Karlsruhe Institute of Technology

Current status of data center for cosmic rays based on KCDC

GRID-2018, Dubna

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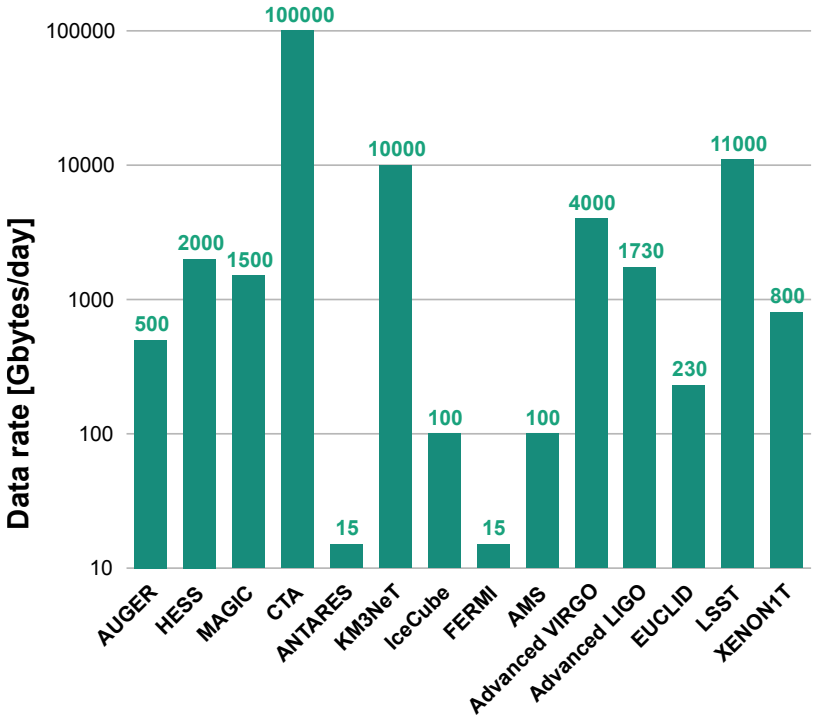
INSTITUTE FOR NUCLEAR PHYSICS (IKP)

Introduction:
The astroparticle physics data rate



Modern astroparticle experiments data rate [Gbytes/day]*

- Wide range of experiments;
- Looking at the same sky with different eyes: different detectors, different phenomena under the study;
- 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

*APPEC brochure on Computing, 2016

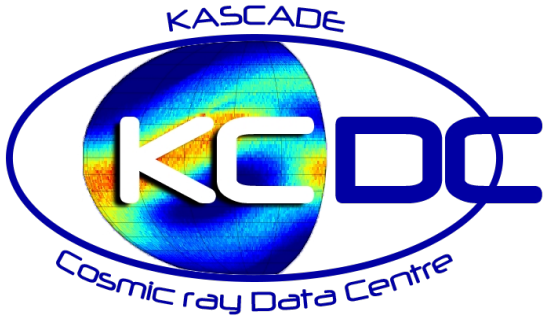
German-Russian Astroparticle Data Life Cycle

Matrosov Institute
for System Dynamics
and Control Theory

KASCADE - Grande
KArlsruhe Shower Core and Array DEtector - Grande

KASCADE

- Proposed in 1989—disassembled in 2013;
- Aimed at studying processes at the edge of the Galaxy and beyond by observing extended atmospheric showers (EAS);
- Consisted of:
  - scintillators detecting e, γ, μ:
    - KASCADE - 256 stations;
    - GRANDE - 37 stations;
  - Hadronic callorimeter;
  - Radiodetector LOPES detecting e, e^+;



- Recognized astrophysical results were 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 and still operating

