

MAGI

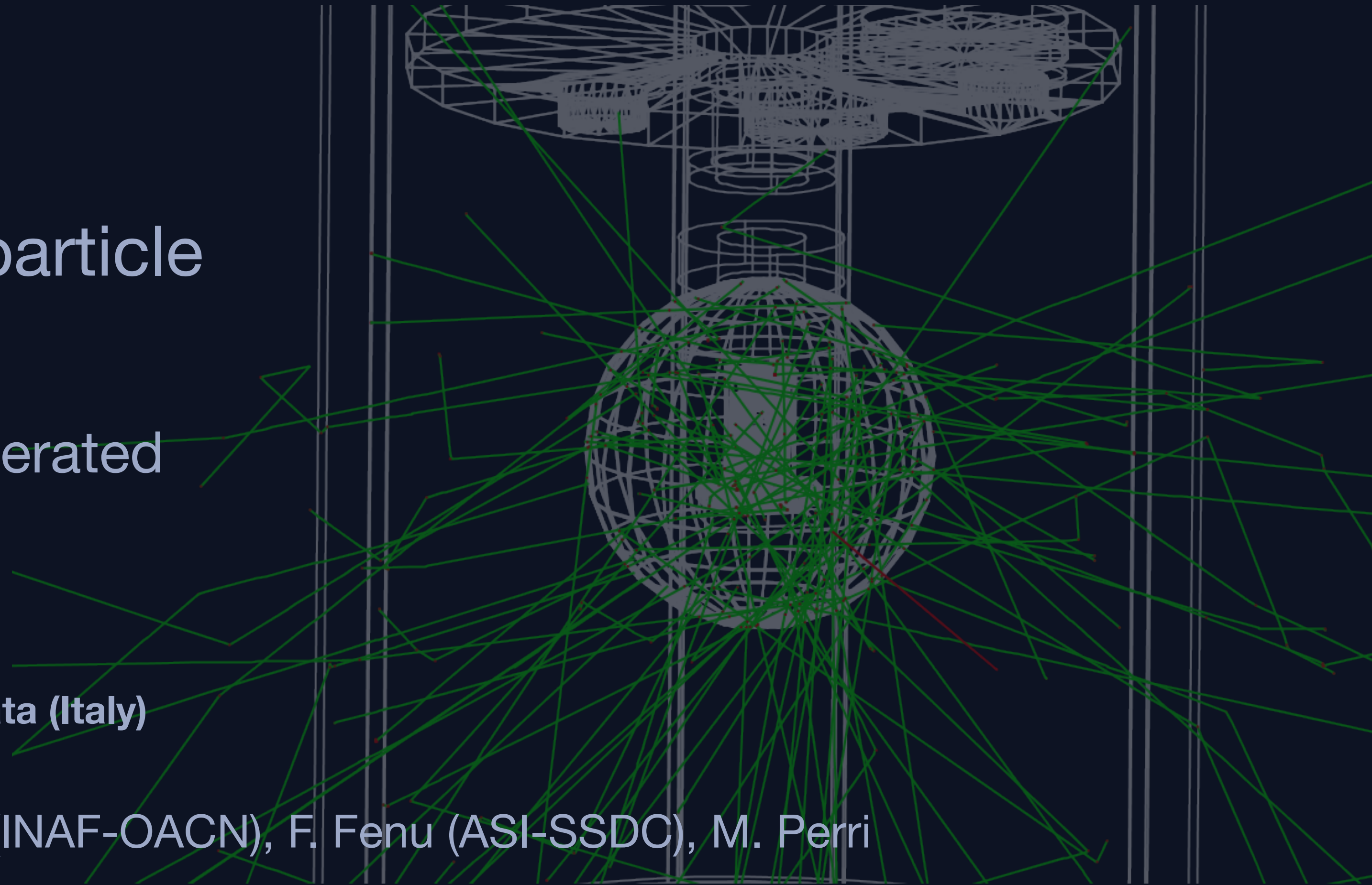
Multivariate Autoencoder for particle Generative Inference

