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

Preliminary 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**

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	90	70	60	280	90	90	90	
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		N	N	N	N	N	N	N	
target 2	thickness	mg/cm2	24.65	24.65	24.65	94.55	24.65	24.65	24.65	
cryo tgt	element		Al	Al	Al		Al	Al	Al	
window	thickness	mg/cm2	38.6	38.6	38.6		38.6	38.6	38.6	
exit	element		Be	Be	Be	Be	Be	Be	Be	
window	thickness	mg/cm2	93.8	93.8	93.8	93.8	93.8	93.8	93.8	
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	0.55	0.52	0.39	0.09	0.55	0.63	0.69	
the fence post	method 2	urem/hr								
(run time)	conservative	urem/hr	0.55	0.52	0.39	0.09	0.55	0.63	0.69	
dose per setup		urem	6	5	4	1	23	104	643	784.6
% of annual dose budget		%	0.1	0.1	0.0	0.0	0.2	1.0	6.4	7.846
% of allowed dose for the total time										58.5
% of allowed dose for the run time only										58.5

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

date form issued: October 15, 2020 *authors:* P.Degtiarenko

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Radiation budget for GEn

Using same material thicknesses, my rough estimations and Pavel's simulation results are in rough agreement;
My numbers are slightly higher

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.

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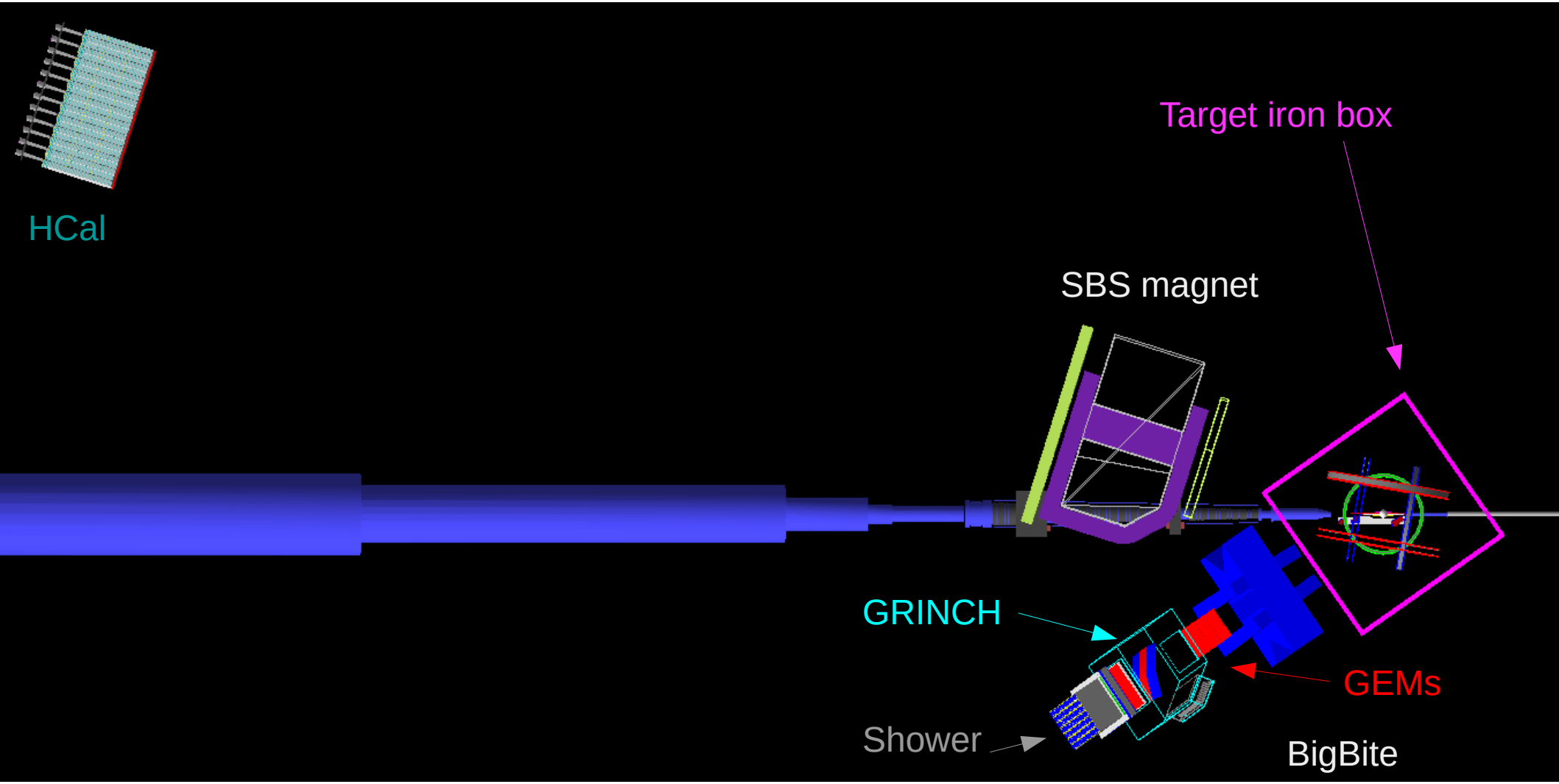
GEn geometry implementation in G4SBS



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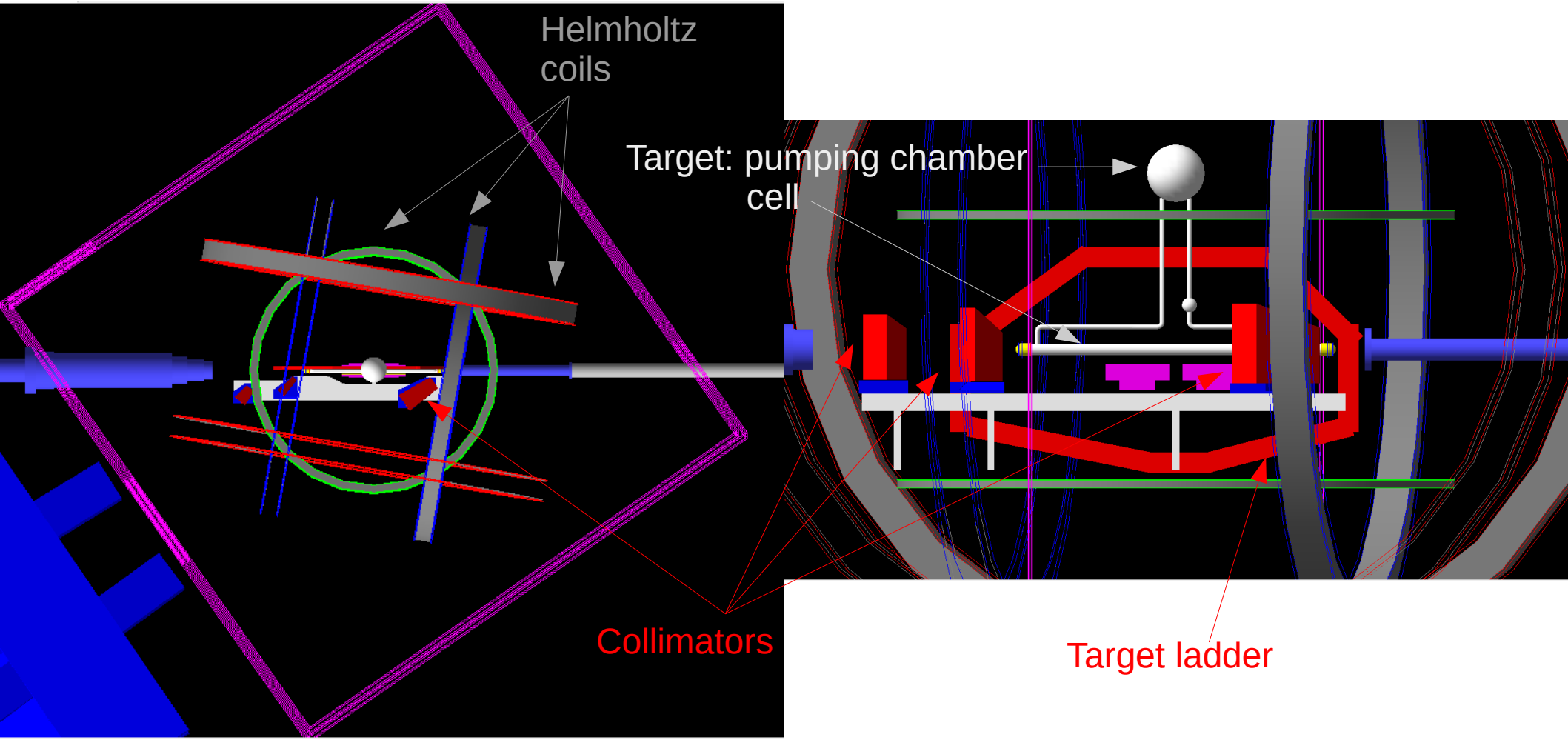
GEn geometry implementation in G4SBS

