Radiation Backgrounds for the APEX experiment

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Radiation Physics Group at RadCon

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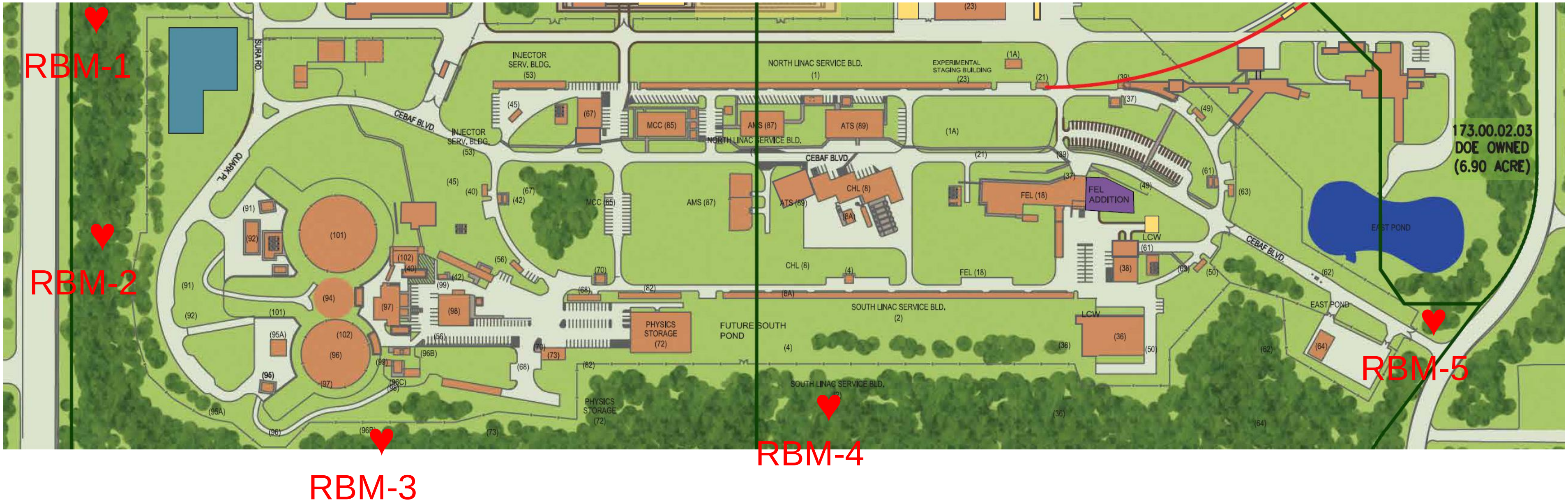
Contents

Shielding Design at JLab

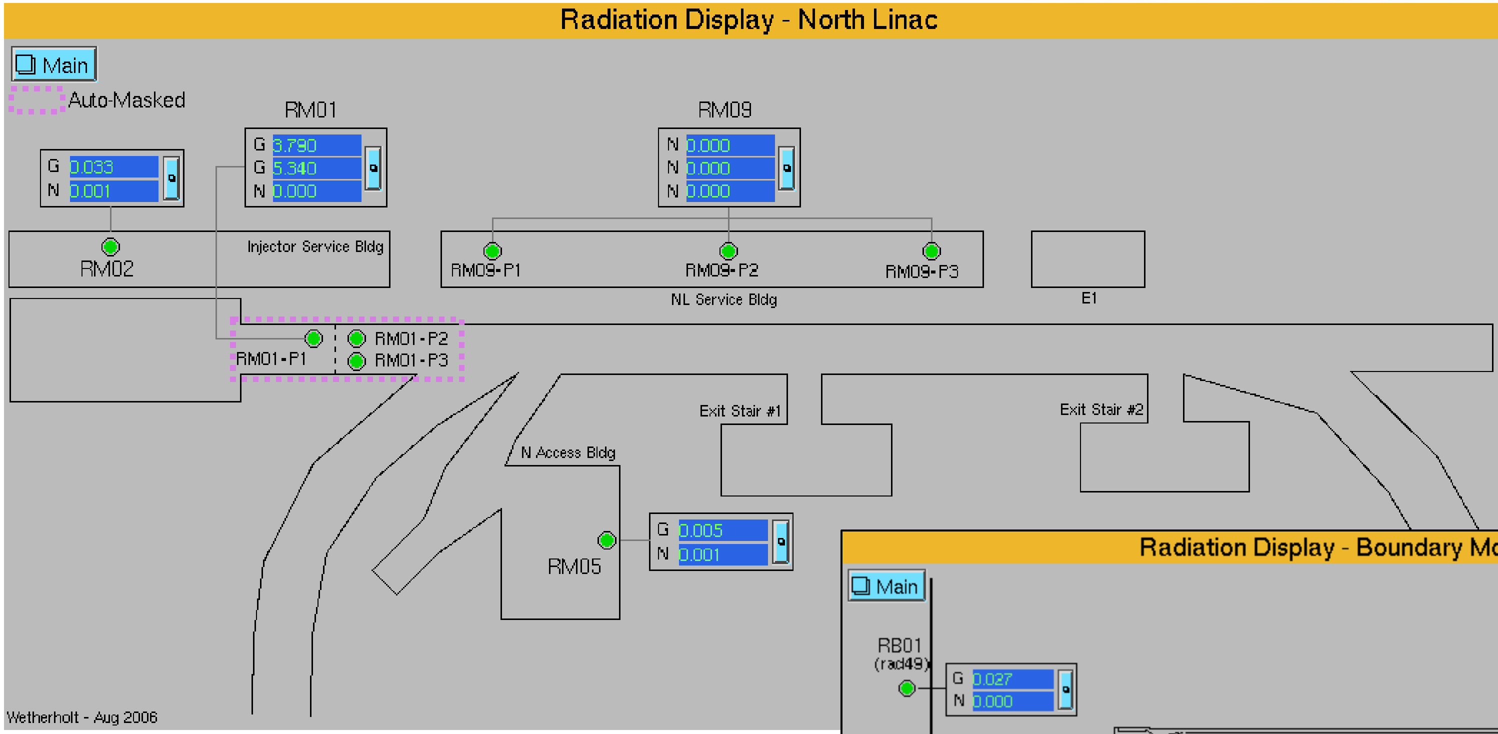
- JLab Radiological Control Policy (ES&H Manual, Radiation Control Supplement §111-06, §211-05) sets the Design Goals:
  - maintaining individual worker dose less than
    - 250 mrem (2.5 mSv) per year (Radiological Workers)
    - 10 mrem (0.1 mSv) per year (General Employees, Population)
  - preventing degradation of groundwater quality
  - controlling contamination by engineered means where possible
  - minimizing the generation of radioactive material
- Practical Design Criteria based on the Design Goals
  - Routine Continuous Beam Operations
    - Below 250 mrem to radiation worker in a 2000 hours work year
    - Below 10 mrem to non-radiation worker in a work year
    - !!! Below 10 mrem **to public** beyond the fence through a **full** year
  - Maximum Credible Accident: limit 15 rem (0.15 Sv) per occurrence

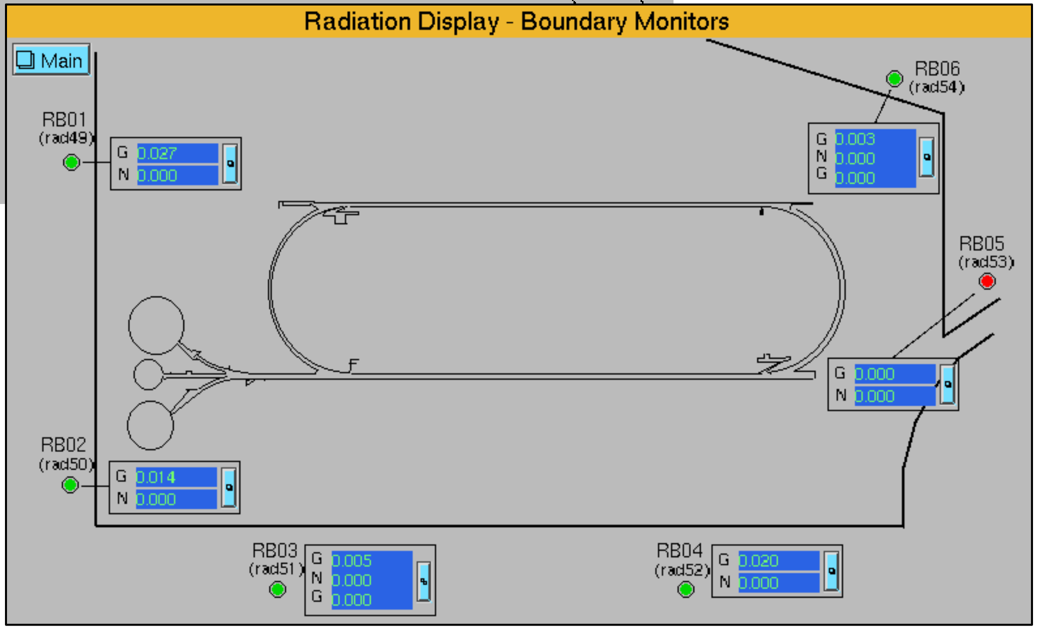
CEBAF Area Map



- Environmental Radiation Boundary Monitors 1-6
  - Moderated He-3 proportional neutron counters
  - Standard Ionization Chamber Monitors
  - High Pressure Environmental IC (New)

