University of Connecticut

Super BigBite Spectrometer: simulation and software update

Hall A collaboration meeting

Jefferson Lab, Jan 18-19, 2017

Eric Fuchey

(University of Connecticut)

On behalf of SBS collaboration / Software group

Outline

Overview of SBS

SBS Software/simulation project:
- Scope, requirements;
- organization: responsibilites and milestones;

Current status and activities:
- simulation;
- analysis framework;

Summary

Overview of SBS

See Mark Jones' presentation for more details

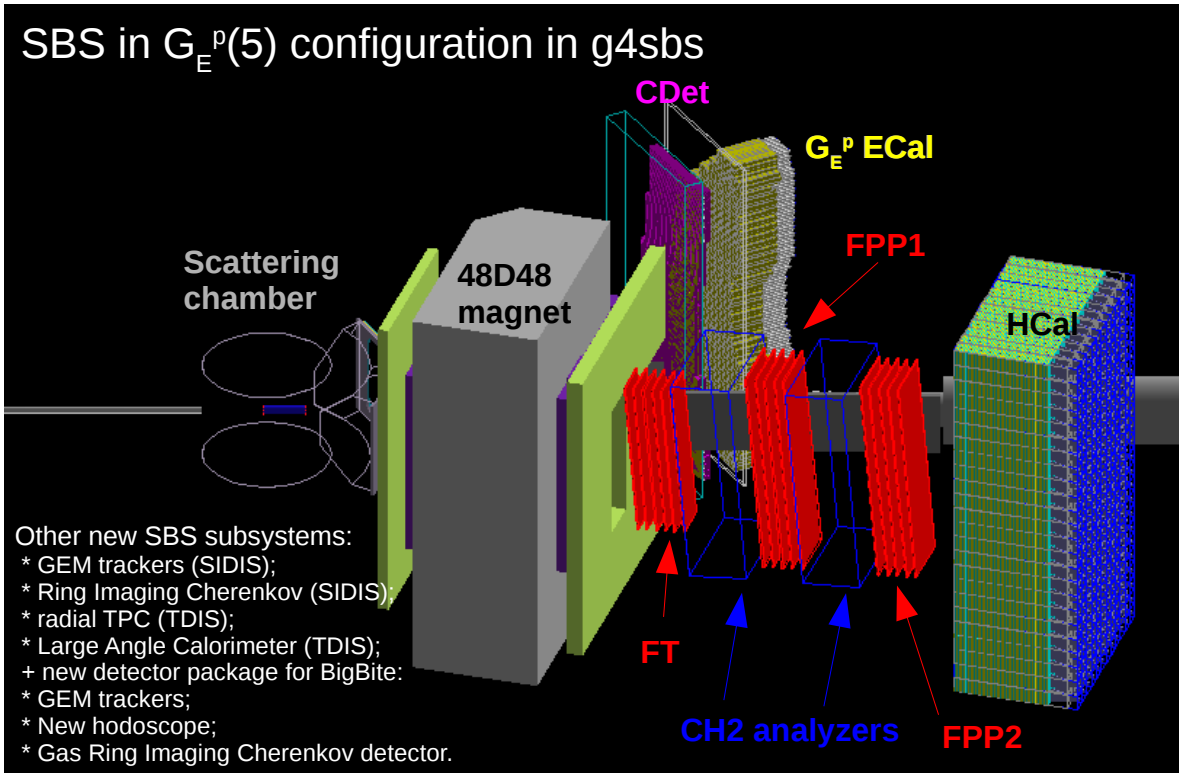
Super BigBite spectrometer:

One of the *major new projects* for Hall A @ 12 GeV (with Moller and SoLID):
Medium solid angle spectrometer with a *modular* detector package behind a dipole magnet.
=> Many new subsystems with large nb of channels / events sizes (wrt Hall A standards)
Earliest run start: ***2019***, ***184*** *(**+27** cond.) running days approved;*
=> major occupation for Hall A collaboration for *many years*.

