Dual-Phase TPC Separation Grid Development and Production in Darkside-20k Prototypes

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Presentation Focal Points

Workings and advantages of dual-phase TPCs

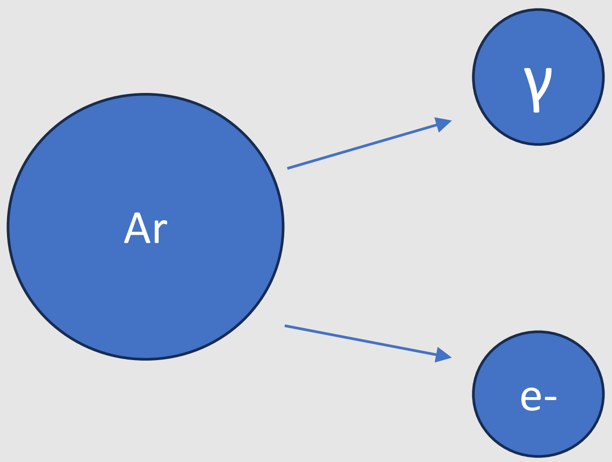
Objectives and methods of separation grid assembly

A Profile of Dark Matter

- Theorized from *strong* astrophysical evidence (gravitational)
- Slow, stable, massive particles without EM interactions
- No direct detection … yet!

Particle Zoo's Dark Matter Plush

To Detect the Undetected



- Liquid scintillator target (noble liquids common)

