A new high voltage cable feedthrough concept for future dark matter and neutrino experiments

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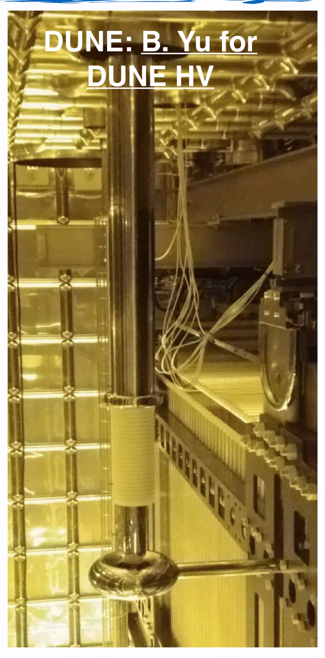
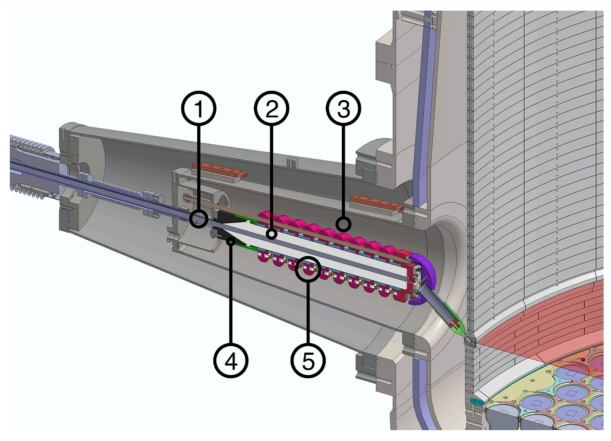
on the behalf of the DarkSide collaboration

Experiments demands higher HV

- Future physics experiments using liquid noble gas time projection chambers (TPCs) are becoming bigger and bigger, and so their high voltage (HV) requirements!
- HV is delivered to the detector by a HV feedthrough (FT): device penetrating a cryostat designed not to cause an electric breakdown in the cryogen
- Conventional HV FTs need a redesign

