THE UNIVERSITY OF CHICAGO

Rethinking the use of Geant4 in LArSoft

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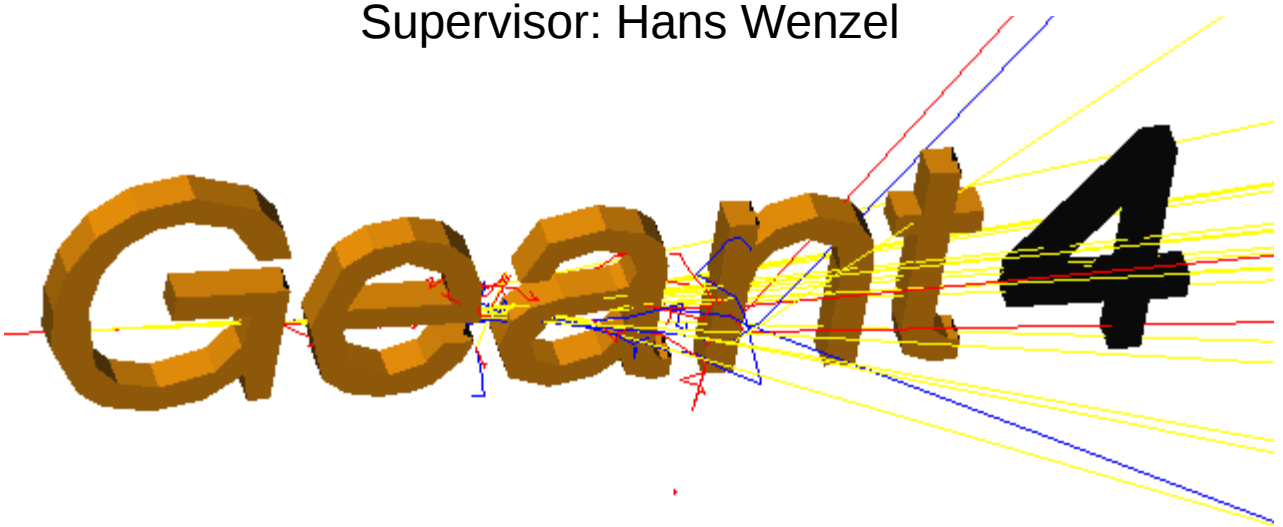
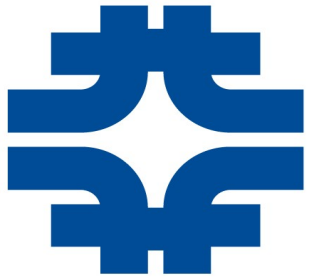


