Reinterpretation of a search for long-lived particles

CHEHAB THOMAS
MASTER 2 COSMOS, CHAMPS, PARTICULES

LLP Workshop

Laboratoire de Physique de Clermont

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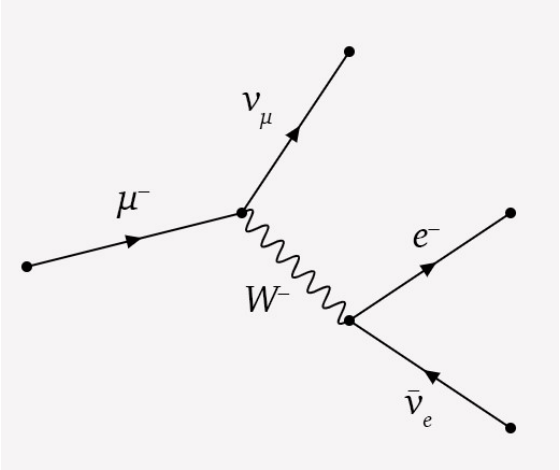
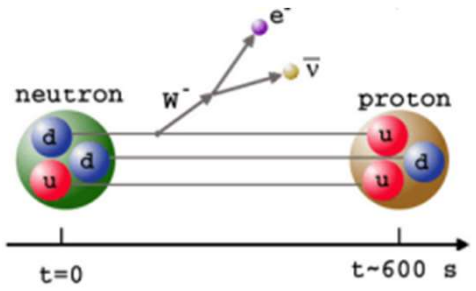
Long Lived Particles (LLPs)

- Particles with a **macroscopic** lifetime.
- **Exist** in the Standard Model (muon, neutrons…).
- Many of the scenarios proposed to address some of the open questions of the Standard Model (SM) **predict** their existence.
- Different ways to occur : small coupling, heavy mediator, particles very close in mass.

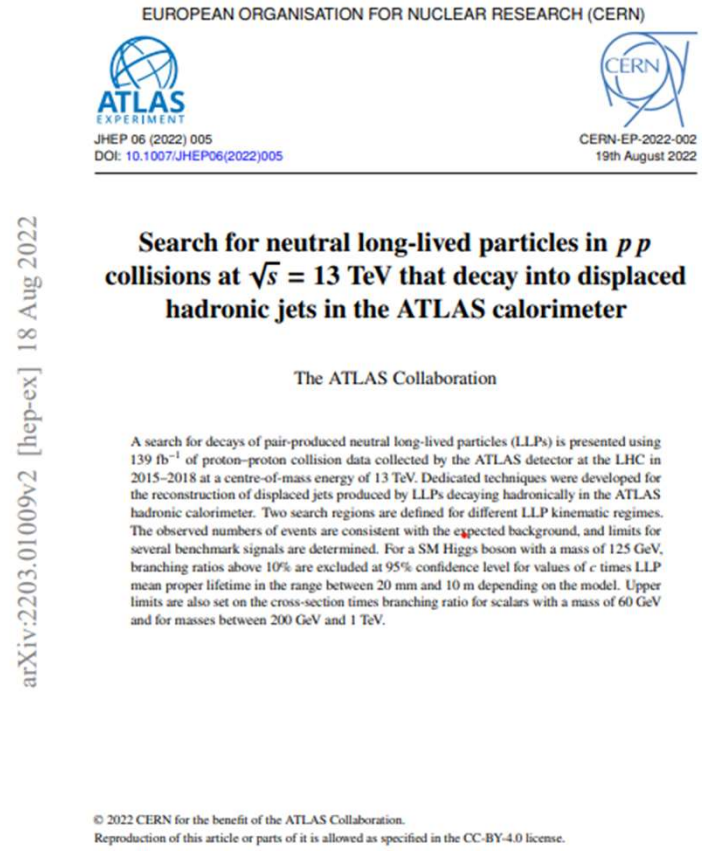


Muon decay.



Neutron decay. [L.Corpe]

The ATLAS search for pairs of displaced hadronic jets from LLPs



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19th August 2022

Search for neutral long-lived particles in pp collisions at $\sqrt{s} = 13$ TeV that decay into displaced hadronic jets in the ATLAS calorimeter

The ATLAS Collaboration

A search for decays of pair-produced neutral long-lived particles (LLPs) is presented using 139 fb^{-1} of proton–proton collision data collected by the ATLAS detector at the LHC in 2015–2018 at a centre-of-mass energy of 13 TeV. Dedicated techniques were developed for the reconstruction of displaced jets produced by LLPs decaying hadronically in the ATLAS hadronic calorimeter. Two search regions are defined for different LLP kinematic regimes. The observed numbers of events are consistent with the expected background, and limits for several benchmark signals are determined. For a SM Higgs boson with a mass of 125 GeV, branching ratios above 10% are excluded at 95% confidence level for values of c times LLP mean proper lifetime in the range between 20 mm and 10 m depending on the model. Upper limits are also set on the cross-section times branching ratio for scalars with a mass of 60 GeV and for masses between 200 GeV and 1 TeV.

