Centro Brasileiro de Pesquisas Físicas

CBPF

Deep Learning for Shower Parameter Reconstruction in Water Cherenkov Detectors

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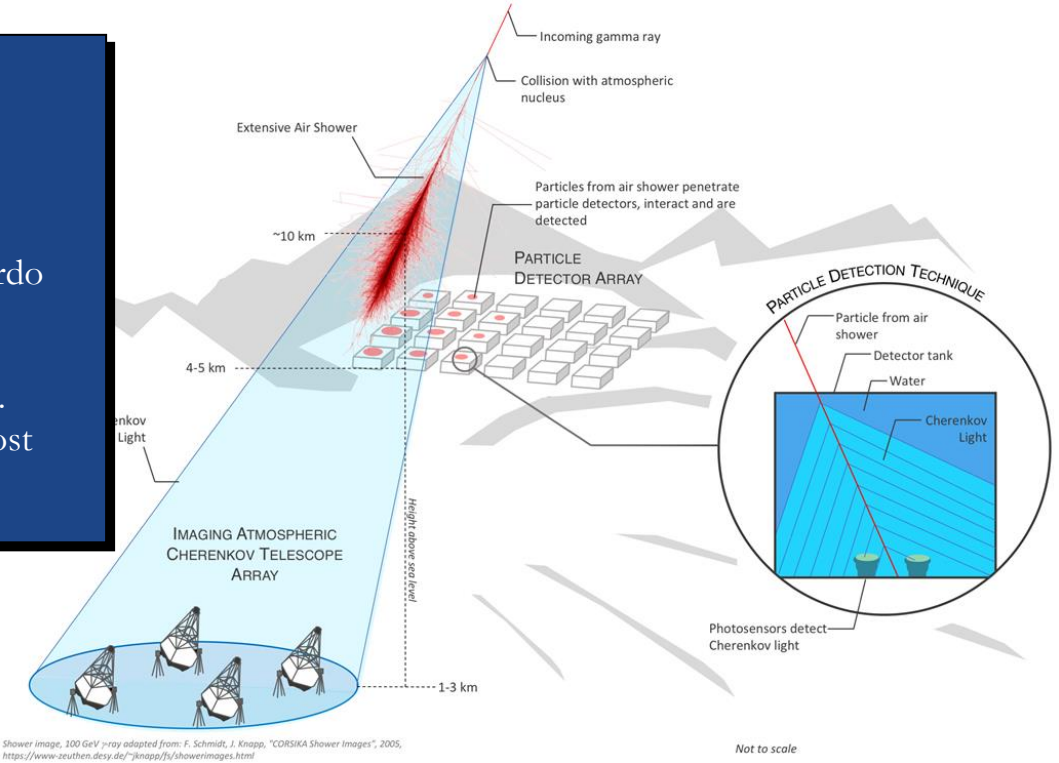
Motivation

Our work is developed in the context of water cherenkov detectors such as the ones proposed for The Southern Wide-Field Gamma-ray Observatory (SWGO).

Teams involved:
CBPF Team -> Clécio Bom, Luciana Dias, Ronald Shellard, Arthur Moraes, Ulisses de Almeida, Luís Mendes, Marcio Albuquerque.

LIP – Portugal Team -> Rúben Conceição, Bernardo Tomé, Mário Pimenta.

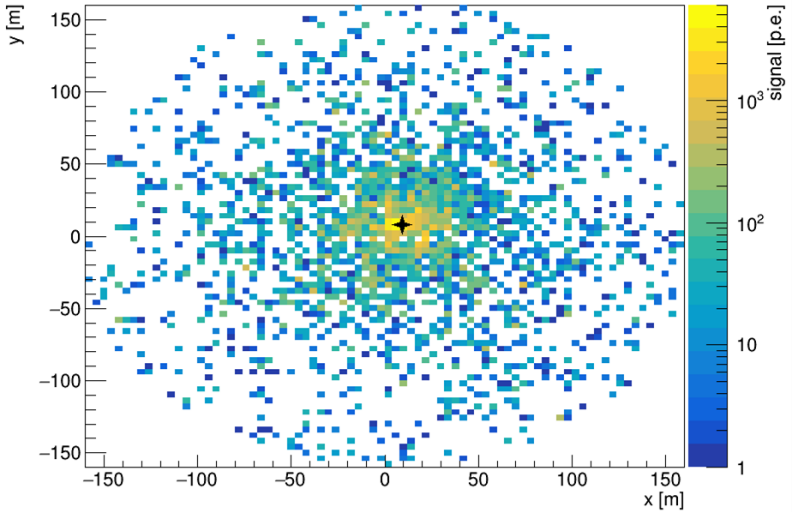
See a great talk about SWGO tomorrow by Ulisses. SWGO is future observatory that is estimated to cost around 60M dollars.



