Spherical proportional counters: development improvement and understanding.

June 1st 2018

Alexis Brossard
News-G collaboration

Outline

-Detector Principle

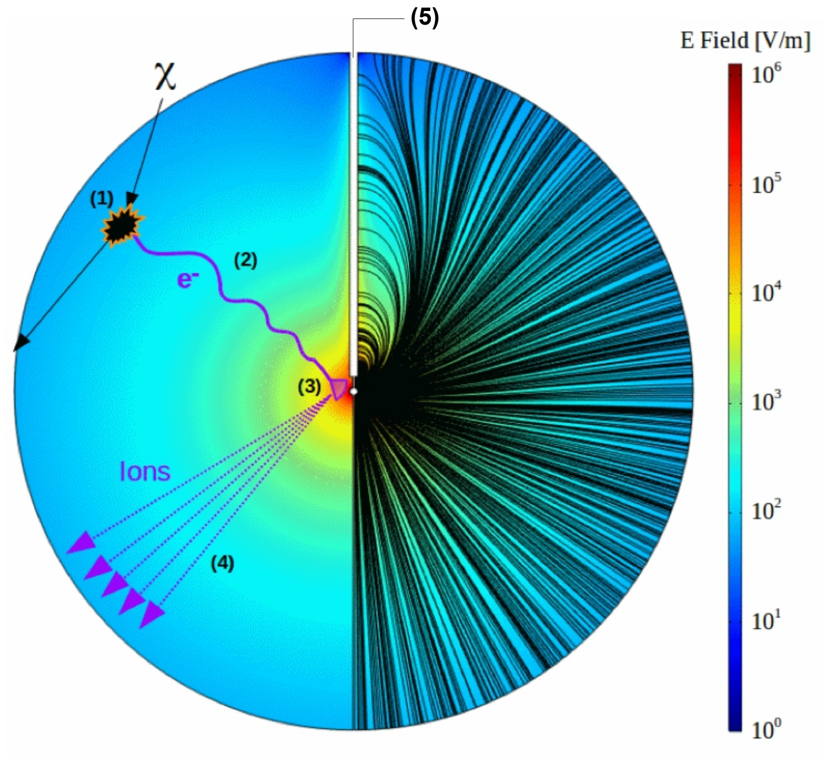
-Sensor development

-Gas effects

-Laser

-Results and future

Detector principle



-1 Particle ionizes gas.

-2 Primary electrons drift toward the sensor.

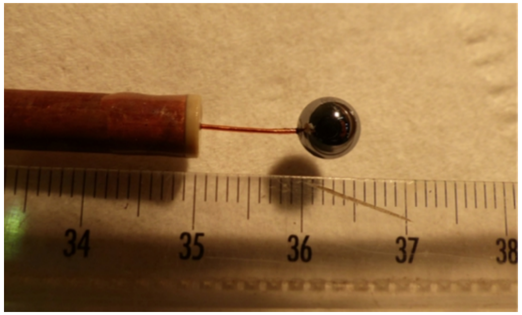
-3 Close to the sensor, secondary ion/electron pairs are produced.

-4 Signal is induced by the motion of secondary ions.

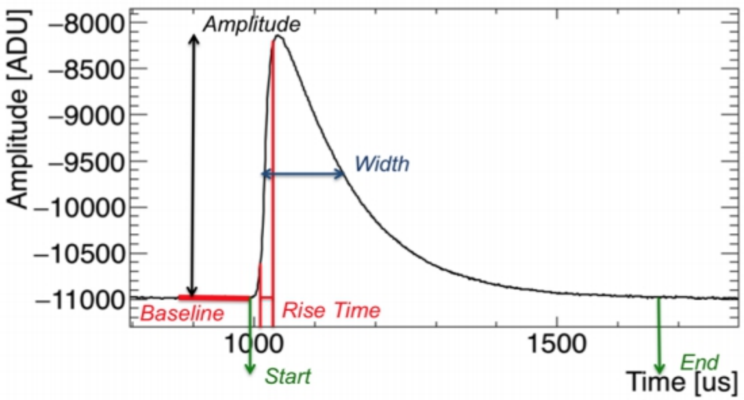
-5 The signal is processed by a pre-amplifier and digitized.

