

CLAS12 Luminosity Upgrade

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- 1 Introduction
- 2 Drift Chamber Occupancy
 - Occupancy Definition
 - CLAS Occupancies
- 3 Simulation Methods
 - Beam-on-target Method
 - Explicit Event Generation Method
- 4 New Simulation
 - Results with Beam-on-target Method



Outline

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Goal: Increase CLAS12 Running Luminosity

by an order of magnitude or more

Why?

- **More** physics!
- Access to smaller and more interesting cross sections
- 6 months Vs 6 years, or “time as grad student” Vs “entire of career”

Where to start?

- **Identify** and **reproduce** anticipated limit: $\mathcal{L} \simeq 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- Drift Chamber hit occupancy is a good place to start

How to proceed?

- ① What **modifications** can make an improvement, e.g., better electronics/algorithms
- ② What **supplemental** detectors can overcome these limitations?
- ③ What **replacement** detectors can overcome these limitations?



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Hit Occupancy

Definition

- Δt is the detector response time
- For the DC Δt is the longest drift time for the unit cell:
 $\Delta t \simeq 250 - 500$ ns
- The hit occupancy is the probability of at least one hit within the time interval Δt

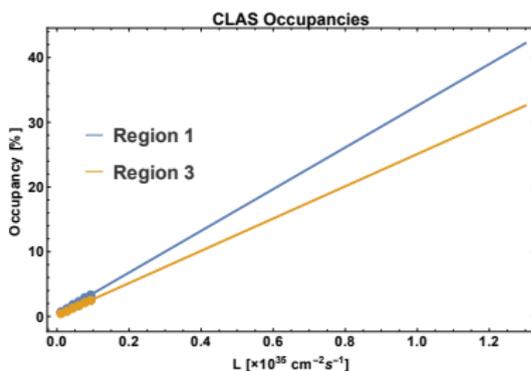
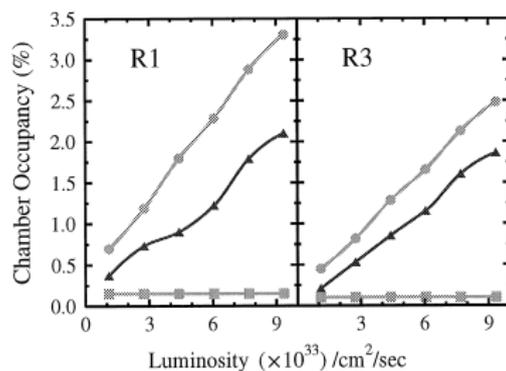
Occupancies above a few % lead to poor tracking efficiency

Mitigating high DC occupancy induced inefficiency:

- Unit cell size \rightarrow drift time: CLAS12 DC has twice the segmentation
- Lower voltages/current \rightarrow lower discriminator threshold: will not know until in the hall
- Beam current \rightarrow run at **lower luminosity**
- Deal with it offline:
 - Overlapping hits \rightarrow improve algorithms
 - Better resolution/vertexing/tracking \rightarrow tighter cuts



CLAS Occupancies



CLAS12 Occupancy Estimates from CLAS

- Extrapolating to 10^{35} we should expect $\mathcal{L} \sim 20\text{-}30\%$
- Better segmentation $\rightarrow \mathcal{L} \sim 10\text{-}15\%$
- Shielding and other improvements $\rightarrow \mathcal{L} \sim 1\%$

Of course, CLAS \neq CLAS12

All previous work predicts CLAS12 DC occupancies $\leq 1\%$ at $\mathcal{L} = 1 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$

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Simulations of $\mathcal{L} \simeq 1.0 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$

Two different methods

Beam-on-target

Throw electrons from upstream
electrons at the target

- Simplest approach
- Relies heavily on Geant4
- Computationally expensive

Explicit event generator

Generate events only in the phase
space covered by the apparatus

- More sophisticated
- Must include most important processes
- Relatively fast

Some numbers for reference

Target	Beam current	e^- flux	Luminosity
LH2	I [nA]	Φ_e [s^{-1}]	\mathcal{L} [$\text{cm}^{-2}\text{s}^{-1}$]
5 cm	100	6.24×10^{11}	1.3×10^{35}

Region	I	II	III
Δt	250 ns	400 ns	500 ns



Beam-on-target Method

With:

- $\Delta t = 500$ ns
- $N_e = \Phi_e \Delta t \simeq 312\text{k}$ events per time interval
- N_S events simulated
- $N_O = \frac{N_S}{N_e}$ occupancy normalization

Computational Challenge

If a 1% occupancy is expected

- To get 10% relative uncertainty
- $N_{hits} \geq 100$ such that $\frac{1}{\sqrt{N_{hits}}} \leq 0.1$
- $100 \times 1\% = 100 N_e = 31.2$ M events for 100% hit probability
- $N_S = 100 N_e \times N_{hits} \sim 3.2 \times 10^9$

Need 3-4 billion events!

