Gen ERR charge item 6:
Radiation and Shielding

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October 22nd, 2020

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Jefferson Lab

Are the radiation levels expected to be generated in the hall acceptable? Is any local shielding required to minimize the effects of radiation in the equipment?

To address this, we need:

*** Evaluation of radiation budget for G_E^n**

*** Evaluation of beam induced background in the individual detectors for G_E^n**

Radiation budget for GEn

Estimation of radiation budget for GEn by P. Degtiarenko

Hall: A — **RADIATION BUDGET FORM** — *page:* 1 of 1

Exp. # GEn E12-09-016 **rev: 0** **run dates: TBD** **name of liaison: Todd Averett, Eric Fuchey**

setup number			1	2	3	4	5	6	7	
beam	energy	GeV	4.4	4.4	4.4	4.4	4.4	6.6	8.8	*totals:*
	current	uA(CW)	60.0	60.0	60.0	5.0	60.0	60.0	60.0	
exp't	element		He-3	N	H	C	He-3	He-3	He-3	
target	thickness	mg/cm2	97	904	65	280	97	97	97	
add'l	element		Be	Be	Be	Be	Be	Be	Be	
target 1	thickness	mg/cm2	46.9	46.9	46.9	46.9	46.9	46.9	46.9	
add'l	element		Al	Al	Al	Al	Al	Al	Al	
target 2	thickness	mg/cm2	2.8	2.8	2.8	2.8	2.8	2.8	2.8	
add'l	element		N	N	N	N	N	N	N	
target 3	thickness	mg/cm2	26	26	26	97.8	26	26	26	
cryo tgt	element		Al	Al	Al		Al	Al	Al	
window	thickness	mg/cm2	83	83	83		83	83	83	
exit	element		Be	Be	Be	Be	Be	Be	Be	
window	thickness	mg/cm2	93.9	93.9	93.9	93.9	93.9	93.9	93.9	
time	run time	hours	10	10	10	10	41	165	929	1175
	(100% eff.)	days	0.4	0.4	0.4	0.4	1.7	6.9	38.7	49.0
	installation	hours								0
	time	days	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at	method 1	urem/hr	0.68	2.91	0.50	0.09	0.68	0.77	0.85	
the fence post	method 2	urem/hr								
(run time)	conservative	urem/hr	0.68	2.91	0.50	0.09	0.68	0.77	0.85	
dose per setup		urem	7	29	5	1	28	128	787	983.8
% of annual dose budget		%	0.1	0.3	0.1	0.0	0.3	1.3	7.9	9.838
% of allowed dose for the total time										73.34
% of allowed dose for the run time only										73.34

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

date form issued: October 19, 2020 *authors:* P.Degtiarenko

<10% of annual dose budget
<100% of allowed dose for the period

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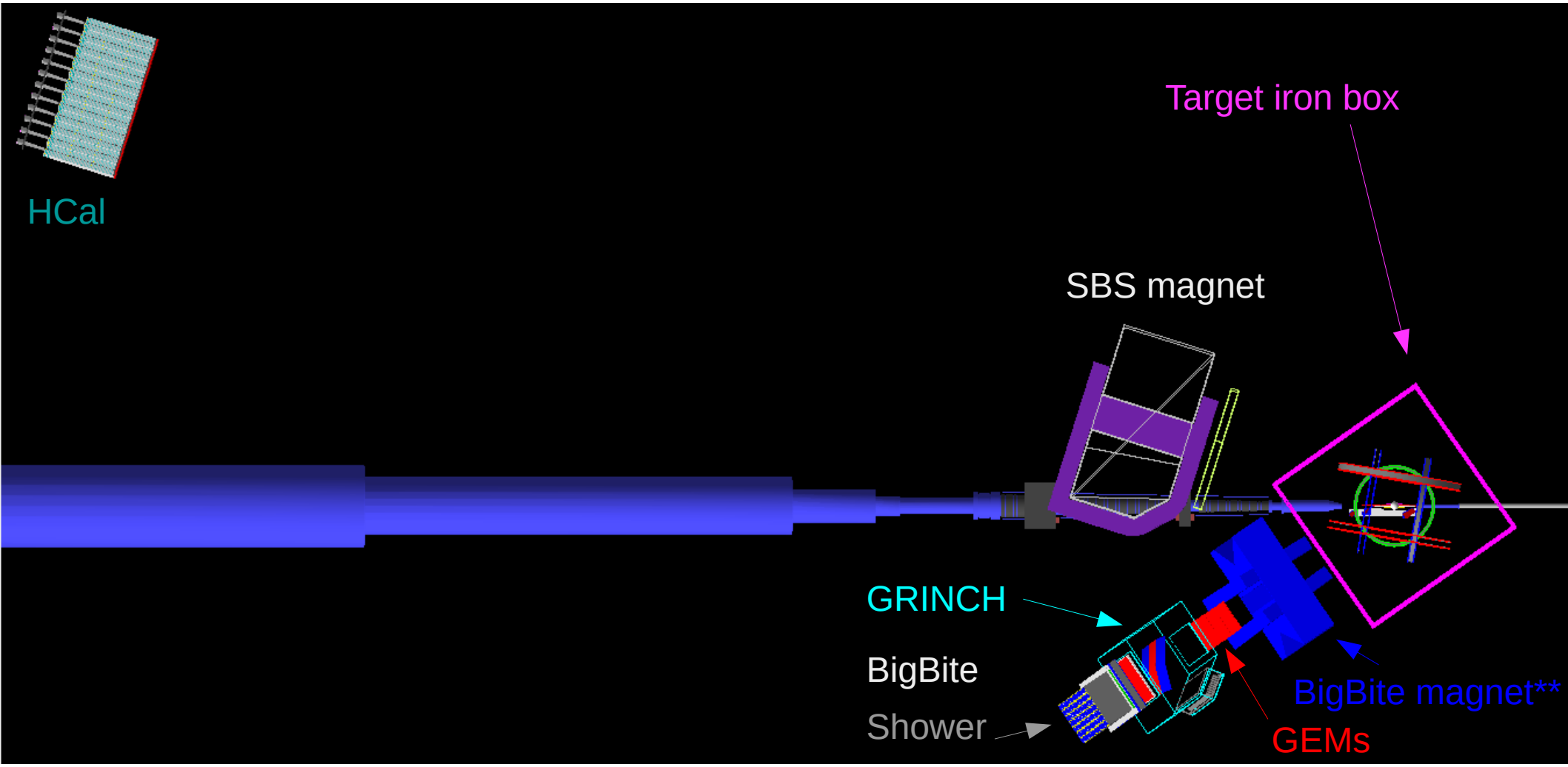
GEn geometry implementation in G4SBS



