MonteCarlo results: nBLM response to ESS scenarios

Laura Segui
IRFU-CEA/Saclay

nBLM PDR1.2 review meeting
10/07/2017

OUTLOOK

- Simulations strategy
- Accidental vs 0.01 W/m scenarios
    - Slow module
    - Fast module
- Detector position studies
- Conclusions

Simulations Strategy

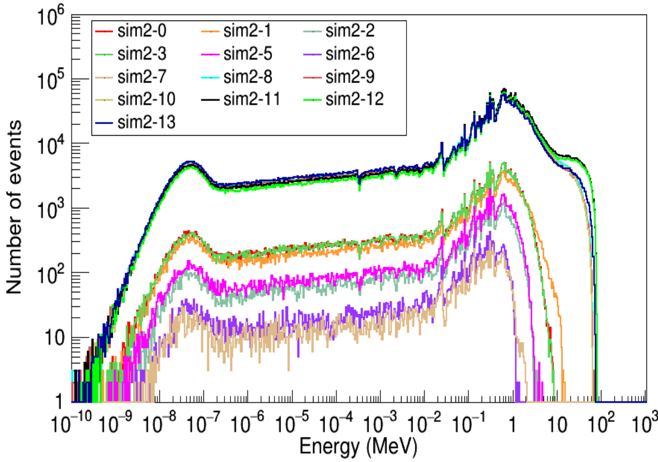
Discussed in PDR1.1

- Simulations performed by the BI-ESS group and summarized in report *CHESS, ESS-0066428, 2016: I. Dolenc Kittelman, "Report regarding the MC simulation for BLM-focus on the nBLM"* [1]
  - Simulate loss scenarios, save secondary produced particles that enter in a nBLM phantom volume placed along the DTL.
- The output (*mcpl* format) → the input in the nBLM simulations
- In the mcpl file there are for each produced particle:
  - Particle energy
  - Momentum
  - Position
  - Time
  - Plus a pdgCode to identify the particle
- Time from ESS simulation has been added to the G4-nBLM simulation *GlobalTime*
  - Time from the ESS simulation == time since proton lost to particle creation
  - G4-nBLM *GlobalTime* == time since particle creation in the geant4 simulation to interaction in the gas in the nBLM chamber.

→ Therefore, we are taking into account the total time since lost starts until detection in the nBLM detectors. In [1] it is specified that the lost has been considered instantaneous and therefore, the time of the development of the lost is not included.

Simulations Strategy

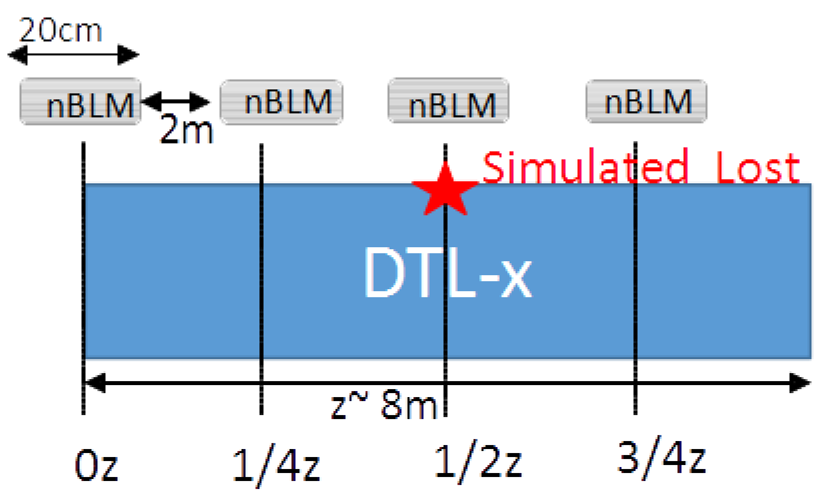
- 13 localized loss scenarios simulated in [1]
  - All in DTL-1 and DTL-5
  - Known number of protons, fix energy, lost in a point
- Used 7/13 as the nBLM-G4 input
- Different parameters some of them
  - Pencil beam vs Gaussian (σ_{xy} =0 or 1)
  - Opposite direction than the nBLM phantom volume



ESS file	Loss location	Proton Energy (MeV)	Protons simulated	Bunches simulated	Neutrons produced in scenario	N's/ bunch	Comments
sim2-0	Mid DTL-1	11.5	6.00E+08	5.45E-01	2.90E+05	5.31E+05	Max θ in DTL1, 50mrad, σ_{xy} = 1mm
sim2-1	¾ DTL-1	17.9	1.00E+08	9.09E-02	2.33E+05	2.56E+06	Max θ in DTL1, 50mrad, σ_{xy} = 1mm
sim2-3	Mid DTL-1	11.5	6.00E+08	5.45E-01	2.86E+05	5.24E+05	Same as sim2-0 but φ = -90°, σ_{xy} = 1mm
sim2-8	Start DTL-5	71.8	4.00E+07	3.64E-02	4.33E+06	1.19E+08	Max θ in DTL5 10 mrad, σ_{xy} = 0
sim2-11	End DTL-5	86.5	4.00E+07	3.64E-02	4.38E+06	1.20E+08	Max θ in DTL5 10 mrad, σ_{xy} = 1mm
sim2-12	End DTL-5	86.5	4.00E+07	3.64E-02	3.94E+06	1.08E+08	Same as sim2-11 but σ_{xy} = 0
sim2-13	Mid DTL-5	79.3	4.00E+07	3.64E-02	3.94E+06	1.08E+08	Max θ in DTL5 10 mrad, σ_{xy} = 0

Simulations Strategy

- nBLM geometry defined in Geant4
  - Geometry simulated: “standard” one
  - Geometry optimization first PDR. Finish with tests
- ESS scenarios output read as input
  - Used only the produced neutrons as input (so far)
  - Simulate > 10^8 neutrons per run
- nBLM placed at different locations around the DTLs
  - 4 on top of each DTL from where the lost is produced
  - Placed following recommendations in [1]
  - Use same reference system
  - Studied also position between tanks and on side
- Simulated accidental losses:
  - Known number of protons at fix energy in a point
  - Used to scale to the case of 1% 1W/m in 14Hz

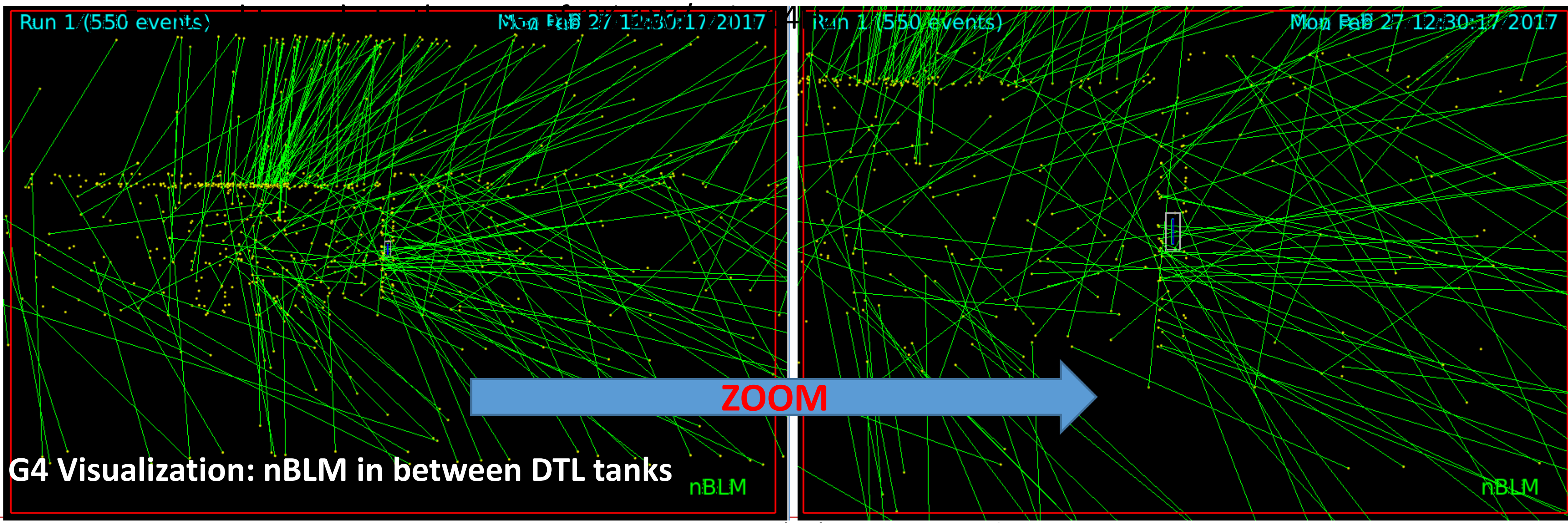


Parameter	“Standard” value
Slow module	
Cd thickness	1.0 mm
Polyethylene thickness	4.0 cm
Aluminium chamber thickness	1.0 mm
B_4C thickness	1.5 µm
Drift Distance	5.0 mm
Micromegas surface	10x10cm^2

Fast module	
Polypropylene thickness	2.0 mm
Aluminium internal layer	50.0 nm
Aluminium chamber thickness	1.0 mm
Drift Distance	5.0 mm
Micromegas surface	10x10cm^2

