FLUKA Simulation of Top-off Injection Accident at National Synchrotron Light Source

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Overview of Presentation

- National Synchrotron Light Source-II
- Top-off Injection at the Light Sources
- Top-off Injection Accident Scenarios
- FLUKA Simulation Methodology
- Geometry for FLUKA Simulation
- Results of Simulation
- Summary Results and Conclusions

NSLS-II Electron Accelerators

Linac Beam Energy 200 Mev

Linac Beam Current 15 nA

Maximum Booster Energy 3000 MeV

Maximum Booster Charge 15 nC

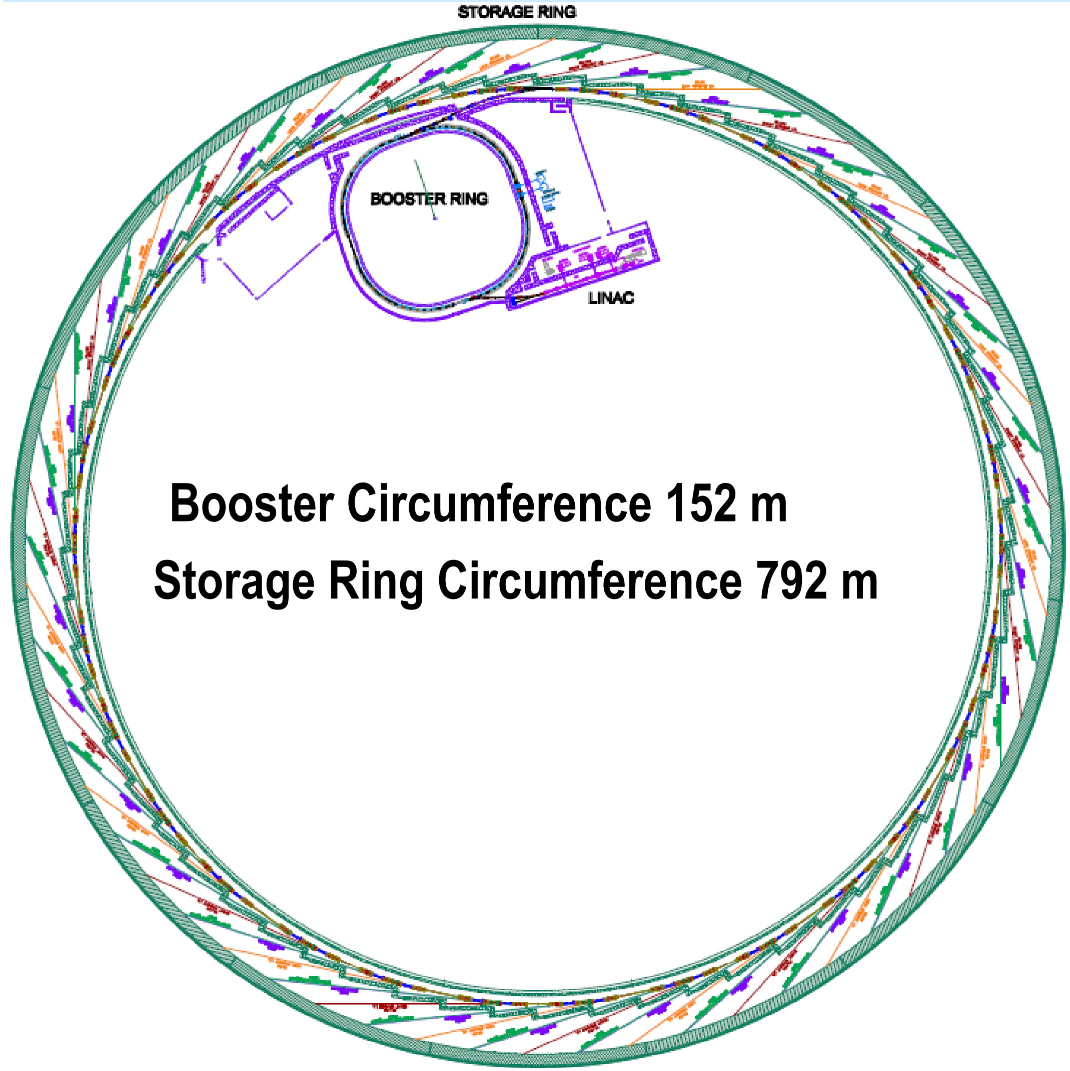
Top-off Injection Frequency ~1 p/min

Stored Beam Energy 3000 MeV

Stored Beam Current 500 mA

Estimated Beam Life Time ~3hrs

Beam Current Stability Specified ~1%



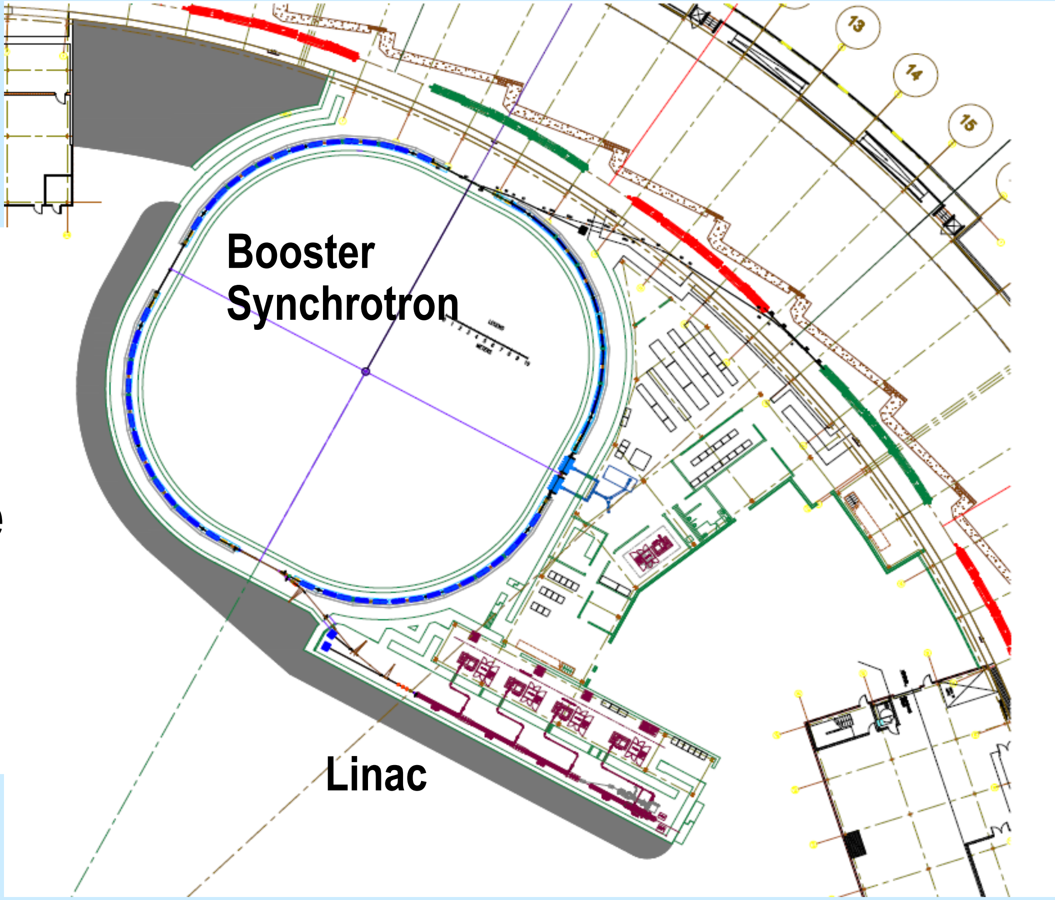
Booster Circumference 152 m

Storage Ring Circumference 792 m

Injection Region of NSLS-II

Maximum Booster Injection Capability : 1 Hz (15 nC/s)

Xrays are generated by the 30 Insertion Devices and 30 Dipole Magnets and come out of the Storage Ring through beam ports on the ratchet wall



