ProtoDUNE Dual-Phase Liquid Argon TPC

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A little devinette

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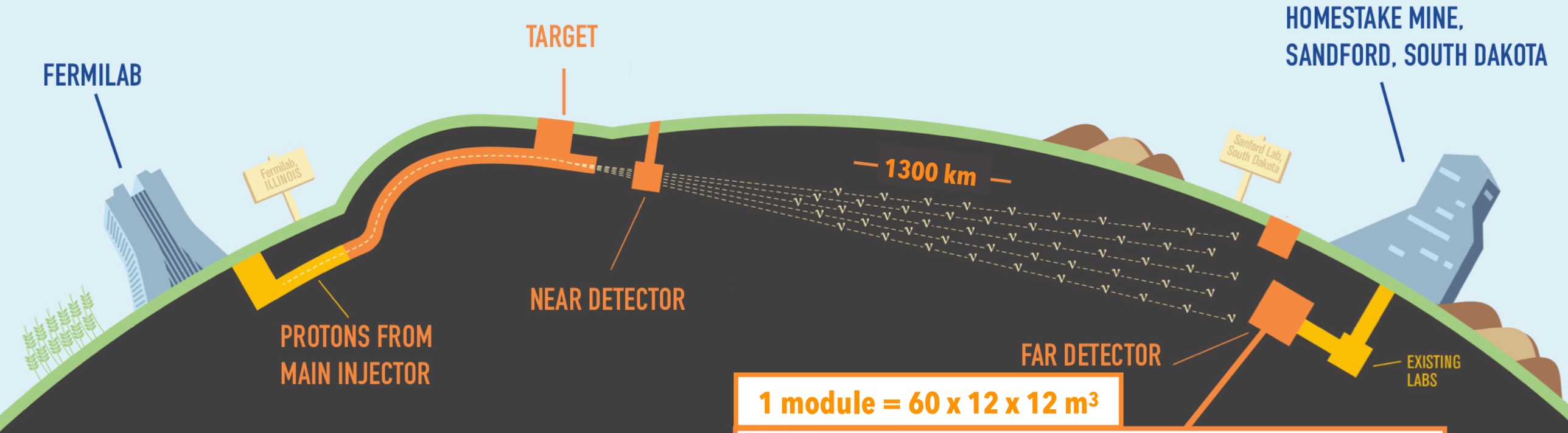
The Deep Underground Neutrino Experiment (DUNE)

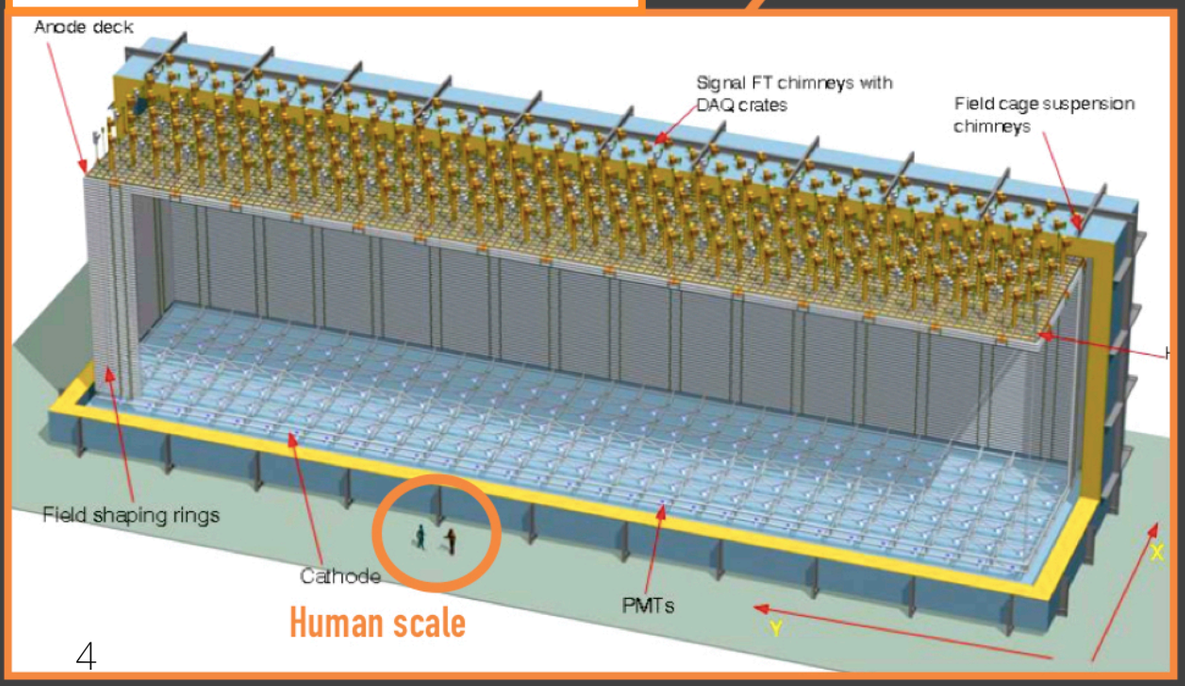
1100+ collaborators from **180+ institutions** in **30+ countries** all over the world

SETUP

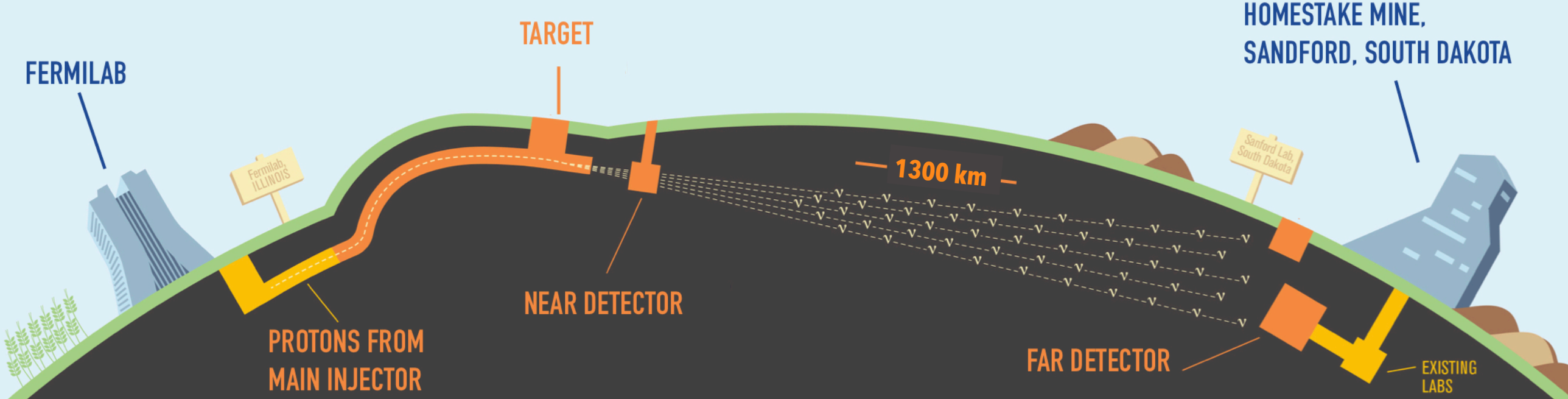


- Very Long Baseline experiment (~ 1300km)
- Beam of mainly ν_μ or anti-ν_μ , [0.5 - 8] GeV
- 4 Cryostats 10 kt of LAr each
- Technology needs large scale validation

1 module = 60 x 12 x 12 m³



DEEP UNDERGROUND NEUTRINO EXPERIMENT



Accelerator Neutrino: oscillation $\nu_\mu \longrightarrow \nu_e$ (ν_e appearance) and $\nu_\mu \longrightarrow \nu_\mu$ (ν_μ disappearance) interesting to:

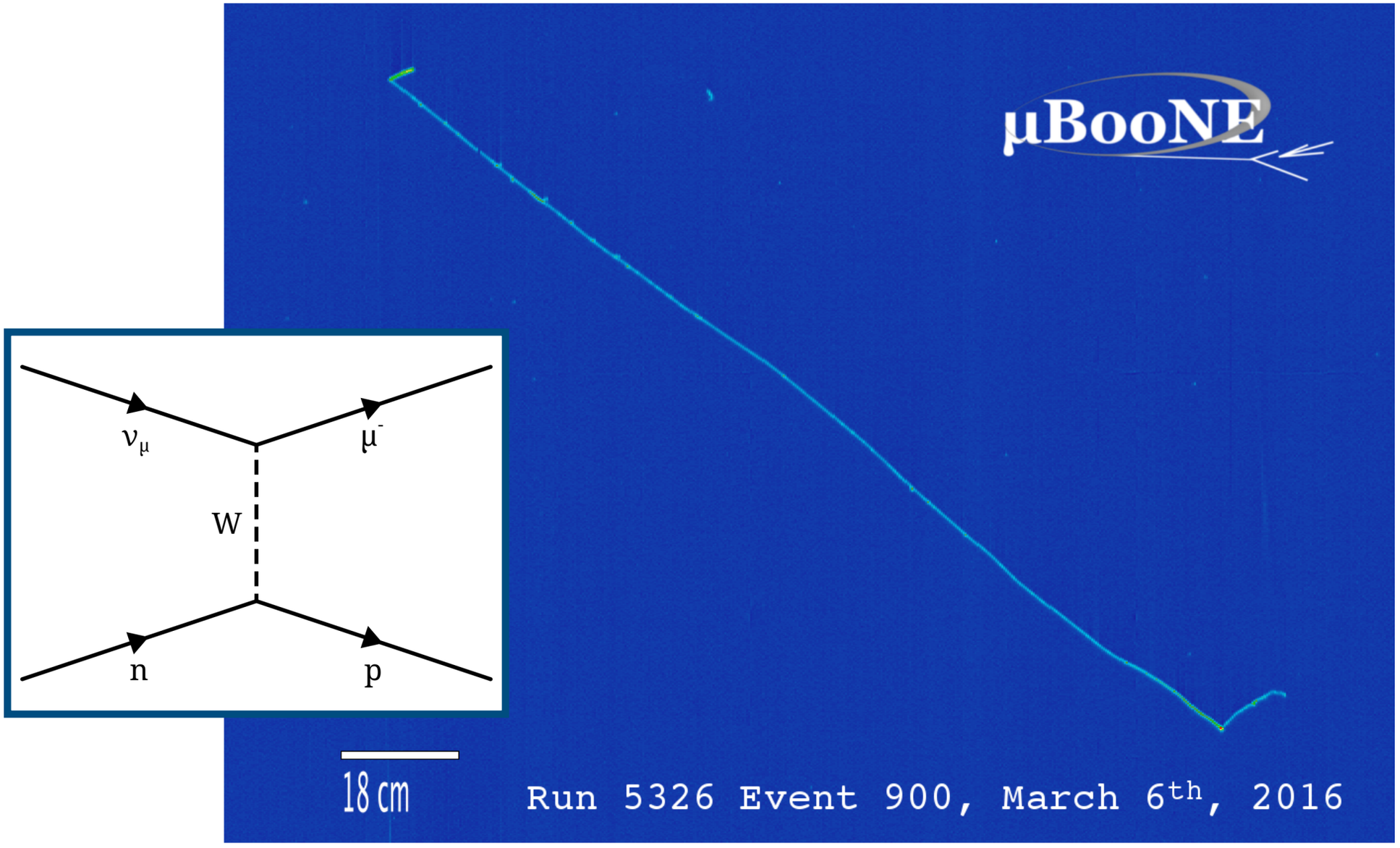
- Precision measure on oscillation parameters
- Mass Hierarchy
- Discovery of CP violation for leptons

Neutrinos from natural sources:

- Capability to detect and study neutrino from the supernovae core collapse
- Study of the atmospheric neutrino flux

What will happen inside the detector

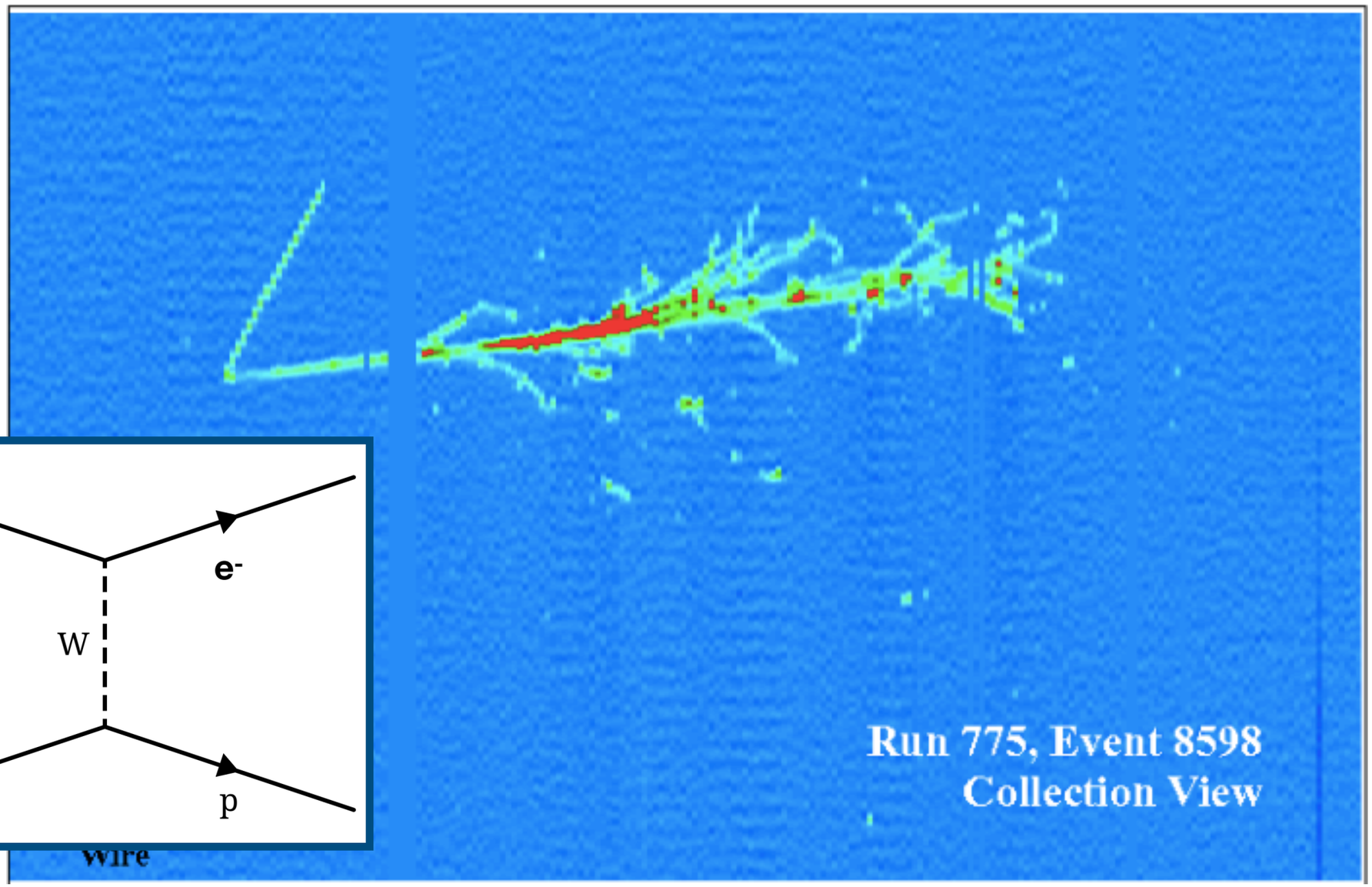
Muon-neutrino (ν_μ) events



« QE-ν_μ CC »

What will happen inside the detector

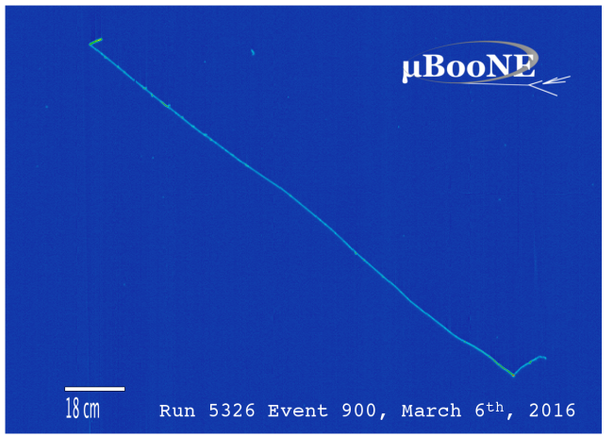
Electron-neutrino (ν_e) events

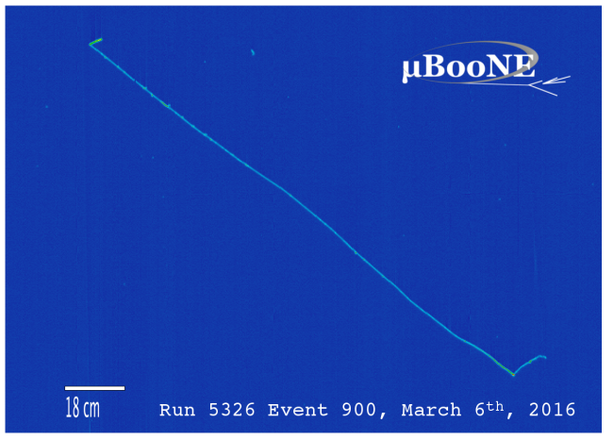


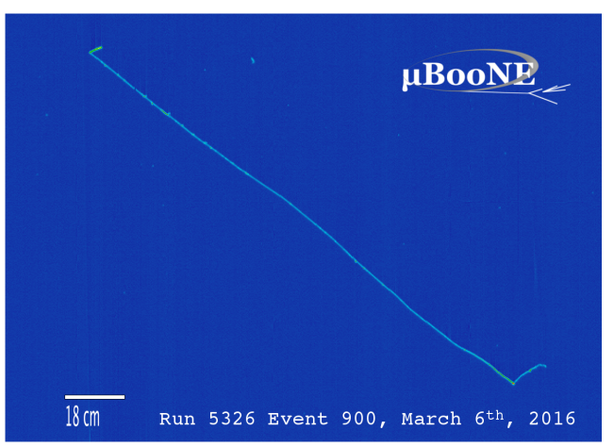
« QE-ν_e CC »

What we are looking for regarding… θ_{23}

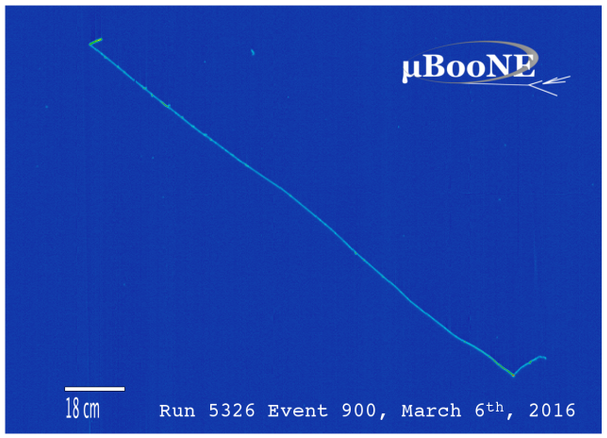
Less ν_μ interactions in the far detector

