Karlsruhe Institute of Technology

dark matter wimp search in noble liquids DARWIN

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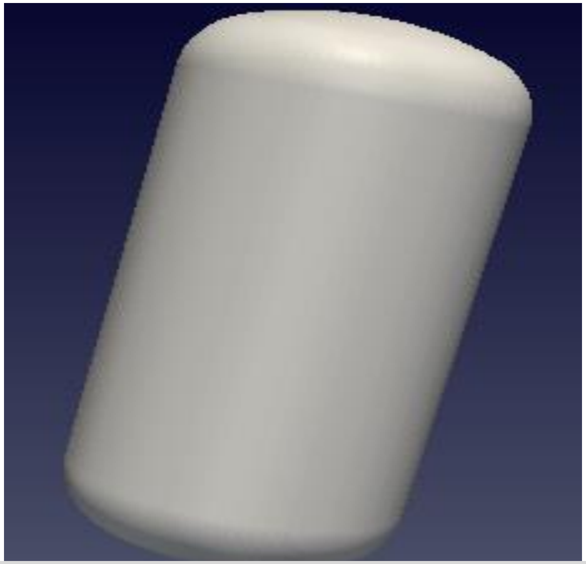
Electrostatic Field Calculations for DARWIN

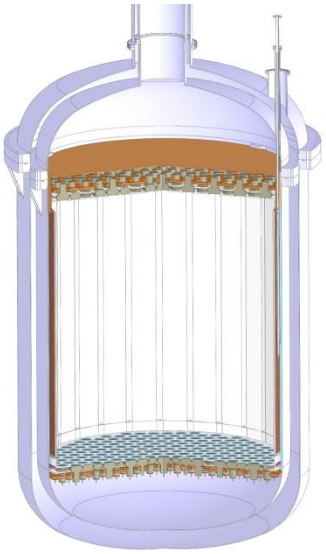
DARWIN Meeting
Naples 9.12. – 11.12.2013

Julien Wulf, KIT Institute of Experimental Nuclear Physics (IEKP)

