Using modern machine learning methods on KASCADE data for outreach and education

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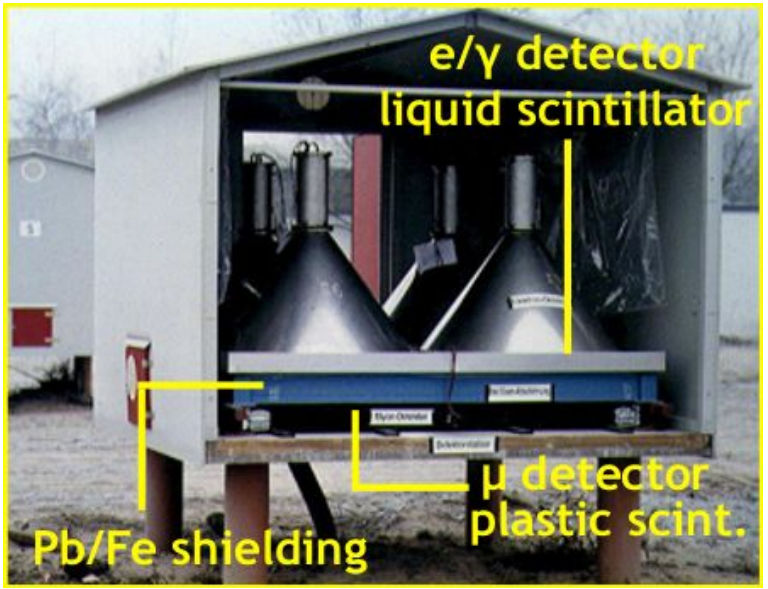
KASCADE experiment

- Location: 110 m a.s.l., 49◦ N, 8◦ E, KIT-Campus North, Karlsruhe, Germany;
- Operation time: 1996 October – 2010 May

  ⇒ effective time ~ 4223.6 days;
- Area: 200 × 200 m^2 ;
- 252 scintillator detectors;
- E = 100 TeV – 80 PeV;
- Ne (> 5 MeV);
- Ntr μ (> 230 MeV, r = 40 − 200 m).



KASCADE Cosmic-Ray Data Center (KCDC)

- created in 2013
- only open-source technologies
- all-in-one: data center, archive, information and educational platform
- http://kcdc.ikp.kit.edu

German-Russian Astroparticle Data Life Cycle Initiative (GRADLCI)

- 2018 - this year
- collaboration between KASCADE and TAIGA researchers
- directions: KCDC extension, multimessenger astroparticle physics, data engineering and machine learning for astroparticle physics, outreach (via astroparticle.online)
- https://gradlc-dc.ikp.kit.edu/

