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Freiburg R&D activities:

PANCAKE- large scale test platform and Single Phase TPC

Nagoya Workshop, February 14th - 16th, 2024

Julia Müller, University of Freiburg
julia.mueller@physik.uni-freiburg.de

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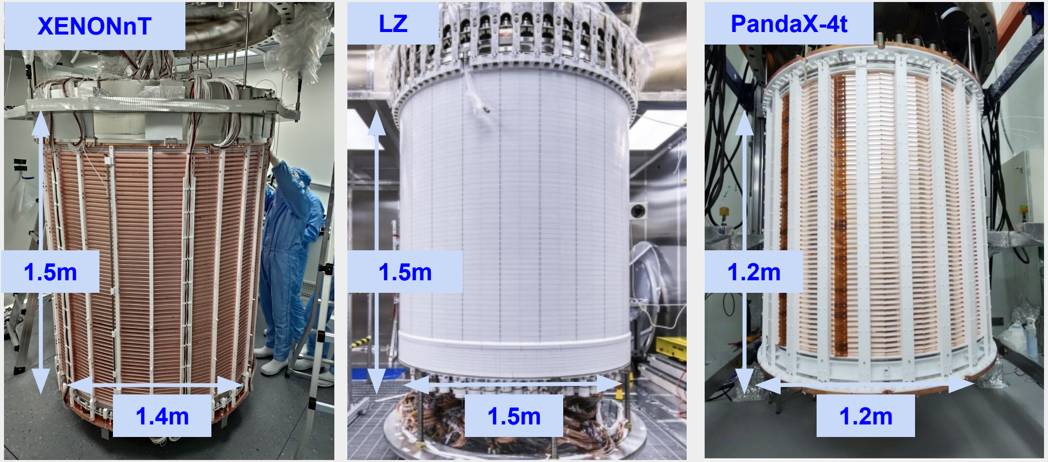
Current LXe Dual-Phase Detectors & the **Future**

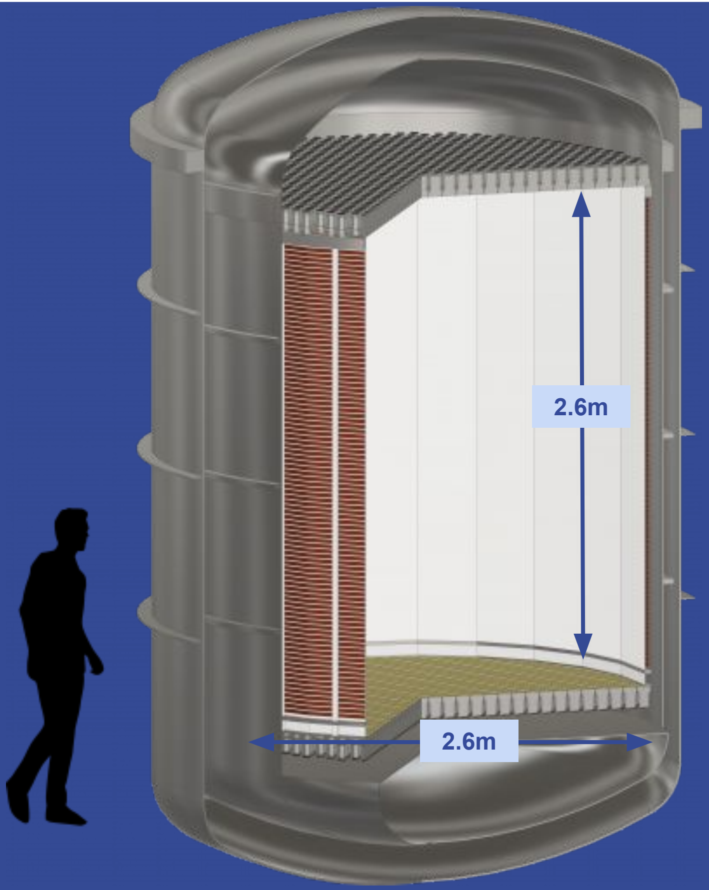


Future:

e.g. DARWIN (arXiv:1606.07001)

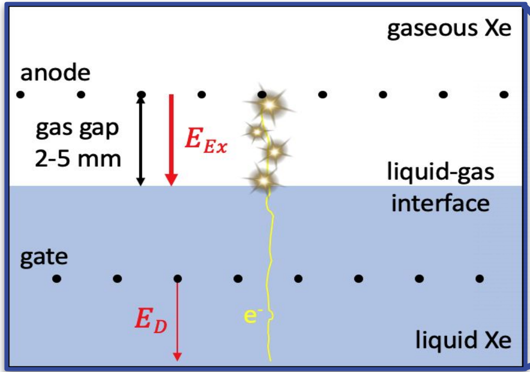
- LXe based TPC with 2.6m
- total xenon mass of 50t at -100°C
- ultra-low background

→ **technical realization will be challenging!!**

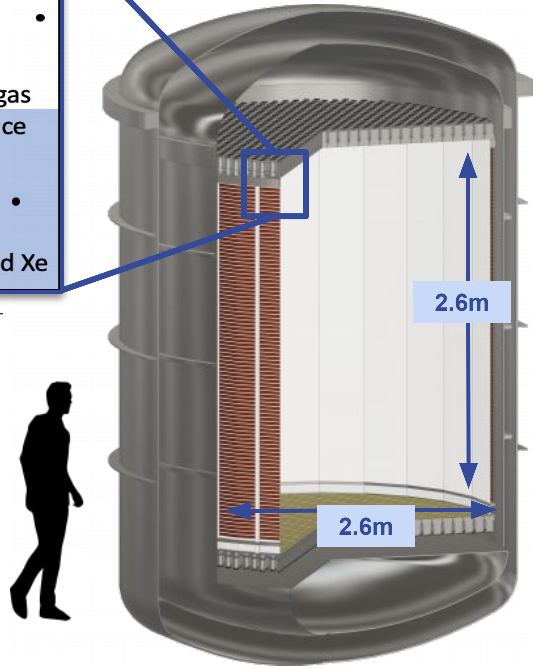


One challenge: **Electrodes**

- top stack electrodes:
  extraction and amplification field
- cathode and gate create drift field
- high optical transparency necessary
- more material →more background

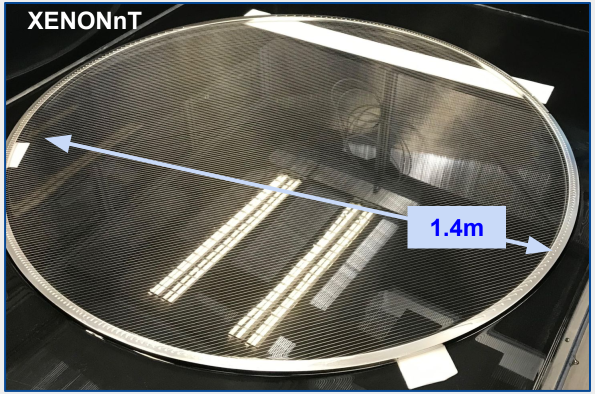


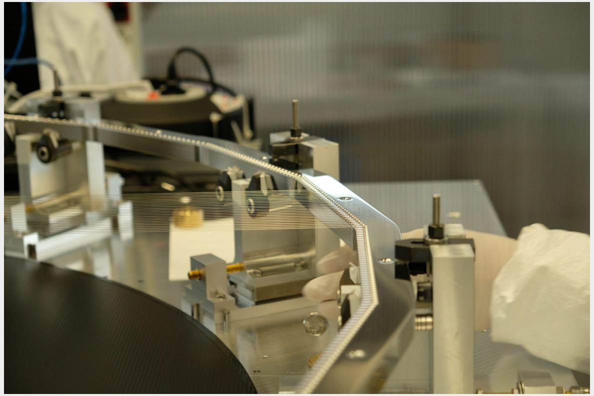
F. Kuger *et al* 2022, arXiv:2112.11844



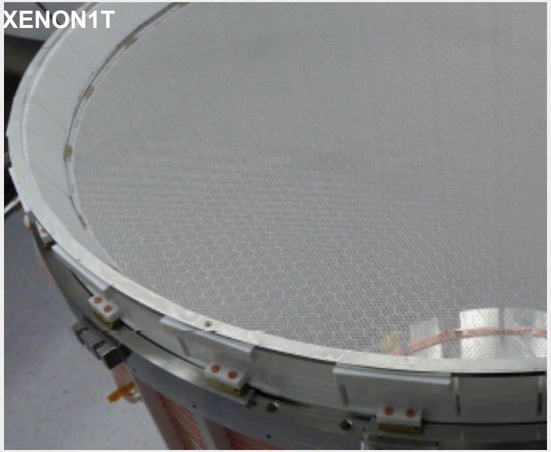
All electrodes - but different technologies

Parallel wires

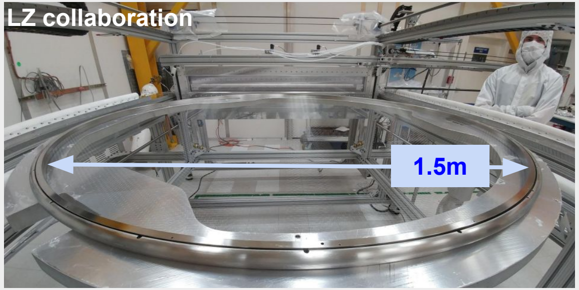




Etched Mesh



Woven mesh



Many more ideas on electrodes design!

