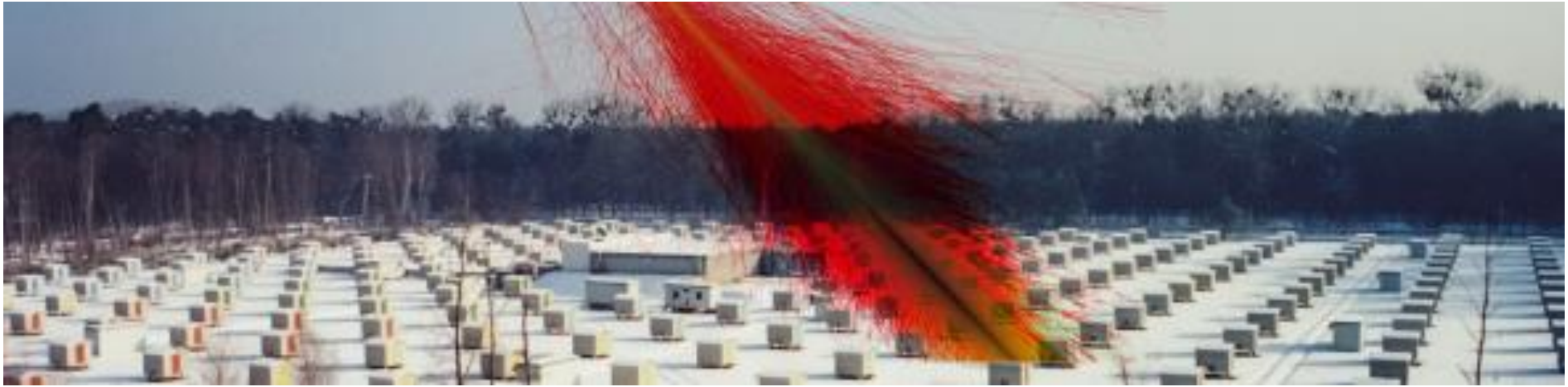
The KASCADE Cosmic ray Data Centre: KCDC