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



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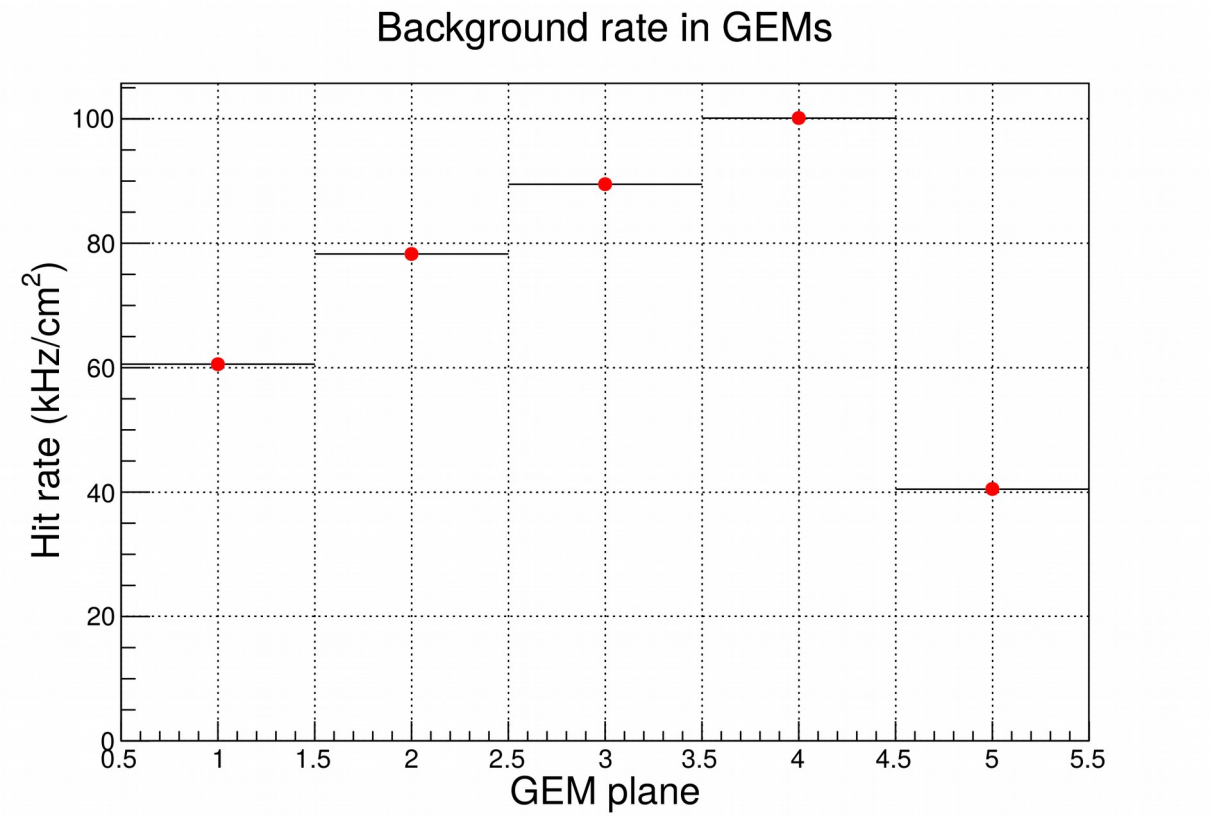
Detector rates / occupancies:
GEMs



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;

