

## Evaluation of Your Current Proposal:

### Title: Fusion Breeder Blanket Simulations with OpenMC: Optimization of Geometry and Composition

#### Pros:

- ✓ **Strong Relevance** – Fusion energy is a growing field, and breeder blankets are a critical research area.
- ✓ **Computational Focus** – Uses OpenMC, aligning well with your coding and simulation skills.
- ✓ **Employability** – Strong in both nuclear fusion (high-demand) and computational physics.
- ✓ **Extensible** – Can be expanded into further research if you continue into a PhD.
- ✓ **Feasibility** – OpenMC is well-supported, and you likely have prior experience using it.

#### Potential Issues & Suggestions:

⚠ **Novelty** – There's been a lot of work in this area. How will you make it unique? Consider:

- Investigating novel materials for better breeding ratios.
- Hybrid simulations (OpenMC + a thermal-hydraulic code).
- Using machine learning to optimize geometry.

⚠ **Interdisciplinarity** – If you want to keep photonics/quantum open, this leans entirely nuclear. Could you link neutron transport to photonics somehow?

Overall, **this is a strong and feasible project that enhances employability, especially in nuclear fusion.**

Suitability Rating:

- 📌 **Interest Match: 9/10**
- 📌 **Employability: 9/10**
- 📌 **Feasibility: 9/10**
- 📌 **Novelty: 7/10 (Can be improved with unique angles)**

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## Alternative Project Proposals

Here are some alternatives, categorized based on your nuclear and photonics interests.


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### 1. Monte Carlo Simulation of Neutron Transport in Novel Fusion Materials

💡 **Description:**

- Use OpenMC or MCNP to model neutron interactions in novel structural materials for fusion (e.g., high-entropy alloys, lithium-lead compounds).
- Study radiation damage and neutron multiplication effects.
- Compare with experimental data (if available) or other simulation tools.

 **Interest Match: 8.5/10**

 **Employability: 9/10** (Good for nuclear research careers)

 **Feasibility: 9/10**


 **Novelty: 8/10**


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## 2. Hybrid Nuclear-Photonics Concept: Neutron-Induced Light Emission for Reactor Monitoring


 **Description:**

- Explore ways to use scintillation or Cherenkov radiation in fusion environments.
- Simulate how neutron interactions generate detectable photonic signals.
- Applications: Reactor diagnostics, neutron detection, or radiation shielding.

 **Interest Match: 9/10** (Combines nuclear and photonics)

 **Employability: 8/10** (More niche, but valuable for experimental nuclear physics or sensing research)

 **Feasibility: 7/10** (More challenging than pure nuclear simulation)

 **Novelty: 9/10** (Less explored field)

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## 3. Quantum-Inspired Optimization for Fusion Reactor Simulations

 **Description:**

- Use quantum-inspired algorithms (e.g., variational quantum eigensolvers, tensor networks) to optimize plasma confinement or neutron transport simulations.
- Apply to OpenMC simulations or magnetic confinement models.

 **Interest Match: 8/10**

 **Employability: 9/10** (Fusion + quantum computing is highly sought after)

 **Feasibility: 7/10** (Quantum computing tools are still developing)

 **Novelty: 9/10** (Emerging field)

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## 4. Photonic Crystals for High-Efficiency X-Ray Shielding in Fusion Reactors

### Description:

- Use computational methods (e.g., FDTD, COMSOL) to design photonic crystal structures that can filter or absorb high-energy X-rays in fusion reactors.
- Compare against traditional shielding materials.

 **Interest Match: 8.5/10**

 **Employability: 8.5/10**

 **Feasibility: 7.5/10** (Requires strong photonics simulation expertise)

 **Novelty: 9/10**

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### Final Thoughts

Your current proposal is strong and well-suited for employability in nuclear fusion research. However, if you want **more novelty or interdisciplinary work**, consider integrating photonics or quantum-inspired approaches.

Would you like help refining your breeder blanket project to make it more unique? Or do any of these alternative projects interest you?

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## Specific Proposals around Breeder Blankets

A list of project proposals, informed by my research area interests around nuclear fusion.

These were informed by my skills:

- Strong general python skills (lots of placement experience in building large projects, data analysis, some ML experience etc.)
- Simulation experience (including using openMC for monte-carlo in python)
- Nuclear Fusion (placement)

And my strong general interest in the nuclear fusion field. Lots of these concepts were already discussed with some of the scientists at the fusion plant I worked at (Tokamak Energy), but none of them are a continuation of my project there (which was in plasma - diagnostic optics).

## **1. Neutron Transport and Tritium Breeding Analysis in Advanced Blanket Geometries (e.g., Functionally Graded Materials / Novel Materials)**

### **Description:**

- Investigate non-uniform material distributions (e.g., functionally graded lithium-lead blankets).
  - Simulate neutron interactions in advanced materials (e.g., lithium ceramics, liquid lithium, high-entropy alloys).
  - Compare results to standard homogeneous blankets for TBR and neutron economy.
  - Use OpenMC to model neutron transport in these complex geometries.
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## **2. Coupled OpenMC + Thermal-Hydraulics Simulations for Breeder Blanket Performance Assessment**

### **Description:**

- Integrate neutron transport simulations (OpenMC) with thermal-hydraulics tools (e.g., OpenFOAM, ANSYS Fluent).
  - Study how coolant flow affects neutron absorption and tritium production.
  - Optimize cooling efficiency while maintaining a high tritium breeding ratio.
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## **3. Neutron Transport Analysis of implementing Neutron Reflector Materials to Reduce Fusion Ignition Point.**

### **Description:**

- Use OpenMC to model neutron transport for Materials / Breeder Blankets with deliberately high reflectivities materials ( potentially artificially set high reflectivities / scattering cross section ).
  - Compare results to standard homogeneous blankets for TBR and neutron economy.
  - By increasing reaction chamber neutron flux, investigate any non-negligible reduction in ignition factor.
    - This is a personal idea that I discussed on an internship, perhaps too novel an idea.
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## **4. Multi-Objective Optimization of Breeder Blanket Design Using Optimisation (Genetic) Algorithms**

### **Description:**

- Use genetic algorithms to optimize breeder blanket parameters such as material composition, coolant flow, and geometry.
- Define multiple objectives: tritium breeding ratio (TBR), neutron economy, and structural integrity.

- Implement optimisation within OpenMC coupled with Python-based optimization algorithms to converge to an optimal solution based on a defined cost function(e.g., DEAP or SciPy etc. ).
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## **5. Machine Learning for Surrogate Modeling of Breeder Blanket Neutron Transport**



### **Description:**

- Train a machine learning model (e.g., neural networks (keras / tensorflow / pytorch), Gaussian processes) to predict neutron transport in breeder blankets / points of highest thermal load / TBR for certain input parameters (dimensions / aspect ratio of reactor).
- Use OpenMC to generate training data, then develop a faster predictive model
  - Would be ideal if pre-existing fusion data was found to train model on, training data would be critical for the project.
- Applications: Real-time optimization and uncertainty quantification in reactor design.