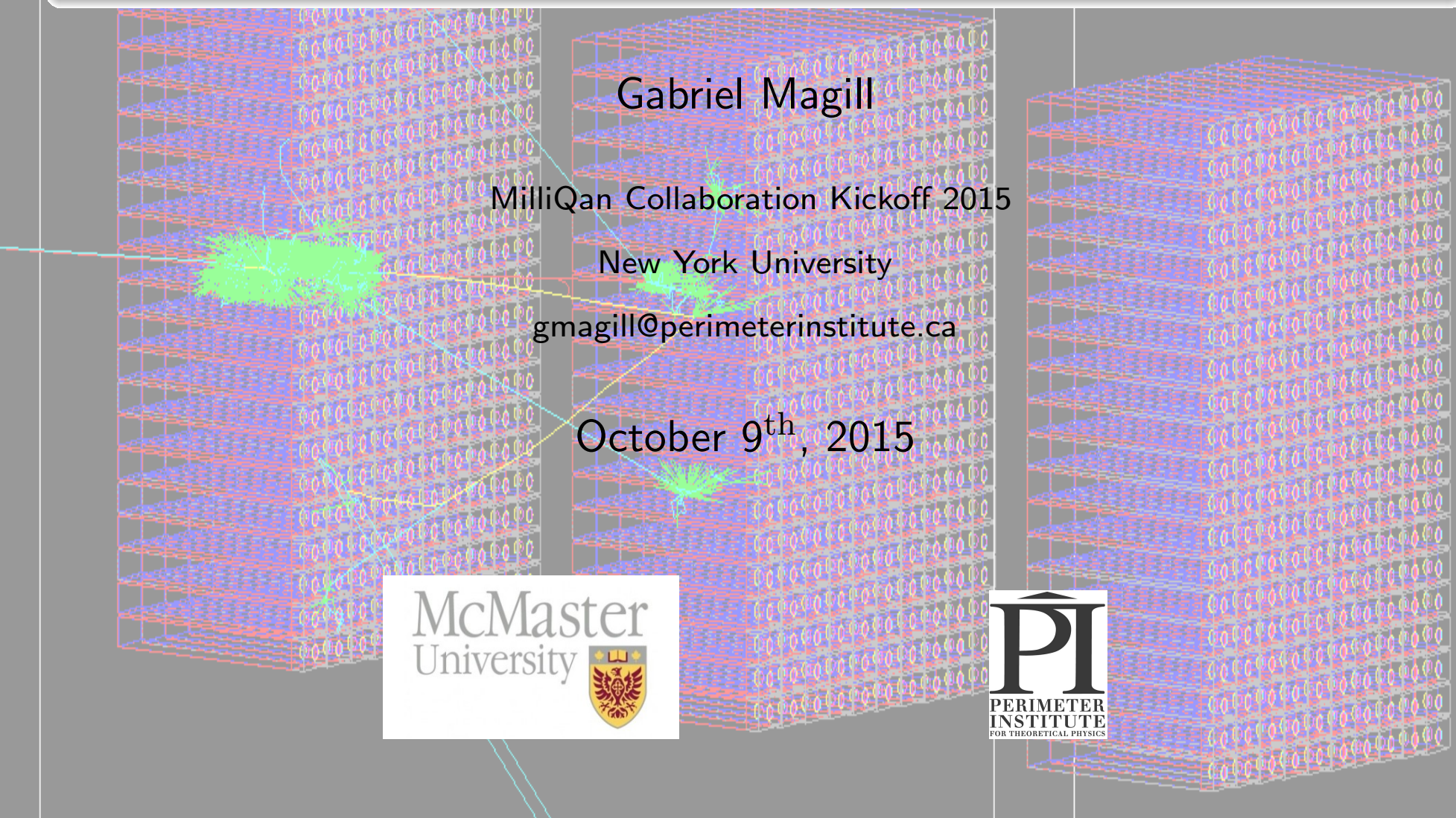
# Milli-Charged Particles at the LHC




Gabriel Magill

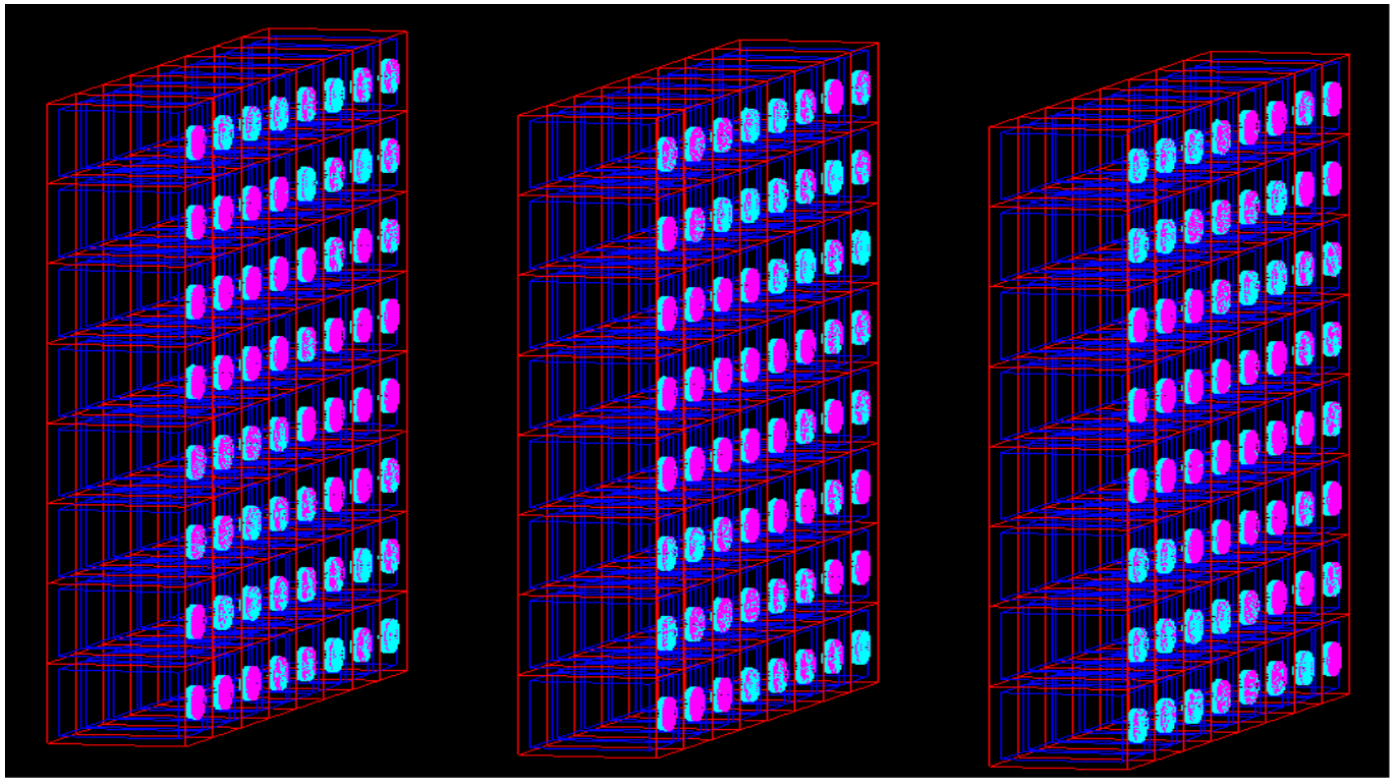
MilliQan Collaboration Kickoff 2015

New York University

gmagill@perimeterinstitute.ca


October $9^{\text{th}}$, 2015

# Simulation in Action!

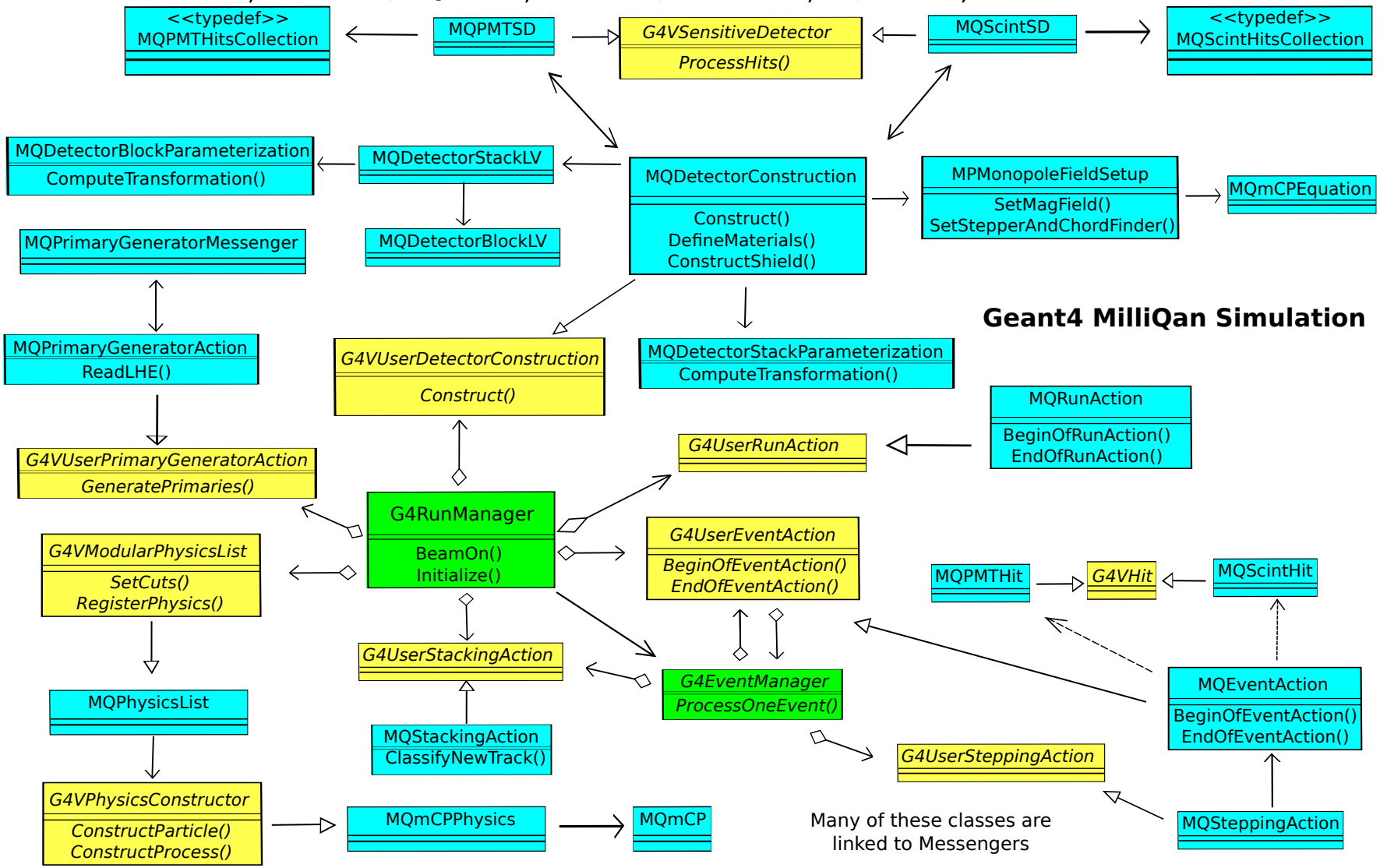


# About the Simulation

- Begun by James London (OSU)
  - Geometry parameterization and scintillator/pmt design
- Inhereted in May 2015
- Geant4
- Calculate $3\sigma$ sensitivity and 95% C.L. exclusion on the mass and charge
  - Compare with poisson estimates (1410.6816)
- Required for official proposal
- Used to calibrate the experiment