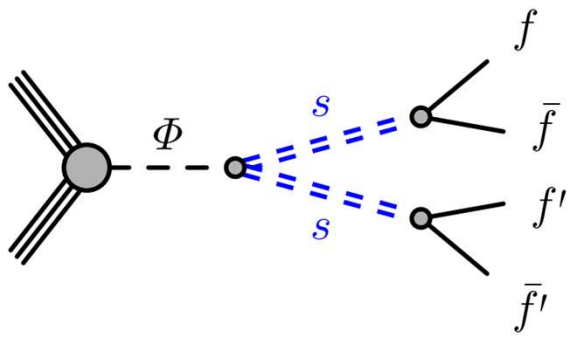
arXiv:2203.01009

The ATLAS search for pairs of displaced hadronic jets from LLPs

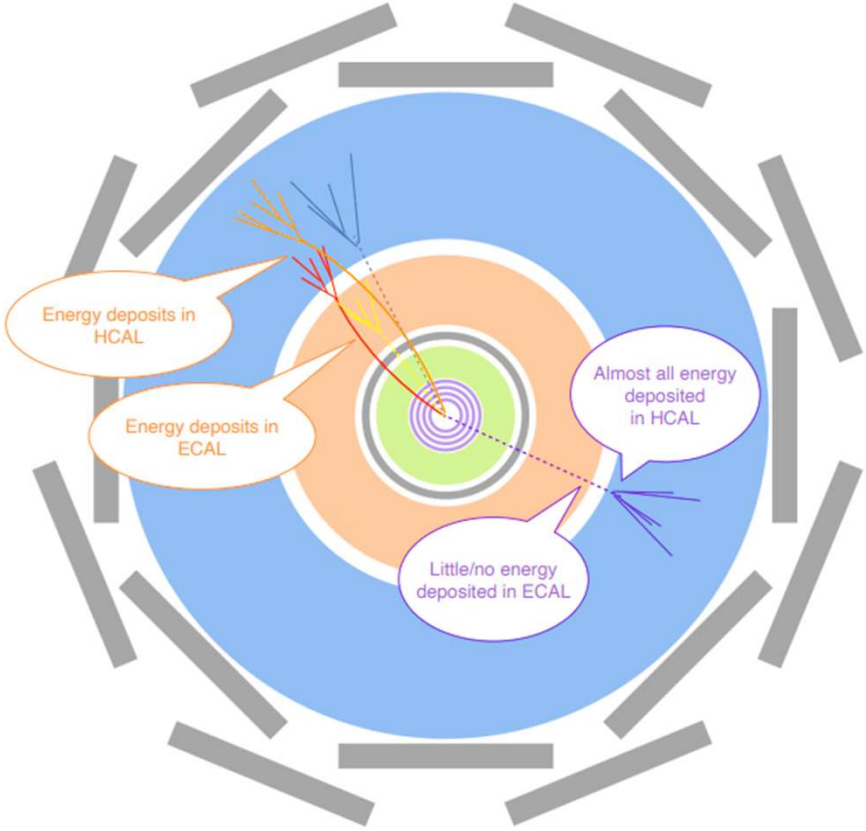
arXiv:2203.01009

- **Benchmark model** that involves a Hidden Sector (HS) -> LLPs **(s)**.
- The SM and HS are connected via a **heavy neutral boson Φ**.

Process used as the benchmark model.



- m_Φ = [60-1000] GeV ; m_s = [5-475] GeV.
- If decay is in the **calorimeter**, the jet will be narrower, trackless, with a higher proportion of its energy in the Hcal.

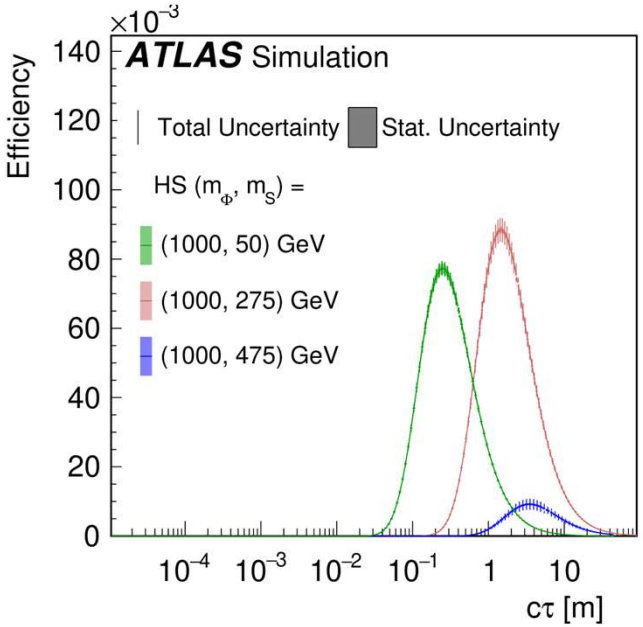


Interactions of standards particles and LLPs with the ATLAS detector [L.Corpe].

The ATLAS search – The extrapolation

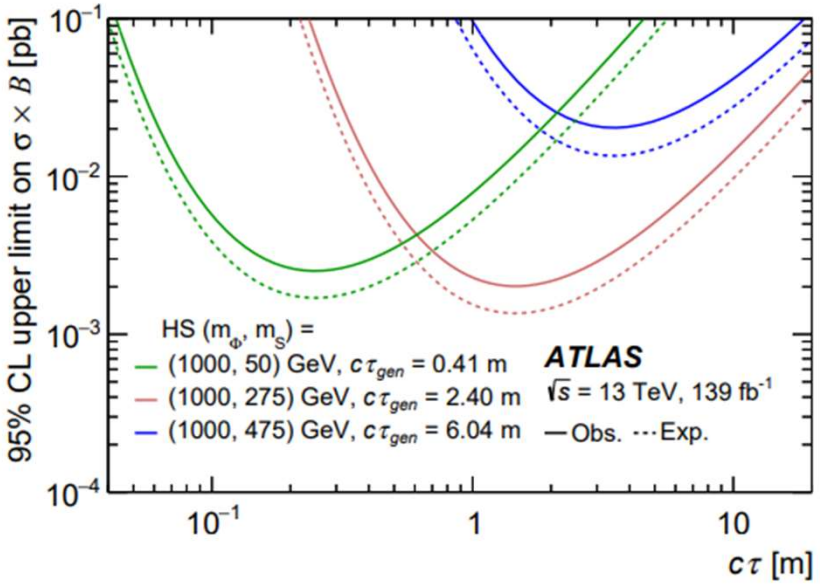
Each sample is generated for a given lifetime assumption.
It is necessary to extrapolate the limits across lifetimes.
This is performed using a reweighting method.

$$w(t) = \frac{\tau_{\text{gen}}}{\exp(-t/\tau_{\text{gen}})} \cdot \frac{\exp(-t/\tau_{\text{new}})}{\tau_{\text{new}}}.$$



$$\text{Efficiency} = \frac{\text{Nbr of selected event}}{\text{Total nbr event}}$$

