A Drift Chamber Tracker for SAND

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DUNE-Italia Collaboration Meeting, Ferrara

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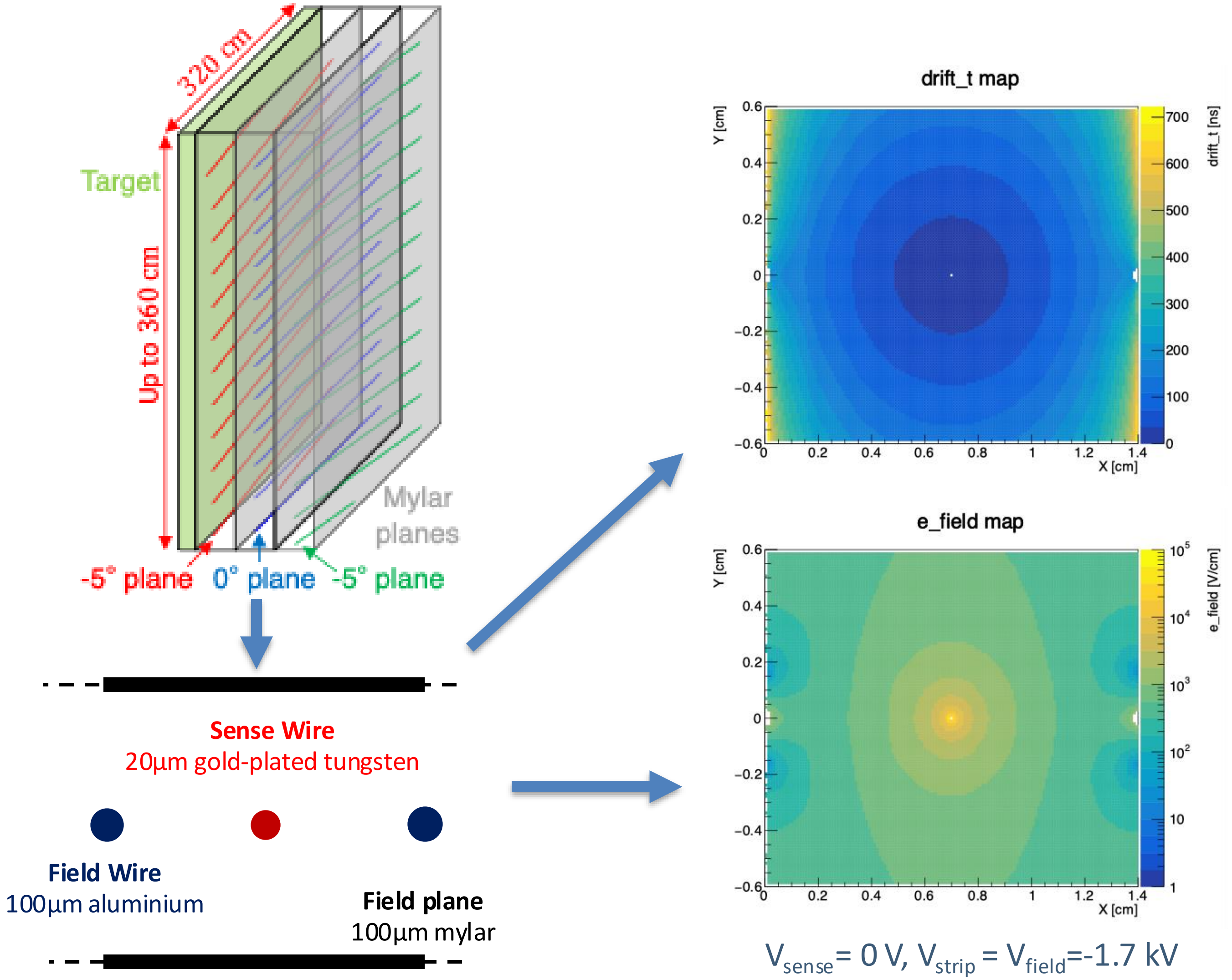
Motivations

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

Module layout

- In each module/station:
  - Target layer (CH_2 or C)
  - 3 multiwire planes at stereo angles: -5°, 0°, +5° with respect to the B-axis
  - Ar/CO_2 (85/15%) mix. at ~1 atm
- Current unit cell:
  - 1.4 x 1.2 cm^2
  - Grounded sense wires
  - Mylar plane electrodes
- Garfield++ simulation of the cell



