A new concept of a High Voltage Cable Feedthrough

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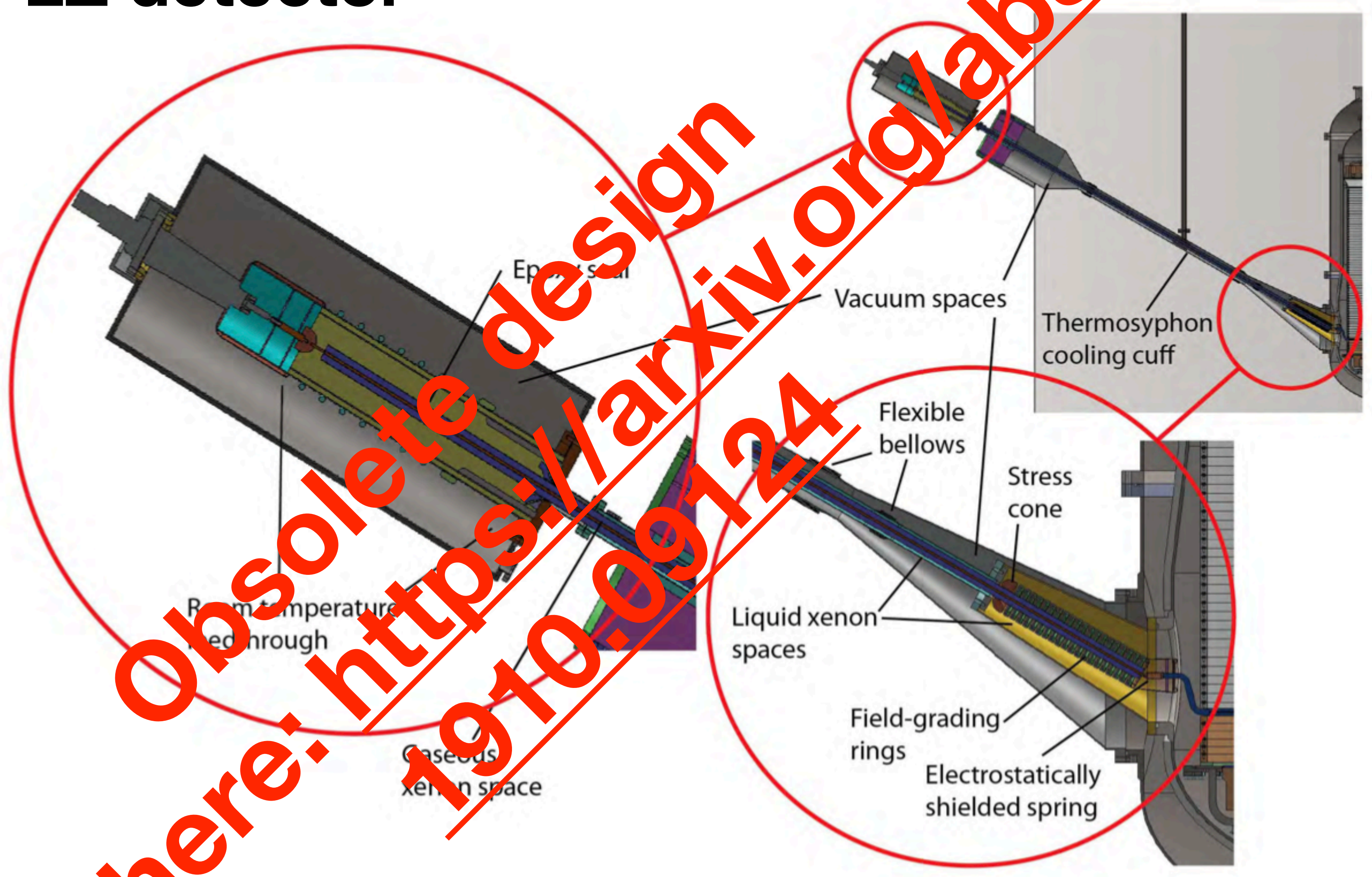
Experiments demands higher HV

- Physics experiments featuring liquid noble gas time projection chambers (TPCs) are becoming larger in scale, and consequently so have their high voltage (HV) requirements

- HV is delivered to the detector by a HV feedthrough (FT), a device penetrating the cryostat specifically designed not to cause an electric breakdown in the cryogen

