The DUNE ND Optimization Task Force - GENIE & Geant4

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Fermilab

GENIE

- GENIE ν event generator https://genie.hepforge.org
  - brings together: geometry + flux + ν physics + hadronization/FSI
    - total cross section + flux + geometry ➙ vertex
    - model choices + hadronization/FSI ➙ particles leaving nucleus
- GENIE toolkit vs. application
  - embedded in `nutools` vs. standalone `gevgen_fnal` (formerly `gevgen_numi`)
  - no significant difference ... just integration into ART, configurability
    - possibility of input module for reading GENIE native format
- Geometry: ROOT representation (GDML input is fine)
  - GENIE needs to know ahead of time all the isotopes present
    - Xe131 is a new addition (as was Be earlier this year)
- Flux can take many forms
  - histograms of E ν for each ν flavor
  - simple ν rays: x4 + p4 + flavor (+ aux info)
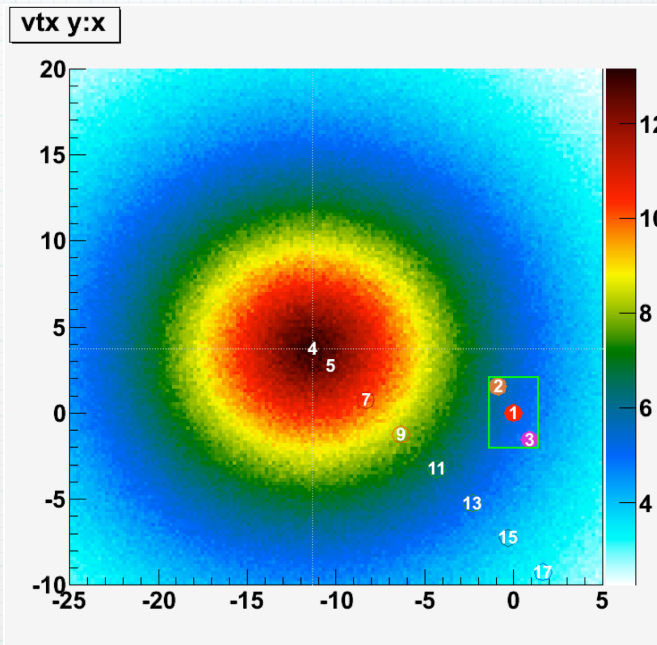 - detailed ntuples (dk2nu) holding ancestor info

GENIE Flux - Histograms

- Histograms … are easy to understand
- But for a NearDet they are misleading
  - don't properly represent the correlation of energy/intensity over the volume of the detector
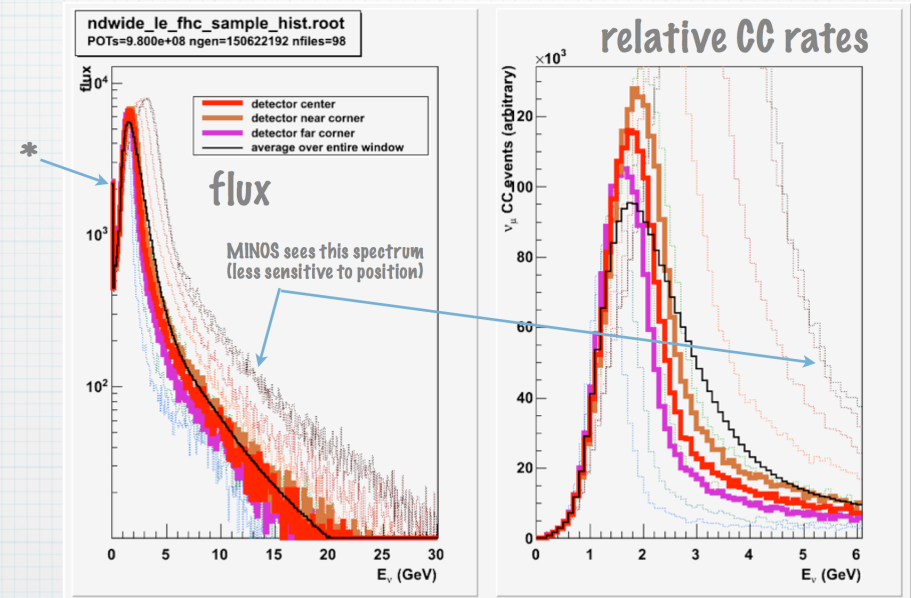 - missing a lot of information that one might want for reweighting or systematics

