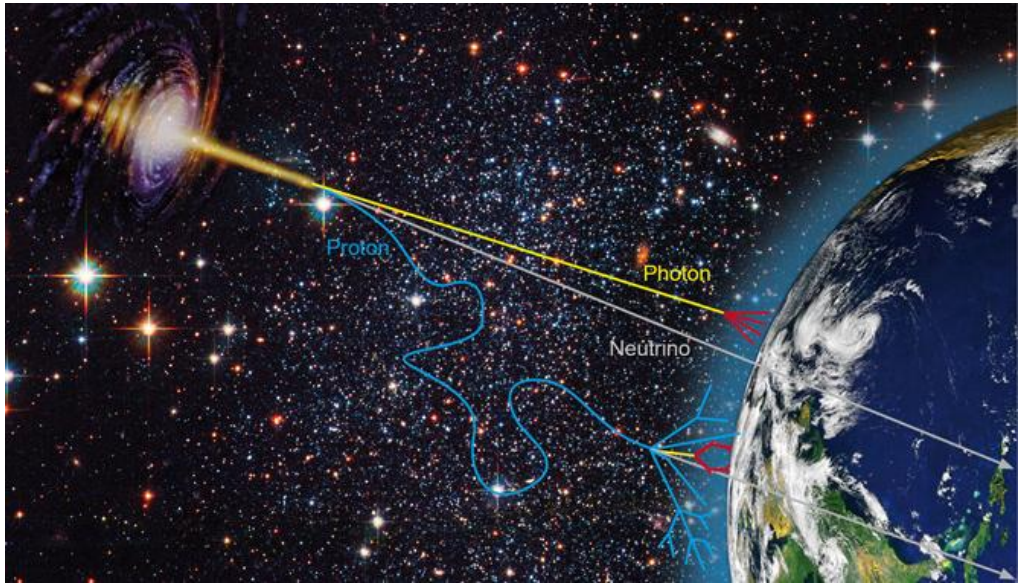
Karlsruhe Institute of Technology

Cu mic cu mare... dincolo de Soare
08.10.2011, Facultatea de Fizica, U. Bucuresti

Experimente de mare anvergura in fizica radiatiei cosmice de energii ultra inalte



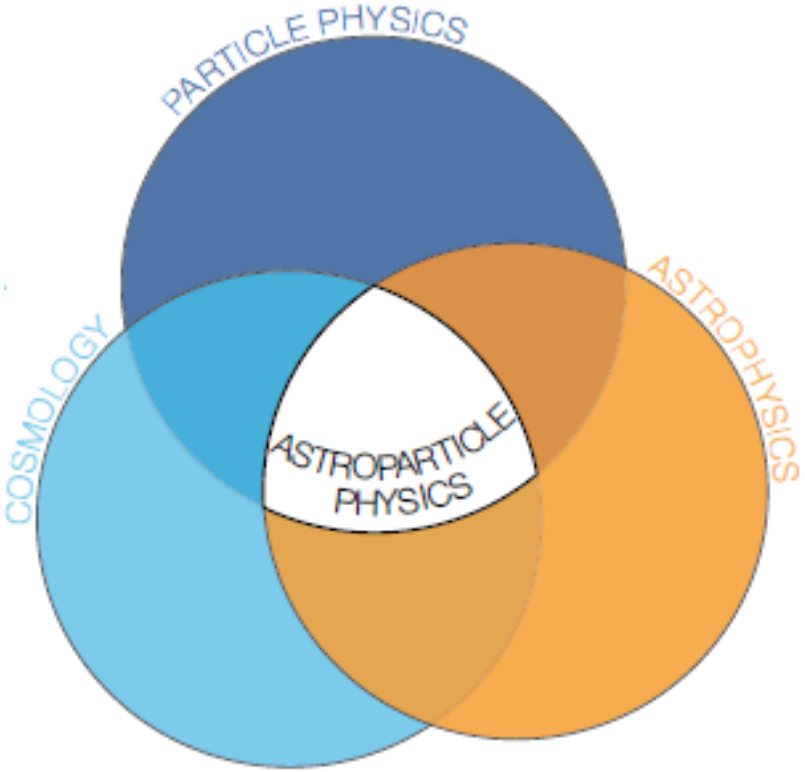
Dr. Isar, Paula Gina

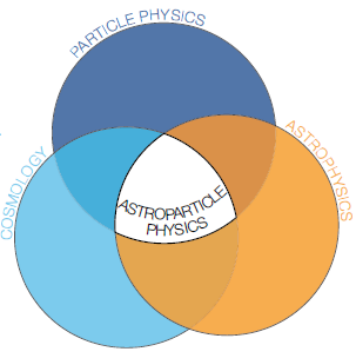
Institutul de Stiinte Spatiale (ISS) Bucuresti

isar@spacescience.ro

Content

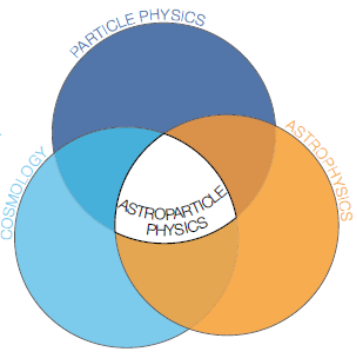
- Introduction
- Motivation
- Objectives
  1. Cosmology
  2. Particle Physics
  3. Astrophysics
- Status & Perspectives
- Summary & Outlook





Astroparticle Physics

- multidisciplinary field of research that deals with the study of particles coming from the Universe.
- rapidly growing field of research at the intersection of:
  1) Particle physics study the intimate structure of matter and the fundamental laws that govern their interactions, e.g. the physics of the smallest scale of the Universe.
  2) Astronomy and Astrophysics study the structure of the Universe and its evolution from the initial hot Big Bang.
  3) Cosmology links the theory of Particle physics with that of the very early Universe.



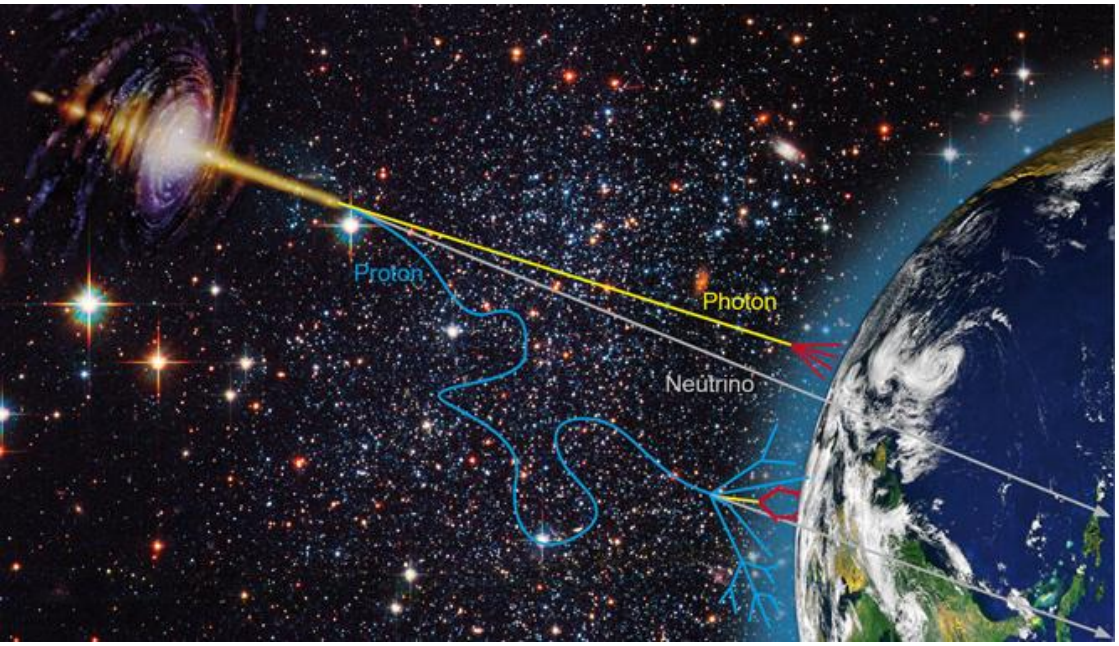
AStroParticle ERAnet

- ASPERA is
  - a network of 24 national government agencies responsible for coordinating and funding national research efforts in Astroparticle Physics
  - funded by the European Commission
- http://www.aspera-eu.org

