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Recent Developments in the Spherical Proportional Counter for NEWS-G

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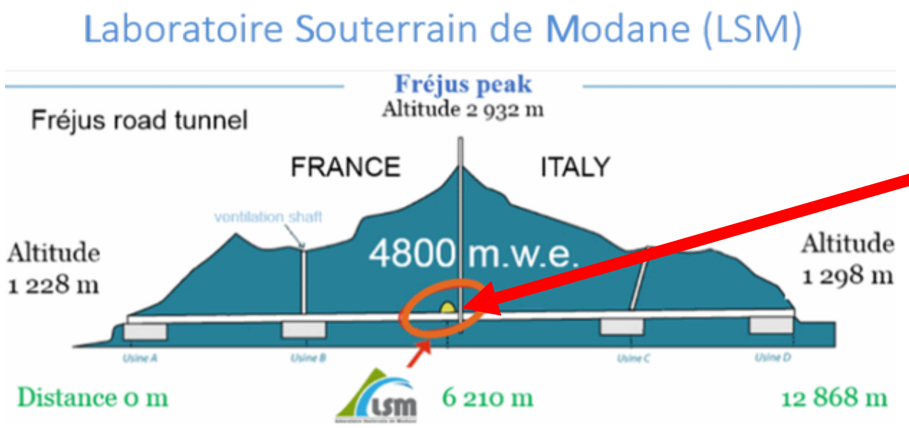
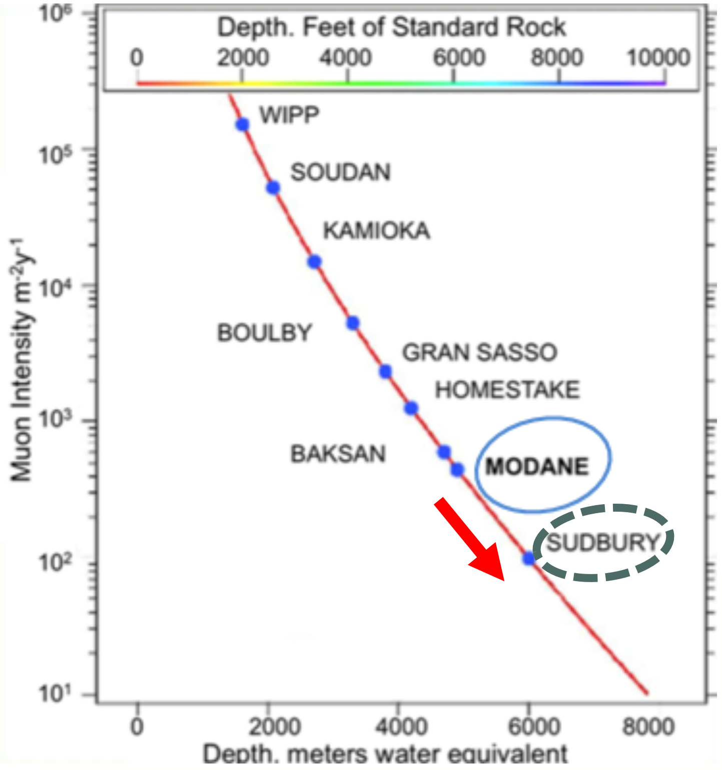
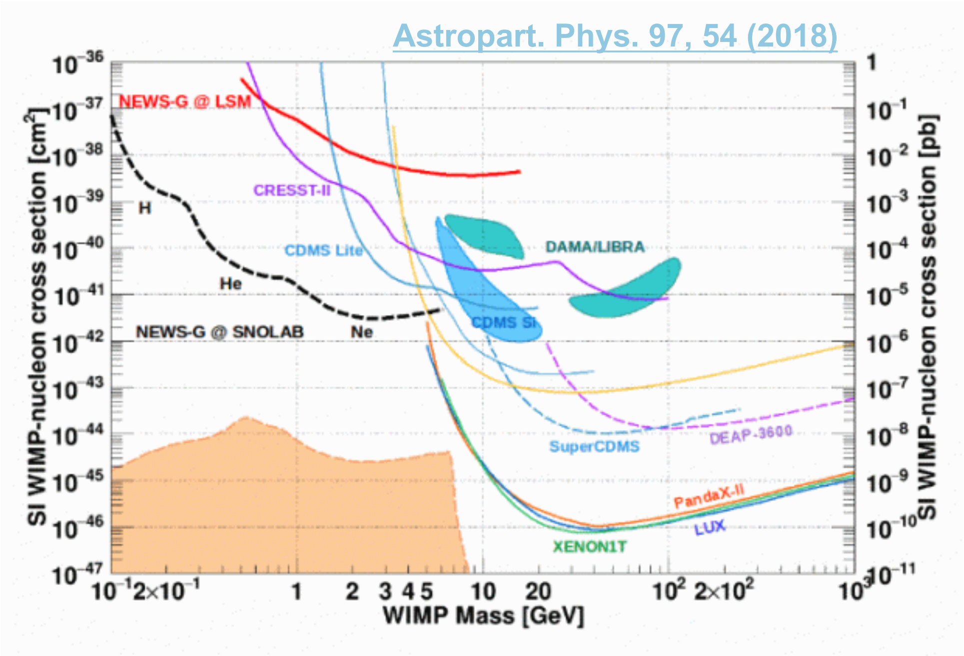
NEWS-G

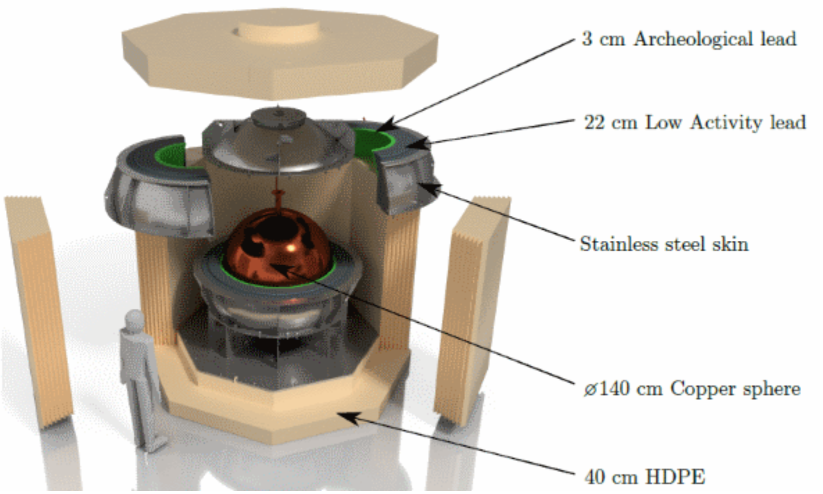
International collaboration using SPCs in a direct search for light Dark Matter (DM)