V_{sense}= 0 V, V_{strip} = V_{field}=-1.7 kV

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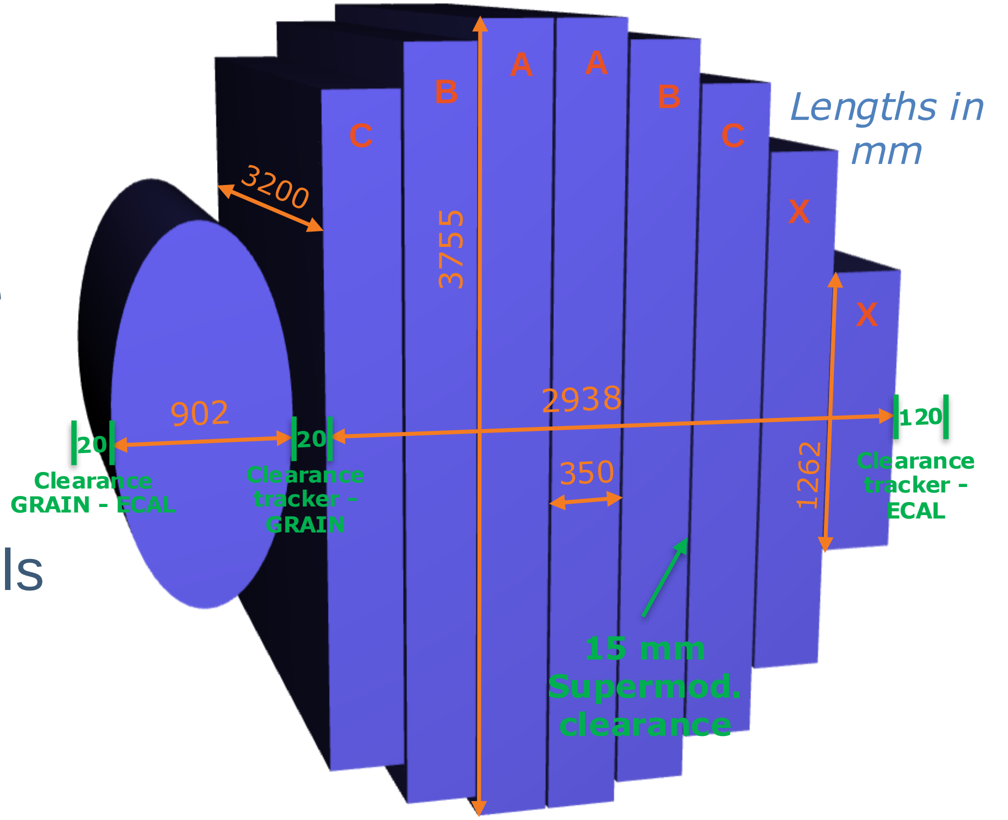
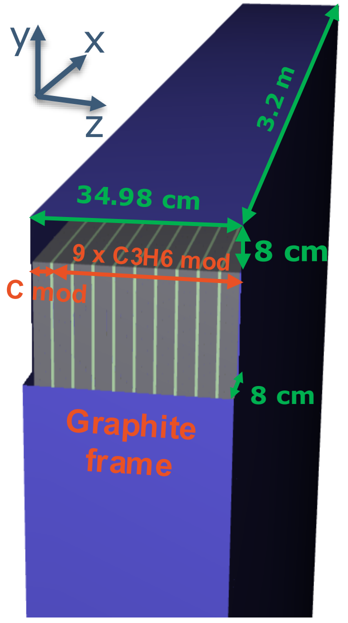
Potential detector layout

- 8 “super-modules” in the inner volume: 6 symmetrical+ 2 downstream
- Removed the TRD compared to the base design
- 9 C_3H_6-modules and a C-module in each super-module
- ~240 planes
- 1.4x1.2 cm^2 cells: ~5x10^4 channels
- 2x1 cm^2 cells: ~3.6x10^4 channels





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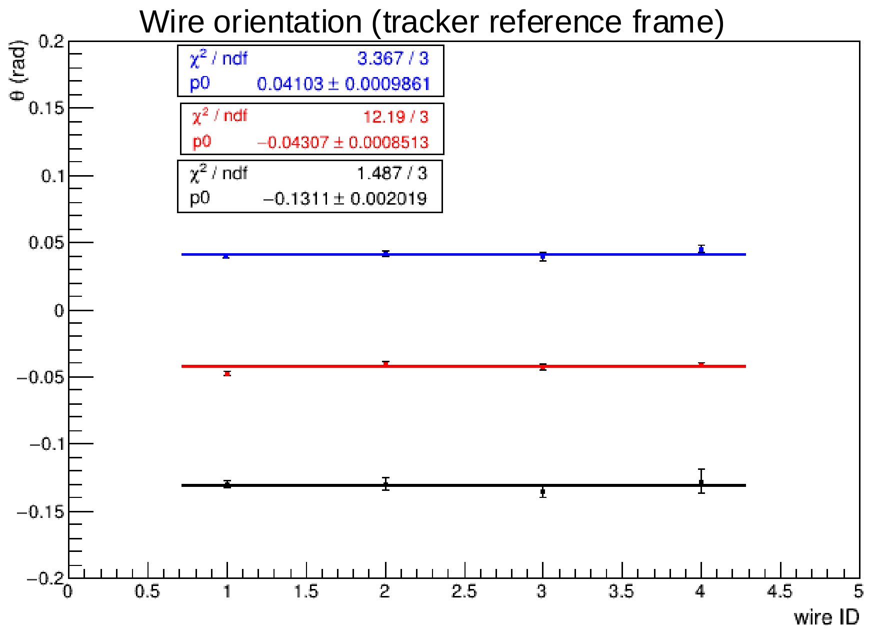
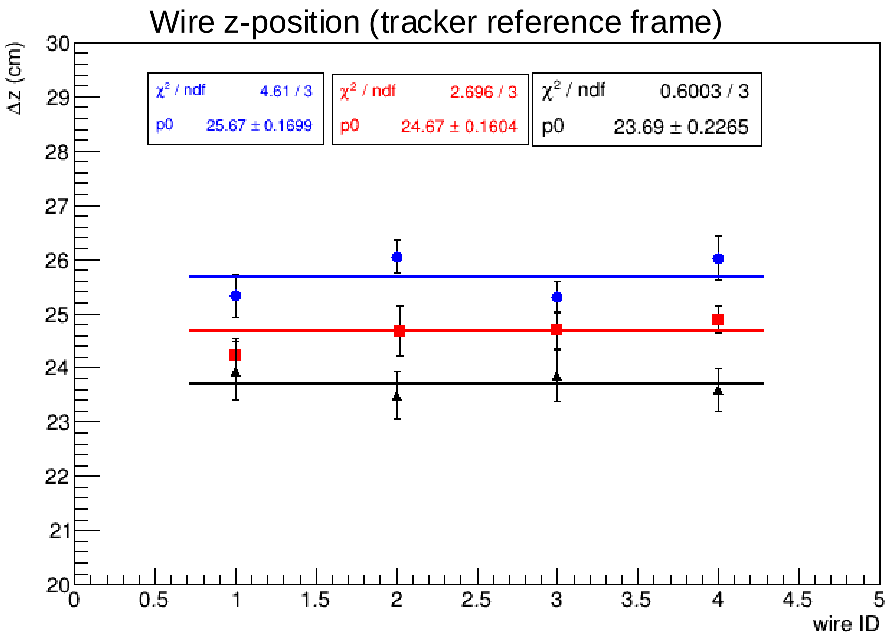
Small-scale prototype design

