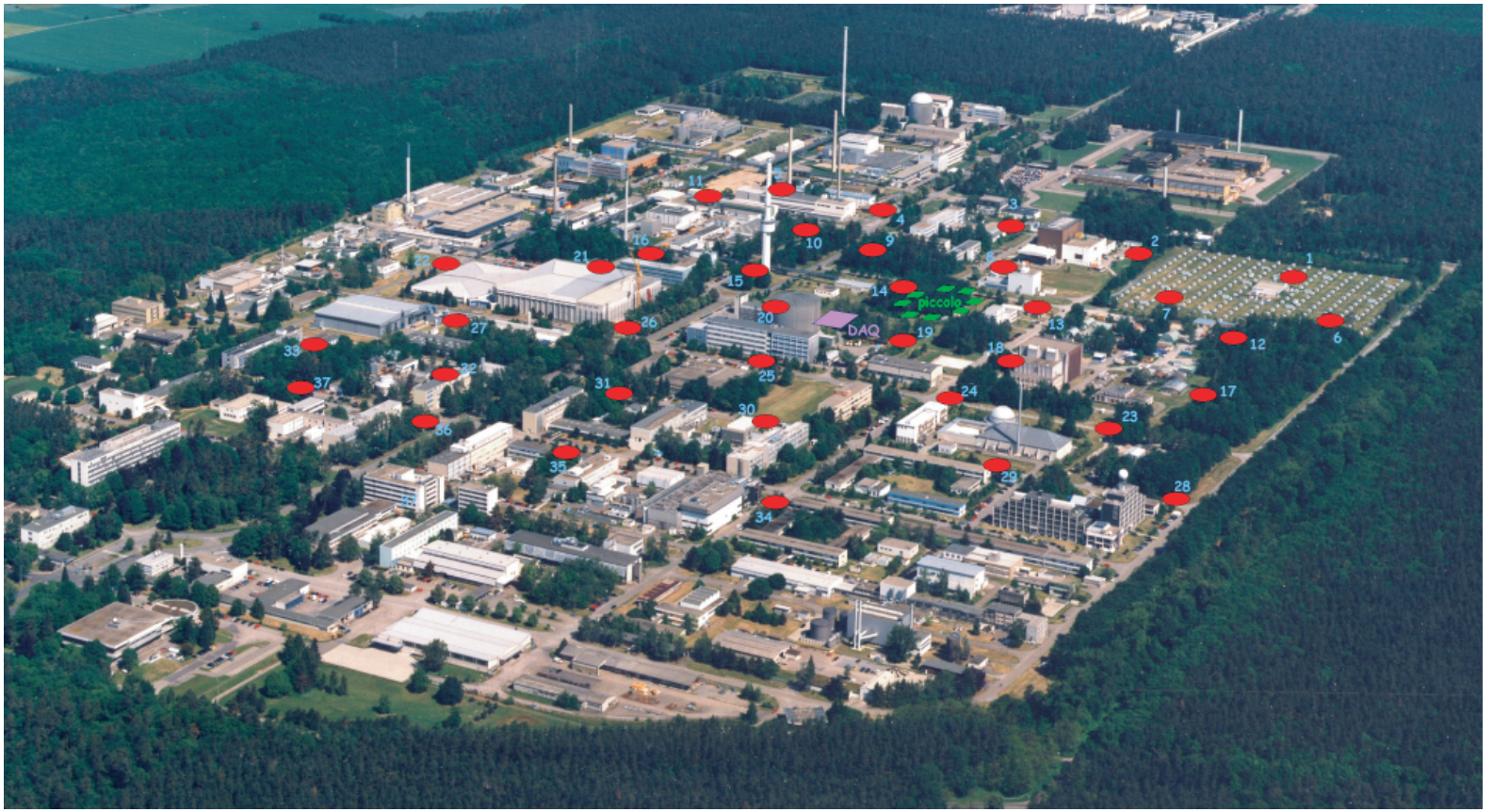
# *Status of the KASCADE-Grande experiment*

*H. Ulrich, Institut für Kernphysik, Forschungszentrum Karlsruhe*
*for the KASCADE-Grande collaboration*




*HEP 2007, Manchester, England*

*short overview ...*

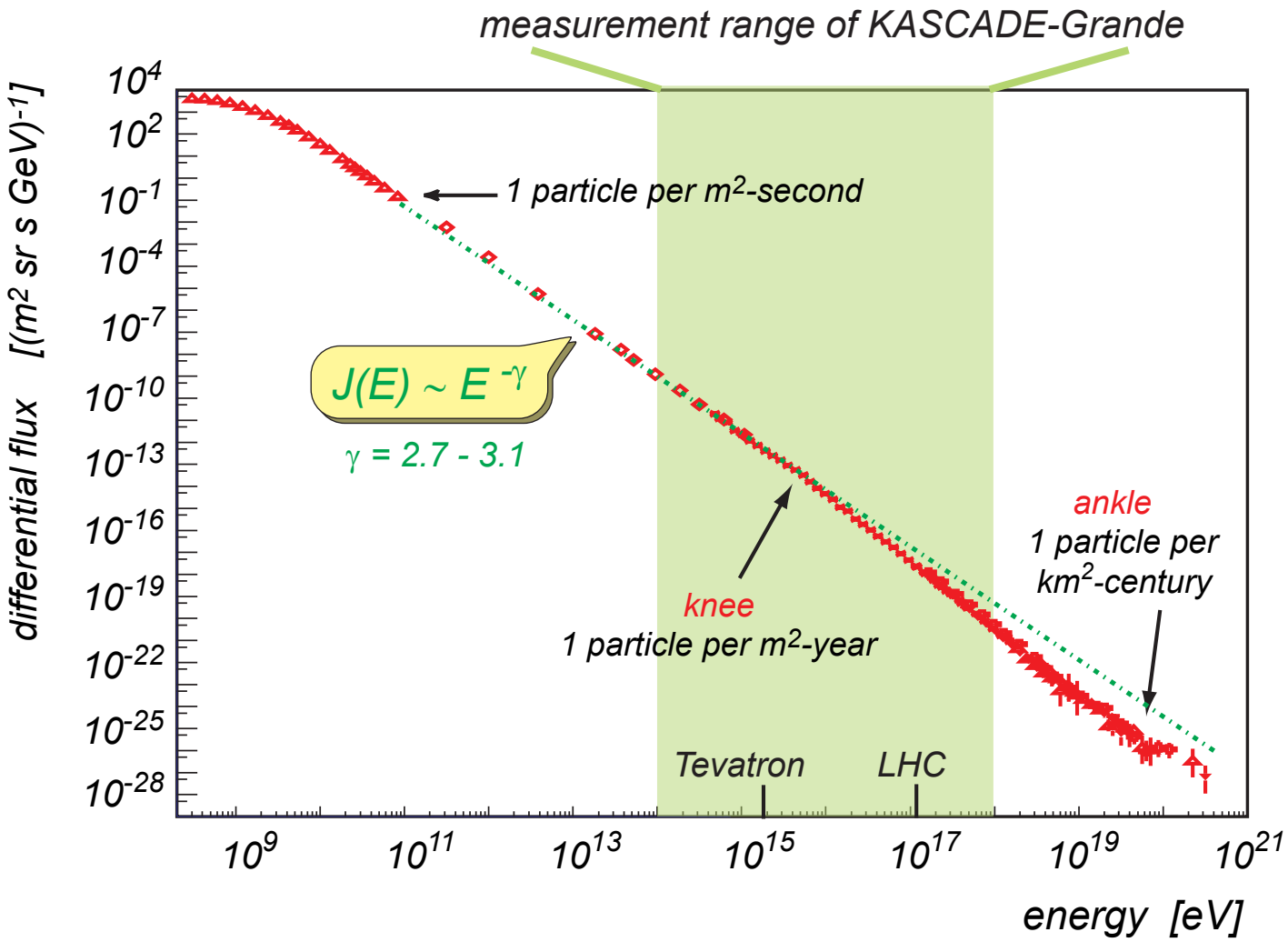
*cosmic rays around/above the knee - what's it all about*