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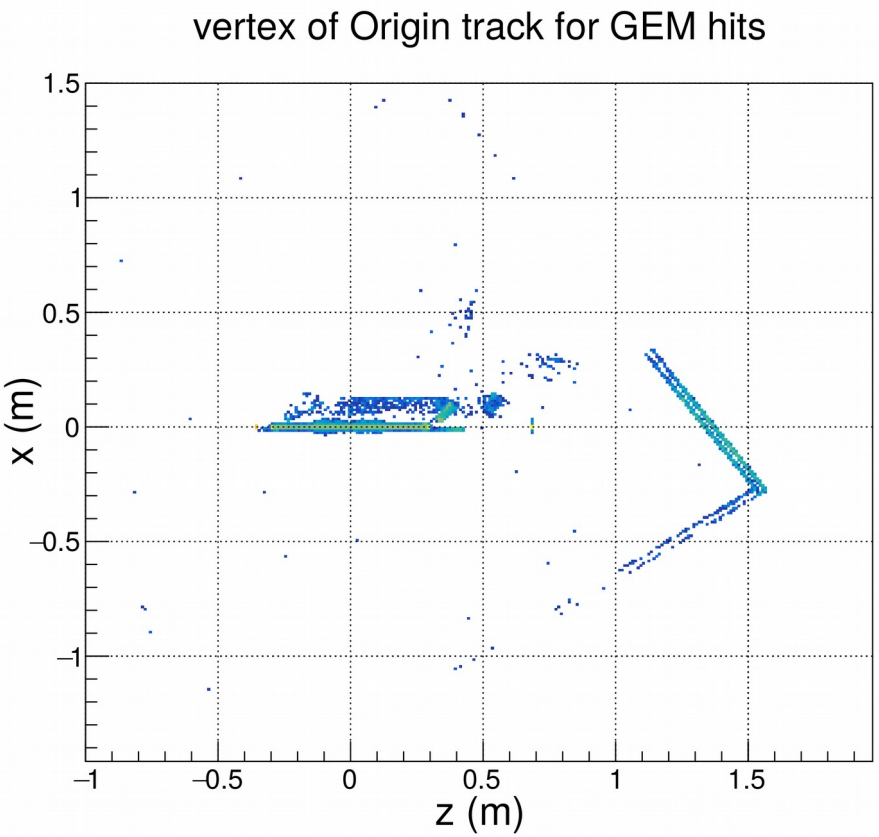
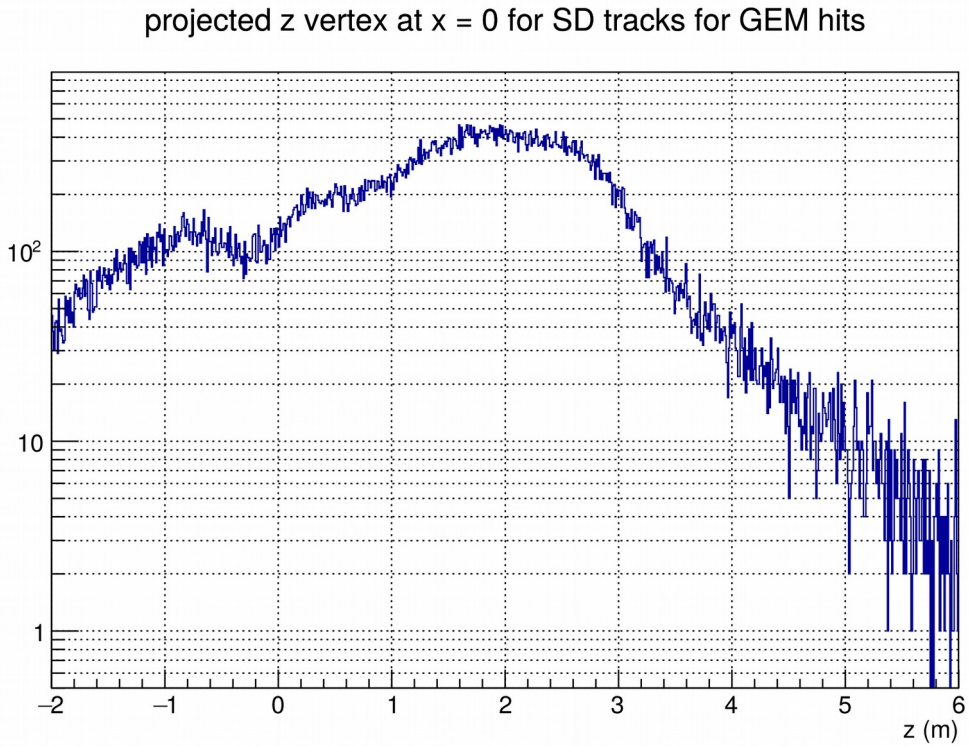
Detector rates / occupancies:
GEMs

Origin of GEM background:



Target area



A significant fraction of the background does come from the downstream beam pipe and could probably be shielded.

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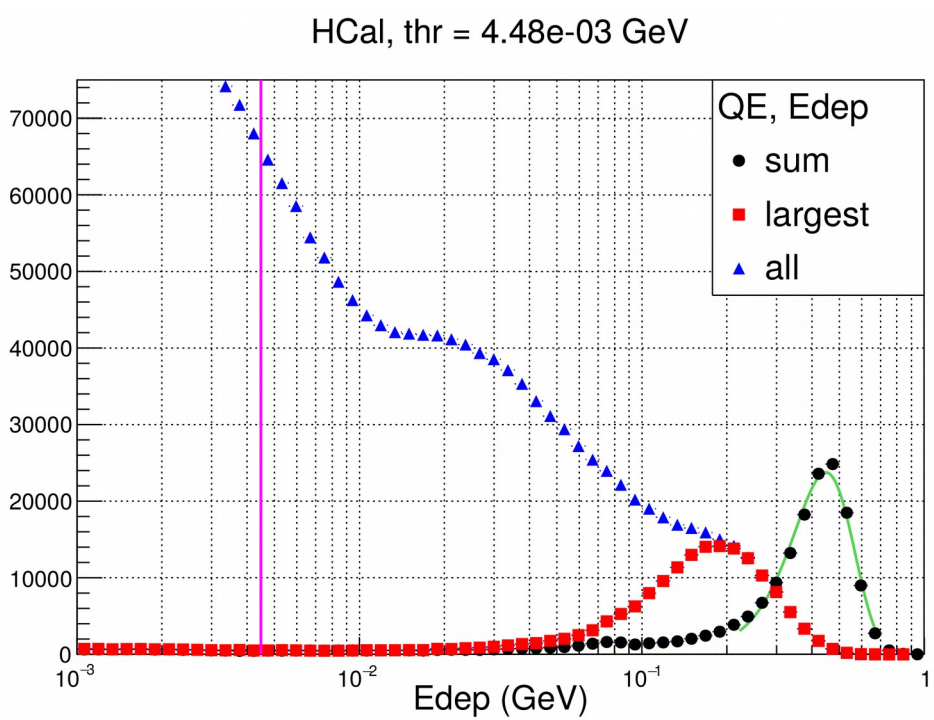
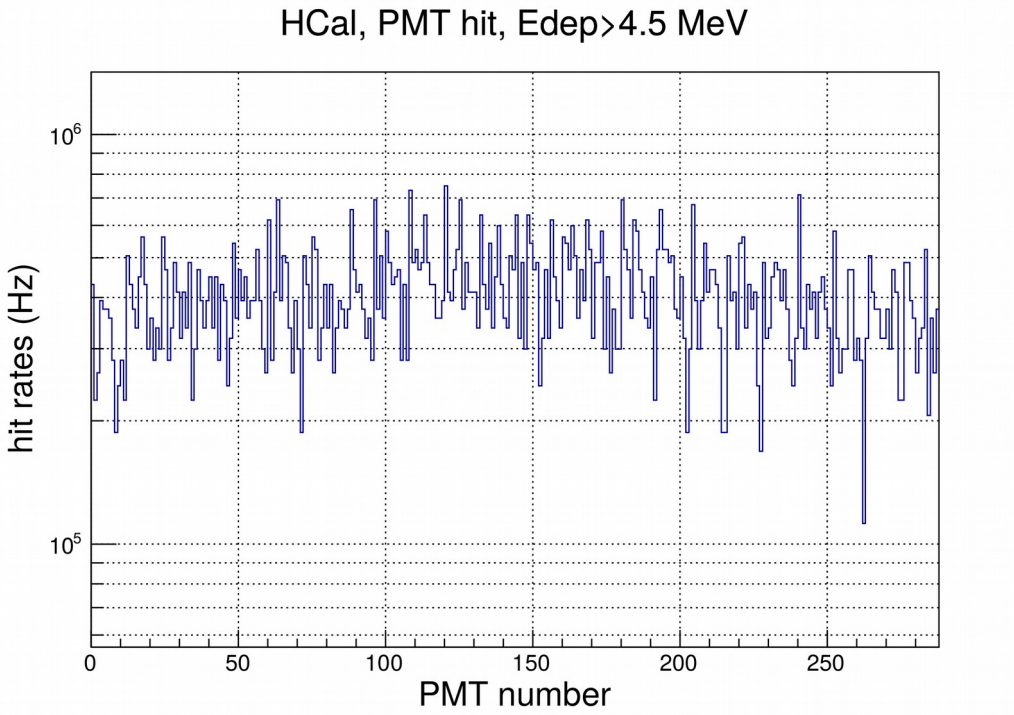
Detector rates / occupancies:
HCal