- Chamber designed and operated at INFN-Bologna:
  - ~30x30 cm^2 area
  - 3 staggered wire planes (-5°,0°,+5°)
  - 2x1 cm^2 cells
  - $\Delta V_{\text{field/sense}} \simeq 3.2\text{ kV}$, grounded planes
  - repurposed hardware from KLOE
- Running with cosmics
- Scintillator-based tracking system (~2 mm resolution)
- Readout by CAEN digitizers: 12 instrumented channels


Channel alignment

- Wire positions and orientations reconstructed from tracker data
- Fits are consistent with the nominal chamber geometry





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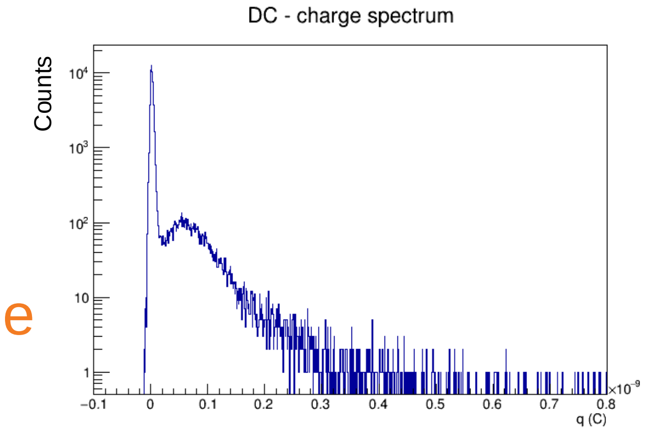
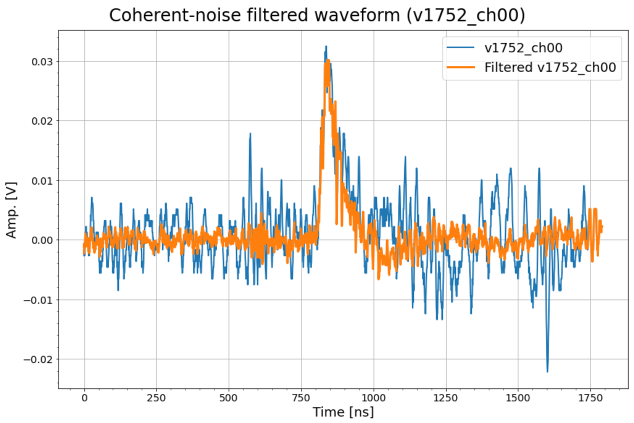
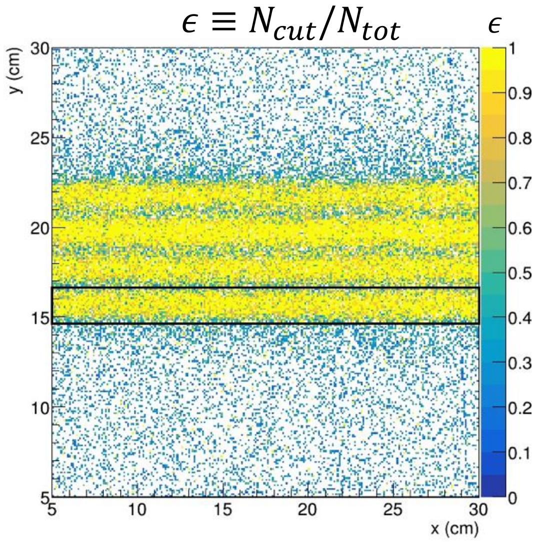
Channel Efficiency

- Studied the cell response for several voltage configurations
- Noisy setup: implemented coherent-noise subtraction and peak finding algorithms





