# FKeras: A Sensitivity Analysis Tool for Edge Neural Networks

**Olivia Weng**, Andres Meza, Quinlan Bock, Benjamin Hawks, Javier Campos, Nhan Tran, Javier Duarte, Ryan Kastner

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Fermilab UC San Diego hls4ml

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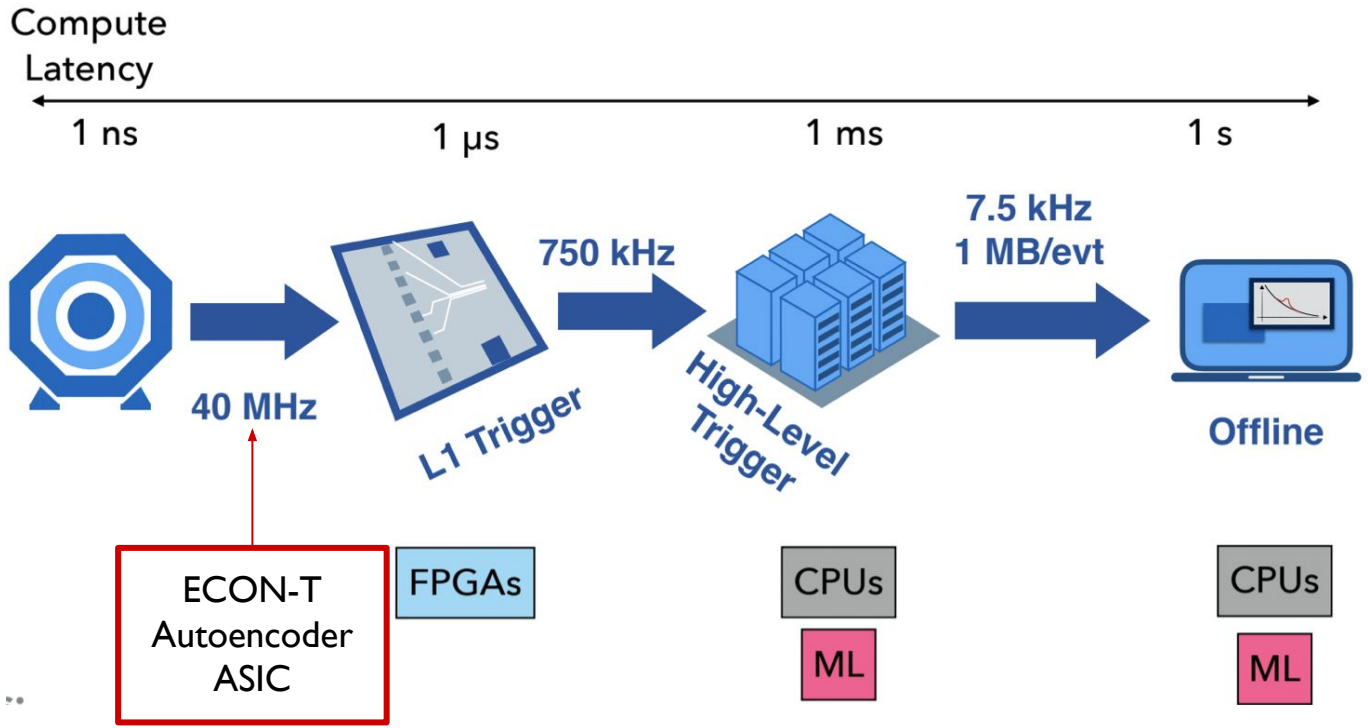
When do **hardware faults** occur?

# Example: LHC's CMS Data Processing Pipeline



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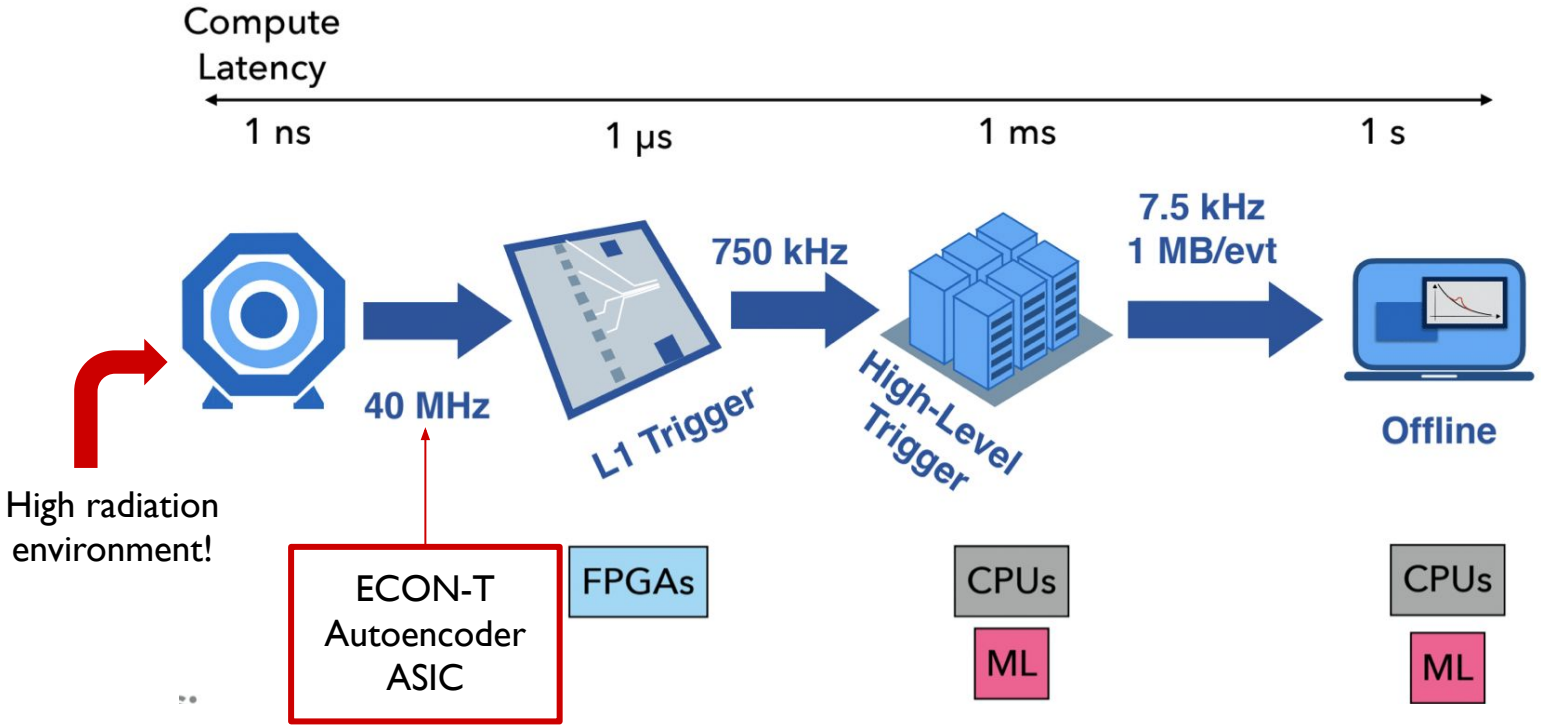


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How does the ECON-T Autoencoder **tolerate** radiation?