⌀ 60 cm SPC, SEDINE, currently in operation in LSM







⌀140 cm SPC to be installed in SNOLAB at the end of this year

Spherical Proportional Counter

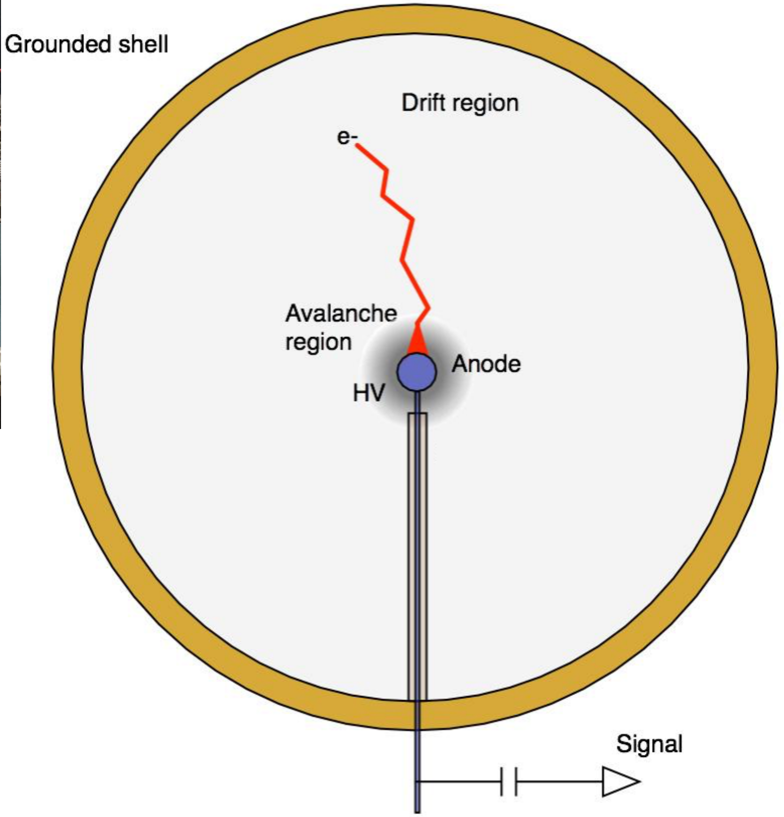
I.Giomataris et al ,JINST,2008, P09007

$$E_r = V_0 \cdot \frac{r_a r_b}{(r_b - r_a) r^2}$$

V_0 = anode voltage
r_a = radius of anode
r_b = radius of sphere

- Spherical Proportional Counter proposed by I. Giomataris
- Sphere filled with desired gas mixture and pressure
- Electrons from ionisation in the gas drift to the anode where they are amplified

SPC used for R&D at CEA Saclay



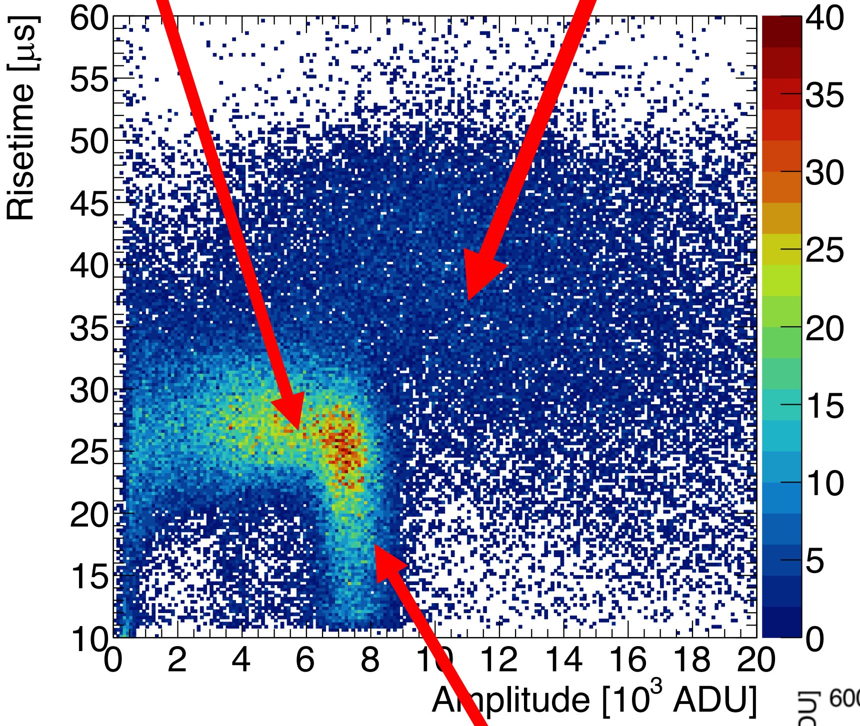
LEP cavity, now an SPC

G. Charpak and I. Giomataris

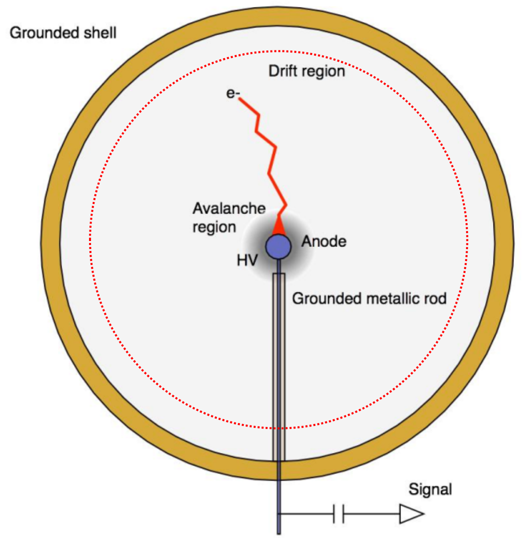
Fiducialisation and Background Rejection

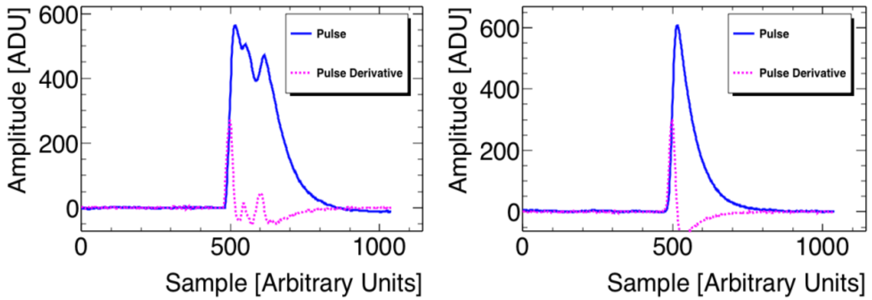
Surface

Cosmics + other backgrounds

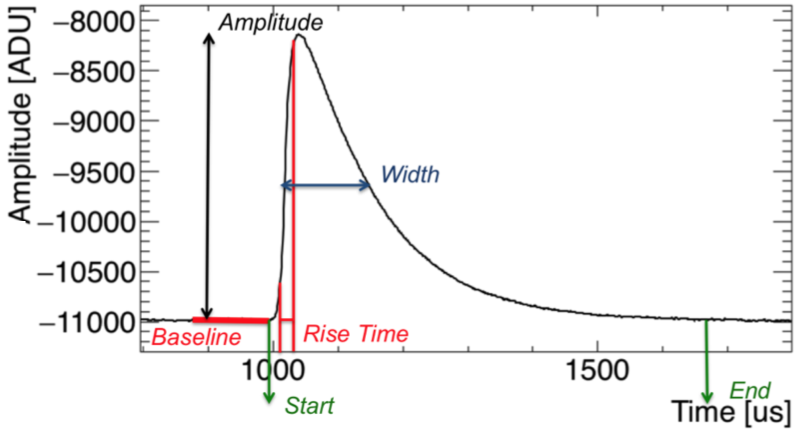


"Volume Events"