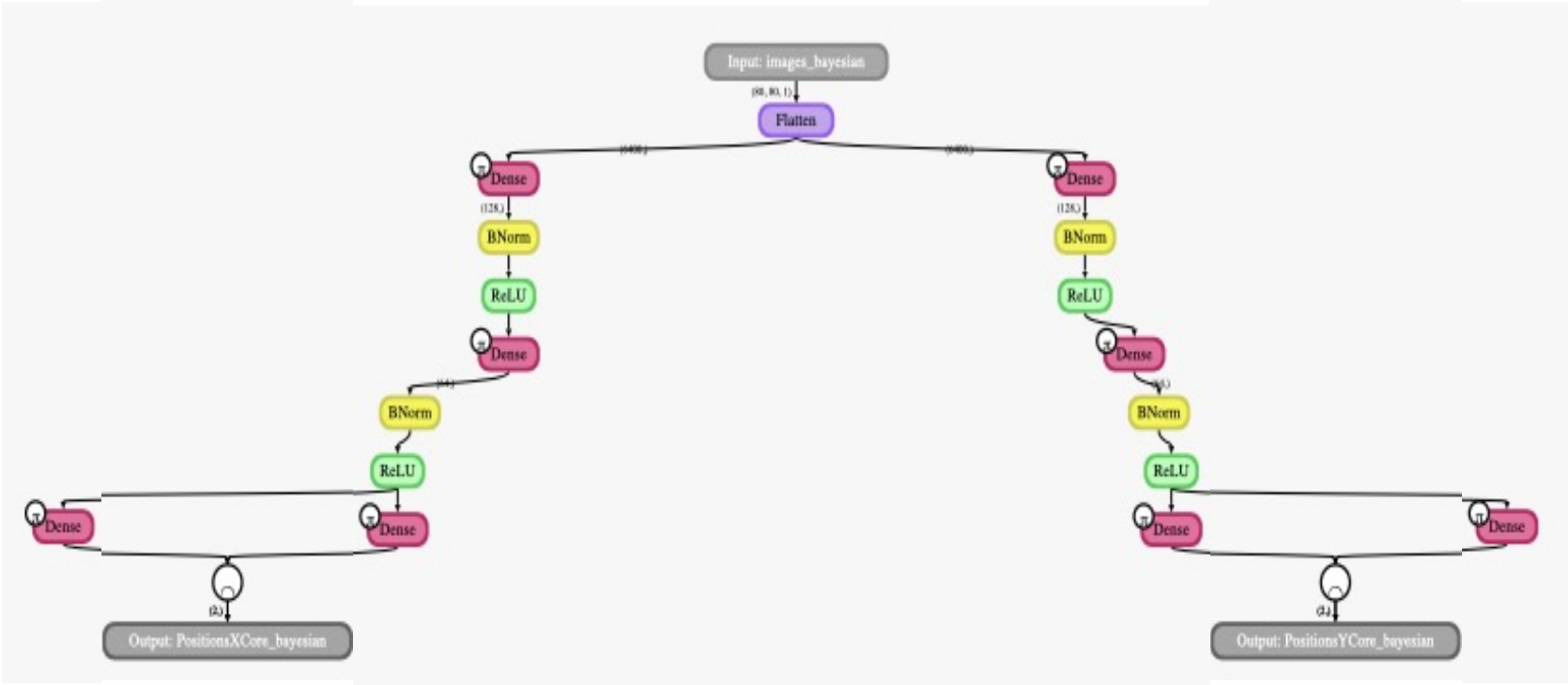
The Southern Wide-field Gamma-ray Observatory

Motivation

From shower simulations we made use of Deep Learning algorithms to perform regression problems. We are focusing on recovereing the x_core and y_core and ground Energy in particular when the event is near the borders or even if the core are beyond the detector limits.



