Innovative electrodes for xenon based dual-phase time projection chambers for direct dark matter detection

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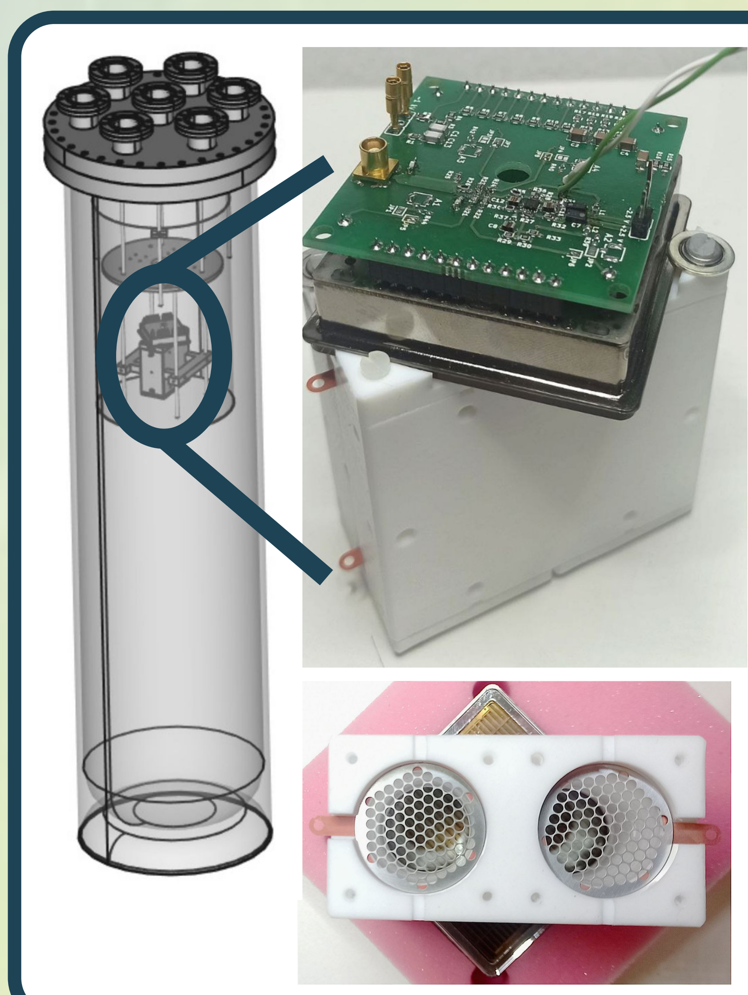
INFN LNGS CREO

This work is based on the **realization of transparent conductive electrodes** (**TCE**s): **conductive films** (thickness **5nm) deposited on transparent supports** (**UV grade fused silica** or **CaF_2** windows), for the next-generation Dual Phase Time Projection Chambers (**DP-TPCs**). Indium-Tin-Oxide (**ITO**) and Al_2O_3-doped Zinc-Oxide (**ZAO**) **TCE**s **were already designed and fabricated in collaboration with the CREO laboratories** (in L'Aquila).

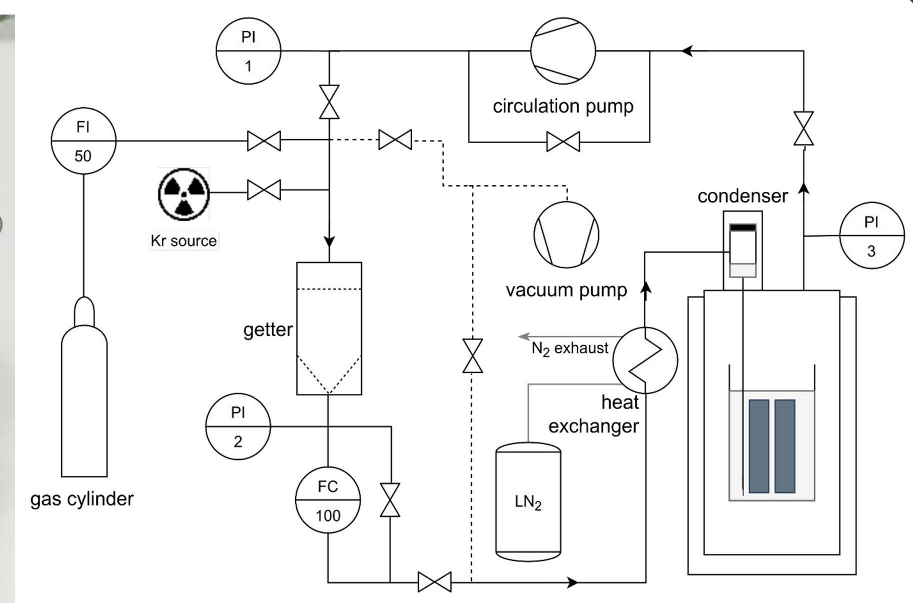
Test facility:

