About Photon Search at Low Energies and SD433 characterization

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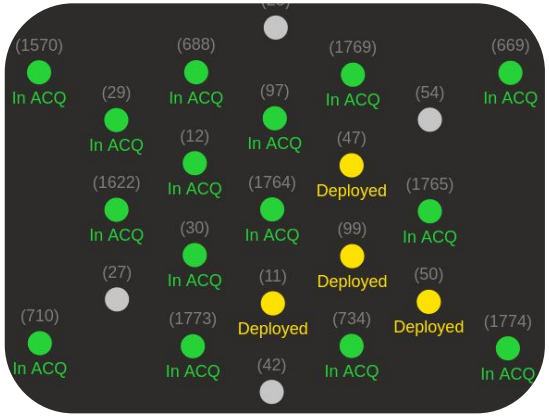
HIRSAP Annual Meeting

Recap

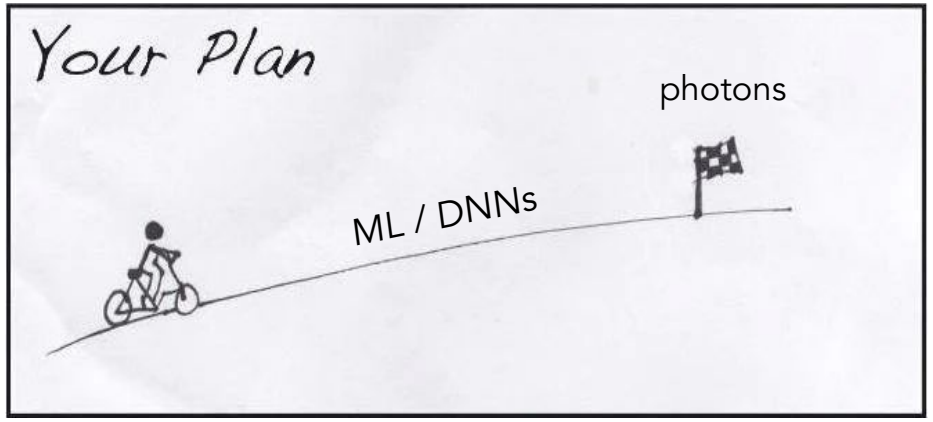
Goal: SD433+UMD Photon Search

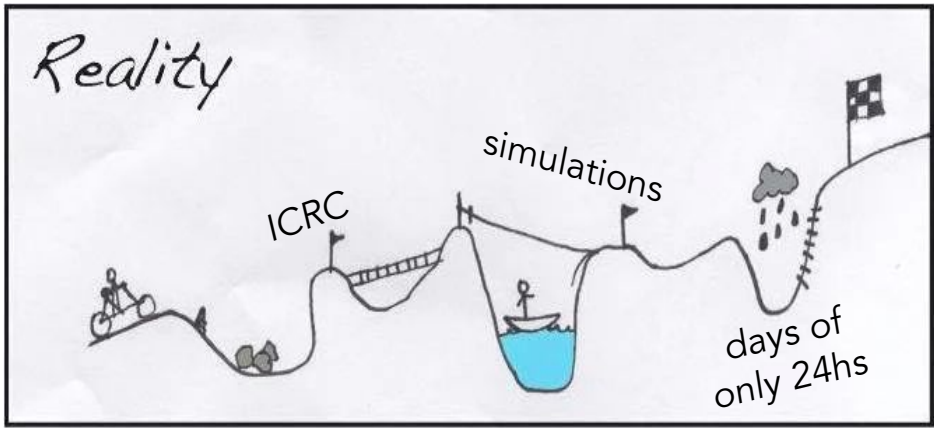


Energy Range: lg(E/eV) ∈ (16.X, 17.3)

Personal Goals:

- Increase exposure using a general and robust model
- Acceptance of the study by the Collaboration





A little bit of ML/DNNs for Photon Search

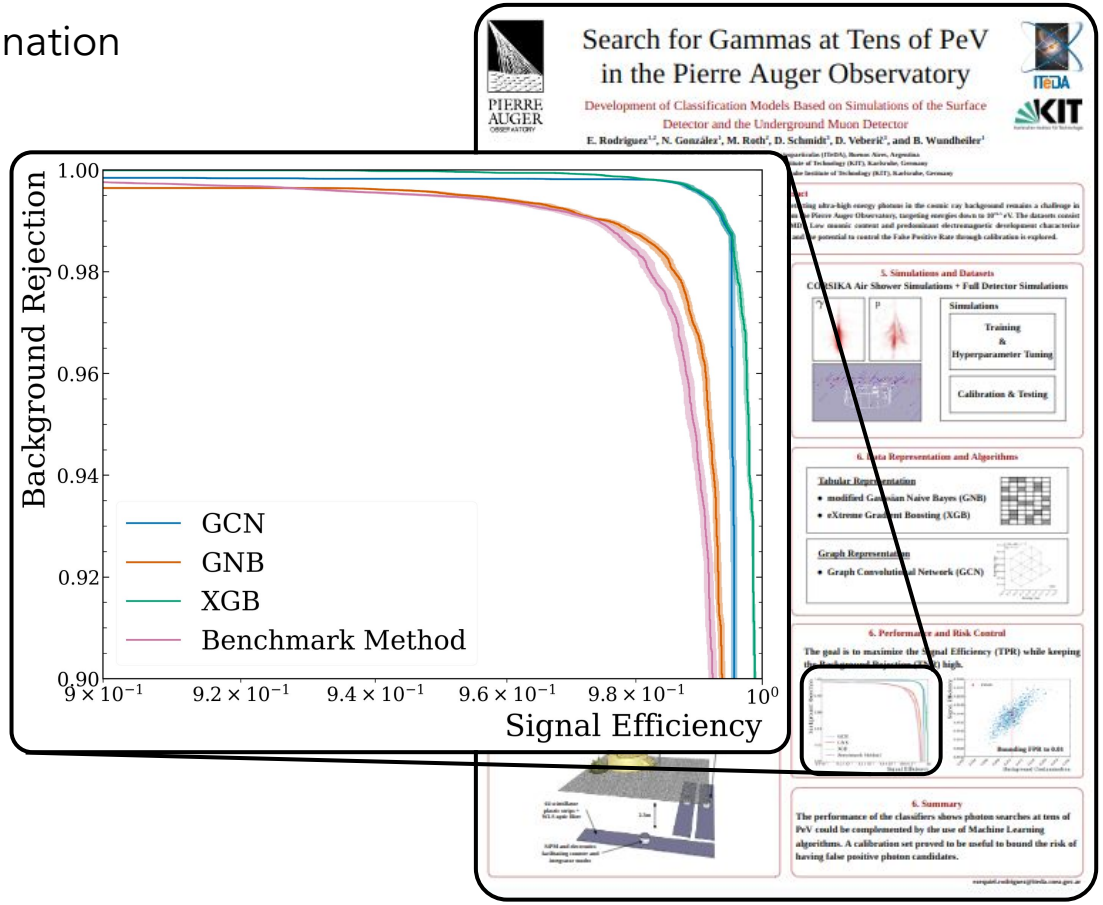
Optimism to enhance photon-hadron discrimination
(ML Task Call, March 2023)