# ECON-T Radiation Tolerance

- ECON-T employs **triple modular redundancy (TMR)** to its registers



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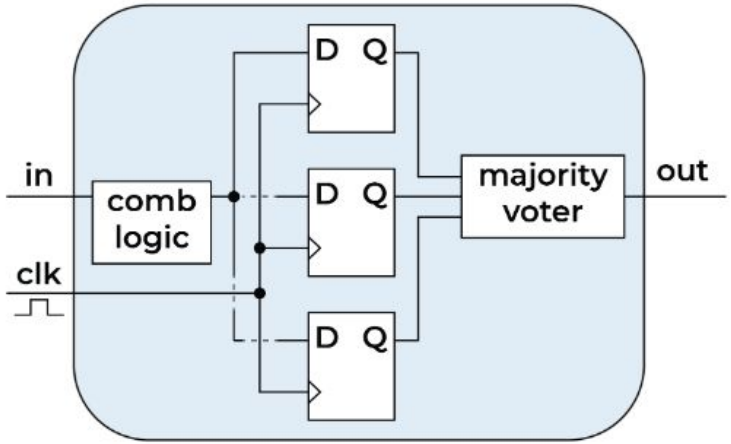




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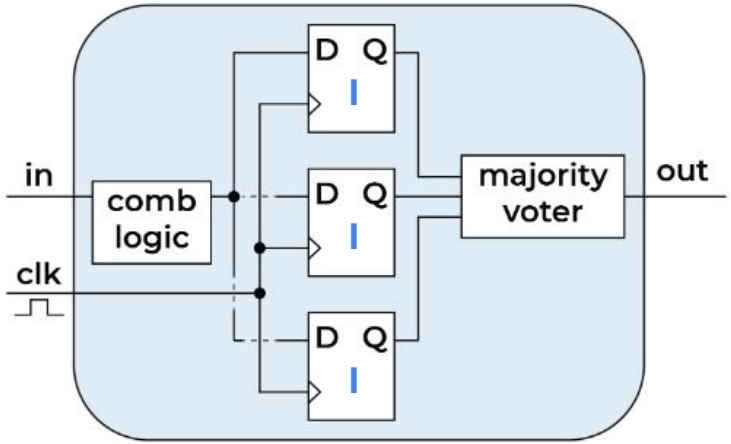




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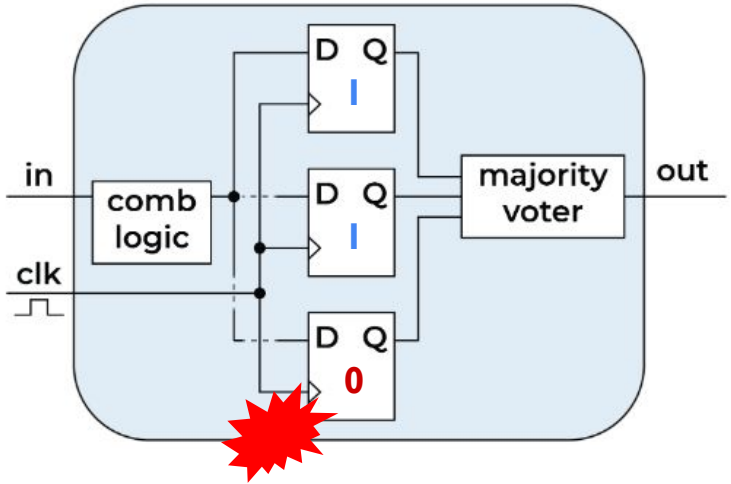


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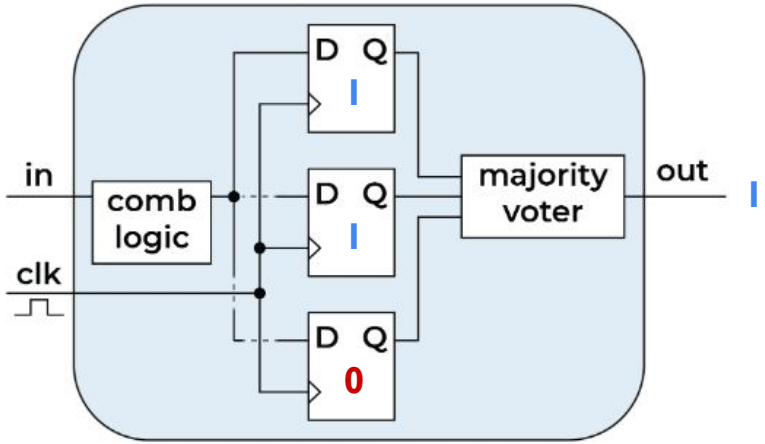




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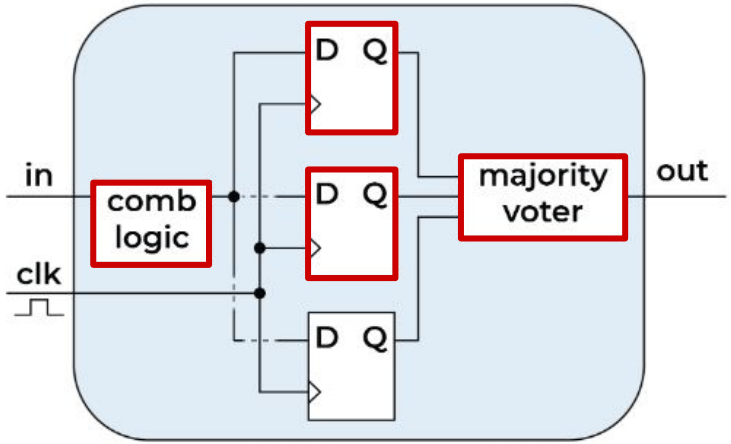


**TMR incurs ≥200% area overhead!**



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How can we **reduce** radiation tolerance **costs**?

Observation: Tolerance only applied to **hardware**

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What about **software**?

How should we assess the **fault sensitivity** of NN **software**?