A generative ML framework for accelerated
multi-stage particle simulations

Francesco Monastra

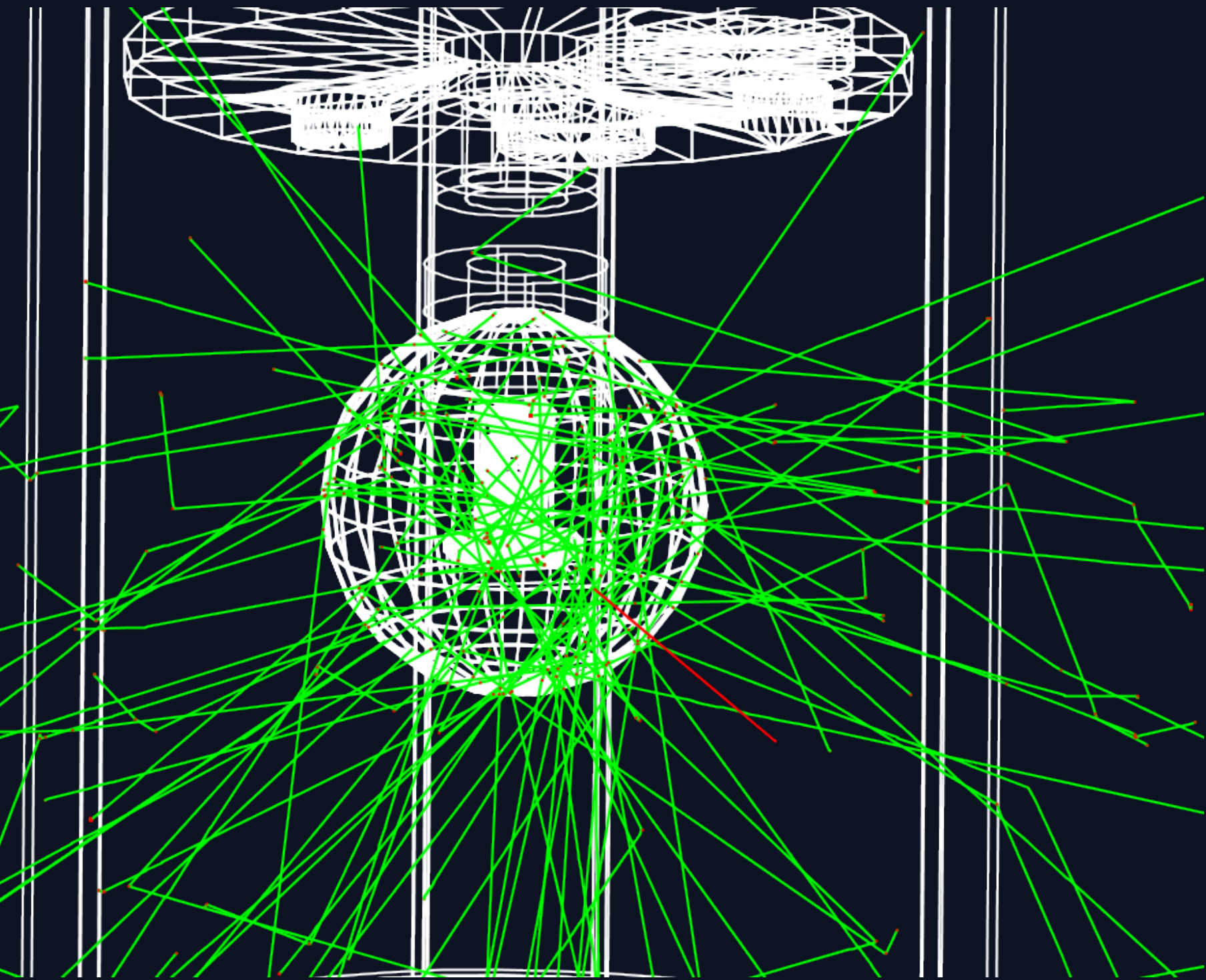
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THE PROBLEM