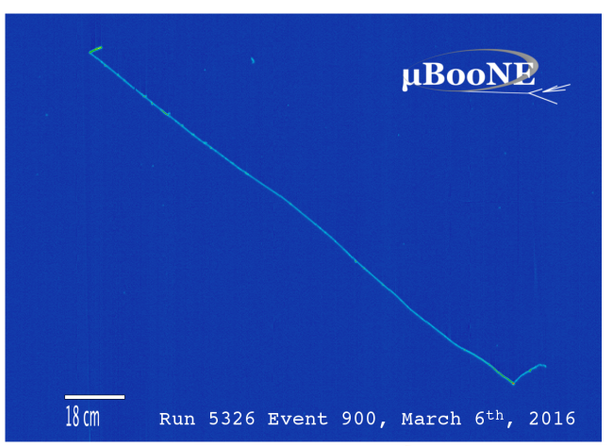






1300km

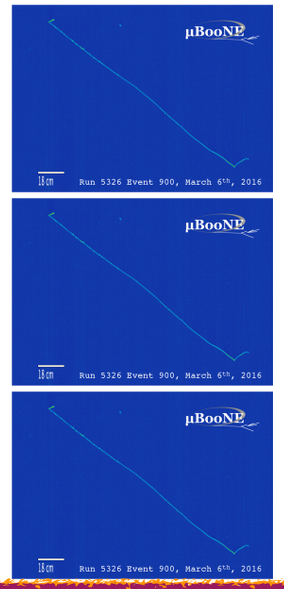




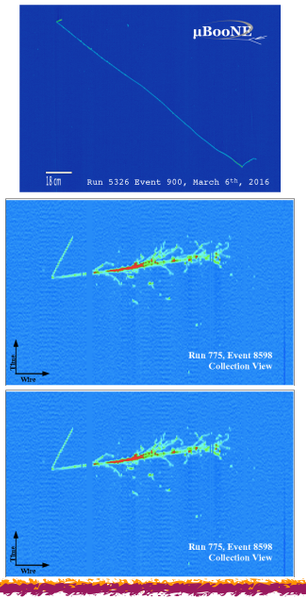
What we are looking for regarding… δ_{CP} and Δm_{13}

Asymmetry between ν_μ and anti-ν_μ oscillations

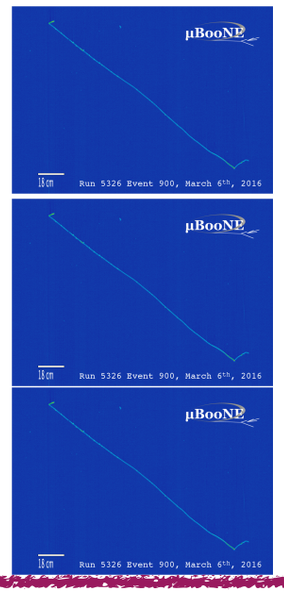
Neutrino mode



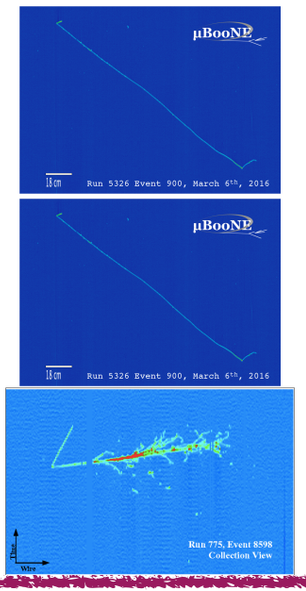
1300km



Anti-neutrino mode



1300km

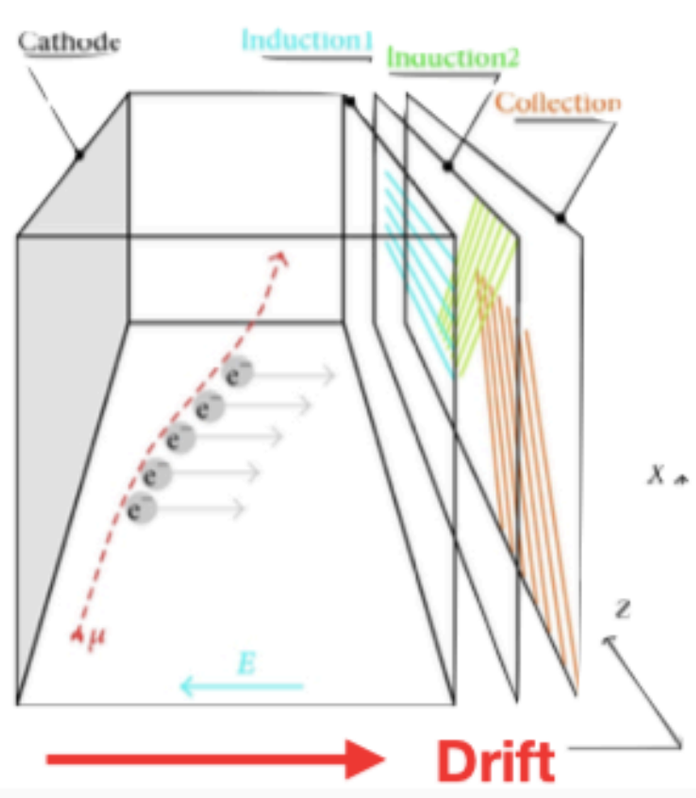


The ProtoDUNEs

Two designs for the LArTPC

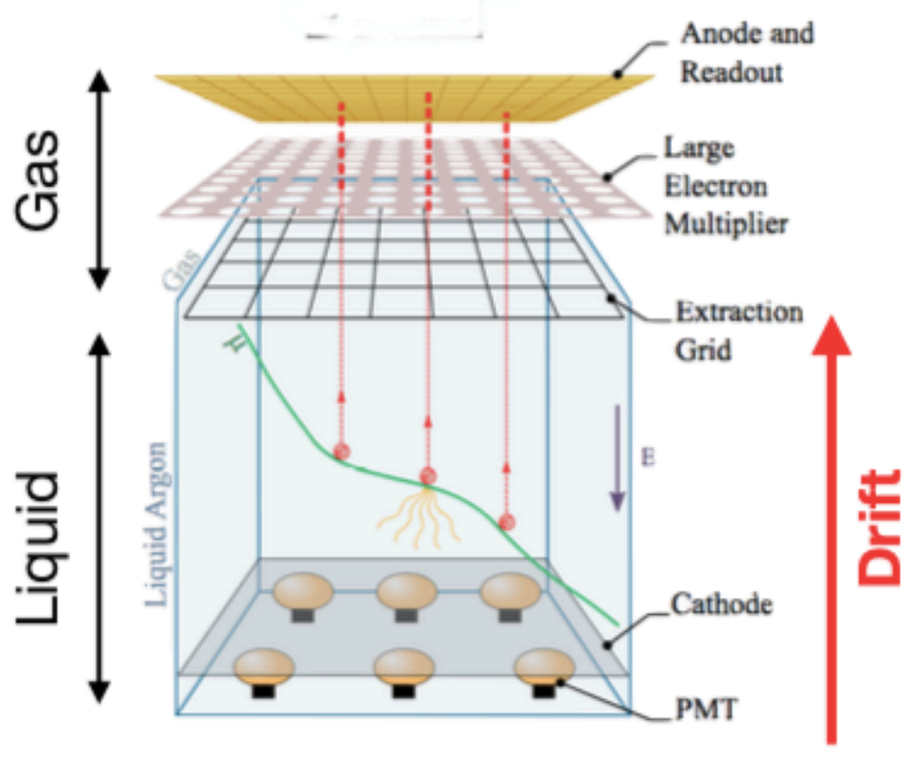
Single phase (SP)

- Only liquid Ar
- Horizontal drift
- Max drift distance limited by Ar purity: 3.6 meters in DUNE



Dual phase (DP)

- Liquid and Gas Argon
- Vertical drift
- Amplification in gas
- 2 collection views



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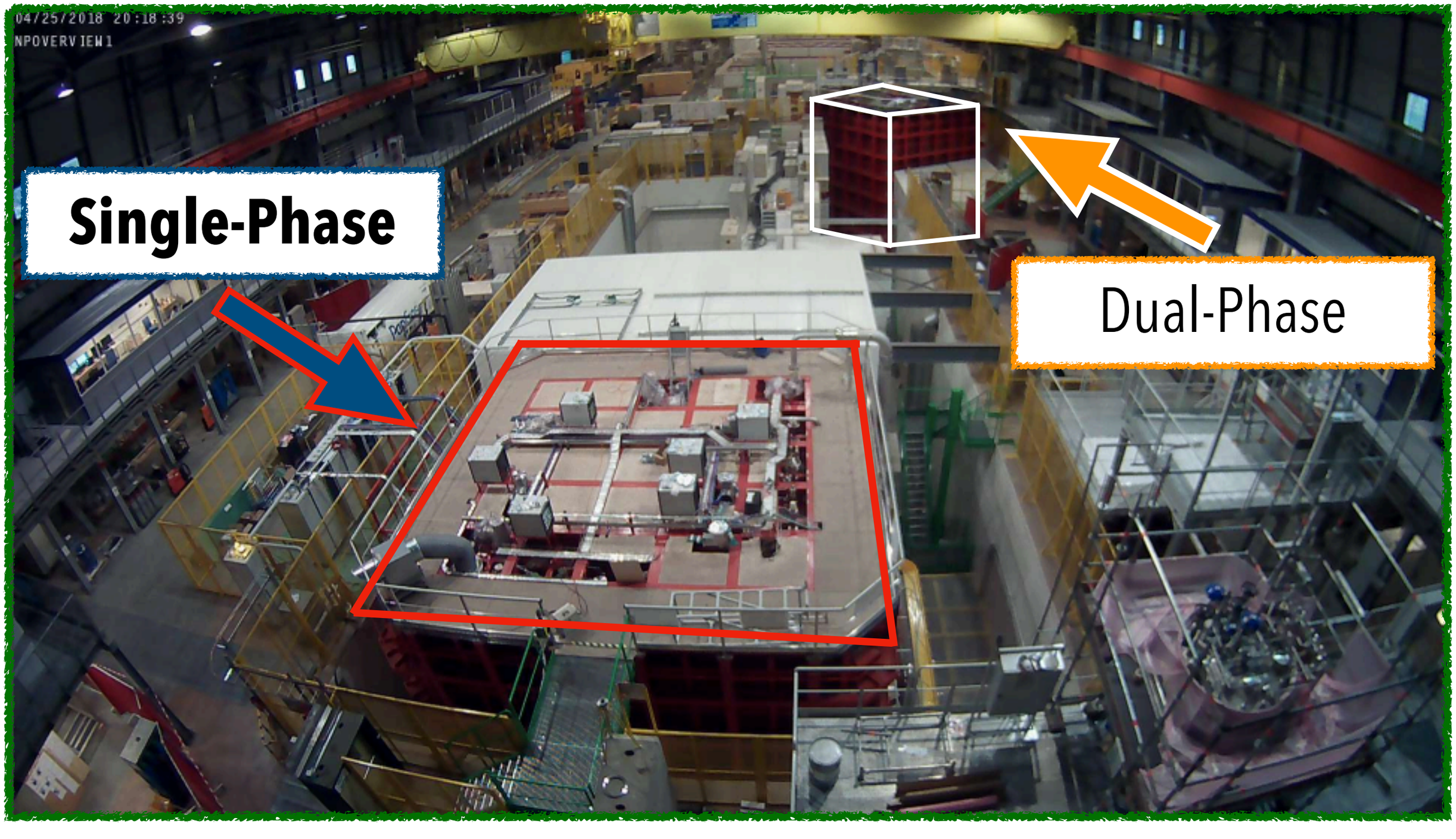

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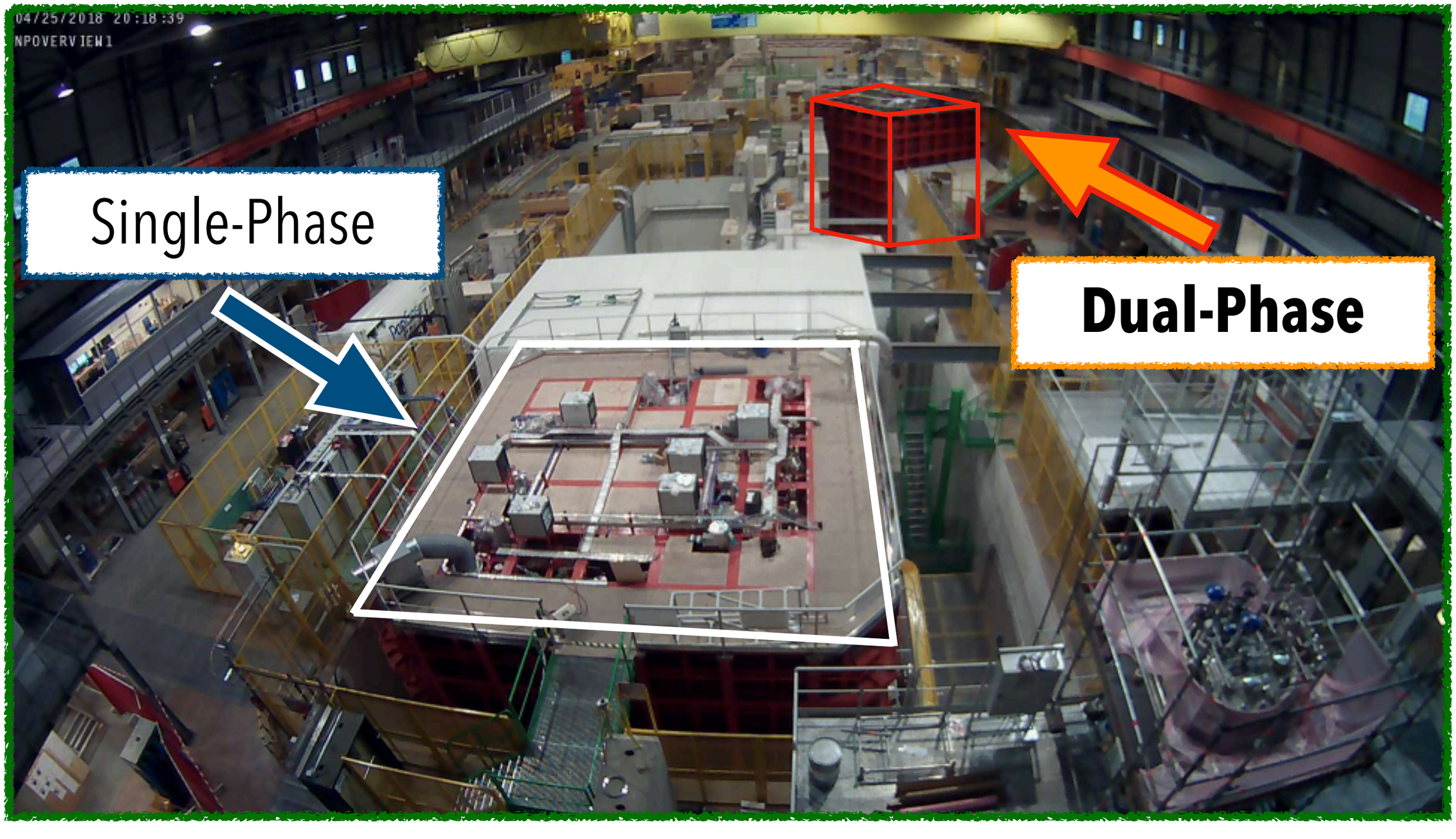


Two designs for the LArTPC

Status and future plans

Single phase (SP)

- End of construction in May 2018
- Comissioning May 2018
- Beam + cosmic data taken between fall 2018 and early 2019
- On-going analysis of the data

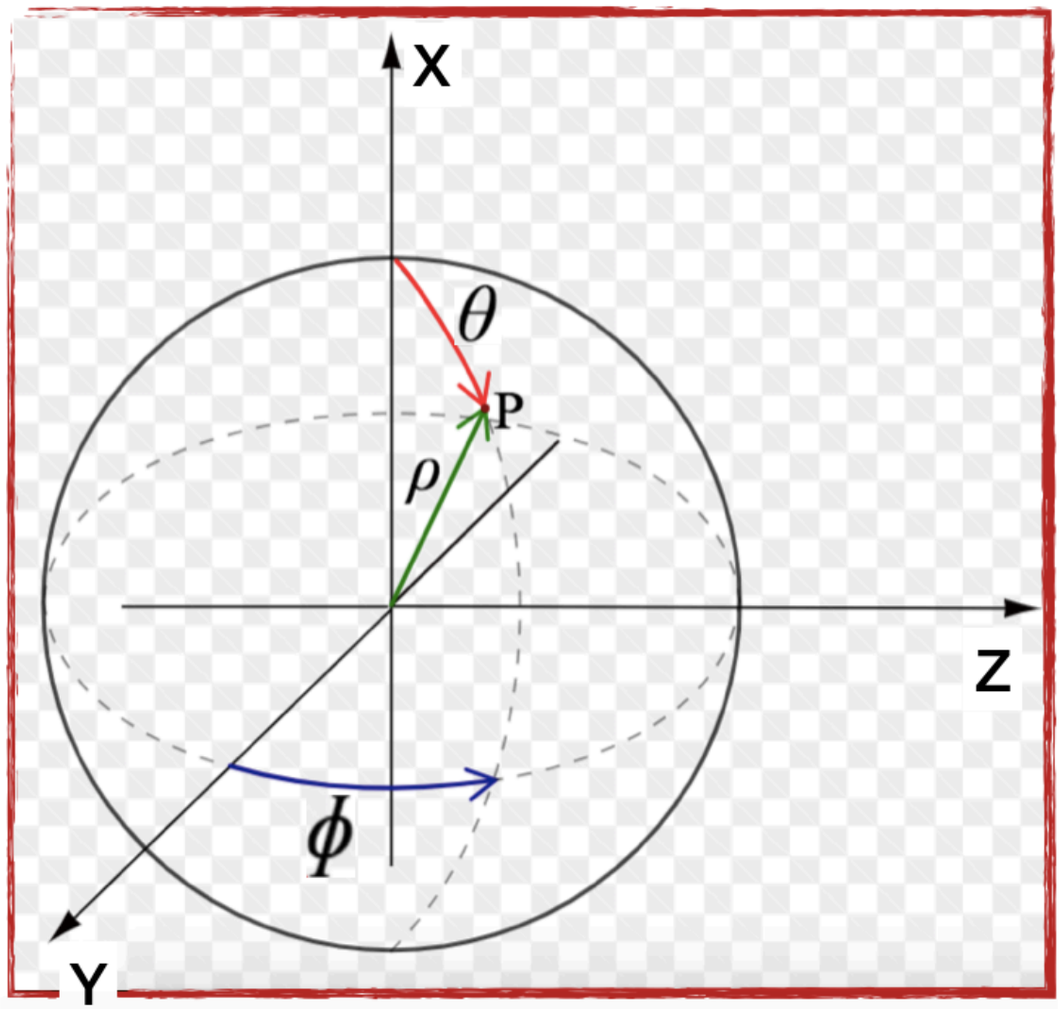
Dual phase (DP)

- End of construction June 2019
- Comissioning July 2019
- Cosmic data taking started in August 2019
- Beam data in 2021