Where the "v" are

- plot flux intensity
  - irrespective of energy spectrum
- numbered circles represent sample locations
- ND 2x3 = ~green box
- gray crosshairs at beam center

vtx y:x

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Change in Spectrum

ndwide_le_fhc_sample_hist.root
POTs=9.800e+08 ngen=150622192 nfiles=98

flux

*

detector center
detector near corner
detector far corner
average over entire window

MINOS sees this spectrum
(less sensitive to position)

E_ν (GeV)

relative CC rates

$\times 10^3$

ν_μ CC events (arbitrary)

E_ν (GeV)

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GENIE Flux - Dk2Nu

- Ideal … what comes out of the beam simulation
- But not quite integrated into GENIE and/or ART
  - use in `GENIEHelper` (`nutools`) requires GENIE R-2_10_0
  - to fully support it (ancestor info) `MCFlux` needs changes

  - probably all doable by the end of the year

GENIE Flux - GSimpleNtpFlux

- Use existing GENIE flux driver (part of Dk2Nu package) to evaluate the flux over a "flux window", output the results in this form
- This format is completely integrated into `GENIEHelper`
  - an annoying intermediate step …
  - space inefficient
  - doesn't contain all the desired reweighting info (esp. not ancestor list)
    - but does contain more than simple histograms (e.g. parent info)

  - usable today

GENIE - Systematics

- Beyond the flux systematics, GENIE itself has uncertainties
- GENIE provides a mechanism for calculating weights for variations of some parameters it used
  - can't reweight what didn't happen
    - e.g. no MEC generated, no reweighting ..
  - some parameters aren't reweightable
- requires reconstruction of GENIE event record
  - ART `MCTruth` + `GTruth` is sufficient for this
    - GENIE R-2_10_0 will allow fix one minor (insignificant) fix
  - NOvA has a scheme of using this … not entirely happy
  - may need refactorization; reduction of what is varied

  - this will take some work over next 12 months

Geant4 - non-LAr Tech

- Geant4 needs a geometry in memory - it's own format
  - GDML is sufficient to generate this
- `NuTools/G4Base`'s purpose is to make this easy
  - used by both LArSoft and NOvA
    - needs some classes written, registered w/ `UserActionManager`
    - primarily for recording "hits" (energy depositions)

  - this will take some work over next 12 months
  - shouldn't be too difficult to get basics working (year's end)
  - no need to reinvent most wheels on this vehicle:
    - Begin/EndRun
    - Begin/EndEvent
    - Pre/PostTracking
    - SteppingAction
    - Stacking

Geant4 - Systematics

- Geant4 propagates particles out of the nucleus ➛ "hits"
  - depends on collection of physics models — PhysicsList
- Should be easy to change PhysicsList
  - though, I'm more familiar with how G4Base is integrated into NOvA
    - perhaps needs some tweaking
- Not easy to change parameters of physics models
  - pressure on Geant4 collaboration to allow this
  - not going to seriously available in the time scale under discussion

Questions?

Intensity Frontier at FNAL

Active, rich & varied program.
Projects include flagships for
Fermilab's future.

Muon Experiments
including both μ source and detectors

muon g-2

mu2e

Neutrino Beams
present & future (and recent past)

- NuMI (Main Injector)
  - LE & ME target/horn configurations
- Booster Neutrino Beam
- LBNF under design

† ran previously
‡ currently running

Neutrino Detectors
including test beam related experiments

MINOS [+] ‡   (Near & Far detectors - magnetized)

MINERvA ‡ (fine grained & multi-target material)

NOvA ‡ (Near & Far detectors - off-axis)

LArIAT / ArgoNeuT †
(same small LAr detector in test beam / NuMI beam)