*the KASCADE experiment and its results*

*KASCADE-Grande - setup and reconstruction*

*first results and ongoing analyses*

# The cosmic ray energy spectrum




follows a power law

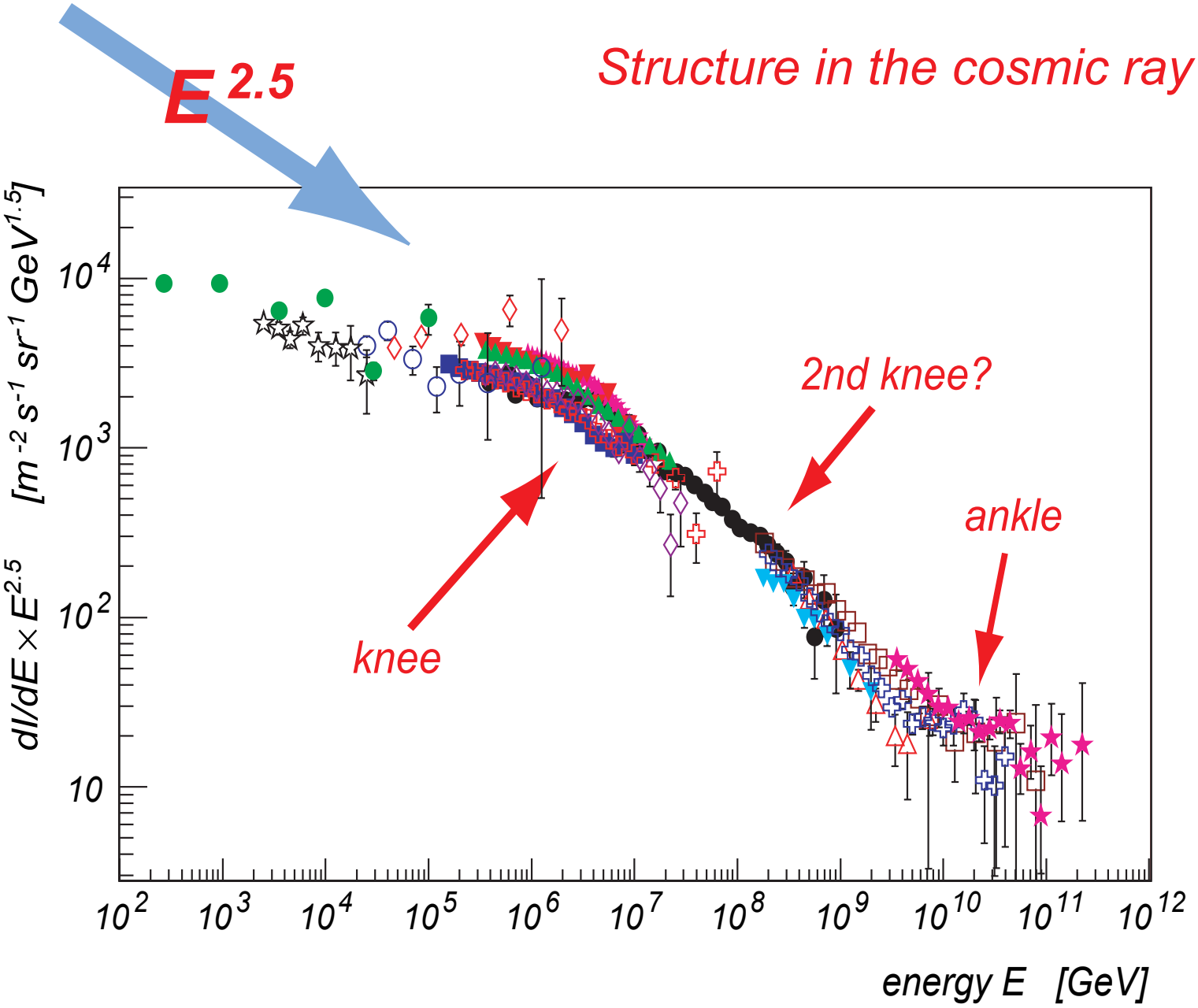
change of index (knee) around $4 \times 10^{15}$ eV

knee region between $10^{14}$ eV and $10^{17}$ eV

making structures visible:

scaling of flux by $E^{\text{something}}$

# Structure in the cosmic ray energy spectrum




*What happens further on?*

*Does the 2nd knee exist? Where?*

*flux too small for direct measurements*

*detection via extensive air showers*

# Detection of air showers

*detection of secondary particles with detectors at ground*

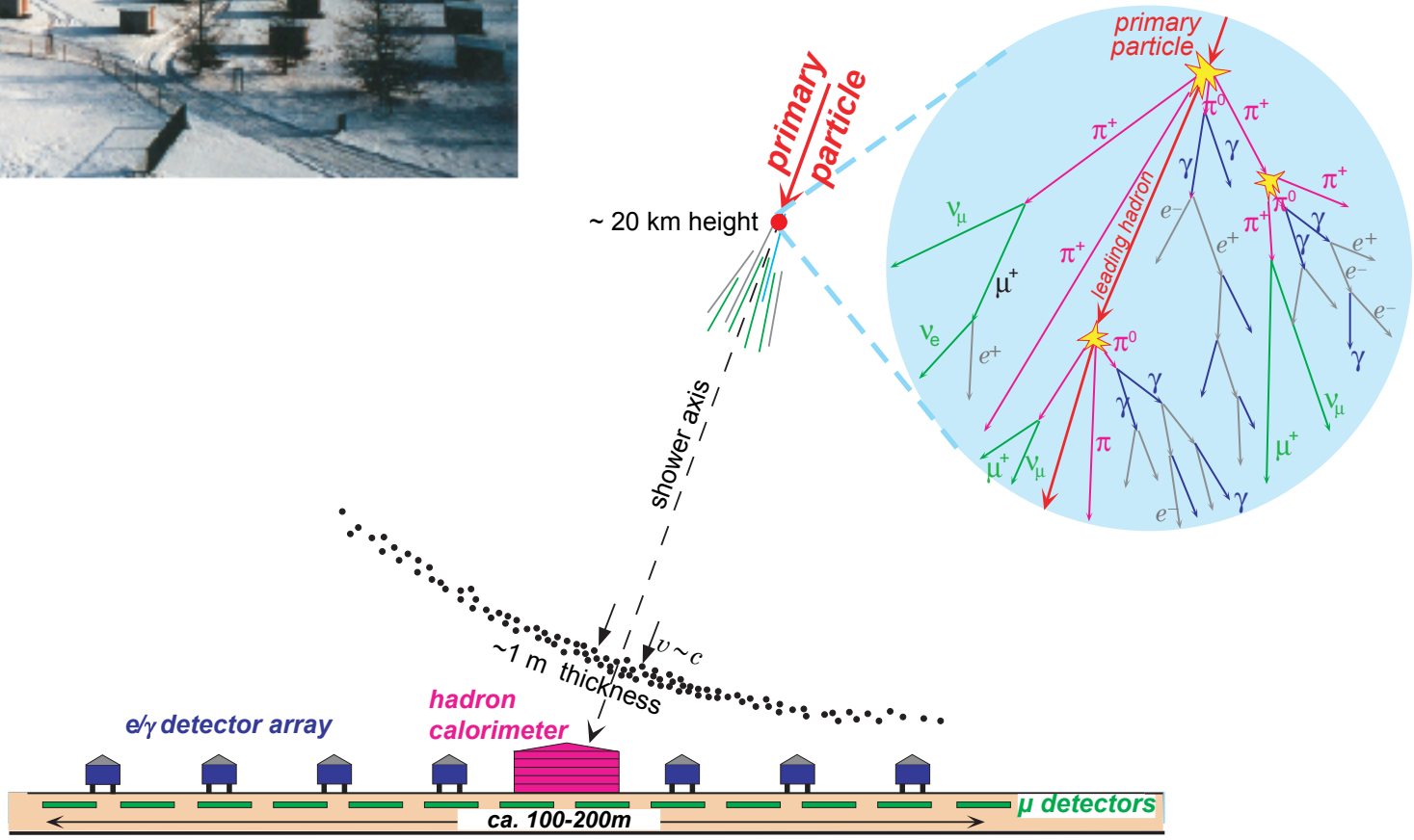
*back-calculation of properties of the primary particle*

