Radiation studies from nuclear targets

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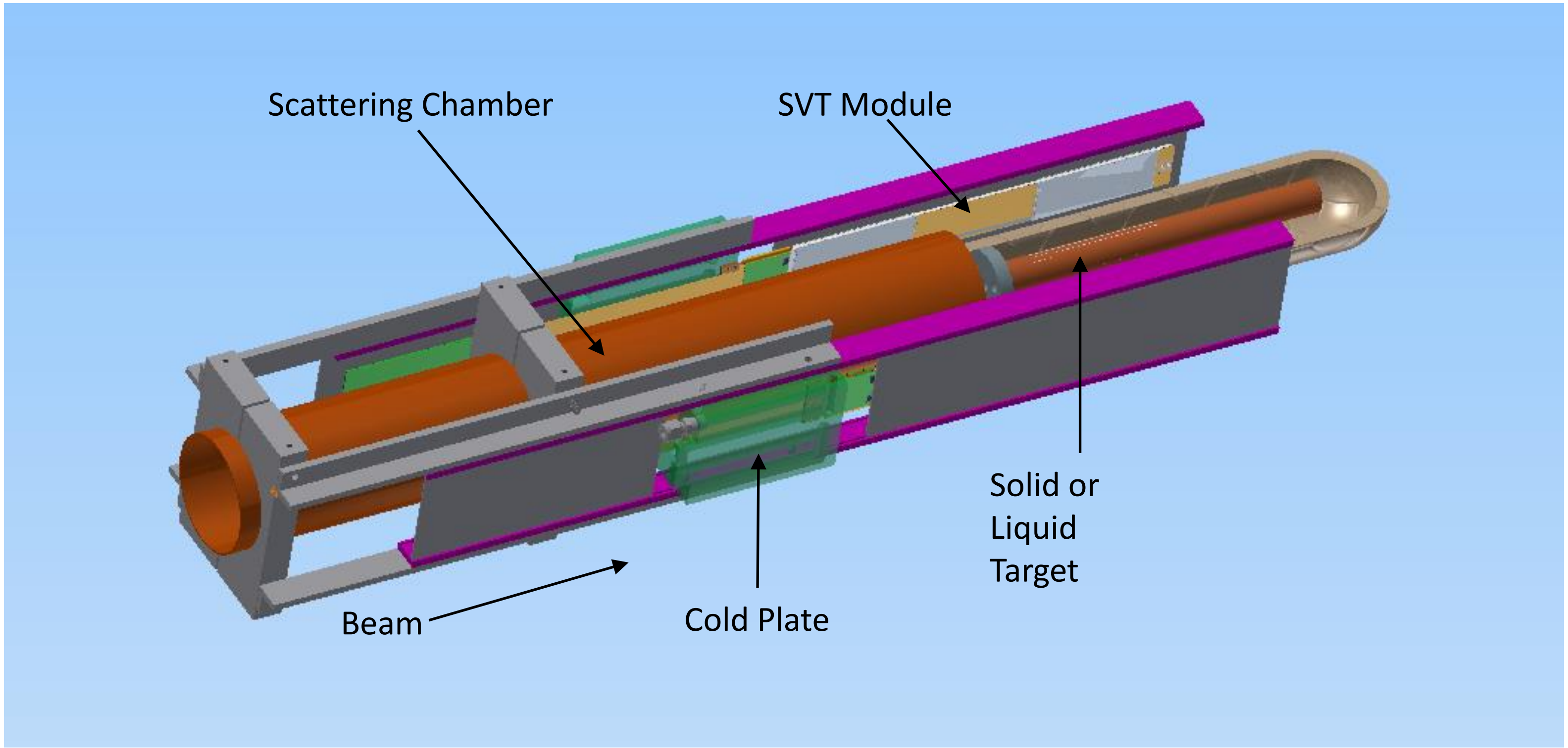
Test goals

