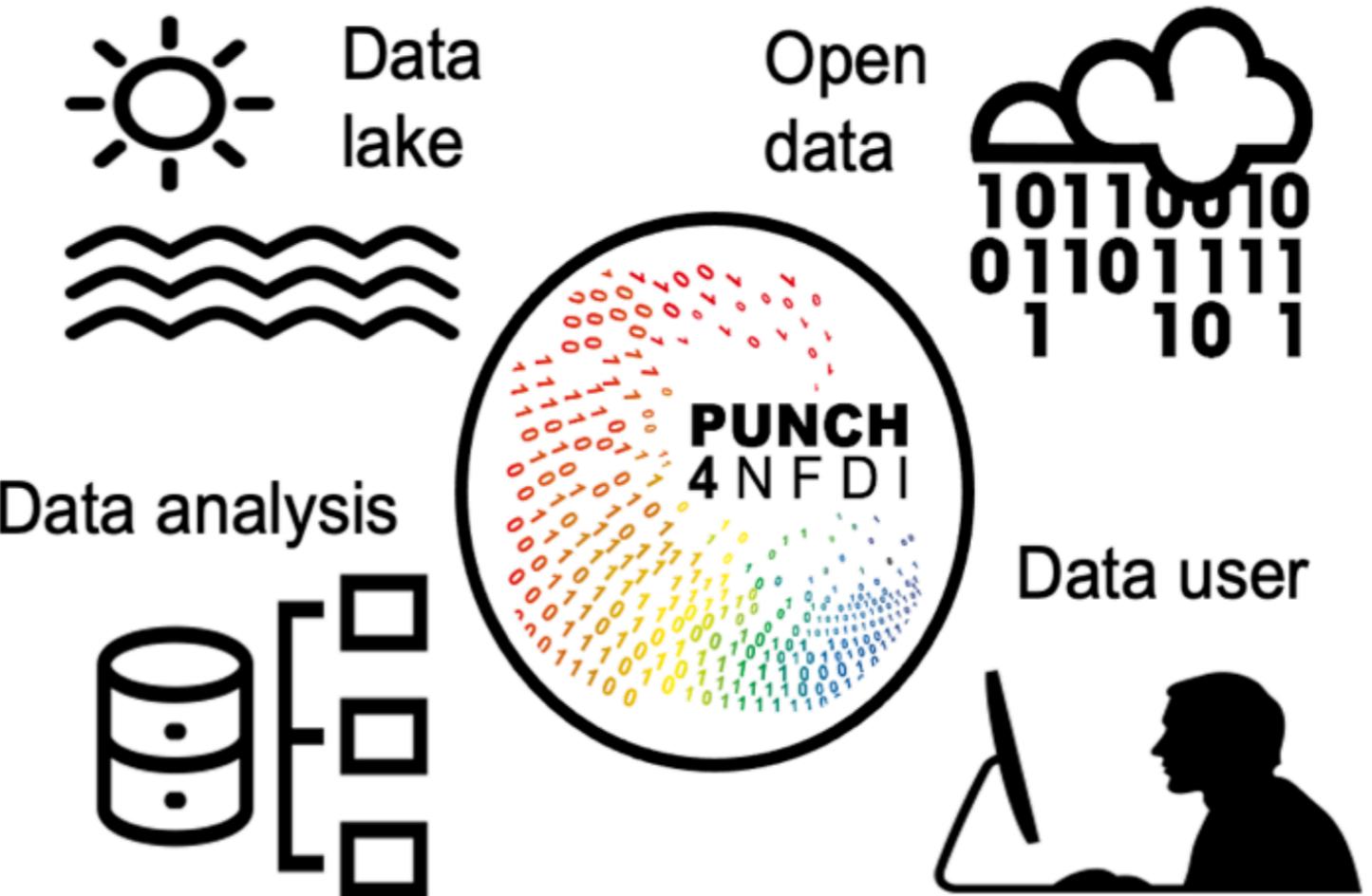


Astroparticle / high-energy community

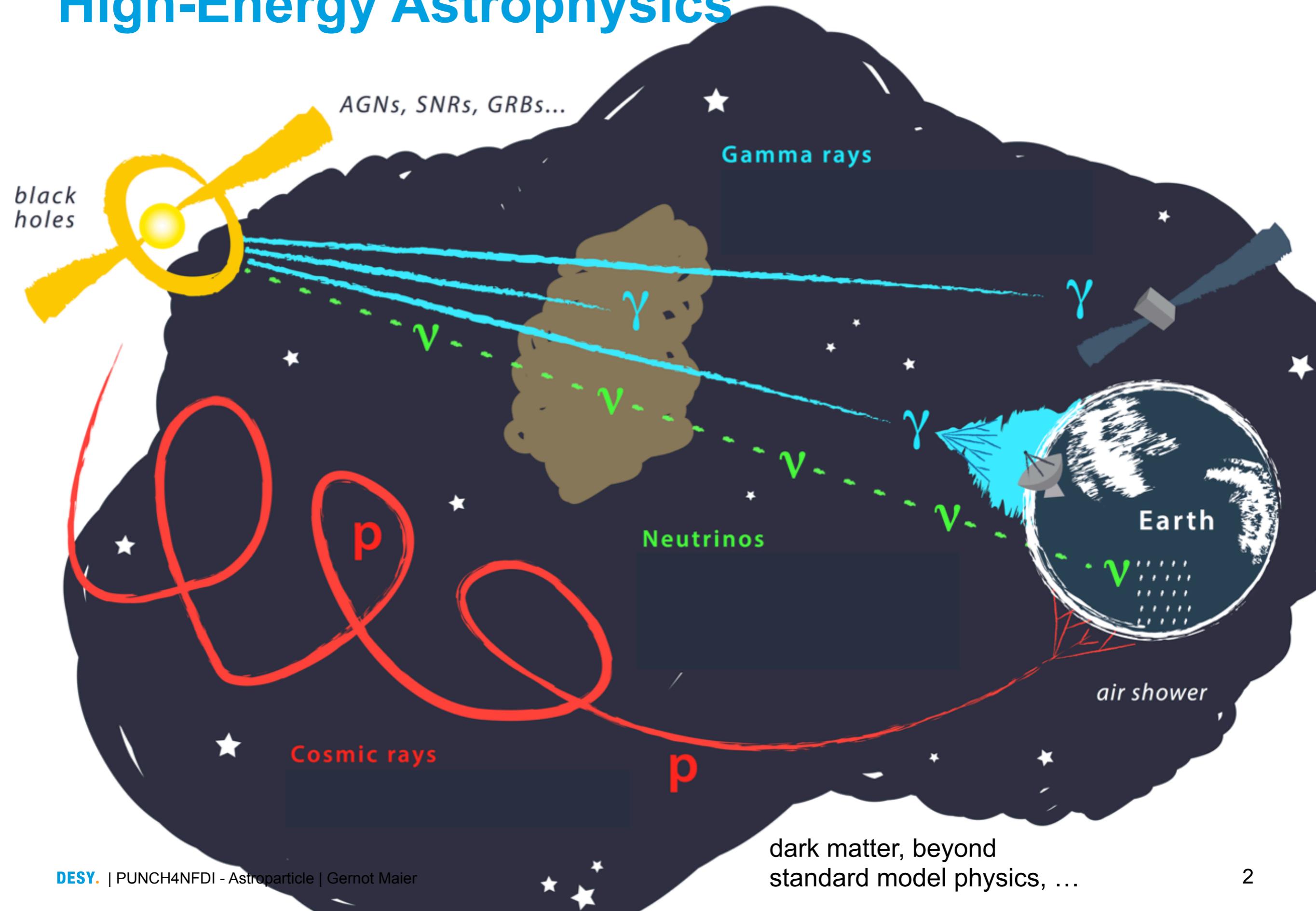
PUNCH4NFDI Open Data Workshop

2021, Feb 11

Gernot Maier



High-Energy Astrophysics



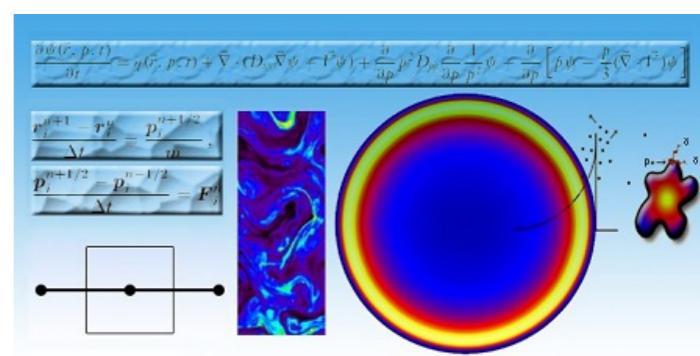
Astroparticle

Theory, Experiments, Observatories.

