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Neutrino Physics Masterclasses

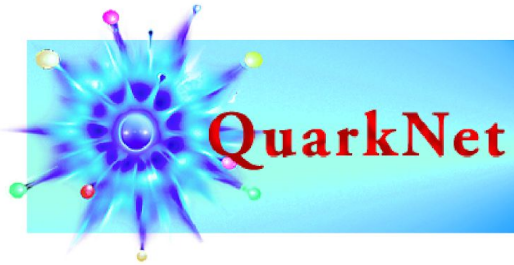
Shane Wood
QuarkNet National Staff Teacher
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www.QuarkNet.org



U.S. DEPARTMENT OF
ENERGY | Office of
Science

 **Fermilab**

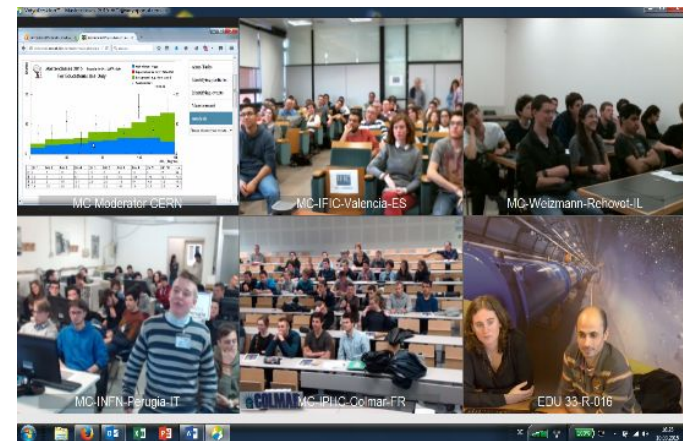


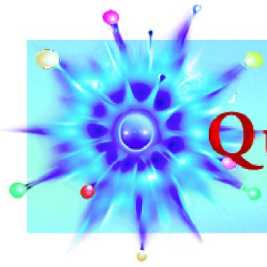
What is a Masterclass?

High school students (13k+/year) come to a research lab to be “*scientists for one day*”

- Introduction to particle physics
- Hands-on: data from
 - LHC ([ATLAS](#), [CMS](#), [ALICE](#), [LHCb](#))
 - Neutrino experiments ([MINERvA](#))
 - [Belle II](#)
 - [Particle Therapy](#) (treatment plan)
- International video conference
(3-5 groups + CERN / Fermilab / KEK / GSI)

**Like a masterclass in the arts...
but in particle physics!**






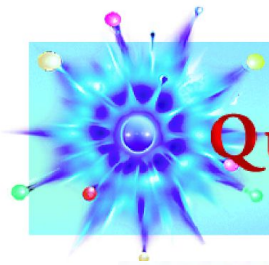


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What is a Masterclass?

Sample agenda...

- 09:00 Welcome, **Sign-In** & Ice Breaker (Shane will complete **attendance summary** )
- 09:30 Introductory Talk (Greg)
- 10:30 Tour 1 Nano Lab/Clean Room
- 11:30 **Analysis Talk** (Greg & Shane)
- 12:30 Lunch with a physicist (lunch provided)
- 13:30 Data Analysis - MINERvA **Student Start Page**: <http://tiny.cc/mmc-go>
- 14:30 Tour 2 - Mu2e Lab
- 15:00 Discussion of results, Q&A
- 15:45 Break; set up for videoconference
- 16:00 Video conference (**connect with Zoom**)
- 16:35 End of day survey (**student survey** , **teacher/mentor survey** )
- ~16:45 End of day



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<https://physicsmasterclasses.org>



International Masterclasses

19th International Masterclasses 2023



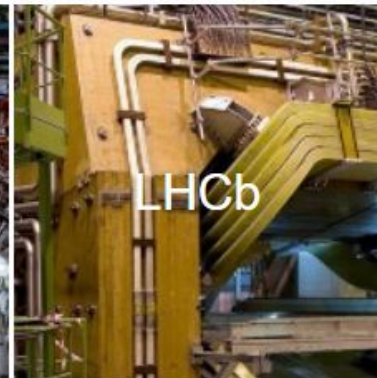
ATLAS



ALICE



CMS



LHCb



BELLE II



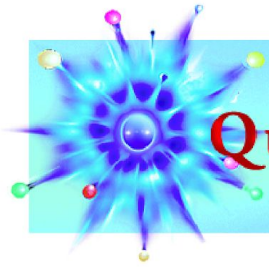
MINERvA



Particle
Therapy



Pierre Auger



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Neutrino-based Masterclasses