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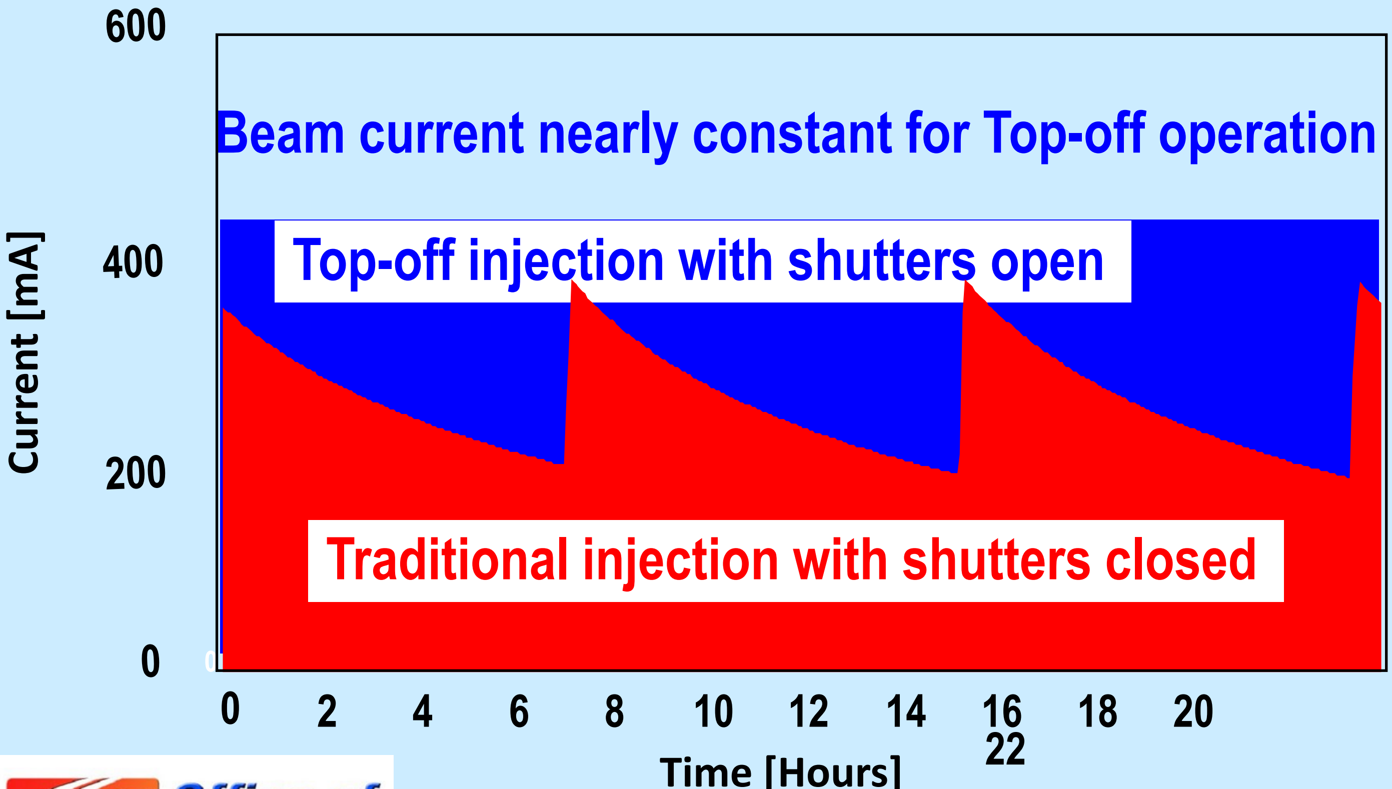
What is Top-off Injection ?

- *Top-off injection is quasi-continuous injection into the storage ring at shorter intervals with the x-ray shutters open, adopted by almost all modern synchrotron light sources. Top-off Injection makes stored beam current to be quasi-constant (~1% for NSLS-II).*



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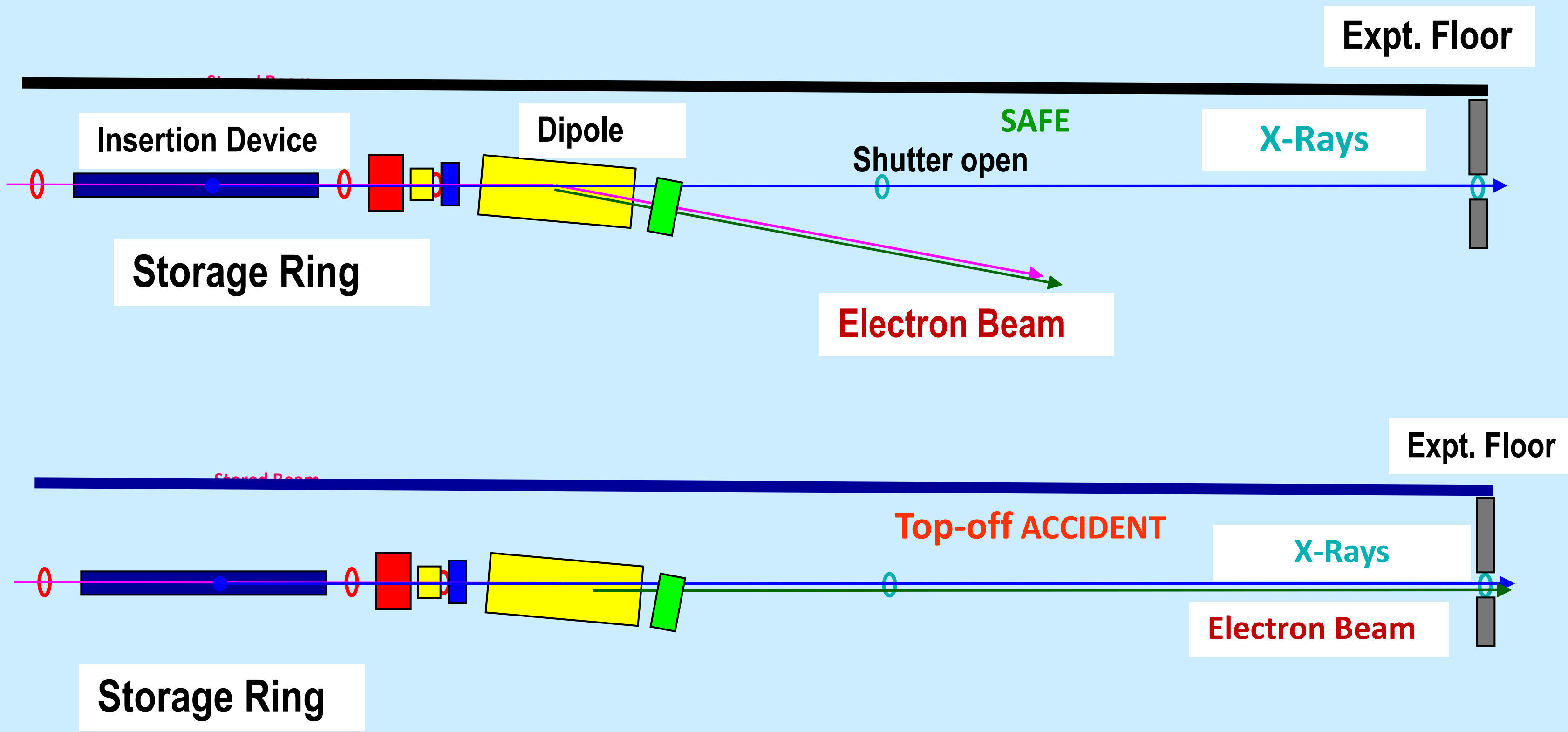
Advantages of Top-off Injection

- Beam current stability within specified limit
- Avoid beamline shutter cycling during each injection
- Thermal stability of beamline optics avoiding drifts