Radiation Monitoring Online at CEBAF



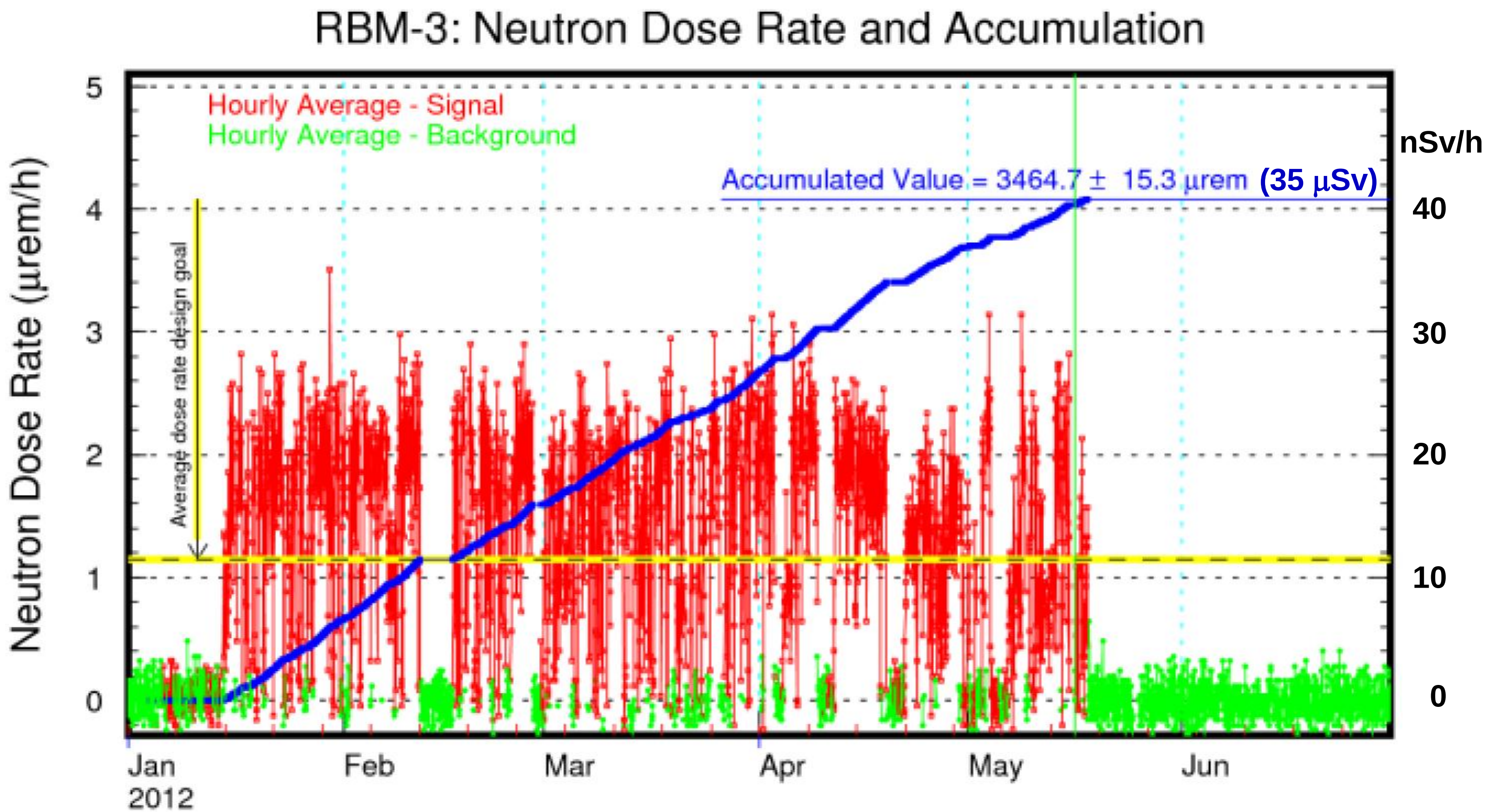


Two examples of the online radiation monitoring screens:

- North Linac area
- Boundary Monitors

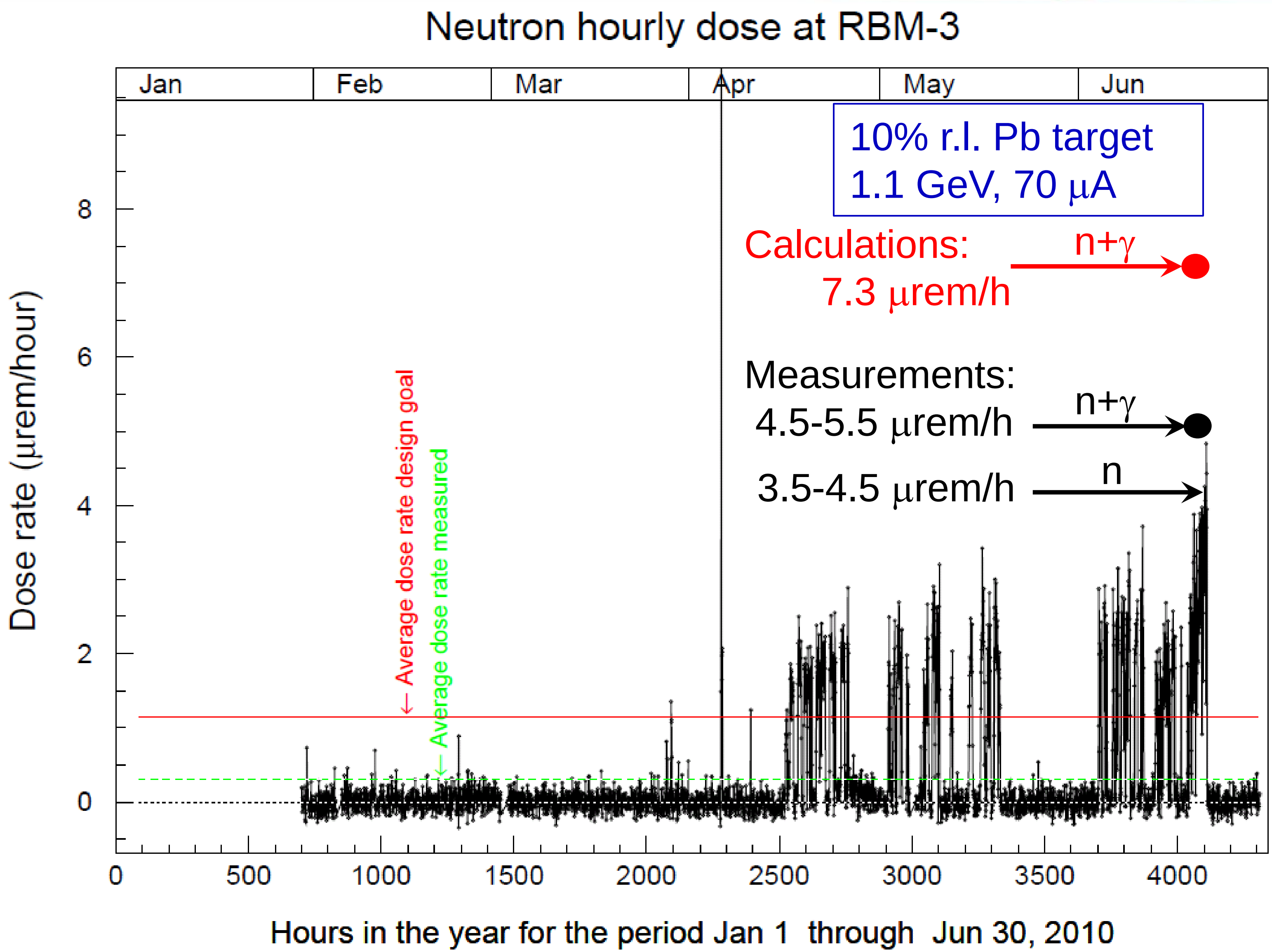
Environmental Neutron Dose Rates

Measurements in January – June, 2012



RBM-3 location at CEBAF boundary closest to Hall C (90 m)

