DRIFT CHAMBER DESIGN

Meeting della collaborazione DUNE-Italia

Lecce, 6/11/2023

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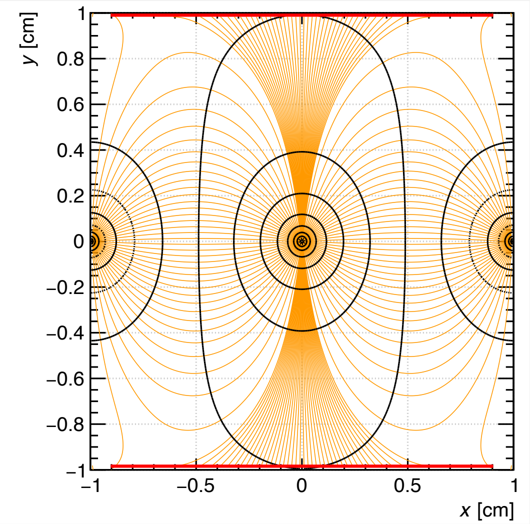
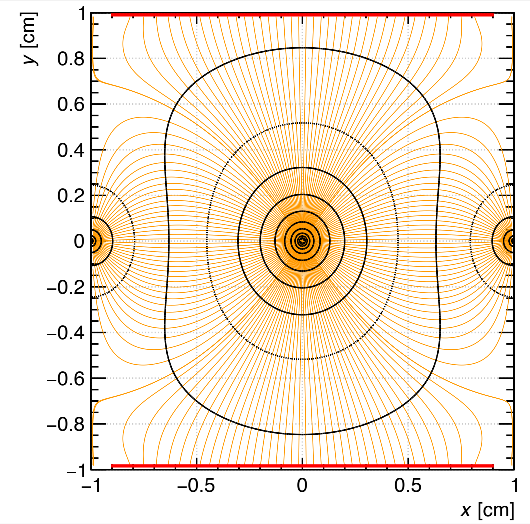
MOTIVATIONS

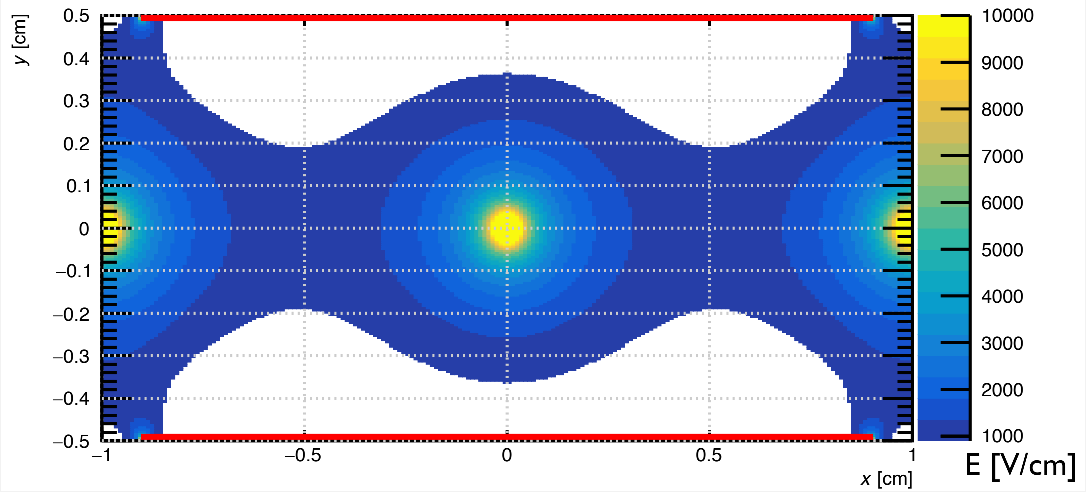
- A potential backup design to the STT for the tracking system in SAND.
- The hope is to reduce complexity:
  - in the mechanical design and setup, by having wider connected drift volumes kept at a lower pressure.
  - in the number of channels, by having a smaller number of sense wires with a wider spacing.
- Physics performance would need to be comparable to that of STTs.