# Class Diagram

- Based on */exoticphysics/monopole* & */optical/LXe*



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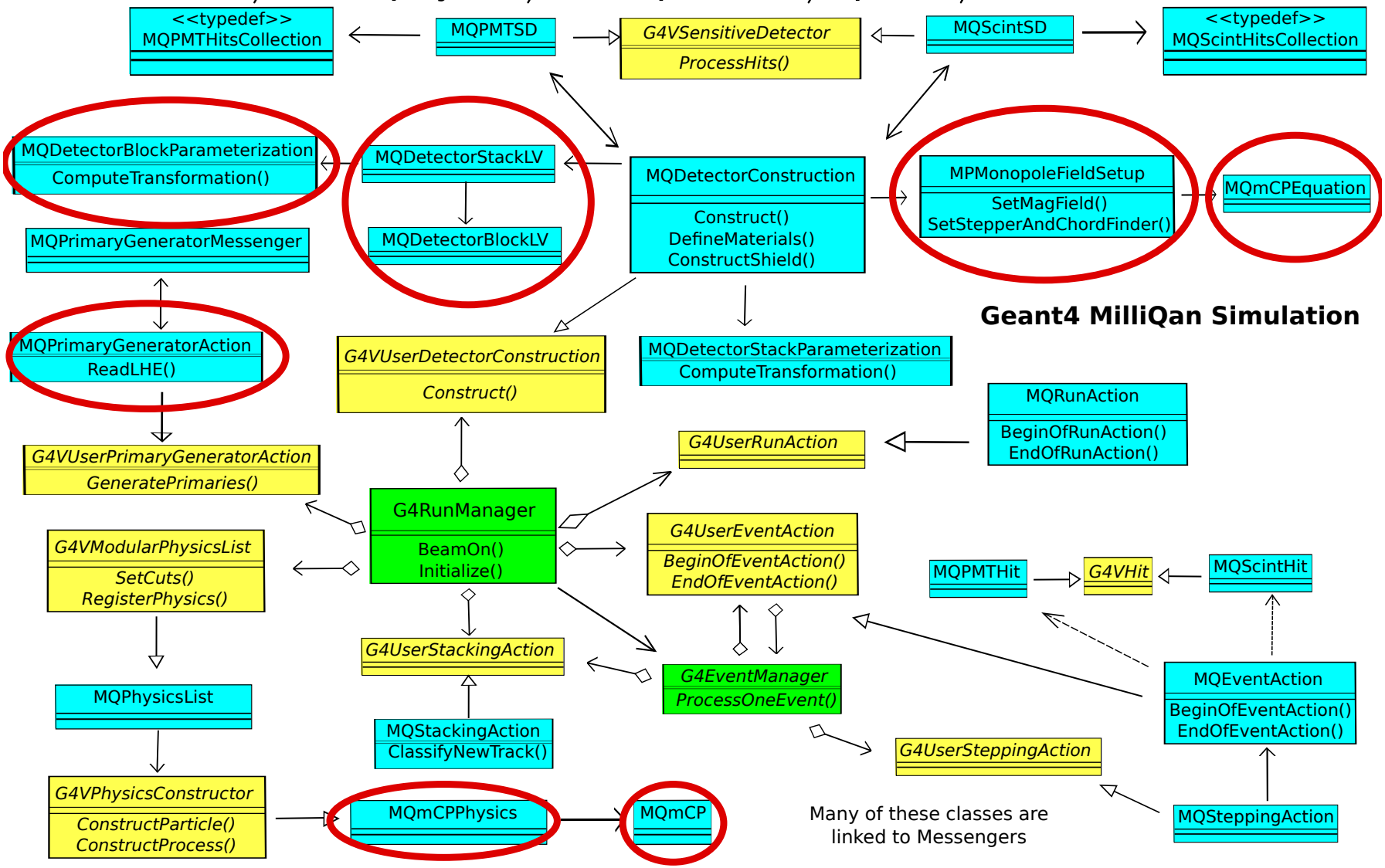

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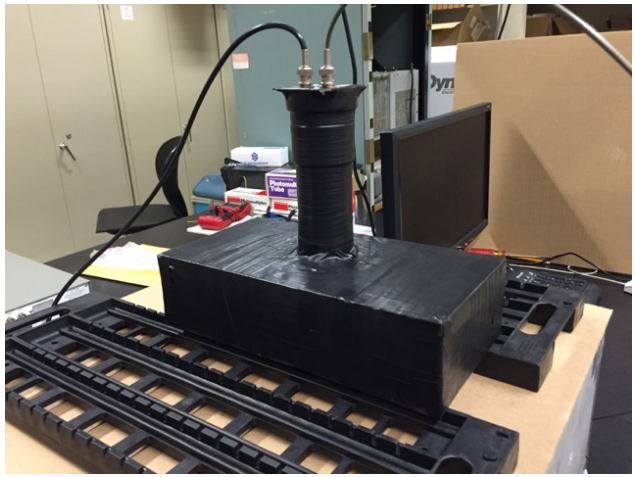

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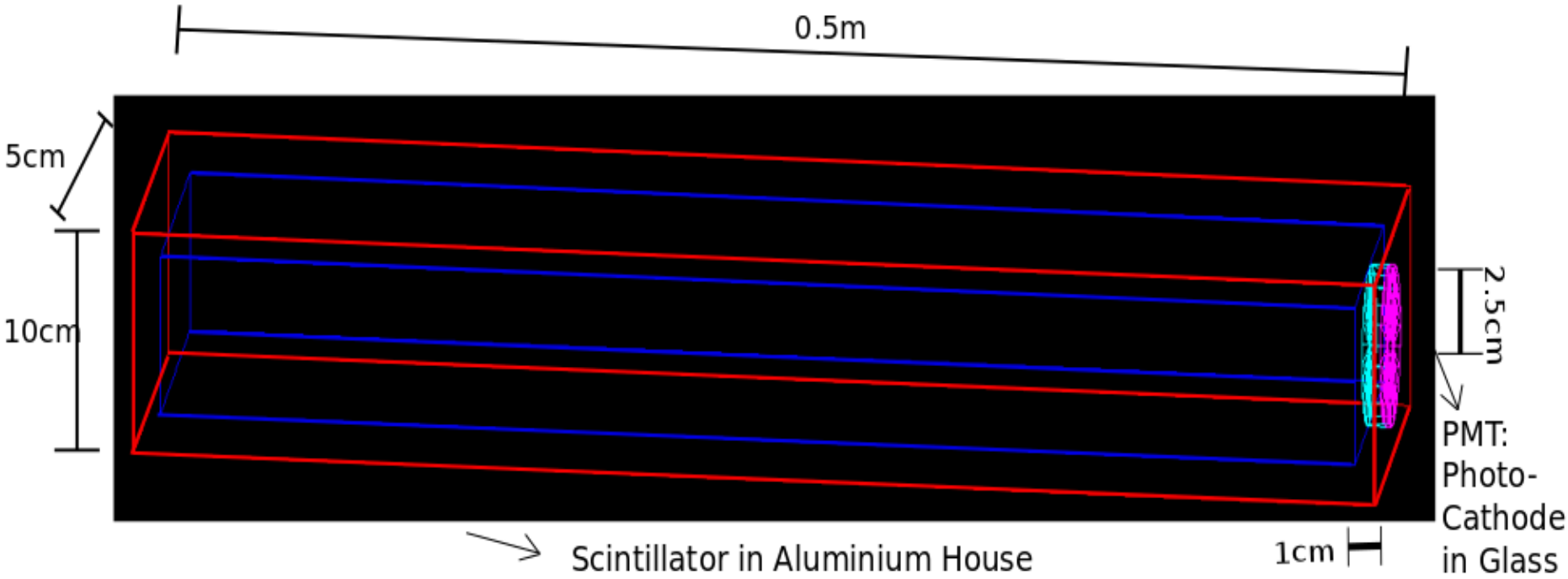