Environmental Dose Rates: PREX'2010



APEX Environmental Radiation Evaluation

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

Exp. # E12-009 **rev:** **run dates: 2012** **name of liaison: B. Wojtsekhowski**

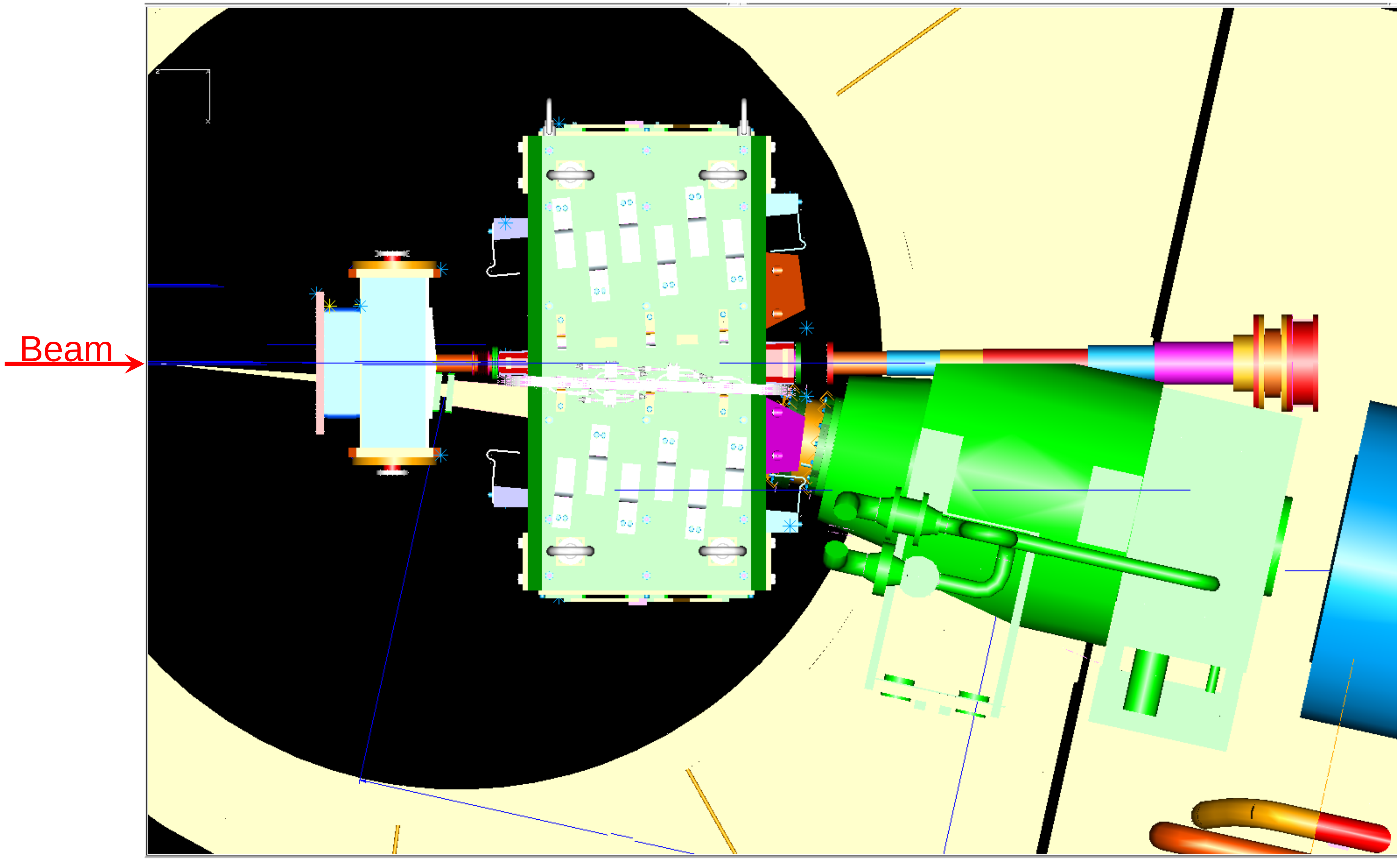
setup number			1	2	3	4		
beam	energy	GeV	1.100	2.200	3.300	4.400		*totals:*
	current	uA(CW)	50.0	70.0	80.0	60.0		
exp't target	element		C	W	W	W		
	thickness	mg/cm2	300	270	540	540		
	dist. to pivot	m	0.0	0.0	0.0	0.0		
	Z		6	74	74	74		
	A		12	184	184	184		
critical window	radius	cm	3.5	3.5	3.5	3.5		
	dist. to pivot	m	2.25	2.25	2.25	2.25		
scattering weighting factor			0.50	0.50	0.50	0.50		
time	run time	hours	144	144	144	288		720
	(100% eff.)	days	6.0	6.0	6.0	12.0		30.0
	installation	hours						0
	time	days	0.0	0.0	0.0	0.0		0.0
dose rate at the fence post (run time)	method 1	urem/hr	0.62	2.16	4.76	3.31		
	method 2	urem/hr						
	conservative	urem/hr	0.62	2.16	4.76	3.31		
dose per setup		urem	89	310	685	954		2038
% of annual dose budget		%	0.9	3.1	6.8	9.5		20.38
							% of allowed dose for the total time	247.95
							% of allowed dose for the run time only	247.95

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

date form issued: November 16, 2011 *authors:* P.Degtiarenko

- First estimates done in 2011 using the standard tool ELEC5
- New calculations using the GEANT3/DINREG Monte Carlo

APEX Environmental Radiation Evaluation



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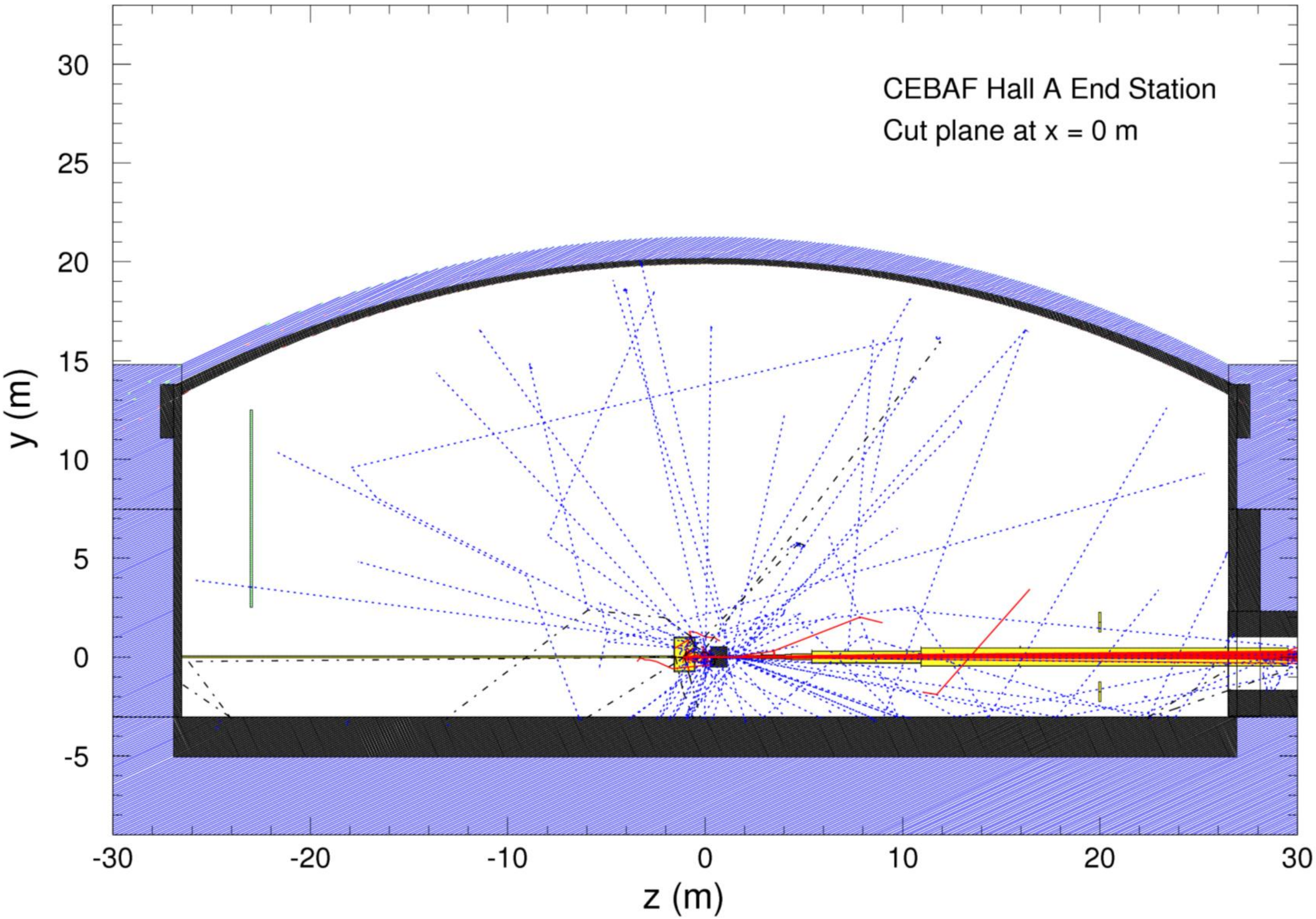