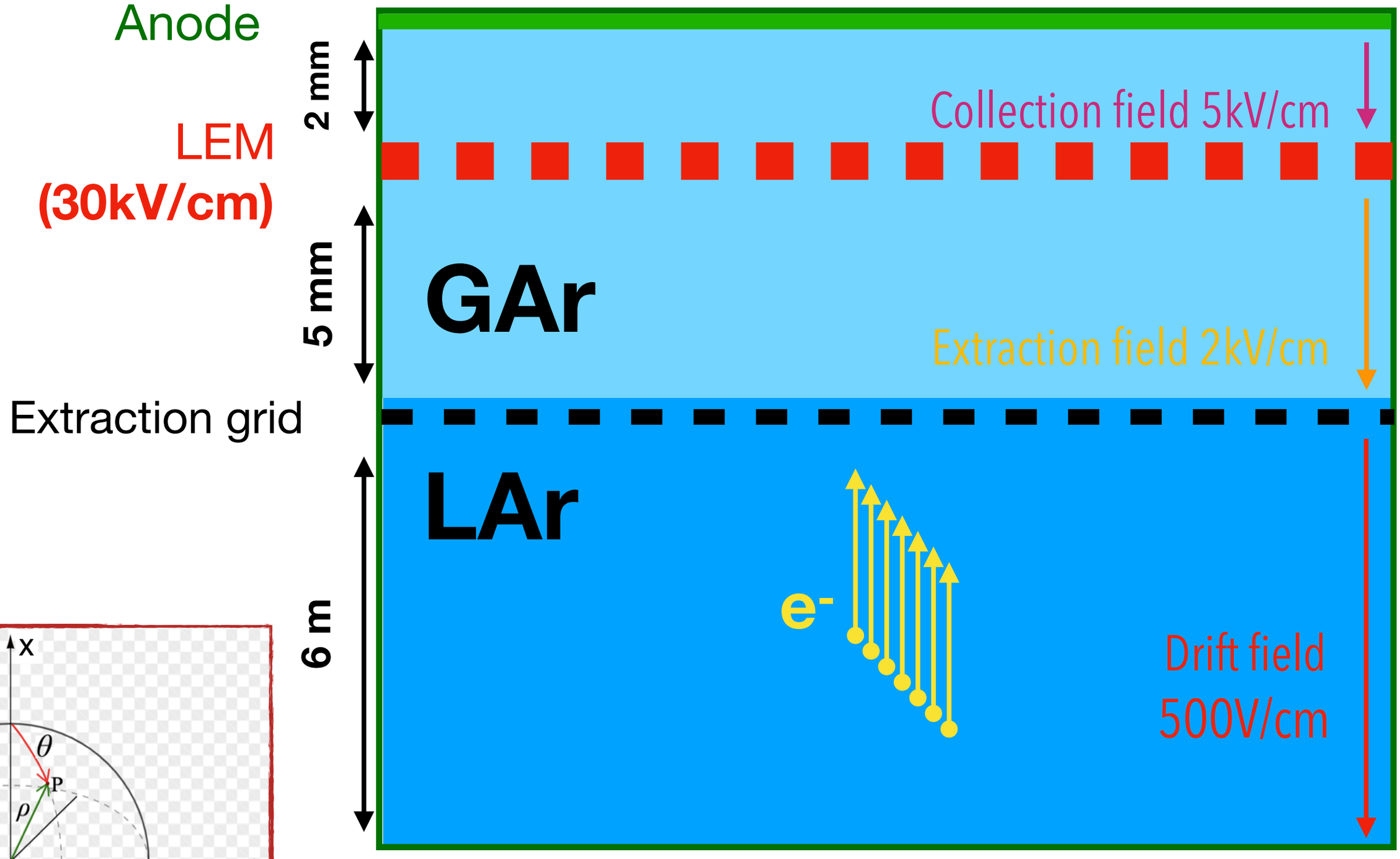
The ProtoDUNE **Dual-Phase LArTPC**

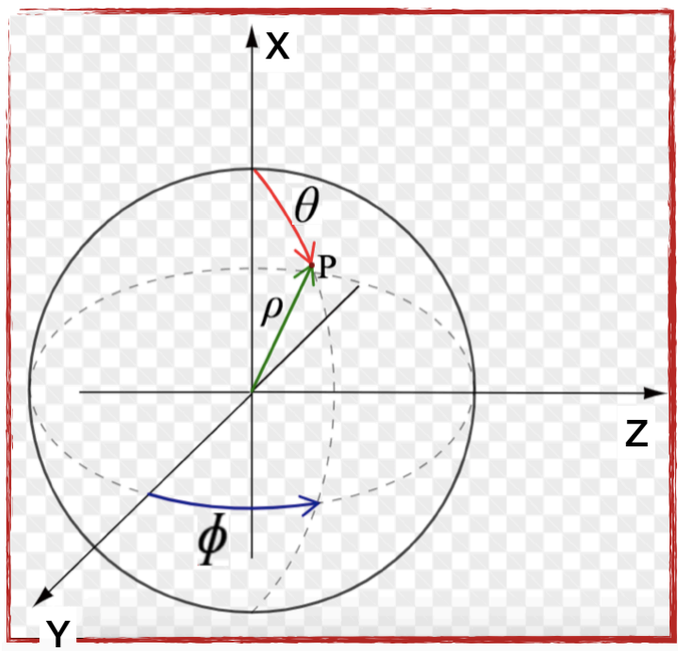
Let’s clarify something first…

Dual-Phase design is **using *standard spherical angles*** definition

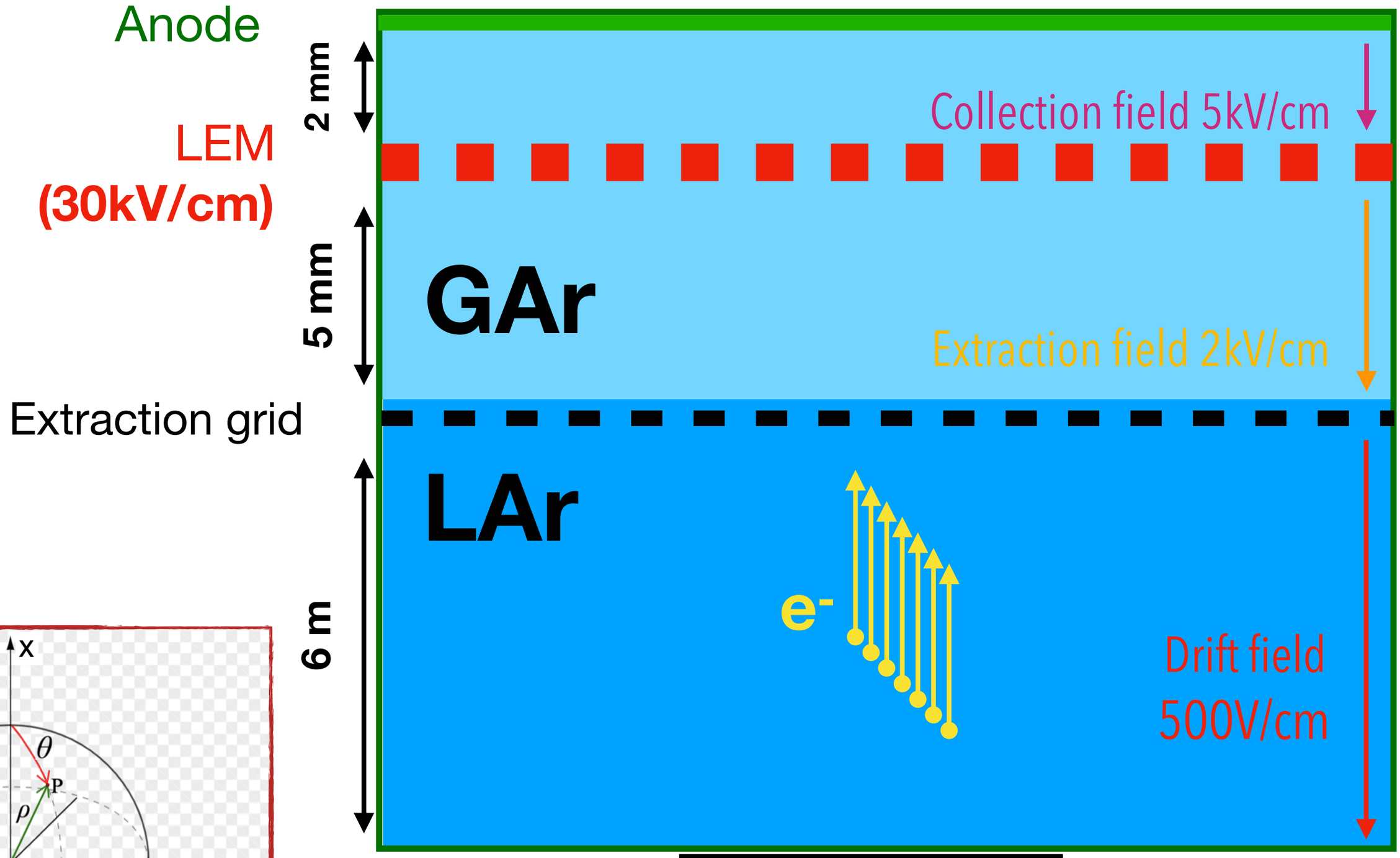


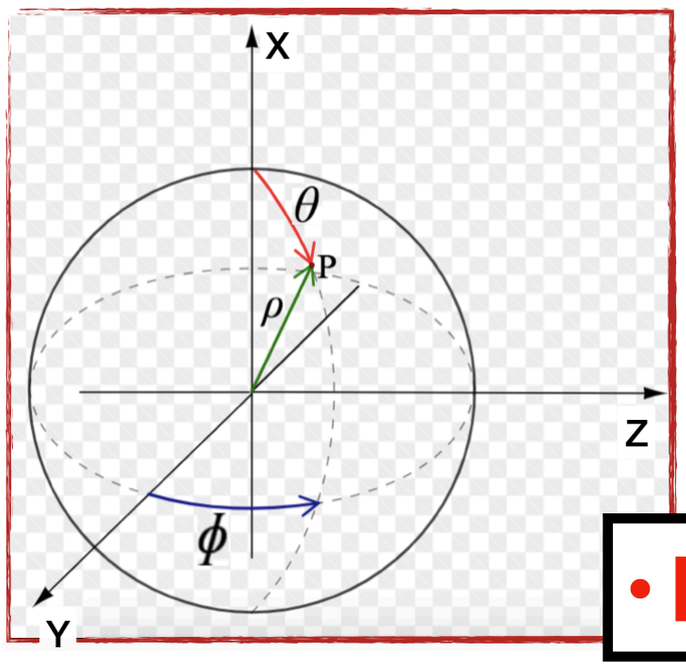
ProtoDUNE Dual-Phase LArTPC





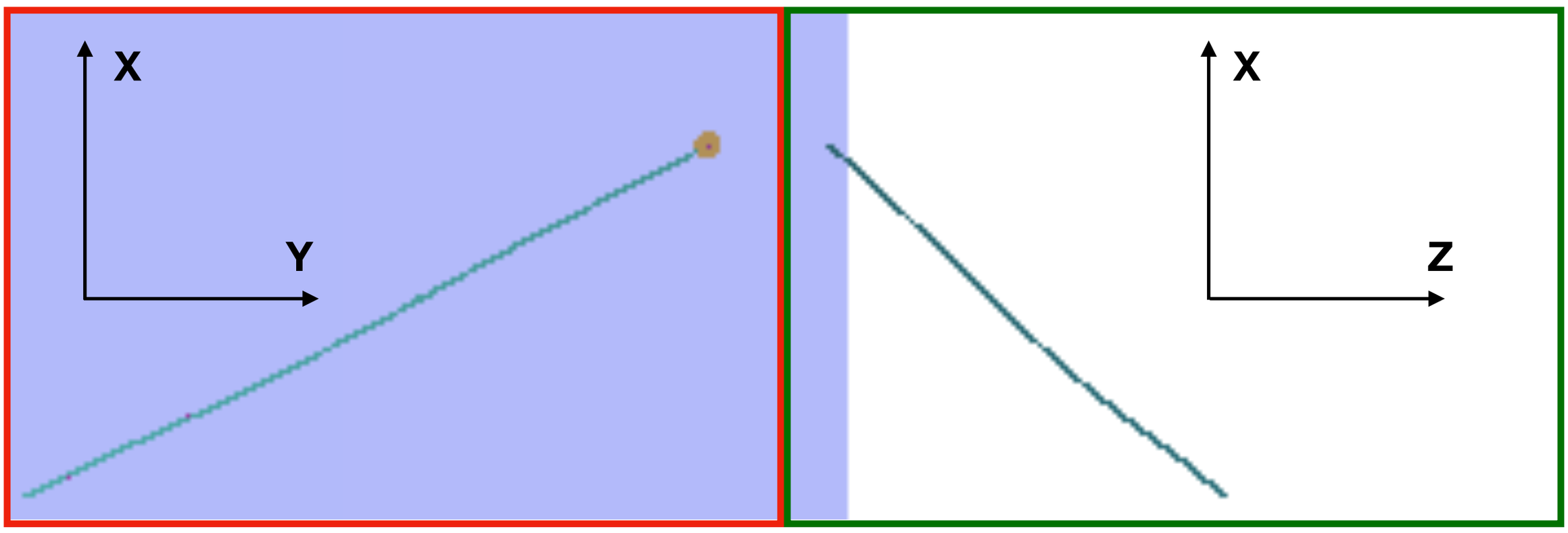
ProtoDUNE Dual-Phase LArTPC

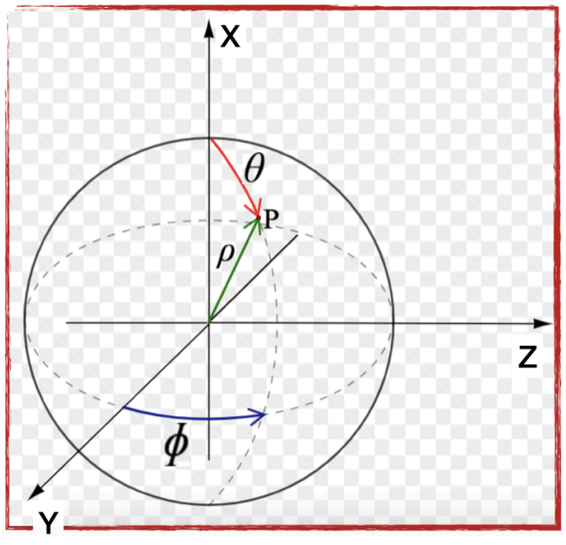




- **Argon purity**
- **Drift field homogeneity**
- **LEM+Grid stability**

ProtoDUNE Dual-Phase LArTPC
Details on 2-view signal collection





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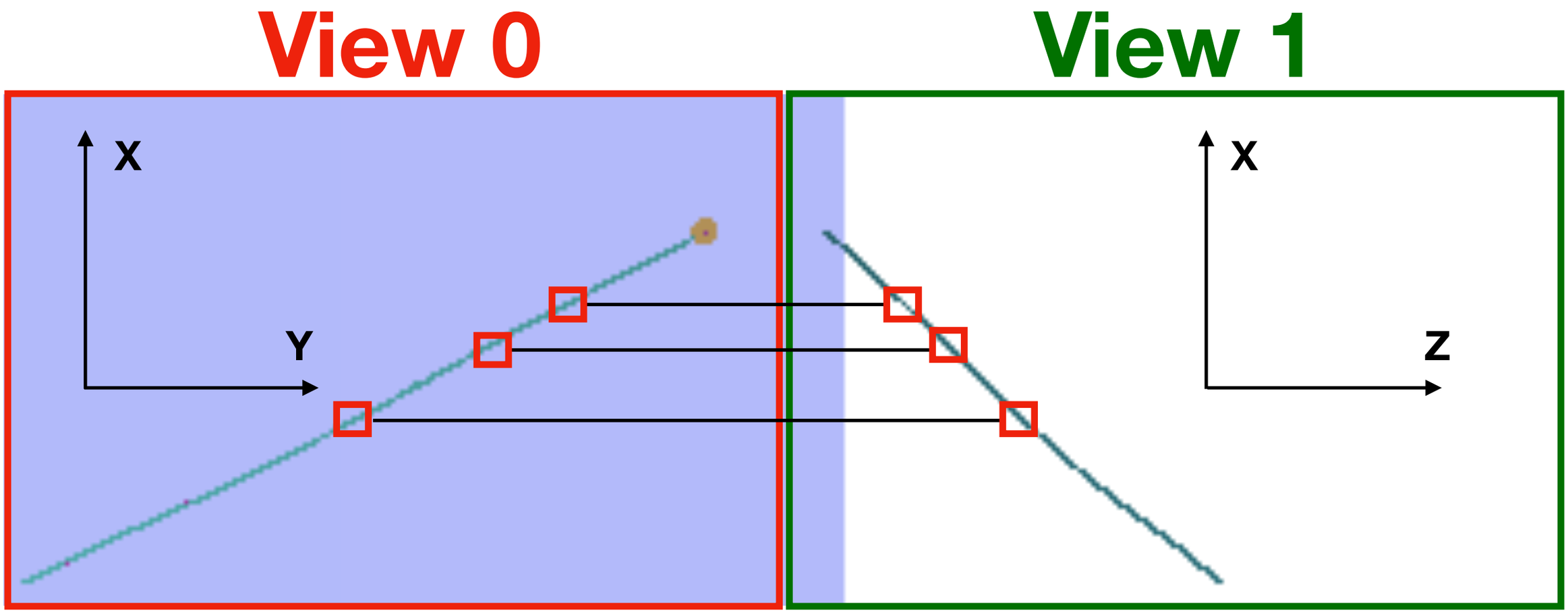
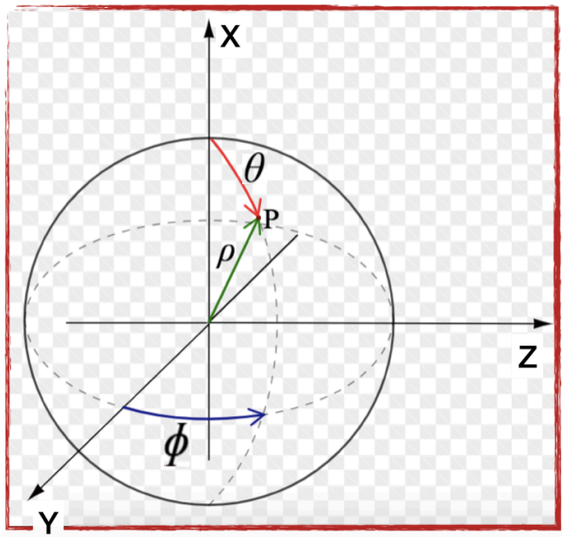


