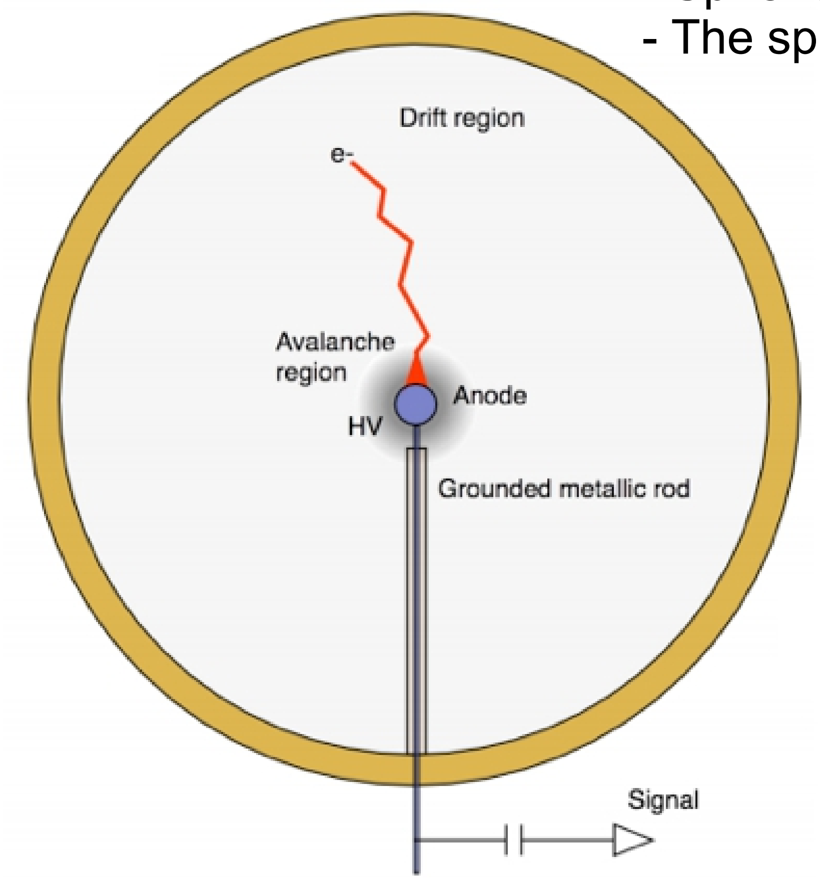
Cap congress 2017

Sensor development for spherical gas detector for dark matter search

Alexis Brossard
On behalf of News-G collaboration

Principle of detection



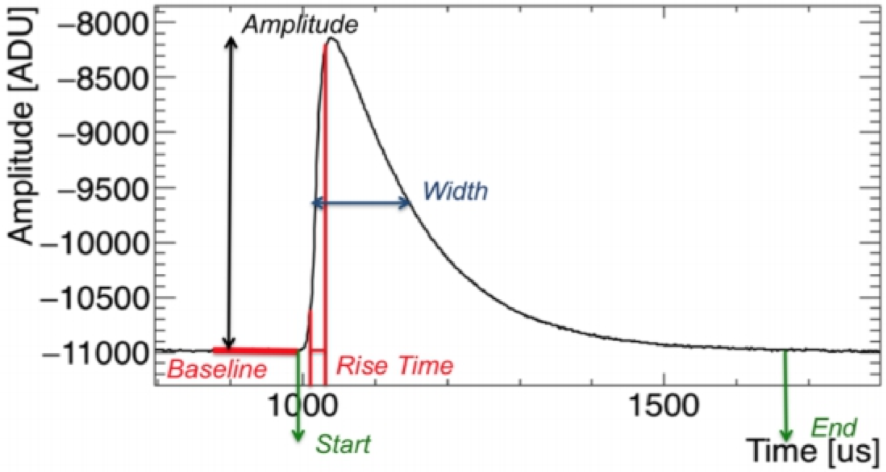
- Spherical cavity filled with gas.
- The sphere is grounded and HV is applied on a spherical sensor.

$$E(r) \approx \frac{V}{r^2} r_{anode}$$

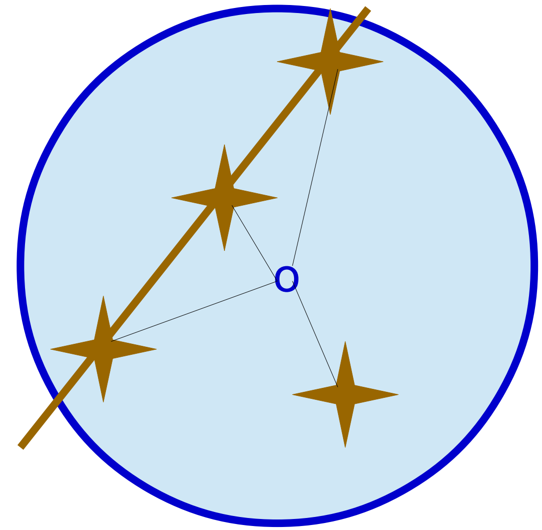
-Particle ionizes gas.
-Primary electrons drift toward the sensor.
-Close to the sensor, secondary electron/ion pairs are produced.
-Signal is induced by motion of secondary ion.
-This signal is processed by a pre-amplifier and digitized.

-Possibility to use large range of target mass.
-Sub-keV energy threshold.
-Identification of point like energy deposition

