Development of Cathode High Voltage Feedthrough for DarkSide and TPC HV related Studies

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HVNL13 @ FNAL
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HVNL13-FNAL
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DarkSide Collaboration

Augustana College, USA
Black Hills State University, USA
Brookhaven National Laboratory, USA
Fermilab, USA
Lawrence Livermore National Laboratory, USA
Pacific Northwest National Laboratory, USA
Princeton University, USA
SLAC, USA
Temple University, USA
University of Arkansas, USA
University of California at Los Angeles, USA
The University of Chicago, USA
University of Hawaii, USA
University of Houston, USA
University of Massachusetts at Amherst, USA
Virginia Tech, USA

APC Paris, France
IHEP, China
INFN Laboratori Nazionali del Gran Sasso, Italy
INFN and Università degli Studi Genova, Italy
INFN and Università degli Studi Milano, Italy
INFN and Università degli Studi Napoli, Italy
INFN and Università degli Studi Perugia, Italy
INFN and Università degli Studi Roma 3, Italy
Institute for Nuclear Research, Ukraine
IPHC Strasbourg, France
Jagiellonian University, Poland
Joint Institute for Nuclear Research, Russia
Lomonosov Moscow State University, Russia
RRC Kurchatov Institute, Russia
St. Petersburg Nuclear Physics Institute, Russia

DarkSide
A scalable, zero-background technology

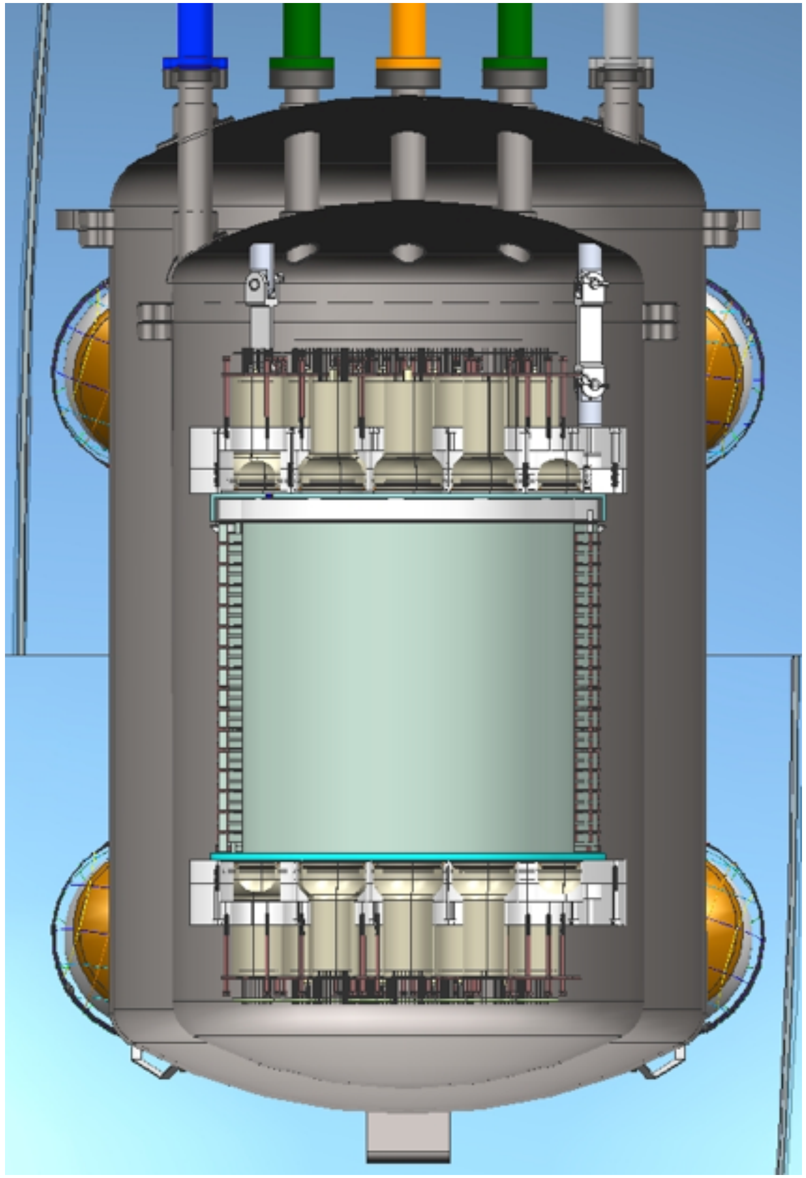
- Pulse shape of primary scintillation provides very powerful discrimination for NR vs. EM events:
  - Rejection factor $\geq 10^8$ for > 60 photoelectrons:
    - theoretical hint from Boulay & Hime, AstropartPhys **25**, 176 (2006)
    - experimental demonstration from WARP AstropartPhys **28**, 495 (2008)
    - recent confirmation from DEAP
- Ionization/scintillation ratio is a strong and semi-independent discrimination mechanism:
  - Rejection factor $\geq 10^2$-10^3 (Benetti et al. (ICARUS) 1993; Benetti et al. (WARP) 2006)
- Spatial resolution from ionization drift localizes events, allowing rejection of multiple interactions, "wall events", etc.
- High Efficiency Neutron Veto scintillator Shield
- Muon Veto water shield
- Underground argon
  - Production and refinement demonstrated in Princeton & Fermilab
  - Rejection factor ≥100!

Underground Argon Extraction Plant (150 of 150 kg collected)

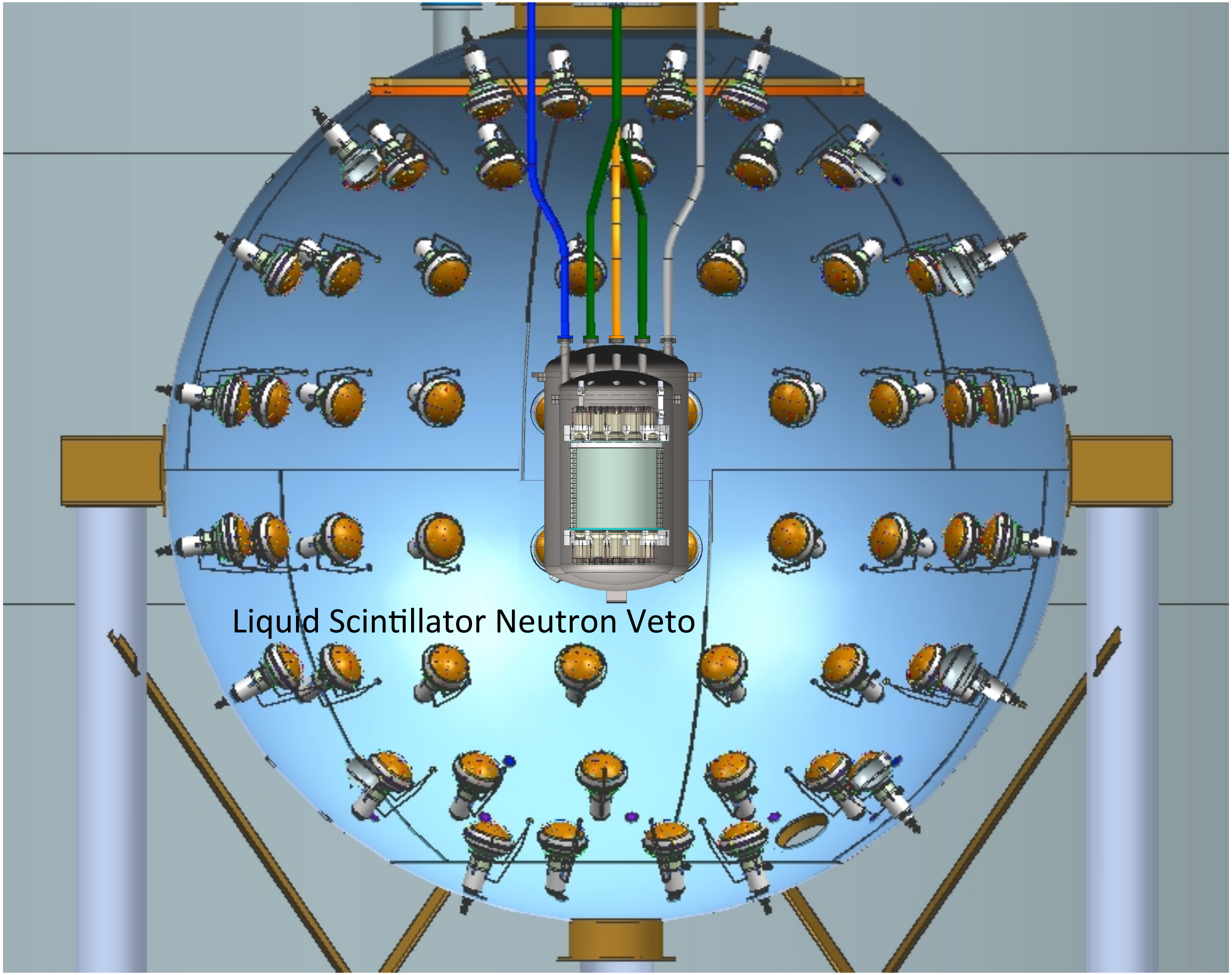
Cryogenic Distillation Column

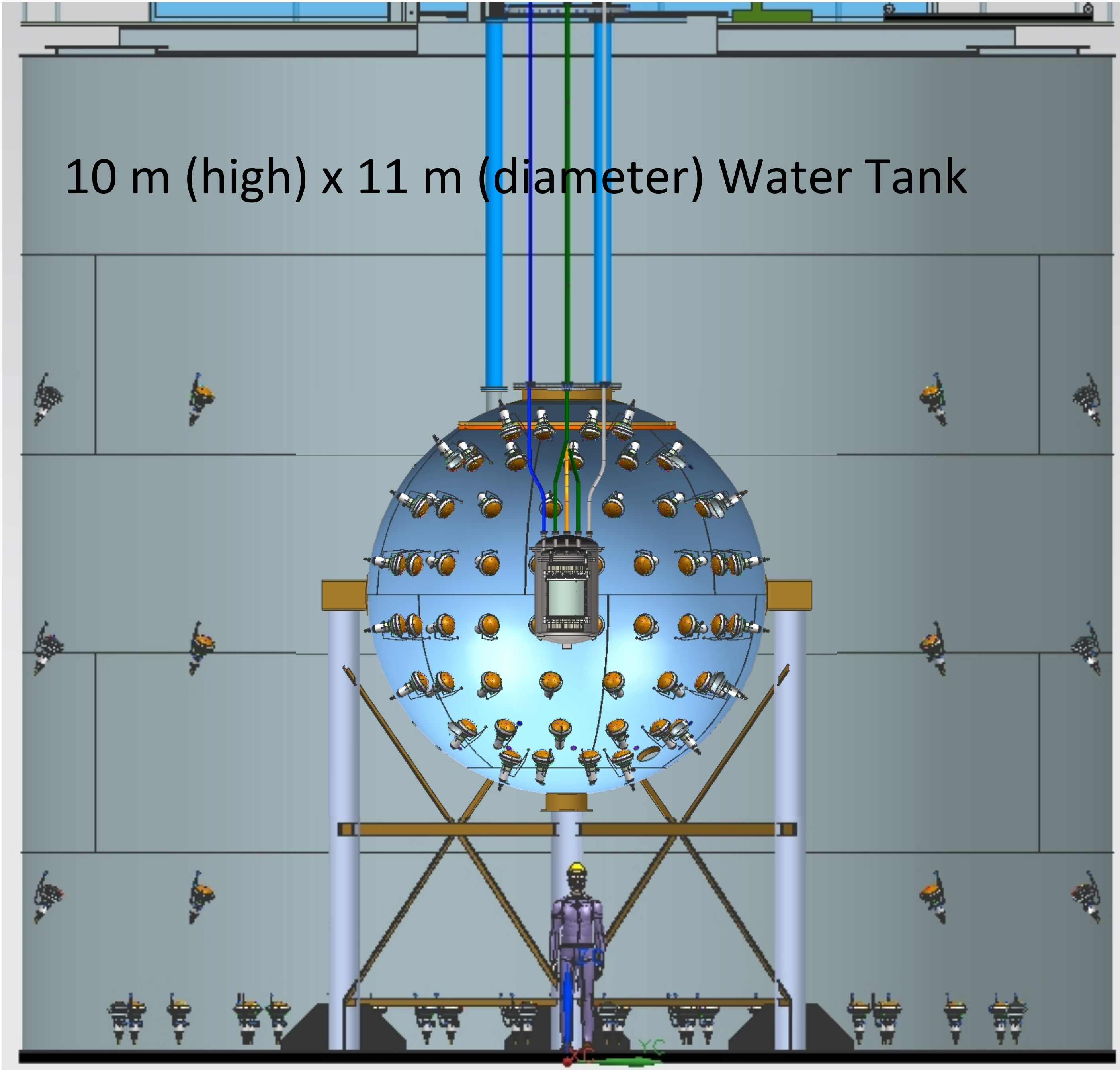
Assembled and operated at the Fermilab PAB

Special thanks to PAB staff!



Liquid Argon
TPC
& Cryostat


Liquid Scintillator Neutron Veto


10 m (high) x 11 m (diameter) Water Tank

LSV

LSV

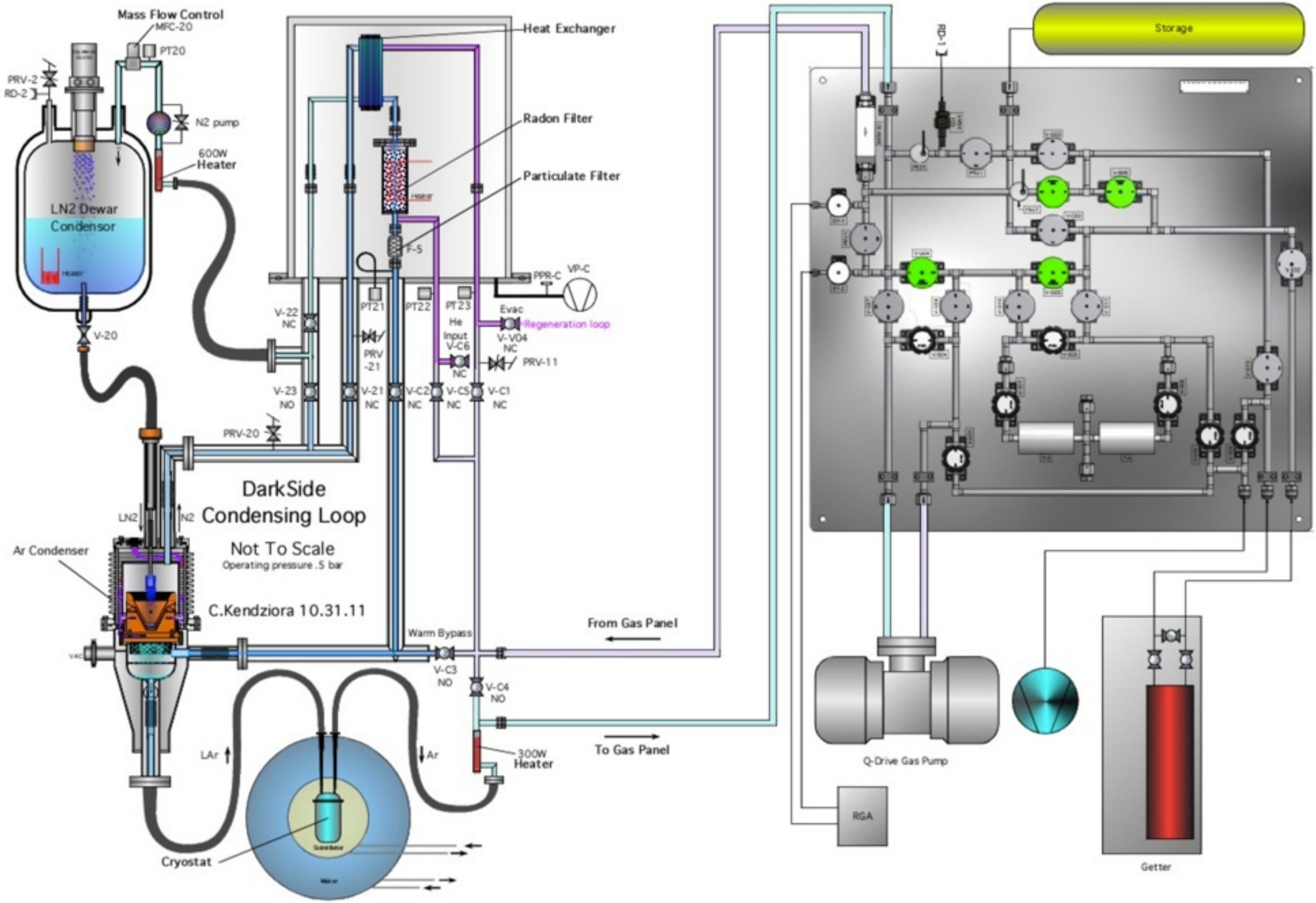
CR1 radon suppressed clean room

CRH radon suppressed clean room

Obtained ≲5 mBq/m3 in >100 m3 CRH!!!

