Charged Cosmic Ray Physics

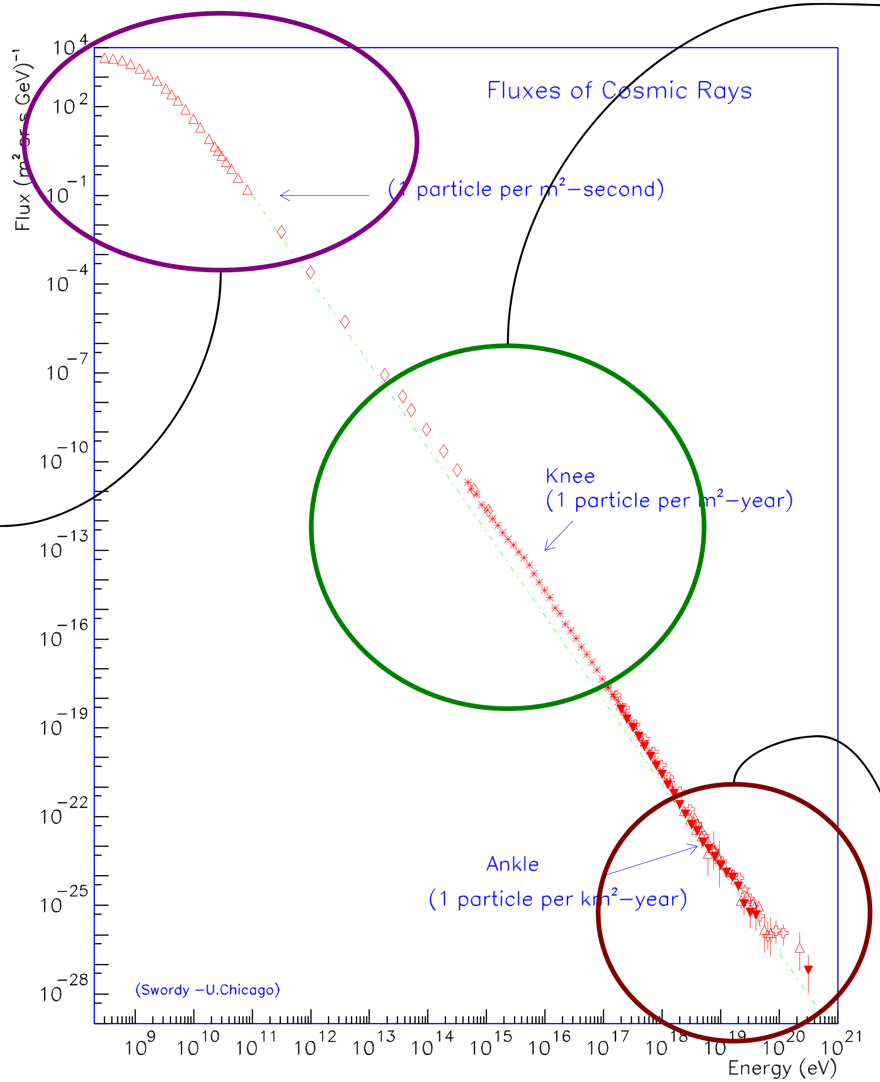
hip region:

- absolute flux of var. primaries

→cosmology

- antimatter

→SUSY



knee region:

- CR composition
- knee position for var. primaries

→ CR source type?

→ CR travel distance?

ankle region:

- GZK cutoff
- CR direction

→ CR point sources

→ GZK cosmology

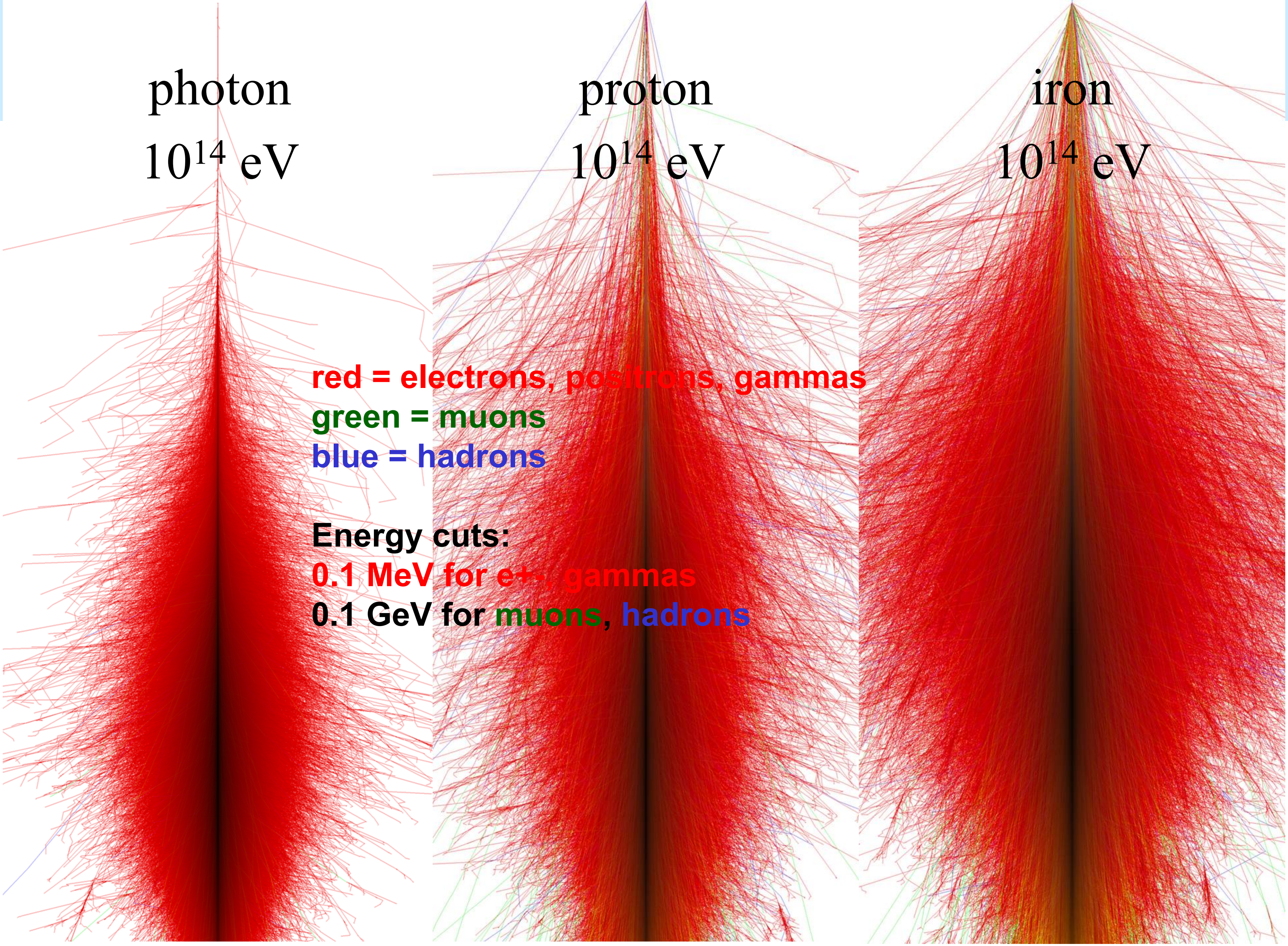
How to measure Cosmic Rays

Direct Measurements (E < 10^{15} eV):

- Balloon
- Satellite

Indirect Measurements (EAS, E > 10^{15} eV):

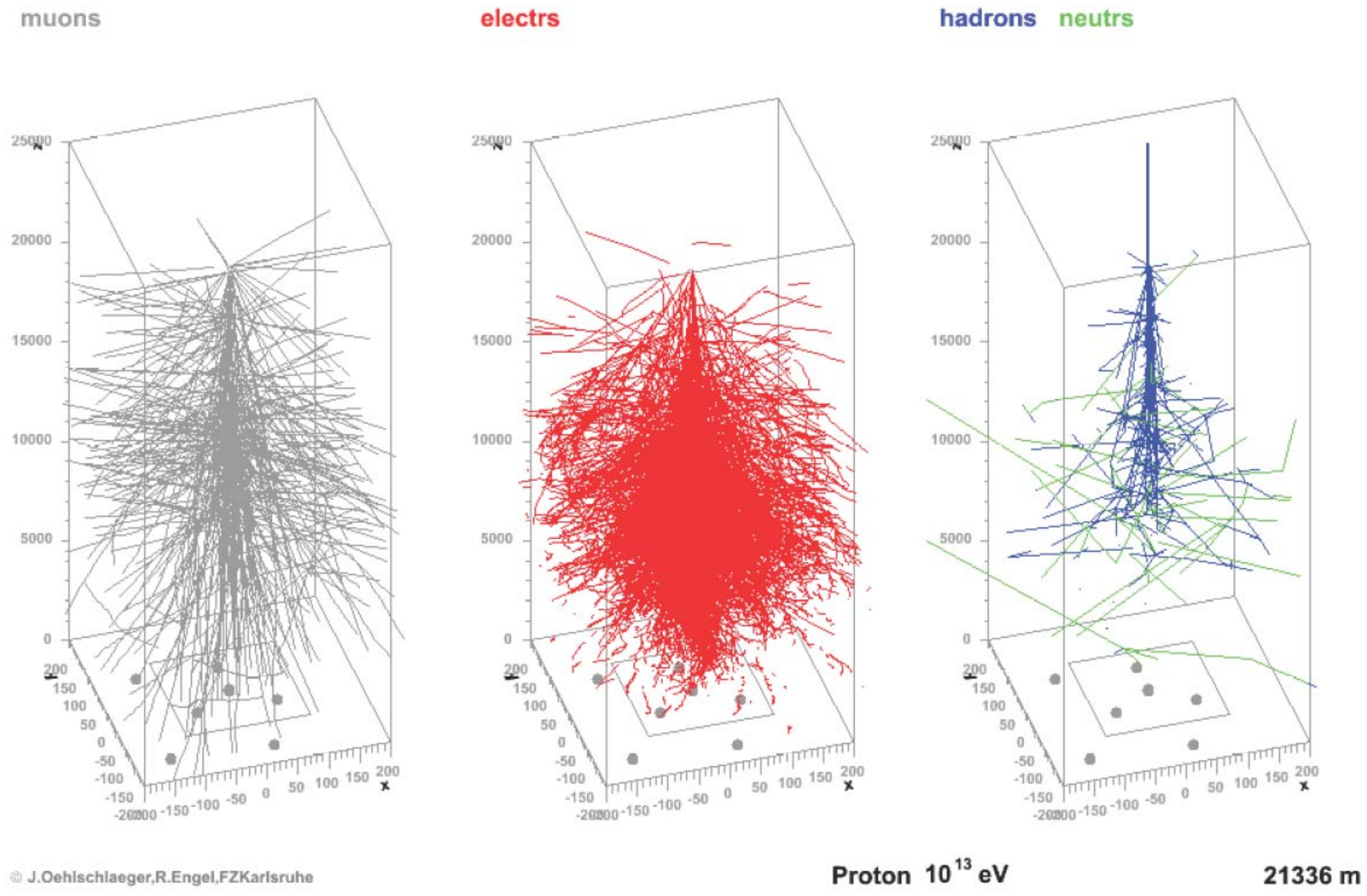
- Scintillator detector array
- Cherenkov counter array
- Tracking chambers
- Cherenkov tank detector array
- Fluorescence telescopes
- ... (?)



red = electrons, positrons, gammas
green = muons
blue = hadrons

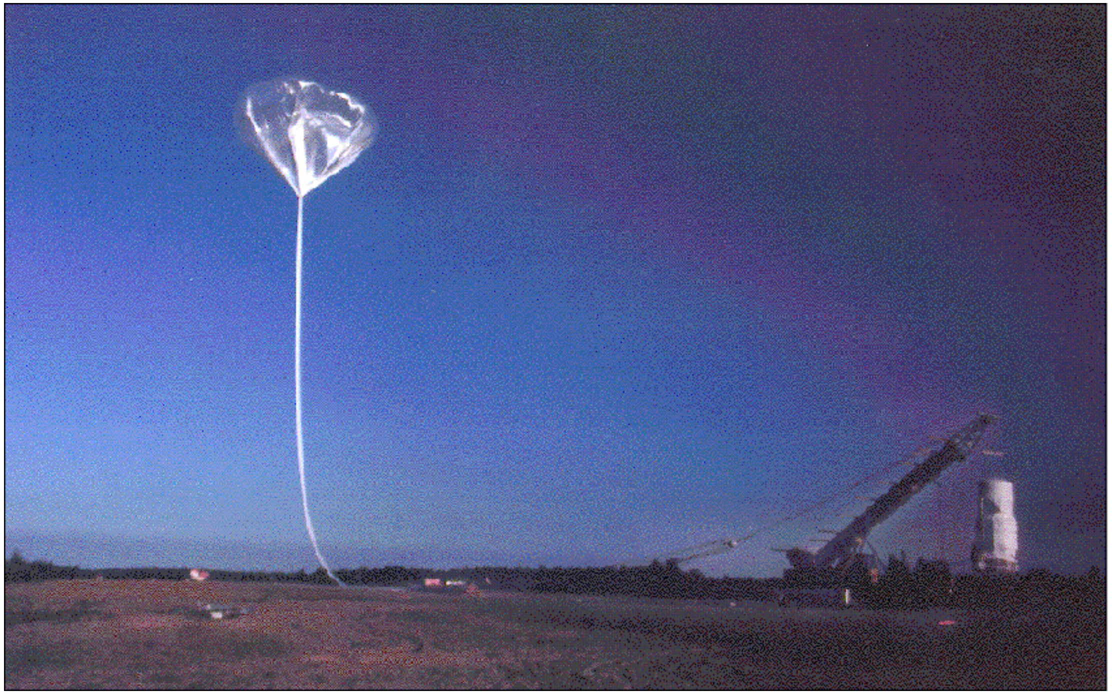
Energy cuts:
0.1 MeV for e+-, gammas
0.1 GeV for muons, hadrons

Sketches of single components –proton shower



© J.Oehlschlaeger,R.Engel,FZKarlsruhe

Balloon Measurements: CAPRICE98



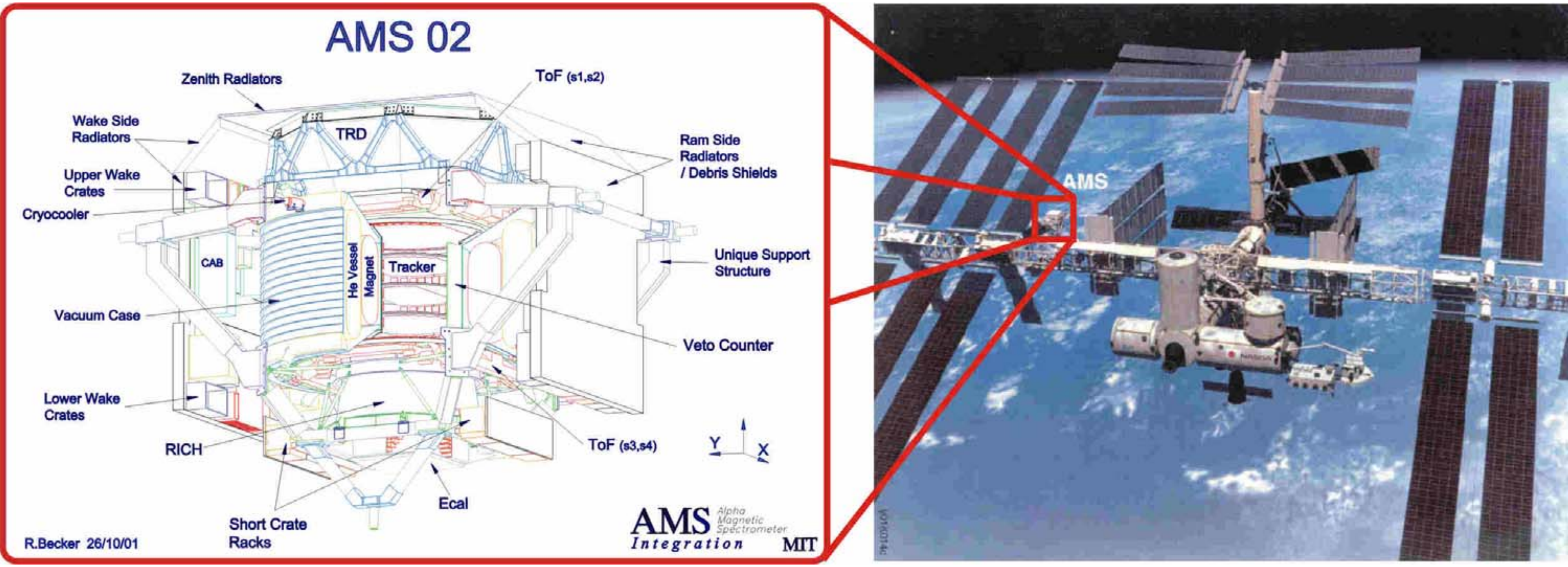
New Mexico → Arizona, US, 1998

at 5.5 g/cm^2 ~ 37 km ~ 4.5 mbar

p, He: 3 – 350 GeV

p^{-}, d^{-}: 3 – 49 GeV

Satelliten-Experimente

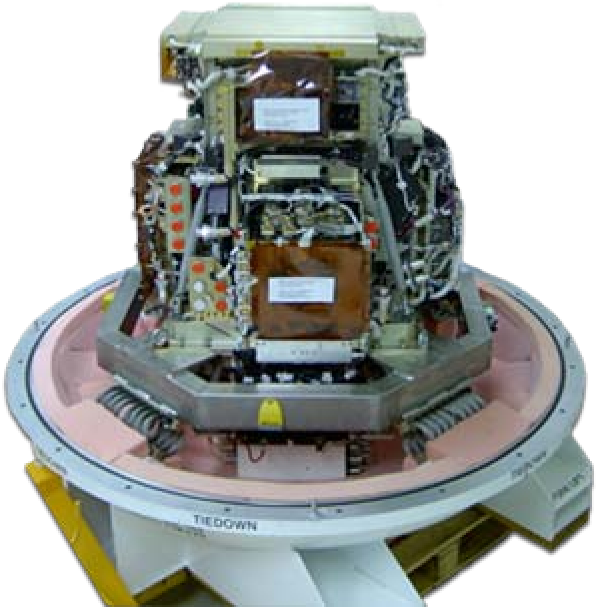


ISS Höhe: ~ 340 km

Startdatum: 29. July 2010, Endeavour STS-134

Satellite Measurements: PAMELA

PaMeLa a Payload for Antimatter Matter Exploration and Light–nuclei Astrophysics

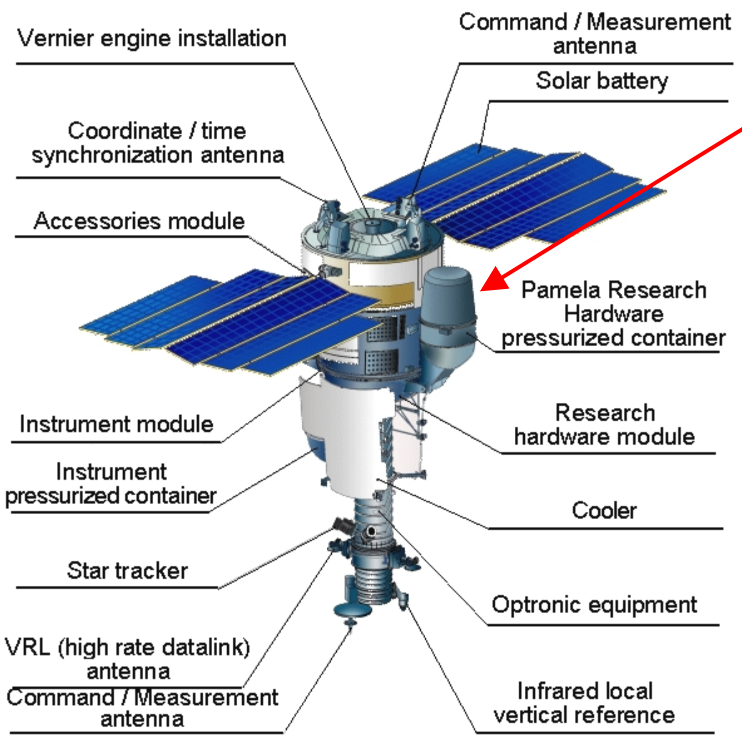


altitude: 350 – 600 km

p, He, Be, C:	0.08 – 700 GeV
p^-:	0.08 – 190 GeV
e^-:	0.05 – 400 GeV
e^+:	0.05 – 270 GeV