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

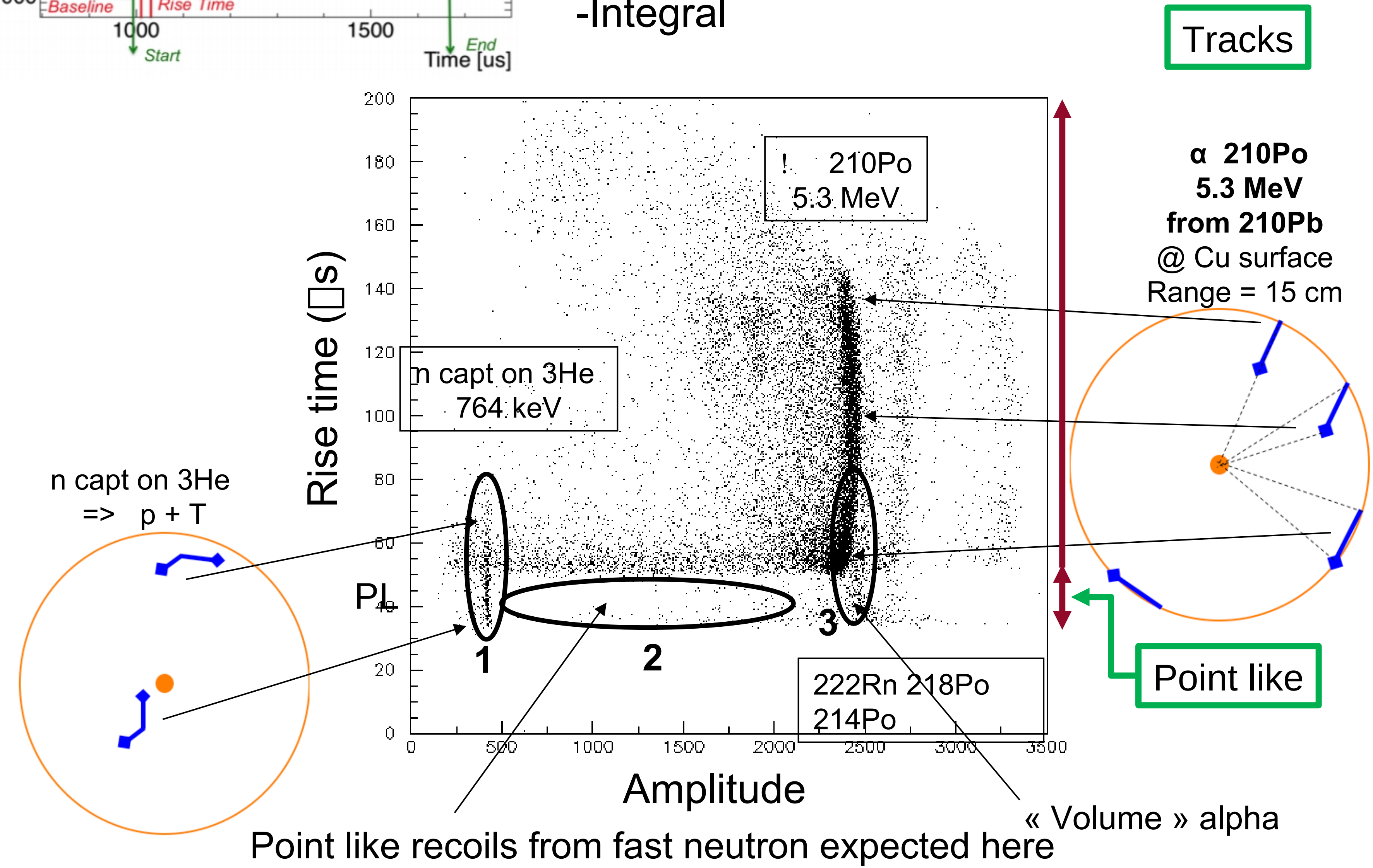
-Dark matter search
-Neutrino physics



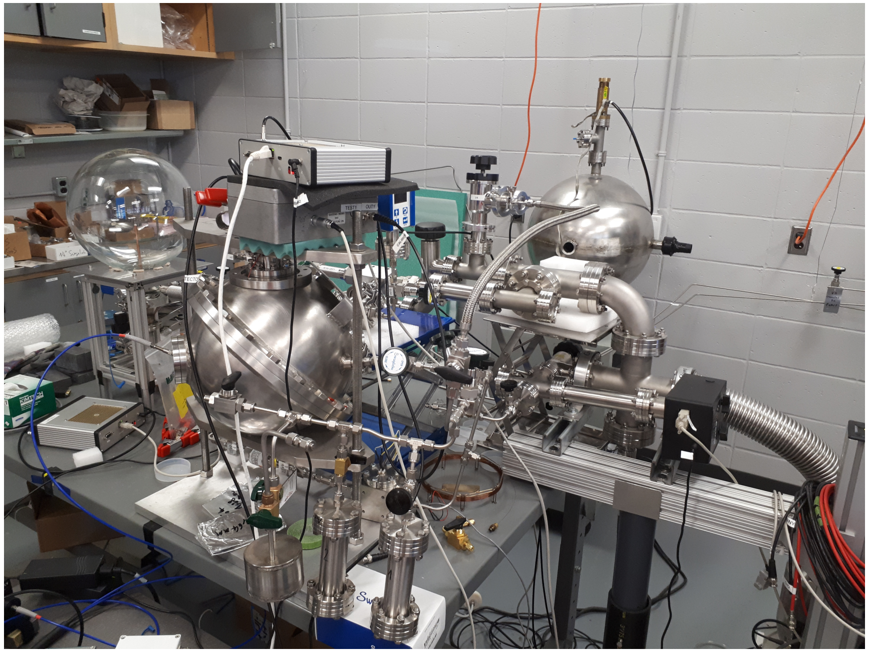
Detector principle



- Rise time
- Amplitude
- Baseline
- Noise
- Width
- Integral



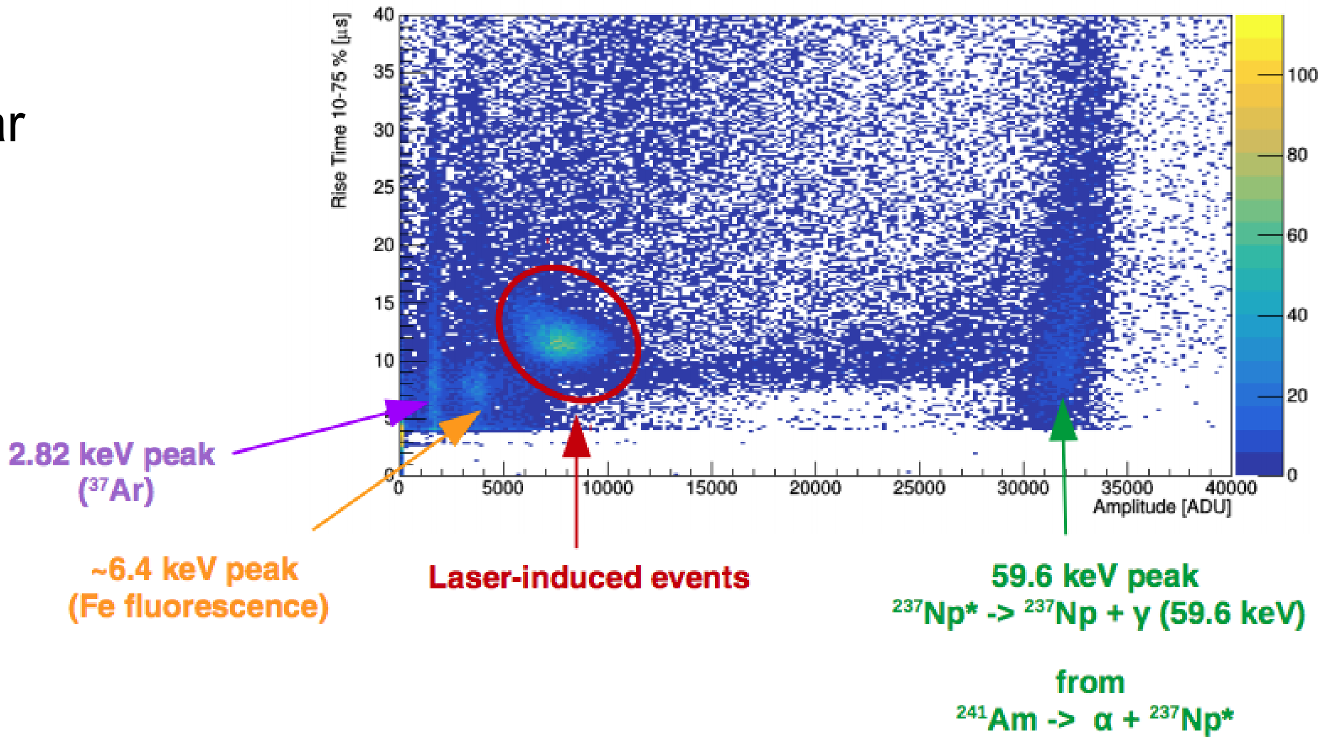
Detector principle



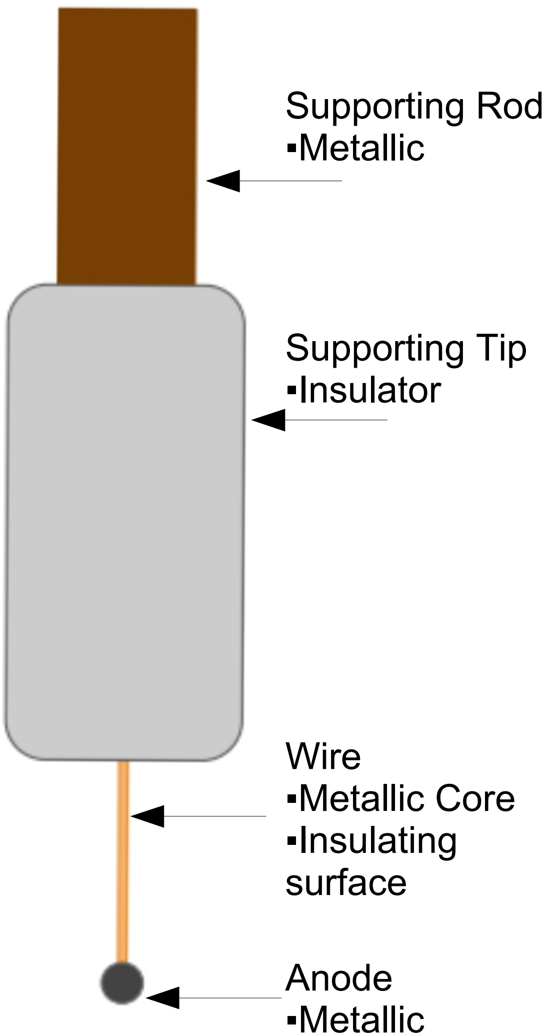
30 cm diameter sphere.
Gas circulation and filtration
Residual gas analyser.

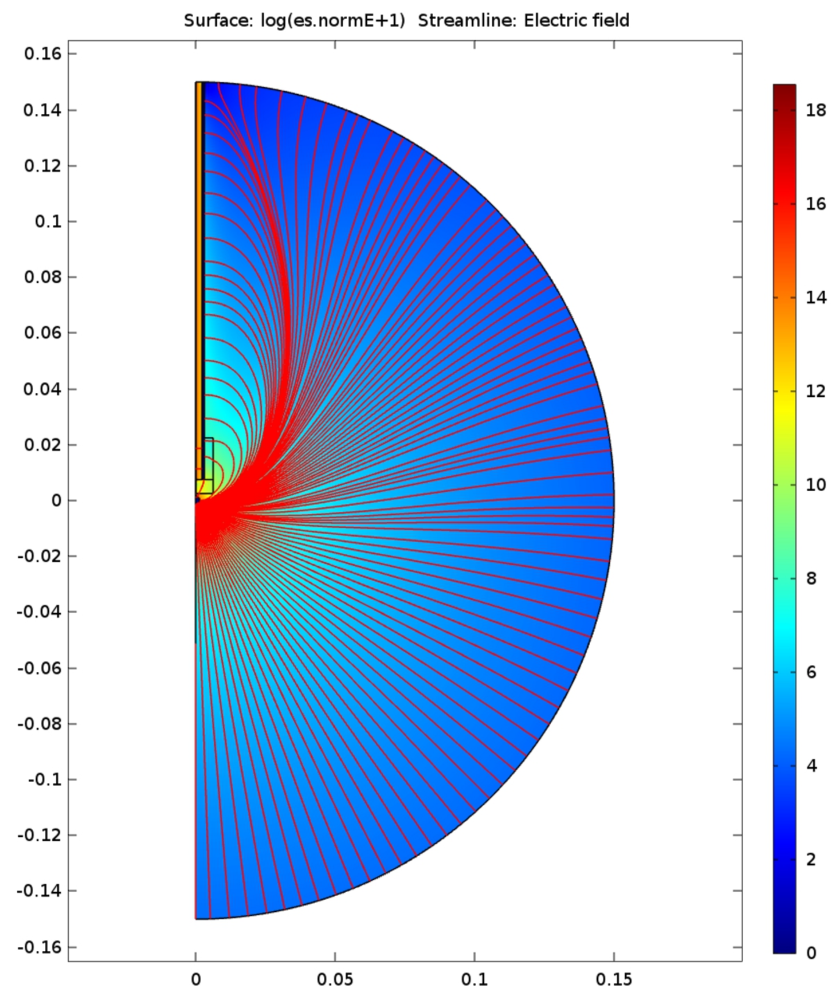
2 mm sensor.
98% Ar + 2% CH_4 at 500 mbar

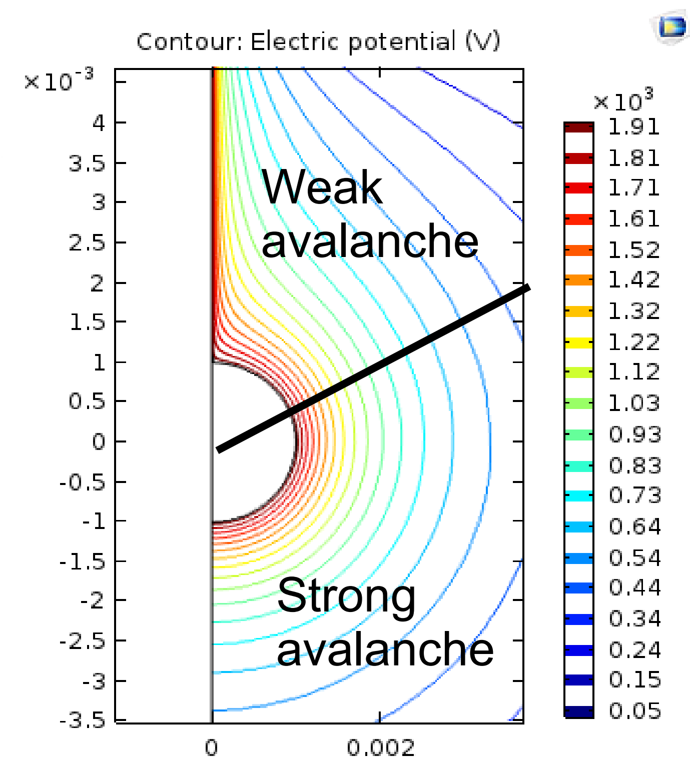
Calibration:
Americium/Beryllium
^{55}Fe
^{37}Ar
Solid state laser