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



Resulting rates: 300-500 kHz
=> Occupancy (100ns gate): 3-5%

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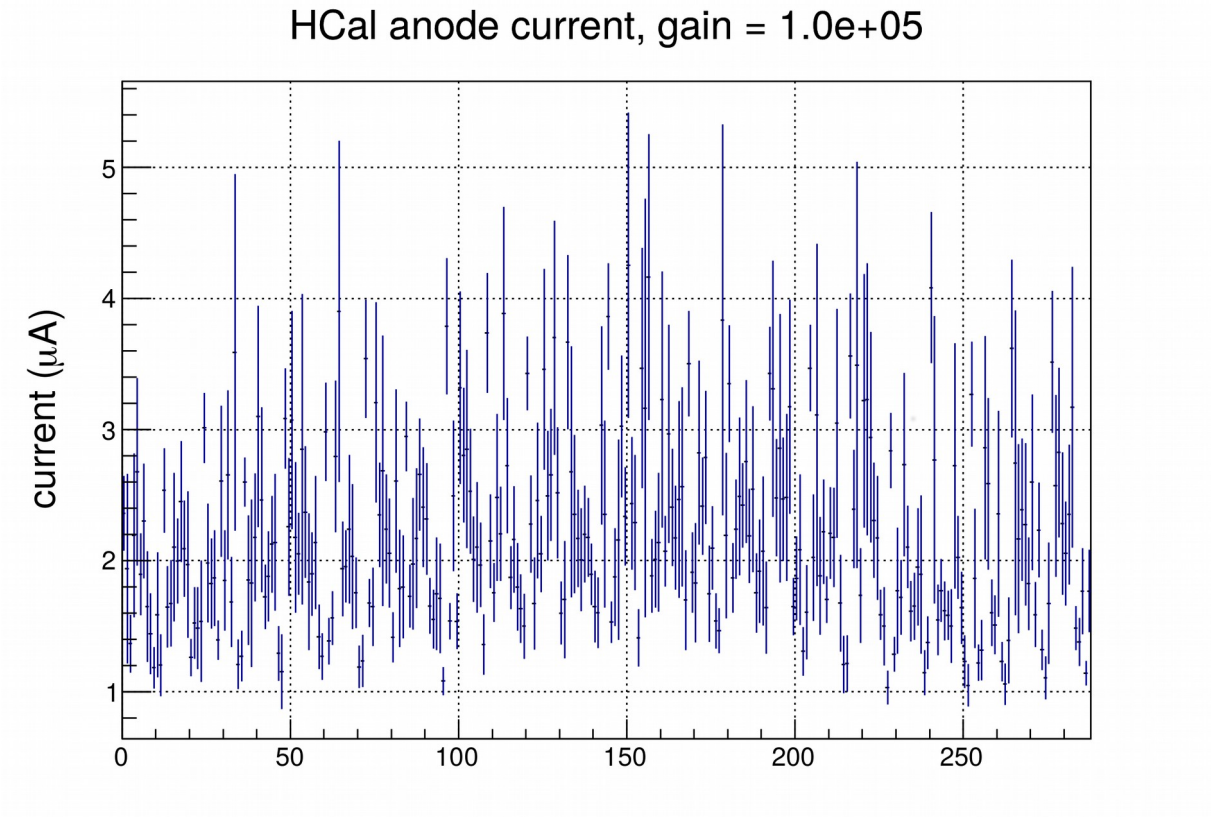
PMTs anode currents:
HCal

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



2-5 uA drawn: 2-5 mC drawn over GEn 10.18 GeV2 alone

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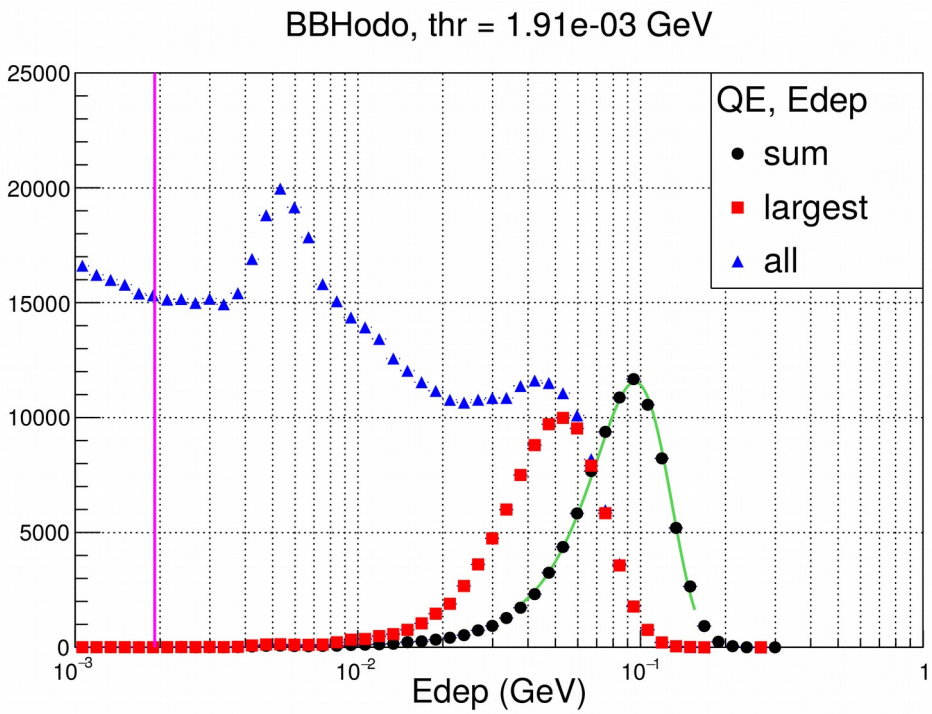
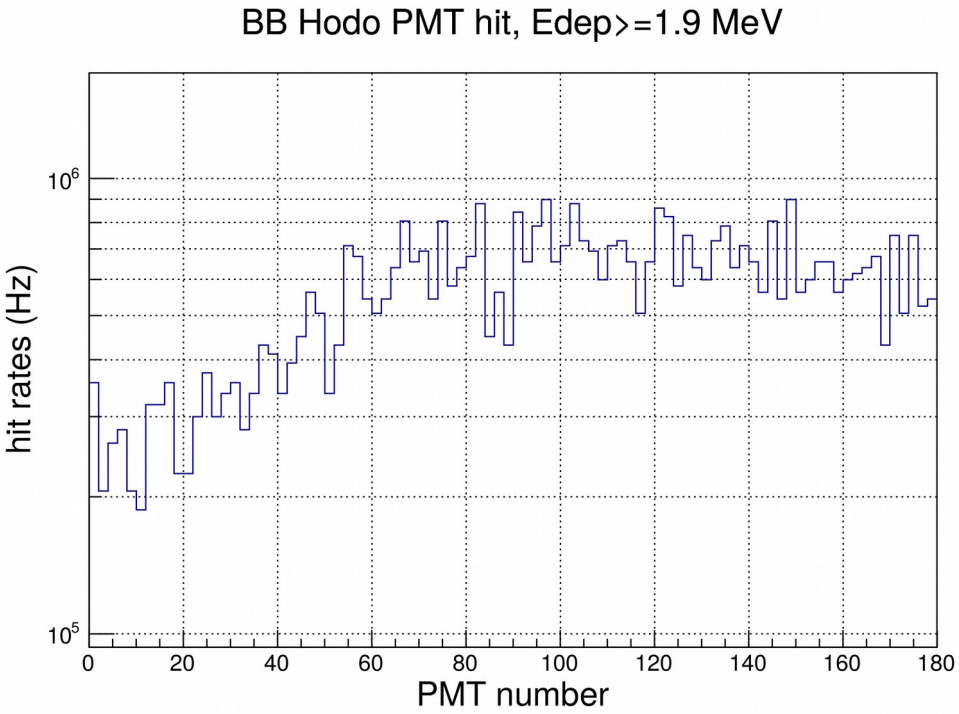
Detector rates / occupancies:
BB Hodoscope