Machine learning for KASCADE

ML Models

- DecisionTree
- Random Forest
- CNN

Hadronic interaction models

- QGS-jet4
- EPOS-LHC
- Sibyll-23c

Classification

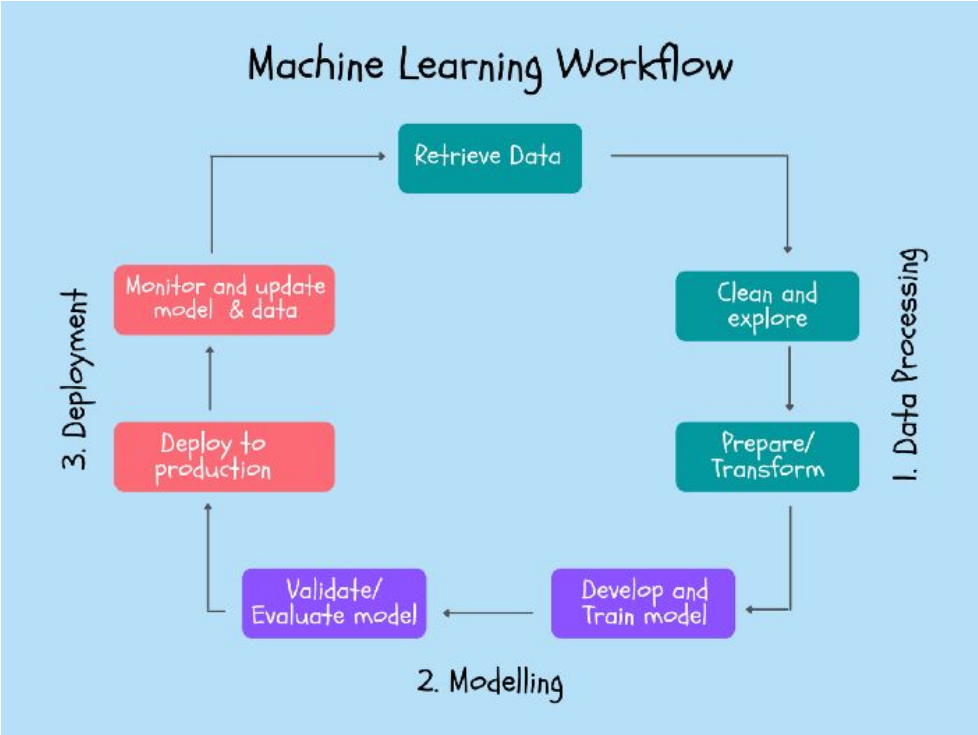
- binary
- multiclass (via particle mass reconstruction)

More in:

ICRC-2021, 13/07/2021, 18:00:

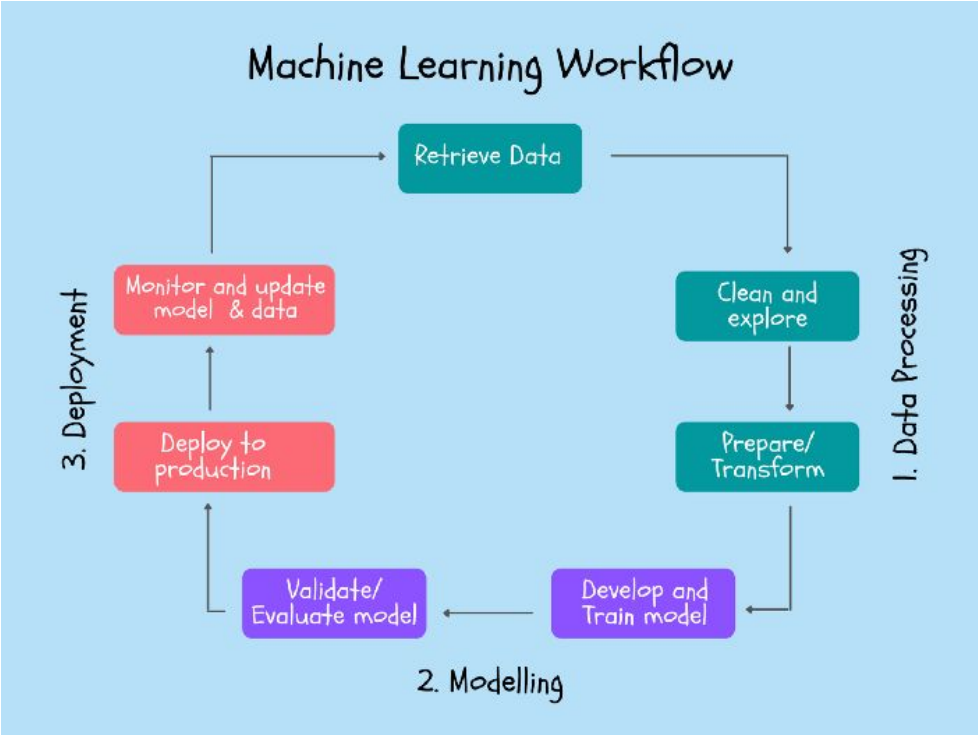
D. Kostunin, I. Plokhikh, M. Ahlers, V. Tokareva, V. Lenok, P. Bezyazeekov, S. Golovachev, V. Sotnikov, R. Mullyadzhanov, E. Sotnikova, New insights from old cosmic rays: A novel analysis of archival KASCADE data

