The XENON1T Time Projection Chamber

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XENON Dark Matter Project

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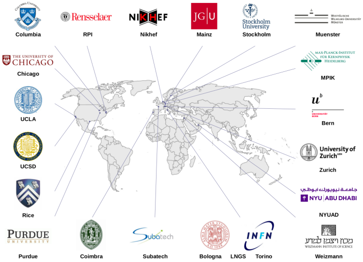
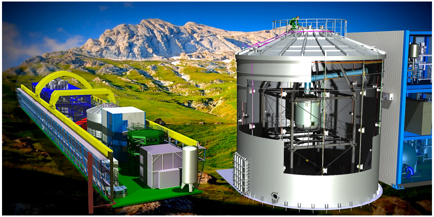
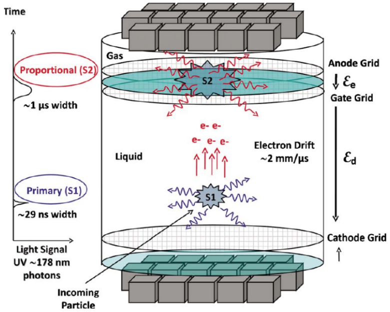
The XENON1T Experiment

- Direct detection of dark matter in the form of WIMPs (Weakly Interacting Massive Particles) via their elastic scattering off xenon nuclei.
- Currently under construction in Hall B of LNGS and commissioning of several subsystems.
- $\sim$ 1 t LXe in the fiducial volume (2 tons of target LXe).
- Low radioactivity components. $<$0.75 events/ (tonne $\cdot$ year) in the region of interest.





Direct dark matter detection with XENON1T

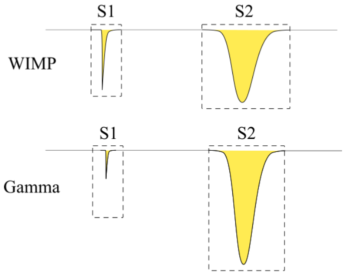


Principle:

- Prompt scintillation in LXe (S1), λ =178 nm.
- Secondary scintillation (S2) in GXe.
- (S1/S2) ratio depends on dE/dx and allows discrimination between nuclear/electronic.

Event Reconstruction:

- Hit pattern of the S2 signal on top PMTs gives X-Y $\delta r<3$ mm.
- Drift time provides Z coordinate $\delta z<0.3$ mm.



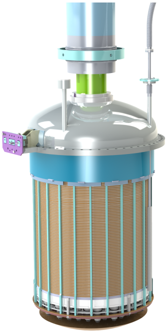
The XENON1T TPC

- Low radioactive 3" PMTs from Hamamatsu model R11410 on top (127) and bottom (121) arrays **arXiv:1503.07698 [astro-ph.IM]**.
- Selected material for the TPC: PTFE 99% reflectivity, Torlon, PEEK, Kapton, OFHC and Stainless steel.
- Drift field of order of $\mathcal{O}(1\ \mathrm{kV/cm})$. Extraction field of order $\mathcal{O}(10\ \mathrm{kV/cm})$ at liquid-gas interface.
- Extensive electric field simulations in order to find the best electrode structure and to ensure the electrical safety of the detector.

XENON1T Electrical Requirements

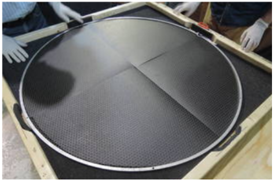
Electrical Requirements:

- Drift field order of $\mathcal{O}(1\ \mathrm{kV/cm})$ for good nuclear/electronic discrimination and drift velocity saturation.
- Extraction field of order $\mathcal{O}(10\ \mathrm{kV/cm})$ at liquid-gas interface to ensure a 100% extraction efficiency.
- Avoid sparks inside the detector.



Simulation Tools:

- Developed a new simulation software, which takes advantage of the Boundary Element Method
- Calculations of large scale geometries with small scale structures are fast and need less memory than the FEM.



