Long BaseLine Neutrino Experiments

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3rd ComHEP: Colombian Meeting on High Energy Physics (Cali, Colombia)

Universidad Antonio Narino
Bogota, Colombia

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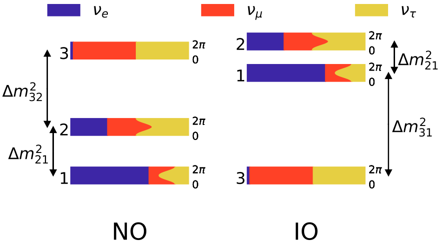
Content

flavour — atmospheric — accelerator/reactor — solar — mass

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix}=\begin{pmatrix}1&0&0\\0&c_{23}&s_{23}\\0&-s_{23}&c_{23}\end{pmatrix}\begin{pmatrix}c_{13}&0&s_{13}e^{-i\delta}\\0&1&0\\-s_{13}e^{i\delta}&0&c_{13}\end{pmatrix}\begin{pmatrix}c_{12}&s_{12}&0\\-s_{12}&c_{12}&0\\0&0&1\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

where $c_{ij}=\cos\theta_{ij}$, $s_{ij}=\sin\theta_{ij}$



Standard Neutrino Picture

- Neutrinos are massive
- Mass squared differences
- Mixing angles θ_{12}, θ_{23}, θ_{13}
- What is the value of δ_{CP}?
- Absolut neutrino mass?
- What is the mass hierarchy?
- Dirac or Majorana?

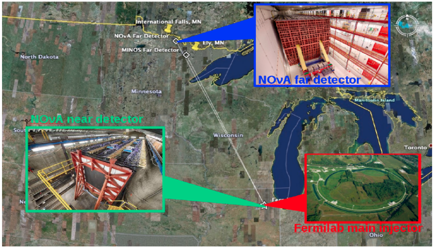
Content

- Introduction
- Long-Baseline Neutrino Experiments
- DUNE Overview
- The DUNE Single Phase Photon Detection System (PDS-SP)
- The Contribution of Latin America to the PDS-SP
- Summary

LBL Recipe

- An intense beam of proton is focused onto a target
- Secondary particles produced from the target are focused by magnetic horns
- The focused particles traverse a long decay region where neutrinos are produced
- A Near detector is needed to measure the initial neutrino Flux
- A Far detector is used to measure the appearence/disappearence of a neutrino flavour

Experiment	Operational	Peak E_ν	Baseline	Detector
K2K	1999 – 2004	1 GeV	250 km	Water Čerenkov
NuMI/MINOS	2005 – 2011(?)	3 GeV	735 km	Steel/Scintillator
CNGS/OPERA	2008–	17 GeV	732 km	Emulsion
T2K	2010–	0.7 GeV	295 km	Water Čerenkov
NOνA	2012(?)–	1.8 GeV	810 km	Liquid Scintillator



LBL Beamline

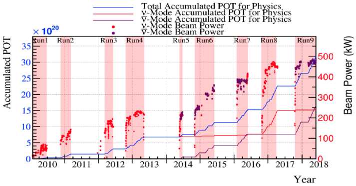
T2K

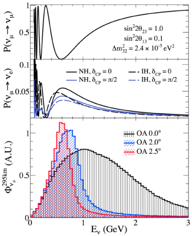
It uses the J-PARC beam

Achieves up to 500 kW

POT total: 3.16×10^{21}

The beam is $2,5\,^0$ off-axis with respect to the far detector.





