Dose calculation for Top-up operation at CLSI: HXMA beam line

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Radiation Safety at Synchrotron Radiation Sources
Brookhaven National Laboratory, NY, USA

Scopes of presentation

This presentation highlights:

- The design features and results of a Monte Carlo model to study the dose distribution for HXMA BL under three beam loss scenarios
- Provide initial results of the radiation measurements for a given beam loss scenario
- Initial evaluation of the measurement data with model results

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Limitations: Modeling study

- The Geometric model was designed based on KEY Components of the Front end and POE of HXMA beam line
- The idea was to simulate the 'WORST CASE' scenario; The surrounding obstacles were not considered
- It was assumed that the estimated doses would be the worst for a given beam loss scenario

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Basic Assumptions: Top Up

Safety Dose Limit: Top up and Decay mode

*) For Nucl Eng Worker (NEW), the maximum total integrated dose over one hour is 5 μSv in the Controlled Access Zone (CAZ). Equivalent to **10** mSv over 2000 working hours per year. For non-NEW, yearly dose is 1 mSv (0.5 μSv. h^{-1}); for public, yearly dose is 50 μSv.

*) The radiation dose to a **worker** from a SINGLE event of beam loss is **1** mSv.

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Shielding: Phase I Beam lines

Shielding Design Features: Phase I

ENCLOSURE TYPE	Beamline #	LEAD THICKNESS REQUIREMENTS (mm)	LEAD THICKNESS REQUIREMENTS (mm)	LEAD THICKNESS REQUIREMENTS (mm)
		ROOF	SIDEWALL (FRONTWALL)	BACKWALL
POE	11ID-1	10	10(30 locally)	30(130 locally)
	11ID-2	10	10(30 locally)	30(130 locally)
	10ID-1	10	10(30 locally)	30(130 locally)
	08ID-1	10	10(30 locally)	30(130 locally)
	06ID-1	**10**	**10(30 locally)**	**30(130 locally)**
POE	08ID-1	10	10(30 locally)	30(130 locally)
SOE	08ID-1	1.0	1.0	3.0
	06ID-1	3.0	4.0	5.0

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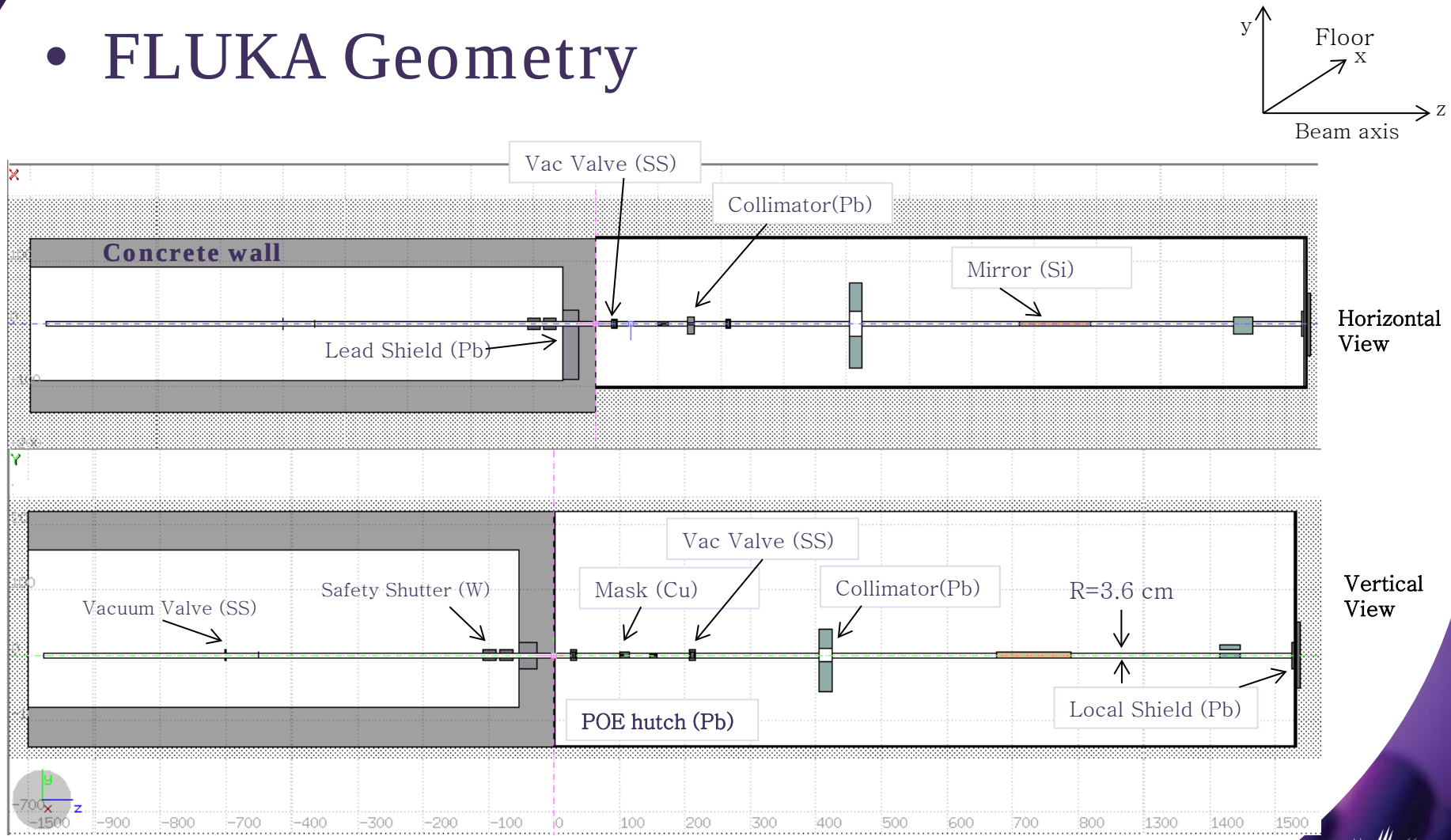
Monte Carlo Model

- FLUKA Geometry



HXMA beam line

FLUKA GeoView

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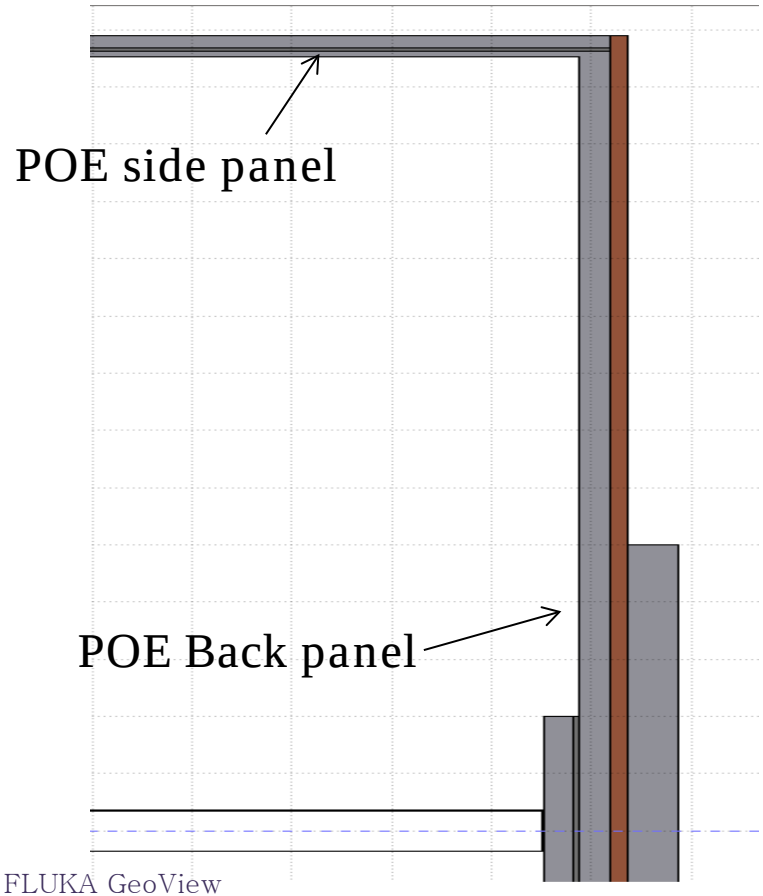
Monte Carlo Model

- FLUKA Geometry: POE side and back panel



FLUKA GeoView

* POE side wall has 1 cm lead wall, floor to ceiling; with 2 cm local shield at + - 50 cm of the beam line.

* POE back wall has 3 cm lead wall, floor to ceiling; Guillotine 3 cm, local shielding at the back 5 cm at + - 50 cm of the beam line.

Phase I beam line; e.g. HXMA

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Top up Operation

- Probable Beam loss scenarios

The following THREE scenarios are suggested by the Accelerator Operation Department and are being studied with safety shutter open:

Loss scenario	Description	Consequence	POE scenario
The INJECTED beam is miss-steered	*) Deviation < 4 mrad	Captured in the magnetic field	No effect
	*) Deviation > 4 mrad	Hit vacuum wall: Either horizontally or vertically	*) Horizontally lost beams are obstructed by other front end components *) Vertically lost beams may hit POE ceiling
The INJECTED beam skips from the magnetic field	Hit components in the ring	Create shower in the front end	Dose level out of the POE side wall may be elevated
The INJECTED beam skips from the magnetic field	Hit components INSIDE the POE	*) May hit thick target like mask made of Cu *) May directly hit the optical components (Focussing mirror made of Si)	Dose level out of the POE side wall may be elevated

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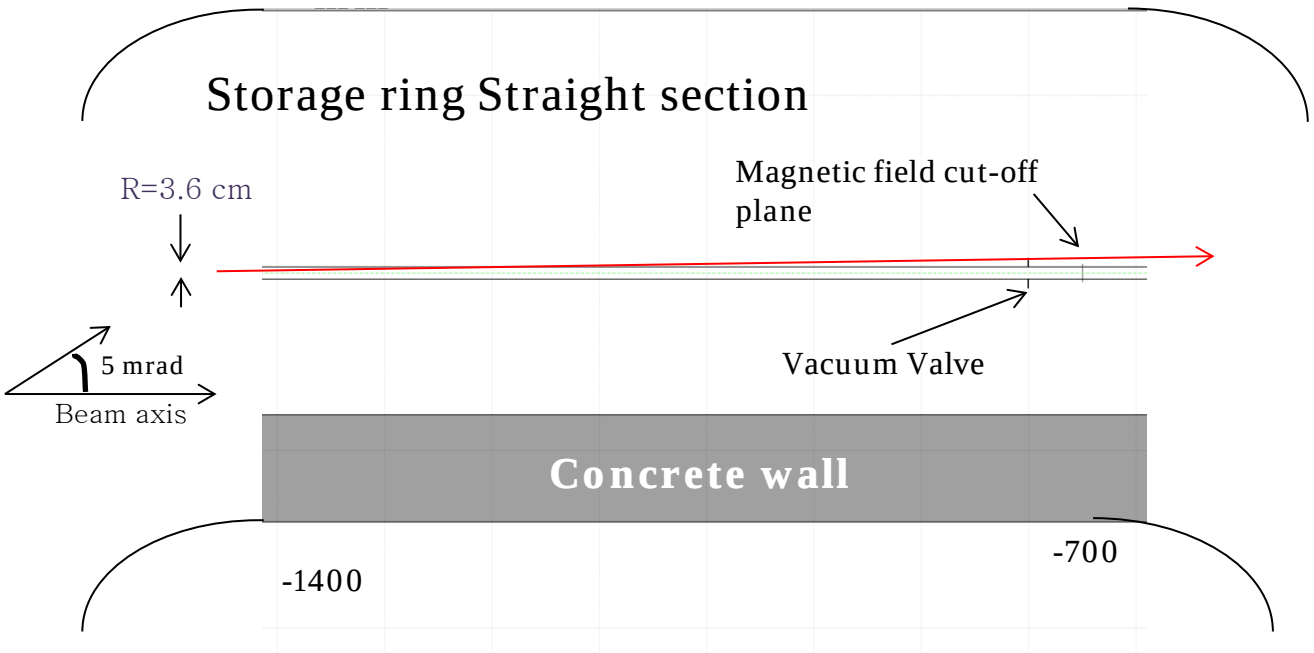
Case 1: Beam miss-steering

Electron is miss-steered in Straight section



Beam profile : Gaussian shaped; σ_x=0.22, σ_y=0.02

Source information:

The injected beams miss-steered ≥5, captured in the magnetic field

Below that, the electron beam is captured within magnetic field

The unit of the dose presented in this document is μSv. The amount of beam loss per event is 1 nCoul/s of beam injection.

