SBS simulation and software update

Hall A/C collaboration meeting

Jefferson Lab, June 22-23, 2017

UCONN Jefferson Lab

Overview

SBS Project overview

=> presented by Andrew

Software/simulation project:

- organization, responsibilites and milestones;

Current status and activities:

- simulation;
  * Recent results : Detector backgrounds for G_M^n
- analysis framework;
  * Progress on tracking with G_M^n

Summary

Software/simulation project organization

* **Major goal:** "End-to-end" simulation:
production of pseudodata + simulation of data sizes;
=> analysis chains : detectors decoding, reconstruction, physics

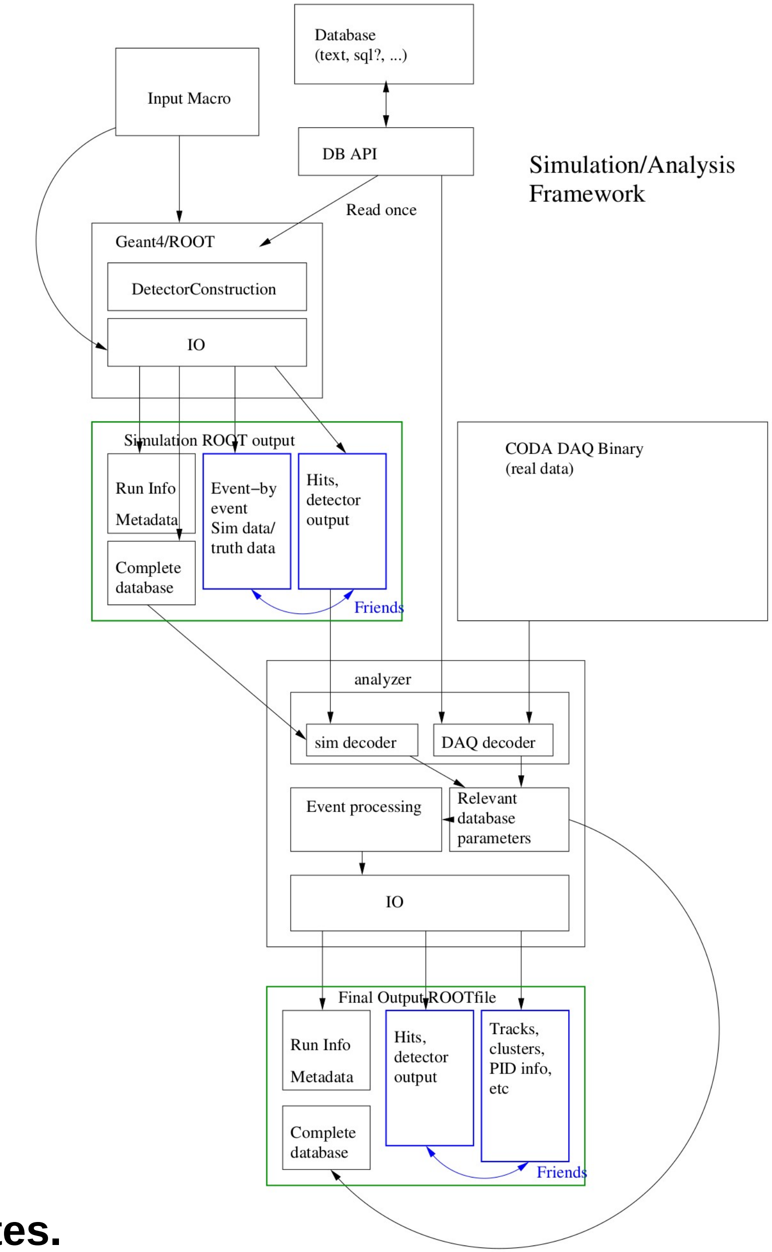
* Both simulation and analysis framework need to be:
  → *modular* (ease configuration changes);
  → *accessible* (ease handling for new people);
  → *flexible* (ease inclusion of new configurations);

* 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).
  → migrating to redmine for project management

Well defined responsibilities and milestones (next 2 slides)

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/fall 2019).
=> critical given high luminosities / high detectors and DAQ rates.



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

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

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 @ GMn experimental readiness review (June, 15-16, 2017):

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

Seamus Riordan (ANL) | Software and Tracking | Jun 15, 2017 | 12 / 20

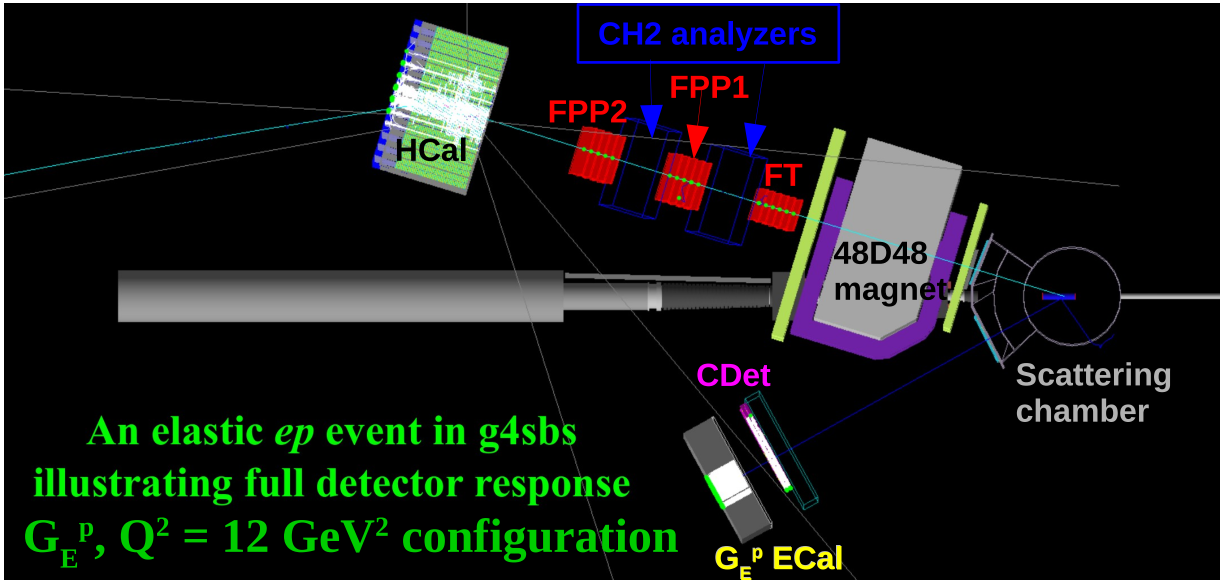
=> We are pretty much on track so far.

UCONN Jefferson Lab

Simulation: current status

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)
Documnetation: *https://hallaweb.jlab.org/wiki/index.php/Documentation_of_g4sbs*

* Mostly complete g4sbs geometry:
  - needs polarized target installation for ^{3}He experiments (G_E^n, SIDIS) + Sieve slits for optics studies;
* Full detectors response for GEMs, *Cherenkovs detectors*, *ECals*, *HCal*, and *CDet* (*optical photons*).



* Complete range of generators: Elastic, DIS, resonance production, π production (Wiser), SIDIS, Pythia.
=> update of detector occupancies and DAQ trigger rates (see following for G_M^n).
* Detailed magnetic field maps (TOSCA) available for : G_E^p @ 12 GeV^2; G_M^n @ 13.5 GeV^2;
  - eventually needed for other experiments/configurations (for those : SBS uinform field).

UCONN Jefferson Lab

Recent simulation results (G_M^n ERR):

G_M^n GEM electronics dose rate (courtesy of F. Obrecht)

GEOMETRY

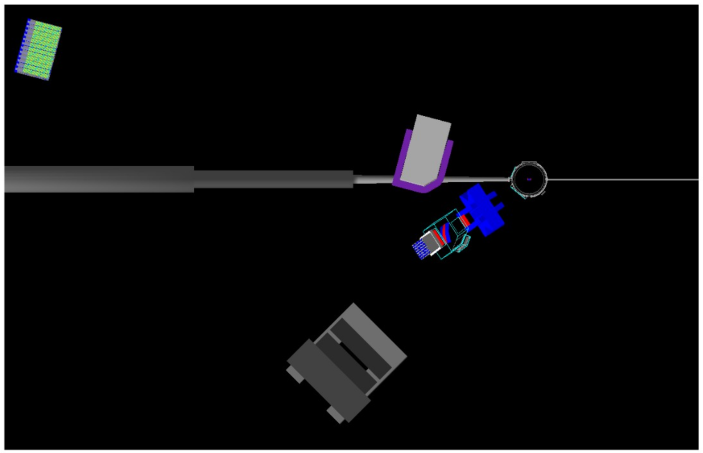


Figure: The hut face is located roughly 7.2 m from the target in the xz plane at a central angle of 45 degrees. All hut materials are steel.

