Simulation and Performance of Radiation Shielding for Recent And Future Parity-Violating Electron Scattering Experiments at Jefferson Lab

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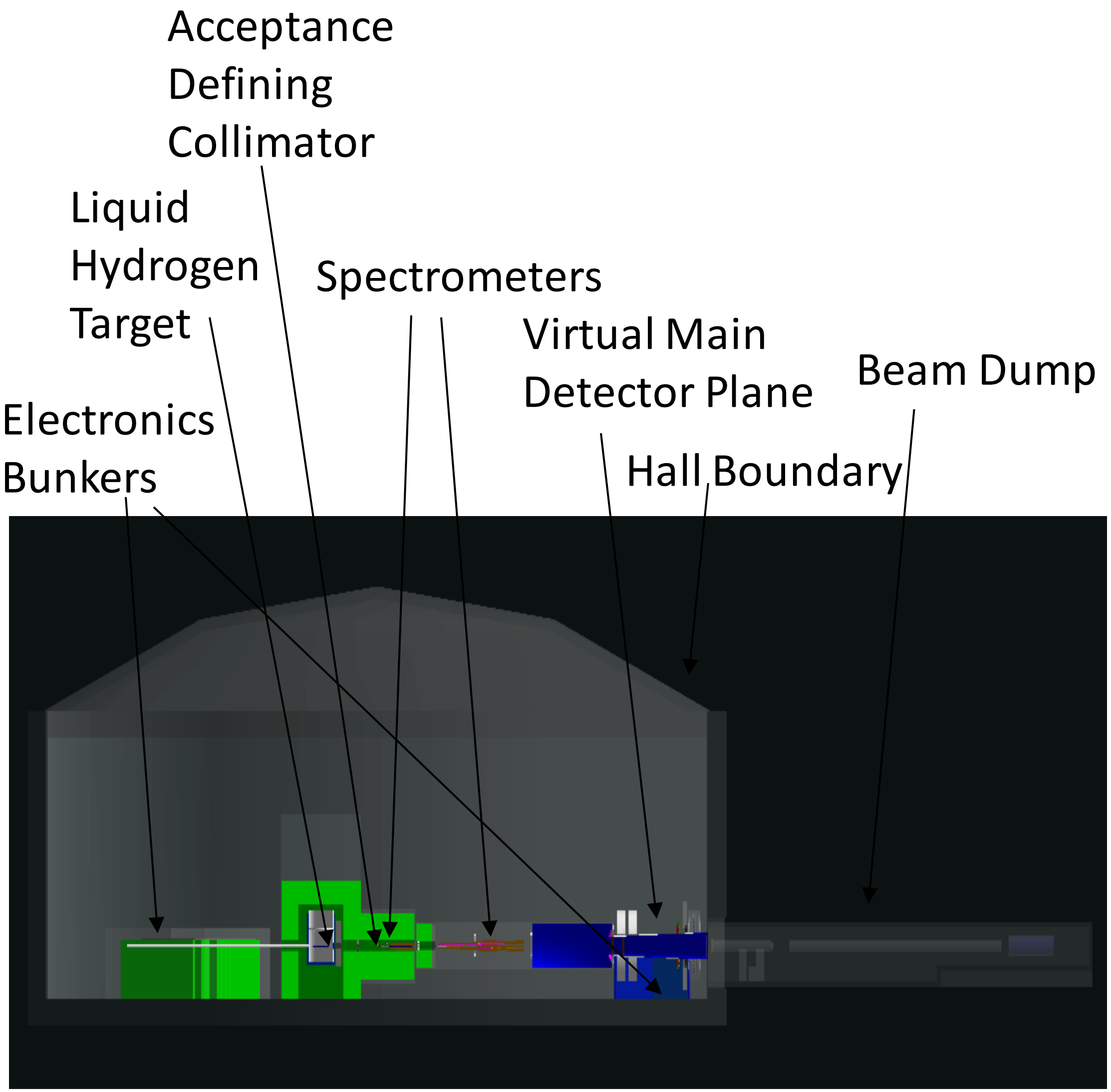
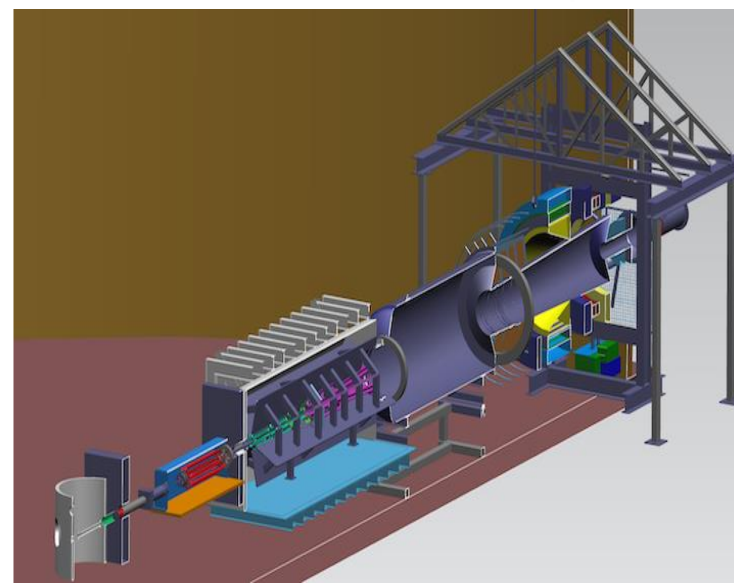
Introduction

