AIDA 2020

WP8: Very high voltage

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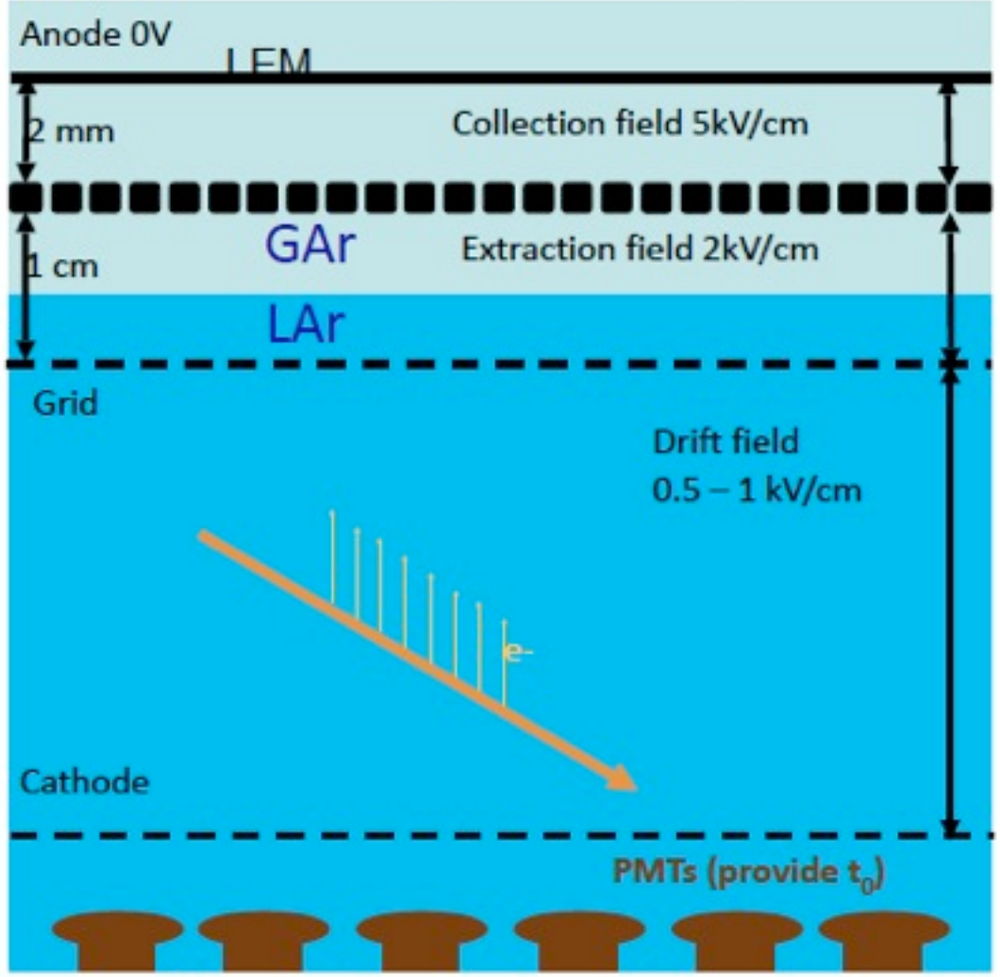
ETHZ

Why very high voltage?

- LAr TPCs are popular detectors inside neutrino and dark matter experiments. They are based on the idea that in highly pure Argon, ionization tracks can be drifted over distances of the order of meters.

- One of the challenges of this kind of detectors is to **provide the require high voltage (HV) to the cathode to drift the electrons such distances**. This implies being able to feed the voltage to the detector but also we have to guarantee a safe operation avoiding reaching very high fields inside the different parts of the TPC (It can cause sparks that can damage parts of the detector).

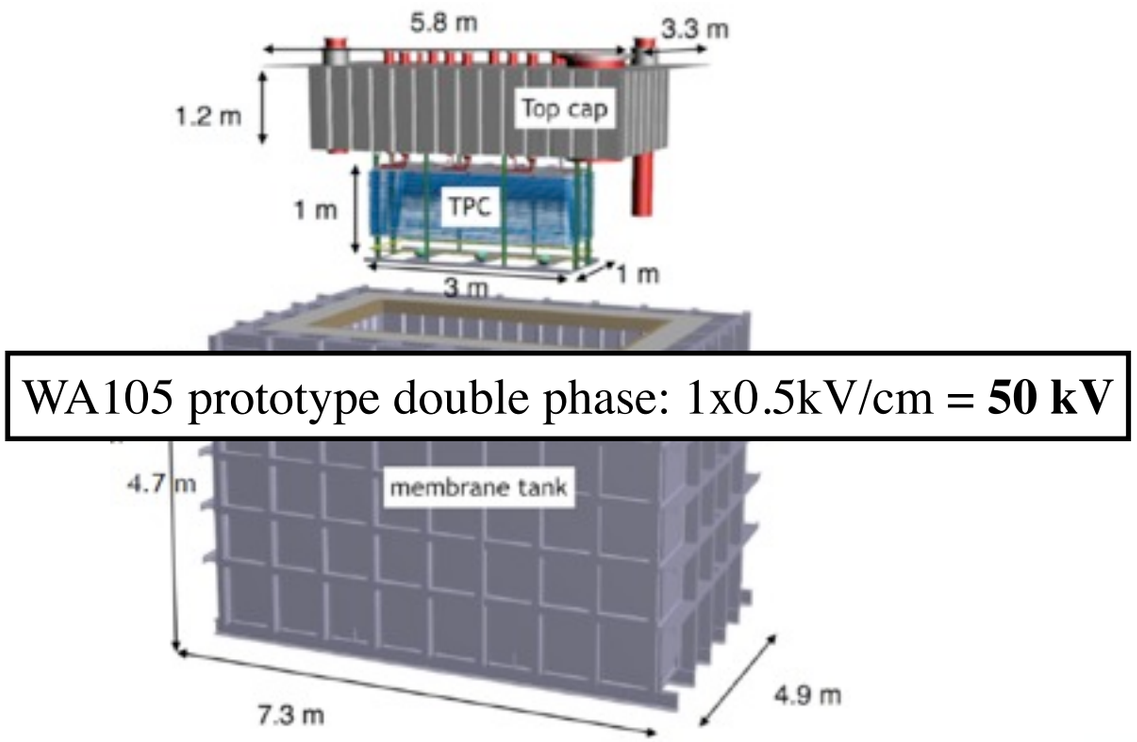
Concept of double-phase LAr TPC (Not to scale)



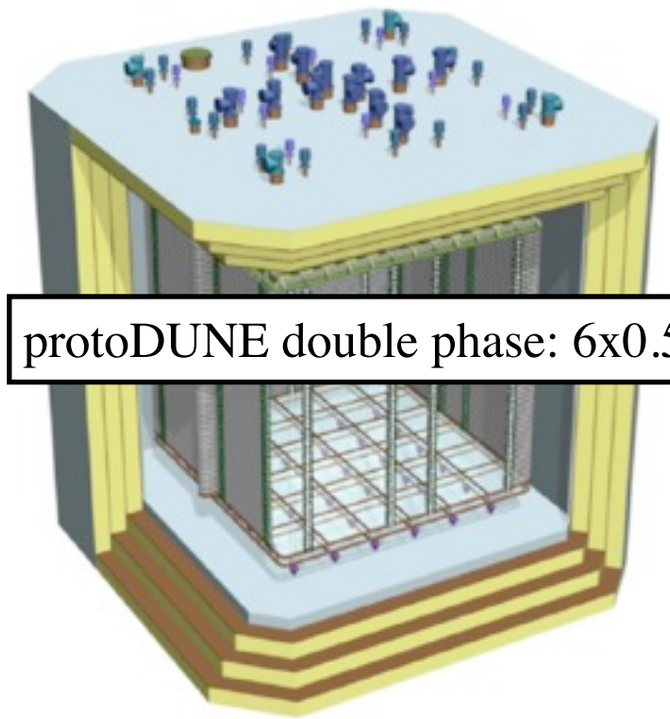
- Other important issue are the **study of the phenomena related to high fields in noble gases and liquid**. The dielectric strength of LAr was reported to be 1.4MV/cm (Swan and Lewis 1960). Recent experiments (F.Bay et al. 2014) found that the dielectric rigidity of LAr is larger than 100 kV/cm when the temperature is below the boiling point. However, when the LAr is boiling they found sparks at lower fields such as 40 kV/cm.