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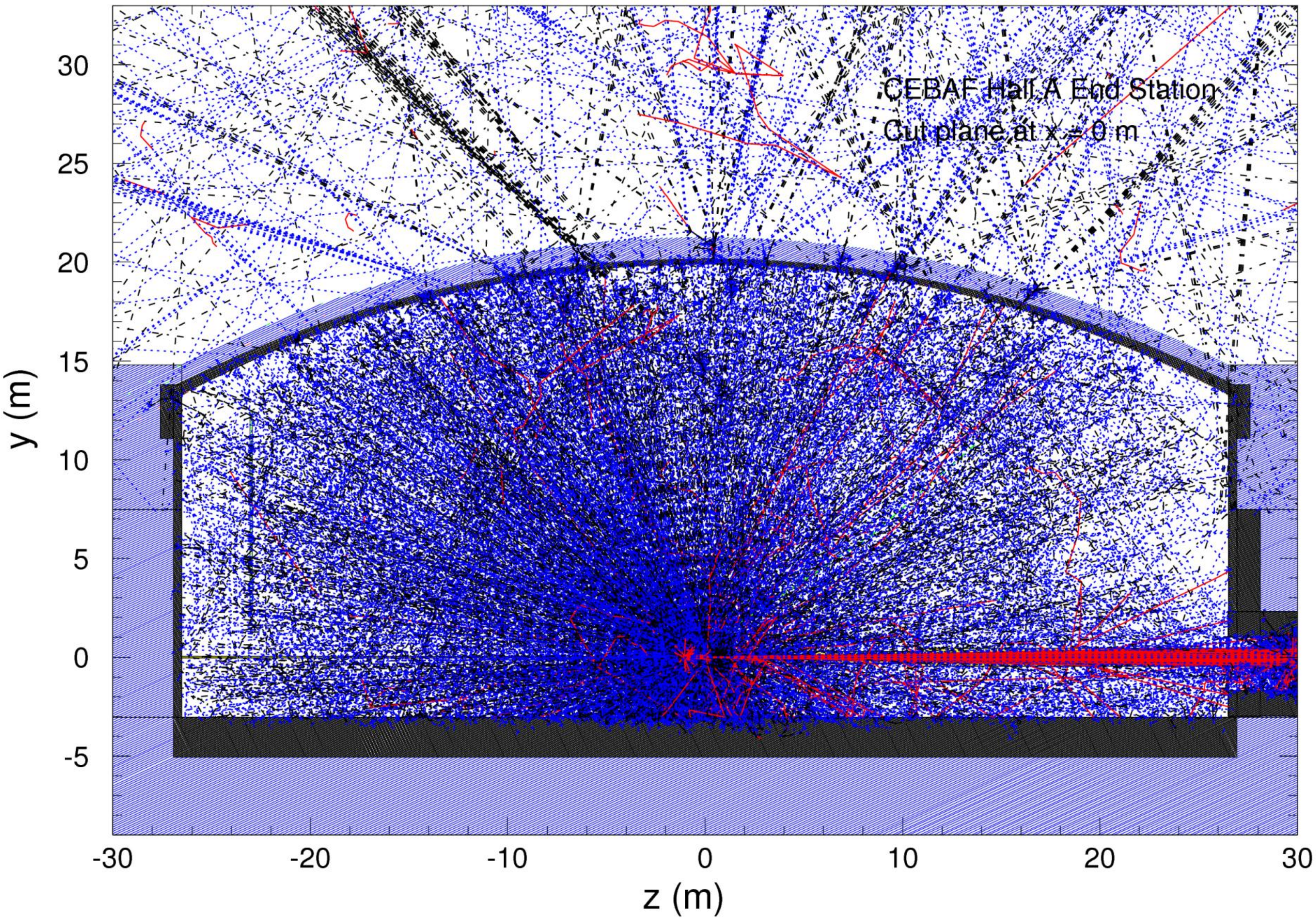
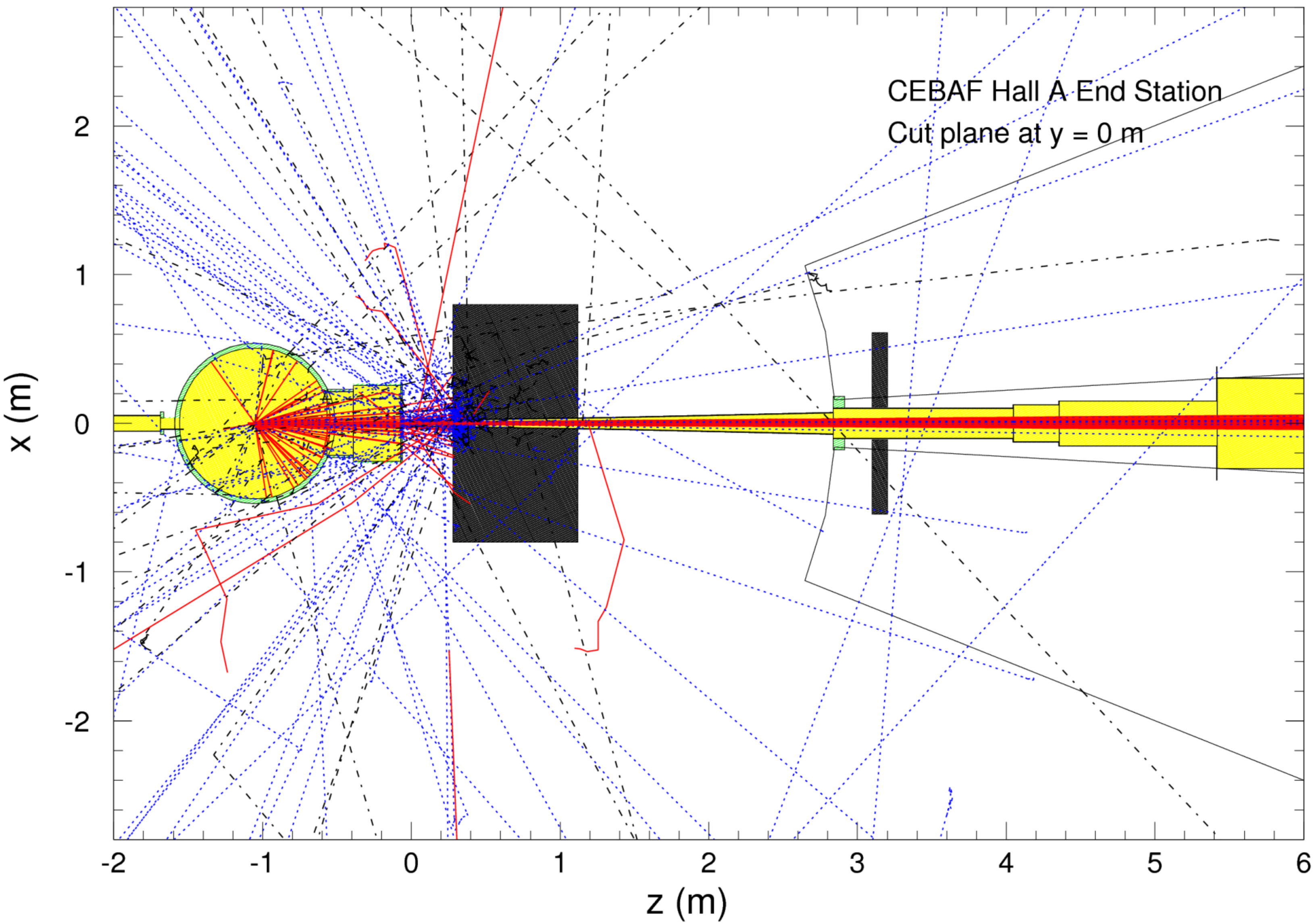


