GMN ERR: Radiation Levels and Local shielding

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University of Connecticut and Jefferson Lab
GMN experiment readiness review
June 16, 2017

Acknowledgements:

- The vast majority of the MC simulation work presented here was performed by UConn postdoc Eric Fuchey and UConn graduate student Freddy Obrecht
- Support from US Department of Energy, Award ID #DE-SC0014230

Outline

- Radiation Budget Form
- GEANT4 Monte Carlo simulation of GMN layout
  - Background rates in low-threshold detectors
  - Radiation dose rates in rad-sensitive detectors
  - Radiation levels in GEM electronics hut and SBS bunker
  - Local shielding design
- Beamline activation
  - Detailed run plan of config. changes.
  - Expected radiological survey map as a function of time.
  - Personnel exposure during configuration changes
- Summary and conclusions

Hall: A

RADIATION BUDGET FORM

Exp. # GMn E12-09-016 **rev:** 0 **run dates:** 2019 **name of liaison:** Eric Fuchey

setup number			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
beam	energy	GeV	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	6.6	6.6	6.6	8.8	8.8	8.8	8.8	8.8
	current	uA(CW)	19.2	52.4	30.9	19.2	39.0	30.9	24.0	58.1	24.0	24.0	52.5	22.5	30.0	52.5	30.0	30.0	53.3
radiator	element																		
	thickness	mg/cm2																	
	dist. to pivot	m																	
	Z		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
exp't target	element		D	H	Al	D	H	Al	D	H	Al	D	H	Al	D	H	Al	D	H
	thickness	mg/cm2	2435	1062	935	2435	1062	935	2435	1062	935	2435	1062	935	2435	1062	935	2435	1062
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Z		1	1	13	1	1	13	1	1	13	1	1	13	1	1	13	1	1
	A		2	1	27	2	1	27	2	1	27	2	1	27	2	1	27	2	1
cryo tgt window	element		Al	Al		Al	Al		Al	Al		Al	Al		Al	Al		Al	Al
	thickness	mg/cm2	83	83		83	83		83	83		83	83		83	83		83	83
	dist. to pivot	m	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0
	Z		13	13	0	13	13	0	13	13	0	13	13	0	13	13	0	13	13
	A		27	27	0	27	27	0	27	27	0	27	27	0	27	27	0	27	27
critical window	radius	cm	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
	dist. to pivot	m	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10
scattering weighting factor			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
time	run time	hours	30	69	7	30	24	7	30	32	6	30	8	4	24	8	3	48	9
	(100% eff.)	days	1.3	2.9	0.3	1.3	1.0	0.3	1.3	1.3	0.3	1.3	0.3	0.2	1.0	0.3	0.1	2.0	0.4
	installation	hours																	
	time	days	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at the fence post (run time)	method 1	urem/hr	0.97	0.53	1.35	0.97	0.39	1.35	1.21	0.59	1.05	1.37	0.53	1.10	1.87	0.55	1.58	1.87	0.56
	method 2	urem/hr																	
	conservative	urem/hr	0.97	0.53	1.35	0.97	0.39	1.35	1.21	0.59	1.05	1.37	0.53	1.10	1.87	0.55	1.58	1.87	0.56
dose per setup		urem	29	36	9	29	9	9	36	19	6	41	4	4	45	4	5	90	5
% of annual dose budget		%	0.3	0.4	0.1	0.3	0.1	0.1	0.4	0.2	0.1	0.4	0.0	0.0	0.4	0.0	0.0	0.9	0.1

date form issued: May 15, 2017 *authors:* P.Degtiarenko

Hall: A

RADIATION BUDGET FORM

Exp. # GMn E12-09-016 **rev: 0** **run dates: 2019** **name of liaison: Eric Fuchey**

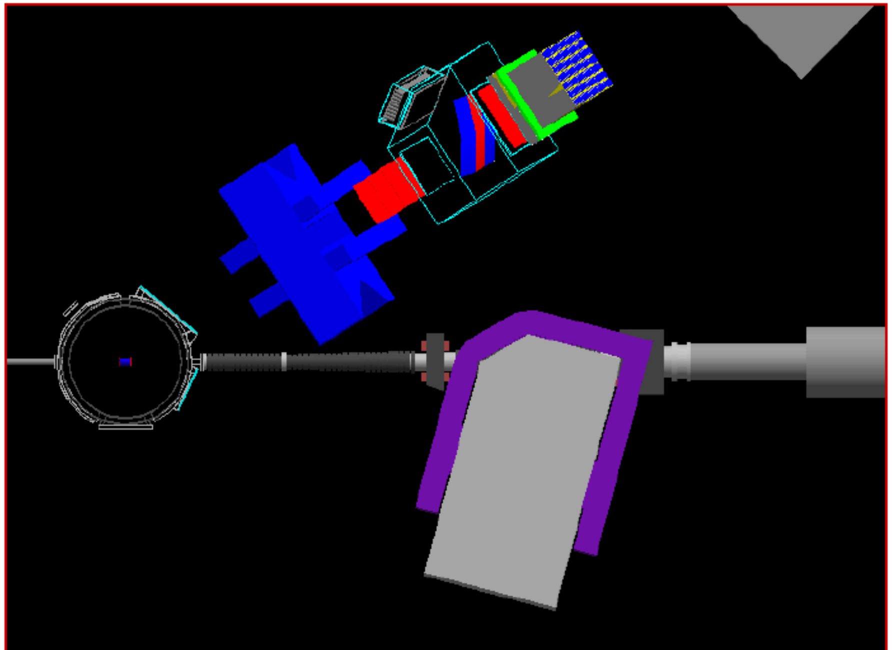
setup number			18	19	20	21	22	23	24	25	26	27	
beam	energy	GeV	8.8	11.0	11.0	11.0	4.4	4.4	4.4	4.4	4.4	4.4	*totals:*
	current	uA(CW)	30.0	30.0	55.4	30.0	20.0	20.0	60.0	20.0	20.0	60.0	
radiator	element						Cu	Cu		Cu	Cu		
	thickness	mg/cm2					772	772		772	772		
	dist. to pivot	m					-0.15	-0.15		-0.15	-0.15		
	Z		0	0	0	0	29	29	0	29	29	0	
	A		0	0	0	0	64	64	0	64	64	0	
exp't target	element		Al	D	H	Al	H	Al	H	H	Al	H	
	thickness	mg/cm2	935	2435	1062	935	1062	935	1062	1062	935	1062	
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Z		13	1	1	13	1	13	1	1	13	1	
	A		27	2	1	27	1	27	1	1	27	1	
cryo tgt window	element			Al	Al		Al		Al	Al		Al	
	thickness	mg/cm2		83	83		83		83	83		83	
	dist. to pivot	m		0.0	0.0		0.0		0.0	0.0		0.0	
	Z		0	13	13	0	13	0	13	13	0	13	
	A		0	27	27	0	27	0	27	27	0	27	
critical window	radius	cm	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	
	dist. to pivot	m	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	
scattering weighting factor			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
time	run time (100% eff.)	hours	4	100	13	8	12	2	3	24	2	6	543
		days	0.2	4.2	0.5	0.3	0.5	0.1	0.1	1.0	0.1	0.3	22.6
	installation time	hours											0
		days	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at the fence post (run time)	method 1	urem/hr	1.58	1.94	0.59	1.65	1.57	2.53	0.61	1.57	2.53	0.61	
	method 2	urem/hr											
	conservative	urem/hr	1.58	1.94	0.59	1.65	1.57	2.53	0.61	1.57	2.53	0.61	
dose per setup		urem	6	194	8	13	19	5	2	38	5	4	676.46
% of annual dose budget		%	0.1	1.9	0.1	0.1	0.2	0.1	0.0	0.4	0.1	0.0	6.7646
% of allowed dose for the total time													109.13
% of allowed dose for the run time only													109.13

If > 200%, discuss result with Physics Research EH&S officer

date form issued: May 15, 2017 *authors:* P.Degtiarenko

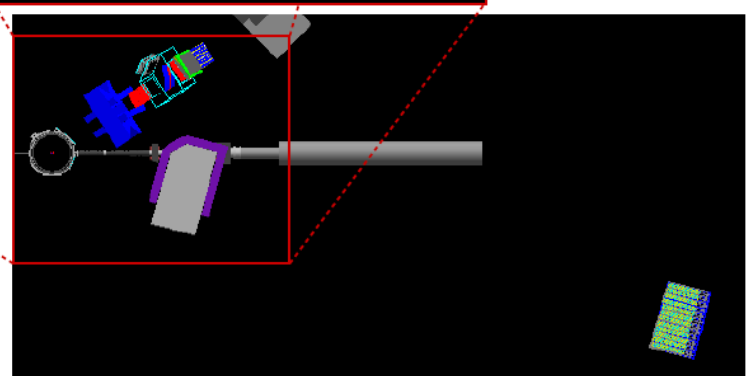
Reminder:
G_M^n setup update

Updated G_M^n beamline in g4sbs with the actual design:



- 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).