Why very high voltage?

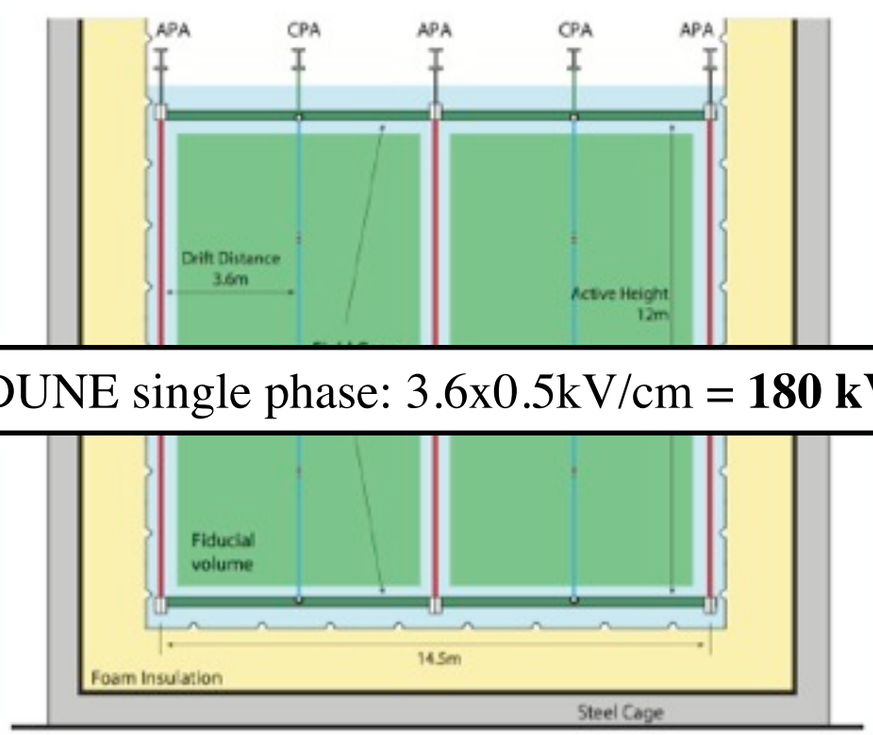
Large detectors require longer drift distances ➜ higher voltages



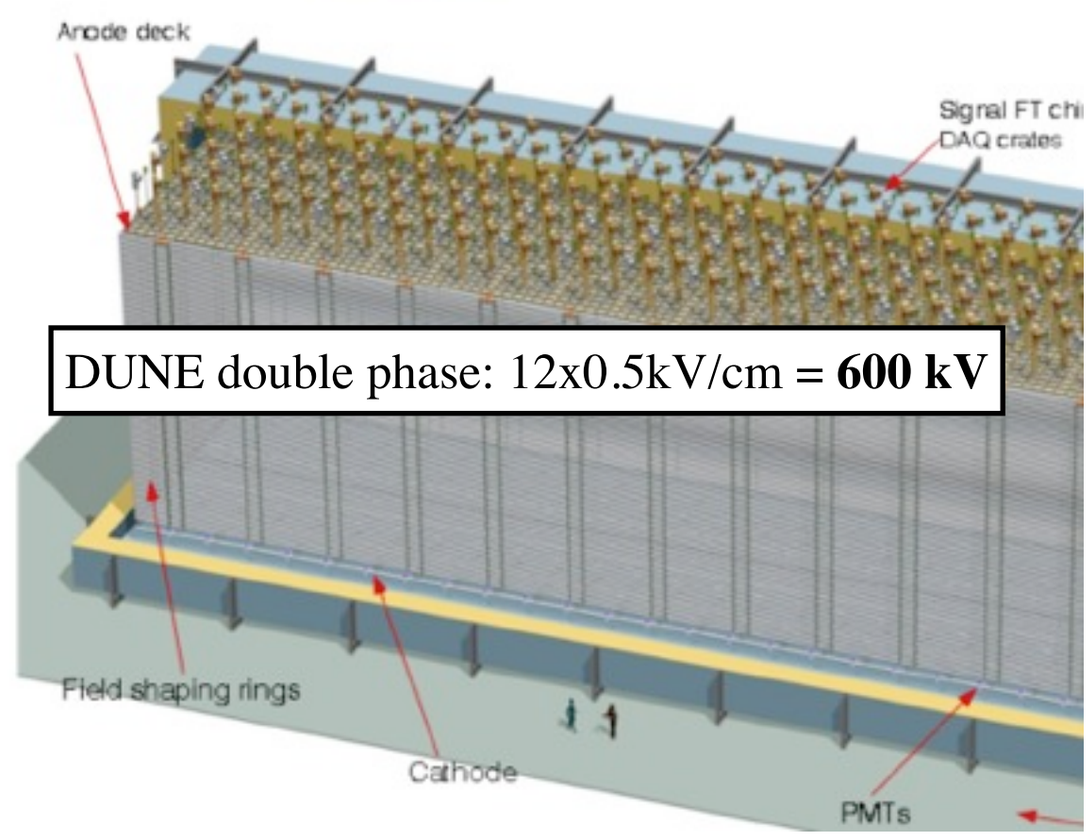
WA105 prototype double phase: 1x0.5kV/cm = **50 kV**



protoDUNE double phase: 6x0.5kV/cm = **300 kV**



DUNE single phase: 3.6x0.5kV/cm = **180 kV**



DUNE double phase: 12x0.5kV/cm = **600 kV**

Ingredients for high voltage system

▸**<u>Generation</u>:** The power supply should be able to provide the maximal operation high voltage (HV) and the power cable should be rated for this voltage.

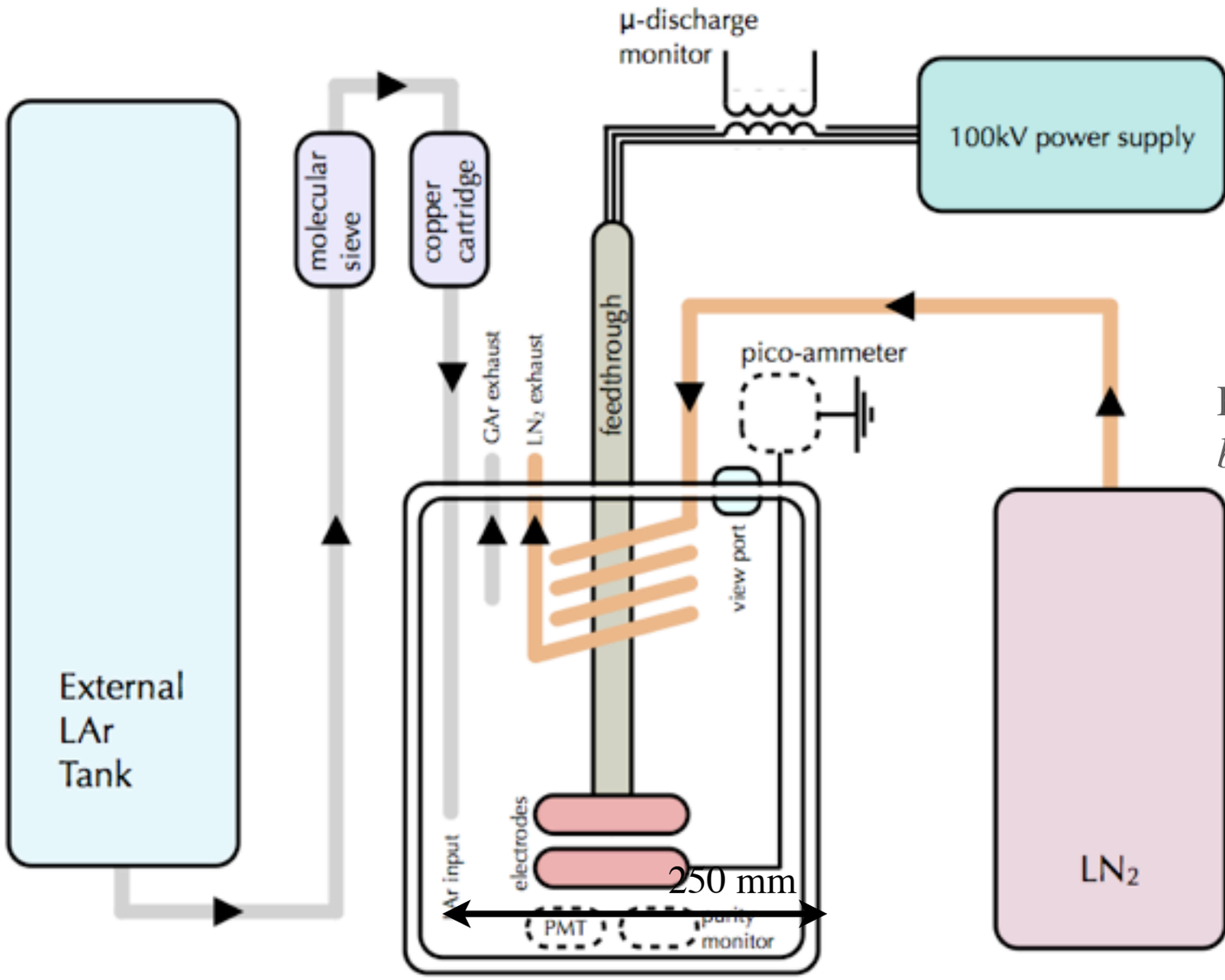
▸**<u>Transmission</u>:** The HV feedthrough (HVFT) should be designed to sustain this maximal operation HV.

