SND@LHC

Emulsion detector and data analysis exercise

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CERN

LHC
Scattering and Neutrino Detector at the LHC

Disclaimer

- This exercise is assumed that you have learned some basic knowledge about Neutrinoes from the first two talks this morning.

- We only focus on how data is analyzed from one of Neutrino detectors (SND@LHC) today. Other experiments might have slightly different analysis methods according to physics model/motivation.

GitHub for hands-on session

https://github.com/sirawitsae/ROOT-for-CNX-workshop

GitHub for hands-on session

README

Emulsion data analysis workshop and Software Carpentry workshop ROOT session

This repository contains the material used for the Emulsion data analysis and some Root tutorials at the Particle Detection: from Ground to Space and Space Weather Impact workshop in February 2024.

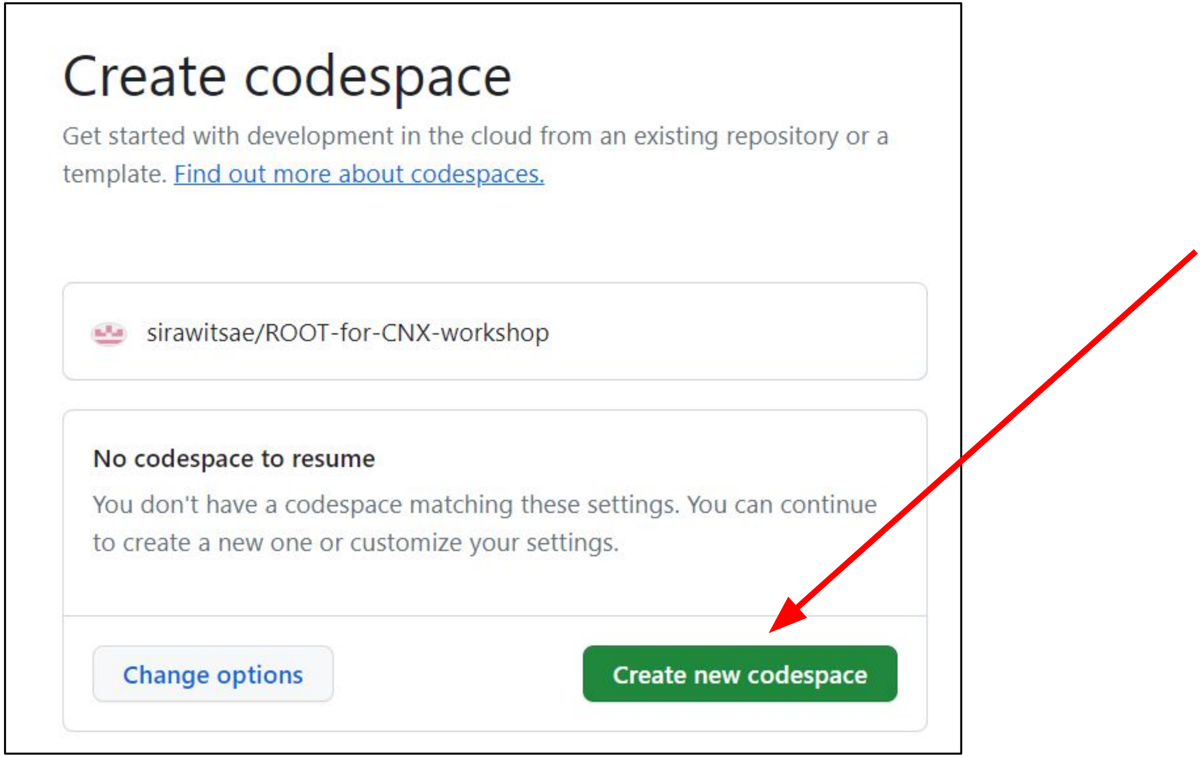
For the Emulsion data analysis workshop open GH Codespaces

For Software Carpentry workshop ROOT session (Extra) open GH Codespaces

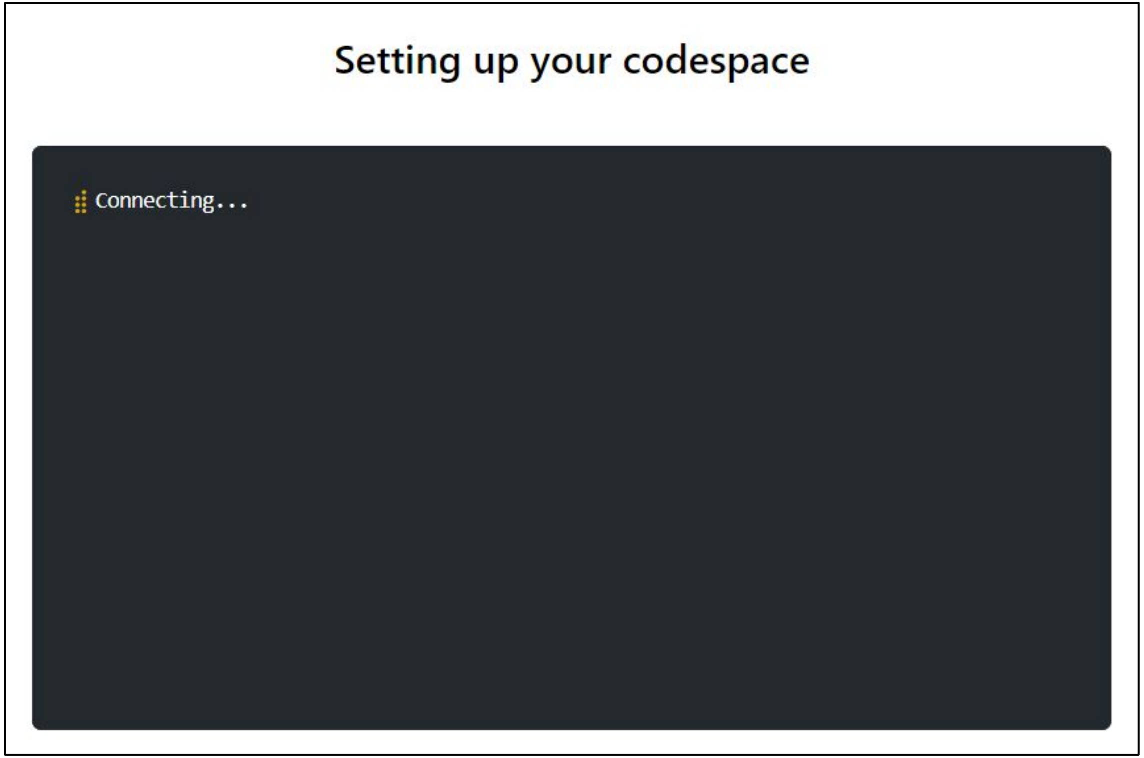
Part of the material has been reused from:

- Other ROOT training courses: https://github.com/root-project/training
- Oksana Shadura's (@oshadura) ROOT training: https://github.com/oshadura/carpentries-root-training