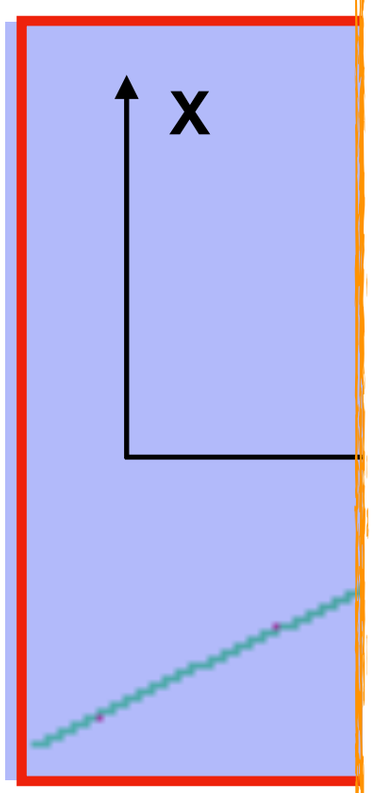


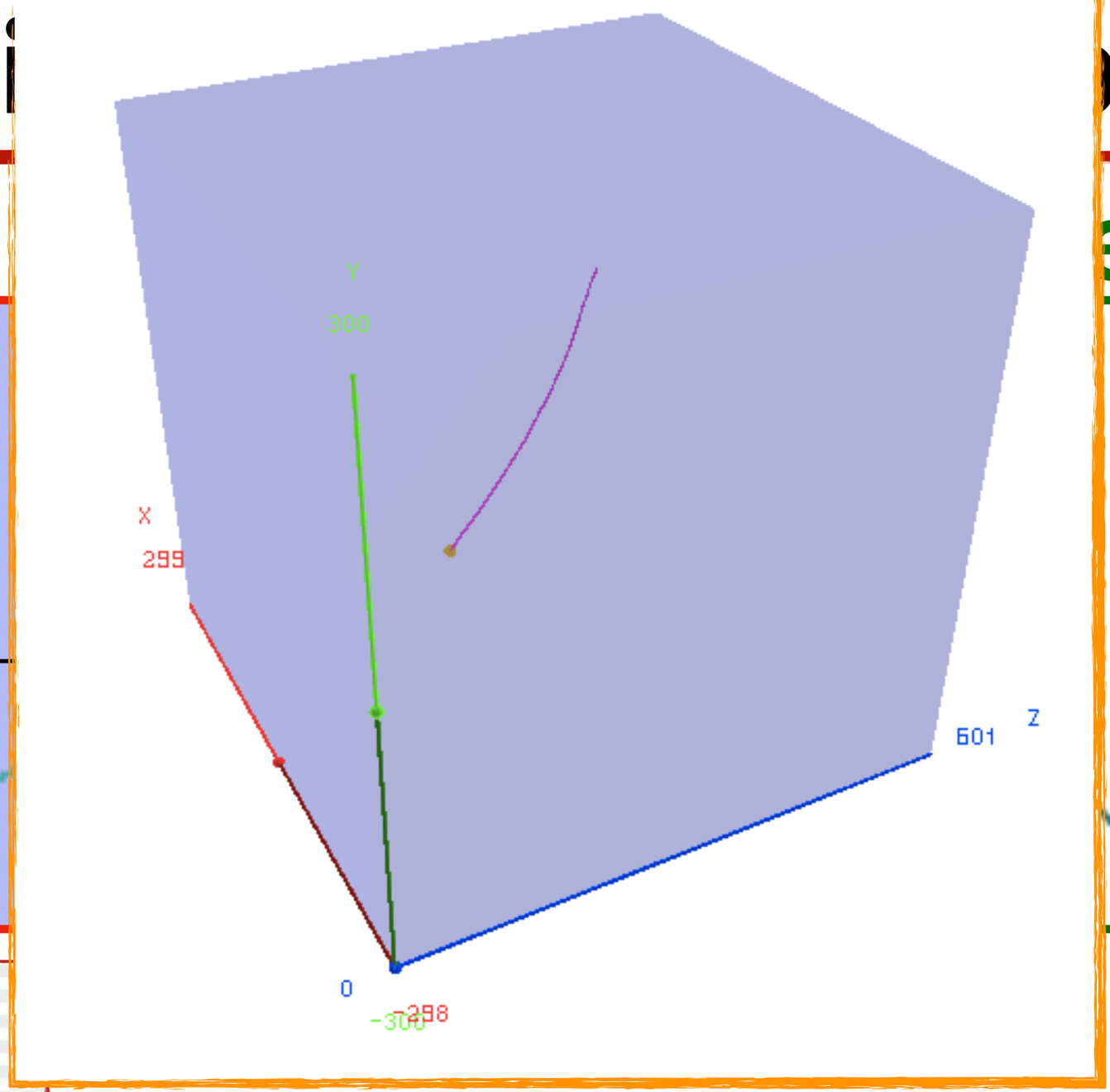
2D pictures -> Matching X-> 3D picture

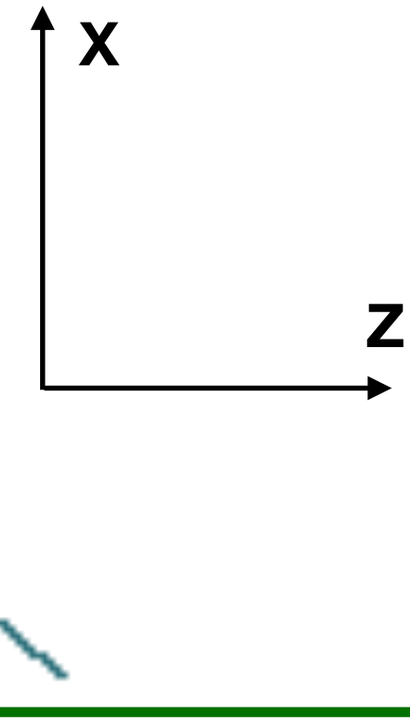
ProtoDUNE Dual-Phase LArTPC

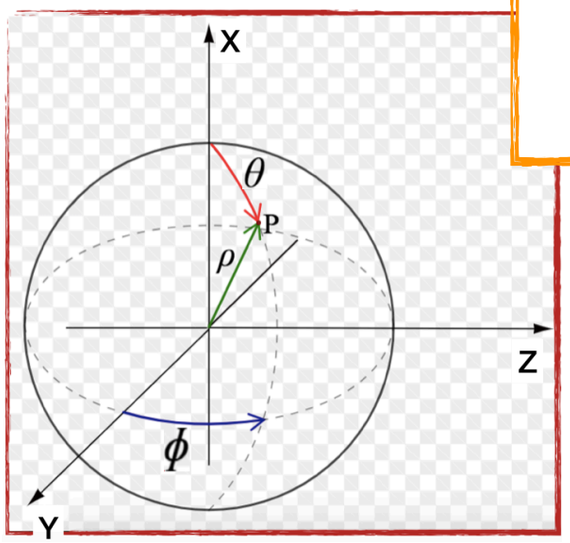
Detai llection

ew 1









2D pictures -> Matching X-> 3D picture

ProtoDUNE Dual-Phase LArTPC

Goals for the prototype :

➡ Achieve long term stability of the detector (electric field, purity, LEM+grid, temperature)

➡ Perform the energy calibration

➡ Test and develop reconstruction algorithm (hits and trajectories)

Currently taking cosmic data

Will take beam data in 2021…

A small hint for the devinette

My PhD can be divided into three activities :

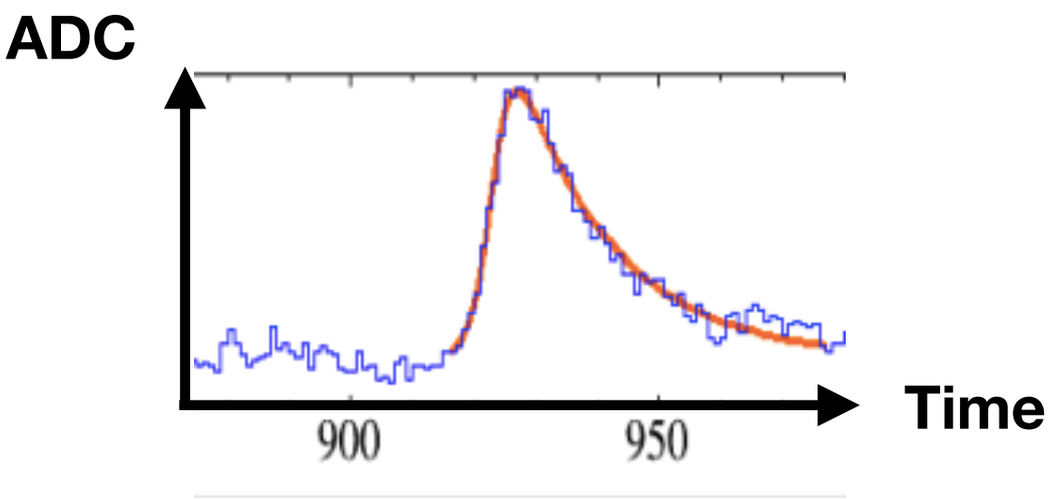
1. Test the existing reconstruction algorithms

2. Adapt them to our Dual-Phase detector

3. Extract the physics potential of the design

What do I reconstruct exactly ?

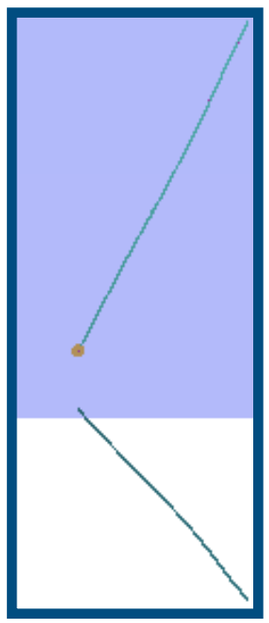
1. Hits



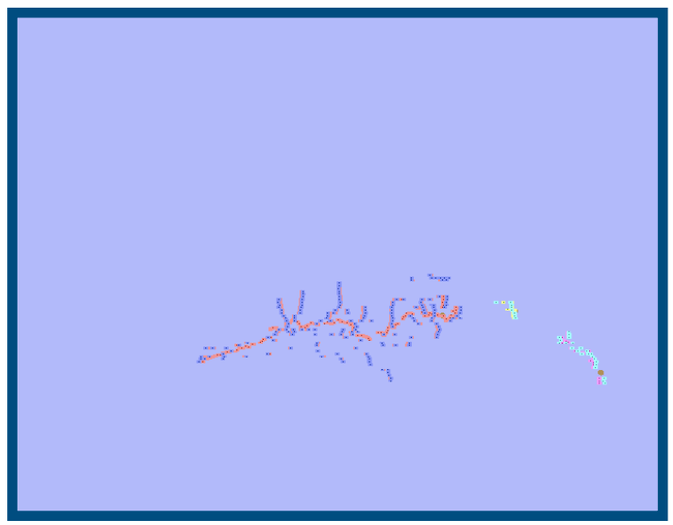
Reconstructed ionization signal
on a particular wire at a particular time (2D)

2. Trajectories

Tracks



Showers



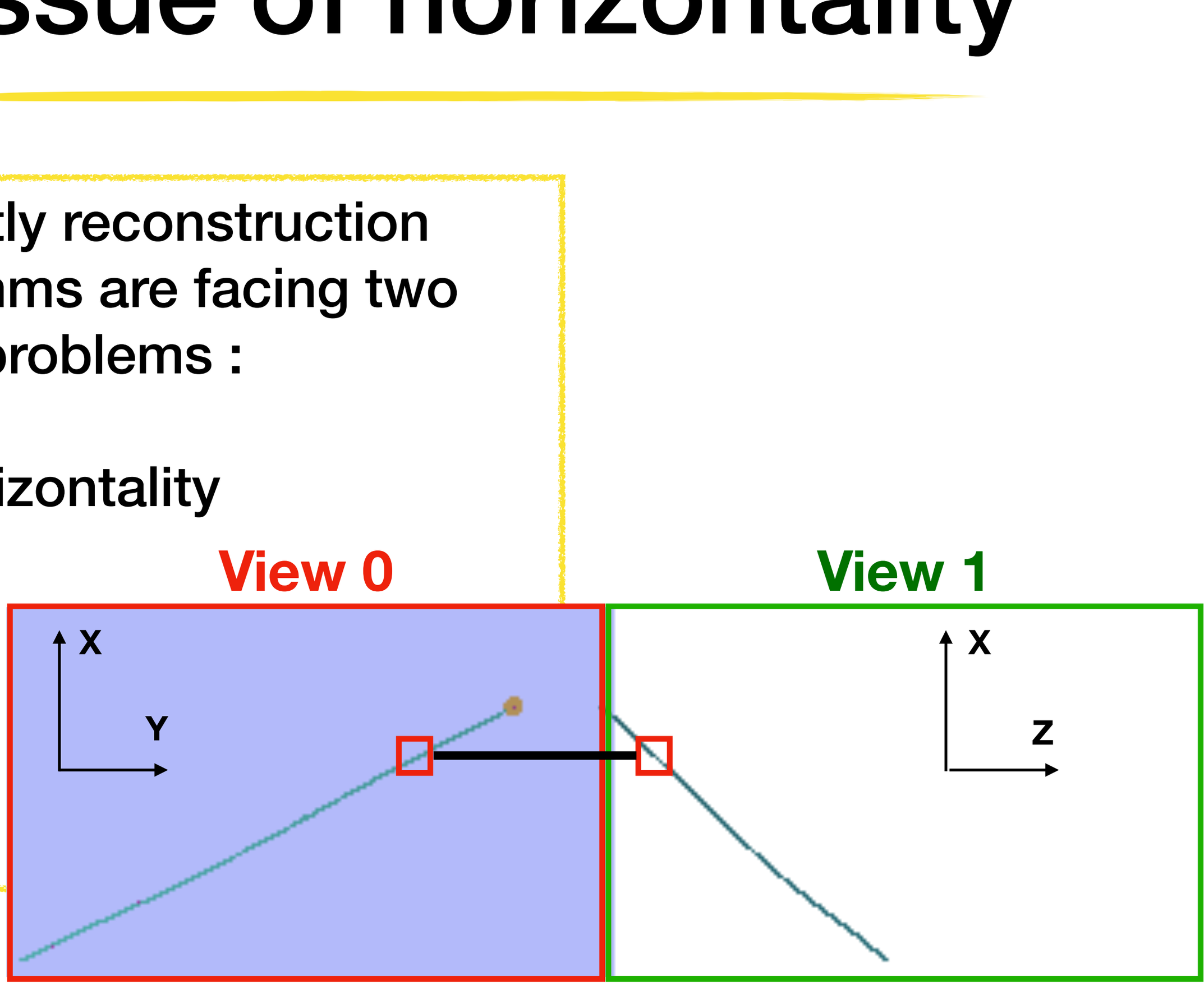
Cluster of 3D hits from the same particule

Me talking

Issue of horizontality

Currently reconstruction algorithms are facing two major problems :

1. Horizontality

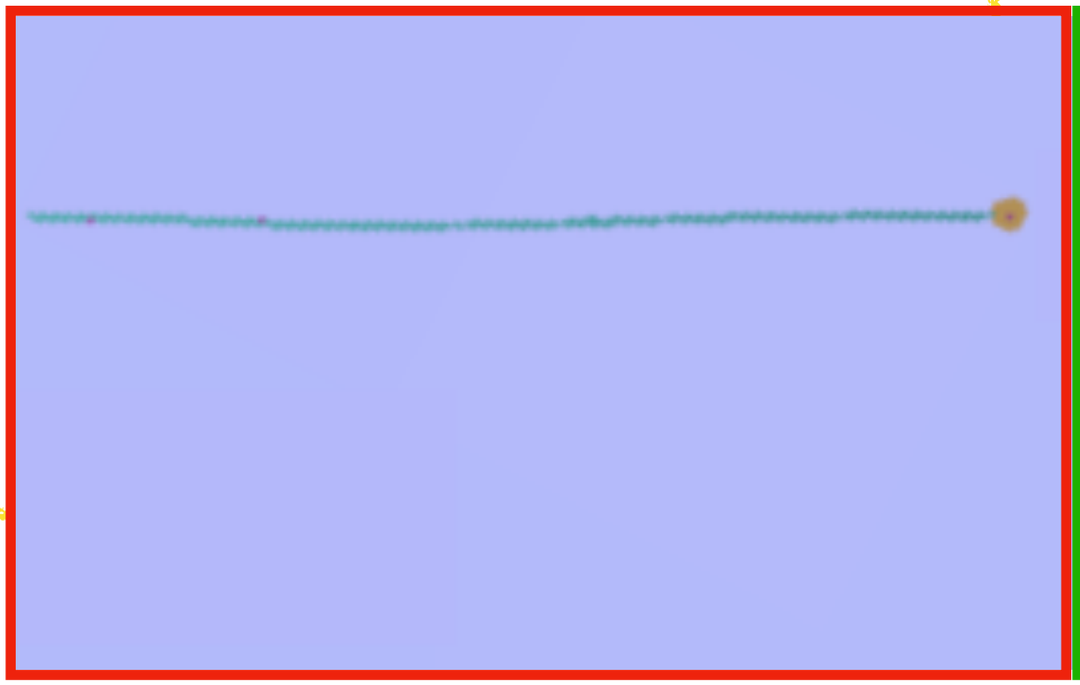


Issue of horizontality

Currently reconstruction algorithms are facing two major problems :

1. Horizontality

View 0



View 1

Issue of horizontality

Currently reconstruction algorithms are facing two major problems :

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Issue of horizontality

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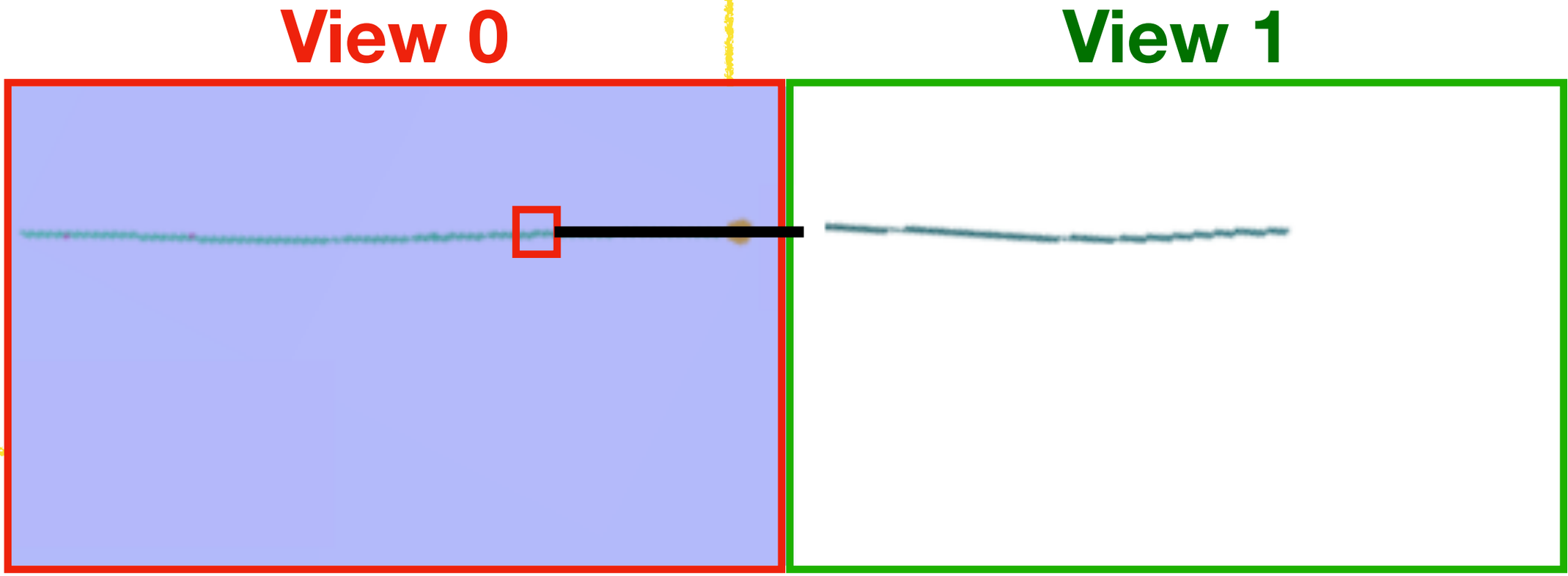