Disadvantages of Top-off Injection

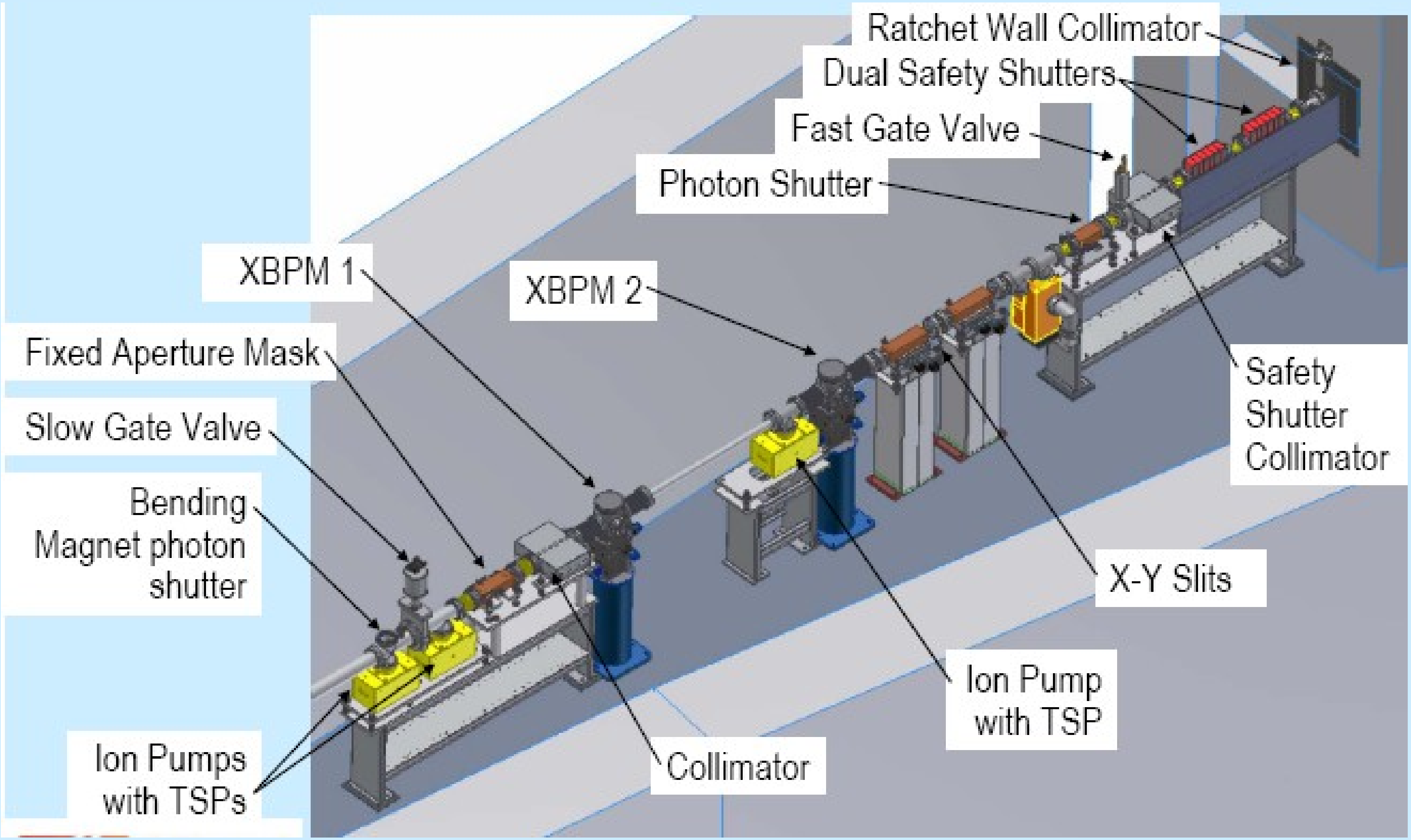


Top-off Injection Accident Scenarios

- Injected electron beam conveyed down through the beamline front end and intercepted by the front end apertures, even if the magnet lattice settings are within the interlocked range with the x-ray shutters open

- Injected electron beam conveyed down through the front end to the Optics Enclosure and intercepted by the beamline components in the Optics Enclosure due to redundant interlock failures during top-off injection

Front End Components at NSLS-II



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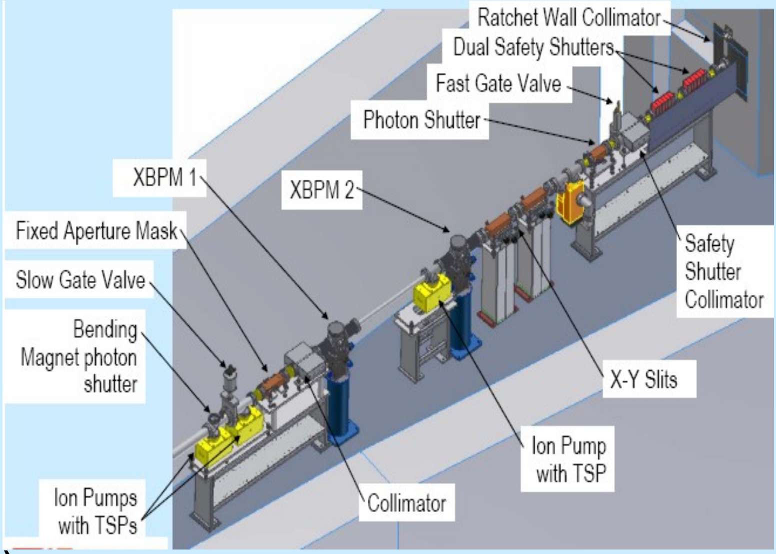
Radiological Simulations

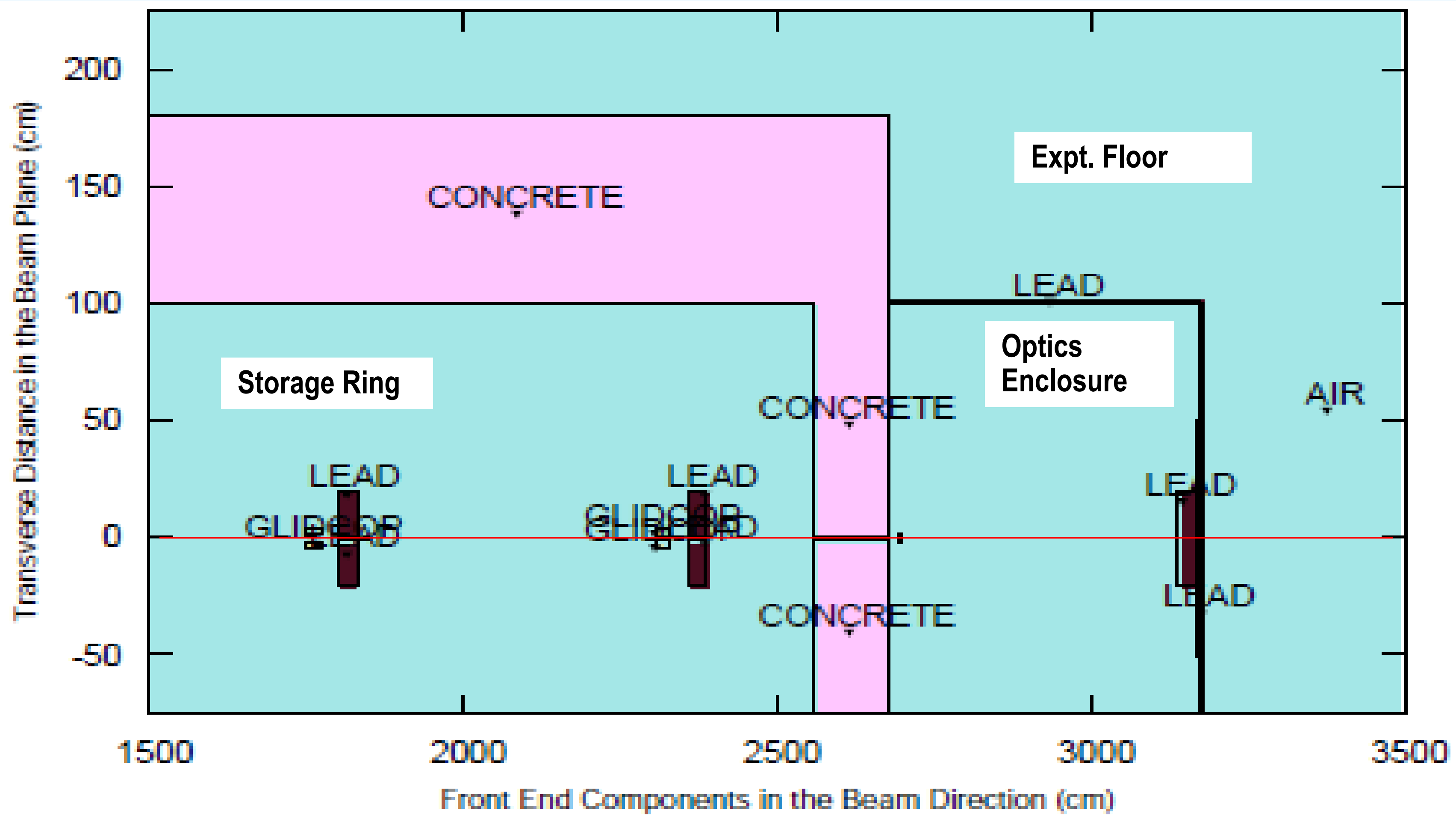
- FLUKA Monte Carlo simulations have been performed to analyze the radiological implications of top-off injection accident at NSLS-II
- The full injected electron beam of 15 nC/s was made to incident on the fixed mask aperture, photon shutter or a beamline component in the First Optics Enclosure
- Ambient dose equivalent rates have been calculated along the storage ring concrete wall at the experimental floor or at around the First Optics Enclosure (occupied regions)

