
Artificial intelligence in radiation dosimetry

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Outline

- Artificial Intelligence and Machine Learning in Dosimetry
- Examples for Machine Learning with Dosimetry Calculations
- Other Use Cases and Opportunities for ML related to Radiation Dosimetry
- Take-Home Message

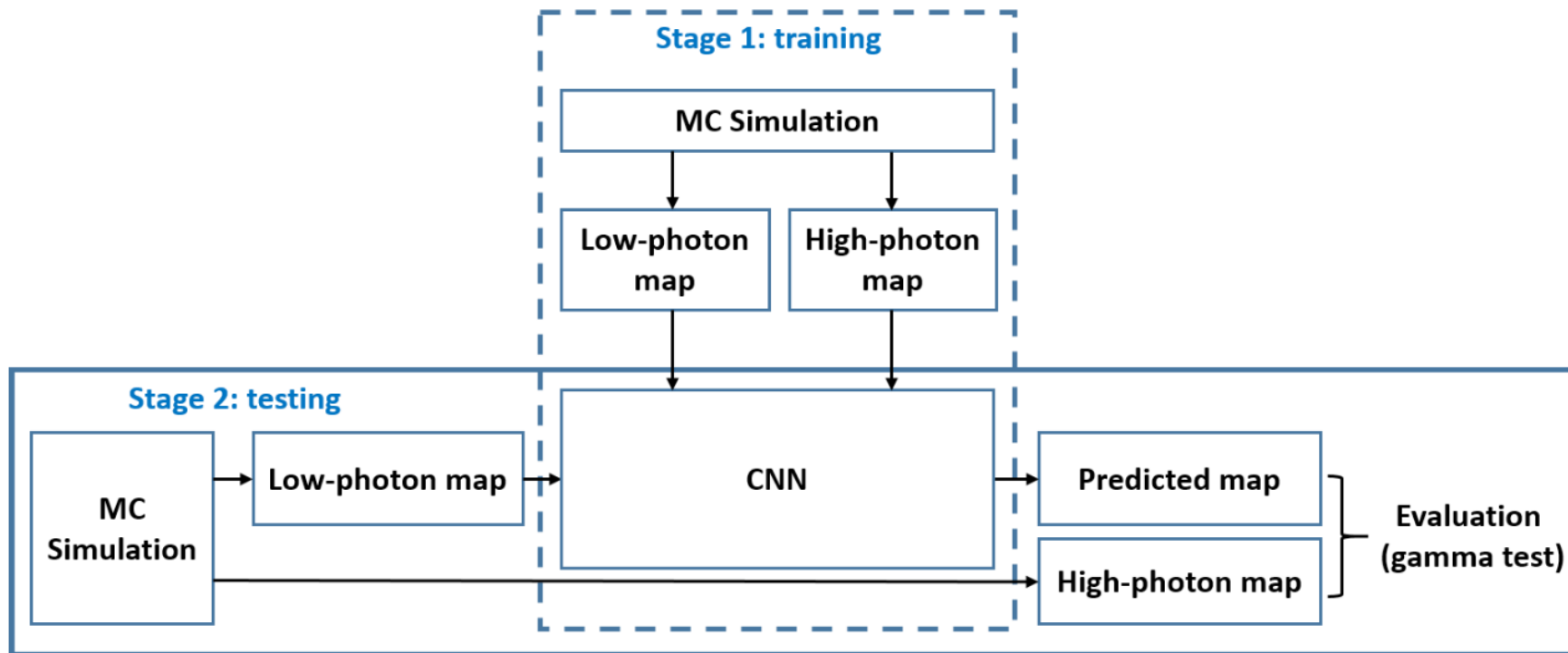
Where do we encounter AI in radiation dosimetry?

- Application of AI for auxiliary tasks such as documentation, training, ...
- Dosimeters or detectors containing AI-based software
- AI-based data analysis
 - Regression tasks (denoising, filtering, ...)
 - Spectra de-convolution
 - Predicting data that were not measured
 - ...
- AI-supported computational dosimetry
- AI-augmented computational dosimetry

(Some) AI applications in computational dosimetry

- Denoising of Monte Carlo simulations (Neph 2019; Peng 2019; Javaid 2019, 2021; ...)
- Dosimetry in molecular radiotherapy (Arabi&Zaidi 2020, ...)
- Online personal dosimetry (Abdelrahman et al. 2020; O'Connor 2022; Van Hoey 2022, ...)
- “Outsourcing” intensive computations (Wu 2021; He 2025)
- Learning the relation between beam settings and dose maps (Kontaxis 2020, ...)
- Mapping of dose distributions (Nguyen 2019; Mentzel 2022a,b 2023; Pastor-Serrano 2022)
- ...

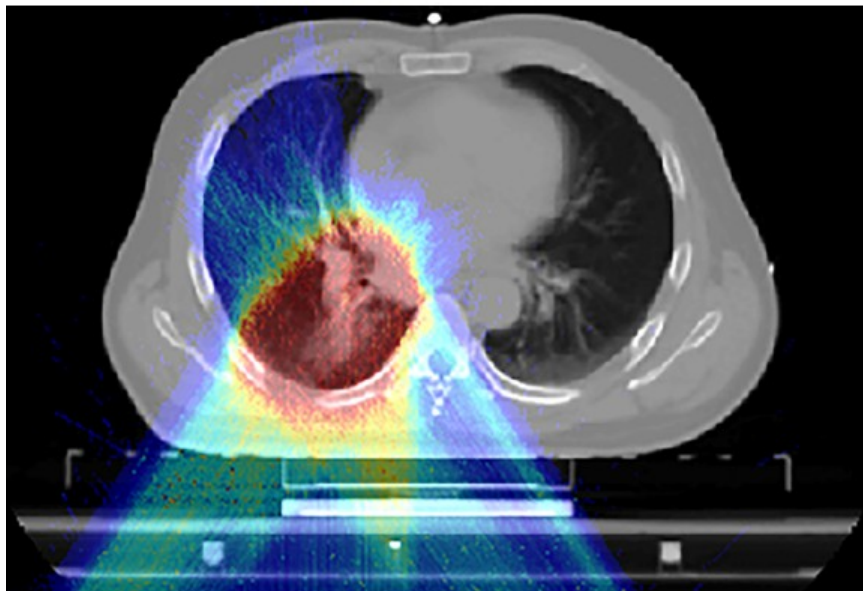
Denoising by learning relation between images



