Lecture 5

Present and next generation instrumentation

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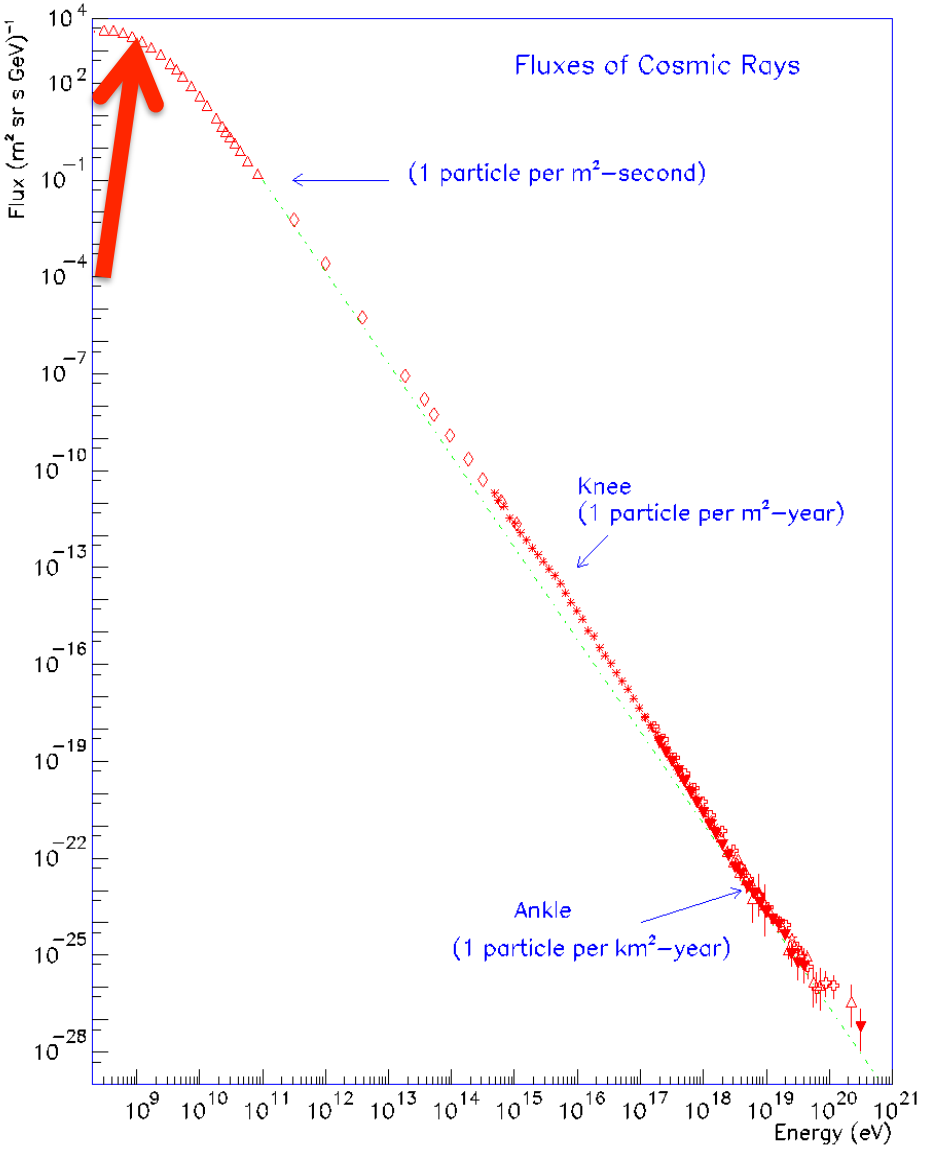
What do we ~~want to~~ could know about CRs?

What are the sources of the bulk of the cosmic ray flux on the Earth?

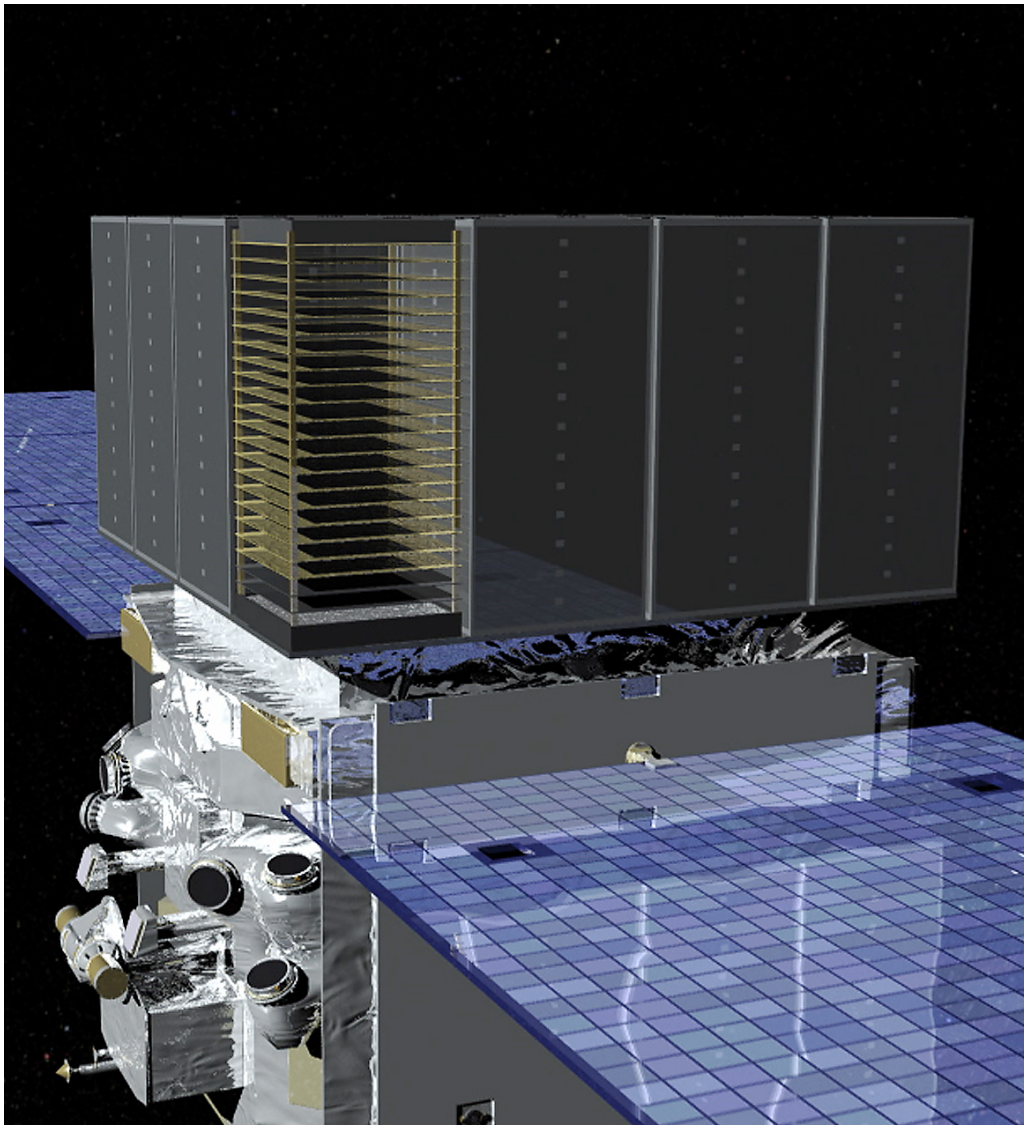
– Identification of the sources is possible only with the tools of multi-wavelength and multi-messenger astronomy.



High-energy gamma-ray astronomy

Fermi telescope is operational since 2008. Will collect data for still for another several years.

Impact of Fermi on the problem of the origin of Cosmic Rays is still not fully explored.