- Nuclear and/or electron recoils

$$? + Ar \rightarrow Ar^*$$

$$Ar^* \rightarrow Ar + \gamma + e^-$$

- Many prior detectors only utilized the light signal

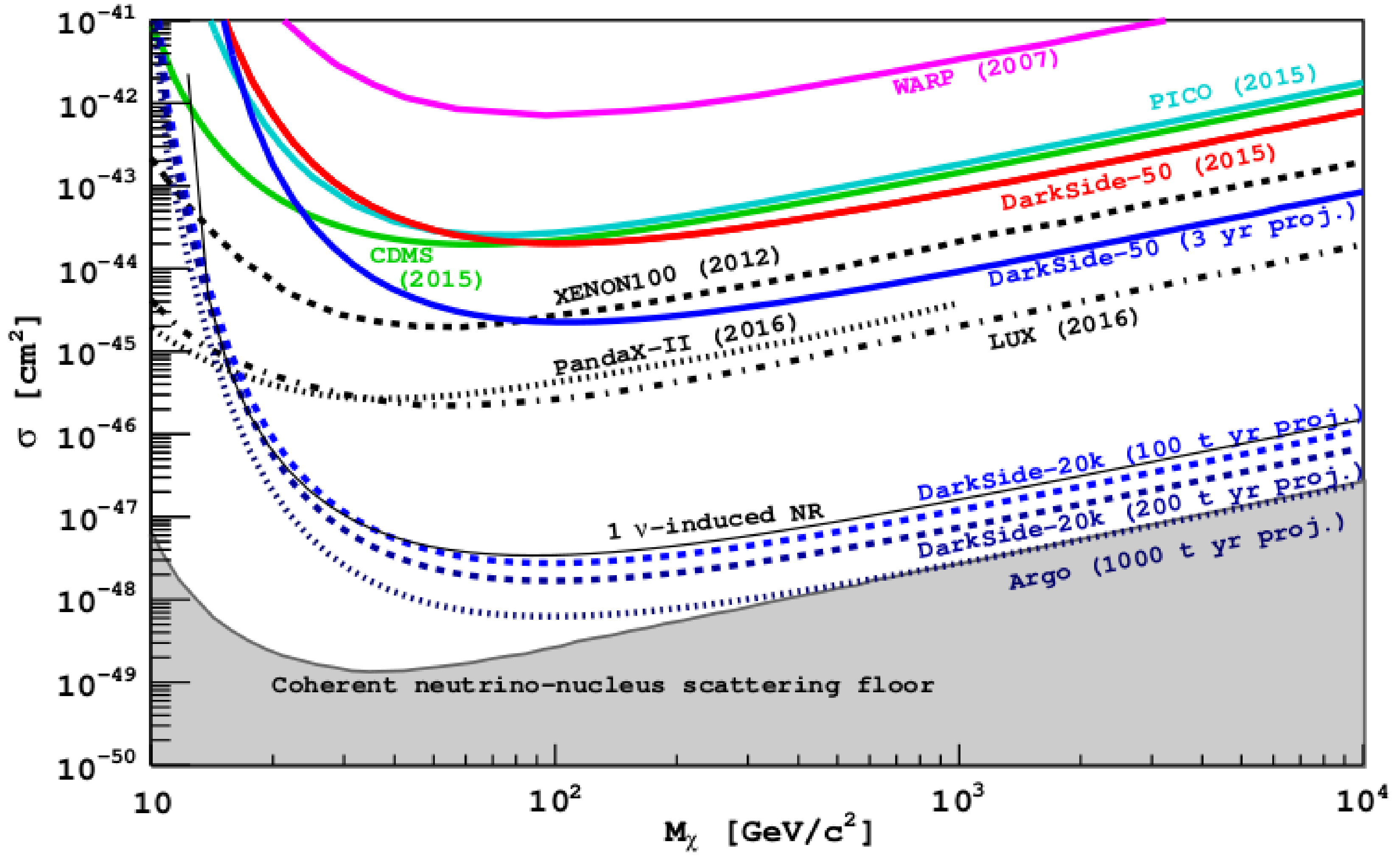


Fig. 1. Current results of direct dark matter search experiments (inspired by the corresponding figure in Ref. [16] and adapted to include the most recent results from references cited elsewhere in this section). The mean exclusion sensitivities for the full exposure of DarkSide-50, for DarkSide-20k, and for Argo (accounting for the ν-induced background) are shown. For comparison, the mean exclusion sensitivity for a generic argon-based experiment with a 30 keV_{nr} threshold, 100 % acceptance for nuclear recoils, and expectation of one coherent neutrino-nucleus scatter during the lifetime of the experiment is also shown. The grey shaded region is bounded from above by the "coherent neutrino-nucleus scattering floor", the ultimate experimental reach for a xenon based experiment with arbitrary exposure, limited by the uncertainty on the ν-induced background, introduced in Ref. [17].

(Aalseth, 2018)

Darkside-20k and Dual-Phase TPCs

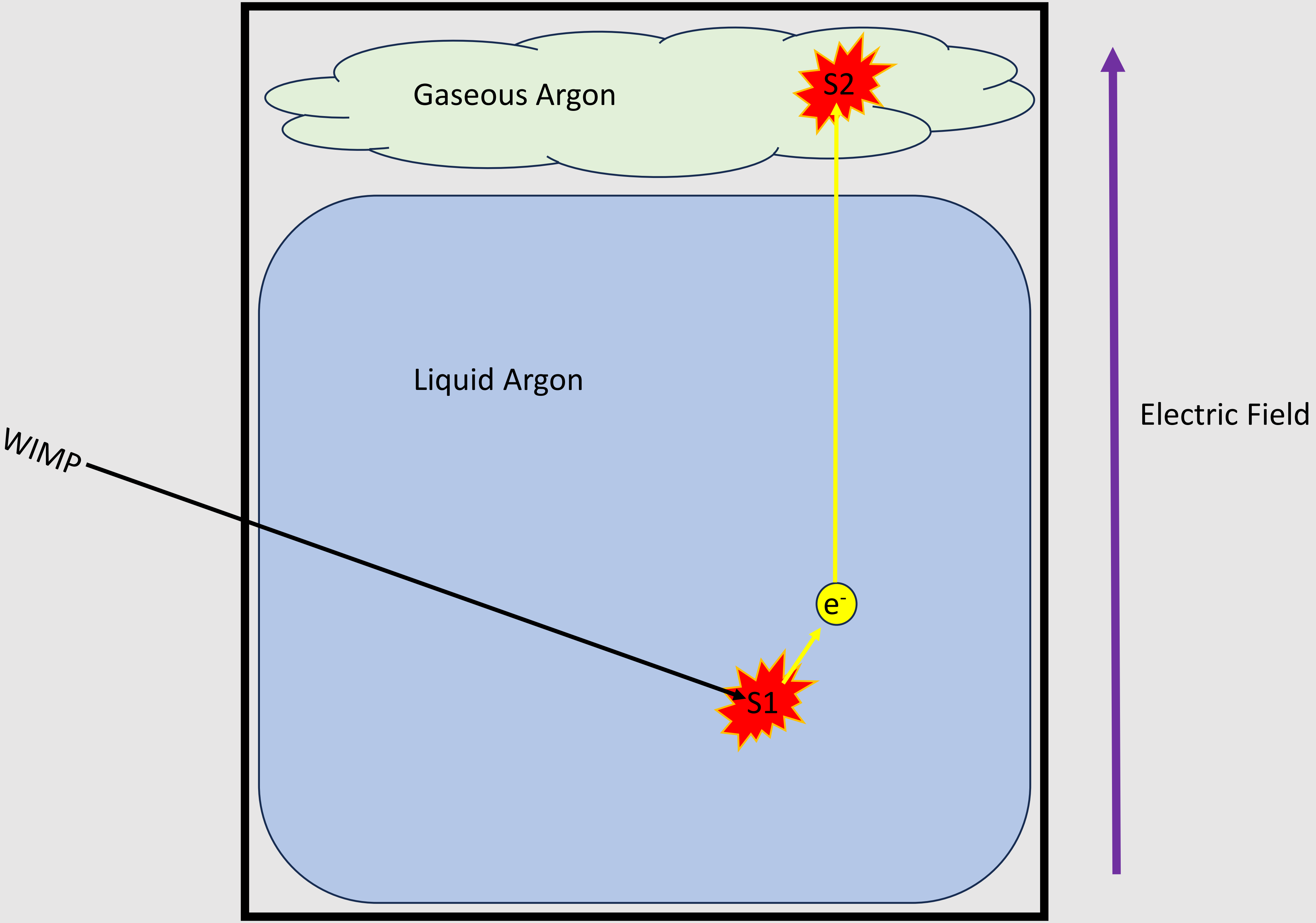
- Eliminating backgrounds is the key to success and sensitivity