Outline



- Simulation of Liquid Argon TPC

  Introduction

  Step Limiter

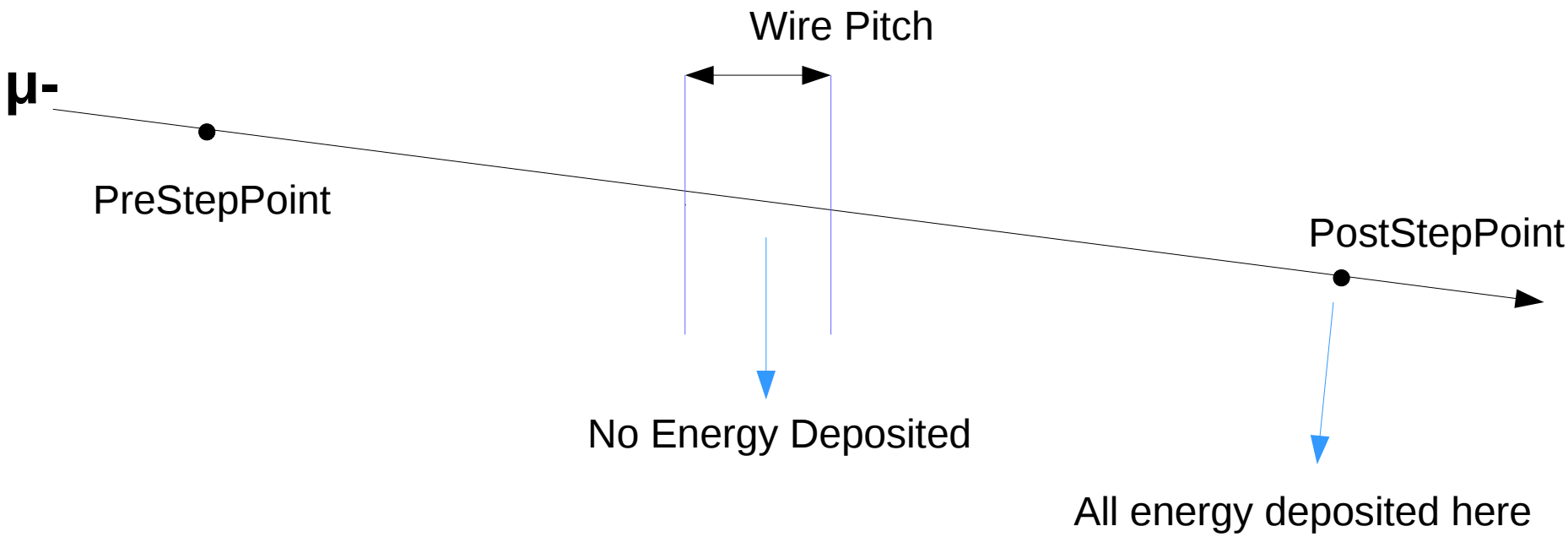
  Divided Steps

  Segmented Geometry

Introduction

The scope of this project was to look into the details of LArSoft simulation and to question if a voxelized geometry is the best way to match energy deposits to the readout pitch.

Matching Step Length and Readout Pitch



Geant4 adjusts the step size according to the physics, and for some processes, the step size is much greater than the readout pitch.

For energy deposits, we expect landau distributions with a most probable value at 2.1 MeV/cm (muon approximates minimum ionizing particle)

Liquid Argon Specifics

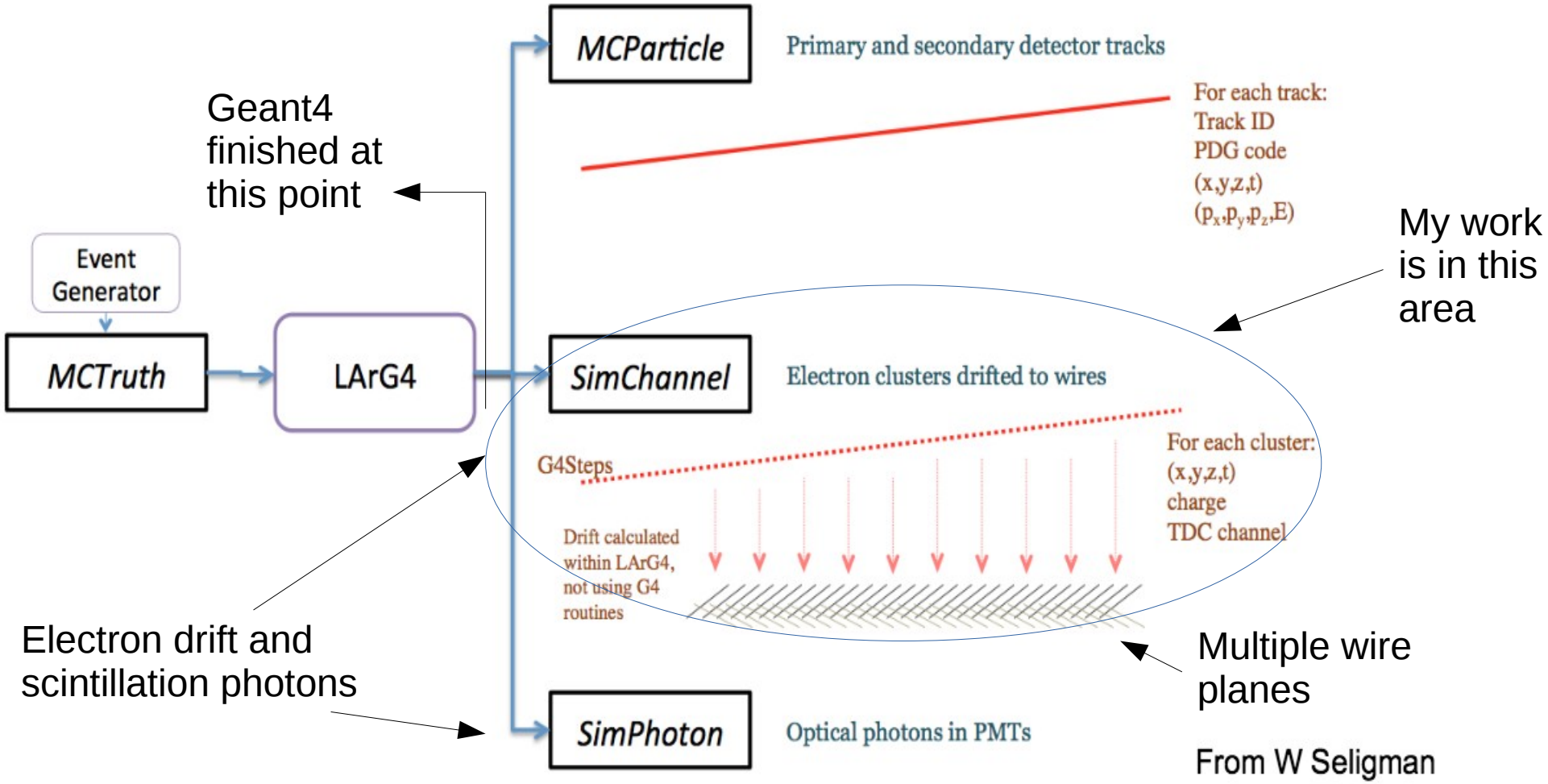
- Steps must be matched to readout pitch
- Scintillation and Ionization compete
- dE/dX = 2.1 MeV/cm
- Ionizing: 23.6 eV per electron/ion pair
- Scintillation: 19.5 eV per photon

