

Overview of ProtoDUNE-SP and Initial Study of Space Charge

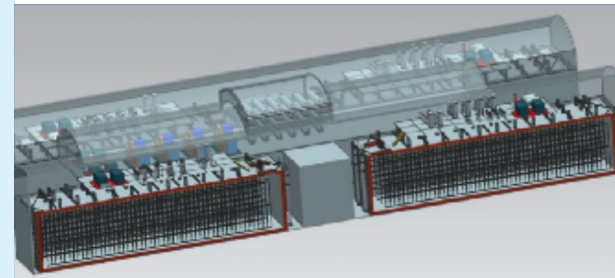
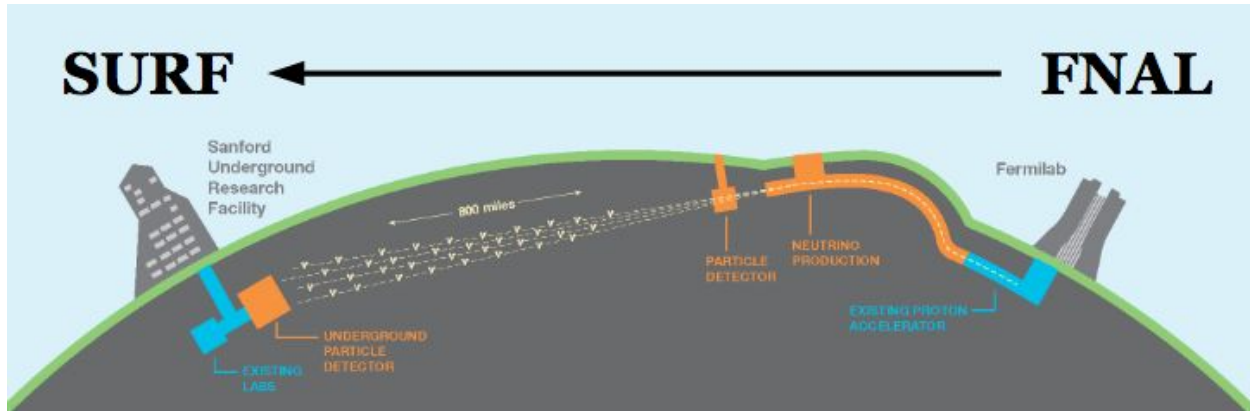
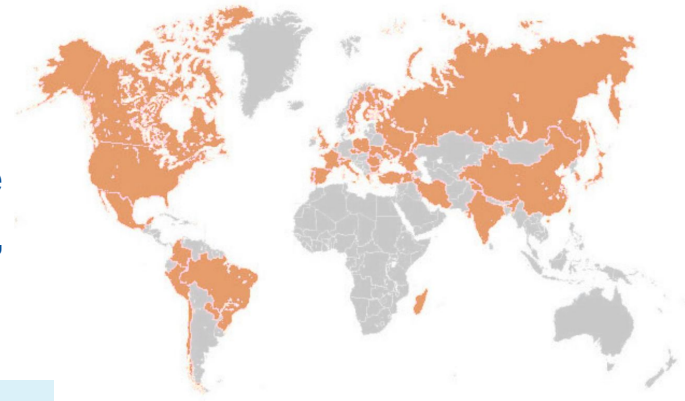
Hannah Rogers