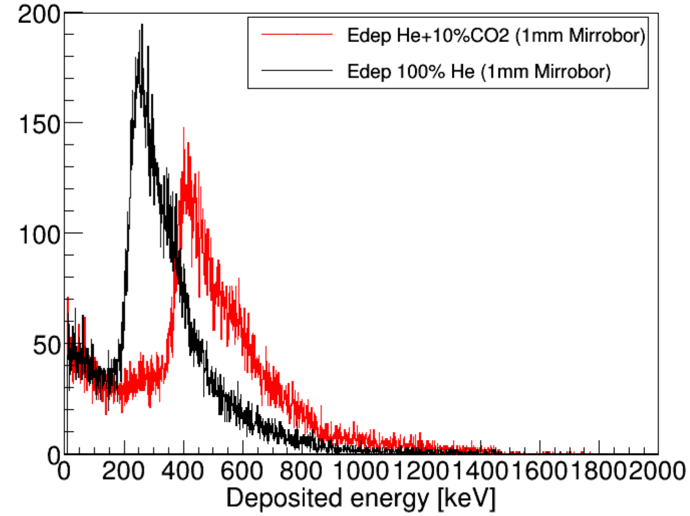
Simulations Strategy

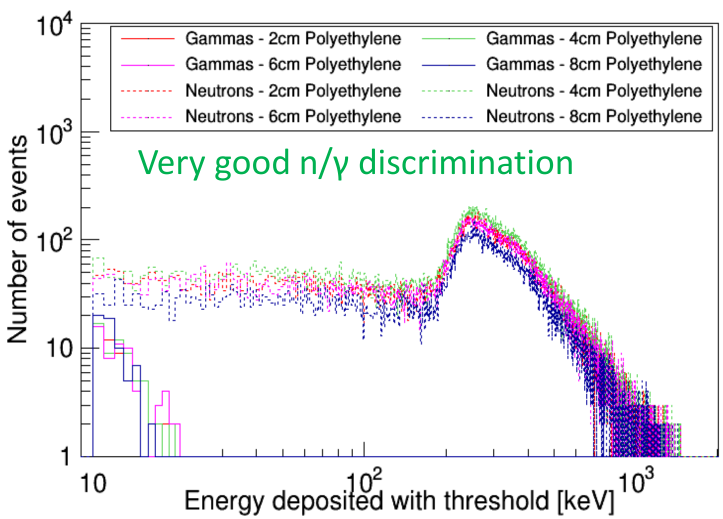
- nBLM geometry defined in Geant4
  - Geometry simulated: "standard" one
  - Geometry optimization first PDR. Finish with tests
- ESS scenarios output read as input
  - Used only the produced neutrons as input (so far)
  - Simulate > 10^8 neutrons per run
- nBLM placed at different locations around the DTLs
  - 4 on top of each DTL from where the lost is produced
  - Placed following recommendations in [1]
  - Use same reference system
  - Studied also position between tanks and on side
- Simulated accidental losses:
  - Known number of protons at fix energy in a point



Analysis

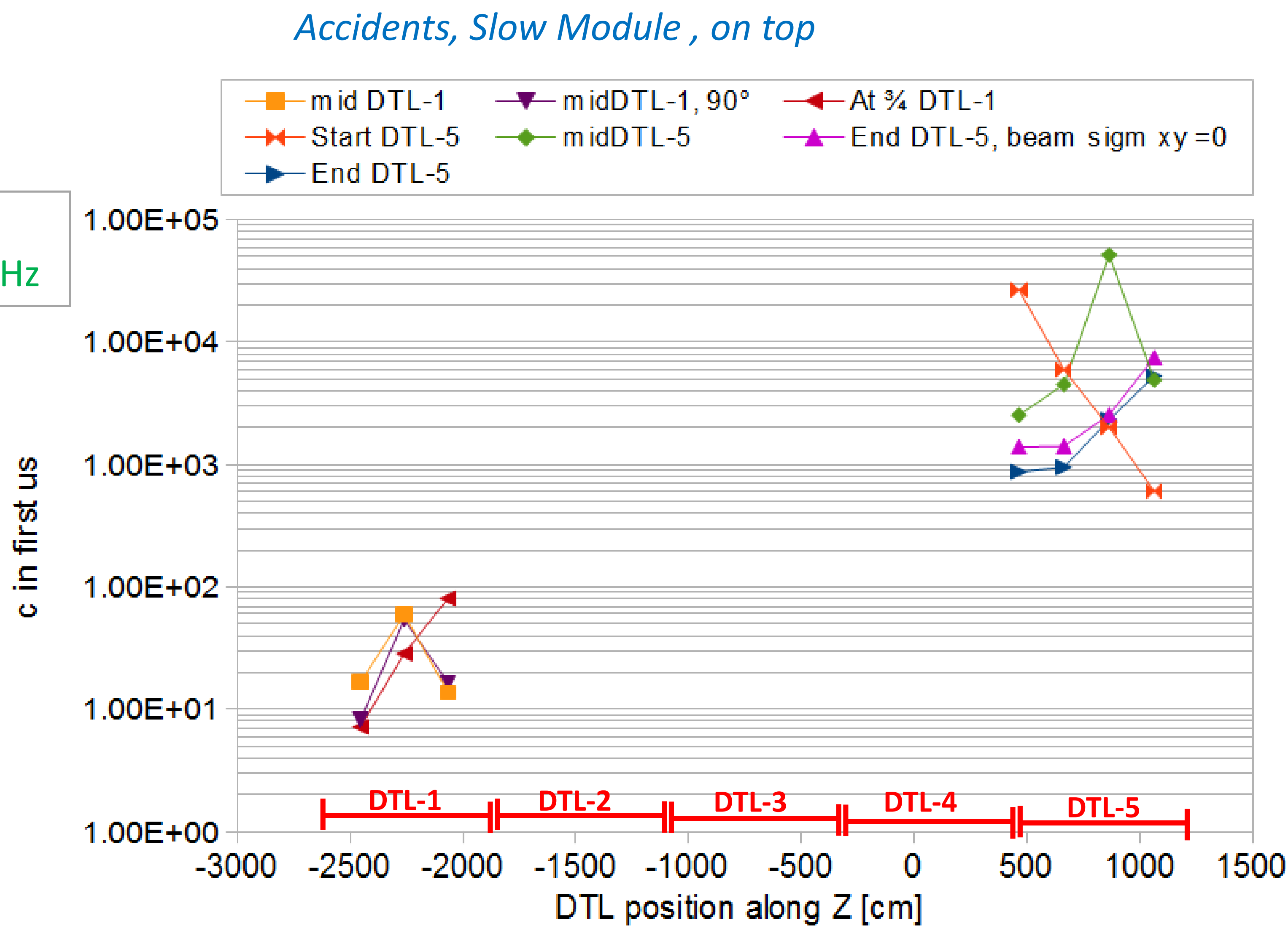
- Every neutron that deposit energy in the nBLM gas volume is recorded and saved
- Only events that deposit >10 keV are considered
- The electronics and electric field are not simulated
  - Small drift volume → any particle detected
- To study response under ESS scenarios calculate:
  - Expected rates
  - Time response.
    - Largely studied in [2]
- For the rates:
  - Frequency in DTL shorter than the time response of the *slow detector* (100% events in ~180 μs)
  - Bunches will start overlapping in case of accidents
  - Calculate how many counts lost in 1st μs
  - For 0.01 W/m loss considered peak count rate (equal loss in each pulse)