Single electrode sensor:

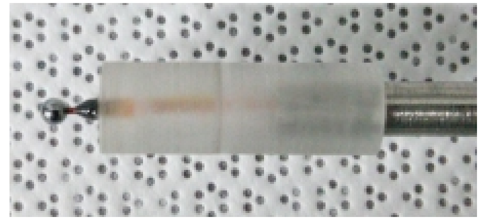


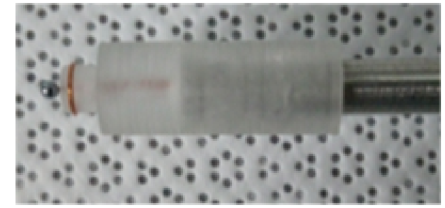


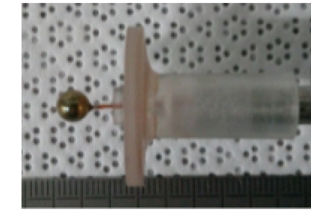


Sensor development

What we expect:
Stable with time
Homogenous response

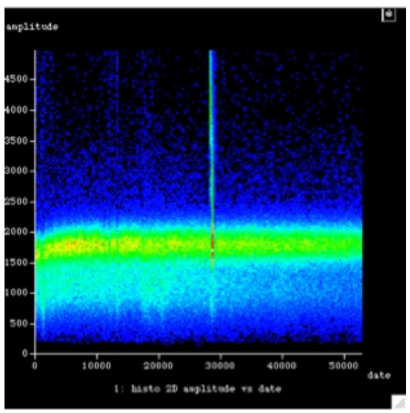


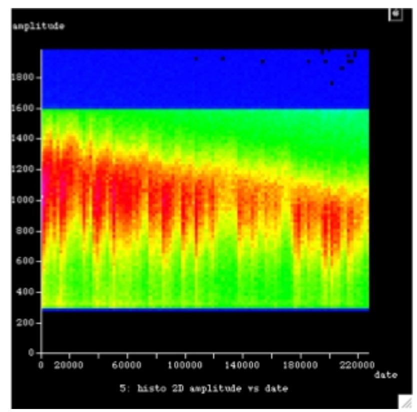




Charging up

Instability

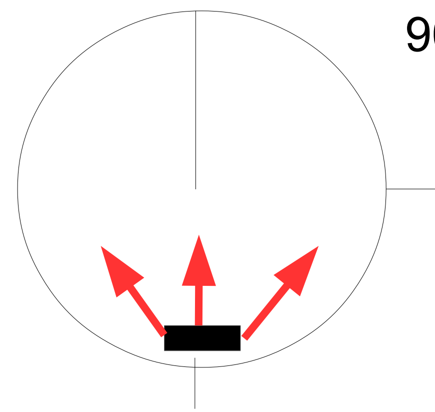




Amplitude

Date

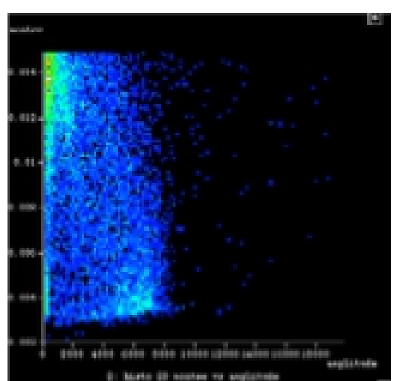
Fe 55 X-ray source

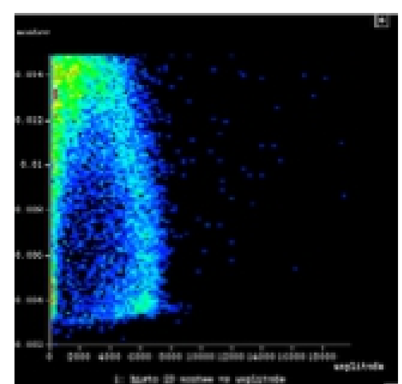


90 deg

180 deg

Inhomogeneous response

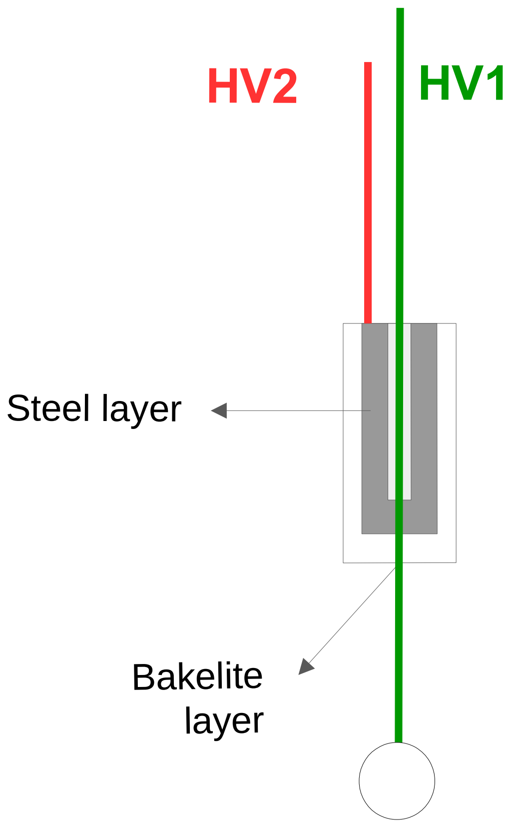


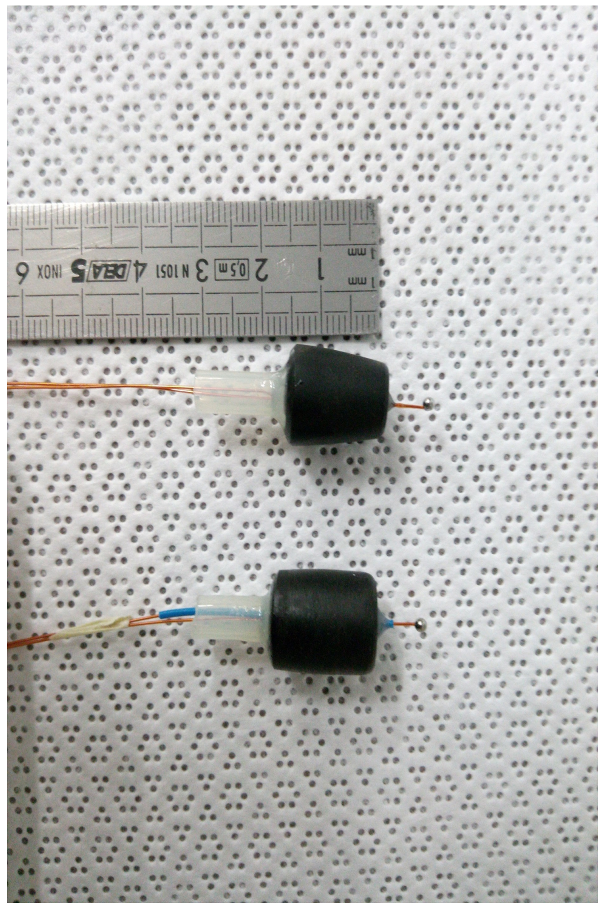


Rise Time

Amplitude

The bakelite resistive umbrella





<u>Bakelite</u>
Chemical Formula:
(C6-H6-O.C-H2-O)x

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

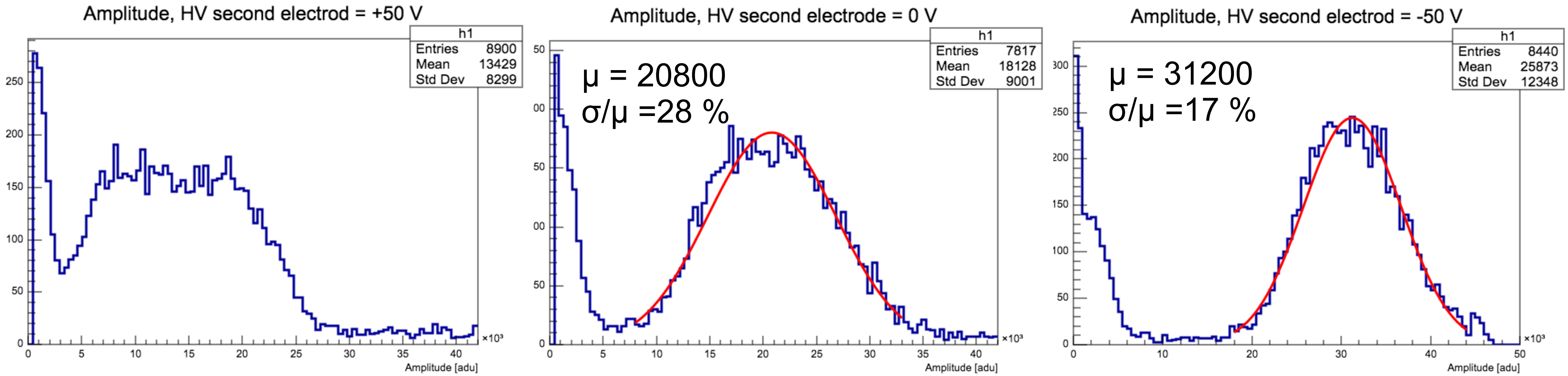
Advantages:

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

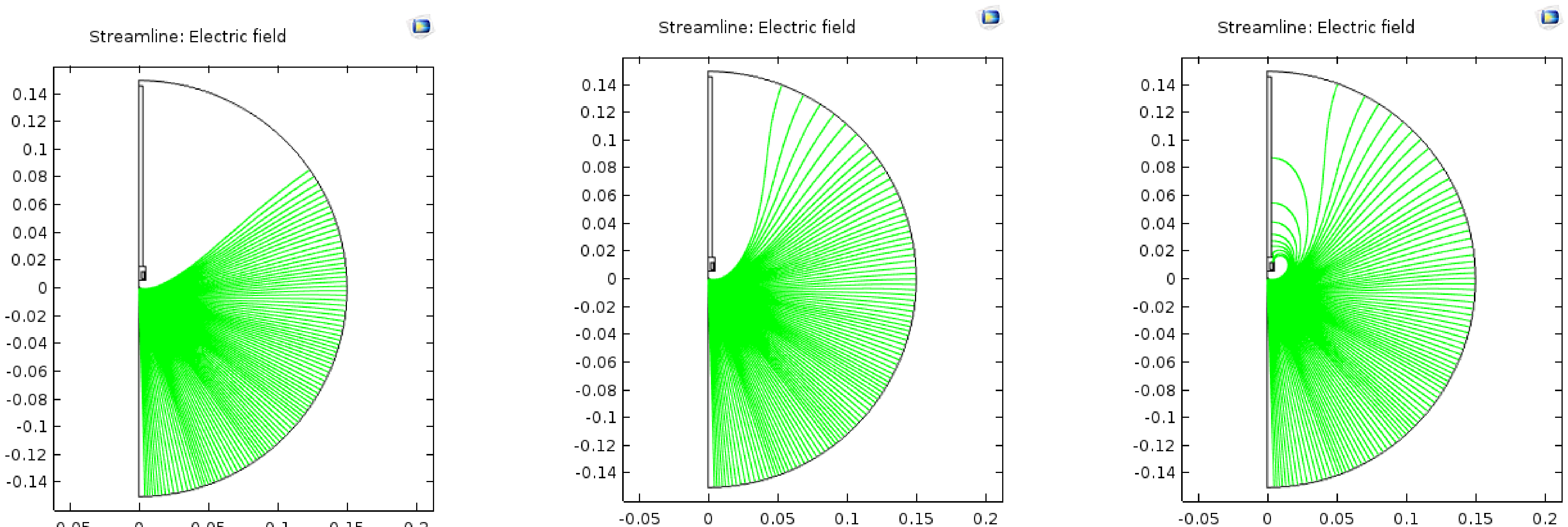
Sensor development

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

Source: ^{37}Ar Electronic capture released 0.27 or 2.8 keV

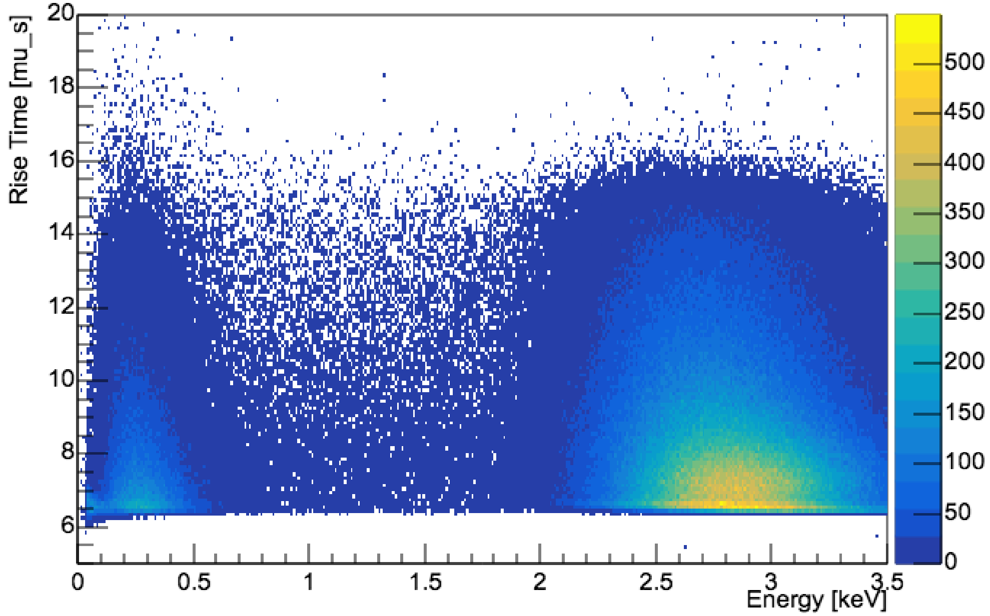


Electric filed lines reaching the lower half of the sensor

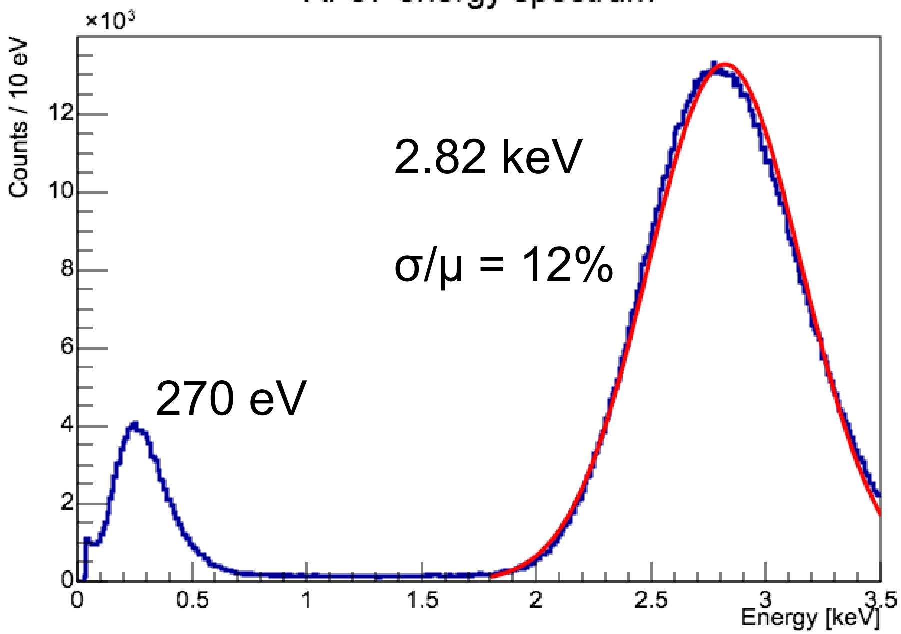


HV2 = +50 V　　HV2 = 0 V　　HV2 = -50 V

Rise time vs amplitude distribution



Ar 37 energy spectrum



Ar-37 events recorded with a 30-cm SPC filled with 500 mbar of Ar + 2 % CH_4.

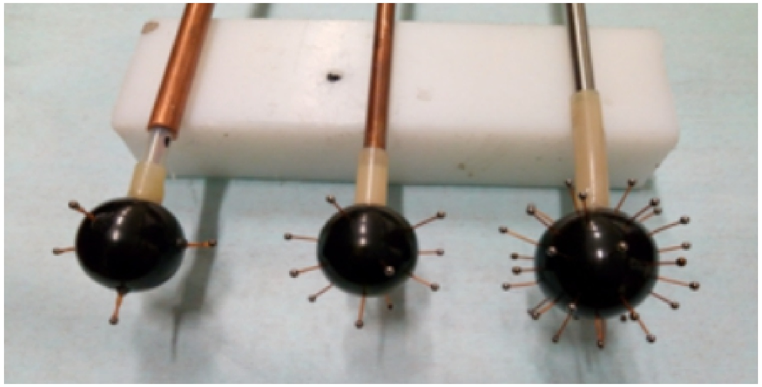
Two millimetre ball with
HV1 = 2020 V and HV2 = -120 V

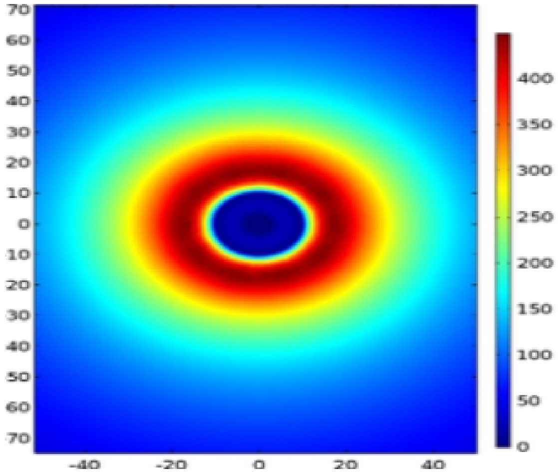
-Amplification is driven by the ball size. Smaller ball gives higher amplification.

