Detecting Muons in the Pion Background for Hall C

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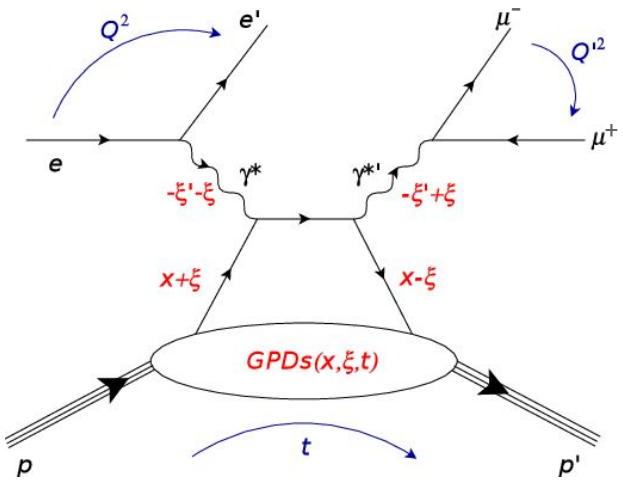
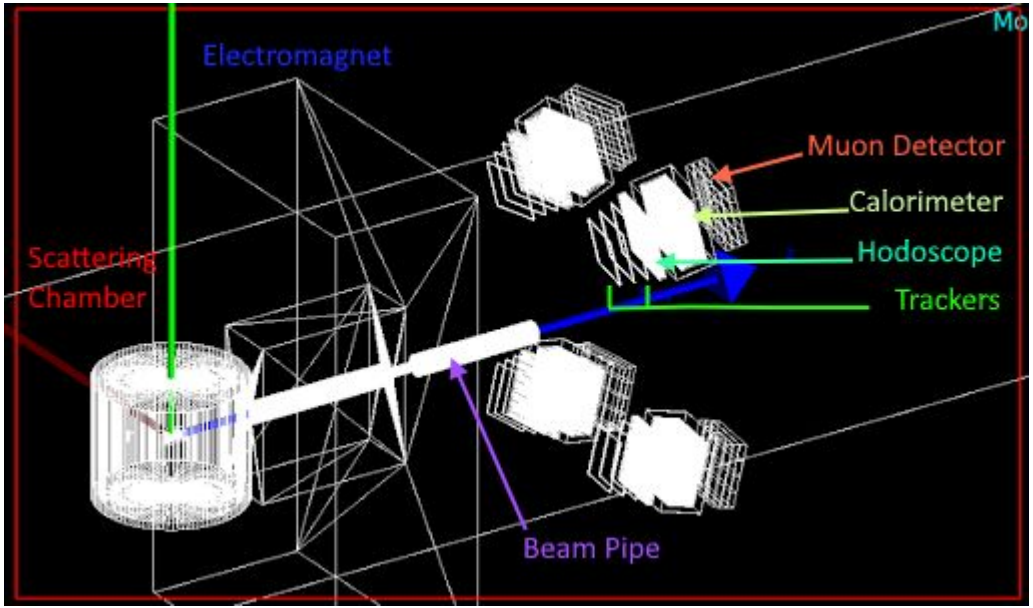
Double Deeply Virtual Compton Scattering (DDVCS)

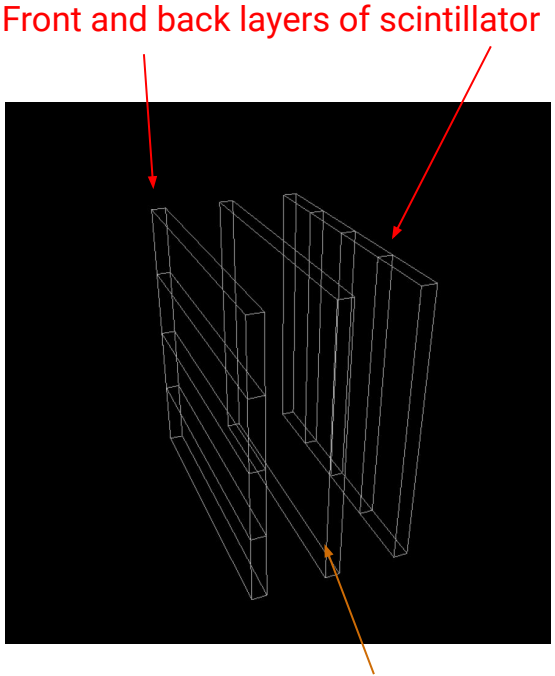
- Electron beam with fixed hydrogen target
- mu- / mu+ pair production
- 7D Phase Space: X_{bj}, t, Q^2, Q'^2, θ, ϕ, ϕ_L