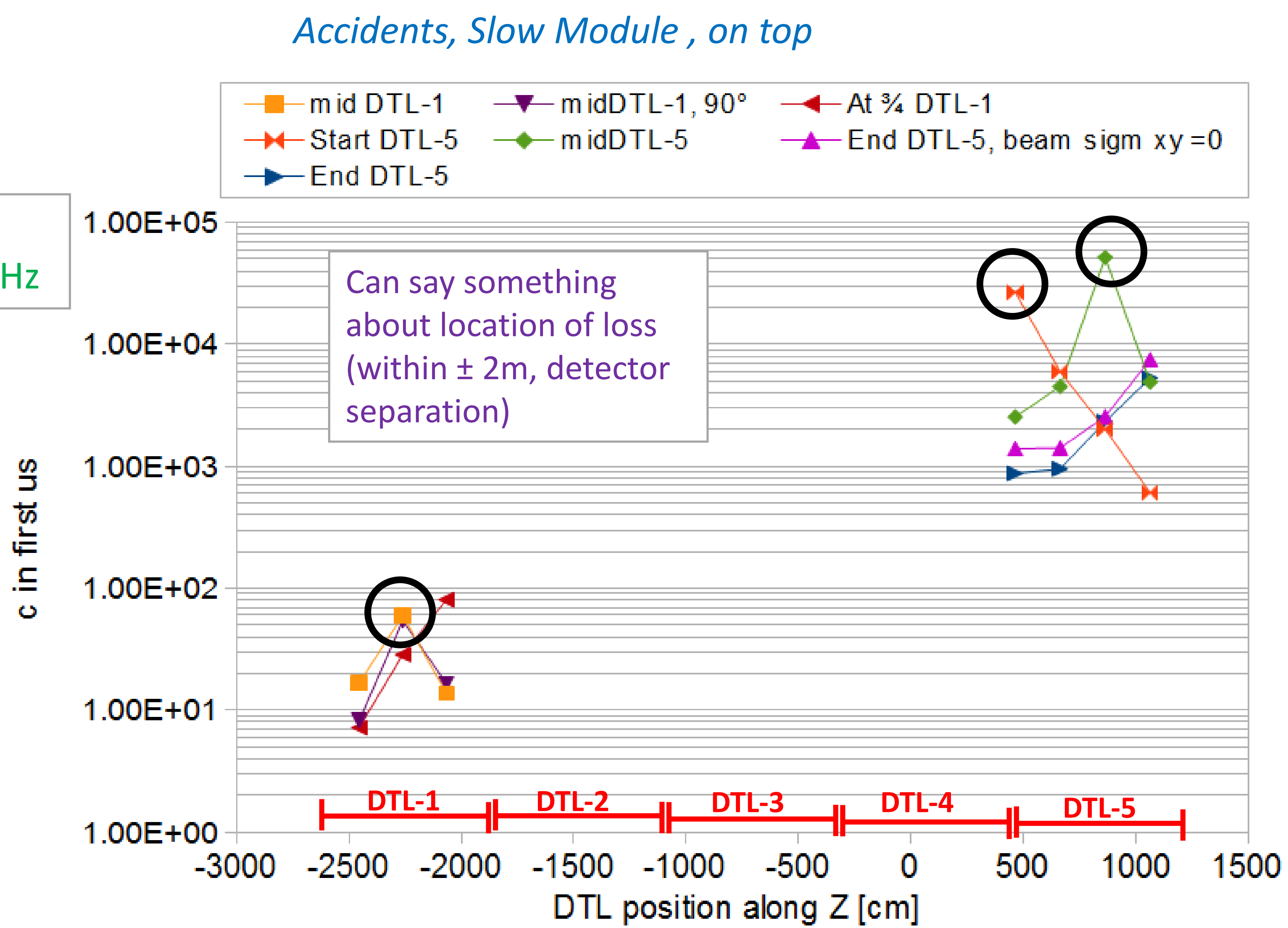


nBLM RESPONSE TO ESS SCENARIOS – ACCIDENTS SLOW

Rates of
10 MHz – 60GHz

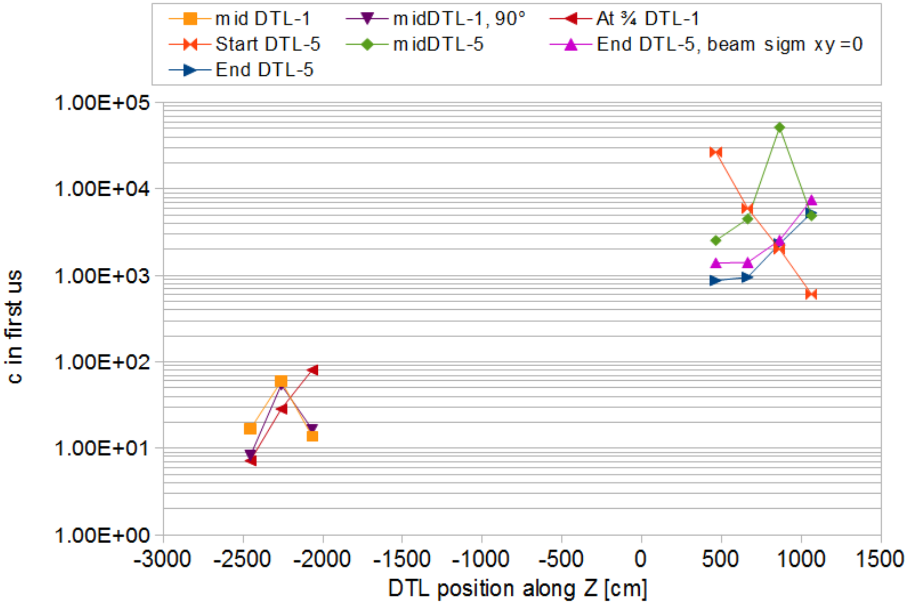


Rates of
10 MHz – 60GHz



Accidents, Slow Module , on top

Rates of
10 MHz – 60GHz



Lowest and highest estimated high rate

- Compare scenarios mid DTL-1 (yellow) and midDTL1 -90 (purple) (sim2_0 and sim2_3)
- Results obtained are the same within ~2σ maximum in both cases.
- Also comparing them if placing the detector on the side (next slides).

Pencil-beam vs Gaussian (1mm)

- Compare End DTL-5 magenta and blue
- Very similar result on loss, smaller further from loss for pencil beam

nBLM RESPONSE TO ESS SCENARIOS – ACCIDENTS SLOW

Accidents in DTL-1

ESS input	nBLM	c/bunch	Accidents c in the first μs (MHz)
Sim2-0 Mid DTL-1	det1	---	---
	det2	1.70 ± 0.04	16.70 ± 4.09
	det3	7.45 ± 0.04	59.81 ± 7.73
	det4	3.21 ± 0.03	13.82 ± 3.72
Sim2-1 @ ¾ DTL-1	det1	---	---
	det2	1.24 ± 0.05	7.20 ± 2.68
	det3	4.14 ± 0.10	28.60 ± 5.35
	det4	11.57 ± 0.16	80.76 ± 8.99
Sim2-3 Mid DTL-1 (-90°)	det1	---	---
	det2	1.58 ± 0.03	8.21 ± 2.87
	det3	6.02 ± 0.05	54.28 ± 7.37
	det4	2.95 ± 0.04	16.64 ± 4.08

Accidents in DTL-5

ESS input	nBLM	c/bunch	Accidents c in the first μs (GHz)
Sim2-8 Start DTL5	det1	2793.69 ± 17.38	26.83 ± 0.16
	det2	815.91 ± 9.40	0.59 ± 0.08
	det3	409.36 ± 6.65	0.20 ± 0.04
	det4	258.34 ± 5.29	0.06 ± 0.002
Sim2-11 End DTL-5	det1	314.18 ± 5.85	0.14 ± 0.04
	det2	336.00± 6.05	0.14 ± 0.04
	det3	599.35 ± 8.09	0.26 ± 0.05
	det4	1174.69 ± 11.32	0.75 ± 0.09
Sim2-13 Mid DTL-5	det1	530.48 ± 7.22	0.25 ± 0.05
	det2	827.69 ± 27.76	0.45 ± 0.07
	det3	3758.40 ± 42.95	51.79 ± 0.23
	det4	769.65 ± 19.44	0.49 ± 0.07

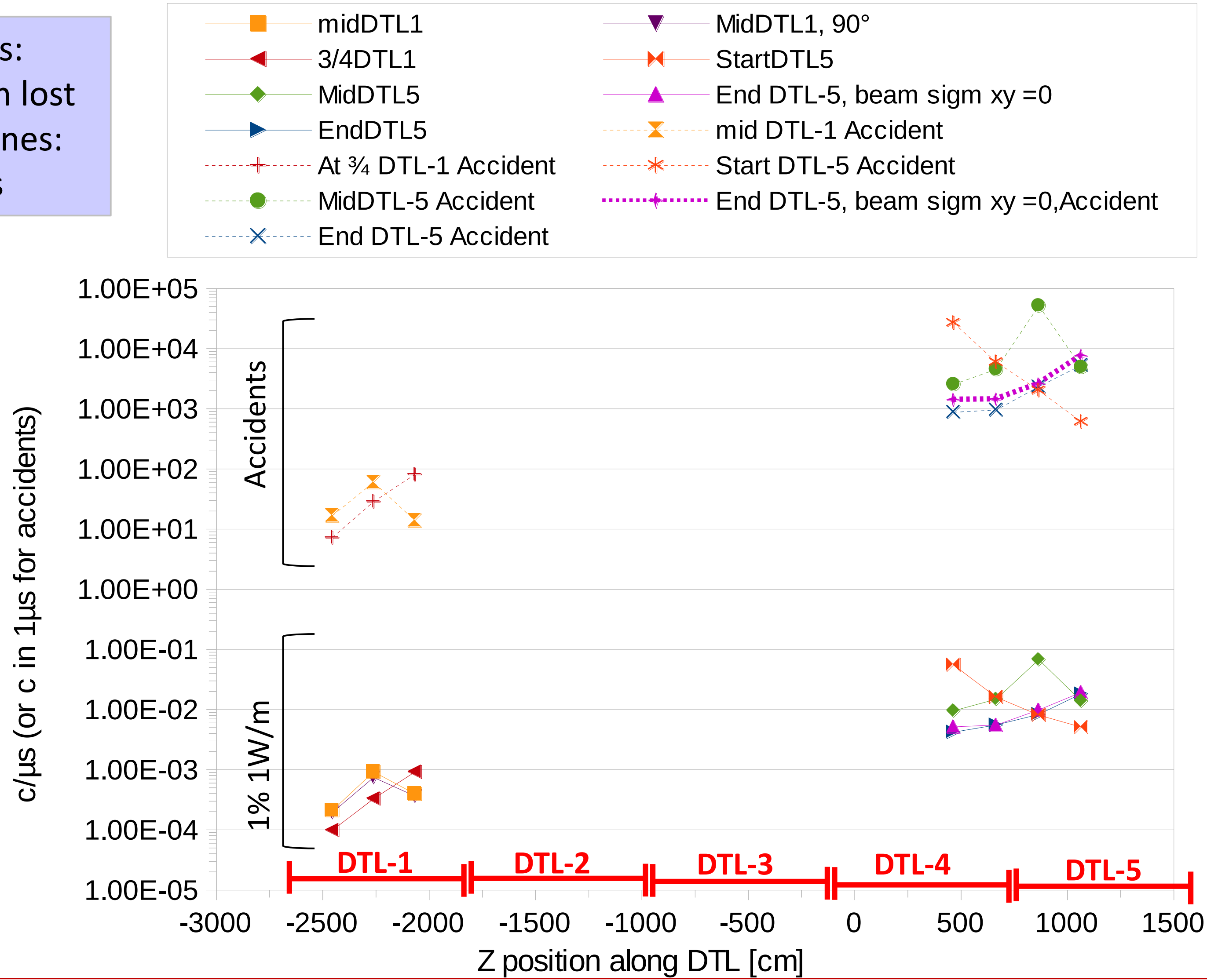
nBLM RESPONSE TO ESS SCENARIOS – 1% 1W/m SLOW