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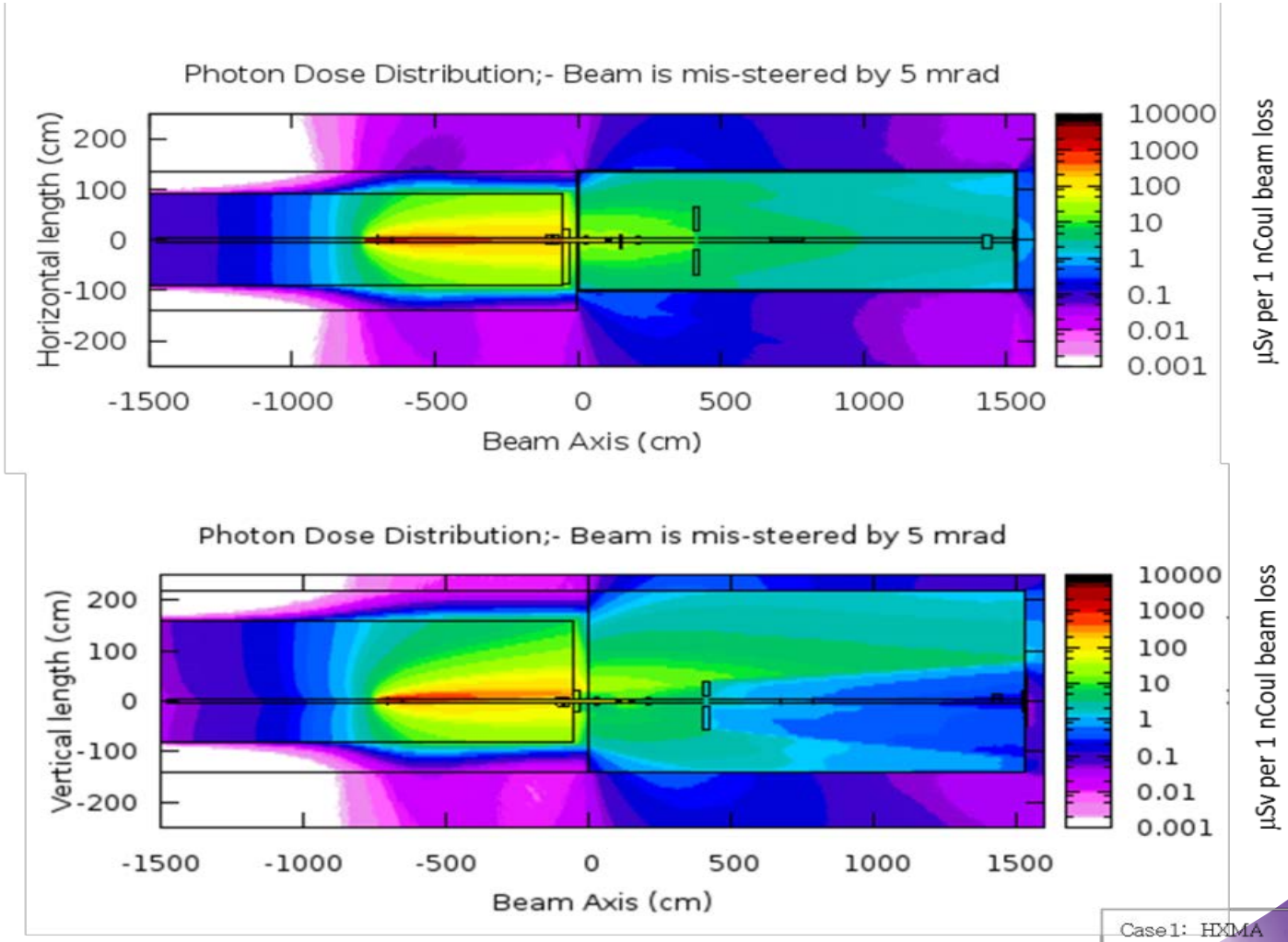
Case 1: Beam miss-steering

Beam miss-steered in straight section (SSH Open)

Beam line safety shutter is open



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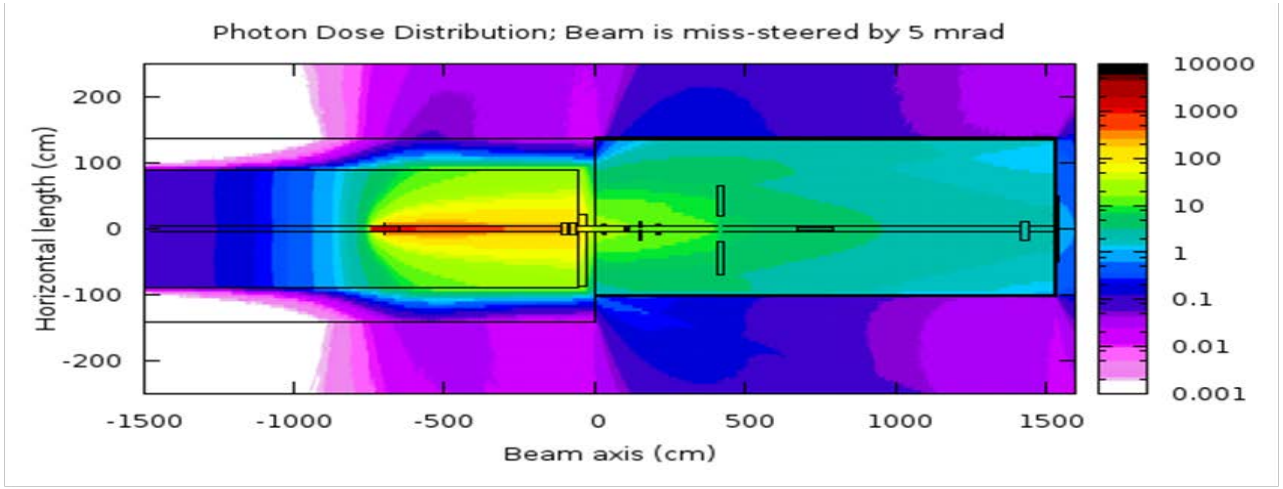
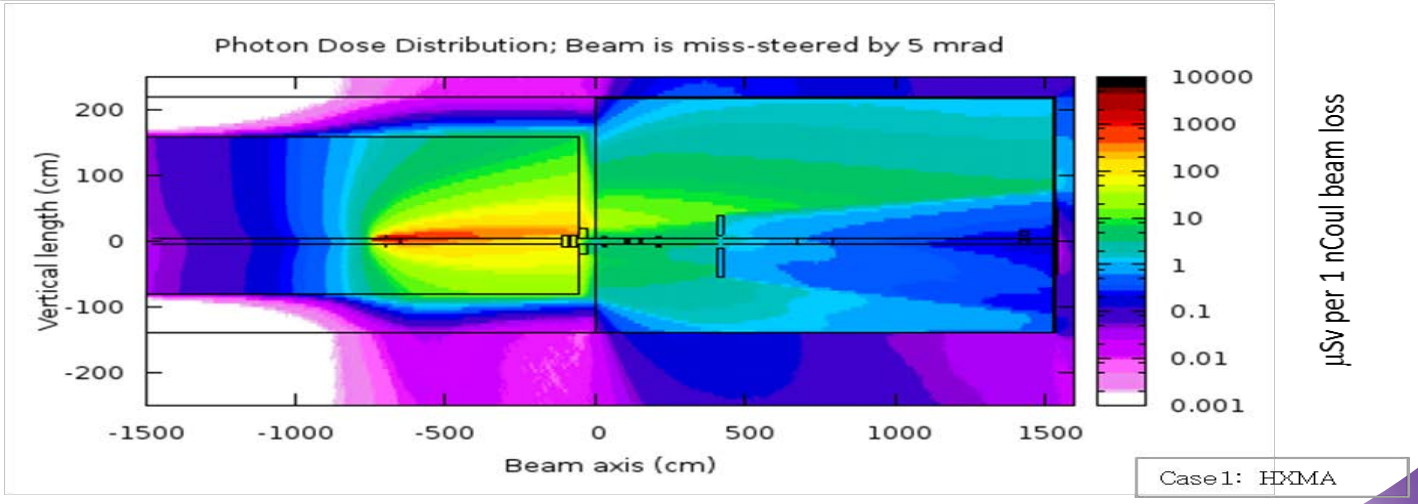
Case 1: Beam miss-steering

Beam miss-steered in straight section (SSH Closed)

Beam line safety shutter is closed





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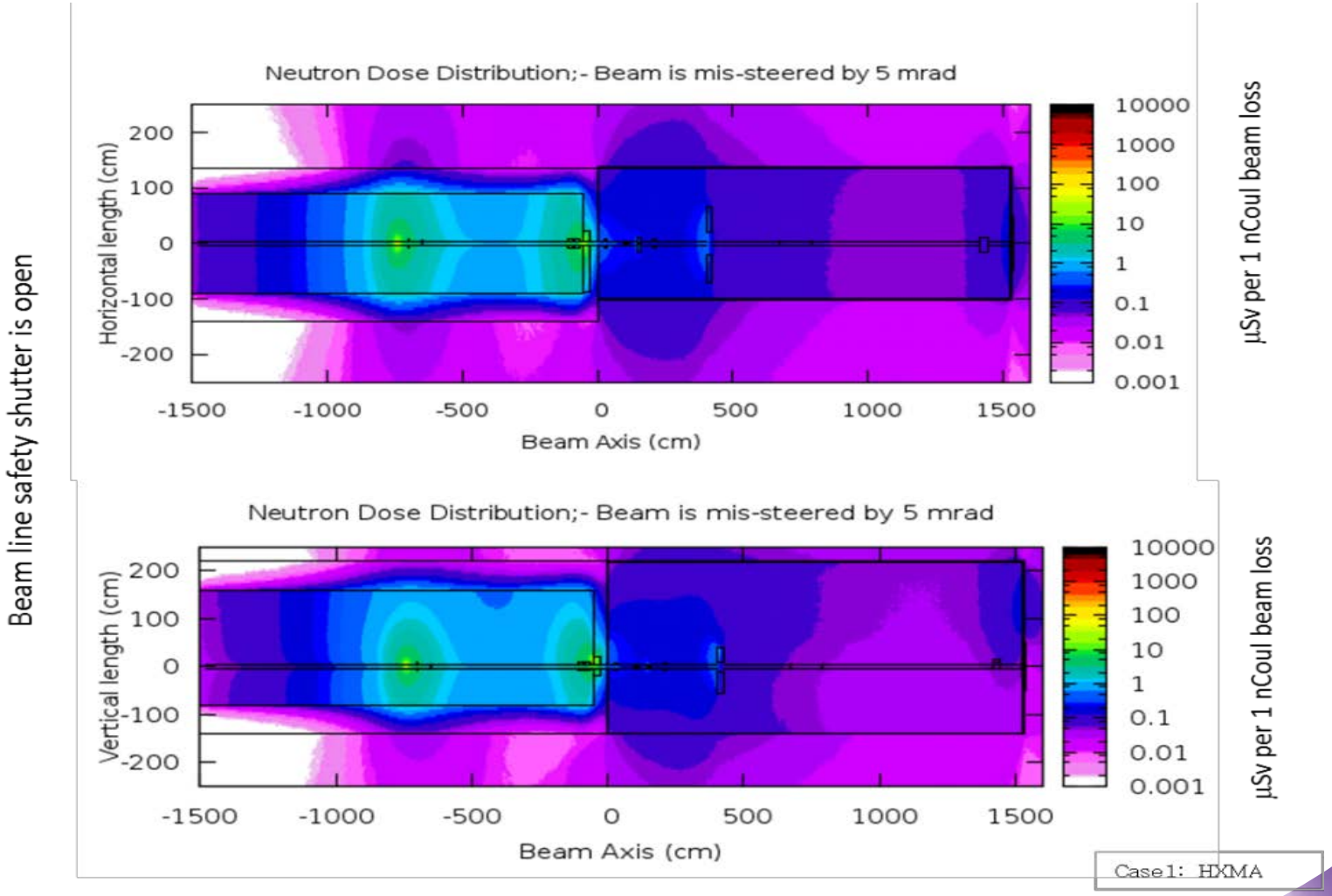

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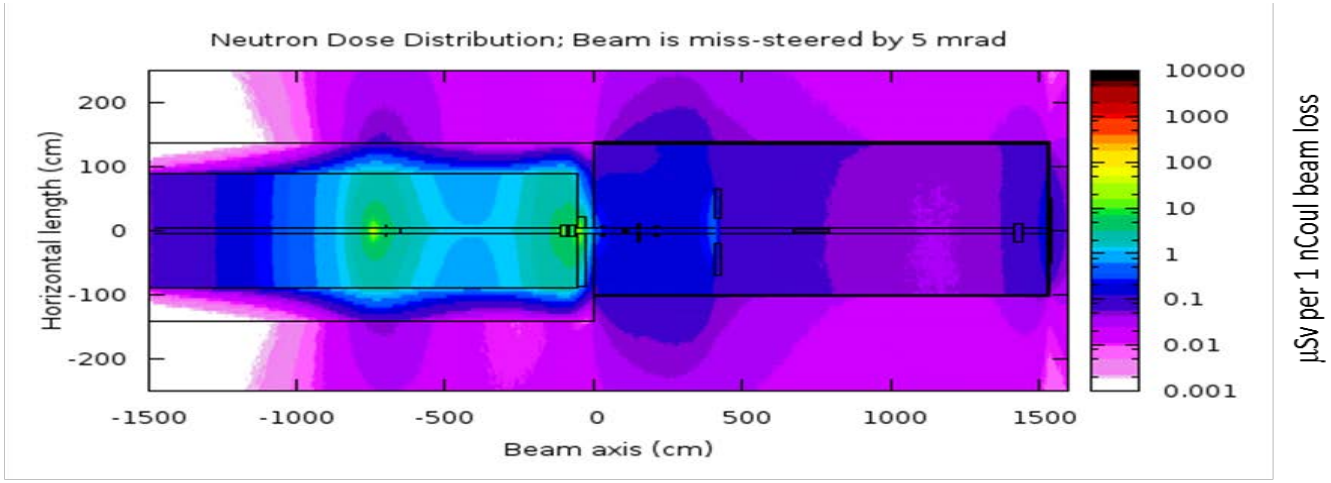
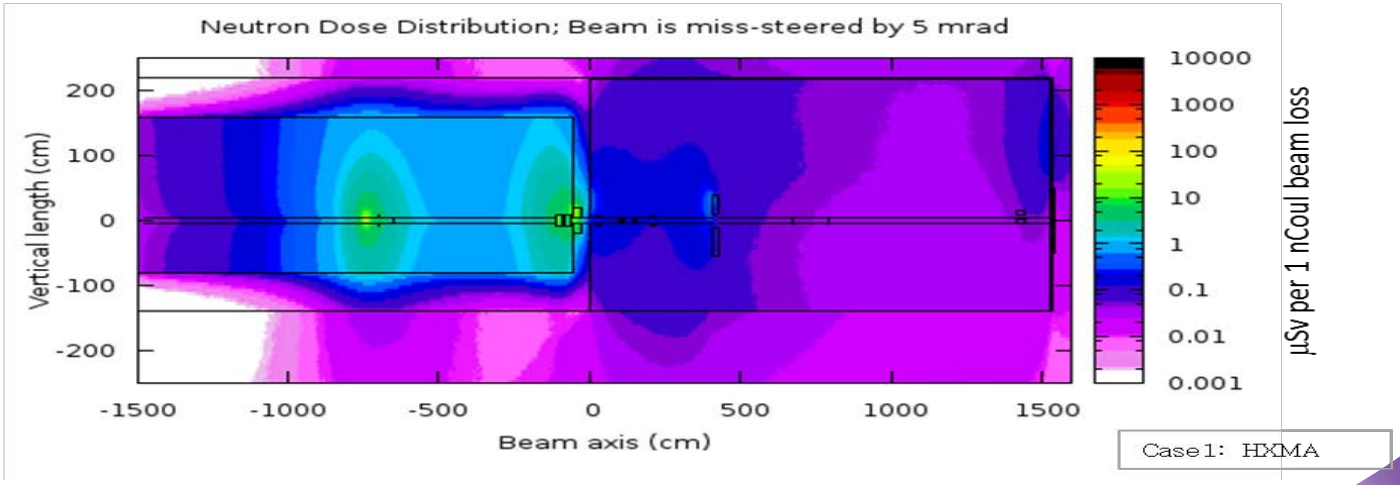
Case 1: Beam miss-steering