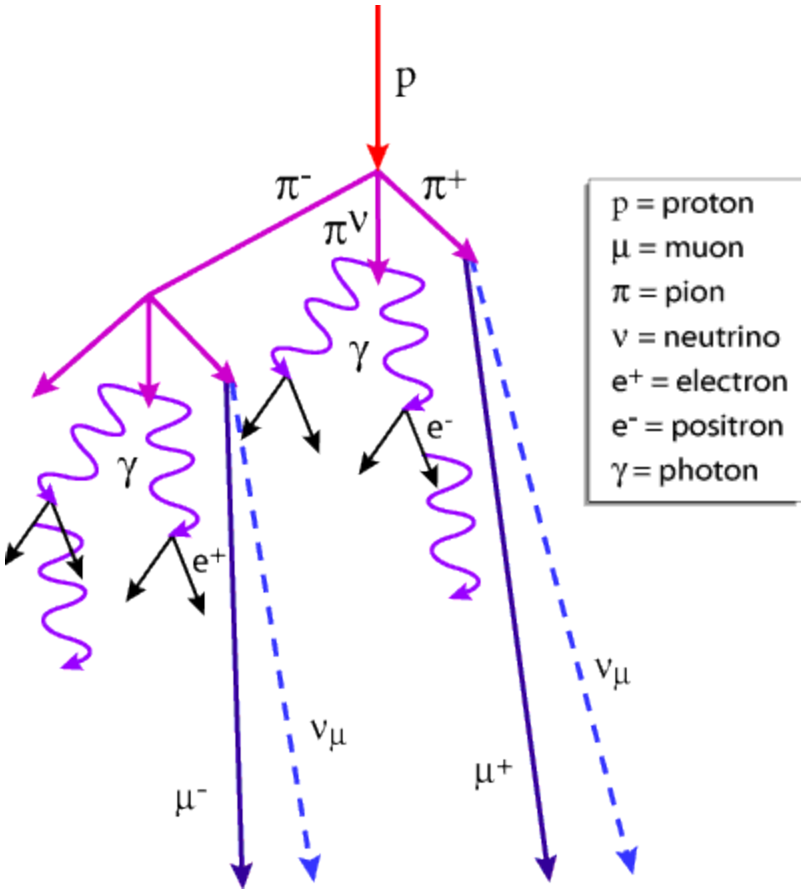


Multimessinger approach

(charged particles, photons and neutrinos)



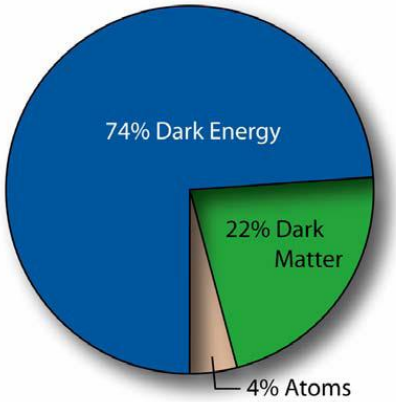
E.g. cascading interactions



Photons and neutrinos travel straight!

➢See talk by V.Popa, 15:00, A3

Motivation



- What is the Universe made of?
  - 4% normal baryonic matter, 73% dark energy, 23% dark matter
- Do protons have a finite life time?
  - GUTs of particle physics predict the proton has a finite lifetime
- What are the properties of neutrinos?
  - Massive neutrinos, i.e. physics beyond the SM of particle physics
- What is the origin of cosmic rays ?
  - Galactic/Extragalactic. Their puzzler/mystery is going to be solved
- What do neutrinos tell us?
  - Neutrino oscilations. New physics?

➢ Major projects are involved to answer these questions.

Infrastructure

- *Underground laboratories*
  - Well shielded against particles from cosmic rays, allow the study of extremely rare phenomena, e.g. 2β-decay, DM, p-decay (LNGS, LAGUNA – megaton-scale detector, in design)
- *Observatories*
  - "facilities", offering research possibilities to a wide community, *generally large installed in 'open' media (KM3Net, IceCube, Auger)*
- *Space-based platforms*
  - E.g. satellites, able to identify and measure particles (charged - PAMELA, gammas - GLAST), before they interact with the Earth's atmosphere

The high energy Universe

(from puzzle to mystery)

- High-energy cosmic rays are observed
  - Directly (shuttles, balloons)
  - Indirectly - through induced air showers (particles, fluorescence light, radio emission)

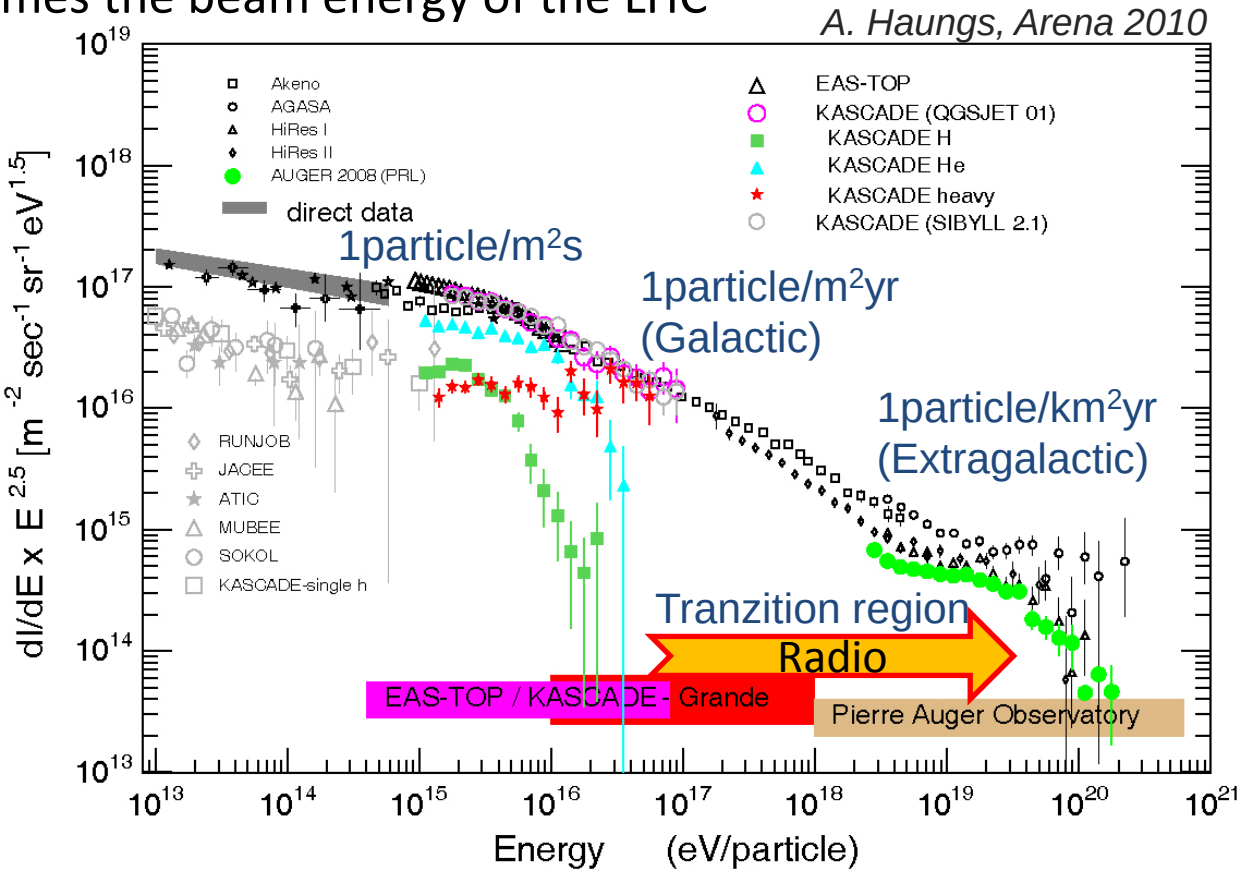


1912: Hess' discovery of CRs
1936: Nobel Prize in Phys.