  → corresponds to 63 nm, in UV range
- Charge attenuation
- Space charge distortions caused by slow moving ions

All has to be included in Simulation

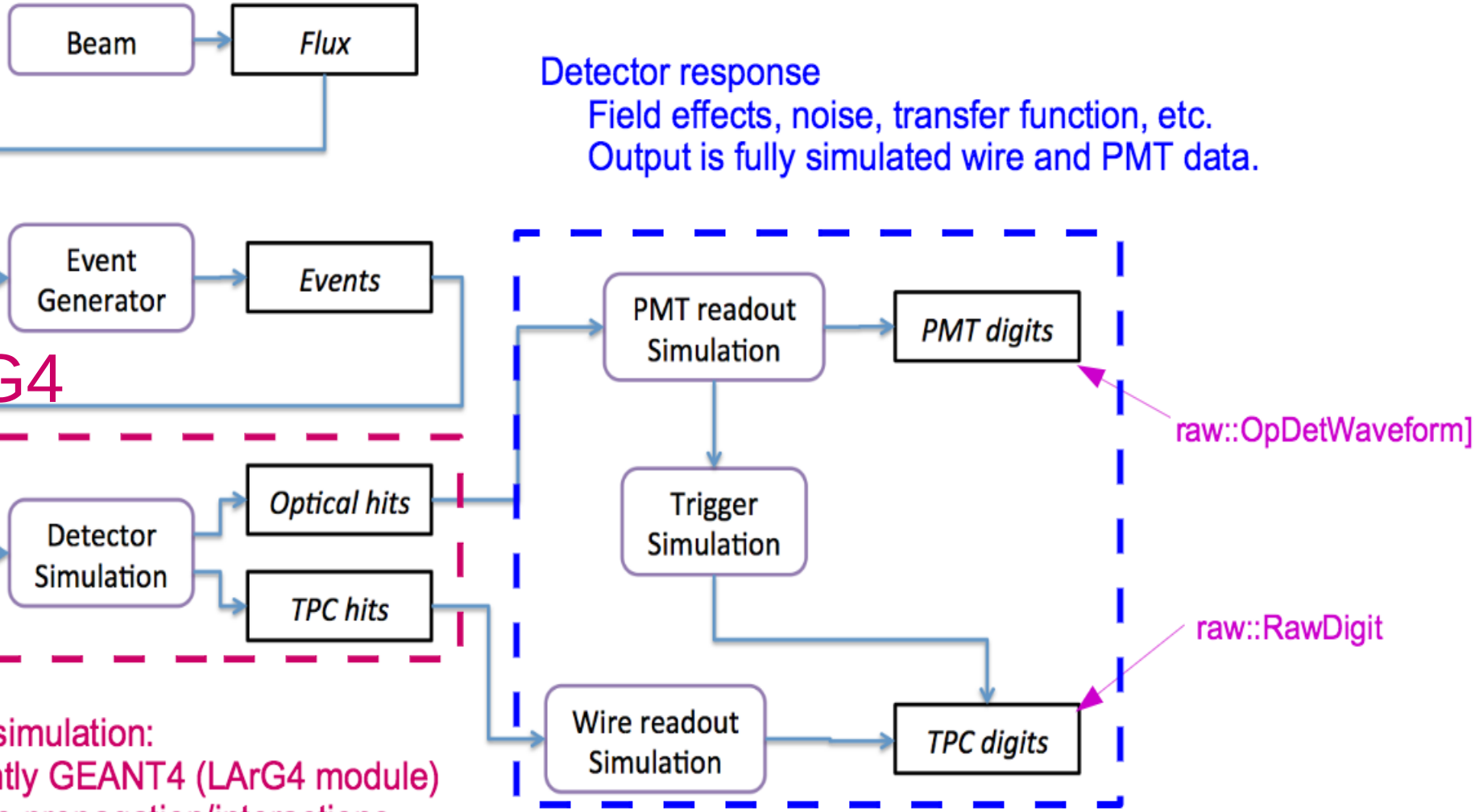
} (Ereditato)