• Theory and Simulations

• Experiments

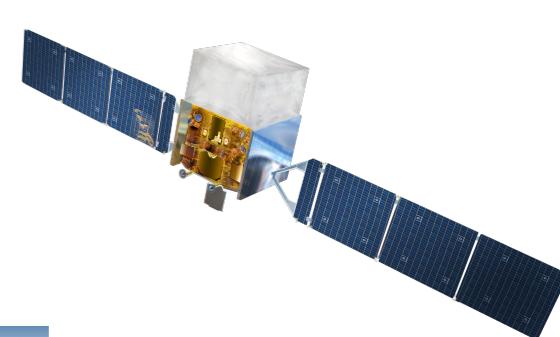
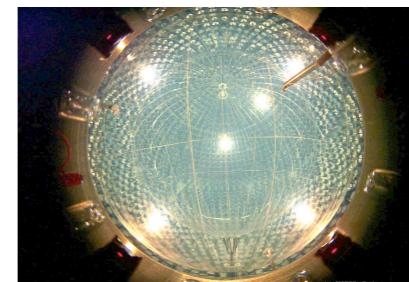
- large international collaborations
(IceCube, Auger, H.E.S.S., ...)



- national collaborations / groups
(CONUS, neutron-monitors, ...)

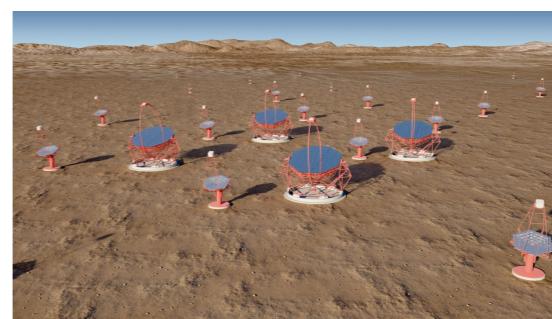
• Observatories

- international organisations
(NASA, ESO, CTAO, ...)



