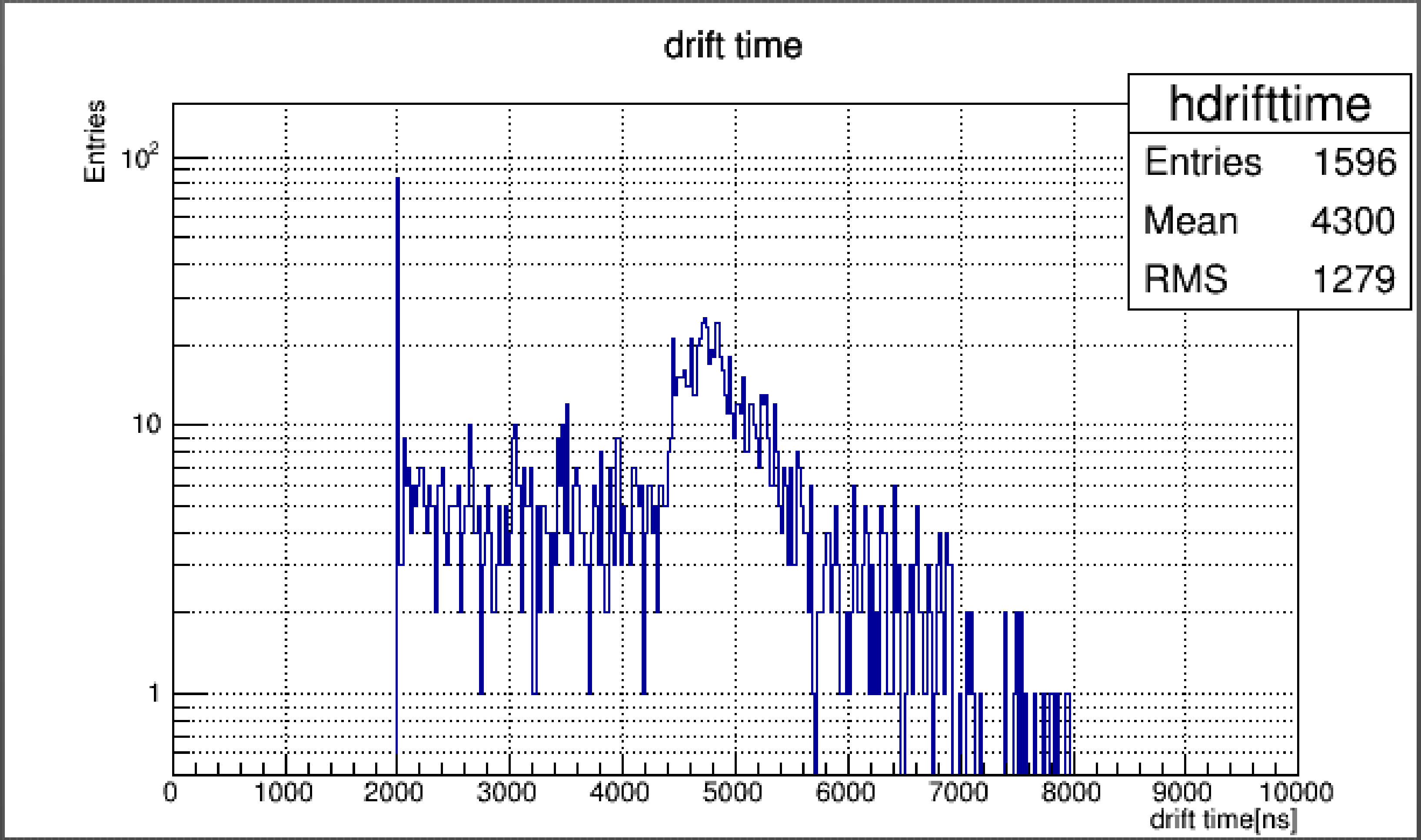


4.9kV

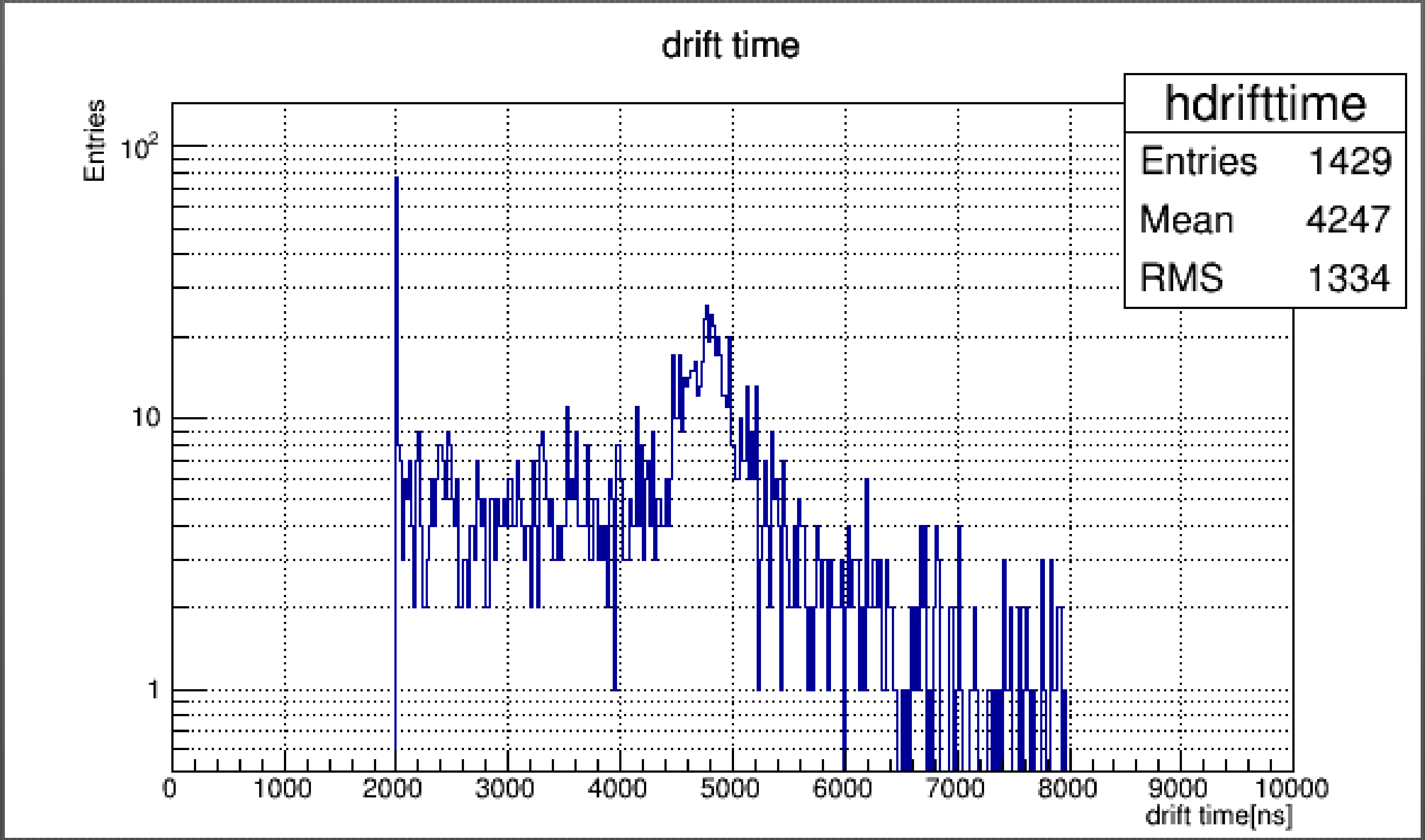


drift time
hdrifttime
Entries 3478
Mean 3896
RMS 1206
Entries
10^2
10
1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
drift time[ns]