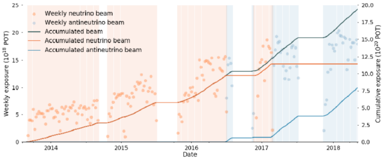
NOνA

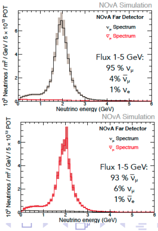
It uses the NuMI beam

Nominal 700 kW since 2017

POT total: 15.66×10^{20}

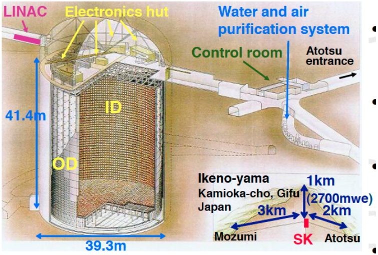
The beam is $0,84\,^0$ off-axis with respect to the far and near detector.



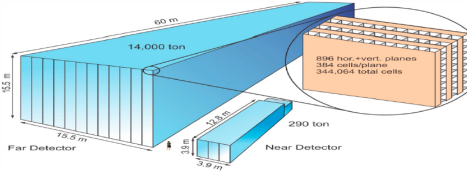


LBL Detectors

T2K
Two Near detectors: ND280 and INGRID
ND280 is composed of trackers, a combination of fine grained detectors
and Ar TPCs
INGRID: on-axis scintillator light detector
Far Detector: Water-Cherenkov detector with $50\,\mathrm{kTon}$ of ultra-pure water



NOνA
Two identical detectors (except for the size)
Detectors are made of 344000 cells highly reflective plastic PVC
filled with liquid scintillator.
Near Detector: $0.3\,\mathrm{kTon}$ $1\,\mathrm{Km}$ from source
Far Detector: $14\,\mathrm{kTon}$ Readout made via WLS fibers to avalanche photo diode array



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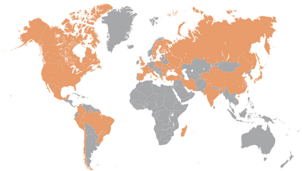
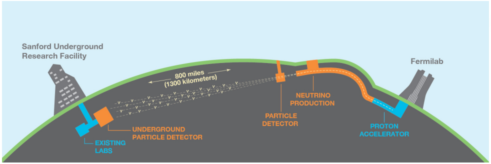
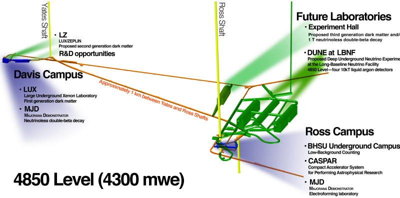
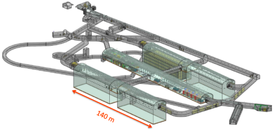
DUNE Project

- Measure of ν_e and $\bar{\nu_e}$ appearance and ν_μ and $\bar{\nu_\mu}$ disappearance over a long baseline
- It will use a high-intensity neutrino beam and high-resolution massive detectors
- International science collaboration with strong participation of LA





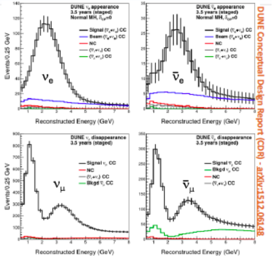


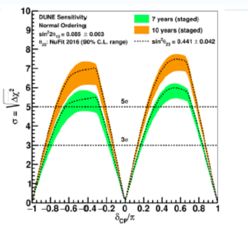


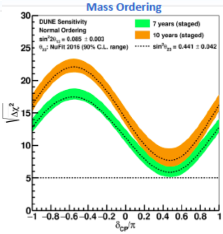
DUNE Physics Program

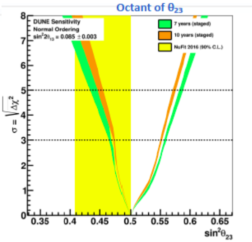
Program Physics with primary goals:

- Probe leptonic CP violation
- High-precision measurement of neutrino mixing parameters
- determinate ν mass ordering
- detection of supernova neutrinos
- search for BSM Physics