Physics programs:

- Form factors at *high* Q^2:
  * G_M^n (LD_2), G_E^n (pol. ^3He);
  * G_E^p (LH_2, recoil pol);
- Semi-Inclusive DIS (pol. ^3He);
- Tagged DIS (cond. approved);

=> Major physics impact;
(Good opportunity for grad students, young postdocs to join)
=> challenging measurements: high luminosities, high detectors and DAQ rates;



SBS Software/simulation: scope and requirements

Simulation:

***** Estimation of physics and background rates, detector occupancies;
***** Experimental requirements, configuration optimization;
***** Radiation dose rates + shielding designs;
***** Data sizes, DAQ requirements + design of trigger logics
***** Detectors performances (resolutions in position, time, energy)
***** Magnetic field maps for SBS and BigBite (optics / spin transport,...)
***** Realistic detector response (digitization);
=> ***Production of pseudo-data to test analysis software***;

Analysis software:

***** Detector decoders (DAQ / online analysis)
***** Robust reconstruction algorithms (tracking, clustering);
***** Optics / spin transport;
***** Particle ID;
***** Coherent event reconstruction:
- between detectors in a single arm;
- between multiple arms;

***** Calibration scripts;
***** Event displays;
***** Physics analysis scripts;

Strong requirement:
Online and offline analysis both need to be ready and tested,
and pseudo-data sets have to be analyzed before data taking (likely spring 2019)**.**
=> critical given high luminosities / high detectors and DAQ rates.

Software/simulation project organization

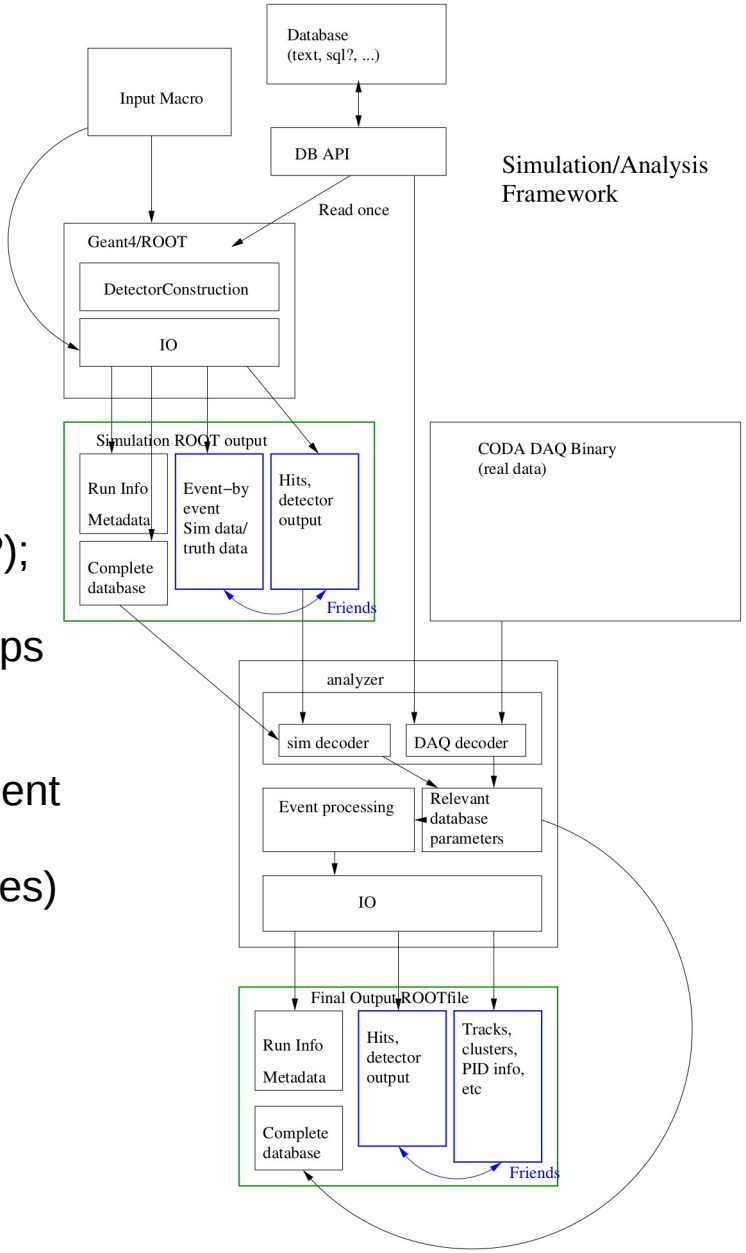
***** Major goal: "End-to-end" simulation:
production of pseudodata + simulation of data sizes;

***** Both simulation and analysis framework need to be:
→ *modular* (ease configuration changes);
→ *accessible* (ease handling for new people);
→ *flexible* (ease inclusion of new configurations);

***** Also need:
- Well defined IO formats and standards
- Flexible database to accomodate both MC and data (SQL ?);

***** Requires significant coordination between working subgroups
→ 1 dedicated software meeting every 2 weeks
(in addition to SBS weekly meeting).
+ About to migrate to e.g. Redmine for project management

**** Well defined responsibilities and milestones*** (next 2 slides)



Software/simulation organization: responsibilities

General purpose software

Analyzer development	O. Hansen (JLab)
Front-end decoders	A. Camsonne (JLab)
Event Reassembly	JLab DAQ group