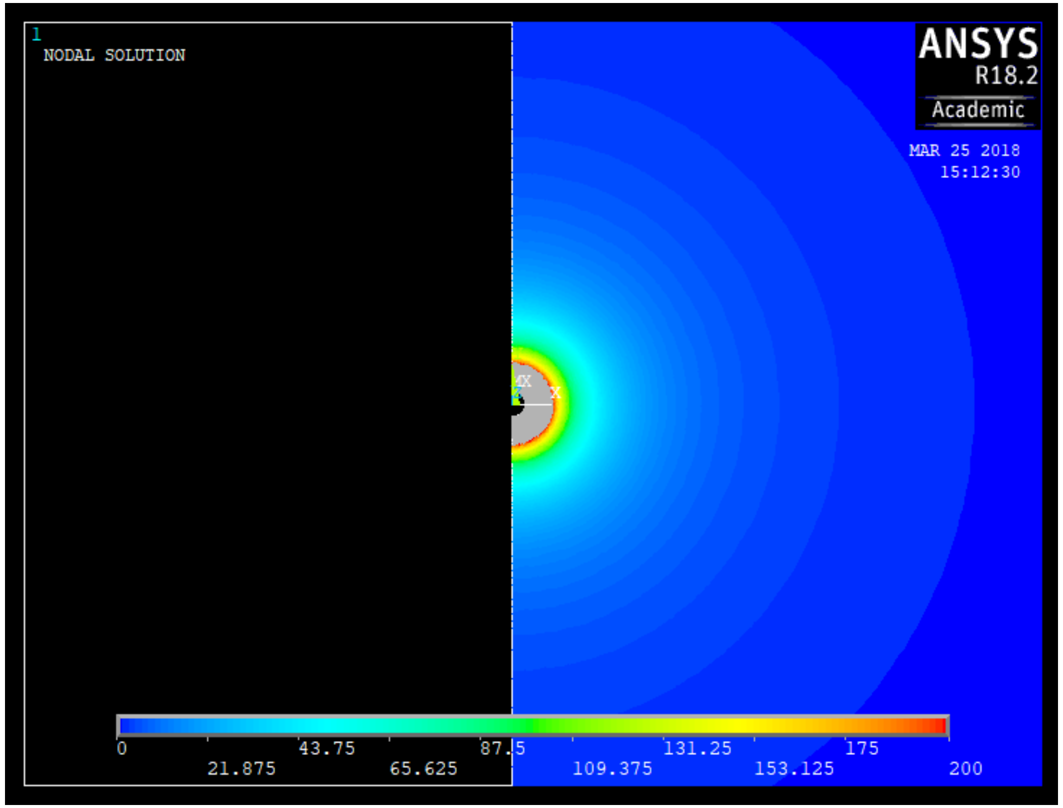


- Electric field within the detector is crucial
  - Gain dependence
  - Electron collection from large radii
  - Fiducialisation through rise time
  - Background rejection through pulse-shape analysis

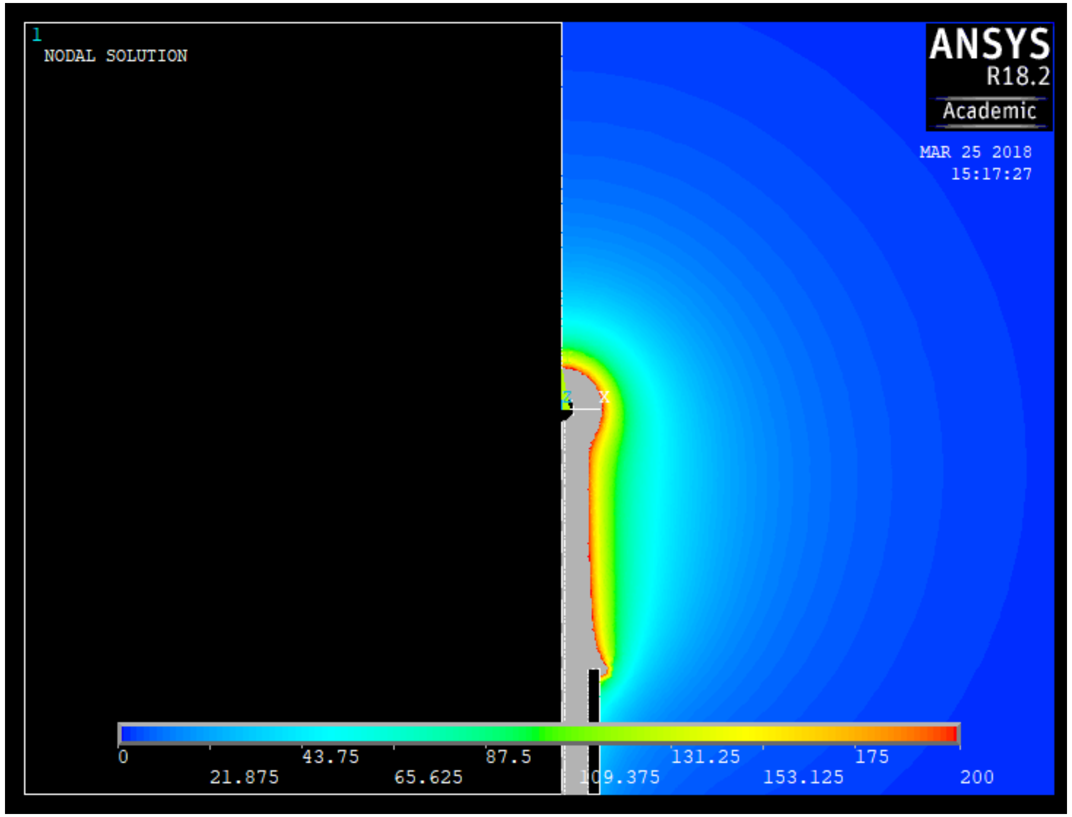


A Realistic Geometry

In reality the anode is attached to a wire to supply the high voltage and this wire is surrounded by a grounded rod