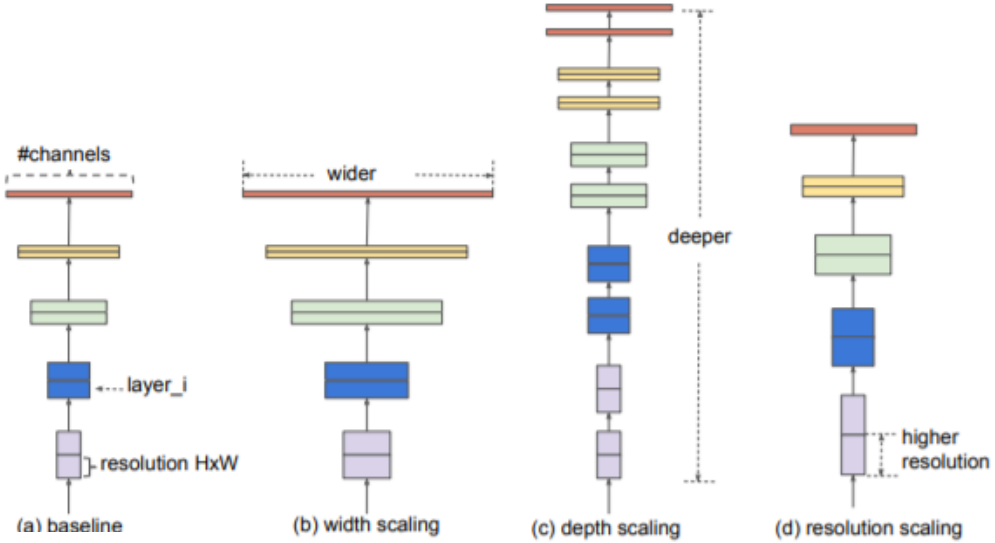
Network Dense

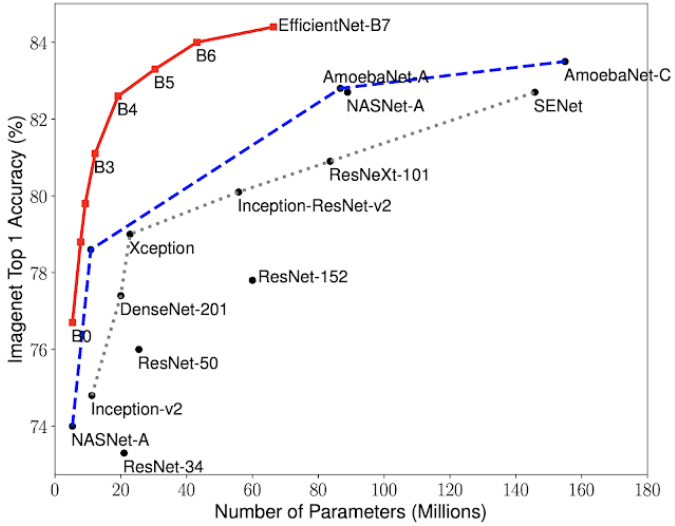


EfficientNet Model

Based on compound scaling method is to perform a grid search to find the relationship between different scaling dimensions of the baseline network under a FLOPS constraint.
This determines the appropriate scaling coefficient for each of the dimensions mentioned above.

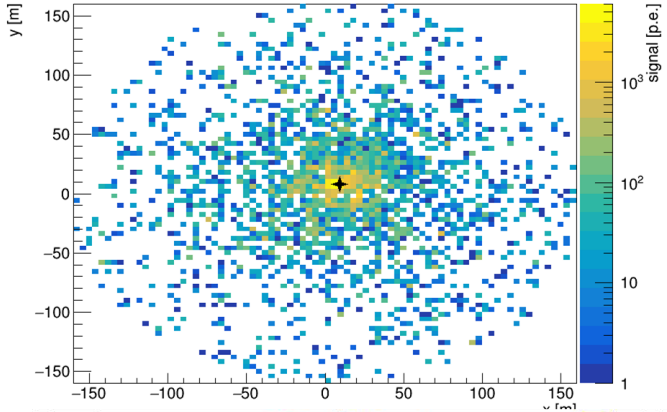
$$\text{depth: } d = \alpha^{\phi}$$
$$\text{width: } w = \beta^{\phi}$$
$$\text{resolution: } r = \gamma^{\phi}$$

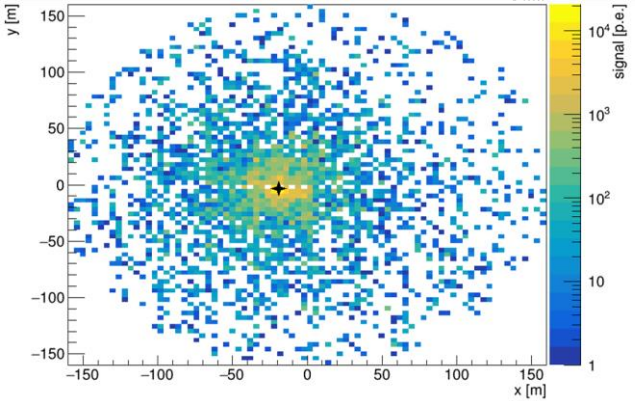


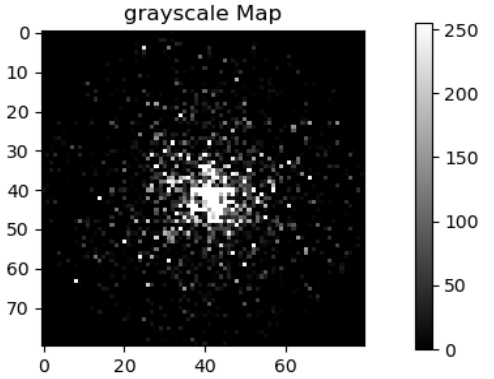


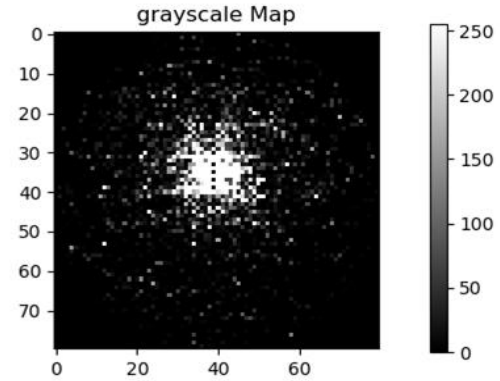
The optimization process is performed by an AutoML algorithm (MNAS).
The method search for performance with low complexity.