Front End & Beamline Components Simulated in FLUKA

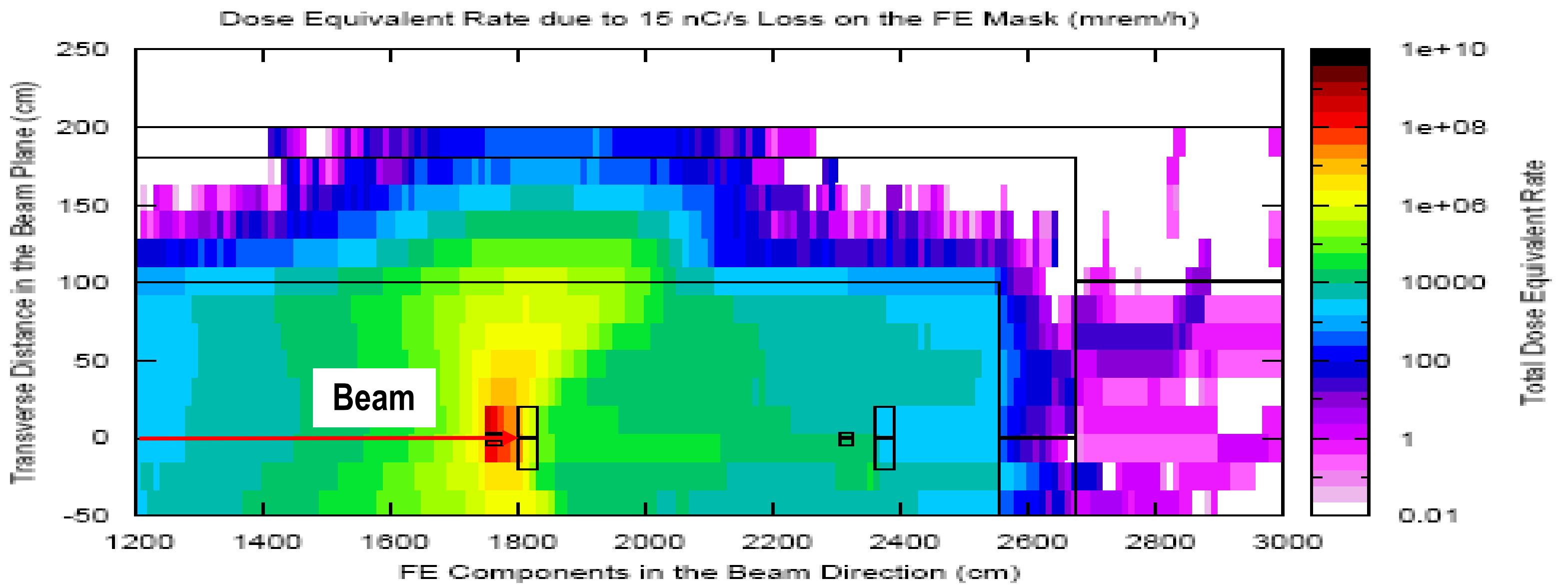
- Glidcop Fixed Mask Aperture
- Lead Collimator 1
- Glidcop Photon Shutter
- Lead Collimator 2
- Lead safety Shutters
- Storage Ring Lateral wall (Concrete)
- Storage Ring Ratchet Wall (Concrete)
- Lead Ratchet Wall Collimator (Embedded)
- Optics Enclosure Lateral Wall (lead)
- Optics Enclosure Downstream Wall (lead)
- Optics Enclosure Downstream Wall – lead -1 m^2
- Optics Enclosure Copper Mask
- Bremsstrahlung Stop in the Optics Enclosure (lead)