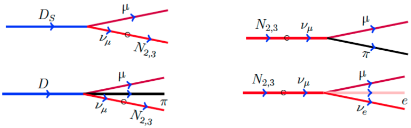


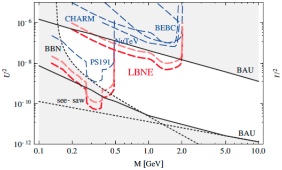






HNL Signature in DUNE



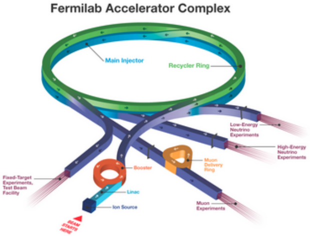


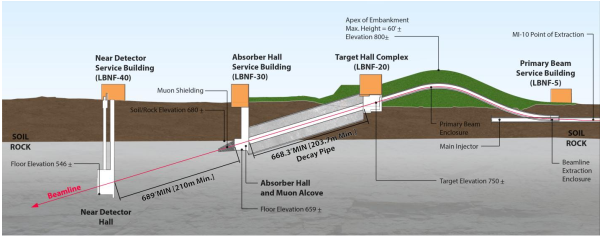
http://arxiv.org/pdf/1307.7335

1. HNL produced through weak decay of heavy mesons and baryons
2. The mesons produced by scattering off of LBNE beam
3. HNL detected in the ND
4. For $500 MeV < M_N < 2 GeV$ production via D-Mesons
5. For $140 MeV < M_N < 500 MeV$ production via K-Mesons
6. For $50 MeV < M_N < 140 MeV$ production via π-Mesons

The LBNF Beamline

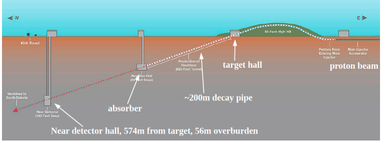
- The LBNF neutrino beam will be produced using $60 - 120\,\mathrm{GeV}$ protons from Fermilab's main injector
- Initial nominal power of $1.2\,\mathrm{MW}$ (10^{14} protons-on-target/sec)
- In the future upgradeable to $2.4\,\mathrm{MW}$
- Can run in neutrino (FHC) and antineutrino (RHC) modes by switching polarity of magnetic horns
- Wideband beam enables use of second maximum and enhances probing BSM phenomena

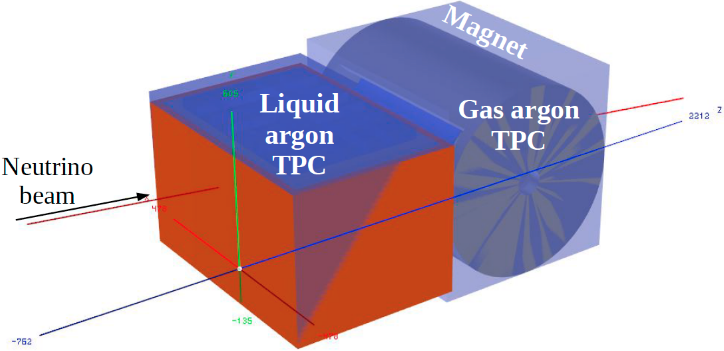




The DUNE Near Detector

- ND located $574m$ downstream of production target
- dedicated to measure flux, cross-section and to constrain detector uncertainties
- System composed of multiple detectors:
  - Finely-segmented pixel readout LArTPC
  - Magnetized Multipurpose tracker
  - Electromagnetic calorimeter
  - Muon Chambers

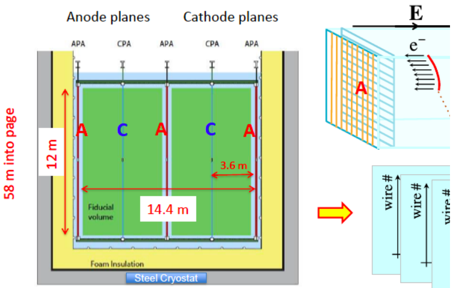




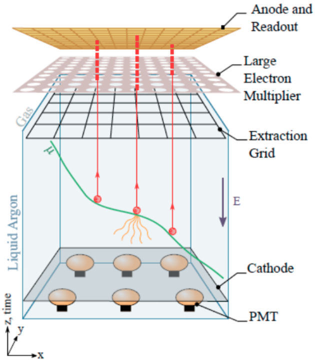
The DUNE Far Detector

- Liquid Argon Time projection Chambers (LArTPC)
- Two technologies: Single Phase and Dual Phase