INITIAL DEVELOPMENT STEPS

- The base concept: alternating field and sense wires with planar electrodes for field shaping and drift-volume separation:
  - no grading wires for design simplicity
  - gaps between the planar electrodes to allow for gas passage.
- First step in the design process was definition of the base cell configuration:
  - spacing and orientation of the wires and electrodes
  - wire and electrode thicknesses and voltages.
  - composition and pressure of the gas mixture
- Aiming at a simple relation between DCA and drift time: ideally linear.
- Toy cell implemented in Garfield++ simulation software to compute the Electric field, drift properties and signal production.

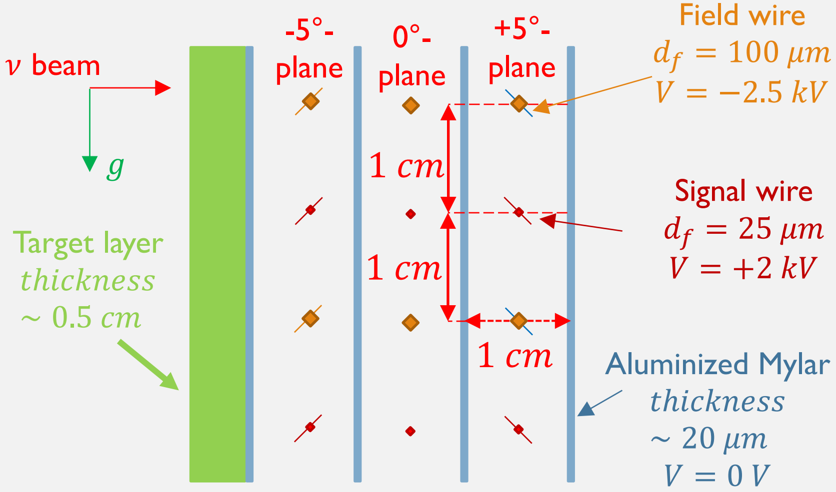


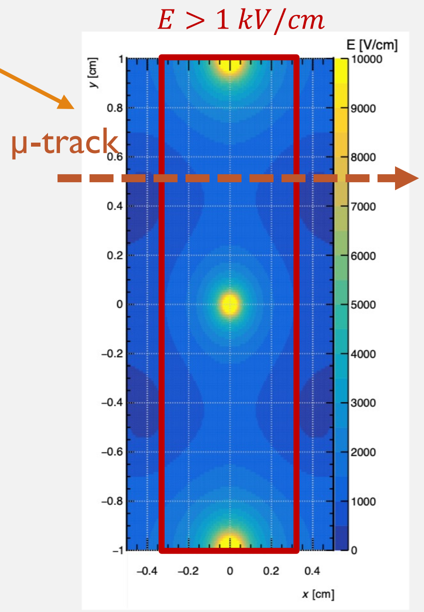




DEFINITION OF A BASELINE MODULE

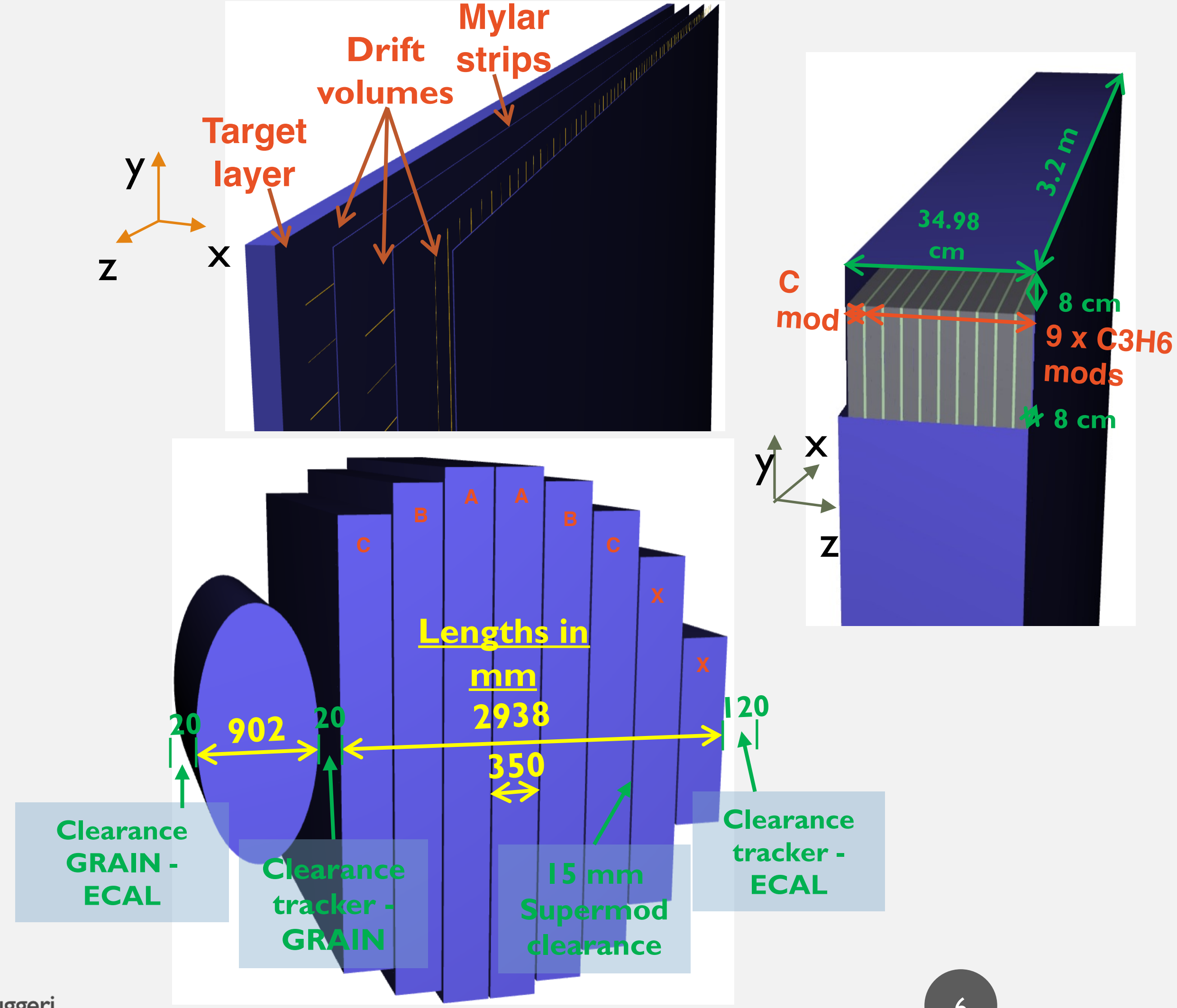
- Defined the configuration of a base cell: anode sense wires and cathode field wires with a 1 cm step. Cells are closed by grounded strips (1 cm thickness).
- Gas mixture (Ar/CO2 at 85%/15%) and voltages fixed aiming at sufficient gas gain ($\sim 10^5$) and $\sim$constant v_{drift} along the wire plane.
- A chamber module consists of:
  - A target layer of the required material.
  - Three wire planes in a $-5°,\ 0°,\ +5°$ configuration with respect to the B-field axis.
- Reduction of L-R ambiguity and optimal resolution in the bending direction with most of the readout channels on the same side.





DETECTOR LAYOUT

- Size of a module is consistent with an STT one, excluding the TRD.
- Supermodules consisting of: 1 C-target module + 9 C3H6-target modules.
- 8 supermodules can be fitted in the remaining SAND volume: 6 symmetric and 2 downstream.
- This preliminary configuration was implemented in the SAND simulations (thanks to G. Ingratta).
- The geometry includes updated GRAIN dimensions and clearances between supermodules.