** need field clamp upstream of BB magnet;

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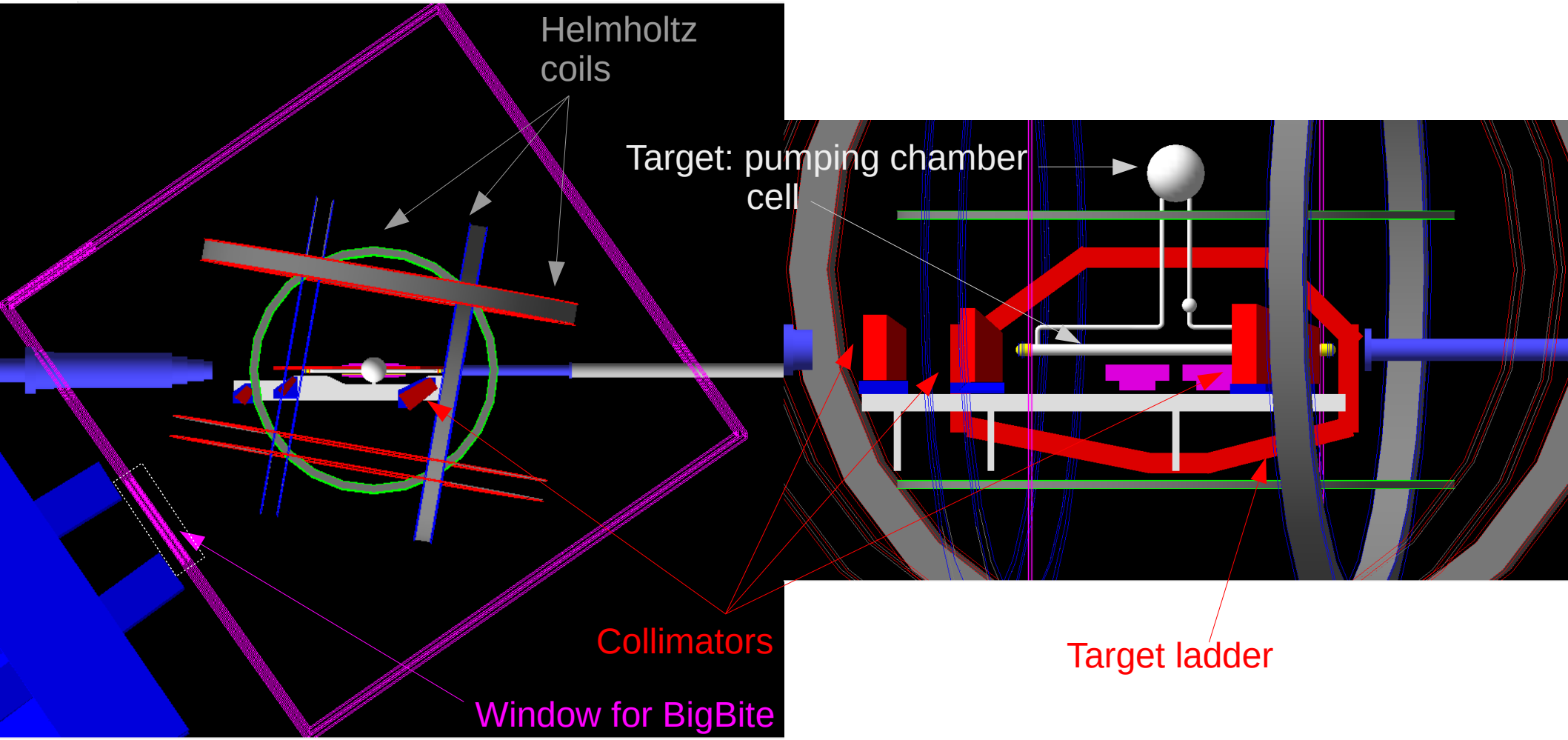
GEn geometry implementation in G4SBS

Fully detailed target geometry: helmhotlz coils, target ladder, collimators



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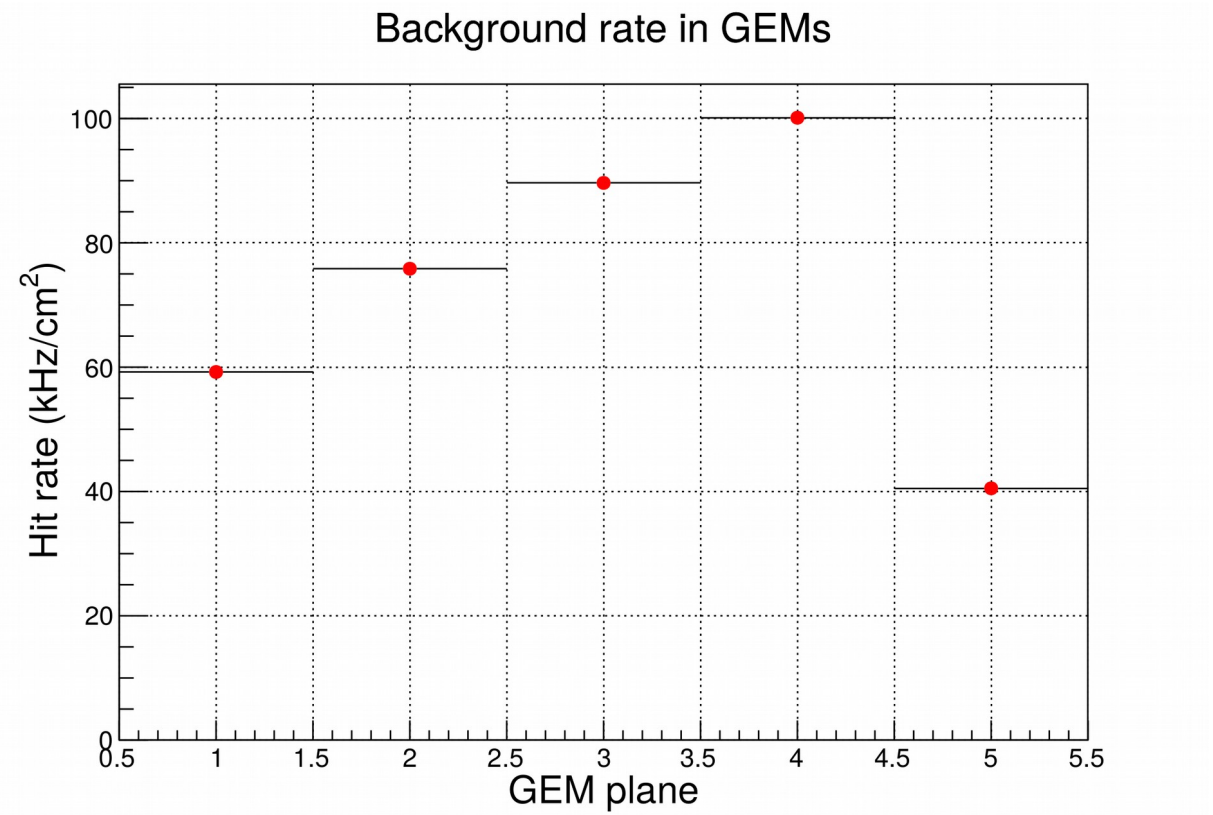
Detector rates / occupancies:
GEMs



Background in GEMs for GEn 10.18 GeV2 with target collimators comparable to GMn 13.5 GeV2 with full beam line shielding.
From the studies made with GMn:

- Such rates are manageable for the tracking
- GEM occupancies at 100 kHz/cm2: * 25-30% with only zero suppression;
  * 10-15% with pulse shape selection;

