SoLID Simulation

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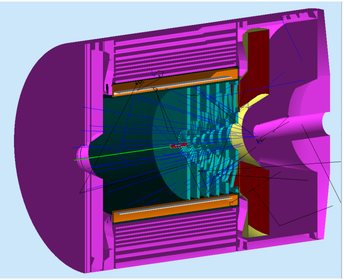
Outline

- (sol)gemc Overview and Updates
- Background Rates
- Baffles
- Optics
- Tracking
- Forward

(sol)gemc

Present software suite:

- gemc from CLAS12 used as base framework for simulations
  - Geometries/detectors specified in mysql database
  - Modular hit processing
  - Standardized input (lund) and output (EVIO)
  - Visualization

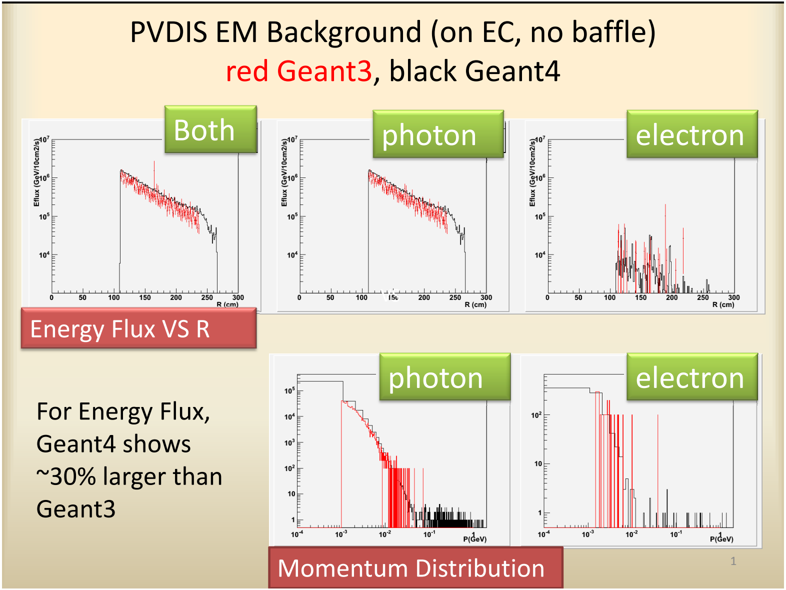


- solgemc is a library package built as an extension
  - solgemc - Builds on functionality, additional hit processes
  - libsolgemc - Built on Hall A analyzer, includes GEM digitization, class representations of GEMs/geometries, tracking
- Stand alone event generators for DIS, $\pi^{+,-,0}$ generation, elastics, ...

(sol)gemc Updates

- gemc
  - geant 4.9.5 changes build process to cmake, some new low EM processes available
  - Mauri integrating with gemc, need to test building for offsite, implications on solgemc
  - Materials can be specified in database - had to add in solgemc before
  - Multiple hits in detector now possible
  - FADC-style digitization to be templated
- libsolgemc
  - Lots of additions - see tracking
- Event generation
  - Elastic ep (en) generation

Background Rates



PVDIS EM Background (on EC, no baffle)

red Geant3, black Geant4

Both

photon

electron

Energy Flux VS R

photon

electron

Momentum Distribution

For Energy Flux, Geant4 shows ~30% larger than Geant3

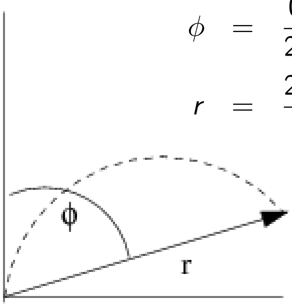
Background Rates - Work

- Need to continue comparison/reconciliation - break down by particle and momentum bins, need more statistics in e^- bins
- Differences with GEANT3 versions need to be considered as well
- Rates need to be quantified for detectors - fed into MC for hit/DAQ rates
    - SIDIS a concern? Need SIDIS event generator?