4.7kV

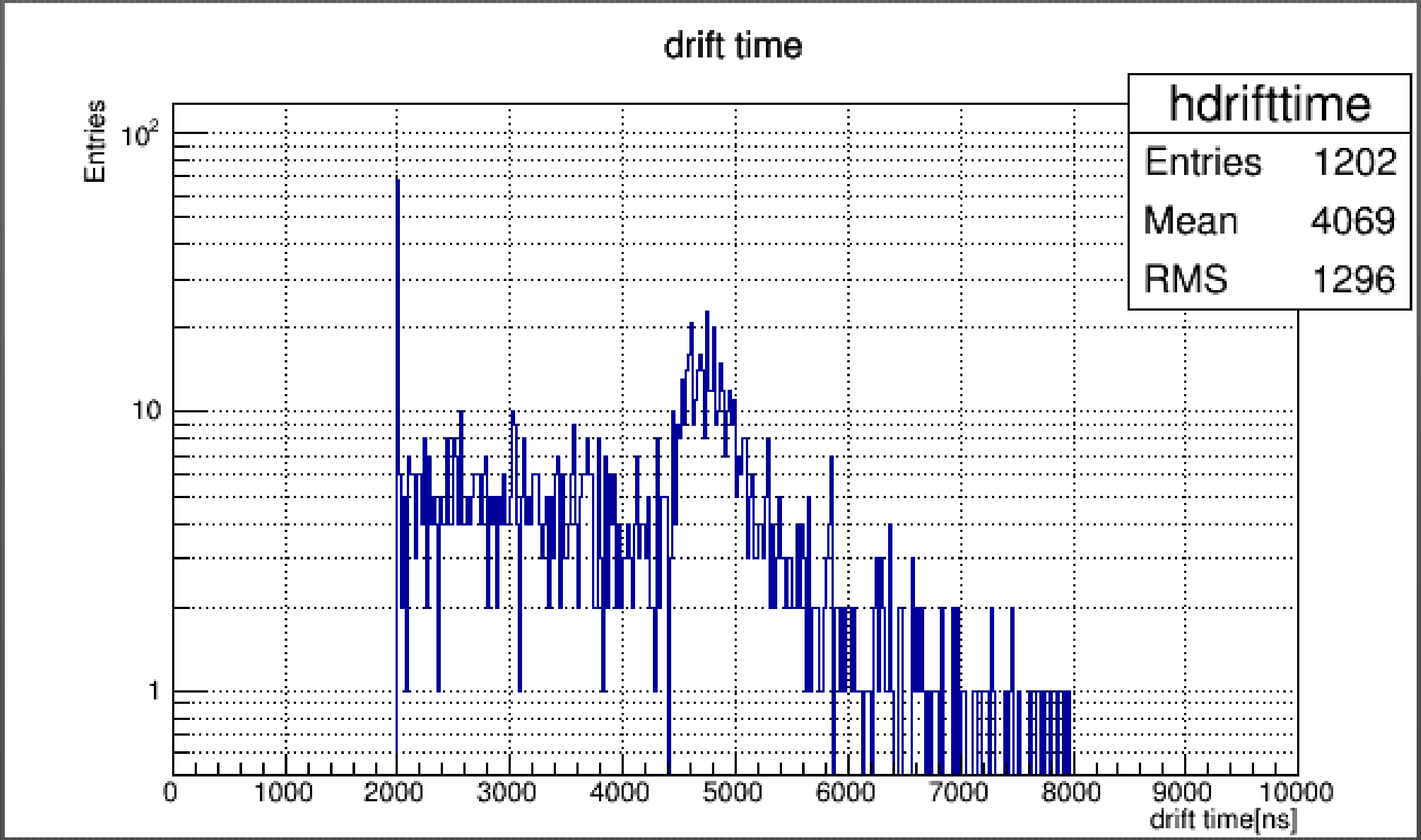

drift time
Entries
10^2
10
1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
drift time[ns]
hdrifttime
Entries 1596
Mean 4300
RMS 1279

4.5kV

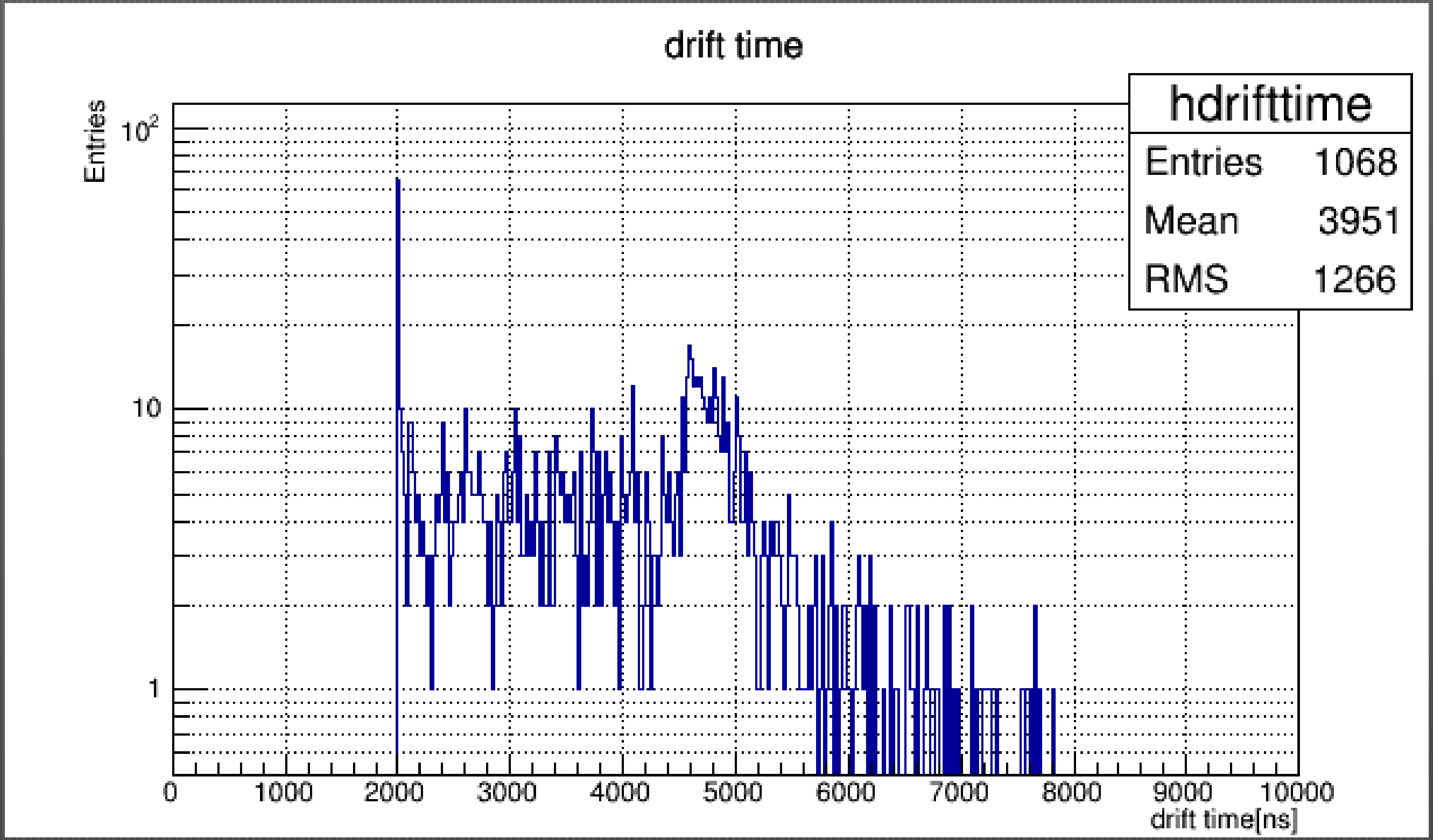


drift time
hdrifttime
Entries 1429
Mean 4247
RMS 1334
Entries
10²
10
1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
drift time[ns]

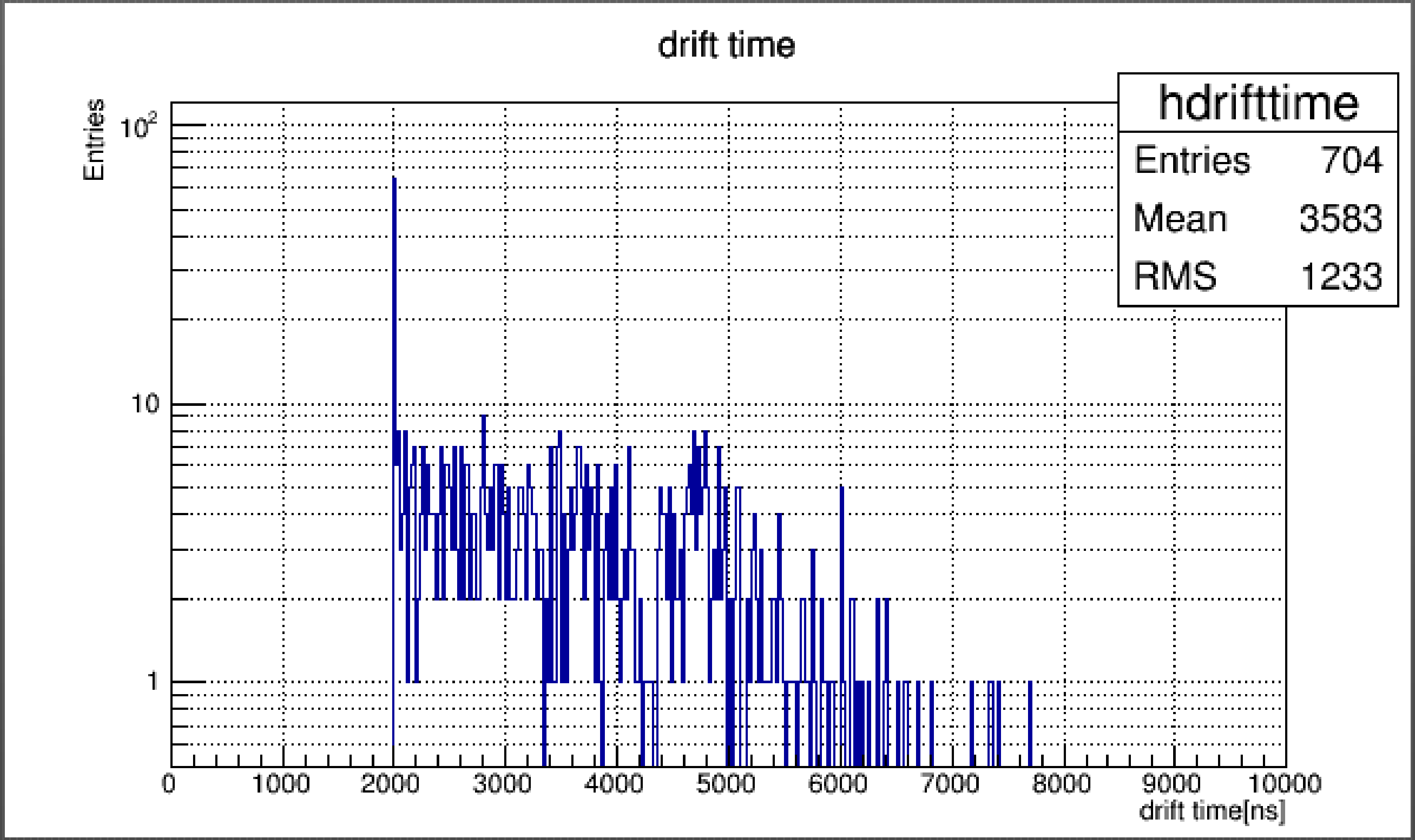
4.2kV


drift time
hdrifttime
Entries 1202
Mean 4069
RMS 1296
Entries
10^2
10
1
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
drift time[ns]