Dataset - core position far from borders

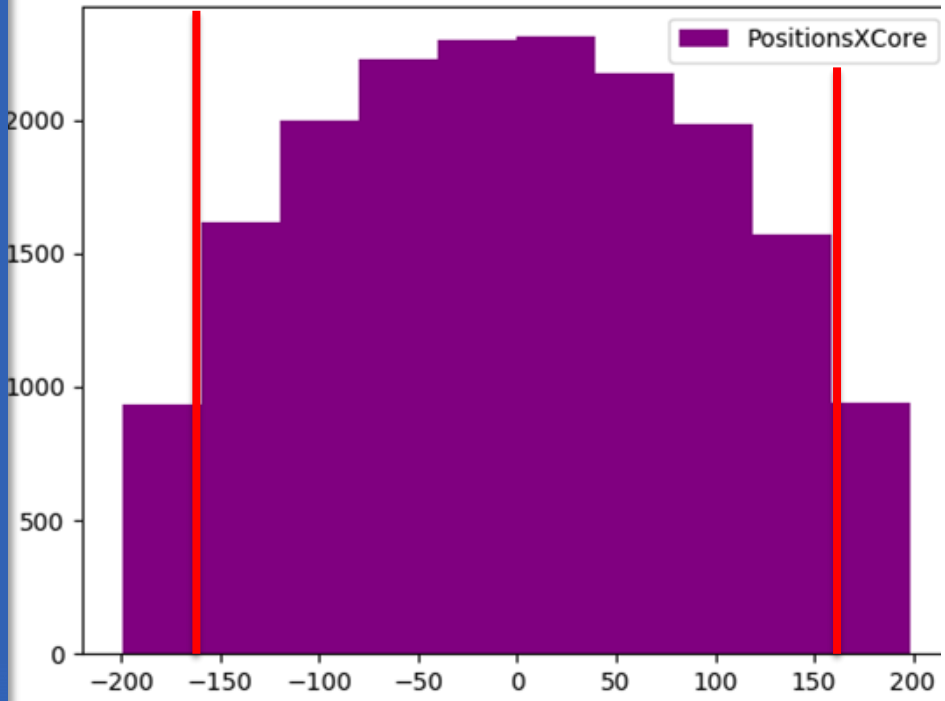


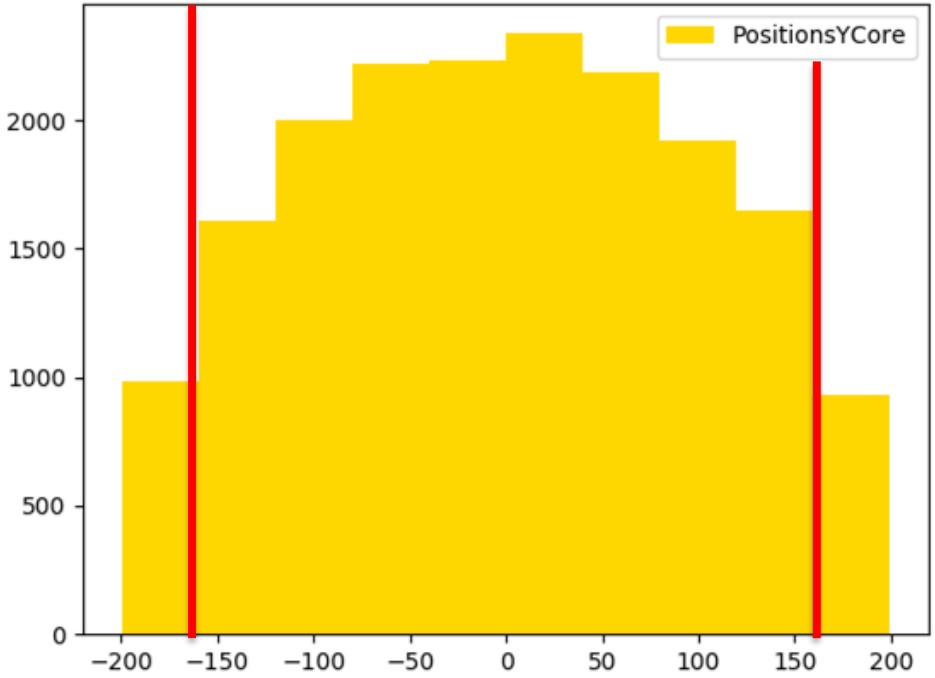




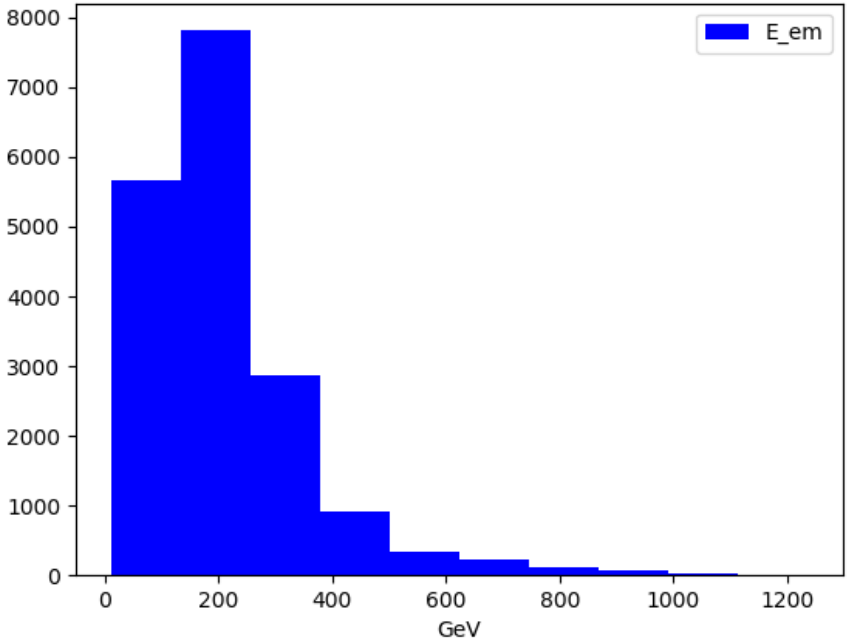


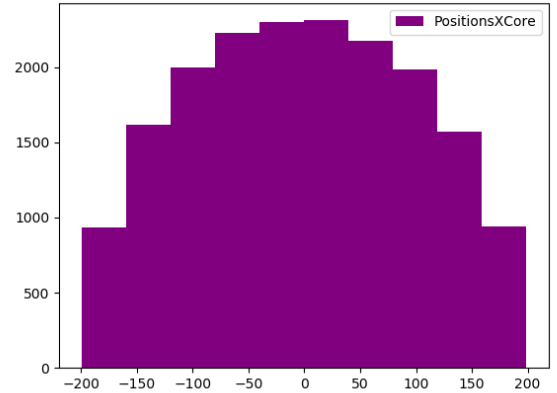
