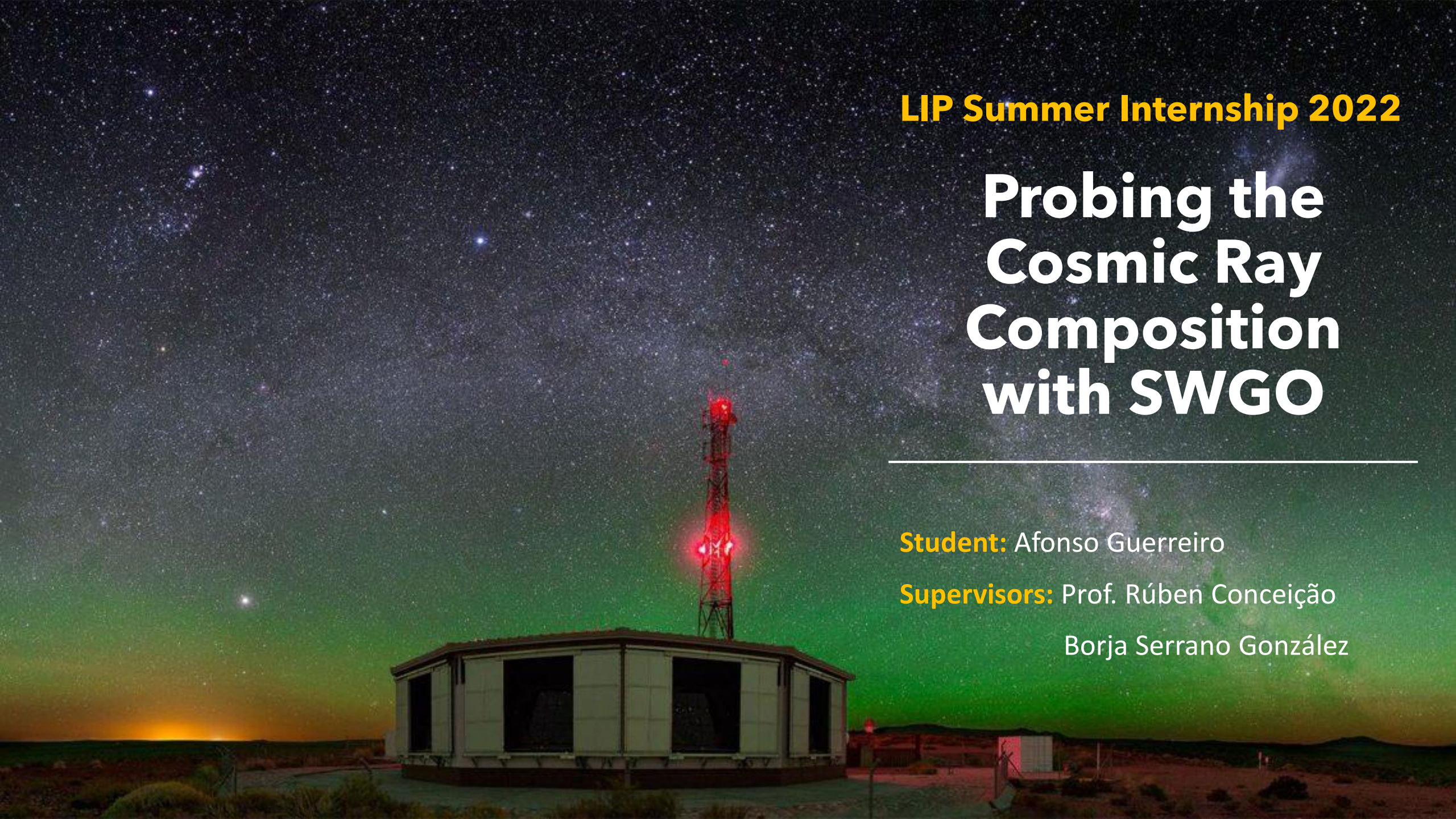

LIP Summer Internship 2022

Probing the Cosmic Ray Composition with SWGO

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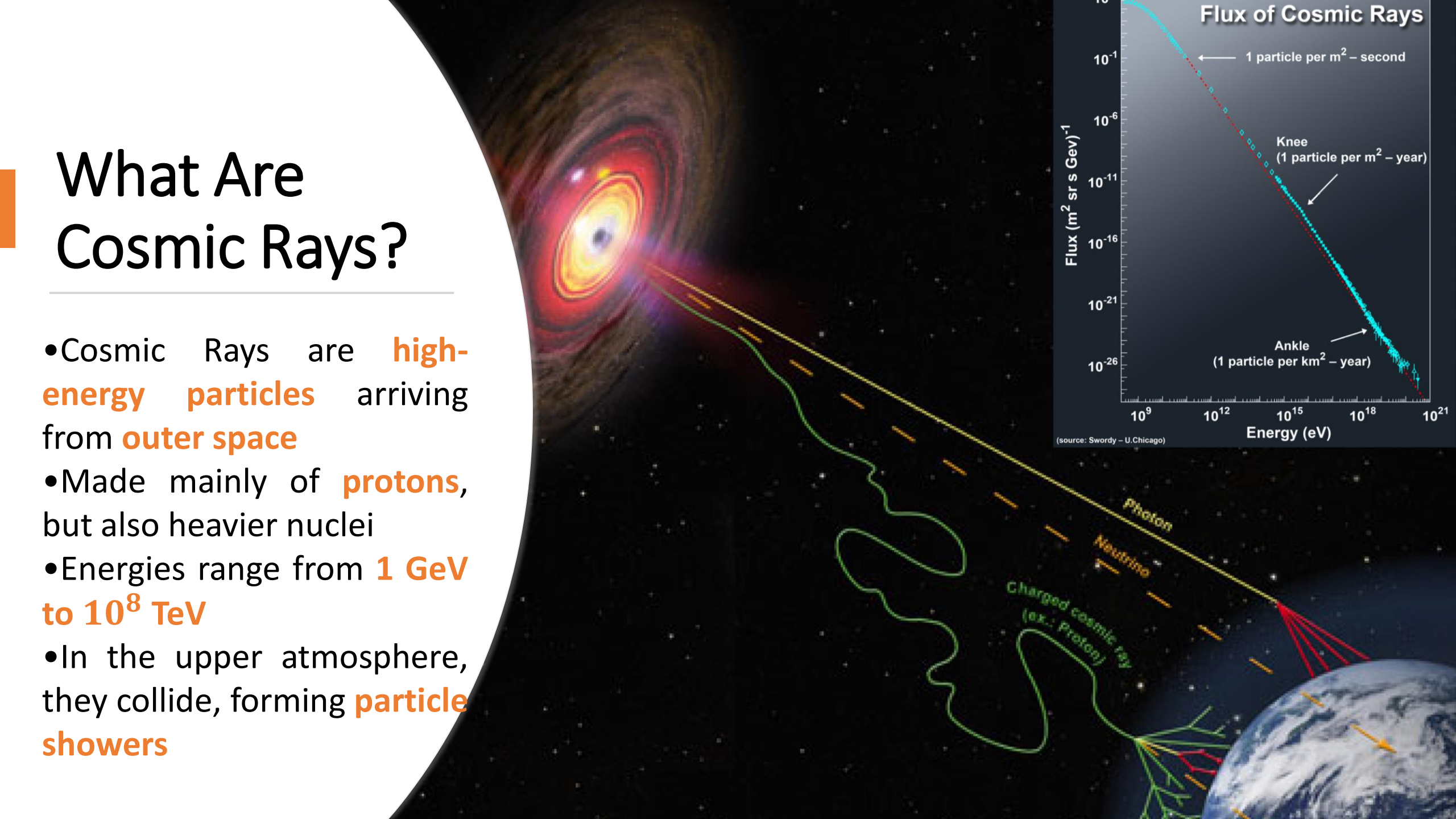
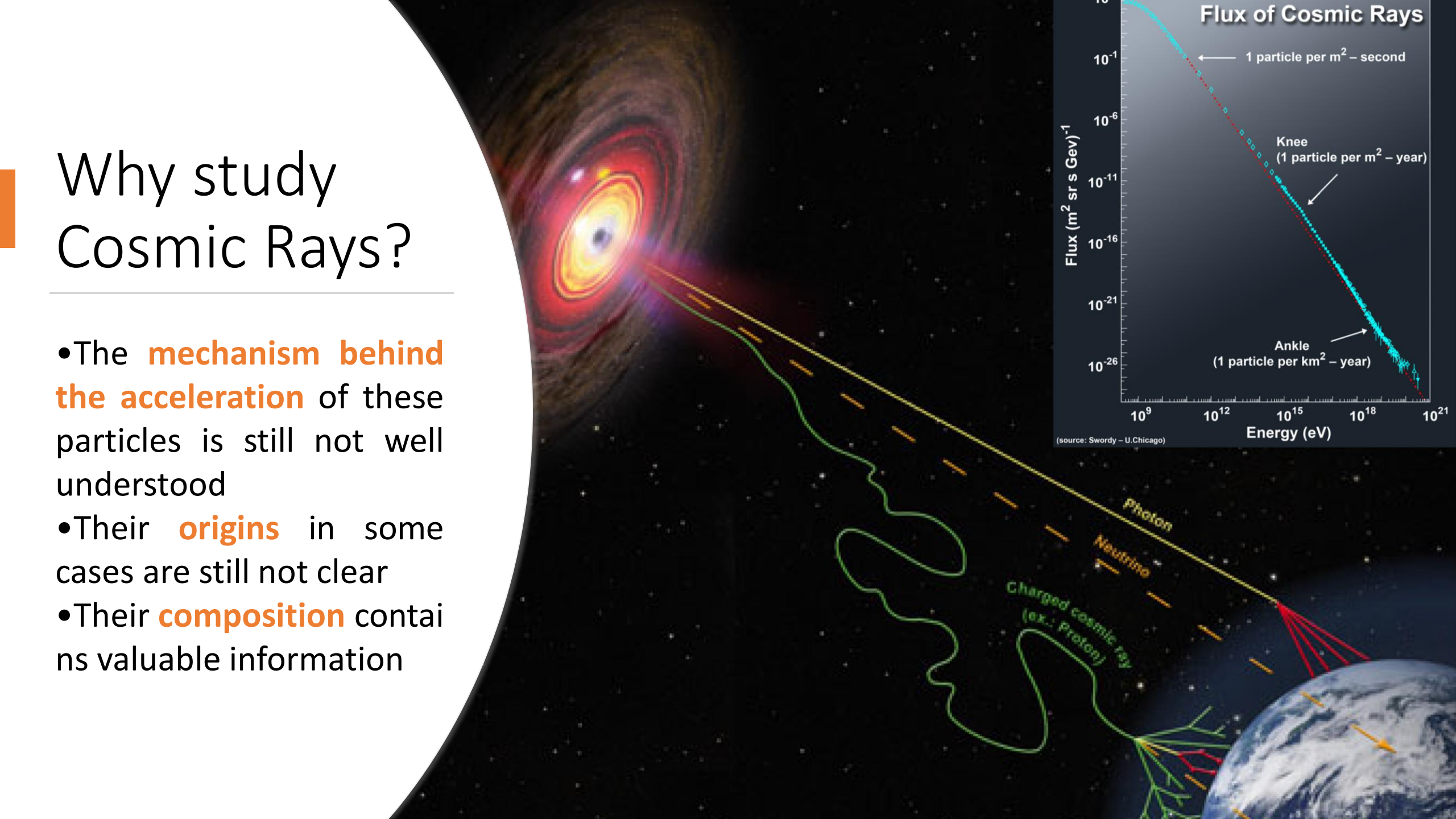
What Are Cosmic Rays?

- Cosmic Rays are **high-energy particles** arriving from **outer space**
- Made mainly of **protons**, but also heavier nuclei