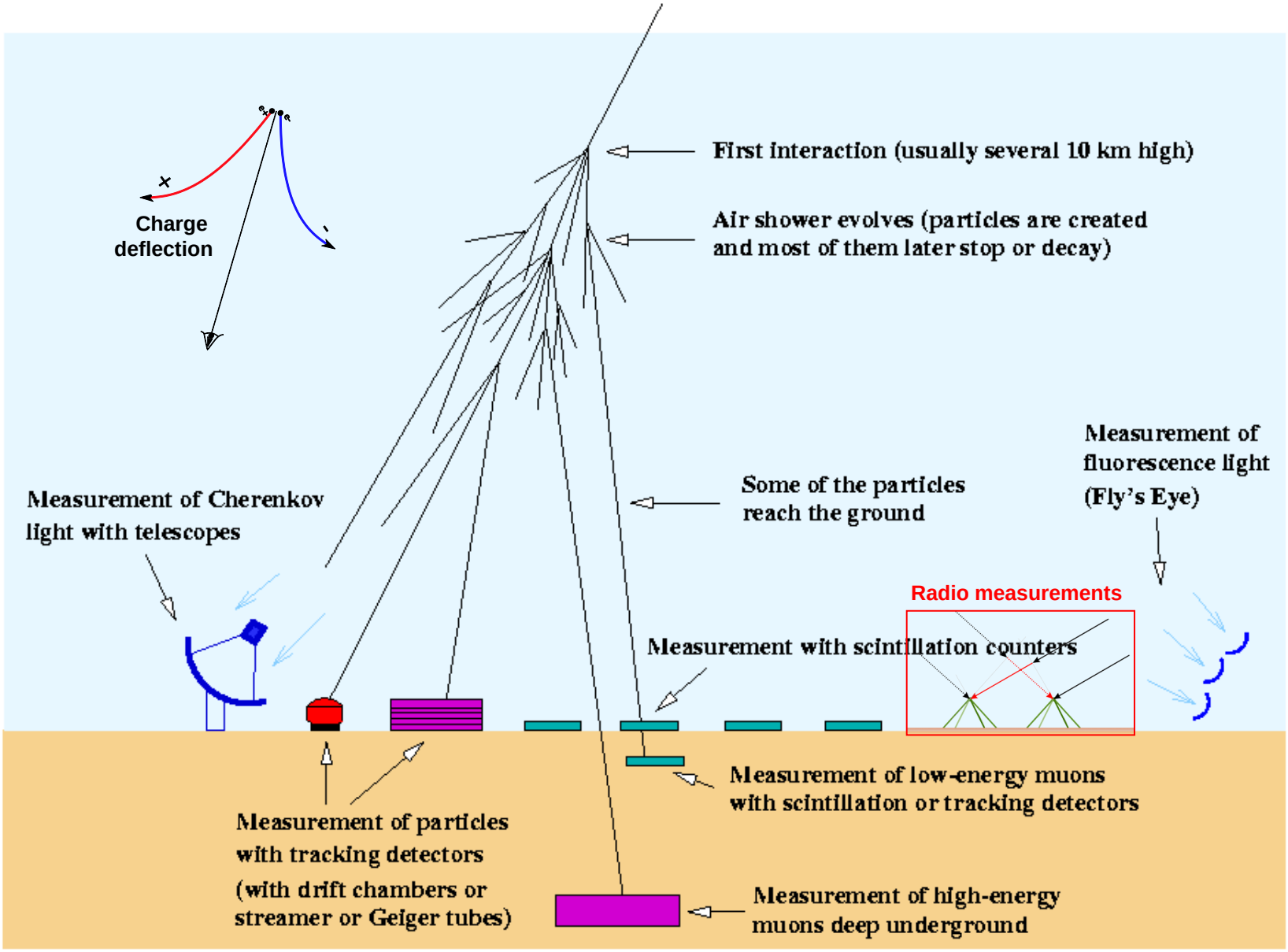
The high energy Universe

(from puzzle to mystery)

- Cosmic rays reach breath-taking energies
  - About 100 billion GeV (10^{20} eV)
  - About 10 million times the beam energy of the LHC
  - Heavy or light?



Measuring cosmic-ray and gamma-ray air showers



(C) 1999 K. Bernlöhr

The high energy Universe

(from puzzle to mystery)

- How can cosmic accelerators boost particles to these energies?
  - Shock fronts of galactic supernova explosions
  - Super-massive black holes
  - Decay of super-heavy relic particles from the Big Bang (?)

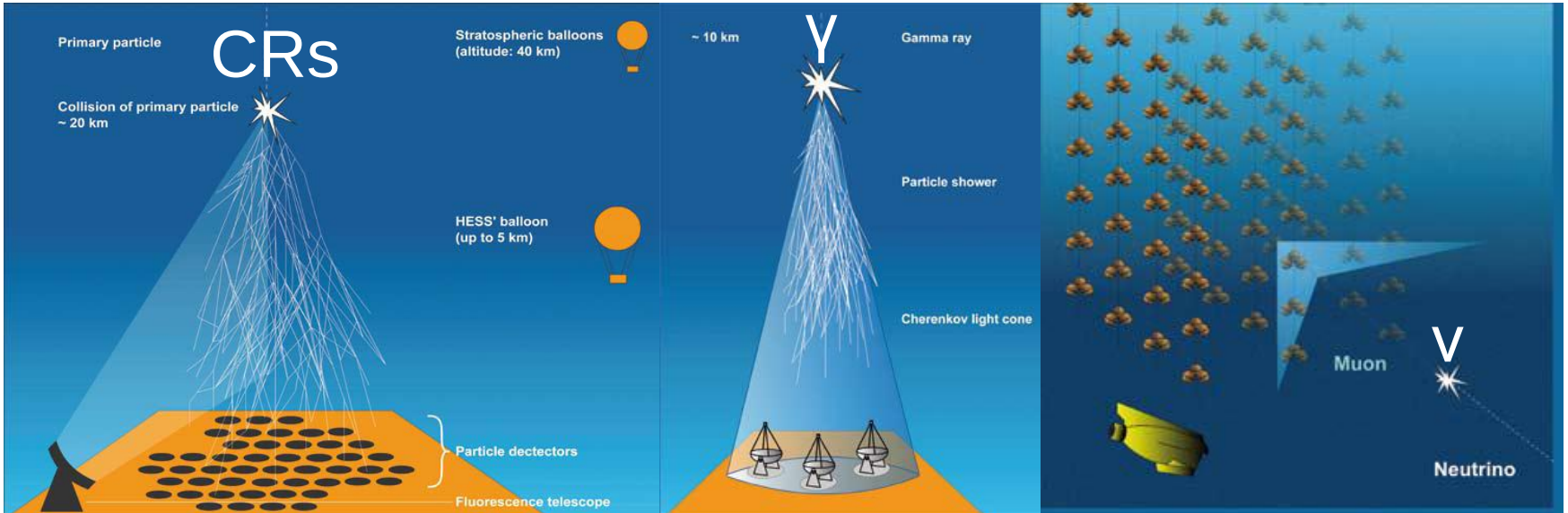


The high energy Universe

(from puzzle to mystery)

- How can cosmic accelerators boost particles to these energies?
  - Shock fronts of galactic supernova explosions
  - Super-massive black holes
  - Decay of super-heavy relic particles from the Big Bang (?)