All electrodes - but different technologies

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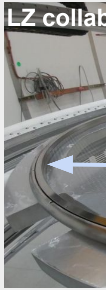
Para

Wove



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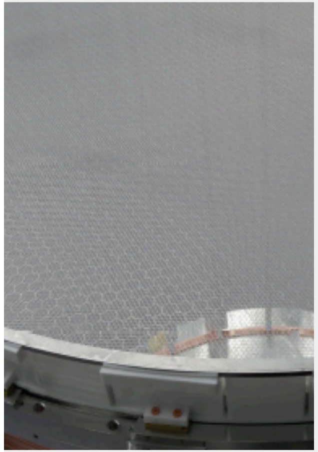

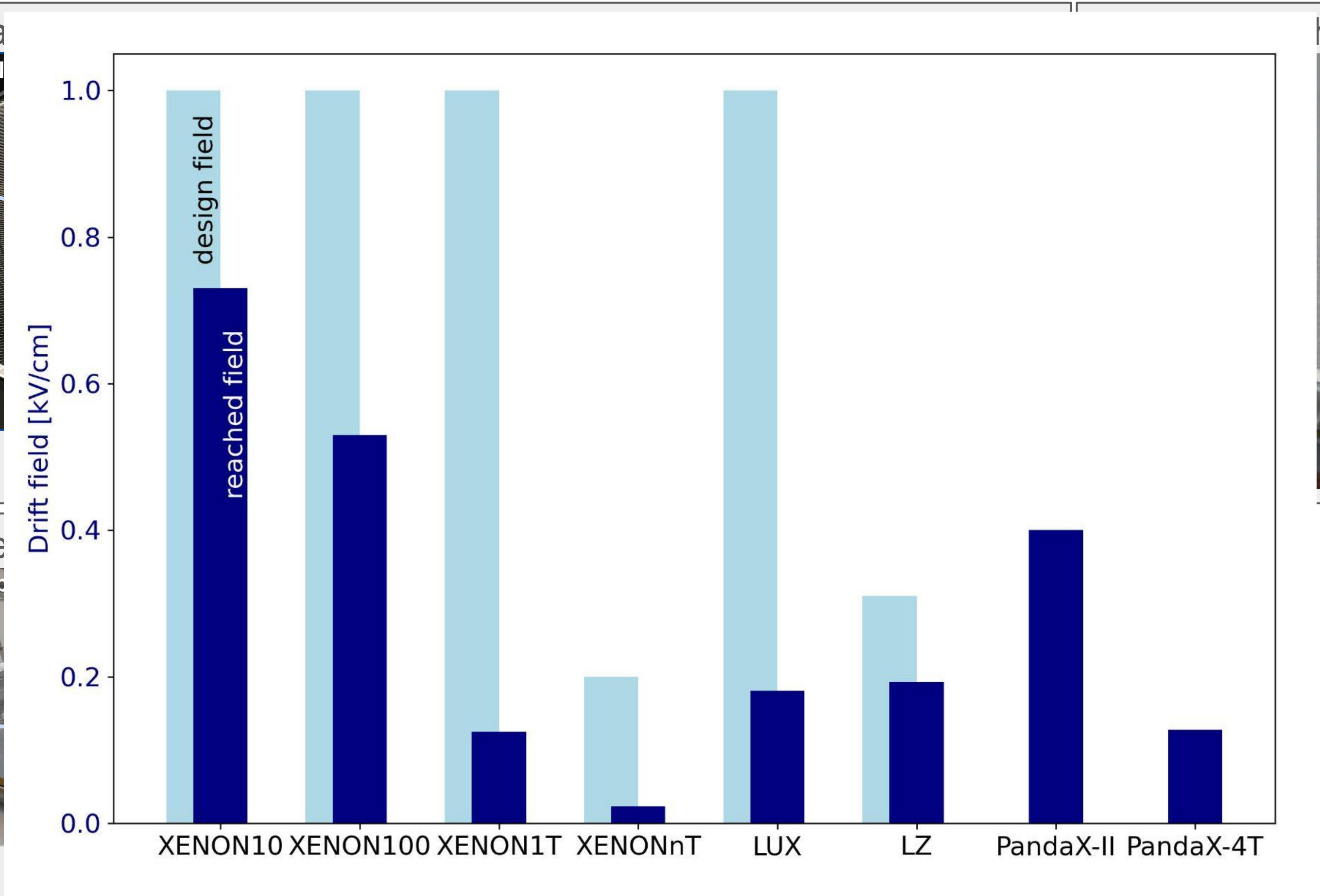

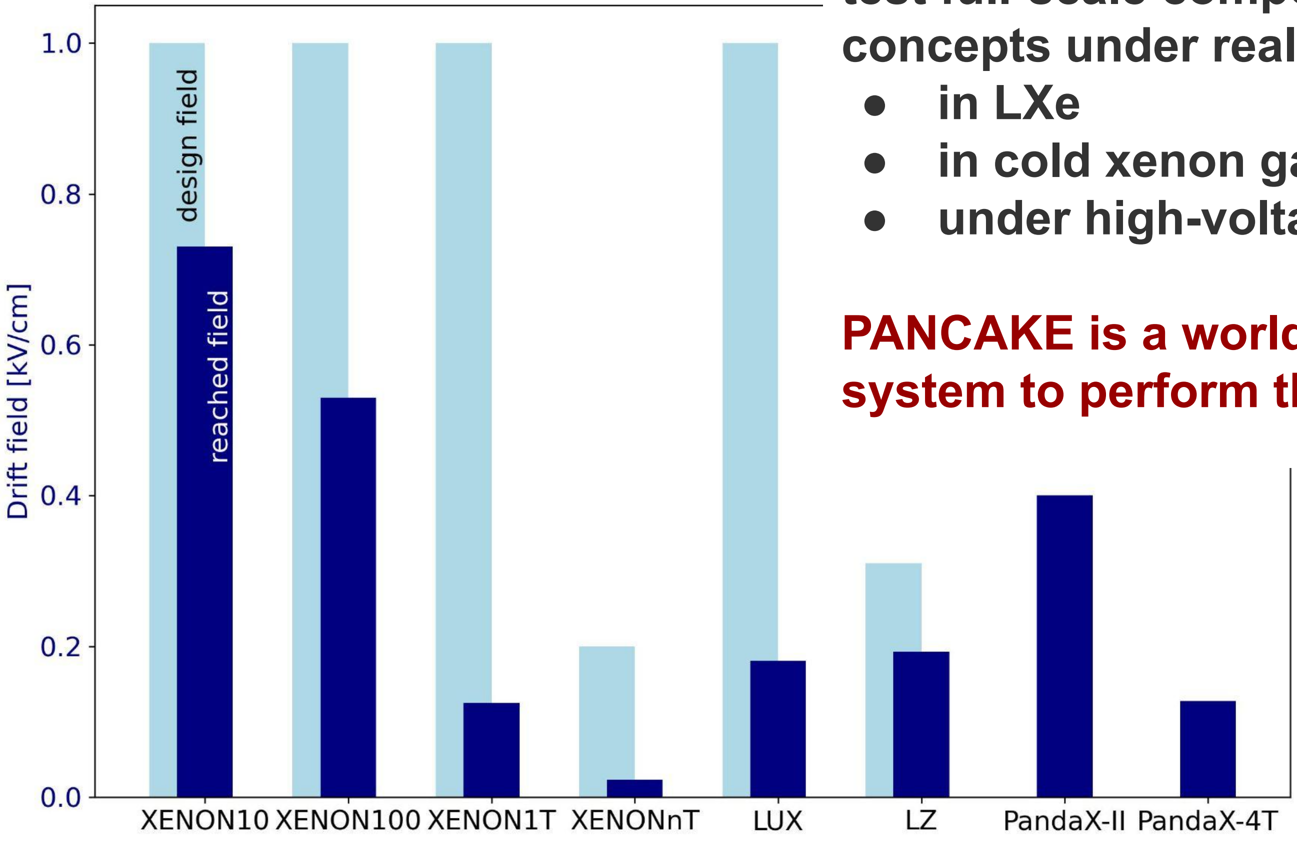

test full-scale components and new concepts under real conditions:

- **in LXe**
- **in cold xenon gas**
- **under high-voltage**

PANCAKE is a worldwide unique system to perform these tests

Test Platform PANCAKE

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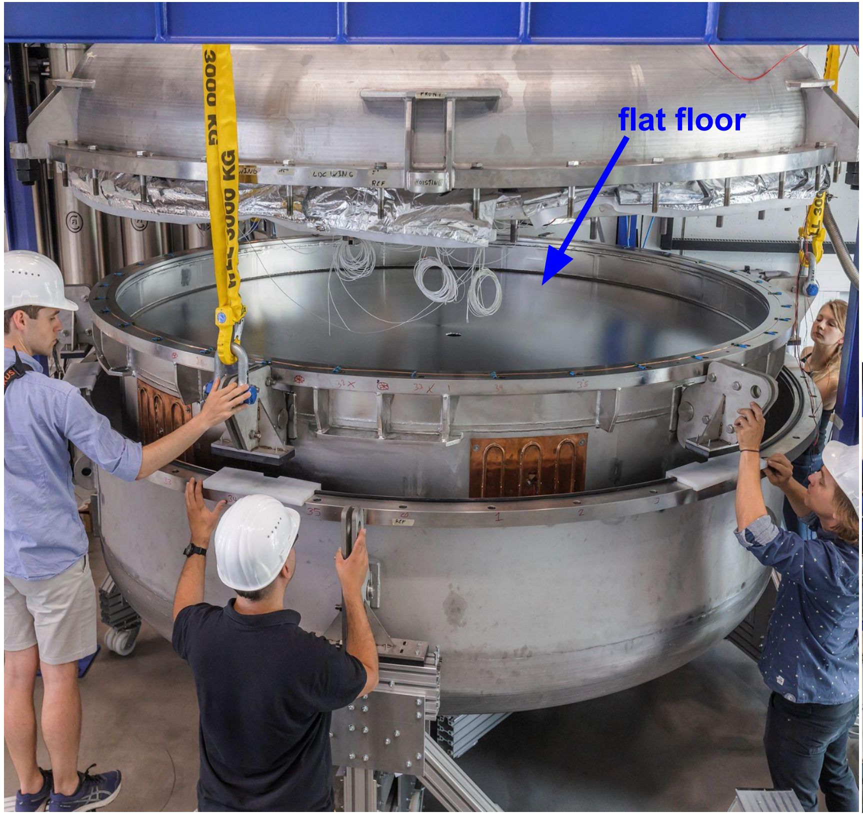
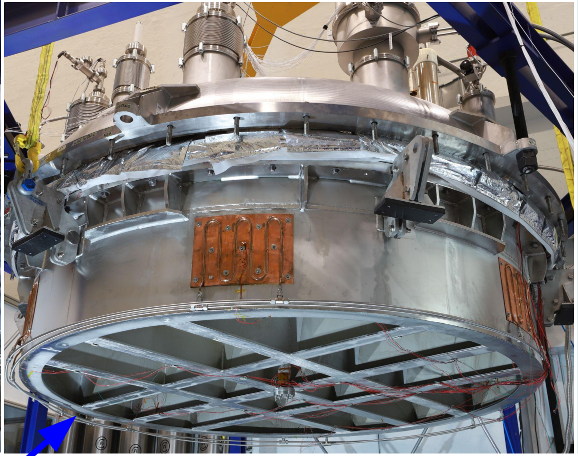
- 5t stainless steel
- double-walled cryostat