These numbers agree with the projections from the proposal

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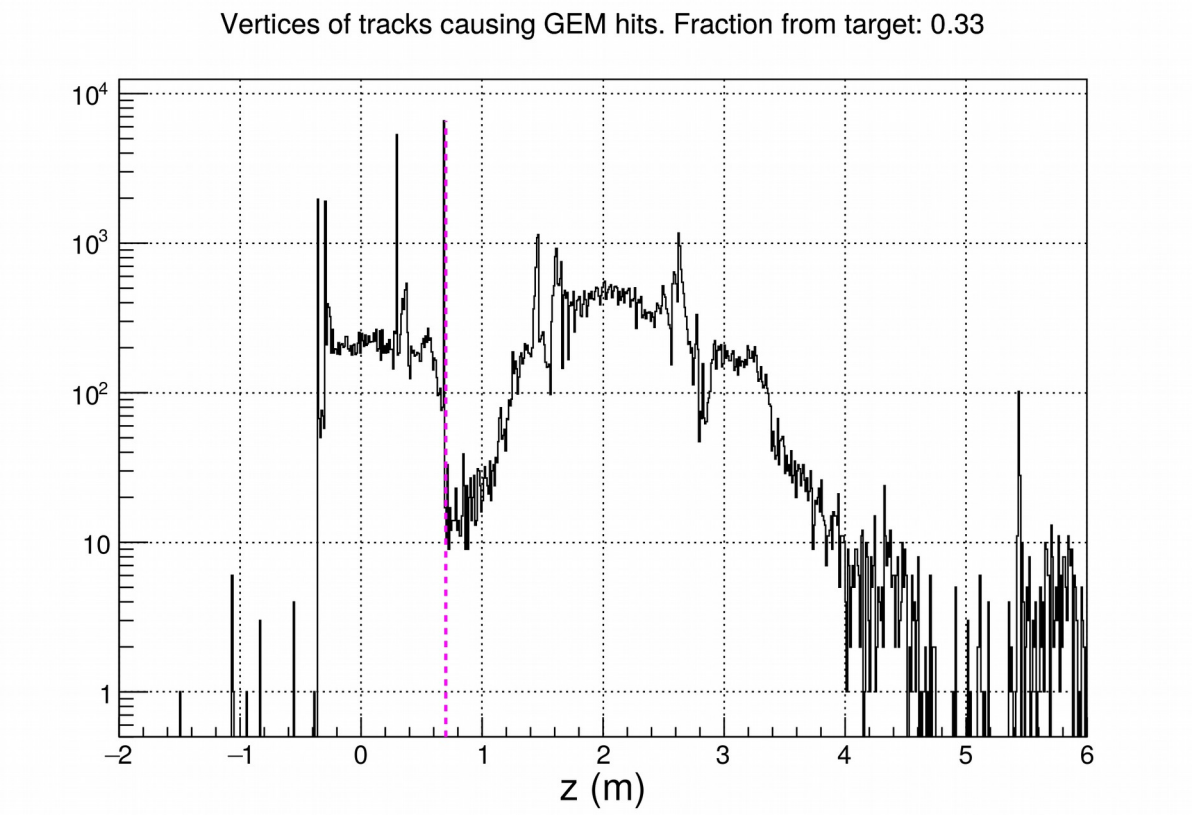
Detector rates / occupancies:
GEMs



Fraction of the background coming from the target area: **33%**
A large fraction of the background can be reduced by shielding.
To obtain a full shielding design, we need a full tosca map and to incorporate the most up-to-date geometry for the iron box.
Note: while shielding is wishable, it is not an absolute necessity (as it could be for GEp or to a lesser extent GMn)

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Detector rates / occupancies:
PMT-based detectors

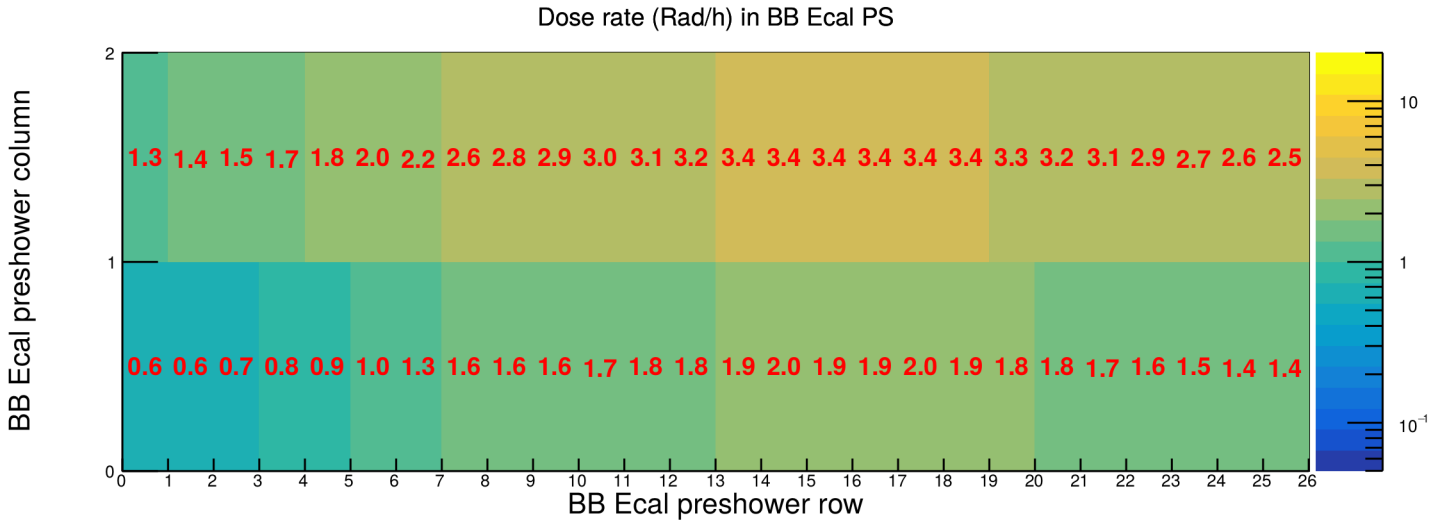
Average rates and occupancies in PMT based detectors.
Occupancies are evaluted assuming a 80 ns data acquisition window.
(conservative assumption)

Detector	Threshold (MeV)	Average rate (kHz)	Occupancy (80 ns)
HCal	4.5	413	3.3 %
Hodoscope	1.9	579	4.6 %
Preshower	15.4	1113	8.9 %
Shower	23.5	148	1.2 %
GRINCH	-	87	0.7 %

Dose rate in BB Preshower/Shower

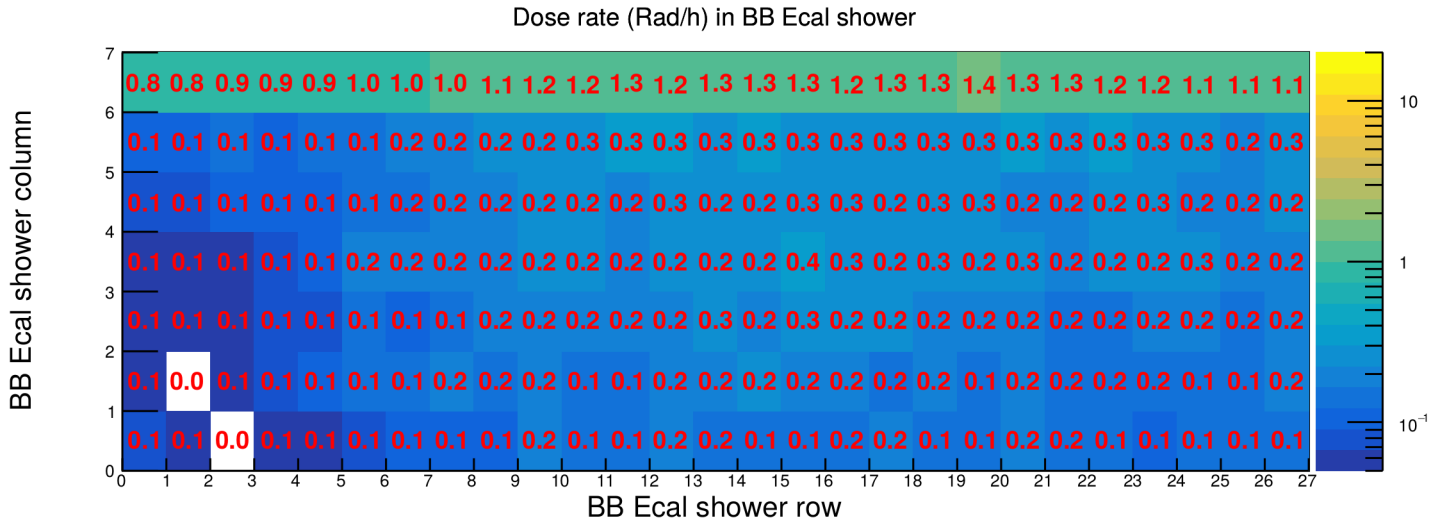
Smaller angle

Larger angle



Smaller angle

Larger angle



Dose rate around 3 Rad/h at for BB PS.
Such a dose rate can be withstood by the new BBPS modules with radiation hard lead glass.