Most of CPU is spent far from the detector



DM1.2 MM

52%

0.50%

SRON XFDM MM

70%

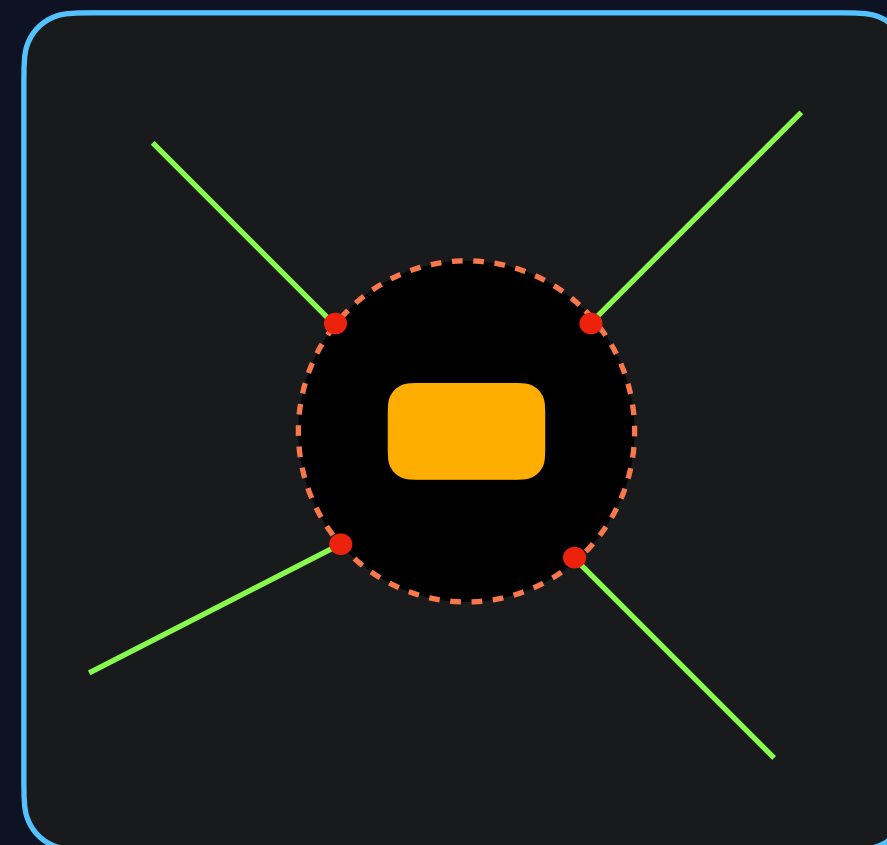
0.69%

Fraction of CPU cost spent in
outer transport

Crossing Efficiency χ
Fraction of events in the inner sphere