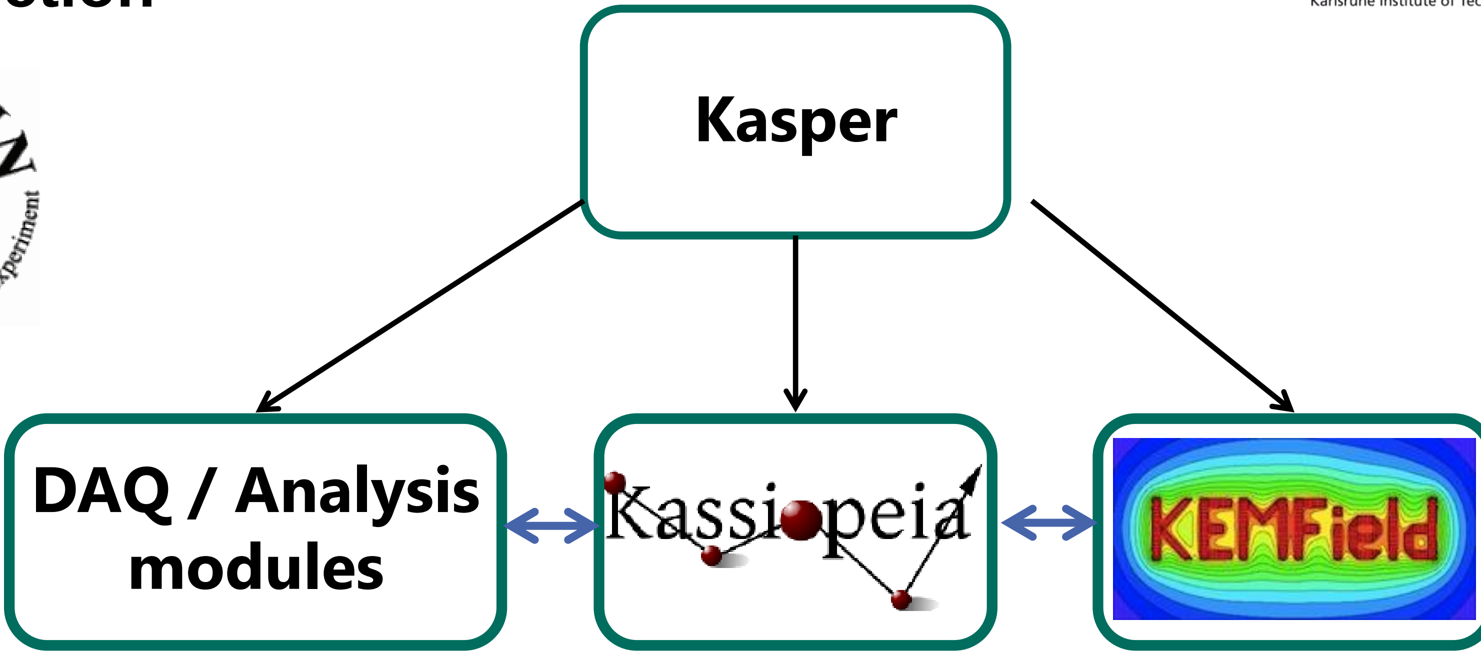
Overview

- Simulation Methods and Tools
- Dual Phase Test Model
- DARWIN Geometry
- Simulation of XENON1T model
- Conclusion





Introduction



- KEMField takes advantage of the **Boundary Element Method** (BEM)
- Calculations of large scale geometries with small scale structures are **fast** and need **less memory** than the FEM.

Boundary Element Method

- **Charge density** on each electrode surface element is **constant**.
- Each element is defined by its **type**, **coordinate** and **voltage**.

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

Charge Density of Subelement j

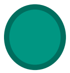
Potential of subelement i (input value).

$$C_{ij} = C_j(r_i) = \frac{1}{4\pi\epsilon_0}\int_{S_j}\frac{1}{|\vec{r}_i - \vec{r}_S|}d^2\vec{r}_S$$

Coulomb Matrix Element depends on geometry of electrodes; it represents the potential at the centre of subelement i in relation to subelement j with unit charge density.

Robin Hood Algorithm

- For an exact CAD-based model of the DARWIN TPC, the dimension of the problem is very high.
- Solution: Solve this problem iteratively with the so-called Robin Hood method.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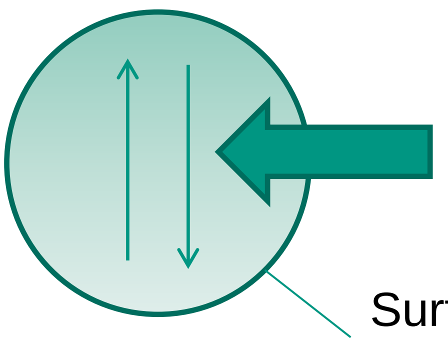
Model case: single charge at a metal sphere.



Rearrangement of the charges to maintain an equipotential surface.

Surface hold at potential U_0 (boundary)

Stable configuration once boundaries are fulfilled.

P. Lazic, H. Stefanic, H. Abraham
Journal of Comp. Physics 213, 117

Robin Hood Algorithm

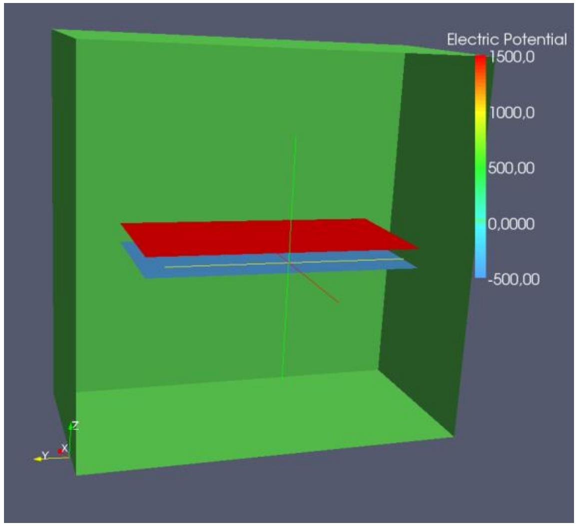
- The algorithm is very logic, because behaviour of **nature is reflected** in the algorithm.
- Electrostatic problems lead to **diagonal-dominant** matrices, hence the algorithm **converges very fast** ($< N^2$)
- The iterative method has a memory usage of order N, not N^2 like the direct methods.
- This alogorithm can be easy **parallelized**, it is very advantageous in this context that the memory usage is of order N.