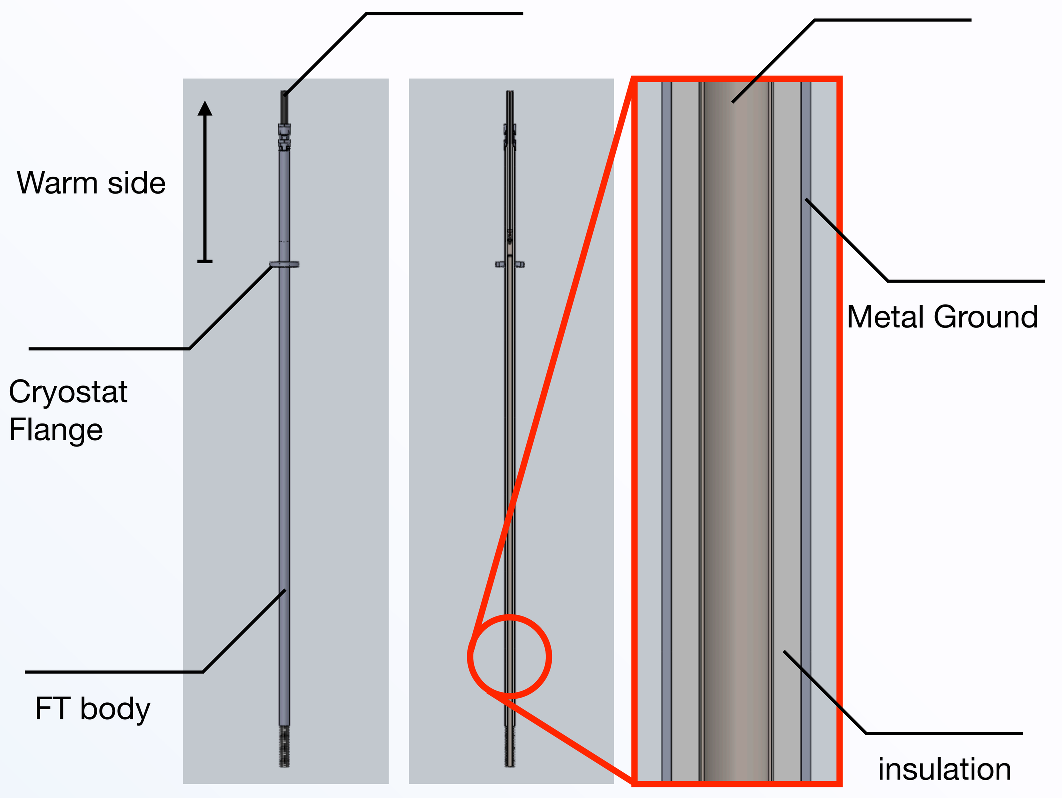




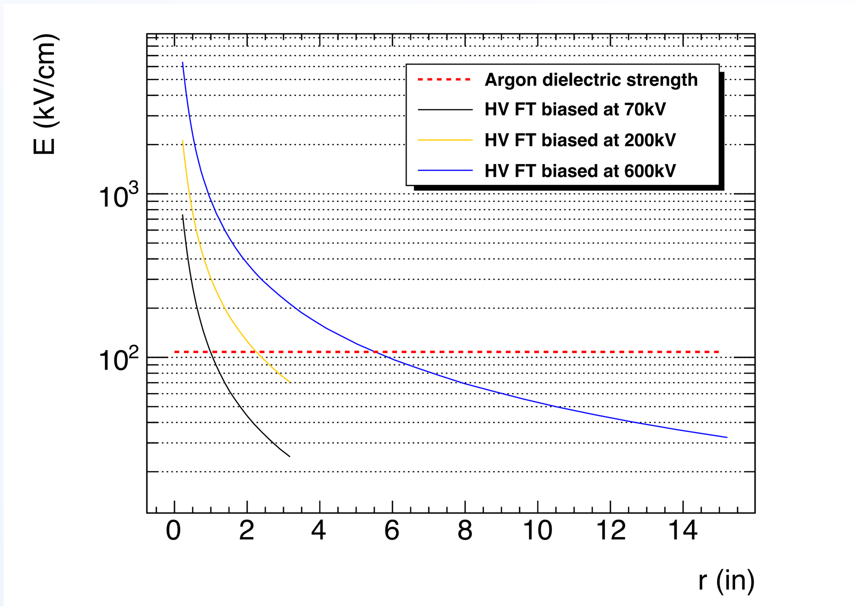
LUX-ZEPLIN: HV delivery FT

Conventional design HV FT

- Often couple a metal with an insulator and have the strongest field strength located near the end of the ground termination
- To avoid electric breakdown, FTs are sized thanks to E ∝ 1/r (E is the electric field, and r distance from central conductor)
  - Note: **higher the biasing voltage (which determines E) the bigger the FT's outer diameter must be**