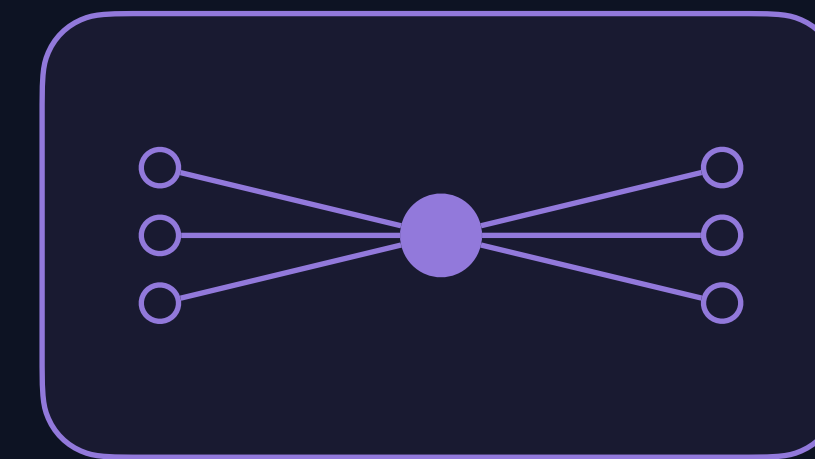
•THE IDEA•

OUTER SIMULATION - once



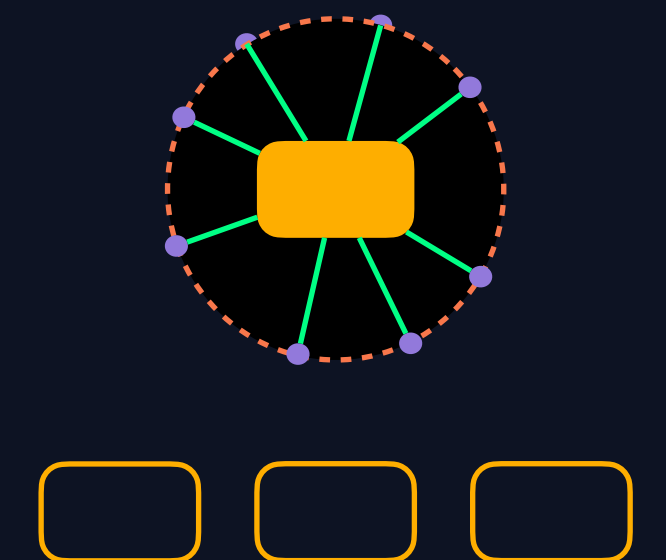
Record every crossing

MAGI TRAINING - once



Learn the crossing population

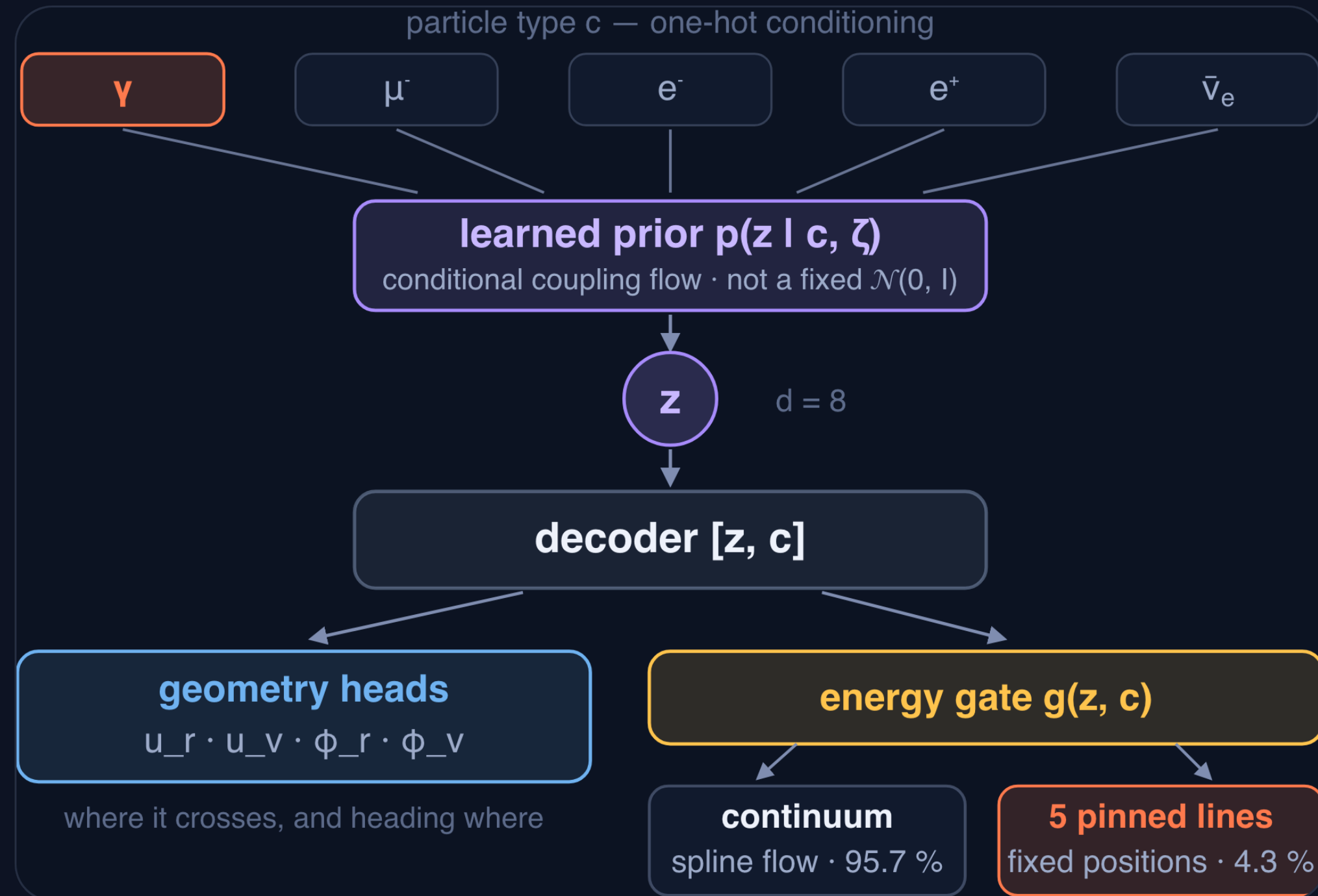
INNER SIMULATION - repeatedly