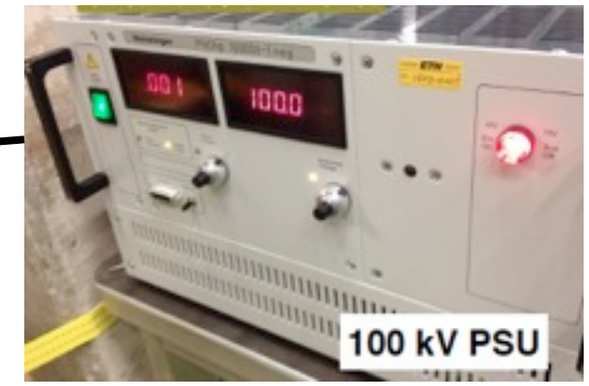
▸**<u>Design</u>**: The shape of the field cage and the cathode should be designed to avoid critical field regions (maximal electric field above 40 kV/cm).

➡**<u>Simulations</u>**: simulations of the HVFT using the COMSOL multiphysics software will be performed with the aim of understand the field along all the HVFT and the influence of the different parameters of the HVFT design in the computed electric field. The results can help to future HVFT designs.

What has been done

"ICARUS design"150 kV High Voltage feedthrough (HVFT) was used to test the rigidity of LAr in a dedicated setup





F. Bay et al. "*Evidence of electric breakdown induced by bubbles in liquid argon*" arXiv: 1401.2777

The dielectric rigidity of LAr with temperature below the boiling point is larger than 100 kV/cm

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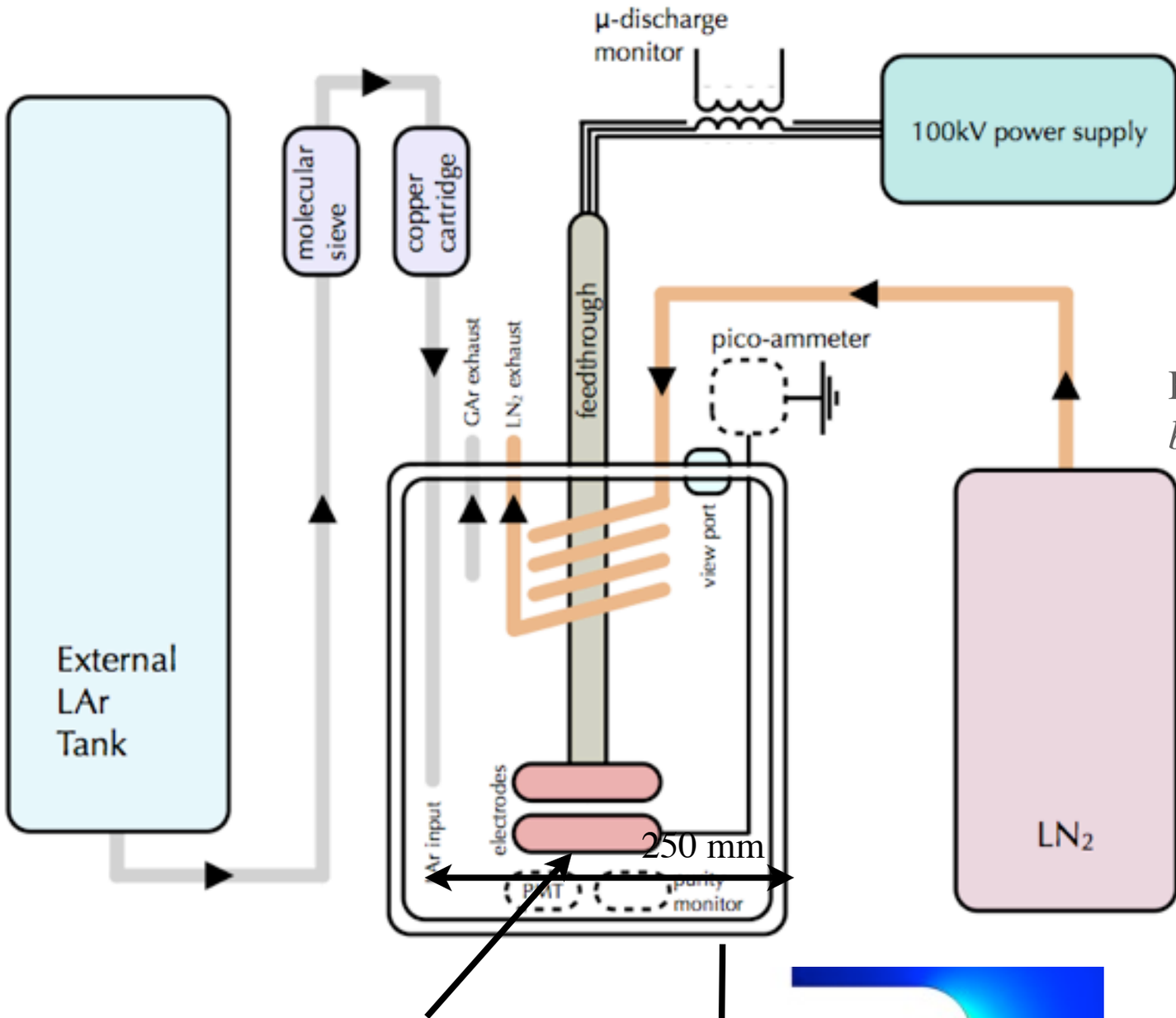