Reminder: settings for G_M^n kinematics

Considered settings for all kinematics:

G_M^n BigBite settings: (10 cm LD_2 target)						
Q^2 (*) [GeV^2]	θ_{BB} (*) [deg]	d_{BB} (*) [m]	E_{beam} (**) [GeV]	$\mathcal{L}$ (**) [$A^{-1}cm^{-2}s^{-1}$]	I_{beam} (**) [µA]	Beam time [h] (**)
3.5	32.5	1.80	4.4	0.7 x 10^{38}	**11.0** (44.0)	12
4.5	41.9	1.55	4.4	1.4 x 10^{38}	**22.0** (44.0)	12
5.7 (6.0)	58.4	1.55	4.4	2.8 x 10^{38}	**44.0**	18
8.1 (8.5)	43.0	1.55	6.6	2.8 x 10^{38}	**44.0**	18
10.2 (10.0)	34.0	1.75	8.8	1.4 x 10^{38}	**22.0** (44.0)	24
12.0	44.2	1.55	8.8	2.8 x 10^{38}	**44.0**	48
13.5	33.0	1.55	~~8.8~~ 11.0	2.8 x 10^{38}	**44.0**	96

(*) Taken from Robin Wines slides at last collaboration meeting
(**) taken from G_M^n update (E-09-019) at PAC35, obviously assuming 10cm LD_2.

NB: we may tentatively consider 2.8 10^{38} cm^{-2s-1} (i.e. 44µA) for *all* kinematics

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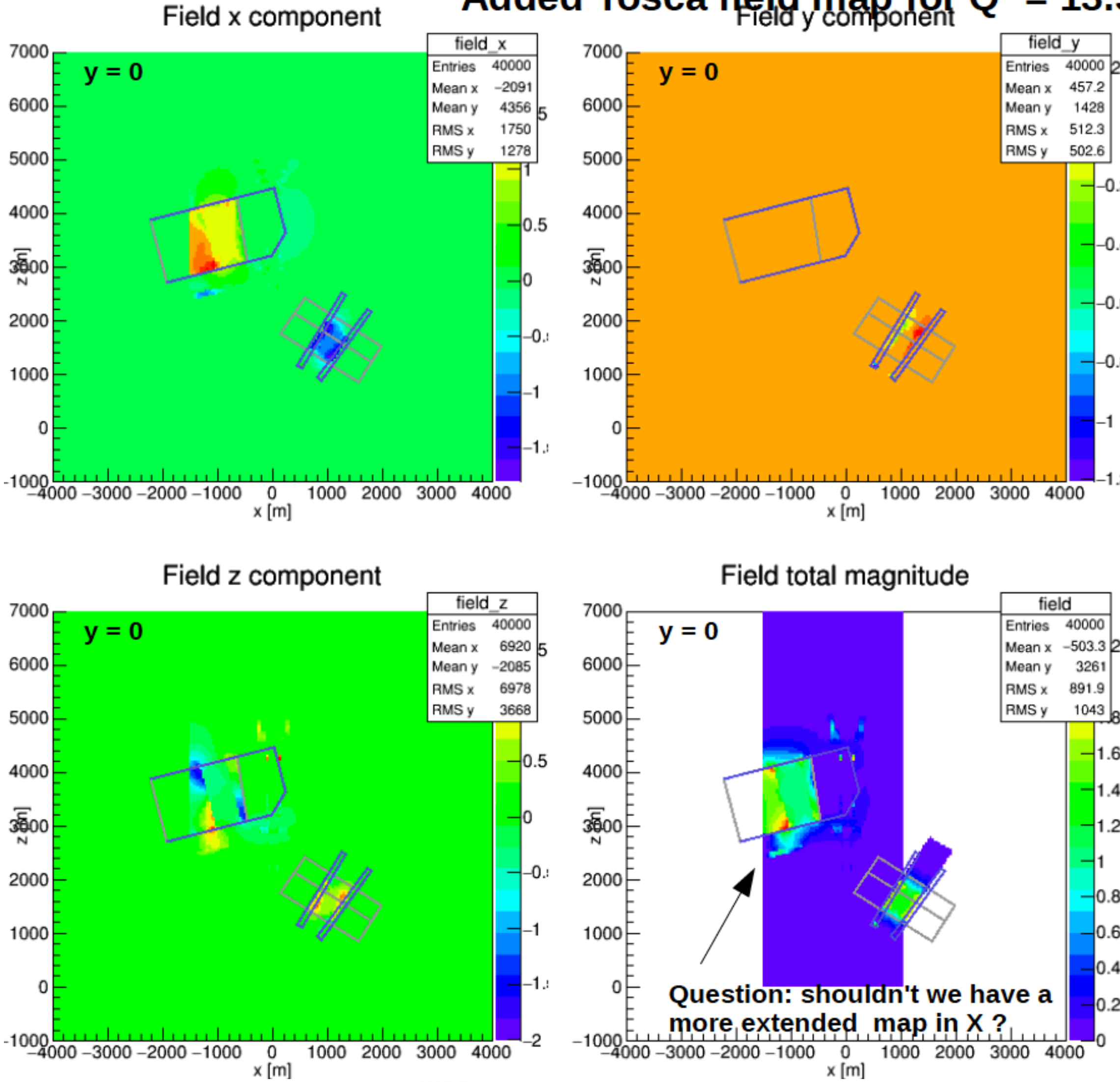
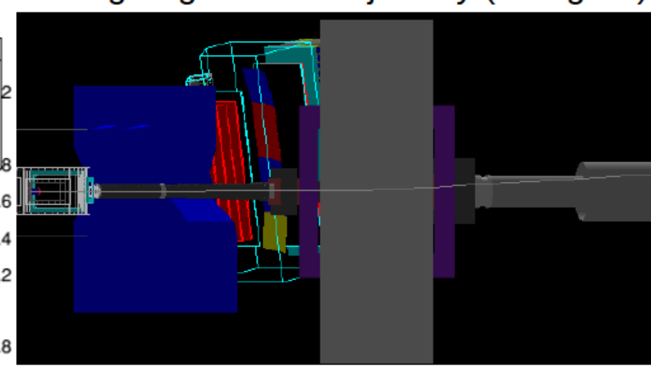
Reminder:
Update of G_M^n setup in g4sbs

Added Tosca field map for Q^2 = 13.5 GeV^2



Charged geantino trajectory (charge +)