CLs method + pyhf



Results from simultaneous background fit

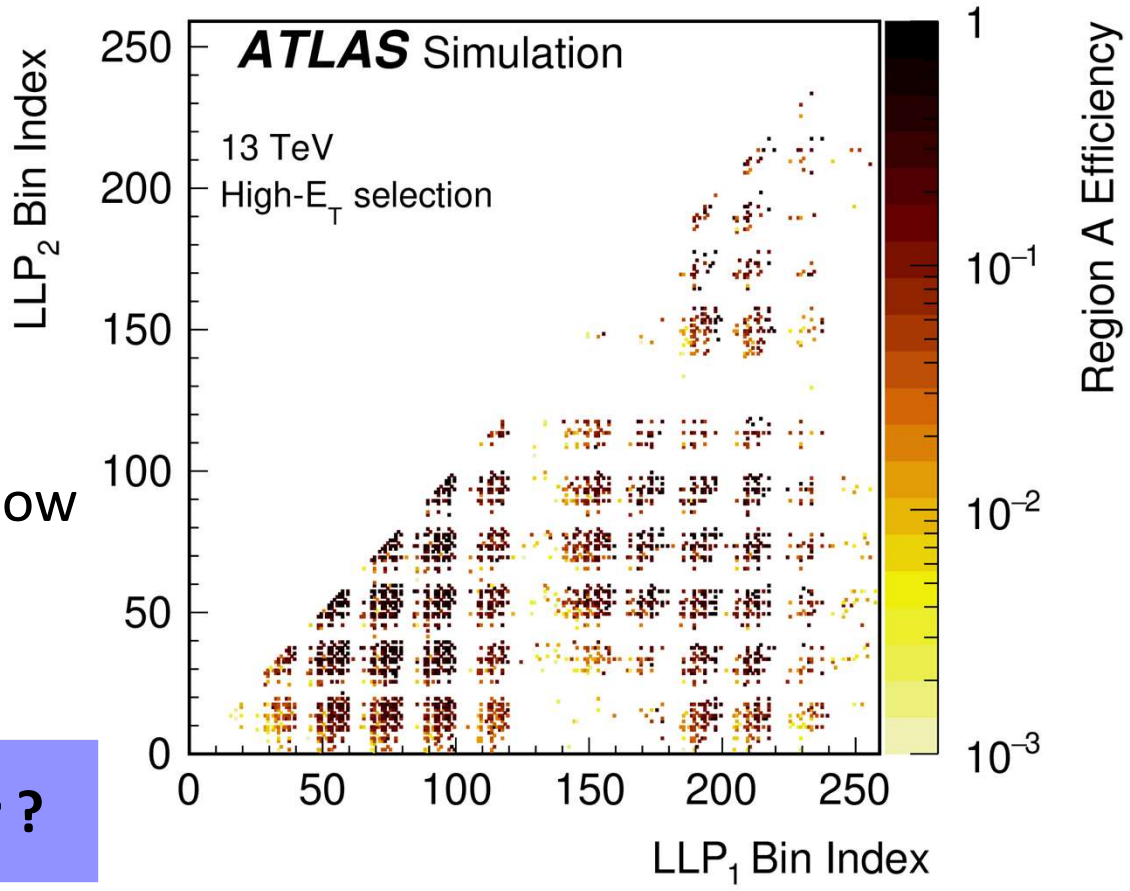
Re-interpretation material - The map

arXiv:2203.01009

- Each pixel is a c, b, t , τ bin.
- Blocks of 4 are a pT bin.
- Blocks of 5x4 are an Lxy or Lz bin.
- Symmetric in LLP1-2.
- Uses only the region A

For efficiencies above 0.5%, results typically accurate to **around 25%**, below they should not be used for re-interpretation.

How easy it is for an external user ?

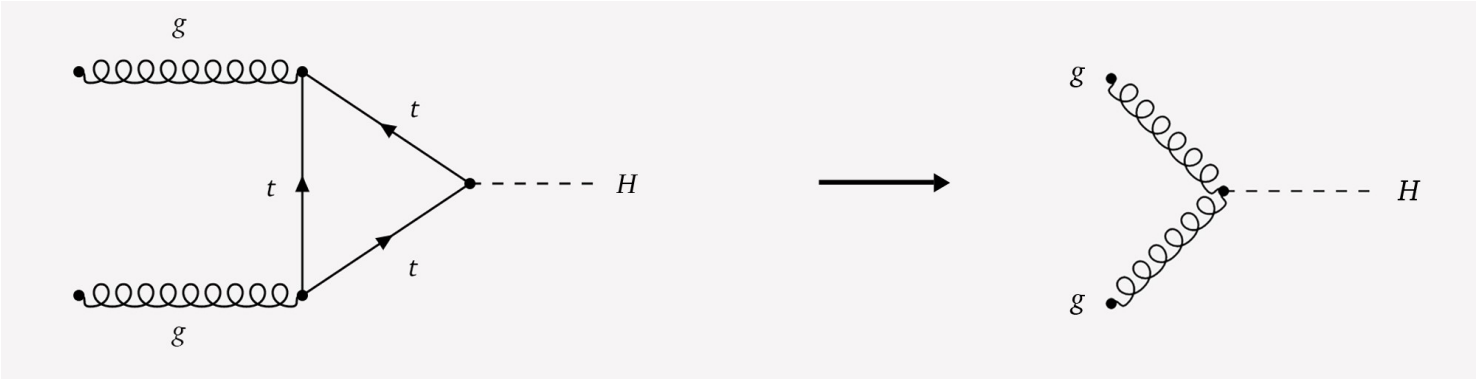


Validating the map with user-generated event samples

Event Generation for benchmark model – Mad graph

Hidden Abellian Higgs Model (HAHM)

- **Toy model (used for its kinematics, distributions…)**
- **Same as ATLAS**
- **Not easily accessible**



Approximation of the production process.

Event Generation – Changing the Lifetimes

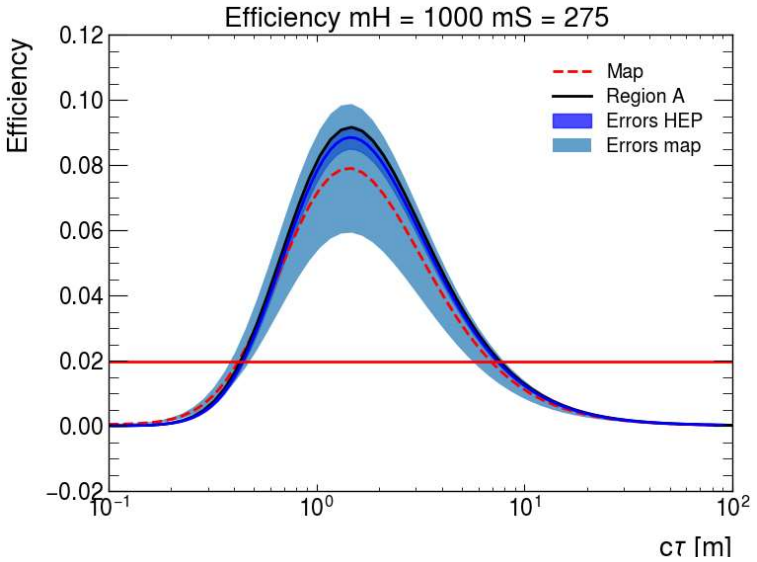
Using a function that outputs a number between 0 and 1 from a decreasing exponential (Lifetime in the Rest frame of the particle).

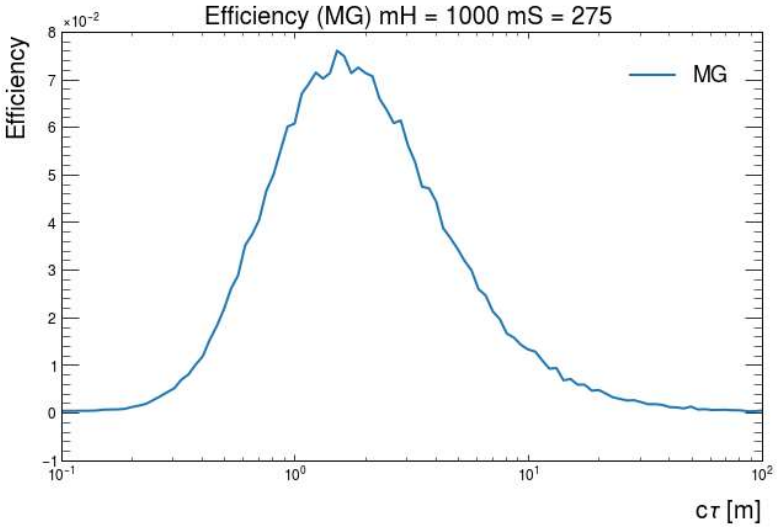
$$\text{Lifetime} = -1 \times \text{avgtau} \times \log(\text{t})$$

Lifetime function.