SBS specific

Repository maintenance	S. Riordan
Simulation maintenance	UConn
MPD decoding	SBU, JLab, UVA, INFN
GEM Tracking	INFN, JLab, UConn
HCal Analysis	G. Franklin (CMU)
ECal analysis	A. Puckett (UConn)
CDet analysis	CNU (P. Monoghan, E. Brash)
GRINCH analysis	T. Averett (W&M)
BigBite analysis	S. Riordan

Experimental analysis

GMn	B. Quinn (CMU)	Bigbite, HCal
GEn	S. Riordan (SBU)	Bigbite, HCal, 3He target
GEp	E. Cisbani (INFN)	ECal, CDet, SBS w/ FT, FPPs GEM trackers
SIDIS	A. Puckett (UConn)	Bigbite, SBS w/ GEM trackers and RICH
TDIS	D. Dutta (SBU)	SBS e − w/ GEM trackers and RICH, LAC, RTPC

Software/simulation organization: Milestones

Slide from S. Riordan presentation @ last 12 GeV software review (Nov, 10-11, 2016):

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 fully analyze 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

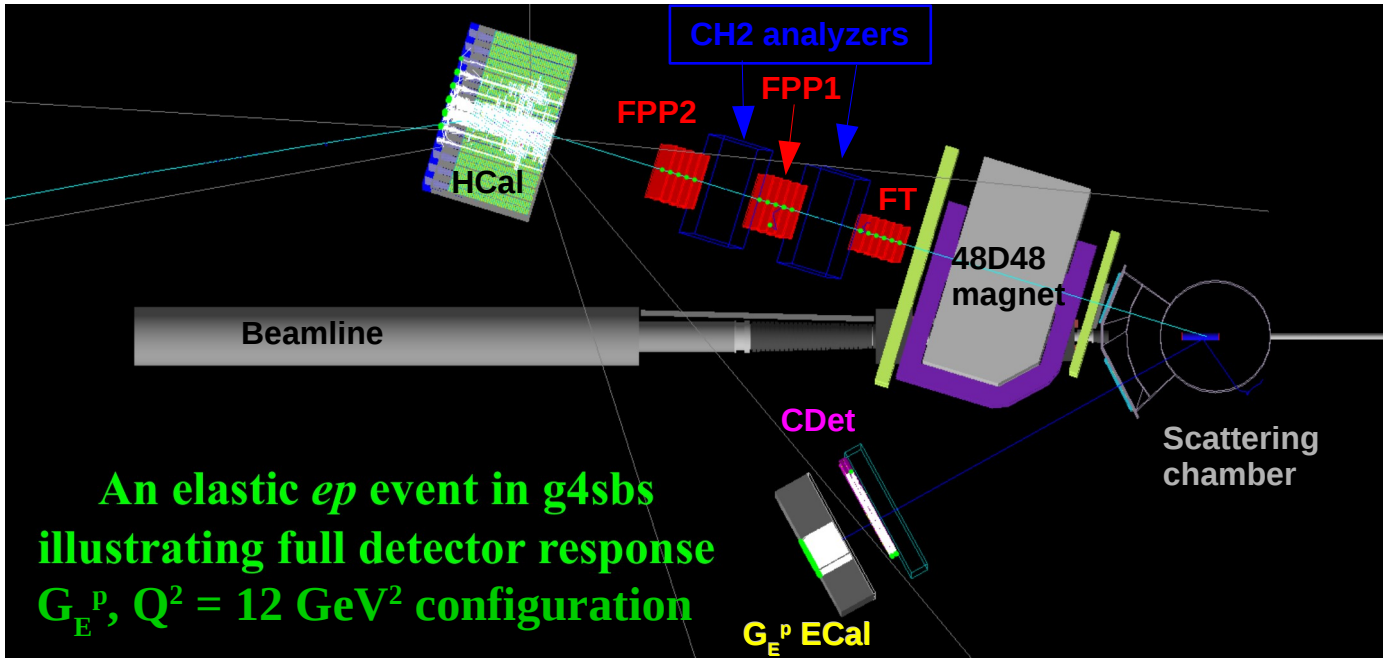
Seamus Riordan — SBS 2016 | SBS Computing | 16/17

=> Milestones agreed by SBS collaboration to be achievable.
=> Software review final report under production; reviewers satisfied with content related to SBS.