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

Achinos sensor

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

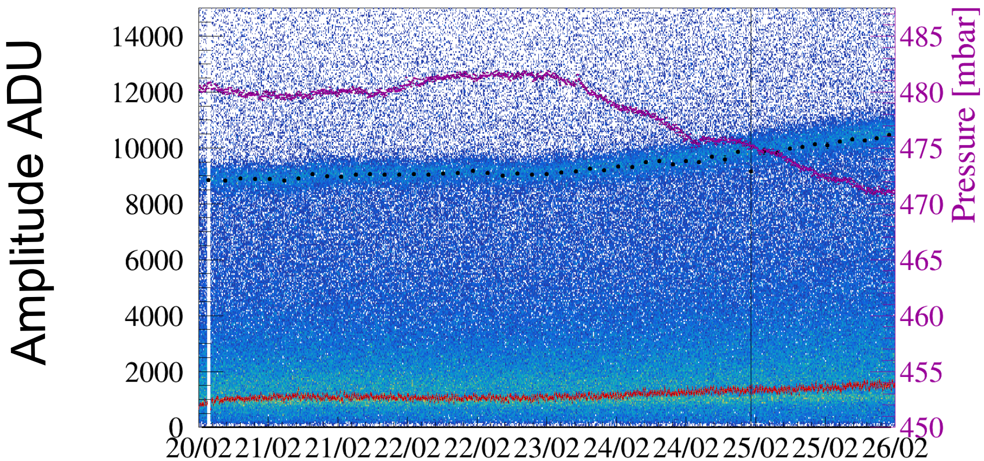


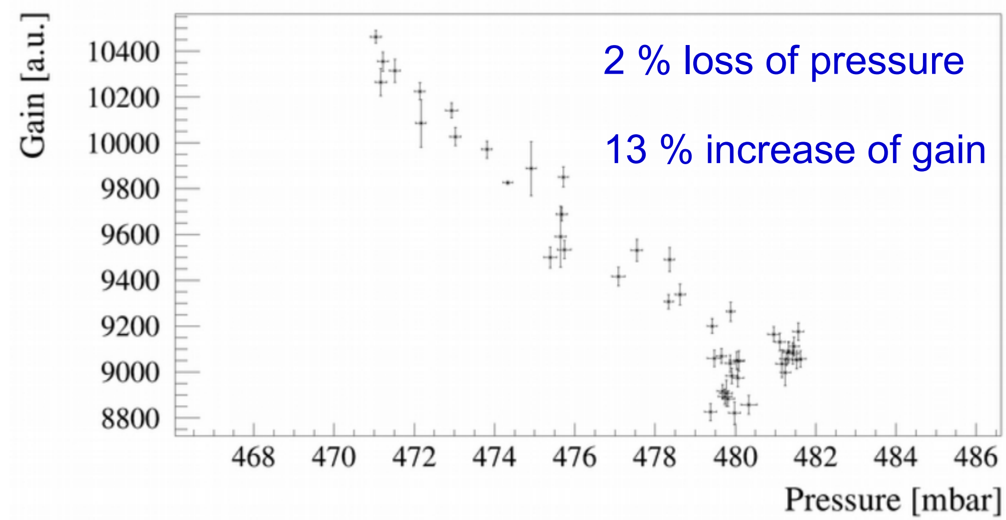


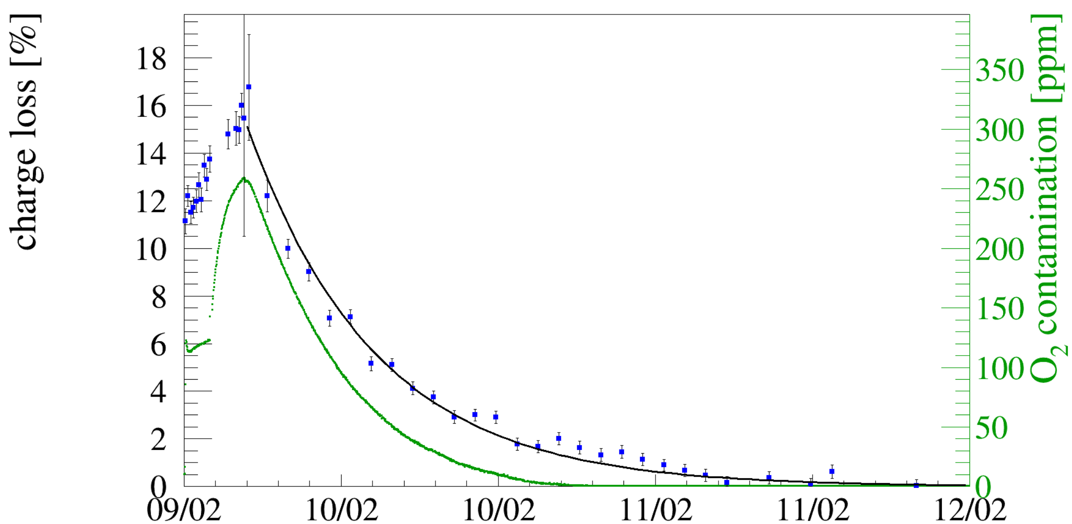
-Amplification is driven by size of each small ball.

-Volume electric field is driven by Achinos structure

Gas effects



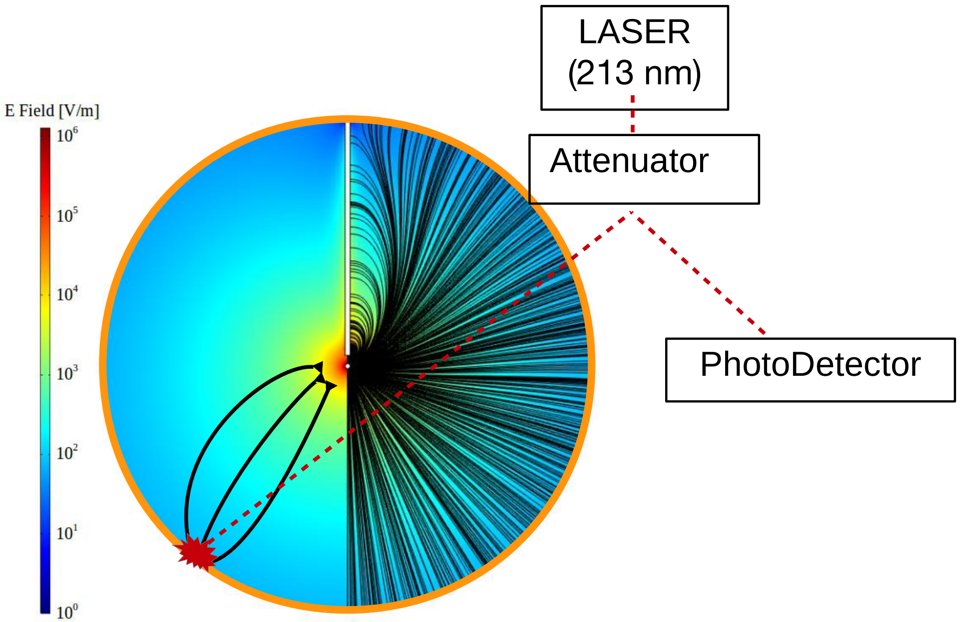




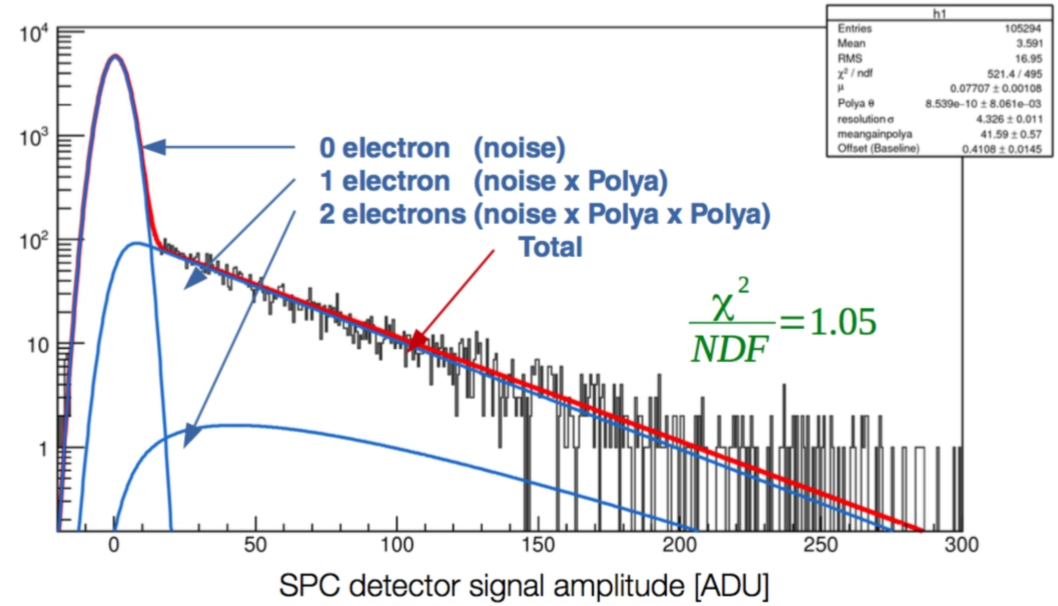
O2 contamination induces electron trapping. Primary electron emitted at large radius are more trapped inducing rise time vs amplitude correlation. This can be avoid using a purifier and circulation.

