

Detecting Muons in the Pion Background for Hall C

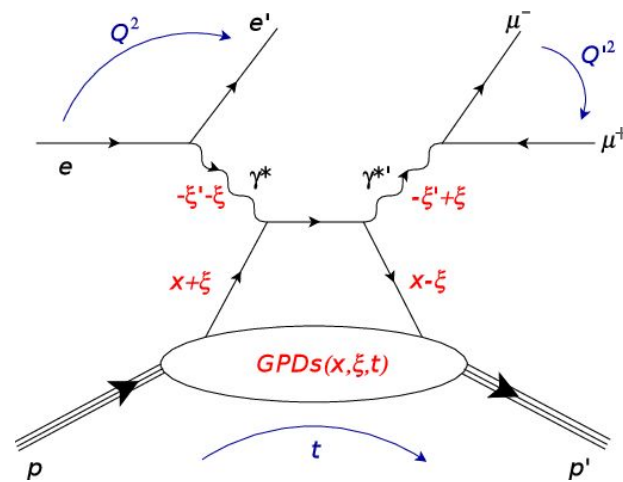
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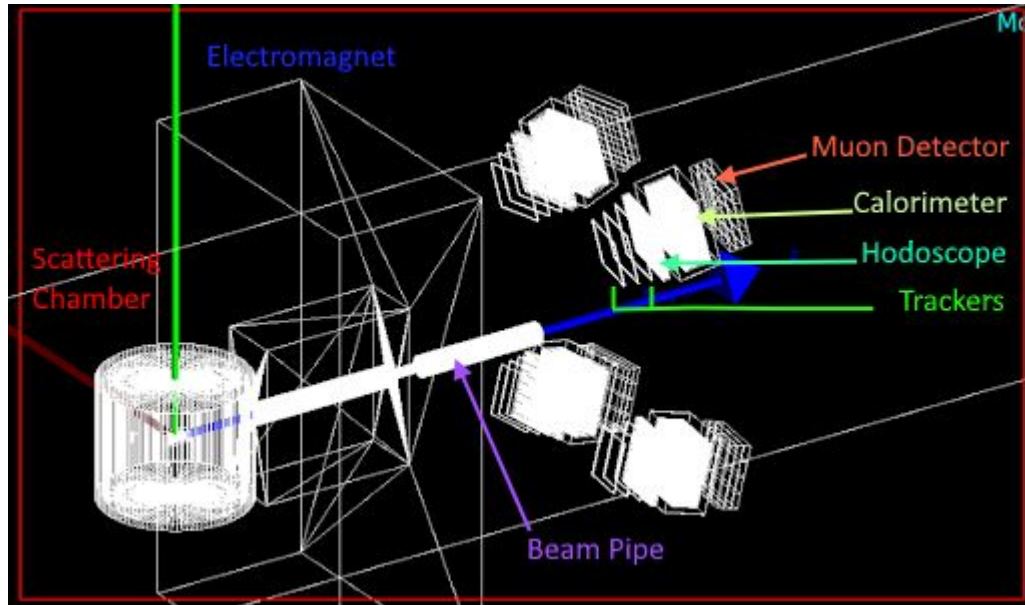
Double Deeply Virtual Compton Scattering (DDVCS)

- Electron beam with fixed hydrogen target
- μ^- / μ^+ pair production
- 7D Phase Space: $X_{bj}, t, Q^2, Q'^2, \theta, \phi, \phi_L$

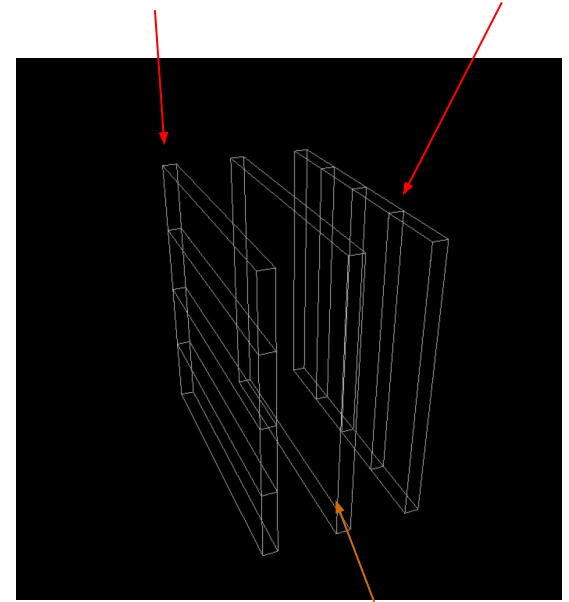


S. Zhao (DOI: <https://doi.org/10.22323/1.346.0068>)

DDVCS Experiment Setup



Front and back layers of scintillator



Absorber (iron, lead, etc)