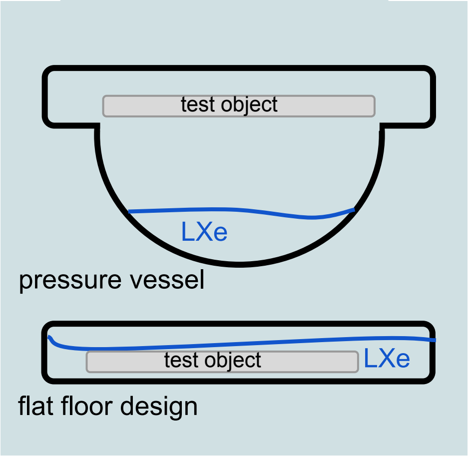
Test Platform PANCAKE



- 5t stainless steel
- double-walled cryostat
- **flat-floor design → save xenon**
- 400kg xenon (inventory)
  - liquid level: 2cm on 2.7m
  - liquid level: 6cm on 1.5m
- storage capacity: 600kg, expandable

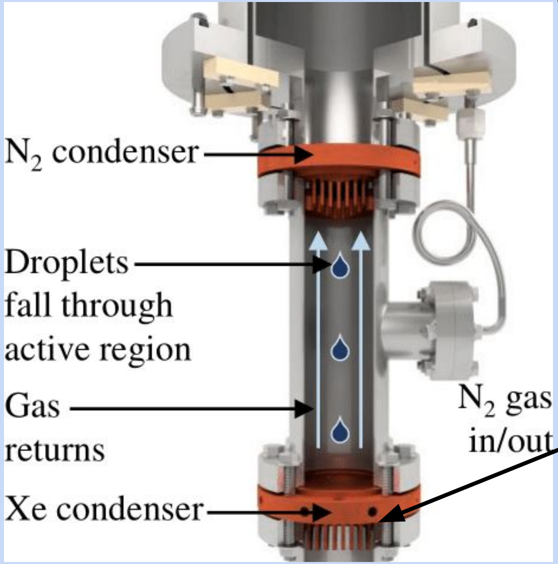


stiffening structure for flat floor



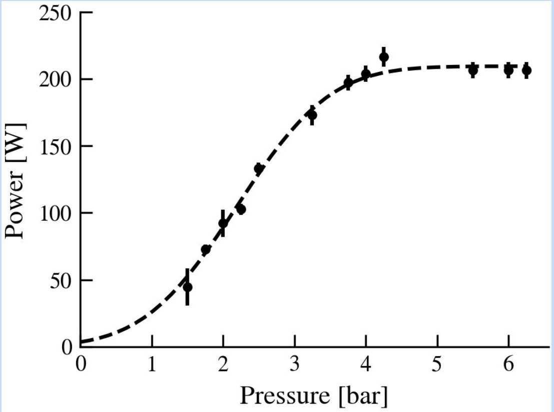

250 k
APOLLO

Cooling with liquid nitrogen



Thermosyphon:

- three regions
- up to ~ 200W adjustable cooling



Pre-cooling system of the inner cryostat:

- 6 copper plates with pipes
- cooling power of several kW

Heat load @ -100°C < 100 W

Current Instrumentation

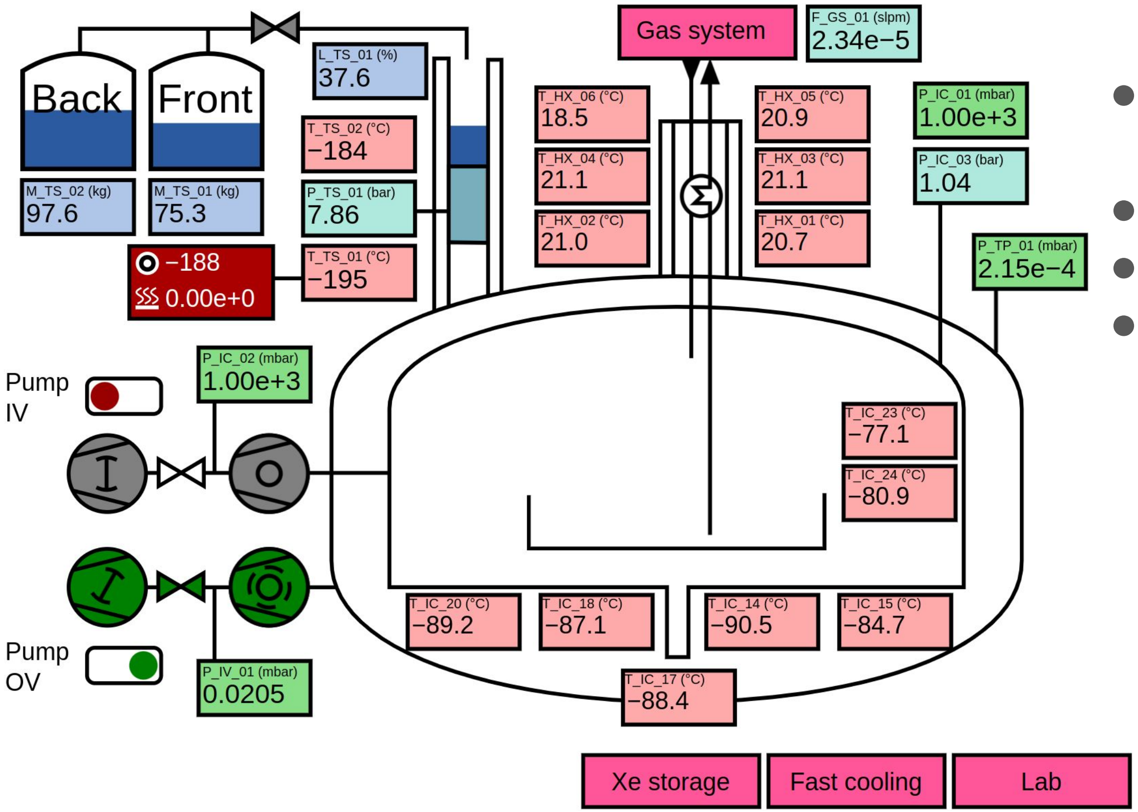
PMT array of 19 x 3” Hamamatsu R11410-21 PMTs

heated cameras for cold xenon gas

level meter for xenon filling height

…plus PT100s, pressure sensors, scales, load cells

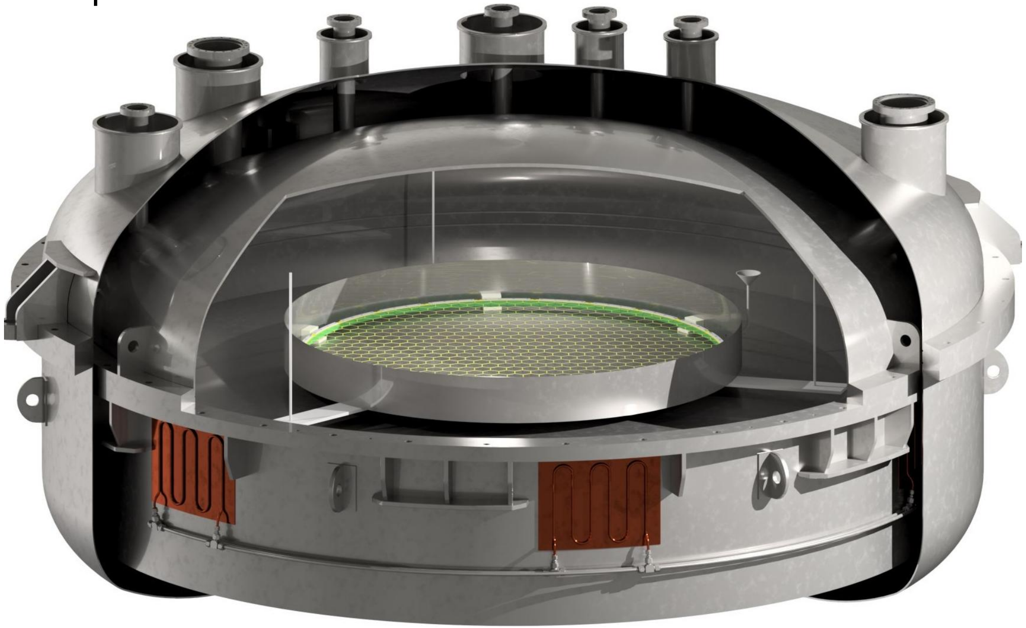
Slow Control



- home build slow-control software Doberman
- used for 4 of our experiments
- Doberman on github
- arXiv: 1607.08189

