Introductory notes

LBNC Physics Subpanel Call

Ryan Patterson

October 15, 2018

Direction for this meeting

- **The subpanel provided a list of items that are timely to discuss in detail.**
  - ProtoDUNE analysis and input to the TDR
  - Implementation of the ND concept in CP sensitivity studies
  - Role of alternative neutrino generators in TDR studies
  - Neutrino energy reconstruction strategy, in particular neutrals
  - Plans for DUNE-PRISM studies in the TDR

- **Three talks will cover these:**
  - **Tingjun Yang** on ProtoDUNE
  - **Chris Marshall** on FD+ND oscillation fits
  - **Mike Wilking** on DUNE-PRISM

- **But first, I will give the top headlines from other areas in Physics**

Organization

Physics Coordination

Ryan Patterson
Deputy: Elizabeth Worcester

Recent change(s) shown in red

Also new and physics-adjacent:
- ND CDR editors
- ND Design Group
- Calibration Consortium
- Computing Consortium

Physics groups

FD Sim & Reco
Chris Backhouse
Alex Himmel
Tingjun Yang

ND Physics
Mike Kordosky
Steve Manly

Long Baseline
Chris Marshall
Dan Cherdack
Mayly Sanchez

BSM/Exotics
Alex Sousa
Jae Yu

High-*E* / NDK
Lisa Koerner
Vitaly Kudryavstev
Greg Pawloski

Low-*E* / SNB
Ines Gil Botella
Kate Scholberg
Alex Friedland

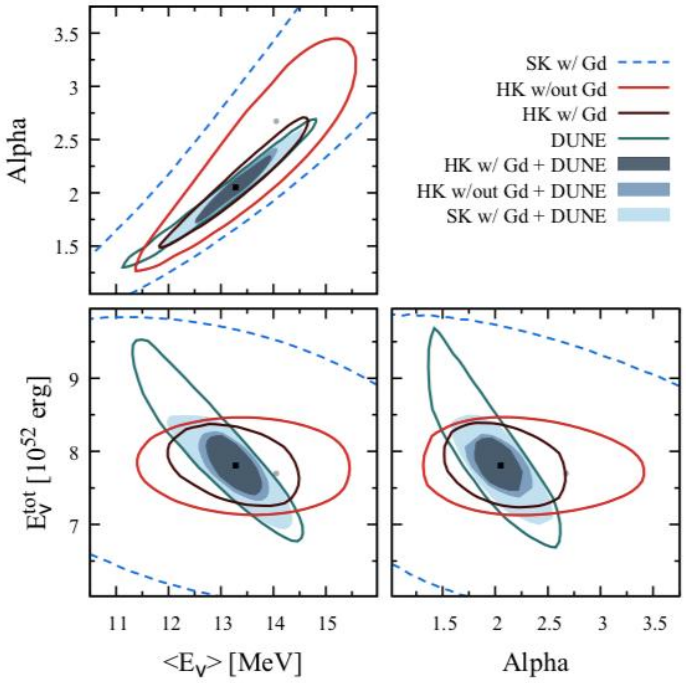
ProtoDUNE
Tingjun Yang
George Christodoulou

