Slides for ProtoDUNE-SP and 2x2 Module Detector Physics Discussion

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Personal Requests

ProtoDUNE-SP Hadron Physics

ProtoDUNE-SP hadron physics analyzers treated analyses as necessary for tuning Geant4 for neutrons, pions, protons, and kaons traversing argon.

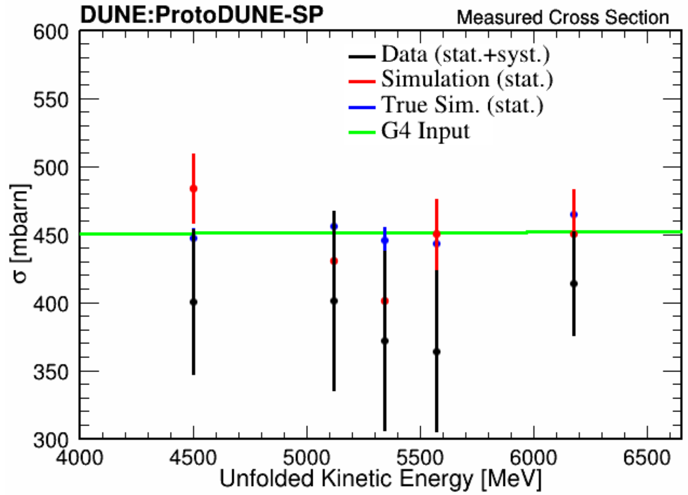
- Impacts DUNE with secondary interactions of particles scattering on argon.
- Geant4RW (*JINST* **16** P08042) used to reweight events based on track length and G4 input cross section
  - Already used by ProtoDUNE-SP, uses G4 trajectories to generate weights.

- Proposal: Use G4RW with bounds for throws dictated by the ProtoDUNE-SP and ProtoDUNE-HD.
  - One way to run analysis with direct physics-motivated reweight.
- Example: Kaon analysis (preliminary using one data run)
- What other ways can ProtoDUNE-SP help constrain secondary interactions on argon?

Analyses impacted by electron diverters. Used a broken track systematic uncertainty that could be applicable to other detectors (See Jake Calcutt's technical note on pion cross section).

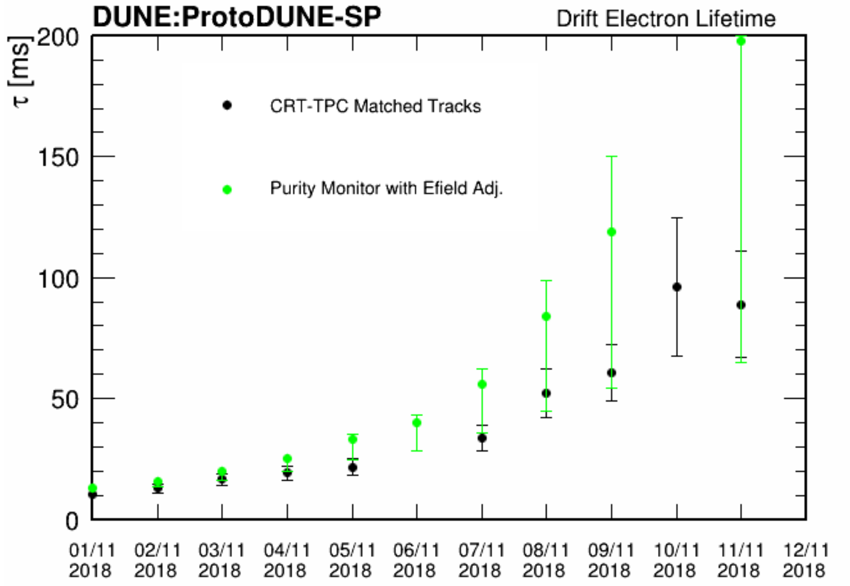
Bayesian-like unfolded cross section (~380 mbarns) with a true G4 input cross section of 450 mbarns.

If this is the final measurement, then the suggested one sigma for G4RW would be 15% for kaons in Ar.



ProtoDUNE-SP Detector Physics: Impurity Calibration

- Proposal from Leigh: Upgrade next FD lifetime to ideally 48 ms, or at least 35 ms (current PDSP simulation lifetime).
  - Why 48 ms?
    - That lifetime is both attainable and the minimum lifetime whereby dQ/dx uncertainty from impurities is known to 1% (TDR spec.) even if the uncertainty of the electron lifetime measurement is 100%.
      - Fractional uncertainty of dQ/dx is sigma(tau)/(2*tau*tau) (See Josh Klein's docdb-14926)
  - Can we use a more conservative number?
    - 8 ms and 20 ms were what was used once it was verified 3 ms was too low (the lifetime used for MCC11).
- What do we need from ProtoDUNEs?
  - Verification purity monitor and TPC lifetime measurements agree consistently and can constrain one another over all two years (ProtoDUNE-SP detector paper and performance paper only proved this for one week of data-taking).



