Neutron and Gamma Radiation Measurement at FLASH Accelerating Modules 4 and 5 running at High Gradients

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FLASH Seminar @ DESY

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Radiation Exposure SUMMARY

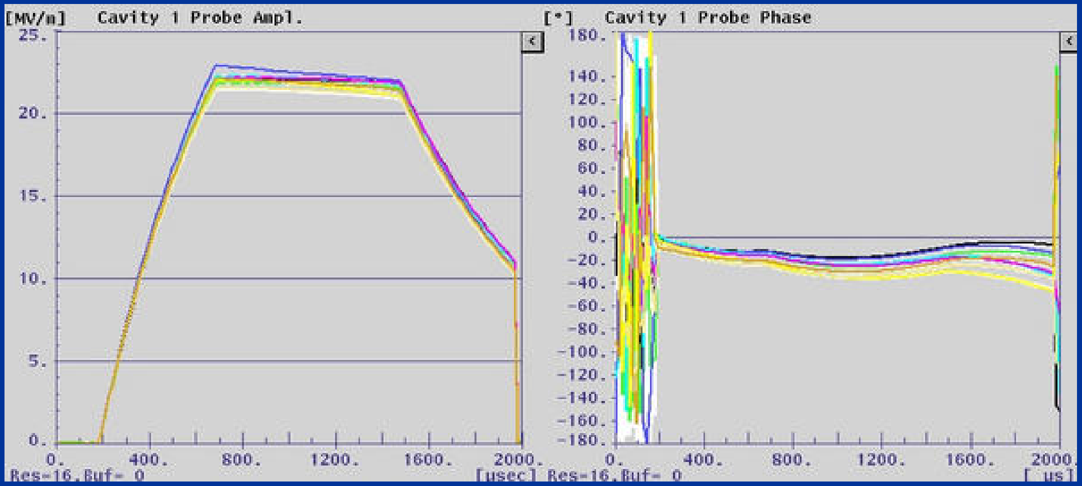
1st Day (07-08-06)

RF-Gun Status: OFF
Duty Cycle (Rep rate): 10 Hz
Start: 16.00 hr
Stop: 9.30 hr (08-08-06)
Exposure Duration: 17h 30min
Gradient (ACC4): ~ 22 MV/m
Gradient (ACC5): ~ 22.5 MV/m
Cavity Status: All Cavities are in Operation

2nd Day (08-08-06)

RF-Gun Status: OFF
Duty Cycle (Rep rate): 10 Hz
Start: 11.00 hr
Stop: 14.10 hr (09-08-06)
Exposure Duration: 26h 10min
Gradient (ACC4): ~ 14 MV/m
Gradient (ACC5): ~ 30 MV/m
Cavity Status: All Cavities are in Operation

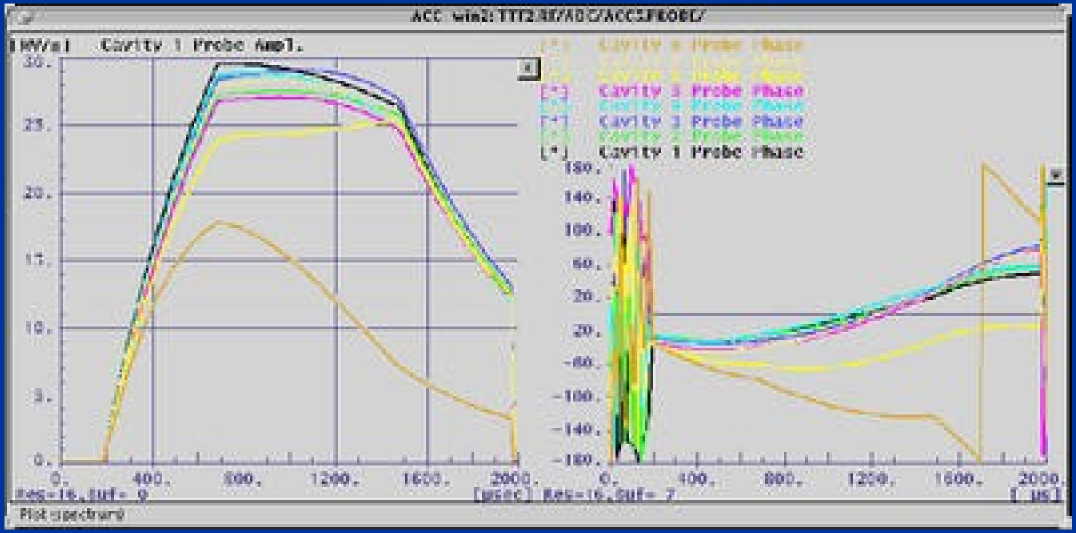
GRADIENT HISTORY



Date: 07-08-06

G_{AV} ~ 21 MV/m

(ACC 5 & ACC4)