SBND
(Short Baseline Near Detector Expt, formerly LAr1ND)
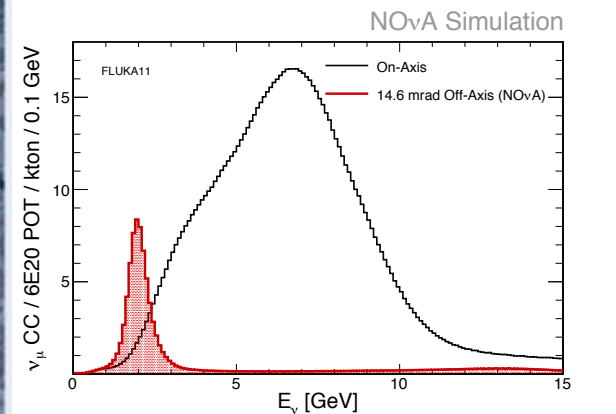
ANNIE
(to study neutron production in water using BNB ν)

μBooNE
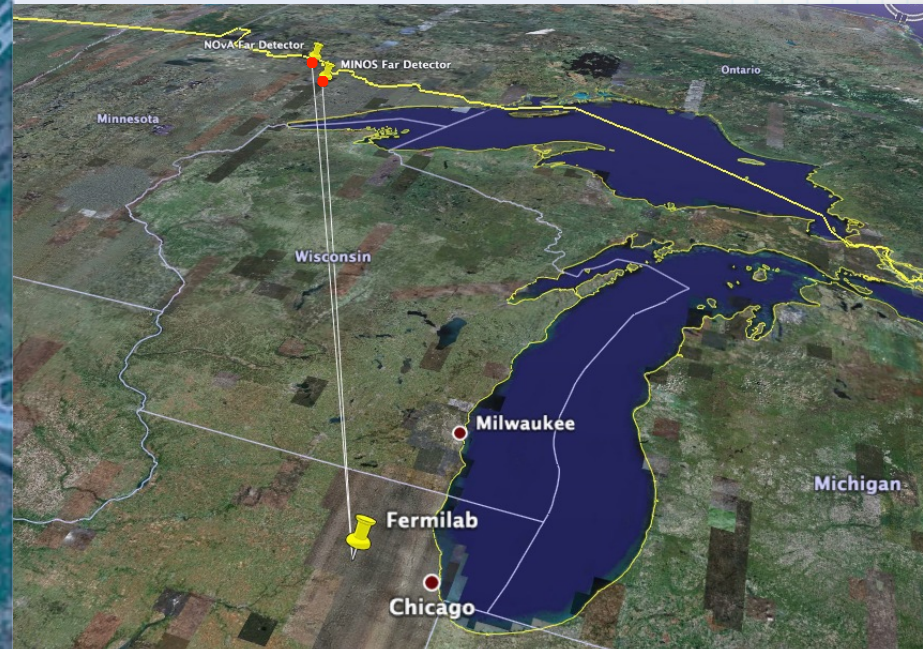
miniBooNE †

ICARUS-T600
(to be refurbished & moved from Gran Sasso National Lab
in Italy to serve as BNB Far Detector)

DUNE
(Deep Underground Neutrino Experiment, formerly LBNE)
(Near & Far detectors + test beam prototypes at CERN)

you are here

to Minnesota

test beam

fixed target

NuMI beam
(MINOS, NovA)

linac

muon
campus

booster

booster
neutrino
beam

to South Dakota
(LBNE)

muons   nuclei

kaons

Main Injector
and Recycler

Project X

Tevatron Ring
(decommissioned)