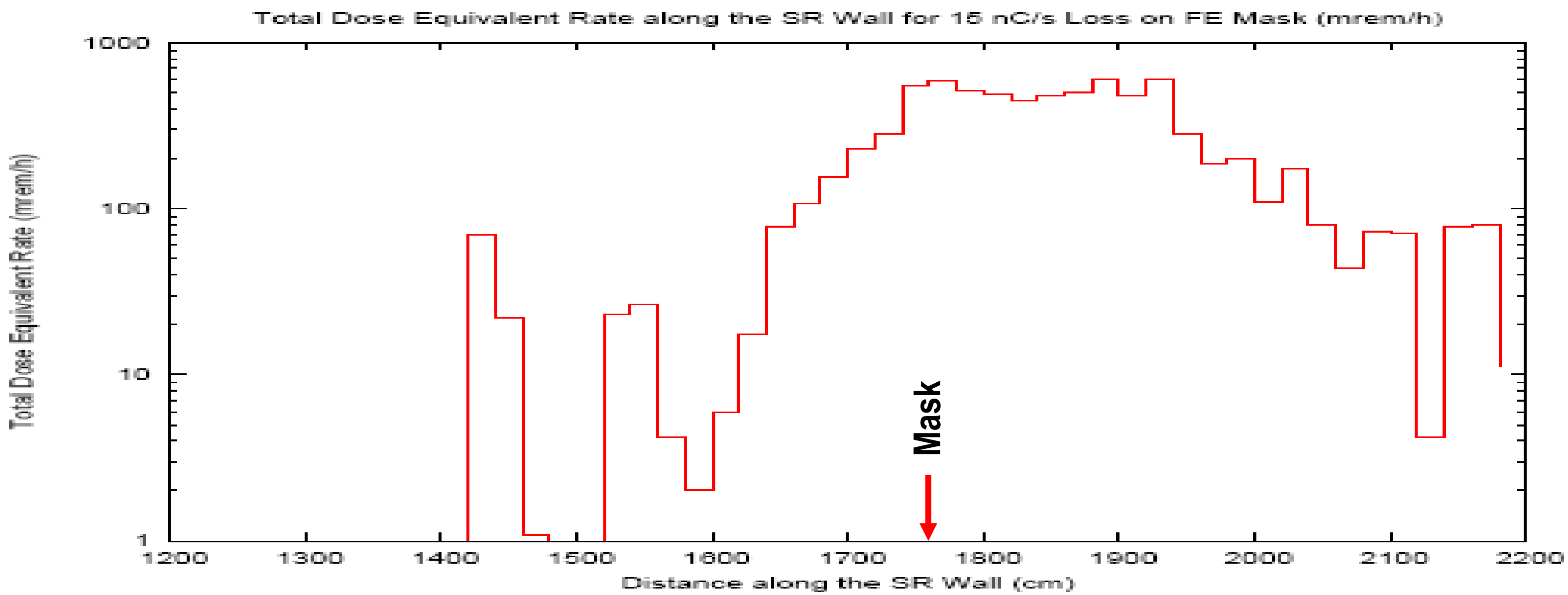


Front End & Beamline Components in the FLUKA Simulation

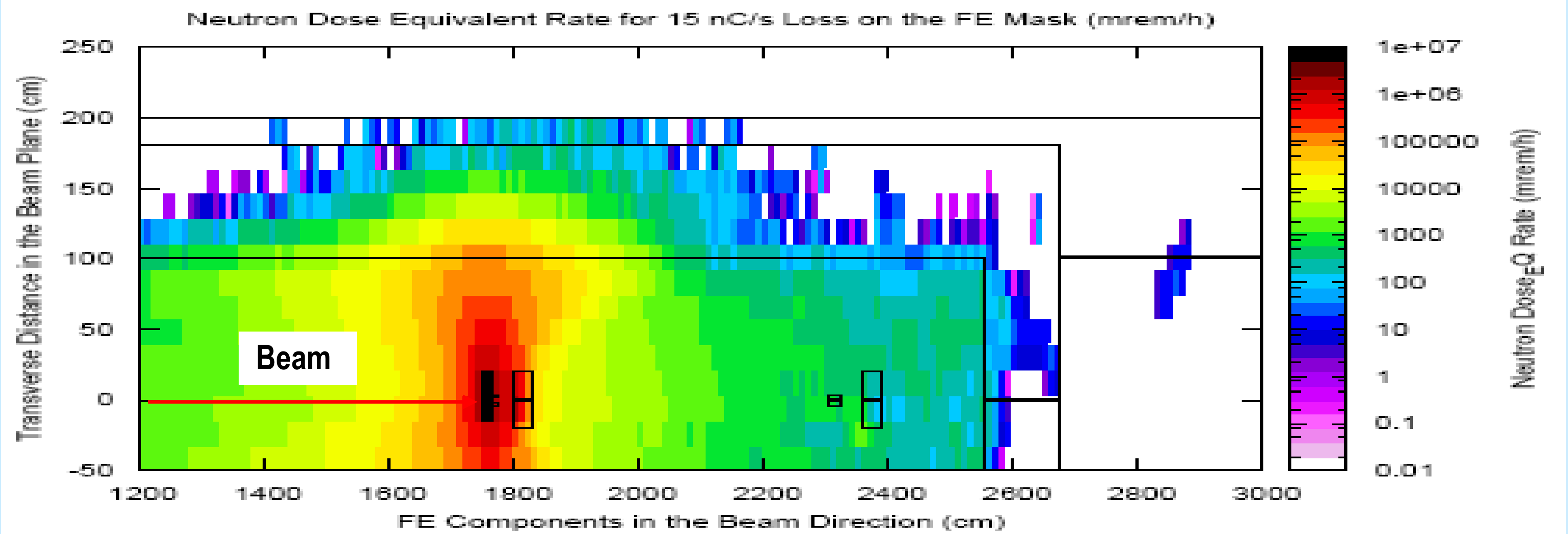


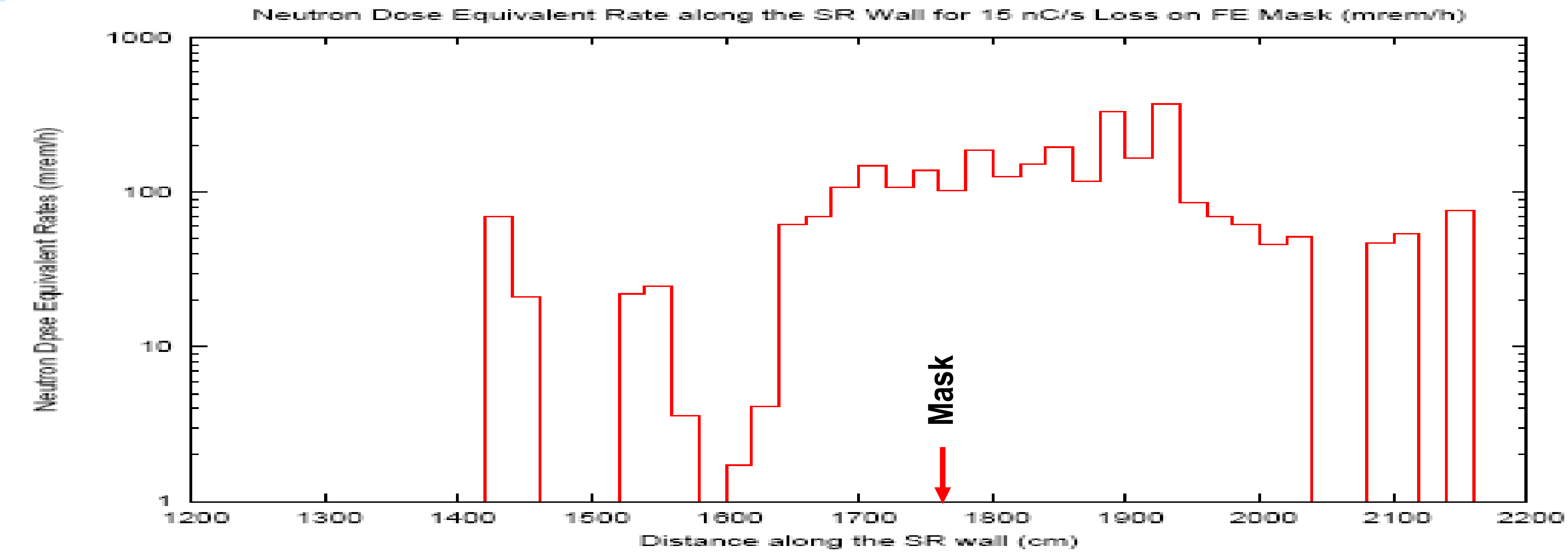
Total Dose Rate Distribution
Injected Beam on Front End Mask



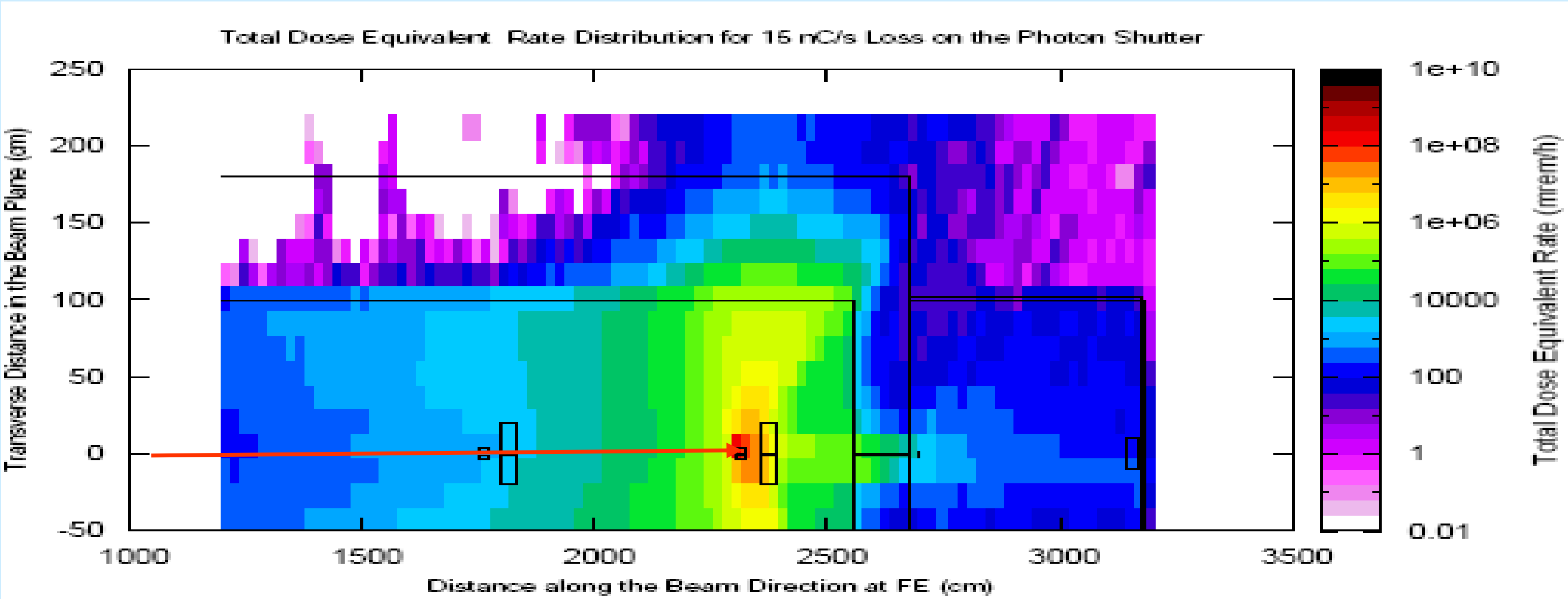


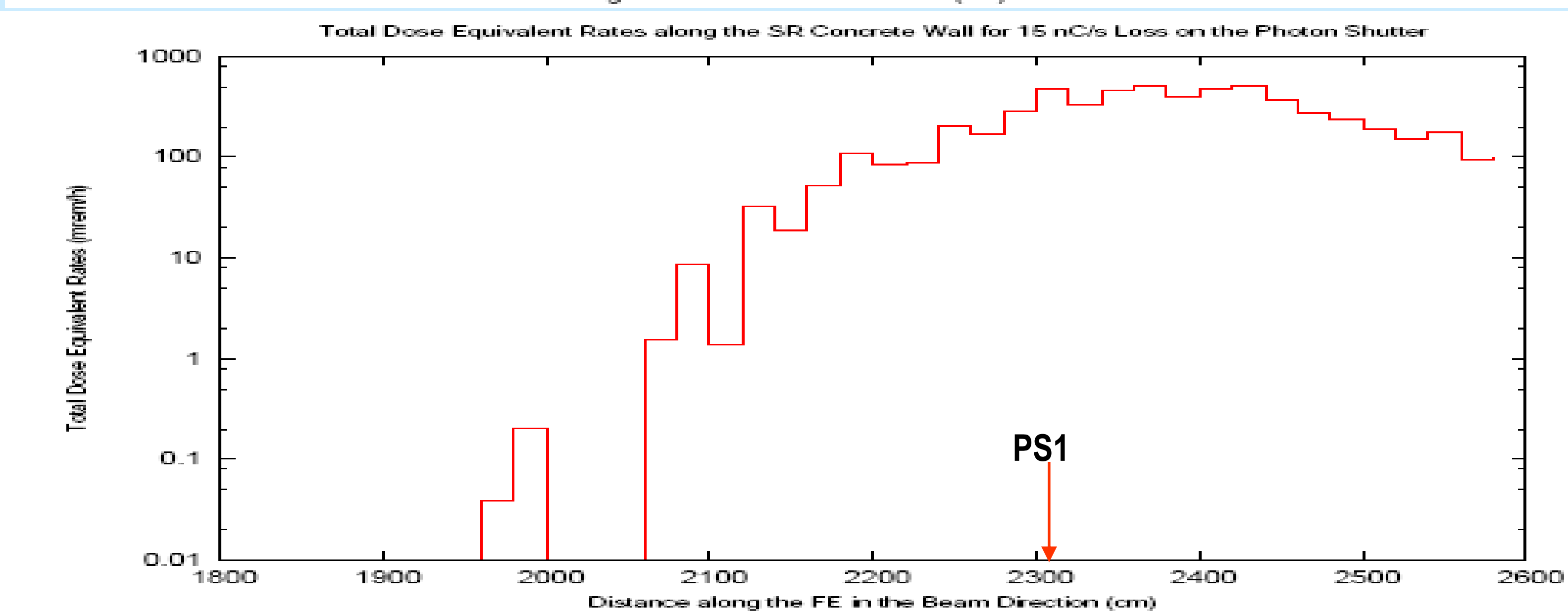
Neutron Dose Rate Distribution
Injected Beam on Front End mask





