# SoLID Software Development

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for the SoLID Software Group

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# Software Group

- Several active collaborators in software development:

| | |
|---|---|
| Seamus Riordan | University of Massachusetts, Amherst |
| Ole Hansen | Jefferson Lab |
| Richard Holmes | Syracuse University |
| Xin Qian | Caltech |
| Lorenzo Zana | Syracuse University |
| Zhiwen Zhao | University of Virginia |

# Outline

- Framework Overview
- Event generators, backgrounds
- Baffles
- GEM digitization

# Software Goals

Ultimate software goals in planning SoLID:

- Optimize figure-of-merit for experiments
- Understand experimental background rates and asymmetries
- Optimize detector designs and verify experimental needs
  - Tracking detectors,PID,Calorimetry
  - DAQ
- Understand magnetic optics and produce optimized PVDIS baffle design
- Produce fully digitized simulated experiment events for analysis

Design philosophy:

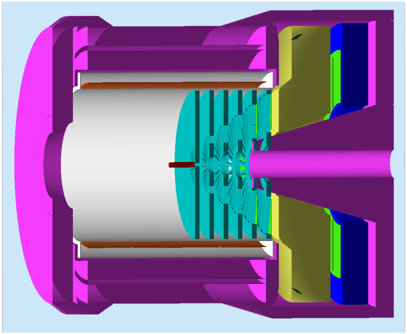
- Use modern simulation package
- Have flexible event input for stand-alone generators
- Have standard set of output
- Avoid hardcoding geometries to allow ease of design changes
- Avoid reinventing the wheel

# (sol)gemc Overview

- GEANT3/comgeant used for original PVDIS and SIDIS proposals, but no longer supported
- Geant4 still actively being developed, can be implemented to meet our needs

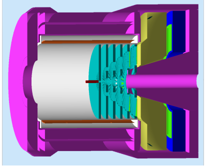
GEMC - Geant4 base:

- Originally developed for CLAS12 simulations
- Uses SQL for storing geometry,materials,fields - no hardcoded geometries
  - perl script interface for generating geometries
  - Magnetic field maps are stored locally but described in tables



# (sol)gemc Overview

- GEMC, cont'd
  - Advanced GUI and visualization included
  - Modularized event hit processing
  - Input using LUND format - text file tables
  - Output to EVIO - used in JLab CODA data
    - Data organized into banks storing float and integer data
    - Tools available to decode into ROOT or other formats



- solgemc extension
  - Can replace/add capabilities without interfering with gemc
  - Extend data input formats
    - SOLLUND format - includes event weights
  - Write new hit processes, customize output data
- libsolgem - post analysis package
  - Built using Hall A analyzer - Object oriented detector analysis
  - Can evio input, can generate ROOT output

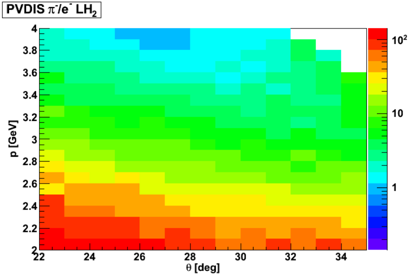
# Event Generators

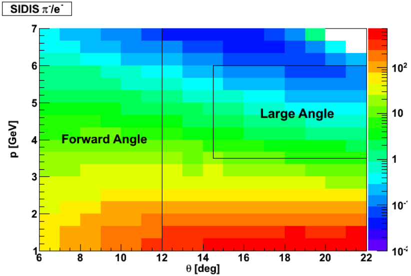
Written several stand-along event generators

- Standardized for GEMC
- DIS rates, PV asymmetries with CTEQ6
- $\pi^{\pm}$, $\pi^0 \to \gamma\gamma$ with Wiser code
  - Param. SLAC data from $\pi$ prod. with equivalent $\gamma$ approx.
- Elastic with nucleon FFs

To do:

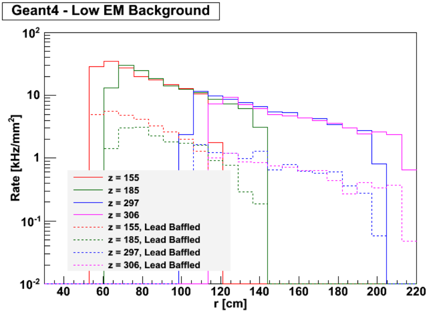
- $\Lambda$ decay - self-analyzing
- $\pi$ asymmetries
- Radiative effects