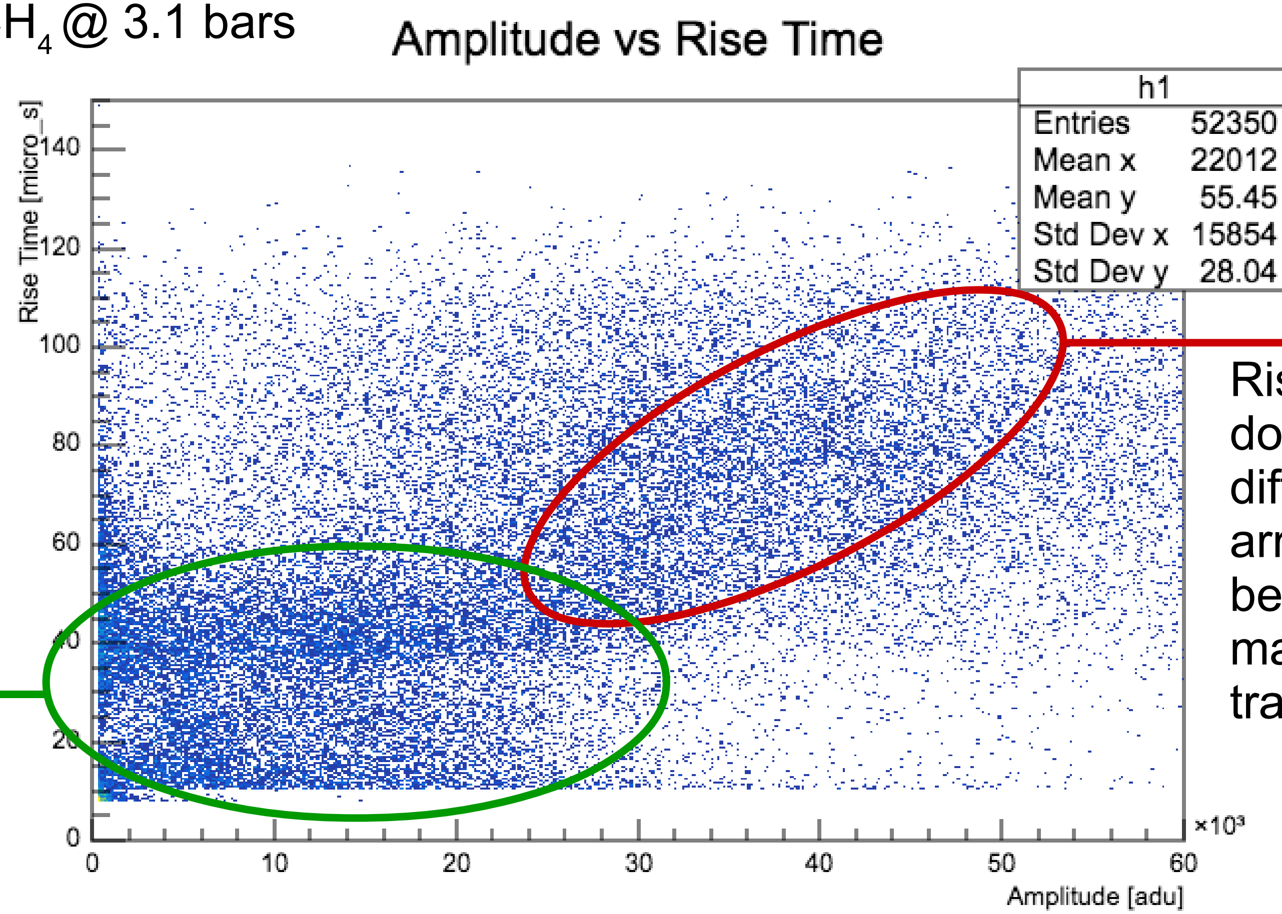
Pulse shape discrimination



-Baseline
-Noise
-Amplitude
-Width
-Integral
-Rate



99.3 % Ne , 0.7% CH_4 @ 3.1 bars



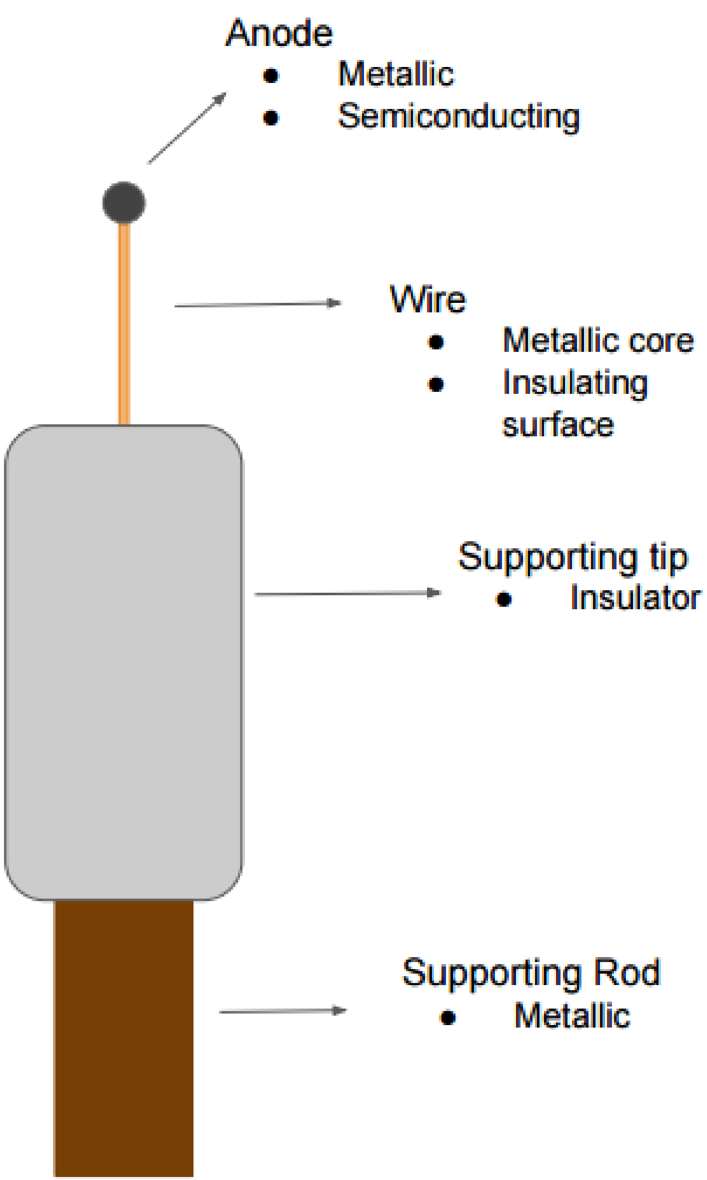
Point like events:

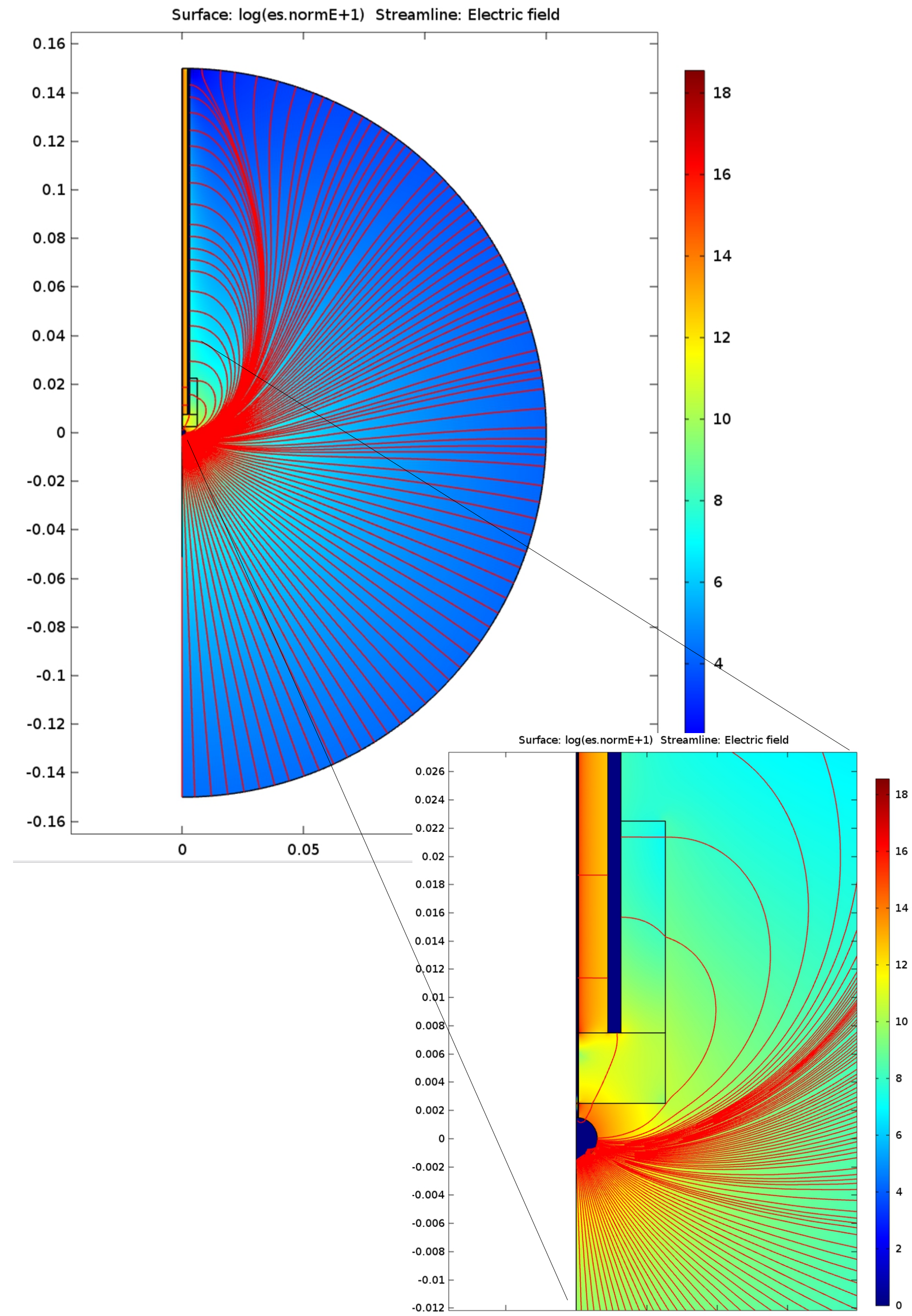
Rise time dominated by diffusion of electron. Related to the distance from the sensor.

Track events:

Rise time dominated by difference of arrival time between min and max radius of the track

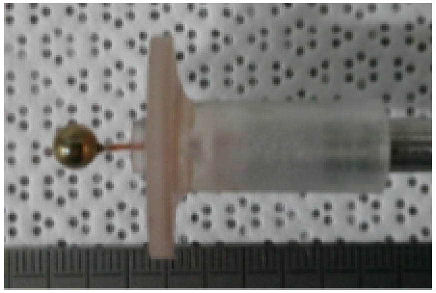
Single electrode sensor:

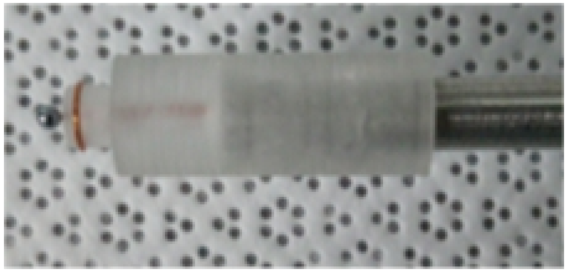


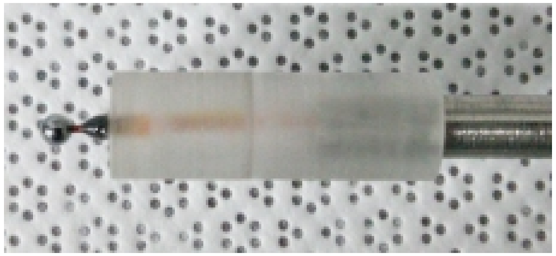


Sensor Development

Few sensors have been tested:







What we expect:

Stable with time

Homogenous response

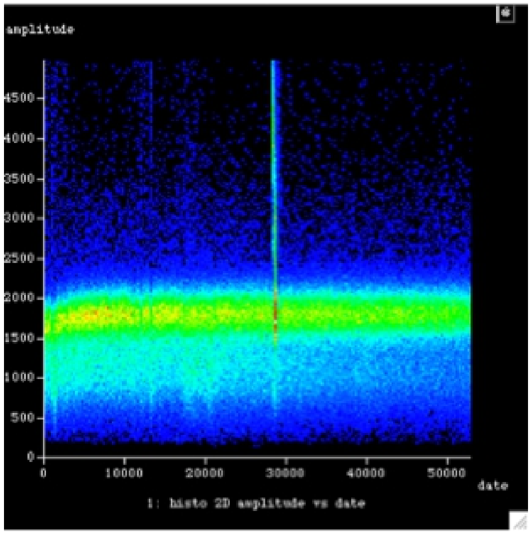
Avoid charges accumulation and gain/rate dependencies

Development done at:
-Thessaloniki University; Ilias Savvidis
-LSM; Ali Dastgheibi-Fard
-CEA Saclay; Ioanis Giomataris, Ioanis Katsioulas

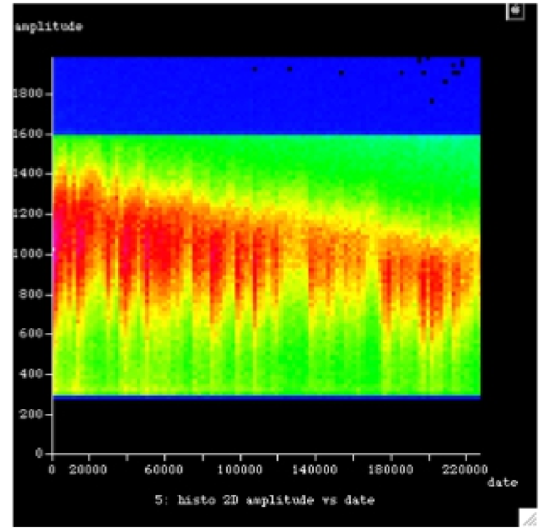
Problems faced

Fe 55 source

Charging up



Instability

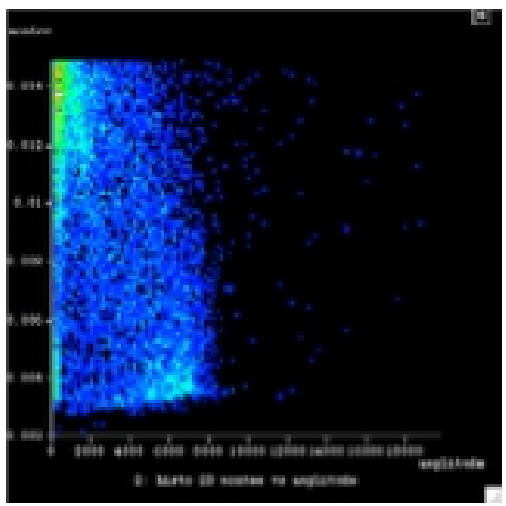


Amplitude

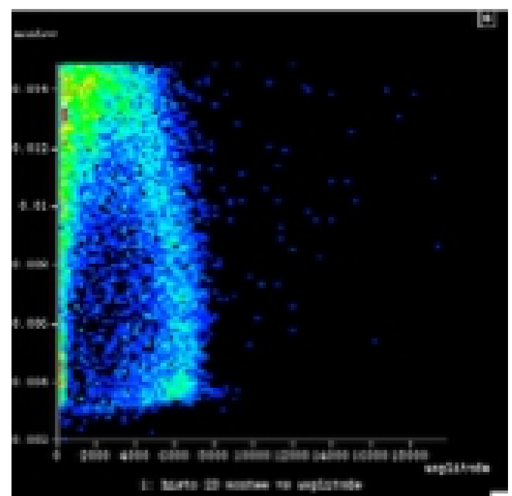
Date

Inhomogeneous response

90 deg

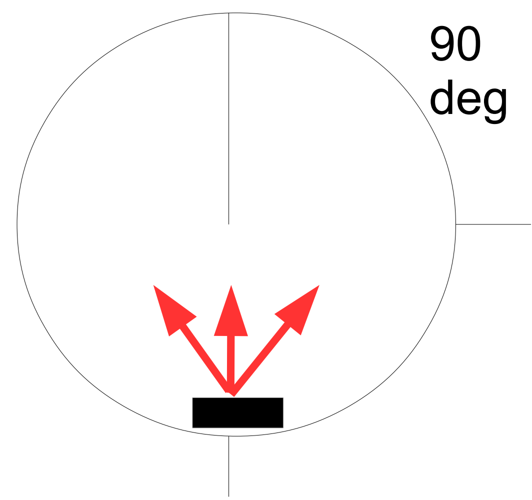


180 deg



Rise Time

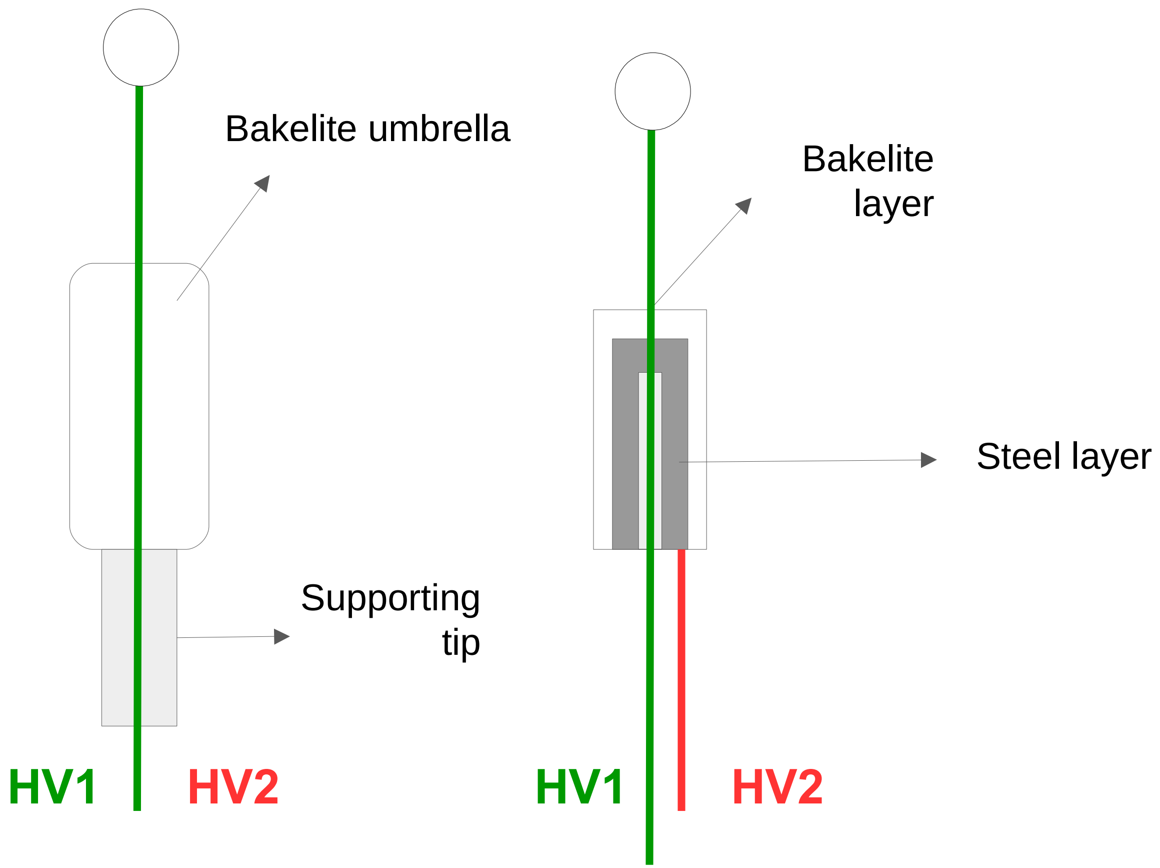
Amplitude



180 deg