PUNCH4NFDI Open Data Workshop
11 February 2021

Andreas Haungs

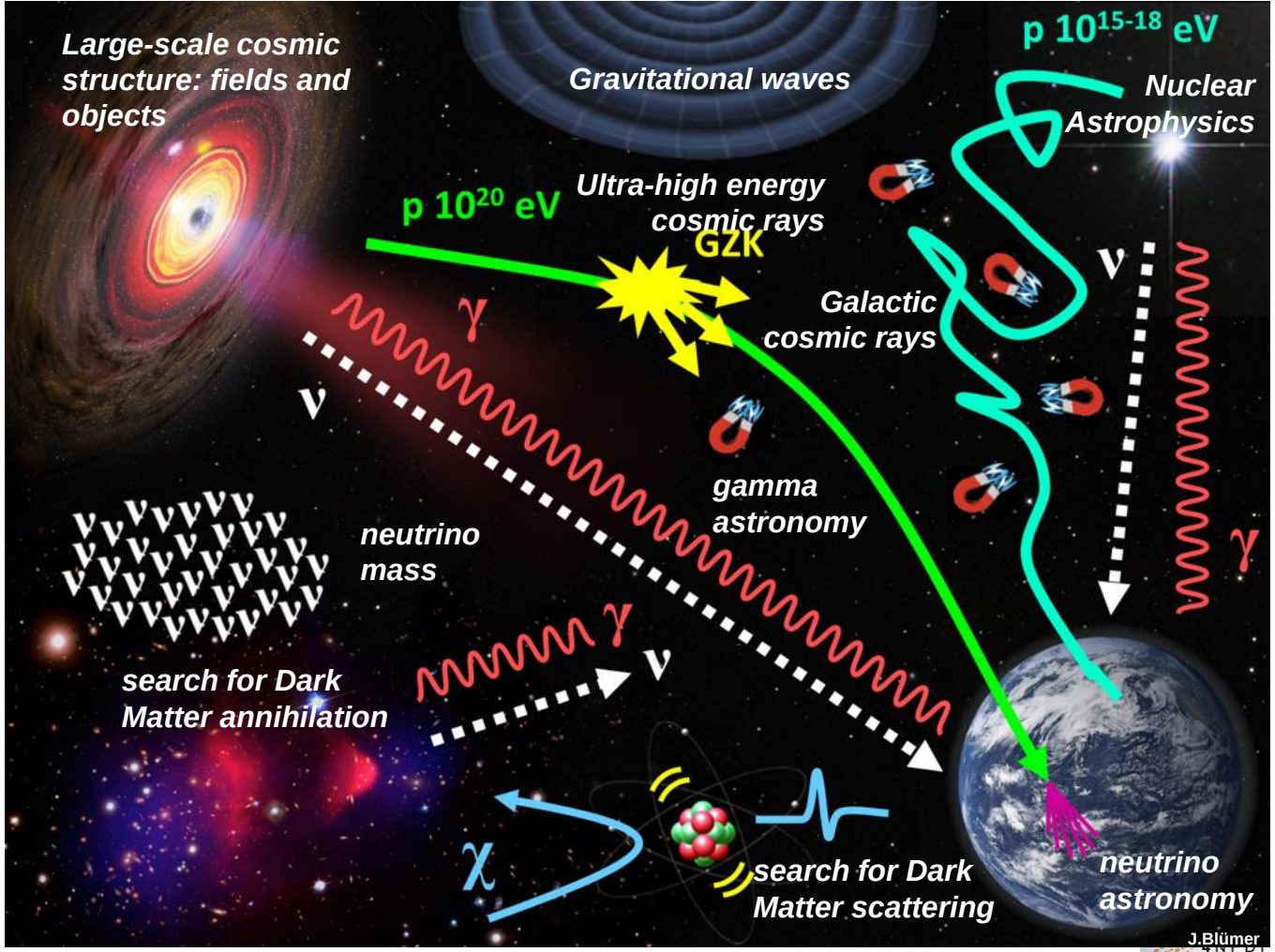
Open access of scientific data:
https://kcdc.ikp.kit.edu



Astroparticle Physics: Understanding the Multi-Messenger and the Dark Universe

This requires a combination of the measurements of the globally distributed experiments

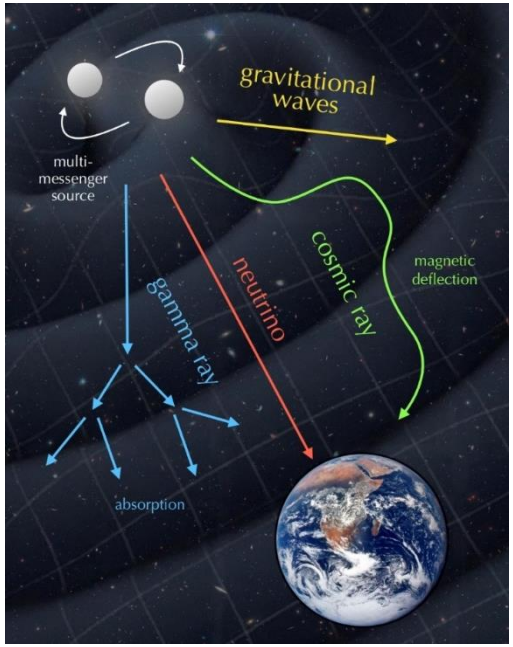
experiment-overarching Data Management needed!

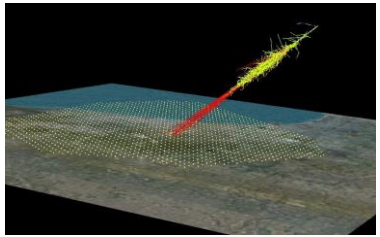


Multi-Messenger Astroparticle Physics

= a major pillar in High-Energy Astroparticle Physics

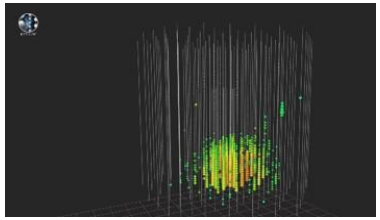
- Required to understand the sources of cosmic rays and the physics processes in the high-energy Universe
- Needs long-term operational observatories
  - Benefits from synergies in simulation and reconstruction (Big Data Analytics)
  - Needs common data description and access (Research Data Management)
  - Fosters Open Data common platforms (Data Curation)