Also: Calibration Task Force
Sowjanya Gollapinni, Kendall Mahn

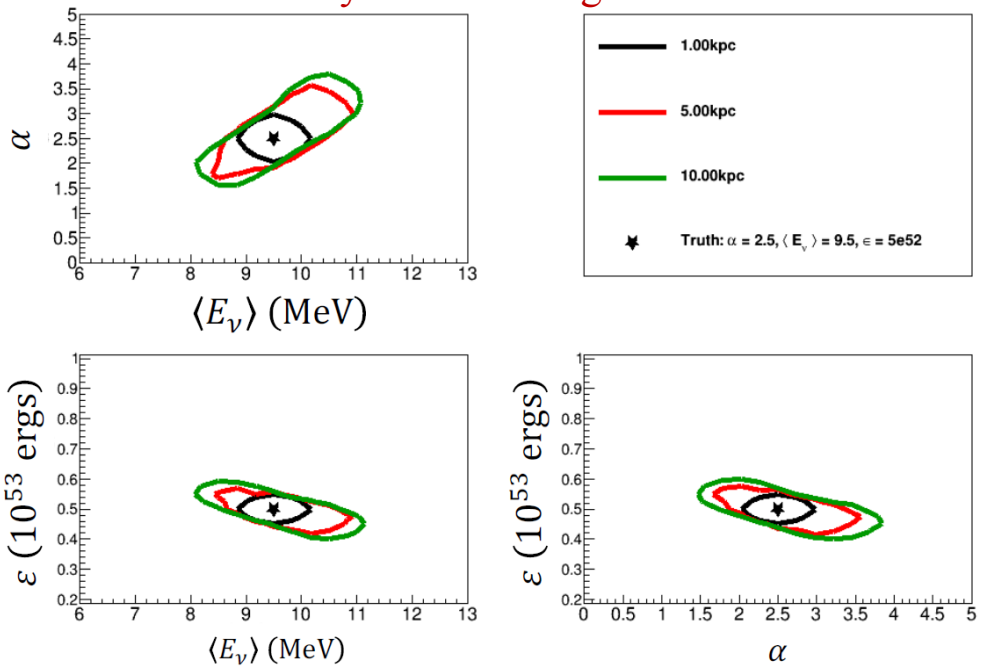
SNB Working Group

- **Recent milestone reached**: sensitivities for benchmark astrophysical observables using full end-to-end reconstruction
  - Spectrum often described using the pinched-thermal* model. Of interest: spectral parameters vs. time (and flavor)

Example from recent theory paper
Nikrant *et al.*, 1711.00008

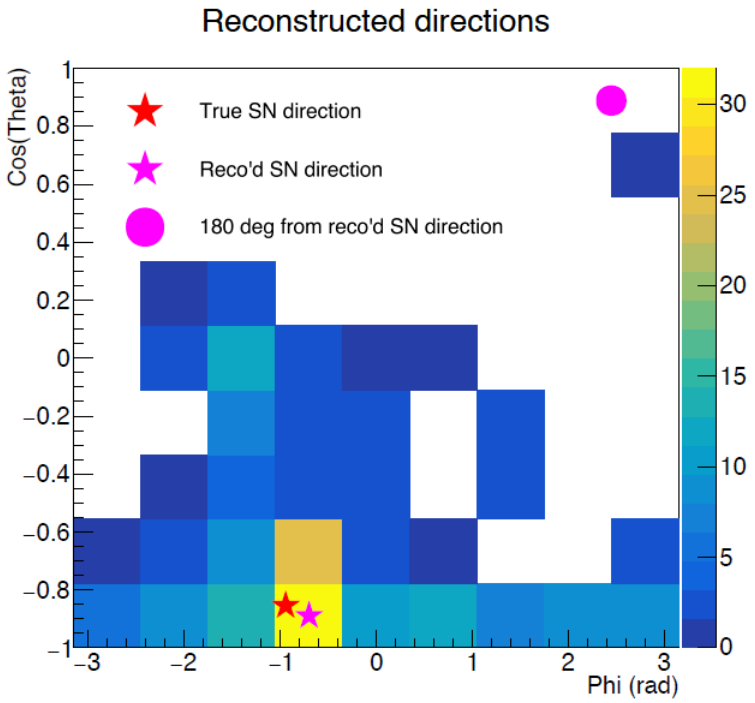


Preliminary version using DUNE sim/reco

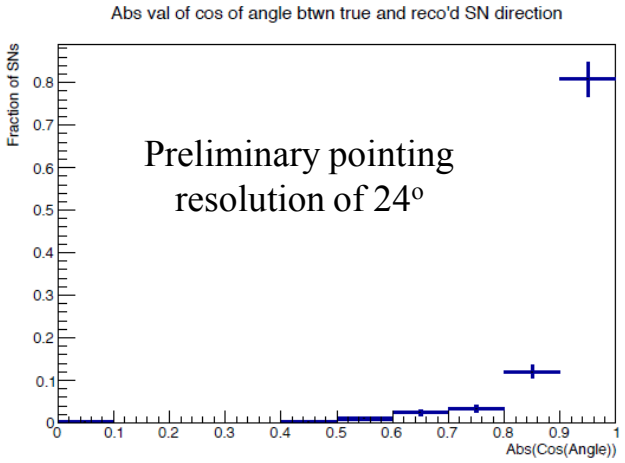


* $\phi(E_\nu) = \mathcal{N}\left(\frac{E_\nu}{\langle E_\nu \rangle}\right)^{\alpha} \exp\left[-(\alpha+1)\frac{E_\nu}{\langle E_\nu \rangle}\right]$

