Reconstruction in the DUNE Near Detector Muon Spectrometer

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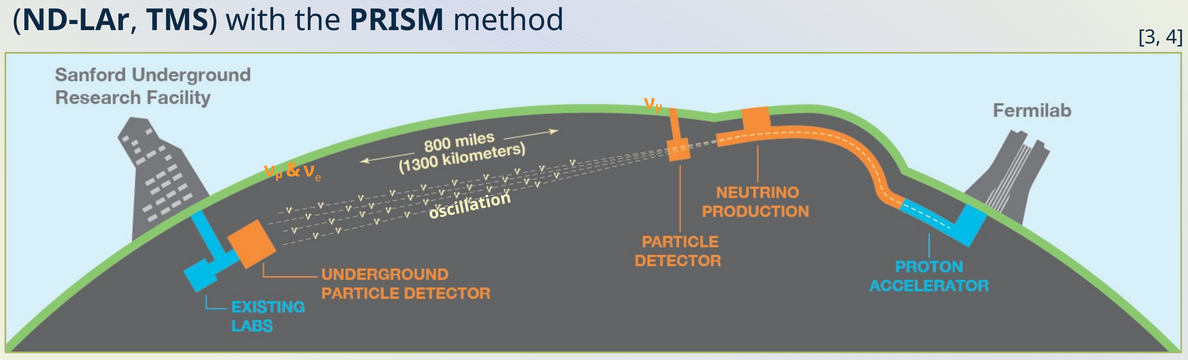
Digital version with alt text

DUNE – Deep Underground Neutrino Experiment

Next generation **long baseline neutrino experiment** based at Fermilab, USA

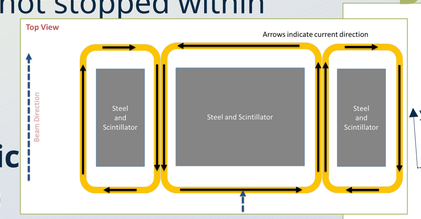
- Precision measurements of **ν oscillation ($\sin^2\theta_{23}$)**, origin of matter (**CP violation**), unification of forces (**proton decay**), black hole formation (**SN neutrinos**)
- Near detector complex with on-axis (**SAND**) and off-axis movable components (**ND-LAr**, **TMS**) with the **PRISM** method

[3, 4]

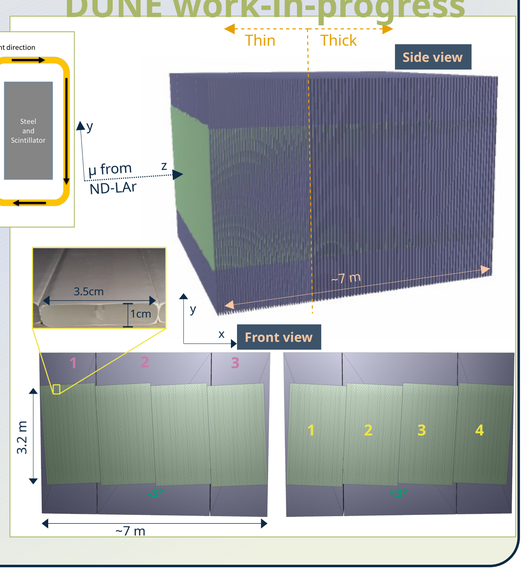


TMS – The Muon Spectrometer

- Detect and measure **muons** not stopped within upstream ND-LAr
- **Magnetic field** of 1T by coils
- **Alternating steel and plastic scintillator** (100 layers each)
- **Steel** in **3 plates**, 2 cm gaps in between plates
  - Upstream 40 layers **1.5 cm thin**
  - Downstream 60 layers **4 cm thick**
- **Scintillator** in **4 panels** each with 48 bars
  - Readout by WLS fibers and top-mounted SiPMs
  - Scintillator layers are alternately **rotated by 3°**



DUNE work-in-progress

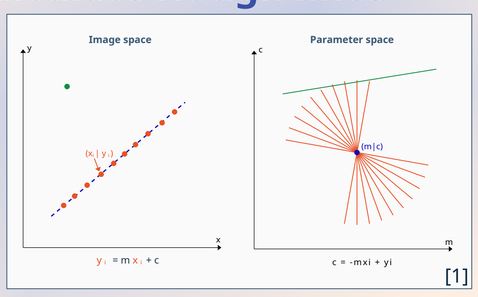


Reconstruction for TMS

1) Cluster hits in time (time slicing)

2) Hough transformation – calculate Hough lines

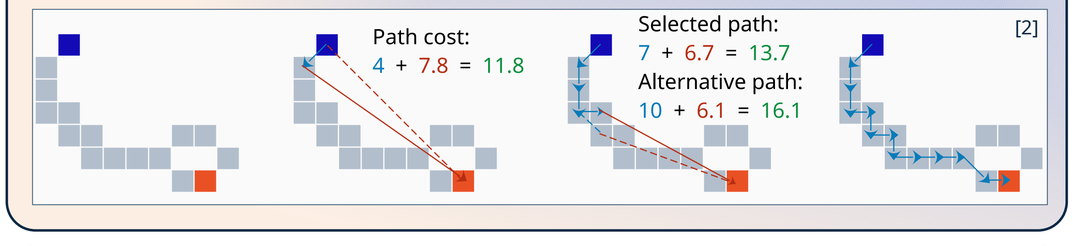
- **Point** in image space is **line** in parameter space
  - All slopes and intercepts that can result in this point
- **Points** on **same line** in image space are **lines** with **one crossing** in parameter space
  - Representing the image space line's slope and intercept