A cryogenic test facility (**STAR**) is currently being installed at Laboratori Nazionali del Gran Sasso. **It will provide a clean liquid xenon (LXe) environment,** in which TCEs characterization will take place.

- **2 Parallel cylindrical LXe Teflon Chambers** are suspended in the external cryostat;
- A **TCE** will be placed **in the upper face** of each chamber acting as anode, and a **steel grid in the bottom face** as cathode;
- The chambers end-caps are instrumented with a **multianode Photomultiplier Tube** (PMT) **R12699-406-M4**;
- The **cryogenic system** consists of a **cryostat** and a **xenon re-circulation circuit**;
- The cryostat is equipped with a **xenon gas (GXe) condenser** cooled by a **Cryomech PT60 single-stage pulse tube cryocooler**;
- **A liquid nitrogen powered heat exchanger** pre-cools the input GXe for the condenser;
- The GXe is purified through a **SAES PS4-MT3 getter**;
- The gas flow is promoted by a circulation pump (**Metal Bellows MB-111**) and regulated by a **Sierra SmartTrack 100 gas flow controller**;
- The system allows the injection of **^{83m}Kr isotopes** into the re-circulation line, as a **calibration source**;



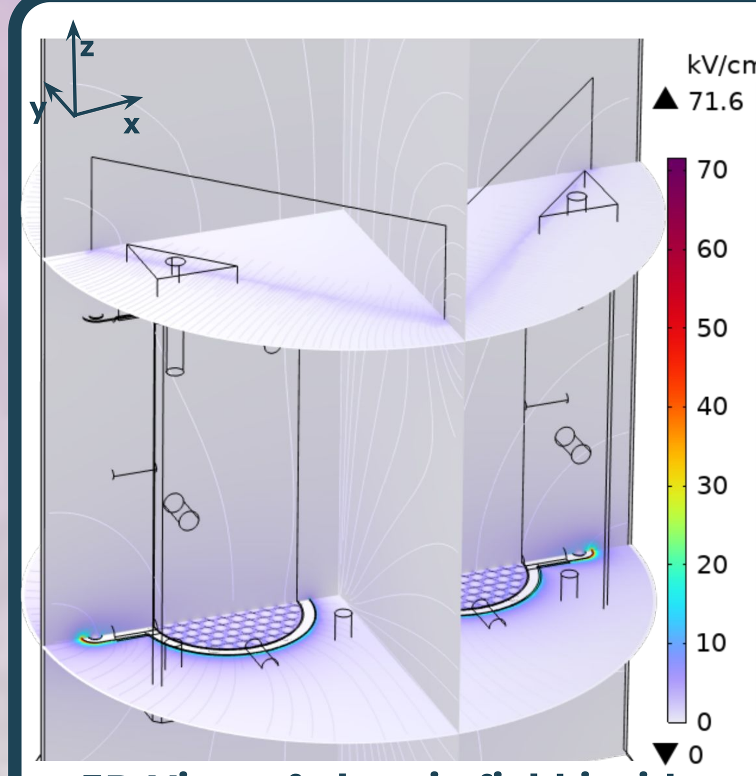
2 Parallel cylindrical chambers inside the cryostat: frontal view (upper figure) and from below (lower figure).



