SoLID Simulation Software Development

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for the SoLID Software Group

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Software Group

- Several active collaborators in software developement:

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Ole Hansen	Jefferson Lab
Richard Holmes	Syracuse University
Seamus Riordan	Stony Brook University
Lorenzo Zana	Edinburgh
Zhiwen Zhao	Old Dominion/JLab

Outline

- Framework Overview
- Event generators
- GEM digitization
- Optics

Software Goals

Ultimate software goals in planning SoLID:

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

Design philosophy:

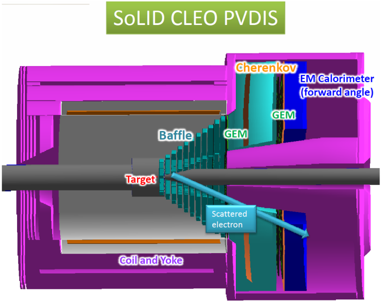
- Use modern simulation package
- Have flexible event input for stand-alone generators
- Have standard set of output
- Avoid hardcoding geometries to allow ease of design changes
- Avoid reinventing the wheel

(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

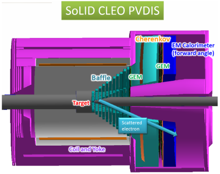
GEMC - Geant4 base:

- Originally developed for CLAS12 simulations
- Uses SQL (or stand alone with v2.0) for storing geometry,materials,fields - no hardcoded geometries
  - perl script interface for generating geometries
  - Magnetic field maps are stored locally but described in tables



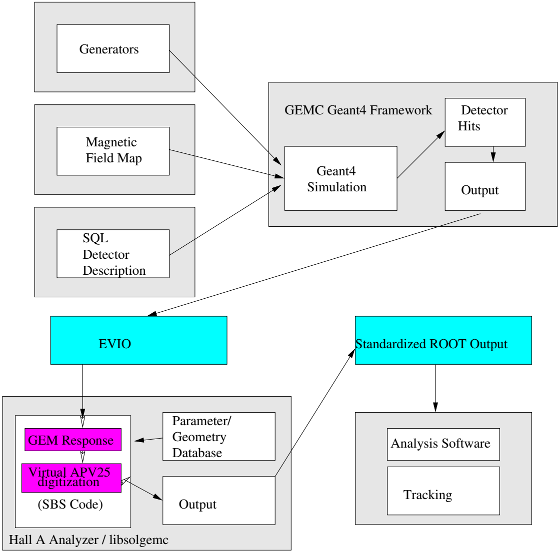
(sol)gemc Overview

- 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

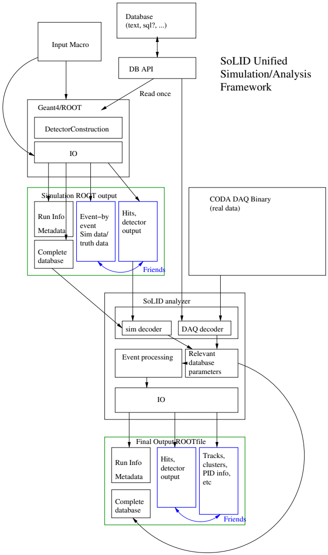


- solgemc extension
  - Can replace/add capabilities without interfering with gemc
  - Extend data input formats
    - SOLLUND format - includes event weights
  - Write new hit processes, customize output data
- libsolgem
  - Additional library for analysis
  - Built using Hall A analyzer, ROOT, evio as toolkit

Framework Diagram



Framework Diagram - Forward



- Some restructuring is desired to meet our needs for a large project
- For development of reconstruction/analysis software integration with is imperative
- Coherent descriptions with configurations, simulation input need to be tied with output files
- Final analysis framework needs to be identified and developed

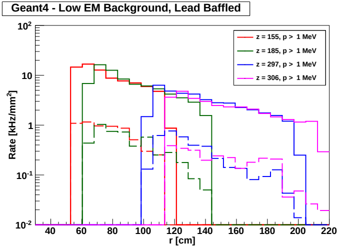
Event Generators

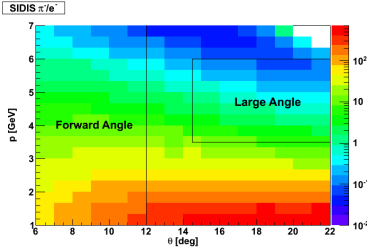
Written several stand-along event generators

- DIS rates, PV asymmetries with CTEQ6
- $\pi^{\pm}$, $\pi^0 \to \gamma\gamma$, $K^{\pm}$, p with Wiser code
    - Param. SLAC data from π prod. with equivalent γ approx.
- SIDIS generator
- Elastic with nucleon FFs