On behalf of the DUNE Collaboration

APS Denver - April 15, 2019

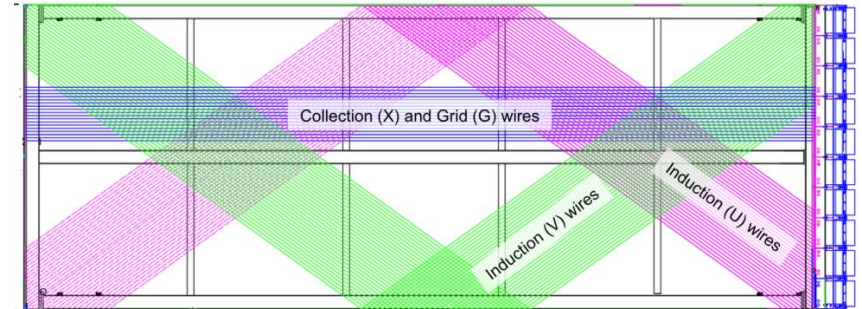
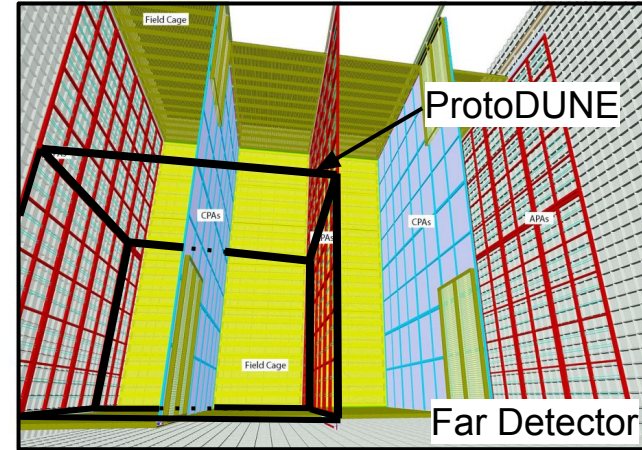
Dune Underground Neutrino Experiment

- Long baseline (1300 km) accelerator neutrino experiment spanning between Chicago and South Dakota
- Large (40 kt) LArTPC far detector plus near detector
 - Far detector deep (1.5 km) underground at Homestake Mine
- Physics goals: ν oscillations (mass ordering, δ_{CP} , θ_{23} , θ_{13}), baryon number violation (e.g. nucleon decay), supernova burst neutrinos

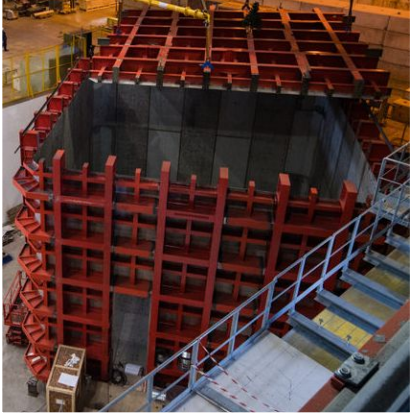


ProtoDUNE Single Phase

- Test of single-phase far detector technology
- Currently largest single-phase LArTPC
 - 0.77 kt liquid argon
- Contains 6 modular drift cells
 - 3.6 m drift length
 - Suspended Anode (APA) and Cathode (CPA) Plane Assemblies
 - Wrapped wires form induction planes
 - ~ 5mm wire pitch
 - 500 V/cm drift electric field