Use a Geant-4 based simulation to quantify the performance of shielding equipment in mitigating radiation effects that will impact **equipment** and personnel over the lifetime of the MOLLER Experiment.

Reasonable confidence in the accuracy of the simulation predictions because the shielding design principle was demonstrated to be a success for the PREX-II experiment.



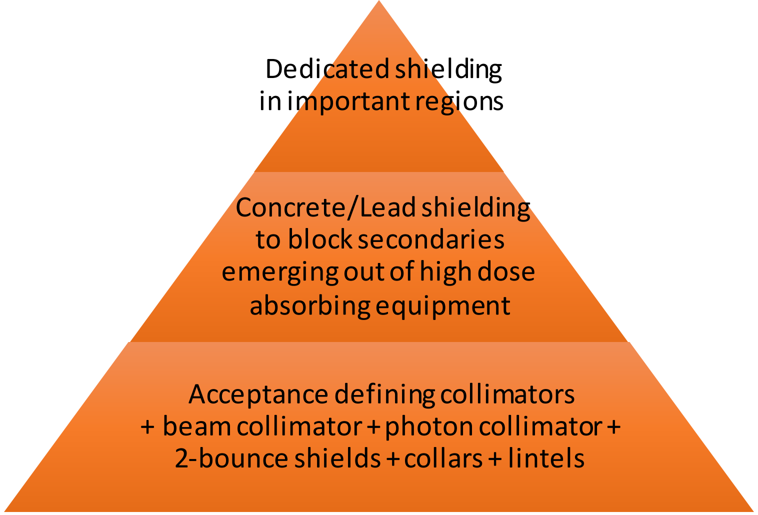
Simulation Implementation

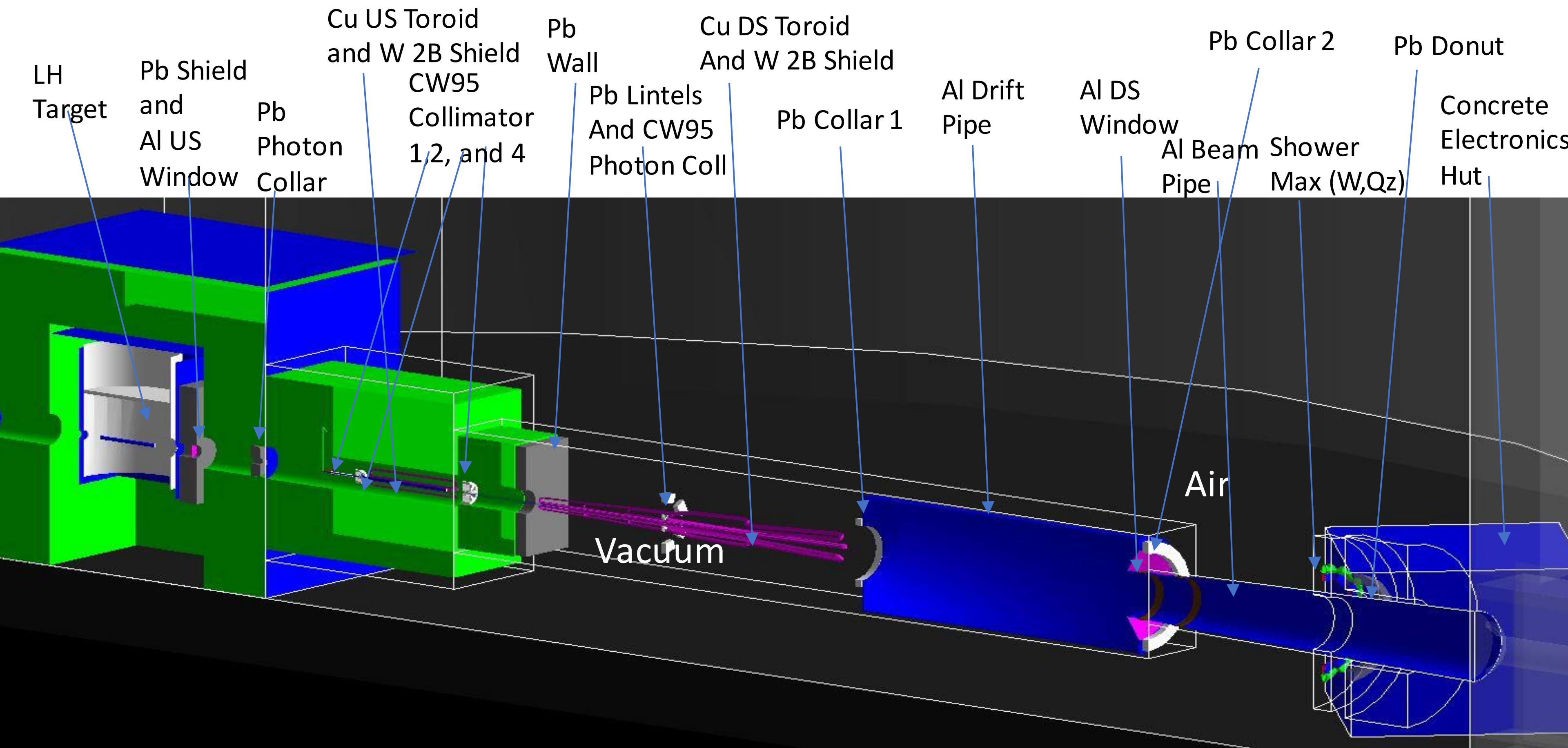


CAD Model

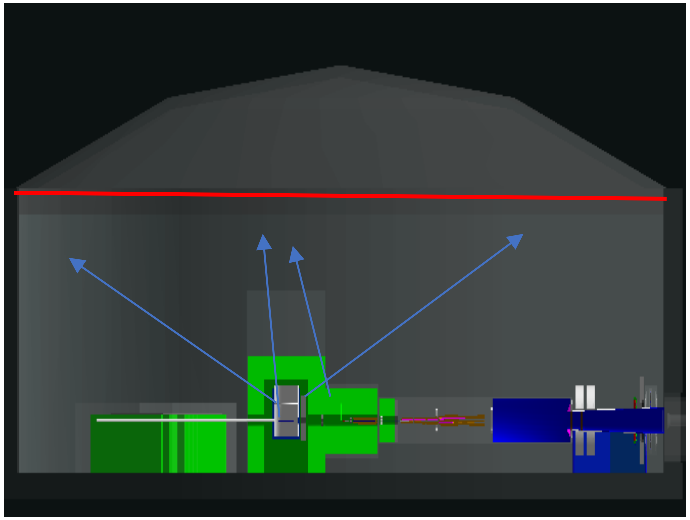
Shielding Design Principle

Important regions to observe:
1) Experimental hall boundary
2) Detector region and electronics bunkers
3) Spectrometers





Experimental Hall Boundary



We look at high energy (>30 MeV) neutron dose reaching the roof of the hall.

Known scale factor between measured dose outside the hall and simulated dose reaching the roof (PREX experience).

Estimated MOLLER dose under different shielding configuration well within radiation safety limits.

	Estimated (mrem/yr)	Measured (mrem/yr)
MOLLER	2.4	N/A
PREX-I	N/A	1.34
PREX-II	0.9-2.2	1.24

Radiation dose predicted for MOLLER compared to PREX-I and PREX-II. The USDOE/Jefferson Lab radiation limit for personnel protection is 100/10 mrem/yr.