- Energies range from **1 GeV to 10^8 TeV**
- In the upper atmosphere, they collide, forming **particle showers**



Why study Cosmic Rays?

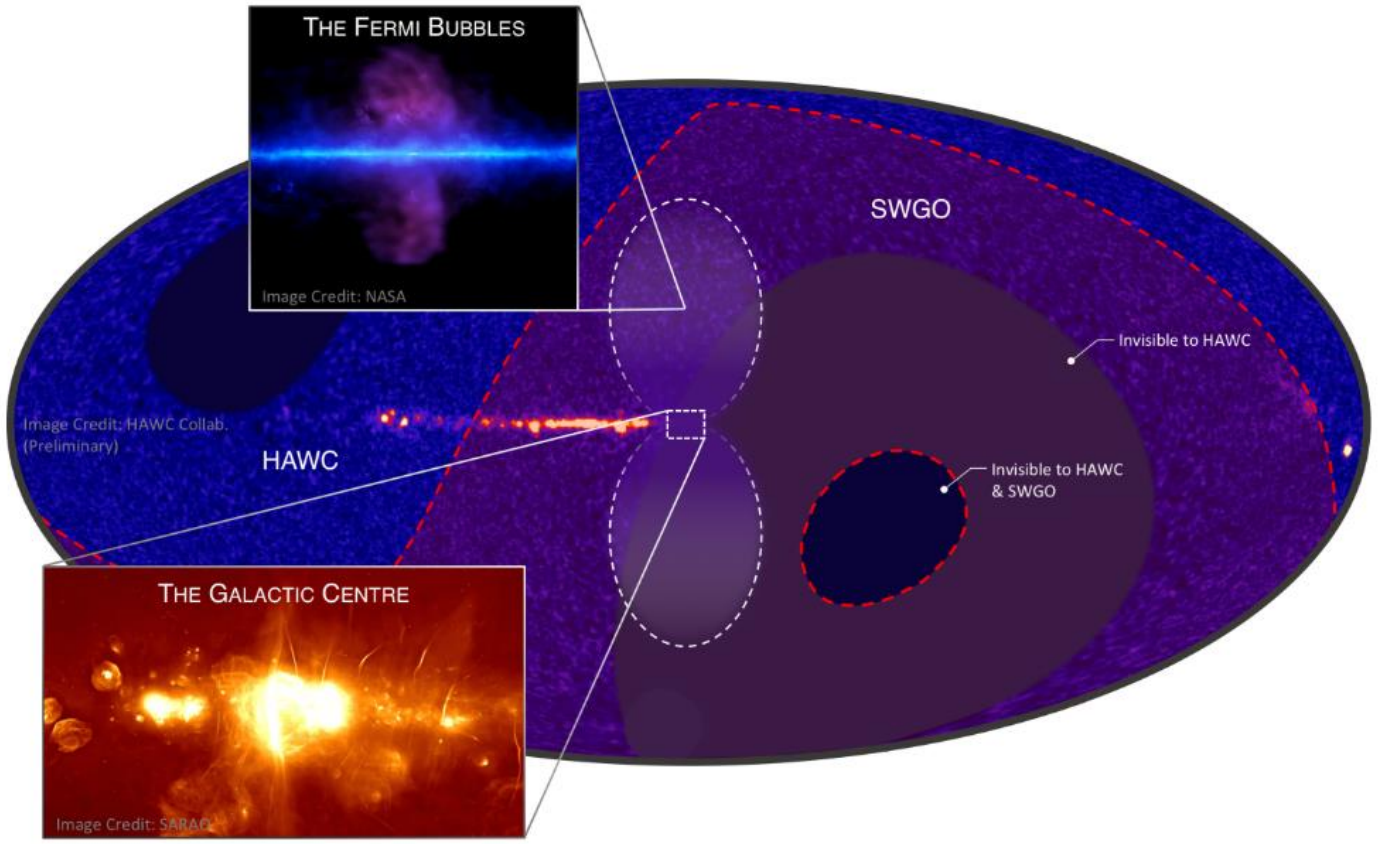
- The **mechanism behind the acceleration** of these particles is still not well understood
- Their **origins** in some cases are still not clear
- Their **composition** contai ns valuable information



