ProtoDUNE-SP TPC analysis updates and paper status

Tingjun Yang (FNAL)

DUNE Collaboration Phone Call

Nov 8, 2019

Introduction

- In this talk, I will give an update on the ProtoDUNE-SP TPC analysis. Flavio will cover the photon detector updates later.
- Forming of new task forces
  - Simulation TF
  - EM-shower TF
- Improved understanding of LAr properties
  - Diffusion
  - Electron lifetime
- Paper status (TPC sections)

New Task Forces

- Simulation TF – convener: Wenqiang Gu
  - Integrate refactorized larg4
  - Integrate wire-cell simulation
  - Wenqiang give a nice report at this week's DRA meeting. Some results will be highlighted in this talk.
- EM-shower TF – convener: Aaron Higuera
  - Track/shower identification
  - Electron energy resolution
  - Pi0 mass reconstruction
  - Great progress as well.

Refactorized Larg4

- New interface to Geant4 developed by Hans Wenzel (FNAL)
  - Easy access to reference physics lists + extensions
  - Updated OpticalPhysics in G4
    - Scintillation properties are attached to the materials
    - Can have any number of scintillating materials (e.g. LAr and plastic scintillator)
- Simulation of all detector components is being migrated to the new framework
  - TPC: Dave Rivera
  - Photon detector: Wei Mu
  - CRT: Richie Diurba, Dave Rivera

Ready to be tested

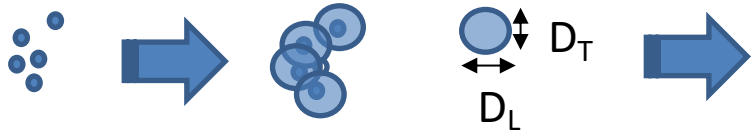
In progress

Configurable (fhicl) options in physics list service

```
19 artg4tk::PhysicsListService::PhysicsListService(fhicl::ParameterSet const & p, art::ActivityRegistry &) :
20   PhysicsListName_( p.get<std::string>("PhysicsListName","FTFP_BERT")),
21   DumpList_( p.get<bool>("DumpList",false)),
22   enableNeutronLimit_(p.get<bool>("enableNeutronLimit",true)),
23   NeutronTimeLimit_(p.get<double>("NeutronTimeLimit",10.*microsecond)),
24   NeutronKinELimit_(p.get<double>("NeutronKinELimit",0.0)),
25   enableStepLimit_(p.get<bool>("enableStepLimit",true)),
26   enableOptical_(p.get<bool>("enableOptical",true)),
27   enableCerenkov_( p.get<bool>("enableCerenkov",false)),
28   CerenkovStackPhotons_( p.get<bool>("CerenkovStackPhotons",false)),
29   CerenkovMaxNumPhotons_(p.get<int>(" CerenkovMaxNumPhotons",100)),
30   CerenkovMaxBetaChange_(p.get<double>("CerenkovMaxBetaChange",10.0)),
31   CerenkovTrackSecondariesFirst_( p.get<bool>("CerenkovTrackSecondariesFirst",false)),
32   enableScintillation_( p.get<bool>("enableScintillation",true)),
33   ScintillationStackPhotons_( p.get<bool>("ScintillationStackPhotons",false)),
34   ScintillationByParticleType_( p.get<bool>("ScintillationByParticleType",true)),
35   ScintillationTrackInfo_( p.get<bool>("ScintillationTrackInfo",false)),
36   ScintillationTrackSecondariesFirst_( p.get<bool>("ScintillationTrackSecondariesFirst",false)),
37   enableAbsorption_( p.get<bool>("enableAbsorption",false)),
38   enableRayleigh_( p.get<bool>("enableRayleigh",false)),
39   enableMieHG_( p.get<bool>("enableMieHG",false)),
40   enableBoundary_( p.get<bool>("enableBoundary",false)),
41   enableWLS_( p.get<bool>("enableWLS",false)),
42   BoundaryInvokeSD_( p.get<bool>("BoundaryInvokeSD",false)),
43   verbositylevel_( p.get<int>("Verbosity",0)),
44   WLSProfile_( p.get<std::string>("WLSProfile","delta"))
```