Test multiple designs

THE MODEL

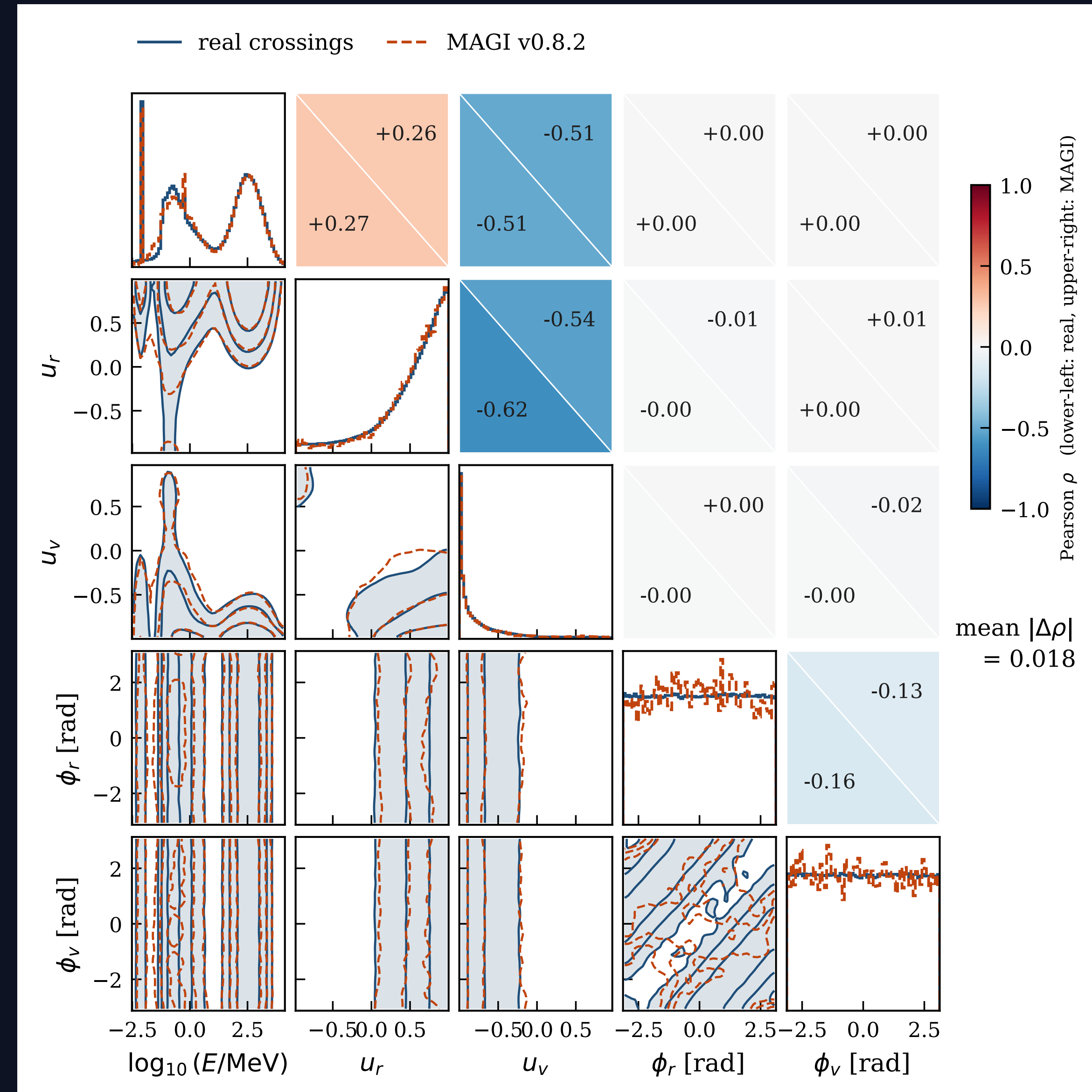
One conditional VAE



- cVAE conditioned on particle species
- Energy head gates a conditional spline flow continuum + fixed lines
- Latent prior learnable conditional coupling transform