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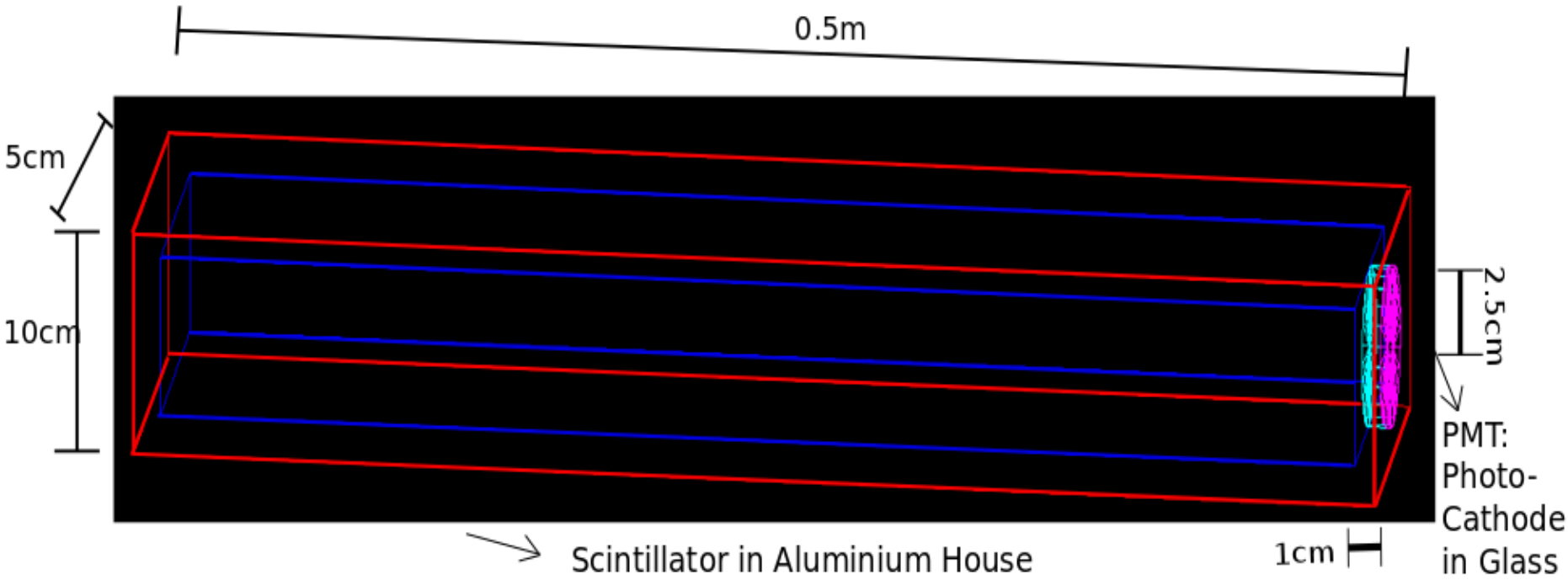

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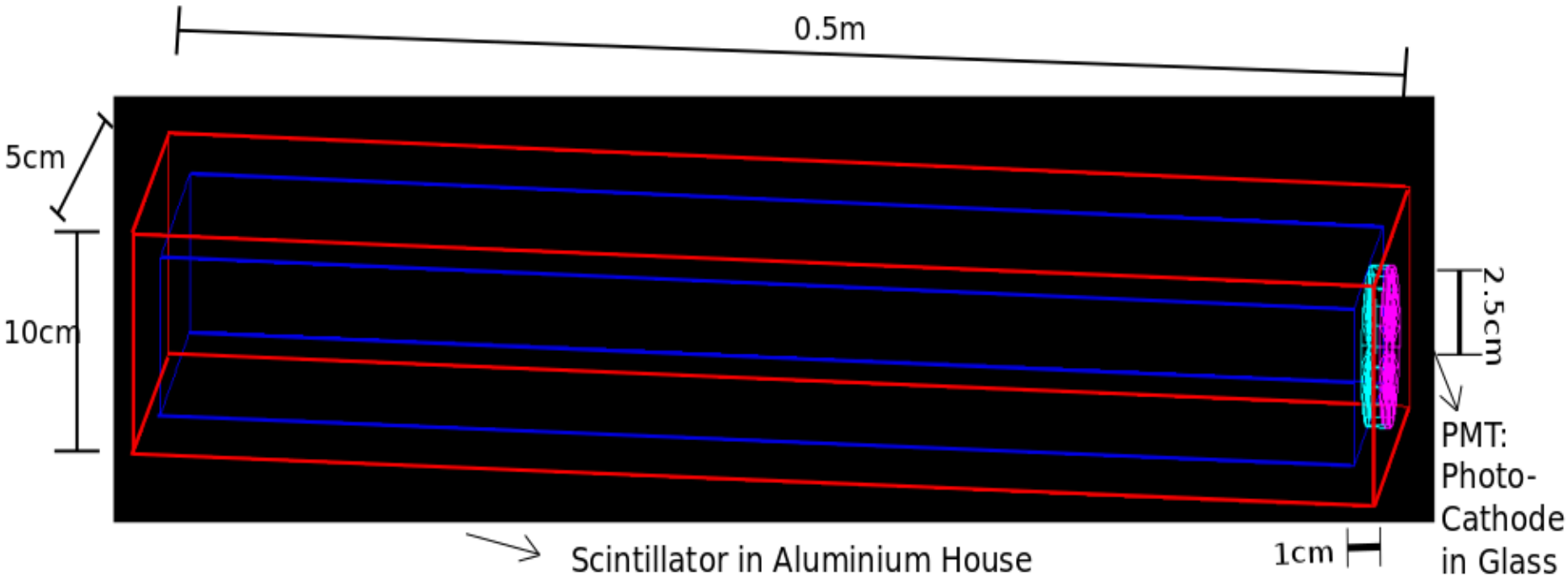

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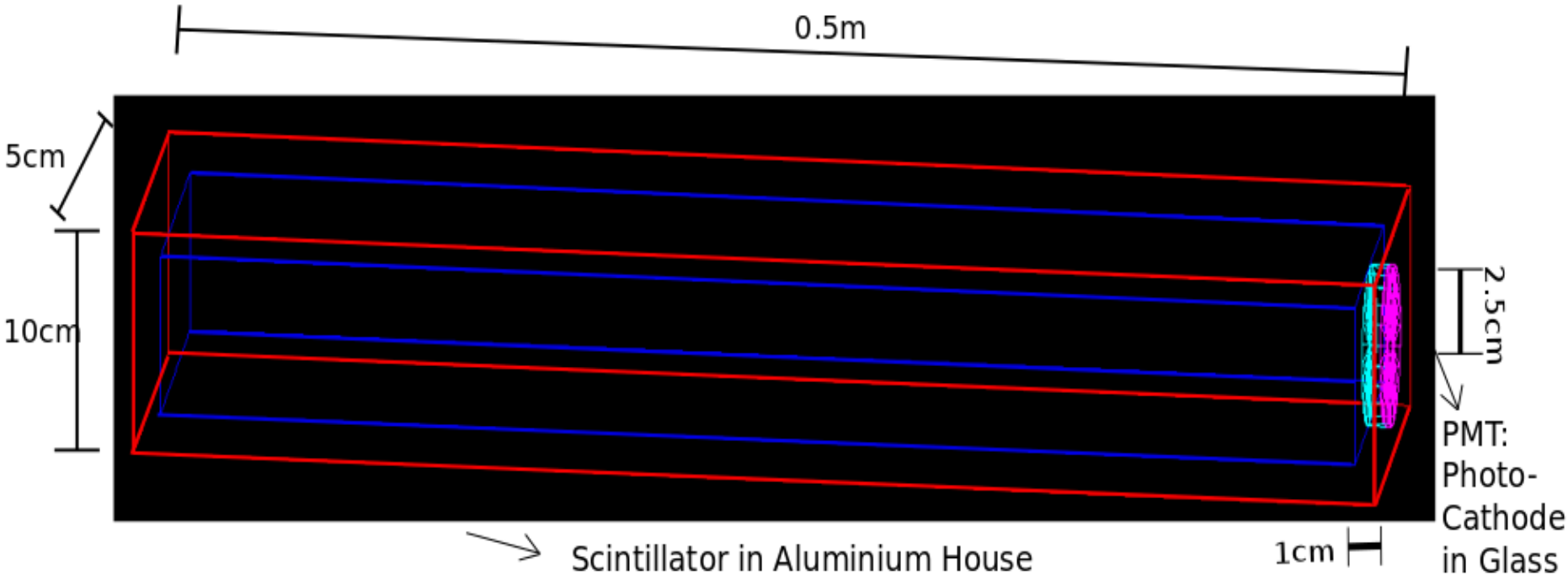

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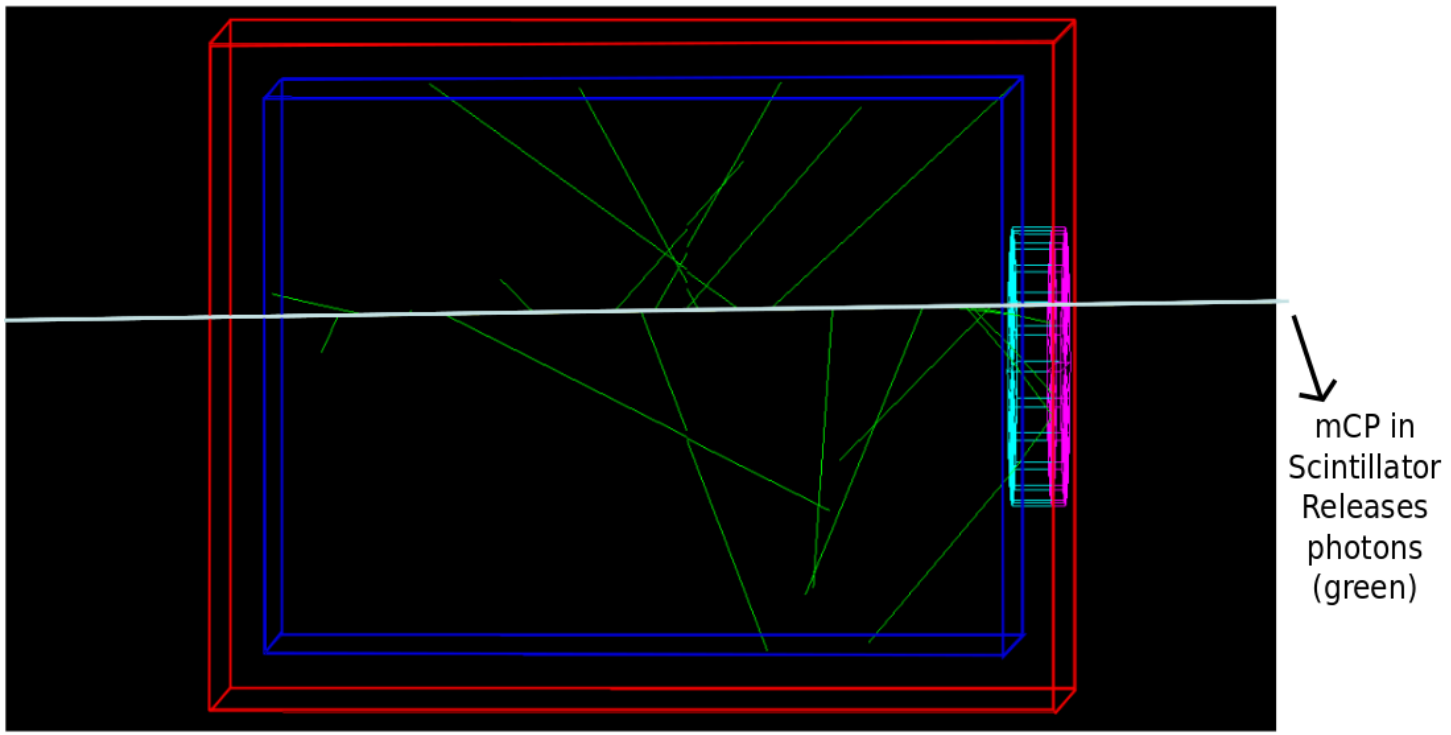