Southern Wide-field Gamma-ray Observatory (SWGO)

- A **gamma-ray observatory** based on ground-level particle detection
- Covering an energy range from **100s of GeV to 100s of PeV**

- Located in **South America** at a latitude between 10 and 30 degrees south
- At an **altitude of 4.4 km or higher**

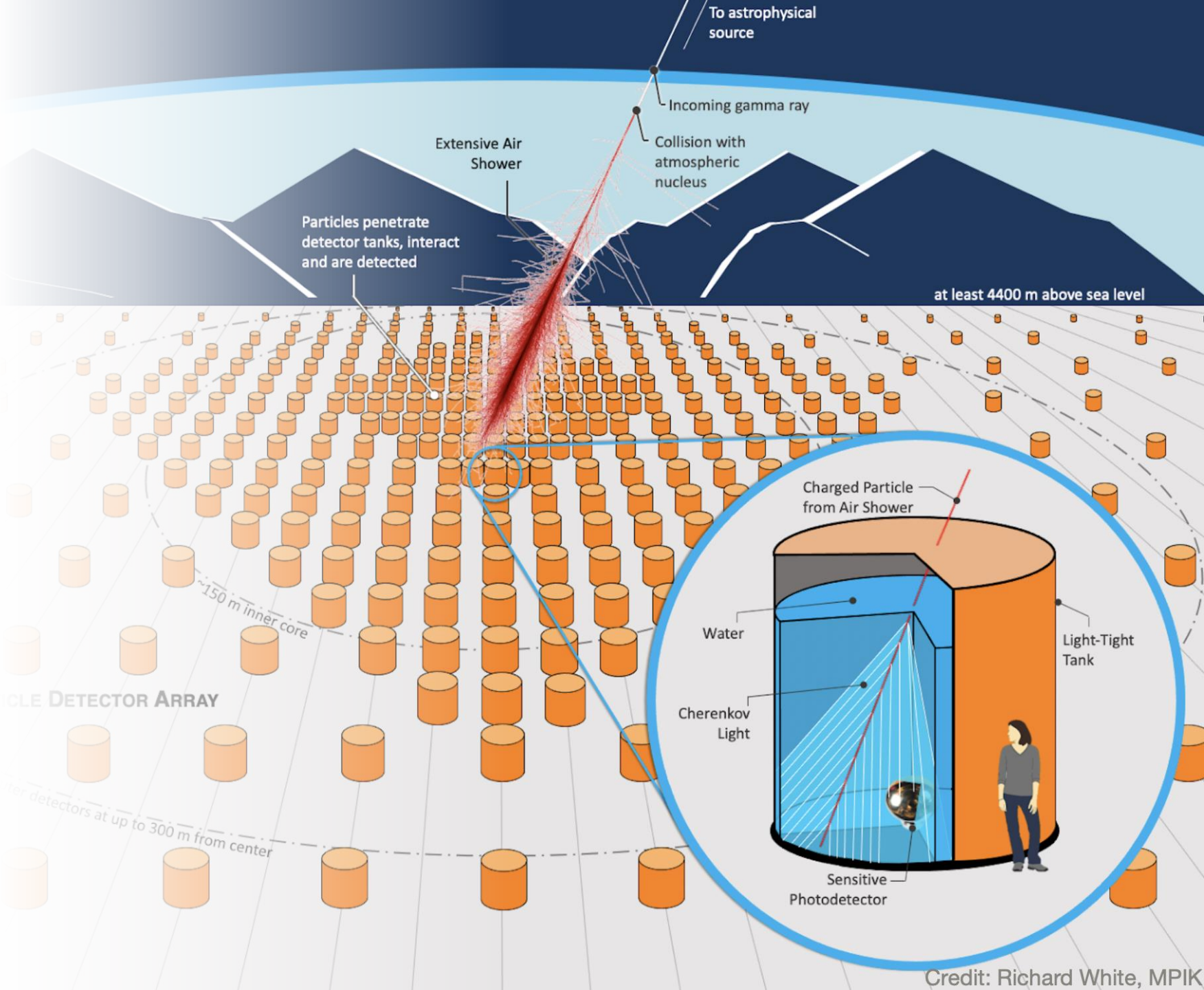


Detection Process

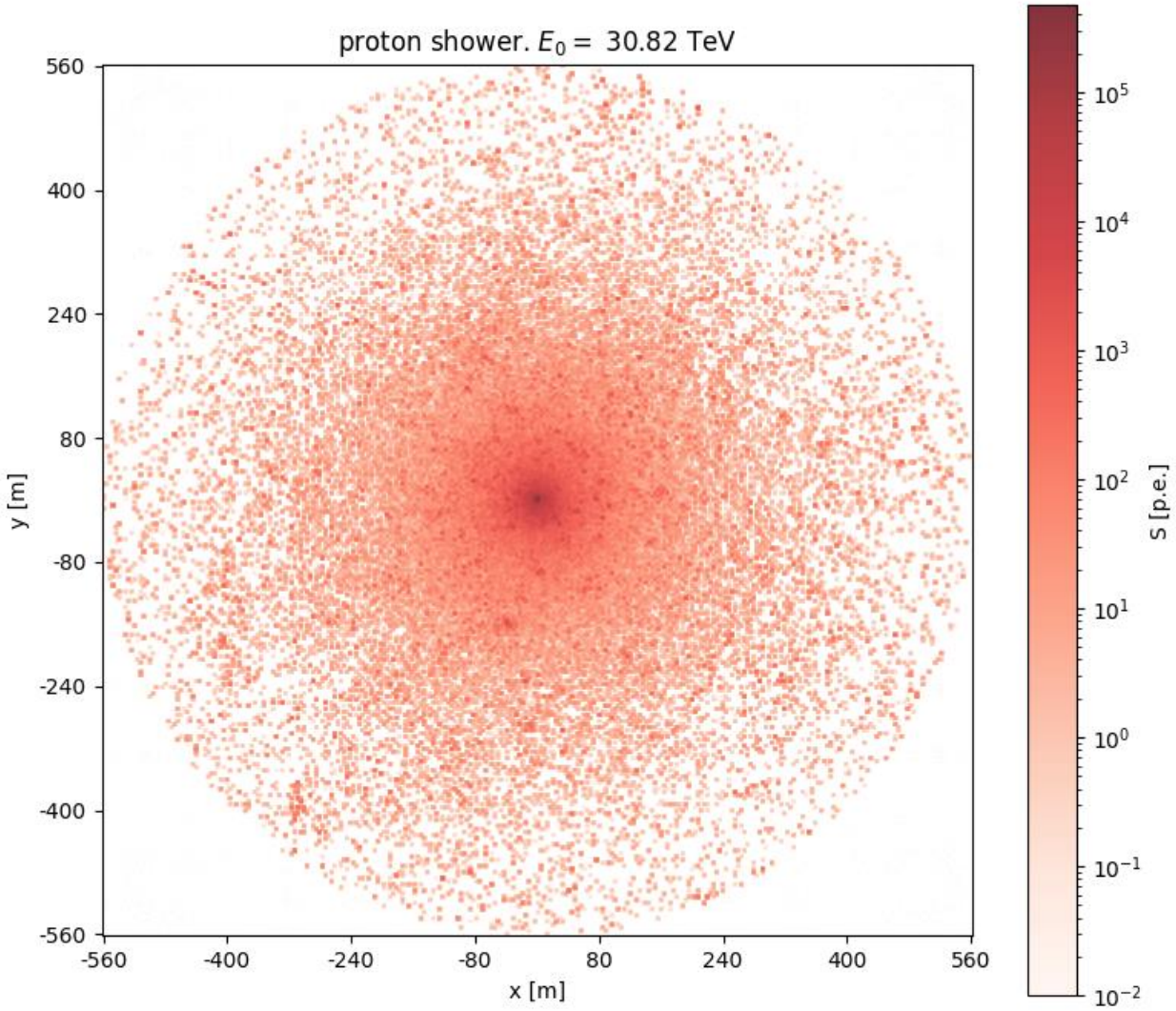
1. The incoming **gamma ray** interacts with the atmosphere generating a particle shower

