The DUNE ND Simulation framework.

AHCAL Main Meeting

Eldwan Brianne
DESY
Hamburg, 13th December 2018
Outline.

1. Motivation
2. ND Simulation framework
3. First optimisation results
4. Outlook and Conclusion
Motivation.
A case for a highly granular calorimeter

Near detector design

- Revolves around a **Liquid Argon TPC** and a **HPgTPC** surrounded by an **ECAL**, a **magnet** and a **muon detector**
- HPgTPC does not have to capabilities to track converted $\pi_0$
  - **Very high granular** ECAL needed!
  - **Reconstruction** of the $\pi_0$ vertex
- **Challenge**: Very low photon energies ~ few 10 to few 100 MeV

[Diagram of near detector design with labels for ArgonCube, HPgTPC, and ECAL]

Photon spectrum from $\pi_0$ decays

[Graph showing photon spectrum with kinetic energy in GeV on the x-axis and counts on the y-axis]
The DUNE ND Simulation framework.
A very versatile software

Framework

- Revolves around ‘art’ → developed by FNAL (used by many ν exp: NOvA, Microboone, DUNE FD…)
- Software divided in services and modules
  - Services → provides geometry, root files handling, internal conditions/functionality
  - Modules → user-managed (analysis, plugins to perform specific tasks..)

Basic event flow

- **G4 simulation** (single particle or neutrinos with GENIE)
- **Readout simulation** (GArTPC/ECAL digitisation/segmentation)
- **Event reconstruction** (track fitting, energy reconstruction, clustering…)
- **Event display** to check all steps
Former ND Geometry design.

ECAL Geometry

- **Geometry:**
  - Redesign of the ECAL \(\rightarrow\) **cylindrical shape** around the TPC
  - New geometry code \(\rightarrow\) courtesy of M. Kordosky with gegede

- **Optimisation** of the geometry code
  - Remove the *explicit description* of each tile
    - \(\rightarrow\) **Simplify** geometry layout
    - \(\rightarrow\) **Faster loading** with G4 and ROOT

- Baseline design
  - 2 mm Cu absorber
  - 5 mm Scintillator
  - 1 mm FR4 (electronics)

- + **integrate other sub-detectors** (ArgonCube + 3DST)
New Geometry Design.

Taking into account the physics

- Mostly physics is going **forward** (~ fixed target experiment)
  - May not need same depth/granularity everywhere
  - However, requires some **understanding and optimisation**

- **First thought:**
  - **Downstream** region with High resolution/granularity
  - **Upstream** region + **Endcaps** with Low resolution/granularity
  - Variable longitudinal segmentation:
    - Thin layers in front for good $E_{\text{res}}$ for low-E photons
    - Thicker layers in the back for containment while keeping compact detector

- **First implementation:**
  - Stave implemented (Barrel with 5 modules and Endcap with 4)
  - Same stave thickness for now downstream and upstream
Simulation with Geant4.

The physics!

- Generate single particle or neutrino events
- **User-defined** step treatment
  - Treatment of TPC hits
  - Treatment of other detectors (ECAL, LAr…)
  - → **Convert** g4 hits into the art framework
- User-defined hit classes containing:
  - **Energy** and **time**
  - **Position**
  - *Any additional information* i.e for ECAL cellID based on geometry and segmentation
Readout simulation.

Detector effects

- **User-specific modules** used for the detector readout
  - *Drift and diffusion* for the GArTPC
  - **SiPM readout and electronic noise** for the ECAL
- Simple readout simulation for the ECAL
  - Based on the *AHCAL experience*
  - Some **assumptions** for Gain, LY, Number of px, dynamic range of the electronics and time resolution → can be changed by user or database later on
- **Segmentation** is implemented here
  - Need some modification now with the new geometry (tile + crossed strips)
  - *Might not be so trivial*
  - Try to **allow for flexible granularity** to facilitate the optimisation study
Reconstruction.
Track fitting, energy reconstruction…

- **Reconstruction modules** handling:
  - Track fitting in the TPC → **ongoing work at FNAL, very promising**
  - Vertex finding (for nu events)
  - **Calorimeter energy reconstruction**

- So far very basic and simple for the ECAL
  - Calibration to MIP, SiPM saturation correction and conversion to MeV

- **In the future**: Try to keep as much as information as possible
  - Clustering, PCA
  - Particle ID
  - $\pi^0$ reconstruction
  - Integration with *PandoraPFA*? (FD is using one Pandora implementation)
Current status.

Some eye candy

- Geometry is generally done and checked
- Software modification is ongoing
  - Simulation is now running with the new geometry
  - Segmentation is the next step
- Continue optimisation of the detector
  - Coordination between Munich/Mainz/DESY
  - Hope for first results with this new geometry by the end of the year/new year
First optimisation results.

**Previous results**

- Lots of work ongoing
- Most previous studies done by Lorentz
- Ongoing at DESY and Mainz (Jan Schaeffer)
- **Very large phase-space** to cover:
  - Absorber thickness
  - Pressure Vessel
  - Granularity
  - Number of layers
  - Scintillator thickness
  - ...
- → **Understand performance** of the detector concept
- → **Scaling** with parameter variation and limitations
Outlook & Conclusion.
Towards a high granular ECAL for a neutrino experiment

- **ECAL for the ND is a challenge**
  - **High granularity** is important to help in photon reconstruction and pointing.
  - Help to locate the primary vertex of $\pi_0$
  - **Space constrains** in the HPgTPC impose a specific ECAL:
    - → **High granularity** to provide good angular resolution
    - → **Contain showers** and achieve a good energy resolution

- **ECAL Optimisation**
  - **Angular resolution** depends mainly on the granularity
  - **Energy resolution** depends mainly on absorber type, thickness and pressure vessel
  - *More studies still ongoing* (mix of absorber thicknesses, study within GArSoft…)

- **Software**
  - **New ECAL design** is implemented into art with GArSoft (*few things left to be ironed out*)
  - → **Optimisation studies can continue using the foreseen framework**
Backup Slides.