Geant 4

FNAL Neutrino Experiments' use of Geant4

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Neutrino Expts @ FNAL

- Multitude of experiments
  - MiniBooNE, MINOS, Minerva, ArgoNeuT, NOvA, MicroBooNE, LBNE
- Geant4 used for two independent purposes
  - beamline simulation
    - protons ⇒ pions/kaons/muons ⇒ neutrinos
  - detector simulation
    - electron showers, muons, hadronic showers
  - different domains, different physics emphasis
- FNAL: 2 current (+ 1 planned) ν beamlines
  - Booster (8 GeV protons on Be target)
  - NuMI (120 GeV protons on carbon target)
    - produce neutrinos (mostly) in the range 0 - 25 GeV
    - 0.25 - 10 GeV of most interest for oscillations
  - LBNE (beamline design studies underway)

PhysicsLists

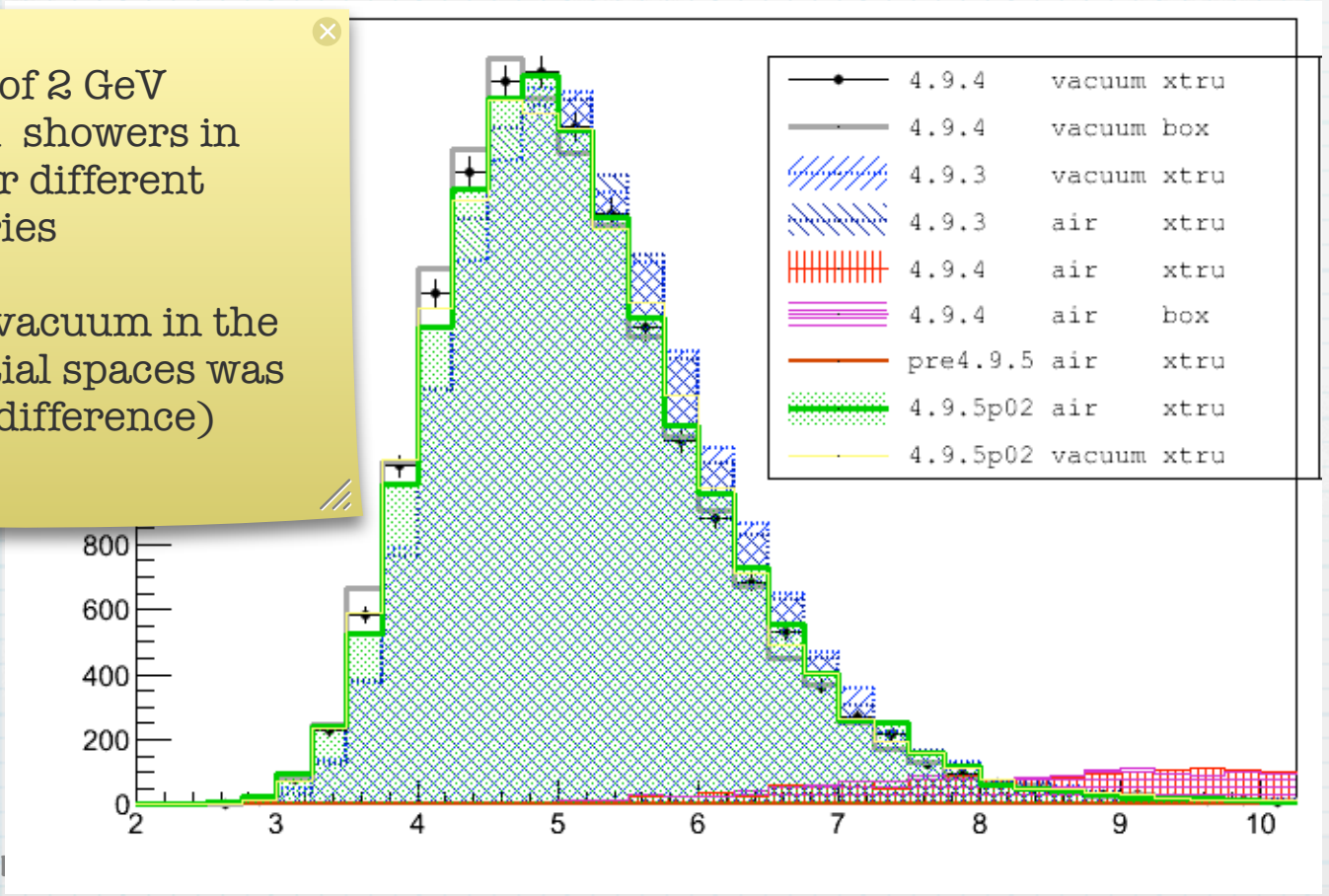
- Choice of PhysicsList?
  - Users worry about applicability of choice for the physics they are doing (a bit of general unease overall)
    - beamline (protons 8 or 120 GeV on Be or C target):
      - Booster used homegrown based on ExN04 as of >5 years ago
      - generally using QGSP_BERT [_HP] currently for NuMI (120 GeV)
        - in past various people have looked at: QCSC, QBBC, FTFC, FTFP, LHEP
    - detectors (both Scintillator and Liquid Argon technology):
      - QGSP_BERT
        - for NOvA 0-5 GeV electron showers are important
        - also hadron showers of few GeV, arising from a few hadrons
  - Are there better choices for these domains?
    - Do we need to write our own?
- Alternative (extensible) physics list factory
  - Not a hard coded fixed list of choices
  - Classes register c'tor w/ factory keyed by name string
    - use "cpp" macro to make this easy for the user
  - Willing to contribute this code for wider use