2. The resultant particles enter the detector producing **Cherenkov radiation**

3. The signal is picked up by **photo-multiplier tubes** in the station

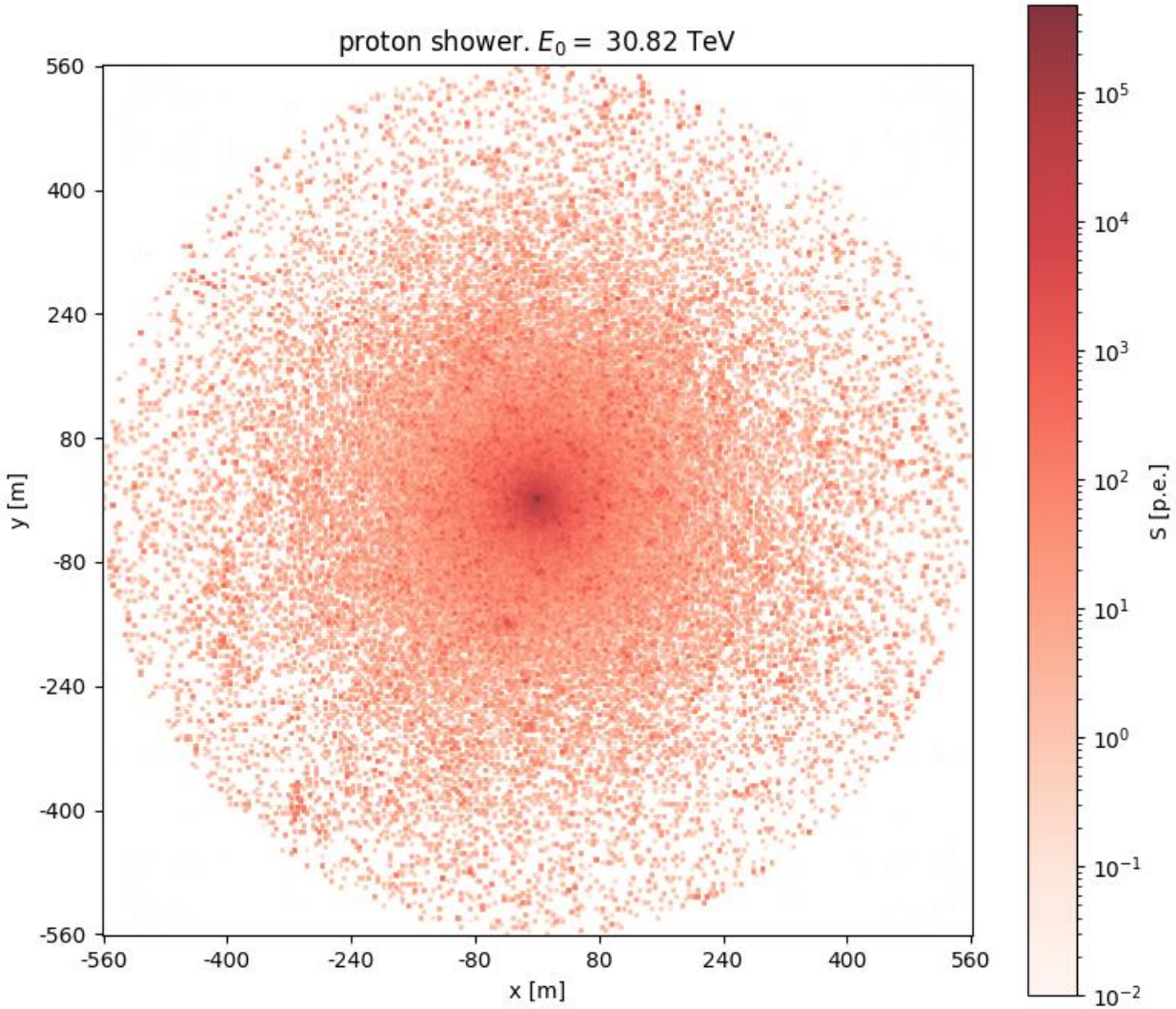


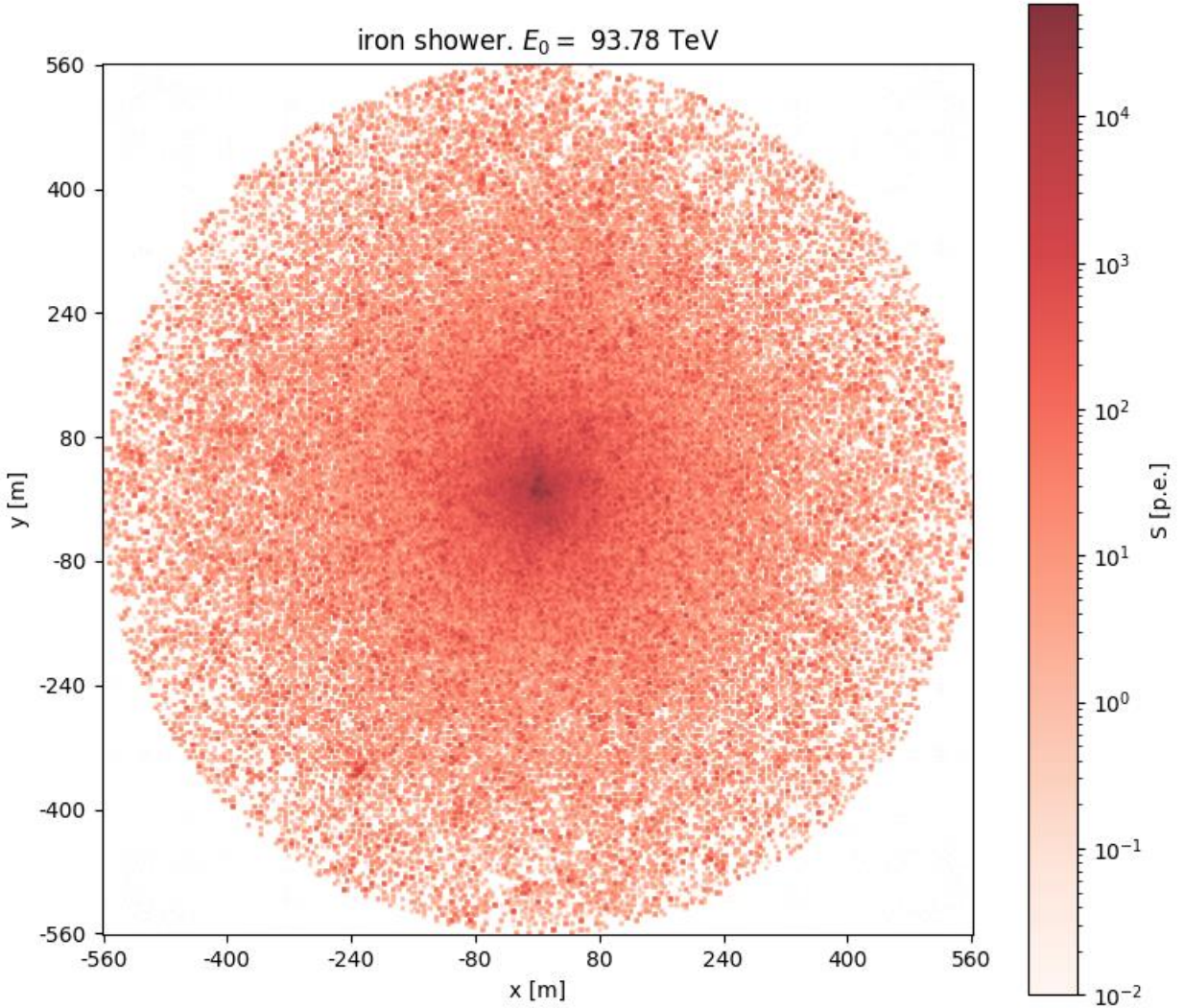
Simulating Cosmic Rays



- The Simulation of extensive air showers was done resorting to **CORSIKA**
  - An energy cut was used to make sure the reconstruced energies of the showers were comparable
  - The particles collected at the ground were converted into a signal
  - All showers are vertical

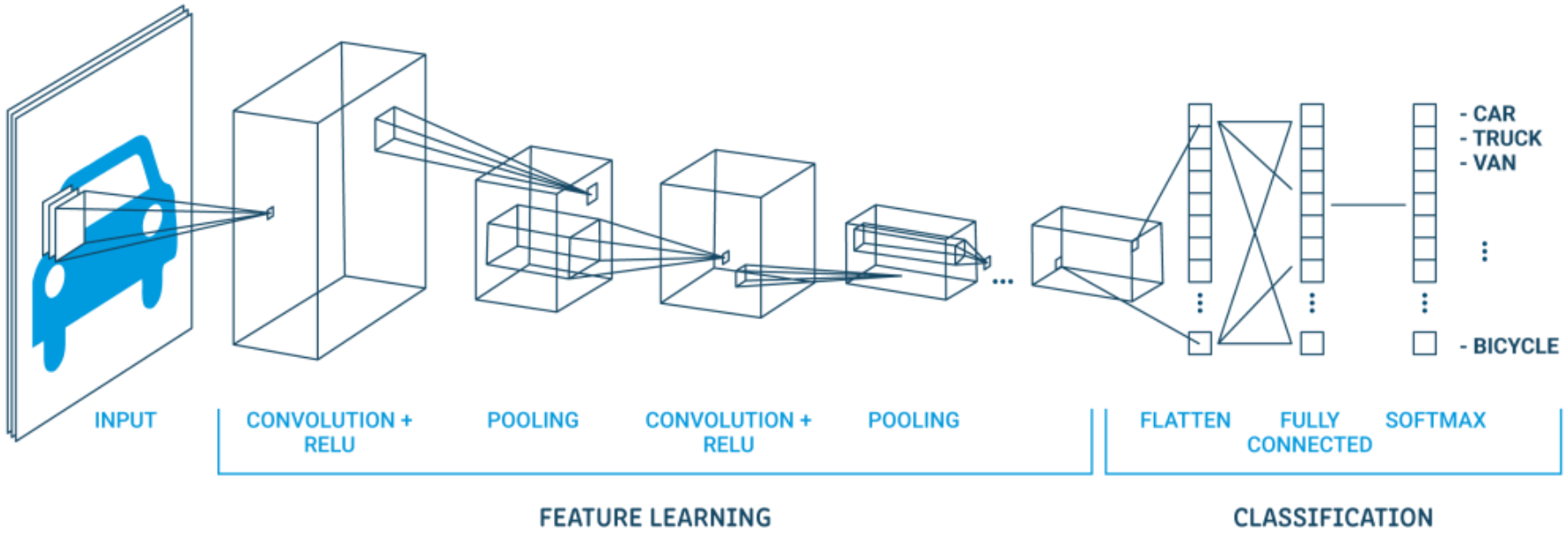
Can we create an algorithm to distinguish proton showers from iron showers?





