# Current status of data center for cosmic rays based on KCDC

GRID-2018, Dubna

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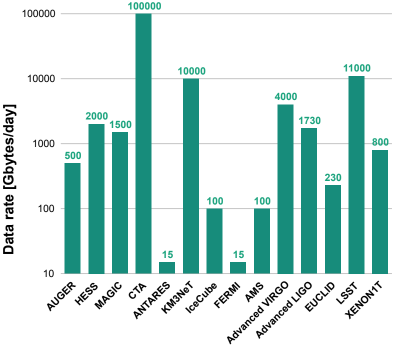
*for the German-Russian Astroparticle Data Life Cycle Group*

INSTITUTE FOR NUCLEAR PHYSICS (IKP)

# Introduction:
# The astroparticle physics data rate




Modern astroparticle experiments data rate [Gbytes/day]*

- More than hundred years of cosmic particle measurements;
- Looking at the same sky with different eyes: different messengers, different detectors;
- Common data rate for astrophysical experiments all together is a few PBytes/yeary, which is comparable to the current LHC output*
- Big data for deep learning

*Berghöfer T., Agrafioti I. et all. Towards a model for computing in European astroparticle physics, Astroparticle Physics European Coordination committee, 2016

# German-Russian Astroparticle Data Life Cycle Initiative*

KIT Karlsruhe Institute of Technology

НИИЯФ МГУ

TAIGA

KIT-IKP
Karlsruher Institut für Technologie
Institut für Kernphysik

ИРКУТСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ 1918

RSF Russian Science Foundation

HELMHOLTZ ASSOCIATION

SCC
Steinbuch Centre for Computing

Matrosov Institute for System Dynamics and Control Theory

KASCADE - Grande
KArlsruhe Shower Core and Array DEtector - Grande

*Granted by RSF-Helmholtz Joint Research Groups

# KASCADE

- Proposed in 1989—disassembled in 2013;
- Aimed at studying high-evergy (galactic) cosmic rays by observing extensive air showers (EAS);
- Consisted of:
  - scintillators detecting $e$, $\gamma$, $\mu$:
    - KASCADE—256 stations;
    - GRANDE—37 stations;
  - Hadronic callorimeter;
  - Digital radio array LOPES detecting $e$, $e^{+}$;
- Important features of cosmic-ray spectrum have been obtained. The data analysis is ongoing;
- KCDC (**K**ASCADE **C**osmic Ray **D**ata **C**enter, http://kcdc.ikp.kit.edu) is a dedicated portal where all the data collected are available online.

# TAIGA

- Started in the mid 90s, is still operating and continiously enhancend

## Tunka-133

- 133 photomultipliers
- measures EAS Cherenkov light

## Tunka-Rex

- 63 antennas
- measures EAS radio-emission

## Tunka-HiSCORE

- 47$\times$4 photomultipliers
- measures EAS Cherenkov light

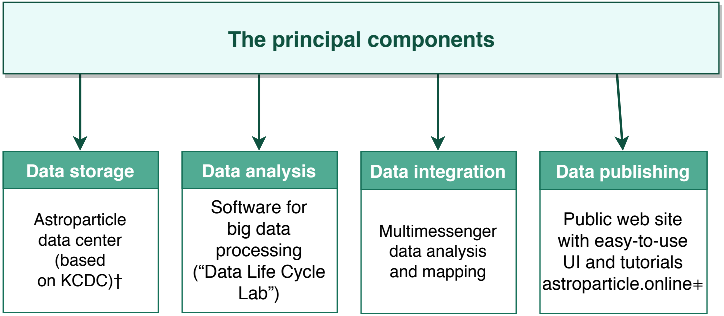
## Tunka-Grande

- 380 scintillators 0.64m$^2$ each
- measures $e/\mu$ from EAS

## Tunka-IACT

- Imaging Air Cherenkov Telescopes
- is being extended

# The project objectives

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† Minh Duc Nguyen, *A distributed data warehouse system for astroparticle physics*, GRID2018 session 10

‡ Yu. Kazarina, *Application of Hubzero platform for the educational process in astroparticle physics*, GRID2018 poster

# Deep into KASCADE-Grande and Tunka data formats

## Different

- Data format (depends on avalilable detectors)
- Dedicated software for analyzing data
- Special system environment for the software

## Common

- Metadata format (e.g. time, location, atmospheric conditions)
- Software for EAS simulation (e.g. CORSIKA)
- Shower parameters
- Theoretical models

## Current state

- Separate APIs and UIs for different experiments

## Our objective

- Unified API and UIs for different experiments

# WMS—workload management system

- The basic idea is to provide a central queue for all users and make all the distributed sites look like local ones;
- Starting from mid 90's are widely used in collider experiments (Dirac, PanDA);
- Dedicated for:
  - Unified usage of the distributed remote data and common data analysis;
  - Conceal various low-level software and provide unified high-level interface;
- Provide the common way to issue tasks to different types of the distibuted sites;
- The same system for the data access, analysis and simulation.