Solenoid Motion

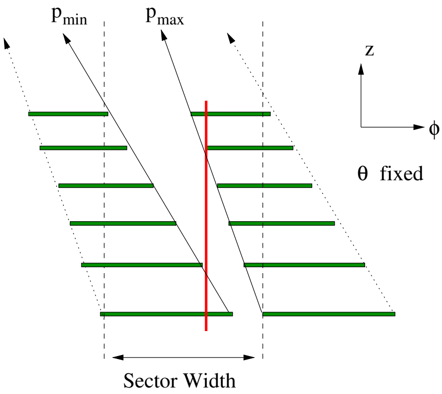
For uniform magnetic field in z direction, particle motion for $v = c$, p [GeV], scattering angle θ as function of z is given by:

$$\begin{aligned} \phi &= \frac{0.3 B_z z}{2p\cos\theta} \\ r &= \frac{2p\sin\theta}{0.3B_z}\sin\left(\frac{0.3B_z z}{2p\cos\theta}\right) \end{aligned}$$



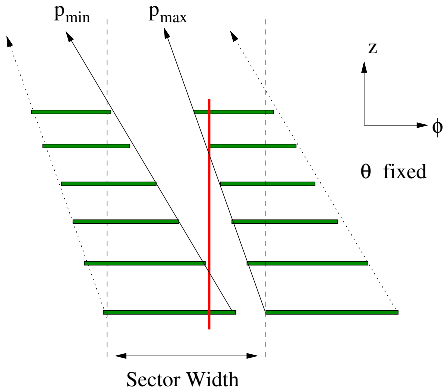
- ϕ is linear in z
- For 11 GeV beam, **worst** particles of interest deviate from linear r by few %

Baffle Design Considerations



- Range of $x_{\rm bj}$ at fixed θ defines cut
- Forbidding line of sight fixes width and spacing
- Too many baffles can have low momentum "jumping"
- Extended targets make the situation more complicated

More Baffle Design Considerations

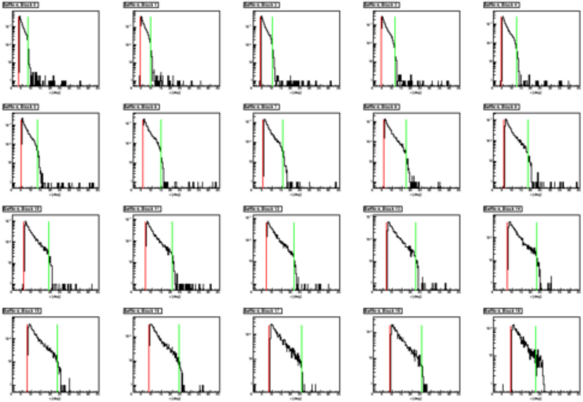


- Too many baffles can also produce backgrounds
- Too many baffles could thin structural integrity
- Raster effects need to be included (not currently present)
- Limiting to 30 slits (Eugene's design)
- Using 6 baffle planes (Eugene's design)

Design from Raytracing

- Raytracing provides best representation for magnet

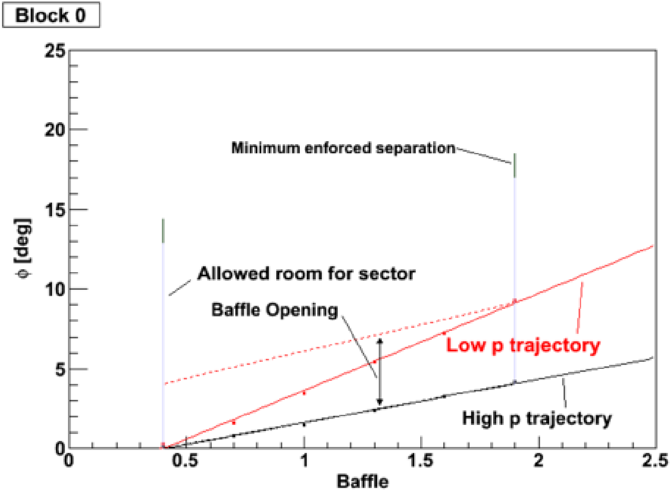
CLEO, last baffle:



- Look at distributions in ϕ at various radial blocks
- Determine widths of distributions

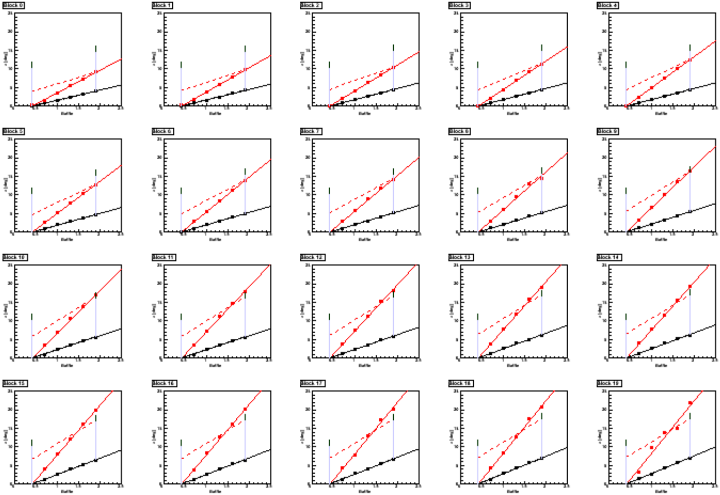
Design from Raytracing (2)