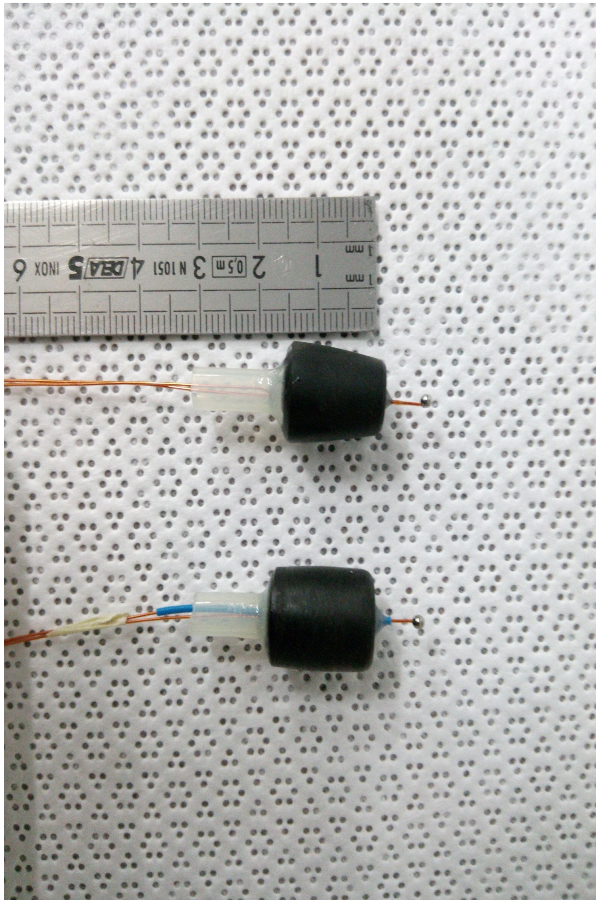
The Bakelite Sensor

The bakelite resistive umbrella



Bakelite
Chemical Formula:
(C6-H6-O.C-H2-O)x

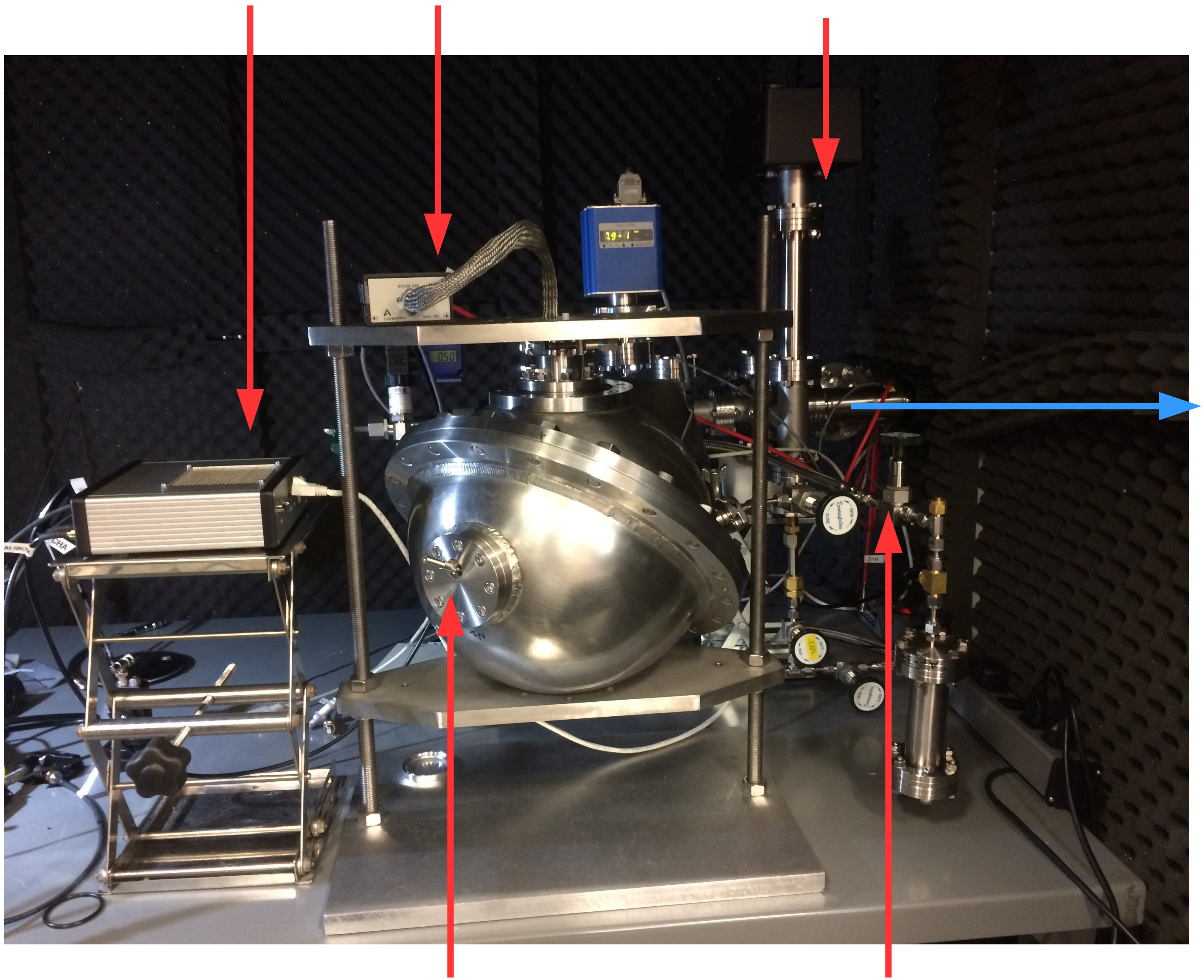
Thermosetting phenol formaldehyde resin, formed from a condensation reaction of phenol with formaldehyde.



Advantages:

- Bakelite resistivity up to ~ 10^12 cm
- Compact and homogenous material

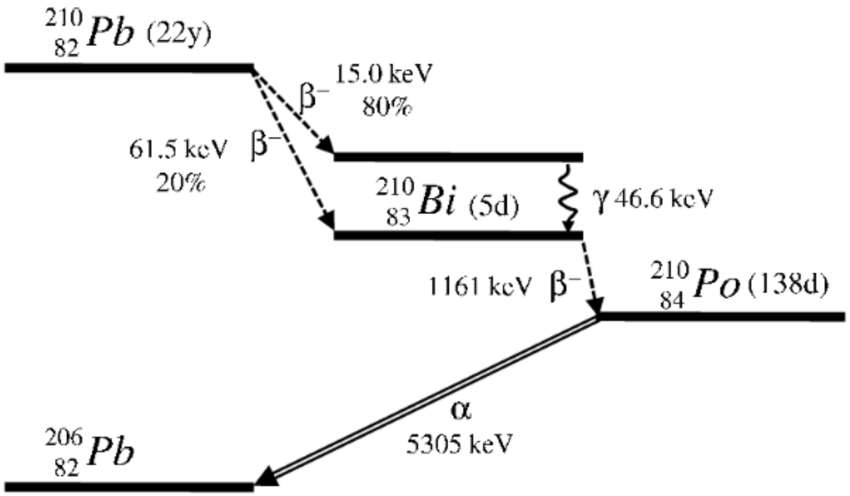
Queen's S30



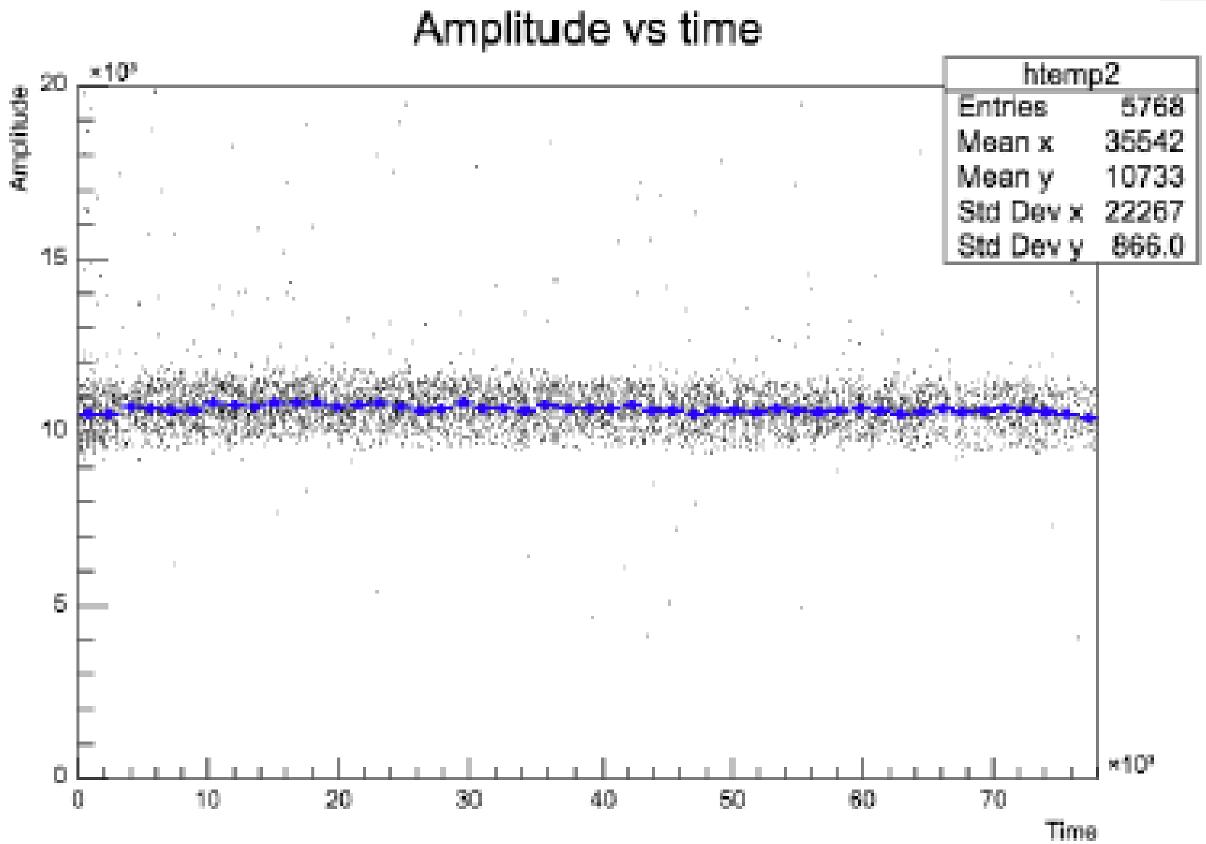
Digitizer
Pre-amplifier
RGA
Pump
Port for radioactive source or laser.
Port for radioactive gas

Stability

Calibration using ^{210}Po alpha at 5.3 MeV.



