Design on the mini-SHINE/MIPS experiment

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Mini-SHINE/MIPS experiment. Two phase approach

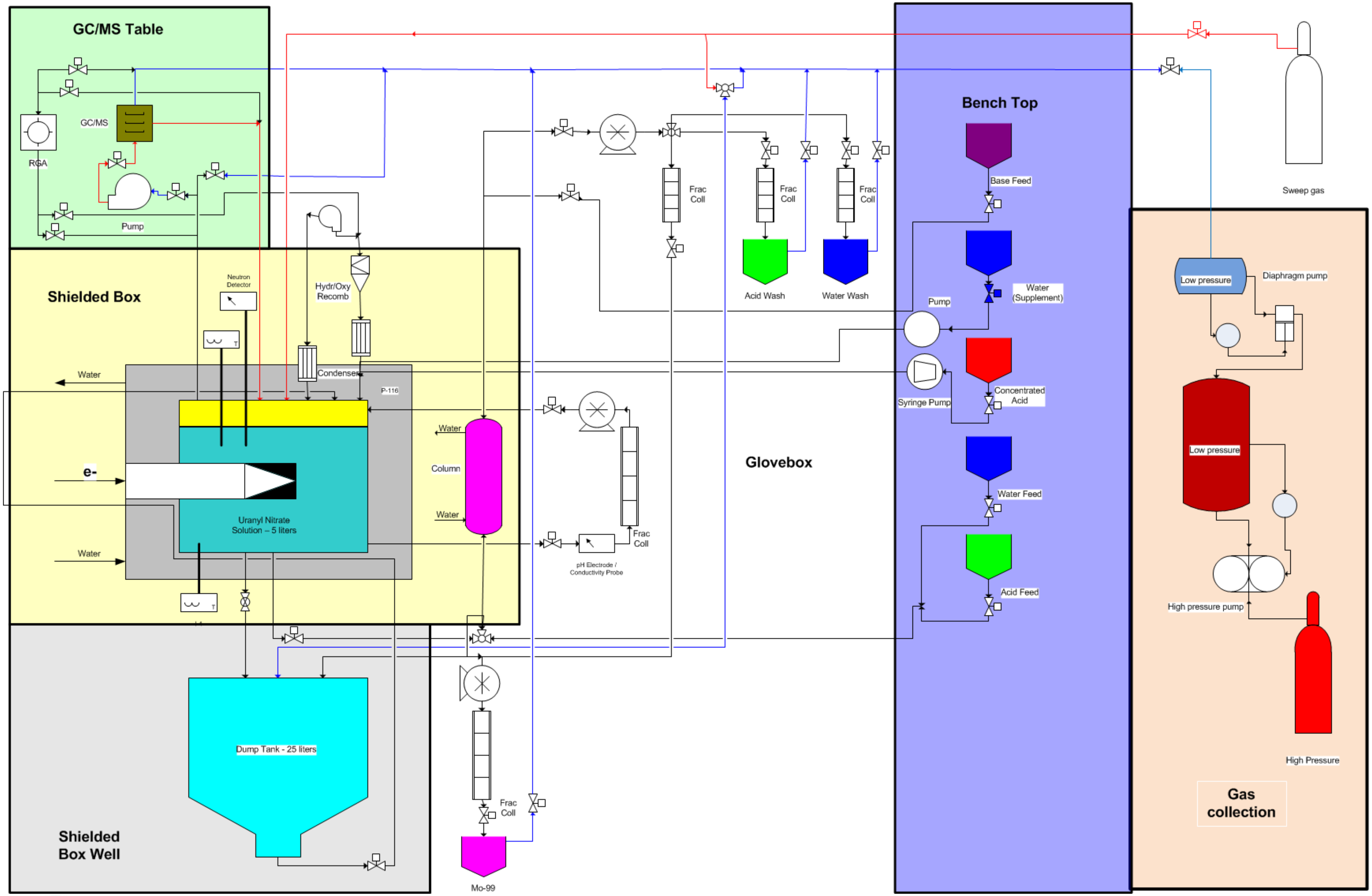
Phase 1

- Linac will be operated at 18 MeV and 10 kW beam power on the target
- 5 L solution will be irradiated with neutrons generated through gamma-n reaction in tantalum target
- The maximum solution power will be $\leq$ 0.05 kW/L.
- Produce up to 2 Ci of Mo-99