GitHub for hands-on session

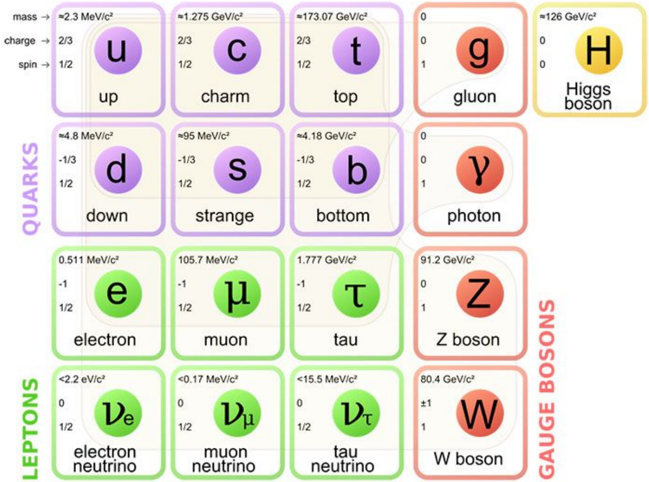


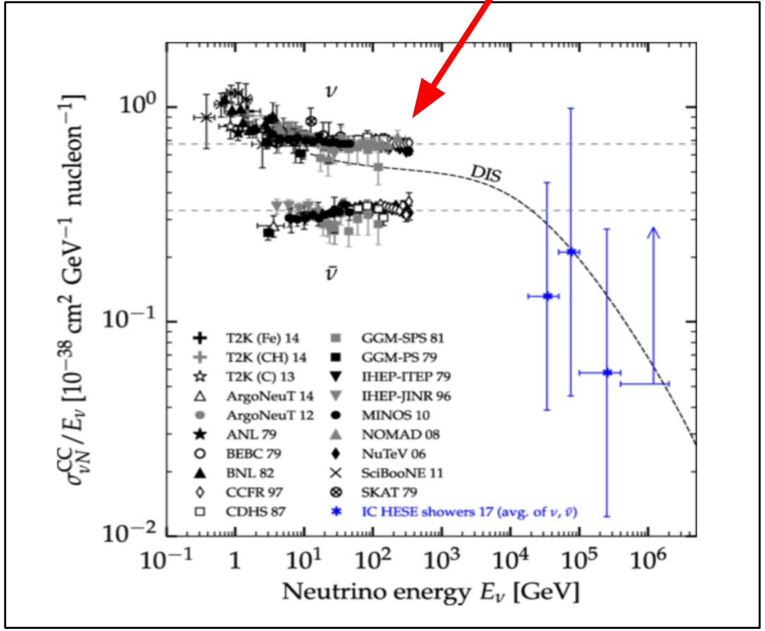
GitHub for hands-on session



What is SND@LHC experiment?

- We study the TeV Neutrinos (high energy Neutrino)!

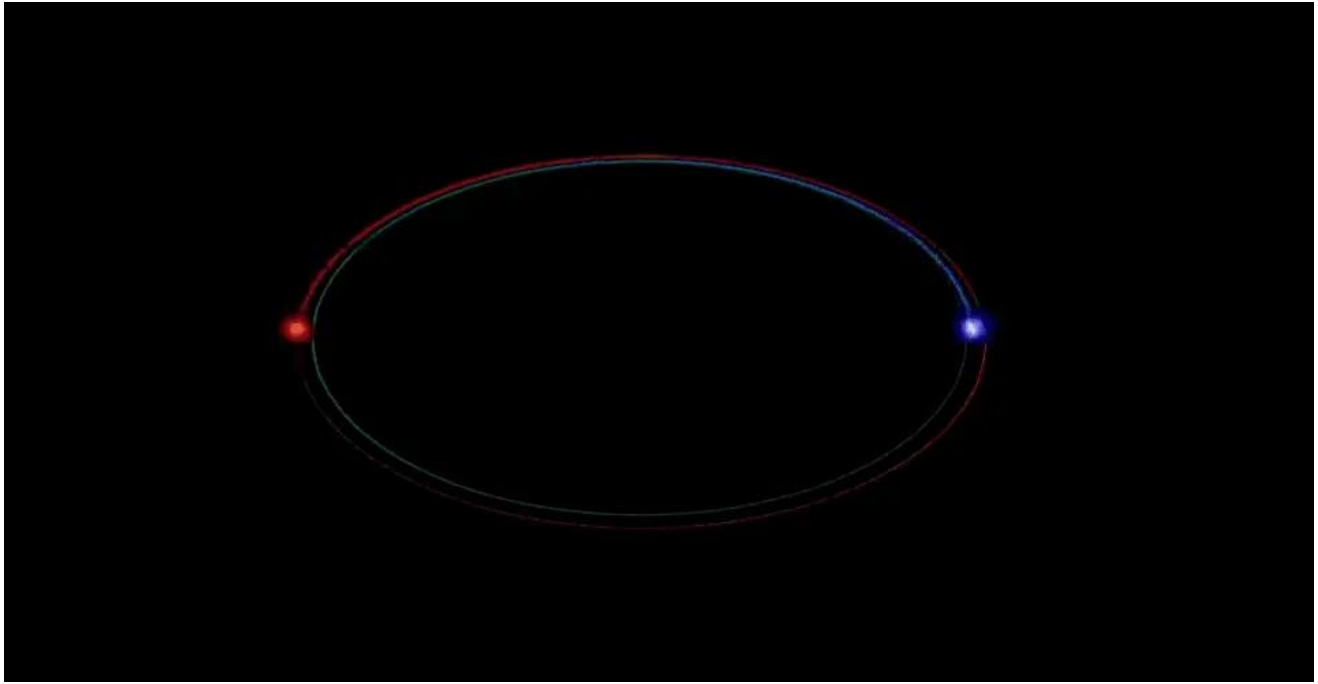




- Why Neutrino?