Dataset - core position near the borders

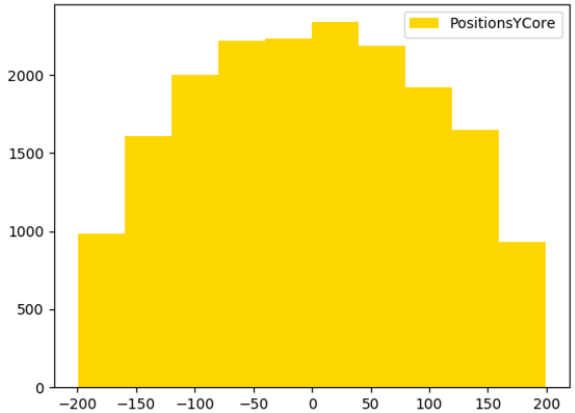




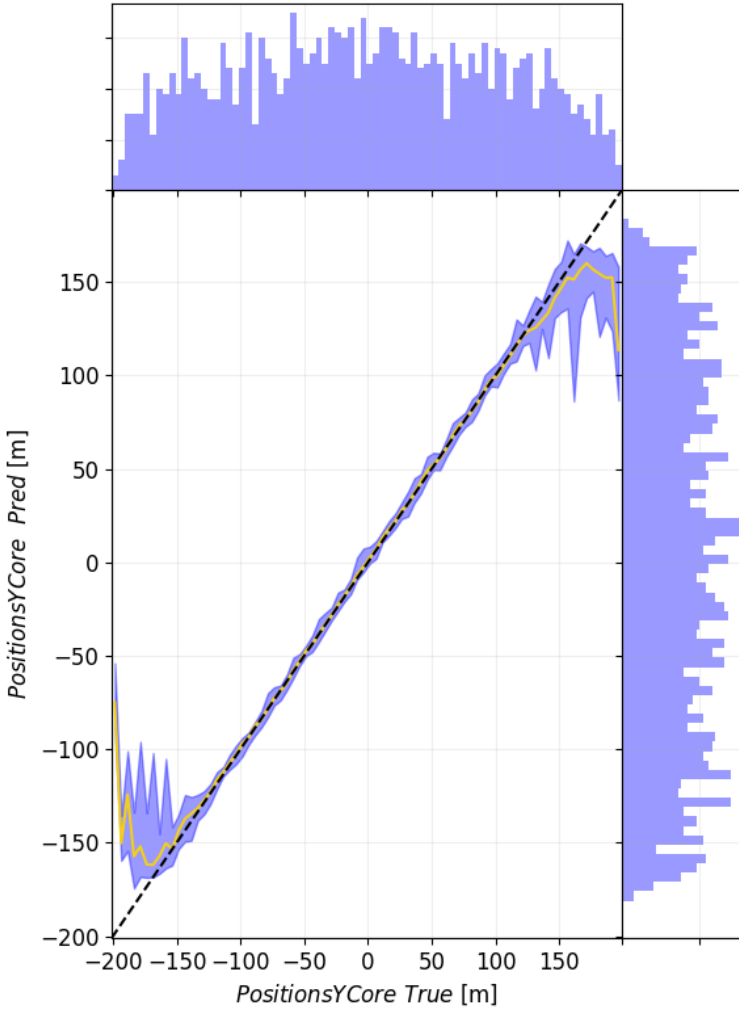
Dataset 02- core position near the borders