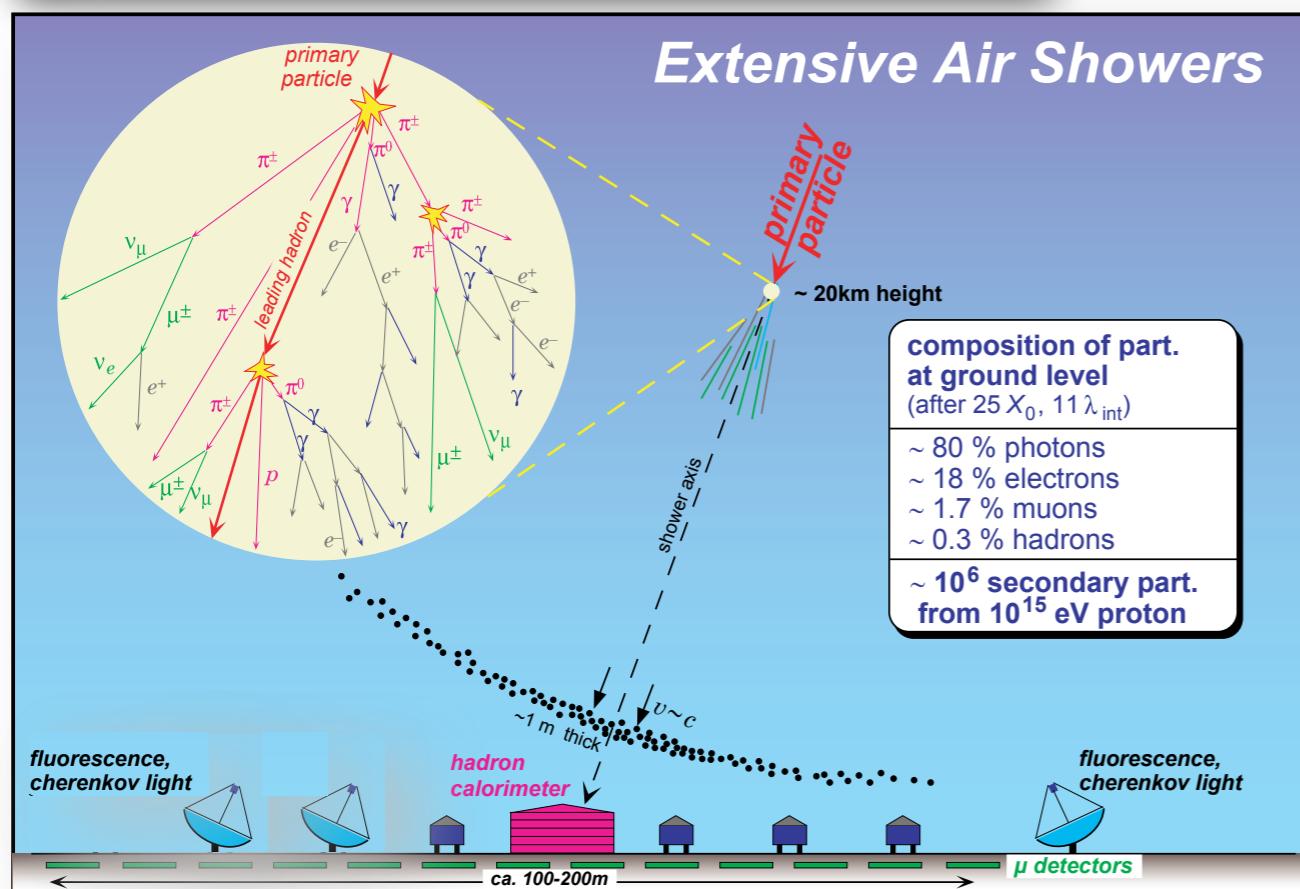
• Detector Development

- e.g. photodetector or optics development



Data structures - Event lists + Instrument Response

Data structure for most physics analysis very simple.



Per Event:

- classification (p, Fe, gamma, ..)
- energy
- direction
- time
- detector state (e.g., pointing)

Observing period

- instrument response (effective detective area, energy migration, point-spread function)
- detector uptime

(obviously on DACQ level and intermediate levels much more complicated)

Fermi Gamma-ray Telescope

A showcase how observatories work

- Gamma-ray telescope operated by NASA
—> survey instrument
(+DOE, institutions in France, Germany, Japan, Italy and Sweden)
- All high-level data products available to the community (<1 day)
- Prompt data (e.g., GRBs) and notification (within <~15 s of detection)
- Services by NASA:
 - data (events+calibration) in common formats (FITS)
 - open source software tools
 - user support desk & documentation
 - cross-mission accessibility (e.g. through NASA's HEASARC archive)
 - catalogues