[1]

3) A* algorithm – shortest path from start to end

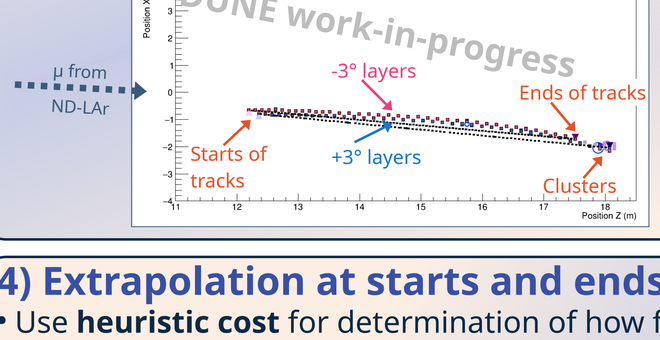
- **Two costs** to determine most efficient path from start to end
  - **Heuristic cost**: 'how far away is the end?'
  - **Connection/ground cost**: 'how far away is the next potential cell?'
- Each cell has **inherent heuristic cost**
- For each connection the **connection/ground cost** is **calculated**
- Choose connection with **lowest sum of both costs**



[2]

Status of reconstruction after Hough and A*

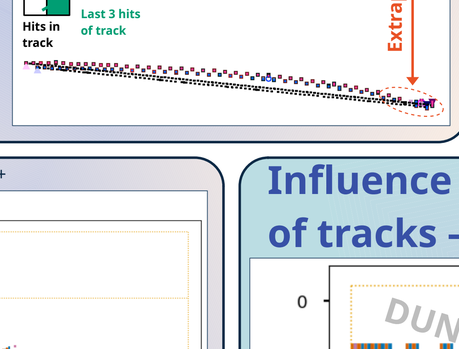
Separate reconstructions for the different oriented layers (±3°)



Near detector complex coordinate system: start of TMS at ~11m

4) Extrapolation at starts and ends of tracks

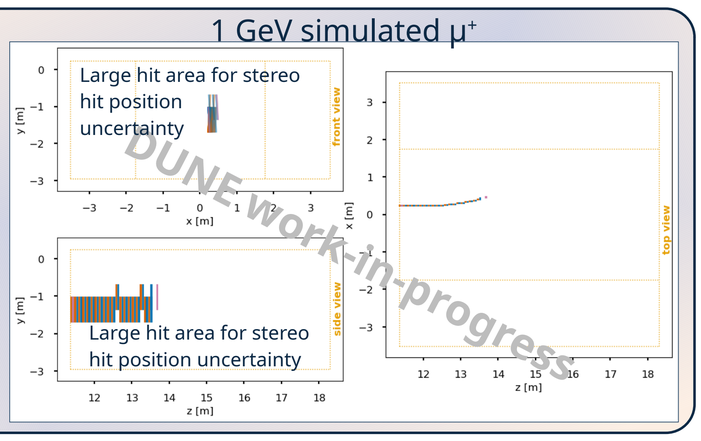
- Use **heuristic cost** for determination of how far away hit is from end of track
- Use only hits that are **within 2 or 4 bar widths** from direction line to be added
- If suitable hit found, connect with **A* algorithm** up to certain **limit**
  - **Higher z** than end of track a.t.m. for direction and **within** certain **distance from end of track**
  - Hit **within 2 or 4 bar widths** from direction line
  - **Up to** sum of both limits



5) 3D matching of tracks

- Match ends of tracks if close enough
  - **Close enough at start and end**: ±3 layers and within 12 bar widths
  - **Close enough in time**: in same time slice + within 30ns
- Put all hits of both tracks into one new
  - **Calculate y coordinate** per orientation pair

1 GeV simulated μ^+



Simulation flow

DUNE work-in-progress

Event kinematics generator: GENIE (3.4) | Particle gun

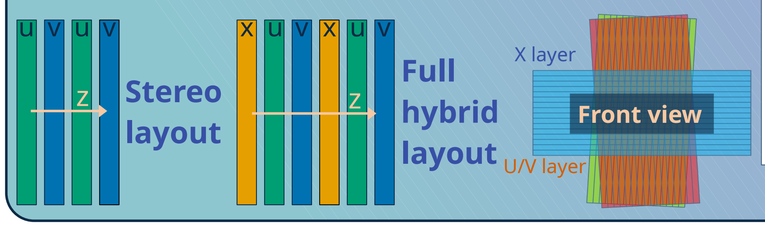
Geometry definition (gdml)

Energy deposition simulation: Generates particles according to event kin. gen. and propagates them in the defined geometry