Tunka-133

- 133 photomultipliers
- measures EAS Cherenkov light

Tunka-Rex

- 63 antennas
- measures EAS radio-emission

Tunka-HiSCORE

- 47 photomultipliers
- measures EAS Cherenkov light

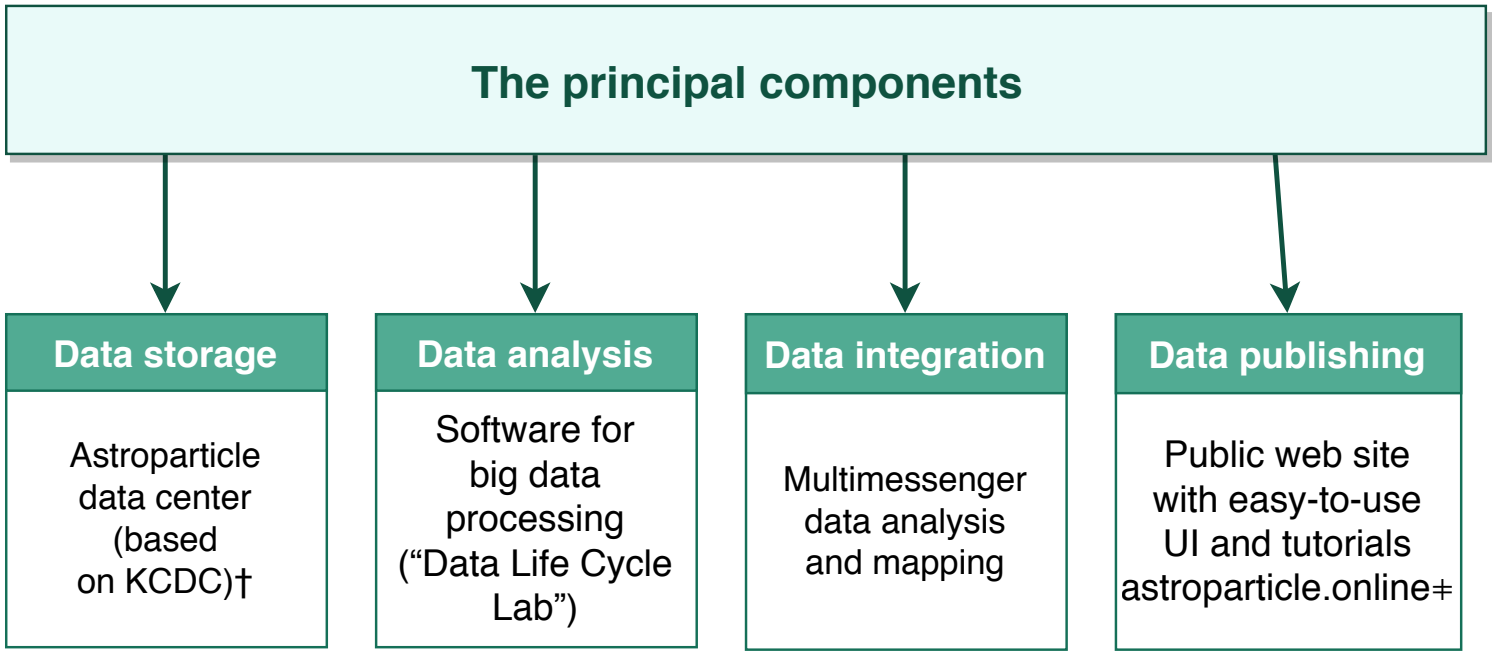
Tunka-Grande

- 380 scintillators 0.64m^2 each
- measures e/μ from EAS

Tunka-IACT

- Imaging Air Cherenkov Telescopes
- is being extended

The project objectives



†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 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 (AliEn, 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

