New approach for gamma-hadron separation at the IceCube Neutrino Observatory

DPG 2024 - Karlsruhe, Germany

March 4, 2024
16:15-16:30, Geb. 20.30: 2.059
Session: T 4 starting at 16:00

Bontempo, Federico
for the IceCube collaboration

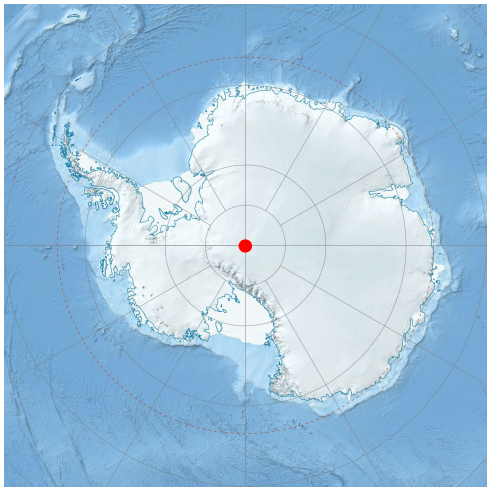
PhD student
Institut für Astroteilchenphysik (IAP)
Karlsruher Institut für Technologie (KIT)
Telefon: +49-721-608-22426
Email: federico.bontempo@kit.edu

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 802729).

www.kit.edu

IceCube Neutrino Observatory

- IceCube Neutrino Observatory is located at the Amundsen–Scott South Pole Station in Antarctica
- The successor of Antarctic Muon And Neutrino Detector Array (AMANDA)



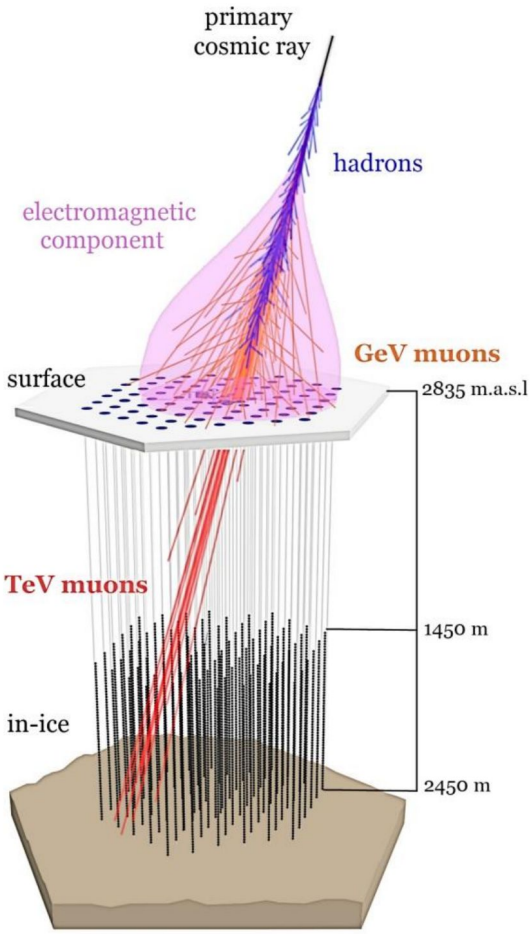
Source: https://icecube.wisc.edu/

Bontempo, Federico - *federico.bontempo@kit.edu*

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

IceCube Neutrino Observatory

- A three-dimensional cosmic ray detector located at the South Pole:
  - IceTop is a 1 km^2 array of 81 stations each with 2 ice-Cherenkov tanks on the surface that serve:
    - to detect cosmic ray air showers generated by interactions of high-energy cosmic rays in the atmosphere
    - Cosmic ray detection
- Measure electromagnetic and muonic components of air shower
- Shower reconstruction (energy, direction, core position)
- IceCube 1 km^3 in-ice array 86 strings with 60 DOMs each:
  - Measure high energy muon (E > 400 GeV)
  - Detection of high energy muons generated by:
    - high energy cosmic rays interacting with the atmosphere
    - neutrino in-ice interaction