Total Dose Rate Distribution
Injected Beam on Photon Shutter





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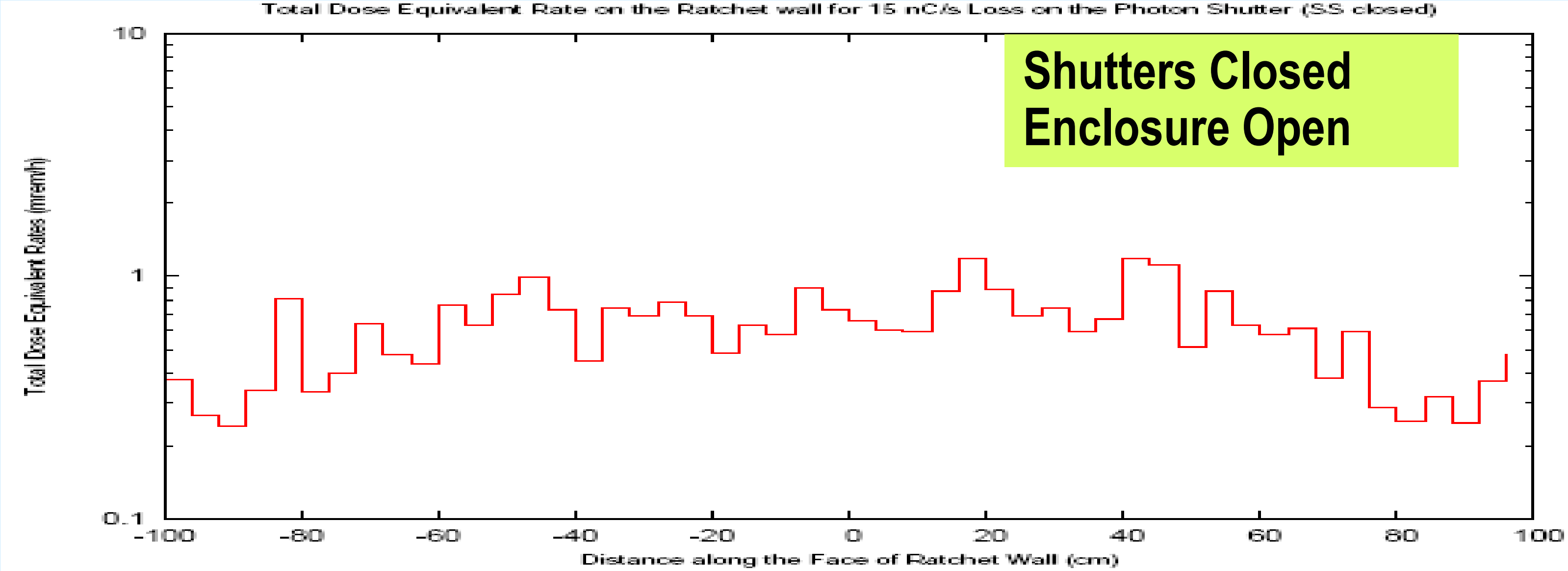
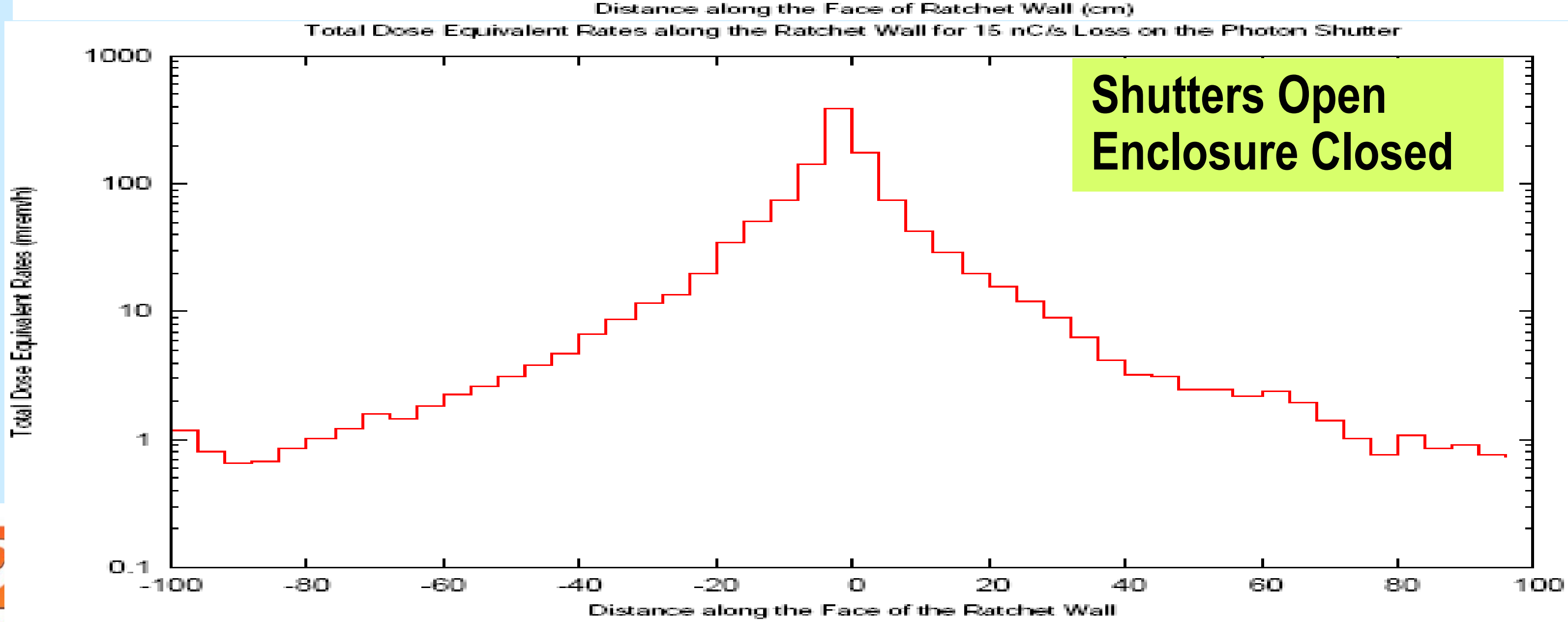
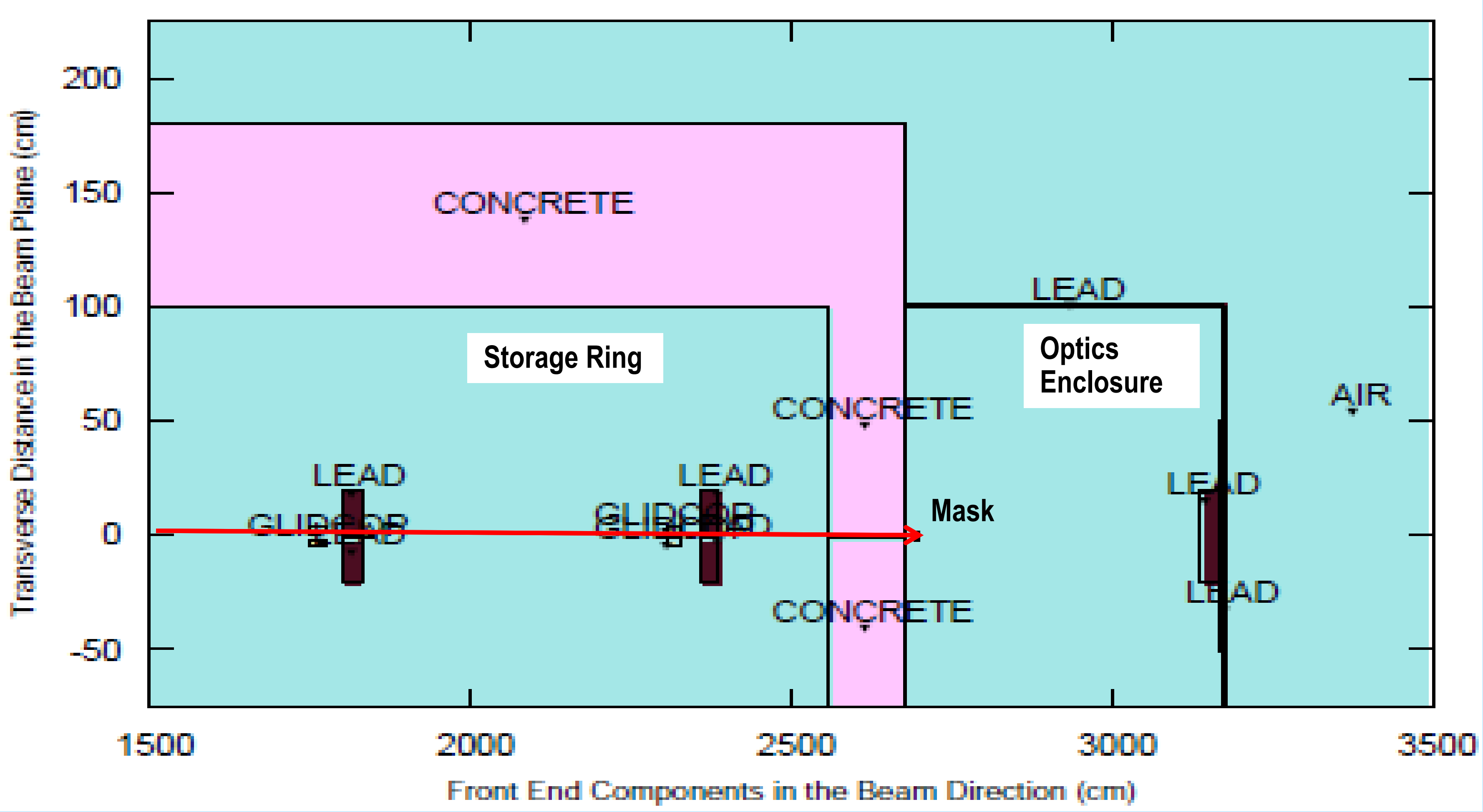
Total Dose Rate on Ratchet Wall inside Optics Enclosure
Injected Beam on Photon Shutter