Date: 08-08-06

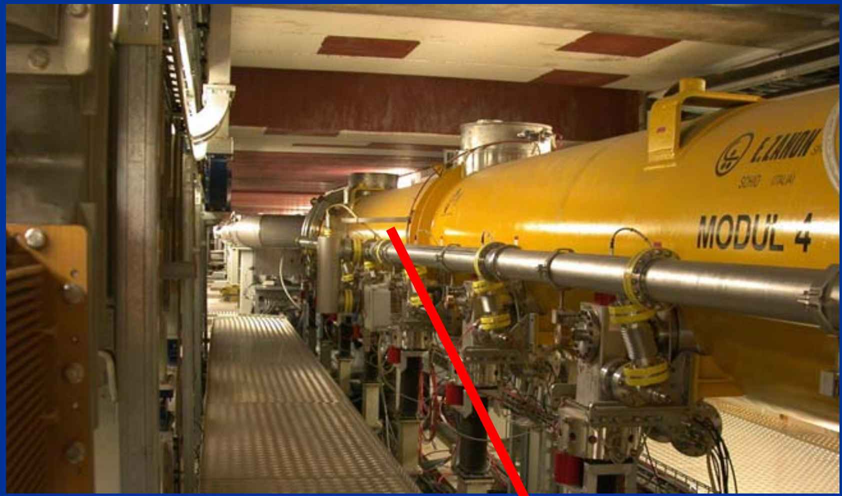
G_{AV} ~ 29 MV/m

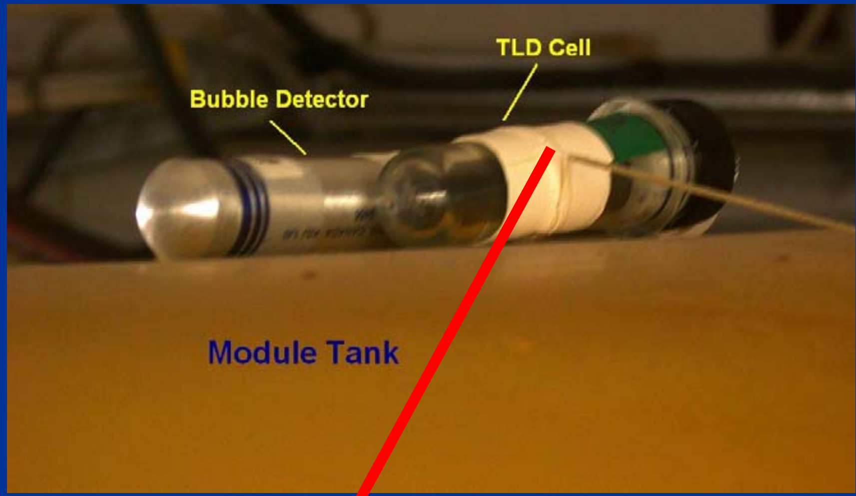
(ACC 5)

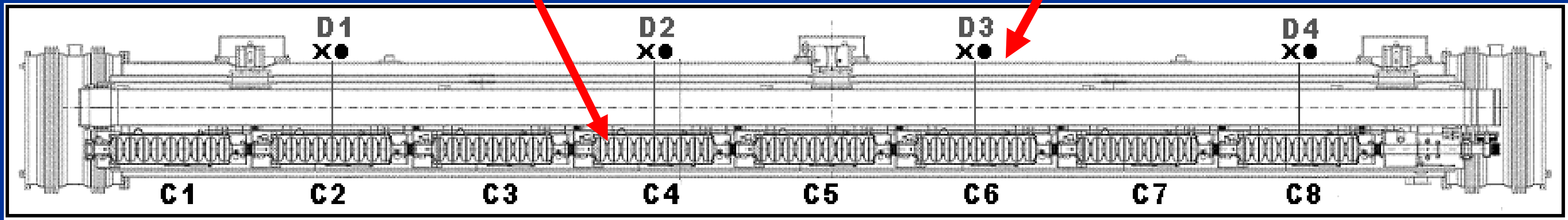
G_{AV} ~ 14 MV/m

(ACC 4)