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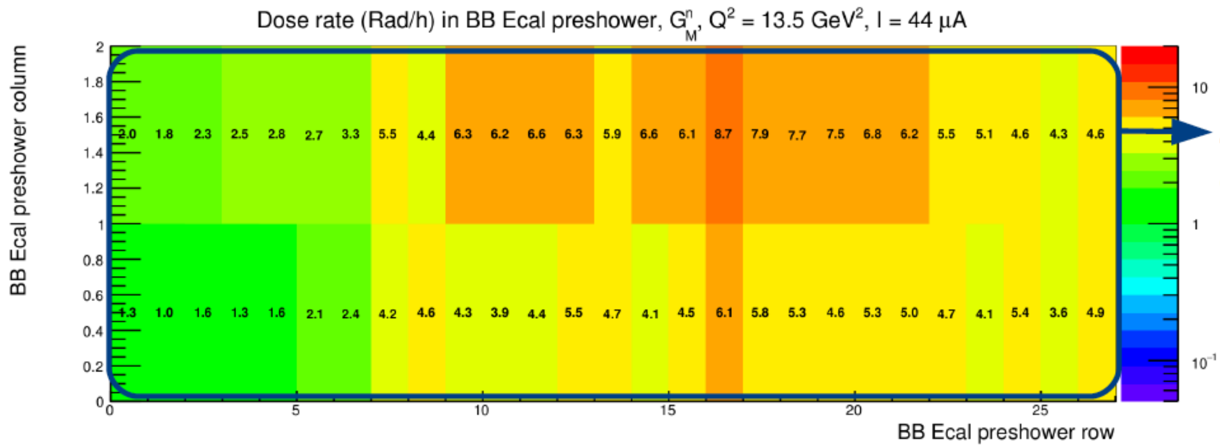
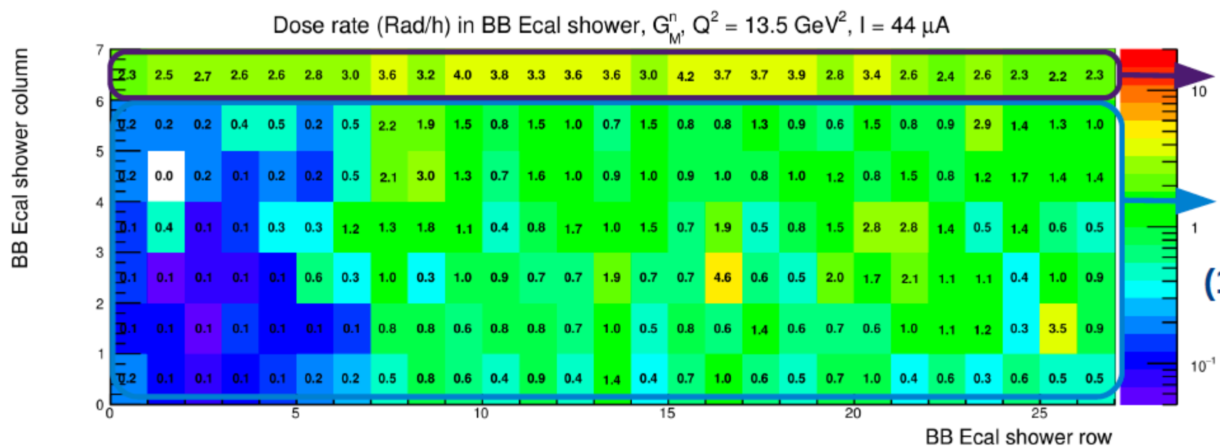
BB Ecal dose rate for G_M^n

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



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

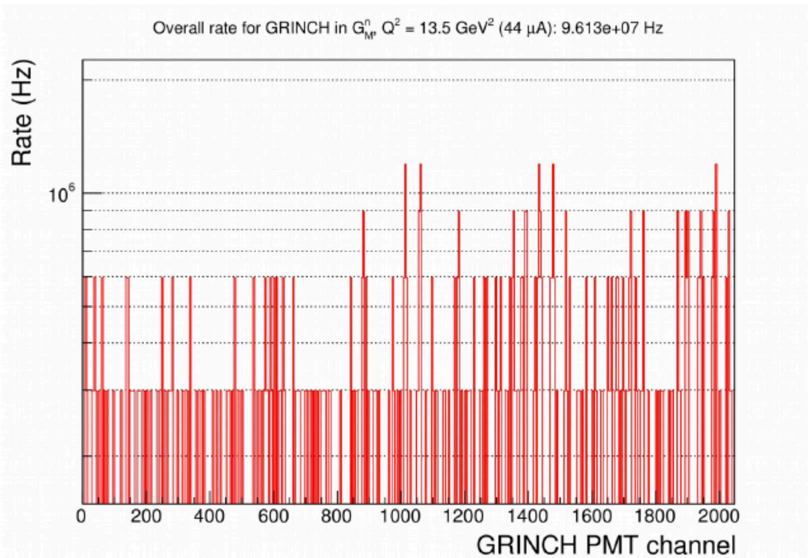
0.9 Rad/h/block avg

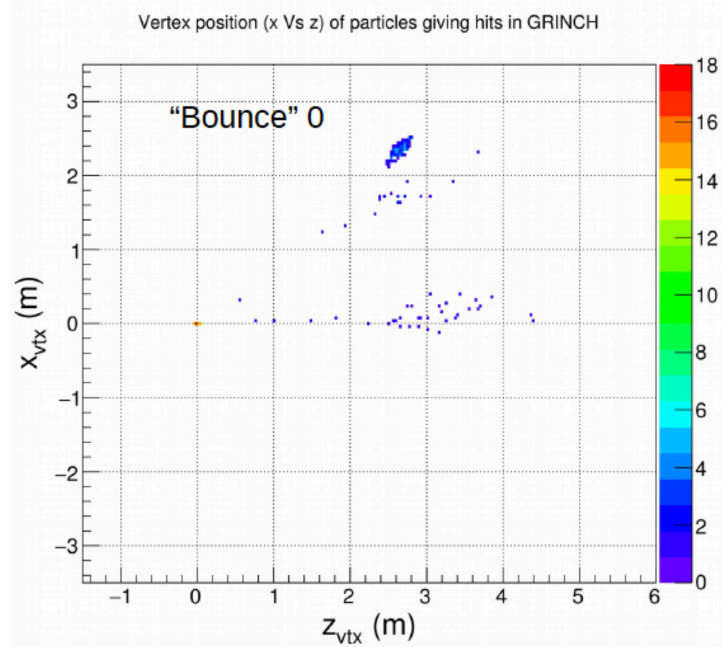
(1.2 Rad/h/block avg over SH)

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

GRINCH rates for G_M^n

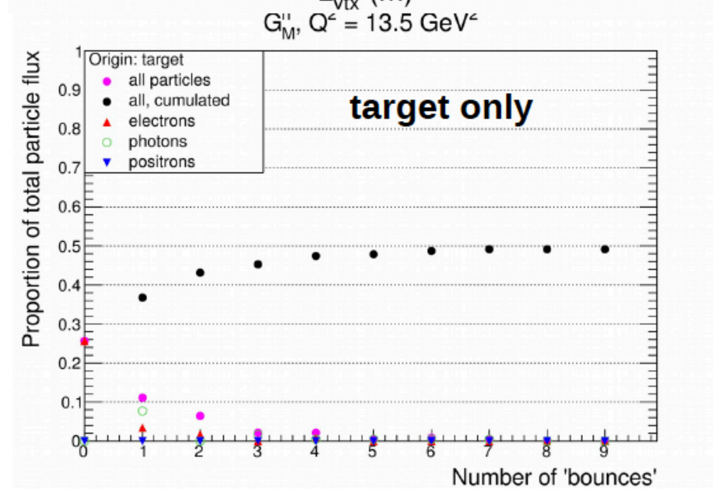
$Q^2 = 13.5\ GeV^2$, $I_{beam} = 44\mu A$, 10 cm LD_2, new setup, uniform SBS field map





96 MHz over detector => ~190kHz/PMT;
(including 50% from target and 30% from 48D48)

=> ~95 kHz from **target**;
(rough agreement with previous calculations);
=> ~55 kHz from 48D48 magnet;
=> the rest (~40 kHz) from beamline, scattering chamber;



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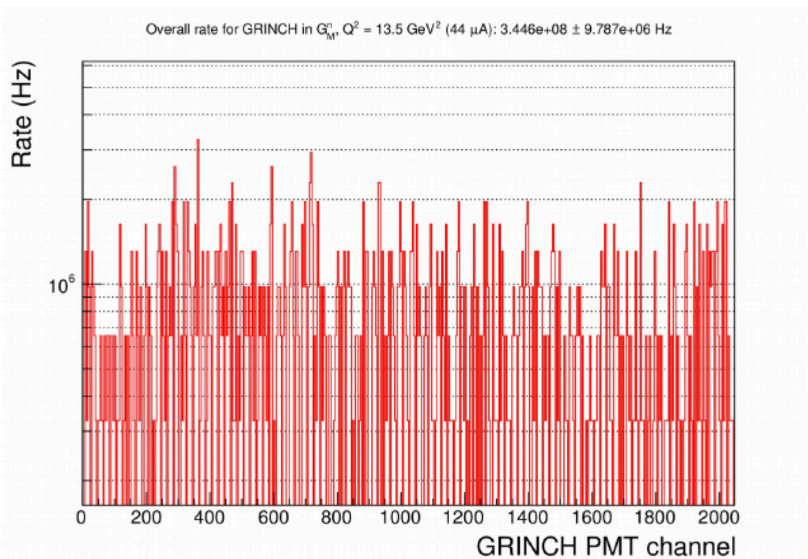
GRINCH rates for G_M^n

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



345 MHz over detector => ~680kHz/PMT;
(including 65% from target and 10% from 48D48);
not easy to deal with, but handleable;