Beam miss-steered in straight section (SSH Closed)

Beam line safety shutter is closed





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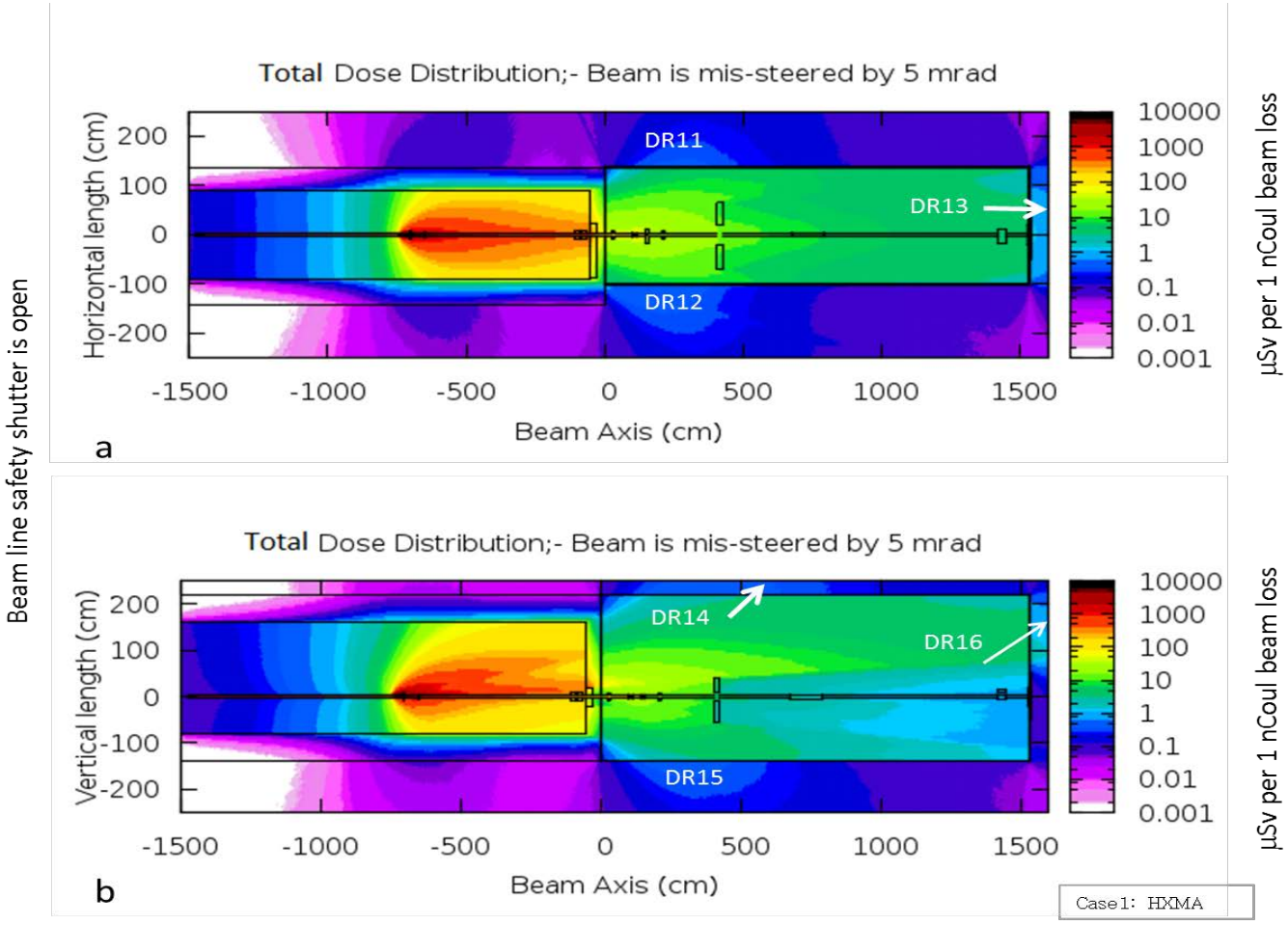

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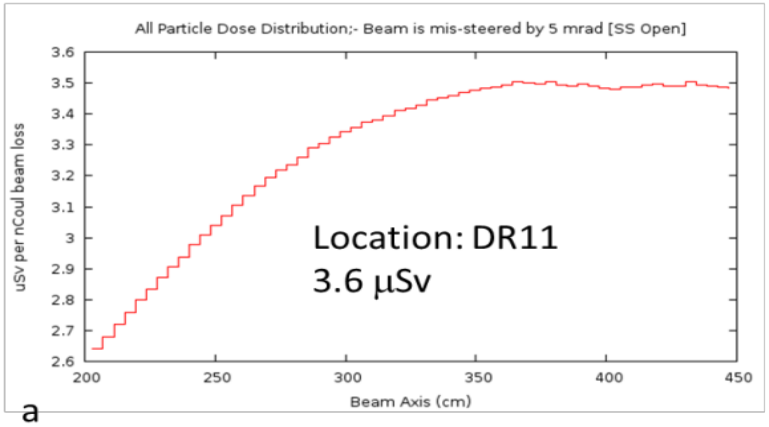
Case 1: Beam miss-steering

Beam is miss-steered in Straight section

Case 1: Horizontal view: Beam line safety shutter open



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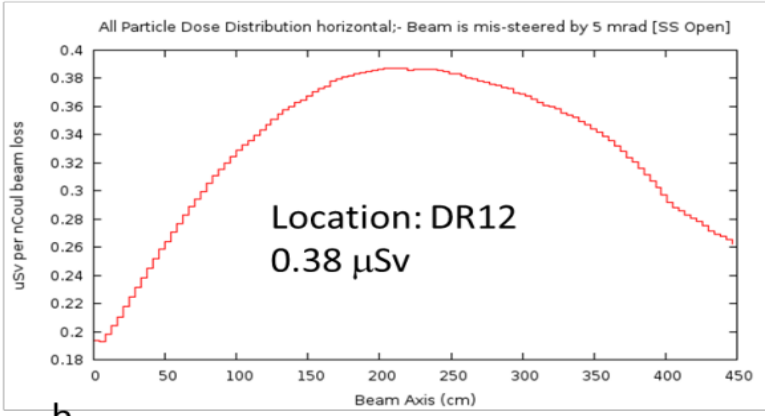

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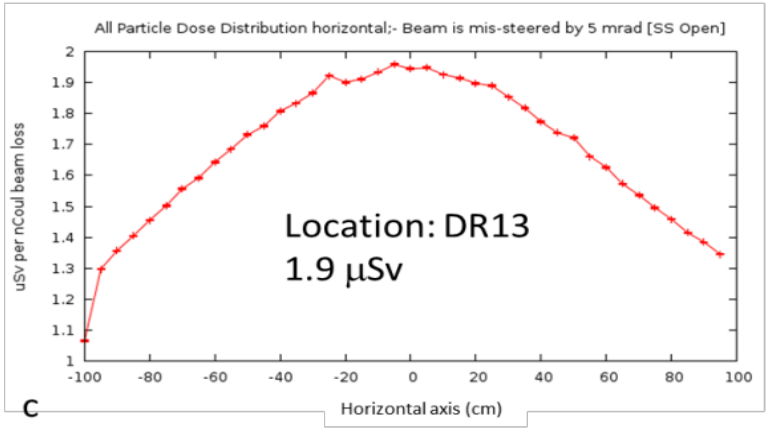

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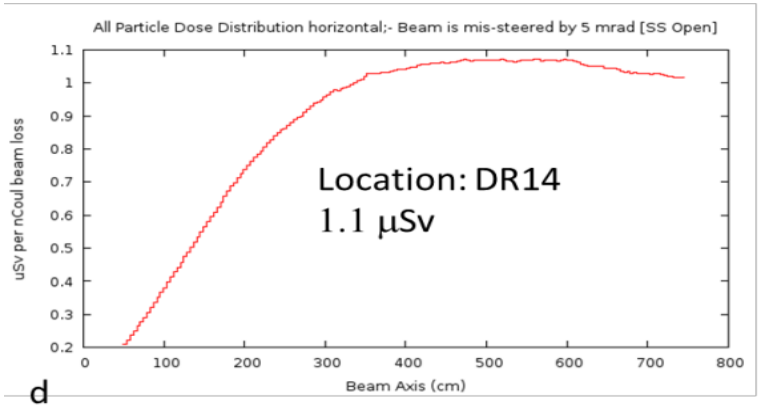
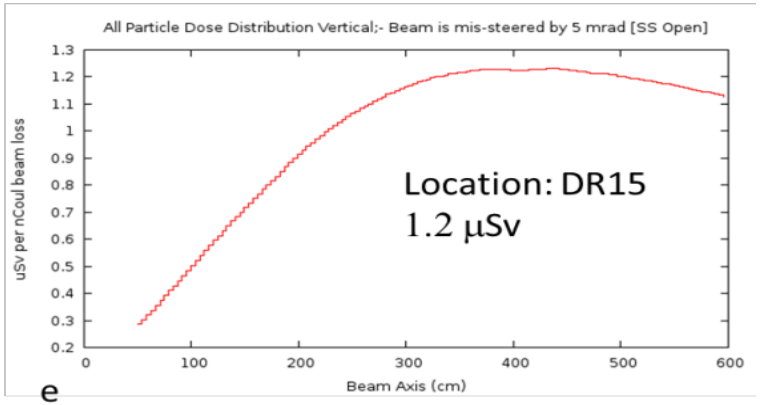
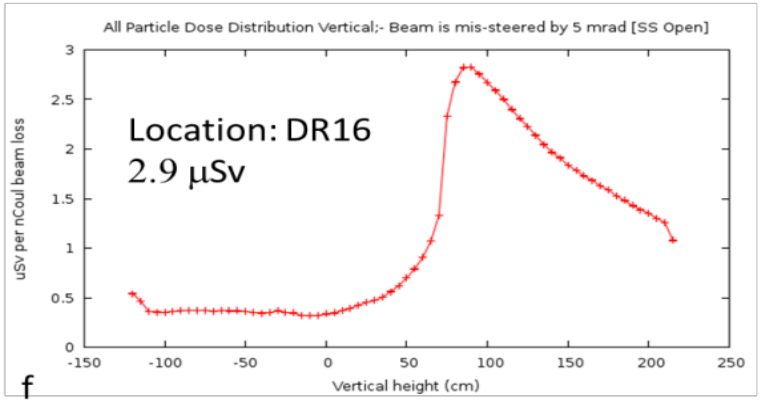
Case 1: Beam miss-steering

Beam is miss-steered in Straight section

Case 1: Vertical View: Beam line safety shutter open







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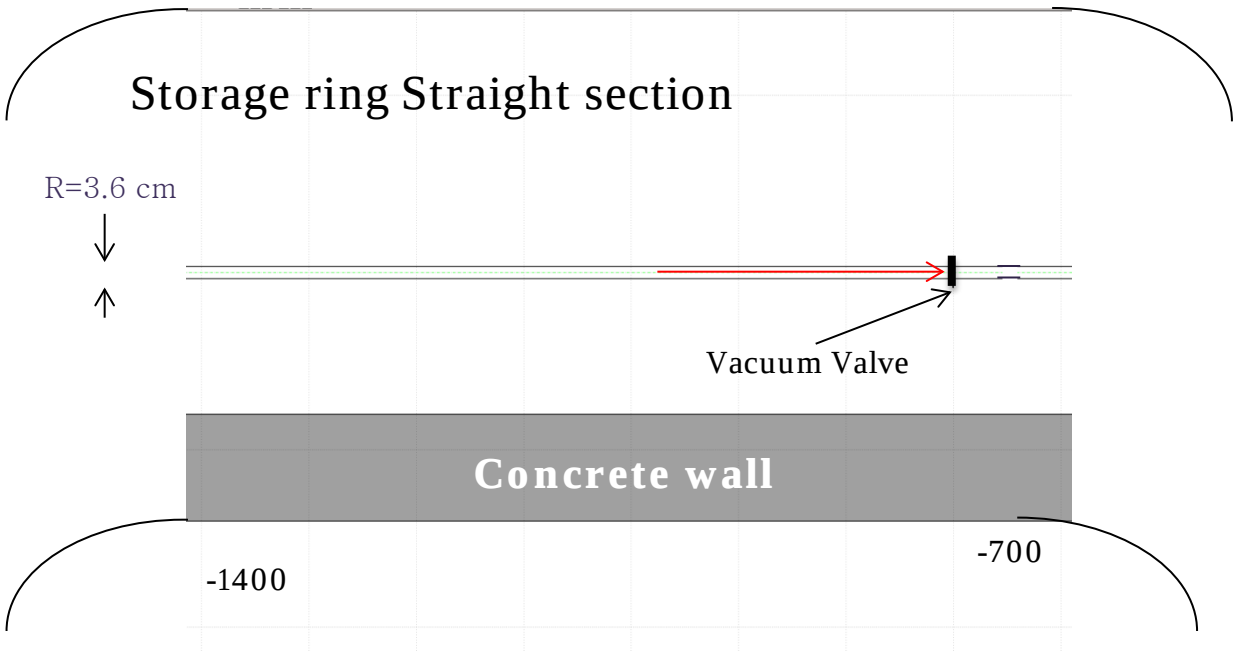
Case 2: Beam hits components