Machine learning workflow



ⓒcredit: Arunn Thevapalan, towardsdatascience.com

Machine learning workflow



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In this talk:

- data workflow engineering
- model deploy

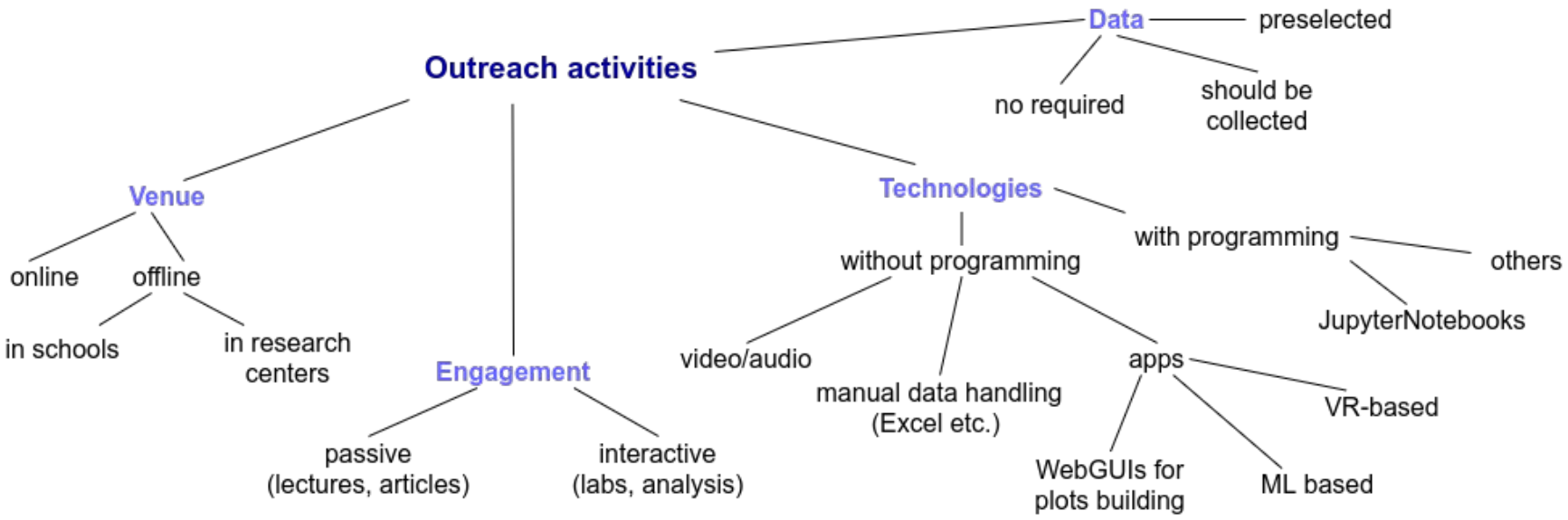
Data workflow engineering

- Data retrieval: KCDC, GRADLCI API
- Data exploration: JupyterHub@KCDC
- Data management: ASW S3
- Preprocessing: IAP computing cluster
- Model training and validation: IAP computing cluster, Google Collaboratory
- Model deploy: Docker, Streamlit
- Project management: JetBrains Space