Considerations for getting baffles



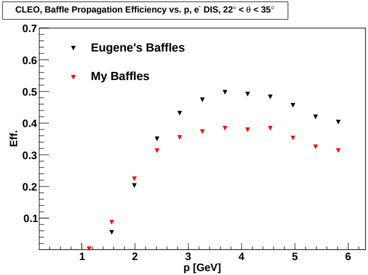
Design from Raytracing (3)

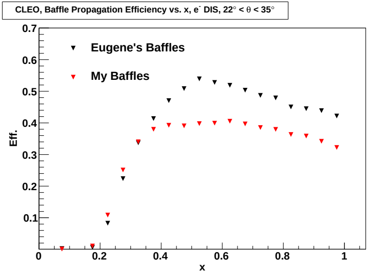
For all CLEO blocks



Results

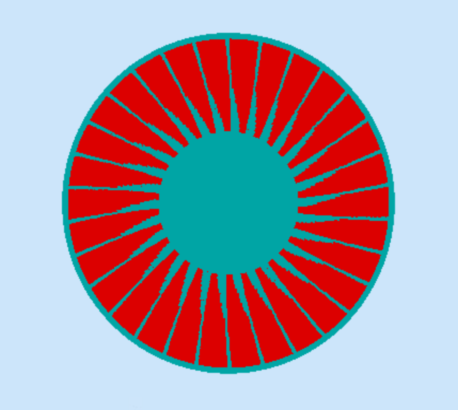
Compared to Eugene:





- Eugene's still come out better, especially in mid-x range

Results



- Can probably improve by opening up lower angles
- Should superimpose results from Eugene's baffles on these - would be enlightening

Optics Calibrations

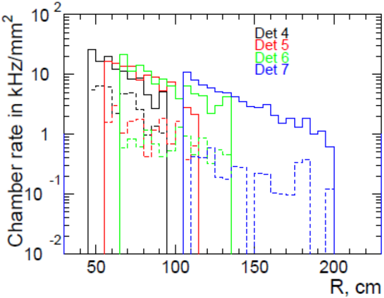
Things to consider:

- Absolute position calibration
  - Plugable holes placed in baffles to act as ray sieve with field off
  - Survey detectors to points on baffles - give fixed position and angle of tracks
  - Need to consider practicalities - which rays to choose, minimize holes in baffles, size of holes, ease of plugability
- Momentum calibration
  - Use elastic ep on LH_2
  - At fixed R on GEM, will have small range of p based on extended target
  - Coverage will be limited but exploit azimuthal asymmetry
  - Different beam energies will give different p at R
  - Need to examine rates and potential beam energies, field strengths

Tracking Scope

Tracking for SoLID unique challenge

- Rates are quite high - up to $8\ \mathrm{kHz/mm^2}$
- Parity quality experiment - systematics possible concern
- Data rates very high - need to do tracking on the fly



Strategy

- Use GEM chambers as coordinate detectors
- Build off experience/work from SBS project
- Characterize tracking early by simulation

Goals

- Benchmarks
  - Tracking rate/how it scales with hits
  - Tracking efficiency (num of real tracks reconstructed/num of real tracks)
  - Effect of noise in clustering/fits (hits replaced with/distorted by noise)
  - Pure noise tracks (ghost tracks)
  - Multi-track reconstruction efficiency
  - Helicity dependence of reconstruction (efficiency and quality)
  - Noise correlation between planes (induced photons)
- Benchmark conditions to map
  - Background rates ×0 through ×5
  - Background rate derivatives (for helicity dependence)
  - Uncorrelated - correlated backgrounds
  - Readout strip configuration: x/y vs. r/ϕ

