SHMS Geant4 for Proton Absorption Correction

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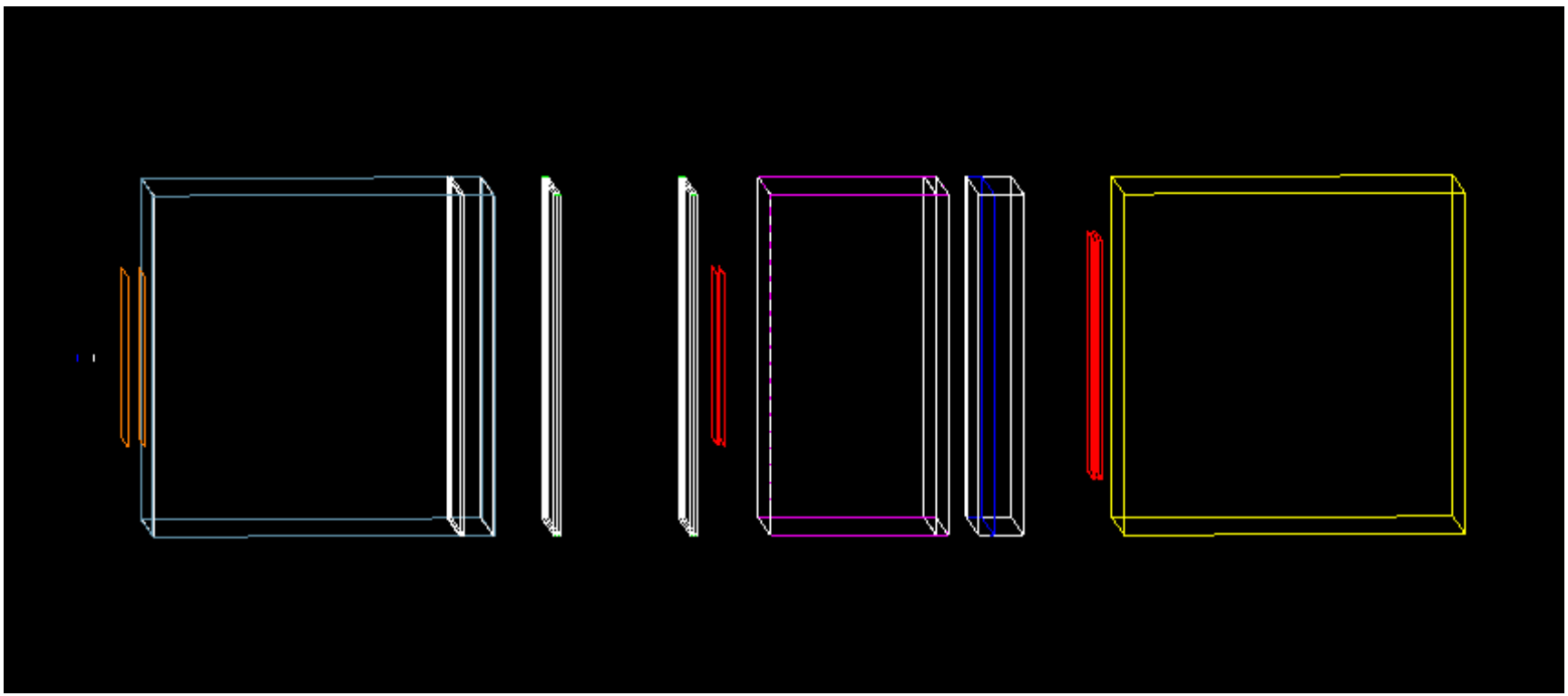
Class List

- **shmsPA** : main method
- **PAActionInitialization** : defines run, event, stepping actions
- **PADetectorConstruction** : detector geometry and materials
- **PAEventAction** : defines data output per event
- **PAHodoscopeHit** : defines data recorded per hit
- **PAHodoscopeSD** : how hit data is processed by sensitive detector
- **PAPrimaryGeneratorAction** : event generation
- **PARunAction** : data output per run
- **PASteppingAction** : actions taken in each step

Detector Construction Overview

- Define materials: key feature is density, interaction lengths
- Define geometry: accurate z-dimensions and arbitrary (2×2 m) xy dimensions
- Semi-accurate z positions of each component
- Option to turn on/off NGC: *detectors.dat*
- Included solid lead glass block as calorimeter



Cherenkov Process

- Need to manually define refractive index of material as function of light energy
- Then add custom stepping action to count NPE in S2Y

```
1  //From PADetectorConstruction::DefineMaterials()
2  G4double energy[4] = {0.77*eV,1.03*eV,1.55*eV,2.07*eV};
3  //corresponds to wavelengths of 1600, 1200, 800, 600 nm
4  G4double nQuartz[4] = {1.457,1.453,1.447,1.443};
5
6  //assign to relevant materials
7  G4MaterialPropertiesTable *mptQuartz = new
       G4MaterialPropertiesTable();
8  mptQuartz->AddProperty("RINDEX", energy, nQuartz, 4);
9  Quartz->SetMaterialPropertiesTable(mptQuartz);
```