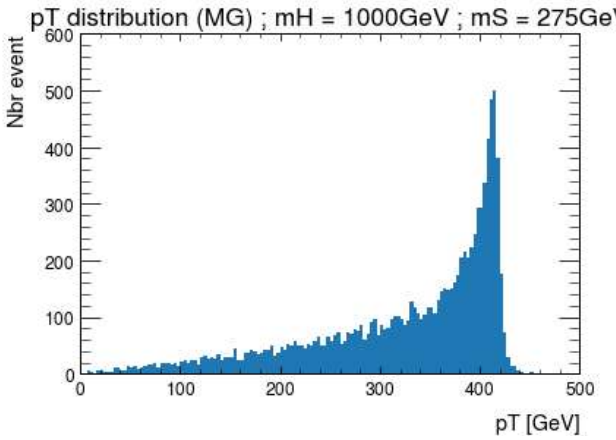
avgtau : Mean lifetime.
t : Random number between 0 and 1.

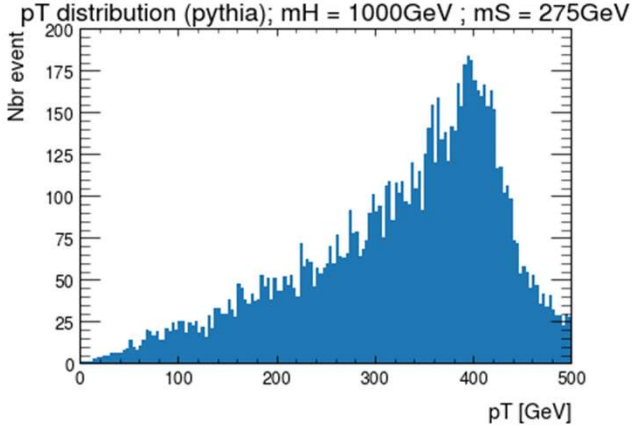
Results for 10 000 events

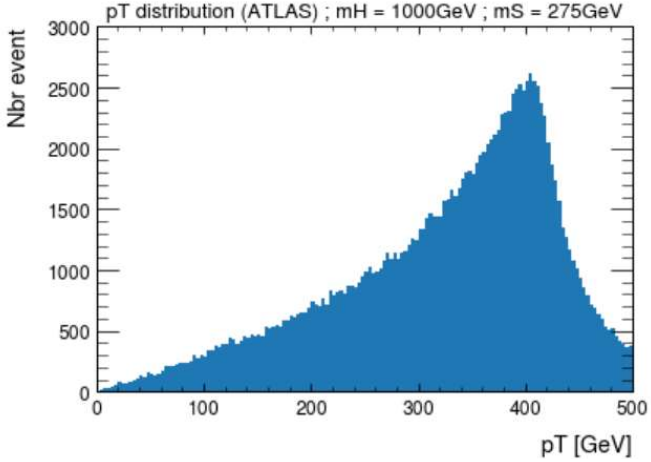


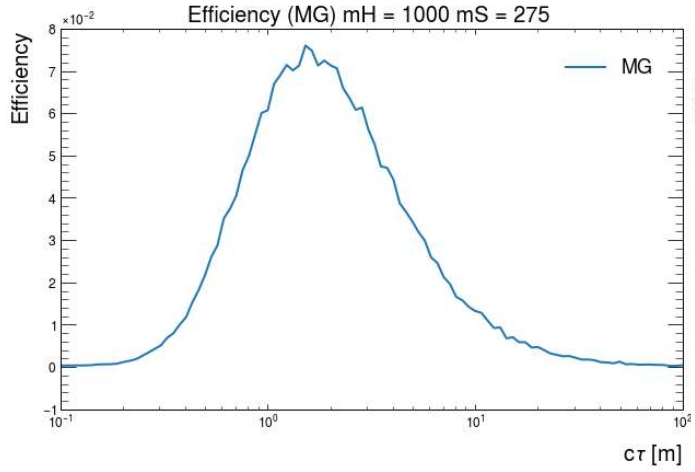


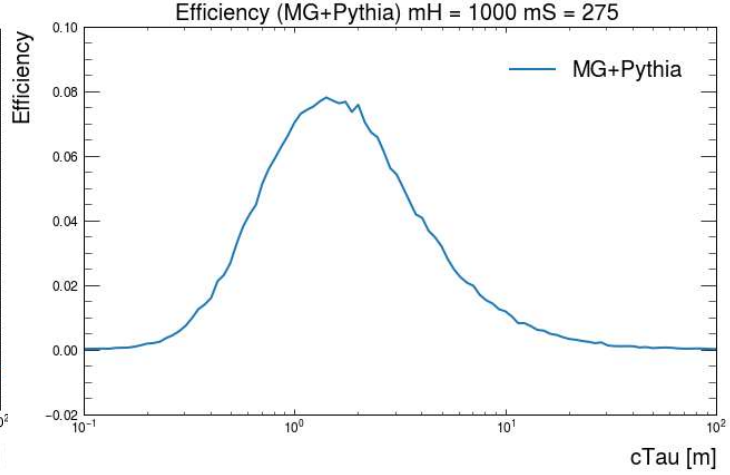
Event Generation – Distributions

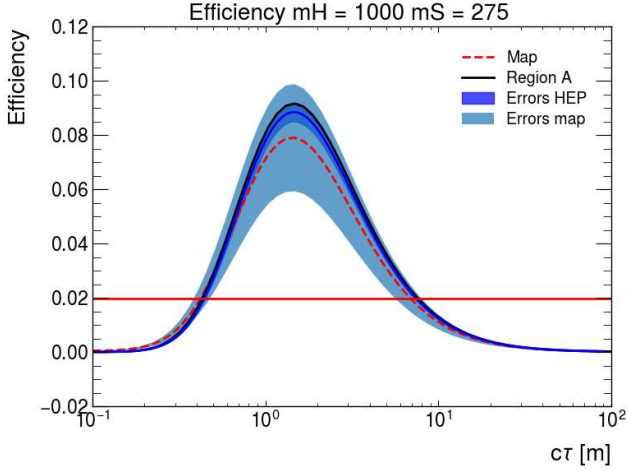










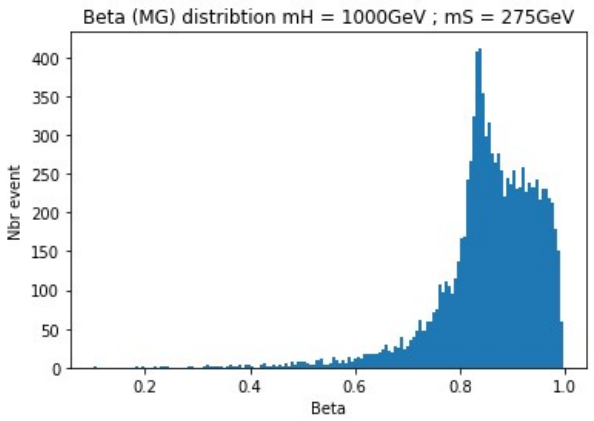


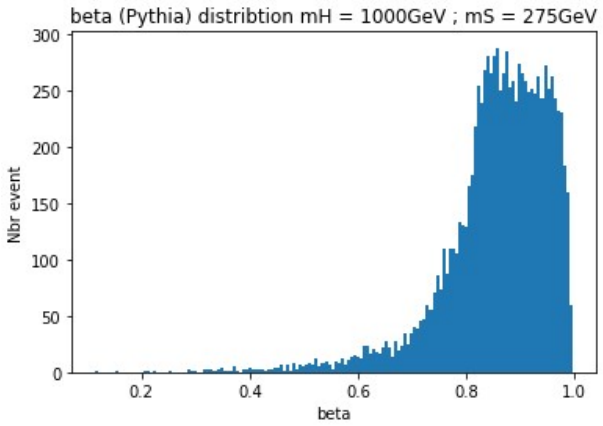
MG

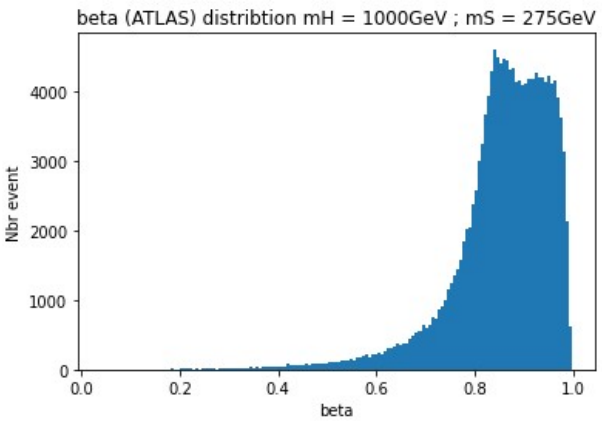