LOCATION OF DOSIMETERS ALONG THE ACC4 & ACC5

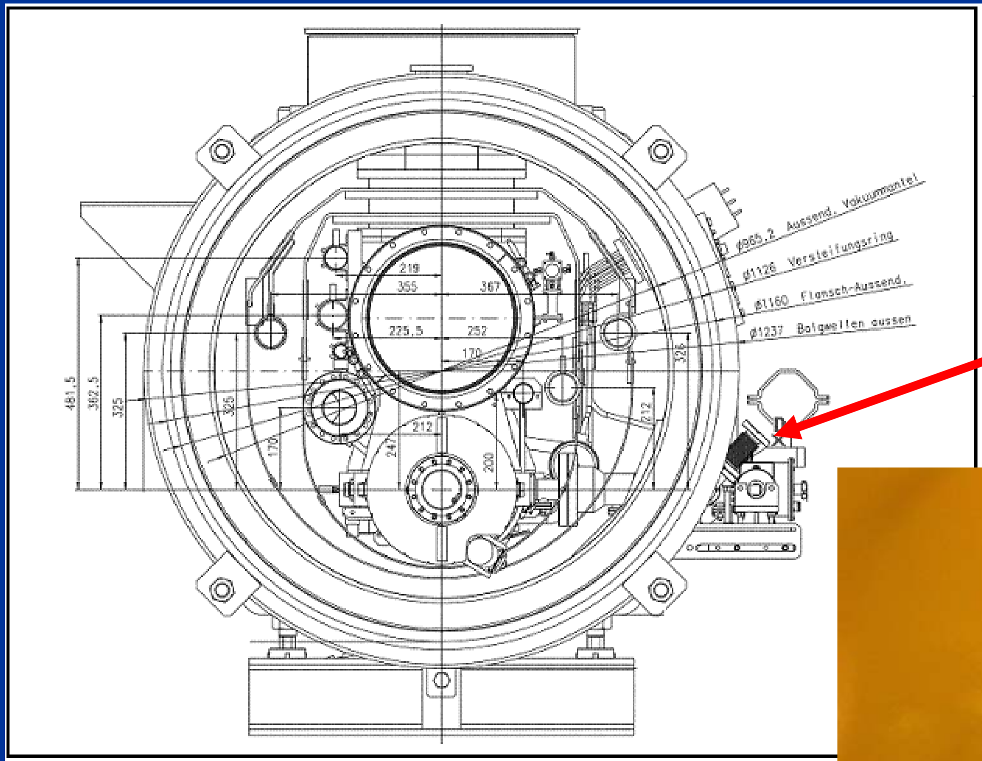




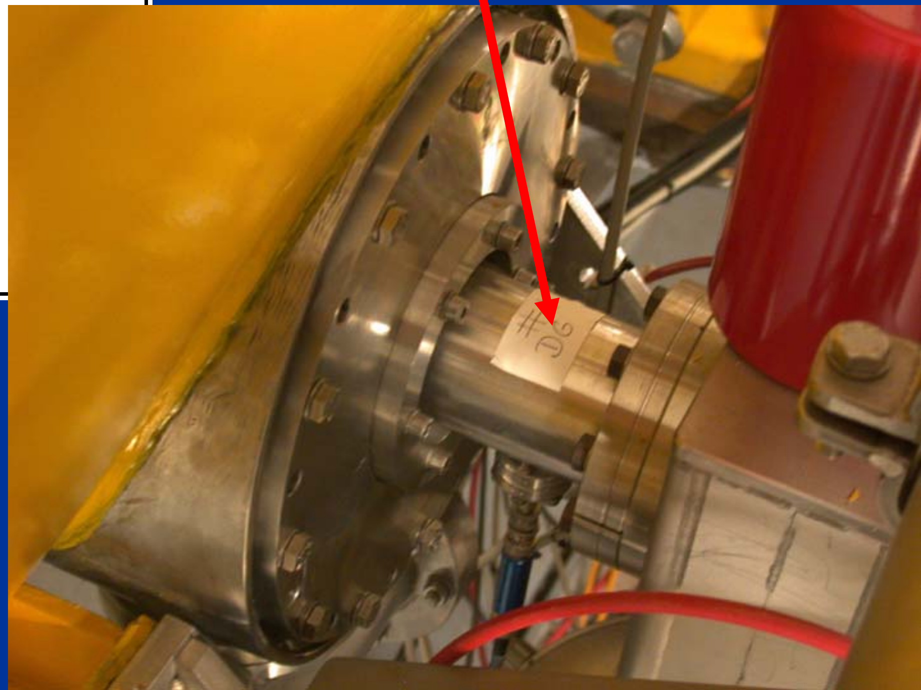


Pairs of TLD Cells (gamma) and Bubble detectors (neutron) were placed atop