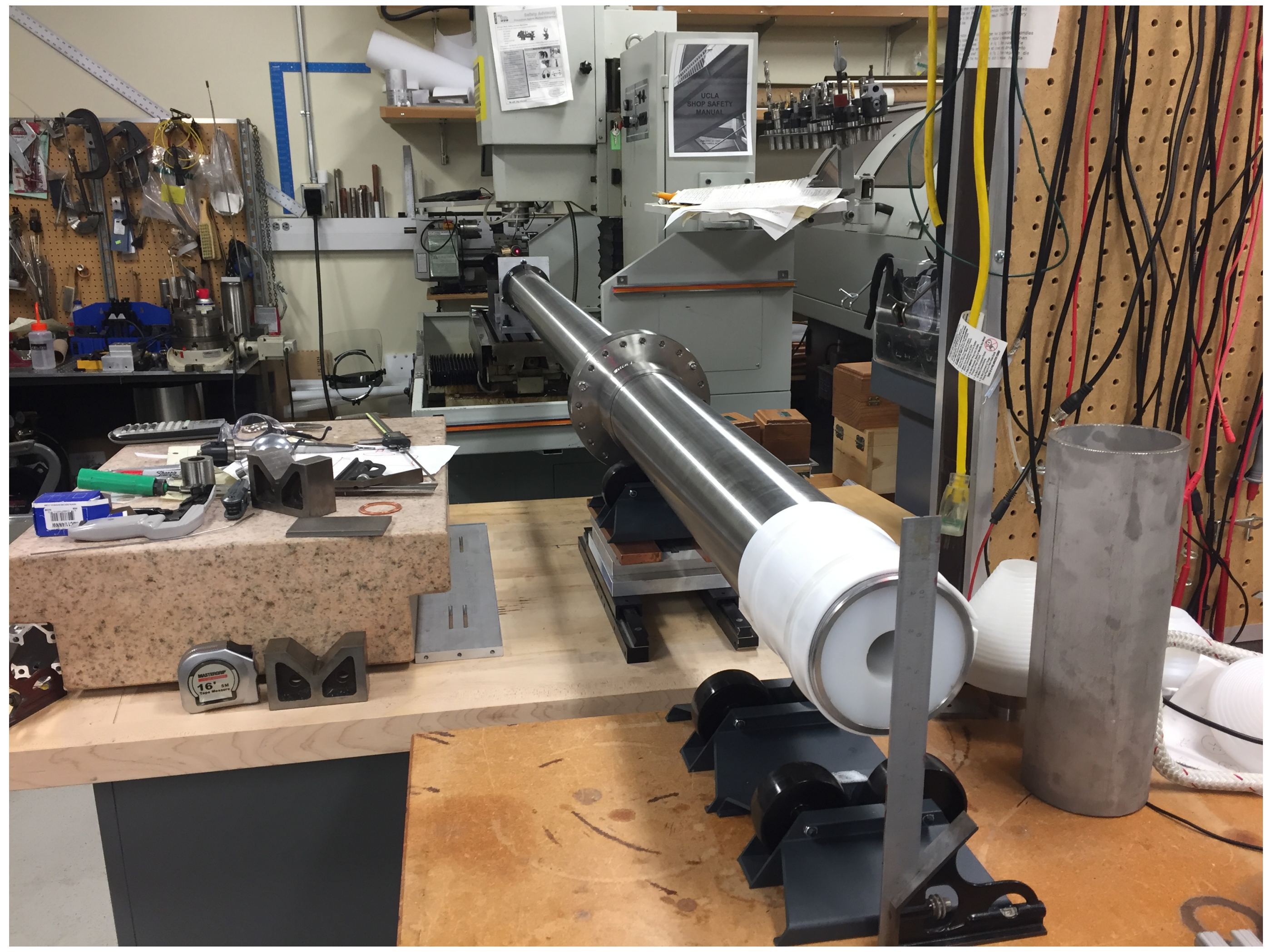
LZ detector



Obsolete design
look here: https://arxiv.org/abs/1910.09124