S. Zhao (DOI: https://doi.org/10.22323/1.346.0068)

DDVCS Experiment Setup





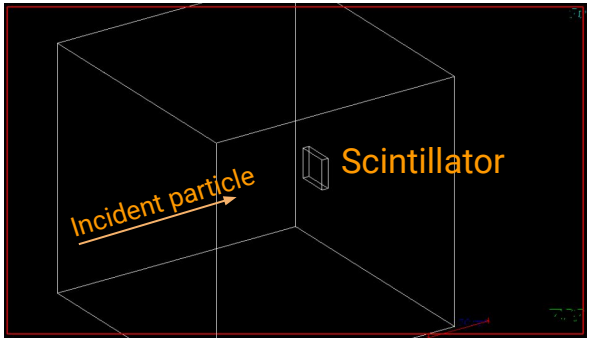
Learned Geant4 to Explore the Possibilities for the Muon Detector

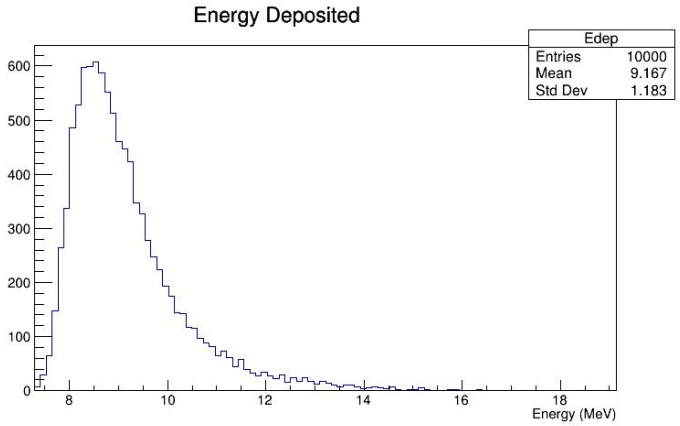
```
G4VPhysicalVolume* MuonDetectorConstruction::Construct()
{
    // Construct the World volume.
    // Define the materials.
    G4NistManager* man = G4NistManager::Instance();
    G4Material* Air = man->FindOrBuildMaterial("G4_AIR");
    G4Box* WorldBox = new G4Box("WorldBox", 2*m, 2*m, 2*m);
    G4LogicalVolume* WorldLV = new G4LogicalVolume(WorldBox, Air,"WorldLV");
    G4VPhysicalVolume* physWorld;
    physWorld = new G4PVPlacement(0, G4ThreeVector(0.,0.,0.), WorldLV, "World", 0, false, 0);

    double_t absorber_thickness = 100*cm;
    double_t absorber_zpos = (absorber_thickness/2);
    double_t gap = 10*cm;
    double_t detector_thickness = 5*cm;
    double_t detector_zpos = absorber_thickness + gap + (detector_thickness/2);

    // Add the muon detector
    G4Box* DetectorBox = new G4Box("DetectorBox", 12*cm, 12*cm, (detector_thickness/2));
    G4Material* ScintMaterial = MuonDetectorConstruction::GetMaterial("Polyvinyltoulene");
    G4LogicalVolume* DetectorLV = new G4LogicalVolume(DetectorBox, ScintMaterial, "ScintillatorLV");
    new G4PVPlacement(0,                                    // rotation
                      G4ThreeVector(0, 0, detector_zpos),   // position
                      DetectorLV,                           // logical volume
                      "Muon_Detector_PV",                   // name
                      physWorld->GetLogicalVolume(),        // its mother  volume
                      false,                                // no boolean operation
                      0);                                   // copy number

    //  Make the muon detector sensitive
    G4VSensitiveDetector* muonSD = new MuonDetectorSD;
    CreateSensitiveDetector(muonSD, DetectorLV);
```

```
    // Construct default run manger
    G4RunManager* runManager = new G4RunManager;

    // Set up DetectorConstruction
    runManager->SetUserInitialization(new MuonDetectorConstruction());

    // Set up PhysicsList
    G4VModularPhysicsList* physicsList = new QBBC;
    runManager->SetUserInitialization(physicsList);
    G4HadronicProcessStore::Instance()->SetVerbose(0);

    // Set up user ActionInitialization
    runManager->SetUserInitialization(new MDActionInitialization);

    // Set up visualization and choose interactive or batch mode
    G4VisManager* visManager = new G4VisExecutive("quiet");
    visManager->Initialize();
    G4UImanager* UImanager = G4UImanager::GetUIpointer();
```