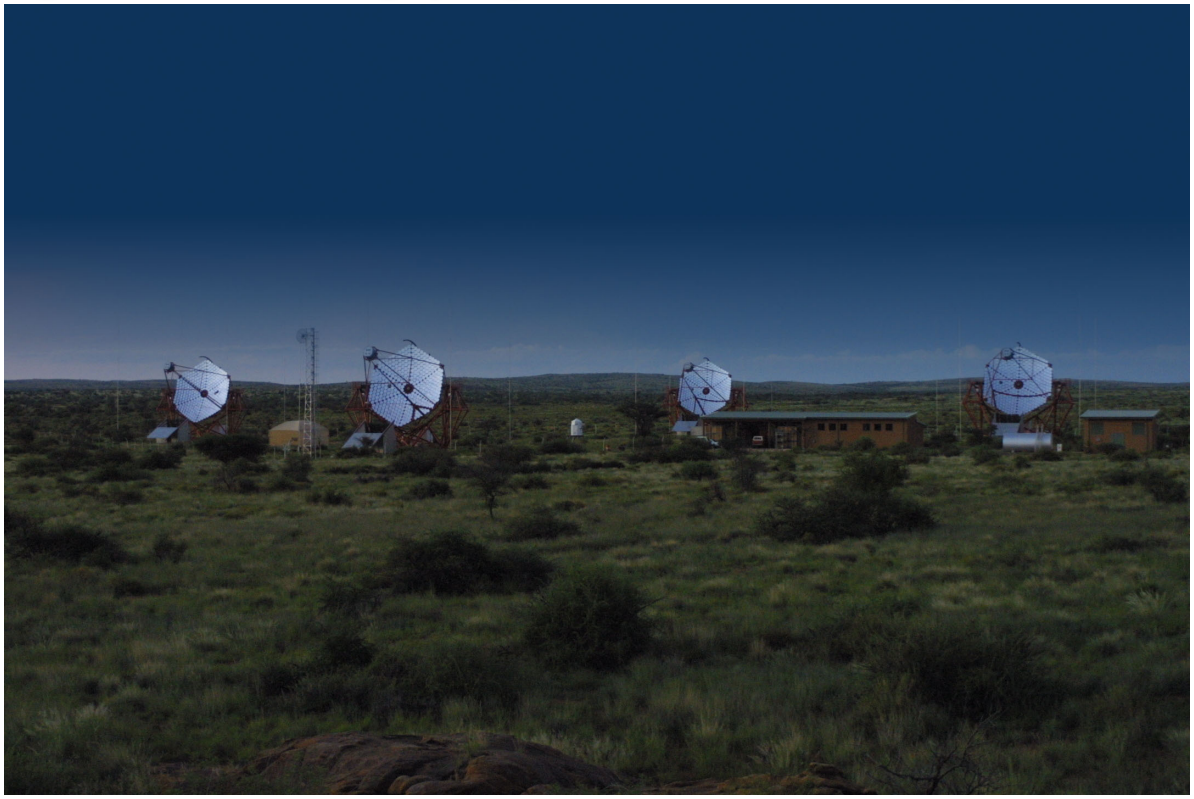


Very High-energy gamma-ray astronomy

Ground based gamma-ray astronomy with Cherenkov telescopes is a young field of science. Was really "opened" in the late 90'th with HEGRA telescope array.

– a set of 5 telescopes with 10 m^2 area dishes, 5^o field-of-view cameras.
– small mirror collective area limited the energy theshold to E_γ >1 TeV
– detected ~10 sources of E_γ >1 TeV gamma-rays in ~5 years of operation.

Very High-energy gamma-ray astronomy

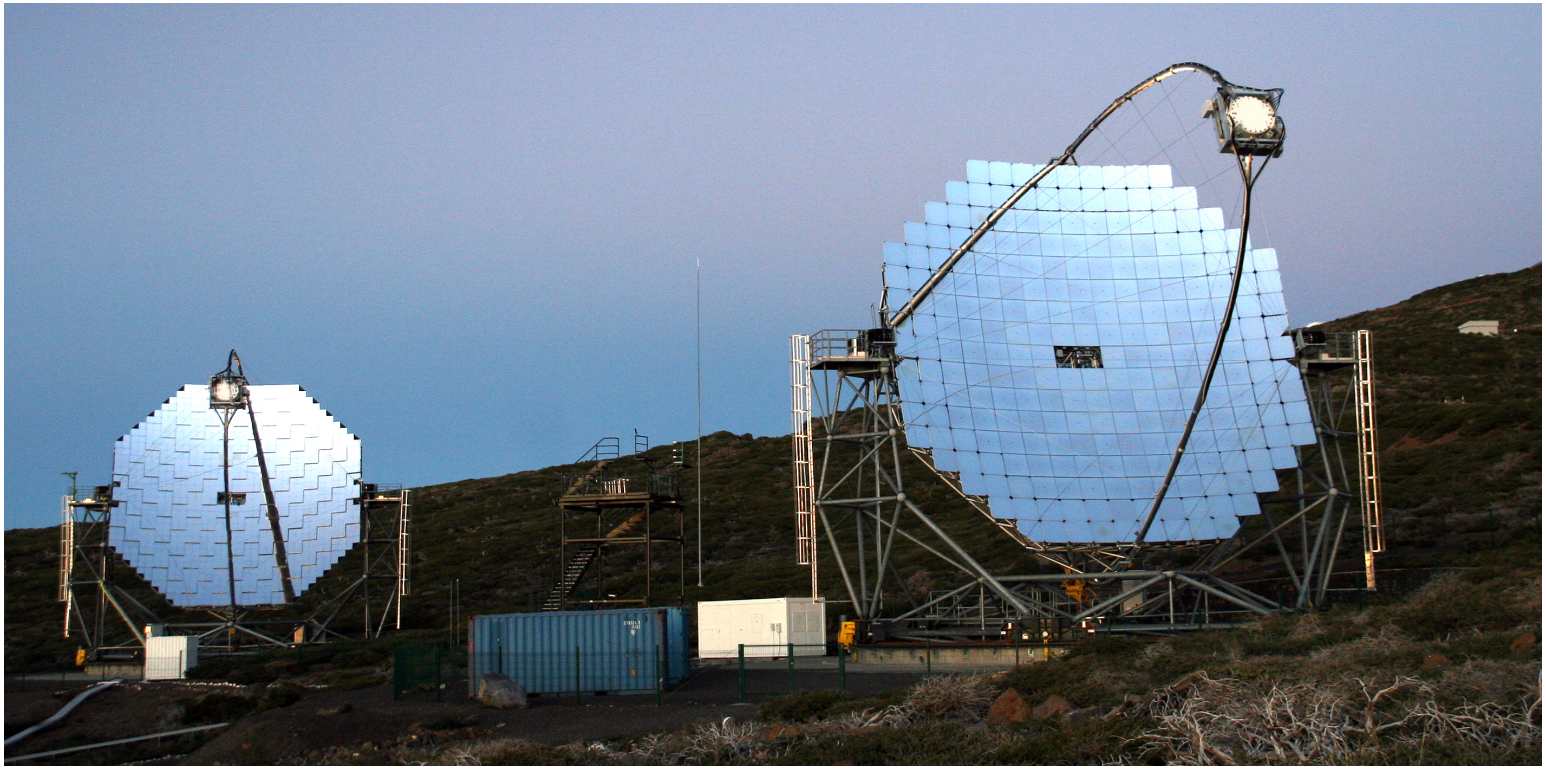


Current generation Imaging Atmospheric Cherenkov Telescope (IACT) arrays are "upgraded" versions of HEGRA.

HESS array in Namibia

- a set of 4 telescopes with dishes of diameter 12 m (~100 m^2 area), 5^o field-of-view cameras.
- larger mirror collective area enabled to lower the energy theshold to E_γ >200 GeV
- detected ~50 sources of E_γ >200 GeV gamma-rays in ~6 years of operation.

Very High-energy gamma-ray astronomy



Current generation Imaging Atmospheric Cherenkov Telescope (IACT) arrays are "upgraded" versions of HEGRA.

MAGIC-II array at La Palma

- a set of 2 telescopes with dishes of diameter 17 m (~200 m^2 area), 3^o field-of-view cameras.
- still larger mirror collective area enables to lower the energy theshold to E_γ >70 GeV
- detected ~50 sources of E_γ >200 GeV gamma-rays in ~1-5 years of operation.