Launch in Bajkonur: 15th June 2006

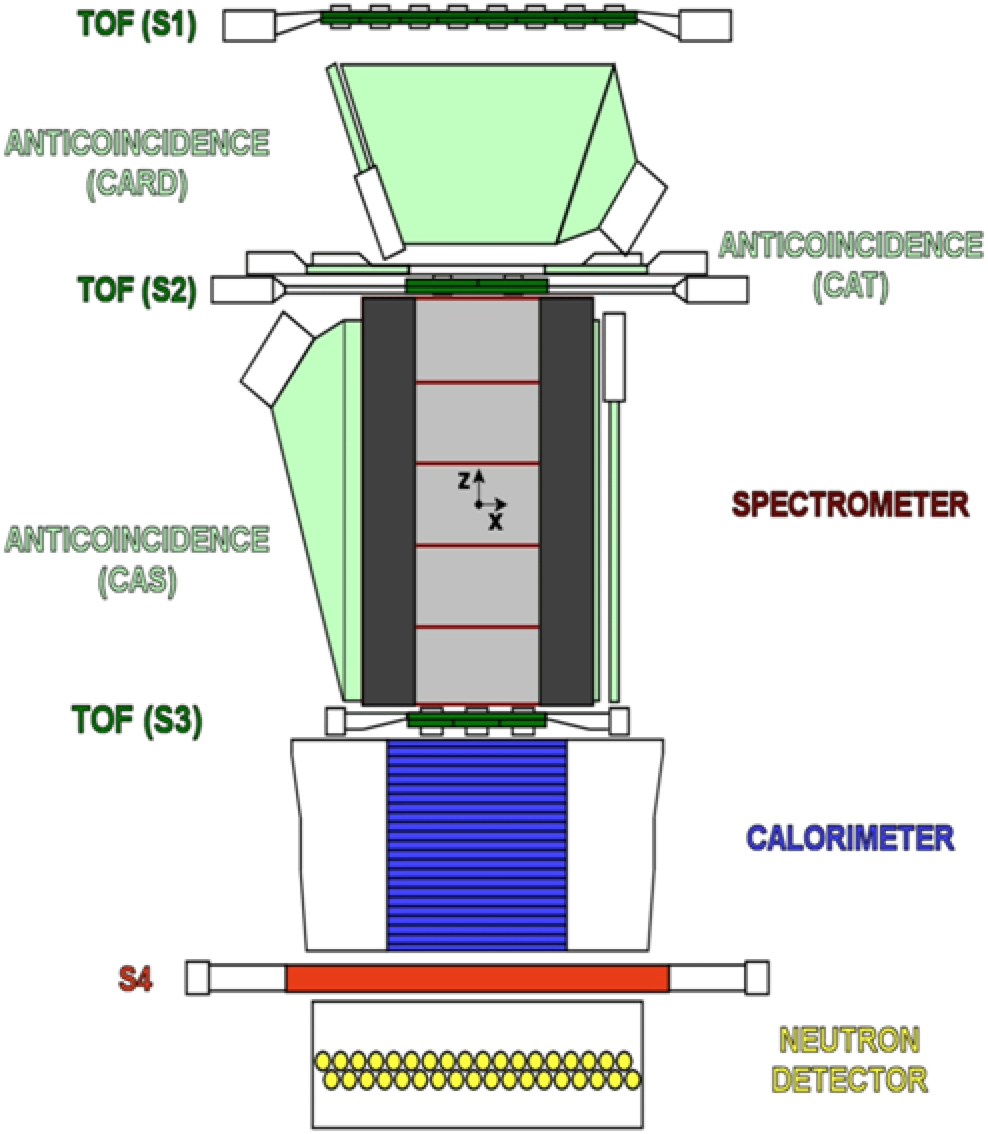
Resurs-DK1 Satellite



PAMELA Detector

Launch of Resours-DK1 with PAMELA antimatter spectometer

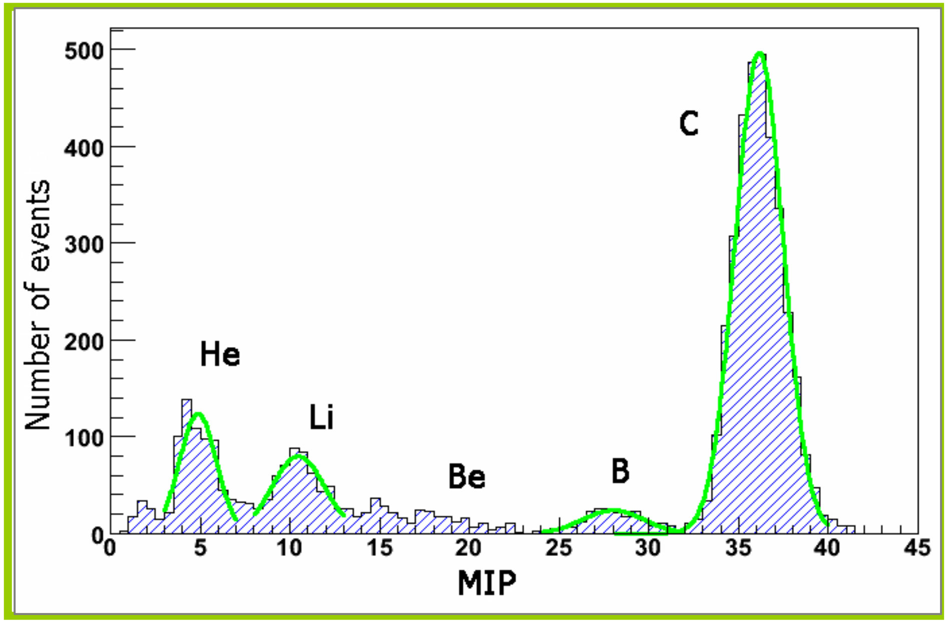

X LOAD 1000 DAN

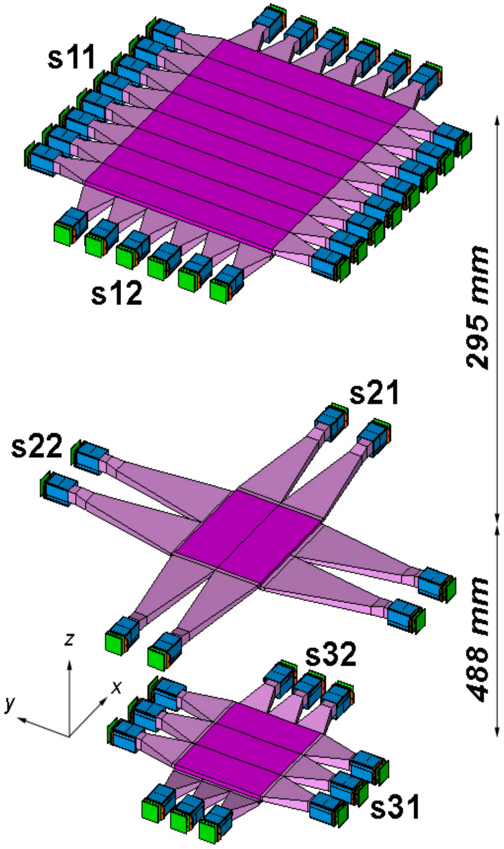

TOF (S1)
ANTICOINCIDENCE (CARD)
ANTICOINCIDENCE (CAT)
TOF (S2)
Z
X
SPECTROMETER
ANTICOINCIDENCE (CAS)
TOF (S3)
CALORIMETER
S4
NEUTRON DETECTOR

The TOF System

- 3 Planes of Scintillators S1, S2, S3
  Each hodoscope plane with 2 crossed layers, segmented in X/ Y strips
- Total: 48 Channels - Ham. PMT R5900

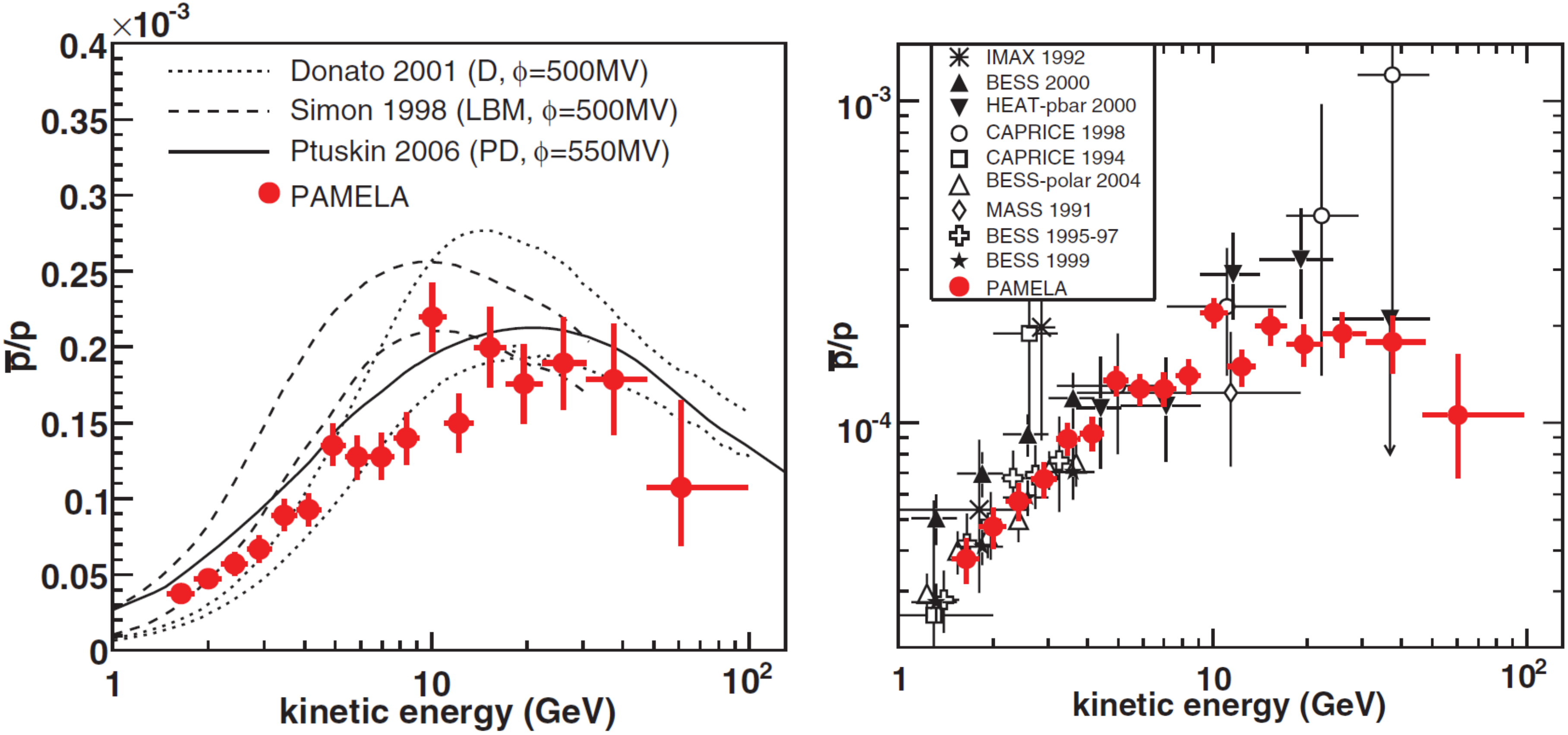
- $\sigma_{paddle} \sim$ 110ps, $\sigma_{TOF} \sim$ 330ps (MIP)





Antiproton-Proton Ratio

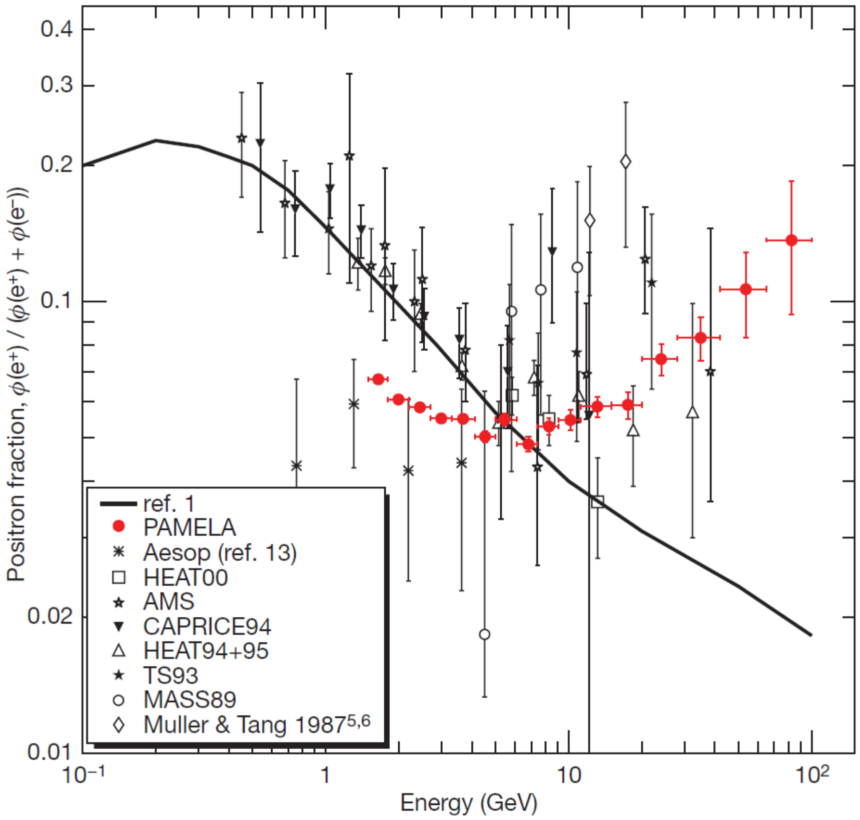
~ 500 days of data, 1 billion triggers



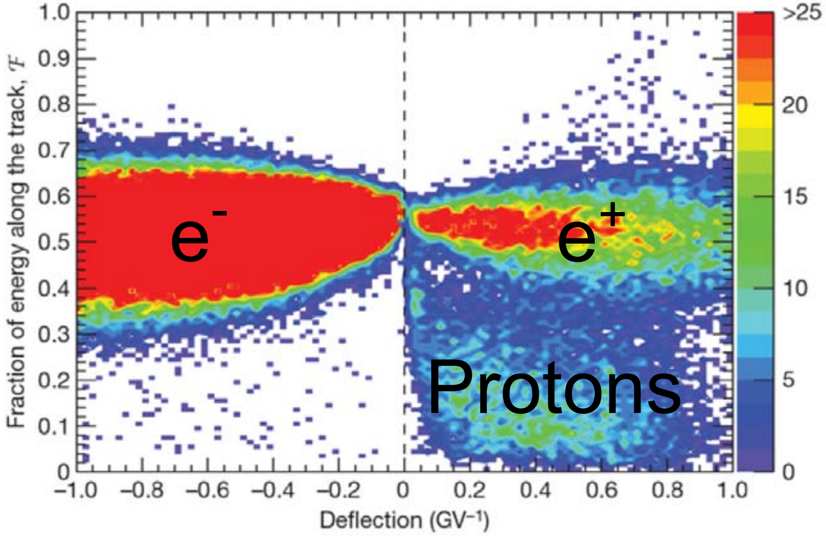
Results agree with theoretical expectations for secondary emission!

Phys. Rev. Lett. **102**, 051101 (2009)

Exciting Result: Positron Fraction!



Separation of positrons and protons

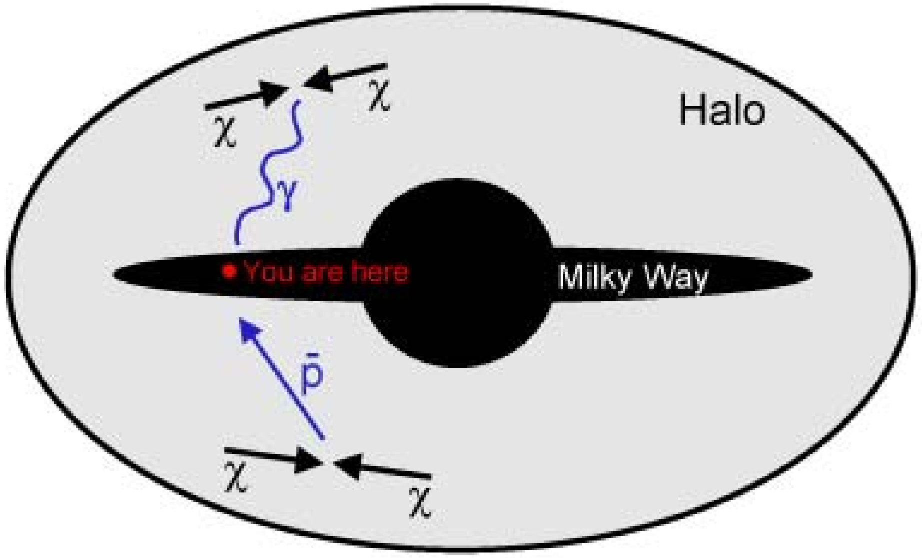


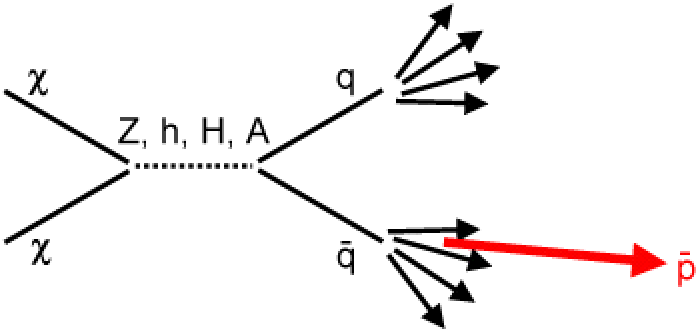
Nature **458**, 607-609 (2 April 2009)

High statistic results disagree with conventional models at high energies!