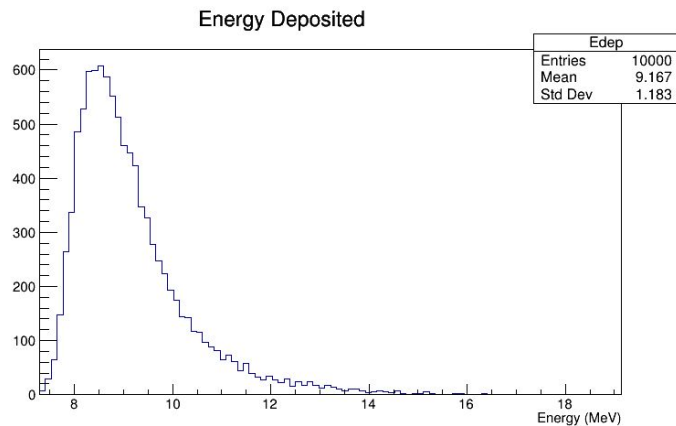
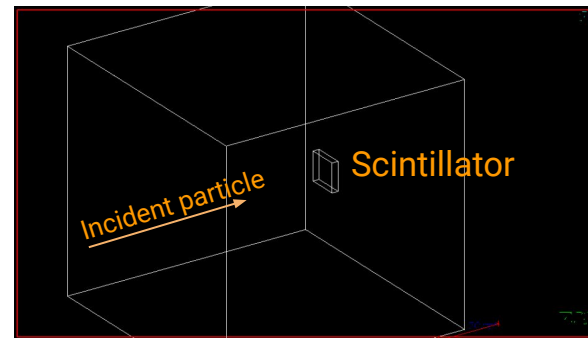
Learned Geant4 to Explore the Possibilities for the Muon Detector

```
38
39 G4VPhysicalVolume* MuonDetectorConstruction::Construct()
40 {
41     // Construct the World volume.
42     // Define the materials.
43     G4NistManager* man = G4NistManager::Instance();
44     G4Material* Air = man->FindOrBuildMaterial("G4_AIR");
45     G4Box* WorldBox = new G4Box("WorldBox", 2*m, 2*m, 2*m);
46     G4LogicalVolume* WorldLV = new G4LogicalVolume(WorldBox, Air, "WorldLV");
47     G4VPhysicalVolume* physWorld;
48     physWorld = new G4PVPlacement(0, G4ThreeVector(0.,0.,0.), WorldLV, "World", 0, false, 0);
49
50     double_t absorber_thickness = 100*cm;
51     double_t absorber_zpos = (absorber_thickness/2);
52     double_t gap = 10*cm;
53     double_t detector_thickness = 5*cm;
54     double_t detector_zpos = absorber_thickness + gap + (detector_thickness/2);
55
56     // Add the muon detector
57     G4Box* DetectorBox = new G4Box("DetectorBox", 12*cm, 12*cm, (detector_thickness/2));
58     G4Material* ScintMaterial = MuonDetectorConstruction::GetMaterial("Polyvinyltoluene");
59     G4LogicalVolume* DetectorLV = new G4LogicalVolume(DetectorBox, ScintMaterial, "ScintillatorLV");
60     new G4PVPlacement(0,
61         G4ThreeVector(0, 0, detector_zpos), // rotation
62         DetectorLV, // position
63         "Muon_Detector_PV", // logical volume
64         physWorld->GetLogicalVolume(), // name
65         false, // its mother volume
66         0); // no boolean operation
67         // copy number
68
69     // Make the muon detector sensitive
70     G4VSensitiveDetector* muonSD = new MuonDetectorSD;
71     CreateSensitiveDetector(muonSD, DetectorLV);
72
73
```