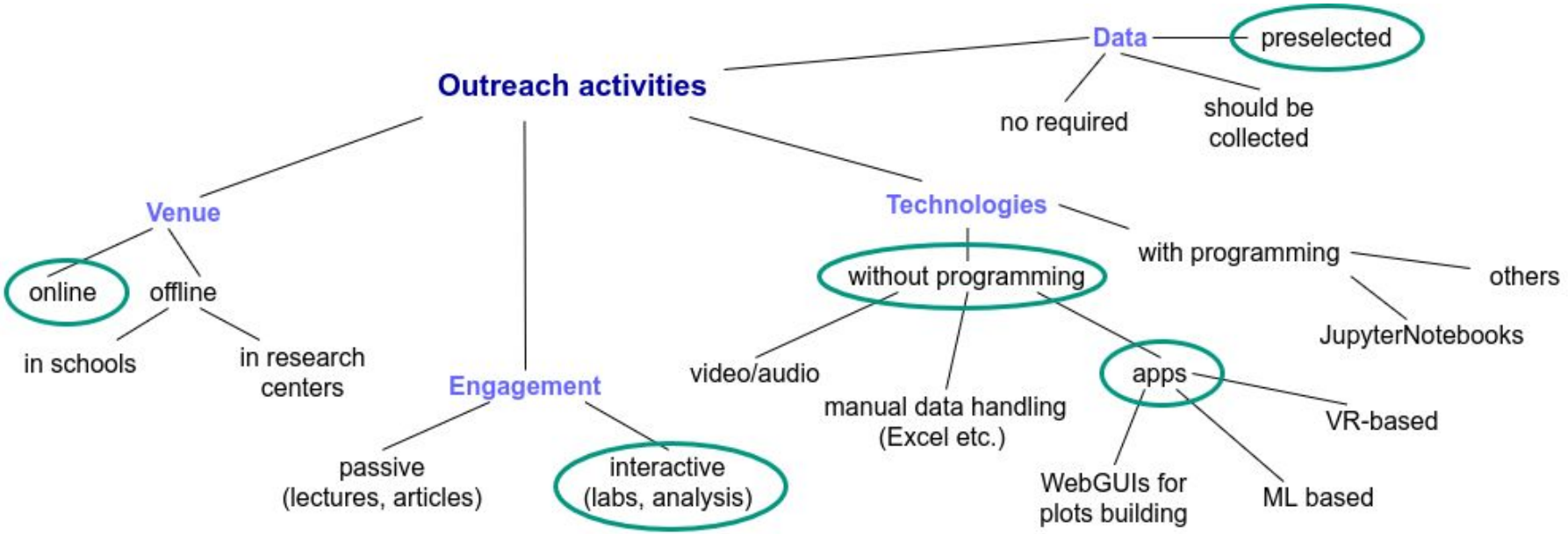
Neural networks for outreach

- Information technology is developing rapidly and finding its application in astroparticle physics
- However, to date, they are seldom used in the development of educational materials
- Online education:
  - Education accessible to everyone
  - Covid-19

Taxonomy of outreach activities in astroparticle physics



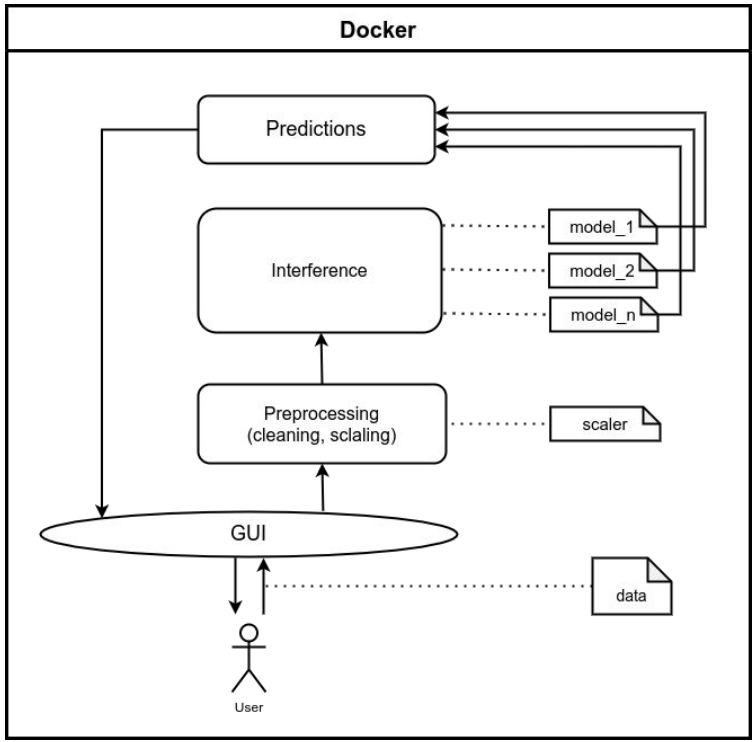
Taxonomy of outreach activities in astroparticle physics