Convolutional Neural Networks (CNNs)

A **Convolutional Neural Network (ConvNet/CNN)** is a Deep Learning algorithm that can take an image as input, assigning importance (learnable weights and biases) to various aspects/objects in the image, becoming able to differentiate one from the other.



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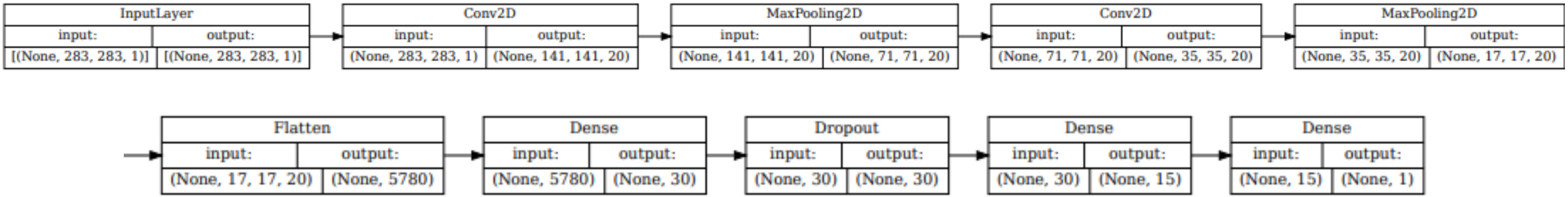
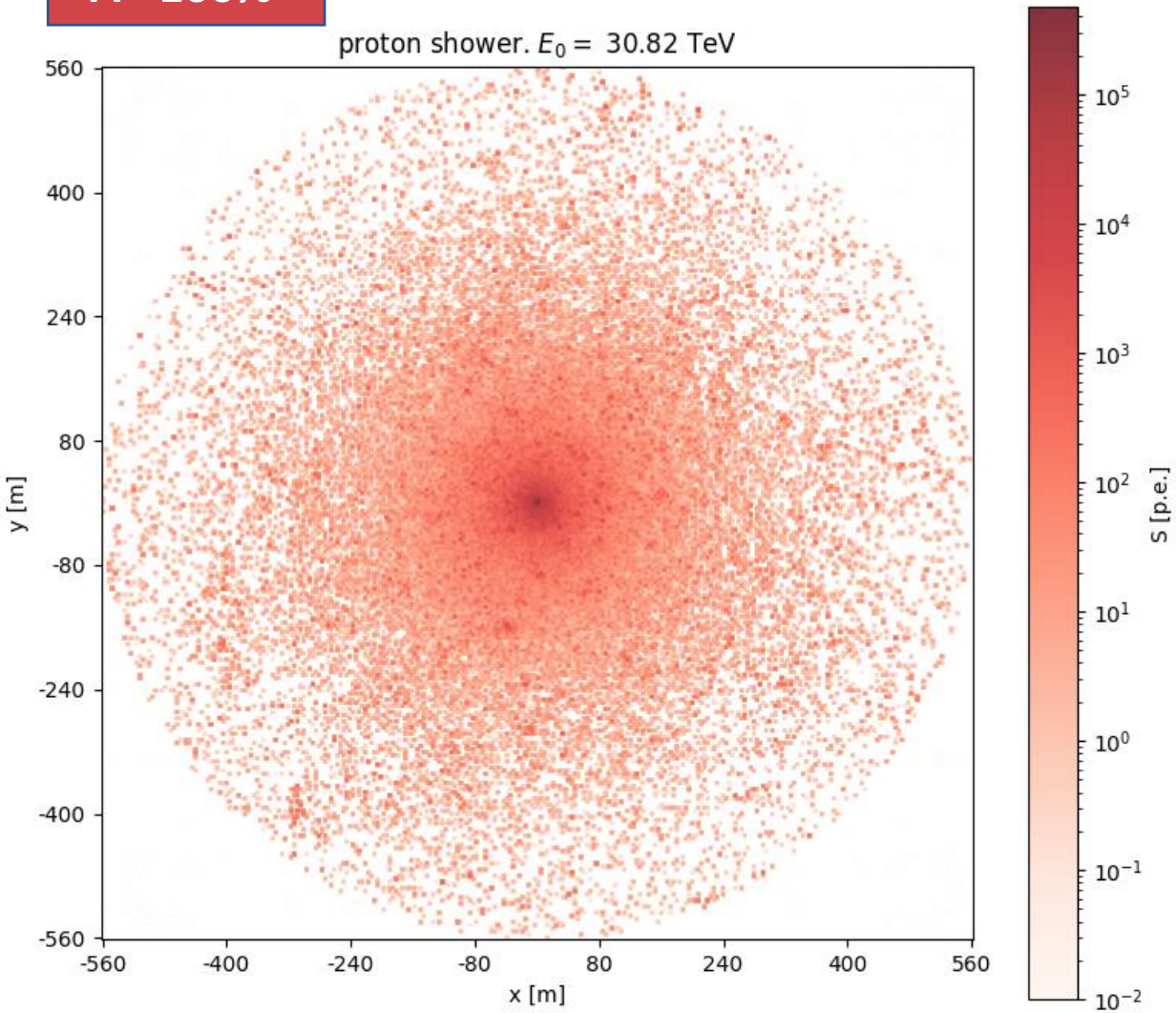
The **structure** of the Network used was