1. MINERvA

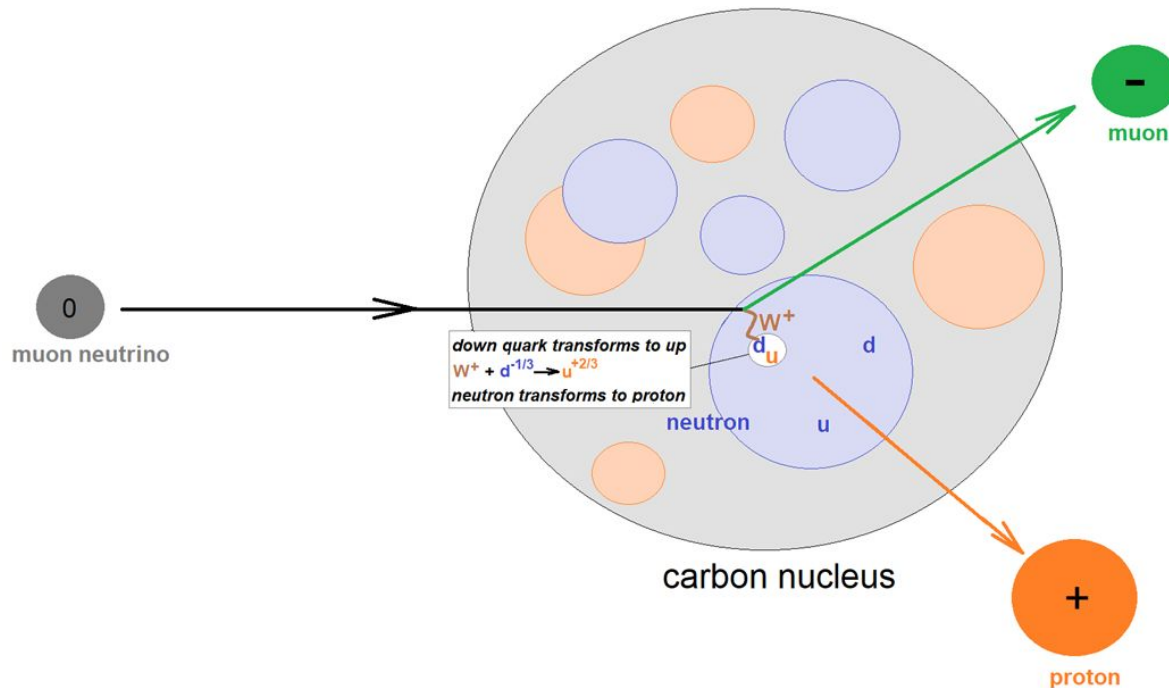
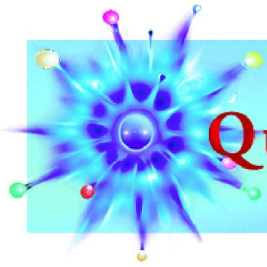
...Has been used for several years