MG + Pythia

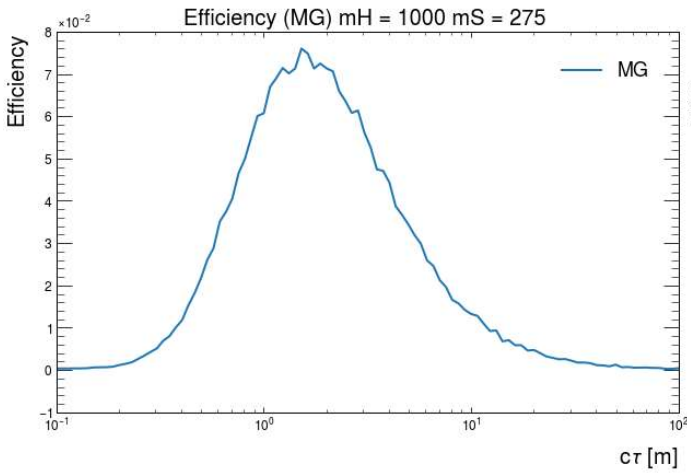
ATLAS

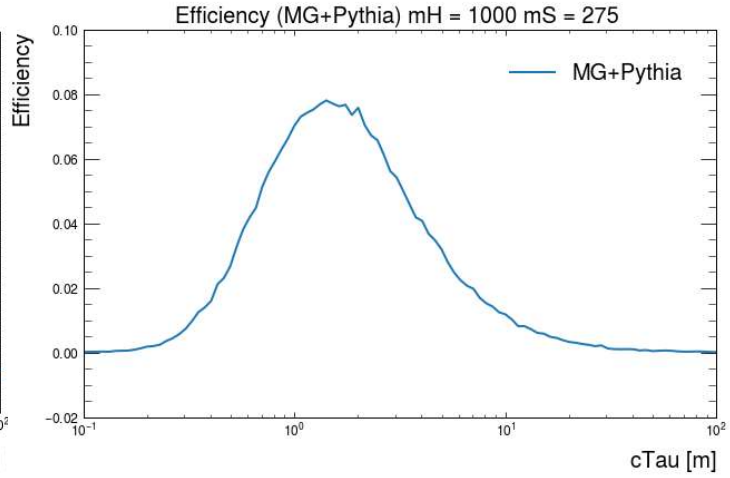
Event Generation – Distributions

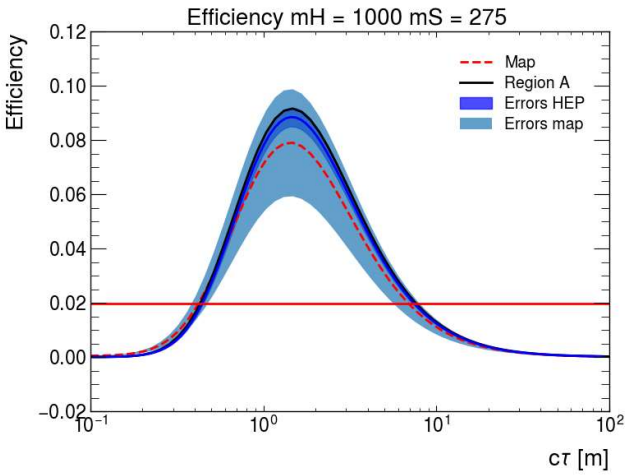










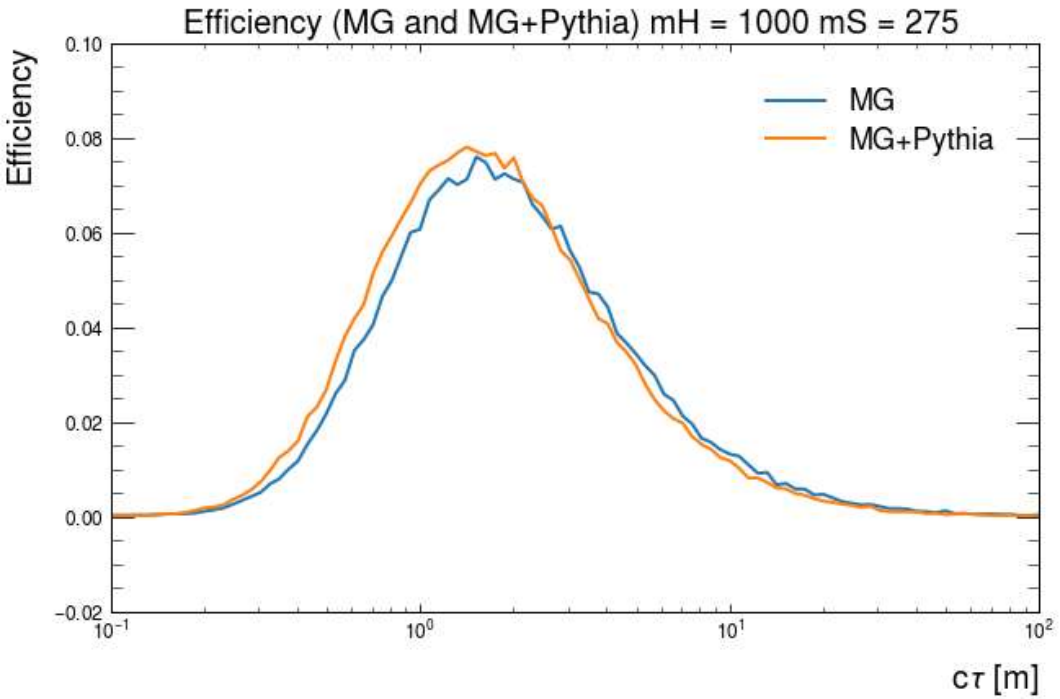


MG

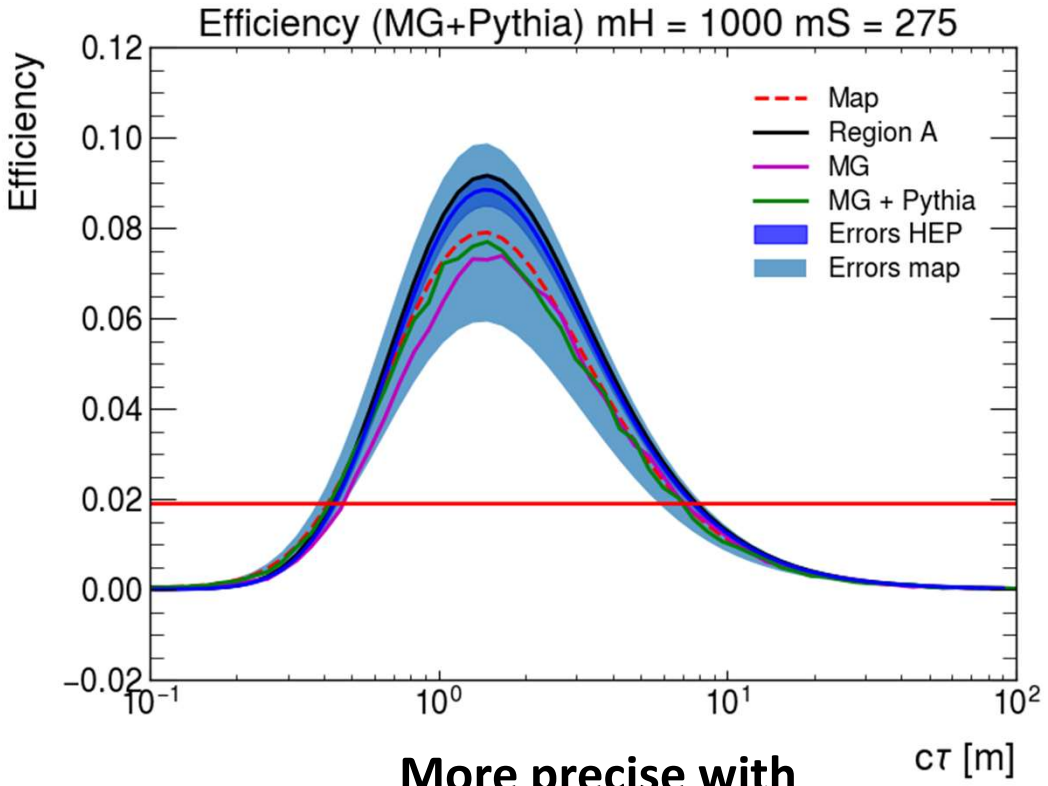
MG + Pythia

ATLAS

Event Generation - Comparison

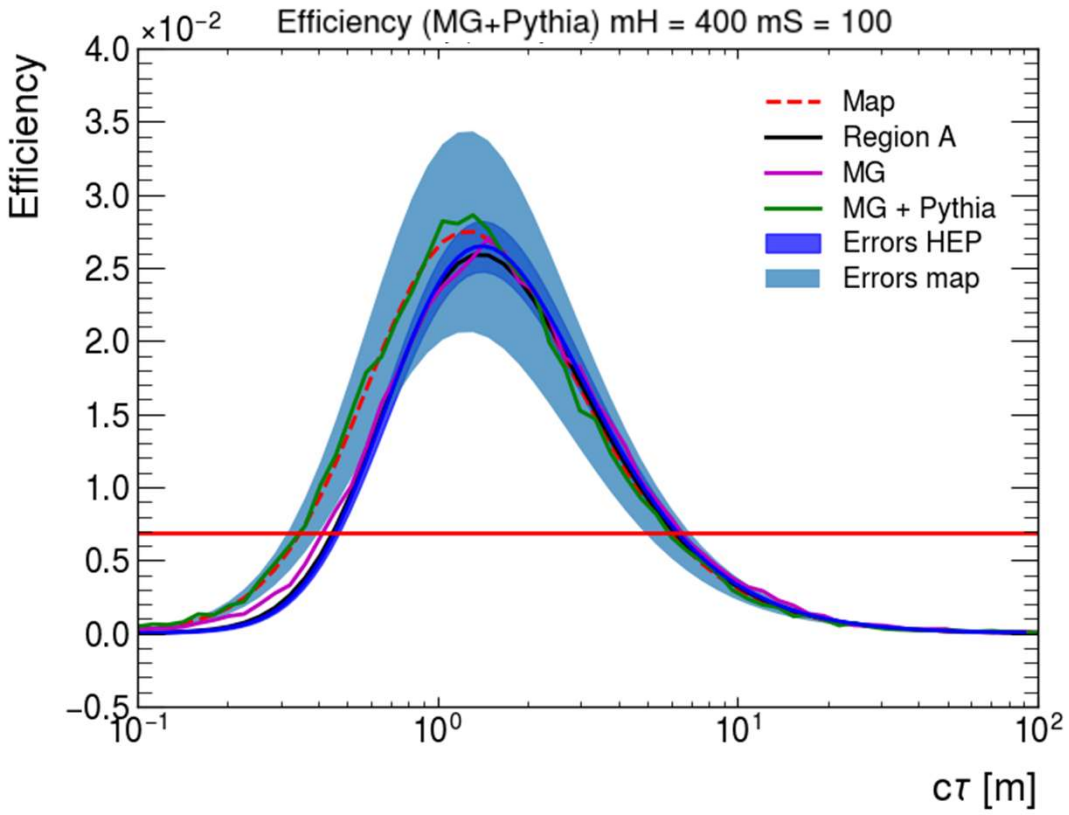


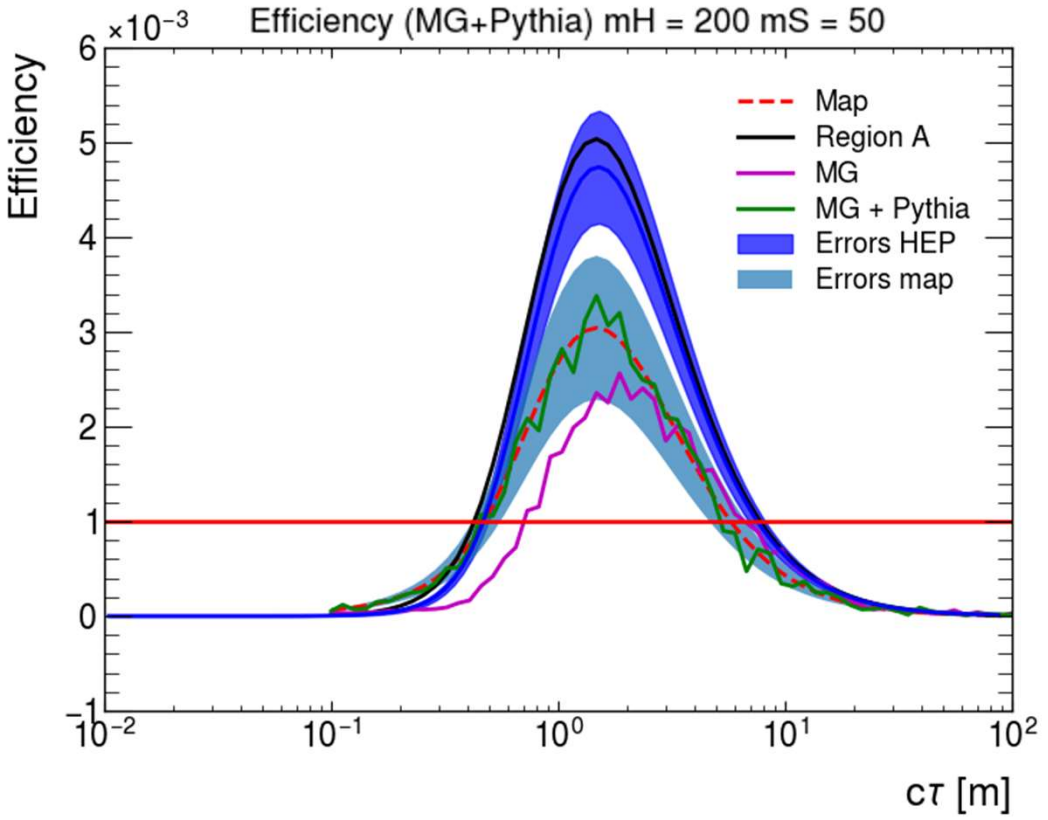
Very similar !



More precise with the hadronization