GEOMETRY II

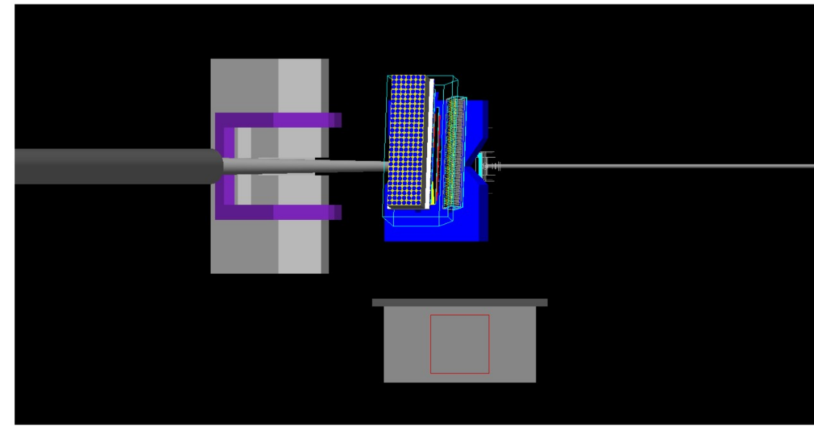


Figure: Hut sits on the floor, or roughly -3 m in the y direction. The red box represents the sensitive region for the purposes of this simulation.

G_M^n ELECTRONICS HUT

$Q^2(GeV^2)$	$\theta_{BB}(deg)$	$d_{BB}(m)$	$E_{beam}(GeV)$	$I_{beam}(\mu A)$
13.5	33.0	1.55	11.0	44.0

- Ran 15 $\times 10^9$ events with the beam generator
- Silicon sensitive region is 101.6 x 101.6 x 2.54 cm^3
- Density of Silicon used = 2.33 g/cm^3
- Total energy deposited = 910 MeV
- Results:

$$\boxed{\text{Dose rate} = 0.016\ \text{rad/hr}}$$

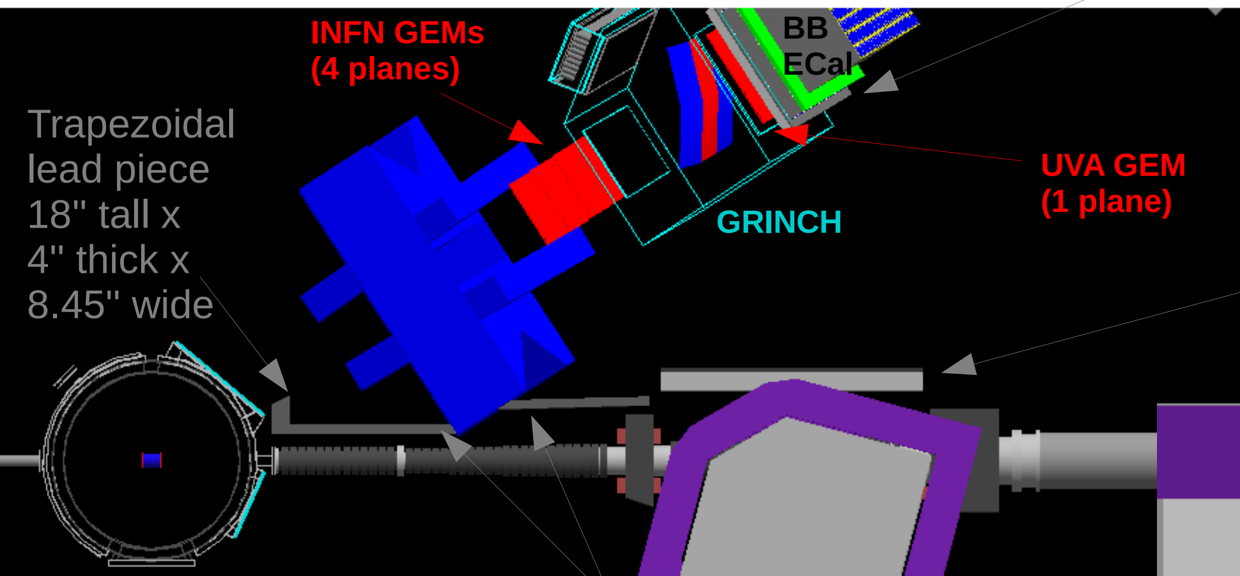
Recent simulation results (G_m^n ERR): G_M^n detector backgrounds

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map

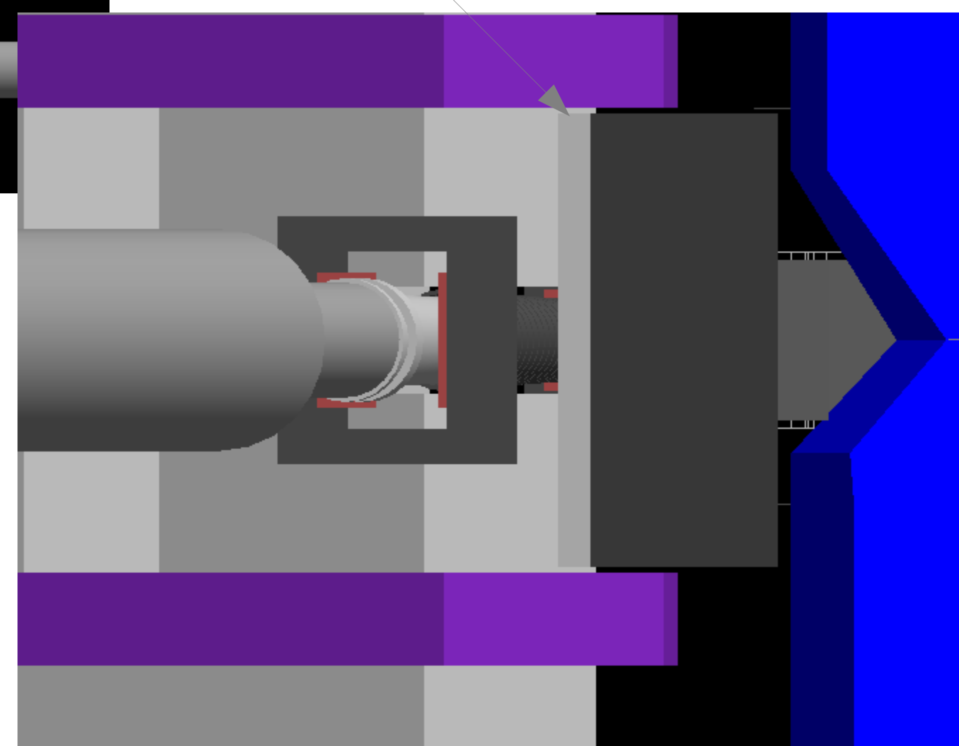
Q^2 = 13.5 GeV^2 : worst case scenario (higher lumi, smaller BB angle)

Shielding design « Iteration 3 »

shielding for ECal : 5cm Al + 1cm steel



4" thick Al + 1" thick lead
(L = 130 cm, h = 150 cm for both)



Lead plates
(18" tall x 2" thick,
L = 37.78" (upstream)
L = 34" (downstream)

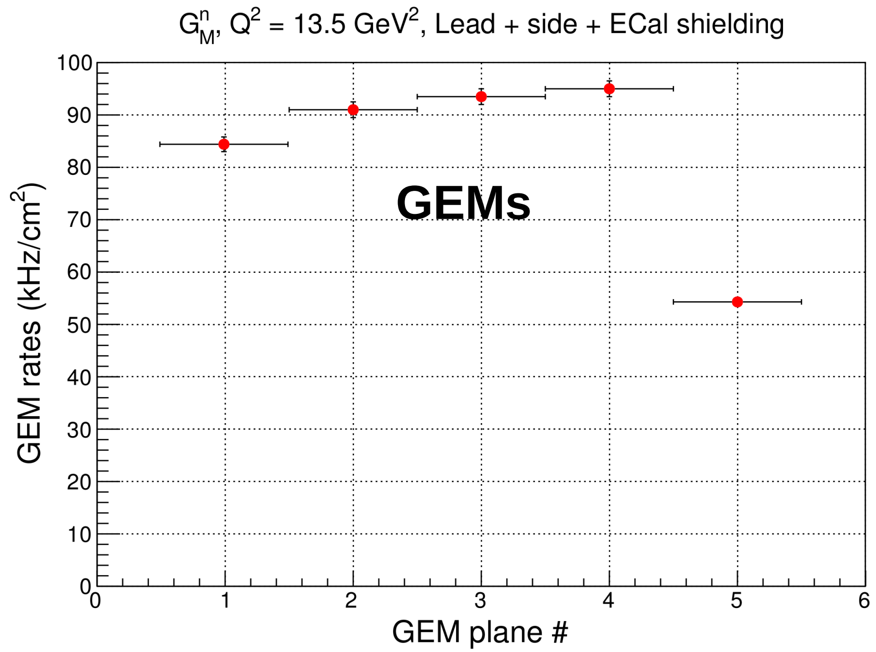
NB : this shielding design is yet to be submitted to the engineers