Goals

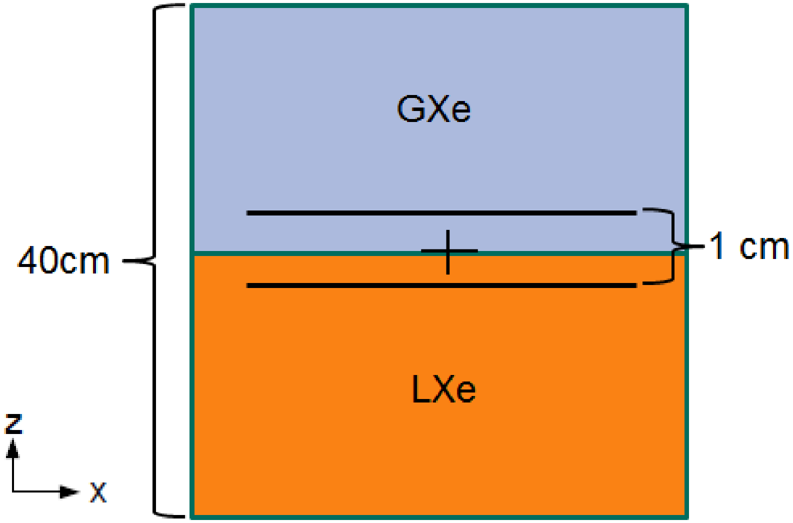
- **Verify results for calculation in two media** (dielectrics) computed with BEM.
- **Test the performance** of the BEM solver on modern **parallelized computing platforms** with normal (CPUs) and graphic processors (GPUs).
- Confirm that **BEM** is more advantageous for **large geometries with small structures** than the finite element method (FEM).

Dual Phase Test Model
Construction

3-D Plate Capacitor



2-D Cross Section



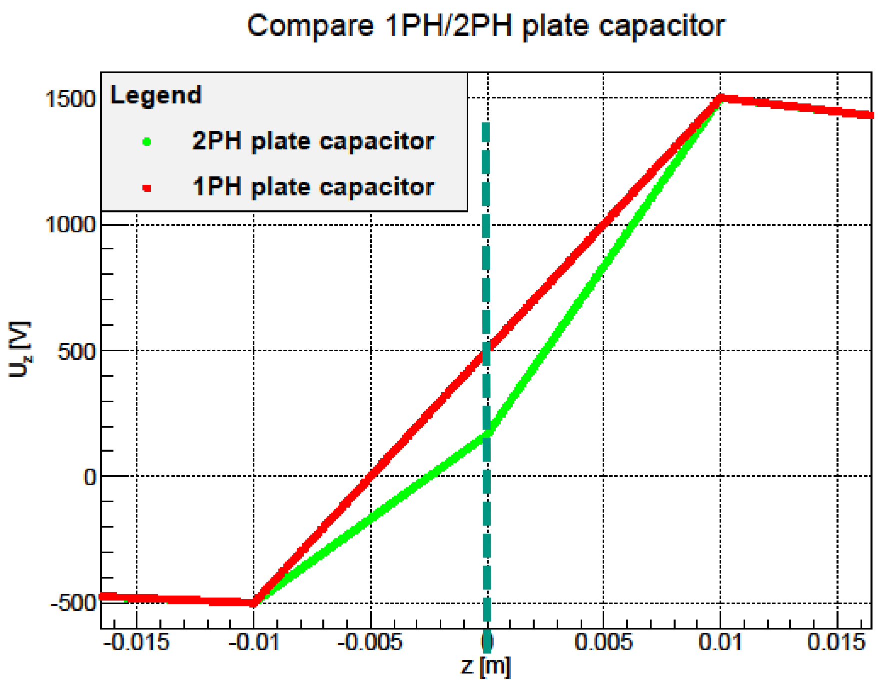
Parameters:

- Cathode: -500V
- Anode: 1500V
- Dielectric constants: $\varepsilon_{GXe}=1$, $\varepsilon_{LXe}=2$

