



Geant 4



# Outstanding NOvA Issues with Geant4

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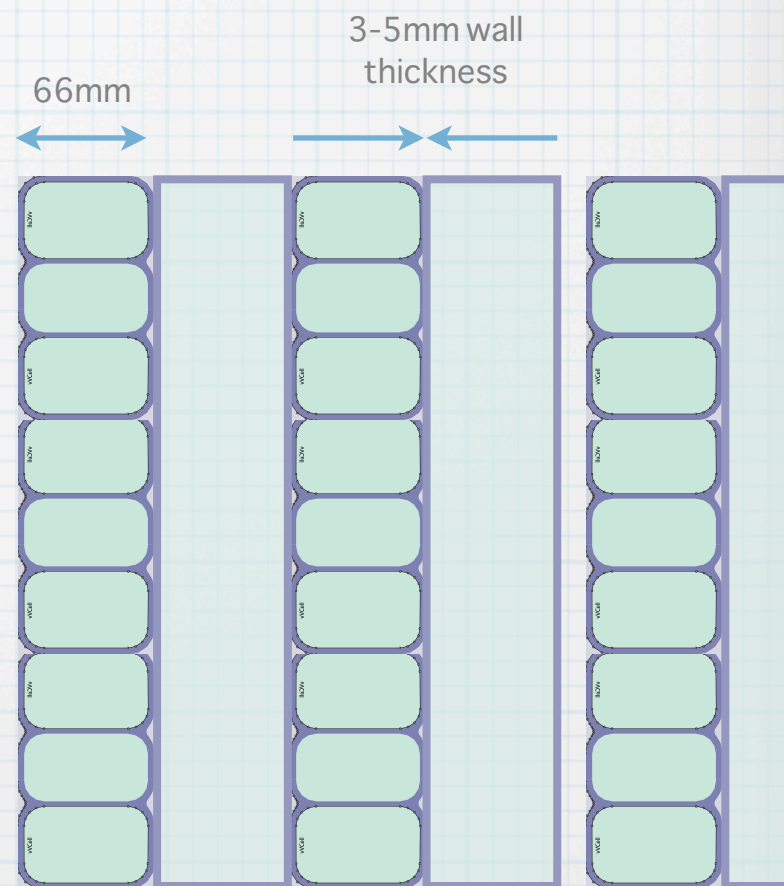
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# NOvA Geometry



- 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



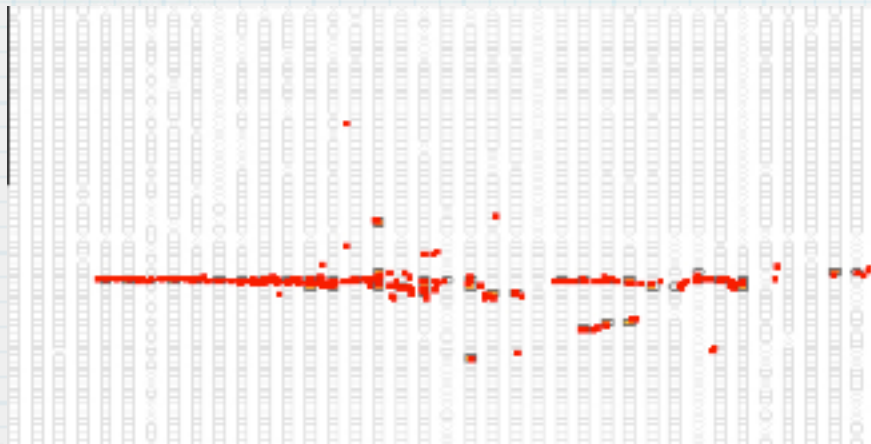


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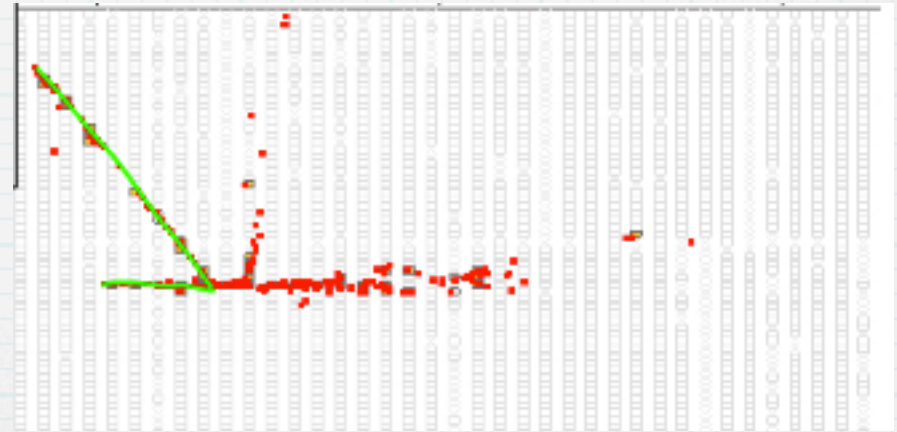
# Geant4 electron showers