Simple web interface

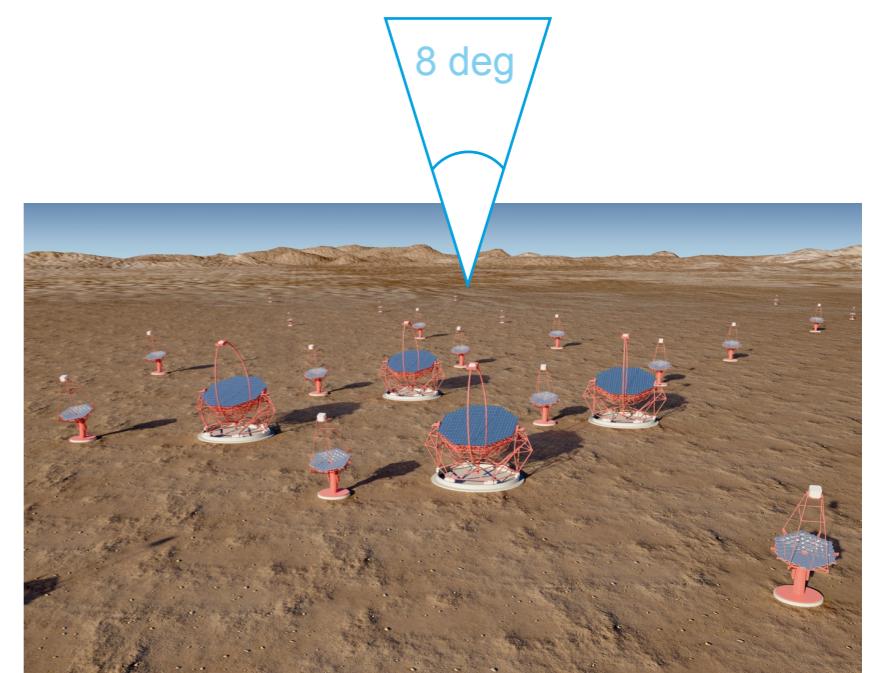
Most publications not by the Fermi Team

1	2021JHEAp..29...40C	2021/03			
	4FGLzoo. Classifying Fermi-LAT uncertain gamma-ray sources by machine learning analysis				
	Chiaro, Graziano; Kovacevic, Milos; La Mura, Giovanni				
2	2021ApJS..252...13A	2021/02			
	First Fermi-LAT Solar Flare Catalog				
	Ajello, M.; Baldini, L.; Bastier, D. <i>and 82 more</i>				
3	2021MNRAS.tmp.244T	2021/01			
	Annihilating Dark Matter Search with 12 Years of Fermi LAT Data in Nearby Galaxy Clusters				
	Thorpe-Morgan, Charles; Malyshev, Denys; Stegen, Christoph-Alexander <i>and 2 more</i>				
4	2021MNRAS.tmp..216O	2021/01			
	Searching for signatures of chaos in γ-ray light curves of selected Fermi-LAT blazars				
	Ostapenko, O.; Tarnopolski, M.; Źywucka, N. <i>and 1 more</i>				
5	2021MNRAS.500.5297A	2021/01			
	Locating the gamma-ray emission region in the brightest Fermi-LAT flat-spectrum radio quasars				
	Acharyya, Atreya; Chadwick, Paula M.; Brown, Anthony M.				
6	2021A&A...645A..62B	2021/01 <i>cited: 1</i>			
	Ornstein-Uhlenbeck parameter extraction from light curves of Fermi-LAT observed blazars				
	Burd, Paul R.; Kohlhepp, Luca; Wagner, Sarah M. <i>and 3 more</i>				
7	2020ApJ...905..114L	2020/12 <i>cited: 1</i>			
	Fermi-LAT Observations of V549 Vel 2017: A Subluminous Gamma-Ray Nova?				
	Li, Kwan-Lok; Hamsch, Franz-Josef; Munari, Ulisse <i>and 4 more</i>				
8	2020ApJ...905..112F	2020/12 <i>cited: 2</i>			
	GRB Fermi-LAT Afterglows: Explaining Flares, Breaks, and Energetic Photons				
	Fraija, N.; Laskar, T.; Dichiara, S. <i>and 4 more</i>				

CTA Gamma-ray Telescope

Future observatory for gamma-ray astronomy.

- Gamma-ray telescope operated by CTAO
—> **pointed instrument**
+developed by a worldwide collaboration
large German contribution
- All high-level data products available to the community (open data after proprietary period)
- Prompt data (e.g., GRBs) and notification (within ~100s of detection)
- Services by CTAO:
 - data (events+calibration) in common data formats (FITS)
 - open source software tools
 - user support desk & documentation
 - cross-mission accessibility (possibly through ESO archive)
 - catalogues



Key difference to Fermi!
Observation proposals led by Principal Investigators

CTA Data policy not finalised yet
(e.g., 1 year of proprietary period; afterwards open).

Similar to X-ray telescopes
(XMM, Chandra)
>50% of all publications based on archival data

Gamma-ray experiments

How to access decades of valuable data.

- Operating gamma-ray observatories
H.E.S.S., FACT, MAGIC, VERITAS
 - operated by international collaborations
 - no sharing of data (and data model); no or limited sharing of software; expert knowledge required
 - legacy archives
 - multi-instrument and multi-wavelength analysis
- ongoing community effort
 - common high-level data formats
 - public software tools
 - workflows and archiving
 - ‘future proof’ - involvement of upcoming instruments (CTA Observatory)



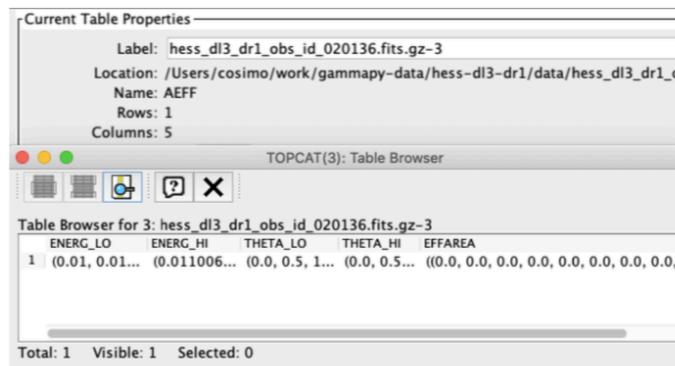
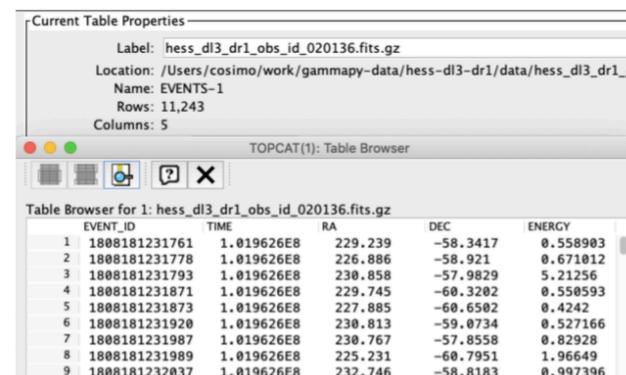
Standardisation of data formats in gamma-ray astronomy

- event level plus instrument response functions

data level	description	size
DL0	raw output of DAQ	~ TB / tel. / night
DL1	calibrated quantities (charge, arrival time)	~ 10 GB / night
DL2	reconstructed shower parameters	~ 10 ² MB / run
DL3	reduced γ ray candidates + response functions	~ 10 ² kB
DL4	science data products: spectra, light curves, skymaps	~ 10 kB

open source
software tools

- based on existing standards in astronomy (see Fermi LAT) with all advantages and disadvantages