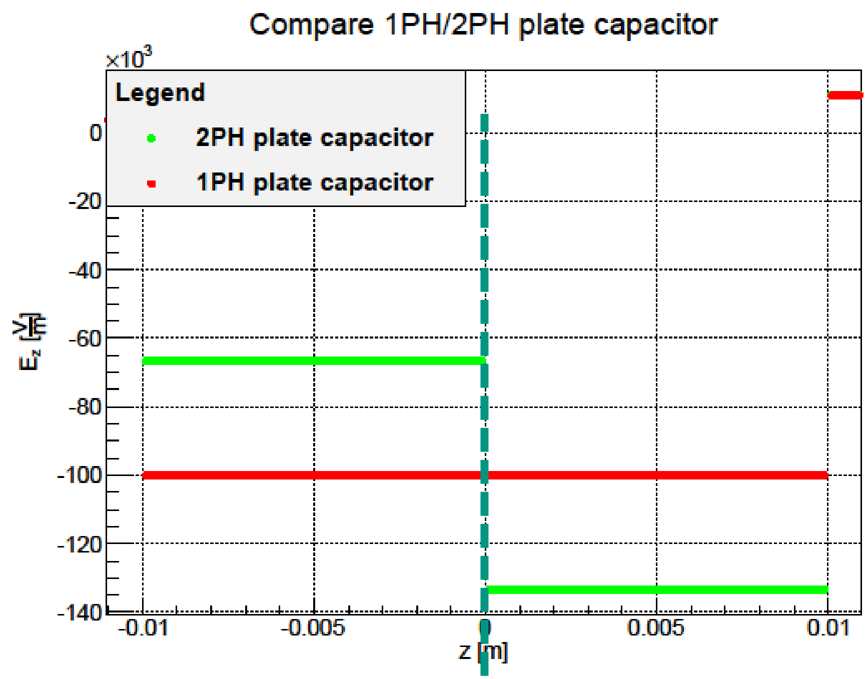
Dual Phase Test Model

Results Plate Capacitor

Electric Potential U



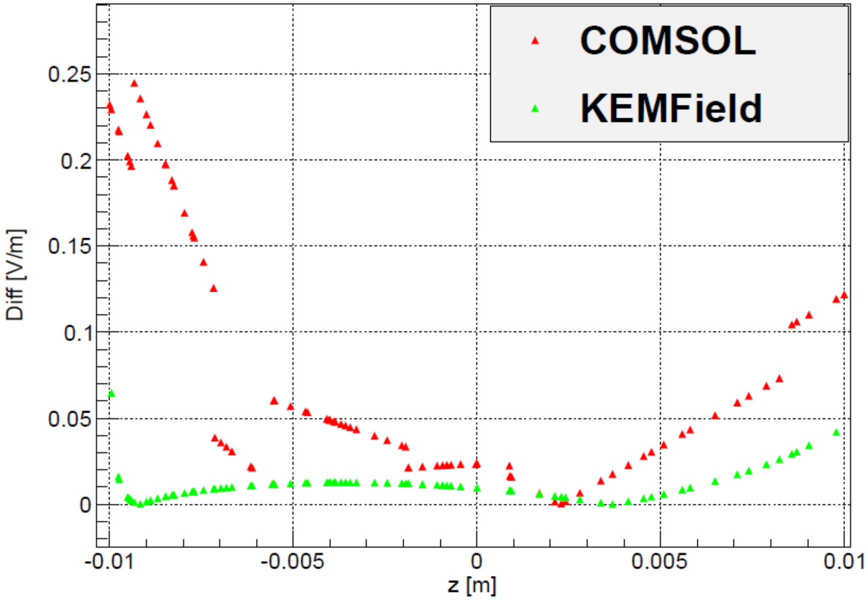
Electric Field Strength E_z



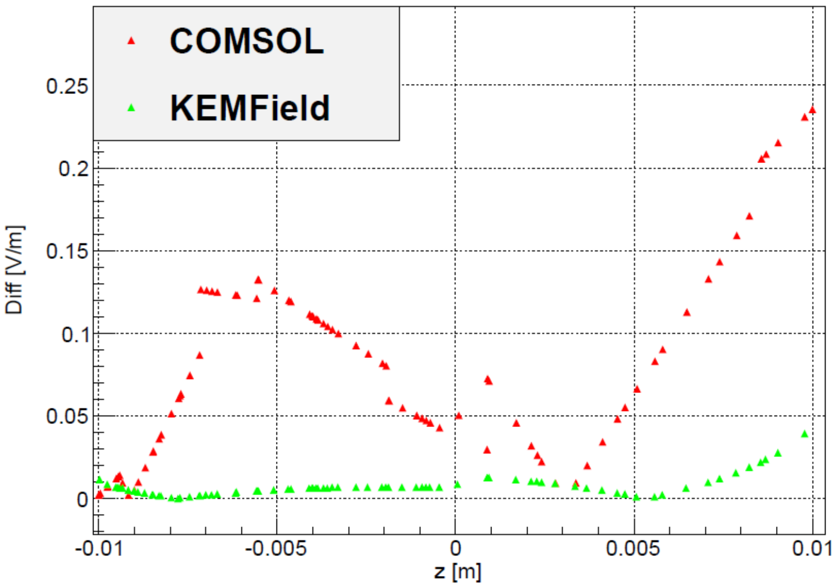
- Calculation along the z-axis at the point x=y=0.