Very High-energy gamma-ray astronomy

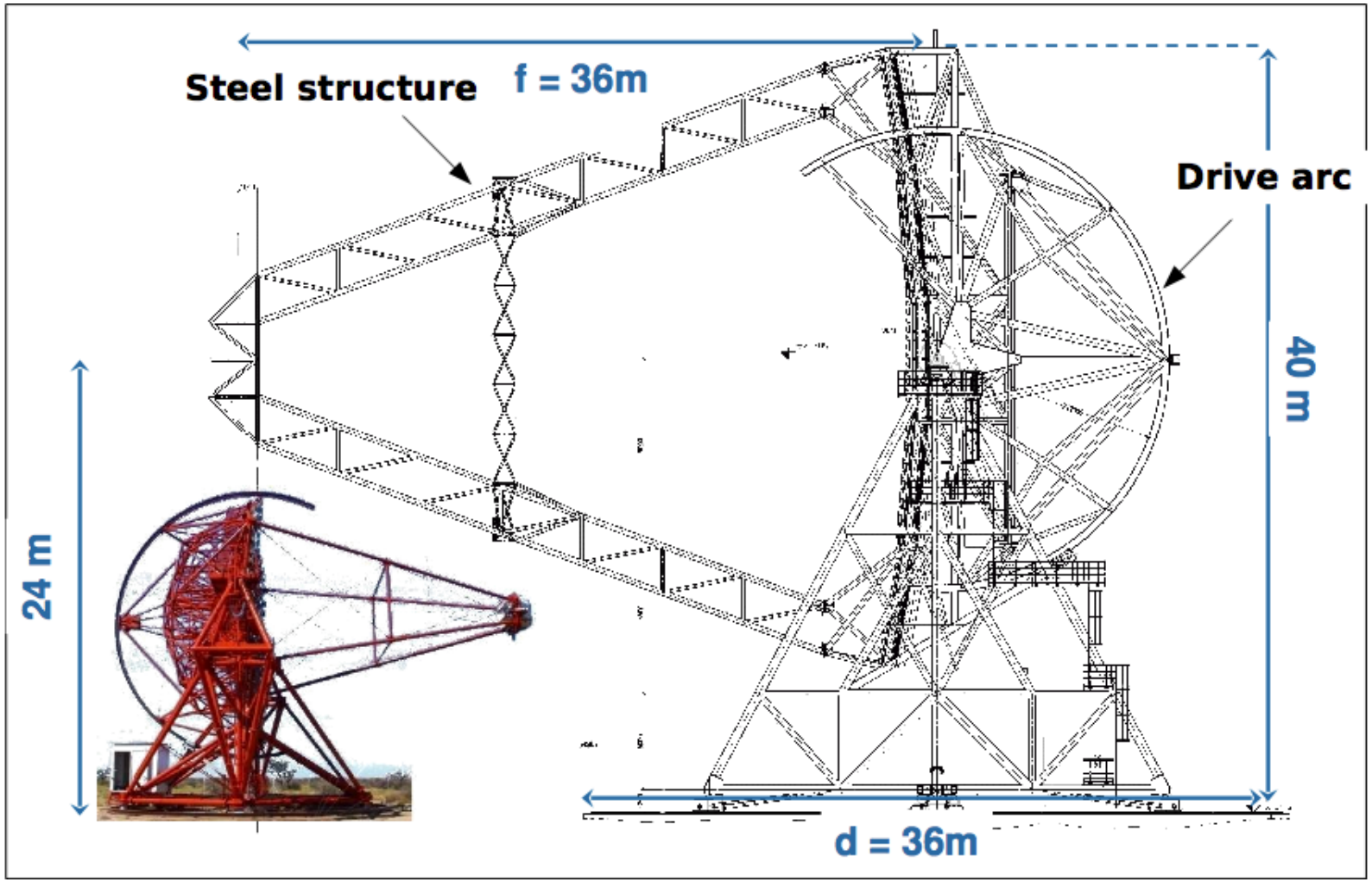
Current generation Imaging Atmospheric Cherenkov Telescope (IACT) arrays are "upgraded" versions of HEGRA

VERITAS array in Arizona

- a set of 4 telescopes with dishes of diameter 12 m (~100 m^2 area), 3^o field-of-view cameras.
- still larger mirror collective area enables to lower the energy theshold to E_γ >200 GeV
- detected ~50 sources of E_γ >200 GeV gamma-rays in ~5 years of operation.

Very High-energy gamma-ray astronomy

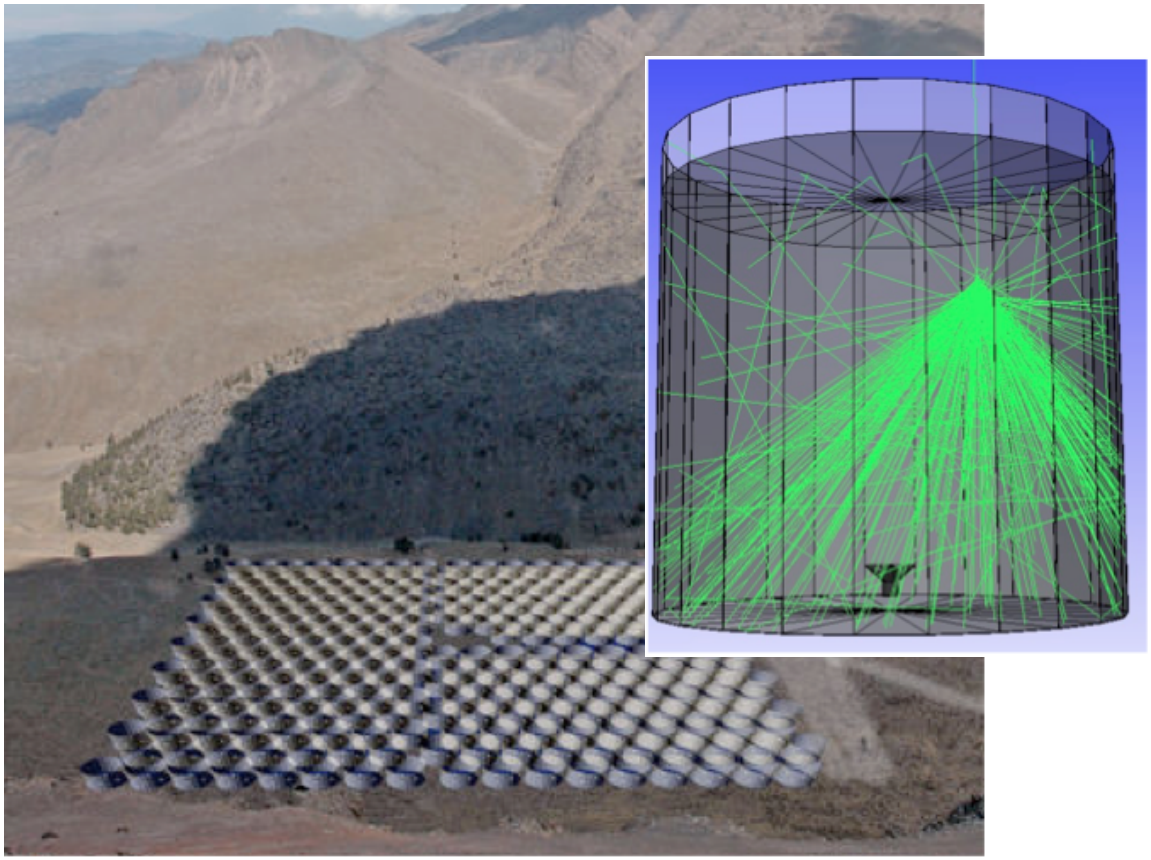
… nearest future



HESS collaboration is currently building a larger size telescope (dish diameter 27 m, collection area ~600 m^2) to achieve a lower energy threshold E_γ>50 GeV.

Very High-energy gamma-ray astronomy

… nearest future



A dense air shower array HAWC (High Altitude Water Cherenkov telescope) is under construciton in Mexico (Sierra Negra, altitude 4100 m a.s.l.).

