



## Capacitive liquid level measurement in the XENON1T time projection chamber

**Christopher W. Geis** 

Johannes Gutenberg-Universität Mainz XENON collaboration

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geisch@uni-mainz.de



Bundesministerium für Bildung und Forschung





## Introduction

### Why is a liquid level measurement in a LXE TPC needed?

### Liquid-Gas- Interface:

#### Scope:

- Dynamic range ~5 mm for XENON1T
- understanding the size of proportional scintillation signal

$$n_{ph} \propto \left(\frac{E}{P} - 1.0\right) P x$$

- monitors thermal equilibrium
- multiple level meters in one plane allow horizontal leveling of detector

### **Overall measurement:**

#### Scope:

- Dynamic range ~1.5 m for XENON1T
- monitors TPC filling process
- monitors recuperation process







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### **Requirement specifications:**

- Feasibility: Choice of capacitive liquid level measurement
- Provide a linear dependence of capacitance to LXe level to enable liquid level measurement
- Low radioactivity of all components
- Highest possible capacitance to increase signal-to-noise properties
- Highest possible capacitance change per height to keep resolution of S2 signal
- Readout with  ${\sim}12.5$  m coaxial cable pair
- Small dimensions

### **Design specifications:**

- 4 short level meters
- Dynamic range of liquid-gas interface: 5 mm  $\rightarrow$  Height of level meter 10 mm
- New or upgraded design of XENON100 SLMs  $\rightarrow$  Factor 15 higher than in XENON100

- 2 long level meters
- Dynamic range of whole TPC: 1 m
  → Height of level meter 1.5 m
- New or upgraded design of XENON100 LLMs  $\rightarrow$  Factor 2 higher than in XENON100



## Short Level Meter Design

### **Capacitor simulation with COMSOL:** - Different designs simulated: **61mn** 0mm Cylindric with square Triple Cylindric **Double Cylindric** - Parametric sweep for liquid fill height Short Level Meter Simulations 30 $\Delta C/h = 1.04 \text{ pF/m}$ - $\epsilon_{_{GXe}} \approx 1$ , $\epsilon_{_{LXe}} \approx 1.96$ 25

- Selection criteria:  $\Delta C/h,$  feasibility and least mass
- → Triple plate capacitor
- $\rightarrow$  Plate thickness: 0.5 mm
- → Space between plates: d = 1 mm
- $\rightarrow C_{GXe} = 16.5 \text{ pF}, C_{LXe} = 26.9 \text{ pF}$
- → Material: OFE Copper

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## Short Level Meter Design

## **Modifications for application in XENON1T TPC:**

- Proximity to HV electrode meshes (anode, gate) affects the electric field inside the capacitor
- This would result in "unreal" liquid level changes if the HV of the electrodes would be changed



 $\leftarrow$  Levelmeter in electric field of anode  $\rightarrow$ 

 $\rightarrow$  Solution: Levelmeter plates have to be shielded by an external grounded cage

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Short Level Meter Design

### **Final Design and implementation in TPC model**



Assembled Short Level Meter



SLM installed on TPC top ring



## Long Level Meter Design

### **Capacitor simulation with COMSOL:**

- Different designs simulated:



- Selection criteria:  $\Delta C/h$ , feasibility and least mass possible

- → Double cylindric capacitor
- → Dimensions: h = 1357 mm, R = 5.5 mm, r = 3 mm
- $\rightarrow$  Pipe wall thickness d = 0.3 mm
- $\rightarrow C_{GXe} = 138 \text{ pF}, C_{LXe} = 270 \text{ pF}$
- $\rightarrow$  Material: Stainless steel



### PCB like capacitors with vertical

or horizontal electrodes

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## Long Level Meter Design

### **Implementation in TPC model**

- Two PTFE pillars widened and hollowed out to host long level meters





## **Readout Tests**

### Liquid nitrogen test:

- Difficult readout of tens of pF with a pair of 15 m long cables with a parasitic capacitance of ~1.5 nF
- Two commercial readout chips tested with a SLM prototype and 15m coaxial cable
  - Smartec UTI
  - ACAM PCap02 (couldn't handle the 15m cable length)



SLM Prototype

- Filling tests possible by submersing the level meter in evaporating LN2
- Comparison to simulation results possible

 $\Delta C/h_{LXe} = 2.23 \cdot \Delta C/h_{LN2}$ 



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## **Readout** Tests



11/14



## Readout Electronics





## Summary & Outlook

### **Summary:**

#### - The XENON1T liquid level will be measured by 4 small and 2 long level meters

- SLMs: Triple-plated:  $\Delta C/h = 1.04 \text{ pF/mm}$
- LLMs: Double-cylindric:  $\Delta C/h = 0.10 \text{ pF/mm}$
- Readout with Smartec UTI chip (RMS = 0.003 pF) allows micrometer resolution
  - SLMs: R = 3 μm
  - LLMs: R = 30 μm

### **Outlook:**

- Finalizing the readout electronics
- Samples of level meter materials under screening
- Fabrication of TPC parts and level meters ongoing
- Cooldown tests of TPC with level meters in cold nitrogen gas in 04/2015
- Begin of installation at LNGS in Italy: End of 05/2015





## **Thank you! Questions?**



http://xenon.physik.uni-mainz.de/

#### http://xenon1t.org

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