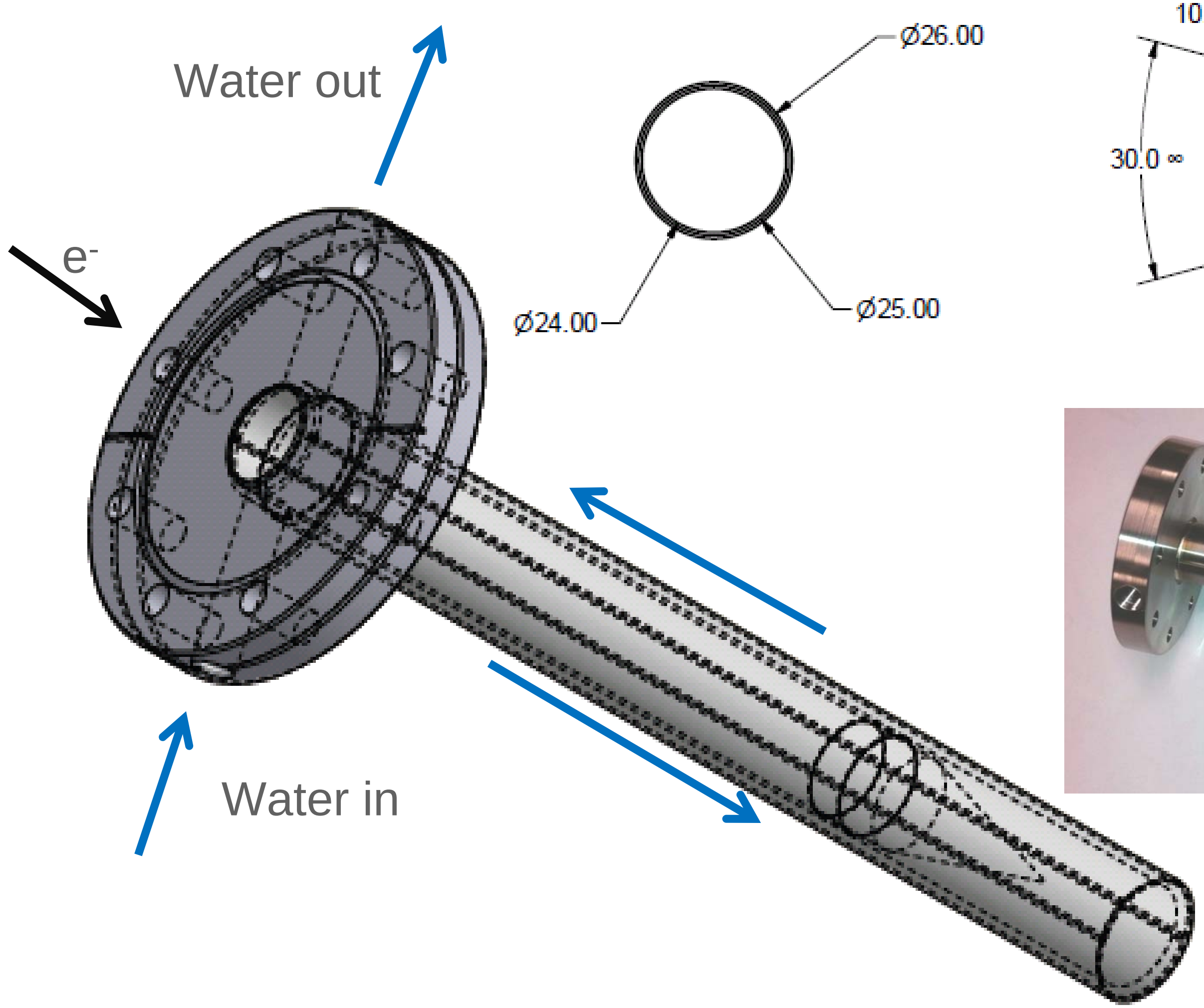
Phase 2

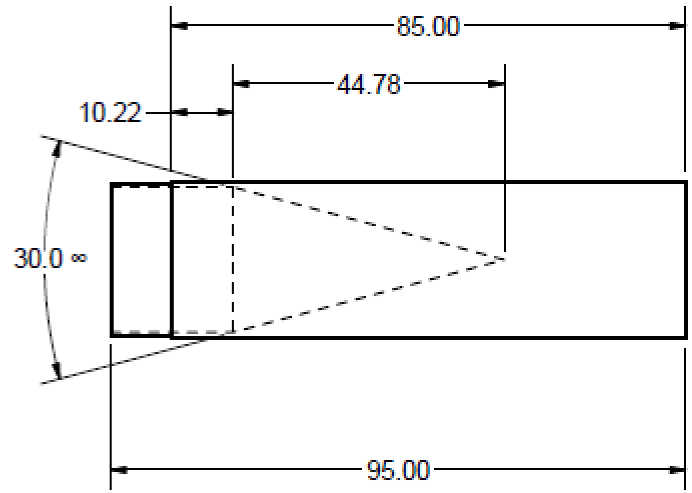
- Linac will be upgraded (December-January 2011) to 58 MeV maximum energy and mini-SHINE/MIPS experiment will be conducted at 35 MeV beam energy and up to 30 kW beam power
- 20 L solution will be irradiated with neutrons generated in depleted-uranium (DU) target
- The maximum solution power will be $\leq$ 0.5 kW/L.
- Produce up to 20 Ci of Mo-99

Mini-SHINE/MIPS experiment (Phase 1)



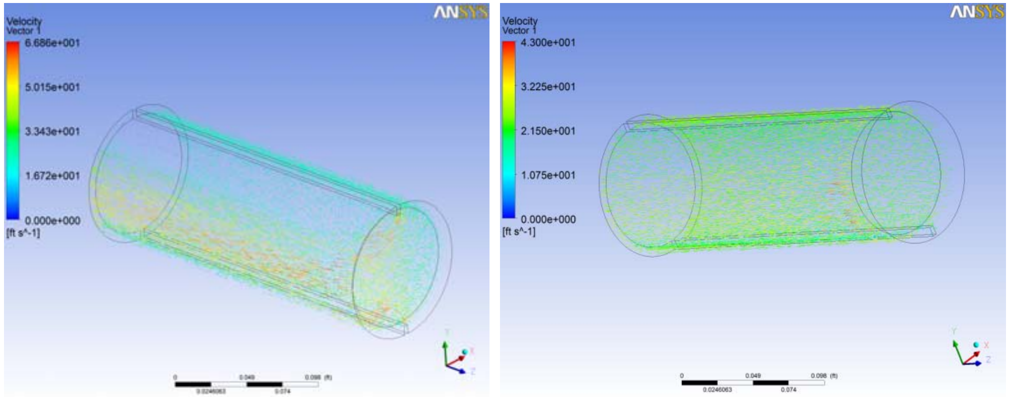
Ta target

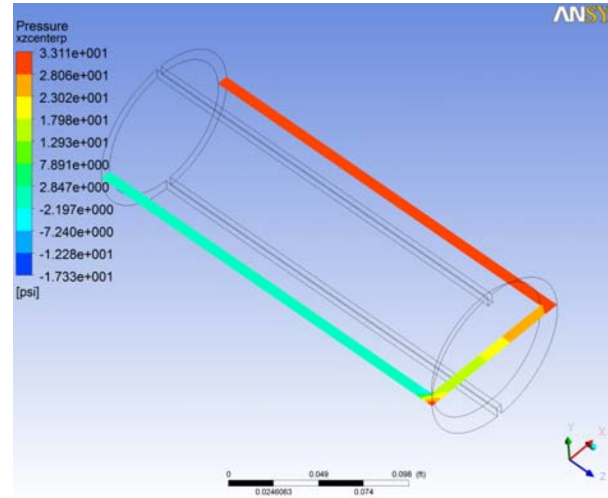

Water out
e-
Water in
Ø26.00
Ø24.00
Ø25.00


85.00
44.78
10.22
30.0 °
95.00

Ta photo-neutron target calculation

Flow **Pressure**





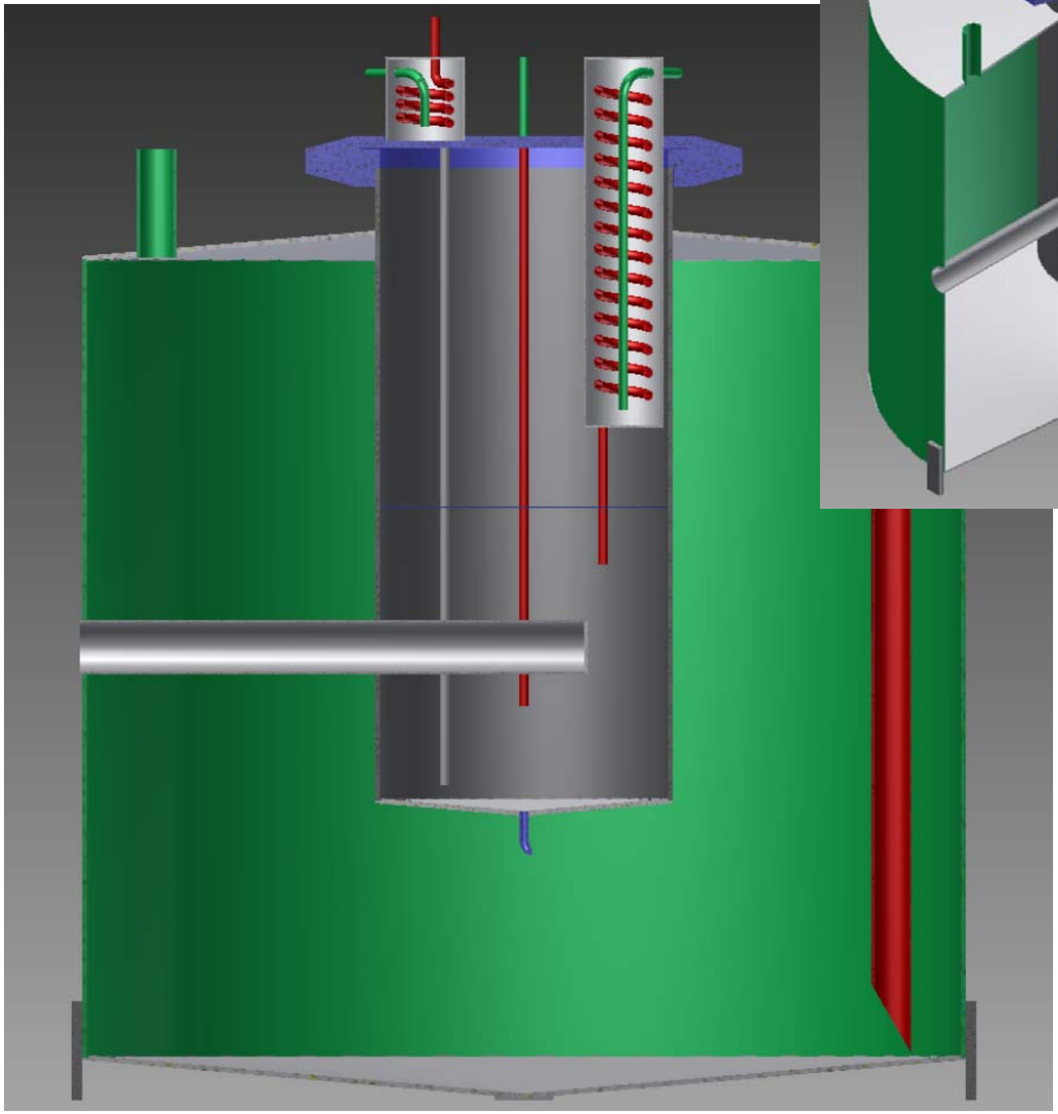
Increase of the spacing at the end of the target made flow pattern less turbulent and pressure drop across the target decreased from 33 psi to 12.5 psi