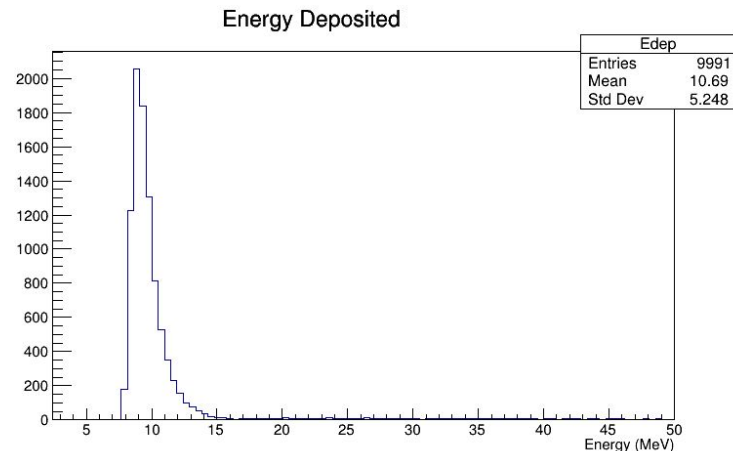
```
74
75 // Construct default run manger
76 G4RunManager* runManager = new G4RunManager;
77
78 // Set up DetectorConstruction
79 runManager->SetUserInitialization(new MuonDetectorConstruction());
80
81 // Set up PhysicsList
82 G4VModularPhysicsList* physicsList = new QBBC;
83 runManager->SetUserInitialization(physicsList);
84 G4HadronicProcessStore::Instance()->SetVerbose(0);
85
86 // Set up user ActionInitialization
87 runManager->SetUserInitialization(new MDActionInitialization);
88
89 // Set up visualization and choose interactive or batch mode
90 G4VisManager* visManager = new G4VisExecutive("quiet");
91 visManager->Initialize();
92 G4UIManager* UImanager = G4UIManager::GetUIpointer();
93
```

- 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



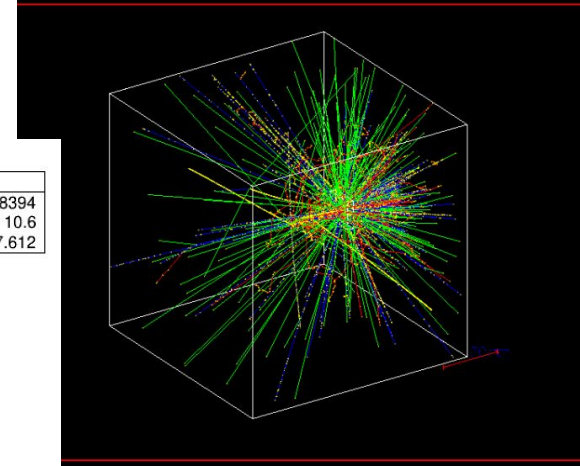
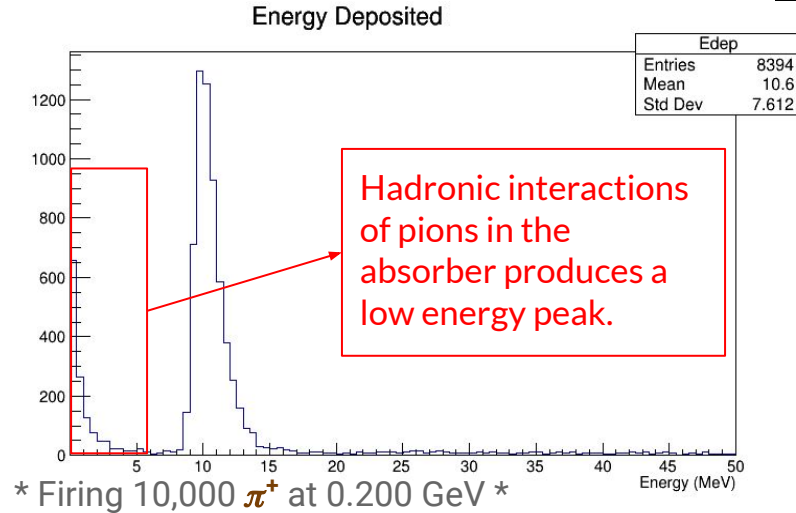
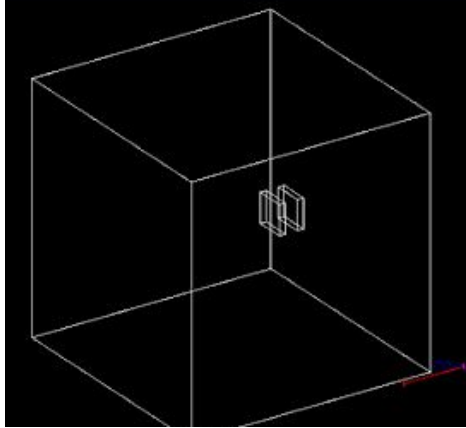
Firing 10,000 μ^- at 0.200 GeV.