- SNB quantitative metrics planned:
  (1) pinched-thermal spectral parameters
  (2) neutrino mass hierarchy determination
  (3) Collective effects and time-dependent shockwave features [maybe]
  (4) SN pointing using elastic scattering [plots below]
  (5) SASI oscillations [maybe]



Reconstructed direction of individual ES events and inferred direction to SN
(full sim/reco example with mock data, though with some caveats)



- SNB Physics group working closely with DAQ and PDS groups (supernova physics is the most demanding driver of those systems)

NDK Working Group

- At right: a slide I showed at a recent LBNC meeting, where we discussed challenges in each group
- Principle NDK challenge was **recruitment of new effort** for these analyses

- Many channels of interest.

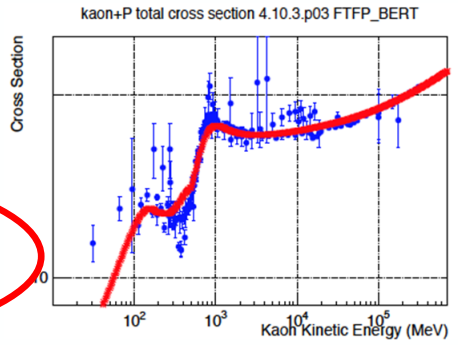
n-nbar osc.: **Reconstruction and selection in place** with good performance. Studying systematics now.

$n \to K^+ e^-$: **Reconstruction and selection in place.** Focusing on increasing efficiency further.

$p \to K^+ \bar{\nu}$: Pursuing parametrized analysis paths in parallel with full reco analysis. **Zero background is achieved with full reco**, but efficiency needs to increase further.

$p \to e^+ \pi^0$: A new effort. Anticipating parametrized analysis at some level.

At right, new GEANT version that fixes bug in kaon propagation. Also, new studies of kaon FSI model uncertainties and their impact on kaon channels.



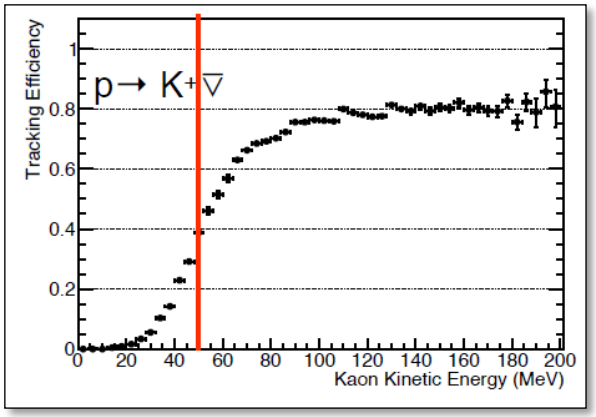
Current challenges for NDK

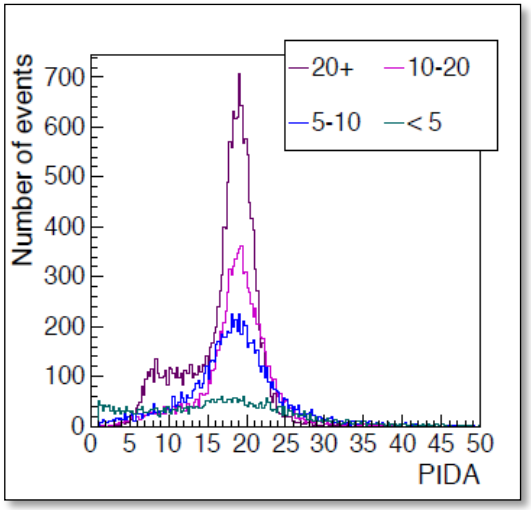
- A very small group. Have had marginal success in recruiting new effort for the many avenues to pursue. (A lot of simultaneous priorities in DUNE!)