*Scale down accidents to 1% 1W/m in 14Hz, **Slow** detector , on top*

Solid lines:
1% 1W/m lost
Dashed lines:
accidents

Accidents
10 MHz – 60GHz

1% 1W/m
0.1 kHz – 700 kHz



nBLM RESPONSE TO ESS SCENARIOS – 1% 1W/m SLOW

*Scale down accidents to 1% 1W/m in 14Hz, **Slow** detector , on top*

Accidents in DTL-1

- Rates for 1%1W/m ~0.1-1 kHz
- Factor ~10^4 between accidents and 1% 1W/m

ESS input	nBLM	1% 1W/m c/ms (kHz)	Accidents c in the first μs (MHz)
Sim2-0 Mid DTL-1	det1	---	---
	det2	0.21 ± 0.01	16.70 ± 4.09
	det3	0.92 ± 0.01	59.81 ± 7.73
	det4	0.396 ± 0.003	13.82 ± 3.72
Sim2-1 @ ¾ DTL-1	det1	---	---
	det2	0.098 ± 0.004	7.20 ± 2.68
	det3	0.33 ± 0.01	28.60 ± 5.35
	det4	0.62 ± 0.01	80.76 ± 8.99
Sim2-3 Mid DTL-1 (-90°)	det1	---	---
	det2	0.195 ± 0.003	8.21 ± 2.87
	det3	0.74 ± 0.01	54.28 ± 7.37
	det4	0.364 ± 0.004	16.64 ± 4.08

Accidents in DTL-5

- Rates for 1%1W/m~ 5 - 68 kHz
- Factor ~10^5 between accidents and 1% 1W/m

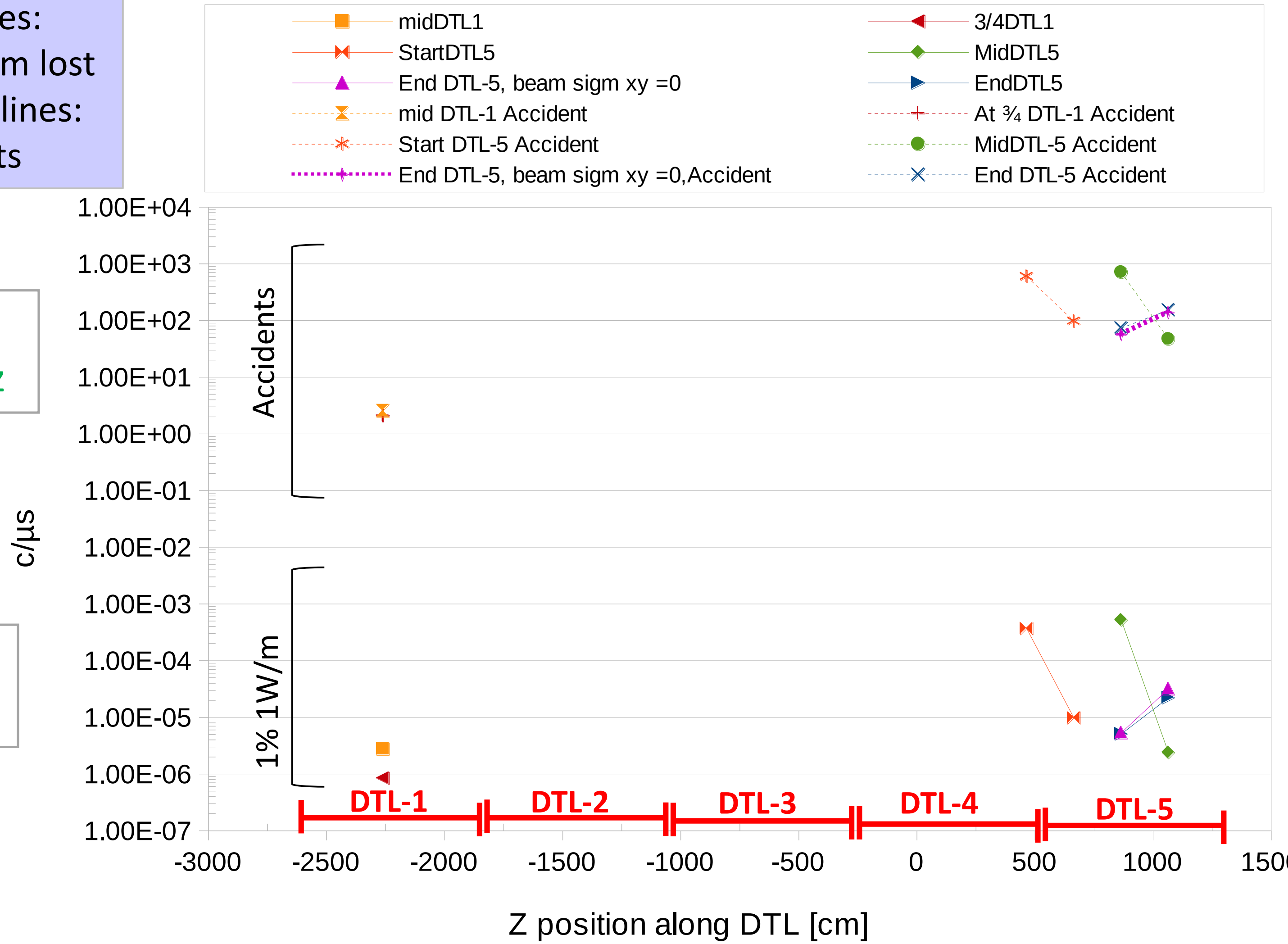
ESS input	nBLM	1% 1W/m c/ms (kHz)	Accidents c in the first μs (GHz)
Sim2-8 Start DTL5	det1	55.25 ± 0.34	26.83 ± 0.16
	det2	16.14 ± 0.19	0.59 ± 0.08
	det3	8.10 ± 0.13	0.20 ± 0.04
	det4	5.11 ± 0.10	0.06 ± 0.002
Sim2-11 End DTL-5	det1	5.17 ± 0.10	0.14 ± 0.04
	det2	5.53 ± 0.10	0.14 ± 0.04
	det3	9.87 ± 0.13	0.26 ± 0.05
	det4	19.34 ± 0.18	0.75 ± 0.09
Sim2-13 Mid DTL-5	det1	9.56 ± 0.13	0.25 ± 0.05
	det2	14.92 ± 0.50	0.45 ± 0.07
	det3	67.72 ± 0.77	51.79 ± 0.23
	det4	13.87 ± 0.35	0.49 ± 0.07

*Same studies for the **FAST** detector, placed also on top Accidents and scale down them to 1% 1W/m in 14Hz, Lower stats in some of the cases studied*

Solid lines: 1% 1W/m lost
Dashed lines: accidents

Accidents
2 MHz – 700 MHz

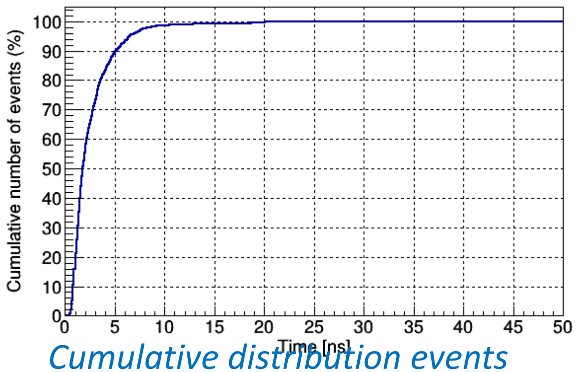
1% 1W/m
1 Hz – 400 Hz



nBLM RESPONSE TO ESS SCENARIOS – FAST

- Rates for 1%1W/m ~10 MHz (DTL-1)
  ~100 MHz – 28 GHz (DTL-5)
- Factor ~10^4 between accidents an d 1% 1W/m

ESS input	nBLM detector	c/bunch	Accidents c/µs (MHz)	1% 1W/m c/ms (kHz)
sim2-0-DTL Mid DTL1	det3	0.060 ± 0.007	22.44 ± 2.54	0.008 ± 0.001
sim2-1-DTL ¾ DTL1	det3	0.030 ± 0.005	10.65 ± 2.09	0.0024 ± 0.0005
sim2-8-DTL Start DTL5	det1	52.70 ± 1.69	18569.94 ± 594.71	1.04 ± 0.03
	det2	1.41 ± 0.28	495.20 ± 97.12	0.028 ± 0.006
sim2-11-DTL End DTL5	det3	0.93 ± 0.16	326.50 ± 56.00	0.015 ± 0.003
	det4	5.51 ± 0.39	1939.82 ± 136.49	0.091 ± 0.006
sim2-12-DTL End DTL5	det3	0.88 ± 0.21	311.14 ± 73.34	0.015 ± 0.003
	det4	3.83 ± 4.34	1348.27 ± 152.66	0.063 ± 0.007
sim2-13-DTL Mid DTL5	det3	82.28 ± 2.01	285970.55 ± 707.65	1.48 ± 0.04
	det4	0.38 ± 0.13	132.85 ± 46.97	0.007 ± 0.002



Cumulative distribution events detected at middle of DTL-5

Accidents in the fast detector
Up to 80c/bunch
→80c in ~ 3ns

1%1W/m in the fast detector
Up to 1c/ms → ~3c/pulse
Over 300 pulses, already 300 counts

In summary

In the DTLs

	Rates	
	1% 1W/m	Accidents (after 1µs)
Slow	0.1 – 68 kHz	10MHz – 60 GHz
Fast	1 – 400 Hz	2-700 MHz

Important to know expected neutron background

- The expected rates for a localized loss or for a scenario of 1% 1W/m emission are very different.
  - Recognize an increment in the emitted neutrons in case of a problem within 1µs
  - With the fast module in much shorter time (few ns).
- We need to include the time for the electronics and signal processing.