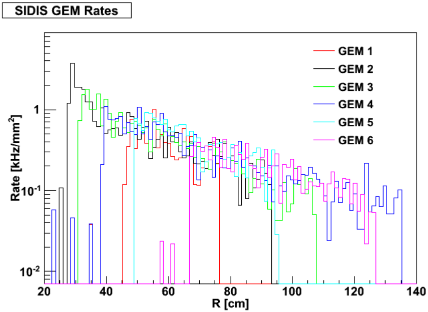


# Background Rates

- Background rates can be evaluated using Geant4 processes and aforementioned generators




- GEANT3 physics had 1 $\mathrm{MeV}$ particle energy cutoff - misses important events (especially for GEM rates)
- Rates consistent with proposal within understood physics
- True GEM rates, E-flux about 2-3 time higher than proposal

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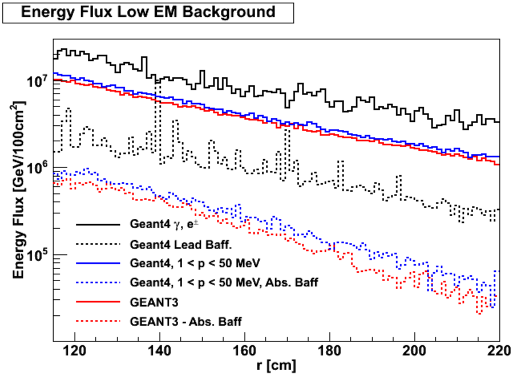


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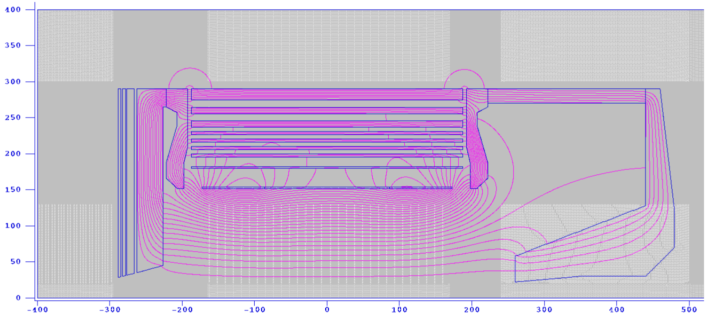
# Baffles - Aside: Magnetic Fields

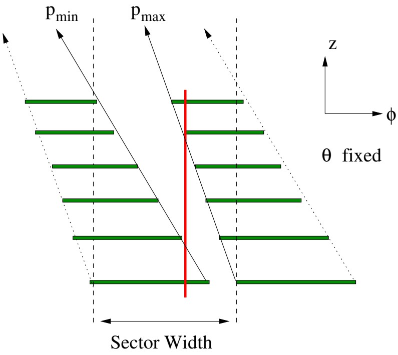
- Baffles would ideally be algorithmically designed for optimization
- Magnetic fields generated using POISSON/Superfish from LANL
- Assumes azimuthal symmetry - final details will have to be done using TOSCA



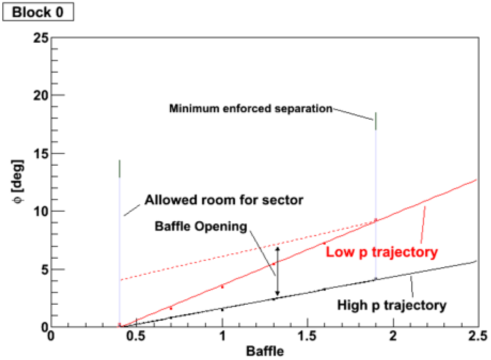
# Baffles

Baffles done for BaBar magnet
Optimization must be done for CLEO

- Baffles purpose:
  - Block line-of-sight photons
  - Black low energy charged background ($\pi$, $e^-$)
  - Maximize acceptance for useful events



# Baffles - Design




- Baffles designed along cutoff, minimum $p$ trajectory and a high $p$ trajectory
- High $p$ trajectory does not specify cut off, but does drive acceptance
- Perform a fit for momenta passing through each radial block

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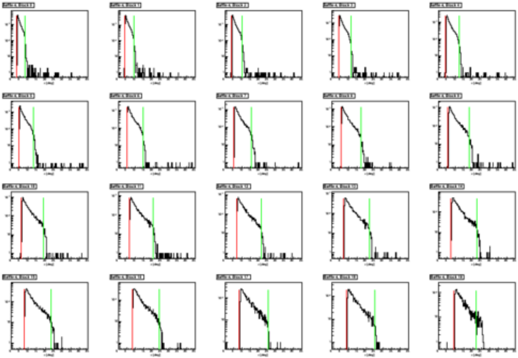