Laser calibration measurements

Set-up

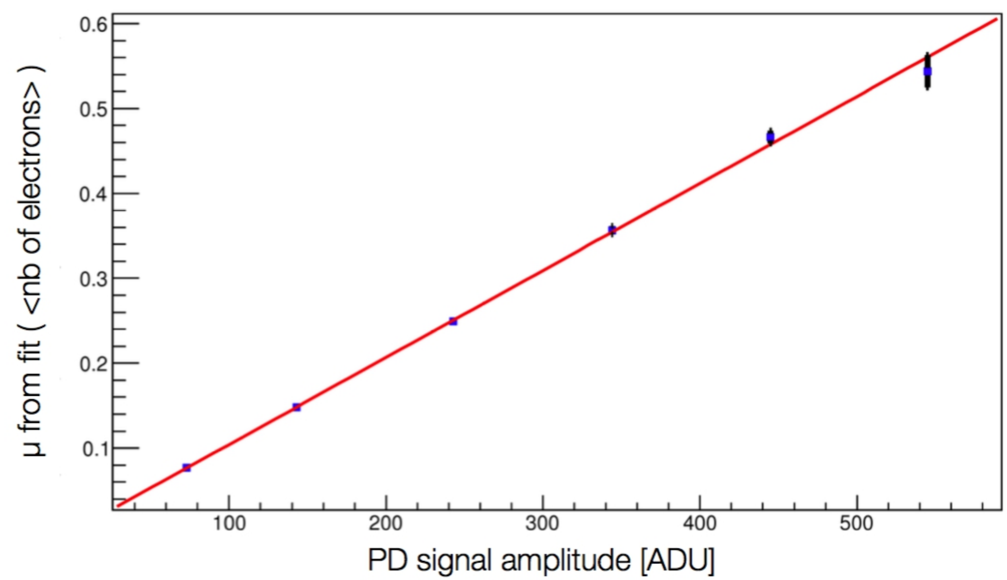


Analysis Methodology



<u>From fit:</u>

mean no. of electrons μ = 0.08
mean gain <G> = 41.6 ADU
baseline resolution = 4.3 ADU ~ 0.1 e
Polya distribution (SER) parameter ~ 0



Applications

<u>with laser</u>:

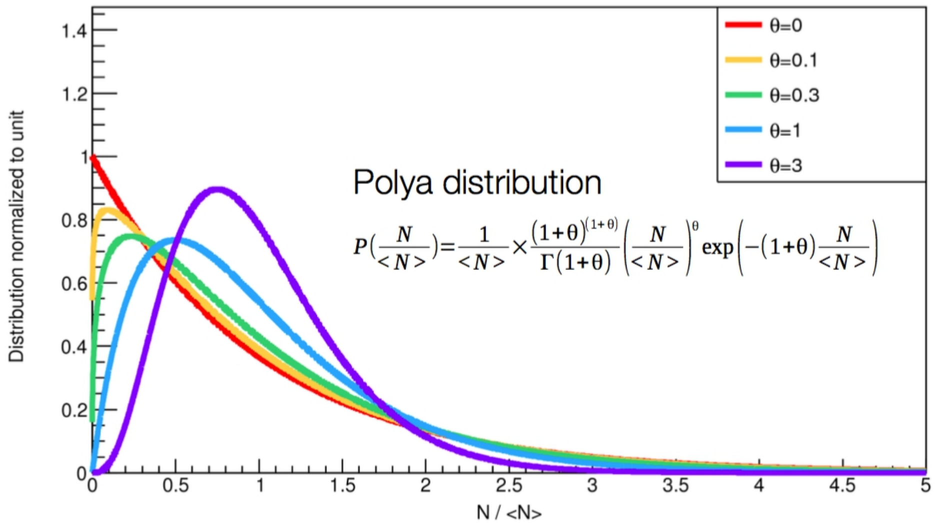
- Drift time and diffusion time measurements
- Attachment rate measurements
- Monitoring of the stability of the detector response
- Single electron response parametrizaton
- Absolute calibration [no. of PEs]

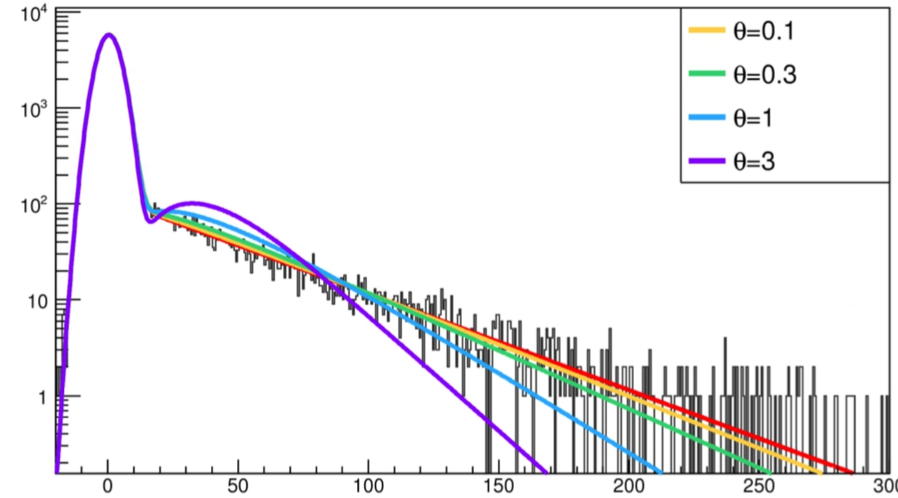
<u>with laser + radioactive source :</u>

- Fano factor measurements
- W-value measurements

Laser calibration measurements

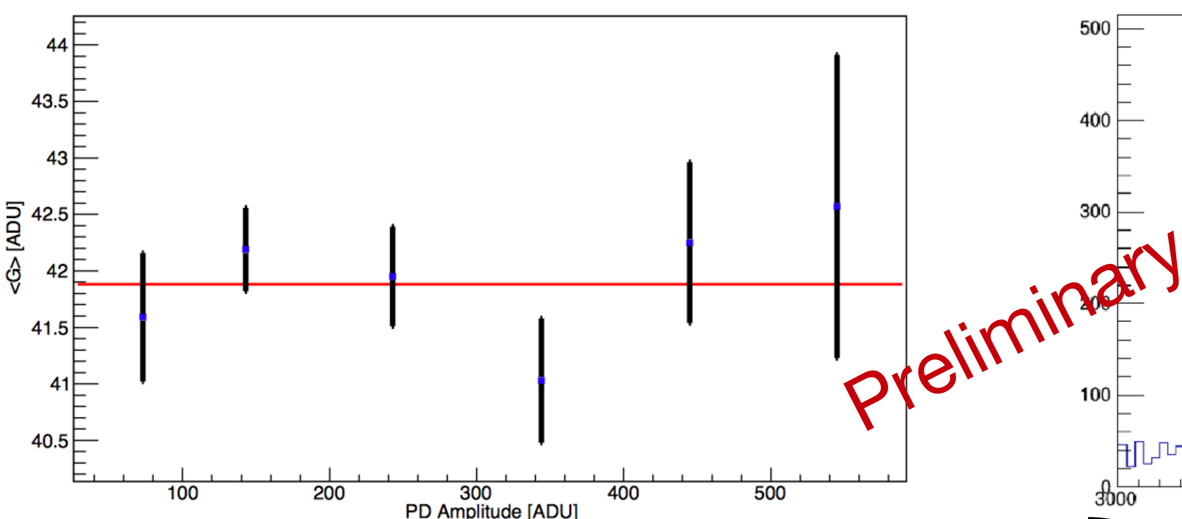
Parametrization of the Single Electron Response (SER)

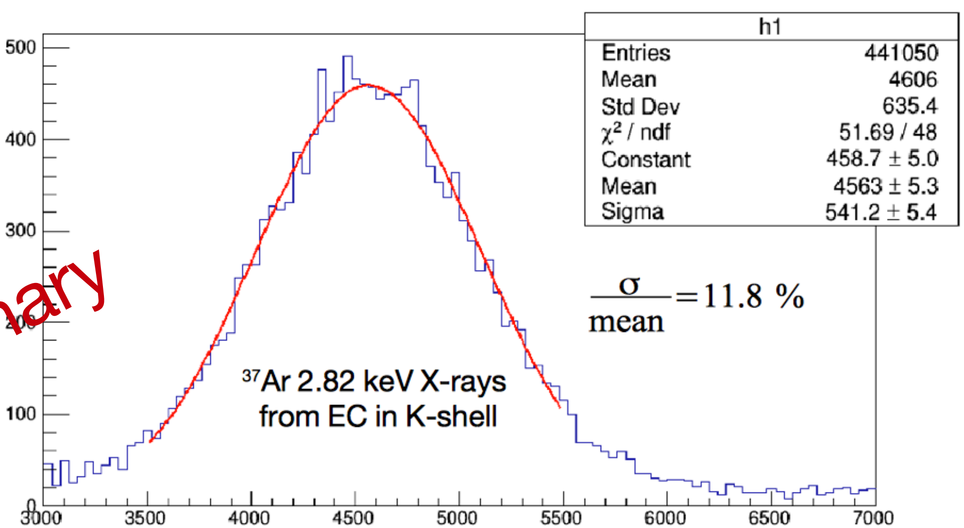




W-value measurement and upper limit on the Fano factor

in 500 mbar of Ar + CH_4 (2%)