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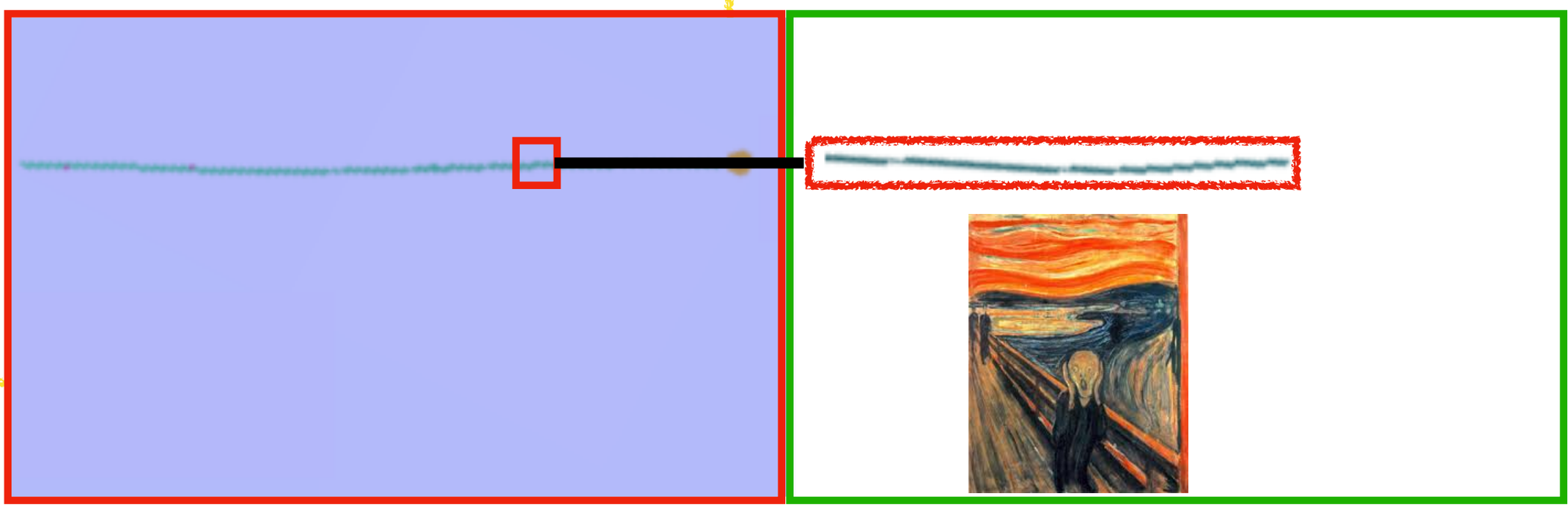

Issue of horizontality

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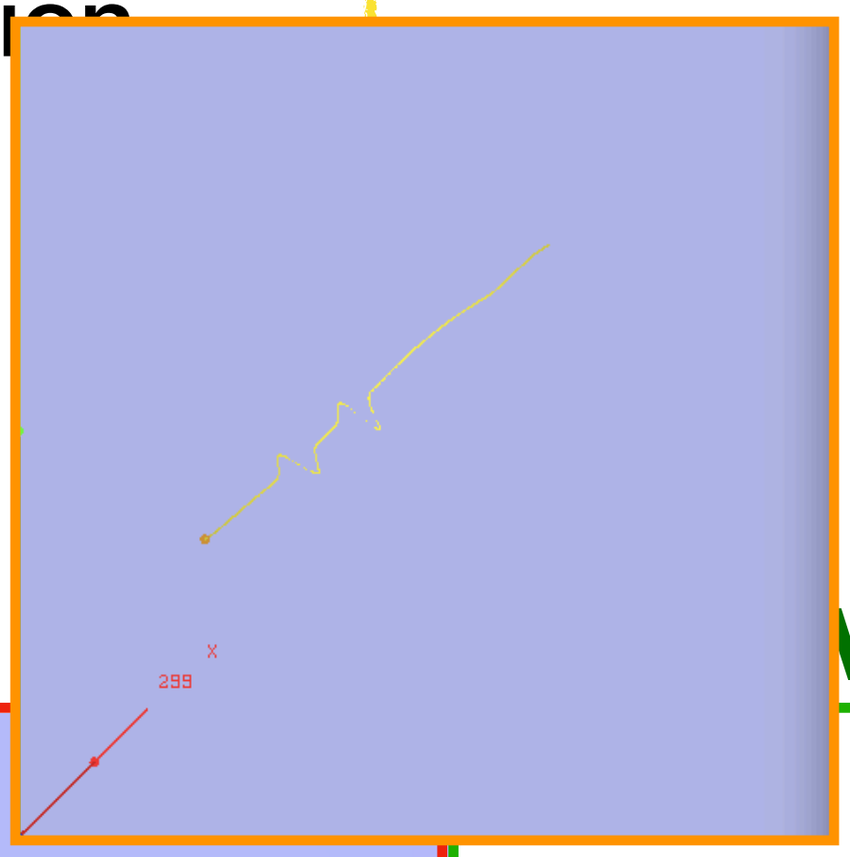
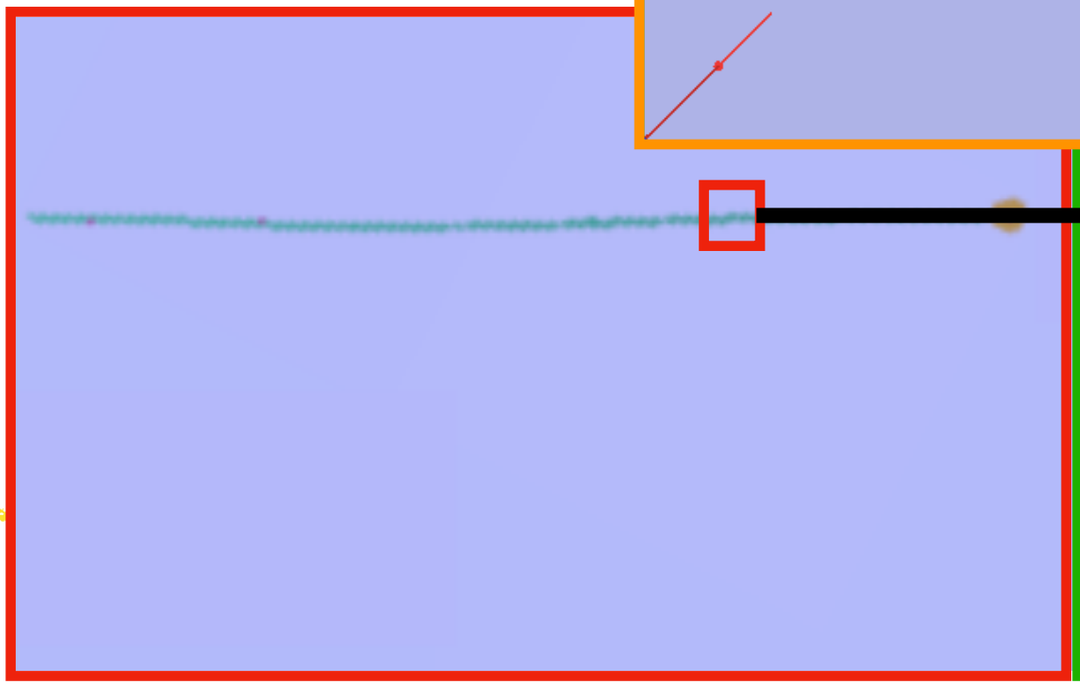


View



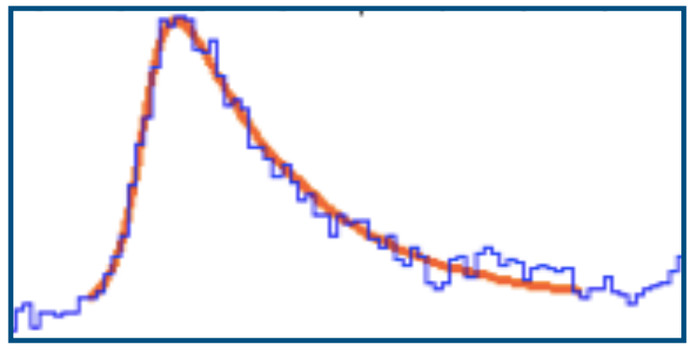
View 1

Issue of view parallelism

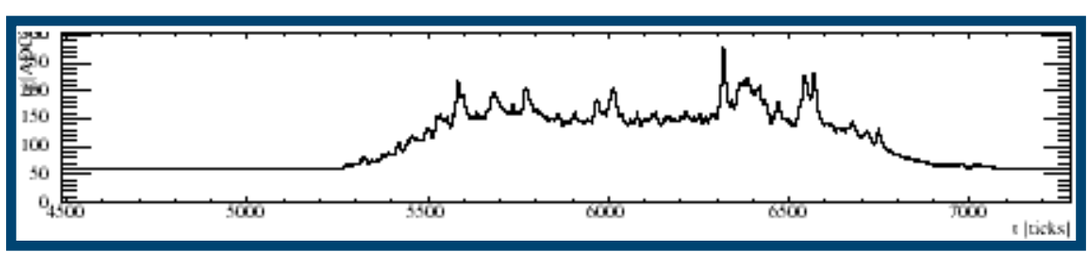
Currently reconstruction algorithms are facing two major problems :

1. Horizontality
2. View parallelism

Normal waveform



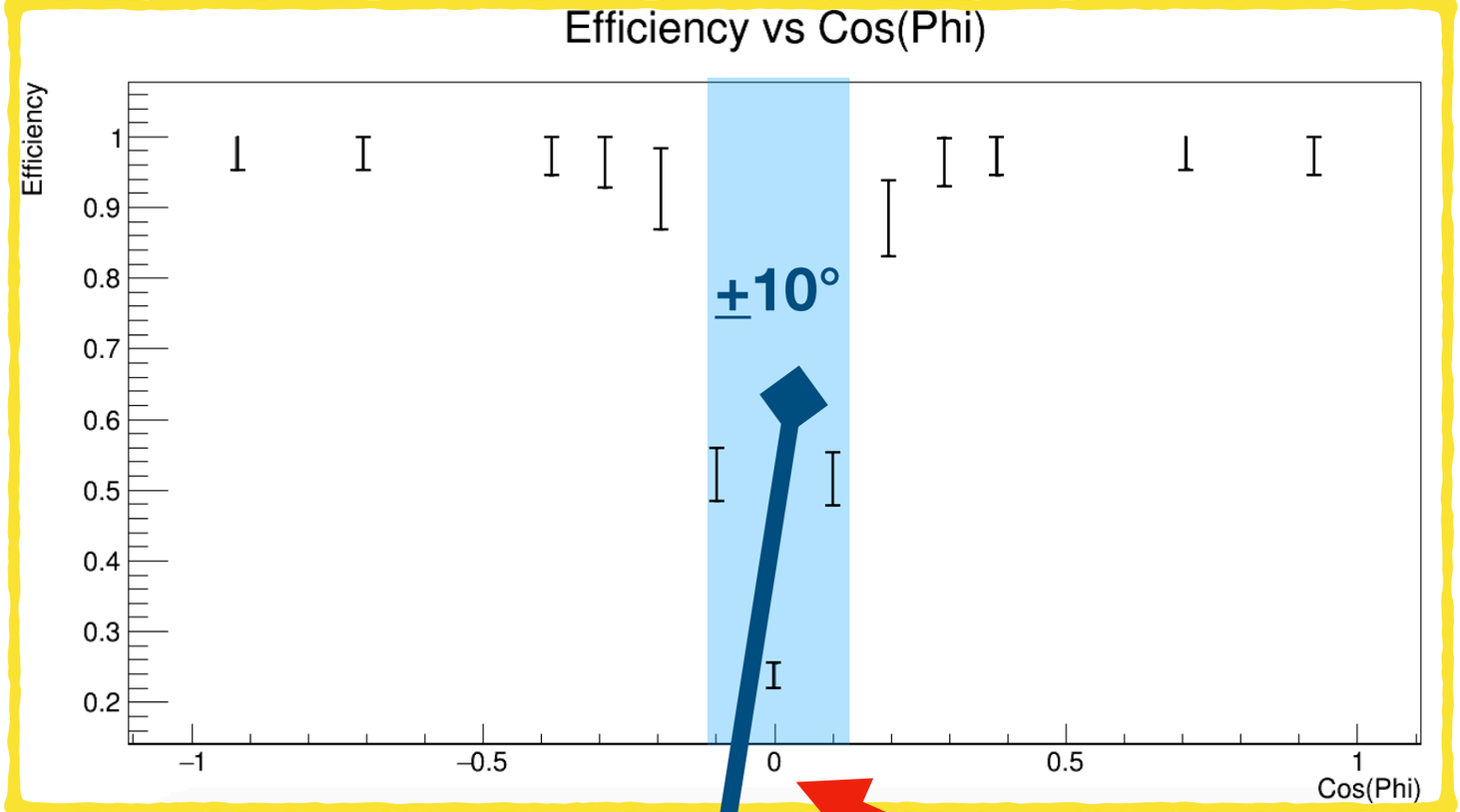
Might look more like this…
much harder to fit

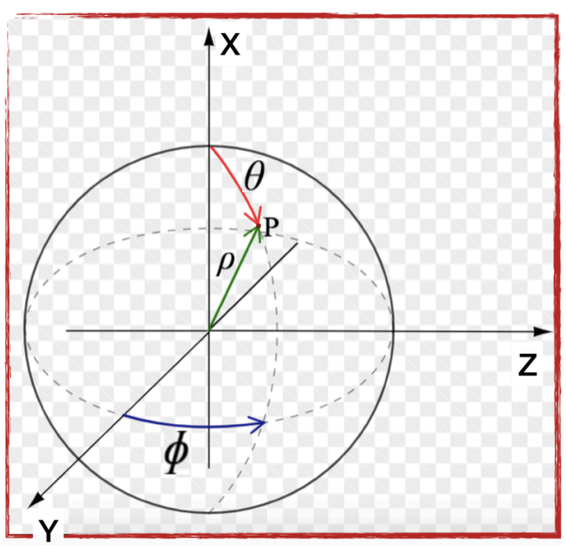


Issue of view parallelism

One example...

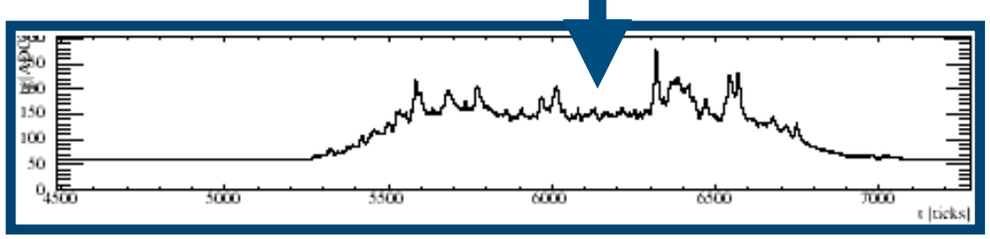
- 30k muons
- Horizontal angle (ϕ) scan from 0 to 180°





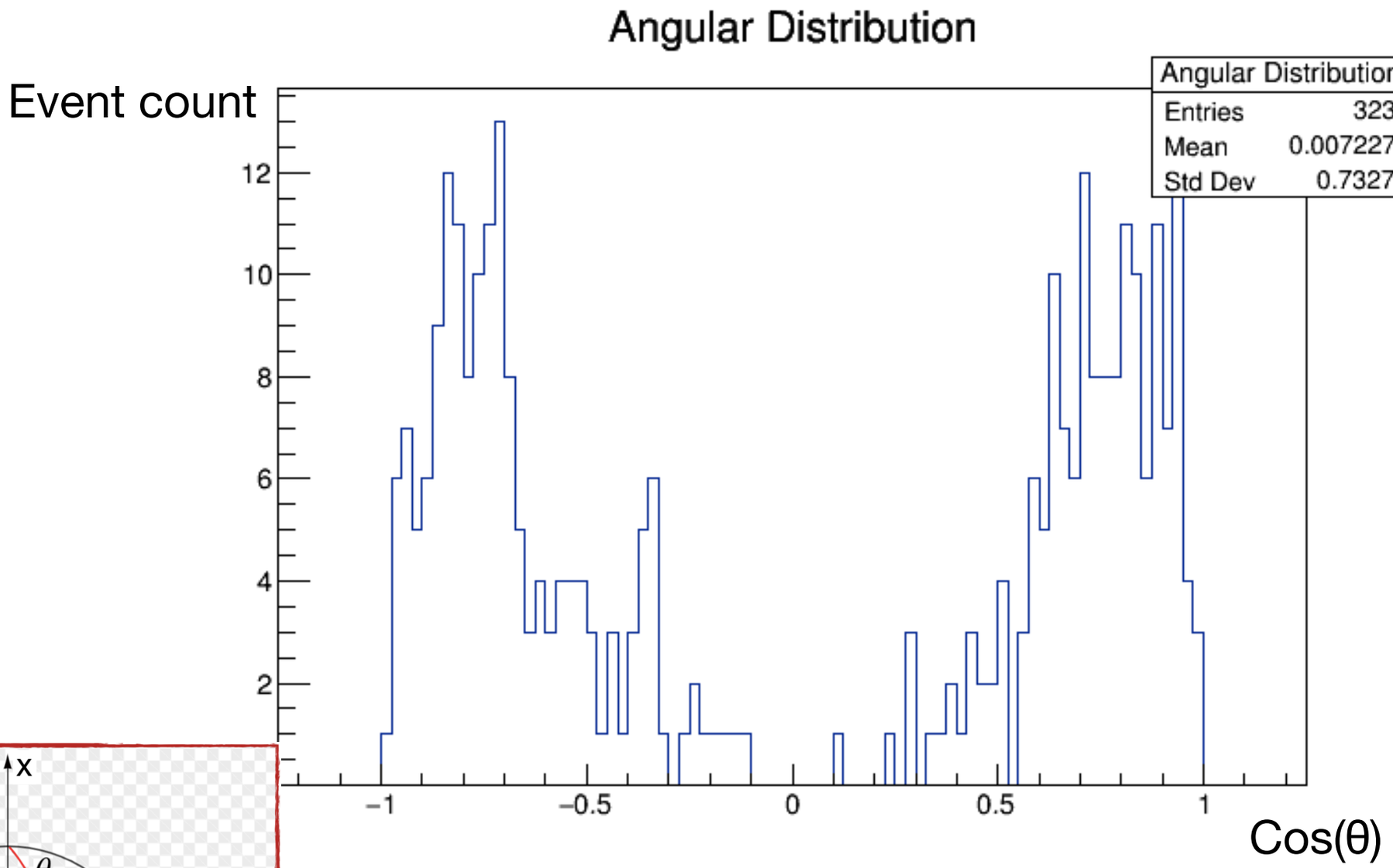
Parallel muons

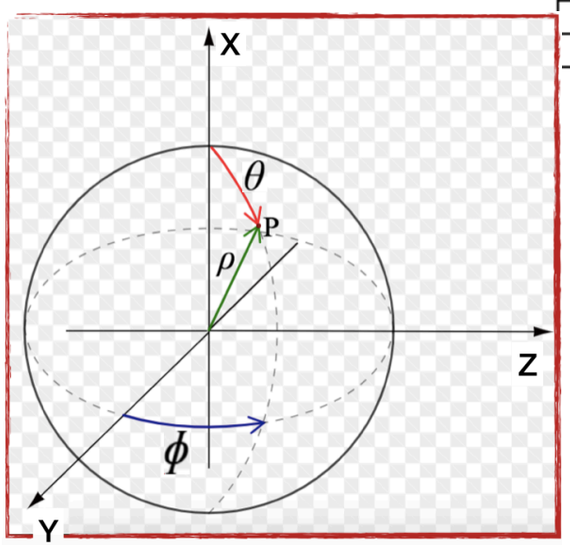
When inside this band (<±10° from parallel)