Jefferson Lab

APEX Environmental Radiation Evaluation



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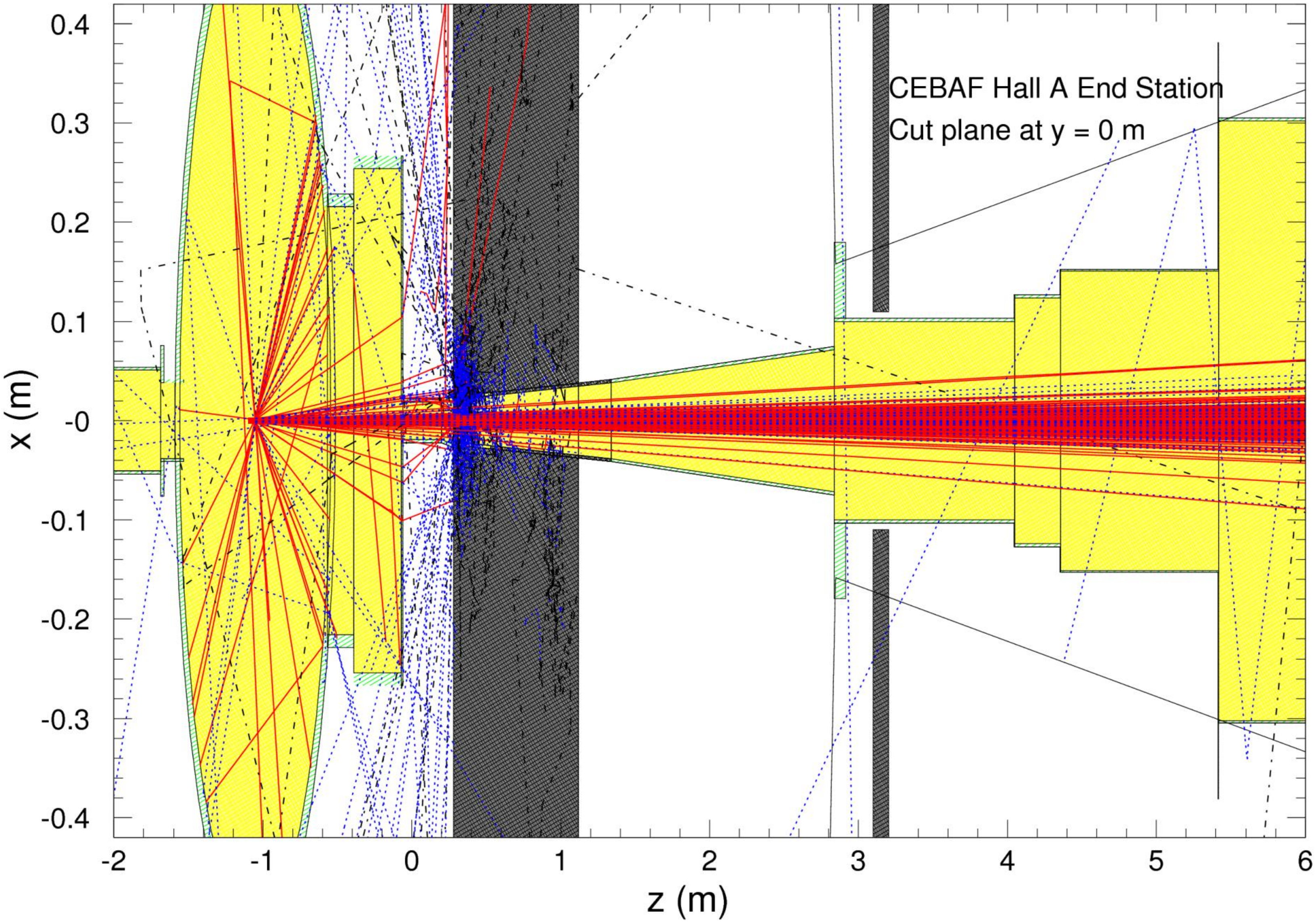
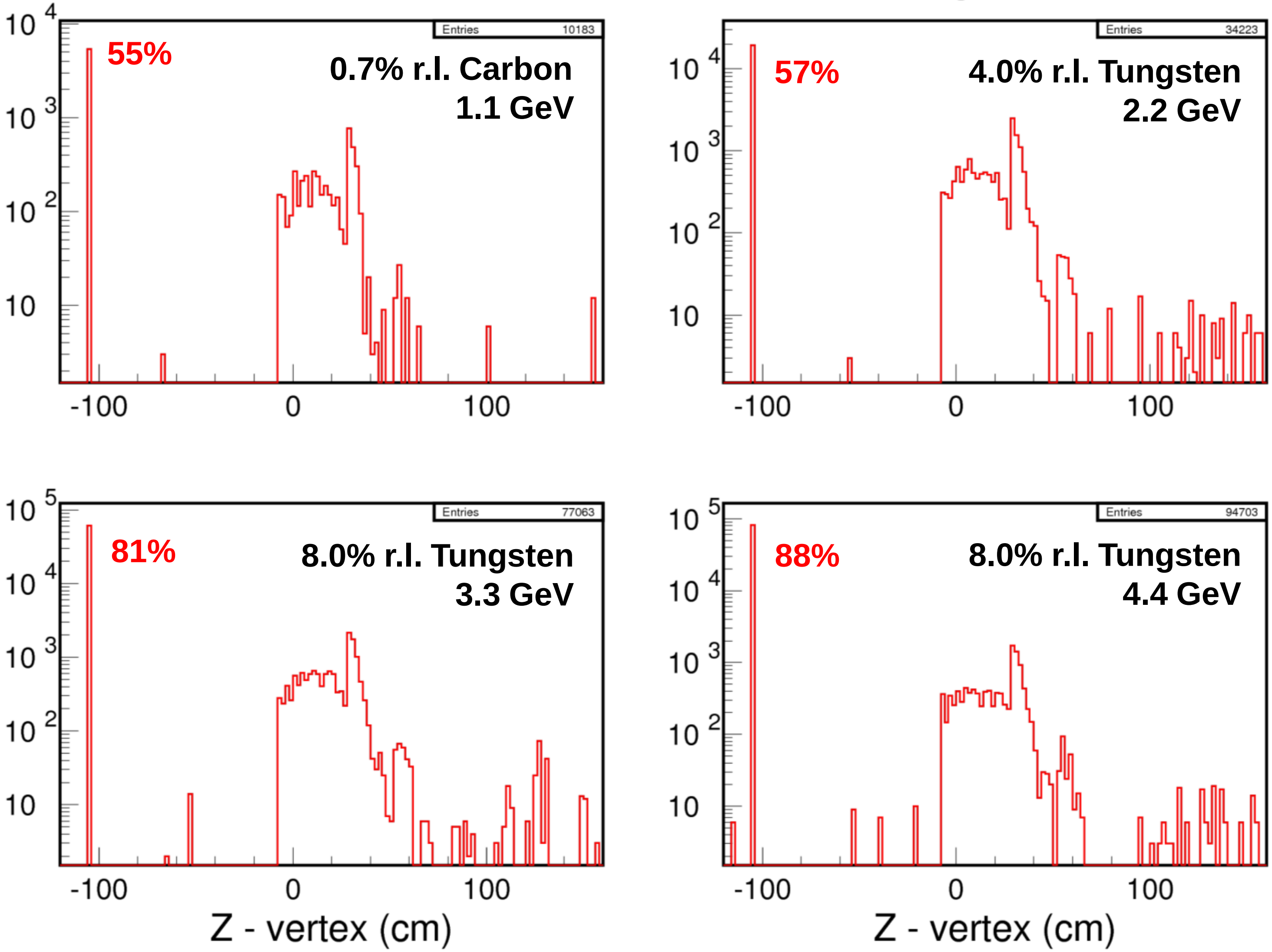