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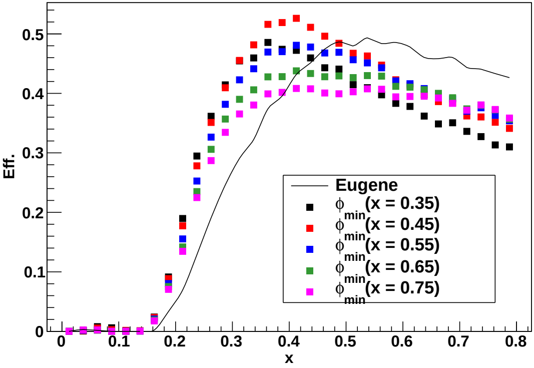
# Baffles - Results

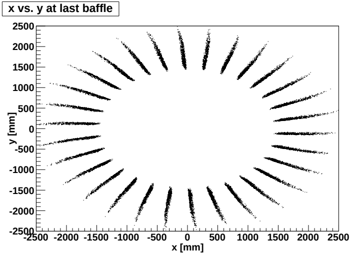
In CLEO field:

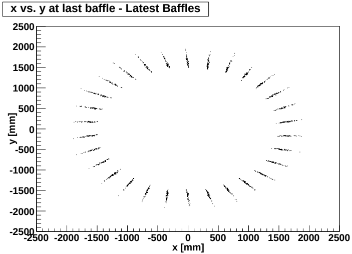



- Scanning different optimization criteria shows choice in emphasis in kinematic range
- Figure-of-merit ultimately decides best set

# Baffles - Photon blocking

Photon acceptance:




Proposal Baffles

Latest

- Reducing acceptance to block photons equates to loss of about 7% acceptance
- Most photons are coming in from back of the target
- Further adjustments can be made to improve blocking

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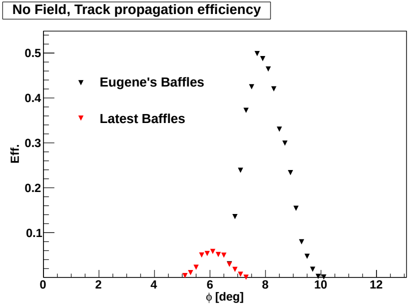


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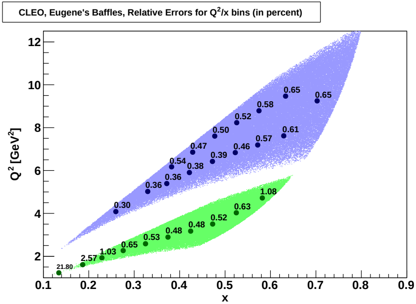


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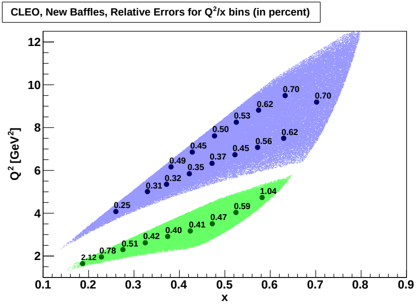
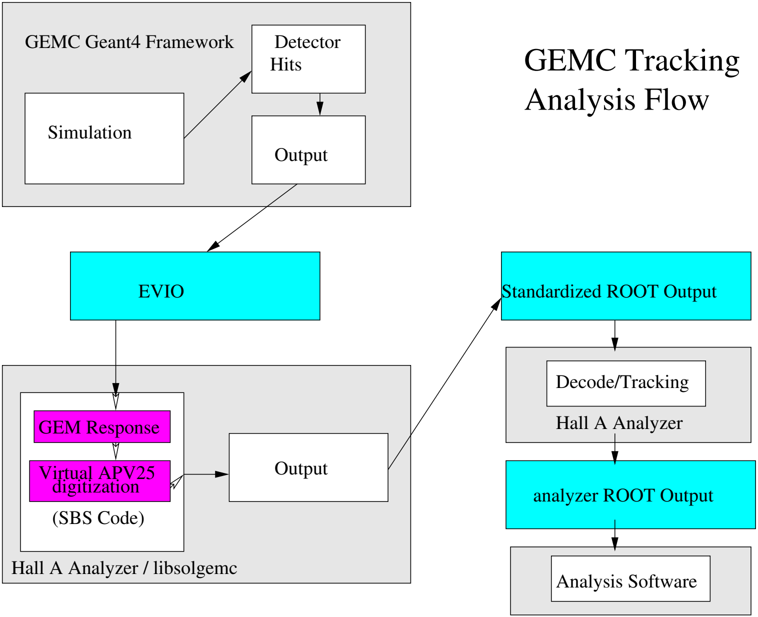



| | Old Baffles | New |
|---|---|---|
| Higher Twist | 1.8e-3 | 1.7e-3 |
| CSV | 0.013 | 0.012 |
| d/u | 0.028 | 0.028 |