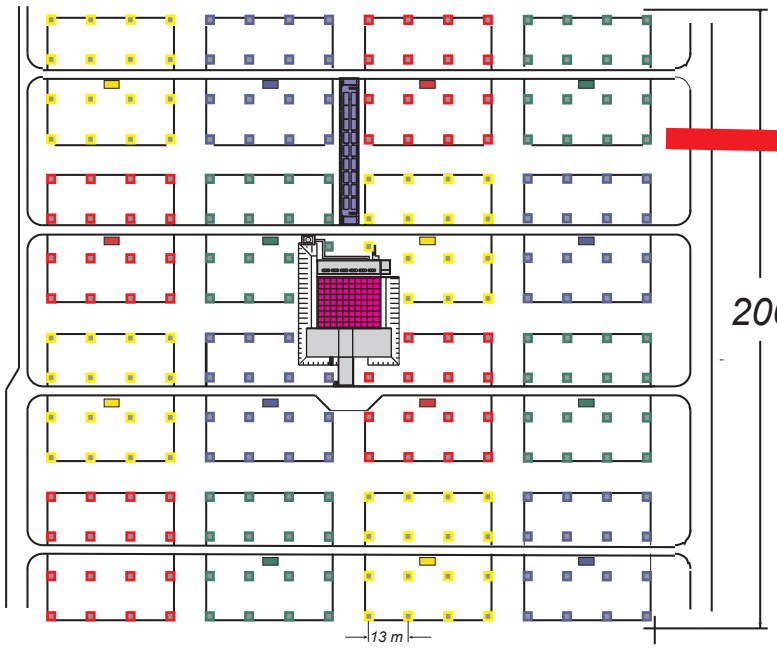
## KASCADE

*designed for energies in knee region*

*measurement of different observables*

*in operation since 1996*





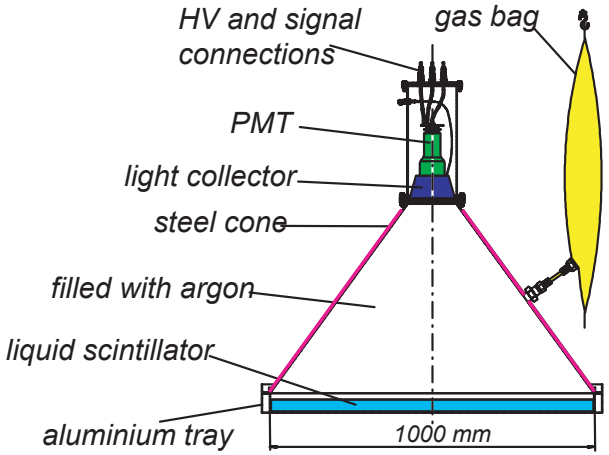

e/γ - detector
(liquid scintillator)

lead/iron absorber

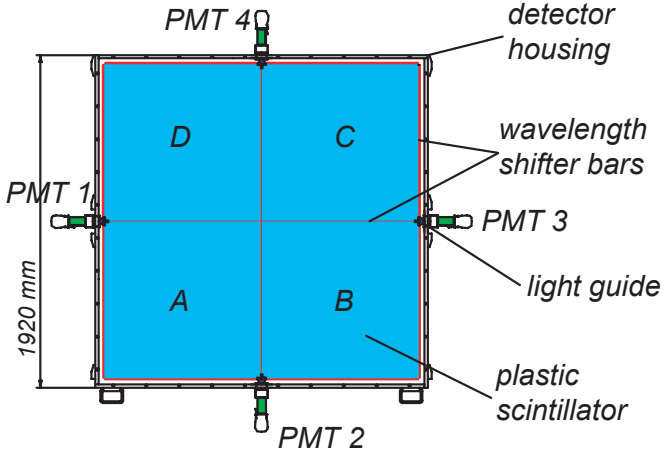
muon detector
(plastic scintillator)

# KASCADE array

*determination of electron number, muon number, shower core and arrival direction of air shower*