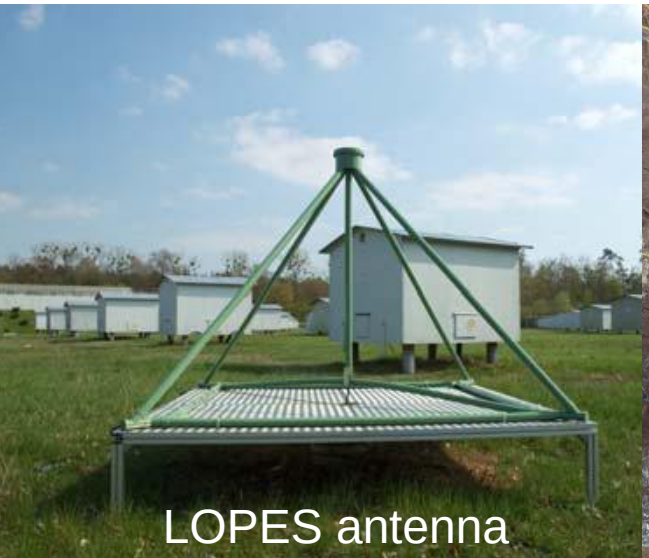
➢ Next generation multi-messenger approach: CRs, *γ-rays, neutrinos*

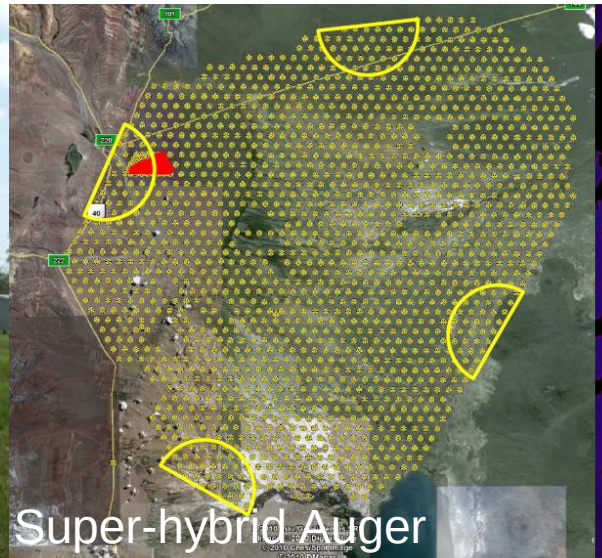


New techniques

(1) Radio-detection of UHE cosmic ray air showers

- LOPES, the Proof-of-Principle @ KASCADE
- Auger/AERA in Argentina
- LOFAR in the EU, (on the Moon?)
- SKA, the (future) Square Kilometer Array


LOPES antenna


Super-hybrid Auger


LOFAR



KASCADE - Grande

- Particle detector (scintillator + muon tracking detector)
- Measure the galactic CRs
- E_p:$10^{15 - 18}$ eV
- Grande - extended KASCADE
- Located At KIT

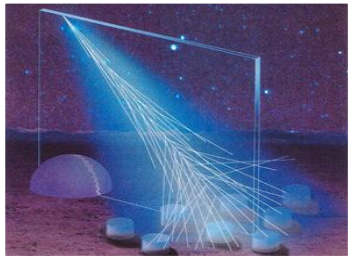
http://www-ik.fzk.de/KASCADE-Grande/



LOPES

- LOFAR Prototype Station
- Radio detector
- $E_p > 10^{16.5}$ eV
- 40 - 80 MHz
- Uses KASCADE & Grande trigger
- Self-trigger: LOPES^{STAR}

http://www.astro.ru.nl/lopes/



Pierre Auger Observatory

- Hybrid detector (fluorescence + water tank)
- Measure the extragalactic CRs
- $E_p > 10^{17.5}$ eV
- Located in Argentina
- Auger-radio: AERA