Comparison with Analytical Solution and FEM

Single Phase Model
Difference to the analytical solution



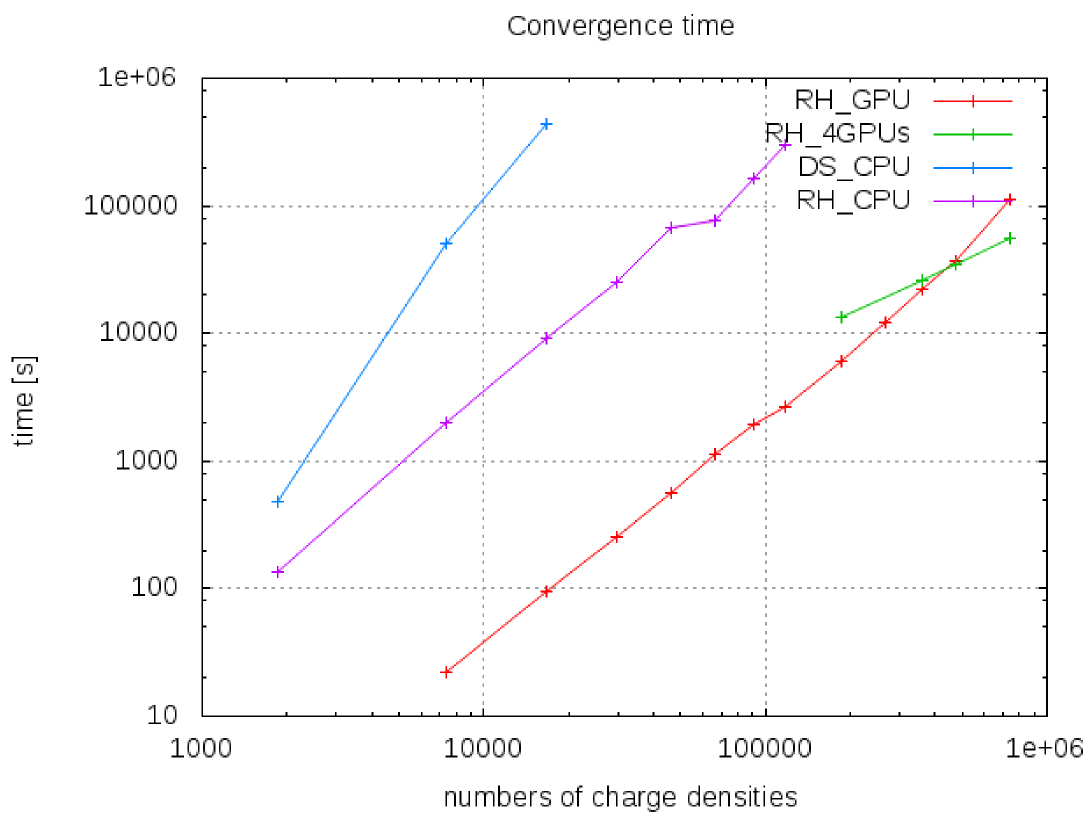
Dual Phase Model
Difference to the analytical solution



- KEMField computes correct values with dielectrics.
- No significant diff. between BEM (KEMField) and FEM (COMSOL).

