FERMILAB-SLIDES-23-117-V

Commissioning the Time Projection Chambers of the SBND experiment

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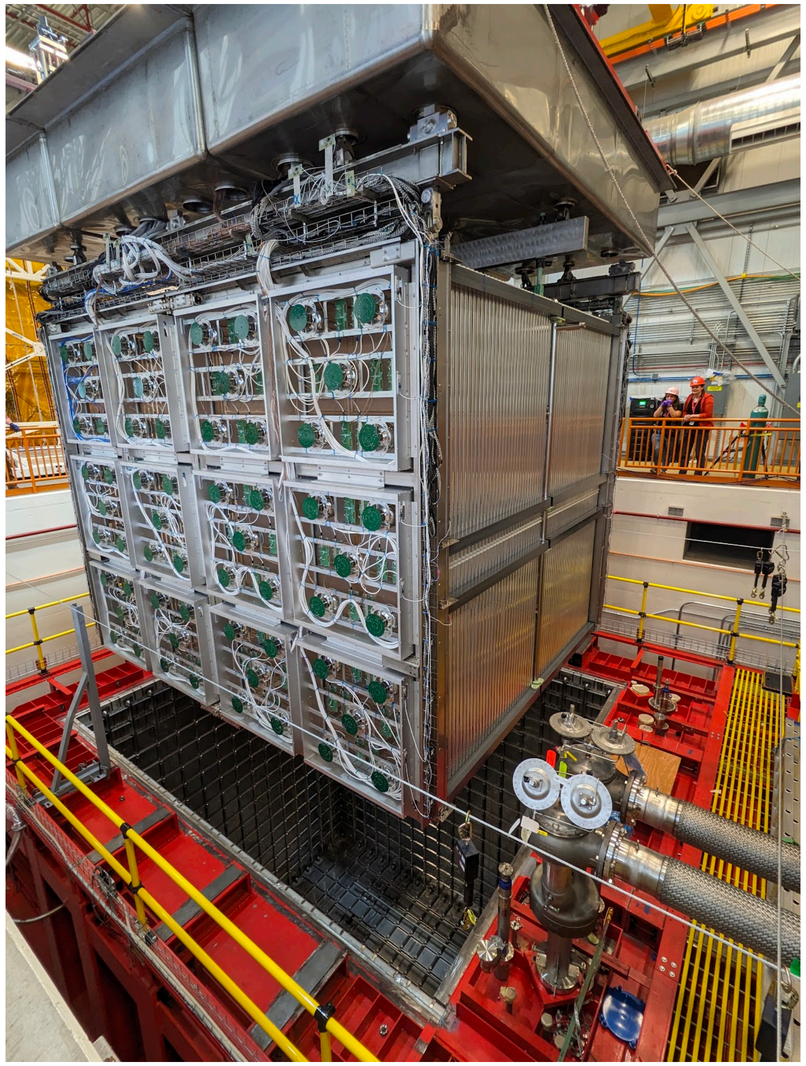
For the SBND Collaboration



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TPC Commissioning

Purpose:

- Ensure that the TPCs are capable of taking **physics-quality data** in a stable manner

Secondary Objective:

- Assess in real time through synergy with

    Slow Controls,
    Data Quality Monitoring
    Operations Team

Which TPC conditions will allow SBND to take physics quality data?

TPC Basics:

1.

2.

3.

Monitoring basics:

5.

6.

7.

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Which TPC conditions will allow SBND to take physics quality data?

TPC Basics:

1. The electric drift field is uniform and stable

2.

3.

Monitoring basics:

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Which TPC conditions will allow SBND to take physics quality data?

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2. We see waveforms from all induction and collection planes
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3. Basic track reconstruction is possible from TPC signals

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5. Monitoring and alarms in place for cathode HV, field cage stability, wire bias, current draw and voltage stability
6. Monitoring and alarms for LAr purity
7. Real-time monitoring of TPC event display

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How do we get there?

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Which TPC conditions will allow SBND to take physics quality data?

How do we get there?

Basics:

1. SBND is cold and full of LAr
2. The electric drift field is uniform and stable
   - TPC components are powered on and ramped up to nominal voltages
3. We see waveforms from all induction and collection planes
   - Assess signal quality with custom software
   - Verify with event display

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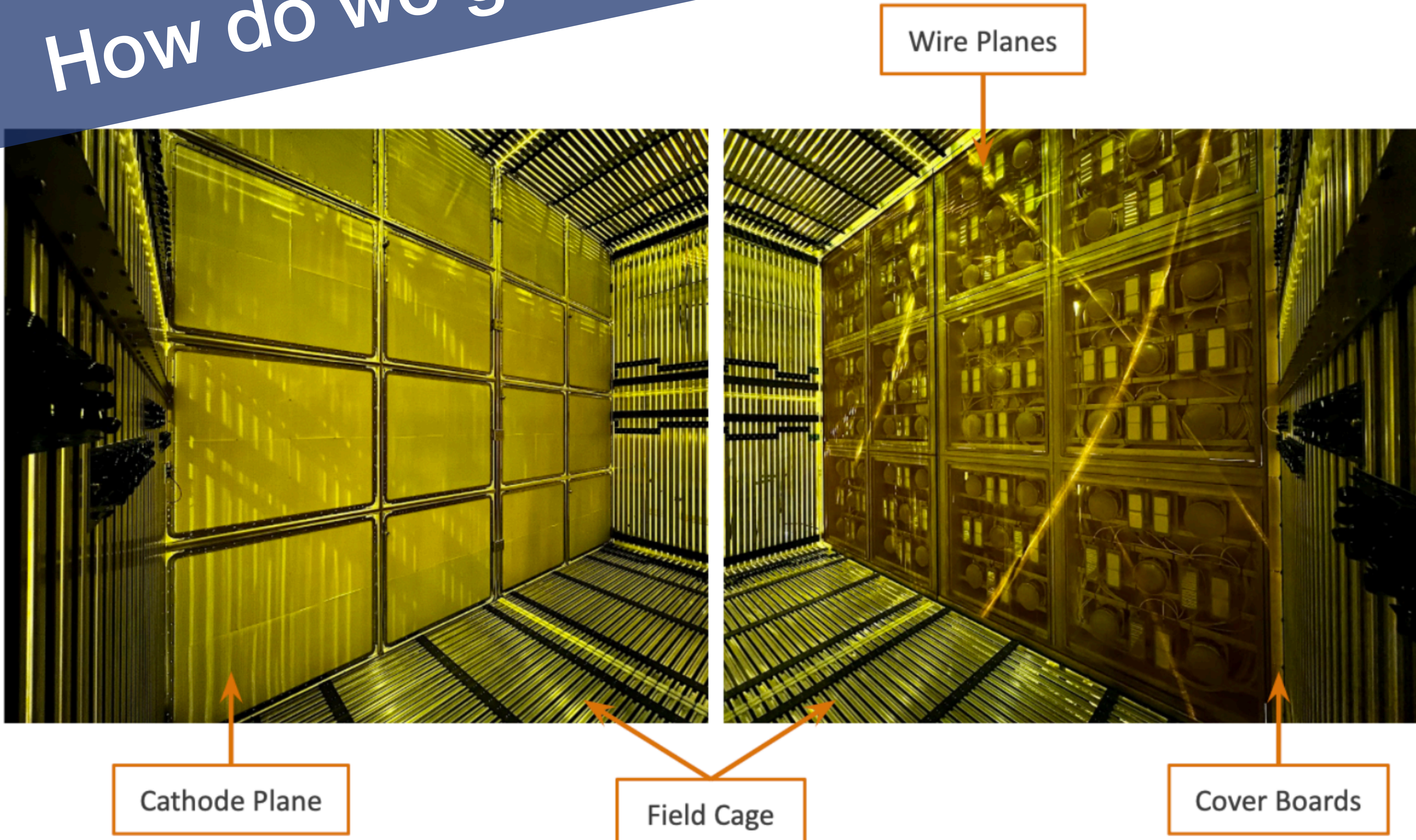