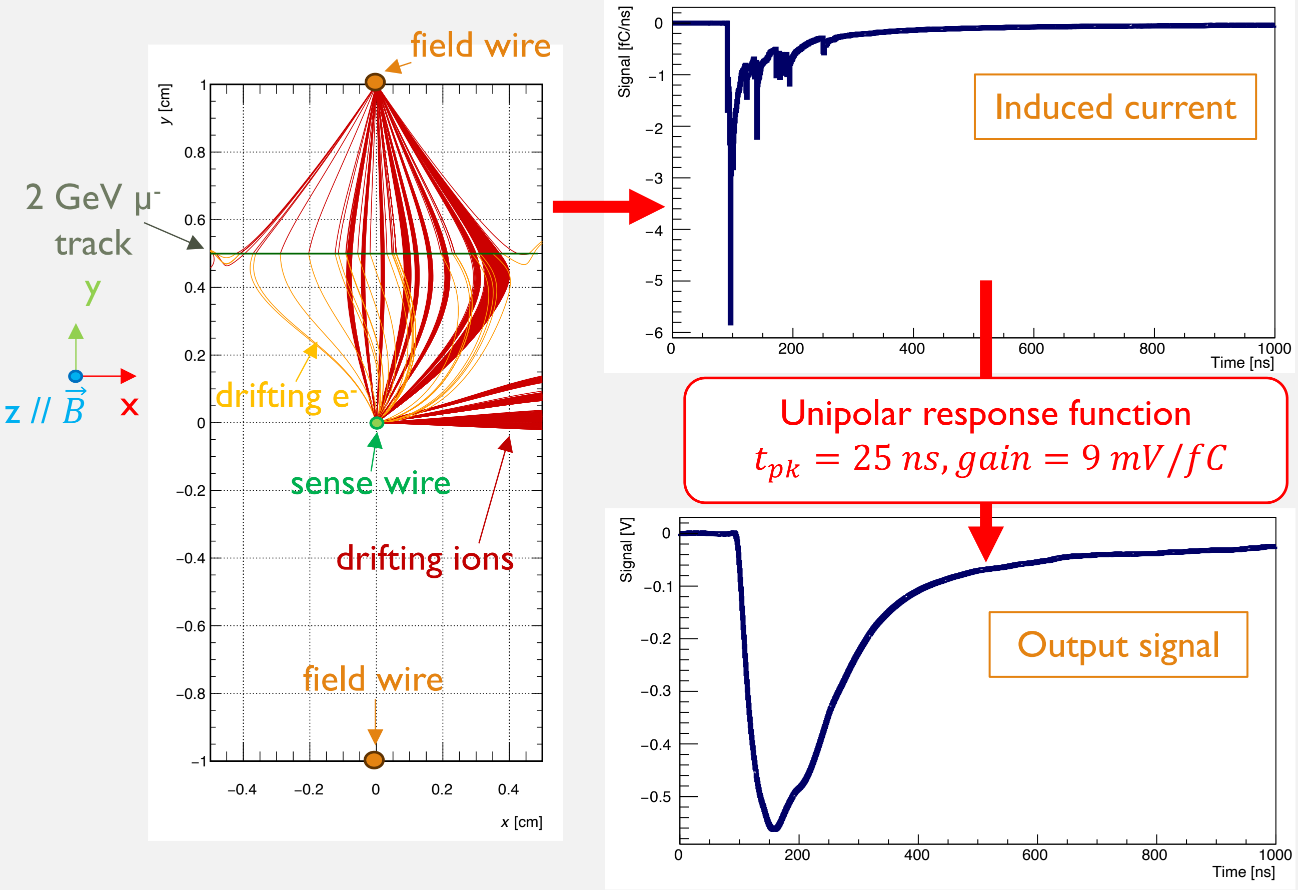
SIGNAL SIMULATIONS IN GARFIELD++

- Garfield implements algorithms for the simulation of:
  - ionization patterns of charged particles (Heed model).
  - charge transport with MC and RKF algorithms (using the latter).
- Induced signals are computed with the Shockley-Ramo theorem:

Induced current ⟶ $$i(t) = -q\boldsymbol{v}\cdot\boldsymbol{E}_w(\boldsymbol{r})$$

