Software and Tracking

Seamus Riordan
`seamus@anl.gov`

Argonne
NATIONAL LABORATORY

June 15, 2017

Overview

- Software Overview and Scope
- Task Responsibilities
- Status and Timeline
- Tracking Simulations

Charge Item

Charge Item 3

Are the responsibilities for carrying out each job identified, and are the manpower and other resources necessary to complete them on time in place?

Charge Item 5a

Have the specific equipment been demonstrated f or readiness to operate the spectrometers (SBS and BigBite) and to achieve the scientific goals of the experiment ? This includes demonstrating:
a) GEM reconstruction efficiency at high rate
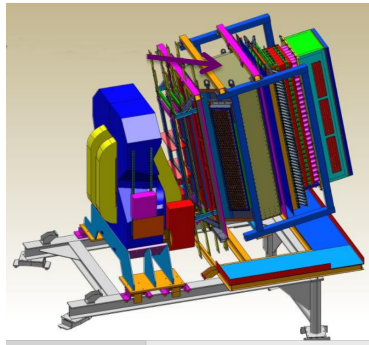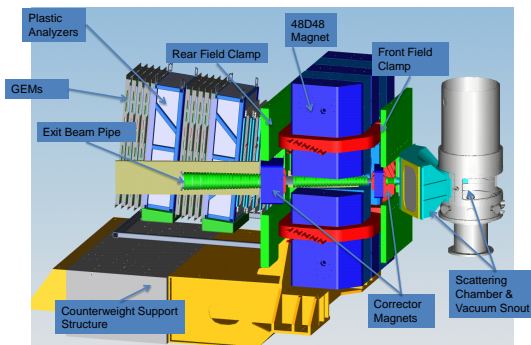
- Several major new systems -
  Experiments have different combinations

SBS Full Event rate	up to $\sim$5 kHz
Several sets of GEM trackers	$\sim$100k strips
Hadronic Calorimeter	288 FADC ch
Electromagnetic Calorimeter	1700 ADC ch
Scint. Coord. Det	2k TDC ch
Gas Cherenkov	550 TDC ch
Scintillator Timing Plane	360 TDC/ADC ch

- Reuse of existing Bigbite EM calorimetry ($\sim$200 PMTs), HERMES RICH ($\sim$2k PMTs)

Software Goals

Need full software chain before start of running

- Need for all stages: development, commissioning, and running
- Event reconstruction and inter-detector correlations will be critical to ensure experimental operation
- Open geometry and high luminosity are new challenge
- Coordinating between subgroups to produce single software package
- Progress tracking now in redmine
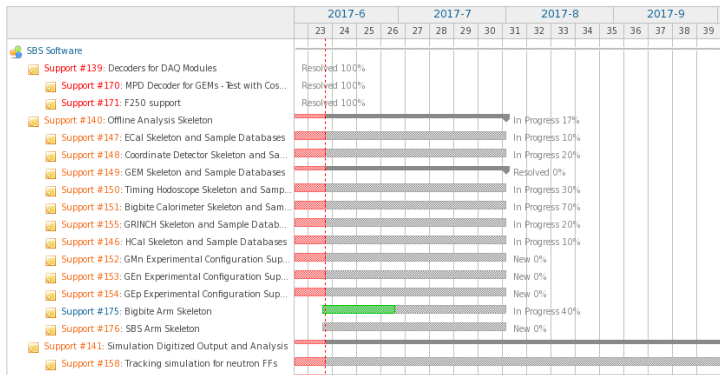
Detector Subsystem Software

- Add to analyzer framework GEMs, CDet, GRINCH, ECal, RICH, Bigbite
- Have GEM classes from previous experiments integrated with TreeSearch tracking
  - Probably single most difficult task
- New decoders written
  - MPD and F250 written and available in repository
- Event displays required
- Individual hardware development groups have taken on responsibility
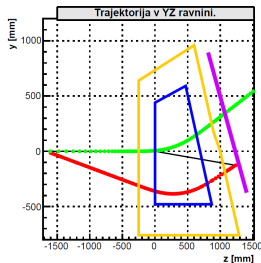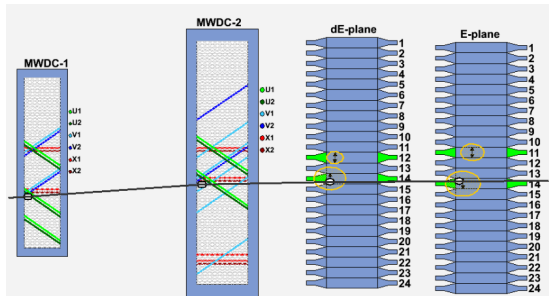
Subsystem Responsibilities