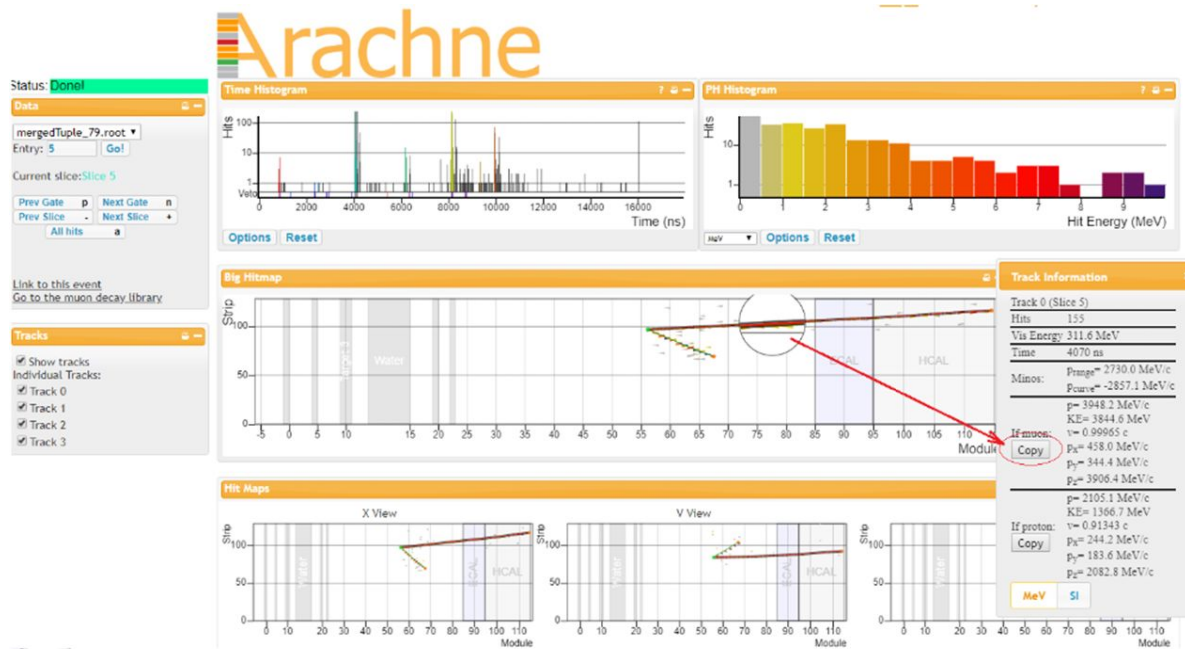
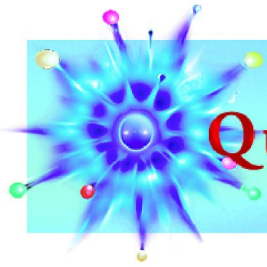
2. NOvA

...Pilot phase → New to IMC

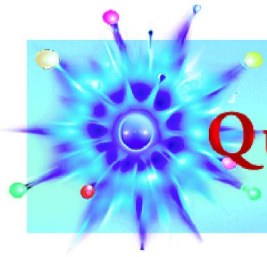




A muon neutrino interacts with a carbon nucleus. The interaction results in a muon and a proton that are ejected from the nucleus. **What happens to the momentum initially carried by the muon neutrino?**