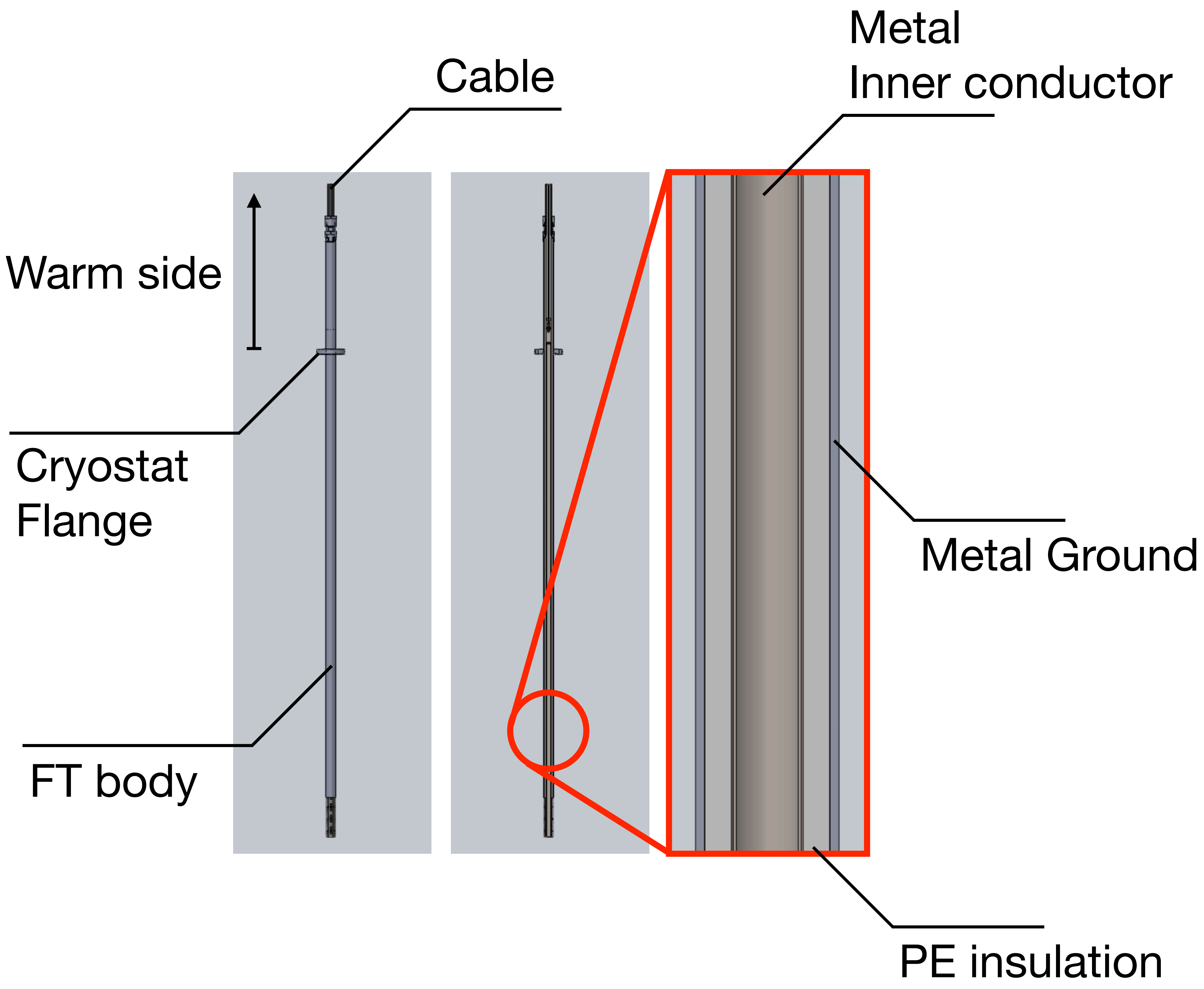
https://iopscience.iop.org/article/10.1088/1748-0221/9/08/T08004

