# Photonuclear event generator comparisons for the Light Dark Matter eXperiment

Fysikdagarna

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# 1. Background

- LDMX aims to perform a zero background search for light dark matter
- The design of LDMX is based on detailed Geant4 studies
  - In particular, photonuclear events are modelled by the Bertini intranuclear cascade (`BERT` in `FTFP_BERT`)
- Geant4's hadronic models are well tested and validated
  - LDMX is sensitive to rates and topologies of rare final states
  - What do the competing models say?

## 1.1. Two questions to answer:

- Are the predicted rates of challenging final states from Bertini accurate?
- Is the LDMX veto strategy sensitive on the particular characteristics of Bertini?

# 2. Challenging event rates

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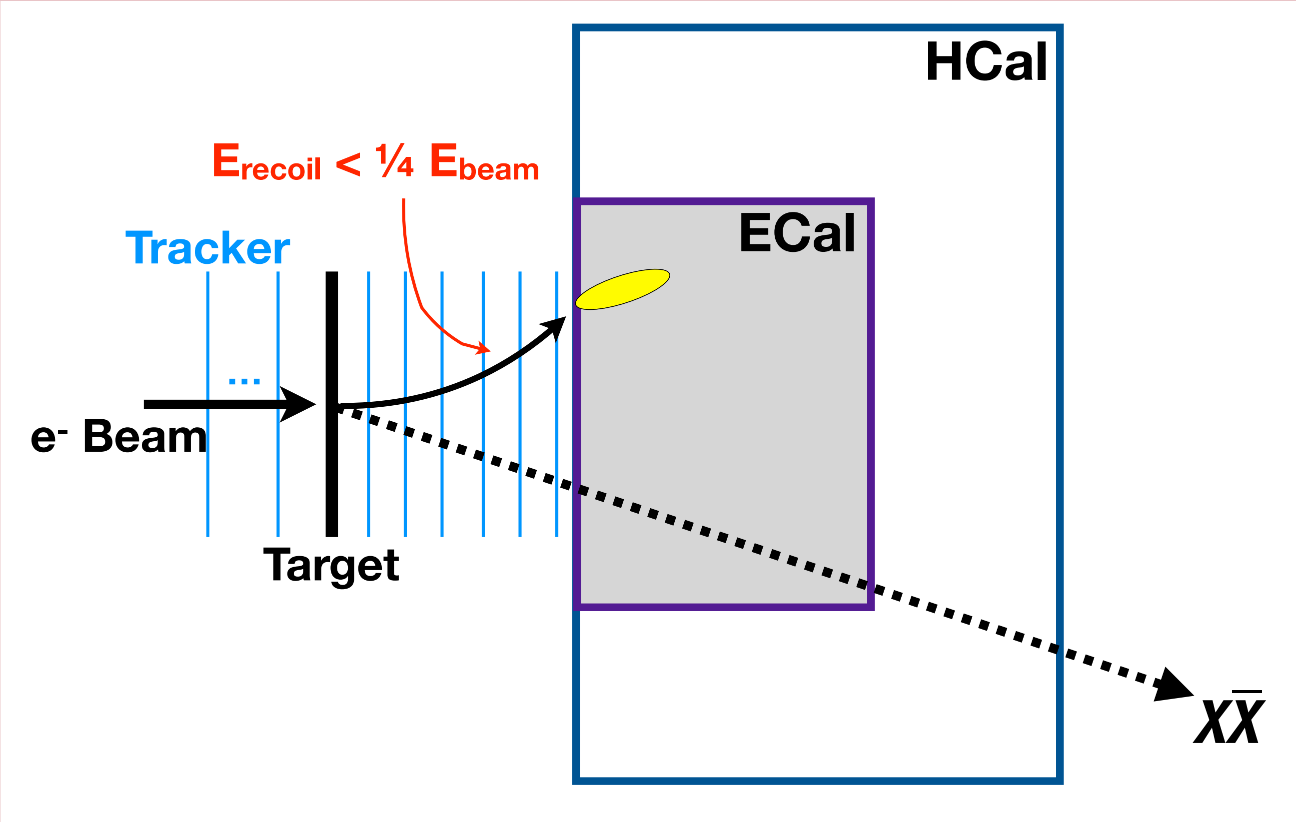
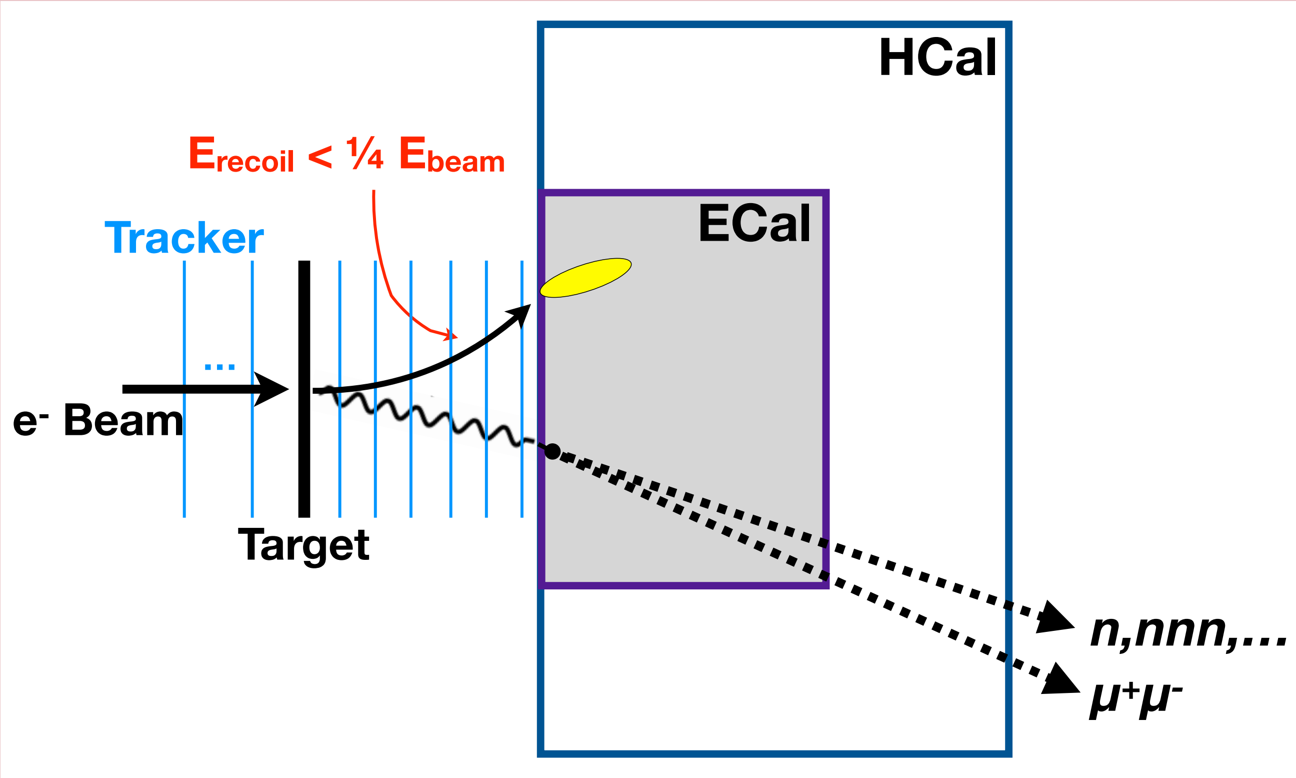
- Standalone simulations
- We have compared the products of 3 GeV $\gamma$ interactions with tungsten using three alternative photonuclear event generators
  - PHITS [1, 2]
  - MCNP [3, 4]
  - FLUKA [5, 6]