Cryogenics, Recirculation and Purification System

Achieved Stability ±0.005psi

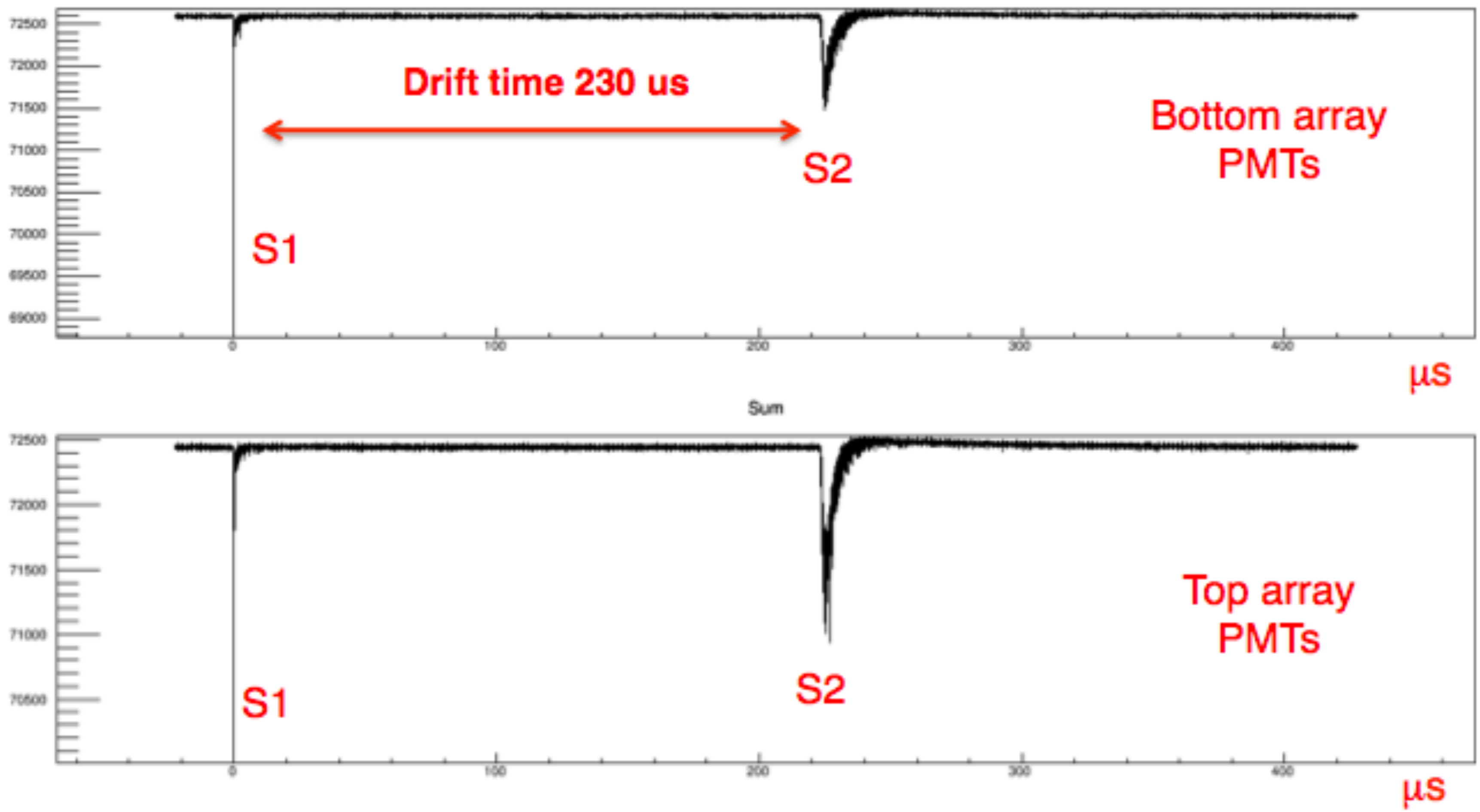


Darkside-50 event display snapshot

Total PMT number: 38
TOP array PMTs: 19
Bottom array PMTs:19

Event: 1
Single interaction

Drift field: 0.2 kV/cm
Extraction field: 3.2 kV/cm
Drift speed: 1 mm/μs
Max drift length: 355 mm

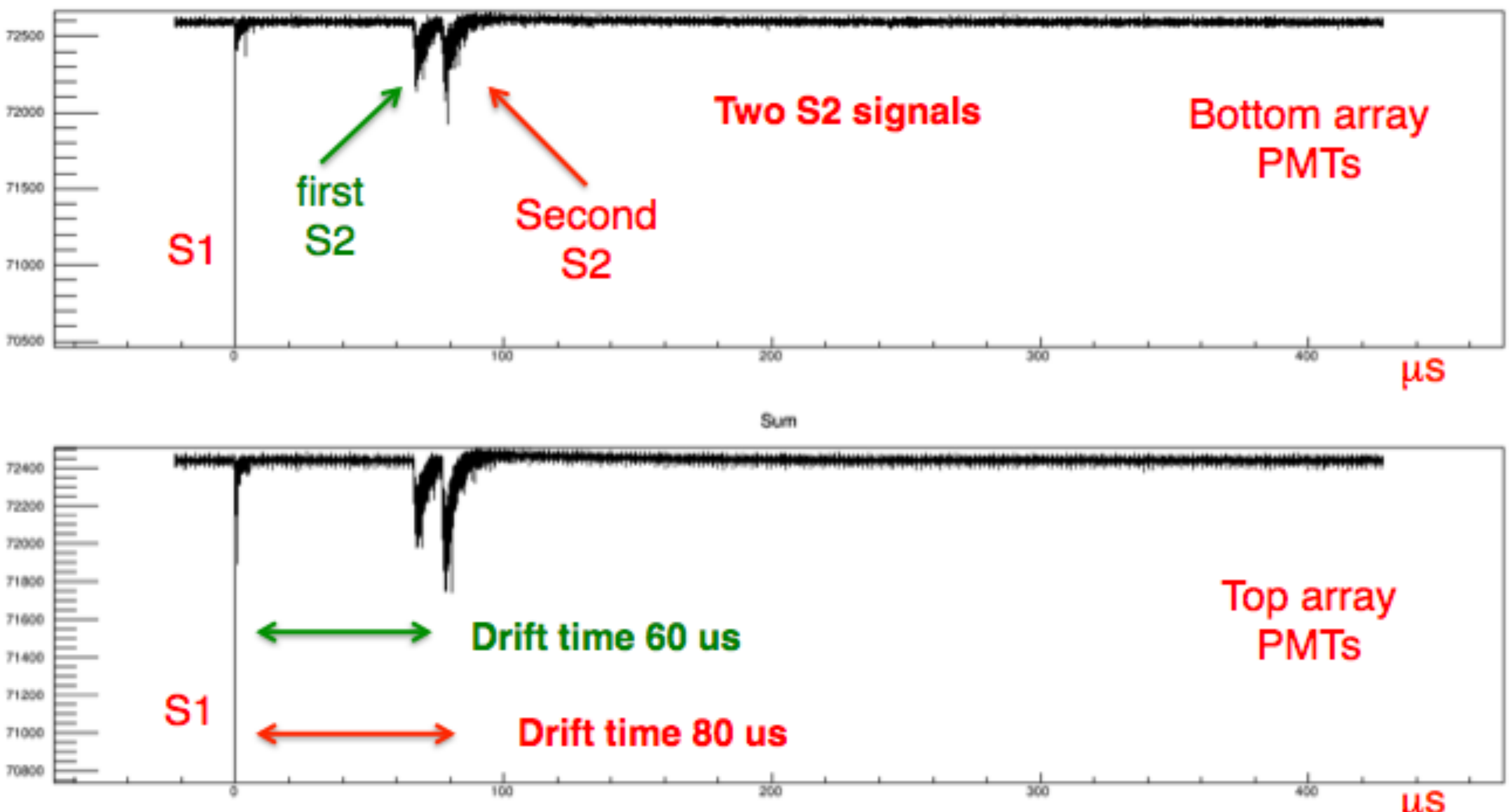


Darkside-50 event display snapshot

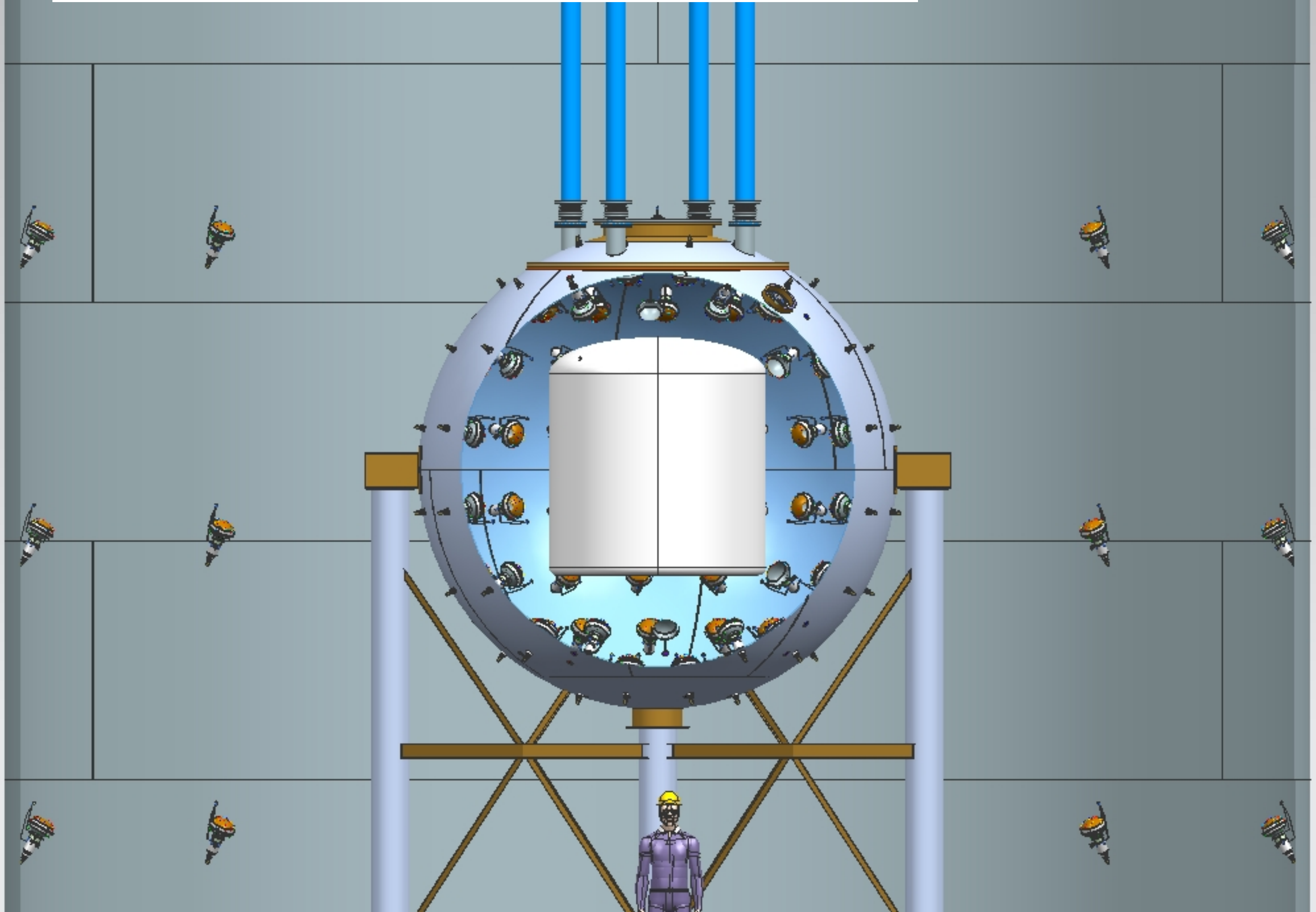
Total PMT number: 38
TOP array PMTs: 19
Bottom array PMTs:19

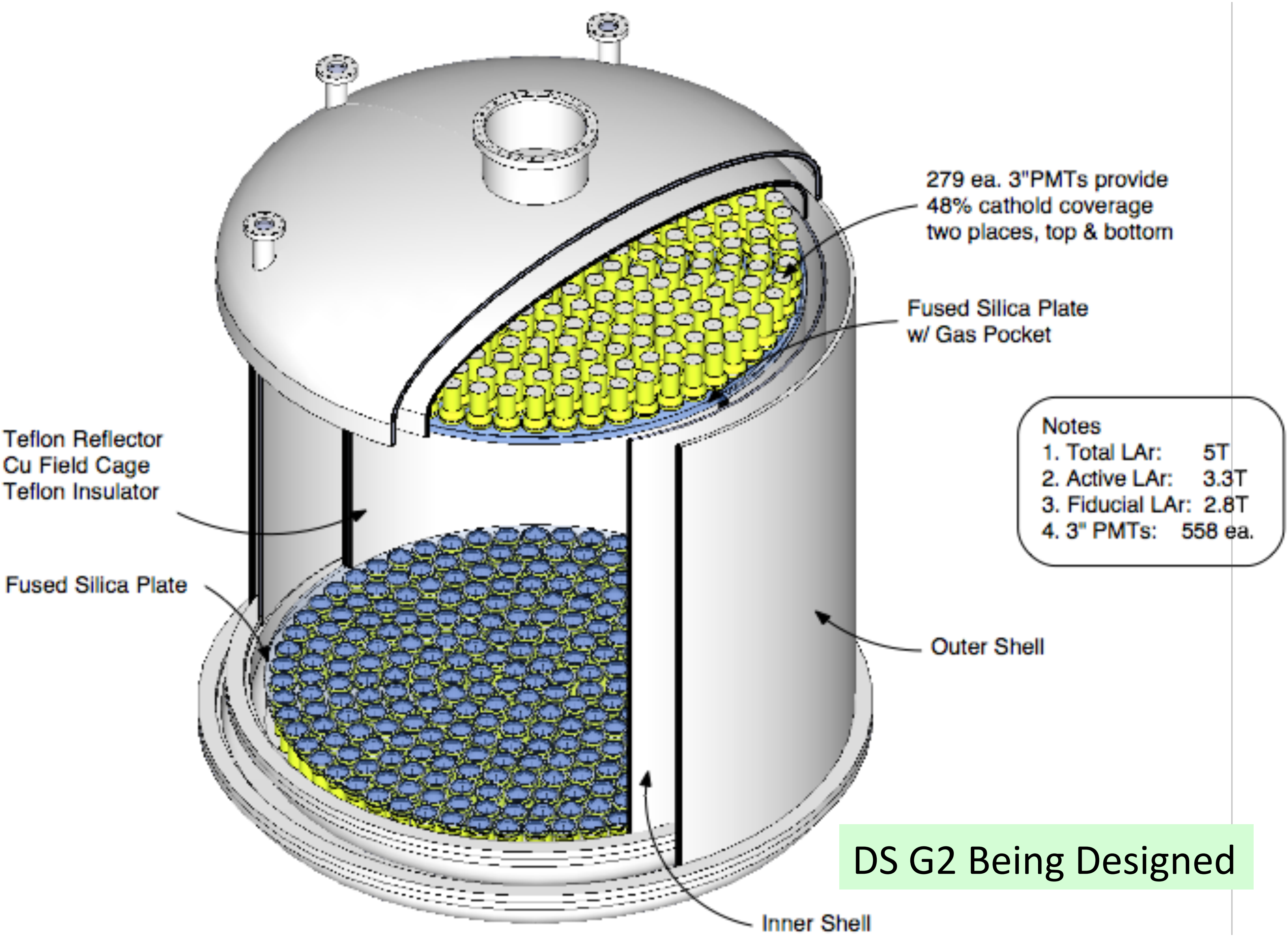
Event: 3
Double interaction

Drift field: 0.2 kV/cm
Extraction field: 3.2 kV/cm
Drift speed: 1 mm/μs
Max drift length: 355 mm