Detector simulation



Simulation workflow

The full detector simulation includes two separable sub-phases



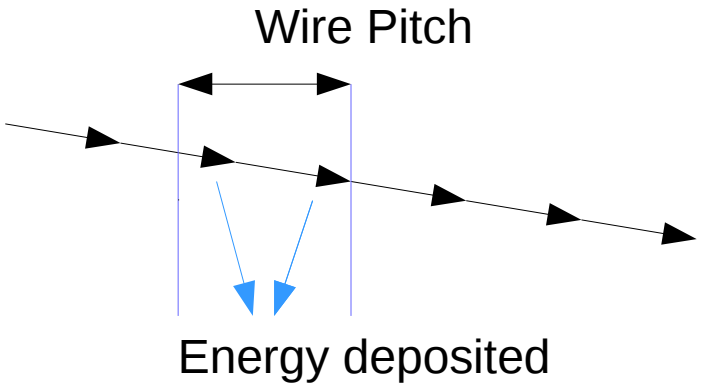
Detector simulation:
Currently GEANT4 (LArG4 module)
Particle propagation/interactions, charge/photon transport.
Output is MC truth information in simb::MCParticle, sim::SimPhoton, sim::SimChannel, sim::AuxDetSimChannel,

From W Seligman

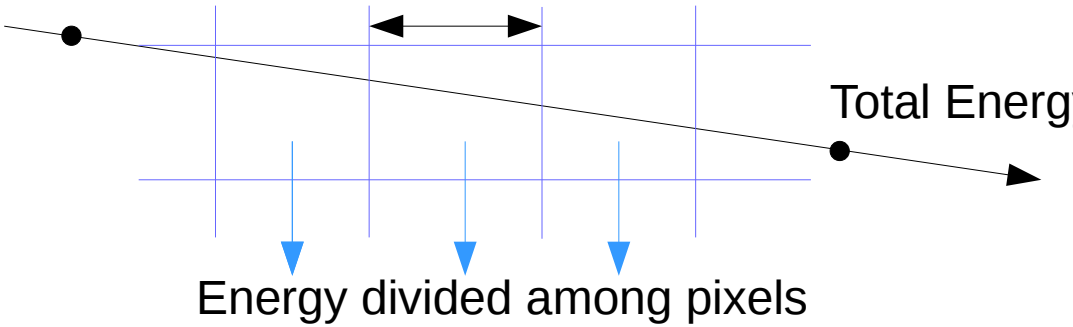
LArG4: Upgrading, Maintenance, and Optimization

- Is voxelization necessary? Are there more efficient implementations?
- Some Liquid Argon specifics (NEST, evaluation of electron drift, etc.) not part of Geant4
- Until recently, oudated physics list contains obsolete models not available in current Geant4. Make us of reference physics list, and optimize physics list?
- Some Geant4 routines were modified (scintillation). That interface is now available in Geant4, but hasn't been released yet.