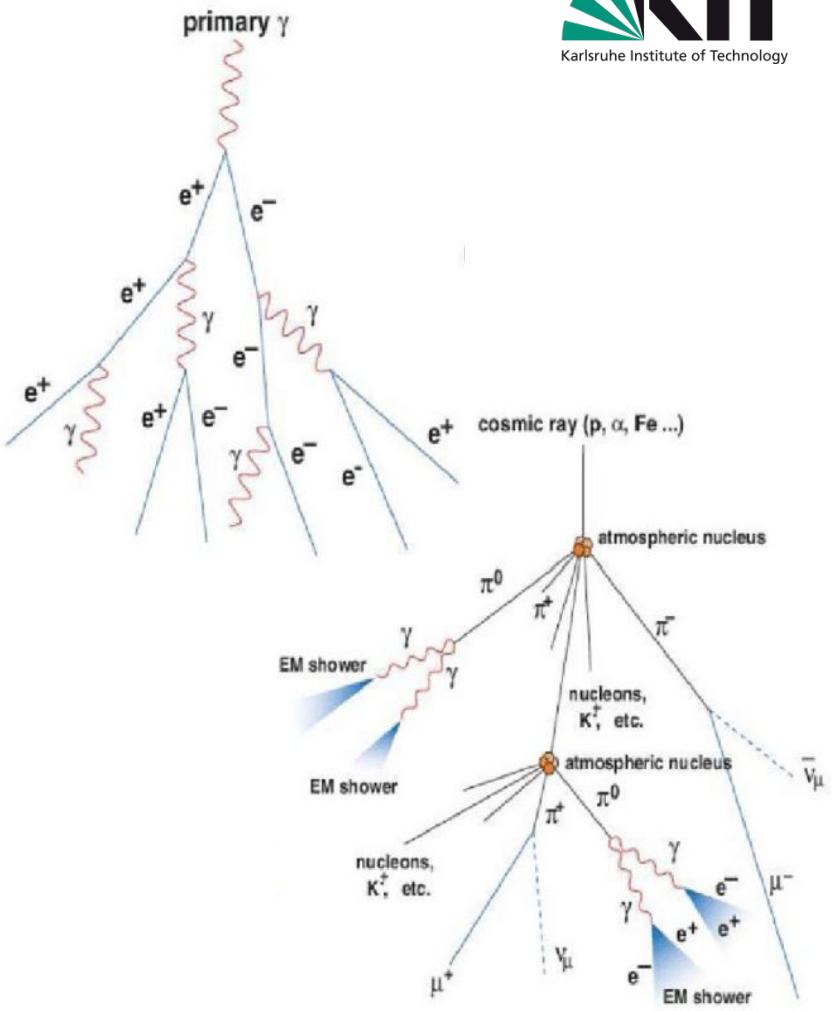
Source: https://icecube.wisc.edu/

Bontempo, Federico - federico.bontempo@kit.edu

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

Gamma-hadron separation

- Gamma-ray induced air showers:
  - fewer muons
  - less shower-to-shower fluctuation
  - narrower lateral spread
- Hadronic air showers:
  - more muons
  - more shower-to-shower fluctuation
  - wider lateral spread
- How to separate them:
  - Calculating the total in-ice charge deposited by high energy muon
  - Reconstructed energy of the primary



Images source: doi: 10.13140/RG.2.1.4140.4969

Bontempo, Federico - *federico.bontempo@kit.edu*

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

What now?

Current goal:

- Investigate lower energies enabled by a new reconstruction approach (< 1 PeV)
- Gamma-hadron separation using in-ice and surface detector

Search for gamma-ray sources:

- IceTop used for the air-shower reconstruction
- In-ice used for measuring the total charge of high energy muon

Next Goal:

- search for gamma-ray sources
- study the emission from the galactic plane

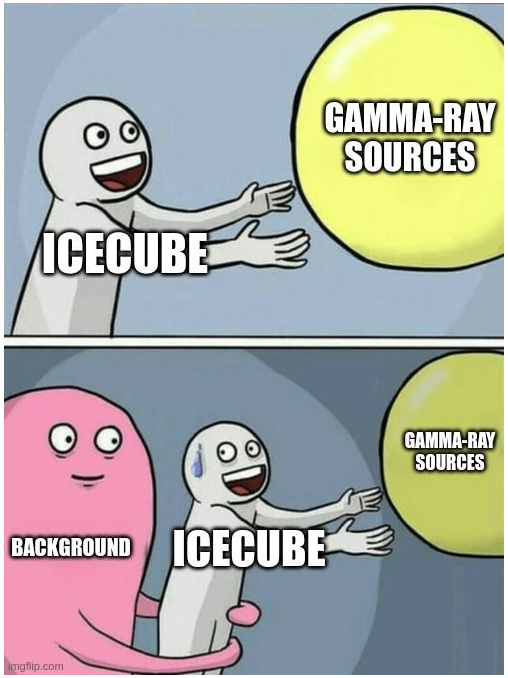
AI humor by ChatGPT

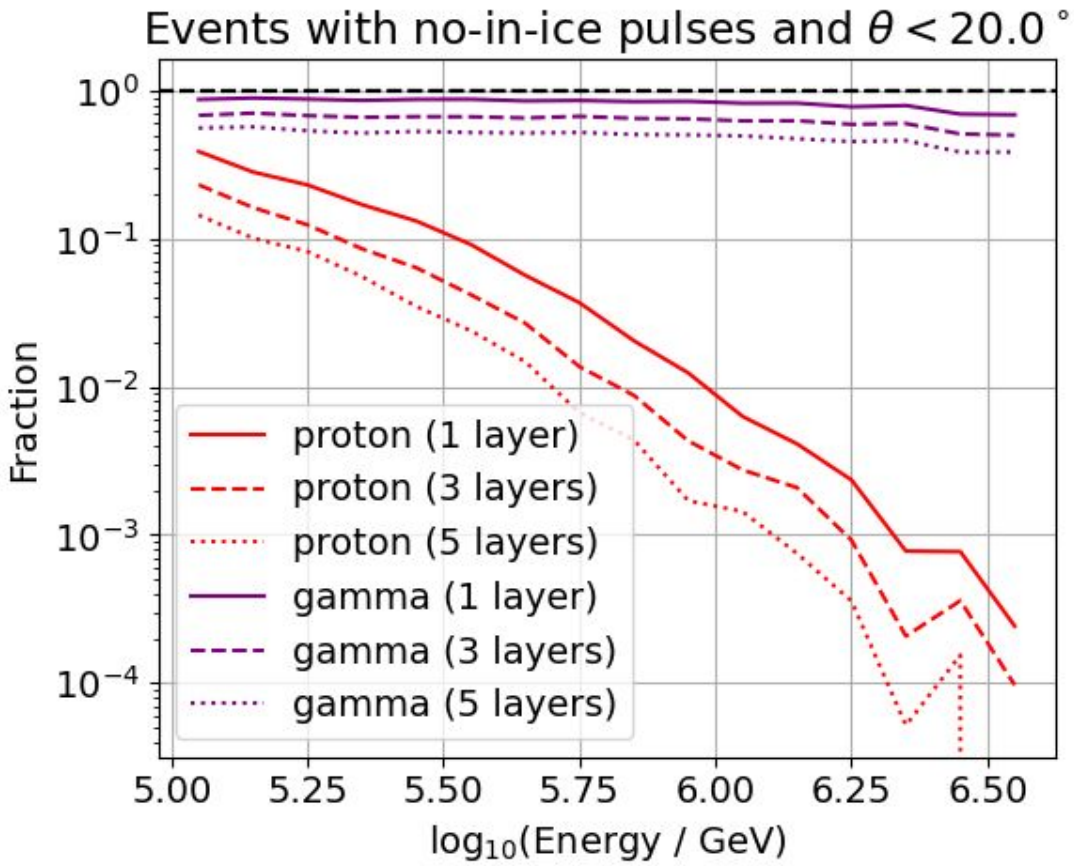
Bontempo, Federico - federico.bontempo@kit.edu

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

High-energy mouns selection

- MC Simulations Sibyll 2.3d
- Events:
  - detected on the surface
  - contained in-ice
- Selected events with:
  - no-in-ice trigger
  - no-in-ice charge





Bontempo, Federico - *federico.bontempo@kit.edu*
Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