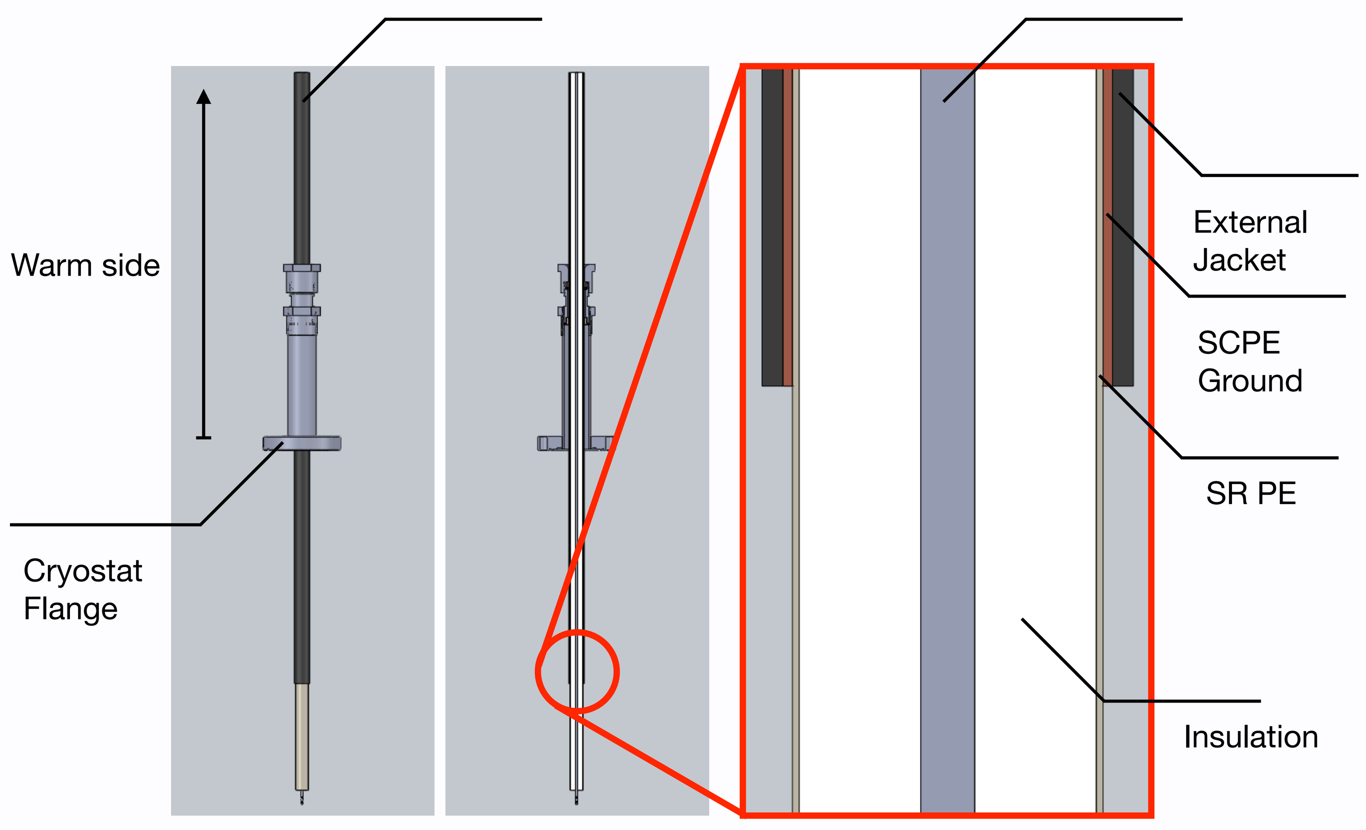
- It is feasible to construct massive FT but it is not practical
- Mismatch in thermal expansion coefficient may allow cryogen to infiltrate and reach regions of high electric field and produce a spark!