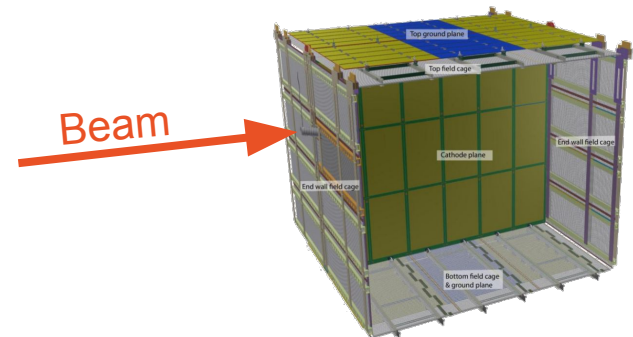


ProtoDUNE at the CERN Neutrino Platform

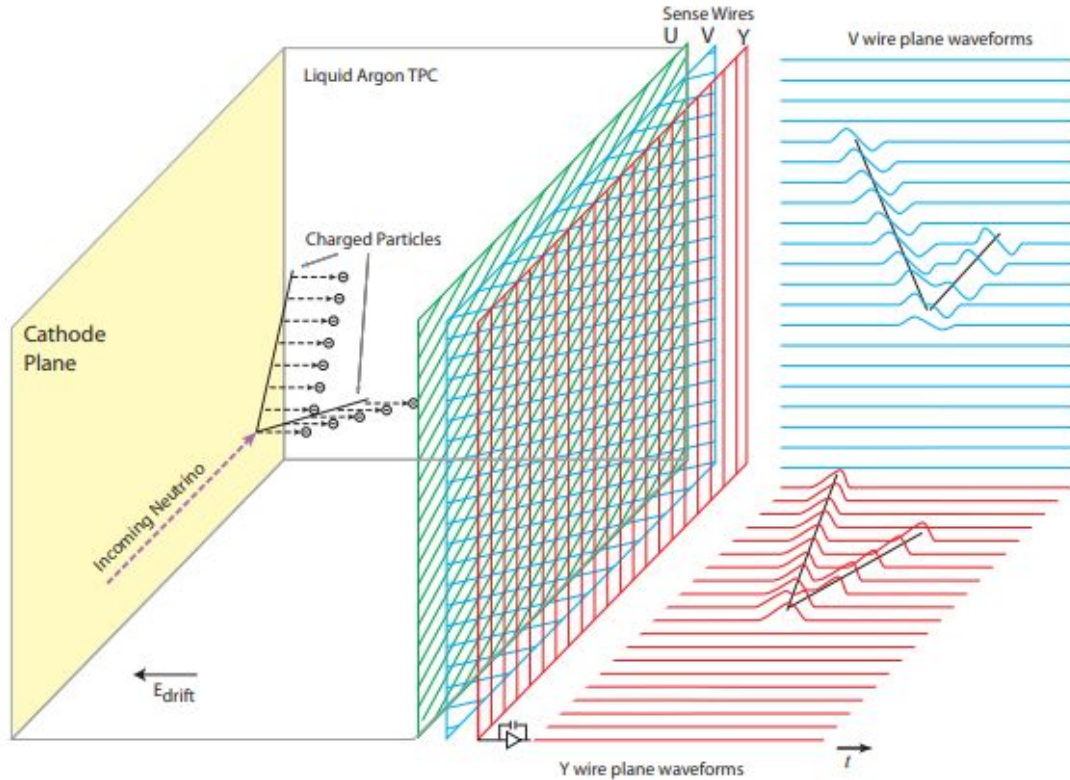


Photos by CERN

- Completed ???
 - 2 TPCs of $\sim 6\text{m} \times 7\text{m} \times 3.6\text{m}$
 - Two APAs and shared CPA
- Located in test beam of protons, pions, kaons, electrons, and muons
 - Momentum: ~ 0.5 to $7\text{ GeV}/c$
 - Useful for calibration studies

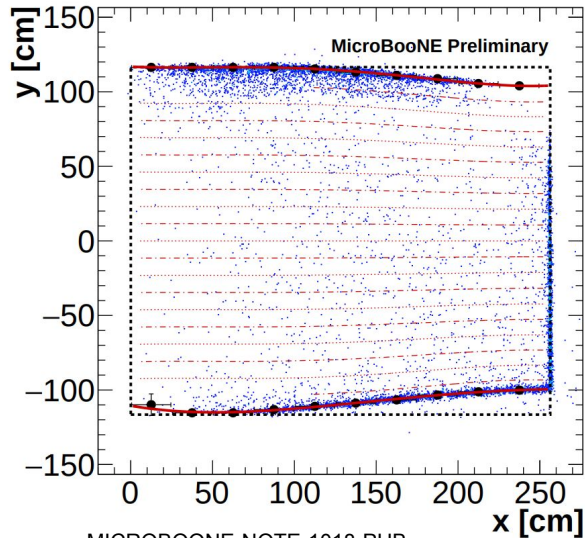
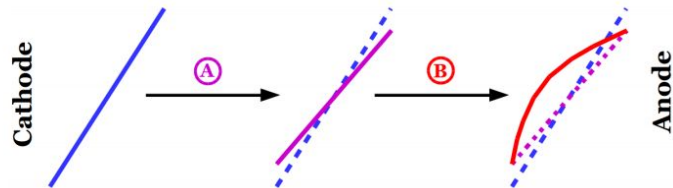


LArTPC Signal Formation



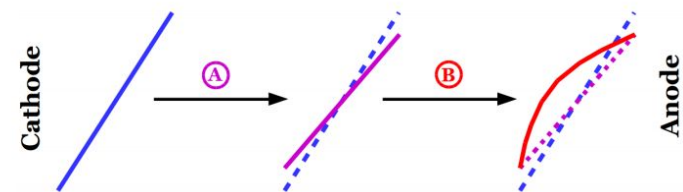
1. Charged particle interacts with liquid argon
 - a. Creates ionization electrons
2. Electric field causes electrons to drift towards anode plane
3. Electrons detected by three wire planes
 - a. Two induction planes with bipolar signal
 - b. One collection plane with unipolar signal