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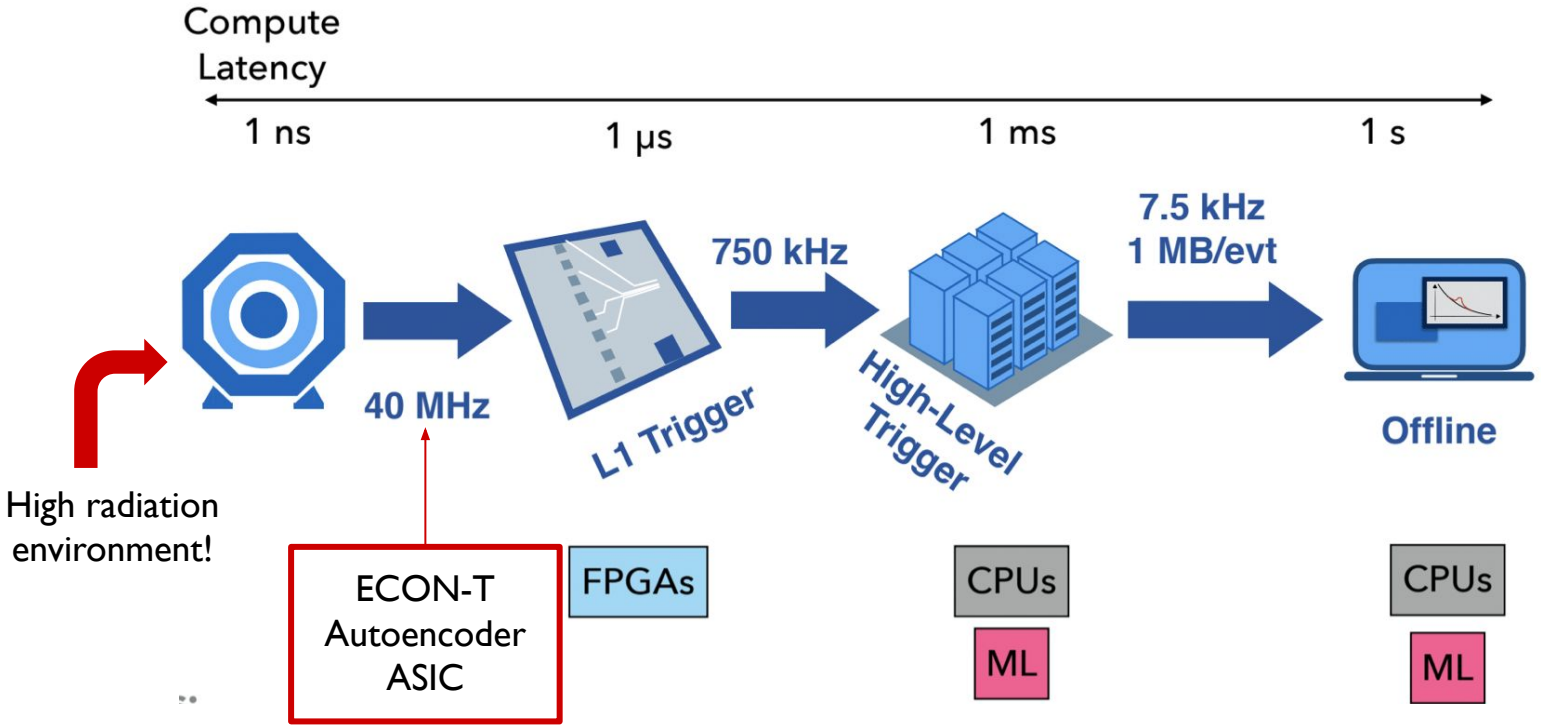




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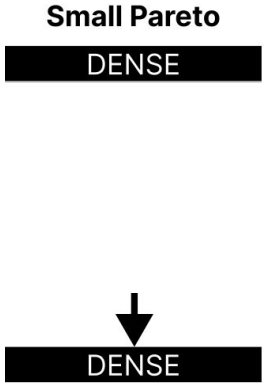

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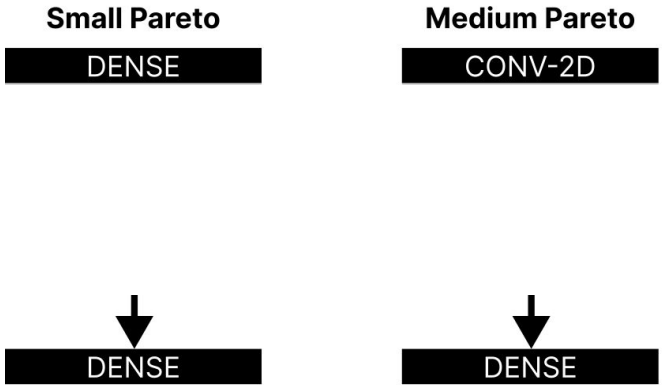

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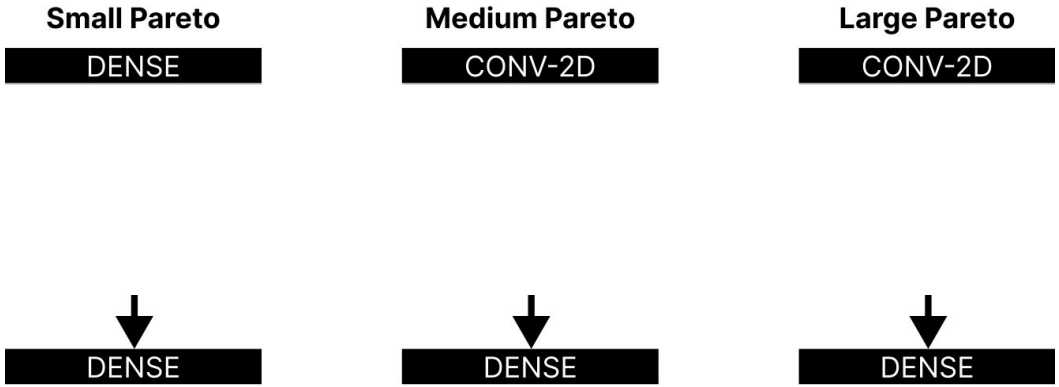

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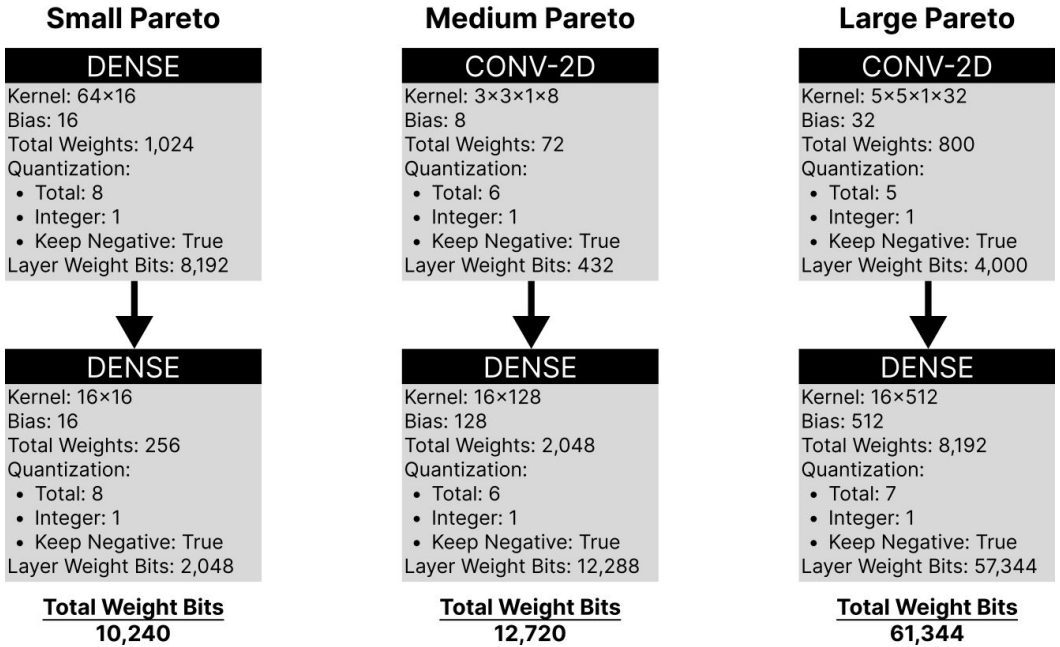