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- MQDetectorBlockLV = Scintillator + PMT
- MQDetectorBlockParameterization = Stack
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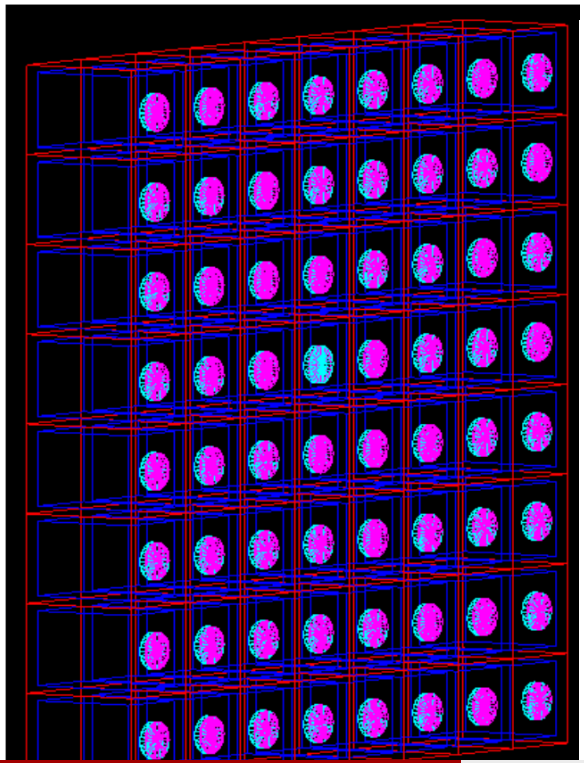
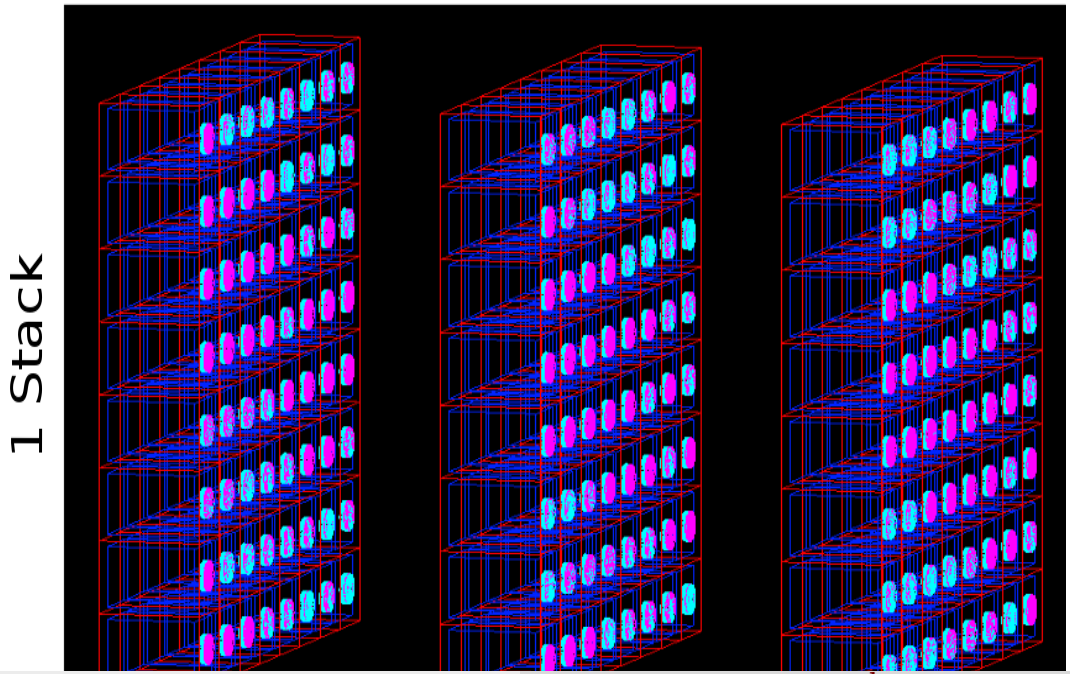
MQDetectorStackLV 8 Blocks




MQDetectorConstruction 3 Stacks



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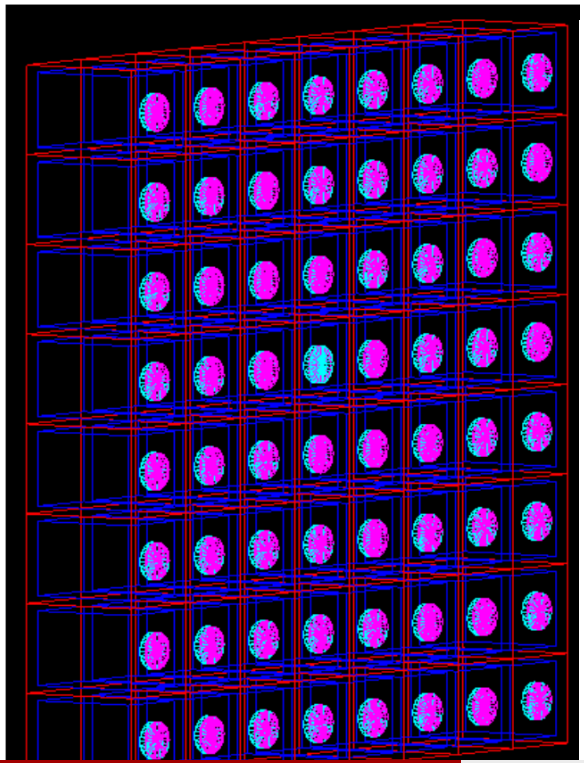


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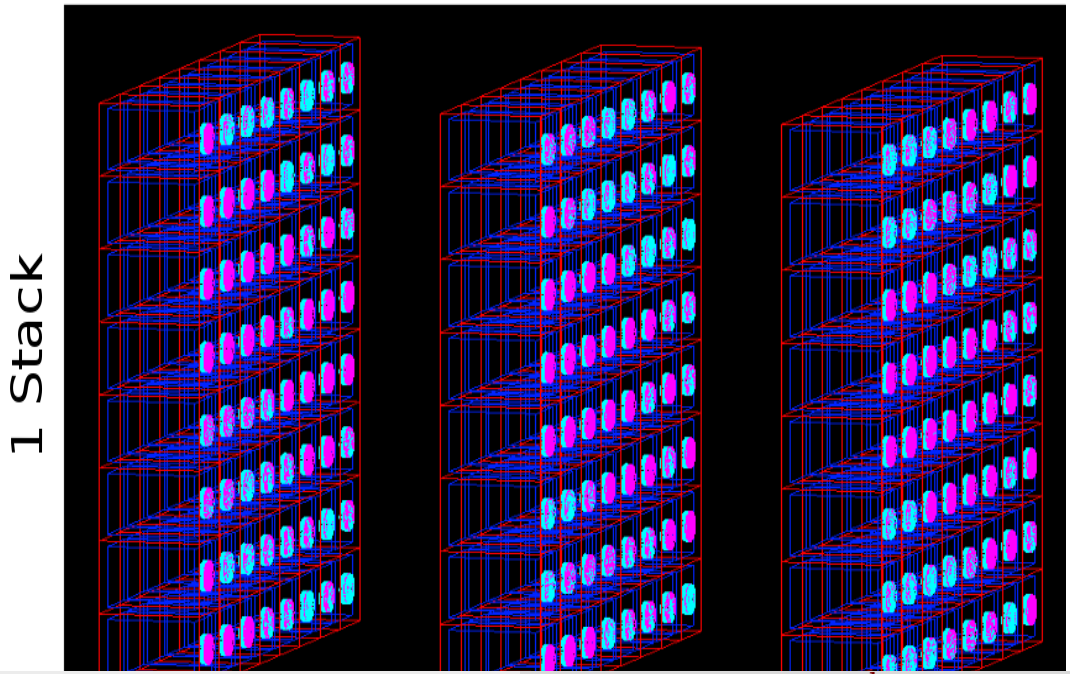

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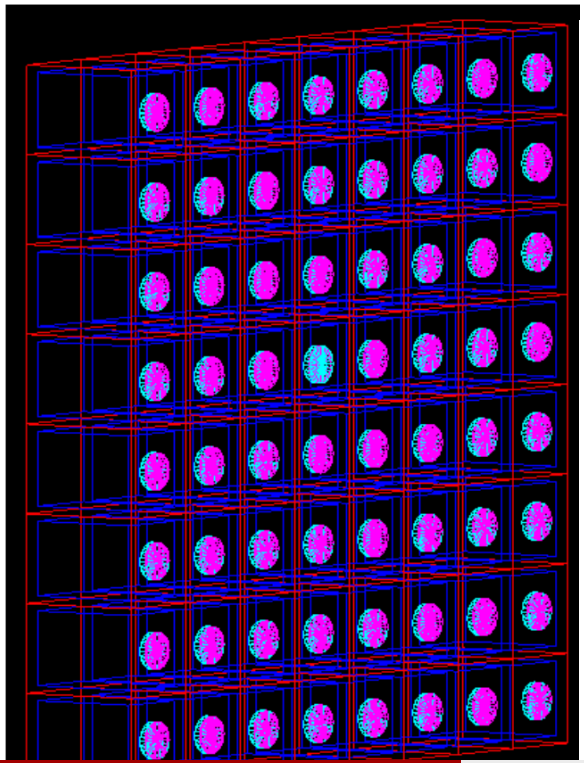


