Proportional Scintillation in LXe

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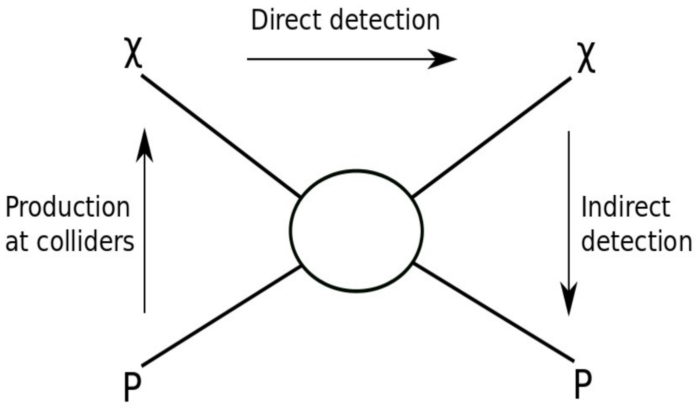
Astroparticle Physics

Physikalisches Institut
Albert-Ludwigs-Universität Freiburg

Detecting Dark Matter



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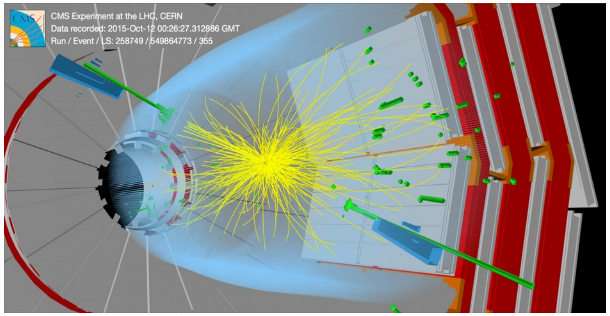
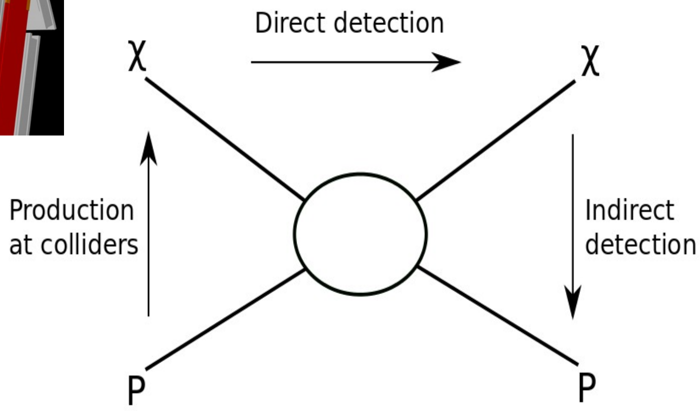
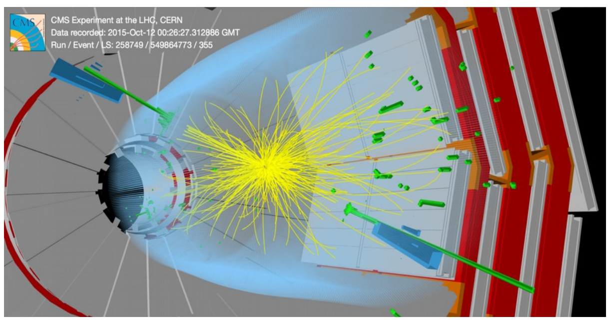


(cms.web.cern.ch/)

Collisions at the LHC





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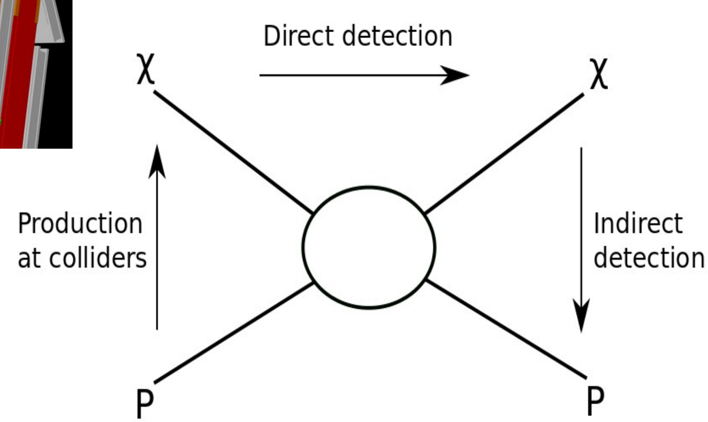
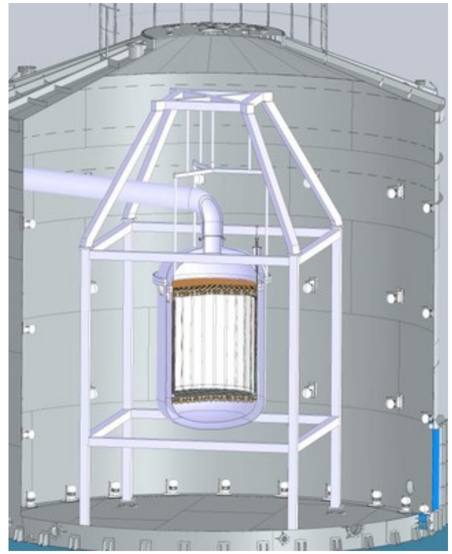


(https://ams.nasa.gov/)

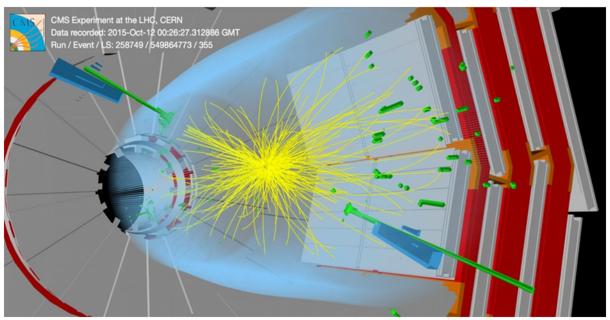
Decay products detected by AMS02

Detecting Dark Matter

Dark matter enters the detector and deposits energy



DARk matter **WI**mp search with liquid xeno**N** (DARWIN)



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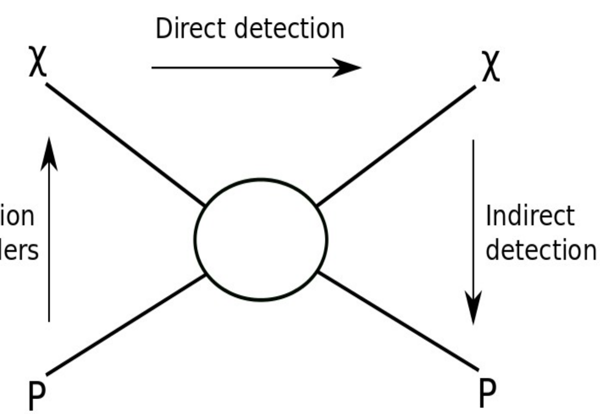

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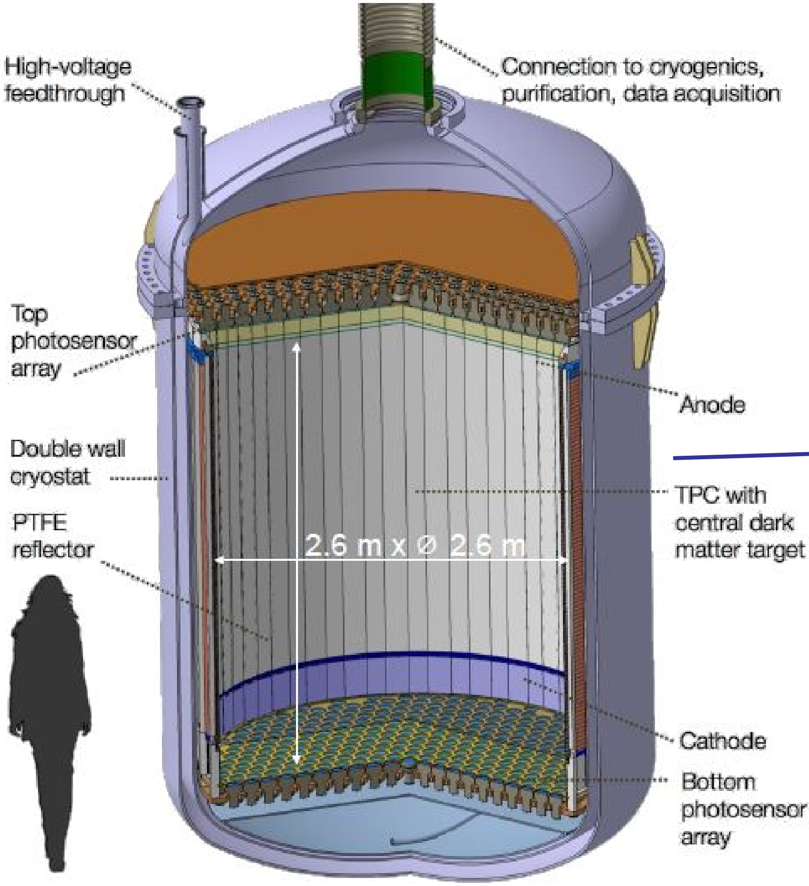
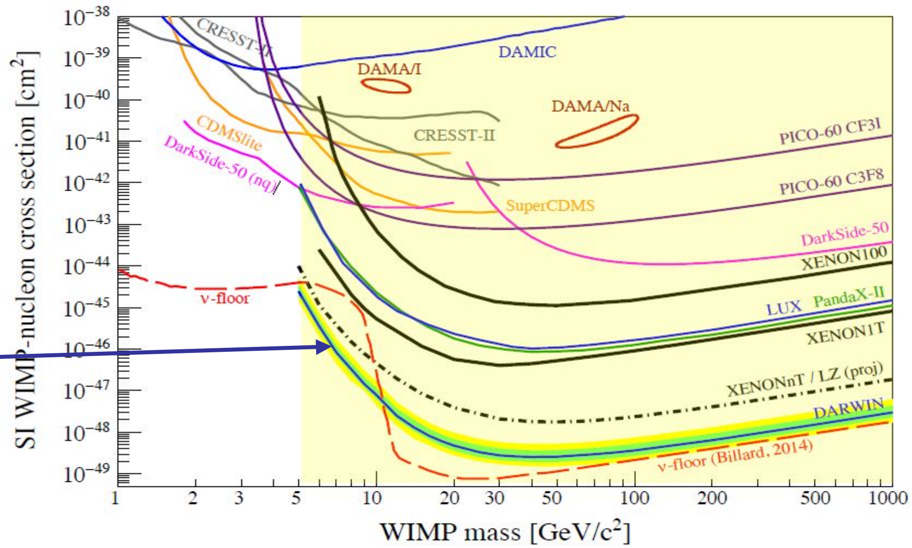
Decay products detected by AMS02

WIMP search with DARWIN

The DARWIN detector searches for WIMPs (Weakly Interacting Massive Particle)



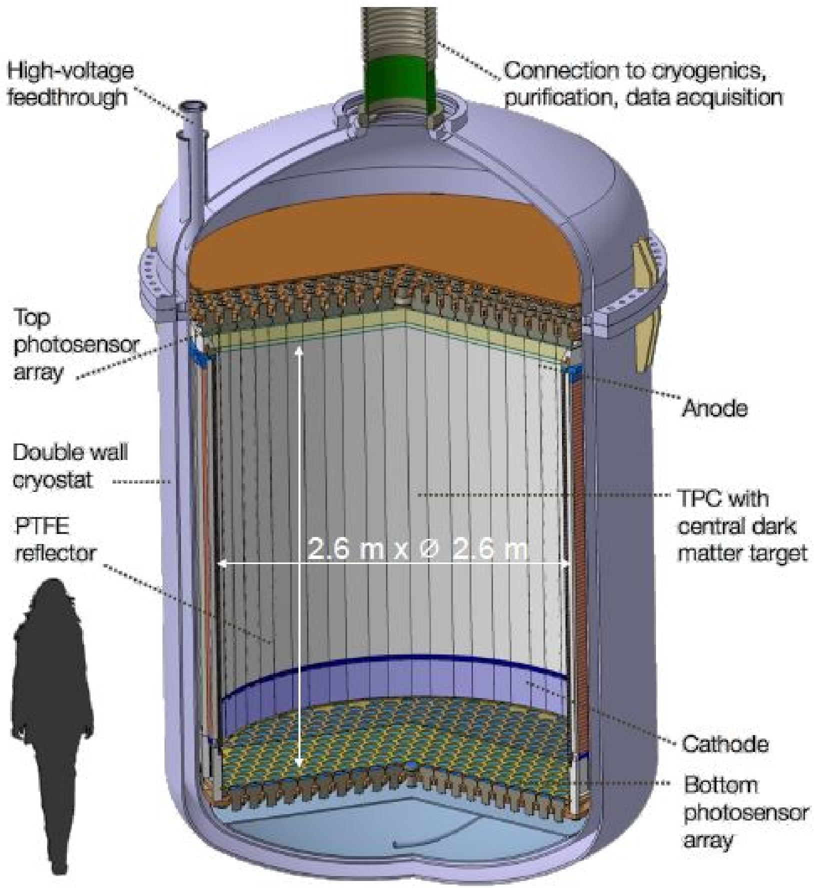


(JCAP A (2016) no.11, 017)