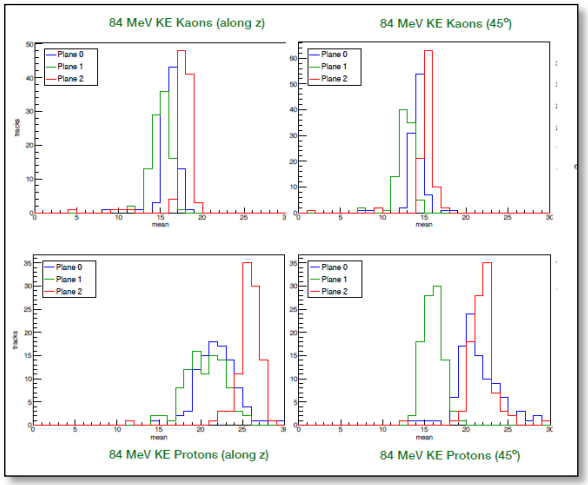
Ryan Patterson 7 Physics Report

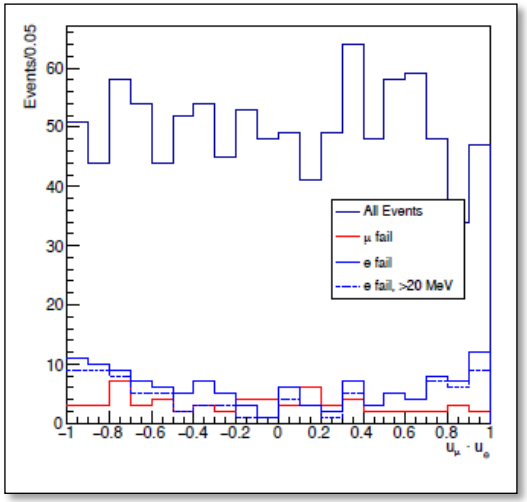
- This summer we stood up a **dedicated analysis subgroup** for the $p \to K^+ \bar{\nu}$ channel, and **elevated the visibility and priority** of this analysis within the collaboration
- Subgroup lead: Hiro Tanaka

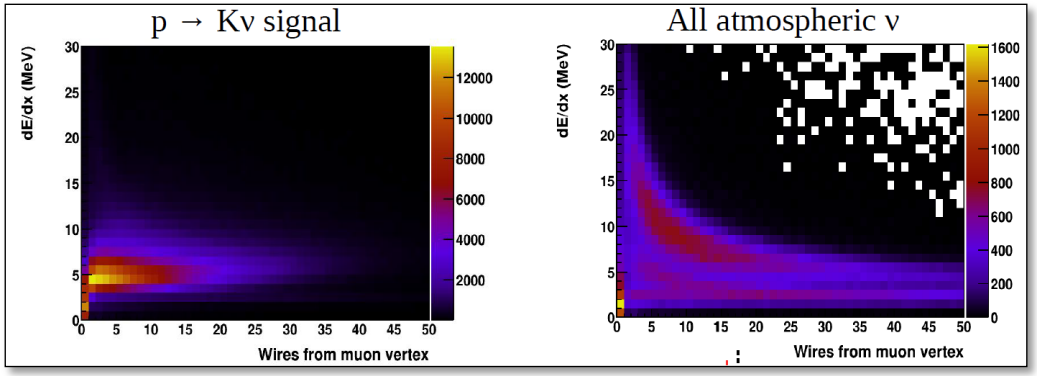
- Ramp up of effort has been excellent. Collection here represents <u>new work from **five different people**</u> (previously just one person) since group formation