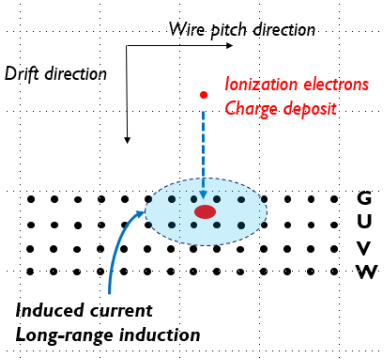
WireCell TPC simulation

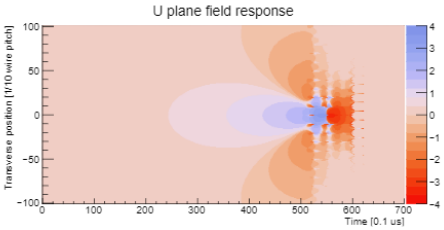
Wenqiang Gu



<SimEnegyDeposit>
* x, y, z, t, # of e

- Ionized electron absorption (lifetime in LAr)
- Gaussian random diffusion
  (longitudinal/transverse) σ^2= 2Dt
- Fluctuation in electron absorption





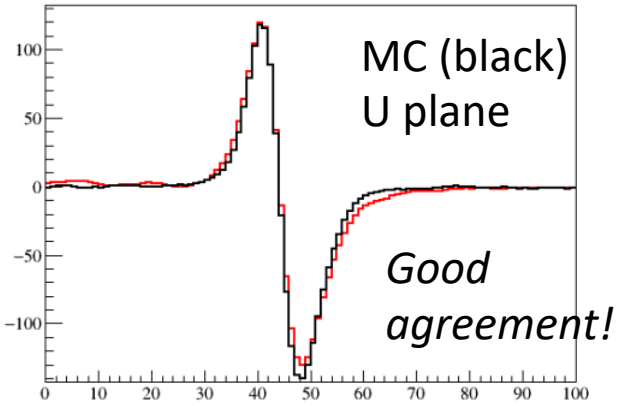
- Electronics response
- Preamp shaping
- AC coupling
- Noise
- Digitizer

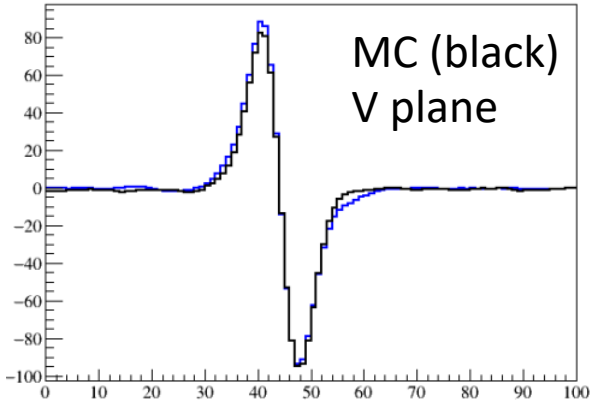
[More reading: DUNE collaboration meeting, May 2019]