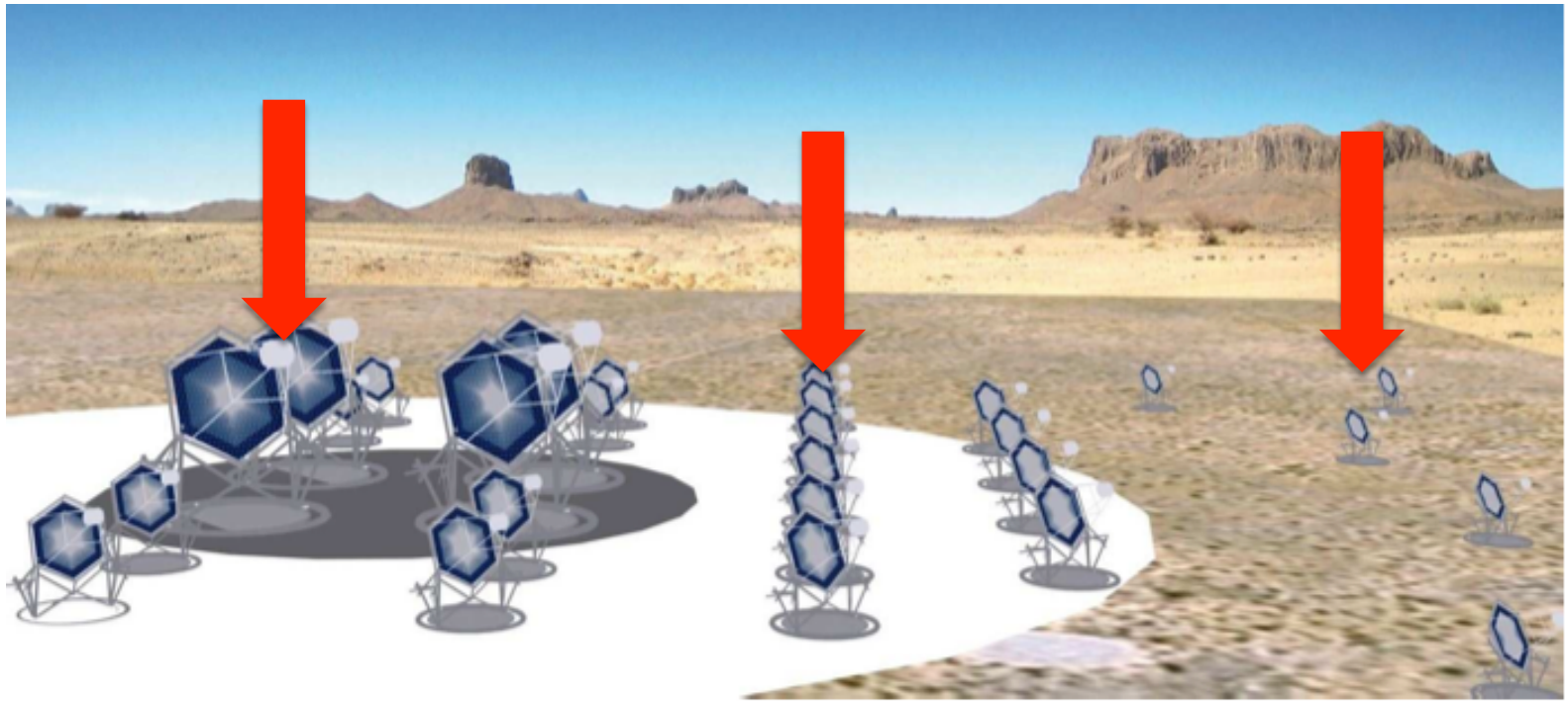
Gamma-ray induced showers are detected with water tanks equipped with PMTs.

High altitude of the site allows to detect air showers induced by E~100 GeV gamma-rays.

Very High-energy gamma-ray astronomy

… near future

CTA collab., 2010, arXiv:1008.3703



Main next-generation project is Cherenkov Telescope Array (CTA).

– A combined array of telescopes of different sizes;

– Large (~30 m diameter dish) telescopes to achieve lowest possible energy threshold;

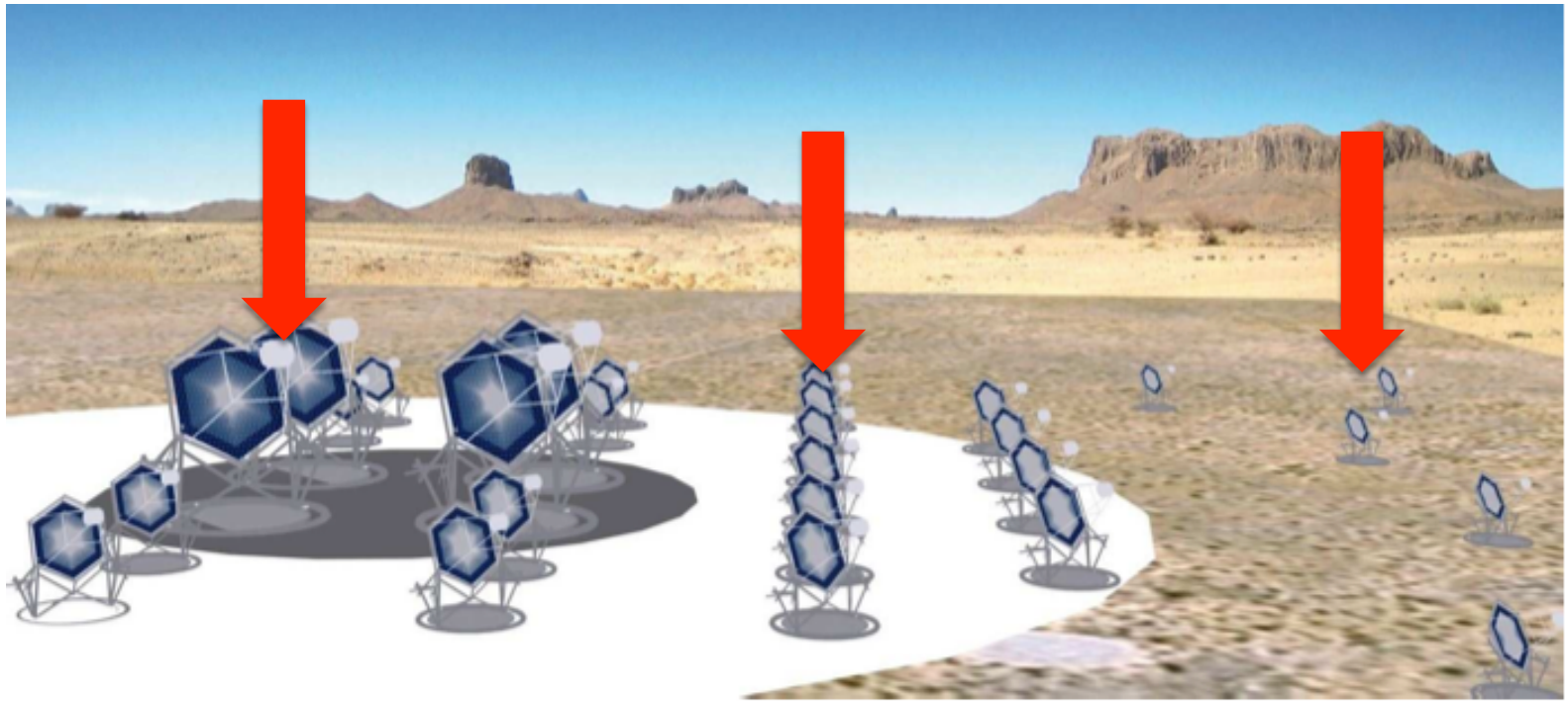
– Medium (~10 m diameter dish) telescopes to get coverage in the "conventional" 0.1-10 TeV energy range, but with larger collection area and better energy+angular resolution;

– Large number of small (~5 m diameter dish) telescopes spread over ~3 km distance, to achive ~10 km^2 collection area needed for detection of 100 TeV γ-rays.