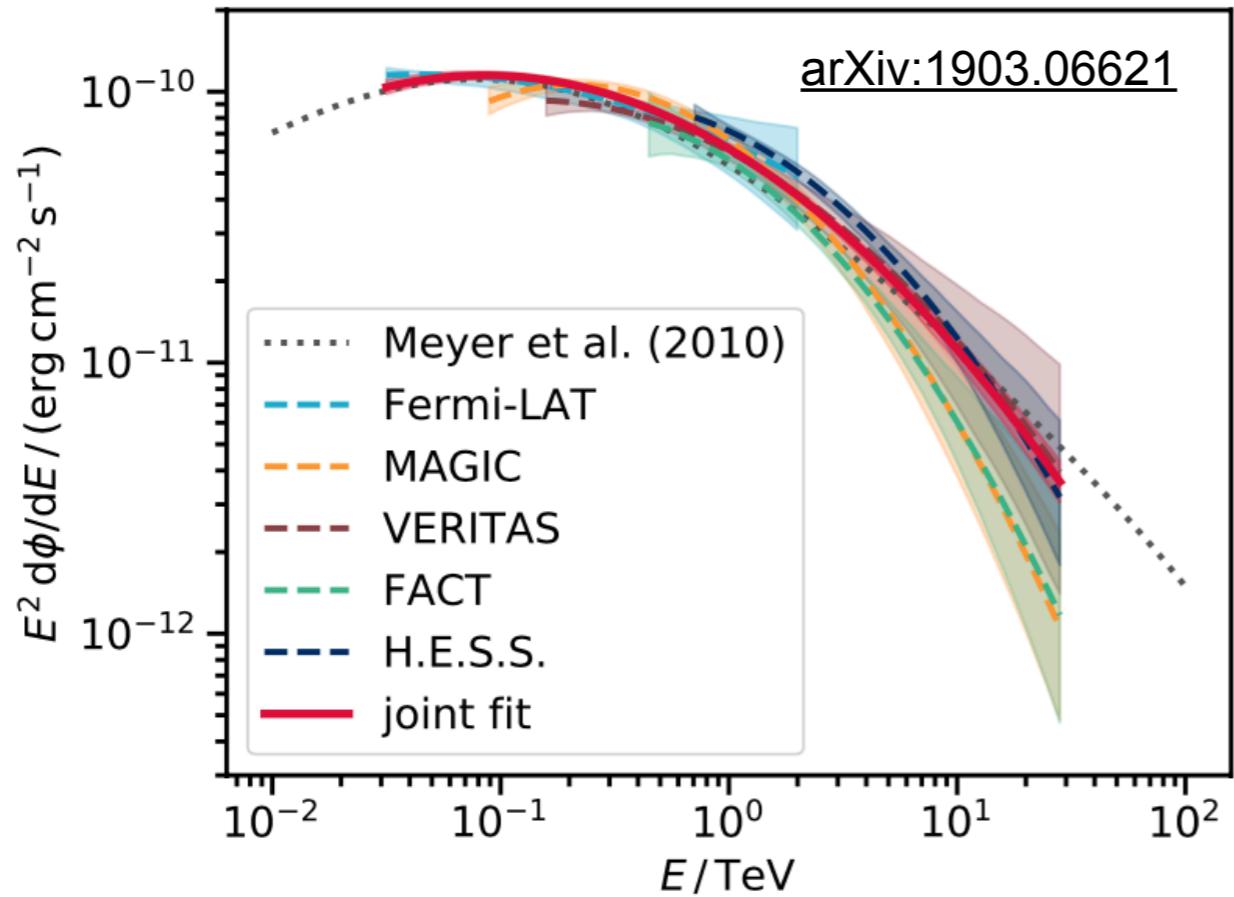


C.Nigro et al (ADASS 2020)