→ primary positron emission from nearby pulsars or **dark matter annihilation**?

Neutralino annihilation





$$\chi + \overline{\chi} \rightarrow X + \gamma$$ (GLAST)

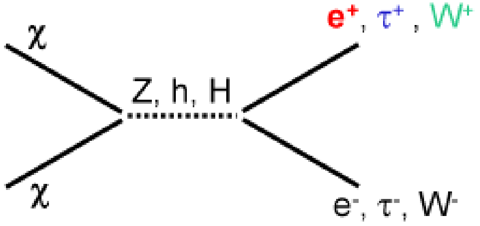
$$+\nu$$ (AMANDA / IceCube)

$$+\overline{p}$$

$$+e^{+}$$

$$+\overline{D}$$

PAMELA
(and Bess,
HEAT, AMS etc.)



Production takes place everywhere in the halo!!

Measurement of primary and secondary CR elements

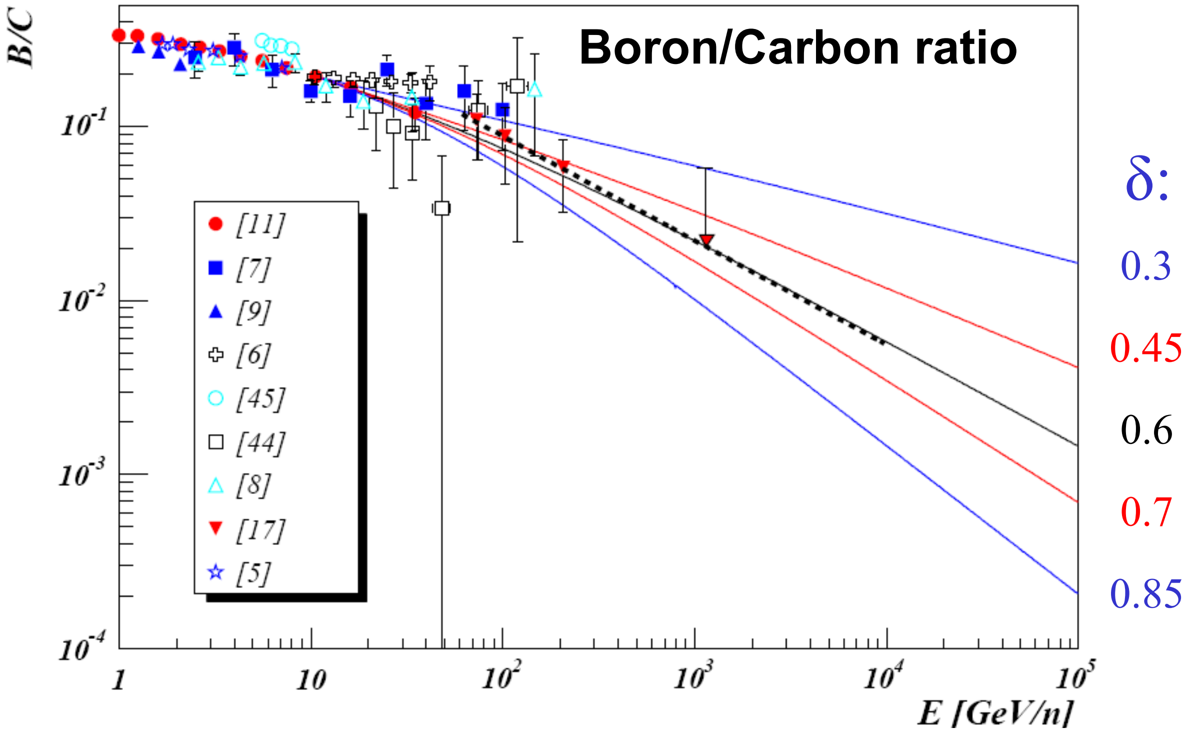
A really CRITICAL point !

The possibility to disentangle exotic signal from pure secondary production depends strongly on the precise knowledge of the parameters which regulate the diffusion of cosmic rays in the Galaxy.

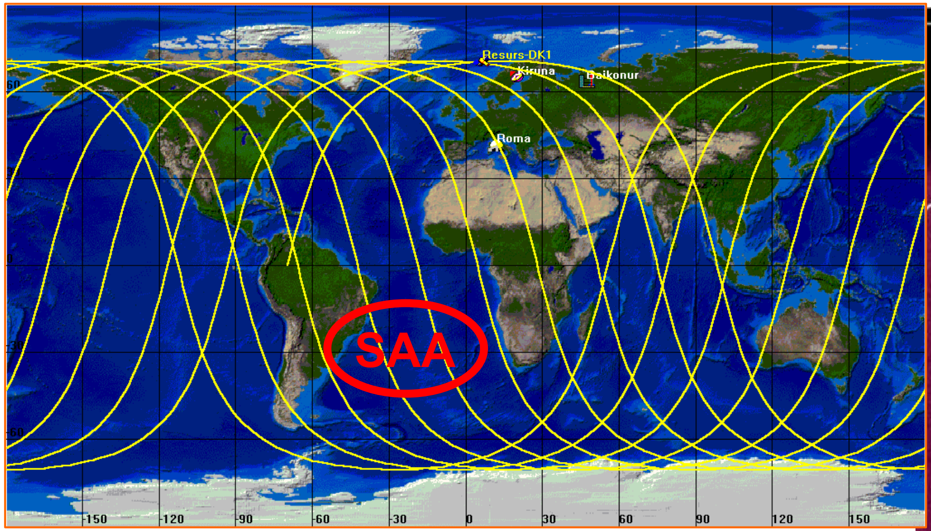
DIFFERENT diffusion coeff.:

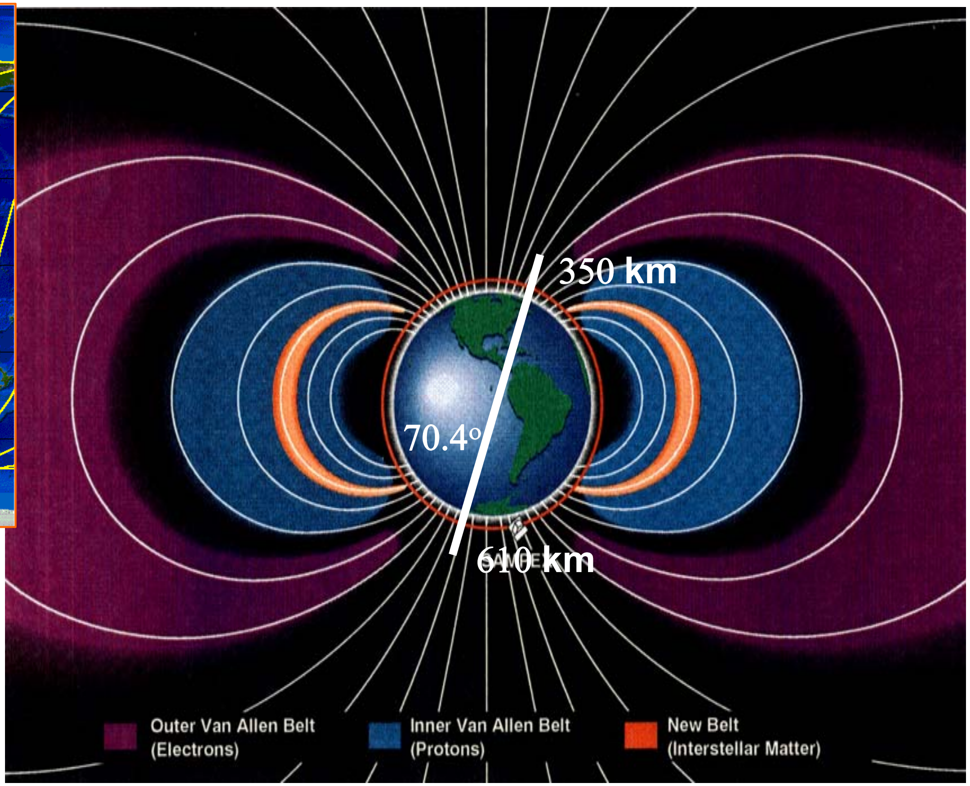
$$K(E) = K_0 R^{\delta}$$

Magnetic rigidity $R = \dfrac{pc}{ze}$



Orbit characteristics





Quasi-polar (70.0°)

Elliptical (350÷600 km)

In the South Pole PAMELA crosses the electron Van Allen belt, and for some orbits the SAA (*South Atlantic Anomaly*)

Trigger & DataRate

TOF Scintillator Coincidence

S1 x S2 x S3 out of Belts and SAA

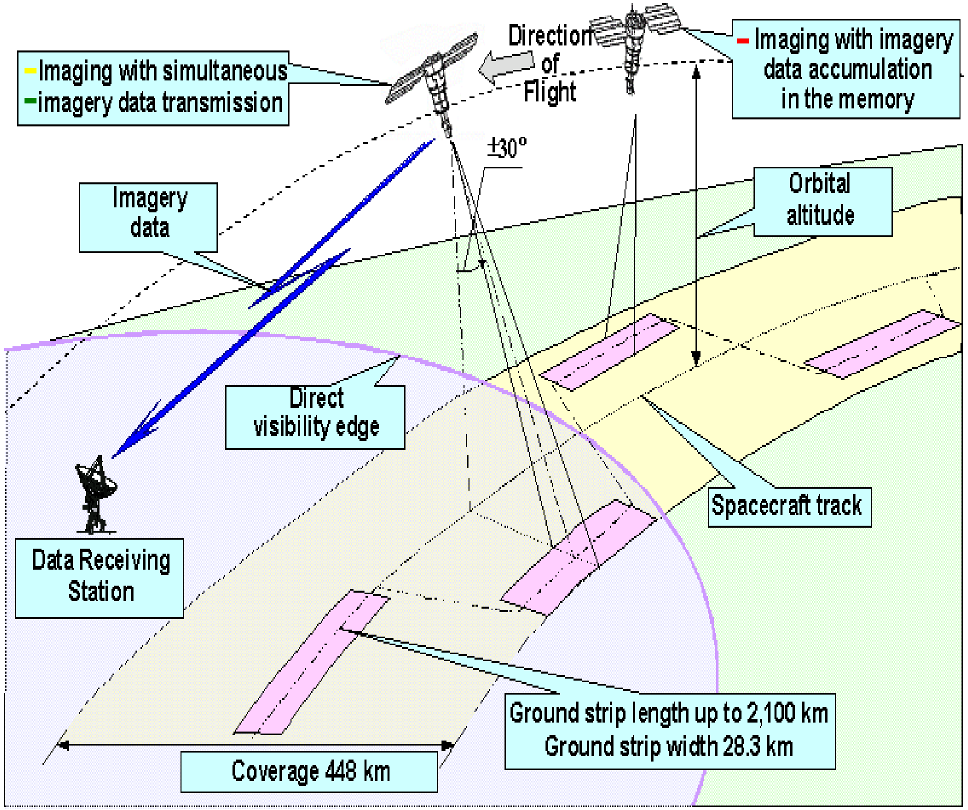
S2 x S3 elsewhere

Average trigger rate 25 Hz (for orbits with SAA).