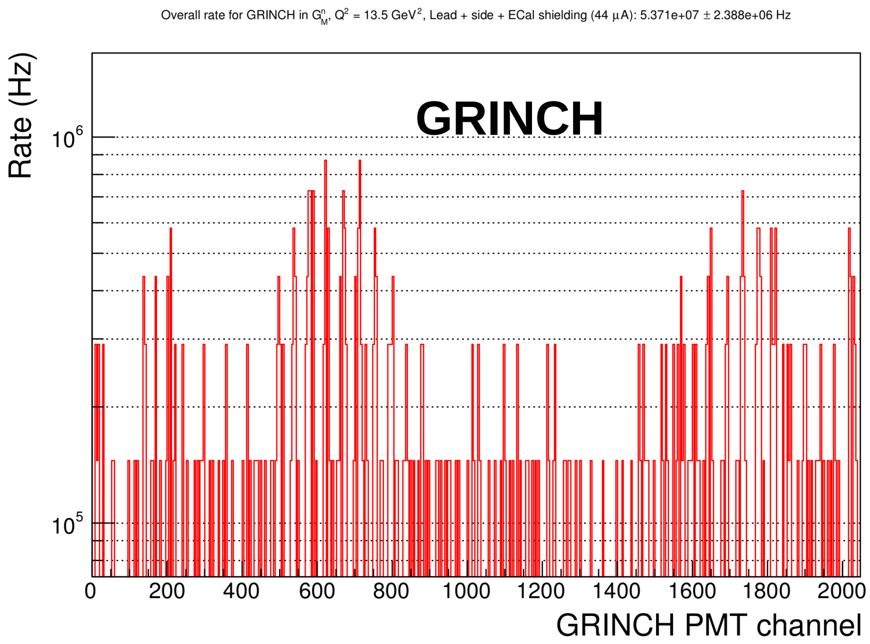
UCONN Jefferson Lab

Recent simulation results (G_m^n ERR): GEM + GRINCH backgrounds

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map,

Beamline shielding « iteration 3 » + ECal shielding





Rates < 100 kHz/cm2 for all planes:
~90 kHz/cm2 for INFN GEM (planes 1-4),
40 % lower than w/o shielding
~55 kHz/cm2 for UVA GEM (plane 5)
4x lower than w/o shielding

~73 % from **target**,
~2% from 48D48,
~6% from BL,
~4% from SC;
Rest (15%) from shielding

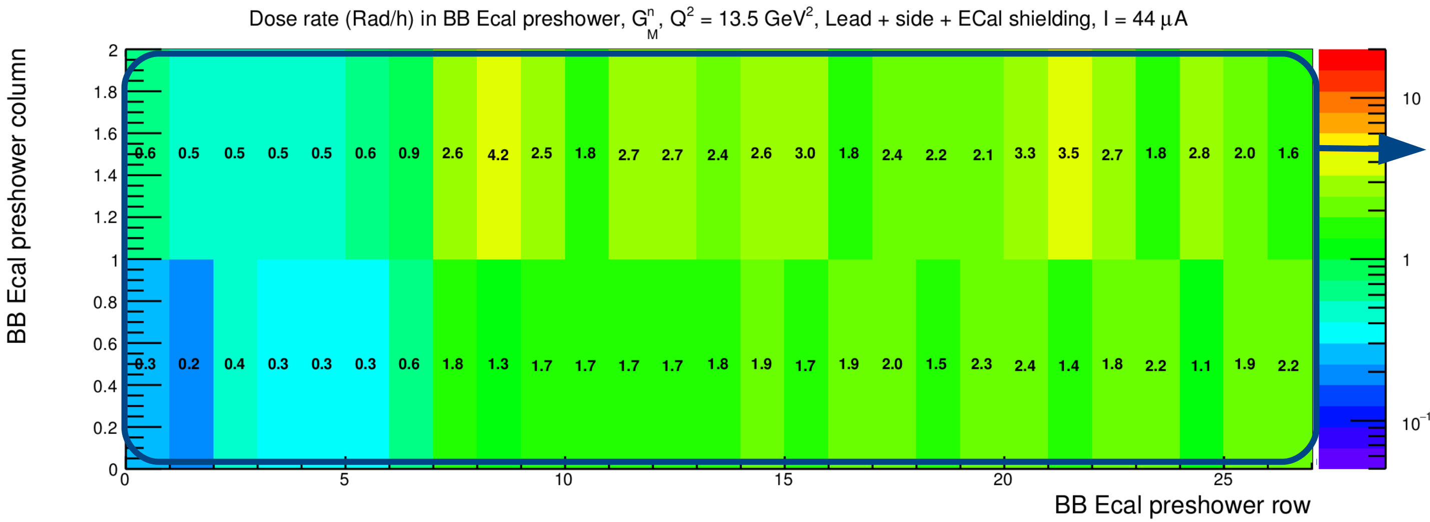
54 MHz over detector
=> average rate per PMT: 106 kHz
6x lower than w/o shielding
~58% (~70 kHz/PMT) from **target**,
~13% (~16 kHz/PMT) from 48D48
~18% (~22 kHz/PMT) from BL,
~8% (~10 kHz/PMT) from SC
Rest (3%) from shielding

UCONN Jefferson Lab

Recent simulation results (G_m^n ERR): BB ECal (PS+SH) dose rate

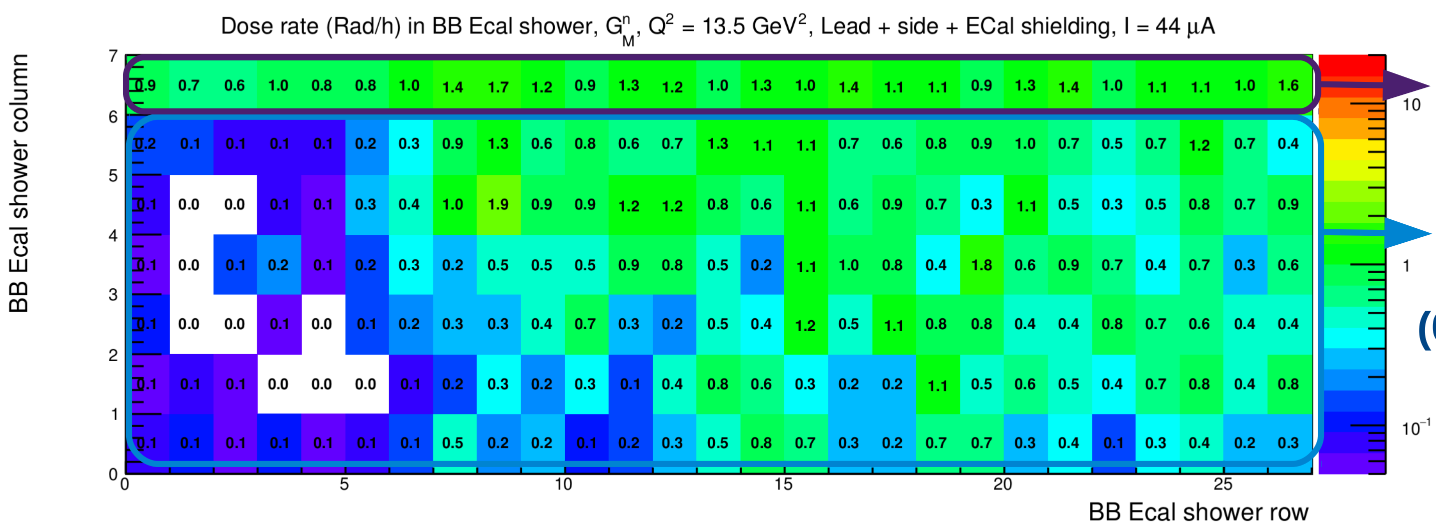
Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map,

Beamline shielding « iteration 3 » + ECal shielding



1.7 Rad/h/block avg over PS

x100 h beam time:
< 200 Rad integrated *for this kinematic*. (20 % of maximal acceptable)



1.1 Rad/h/block avg

0.5 Rad/h/block avg

(0.6 Rad/h/block avg over SH)

All numbers are ~3x lower than w/o shielding

NB : Lead glass performance starts to deteriorate for cumulated radiation dose ≥ 1kRad