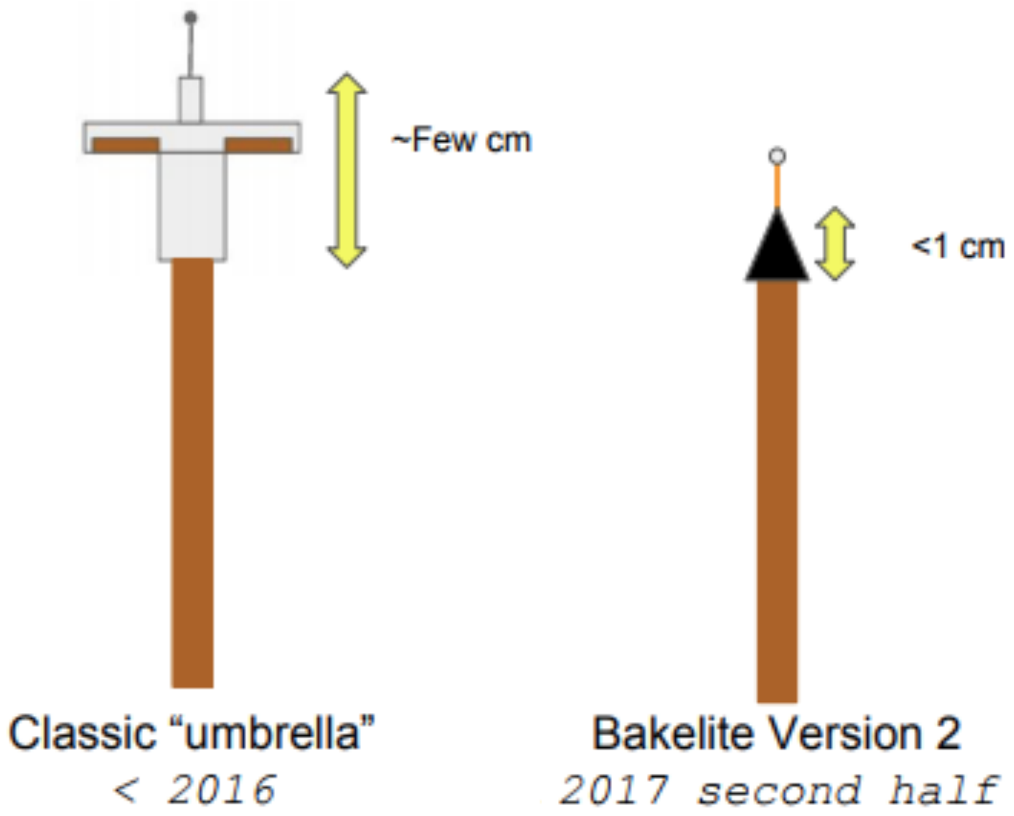
Ideal Case



Anode, wire and grounded rod

Sensor Development

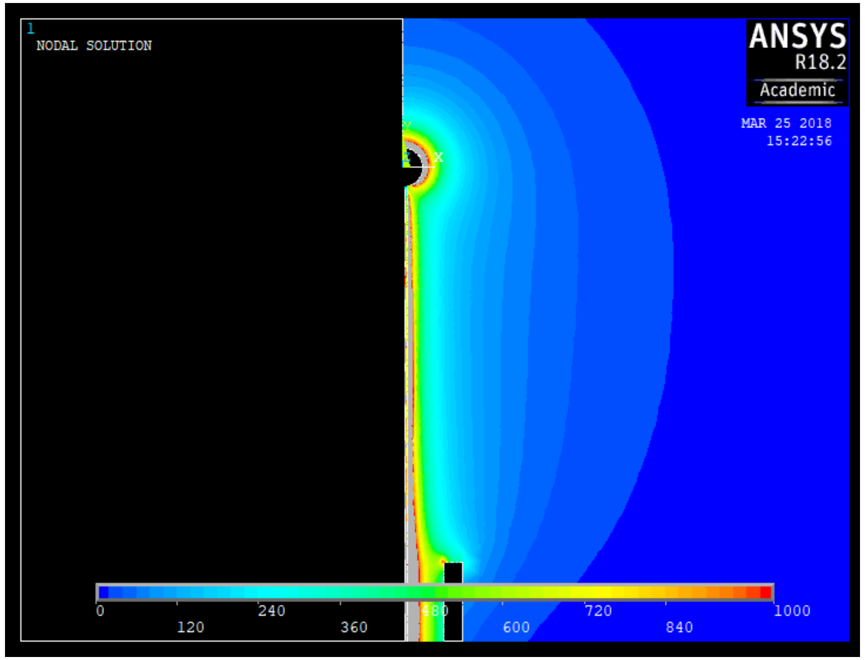
- Necessary to maximise the usable volume in the detector
- Idea: Add a field corrector to rod (umbrella)
- Using insulator
  - Charging up and unstable operation
- Using biased conductor
  - Sparks from the anode
- Using resistive materials
  - Resistivities 10^9 -10^{12} $\Omega \cdot$cm
  - Allow application of a voltage
  - Reduced risk of discharge
  - Tried different geometries



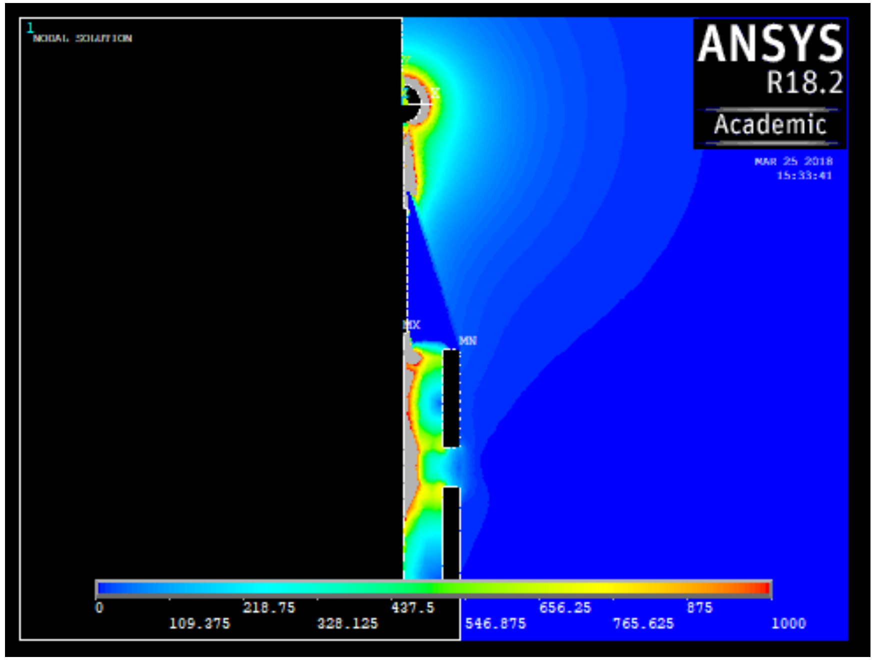
New Sensor Design

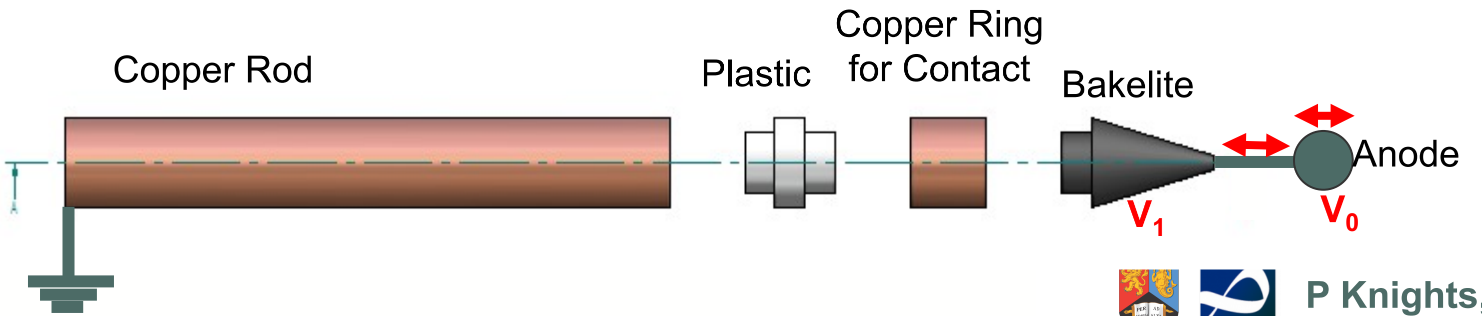
- Simple design
  - Few Components
  - Simple geometry
  - Can easily vary parameters to optimise electric field configuration
- Studied using ANSYS FEM Software
  - V_0 (Anode voltage)
  - V_1 (Umbrella voltage)
  - Separation Umbrella and Anode
  - Anode radius