BUT

- The huge rates expected based on the Montecarlo simulations, for some cases, are too high for individual event counting, as we are talking about GHz.
- Several options to reduce these rates, which can be done during the commissioning phase, are:
  - ➢ Reducing the B4C thickness (range 150 nm – 2 µm) → factor more than 10 reduction
  - ➢ Using natural Boron instead of ^{10}B → factor 5 reduction
  - ➢ Read from just 1 to the 4 strips → factor 4
- Or include current mode in the software and firmware
  - The effect on the sensitivity of the system will be estimated only after performing the planned tests or even during the commissioning phase.

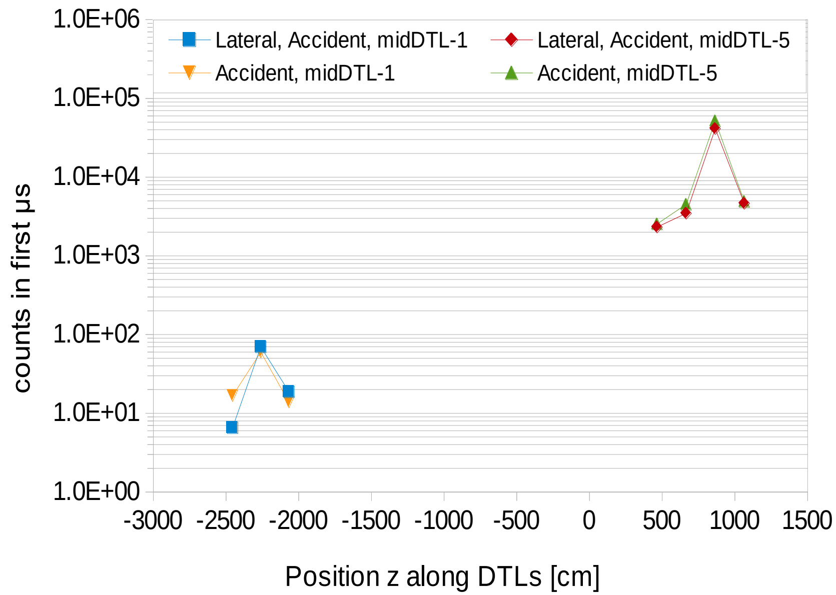
DETECTOR POSITION

- Results shown so far were obtained with the detector on top of the accelerator
- Further studies carried out with the detector
  - on the lateral (65 cm from accelerator walss) and
  - in-between the tanks (centred with the beam)
    - Only fast module

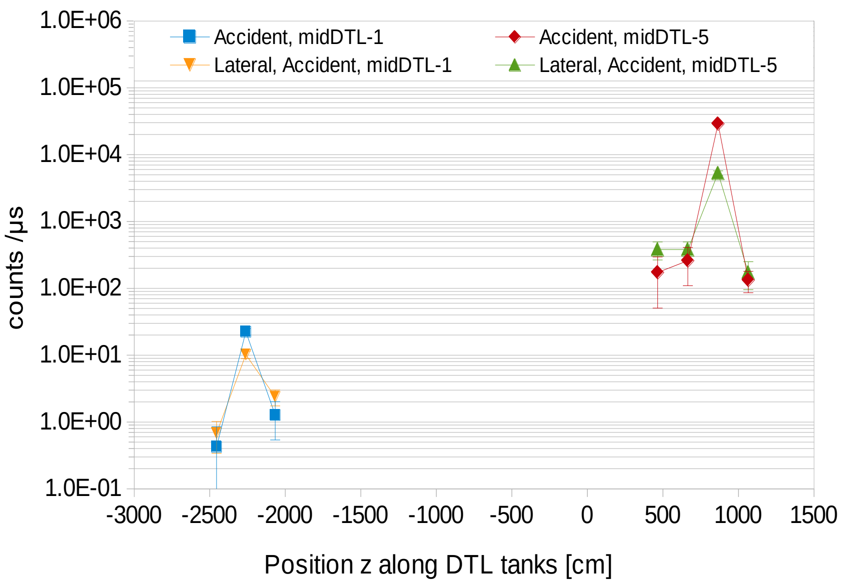
LATERAL

- Two scenarios used: sim2_0 (mid DTL1) and sim2_13(mid DTL5)

Slow Detector



Fast Detector



In-between

- Four lost scenarios used
  - sim2_0 (middle of DTL-1)
  - sim2-1 (at ¾ of DTL-1)
  - sim2-11 and sim2-12 (at ¾ of DTL-5)
- Low statistics
- Higher response closer to loss (1- 90 MHz at low E, 0.8- 5 GHz at high energy)
  - During 1% 1W/m → 0.5 – 11 Hz and 20-300 Hz (DTL1 and DTL5)

ESS input	nBLM detector between	Bunches simulated	Counts detected	c/bunch	c/μs (MHz)
sim2-0-DTL (mid DTL-1)	DTLs 1-2	4315.59	16 ± 4	0.004 ± 0.001	1.36 ± 0.34
	DTLs 2-3	4315.59	2 ± 1	Low stats	Low stats
sim2-1-DTL (¾ DTL-1)	DTLs 1-2	429.69	119 ± 11	0.28 ± 0.03	97.52 ± 8.94
	DTLs 2-3	429.69	2 ± 1	Low stats	Low stats
sim2-11-DTL (end DTL-5)	End of 5	9.17	22 ± 5	2.40 ± 0.51	845.07 ± 180.17
sim2-12-DTL (end DTL-5)	DTLs 4-5	10.19	2 ± 1	Low stats	Low stats
	End of 5	25.46	381 ± 20	14.96 ± 0.77	5268.63 ± 269.92

DETECTOR POSITION -- REMARKS

- Good coverage of accelerator can help identifying position of loss
  - Detector on top or accelerator or on side gives more or less same signal, redundancy?

- In-between detectors can also give information both in the case of 0.01 W/m loss or a higher accident loss.

- Repartition as suggested in [1] is
  - 5 nBLM modules in the MEBT section
  - 11 in the DTLs sections → Agreed to increase it
  - 14 in the spokes sections
  - 4 in the High β section
  - Total 34 over 42 that needs to be deliver

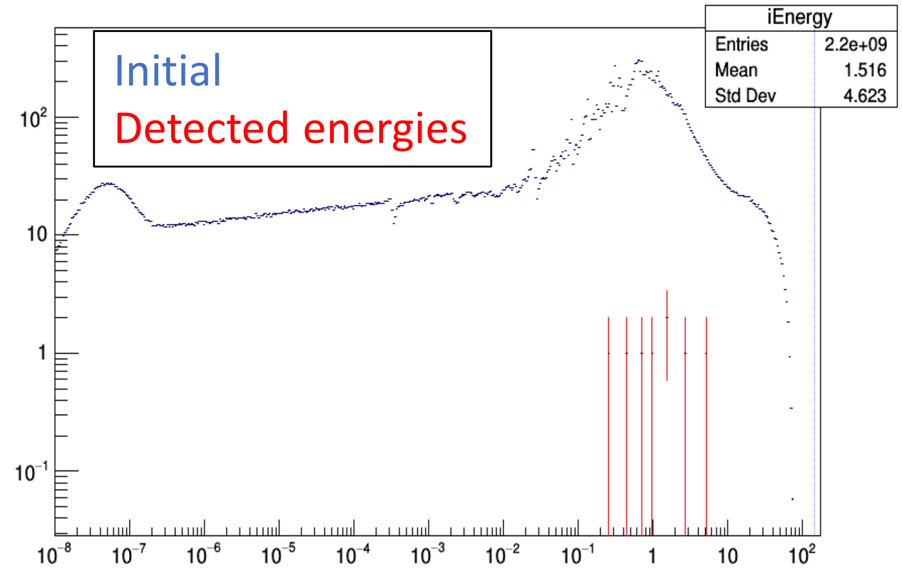
- Only response in DTLs section studied by simulations

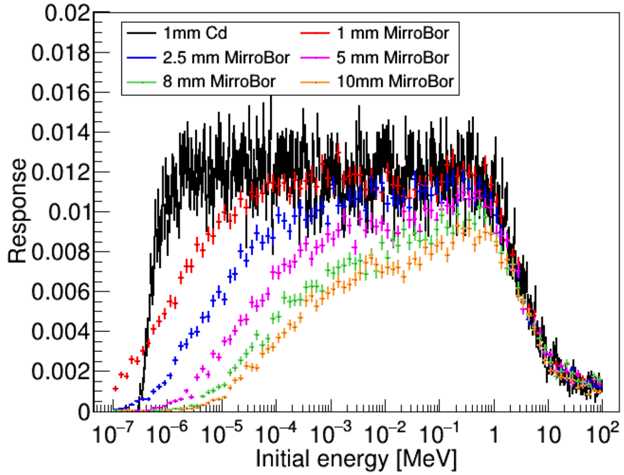
- Coverage per region important to follow with rest of the design:
  - ADC cards and IOC CPU per rack and cables through stubs

Threshold between “thermal” and fast neutrons

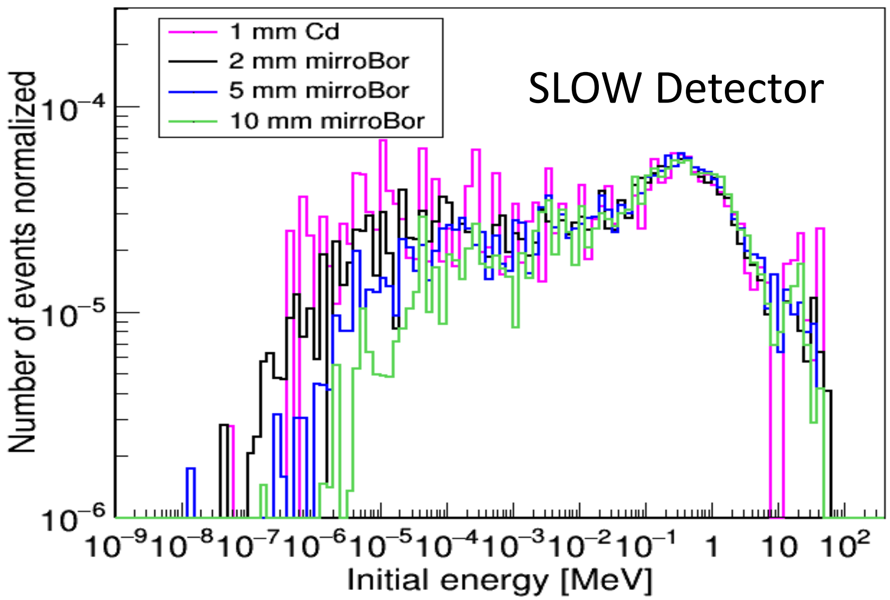
- In [1] it is suggested two possible thresholds to separate between “thermal” and fast neutrons.
  - 0.5 MeV or
  - 50 keV.
- This is naturally obtained in the fast detector
  - only sensitive to initial neutrons energies of ~ 0.2 MeV.
- In the case of the slow we have some merging playing with the Mirrobor thickness, however, the limits suggested in [2] seems quiet unrealistic as will imply a high efficiency loss.