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



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

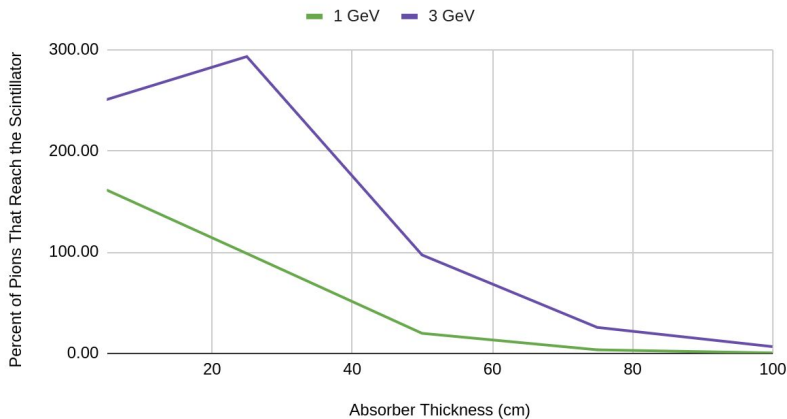
Collisions in the Scintillator at Different Absorber Thicknesses

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

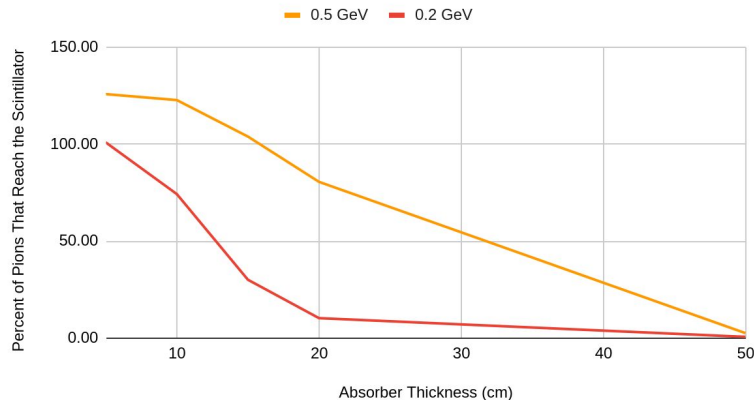
TODO: Study the momenta of the pions that we expect to see while studying DDVCS

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

Collisions vs. Absorber Thickness (cm)



Collisions vs. Absorber Thickness (cm)



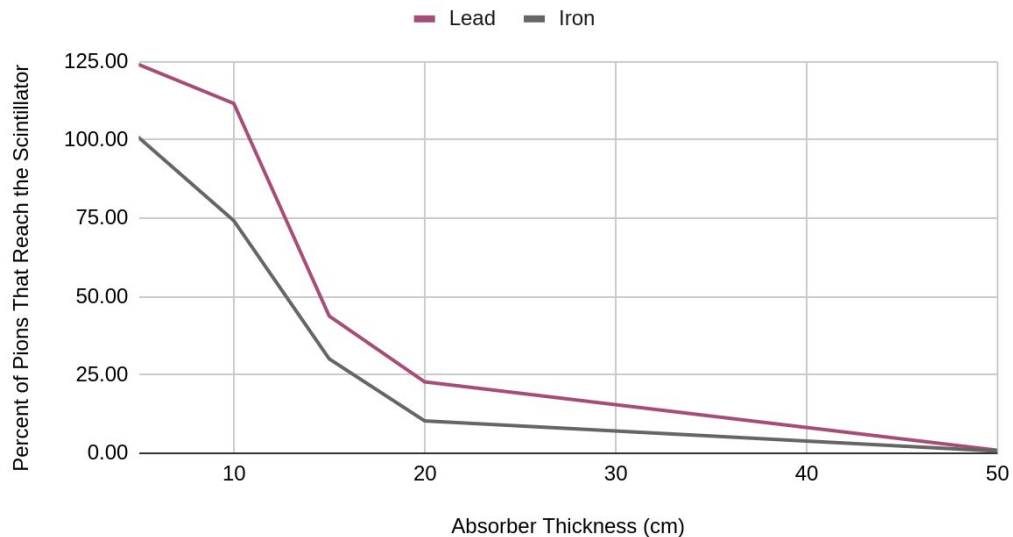
Pion Absorber

- 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

Collisions vs. Absorber Thickness (cm)



TODO: Check different materials at different pion energy.