Space Charge Effect

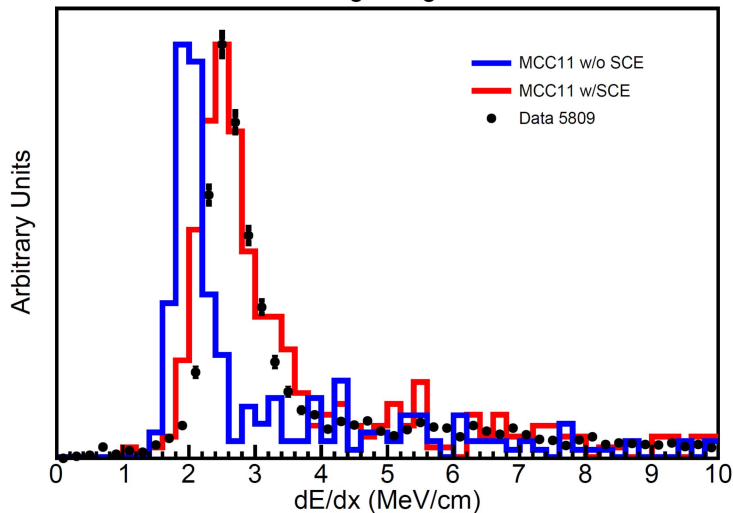


- Build up of slow-moving positive charge distorts electric field from uniform causing:
 1. Variation in charge quenching throughout detector
 2. Change in drift path of ionization electrons
- Not correcting for this leads to:
 1. Calculating the wrong energy of an event
 2. Assuming the charge came from the wrong location in the detector

Space Charge Effect



dE/dx at the beginning of the shower



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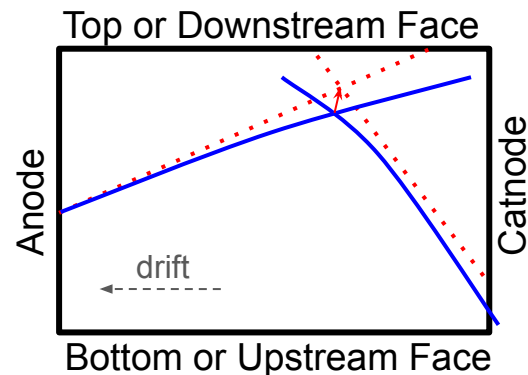
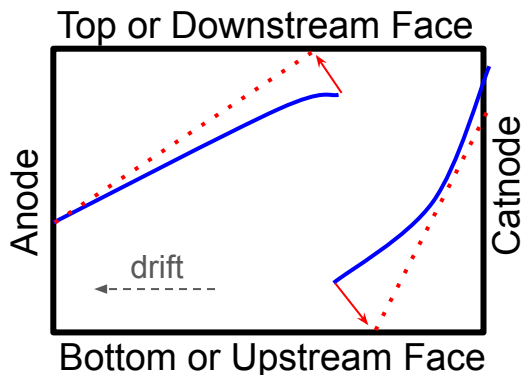
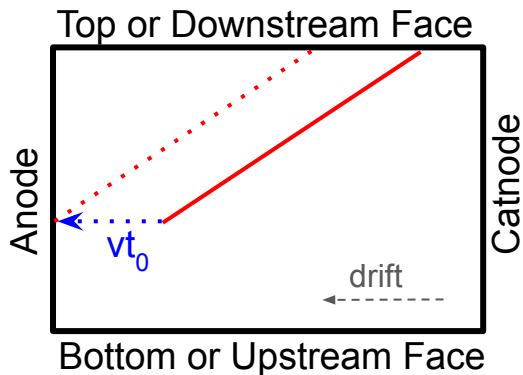
⇒ Poor energy and track reconstruction