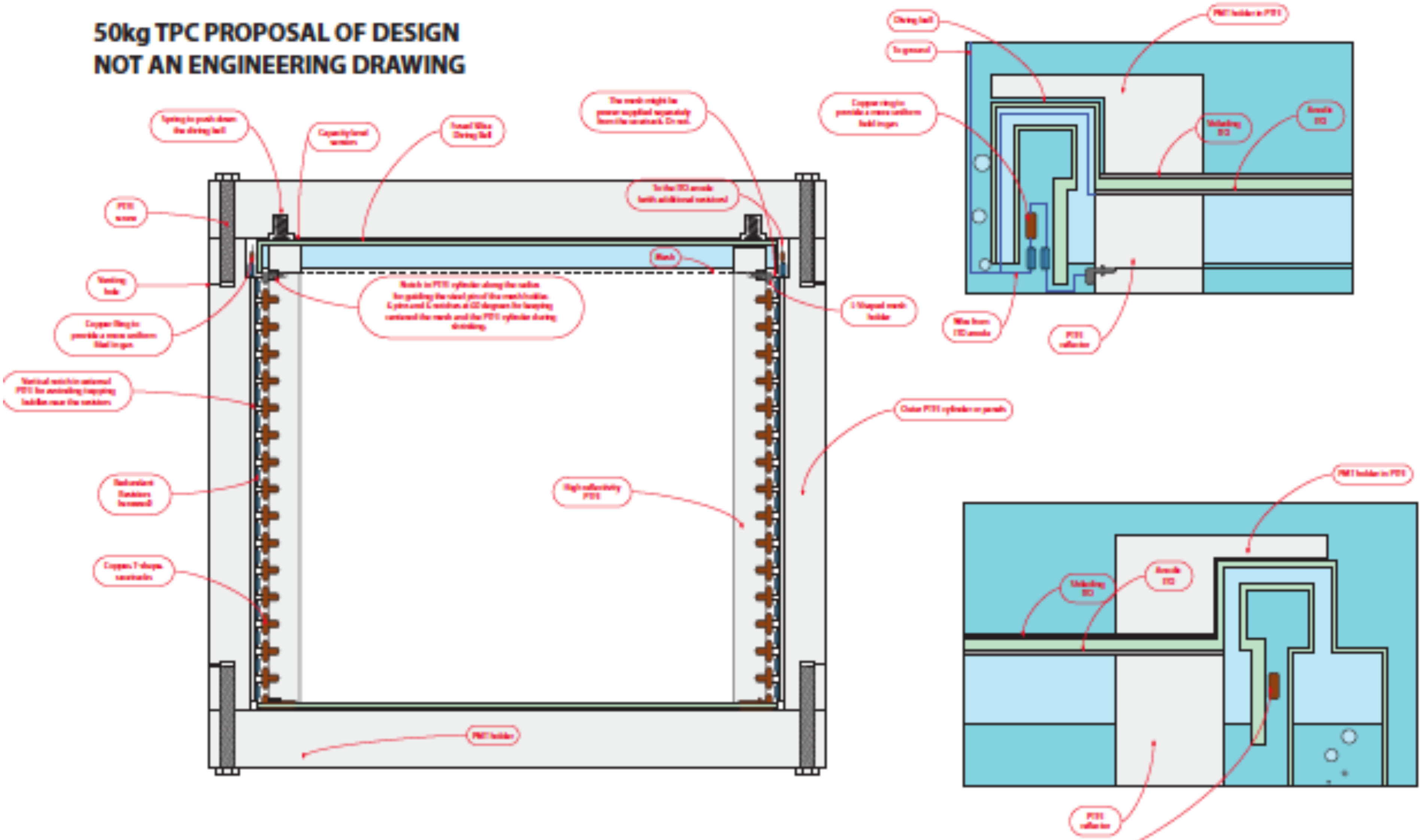


Same infrastructure to host DS G2





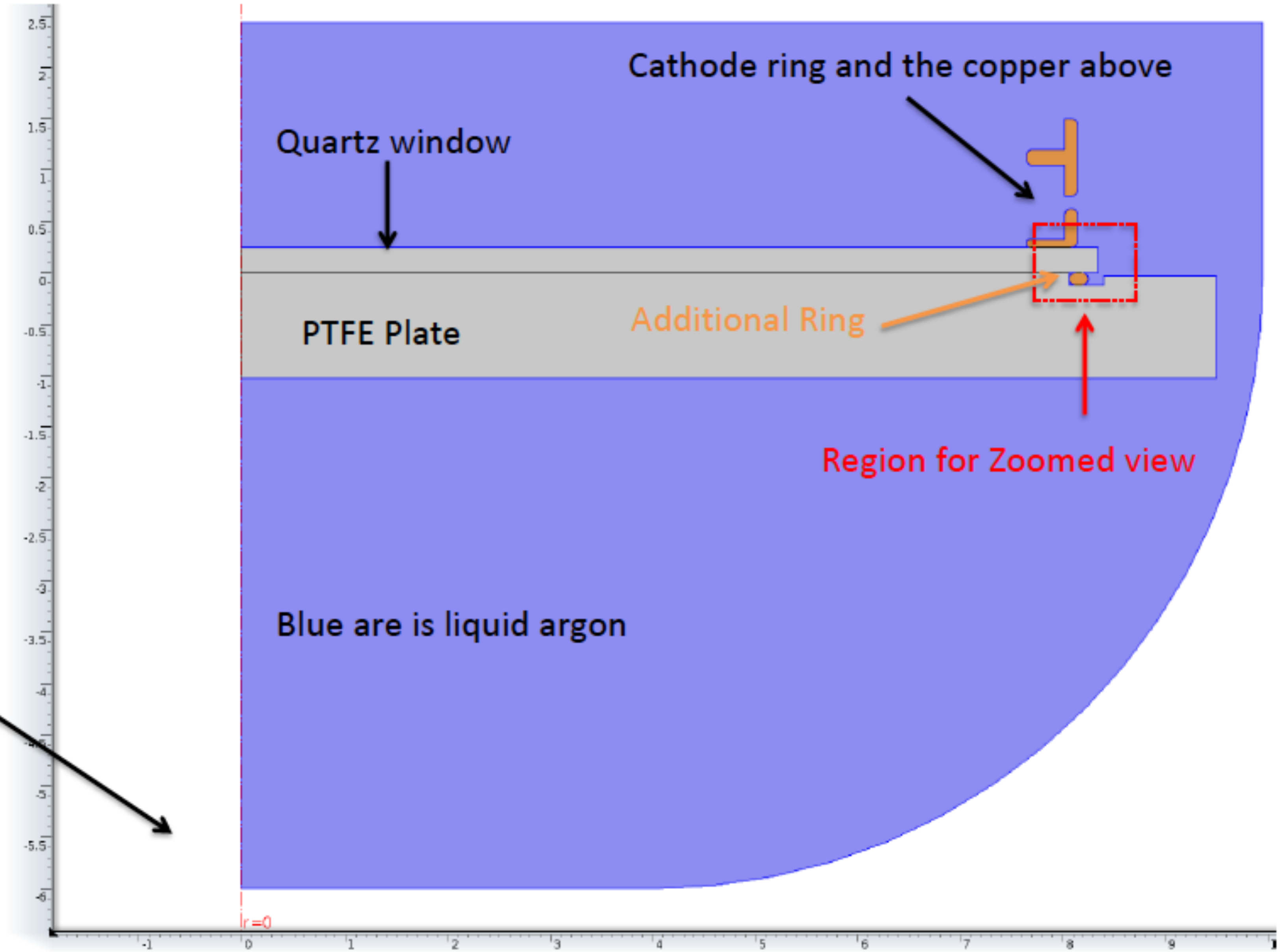
DS G2 Being Designed



Laydown All possible TPC considerations we can think of before engineering: HV, Field cage, thermal, light yield,....

We Model All Critical Details

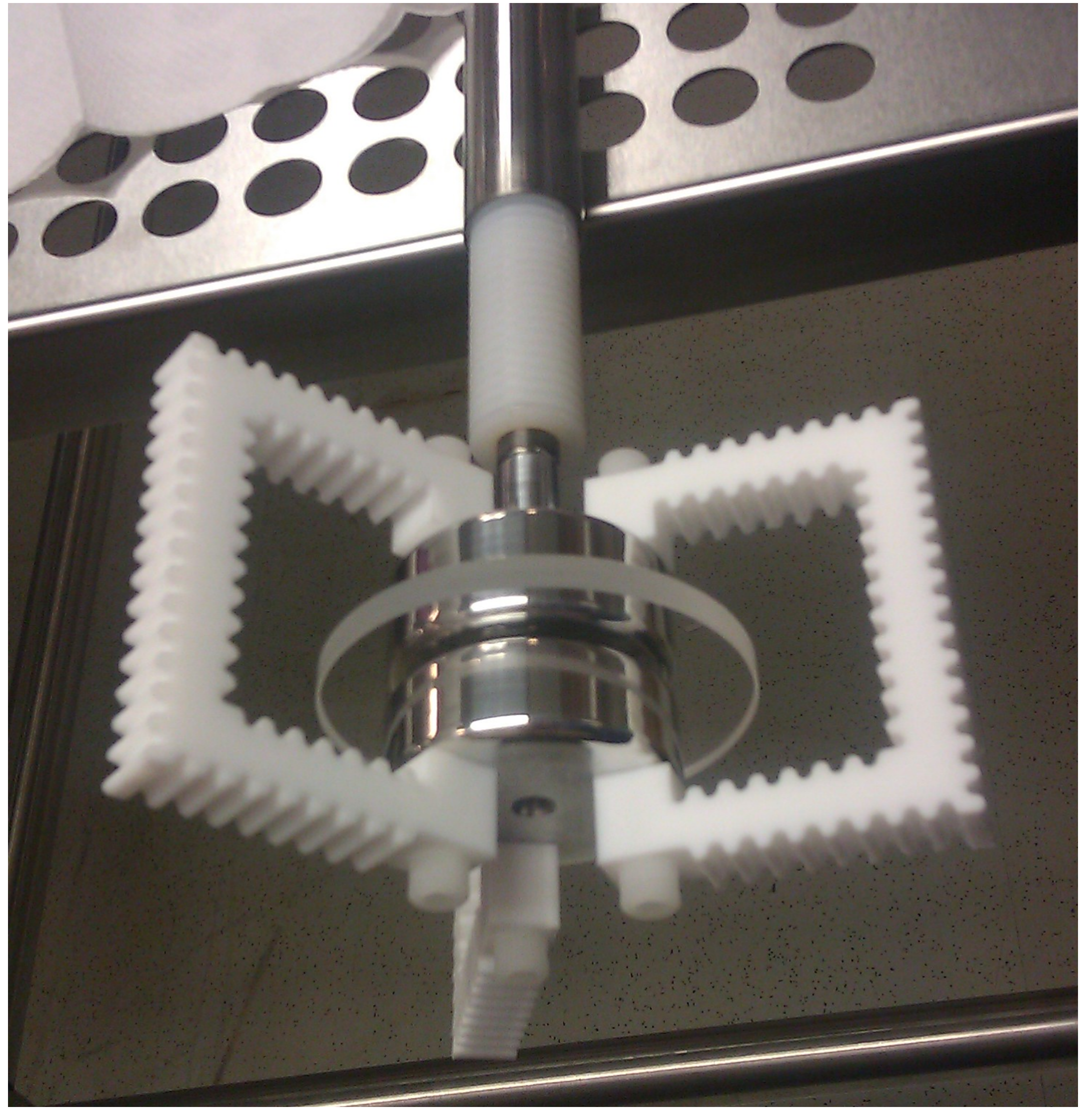
Horizontal and vertical axis unit is inch