Jefferson Lab

APEX Environmental Radiation Evaluation

Vertex Distribution for Neutrons Exiting Roof



Environmental Radiation Evaluation

setup number			1	2	3	4
beam	energy	GeV	1.100	2.200	3.300	4.400
	current	uA(CW)	50.0	70.0	80.0	60.0
exp't target	element		C	W	W	W
	thickness	mg/cm2	300	270	540	540
	dist. to pivot	m	0.0	0.0	0.0	0.0
	Z		6	74	74	74
	A		12	184	184	184
time	run time	hours	144	144	144	288
	(100% eff.)	days	6.0	6.0	6.0	12.0
dose rate at the fence post	method 1	urem/hr	0.62	2.16	4.76	3.31
	method 2	urem/hr	**0.31**	**1.98**	**7.46**	**6.51**

ELEC5 Calculations

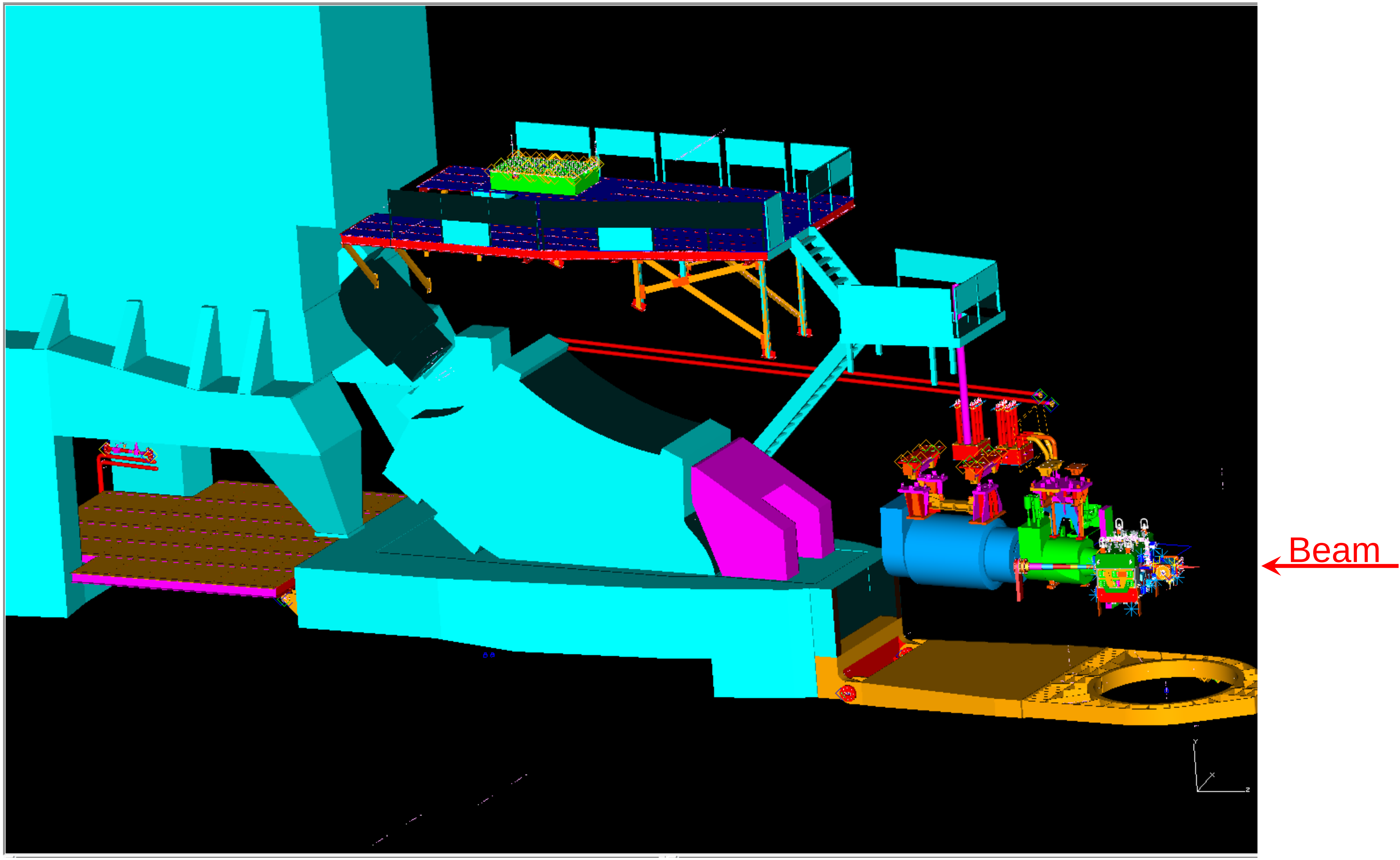
~20% of Yearly Rad.Budget (method 1)

~33% of Yearly Rad.Budget (method 2)

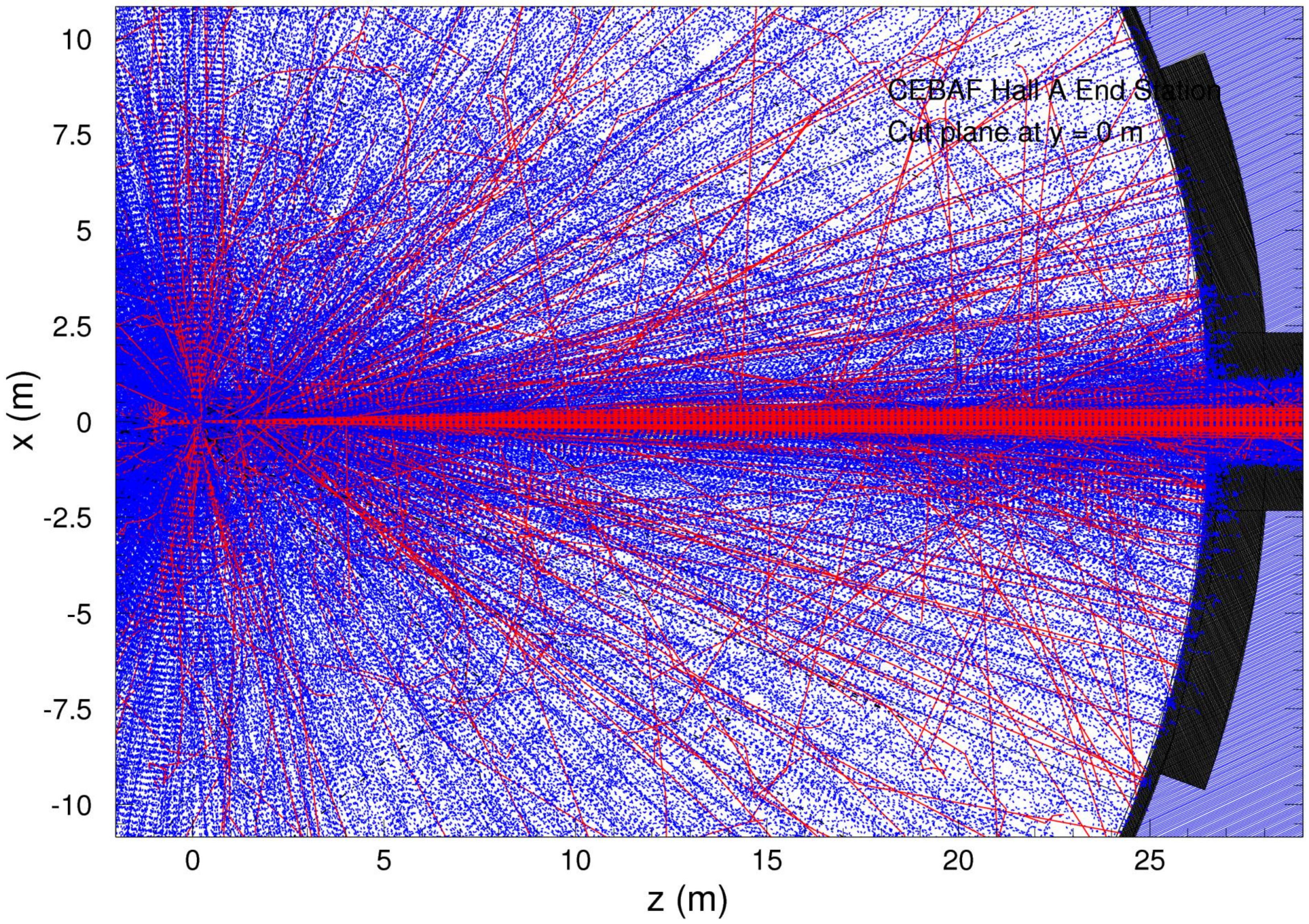
Updated GEANT3/DINREG Calculations

- ❑ First estimates done in 2011 using the standard tool ELEC5
- ❑ New calculations using the GEANT3/DINREG Monte Carlo