UCL

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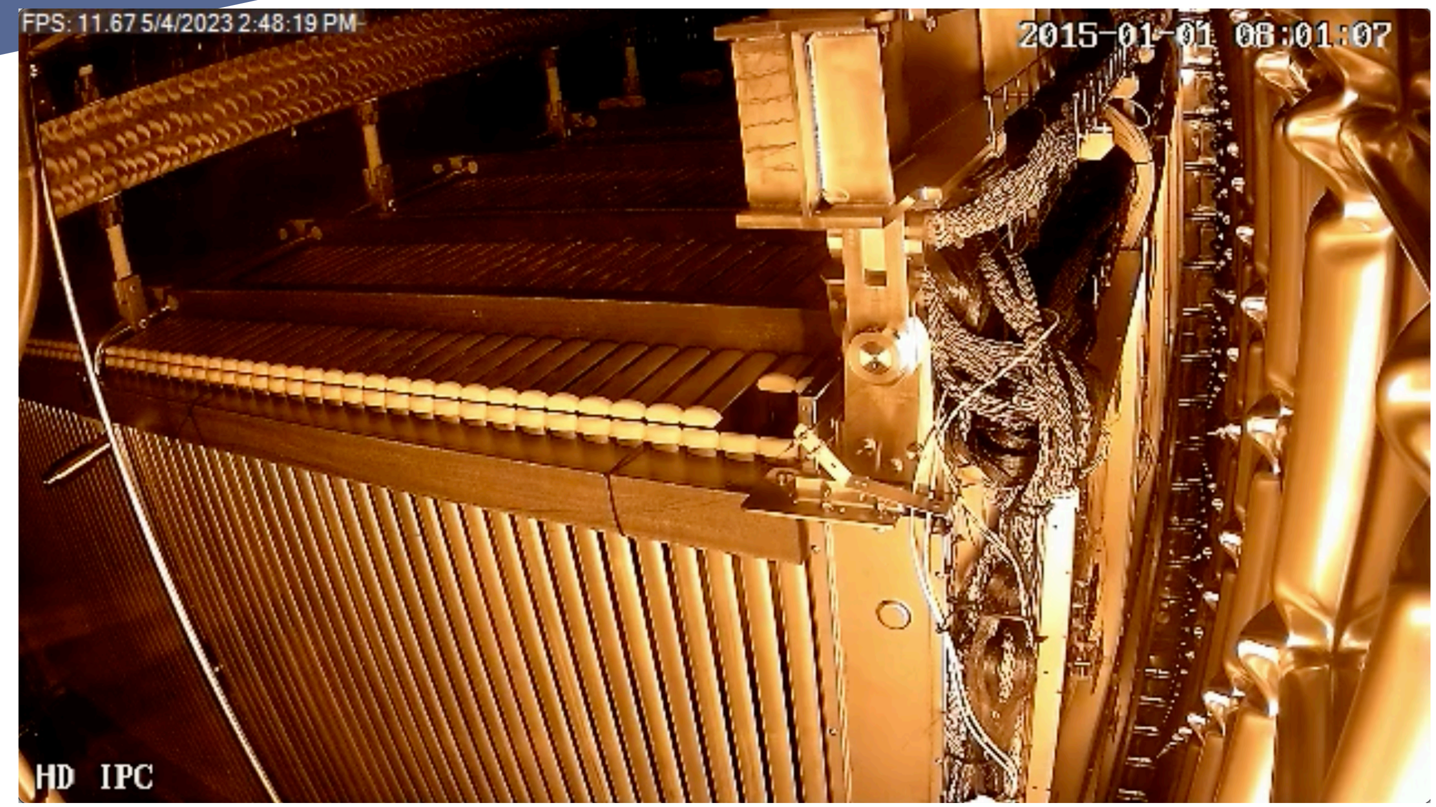
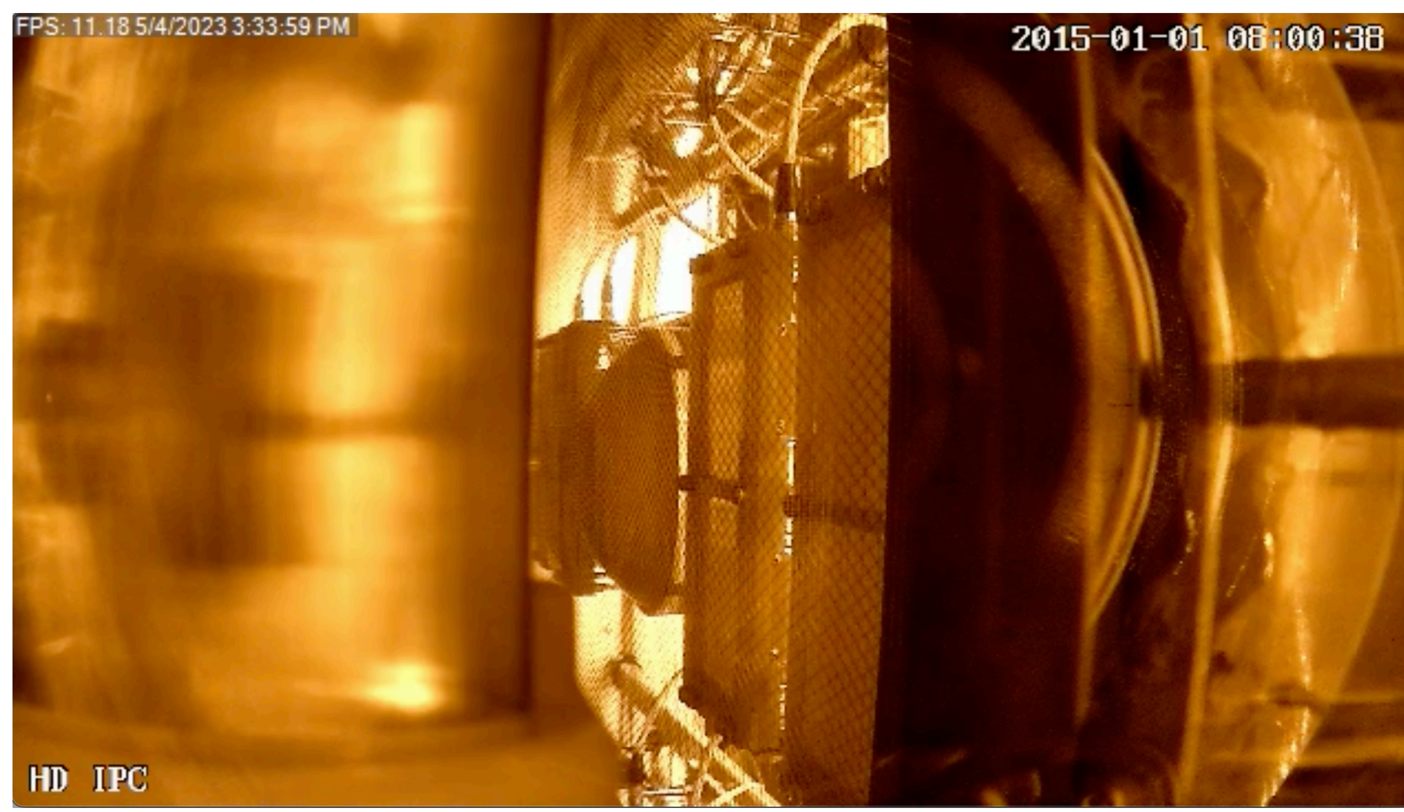
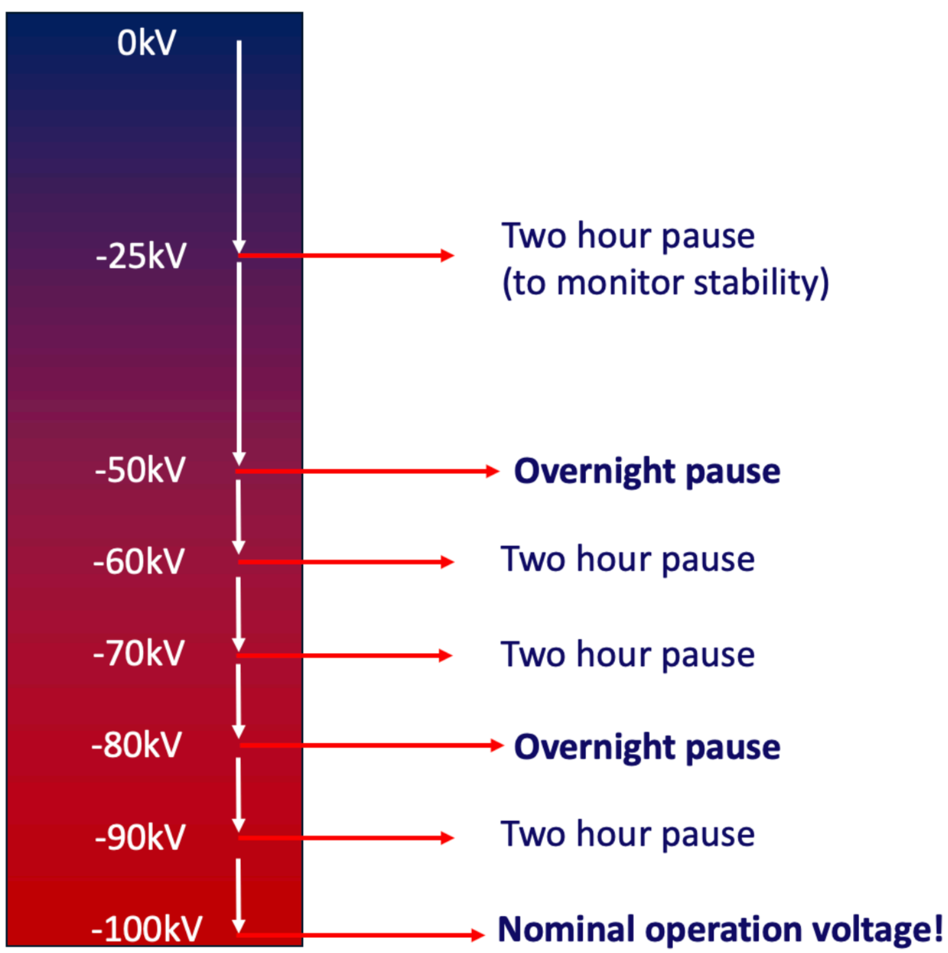
How do we get there?

SHORT-BASELINE NEAR DETECTOR SBND





TPC Ramp-Up Overview



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    - Assess signal quality with custom software

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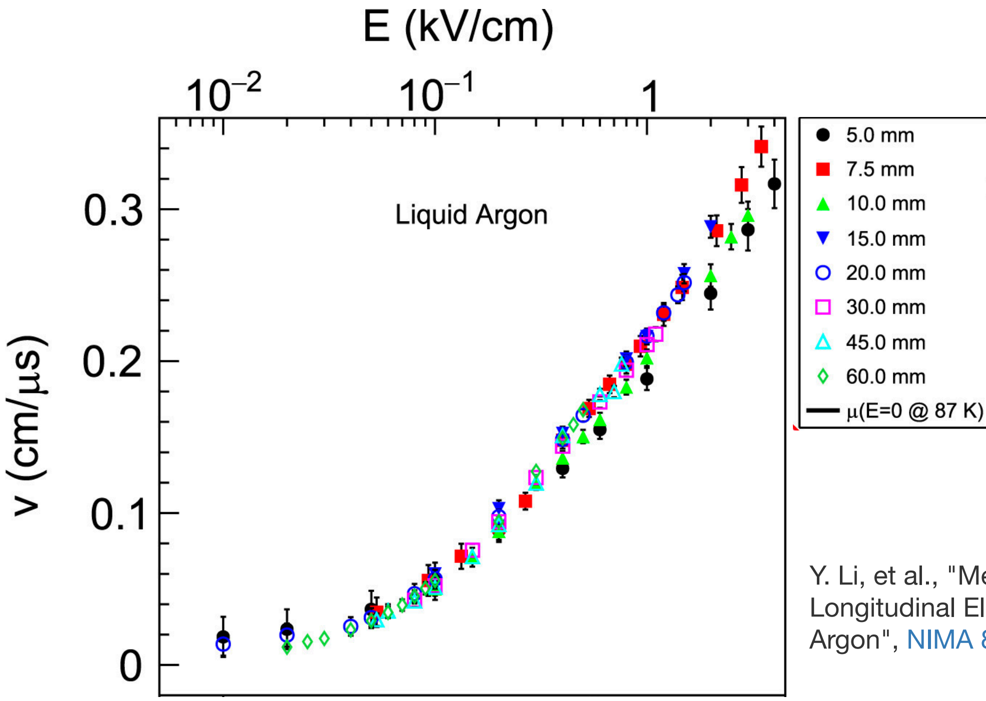
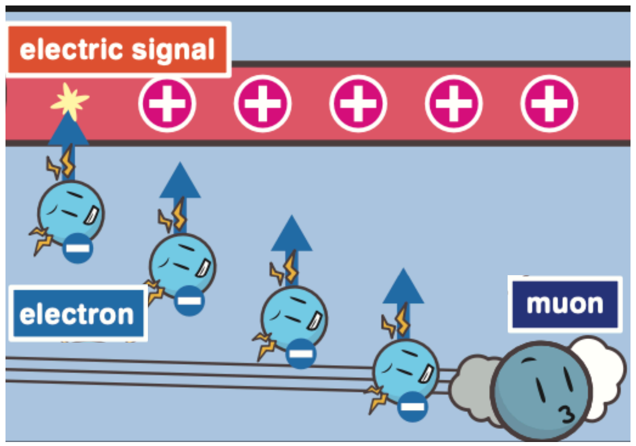
2. The electric drift field is uniform and stable

- Verify the Cathode HV by comparing the drift velocity measured in data to known behaviour as a function of E

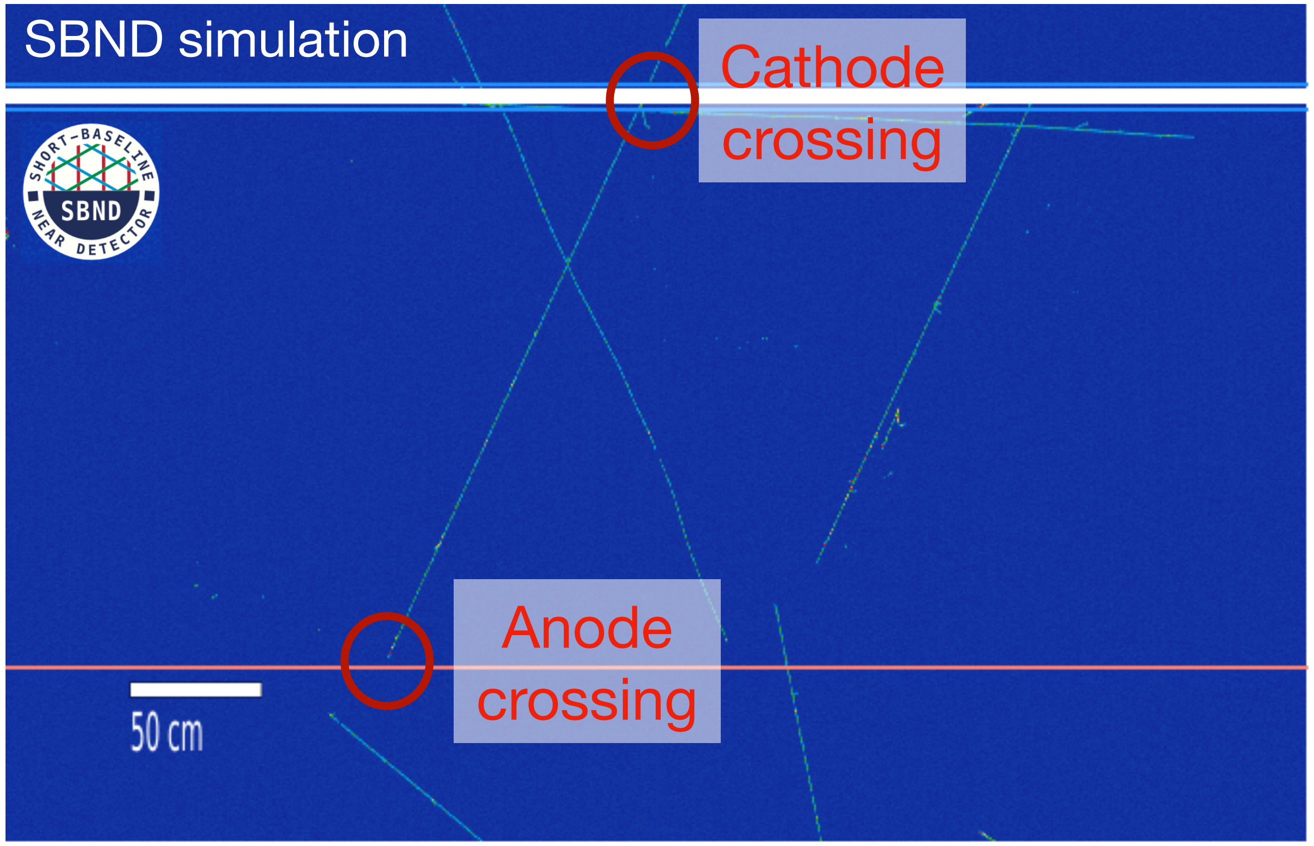
- Assess the uniformity of Drift E-Field and overall Field Cage status by comparing reconstructed endpoints of thorough-going muon tracks in simulation and data studies