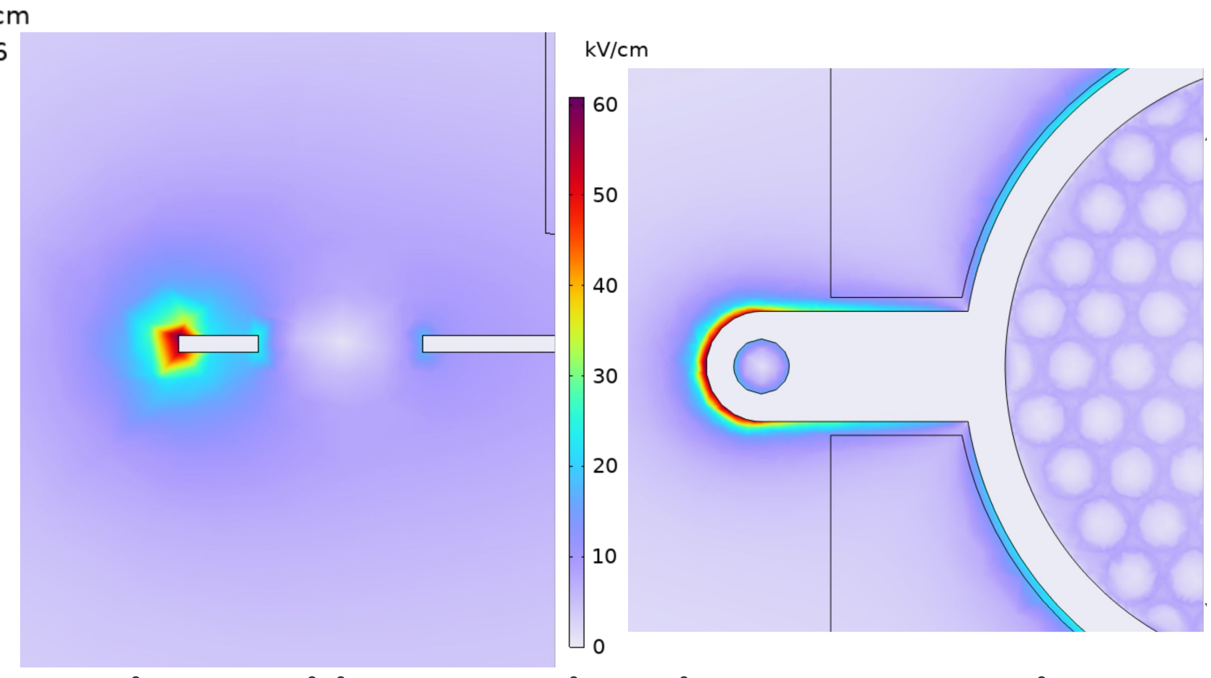
The STAR cryogenic system.

Electric Field simulations:

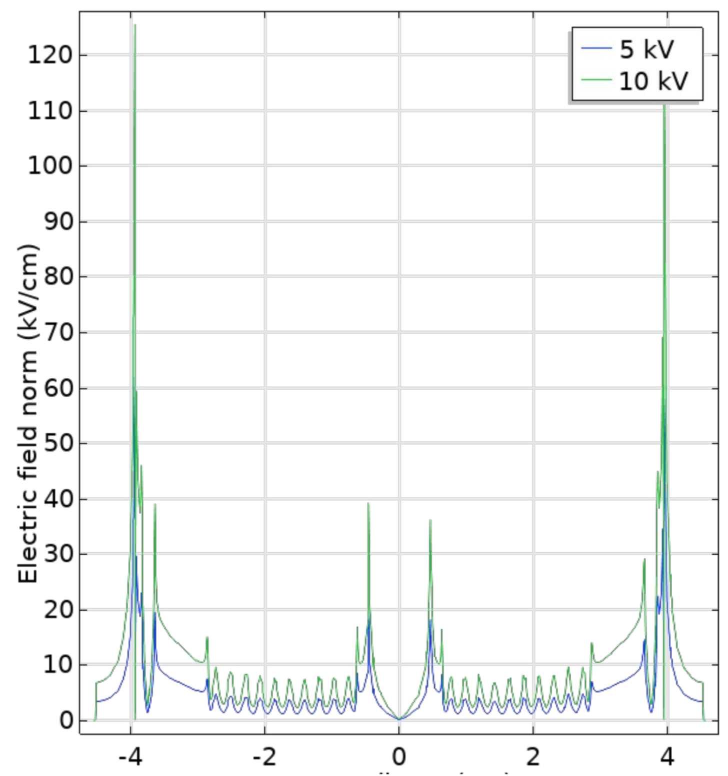
Several **Comsol simulations** have been performed **to evaluate the maximum electric field values** and **the field homogeneity inside the chamber.**



3D View of electric field inside the 2 chambers.