http://www.auger.org/

LOPES @ KIT
Campus North,Germany

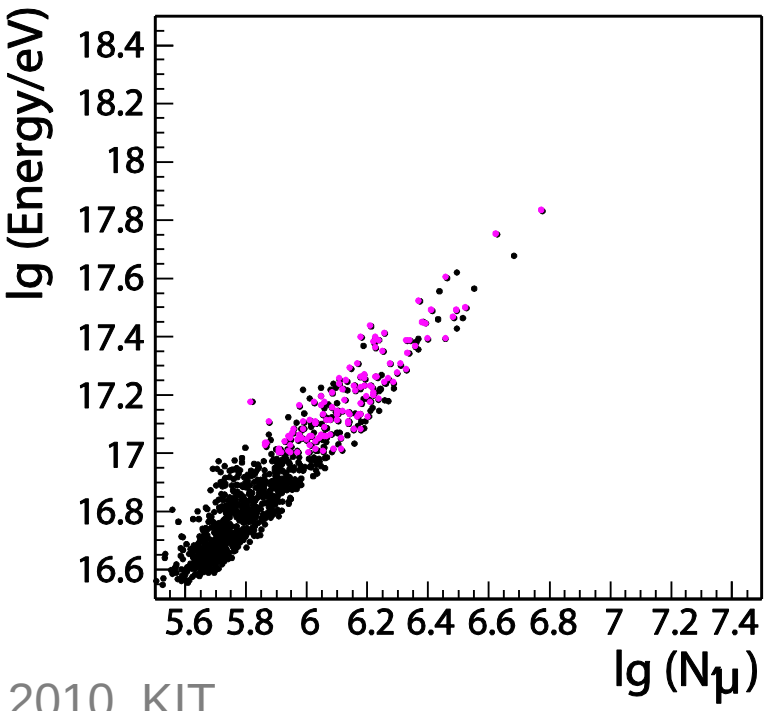

LOPES @ KASCADE

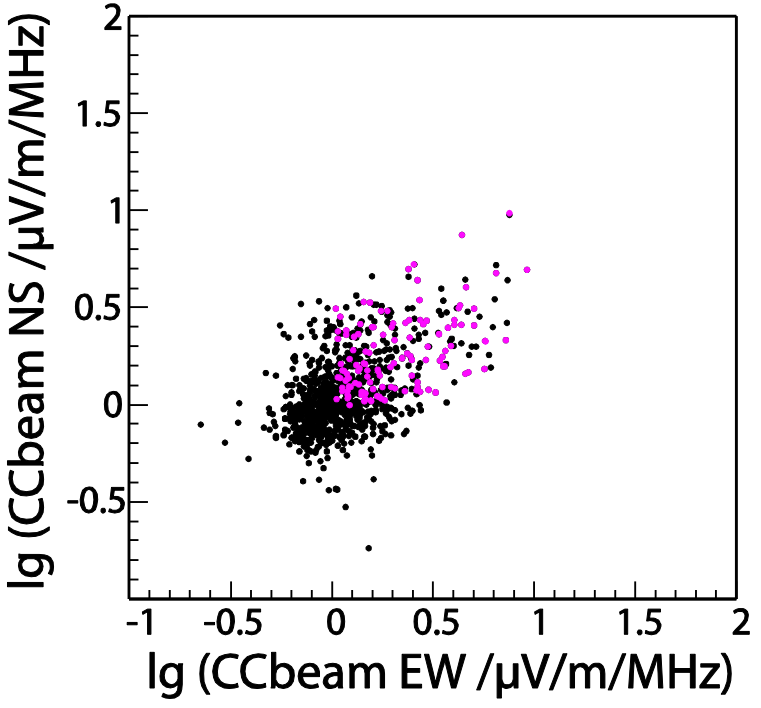
KASCADE

Grande

Event selection: quality cuts

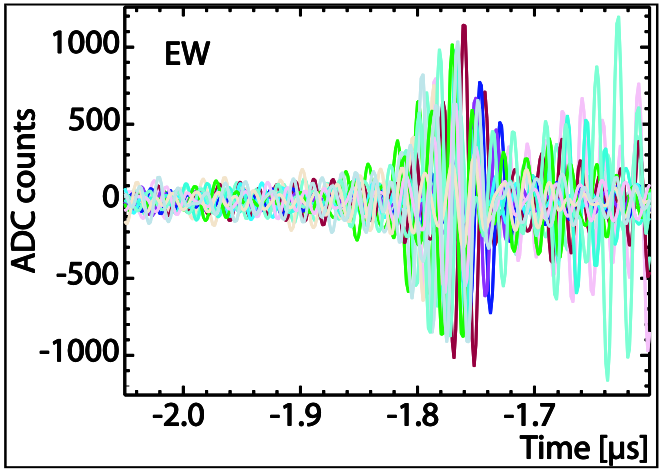
- EAS observables:
  - Core position (KASCADE or Grande)
  - Direction (φ ,$\theta < 40^{o}$)
  - Primary energy ($E_p > 10^{17}$ eV)
- Radio observables: SNR > 4, CCbeam > 1 µV/m/MHz