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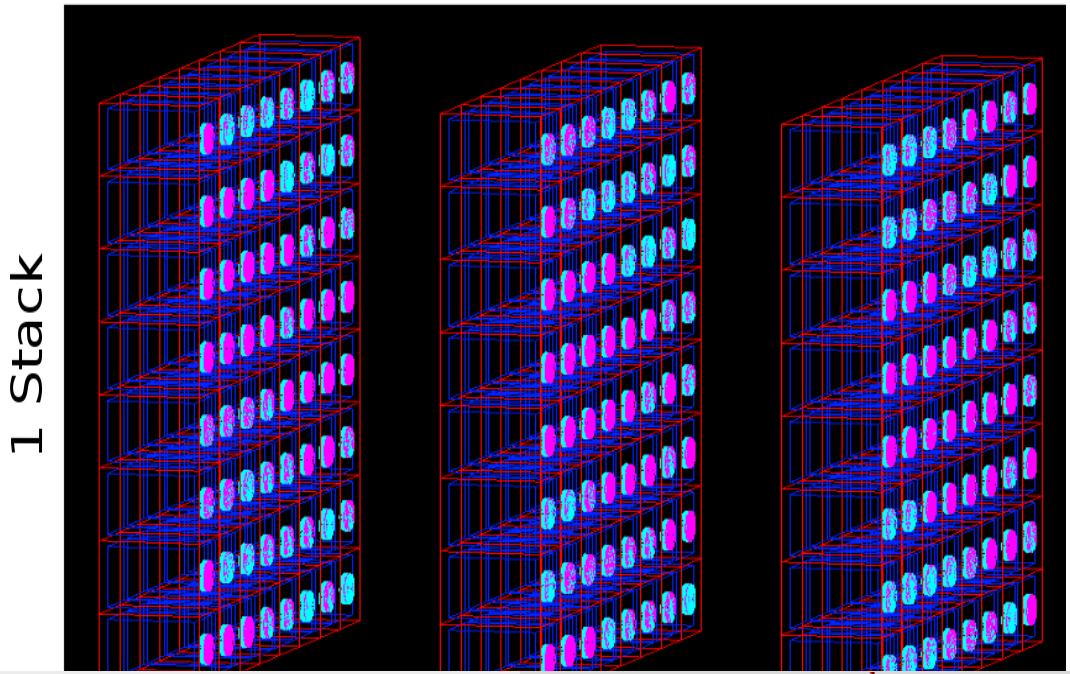

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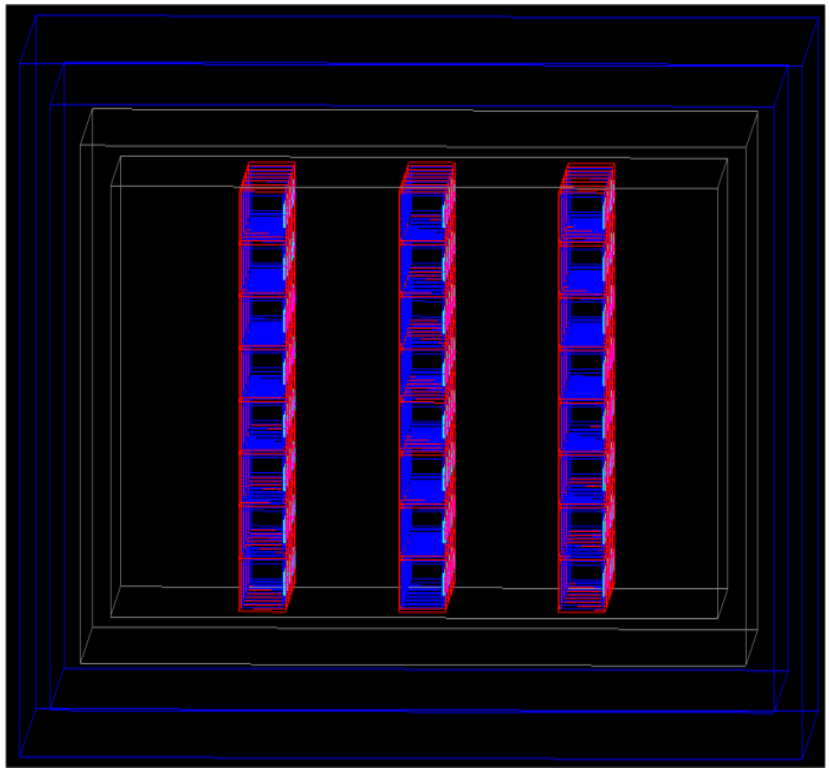
- Two-layer shielding around detectors+concrete wall

Shielding:
Polyethylene
(Blue)
Led (gray)
G4 Boolean
Solid
Subtraction



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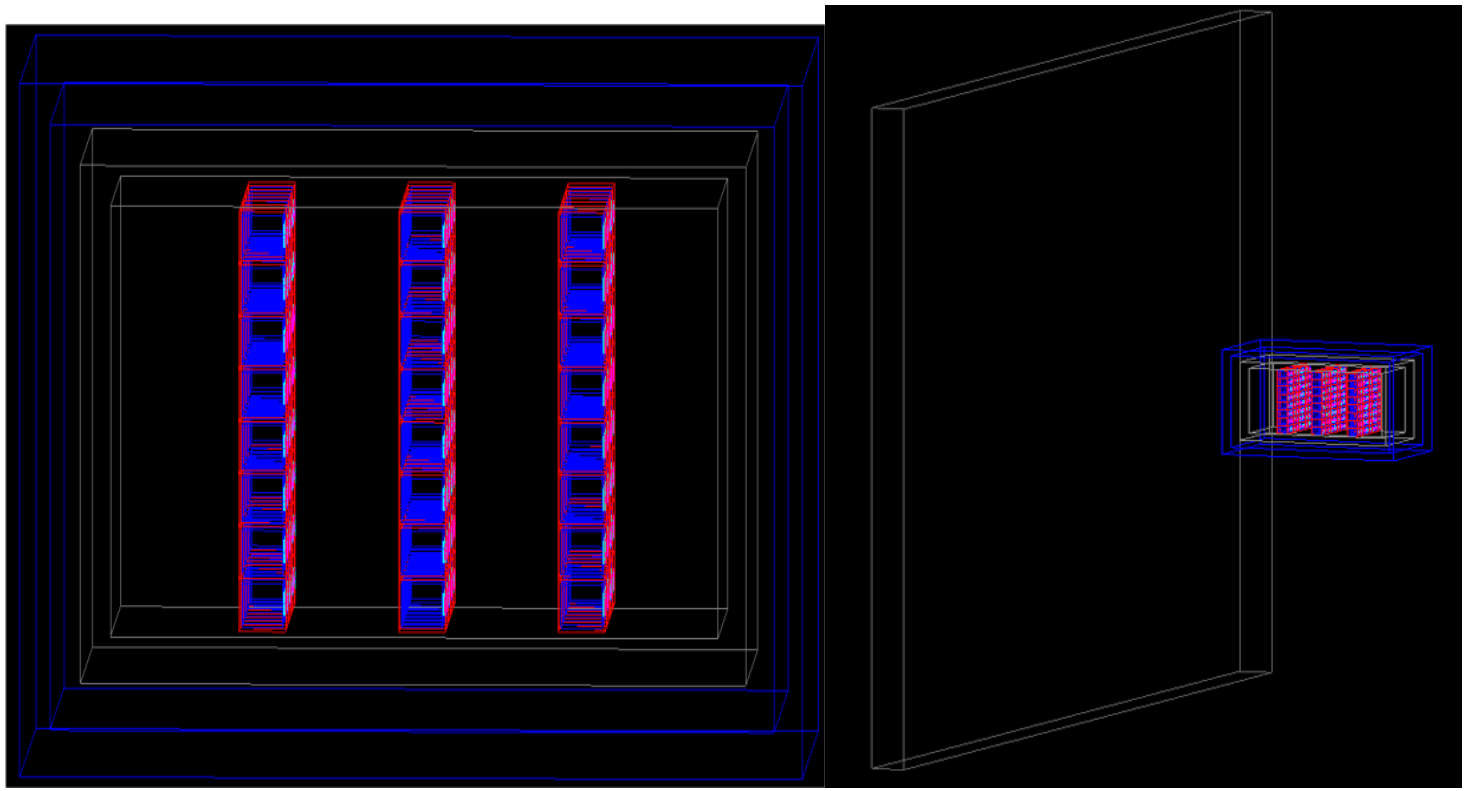