Event Generation - Comparison





Loss of presicion for Low energie samples

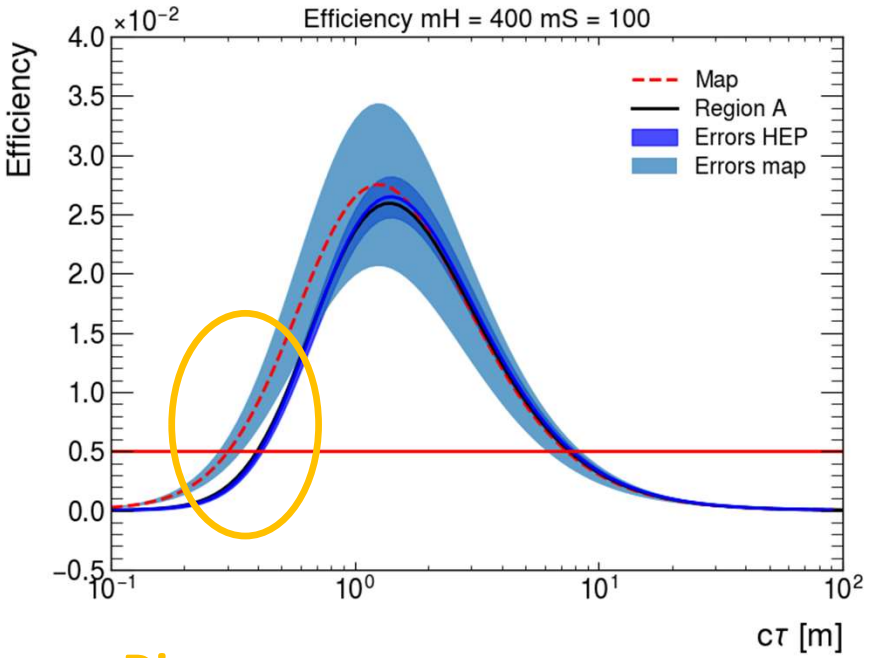
Lesson from validation

Event generation are hard for an external user :

- The benchmark model is **not** easily accessible and **not** described well.
- Lifetimes has to be **changed** by **hand**.
- Internal parameters of the run are **changed** and not documented (masses, width calculation, cuts).

Lesson on the map :