Axial-symmetric 2D geometry is used

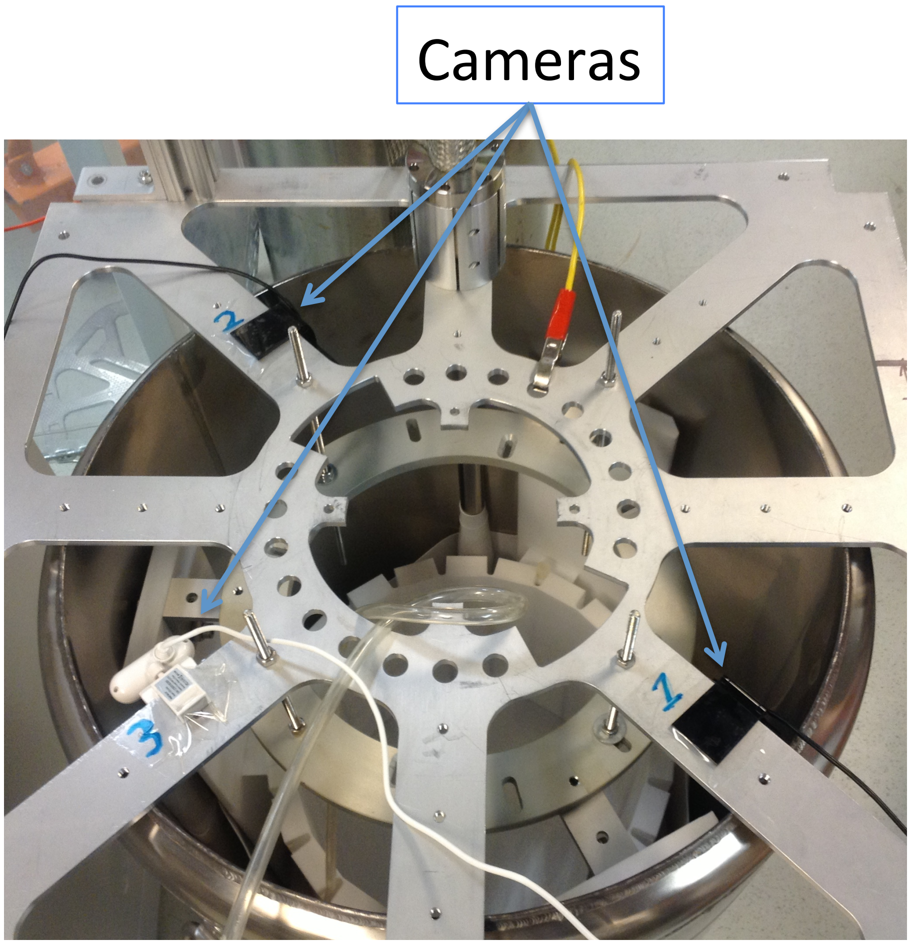
We then validate Each details

Note: Extreme care taken to avoid introducing unknowns



Cathode ITO geometry validation

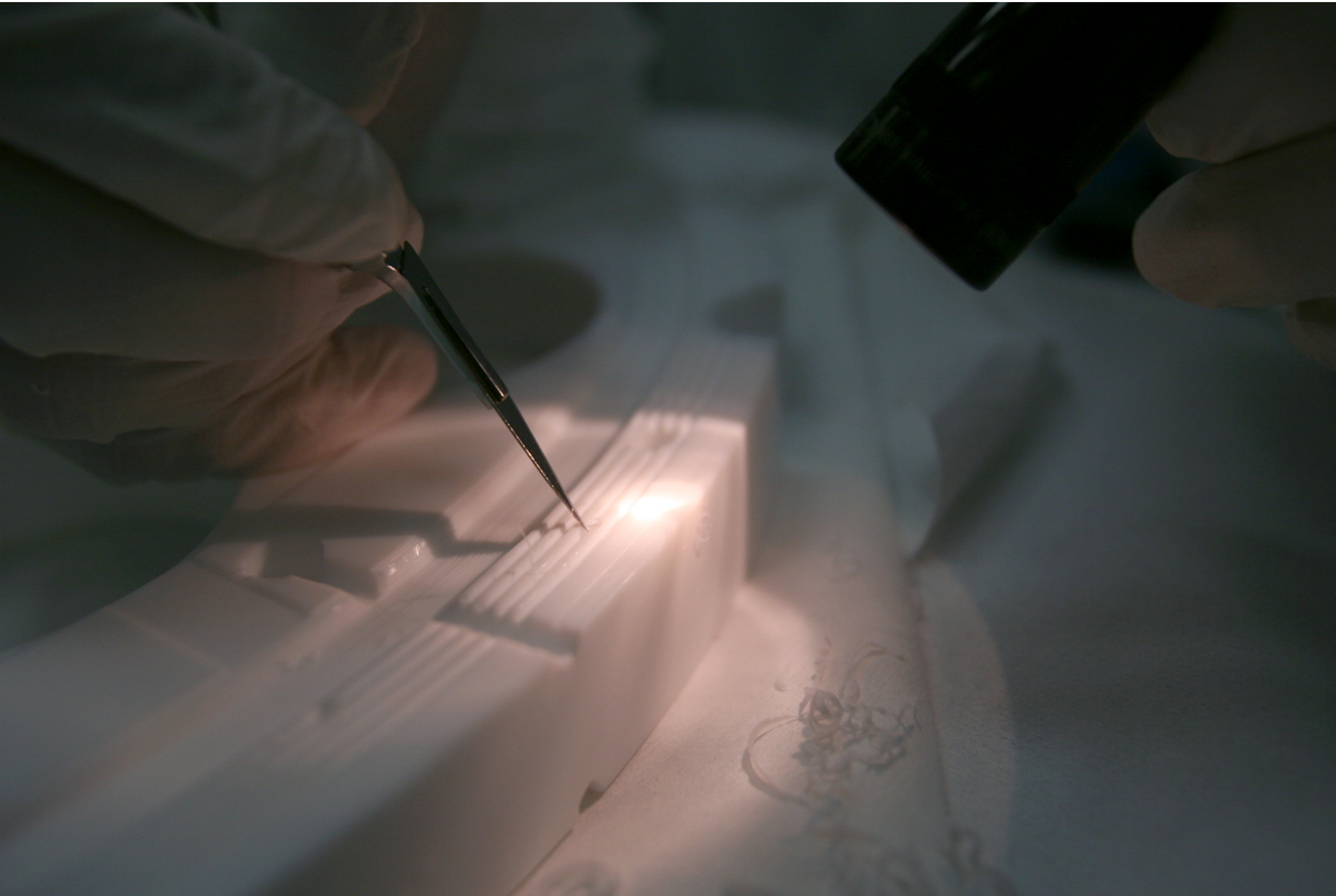
Full scale mock up to test critical HV regions
Validate all details before final deployment!



Full Scale TPC mock up test in identical shape Cryostat with three cameras installed to record suspected areas

In two runs, we positively identified issues and confirmed the final deployment details design

We take care every corner related to HV



HV related feature details everywhere!

HVFT Fabricated for DarkSide

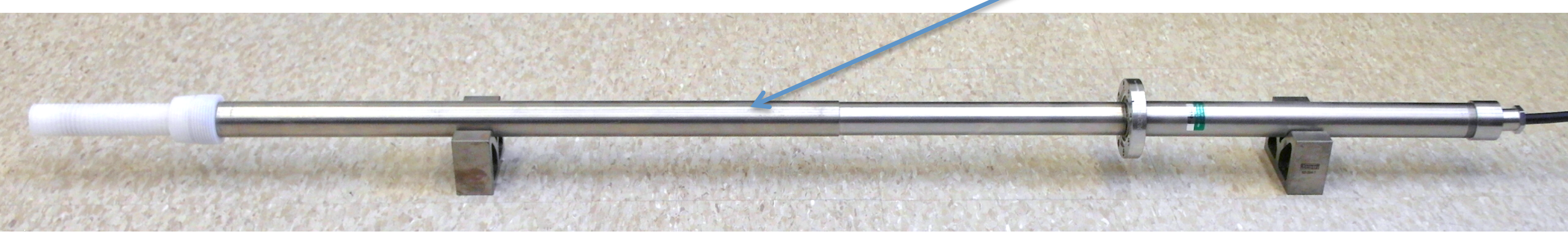
material: Low background Stainless Steel and UHMW PE

DS50

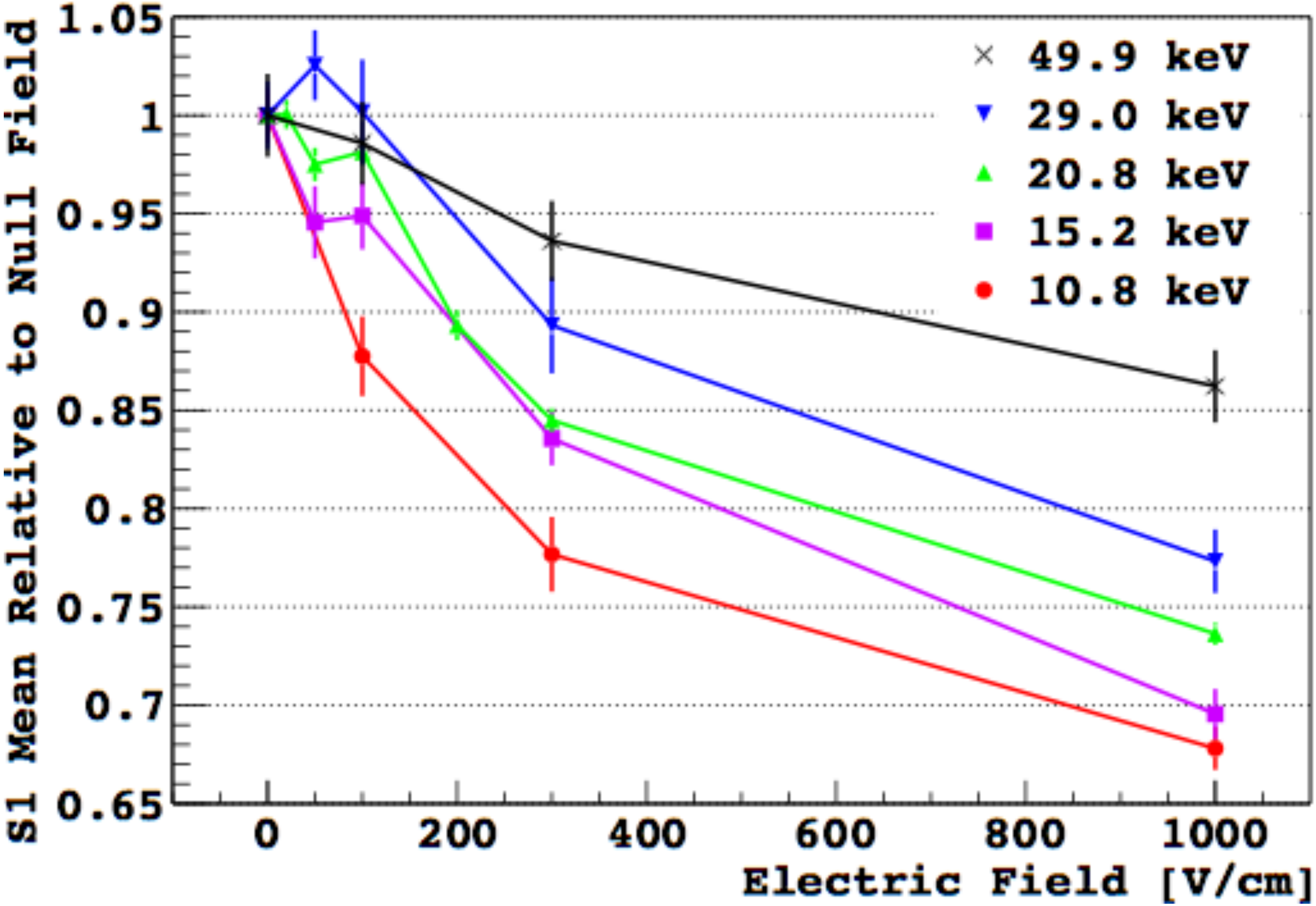
1.0” diameter

1.5” diameter

DS G2



Recent SCENE Results



Past and current estimates of sensitivity for noble liquid TPC dark matter searches assume the light yield for nuclear recoils is only slightly affected by the presence of a drift field

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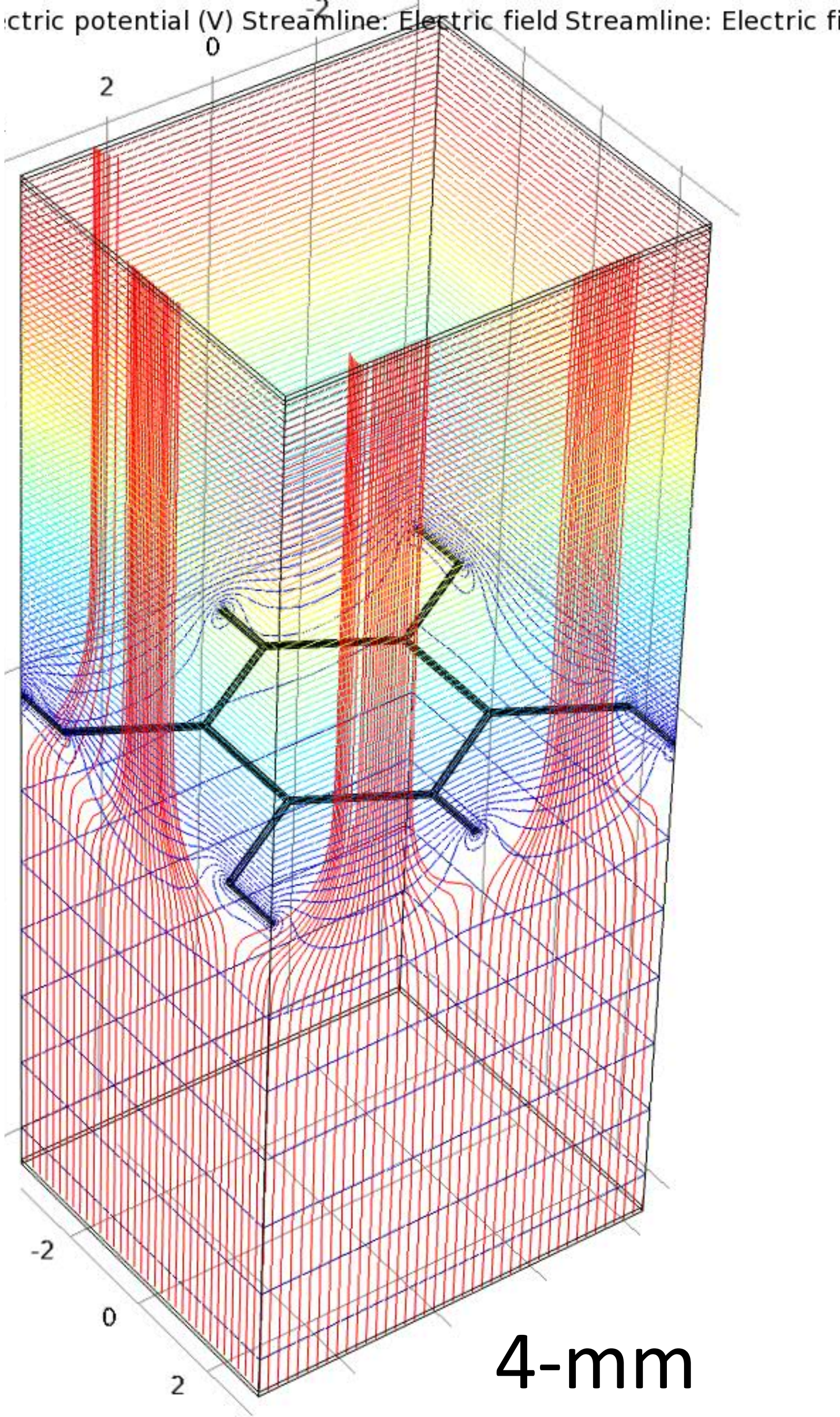
Operate at much lower HV

TPC Optimization related to Mesh Size should we use fine mesh and if yes, how fine should it be?