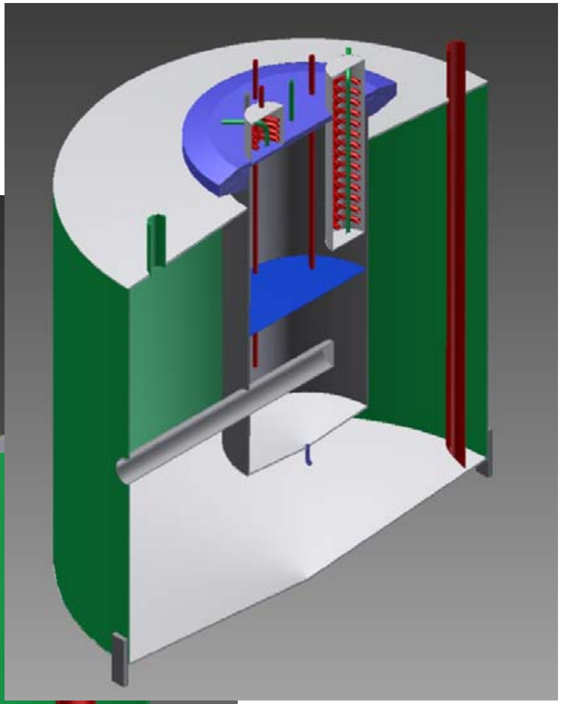
Temperature

- At 10 kW power deposition and 10 gal/min water flow temperature of the target surface <100^{o}C
- Simple geometry of the target will allow to utilize boiling regime of cooling and dissipate up to 20 kW of beam power

5 L solution irradiation vessel

- 5L uranyl nitrate/sulfate solution
- We will use Al 1100 alloy for prototyping, neutron flux measurements and water irradiations and SS 304 for all other irradiations.
- Large access port for gas analysis, flow loop, thermocouple, neutron- flux monitor, etc.
- 6” light-water reflector/cooler