=> ~440 kHz from **target**;
→ **clear discrepency with "no Tosca field" simulations: to be understood!** (next slide)
=> ~70 kHz from 48D48 magnet;
=> the rest (~170 kHz) from beamline, scattering chamber;

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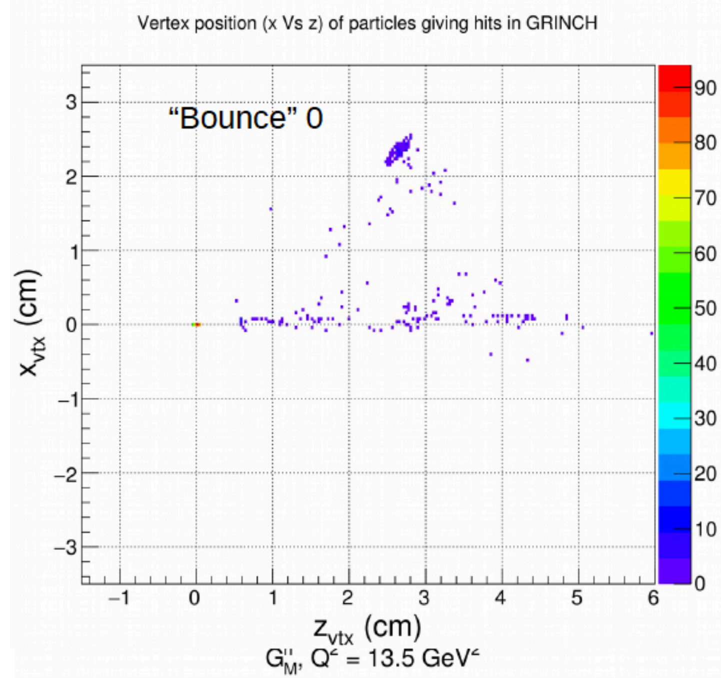

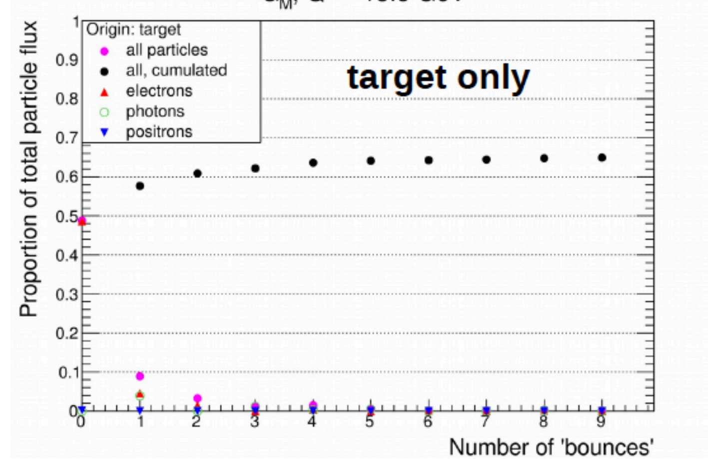

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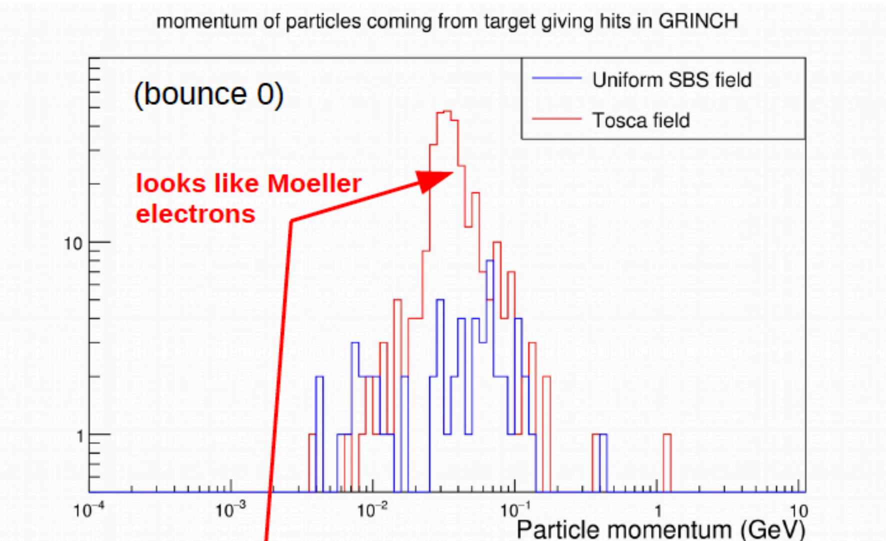
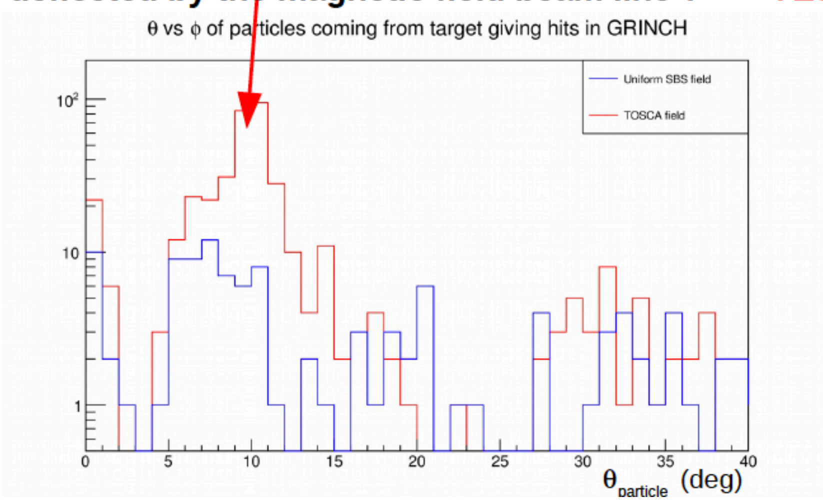
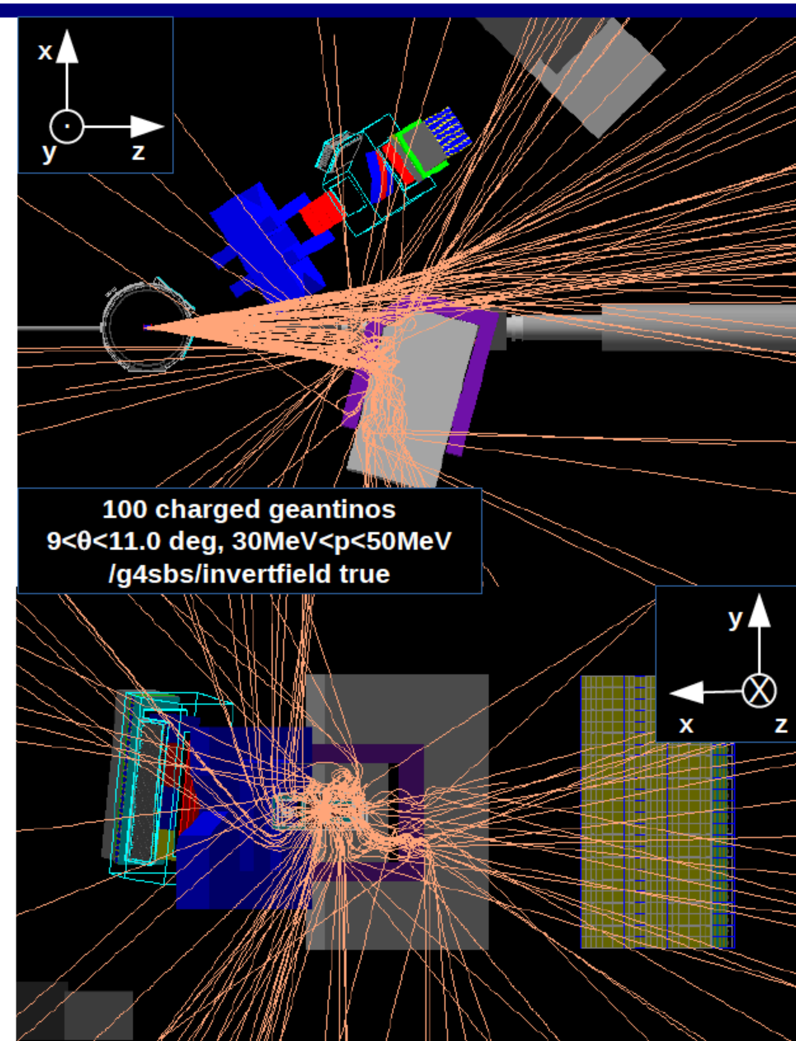
GRINCH rates for G_M^n