30 cm diameter sphere
Gas mixture:
Ar + 2% CH_4 @ 500 mbar



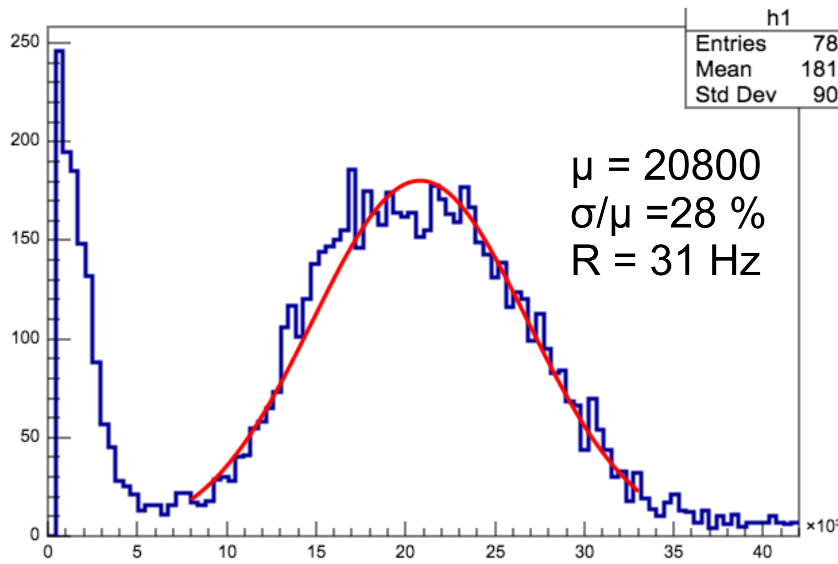
Loss of gain about 2% per day.

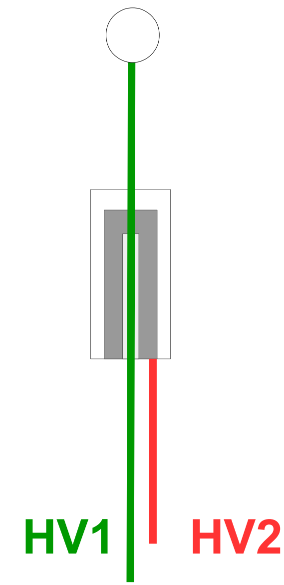
Not necessarily due to the sensor but more due to loss of gas quality.

Influence of HV on second electrode with HV sensor at 1950 V

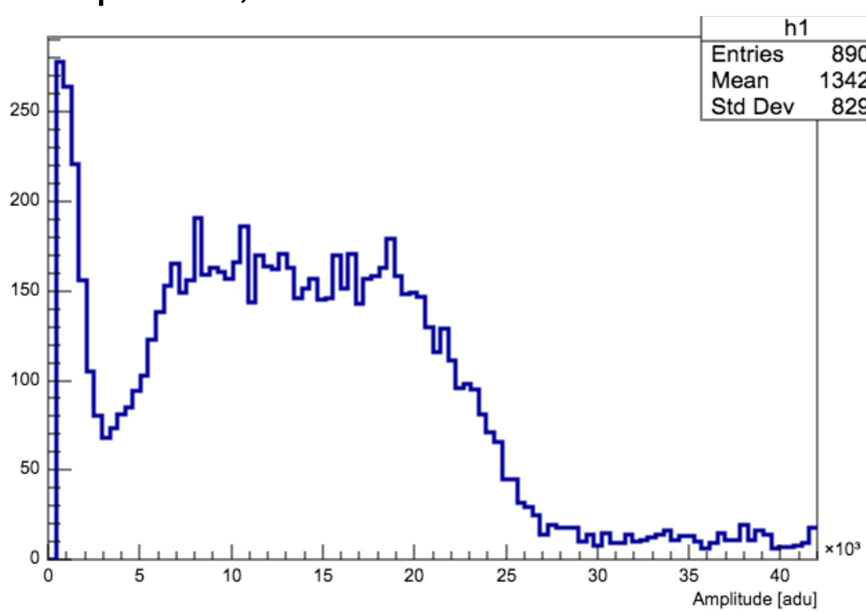
30 cm diameter sphere
Gas mixture:
Ar + 2% CH_4 @ 500 mbar
Source:
^{37}Ar
Electronic capture
released 0.27 or 2.8 keV

Amplitude, HV second electrode = 0 V



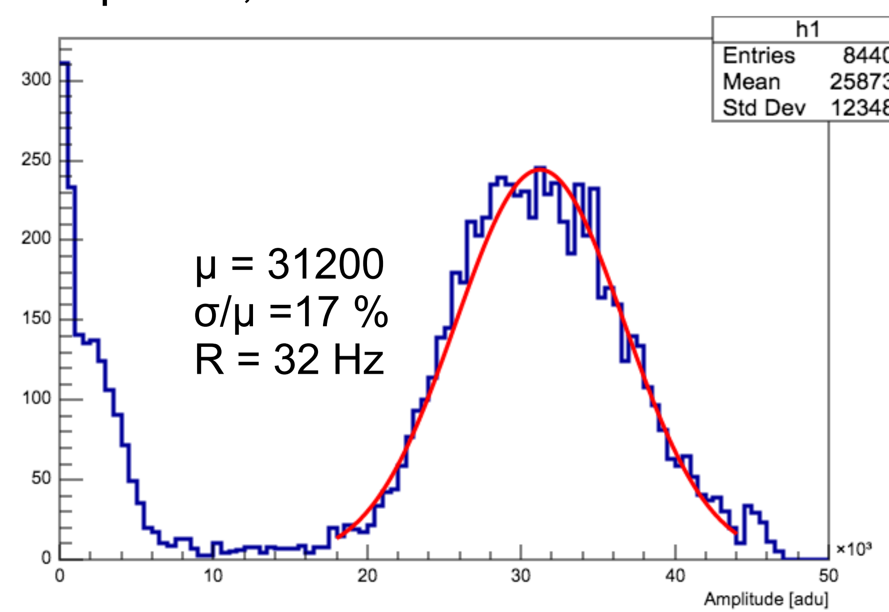


Amplitude, HV second electrode = +50 V



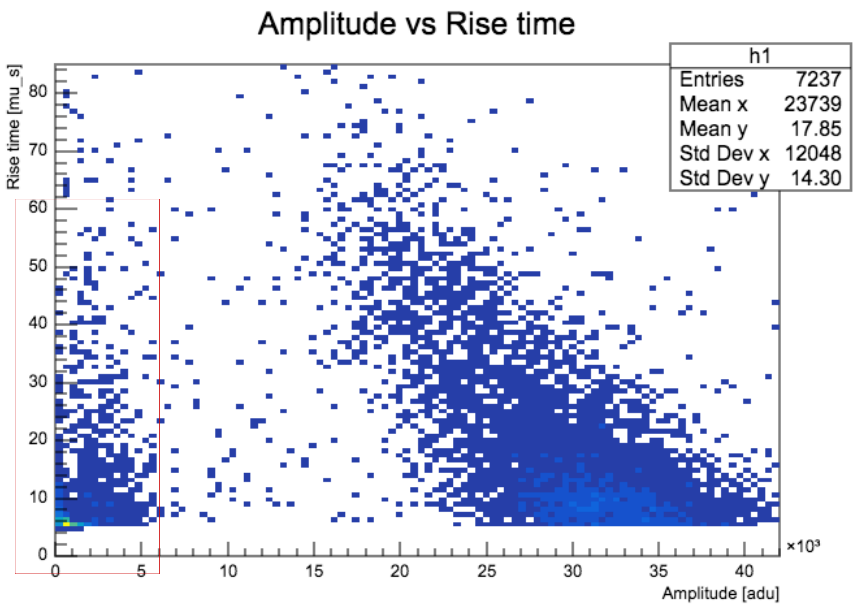
Applying a positive voltage decreases the gain of the detector.