Some numbers for reference

Target	Beam current	e^- flux	Luminosity
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Event Generator

Full Realistic Event Generator!

- Part of InSANE libraries, which uses FOAM for sampling
- Most processes are already included
- Simple to add new cross sections
- Output in any format (LUND, ROOT, PROMC...)
- Save event generator to ROOT file! For later reference or to generate more events without initial integration.

$$\sigma^{\text{total}} = \sum_{x \in \{\text{processes}\}} \int_{V_x} \left(\frac{d\sigma_x}{dp^3} \right) dp^3 = \sum_{x \in \{\text{processes}\}} \sigma_x^{\text{total}}$$

Reconstruction Challenge

See if you can pick out DVCS events while rejecting background (without looking at the input events!)

Just ask me for the LUND files



About the Event Generator

InSANE C++ libraries

Luminosity

$$\mathcal{L} = \sum_m \mathcal{L}_m = \sum_m I \rho_m l_m$$

Rate

$$R_{m,x} = \mathcal{L}_m \sigma_{m,x}^{\text{total}}$$

Random Sampling

- 1 A Phase Space Sampler, $S_{m,x}$, is created for each material and process.
- 2 Randomly choose a sampler with probability $R_{m,x}/R_{\text{Total}}$
- 3 The selected sampler generates an event following the probability distribution given by the cross sections.

- Phase Space Sampler uses the FOAM libraries.
- Initialization gives $\sigma_{m,x}^{\text{total}}$
- Initialization is expensive
- ROOT streamers allow initialized event generator to be saved to file.
- Same event generator can be read from file without the need for initialization.

Lots of other nice features not mentioned...



Explicit Event Generation Method

Cross Sections

$$\sigma^{\text{total}} = \sum_{x \in \{\text{processes}\}} \int_{V_x} \left(\frac{d\sigma_x}{dp^3} \right) dp^3 = \sum_{x \in \{\text{processes}\}} \sigma_x^{\text{total}}$$

Beam Energy	6 GeV	11 GeV
Process	Total XS (nb)	
Møller	22773000.572239	75008636.537296
DIS + radiative tail	127.914648	82.767614
Elastic e-p	5511220.139609	3670739.949604
Elastic radiative tail	24705.403258	12943.687891
π^0 electro-production	14802.150817	17908.403986
π^0 photo-production	568.685398	852.371847
π^+ electro-production	4031.702761	5536.473200
π^+ photo-production	282.355507	486.826279
π^- electro-production	2806.398047	3843.281962
π^- photo-production	198.505161	341.970751
Total	2.83317×10^7	7.87214×10^7

Not shown

Each process has a relevant phase space defined for each final state particle.



Event Generator

Beam Energy	E	6 GeV	11 GeV
Events Simulated	N_{events}	1000000	1000000
Simulated time	$t_{\text{simulated}}$	0.26508 ms	0.09540 ms
Occupancy Norm	$N_o(\Delta t = 500\text{ns})$	1886 events/hit	5240 events/hit
Luminosity	\mathcal{L}	$1.33 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$	$1.33 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
Beam Current	I	100 nA	100 nA
e flux	Φ_e	$6.2422 \times 10^{11} \text{ s}^{-1}$	$6.2422 \times 10^{11} \text{ s}^{-1}$

Occupancy Calculation

$$N_o = \Delta t \left(\frac{N_{\text{events}}}{t_{\text{simulated}}} \right)$$

$$t_{\text{simulated}} \simeq \frac{N}{\sigma_{\text{tot}} I L \rho} e$$

$$\text{Occupancy} = \frac{N_{\text{hit}}}{N_o}$$

Maximum Drift Times

R1 : 250 ns

R2 : 400 ns

R3 : 500 ns

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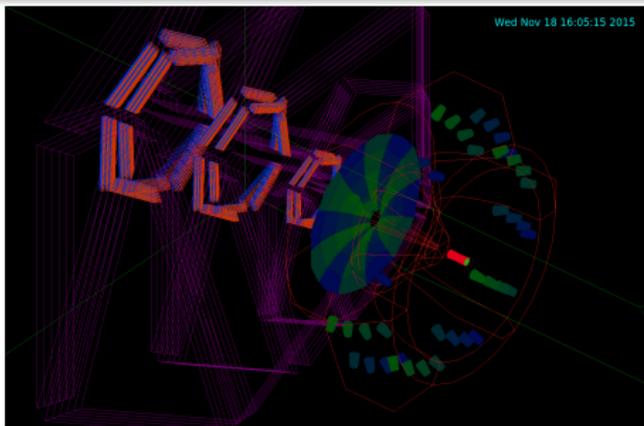
c12sim - CLAS12 Simulation