Comparisons of top purity monitor to TPC measurements made with CRT-tagged tracks (From R. Diurba's thesis).

End of October coincided with a drop of impurity. Beginning of November is the start of the LAr purity recovery.

Discussion

ProtoDUNE-SP Detector Physics Software Improvements

- First experiment to use refactored Geant4 simulation of LArSoft.
    - Improves energy thresholding and combines light and charge simulation into one step.
- WireCell detector simulation used for PDSPProd4 and PDSPProd4a.
    - Adaptable and allows LAr physics parameters to be altered at the detector simulation stage, previously done at G4 stage.

- Are any of these under consideration for the DUNE Far Detector simulation campaign?

ProtoDUNE-SP Detector Physics to Consider

In addition to Leigh's suggestion to use Michel energy reconstruction and electron energy reconstruction analyses in some way.

Can be done after reco.fcl stage:

- Calibration uncertainty
  - ProtoDUNE-SP used MINOS and MicroBooNE calibration method of equalizing dQ/dx as a function of XYZ.
  - Generic dE/dx uncertainty set to 2% by me and 3% by Jake Calcutt.
- Recombination model
  - Could be re-simulated or simply use bounds of ICARUS, ArgoNeuT, or future ProtoDUNE-SP measurements.

Will require some sort of re-simulation at the detector simulation stage:

- Diffusion (re-simulate?)
  - Measurements being made by Elise Hinkle can be used for redone simulation samples.
  - However, PDSP believed diffusion decently understood based on dQ/dx data/MC agreement (see performance paper)
- Electric field
  - Ajib Paudel's thesis measured this and we use a slightly lower electric field, but SCE syst. dominate.

Which of these standout as adaptable for future DUNE analyses?

Module 0 and Module 1 Detector Physics

Studies completed in Module 0 paper that can feed into current ND-LAr work:

- ~2.2 ms electron lifetime measured by Lane (MSU) currently used by Roberto for 2x2 module simulation.
- Improvements and updated light lookup tables for the ArcLight and LCMs in the simulation.

What needs to be in the ND-LAr simulation? Are there detector effects we want to simulated?

What calibration scheme will be used? Do we want to use the same as the Far Detector (probably)?

Studies not done but completed for previous LArTPCs:

- Electric field magnitude and uniformity in the bulk of the detector.
- Full calibration using cosmic muons in the style of ProtoDUNE-SP, MicroBooNE, and MINOS.
- Evaluations of the gain using stopping muons.

Studies for the future:

- Track breaking between modules (Can only be done in 2x2)
- Multi-detector stitching (ND-LAr to TMS/ND-GAr, 2x2 to MINERvA)

Backup Slides

2x2 Modules Hadron Physics

Cosmic only runs from Module 0 and Module 1

- Isolated and detached tracks do exist, implying some hadronic scatter.
    - Bern currently looking at this to test charge and light reconstruction (Igor Kreslo)
    - Can complement Kevin Wood’s studies on full ND-LAr simulation with data.

ProtoDUNE-SP Beam (Slide taken from May Collab. Kaon talk)

- Kaons are of interest for nucleon decay searches in the DUNE Far Detector.
  - Kaons could scatter off the argon preventing the detection of Bragg peak for PID.
- ProtoDUNE-SP has a small amount of high energy kaons to study the cross section of kaons on argon.
  - Result may be fed back into nucleon decay generator FSI modeling (Ex. *Physical Review D* **104**, 053006 (2021)).

		Momentum (GeV/c)			
		1	**2**	**3**	**6 - 7**
e	TOF (ns)	0, 105	0, 105	–	–
	XCET-L	1	1	1	1
	XCET-H	–	–	1	1
μ / π	TOF (ns)	0, 110	0, 103	–	–
	XCET-L	0	0	0	1
	XCET-H	–	–	1	1
K	TOF (ns)	–	–	–	–
	XCET-L	–	–	0	0
	XCET-H	–	–	0	1
p	TOF (ns)	110, 160	103, 160	–	–
	XCET-L	0	0	0	0
	XCET-H	–	–	0	0

Beamline selection criteria based on information from the time-of-flight measurement and Cherenkov detectors (*JINST* **15** P12004).

Momentum (GeV/c)	Pion-like (k)	Proton-like (k)	Electron-like (k)	Kaon-like (k)
0.3	0	0	242.5	0
0.5	1.5	1.5	296.3	0
1	381.8	420.8	262.7	0
2	333.0	128.1	173.5	5.4
3	284.1	107.5	113.2	15.6
6	394.5	70.1	197.0	27.9
7	343.7	58.4	112.9	28.2

Total run statistics by particle candidate from the beamline monitoring system with a rudimentary selection process.