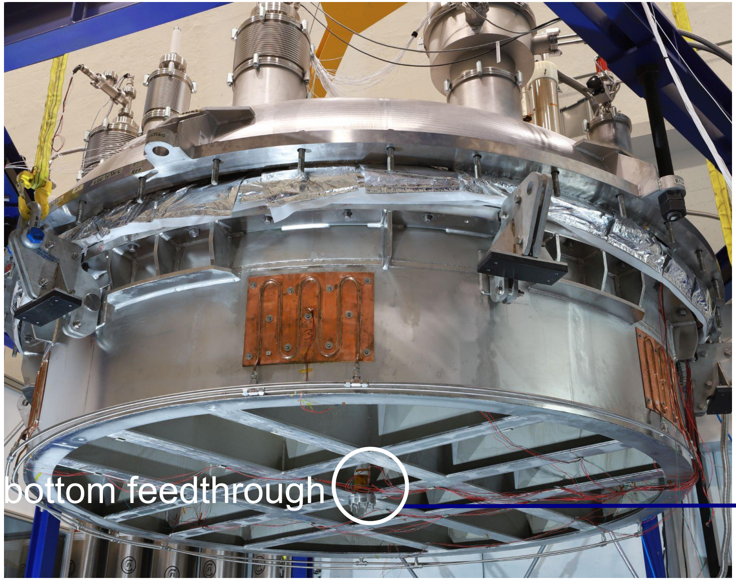
Commissioning of the Platform

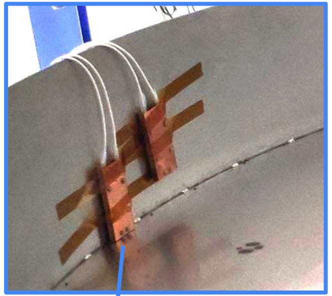
- validate seal tightness of the inner cryosat, several seals tested → **copper-wire seal**
- cooling and liquefaction ability
- test working principle of open-top vessel and liquid level

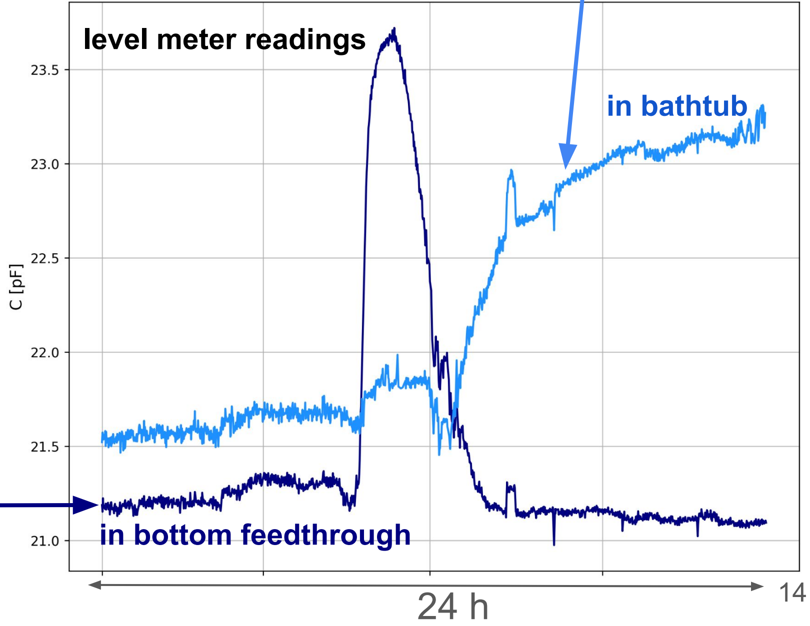


Commissioning with 300kg Xenon

- first filling 50kg xenon → successful!
- started run with pre-cooling inner vessel → minimize ΔT inside
- started filling once floor at -100°C
- @1.6 bar pressure → liquefied into cold bottom feedthrough of inner vessel
- change to thermosyphon cooling → fill bathtub

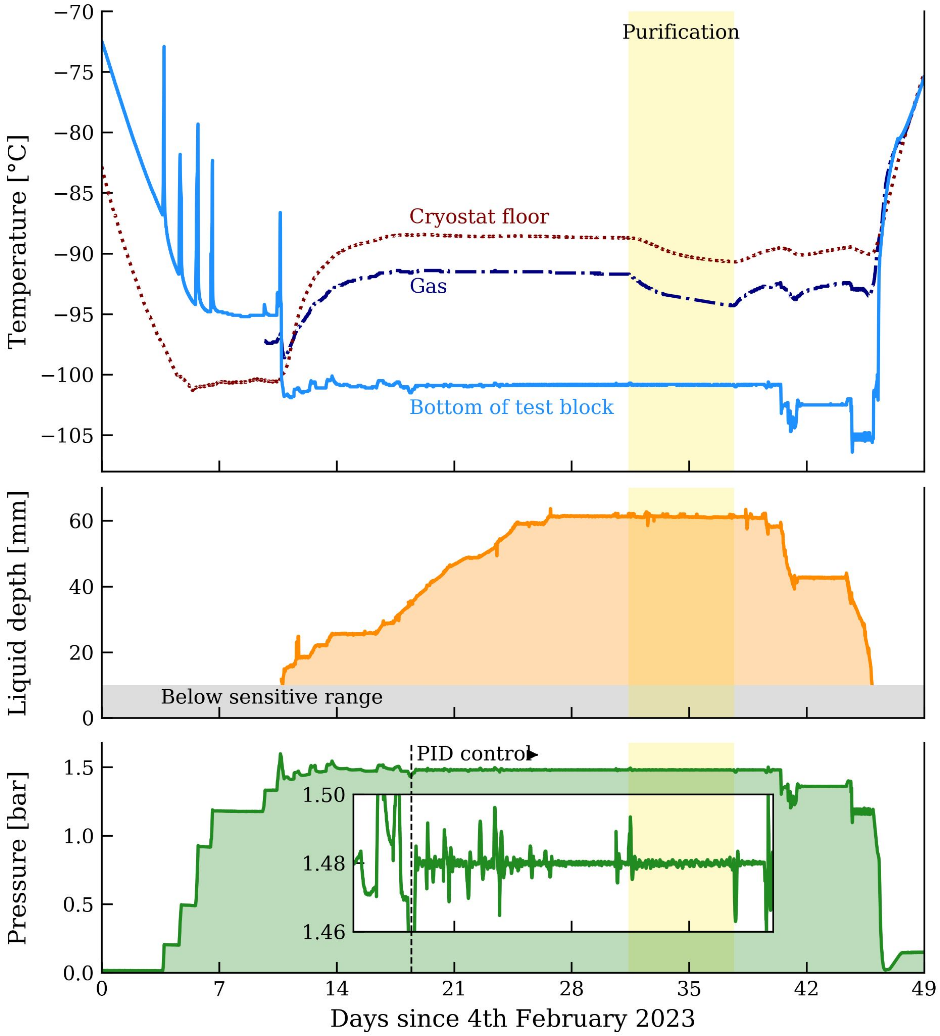






300kg Xenon Run

- filling over 4 weeks at final flow rate of 4.7slpm and pressure 1.48bar
- limit in cooling power due to surface area of copper cold head
- ΔT~ 10K



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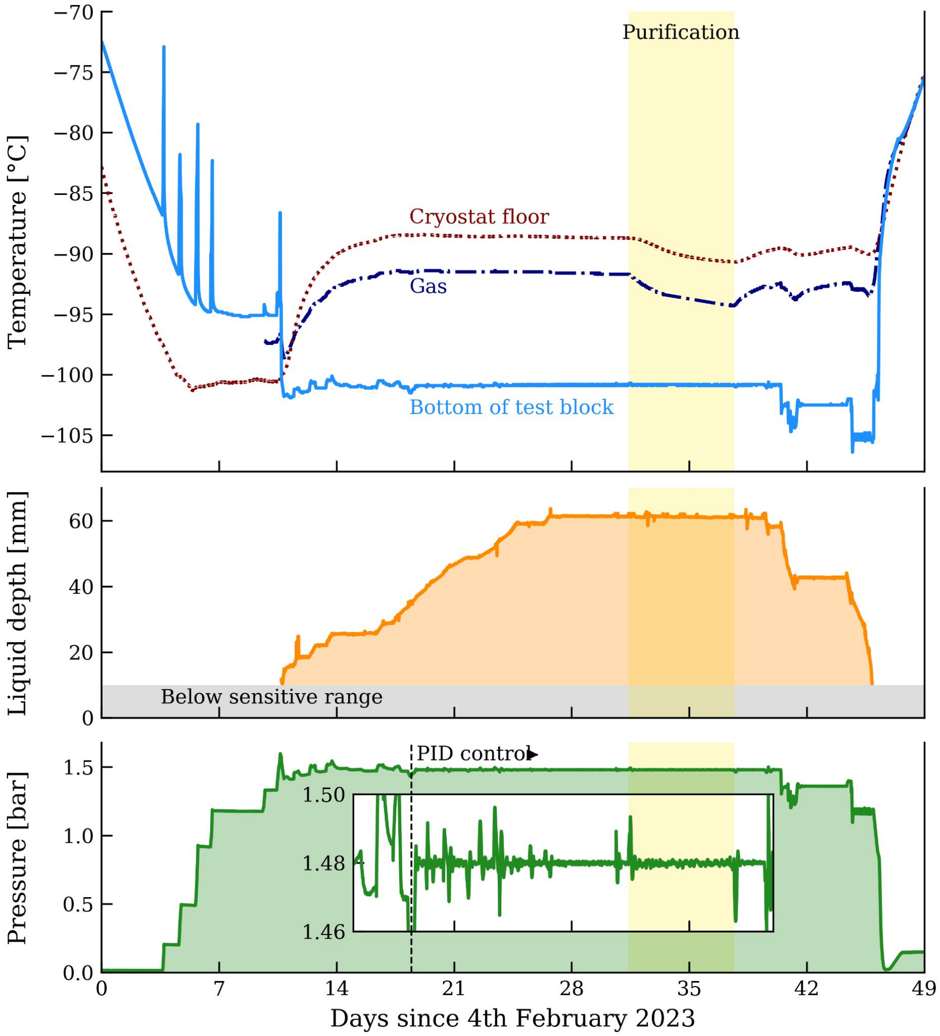
- limit in cooling power due to surface area of copper cold head
- ΔT~ 10K while gas is actually warmer