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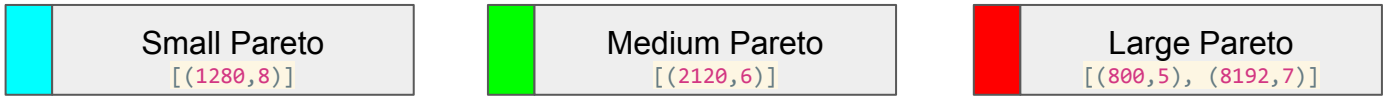

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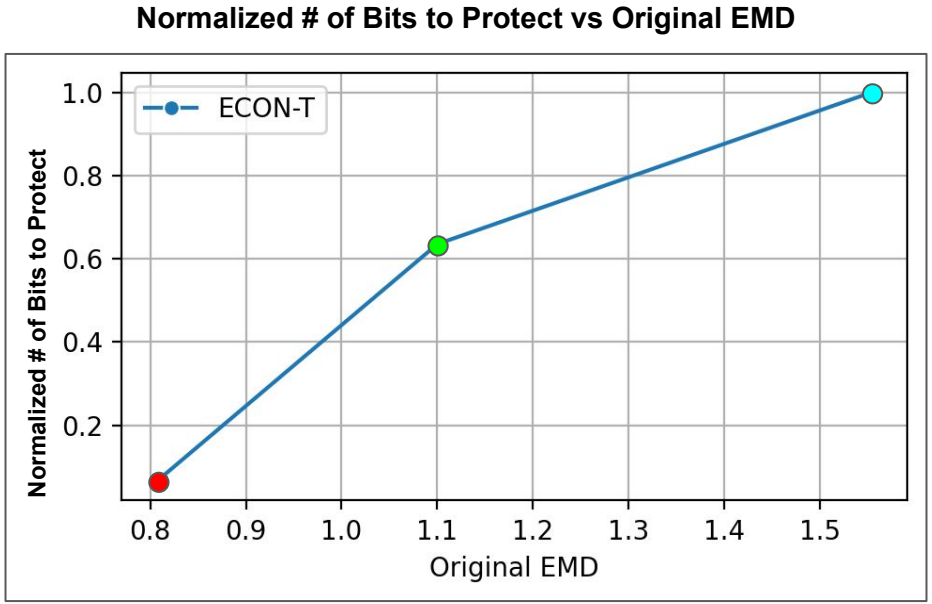


| Small Pareto | Medium Pareto | Large Pareto |
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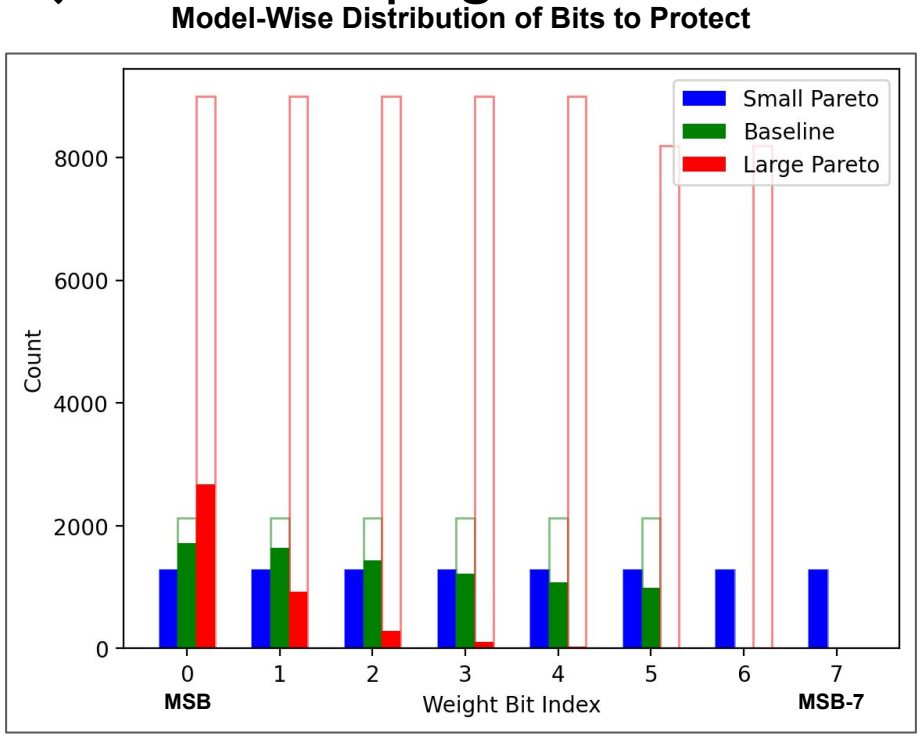


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- Current features:
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  - Bit-level sensitivity metrics

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Can we **quantify** fault sensitivity a priori?

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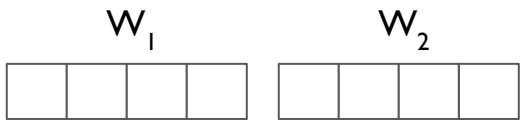

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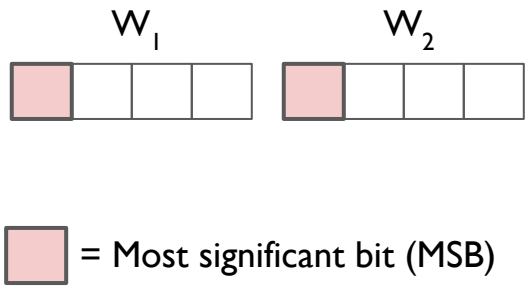

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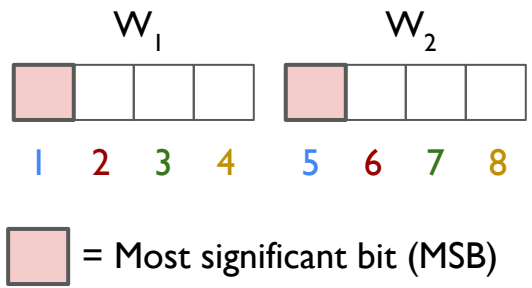