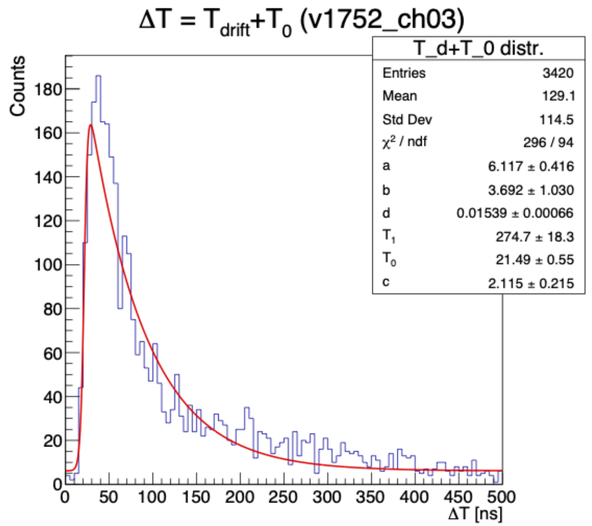
- Non-uniform efficiency across the cell:
  - $\epsilon > 90\%$ close to the wires
  - drop in the outer region likely due to the 200 ns integration window

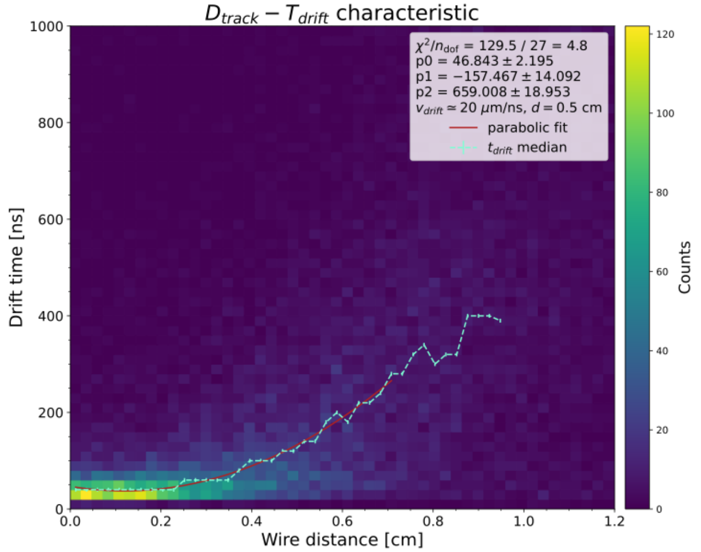


Distance-time relation

- Studied the distance-time relation of the cells to estimate the drift velocity
- Modelled the signal time distribution to determine potential time offsets.
- Low tracker resolution is a limiting factor
- Preliminary estimation of the drift speed from the median t_{drift} values: $\sim 20\ \mu\mathrm{m/ns}$

  → Consistent with MC simulations





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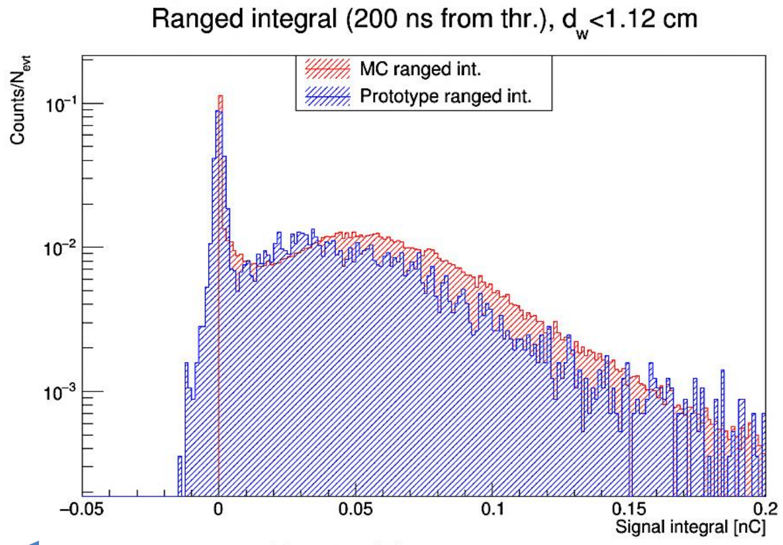
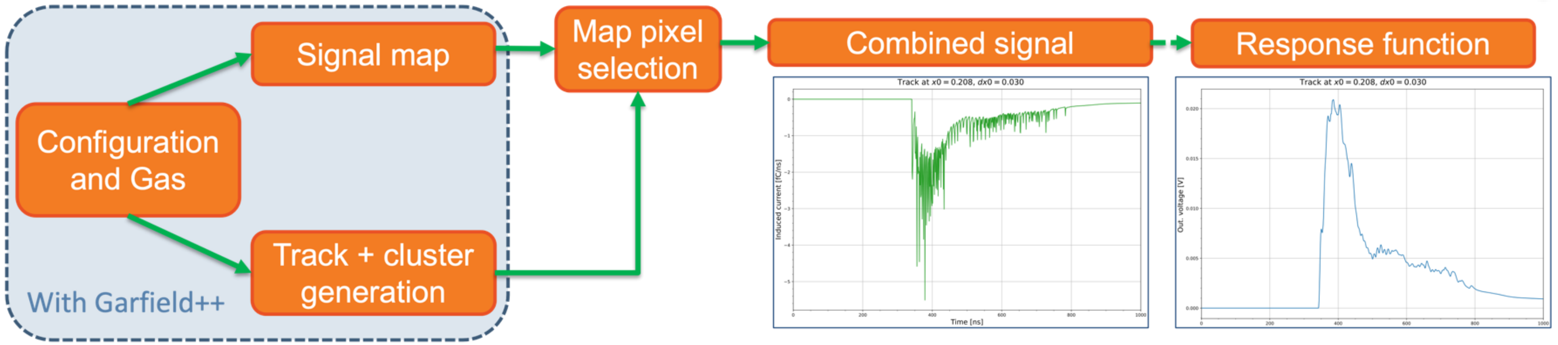
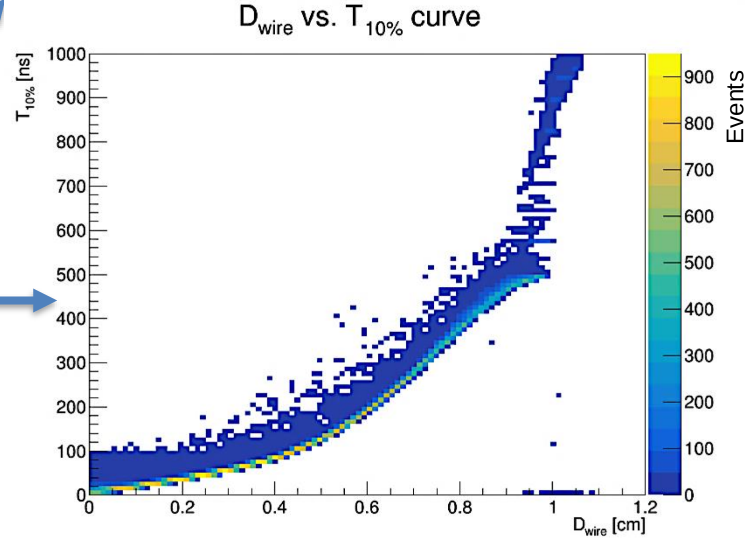
Fast response simulation