Goal:
Sensitivity for spin-independant WIMP-nuclei interactions down to the neutrino floor

40t LXe as detector material

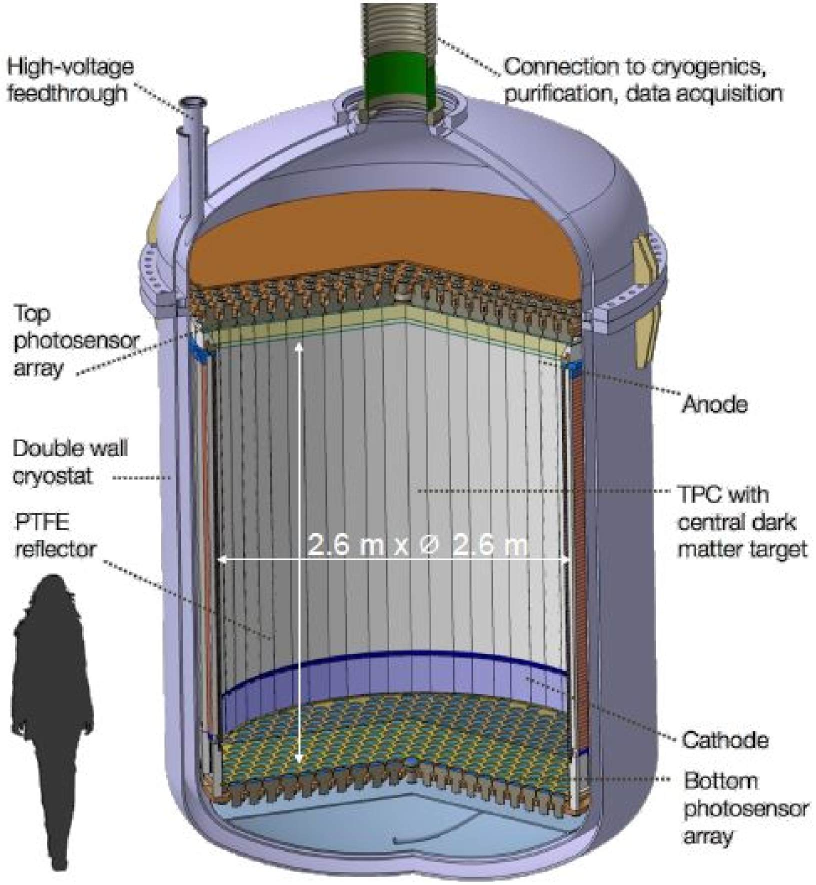
DARWIN Challenges



Challenges:

- Electron drift over long distance
- Scaling: e.g. electrodes ⇨ diameter
- LXe mass (purification)
- Background reduction
  - ^{222}Rn
  - (α,n) neutrons from PTFE
- Light sensors
  - stability
  - low radioactivity
  - high light yield
- ….

DARWIN Challenges



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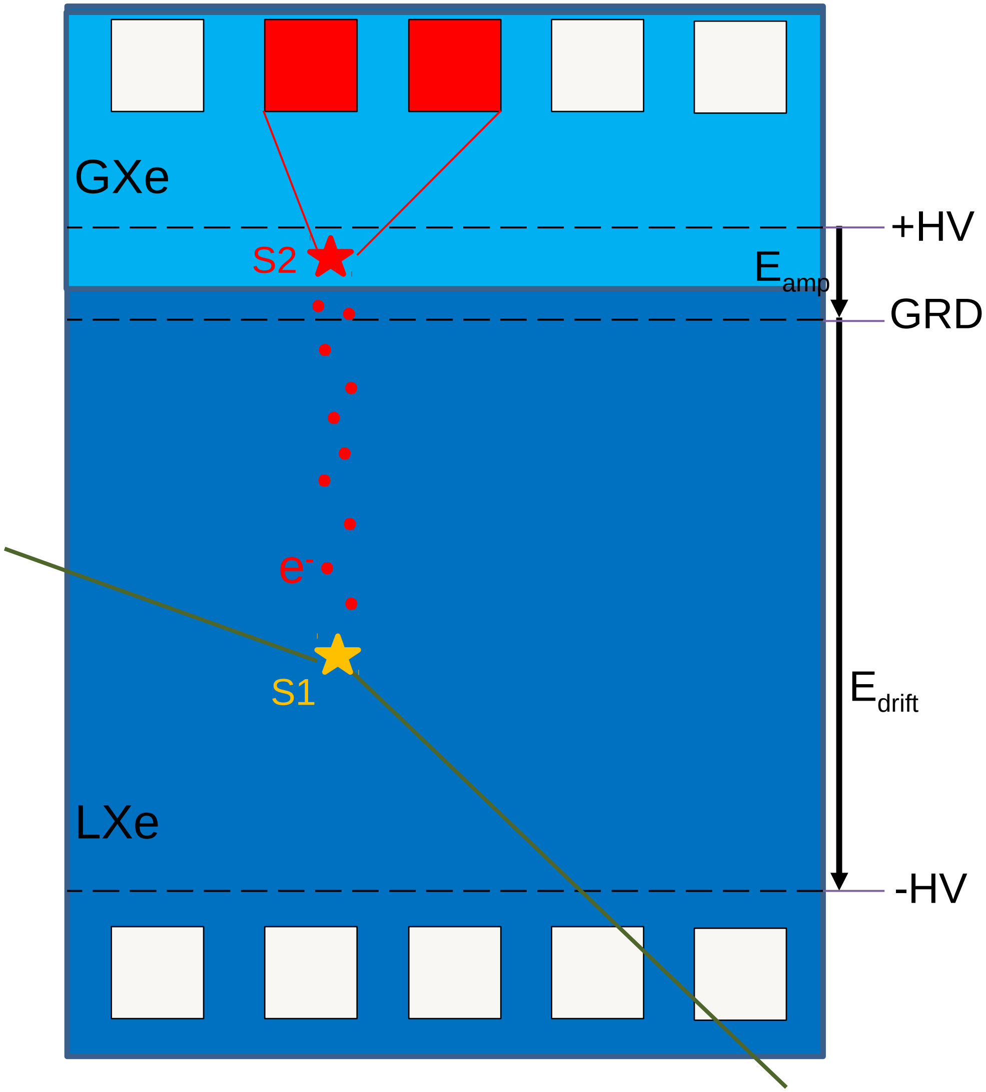
Signal readout in a Time Projection Chamber (TPC)



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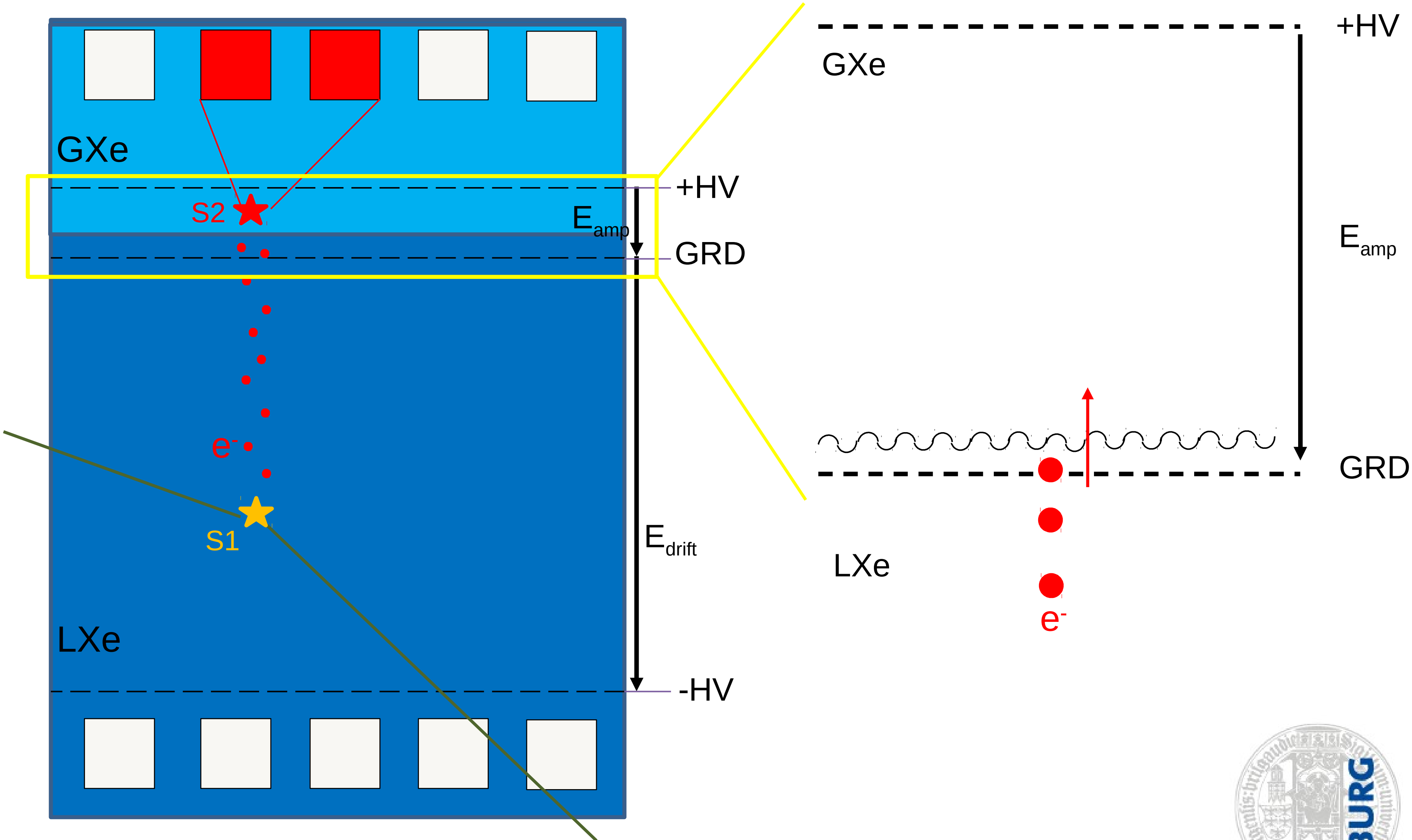