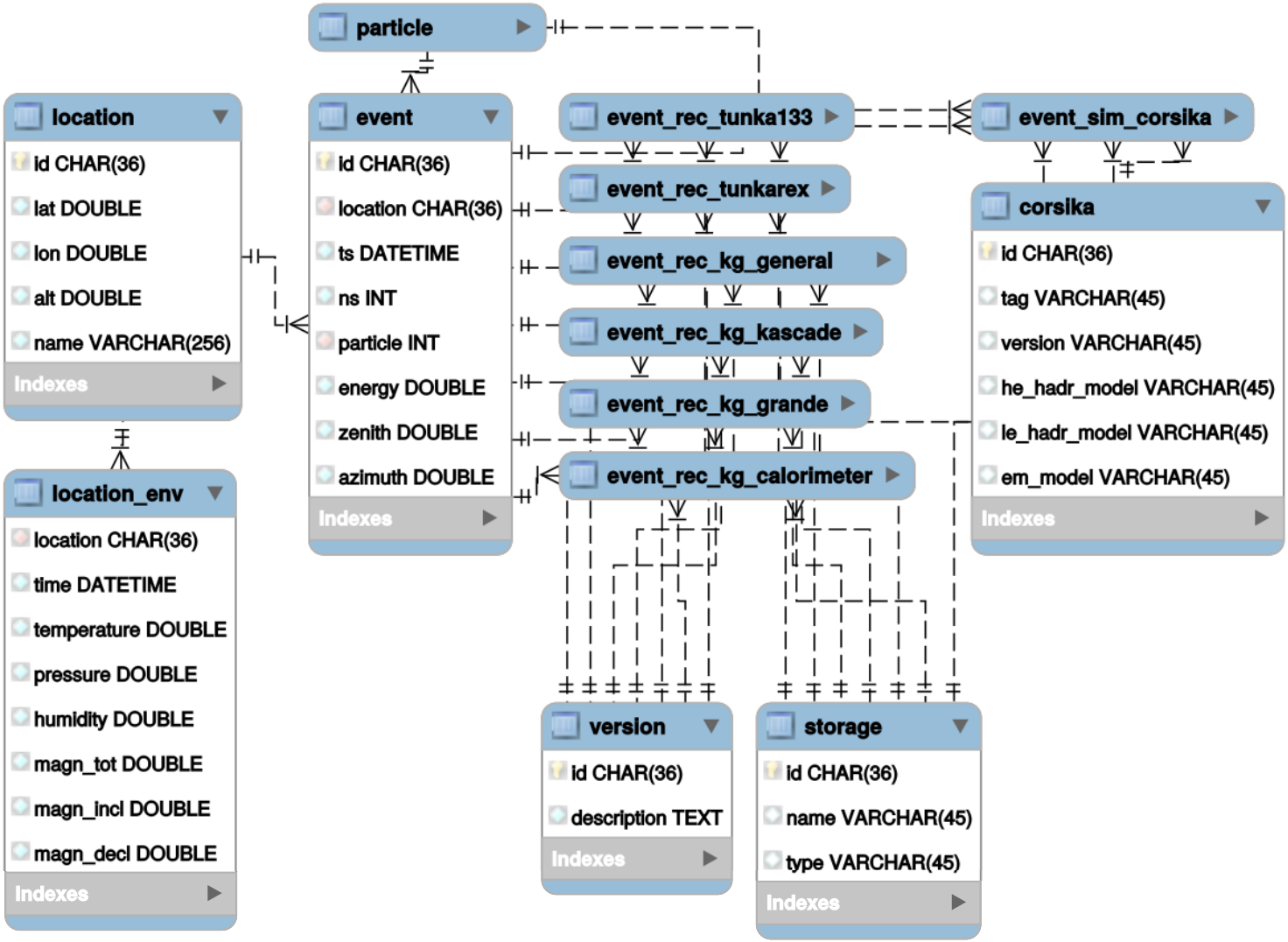
What data do we work with?