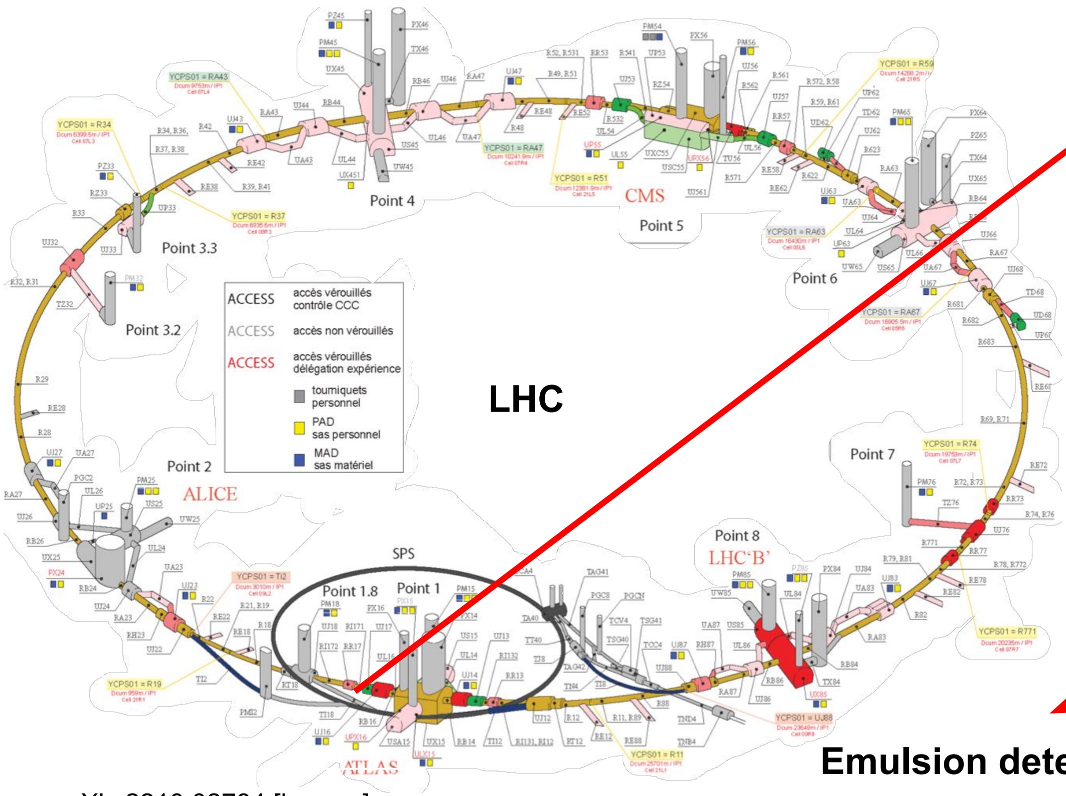
Picture: www.nures.uta.edu

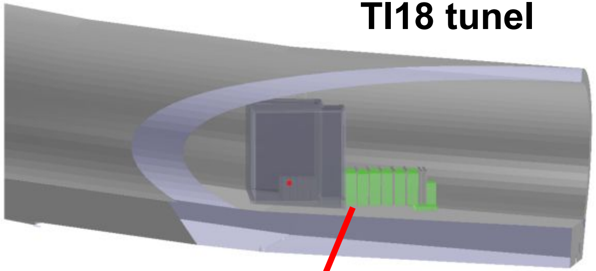
How to produce the particle?

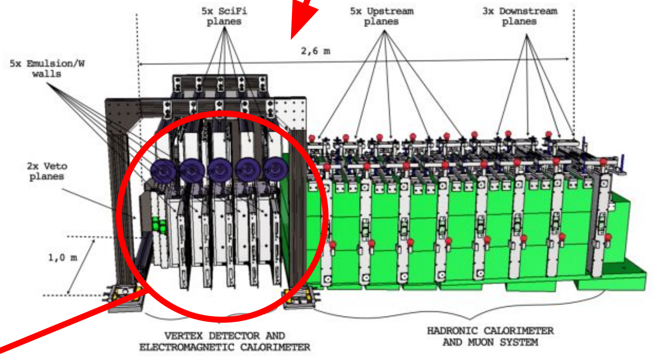


Video: YouTube/bodhisattva prajnananda

SND@LHC Detector







Emulsion detector

SND@LHC detector

Pictures: arXiv:2210.02784 [hep-ex]

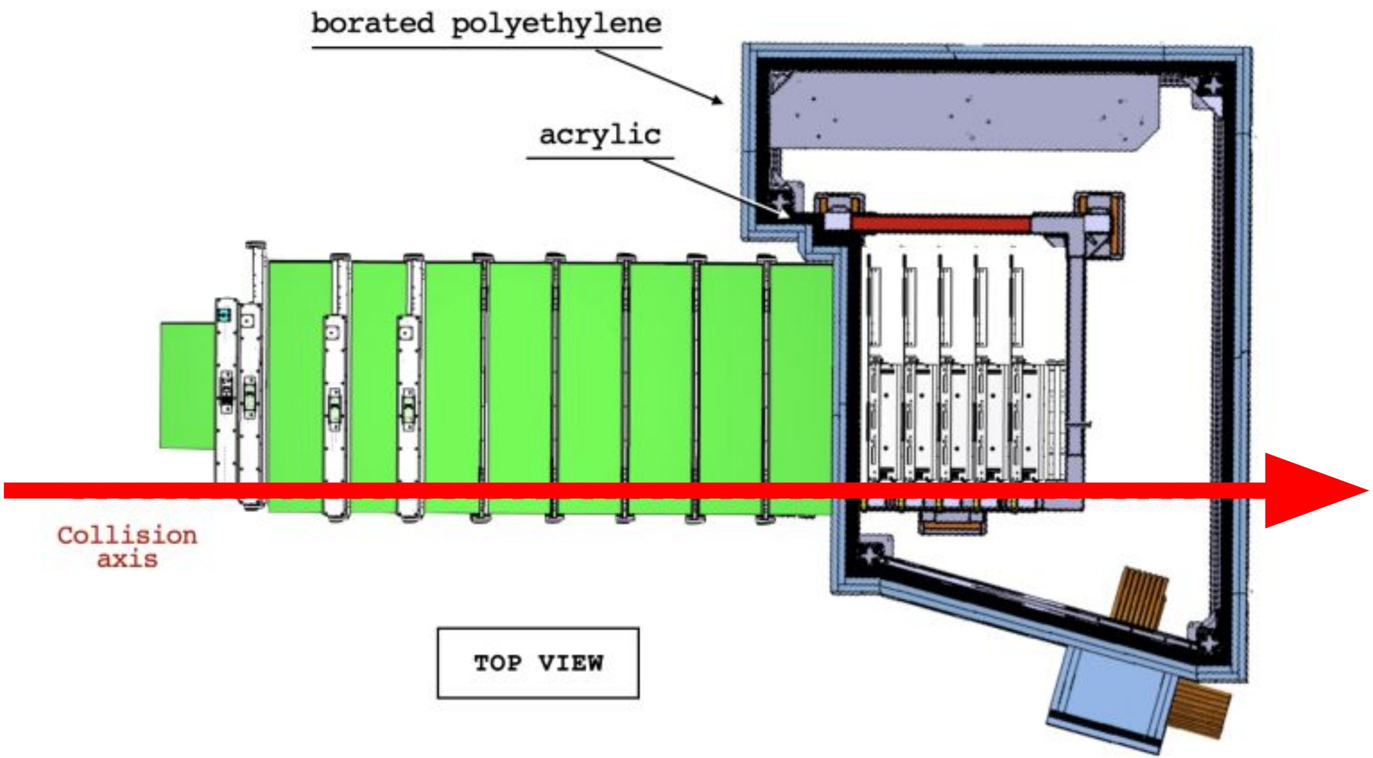
SND@LHC Detector

Mechanical support for detector

Neutron-shielded box

Pictures: arXiv:2210.02784 [hep-ex]