ProtoDUNE - 200kV



Work done by H. Wang et al. see: CPAD 2019

Conventional design HV FT



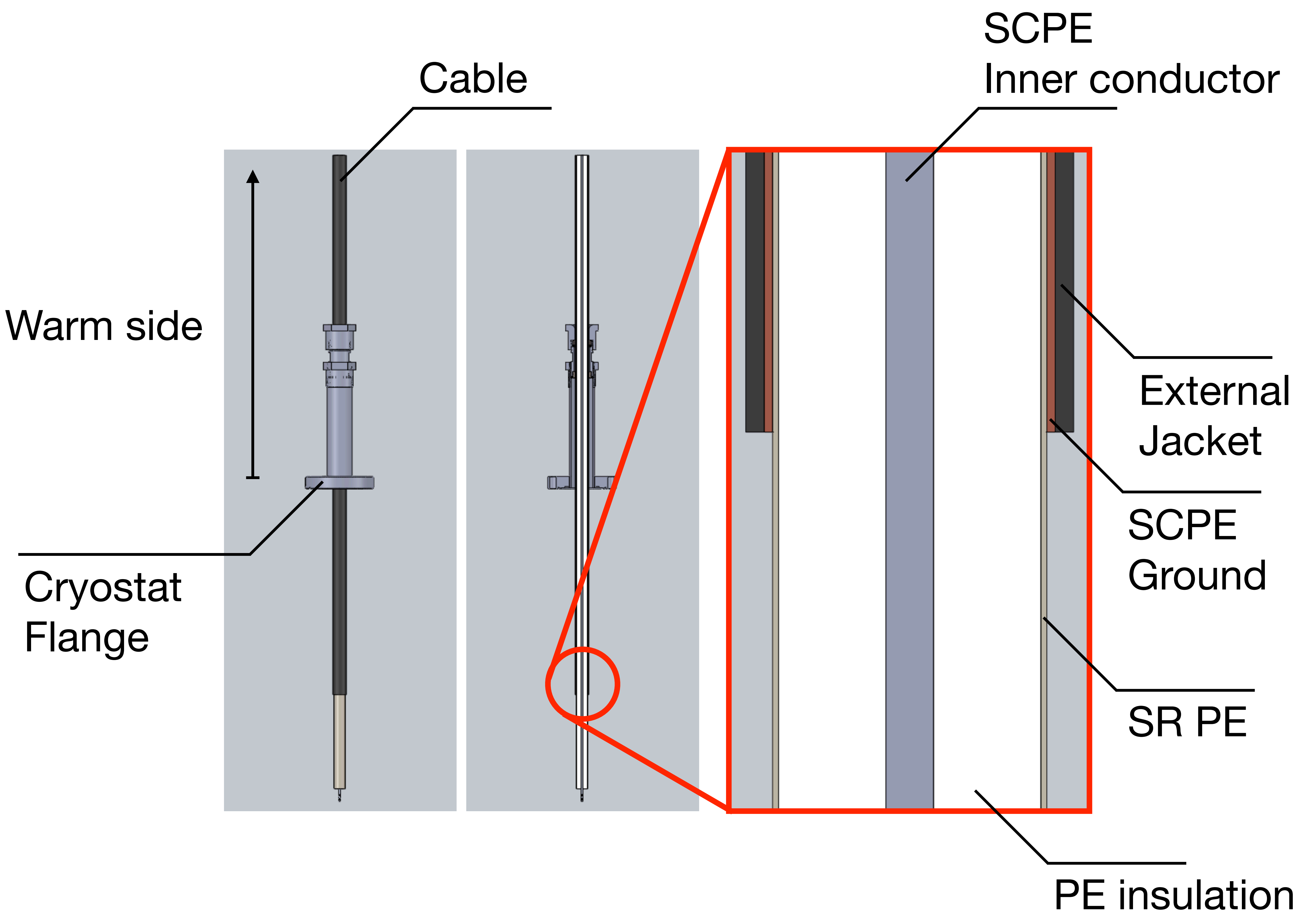
- Often couple a metal with an insulating polymer and have the strongest field strength located near the end of the ground ring

- To avoid electric breakdown (e.g. producing a spark in the cryogen), FTs are sized using the relationship $E \propto 1/r$ where E is the electric field, and r distance from central conductor

    - The higher the biasing voltage (which determines E) the bigger the FT's outer diameter must be - e.g. a 10 in OD FT is required in DUNE to deliver 600 kV

- Even if constructing a massive FT is feasible, it is not practical and still subject to failure: mismatch in thermal expansion coefficients of the materials may allow the surrounding dielectric to infiltrate and reach regions of high electric field

New concept: HV Cable FT



- A co-extruded multi-layered coaxial cable fabricated with a single material
- To preserve the cable's function as a HV FT, a semi-resistive (SR) layer must be added between the existing insulator and ground layers which will continuously confine the electrostatic field lines
    - SR can have tunable resistivity and thickness
- Various solution exists to fabricate the SR layer: carbon black-doped polyethylene, ion implantation, and the usage of semi-resistive epoxies