A Geant4 Simulation

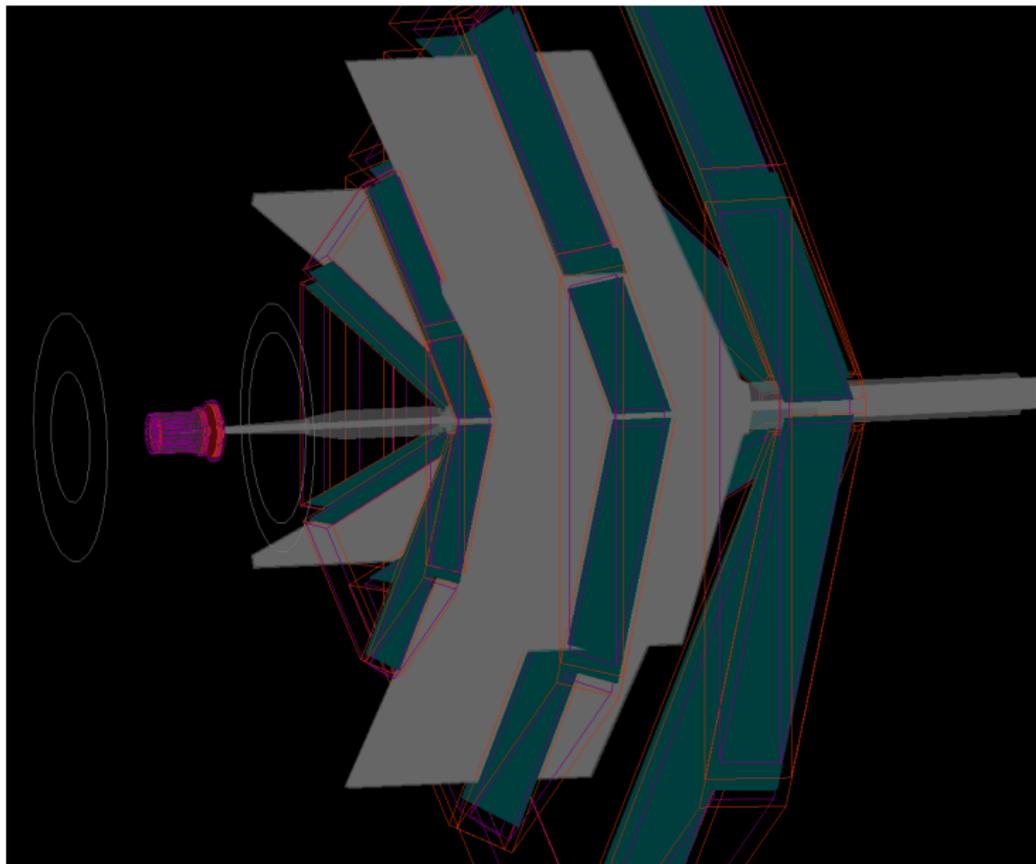
- New simulation **dedicated to CLAS12**
- Fast pure Geant4 implementation (no GEMC used)
- Additionally a set of analysis libraries being developed, `clasdigi`

Status

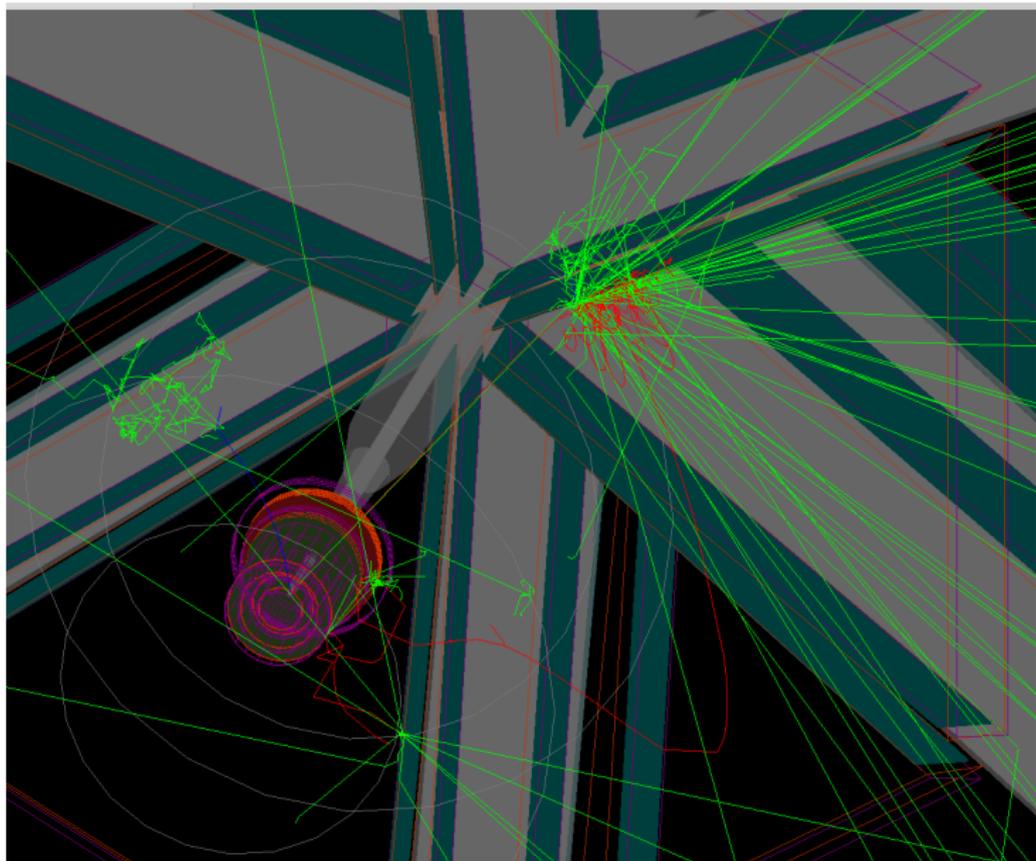
- HTCC, DC, SVT, MVT, beamline Moller shield, Solenoid, Torus
- Same beamline shield as GEMC via GDML