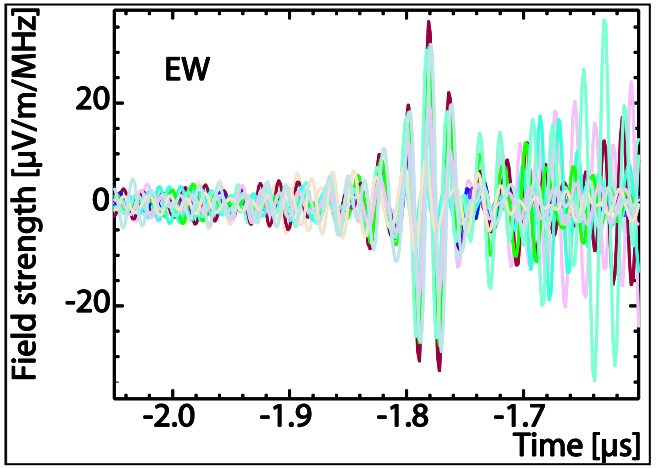




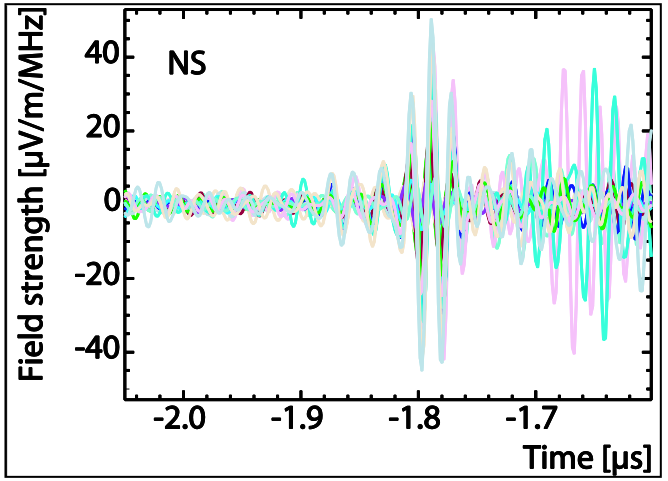
Event example seen in radio

1. Raw data

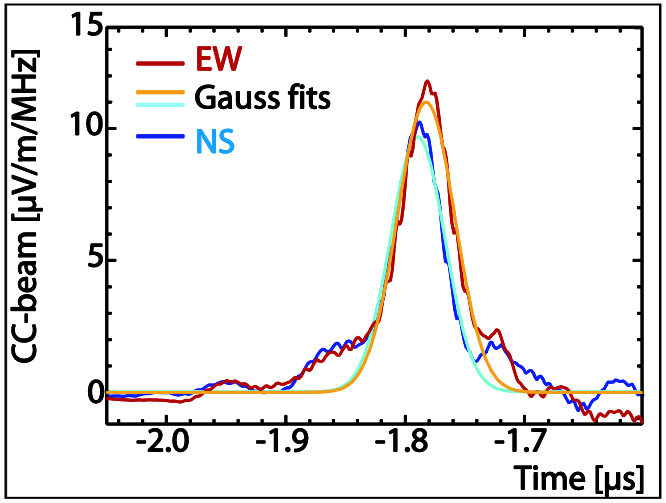




2. Radio signal reconstruction

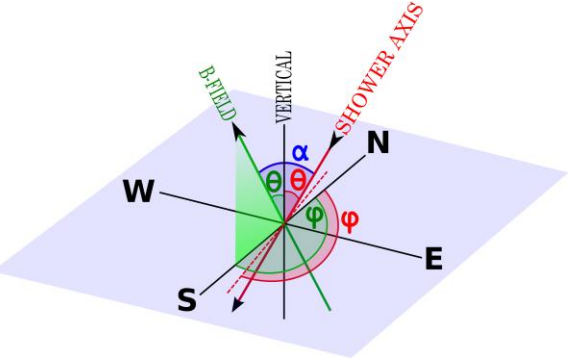


3. Pulse quantification



Isar PhD 2010, KIT

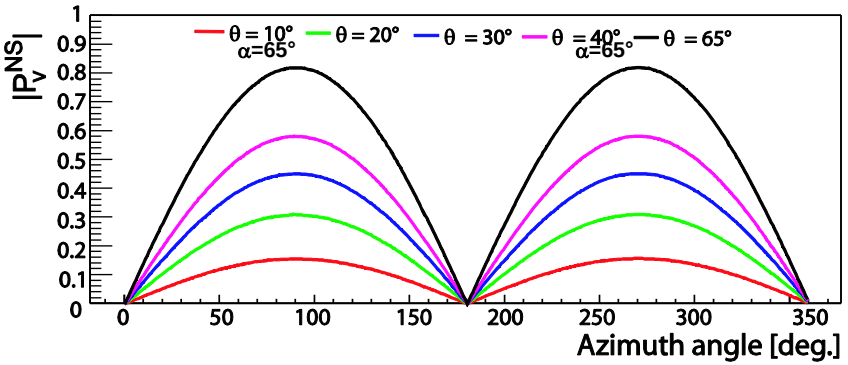
Simplified geomagnetic model

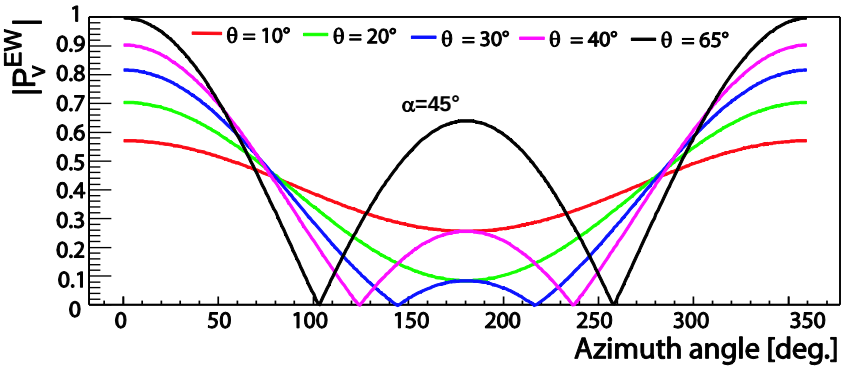


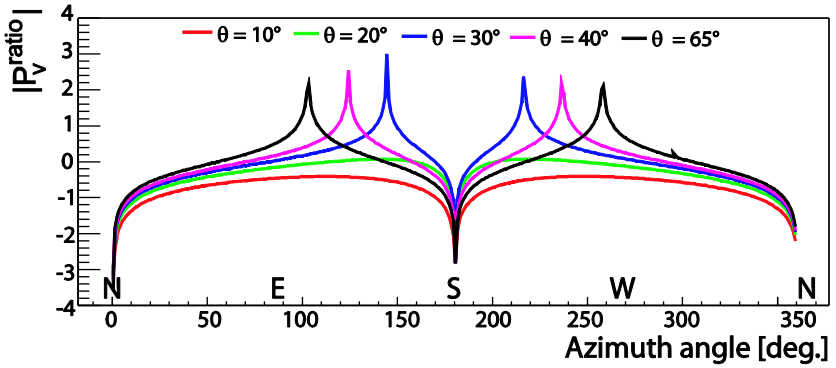
- Azimuth dependence

$$\vec{P}_v = \vec{v} \times \vec{B} = f(\varphi, \theta, \alpha)$$

- Large $\vec{P}_v$ for θ=65°!
- $\vec{P}_{NS}$:expect showers coming from E & W dir.
- $\vec{P}_{EW}$:expect showers coming from N & S dir.
- $\vec{P}_{ratio} = \vec{P}_{NS} / \vec{P}_{EW}$
  - > 0: NS dominat
  - < 0: EW dominat

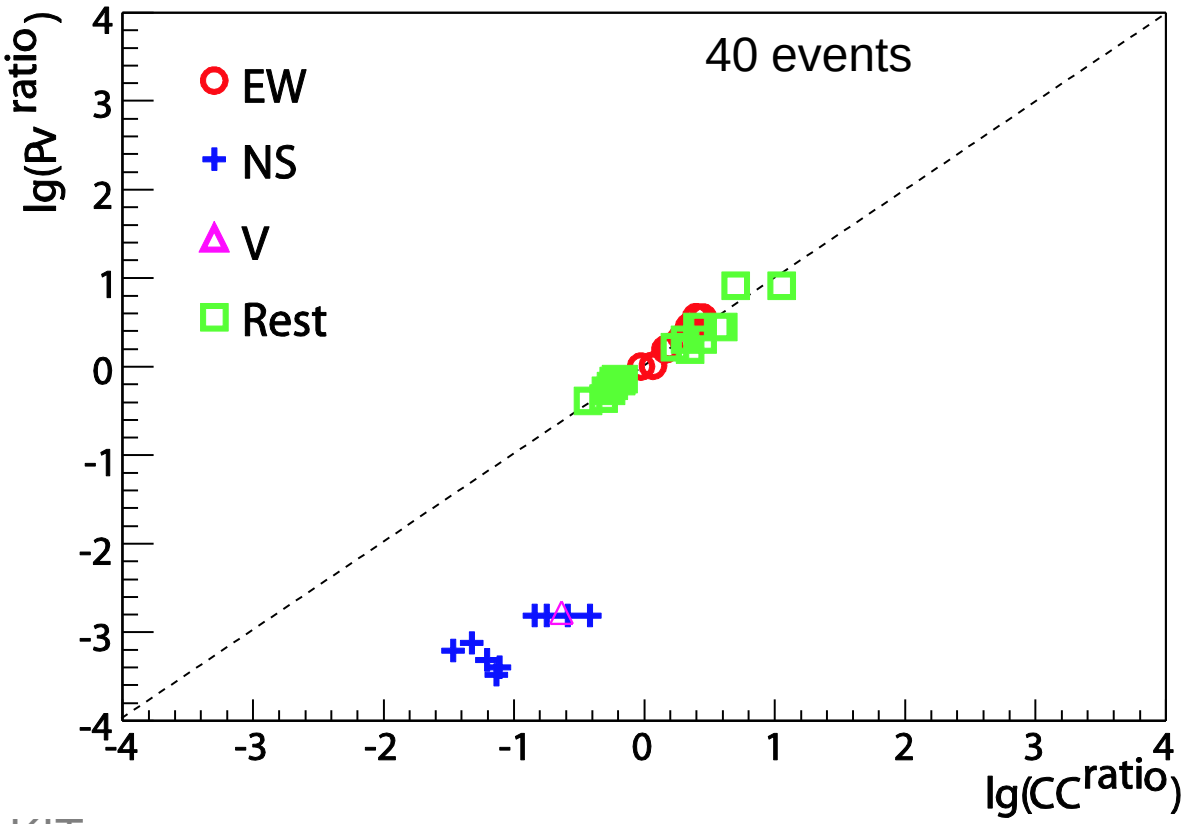






Comparison: Model & Simulation

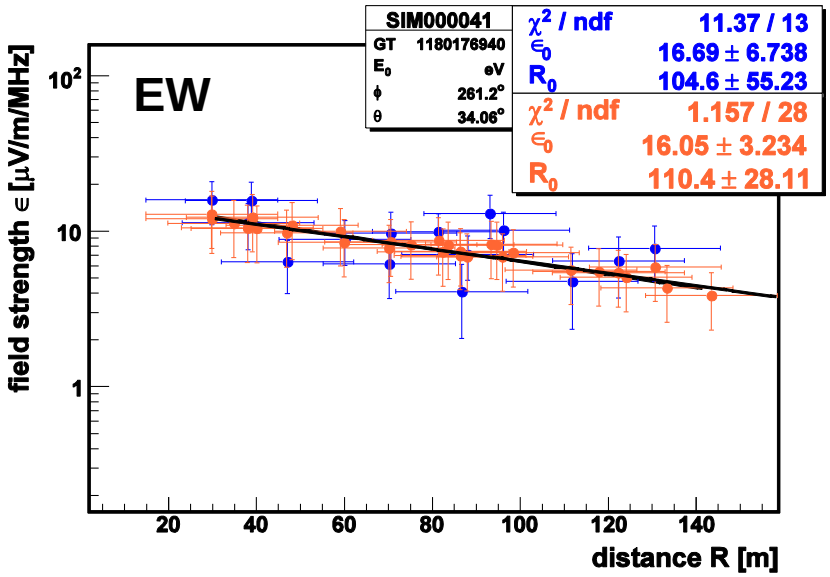
Good agreement observed, except incoming showers from North and South directions. Negative charge excess (~20%) joining the geomagnetic effect?