4.0kV

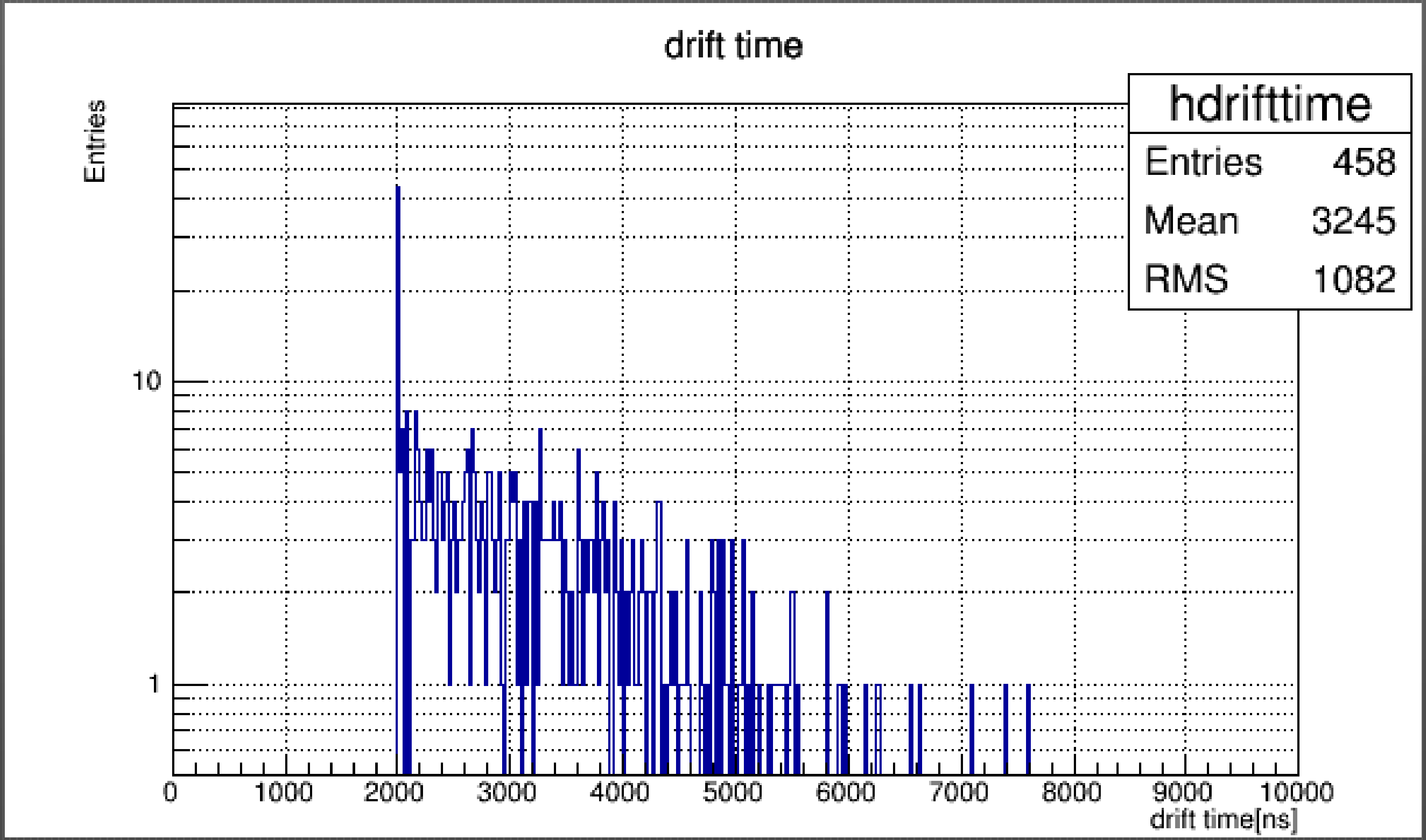

drift time
hdrifttime
Entries 1068
Mean 3951
RMS 1266
Entries
10^2
10
1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
drift time[ns]

3.5kV



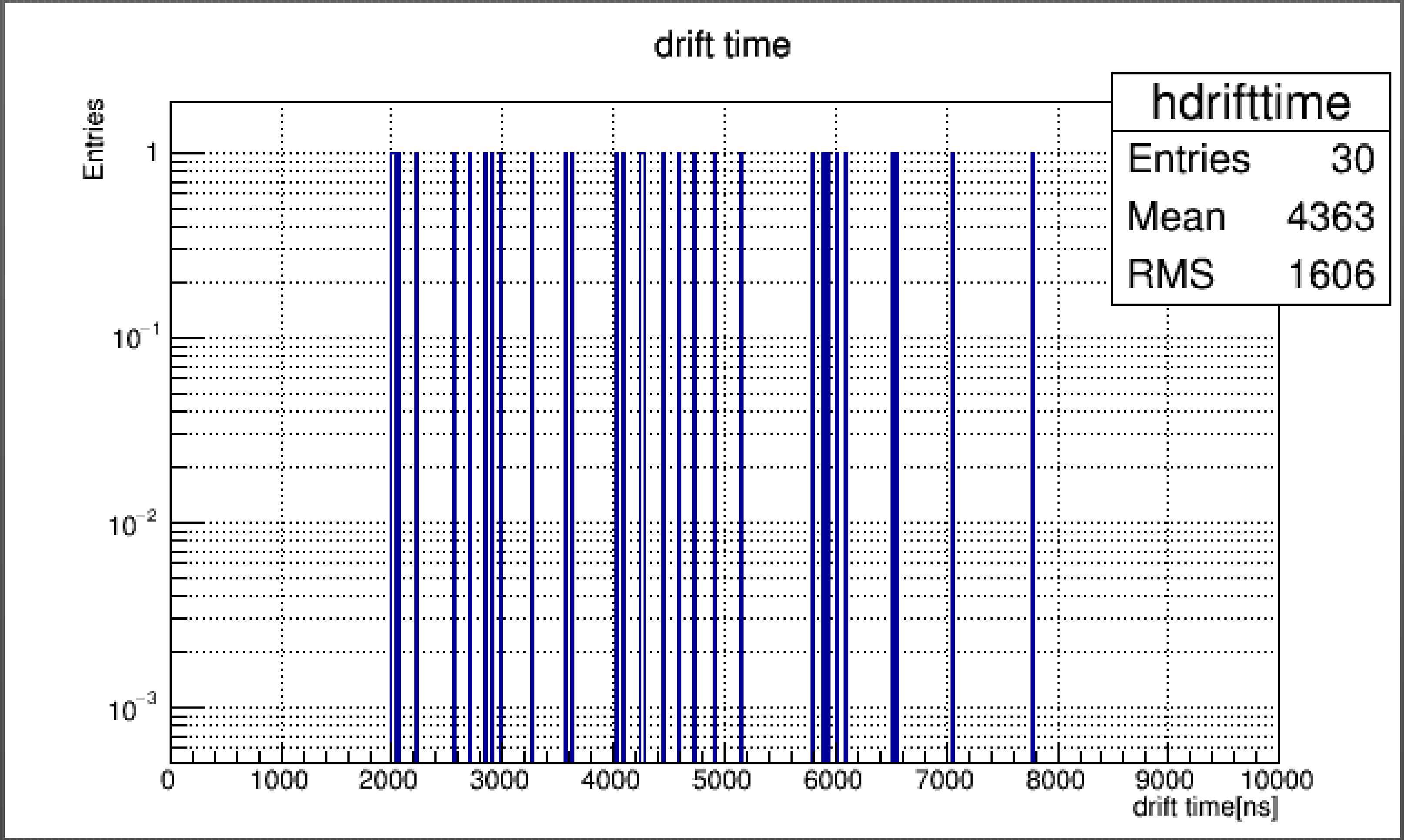
drift time
hdrifttime
Entries 704
Mean 3583
RMS 1233
Entries
10^2
10
1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
drift time[ns]

3.0kV



- Main S2 are from BGs?