Simulation: current status and activities (1)

SBS Simulation (g4sbs): based on Geant4 (compiled against root to allow output root file).
git repository: *https://github.com/JeffersonLab/g4sbs.git* (NB: access to git repo granted by O. Hansen)

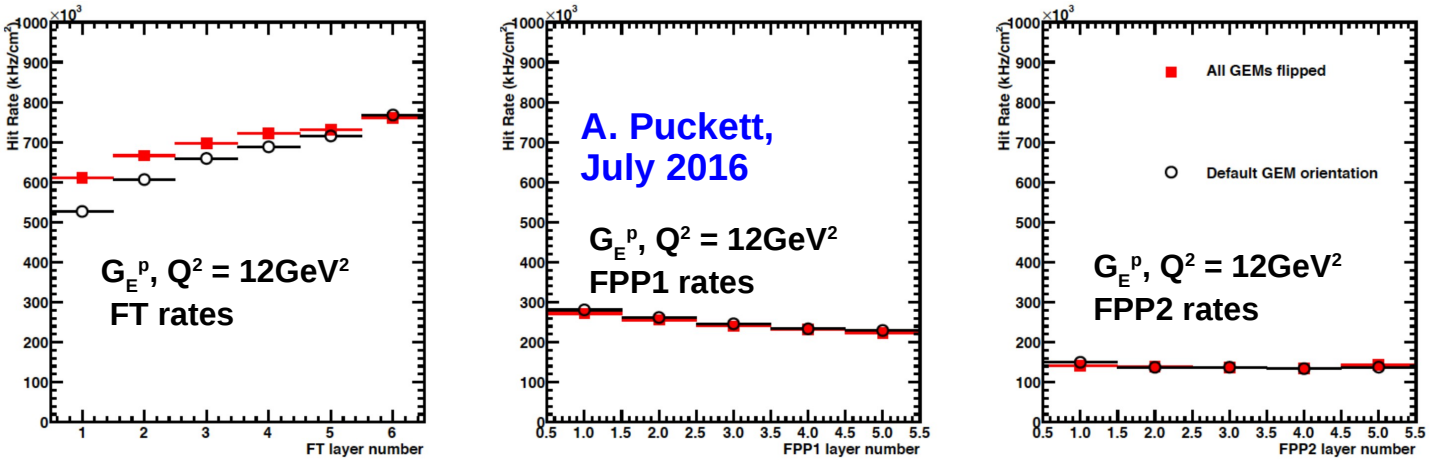
* Simulation well documented and organized: Complete documentation of g4sbs commands: *https://hallaweb.jlab.org/wiki/index.php/Documentation_of_g4sbs*
  + example scripts in git repo + more flexible and intuitive output root tree structures implemented.
* **Mostly complete g4sbs geometry**:
  - complete beamline, scattering chamber, lead shielding, for most experiments.
  - needs scattering chamber, polarized target installation, etc for ^{3}He experiments (GEn, SIDIS);
  - also needs inclusion of Sieve slits (optics, spin transport).
* **Full detectors response** for GEMs, Cherenkovs detectors, ECals, HCal, and CDet (*optical photons*).
* **Digitization of detectors** (ADC/TDC response) **needed**;
  - Started for GEMs;
  - To be done for other detectors:



Simulation: current status and activities (2)

* **Complete range of generators:** Elastic, DIS, N resonance production, single π production (Wiser), SIDIS, Pythia (useful for estimating high energy detector rates w/ minimum bias).
  → **update of detector occupancies and DAQ trigger rates** (underway).
* Detailed magnetic field maps available:
  - full global magnetic field map calculated with TOSCA available for GEp @ 12 GeV^2;
  - also needed for other experiments/configurations (but we have satisfactory approximations).
* spin transport calculation under development;
* GEM electronics radiation level calculation and shielding design underway => should come soon;

Simulation additional needs for production of realistic pseudodata:
* Prevertex external bremstrahlung and multiple scattering;
* **Realistic "event mixing"** (coherent combination of events from different generators):
=> non-trivial.
* optional inclusion of channel failures and miscalibrations desirable.