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Summary and outlook

Are the radiation levels expected to be generated in the hall acceptable?

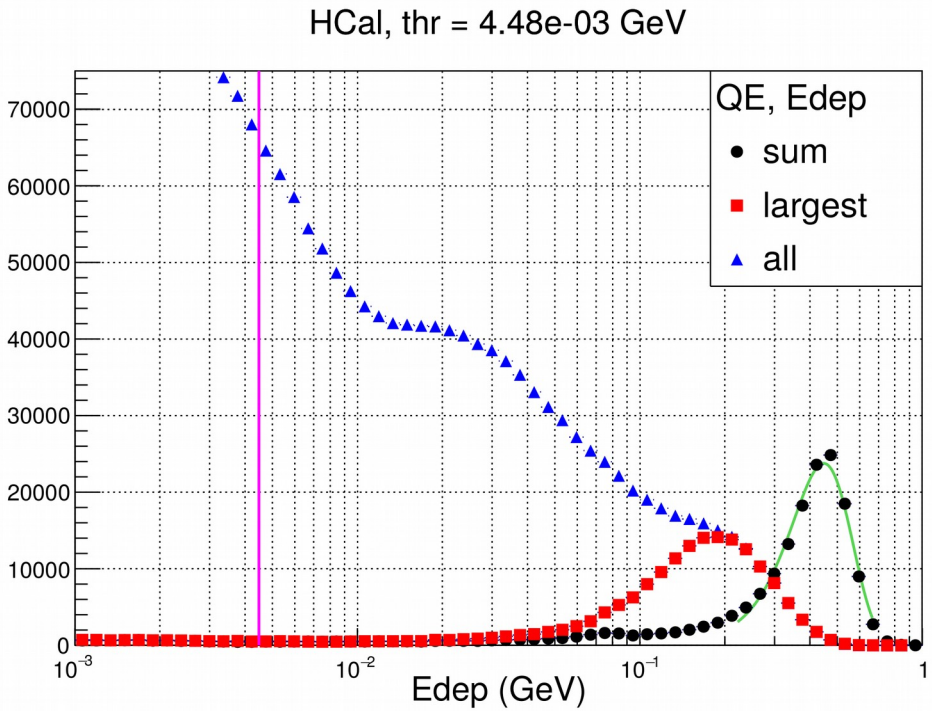
The current radiation budget estimations show that GEn should use at most 10% of the radiation budget, and less than 100% (75%) of the budget allowed for the running period.
The estimations are very close to final, and should not vary by much

Is any local shielding required to minimize the effects of radiation in the equipment?

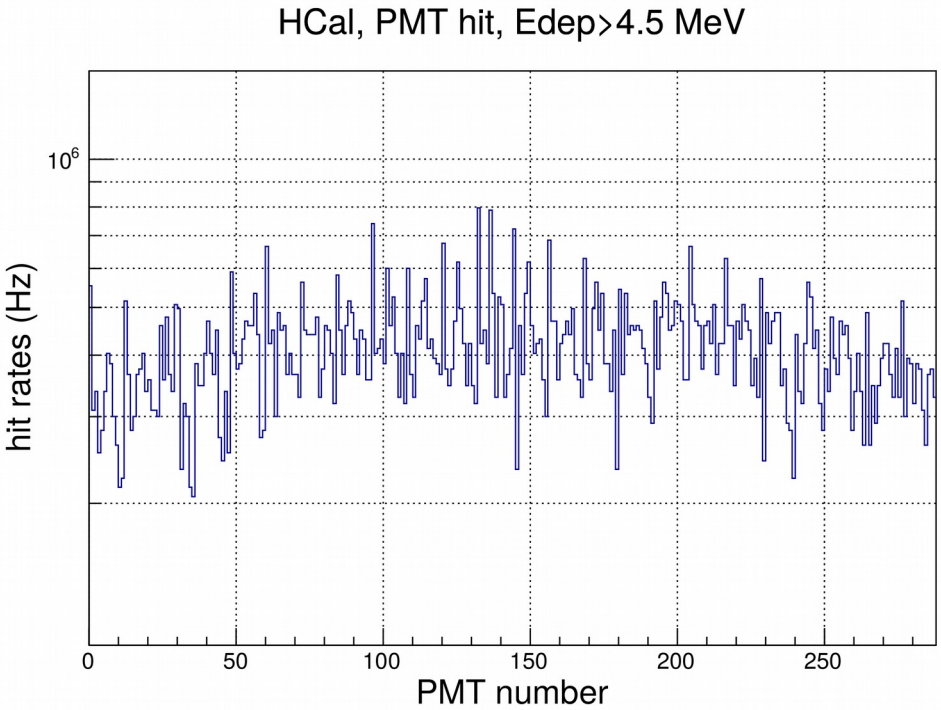
The background levels in the detectors are acceptable and should not significantly affect their performances.
Our simulations do indicate that a large fraction of the background could be shielded; however, a few geometry items need to be finalized and, most importantly, a full Tosca map would be required to optimize this shielding design.