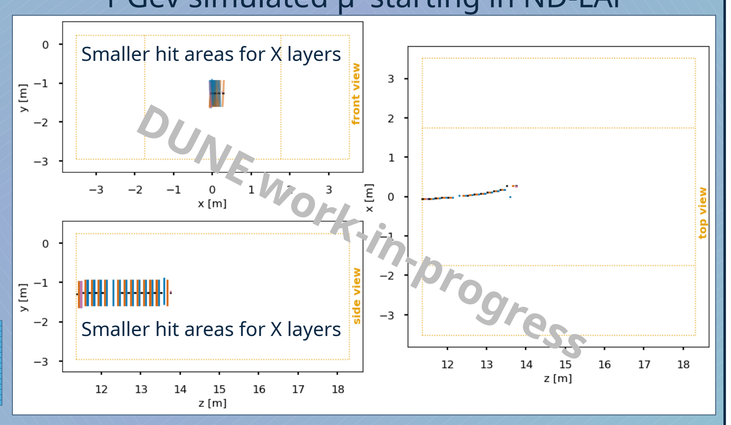
GEANT4 (10.2)

Adding a third orientation

To allow for studies of different geometries the reconstruction was adapted to also use **hits from X (90°) layers** in the matching. This allows for a much **finer reconstruction** of the **y position of a track**.



1 Gev simulated μ^+ starting in ND-LAr



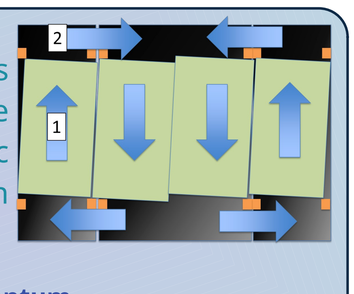
Different geometry layouts – why?

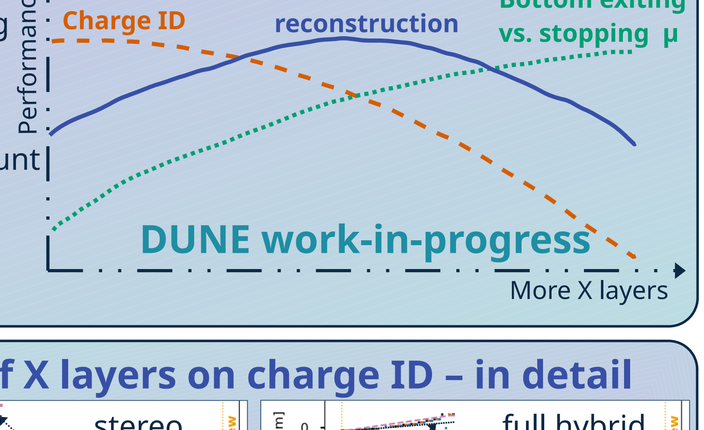
The **stereo layout** with ±3° (U/V) layers has advantages in bend direction (x) but disadvantages in up/down (y)

- Good for **charge ID**
  - Determined by curvature/deviation from straight line
- Bad for **stopping vs exiting muon**
  - Missing/vague information for some down-pointing tracks
- Good and bad for **track length** reconstruction
  - Good in x, bad in y. Both should be taken into account for a correct reconstruction

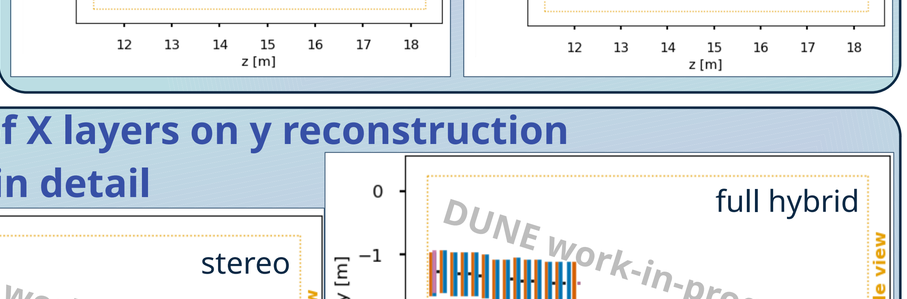
Adding **90° rotated (X) layers** could help with disadvantages of layout.

The arrows indicate the magnetic field direction





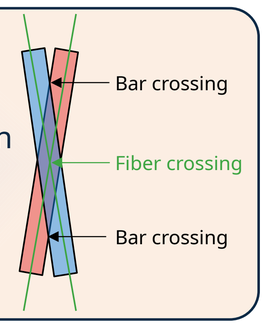
Effect of X layers on charge ID – in detail



Influence of X layers on y reconstruction of tracks – in detail

Calculation of y position

- Layers are tilted against each other by 3°
  - Use **x position of the hit scintillator bars** → calculate geometry y position
  - y = 'Anchor point' in y – ½ tan(90° - 3°) $|x_{bar,1} - x_{bar,2}|$ (fiber crossing)
- The true hit can be anywhere in the **crossing area** though
  - From **fiber crossing** to top of **bar crossing**: ~34cm → uncertainty



More information

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