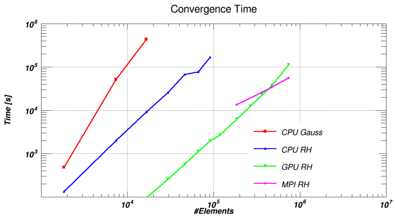
Electric Field Simulation Technique

- New approach with the boundary element method instead with finite element method (*COMSOL*).
- Charge density on each electrode surface element is constant.
- Each element is defined by its type, coordinate and voltage.
  - Potential of sub-element i.

$$U_i = \sum_{j=1}^{N} \sigma_j \cdot C_{ij} \tag{1}$$

  - Charge Density of Subelement j.
  - $C_{ij} = C_j(r_i) = \frac{1}{4\pi\epsilon_0} \int_{S_j} \frac{1}{\vec{r_i} - \vec{r_S}} d^2\vec{r_S}$
  - Coulomb Matrix Element depends on the geometry of the subelement; it represents the potential at the centre of subelement i in relation to subelement j with unit charge density.

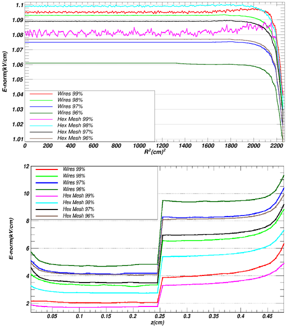
- For an exact model of a TPC, the dimension of the problem is very high.
- Solve this problem iteratively with the so-called Robin Hood method. **arXiv:1111.5035 [physics.comp-ph]**
- Usage of parallelized Robin Hood solver to perform simulation on GPUs.

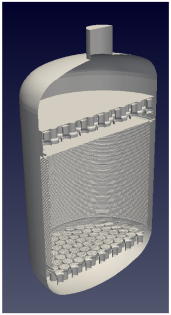


- Optimized the code with OpenCL in order to use GPUs.
- Access of one GPU Cluster in our group.
- Improved calculation time on a GPU in comparison to a CPU ~ 70.

XENON1T TPC Simulation

- Several static field simulation to optimize the electrode structure and to localize high electric field hot spots.
- Ongoing electron tracking in LXe/GXe and S2 simulation.





Electrode	Structure	Optical Transparency
PMT Screening Mesh	parallel wires	94.5%
PMT Screening Mesh	hex mesh	94.5%
Cathode	parallel wires	96%
Gate	hex mesh	93%
Anode	hex mesh	93%

XENON1T TPC Parts Status

Completed:

- The TPC design is finalized and all relevant parts are in production.
- Most of the material has be screened with Gator **arXiv:1103.2125 [astro-ph.IM]**
- MySQL database has been programmed for all the ∼800 TPC parts

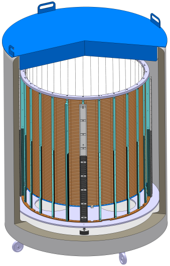
To do:

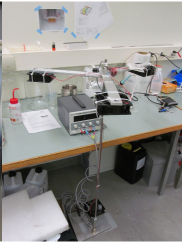
- The TPC field cage will be assembled at UZH and tested for structural deformations.
- Cleaning of all parts in Münster.
- Installation of the TPC inside the Cryostat at LNGS.

XENON1T TPC test

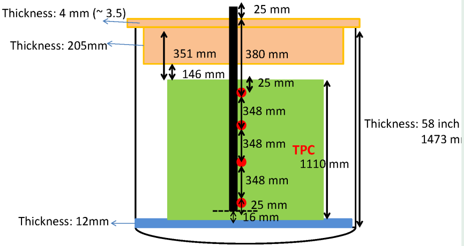
Test Purpose:

- Measurement of the TPC shrinking (mostly PTFE) in order to take the shrinking of the drift region into account for Monte Carlo simulations (LCE).
- Look for any possible deformations and stability. Shrinking @ -100 Degree: $\sim$17.66 mm.
- Tests of the main TPC mechanical components (rings, PTFE and associated hardware)





Experimental Setup

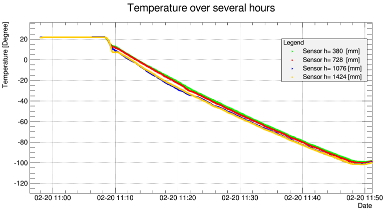


Plan:

- Deformation will be measured using a laser measuring device.
- Cool down to a temperature of around -100 Degree (LXe).
- Temperature uniformity will be achieved with a fan structure.

Ongoing::

- Assembly of the XENON1T TPC in the machine shop highbay of the UZH.
- Cooldown test in the next 2 weeks.