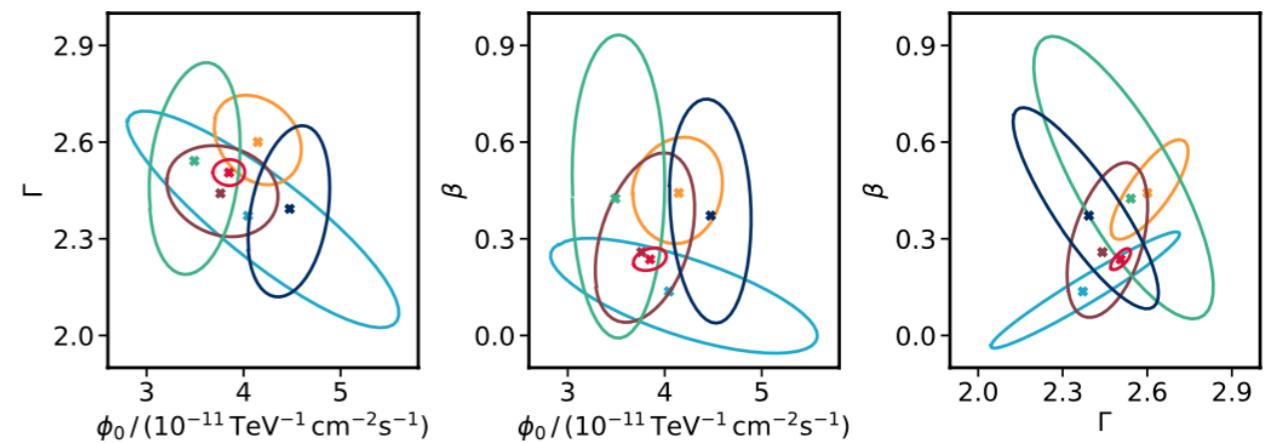


- open source software (e.g., gammapy, ctools)
—> software used for future CTA
- realistic scenario for public data archives
 - e.g., first H.E.S.S. data release
(arXiv:1810.04516, zenodo)

Multi-instrument analysis



Combined energy spectrum of Crab Nebula obtained with data from **five** different instruments
→ joint likelihood taking systematics consistently into account



Reproducibility workflow based on git, docker, zenodo

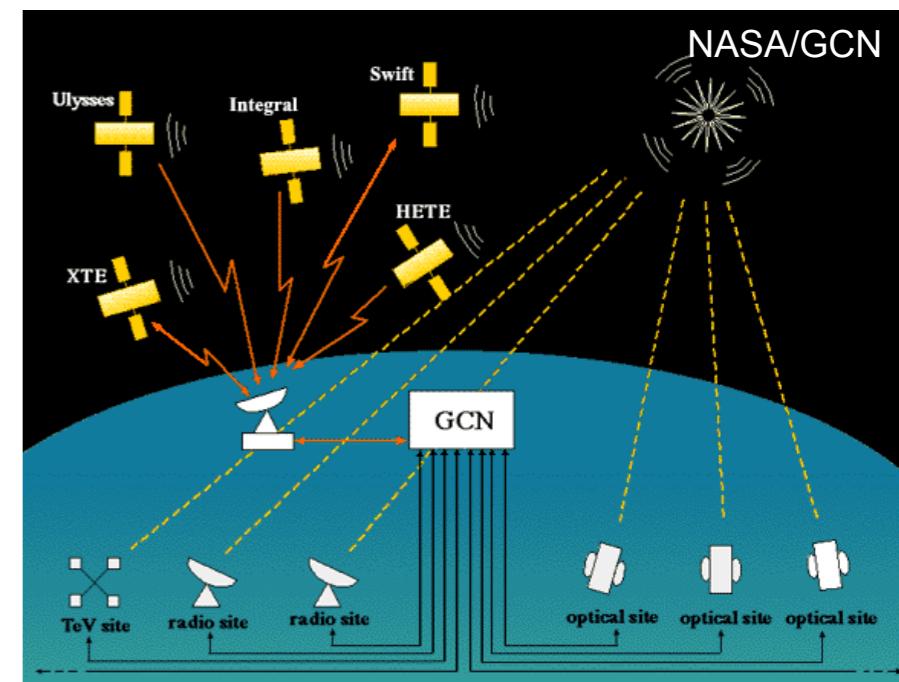
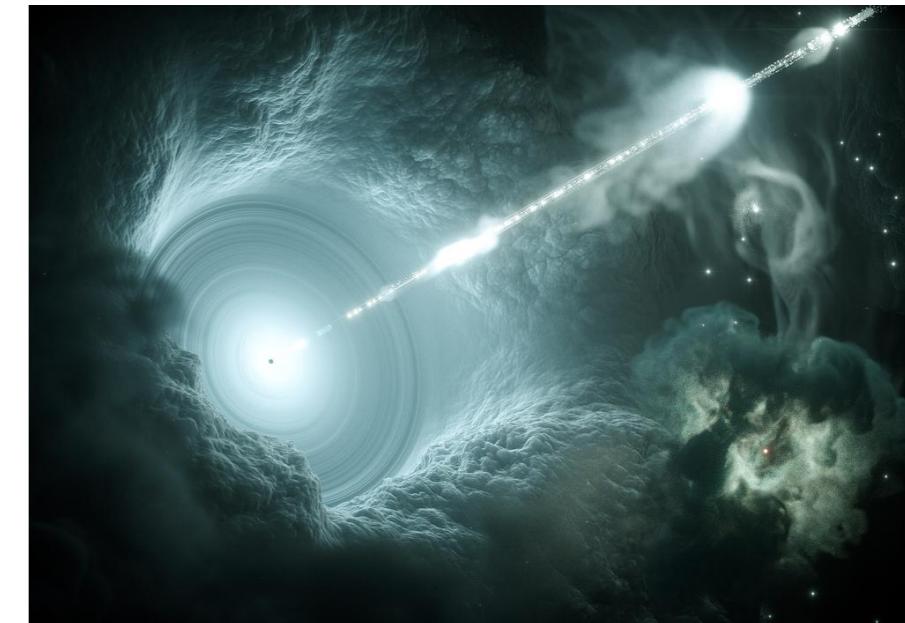
```
FROM gammify/gammify:0.1.1
ADD . /gammify/joint_crab
WORKDIR /gammify/joint_crab
EXPOSE 8000
CMD ["python", "joint_crab.py"]
```

```
FROM gammify/gammify:0.1.1
ADD . /gammify/joint_crab
WORKDIR /gammify/joint_crab
EXPOSE 8000
CMD ["python", "joint_crab.py"]
```