⇒ Incorrect dE/dx

 - Important for particle ID and energy-based calculations

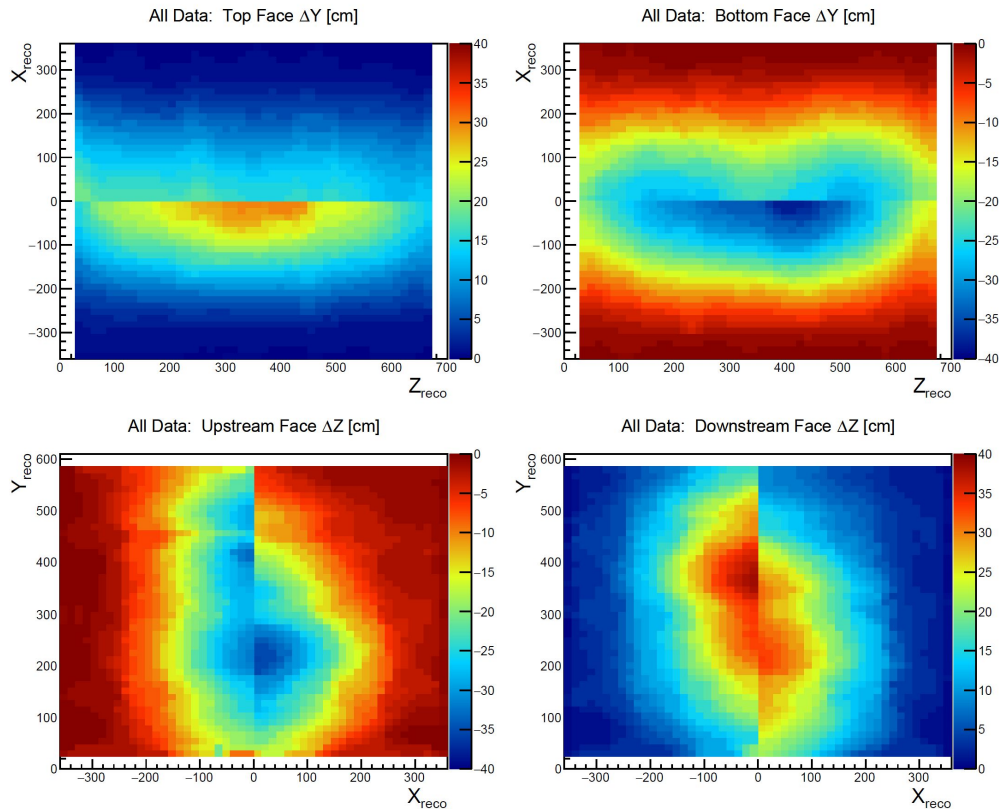
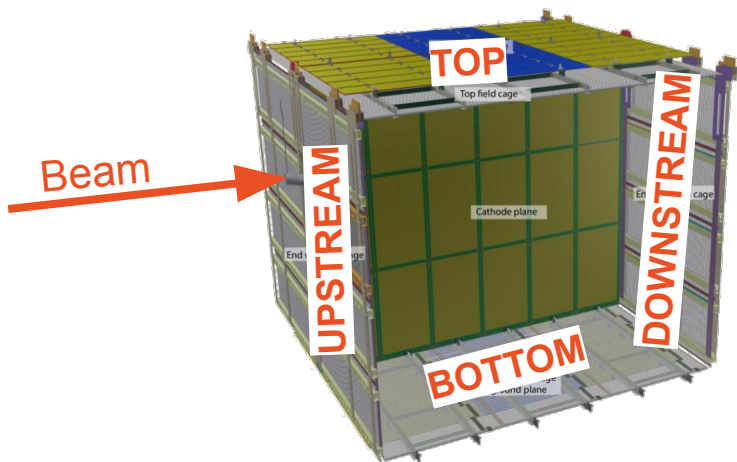
Measuring Spatial Offsets

- Position in drift direction unknown without track start time (t_0)
 - Reconstruction naively assumes $t_0 = 0$ ms
- Through-going anode-/cathode-piercing muons used to measure spatial offsets
 - t_0 determined by shifting track to anode or cathode
 - Muons should cause straight tracks \Rightarrow Curvature due to space charge effect
 - Through-going muons should pierce TPC face \Rightarrow Distance between track end / TPC face used to calculate spatial offset at faces