e/γ - detector



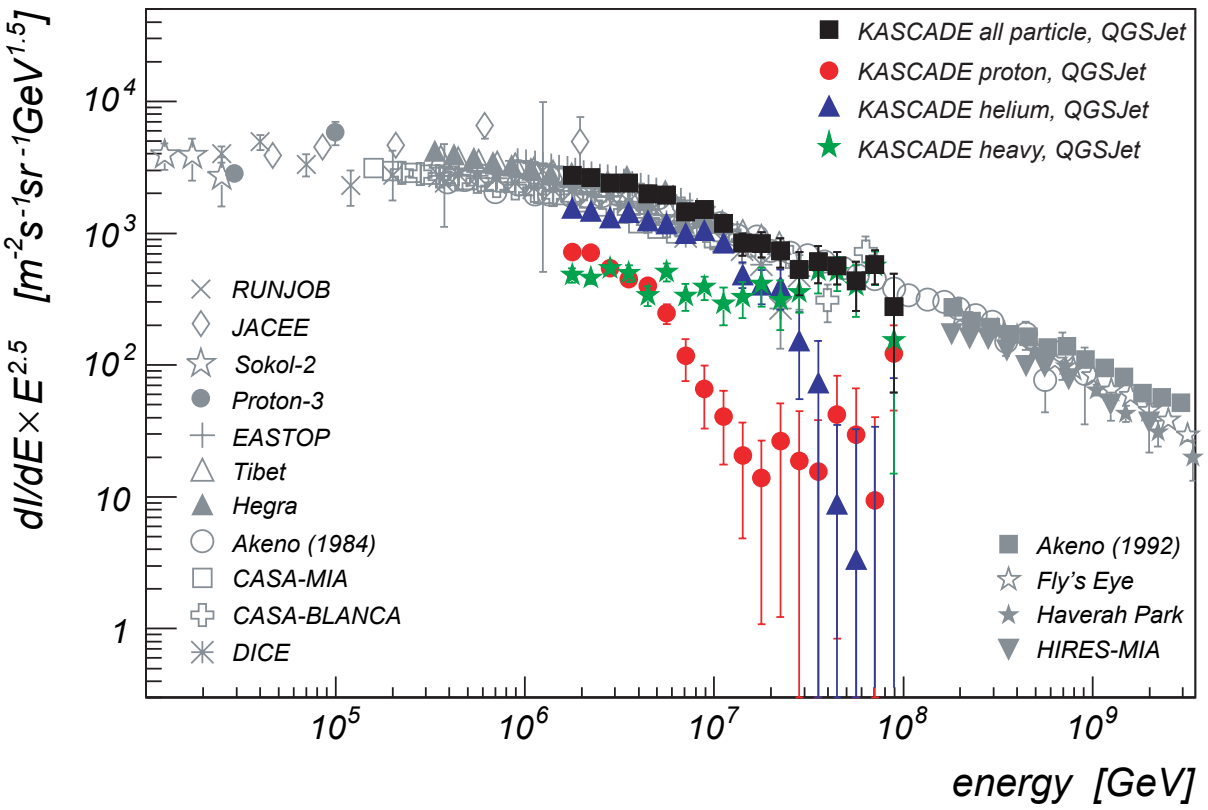

muon detector

# What we have learned from KASCADE ...

*knee structures in spectra of light elements*

*knee in all-particle spectrum caused by superposition*

*composition result strongly dependent on used interaction model*




*iron knee expected at ~$10^{17}$ eV*

*Does the 2nd knee exist?*

*At which energy?*

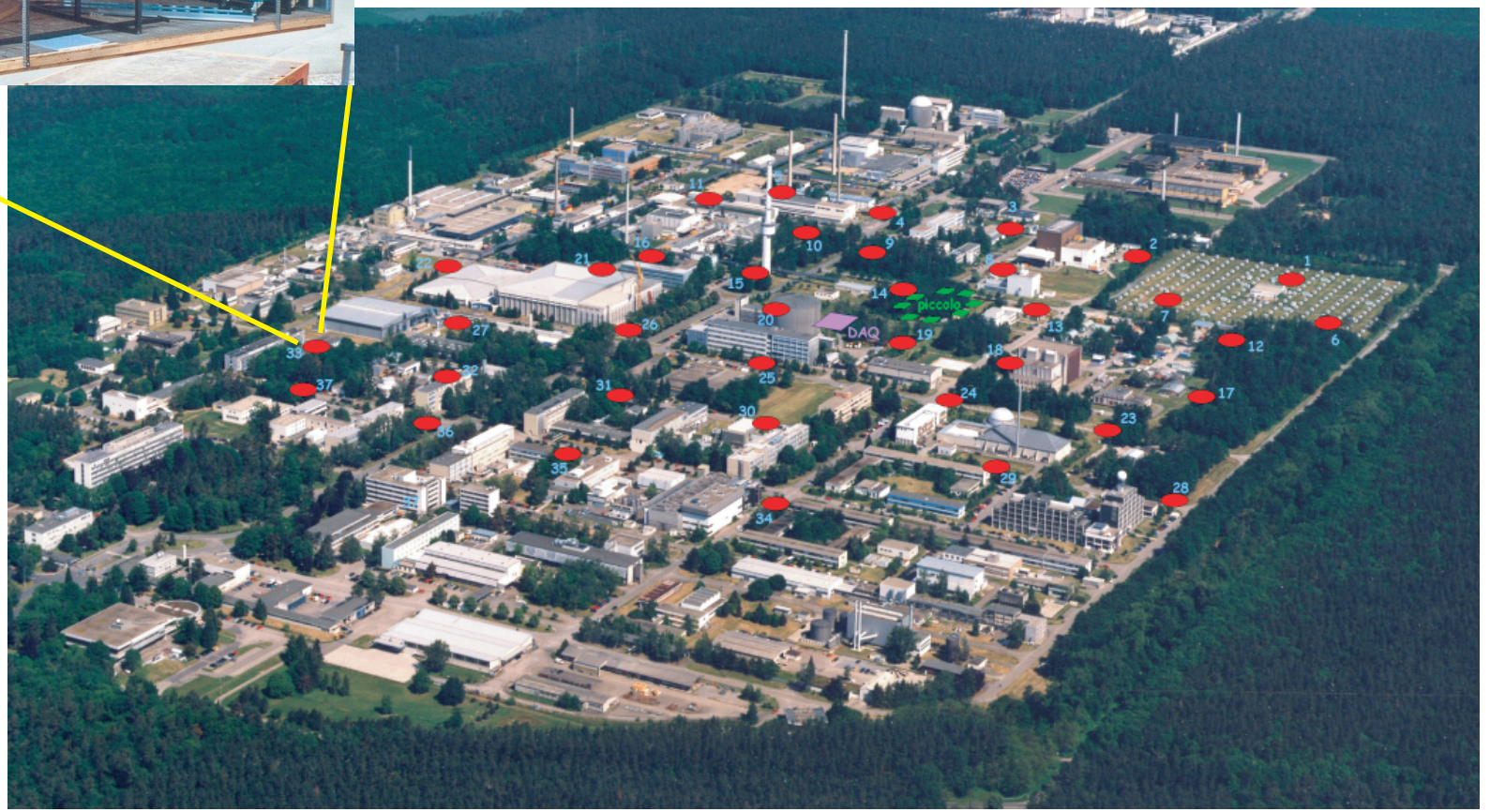
*relation between 2nd knee and expected iron knee?*

*Transition region from galactic to extragalactic cosmic rays?*

*few data between $5 \times 10^{16}$ eV and $10^{18}$ eV*

# KASCADE-Grande


*plastic scintillators (former EAS-Top)*




*37 detector stations (10 $m^2$ each) on area of FZK, total of 0.5 $km^2$ detection area*