- Even with loss of acceptance, FOM is marginally higher

# GEM Digitization/Tracking Framework




GEMC Tracking Analysis Flow

# GEM Response

GEM response parameters tuned on realistic responses observed at COMPASS

- Poisson defines distribution, average number of pairs given by

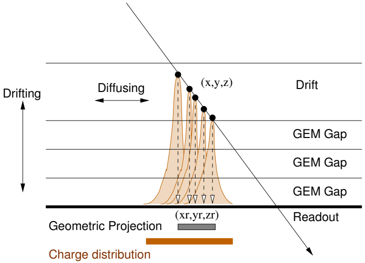
$$\bar{n}_{\text{ion}} = \Delta E / W_i$$

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

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

- Multiplication by Furry or Poisson distribution

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



# Digitization - APV25

APV25 Chips used for digitization

- Provide 3 successive time samples of 25ns
- Timing given by amplitude $A$ and time constant $T_p$

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

Multipeak timing analysis

- Using the timing shape from above, online peak finding can be done with three samples
- Using a CR-RC filter and form of timing on previous page, only three samples are necessary to find peak amplitude

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

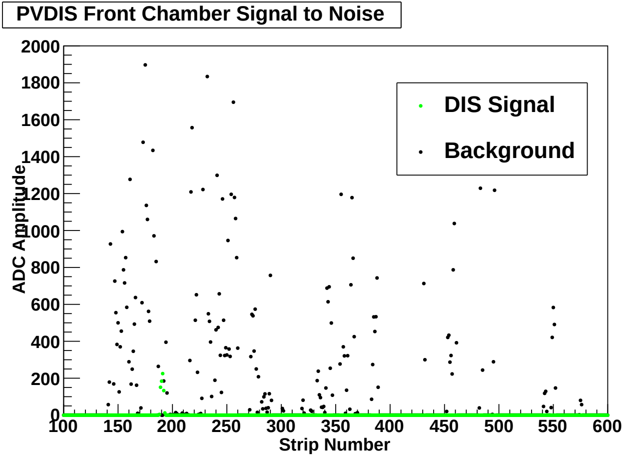
$$w_1 = e^{x-1}, w_2 = -2e^{-1}/x, w_3 = e^{-x-1}/x$$

$x = \Delta t/T_p$, $\Delta t$ is sampling interval

S. Gadomski, et al., Nucl. Instr. and Meth. A 320 (1992) 217.

# Digitization Results

- Now getting first full simulation digitization results




- Signal/background ratio relatively low - improved by deconvolution

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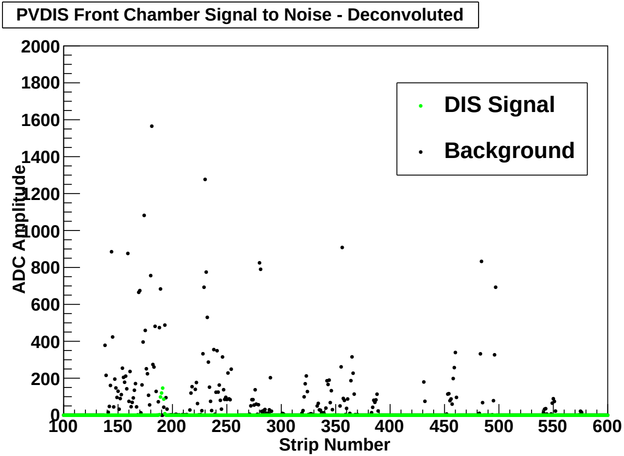


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# Summary

- Development of necessary software well underway
- Suitable framework chosen for scale of project and needs
- Realistic event generators developed
- Auxiliary software for baffle design and digitization in hand

# Optics

Rates for 1 $\mu$A:

| E [GeV] | Rate Range [Hz/mm$^2$] | | | $p$ Range [GeV] | | | $p$ Spread [%] |
|---|---|---|---|---|---|---|---|
| 4.4 | 0.5 | - | 22 | 2.2 | - | 3.5 | 15 |
| 8.8 | $2 \times 10^{-3}$ | - | 0.15 | 3.0 | - | 6.0 | 15 |
| 11 | $5 \times 10^{-4}$ | - | 0.025 | 3.0 | - | 7.0 | 15 |

