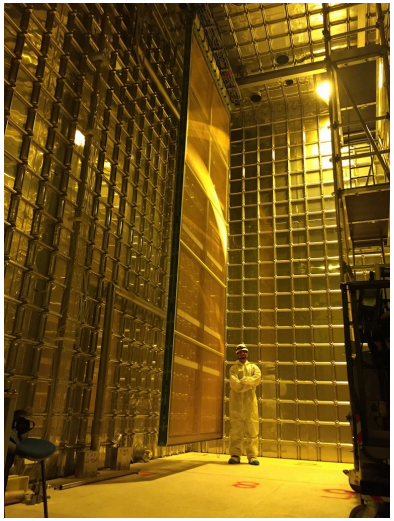
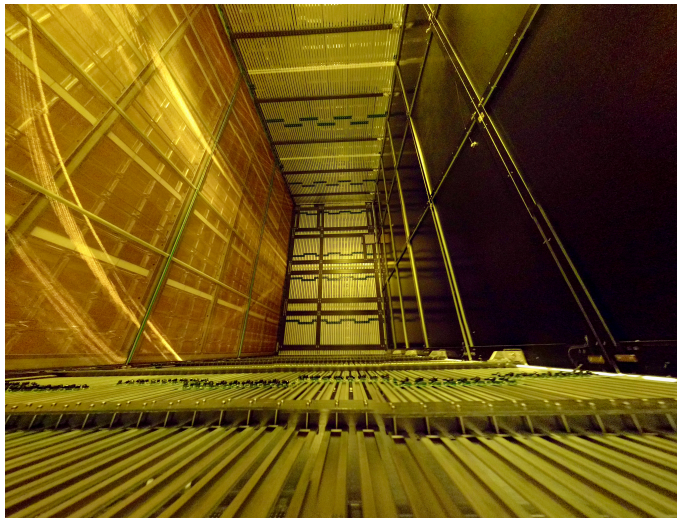
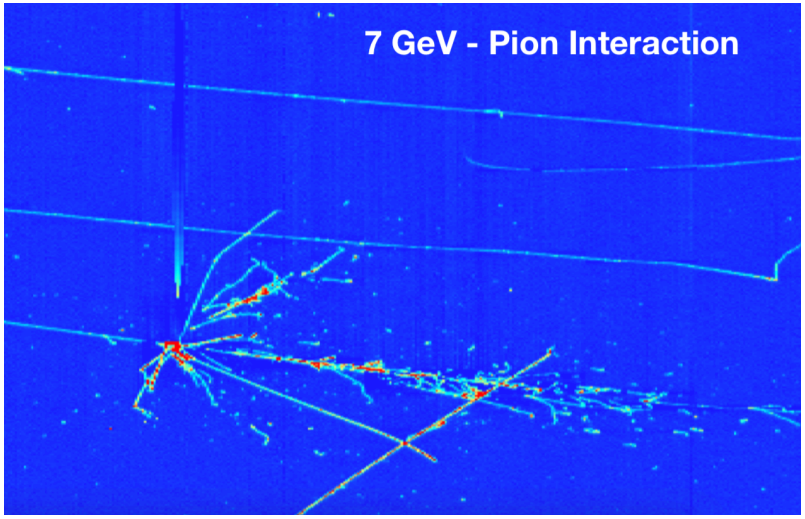
APA Design
and its relationship to detector requirements







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APA Preliminary Design Review (60%), PSL, 03/2019