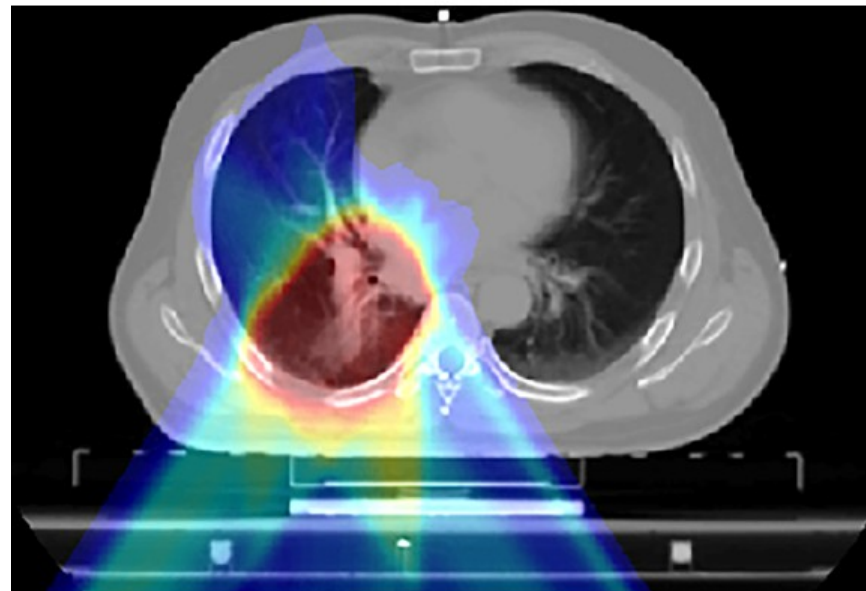
Neph et al. 2019

Denoising by learning relation between images

10^6 protons

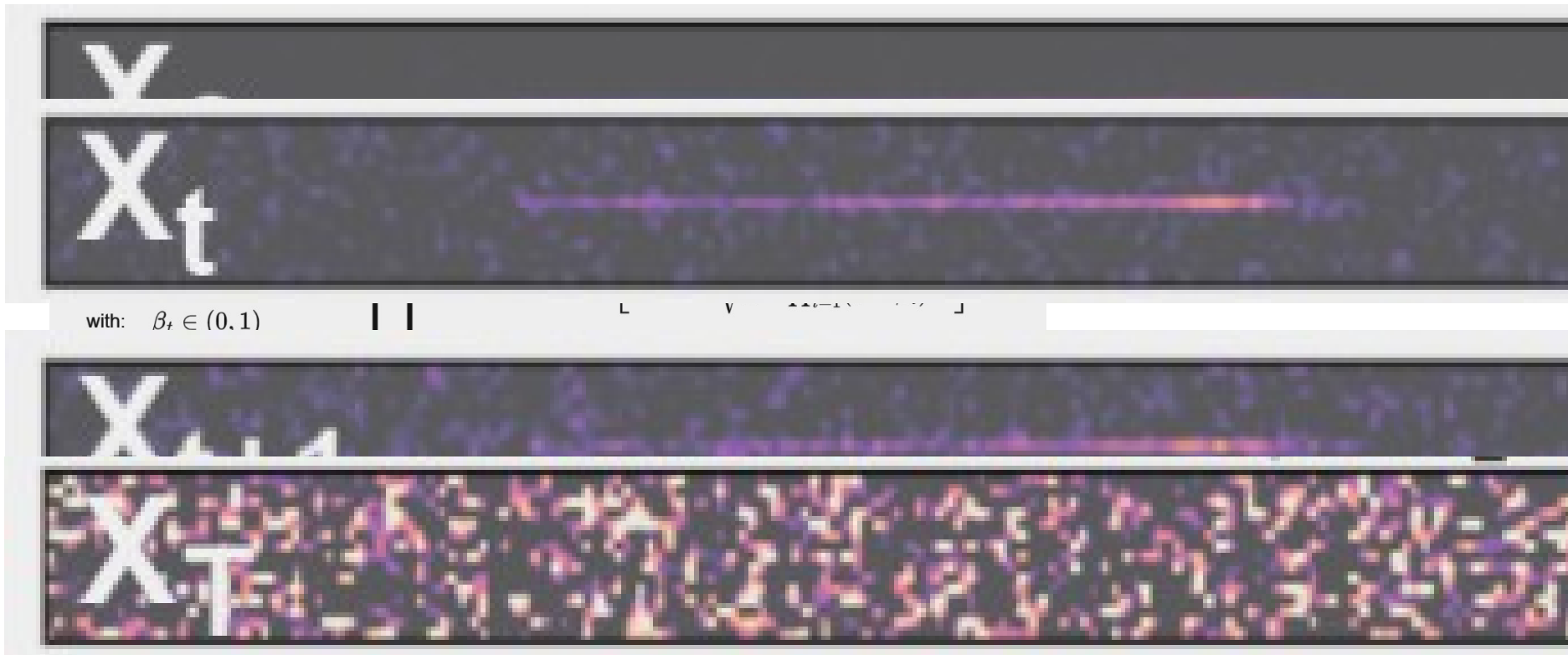


10^9 protons