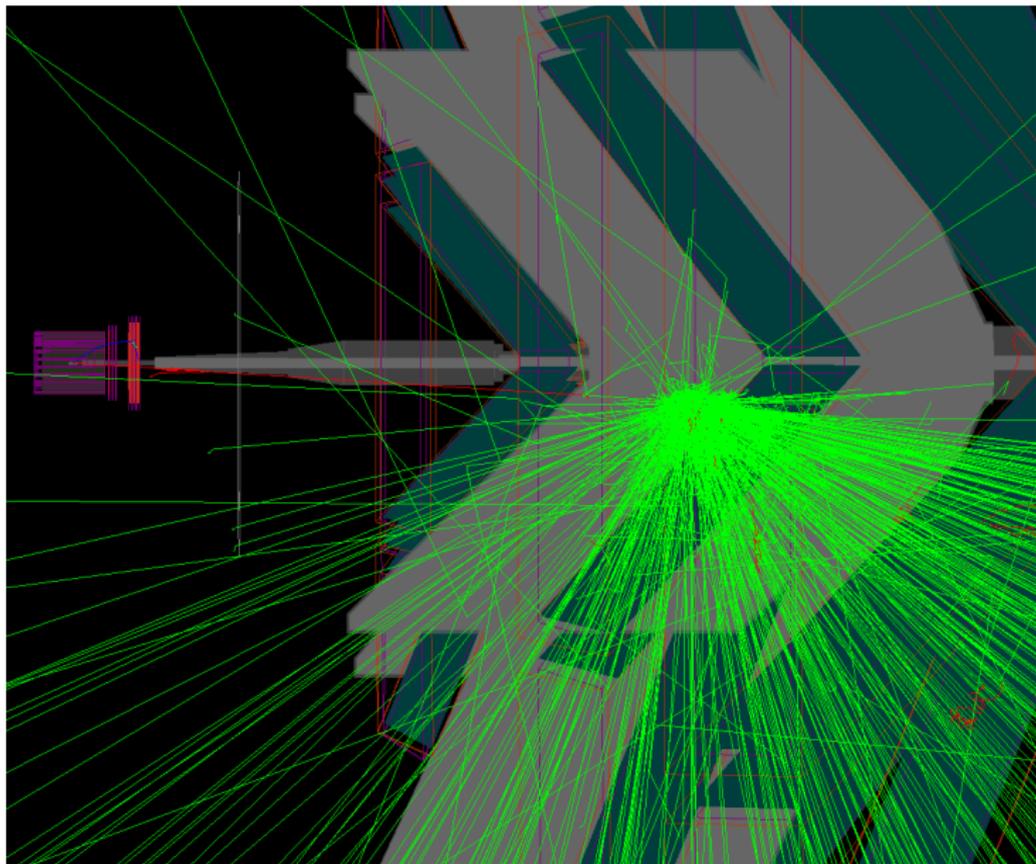
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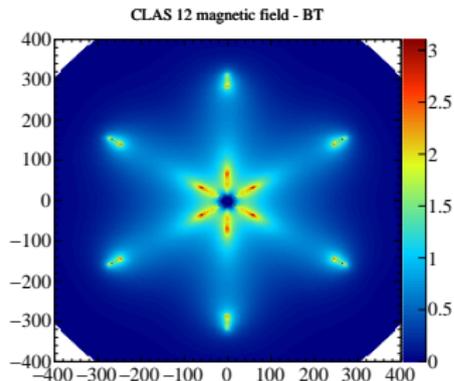
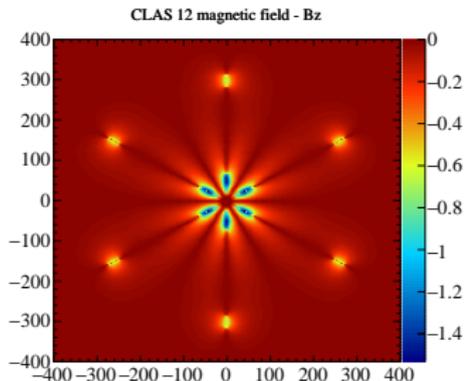
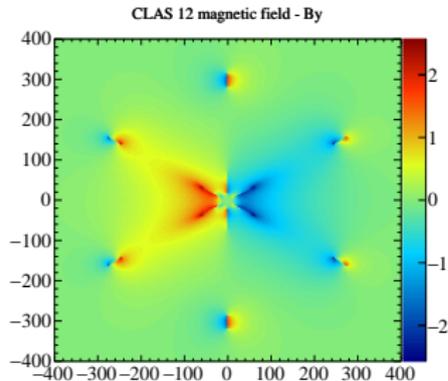
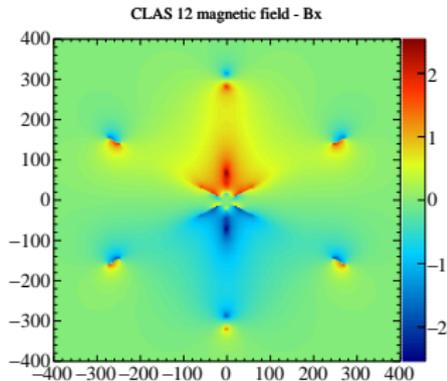