Beam hits Vacuum Valve



Source information:

The injected beam hits the vacuum valve

E=2.9 GeV Electron

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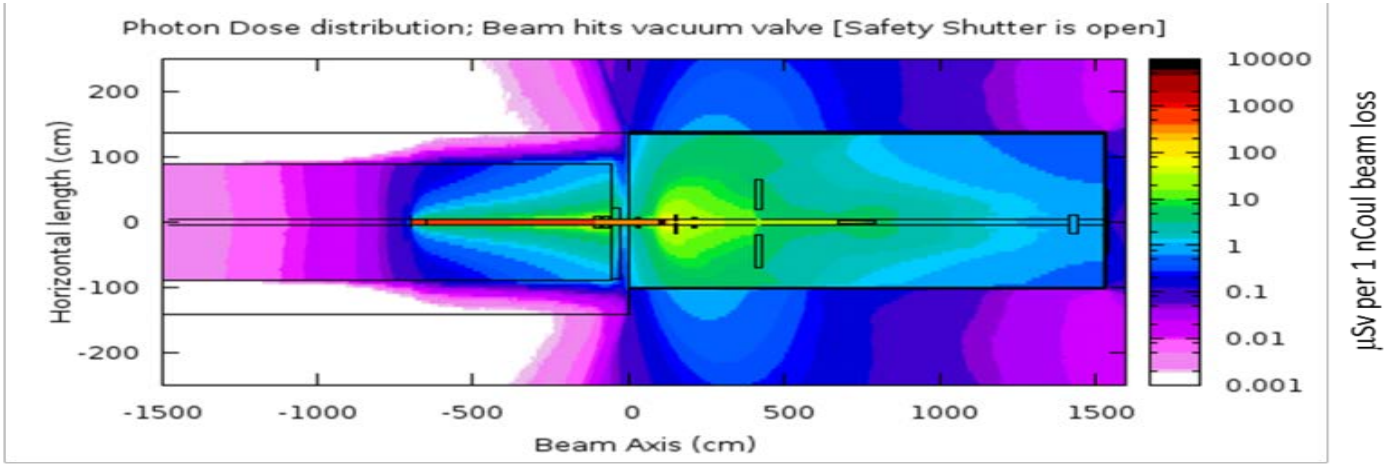
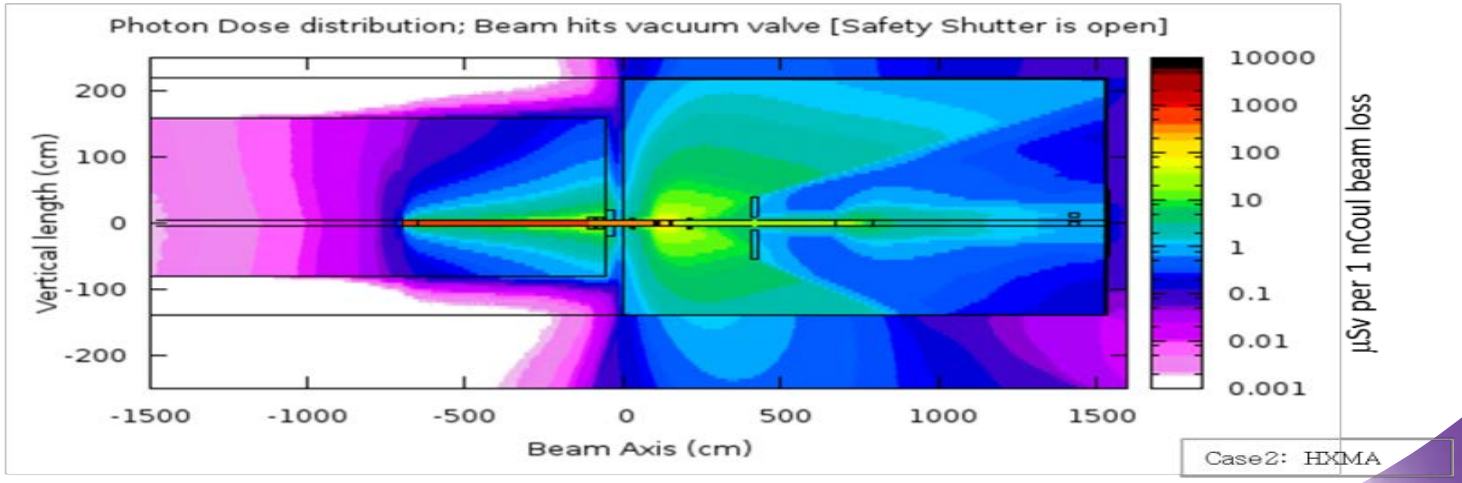
Case 2: Beam hits components

Beam hits Vacuum Valve

Beam line safety shutter open





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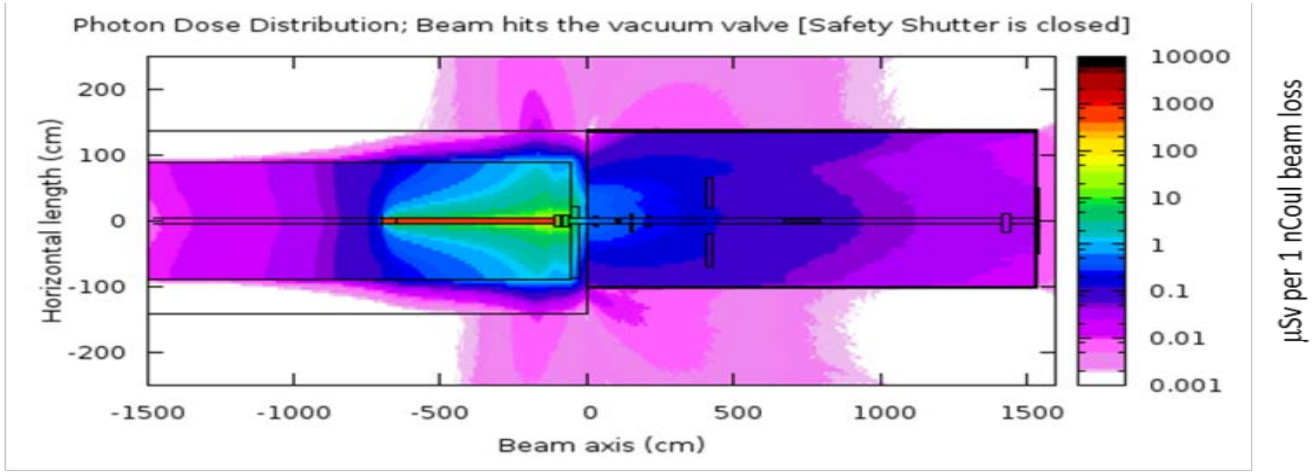
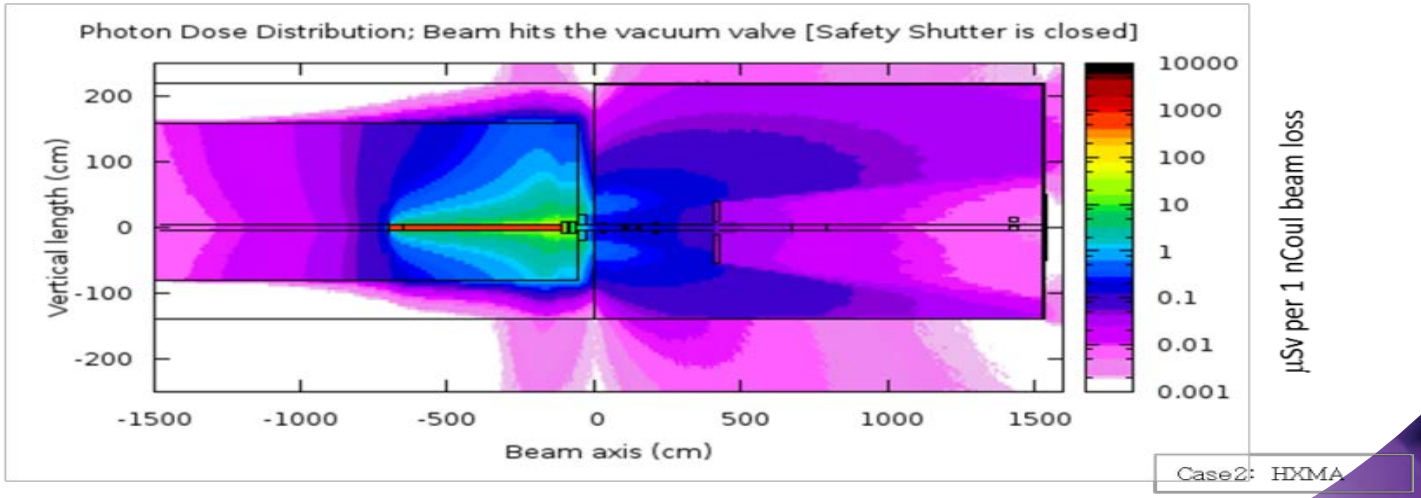
Case 2: Beam hits components

Beam hits Vacuum Valve

Beam line safety shutter is closed





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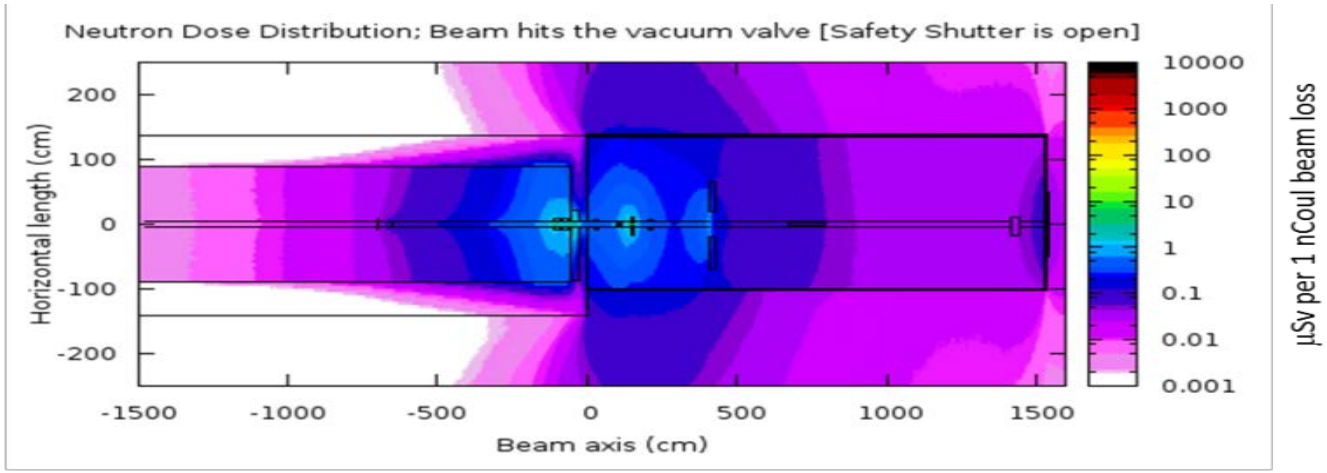