SND@LHC Detector



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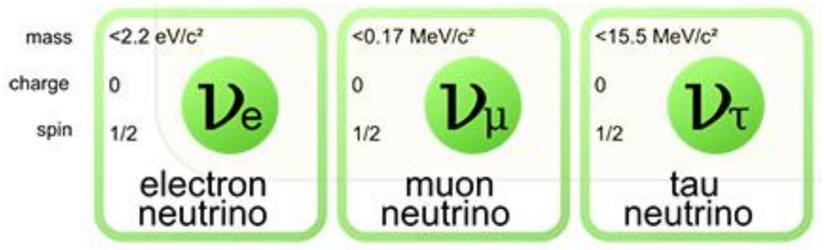
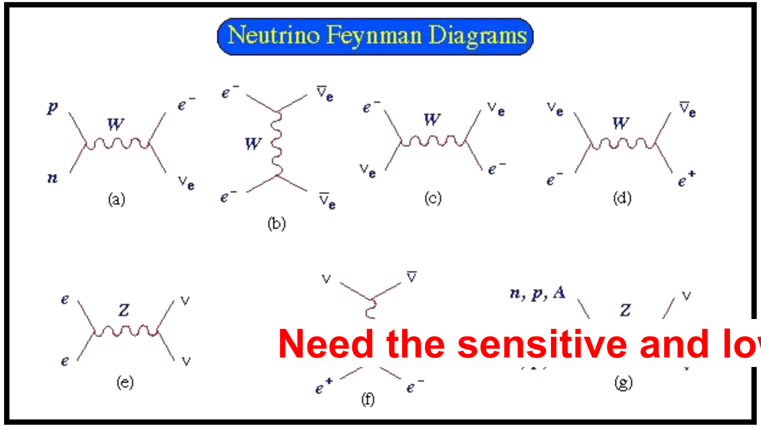
Why Emulsion detector?





- Electrically Neutral
- Low Mass
- Variety of Flavors
- Tau neutrino has a short life time
- Weak Interaction

Need the sensitive and low energy threshold detector!

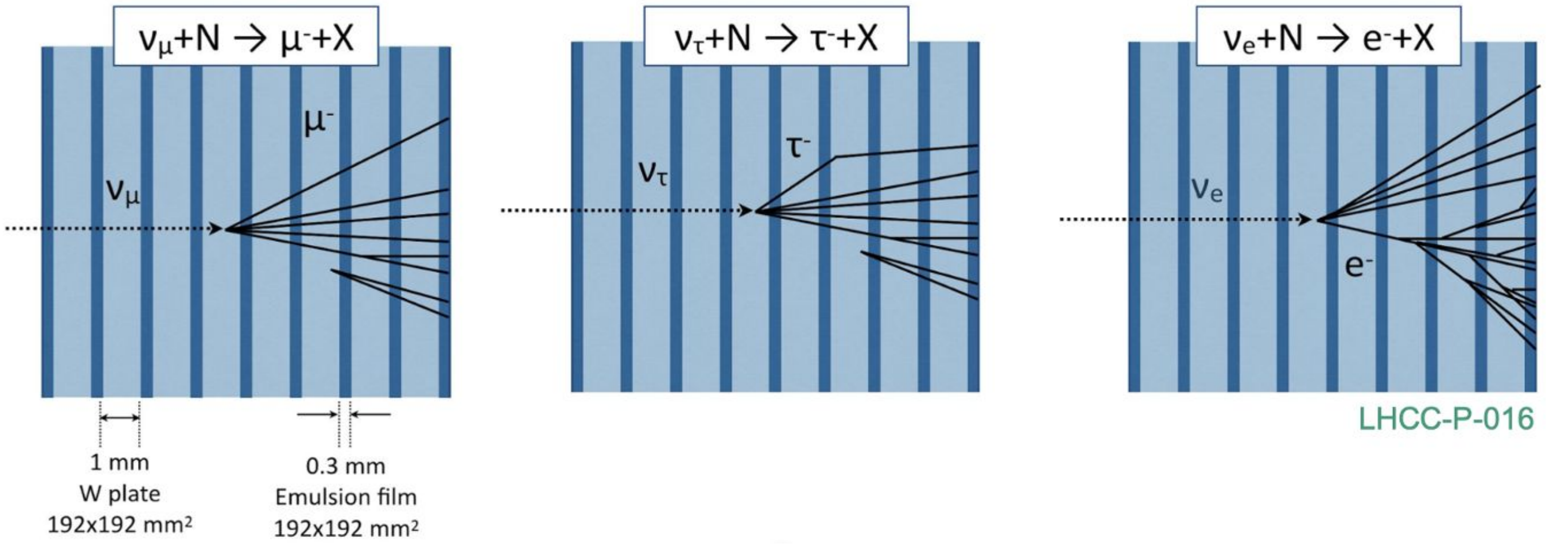
Pictures: arXiv:2210.02784 [hep-ex]

Why Emulsion detector?

- Emulsion detectors consist of layers of photographic emulsion materia
- The charged particles leave tracks as they pass through each layers
- Neutrino interactions with nuclei in the emulsion produce secondary charged particles that leave tracks
- Different neutrino flavour created different tracks pattern
- Emulsion film has finer resolution compare to electronic detectors and can identify the tracks of leptons/neutrinoes differently
- It used as a Neutrino detector in the past (E531@Fermilab, CHORUS@CERN, DONUT@Fermilab, OPERA CNGS1)
- For SND@LHC, we use it as a vertex detector

Pictures: Emulsion for neutrino detectors by Dr Umut Kose (CERN EP-NU)