NOvA Simulation

FLUKA11

On-Axis
14.6 mrad Off-Axis (NOvA)
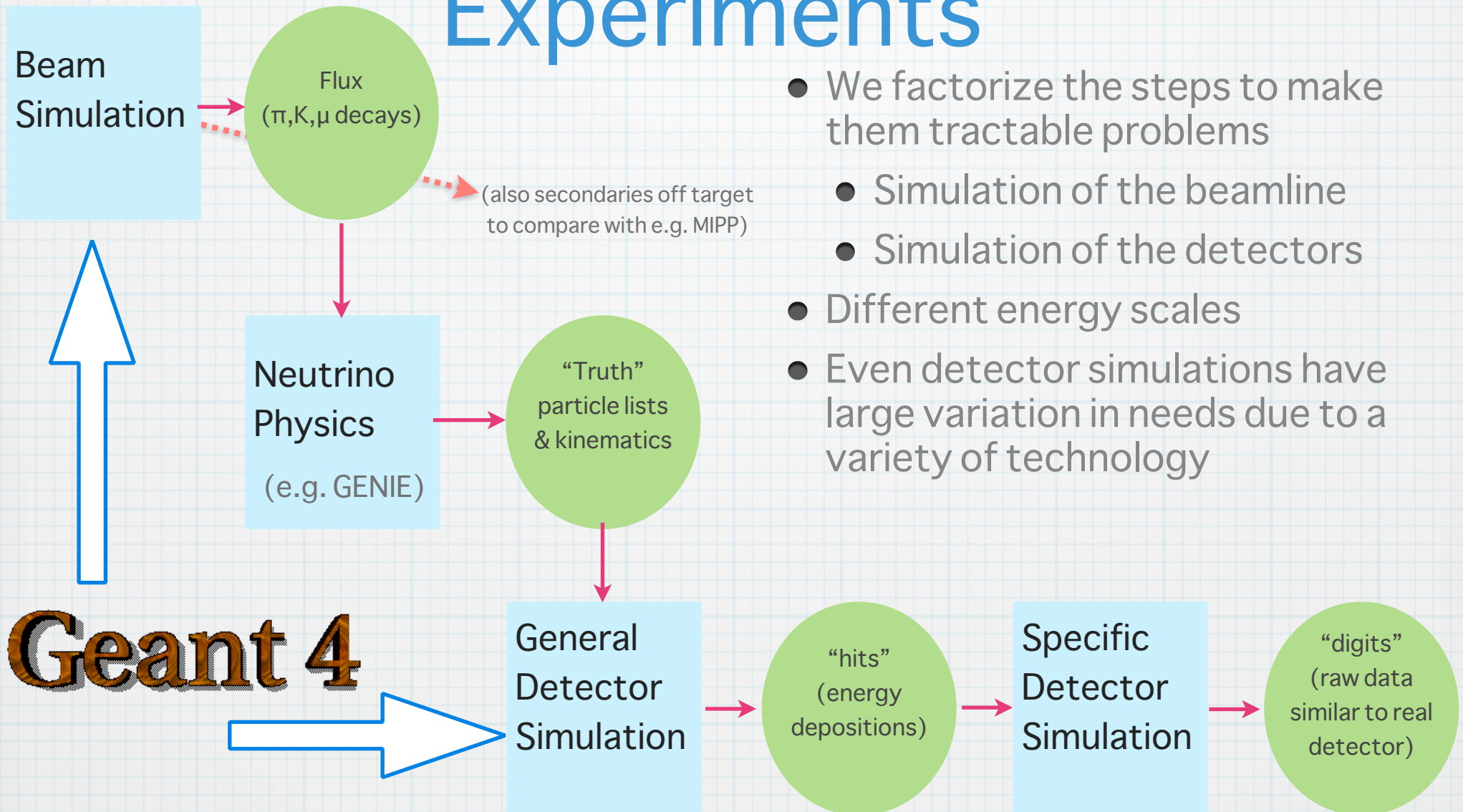
ν_μ CC / 6E20 POT / kton / 0.1 GeV

E_ν [GeV]

protons
neutrinos
muons
target

north

dashed lines indicate planned facilities

General Simulation Workflow & Products in Neutrino Experiments

Beam Simulation

Flux (π,K,μ decays)

(also secondaries off target to compare with e.g. MIPP)

Neutrino Physics

(e.g. GENIE)

"Truth" particle lists & kinematics

- We factorize the steps to make them tractable problems
  - Simulation of the beamline
  - Simulation of the detectors
- Different energy scales
- Even detector simulations have large variation in needs due to a variety of technology

Geant 4

General Detector Simulation

"hits" (energy depositions)

Specific Detector Simulation

"digits" (raw data similar to real detector)

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