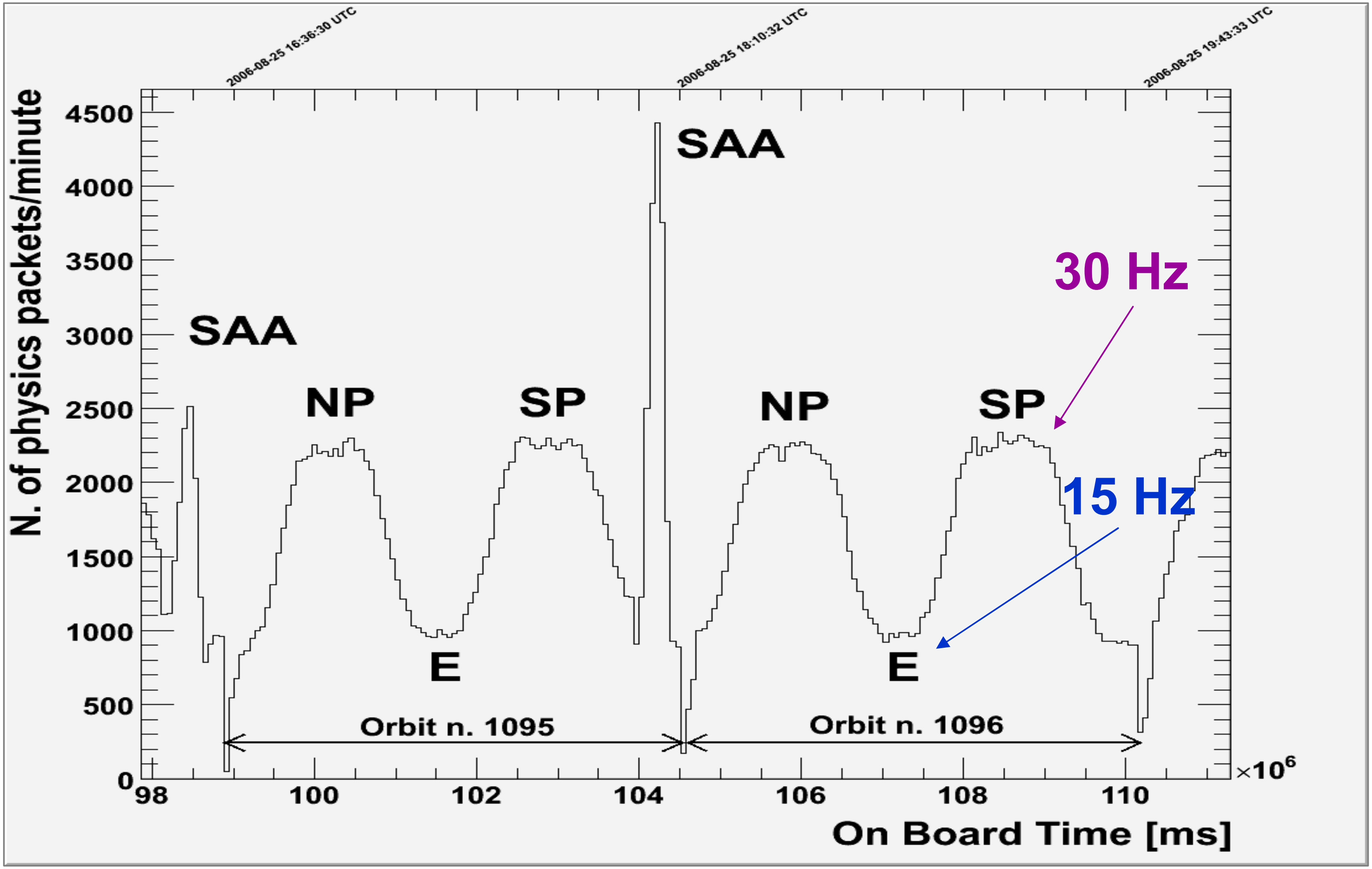
DownLink

25 Hz x 5kB/evt ~ 10 GB/day (compressed mode)

Up to 20 GB daily accumulation + downlink in a few ground-connections

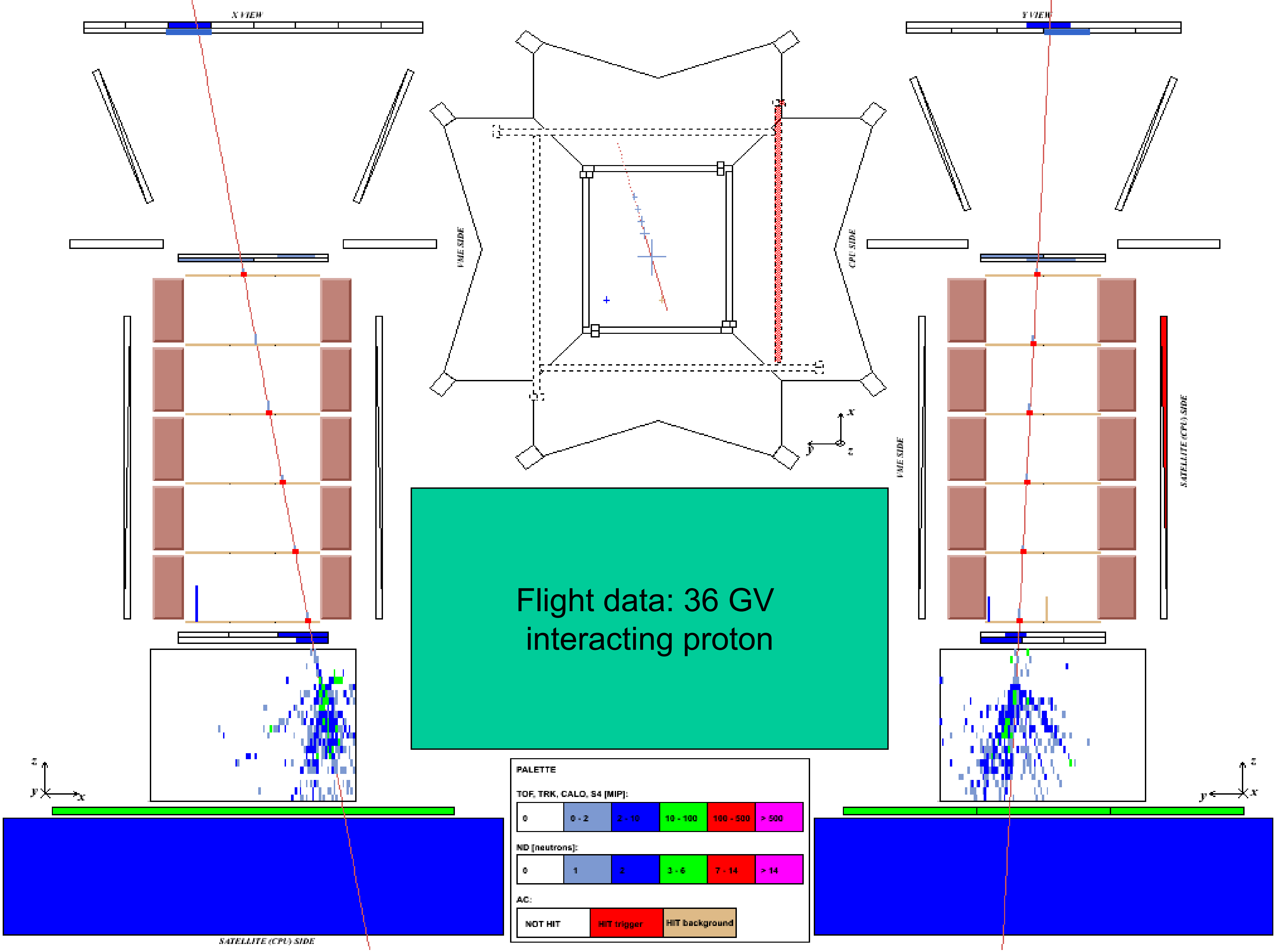


Physics packets rate

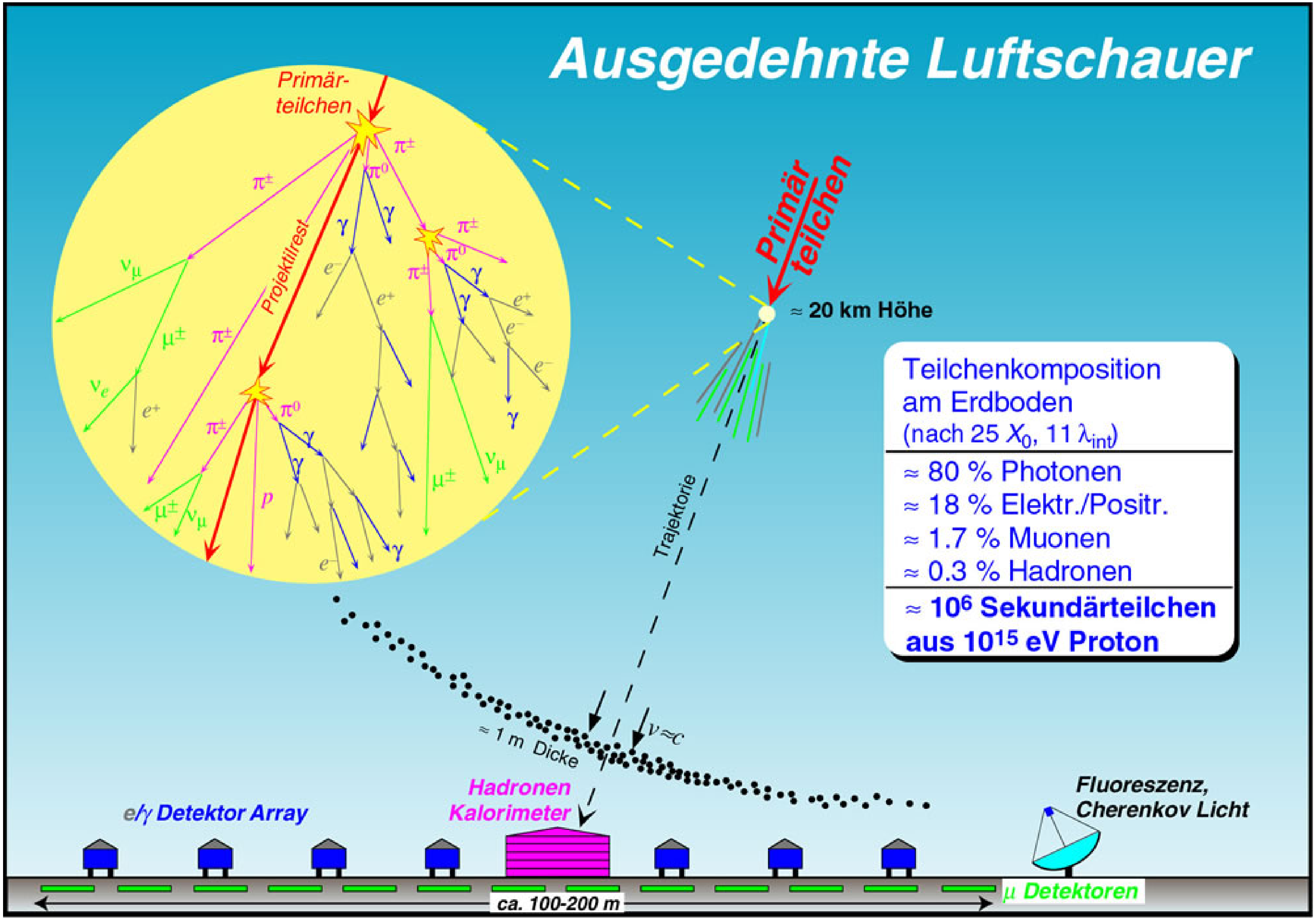


Data rate consistent with the position along the orbit

Flight data: 36 GV interacting proton



Extended AirShowers (EAS): Detection



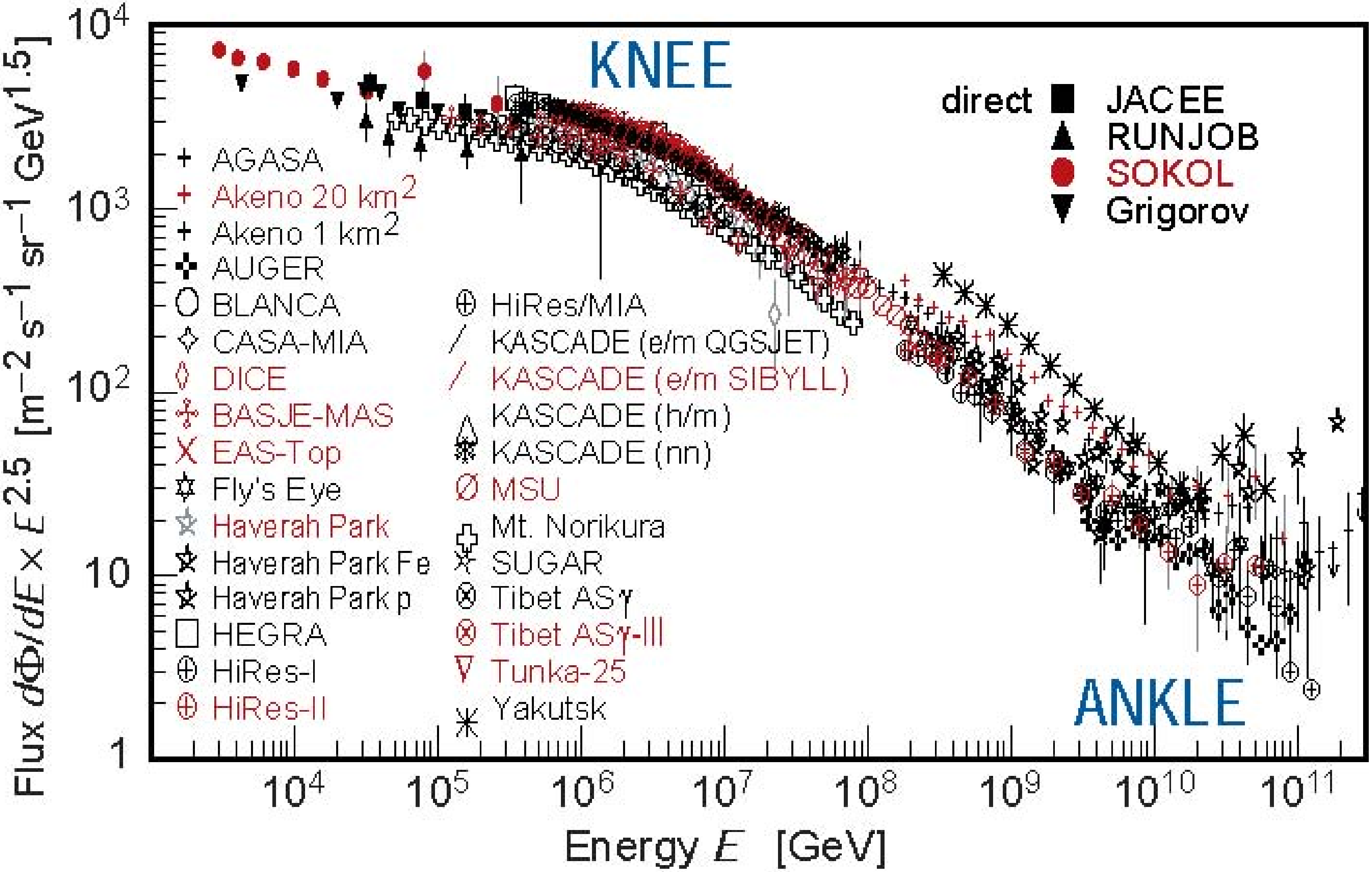
Ausgedehnte Luftschauer

Teilchenkomposition am Erdboden (nach 25 X_0, 11 λ_{int})

- ≈ 80 % Photonen
- ≈ 18 % Elektr./Positr.
- ≈ 1.7 % Muonen
- ≈ 0.3 % Hadronen

≈ 10^6 Sekundärteilchen aus 10^{15} eV Proton

Extended AirShowers (EAS): Results

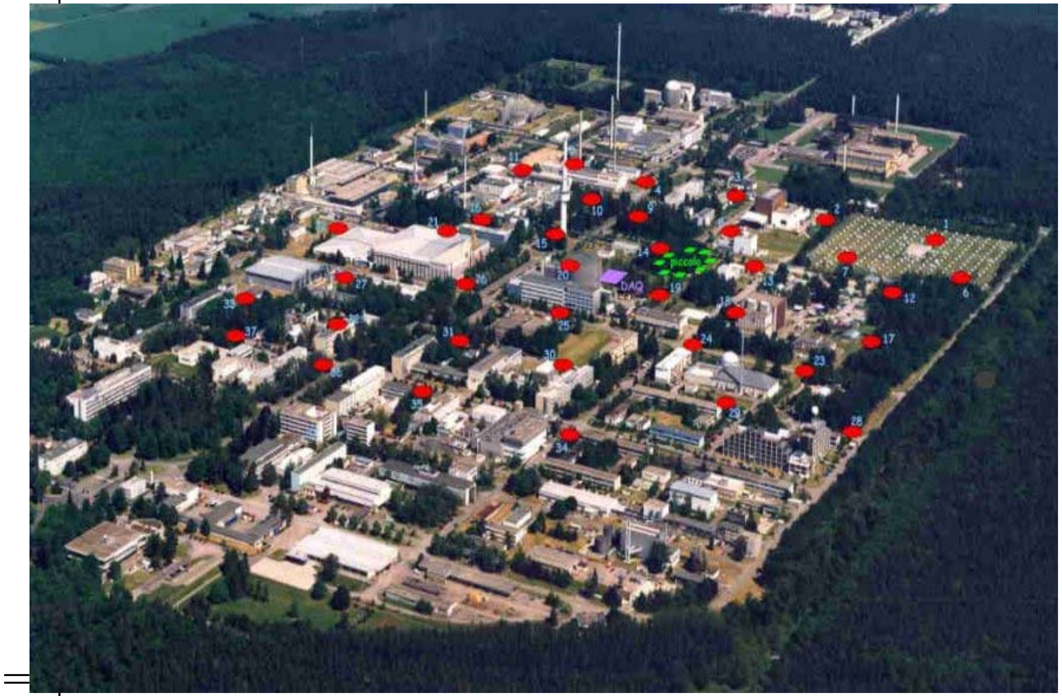


Scintillator Arrays I: KASCADE(-GRANDE)

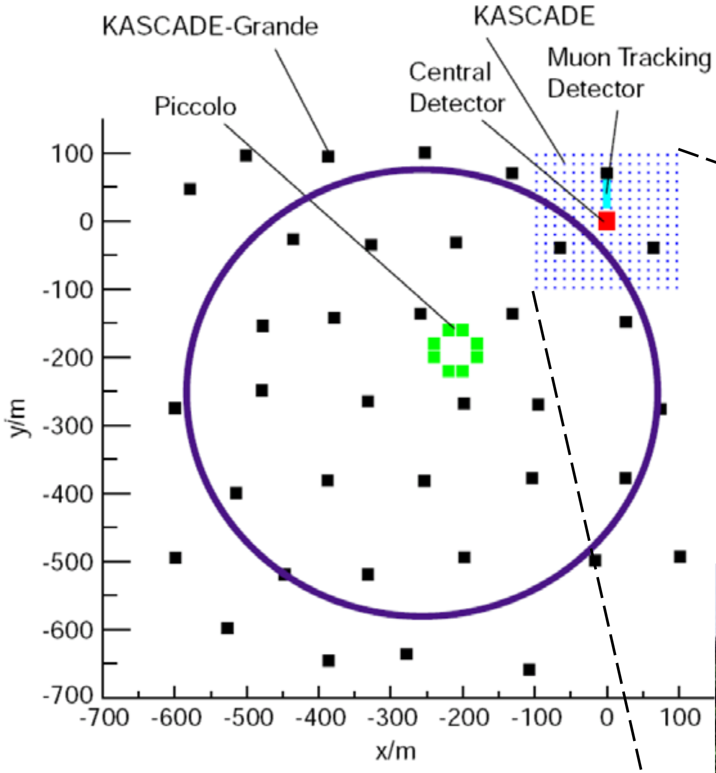
Complex array consisting of:

KASCADE-array:
- hadron calorimeter
- e/μ scintillator array
- muon tracking chamber

GRANDE-array:
- scintillator array:
  - 0.5 m^2
  - 37 stations x 10 m^2 = 370 m^2
- piccolo trigger array

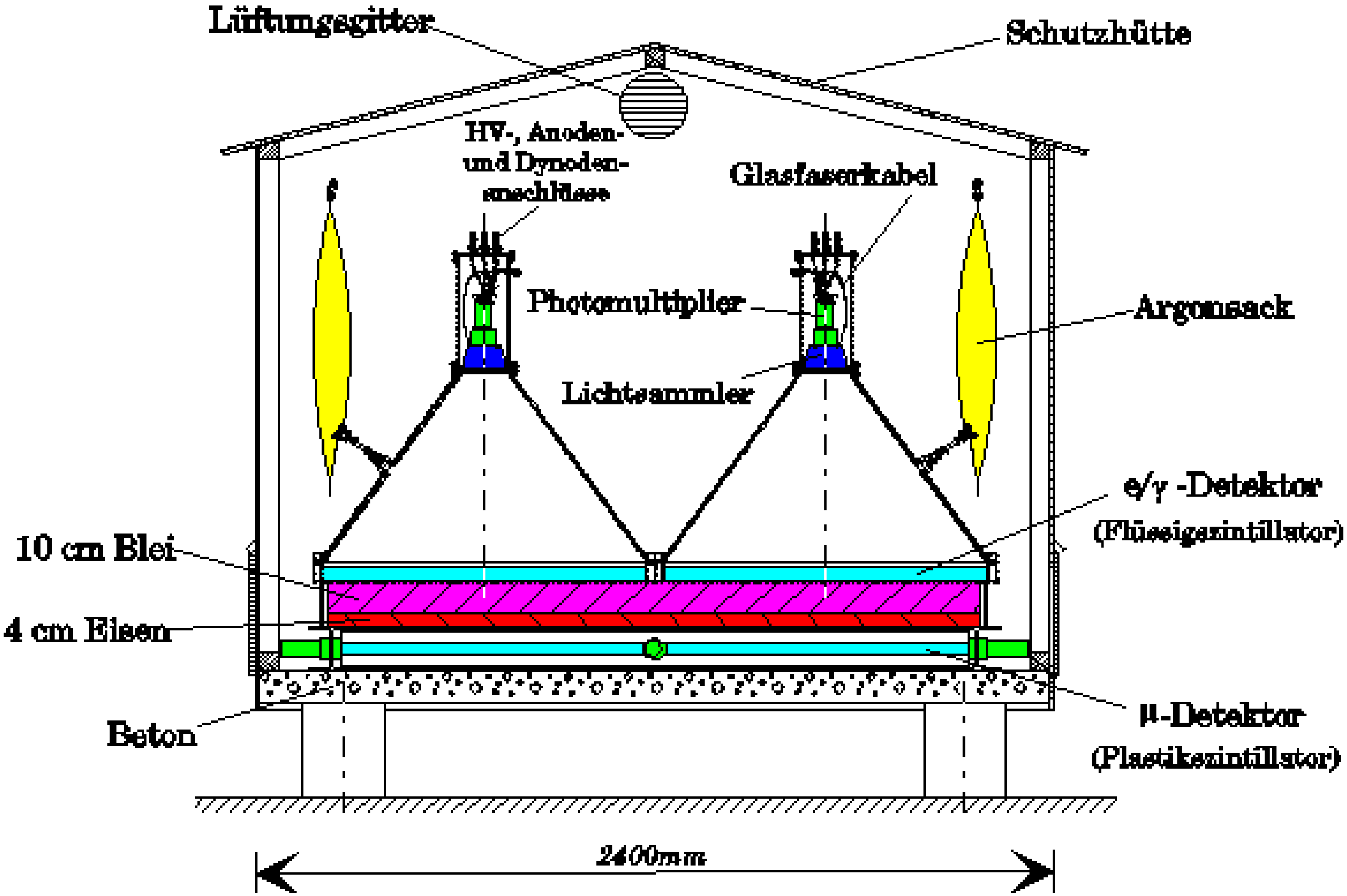


KASCADE-array



- KASCADE
  - Station distance: 13 m
  - Array size: 200 x 200 m^2
- GRANDE
  - Station distance: 130 m
  - Array size: 0.5 km^2