Amplitude, HV second electrode = -50 V

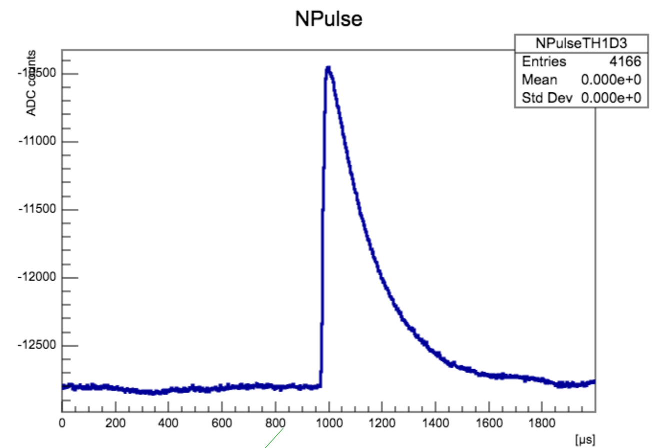


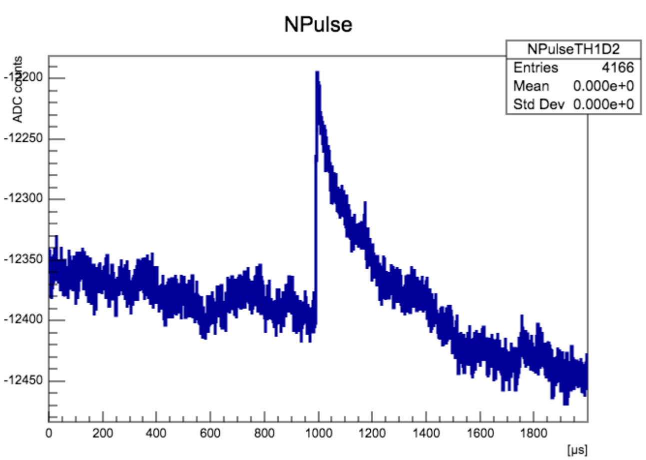
Applying a negative high voltage improves the resolution and the gain of the detector.