  -Passive vetos, active vetos, and signal shape (PSD)

- Even more powerful: coincidence signals (S1 and S2)

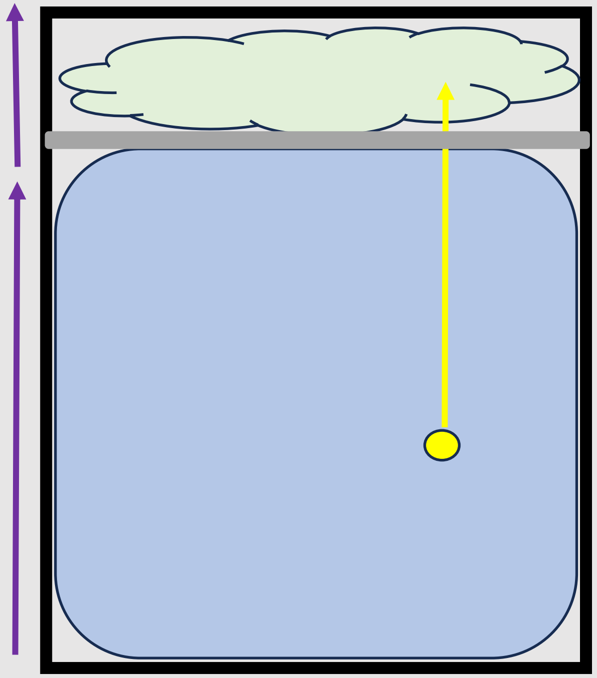
Second phase allows for creation of S2 signal using ionization electrons

(Aalseth, 2018)


Gaseous Argon
S2
Liquid Argon
WIMP
e-
S1
Electric Field

The Electric Fields of DS-20k

- Both a "drift" and "extraction" field are needed
- Elements inside of detector volume!
- Uniformity of fields and transparency of extraction/separation grid