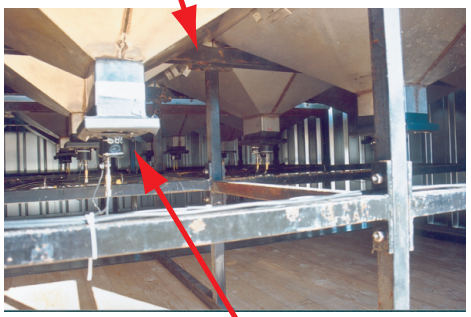
# *Station of Grande-array*


*former EAS-TOP detectors*

*plastic scintillators*

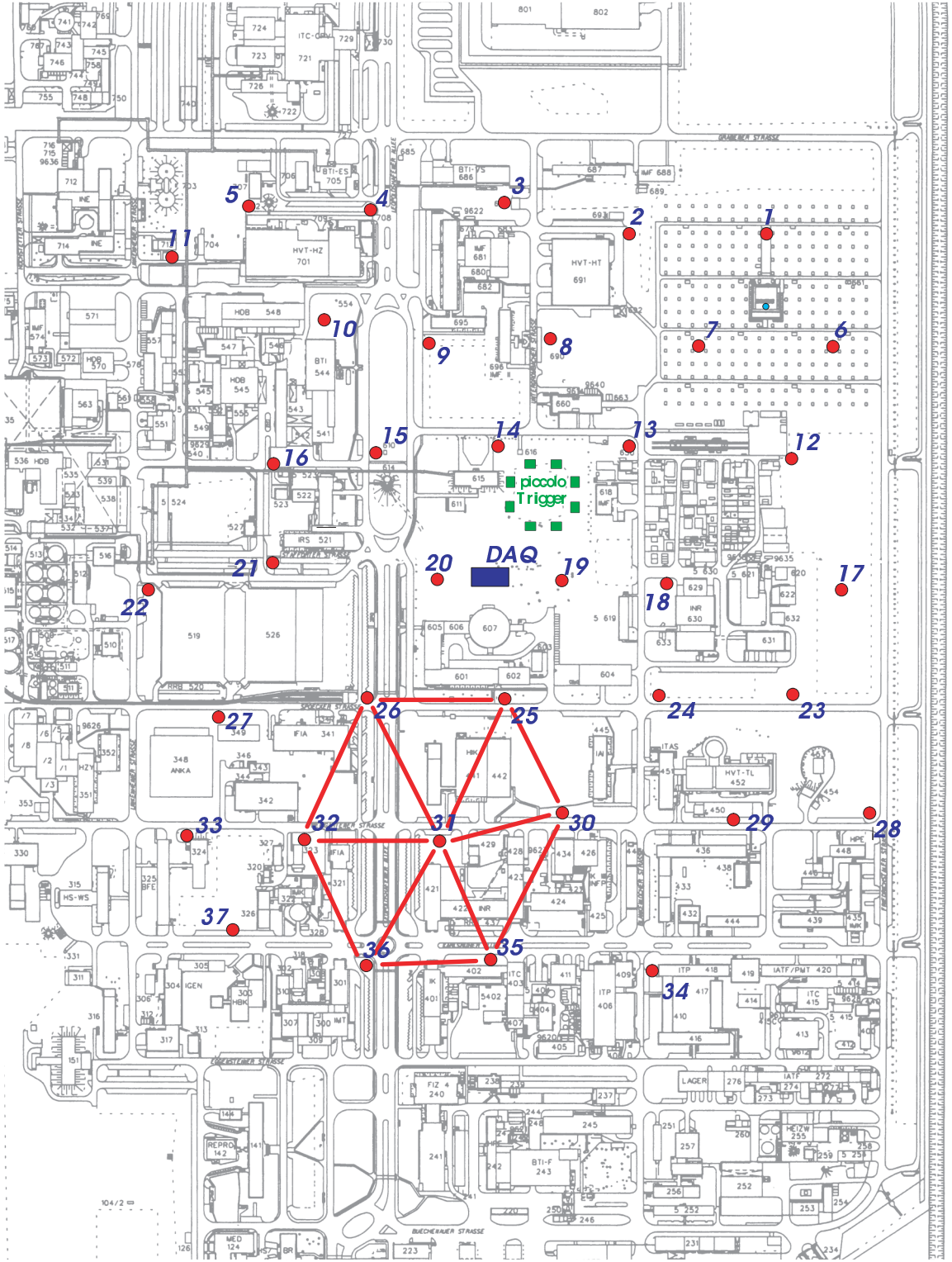
*16 detectors per station*

*total of 10 $m^2$ detection area per station*



*photomultiplier*

*measurement of charged (electrons and muons) air shower component*




## Grande - array

*37 stations distributed in southern part of Forschungszentrum area*

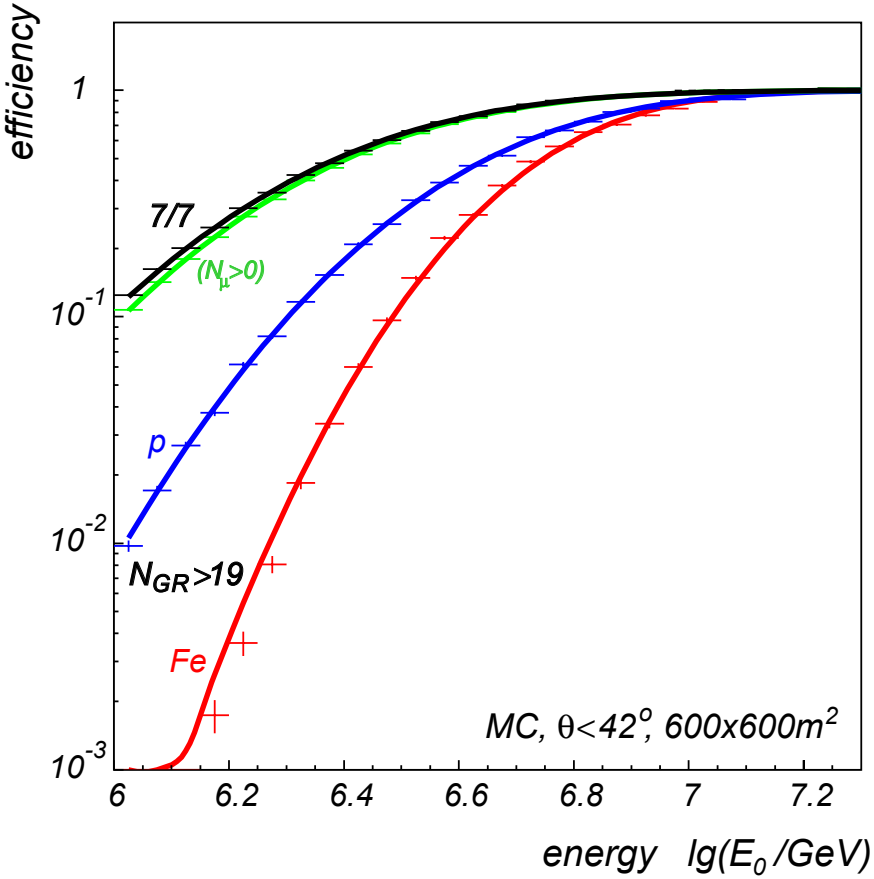
*independent DAQ*

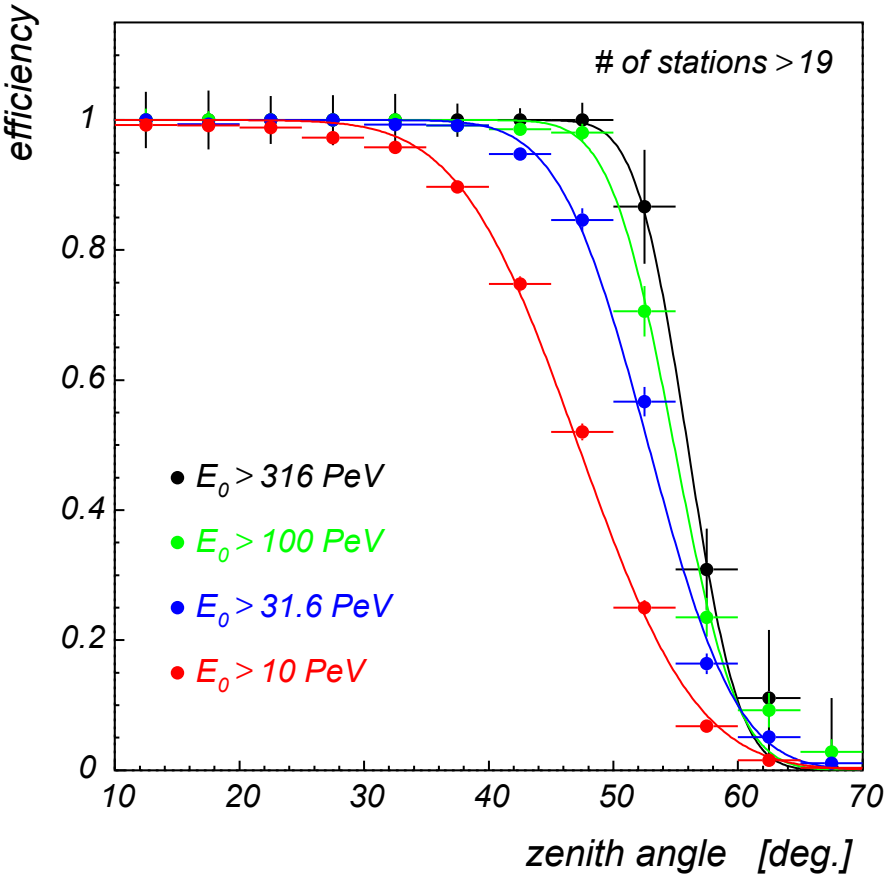
*each neighboring 7 stations constitute a trigger-hexagon*

## Piccolo - array

*scintillation counters (8 stations) providing common trigger for Grande and KASCADE-components*