Backup

Detector rates / occupancies:
HCal



Threshold of individual hits set to
1% of the sum average



Resulting rates: 300-500 kHz
=> Occupancy (80ns gate): 2.4-4%

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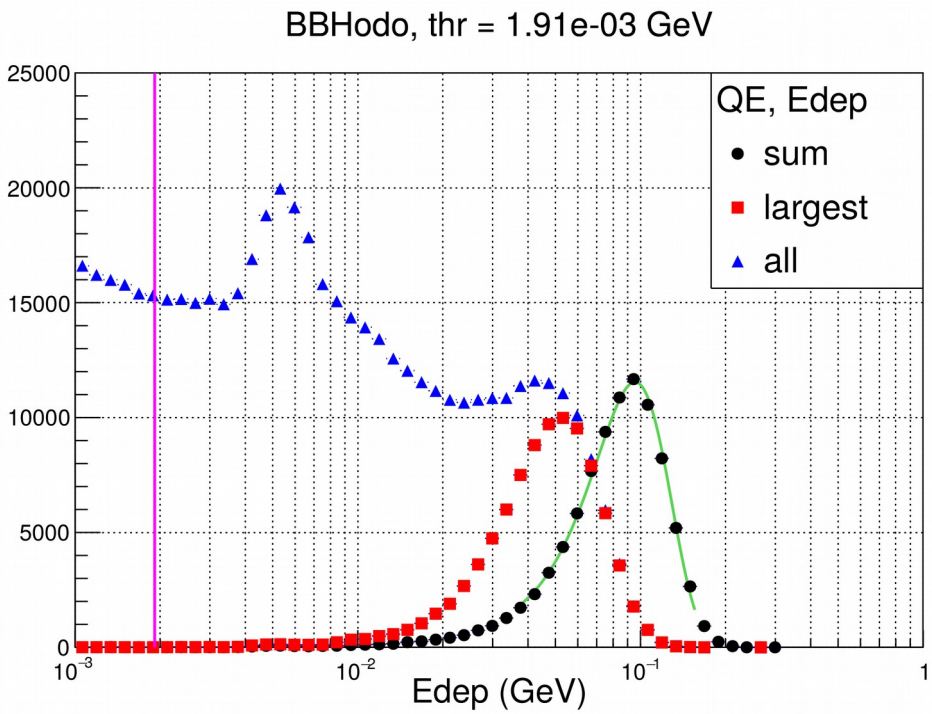
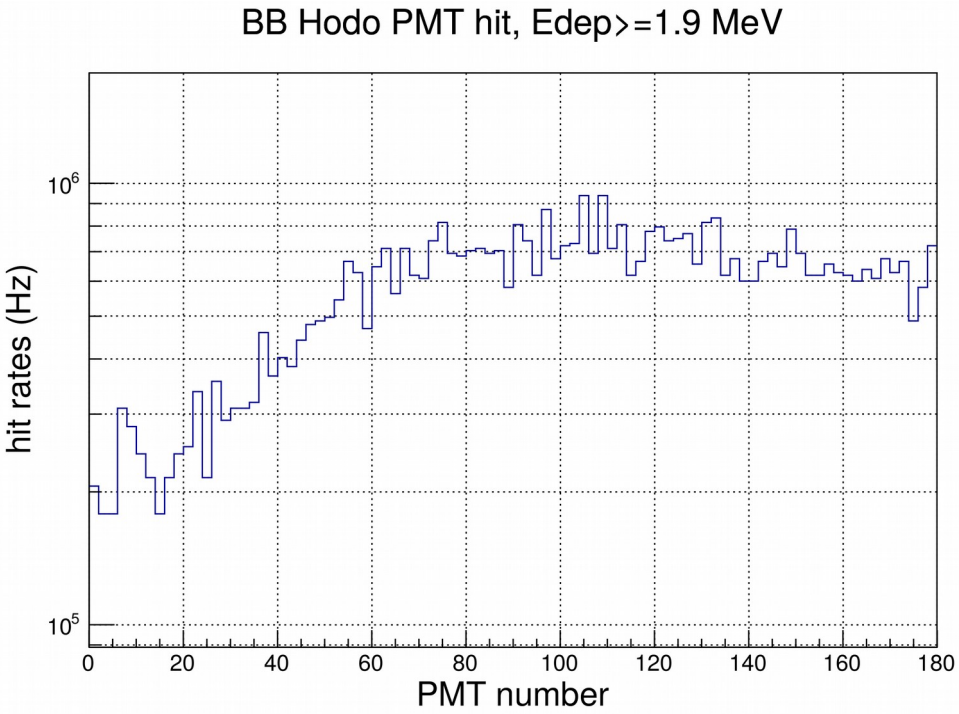
Detector rates / occupancies:
BB Hodoscope



Threshold of individual hits set to 2% of the sum average



Resulting rates: 200-700 kHz
=> Occupancy (80ns gate): 1.6-5.6%

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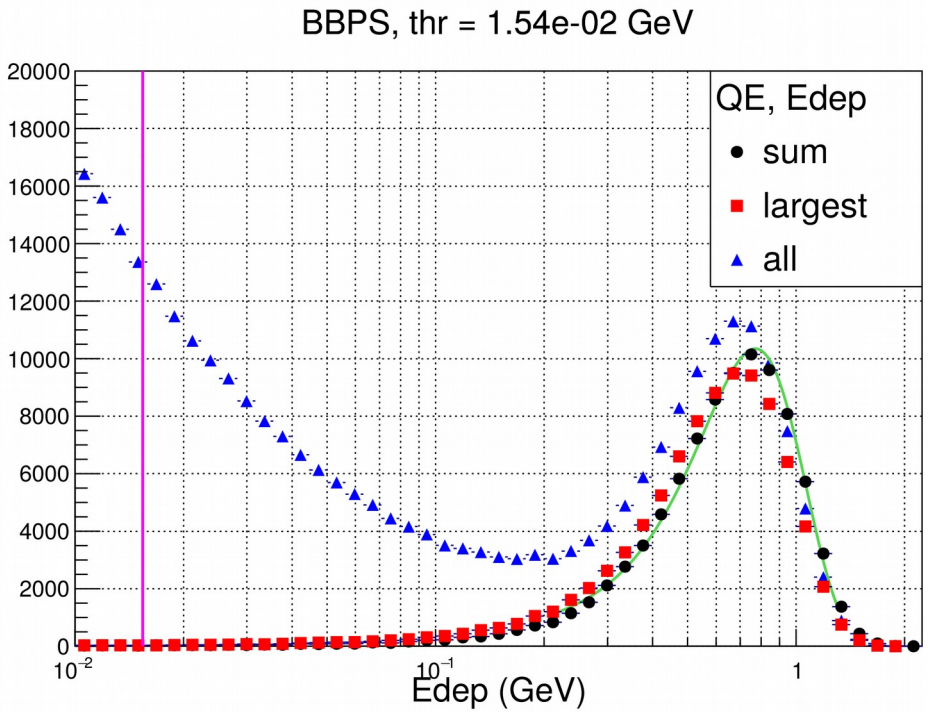
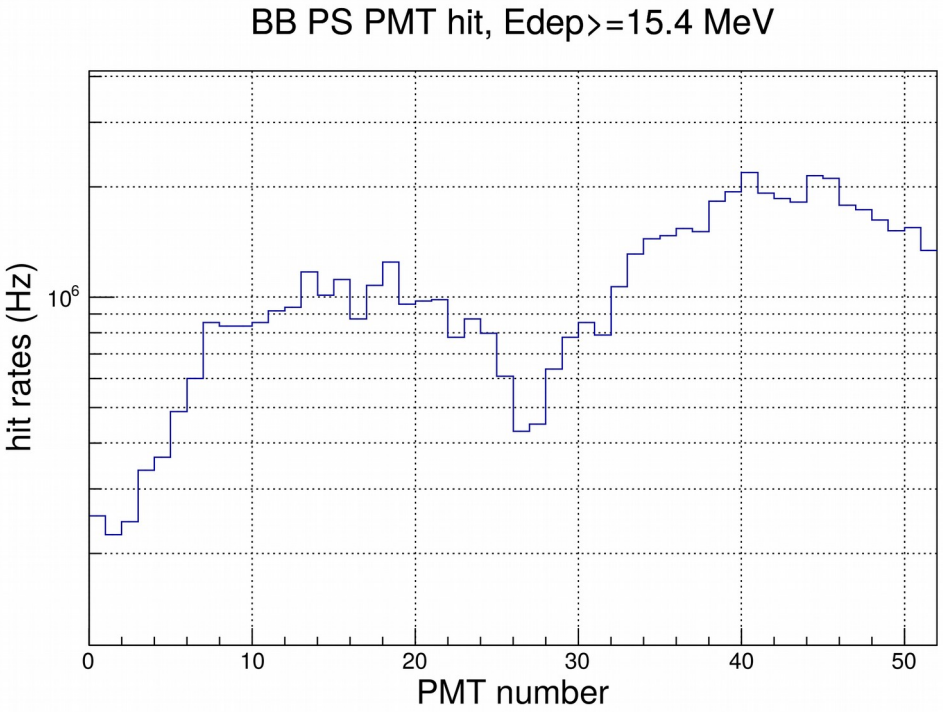
Detector rates / occupancies:
BB PS