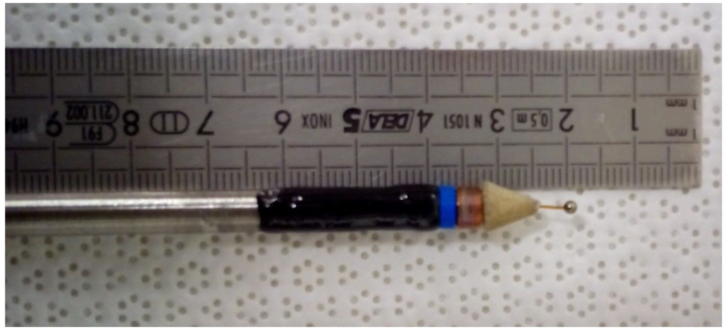
Anode, wire and grounded rod



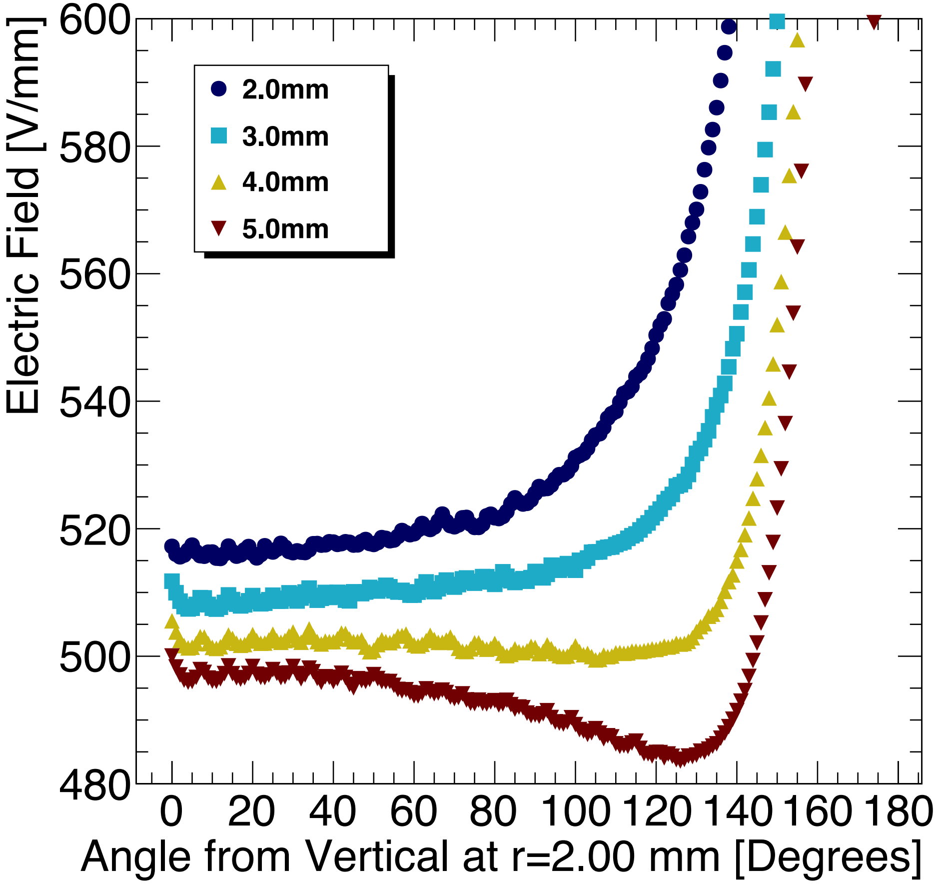
Bakelite Structure

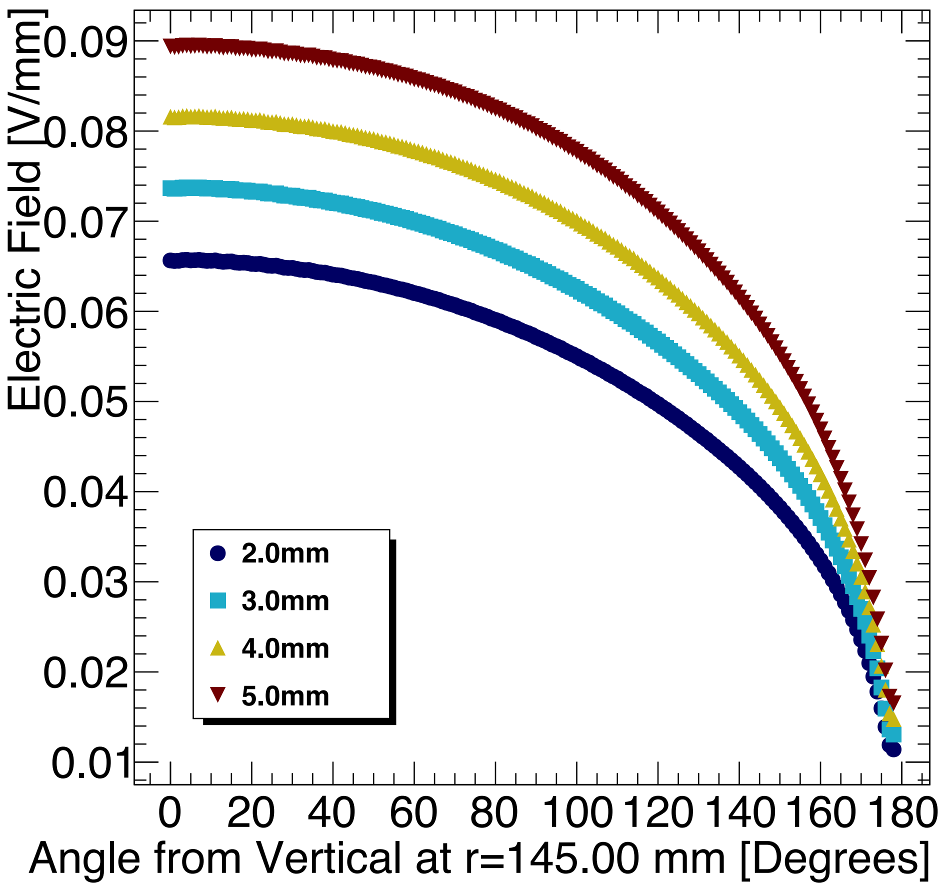


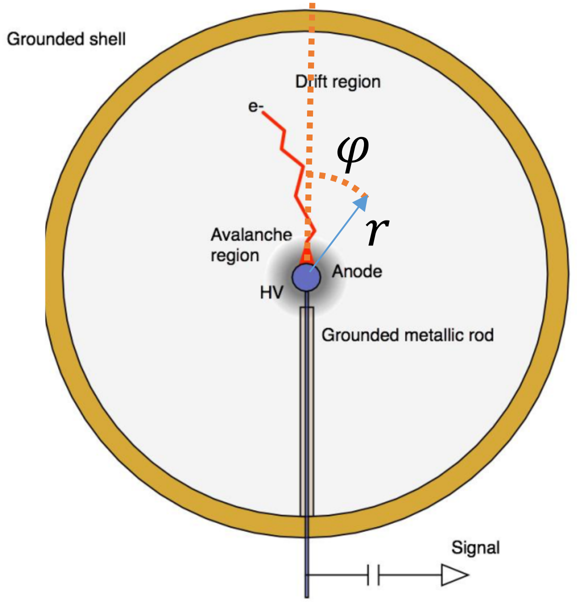




Sensor Design: Anode-Umbrella Separation







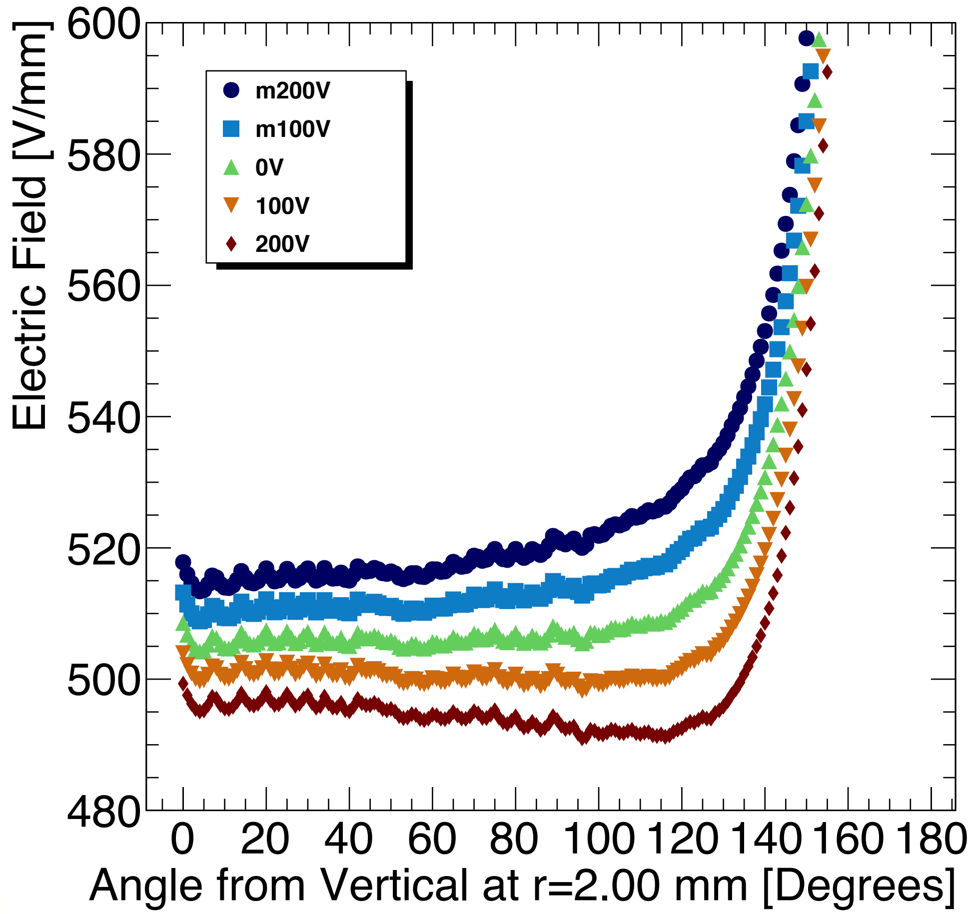
r_a= 1 mm

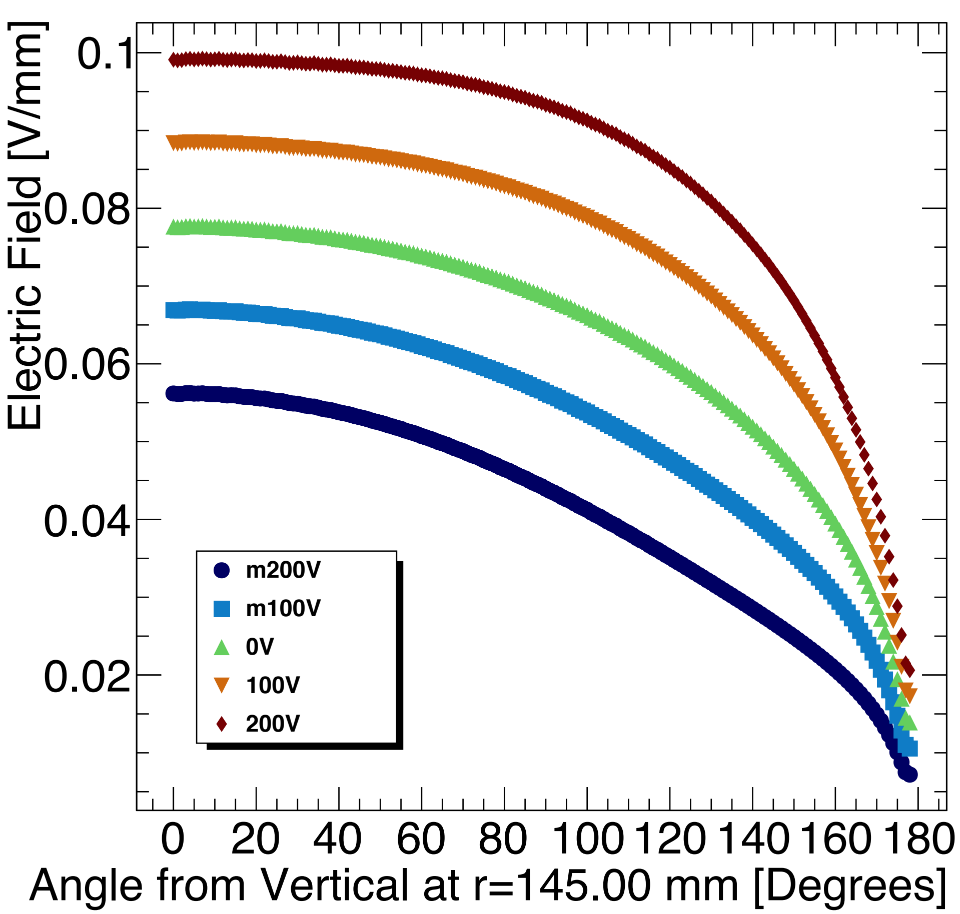
r_b = 150 mm

V_0 = 2000 V

V_1 = 0 V

Sensor Design: Umbrella Voltage