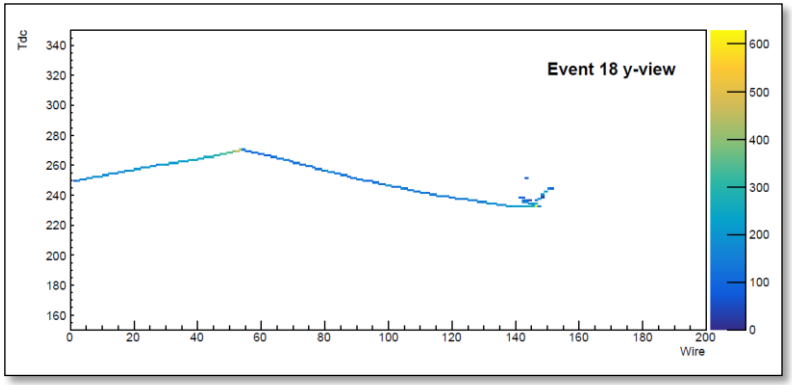








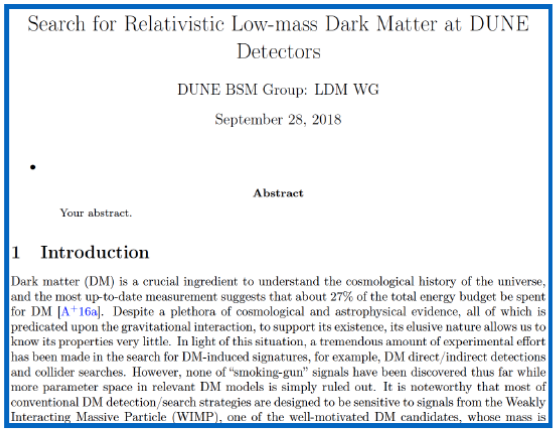




BSM Working Group

- **Internal documentation** for key analyses starting working group review. Docs will go to full collaboration soon.

  This step is particularly relevant for BSM group since we cannot devote much space to the details of each BSM analysis.



Search for Relativistic Low-mass Dark Matter at DUNE Detectors

DUNE BSM Group: LDM WG

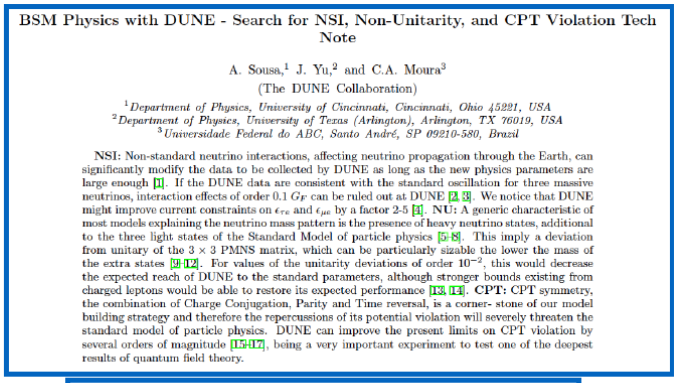
September 28, 2018

Abstract

Your abstract.

1 Introduction

Dark matter (DM) is a crucial ingredient to understand the cosmological history of the universe, and the most up-to-date measurement suggests that about 27% of the total energy budget be spent for DM [A+16a]. Despite a plethora of cosmological and astrophysical evidence, all of which is predicated upon the gravitational interaction, to support its existence, its elusive nature allows us to know its properties very little. In light of this situation, a tremendous amount of experimental effort has been made in the search for DM-induced signatures, for example, DM direct/indirect detections and collider searches. However, none of "smoking-gun" signals have been discovered thus far while more parameter space in relevant DM models is simply ruled out. It is noteworthy that most of conventional DM detection/search strategies are designed to be sensitive to signals from the Weakly Interacting Massive Particle (WIMP), one of the well-motivated DM candidates, whose mass is



BSM Physics with DUNE - Search for NSI, Non-Unitarity, and CPT Violation Tech Note

A. Sousa,[1] J. Yu,[2] and C.A. Moura[3]

(The DUNE Collaboration)

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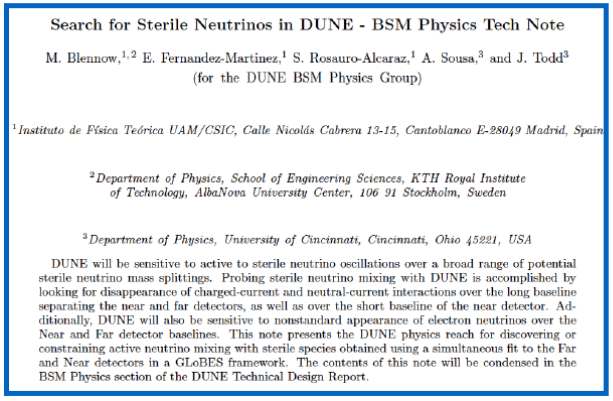
[2]*Department of Physics, University of Texas (Arlington), Arlington, TX 76019, USA*
[3]*Universidade Federal do ABC, Santo André, SP 09210-580, Brazil*