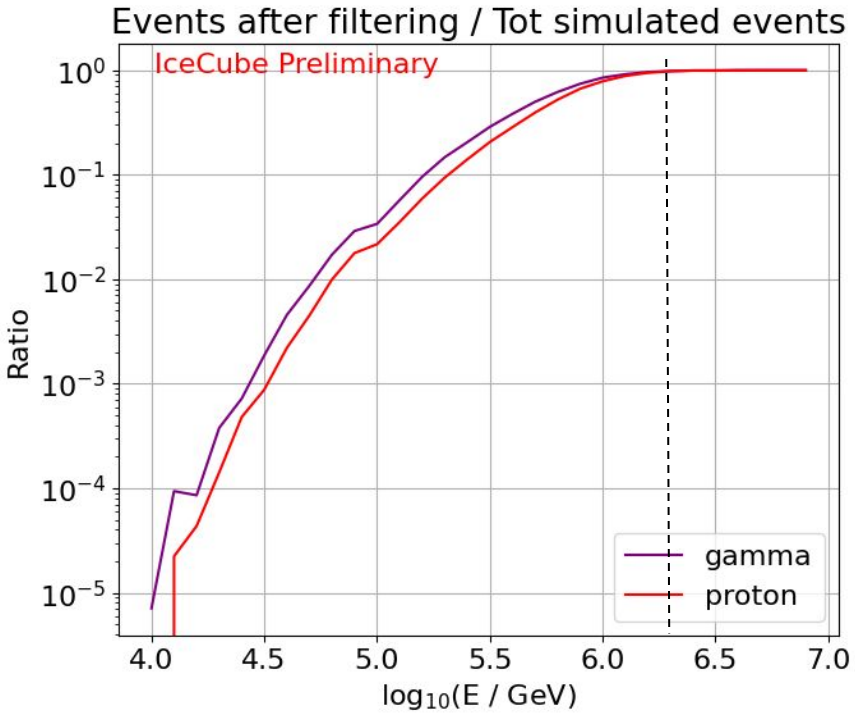
Low energy reconstruction

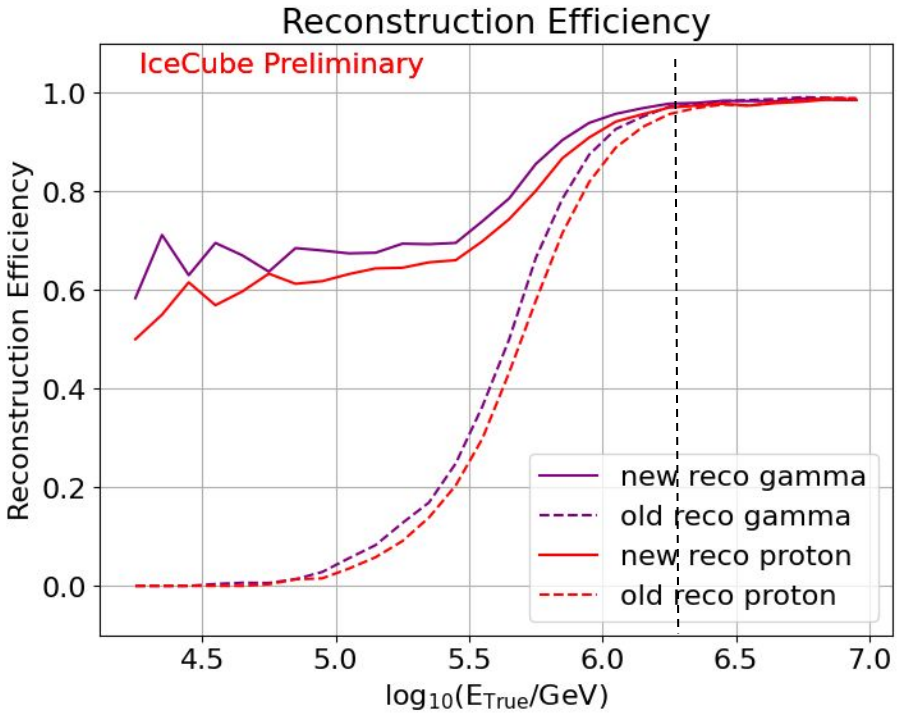
- Trigger and filtered (left)
- Filtered to reconstructed (right)