Threshold of individual hits set to 2% of the sum average



Resulting rates: 300 kHz - 2 MHz
=> Occupancy (80ns gate): 2.4-16%

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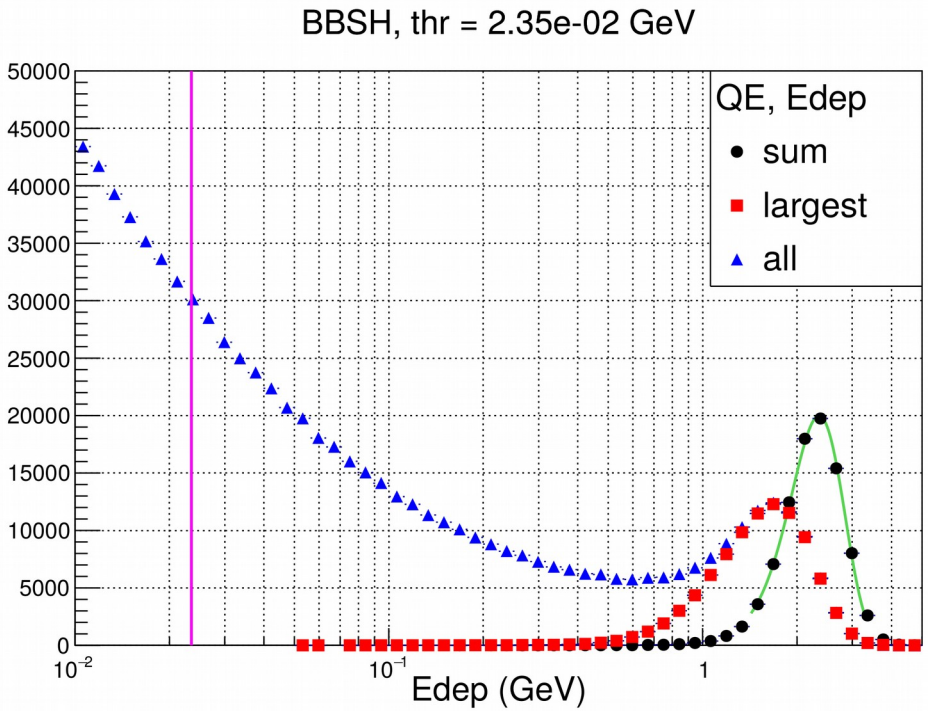
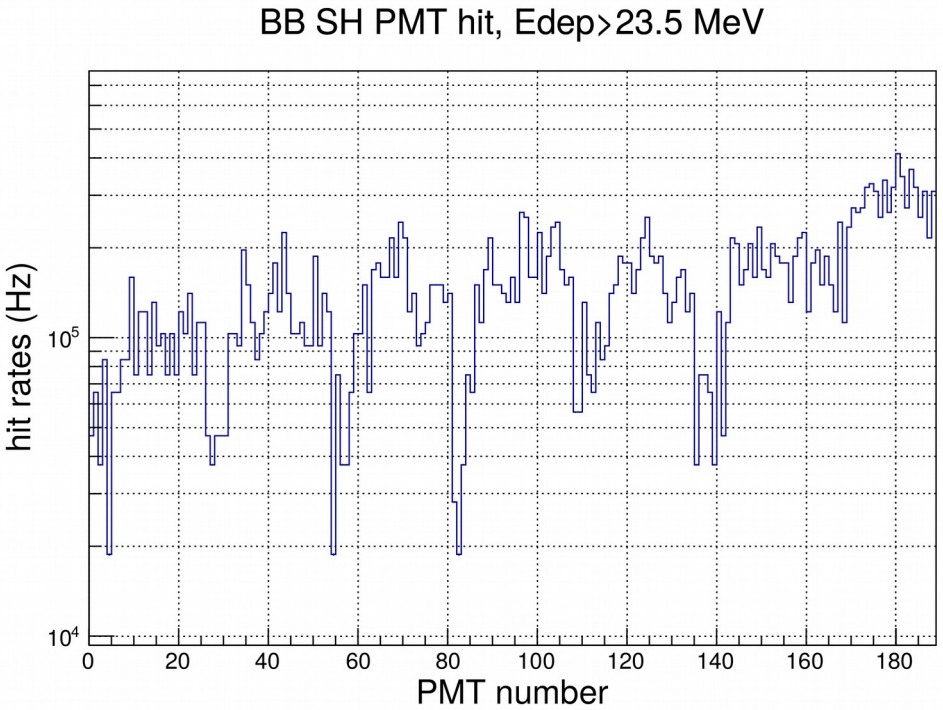
Detector rates / occupancies:
BB SH



Threshold of individual hits set to
1% of the sum average



Resulting rates: 100-200 kHz
=> Occupancy (80ns gate): 0.8-1.6%

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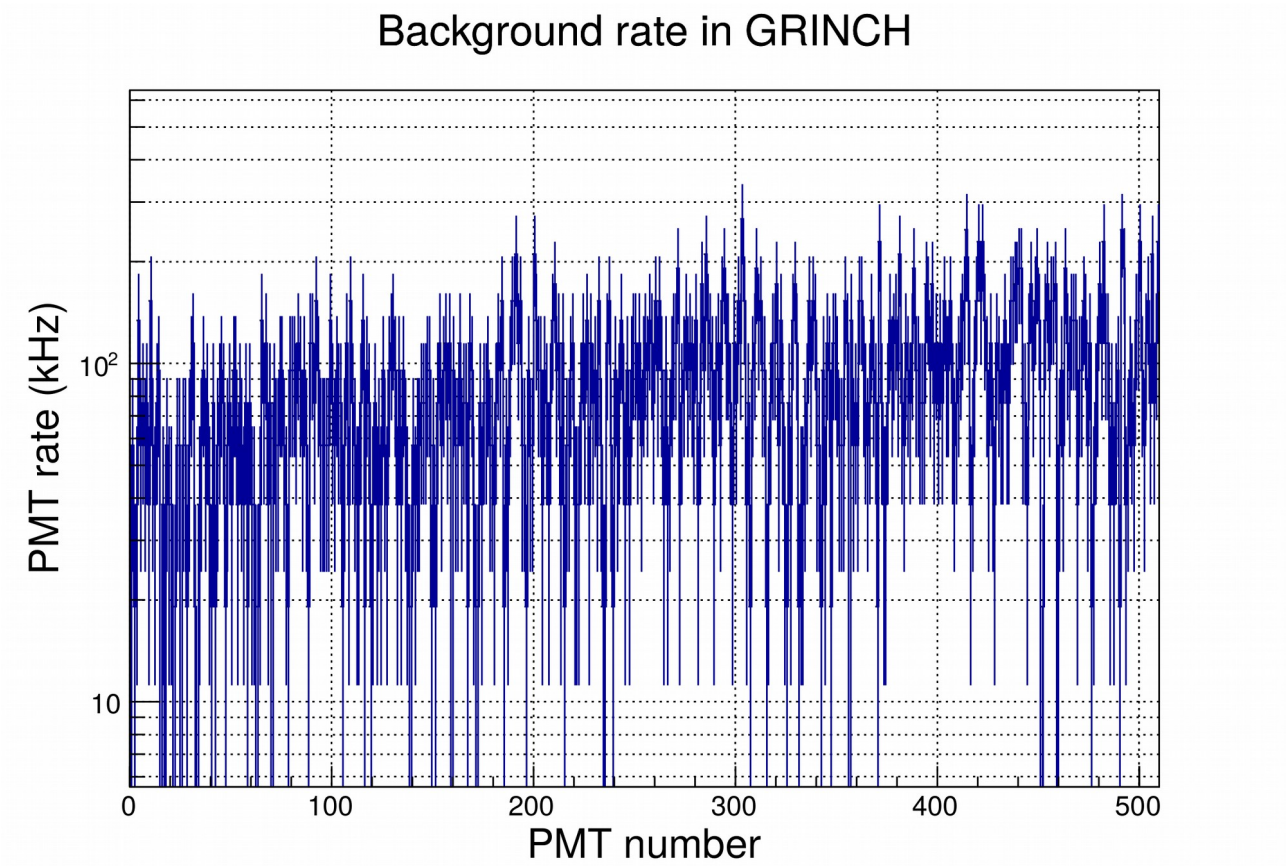
Detector rates / occupancies:
GRINCH