c12sim - CLAS12 Simulation



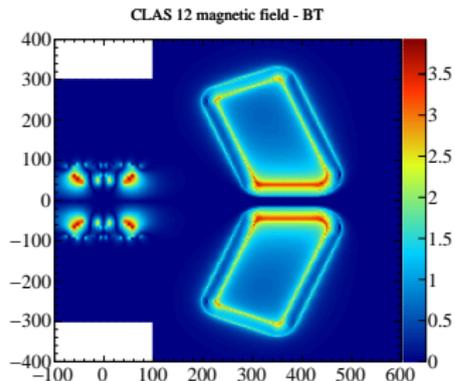
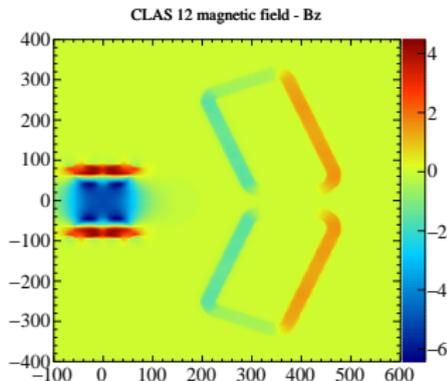
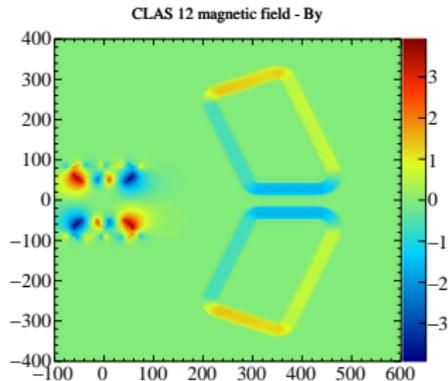
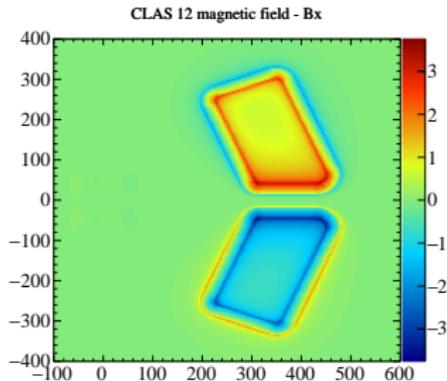
Magnetic Field

clasdigi

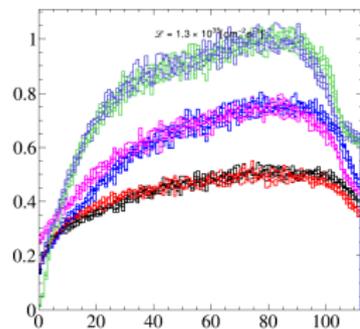
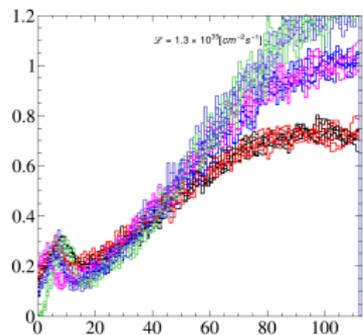
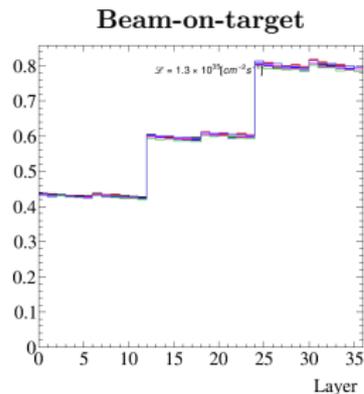
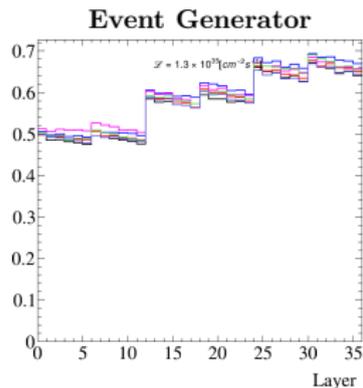