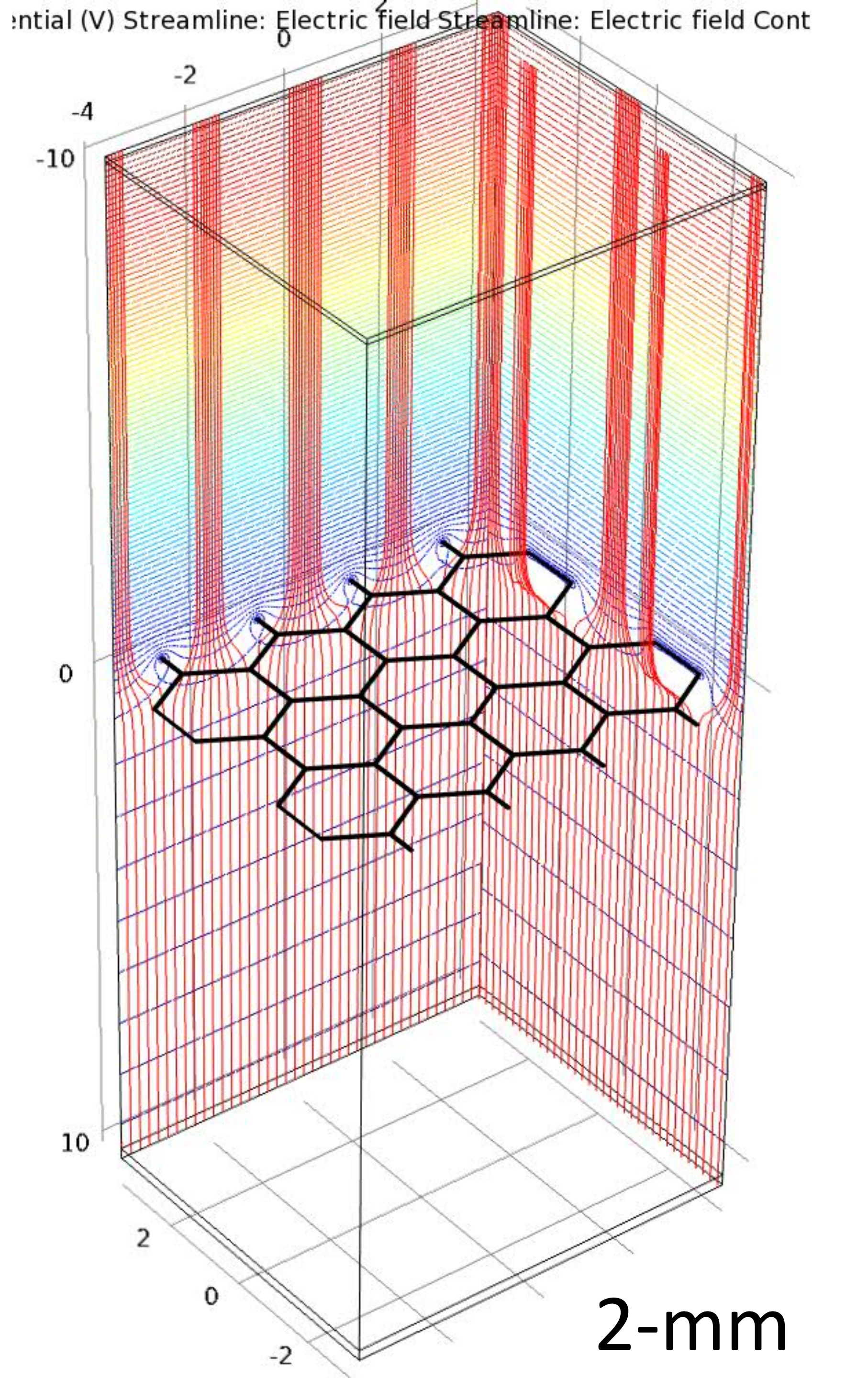
- Optical Transparency
- Electron Transparency
- Electron Drift Path (path length)
- Effect on longitudinal diffusion
- Level Measurement (gap)
- S2/S1 vs S1 Cut efficiency

Purpose of this note

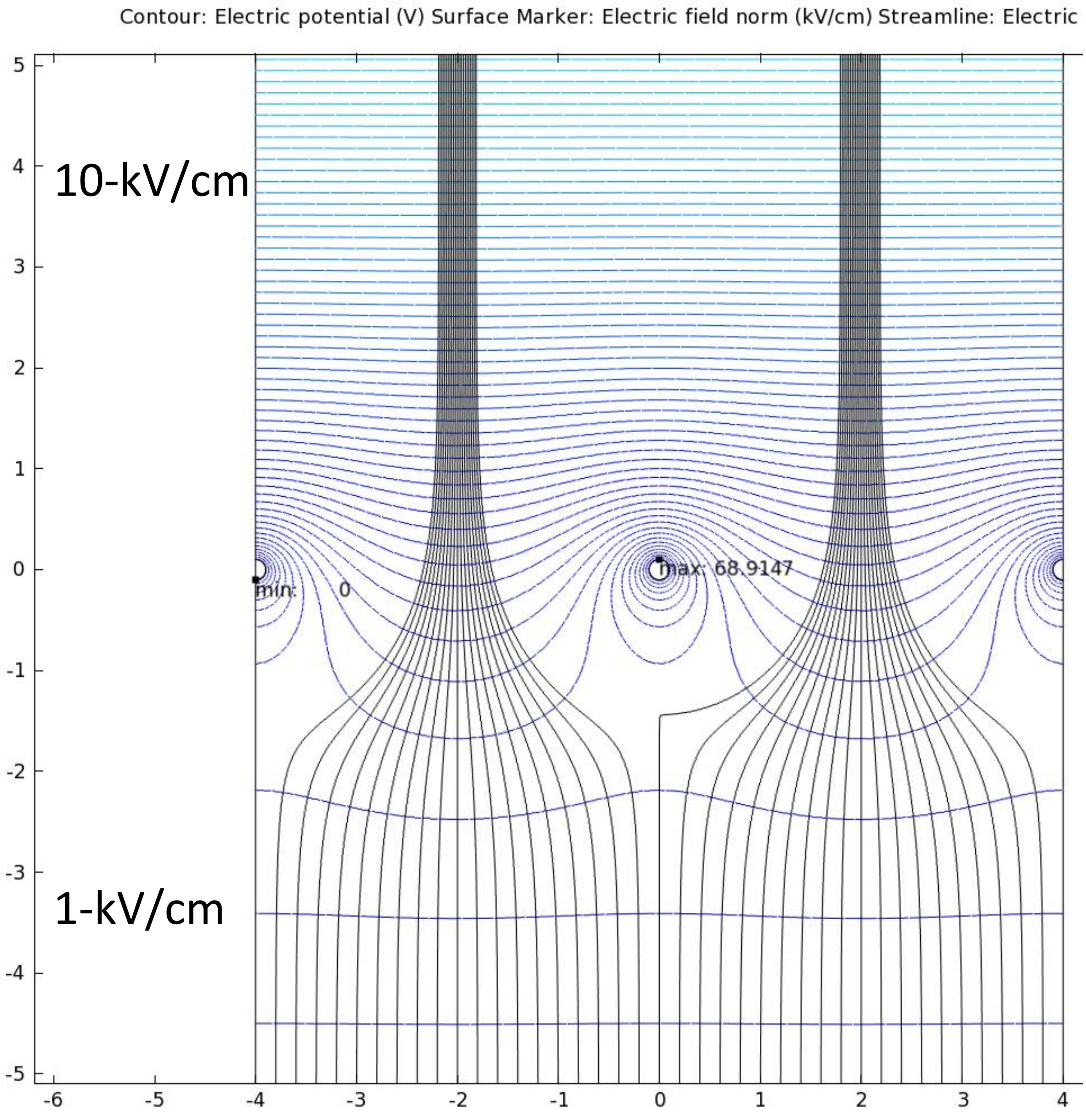
- To clarify that the field strength around mesh wire is constant when:
  - Field ratio and Optical transparency is fixed.
- Then go with finer mesh:
  - as fine as mechanically possible
  - Less field leakage
  - Less lateral drift shifts of electrons
  - Less drift path difference for different start point
  - Total mass of mesh is less



ctric potential (V) Streamline: Electric field Streamline: Electric fi
4-mm



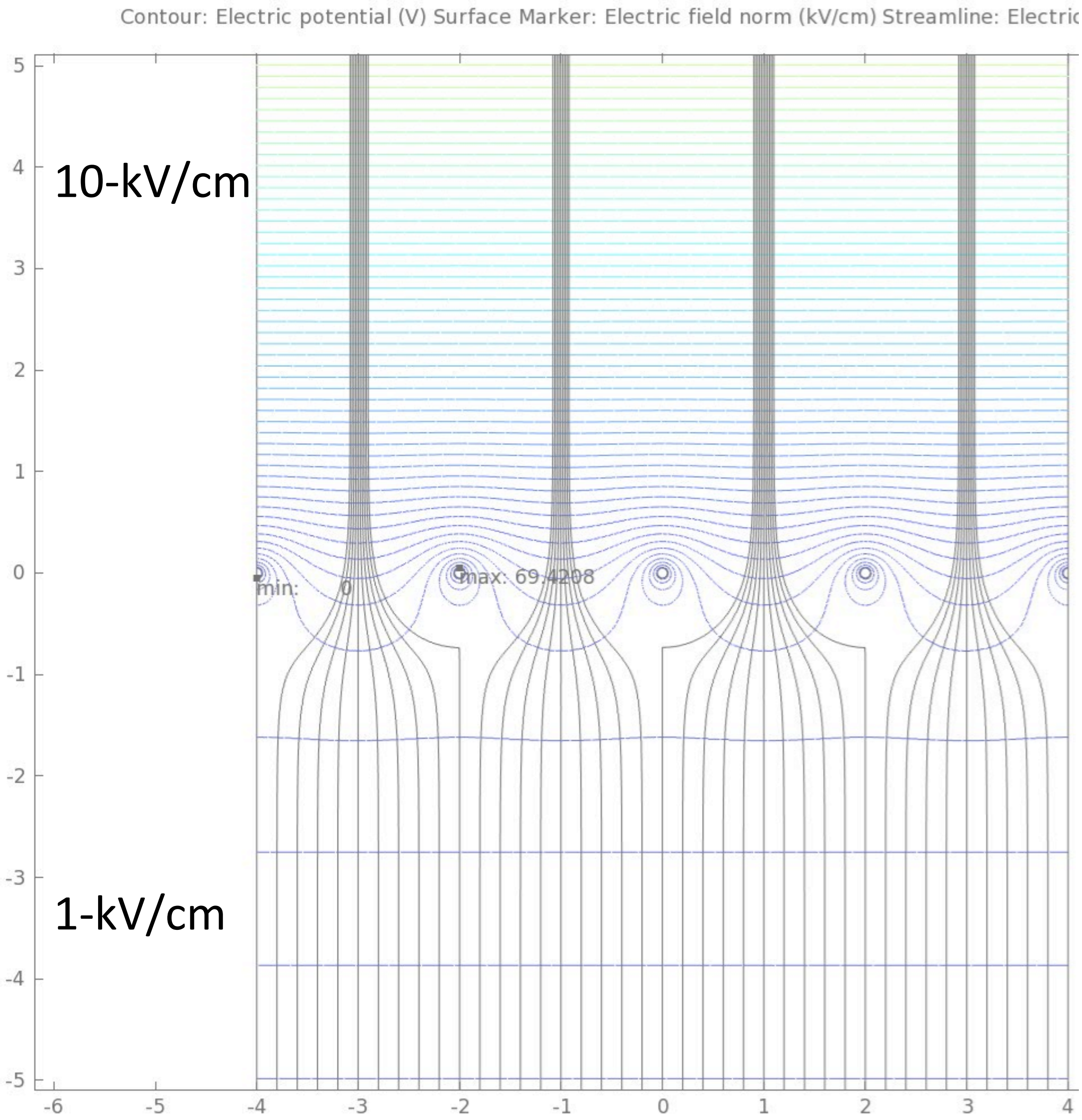
ential (V) Streamline: Electric field Streamline: Electric field Cont
2-mm