Resulting rates (no threshold!): 50-200 kHz
=> Occupancy (80ns gate): 0.4-1.6%

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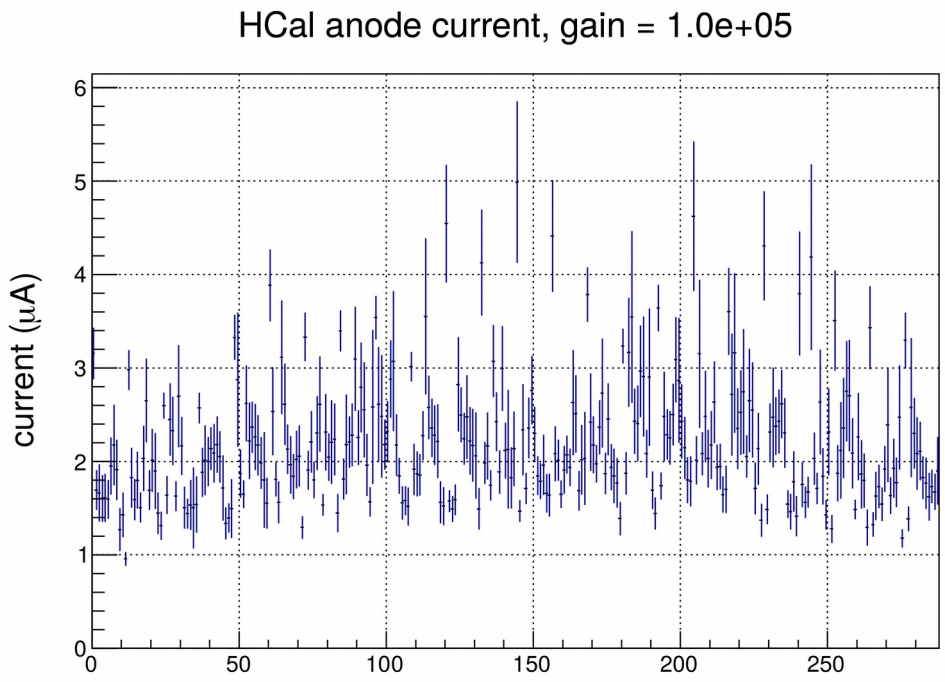
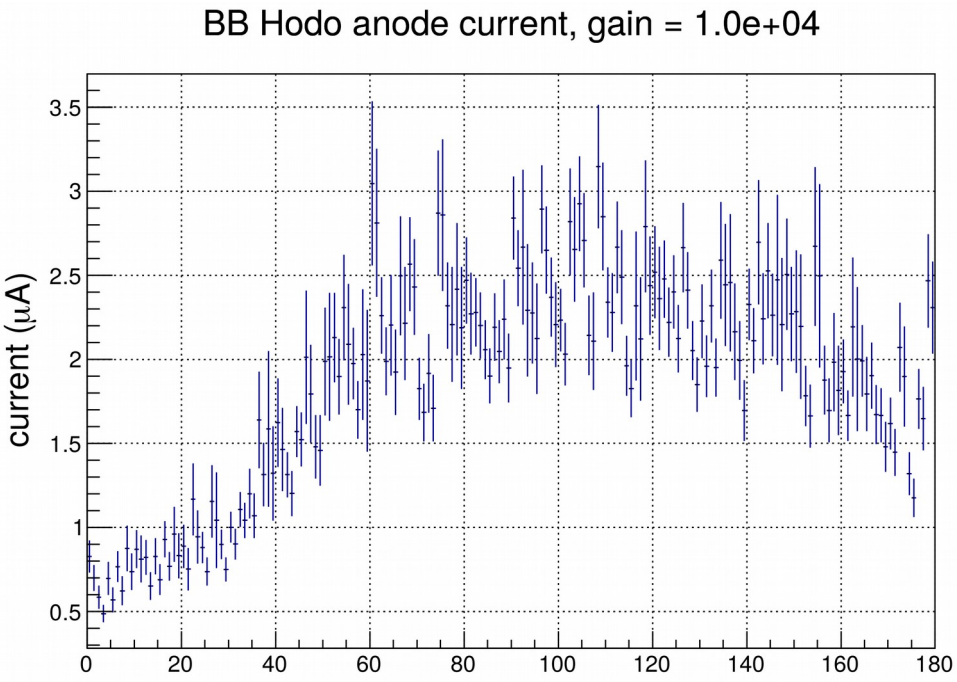
PMTs anode currents:
HCal / hodoscope

Anode current estimation: using the sum of **all** p.e. detected in the PMTs





HCal:
2-5 uA drawn (2.2 uA average);
2-5 mC drawn over GEn 10.18 GeV^2.

BBHodo:
1-3 uA drawn (1.9 uA average);
1-3 mC drawn over GEn 10.18 GeV^2.

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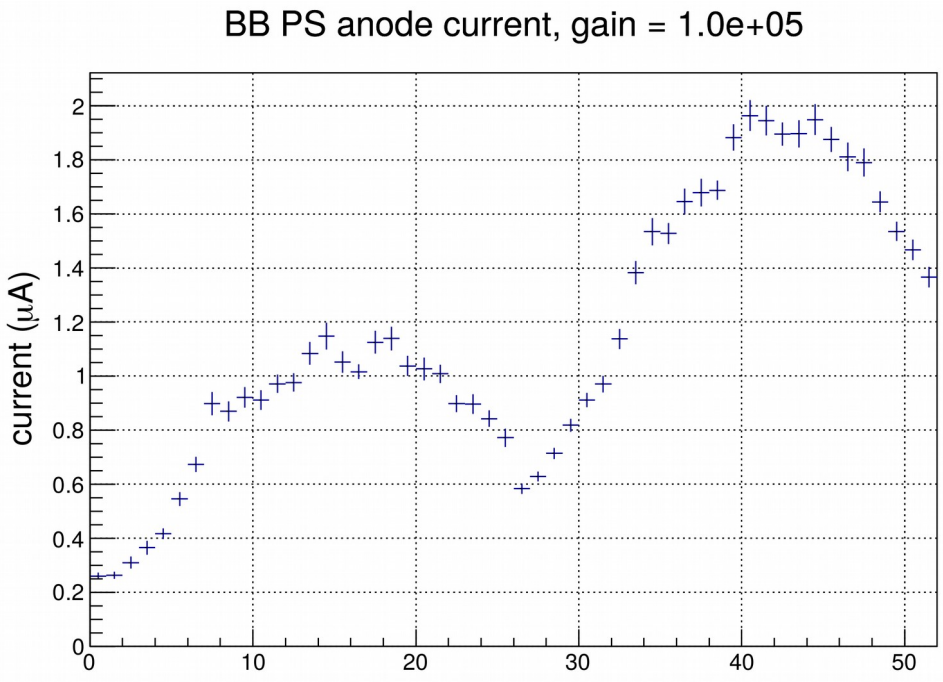
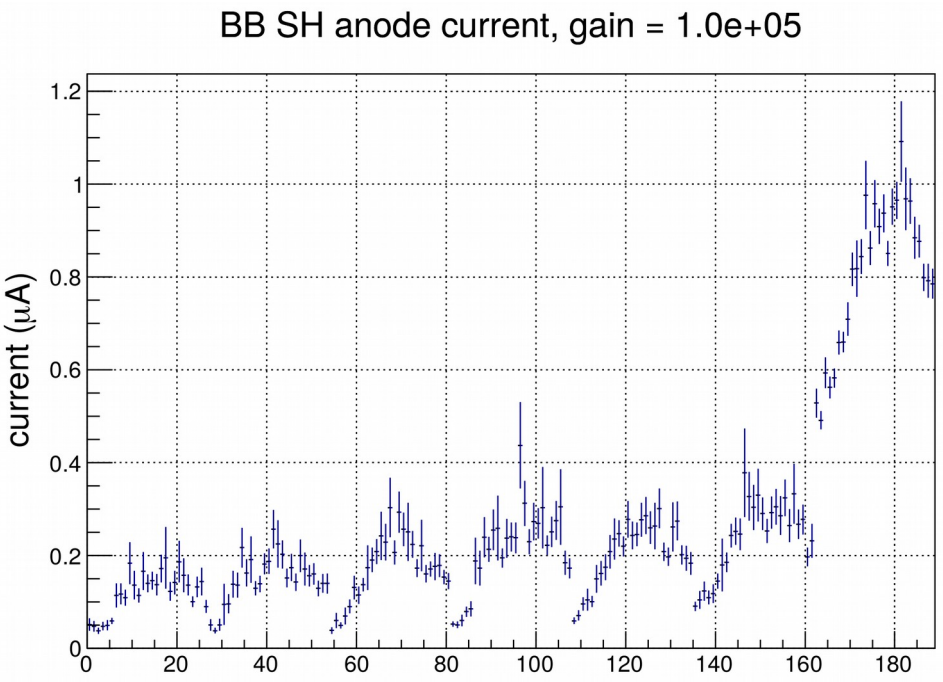
PMTs anode currents:
BB PS