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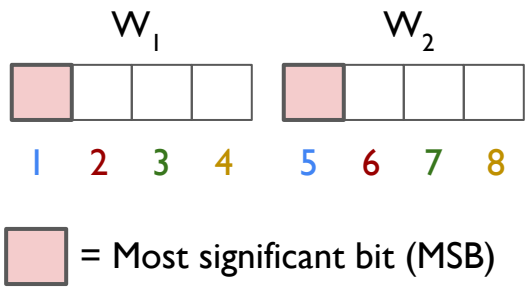

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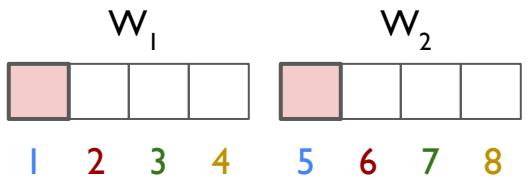


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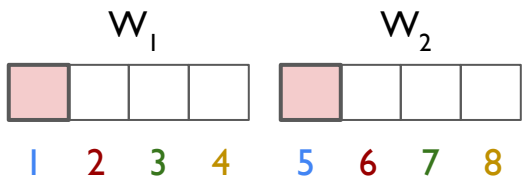


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Ranking:

3 ← High sensitivity
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6
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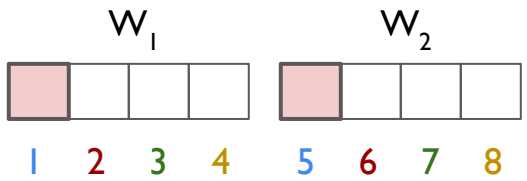


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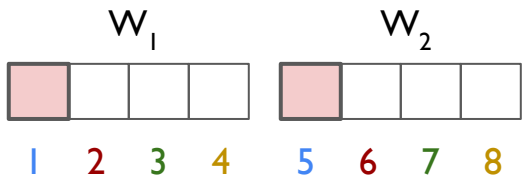


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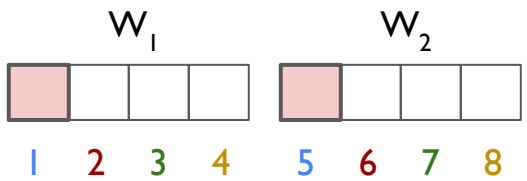


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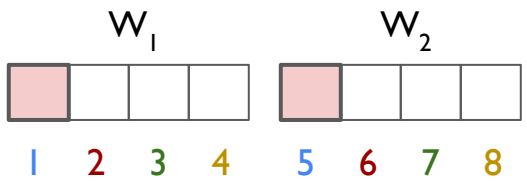


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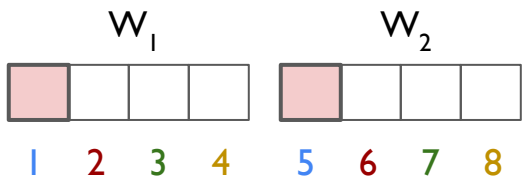


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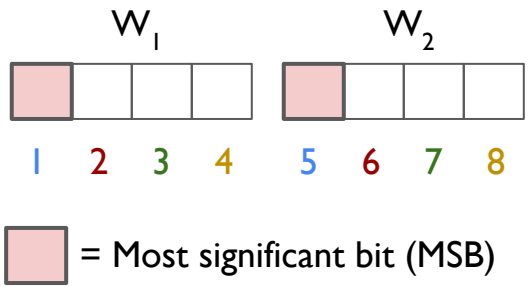

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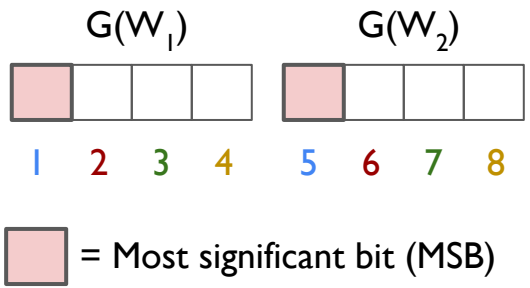

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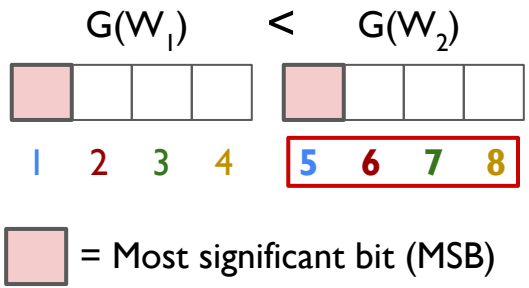

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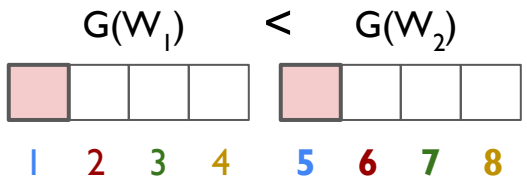


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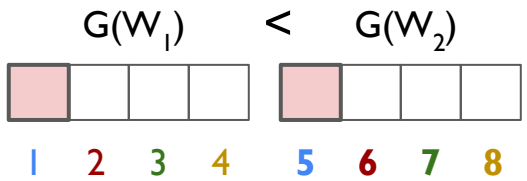


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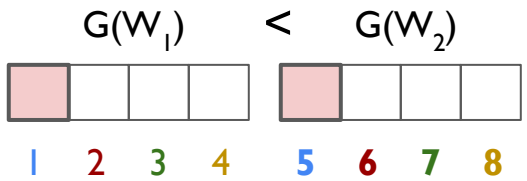


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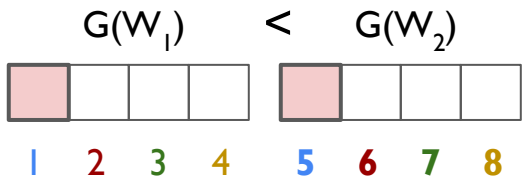


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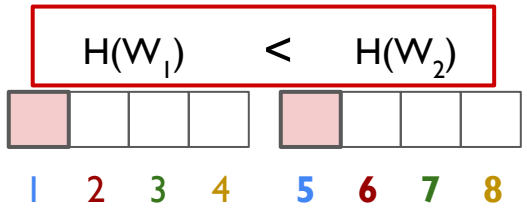


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How do these metrics **compare** with a perfect ranking?