Analysis: Current status and activities

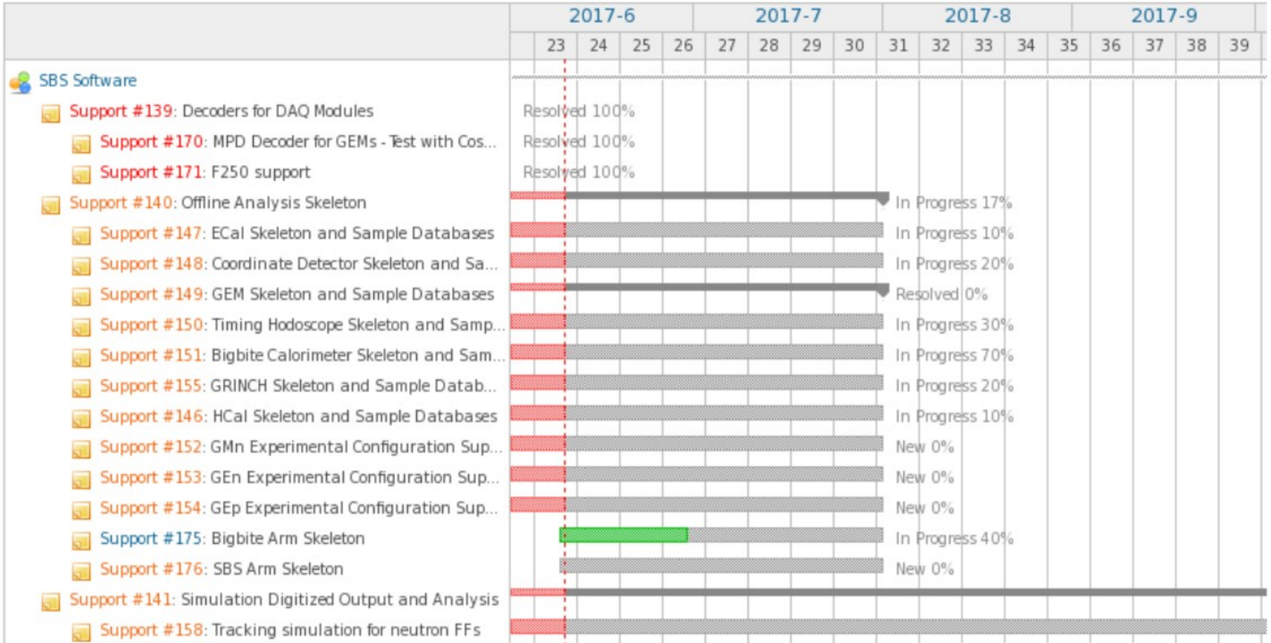
Analysis framework: based on Hall A Analyzer (*http://hallaweb.jlab.org/podd/*)
git repository: *https://github.com/JeffersonLab/SBS-offline.git*

* 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;
* we have been migrating to redmine for the software project management

* Following decoders have been written and included into the repository: MPD (GEMs), F250 (HCal)
  - other decoders (GRINCH, RICH, ECal, CDet, Timing hodoscope) underway;
  - add the following to analyzer framework : GEMs, CDet, GRINCH, ECal, RICH, Bigbite

* GEM tracking in progress (next slide);



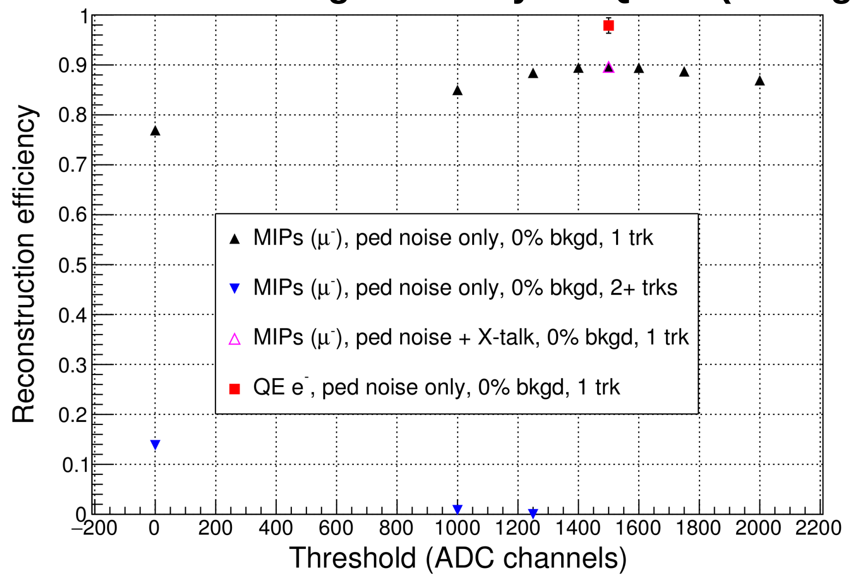
Analysis activities: GEM tracking

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 (FT) + bridging with FT (FPPs);

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).

90 % MIP tracking efficiency
(including pedestal noise and cross talk)
=> **98 % tracking efficiency for QE e$^-$. (no bkgd)**



* *Needs to be redone with the latest simulation*, and integrated into the SBS package :
→ inclusion of the lastest version of the digitization code developed for SoLID, including more realistic avalanche model, cross talk, pedestal noise (courtesy from W. Xiong).
→ interfaced with TreeSearch, analyzer, etc...
- In ideal conditions (0 % bkg), track fitting works;
- Issues adding background under investigation ;
* Additional neural networks algorithms being developed by INFN collaborators.

Summary

*** Efforts on SBS software development have kept ramping up steadily;**

*** 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 completed soon;**

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

Thank you for your attention !

Overview of SBS project

See Andrew's 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 (^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;

CDet
G_E^p ECal
Scattering chamber
48D48 magnet
FPP1
HCal
FT
CH2 analyzers
FPP2

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/fall 2019)**.**

=> critical given high luminosities / high detectors and DAQ rates.

Simulation: current status and activities

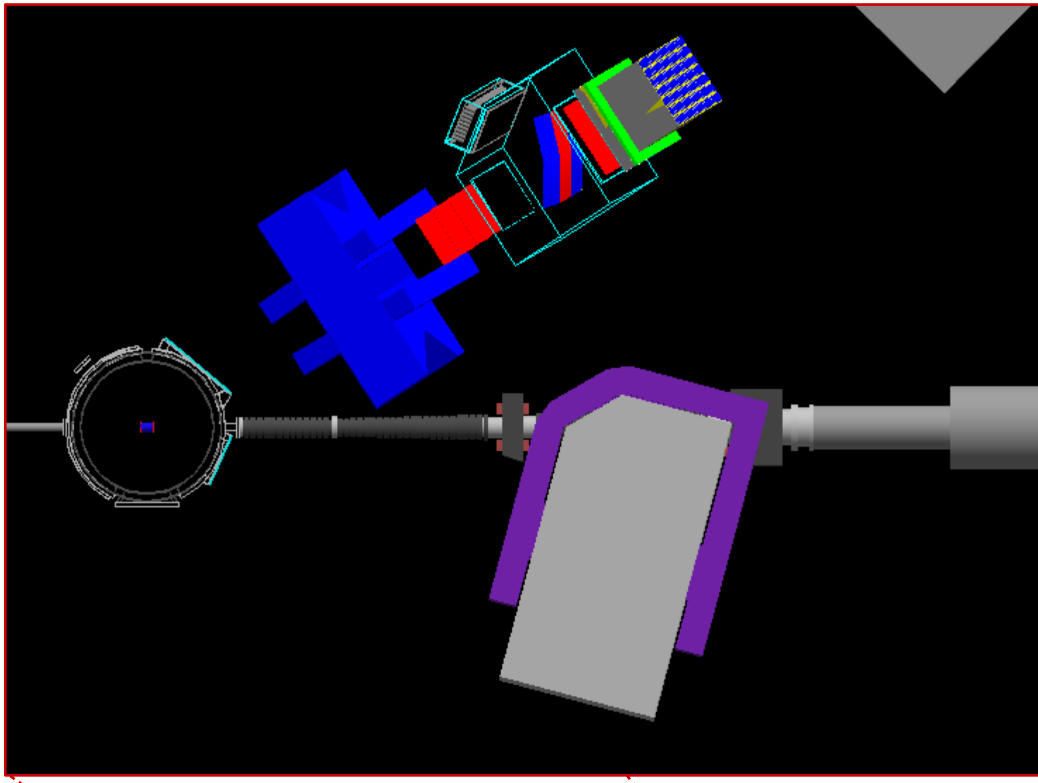
Simulation additional needs for production of realistic pseudodata:

* Digitization of detectors (ADC/TDC response);
  - pretty much done for GEMs;
  - To be done for other detectors:
* 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.