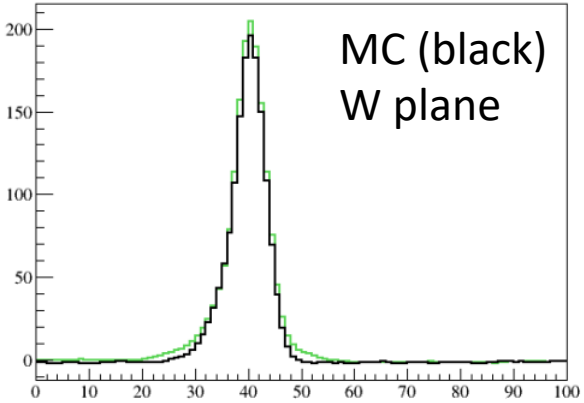
Improved TPC signal simulation

Wenqiang Gu
Ajib Paudel

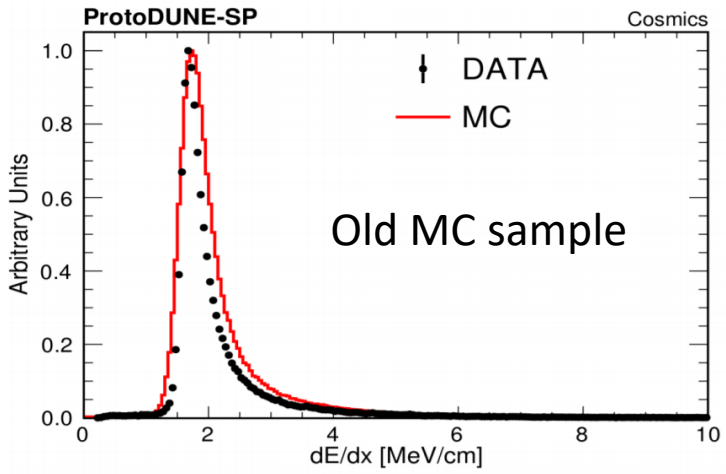
Raw waveforms

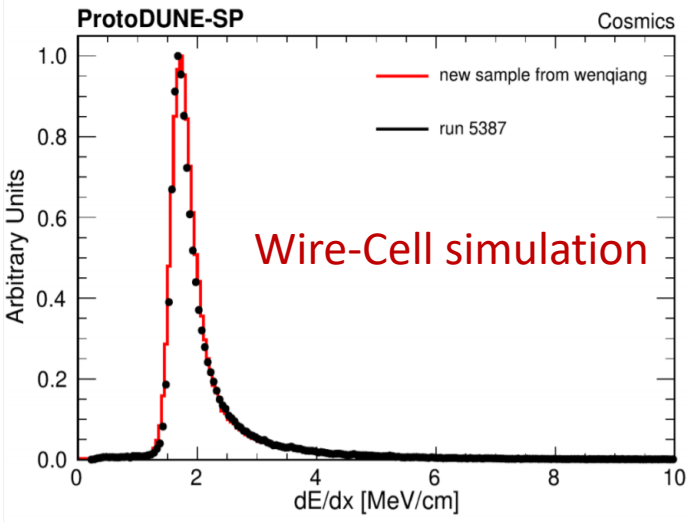






Cosmic muon dE/dx

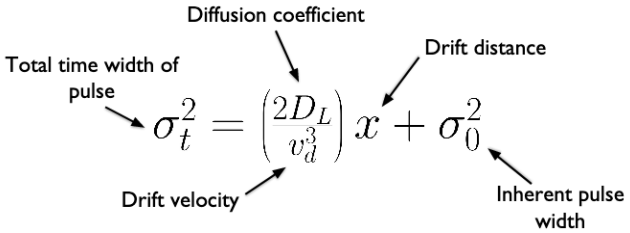


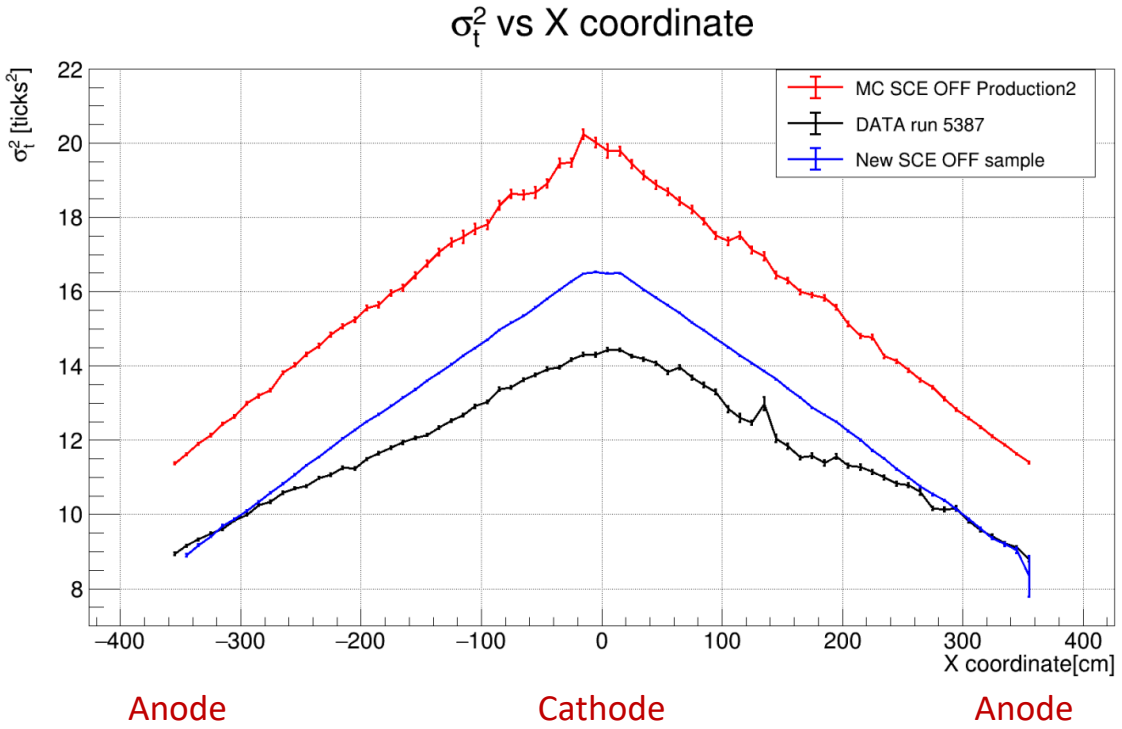


Diffusion studies

Ajib Paudel

- Diffusion smears the signal at longer drift distance.
  - Can be measured using hit_RMS^2 vs x



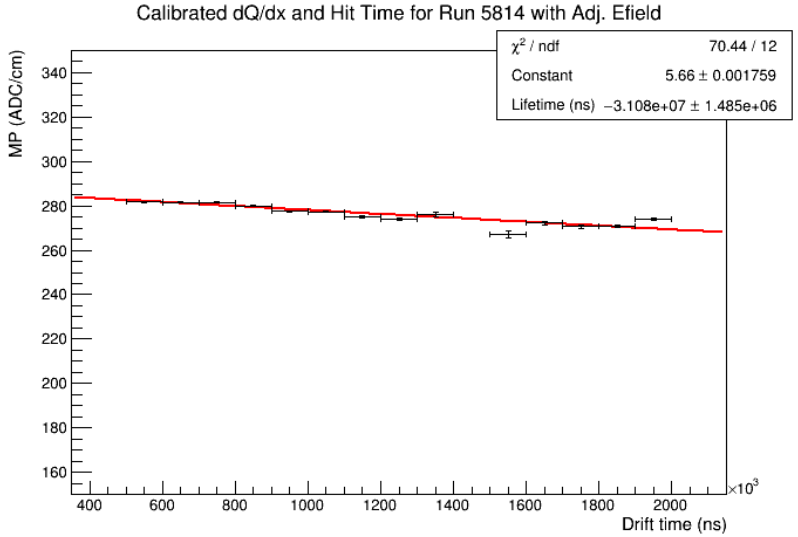


- New simulation improves the modeling of inherent pulse width (σ_0).