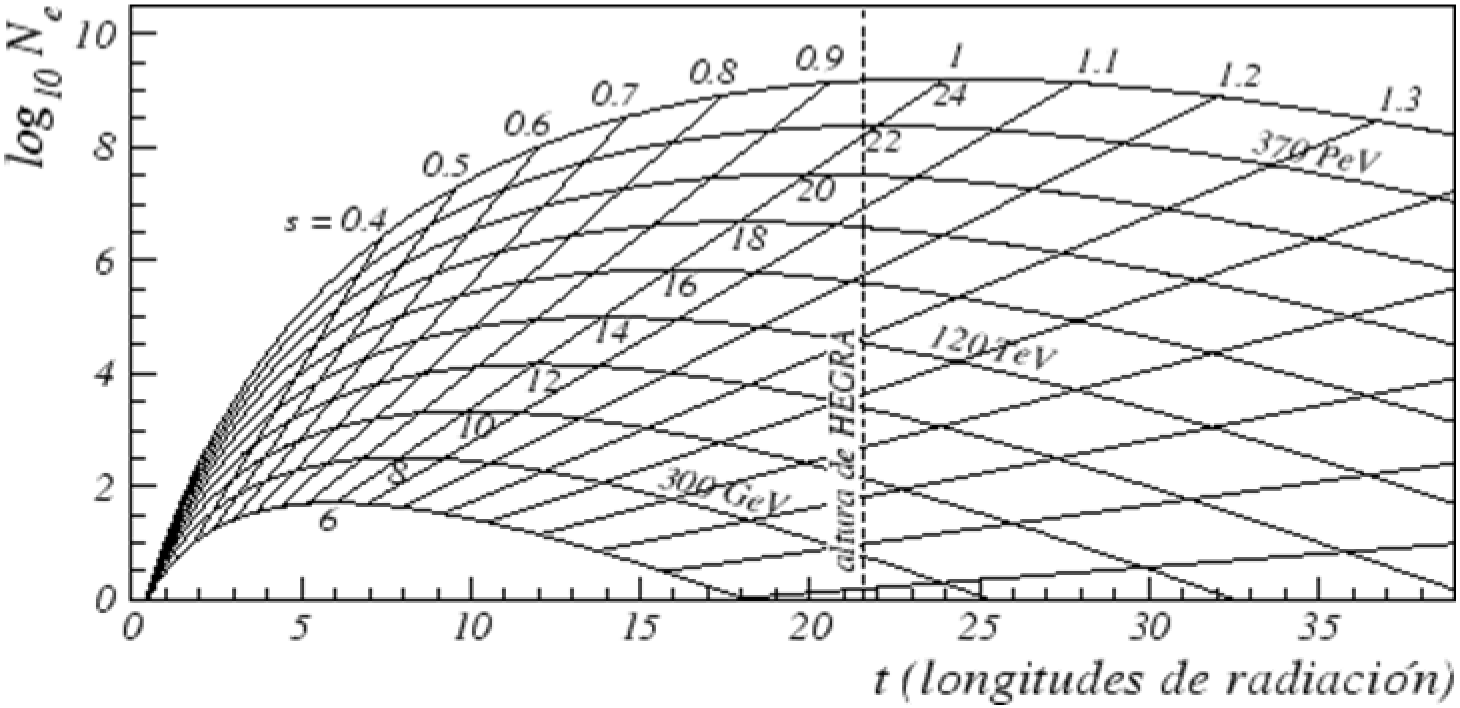
KASCADE-array: Detectors



Longitudinal Profiles - Energies

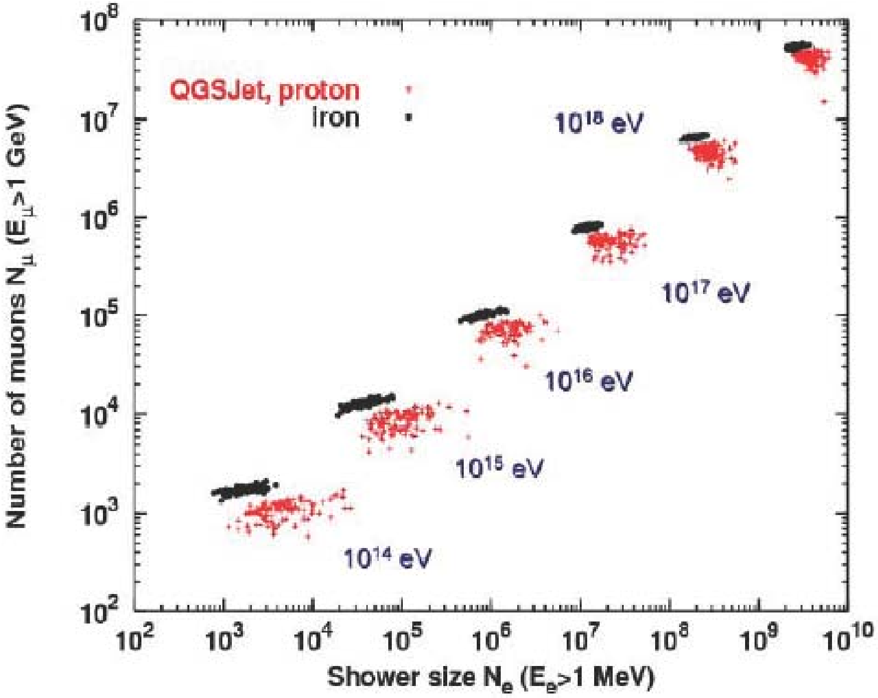
Shower Maximum:

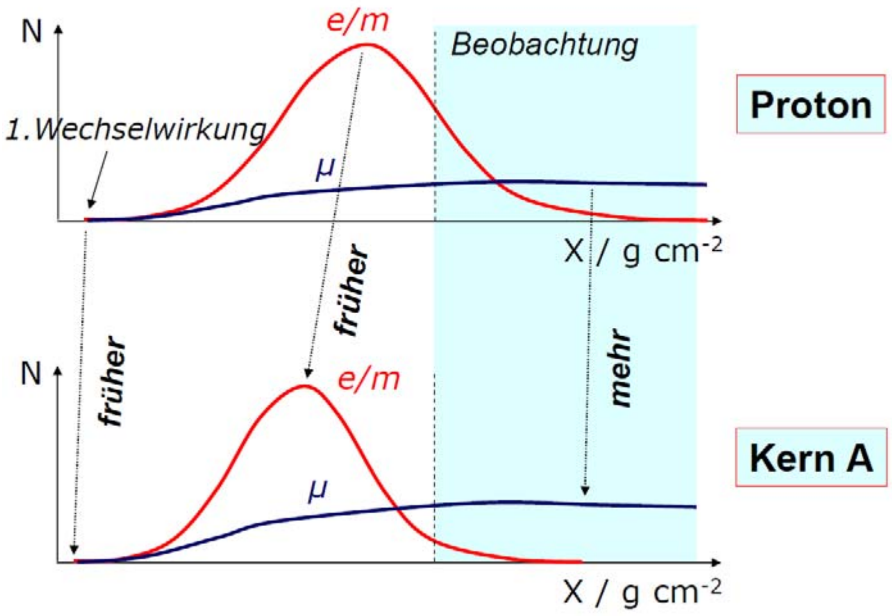
$$X_{max} \sim \ln(E_0)$$



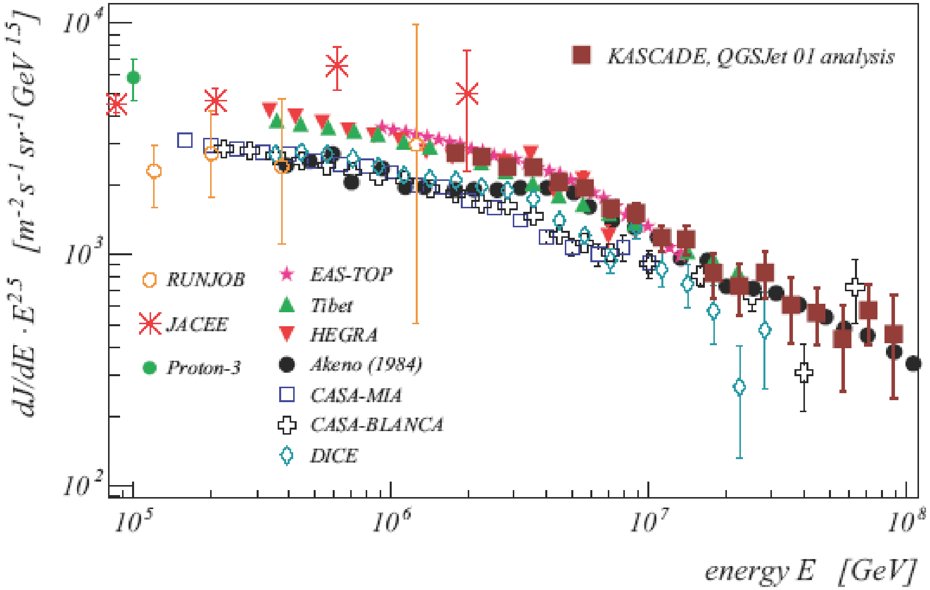
Longitudinal Profiles – e/μ-ratio

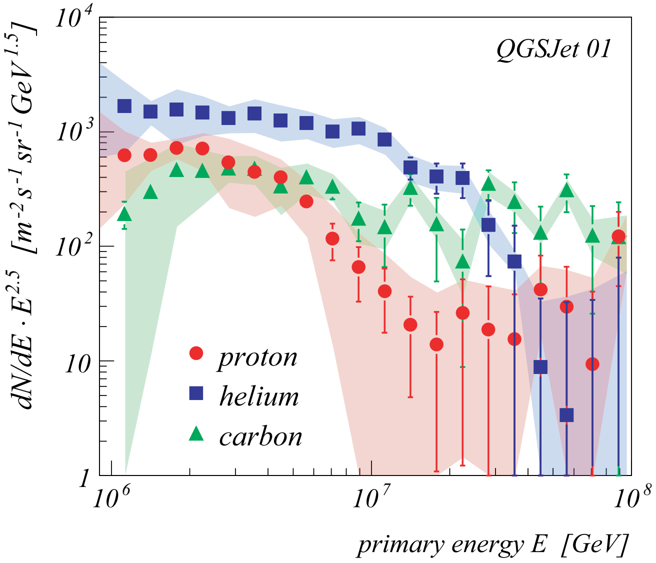
On ground level, Fe showers are older than p showers → weaker em. component → e/μ-ratio lower





KASCADE: Results



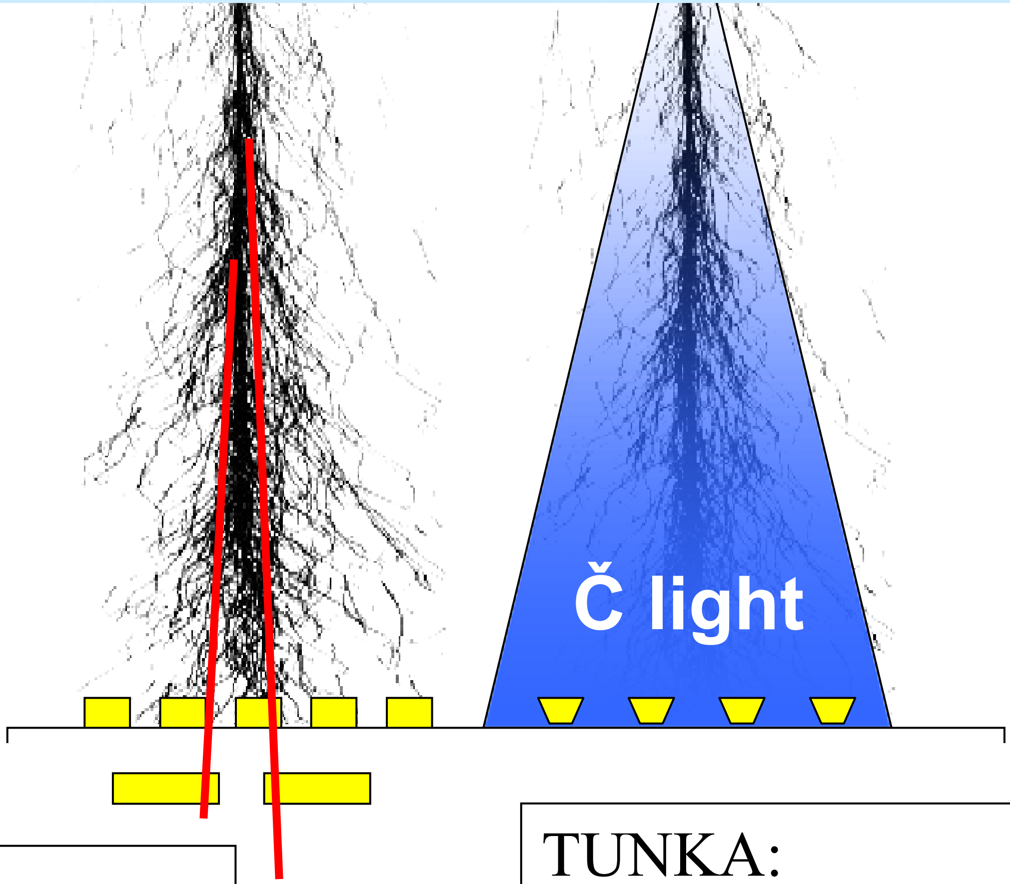


integral knee: index change from -2.7 to -3.1 at (3.96 ± 0.84) PeV

knee positions: $E_p < E_{He} < E_C < E_{Fe}$

(Plots & Values: H. Ulrich, Kascade Collaboration)

Cherenkov Counter Arrays: TUNKA



KASCADE:

CR Composition from e/μ fraction

TUNKA:

CR Composition from depth of shower maximum determination

TUNKA: Array

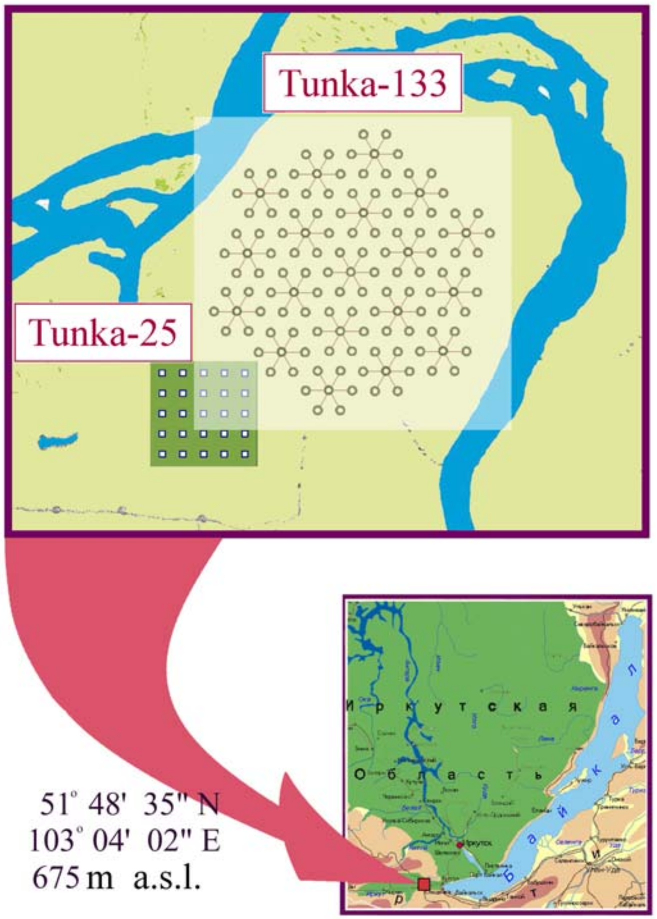
Tunka Valley, Lake Baikal, RUS

TUNKA-25:

- 0.11 km^2
- 25 stations
- 6 x $10^{14} < E < 10^{17}$ eV

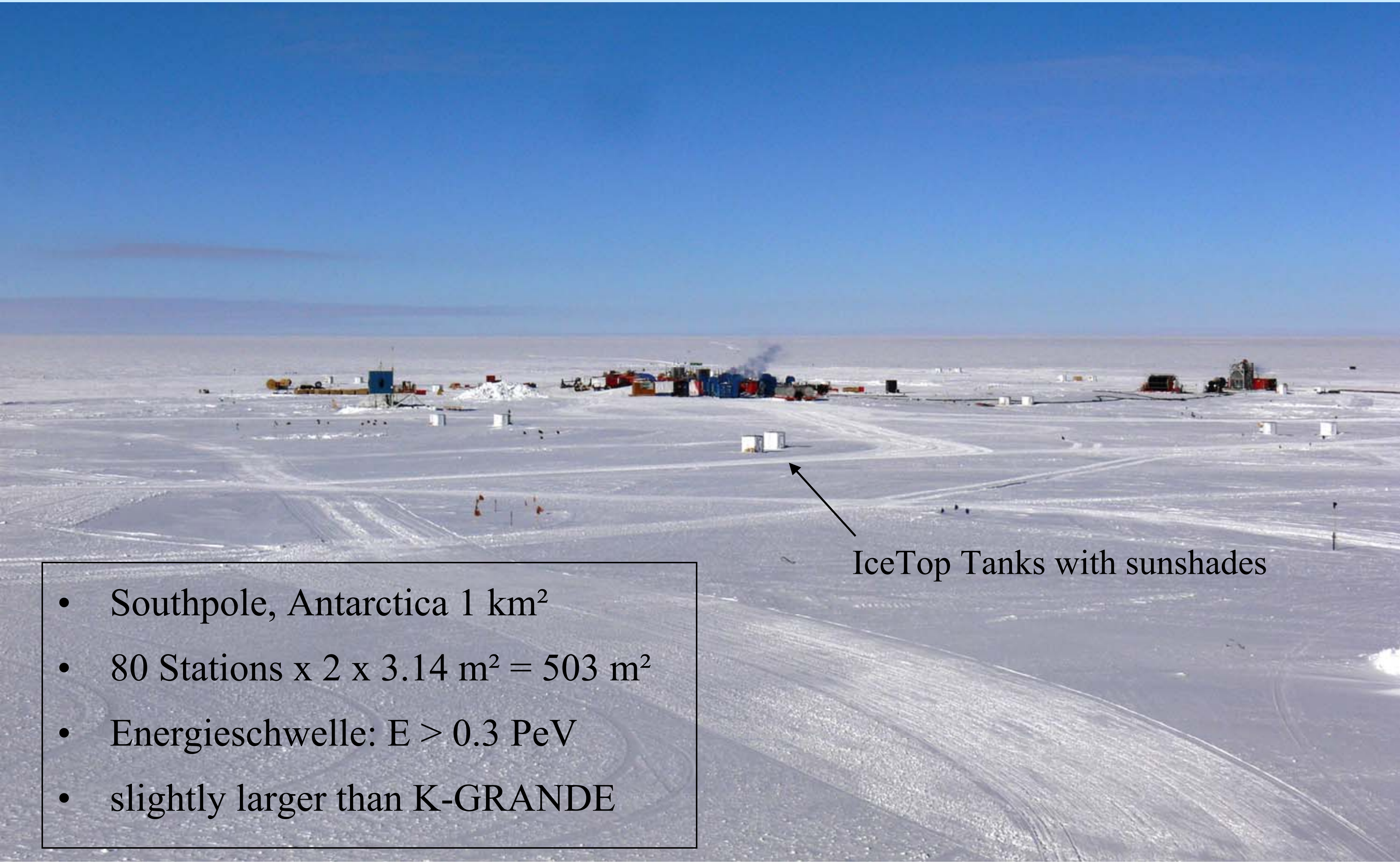
TUNKA-133:

- 1 km^2
- 133 (bigger) stations
- 6 x $10^{14} < E < 10^{18}$ eV



51° 48' 35" N
103° 04' 02" E
675 m a.s.l.