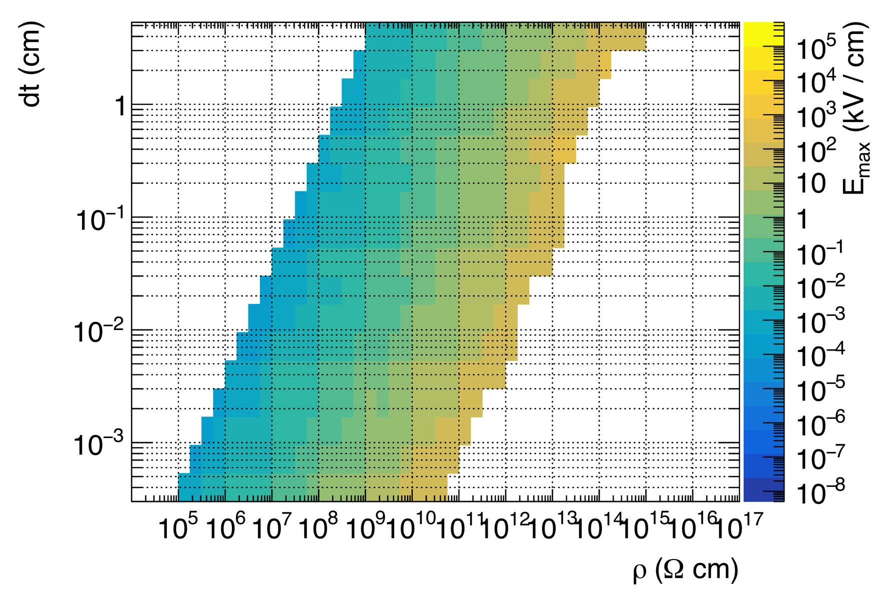
Results from COMSOL for HV FT's insulation optimization. Maximum field E vs.radius r when FT is in liquid argon

New Concept: HV Cable FT

- Co-extruded multi-layered coaxial cable fabricated with a single material with a **semi-resistive (SR) layer added** between the insulator and ground
- SR layer:
  - continuously confine the electrostatic field lines
  - can have tunable resistivity and thickness



- Parameter space for SR layer in a commercial cable fully made of PE
  - Cable biased at -70kV
  - Exposed SR length is 5''
- Allowed region determined by maximum allowed field lower than argon electrical strength (<108kV/cm) and dissipated power below bubble formation (<1mV/cm²)

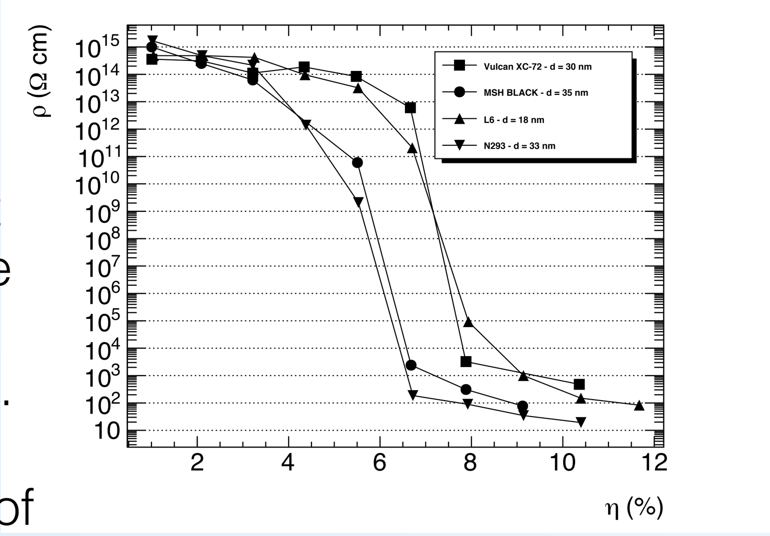


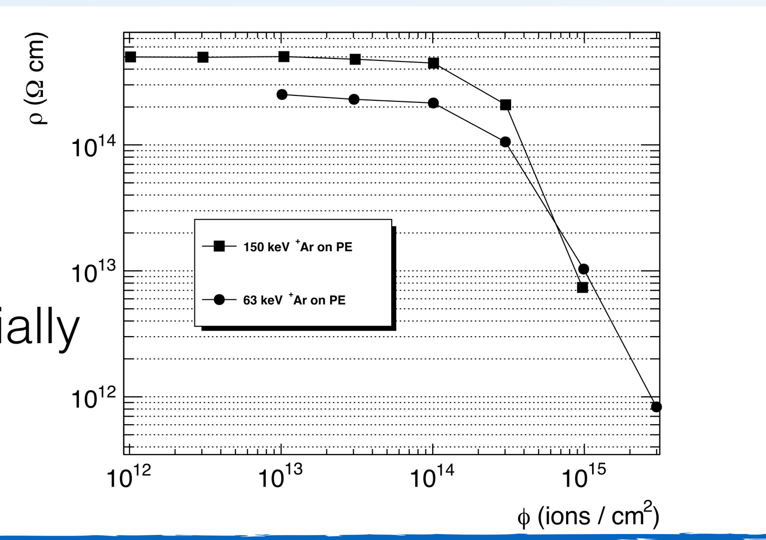
Results from COMSOL for HV FT's parameter space for resistivity (ρ) and thickness (dt) of SR PE