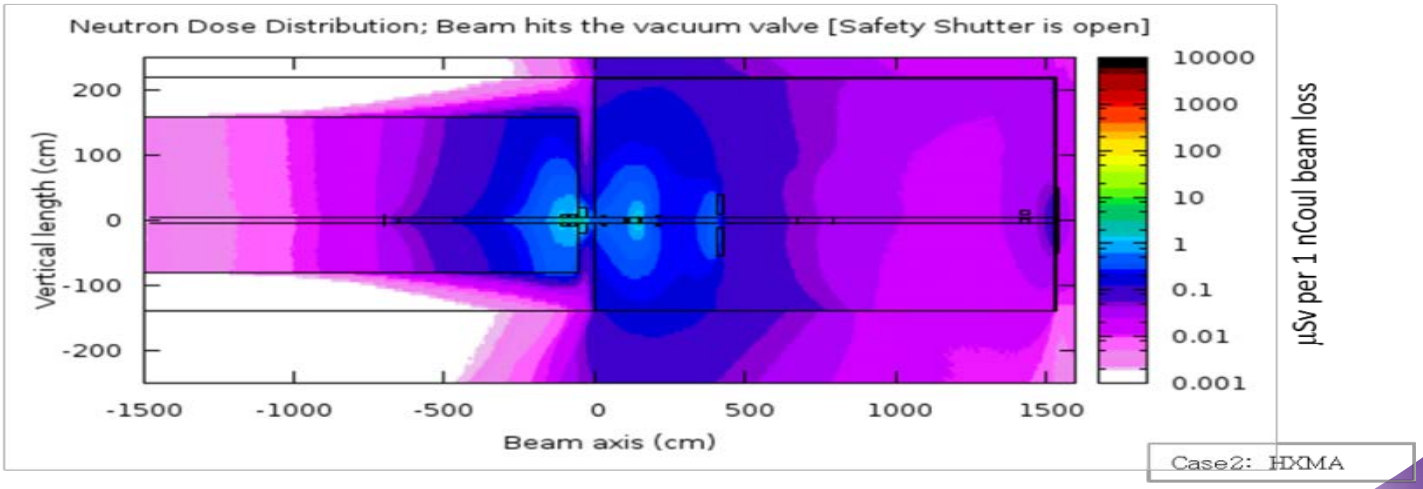

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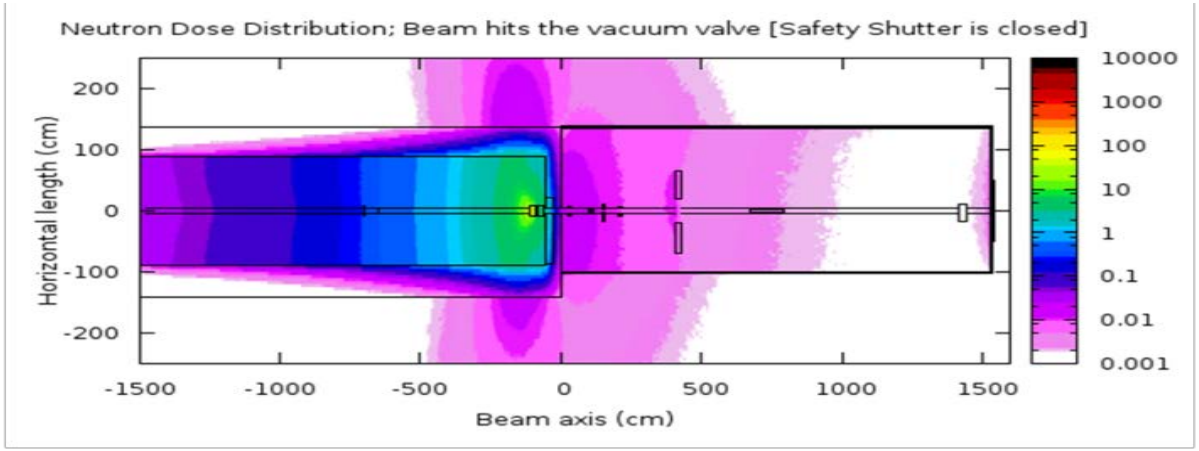
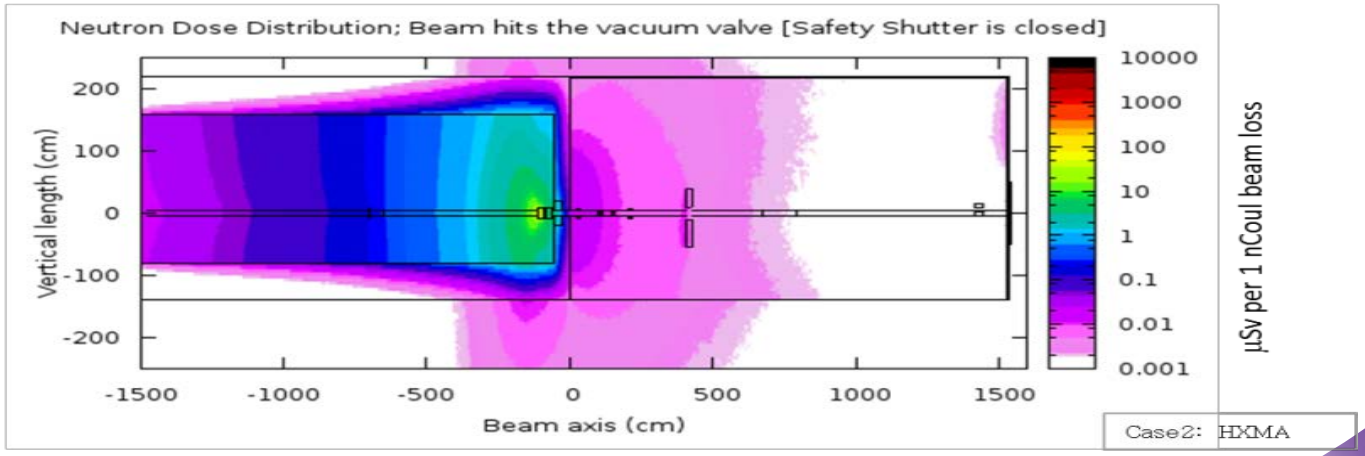
Case 2: Beam hits components

Beam hits Vacuum Valve

Beam line safety shutter is closed





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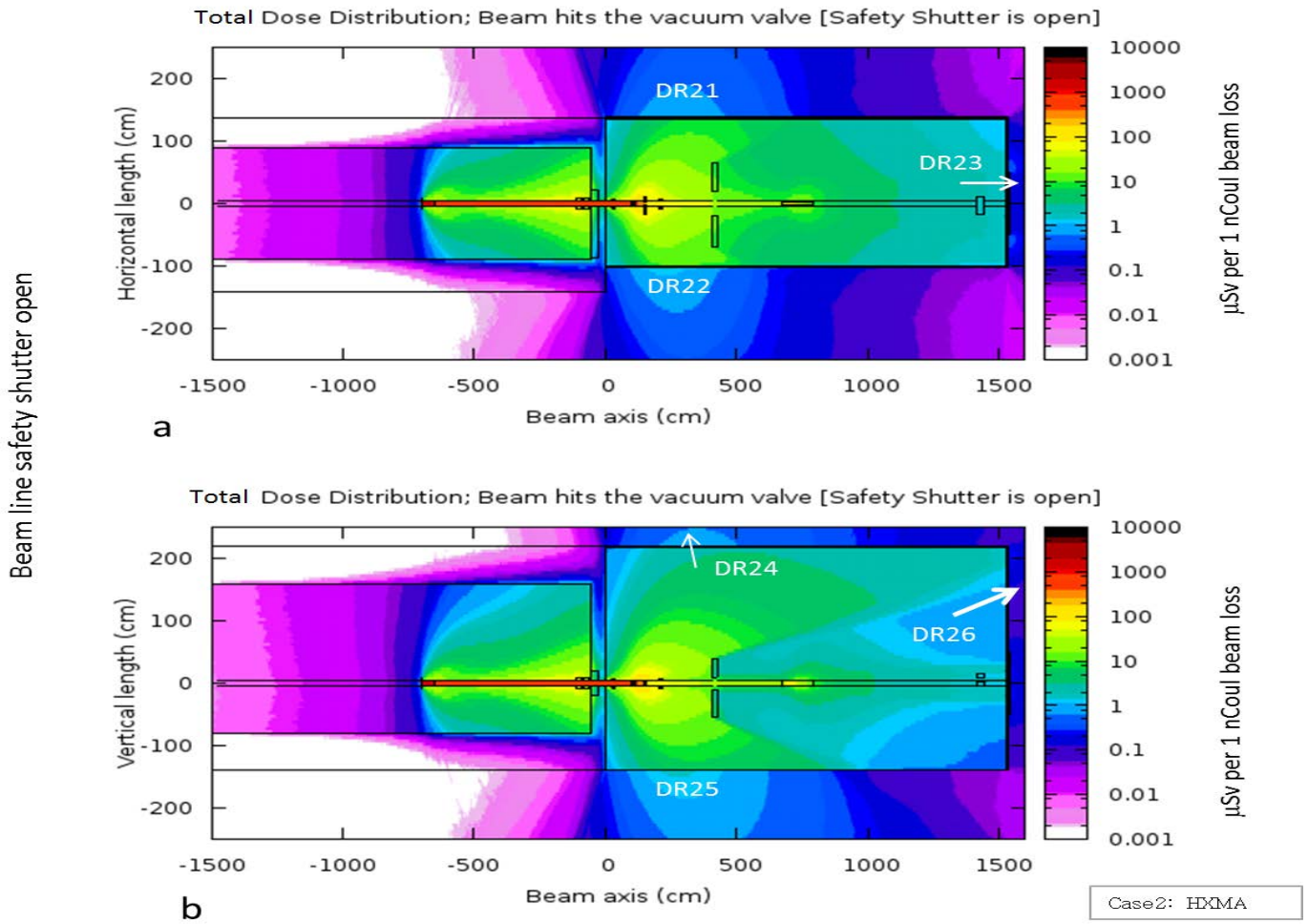
Case 2: Beam hits components

Beam hits Vacuum Valve



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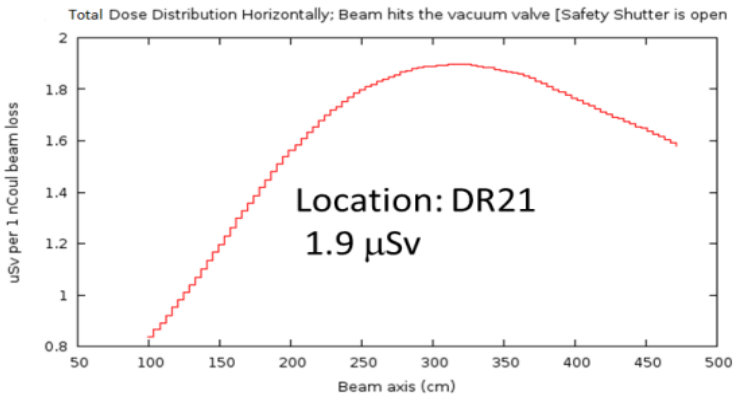
Case 2: Beam hits components

Beam hits Vacuum Valve

Case 2: Horizontal view: Beam line safety shutter open



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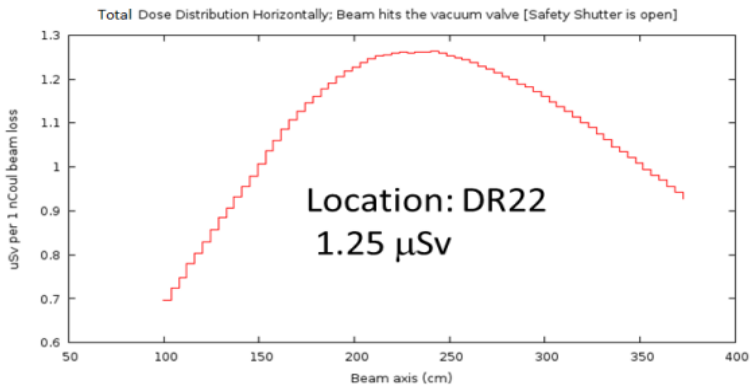

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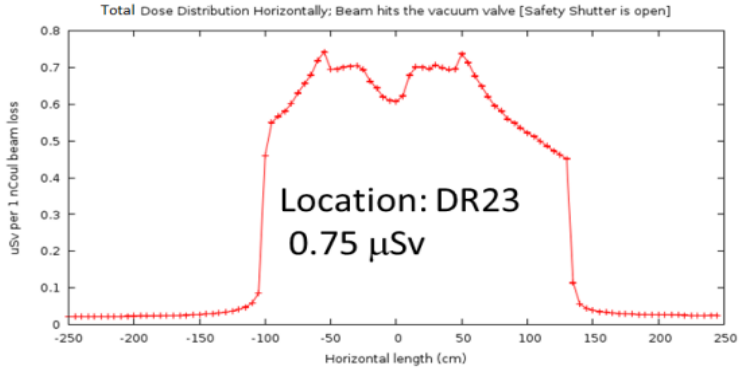

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Case2: HXMA

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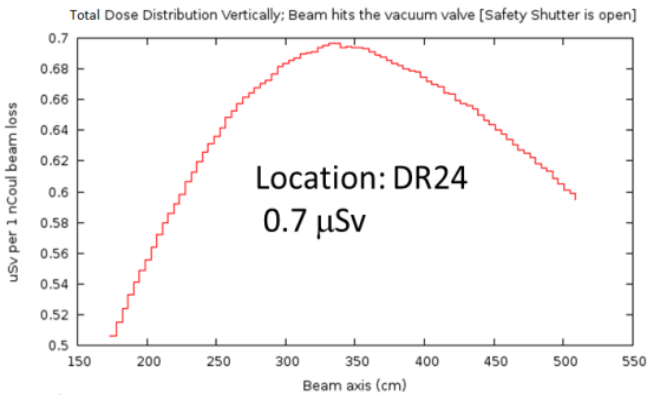
Case 2: Beam hits components

Beam hits Vacuum Valve

Case 2: Vertical View: Beam line safety shutter open



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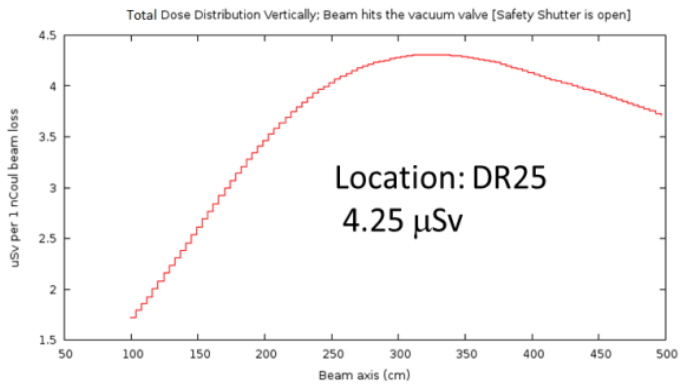

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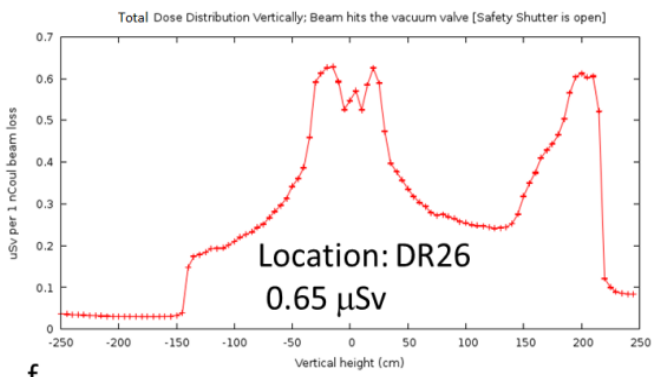