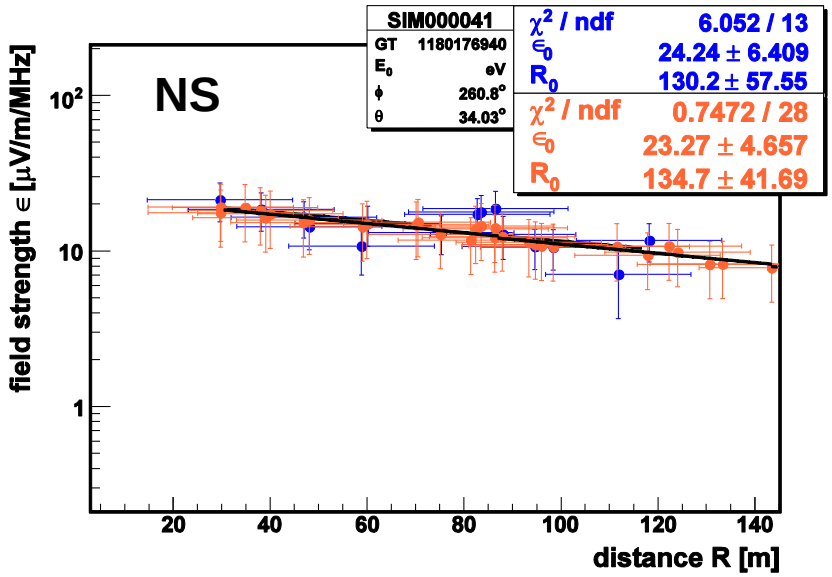


Lateral distribution

Event example: shower coming from West direction gives comparable results in both polarizations (for sim. and data)

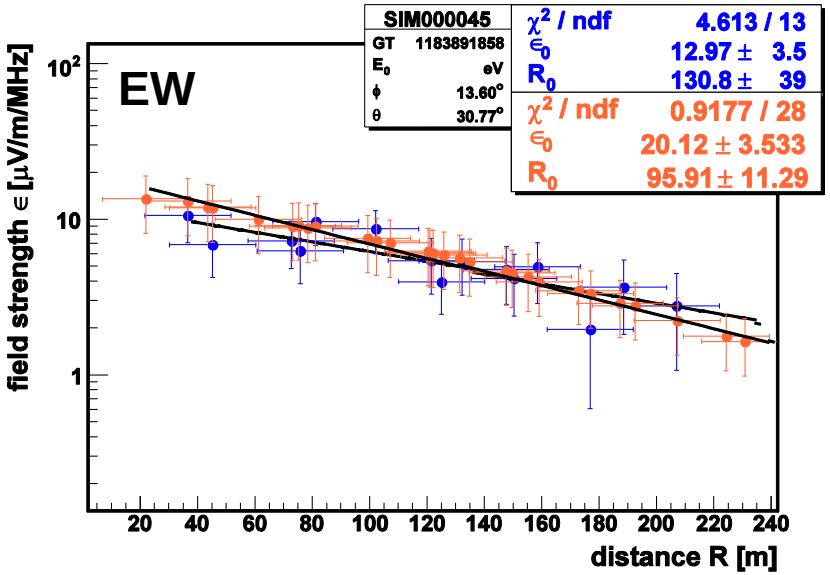
Fitting function: $\varepsilon \sim \varepsilon_0 \exp(-R/R_0)$

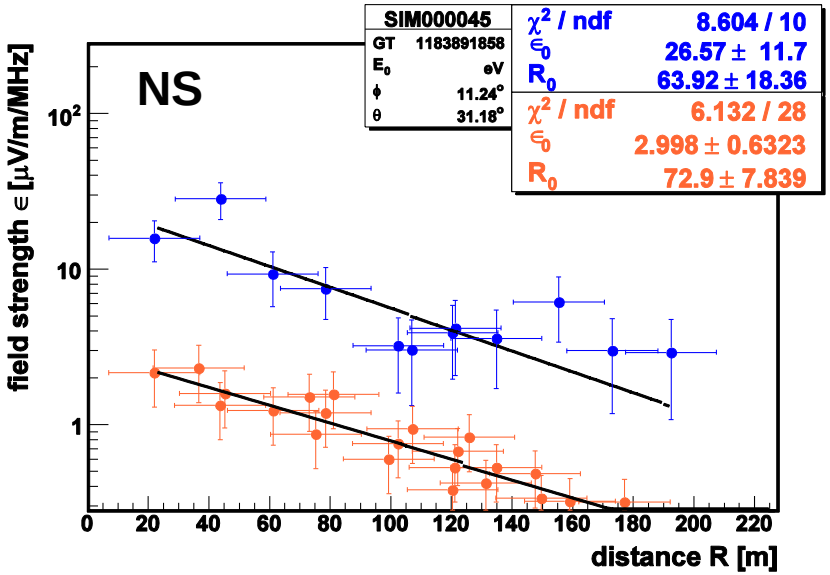




Lateral distribution

Event example: shower coming from North direction gives signal in both polarizations: another hint to an additional emission mechanism besides the geomagnetic effect.





Radio@ LOFAR

Low Frequency Array (10 - 270 MHz) of LOPES stations



36 Duch stations + 8 international (DE, FR, SE, UK, ..)

… up to 1500 km spacing



- Coincident trigger by scintilators with shower information for primary energies > 10^{17} eV
- High density of antennas, good LDF (5km^2 core, 1800 stations)

Radio@ AUGER/AERA

there is 1st super-hybrid detection in radio + fluorescence + water

Low background RFI

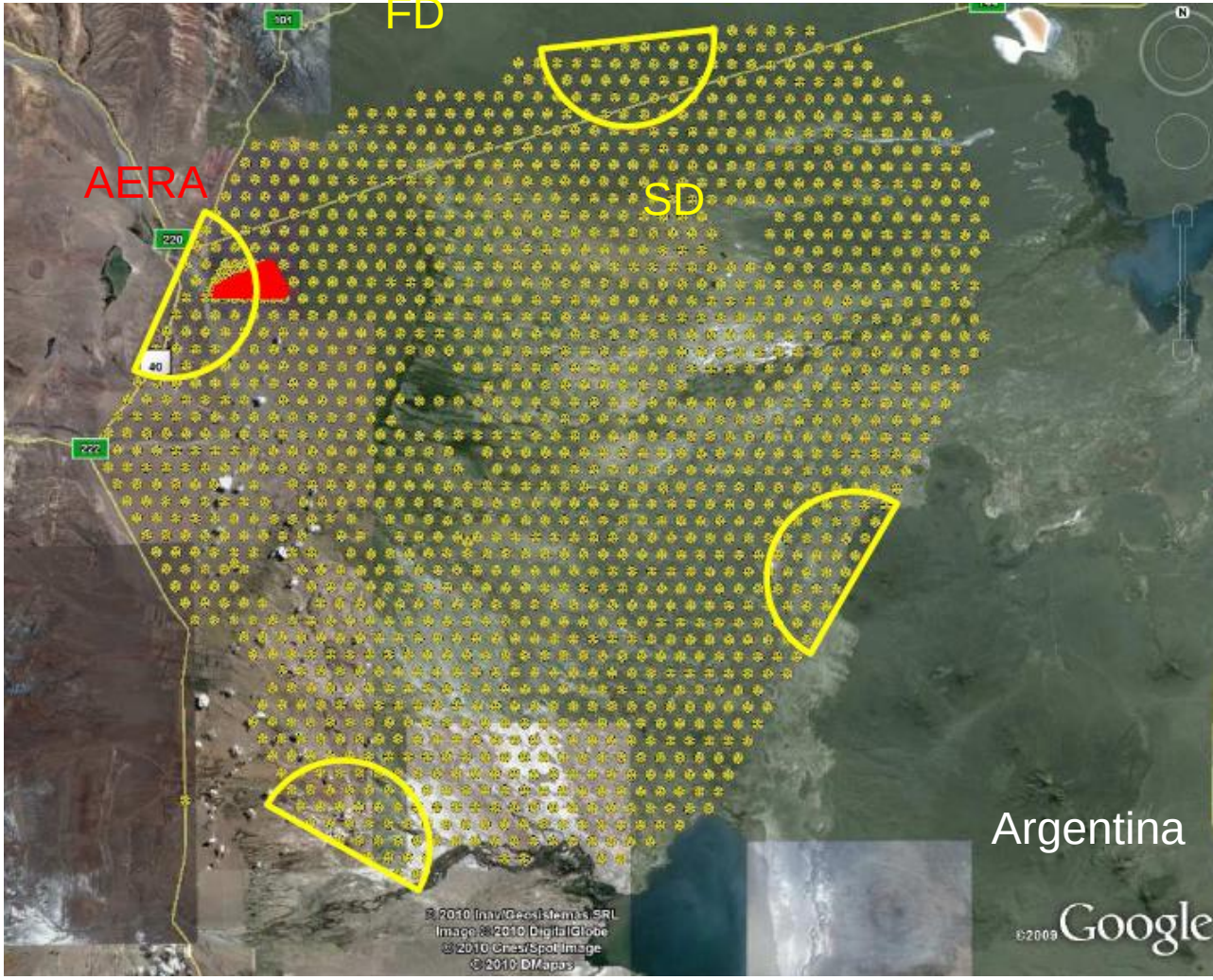
High energy, > 10^{17} eV

(20km^2, 150 radio ant.