Magnetic Field

clasdigi



Hit Yields: Event Generator Vs. Beam-on-target



Self consistent check

Both methods produce roughly the same result.
Angular dependence different but averages out.



Summary

- Full and realistic event generator developed
- Event generator validated by beam-on-target method
- New simulation **dedicated to CLAS12** available
- Additional analysis libraries also available `clasdigi`
- Event Generator can be used for quick design feedback
- Need to understand the source of a significant difference between `GEMC` and `c12sim`



Thank You!



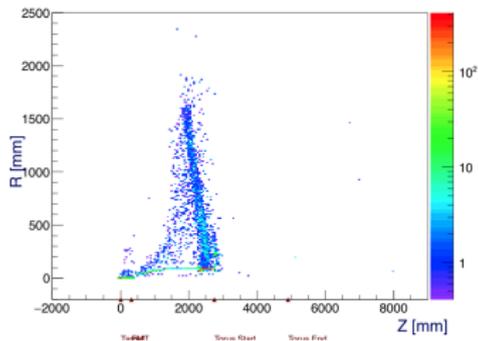
Backup



Hit sources

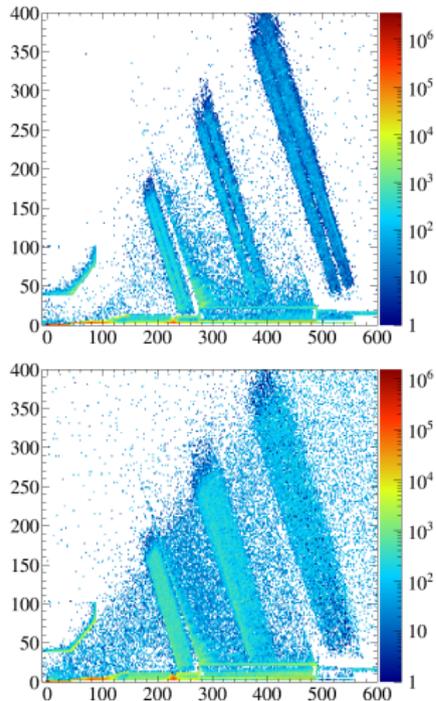
GEMC (M. Ungaro)