Conclusion

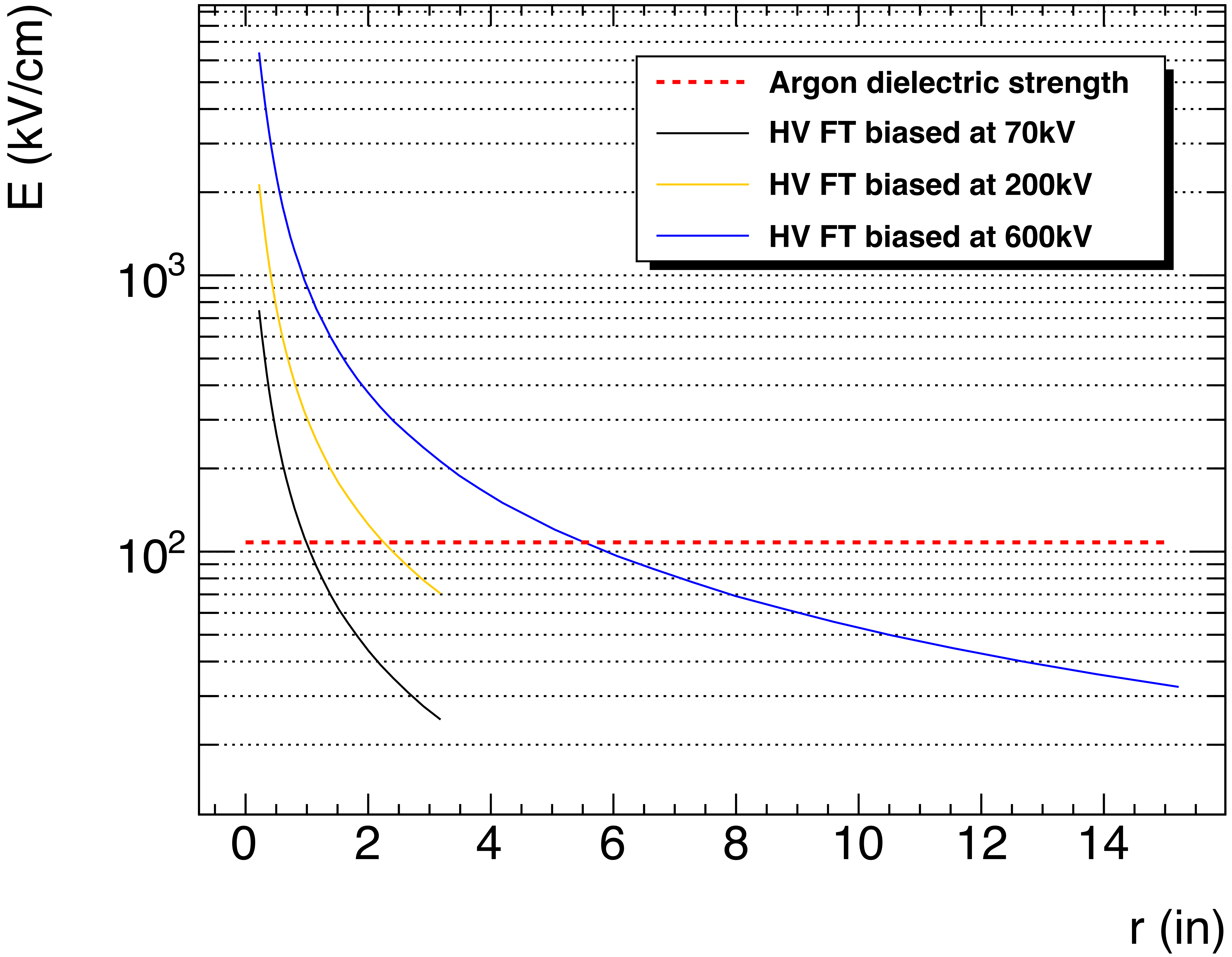
- This work, done in the DarkSide and DUNE collaborations, will benefit any future experiments that need to deliver high voltage into a cryogenic environment

  - Future work and R&Ds will focus on the feasibility of the different options to make the SR layer

- For more information LoI: https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF8_IF0-031.pdf