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



Resulting rates: 200-500 kHz
=> Occupancy (100ns gate): 2-5%

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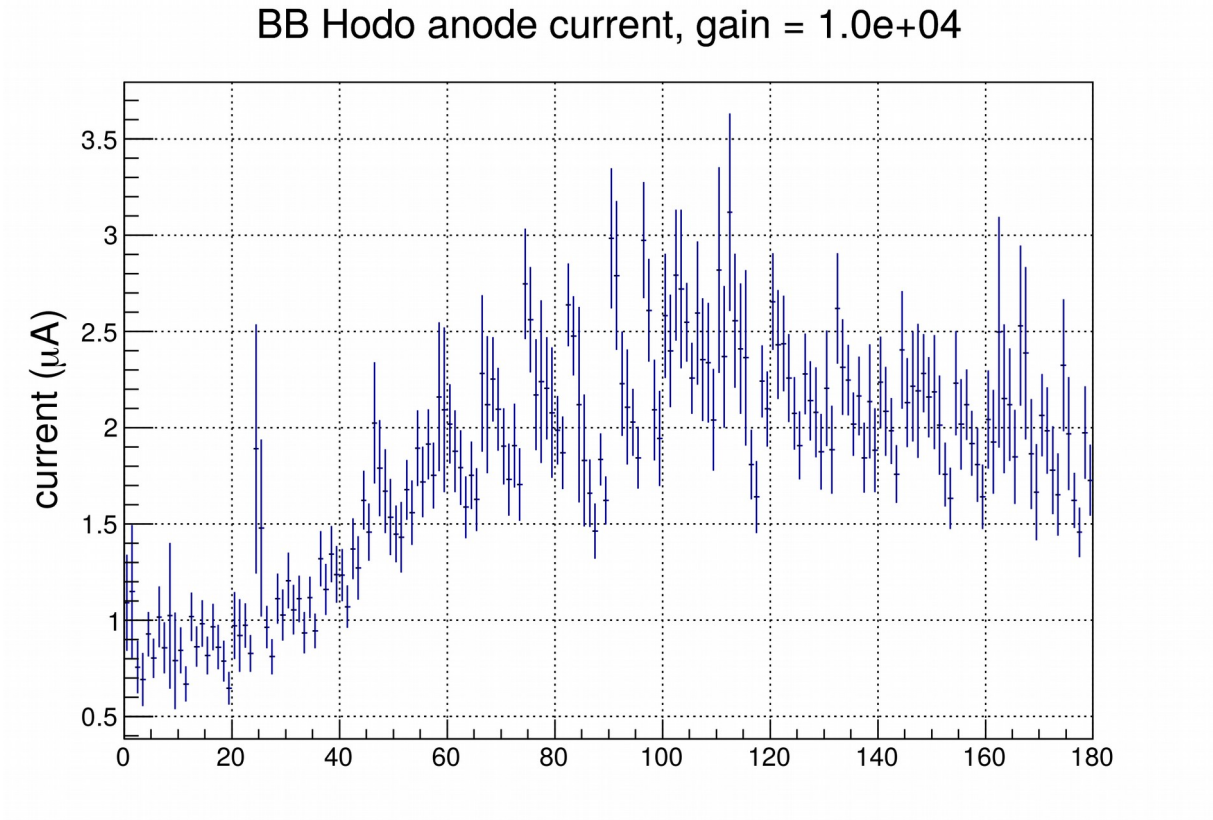
PMTs anode currents:
BB Hodoscope

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



1-3 uA drawn: 1-3 mC drawn over GEn 10.18 GeV2 alone

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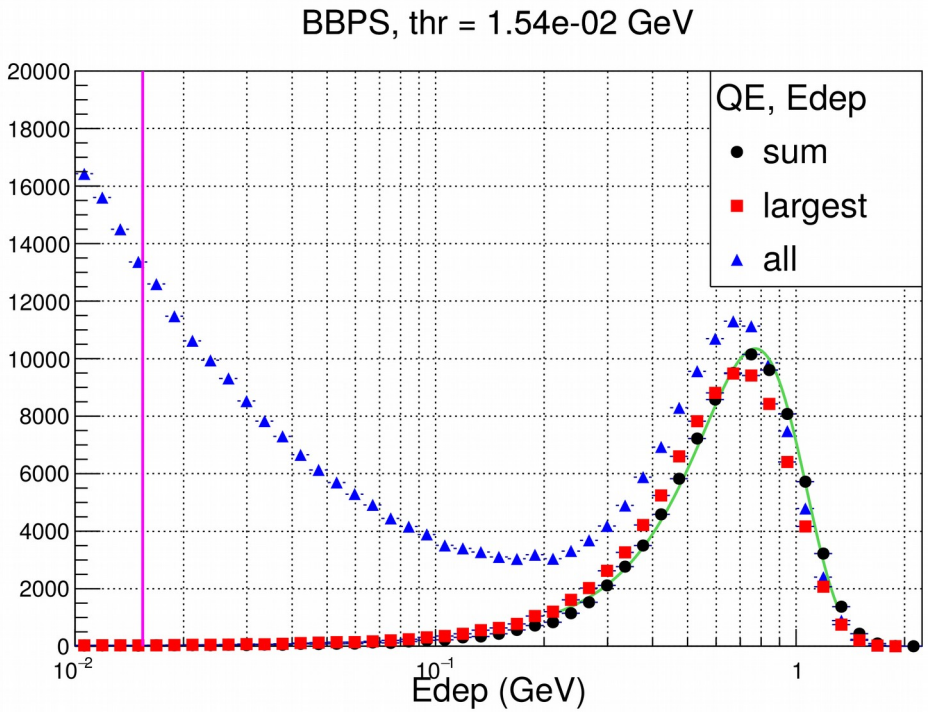
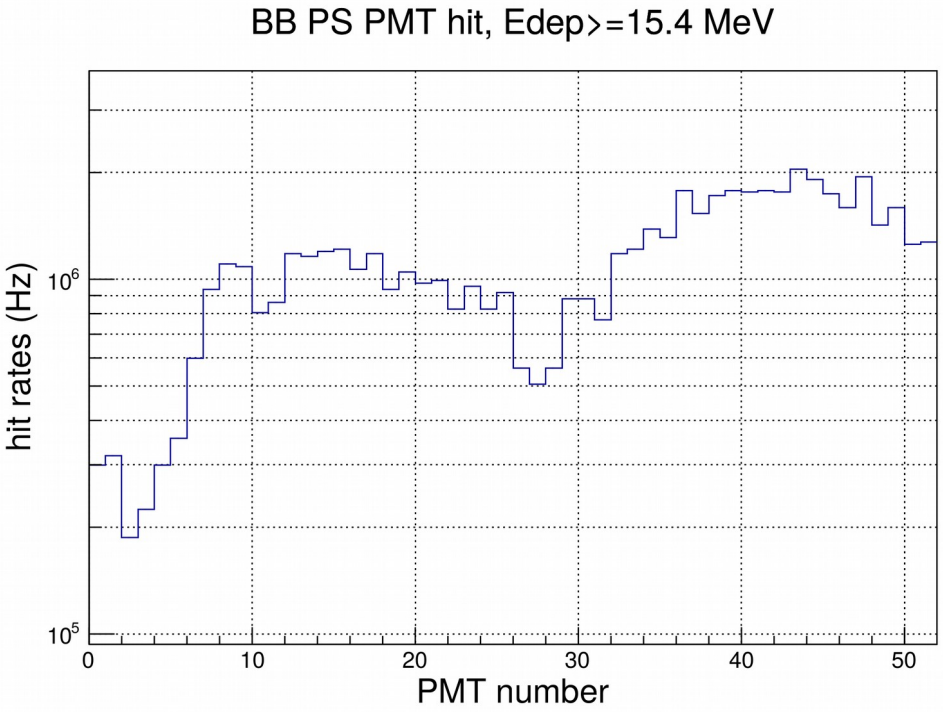
Detector rates / occupancies:
BB PS