Roadmap

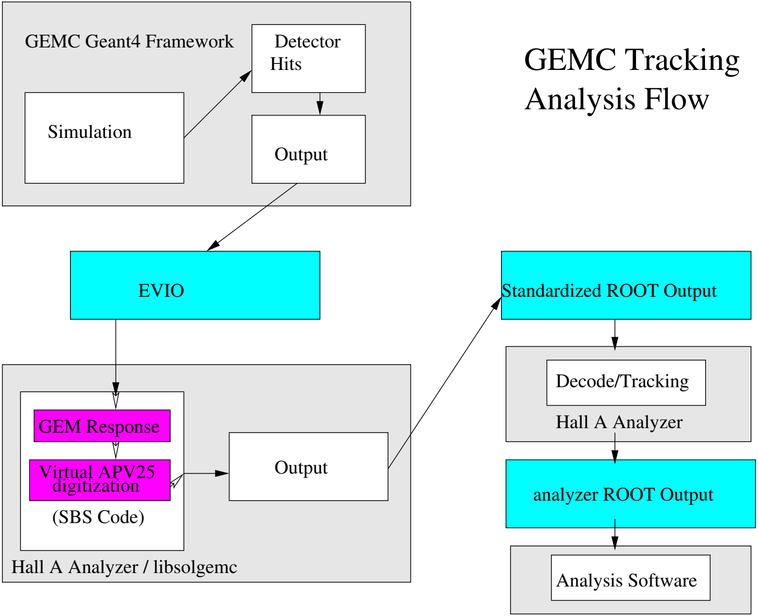
General considerations

- Defined input and output data structures for tracking code
- Output from tracking should be kept standardized so we can easily compare

Development

- Input and output standards in place
- Developed GEMC banks output in SBSGEM hit process
- Created library, libsolgemc, for loading banks output, representing GEM hits/strips/geometries, clustering/tracking code
- For library, built on Hall A analyzer, ROOT output
- Potential Parallel activities
  - Implement other algorithms into libsolgemc
  - Evaluate benchmarks

Framework


GEMC Geant4 Framework

Detector Hits

Simulation

Output

EVIO

GEMC Response

Virtual APV25 digitization

(SBS Code)

Output

Hall A Analyzer / libsolgemc

GEMC Tracking Analysis Flow

Standardized ROOT Output

Decode/Tracking

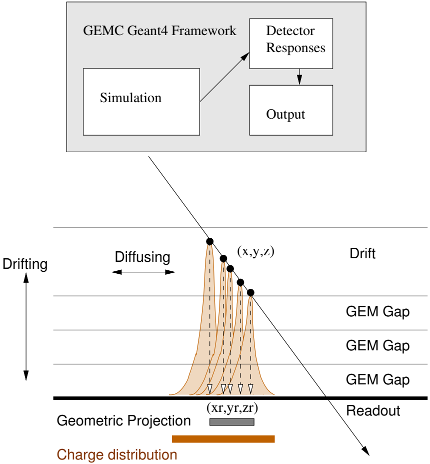
Hall A Analyzer

analyzer ROOT Output

Analysis Software

GEMC Integration with SBS GEM Code

- GEMC outputs raw hits in several GEM layers
  - Tag by ID number - e.g. XXYY, XX defines chamber, YY defines chamber region
  - Hits in drift gap, position of gap entrance and exit, and in readout strip plane



GEM Response - Space

GEM response parameters tuned on realistic responses observed at COMPASS

- Discrete ionization points and energy deposited defined by Geant4, written out
- Poisson defines distribution, average number of pairs given by

$$\bar{n}_{\mathrm{ion}} = \Delta E / W_i$$

- Diffusion and drift, governed by diffusion coefficient D, assume constant v

$$\sigma_s(t) = \sqrt{2Dt}$$

GEM Response - Gain, Digitization for Time

- Multiplication by Furry distribution

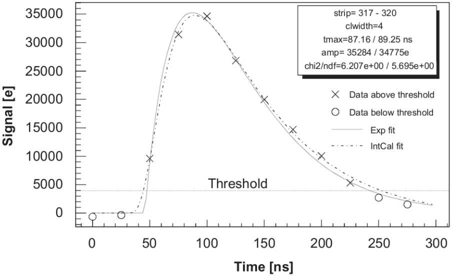
$$f_{\mathrm{Furry}} = \frac{1}{\bar{n}} \exp\left(-\frac{n}{\bar{n}}\right)$$

- Now have Gaussian distribution - associate with set of strips (strip geometry first relevant here)