Analysis: Current status and activities

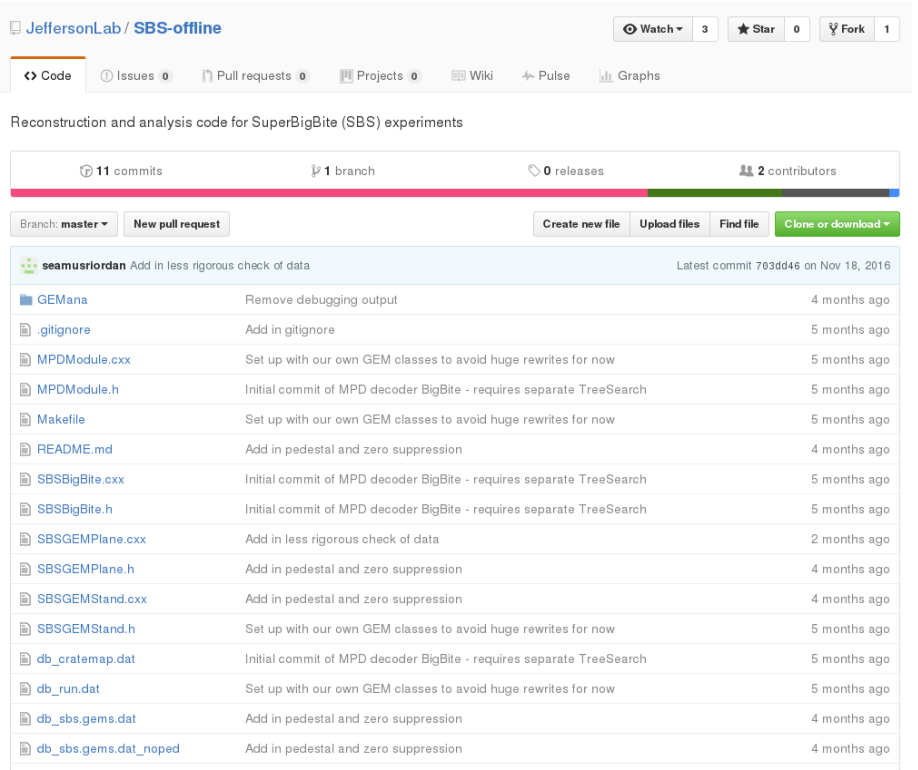
Analysis framework: based on Hall A Analyzer (*http://hallaweb.jlab.org/podd/*)
git repository: *https://github.com/JeffersonLab/SBS-offline.git*
(NB: access to git repo granted by O. Hansen)

* we have a working whitepaper:
https://hallaweb.jlab.org/12GeV/SuperBigBite/documents/sbs_soft_whitepaper.pdf

* SBS-offline repository provides a basic structure to plug in the different analysis components;

* **Decoders need to be written and included into the repository**:
  - MPD decoder (GEMs) already exists;
  - still missing decoders for GRINCH, RICH, ECal, HCal, CDet + HCal FADC class;

* **GEM tracking in progress (next slide)**;



Analysis activities: GEM tracking

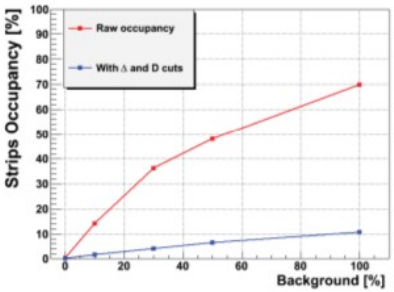
GEM tracking requirements:
- Straight tracks (tracking in field free region);
- use of magnet optics;
- Use of calo cluster position to assist track fit;

***Most constraining*: SBS GEp FT+FPP GEMs:**
very high rate (≥ 500 kHz/cm^2);
→ Requires kinematic correlations with e^- arm to assist track fit;

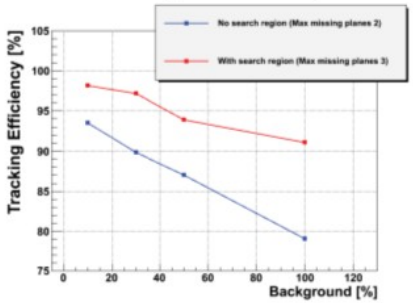
Significant amount of work already made, in common with SoLID:
* Significant work under realistic tracking conditions has already done with *Hall A TreeSearch*
* So far, tracking under realistic conditions have been made only for FT (highest occupancy).

2011 GEp tracking study by Vahe Mamyam (CMU)

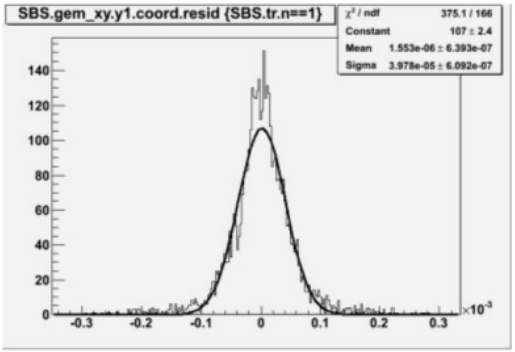
Front tracker GEM strip occupancy



Tracking Efficiency



Track reconstruction accuracy



- Realistic digitization of GEM & electronics response
- Simplifying assumptions made (see next)
- > 90% tracking efficiency
- 5% ghost track probability
- ≈ 40 μm track position resolution