FAST Detector





SLOW Detector but with a initial flux constante in all E



THANK YOU

References

[1] I. Dolenc Kittelman, “Report regarding the MC simulation for BLM-focus on the nBLM,” CHESS, ESS-0066428, 2016.
[2] nBLM PDR12,

BACK-UP

USING THE ACCIDENTS TO SCALE TO 1W/m

Method

1. Calculate the power lost in the scenario: W = Ep x I = Ep x Np
   - Assume Np per second
2. Used it to normalize the events detected in the scenario to the case of 1W/m
3. Normalize also by the number of neutrons we simulate, N_N, and the number of neutrons produced in the scenario, N_N^{Simu}
4. Normalize by the time, for example, assume lost is produced per pulse (2.86ms)
   - We divide by it and pass it to µs that is the time of reaction needed

$$c_{det} * \frac{N_N}{N_N^{Simu}} * \frac{1W/m}{xW/m} * \frac{1}{Active\,Time}$$

ESS Input	Position of the loss	Ep (MeV)	Ep (J)	N_P	N_N	W/m/s
sim2-0-DTL	Mid DTL-1	11.5	1.84×10^{-12}	6.00×10^{8}	2.90×10^{5}	1.10×10^{-3}
sim2-1-DTL	¾ DTL-1	17.9	2.86×10^{-12}	1.00×10^{8}	6.68×10^{4}	2.86×10^{-4}
sim2-3-DTL	Mid DTL-1	11.5	1.84×10^{-12}	6.00×10^{8}	2.86×10^{5}	1.10×10^{3}
sim2-8-DTL	Start DTL-5	71.8	1.15×10^{-11}	4.00×10^{7}	4.33×10^{6}	4.60×10^{4}
sim2-11-DTL	End DTL-5	86.5	1.38×10^{-11}	4.00×10^{7}	4.38×10^{6}	5.54×10^{4}
sim2-12-DTL	End DTL-5	86.5	1.38×10^{-11}	4.00×10^{7}	3.94×10^{6}	5.54×10^{4}
sim2-13-DTL	Mid DTL-1	79.0	1.26×10^{-11}	4.00×10^{7}	3.94×10^{6}	5.06×10^{4}

nBLM RESPONSE TO ESS SCENARIOS – 1% 1W/m SLOW

*Scale down accidents to 1% 1W/m in 14Hz, **Slow** detector , on top*

Accidents in DTL-1

- Rates for 1%1W/m ~0.1-1 kHz
- Factor ~10^4 between accidents and 1% 1W/m

ESS input	nBLM	c after normalization	1% 1W/m c/ms (kHz)	Accidents c in the first μs (MHz)
Sim2-0 Mid DTL-1	det1	---	---	---
	det2	842 ± 20	0.21 ± 0.01	16.70 ± 4.09
	det3	3685 ± 21	0.92 ± 0.01	59.81 ± 7.73
	det4	1586 ± 13	0.396 ± 0.003	13.82 ± 3.72
Sim2-1 @ ¾ DTL-1	det1	---	---	---
	det2	393 ± 17	0.098 ± 0.004	7.20 ± 2.68
	det3	1317 ± 31	0.33 ± 0.01	28.60 ± 5.35
	det4	3678 ± 52	0.62 ± 0.01	80.76 ± 8.99
Sim2-3 Mid DTL-1 (-90°)	det1	---	---	---
	det2	779 ± 14	0.195 ± 0.003	8.21 ± 2.87
	det3	2978 ± 26	0.74 ± 0.01	54.28 ± 7.37
	det4	1458 ± 19	0.364 ± 0.004	16.64 ± 4.08

nBLM RESPONSE TO ESS SCENARIOS – 1% 1W/m SLOW

*Scale down accidents to 1% 1W/m in 14Hz, **Slow** detector , on top*

Accidents in DTL-5

- Rates for 1%1W/m~ 5 - 68 kHz
- Factor ~10^5 between accidents and 1% 1W/m

ESS input	nBLM	c after normalization	1% 1W/m c/ms (kHz)	Accidents c in the first μs (GHz)
Sim2-8 Start DTL5	det1	$(22.12 \pm 0.14)10^4$	55.25 ± 0.34	26.83 ± 0.16
	det2	$(6.46 \pm 0.07)10^4$	16.14 ± 0.19	0.59 ± 0.08
	det3	$(3.24 \pm 0.05)10^4$	8.10 ± 0.13	0.20 ± 0.04
	det4	$(2.05 \pm 0.04)10^4$	5.11 ± 0.10	0.06 ± 0.002
Sim2-11 End DTL-5	det1	$(2.07 \pm 0.04)10^4$	5.17 ± 0.10	0.14 ± 0.04
	det2	$(2.22 \pm 0.04)10^4$	5.53 ± 0.10	0.14 ± 0.04
	det3	$(3.95 \pm 0.05)10^4$	9.87 ± 0.13	0.26 ± 0.05
	det4	$(7.74 \pm 0.07)10^4$	19.34 ± 0.18	0.75 ± 0.09
Sim2-13 Mid DTL-5	det1	$(3.83 \pm 0.05)10^4$	9.56 ± 0.13	0.25 ± 0.05
	det2	$(5.98 \pm 0.20)10^4$	14.92 ± 0.50	0.45 ± 0.07
	det3	$(27.12 \pm 0.31)10^4$	67.72 ± 0.77	51.79 ± 0.23
	det4	$(5.56 \pm 0.14)10^4$	13.87 ± 0.35	0.49 ± 0.07

nBLM RESPONSE TO ESS SCENARIOS – FAST

- Rates for 1%1W/m ~10 MHz (DTL-1)
  ~100 MHz – 28 GHz (DTL-5)
- Factor ~10^4 between accidents an d 1% 1W/m

ESS input	nBLM detector	c/bunch	Accidents c/µs (MHz)	c after normalization	1% 1W/m c/ms (kHz)
sim2-0-DTL Mid DTL1	det3	0.060 ± 0.007	22.44 ± 2.54	32 ± 4	0.008 ± 0.001
sim2-1-DTL ¾ DTL1	det3	0.030 ± 0.005	10.65 ± 2.09	10 ± 2	0.0024 ± 0.0005
sim2-8-DTL Start DTL5	det1	52.70 ± 1.69	18569.94 ± 594.71	4180 ± 134	1.04 ± 0.03
	det2	1.41 ± 0.28	495.20 ± 97.12	111 ± 22	0.028 ± 0.006
sim2-11-DTL End DTL5	det3	0.93 ± 0.16	326.50 ± 56.00	61 ± 11	0.015 ± 0.003
	det4	5.51 ± 0.39	1939.82 ± 136.49	363 ± 26	0.091 ± 0.006
sim2-12-DTL End DTL5	det3	0.88 ± 0.21	311.14 ± 73.34	58 ± 14	0.015 ± 0.003
	det4	3.83 ± 4.34	1348.27 ± 152.66	252 ± 29	0.063 ± 0.007
sim2-13-DTL Mid DTL5	det3	82.28 ± 2.01	285970.55 ± 707.65	5940 ± 145	1.48 ± 0.04
	det4	0.38 ± 0.13	132.85 ± 46.97	27 ± 10	0.007 ± 0.002

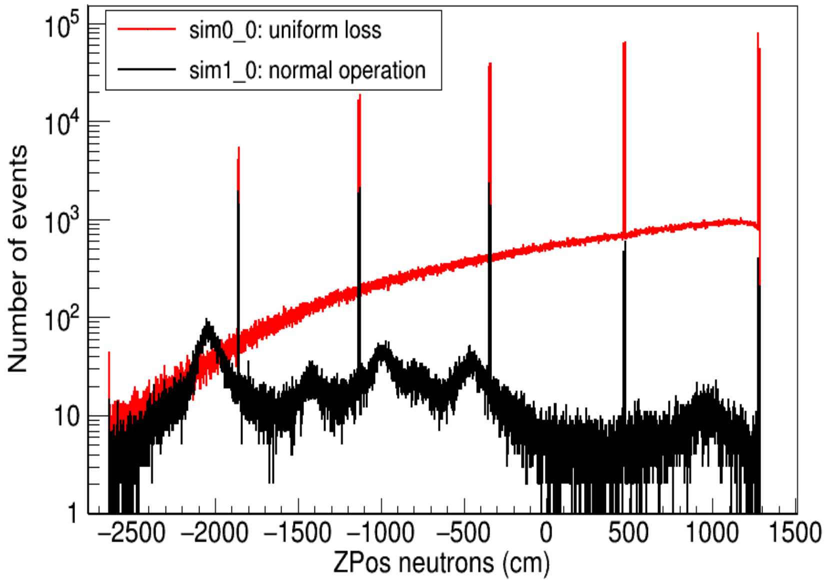
In-between

- Four lost scenarios used
  - sim2_0 (middle of DTL-1)
  - sim2-1 (at ¾ of DTL-1)
  - sim2-11 and sim2-12 (at ¾ of DTL-5)
- Low statistics
- Higher response closer to loss (1- 90 MHz at low E, 0.8- 5 GHz at high energy)