≤ 0.018

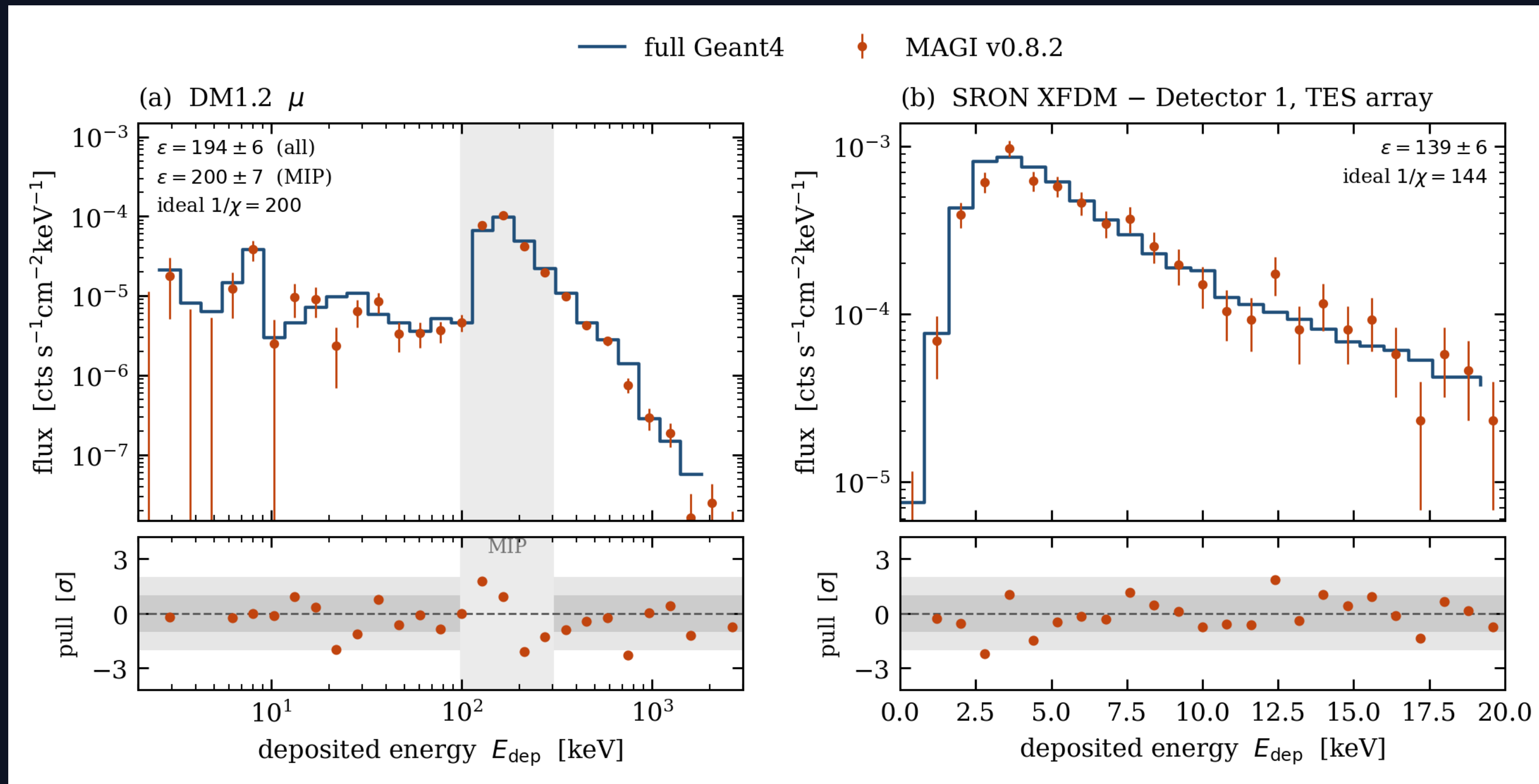
Maximum mean correlation residual for validation datasets



DM1.2 Cosmic Rays Distributions

DOES IT WORK?

Validated downstream



DM1.2 and SRON XFDM with cosmic rays muons.
Different Mass Model and detector design.
Full simulation spectra are validated against real measurements.

Crossings pushed **back** through
Geant4 mass model.

We compare measured spectrum
with **full Geant4 simulation** and
MAGI resampling and injection.