* ***Needs to be redone with the latest simulation*, and integrated into the SBS package:**
→ inclusion of the lastest version of the digitization code developed in SoLID, including more realistic avalanche model, cross talk, pedestal noise (courtesy from W. Xiong, Duke).
→ right now, focus on interfacing with TreeSearch and analyzer.
* **Additional neural networks algorithms being developed by INFN collaborators.**

Summary

*** Efforts on SBS software development are steadily ramping up;**

*** Clear road map: Milestones and responsibilites well defined.**
→ approved by SBS collaboration;

*** There is still long way to go: *Everyone is welcome to join!*;**

*** Simulation is in good shape, and produces useful results;**
→ continuous improvement will keep going;

*** Current focus on GEM tracking, raw data decoders;**

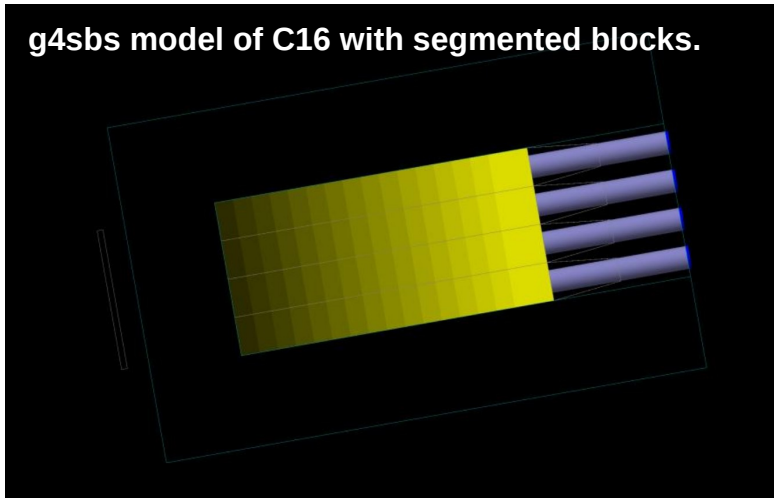
*** Nov. 2016 Software review (final report under production).**
- reviewers satisfied with content related to SBS.

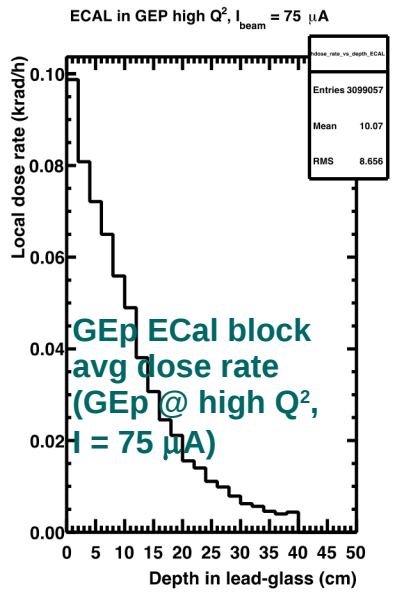
Thank you for your attention !

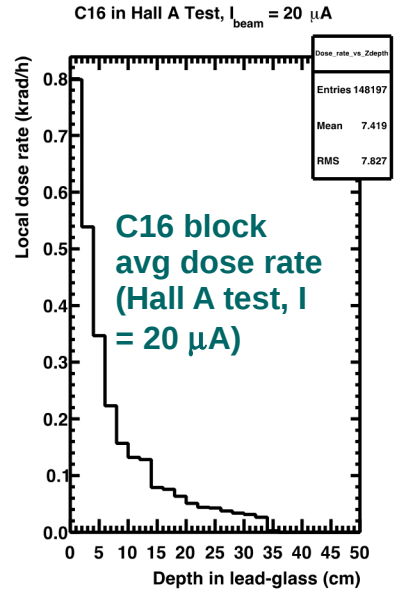
Simulation activities

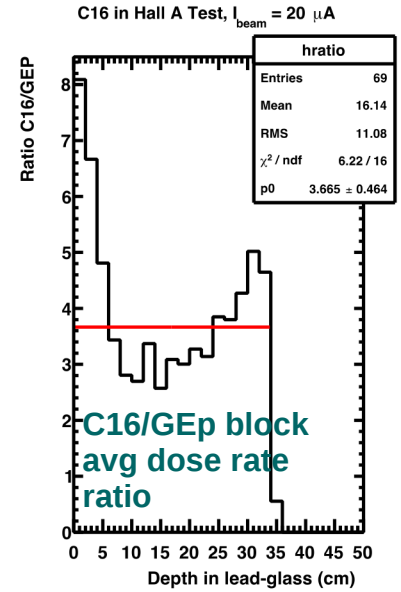
Other recent progress:

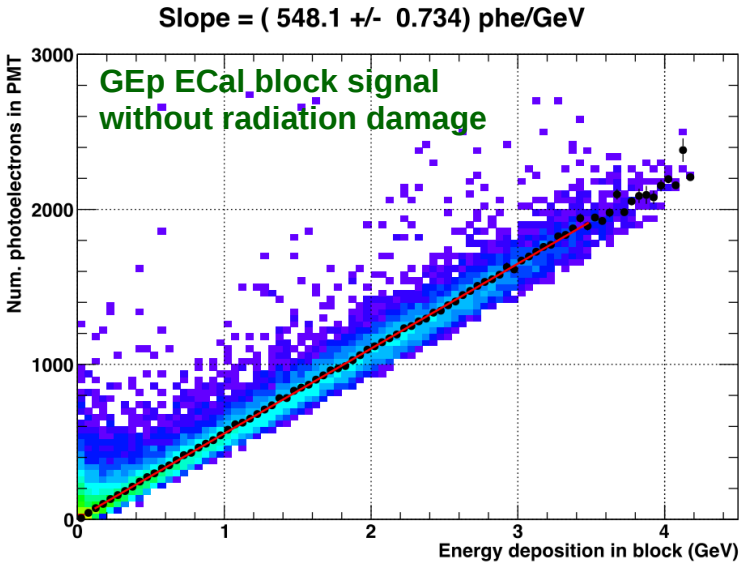
* Simulation of GEp ECal prototype C16 to study radiation damage done (DOE requirement). Report at: *http://cinder.physics.sunysb.edu/sbssimwg/20160219/Report_on_Ecal_prototype_test-ver2.pdf*