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



Resulting rates: 300 kHz - 2 MHz
=> Occupancy (100ns gate): 3-20%

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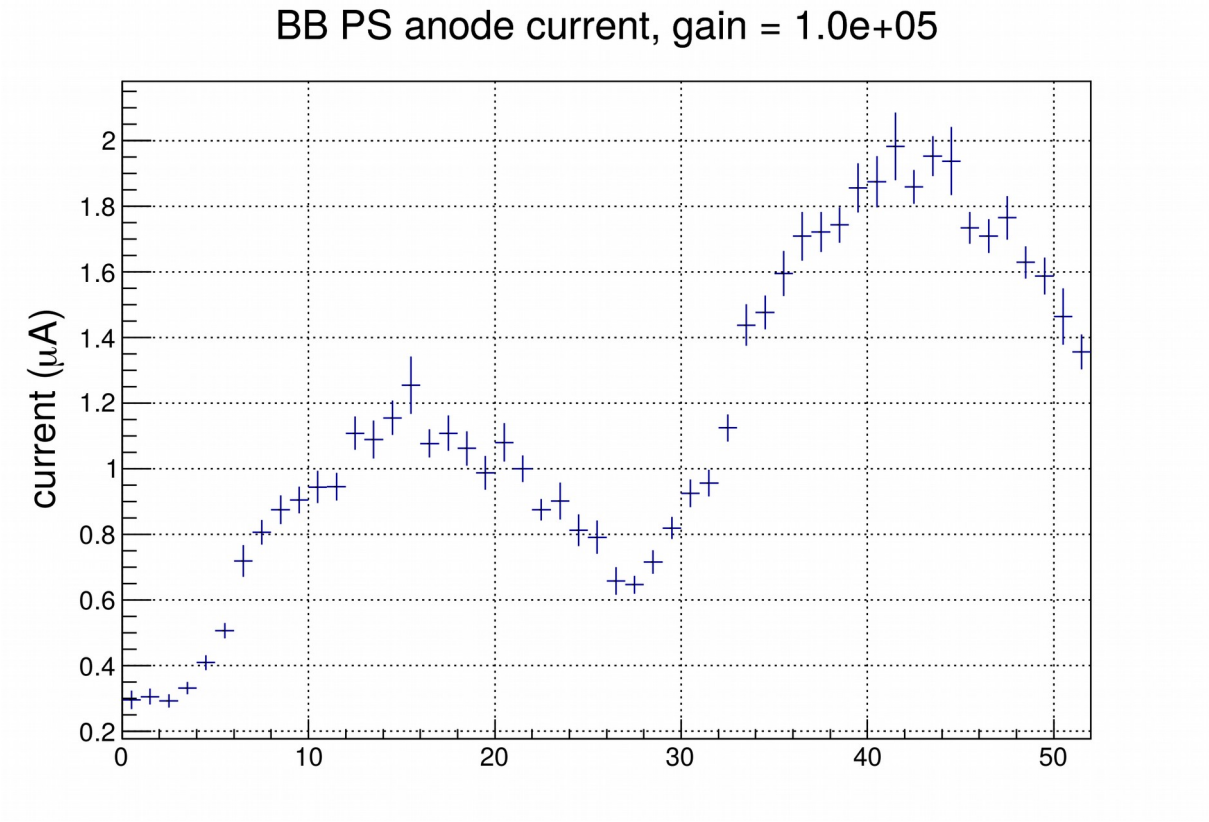
PMTs anode currents:
BB PS