Very High-energy gamma-ray astronomy

… near future

CTA collab., 2010, arXiv:1008.3703

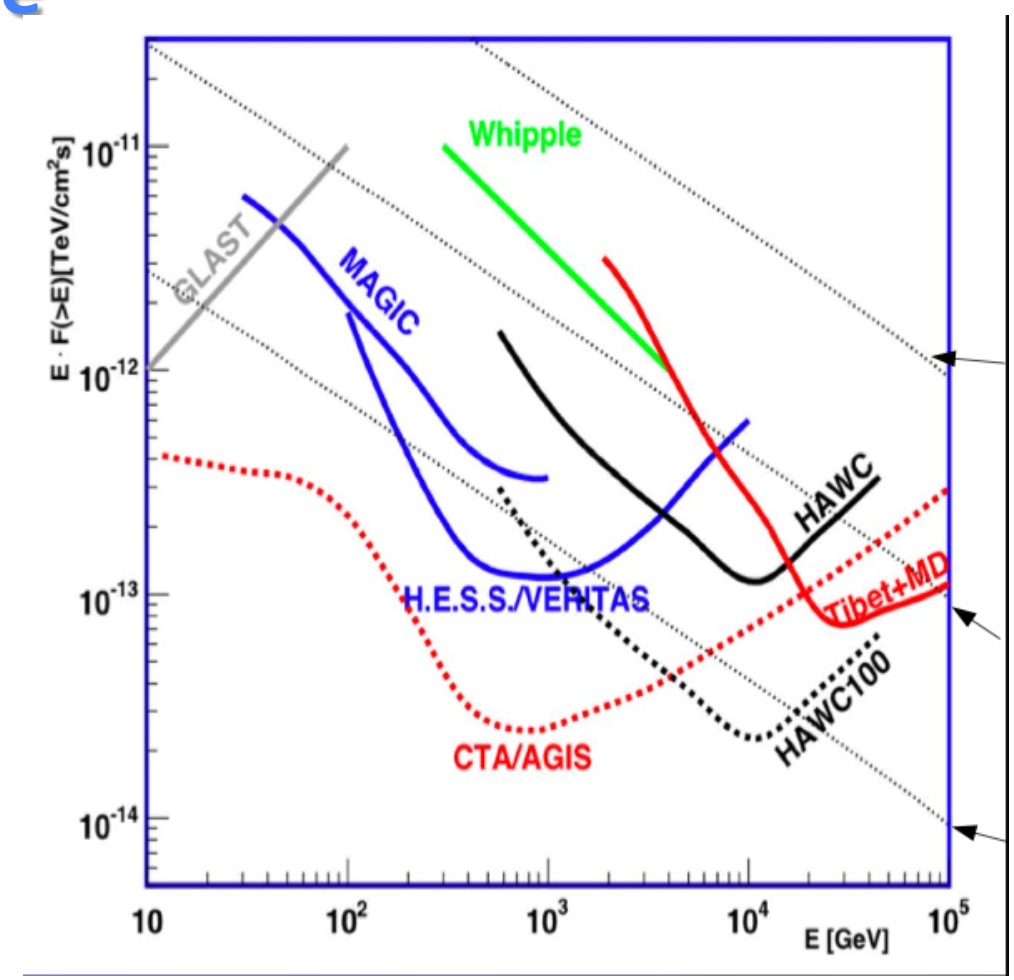


Funded by the EU + national contributions. Currently in the "prototyping" phase.

Construction phase is expected to start in the next ~5 yr.

Very High-energy gamma-ray astronomy

… near future



New generation of VHE gamma-ray telescopes will allow increase of sensitivity by a factor of ~10 compared to the present generation instruments.

It will also extend the window for astronomical observations to $E_\gamma \geq 100$ TeV

What do we ~~want to~~ could know about CRs?

What are the sources of the bulk of the cosmic ray flux on the Earth?

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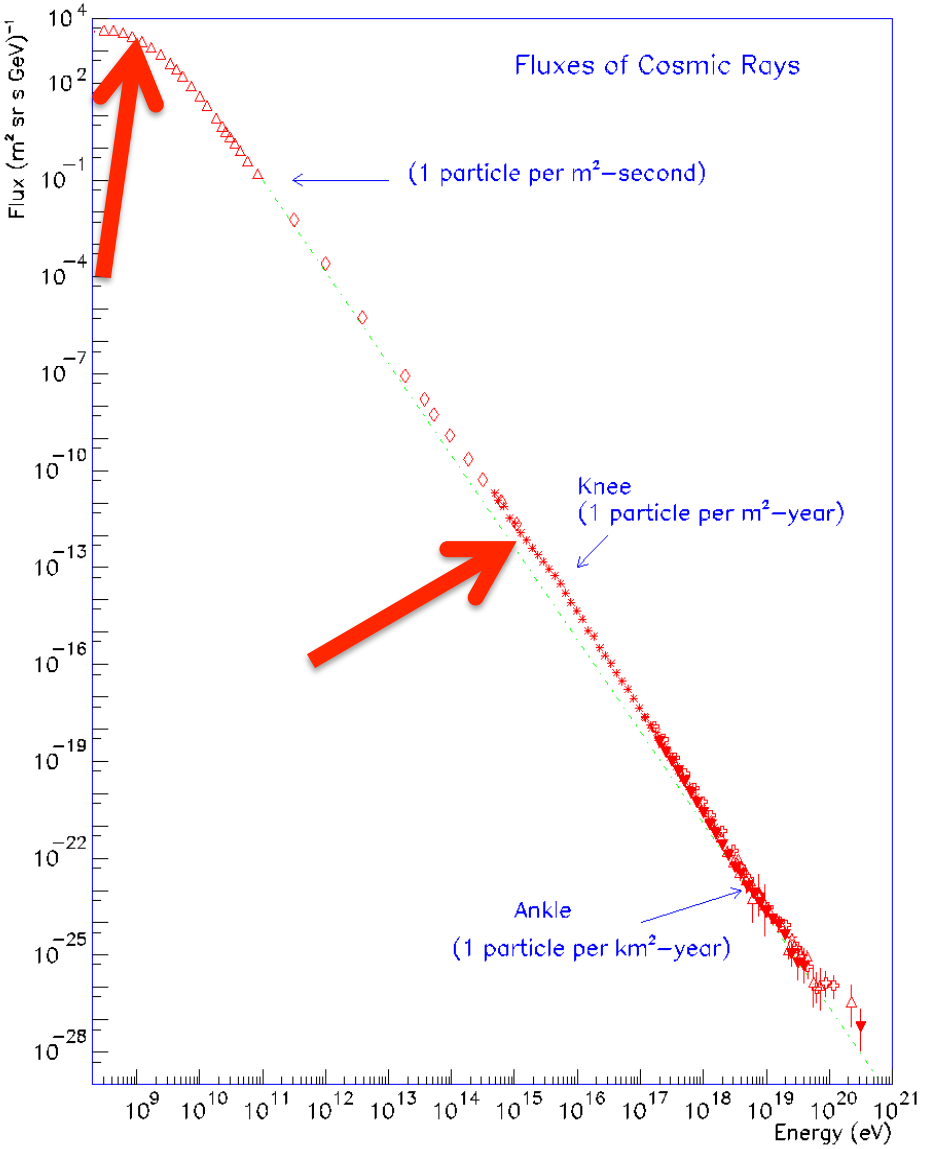
What is the origin of the "knee" of the cosmic ray spectrum? What sources (Galactic ?) are responsible for the CR flux in the "knee" energy region?



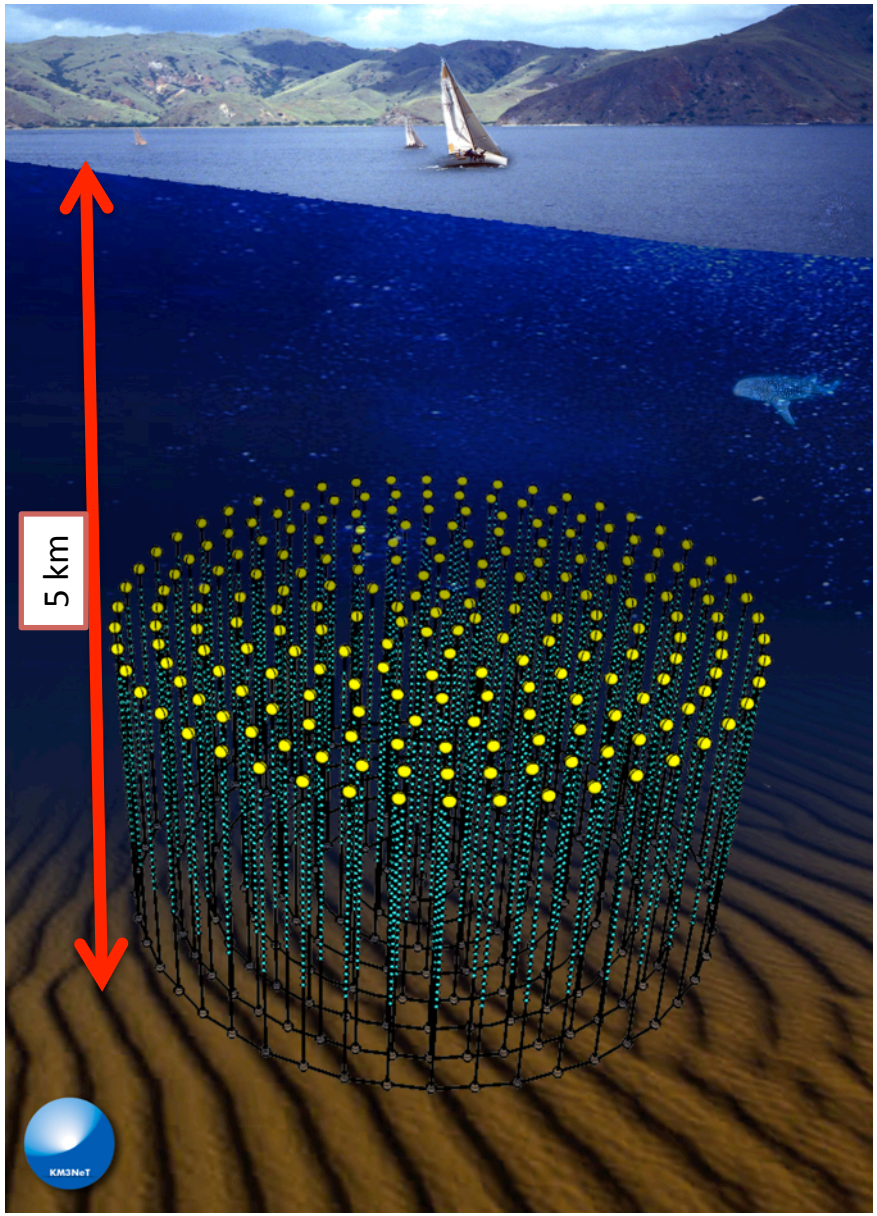
Very-high-energy neutrino astronomy

Km^3 class detectors of very-high-energy neutrinos.