Explored:

- Bayesian Models
- Tree-Based Boosted Models
- Simple Graph Neural Networks

Initial tests to constraint FPR in testing sets
(KITeDA Call, August 2023)

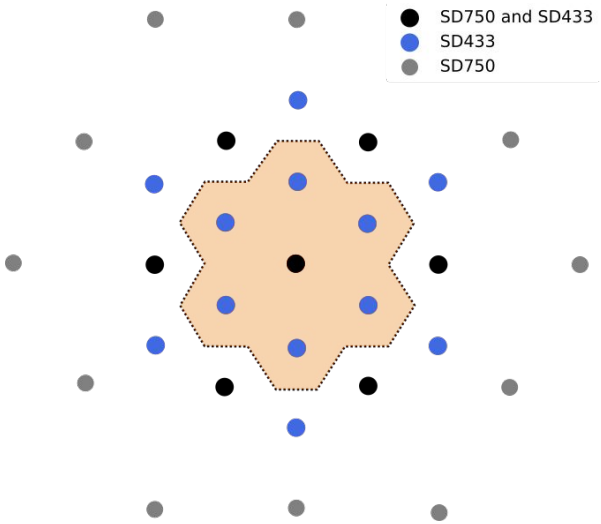
Informal poster presentation in
Carl-Zeiss-Stiftung Summer School
(Heidelberg University, August 2023)

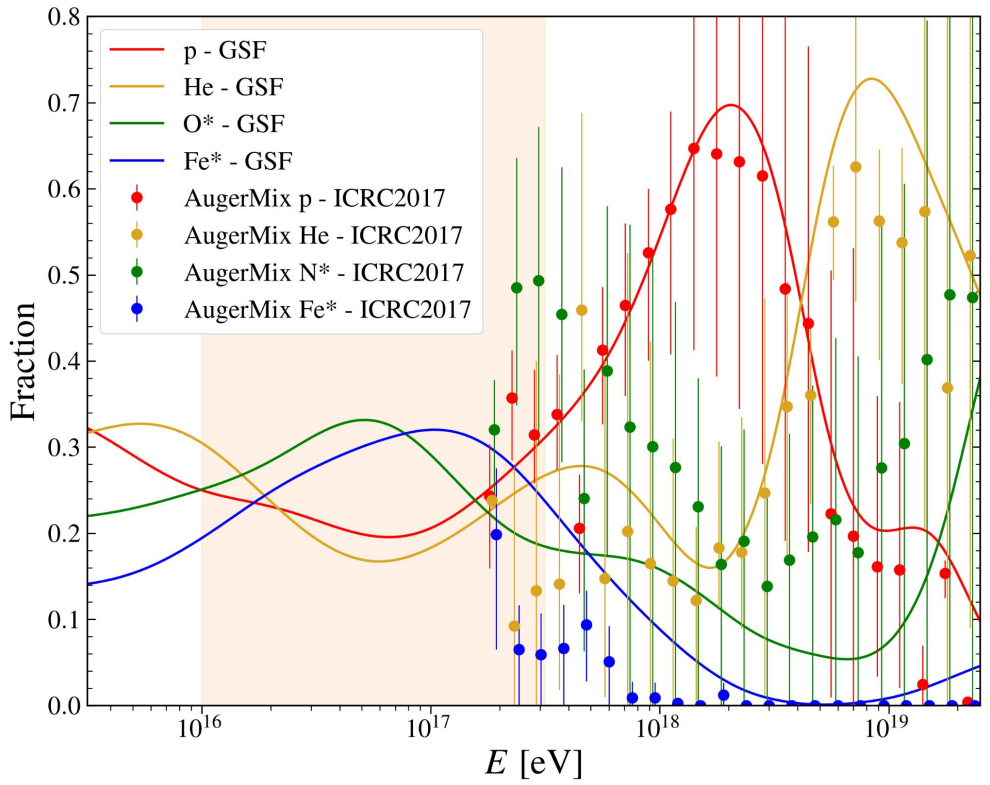


A lot of SD433 Efficiency and Energy Response

Latest update on past Collaboration Meeting (Spectrum Session)

- SD433 → lowest energy range array
- No FD measurements
- Emphasis on Composition