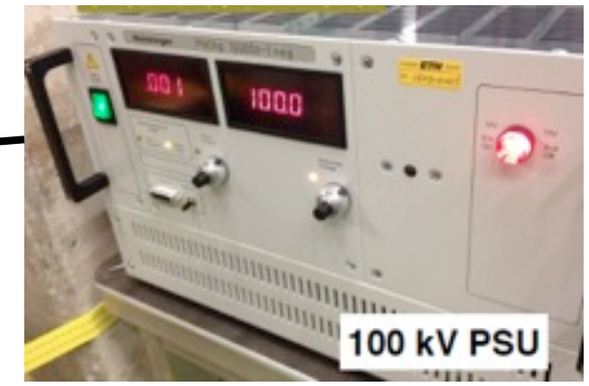

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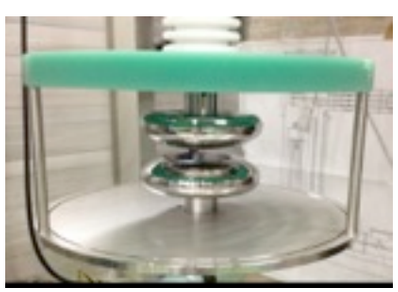
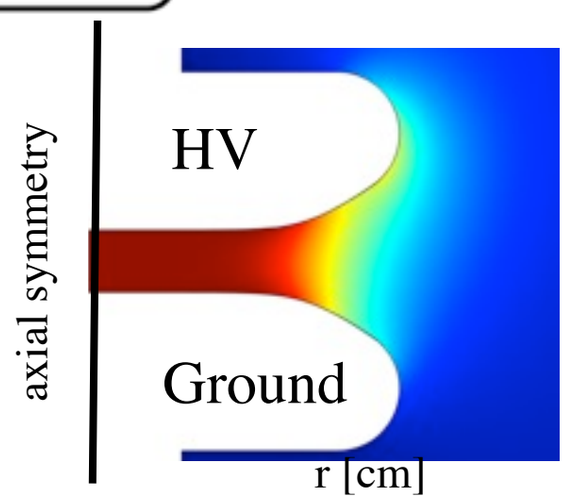
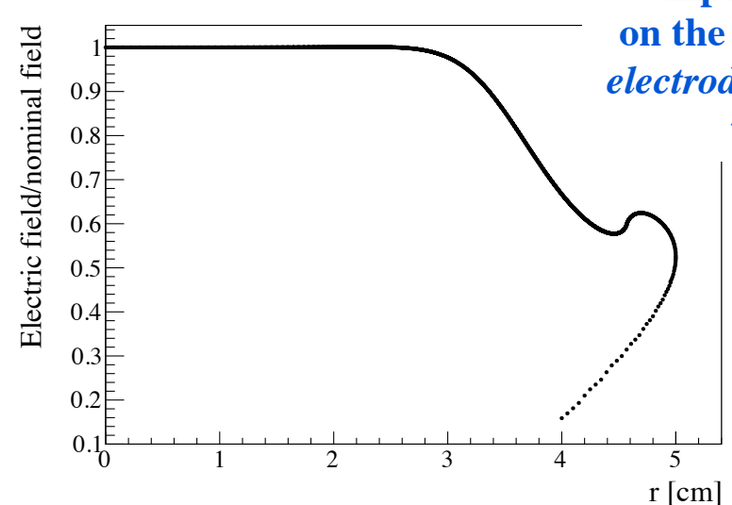
Rogowski profiles
High field region confined between the two electrodes



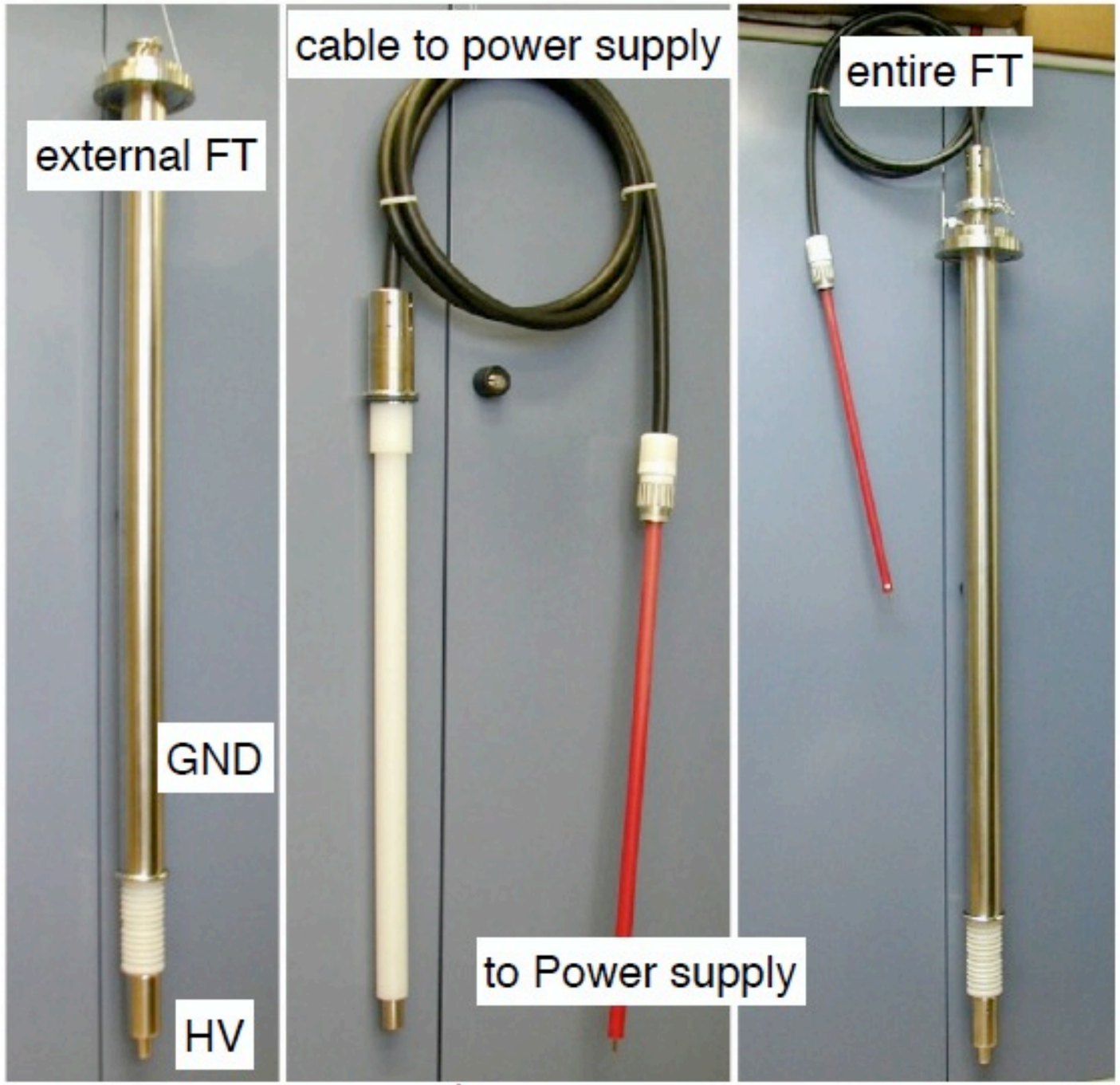


Computed electric field on the profile of the *top electrode* as a function of the radius

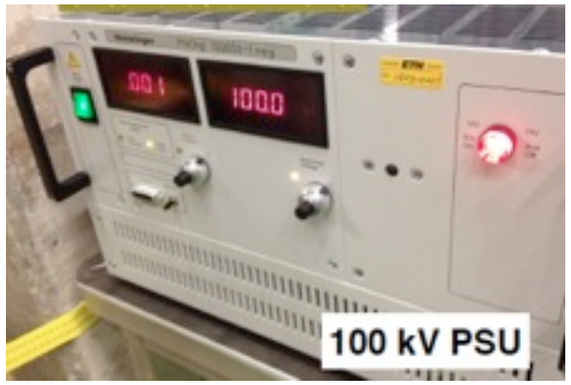


What has been done

<u>ICARUS HVFT</u>: can sustain voltages up to **150 kV**



Heinzinger **100 kV** PSU



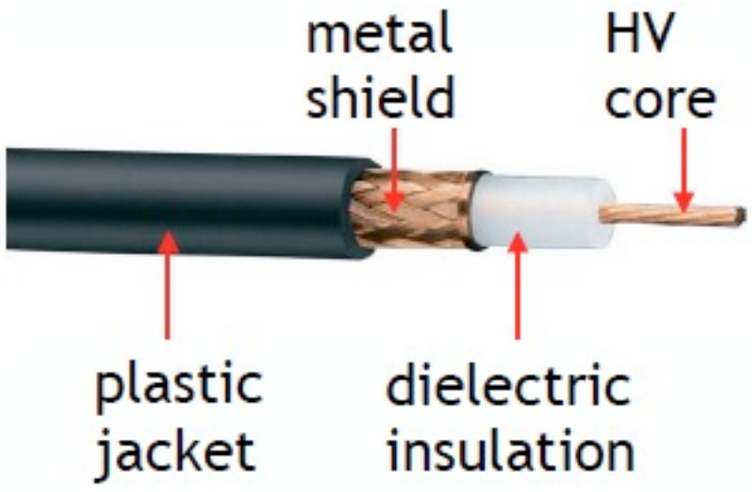
- **<u>Principle</u>:** A coaxial geometry with an inner conductor (HV) and an outer stainless-steel conductor (ground) insulated by high-density polyethylene.
- The dielectric insulator provides tightness in cryogenic temperature.
- The cylinder is long enough to feed the HV below LAr level.
- The insulator is in a finned shape to increase the path to limit surface discharge.