Current Status

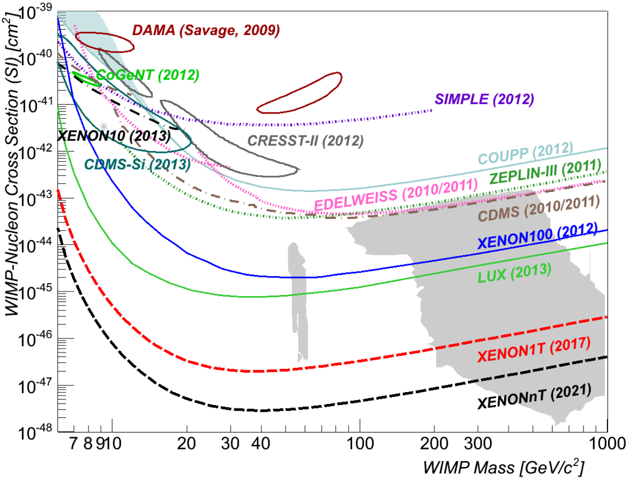
Summary and outlook

- A new electric field simulation software has been developed for the XENON1T TPC and will be extended for particle tracking in the future.
- S2 simulation module already has been verified with the XURICH-II detector
- The XENON1T TPC design is fixed and the parts are under production at different machine shops.
- The XENON1T TPC is under assembly and testing for structural deformations at the UZH in these days.
- The installation at LNGS is planned to be in October 2015.

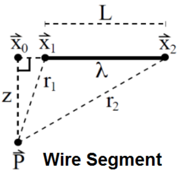
Any Questions?

Back Up

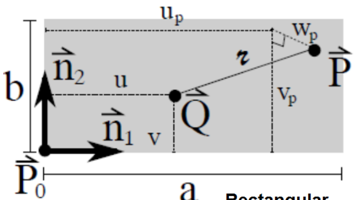
Back Up - Xenon1T Exclusion Plot



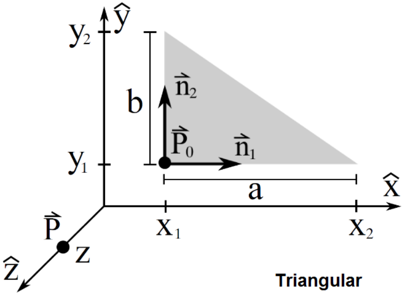
Back Up - Subelements primitives



Wire Segment

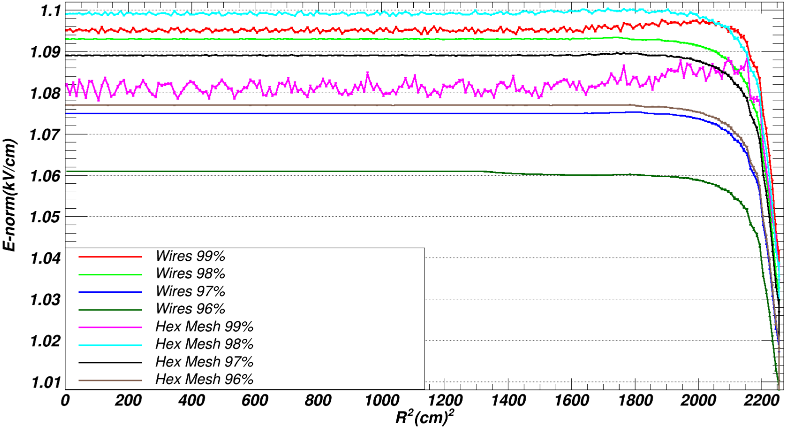


Rectangular



Triangular

Back Up - Meshes Results



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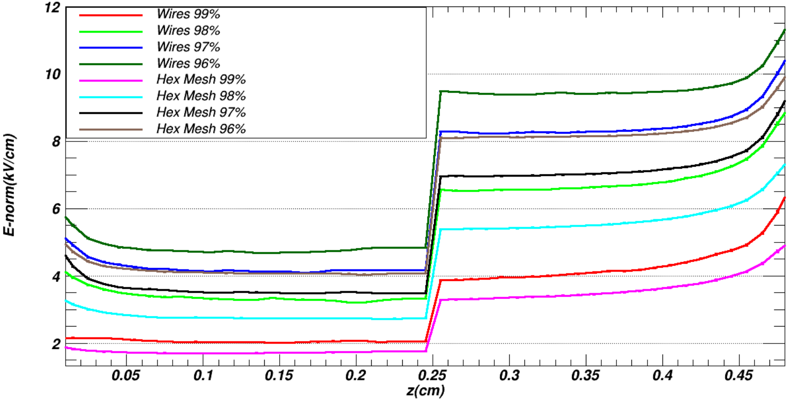

Back Up - Setup