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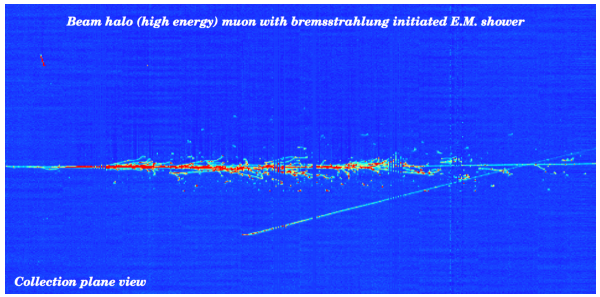
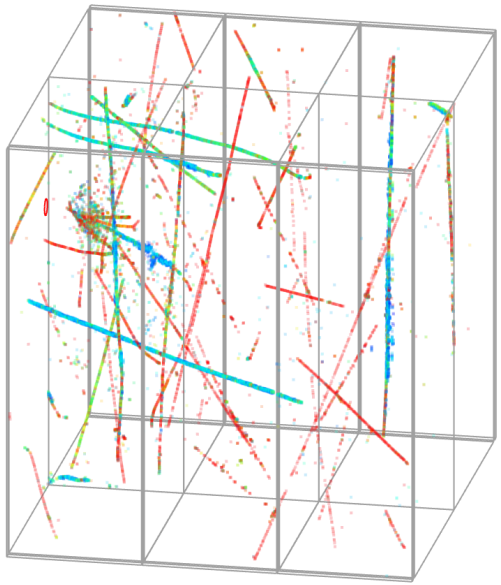
The DUNE FD Anode Plane Assemblies

In a Single Phase Liquid Argon Time Projection Chamber particles are detected through their ionisation charge which is drifted and measured on a suitable anode to reconstruct their:

- Trajectory in 3D (*tracking, vertexing*)
- dE/dx and range (*PID*)
- Total deposited energy (*calorimetry*)





The Anode Plane Assembly is therefore the “heart” of the TPC, much like a digital camera’s chip.

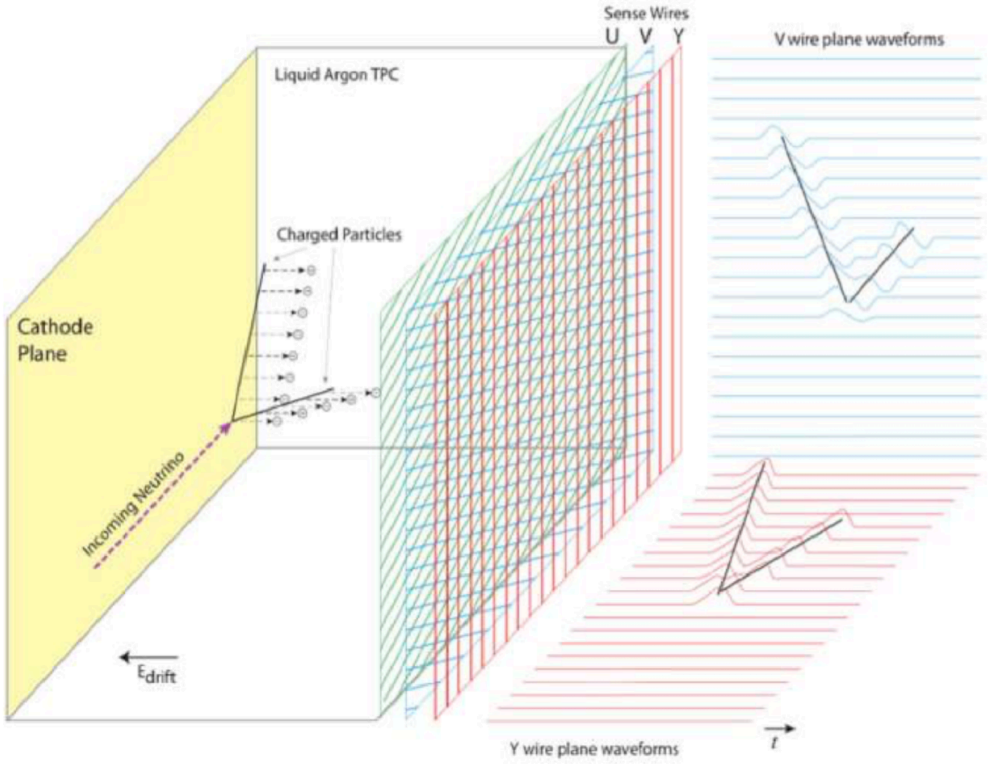
The APAs are critical for the quality of the TPC data.