Data Acquisition System

The screenshot displays the Run Control rcGui-2 interface. On the left, a terminal window shows the following log output:

```
scout : ROC: ROC1
[Info] - Sending Control Event... Done
[Info] - PRESTART
[Info] - rcl (agent transition): Got the request to go
Command go Payload count = 7
Payload Name.type = conf:15
Payload Name.type = bak.lst_PEB1_23
Payload Name.type = conf:15
Payload Name.type = r0Stream_15
Payload Name.type = conf:15
Payload Name.type = up.lst_PEB1_23
Payload Name.type = r0Stream_15
[Info] - activating
[Info] - Sending Control Event... Done
RL: rolp->sdproc = 5
[Info] - Entering User Go
RL: Existing (5)
[Info] - active, events taken so far 4
[Info] - Do not understand the command: session/control/rnGo
[]

scout : PEB: PEB1

Ewu PEB1 got waiting for PRESTART event in module EbModule
Ewu PEB1 got PRESTART event in module EbModule
Ewu PEB1: state set to ACTIVE

InfoChannel Ewu Int got 60 event from ROC1
chocRecordSequence: record ID out of sequence, got 1, expecting 3, type = ROC
[Info] - name = ROC1
[Info] - mode: wrote 30 from built thread
[Info] - got all 60 events
EFFICIENT copying is NOT possible:

Terminal
File Edit View Search Terminal Help
bash-4.4$ pwd
/home/coda
bash-4.4$ jcredit
bash-4.4$ []

Terminal
File Edit View Search Terminal Help
bash-4.4$ jeviodmp
kiting.
bash-4.4$ []
```

The main control panel on the right includes the following sections:

- Control**: Sessions, Configurations, Options, Expert, User, Help
- Run Parameters**: Expid (empty), Session (session), Configuration (PEB1)
- Output File**: /home/coda/coda_3_10data/testconfig_2.evio.0
- User RTV**: %(config) unset, %(dir) unset
- Run Status**: Run Number (2), Run State (Active), Event Limit (empty)
- Watch Component**: PEB1, Data Limit (empty)
- Total Events**: 1,830,490
- Time Limit (min.)**: (empty)
- Event Rate Graph**: A line graph showing a peak in event rate around 18:30:00. The Y-axis ranges from 0 to 600,000. The X-axis shows time from 18:30:00 to 18:30:30. The peak reaches approximately 500,000 events.
- Table**: A table with columns: Name, State, EvtRate, DataRate, IntEvtRate, IntDataRate.
- Log Table**: A table with columns: Name, Message, Time, Severity.

Name	State	EvtRate	DataRate	IntEvtRate	IntDataRate
PEB1	active	0.0	0.0	65279.1	57445.6
ROC1	active	0.0	0.0	66650.0	56531.9

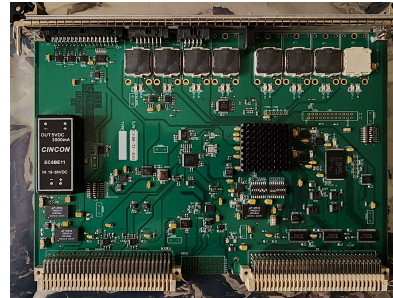
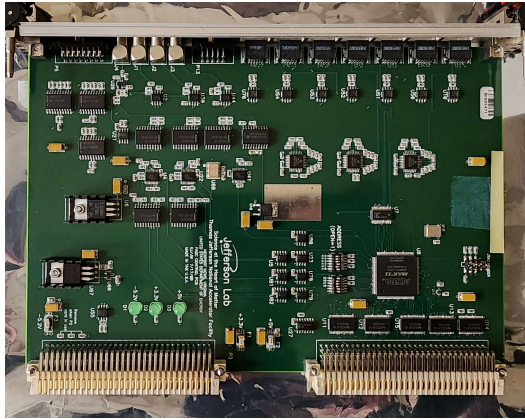
Name	Message	Time	Severity
rcGui-2	Configure is started.	18:33:06 01/16	INFO
sms_config	Configure succeeded.	18:33:11 01/16	INFO
sms_config	Download is started.	18:33:15 01/16	INFO
sms_config	Download succeeded.	18:33:17 01/16	INFO
sms_config	Prestart is started.	18:33:26 01/16	INFO
sms_config	Prestart succeeded.	18:33:30 01/16	INFO
sms_config	Go is started.	18:33:30 01/16	INFO
PEB1	Emu PEB1 go: waiting for PRESTART event in module EbModule (client msg)	18:33:32 01/16	Info
sms_config	Go succeeded.	18:33:33 01/16	INFO

Data Acquisition System

CONCURRENT
TECHNOLOGIES



Single board computer



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

Slide From Deb

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!