- Garfield++ to model drift and signal response
- Full particle simulation in Garfield++ is too slow → response by combining discrete electron signals.
- Customized G++ code to avoid overflows/slowdowns
- Toy MC simulation to validate prototype results







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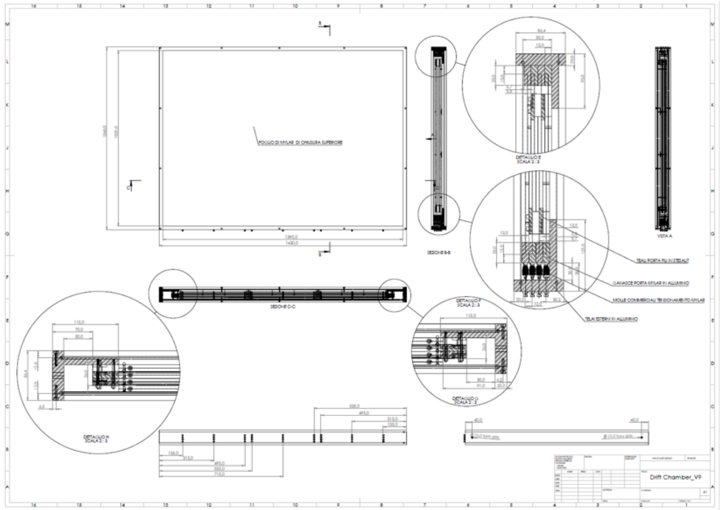
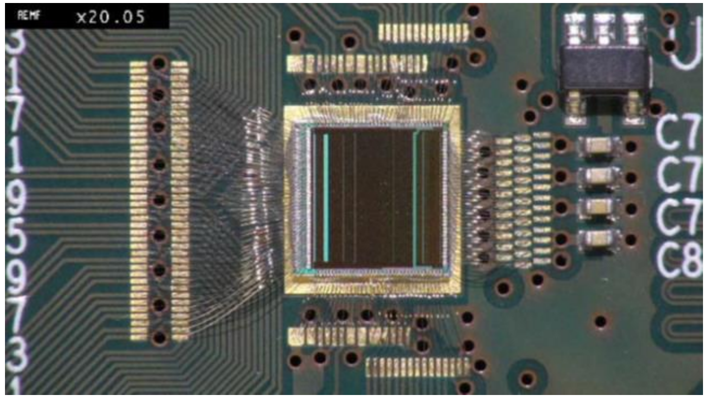
Medium-scale prototype

- Final single module analogue, 3 wire planes:
  - 120x80 cm^2 area
  - 1.4x1.2 cm^2 cells, grounded sense wires
  - ~180 channels
  - Read-out based on the TIGER ASIC
- Ongoing mylar foil creep tests
- Construction set to start in the near future
- Testbeam planned for early 2025





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Conclusions and prospects

- Small-scale prototype:
  - Tested with cosmics at several field configurations
  - Good detector alignment, non-uniform efficiency across the cell
- Drift-chamber option included in sandreco simulation and tracking algorithm
- Ongoing detector performance studies.
- Medium-scale prototype:
  - Ongoing procurement
  - Garfield++ response simulation
  - TIGER demo board is under test in Bologna