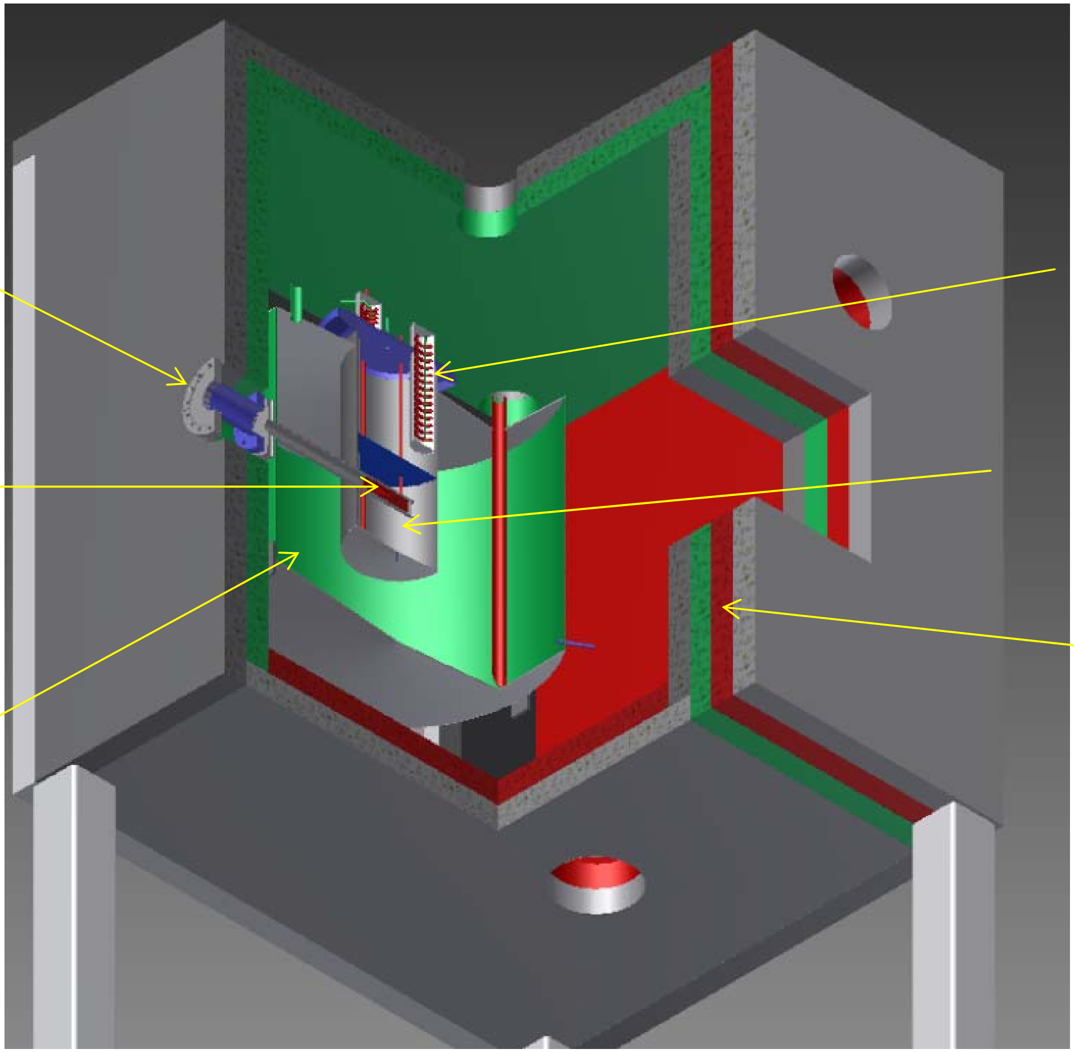


5L solution volume installation in the shielded cell

Electron beam

Ta target

Water reflector

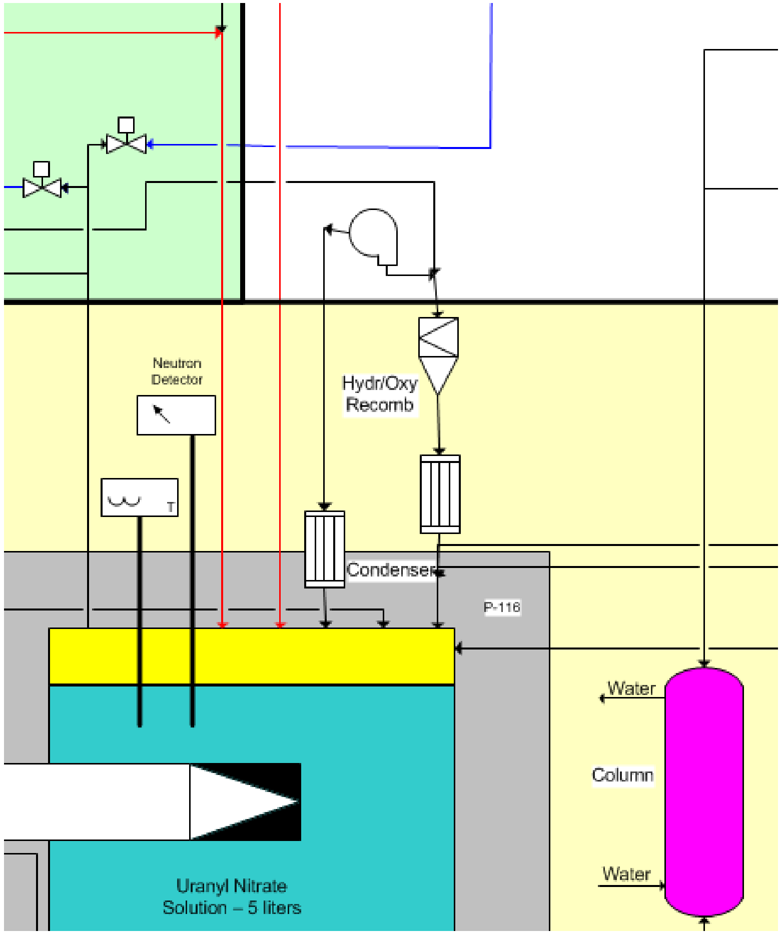


Condensers

Uranyl sulfate/nitrate solution

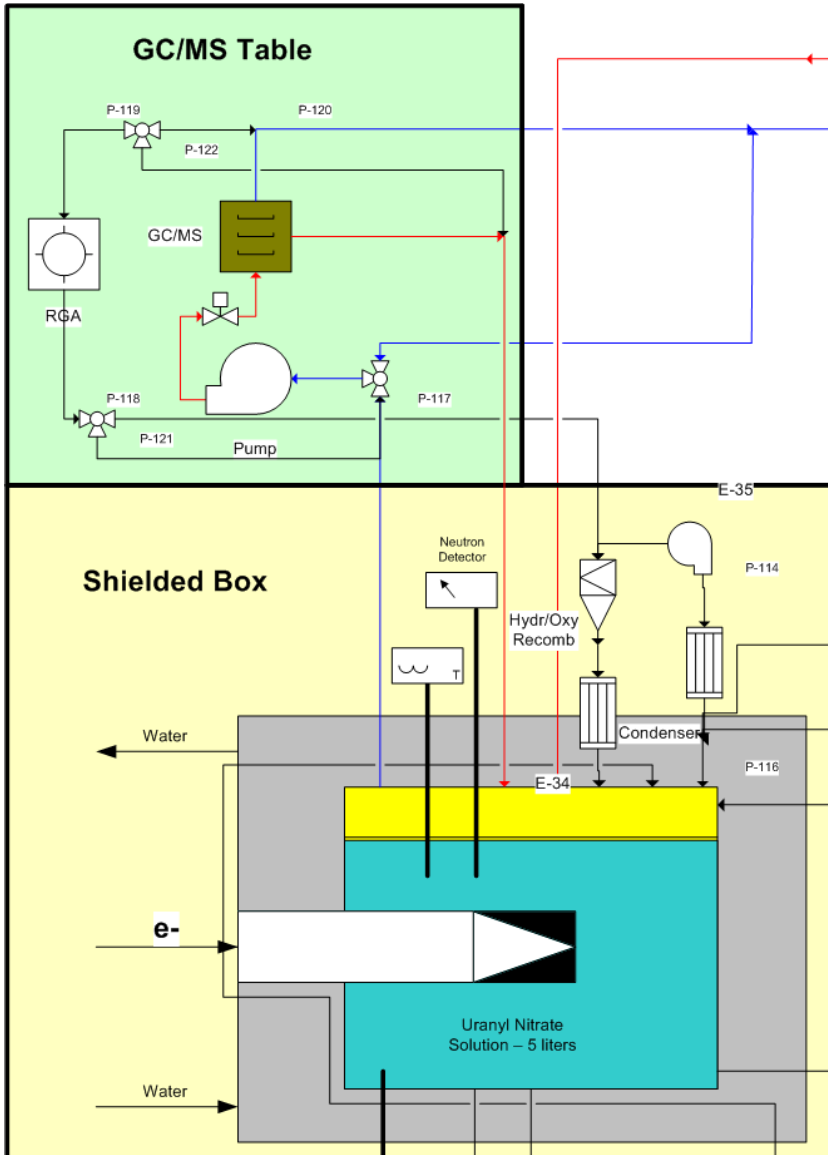
Shielded cell

Catalytic converter



- Expected generation rate of radiolytic gases ~75 mL/min (H_2/O_2) at 0.2 kW fission power.
- A condenser will be situated before and after the recombiner to remove the bulk of the water vapor from the gas stream
- To reduce the size of the gas capturing system, a closed-loop gas system will be utilized.
- A Class I/Division I/Group B explosion proof diaphragm pump will be used to create a high flow rate through the plenum.
- A Pt/Pd on alumina honeycomb catalyst was supplied by the Ford Motor Company. The open design of the catalyst also allows to handle the expected flow rates (1-3 L/min) . Catalyst performance was tested and we verify radiation stability of the catalyst soon.
- Modeling of the main irradiation volume and plenum is under way to determine the required flow rate to dilute the hydrogen gas sufficiently.
- Catalyst itself will occupy a small volume - ~2” diameter by 2” long. The diaphragm pump and condensers will occupy significantly more space.

Gas analysis

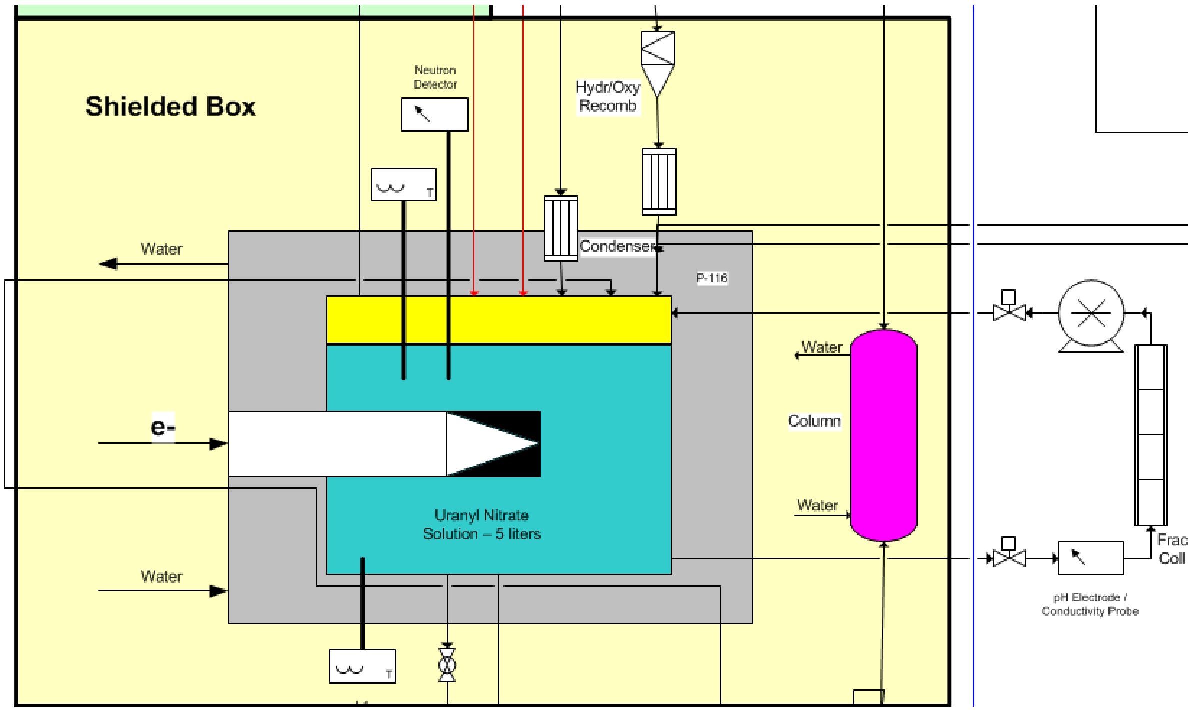


Atmospheric RGA

GC/MS

Gas sampling loop is now assembled and is tested at Van de Graaff accelerator facility

Sample loop for pH, conductivity measurements, and sample collection



pH and conductivity meter sample loop

- Continuous operation
- Radiation stability
- Ready to be tested at Van de Graaff facility for radiation stability