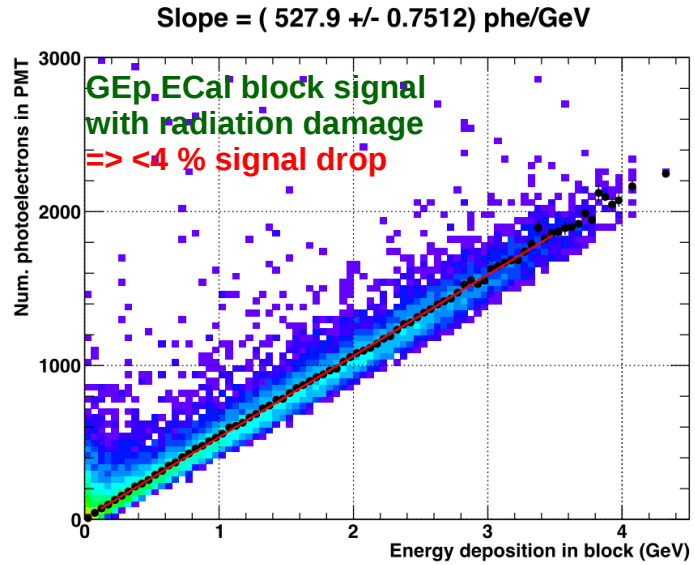






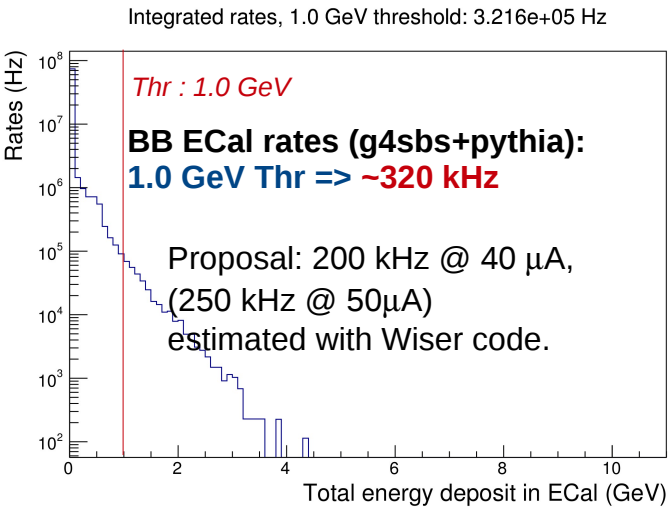


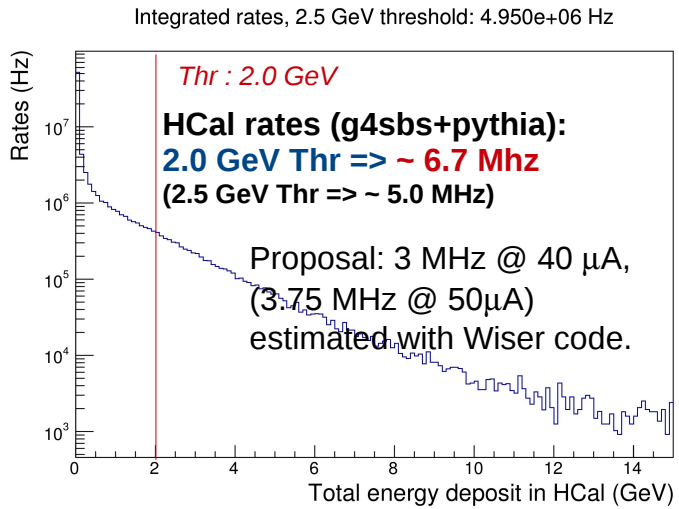


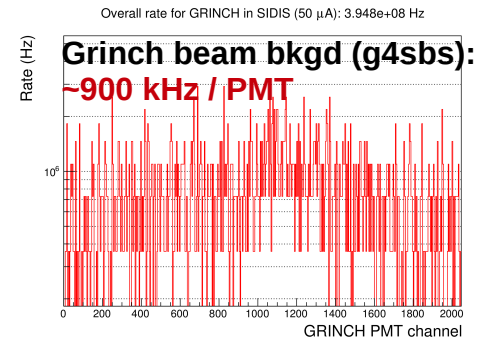


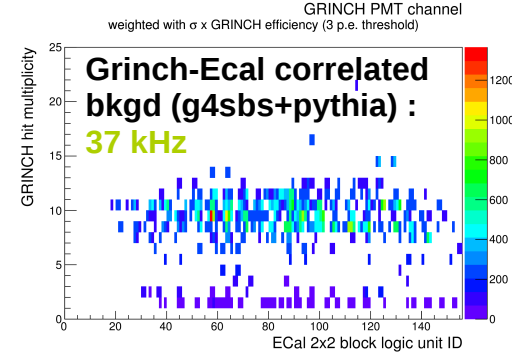
Simulation activities

g4sbs with Pythia application:
Update of detector occupancies and DAQ trigger rates for SIDIS
(50 μA on 60 cm ^{3}He)



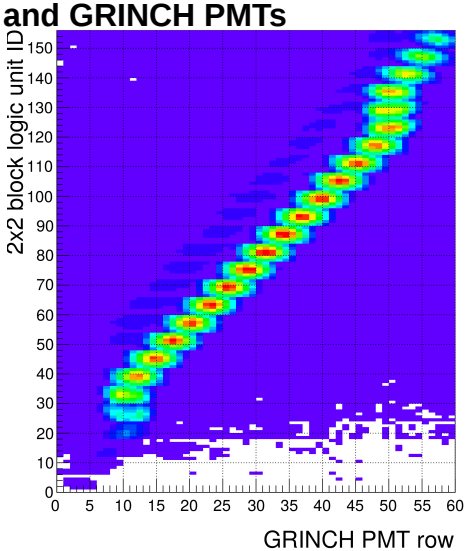


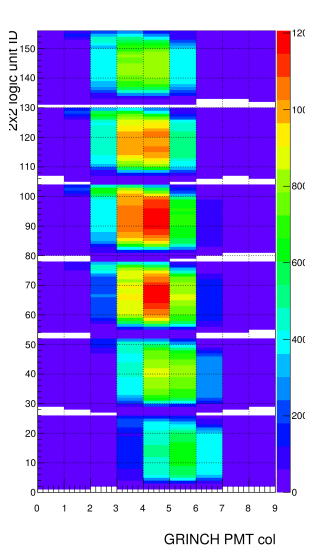




Trigger combining ECal and HCal singles, in a 30ns window: **48 kHz**.
Proposal: 18KHz @ 40 μA (28KHz @ 50 μA).

Correlations between BB ECal logic unit modules and GRINCH PMTs





Inclusion of GRINCH in BB trigger:

* divide BB Ecal in (overlapping) 2x2 block logic units
* associated with 9x5 Grinch PMT group (10ns, 3 p.e. cut):
  Occupancy <1 % → 3 % (30ns)
* 1.0 GeV threshold on ECal logic units:
  Individual rate: 6.3 kHz
* GRINCH-ECal AND: 0.19 kHz;
* OR of all modules : 8.0 kHz (uncorr.);
* Correlated GRINCH-ECal background rates: 37 kHz;
* Uncorrelated+Correlated: 38 kHz;
* AND with HCal singles (6.7 MHz):

=> SIDIS trigger rates : 7.6 kHz
DAQ rate decrease by factor 6