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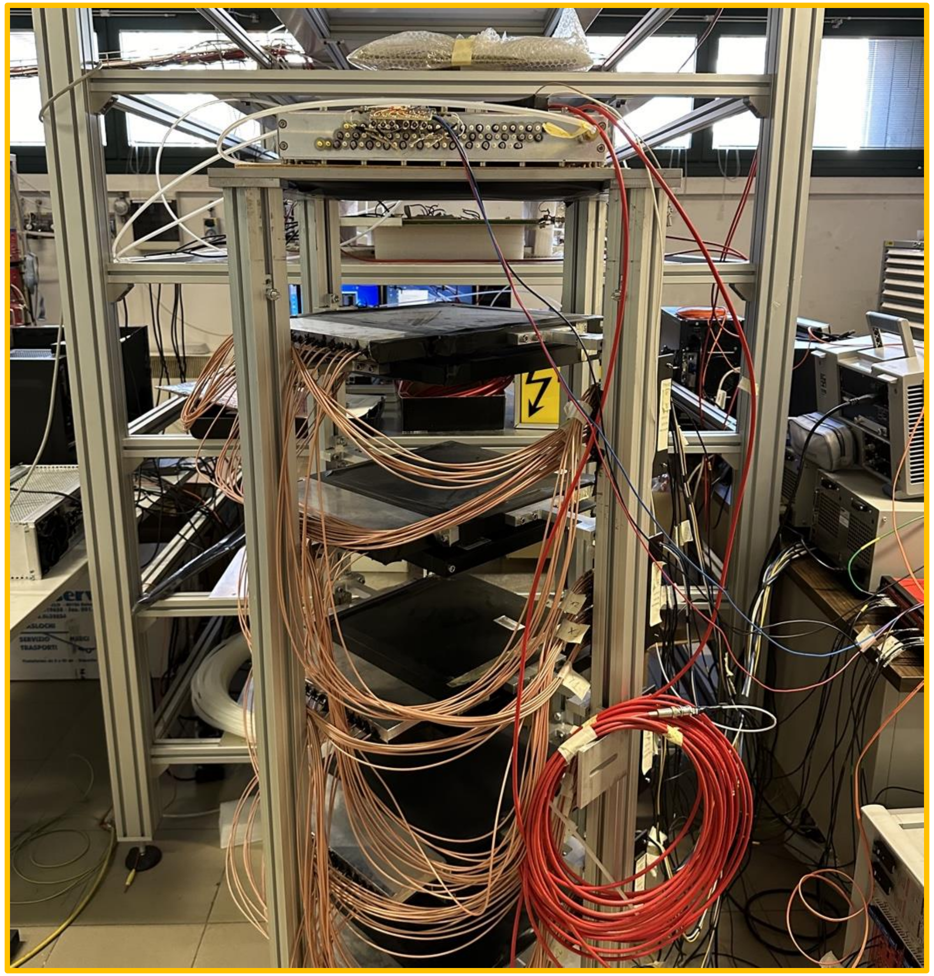
Back-up

Small-scale prototype setup

From Top to Bottom:

- Plastic Scintillator:
  - size: 15x15 cm2;
  - Thickness 1 cm;
  - readout 1 PMT:
    - Hamamatsu R9880
    - Direct coupling
- Plastic Scintillator:
  - size: ~ 30 x30 cm^2;
  - Thickness ~2 cm;
  - readout 2 PMTs
    - Fiber Coupling
- Drift Chambers (3 Layers):
  - Readout 12 channels (4 per layer)
  - KLOE pre-amplifiers: ~1.5 mV / fC
- Tracking system: position resolution ~2mm