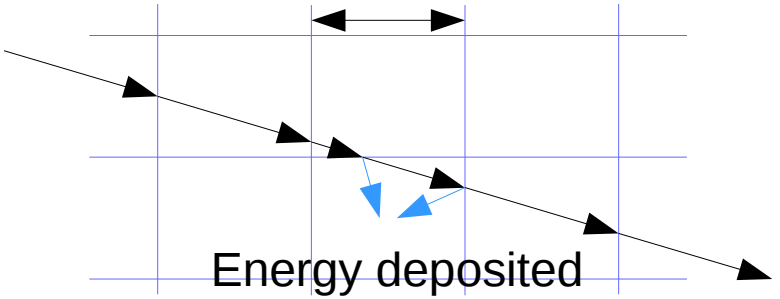
Solutions



Step Limiter



Divided Step



Segmented Geometry
(currently implemented in a parallel readout geometry)

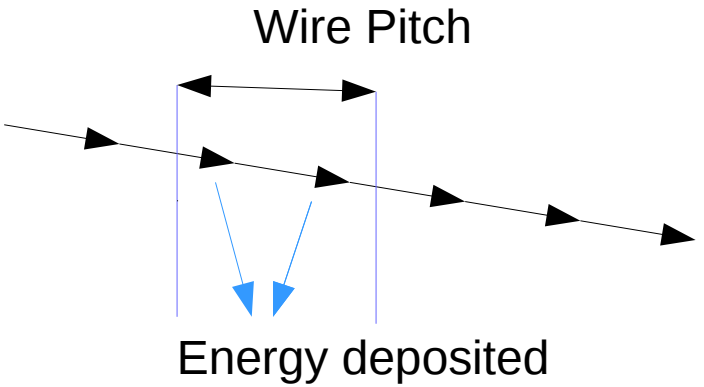
Step Limiter

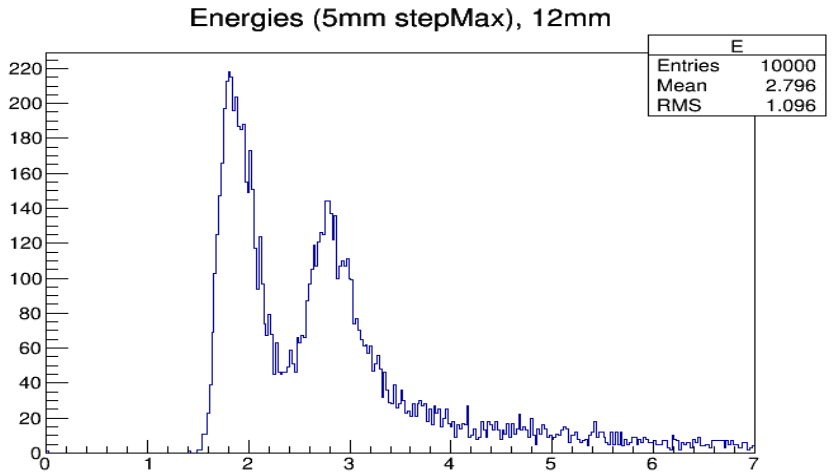
+ Very Simple to implement

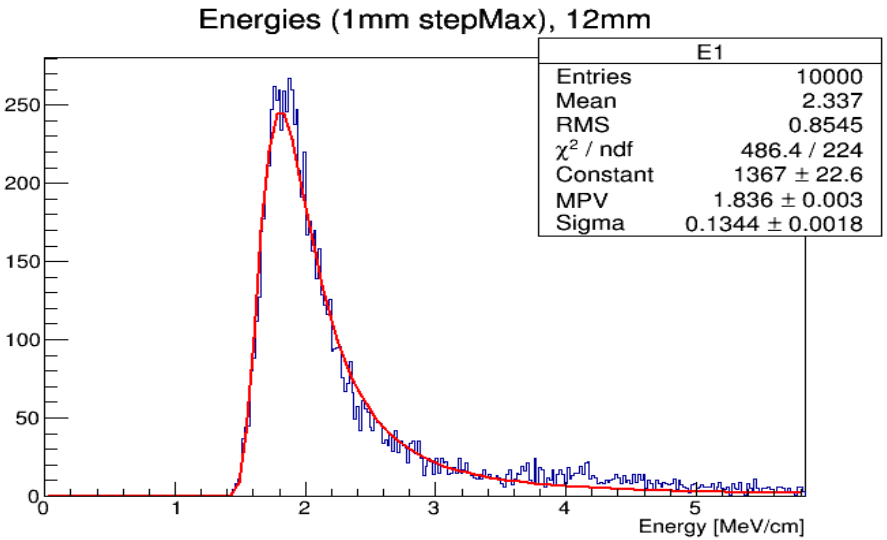
+ No added memory costs to realize the geometry