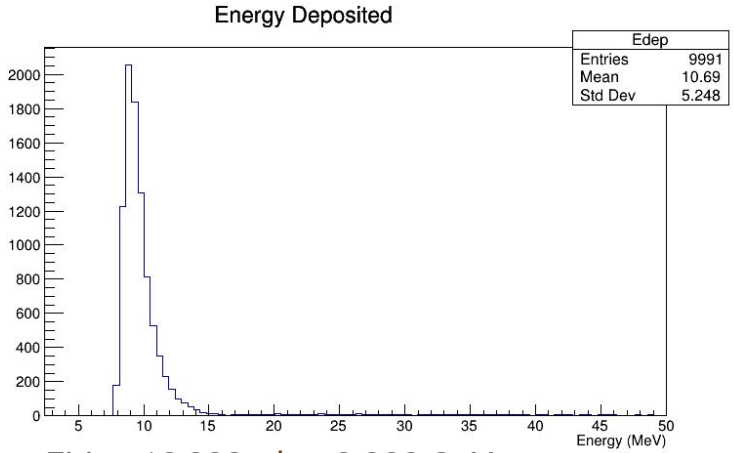
- World Box:
  - (4 m, 4 m, 4 m)
  - Air
- Scintillator:
  - (24 cm, 24 cm, 5 cm)
  - Polyvinyltoluene
- Physics List: QBBC

Energy Deposition of Muons and Pions





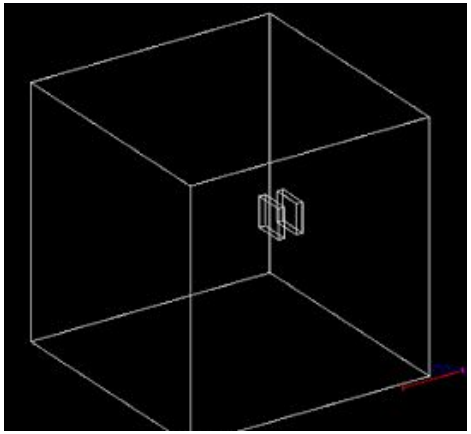
Firing 10,000 μ^- at 0.200 GeV.