Event Generation

- Read in focal plane variables from real data (run 5055)
- Define focal plane as $z = 0$, then $xfp = x(0)$, $yfp = y(0)$
- $ztar$ is chosen as center of 10cm LH2 target
- Given $xpfp = dx/dz$ and $ypfp = dy/dz$, approximate positions at target as:

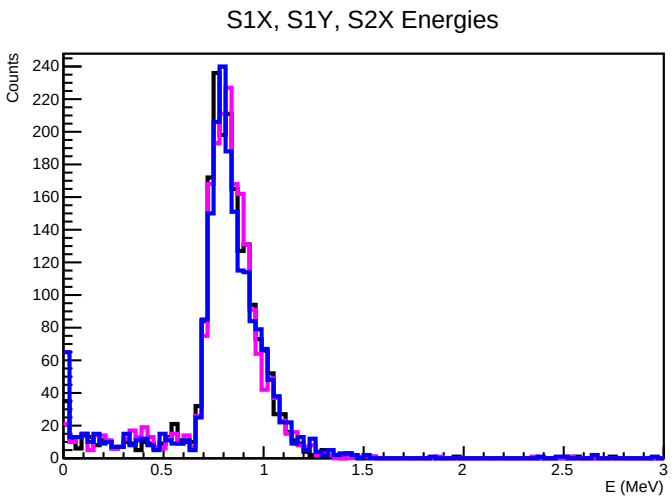
$$xtar = xfp + xpfp * ztar$$

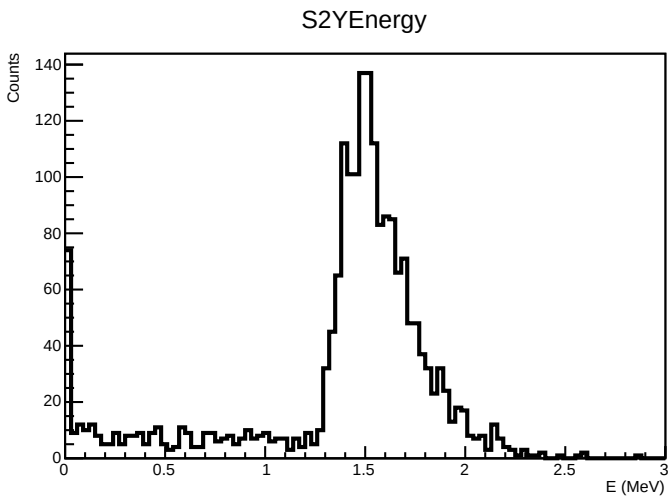
$$ytar = yfp + ypfp * ztar$$

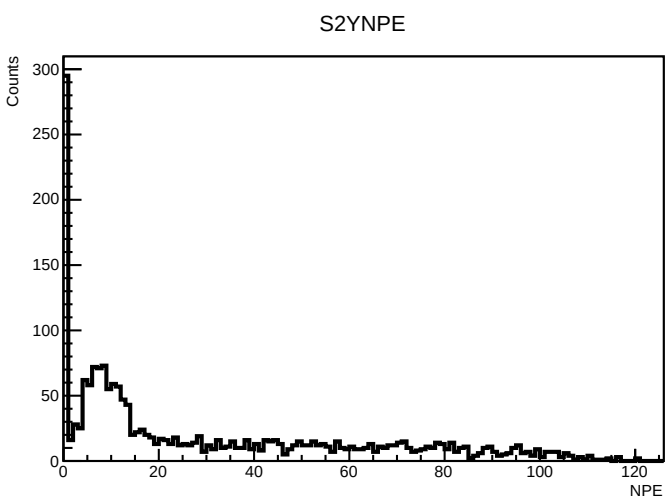
- Generate event at $(xtar, ytar, ztar)$ with momentum direction $(xpfp, ypfp, 1)$