Y. Li, et al., "Measurement of Longitudinal Electron Diffusion in Liquid Argon", NIMA 816, 160 (2016). [arXiv]



Exploration of Particle Physics and Cosmology with Neutrinos



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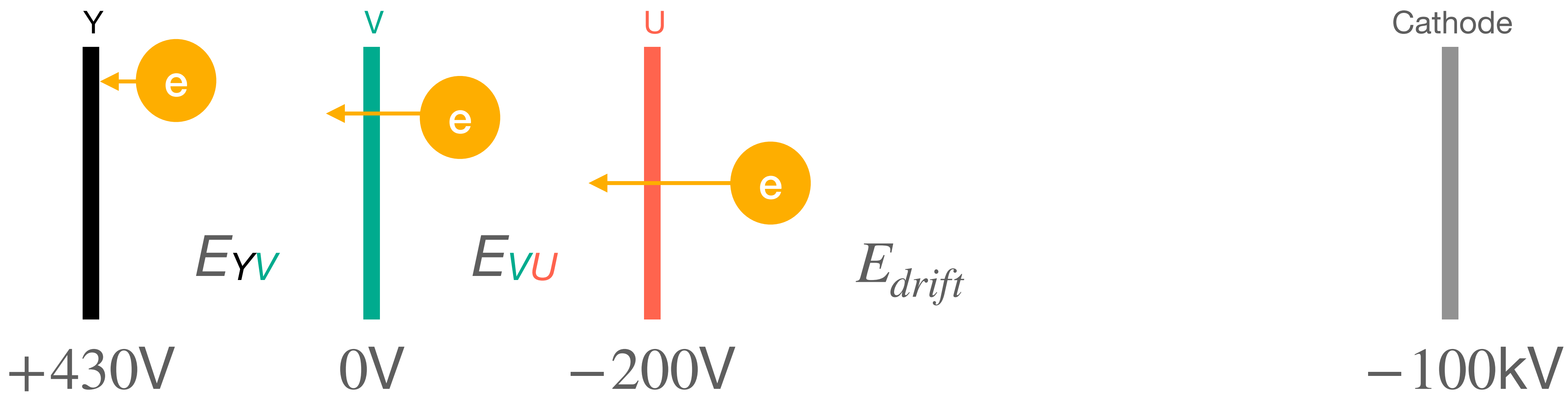
3. We see waveforms from all induction and collection planes

   - Assess signal quality with custom software

   - Verify with event display

3. We see waveforms from all induction and collection planes

- Noise characterisation and mitigation
- Induction plane transparency Verification and Optimisation



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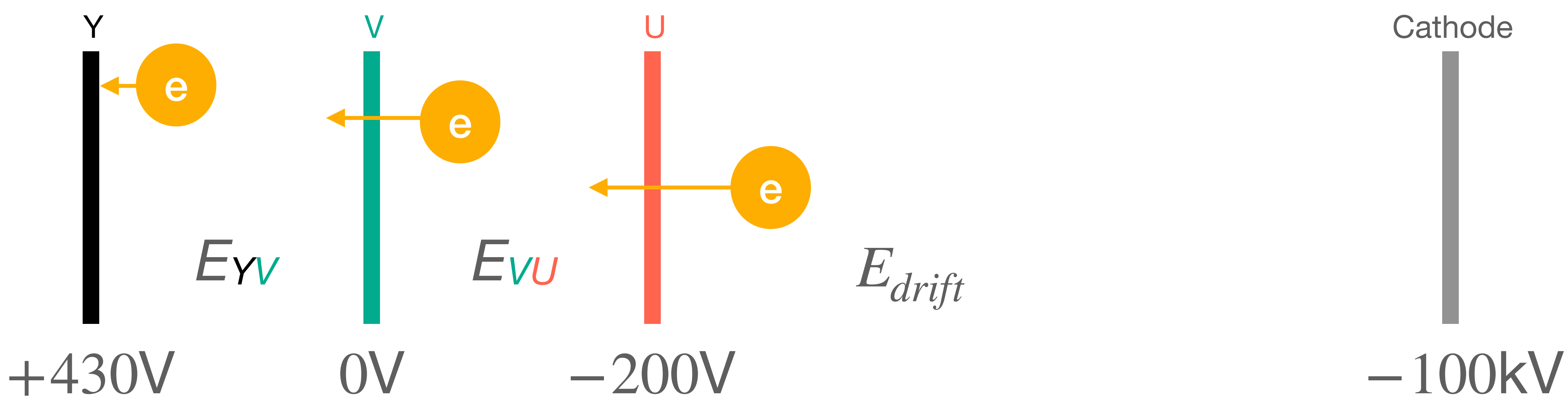
3. We see waveforms from all induction and collection planes

SBND

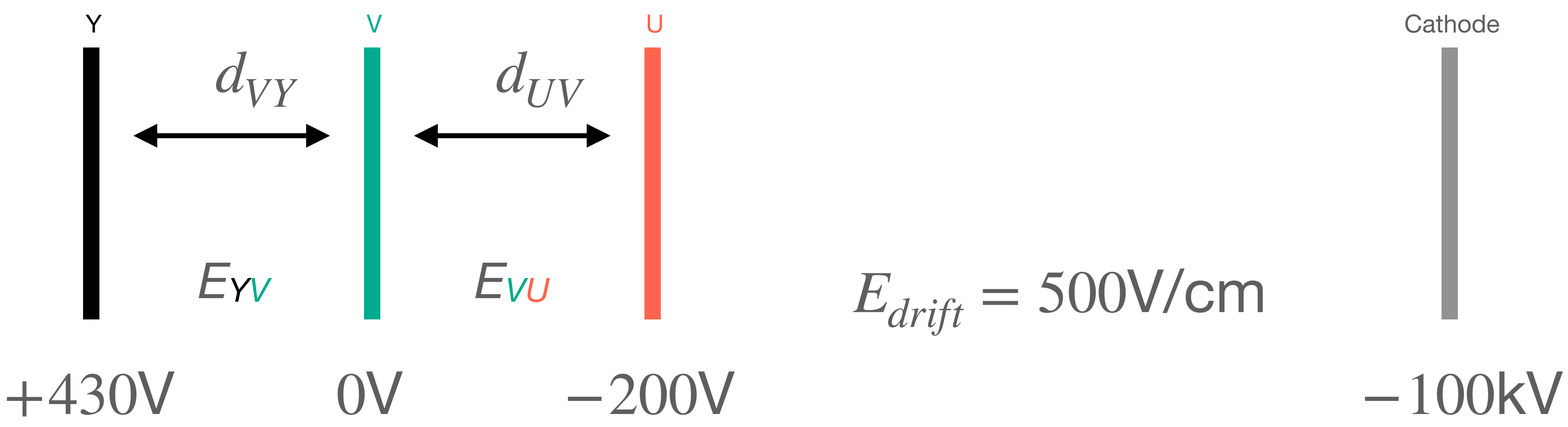
- Noise characterisation and mitigation
- Induction plane transparency Verification and Optimisation

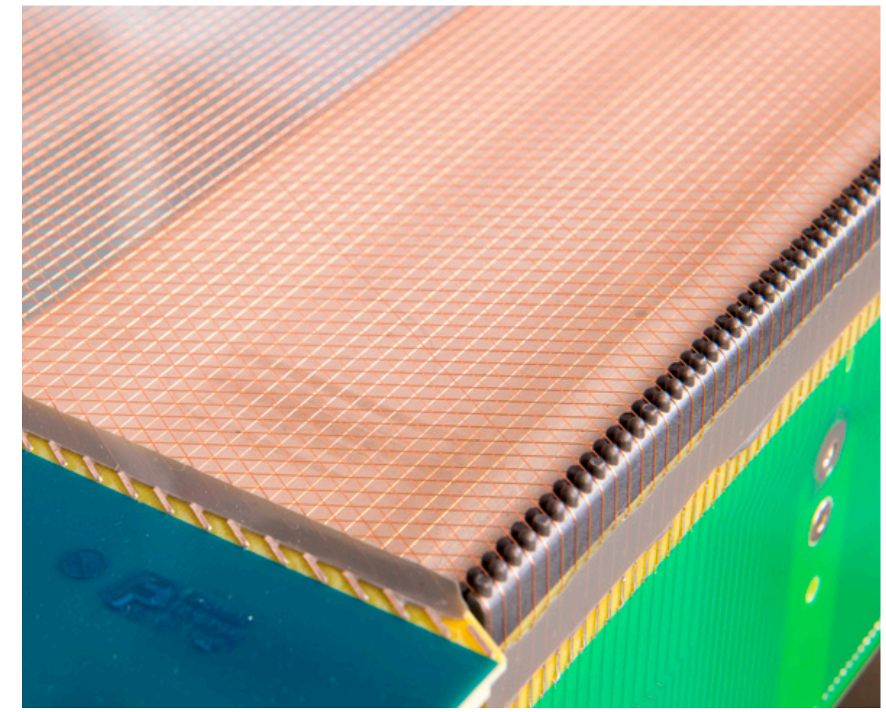


1. Induction plane transparency is essential for calorimetry and TPC signal processing

2. Transparency depends on the E-field between the planes, and on the distance between the wires

3. We see waveforms from all induction and collection planes





Transparency condition

$$E_{after} \geq \frac{1+\rho}{1-\rho} E_{before}$$

$$\rho = \frac{2\pi r_{wire}}{d}$$

Nominal values

$$r_{wire} = 75 \pm 5 \text{ nm}$$

$$d = 3 \pm 0.5 \text{ mm}$$

$$d_{plane} = 3 \pm 0.5 \text{ mm}$$

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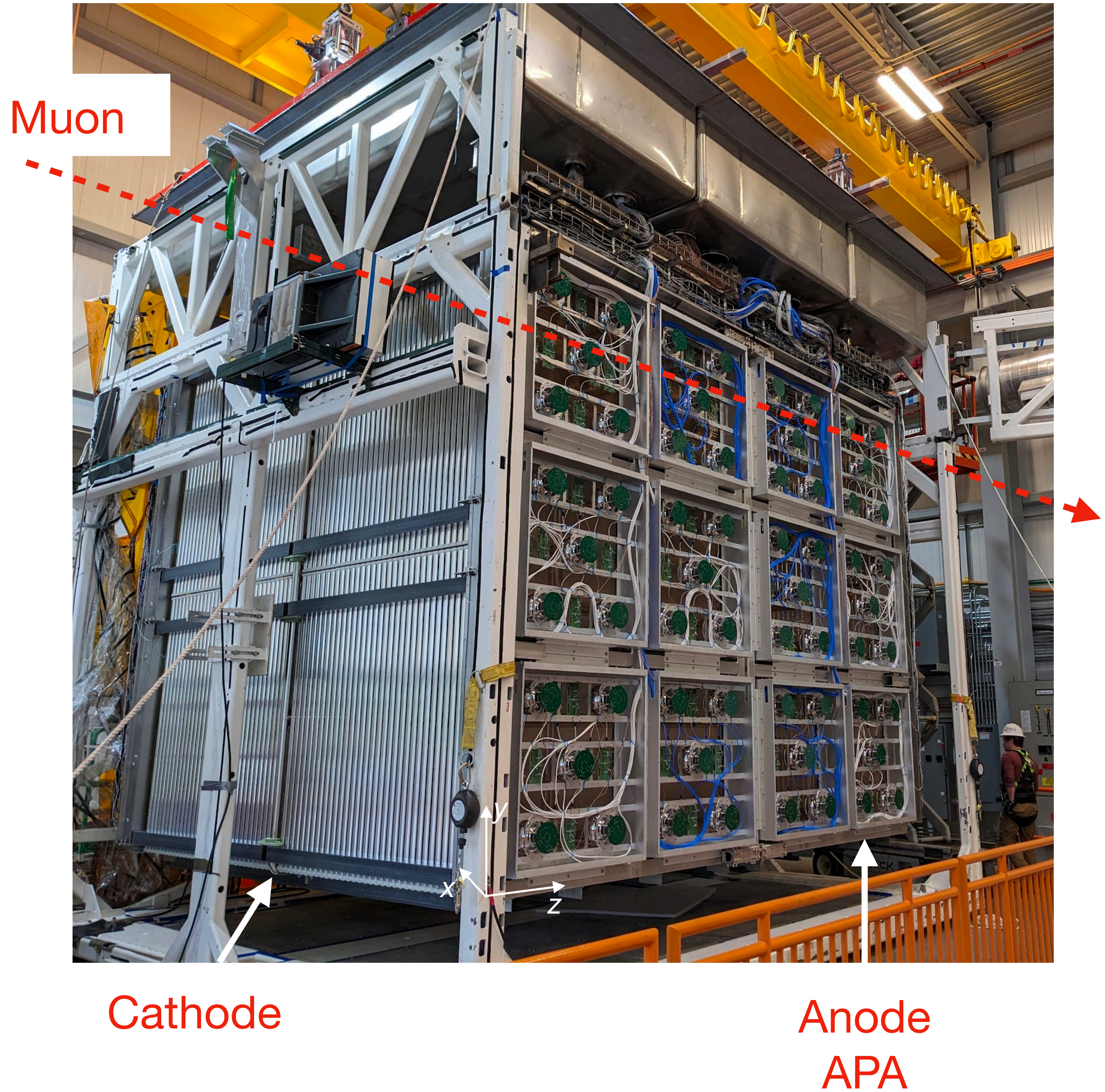
Induction plane transparency Verification and Optimisation:

1. Select events with through-going muons parallel to the planes



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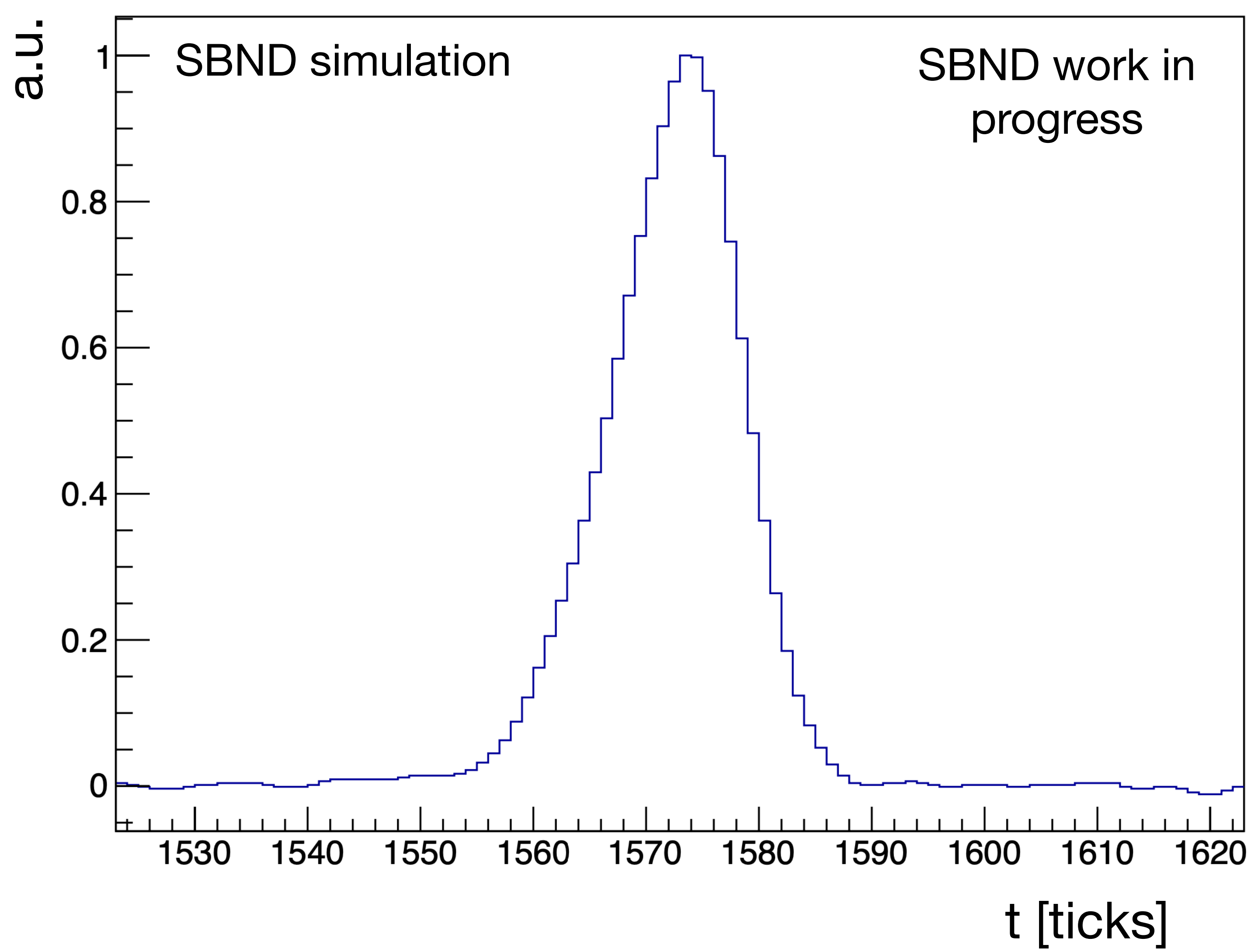
Induction plane transparency Verification and Optimisation:

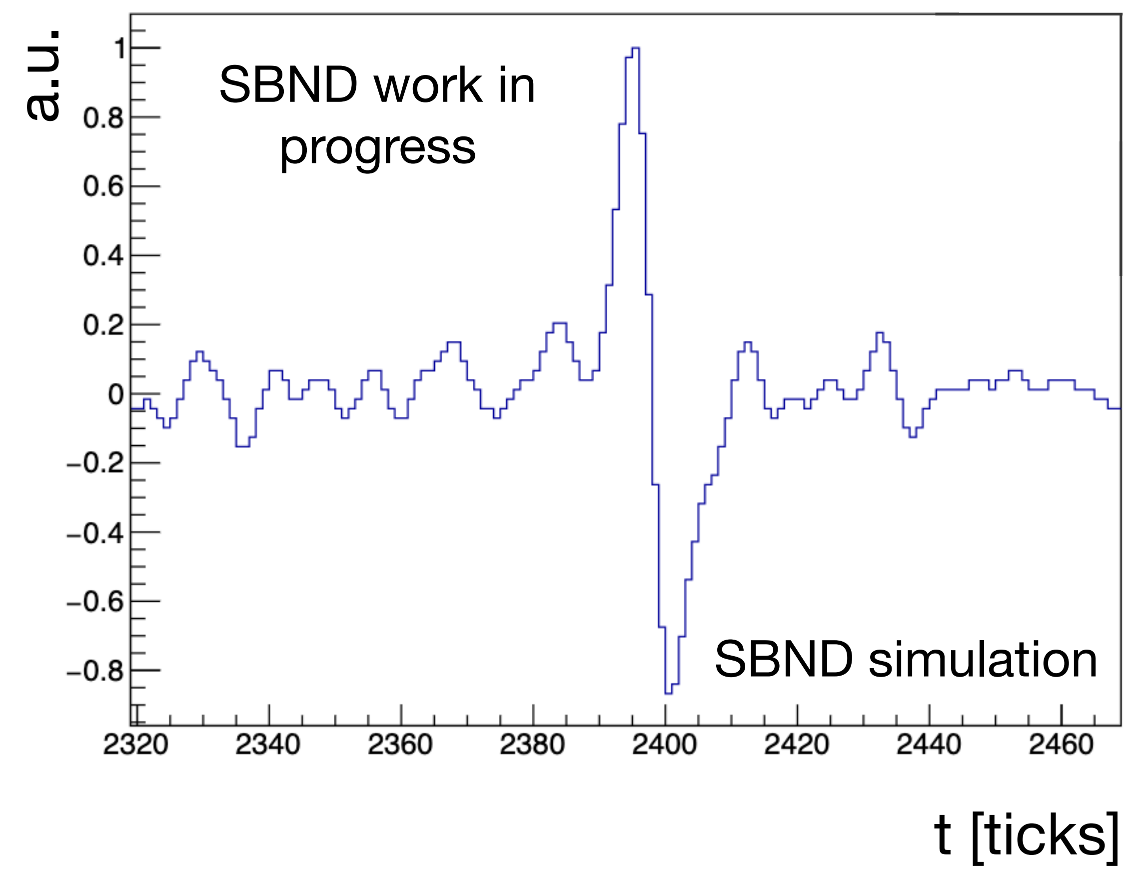
1. Select events with through-going muons parallel to the planes

2. Perform a data-driven fit to the waveforms from each plane

Single Collection plane waveform

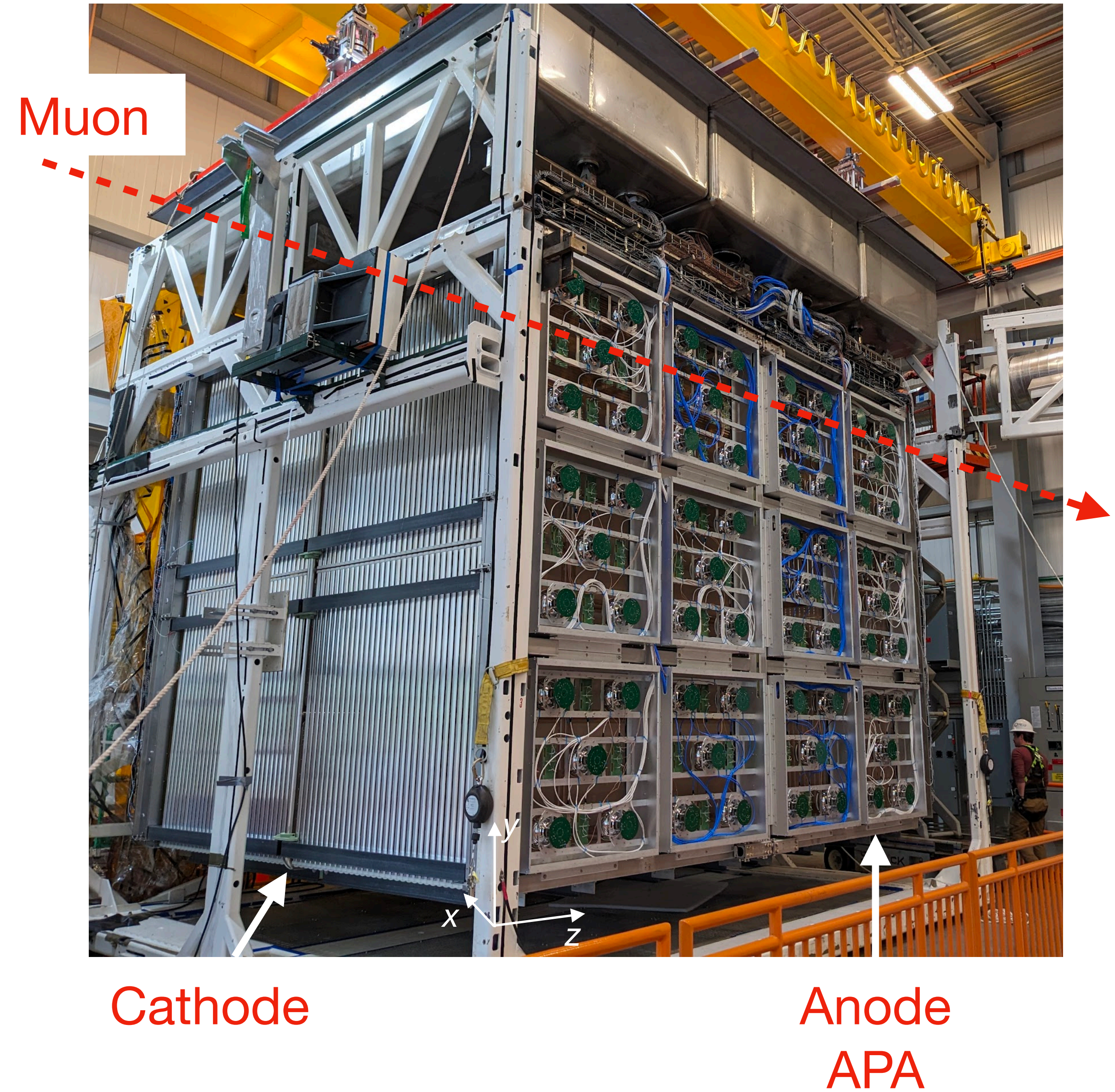


Single Induction plane waveform



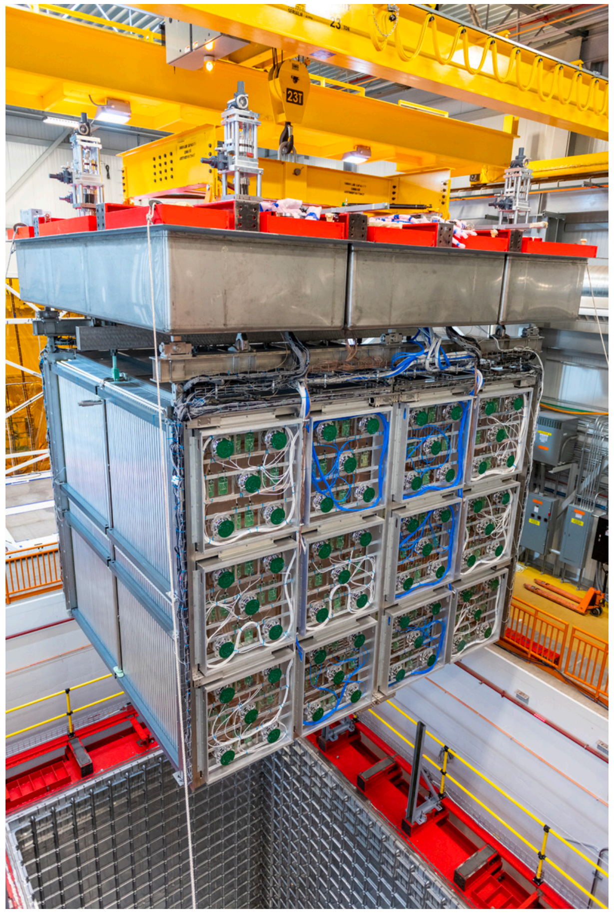
Induction plane transparency Verification and Optimisation:

1. Select events with through-going muons parallel to the planes
2. Perform a data-driven fit to the waveforms from each plane
3. Identify plane regions where less charge is detected
4. Apply fine corrections to the wire bias settings to mitigate transparency issues
5. Evaluate transparency in 2D fine bins (*y*, *z*)



Conclusion

- Commissioning SBND's TPCs is essential to ensure that the detector is capable of taking physics-quality data in a stable manner
- Requirements for physics-quality data:
  - The electric drift field is uniform and stable
  - We see waveforms from all induction and collection planes
  - Basic track reconstruction is possible from TPC signals
  - Real-time Monitoring and alarms in place
- Studies:
  - Detector ramp-up
  - Cathode HV, field cage and drift E-field verification
  - Noise characterisation and mitigation
  - Induction plane transparency studies



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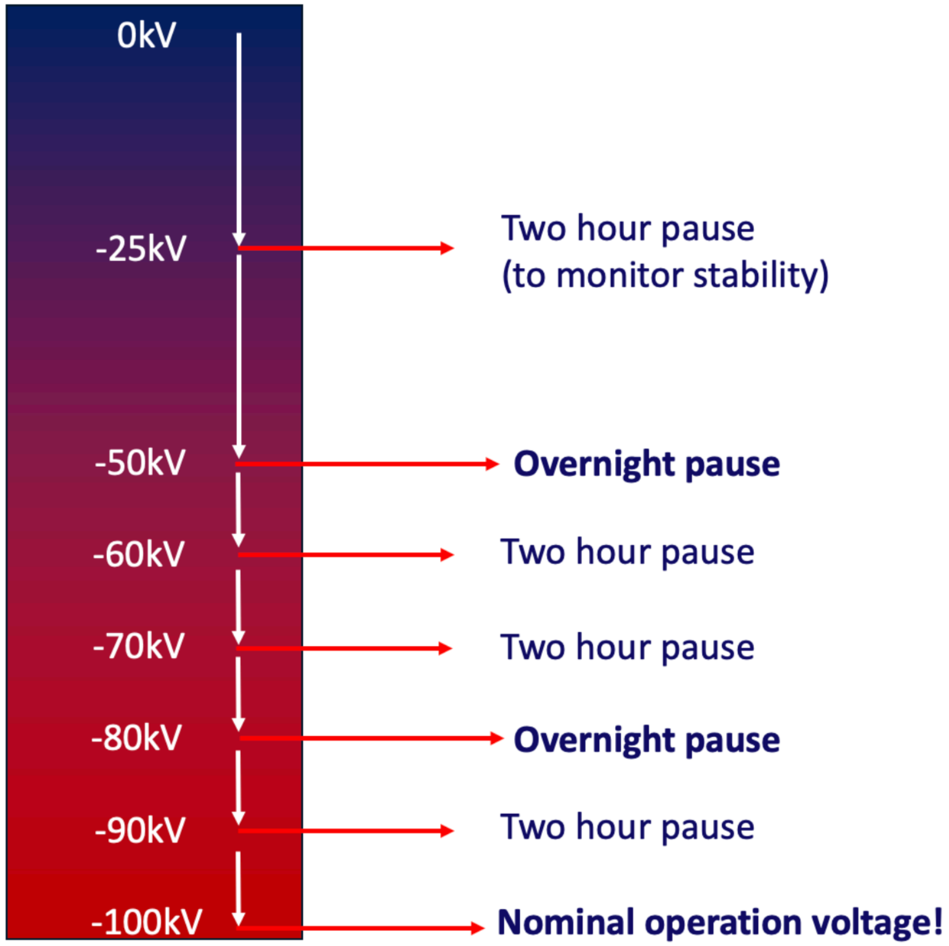
Backup

- We have a TPC Ramp-Up Plan for each subsystem
- Cold electronics check before and after each ramp stage
- Continuous monitoring of current and voltage stability of all TPC components
- Monitoring with cameras after the ramp-up

TPC Ramp-Up Overview



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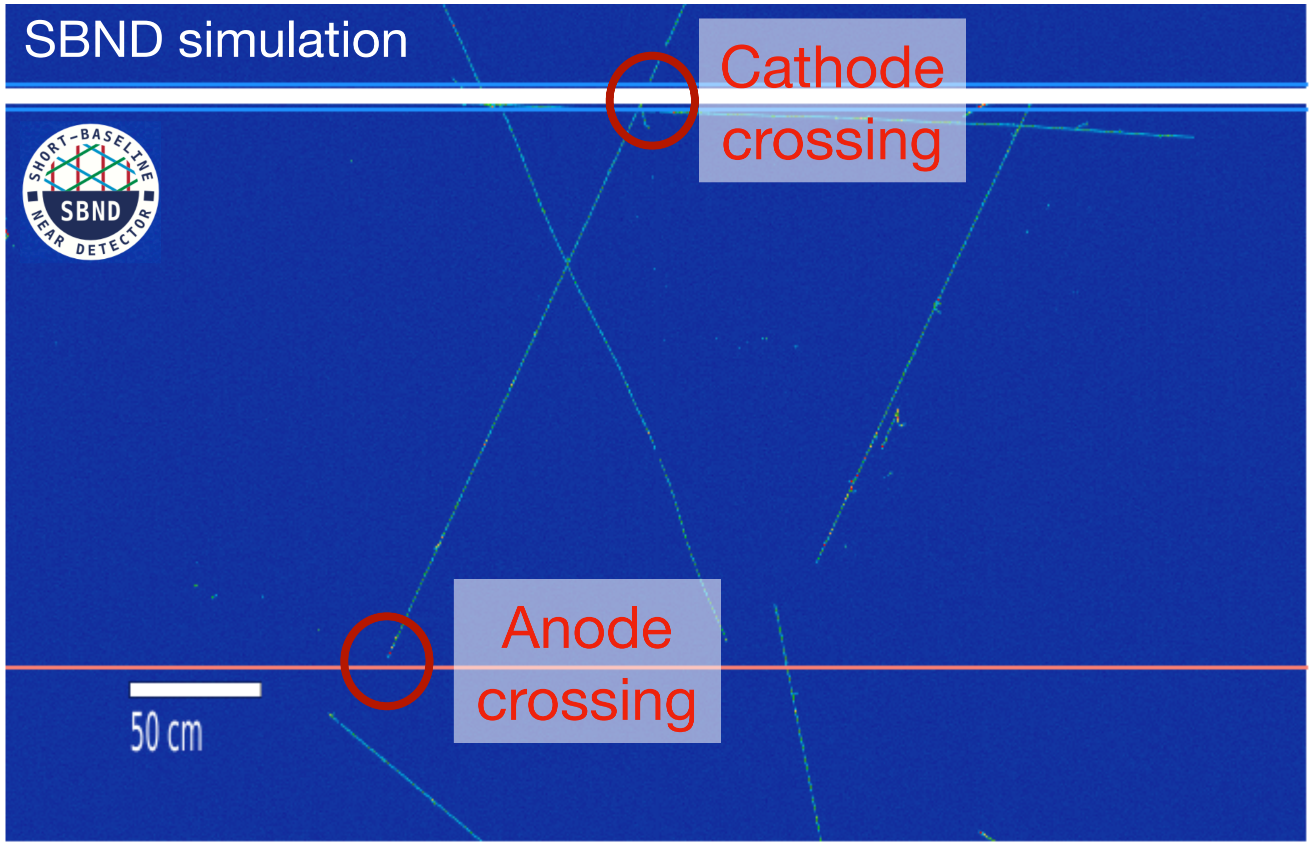
2. The electric drift field is uniform and stable

Cathode HV Verification:

1. Measurement of the maximum drift time for tracks that cross both the anode and the cathode

2. Estimate the drift velocity, E-field and actual cathode HV



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2. The electric drift field is uniform and stable

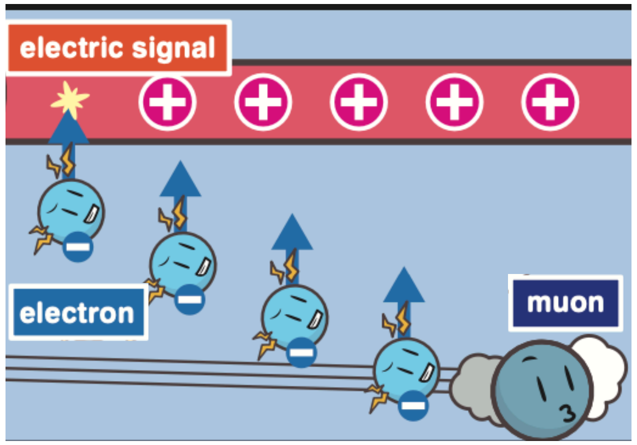
Field Cage and Drift E-Field Verification:

1. Is the drift E-field uniform?

2. Method already tested by ICARUS collaboration

3. Compare simulation and data when reconstructing the endpoints of through-going muon tracks

4. The difference will shed light on field distortions, that impact electron trajectories

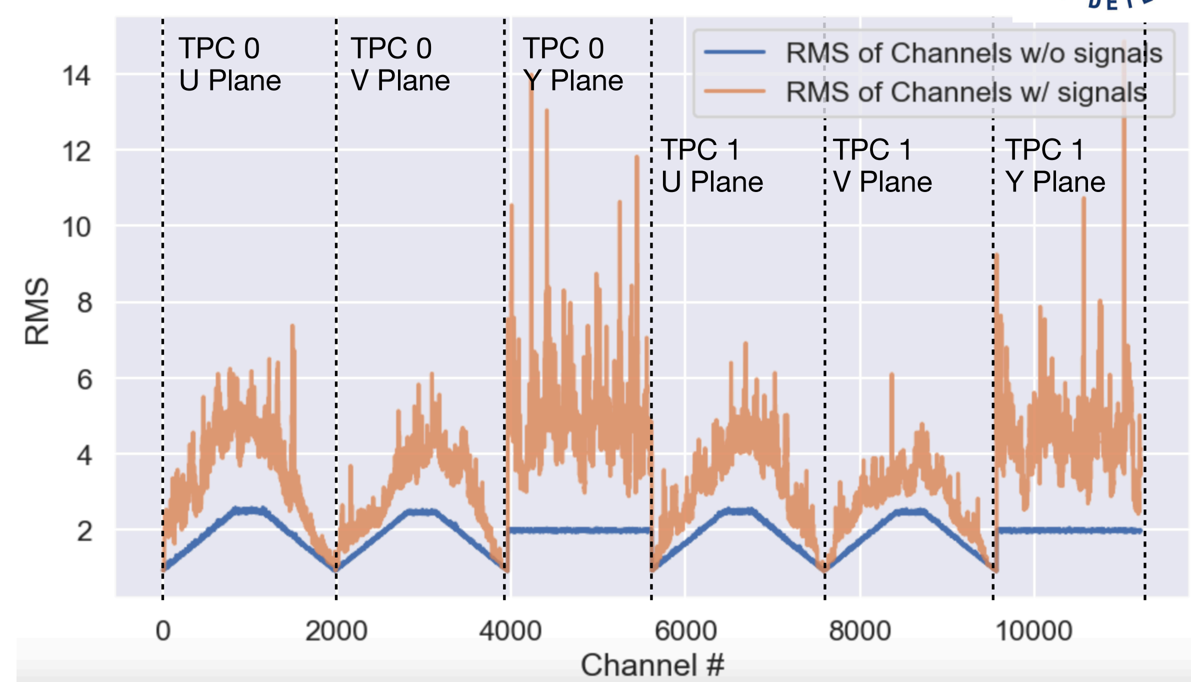


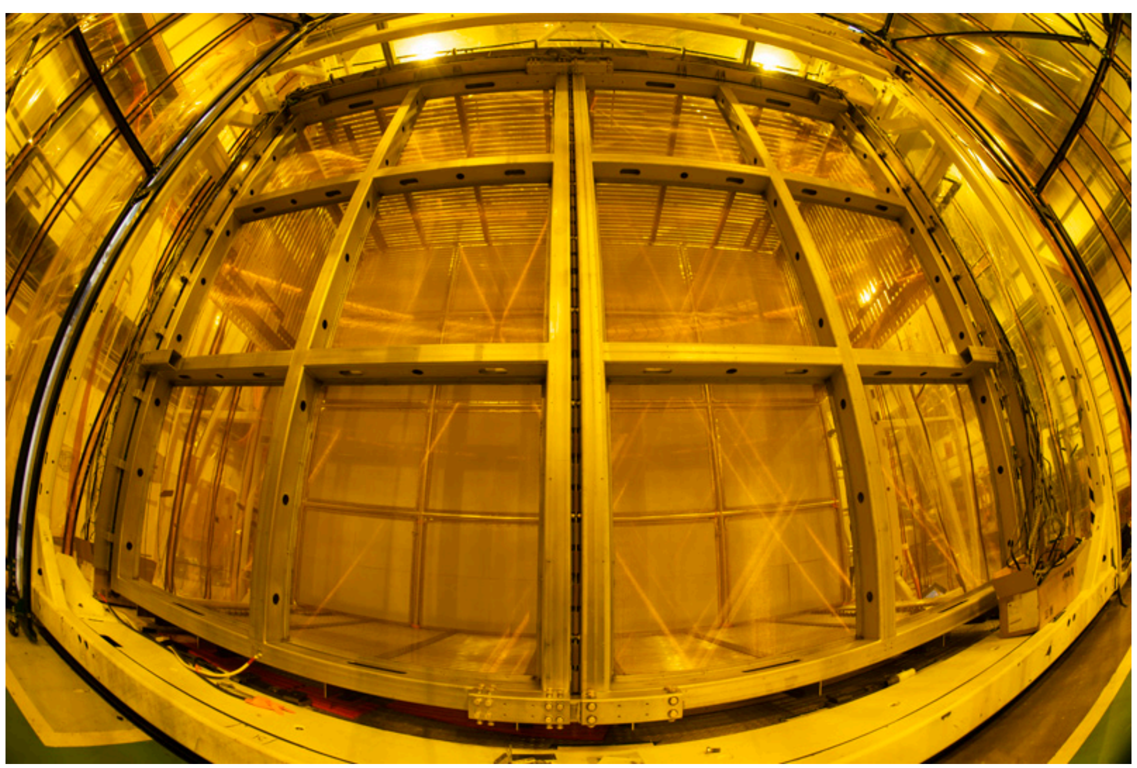
Exploration of Particle Physics and Cosmology with Neutrinos