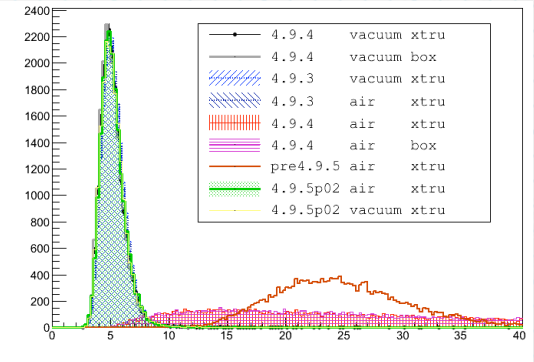
Electron Showers Issue

- Last meeting followed up on earlier report
  - reported in forum on Oct 13, 2011; there was some prior interactions w/developers
  - http://hypernews.slac.stanford.edu/HyperNews/geant4/get/emprocess/1095.html
  - FNAL identified it as problem w/ G4UrbanMscModel93
    - locally tried, unsuccessfully, to pinpoint numerical instability in the code
  - patched in 4.9.5p01 and beyond
    - protects against this instability under certain conditions

"width" of 2 GeV electron showers in NOvA for different geometries

(air vs. vacuum in the interstitial spaces was the key difference)





- NOvA would like to thank all those responsible for this fix

Backup Slides
-
repeat of 2012-03-26 talk

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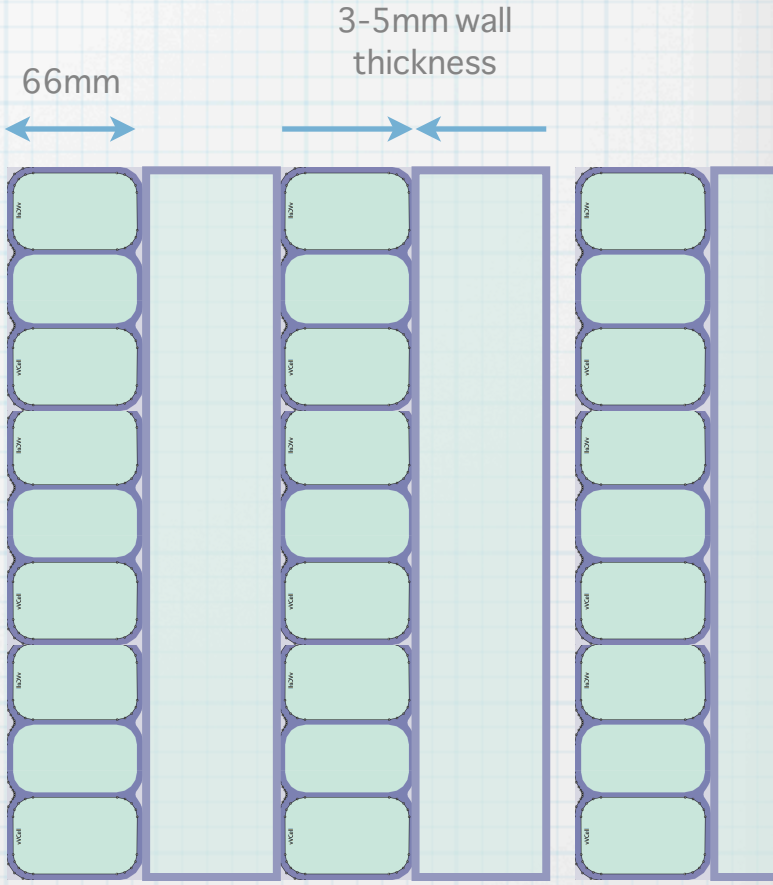
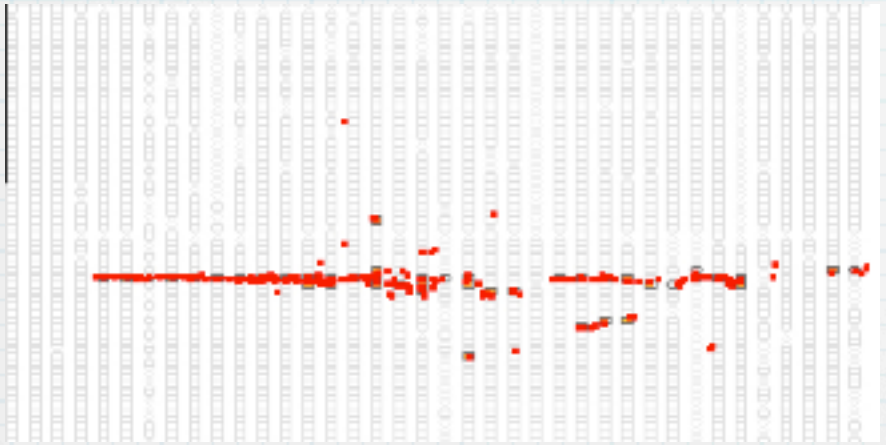
NOvA Geometry