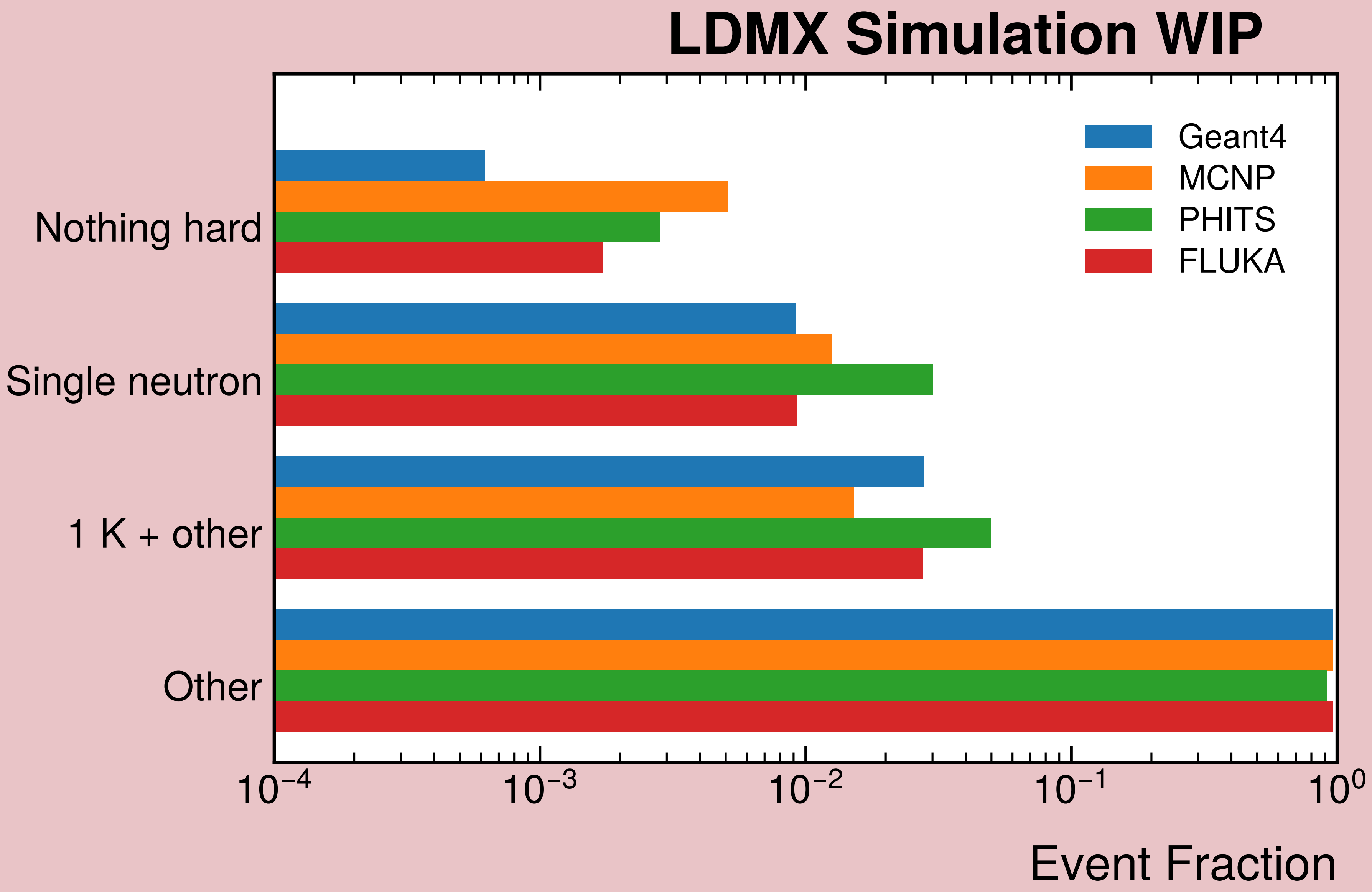
# 2.1. What constitutes a challenging event?