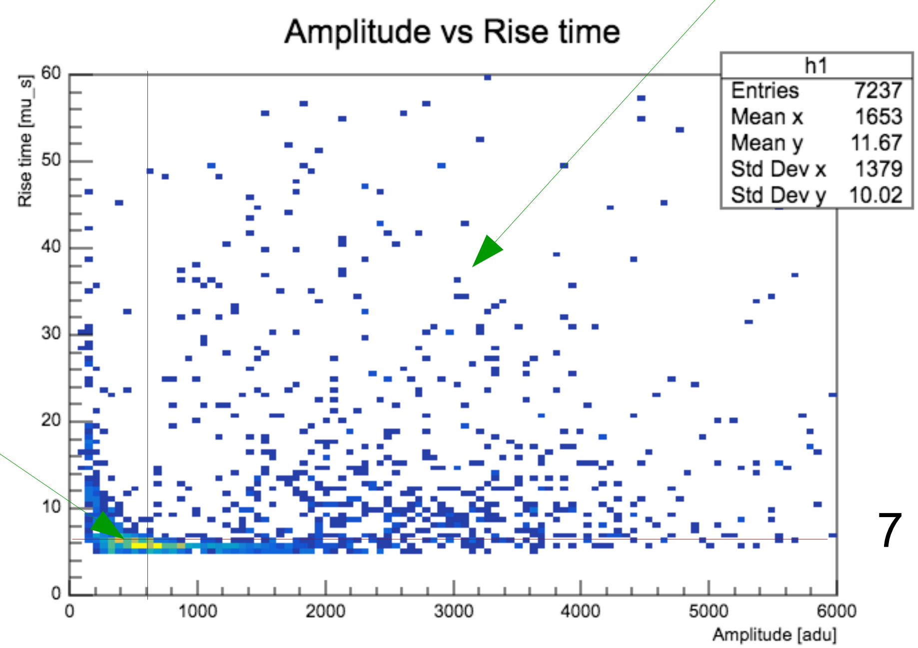
Calibration at low energy



Physical pulse







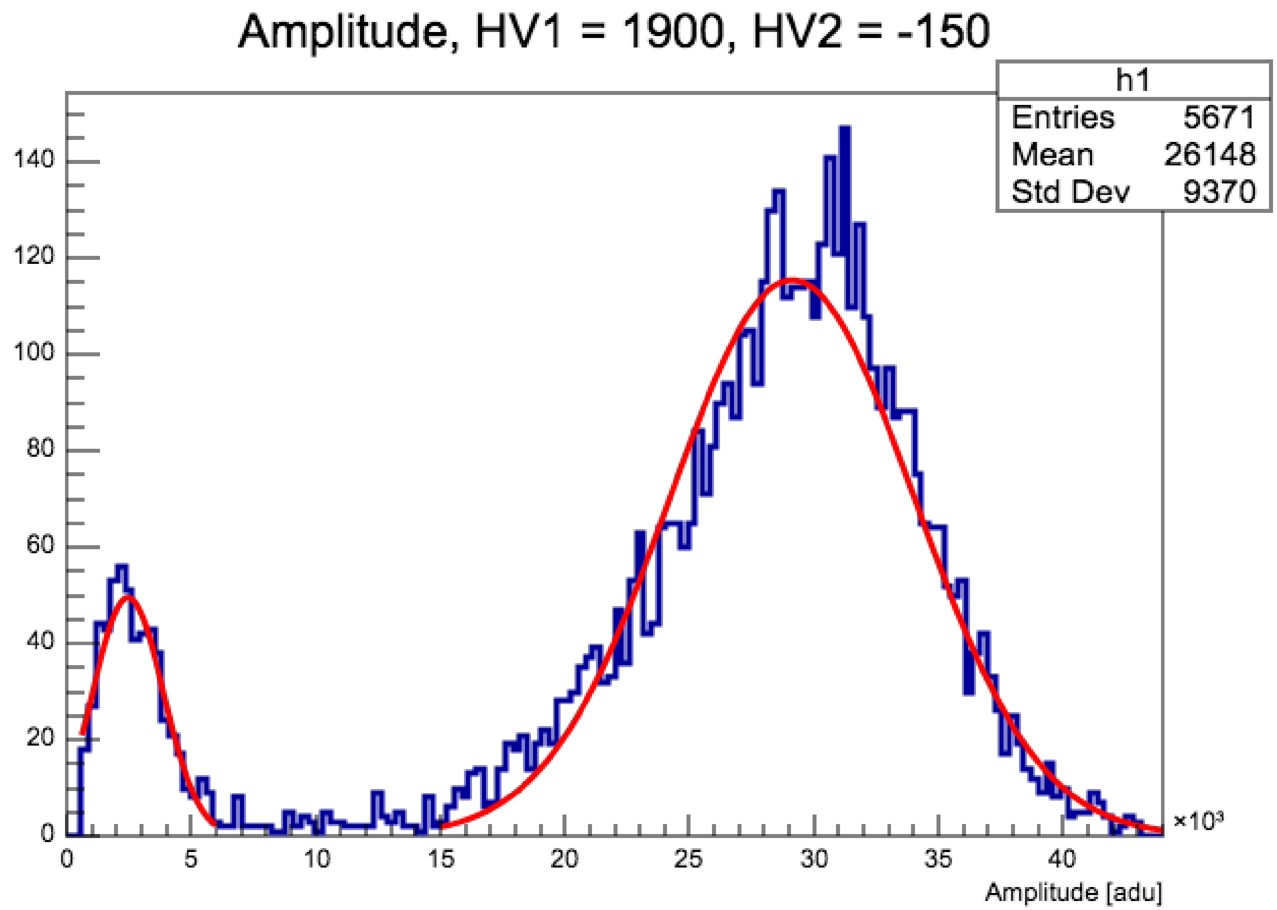
7 µs

Physical pulse due to
other excitations
And electronic noise

600 adu

Ar + 2% CH_4 @ 500 mbar, HV1 = 1900 V, HV2 = -150V

Calibration at low energy



μ_1 = 2467
σ_1/μ_1 = 57 %
R_1 = 3 Hz

L capture:
0.2702 keV
BR = 0.0890

μ_2 = 29125
σ_2/μ_2 =17 %
R_2 = 28 Hz

K capture
2.8224 keV
BR = 0.9017

Ar + 2% CH_4 @ 500 mbar

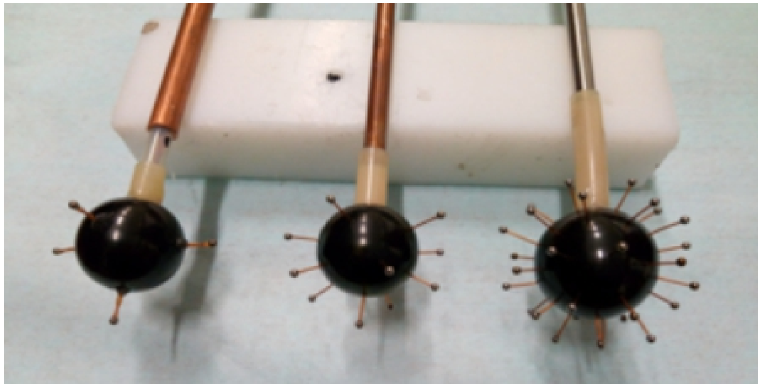
Other development: Achinos sensor

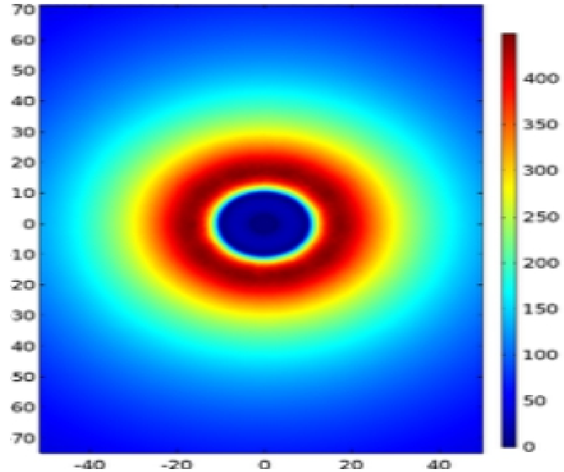
-Amplification is driven by the ball size. Smaller ball gives higher amplification.

-Electric field far from the sensor is proportional to sensor radius. In large diameter sphere, a too small sensor gives a to weak electric field at large distance, then electron attachment induce a loss of signal.

Achinos sensor

$$E(r) \approx \frac{V}{r^2} r_{anode}$$



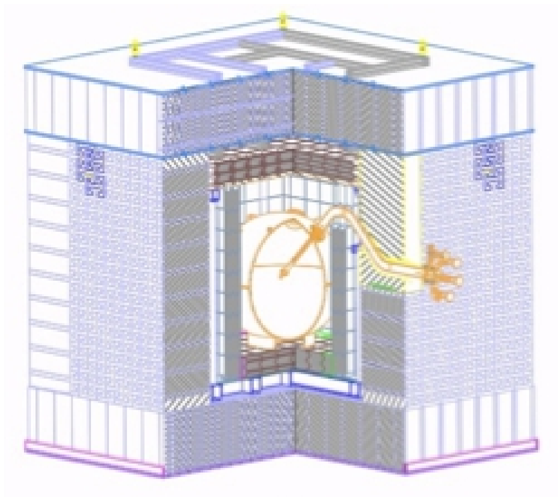


-Amplification is driven by size of each small ball.

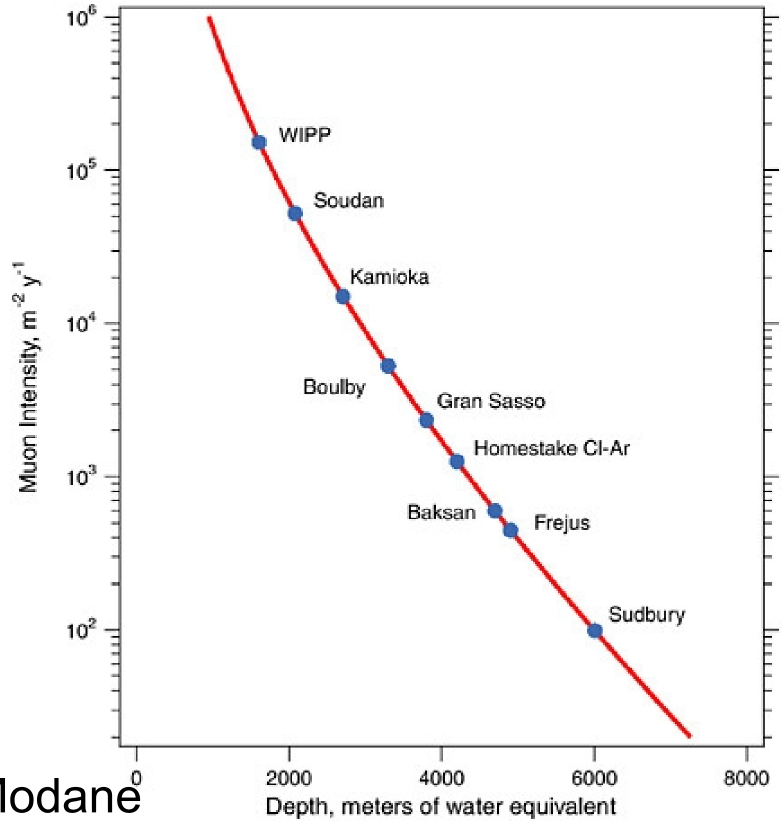
-Volume electric field is driven by Achinos structure

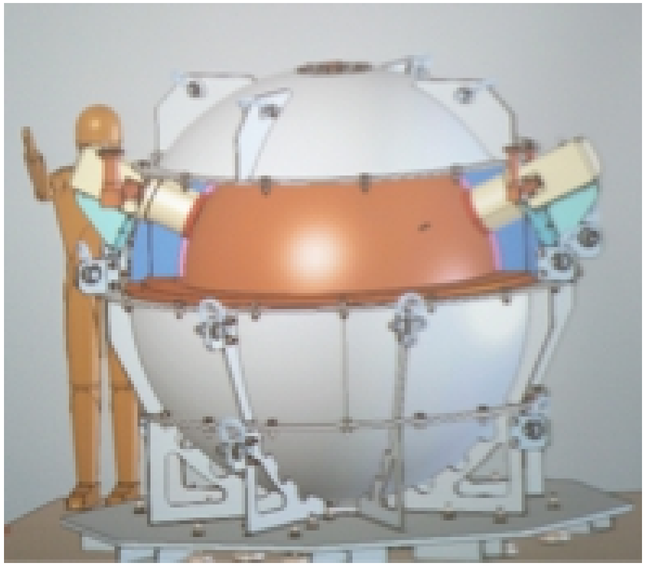
-Thessaloniki University; Ilias Savvidis

News-G collaboration



SEDINE
60 cm diameter sphere.
Currently taking data at the Laboratoire souterrain de Modane





NEWS-SNO
140 cm diameter sphere.
Will be installed at SNOLAB next year.

Monday:
Quentin Arnaud: Final results on the search for low-mass WIMPs with the NEWS-G experiment.
Daniel Durnford: Calibration schemes for Spherical Gas Detectors.

Thursday
Gilles Gerbier: Status of NEWS-G experiment
Philippe Di Stefano: Quenching measurements for a spherical detector at the COMIMAC facility

collaboration

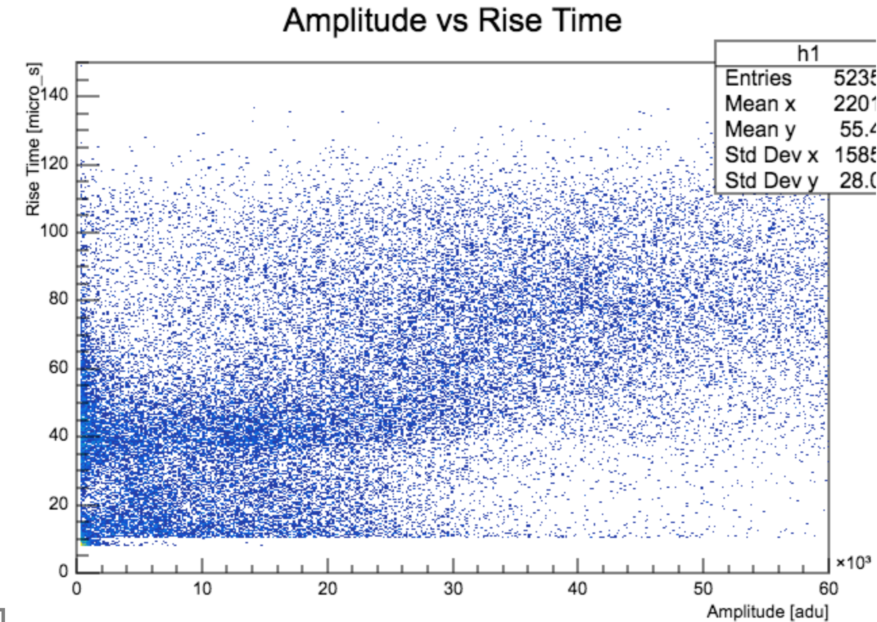
- **Queen's** University Kingston – G Gerbier, P di Stefano, R Martin, T Noble, D Dunrford
A Brossard, A Kamaha, P Vasquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, M Chapellier
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis
- **IRFU** (Institut de Recherches sur les Lois fondamentales de l'Univers)/**CEA Saclay** -I Giomataris, M Gros, C Nones, I Katsioulas, T Papaevangelou, JP Bard, JP Mols, XF Navick,
  - Sensor/rod (low activity, optimization with 2 electrodes)
  - Electronics (low noise preamps, digitization, stream mode)
  - DAQ/soft
- **LSM** (Laboratoire Souterrain de Modane), IN2P3, U of Chambéry - F Piquemal, M Zampaolo, A DastgheibiFard
  - Low activity archeological lead
  - Coordination for lead/PE shielding and copper sphere
- **Thessaloniki University** – I Savvidis, A Leisos, S Tzamarias, C Elefteriadis, L Anastasios
  - Simulations, neutron calibration
  - Studies on sensor
- **LPSC** (Laboratoire de Physique Subatomique et Cosmologie) **Grenoble** - D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements at low energy with ion beams
- **Technical University Munich** – A Ulrich, T Dandl
  - Gas properties, ionization and scintillation process in gaz
- **Pacific National Northwest Lab** - E Hoppe, D Asner
  - Low activity measurements, Copper electroforming
- **RMCC (Royal Military College Canada) Kingston** – D Kelly, E Corcoran
  - 37 Ar source production, sample analysis
- **SNOLAB –Sudbury** – P Gorel
  - Calibration system/slow control
- **University of Birmingham**- Kostas Nicolopoulos
  - Simulations, analysis, R&D
- **Associated lab : TRIUMF** - F Retiere
  - Future R&D on light detection, sensor