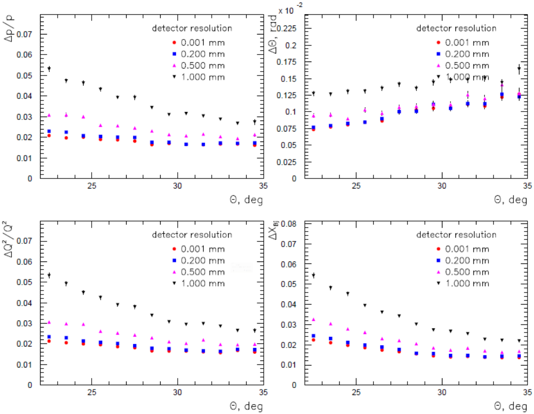
To get at least 200/cm/sector at 50 $\mu$A:

| E [GeV] | $t$[hr] |
|---|---|
| 4.4 | 0.006 |
| 8.8 | 1.6 |
| 11 | 6 |

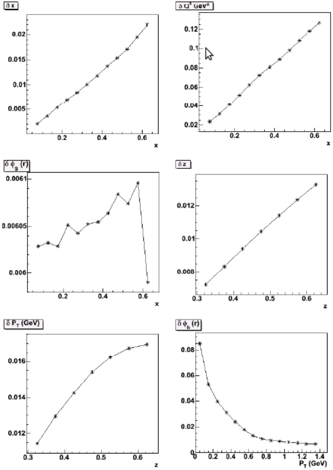
- Need to calibrate $2 - 6$ GeV for the experiment
- 8.8 matches that pretty well for $p$ range at given $\theta$
- Few days at 6.6 and 8.8 probably gives very good $p$ coverage. Combining with 4.4 GeV with field scan would probably be sufficient
- Working on simulated calibration

# PVDIS Resolution

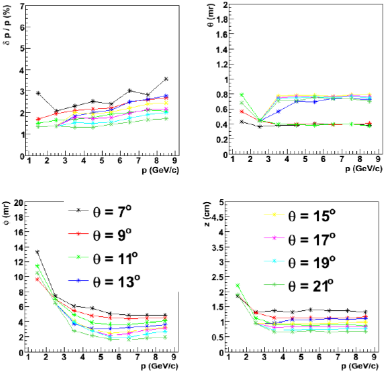
- Previous studies showed that multiple scattering effects will dominate over GEM resolutions in PVDIS
- With 6° wires, get $\delta x = 526\ \mu\mathrm{m}$, $\delta y = 55\ \mu\mathrm{m}$ (with 100 $\mu\mathrm{m}$ base resolution)
- Should be limited by multiple scattering effects



# SIDIS Resolution

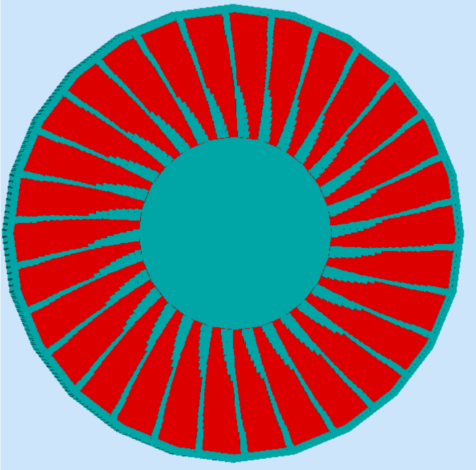



1.8% delta_p/p, 0.6 mr in polar angle
6 mr in azimuthal angle.
Acceptable in azimuthal angle and PT




- Resolution for SIDIS kinematics also sufficient
- Multiple scattering with $^3\mathrm{He}$ target effects negligible

# Baffles - Shape



- Baffle shape not smooth on outer angle - should consider small variations to correct this
- Optimization of field could help, possibly fewer sectors?

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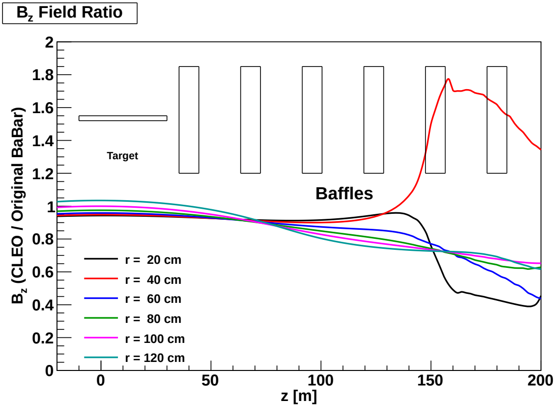


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