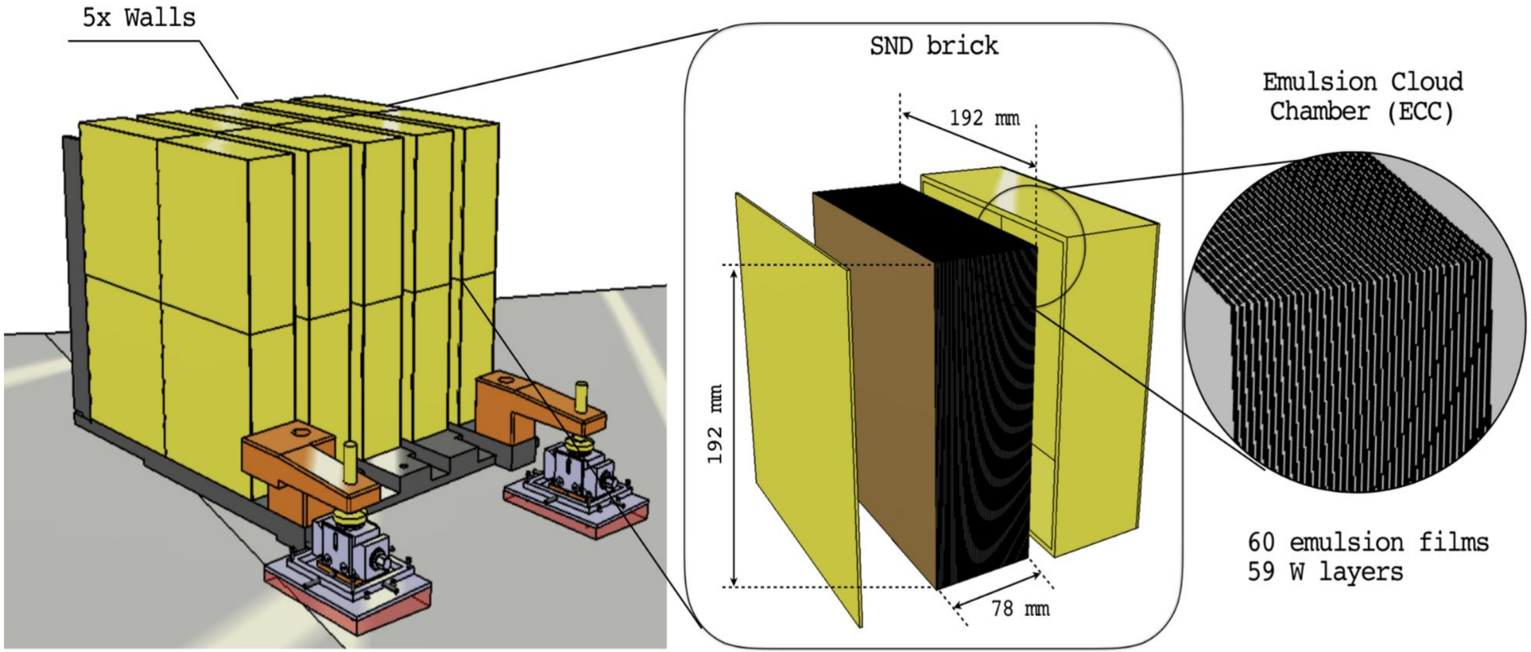
Why Emulsion detector?



Different tracks between three neutrino flavors can be observed by Emulsion Detector

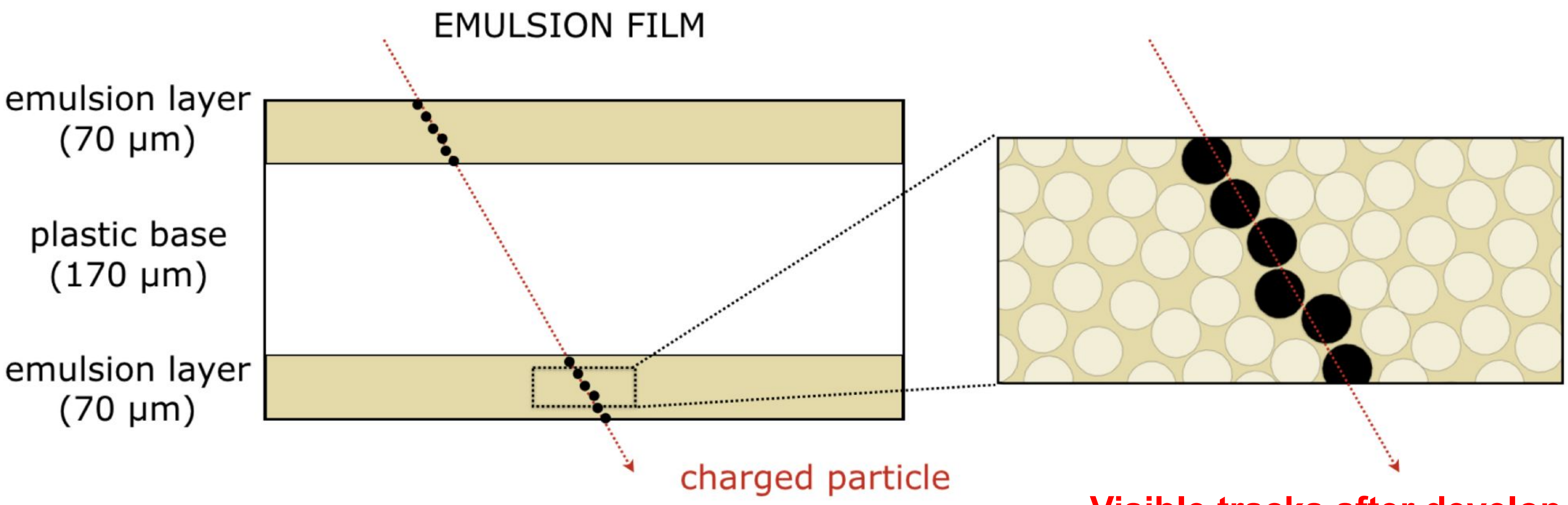
Pictures: Albert's talk

Emulsion Detector at SND@LHC



Pictures: arXiv:2210.02784 [hep-ex],

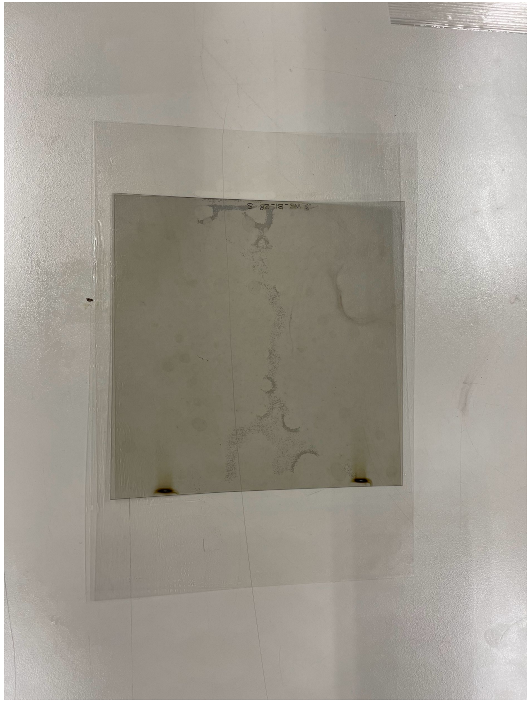
Emulsion Detector at SND@LHC

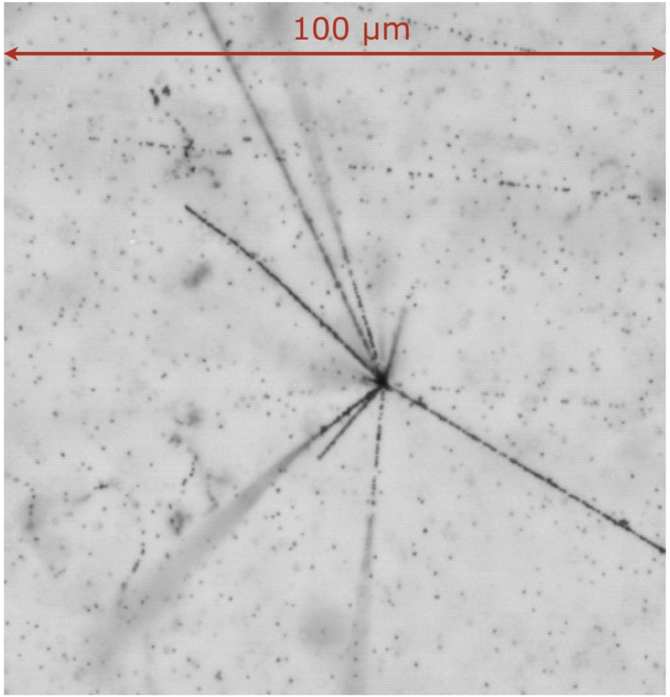


Visible tracks after develop

Pictures: arXiv:2210.02784 [hep-ex]