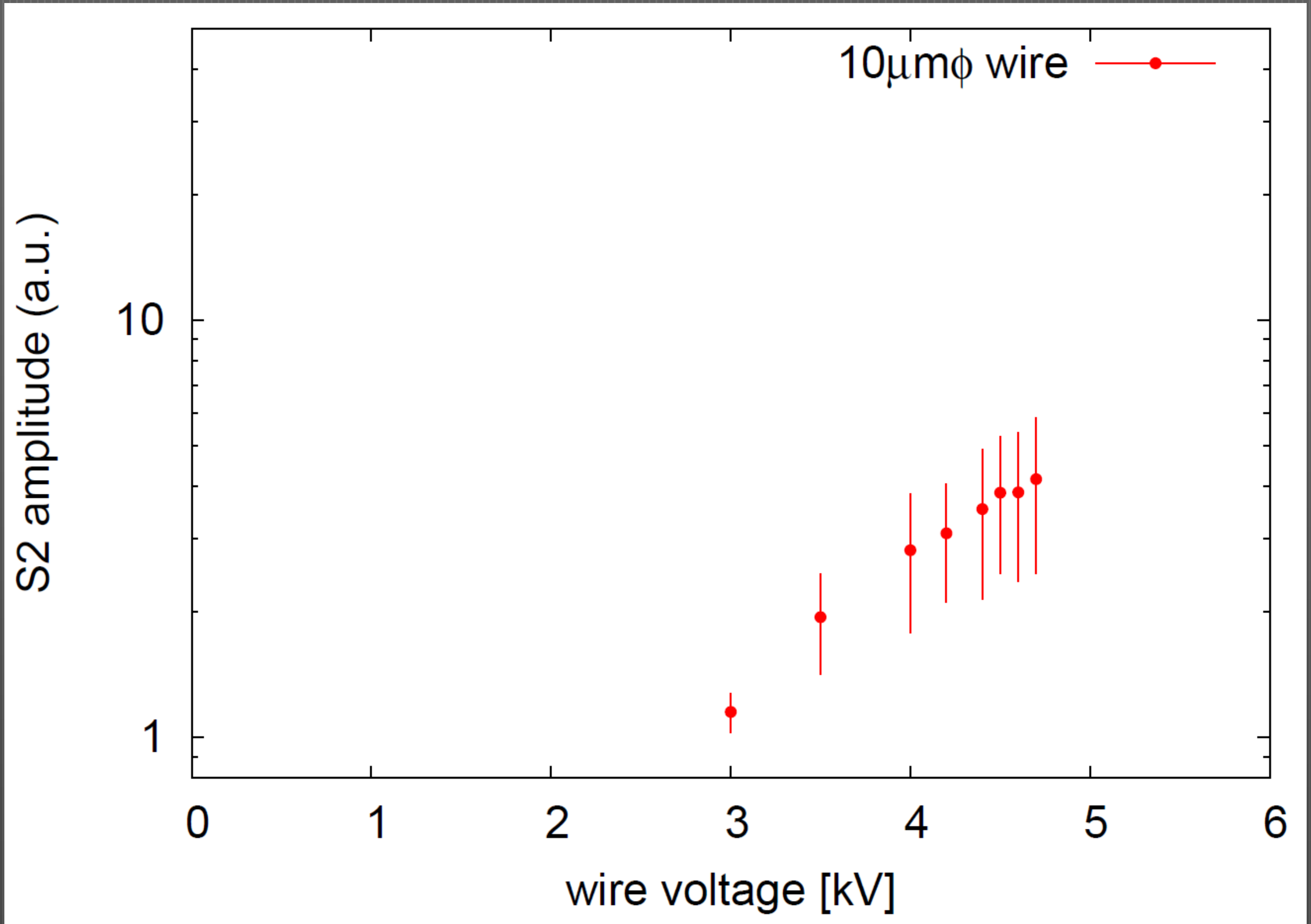
2.0kV



drift time
hdrifttime
Entries 30
Mean 4363
RMS 1606
Entries
1
10⁻¹
10⁻²
10⁻³
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
drift time[ns]

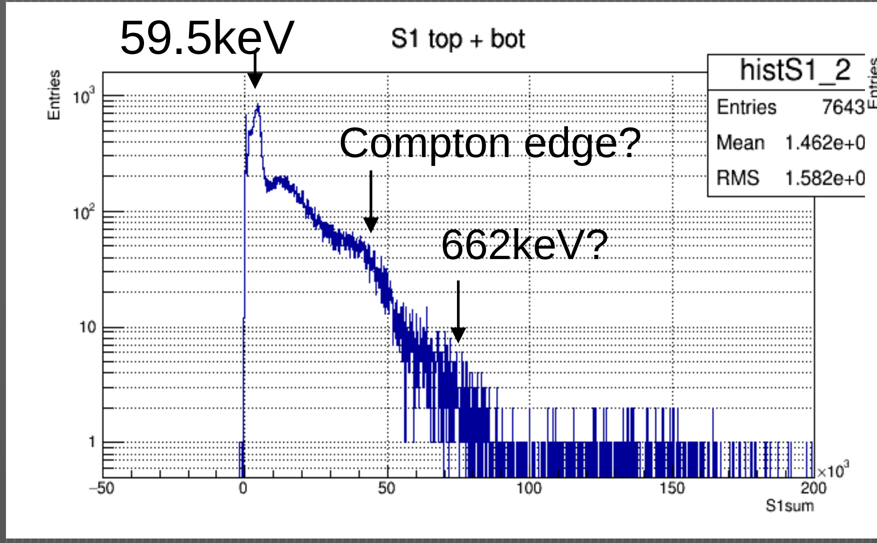
- NO S2

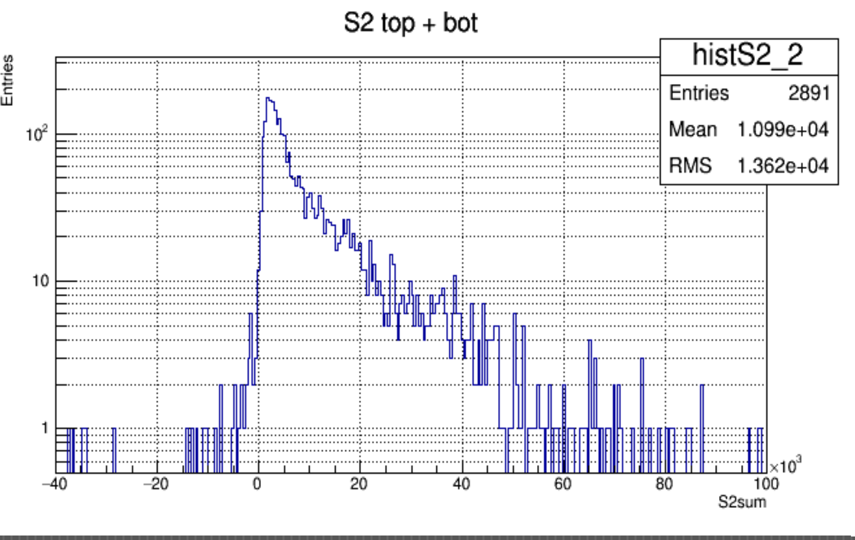
S2 amplitude as a function of wire voltage

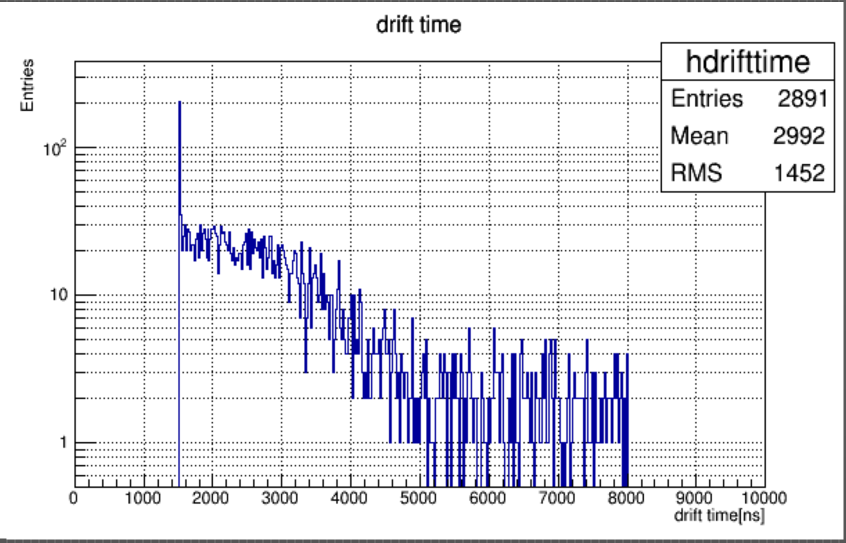


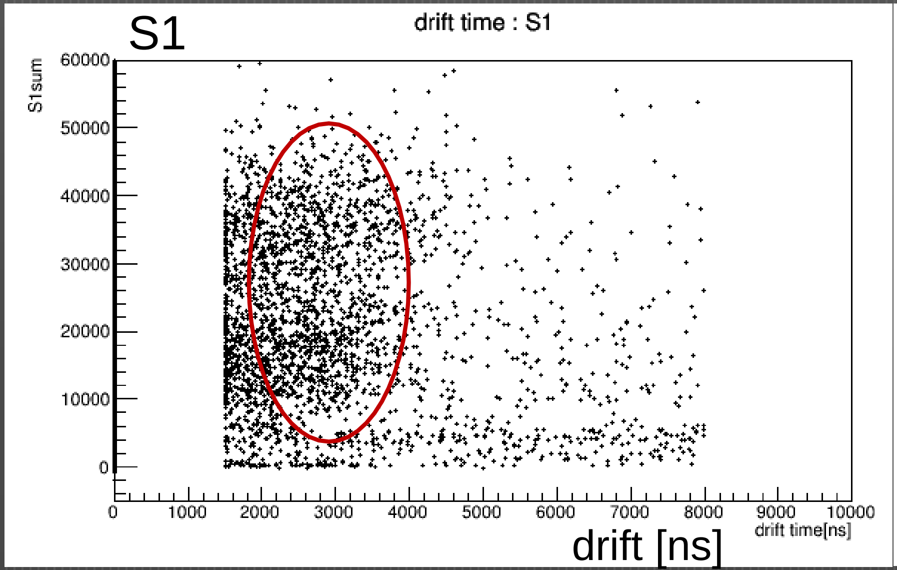
- Fine scan below 3kV must be done.