every 2nd Cavity, indicated as D1, D2, D3 and D4

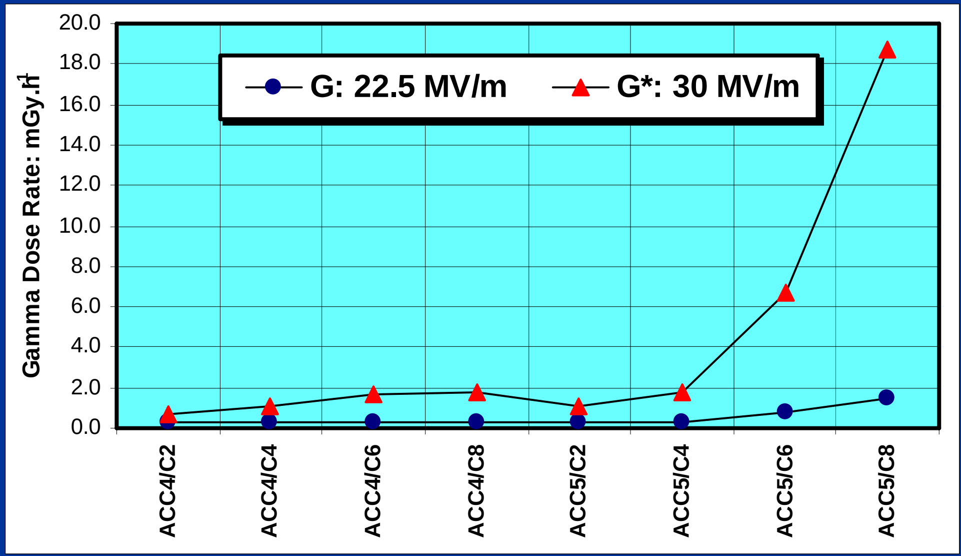
LOCATION OF DOSIMETERS ON POWER COUPLER



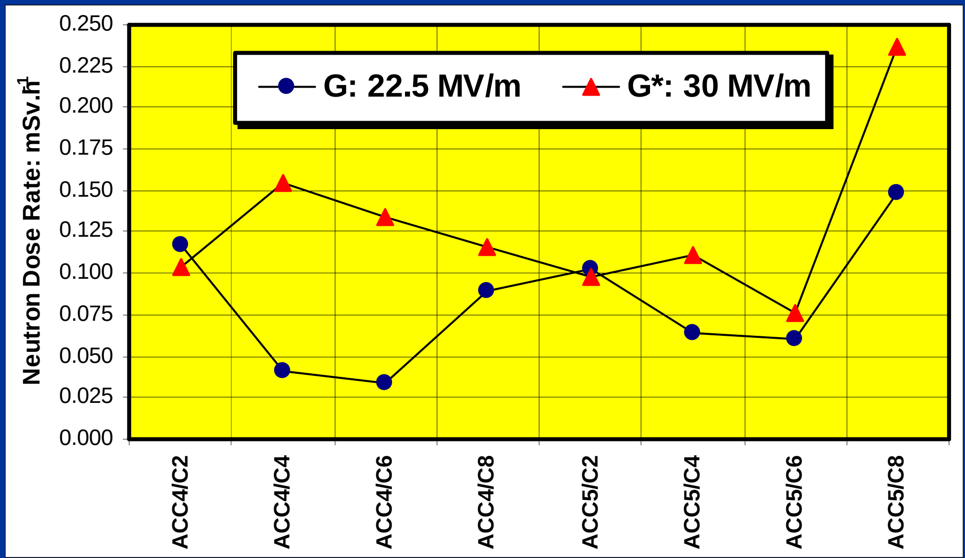
GAF- Film Dosimeter



RESULTS (1)