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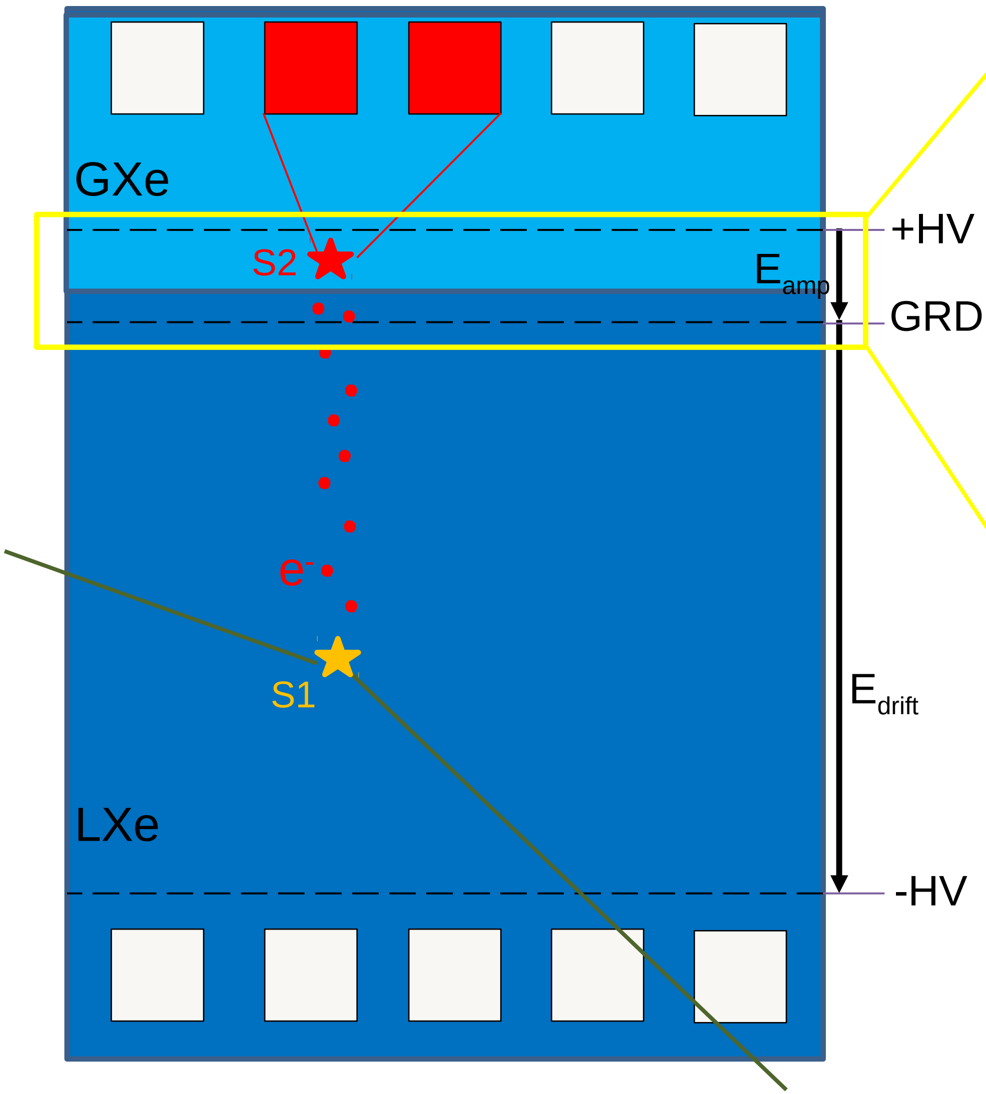
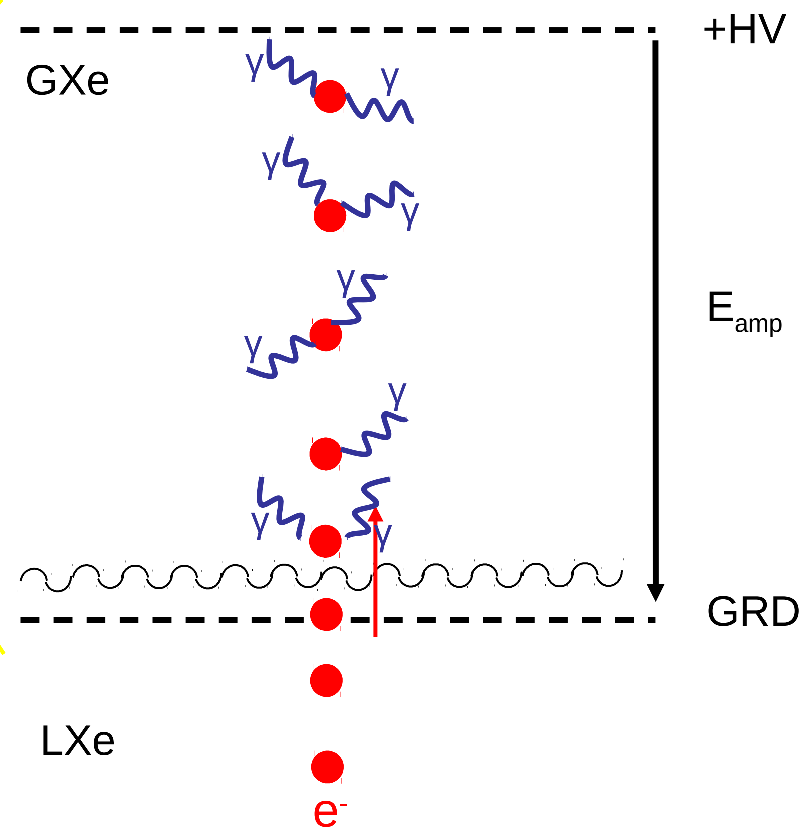


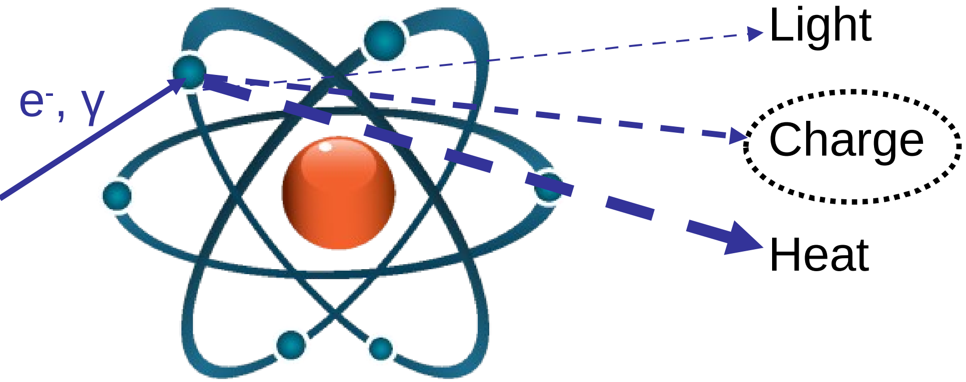


Charge signal:

- Photons along drift path
- Proportional scintillation in GXe

Signal readout in a Time Projection Chamber (TPC)

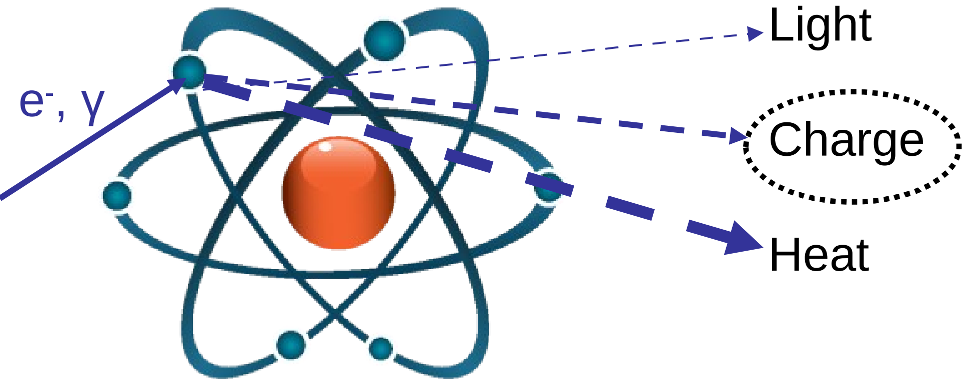
Electronic Recoil (ER)



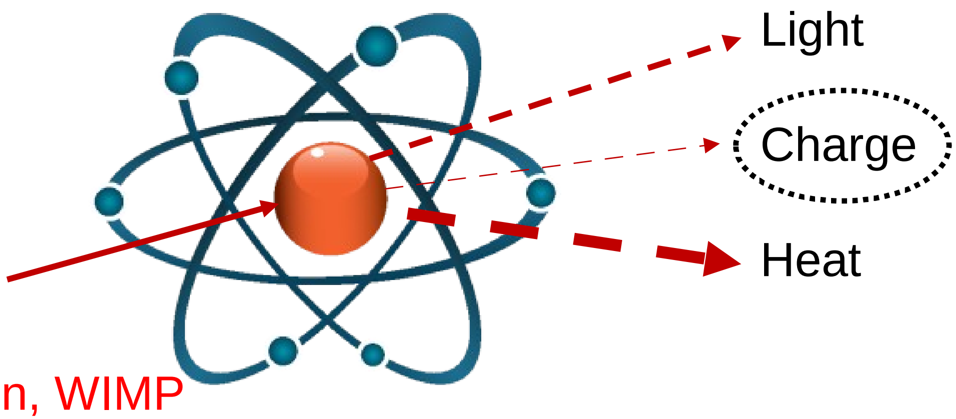
$$E_0 = N_i E_i * \ N_{ex} E_{ex} * N_i \varepsilon$$

Signal readout in a Time Projection Chamber (TPC)

Electronic Recoil (ER)



Nuclear Recoil (NR)



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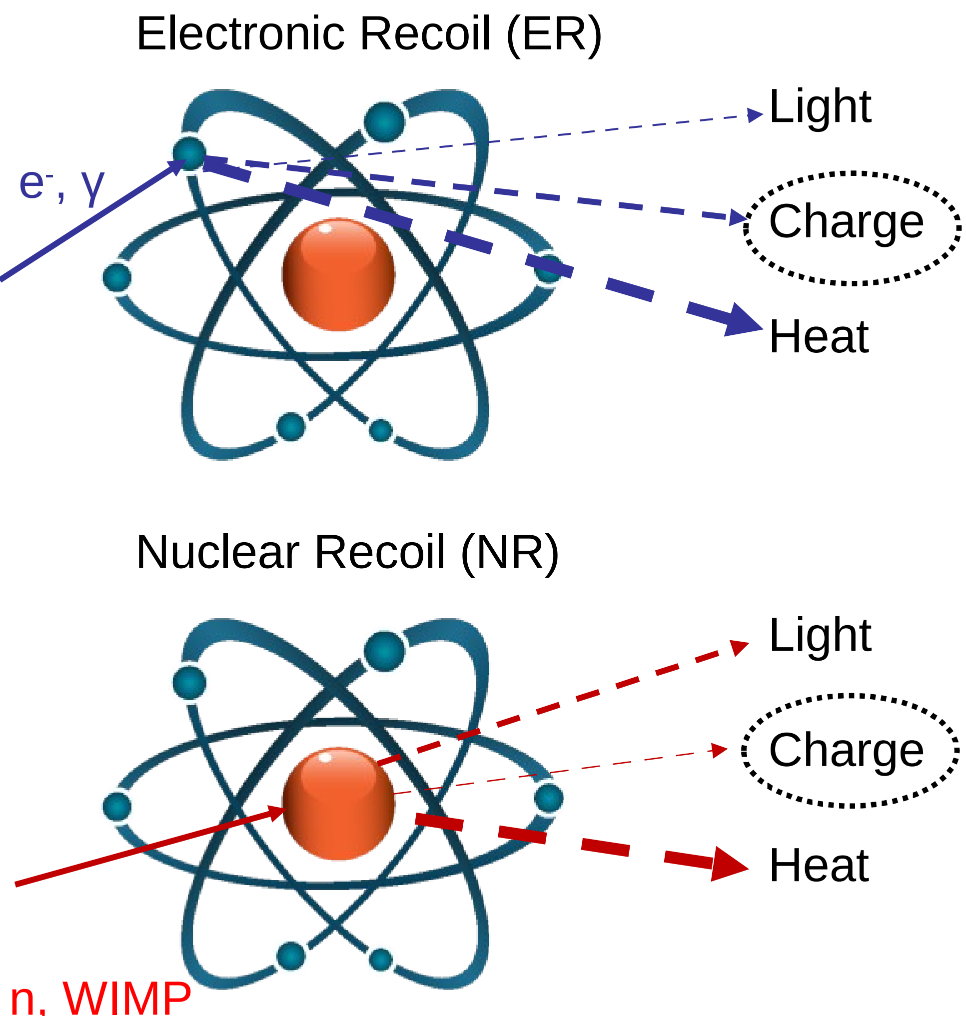
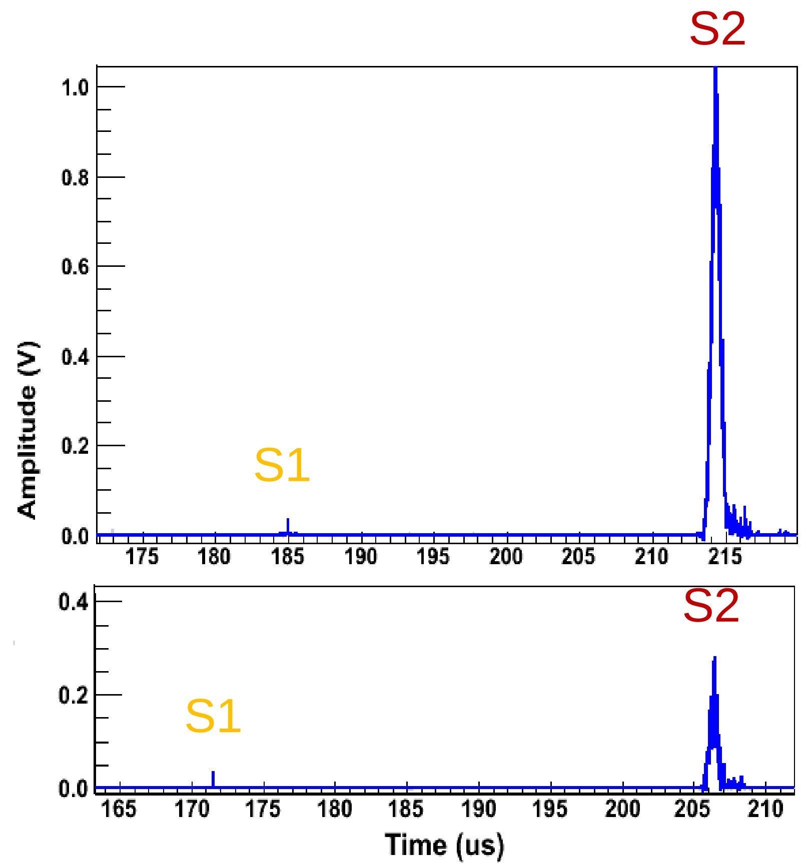
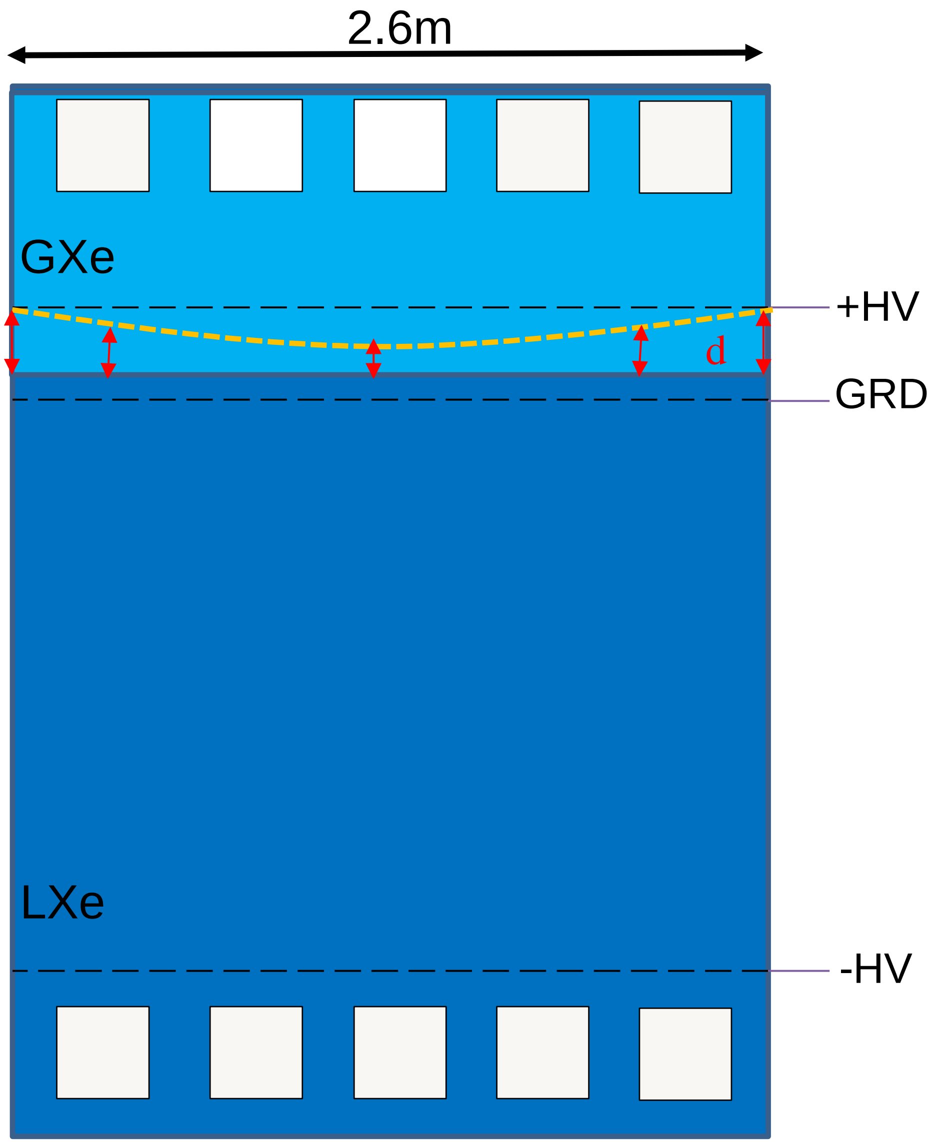