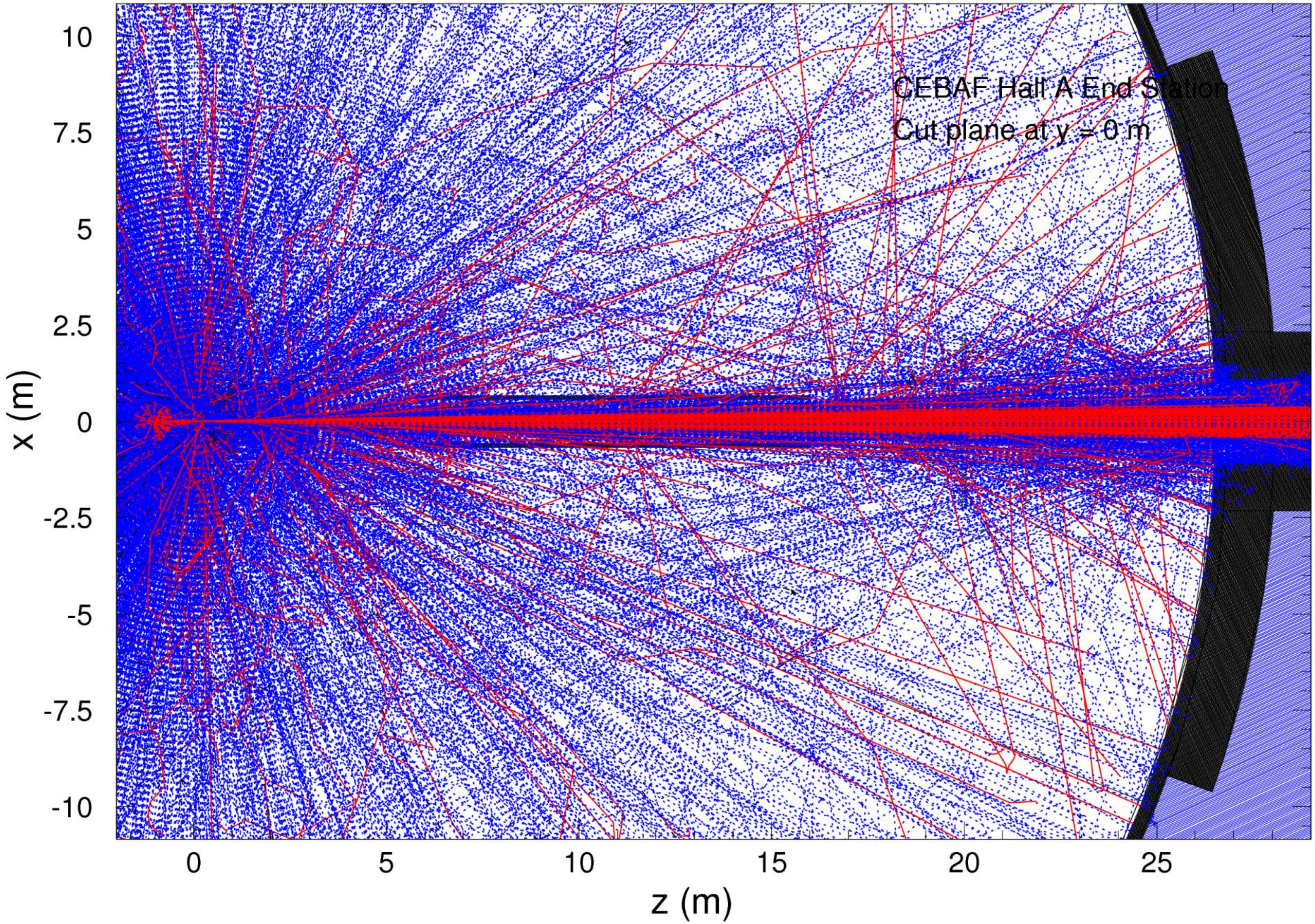
APEX Environmental Radiation Evaluation



APEX Radiation Backgrounds in the Hall



APEX Radiation Backgrounds in the Hall



APEX Dose Rates Downstream

Dose Rates Downstream around Beam Dumpline (R/h, rem/h)