Interactive data analysis applications

- VR based applications by IceCube
- Cazadores de rayos gamma (gamified JupyterNotebooks) by MAGIC
- Cosmic@Web by DESY (earlier example - Showers of knowledge)
- *Online tools of the Gravitational Wave Open Science Center:*
    - *Gravity Spy (citizen science)*
    - *Black Hole Hunter*
- *Bayesian Deep Learning for Galaxy Zoo DECaLS*
- *Astroparticle CNN Client for TAIGA by GRADCL Initiative*

KASCADE ML Application scheme



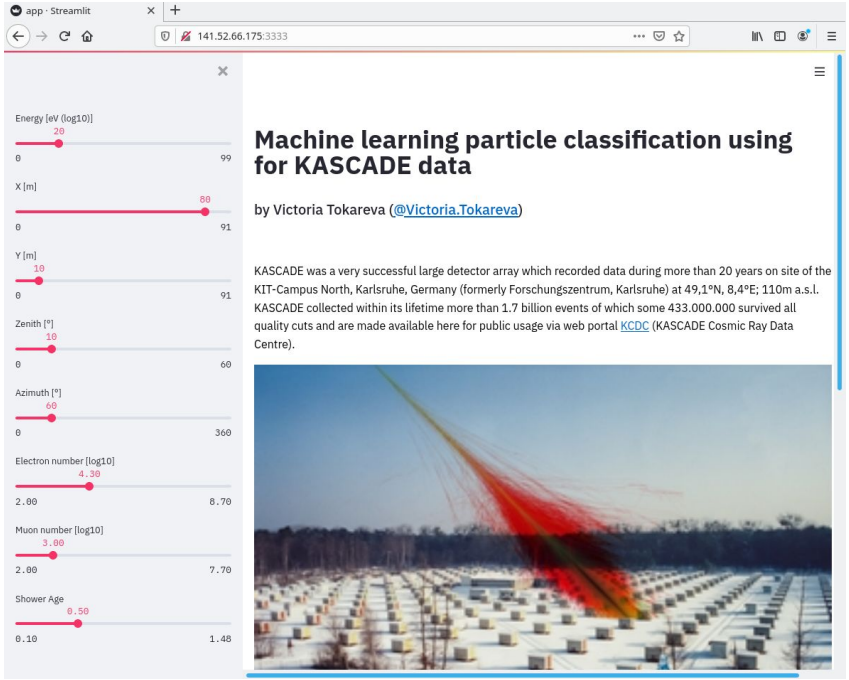
Implementation:

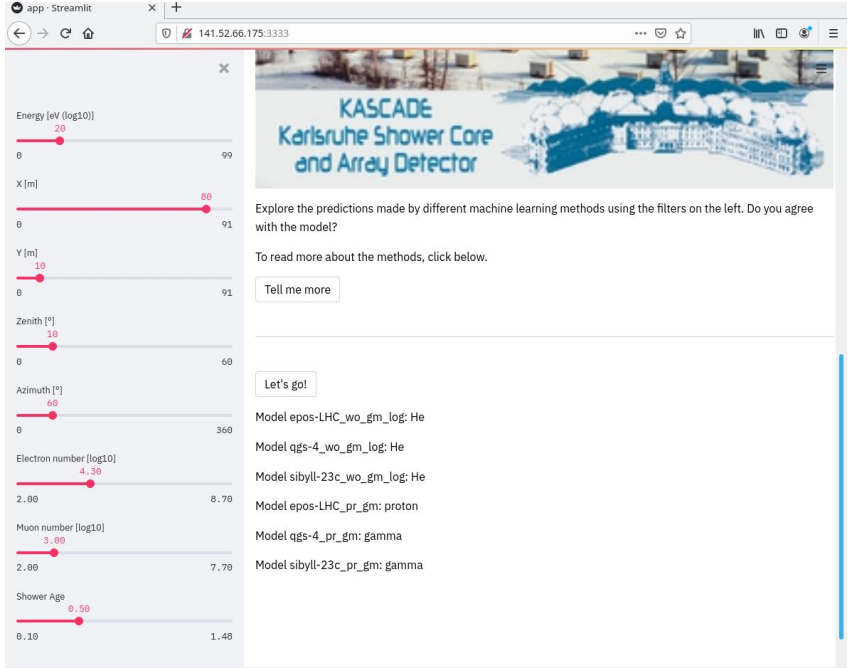
python3.8,
pandas, numpy, sklearn, streamlit,
html/css,
pipenv,
Docker

Testbed:

Singularity, IAP local network

KASCADE ML Application demo GUI





Possible improvements

- Add CNN model(s)
- Add gamification
- Improve interface
- Allow users to load their own ML models
- Publish outside of KIT inner network

In this talk we:

- Gave an overview of machine learning workflow and discussed it using machine learning activities for KASCADE experiment as an example
- Discussed usage of machine learning and other topical IT technologies for outreach in astroparticle physics
- Introduced a concept of ML-based outreach application based on KASCADE data
- Shared the application schema, interface and details of the implementation
- Shown how to deploy machine learning models in a way one can use them for educational purposes

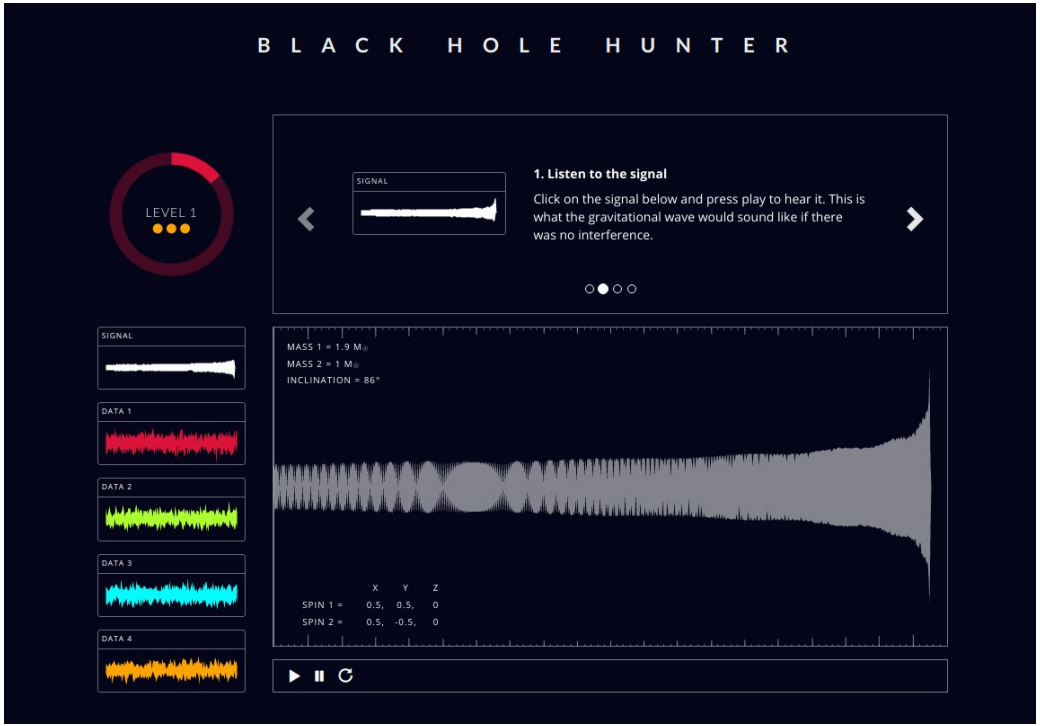
Karlsruher Institut für Technologie

Thank you for your attention!