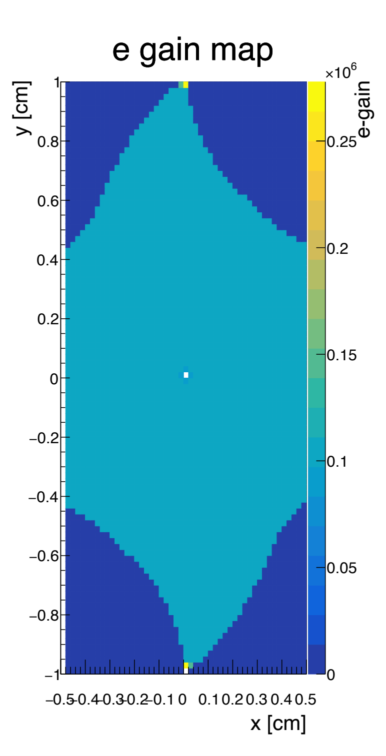
Charge velocity ↑ ↑ Weighting field

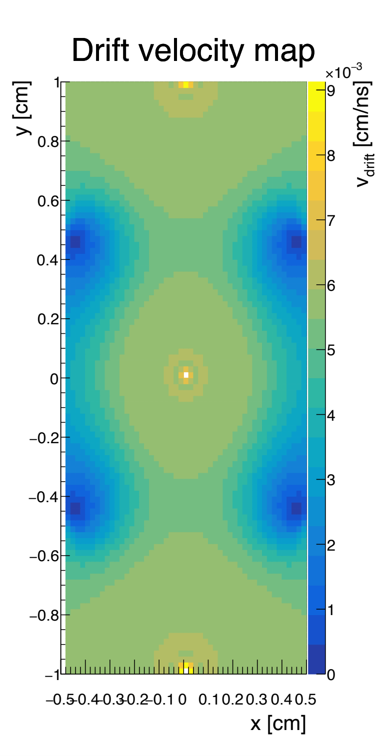
- Signals can be convolved with a detector response function.
- Current issues with the simulations:
  - RKF interface with current geometry is buggy: very slow simulations (>20 mins for each track).
  - Field must be computed at each execution.

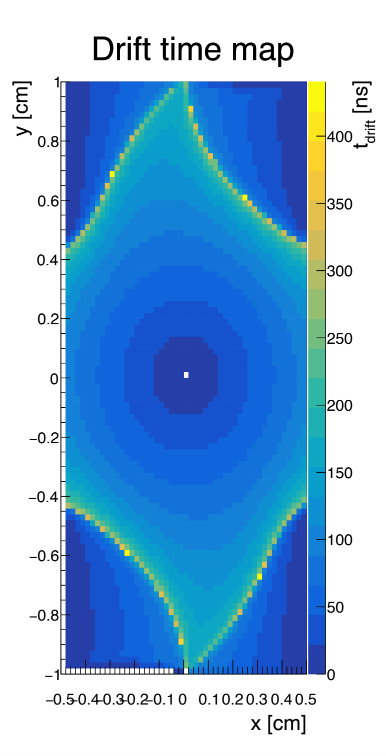


MAPPING OF THE DRIFT PARAMETERS

- Mapping the drift parameters (t_{drift}, v_{drift}, gain, etc…) and the induction signals from electrons:
  - to completely characterize the cell (drift parameters are attributes of the drift charges)
  - to simulate track signals by combining single electron signals.
- Voxelized a base dector cell with 200 μm steps: computed the electron drift properties and signal induced on the sense wire at each step. Results saved to ROOT files.
- Both horizontal and stereo cells were mapped.
- Drift velocity and drift time maps support our design choice.