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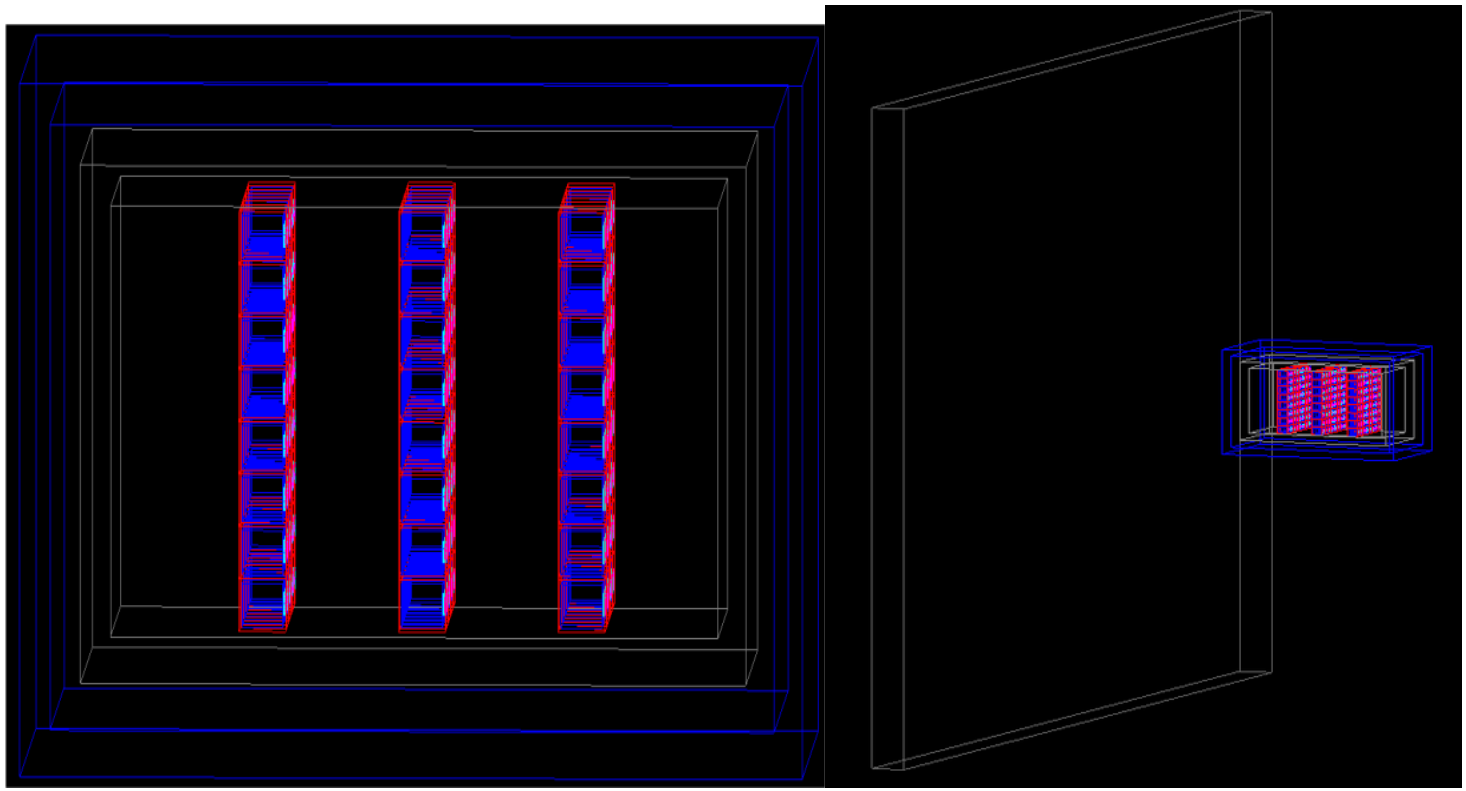
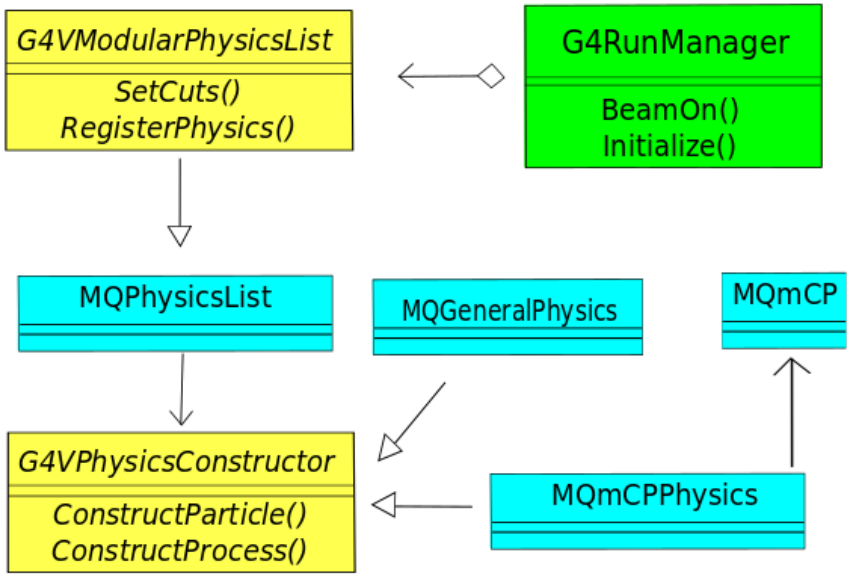


# What's missing - Geometry

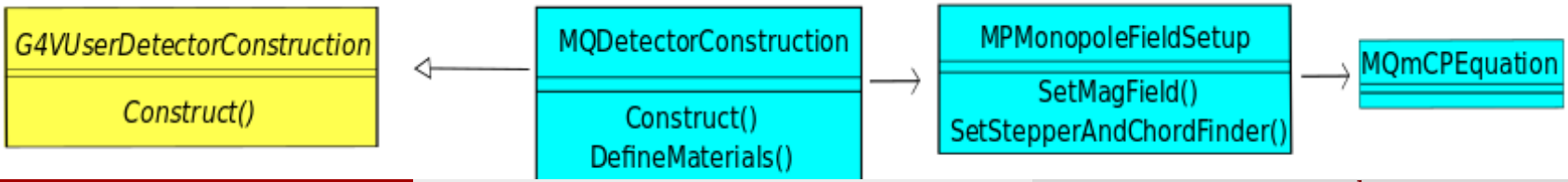
- Functionality to rotate (align along vector) experiment (in progress)
- Projective scintillators
- Physical dimensions, material
- Better modeling of material in between interaction point and experiment

# What's done - Physics

- mCP Particle (derived class from G4ParticleDefinition)
  - Arbitrary valued mass, electric and magnetic charge
- G4hIonisation for mCP




- Global magnetic field
  - Stepper + chord finder based of derived G4EquationOfMotion class



# What's done - Physics

- Placeholders for scintillator and PMT properties

Scintillator:

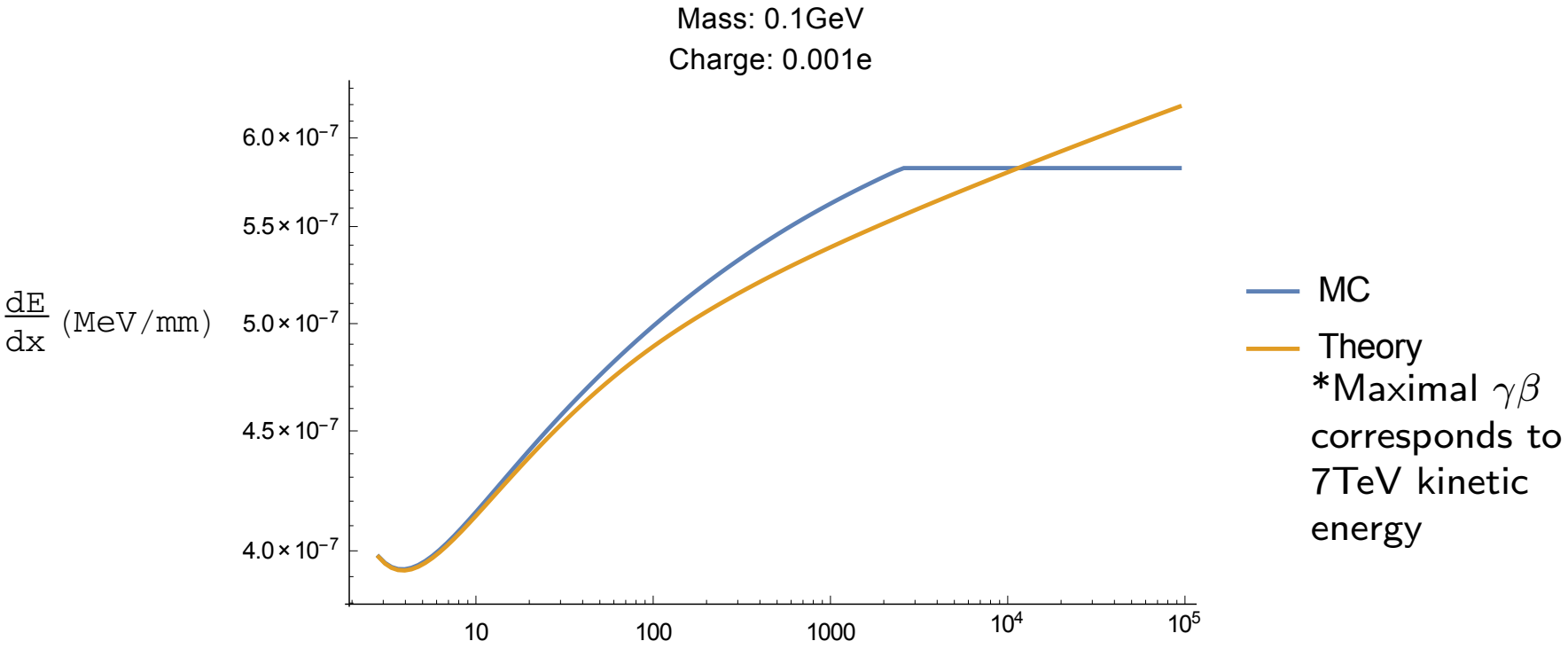
```
En = { 7.0eV, 7.07eV, 7.14eV };
SCINT = { 0.1, 1.0, 0.1 };
RIND = { 1.59, 1.57, 1.54 };
ABSL = { 35cm, 35cm, 35cm };
(FASTCOMPONENT, En, SCINT, num);
(SLOWCOMPONENT, En, SCINT, num);
(RINDEX, En, RIND, num);
(ABSLENGTH, En, ABSL, num);
(SCINTILLATIONYIELD, 12. / MeV);
(RESOLUTIONSCALE, 1.0);
(FASTTIMECONSTANT, 20ns);
(SLOWTIMECONSTANT, 45ns);
(YIELDRATIO, 1.0);
SetBirksConstant(0.126 mm / MeV);
ScintillatorHouseReflectivity
```

Photocathode:

```
EFF={1.,1.};
en={7.0eV, 7.14eV}
ReR={1.92,1.92};
ImR={1.69,1.69};
(EFFICIENCY,en,EFF,num);
(REALRINDEX,en, ReR, num);
(IMAGINARYRINDEX, en, ImR, num);
PMTHouseReflectivity
G4OpticalSurface(opsurf,
glisur,polished, dielectric_metal);
```

# Validation

## Energy loss of mCP through carbon




$$\left.\frac{dE}{dx}\right|_{Theory} = \rho K \epsilon^2 \frac{Z}{A}\frac{1}{\beta^2}\left(\ln\left[\frac{2m_e c^2\beta^2\gamma^2 W_{max}}{I^2}\right] - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right)$$

$\delta(\beta\gamma)$ follows Sternheimers parameterization (function by parts fitted to material)

$W_{max}$ max E transfer to e- $I$: mean excitation energy

$\text{dedx[i]}_{MC}$ = 'G4EmCalculator'.ComputeElectronicDEDX(ekin[i], mCP, matName);