- 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, distribured storage for events could be useful

Proposed cosmic-ray metadata structure



Data analysis

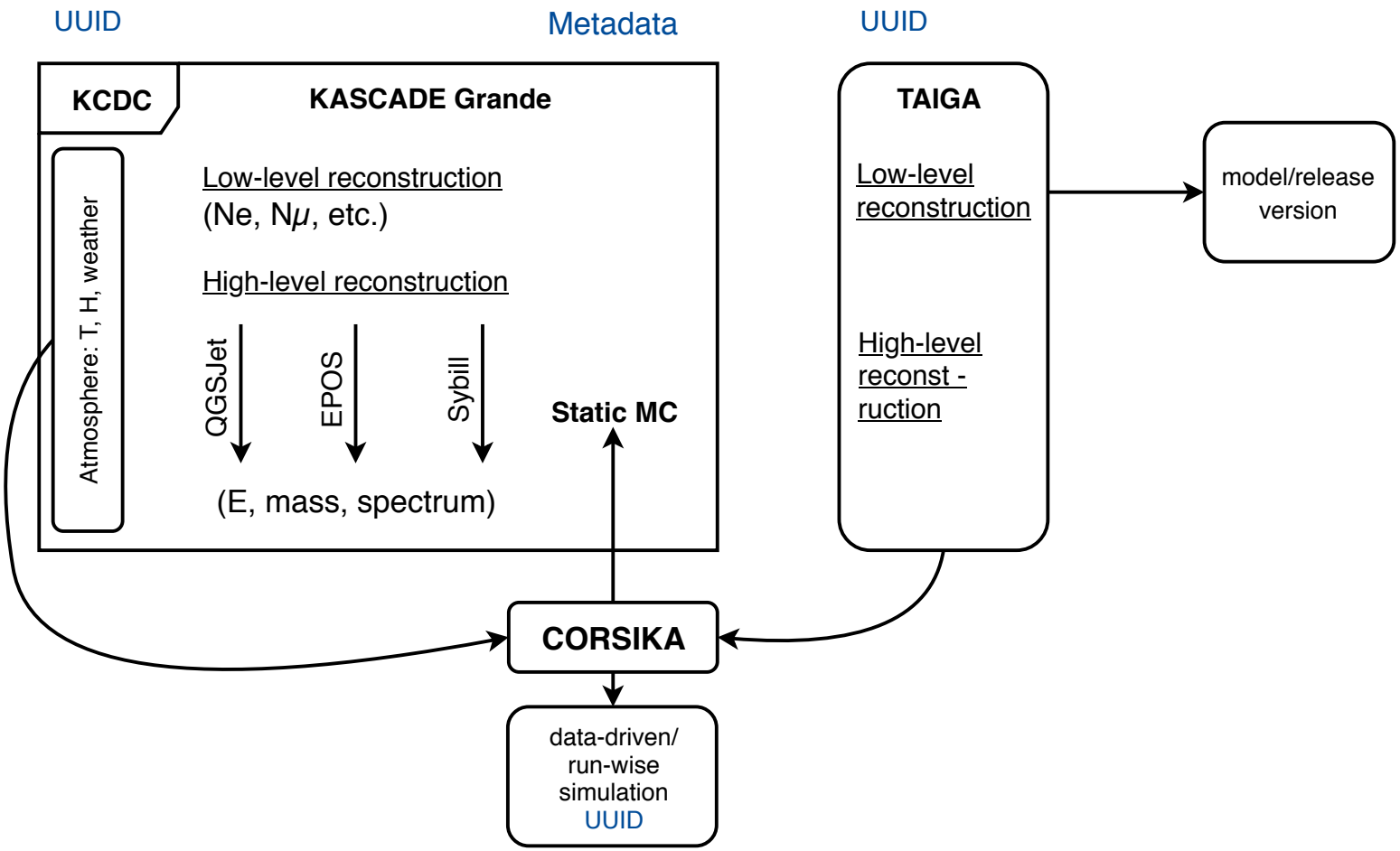
- Software for data analysis depends on a particular experiment
  - Problem: It may even require dedicated system environment
  - ▶ Solution: Virtualization could be useful
- Data analysis requires huge amounts of input data
  - Problem: It is often more optimal to perform it on the same site the data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

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 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 oureach activities are being explored.
  The joint resource **astroparticle.online** is created to provide access to KASCADE and TAIGA data.

Conclusion

- The constantly growing amount of accumulated astroparticle data and the request for the multi-messenger astronomy and machine learning, enable us to develope 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 γ-rays, which could be a notable step forward in multi-messenger astroparticle physics.