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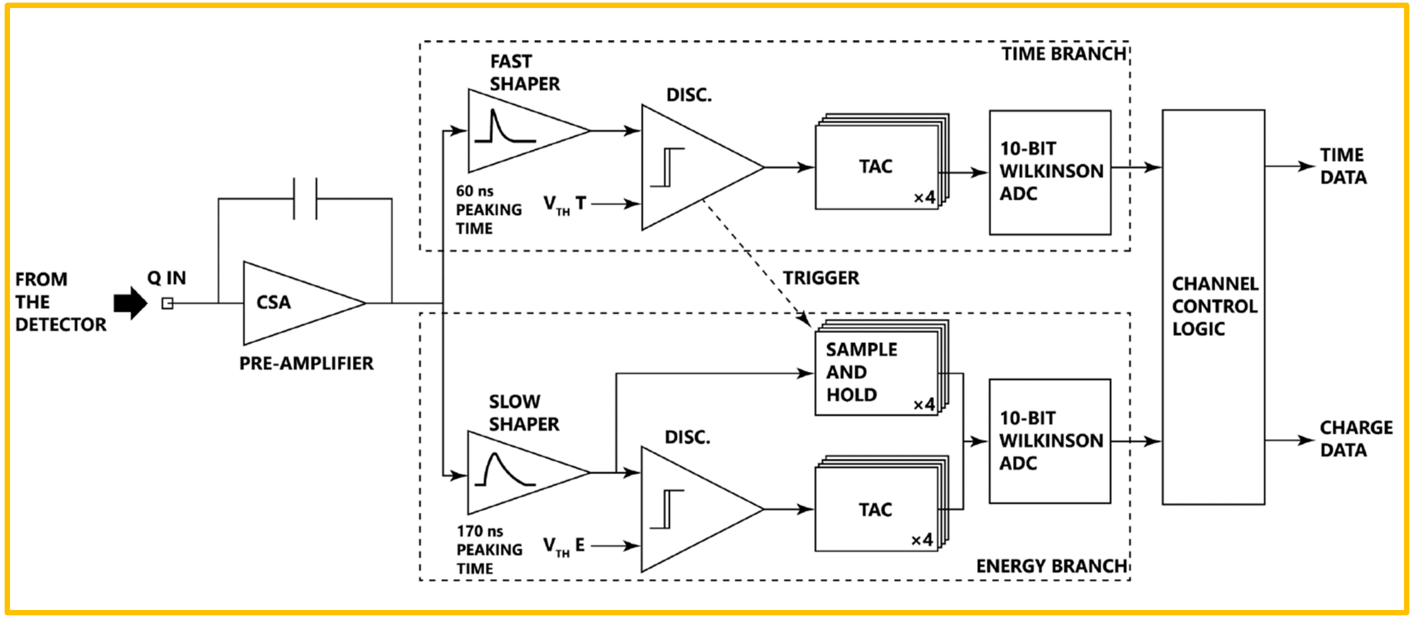
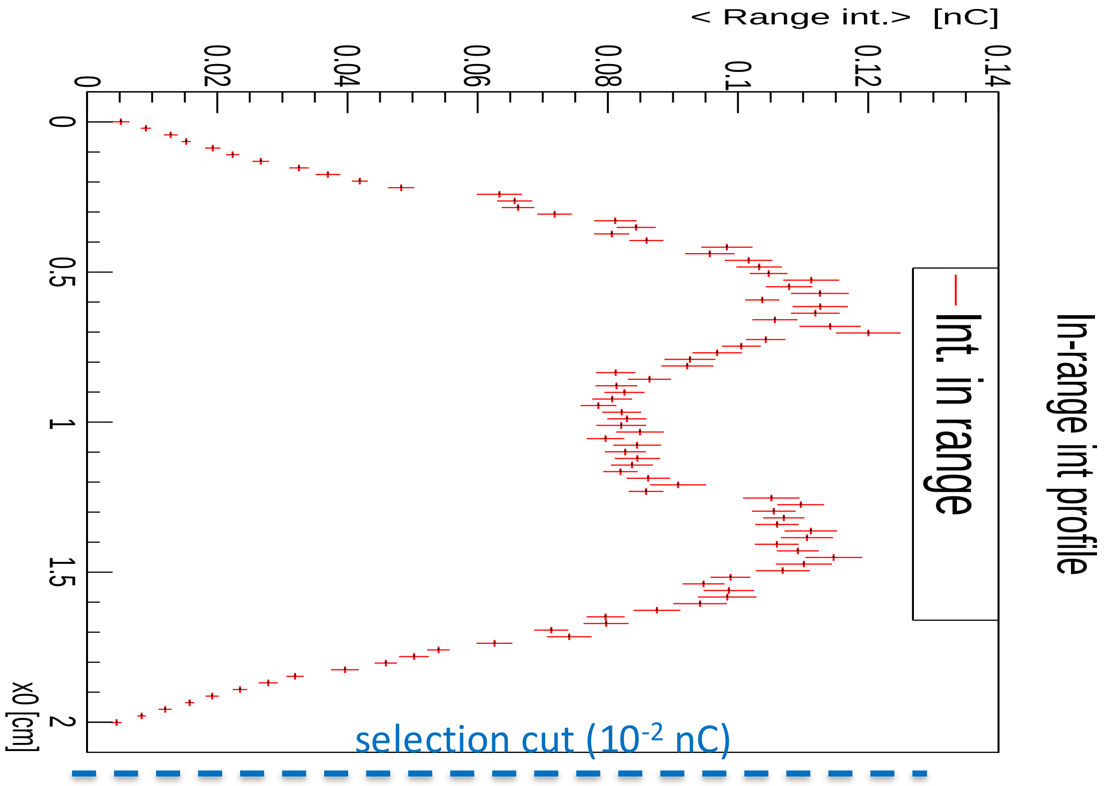
Readout – TIGER ASIC

- UMC 110nm technology
- 64 channels per ASIC (2 ASIC per FEB)
- Time and charge measurement
- One demo board is now in Bologna