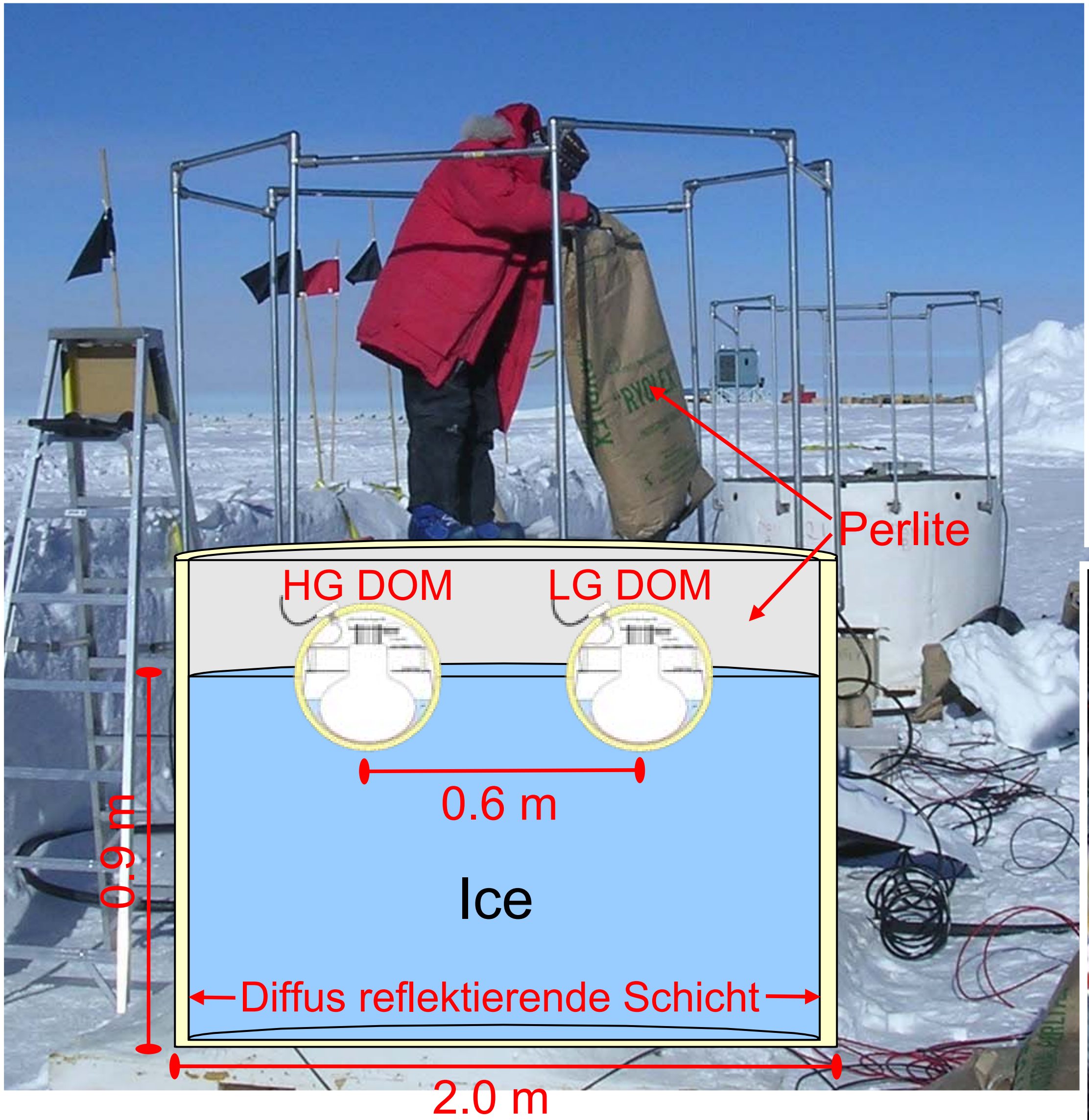
Cherenkov Tank arrays: IceTop

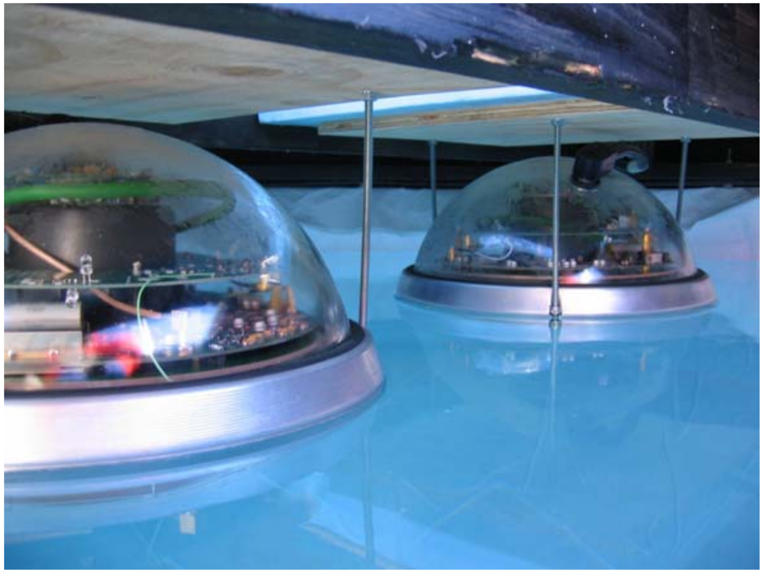


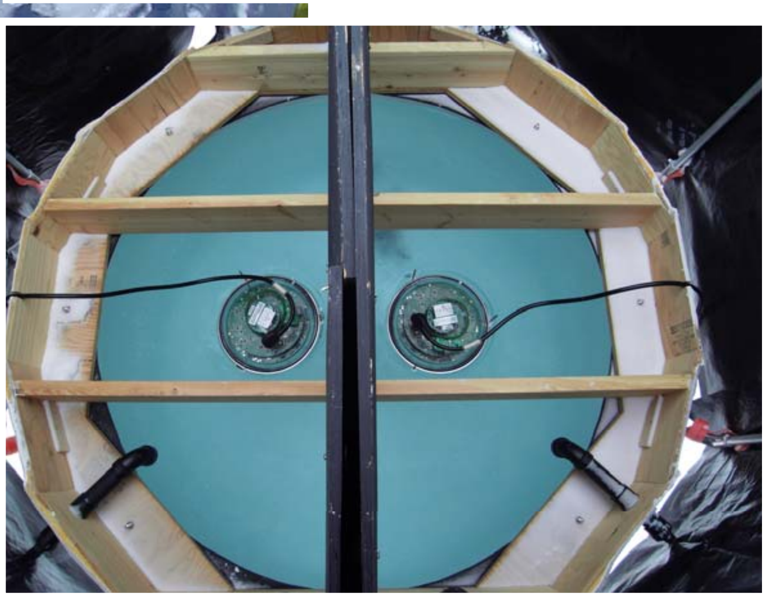
IceTop Tanks with sunshades

- Southpole, Antarctica 1 km²
- 80 Stations x 2 x 3.14 m² = 503 m²
- Energieschwelle: E > 0.3 PeV
- slightly larger than K-GRANDE

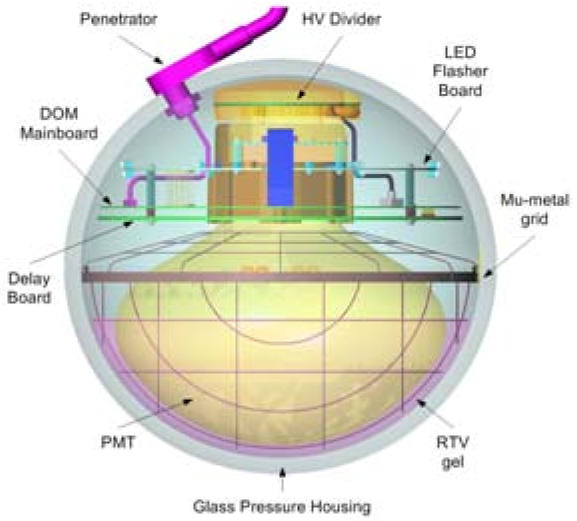
IceTop Tanks







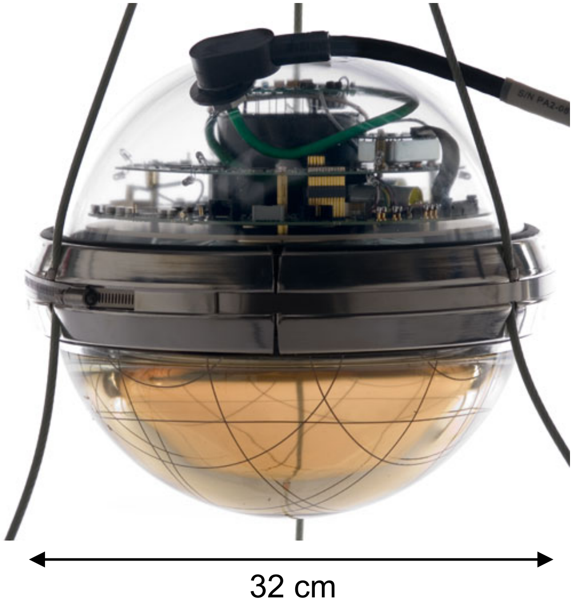
Digitales Optisches Modul



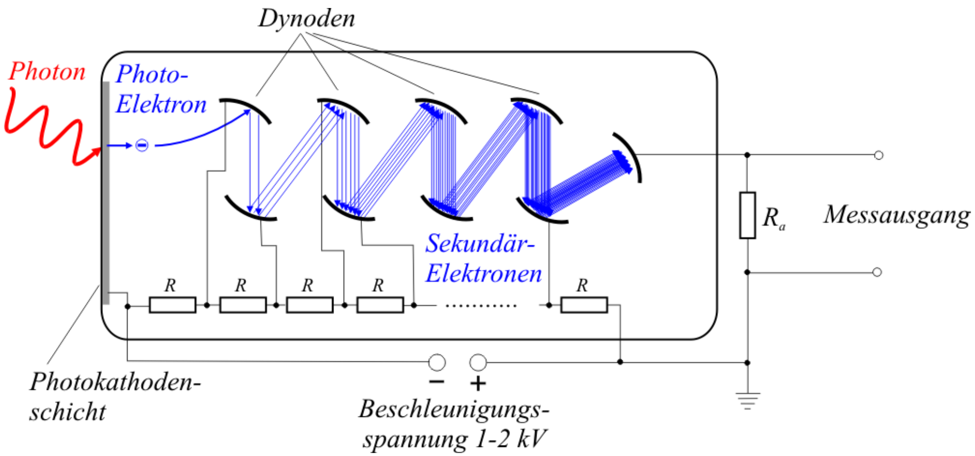
- Minimiere Signalverlust
- Minimiere Anzahl der Auslesekanäle (Kabel)
- Minimiere Datenaufkommen

→ PMT mit integrierter HV-Versorgung
→ Digitalisierung
→ Lokale Koinzidenz mit Nachbarn
→ Kalibrierung und Tests
→ Autonome Steuerung

} **DOM**

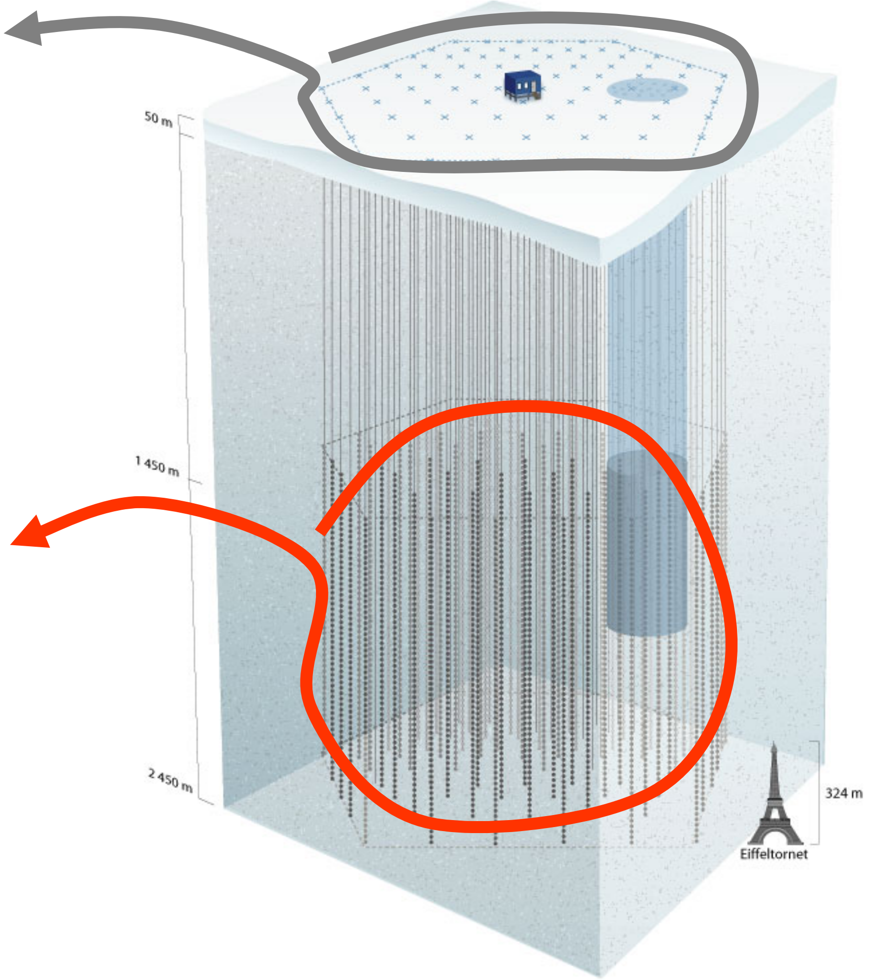


Funktionsweise eines Photomultipliers (PMT):