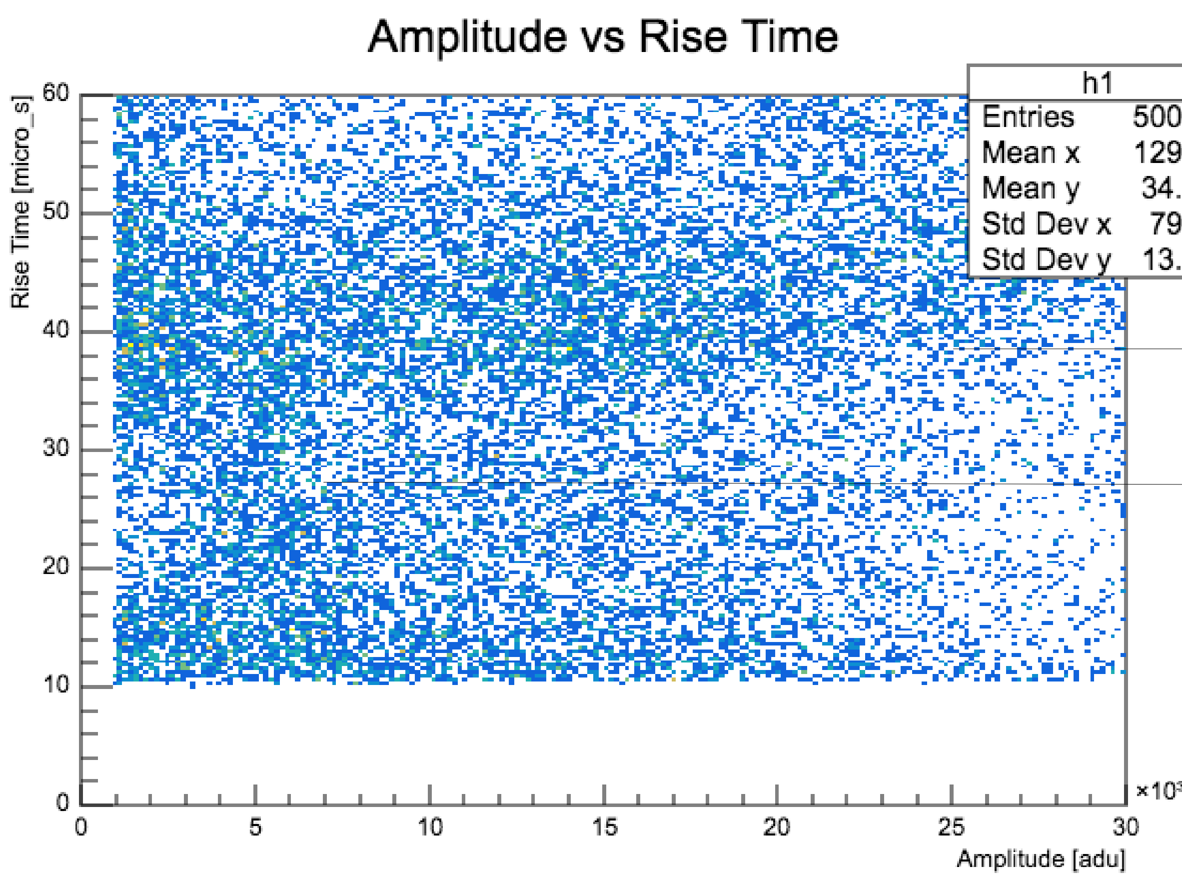
THANK YOU FOR YOUR ATTENTION

April 2017

BACKUP

Sedine, Neon run, 40 days, Ne + 0.7 % CH_4 at 3,1 bars

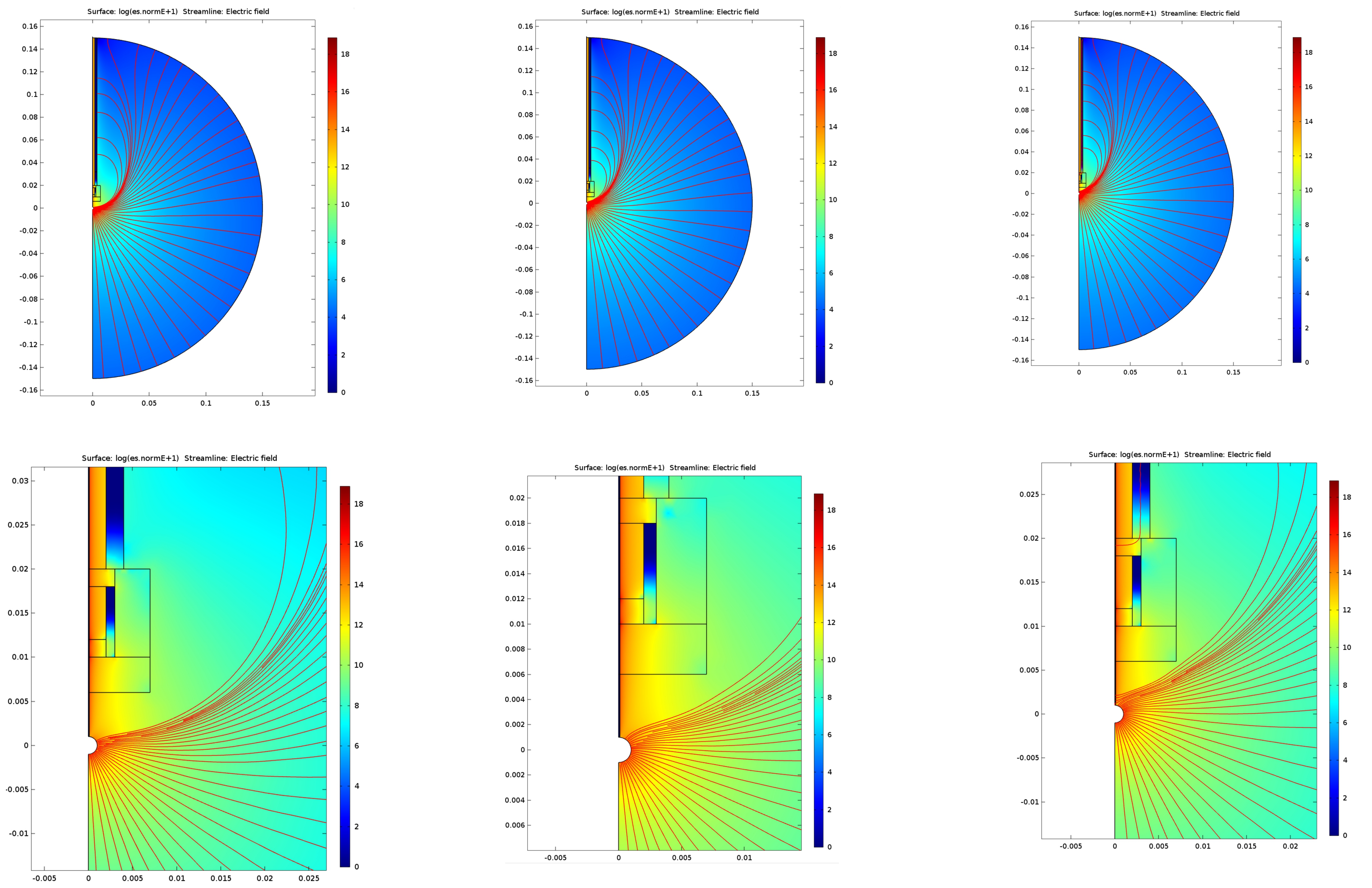




Pb 210 on inner surface

8 keV fluorescence from copper

Comsol simulation of the electric field. HV1 = 1950 V



HV2 = -50 V

HV2 = 0 V

HV2 = +50 V