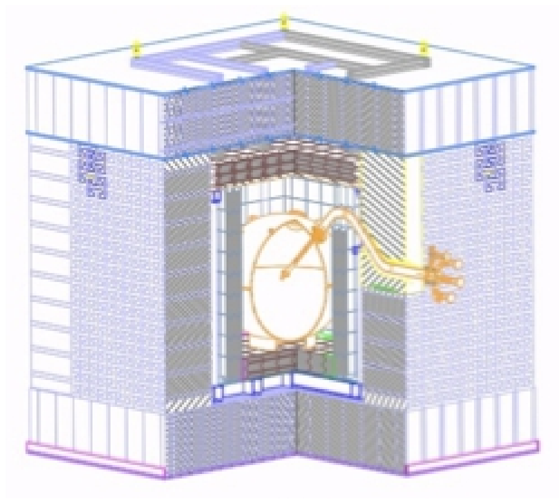


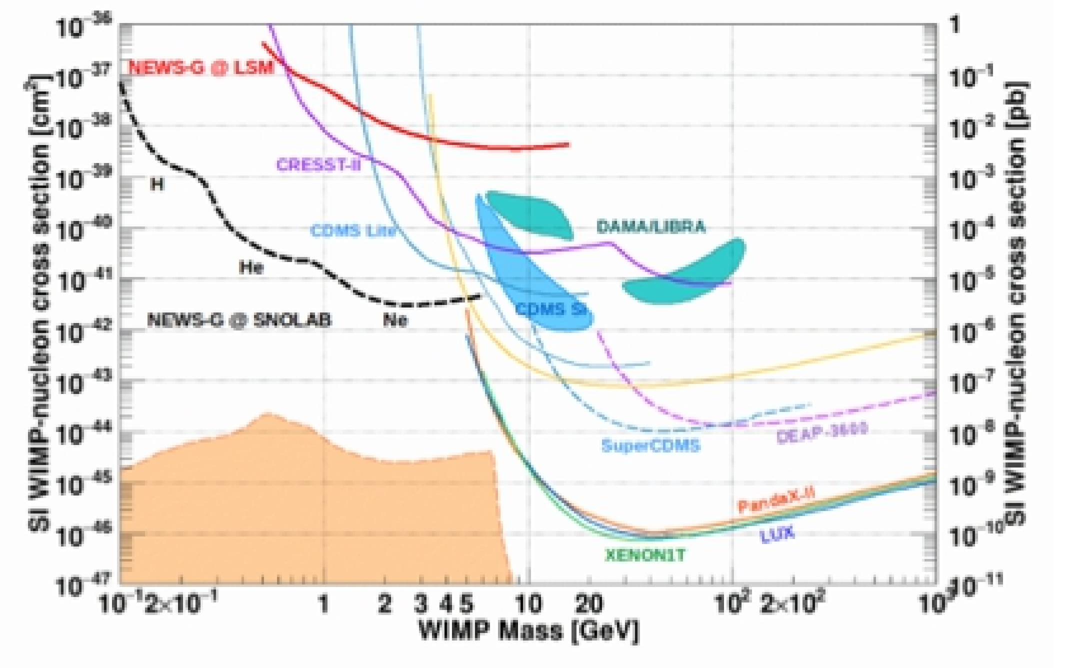
<Gain> ~ 41.9 ADU
&
2820 keV peak @ 4563 ADU

W ~ 25.9 eV

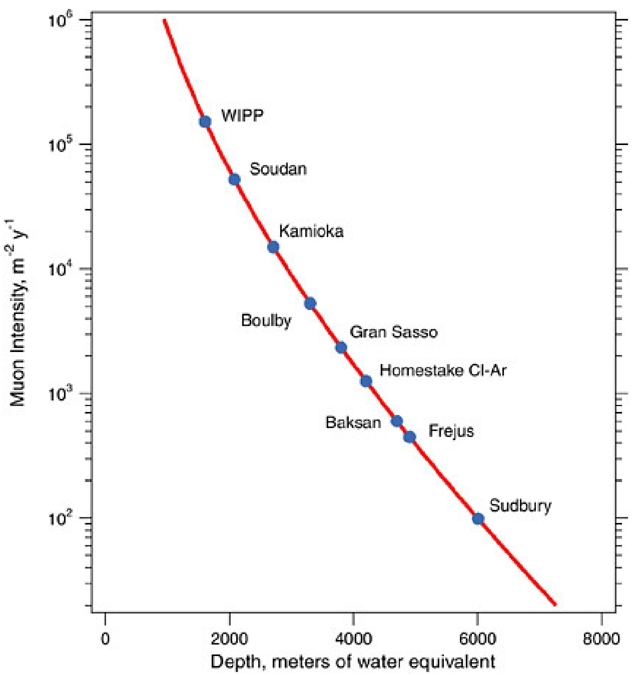
Results and future

SEDINE 60 cm detector operating at LSM

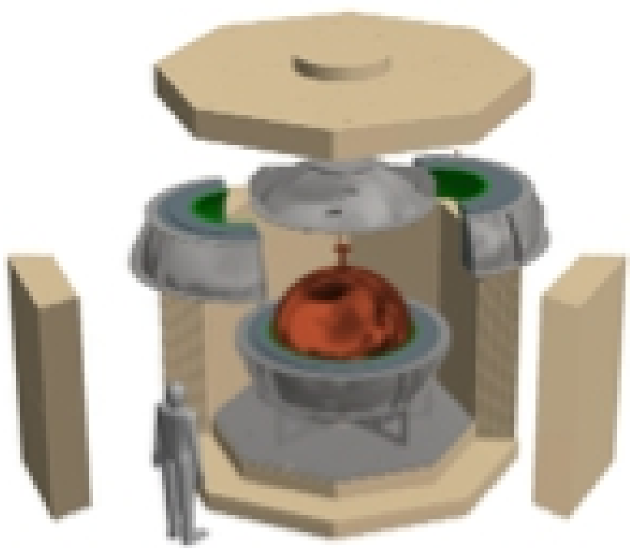




First results for NEWS-G at LSM:
NEWS-G collaboration, Astropart. Phys. 97, 54 (2018), doi: 10.1016/j.astropartphys.2017.10.009



NEWS-G at SNOLAB to be installed during summer 2019.



140 cm detector to be operated at SNOLAB
Shielding:
40 cm PE
22 cm VLA Pb
3 cm archaeological lead

NEWS-G collaboration 2018

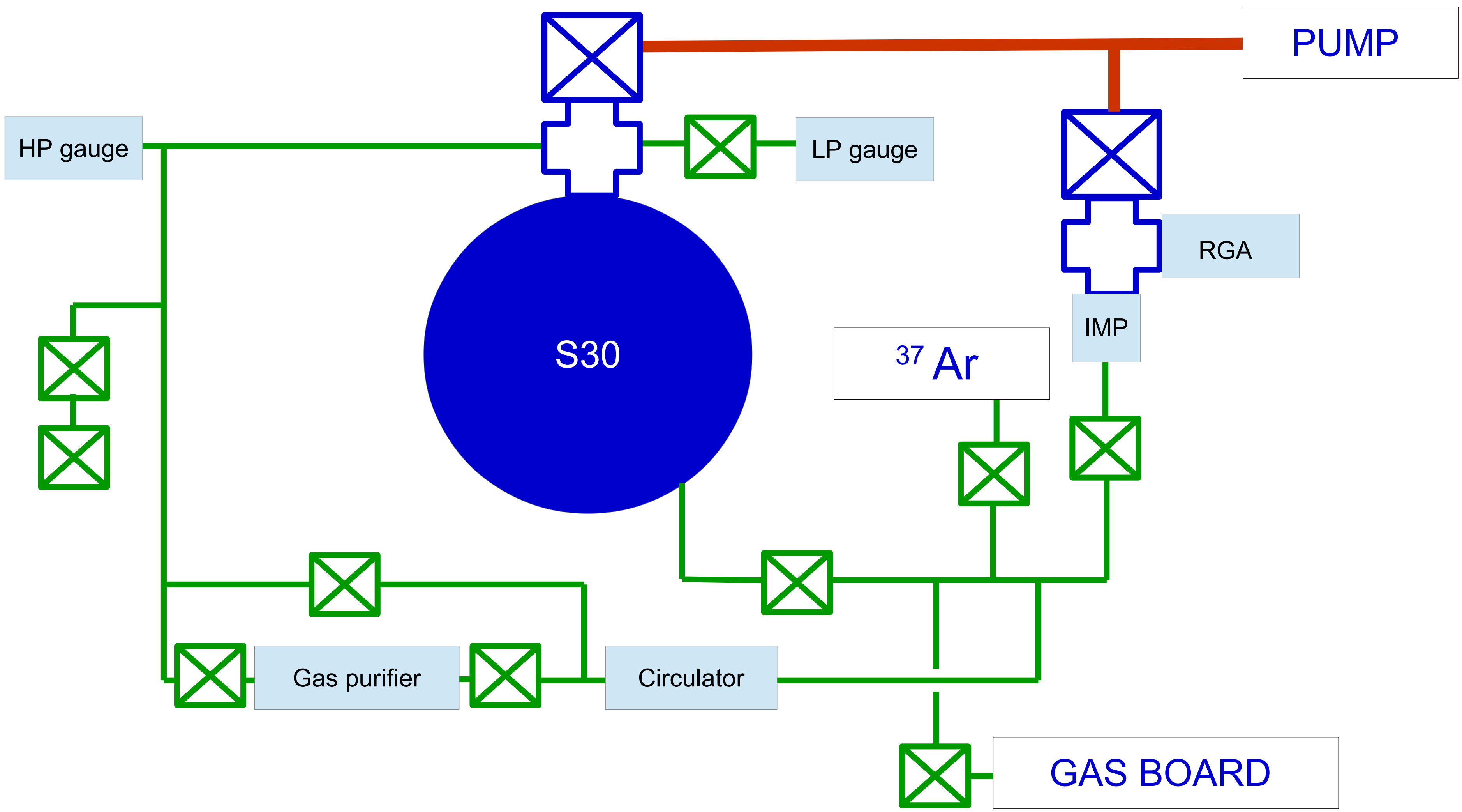
- **Queen's University Kingston** – **G Gerbier**, P di Stefano, R Martin, G Giroux, T Noble, D Dunrford, S Crawford, M Vidal, A Brossard, P Vazquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, M Chapellier, A Ronceray, P Gros, J Morrison, C Neyron
  - Copper vessel and gas set-up specifications, calibration, 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
  - 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
- **Pacific National Northwest Lab** – E Hoppe, R Bunker
  - 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** – K Nikolopoulos, P Knights
  - Simulations, analysis, R&D
- **Associated labs : TRIUMF** - F Retiere,