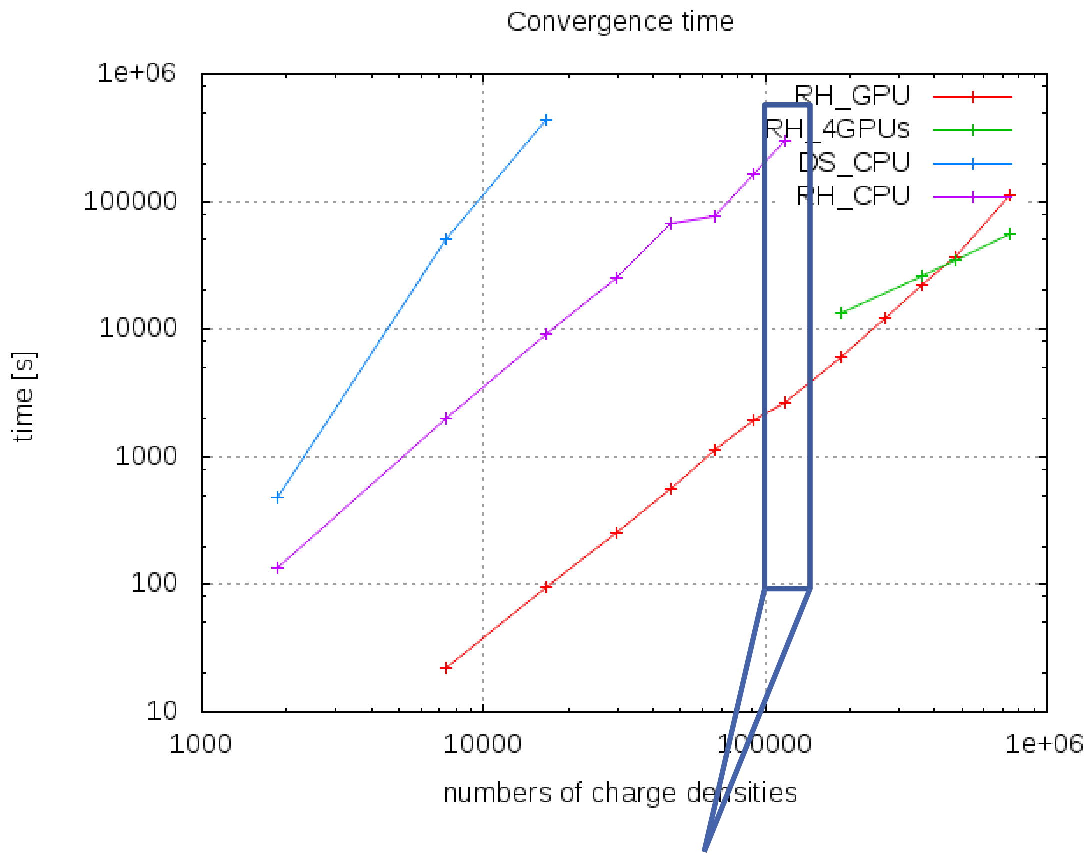
Dual Phase Test Model

Calculation Time



- Usage of parallelized Robin Hood solver to perform simulation on GPUs.
- At the KIT we have access to two GPU clusters.
- Amazing calculation time on a GPU.
- Also able to compute on more than one GPU.

Dual Phase Test Model
Calculation Time



- Usage of parallelized Robin Hood solver to perform simulation on GPUs.
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Elements: 118400 **CPU:** 3.5 days **GPU:** 43min

DARWIN Geometry

Technical Implementation

GeometryBuilder

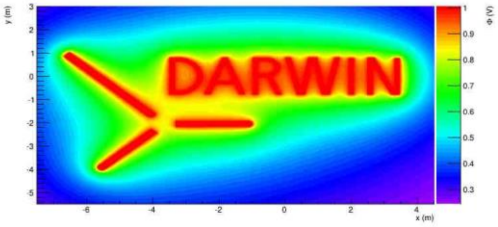
- Create discretized model
- Define geometrical parameters
- Visualization of the geometry

Output in ASCII Files

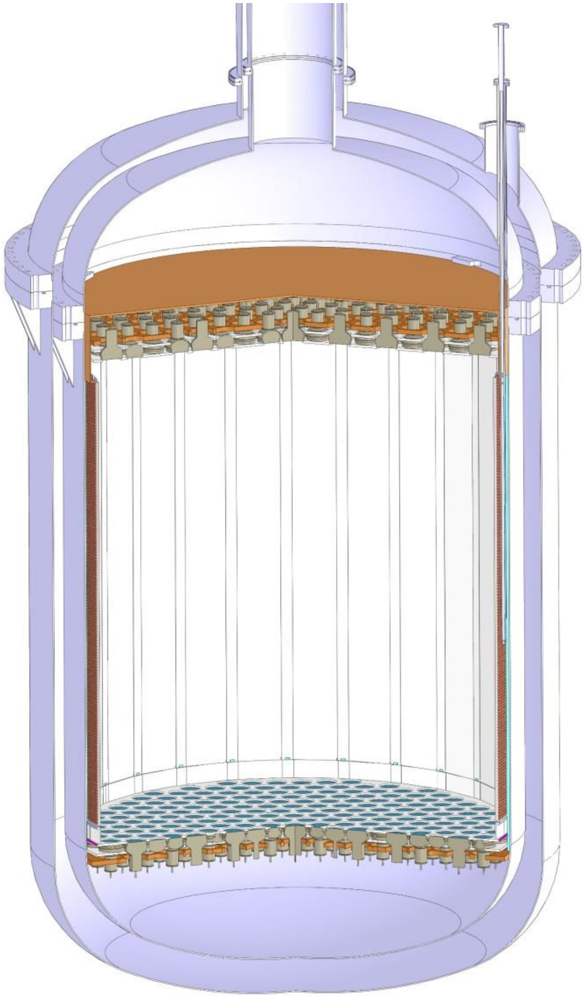
- Separation between geometry and field calculation

