Comparative Assessment of Spallation Target Materials

Neutron Source NSC KIPT: A Geant4 Simulation Study

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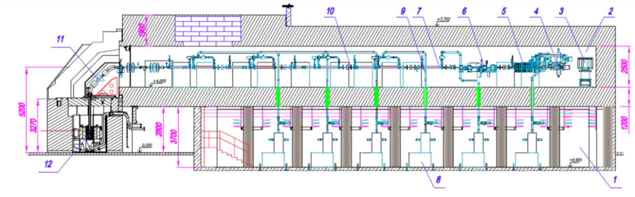
Talk roadmap (5 minutes)

1. NSC KIPT project context and why this study matters.
2. Physics principles: $e^- \to \gamma \to (\gamma, n) \to n$.
3. Geant4 model and engineering assumptions.
4. Comparative results for W-Ta and U-Mo targets.
5. Practical recommendation and next steps.

Project context and status

- Goal: maximize neutron yield while controlling heat load and material damage in a compact electron-driven source.
- Legacy: NSC KIPT neutron source was designed as a multipurpose facility for research and applications.
- Current focus: simulation-based optimization under constrained operation and maintenance conditions.
- This presentation reports a **physics-consistent comparison** of candidate target materials.



Source: project blueprint image from repository.

Physics principles behind neutron production

- Primary process chain in the model:

$$e^- \rightarrow \gamma \rightarrow (\gamma, n) \rightarrow n$$

- High-energy electrons generate bremsstrahlung photons in target plates.
- Photonuclear interactions produce neutrons with broad angular and energy distributions.
- Key trade-off: higher neutron yield vs. higher local energy deposition, NIEL proxy, and gas production (H/He).

Model summary source: `Data/physics_model_principles.md`.

Implemented Geant4 model (what is actually simulated)

- Reference physics list: `QGSP_BIC_HPT`, with configurable production cut.
- Event-level primary generator includes energy spread, spatial profile, angular divergence, halo, and tilt defects.
- Scoring in target plates: `edep`, neutron exits, surface crossings, NIEL proxy, and H/He gas proxies.
- Normalization basis: all KPIs are first reported **per primary electron**.

Source: `Data/physics_model_principles.md`.

Target options and comparison KPIs

Compared targets

- W-Ta
- U-Mo

Main results requested

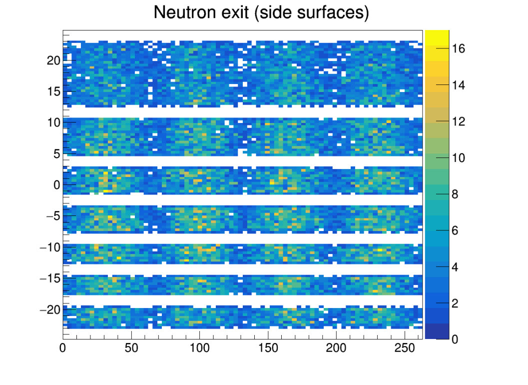
- `photons_above5MeV_per_electron`
- `neutrons_model_exit_per_electron`

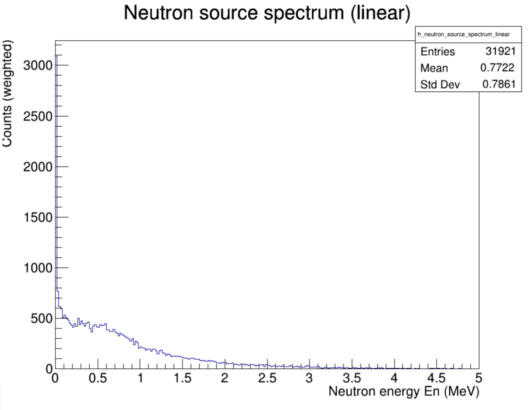
Source: `Data/Important_data`.