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



1-2 uA drawn: 1-2 mC drawn over GEn 10.18 GeV2 alone

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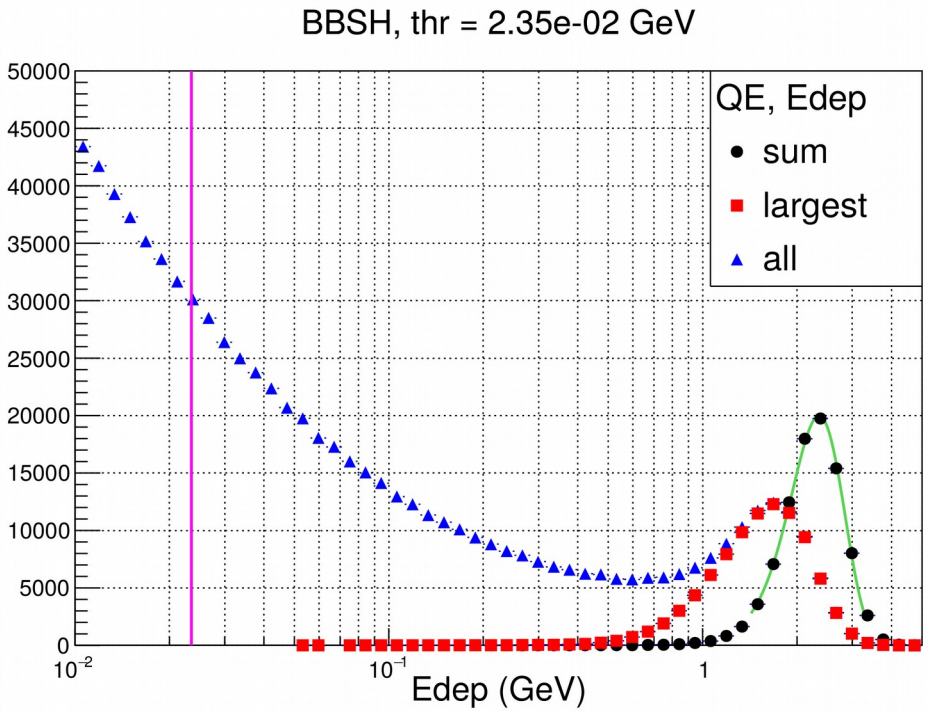
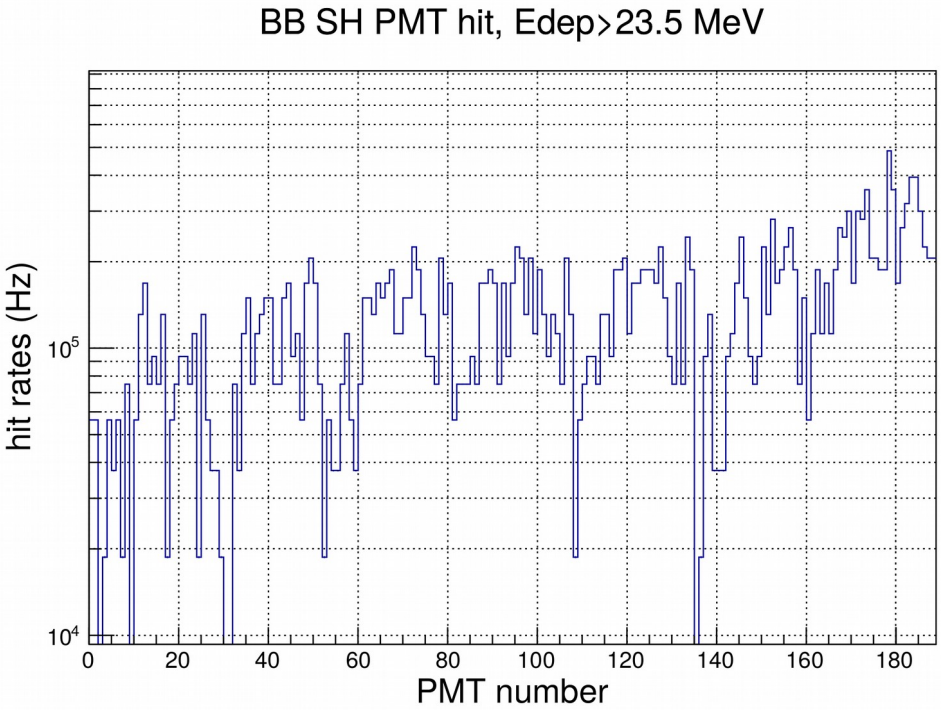
Detector rates / occupancies:
BB SH



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



Resulting rates: 100-200 kHz
=> Occupancy (100ns gate): 1-2%

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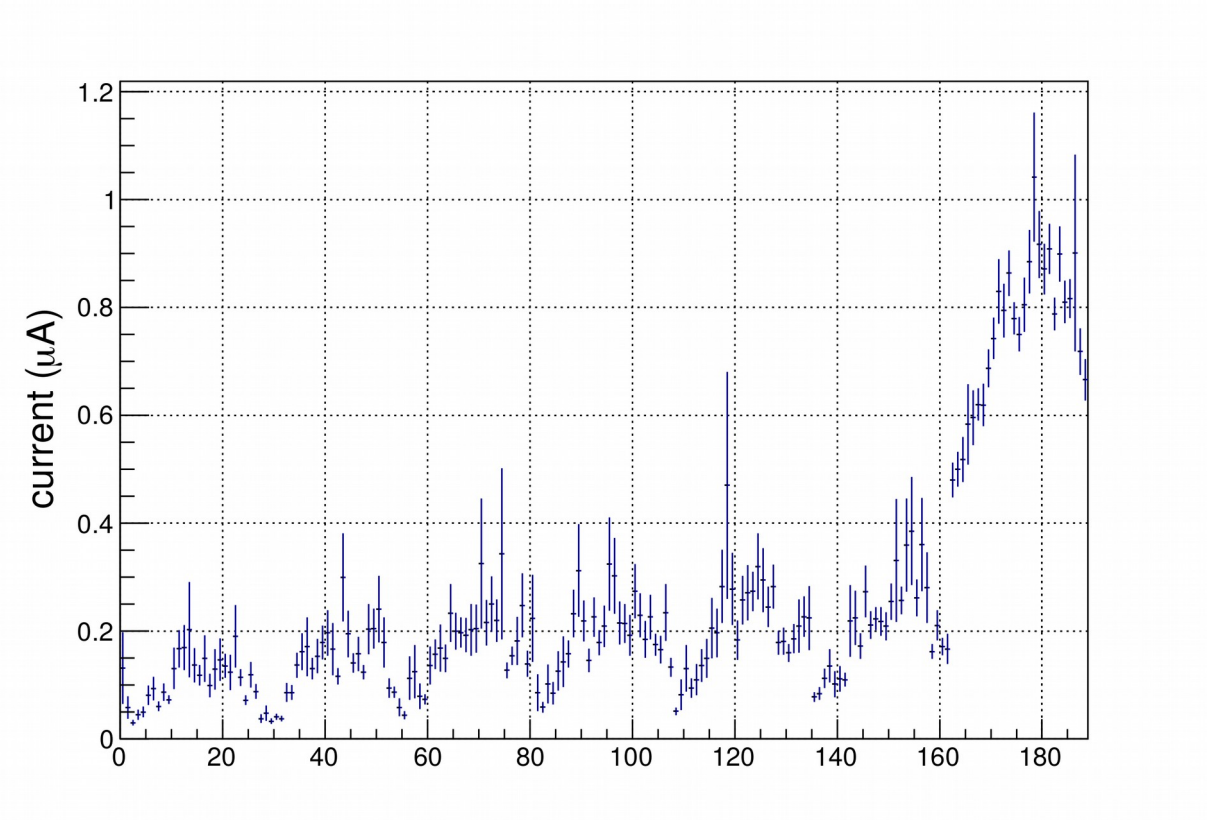
PMTs anode currents:
BB SH