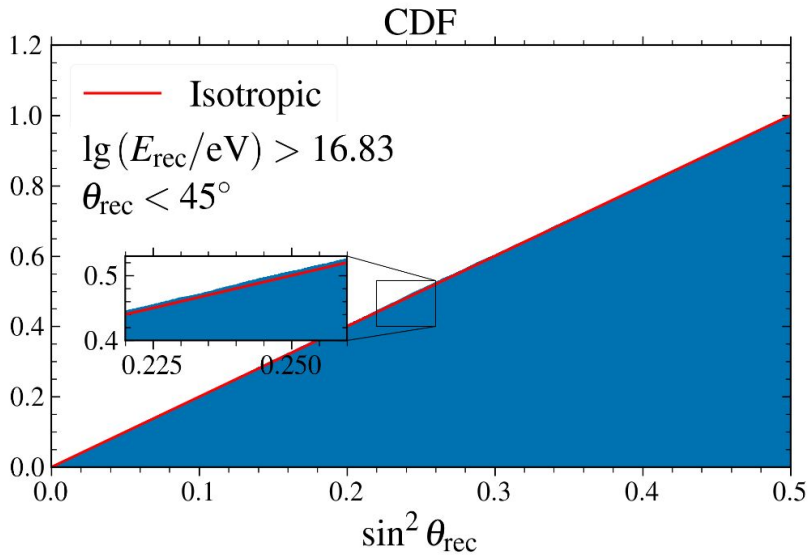


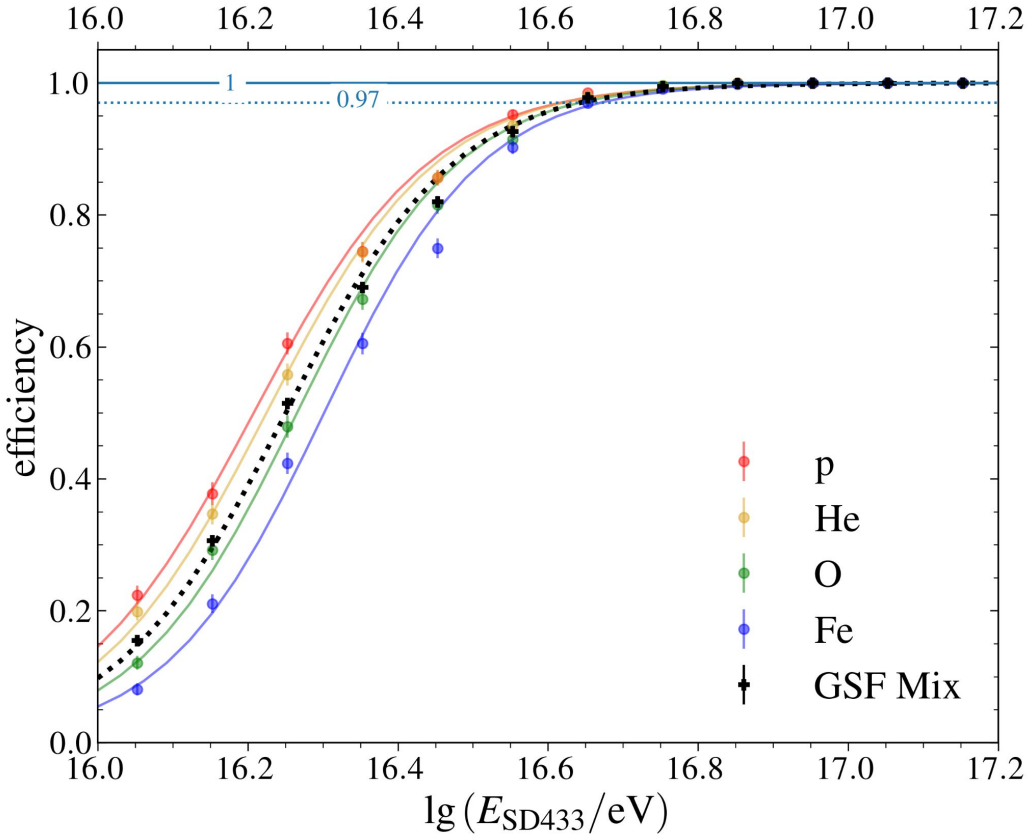


SD433 Efficiency

Detector Efficiency study with simulations.

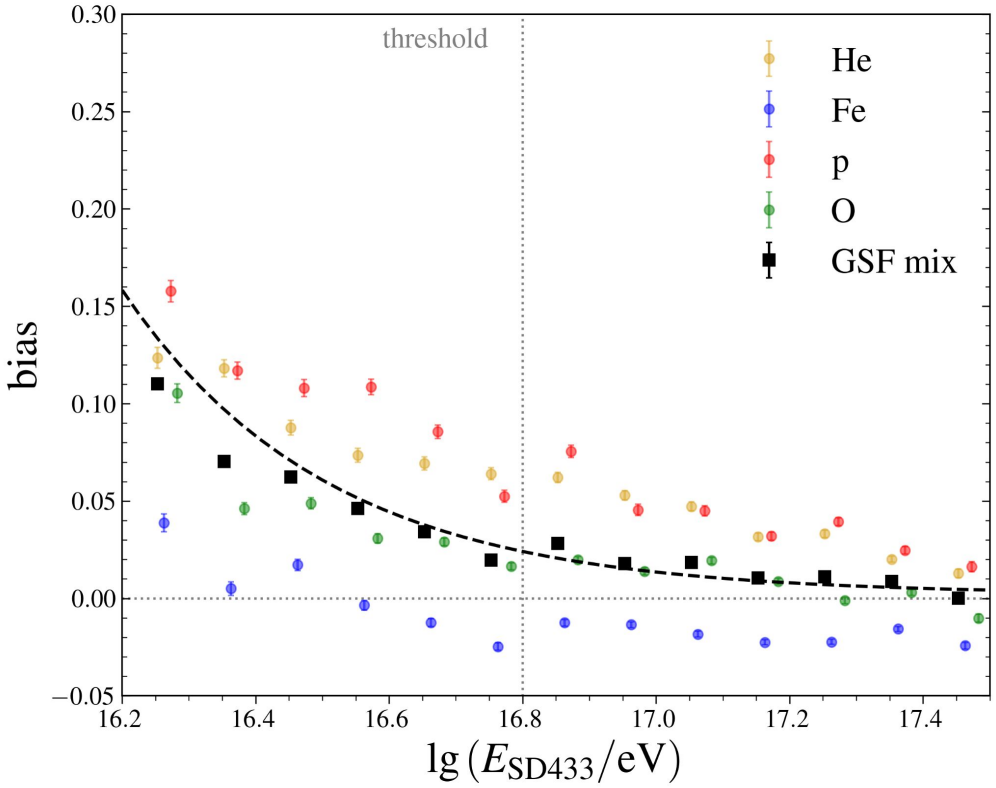
Full efficiency threshold definition based on self-consistency checks with data.

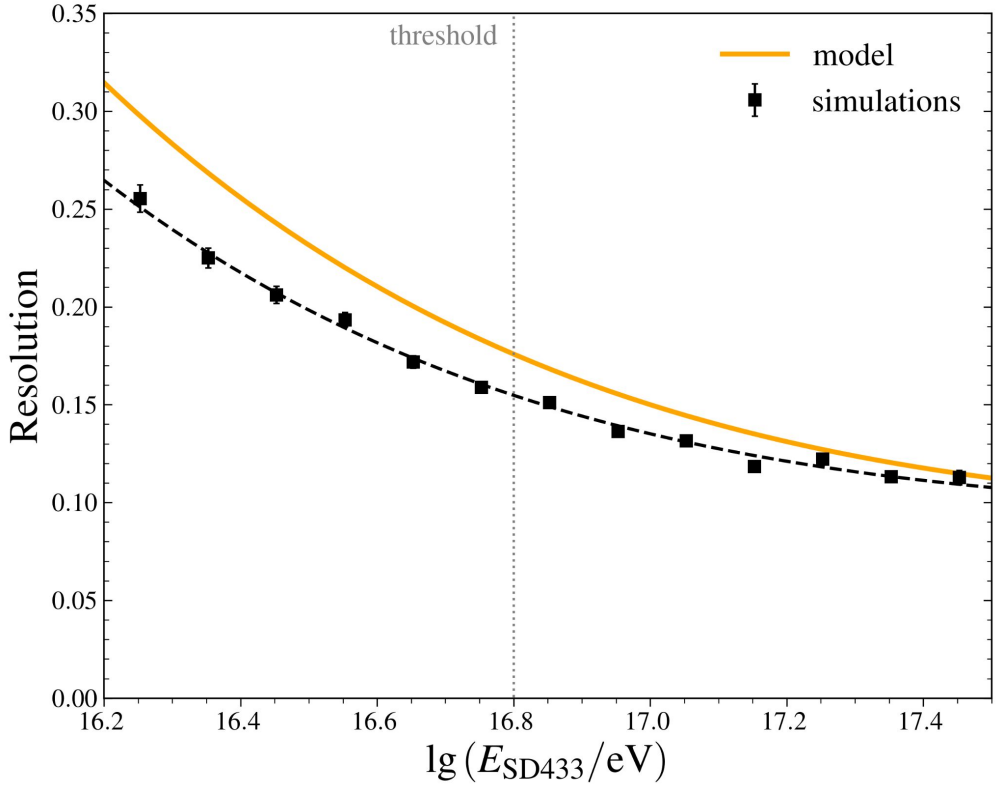




SD433 Energy Bias and Resolution

Characterization of the SD433 energy response.