# Data-oriented approach

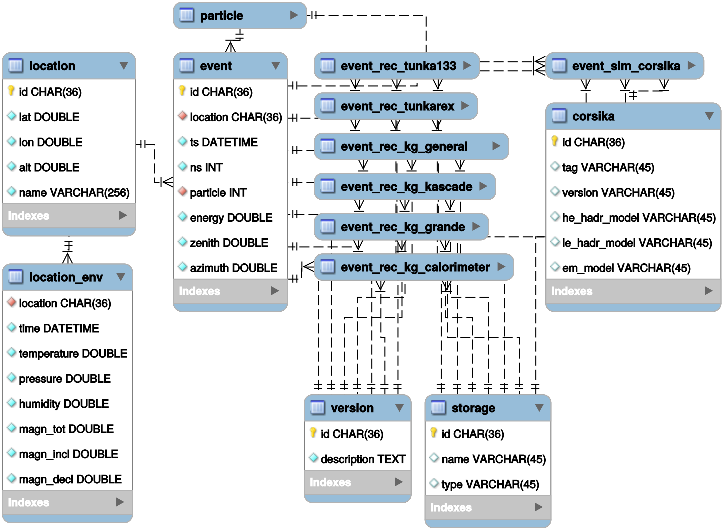
What data do we work with?

- Data types:
  - Raw detector readouts;
  - Pre-analyzed events;
  - Metadata
- Data structure:
  - Different formats;
  - Different messengers;
  - Common metadata

Our approach:

- It is proposed to store unique event id and metadata in the unified database
- With growing data sizes, distributed storage for events could be useful

# Proposed cosmic-ray metadata structure



# Data analysis

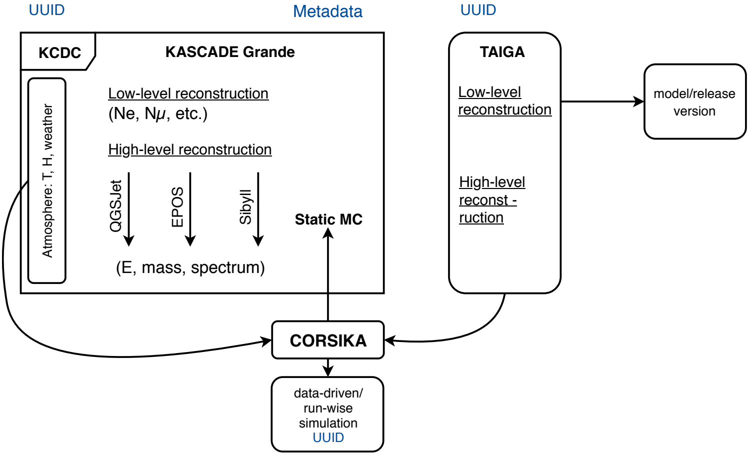
- Software for data analysis depends on a particular experiment
  - Problem: It may even require dedicated system environment
  - ▶ **Solution: Virtualization**
- Data analysis requires huge amounts of input data
  - Problem: It is often more optimal to perform it on the same site the data are stored
  - ▶ **Solution: Job management**

# Simulation

| Feature | | Consequence |
|---|---|---|
| The software for EAS simulation (e.g. CORSIKA) does not depend on a particular experiment | $\Rightarrow$ | Simulations require standartized system environment |
| Simulations require small amounts of input data<br>Simulations can be done independently for different events | $\Rightarrow$ | Simulations are easily scalable |
| Simulations require a lot of computing resources | $\Rightarrow$ | HPC sites are needed |

**Distributed computing could be useful**

# Distributed analysis and simulation scheme



# Current status

- The KASCADE project has a data center called KCDC, that is planned to serve as the basis for the future common center for data access;
- The differences in the data formats were analyzed and solutions for organizing storage and distributed data processing were proposed;
- A scheme of a relational database for the future data center is designed using a metadata-based approach;
- The possibilities to apply the results of the project to educational and outreach activities are being explored.
  The joint resource **astroparticle.online** is created to provide access to KASCADE and TAIGA data and metadata.

# Conclusion

- The constantly growing amount of accumulated astroparticle data and the request for the multi-messenger astronomy and machine learning, enable us to develop a unified system for astroparticle data storage and processing;
- KASCADE is the only astroparticle experiment so far that has fully published its data and has a software infrastructure for data access and online analysis (KCDC);
- The pecularities of data format and acquisition make it impossible to utilize 'from scratch' the solutions widely used in collider experiments;
- We are developing a new approach to the astroparticle data life cycle for combined analysis of the KASCADE and TAIGA data;
- The built-up infrastructure will be used to analyze combined data sets with large statistics, allowing to study galactic sources of high-energy $\gamma$-rays, which could be a notable step forward in multi-messenger astroparticle physics.

# Thank you
# for your attention!

# The German-Russian Astroparticle Data Life Cycle collaboration I

TAIGA—Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy (see taiga-experiment.info);

KASCADE-Grande—KArlsruhe Shower Core and Array DEtector—Grande (see www-ik.fzk.de/KASCADE_home.html);

KIT-IKP—Institute for Nuclear Physics Karlsruhe Institute of Technology

SCC—Steinbuch Centre for Computing Karlsruhe Institute of Technology

# The German-Russian Astroparticle Data Life Cycle collaboration II

SINP MSU—Skobeltsyn Institute Of Nuclear Physics Lomonosov Moscow State University

ISU—Irkutsk State University

ISDCT—Matrosov Institute for System Dynamics and Control Theory

# References


- Berghöfer T., Agrafioti I. *et al.* Towards a model for computing in European astroparticle physics, Astroparticle Physics European Coordination committee, 2016,
  web-source: `http://appec.org/wp-content/uploads/Documents/Docs-from-old-site/AModelForComputing-2.pdf`;
- KCDC—**K**ASCADE **C**osmic Ray **D**ata **C**enter,
  web-source: `http://kcdc.ikp.kit.edu`;
- KASCADE-Grande official site,
  web-source: `http://www-ik.fzk.de/KASCADE_home.html`;
- TAIGA collaboration official site,
  web-source: `http://taiga-experiment.info`;
- Astroparticle.online—outreach resource,
  web-source: `http://astroparticle.online`.