2D view of critical planes in which we have the highest electric field values: xz (left) and xy (right) plane view in correspondence of the bottom steel grids.



Electric field values along the xy bottom grid critical plane (z fixed).

The chambers are **supplied with copper spacer rings,** placed in the upper and bottom chambers faces:

- The upper rings are grounded;
- **-1kV** is the exercise potential for the PMT;
- The bottom grids are taken to:
  - **5kV**
  - **10kV**

LXe is predicted to have a large bulk breakdown field of approximately 1 MV/cm **[1].**

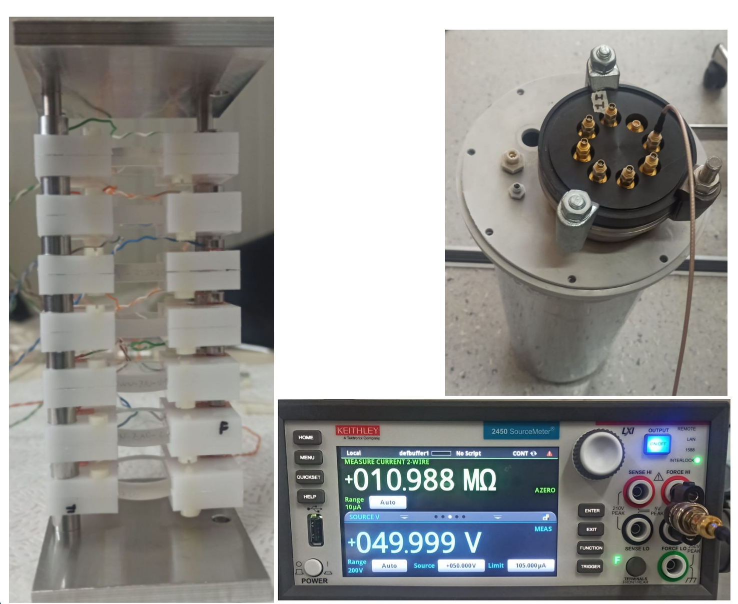
No breakdown voltage exceeded.

Conductivity test:

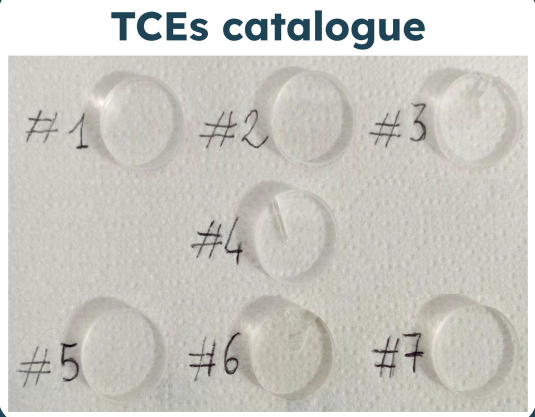
The resistance values were measured at cryogenic temperatures for the different assembled TCEs. They were arranged along a vertical structure, made of derlin clips electrically connected to a source meter.

- 7 TCEs have been tested in a dewar constantly filled with liquid nitrogen **LN_2**:
  - **#1,3** in **CaF_2** with **ITO** deposit;
  - **#2** in **UVFS** with **ITO** deposit;
  - **#4** in **CaF_2**, virgin;
  - **#6,7** in **CaF_2** with **ZAO** deposit;
  - **#5** in **UVFS** with **ZAO** deposit.
- Resistance values have been measured in 2 runs:
  - a **1st run** of **7 days: only #3,5,6,7** worked;
  - a **2nd run** of **23 days: only #2,3,5,7** worked;
- After 1st run **#3,4,6 (CaF_2)** cracked due to the presence of a temperature gradient (avoided in the 2nd run). **Conductivity NOT COMPROMISED**;
- **2nd run appears more stable** with respect to the 1st possibly due to losing electric contacts in the 1st run;
- **Systematic errors** in the plot **due to pressure variations** (±40 mbar corresponding to ±2K in temperature). The instrument uncertainty is negligible (0.8Ω).