# KASCADE-Grande: efficiencies

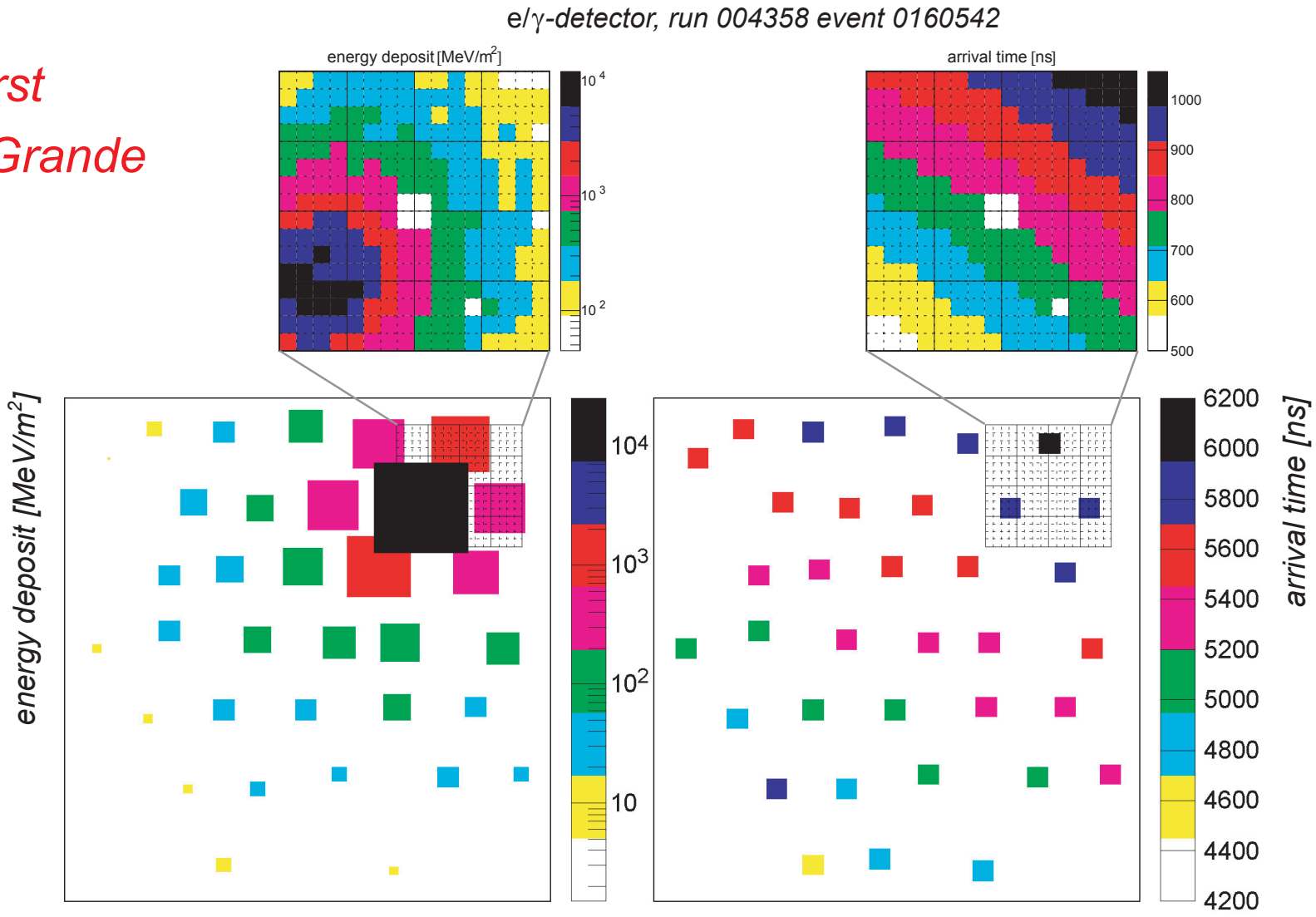


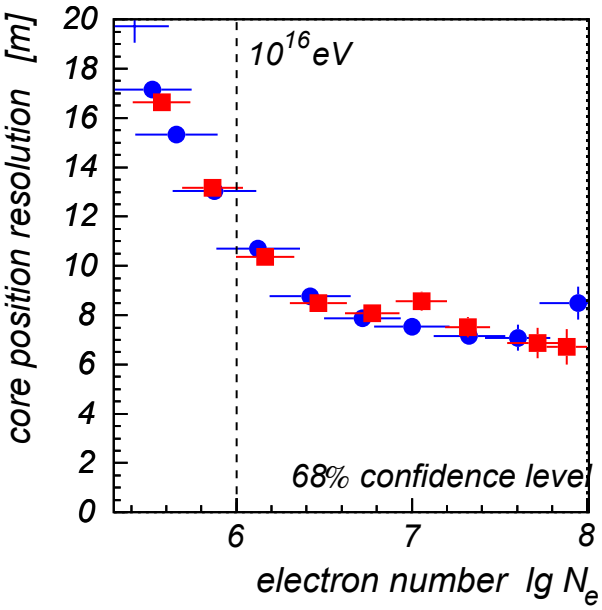



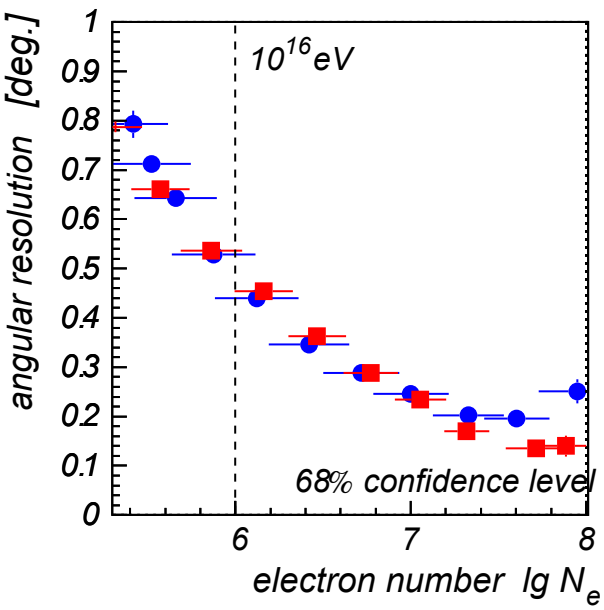

100% Effizienz @ $3x10^{16}$eV up to θ=42°

overlap with original KASCADE experiment

*one of the first KASCADE-Grande events*






# Reconstruction accuracies (I)

*full EAS & detector MC*
*(CORSIKA 6.307 & GEANT 3.21)*

● *protons* ● *iron*

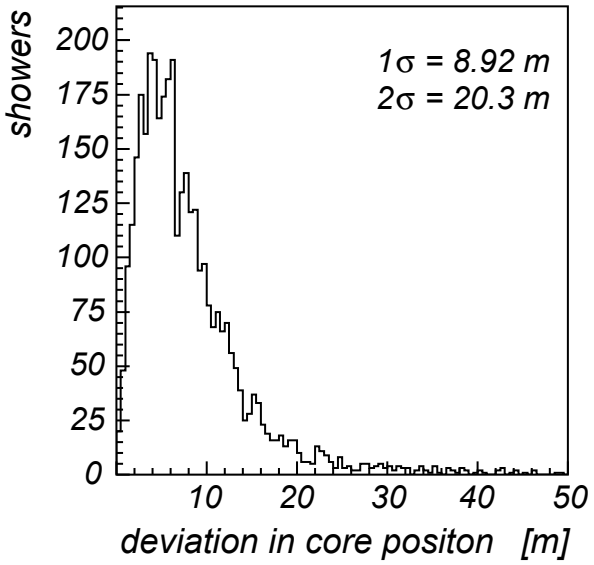
*500 x 600 m$^2$, 0.4 < s < 1.4,*
*$N_{GR}$ > 19, θ < 30°*

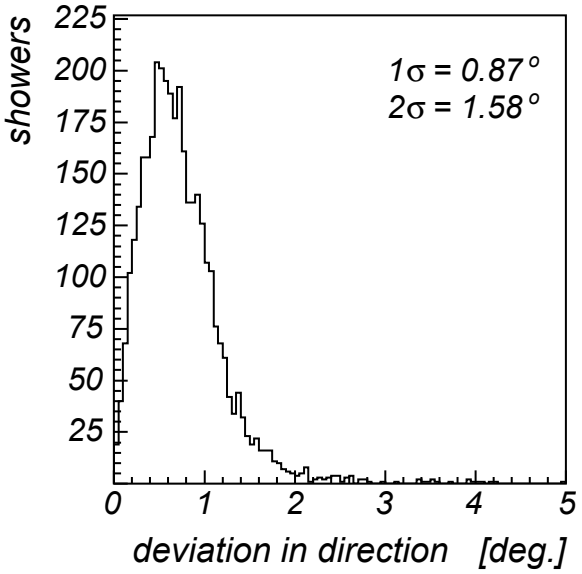
## *Comparison between Grande & array*

*DATA independently analysed, $N_e > 10^6$*

*position error consistent with array reconstruction error (about 1 m)*

*directional deviation slightly larger than expected from an array resolution (add. time delays of about 1-2 ns)*

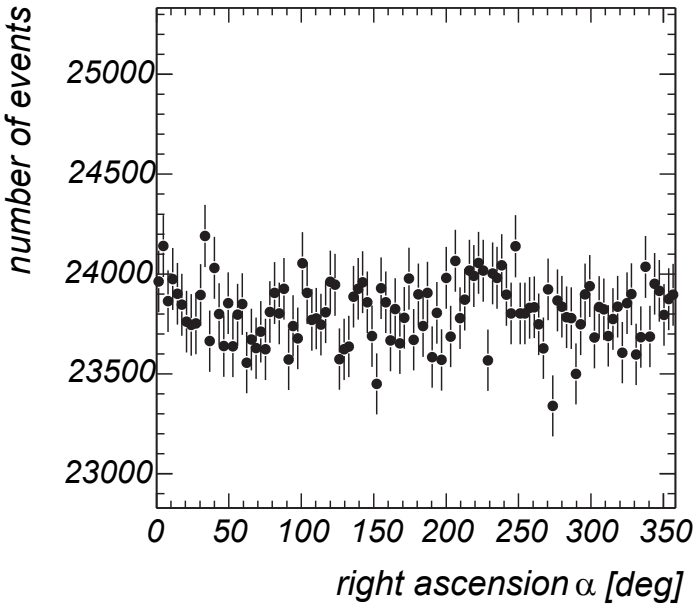


# *Directional analyses:*

## *large scale anisotropy*

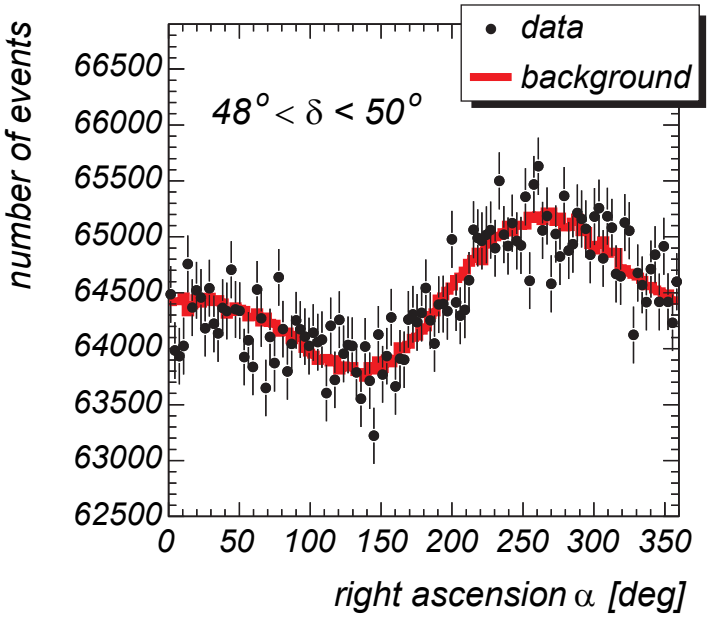
*investigation of variations in rate dependent on right ascension*