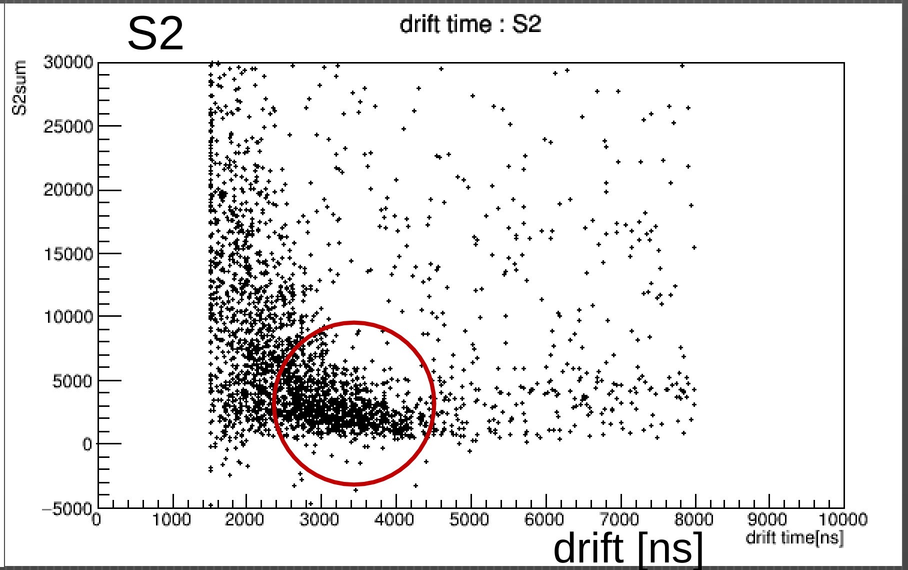
^{137}Cs 662keV irradiation from outside



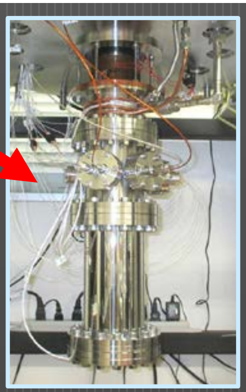








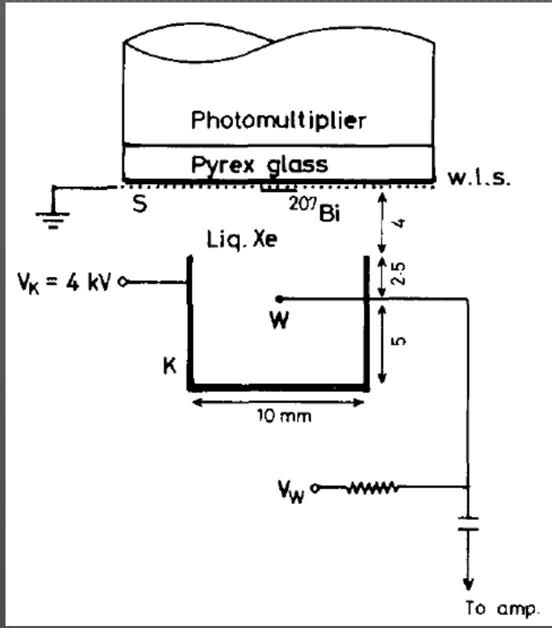
^{137}Cs

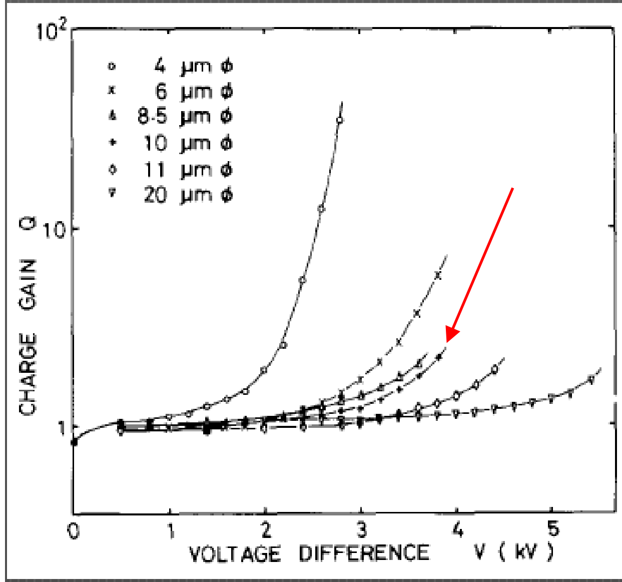


- @4.2kV
- S2 by ~100keV was confirmed

Previous works

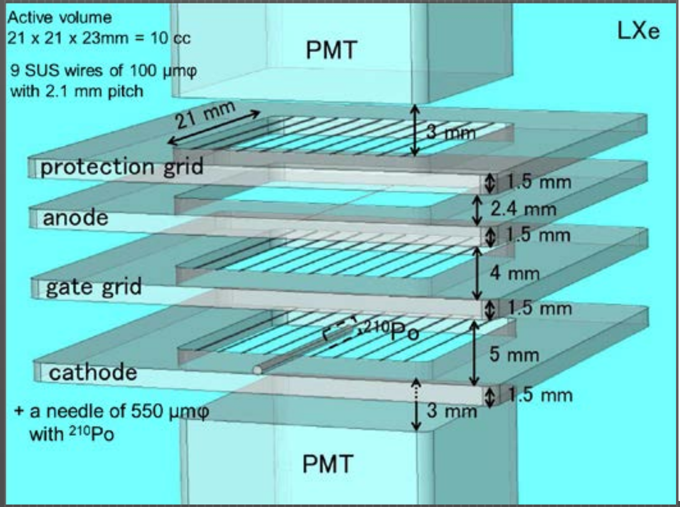
- 1MeV β from ^{207}Bi
  - S2 threshold 410kV/cm

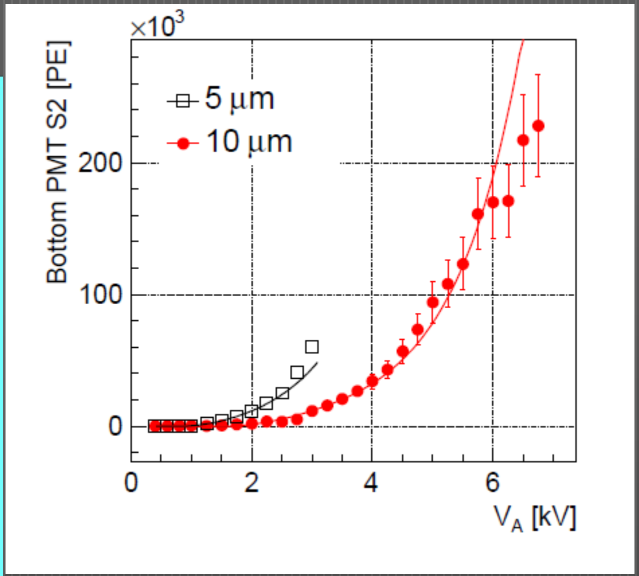




K. Masuda et al. NIMA 160(1979)247

- 5.3MeV α from ^{210}Po
  - S2 threshold 412±10kV/cm





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

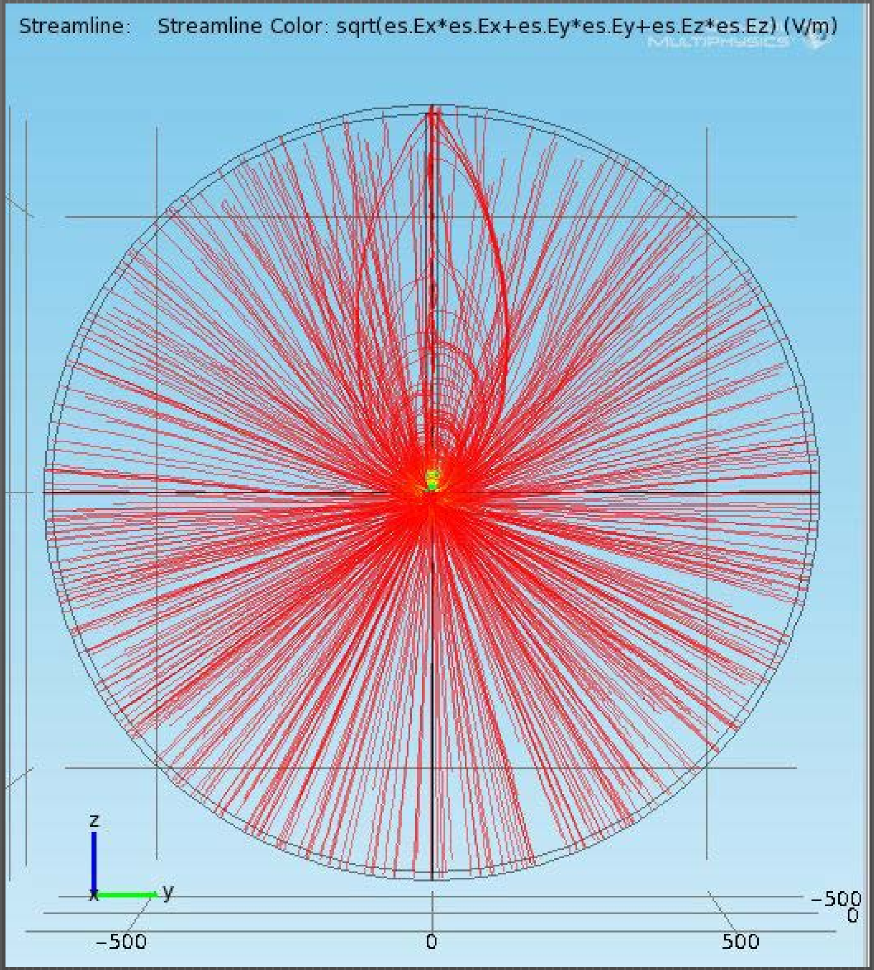
~2.5kV ~400kV/cm is consistent with our α + γ results.