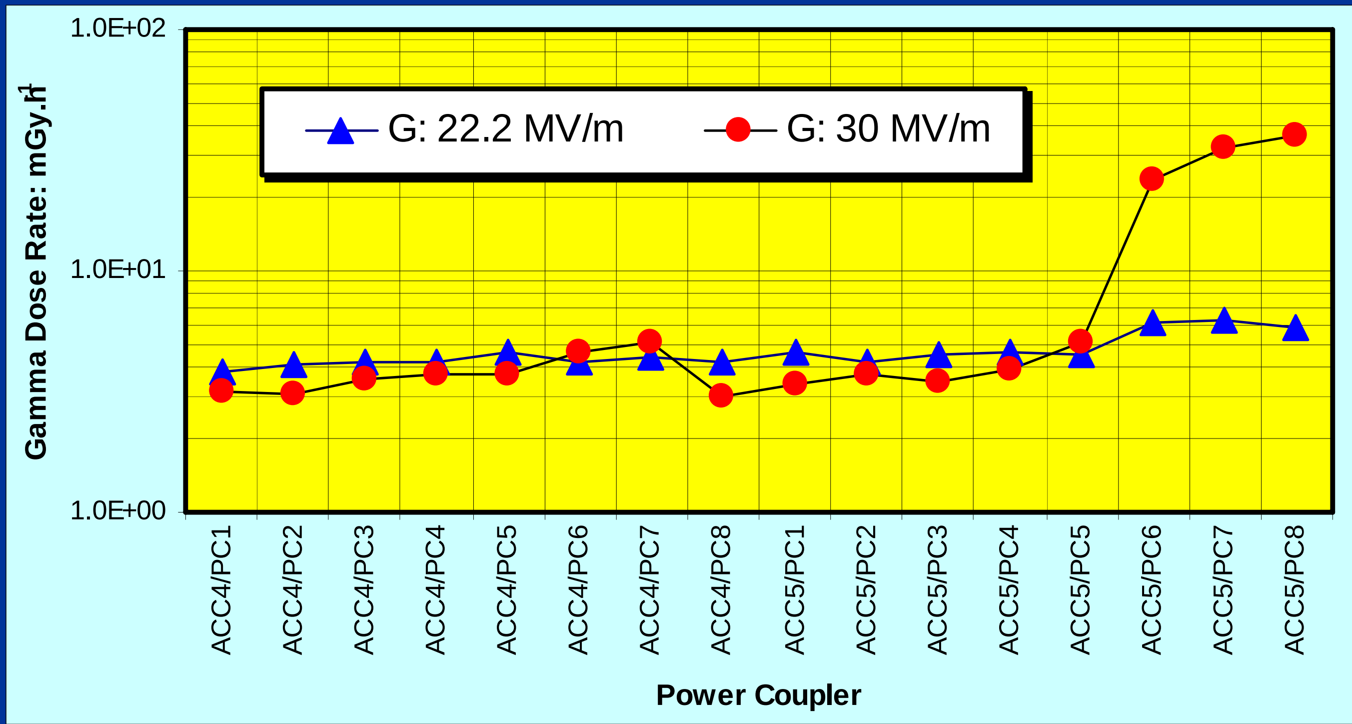


Gamma Dose Rate at selected locations on the Modules ACC 4 and ACC 5



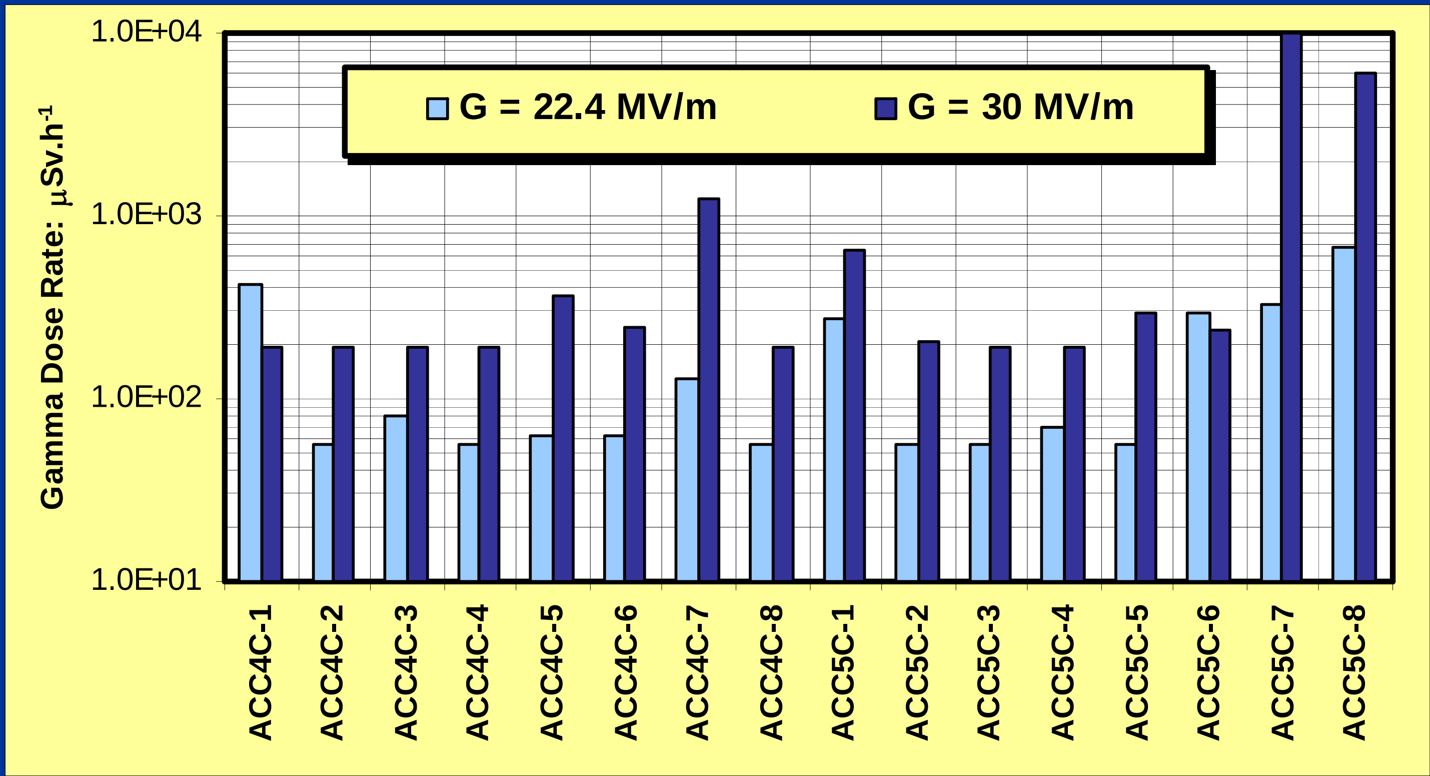
Neutron Dose Rate at selected locations on the Modules ACC 4 and ACC 5

RESULTS (2)



Gamma Dose rate measured at every Power Coupler of the Modules ACC 4 and ACC5 using GAF Chromic Films