Some work on data

Vertical angle (θ) distribution of reconstructed cosmics





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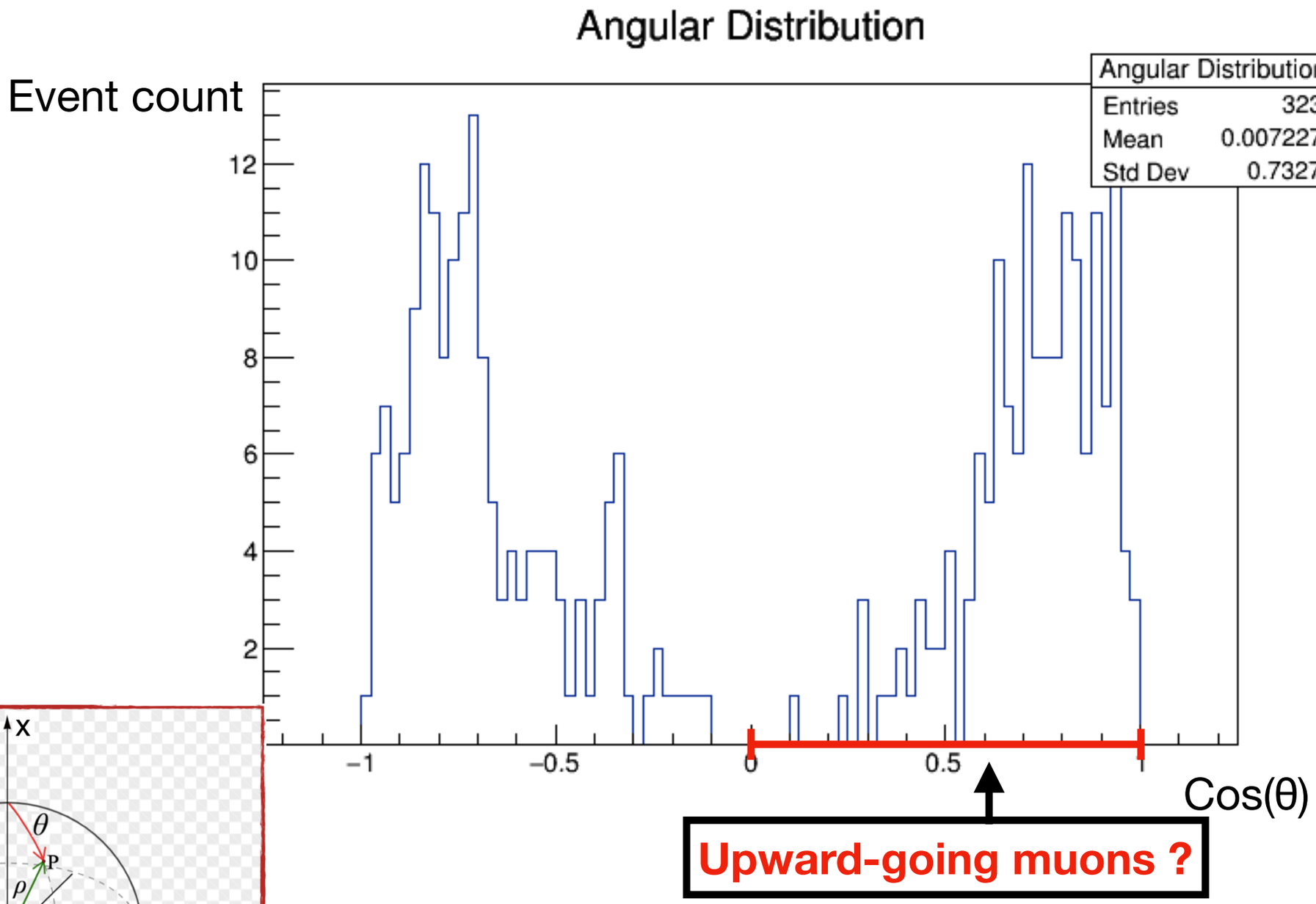

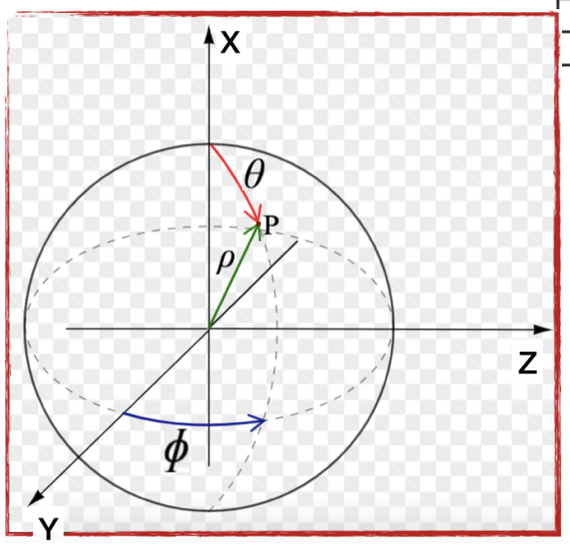

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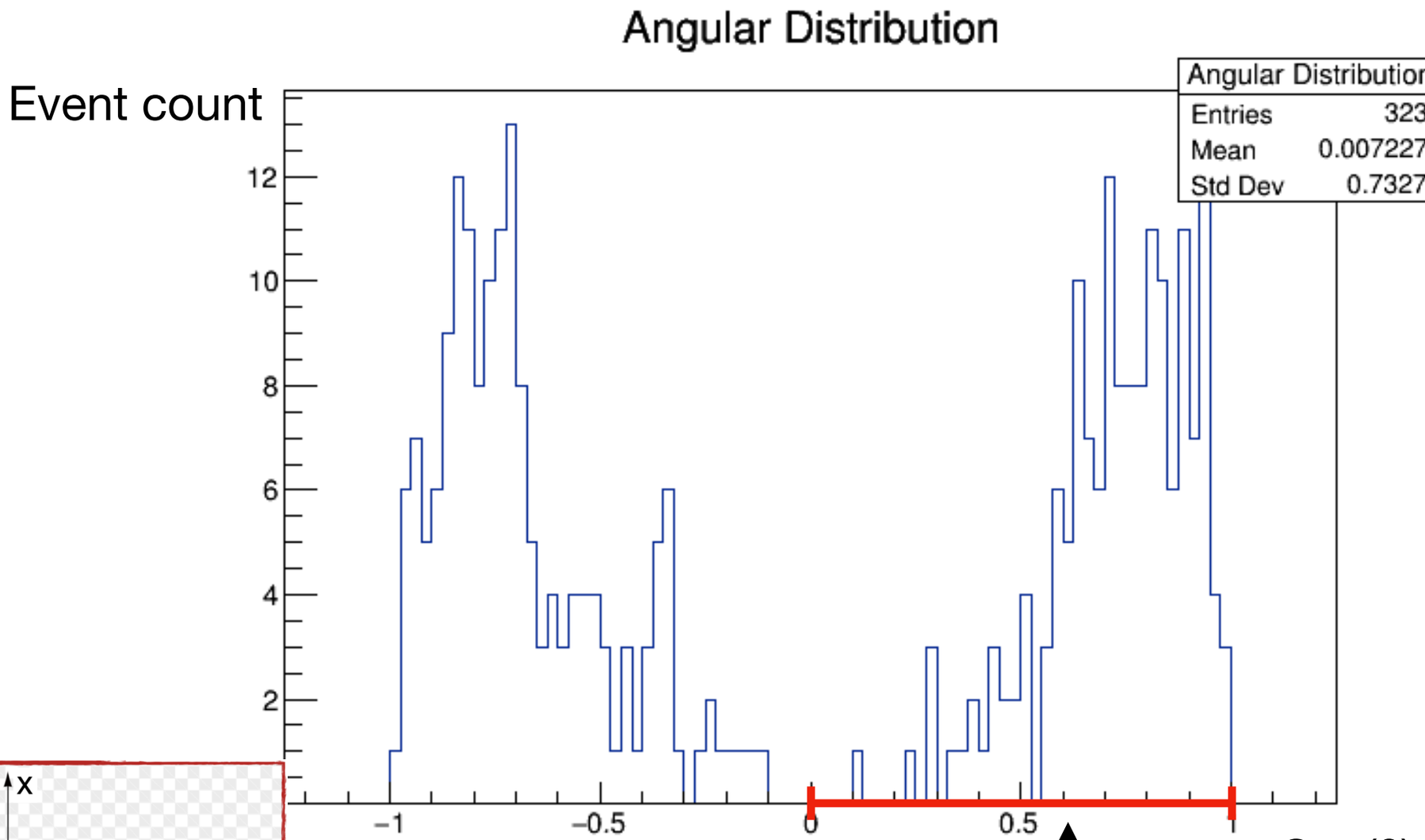
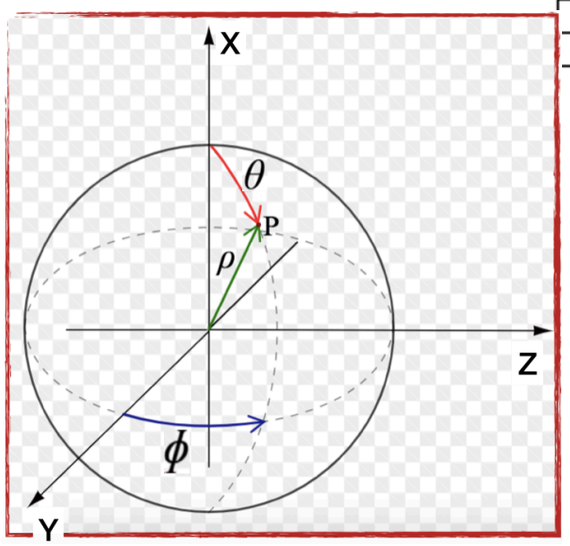


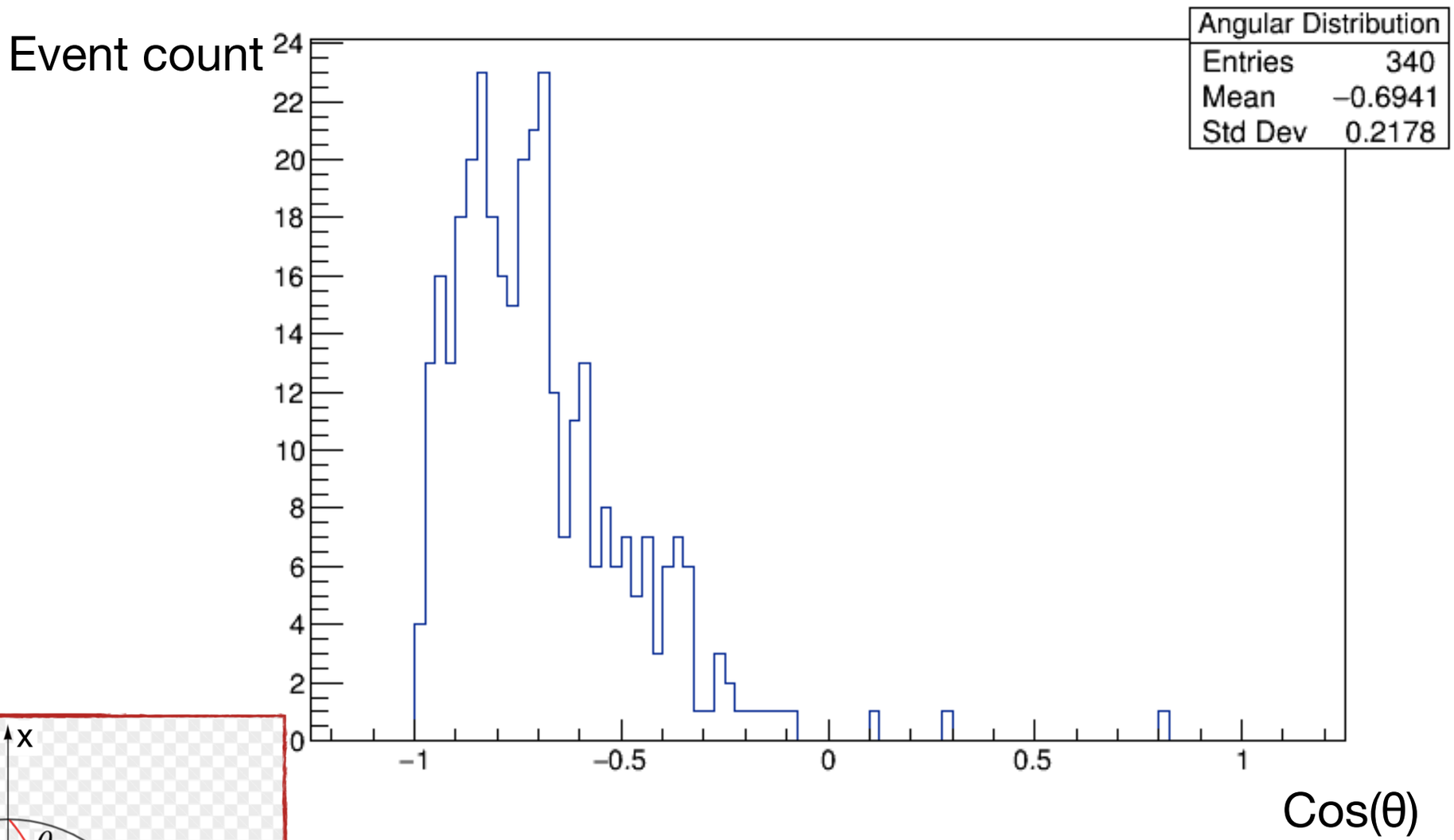


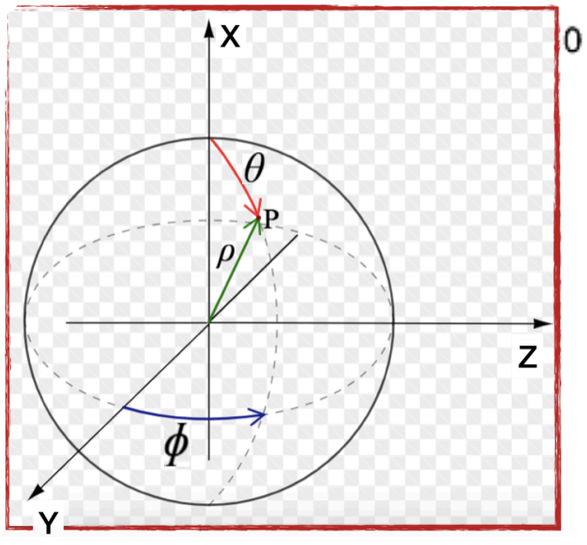
Upward-going muons ?

Reconstruction algorithm was made for Single-Phase geometry

Some work on data

Vertical angle (θ) distribution of reconstructed cosmics





Modified vertex finding algo to choose hit with highest X instead of highest Y

Summary and future plans

- DUNE experiment is expecting to measure
  - ✳ θ_{23}
  - ✳ δ_{CP}
  - ✳ Mass hierarchy
- Dual-Phase prototype of the far detector is taking data
- Dual-Phase technology is a big challenge

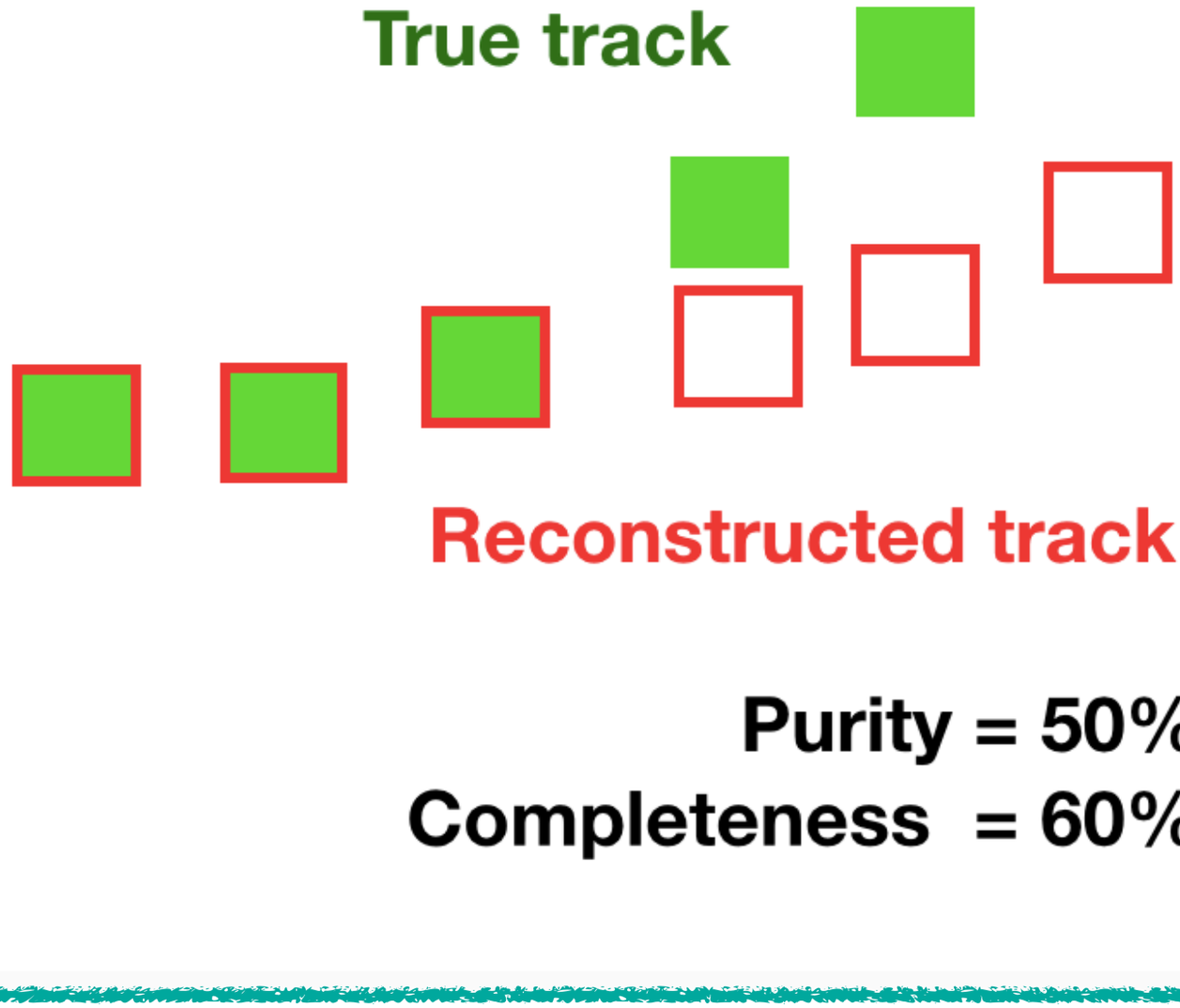
- Change Hit reconstruction algo for parallel tracks
- Change 3D matching algo for horizontal tracks
- Include charge info in the 3D matching decision