- The full search uses a simultaneous **S+B** fit of ABCD regions, but these studies used just **region A** results: this is clearly a fine approximation!
- The limits set on the map seems to work at high lifetimes but are maybe **too loose** at low lifetimes.



Discrepancy

Thanks for listening

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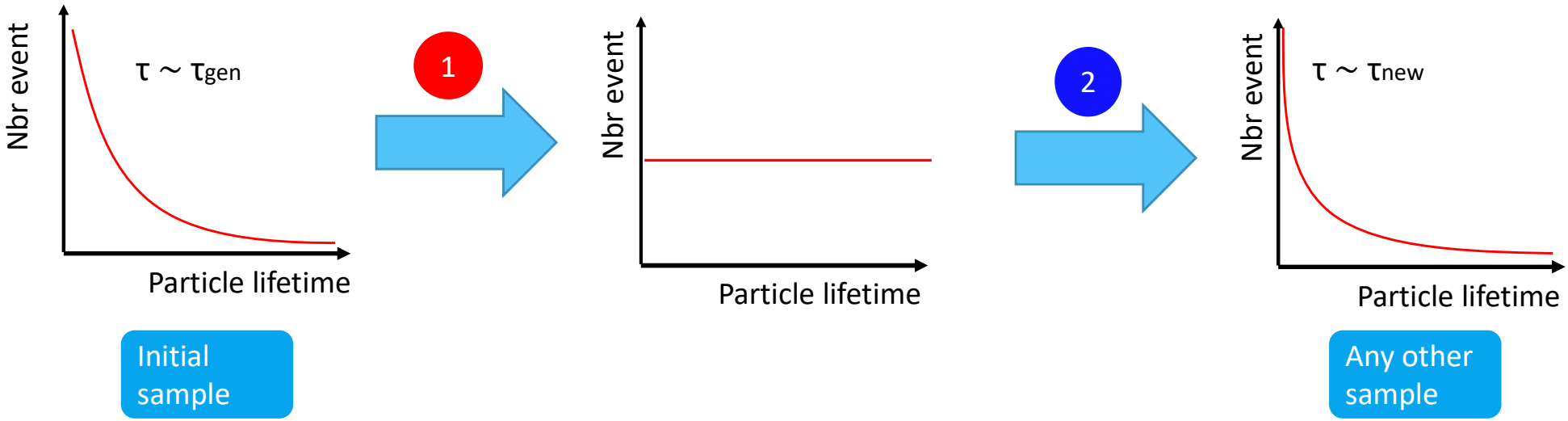
Backup - The weight

arXiv:2203.01009

$$w(t) = \frac{\tau_{\text{gen}}}{\exp(-t/\tau_{\text{gen}})} \cdot \frac{\exp(-t/\tau_{\text{new}})}{\tau_{\text{new}}}.$$