PIERRE AUGER OBSERVATORY

cta cherenkov telescope array

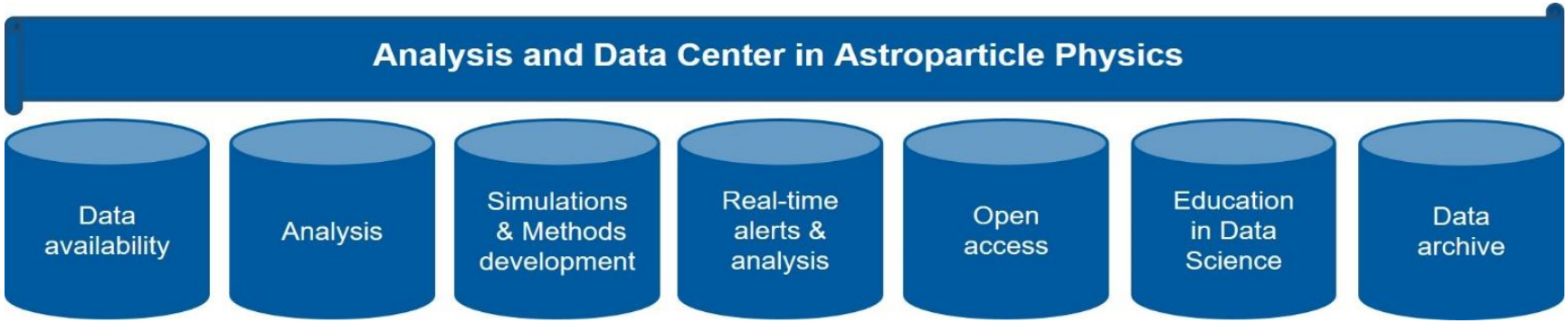


ICECUBE

LIGO VIRGO

PUNCH 4NFDI

Vision and Mission



all FAIR!

Partly realized in individual experiments

in PUNCH4NFDI

Findable
Accessible
Interoperable
Reusable

German Astrophysical Virtual Observatory

KASCADE KCDC Cosmic ray Data Centre

opendata CERN

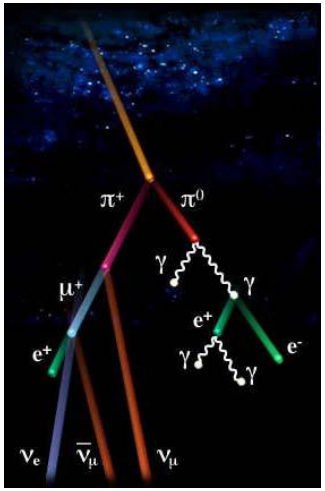
PUNCH 4NFDI

WLCG Worldwide LHC Computing Grid

GridKa

VISPA

KASCADE



KArlsruhe Shower Core and Array DEtector

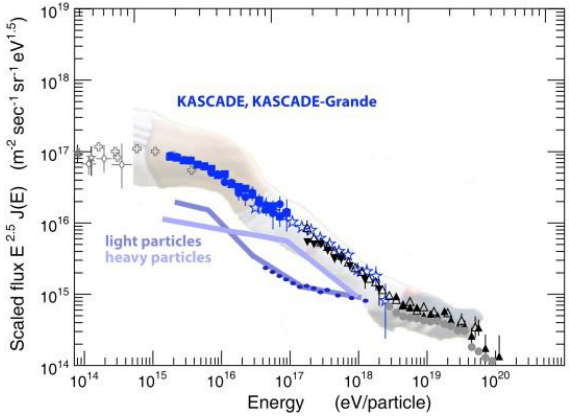
High energy cosmic ray measurements by detection of air showers

physics topics:

- sources, acceleration mechanisms and propagation of cosmic rays
- knee structure of the energy spectrum
- search for anisotropy in the incident direction
- hadronic interactions in the atmosphere

-- and more…..