ESS input	nBLM detector between	Bunches simulated	Counts detected	c/bunch	c/µs (MHz)	1% 1W/m c/µs
sim2-0-DTL (mid DTL-1)	DTLs 1-2	4315.59	16 ± 4	0.004 ± 0.001	1.36 ± 0.34	4.78E-07
	DTLs 2-3	4315.59	2 ± 1	Low stats	Low stats	
sim2-1-DTL (¾ DTL-1)	DTLs 1-2	429.69	119 ± 11	0.28 ± 0.03	97.52 ± 8.94	1.10E-05
	DTLs 2-3	429.69	2 ± 1	Low stats	Low stats	
sim2-11-DTL (end DTL-5)	End of 5	9.17	22 ± 5	2.40 ± 0.51	845.07 ± 180.17	1.98E-05
sim2-12-DTL (end DTL-5)	DTLs 4-5	10.19	2 ± 1	Low stats	Low stats	
	End of 5	25.46	381 ± 20	14.96 ± 0.77	5268.63 ± 269.92	3.08E-04

nBLM RESPONSE UNDER ACCELERATOR NORMAL OPERATION

- Two approaches to normalize the number of detected events, c_{det}, in the nBLM modules.
- Main Q's: *How many protons of each energy have been produced?*



Method

1. Assume the protons simulated in the ESS scenario were distributed evenly along the 40 m → N_P^{Simu}/m
2. We can obtain the proton energy along the accelerator distance [3].
   Its ~ linear along the DTLs
3. Calculate how many protons of the energy in the region are needed to:
   1. To have 1W/m → N_P
   2. Or the other approach is to use [4] with a powerloss per meter calculation. From the expected loss we calculate → N_P
4. Obtain the number of neutrons/m produced for the positions we located the nBLM → N_N^{Simu}/m
5. Normalize by the number of neutrons we simulated → N_N
6. We are assuming that the only protons that contribute to the lost produced in a given region are the ones in this region.

$$c_{det} * \frac{N_P}{N_P^{Simu}} * \frac{N_N}{N_N^{Simu}/m} * \frac{1}{Active\,Time}$$

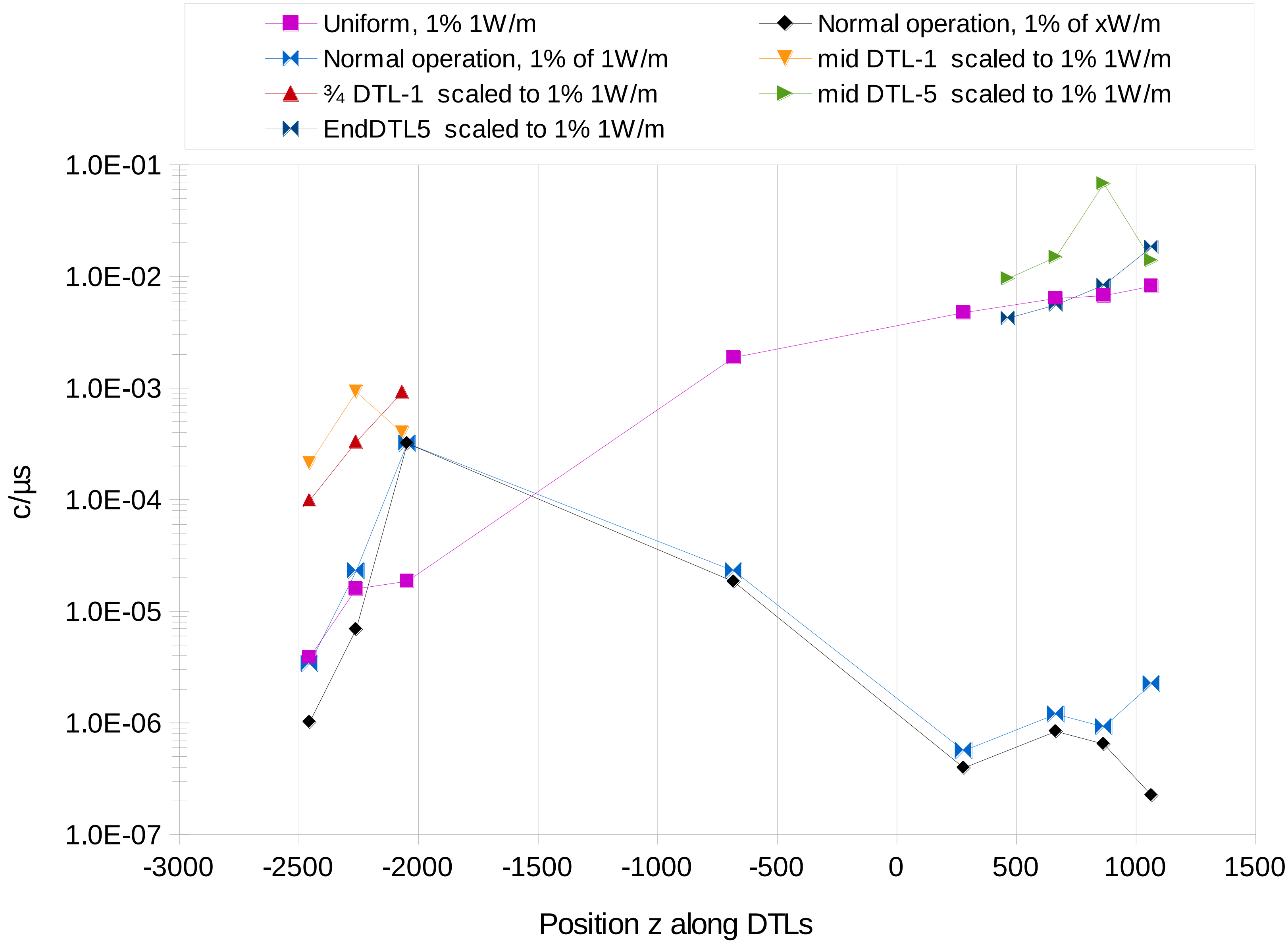
Similarly to the normal case, we have to know the normalization factor

Method

1. Calculate N_P needed to produce a loss of 1W/m taking into account the energy of the proton at each position.
2. 10^8 protons were simulated- -> assume again that they have been distributed uniformly along the DTLS --> N_P^{simu} as before, $N_P^{simu} = 10^8/40$
3. Obtain the number of neutrons produced/meter → $\mathbf{N_N^{Simu}/m}$
4. Normalize by the number of neutrons simulated → $\mathbf{N_N}$
5. Also in this case we are assuming that the only protons that contribute to the lost produced in a given region are the ones in this region.

$$c_{det} \cdot \frac{N_N}{N_N^{Simu}} \cdot \frac{1W/m}{x\,W/m} \cdot \frac{1}{\text{Active Time}}$$

nBLM RESPONSE UNDER ACCELERATOR NORMAL OPERATION



nBLM RESPONSE UNDER ACCELERATOR NORMAL OPERATION

UNIFORM
SLOW

1% 1W/m in 14 Hz	
Z position (cm)	c/ms (kHz)
-2649	----
-2455	0.004 ± 0.001
-2261	0.016 ± 0.001
-2047	0.019 ± 0.001
-681.5	1.88 ± 0.09
280	4.74 ± 0.04
665	6.36 ± 0.07
865	6.70 ± 0.06
1065	8.16 ± 0.33

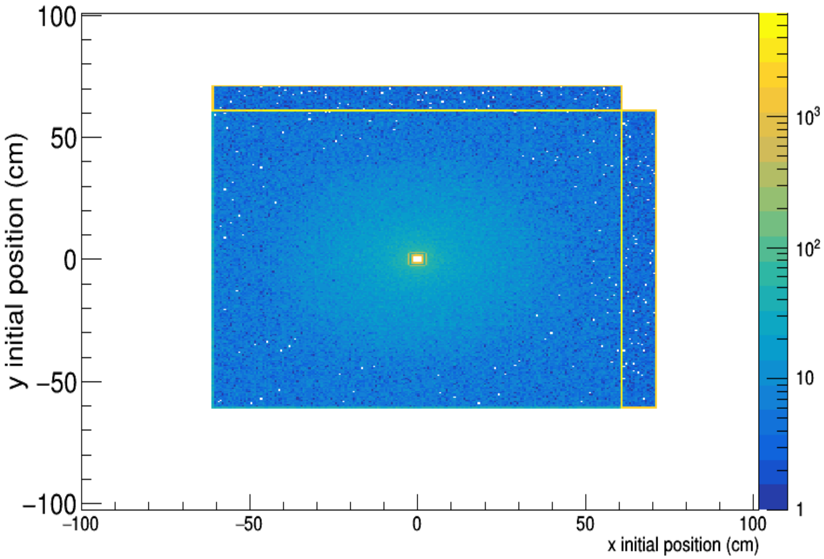
nBLM RESPONSE UNDER ACCELERATOR NORMAL OPERATION

	"Normal" operation, 1% of the power loss in 14 Hz				
	Normal scenario, Sim1_0		Uniform,1W/m Sim0_0	Accidents scale to 1% 1W/m	Accidents
Z position (cm)	Assuming 1W/m *c/s (1Hz)*	Using values from [4] *c/s (1Hz)*	*c/ms (1kHz)*	*c/ms (1kHz)*	*c in 1st µs (1MHz*
-2649	----	----	----	---	---
-2455	3.39 ± 0.10	1.02 ± 0.03	0.004 ± 0.001	0.21 ± 0.01	16.70 ± 4.09
-2261	22.95 ± 0.46	6.89 ± 0.14	0.016 ± 0.001	0.92 ± 0.01	59.81 ± 7.73
-2067				0.396 ± 0.003	13.82 ± 3.72
-2047	319.07 ± 2.80	319.07 ± 2.80	0.019 ± 0.001		
-681.5	23.01 ± 0.46	18.41 ± 0.37	1.88 ± 0.09		
280	0.56 ± 0.01	0.40 ± 0.01	4.74 ± 0.04		
665	1.20 ± 0.03	0.84 ± 0.02	6.36 ± 0.07	14.92 ± 0.50	4518.26 ± 67.22
865	0.92 ± 0.02	0.65 ± 0.02	6.70 ± 0.06	67.73 ± 0.78	51790.90 ± 227.5
1065	2.24 ± 0.06	0.22 ± 0.01	8.16 ± 0.33	13.87 ± 0.35	4914.98 ± 70.11