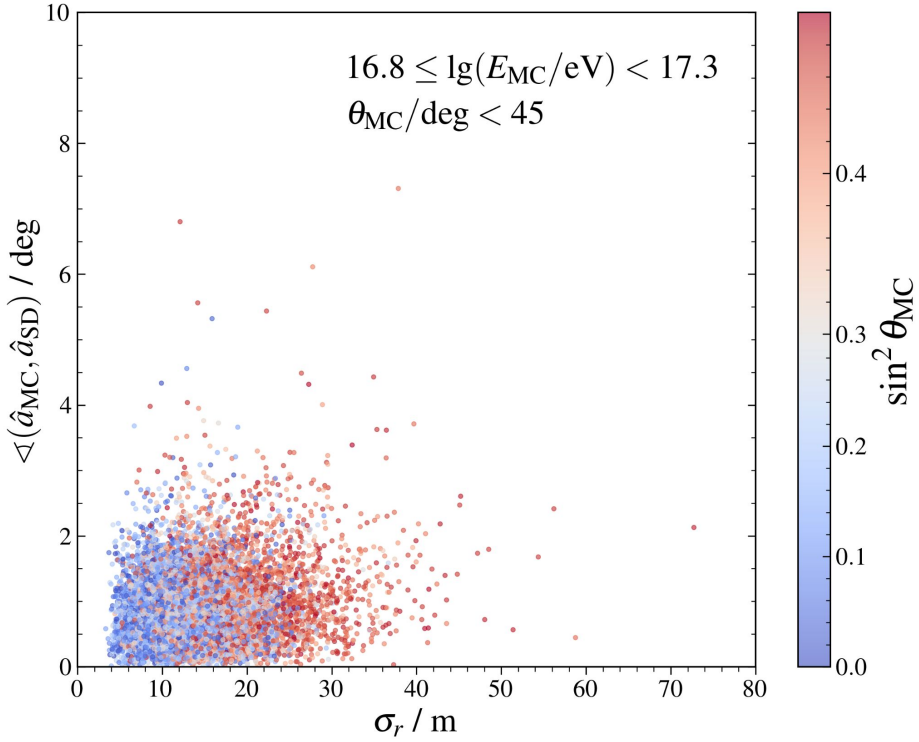




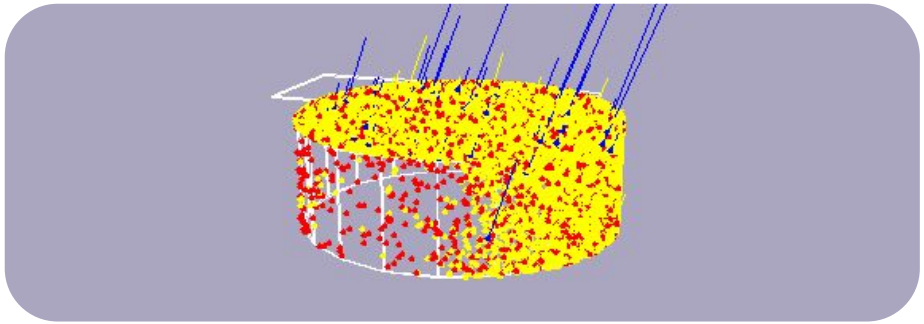
Photon Simulations Quality Checks

High- and trace-level quality validation of photon simulations (Foundations session of latest Coll. Meeting)

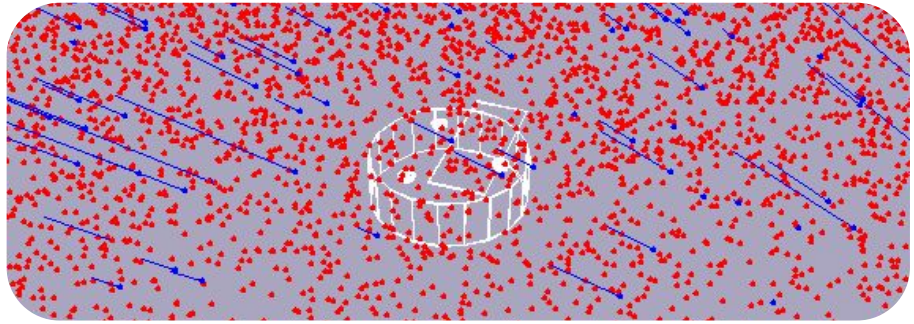
Strategies to catch artifacts on the way.



Pure SD simulation



SD + UMD simulation



Opening the game

Standard Apps

- Sd433 {Sim/MCReconstruction/SimRec}
- MdSd433 {Sim/MCReconstruction/SimRec}

} E.R. and LIP team

- MdSdInfill {Sim/MCReconstruction/SimRec}

} AMIGA team

Bootstraps for Phase {I, II} and {w,wo} dense rings.

Simple but useful validation in CI

MdSdReReconstruction: Offline to ADST Streaming validation

Next Steps

Full focus on photon search.

- Definition/training/testing of the discrimination model
  - Include raw MD trace
  - Include SD trace (not only integrated signal)
- Stress the model to test robustness
- Understand the model (XAI)
- Lots of discussions within the ML and Neutral Particles