C.Nigro et al (ADASS 2020)

Transient Alert streams

- multi-wavelength and multi-messenger
 - gravitational waves, radio (SKA), optical (V.Rubin, ZTF), X-ray, gamma rays (CTA), neutrinos (IceCube), cosmic rays (Auger), ...
 - few alerts per year to millions / day
- **alert streams almost by definition public data**
(alternative: private with many bilateral MoUs)
- automatic & reprocessed alerts
 - automatic = telescope repointing without human interaction; real-time analysis and feedback
- alert processing increasing complex
 - (no) follow up, real-time results



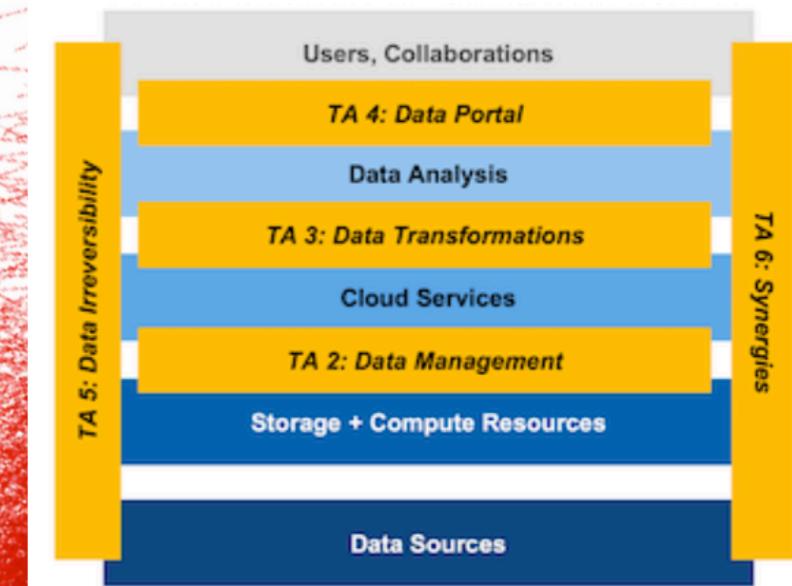
VO Events = standard protocol for transient events (XML)

transient broker systems

alert processing, filtering, augmentation, prioritising, archiving (e.g., AMPEL)

Conclusions & PUNCH4NFDI

- science data portal & archives
 - data/software/documentation/support
 - MC / theory / modelling
- efficient management of research data products
 - observatory model
- data transformation & maximum exploitation by combination of data sets
 - standards for data and metadata
 - open analysis tools & community software
 - cross-disciplinary interest on data
- real-time decisions for transient science
- outreach, citizen science, training



Open-data activities

- Pierre Auger Observatory: <https://www.auger.org/index.php/science/data>
- KASCADE (KCDC): <https://kcdc.ikp.kit.edu/>
- IceCube: <https://icecube.wisc.edu/science/data>
- KM3Net: <https://www.km3net.org/km3net-infradev/open-access-to-km3net-data/>
- ANTARES: <https://antares.in2p3.fr/publicdata.html>
- MAGIC: <http://opendata.magic.pic.es/>
- HESS: <https://www.mpi-hd.mpg.de/hfm/HESS/pages/dl3-dr1/>
- FACT: <https://fact-project.org/data/>
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