Presentation Focal Points

~~Workings and advantages of dual-phase TPCs~~

Objectives and methods of separation grid assembly

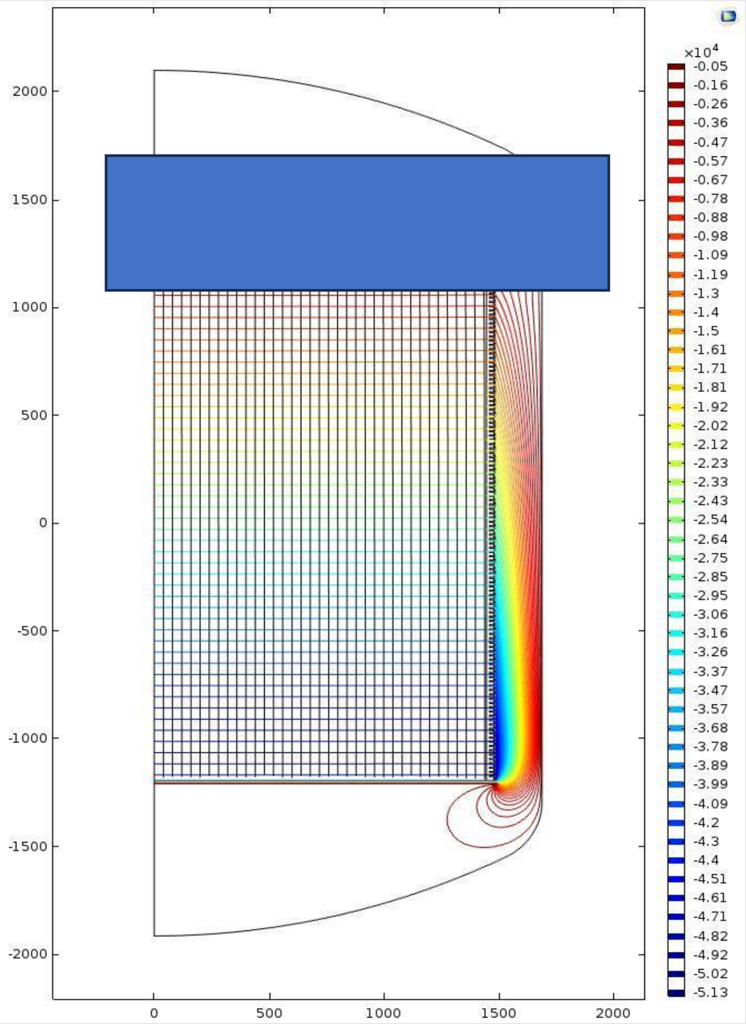
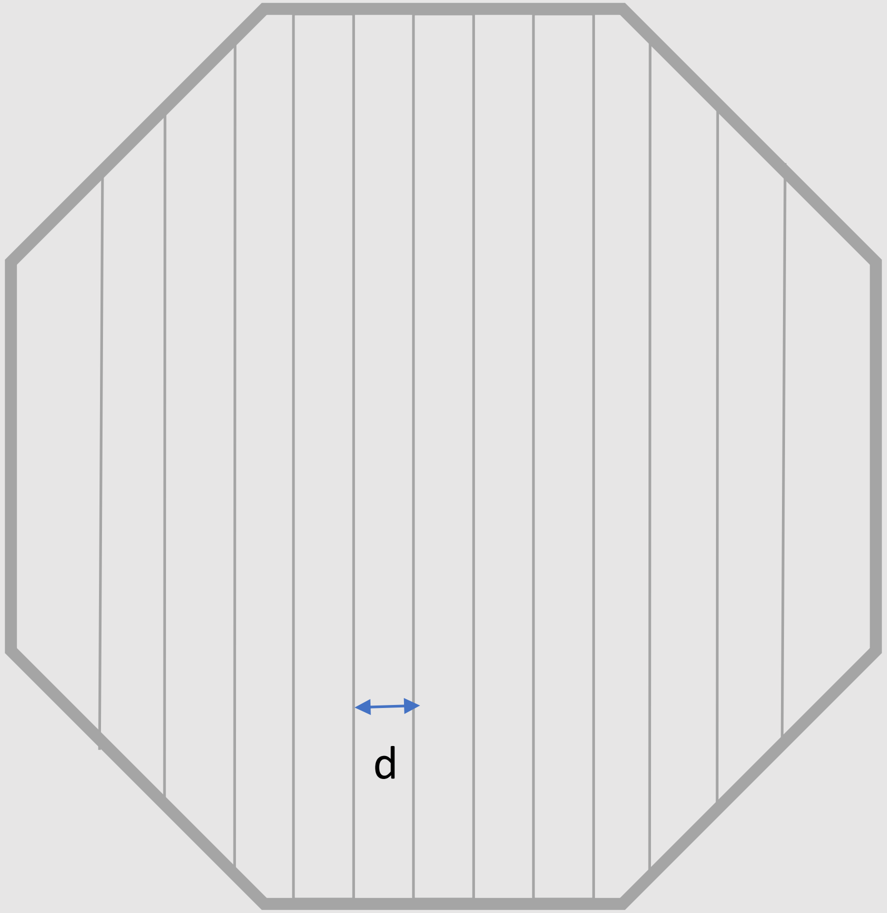


Fig. 52. Simulation of the electrostatic field for the DS-20k LAr TPC in a 2D axial symmetric approximation with horizontal axis r and vertical axis z, in units of millimeters. Contours represent equipotential lines with the color bar on the right side showing the potential in units of volts, and streamlines represent the field lines inside the field cage. Tuned $R_g = 0.225\,\mathrm{G}\Omega$ for $200\,\mathrm{V/cm}$ drift field and $4.2\,\mathrm{kV/cm}$ electroluminescence field, resulting in field lines that are uniformly distributed.