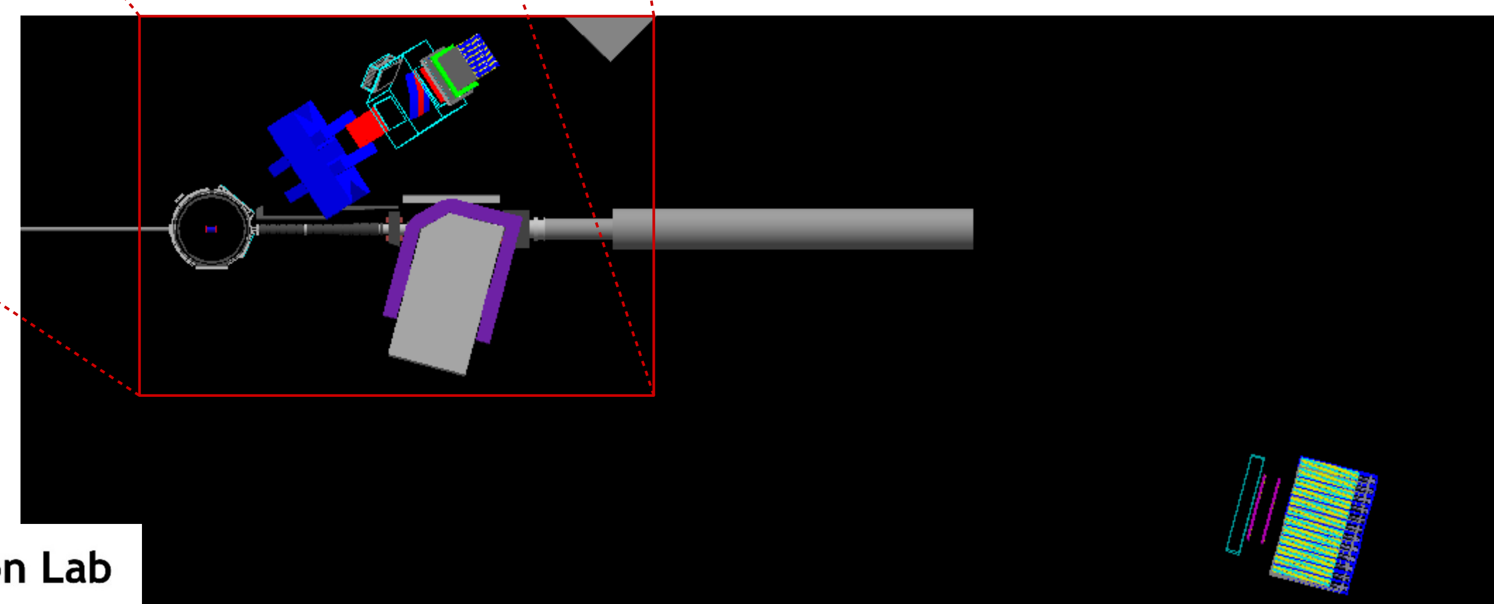
G_M^n setup



- Conic vacuum line weldment;
- spool piece;
- inner and outer magnetic shieldings;
- beam corrector magnets;

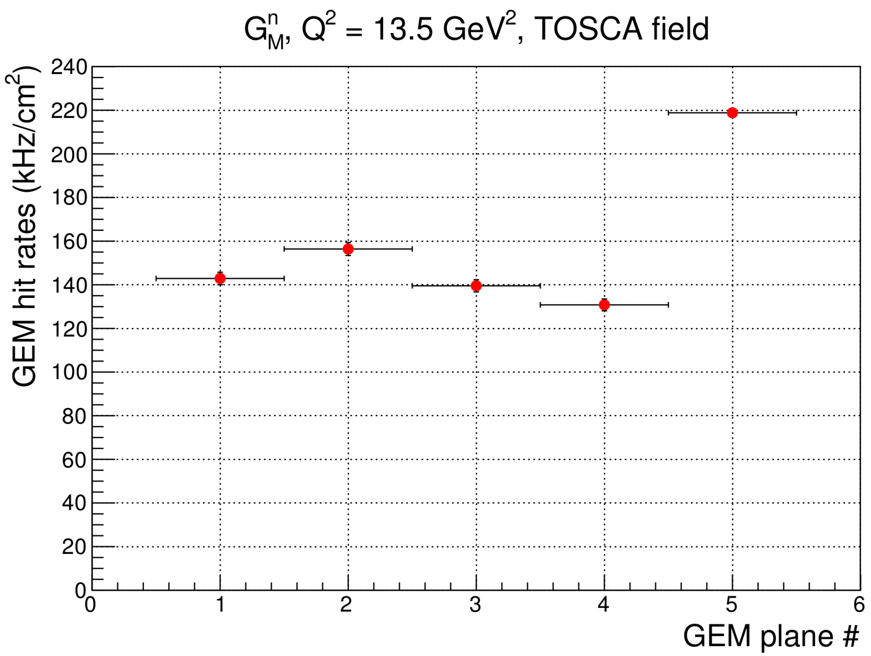
Configuration of the two later items can be changed with a new command:
/g4sbs/beamlineconfig <int>
The integer being equal to the beamline configuration number convention used by the engineers:
1 for G_E^p, 2 for G_E^n,
3 for G_M^n (all Q2 but higher),
4 for G_M^n (higher Q2 + calibrations).

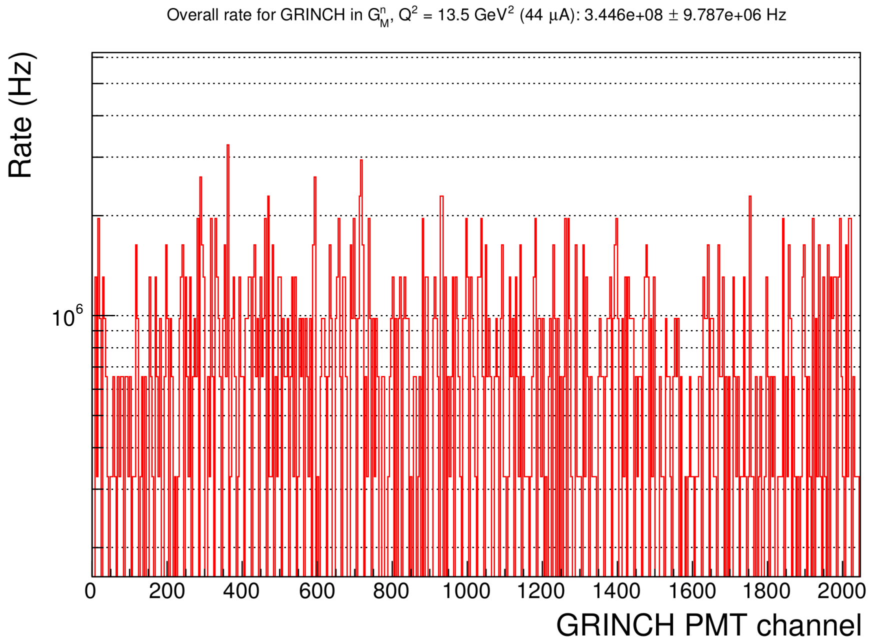
+ (very recent) : CDet and CH2 filter



GEM, GRINCH rates for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map, NO SHIELDING





New setup, TOSCA field map:
~140kHz/cm^2 per GEM for INFN GEMs (front),
220kHz/cm^2, for UVA GEM (behind GRINCH)
70% from **target**, 4% from 48D48;
11% from beamline; 5% from scattering chamber;

=> consistent with the rate change observed on GRINCH: the back of the detector package seems more affected by the front.

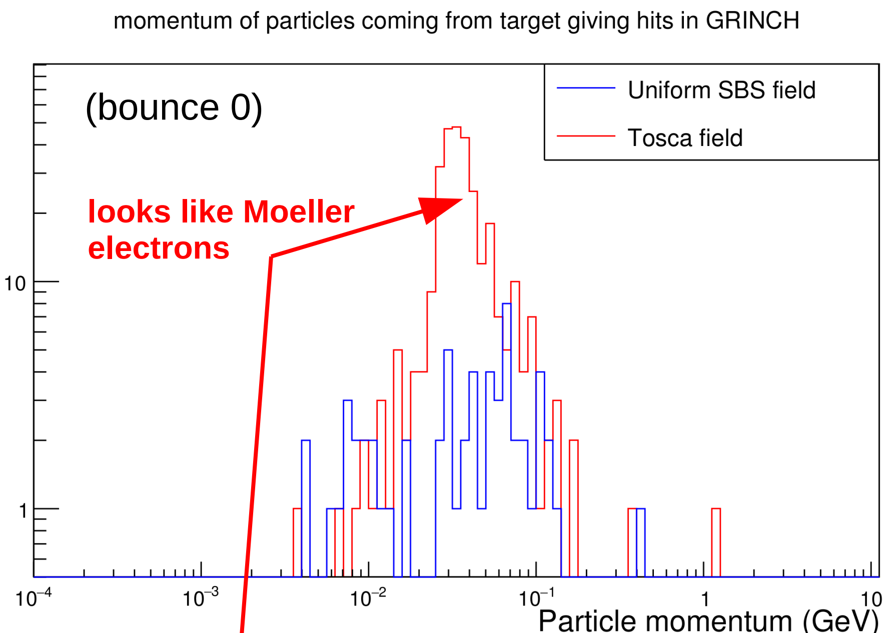
Again, rates are rather high, but can be handled...