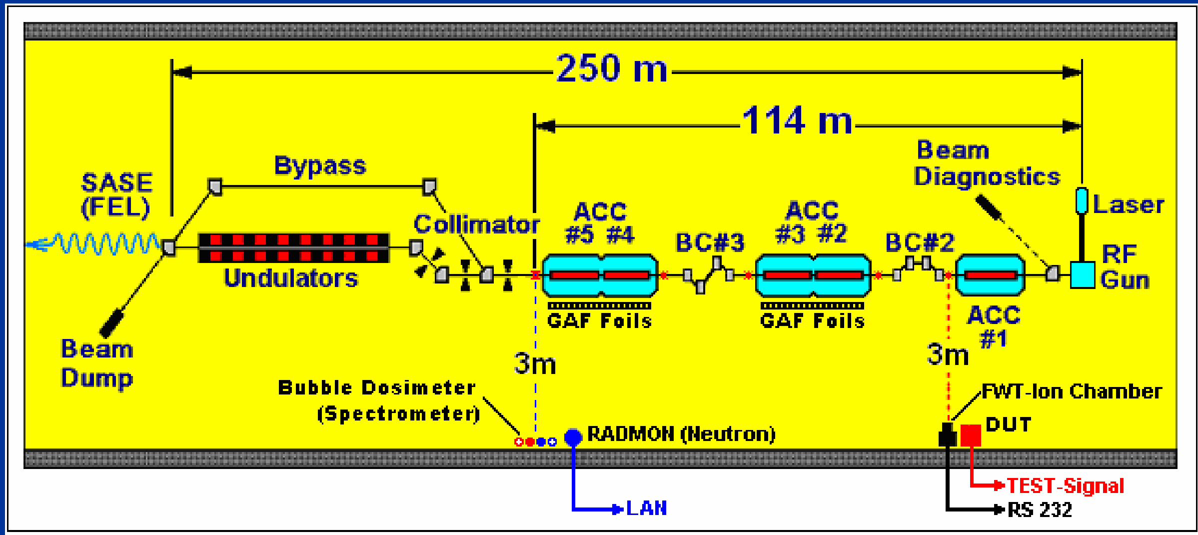
RESULTS (3)



The gamma dose rates emanating from each of 16 cavities were unfolded using the readings of 8 gamma dosimeters. It has been assumed that the radiation source was a point source located at the centre of 5th cell of each cavity.

NEUTRON DETECTION (SPECTROMETRY)

We have estimated a 3 bin neutron spectrum near ACC 5 (3m) module using superheated Bubble Dosimeters during routine FLASH operation



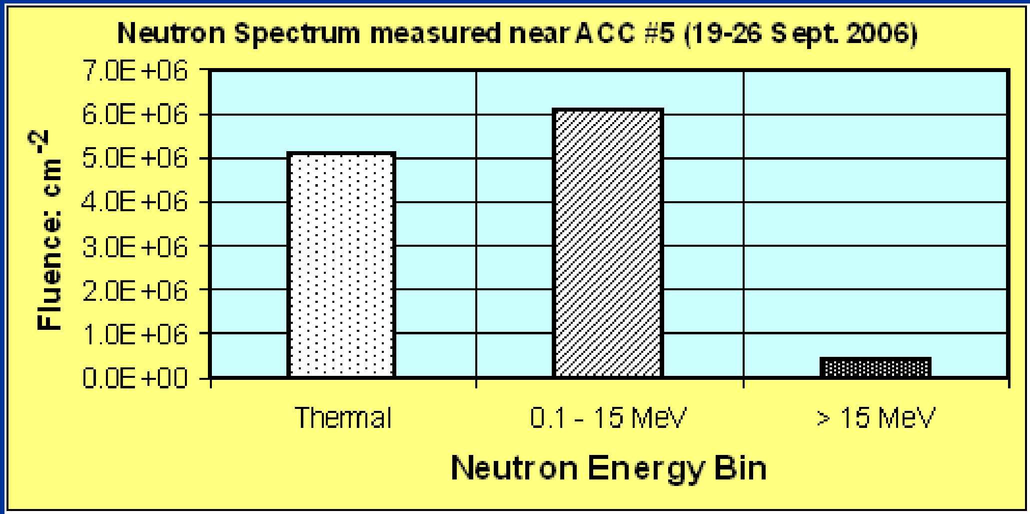
Bubble Dosimeter parameters and results summary

Dosimeter Specifications	Filter Type	Bubble Counts	Φ(Thermal-0.1 MeV) [cm^{-2}]	Φ(0.1-15 MeV) [cm^{-2}]	Φ(> 15 MeV) [cm^{-2}]
BDT1 (Red/Hollow circle)	None	Nt1	kt(Nt1-Nt2)/*1		
BDT2 (Red/Full circle	2mm Cd	Nt2			
BDPND1 (Blue/Hollow circle)	None	Nf1		kf Nf1/*2	kf(Nf2-Nf1)/*3
BDPND2 (Blue/Full circle)	20mm Pb	Nf2			

Photoneutrons are produced when the accelerated field emission electrons, also RF-Gun dark current exceed the threshold energy, for Niobium: E_{Thres} ~ 10 MeV

RESULTS (4)

The 3 bin neutron energy spectrum near ACC 5 during routine operation evaluated using superheated emulsion (bubble) dosimeters.