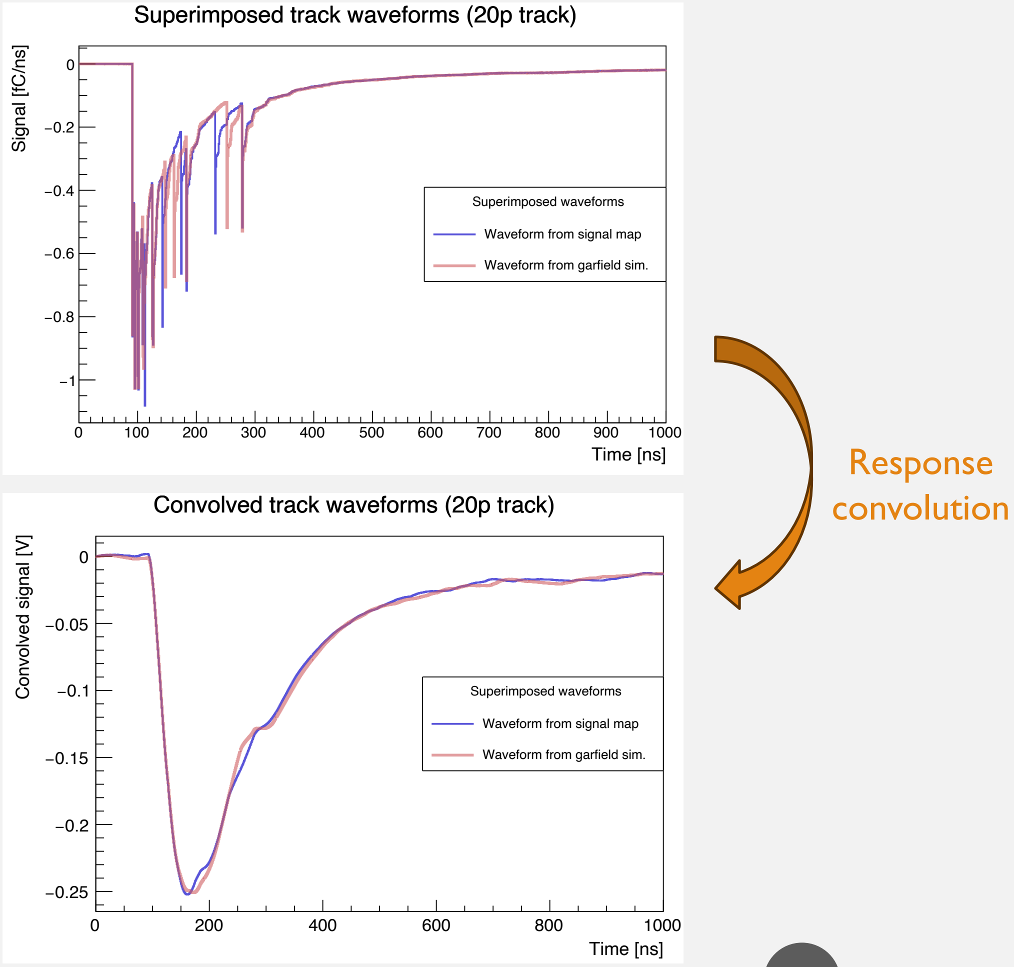






DISCRETIZED SIMULATION OF SIGNALS

- In Garfield++, signals from track primary e^-/ions are summed separately bin-by-bin.
- Response obtained by summing single e^- at each point in the trajectory. Ions neglected for simplicity.
- Algorithm accounts for cell periodicity.
- Comparison between toy tracks at different starting points and angles.
- Convolution can be performed separately.
- Sub-optimal features:
  - Finite resolution: deviations are less relevant in the convolved signal.
  - Producing and storing map files is not particularly efficient.



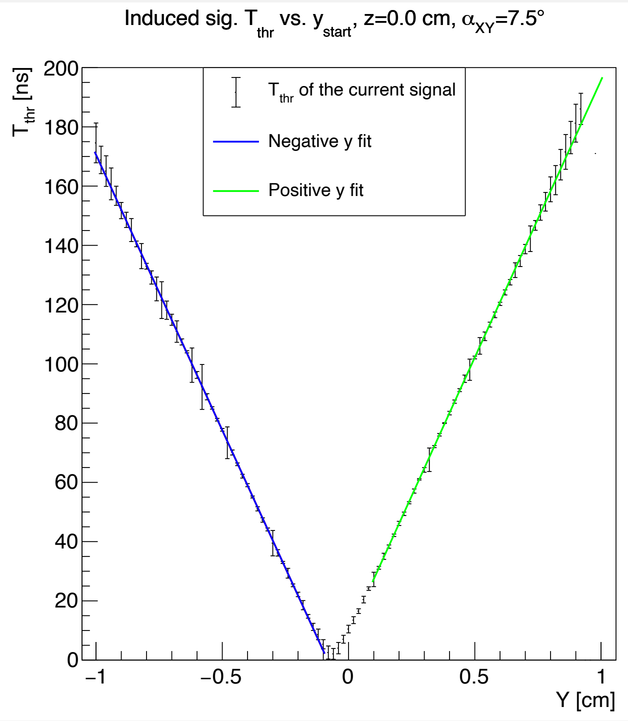
DRIFT TIMES FROM FULL TRACKS

- The discretized response is useful for studying signal waveforms and may be integrated in the detector simulation.
- However, a simplified reconstruction could use the drift times to determine positions.
- Time-over-threshold of the induced current from full-track simulations at several starting points and angles: 100 tracks at each point.
- Signal times are linear w.r.t. the DCA ➔ effective drift velocity can be defined.