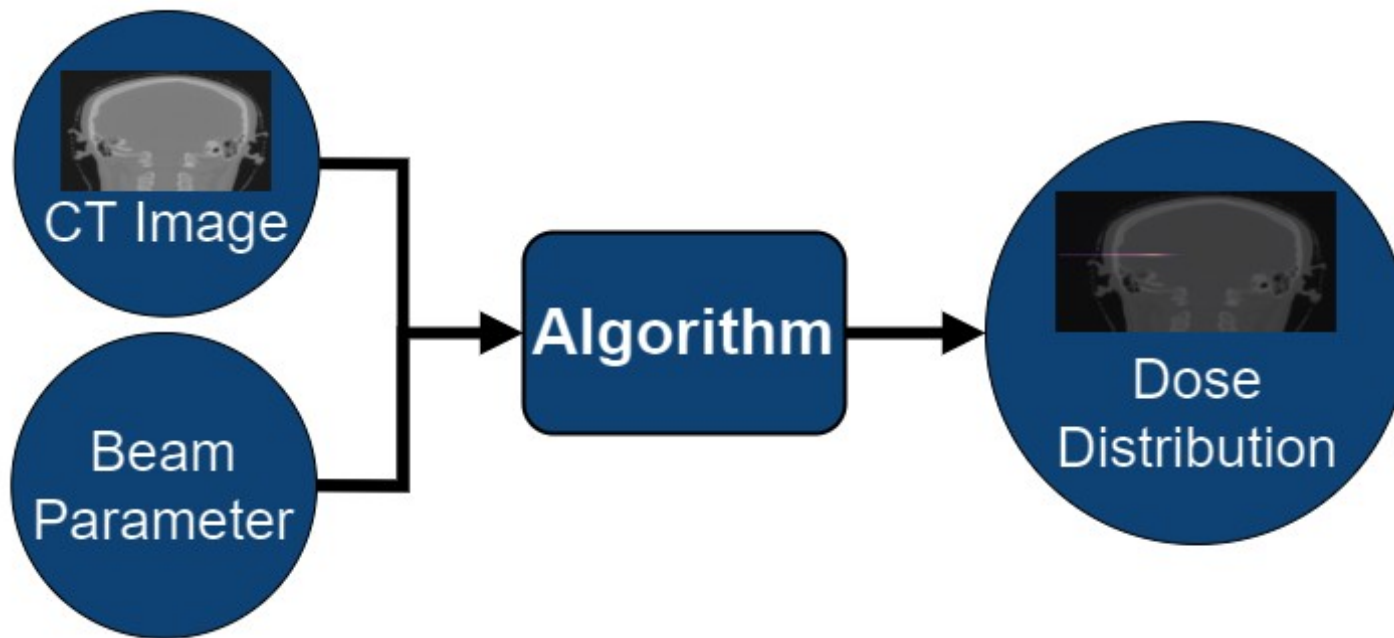


Javaid et al. 2021

Denoising by conditional diffusion models

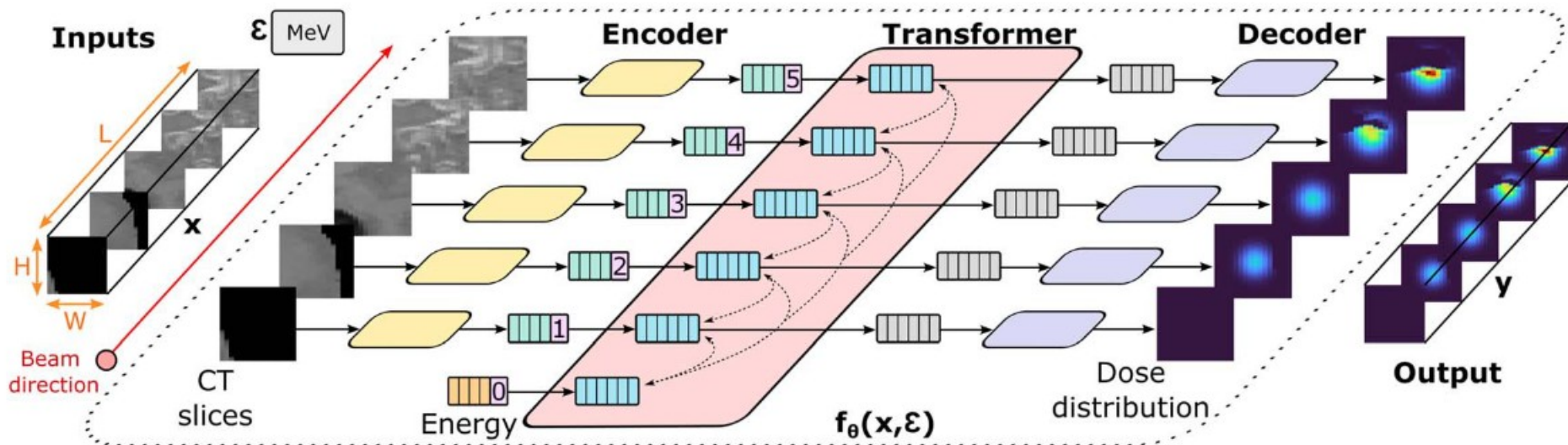


General setup (for conditional learning)