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Case2: HXMA

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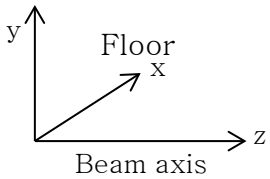
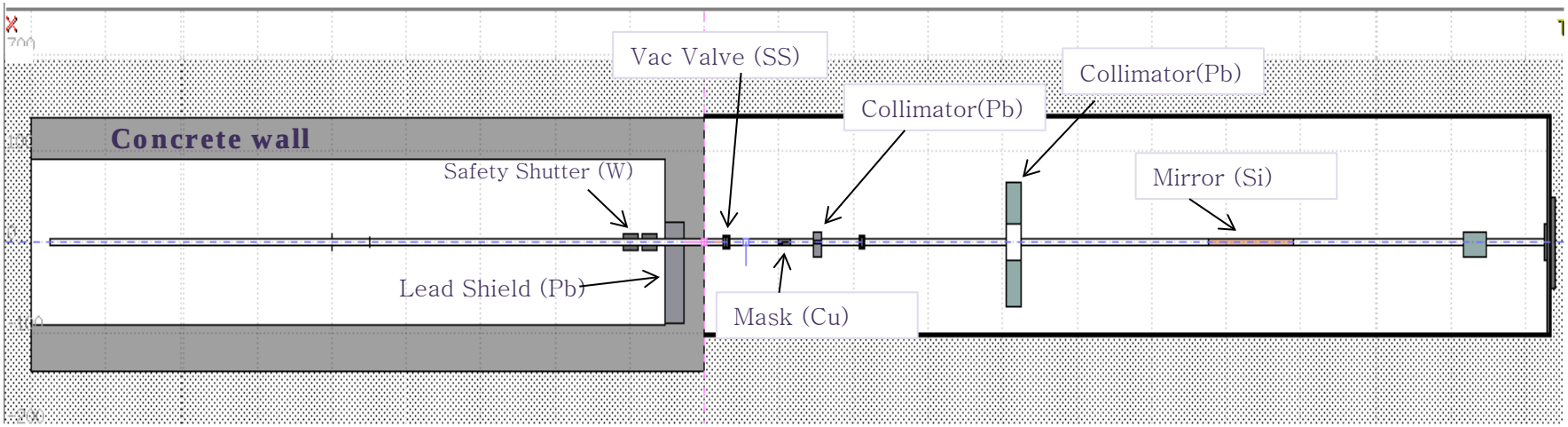
Case 3: Beam hits Opt Components

Beam hits Opt Components inside POE



Horizontal View



The optical components and will be used as target

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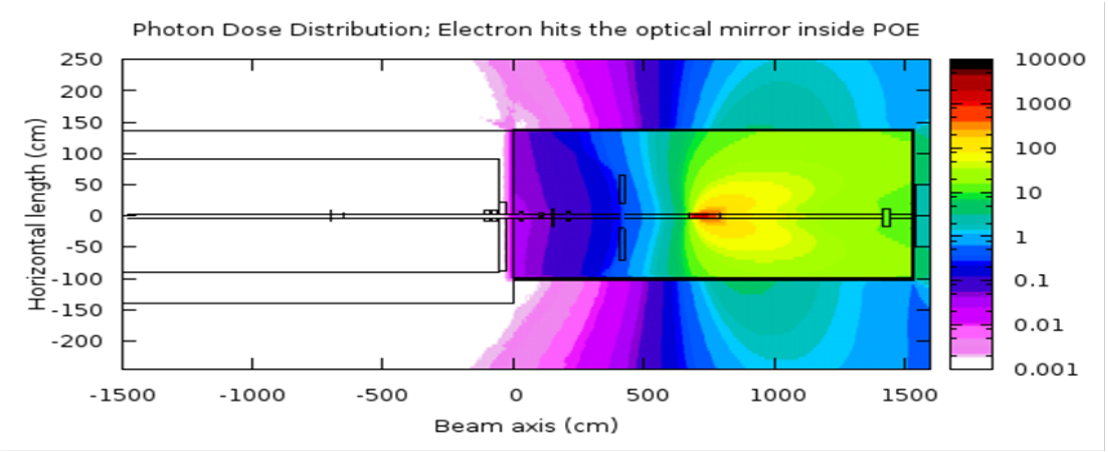
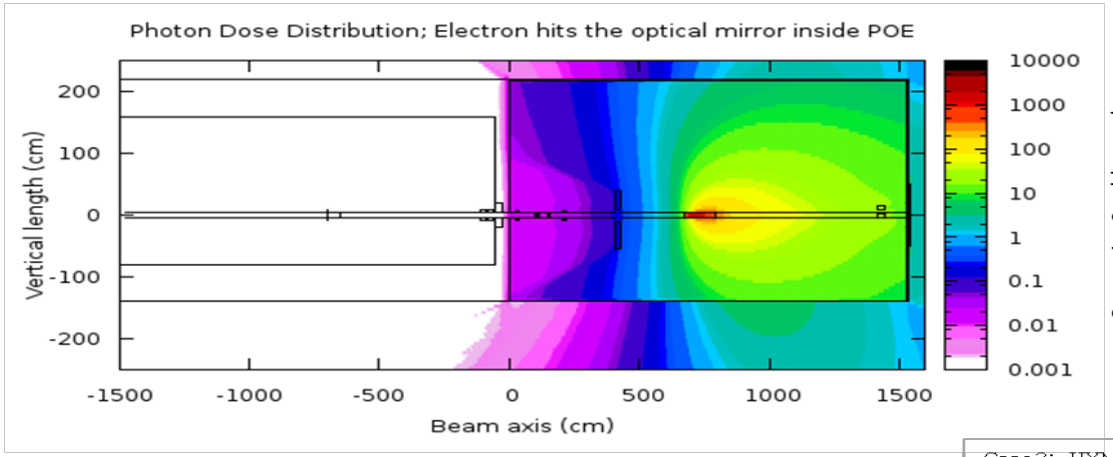
Case 3: Beam hits Opt Components

Beam hits Opt Components inside POE





Case3: HXMA

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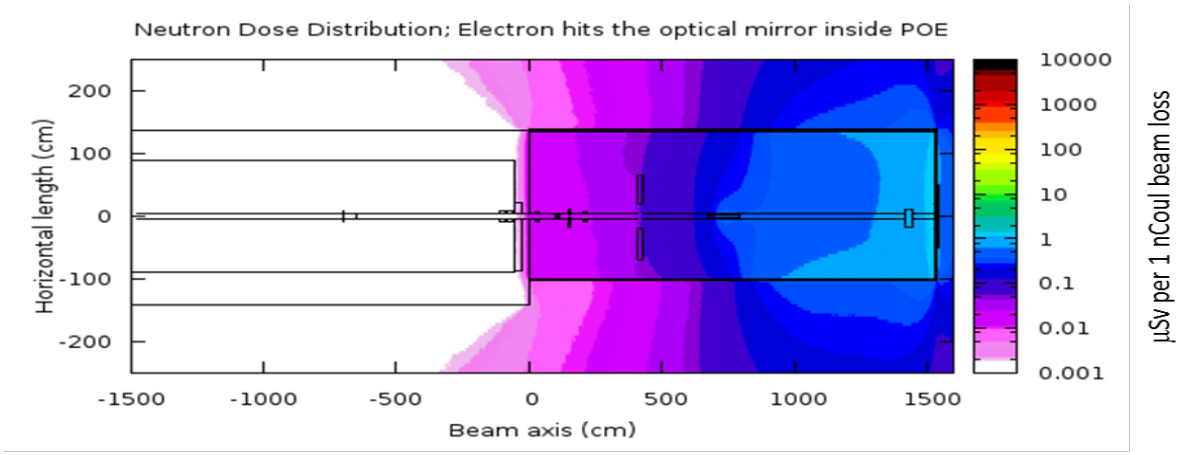
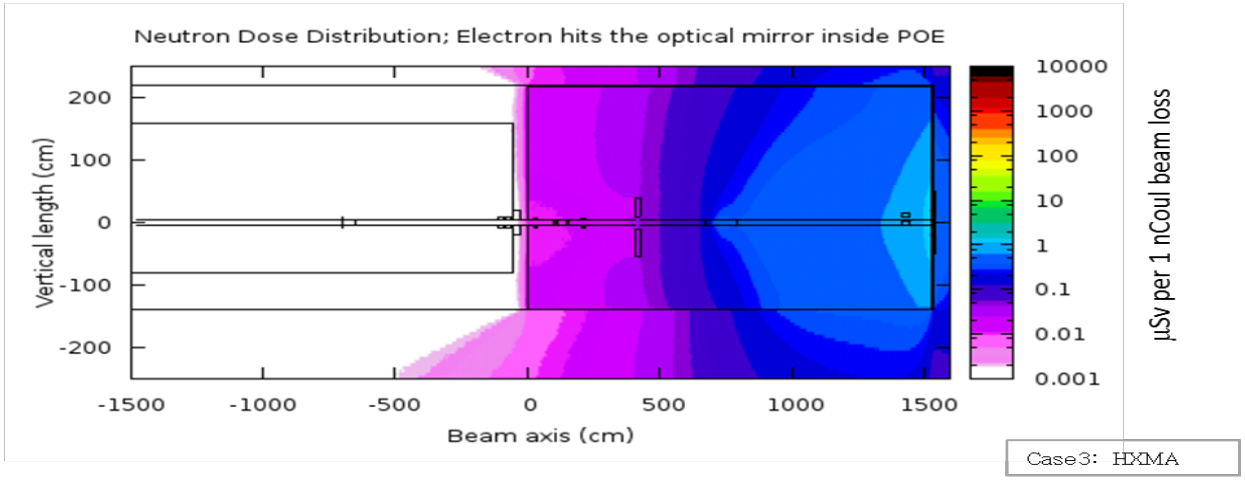
Case 3: Beam hits Opt Components

Beam hits Opt Components inside POE





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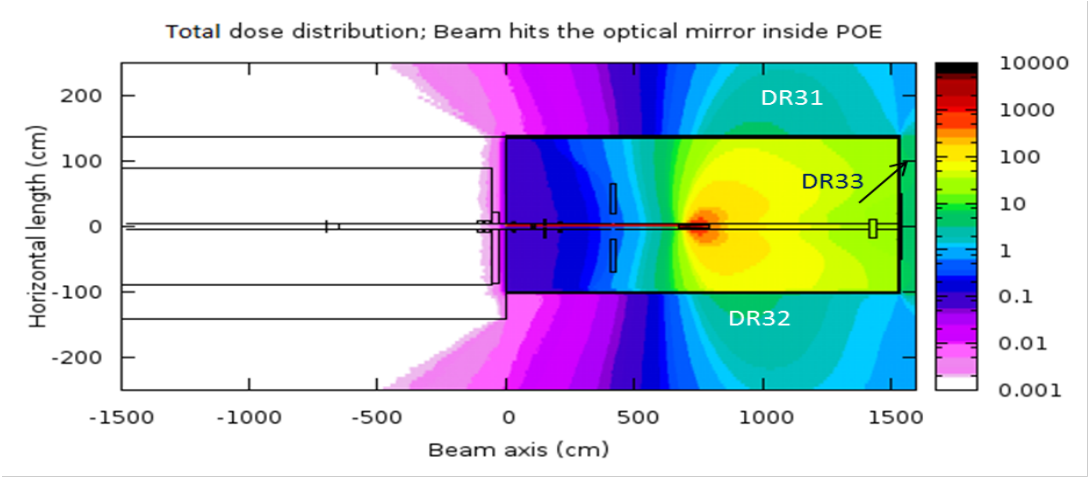
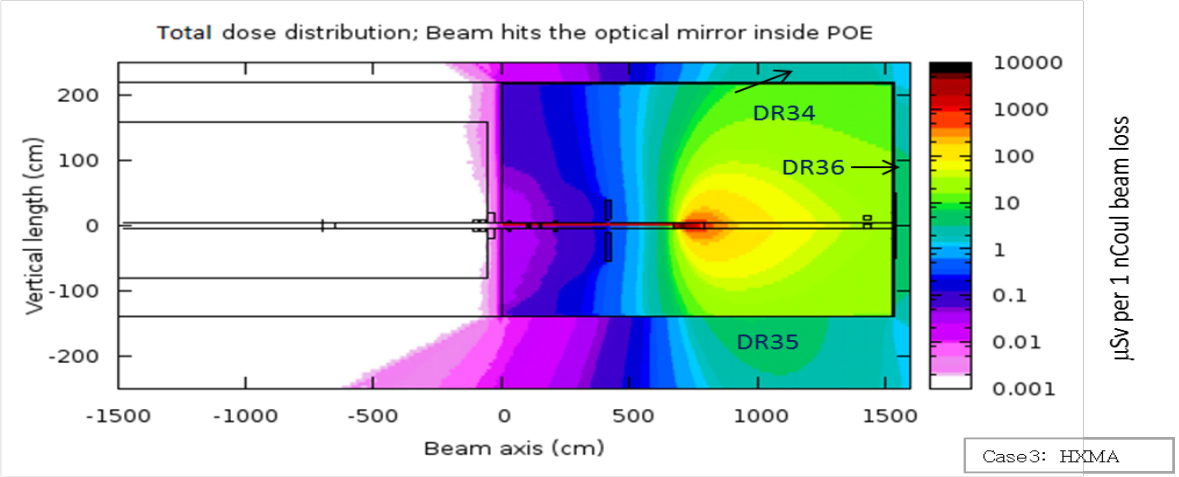
Case 3: Beam hits Opt Components

Beam hits Opt Components inside POE





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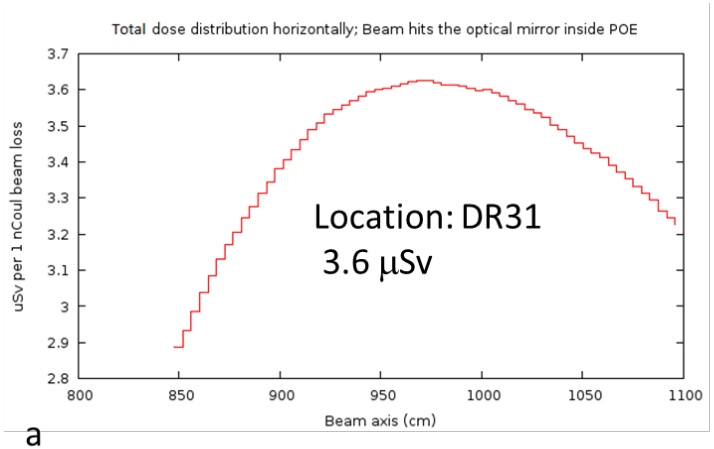
Case 3: Beam hits Opt Components