$$E_0 = N_i E_i * \; N_{ex} E_{ex} * N_i \varepsilon$$

To date: Proportional Scintillation in GXe
Test this in LXe!

From dual-phase to single-phase



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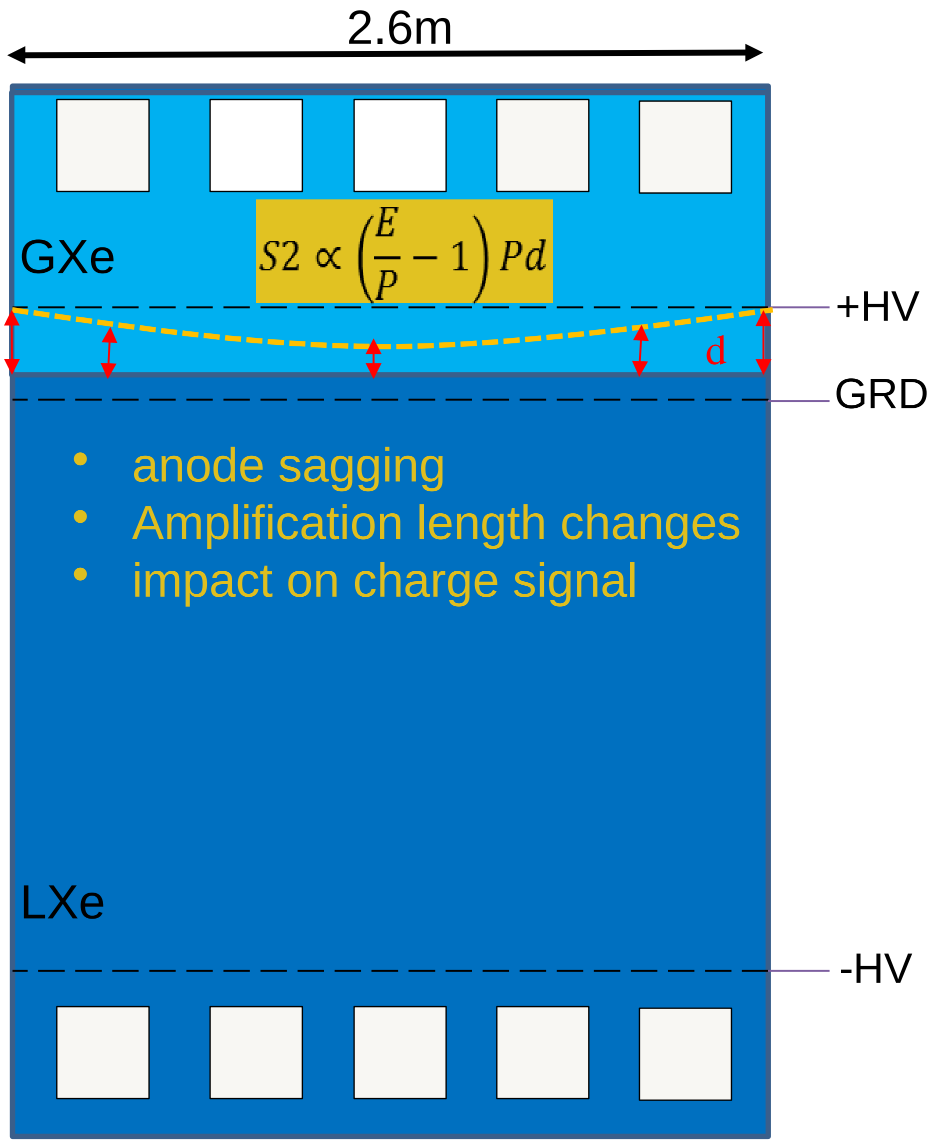
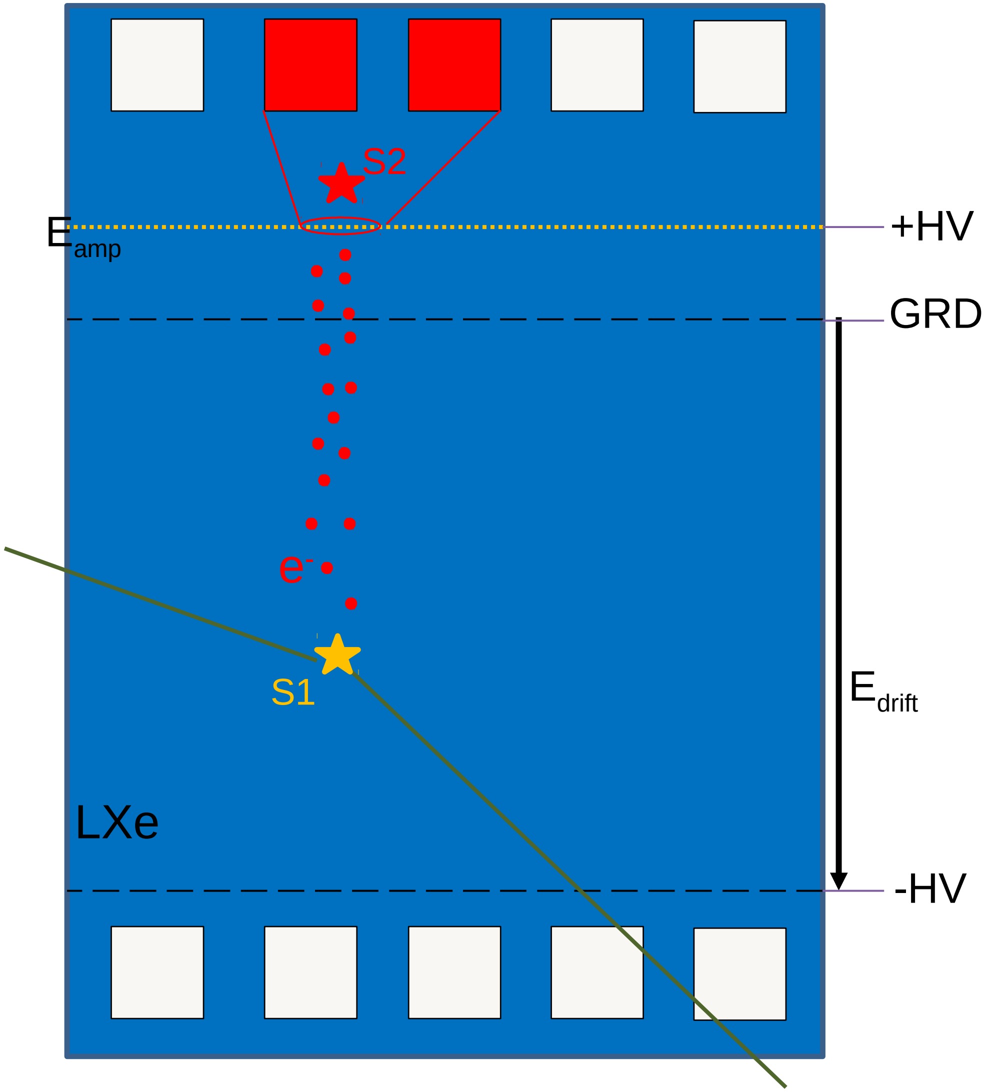


- anode sagging
- Amplification length changes
- impact on charge signal

From dual-phase to single-phase



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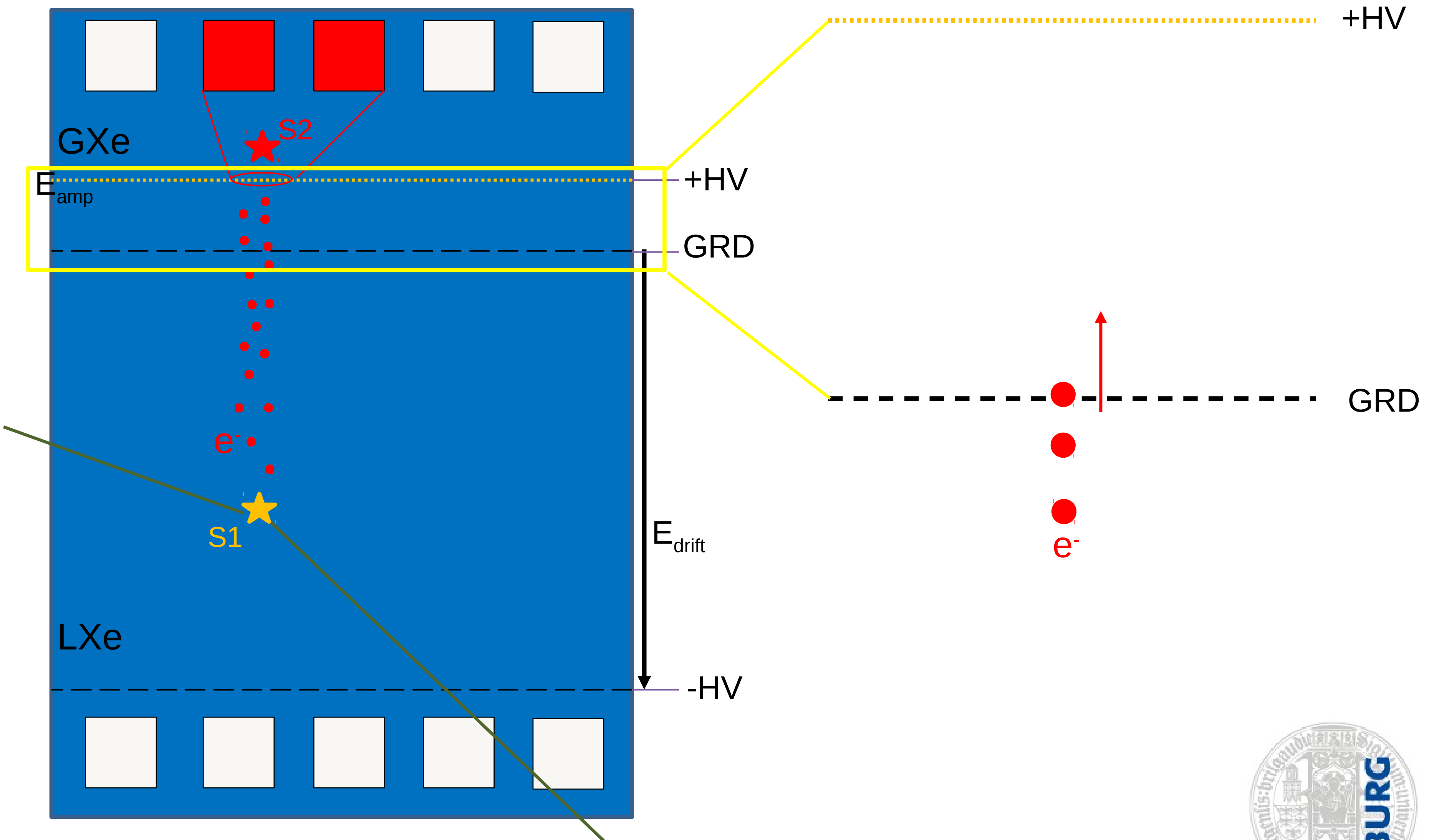