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



0.2 - 1 uA drawn: 0.2 - 1 mC drawn over GEn 10.18 GeV2 alone

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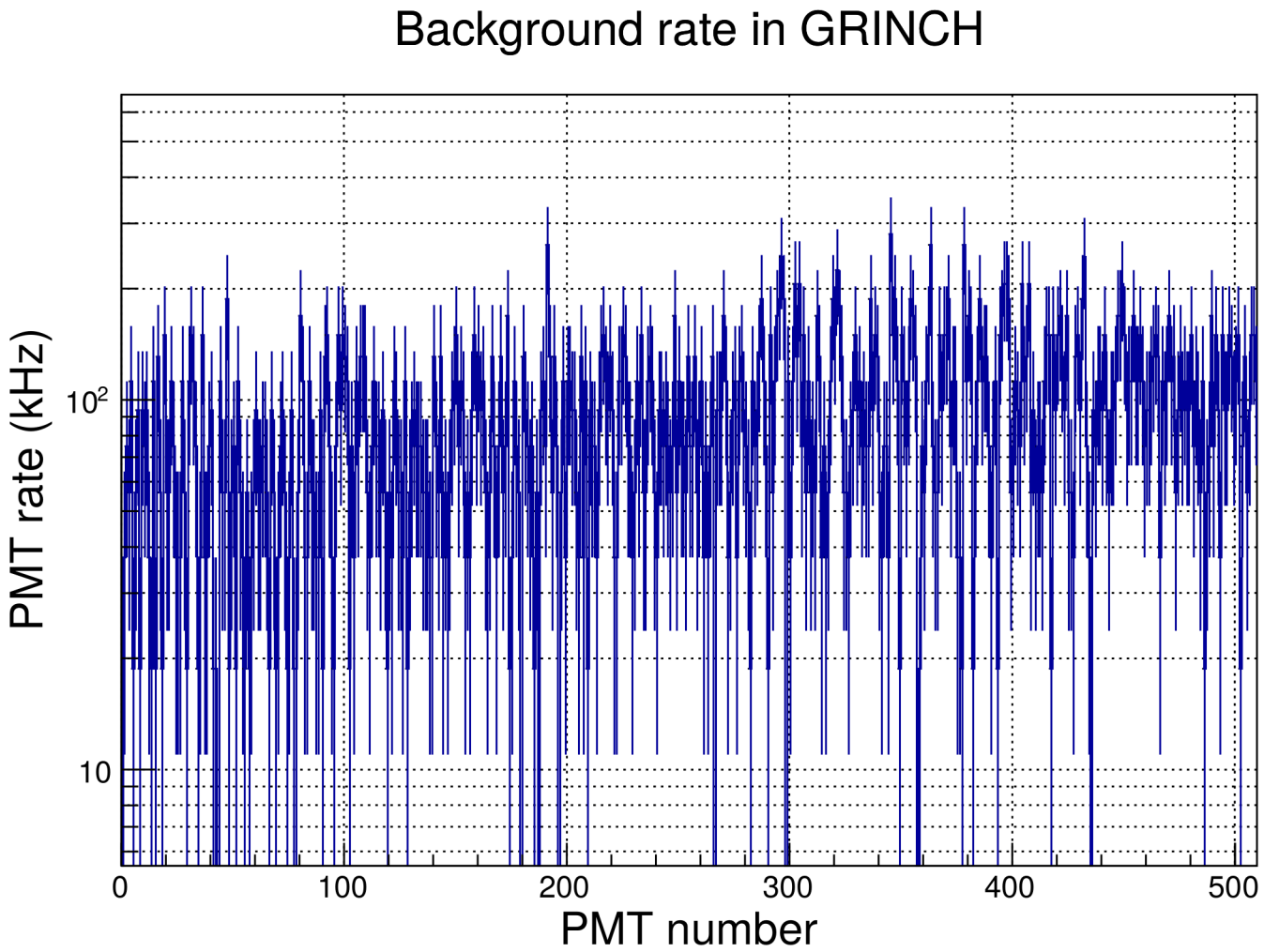
Detector rates / occupancies:
GRINCH



Resulting rates: 100-200 kHz
=> Occupancy (100ns gate): 1-2%
Number of PMTs low enough that current drawn is not a concern

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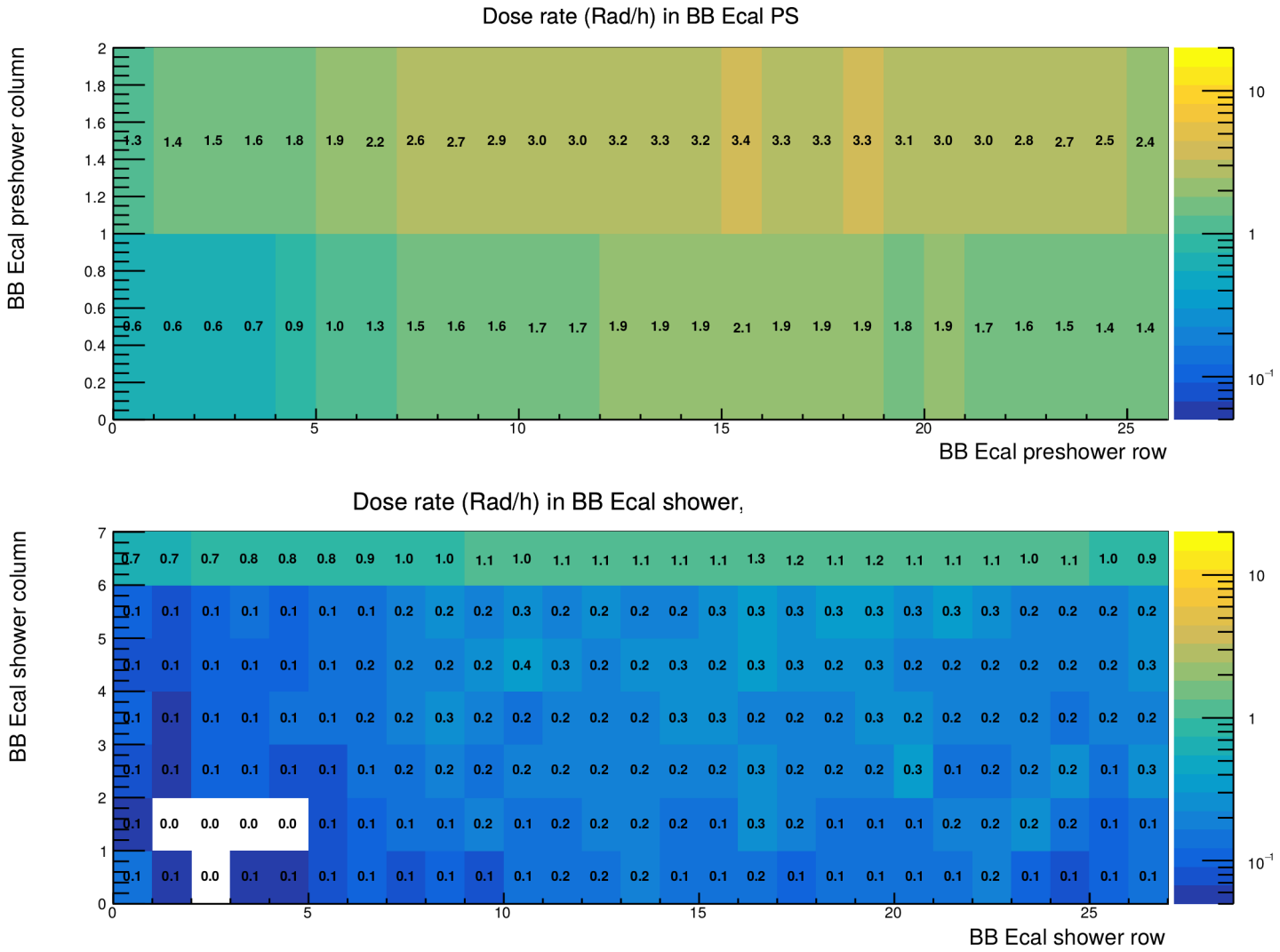
Dose rate in BB PS/SH



Dose rate around 3 Rad/h for BB PS. BBPS blocks changed for GMn, to withstand higher does rates.

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 12.3% of the radiation budget, and less than 100% of the budget allowed for the running period.
The estimations are not finalized, but the worse estimation should be conservative.

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

The background levels in the equipment are acceptable and should not significantly affect their performances
However, our simulations show that we might achieve a further reduction of the background levels by shielding the BigBite detector from the beam line.

Backup