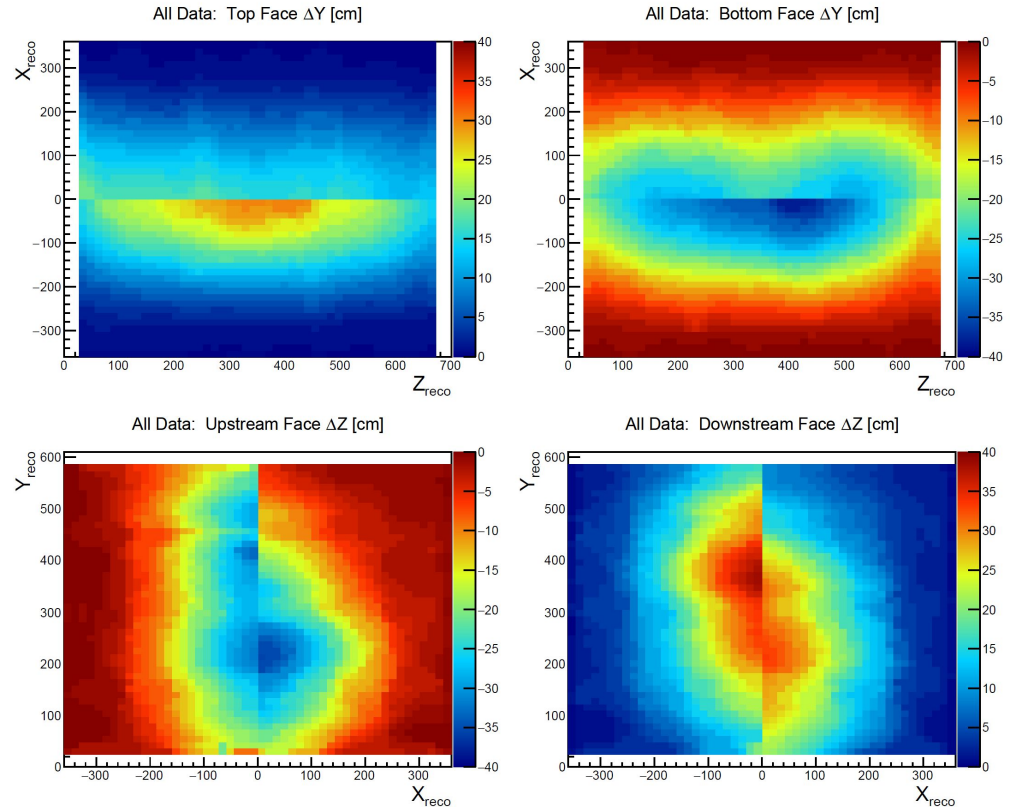
Offsets from Faces at ProtoDUNE

- Spatial offsets at faces measured using ProtoDUNE



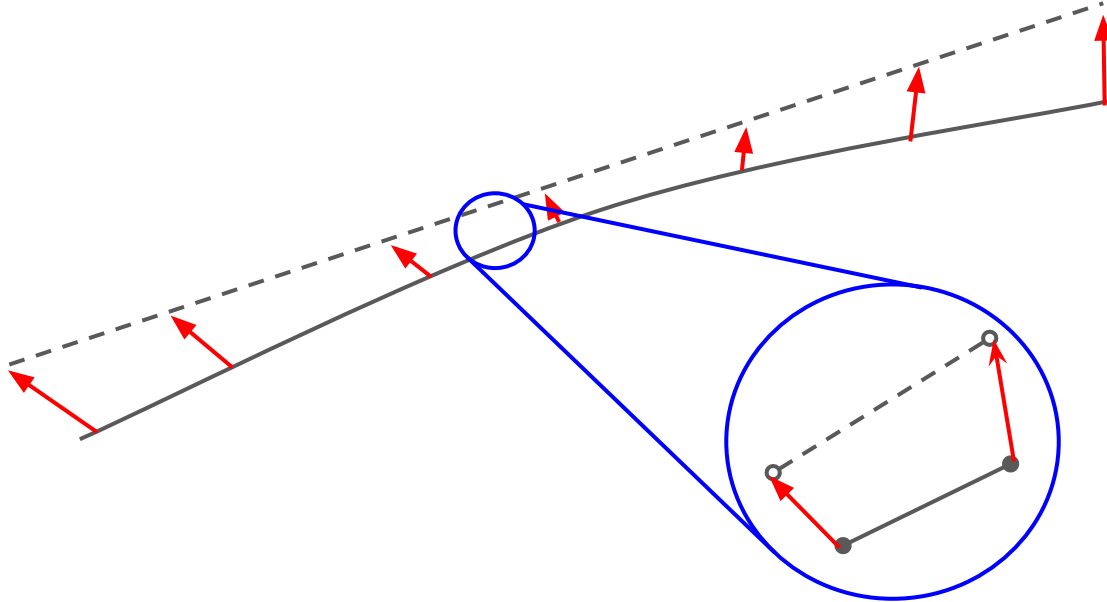
Offsets from Faces at ProtoDUNE

- Spatial offsets at faces measured using ProtoDUNE
- Used to calculate:
 1. Spatial distortion map from true position to reconstruction positions (used in simulation)
 2. Spatial distortion map from reconstructed to true positions (used in calibration)
 3. Electric field distortion map (used in simulation and calibration)



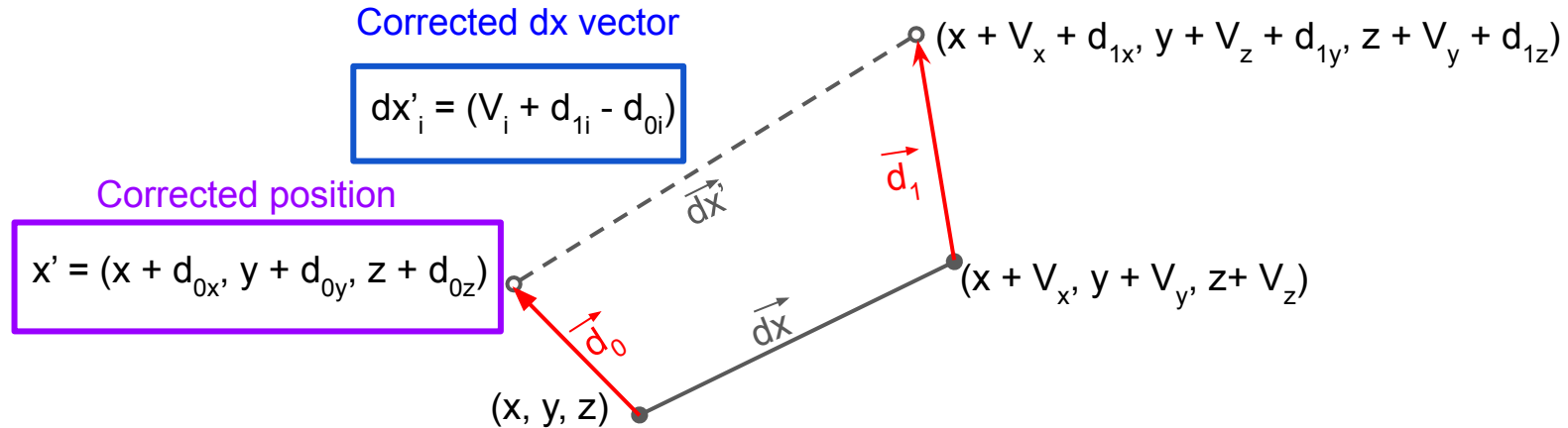
Calorimetry Calibration Corrections

- Calorimetry information (dQ/dx or dE/dx) is affected by both spatial and electric field distortions
- From spatial distortions, both **position** and **dx vector** must be corrected



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- From spatial distortions, both **position** and **dx vector** must be corrected
- Corrected **electric field** used to calculate dE/dx

$$\frac{dE}{dx} = f \left(\frac{dQ}{dx}, |\vec{E}| \right)$$

Previous spatial
correction



Electric field
correction



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- From spatial distortions, both **position** and **dx vector** must be corrected
- Corrected **electric field** used to calculate dE/dx
- Calibrated calorimetry should reduce systematics on energy-dependent calculations

Summary

- ProtoDUNE-SP is currently the largest single-phase LArTPC
- ProtoDUNE-SP is a prototype for the single phase DUNE far detectors
 - Far detectors will be ~ ??? times larger but use similar technology
- Space charge distorts the electric field and causes apparent offsets in position
- First measurements of the spatial offsets due to space charge can be used to build calibration maps
 - Correcting for space charge in reconstruction allows more accurate calorimetry calculations

Thank you!