Results


150
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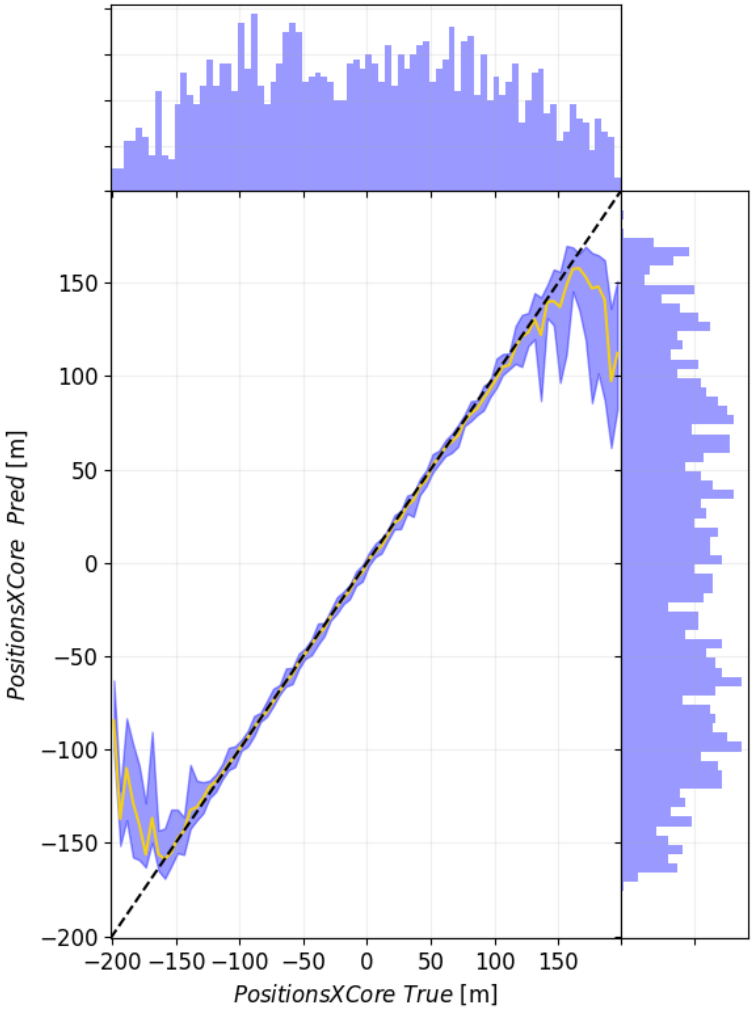
−200 −150 −100 −50 0 50 100 150
PositionsYCore Pred [m]
PositionsYCore True [m]


150
100
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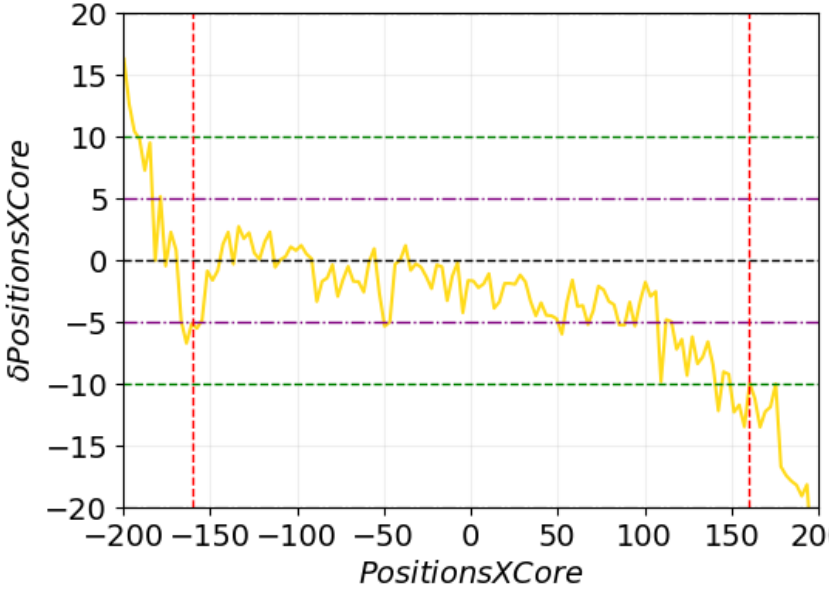
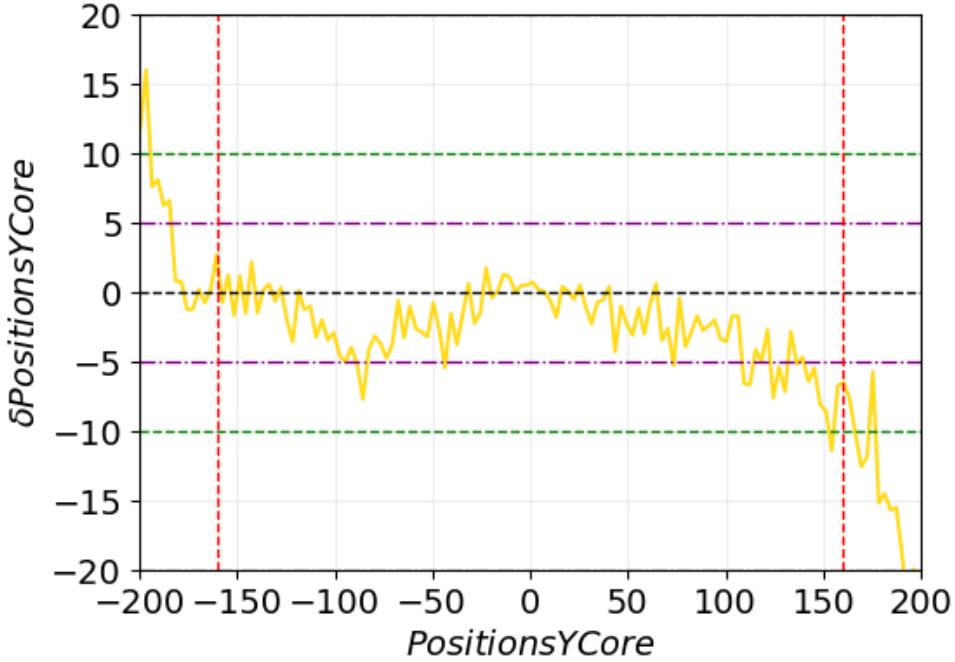
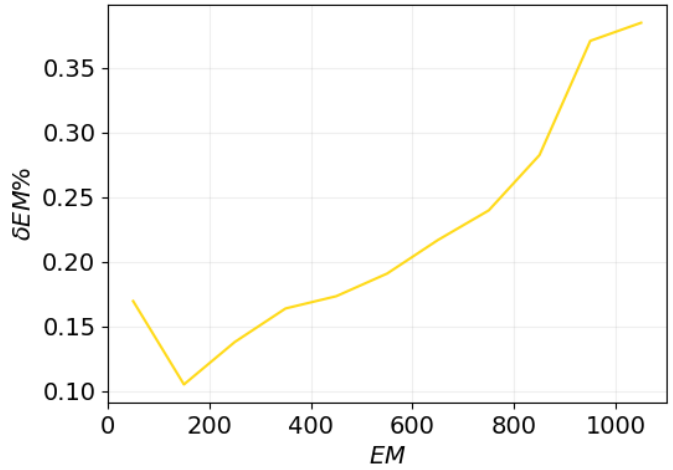
−200 −150 −100 −50 0 50 100 150
PositionsXCore Pred [m]
PositionsXCore True [m]