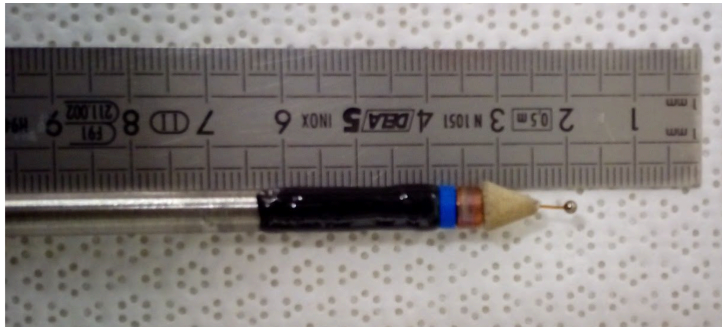




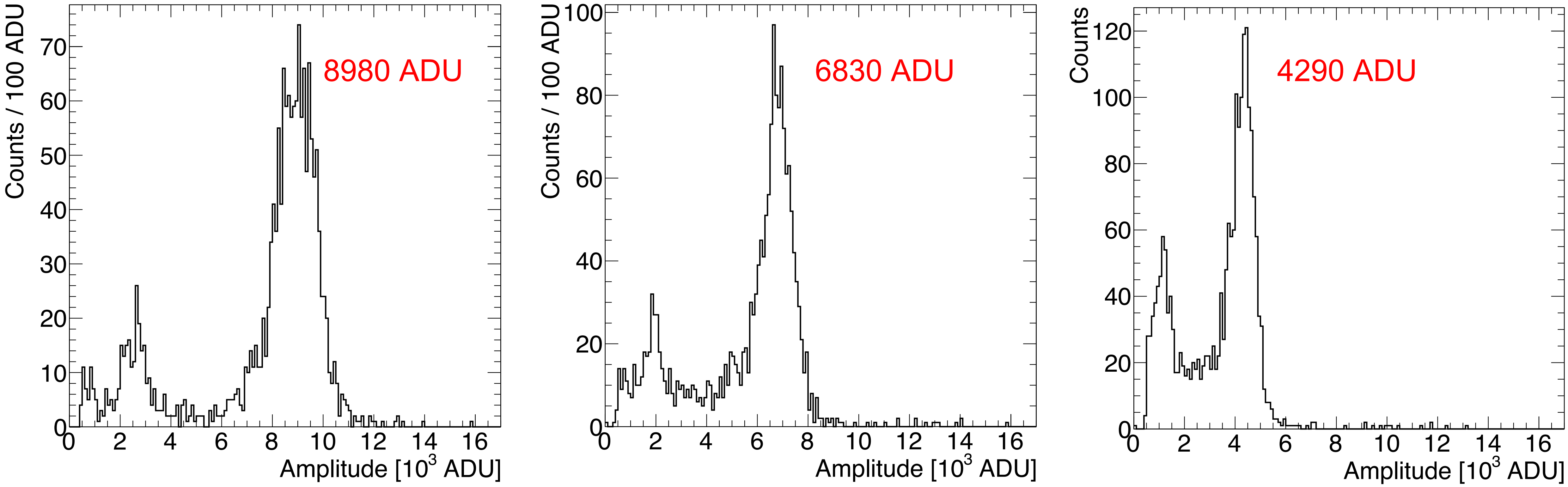
r_a= 1 mm
r_b = 150 mm
V_0 = 2000 V
Separation = 3.5 mm

Sensor Design: Measurements

- Fe55 Source – 5.9 keV x rays
- 30 cm diameter test sphere operating at 600 mbar of He + 10% CH_4
- Anode Diameter = 2 mm, Separation = 3.5 mm



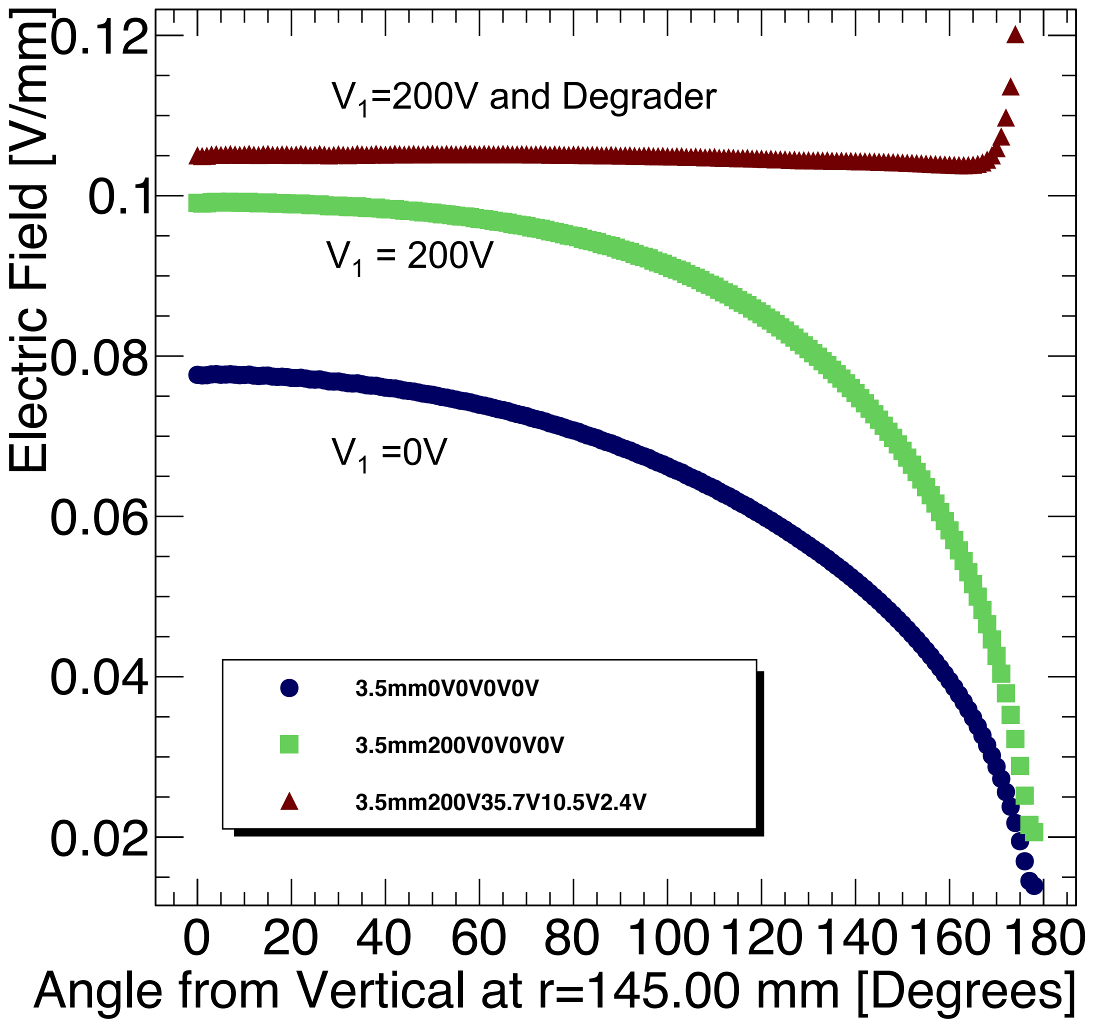
V_1 -200 V V_1 0 V V_1 200 V

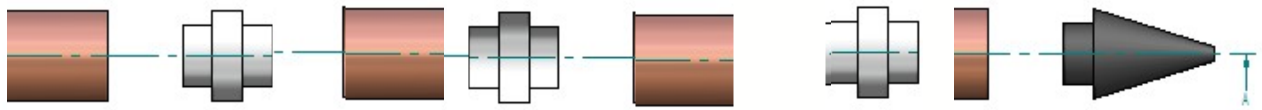


- Gain reduced by presence of positive voltage on umbrella - electric field near anode reduced

Voltage Degrader

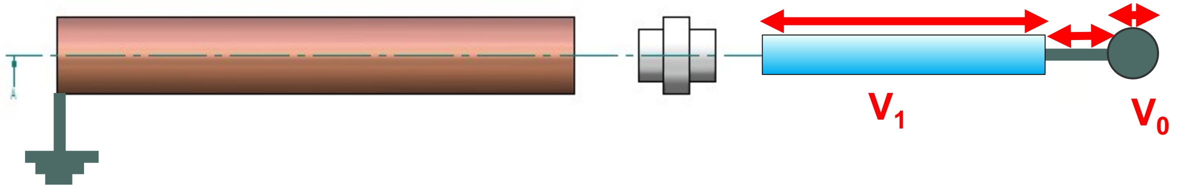
- Optimal design: voltage degrader chain
  - Many small pieces to make up the rod
  - Pieces set to gradually decreasing voltages umbrella to outer sphere
- Segmenting rod can make a three part degrader
  - Substantial improvement to the outer electric field
  - However, practically challenging