345 MHz over detector => ~680kHz/PMT;
not easy to deal with, but handleable;

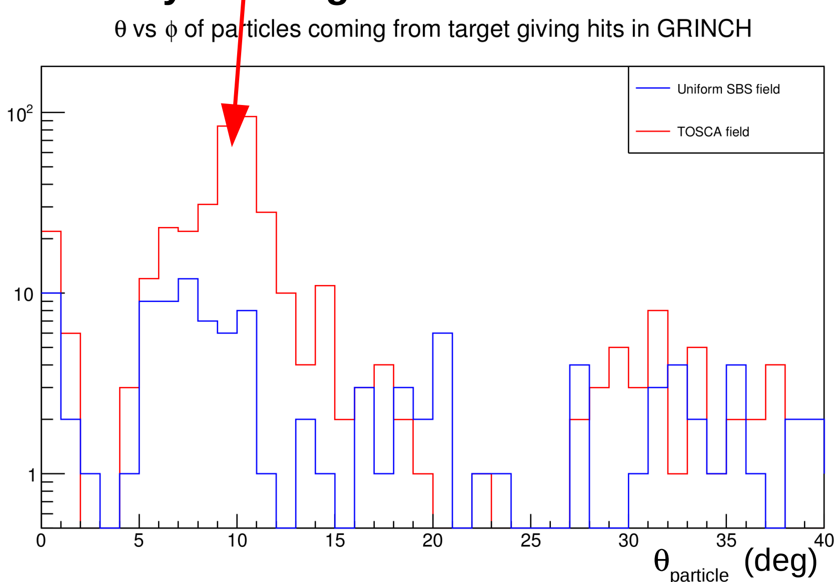
=> 410 kHz (60%) from **target**;
→ clear discrepency with "no Tosca field" simulations: to be understood! (next slide)
55 kHz (8%) from 48D48 magnet;
135 kHz (20%) from beam line;
60 kHz (9%) from scattering chamber;

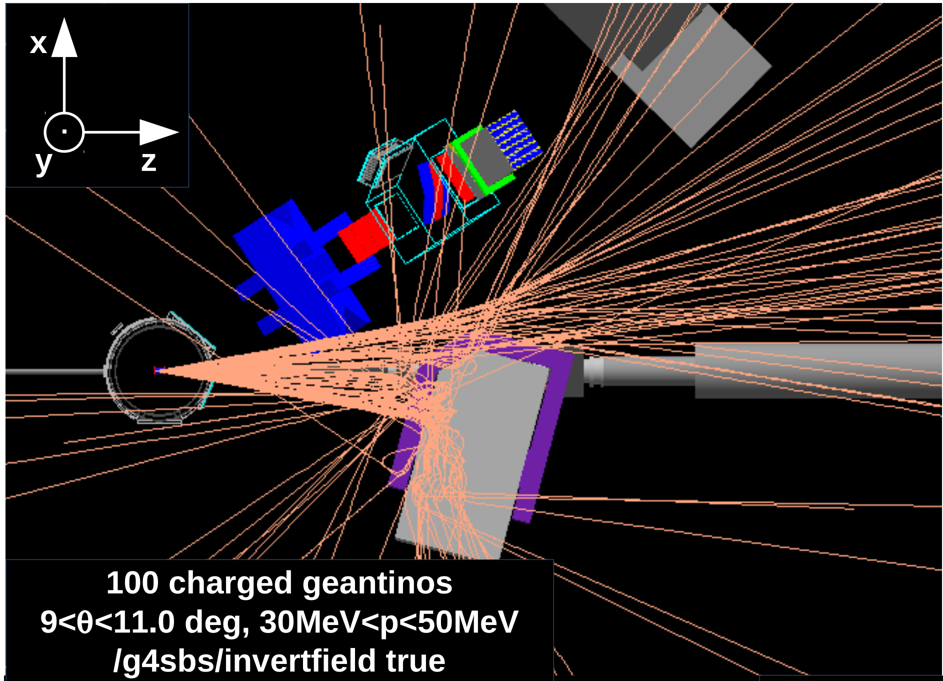
GRINCH rates for G_M^n

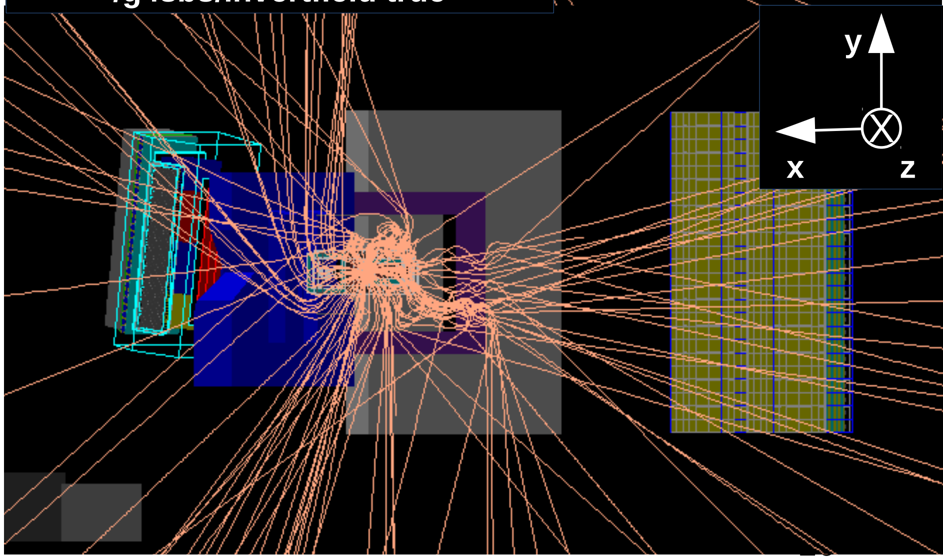
Explaination for GRINCH, UVA GEM rates with TOSCA



Could low angle/low energy Moeller electrons be deflected by the magnetic field beam line ? => YES



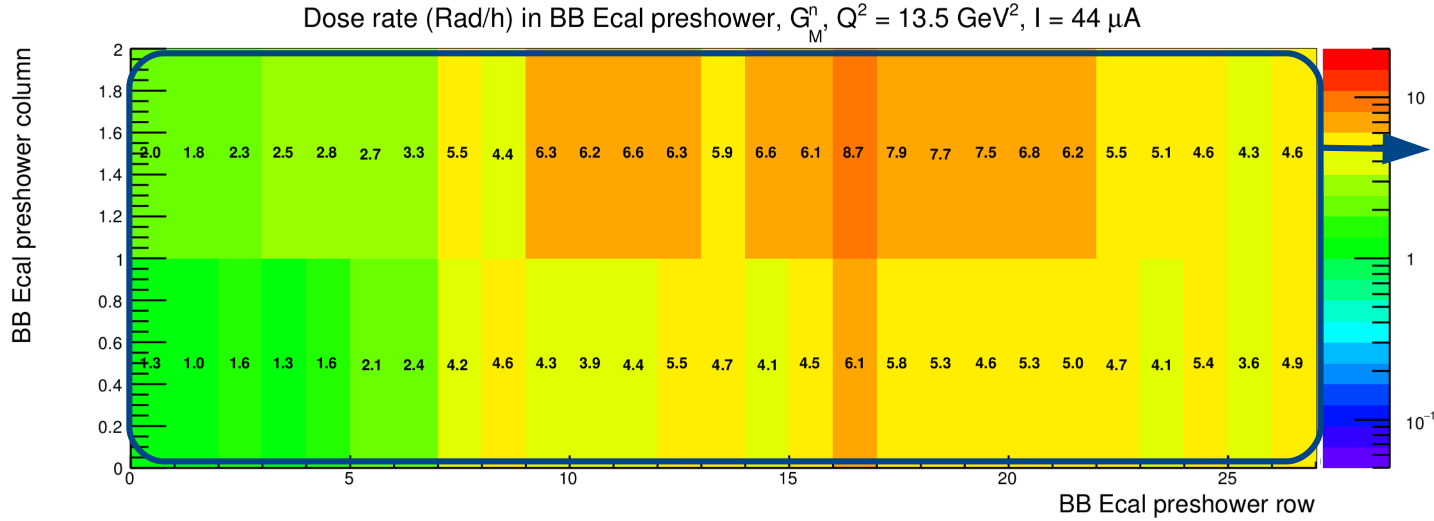




We might be able to shield that...