- Observed large angle change for high energy ( $\sim 2\text{GeV}$ ) electrons
- “multiple scattering” identified as an issue
  - step was attributed to G4UrbanMscModel193 process



vacuum between planes



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



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# Geant4 electron showers

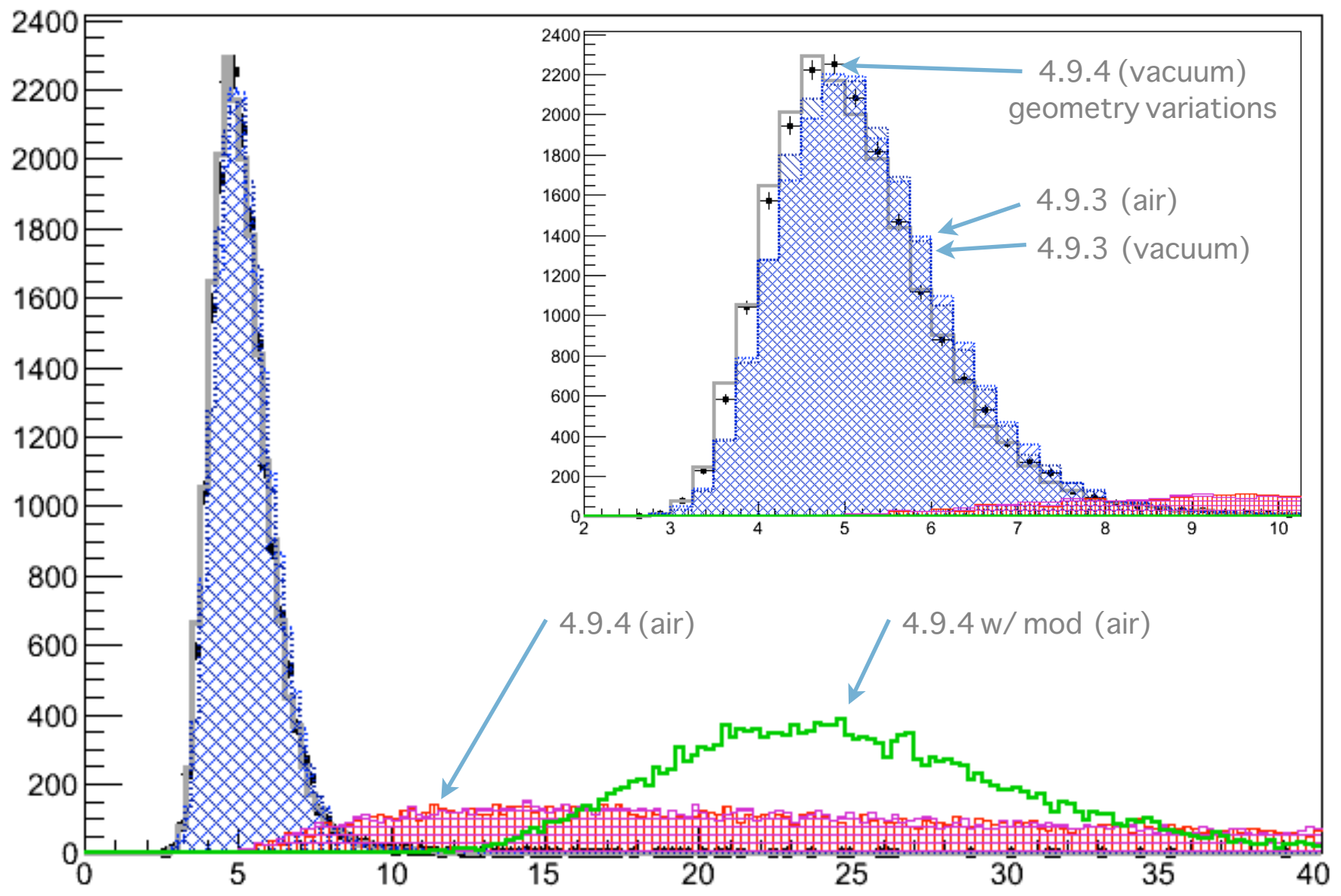


- There must be a fundamental numeric instability in `SampleCosineTheta` that turns small `theta0` (mean angle?) into a chosen  $\cos\theta$  that is unreasonably far from 1
- Geant4 team sent a proposed fix
  - old: `if(theta0 < tausmall) return cth;`
  - new: `if(theta0*theta0 < tausmall) return cth;`
  - `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

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

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

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

$$g_3(u) = C_3 \quad -1 \leq u \leq 1$$

where  $u = \cos\theta$ ,  $0 \leq p, q \leq 1$

$g_i$  are simple functions normalized over the range  $u \in [-1, 1]$

- for small  $\theta_0$  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