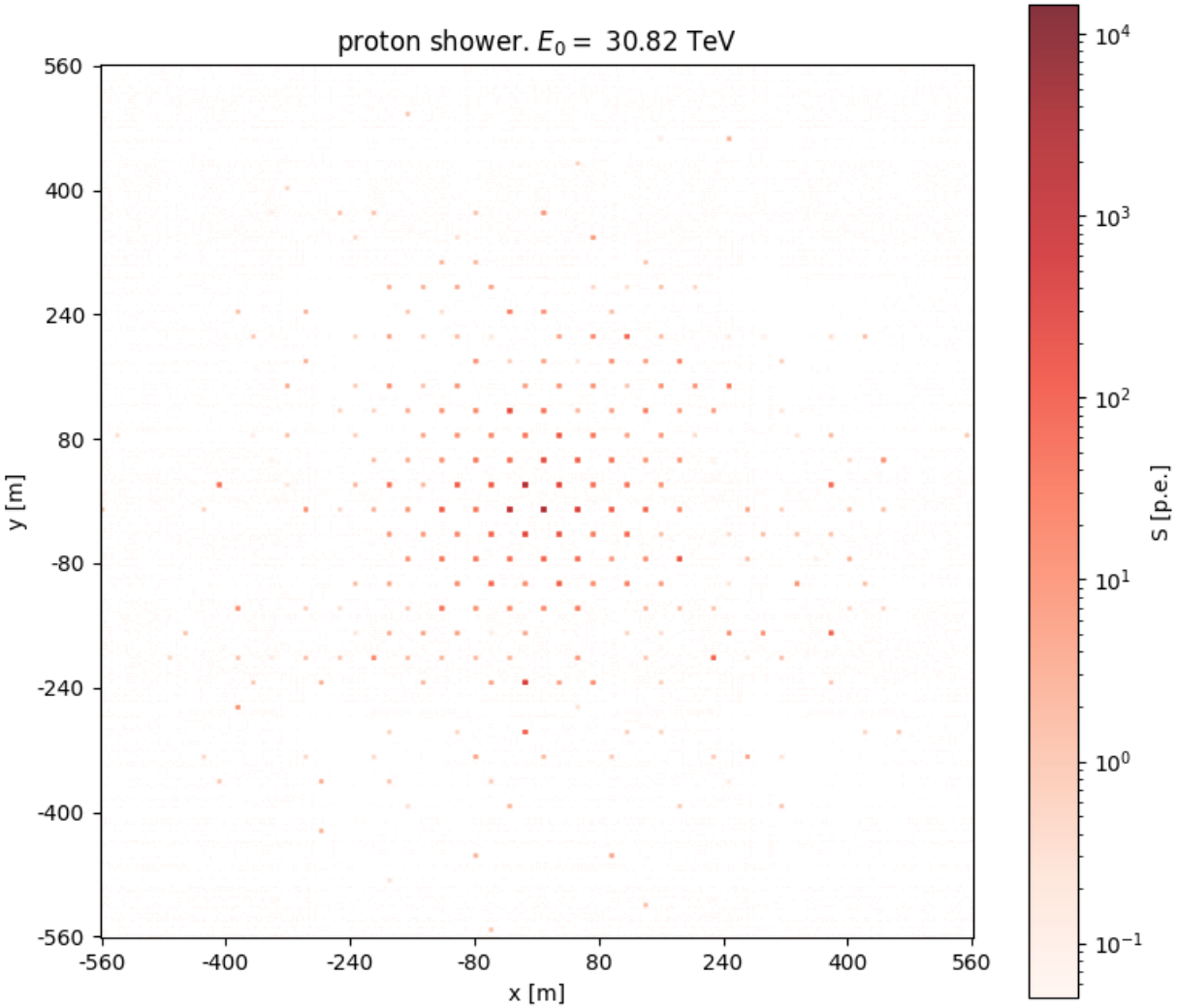


The **Fill Factor(FF)** is the ratio of the are occupied by detectors to its total area