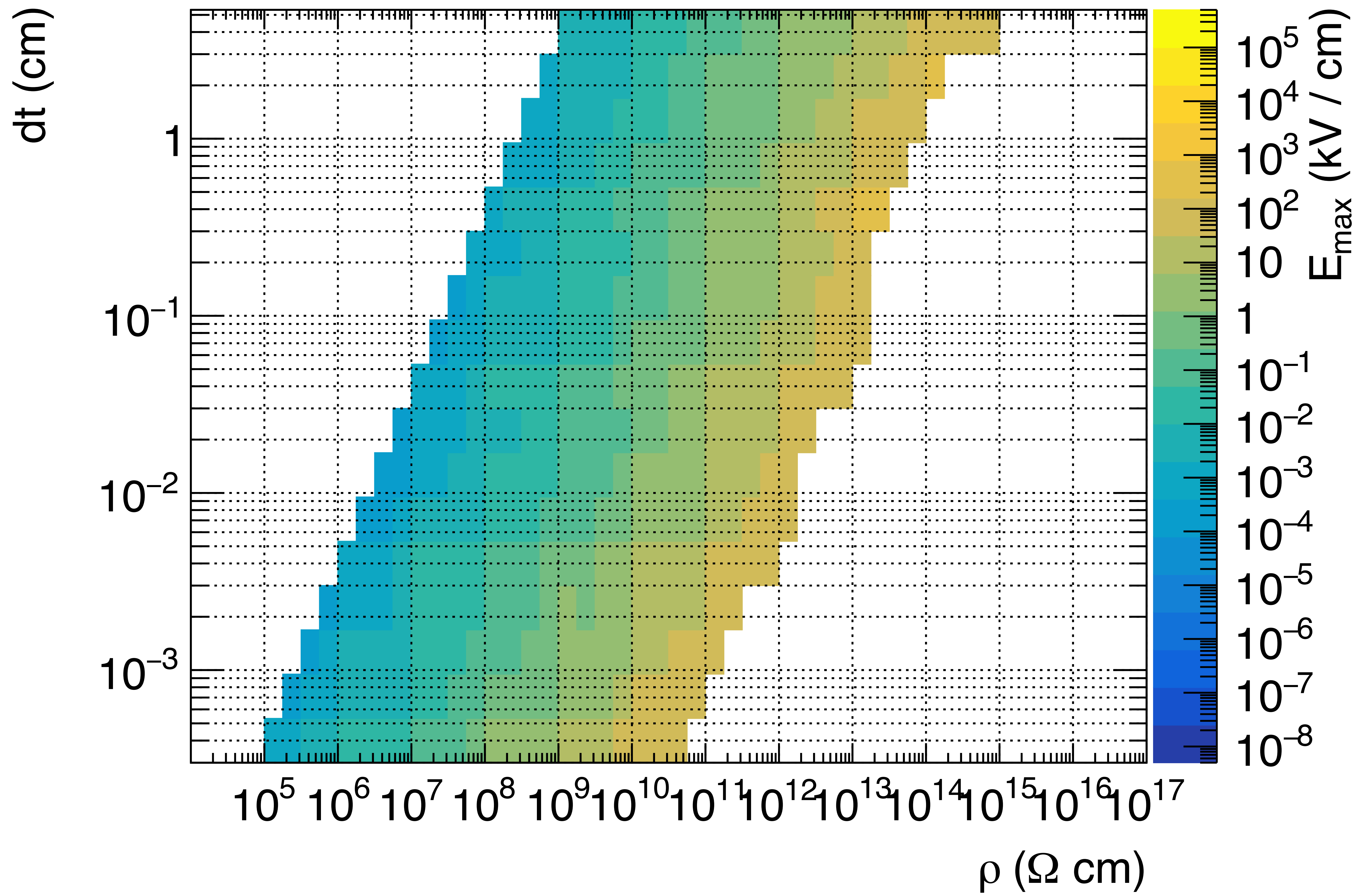
Backups

HV FT optimization



Results of a COMSOL simulation to optimize the size of the HV FT's insulating layer. It shows the maximum field strength E in the cryogen, as a function of radius r when the HV FT is immersed in liquid argon and different biasing voltages are applied.
The voltage bias of 70 kV is DarkSide-20k's requirement while 600 V is for the DUNE dual-phase experiment

SR layer parameter space



Results of a COMSOL simulation for the available parameter space in resistivity (ρ) and thickness (dt) of the SR layer in a PE HV cable FT.
The cable is biased at 70 kV and immersed in liquid argon. The primary dimensions of the HV cable FT are taken from the commercially available version (cable features a 0.08in-thick SCPE core conductor, a 0.44in diameter PE insulator, and a 0.01in-thick SCPE wall ground).
The length of the exposed SR layer (from ground to HV) is 5 in. The allowed region is determined requiring both that the maximum field does not exceed the argon gas electrical strength limit (E < 108 kV/cm) , and the dissipated power is below the safe bubbling formation threshold of 1 mW/cm^2