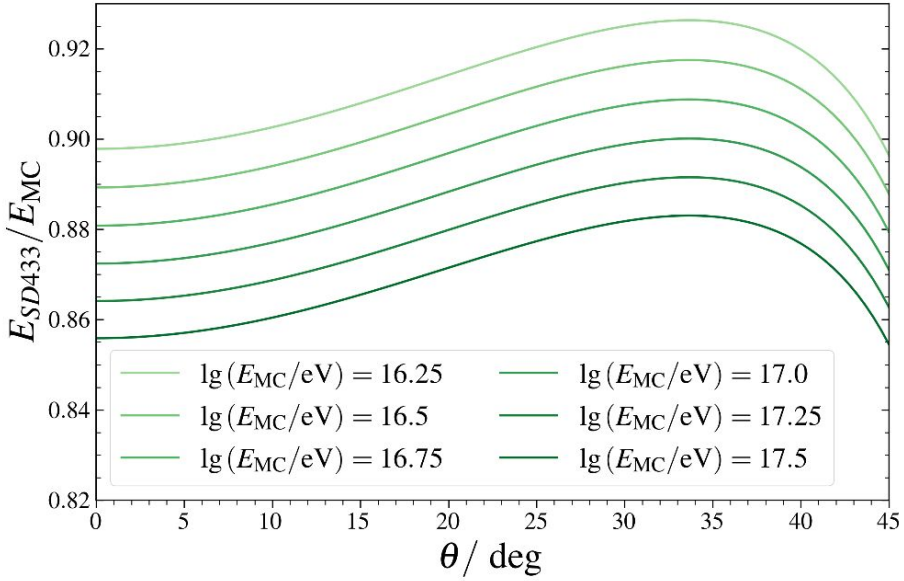
  Tasks are expected

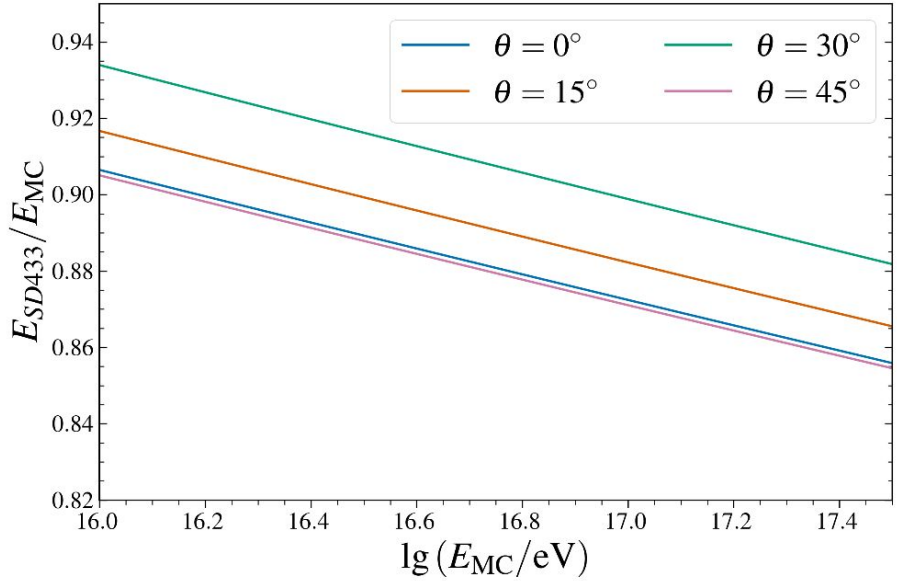
Backup

Energy Scales

$$E_{MC} \xrightarrow[\text{cal}_{\text{MC}}]{} S_{30,\,\text{MC}} \rightarrow S_{300} \rightarrow S_{30,\text{data}} \rightarrow E_{\text{SD433}} \quad \text{i.e.} \quad E_{\text{SD433}}(E_{\text{MC}}, \theta)$$

Same CIC and energy calibration implementations have been run for all steps.