General Purpose Software

analyzer Development	Hansen
Front End Decoders	Camsonne
Event Reassembly	JLab DAQ Group

SBS Specific

	Contact	Supporting Groups
Repository Maintenance	Riordan	JLab
MPD Decoding	Riordan	JLab, UVA, INFN
GEM Tracking	Puckett	UConn, INFN, JLab
HCal Analysis	Franklin	CMU
Coord. Det	Monaghan	CNU
GRINCH	Averett	WM
BigBite Legacy	Riordan	JLab

GMn Analysis

GMn	Quinn

Experiment Analysis Software

- Need development for analysis of each specific experiment
- Algorithms for PID and associating between detectors/arms needs to be in place
- Optics, target specific analysis very important
- Scripts for commissioning and calibration
- Framework for offline analysis software

Simulation

`http://github.com/JeffersonLab/g4sbs`
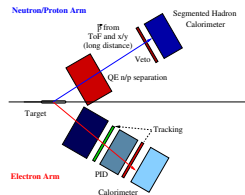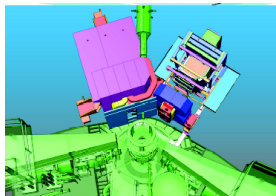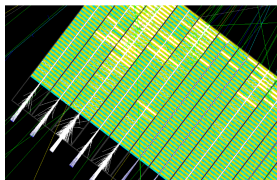
- Full Geant4 Monte Carlo for all experiments
- Under continuous development since 2010
- Event generators to cover physics and backgrounds
  - Elastic, quasielastic, DIS, π, Pythia, ...
  - Random backgrounds
- Detailed detectors with full responses, optical photon production
- Includes beamline, shielding, support structures for backgrounds and radiation studies
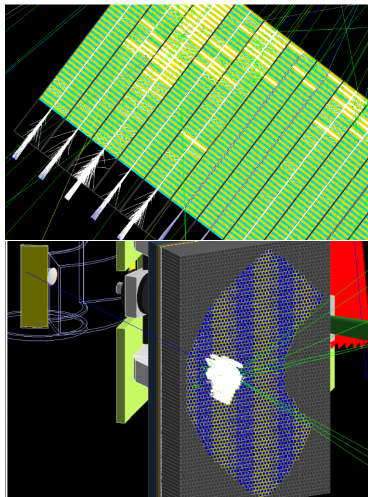
Further Experiment Analysis Software

- Major goal of "end to end" simulation with production of pseudodata - simulation of data sizes

- Requires realistic digitization of new subsystems from Geant4 responses

- Ultimate demonstration of event-by-event analysis for full experiment

- Non-trivial and requires well defined standards/interfaces for flexible design
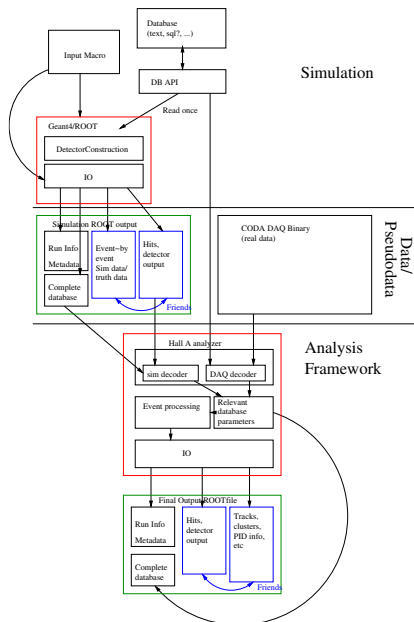
Current Status
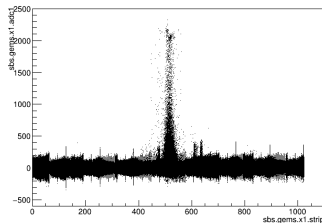
Have working whitepaper and repository