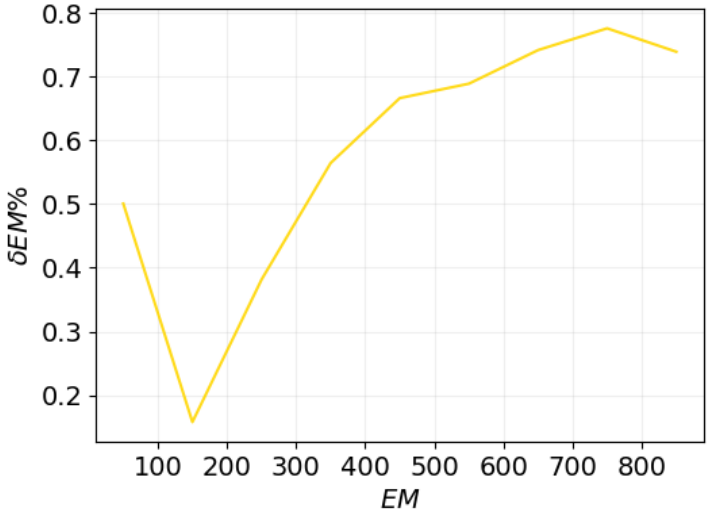
Results – Ground energy Regression – dense Network