Construction of IceCube detector in the Antarctic ice is completed. Data taking is on-going.

A European project of a km^3 scale detector in the Mediterranean is in the "preparatory" (in terms of the European FP7 network program) phase.

Construction is expected to start in the next several years (?)



What do we ~~want to~~ could know about CRs?

What are the sources of the bulk of the cosmic ray flux on the Earth?

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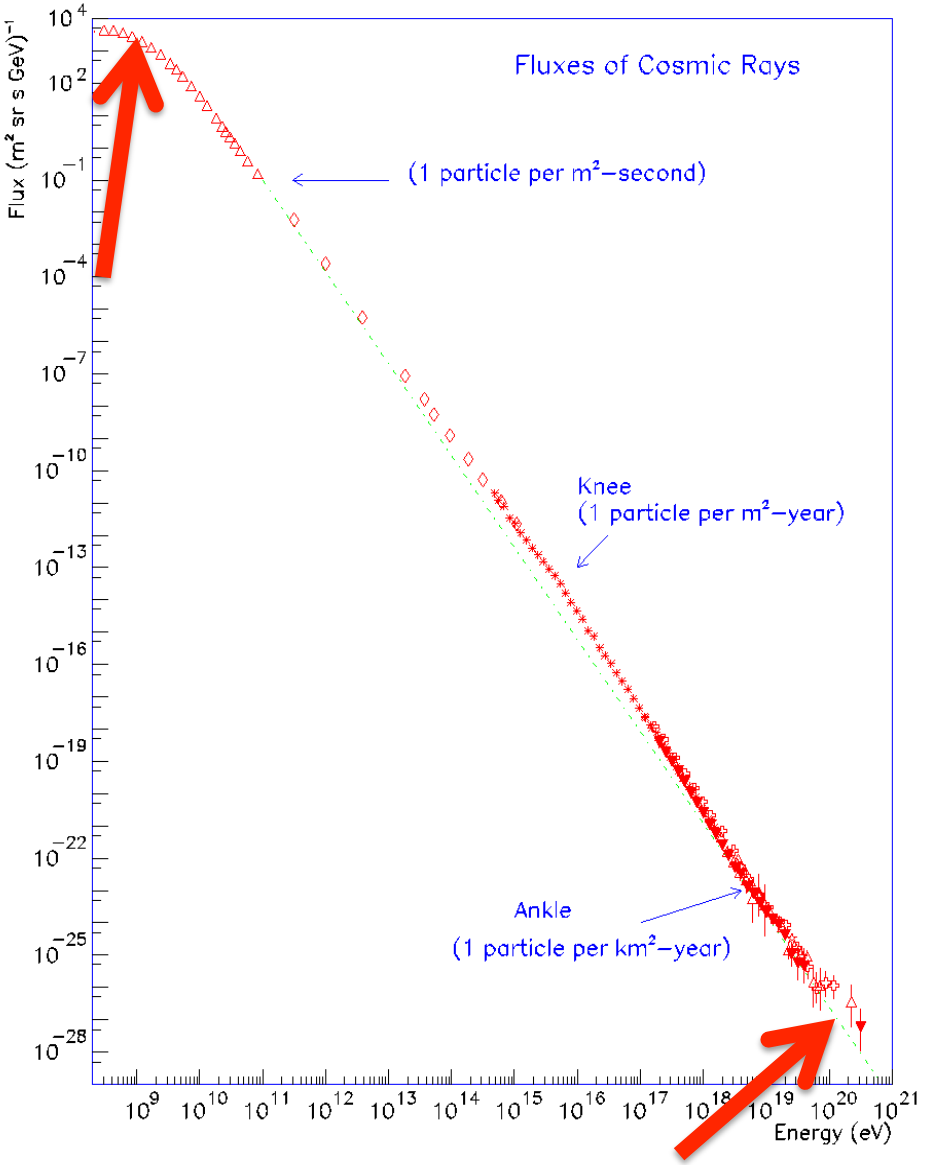
What are the sources of the highest energy cosmic rays?

– What kind of particles is contributing to the highest energy CR flux (protons, heavy nuclei)?
– Sources of UHECR could possibly be found by the back tracing of UHECR arrival directions.
– Dramatic increase in the effective collection area, much beyond 3000 km^2 of Pierre Auger Observatory is needed.



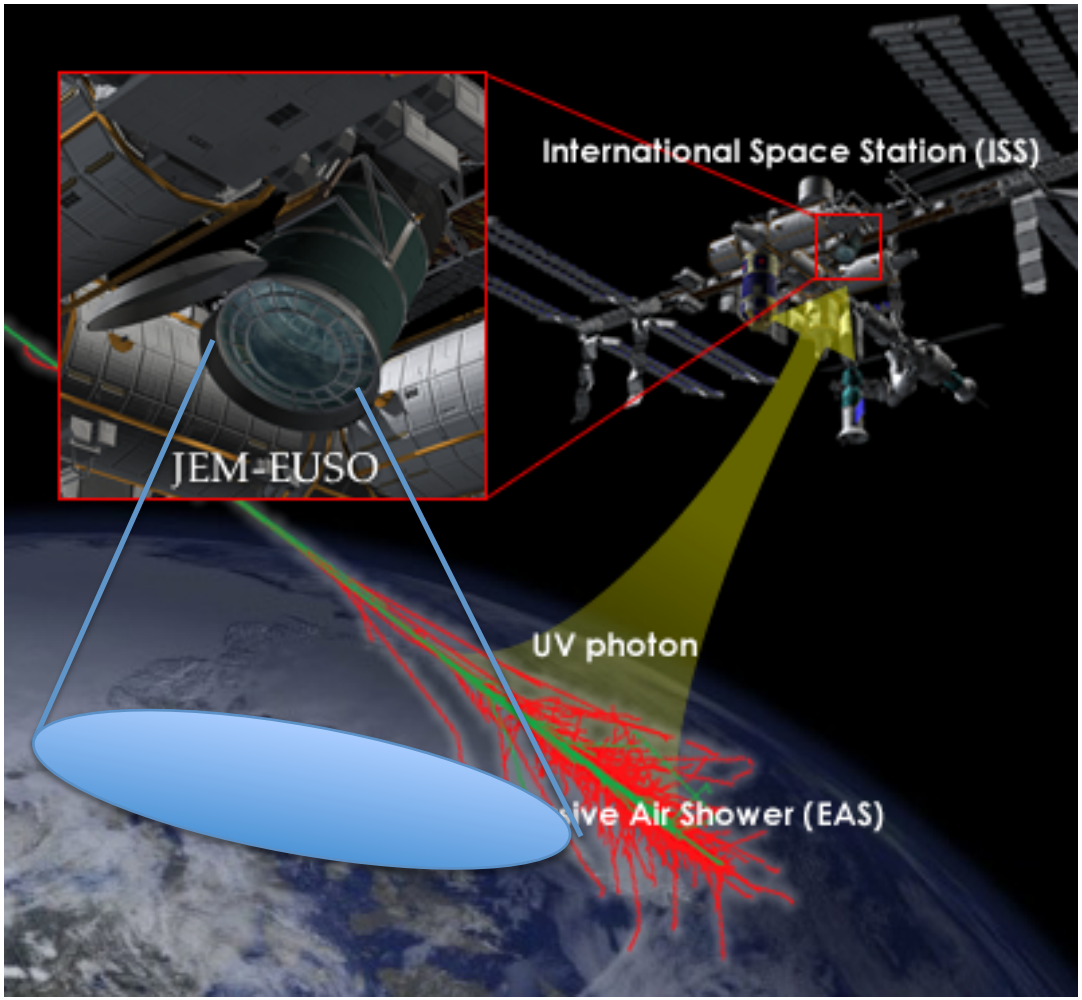
UHECR astronomy/physics

Factor of ~30 increase of collection area could be achieved with a fluorescence telescope intalled on a spacecraft.