<u>Next steps</u>: towards higher voltages

High voltage power supply and **cable**

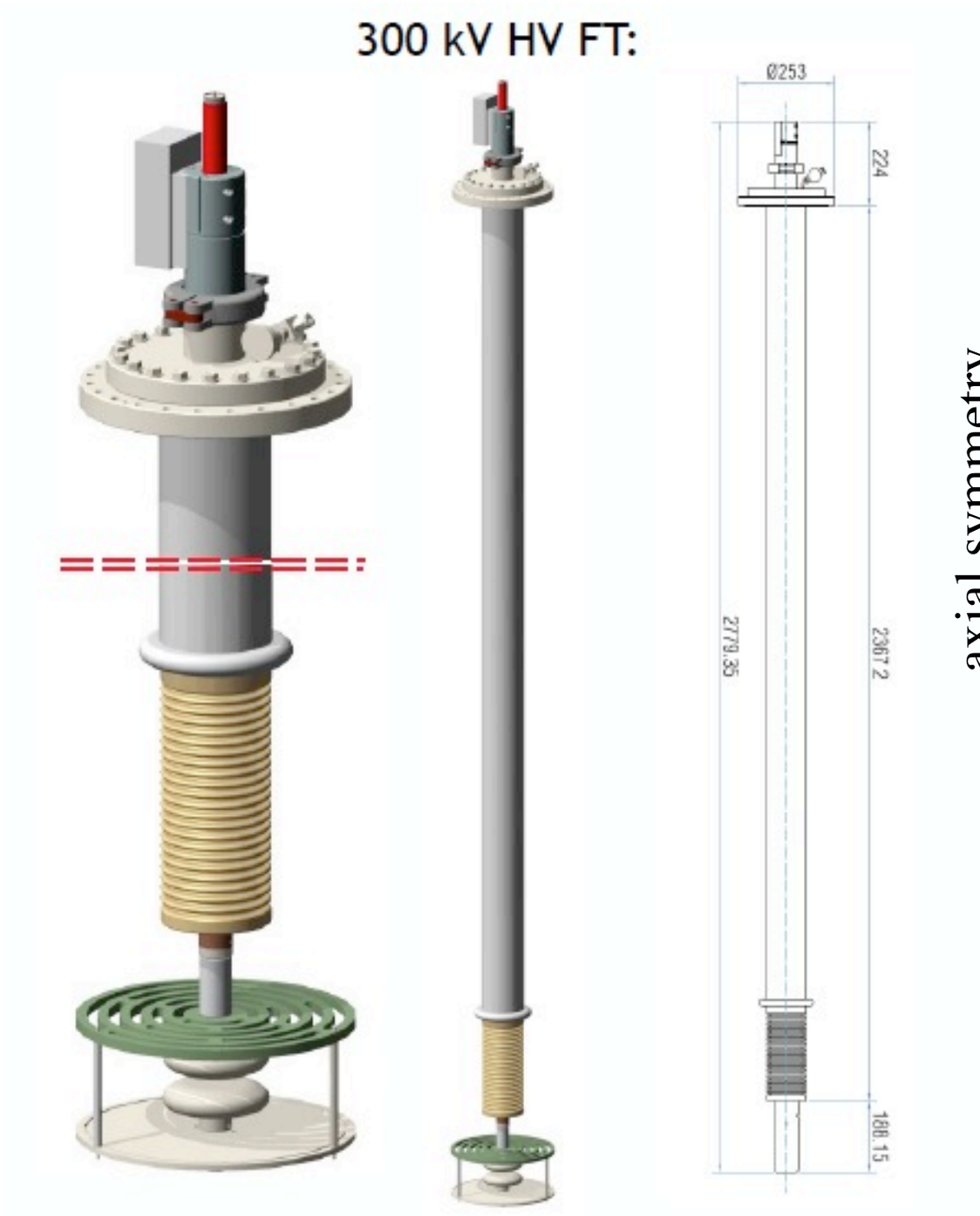
Heinzinger 300 kV PSU (already at CERN)

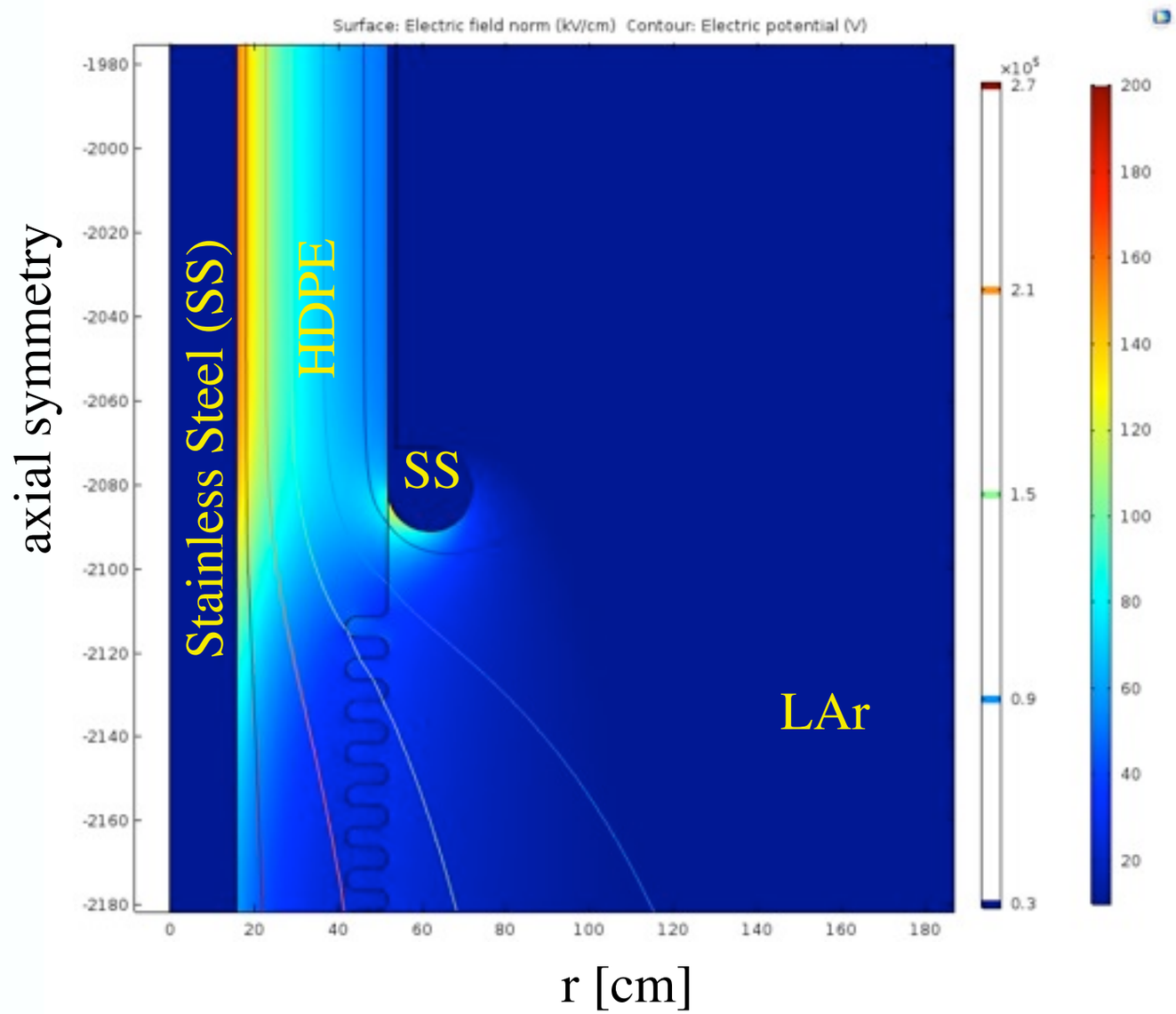
- Cockcroft-Walton generator or Greinacher Multiplier power supply. Very stable (0.001% over 8hrs) Low ripple (<0.001%pp).
- Unique units 400 kV exists and have already been produced.
- An R&D phase with industrial partners considered to develop 600 kV-able power supply.
- 300 kV enough for the protoDUNE double phase.