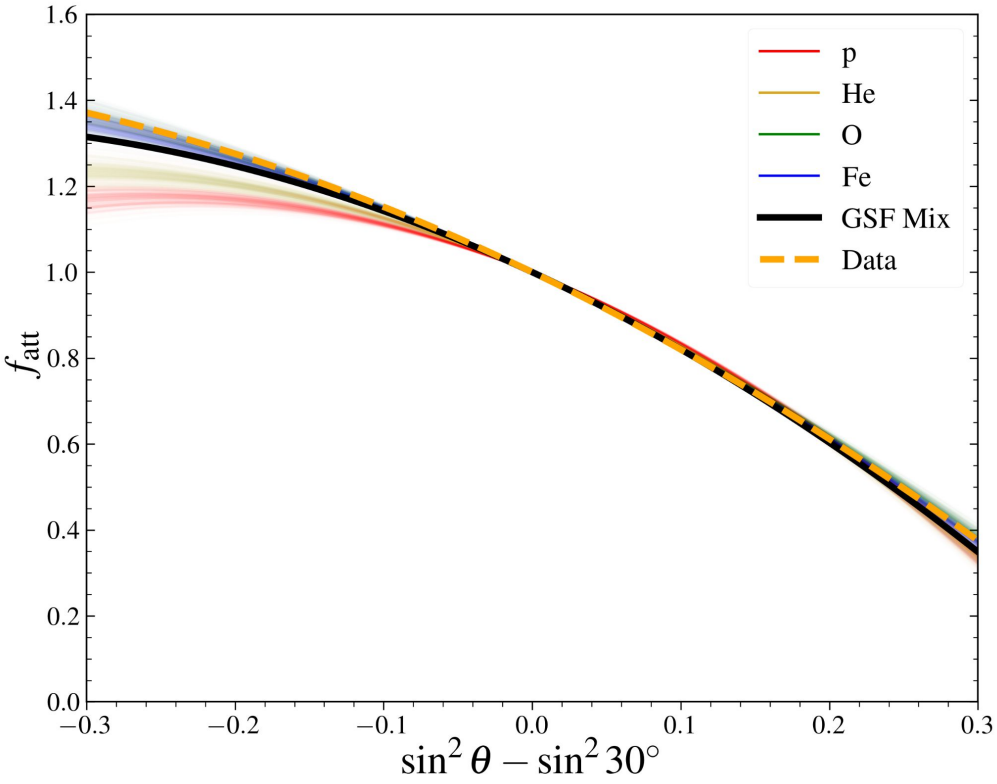


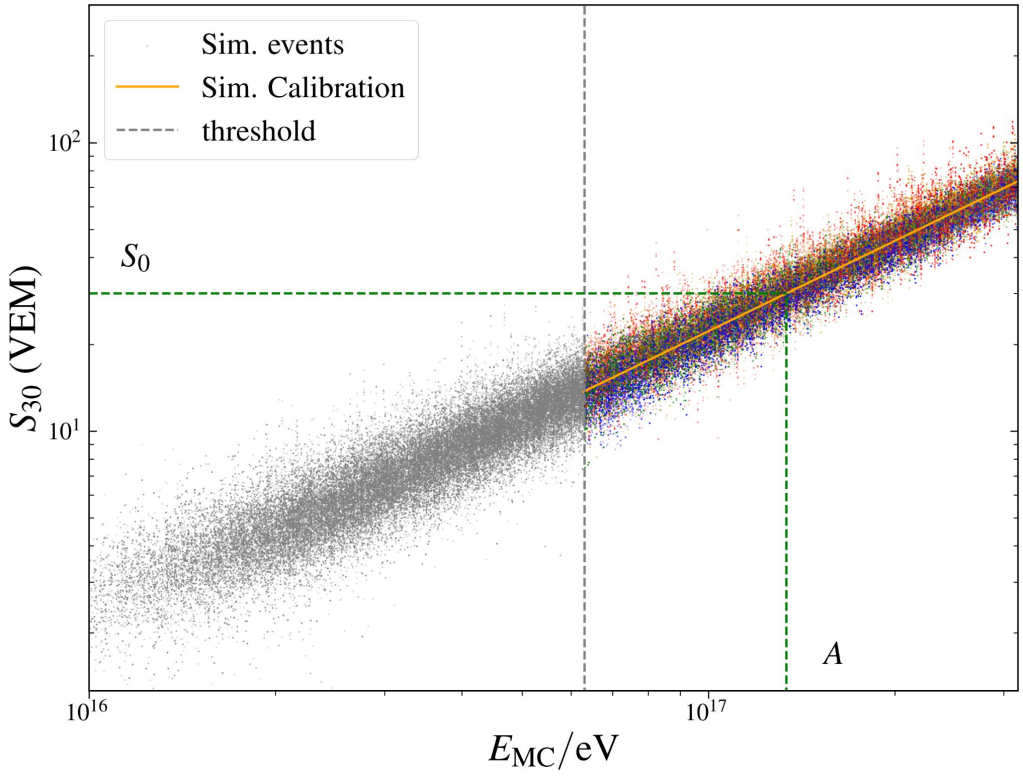


*Energy Scale transformation taken from A. Coleman, GAP2018-045

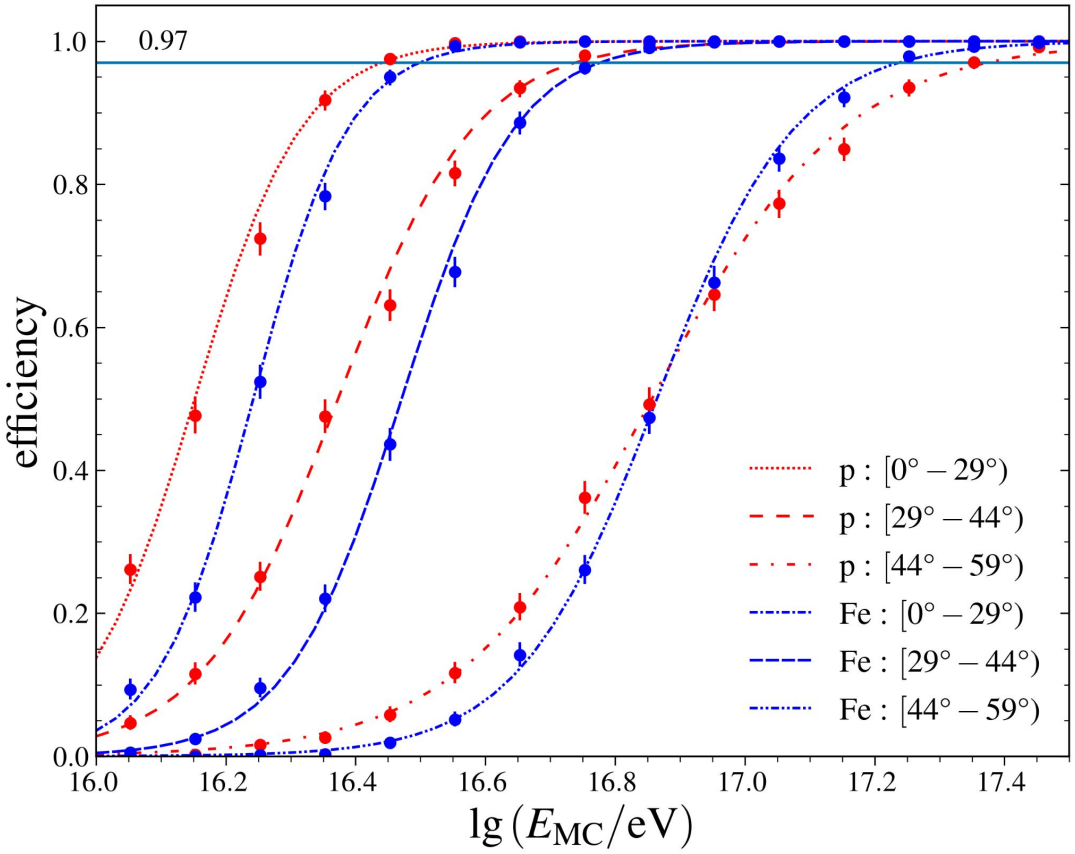
CIC and Calibration

Consistent code implementation for simulations and data.