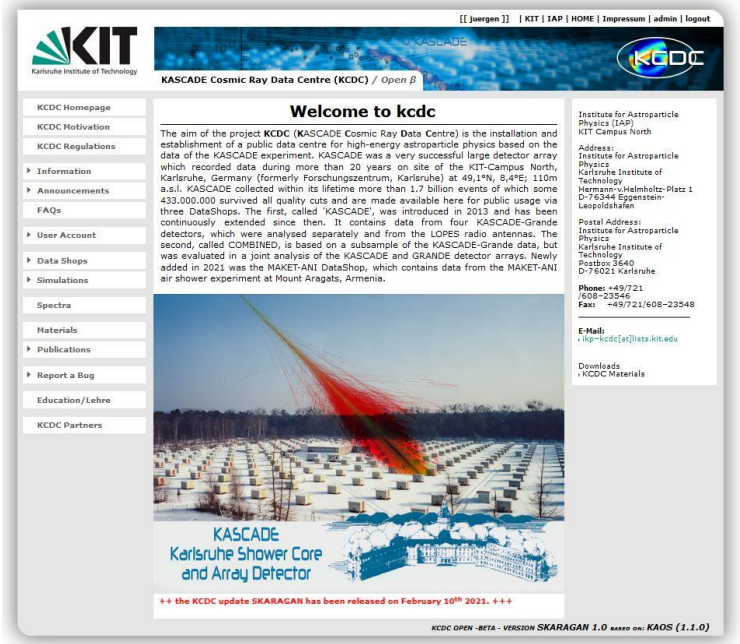
Data collection from 1993 to 2013



KASCADE Cosmic ray Data Centre

#KCDC_KIT

- **Motivation and Idea of KCDC:**
  - public access to the data
  - data has to be preserved for future generations
- **Web portal:**
  - modern software solution
  - release the software as Open Source
  - educational courses
- **Data access:**
  - $4.3 \cdot 10^8$ EAS events (KASCADE, -Grande, LOPES)
  - Metadata
  - simulation data
  - spectra
- **Pioneering work in publishing research data in astroparticle physics**



https://kcdc.ikp.kit.edu/

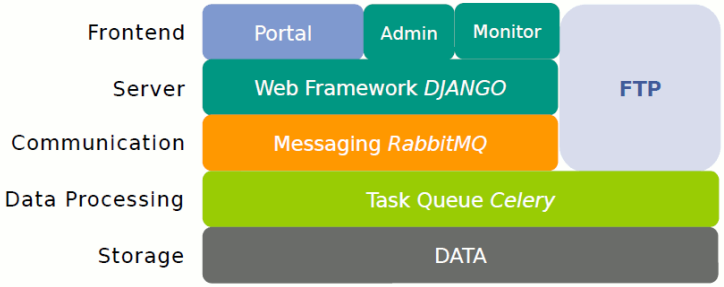
[J.Phys.Conf.Ser. 632 (2015) 012011]
[EPJ C78 (2018) no.9, 741]

KCDC in a nutshell

providing open access to astroparticle physics research data as required by funding agencies

- **data provider**
  - **follows the “Berlin Declaration on Open Data and Open Access”**
  - **free, unlimited, open access to KASCADE cosmic ray data**
  - **selection of fully calibrated quantities and detector signals**
  - **reliable data source**
  - **UUIDs**
  - **guaranteed data quality**
- **information platform**
  - **experiment description**
  - **meta information for data analysis**
  - **physics background**
  - **use of modern and open source web technologies**
  - **tutorials (focused on teachers and pupils)**
  - **spectra (high level results)**
- **as long-term digital data archive**
  - **archive of software and data**
  - **for the collaboration**
  - **for the public**