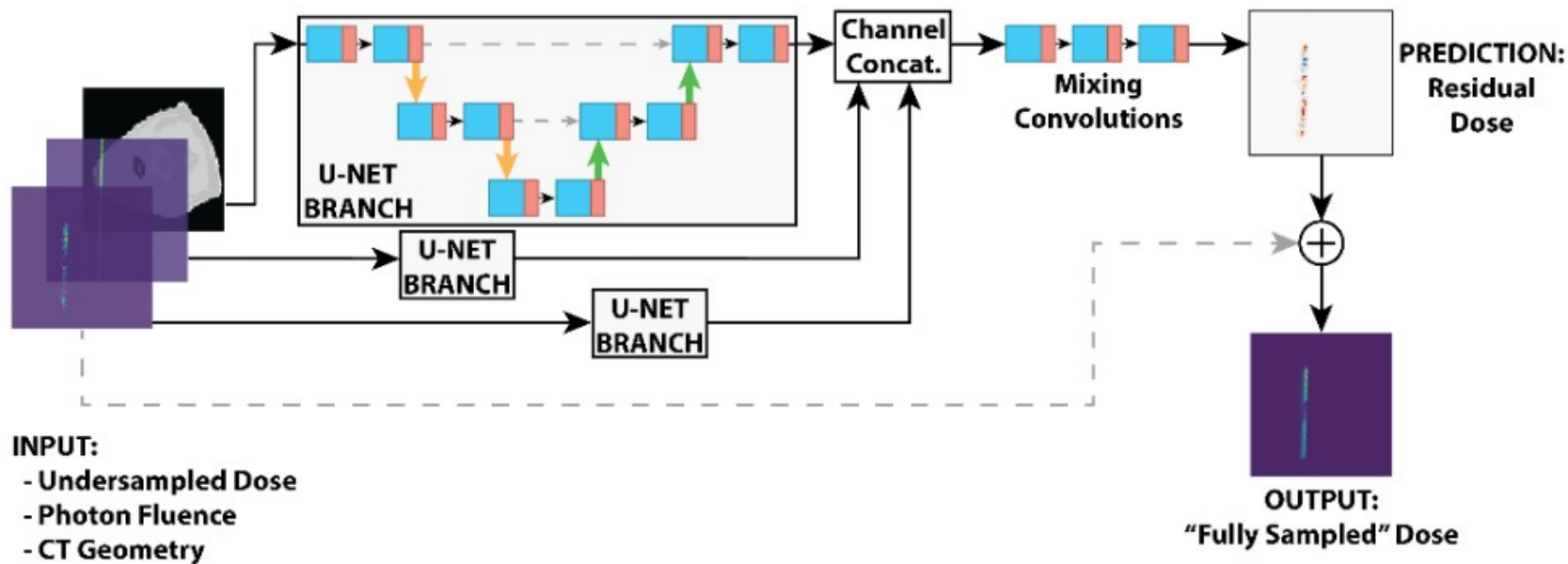
Credit: Miriam Schwarze

Dose transformer algorithm (DoTA)



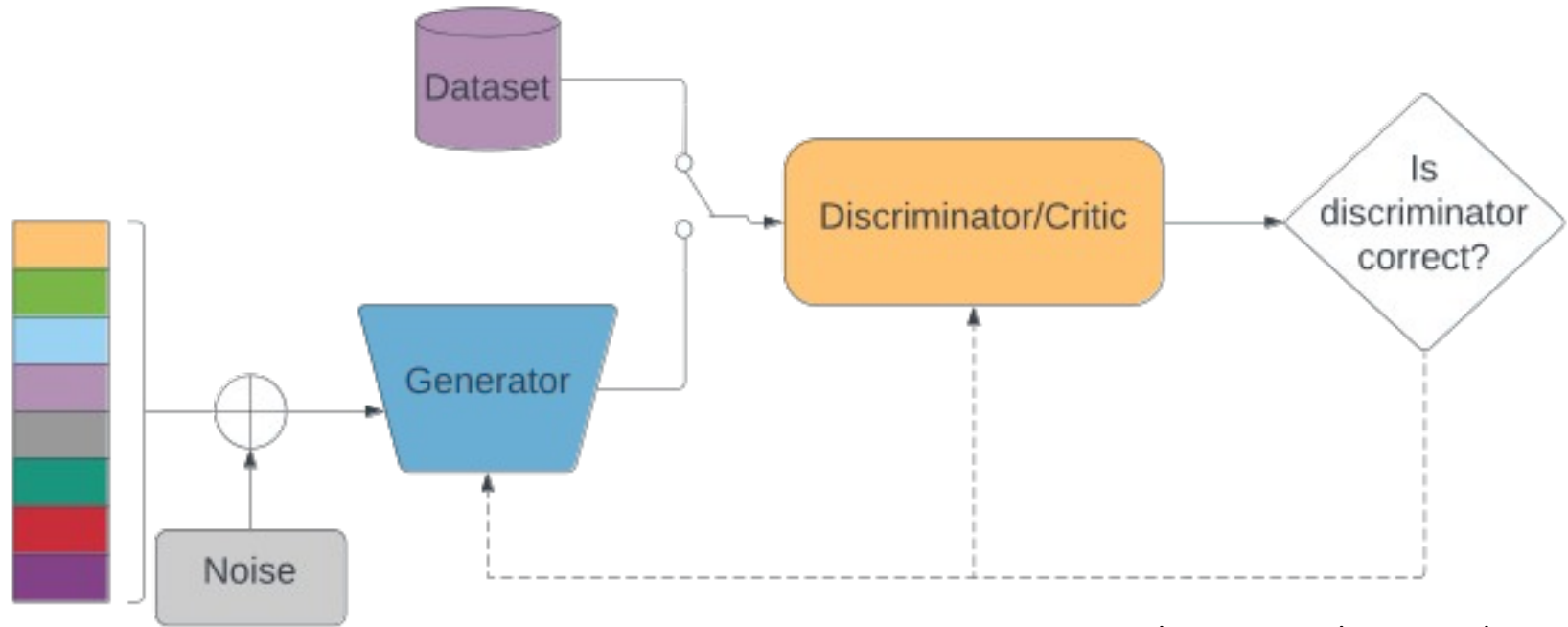
Pastor-Serrano & Perkó 2022

Reconstructing dose maps from undersampled data



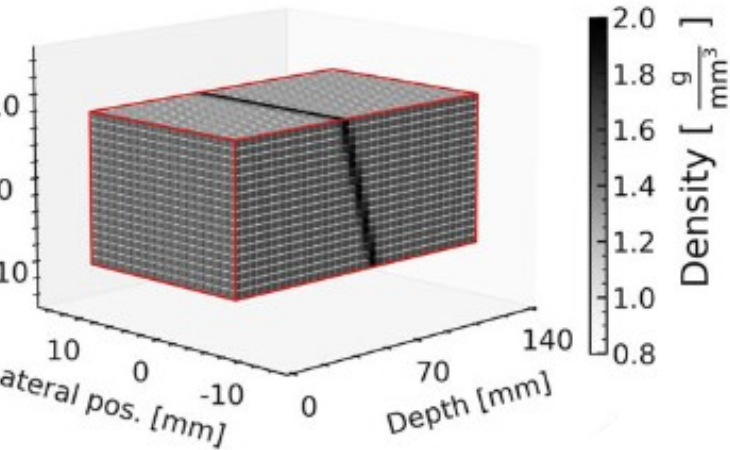
Neph et al. 2019

Generative Adversarial Network (GAN)