Setup 1

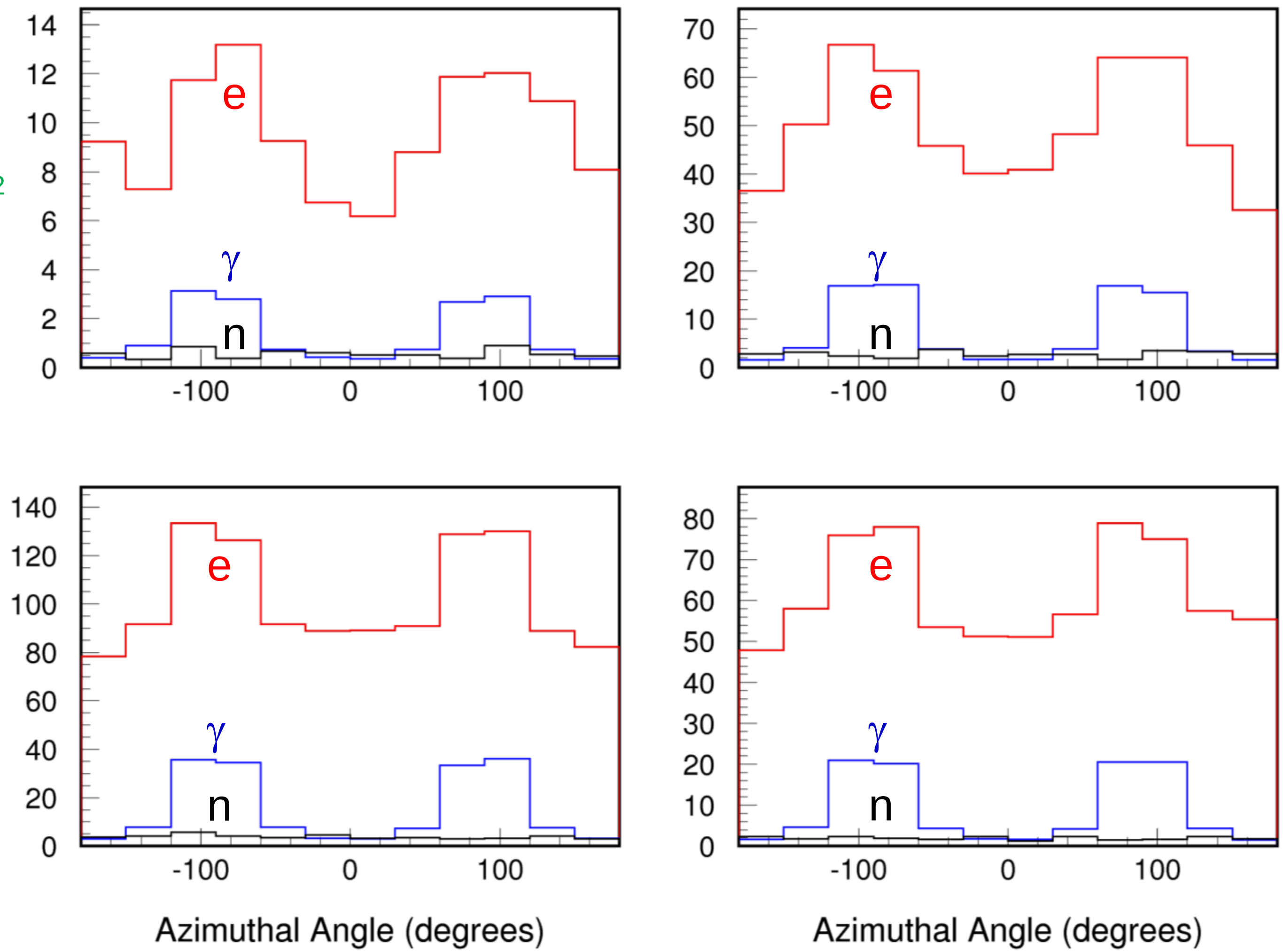
Carbon
0.7% r.l.
300 mg/cm^2

1.1 GeV
50 μA

Setup 2

Tungsten
4.0% r.l.
270 mg/cm^2

2.2 GeV
70μA



Setup 3

Tungsten
8.0% r.l.
540 mg/cm^2

3.3 GeV
80 μA

Setup 4

Tungsten
8.0% r.l.
540 mg/cm^2

4.4 GeV
60μA

APEX Radiation Evaluation Results

APEX E, Current GeV, μA	Target x_0, t % r.l., mg/cm^2	Dose Rates: Upstream R/h, rem/h	Downstream in Shadow R/h, rem/h	Downstream no Shadow R/h, rem/h	CEBAF Boundary μrem/h
1.1GeV, 50μA	Carbon 0.7% r.l. 300 mg/cm^2	e: 0.010 γ: 0.030 n: 0.170	e: 7.50 γ: 0.40 n: 0.52	e: 12.0 γ: 2.8 n: 0.5	n+γ: 0.31
2.2GeV, 70μA	Tungsten 4.0% r.l. 270 mg/cm^2	e: 0.055 γ: 0.138 n: 0.944	e: 37.5 γ: 1.6 n: 2.6	e: 64.0 γ: 16.5 n: 2.6	n+γ: 1.98
3.3GeV, 80μA	Tungsten 8.0% r.l. 540 mg/cm^2	e: 0.173 γ: 0.350 n: 2.090	e: 90.5 γ: 3.0 n: 3.7	e: 125.0 γ: 34.0 n: 3.7	n+γ: 7.46
4.4GeV, 60μA	Tungsten 8.0% r.l. 540 mg/cm^2	e: 0.116 γ: 0.230 n: 1.380	e: 50.0 γ: 1.5 n: 1.9	e: 78.0 γ: 20.0 n: 1.9	n+γ: 6.51

Shielding Improvements (if Possible)

- Shadow shield from the target (90 degrees and back)
- Wider opening in the Septum magnet (at least vertically)
- Design critical opening aperture inside (~25 cm) the Septum magnet
- Shadow shield from the Septum exit to protect electronics downstream
- Shadow shield for the whole beam line to protect electronics downstream

Conclusions

- Radiation environment for the APEX experiment was re-evaluated
- New estimates are obtained for the radiation produced at CEBAF boundary, as well as for the general radiation background in the Hall
- Boundary Radiation Budget for this experiment is expected to consume about 33% of the yearly allocation for JLab
- The proposed experimental configuration with the critical beam dumpline opening angle of ~0.91 degrees seems to be close to optimal for this experiment, if the critical window is inside the Septum magnet
- Radiation dose rates in the Hall are expected to be severe, and shadow shielding configurations should be designed and installed to protect radiation-sensitive equipment
- The beam line exiting the Interaction Chamber, as well as the entrance aperture of the Septum magnet are expected to be activated during the experiment; measures should be provisioned to protect personnel during accesses.

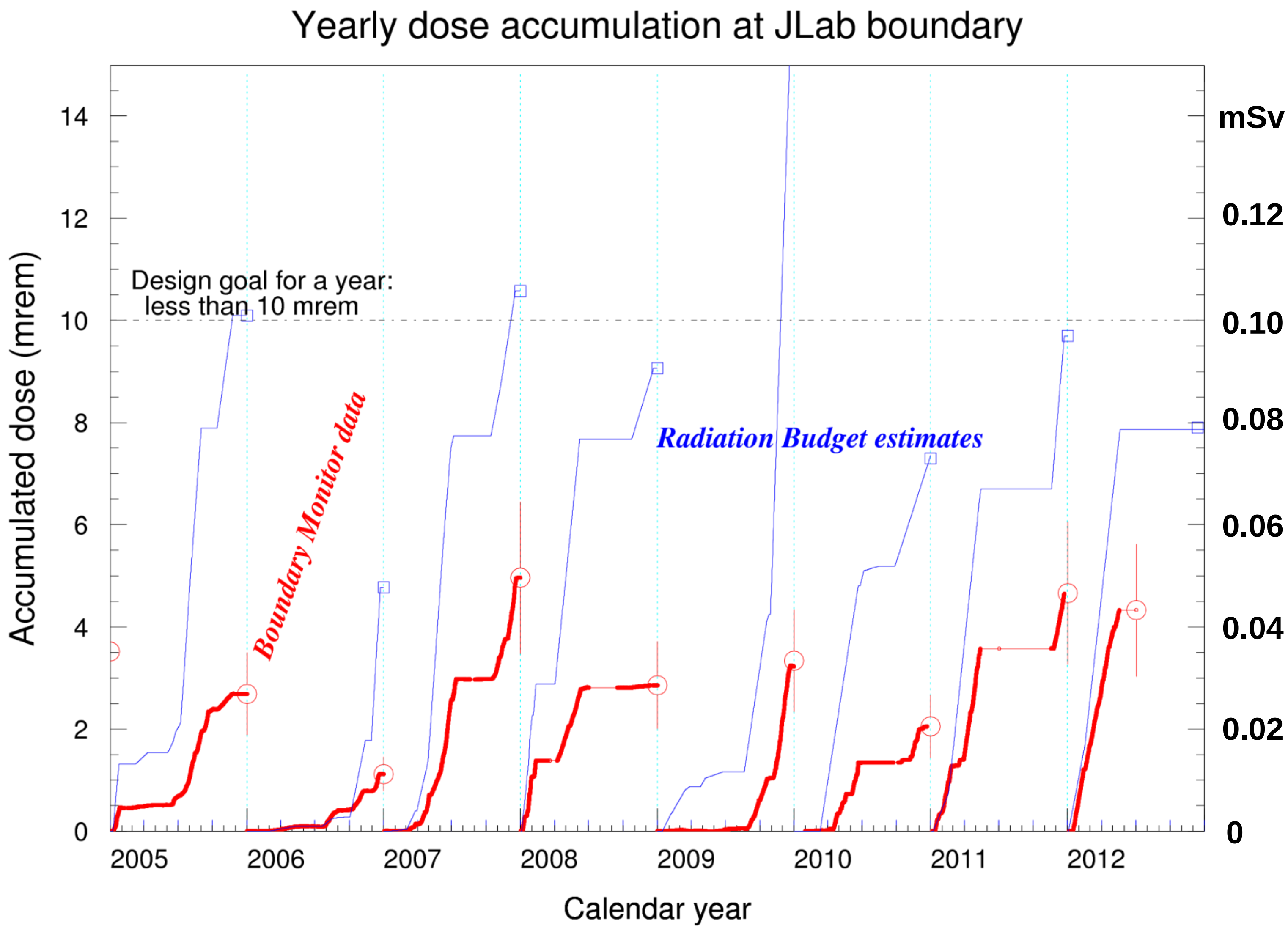
Extra Slides

Facility Design Guidelines: 10CFR835

- §835.1001 rule: maintain radiation exposure in controlled areas ALARA through engineered and administrative controls

- §835.1002 specifies objectives for facility design and modifications:
  - Use of optimization methods to achieve ALARA in developing and modification of facility design and physical controls
  - The design objective for controlling personnel exposure: keep the dose accumulation ALARA, and below 1 rem in a year
  - Avoid releases of airborne radioactive material to the workplace atmosphere under normal conditions
  - Include in the design, and in material selection, features that facilitate operations, maintenance, decontamination, and decommissioning

Environmental Dose History 2005-2012



Environmental Gamma Dose Rates

Environmental Spectroscopic High Pressure Ionization Chambers at the boundary: RBM-3 and RBM-6 sites

Difference
"Signal IC – Background IC"
= SHPIC3 – SHPIC6

Same background subtraction technique applied as in the case for neutrons

Dose rates from operations visible at a level of few percent of natural background

Gamma contribution to the dose at the boundary: ≈20%