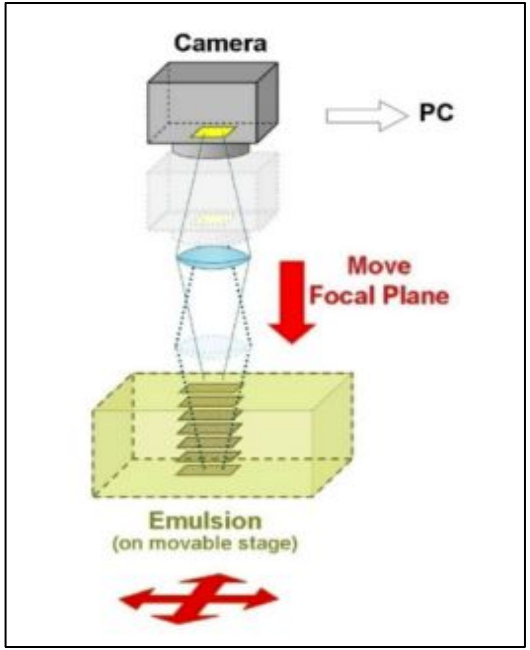
Emulsion Detector at SND@LHC

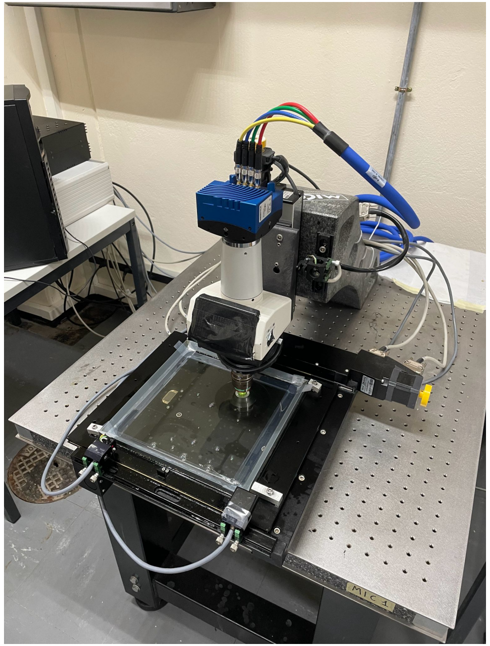


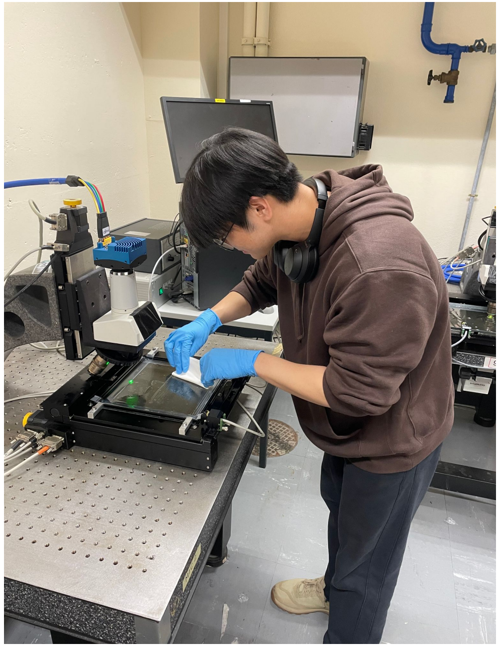


Pictures: Dr. Chayanit Asawatangtrakuldee, arXiv:2210.02784 [hep-ex]

How to collect the Raw Data?

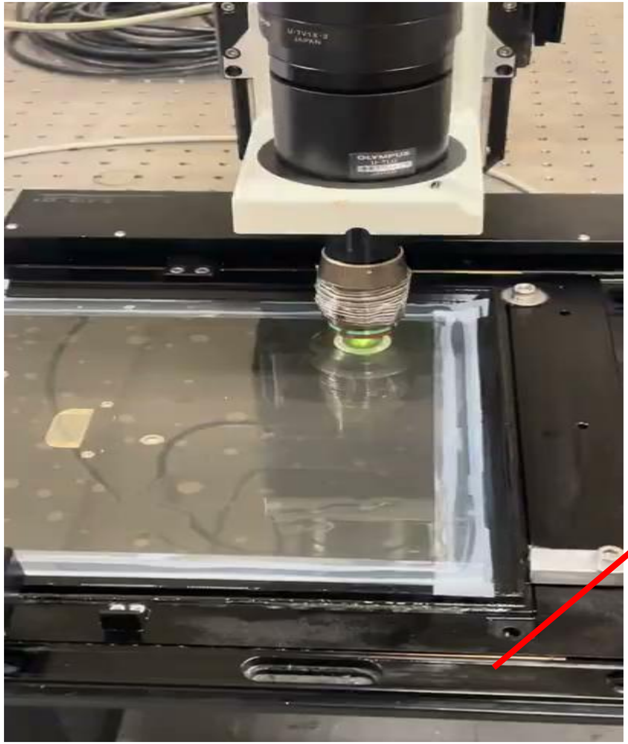






Pictures: arXiv:2210.02784 [hep-ex], Dr. Chayanit Asawatangtrakuldee

How to collect the Raw Data?



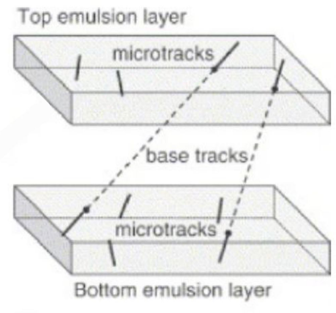
What's next?