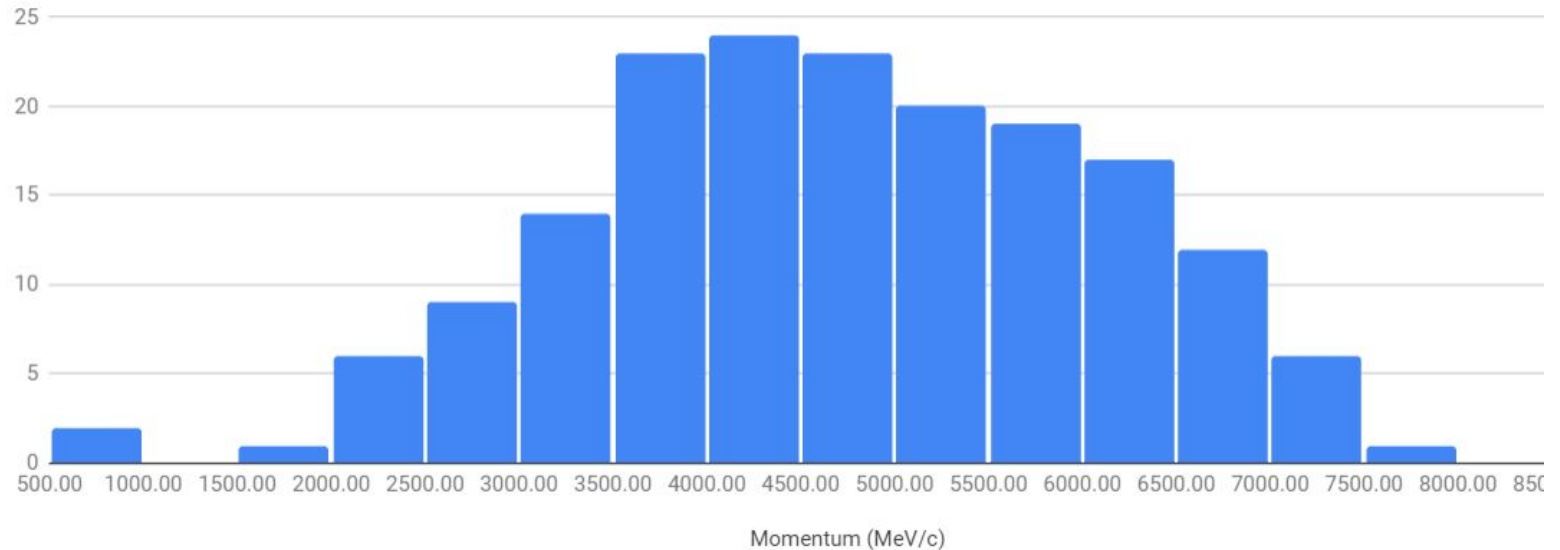
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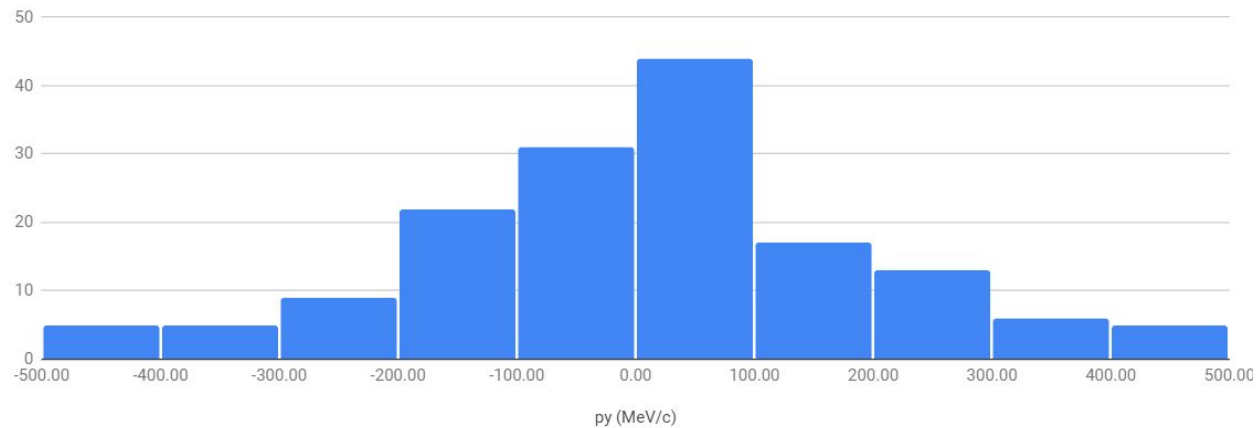
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MINERvA Masterclass

Histogram of p_z (beam direction)



Histogram of p_y





NOvA Masterclass

New, Focuses on a Result About the Neutrino as a Particle

Piloting with Teachers

- University of MN Center Teachers
- Neutrino Fellows
- Summer 2022 workshops (4)

Piloting with Students

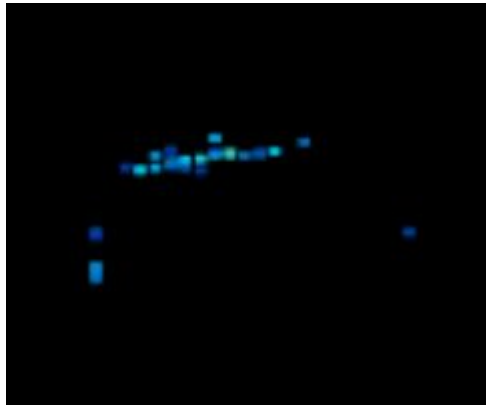
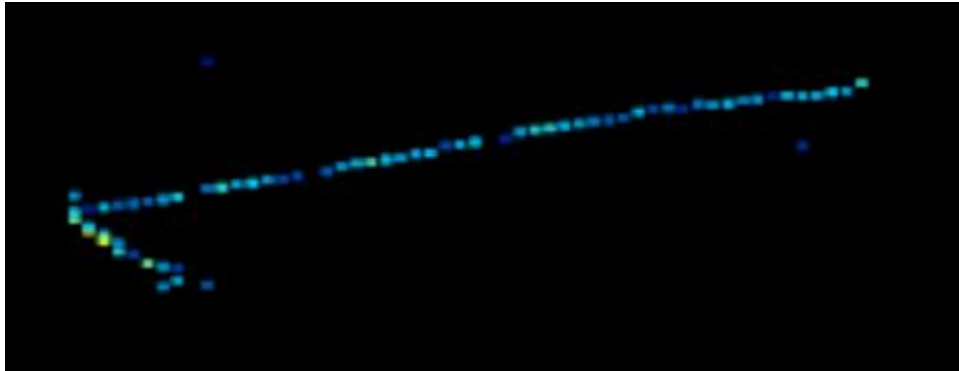
- April 23, 2022 at University of MN
- Phase 2 pilot in IMC 2023