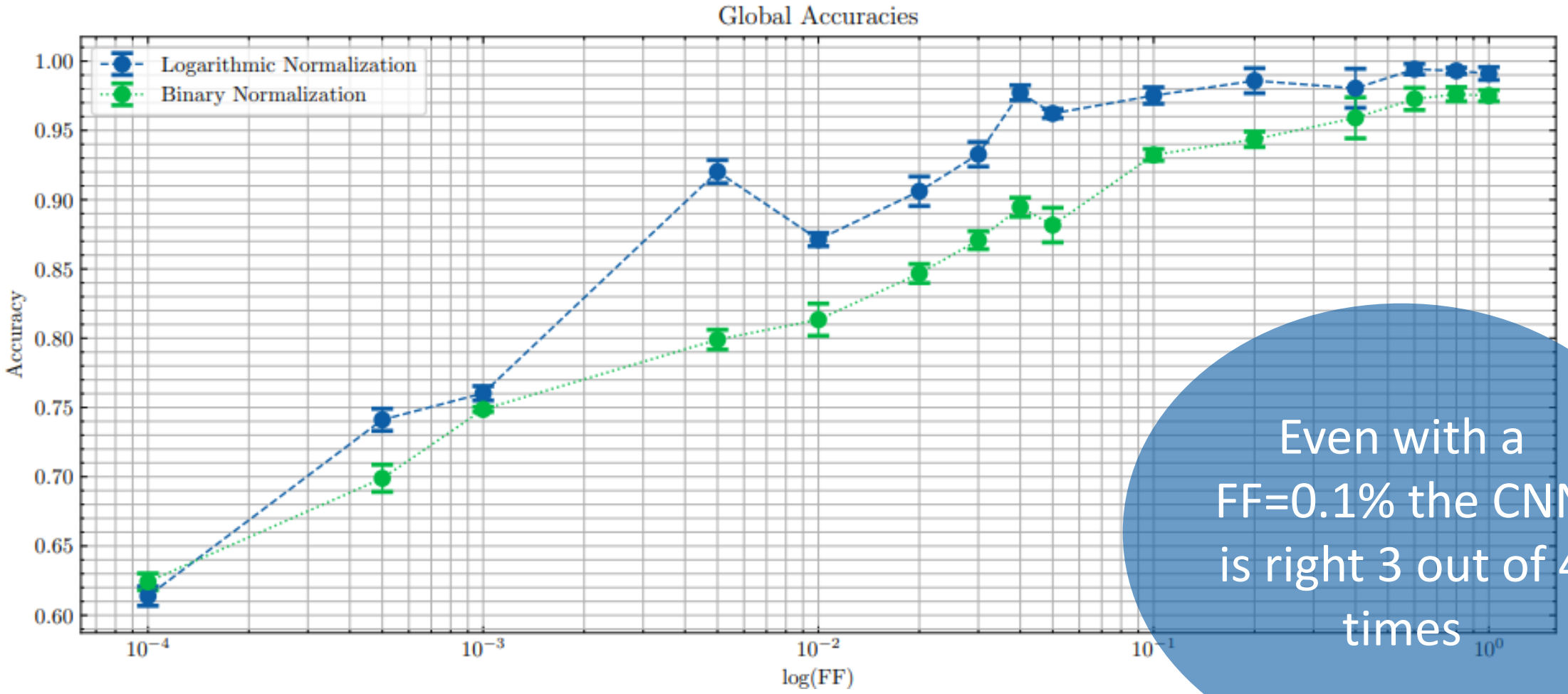
FF=100%



FF=1%



Results

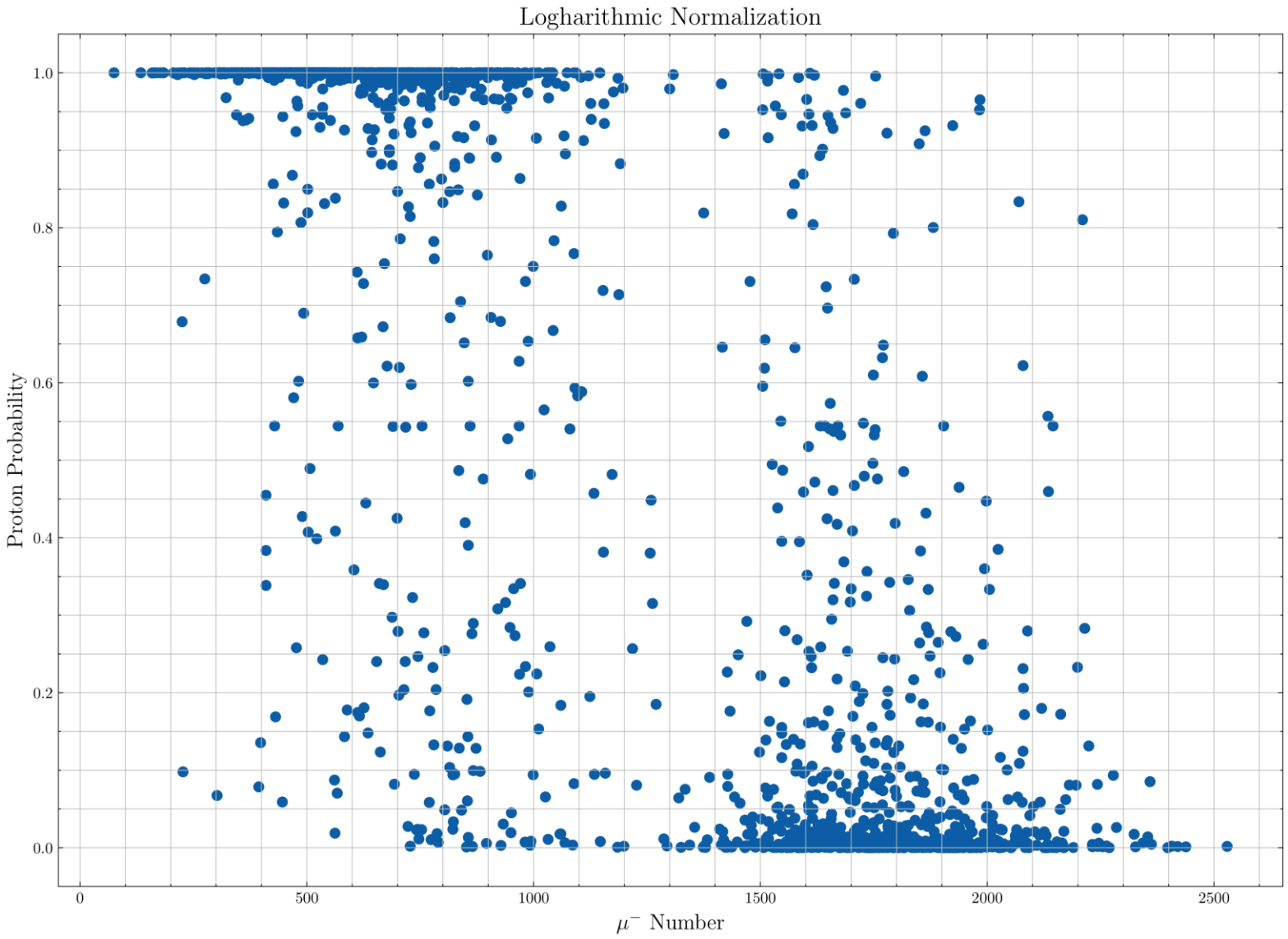


Even with a FF=0.1% the CNN is right 3 out of 4 times

Logarithmic Normalization->Used the Log of the signal normalized between 0 and 10

Binary Normalization-> Cell is either 1 (active) or 0 (inactive)

FF=1%



- Number of muons very **sensitive to composition**
- The measurement of the number of muons is **very hard** to obtain
- **No correlation** between CNN predicition and number of muons