Wire planes

In principle two wire planes at an angle, with analog and timing information would be sufficient.

However multiple layers provide:

- Redundancy (inefficiencies, bad channels)
- Resolution of ambiguities (high occupancy events)



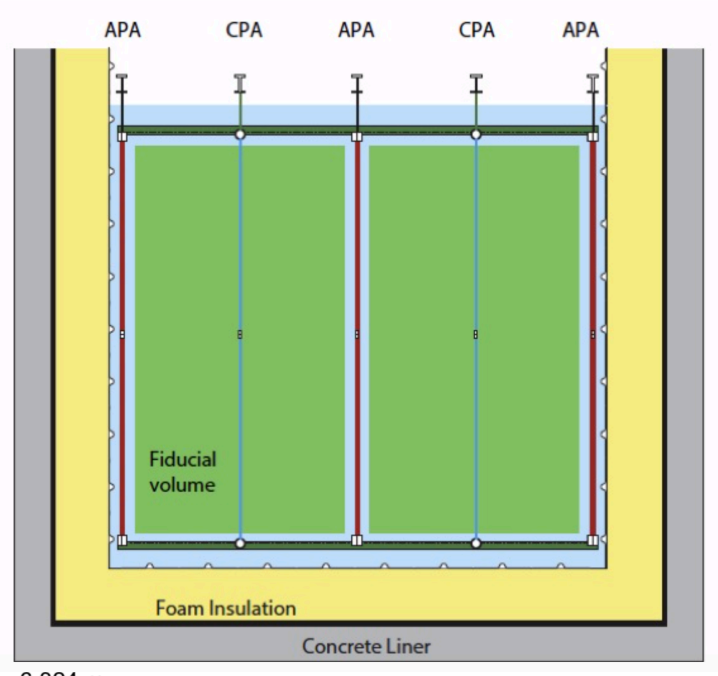
You also want a well-controlled electric field arrangement near the sensing wires.

Hence two induction planes U, V (+/- 35.7°) and one collection plane X (vertical) between a shielding plane G (vertical) and a grounded mesh

The “wrapped” APAs

- In a DUNE FD module the APAs in the middle must collect charge coming from two drift volumes: both APA sides must be active
- We want to keep R/O channel count low (cost) and have electronics only on one side (to maximize active area)

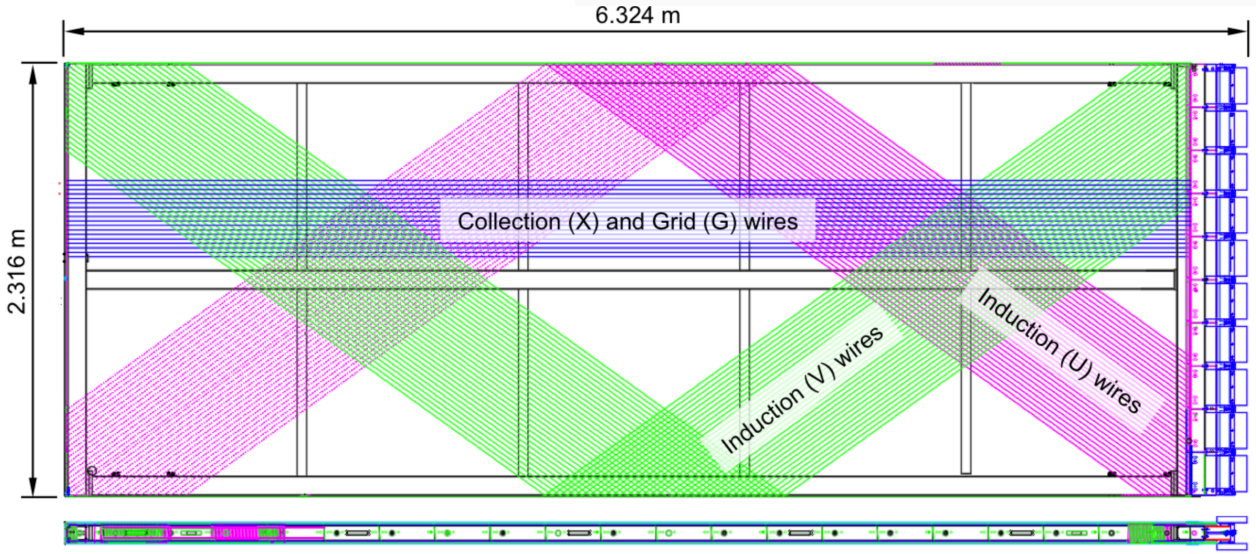
These requirements are met by wrapping wire planes around the APA frame