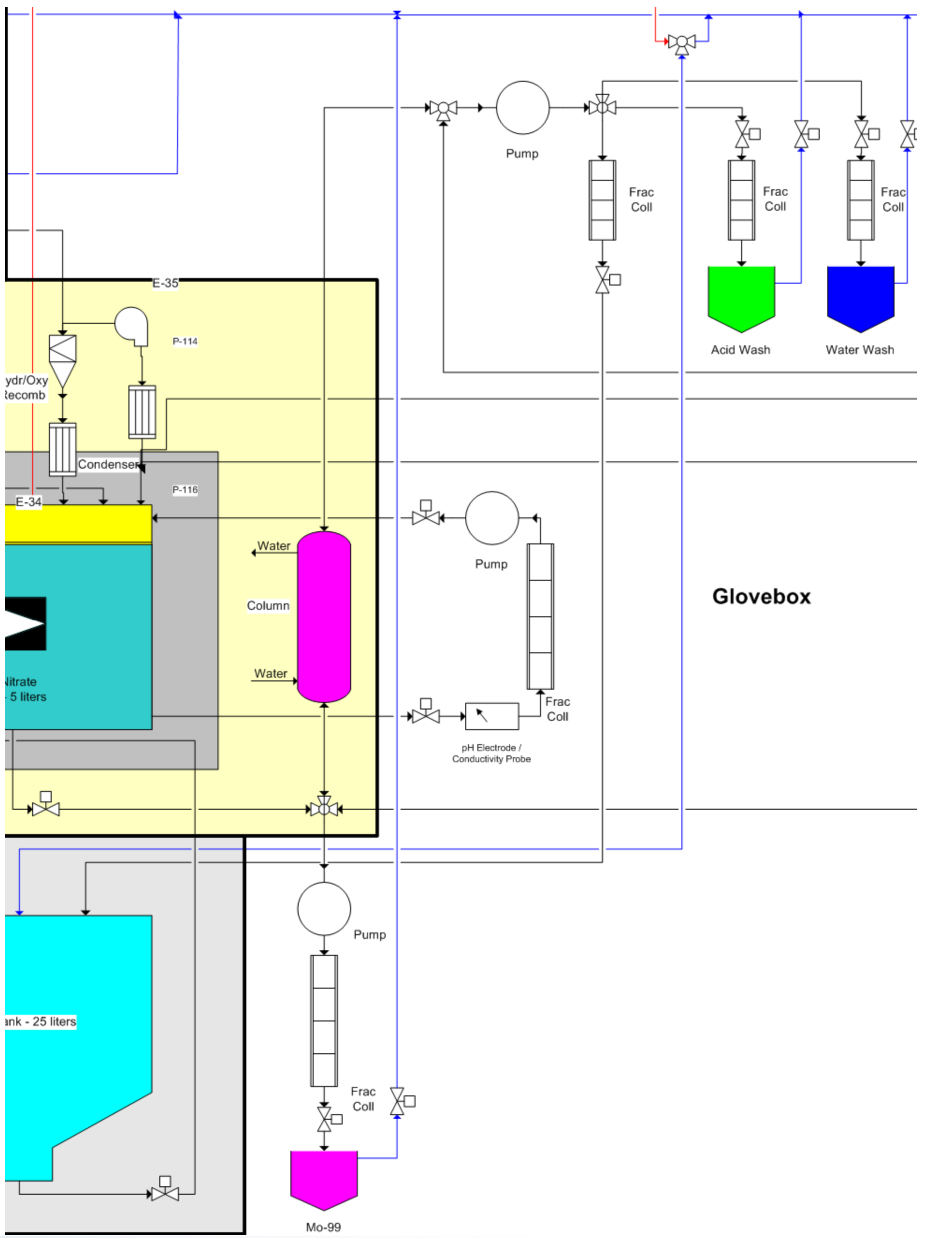
Sample collection system

- The samples range in volume from 1-5 mL
- The samples must be able to be collected without the release of entrained gases into the glovebox atmosphere
- The samples must be collected remotely
- Two designs are currently been evaluated

Separation system design and operations

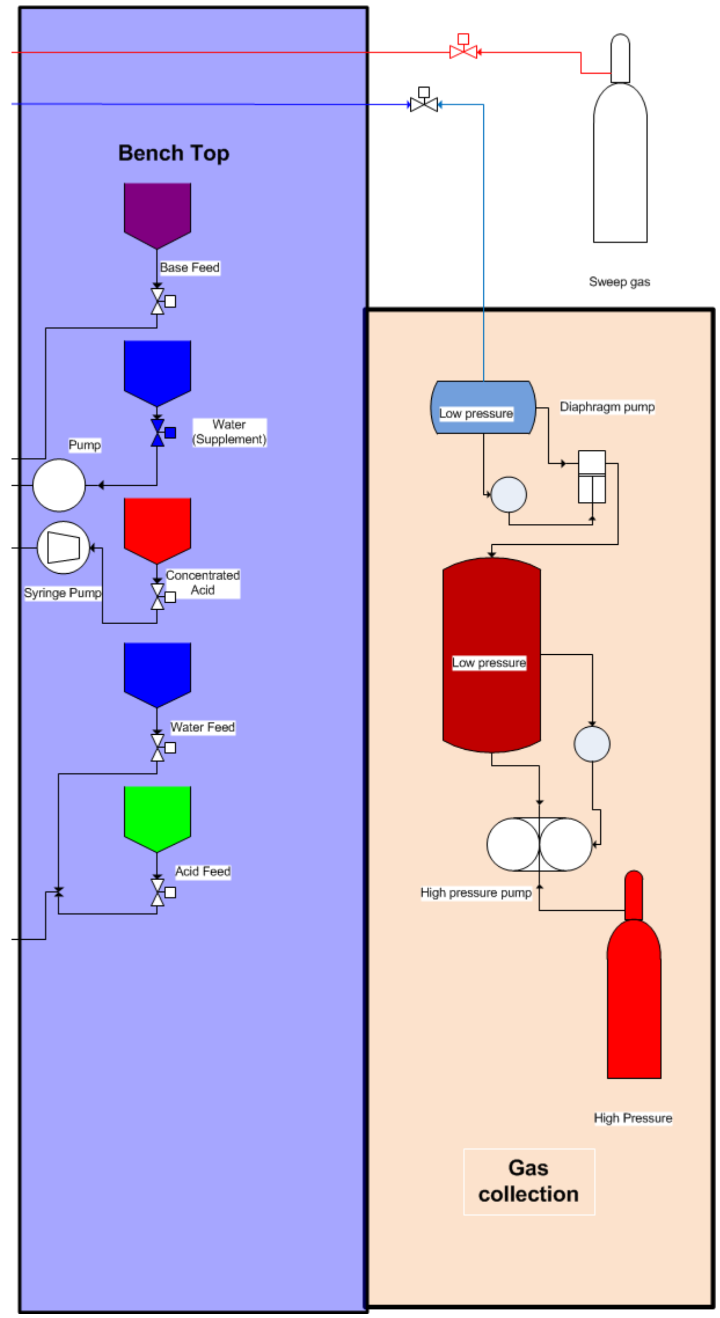
Separation system for 5L solution

- 2 cm ID x 10 cm L S110 column
- Loading at 12.3 cm/min and stripping at 10 cm/min
- Optimization currently underway
- $KMnO_4$ may be added to water wash and strip solution
- 5 L of irradiated uranyl sulfate/nitrate will be passed through the column in the up-flow direction
- Column run will be done in shielded box
- Acid wash and water wash will be performed in the up-flow direction
- Stripping of the Mo-99 will be performed in the down-flow direction
- Strip product solution (Mo-99) will be transferred to a lab for purification using the LEU-Modified Cintichem process