- CNN is picking **shower pattern** features sensitive to composition

Conclusions

1. A **Machine Learning algorithm** can be used to distinguish between proton and iron showers

2. **Good Discrimination** can be attained until values of $FF \sim 1\%$

3. The CNN is picking information on the **shower footprint** rather the shower muon content

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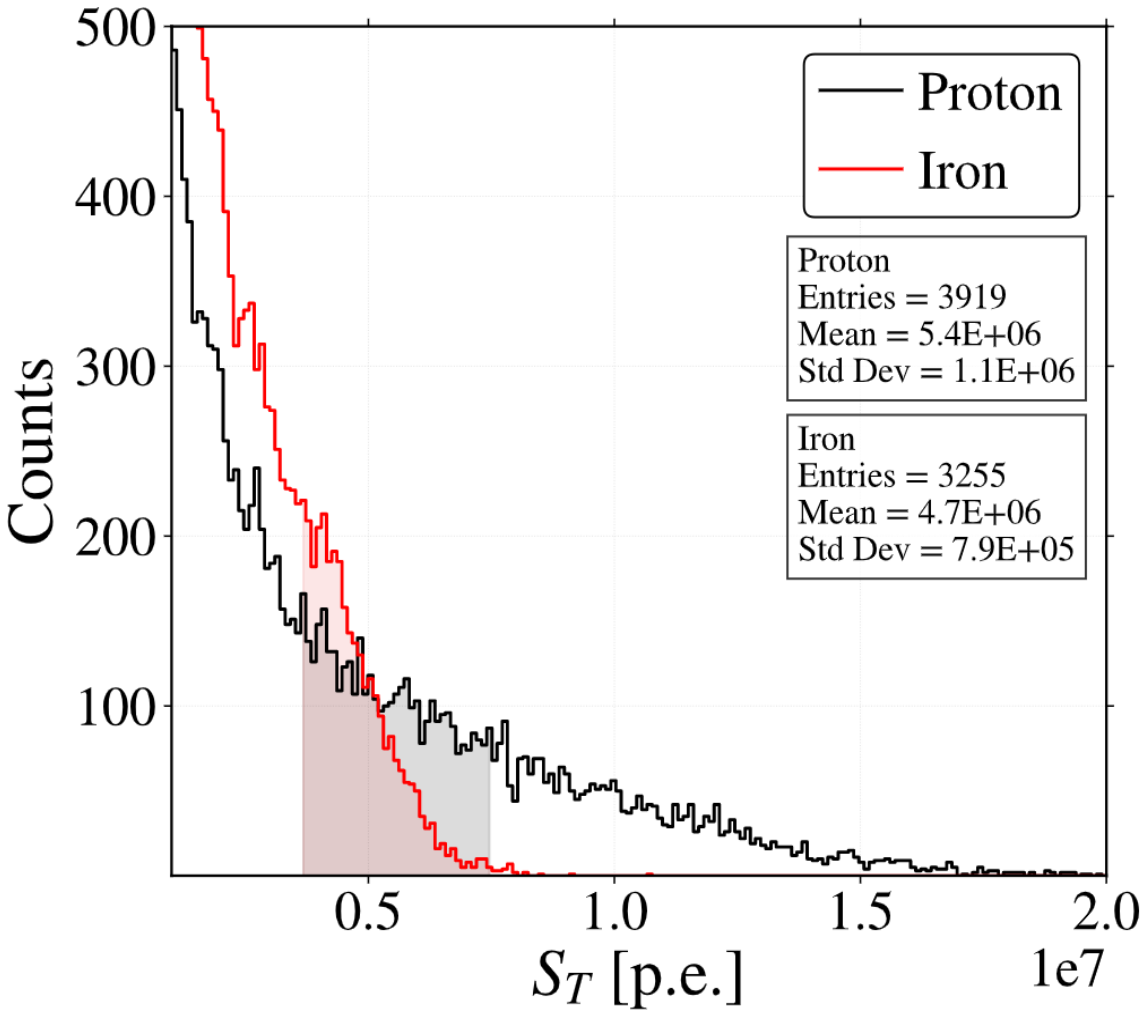
Thank you for you attention

Adicional Slides



- Shaded area corresponds to **selected events**
- Energies range from **40 to 60 TeV**