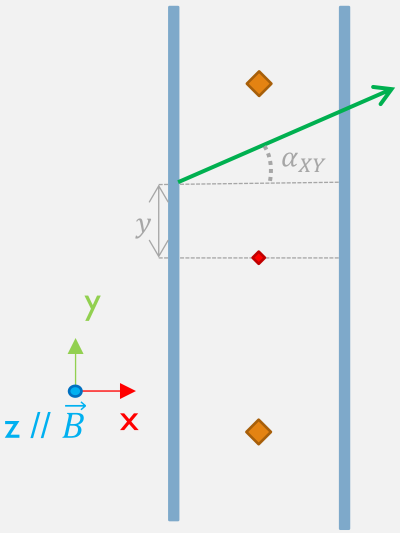
$$d_{CA} = \pm\left(\frac{(t_{thr} - p_0)}{p_1} + h_{width} \cdot \tan\alpha_{XY}\right) \cdot \cos\alpha_{XY} \Longrightarrow$$

$$\Longrightarrow v_{eff} \equiv \left|\frac{d_{CA}}{t_{thr}}\right| = \cos(\alpha_{XY}) \cdot \frac{t_{thr}}{p_1} \simeq 53\ \mu m/ns$$

- Constant v_{drift} design criterion is supported.

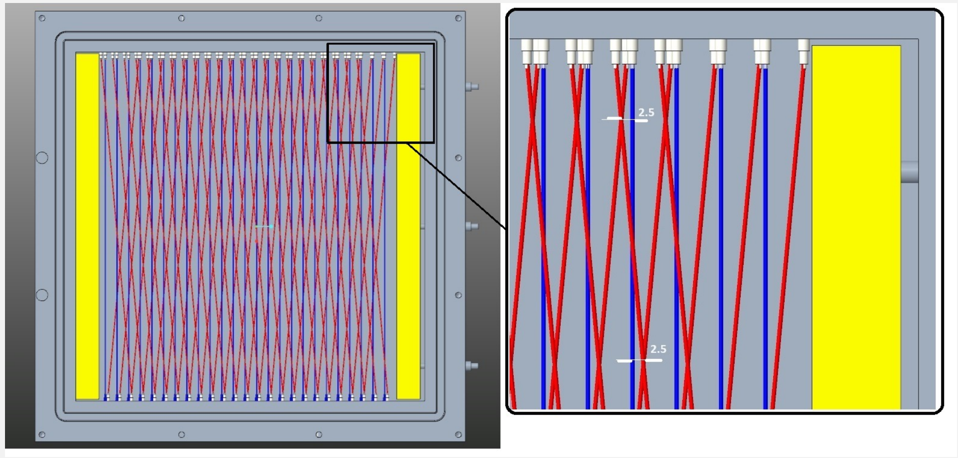


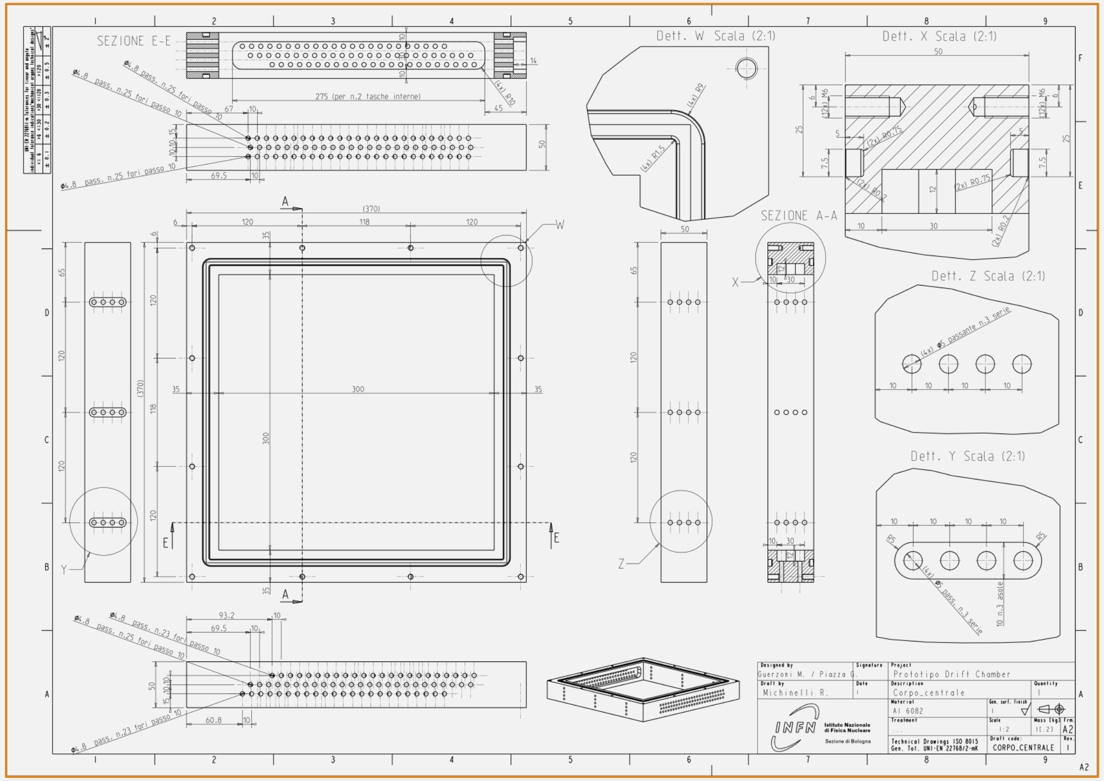
	Negative Y	Positive Y
$\chi^2/N.dof$	$10.7/44$	$13.2/40$
$p0$ [ns]	-15.4 ± 0.3	8.6 ± 0.3
$p1$ [ns/cm]	-186.0 ± 0.7	187.1 ± 0.7