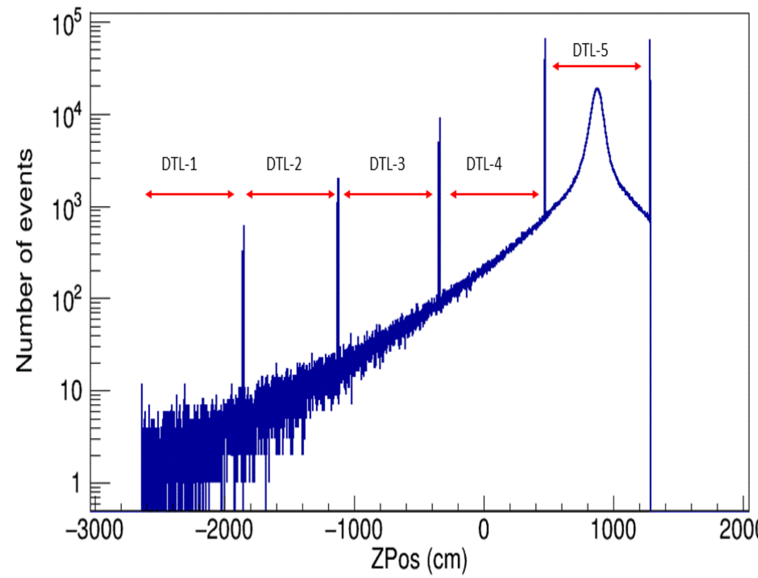
nBLM RESPONSE UNDER ACCELERATOR NORMAL OPERATION

NORMAL
SLOW

	1% of the power loss distributed in 14 Hz	
	c/s (1 Hz)	
Z position (cm)	1% 1W/m	1% of values from [4]
-2649	----	----
-2455	3.39 ± 0.10	1.02 ± 0.03
-2261	22.95 ± 0.46	6.89 ± 0.14
-2047	319.07 ± 2.80	319.07 ± 2.80
-681.5	23.01 ± 0.46	18.41 ± 0.37
280	0.56 ± 0.01	0.40 ± 0.01
665	1.20 ± 0.03	0.84 ± 0.02
865	0.92 ± 0.02	0.65 ± 0.02
1065	2.24 ± 0.06	0.22 ± 0.01

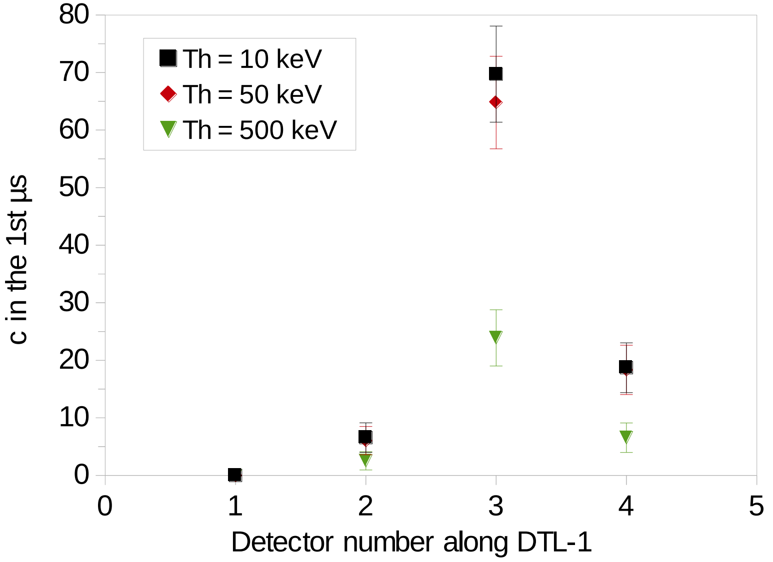


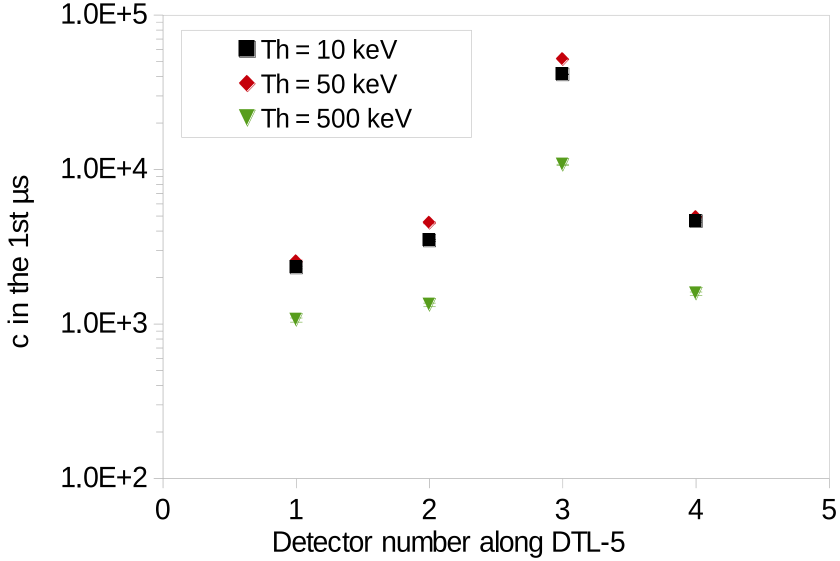
100
50
0
−50
−100
y initial position (cm)
−100
−50
0
50
100
x initial position (cm)
10^3
10^2
10
1

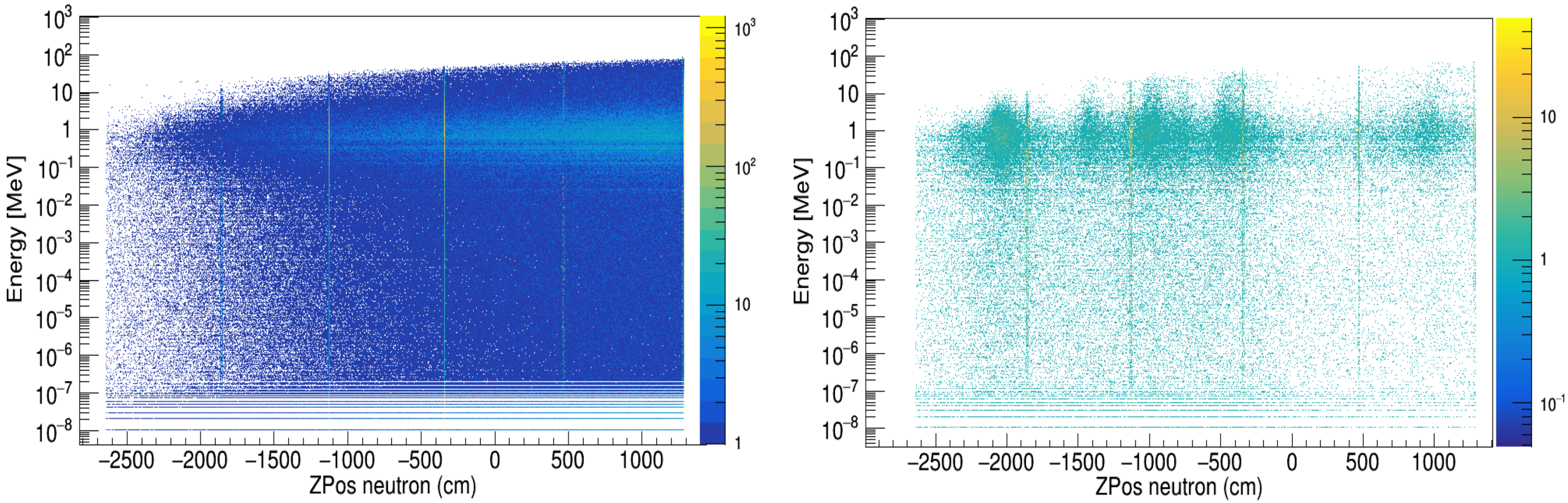


10^5
10^4
10^3
10^2
10
1
Number of events
DTL-1
DTL-2
DTL-3
DTL-4
DTL-5
−3000
−2000
−1000
0
1000
2000
ZPos (cm)

Different deposited energy threshold – slow detector







Energy vs z-position for the neutrons produced in the losses in the uniform loss scenario simulated from ESS (sim0_0) at the left and for the normal operation scenario (sim1_0) at the right.