Beam hits Opt Components inside POE



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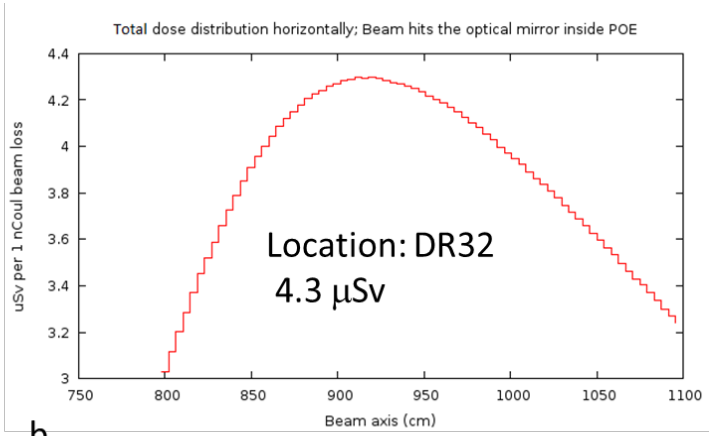

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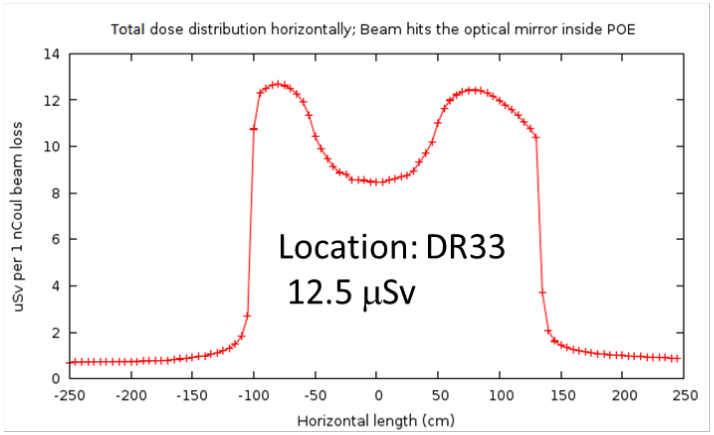

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Case3: HXMA

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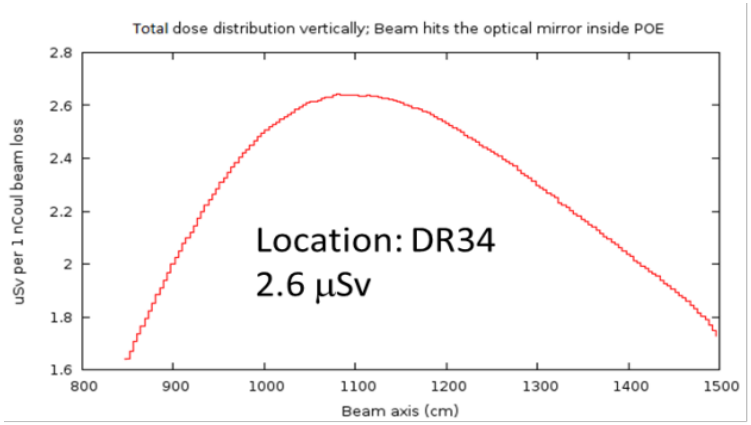
Case 3: Beam hits Opt Components

Beam hits Opt Components inside POE



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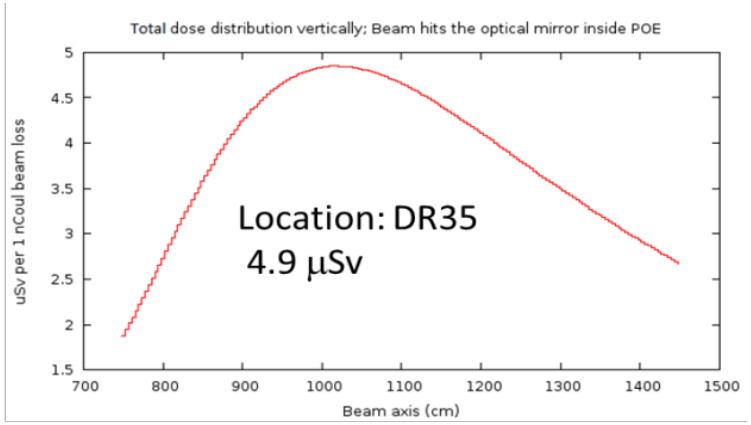

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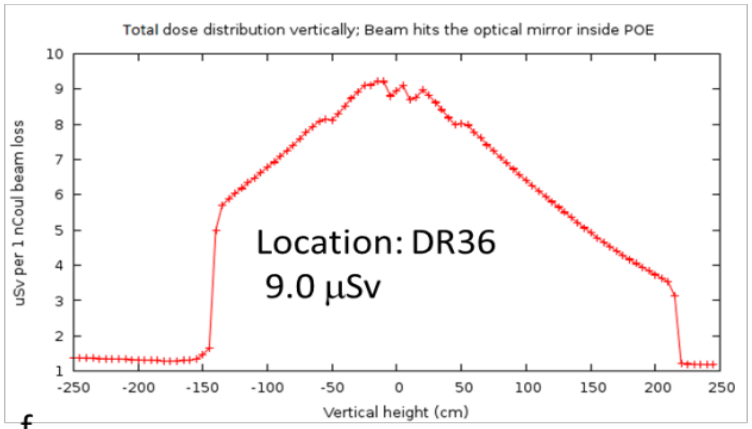

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Case3: HXMA

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Summary: Model Results

Doses around POE hutch: 3 Scenarios

	Doses in μSv / nCoul								
Loss Scenarios	Case: 1 Electron beam is miss-steered			Case: 2 Beam hits components in the FE			Case: 3 Beam enters the POE hutch and hits the optical component		
	R11 & R14	R 12 & R15	R 13 & R16	R21 & R24	R22 & R25	R 23 & R26	R31 & R34	R 32 & R35	R 33 & R36
Horizontal	3.6	0.38	1.9	1.9	1.25	0.75	3.6	4.3	12.5
Vertical	1.1	1.2	2.9	0.7	4.25	0.65	2.6	4.9	9.0

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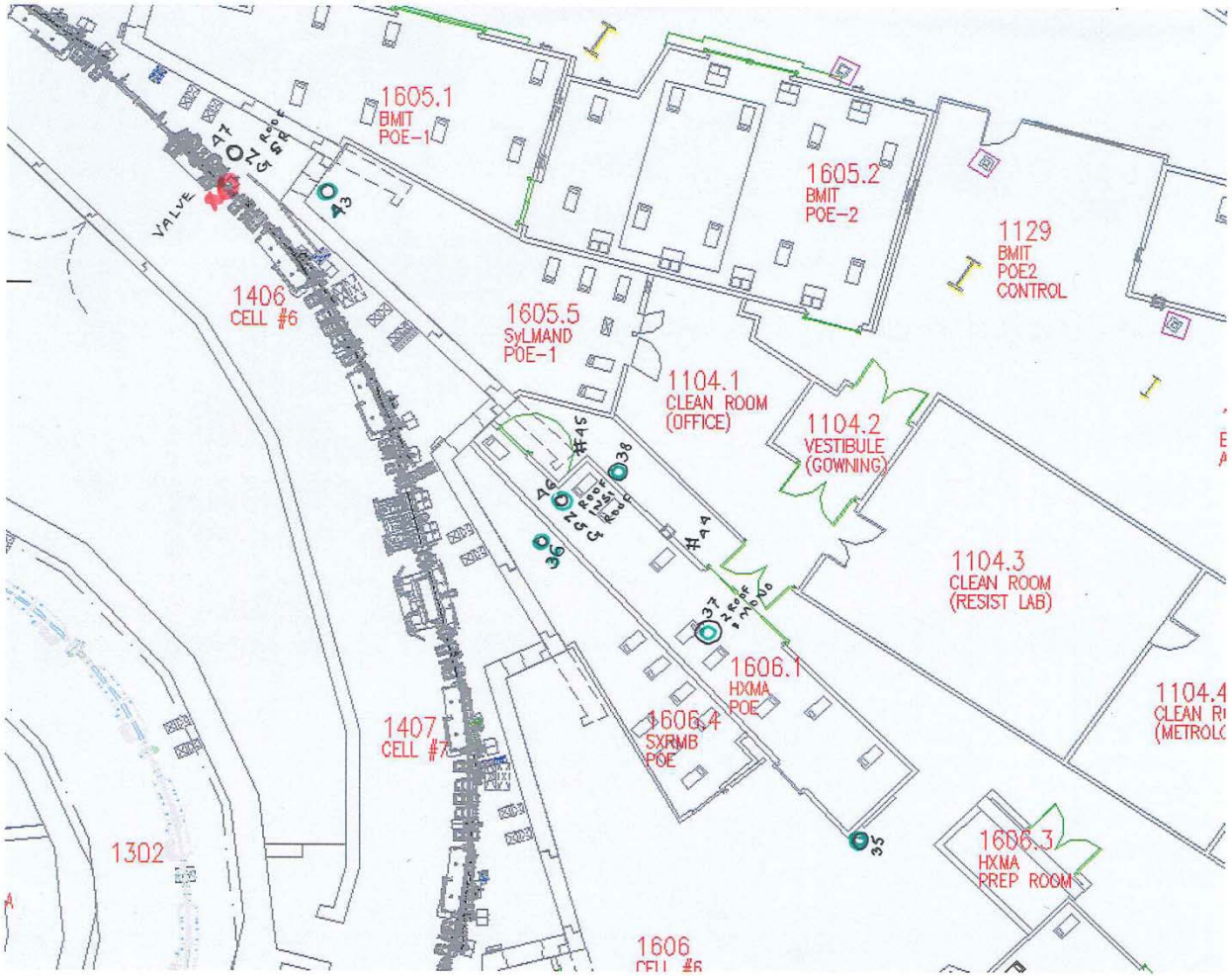
Radiation Measurement

Lay out plan: Hxma Beam Line



UNIT [Channel]	DETAILED LOCATION
35	HXMA POE Outside Backwall
1	HXMA POE Outside Backwall
2	HXMA POE Outside Backwall
36	SXRMB POE
1	SXRMB POE
2	SXRMB POE
37	HXMA POE Roof - over mono
1	HXMA POE Roof - over mono
2	HXMA POE Roof - over mono
3	Inside HXMA POE over mono
38	HXMA POE Sidewall
1	HXMA POE Sidewall
2	HXMA POE Sidewall
43	Sylmand POE
1	Sylmand POE
2	Sylmand POE
44	HXMA POE Front Door
1	HXMA POE Front Door
2	HXMA POE Front Door
45	HXMA POE Side Door
1	HXMA POE Side Door
2	HXMA POE Side Door
46	HXMA POE Roof - 3.5m from SR wall
1	HXMA POE Roof - 3.5m from SR wall
2	HXMA POE Roof - 3.5m from SR wall
3	Inside HXMA POE over collimator
47	SR Roof over top of valve
1	Inside SR next to valve
2	SR Roof over top of valve

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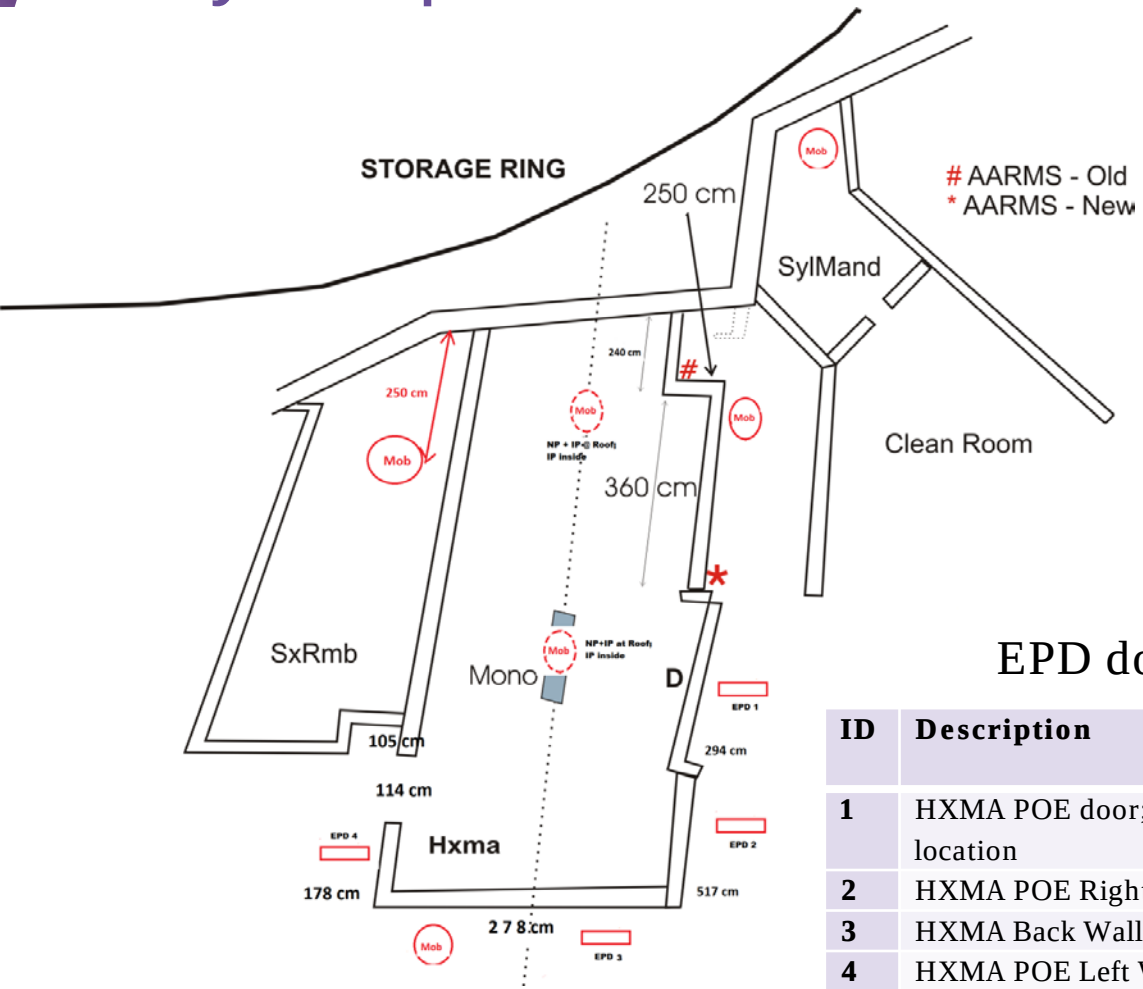
Radiation Measurement