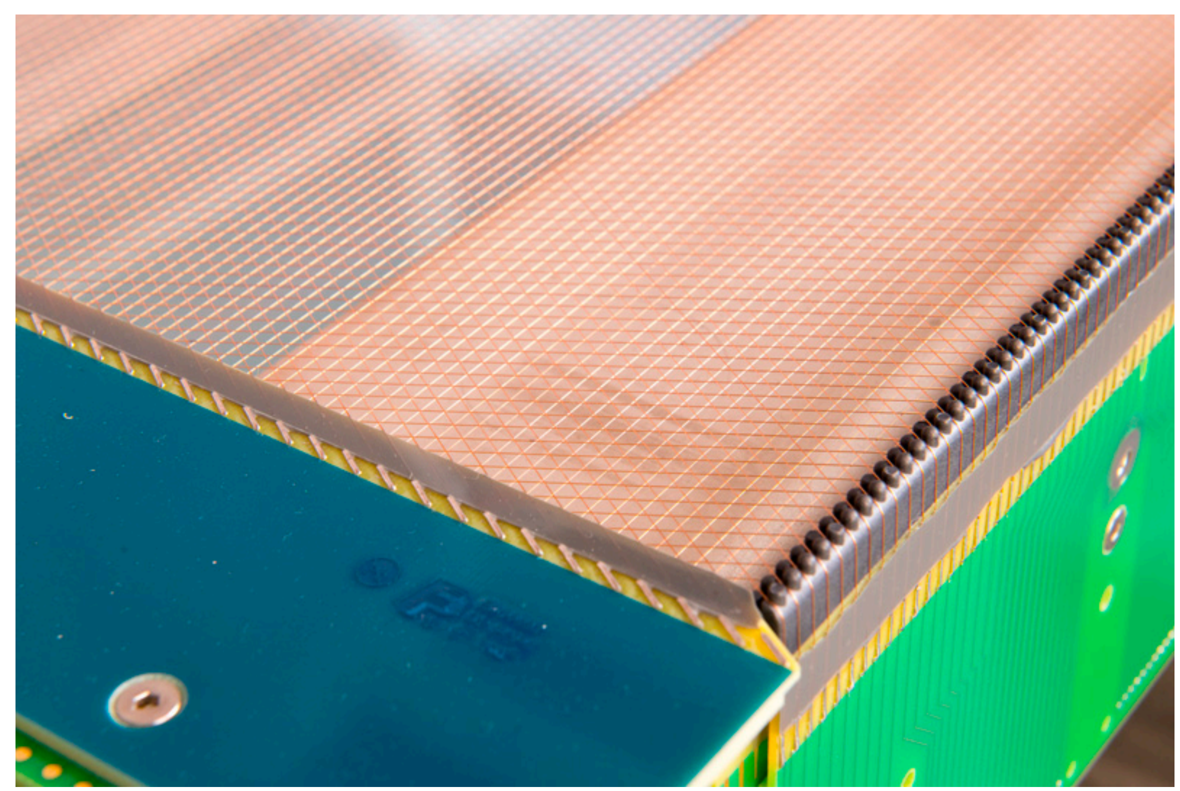
Noise characterisation and mitigation:

1. Switch on detector systems one by one
2. Monitor TPC waveform signals with DAQ
    1. RMS of waveform baselines
    2. FFT of waveform baselines (helpful for understanding frequencies and thus sources)

SBND simulation

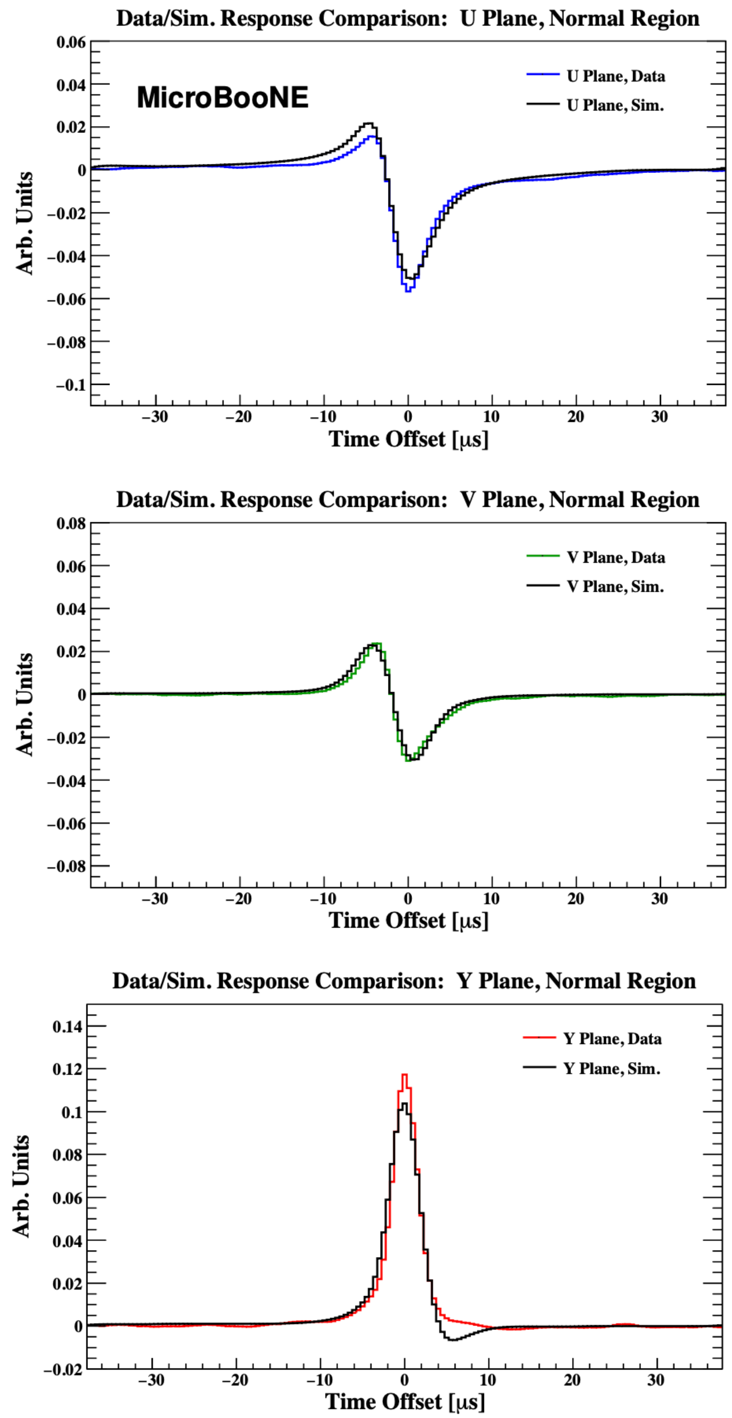






wire plane transparency study strategy

Example: Microboone waveforms

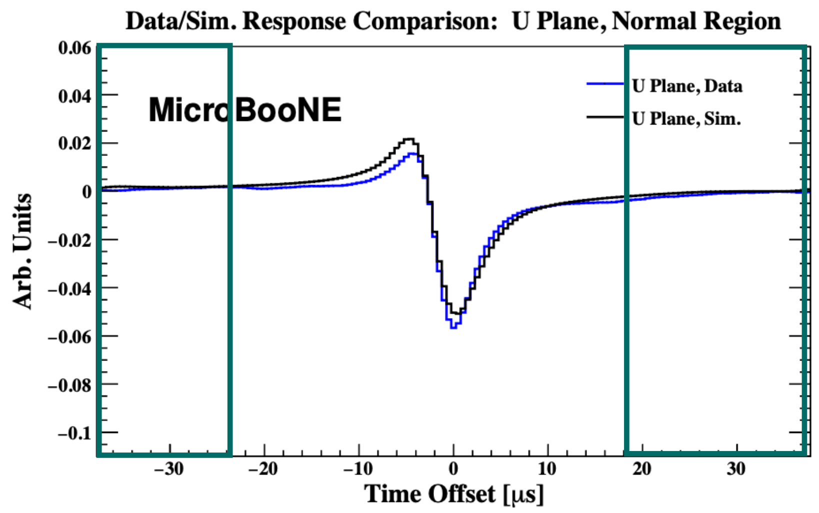


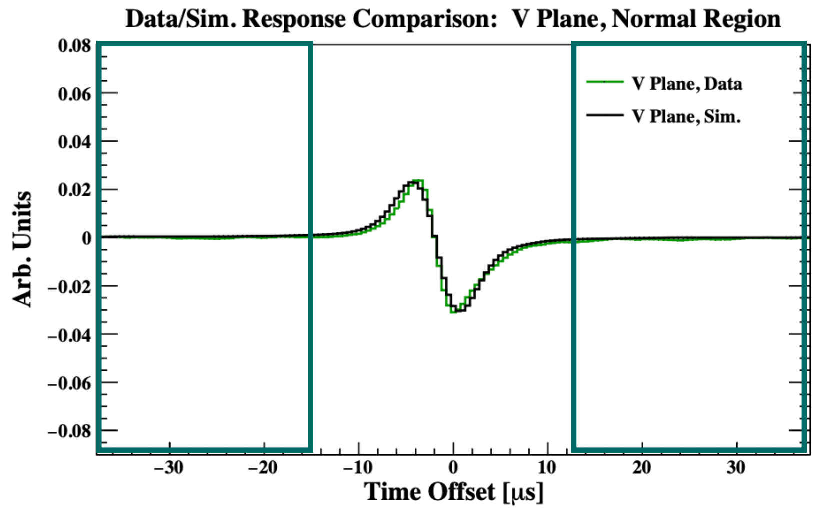
- Compare waveforms from different planes
- Compare waveforms from different positions on the same plane
- Need to fit the waveforms!