Next steps: towards higher voltages

HVFT for WA105 3x1x1 and protoDUNE double phase: A design scaled up from the one used in ICARUS





The HVFT is in fabrication by CINEL

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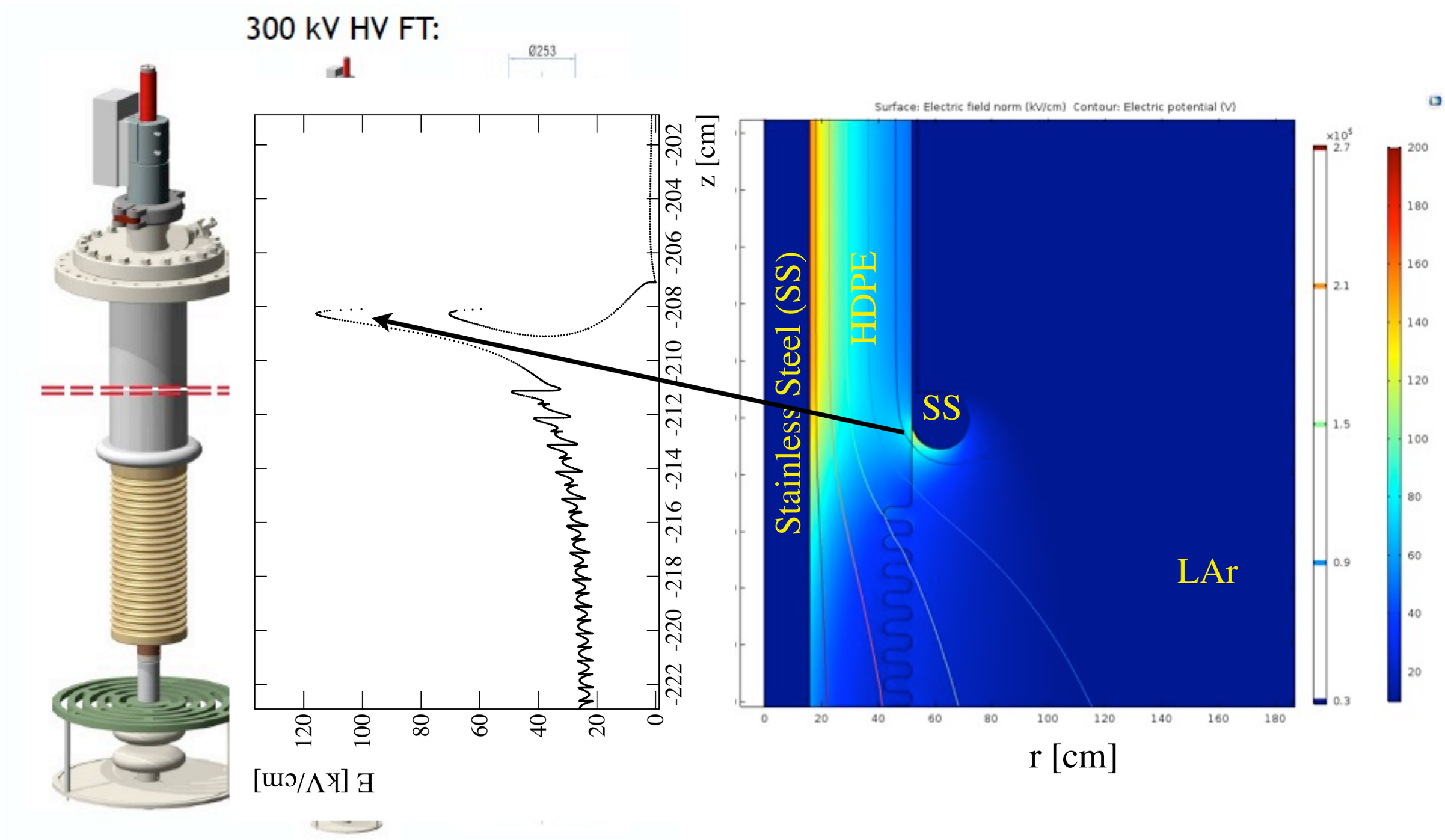

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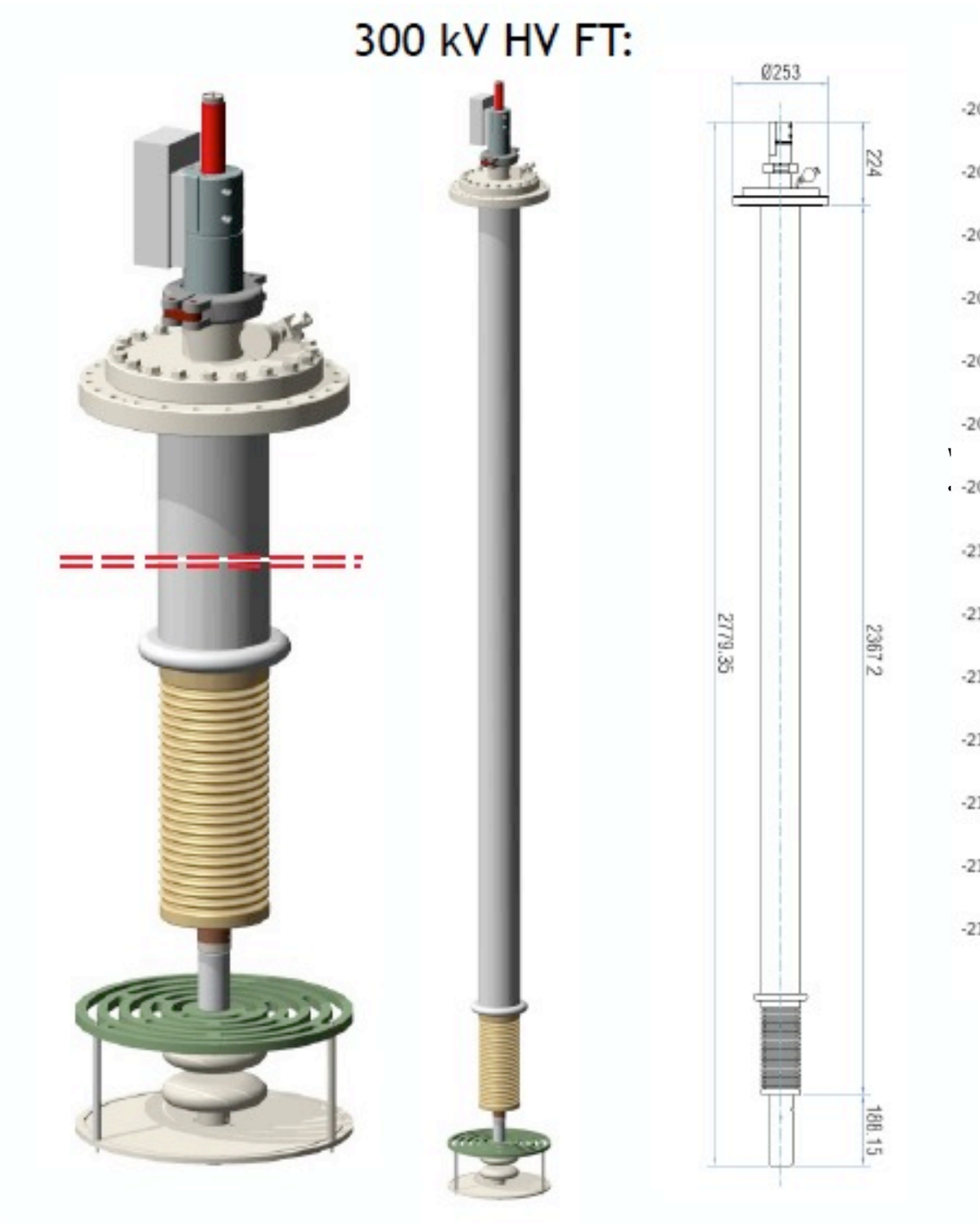