`http://hallaweb.jlab.org/12GeV/SuperBigBite/documents/sbs_soft_whitepaper.pdf`

`http://github.com/JeffersonLab/SBS-offline`

- Now transitioning from hardware development to analysis

- Responsibilities within subgroups defined

- Raw data analysis chain partially defined
  - Reusing existing framework from legacy detectors
  - GEM MPD decoding with examples
  - UVA, INFN, Hampton collaborators with production GEM experience
  - Remaining systems need skeletal definition for subgroups to fill in

- Postdoc Eric Fuchey (UConn) actively working on next iteration of tracking

sbs.gems.x1.adc1:sbs.gems.x1.strip

Future SBS Software Milestones

- Nov 2016 - Software Review
- Jan 2017 - Start Digitized Simulation Output
- Apr 2017 - Decoders for all DAQ modules written
- Jul 2017 - Each detector system in analyzer, experiment configurations, basic reconstruction algorithms
  - Can analyze channel-level raw data at this point
- Dec 2017 - Simulation Interfaced to analysis, Have detector event displays, calibration scripts
- Jan 2018 - Start simulated analysis for detector reconstruction
- Jun 2018 - Begin simulated experimental analysis for core form factor experiments
- Jan 2019 - Ready for beam for form factor, start simulated experimental analysis for SIDIS and TDIS

- Spring 2019 likely earliest start of neutron experiments
- Spring 2020 likely earliest start for GEp

GEM Tracking Requirements

Common: straight tracks (field-free region)

- **BigBite:** GEMs, assisted by ECAL; low rate; BigBite optics
- **SIDIS H-arm:** GEMs, assisted by HCAL; low rate; 48D48 optics
- **GEp(5) front:** GEMs, restricted to narrow search region; very high rate; requires iterative kinematic correlation analysis; 48D48 optics
- **GEp(5) back:** GEMs, similar search region; high rate; requires bridging between tracker regions

Each item involves (somewhat) different reconstruction algorithm.
Significant code sharing possible, if well planned

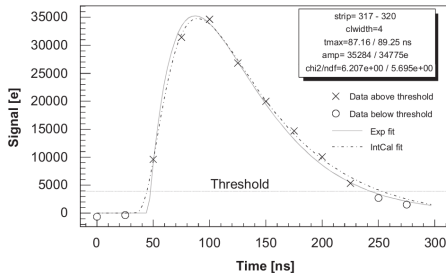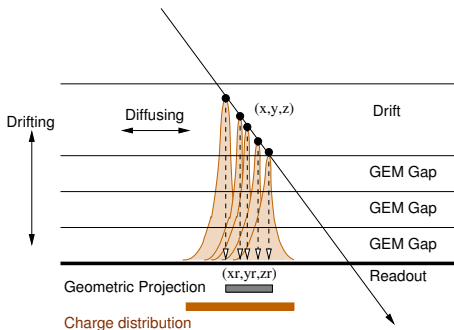- Expect rates up to $\sim 500 \ \mathrm{kHz/cm^2}$ for GEp
- Expect rates up to $\sim 100 \ \mathrm{kHz/cm^2}$ for this experiment

GEM Rates for GMn
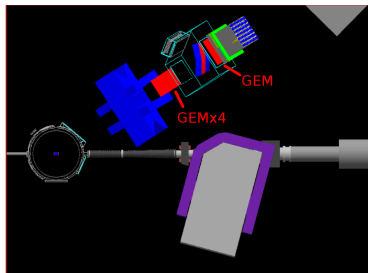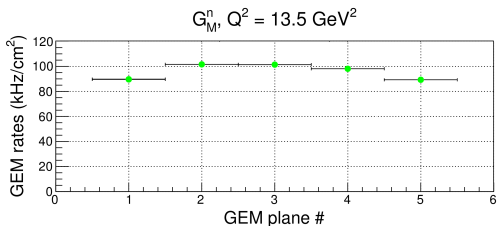
- Rates on GEMs depending on implemented shielding design - need to iterate with engineers
- Deconvoluted occupancy will be about 10-15%
- Pedestal noise and cross talk increases factor ~1.3

Digitization description

- GEM responses based on observed data for charge cloud strength and size
- Ionization in gas volumes amplified with statistical process and over several strips
- APV25 time response applied based on shaping circuit (width ~ 200 ns) with 3-sample deconvolution applied
- Background and pedestal noise superimposed out of time