Explaination for discrepency of TOSCA vs uniform SBS field map



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

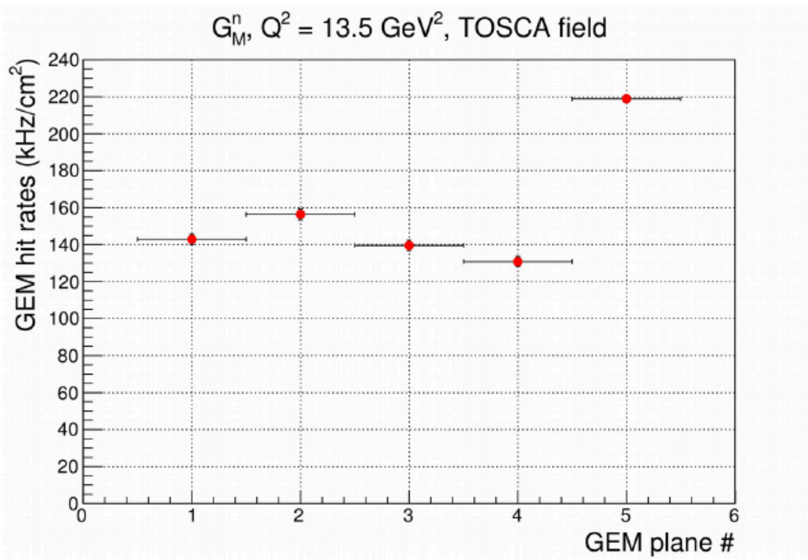




We might be able to shield that...

GEM rates for G_M^n

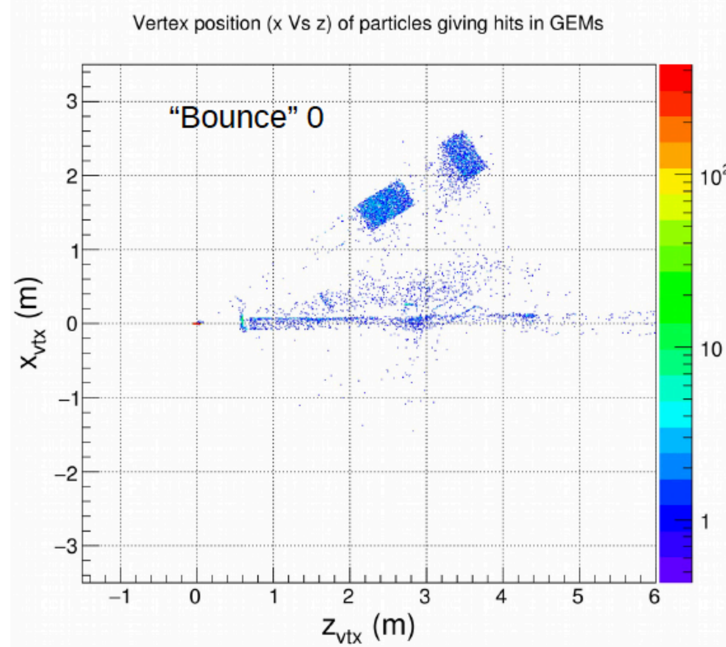
Q^2 = 13.5 GeV², I_{beam} = 44μA, 10 cm LD_2, new setup, Tosca field map

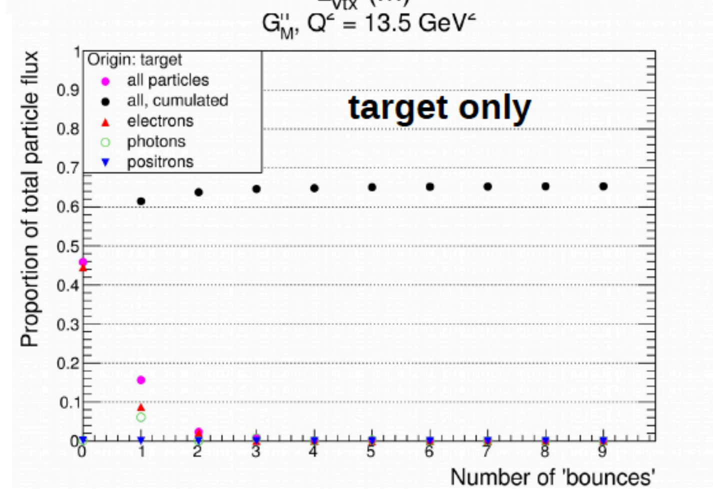


New setup, TOSCA field map:
~140kHz/cm² per GEM for INFN GEMs (front),
220kHz/cm², for UVA GEM (behind GRINCH)
including 65% from target and 5% from 48D48;

=> 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...





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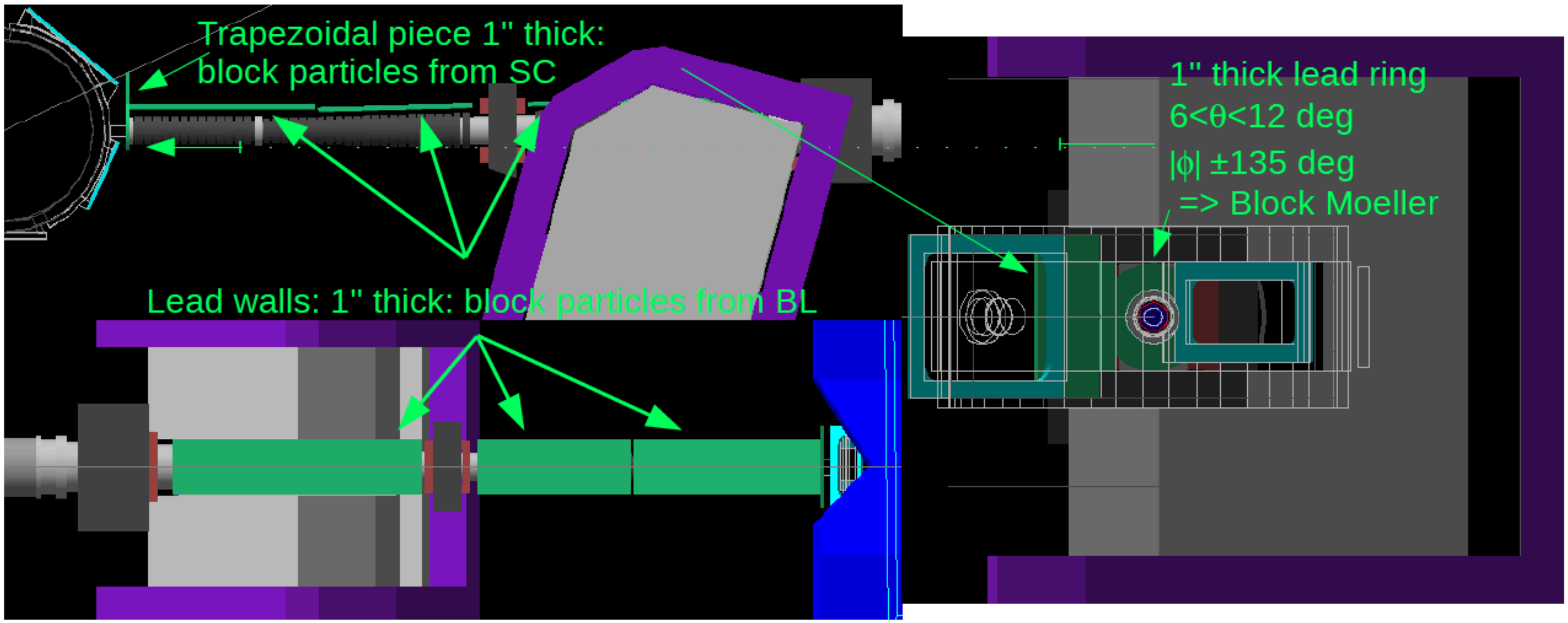
Beamline shielding for G_M^n

First Iteration

Q^2 = 13.5 GeV², I_{beam} = 44μA, 10 cm LD_2, new setup, Tosca field map

Preliminary design:



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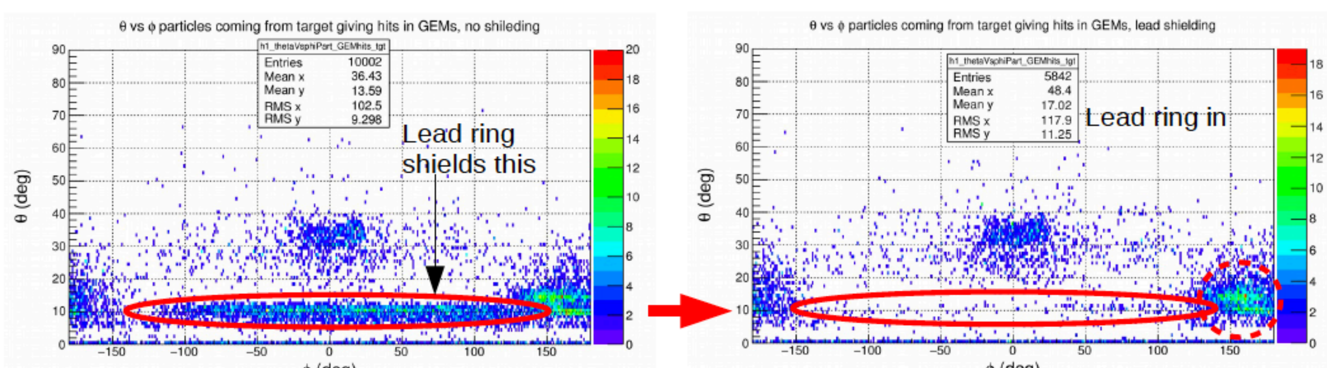

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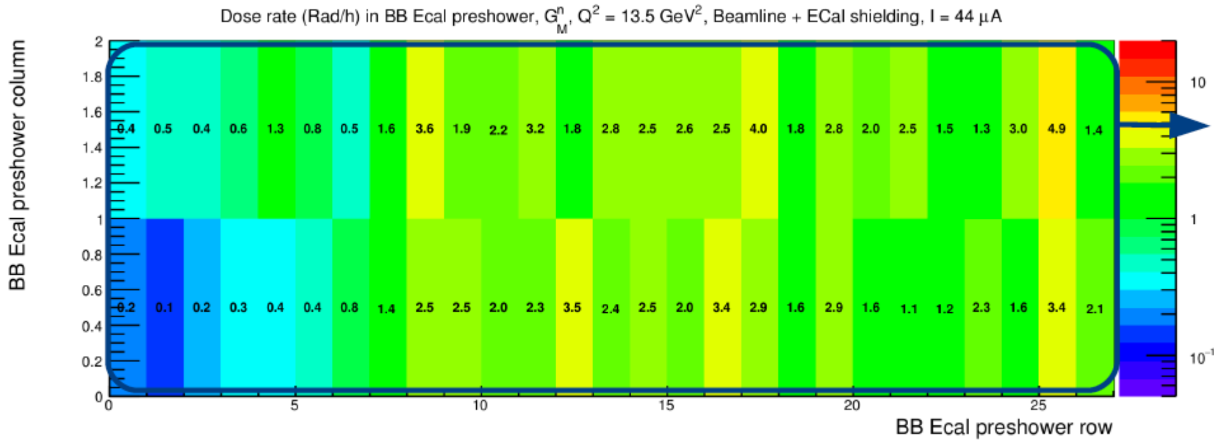
BB Ecal dose rate for G_M^n

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

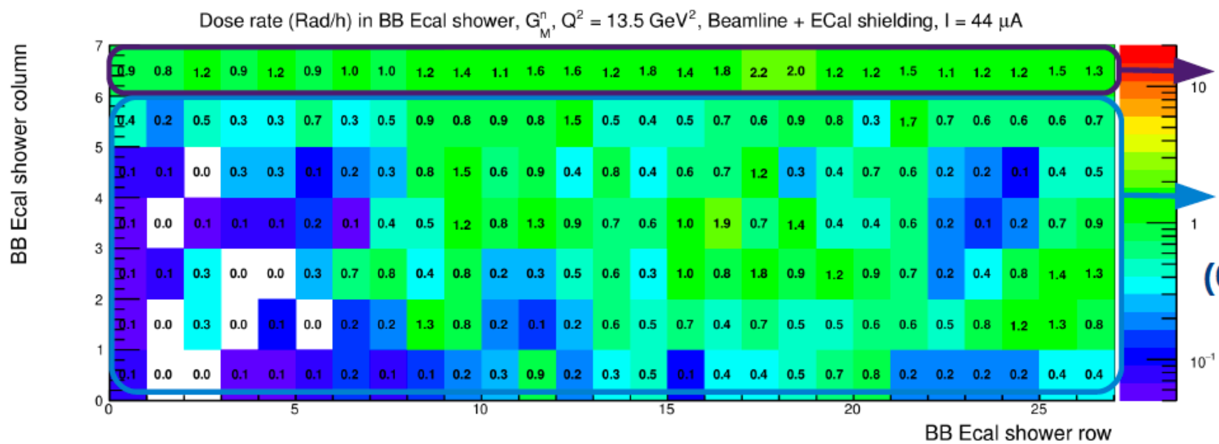
Beamline shielding + ECal shielding (1 cm steel + 5cm Al)



1.9 Rad/h/block avg over PS

Factor ~2.5 drop (wrt no lead shielding)

x100 h beam time: <200 Rad integrated *for this kinematic*.
Max dose for a single block: <500 Rad.



1.3 Rad/h/block avg

0.5 Rad/h/block avg

(0.6 Rad/h/block avg over SH)

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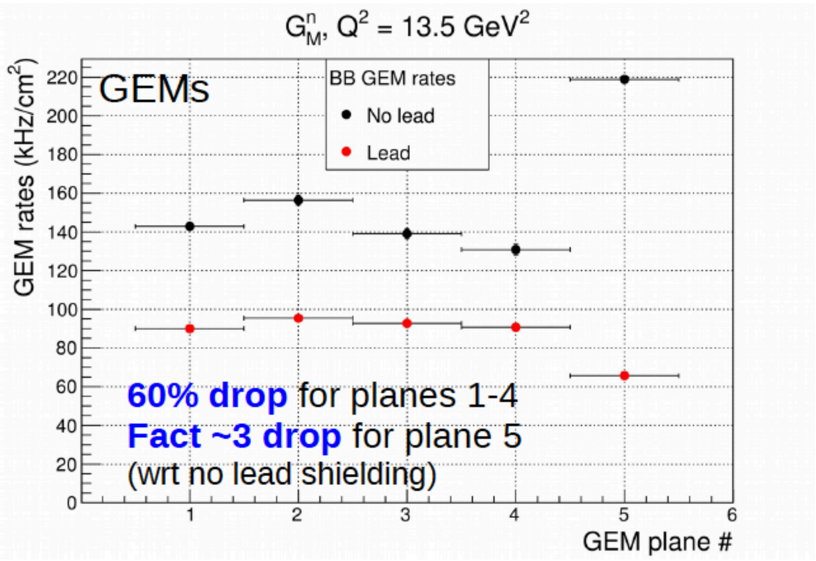
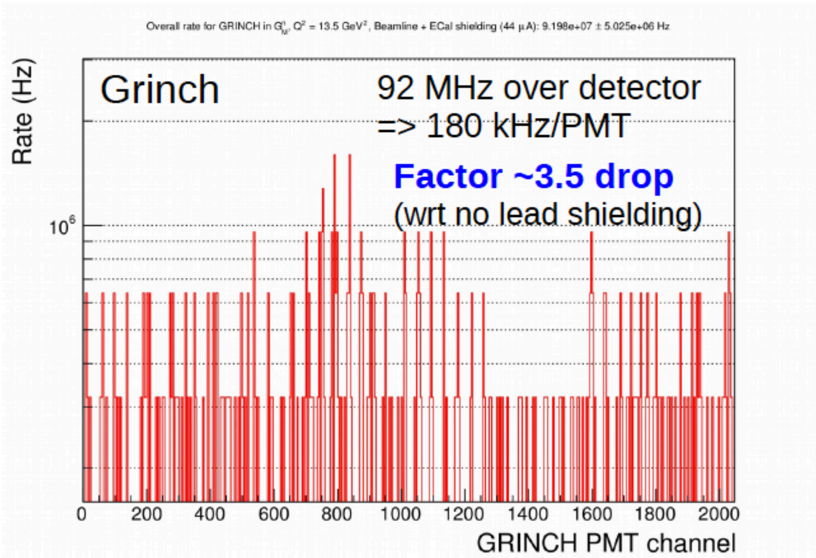
All detector rates for G_M^n