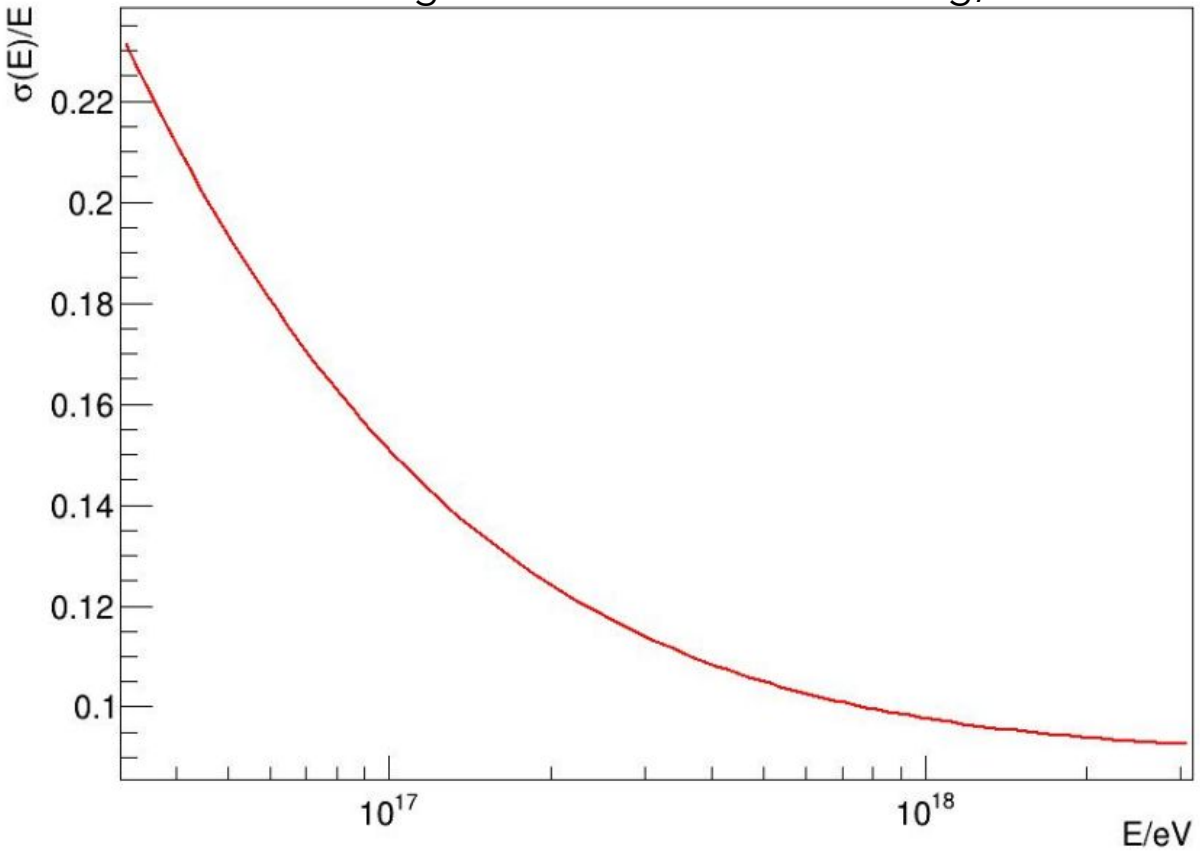


Efficiency Dependency with Mass Composition and Zenith Angle



Previous Resolution Model

D. Ravignani. Collaboration Meeting, Nov 2022



$$R_{433}^2 = R_{sh}^2 + \frac{R_0^2}{E/E_0}$$

$$R_0^2 = 12\%$$

$$R_{sh}^2 = 9\%$$

$$E_0 = 10^{17}\,\mathrm{eV}$$

Standard Thinning

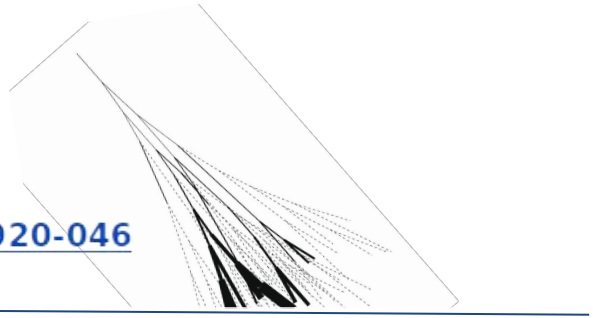
Secondary particles may be (re)weighted according to its kinetic energy

$$w_i = \frac{w_i'}{F_i} \qquad F_i(E_i) = \begin{cases} 1 & E_i \geq E_t \\ \dfrac{E_i}{\sum_k \tilde{E}_k} & \text{otherwise} \end{cases}$$