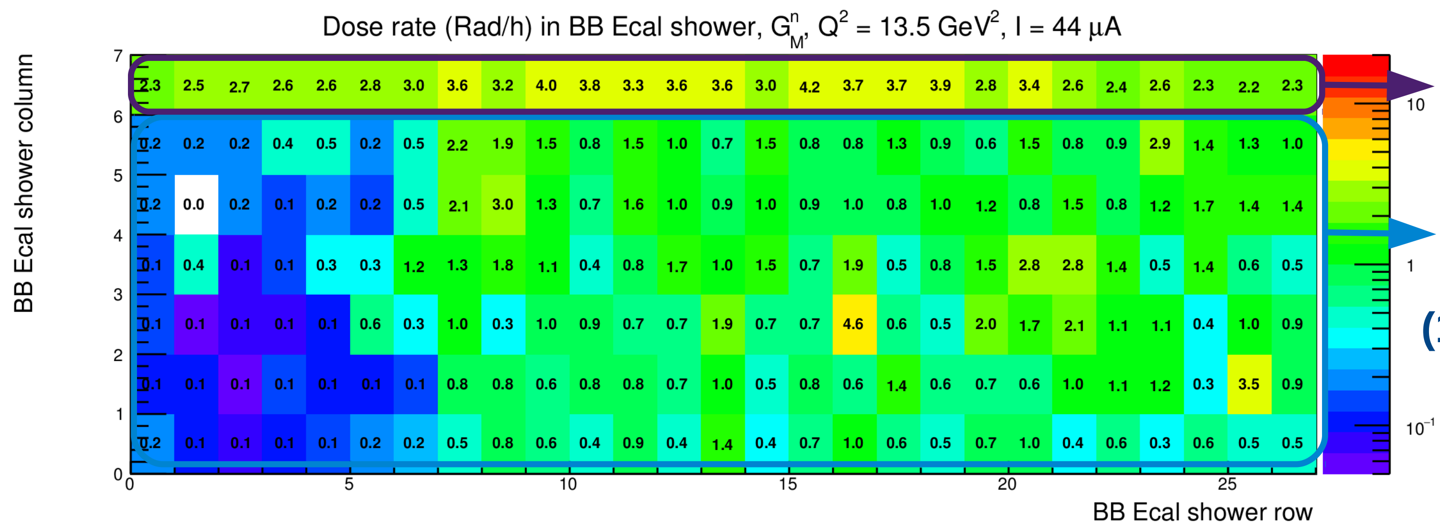
BB Ecal dose rate for G_M^n

Q^2 = 13.5 GeV^2, I_{beam} = 44µA, 10 cm LD_2, new setup, Tosca field map, NO SHIELDING



4.6 Rad/h/block avg over PS

x100 h beam time: 460 Rad integrated *for this kinematic*.
Max dose for a single block: ~900 Rad.



3.1 Rad/h/block avg

0.9 Rad/h/block avg

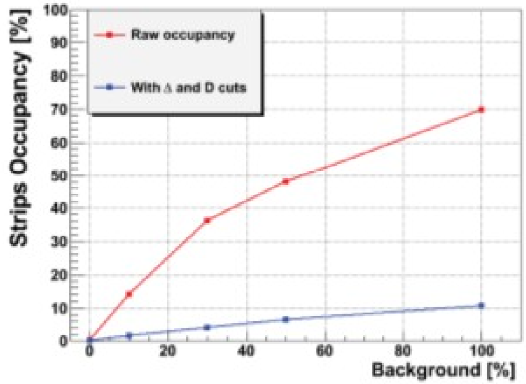
(1.2 Rad/h/block avg over SH)

No additional shielding: Previous studies (SBS soft/simu meeting 2017/03/22) showed it could be shielded easily

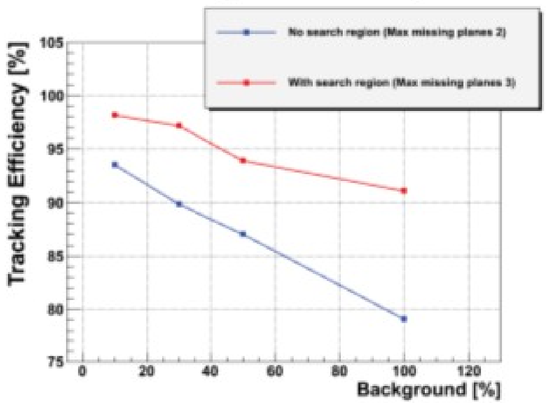
NB : Lead glass performance starts to deteriorate for cumulated radiation dose ≥ 1kRad

2011 GEp tracking study by Vahe Mamyam (CMU)

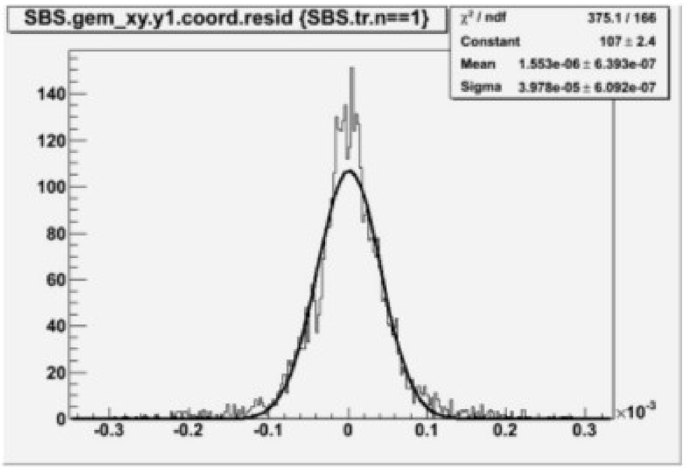
Front tracker GEM strip occupancy



Tracking Efficiency



Track reconstruction accuracy



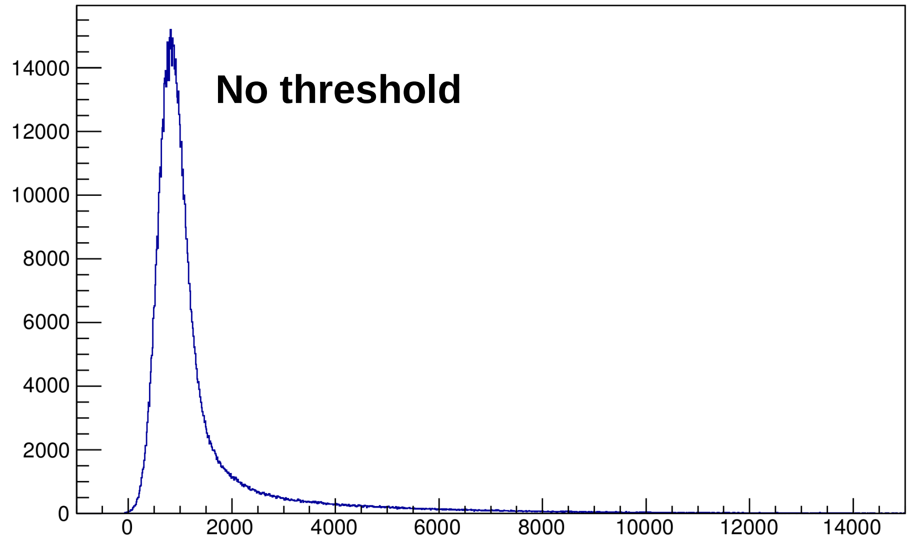
- Realistic digitization of GEM & electronics response
- Simplifying assumptions made (see next)
- $> 90\%$ tracking efficiency
- 5% ghost track probability
- ≈ 40 μm track position resolution

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

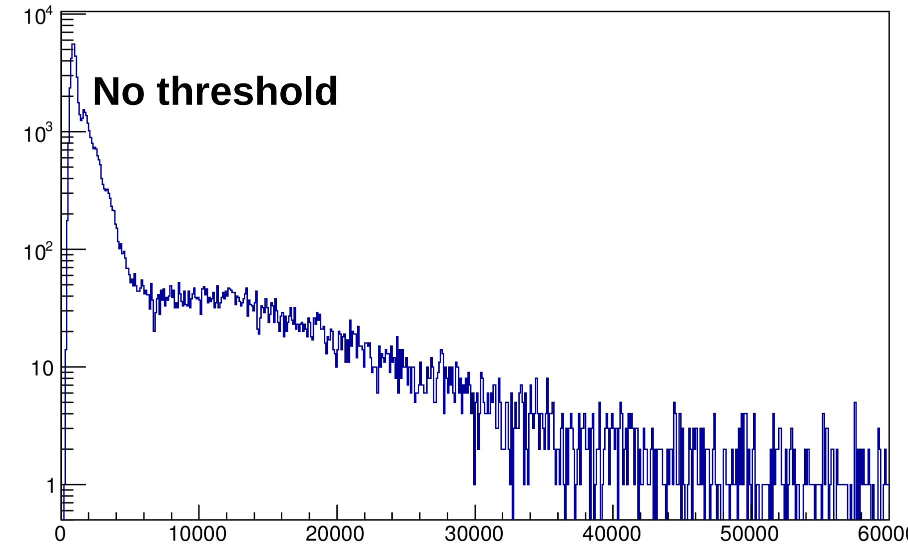
Tracking: ADC spectra
Simulation vs cosmics data