(Aalseth, 2018)



General grid shape,
wire pitch "d"

DS Mockup = 231 wires

An Effective Grid: Uniform and Transparent

- For cylindrical wires, separated by pitch d, it turns out that *"deviations from uniformity in the field are therefore small even when |x| is of the same magnitude as d"*
- Shielding inefficiency σ is:

$$\sigma \approx (d/2\pi p) * \log(d/2\pi r)$$

where p is the grid-to-anode distance, **so to minimize σ we want p > d**

- We don't want to do this with r ~ d, because of the condition for low grid interception:

$$\Delta V_a/\Delta V_c > (p + p\rho + 2lp) / (a - a\rho - 2lp)$$

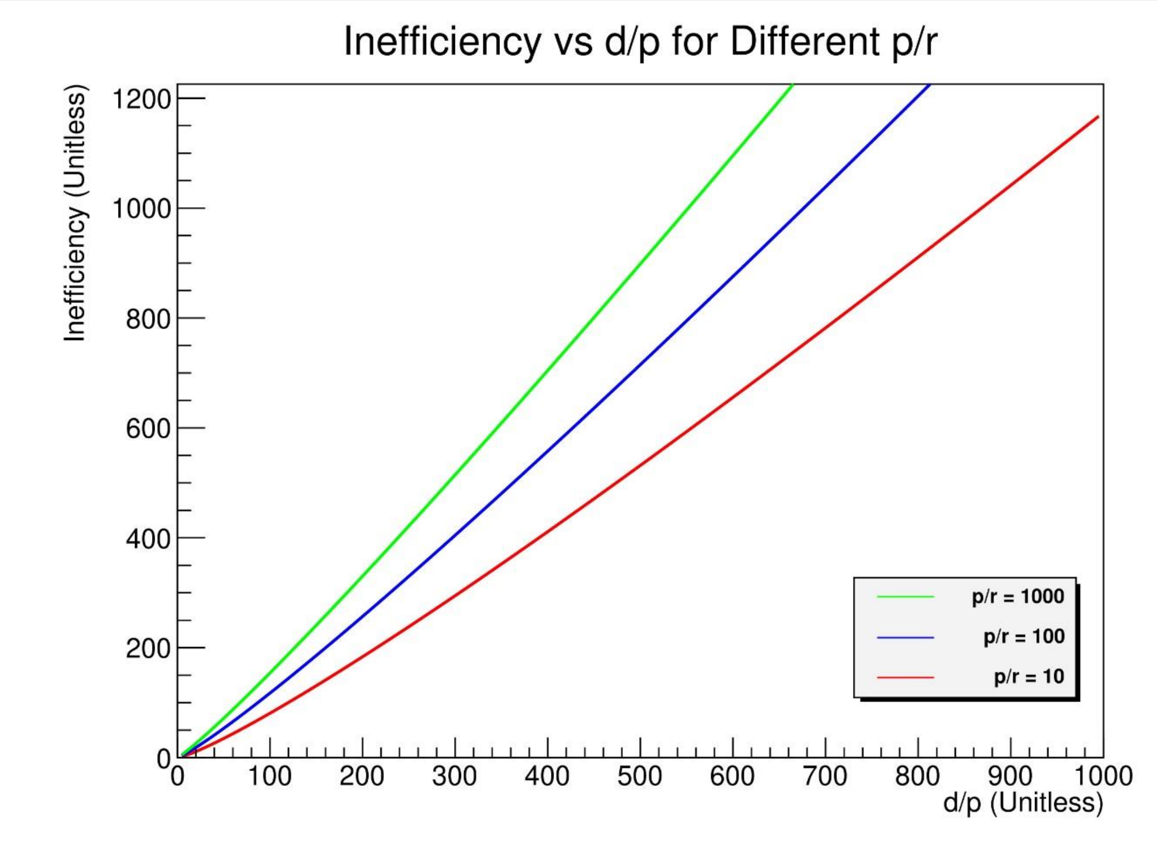
where $\rho = 2\pi r/d$

(Quote and formulae: Bunemann, 1949)