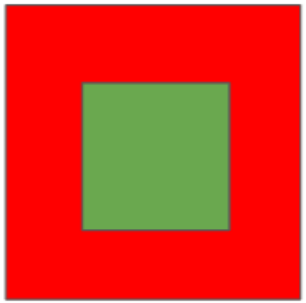




Results – Ground energy Regression – dense Network



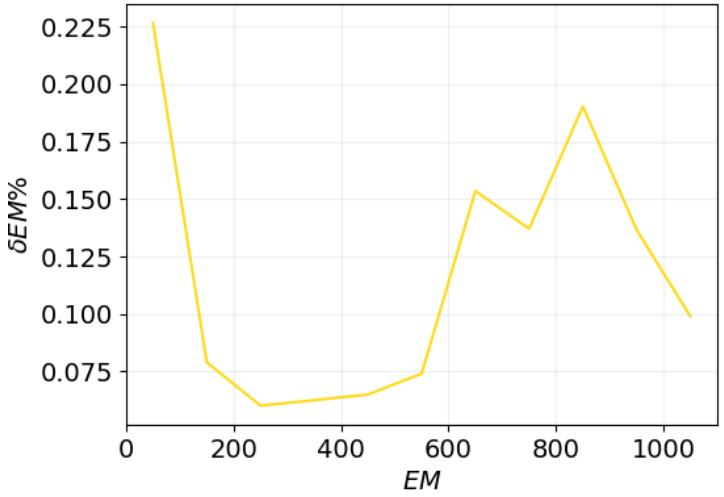


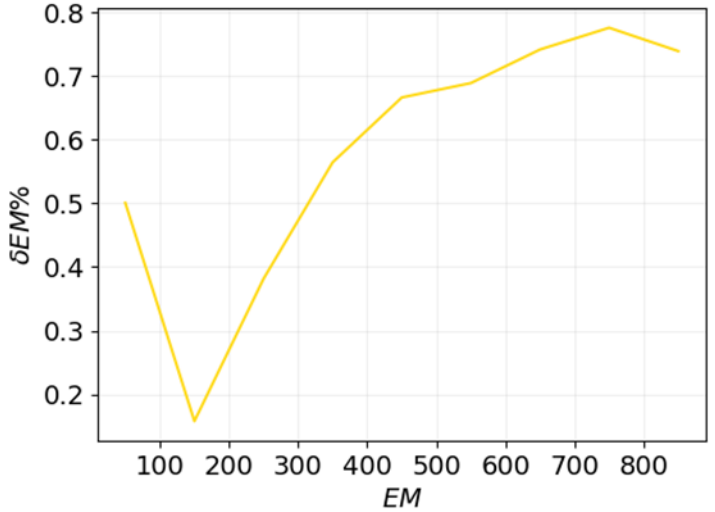


The X and Y core area (green)
limited > -160 and < 160

The X core area (green)
limited < -160 or > 160

Results – Ground energy Regression – EfficientNet

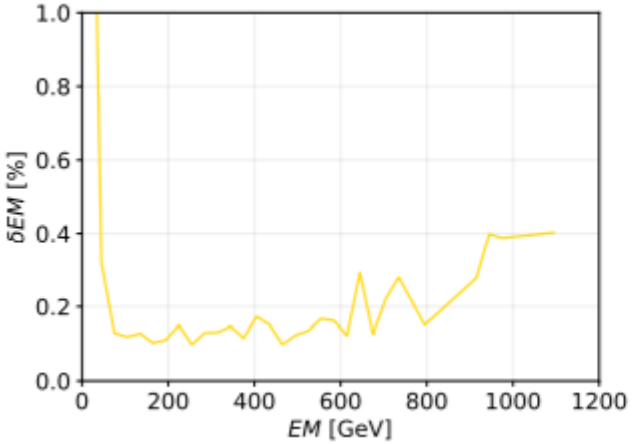


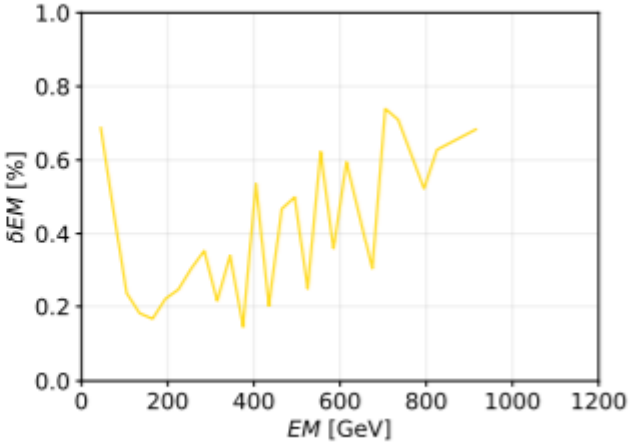


The X and Y core area (green)
limited > -120 and < 120

The X core area (green)
limited < -160 or > 160

Results – Ground energy Regression – Bayesian EfficientNet

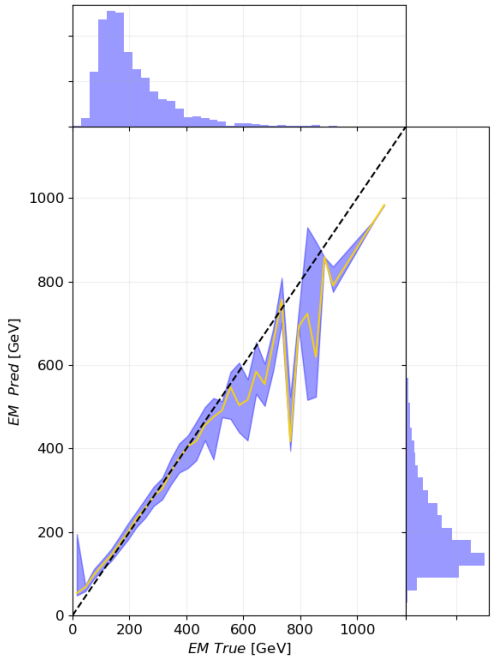


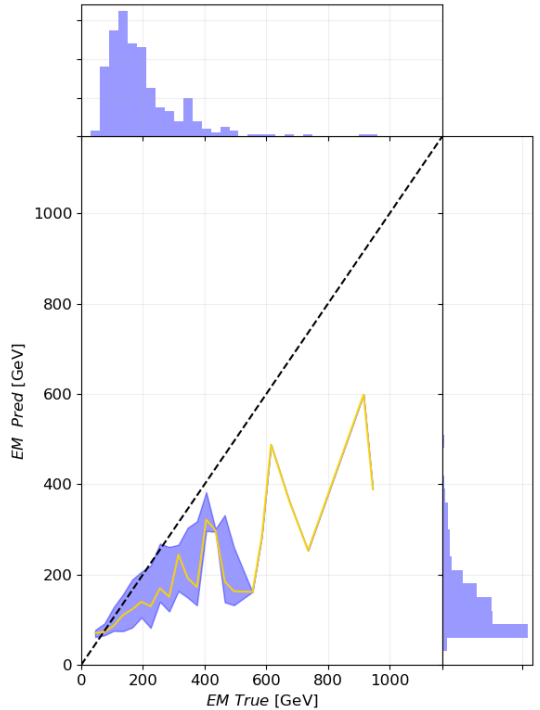


The X and Y core area (green)
limited > -120 and < 120

The X core area (green)
limited < -160 or > 160

Results – Ground energy Regression – EfficientNet





The X and Y core area (green)
limited > -120 and < 120

The X core area (green)
limited < -160 or > 160

What's next?

We have some evidence that modelling using Deep Learning can reach Science quality standards.

The network seems to learn even if we train with border only. We probably need more simulations.

We underestimate the ground energy when the center is outside the detector.

We are currently optimizing the network and evaluatimg new architectures.

We probably need more simulations in particular covering the high energies range.

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