JEM-EUSO is a Japanese-led collaboration to put a fluorescence telescope on Internation Space Station.

JEM-EUSO is a 2.5 m diameter refractor telescope, with a field-of-view 60^{o}. Effective Collection area is $\pi\times(400\ \mathrm{km})^4/4\approx10^5\ \mathrm{km}^2$.

Expected to be launched in 2015 and operate for ~5 yr.



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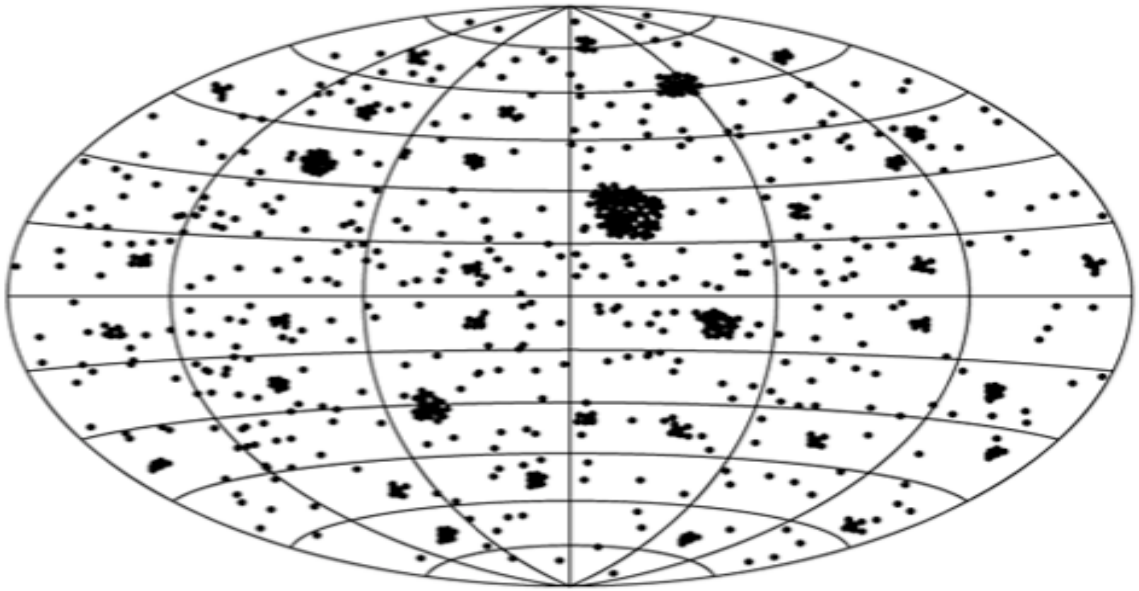
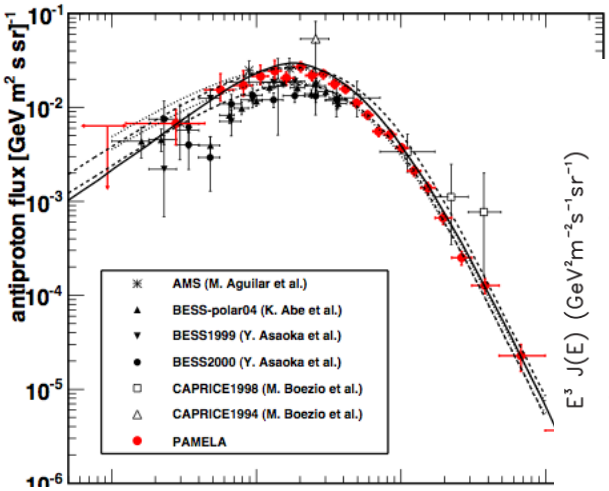
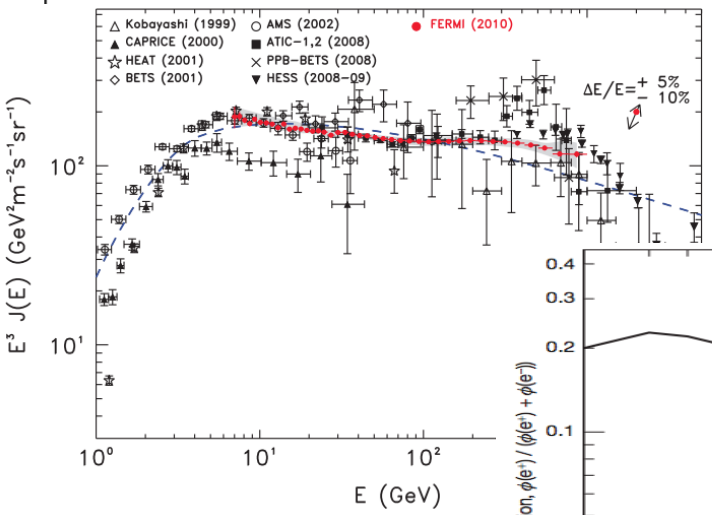
Expected to be launched in 2015 and operate for ~5 yr.

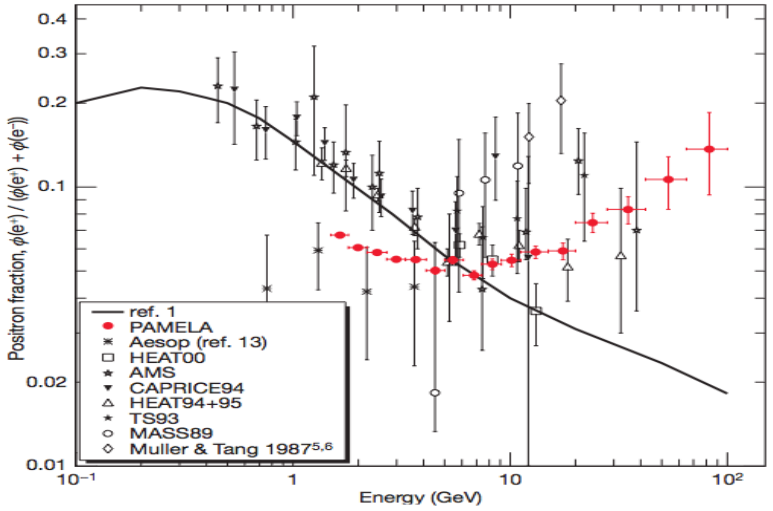
Will detect ~10^3 UHECR events with energy above 5×10^{19} eV.



CR electrons, positrons & anti-protons







What are the sources of CR electrons with energies in the TeV range?

Are there nearby sources of CR positrons or they are of "secondary" origin?

What is the origin of "anomaly" in the positron spectrum?

Are there signatures of DM annihilation in the DM halo of the Galaxy?

Low energy CR physics

AMS-2 detector will be installed on the International Space Station in April 2011.