TL;DR I spend too much time on my computer

Reconstruction performance

2 quantities are used to **evaluate the quality** of the reconstruction:

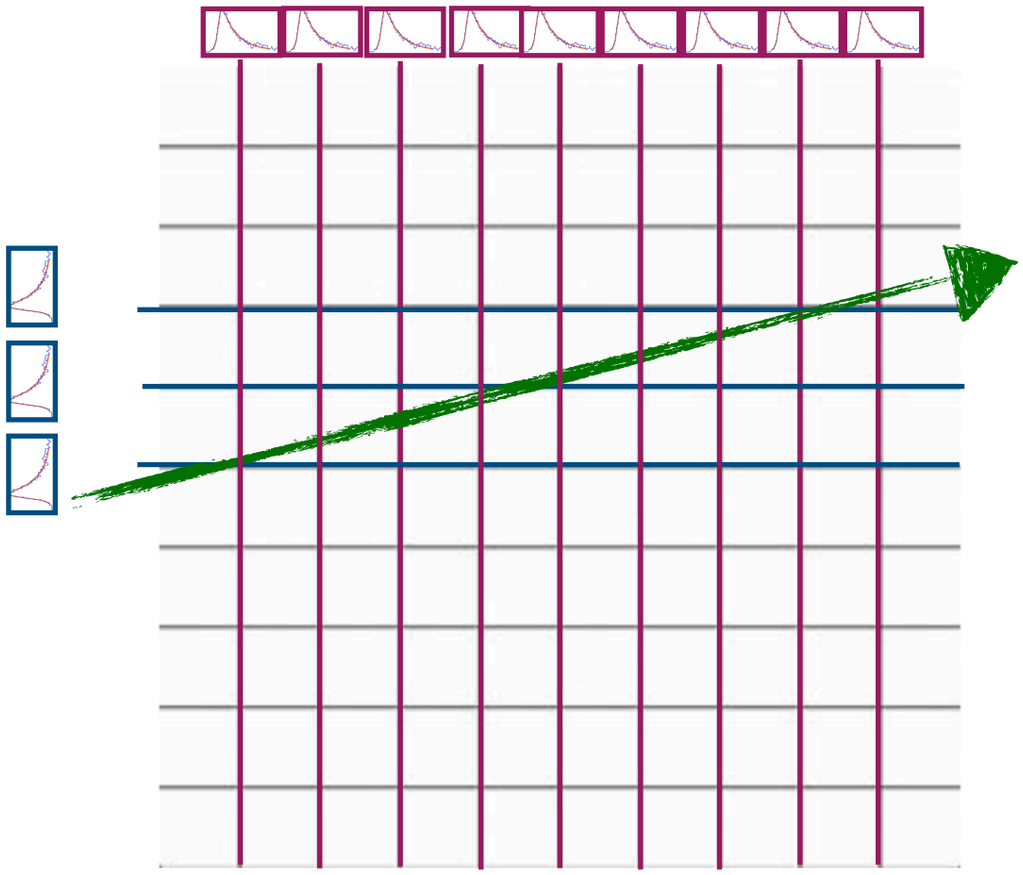
- **Purity**
  Proportion of the reconstructed track that actually belongs to the true track
- **Completeness**
  Proportion of the true track that is contained in the reconstructed track



DUNE's Dual-Phase Liquid Argon TPC

Details on signal collection

Sketch of the Dual-Phase CRP

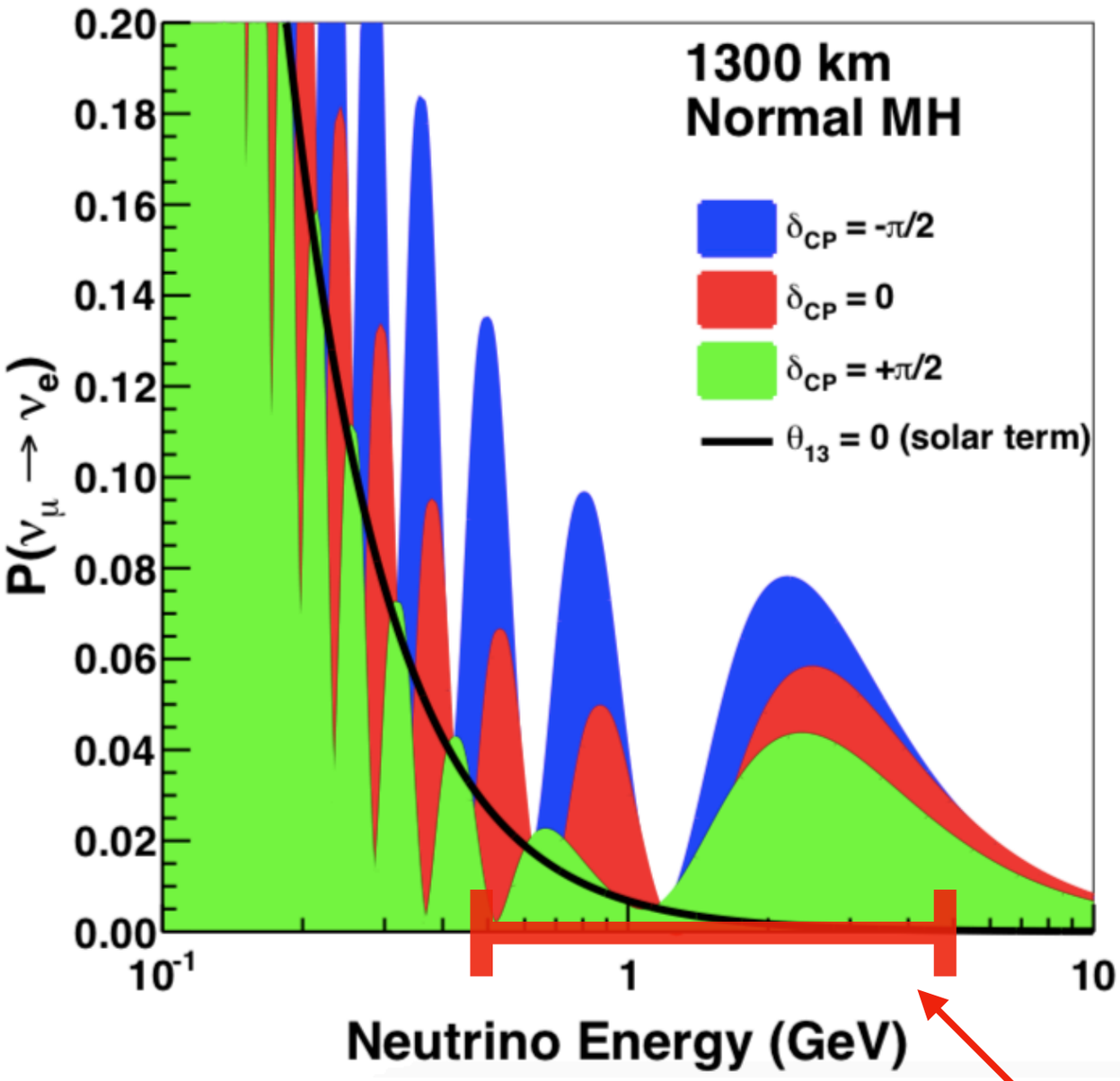


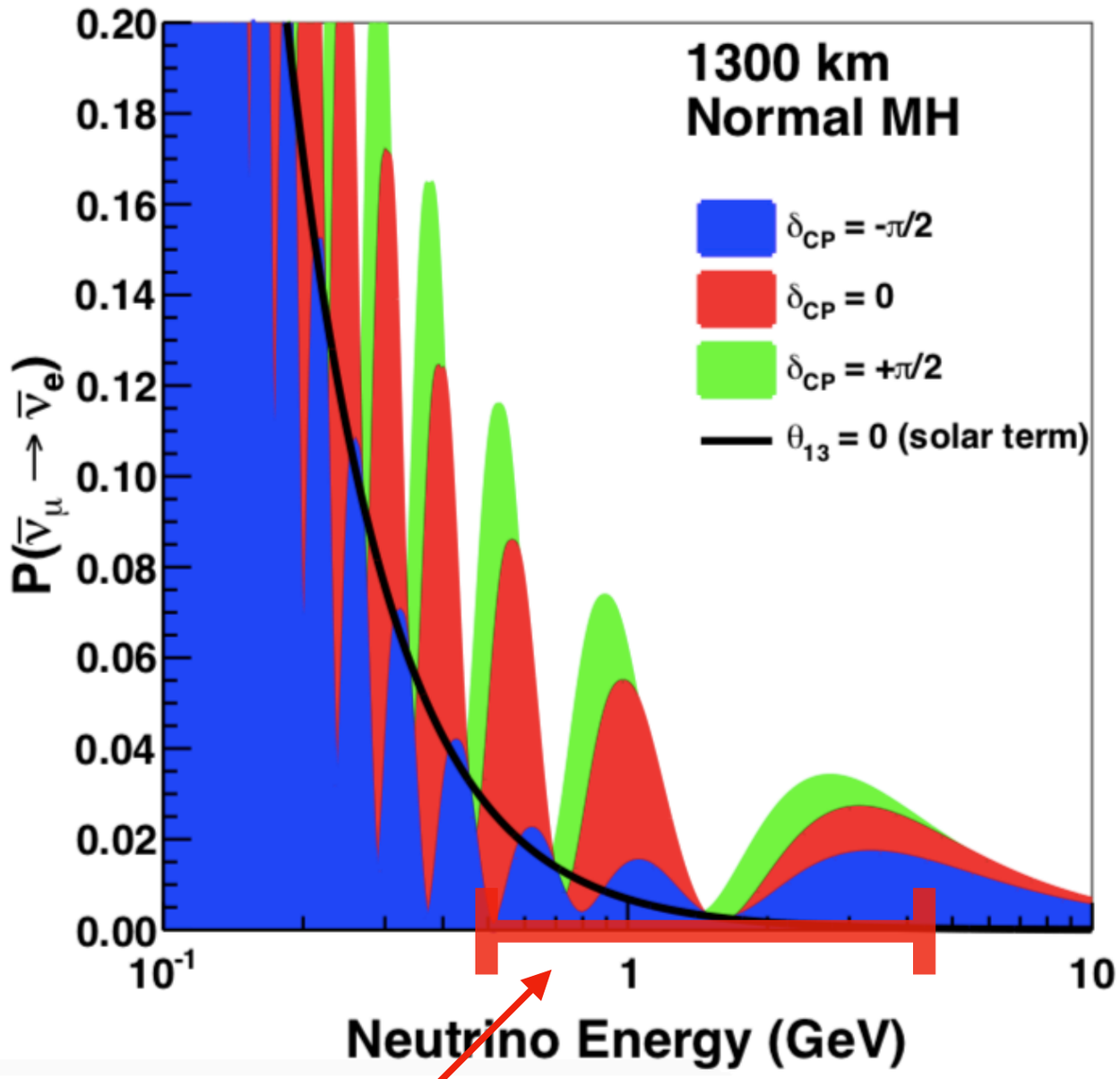
Wires for View 0

Wires for View 1

One view = Vertical (X) + Horizontal (Y or Z)