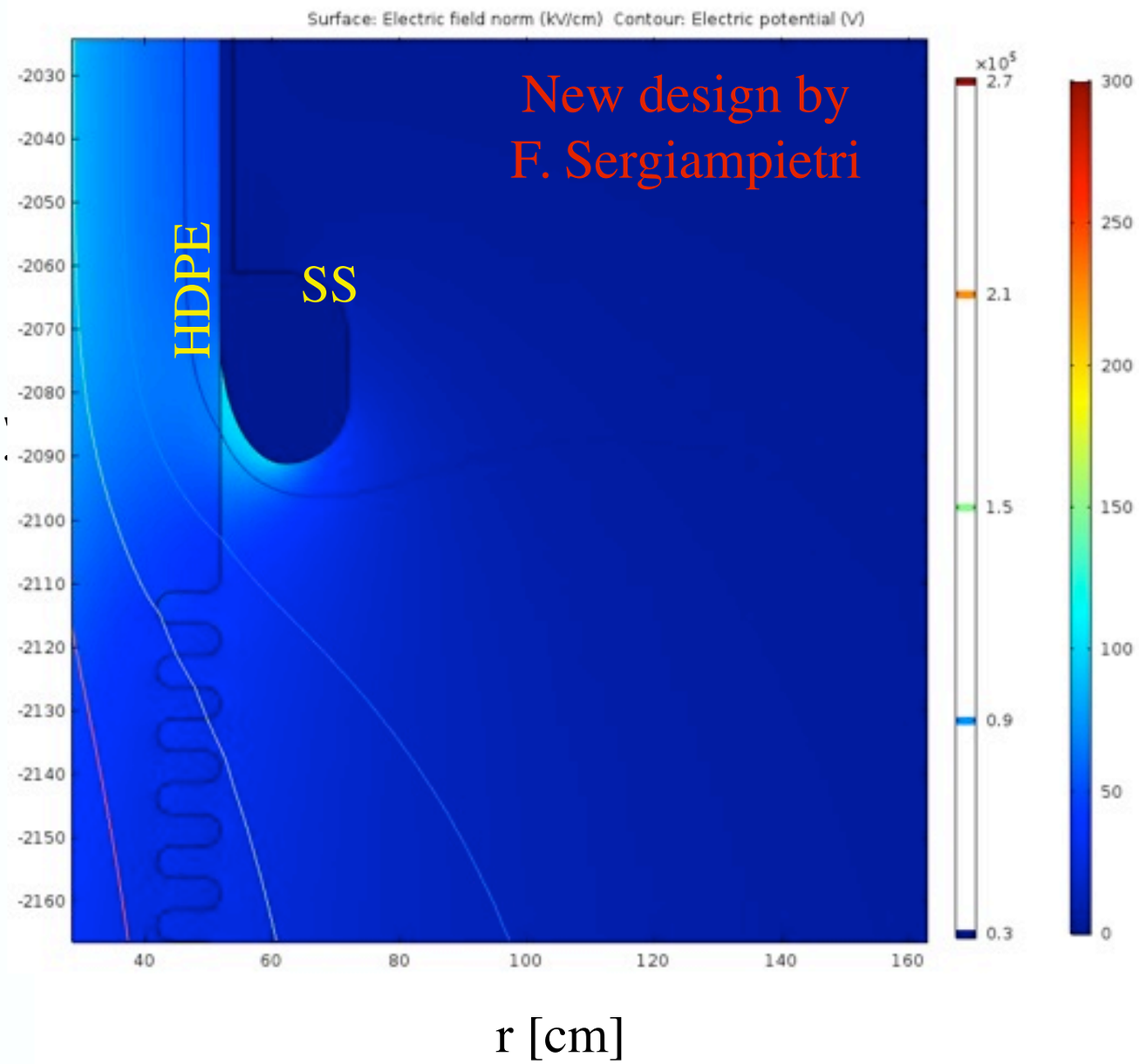

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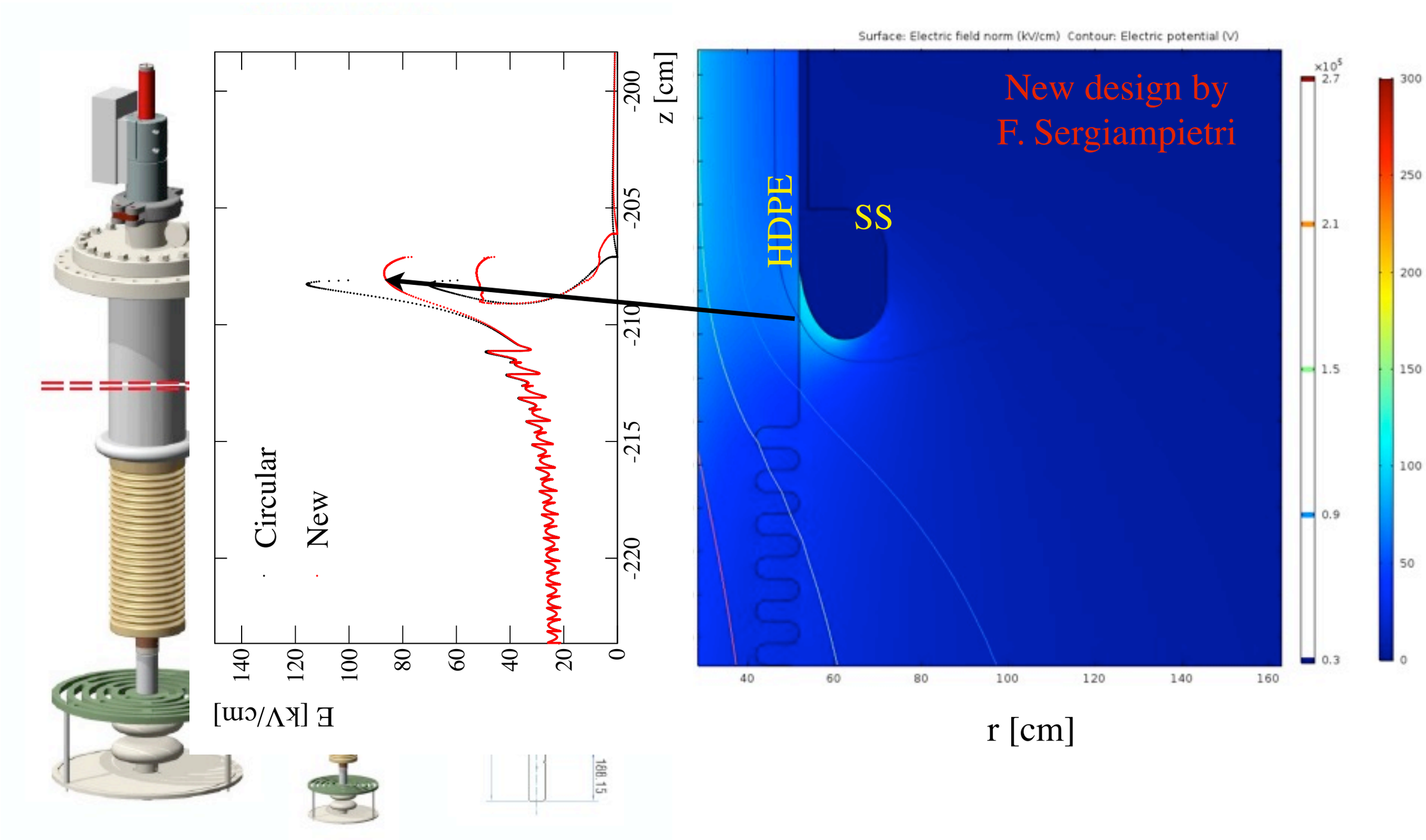