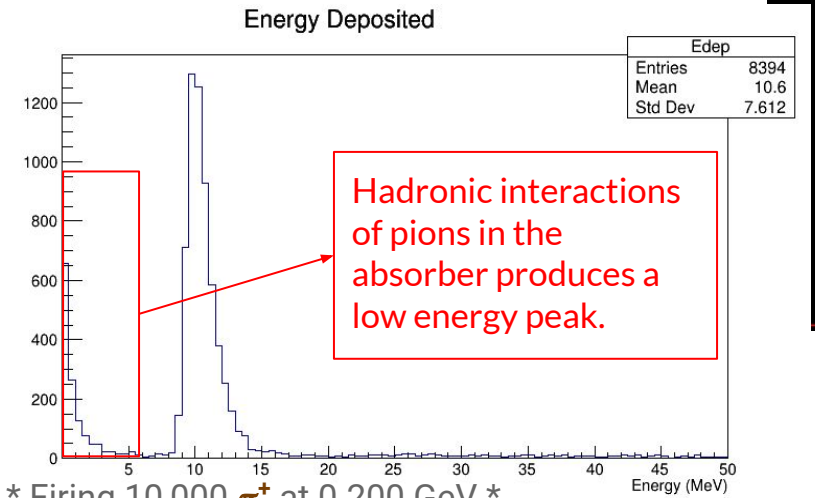


Firing 10,000 π^+ at 0.200 GeV.

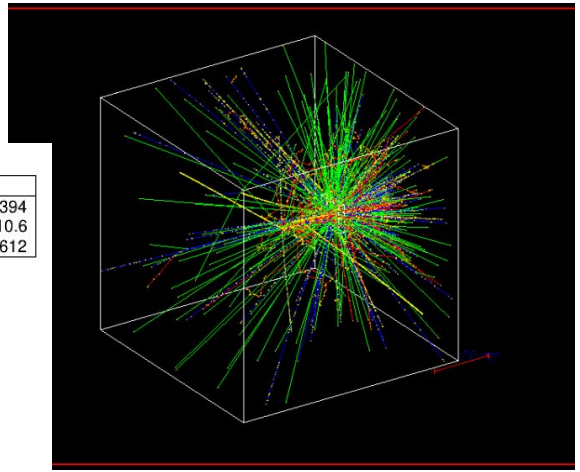
Pions and Muons deposit a similar amount of energy into the scintillator.

Pion Energy Deposition in Scintillator





* Firing 10,000 π^+ at 0.200 GeV *



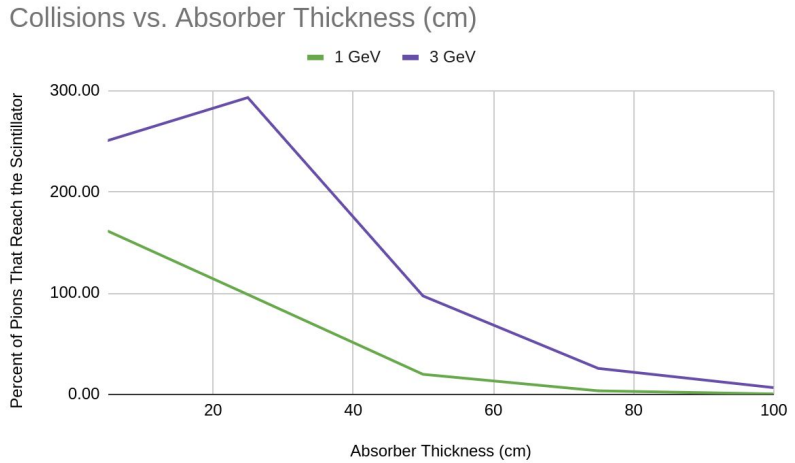
The addition of the absorber introduced a low-energy peak due to QCD interactions of the pions with the Iron.

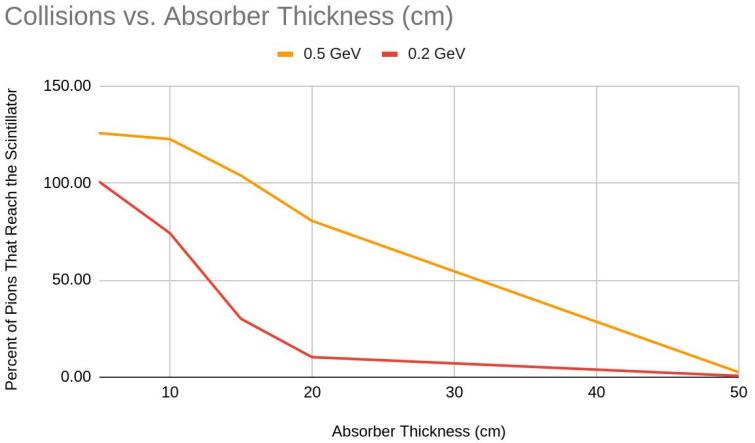
Collisions in the Scintillator at Different Absorber Thicknesses

- 90% of all pions and secondary particle collisions are blocked with 1 m of Iron at 3 GeV.