Lay out plan: Hxma Beam Line



EPD doses

ID	Description	Dose µSv
1	HXMA POE door;- Middle location	3
2	HXMA POE Right Side wall	2
3	HXMA Back Wall	8
4	HXMA POE Left Wall	3

UNIT [Channel]	DETAILED LOCATION
35	HXMA POE Outside Backwall
1	HXMA POE Outside Backwall
2	HXMA POE Outside Backwall
36	SXRMB POE
1	SXRMB POE
2	SXRMB POE
37	HXMA POE Roof - over mono
1	HXMA POE Roof - over mono
2	HXMA POE Roof - over mono
3	Inside HXMA POE over mono
38	HXMA POE Sidewall
1	HXMA POE Sidewall
2	HXMA POE Sidewall
43	Sylmand POE
1	Sylmand POE
2	Sylmand POE
44	HXMA POE Front Door
1	HXMA POE Front Door
2	HXMA POE Front Door
45	HXMA POE Side Door
1	HXMA POE Side Door
2	HXMA POE Side Door
46	HXMA POE Roof - 3.5m from SR wall
1	HXMA POE Roof - 3.5m from SR wall
2	HXMA POE Roof - 3.5m from SR wall
3	Inside HXMA POE over collimator
47	SR Roof over top of valve
1	Inside SR next to valve
2	SR Roof over top of valve

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Radiation Measurement

Detectors specifications

STATION TYPE	IOC	UNIT ID Channel ID	EQUIP TYPE [Canberra made]	PV	DETAILED LOCATION
MOBILE	IOC2406-116	35	ADM	N/A	HXMA POE Outside Backwall
		1	IP100	GP2406-13	HXMA POE Outside Backwall
		2	NP100B	NP2406-13	HXMA POE Outside Backwall
MOBILE	IOC2406-116	36	ADM	N/A	SXRMB POE
		1	IP100	GP2406-14	SXRMB POE
		2	NP100B	NP2406-14	SXRMB POE
MOBILE	IOC2406-116	37	ADM	N/A	HXMA POE Roof - over mono
		1	IP100	GP2406-15	HXMA POE Roof - over mono
		2	NP100B	NP2406-15	HXMA POE Roof - over mono
		3	IP100	TP2406-15	Inside HXMA POE over mono
MOBILE	IOC2406-116	38	ADM	N/A	HXMA POE Sidewall
		1	IP100	GP2406-16	HXMA POE Sidewall
		2	NP100B	NP2406-16	HXMA POE Sidewall
MOBILE	IOC2406-307	43	ADM	N/A	Sylmand POE
		1	IP100	GP1606-401	Sylmand POE
		2	NP100B	NP1606-401	Sylmand POE
PERMANENT	IOC2406-307	44	ADM	N/A	HXMA POE Front Door
		1	IP100	GP1606-01	HXMA POE Front Door
		2	NP100H	NP1606-01	HXMA POE Front Door
PERMANENT	IOC2406-307	45	ADM	N/A	HXMA POE Side Door
		1	IP100	GP1606-101	HXMA POE Side Door
		2	NP100B	NP1606-101	HXMA POE Side Door
MOBILE	IOC2406-307	46	ADM	N/A	HXMA POE Roof - 3.5m from SR wall
		1	IP100	GP1605-501	HXMA POE Roof - 3.5m from SR wall
		2	NP100B	NP1605-501	HXMA POE Roof - 3.5m from SR wall
		3	IP100SI	TP1605-501	Inside HXMA POE over collimator
MOBILE	IOC2406-307	47	ADM	N/A	SR Roof over top of valve
		1	IP100	GP1605-101	Inside SR next to valve
		2	NP100B	NP1605-101	SR Roof over top of valve

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Radiation Measurement

Injection Protocol

Time [April 23, 2013]	Hxma Safety shutter status	Beam Loss
20:20	SSH open	Normal Beam
20:45	SSH closed	Normal Beam
21:20	SSH closed	1 shot hit VV
21:30	SSH open	1 shot hit VV
22:00	SSH Open	5 shot hit VV
22:10	SSH Closed	5 shot hit VV
22:20	SSH Closed	10 shot hit VV
22:30	SSH Open	10 shot hit VV
22:55	SSH Open	Continuous

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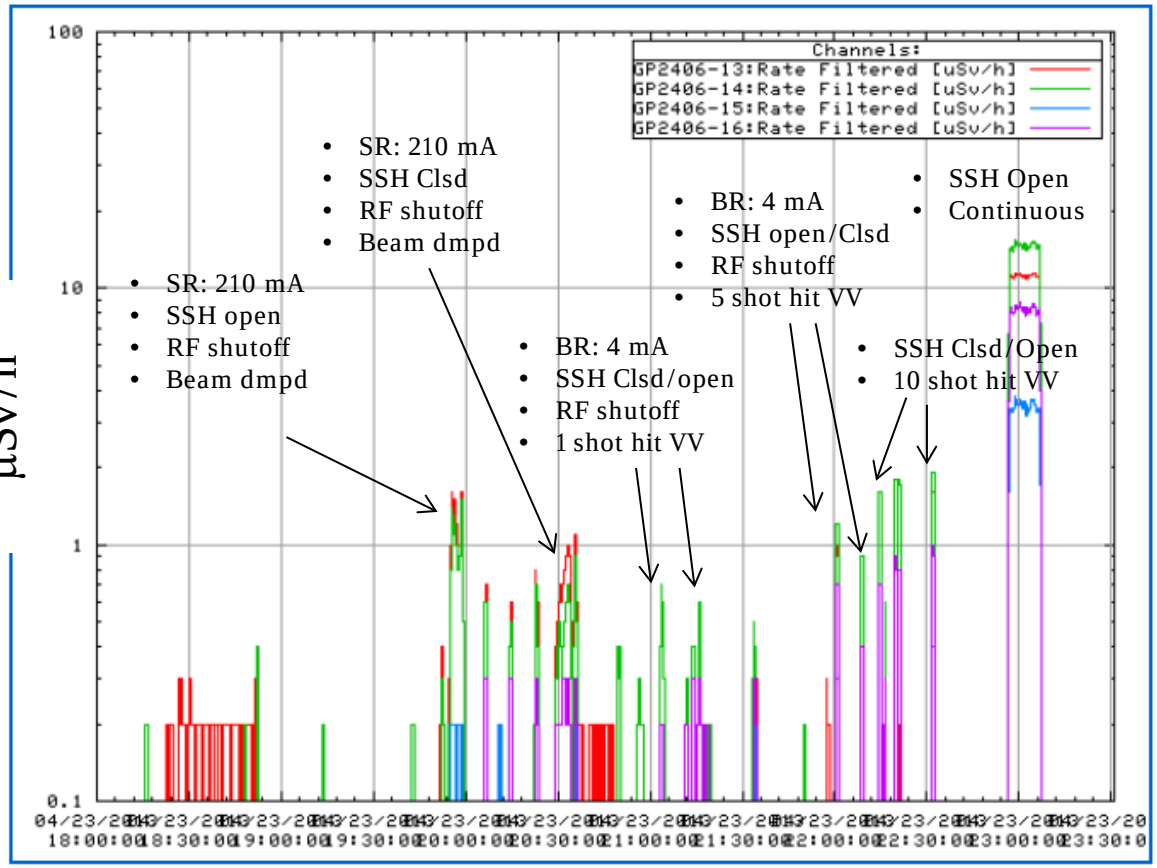
Radiation Measurement

Measurement data: Example 1: Photon Doses

Channel Plot



Unit		Locations
35	GP2406- - 13	HXMA POE Outside Backwall
1		HXMA POE Outside Backwall
2		HXMA POE Outside Backwall
36	GP2406- - 14	SXRMB POE
1		SXRMB POE
2		SXRMB POE
37	GP2406- - 15	HXMA POE Roof - over mono
1		HXMA POE Roof - over mono
2		HXMA POE Roof - over mono
3		Inside HXMA POE over mono
38	GP2406- - 16	HXMA POE Sidewall
1		HXMA POE Sidewall
2		HXMA POE Sidewall

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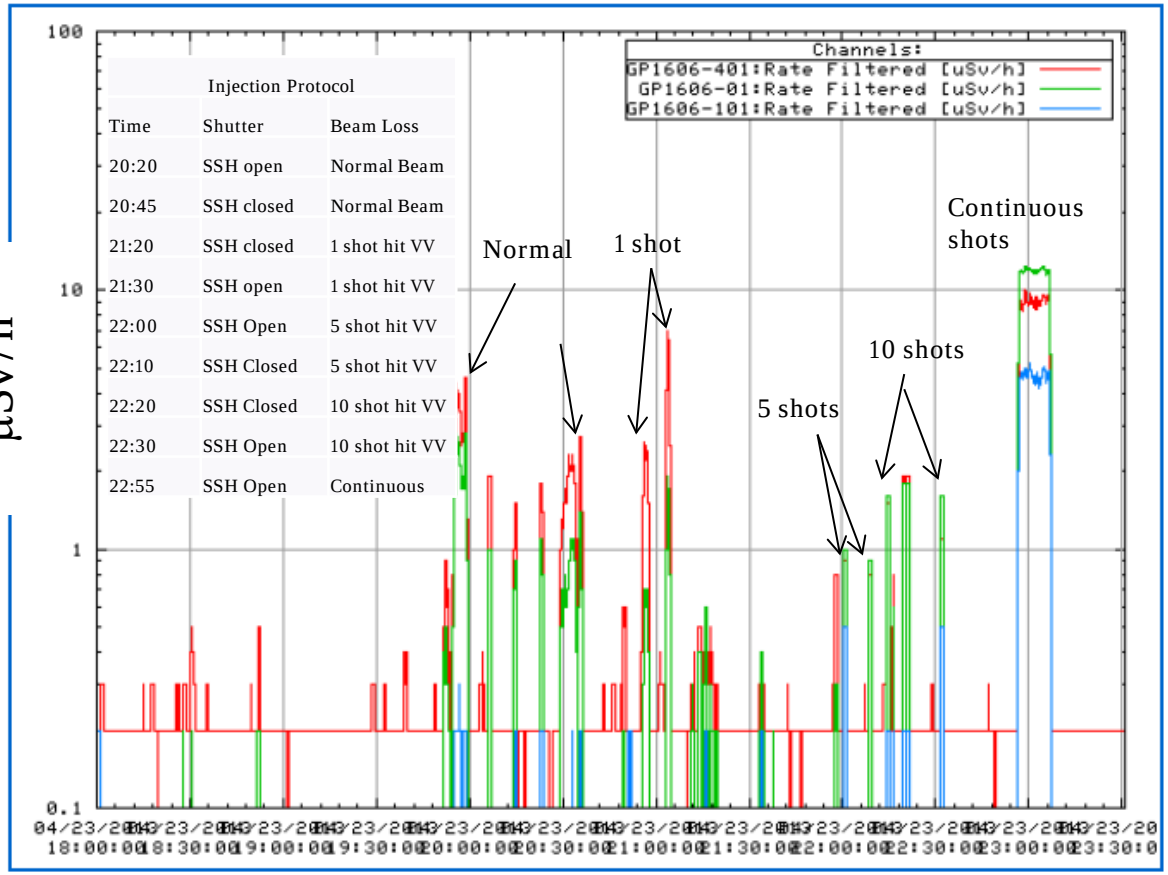
Radiation Measurement

Measurement data: Exam: 2: Photon Doses

Channel Plot



Unit		Locations
43	GP1606-401	Sylmand POE
1		Sylmand POE
2		Sylmand POE
44	GP1606-01	HXMA POE Front Door
1		HXMA POE Front Door
2		HXMA POE Front Door
45	GP1606-101	HXMA POE Side Door
1		HXMA POE Side Door
2		HXMA POE Side Door

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Uncorrected / Unprocessed

Radiation Measurement

Summary of data:

Injection Type	HXMA Safety Shutter Status	Type of Det	Maximum Dose rate in μSv/hour	
			Dose in μSv/hour [**NO correction factor applied**]	Location
Beam dumped with RF shut off @ 210 mA	Open	Photon	4	Sylmand POE
		Neutron	9	Sxrmb POE
	Closed	Photon	2	Sylmand POE
		Neutron	6	Sxrmb POE
1 Shot hit VV	Closed	Photon	2.5	Sylmand POE
		Neutron	3	Sxrmb POE
	Open	Photon	7	Sylmand POE
		Neutron	2.5	Hxma POE roof
5 shots hit VV	Open	Photon	1.2	Sxrmb POE
		Neutron	8	Sxrmb POE
	Closed	Photon	0.9	Sxrmb POE
		Neutron	4	Hxma POE roof
10 Shots hit VV	Closed	Photon	1.5	Sxrmb POE
		Neutron	7	Hxma roof
	Open	Photon	2	Sxrmb POE
		Neutron	10.5	Sxrmb POE
Continuous Injection [13 min]	Open	Photon	16	Sxrmb POE
		Neutron	90	Sxrmb POE

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Conclusion and Future tasks

- The dose-rates measured outside of HXMA-POE [user area] did not exceed the safety dose limit [5 μSv/h]
- Initially, a fairly good agreement was found between the model data and the experimentally data. The experimental data are required to be corrected for Back ground, dead time and pulse mode energy responses
- In future, the data will analyzed following standard procedure[1]
- The Radiation measurement will be continued for 11 more beam lines

Ref 1: Ott K et al, Rad Protection Dos, 2004