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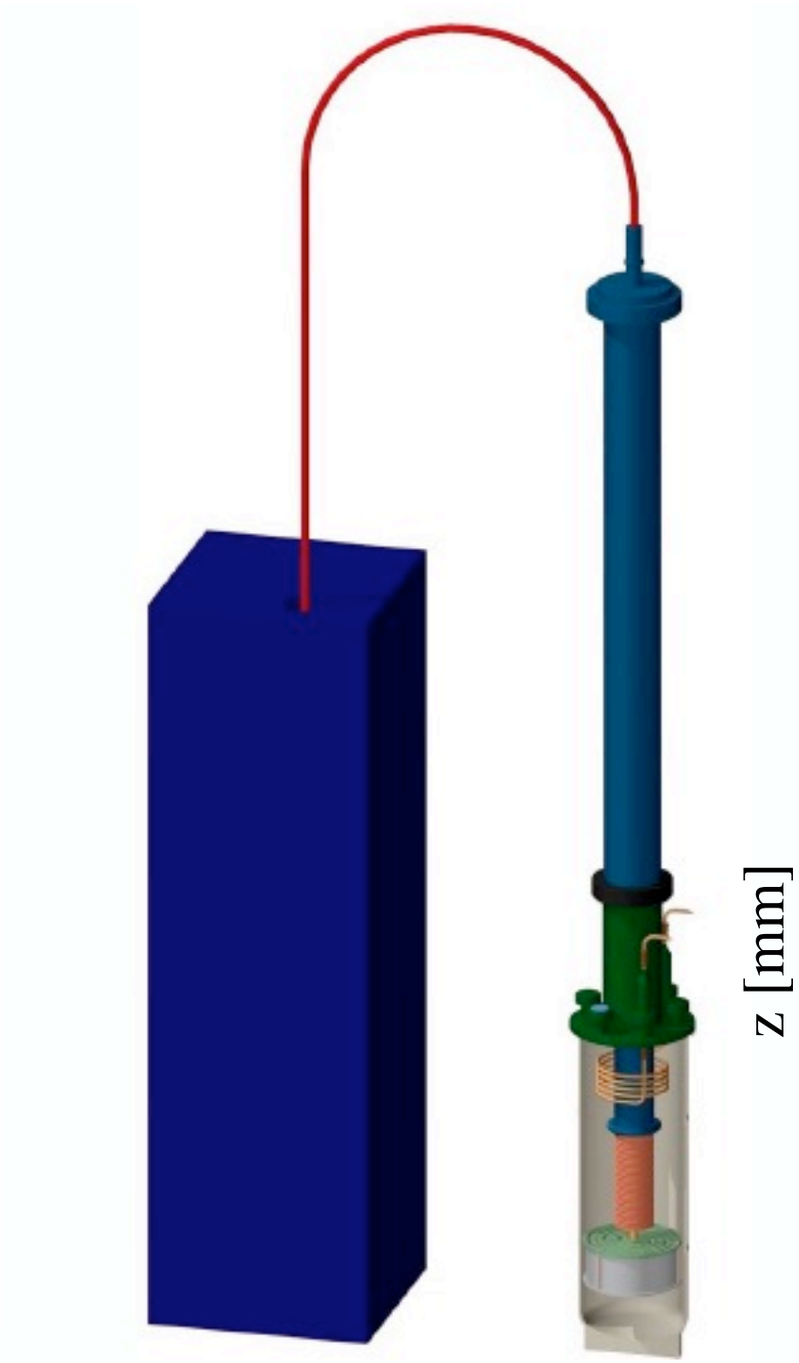
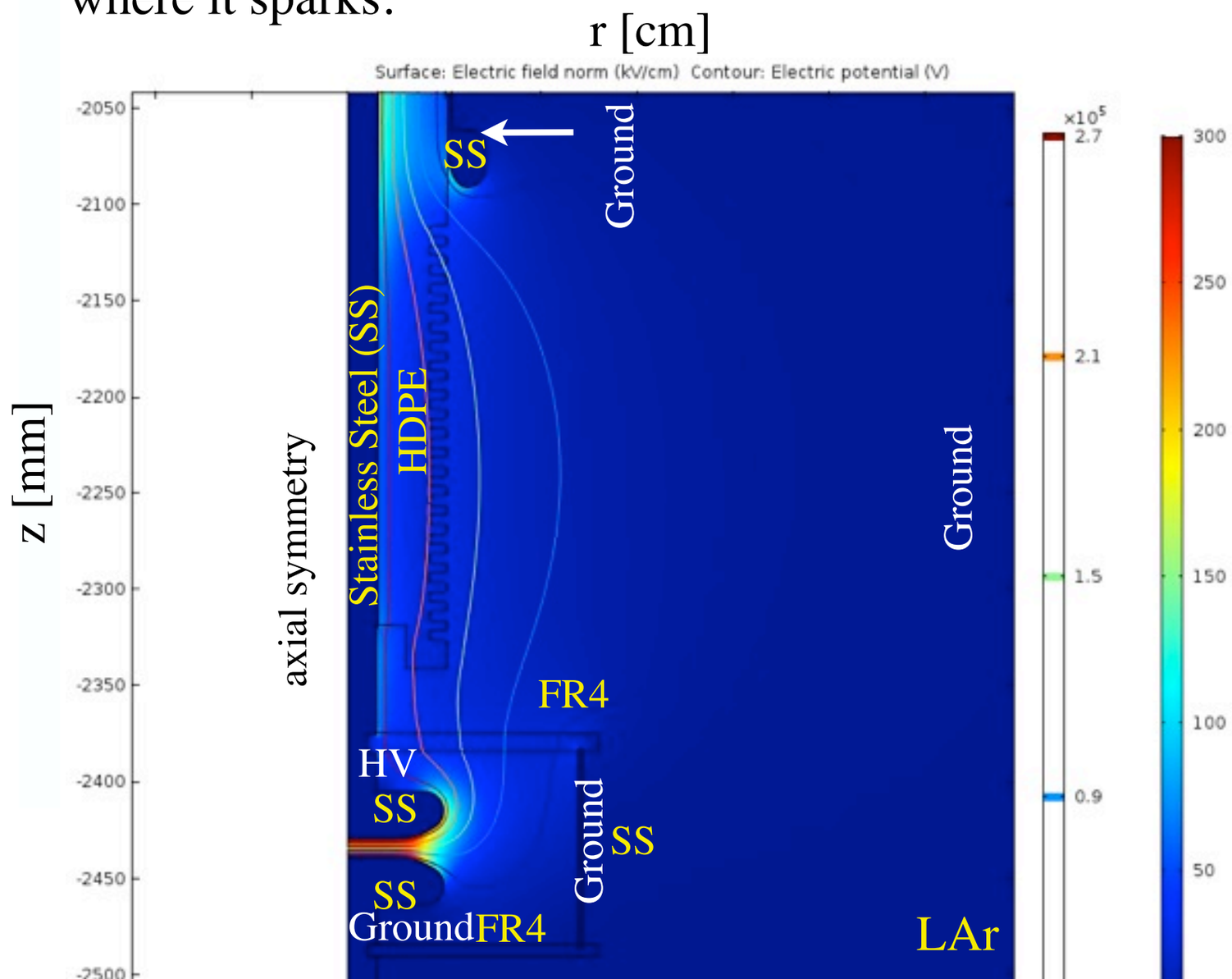
Next steps: towards higher voltages

300 kV test planned to be done at CERN

- Dedicated setup (similar to previous tests) to determine what HVFT can safely sustain.
- Study the effect of changing the distance between the electrodes.
- Effect of purity (purity monitor).
- Include cameras in the setup to determine when and where it sparks.





Summary

- Generating and sustaining very high voltages are one of the major challenges for LAr TPCs. A worldwide dedicated effort inside DUNE is being carried out.

- A dedicated R&D program in WA105 is being carried out to reach the goals of the high voltage system.

- The timescale of this R&D is perfectly in line with the AIDA WP8 derivable.

- In the near future a dedicated test to determine if HVFT can sustain voltages as larger as 300 kV will be performed at CERN.