FieldCalculation

- Choose region of interest
- Create ROOT TFile



DARWIN Geometry
Recent Model



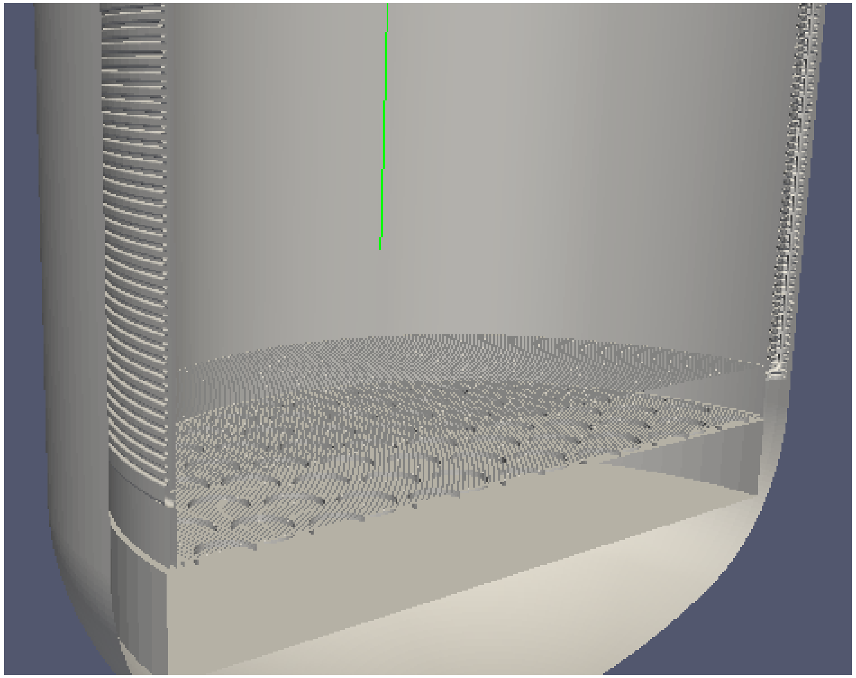
Height (TPC)	Diameter (TPC)	Volume (TPC)	#Elements (Simulation)
2.30 m	1.88 m	6.4 m^3	approx. 9 million

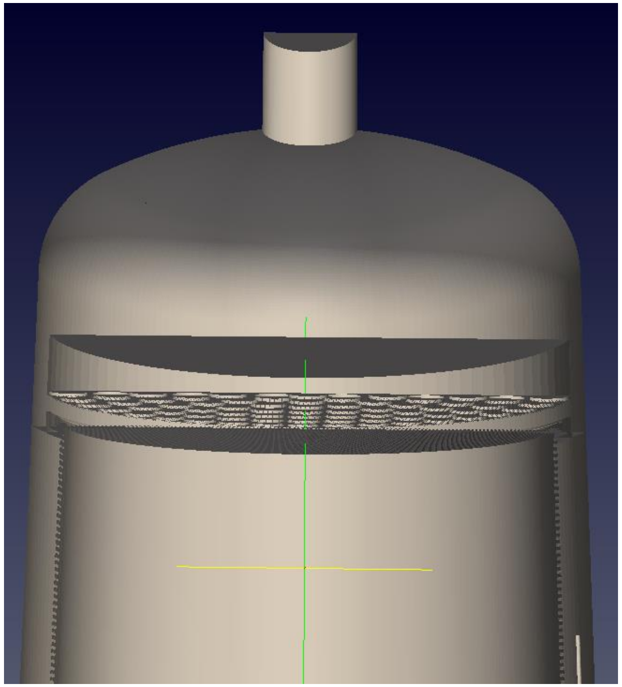
- DARWIN geometry is very similar to the Xenon1T geometry.
- DARWIN geometry is 2x larger than the Xenon1T geometry.
- Ongoing: First Xenon1T EM simulation.