4-mm mesh
Strip size
200-um

Emax around
thin strip

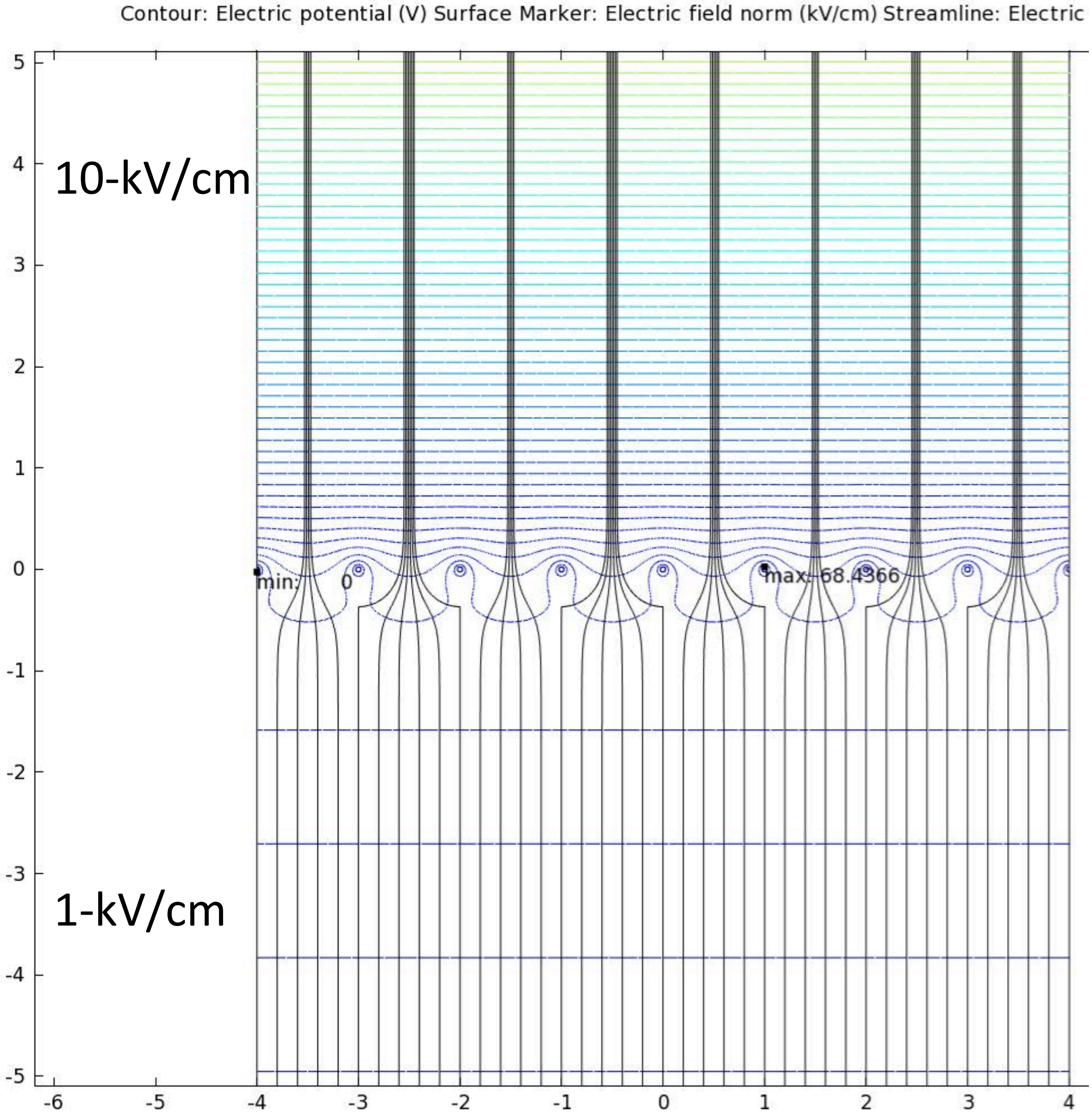
68.9-kV/cm



2-mm mesh
Strip size
100-um

Emax around
thin strip

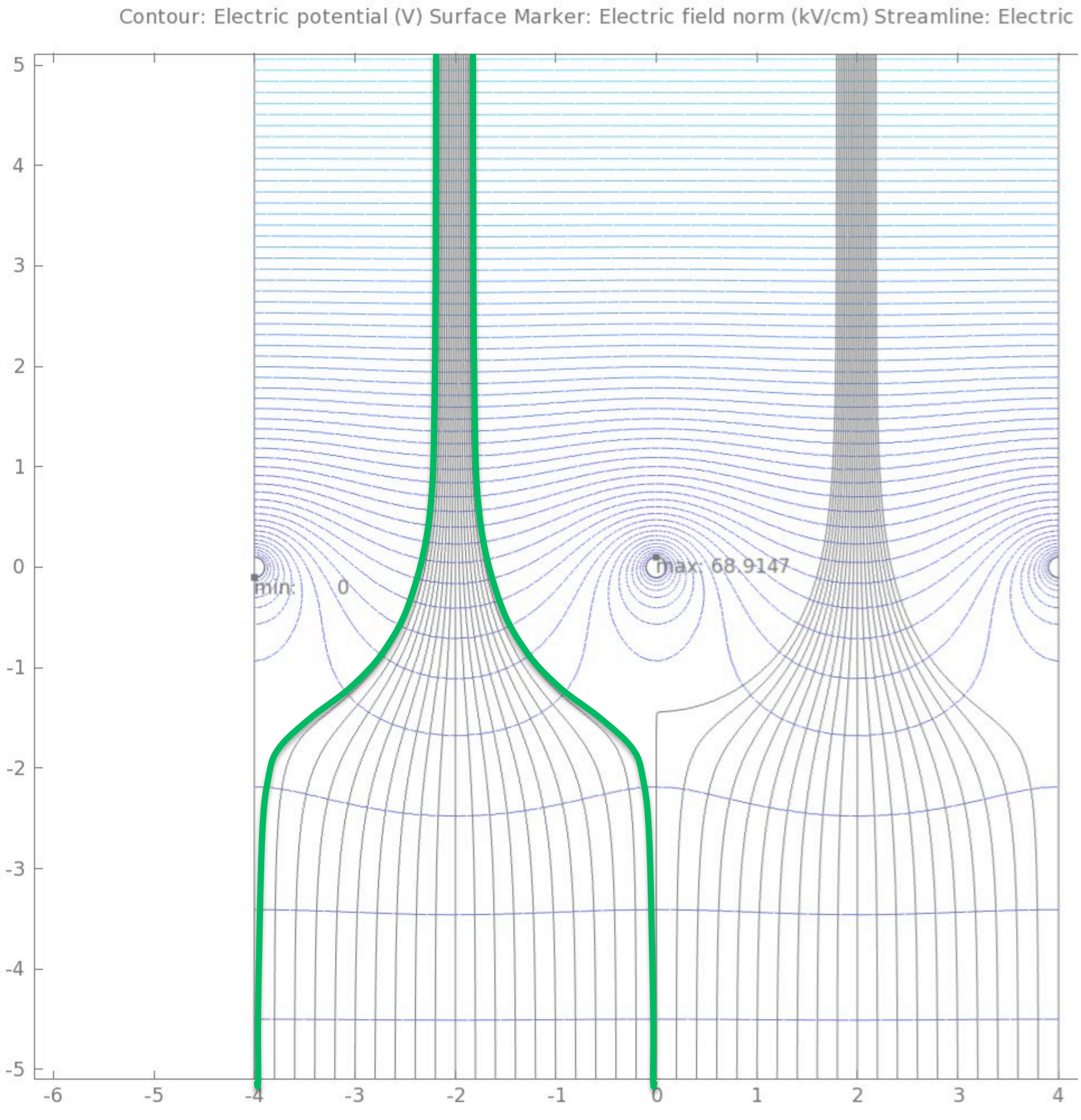
~69.4-kV/cm



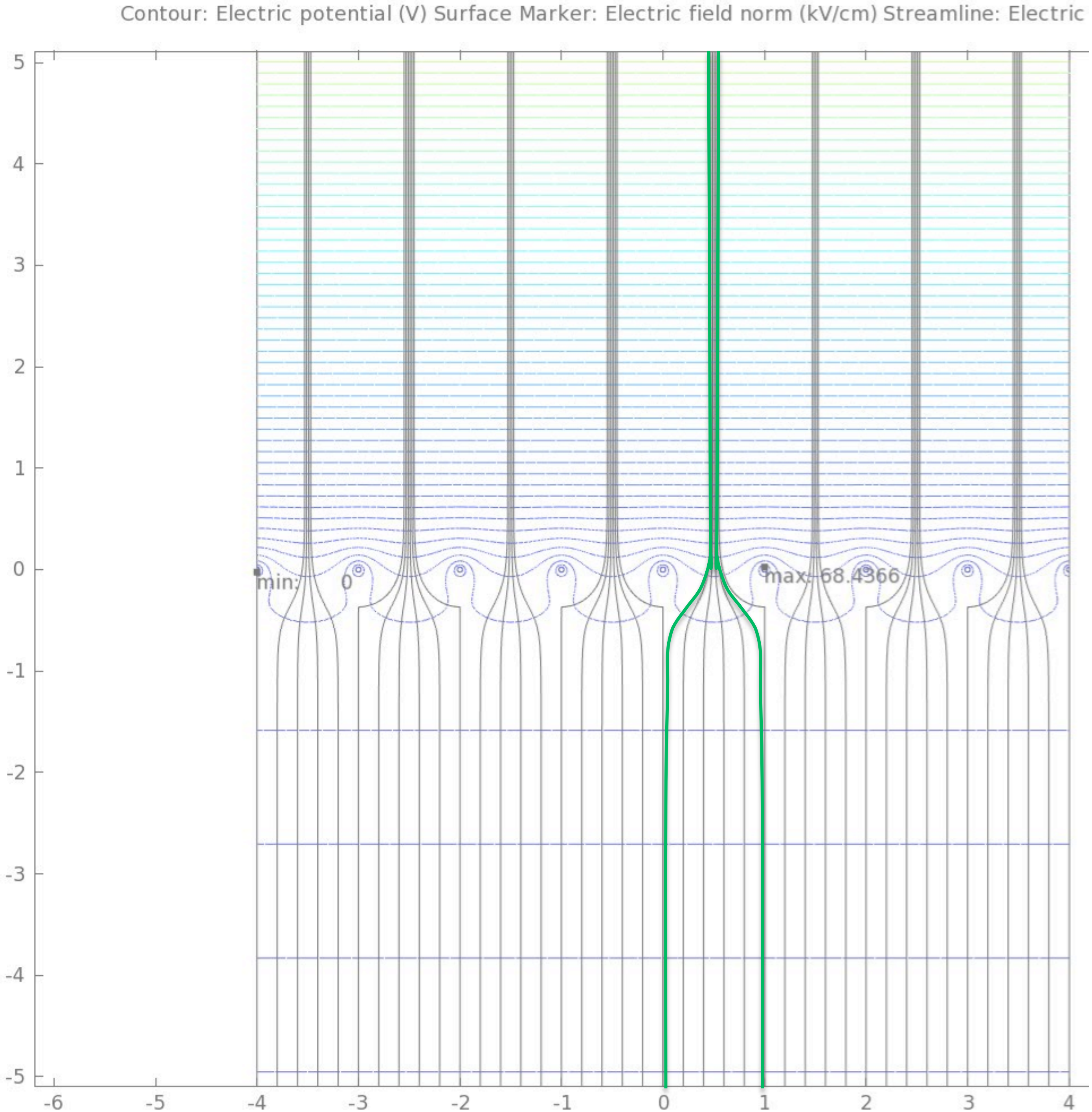
1-mm mesh
Strip size
50-um

Emax around
thin strip

~68.4-kV/cm



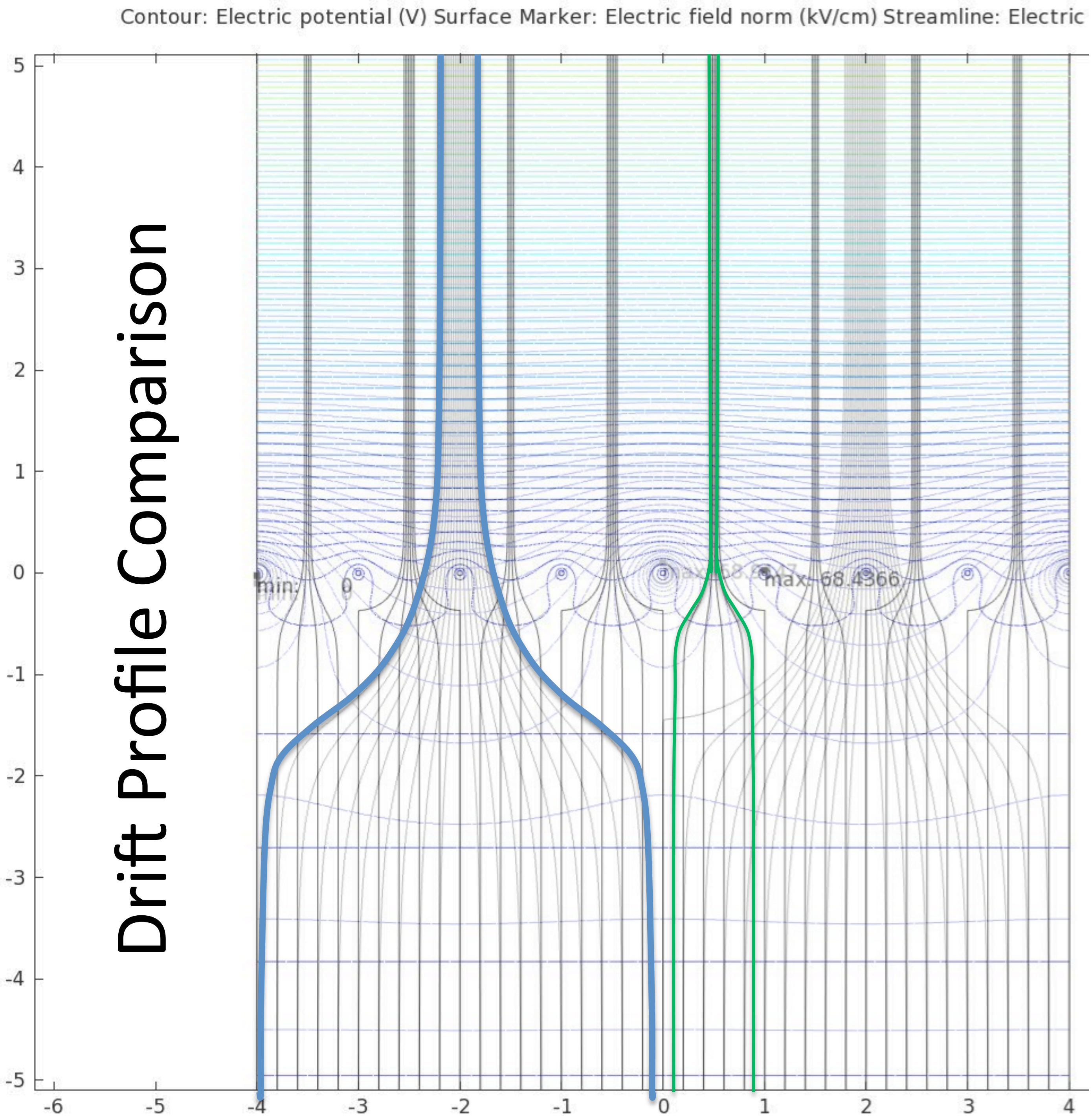
4 mm pitch
Mesh
Max
Lateral
displacement
2-mm