- Validate simulations by measuring radiation dose at various locations around the target
- Measure occupancies and the leakage currents in the silicon sensors
- Measure rates and occupancies in all CLAS12 detectors

Nuclear target test run wiki: https://clasweb.jlab.org/wiki/index.php/Nuclear_target_test

SVT Modules on Scattering Chamber



Dosimetry

Our regular dosimeters

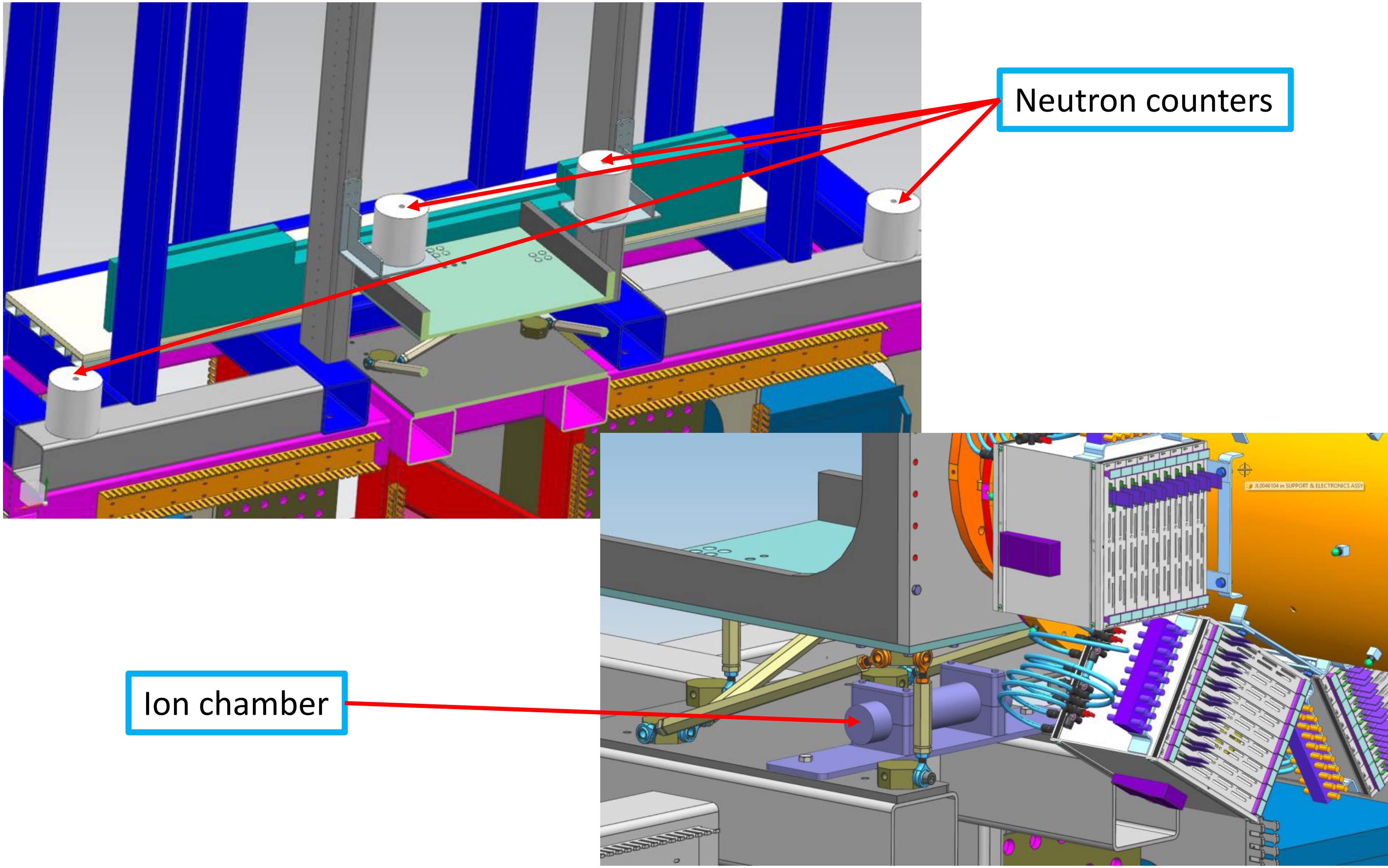
- Photons (X and gamma rays) with energies between 5 keV to 20MeV with a detection range of 5 mrem to 1000 rem.
- Beta particles with energies greater than 150 keV(expressed as average energy) with a detection range of 20 mrem to 1000 rem.
- Fast neutrons with CR-39: 40 keV to 40 MeV with a detection range of 20 mrem to25rem.
- Thermalized neutrons with CR-39: less than .5 KeV with a minimal detection range of 10 mrem to a maximal detection range of 5 rem.
- Cost $40/piece. Reading off-site. Turnaround time 10 days.