…to minimize σ we want p > d

$$\sigma \approx (d/2\pi p) * \log(d/2\pi r)$$

$$\Delta V_a/\Delta V_c > (p + p\rho + 2lp) / (a - a\rho - 2lp)$$



Grid Specifications:

3mm pitch
200μm wire

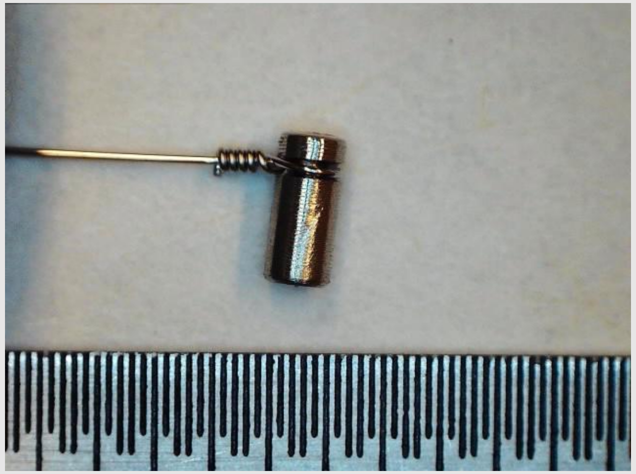
(Quote and formulae: Bunemann, 1949)

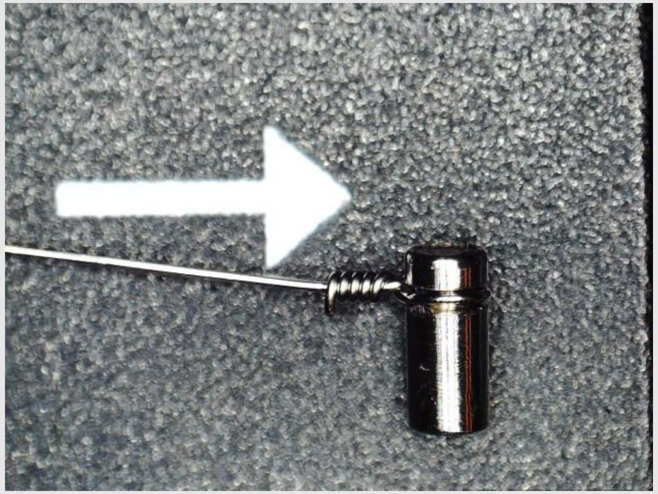
An Effective Grid: In One Piece

- Inside the TPC the temperature is < 87K -> thermal stress
- The wires repel one another -> EM force
- The wires are suspended in liquid -> buoyant force

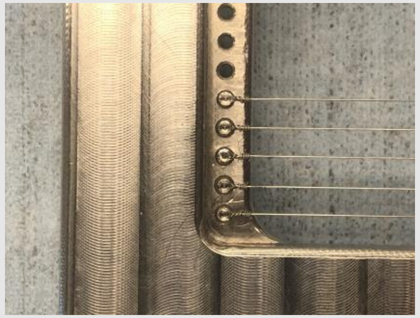
- For grid uniformity, shape is essential, thus tension is needed
- 2-3N is sufficient and not excessive