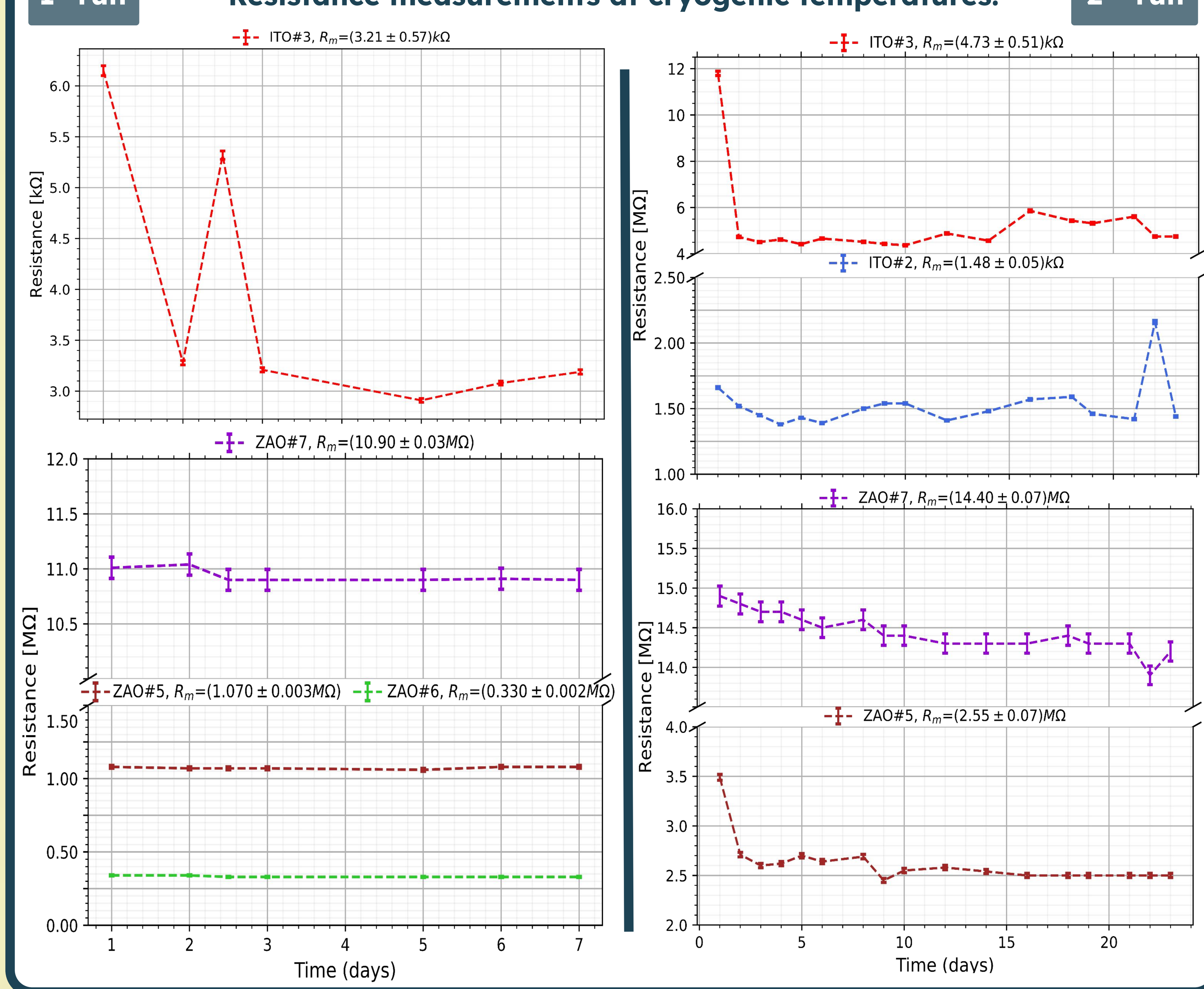
Experimental setup



TCEs catalogue



Resistance measurements at cryogenic temperatures.



Conclusions & future works:

- **Stable behaviour of TCEs' conductivity** at cryogenic temperatures observed, in particular for those with ZAO deposit;
- **Resistance median values seems to increase in the 2nd run but we don't observe the same behaviour at r.t.**;
- **UVFS is preferable** for **mechanical stability** and also **purity** (fluorine may contribute to the background because of α-n high cross section);
- **We are ready to conduct the characterization of these so fabricated TCEs in our STAR facility at LNGS:**
  - evaluate TCEs performances under electric field in LXe cryogenic environment;
  - transparency measurements to xenon scintillation light.

[1] J. Watson et al., Study of dielectric breakdown in liquid xenon with the XeBrA experiment