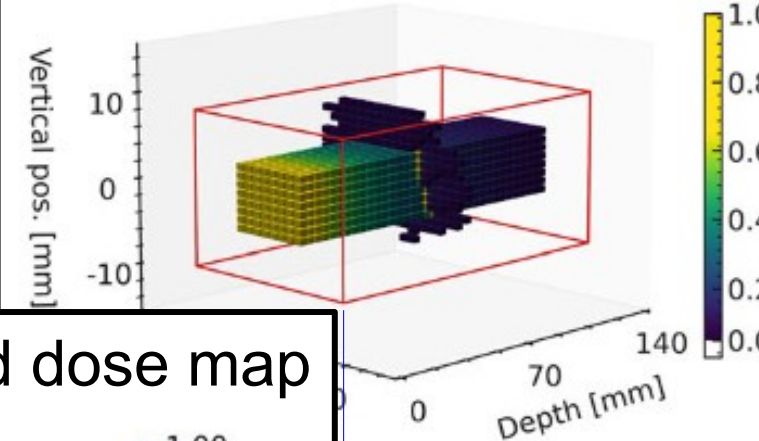
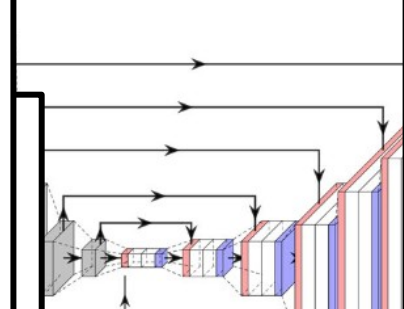
Credit: Rustam Zhumagambetov

at H-densities map
(ICOM images)

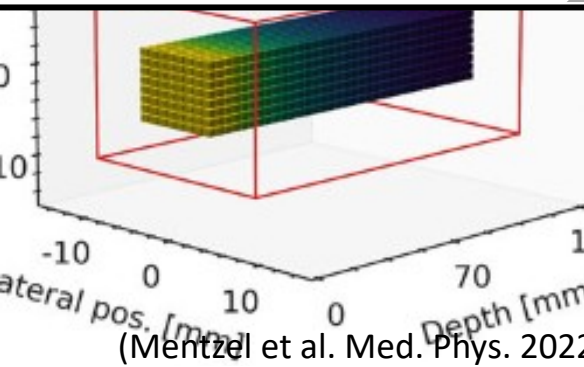


dose prediction

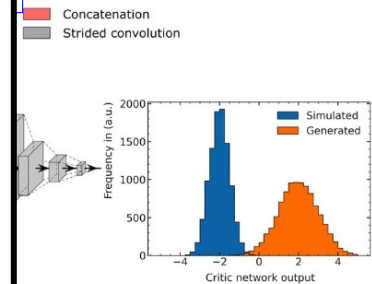
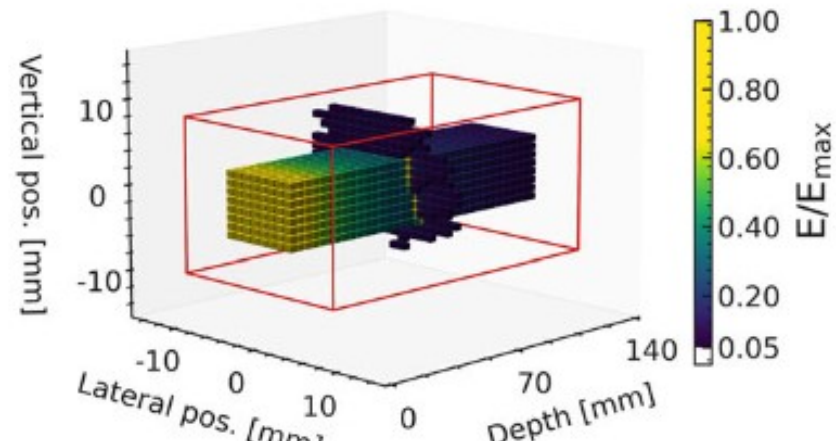
Output: dose map in patient



Output 3: simulated dose map



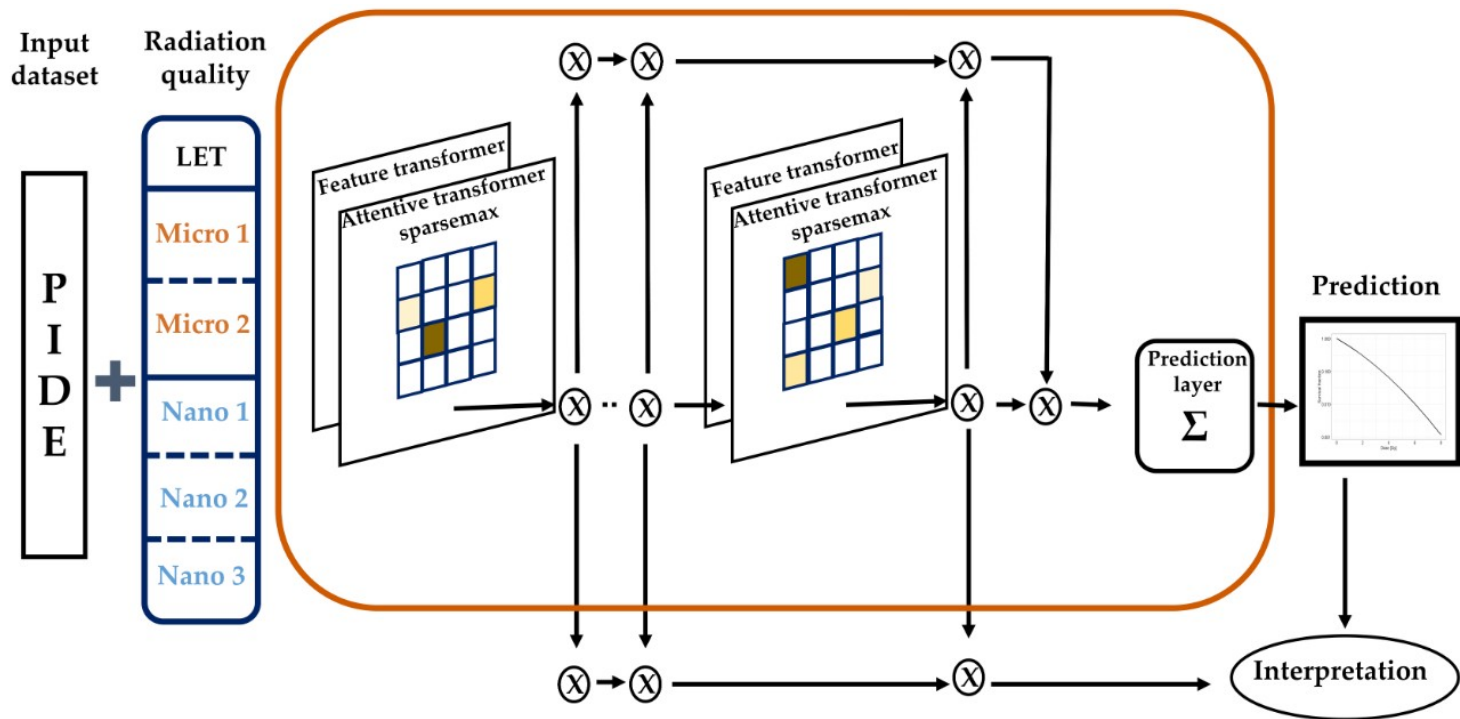
(Mentzel et al. Med. Phys. 2022)