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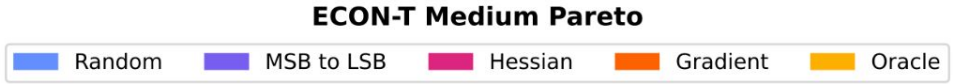

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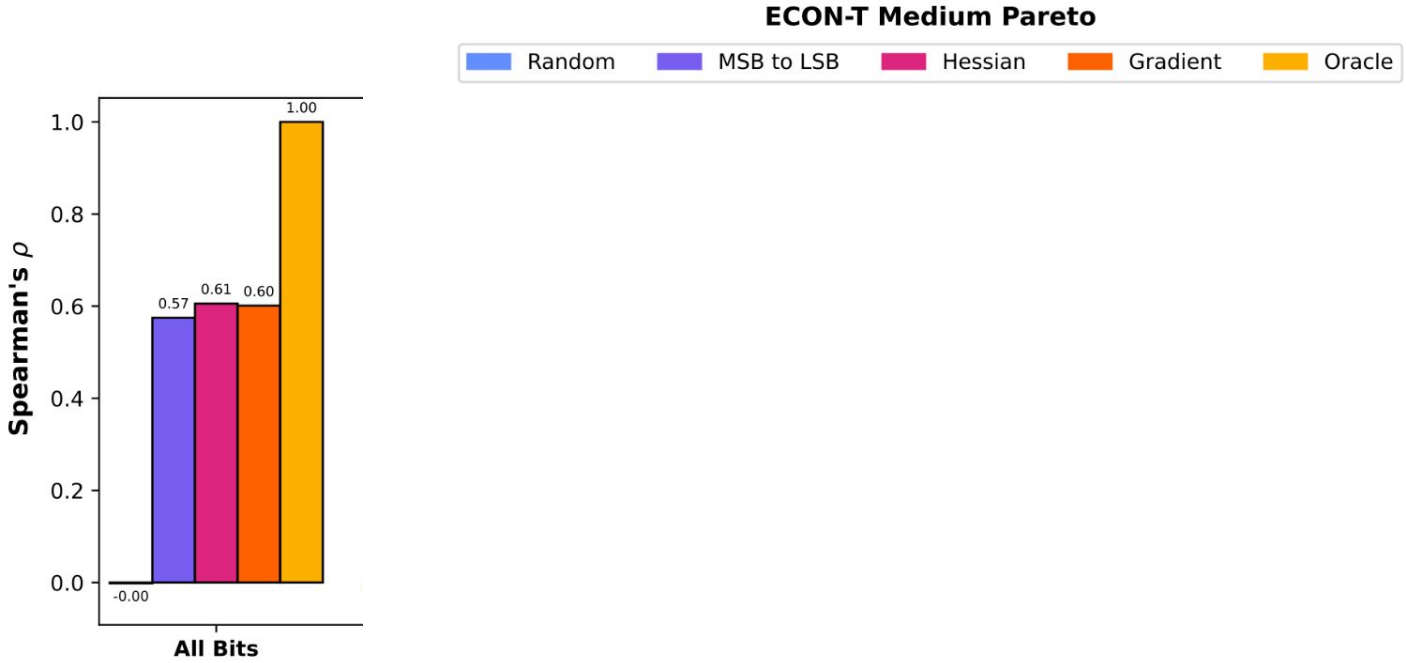

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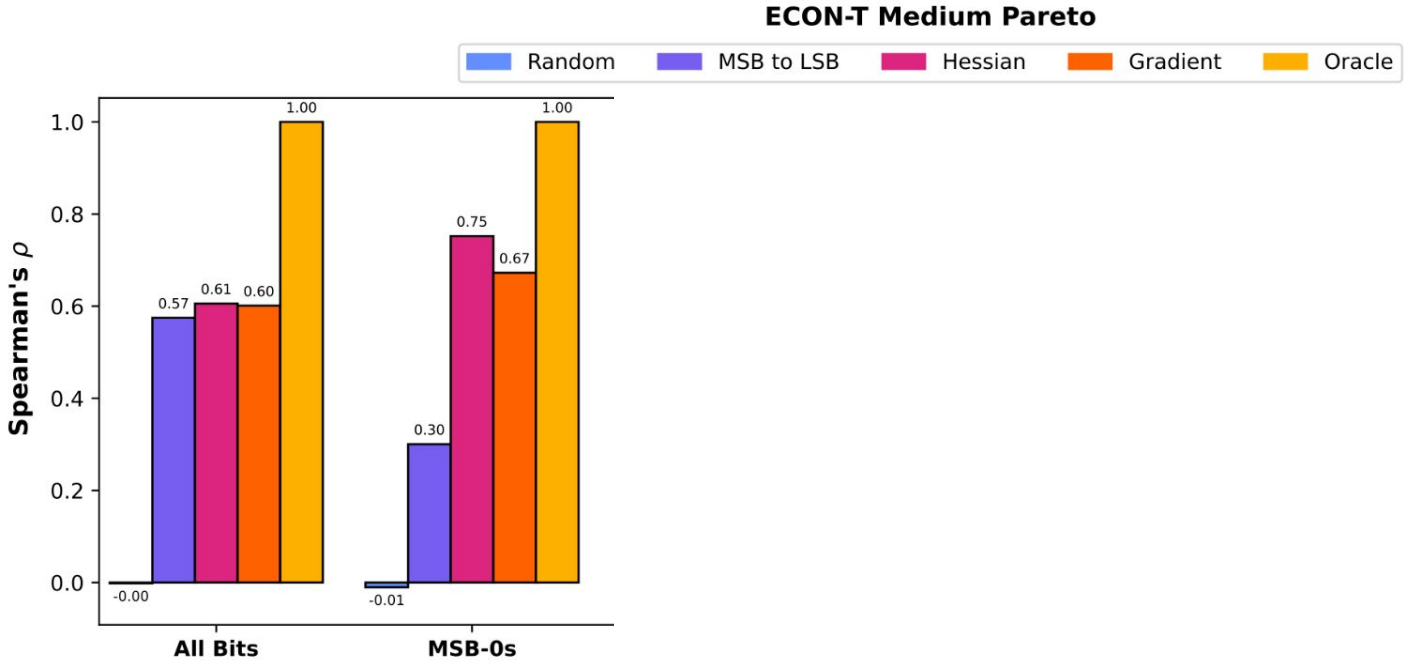