*harmonic analysis:*
*Fourier expansion, amplitude and phase of 1. harmonic*

## *small scale anisotropy - point sources*

*calculation of estimated background*




*comparison between measured events and background for every direction*

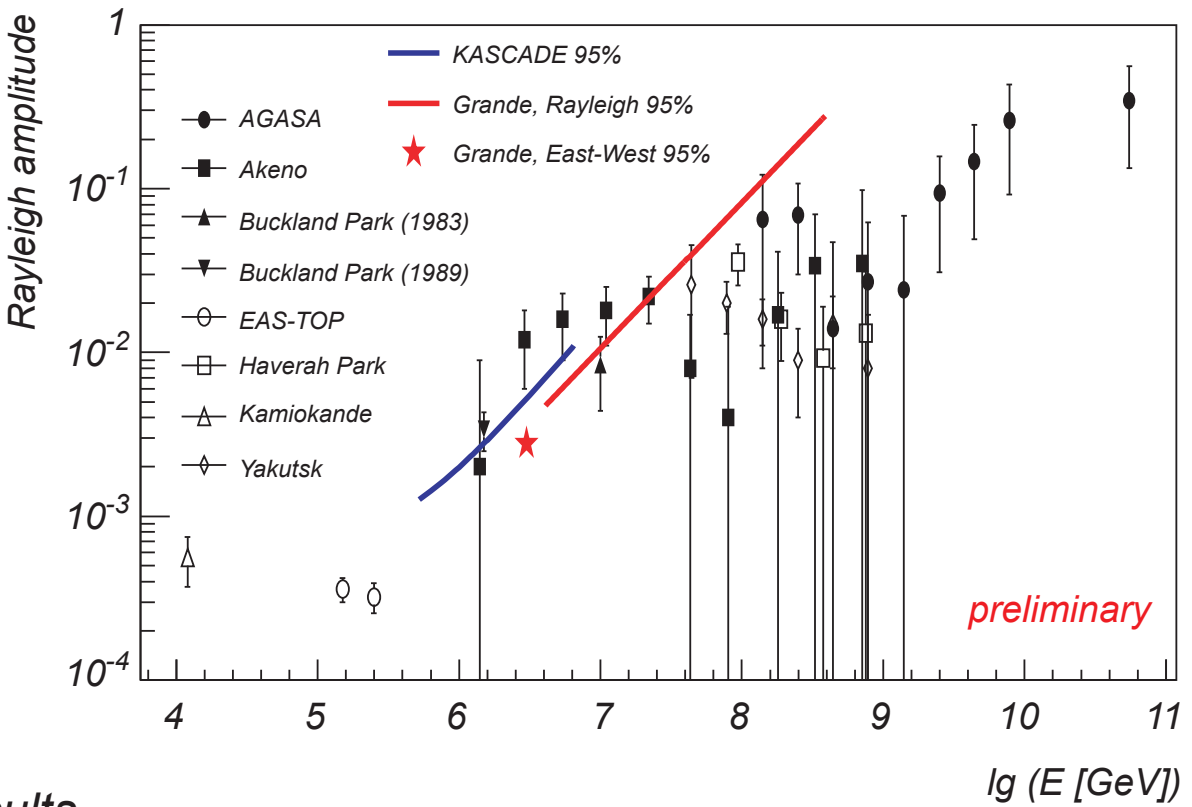
# *Large scale anisotropy - harmonic analysis*

*analysis of rate variations dependent on right ascension*

*no significant anisotropy found*

*neither amplitude nor phase*

→ *only upper limits*

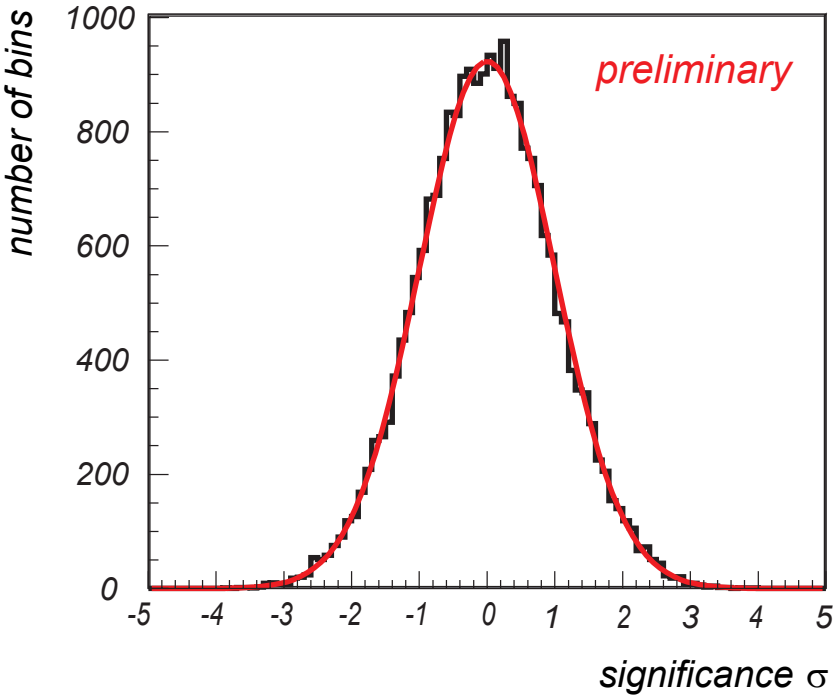



*nice agreement with KASCADE results*

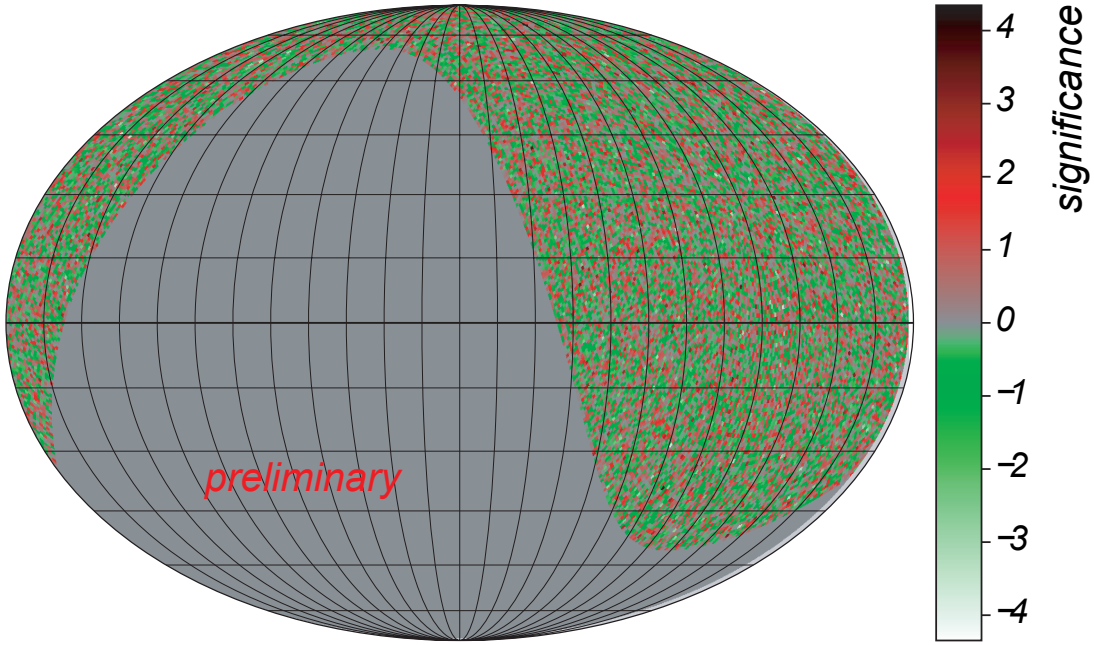
# Search for point sources

*comparison between observed number of showers and estimated background (Li-Ma analysis)*