How to make the semi-resistive layer?

A. **PE+carbon blacks (CB):** difficult (non-linear behavior) but possible to tune resistivity by varying CB concentrations and particle sizes. SR layer directly co-extruded
B. **Ion implantation:** ion irradiation of at different fluencies ϕ could locally induce SR. Optimization is feasible but difficult. SR obtained via table top vacuum chamber for irradiation
C. **Semi-resistive epoxy:** commercially available, carbon content can be tuned. SR optioned by coating

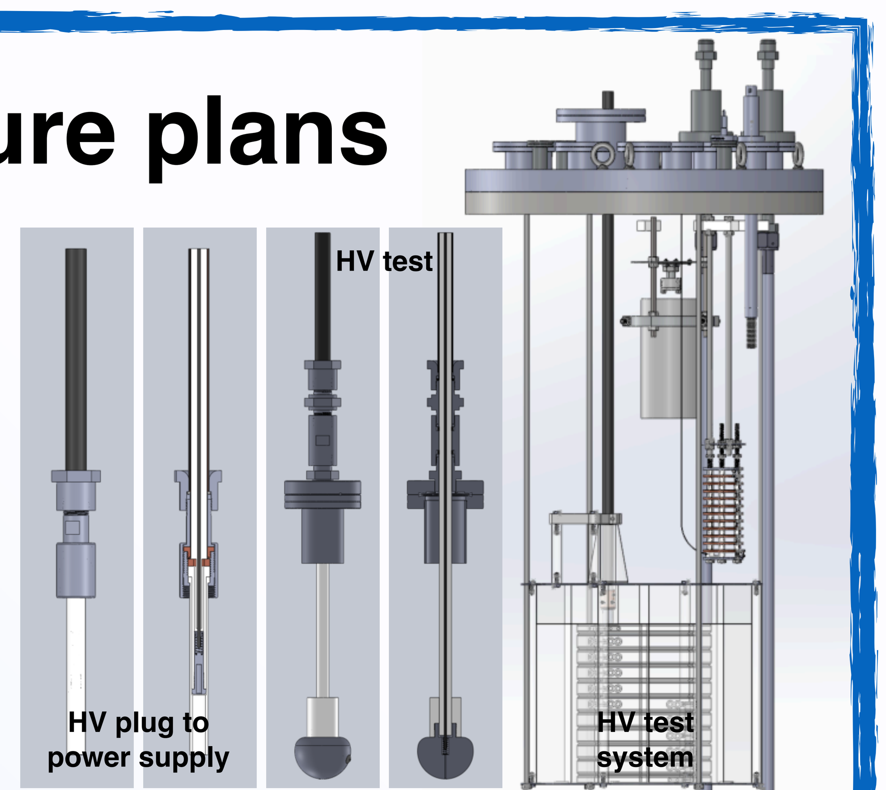
Up: results for PE filled with different concentrations of CB
Down: results for PE implanted with +Ar at various ϕ





Current and Future plans

- Tests of a commercially available fully PE cable (no SR layer) are ongoing
- In parallel R&D exploring the feasibility of options A, B, and C are ongoing at UC Davis
- Timeline:
  - Preliminary version of the HV cable FT will be used in the DarkSide program in DarkSide-Proto (2022)
  - Final version of the HV cable FT foreseen for 2024 for the operation of DarkSide-20k



Ongoing R&D @ UC Davis

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