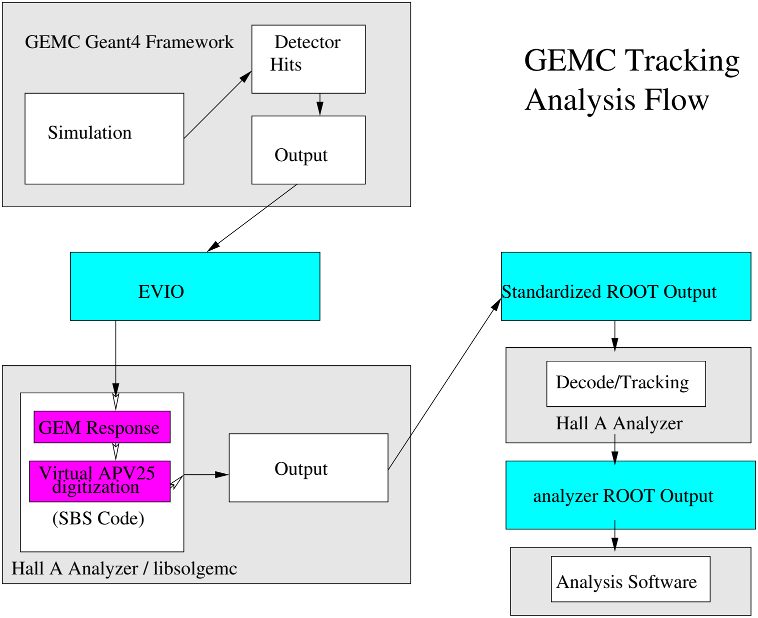
To incorporate:

- Λ decay - self-analyzing (exists)
- Resonance (exists)
- Radiative effects - have working group





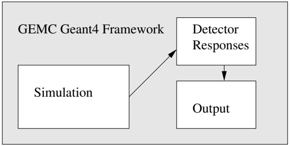
Framework


GEMC Geant4 Framework
Detector Hits
Simulation
Output
GEMC Tracking Analysis Flow
EVIO
Standardized ROOT Output
Decode/Tracking
Hall A Analyzer
GEM Response
Virtual APV25 digitization
(SBS Code)
Output
analyzer ROOT Output
Hall A Analyzer / libsolgemc
Analysis Software

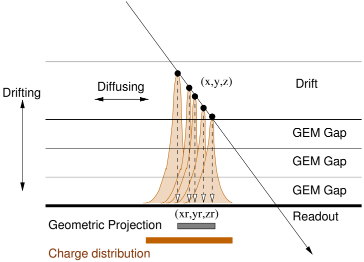
GEMC Integration with SBS GEM Code

Overview

- GEMC outputs raw hits in G4 volumes
- Wrote generic interface for postprocessing in libsolgemc
- Can be extended to other detector systems



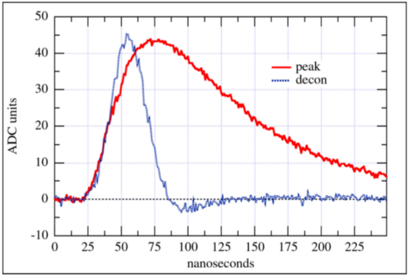
- Digitization needs to have several regions in GEM read out
- Diffusion and evolution of charge cloud done in post-processing using data-based models



Digitization - APV25

APV25 Chips used for digitization

- Provides zero supression
- Adjustable shaping time
- Pipelined readout into custom VME



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

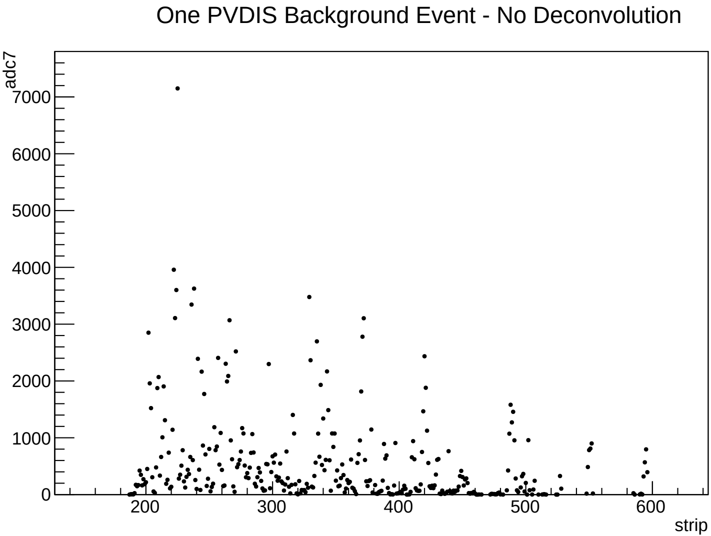
$$s_k = w_1 v_k + w_2 v_{k-1} + w_3 v_{k-2}$$
$$w_1 = e^{x-1}, w_2 = -2e^{-1}/x, w_3 = e^{-x-1}/x$$