# 2.2. Results

- Generally agreement
- Largest deviation seen for two categories
  - “Nothing hard”
    - Very high low-energy nucleon multiplicity events
  - Single hard neutron
- ⇒ Important inputs for the design and physics requirements

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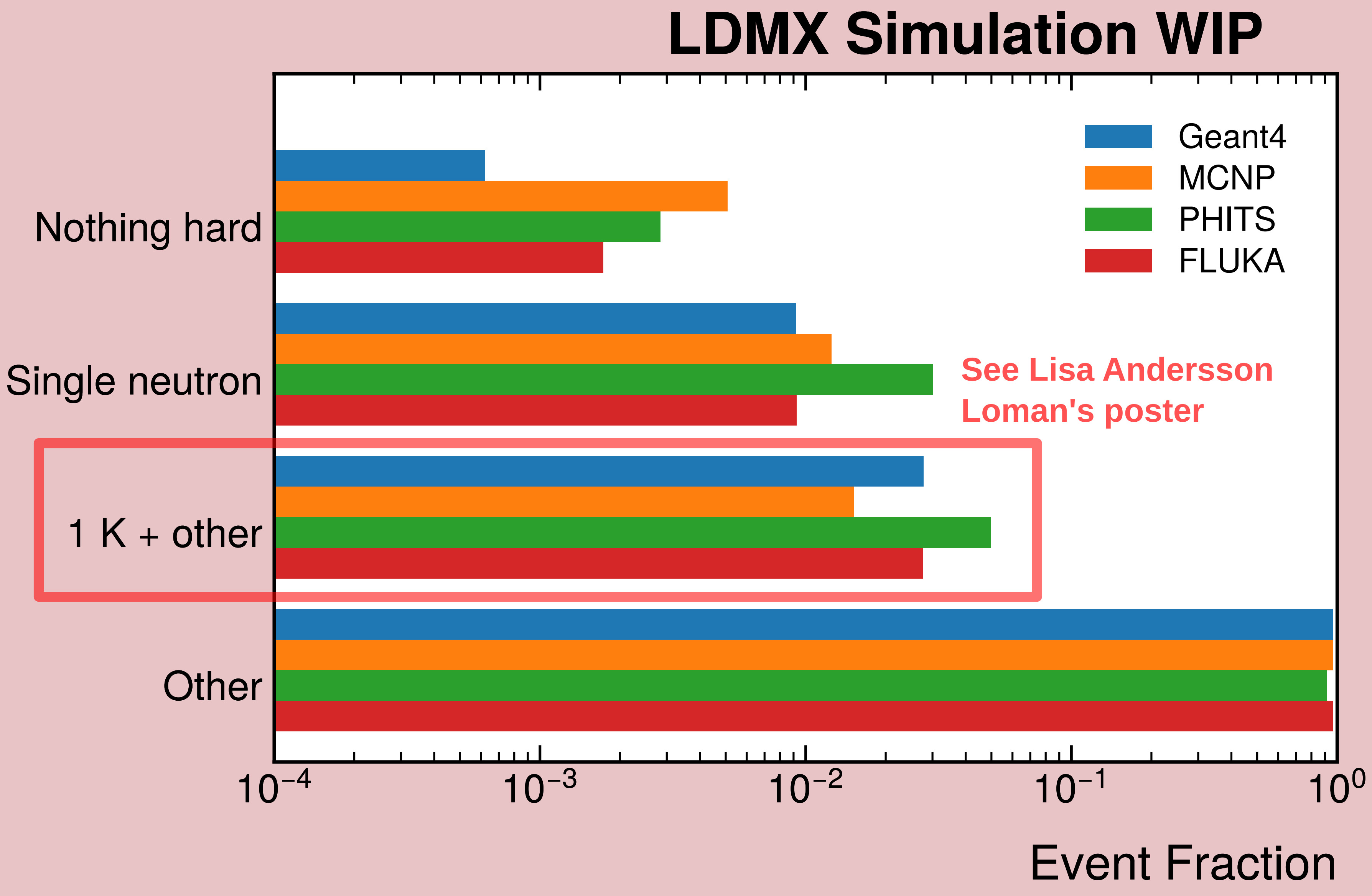

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  - With a different model for photonuclear interactions

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- Standalone simulations aren't enough
  - Requires running a complete Geant4 simulation and reconstruction chain
  - With a different model for photonuclear interactions
- FLUKA's hadronic code can be accessed in Geant4 through an interface developed by FLUKA.cern

## 3.1. Simulation performance

- Generating a full simulation dataset to study this subset of final states would be wasteful
- Event generation is fast but detector modelling and tracking is slow
- However, fixed target: Photonuclear interaction occurs in the middle of the simulation
  - Depends on the full simulation history
- Typical solution: Artificial enhancement of production cross-sections and/or changes to the modelling

# 3.2. Efficient generation of rare events

- Instead: On a photonuclear interaction
  - Run the event generator until you get the kind of final state that you are interested in
  - Avoids changing any physical properties
  - Provides *orders of magnitude* faster simulation, around 300 times faster for the cases shown today
  - Requires some care

# 3.3. Results from initial analysis

- We’ve used this technique to generate two datasets corresponding to ≈ 4e14 EOT for the two categories
- Without performing any optimization of the analysis chain and only looking at
  - Trigger performance
  - Ecal veto
  - Hcal veto
- *We are able to veto all of these events with both photonuclear models*

# 4. Outlook

- More detailed studies with an optimized analysis chain
  - Focus on impacts for the detector design
- Run the analysis for 8 GeV beam
- Applying the event generation technique for Kaon studies (see poster by Lisa Andersson Loman)
- Further MC scrutiny (see poster by Jaida Raffelsberger)

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# 5. Model references


- [1] T. Sato et al. 2018, J. Nucl. Sci. Technol. 55, 684-690
- [2] Y. Nara et al. 2000, Phys. Rev. C61 024901
- [3] C.J. Werner et al. 2018, LA-UR-18-20808
- [4] S.G. Mashnik et al. 2012, LA-UR-12-01364
- [5] C. Ahdida et al. 2022 Frontiers in Physics 9, 788253
- [6] G. Battistoni et al. 2015 Annals of Nuclear Energy 82, 10-18

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