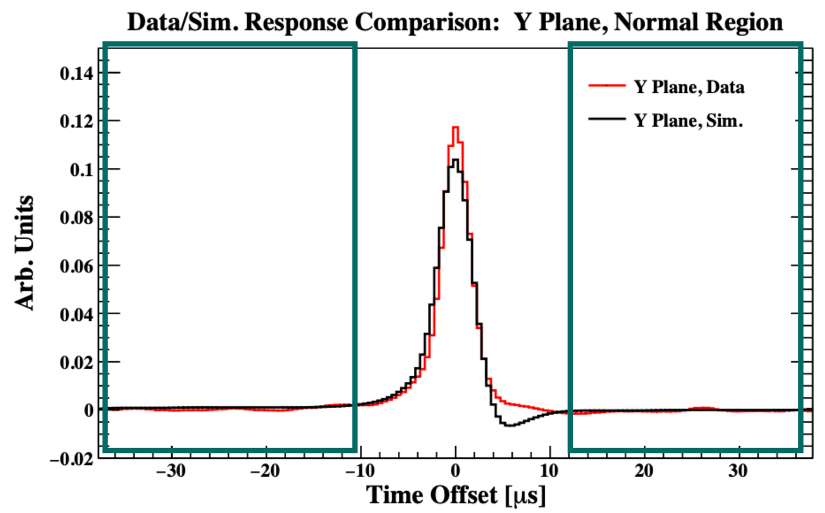
2018 JINST 13 P07007

Creating a template

1. Extract pulse segments from waveforms
2. Fit baseline (before and after)

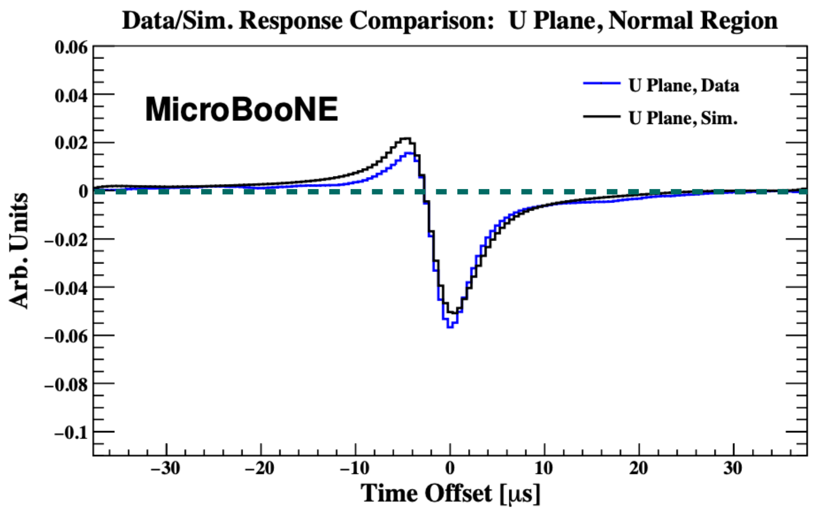


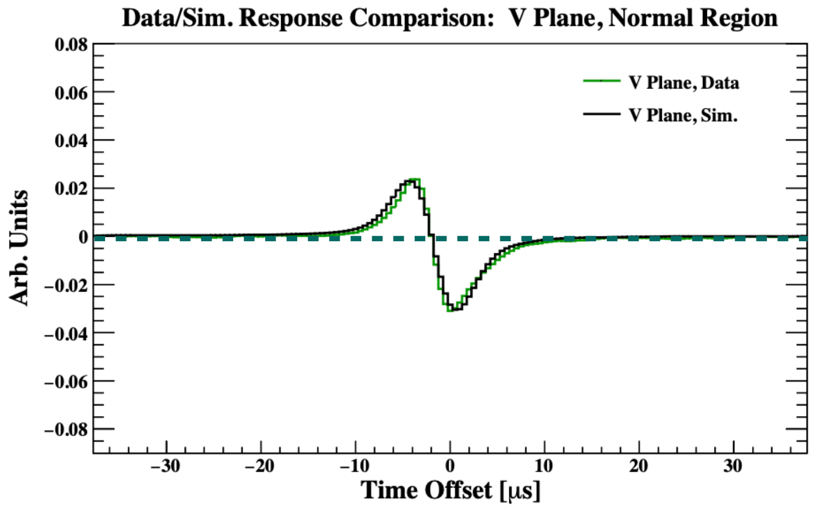




Creating a template

1. Extract pulse segments from waveforms
2. Fit baseline (before and after)
3. Take baseline to find crossing point of bipolar pulses (U, V), use to align bipolar pulses from same wire





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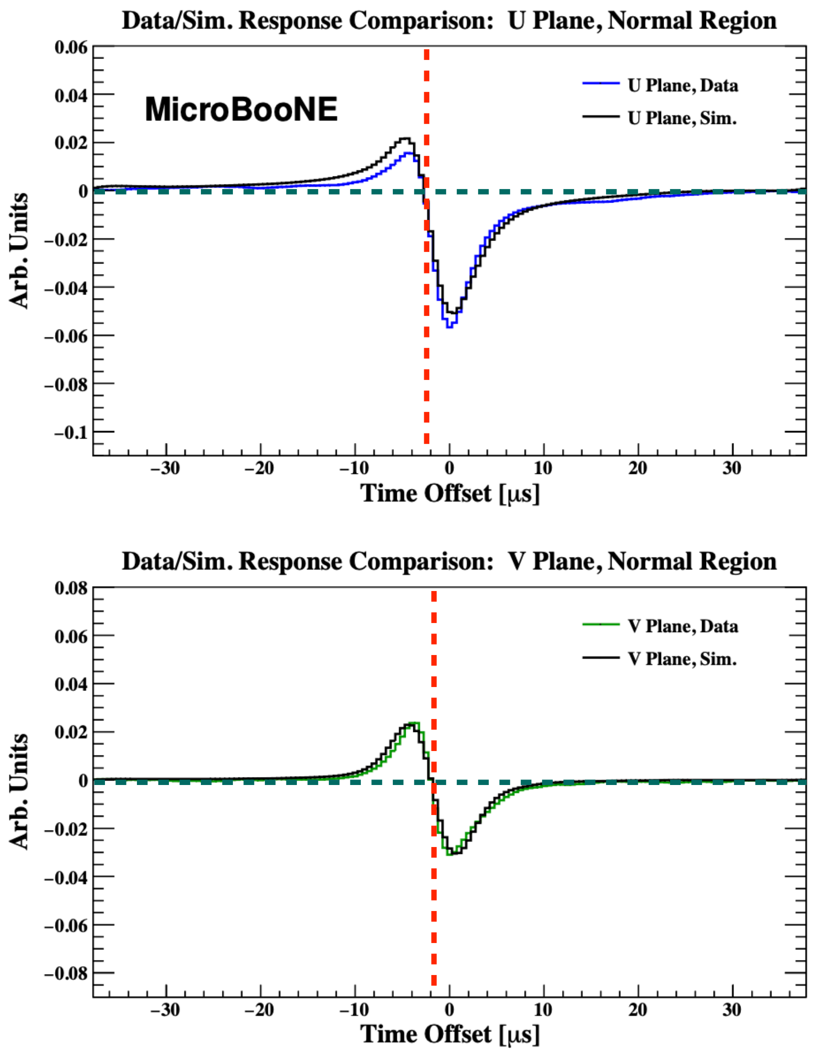
Creating a template

1. Extract pulse segments from waveforms
2. Fit baseline (before and after)
3. Take baseline to find crossing point of bipolar pulses (U, V), use to align bipolar pulses from same wire
4. Make half template functions
    1. Cut each induction plane pulse into positive and negative segments (at baseline crossing point)
    2. NB. negative U and V pulses should be identical, but cross check for detector systematic



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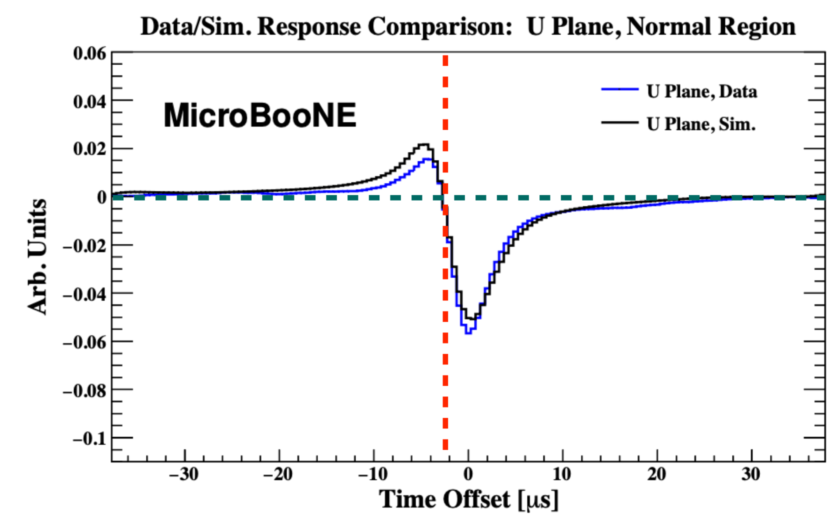
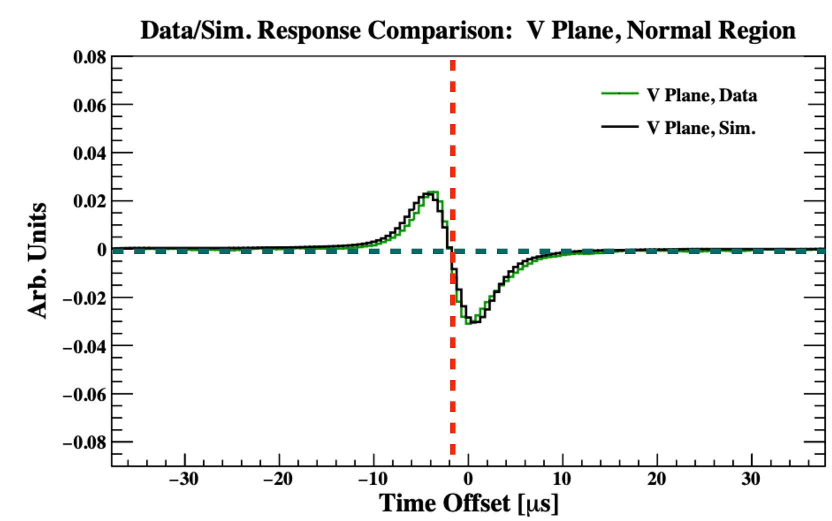
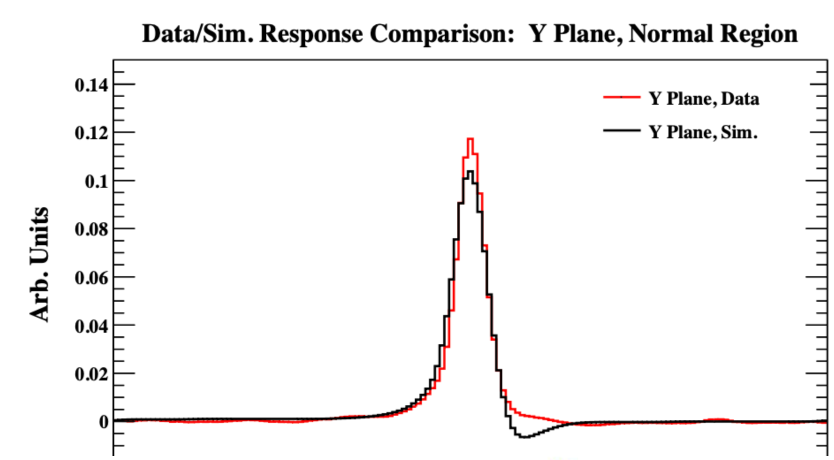
Creating fit templates

1. Extract pulse segments from waveforms
2. Fit baseline (before and after)
3. Take baseline to find crossing point of bipolar pulses (U, V), use to align bipolar pulses from same wire
4. Make half template functions
    1. Cut each induction plane pulse into positive and negative segments (at baseline crossing point)
    2. NB. negative U and V pulses should be identical, but cross check for detector systematic
5. Fit gaussian to unipolar pulses to align Y plane pulses
6. Normalise so pulse heights / widths / baselines are the same
7. Add together to make low-noise template pulse