Lower energy S2 investigation needs higher voltage

- But, @5kV current SHV-based system got discharged in GXe phase.

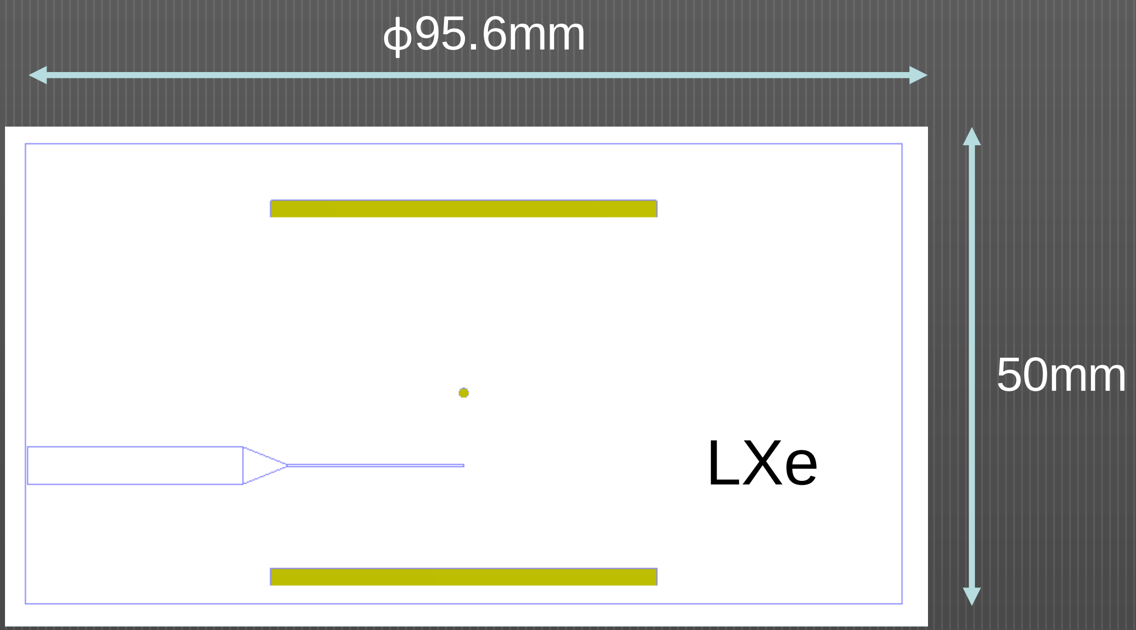
Simulation studies on the electrode for spherical detector