Preliminary crosscheck with FLUKA by Jefferson Lab RadCon yields similar conclusions

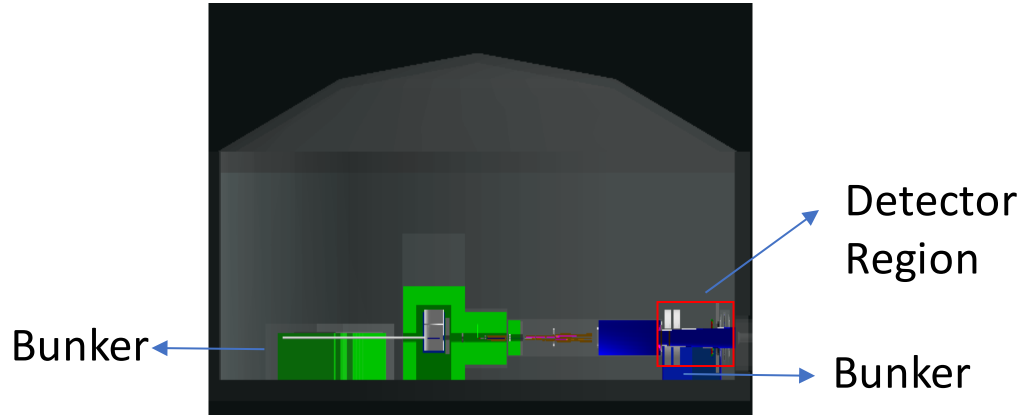
Detector Region and Electronics Bunkers

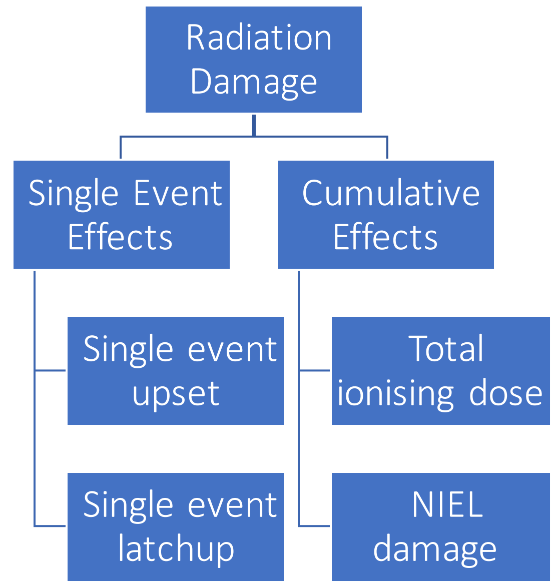
Detector Region

Assessed background levels during measurement as well as single event effects and cumulative damage to detector PMTs, bases and GEM electronics. Single event effects are not a concern for the detectors since the estimated flux is similar to previous experiments. **Total ionising dose estimated to be ~60 kRad for PMTs, a factor of 5 below safety limit for degradation**. NIEL damage also within the safety limit.

Electronics Bunkers

The bunkers will house magnet power supplies and controllers as well as sensitive electronics. NIEL damage estimates are orders of magnitude below the safety limit.

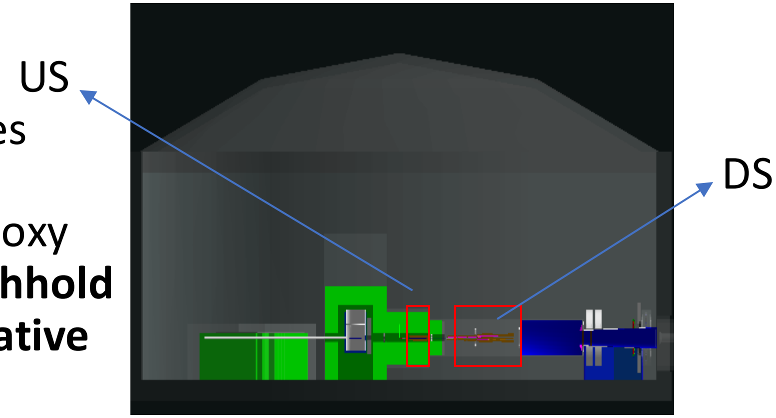




Component	Detector PMTs	GEM electronics	Bunker dose
Radiation Level (n 1Mev eq)	1e12	4e12	1e9

NIEL damage estimates. The safety limit for commercial electronics is about 1e13 n 1MeV eq.