1600 water tanks
(1.5 km spacing)

4 optical telescopes
-> mass sensitivity

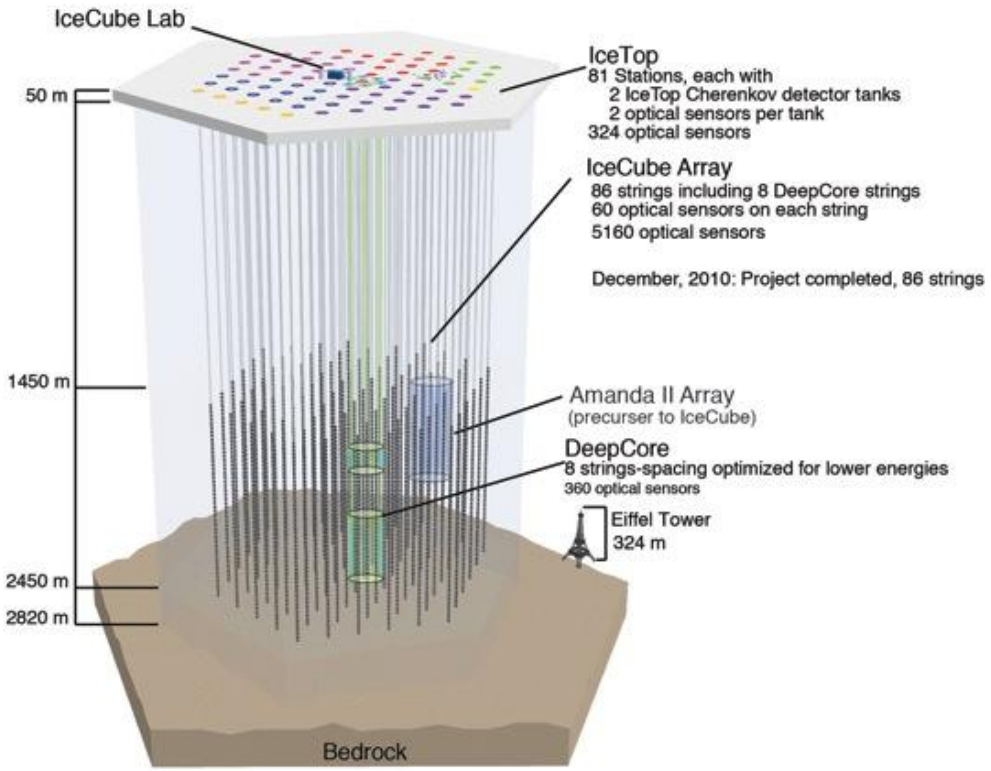
➢Romania
(IFIN-HH, UB, UPB, ISS?)
is associated to Auger



New techniques

(2) Acoustic-detection of UHE neutrinos

- *IceCube*, under construction

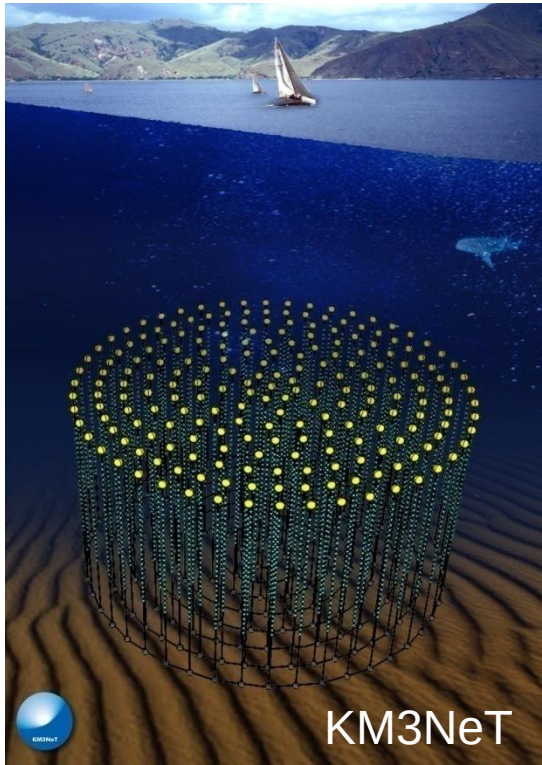


New techniques

(2) Acoustic-detection of UHE neutrinos

- *IceCube*, under construction
- *KM3NeT*, design stage

➢ Romania (ISS) is one of the 10-countries which form the KM3Net consortium



New techniques

(3) Photo-detection of UHE gamma rays

- CTA, *Imaging air Cherenkov telescopes*

➢ *New window of electromagnetic radiation from space*

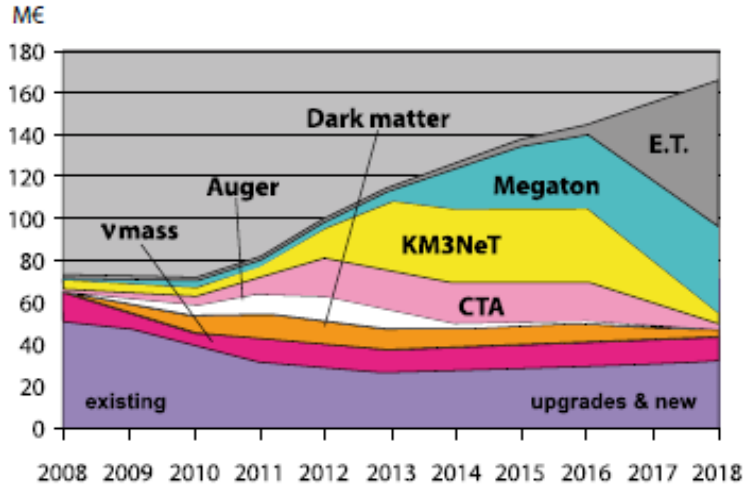






Summary

- Answering to most fundamental questions of physics would mark a major break-through in understanding our Universe
- 7 European Priority Experiments in Astroparticle Physics



3/7 for The High-Energy Universe!

Neutrinos - ***KM3Net,***

Gamma-rays – ***CTA,***

Charged Cosmic Rays – ***Auger***

- Education & Outreach
  - ✓ Astroparticle physics is not only an important element of teaching, but also challenges imagination and curiosity of a broad audience

Outlook



- A lot to do in the exciting field!
- One could think of a next generation detection array..
- Referencies

1. Astroparticle physics, the European strategy, satus and perspective

   http://www.aspera-eu.org/

1. Cosmic Bullets: High Energy Paticles in Astrophys. by R.Clay, B.Dawson
2. Introduction to UHECRs by Pierre Sokolsky
3. High Energy Cosmic Rays by Tudor Stanev
4. Cosmic Rays and Particles Physics by Geisser
5. …