- Diffusion constant can be tuned to improve the slope.

Electron lifetime measurement

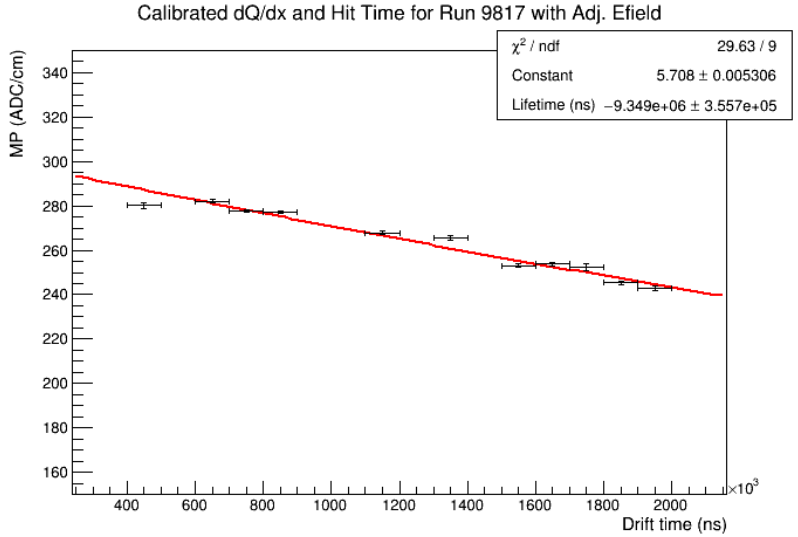
Richie Diurba

- Use CRT tagged horizontal cosmic tracks – parallel to the wire planes, drift distance provide by CRT.
- Using the track segment in the middle of TPC where spatial distortion in y,z caused by space charge is minimal.
- Use E-field map to correct for recombination effects (~2.5% over the full drift distance)



Run 5814: Nov 8, 2018

Lifetime: 31±1 ms



Run 9817: Oct 11, 2019

Lifetime: 9.3±0.4 ms

Performance paper status (TPC sections)