NSI: Non-standard neutrino interactions, affecting neutrino propagation through the Earth, can significantly modify the data to be collected by DUNE as long as the new physics parameters are large enough [1]. If the DUNE data are consistent with the standard oscillation for three massive neutrinos, interaction effects of order 0.1 G_F can be ruled out at DUNE [2, 3]. We notice that DUNE might improve current constraints on $\epsilon_{\tau\tau}$ and $\epsilon_{\mu\mu}$ by a factor 2-5 [4]. **NU:** A generic characteristic of most models explaining the neutrino mass pattern is the presence of heavy neutrino states, additional to the three light states of the Standard Model of particle physics [5–8]. This imply a deviation from unitary of the 3×3 PMNS matrix, which can be particularly sizable the lower the mass of the extra states [9–12]. For values of the unitarity deviations of order 10^{-2}, this would decrease the expected reach of DUNE to the standard parameters, although stronger bounds existing from charged leptons would be able to restore its expected performance [13, 14]. **CPT:** CPT symmetry, the combination of Charge Conjugation, Parity and Time reversal, is a corner- stone of our model building strategy and therefore the repercussions of its potential violation will severely threaten the standard model of particle physics. DUNE can improve the present limits on CPT violation by several orders of magnitude [15–17], being a very important experiment to test one of the deepest results of quantum field theory.



Search for Sterile Neutrinos in DUNE - BSM Physics Tech Note

M. Blennow,[1,2] E. Fernandez-Martinez,[1] S. Rosauro-Alcaraz,[1] A. Sousa,[3] and J. Todd[3]

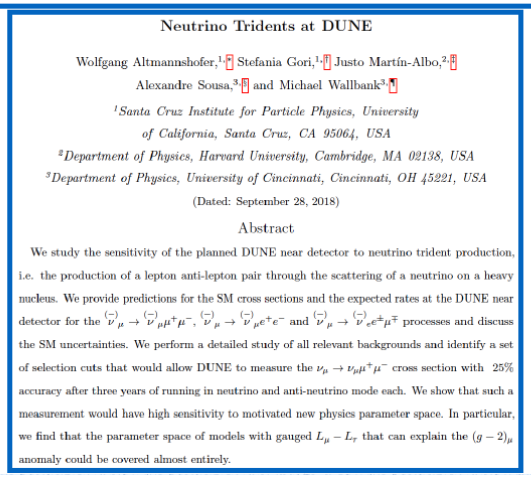
(for the DUNE BSM Physics Group)

[1]*Instituto de Física Teórica UAM/CSIC, Calle Nicolás Cabrera 13-15, Cantoblanco E-28049 Madrid, Spain*

[2]*Department of Physics, School of Engineering Sciences, KTH Royal Institute of Technology, AlbaNova University Center, 106 91 Stockholm, Sweden*

[3]*Department of Physics, University of Cincinnati, Cincinnati, Ohio 45221, USA*

DUNE will be sensitive to active to sterile neutrino oscillations over a broad range of potential sterile neutrino mass splittings. Probing sterile neutrino mixing with DUNE is accomplished by looking for disappearance of charged-current and neutral-current interactions over the long baseline separating the near and far detectors, as well as over the short baseline of the near detector. Additionally, DUNE will also be sensitive to nonstandard appearance of electron neutrinos over the Near and Far detector baselines. This note presents the DUNE physics reach for discovering or constraining active neutrino mixing with sterile species obtained using a simultaneous fit to the Far and Near detectors in a GLoBES framework. The contents of this note will be condensed in the BSM Physics section of the DUNE Technical Design Report.



Neutrino Tridents at DUNE

Wolfgang Altmannshofer,[1,*] Stefania Gori,[1,†] Justo Martín-Albo,[2,‡]

Alexandre Sousa,[3,§] and Michael Wallbank[3,¶]

[1]*Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064, USA*

[2]*Department of Physics, Harvard University, Cambridge, MA 02138, USA*

[3]*Department of Physics, University of Cincinnati, Cincinnati, OH 45221, USA*

(Dated: September 28, 2018)