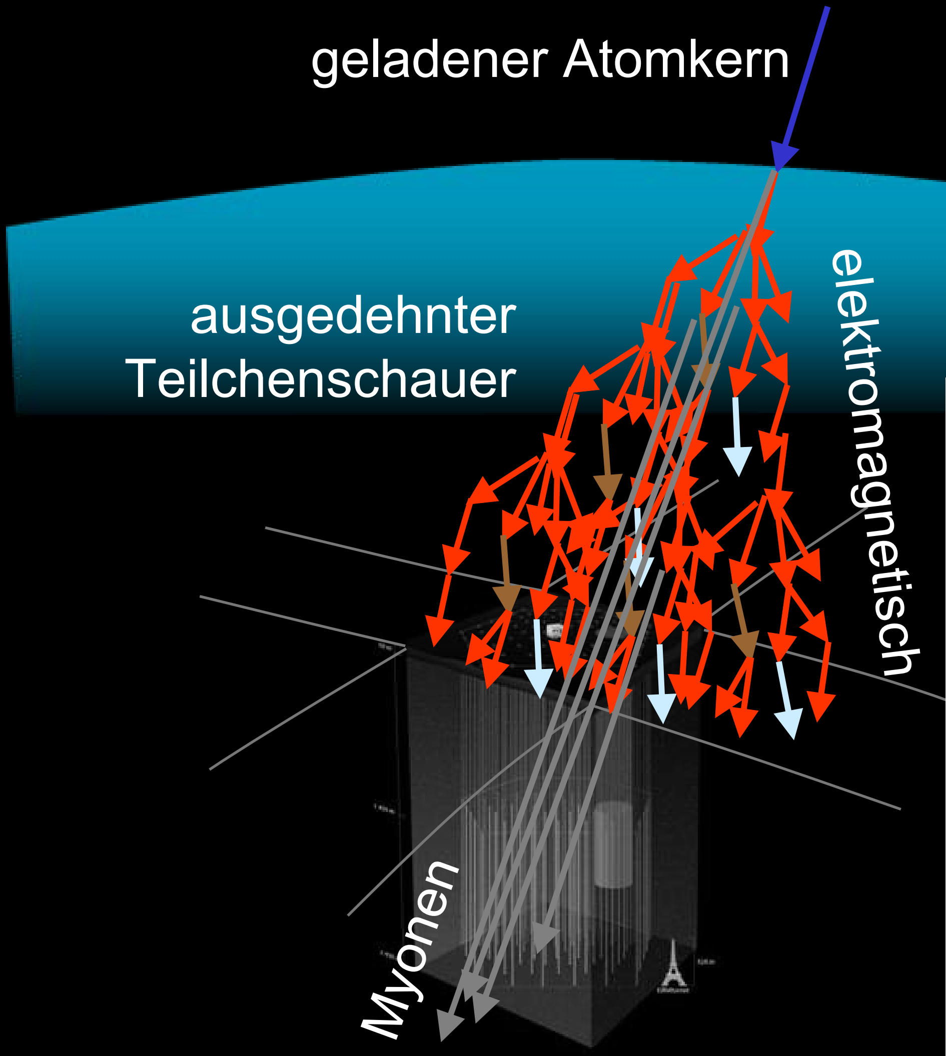
Neutrinoteleskop IceCube

‚IceTop‘:
320 optische Sensoren
... in 160 Eistanks
...auf **1 km² Fläche**

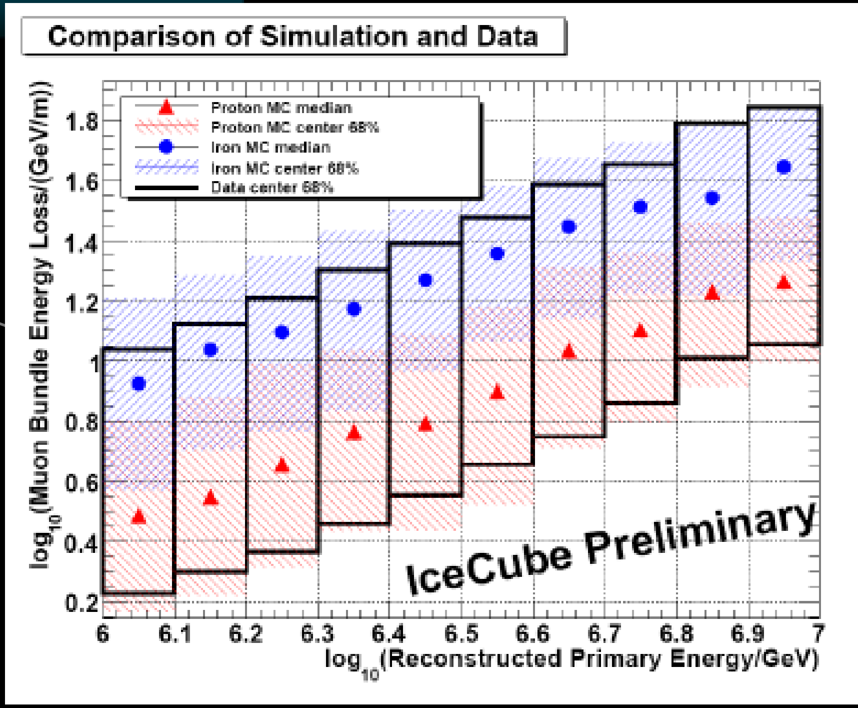


4800 optische Sensoren
... an 80 Trossen
...in **1 km³ Eis**

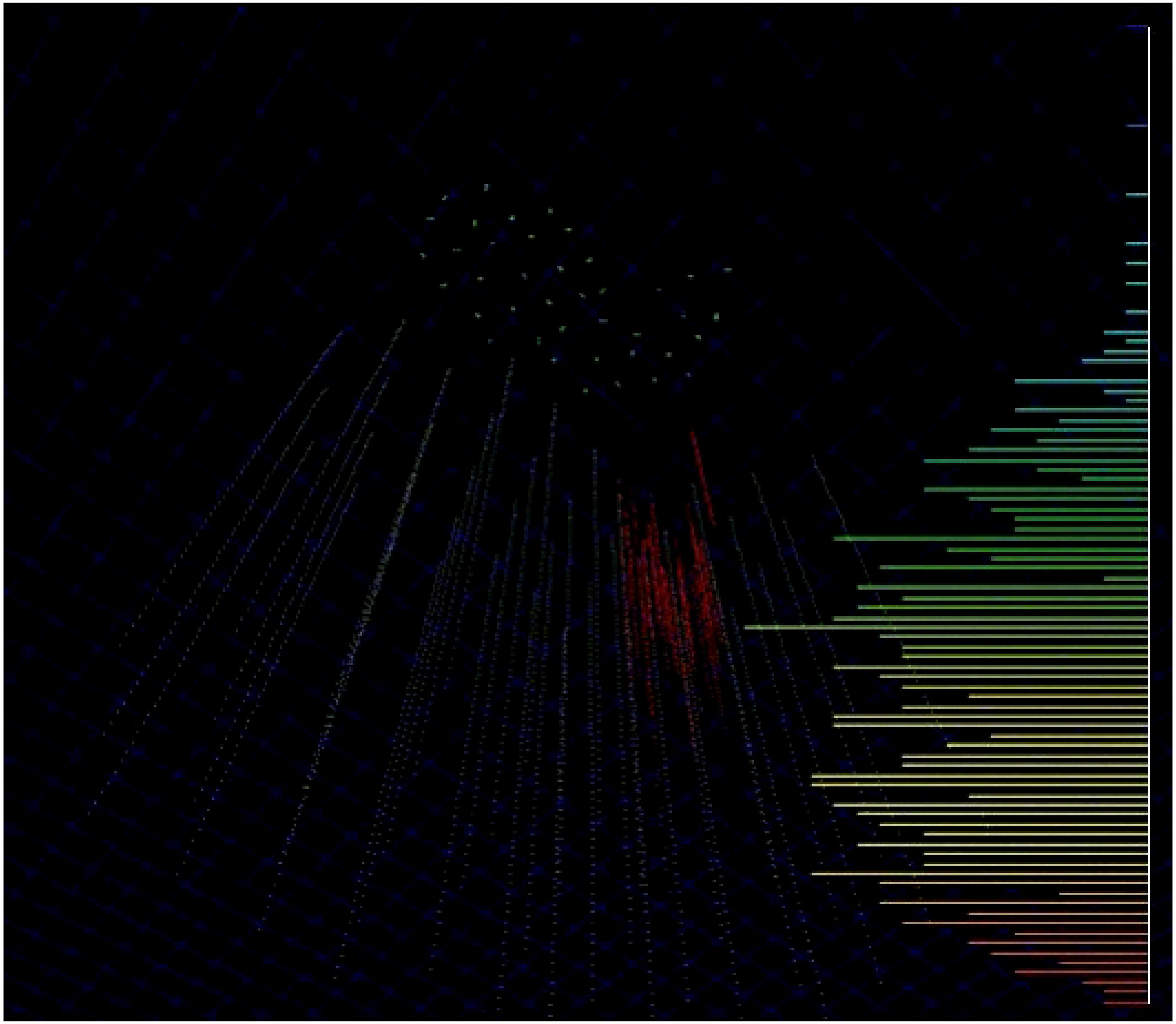
Luftschauer, Atomkerne und Myonbündel



→ Signatur:
Licht in mehreren IceTop-Tanks und/oder eine lange, sehr helle Lichtspur im Eis



Koinzidentes Ereignis



HiRes: Telescopes

HiRes-1:

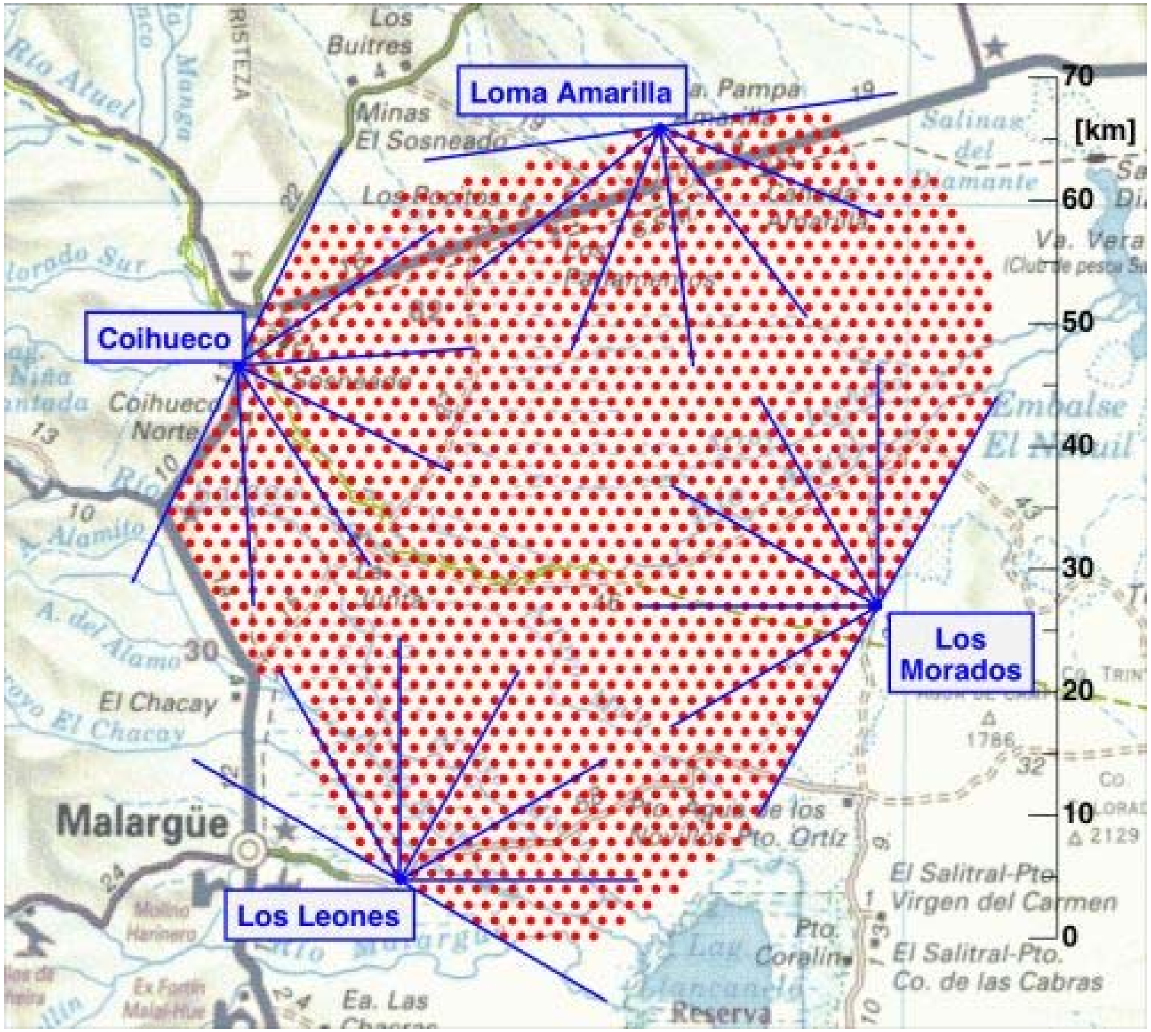
- $10^{18.5} - 10^{20.5}$ eV
- 21 mirrors
- 3° - 17° elevation
- 5 m^2 mirrors
- 256 pixel camera

HiRes-2:

- $10^{17.2} - 10^{20}$ eV
- 42 mirrors (2 rows)
- 3° - 31° elevation

Auger Observatory

Surface Array + Fluorescence Telescopes



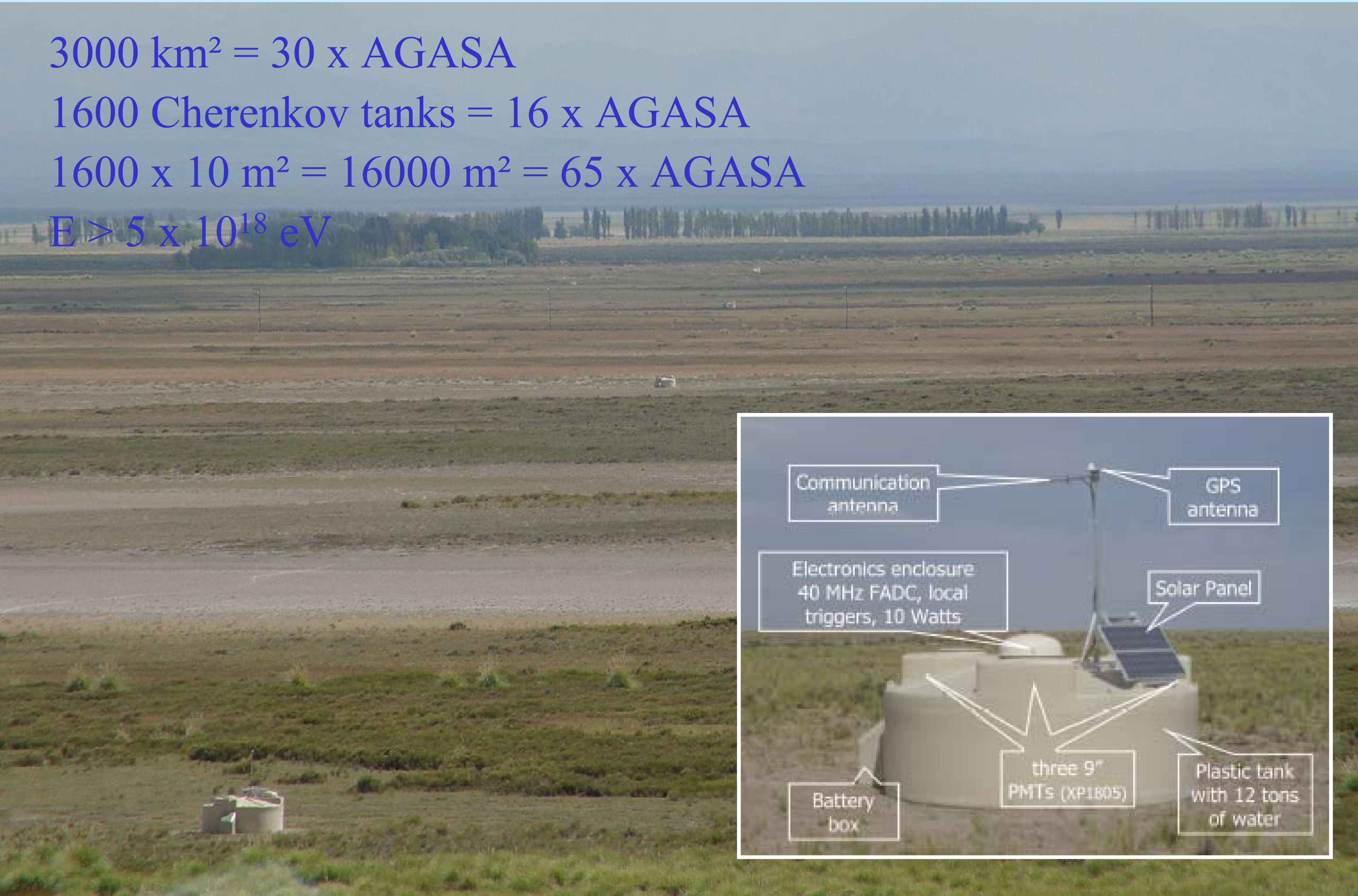
AUGER: Surface Detector

3000 km² = 30 x AGASA

1600 Cherenkov tanks = 16 x AGASA

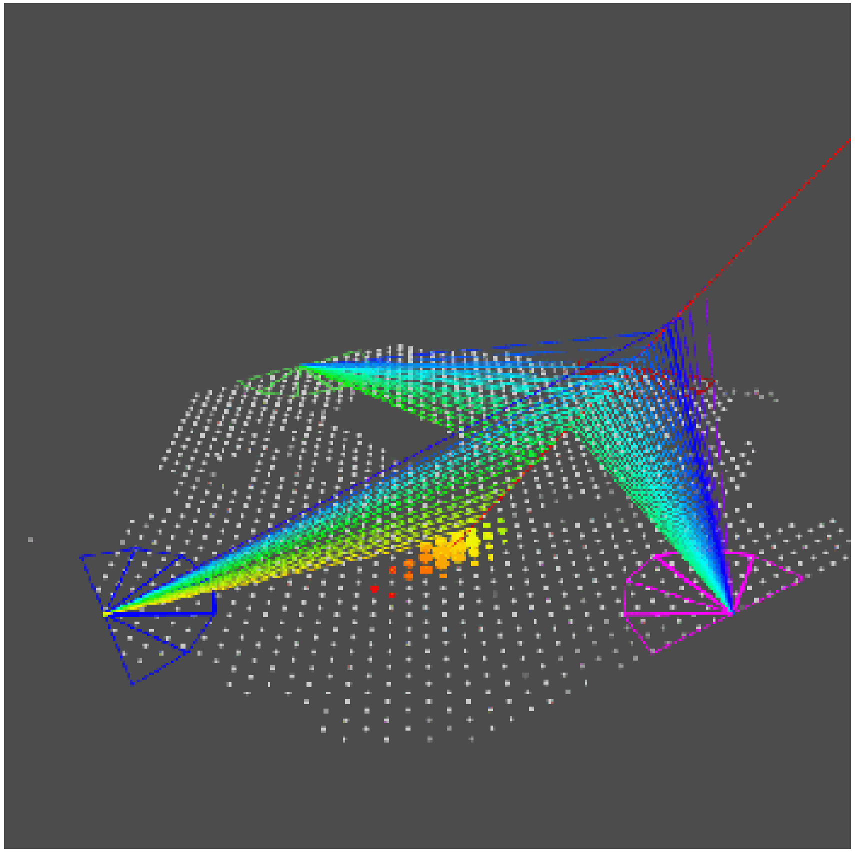
1600 x 10 m² = 16000 m² = 65 x AGASA

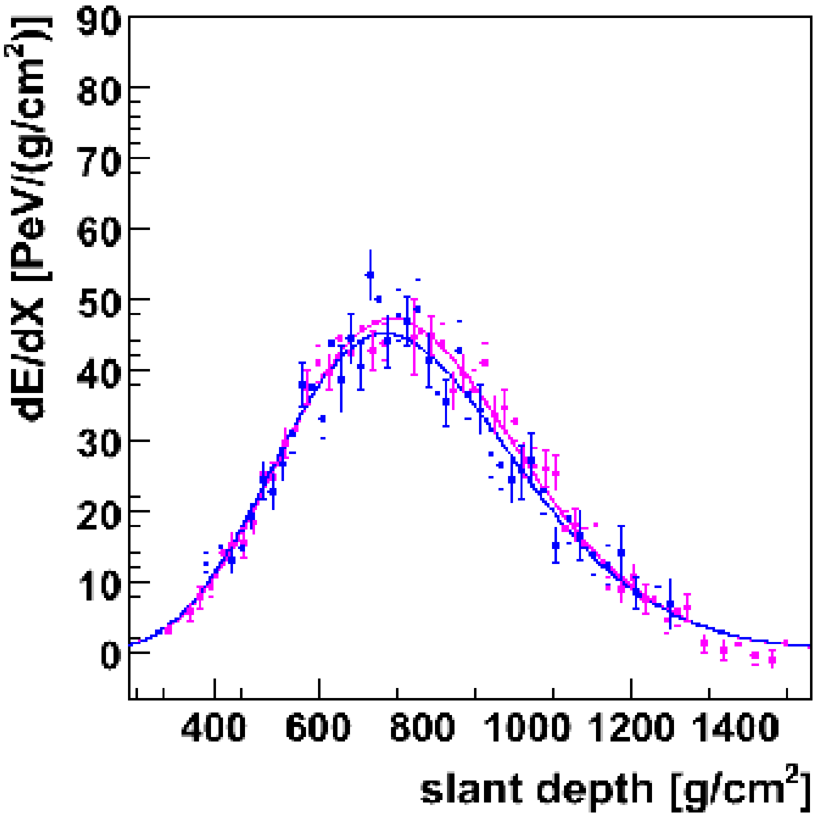
E > 5 x 10^{18} eV



Auger Fluorescence Telescopes

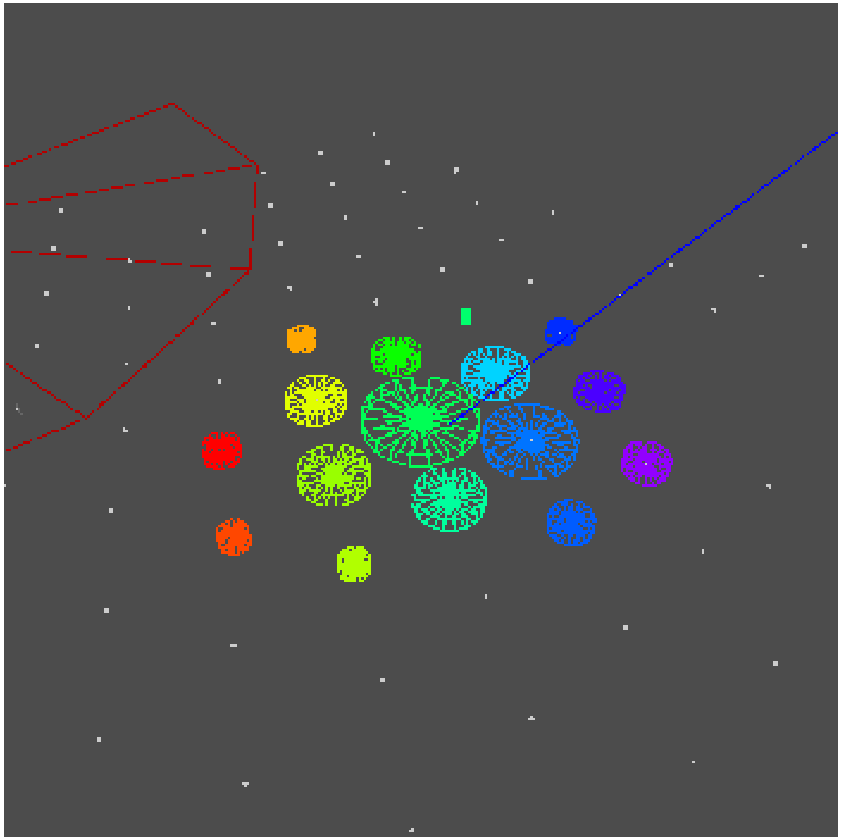
Fluorescence Reconstruction

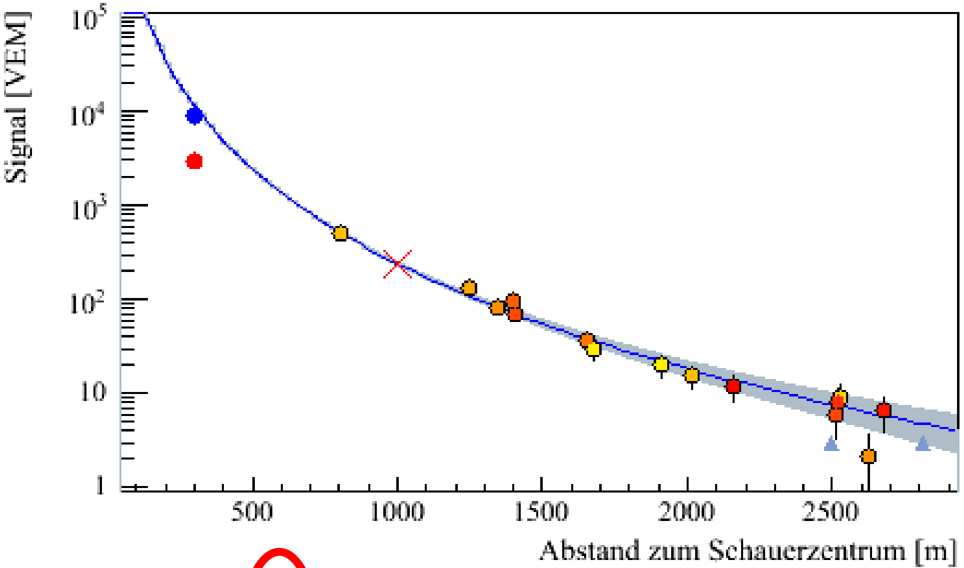


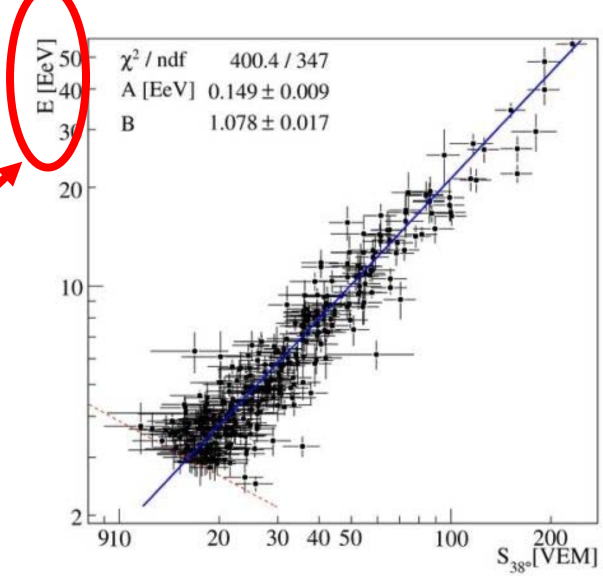


$$E_{prim} \propto \int_{X_1}^{\infty} \frac{dE}{dX}\, dX$$

Surface Reconstruction

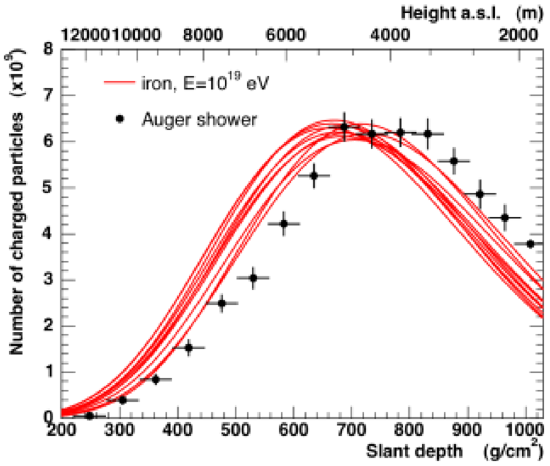


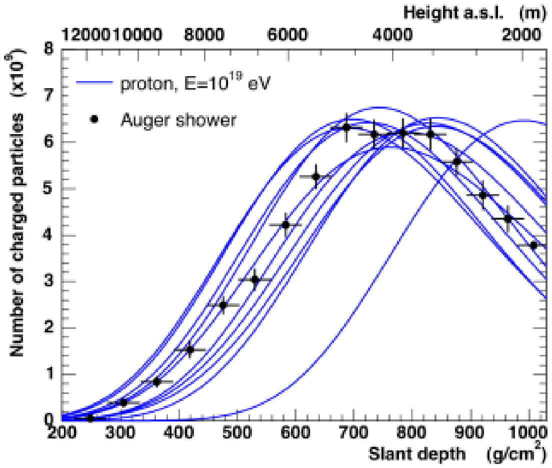




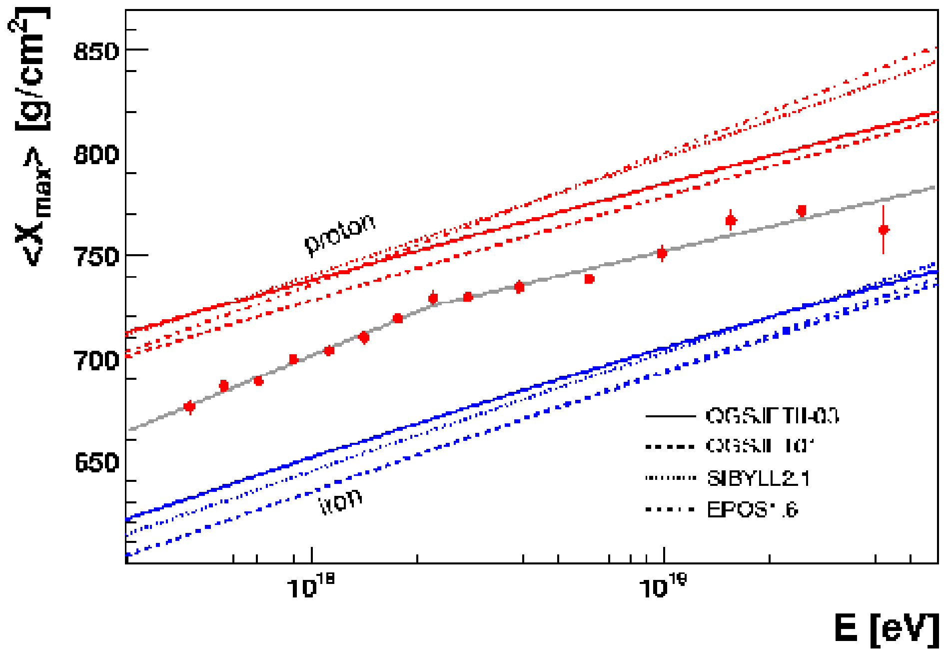
Energy from fluorescence detector

X_{max} and Mass Composition





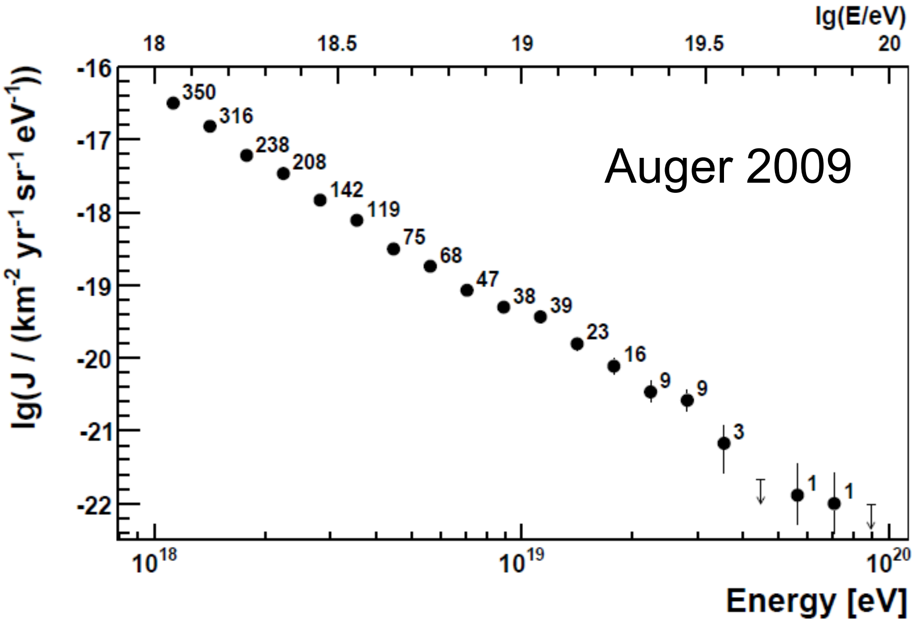
Elongation rate



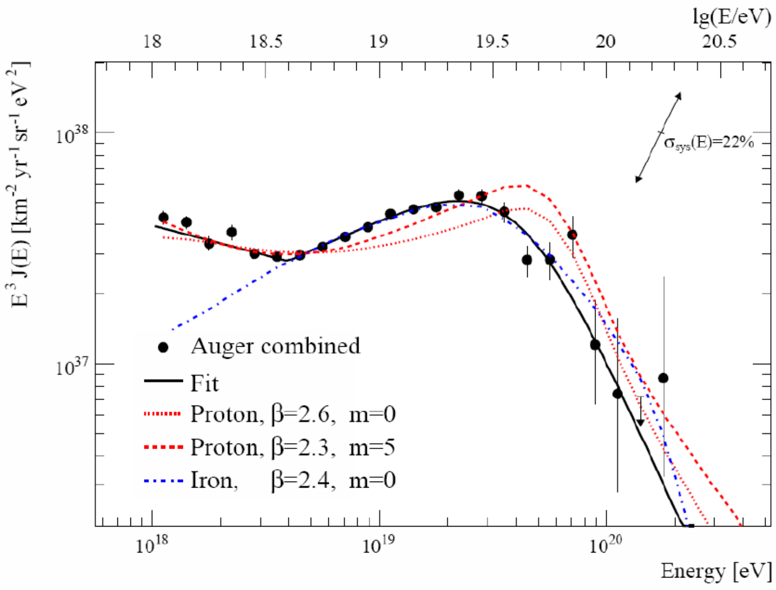
Composition seems the get heavier above 2 x 10^{18} eV

Energy Spectrum

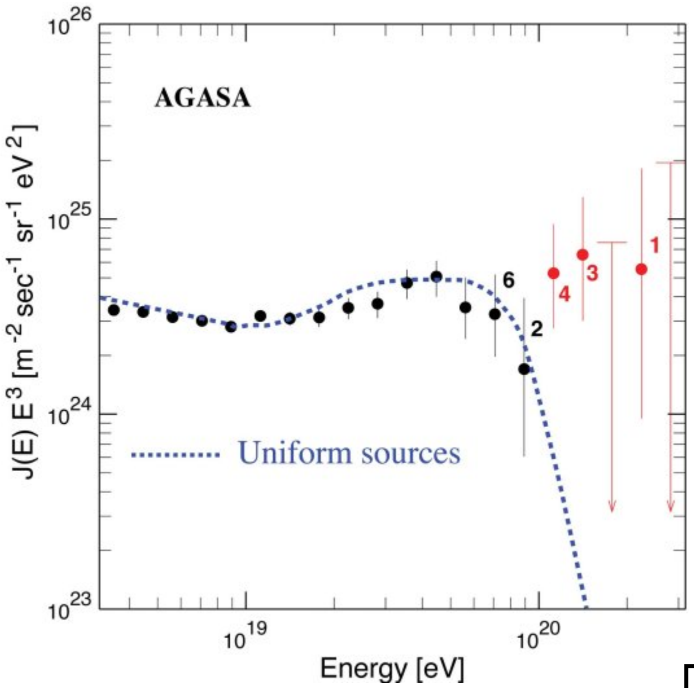
Hybrid Energy Spectrum

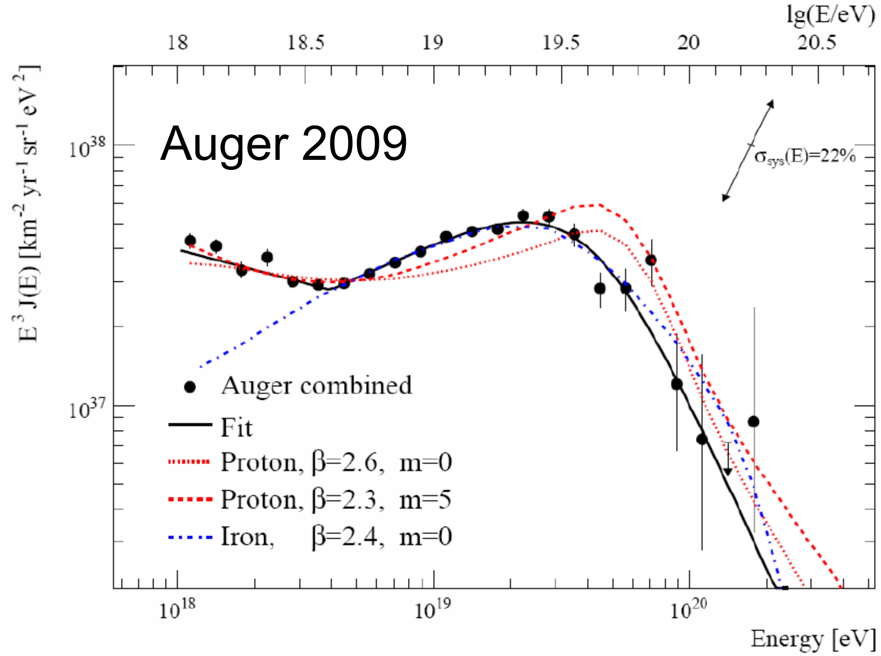


GZK region



UHEAS





Auger and Hires see GZK-Cutoff!

→ Sources of UHECRs are at distances > 50 Mpc

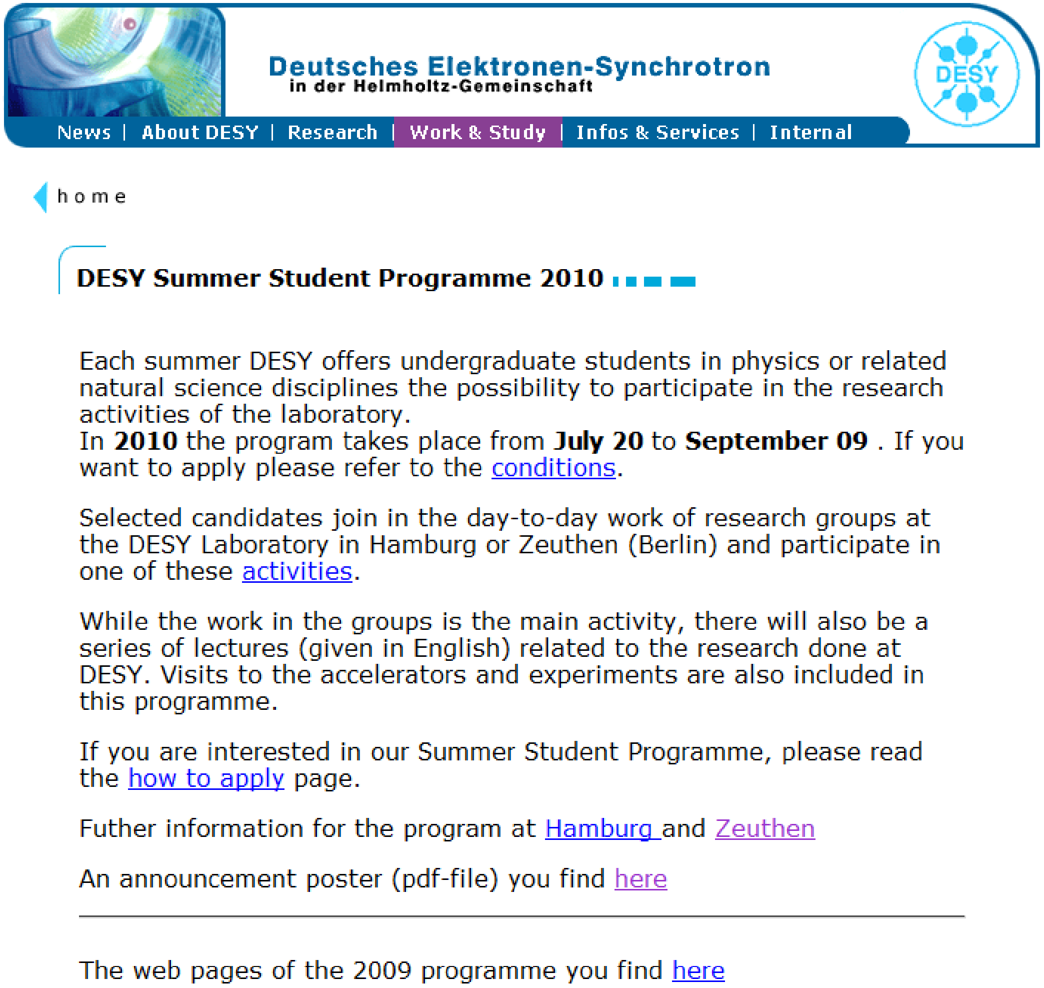
GZK-Effect:

$$p + \gamma \rightarrow \Delta^{+} \rightarrow \begin{array}{l} p + \pi^{0} \\ n + \pi^{+} \end{array}$$

$$(p_p + p_\gamma)^2 \approx M_\Delta^2 \quad \Rightarrow \quad E_p = \frac{M_\Delta^2 - M_p^2}{4\,E_\gamma} \approx 10^{20}\,\mathrm{eV}$$

DESY Summer Students 2010

http://www.desy.de/summerstudents/



DESY Summer Student Programme 2010

Each summer DESY offers undergraduate students in physics or related natural science disciplines the possibility to participate in the research activities of the laboratory.
In **2010** the program takes place from **July 20** to **September 09** . If you want to apply please refer to the conditions.

Selected candidates join in the day-to-day work of research groups at the DESY Laboratory in Hamburg or Zeuthen (Berlin) and participate in one of these activities.

While the work in the groups is the main activity, there will also be a series of lectures (given in English) related to the research done at DESY. Visits to the accelerators and experiments are also included in this programme.

If you are interested in our Summer Student Programme, please read the how to apply page.

Futher information for the program at Hamburg and Zeuthen

An announcement poster (pdf-file) you find here

The web pages of the 2009 programme you find here