Tom Junk, TY

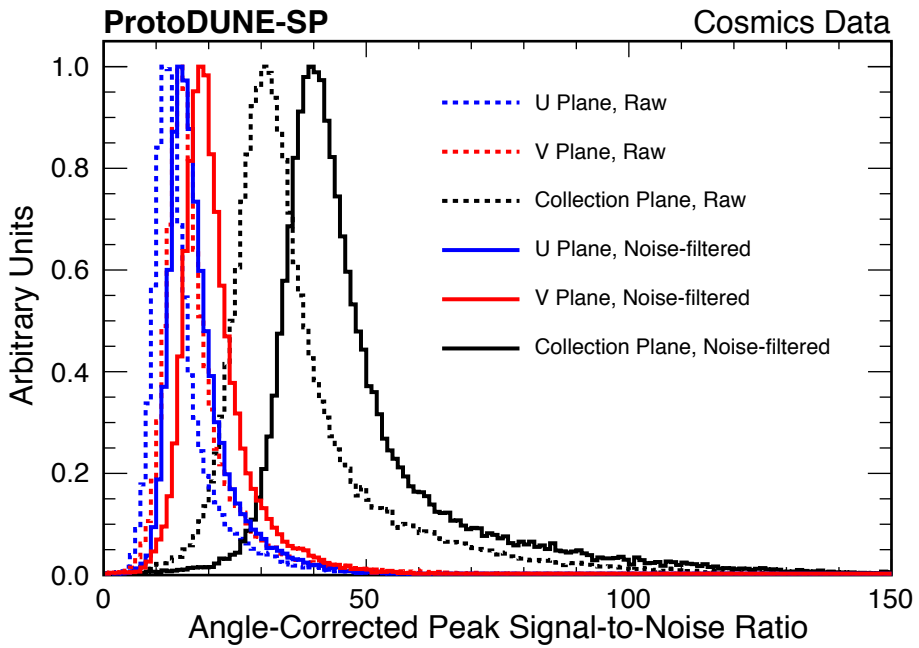
✓ complete

✓ Figures need to be updated

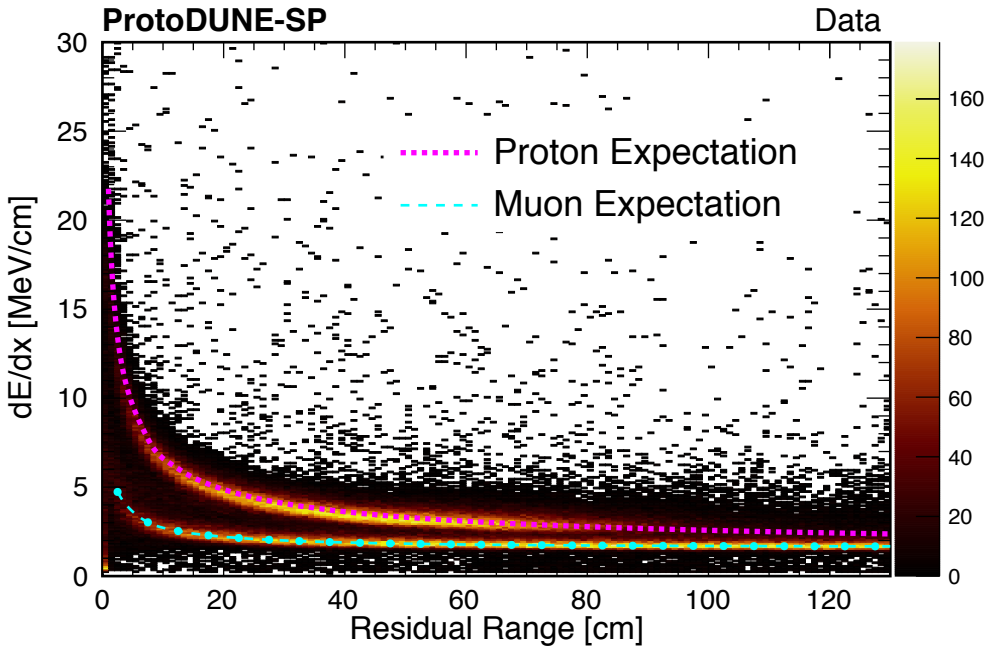
- Most of the subsections are in a good shape and ready to be reviewed.
- For details see my collaboration meeting talk: https://indico.fnal.gov/event/21445/session/19/contribution/92/material/slides/0.pdf

Result highlights

Signal-to-noise ratios



Muon and proton dE/dx



- Now Flavio will show the photon detector results.