EXPLANATIONS

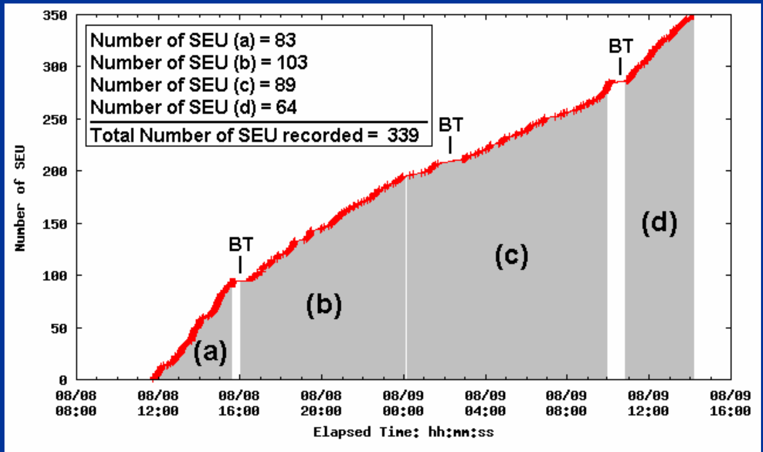
0.1-15 MeV Bin: Giant Dipole Resonance Neutrons/mainly Displacement Damage/some SEU/moderately thick (<1 m) Concrete or Polyethylene shield needed

> 15 MeV Bin: High-Energy tail (Photo-Pion production)/mainly Displacement damage/SEU via primary knockout atom (PKA) process/Thick (>1m) concrete shield.

Thermal Bin: Produced by room scattering of fast neutrons (above cases)/mainly SEU by (n, alpha) reaction with Boron atoms in BPSG in microchip/few mm thick borated polyethylene shield needed.

RESULTS (5)

Estimation of the mean Gradient of the Accelerator Modules using the Real-Time Neutron Monitor (RADMON) installed at 3m from the ACC5



Number of SEU detected by the neutron monitor is displayed as a function of elapsed time. The beam trimming periods are indicated as "BT". The neutron fluence rate is calculated using the calibration factor: k = 3.9×10^{4} cm^{-2}/SEU

Region	Duration	SEU recorded	ϕ_s: $n.cm^{-2}$	Φ_s: $n.cm^{-2}.h^{-1}$	Gradient
(a)	3h30m	83	3.23×10^{6}	9.23×10^{5}	??
(b)	8h	103	4.01×10^{6}	5.01×10^{5}	??
(c)	10h	89	3.46×10^{6}	3.46×10^{5}	??
(d)	3h30m	64	2.49×10^{6}	7.11×10^{5}	??

The accelerator gradient (Col 6) is directly proportional to neutron fluence rate (Col 5) estimated in real-time using the SRAM based neutron monitor.

SUMMARY AND CONCLUSION

We have explicitly evaluated the gamma and neutron dose rates near the ACC 4 and ACC 5 modules produced by field emission electrons in the cavities.

The gamma dose rates were found to be 2 orders of magnitude higher than the neutron dose rates.

Both gamma and neutron dose rates rise exponentially with the increment of the module gradient.

We also have evaluated the gamma dose rate at every power coupler of modules ACC and ACC 5 using GAF Chromic films.

The radiation field emitted by each of the nine cavities per module was unfolded by using the readings (x 8) gamma detector (inverse calculation).

Pin pointed the radiation pattern (characteristic) of individual cavities. This makes us able to distinguish between the “good” and “bad cavity. The “bad” cavities produce stronger radiation field due to higher field emissions.

We have estimated the neutron energy distribution (3 bin spectrum) near the ACC5 During routine linac operation.

The estimated neutron and gamma doses and energy distribution will be used as the source term (benchmark) for various shielding design related tasks of the future XFEL.

THANK YOU FOR YOUR ATTENTION