Simulation of XENON1T Model

Model Dimensions

Height (TPC)	Diameter (TPC)	Volume (TPC)	#Elements (Simulation)
0.983m	0.96m	$0.7m^3$	3.5M

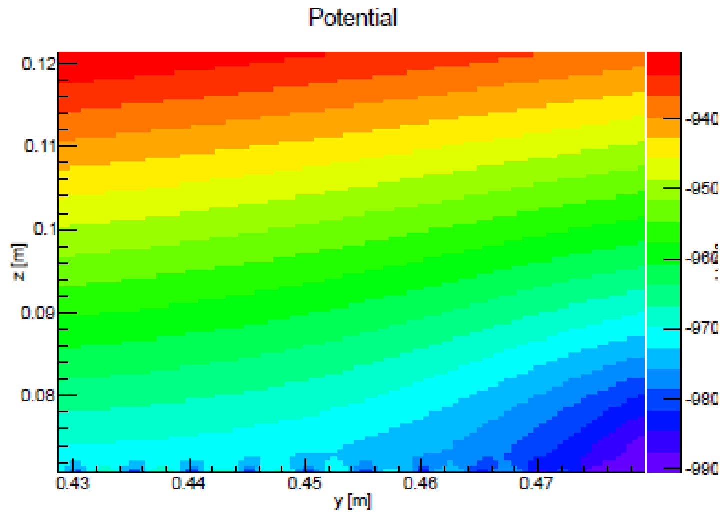


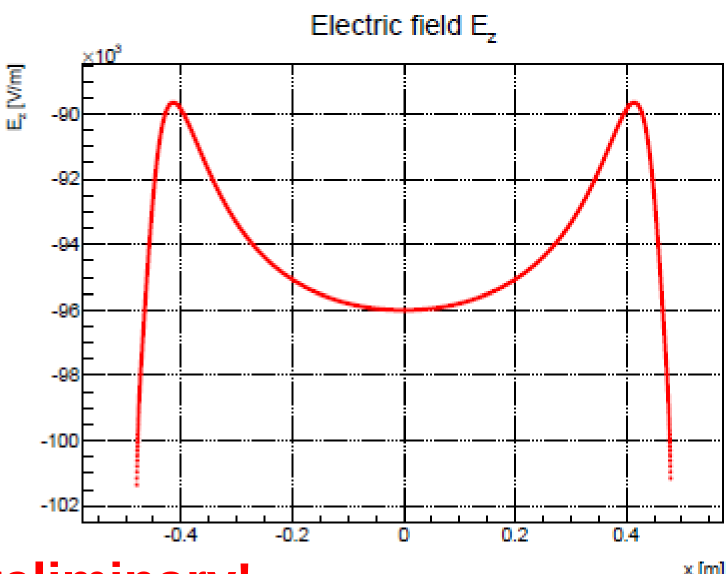


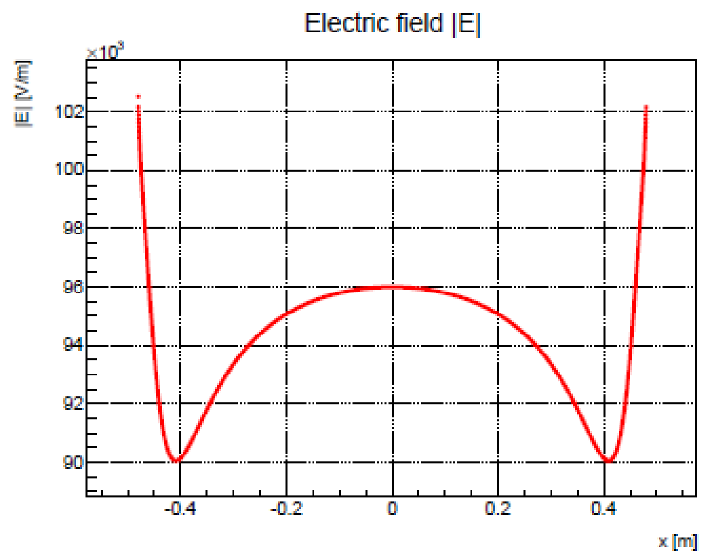
- 18 days calculation time on 1 GPU for an exact model
- Speed up simulation by using more than 1 GPU

Simulation of XENON1T Model

Results







Preliminary!

Summary

Past:

- Building arbitrary TPC geometry with dielectrics.
- CAD import and imports of meshes with external software.
- Ability to calculate on parallelized platforms, like GPUs.
- Full three-dimensional electrostatic field calculation.
- Program for analysis of simulation results.

Present:

- Refinement and optimization of field code.
- Investigation of the discretization

Future:

- Extending code with simulation of particle tracking in LXe

Thanks …

- … for your attention.