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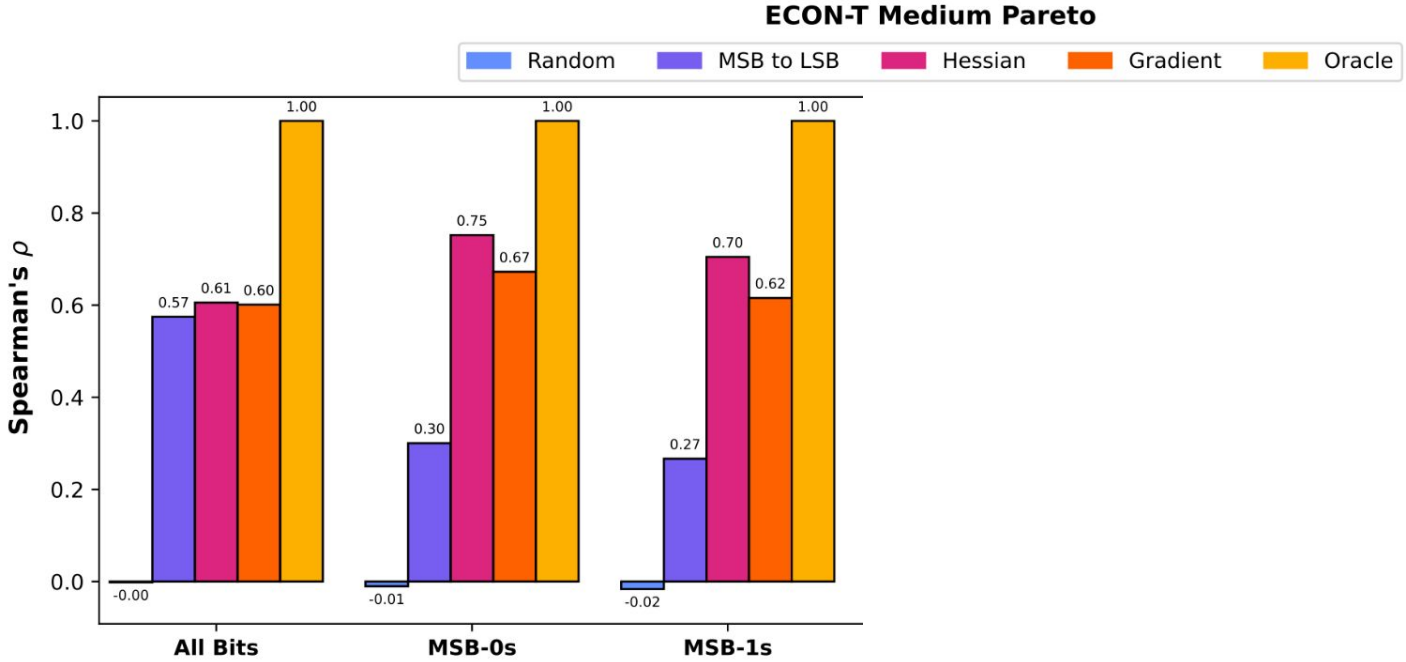

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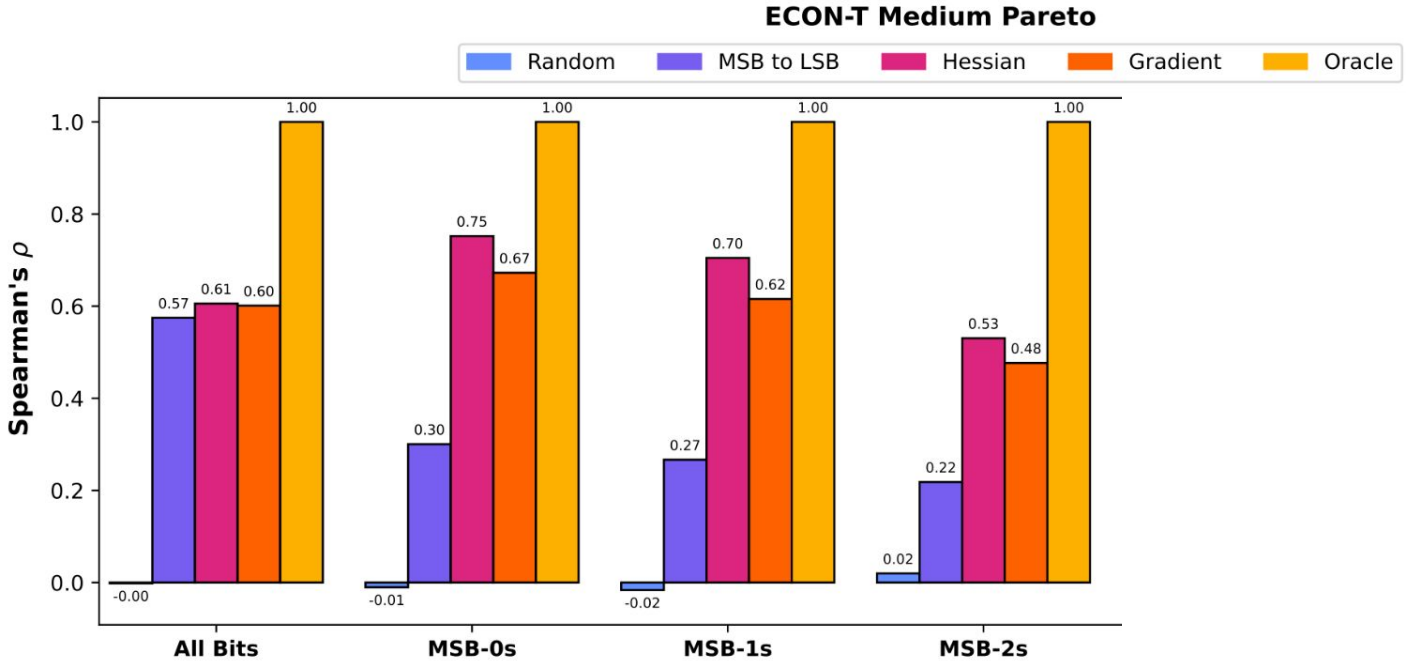

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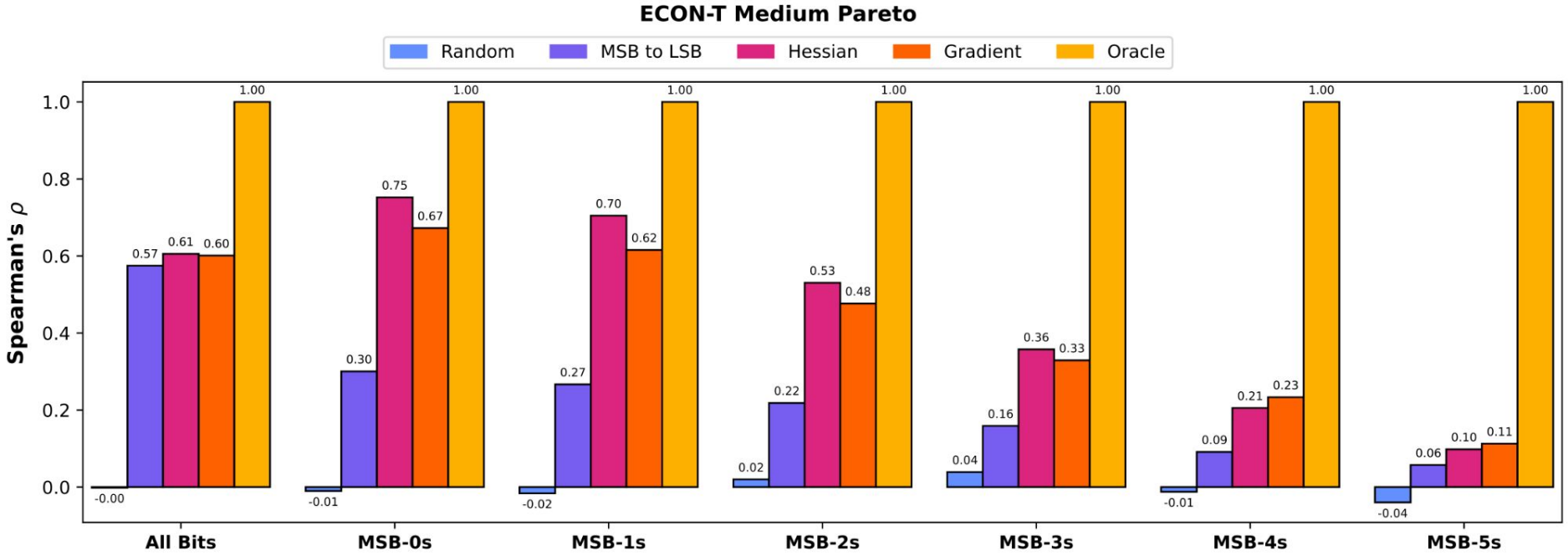