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

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

Digitization Results

- Now getting first full simulation digitization results



Digitization Results

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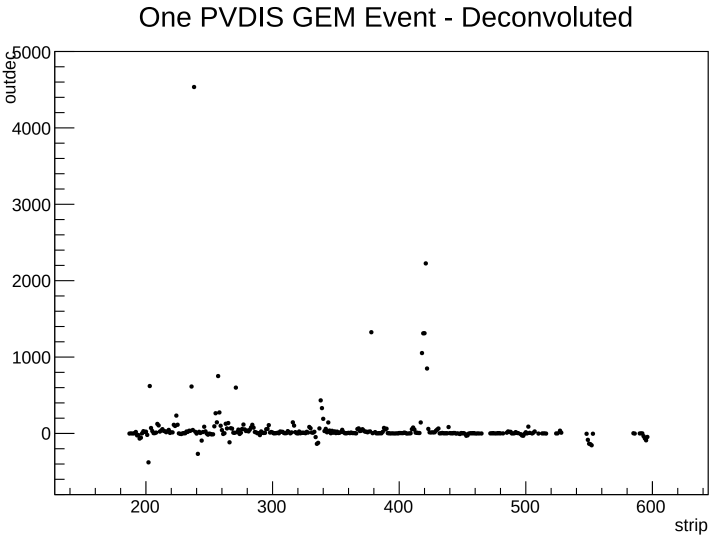


Optics

Rates for 1 μA:

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

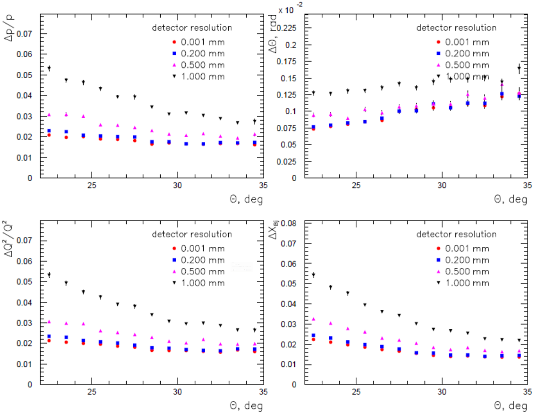
To get at least 200/cm/sector at 50 μA:

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

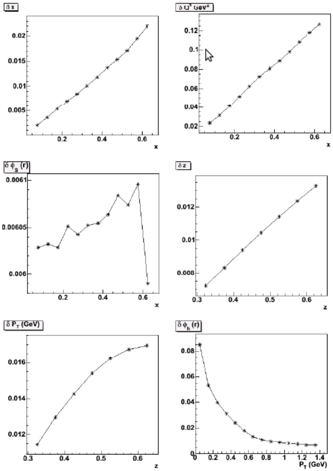
- Need to calibrate $2 - 6$ GeV for the experiment
- 8.8 matches that pretty well for p range at given θ
- Few days at 6.6 and 8.8 probably gives very good p coverage. Combining with 4.4 GeV with field scan would probably be sufficient
- Working on simulated calibration

PVDIS Resolution

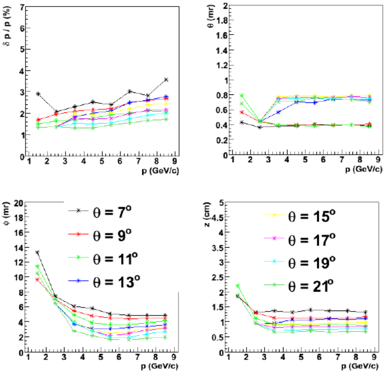
- Previous studies showed that multiple scattering effects will dominate over GEM resolutions in PVDIS
- Reconstructed variables fit to uniform field equations with perturbations
- $\delta Q^2 \sim 1.5\%$, $\delta x \sim 1\%$, $\delta z \sim 0.7$ mm



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 negligable

Summary

- Development of necessary software inplace, portions ongoing
- Suitable framework chosen for scale of project and needs
- Realistic event generators developed
- Auxiliary software for digitization available and is useable for tracking

BACKUP

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 distribtion, average number of pairs given by

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

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

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

GEM Response - Gain, Time

- Multiplication by Furry or Poisson 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)

- Timing given by amplitude A and time constant T_p

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