1 2

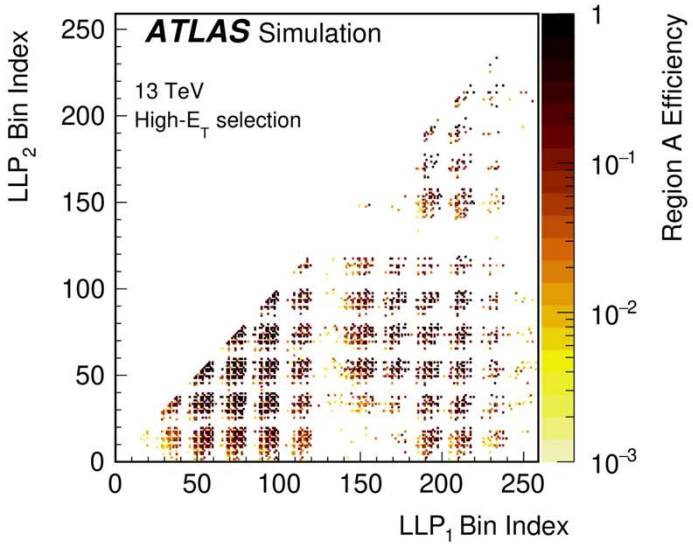


Initial sample

Any other sample

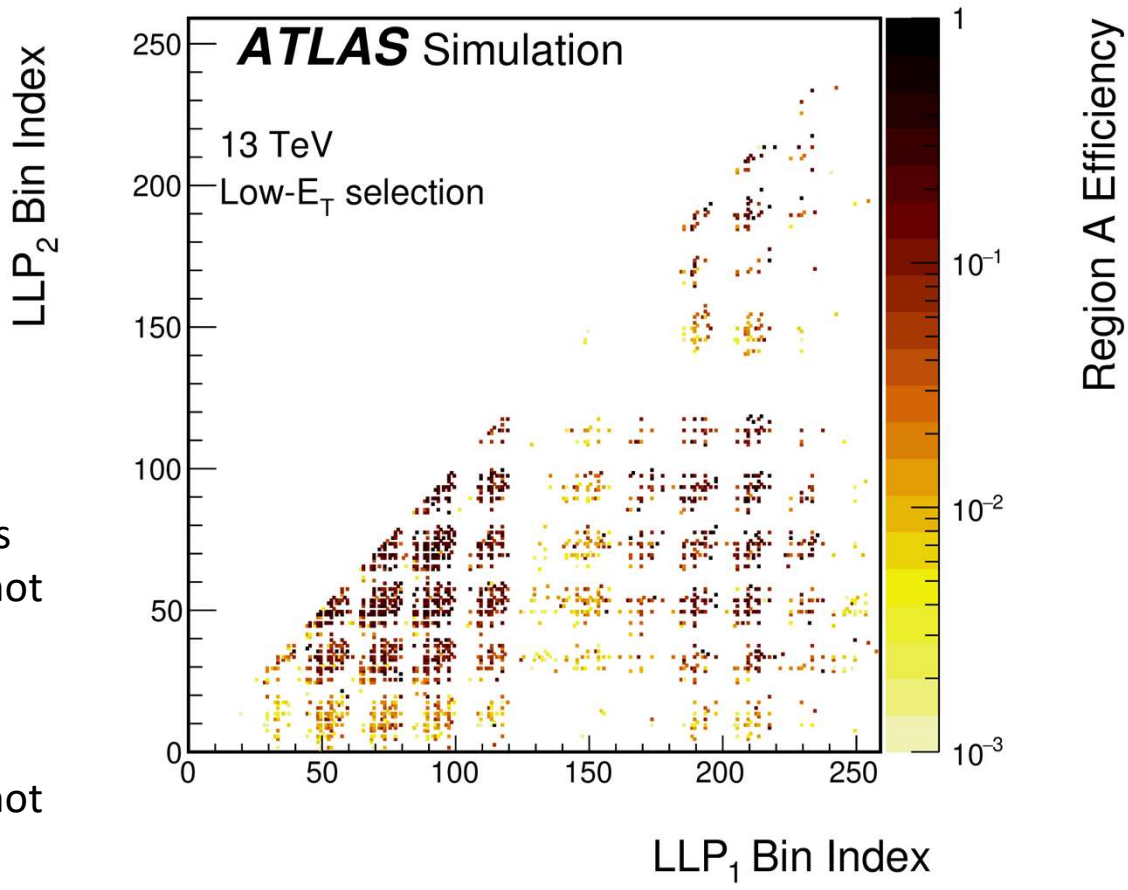
Backup - The map

arXiv:2203.01009

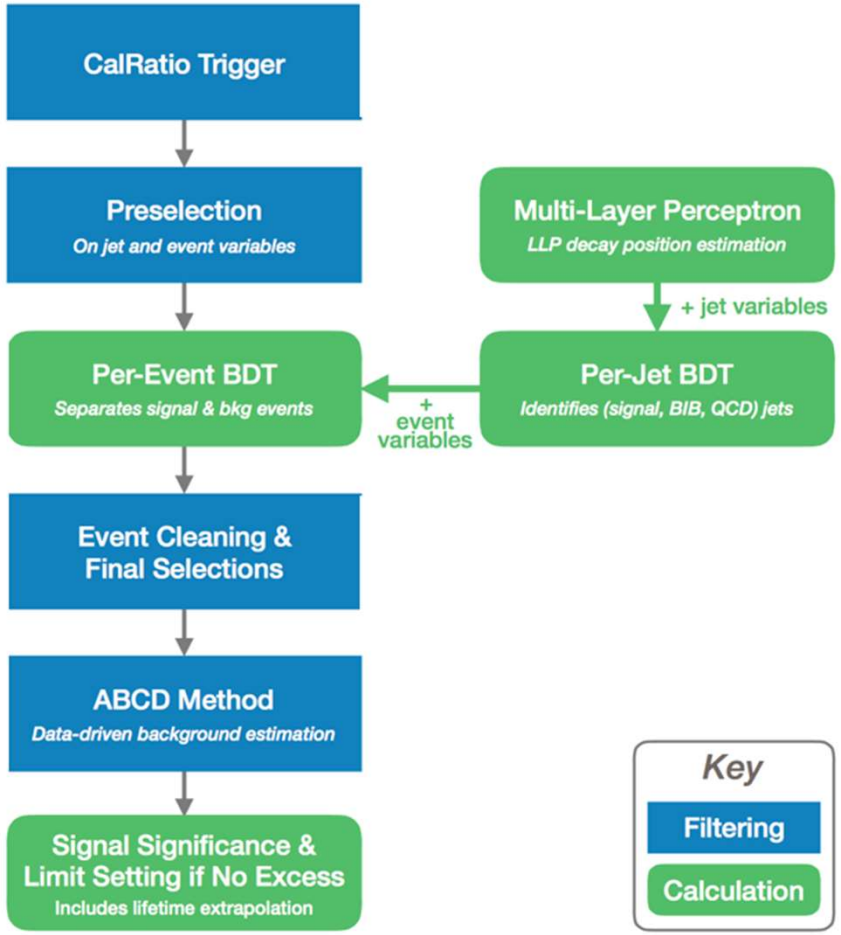


High-ET selections : for efficiencies above 0.5%, results typically accurate to **around 25%**, below they should not be used for re-interpretation.

Low-ET selections : for efficiencies > 0.15%, results typically accurate to **around 33%**, below they should not be used for re-interpretation.



Backup - Trigger



The Trigger [L.Corpe].