Single Phase TPC

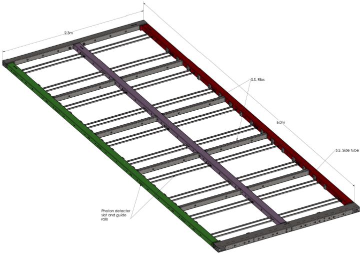


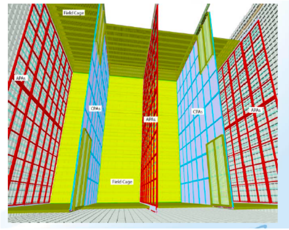
Dual Phase TPC

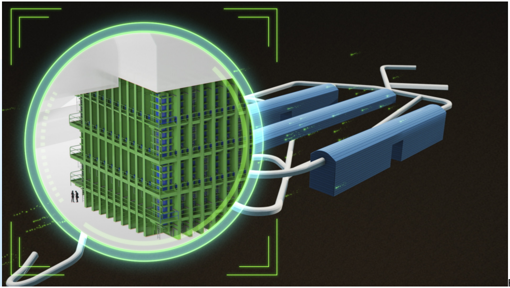


Single phase Detector

- 10 kt fiducial cryostat
- Width $= 14.5\,\mathrm{m}$, Height$=12\,\mathrm{m}$, Length$=58\,\mathrm{m}$
- 150 APAs, 200 CPAs
- PD system integrated
- 385000 Readout Channels
- Start of Construction 2022
- Operational by 2026



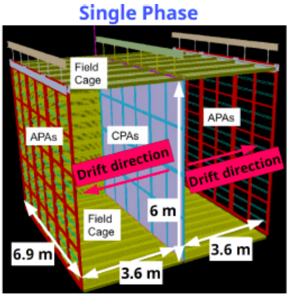




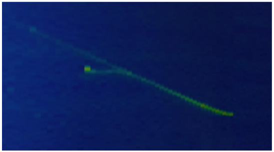
FNAL.gov

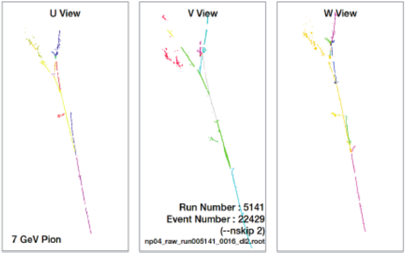
DUNE Prototypes

- At CERN there are builded two prototypes exposes to a test beam at CERN
- Protodune single phase has 420 ton active LAr
- A small TPC prototype is under construction at Fermilab



event display of three views of a cosmic track





Pion Event recorded at Protodune

Content

Photon Detector System

Tasks of the PD

1. Help to the Trigger System
2. Collection total light emitted
3. Help to the Reconstruction and particles identification

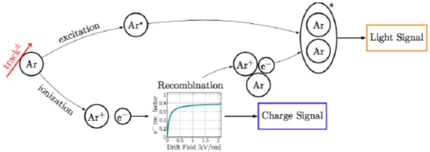
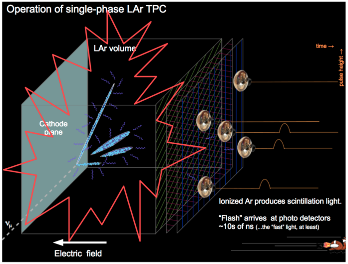
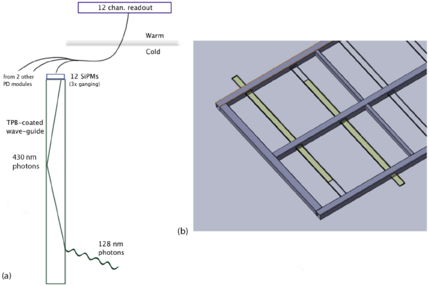