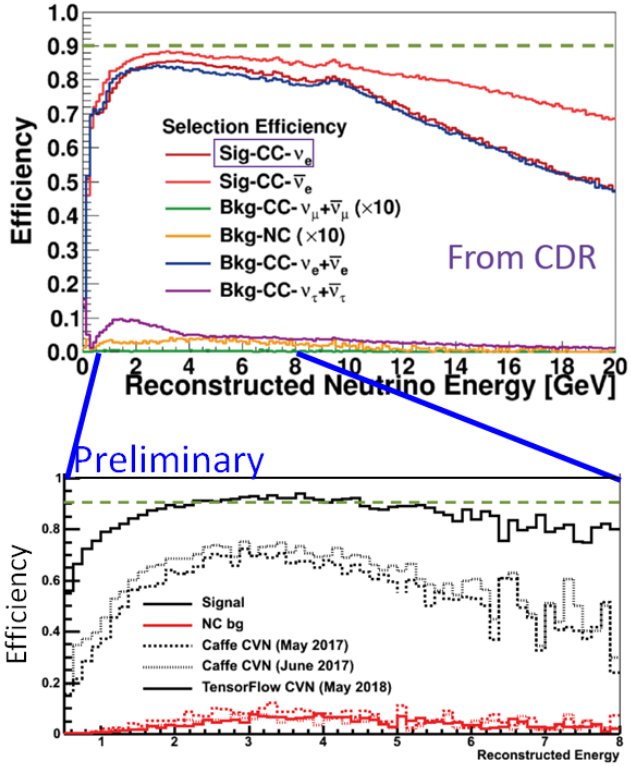
Abstract

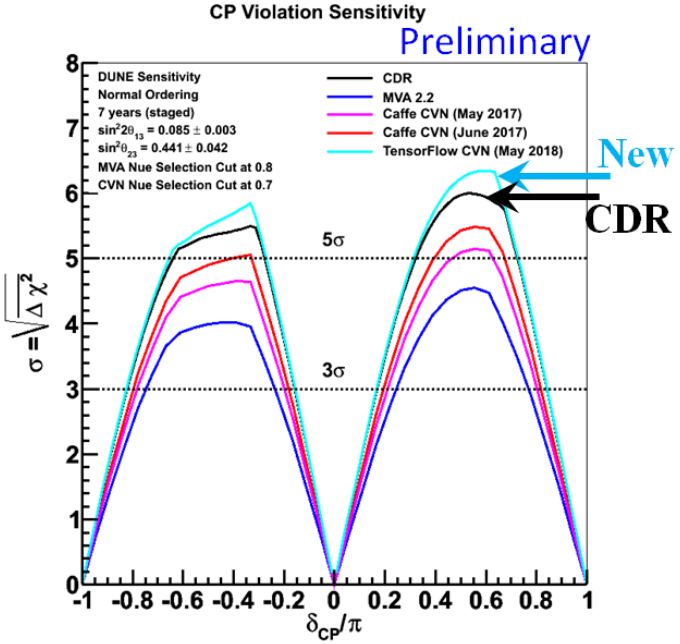
We study the sensitivity of the planned DUNE near detector to neutrino trident production, i.e. the production of a lepton anti-lepton pair through the scattering of a neutrino on a heavy nucleus. We provide predictions for the SM cross sections and the expected rates at the DUNE near detector for the $\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_\mu \mu^+ \mu^-$, $\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_\mu e^+ e^-$ and $\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_e e^\pm \mu^\mp$ processes and discuss the SM uncertainties. We perform a detailed study of all relevant backgrounds and identify a set of selection cuts that would allow DUNE to measure the $\nu_\mu \to \nu_\mu \mu^+ \mu^-$ cross section with 25% accuracy after three years of running in neutrino and anti-neutrino mode each. We show that such a measurement would have high sensitivity to motivated new physics parameter space. In particular, we find that the parameter space of models with gauged $L_\mu - L_\tau$ that can explain the $(g-2)_\mu$ anomaly could be covered almost entirely.

- Also preparing for final re-spin to bring analyses in sync with final TDR assumptions (*e.g.*, final flux estimates, ND fiducial volume).

LBL Working Group

- Reminder: target performance reached with full end-to-end FD simulation and reconstruction
- Selection largely frozen now, though recent technical improvements provide additional efficiency gain especially at low energies.
- **FD+ND fits** and systematics are the overwhelming focus now. (Talks follow.)
- **Dedicated analysis workshop:** November 15th – 17th