- A new reconstruction method allows to retain more events

Measured data

Simulations





Bontempo, Federico - *federico.bontempo@kit.edu*

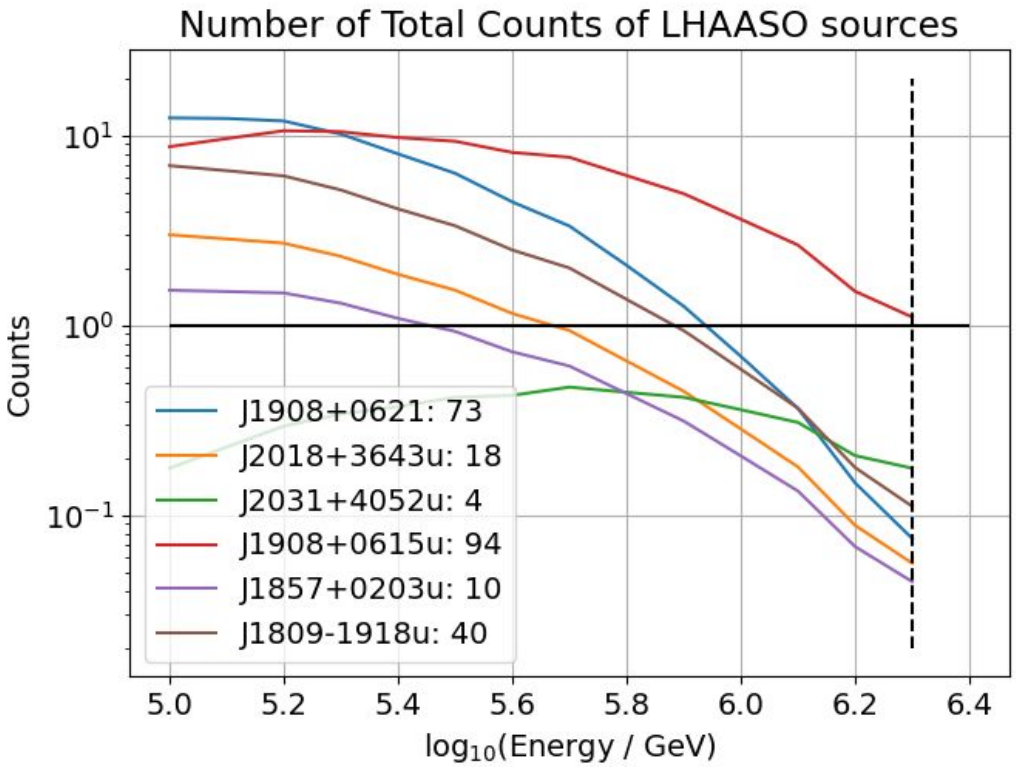
Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

Expected gamma rays per year

- Assuming LHAASO like source in Icecube FOV
- the expected flux

- Applying:
  - Trigger Efficiency
  - Reconstruction Efficiency
  - Selection with the in-ice detector

- Background is function of:
  - Energy
  - Zenith
  - Time



The First LHAASO Catalog of Gamma-Ray Sources

Bontempo, Federico - *federico.bontempo@kit.edu*

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

Summary & Outlook

- The IceCube Neutrino observatory is successfully used for the study of cosmic rays
- IceTop used for the air-shower reconstruction and the in-ice used for measuring the charge deposited by high energy muon
- Gamma-hadron separation can be performed by combining the surface and the in-ice detector
- Next step:
  - identify gamma-ray sources in the southern sky
  - study the galactic plane emission

Bontempo, Federico - *federico.bontempo@kit.edu*
Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