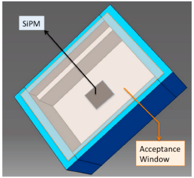
Figure: https://arxiv.org/pdf/1601.02984.pdf

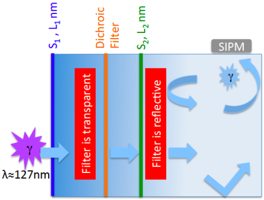




Photon Collection Baseline

1. Light Collection System: Collects photons from a large area and drives towards the actives sensors. X-ARAPUCA is the baseline design
2. Silicon Photonmultipliers (SiPMs): MPPCs are currently the baseline. FBK is being strongly persued
3. Readout electronics: Exploring low cost to waveform high frequency digitization
4. Cold Summing board plus warm digitization





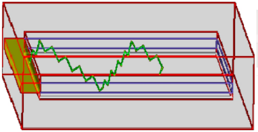


Figure: https://arxiv.org/pdf/1601.02984.pdf

Content

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Design of the Active Ganging boards

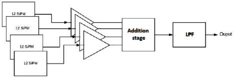
Esteban Cristaldo, Jorge Molina
Carlos Montiel, Diego Aranda

DUNE-SP Photon Detection System
Conceptual Design Review

November 12th, 2018

Design scheme

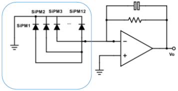
Three stages of the circuit for 48 SiPM:



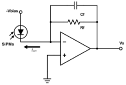
Charge integrators
or transimpedance

3

We want to know if we can amplify **12** SiPM in paralell (active *ganging*) with one output channel.

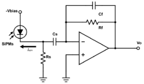


Two preamps models studied



Transimpedance model

- This is a first order low pass filter
- Rf and Cf establish the bandwith and frequency cut point
- Eliminates high frequency noise



Charge integrator model

- This is a second order band pass filter
- Cf and Cs establish the bandwith and frequency cut point
- Eliminates low and high frequency noise

4

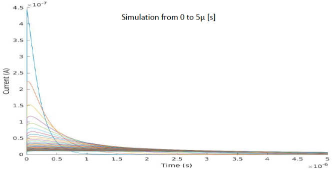
Preamplifier from discrete components

Front-end developement for ARAPUCA TRANSISTOR-BASED VERSION

Presenter: Amaro Lopes

Marcelo Paschoal, Marcelo Lima,
Herman Lima, Rafael Nóbrega

Signals from the SiPMs



4-stage discrete MOSFET operational amplifier - Features

- Very high input resistance (ideally infinity)
- Low output resistance (~35Ω)
- Passive loads (active loads may be used in a next approach)
- Open-loop gain: 87dB
- Open-loop -3dB frequency: ~550 kHz for transistor capacitances = 1pF (commercial transistors may have lower capacitance values)
- Three differential gain stages and one common drain output stage (voltage buffer)

Conclusions

- SiPM model is operational on SPICE
  - Simulated for up to 48 SiPM in parallel (ganging)
  - Implemented using script
- New proposal based on MOSFET
  - Simulated with SiPM model
  - Preliminary simulation tests show reasonable results
- SiPM devices have arrived for testing
- Next steps:
  - components are been selected for purchase
  - Prototyping

Electronics Parameters determination

DEEP UNDERGROUND NEUTRINO EXPERIMENT

UNIVERSIDAD ANTONIO NARIÑO

ELECTRONICS SIMULATION

Maritza Delgado

Nov. 5 , 2018

1

Introduction

Dynamic Range

Goal: Find the maximum number of true photons with different time windows and quantum efficiency.