ML-augmented computational dosimetry

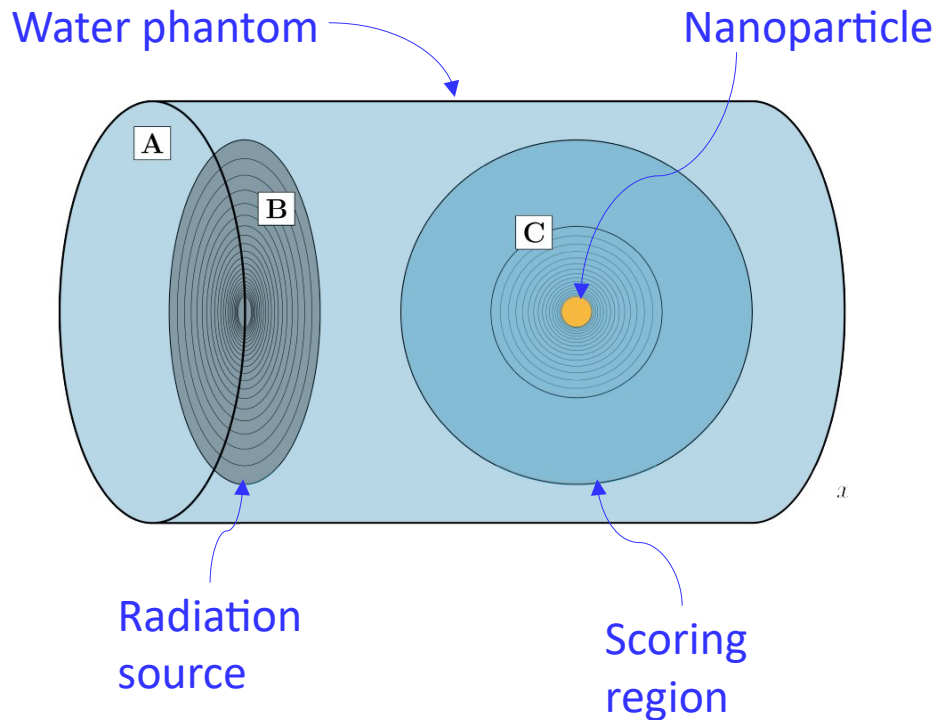
- AI-assisted coding / debugging
- AI generated input cards
- Model parameter search (Bordieri et al. 2026)
- AI-steered variance reduction (Thomas et al. 2025)

Example: Parameter screening for effect modelling



Bordieri et al. (2026)

ML-Augmented Computational Dosimetry



Determining the dose around the nanoparticle is challenging.

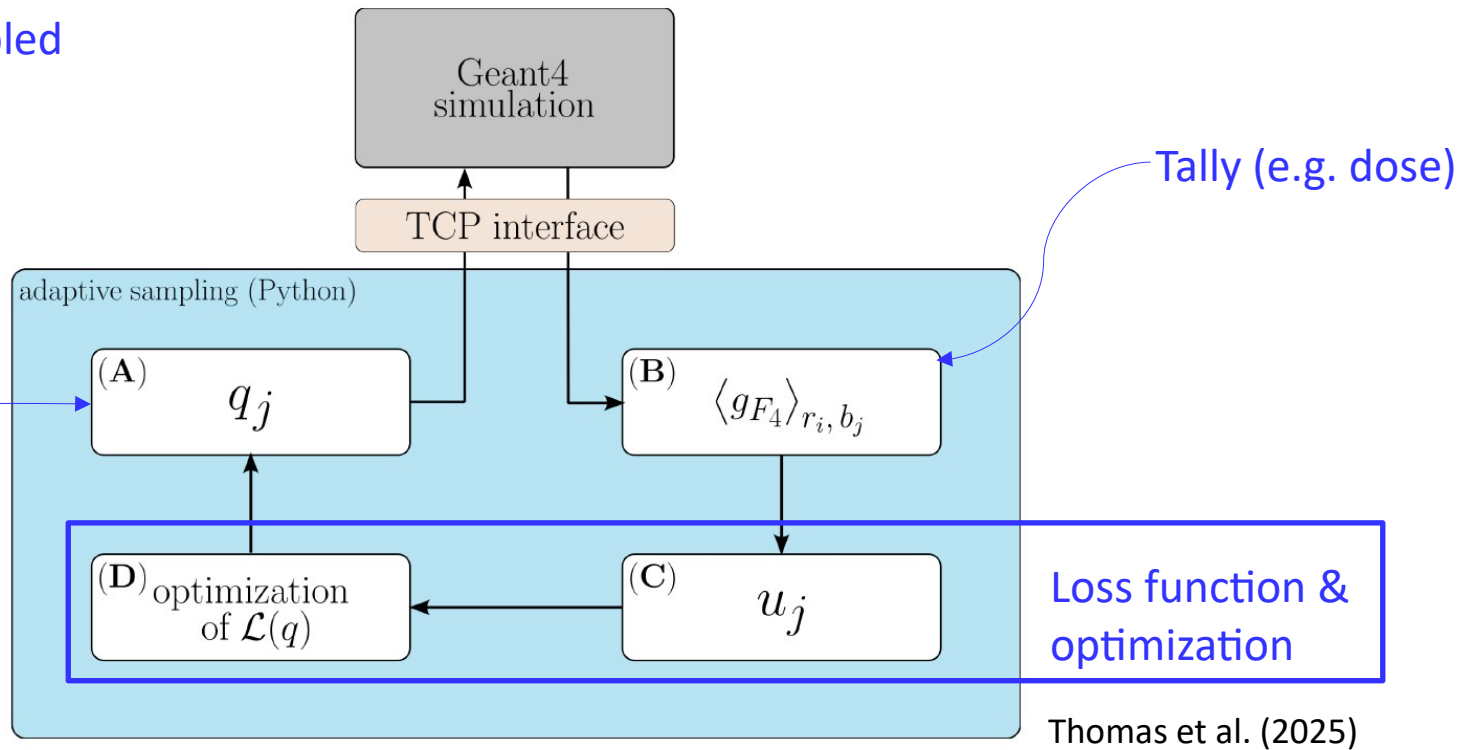
Workarounds:

- Multi-step approaches (e.g. Thomas et al. 2024, PMB)
- Variance reduction (VR) approaches

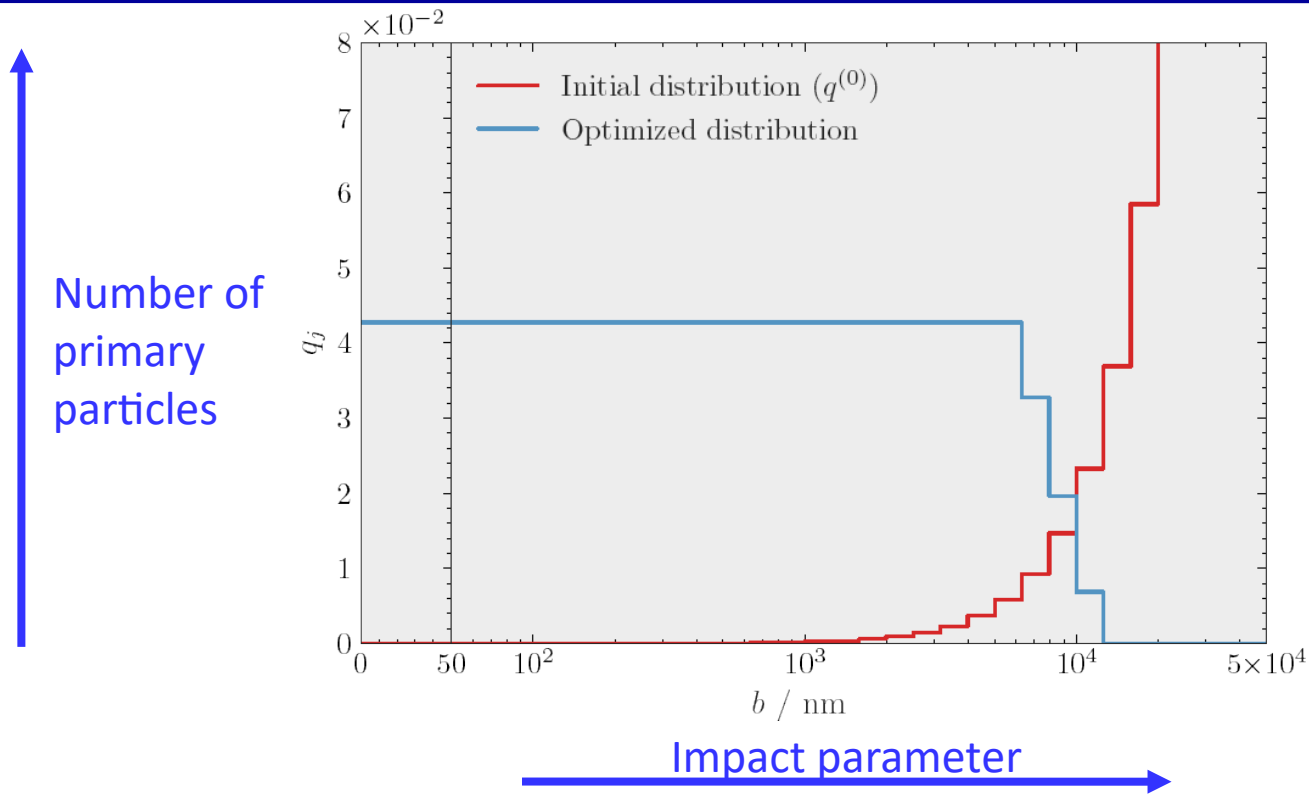
Can ML help optimizing this?