Injected Beam in the Optics Enclosure



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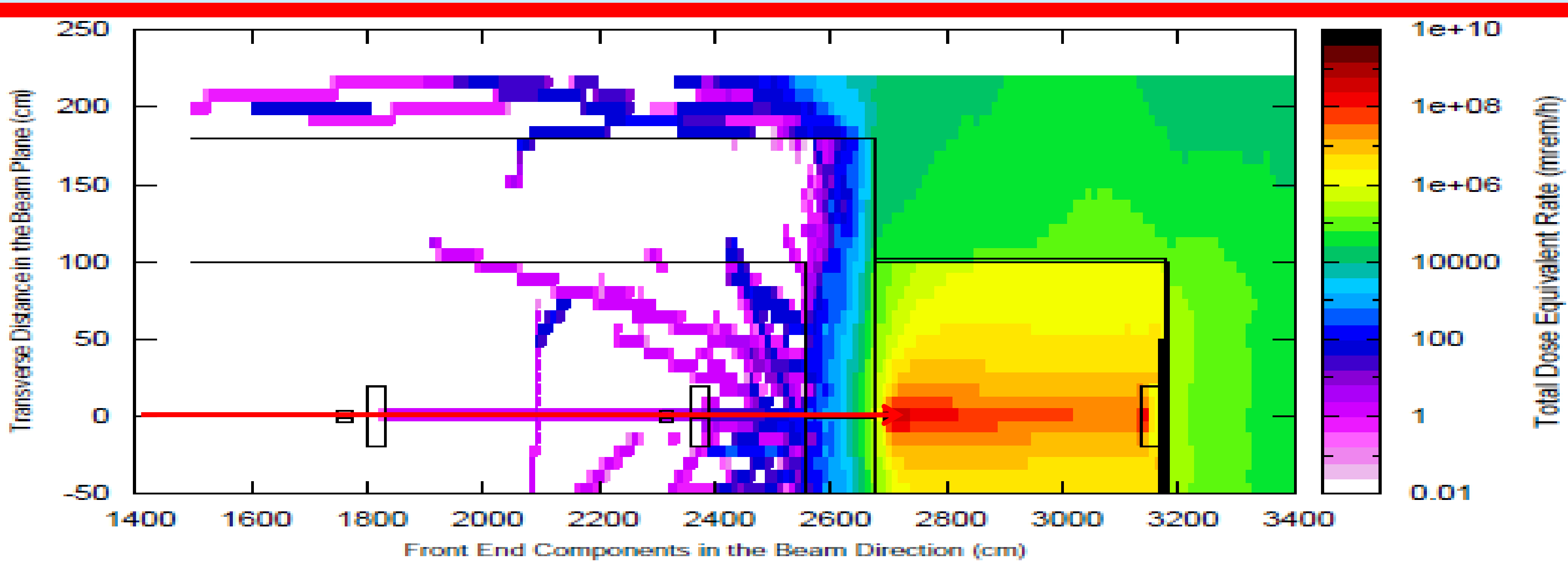
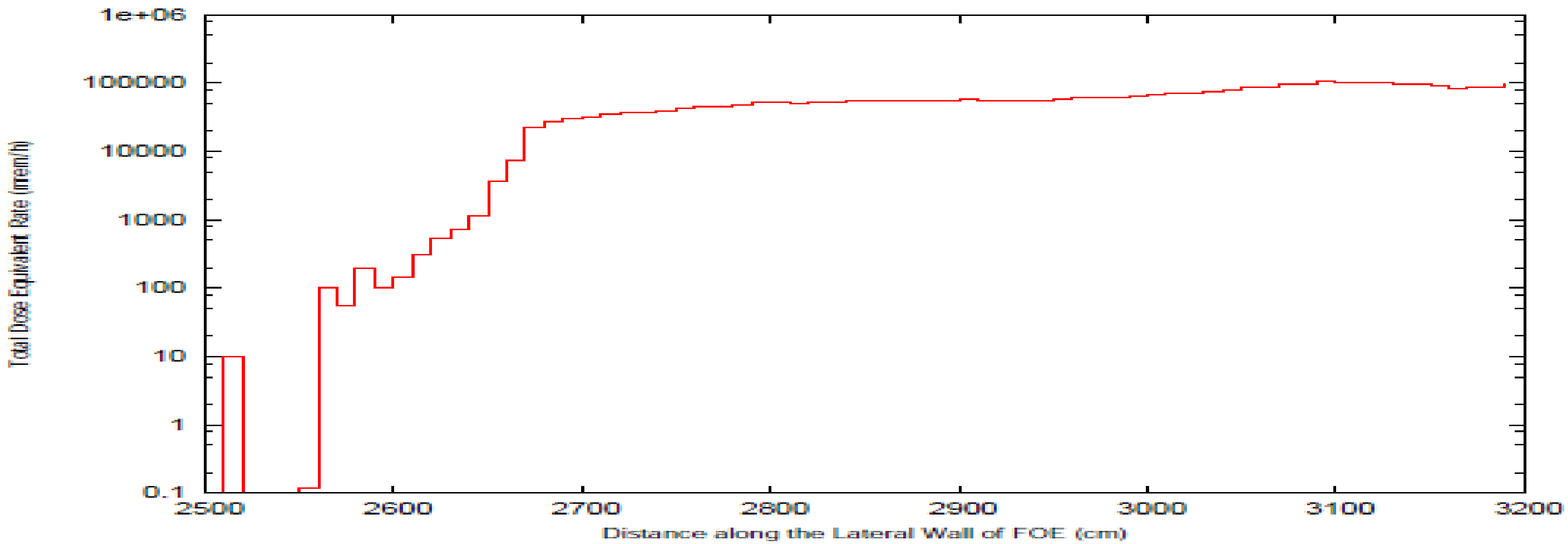
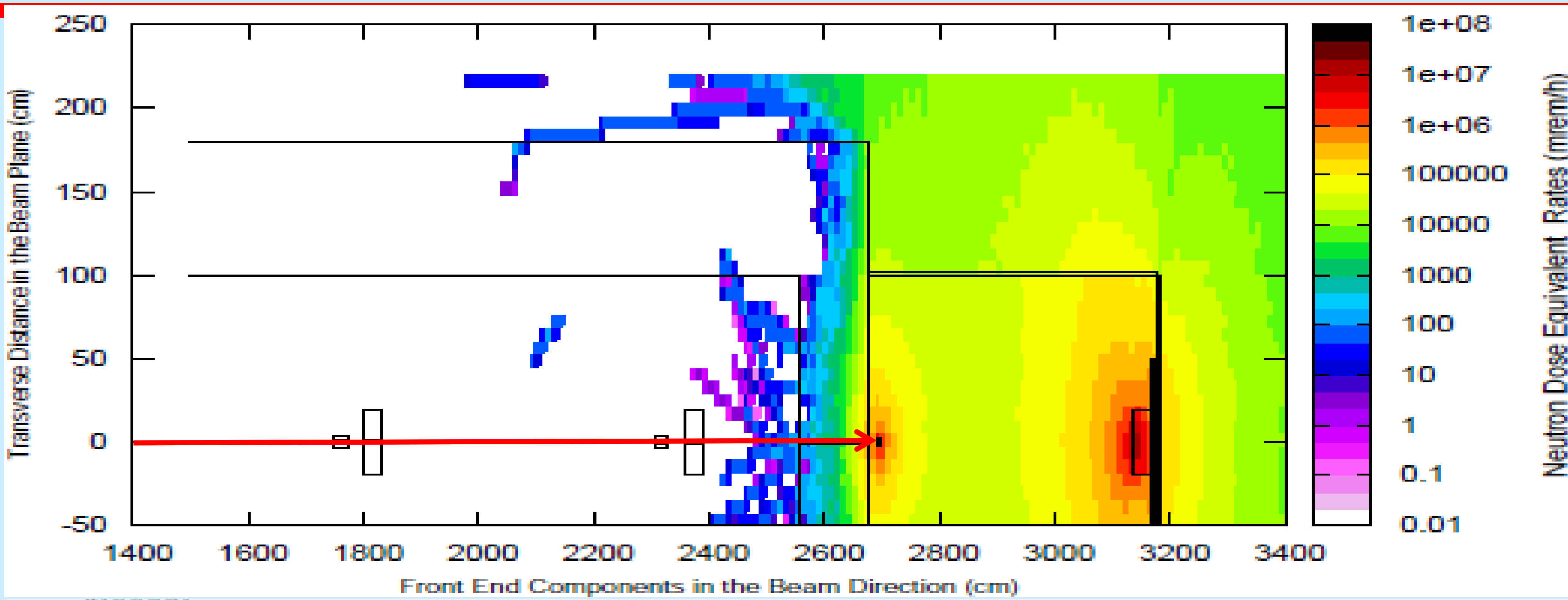
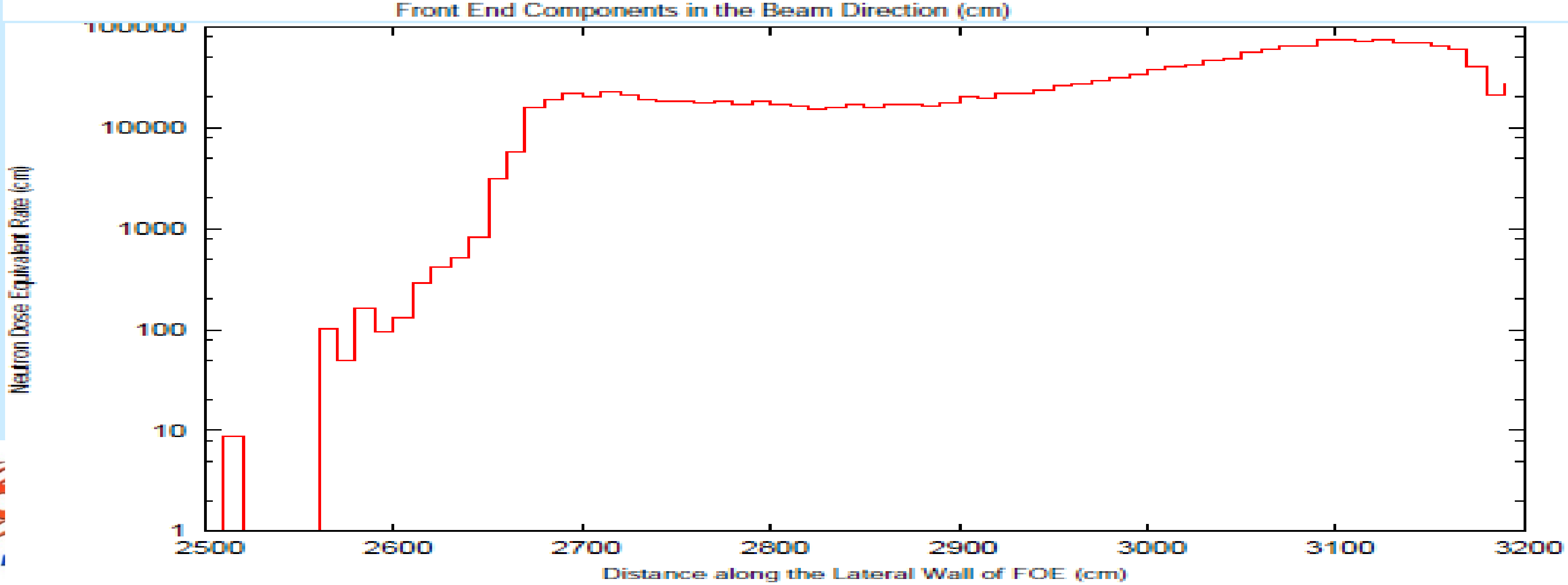
Total Dose Rate along the Side Panel of the Optics Enclosure