+ Gets physics right when Step limiter is about one tenth of the wire pitch

- Takes a long time for small step sizes (> .72 sec/event, .1 mm)







Step Limiter

- In DetectorConstruction.cc:
  - Attach StepLimiter to logical volume of detector

```
G4UserLimits *fStepLimit = new G4UserLimits(maxStepSize);
DetectorLogicalVolume -> SetUserLimits(fStepLimit);
```

- In g4main.cc:
  - Attach StepLimiter process to physics list

```
phys->RegisterPhysics(new G4StepLimiterPhysics());
```

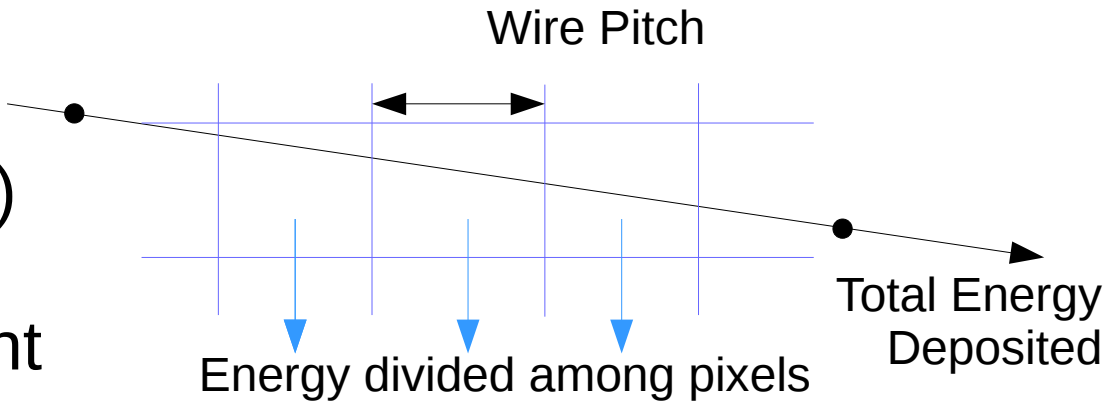
G4VModularPhysicsList

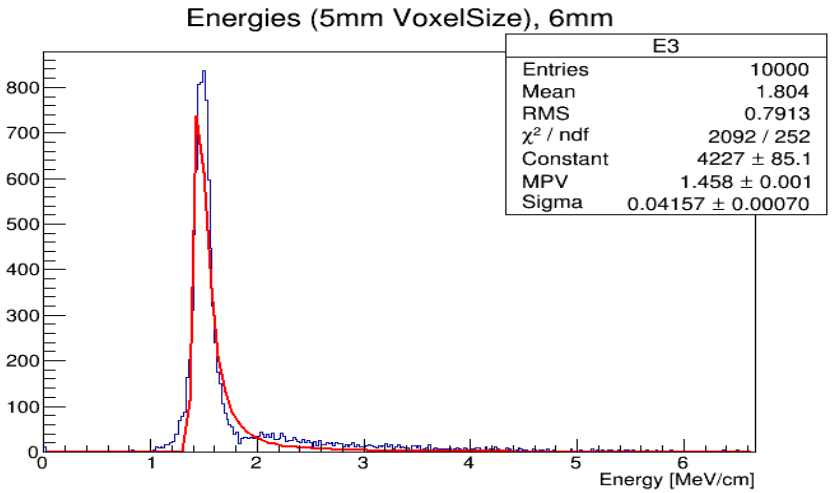
Divided Steps

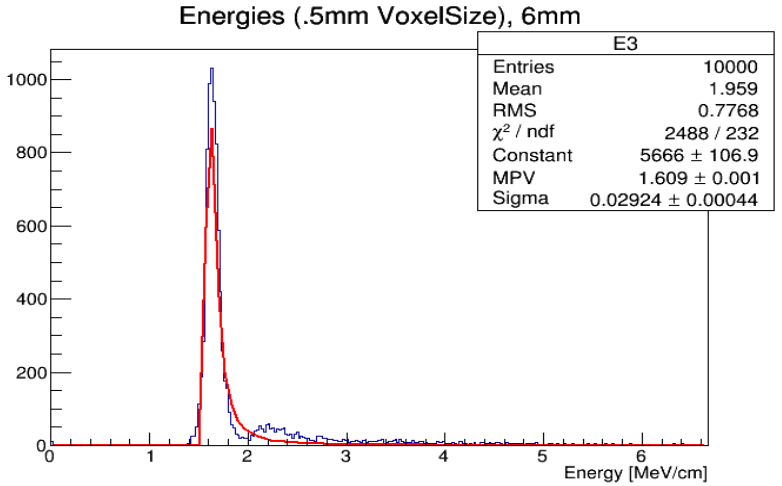
+ Takes little time even for many Divisions (< .06 sec/event)