TODO: Study the momenta of the pions that we expect to see while studying DDVCS

Shooting 10,000 π^+ from the particle gun.



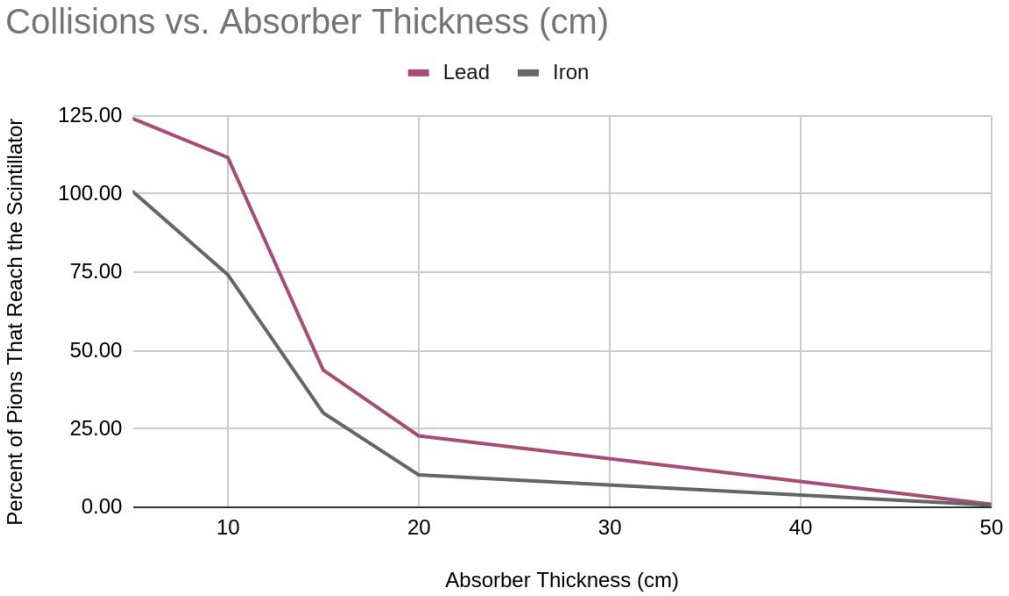


Pion Absorber

- Fired 10,000 pions
- Pion energy 0.200 GeV

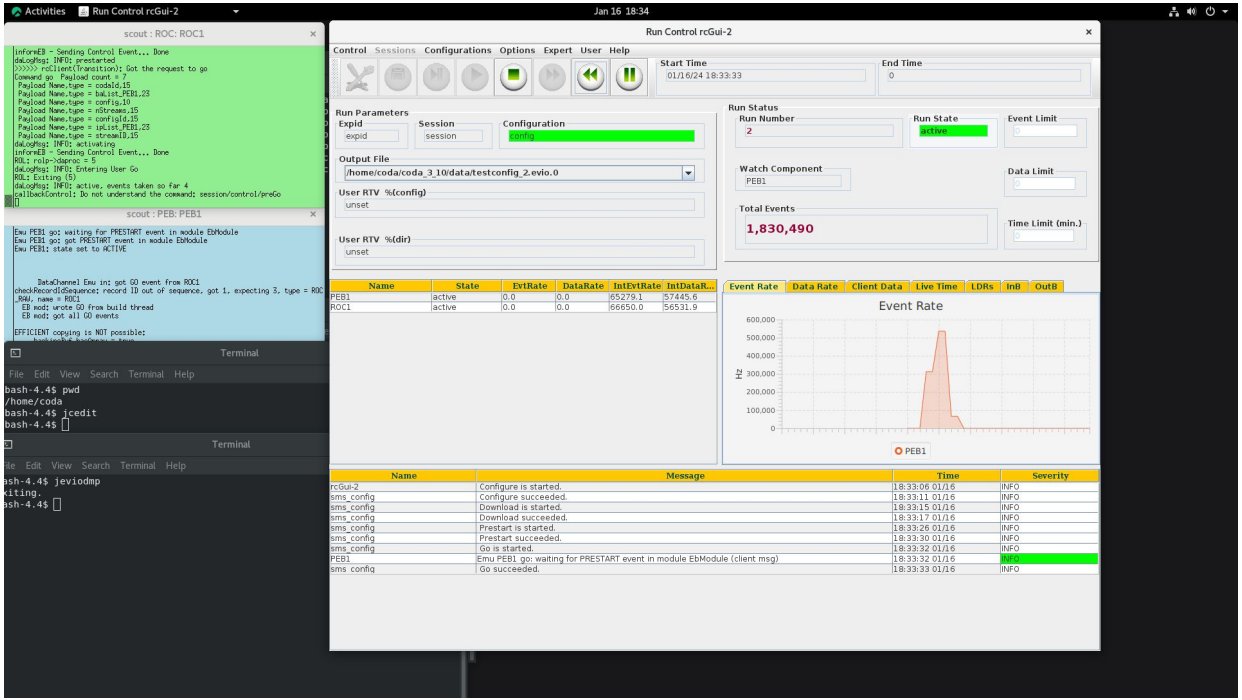
Note:

- Nuclear Interaction Length:
  - Iron: 16.77 cm
  - Lead: 17.59 cm
- Density:
  - Iron: 7.874 g/cm³
  - Lead: 11.34 g/cm³



TODO: Check different materials at different pion energy.

Data Acquisition System

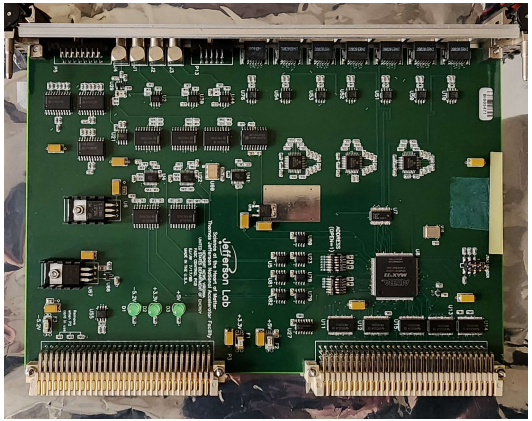


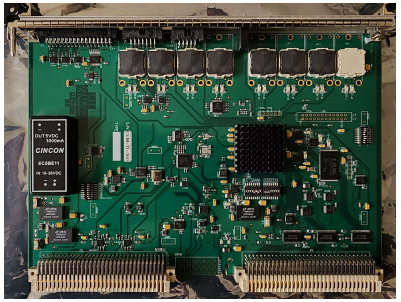
Slide From Deb

https://coda.jlab.org/drupal/system/files/coda/3.10/walkthrough/index.html

Link from Bryan Moffit

Data Acquisition System





From JLab loan: FADC 250Msps, Front panel signal distribution card, and TI module

Slide From Deb

Single board computer

VME 64x crate

Summary

- DDVCS would just require the addition of a muon detector to the unpolarized TCS experiment setup.
- The difficulty of detecting muons is the pion background.
- We could use an absorber (iron, lead, etc) to block pions.
- The absorber causes the pions to exhibit a low energy peak which may be useful for partial PID.
- Roughly 1 m of Iron would be required to brute force block pions with energies up to 3.0 GeV.
- We have begun preparations for assembling a DAQ system in anticipation of building a prototype

Side Note: We are also considering the possibilities of using AI/ML along side traditional PID for the detection of muons in the pion background.

Acknowledgements

Marie Boer ❙ Deb Biswas ❙ Dave Gaskell ❙ Brad Sawatzky

Thank You!