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

Beamline shielding + ECal shielding (1 cm steel + 5cm Al)



(~75% from target and 5% from 48D48);



(~50% from target and 10% from 48D48);

=> ~45 kHz/PMT from **target**;
=> <20 kHz/PMT from 48D48 magnet;
=> the rest (~35 kHz/PMT) from beamline;

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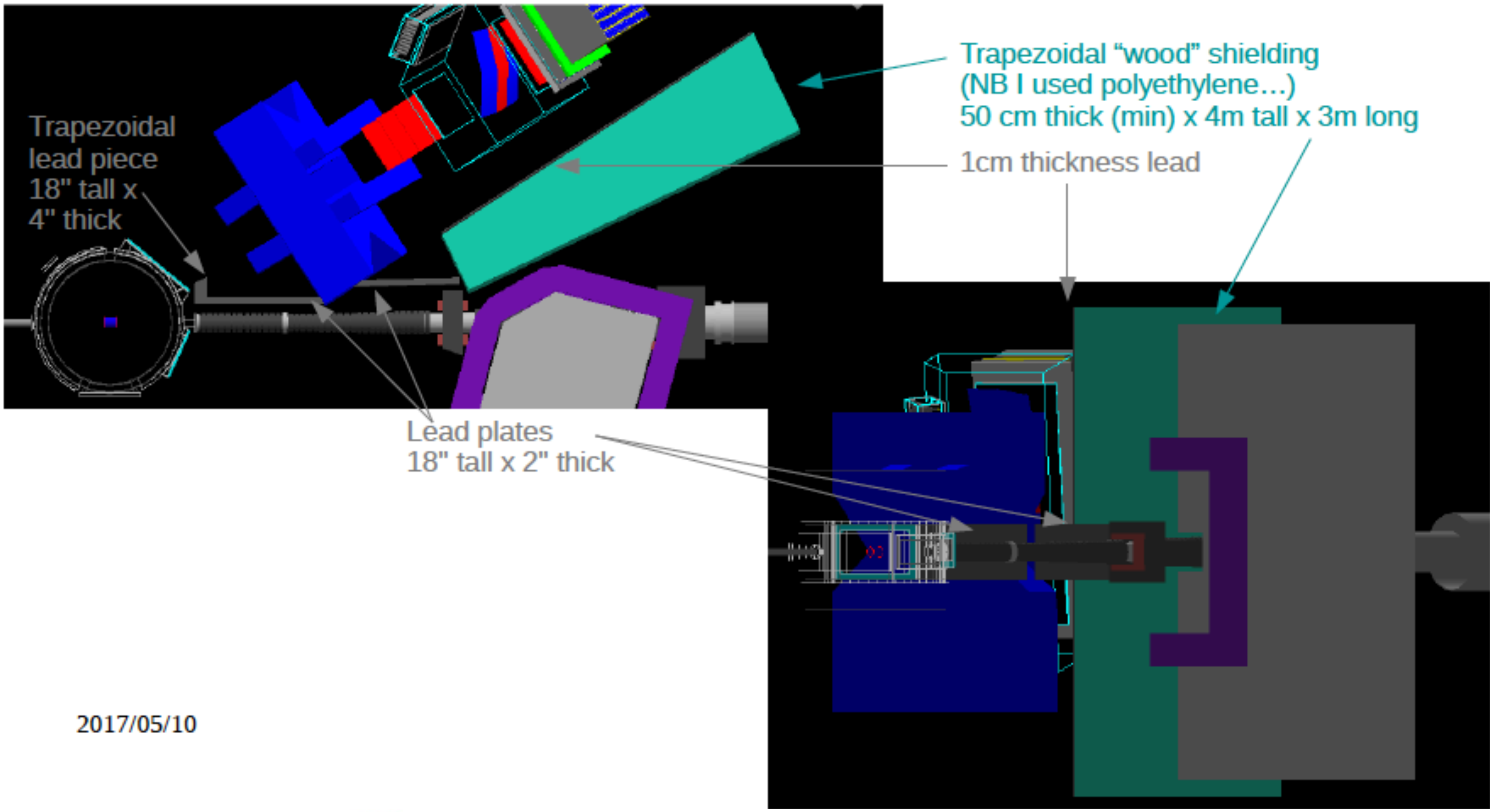
Beamline shielding for G_M^n

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

Preliminary design:

ITERATION 2



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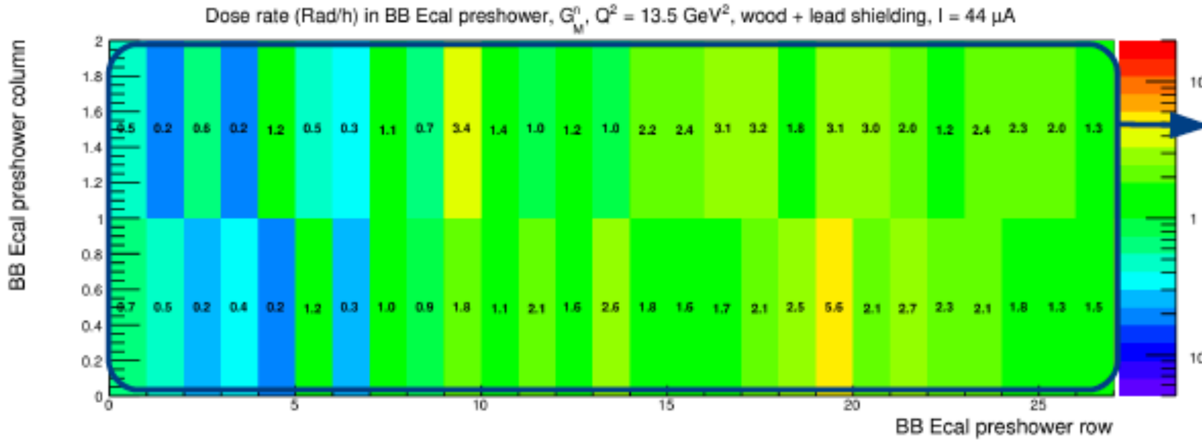
BB Ecal dose rate for G_M^n

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

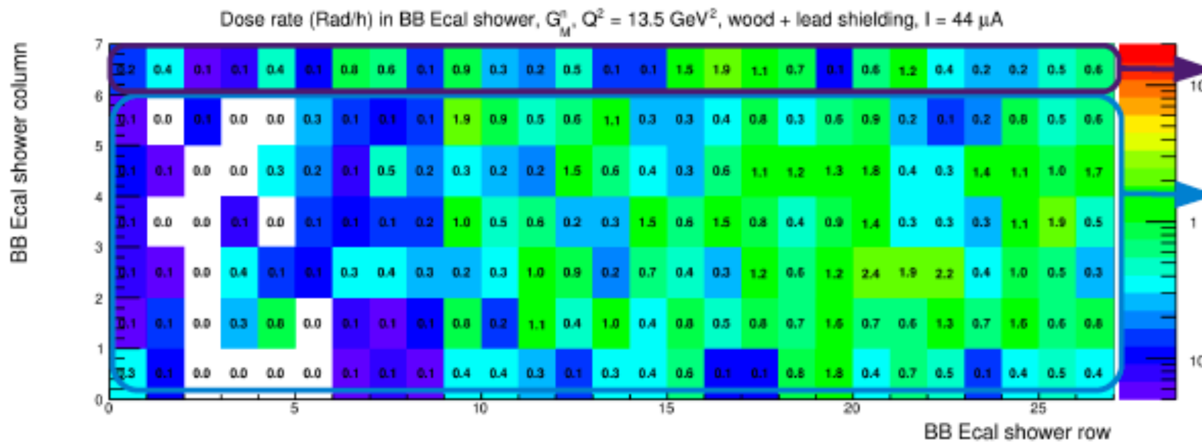
Beamline shielding + ECal shielding (1 cm steel + 5cm Al)



1.6 Rad/h/block avg over PS

Factor ~3 drop (wrt no shielding)

x100 h beam time: <200 Rad integrated *for this kinematic*. Max dose for a single block: <500 Rad.