- liquid depth of ~ 60mm on 1.46m diameter

- maximum purification flow: 15 slpm
- great pressure stability during filling and cycling thanks to active pipeline control of thermosyphon temperature



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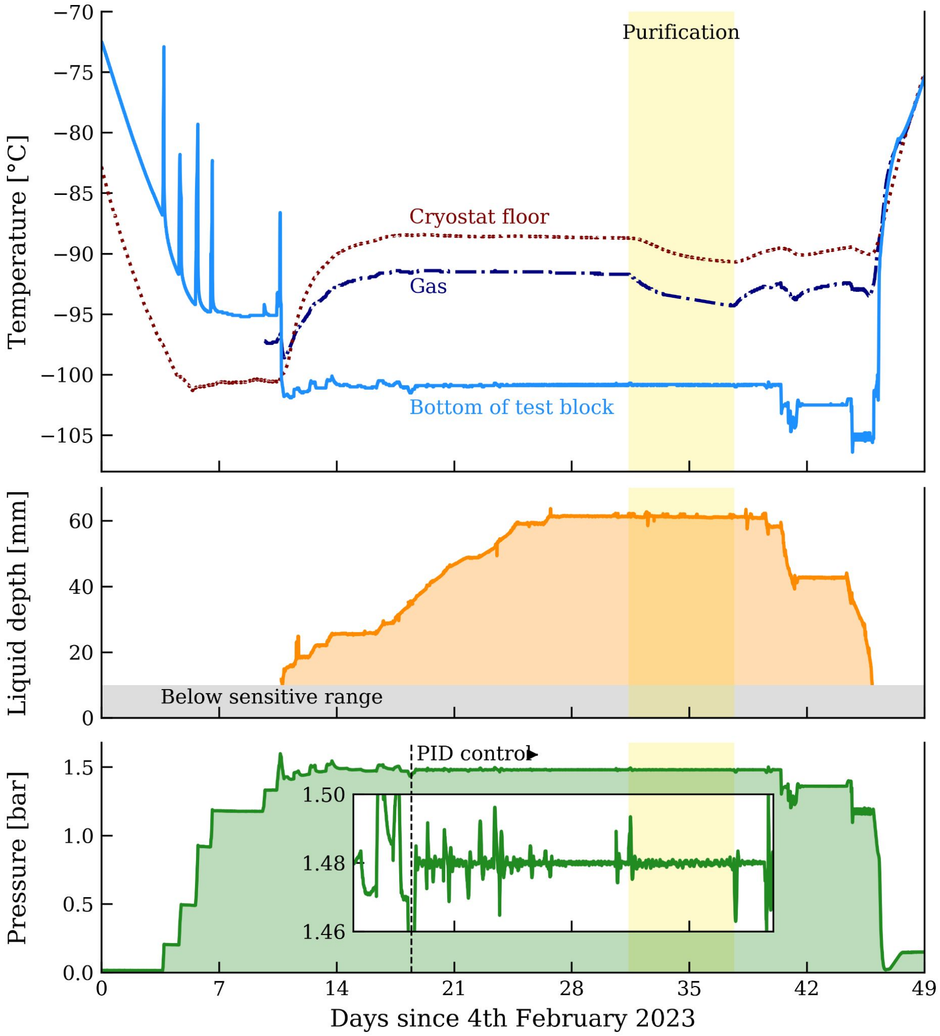
- recuperation of entire xenon over 7 days by cryogenic pumping

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- 2.7m wide test platform
- flat floor design
- successfully commissioned
- arXiv:2312.14785
- working on electrodes
- to be tested in PANCAKE

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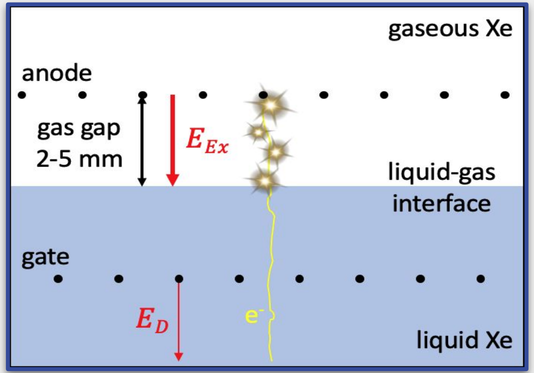
Freiburg R&D activities:

PANCAKE- large scale test platform and
Single Phase TPC

Dual Phase TPC:

- S2 signal generation
  - liquid level control
  - electrostatic sag
  - liquid xenon waves
- total internal reflection (reduced LCE)
- delayed electron extraction at liquid-gas interface

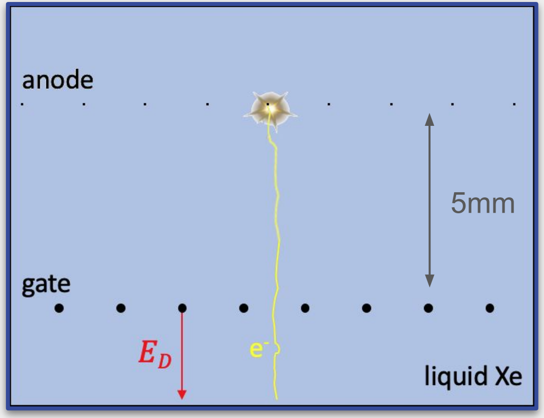


F. Kuger *et al* 2022, arXiv:2112.11844

Single Phase TPC:

fill entire TPC with liquid xenon → avoid challenges

- create proportional scintillation in liquid xenon
- requires high fields > 400kV/cm (E.Aprile, 2014, arXiv: 1408.6206)
- thin anode wires at moderate voltages



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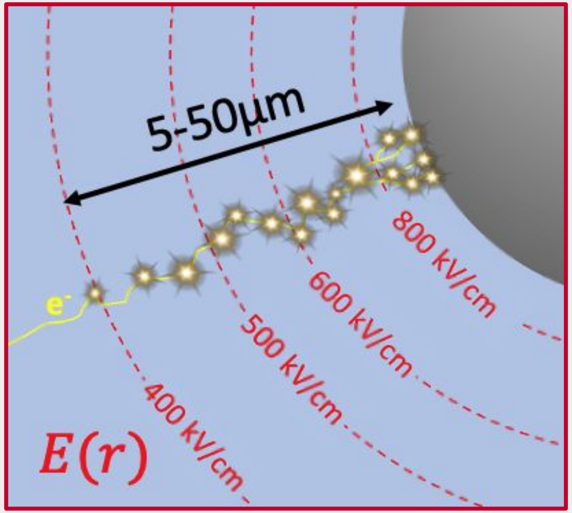

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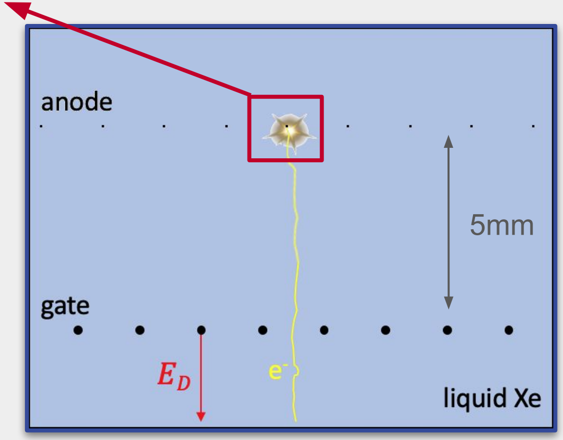
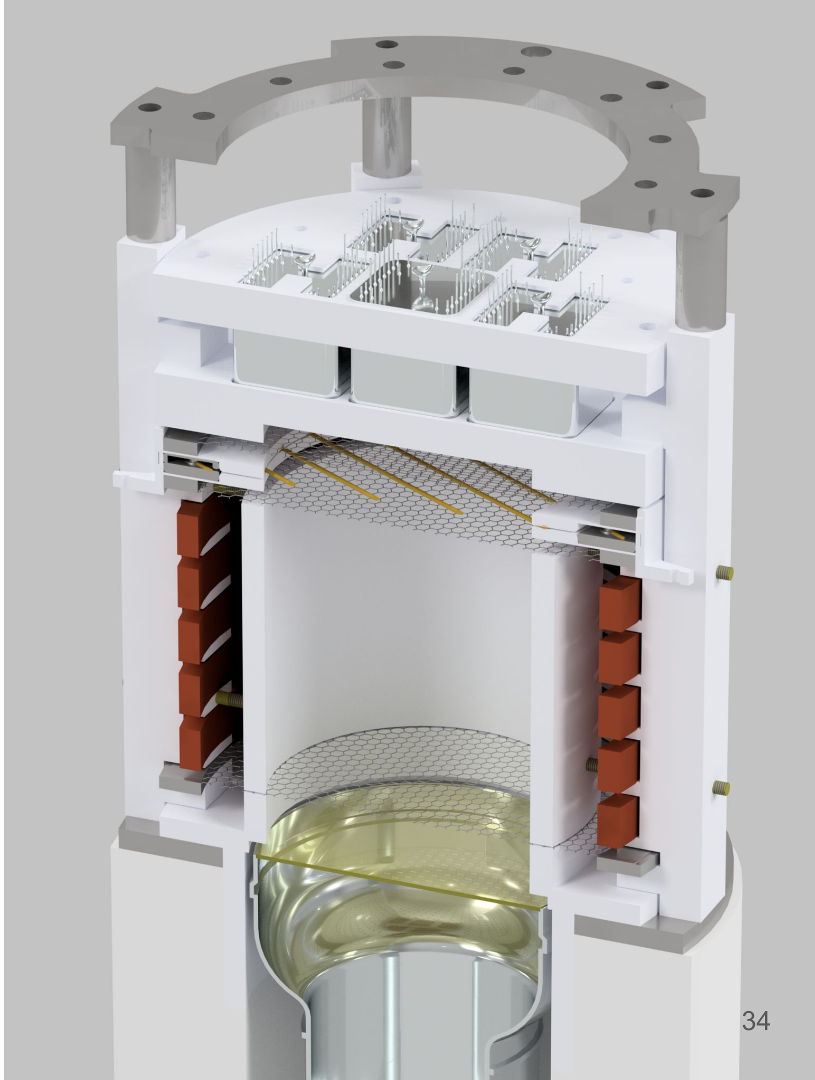