Real time dose monitoring

- BF_3 proportional counter with polyethylene moderator
- B^{10}+n->Li^7+He^4 ,E>0.84 MeV
- Power supply and front-end is provided by RadCon
- DAQ: Connect to discriminator/scaler in EPICS
- Mount two detectors on the target tube upstream of the solenoid
- Another two on the corners of the CVT insertion cart
- Install before RGB
- After RGB install gamma monitor.

Status: Design of mounts is underway and coordinated with magnet group. Cables ordered. We will use JLab discriminators and read to EPICS.

Radiation monitors on CVT Cart



Neutron activation analysis

FAST NEUTRON REGION

Neutron Energy	Element Of Interest	Nuclear Reaction	Half-Life Of Product Nucleus	R/X Available Forms	Typical Purity (Percent)	Notes	Cross-Section (millibarns)
0.1 MeV	Nb	$Nb^{93}(n,n')Nb^{93m}$	13.6 y	Nb	99.837	4	75.2
0.6 MeV	Np	$Np^{237}(n,f)Ba^{140}$	12.8 d	Np	99.9	1	1312
0.8 MeV	Rh	$Rh^{103}(n,n')Rh^{103m}$	57 m	Rh	99.685	4	733
1.2 MeV	In	$In^{115}(n,n')In^{115m}$	4.5 h	In	99.99	4	170
1.4 MeV	Th	$Th^{232}(n,f)Ba^{140}$	12.8 d	Th	99.959		269
1.5 MeV	U-238	$U^{238}(n,f)Ba^{140}$	12.8 d	U	99.942	1,5	296
2.2 MeV	Ti	$Ti^{47}(n,p)Sc^{47}$	3.43 d	Ti	99.876		21.4
2.8 MeV	Zn	$Zn^{64}(n,p)Cu^{64}$	12.8 h	Zn	99.99	4	30
2.8 MeV	Ni	$Ni^{58}(n,p)Co^{58}$	72 d	Ni	99.981	2,4	109
2.9 MeV	S	$S^{32}(n,p)P^{32}$	14.3 d	$S,(NH_4)_2SO$	99.977		64
3.1 MeV	Fe	$Fe^{54}(n,p)Mn^{54}$	310 d	Fe	99.643	4	78
3.9 MeV	Ti	$Ti^{46}(n,p)Sc^{46}$	85 d	Ti	99.876		10
4.4 MeV	Al	$Al^{27}(n,p)Mg^{27}$	9.45 m	Al	99.999		4.12
6.0 MeV	Cl	$Cl^{35}(n,\alpha)P^{32}$	14.3 d	NaCl	99.99	4	3
6.0 MeV	S	$S^{34}(n,\alpha)Si^{31}$	2.62 h	$S,(NH_4)_2SO$	99.977		3
6.0 MeV	Fe	$Fe^{56}(n,p)Mn^{56}$	2.57 h	Fe	99.643	4	1.05
6.8 MeV	Cu	$Cu^{63}(n,\alpha)Co^{60}$	5.27 y	Cu	99.998	4	0.35