R vs Z vertex of tracks in region 1 for physicistsCorrectedBa



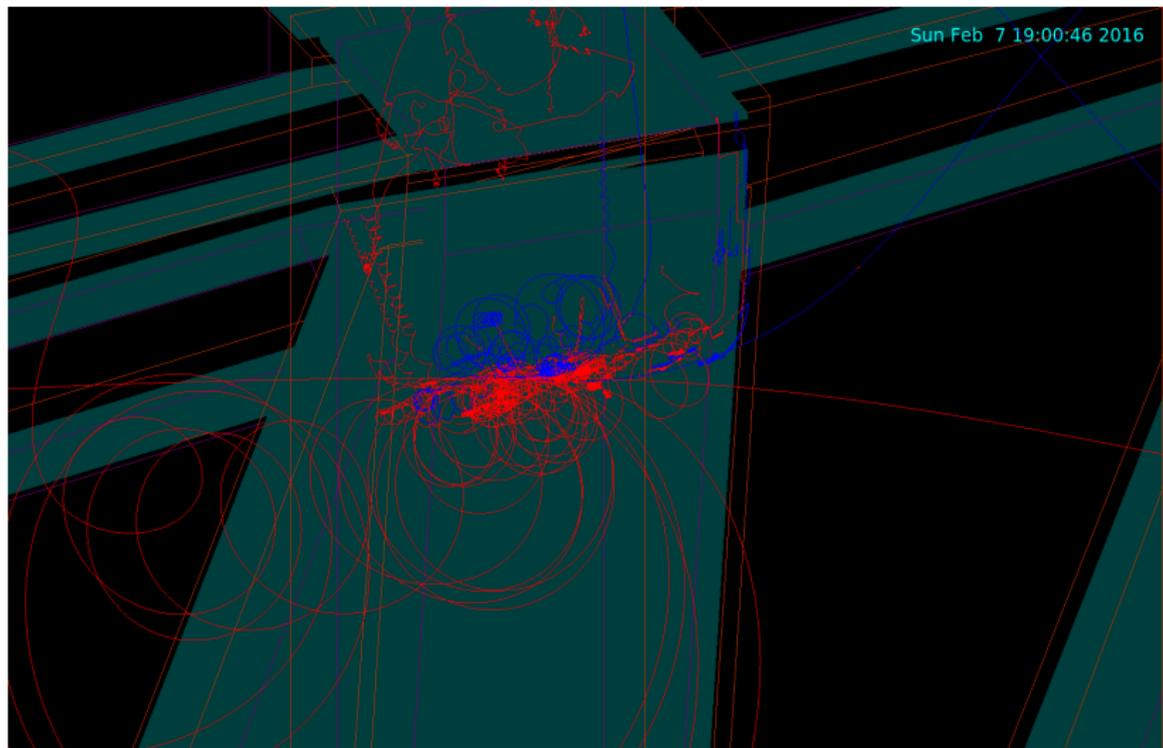
c12sim

r vs Z



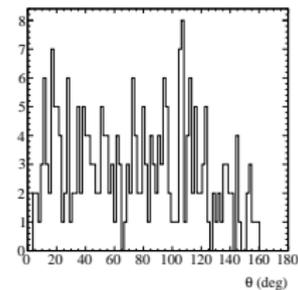
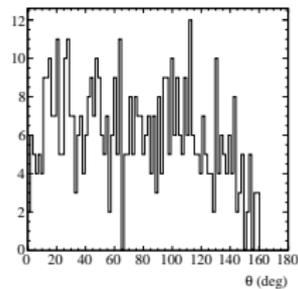
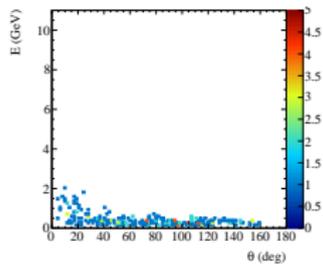
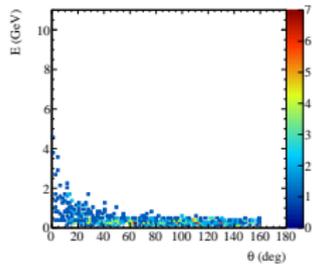
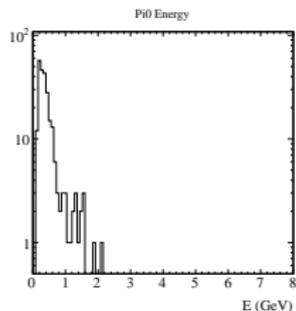
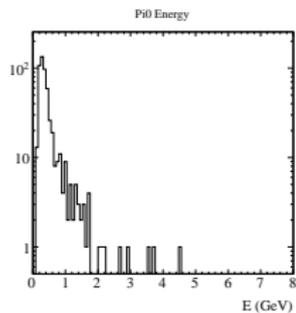
Curler Events

Single event with a large number of hits



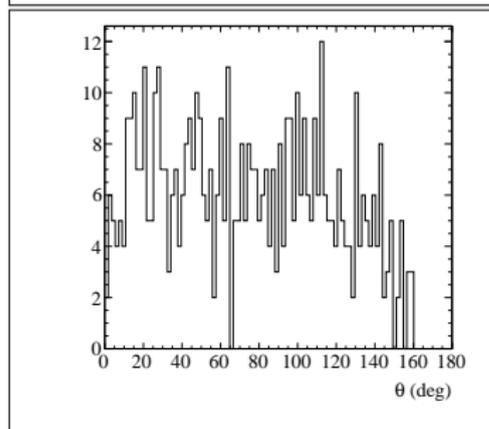
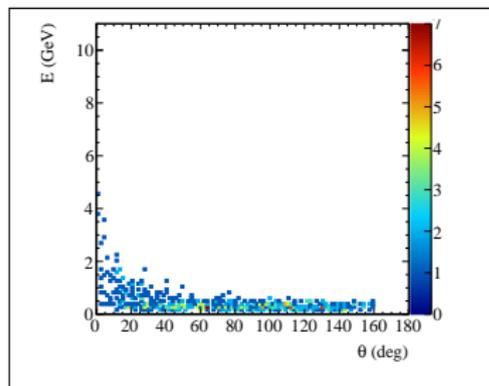
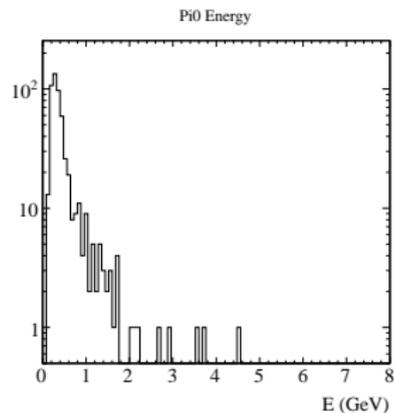
Generated Events