- Data generated by module **SPCounter_module.cc,** based on SimPhotonCounter_module.cc.
- Sample: Beam Neutrinos prodgenie_nu_dune10kt_1x2x6_323_20171227T183346_merged1.root
- The first step was to identify the maximum number of true photons by each Optical Detector per event from PhotonsLite.

2

1.Scale factor

The scale factor was determinated using the effective detector areas and QE values.

- 4.05 cm² (0.00287) (current standard in vanilla larsoft. Close to the current dip-coated design)
- 5.1 (0.00361) (Close to lowest ARAPUA measurement and potential improved dip-coated design)
- 7.44 (0.005265) (Current double-shift light guide)
- 12.8 (0.009059) (Highest ARAPUCA measurement at TallBo)
- 15 (0.01063) (Potential improved double-shift light guide)
- 23 (0.016277) (Highest ARAPUCA measurement)

https://indico.fnal.gov/event/16848/contribution/4/material/slides/0.pdf

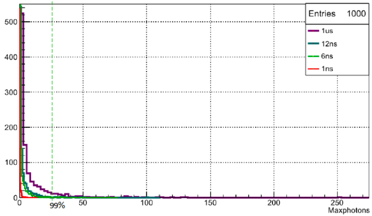
Area (cm^2)	QE	QE/4
15	0,01063	0,002658
30	0,021231	0,005308
45	0,031847	0,007962
60	0,042462	0,010616

One Optical Detector have 4 Channels.

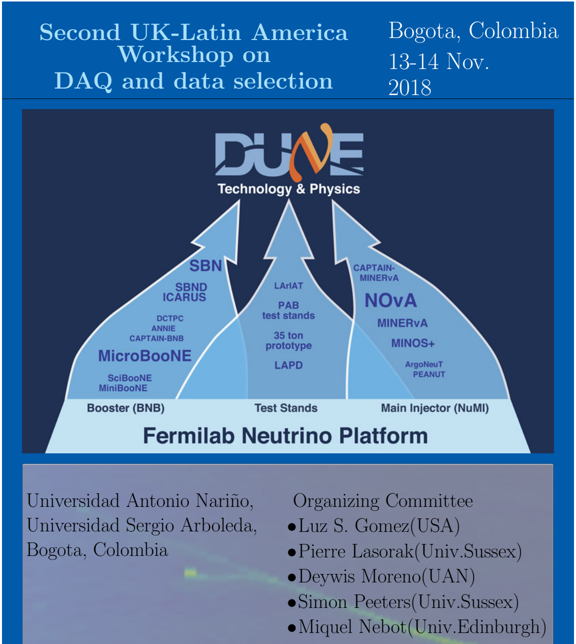
4

1000 EVENTS

2. Effective Area: 15cm²



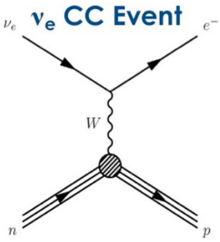
UK LA activities



Summary

1. LBL experiments are ideal tools to test the neutrino physics
2. LBNF/DUNE has become a global international collaboration
3. DUNE has a broad and rich physics program including CP violation probes, mass ordering determination, precision neutrino oscillation measurements. SN neutrinos and BSM searches
4. DUNE prototypes funcional and taking data
5. Strong participation of LA in the Single PD module
6. Looking forward for first DUNE far Detector data in 2024

Backup Slides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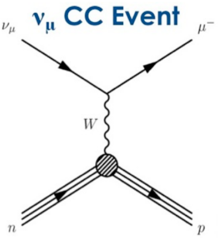
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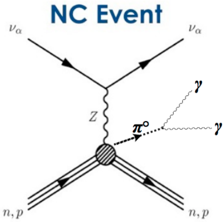
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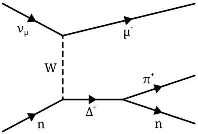
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