# FKeras

- A library that **assesses the fault sensitivity** of (Q)Keras models

- Current features:
  - Fault injection
  - **Bit-level sensitivity metrics**

# Future Work

We want to use FKeras to:

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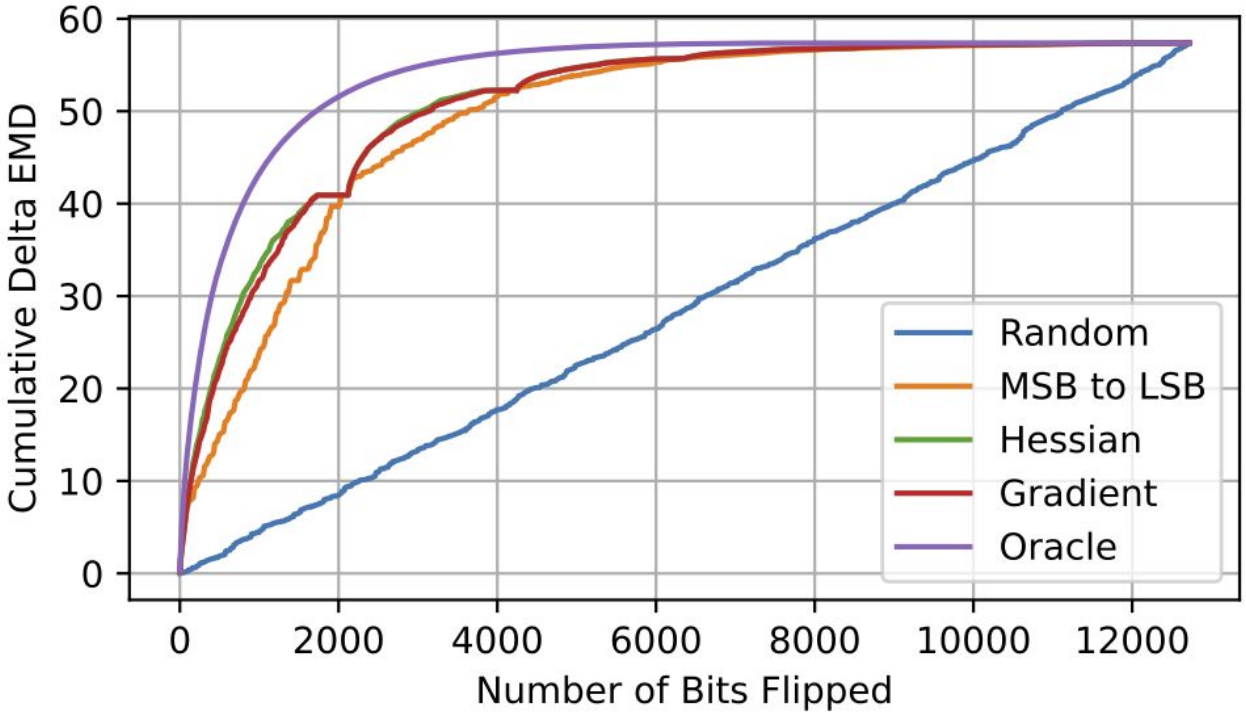
- Perform NN design space exploration that considers fault sensitivity using our metrics
  - How does fault sensitivity interact with performance, area, etc?

# Backup

# How do our metrics compare with a perfect ranking?



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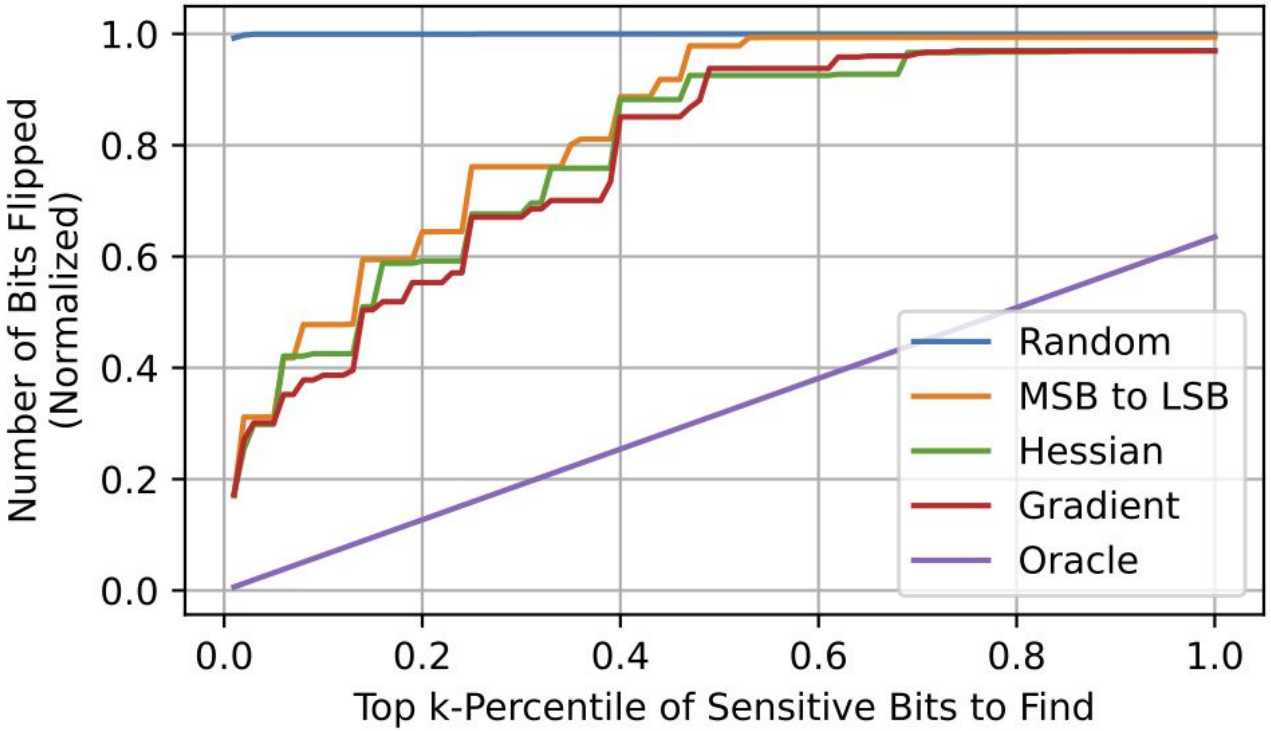

# How to use bit-level sensitivity rankings?

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- Design space exploration