2011 GEp(5) Tracking Study: Proton Arm GEM Track Reconstruction

- Reconstruction algorithm implemented in 2010/11 based on Hall A BigBite MWDC code
- APV25 decoder & analysis
  - Pulse shape deconvolution
  - Noise rejection
  - Cluster finding
- Pattern recognition: TreeSearch in coordinate projections
  - Very fast recursive template matching algorithm
  - Efficiently finds straight lines of hits (within configurable bin width) → roads
  - Used by HERMES, Qweak, OLYMPUS, . . .
- Correlation of roads from different projections via hit amplitude correlation in shared readout planes
- Simple linear minimization fit of correlated hits in 3D
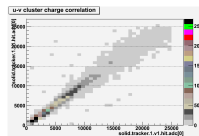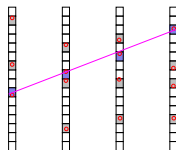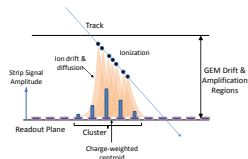
GEM Tracking

GEp5 Tracking Efficiency
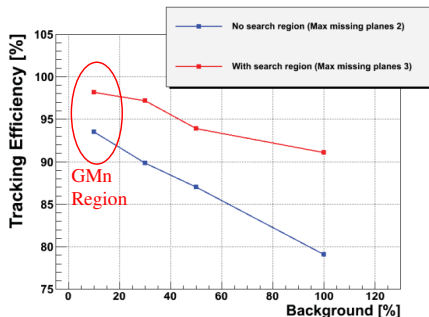
Track reconstruction accuracy
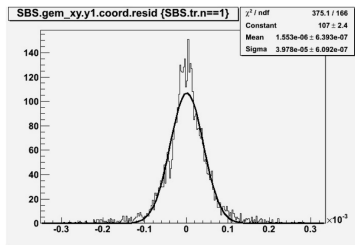
Resolution $\sim 40\ \mu m$
Will provide $\delta p/p \sim 1\%$

- Significant work already done in tracking under realistic requirements with Hall A TreeSearch algorithm
- Have only done realistic tracking for Front (most difficult) tracker to prove feasibility
- Additional neural network algorithms developed by INFN collaborators to test
- Have Postdoc Eric Fuchey (UConn) who is presently engaged with using latest simulation and integrating into SBS package

GEM Test Data

Charge Correlation

- GEMs are being tested in cosmic stand with scintillator trigger
- Have run in Hall from Fall 2016 - ~1.5% occupancy
- Working to add into SBS analysis chain
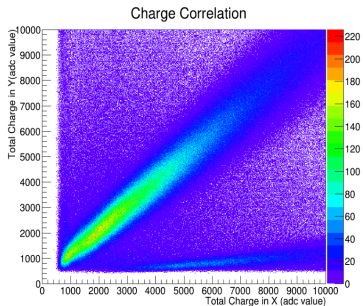
Charge Items Addressed

Charge Item 3

Are the responsibilities for carrying out each job identified, and are the manpower and other resources necessary to complete them on time in place?

	Contact	Supporting Groups
analyzer Development	Hansen	
Front End Decoders	Camsonne	
Repository Maintenance	Riordan	JLab
MPD Decoding	Riordan	JLab, UVA, INFN
GEM Tracking	Puckett	UConn, INFN, JLab
HCal Analysis	Franklin	CMU
Coord. Det	Monaghan	CNU
GRINCH	Averett	WM
BigBite Legacy	Riordan	JLab
Experiment Analysis	Quinn	

Charge Item 5a

Have the specific equipment been demonstrated for readiness to operate the spectrometers (SBS and BigBite) and to achieve the scientific goals of the experiment ? This includes demonstrating:
(a) GEM reconstruction efficiency at high rate

Tracking has been designed and demonstrated for GEp requirements which is a factor of five higher rate. Further analysis is ongoing with test data and GMn simulations.

Summary

- Software efforts by collaboration have been well defined with timeline and milestones
- Responsibilities have been delegated to subgroups under core repository and framework with regular meetings
- Work is transitioning to raw data analysis and revisiting tracking and will move to full event reconstruction in next months