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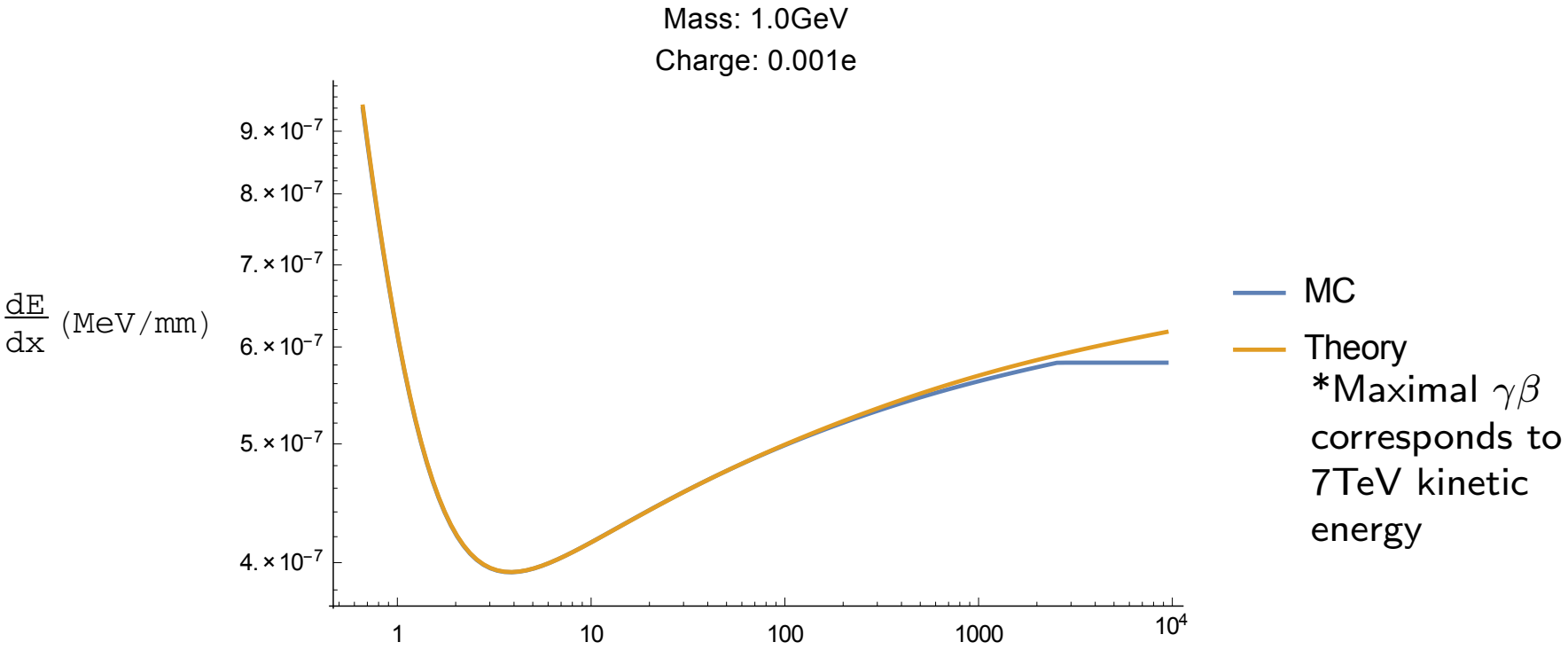


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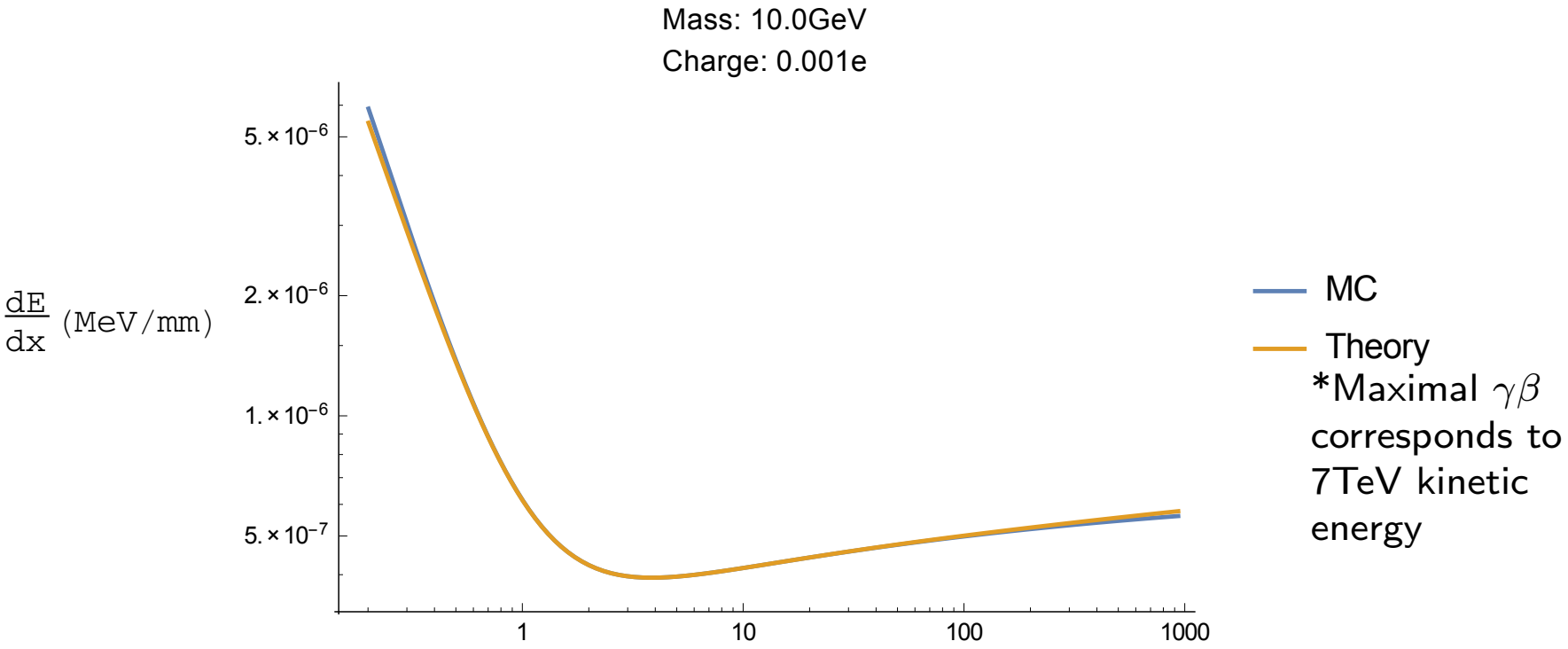


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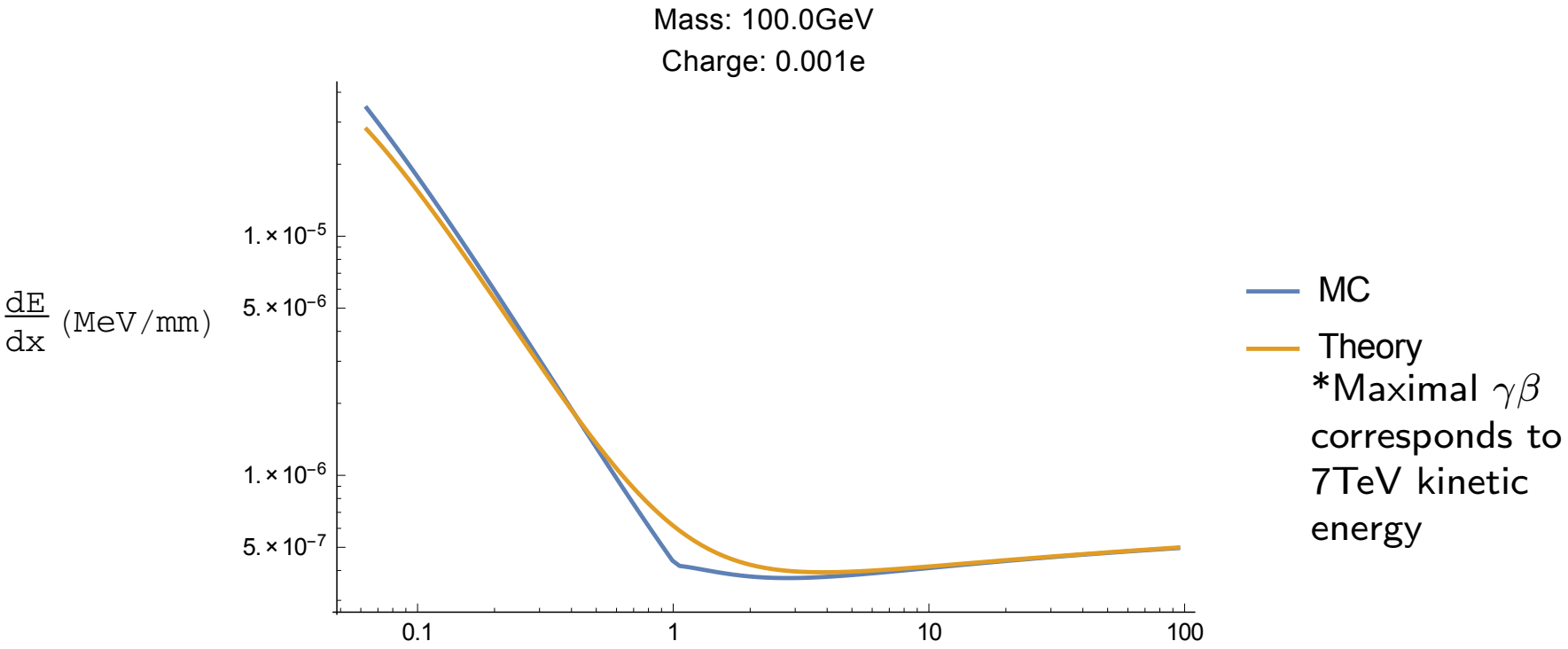