Muons, digitized G4 simulation

x planes ADC all strips (all planes summed), muons

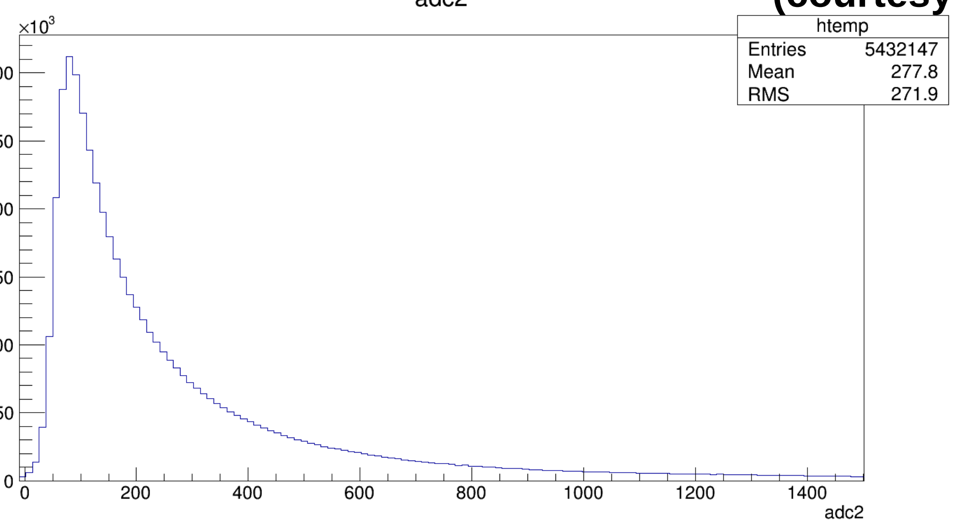


x planes hits ADC (all planes summed), muons (MC backtracks through 5 planes)

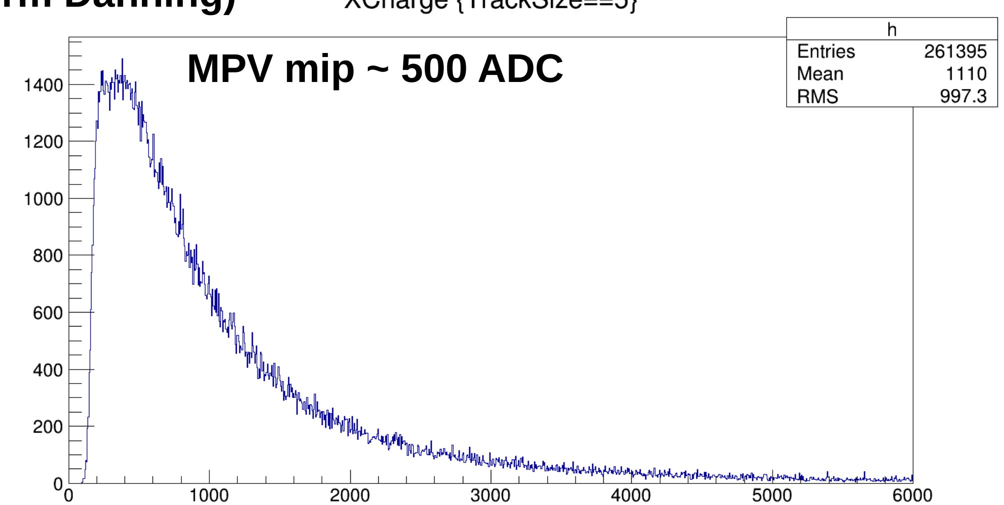


Cosmics data
(courtesy form Danning)

adc2

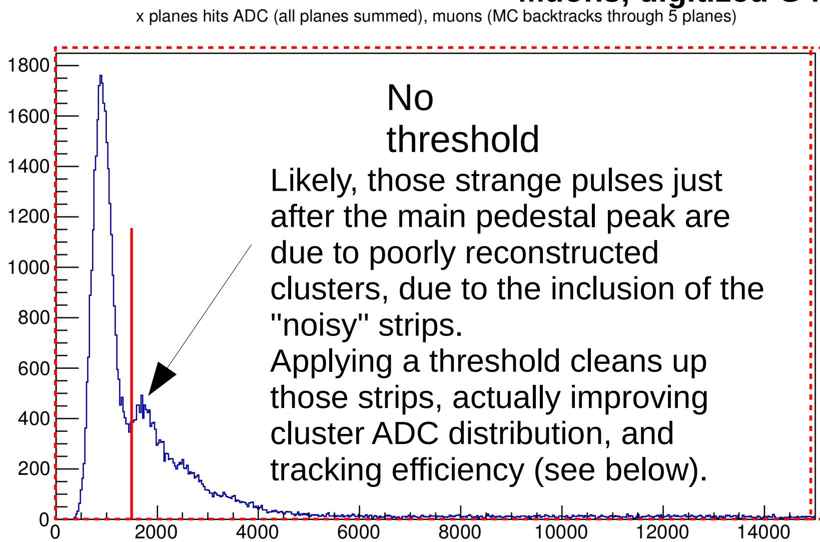


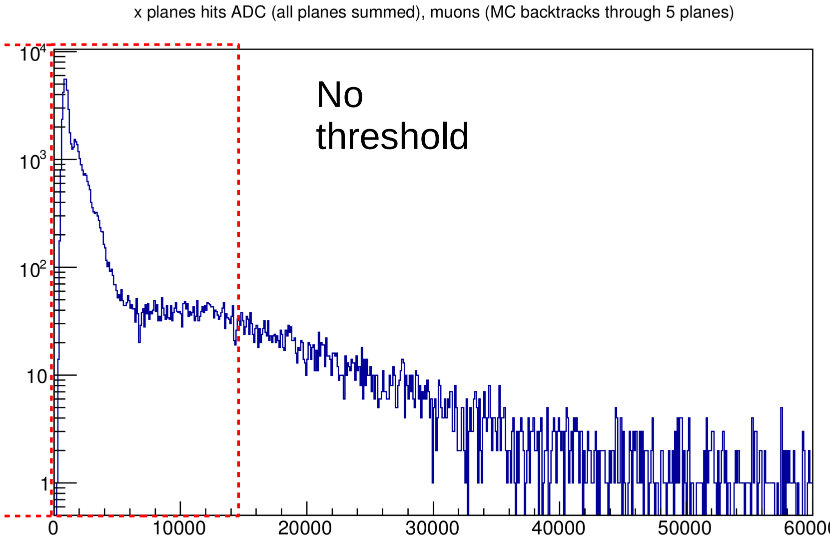
XCharge {TrackSize==5}

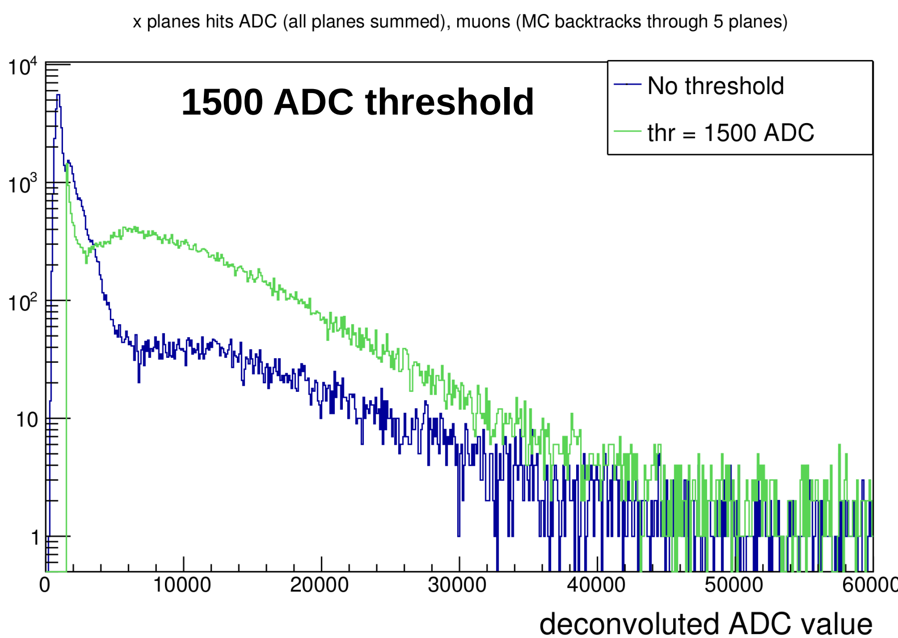


Threshold study

Muons, digitized G4 simulation







90 % MIP tracking efficiency
(including pedestal noise and cross talk)
=> 98 % tracking efficiency for QE e⁻. (no bkgd)