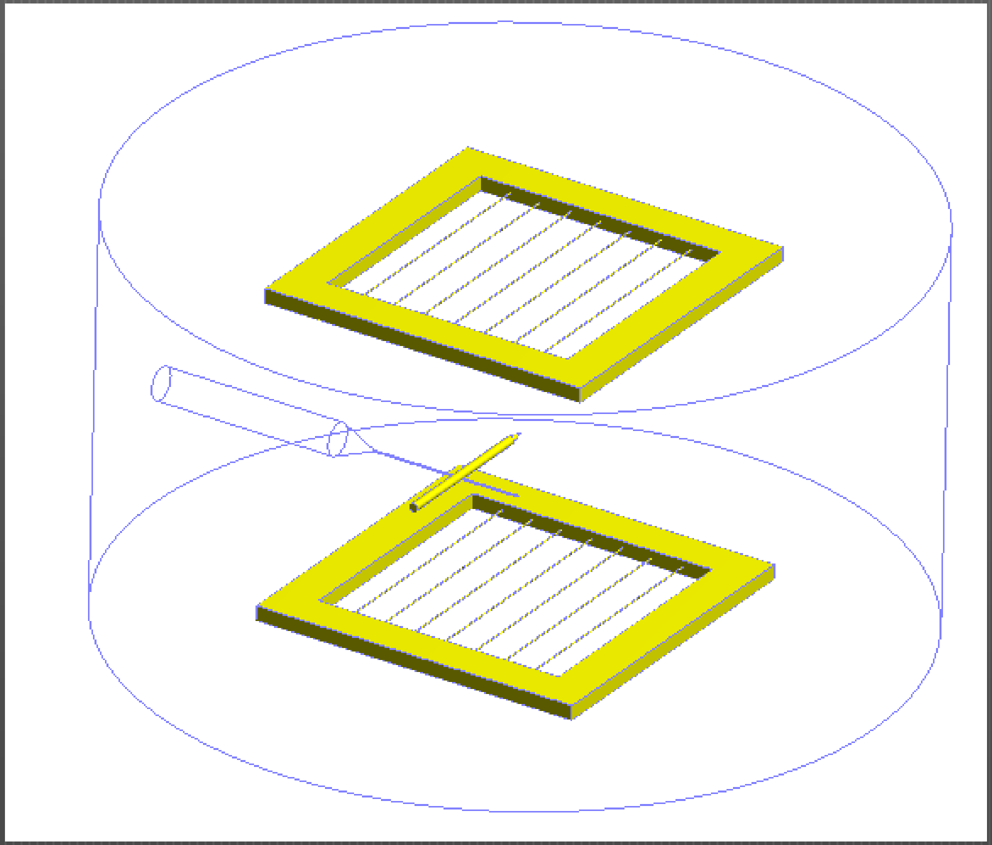
- NEWS electrode



First step: S2 observation with needle in the current setup

- 410kV/cm @surface is needed

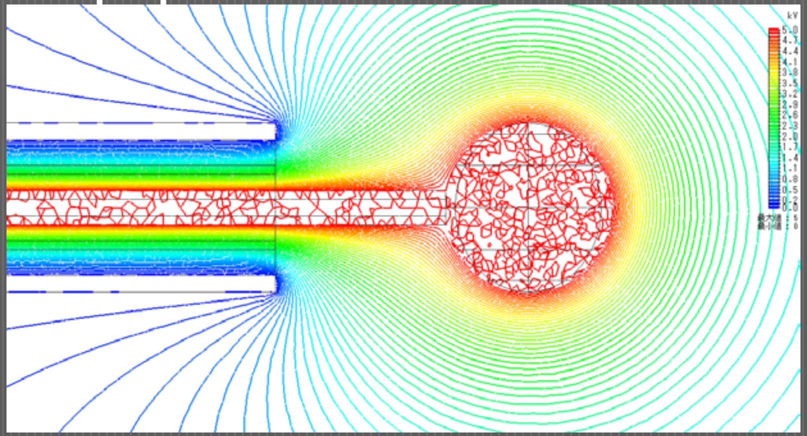


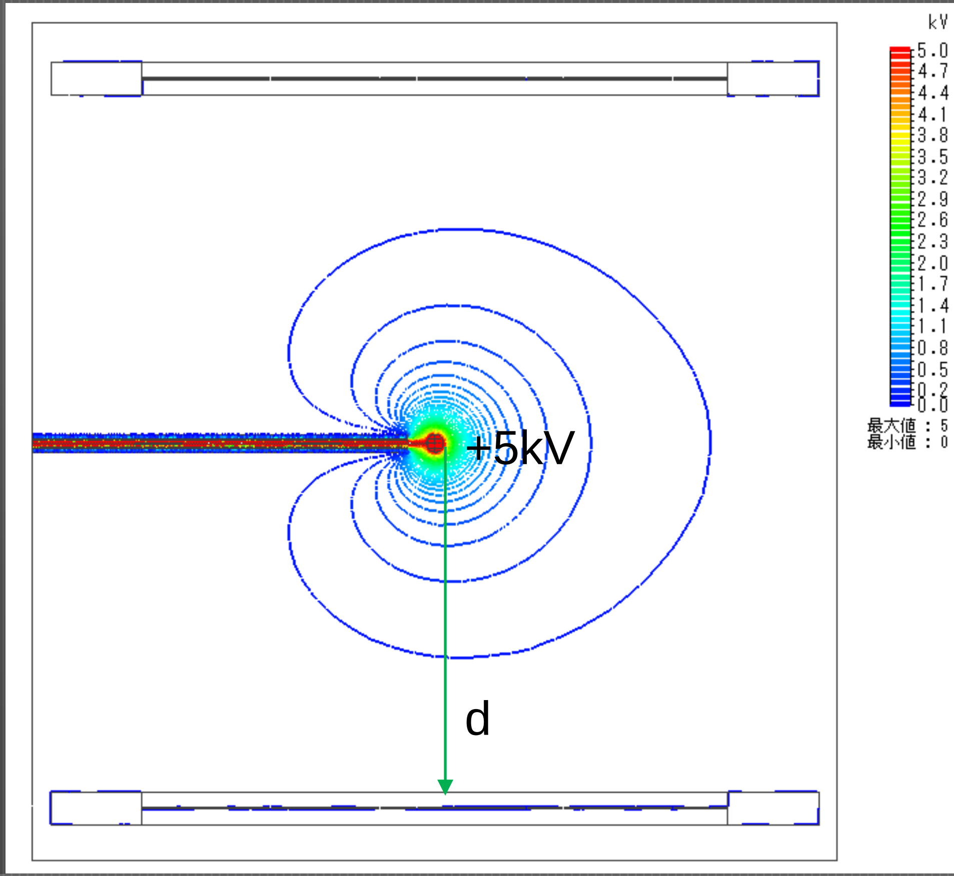


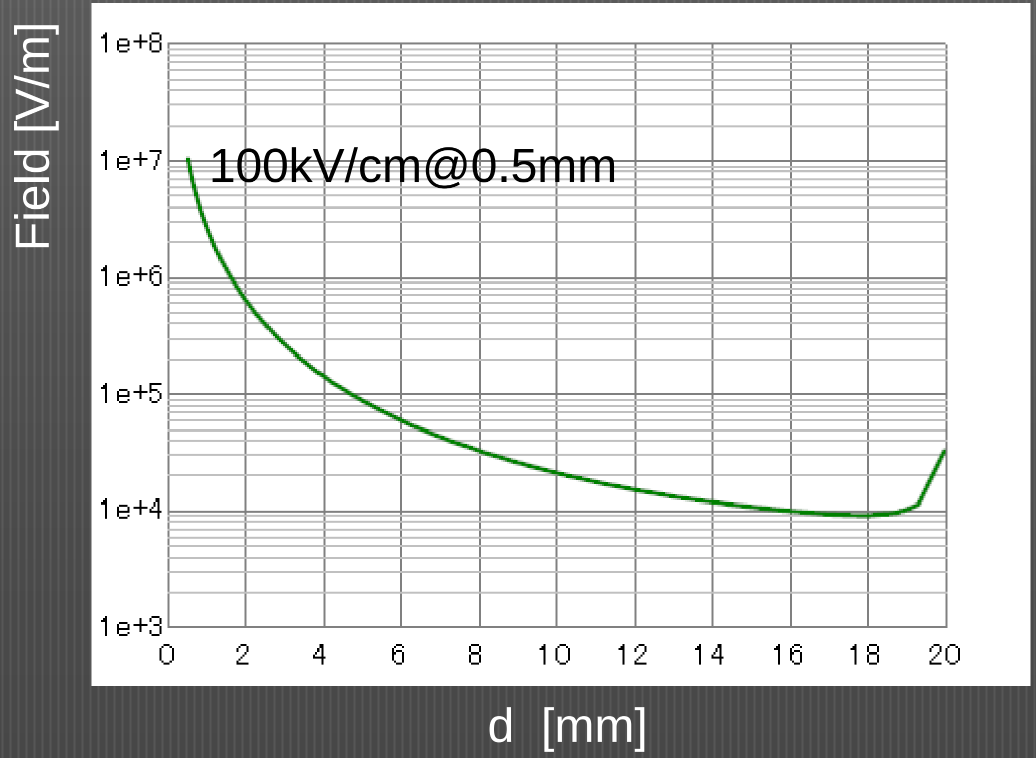
1st attempt

- 1mm ball with guard pipe does not work.
  - Only 100kV/cm for +5kV application

Equipotential line

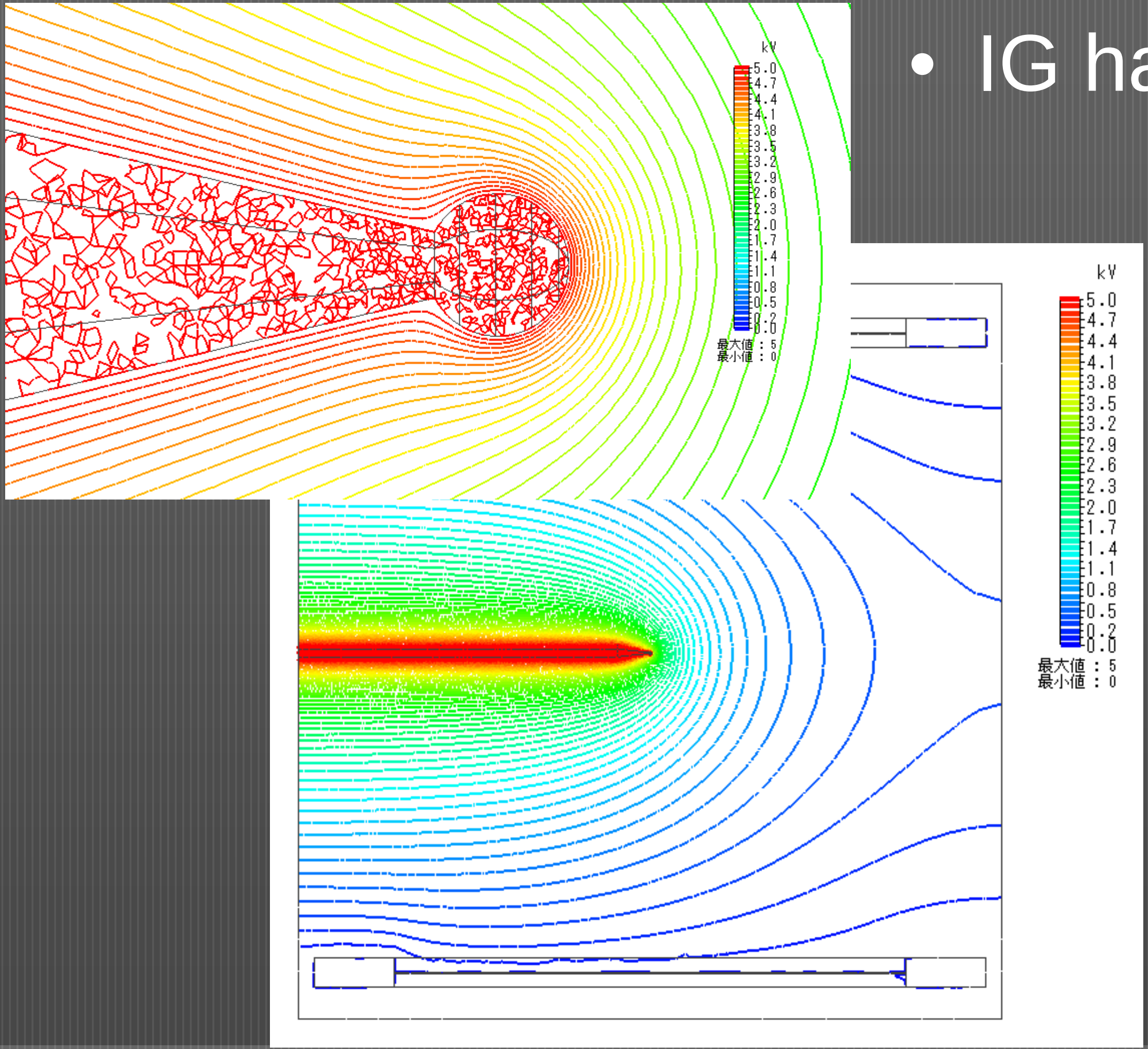


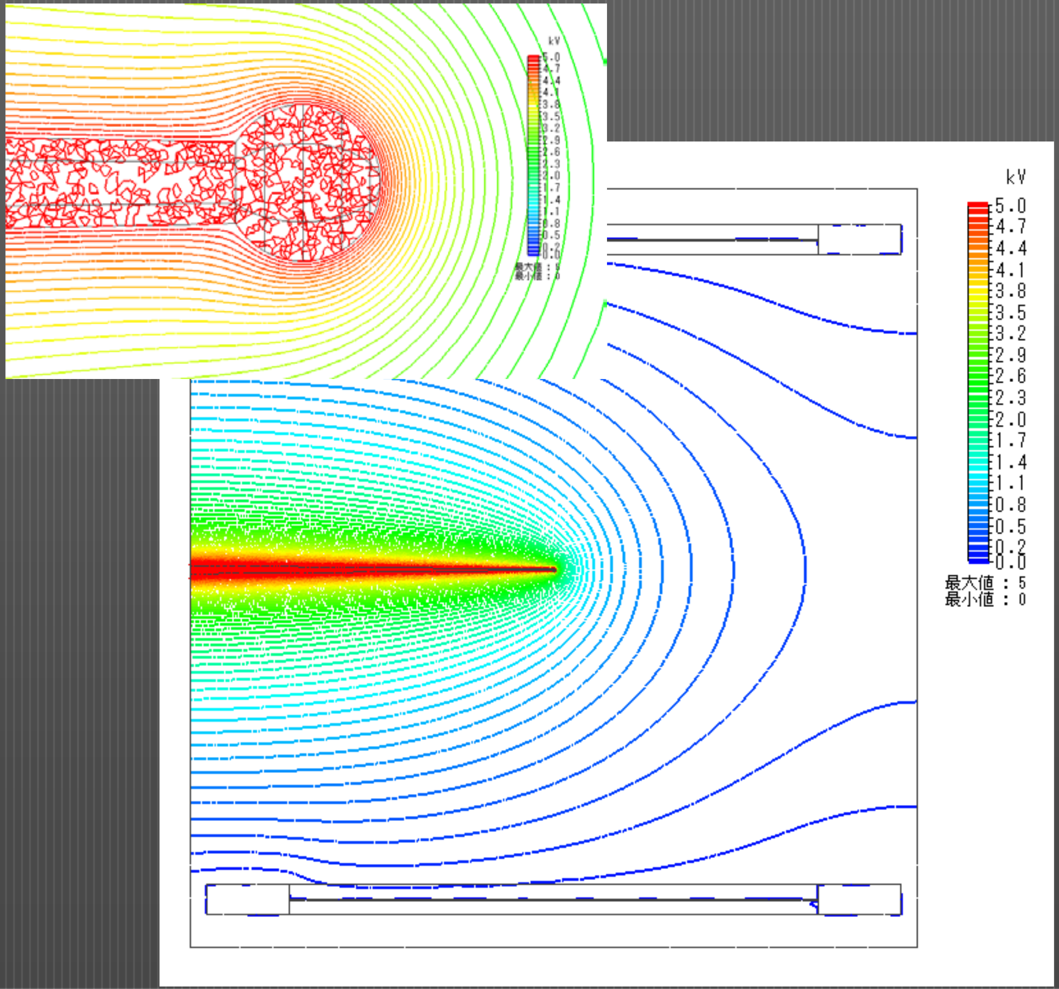




Less than 200μm ball is needed

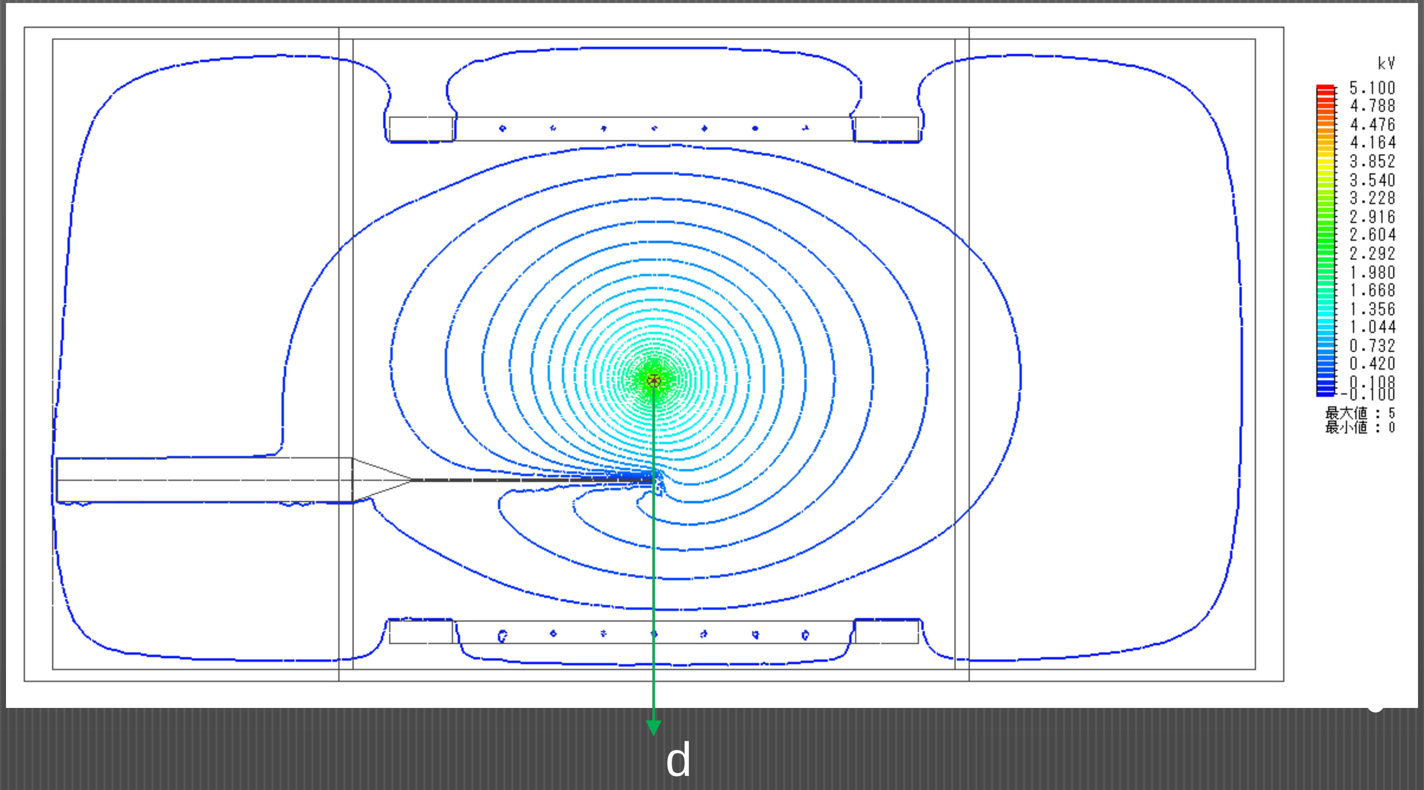