F. Kuger *et al* 2022, arXiv:2112.11844, (modified)

Freiburg's Single Phase TPC

- Dimensions:
  - 7cm height (cathode to gate)
  - 7cm diameter
  - 700g xenon target
  - 10kg total xenon mass
- top array of 7 x (1" x 1") PMTs
- 1 x 3" PMT at the bottom
- was operated as dual-phase TPC



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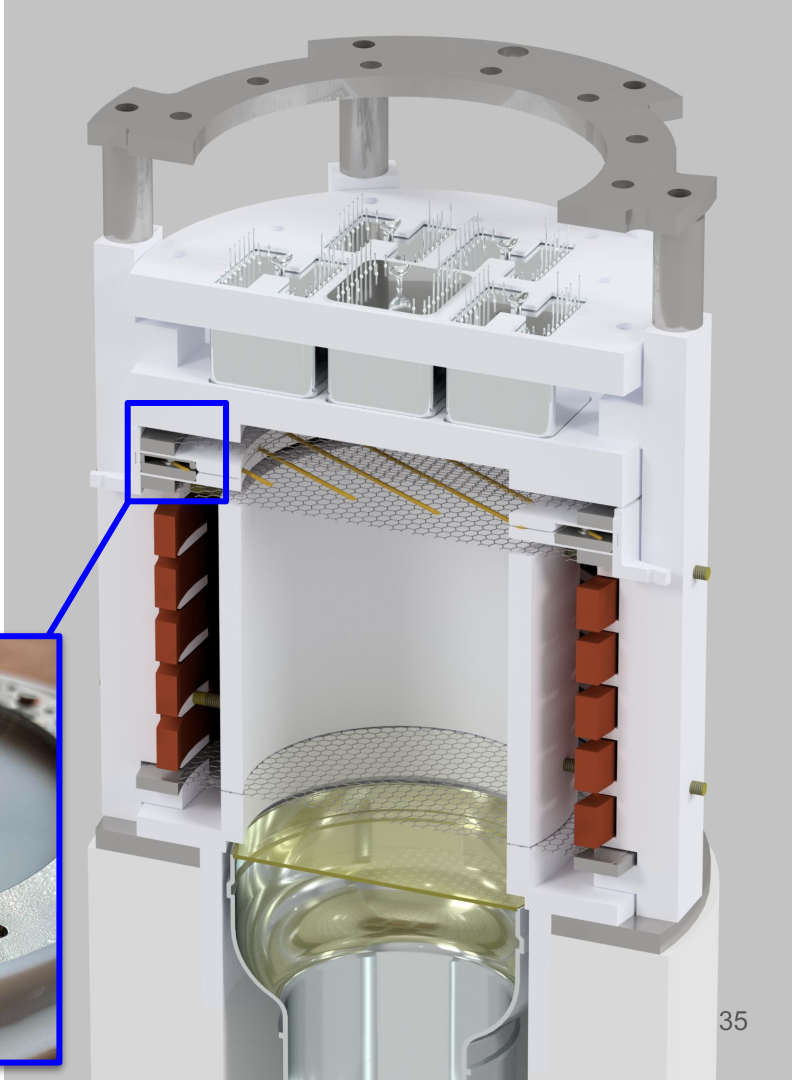
Top Stack Design

- **cathode/screen/gate:** etched stainless steel hex.mesh (t=150um)
- **anode:**
  - Au-plated tungsten wire (California Fine Wire)
  - wire ∅ = 10um
  - pitch p_A = 10mm
  - thin wires electric fields > 400kV/cm at moderate voltage

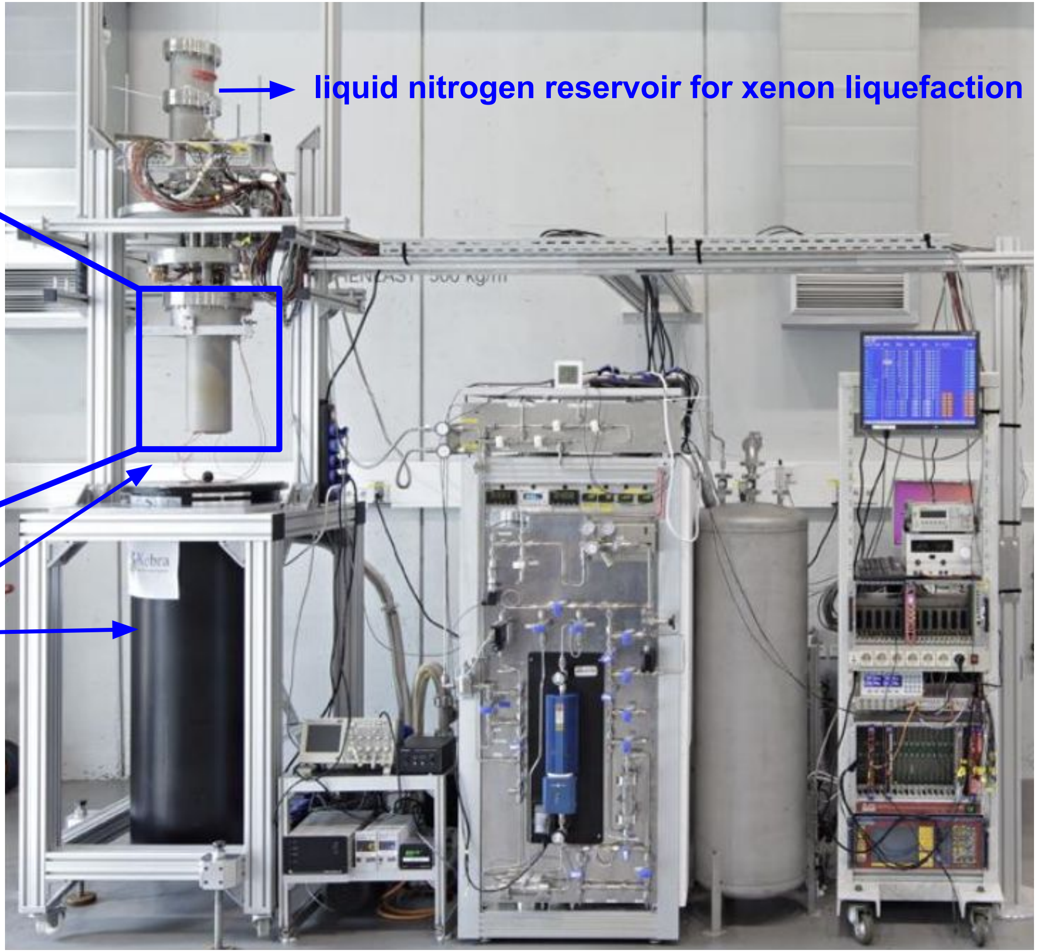
- anode-gate potential differences ΔV_{AG} in range (3.0 - 4.4)kV applied
- applied drift field E_d = 470 V/cm