Anode current estimation: using the sum of **all** p.e. detected in the PMTs





PS:
1-2 uA drawn (1.1 uA average);
1-2 mC drawn over GEn 10.18 GeV^2.

SH:
0.2 - 1 uA drawn (0.3 uA average);
0.2 - 1 mC drawn over GEn 10.18 GeV^2.

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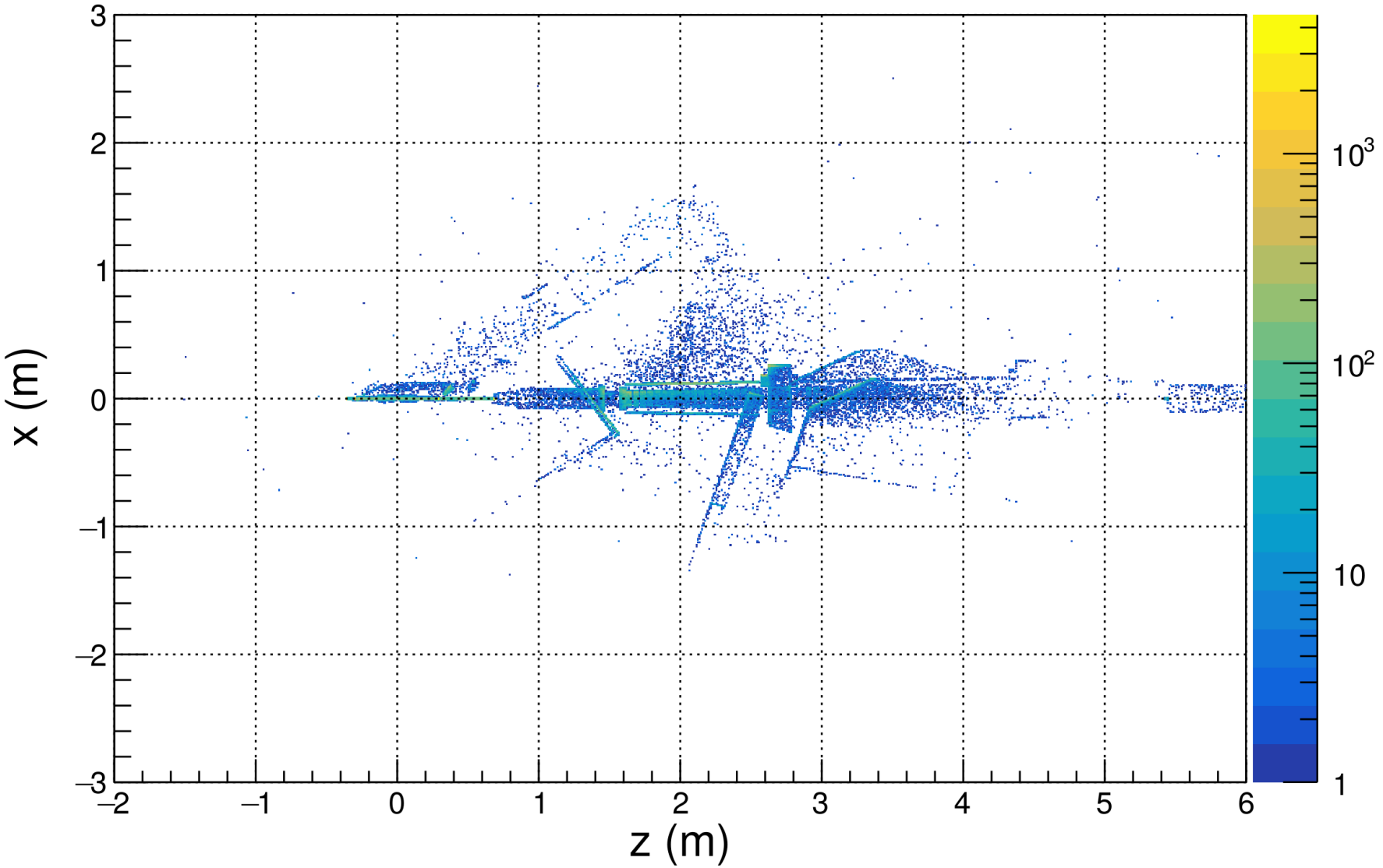
setup number			1	2	3	4	5	6	7	
beam	energy	GeV	4.4	4.4	4.4	4.4	4.4	6.6	8.8	*totals:*
	current	μA (CW)	60.0	60.0	60.0	5.0	60.0	60.0	60.0	
exp't target	element		3He	N	H	C	3He	3He	3He	
	thickness	mg/cm^2	97	904	65	280	97	97	97	
add'l target	element		N	N	N	N	N	N	N	
	thickness	mg/cm^2	26	26	26	97.8	26	26	26	
cryo tgt window	element		Al	Al	Al		Al	Al	Al	
	thickness	mg/cm^2	83	83	83		83	83	83	
entrance window	element		Be	Be	Be	Be	Be	Be	Be	
	thickness	mg/cm^2	46.9	46.9	46.9	46.9	46.9	46.9	46.9	
	element		Al	Al	Al	Al	Al	Al	Al	
	thickness	mg/cm^2	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
exit window	element		Be	Be	Be	Be	Be	Be	Be	
	thickness	mg/cm^2	93.9	93.9	93.9	93.9	93.9	93.9	93.9	
	element		Al	Al	Al	Al	Al	Al	Al	
	thickness	mg/cm^2	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
	run time	hours	10	10	10	10	41	165	929	**1175**
	installation	hours								**0**
	time	days	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	μrem/hr	0.88	3.24	0.73	0.12	0.88	0.98	1.06	
	method 2	μrem/hr								
	conservative	μrem/hr	0.88	3.24	0.73	0.12	0.88	0.98	1.06	
dose per setup		μrem	9	32	7	1	36	161	985	**1231**
% of annual dose budget		%	0.1	0.3	0.1	0.0	0.4	1.6	9.8	**12.3%**
% of allowed dose for the total time										**91.7%**
% of allowed dose for the run time										**91.7%**

Table 1: Estimated radiation budget for GEn. Radiation rate numbers are taken from the GMn E12-09-019 radiation budget form and rescaled by luminosity and material thicknesses.

Detector rates / occupancies:
GEMs

Vertices of tracks causing GEM hits.



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