1mm pitch
Mesh

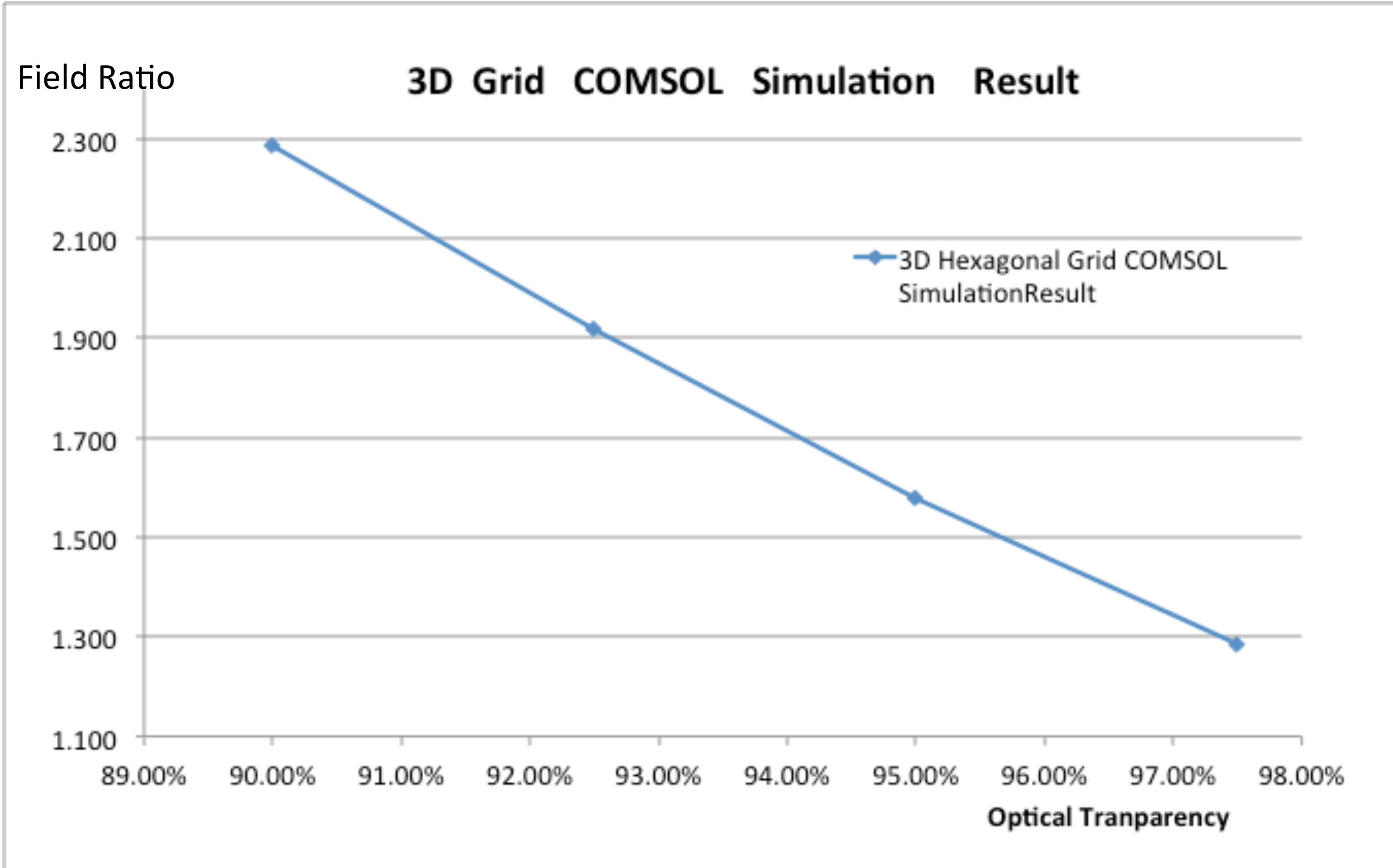
Max
Lateral
displacement
0.5-mm

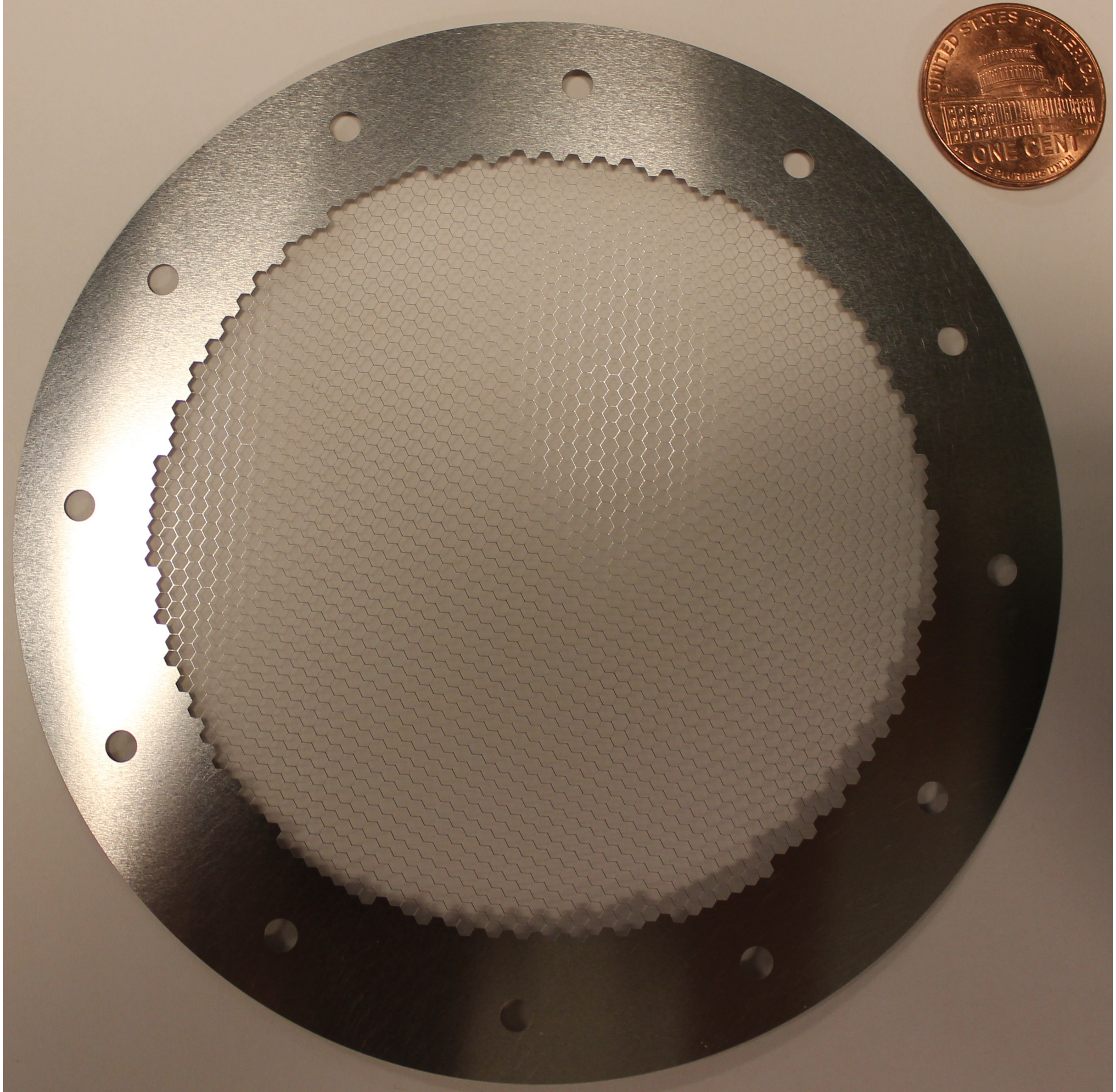
Drift Profile Comparison



Overlap of 4-mm and 1-mm Mesh To Compare Electron Drift Path

Hexagonal Grid electron transparency





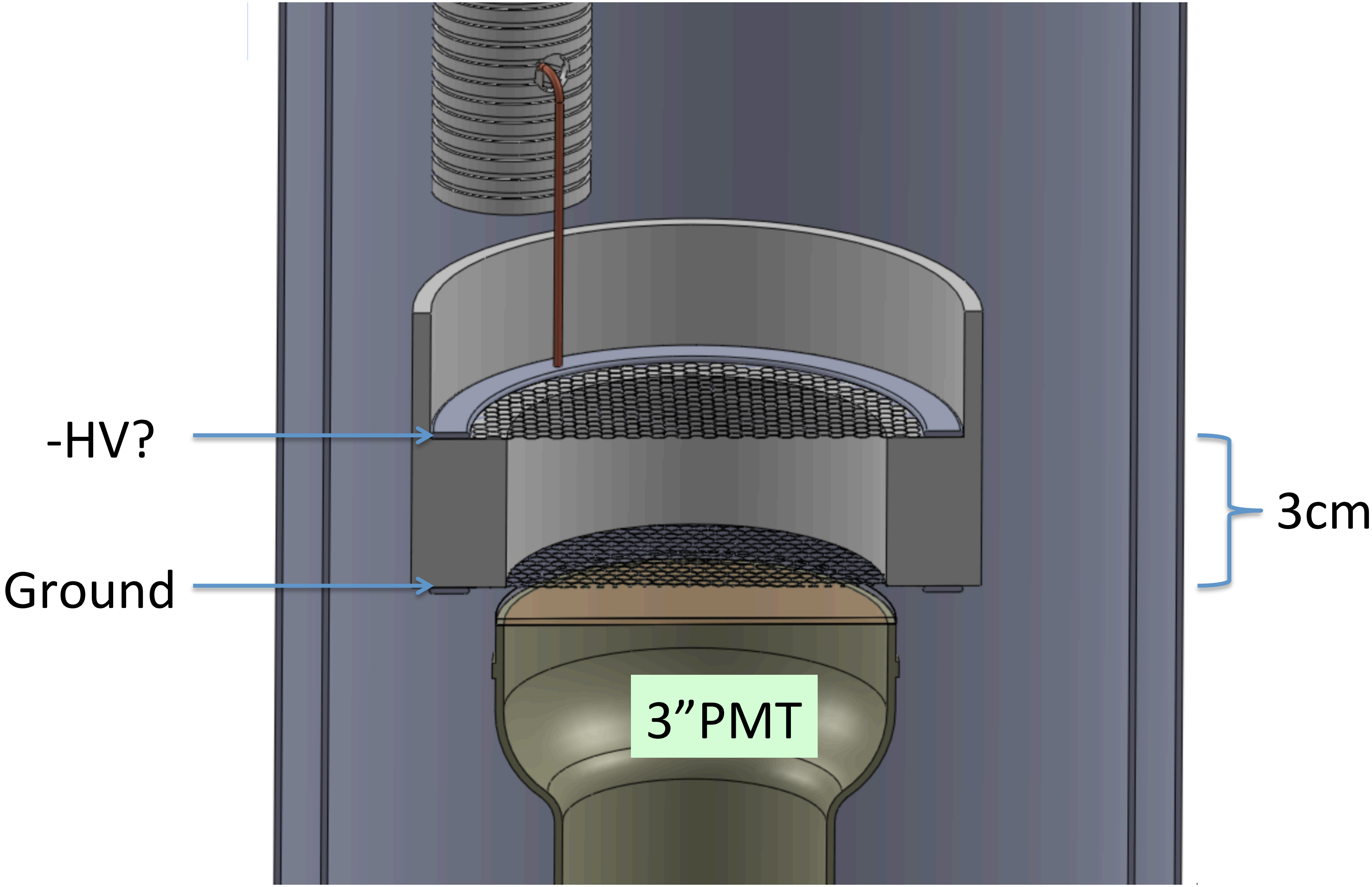
Finished Product

95.1% optical Transparency

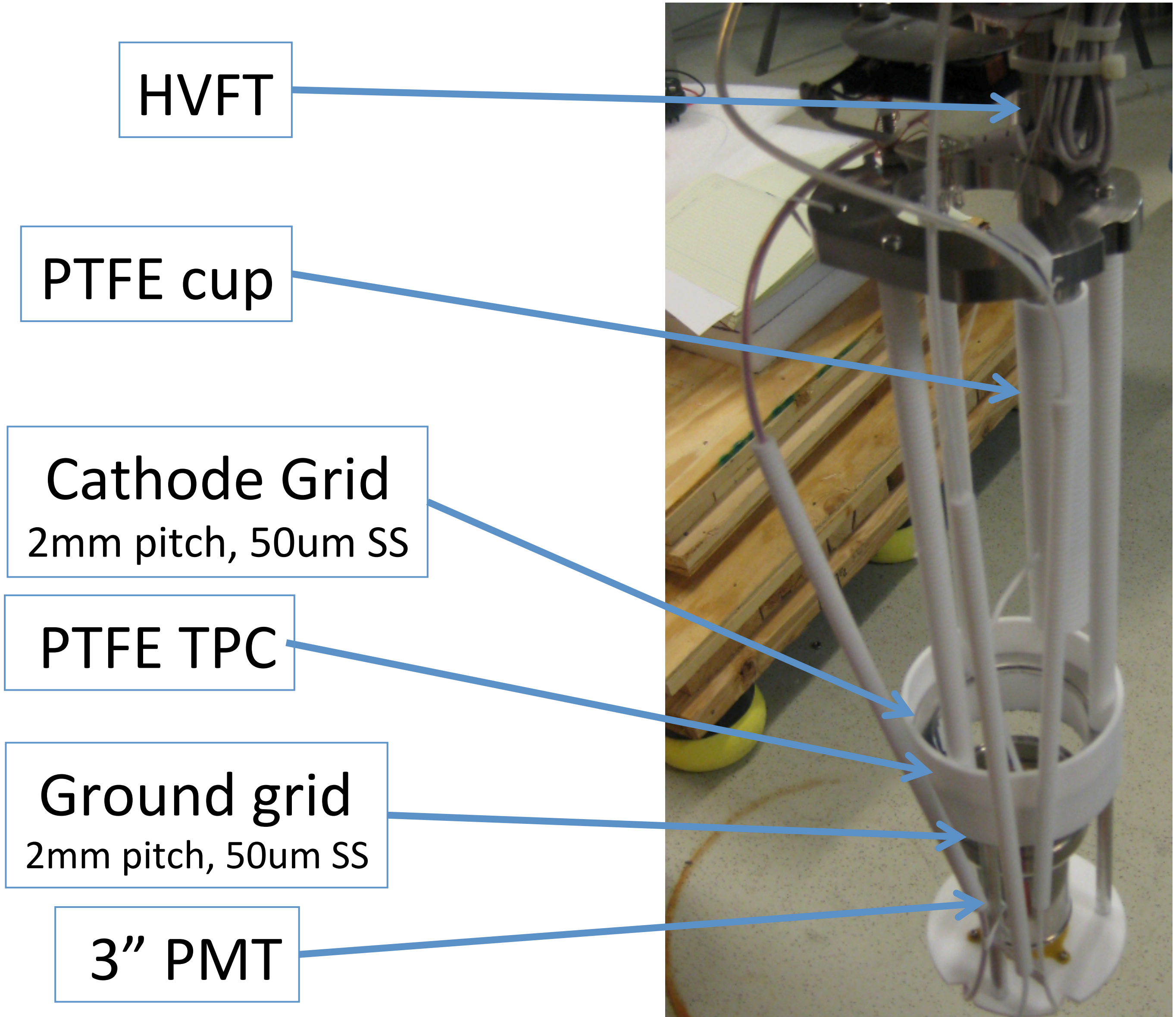
Electron transparency 100% With E2/E1>1.6

What about cathode mesh?

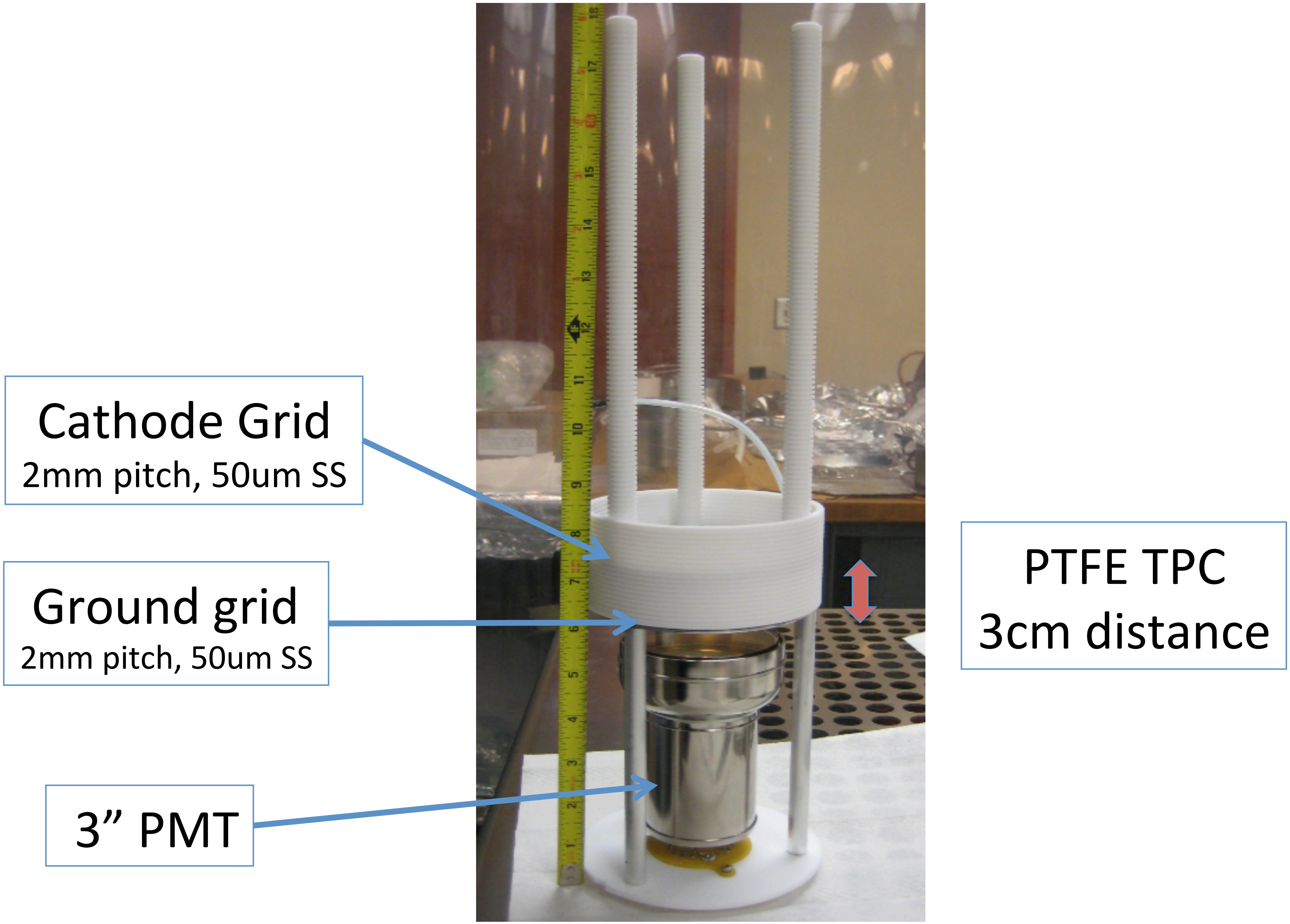
Trying worst case, not special treatment of mesh