ΔV_{AG} [kV]	Surface Fields [kV/cm]
3.0	731
3.4	828
3.8	925
4.2	1023
4.4	1071



XeBRA Platform

arXiv:2208.14815



liquid nitrogen reservoir for xenon liquefaction

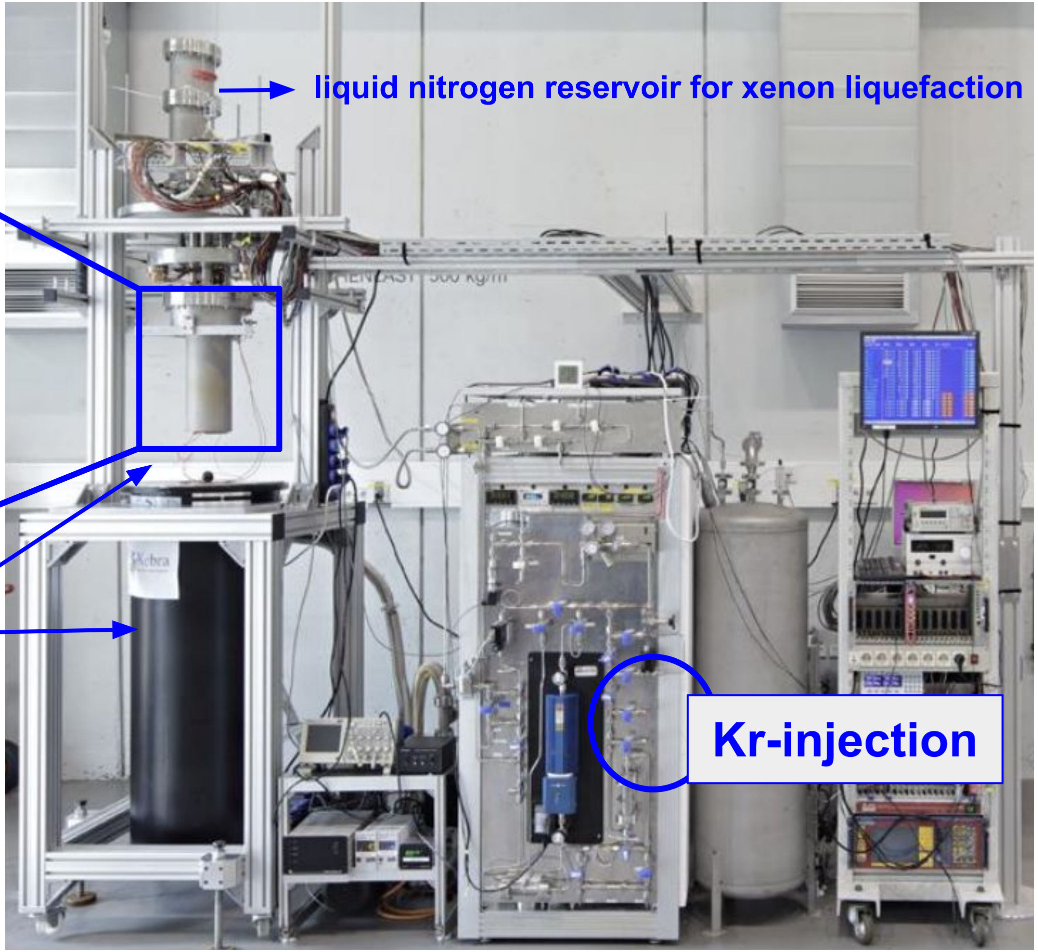
data
acquisition

double wall cryostat
vacuum and mylar foil insulated

gas purification system

XeBRA Platform

arXiv:2208.14815

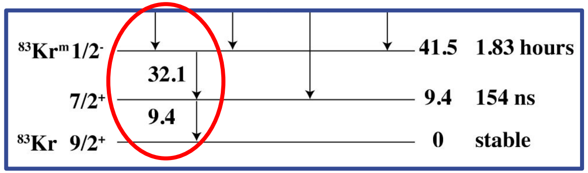


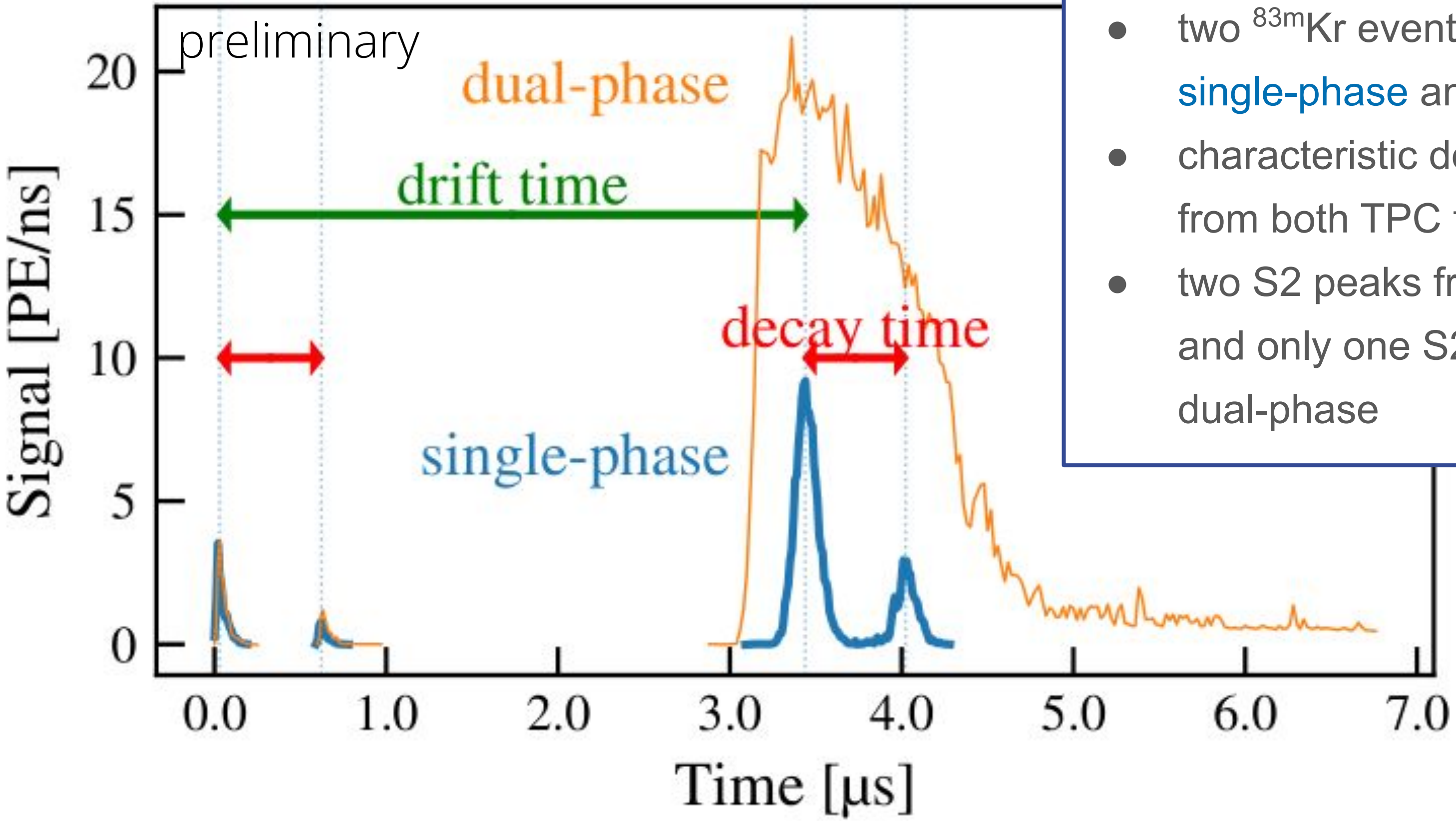
data acquisition

double wall cryostat
vacuum and mylar foil insulated

gas purification system

Detector Characterisation with ^{83m}Kr



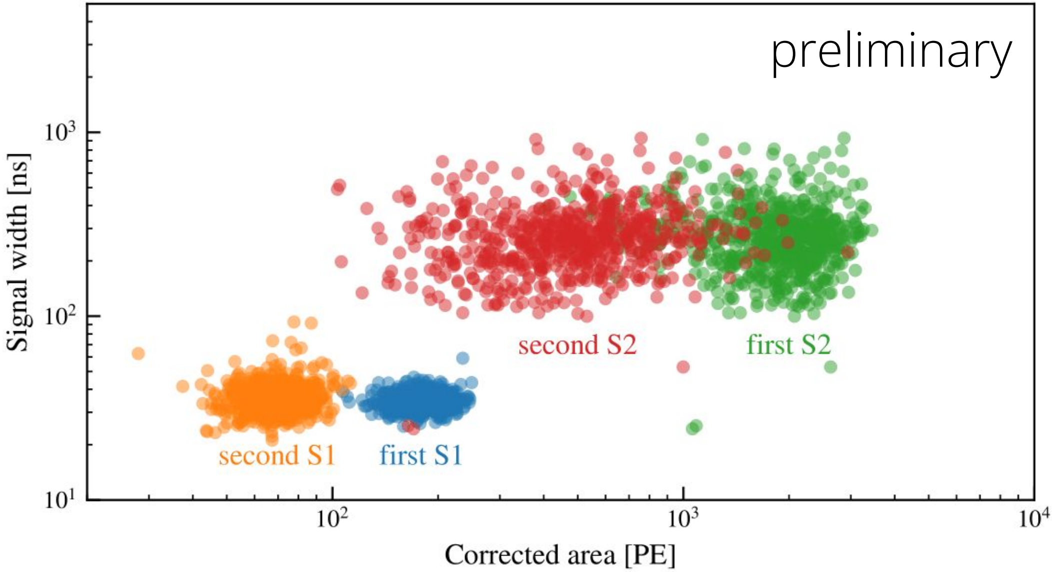


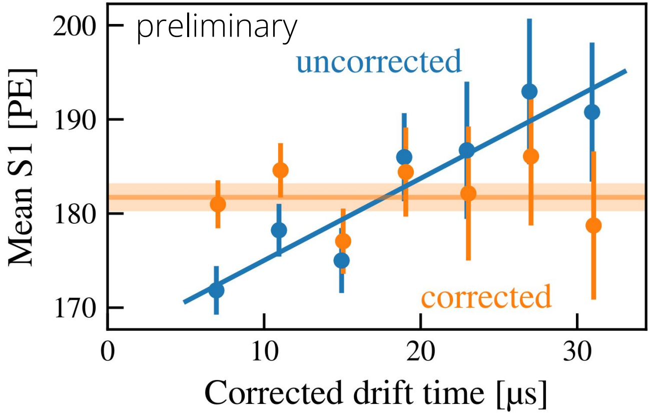
- two ^{83m}Kr event signals from our single-phase and dual-phase TPC
- characteristic double S1-peaks from both TPC types
- two S2 peaks from single-phase and only one S2 peak from dual-phase