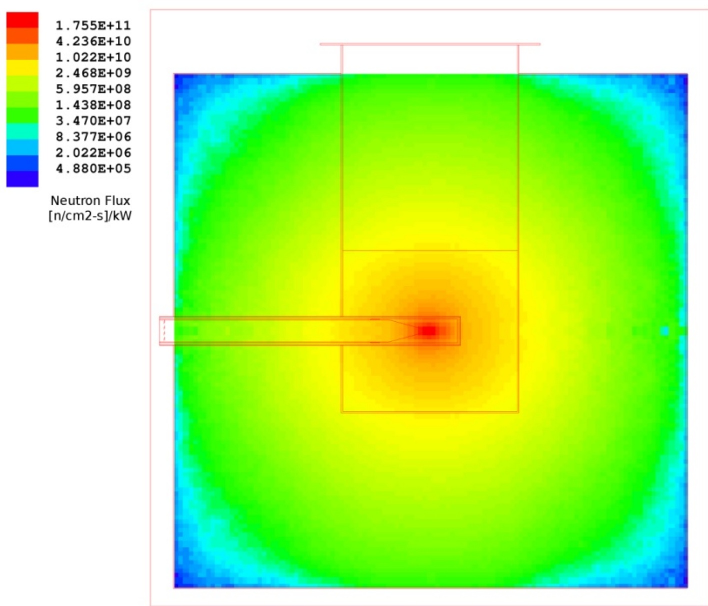


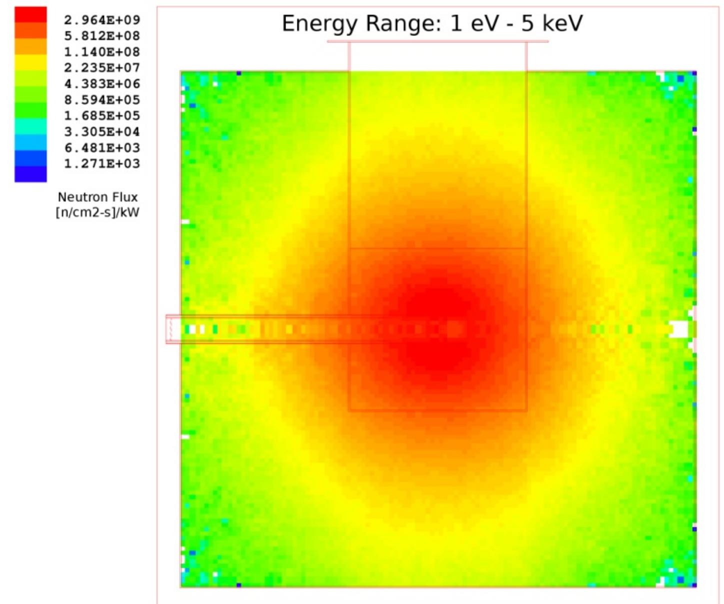
pH, solution-level control, gas collection system, and strip/wash feed solutions location

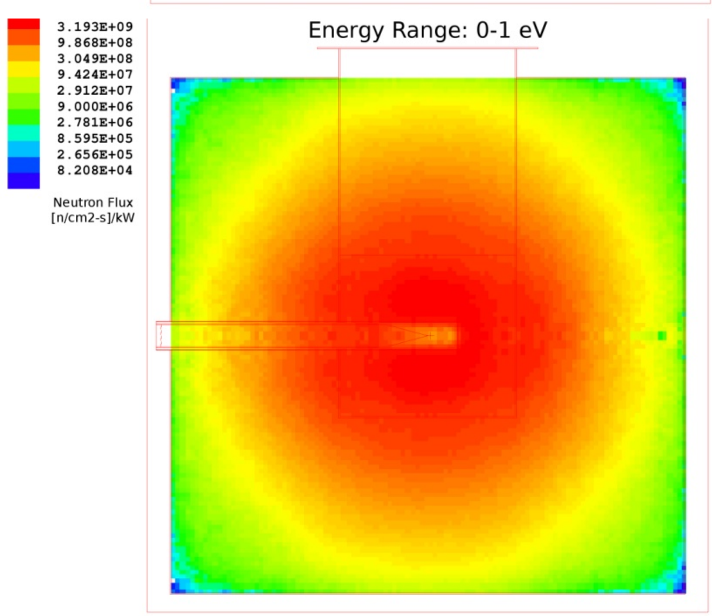
- Separate table for all solutions
- Water supplement and concentrated acid feed to maintain pH in solution during run and to adjust/dilute solution between the runs
- Three tank system to maintain constant pressure in the system
- Closed system, all gasses will be collected and stored for tree month to allow decay