New approach for gamma-hadron separation at the IceCube Neutrino Observatory

DPG 2024 - Karlsruhe, Germany

March 4, 2024
16:15-16:30, Geb. 20.30: 2.059
Session: T 4 starting at 16:00

Bontempo, Federico
for the IceCube collaboration

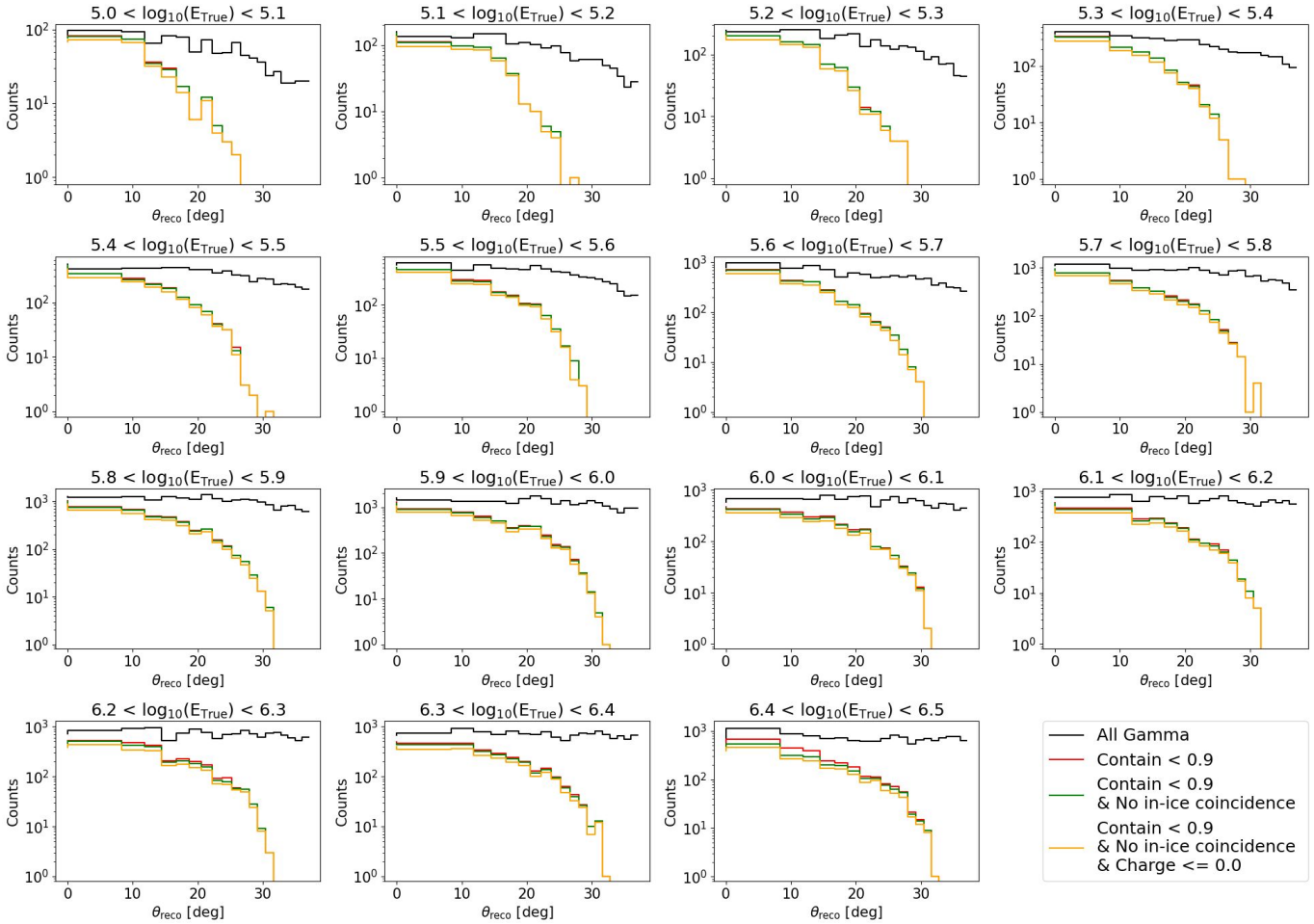
PhD student
Institut für Astroteilchenphysik (IAP)
Karlsruher Institut für Technologie (KIT)
Telefon: +49-721-608-22426
Email: federico.bontempo@kit.edu

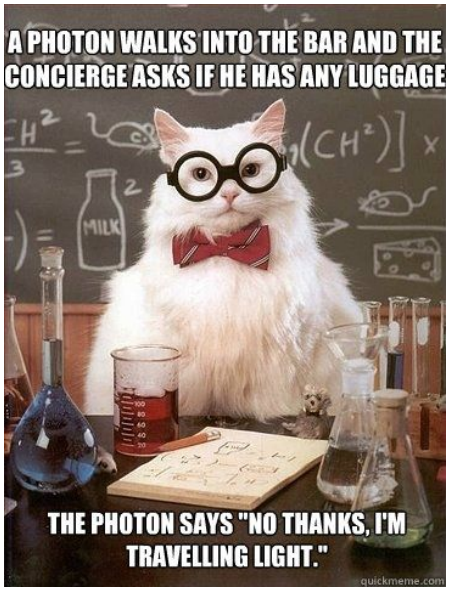
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 802729).