Video: Dr. Chayanit Asawatangtrakuldee

Data Reconstruction

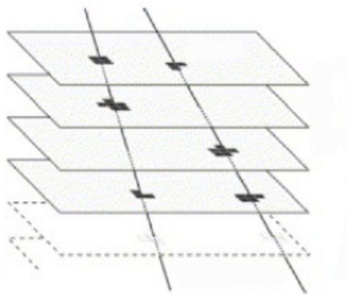
Linking

Creat base tracks

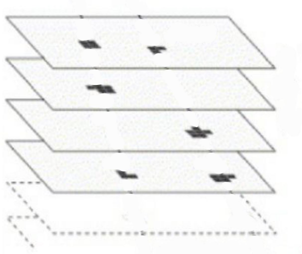


Tracking

Creat volume tracks



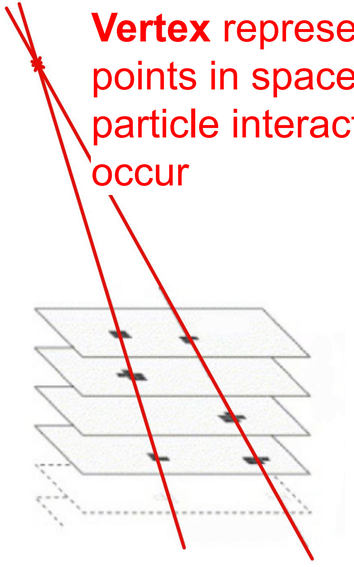
Alignment



Creat reference system
to align every plates

Vertexing

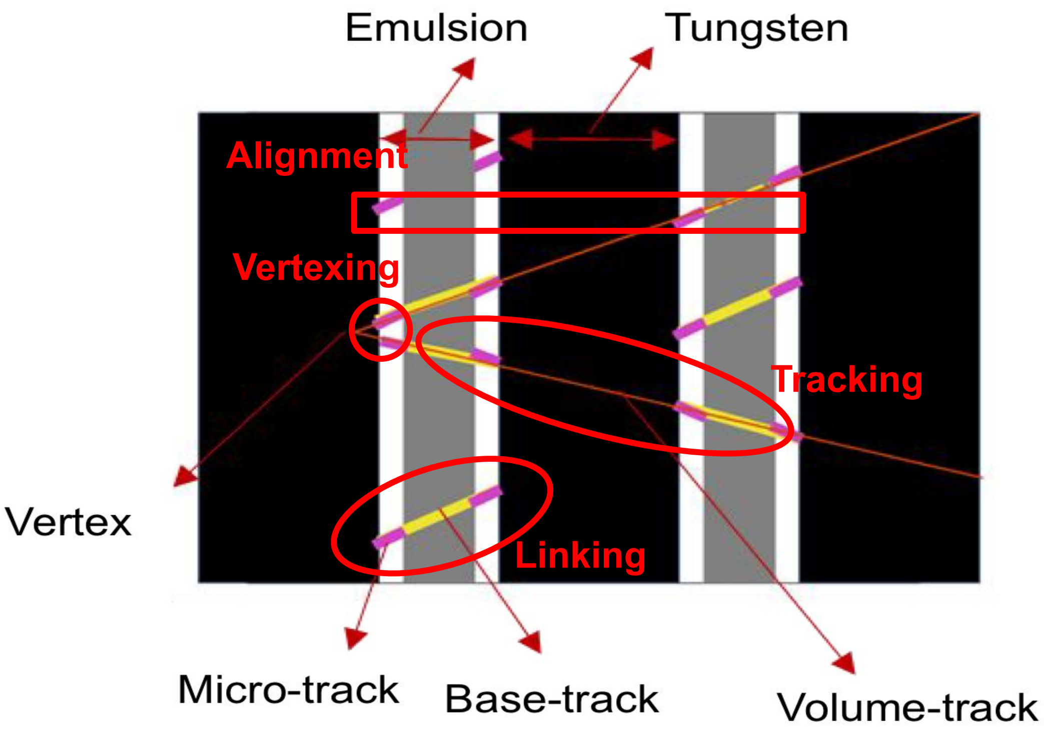
Vertex represent the points in space where particle interactions occur



Use a model to connect
to the starting point

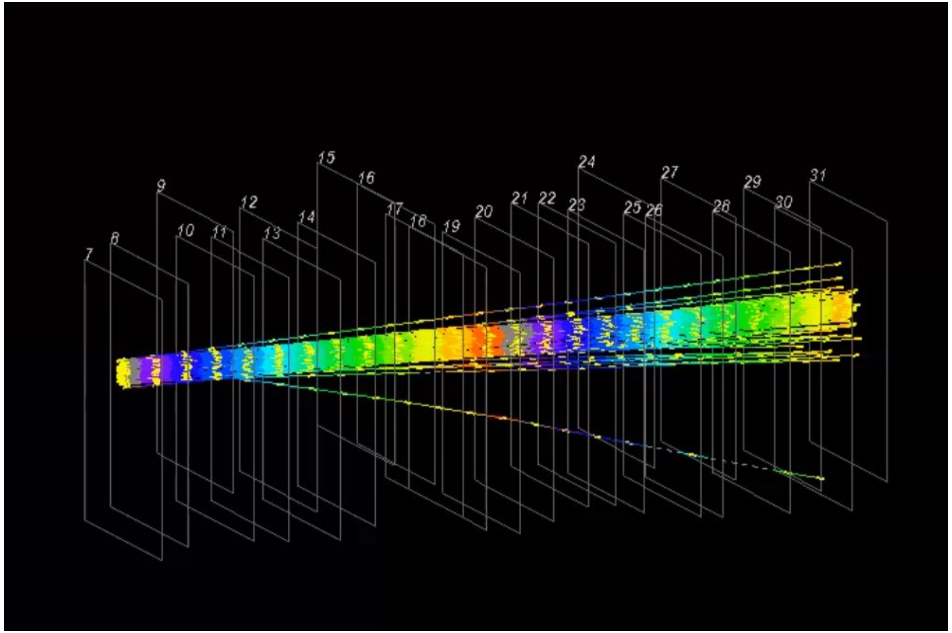
Pictures: SND@LHC Tutorial on emulsion data analysis