Questions? Contact: victoria.tokareva@kit.edu

Backup slides

Example: black holes hunters



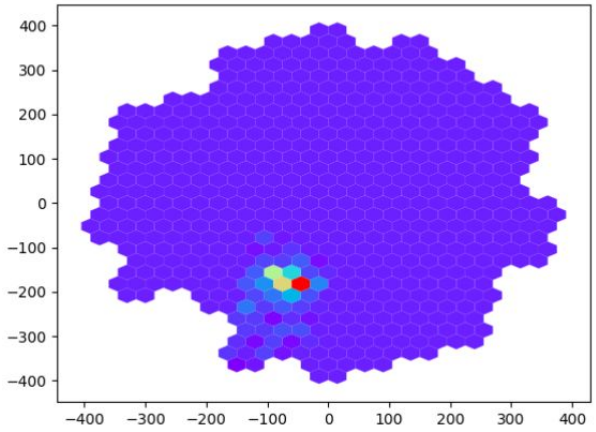
Successful gamification of analysis task through:

- Attractive name and interface
- Levels, lives and points
- clear game scenario

Example: TAIGA CNN client for astropartilce.online

Let's check yourself and determine which type of the particle is it?

5/50



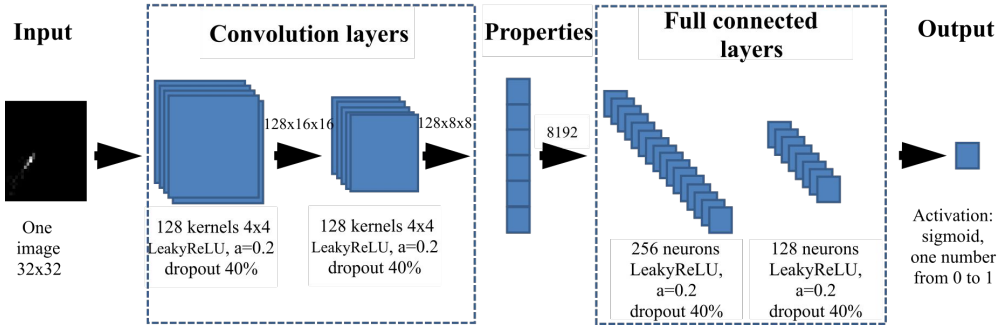
Score: right 1, missed 2, total 2

Your previous answer is correct
This is a gamma with probability: 1.00

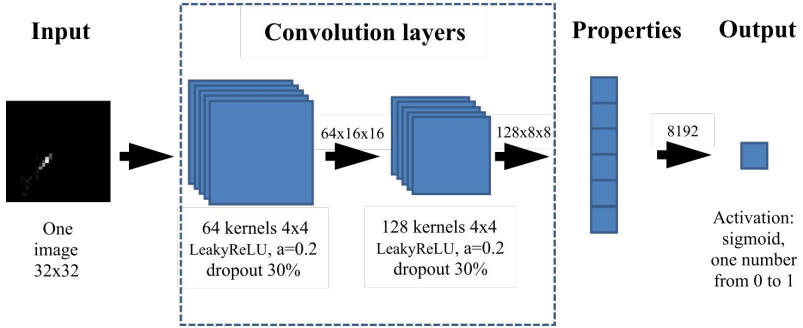
Back ○ Proton ○ Gamma Next Finish

Hint: *In comparison with hadron showers gamma-ray ones have more elliptic shape, less width and major axis pointed to the source. Axes of gamma-induced images are pointed to the center of the camera because the telescope is pointed at a known source that is placed in the center of the telescope's camera.*

Example: TAIGA CNN client for astropartilce.online - 1



Proton discriminator architecture



Gamma discriminator architecture