ML-steered importance sampling

Parameters of sampled
fluence distribution

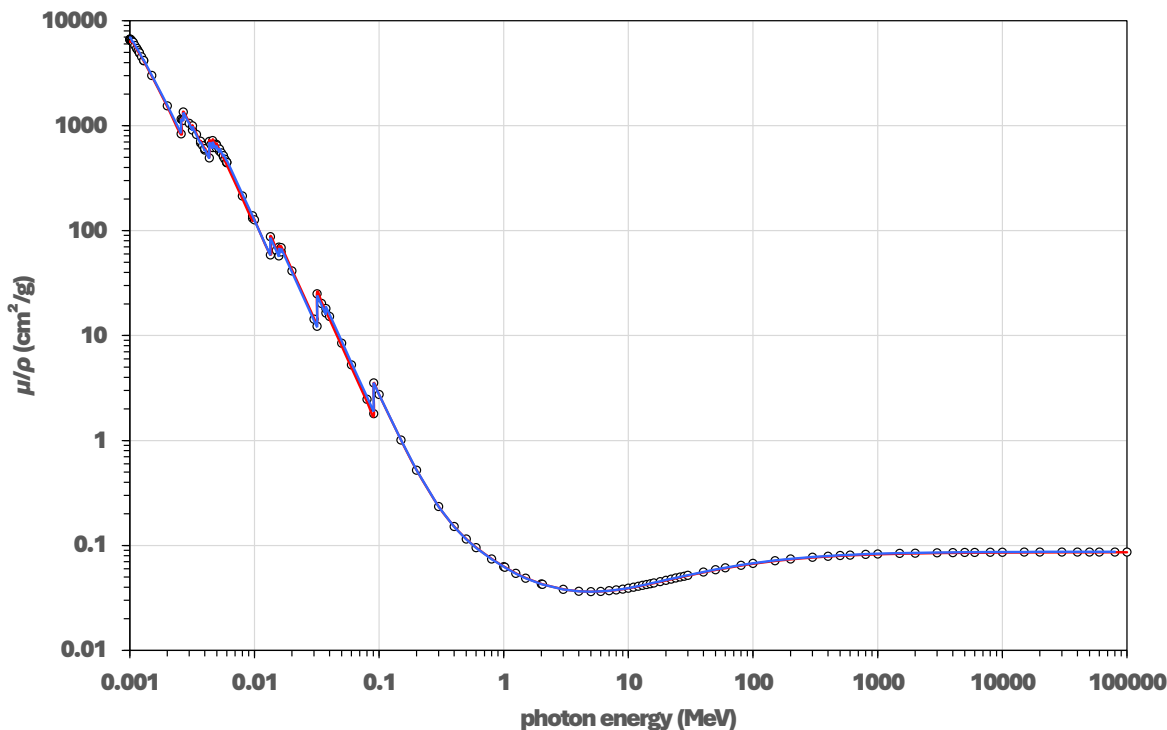


ML-steered importance sampling



Thomas et al. (2025)

Caveat: Don't trust literature



[10.1016/j.radphyschem.2025.113586](https://doi.org/10.1016/j.radphyschem.2025.113586)

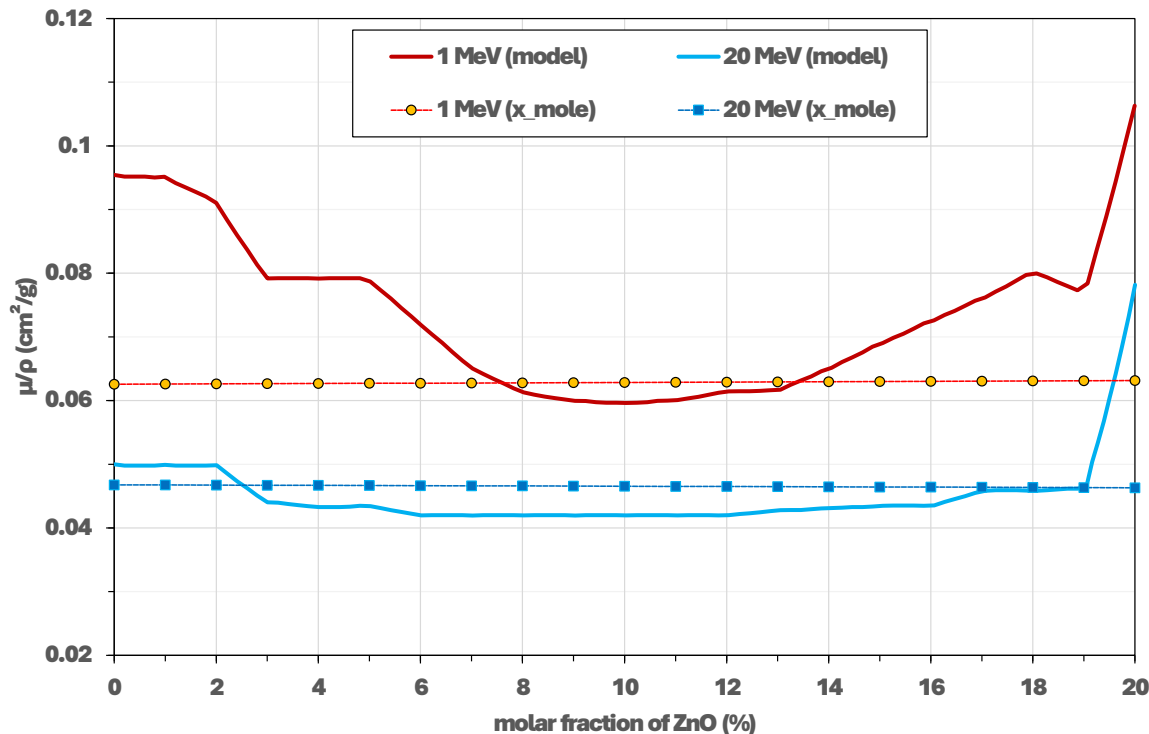
“predictive model for this complex, non-linear relationship,

...

advanced Automated Machine Learning to perform automated model selection, hyperparameter optimization, and ensembling.

results demonstrate that tree-based ensemble models exhibit superior predictive capabilities. “

Caveat: Don't trust literature



[10.1016/j.radphyschem.2025.113586](https://doi.org/10.1016/j.radphyschem.2025.113586)

~~This complex behavior is **physically plausible** and highlights the **model's sophistication**.~~

~~...
The ability of the model to correctly reproduce these nuanced ... trends provides strong evidence that it is not merely a curve-fitting tool but **has learned a meaningful representation of the underlying physics**~~

Take home messages

- There is no one-fits-all ML model
- Try to understand what ML recipes do before using them
- Try to make your ML approach as physics informed as possible
 - ideally by implementing the physics in your model
 - at least by using loss functions reflecting the physics
- Thoroughly check the data you use for training and testing (plot them and their statistical properties)
- Use meaningful quality measures such as χ^2 and gamma index; vanilla ML metrics, such as R^2 , MAE, MSE, RMSE are not physically meaningful

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Thanks for your attention!

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