- Sandwich detector
  - planes of extruded PVC plastic; liquid scintillator cells
  - alternating orientation of cells
- read in from GDML file
- gaps between planes
  - ~5-10 nm for containing shapes
    - extrusion in modules in planes in blocks
    - used to avoid overlaps
    - containing volume either air or vacuum
  - ~mm between “blocks”
  - ~2.5mm scallop grooves
    - for XTRU shape; none for alt BOX geom

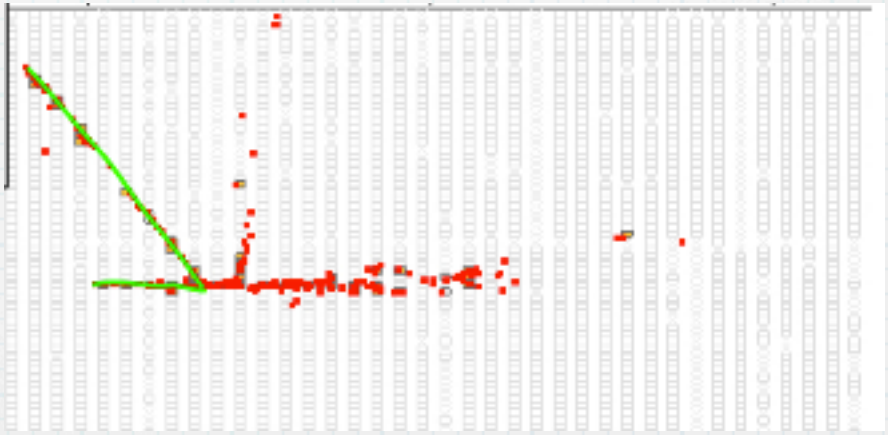


Geant4 electron showers

- Observed large angle change for high energy (~2GeV) electrons
- "multiple scattering" identified as an issue
  - step was attributed to G4UrbanMscModel93 process