- Output timing given by shaped amplitude A and time constant $T_p \sim 50\ \mathrm{ns}$

$$v = A \frac{t}{T_p} \exp\left(-t/T_p\right)$$

- FWHM $\sim 100\ \mathrm{ns}$



Digitization with APV25

APV25 chips used for digitization of GEM signals

- Provide 3 successive time samples of 25ns
- Analog pipelined readout into VME

Multipeak timing analysis

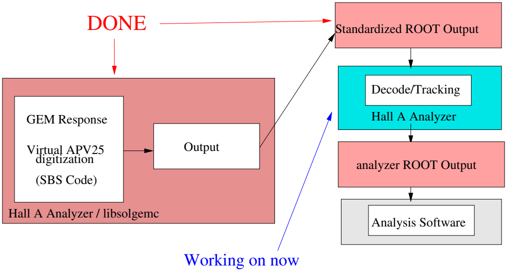
- Using the timing shape from above, online peak finding can be done with three samples
- Given form of timing on previous page, only three samples are necessary to deconvolute peak amplitude

$$s_k = w_1 v_k + w_2 v_{k-1} + w_3 v_{k-2}$$

$$w_1 \sim e^x/x, w_2 \sim 2/x, w_3 \sim e^{-x}/x$$

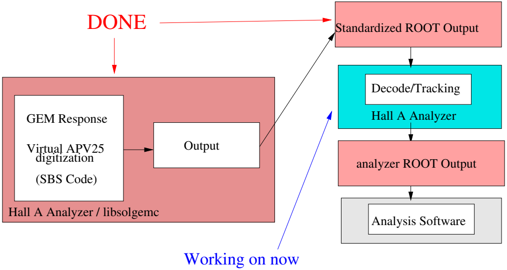
$x = \Delta t/T_p$, Δt is sampling interval
S. Gadomski, et al., Nucl. Instr. and Meth. A 320 (1992) 217.

Tracking Framework



- Digitization framework written
- Reads EVIO file, casts it into data structure, applies GEM response, produces digitized strip hits
- Need to debug any issues - validate with real data? come about with tracking
- Could add further low level effects: Constant pedestal shifts, timing
- Need to add parallel facilities for calorimeter, Cerenkov - not difficult at this stage

Tracking Framework



Working on now:

- Decoding strip hits and putting into tracking
  - Followed similar output as SBS tracking, some version of code already exists
  - Optimal clustering algorithm will need to be evaluated - separate from tracking algorithms
- Should employ amplitude association, amplitude χ^2 check at the end

Algorithms

- Xin's Progressive Algorithm
  - Flexible, works for SIDIS and PVDIS
  - Starts with seed, searches in progressively narrow spatial windows
  - Already shown to be feasible for PVDIS/SIDIS rates
  - Needs to be implemented for analyzer
- Ole's Tree Search Algorithm
  - Requires straight tracks, bend for SoLID sufficiently small; applicable at some level
    - ϕ is linear in z for ideal solenoid
    - r deviates from linear in by few % for lowest p
  - Uses recursive template matching to find tracks
  - Fast and efficient - desirable for SoLID, runs in $O(\log n)$
  - Hasn't been done for these specific environments
  - Implemented for analyzer - need to set up patterns

Milestones 1/2

Complete

- Produce general software as specified above
- Field maps available for CLEO
- Implement Eugene's baffle design and reproduce acceptance
- Simple detector responses (done in GEMC)
- Stolen work from SBS for GEM detailed response
- Useful event generators
- Backgrounds in FLUKA

Milestones 2/2

In progress

- Cerenkov
- Calorimeter
- Reproduce baffle design software
- Background studies in Geant4

Ahead

- Cerenkov in GEMC
- Fully optimized, realistic CLEO baffle, updated FOM
- Finalized yoke for CLEO and field maps
- Additional realistic detector responses/digitization
- Tracking evaluation
- Updated background/radiation hardness studies

Questions

What do we need for director's review, and onward?

- Manpower Division
  - Cerenkov designs - Eric or Simona
  - Calorimeter design - Cal. Group
  - Cerenkov in GEMC - Eric or Simona
  - Rich, Ole, Seamus
    - Hall A Analyzer as general postprocessing framework (all detectors)
    - Tracking framework completed
    - GEM responses/digitization
  - Fully optimized, realistic CLEO baffle, acceptance, FOM - Seamus
    - Basic tracking demonstration in GEMC - with Ole and Rich
    - Full tracking evaluation - with Ole and Rich
    - Background discrepancies reconciled
    - Radiation concerns on electronics/detectors
    - Quantitative DAQ issue analysis - with Alex

Summary

Major points:

- Background rates from GEANT3 need to be reconciled/understood with present software
- Baffles need additional work, but good start is in place
- Several optics ideas need to be worked on
- Progress has been made in realizing goals - path is clear, need time and manpower to complete