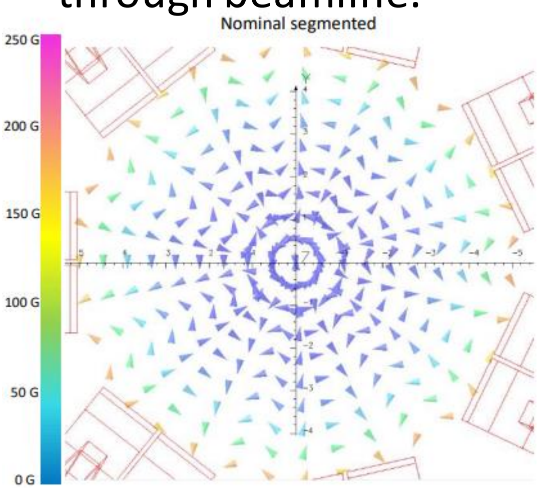
Spectrometers

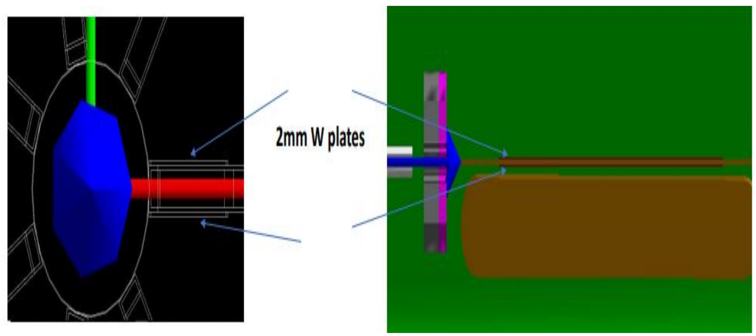


The epoxy in the magnet coils is irradiated by particles coming through the acceptance and the beamline. Dedicated shielding needed to prevent epoxy degradation due to drop in shear strength. **The threshhold limit is about 50 MGy for US magnet. More conservative limit for the DS magnet.**

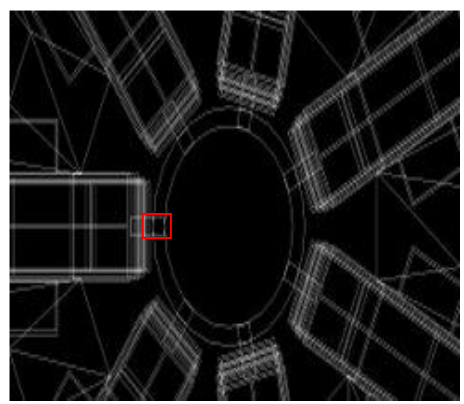
Problem	Solution	Performance

Positrons bent into coils by the magnetic field. For US coils, they come through acceptance and for DS coils, they come through beamline.

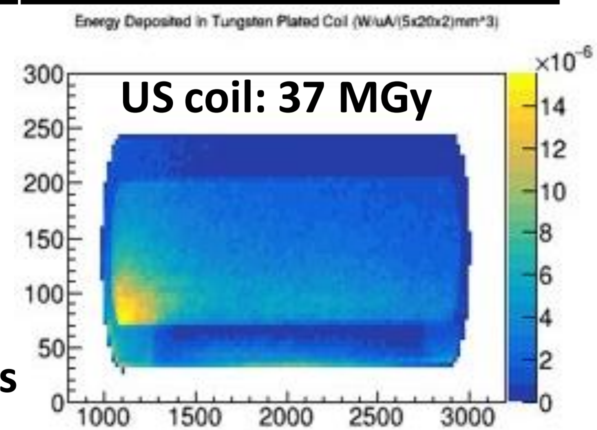


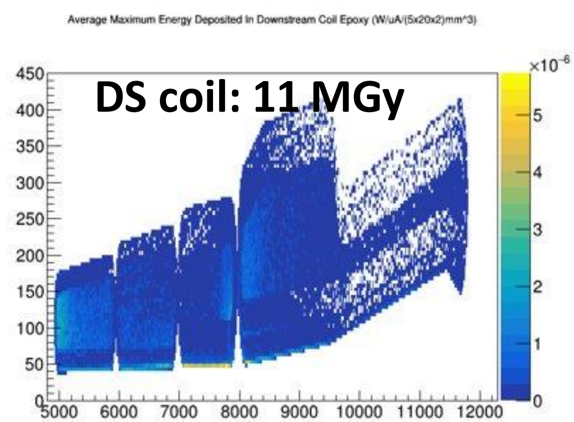


2 mm thick side shields for the US coils



6 mm thick inner radial shields for the DS coils





Conclusion

- We simulated the MOLLER experiment with a geometry implementation that closely matches reality. We identified the need for new shielding elements based on the results.

- The current shielding configuration satisfies both the safety requirements for the personnel, as defined by the Jefferson Lab/USDOE, and the operational safety requirements for the equipment.

- Further optimizations in progress.

Acknowledgements

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