π^0 production



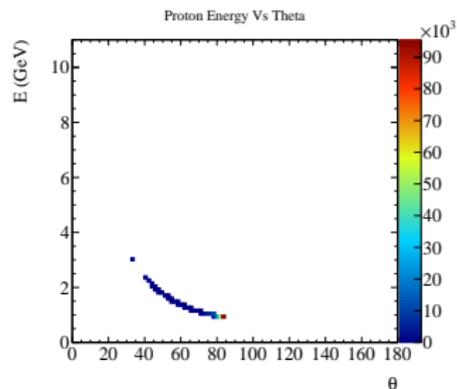
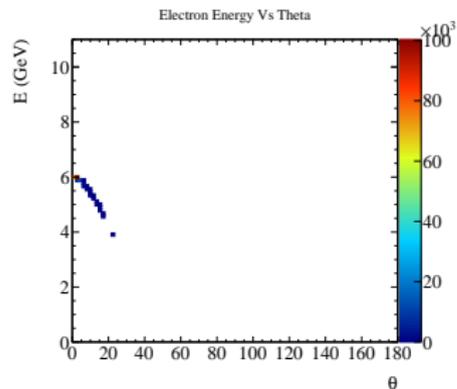
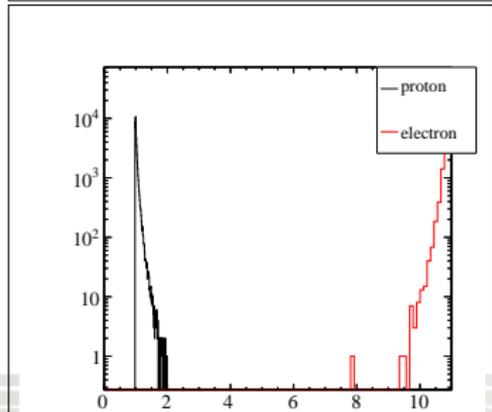
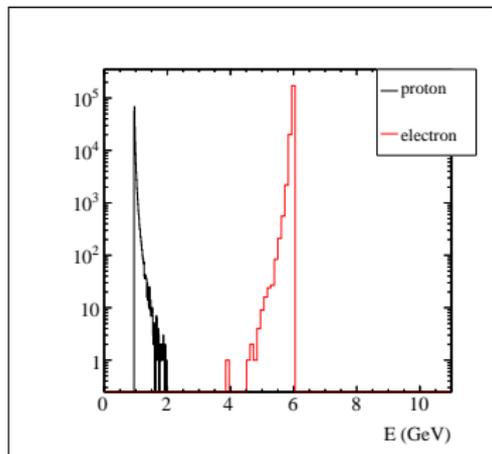
Generated Events

Inclusive π^0



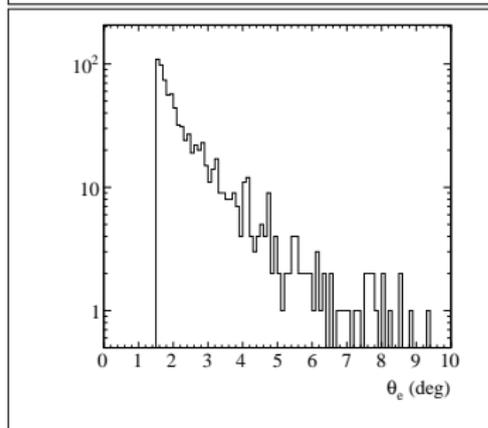
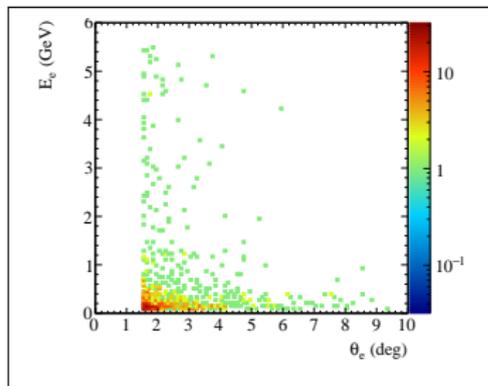
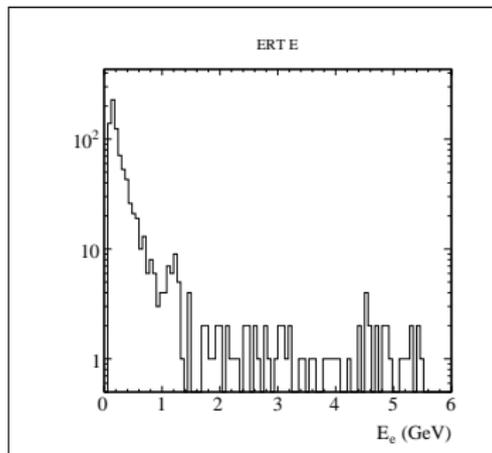
Generated Events

Elastic scattering



Generated Events

Elastic Radiative Tail



Electron Phi