Data Reconstruction

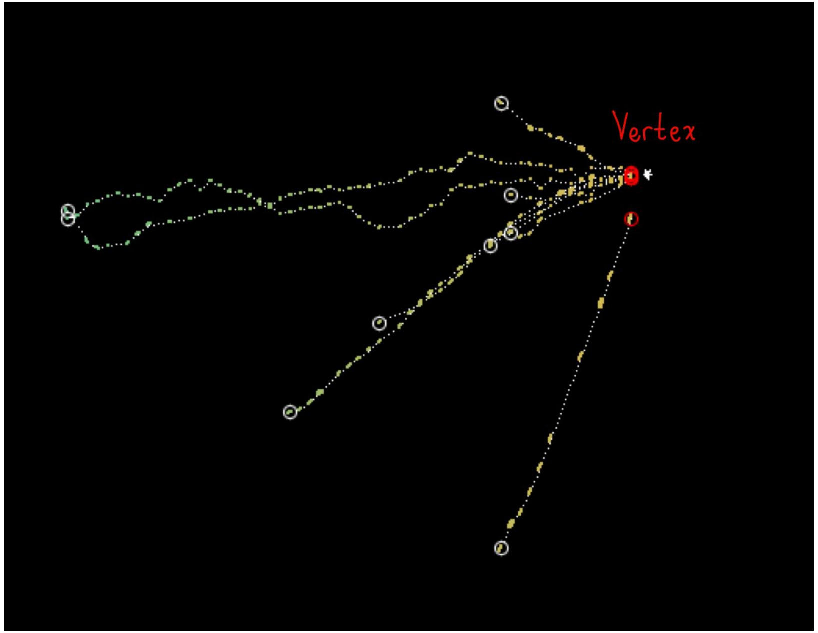


Pictures: SND@LHC Tutorial on emulsion data analysis

Data Reconstruction



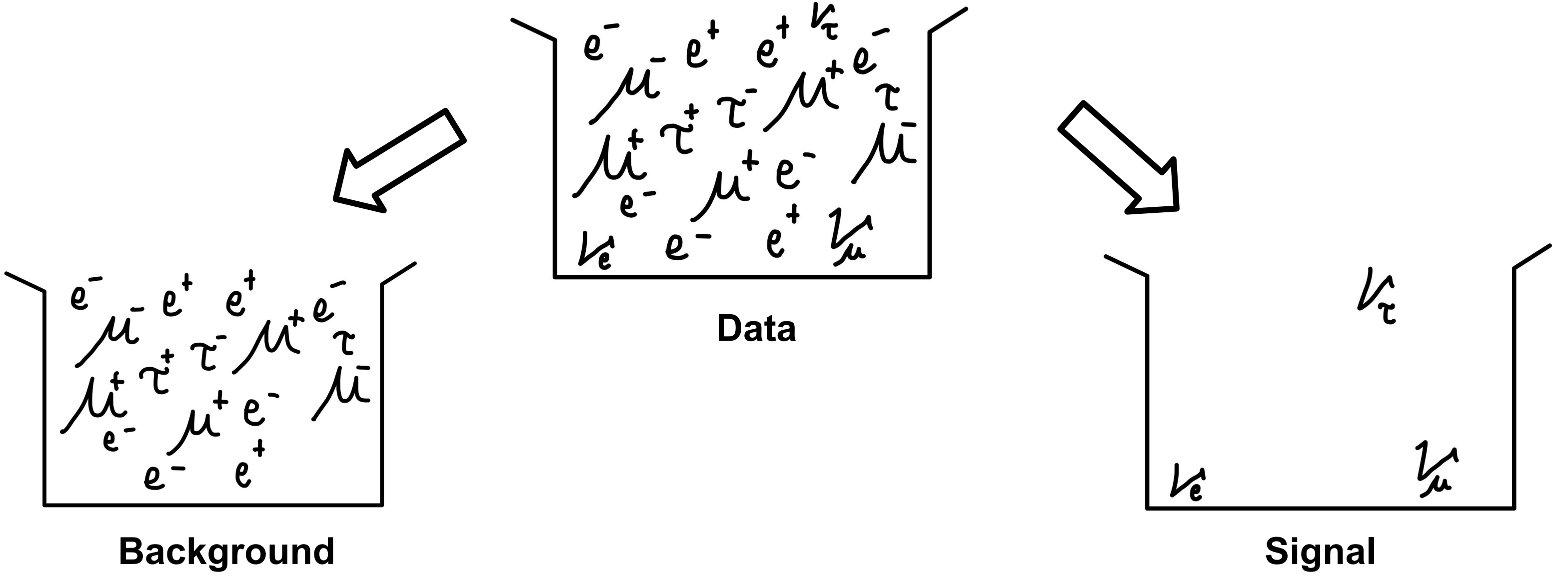
Tracking



Vertexing

Pictures: SND@LHC Tutorial on emulsion data analysis

Data Analysis



We want to extract the signal from the background that we observed

Data Analysis

Cut-based analysis

- Apply selection criteria (a known process) to the data by cutting something that we already know isn't the signal.
- For example, the cut of the data doesn’t match the specific region that we’re expecting (momentum, energy etc.)

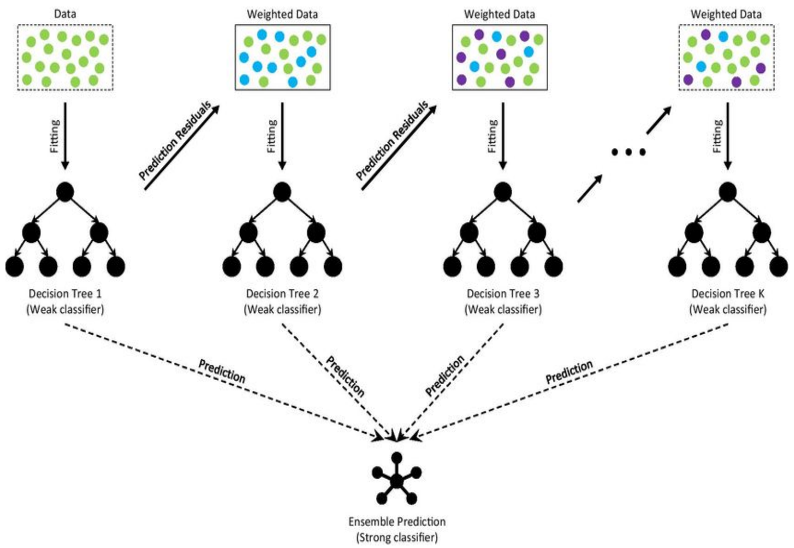
Shape-based analysis

- Focus on the distributional shapes of specific variables and apply them to the data.
- It might be biased toward one specific variable.
- For example, we can use the shape of the momentum from the simulation and compare it with the data to cut the BG.

Multivariable analysis

- Use multiple variables to optimize the separation
- Can capture non-linear relationships between variables using ML
- Reducing bias from using multivariables to classify the signal

Boosted Decision Trees (BDT)



- BDT is a machine learning technique used in <u>classification tasks</u> in high-energy physics
- BDT requires <u>a set of features or variables</u> that describe each event
- Combines <u>decision trees with boosting techniques</u> for improved performance.
- Some feature might be <u>similar btw BG and signal</u> that makes it hard to classify (weak feature)
- The boosted technique will apply <u>different weight</u> to the weak and strong feature
- At the end we'll have a model to classify BG and signal which has a <u>strong separation power</u>

Pictures: DOI:10.1186/s12911-021-01701-9

Features

- **Multiplicity:** number of tracks
- **Mean Impact Parameter:** distance between track and the vertex
- **Max Delta Phi:** maximum difference in the transverse angle
- **Mean Fill Factor:** it's indicate how completeness of data collection in detector systems

  High fill factor > a large fraction of relevant events is captured and included in the analysis
- **Probability:** refers to a measure of the goodness-of-fit associated with the fitted vertex

  position by using Kalman filter prob

ROOT software

- ROOT is a data analysis framework developed by CERN
- Storing complex data objects, including histograms, trees, and graphs, in a compressed and efficient manner
- A branch is a named data element within a ROOT file's tree structure which represent a specific variable associated with the events or objects being stored
- For more detail, https://root.cern

Let’s see the real data!

Q&A

wanna play with more real data from the LHC?

contact us

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Sirawit.saeung@gmail.com