#KCDC_KIT

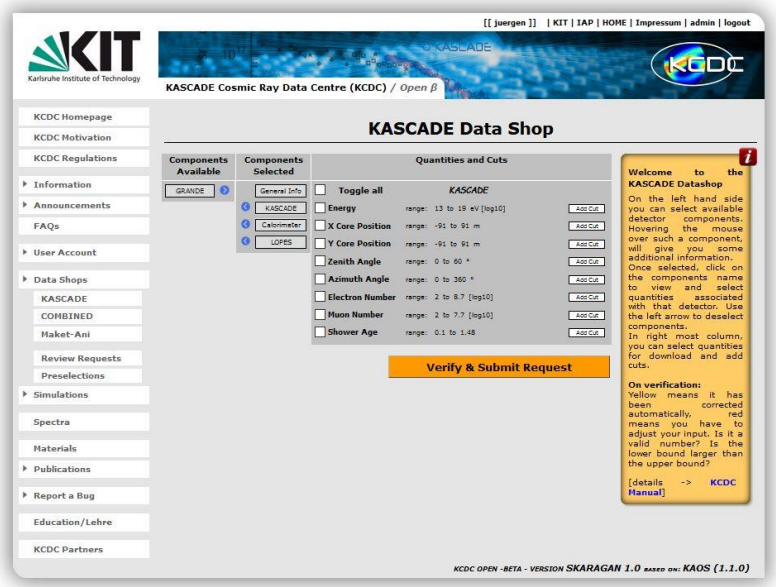


KASCADE KCDC Cosmic ray Data Centre

Karlsruhe Astroparticle KAOS Open data Software

https://kcdc.ikp.kit.edu/

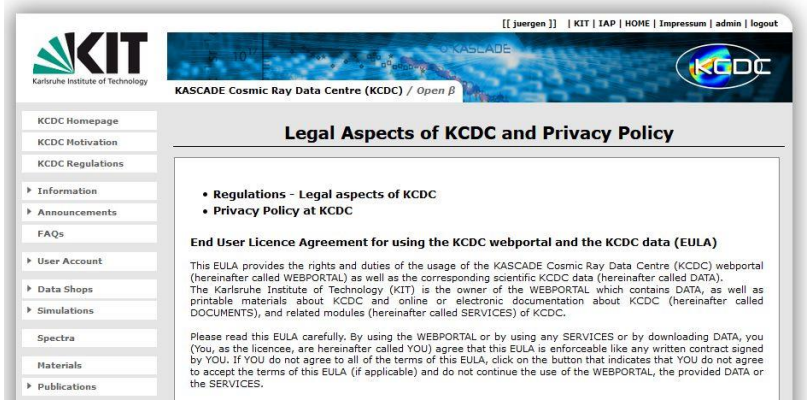
KCDC data shop



Output:

- zip-archive with data, metadata, and the EULA (end user licence agreement)
- Data as ASCII, ROOT and HDF5 files
- Commented header give information about the content

Law and Order



Open data publication:

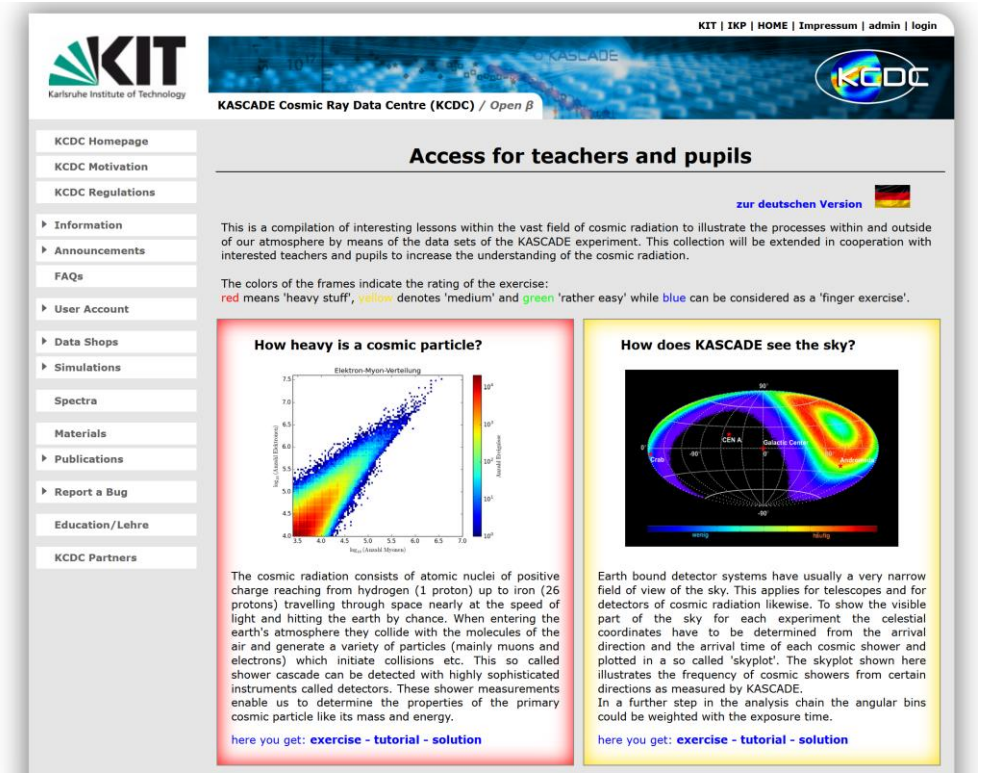
- no ready available open data licence
- free access to data and web portal
- good scientific practice for work with data
- citation of collaboration, KIT, and the web portal mandatory
- free redistribution of data “as is”

KCDC approach:

- licence based on EULA model (as usually for software)
- licence details: following the industry
- flexible and adaptable to our needs
- signed during registration & shipped with each data package

Tutorials and Teaching

- **The goal: Providing the data to a general public**
- **Education portal:**
  - several tutorials are up
    (only in German and English at the moment)
  - knowledge database on KASCADE,
    astrophysics and related topics
  - step by step tutorials of
    simple data analyses
  - including a modern programming
    language code example
  - interpretation and discussion
    of the outcome
  - cooperation with local
    teachers and pupils
  - later offering to teachers dedicated
    lessons for high schools
- **Masterclass based on KCDC**
  - in preparation, thanks to V. Tokareva, K. Link



Physics with KCDC

DRAFT VERSION SEPTEMBER 23, 2019
Preprint typeset using LaTeX style emulateapj v. 12/16/11

LARGE- AND MEDIUM-SCALE ANISOTROPIES IN THE ARRIVAL DIRECTIONS OF COSMIC RAYS OBSERVED WITH KASCADE-GRANDE

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Draft version September 23, 2019

ABSTRACT

We search for anisotropies in the arrival directions of cosmic rays observed by the KASCADE-Grande air shower experiment. The analysis is based on public data of about 23.7 million events with reconstructed primary energies above 1 PeV. We apply a novel maximum-likelihood reconstruction method for the cosmic ray anisotropy, that compensates for spurious anisotropies induced by local detector effects. We find no evidence for a large-scale dipole anisotropy in the data, consistent with official results based on the conventional East-West derivative method. On the other hand, a subset of cosmic rays with median energy of 33 PeV shows strong evidence for a medium-scale feature with an angular diameter of 40 degrees. After accounting for the look-elsewhere effect, the post-trial significance of this medium-scale feature is at the level of 4σ.

Subject headings: cosmic rays — methods: data analysis

1. INTRODUCTION

Cosmic rays (CRs) experience deflections by Galactic and extragalactic magnetic fields before their arrival on Earth. The spatial variation of these magnetic fields in strength and orientation scrambles the particles' arrival direction and time. Combined with the limited energy resolution and livetime of CR observatories, these effects can explain the continuity of the flux of CRs and the mostly isotropic distribution of their arrival directions. However, some CR experiments have achieved the necessary level of statistics to be able to infer weak anisotropies in the arrival directions that reach per-

range from 2 PeV to 8 EeV. This observation would provide valuable data to decipher the transition between Galactic and extragalactic CR sources.