www.kit.edu

High-energy mouns

Gamma simulations - year 2012



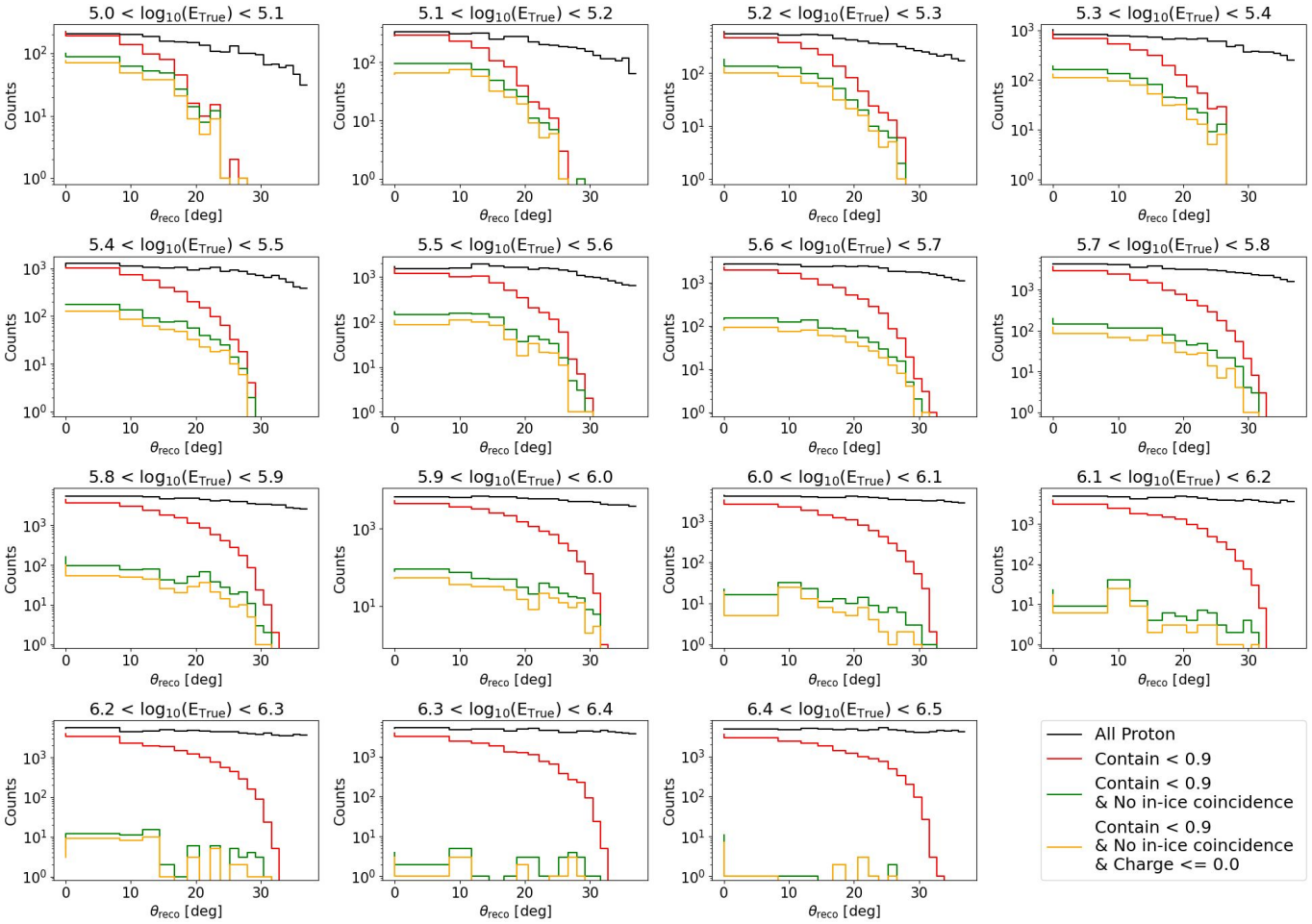


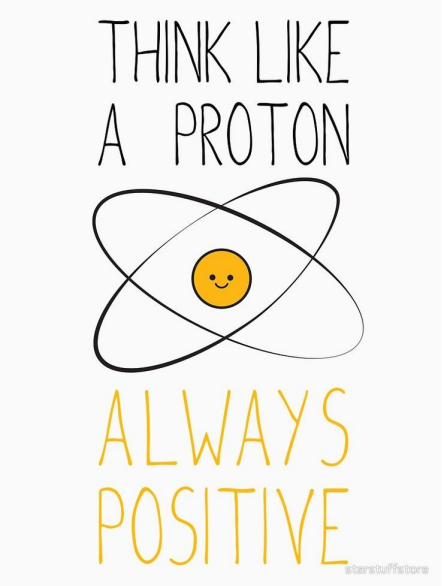
Bontempo, Federico - *federico.bontempo@kit.edu*

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

High-energy mouns

Proton simulations - year 2012



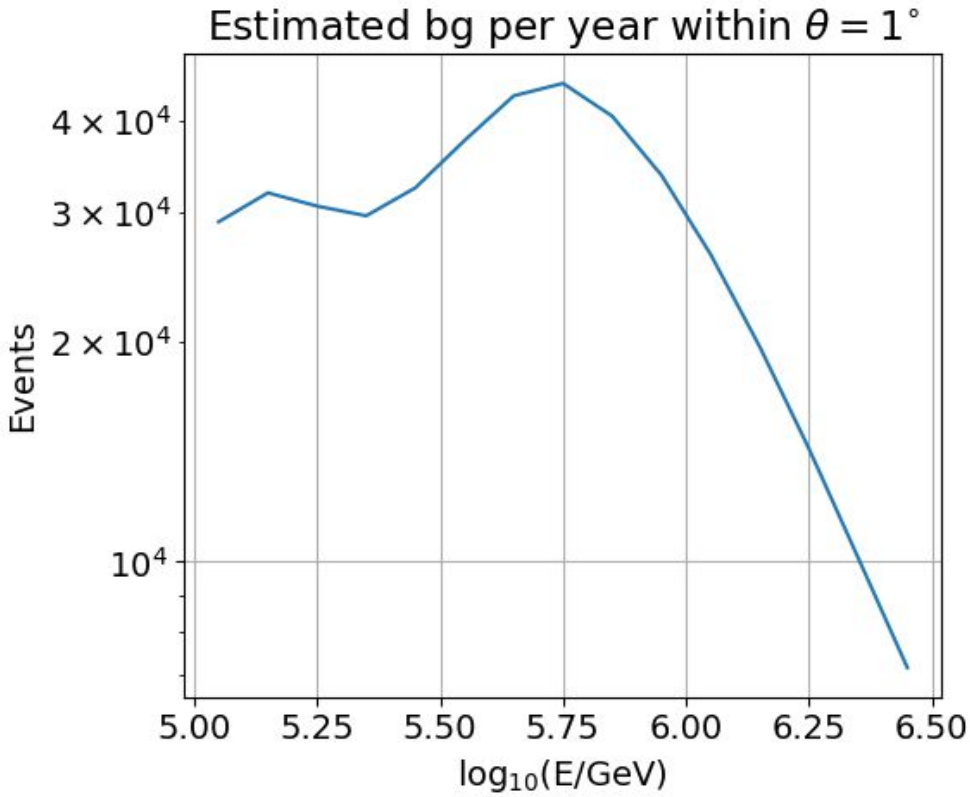


Bontempo, Federico - federico.bontempo@kit.edu

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)

Background Estimation

- Estimated background of potential gamma ray candidates
- Estimation per year 2012
- Events per solid angle
- Number as a function of zenith
-



The First LHAASO Catalog of Gamma-Ray Sources

Bontempo, Federico - *federico.bontempo@kit.edu*

Karlsruher Institut für Technologie (KIT)
Institut für Astroteilchenphysik (IAP)