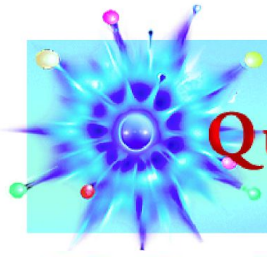




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NOvA Masterclass

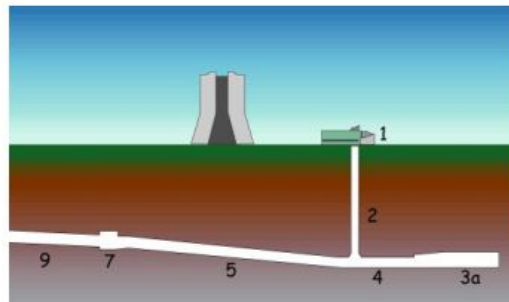


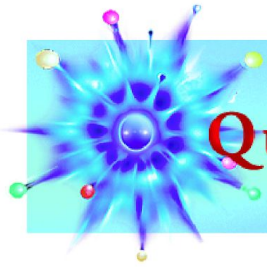


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NOvA Masterclass

NOvA Experiment





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NOvA Masterclass



NOvANearAnalysisV2_YourName.ipynb ☆

File Edit View Insert Runtime Tools Help [Last edited on Aug 3, 2022](#)



+ Code + Text

Instead, let's see if data analysis tools within this Python document can help us analyze the events r

Importing Data

Now, let's officially turn our analysis to the Near Detector. A set of event data from the Near Detector is available to you. As a starting point, we'll want to import it into this Notebook Document to work with.

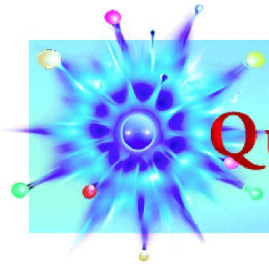
In our notebook, we'll create a "Pandas Data Frame," which is a 2D structure that's able to hold data, and has easy access to many data manipulation and organization tools within the Python environment.

There are many ways to import data. Here we'll use an importing feature that pulls the data in from a "CSV" file that's hosted on a web page (GitHub)

[If you need help with this step, a Screen Shot Tutorial can be found here.](#)

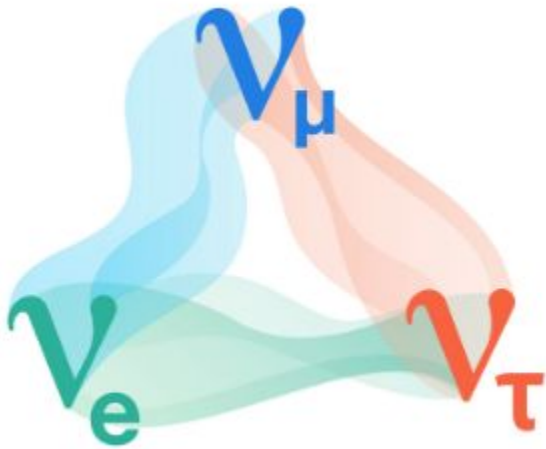
```
[ ] # Importing data into a Dataframe from a web based source
# For this activity, Near NOvA Event Data can be found at this website: https://github.com/ThePAEngineer/NOvAData
# The file you'll want to focus on is called: NOvA-ND-Events.csv
# Once there, click on the file of interest, then copy the link from the "Raw" button, pasting it in the indicated space below

dataImported = pd.read_csv('web link here')
```



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NOvA Masterclass



Students see evidence of
neutrino oscillation.

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