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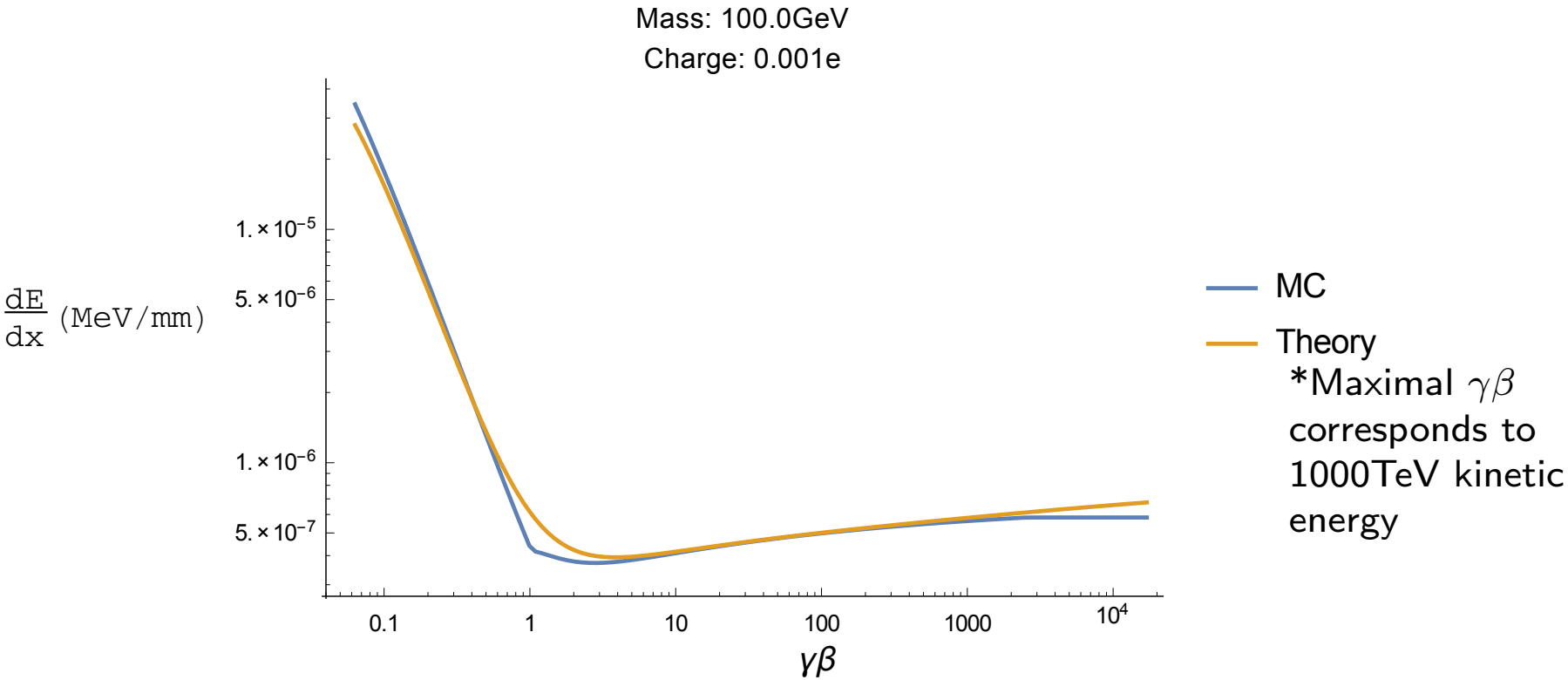


*Maximal $\gamma\beta$ corresponds to 1000TeV kinetic energy

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# What's missing - Physics

- Radiative effects for mCP and other physics:
  - G4hMultipleScattering
  - G4eBremsstrahlung
  - G4Cerenkov
  - G4TransitionRadiation
  - Which ones to take into account? Which ones to ignore?

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| Theo/Sim | 0.001e | 0.01e | 0.1e | 1e |
|---|---|---|---|---|
| 0.1GeV | 0 | 0.02 | 0.41 | 1 |
| 1GeV | 0 | 0.02 | 0.18 | 1 |
| 10GeV | 0 | 0.01 | 1 | 1 |
| 100GeV | 0 | 0 | 1 | 1 |

Ratio between theoretical and simulated radius of curvature

KE = 1 GeV; B=3T; Room = 5m x 5m x 5m

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- Fill in Scintillator/PMT placeholders

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- Local CMS magnetic field: how to get it?
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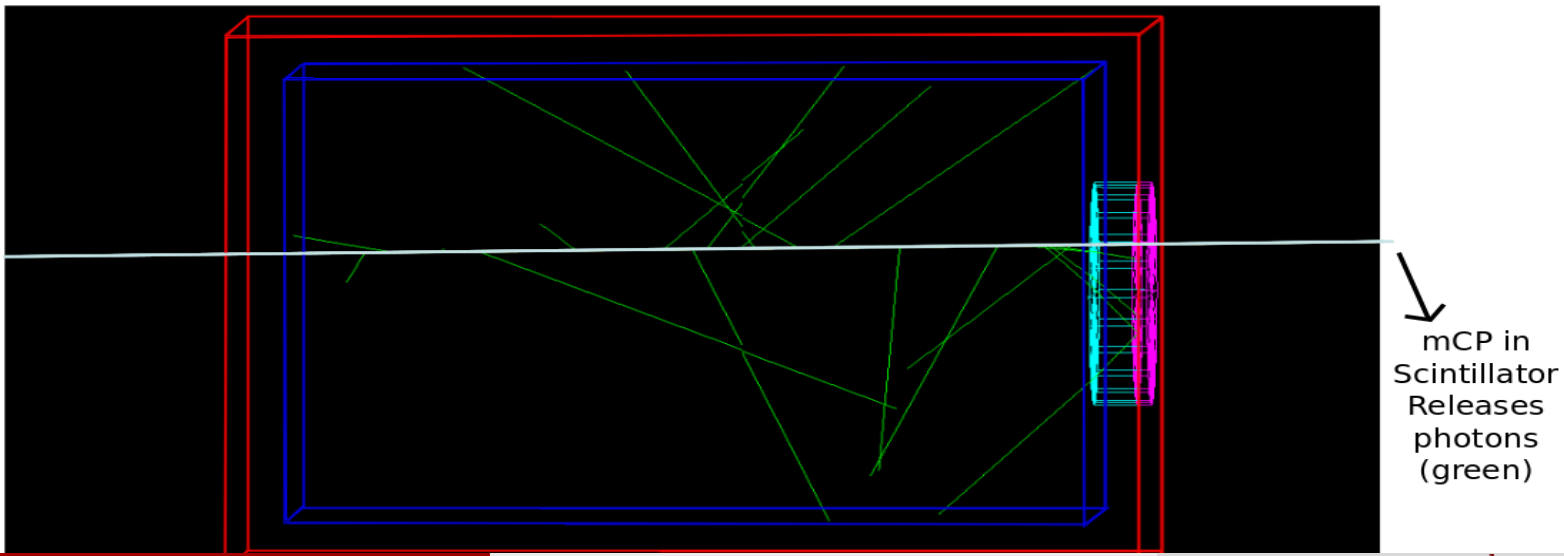
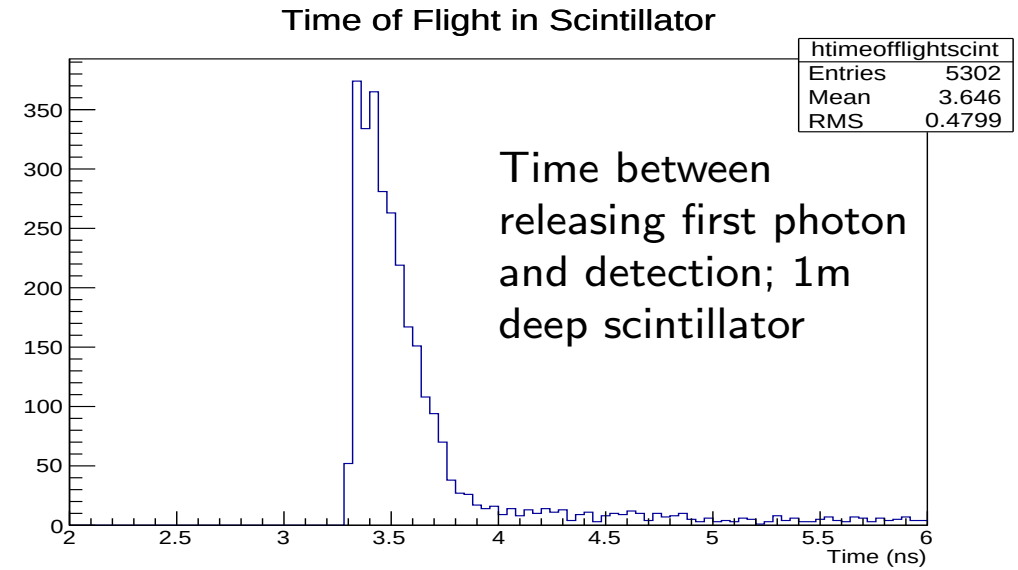
- Fill in Scintillator/PMT placeholders
- Make scintillator / PMT interface more realistic?

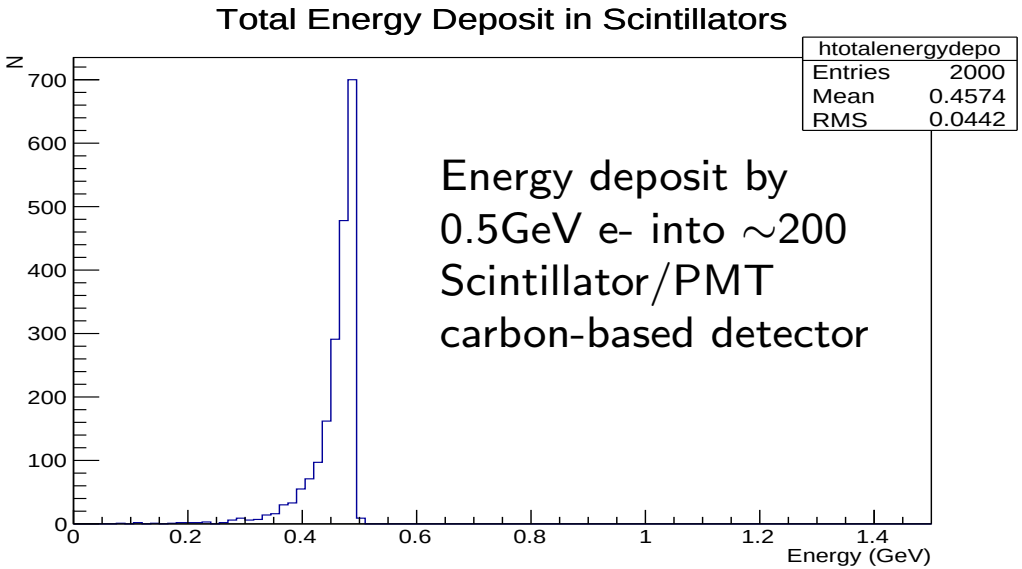


# What's done - Physics Chain

- Feynrules + Madgraph simulation of mCP
- PrimaryGeneratorAction reads in .LHE files
- Scintillators/PMT are G4VSensitiveDetector
  - Records position, time, momentum, energy deposition of steps
- Calculates dE/dx for various materials (ComputeElectronicDEDX)
- Calculates time of flight through scintillator, energy deposition in scintillator
- Outputs all this information to .root Ntuple
- (Very basic) ROOT macro for plotting Ntuple

# Physics Output



# What's missing - Physics Chain

- Build-up ROOT macro
  - Sensitivity/exclusion plots
  - Calibration plots
  - Implement coincidence readout strategy (CAEN)
- Interface with CMS detector simulation
- Backgrounds?
- R-hadrons

# Geant4 School

Attending:
Geant4 Advanced-level Tutorial
October 19th @ MIT

Gladly welcome suggestions and questions!

Gabriel Magill
gmagill@perimeterinstitute.ca
Waterloo, Canada