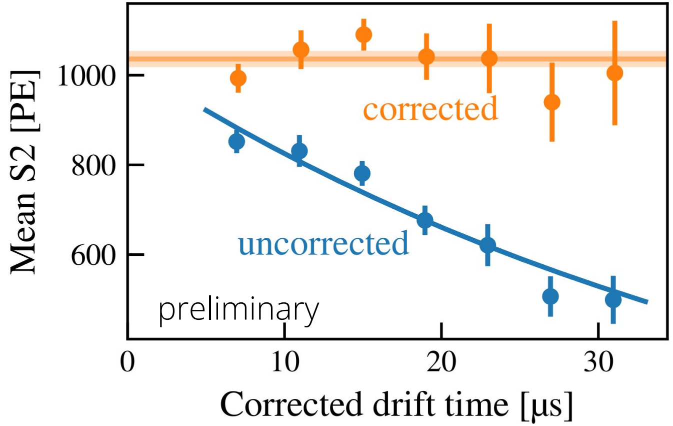
Characterisation with ^{83m}Kr

correct detector response for drift-time (z) dependent effects

- light collection efficiency →S1
- “electron lifetime” → S2







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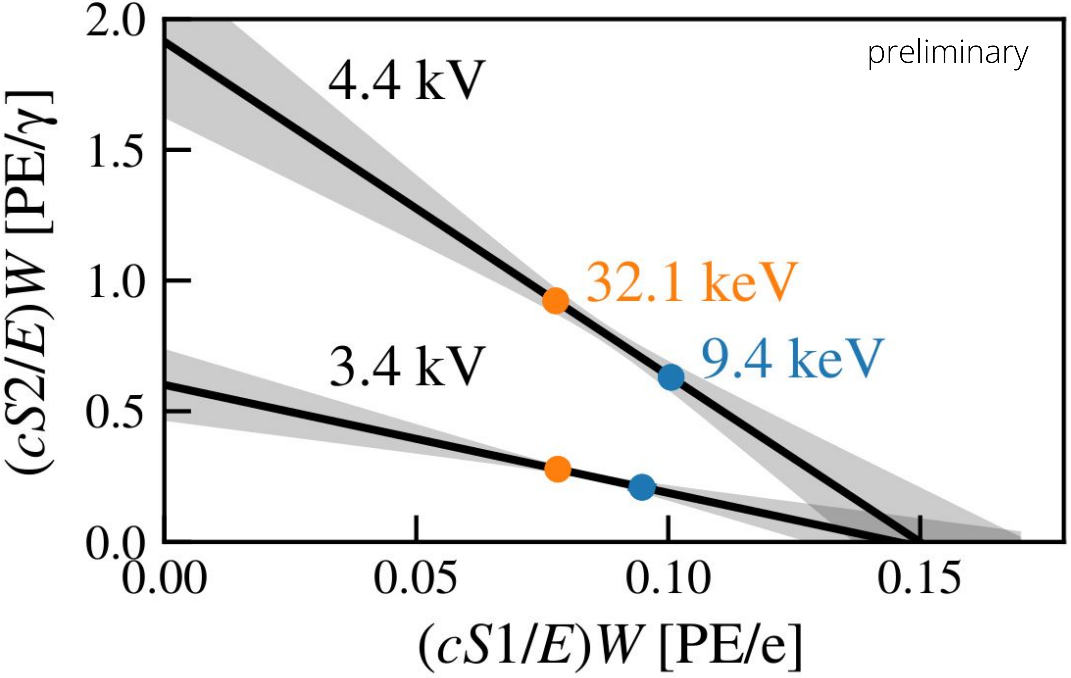
g1 & g2 using ^{83m}Kr

g1: fraction of detected photons (PE/photon)

g2: number of detected photons per electron (PE/electron)

$$E = W\left(\frac{cS1}{g_1} + \frac{cS2}{g_2}\right)$$

W = 13.7 eV/quantum



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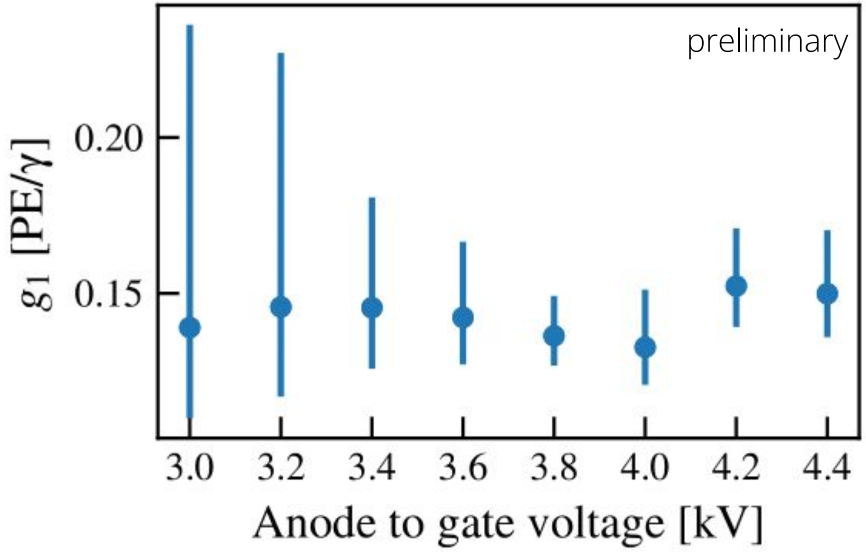
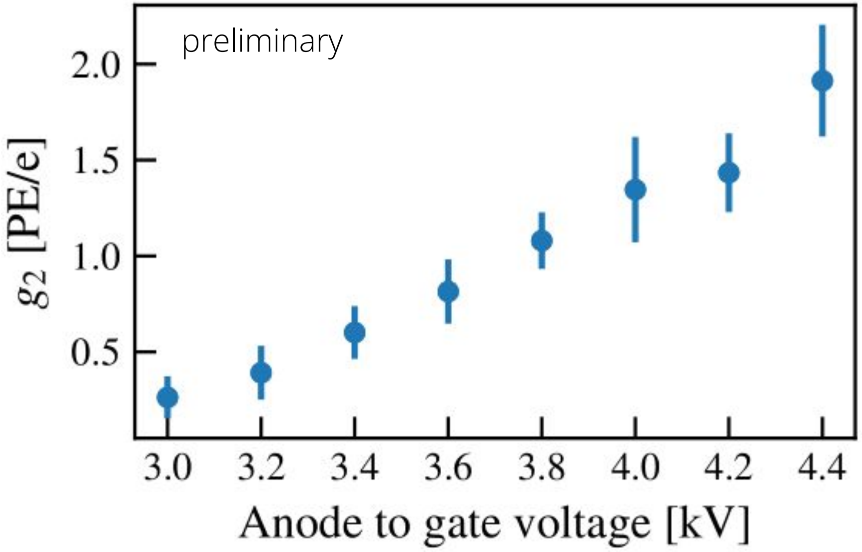
g2: number of detected photons per electron (PE/electron)

from Freiburg **dual phase TPC:** g2 = (5.49 ± 0.05) PE/electron

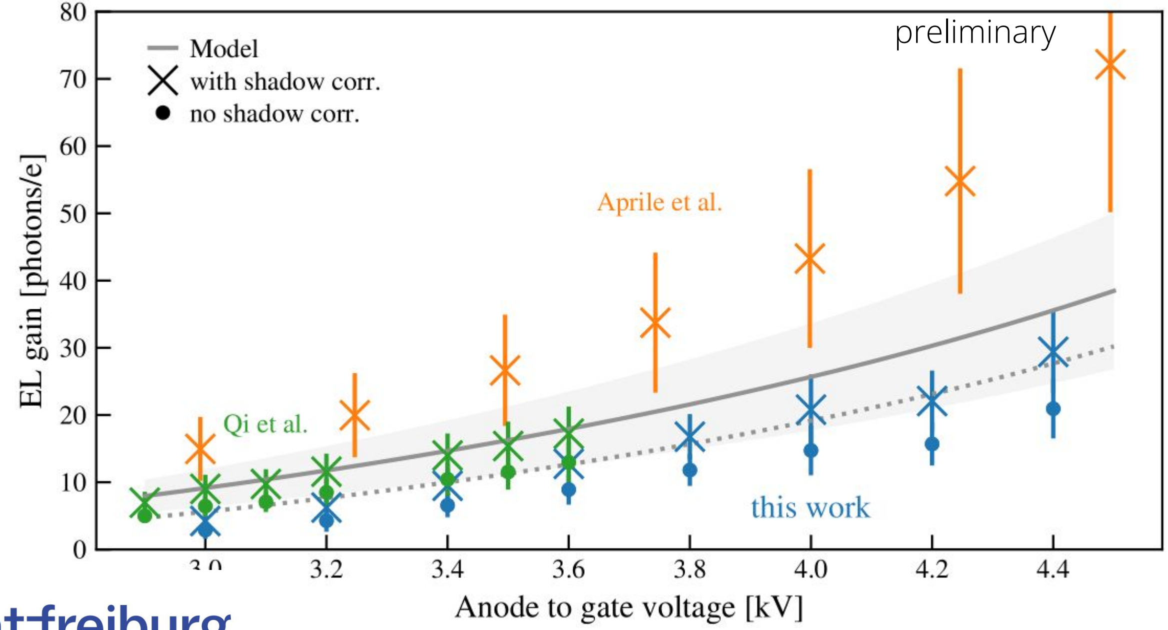




g1 & g2 using ^{83m}Kr

Freiburg dual phase TPC: g2 = (5.49 ± 0.05) PE/electron

Freiburg **single phase TPC:** g2 = (1.9 ± 0.3) PE/e$^-$→EL gain: (29 ± 6) photons/e$^-$

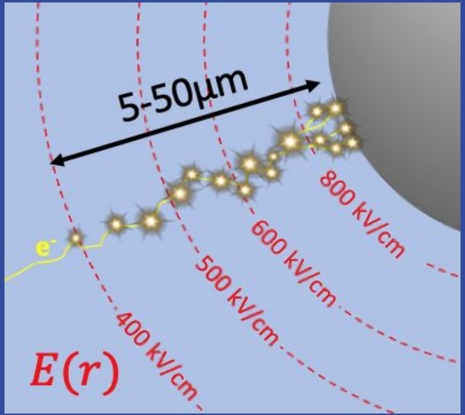


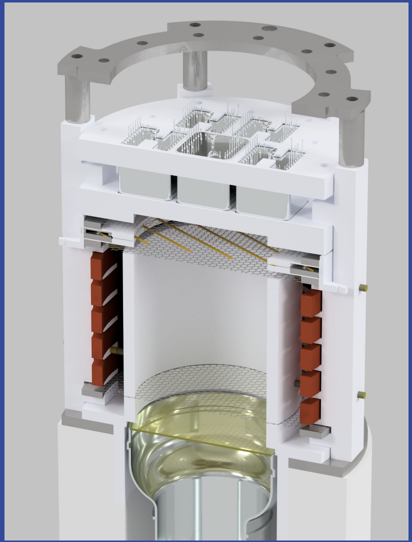
PANCAKE:

- 2.7m wide test platform
- flat floor design
- successfully commissioned
- arXiv:2312.14785
- working on electrodes, to be tested

Single Phase TPC:

- single phase TPC successfully operated, characterized and analysed
- anode with 10um Au-plated tungsten wires
- proportional scintillation observed
- scintillation gain of g2 = (1.9 ± 0.3) PE/e^-





julia.mueller@physik.uni-freiburg.de