Detector-level rate

0.970 ± 0.032

DM1.2 full band
(MIP band: 0.999 ± 0.037)

0.963 ± 0.043

SRON XFDM

WHAT IT BUYS

More statistics and less compute

Statistical Amplification

(events per transported particle)

194 $\pm$ 6

DM1.2

139 $\pm$ 6

SRON XFDM



Speed-up

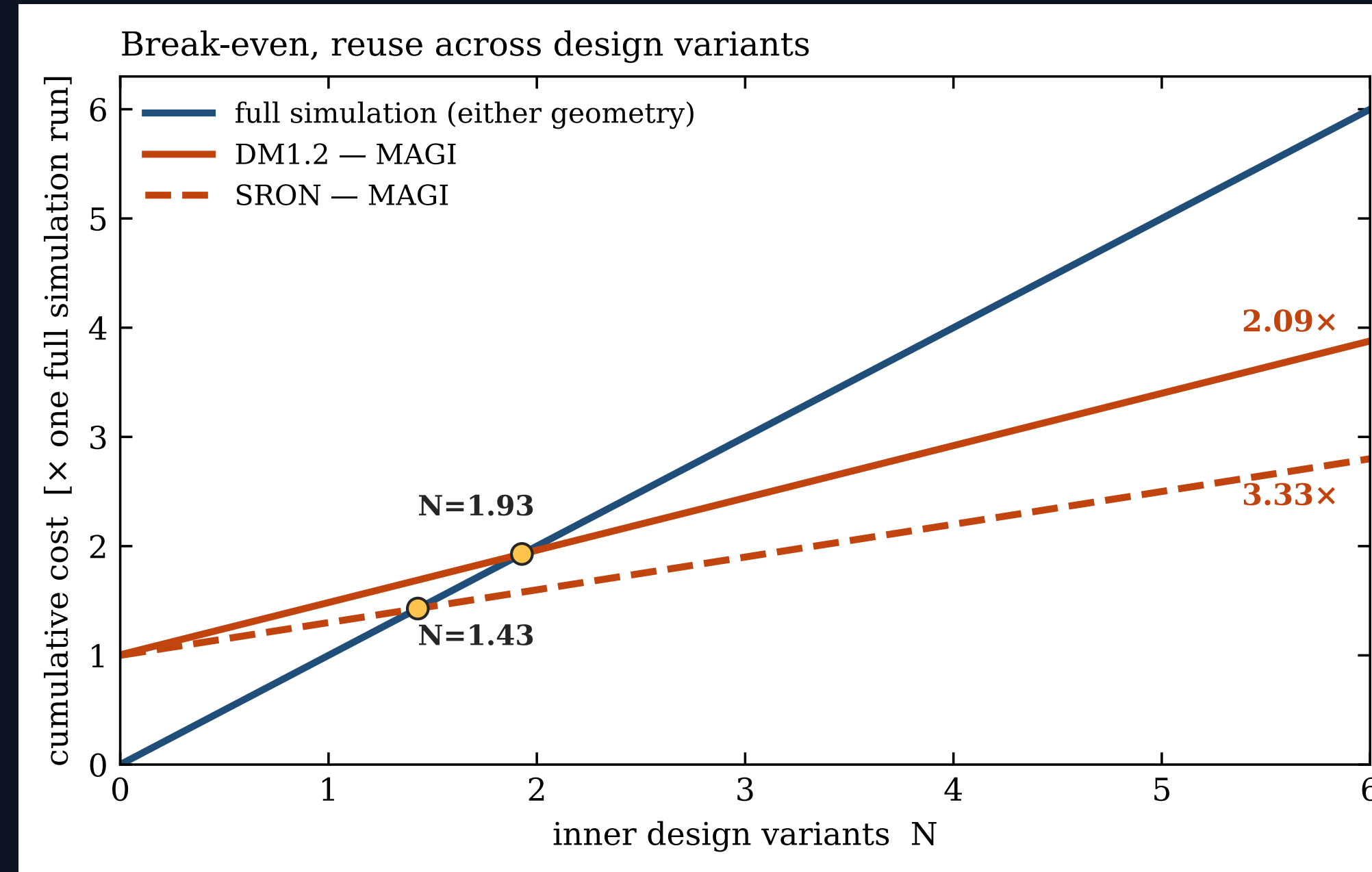
(Net throughput on the same machine)

2.03x

DM1.2

3.33x

SRON XFDM



From 2nd iteration it gets cheaper

On low-statistics cases it gives its best:

E.g. radioactive decays where decay/crossing cost ratio is high

~6670 Statistical Amplification

~9.10⁴x Speed-up

**Achievable,
still under validation**

THANK YOU!

Faster simulations for **instrumental applications**



github.com/francescomonastra/MAGI

Package, manual and examples

NEXT STEPS:

- Complete validation on low-statistics cases
- Improve fluorescence-line generation
- Assess MAGI potential with a full case study and application to NewAthena X-IFU
- Extend beyond spherical sampling geometries

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