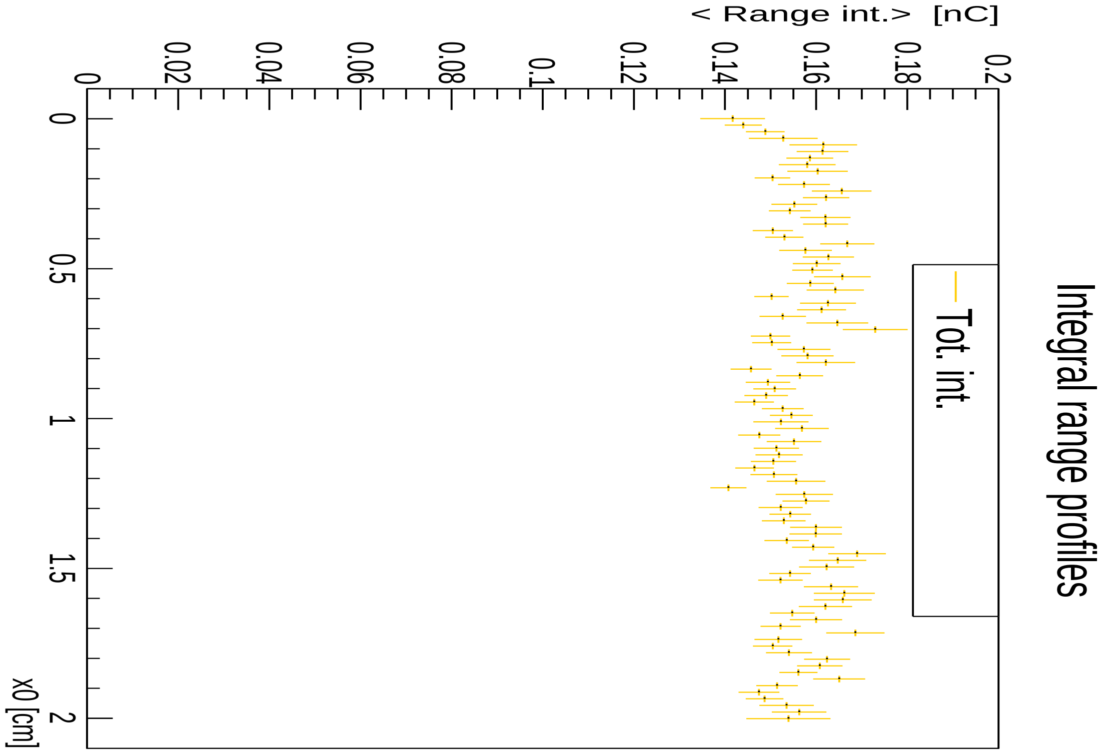
Mean ranged integral over the cell (MC)

- 1D profile over x0 of the ranged-integrals (vertical tracks production)
- Drop in the centre and at the edges
- Consistent with the drop in efficiency at the edges
- Drop at the centre likely due to starting point selection



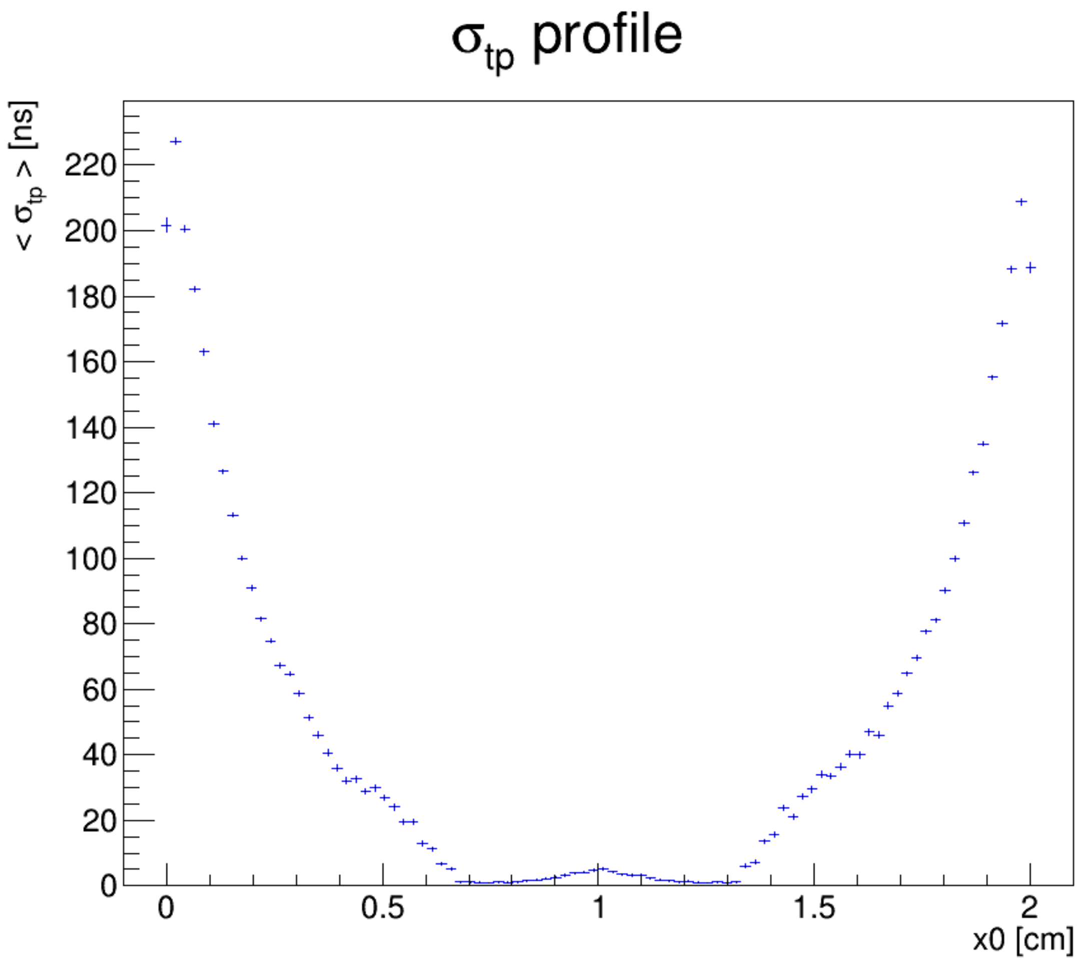
Mean tot-integral over the cell

- Repeating the profile with the total integral
- The distribution is uniform over the range in x0
- Uniform response consistent with single e$^-$ waveforms



Peak time dispersion

- Std. of the peak times within the waveform
- Dispersion increases with the distance
- Potential explanation of the smaller ranged-integral at higher distances



Combined range integrals