vacuum between planes

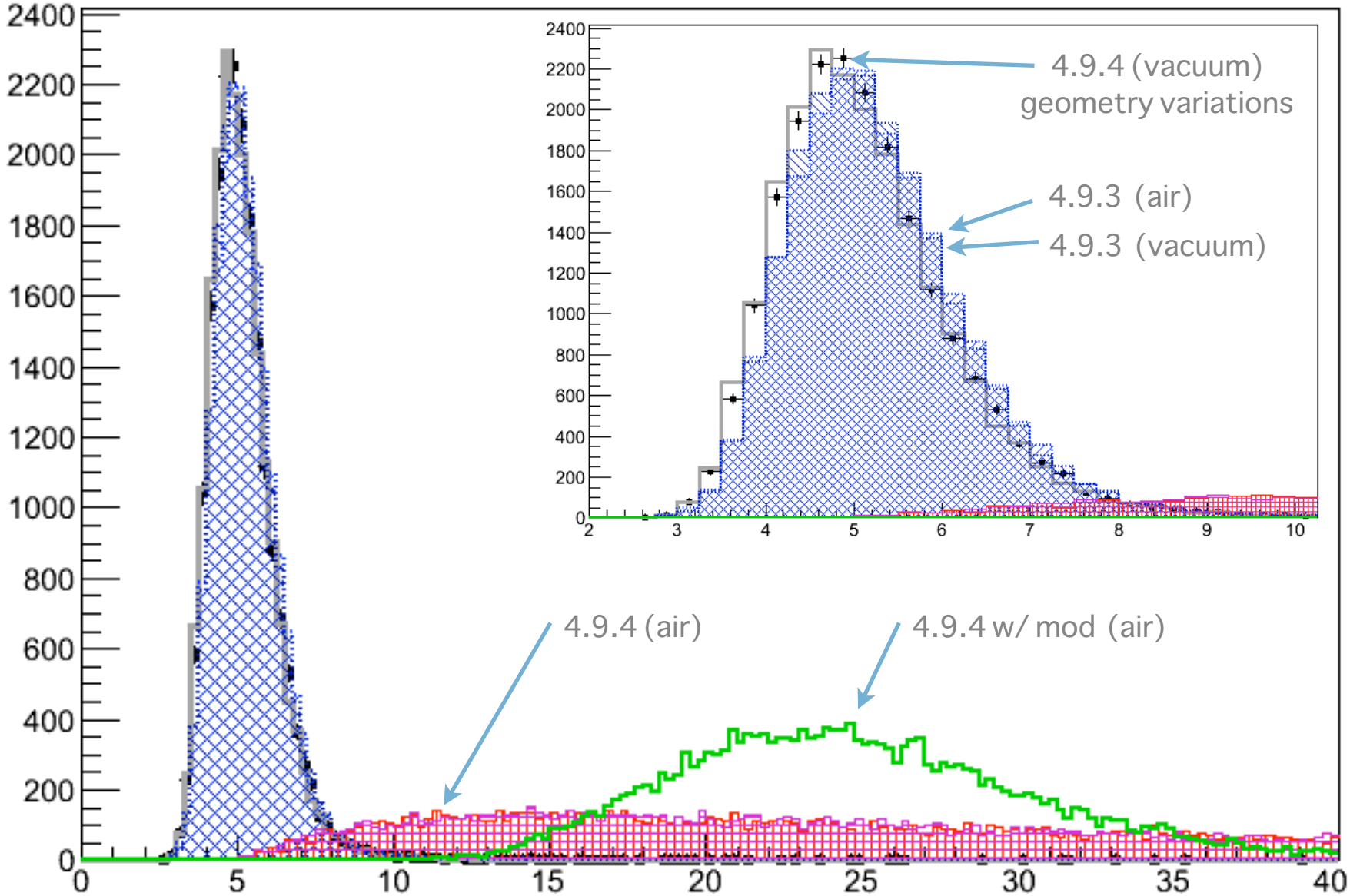


air between planes;
green line is the primary 2 GeV electron

Geant4 electron showers

- There must be a fundamental numeric instability in `SampleCosineTheta` that turns small `theta0` (mean angle?) into a chosen *cosθ* that is unreasonably far from 1
- Geant4 team sent a proposed fix
  - old: `if(theta0 < tausmall) return cth;`
  - new: `if(theta0*theta0 < tausmall) return cth;`
  - `theta0` is a mean scattering angle
  - `cth=1` and `tausmall = 1.0e-16` at this point
- I'm not convinced that this new variation on the cut does anything more than make the problem less frequent

Shower Width



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Urban 2006 (cern-open-2006-077)

- Angular distribution

$$g(u) = p[qg_1(u) + (1-q)g_2(u)] + (1-p)g_3(u)$$

$$g_1(u) = C_1 e^{-a(1-u)} \qquad -1 \le u_0 \le u \le 1$$

$$g_2(u) = C_2 \frac{1}{(b-u)^d} \qquad -1 \le u \le u_0 \le 1$$

$$g_3(u) = C_3 \qquad -1 \le u \le 1$$

where $u = cos\theta$, $0 \le p, q \le 1$
g_i are simple functions normalized over the range $u \in [-1, 1]$

- for small `theta0` for small steps at high energies one physics intuition says to expect p=1, q=1
- not sure I see the left hand constraints in the code