Maximum allowed weight for each component

$$w_{max,EM} = \frac{E_t}{GeV} = \frac{E_0 t_f^{-1}}{GeV}$$

$$\varepsilon = \frac{w_{max,EM}}{w_{max,\mu}} = 100$$



S. Saffi, **GAP2020-046**

E. Santos, A. Yushkov, **GAP2018-043**

Napoli-Praha library settings

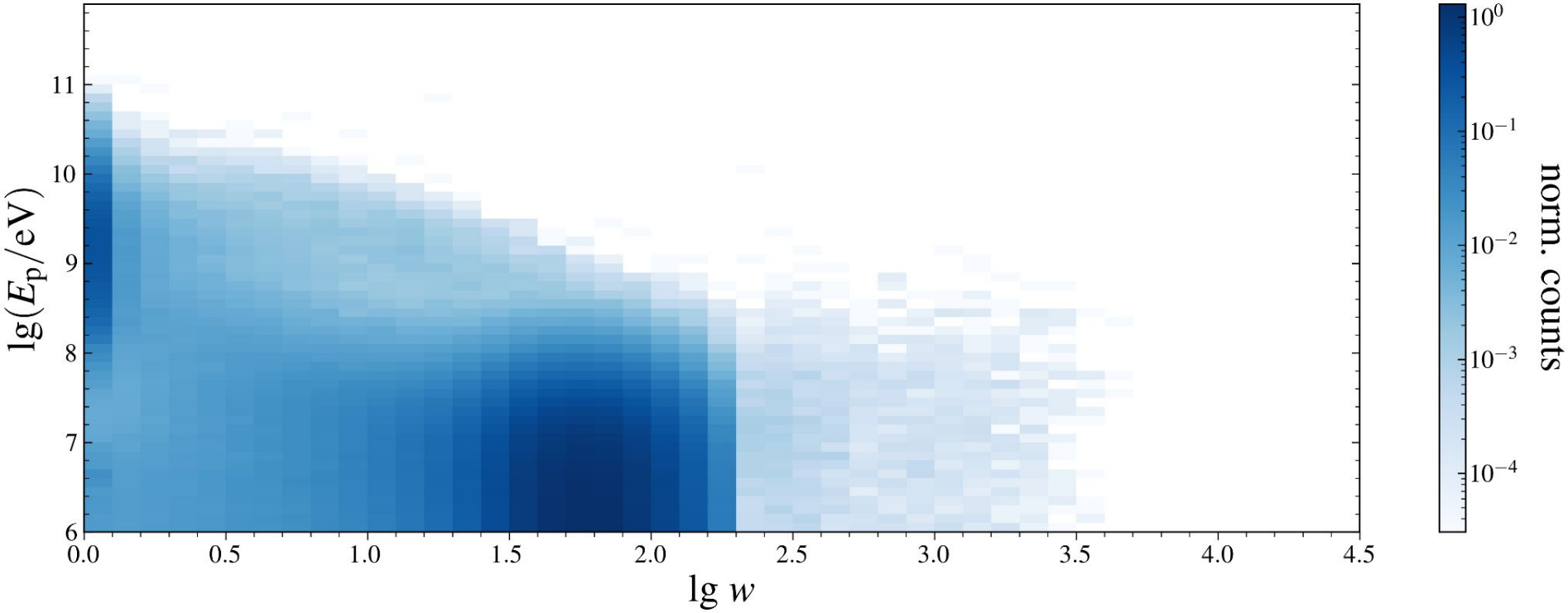
$$t_f = 10^{-6}$$

$$\varepsilon = 100$$

E_0 / eV	E_t / GeV
10^{17}	100
10^{18}	1000
10^{19}	10000

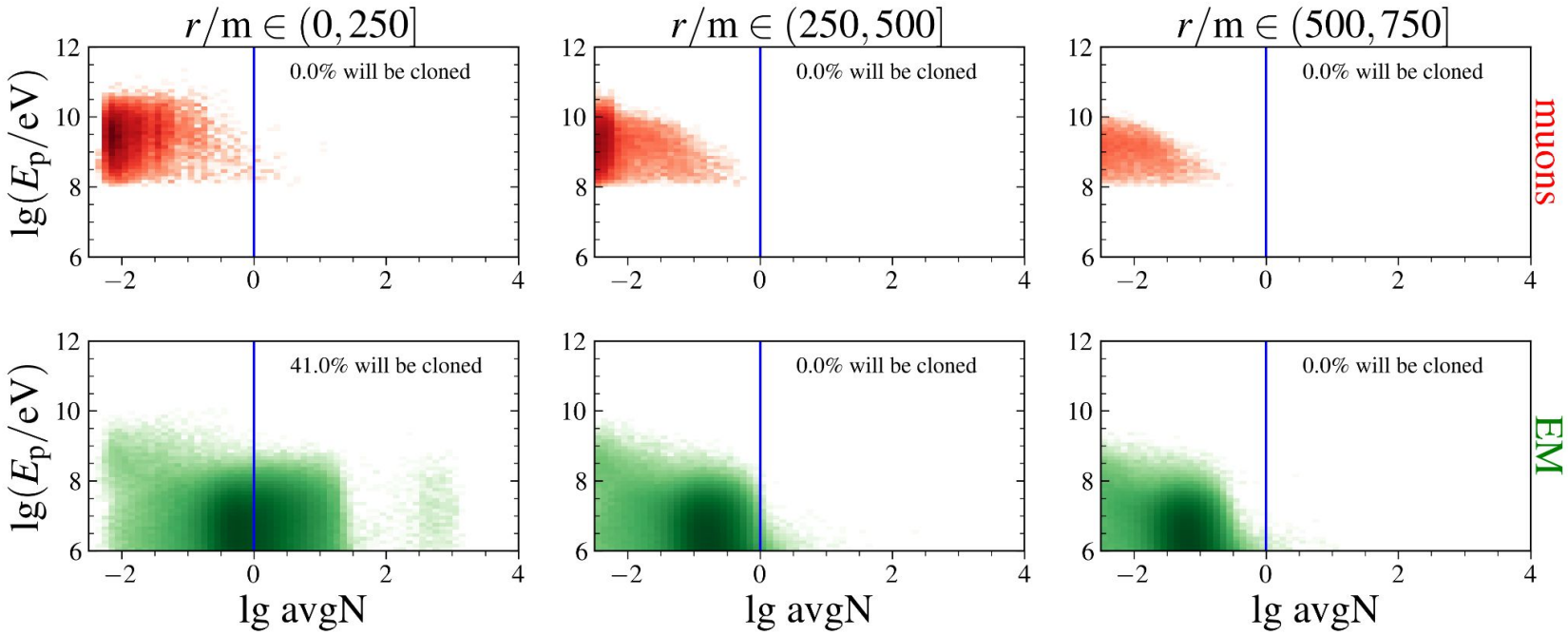
Standard Thinning - $16.8 \leq \log(E_0/eV) < 17.3$ & $\theta < 45°$

Bulk of CORSIKA weights values around 10^2 → 100 times smaller than weights in photons showers with $E_0 > 10^{19}$eV



Un-thinning - SD rescaled weights

Before injection to stations, CORSIKA **weights are rescaled** by a **factor** depending on **effective area**.*
The **new weights** are interpreted as the **average number of particles** reaching the sampling area.

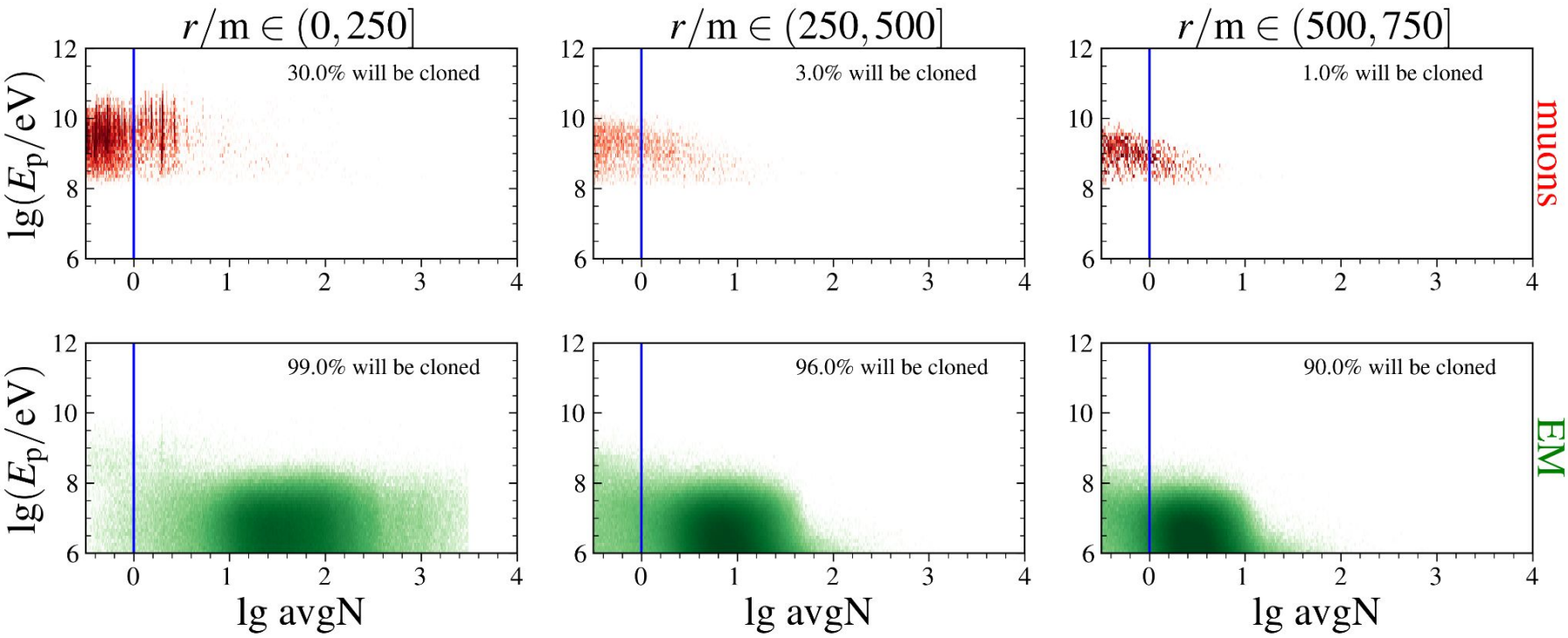


BLUE LINE → cloning threshold

* S. Saffi, B. Dawson, J. Bellido, GAP2015_086

Un-thinning - SD + UMD rescaled weights

Because the **effective area** depends on the **injection volume**, simulating the **UMD** makes a difference.*



More clones close to the shower axis, specially EM particles.

Tracking potentially “pathological” traces

/offline/Modules/SdSimulation/CachedShowerRegeneratorOG/CachedShowerRegenerator.cc

```
unsigned int n = 0;
if (fUseWeightDependentResamplingArea && avgN < 1) {
  // see GAP-2015-086 for details
  if (!sInfo->IsInScaledArea(avgN, pPhi, pLnSqrR)) {
    DUMP_REJECT;
    continue;
  }
  // direct injection
  InsertValue(fShowerData->fWeightStat, sId, 1);
  n = 1;
} else {
  // cloning
  InsertValue(fShowerData->fWeightStat, sId, avgN);
  n = RandPoisson::shoot(fRandomEngine, avgN);
}
```

If (extreme condition/s):

flag the simulation;

<u>extreme conditions</u>

- max value for avgN
- max value for delay
- max value for r
- combination of these

<u>flag the simulation</u>

Stream to a log file.