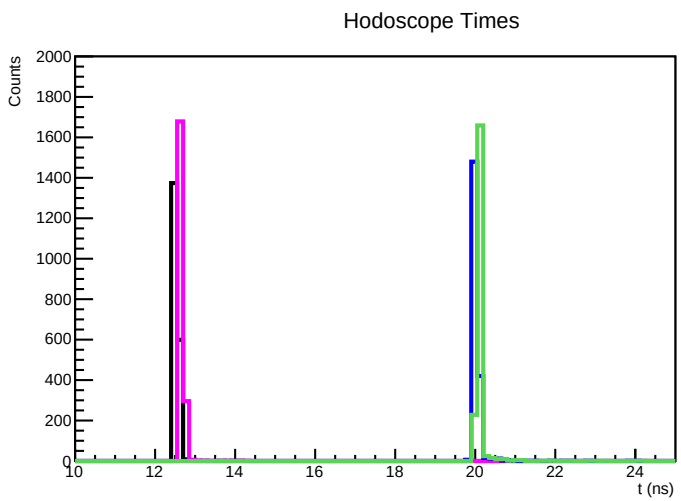
Simulation Output

- PAHodoscopeSD: records energy deposit, time of hit in each hodoscope
- PASteppingAction: records NPE in S2Y









Running Instructions

- Run interactive: *./build/shmsPA*
- Run in batch mode: *./build/shmsPA runPA.mac*
- Run ROOT script *CalcPA.C* on output file (takes filename as argument)

```
1  #runPA.mac
2  /run/initialize
3  /PA/generator/momentum 5 GeV
4  /PA/generator/useGenerated true
5  /PA/generator/setInFile
       run5055kine.txt
6  /gun/particle proton
7  /analysis/setFileName
       proton5GeV1000.root
8  /run/beamOn 1000
```

EXTREMELY preliminary results: 6.4% proton absorption

Reasonableness Checks

- Stability over event samples: 4x2000 events each (run sequentially):

nMissed = {141, 129, 127, 117}

percentCorr = {7.05, 6.45, 6.35, 5.85}

6.4% ± 0.5%

- Note if two distinct event samples are run in parallel, both will return the same nMissed
- Test momentum dependence, different particles (1000 events each):

P (GeV)	nMissed			
	p+	K+	pi+	e+
1	64			
2	62			
5	64	102	83	448
8	64			
10	64			

Where do Events Stop?

Dipole exit	2
HB entrance	1
NGC gas	4
NGC mirror	9
NGC support	8
DC gas	1
DC cathode	6
S1X	7
S1Y	6
HGC gas	10
HGC mirror	7
HGC window	3
AGC tray	11
S2X	7

- Ran 1000 events at central momentum 5 GeV
- Total stopped tracks: 82
- Total missed triggers: 70
- Some stopped tracks produce secondaries that cause a 3/4 trigger (?)
- Also, some missed triggers are not fully stopped tracks