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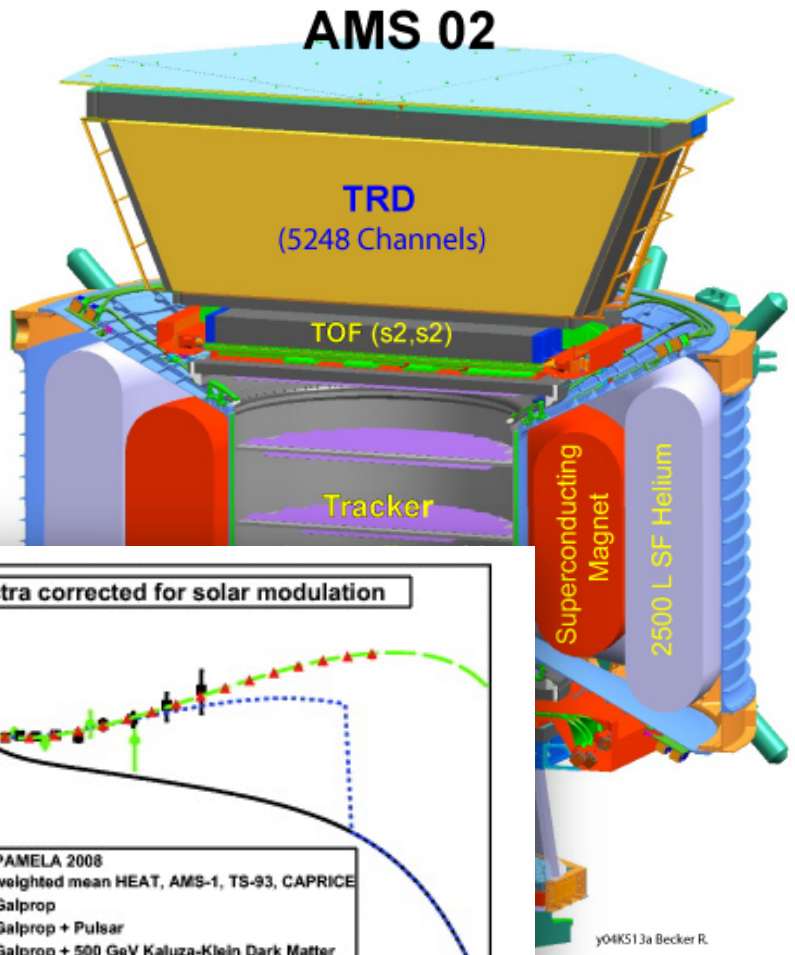
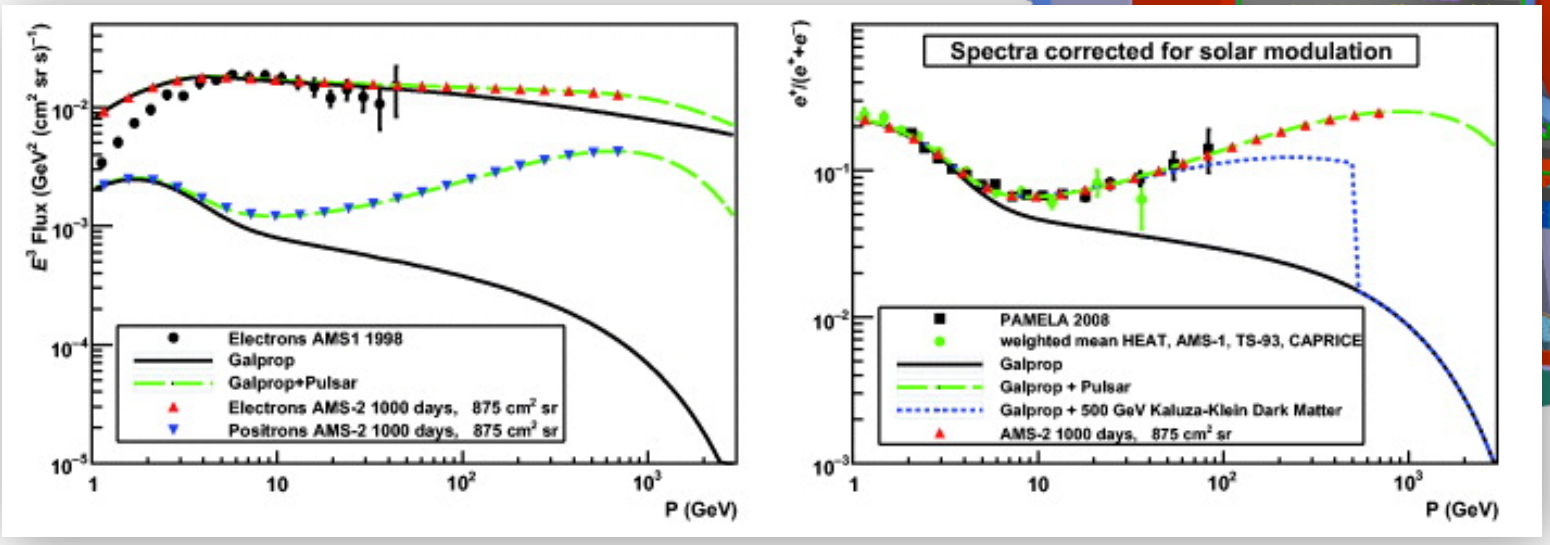
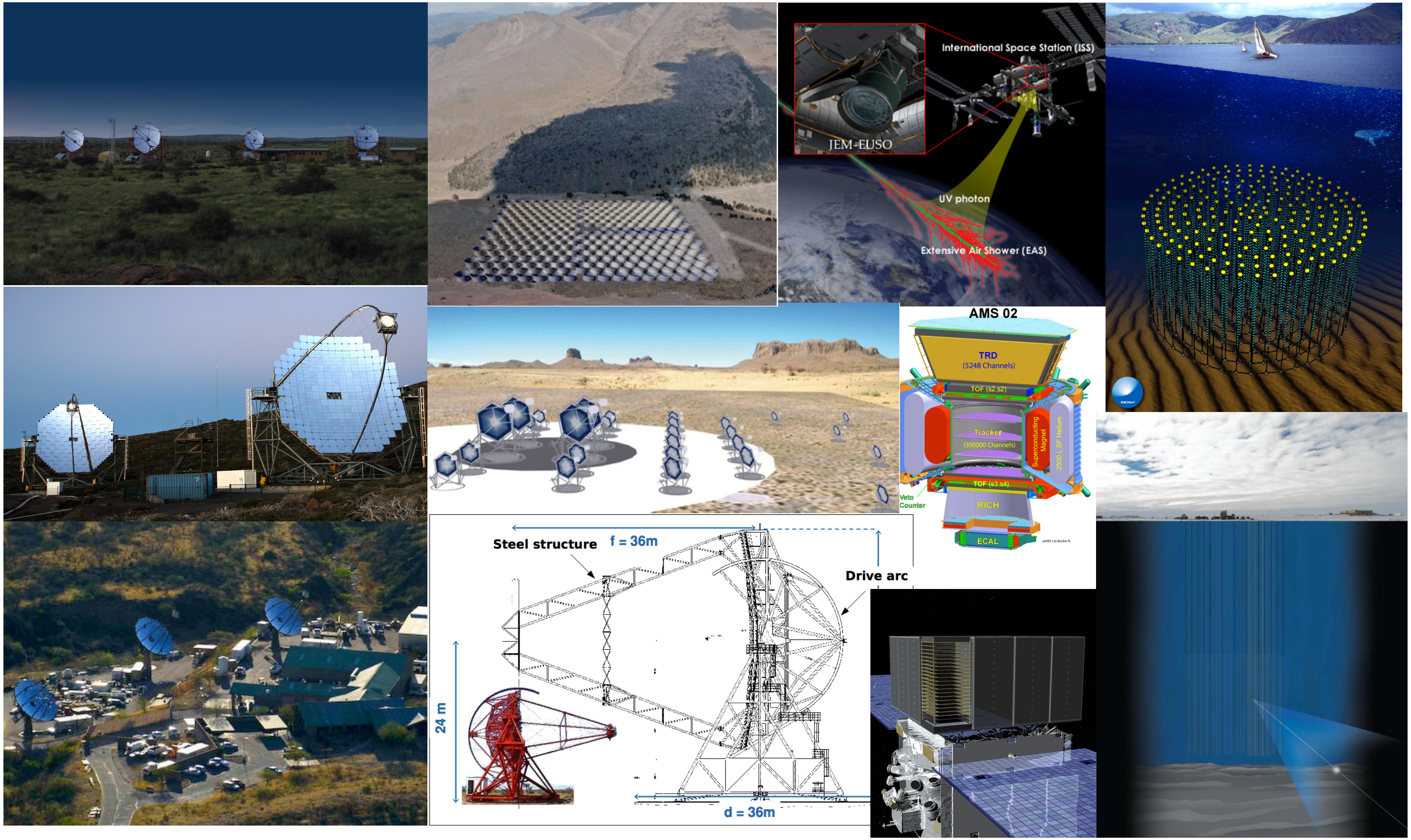
Will provide high statistics measurement of CR electron and positron spectrum in the energy range of Pamela anomaly.





Summary


International Space Station (ISS)
JEM-EUSO
UV photon
Extensive Air Shower (EAS)
AMS 02
TRD
(5248 Channels)
TOF (s2,s2)
Tracker
(300000 Channels)
Superconducting Magnet
2500 L SF Helium
TOF (s3,s4)
Veto Counter
RICH
ECAL
y04K513a Becker R.
Steel structure
f = 36m
Drive arc
24 m
d = 36m