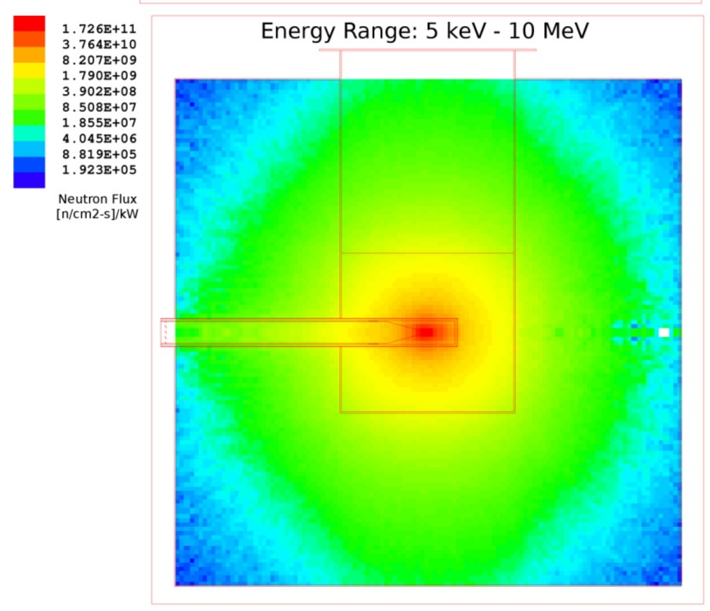


MNCPX calculation for neutron flux for 5 L design

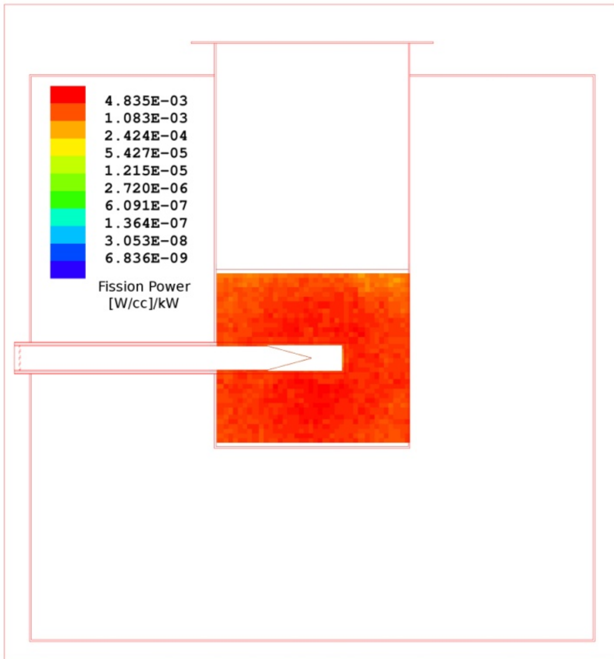


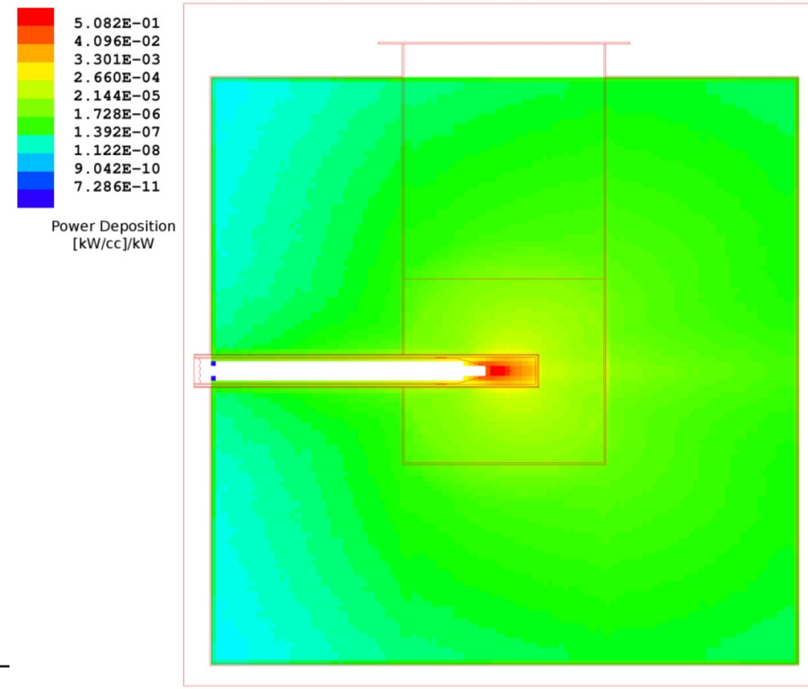


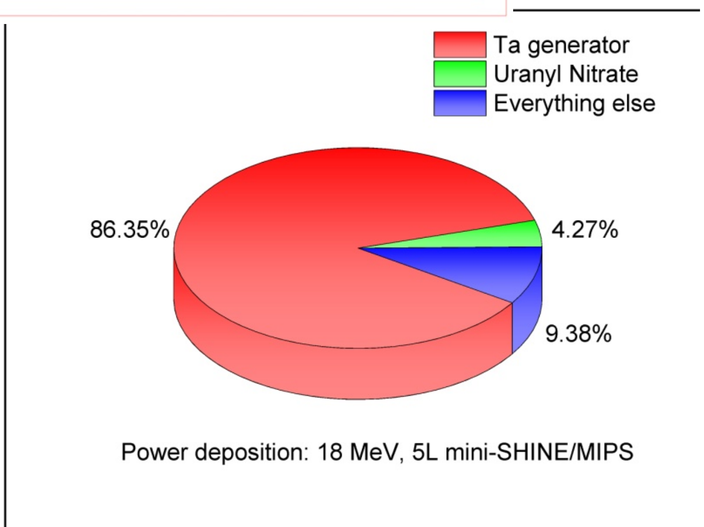




Power deposition calculations



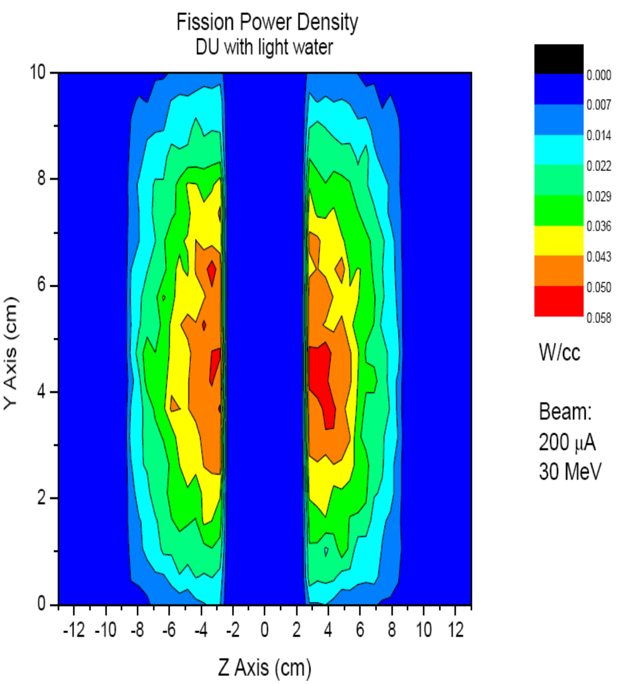


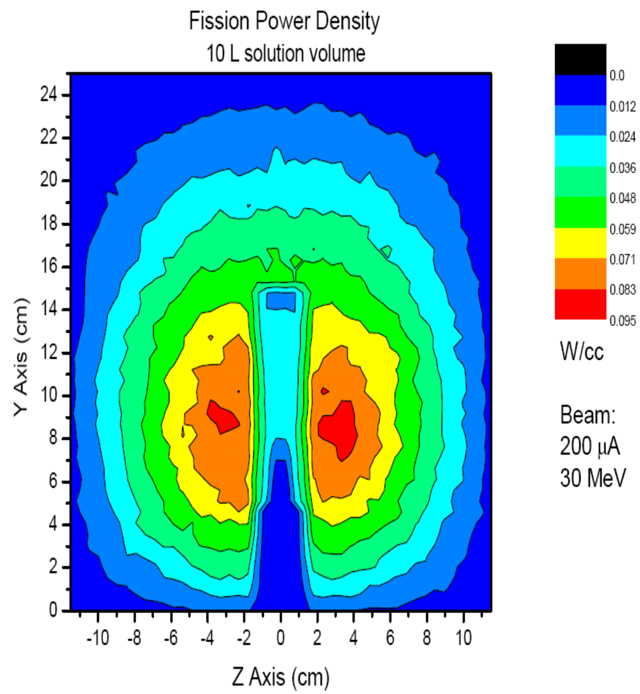


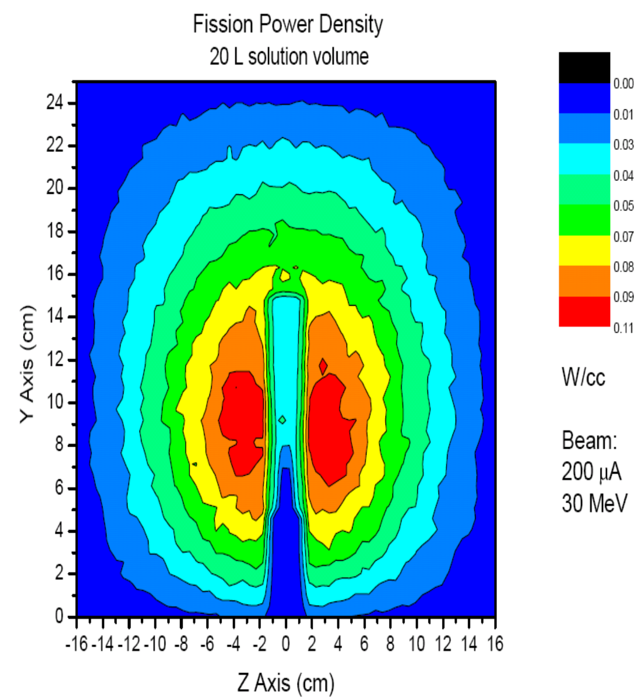
Fissions/e	9.65E-04
e/s per kW at 18 MeV	3.47E+14
Fissions/s per kW	3.35E+11
Total Fission Power [W]/kW	10.7
Average Fission Power Density [W/L]/kW	2.1

For 20 kW beam power
Average fission power: 40 W/ L
Total power deposited in solution: 800W

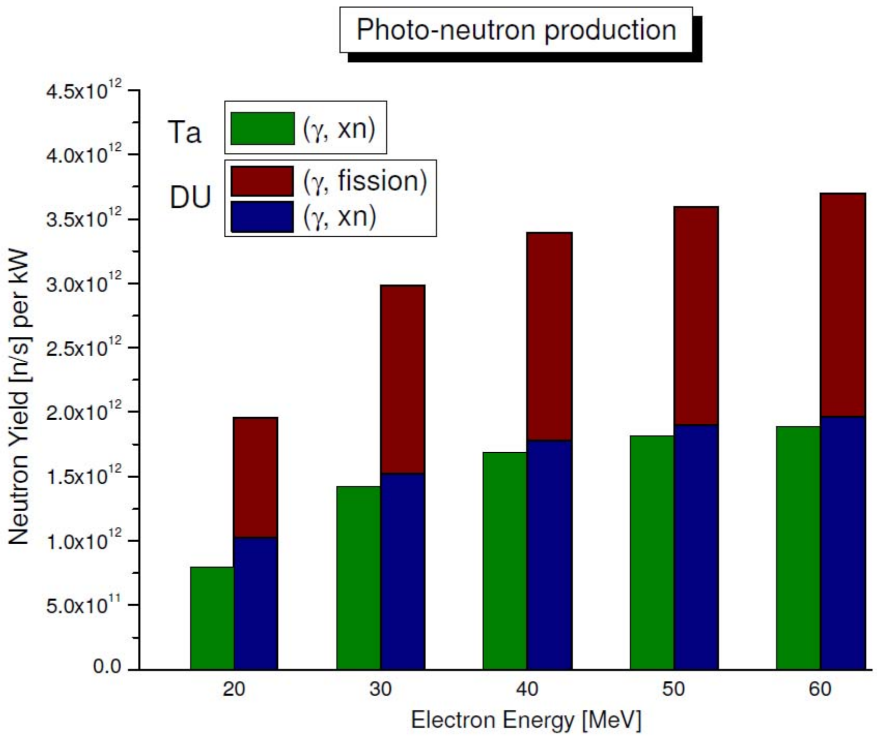
Fission power distribution for different volumes at 30 MeV electron energy