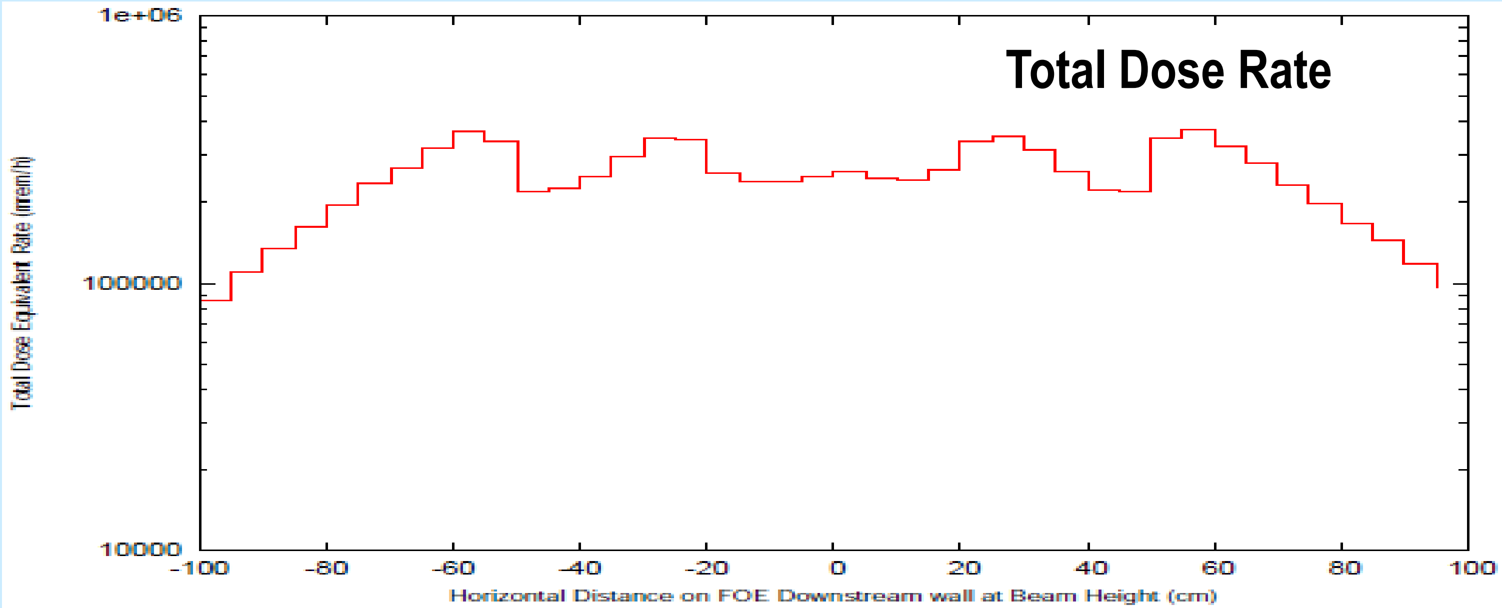


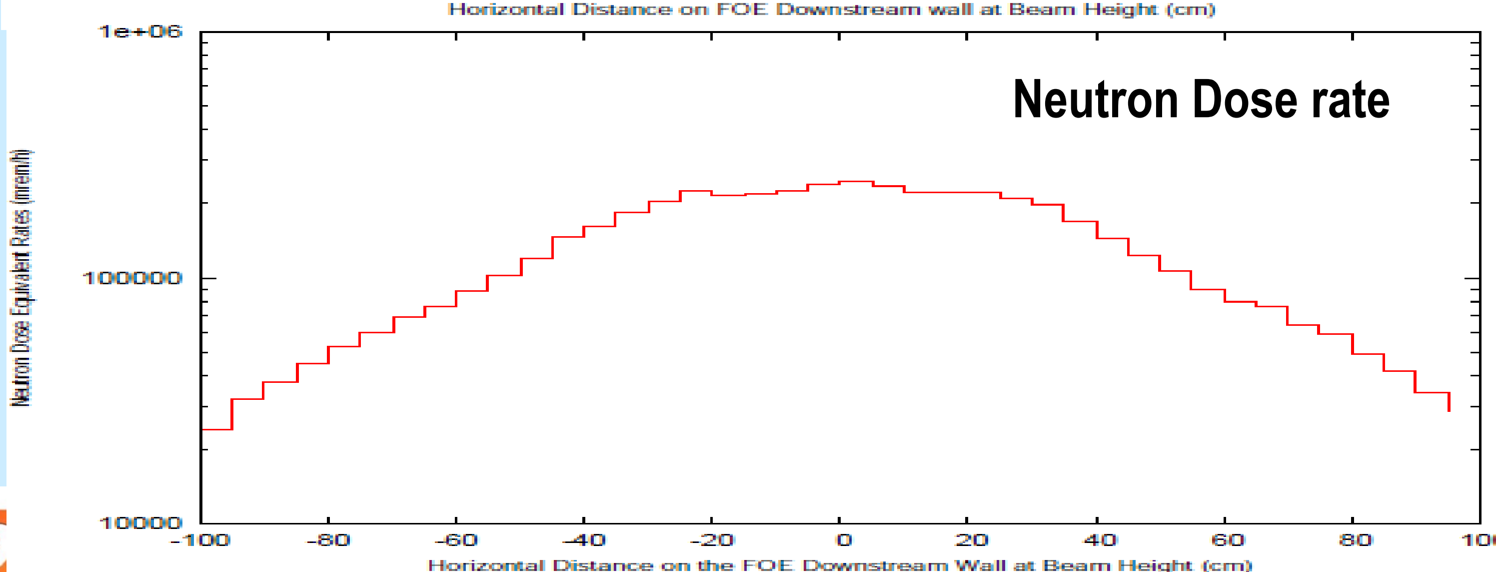
Neutron Dose Rate along the Side Panel of the Optics Enclosure





Dose Rate along the Downstream Panel of the Optics Enclosure





Summary Results & Conclusions

- FLUKA can be effectively used to analyze the radiological consequences of top-off injection accident at Light Sources
- In the event of a full injected beam loss at the NSLS-II front end, the total dose rate at the experimental floor is < 500 mrem/h (5 mSv/h), this corresponds to 0.14 mrem (1.4μSv) per top-off injection pulse of 15 nC (Injection rate 15 nC/s)
- If injected electron beam is intercepted by the front end components inside the storage ring, the area radiation monitors on the expt. floor will be set to trip injection within a few pulses
- The neutron dose rates are calculated as 30-50% of the total dose rates (with ICRP74 weighting factors)
- In the event of full injected beam conveyed down to the Optics Enclosure, the dose rate at the experimental floor is >300 rem/h (3 Sv/h) which corresponds to ~ 80 mrem(0.8 mSv) per pulse of 15 nC
- Fast and redundant interlock systems are required to prevent even the first errant pulse entering the storage ring.

Thanks

- FLUKA Preliminary Workshop at Houston (all the teachers)
- Alberto Fasso (my friend, philosopher and guide)
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