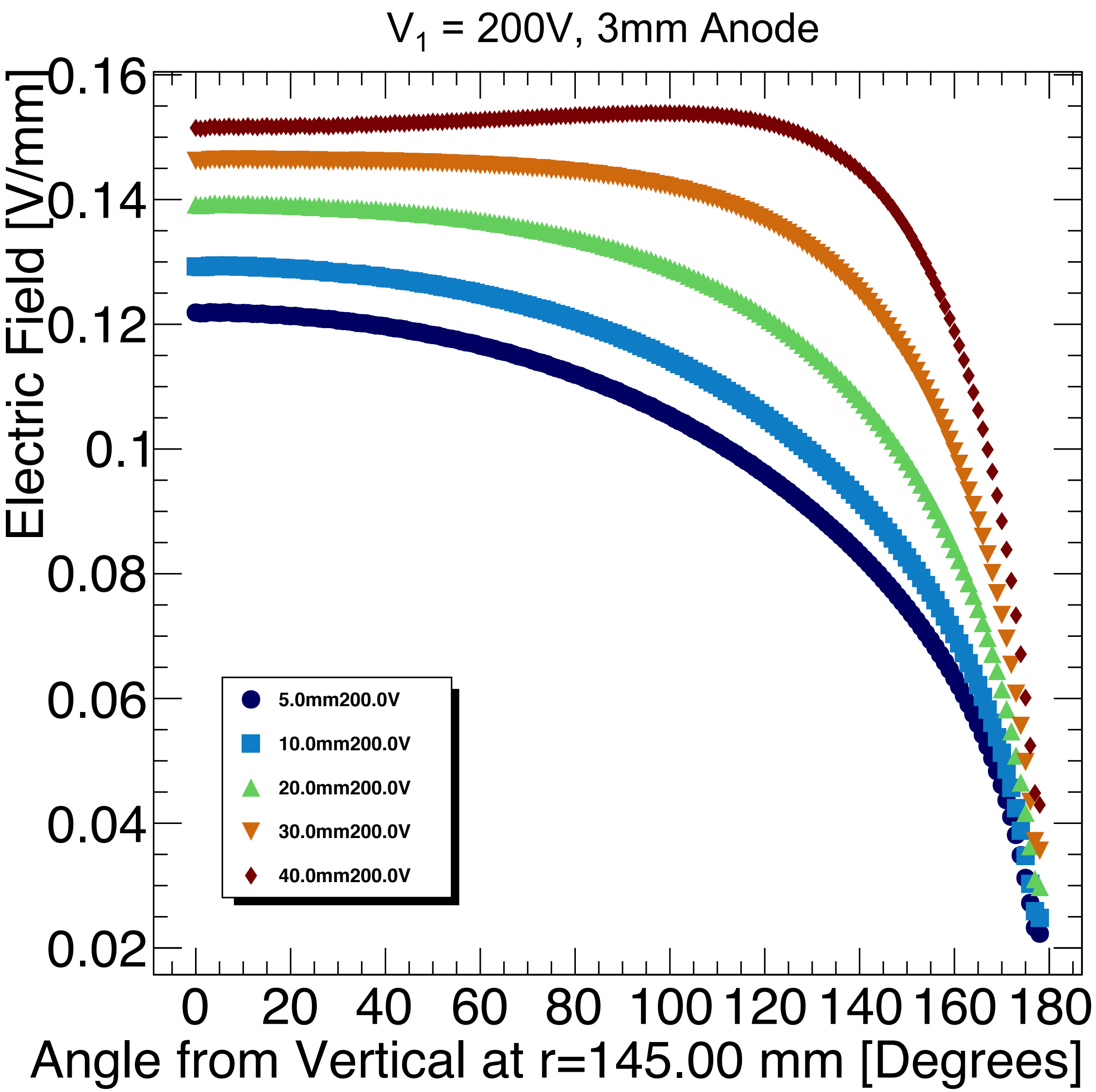




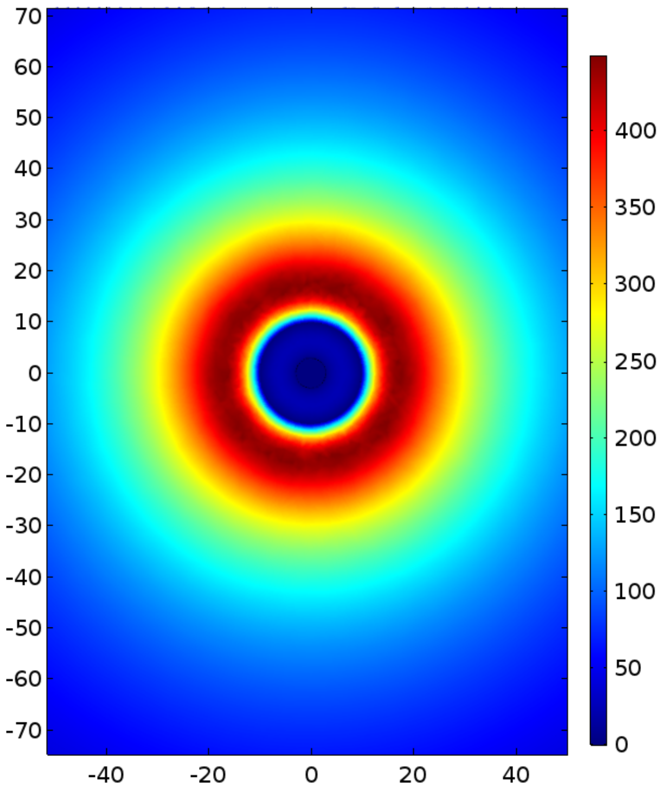
Cylindrical Umbrella

- Longer cylindrical field corrector structures at appropriate voltage may behave like a one-segment degrader
- Potentially further space for optimisation
  - Extra parameter: length of umbrella





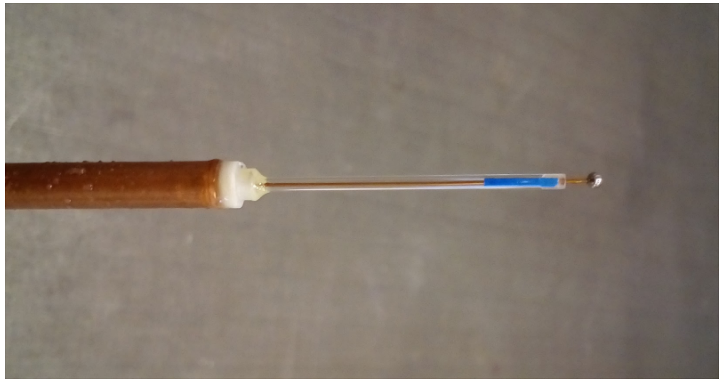
A Multi-ball Anode Structure - ACHINOS



- For larger SPCs and higher pressure operation, for instance NEWS-G SNOLAB, single anode ball may not be enough
  - Avalanche gain and primary electron drift time are linked
- Solution -> "ACHINOS" Multi-ball Structure
  - Gain of a ~mm anode ball
  - Electric field at large radii of an ~10 mm anode

A. Giganon *et al* 2017 *JINST* 12 P12031

Summary and Next Steps



- Quality of electric field crucial for detector operation
- Simulation and measurements performed for various field corrector designs
- Now moving towards implementation for experiment
  - Anode soldering
  - Material for field corrector
  - Electrical contact with field corrector
  - Precision production of sensor components: 3D Printing
- Preparing for next physics run