More about the oscillations

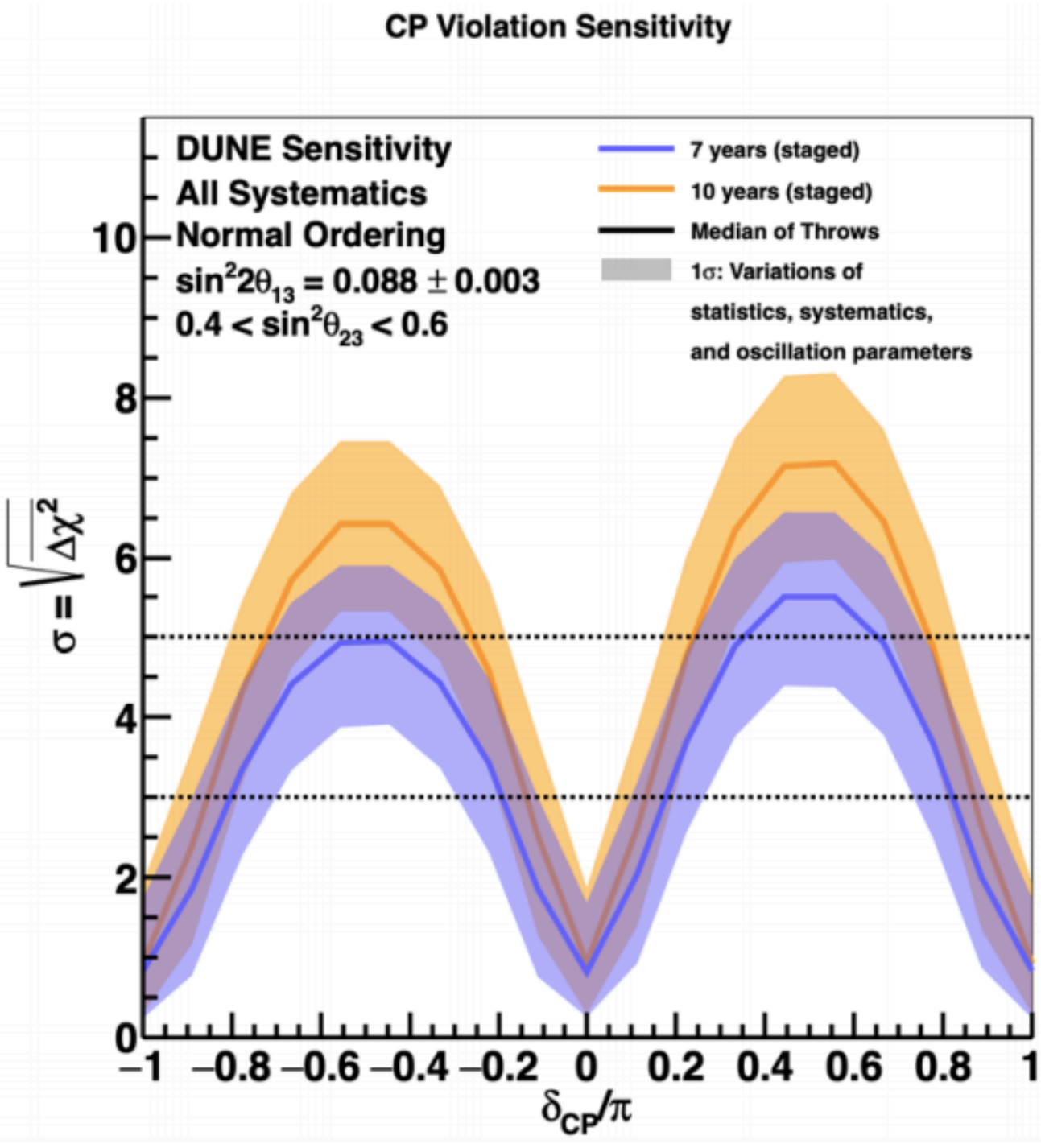


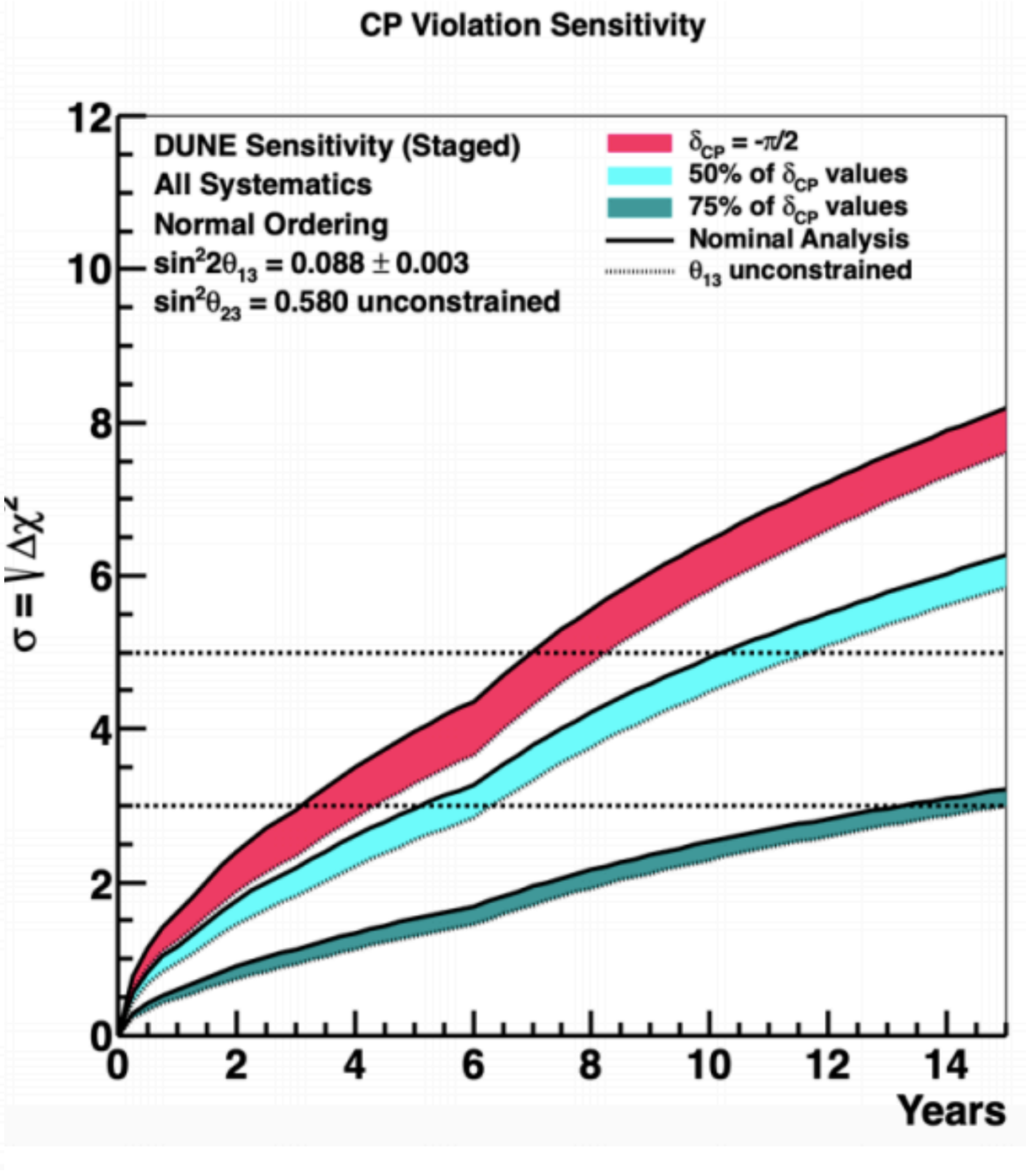


DUNE energy range

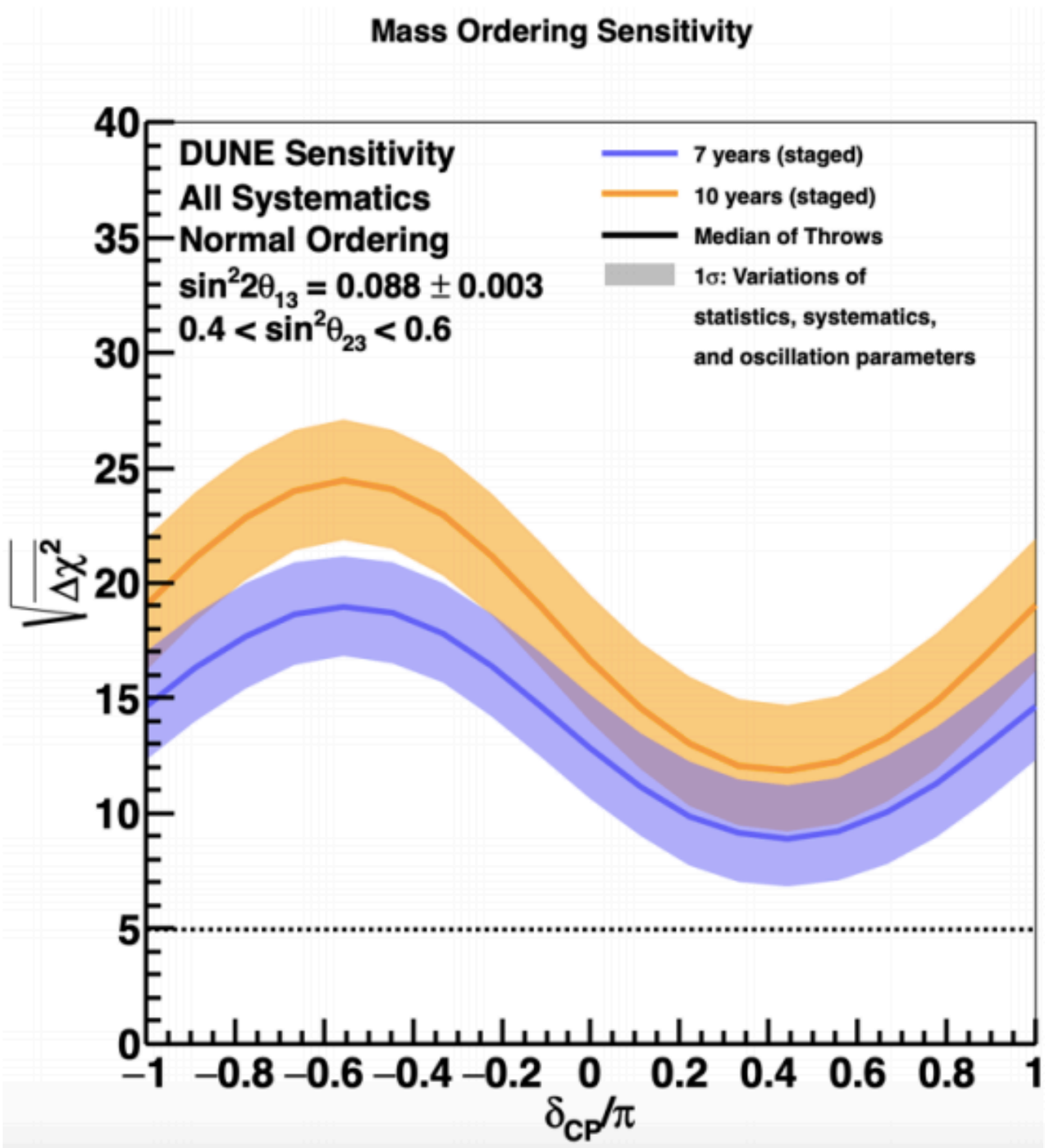
Two maximum available for fitting

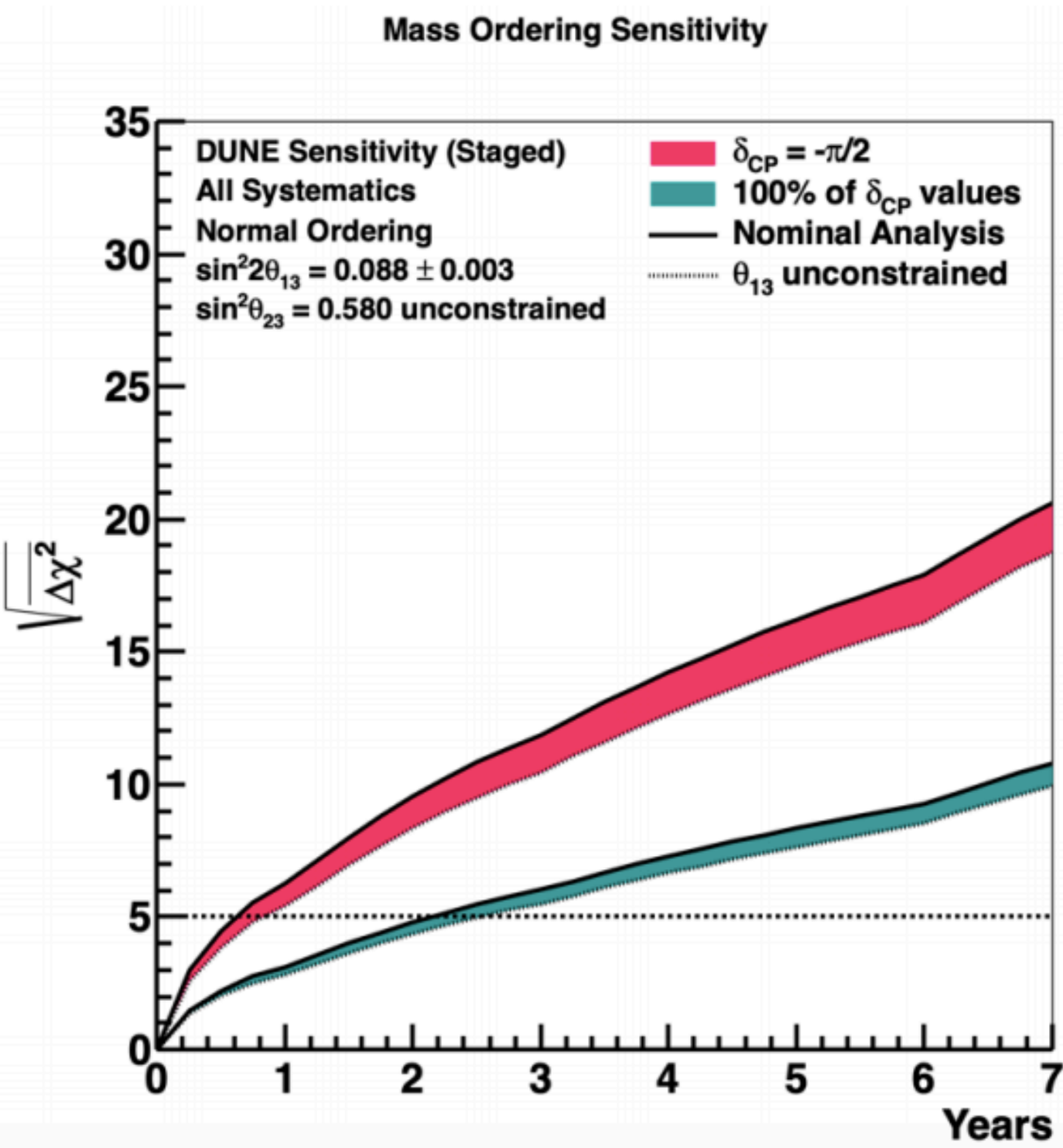
Plot sensitivity δ_{CP}



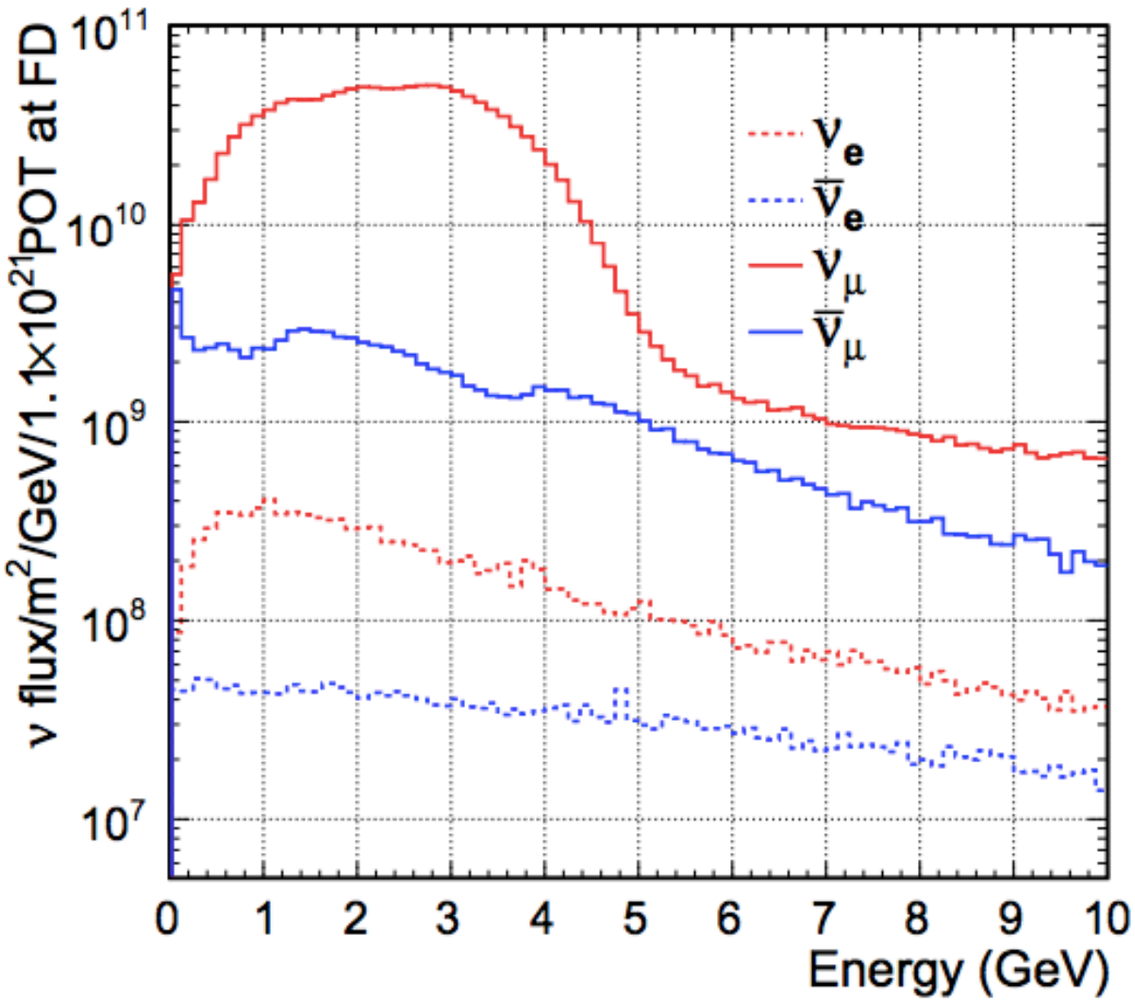


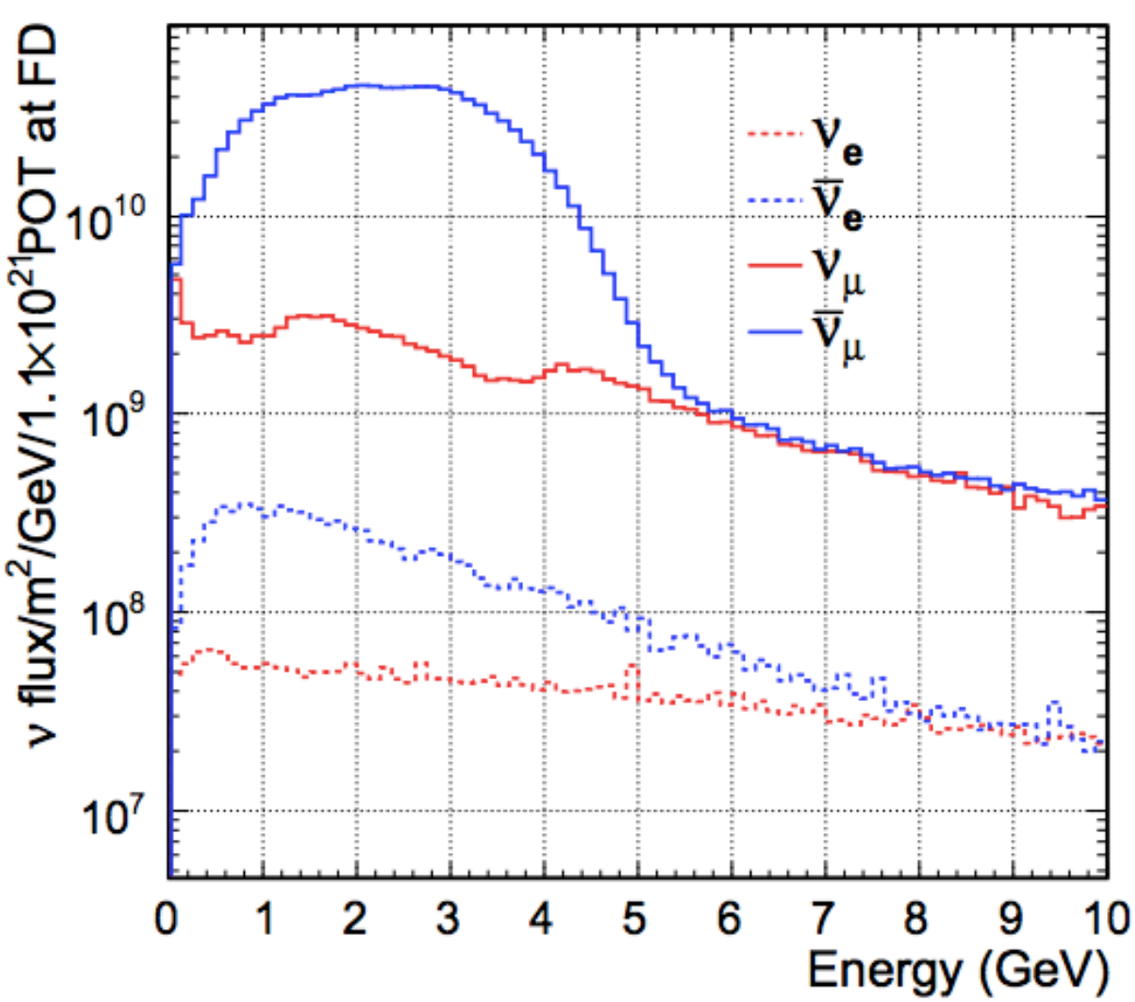
Plot sensitivity
Mass Hierarchy





Flux


ν flux/m²/GeV/1.1×10²¹POT at FD
Energy (GeV)
νe
ν̄e
νμ
ν̄μ


ν flux/m²/GeV/1.1×10²¹POT at FD
Energy (GeV)
νe
ν̄e
νμ
ν̄μ

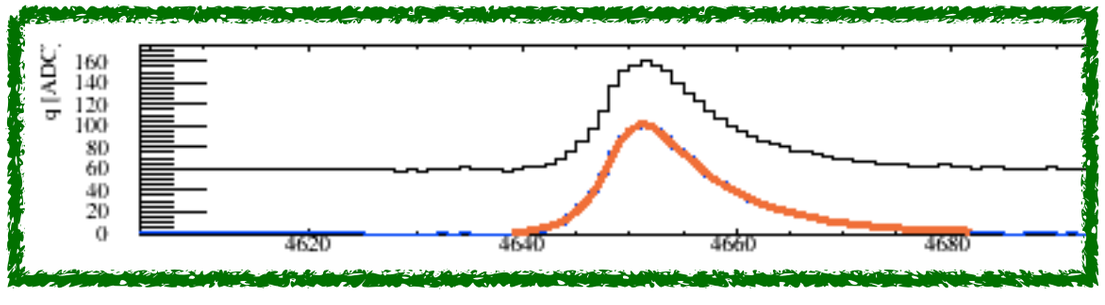
Rates

Expected Events (3.5 years staged)	
ν mode	
ν_μ Signal	6200
$\bar{\nu}_\mu$ CC background	389
NC background	200
$\nu_\tau + \bar{\nu}_\tau$ CC background	46
$\nu_e + \bar{\nu}_e$ CC background	8
$\bar{\nu}$ mode	
$\bar{\nu}_\mu$ Signal	2303
ν_μ CC background	1129
NC background	101
$\nu_\tau + \bar{\nu}_\tau$ CC background	27
$\nu_e + \bar{\nu}_e$ CC background	2

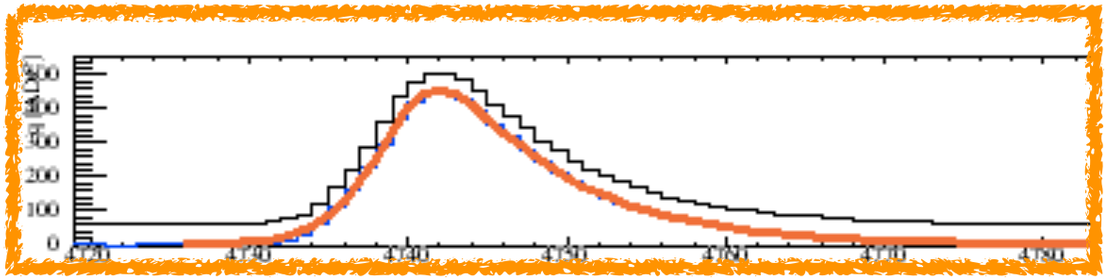
Expected Events (3.5 years staged)	
ν mode	
ν_e Signal NO (IO)	1092 (497)
$\bar{\nu}_e$ Signal NO (IO)	18 (31)
Total Signal NO (IO)	1110 (528)
Beam $\nu_e + \bar{\nu}_e$ CC background	190
NC background	81
$\nu_\tau + \bar{\nu}_\tau$ CC background	32
$\nu_\mu + \bar{\nu}_\mu$ CC background	14
Total background	317
$\bar{\nu}$ mode	
ν_e Signal NO (IO)	76 (36)
$\bar{\nu}_e$ Signal NO (IO)	224 (470)
Total Signal NO (IO)	300 (506)
Beam $\nu_e + \bar{\nu}_e$ CC background	117
NC background	38
$\nu_\tau + \bar{\nu}_\tau$ CC background	20
$\nu_\mu + \bar{\nu}_\mu$ CC background	5
Total background	180

3 different types of waveform encountered with muons

Non-parallel muon



Horizontal parallel muon



Non-horizontal parallel muon