FAST NEUTRON REGION CONTINUED

Neutron Energy	Element Of Interest	Nuclear Reaction	Half-Life Of Product Nucleus	R/X Available Forms	Typical Purity (Percent)	Notes	Cross-Section (millibarn
6.8 MeV	Mg	$Mg^{24}(n,p)Na^{24}$	15.06 h	Mg	99.781		1.52
6.8 MeV	Co	$Co^{59}(n,\alpha)Mn^{56}$	2.57 h	Co,Co-Al	99.995		0.143
7.2 MeV	Al	$Al^{27}(n,\alpha)Na^{24}$	15.06 h	Al	99.999		0.693
7.6 MeV	Ti	$Ti^{48}(n,p)Sc^{48}$	44 h	Ti	99.876		0.303
11.0 MeV	Nb	$Nb^{93}(n,2n)Nb^{92m}$	10.15 d	Nb	99.837	4	0.43
11.5 MeV	V	$V^{51}(n,\alpha)Sc^{48}$	44 h	V	99.975	4	0.08
11.6 MeV	Mn	$Mn^{55}(n,2n)Mn^{54}$	310 d	Mn-Al,Mn-Cu	99.722	3,4	0.244
12.4 MeV	Cu	$Cu^{63}(n,2n)Cu^{62}$	10.1 m	Cu	99.998	4	0.0915
13.0 MeV	Zr	$Zr^{90}(n,2n)Zr^{89}$	79.3 h	Zr	99.739		0.087
13.5 MeV	Ni	$Ni^{58}(n,2n)Ni^{57}$	36 h	Ni	99.981	2,4	0.0056

- Neutron induced reactions. Count decays of product nucleus.
- RadCon used this technique in the past and they have equipment for counting
- Indium foil is a reasonable choice