In this paper we search for anisotropies in the arrival directions of CRs observed with the KASCADE-Grande air shower experiment. The analysis is based on public data provided by the KASCADE Cosmic Ray Data Center (KCDC) (Haungs et al. 2018) and uses a novel maximum-likelihood reconstruction method introduced in Ahlers et al. (2016), that we outline in the following section. We then first study the presence of a dipole anisotropy in the data and compare our re-

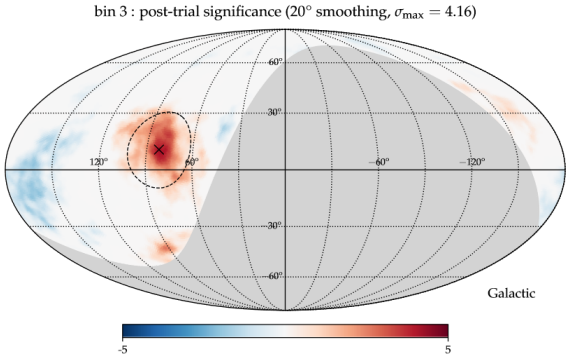


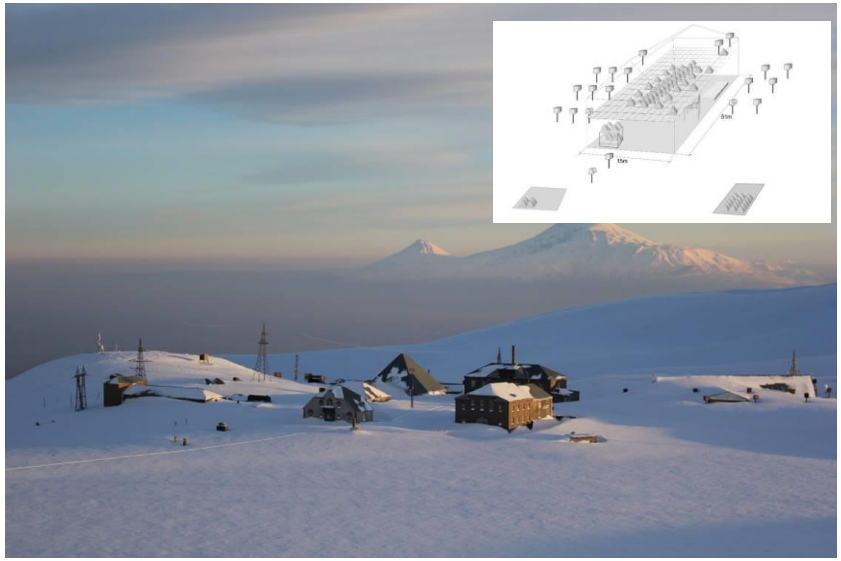
FIG. 3.— Mollweide projection in Galactic coordinates of the post-trial significance of 20° smoothed anisotropies at 33 PeV (bin 3). We use a trial factor $N_{trials} \simeq 14$ in Eq. (12) and show units of Gaussian standard deviations. We indicate the location of the maximum significance by the symbol × and the 20° smoothing radius by a dashed line.

ACKNOWLEDGEMENTS

I would like to thank the KASCADE-Grande Collaboration for sharing their data via KCDC. In particular, I would like to thank Andrea Chiavassa, Ralph Engel, Andreas Haungs, Donghwa Kang, Dmitriy Kostunin, Markus Roth and Jürgen Wochele for their feedback on KASCADE-Grande data and previous anisotropy analyses. This work was supported by VILLUM FONDEN under project no. 18994.

M. Ahlers, Astrophys.J.Lett. 886 (2019) 1, L18

Latest Release



* Thanks to the Maket-Ani Collaboration
(in particular A.Chilingarian, G.Hovsepian)

New:

- **MAKET-ANI (Armenia) Data Shop ***
- **API Interface ➔ e.g., attachment of Jupyter-notebooks foreseen**
- **More spectra (100)**

Next:

- Further extension of KCDC
- Improvement of Tutorials & Outreach
- Publication of KAOS
- KCDC as integral element of the *Analysis and Data Center in Astroparticle Physics*
- KCDC as integral part of the *PUNCH Science Data Platform*

https://kcdc.ikp.kit.edu

Thanks the support of the KASCADE-Grande Collaboration

Thank you!