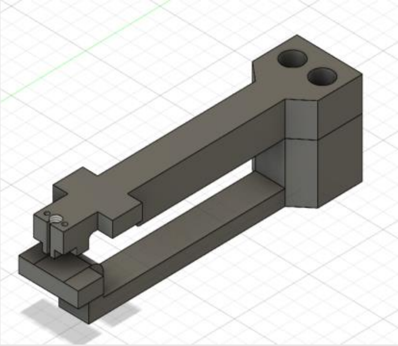
Interchangeable Wires

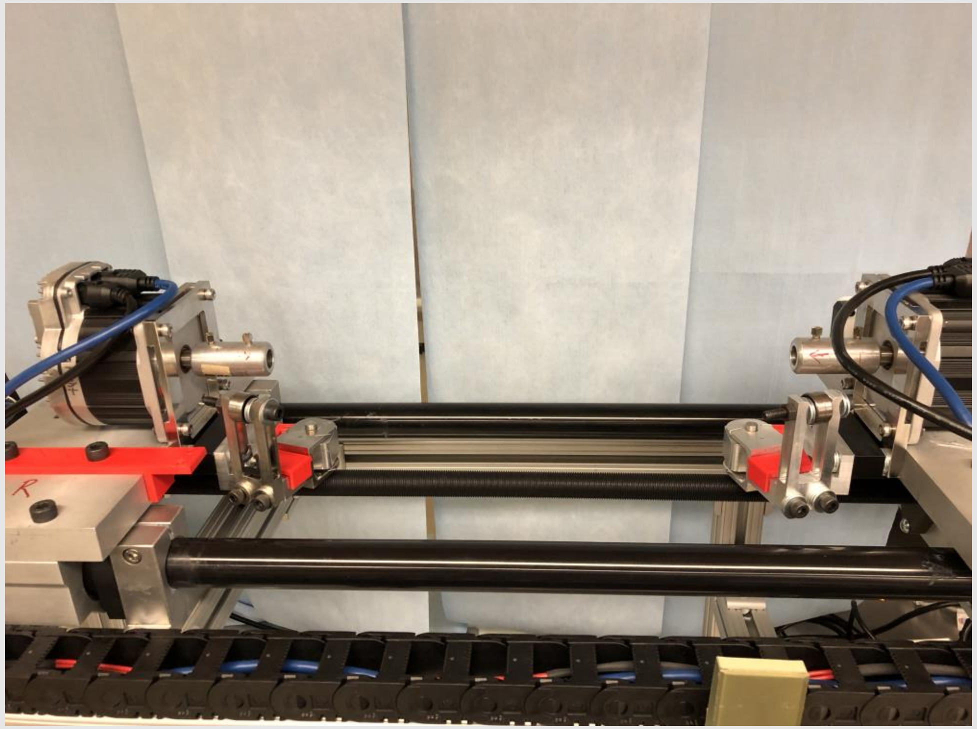


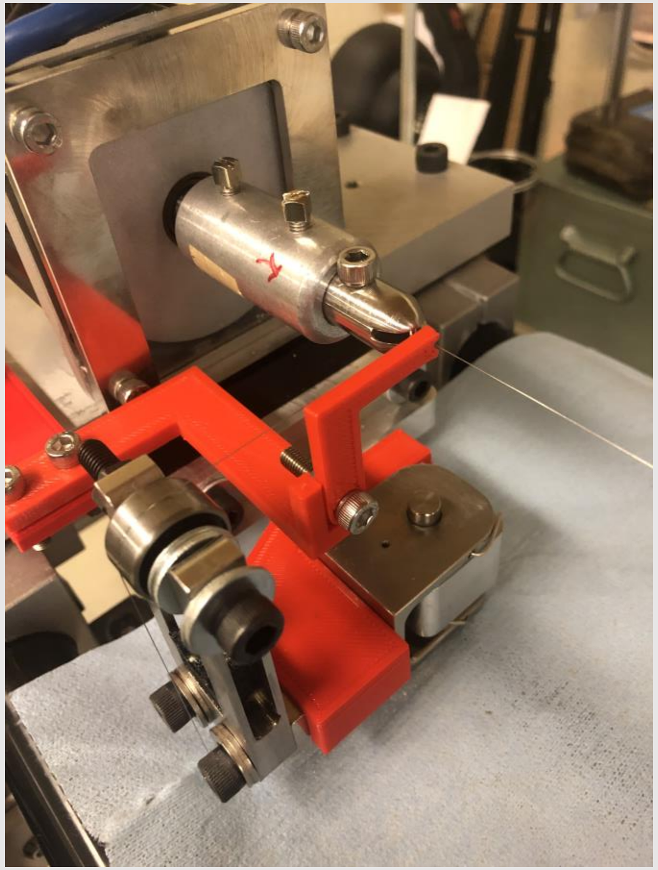


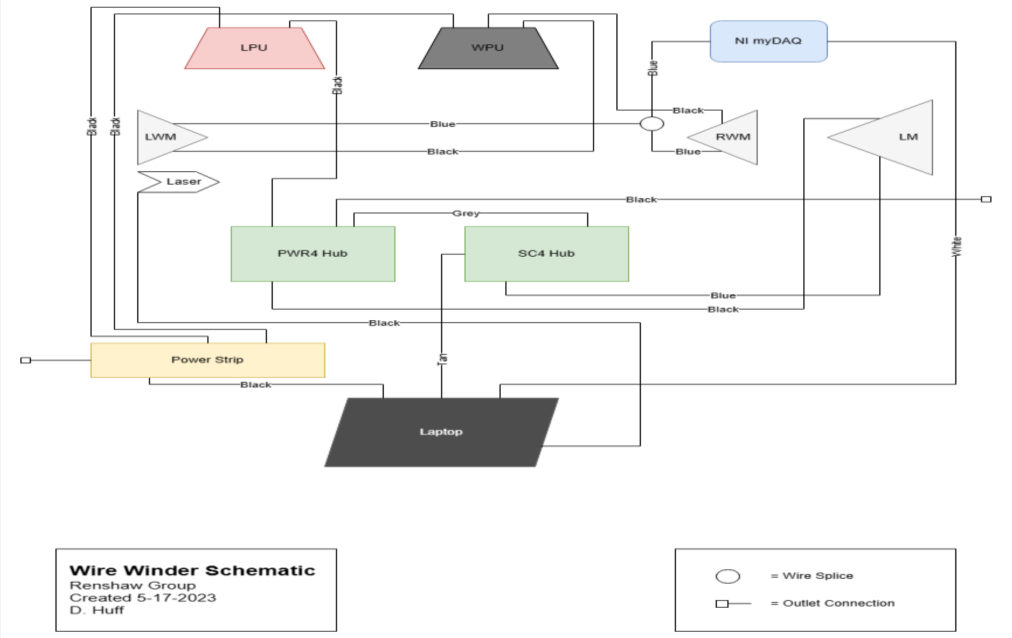
- Wires are made to various lengths/tensions from SS-316 (r = 200μm)
- Fastened to SS-316 pins using twisted end design
- Pins are inserted into holes in the frame using custom tools





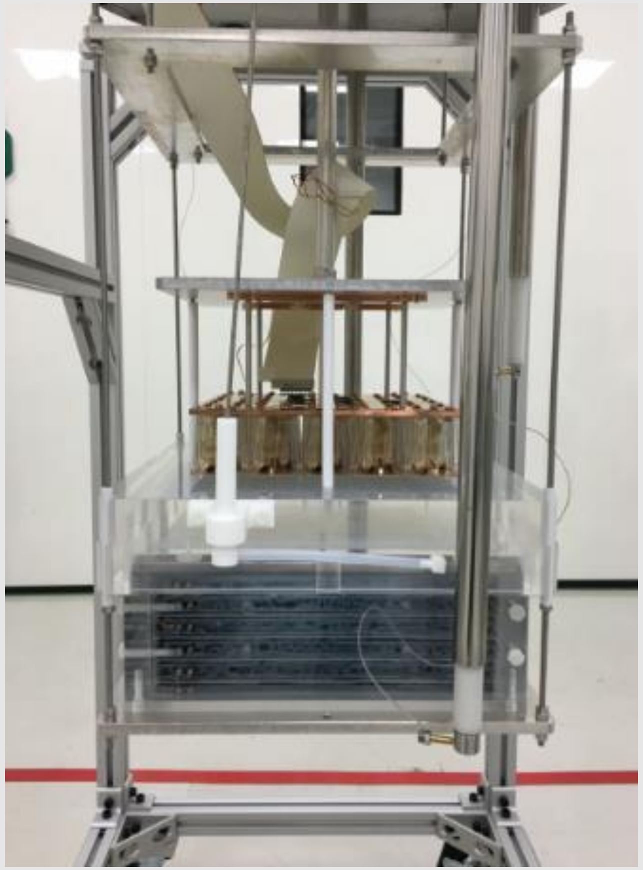





LPU
WPU
NI myDAQ
Black
Blue
LWM
RWM
LM
Laser
Grey
White
PWR4 Hub
SC4 Hub
Tan
Power Strip
Laptop
Wire Winder Schematic
Renshaw Group
Created 5-17-2023
D. Huff
= Wire Splice
= Outlet Connection

Performance of Wires

- Structure holds up to 15N tension – failure mode is unravelling
- Low radioactivity in materials
- High production consistency from QA measurements
- Proto-0 running already
- Mockup (or Proto-1T) wire production underway



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Future Dr. Sebastian Torres-Lara

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References

Aalseth, Craig E., et al. "DarkSide-20k: A 20 tonne two-phase LAr TPC for direct dark matter detection at LNGS." *The European Physical Journal Plus* 133 (2018): 1-129.

O. Bunemann, T. E. Cranshaw, and J. A. Harvey. 1949. DESIGN OF GRID IONIZATION CHAMBERS. *Canadian Journal of Research*. **27a**(5): 191-206.