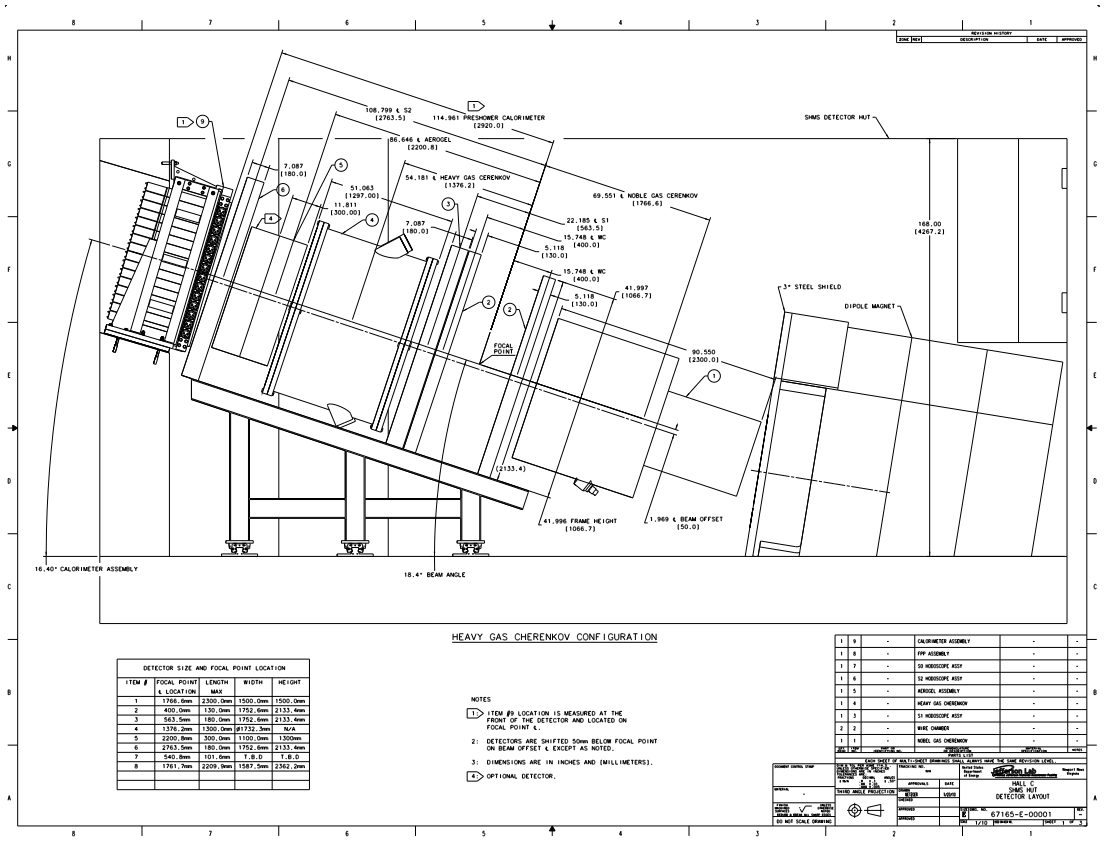
Materials Comparison

- Comparing nuclear interaction length, λ_I
- PDG source: https://pdg.lbl.gov/2004/reviews/atomicrpp.pdf
- Spreadsheet closer to PDG
- Note λ_I (cm) = λ_I (g/cm^2) $\div \rho$ (g/cm^3)

Material	Type	λ_I (cm)		
		Spreadsheet	Geant4	PDG
Al	G4Element	39.70	38.894	39.40
PVT	G4Material	78.77	69.969	78.97
Kapton	G4Material	60.20	55.82	60.42
Aerogel	Custom	680.42	670.3	677.6
Mylar	Custom	61.08	56.32	61.65
LH2	Custom	742	494	717

GEOMETRY DETAILS

z-Positions



	t (cm)	z (cm)
NGC	200	-177
DC1	3.81	-40
DC2	3.81	40
S1X	0.50	56
S1Y	0.50	60
HGC	104.44	137
AGC	26.39	220
S2X	0.50	276
S2Y	2.50	280
Cal	200	392

Target and Windows

	Material	t (cm)	ρ (g/cm^3)
Scattering chamber	LH2	10.0	0.0708
Chamber endcap	Al	0.01	2.70
HB entrance	Al	0.03	2.70
Air	Air	30	0.001205
Dipole exit	Al	0.05	2.70

- Events originate from center of target, travel through 5cm LH2
- No magnets, vacuum tubes included: target is 30 cm from NGC, following estimate of 30 cm air from spreadsheet
- Air density in spreadsheet is 0.001225: Geant4 value closer to true density at 20C, 100 kPa, not considering humidity

NGC

	Material	t (cm)	ρ (g/cm^3)
Entrance window	Tedlar	0.01	1.760
Gas	70/30 Ar/Ne	200	0.0015
Mirror	SiO_2	0.30	2.20
Mirror support	Rohacell	1.80	0.110
Exit window	Tedlar	0.01	1.760

- Spreadsheet has active gas as 1 atm CO_2: changed to noble gas mix at 1 atm
- Spreadsheet has Tedlar density 1.3 (from PDG): Geant4 default is 1.760, Dupont website lists 1.4 (clear film) or 1.7 (white film)
- This document claims entrance/exit windows are aluminum? https://hallcweb.jlab.org/DocDB/0009/000933/001/shms-cerv6.pdf

Drift Chambers

	Material	t (cm)	ρ (g/cm^3)
Entrance window	Mylar	0.0025	1.39
Gas	50/50 Ar/Ethane	3.81	0.00154
Field wires	W	0.0483	19.3
Sense wires	Cu	0.003	8.960
Cathode	Kapton	0.8	1.420
Exit window	Mylar	0.0025	1.39

- Open question: is "effective width" of wires in spreadsheet per DC, or for both total?
- Spreadsheet has density of W=2.70 (PDG lists 19.3, as does Geant)
- Spreadsheet lists Cu/Be mix for sense wires with density 19.3 (I've approximated to just Cu, with PDG density 8.96)

Hodoscopes

	Material	t (cm)	ρ (g/cm^3)
S1X	PVT	0.50	1.032
S1Y	PVT	0.50	1.032
S2X	PVT	0.50	1.032
S2Y	Quartz	2.50	2.650

- Spreadsheet has one line for PVT scintillators with length 1.125
- I have made three different PVT planes with width 0.5 cm of each bar (neglecting overlaps between bars in plane)
- No quartz S2Y in spreadsheet, has been added here

HGC and AGC

	Material	t (cm)	ρ (g/cm^3)
Entrance window	Al	0.10	2.7
Heavy gas	C_4F_{10}	104.44	0.0112
Mirror	SiO_2	0.30	2.32
Exit window	Al	0.10	2.70
Entrance window	Al	0.013	2.70
Aerogel	SiO_2	9.0	0.143
Air	Air	17.10	0.00121
Exit window	Al	0.016	2.70

- HGC active gas in spreadsheet was CO_2 at 1 atm, changed to C_4F_10 at 1 atm
- Only coded one aerogel tray - highest index of refraction = highest density, upper bound on absorption