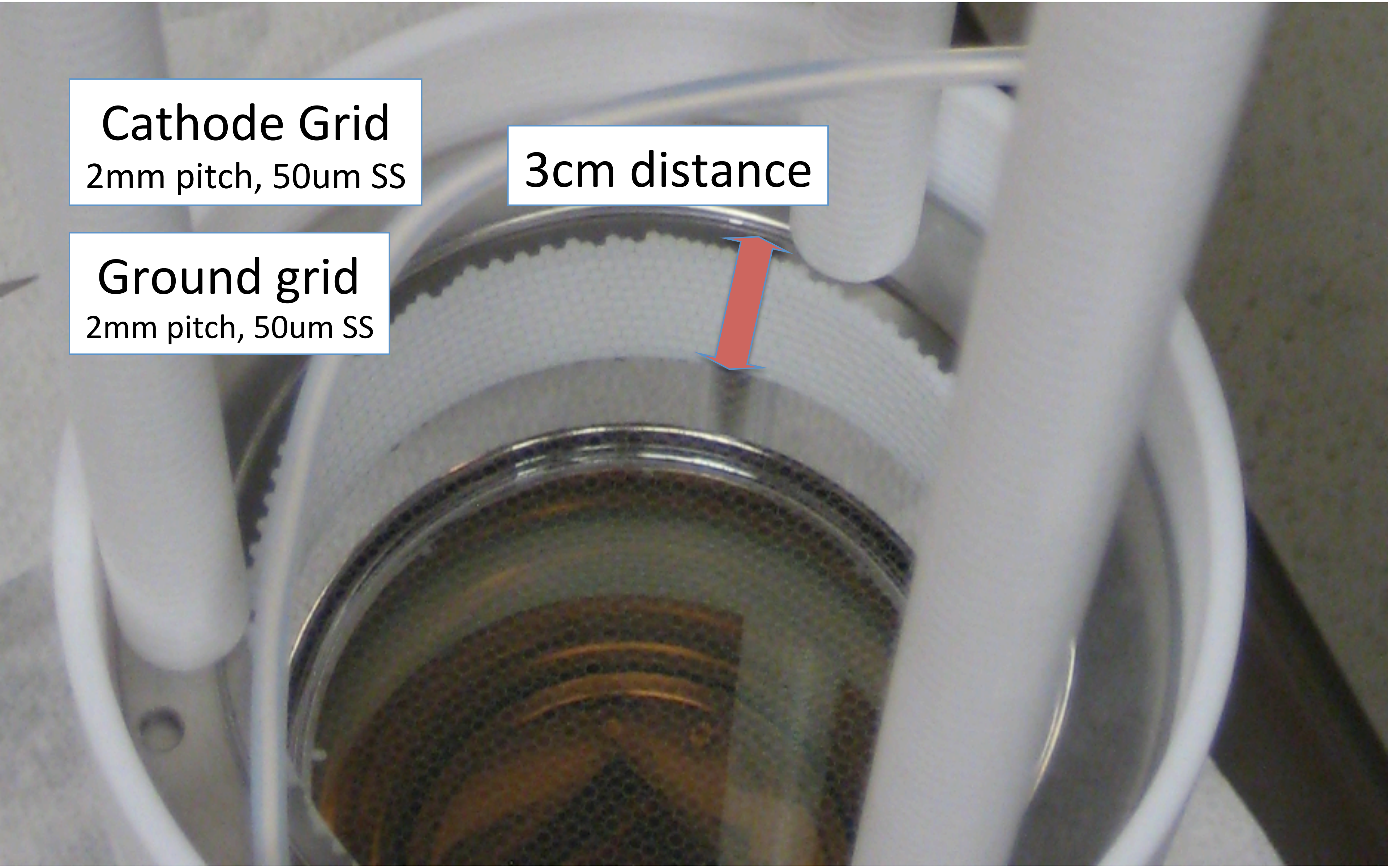
HVFT with “TPC” and 3” PMT



HVFT with "TPC" and 3" PMT



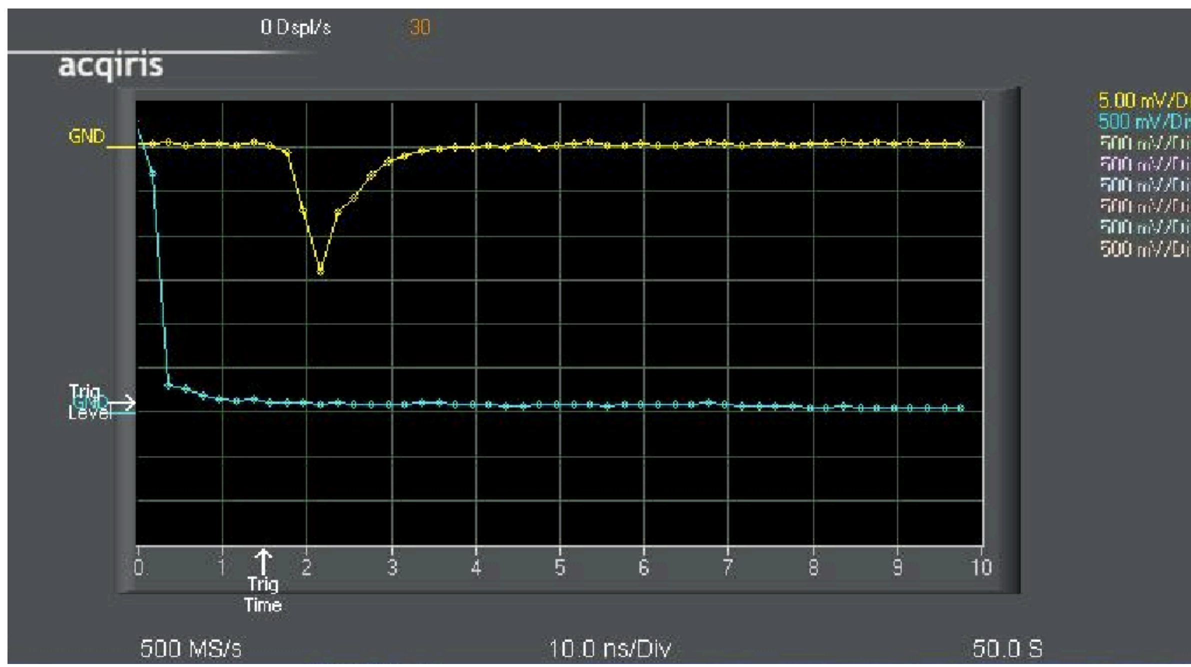
HVFT with “TPC” and 3” PMT



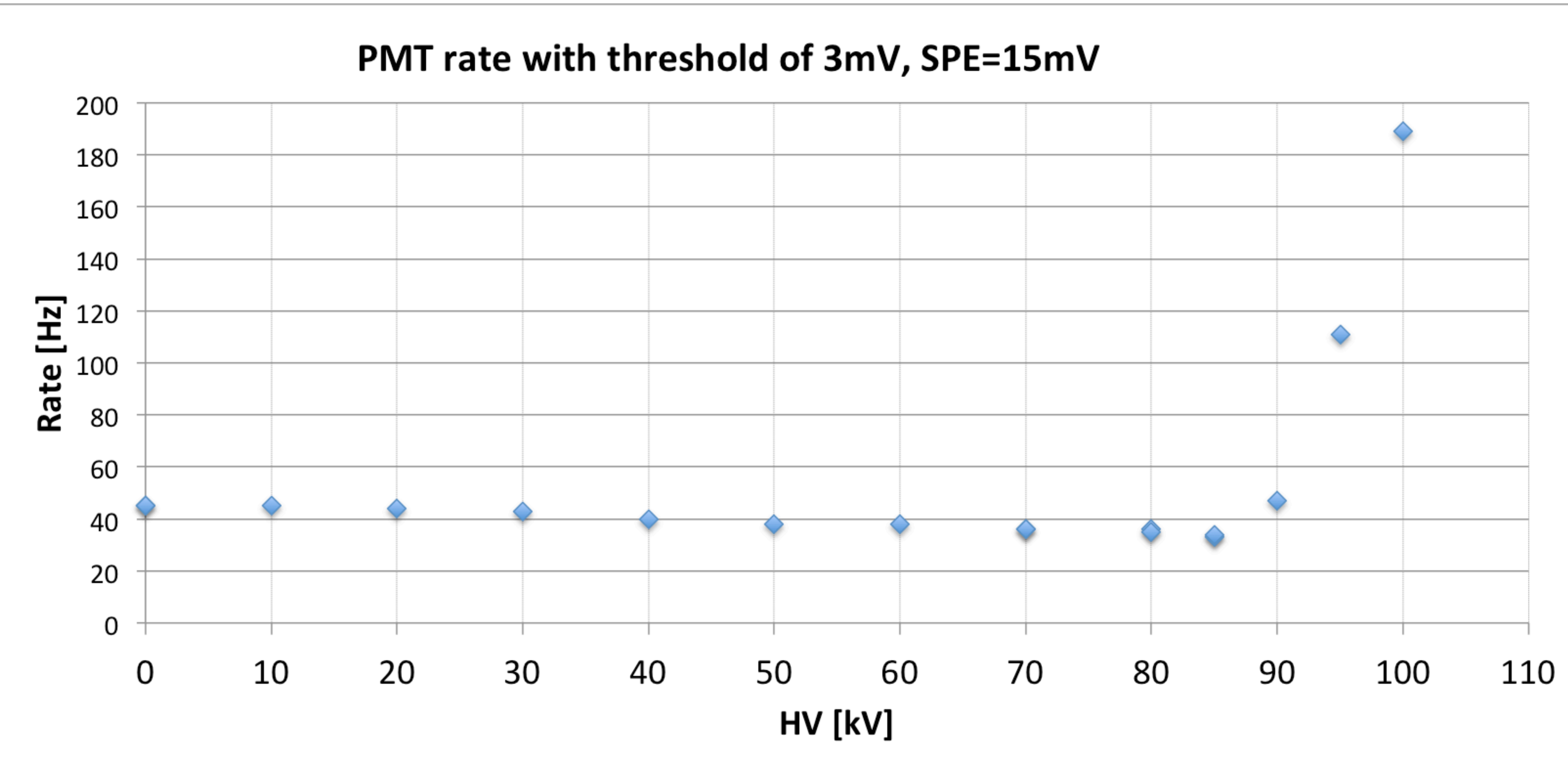
HVFT with “TPC” and 3” PMT

Internal camera view

SPE at 1.5KV bias ~15mV



HVFT with "TPC" and 3" PMT

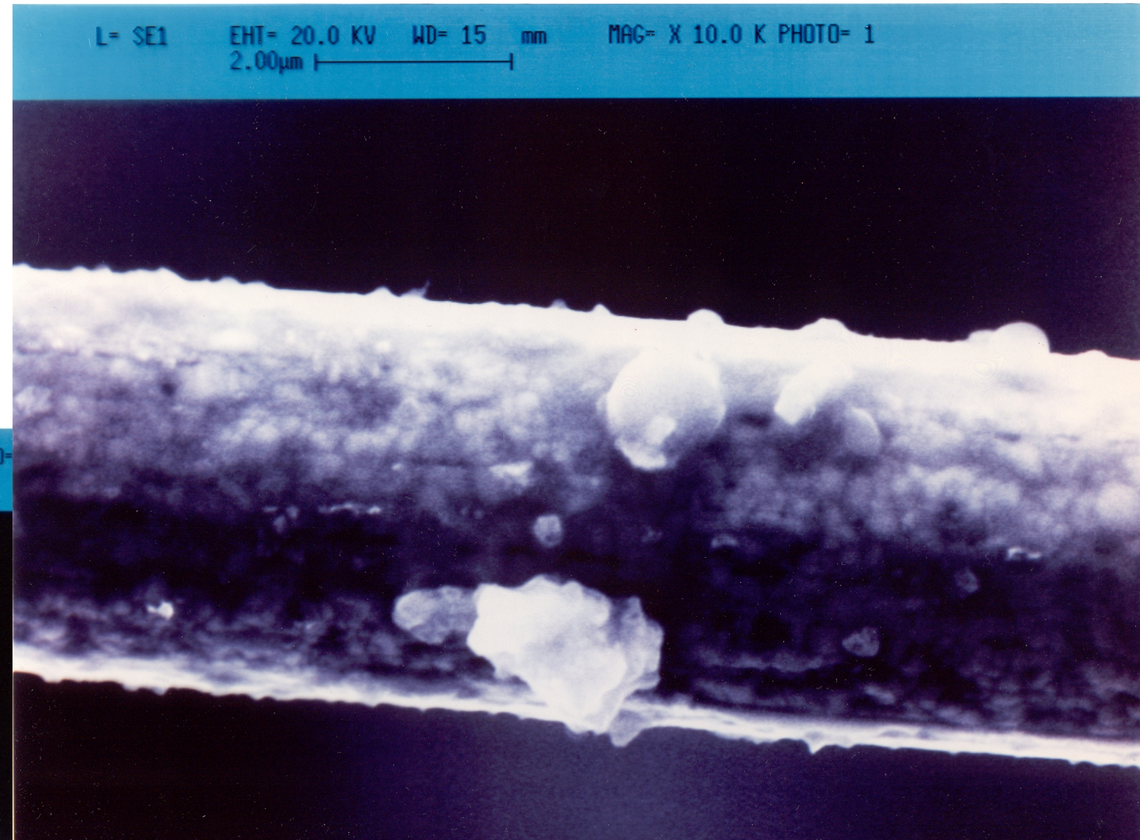


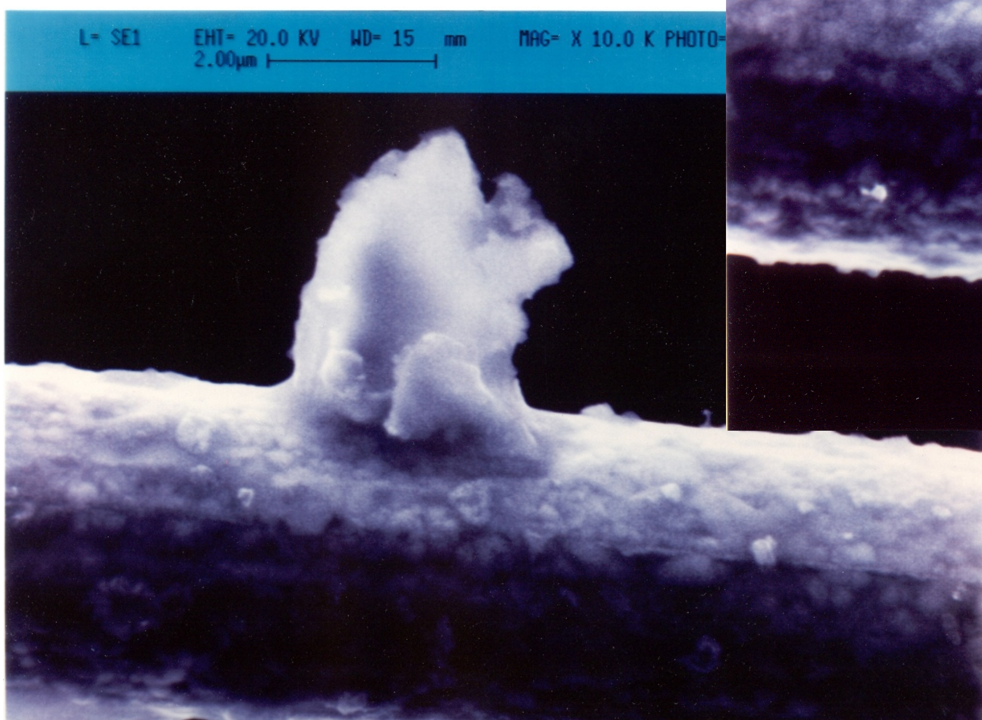
Conclusion

Mesh should be as fine as mechanically possible

Should it be as fine as this!

Actually why not!
These are the wires that I used for proportional scintillation studies





3-µm diameter wires
Hard to see by eye!

Like the jelly beans in this jar, the Universe is mostly dark: 96 percent consists of dark energy (about 70%) and dark matter (about 26%). Only about four percent (the same proportion as the lightly colored jelly beans) of the Universe - including the stars, planets and us - is made of familiar atomic matter.

The End