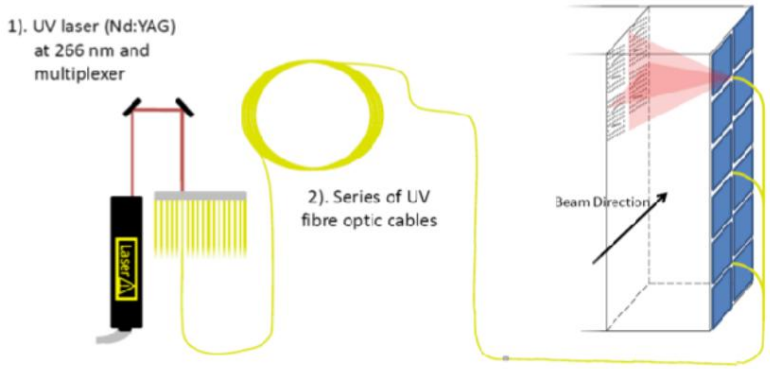


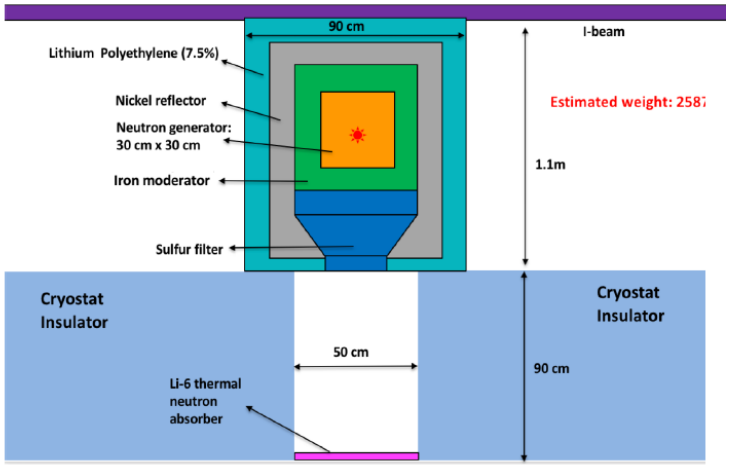


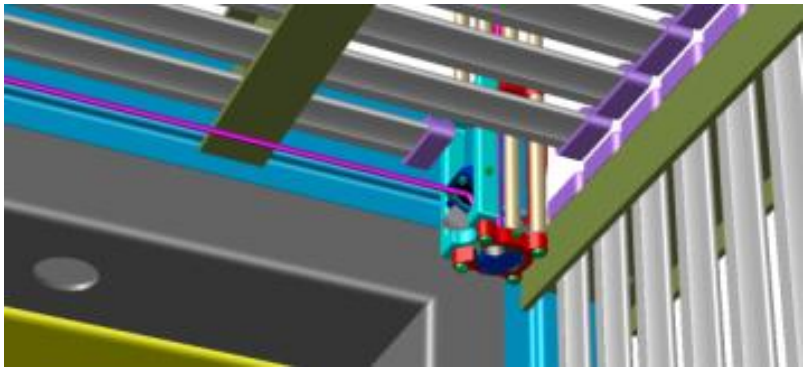
Only efficiencies and energy estimators have been updated for this plot. Systematics treatment is same for all curves (CDR assumptions).

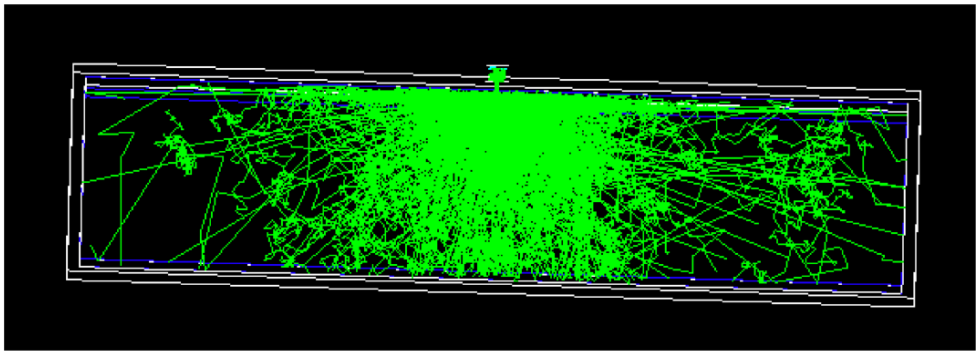
Calibration Task Force (→Working Group)

- Remarkable progress since formation one year ago, now a highly active group
- Executive Board has launched a **Calibration Consortium**, which will work closely with existing calibration/physics groups









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