Standard foils are 0.5-inch diameter

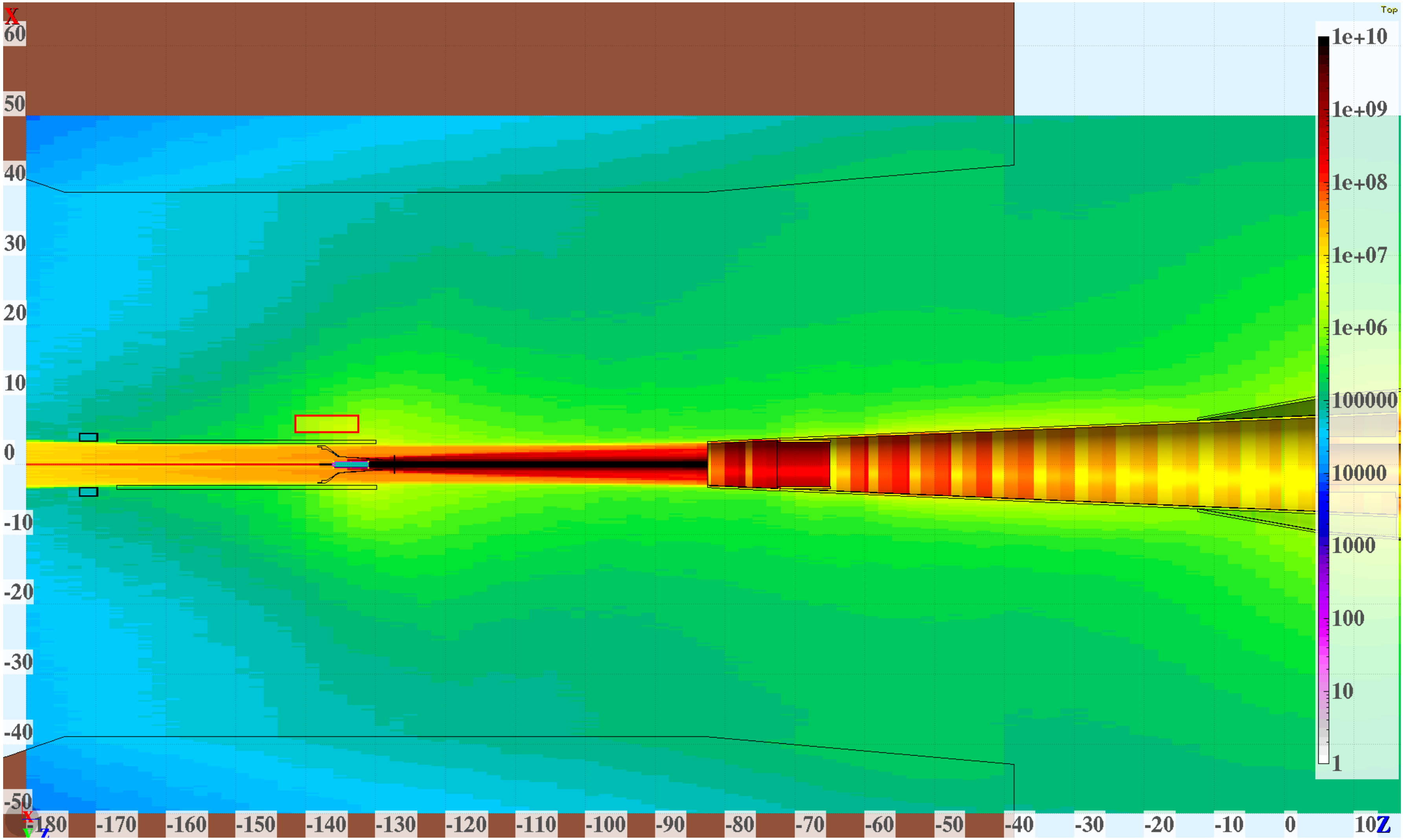
Indium

Neutron energy	Reaction	Half-life of product	Cross section
Thermal 0.025 eV	$In^{115}(n,\gamma)In^{116m}$	54 min	170 barn
Intermediate 1.457 eV	$In^{115}(n,\gamma)In^{116m}$	54 min	3243 barn
"fast" 1.2 MeV	$In^{115}(n,n')In^{115m}$	4.5 hour	170 mbarn

- Use Cd covers to filter out thermal neutrons. Cd absorbs neutrons below 0.4 eV
- Two foils: one bare, the other with Cd covers.
- Irradiation time ~ 4-5hours. For "fast" neutrons will get ~60% of maximum activity. For "slow" neutrons close to maximum activity.

Simulated neutron fluency

5 cm LD2 1 nA 1 hour



Configuration

- Beam energy 10+ GeV (and 4 GeV?)
- Targets: LD2, LHe, Pb (0.125 mm), Sn (0.25 mm)
- Torus polarity: electrons out bending
- Solenoid full field
- Trigger: Inclusive electron trigger
- Standard CLAS configuration
- Lower thresholds on CND (?)
- CVT is removed and replaced by two Si sensors
- Dosimetry
- For each target we allocated up to 12 hours of beam including tuning

Set of measurements for each target

- luminosity scan
  - record rates of all detectors
  - record SVT currents and occupancy
  - DC occupancy
- Take data. Beam current TBD after luminosity scan. Use CND to detect inclusive eA->e'n
- Install dosimeters and activation foils
- Irradiate dosimeters and foils for 4-5 hours. Record beam current and exposure time.
- Take out dosimeters and foils.
- Pass foils to RadCon for counting

Time estimate

- For each target we allocated up to 16 hours
- Transition LD2->LHe 8 hours
- Transition LHe ->Pb 2 days
- Transition Pb -> Sn 1 day

Status and preparations

- ERR - December 3rd
- Target is ready
- Optimize Installation/measurement schedule
- Design insertion/removal fixture for dosimeters and foils Write TOSP for this procedure
- Fabricate SVT mount and dosimeter insertion system
- Prepare RSAD an other paperwork for the run