- Never gets the physics right

- The method averages out all fluctuations







Segmented Geometry (Voxels)

+ Acts as a step limiter

+ Also gets physics right when readout exactly matches voxels

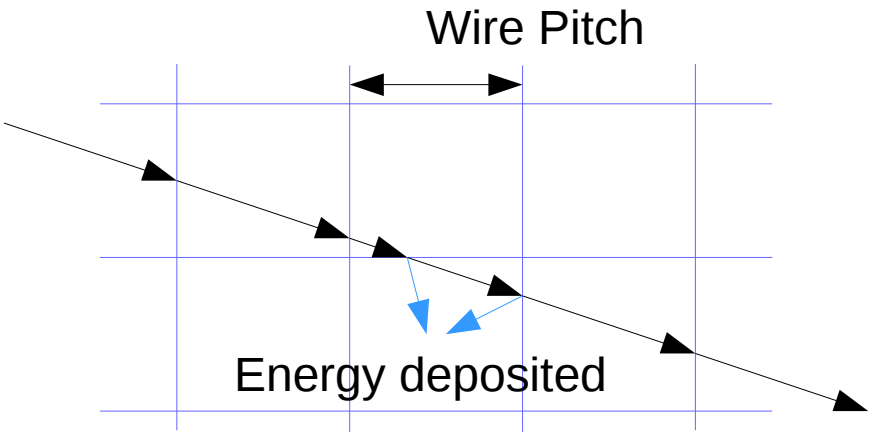
- Deals with many volumes
  Ex: 1m TPC & .3 mm cubes
  = **37,000,000,000** volumes

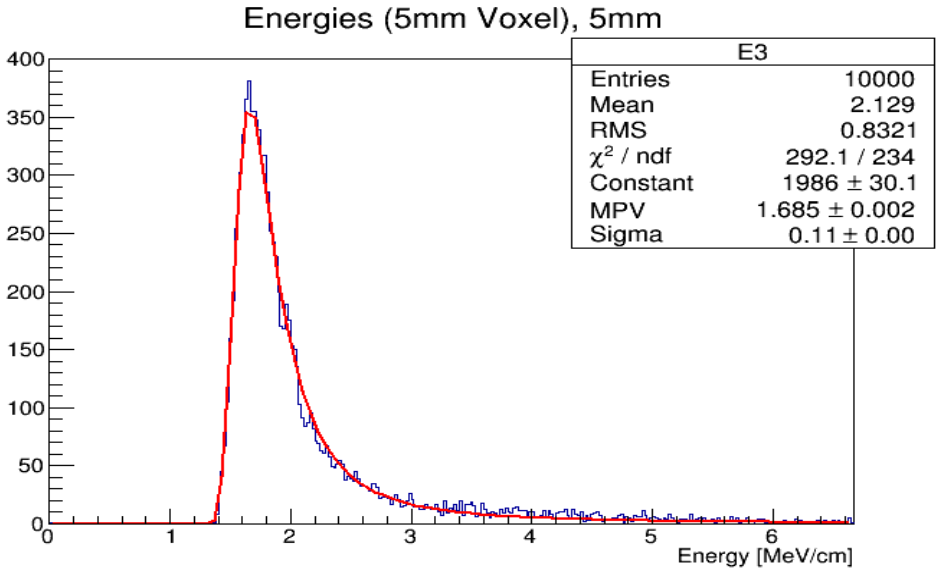
- Takes a long time for small voxel sizes (>.9 sec/event, .1 mm)

- Cannot match wires exactly to voxels (stereo readout)