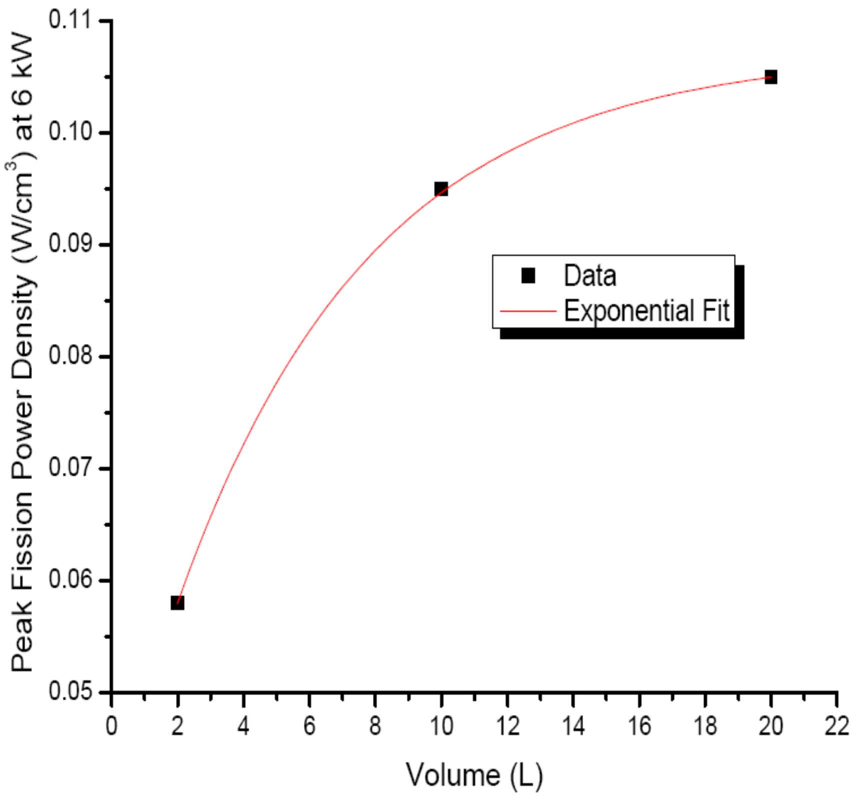




Effect of electron energy and volume of the solution on peak fission power

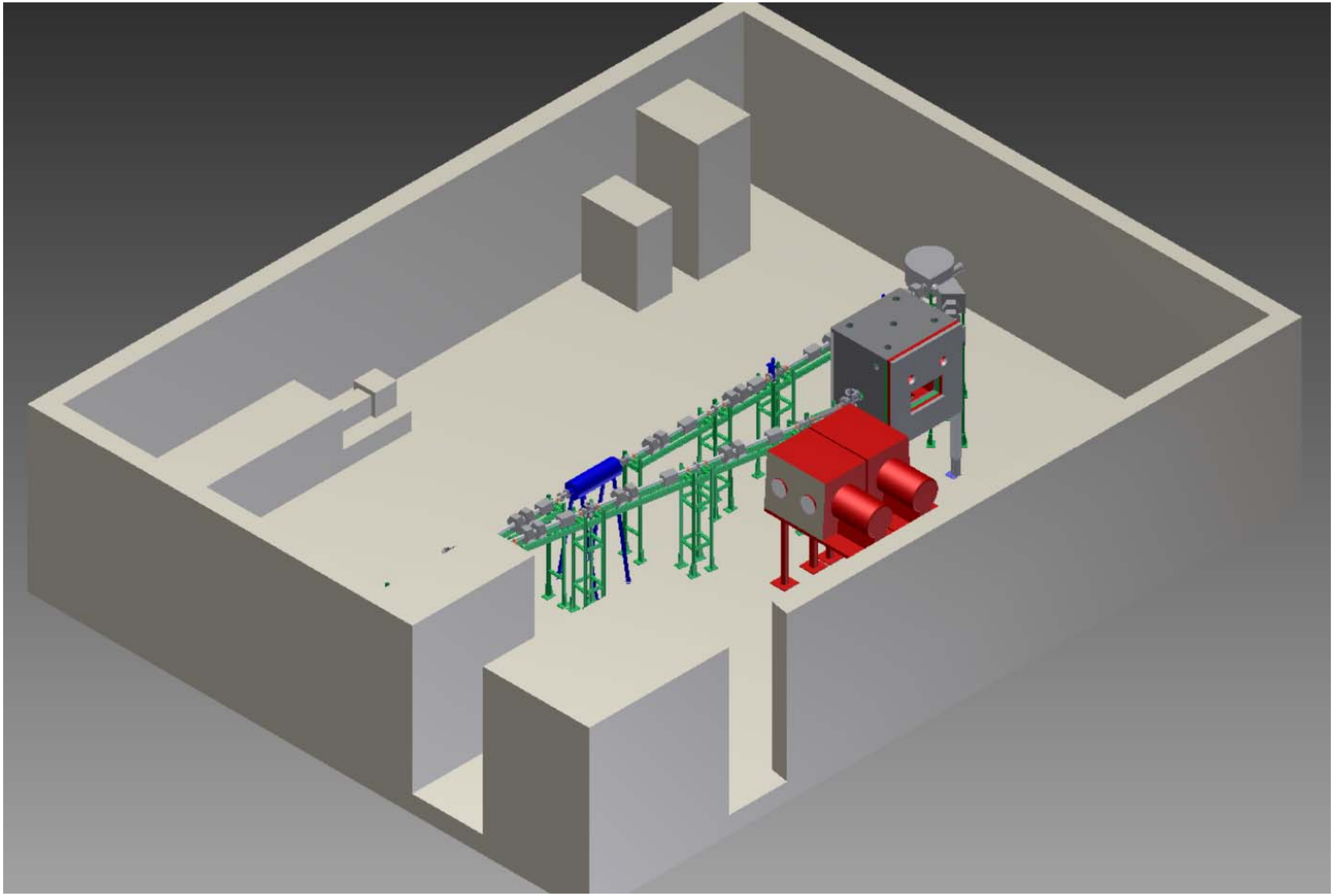


Dependence of photoneutron yields normalized per kW of beam power for Ta and DU targets on electron beam energy simulated with MCNPX



Dependence of the peak power in solution at 30 MeV electron energy on volume of the solution

Irradiation room layout



Shielded Cell

- Shielded cell has 4” lead shielding everywhere except front wall with 8” of lead shilding.
- Shielded cell will allow access to the irradiated solution within a very short time after the end of the irradiation
- Only Mo-99 product solution will be moved to another building, which will minimize impact on radioisotope’s inventory

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Concluding Remarks

- Preparation for mini-SHINE/MIPS experiment at the linac facility are underway
- Phase 1 experiments are planed for December 2011-May 2012 time frame
- Gas evolution rates and pH and conductivity of the solution will be monitored in real time
- Oxidation states of Mo and I partitioning will be evaluated in the samples collected during irradiation
- Multiple concentrations at several powers will be tested
- Samples of Mo-99 can be send to commercial partner for evaluation
- Preparation for 20 L solution irradiation started in November 2011 and irradiation will commerce in August-September 2012.

Acknowledgement

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