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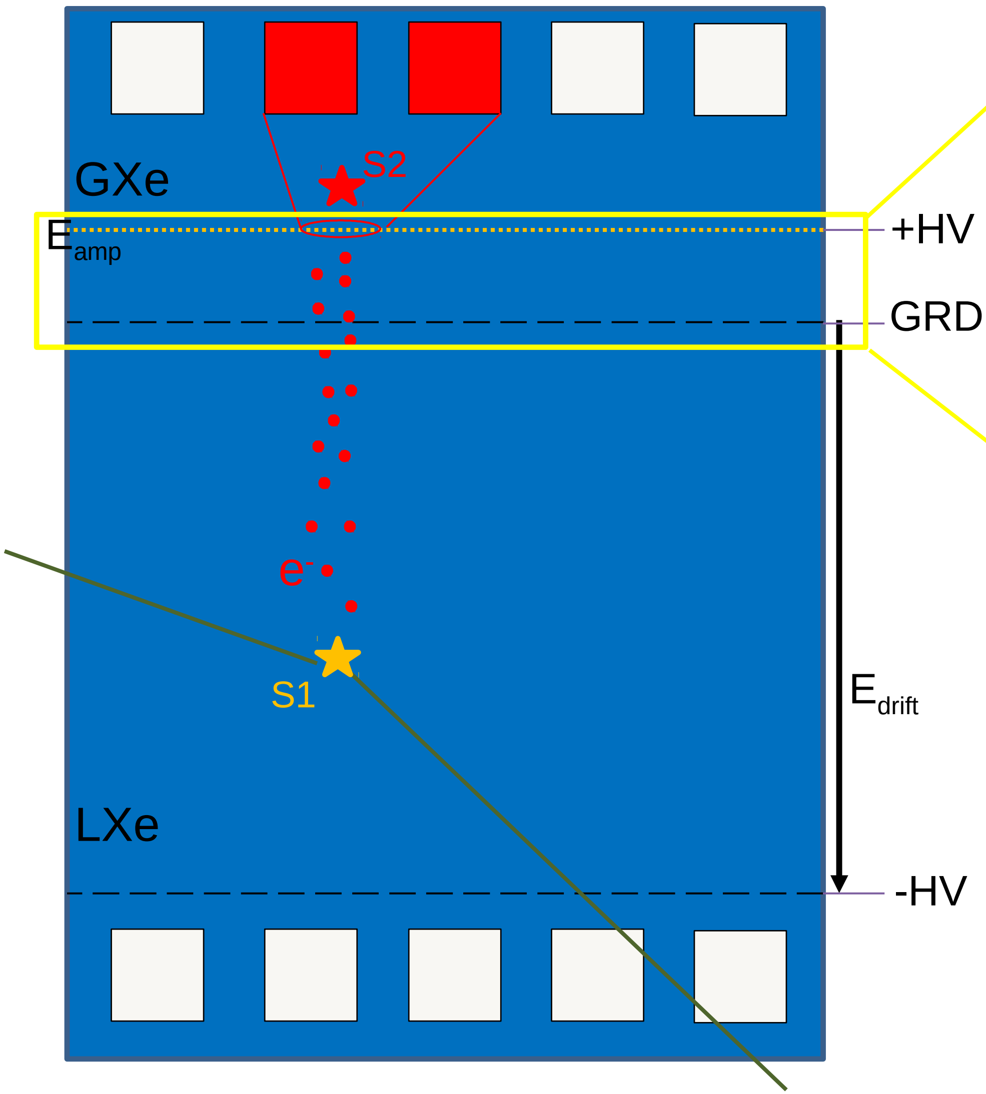
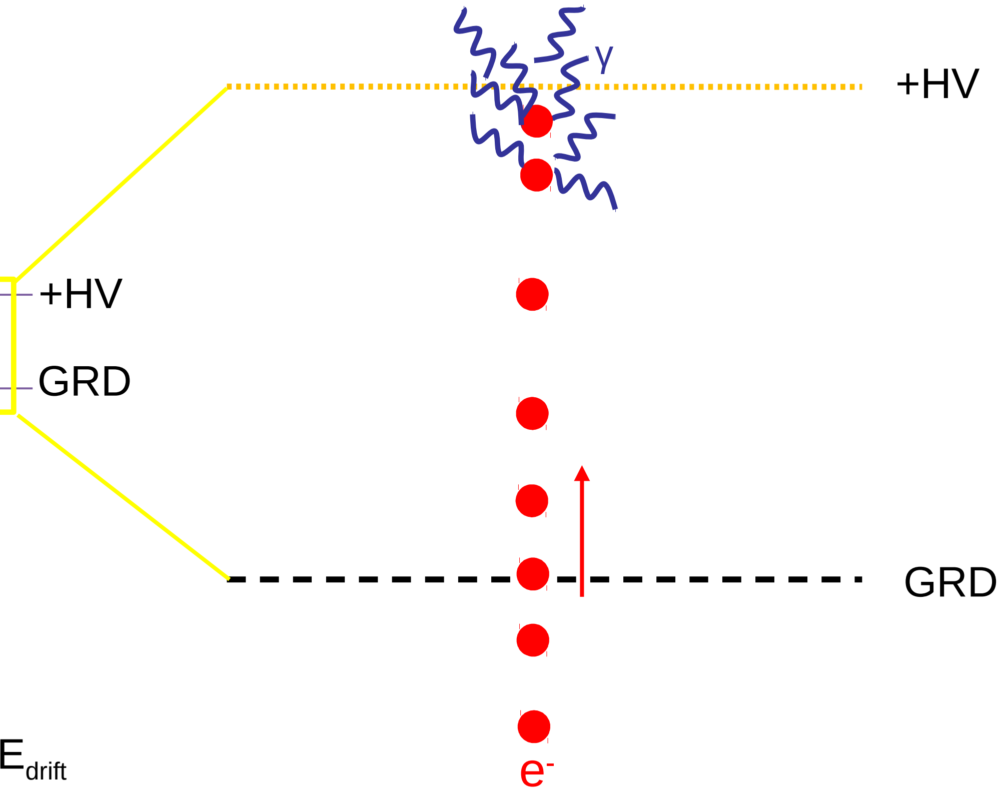
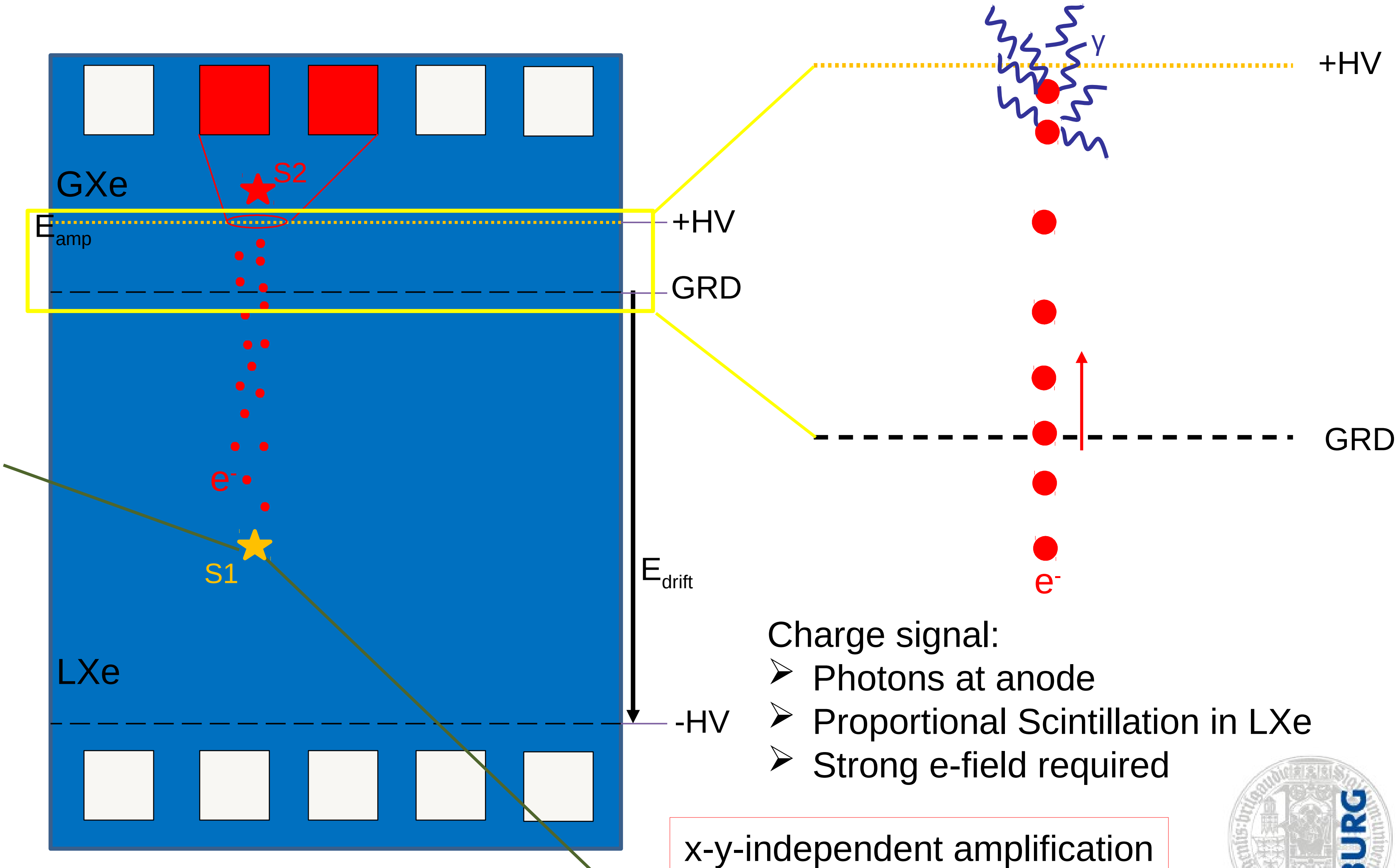




Charge signal:
- Photons at anode
- Proportional scintillation in LXe
- Strong e-field required

From dual-phase to single-phase

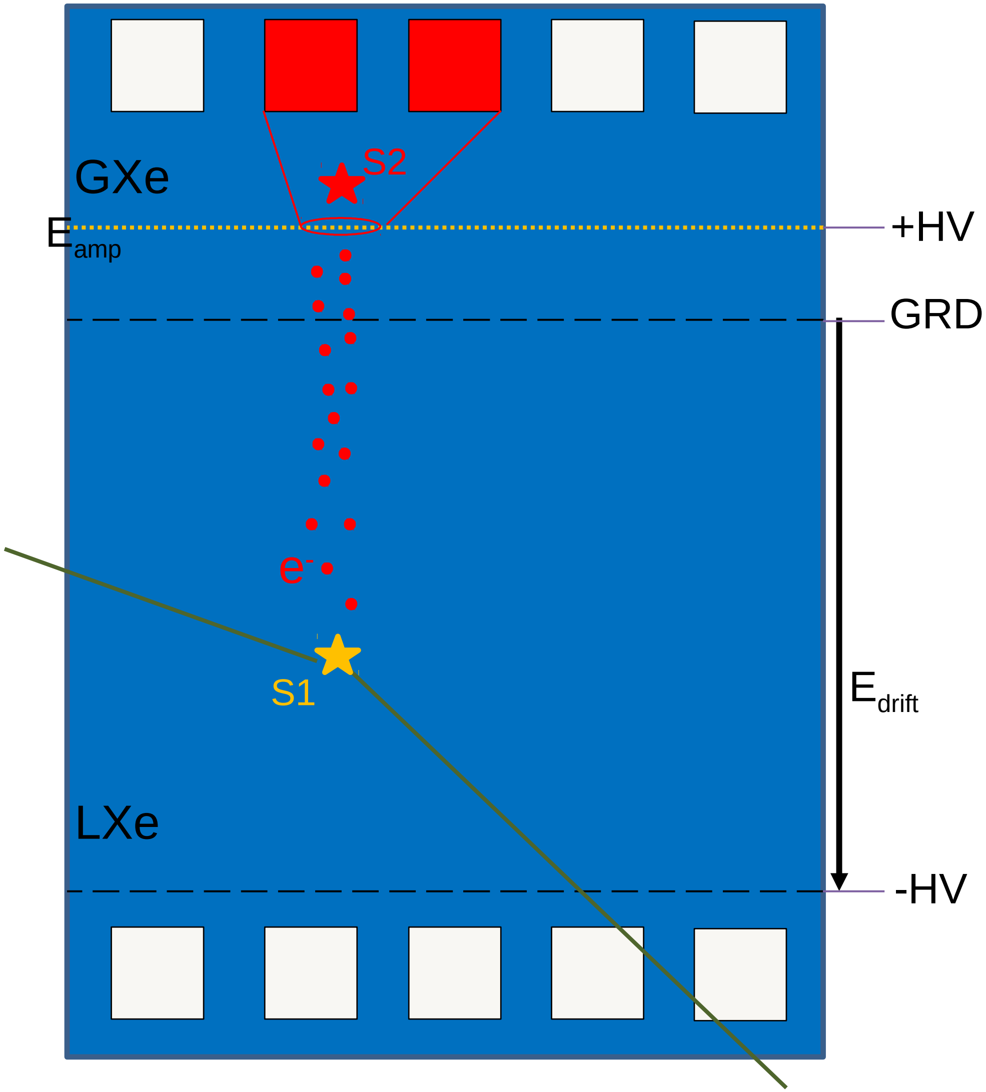


Charge signal:

- Photons at anode
- Proportional Scintillation in LXe
- Strong e-field required

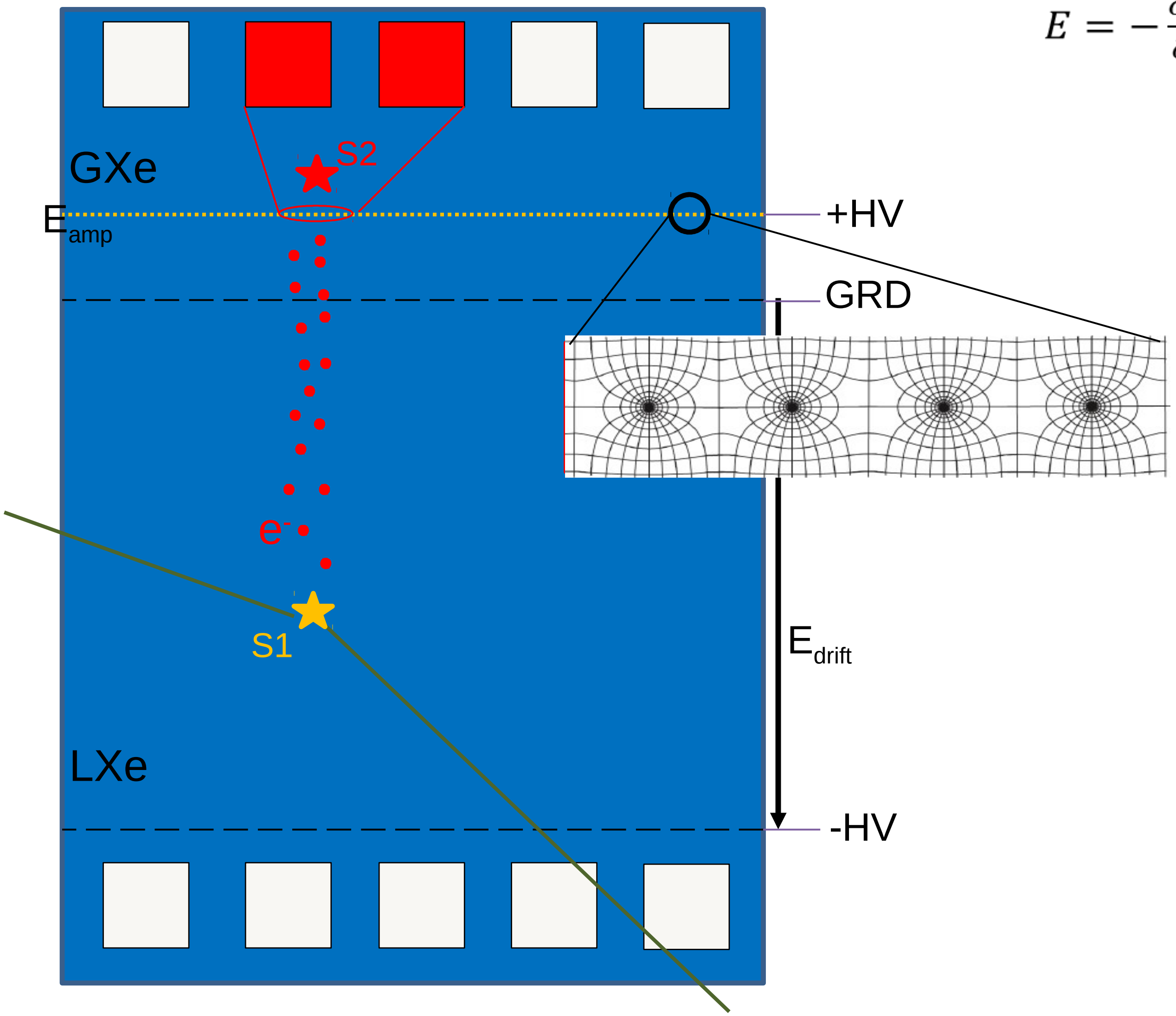
x-y-independent amplification

From dual-phase to single-phase



From dual-phase to single-phase

$$E = -\frac{\partial \phi}{\partial r}\vec{e_r} \approx \frac{\lambda}{2\pi\epsilon_0}\frac{1}{r}\vec{e_r}$$



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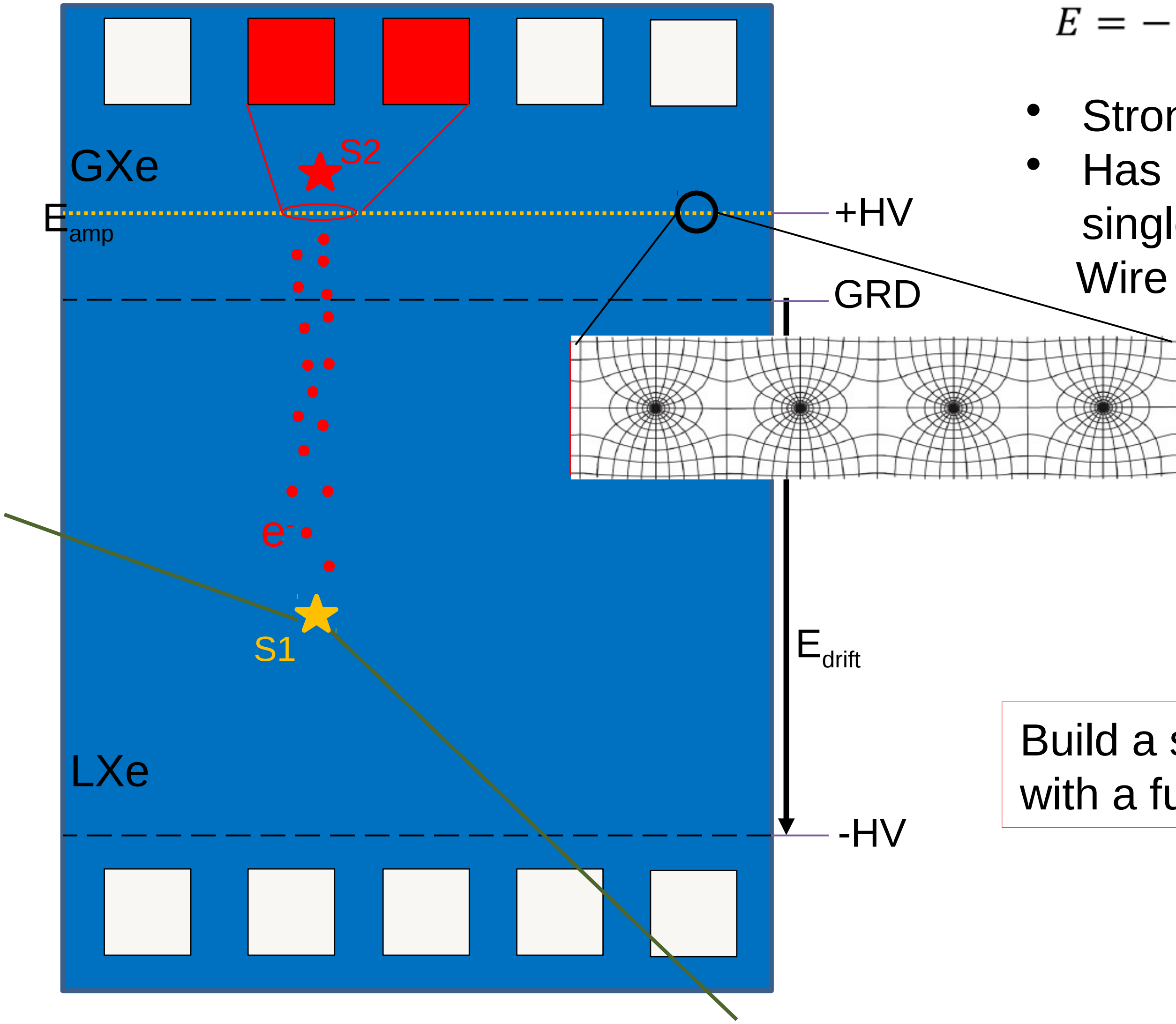


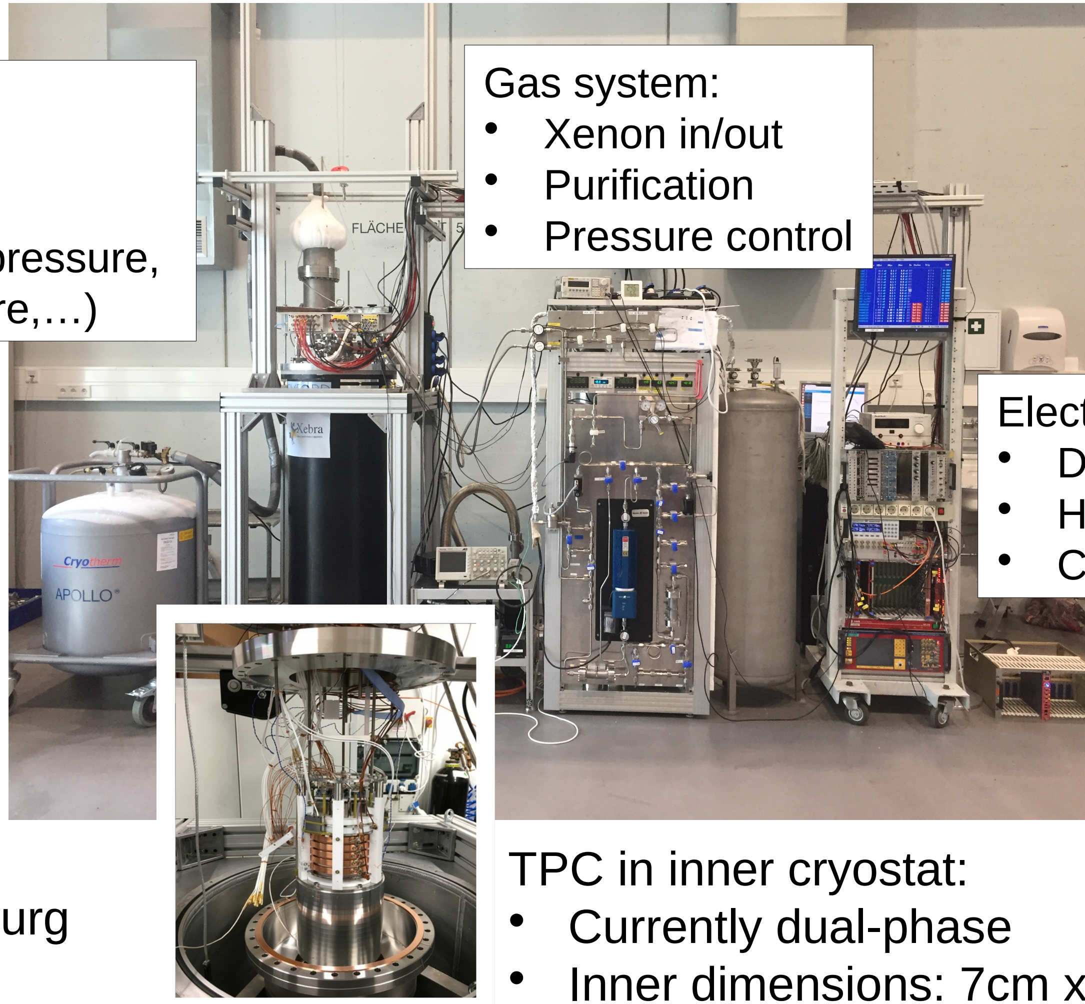
$$E = -\frac{\partial \phi}{\partial r}\overrightarrow{e_r} \approx \frac{\lambda}{2\pi\epsilon_0}\frac{1}{r}\overrightarrow{e_r}$$

- Strong e-field O(10^3 kV/cm)
- Has been demonstrated with one single wire (arXiv:1408.6206)
  Wire diameter 10 µm

Build a single-phase TPC with a full wire grid!