- IG has some experience on 200μm



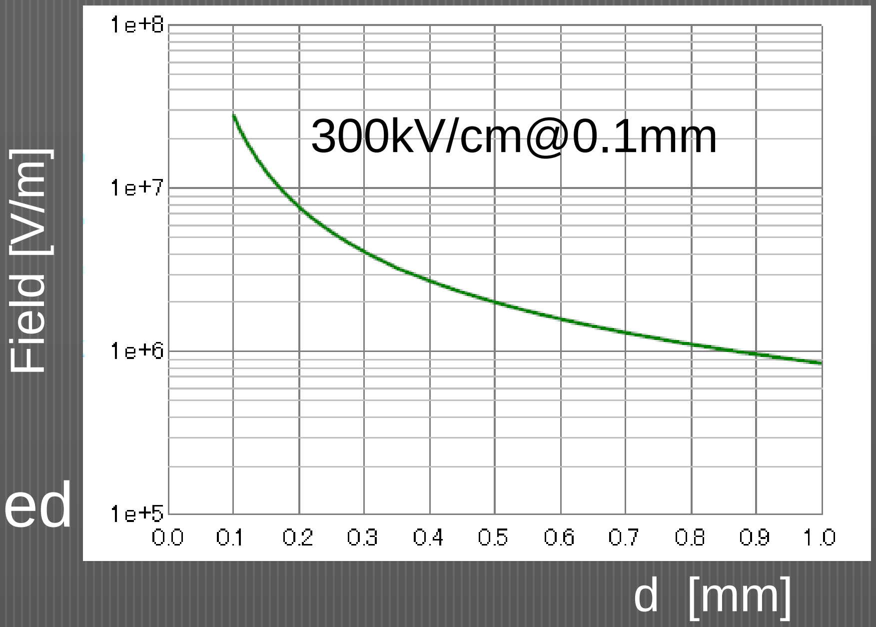


More than 7kV is needed for 200μm ball

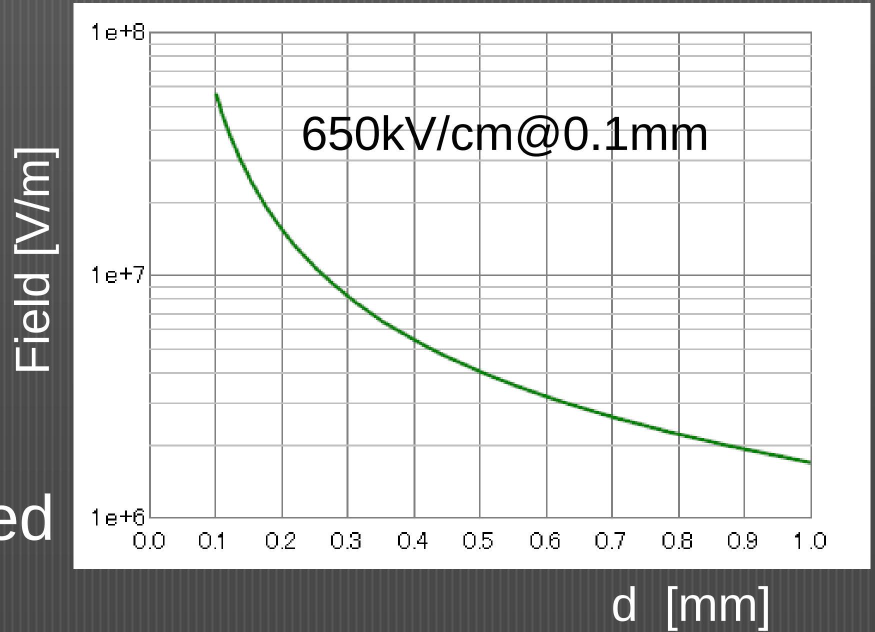
- Improvements on the feedthrough are indispensable



5kV applied



10kV applied



Summary

- No S2 was observed with 0.68mm-thick G-GEM @38kV/cm.
- S2 in LXe was confirmed with 10um wire.
- S2 threshold ~ 400kV/cm.
- S2 threshold for low energy particles (< 100keV) must be investigated by improving the feedthrough.
- Needle electrodes for spherical detectors are under investigation and will be tested.