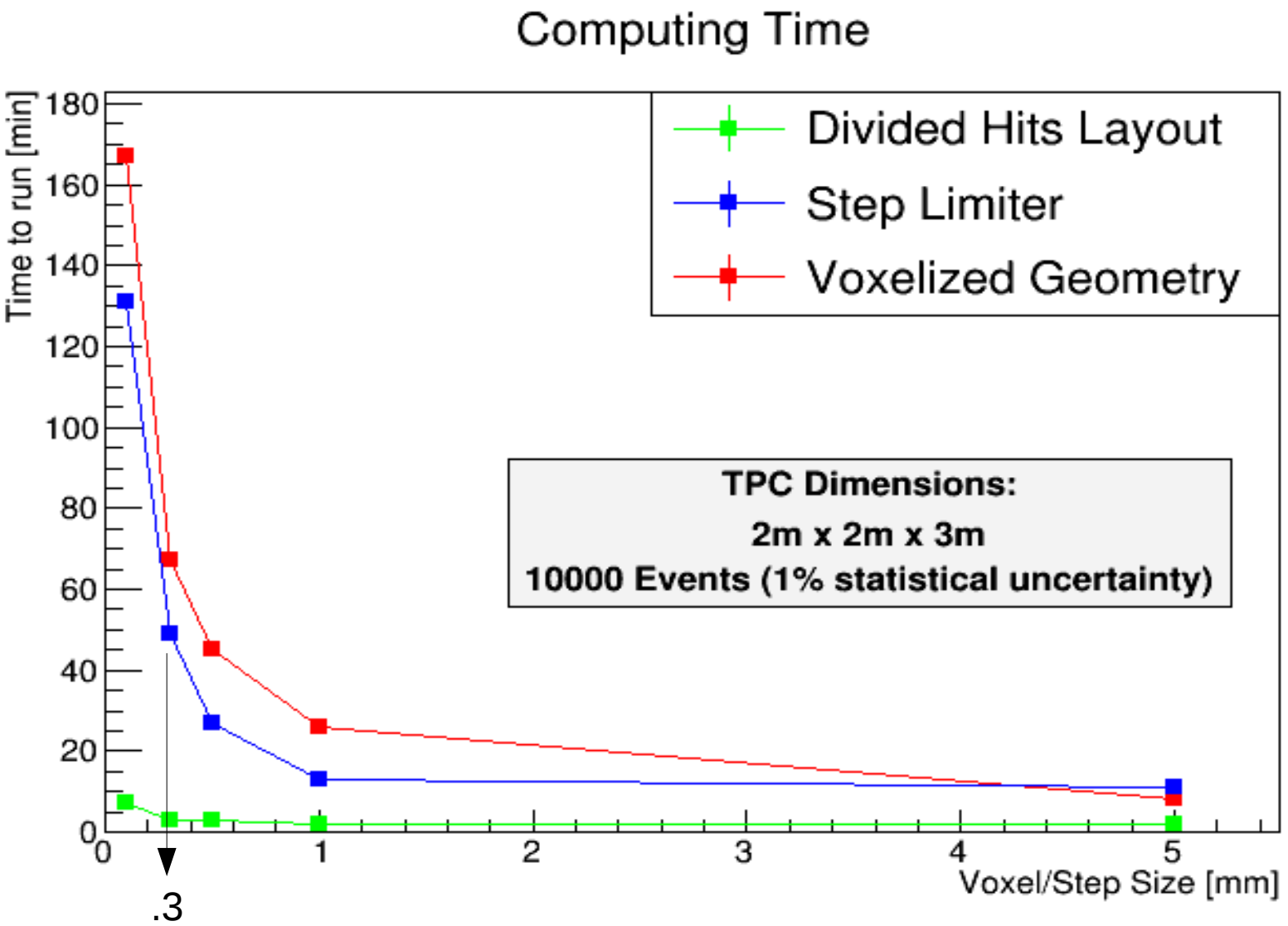
- Very little added memory costs (10MB)

- Currently implemented in LArG4 with voxel size of .3 mm, does not match readout





Timing Comparison



Conclusion/Short Term Plan

- Evaluated three ways to match the step length to the wire pitch, and the step limiter is a good alternative to the segmented geometry which is currently in LarSoft/LArG4
- First part of updating LArG4 is to use reference physics list
- Use of standard Geant4 interfaces instead of modified Geant4 code, work with Geant4 team
- Make upgrading LArG4 to current versions of Geant4 trivial

Thank You!

- Hans Wenzel
- Metcalf Program
- Fermilab PDS group
- LarIAT
- LArSoft group