Apr 2018

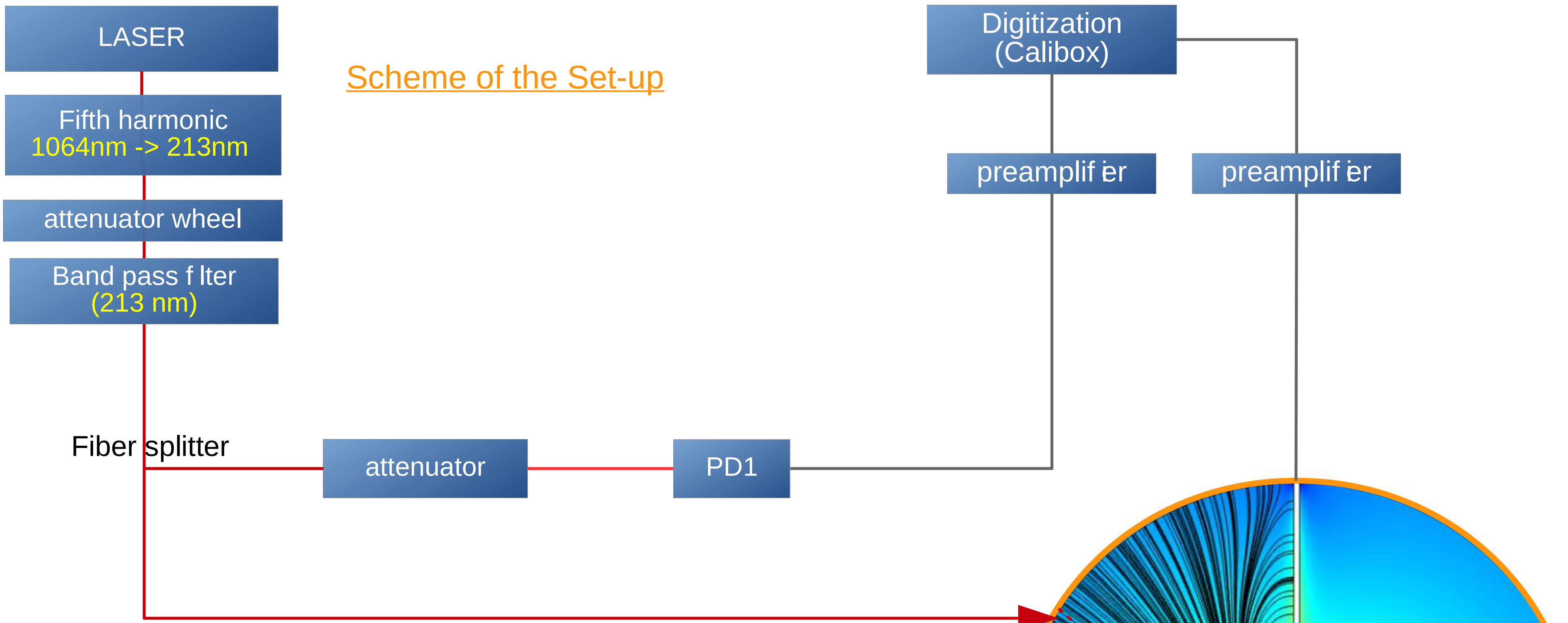
THANK YOU

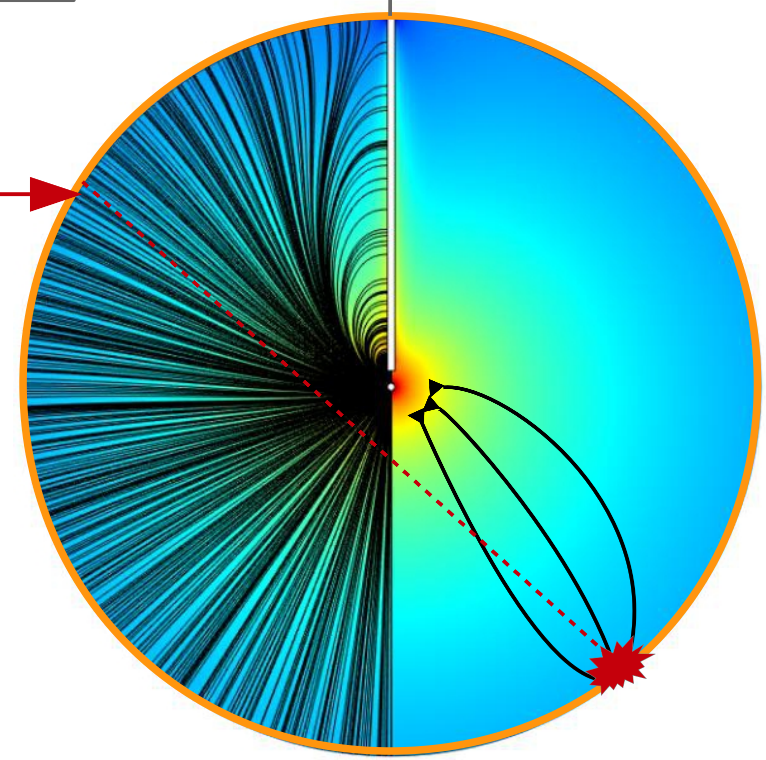
Backup Slides

Gas handling system



Laser calibration





Laser Data

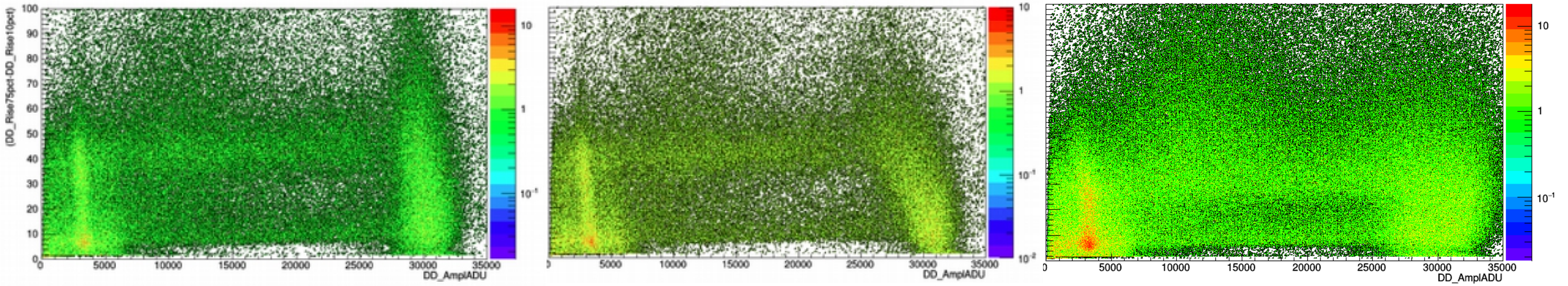
- Single electron response parametrization (θ of Polya)
- Energy calibration / W-value measurements
- Monitoring of the stability of the detector response over time
- Drift and Diffusion time measurements

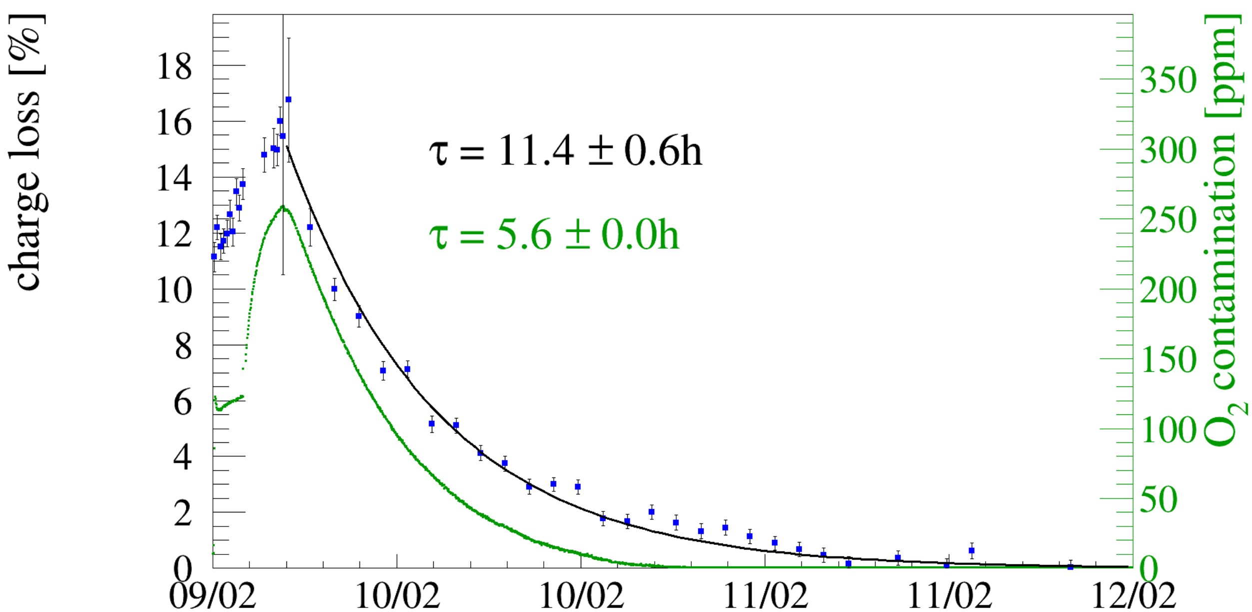
Photodetector (PD)

- Monitoring of the stability of laser
- Start Time (in drift time measurements)

Gas effects

Amplitude vs rise time distribution before and after O_2 injection:





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Influence of HV on second electrode