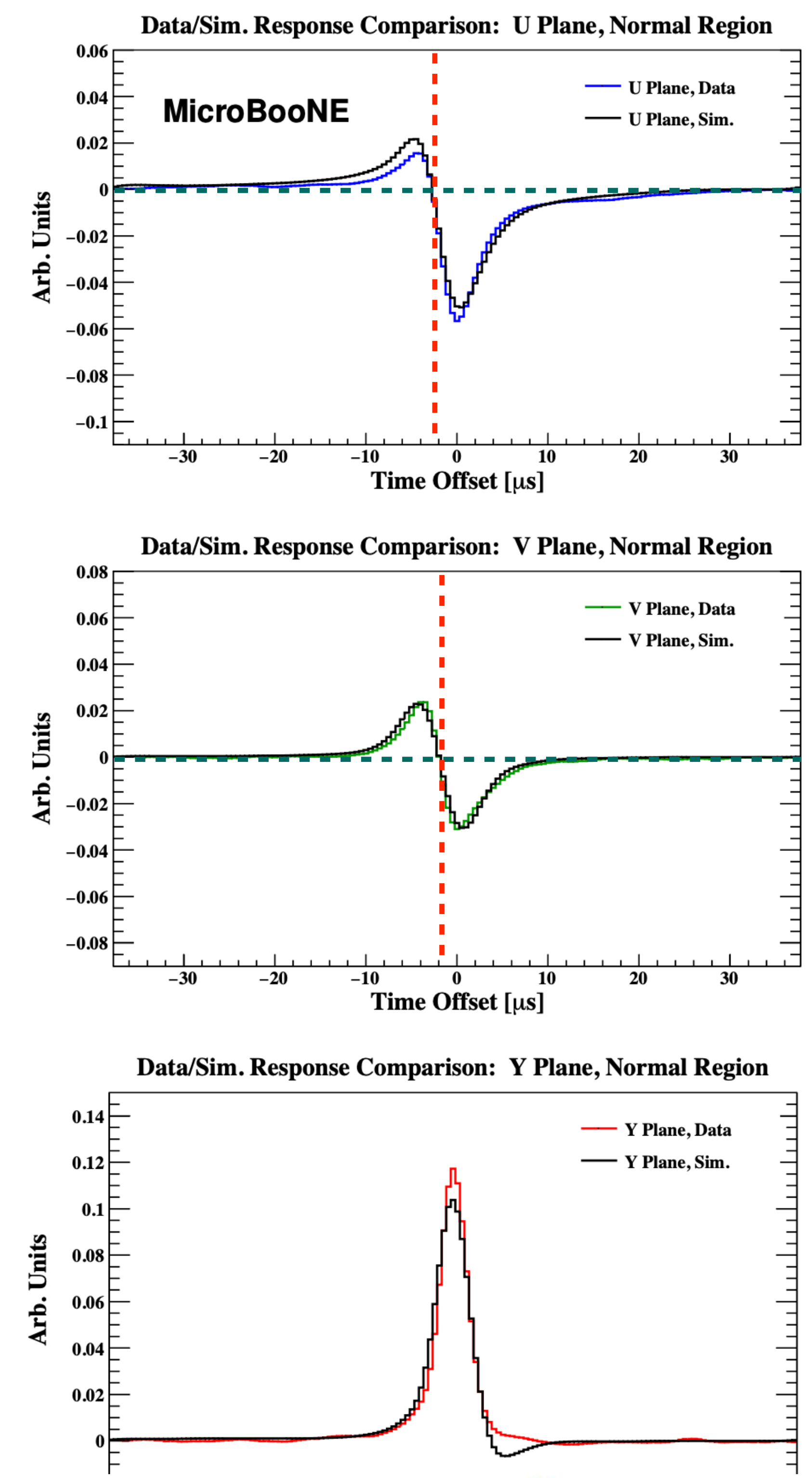






Fit expectations

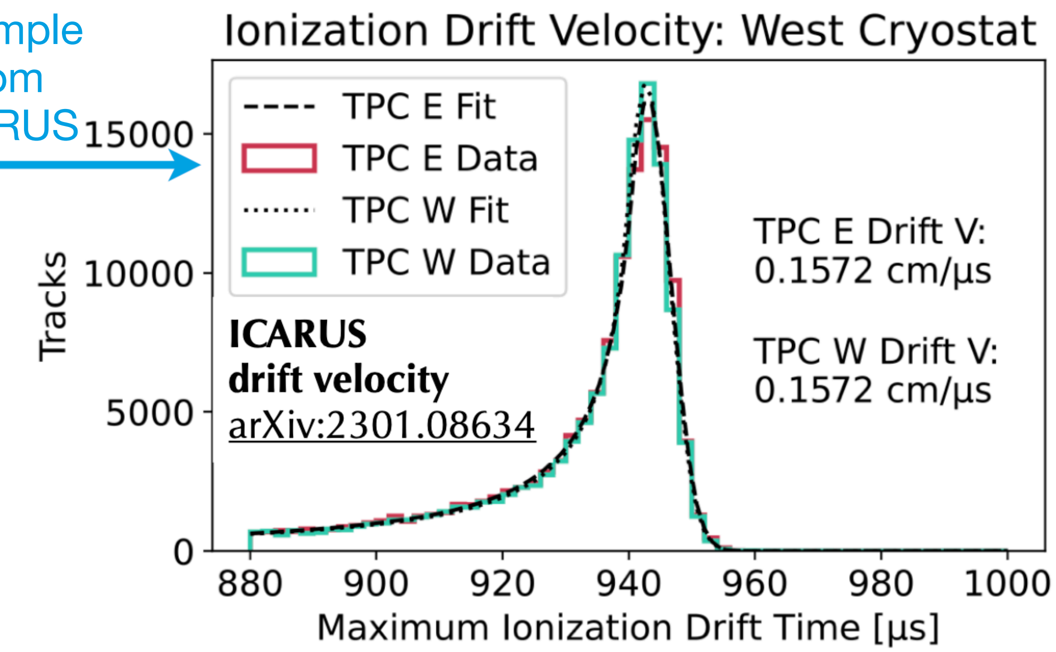
1. Use hit finding algorithm to locate where the waveform is on the plane
2. Scale and fit in amplitude the waveforms with template fit
3. Have 5 fit numbers per hit:
   Y+, V-, V+, U-, U+
4. Take enough data to average over signals from same YZ coordinates
5. look at absolute values
6. look at correlations between values:
   1. Y+ and V- describe same motion of charge: strong correlation
   2. V+ and U- describe same motion of charge: strong correlation
   3. V- and V+ difference, U- and V- difference, V+ and Y+ difference, describe **transparency of V plane**,
   4. U- and U+ difference, U+ and V+ difference, describe **transparency of U plane**



TPC Phase 2b Example Plots

- Drift velocity measurement will be performed to verify cathode HV setting

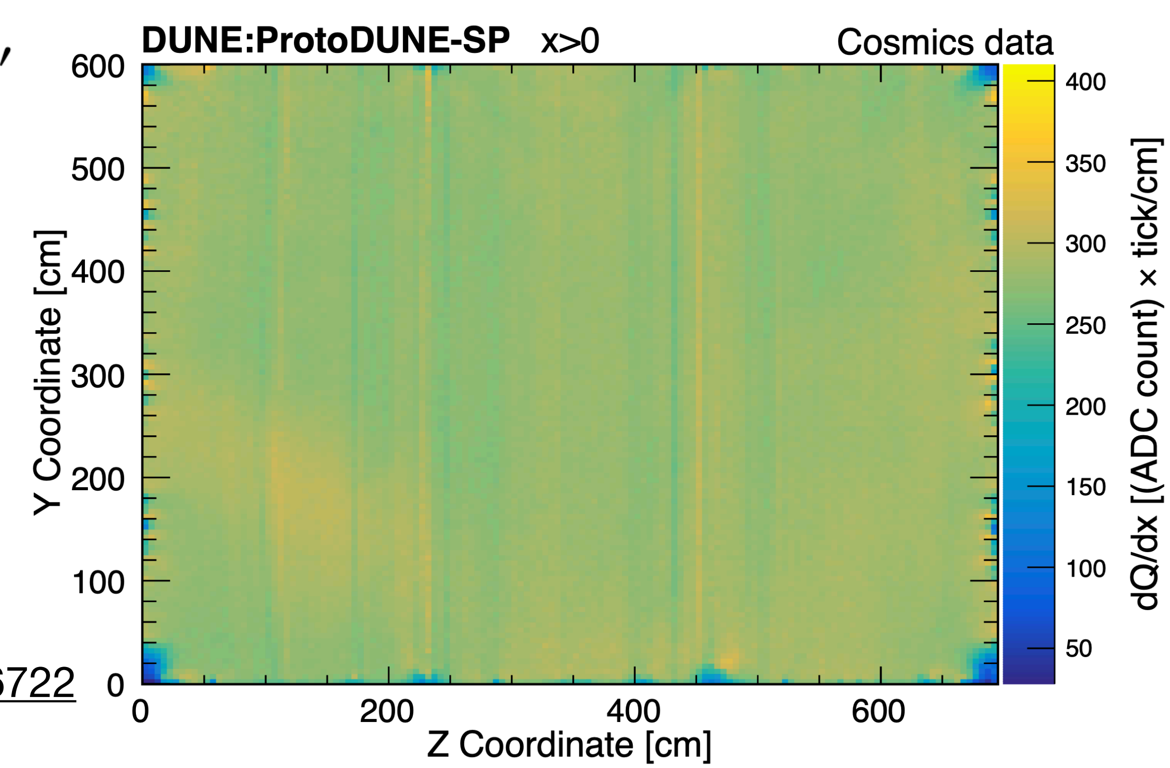
Example from ICARUS



- Induction plane transparency studies will be performed to verify and optimize wire bias voltages, inform bias final voltage settings

Example from ProtoDUNE-SP

arXiv:2007.06722



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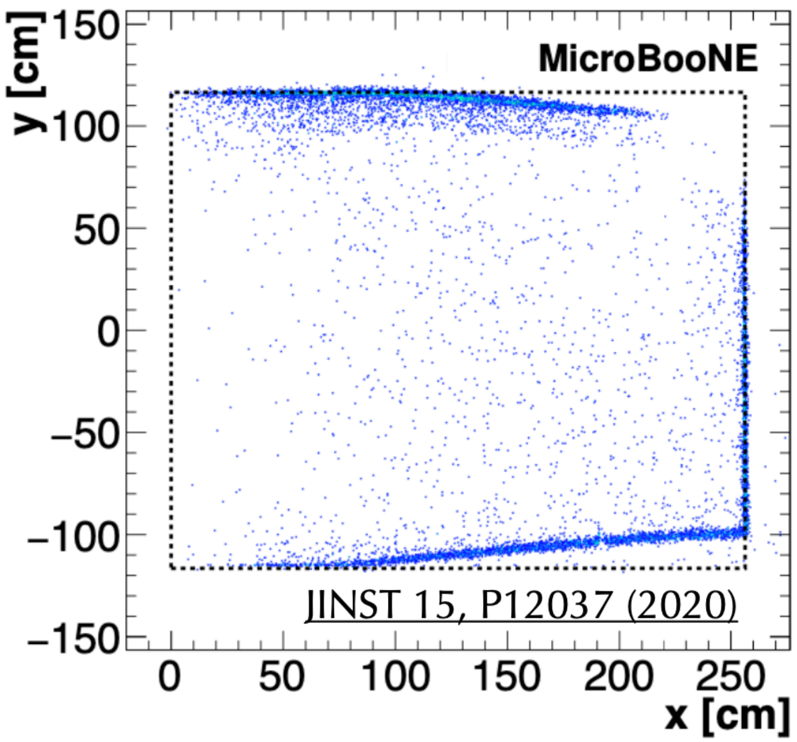
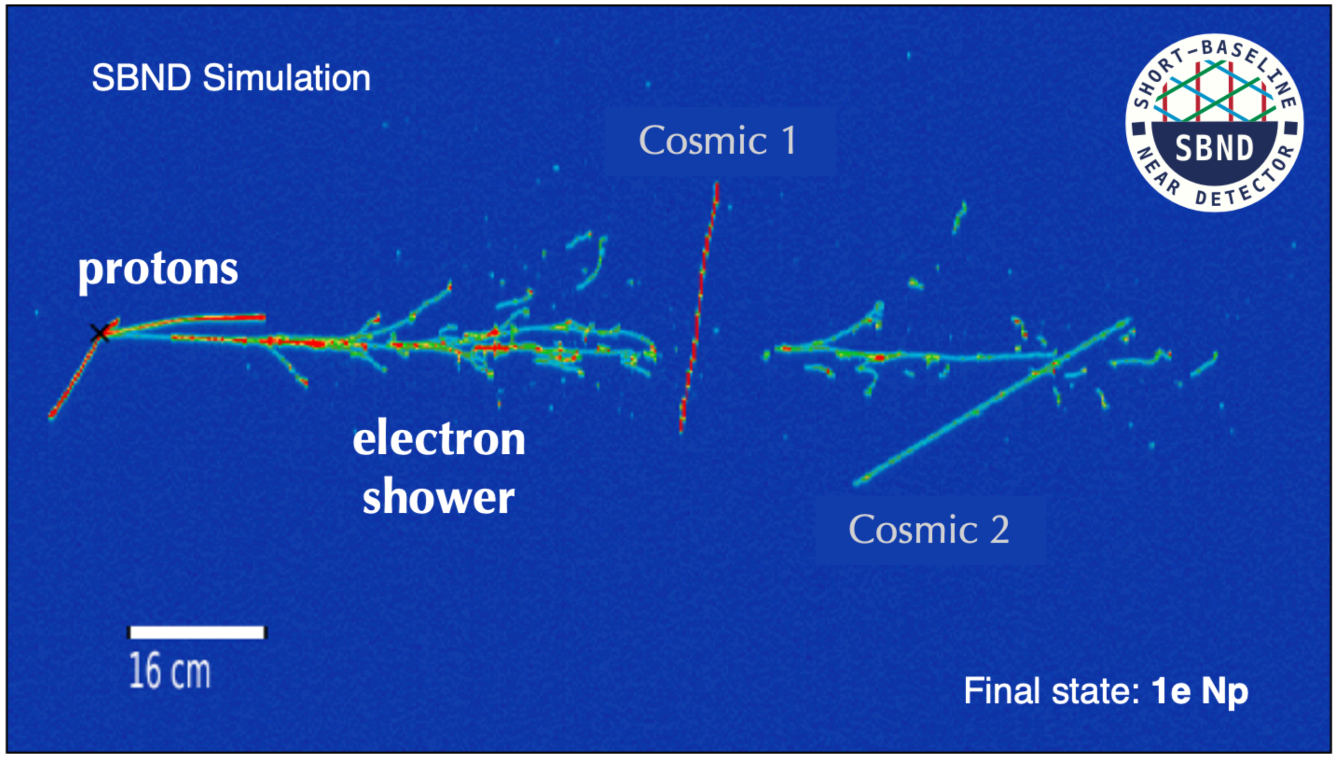
TPC Phase 2b Example Plots

- Tracks with known trajectories (e.g., CRT-tagged tracks) will be used to study E-field map, which will be used to verify the field cage health and to verify field cage termination board and cover board voltages
- By the end of commissioning, will also have validated that the combination of cathode HV, TPC noise, and LAr purity adequate for physics (docdb-1921)





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