The XEBRA test platform

XEnon **B**ased **R**esearch **A**pparatus



Cryostat:
- Cooling
- LXe
- Sensors (pressure, temperature,…)

Gas system:
- Xenon in/out
- Purification
- Pressure control

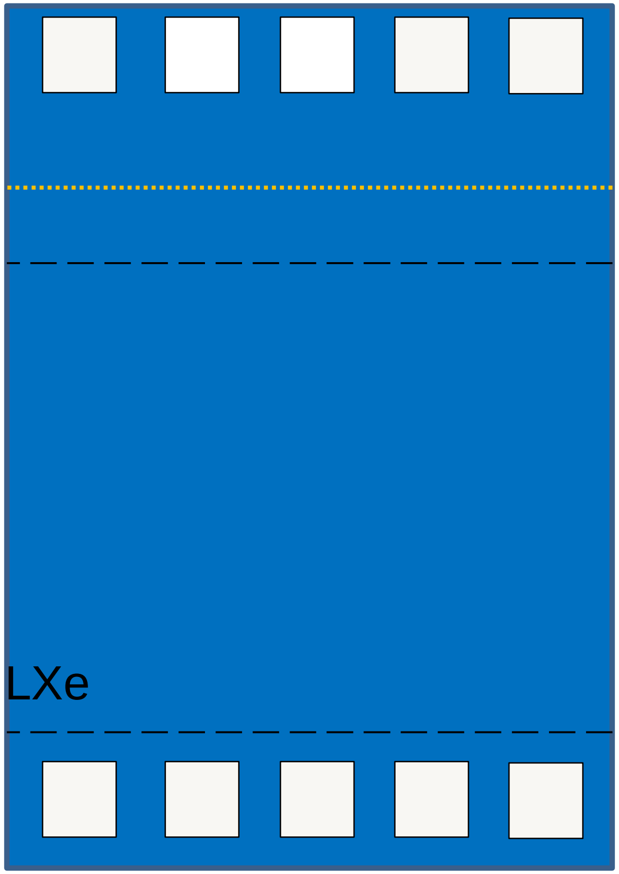
Electronics:
- DAQ
- High voltage
- Control

Located in Freiburg

TPC in inner cryostat:
- Currently dual-phase
- Inner dimensions: 7cm x Ø 7cm

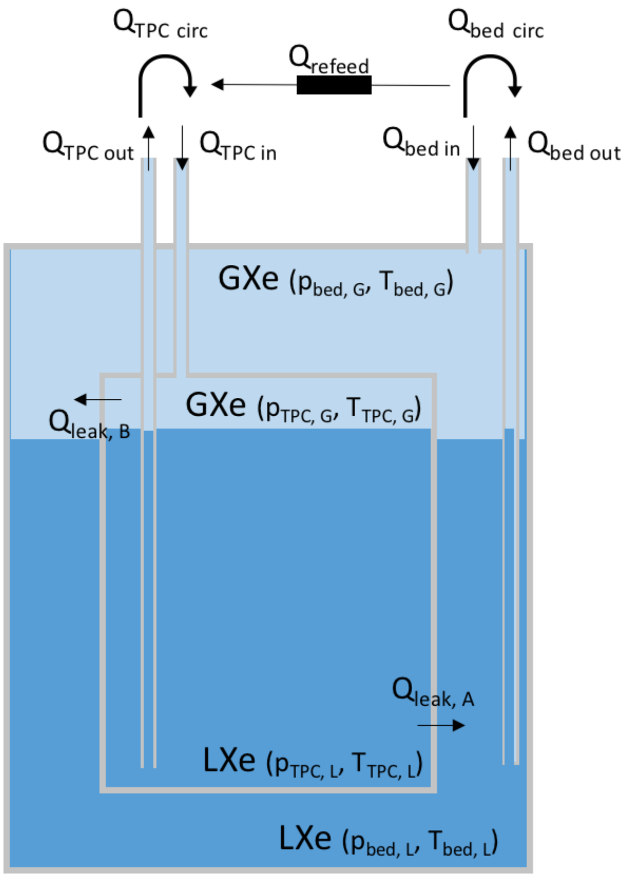
Ongoing R&D towards DARWIN

Single-phase TPC



Goal:
- S2 signal independent along x-y-plane

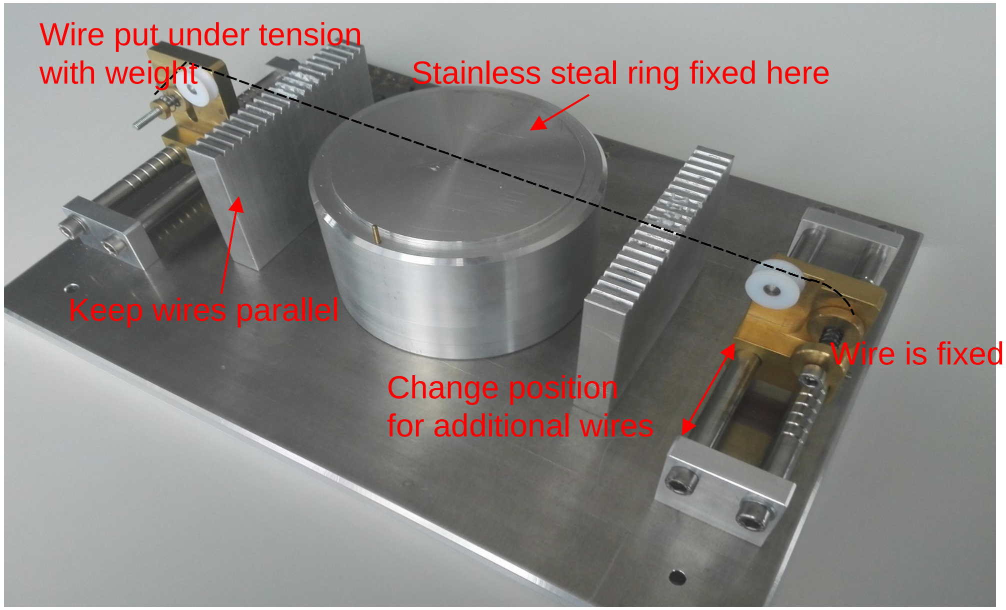
Hermetic TPC



(Sketch by Julia Dierle, AG Schumann, Uni Freiburg)

Goal:
- Reduce ^{222}Rn background down to 0.1 µBq/kg

Amplification with thin wires - status



(Bachelor thesis by Nico Strauß)

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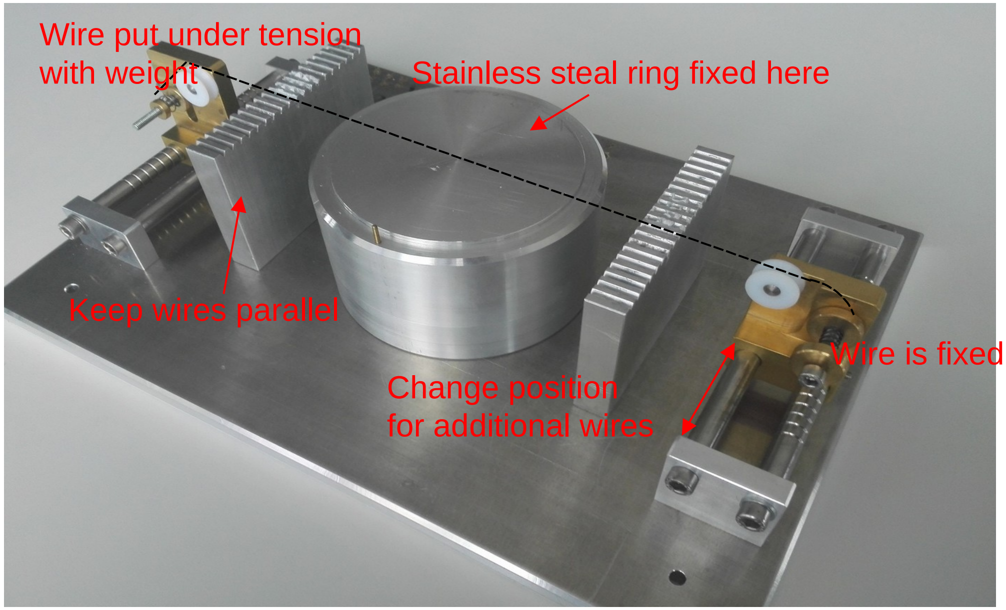

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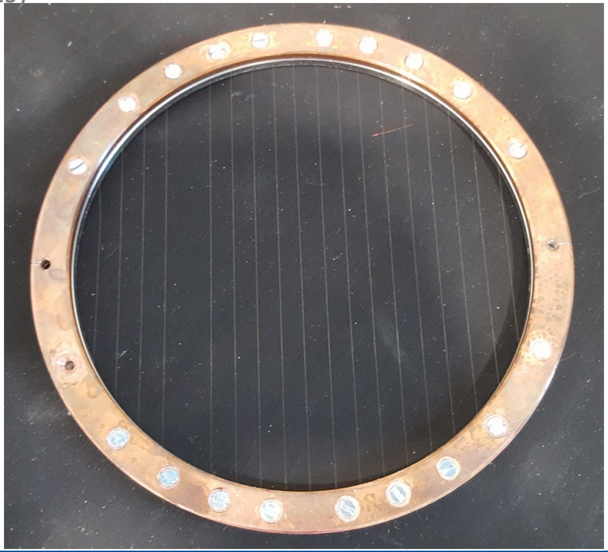

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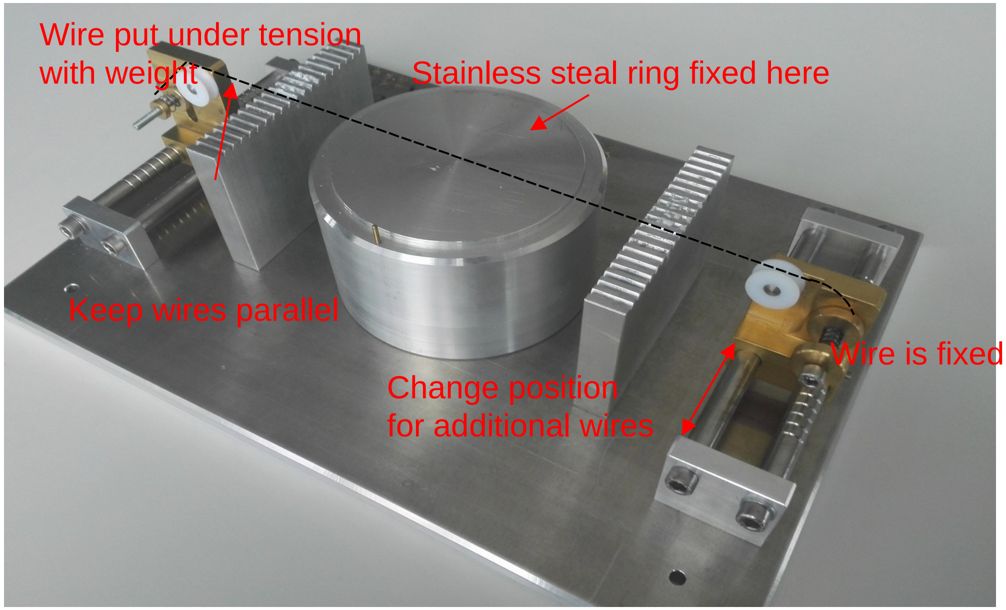

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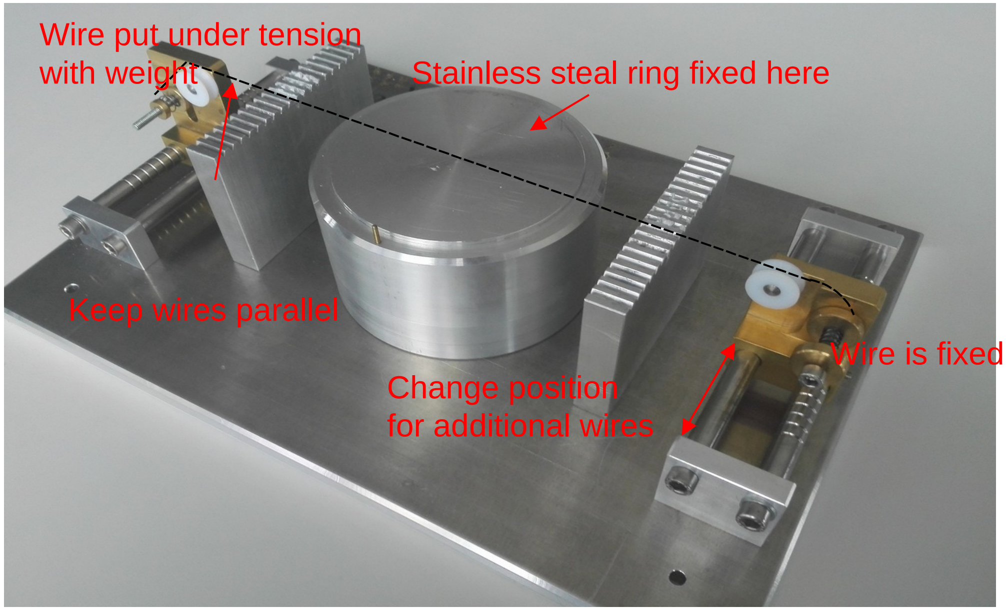
- Full grid consisting of 19 single wires built
- Fits into the TPC