SMALL SCALE PROTOTYPE

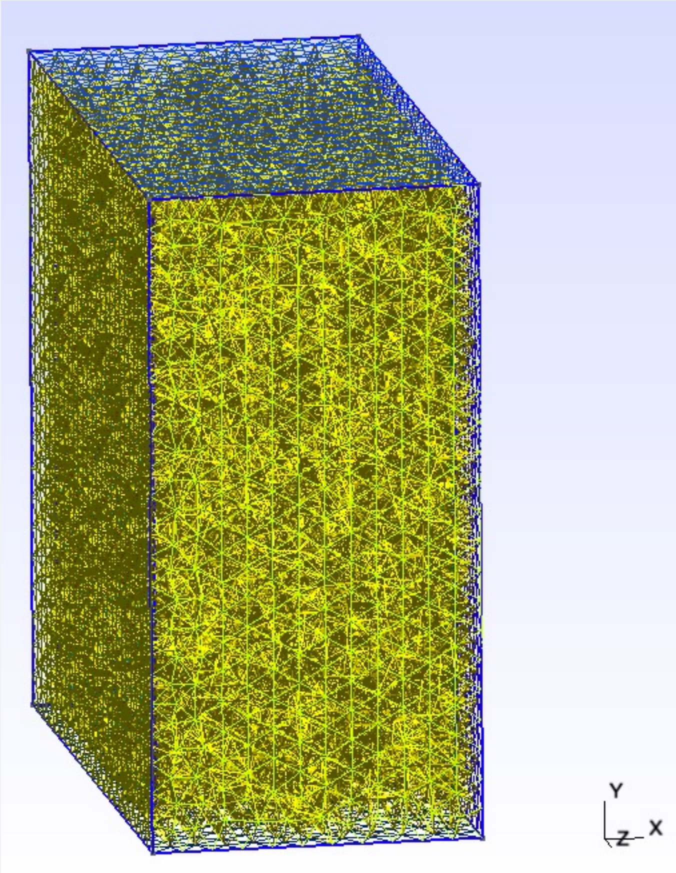
- Current activities for the design and construction of a small 30x30 cm chamber module prototype.
- The aim of the prototype is to gain experience in the construction, operation and readout design of this type of detectors.
- Mechanical design has been finalised, construction to start in the next few weeks.





CURRENT ISSUES

- Full simulations in Garfield take too long: potential issue with the geometry definition.
- Only possible to simulate a few cells: field maps for the full (small scale) geometries would be useful.
- But drift chamber simulations are taxing for FEM software: producing quality meshes with Ansys-Maxwell or gmsh+elmer FEM libraries has not been possible.
- Instrumental effects are not included in Garfield++ simulations: capacitance and admittance matrices estimated from simplified models.



CONCLUSIONS

- Defined the base configuration of a Drift Chamber tracking system for SAND.
- Electric field and drift simulations on the current model so far support the design.
- Current resources only allow simplified simulations: no realistic geometries, electrical/mechanical disturbances.
- Development of a 30x30 cm prototype module is ongoing: initial experience in construction and operation.
- Design of a larger 120x80 cm prototype for design validation is to start.

GRAZIE PER L’ATTENZIONE