0.52 Rad/h/block avg

0.53 Rad/h/block avg

(0.53 Rad/h/block avg over SH)

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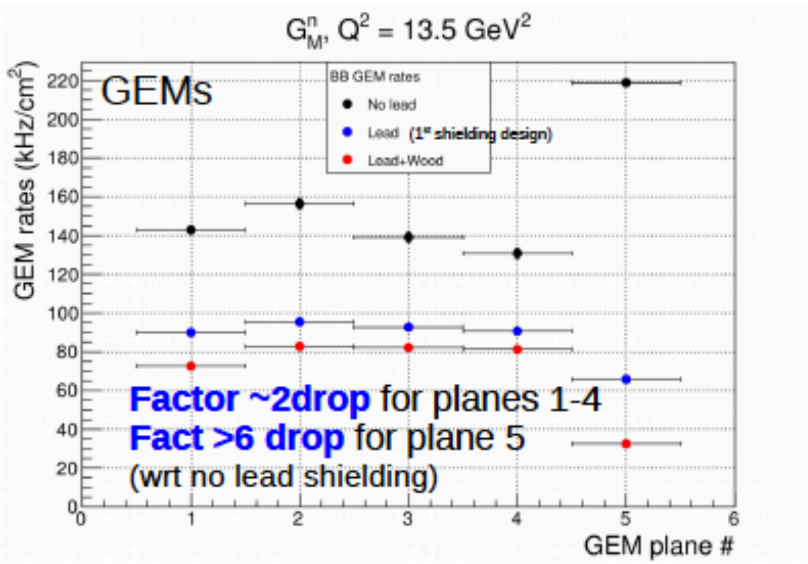
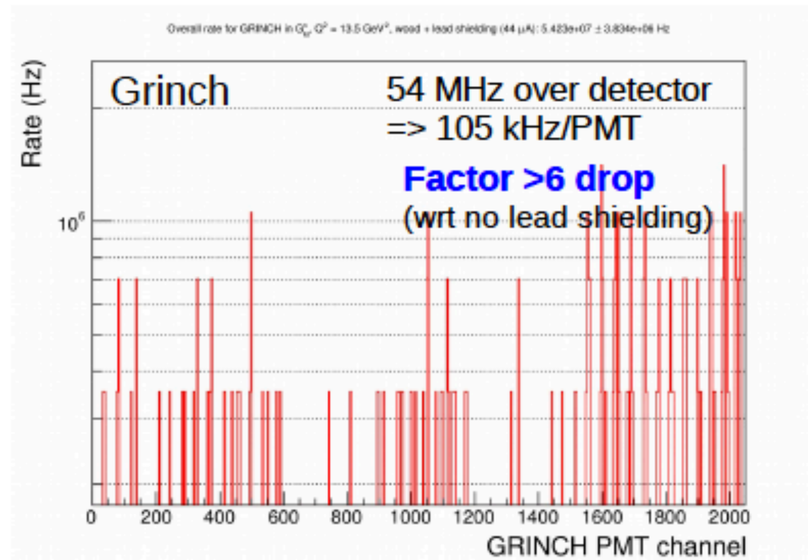
All detector rates for G_M^n

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

Beamline shielding + ECal shielding (1 cm steel + 5cm Al)





78% from **target**,
2% from 48D48,
5% from BL,
3% from SC;

Rest (12%) ? from shielding

82 kHz/PMT (78%) from **target**, (-80%*)
3 kHz/PMT (3%) from 48D48, (-95%*)
7 kHz/PMT (7%) from BL, (-95%*)
3 kHz/PMT (3%) from SC, (-95%*)

Rest (9%) ? from shielding

2017/05/10

(* wrt no lead shielding)

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GEOMETRY

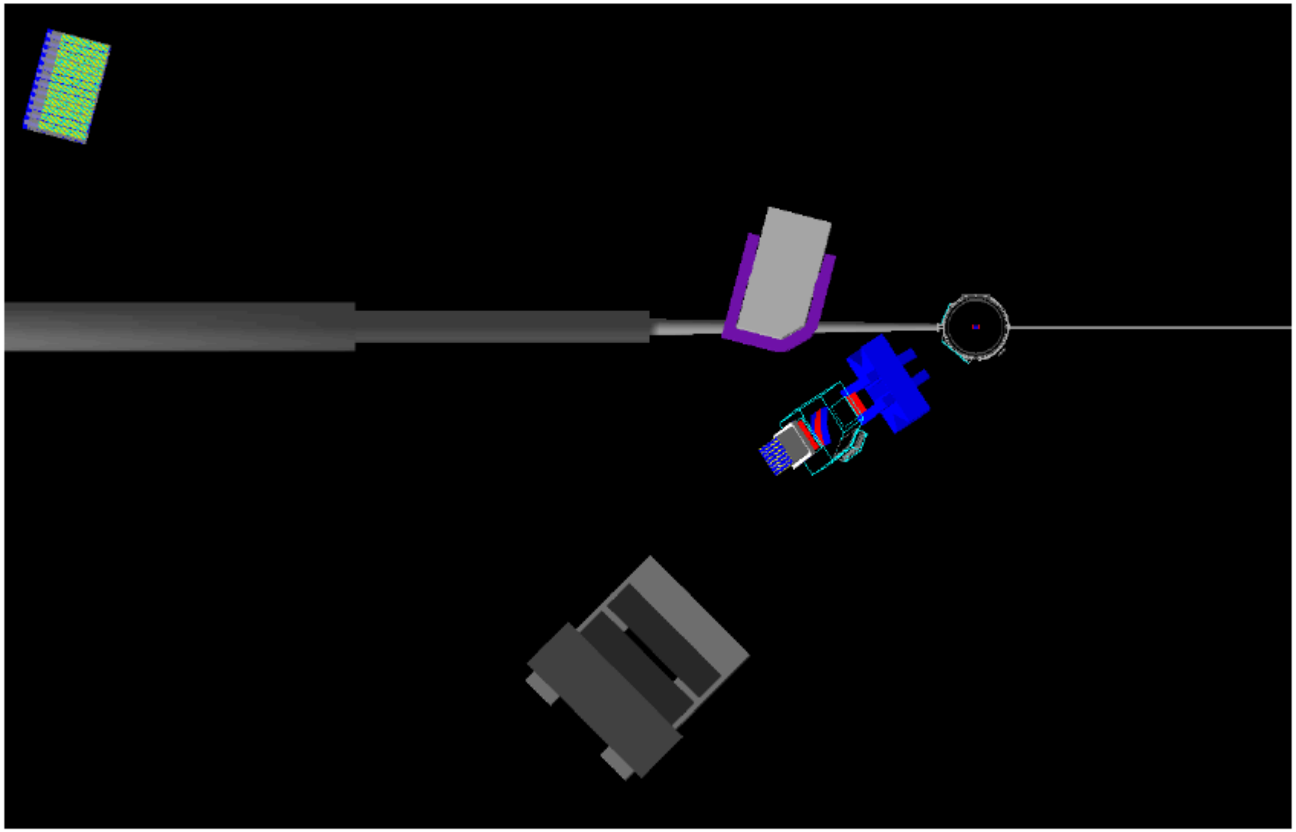

Figure: The hut face is located roughly 7.2 m from the target in the xz plane at a central angle of 45 degrees. All hut materials are steel.

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:

Dose rate = 0.016 rad/hr

Beamline Activation

- Most important question: will the radiation exposure levels to personnel working near beamline during config. changes be acceptable?
- RadCon group in contact with Hall A engineers; drawings needed for calculations "almost done" as of 5/16
- Detailed, time-ordered run plan of beam-times, targets, currents, energies and configuration changes of SBS during GMN has been provided by the GMN spokespeople and sent to RadCon
- No new updates on these calculations since 5/16
- No promises from RadCon on completing these calculations prior to review
- Before ERR: timeline for completion = ??

Summary and Conclusions

- (To be confirmed by RadCon) Standard LH_2/LD_2 targets at luminosities routinely used during 6 GeV era present no major challenges in terms of Rad. budget/personnel exposure during config. changes
- Exhaustively detailed GEANT4 Monte Carlo simulations of GMN in all configurations show tolerable radiation levels in rad-sensitive detectors and readout electronics
- Rates in low-threshold detectors (GRINCH and GEMs) are tolerable even in the absence of local shielding
  - Simulations with TOSCA map show importance of SBS fringe field for detector background rates
  - Moller electrons bent by SBS fringe field significant source of GRINCH background
  - Photon-induced backgrounds most important for GEMs
- Modest local shielding of the downstream beamline and/or BigBite detectors can potentially reduce the background rate by ~2X in GEMs and ~6X in GRINCH PMTs—not critical, but definitely worthwhile.