Properties:

- Gold plated tungsten
- 10 µm diameter
- 5 mm distance in between

Amplification with thin wires - status



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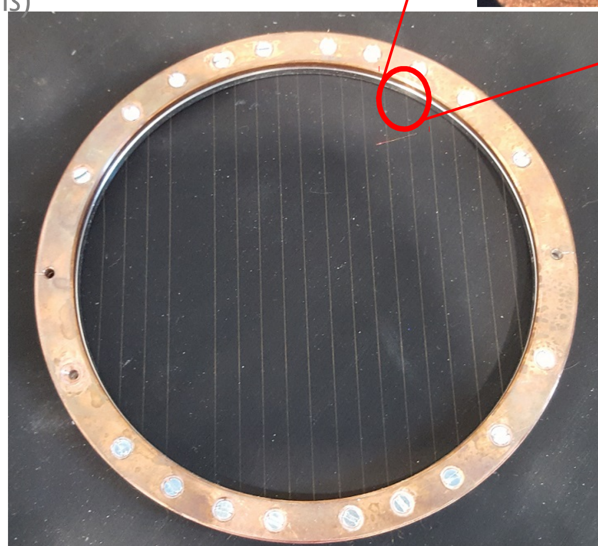
Wires under microscope
- Pressed into copper

- Full grid consisting of 19 single wires built
- Fits into the TPC



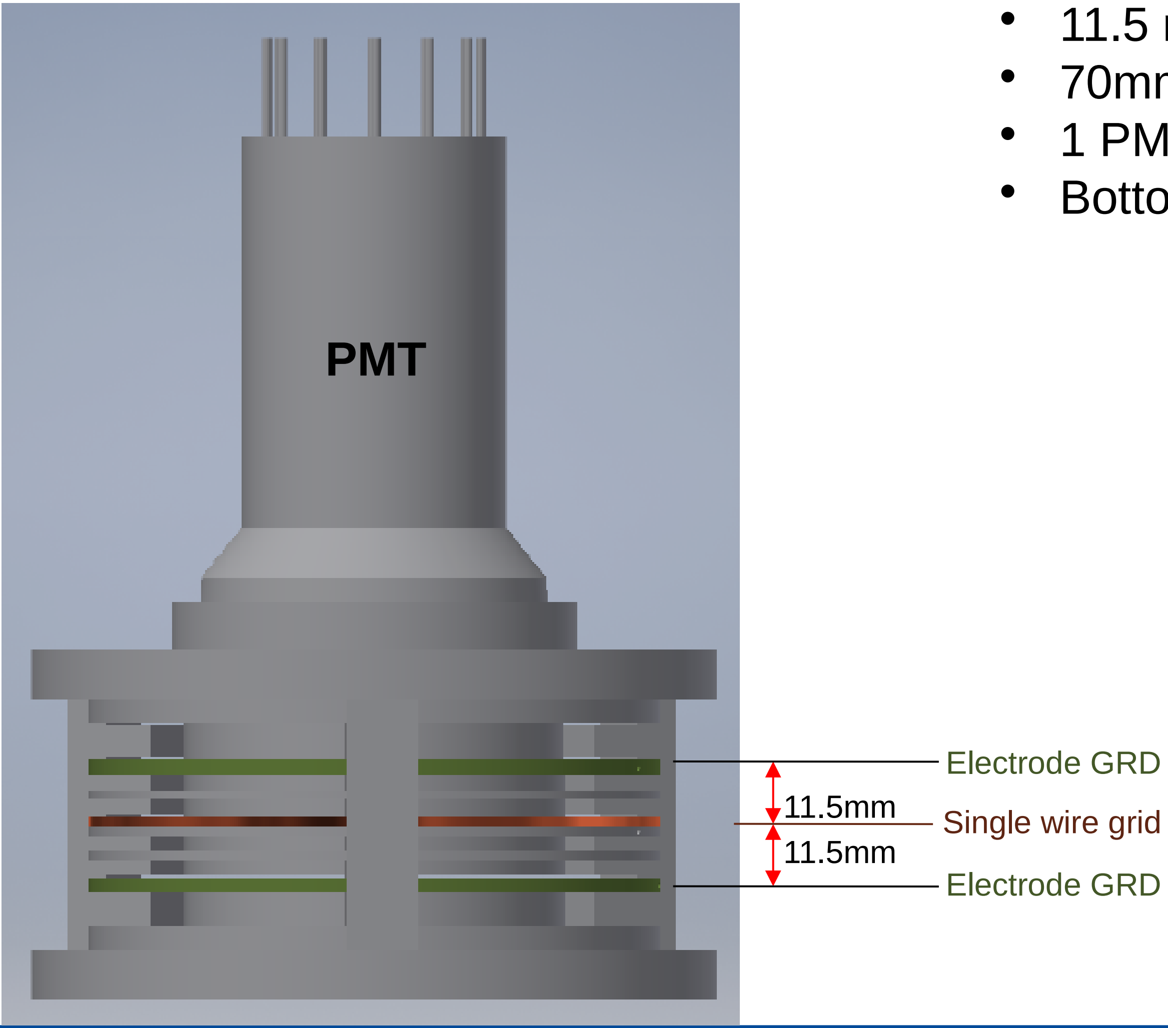
Tested cooling with liquid nitrogen:
- None of the wires broke

Properties:
- Gold plated tungsten
- 10 µm diameter
- 5 mm distance in between

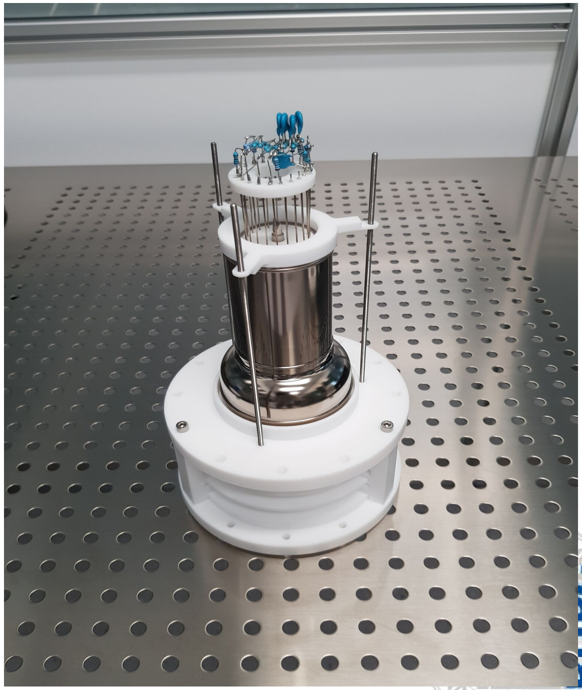
Diameter hair: 100 µm

Amplification with thin wires - status

Device for high voltage tests



- Teflon for high reflectivity
- 11.5 mm drift distance from each side
- 70mm inner reflector diameter
- 1 PMT top side (R11210)
- Bottom side is closed



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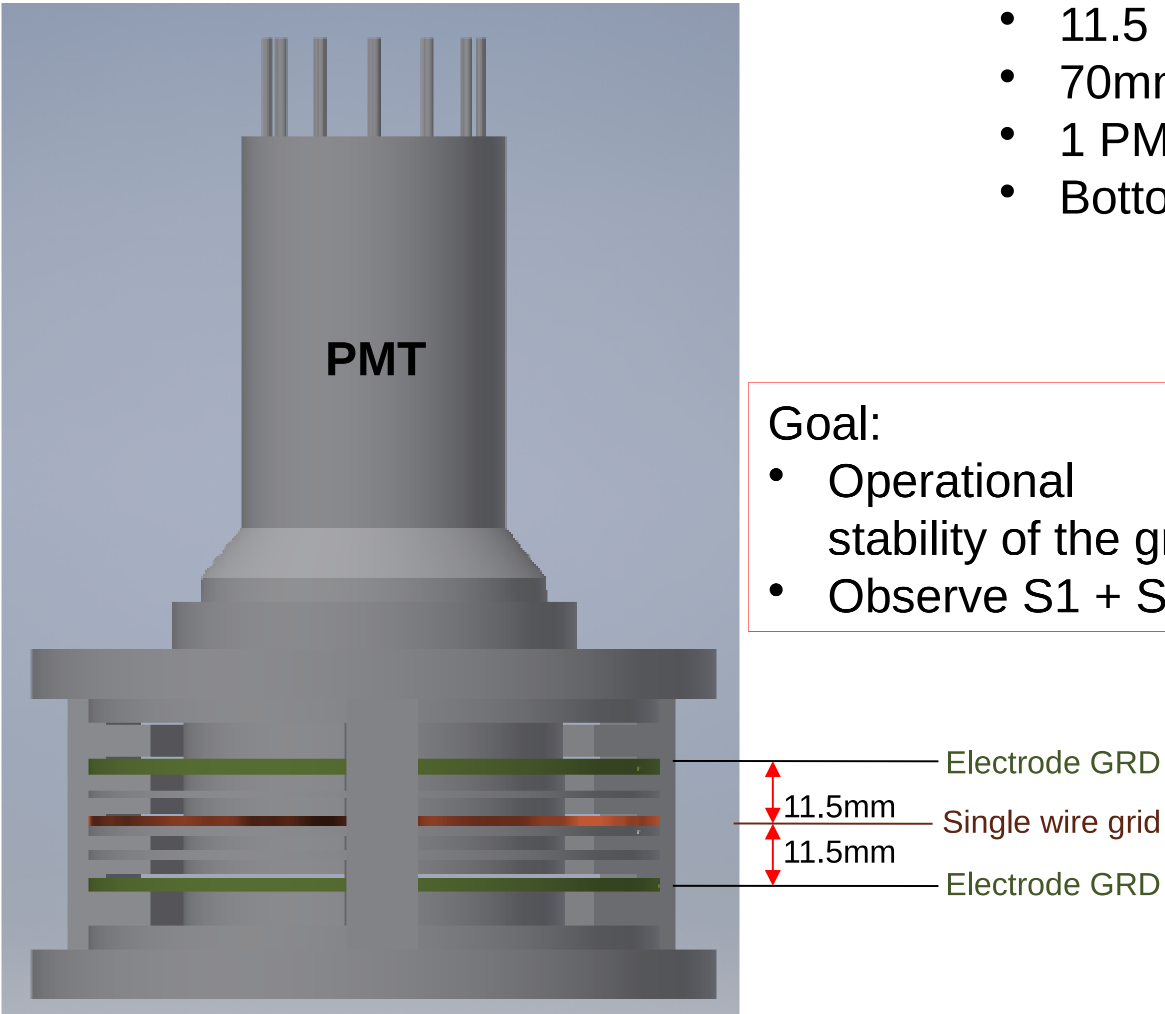
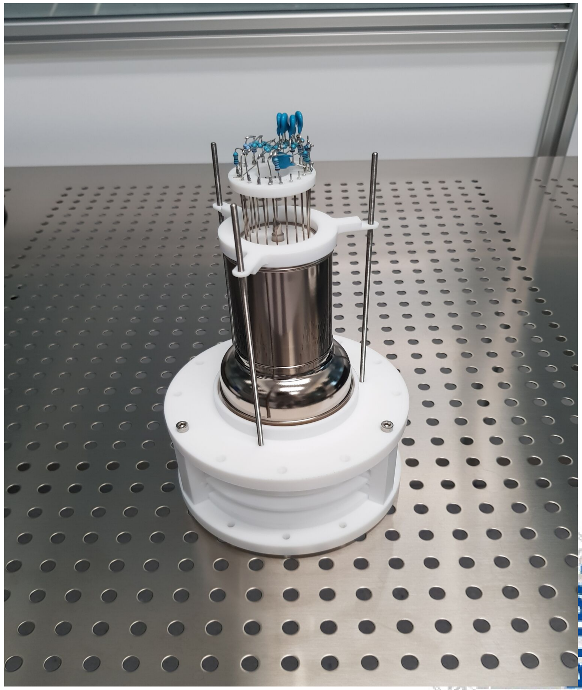


Goal:

- Operational stability of the grid
- Observe S1 + S2



Outlook and summary

What do we want:

- Single-phase TPC
  - S2 independent of x-y-plane
- Compare dual-phase TPC with single phase mode
  - Contestable?
- Understand statistics of amplification at thin wires

What do we have:

- Single wire grids are stable under effect of cooling
- HV test device is ready to maintain

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Chances:

- Reduce intrinsic background of PMTs by self shielding of LXe?
- Impact on S1 threshold?
- Impact on discrimination of electronic and nuclear recoils?

What do we have:

- Single wire grids are stable under effect of cooling
- HV test device is ready to maintain