Also:

- Carry the PDs
- Carry the CE
- Carry wires

Dimensions must be compatible with DUNE underground access

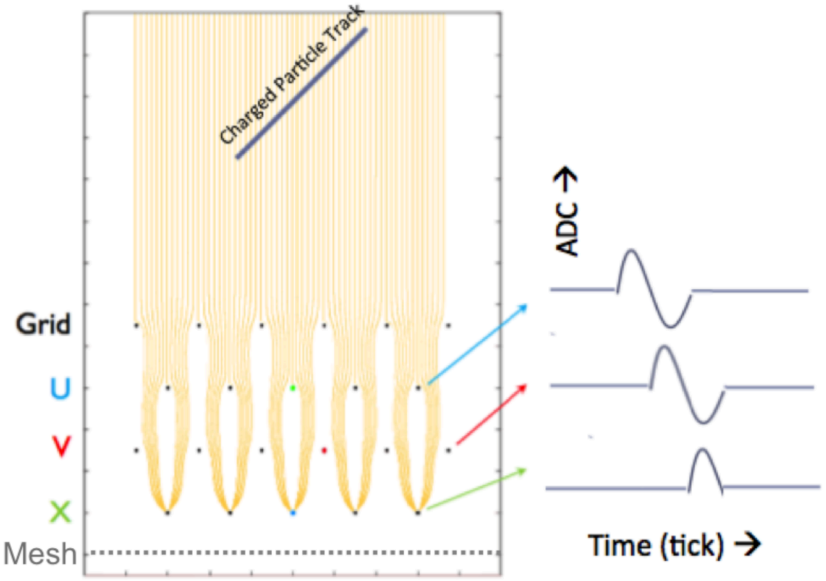


Wire pitch and angles

- 5mm wire pitch achieves the required MIP detection capability
- Allows y-z vertex resolution of 1.5cm (determination of fiducial volume)
- Allows sampling of low energy (short) tracks)
  - electron from supernova neutrino ~25MeV: 3-5cm
  - 50MeV proton: 2cm
  - e/γ separation: radiation length is 14cm, mean free path for pair production is 18cm
- With either 3mm wire pitch or 45^{o} angles (U, V) the MC shows a gain of only 1% in bgr rejection for a purity of 90% in e/γ, a difference too small to go to the higher complexity and cost of implementing either of the two.

Wire layer spacing and tolerances

- A well-controlled electric field arrangement is important for charge transparency between the wire planes
- Simulations also backed by analytical calculations show that we want 5mm wire plane separation and 0.5mm wire pitch and wire layer spacing tolerance.
- Frame planarity tolerances are derived from the above.



Wire tension

- Wires must not sag so that they touch and short
- Wires must not be tensioned near their limit if cool down is not very smooth
- In protoDUNE we started with a 5N nominal tension requirement
- We decided to use APA with a range of tensions of up to 7N
- We are looking in the data for correlations between tension and performance: nothing established yet, if any effect exists it must be very small

- Driven by protoDUNE analysis results we expect that we will be in a position to relax the tension tolerances for production

Conclusions

- The APAs have been studied extensively with electric field calculations and simulations, and with the full FD MC.
- ProtoDUNE data is of unprecedented quality demonstrating the validity of our design and key parameter selection.
- Ongoing protoDUNE offline analysis will establish or reject possible correlations between construction parameters & tolerances and data quality and that will remove most of the remaining risk in setting those for FD production.