Important plots for interpretation

- neutron side-surface map
- plate neutron heatmap
- photon spectra (log and 4.5–30 MeV)
- neutron source spectrum (linear)
- NIEL and He-production by plate

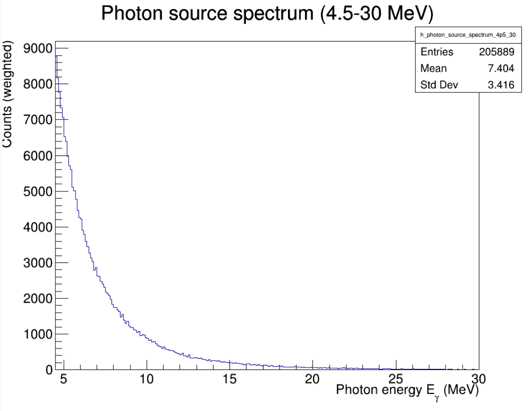
Neutron transport visualization (W-Ta)

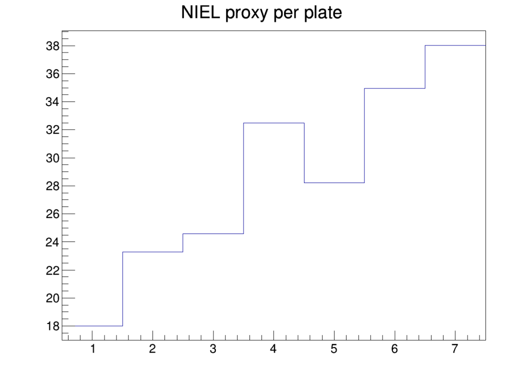




Left: side-surface neutron exit map. Right: source neutron spectrum (linear scale).

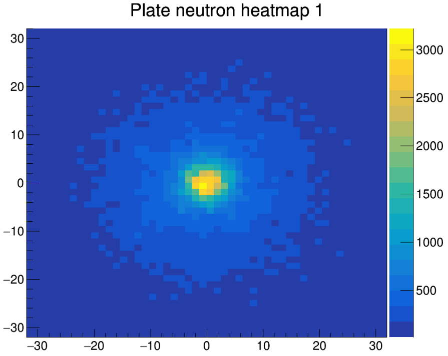
Photon field and plate-wise effects (W-Ta)

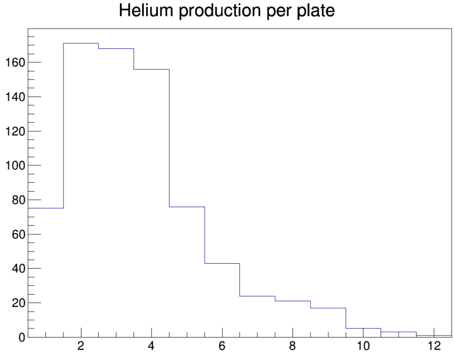




Left: photon spectrum in 4.5–30 MeV range. Right: NIEL proxy per plate.

U-Mo example: heatmap and gas production





Left: neutron heatmap at plate level. Right: He-gas proxy by plate.

Preliminary conclusion and recommendation

- The comparison should be finalized by a single summary table with all KPIs normalized per primary electron.
- Material selection must balance: neutron productivity, thermal load distribution, and long-term radiation damage risk.
- Next immediate step: add numeric values from `particle_yields_per_electron.json` for both targets directly to this deck.

Actionable TODO (next edit):

- insert final KPI table (W-Ta vs U-Mo),
- add uncertainty/comment on model limitations,
- freeze final references slide.

References

- Geant4 collaboration: *Geant4—a simulation toolkit*, NIM A 506 (2003) 250–303.
- Geant4 physics-list documentation (QGSP_BIC_HPT).
- Internal project model notes: `Data/physics_model_principles.md`.
- Internal run outputs: `Data/20260211_172835_W-Ta/*`, `Data/20260212_072836_U-Mo/*`.