*frequency distribution of significances*




*distribution of significances in visible sky*




*no significant excess found*

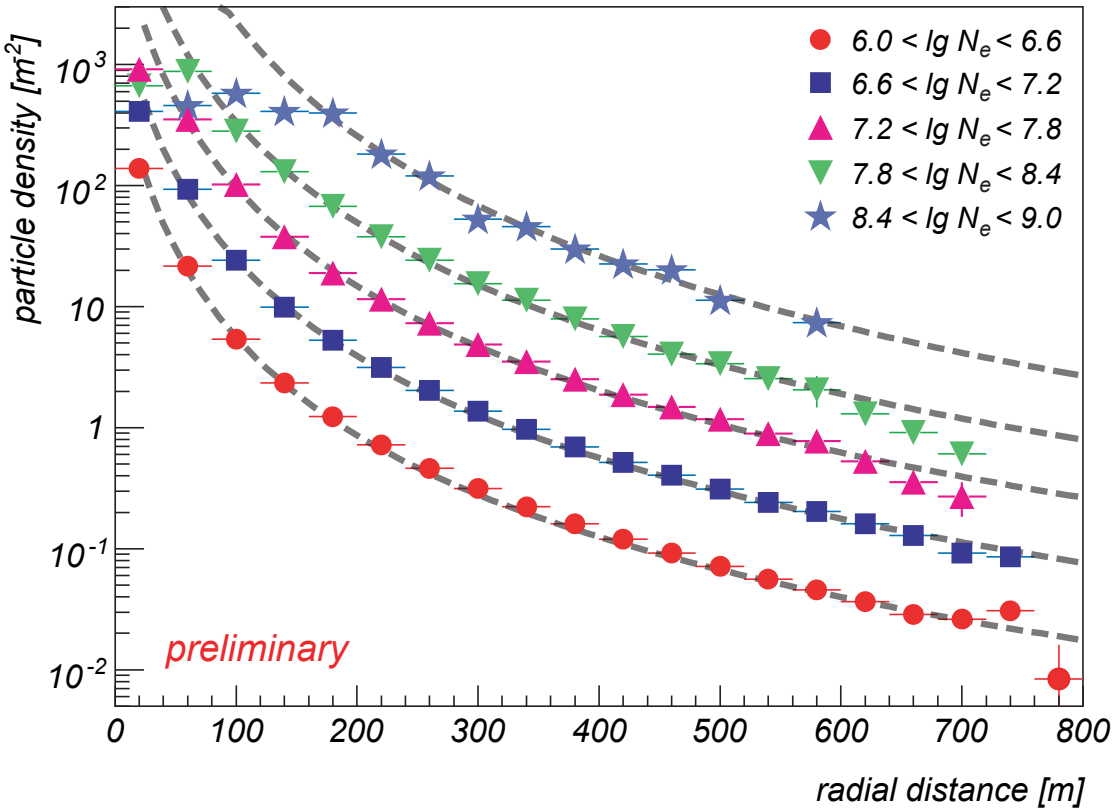
# *Determination of particle numbers - fitting the lateral distribution*

*particle numbers*

→ *shower sizes, key observable*

*fit to densities of charged particles*

$$\rho = N_e \cdot \tilde{c}(s) \cdot \left(\frac{r}{r_0}\right)^{s-\alpha} \cdot \left(1+\frac{r}{r_0}\right)^{s-\beta}$$



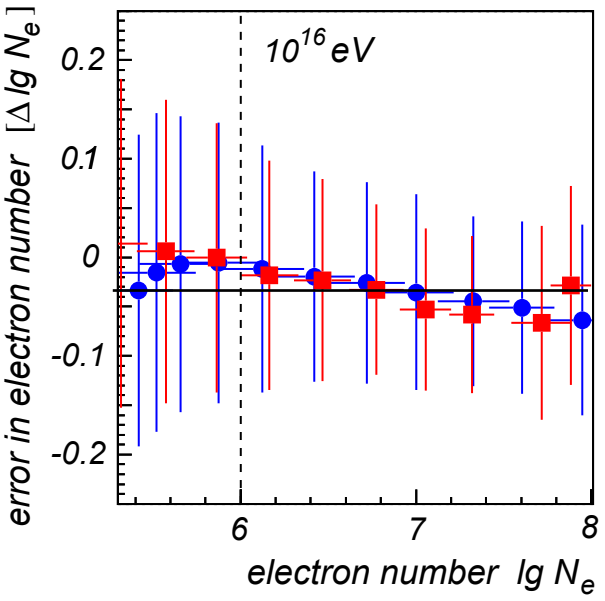

*modified NKG function*

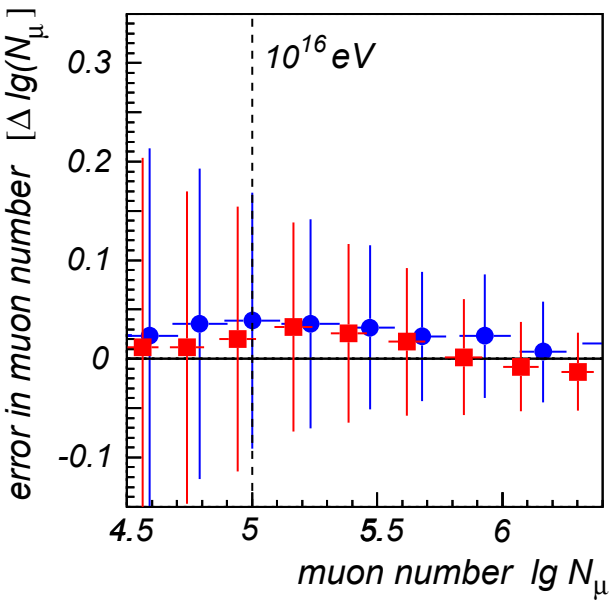
*parameter values:* $\alpha$ = 1.5 , $\beta$ = 3.6 , $r_0$ = 40 m

*muon lateral distribution: Lagutin function*

$$\rho_\mu = N_\mu \frac{0.28}{r_0}\left(\frac{r}{r_0}\right)^{-0.69}\left(1+\frac{r}{r_0}\right)^{-2.39}\left(1+\left(\frac{r}{10r_0}\right)^2\right)^{-1.0}$$

*correction of charged partcile number by muon number* → *electron number*




# Reconstruction accuracies (II)

*full EAS & detector MC (CORSIKA 6.307 & GEANT 3.21)*

● *protons* ● *iron*

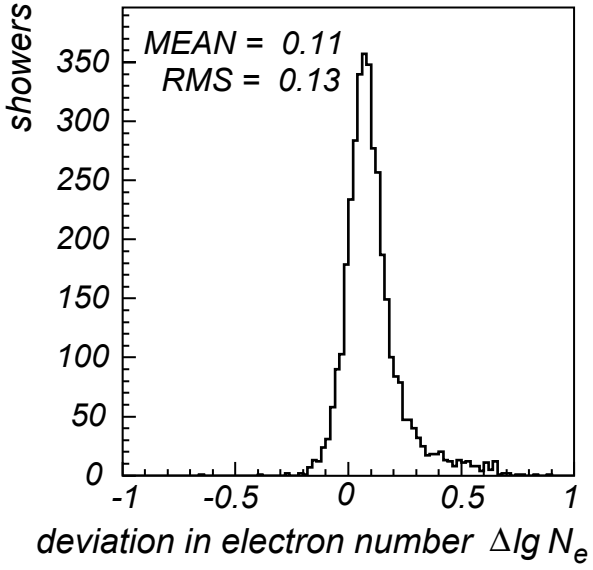
*500 x 600 m², 0.4 < s < 1.4, $N_{GR}$ > 19, θ < 30°*

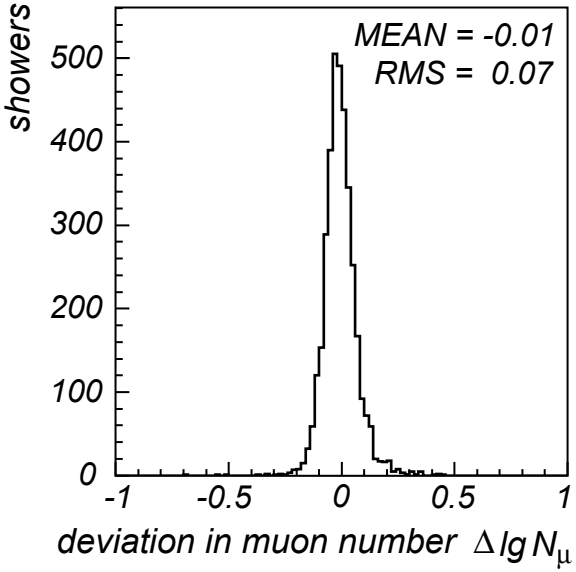
## Comparison between Grande & array

*DATA independently analysed, $N_e > 10^6$*

*slightly larger electron number (25%)*
*RMS dominated by Grande*

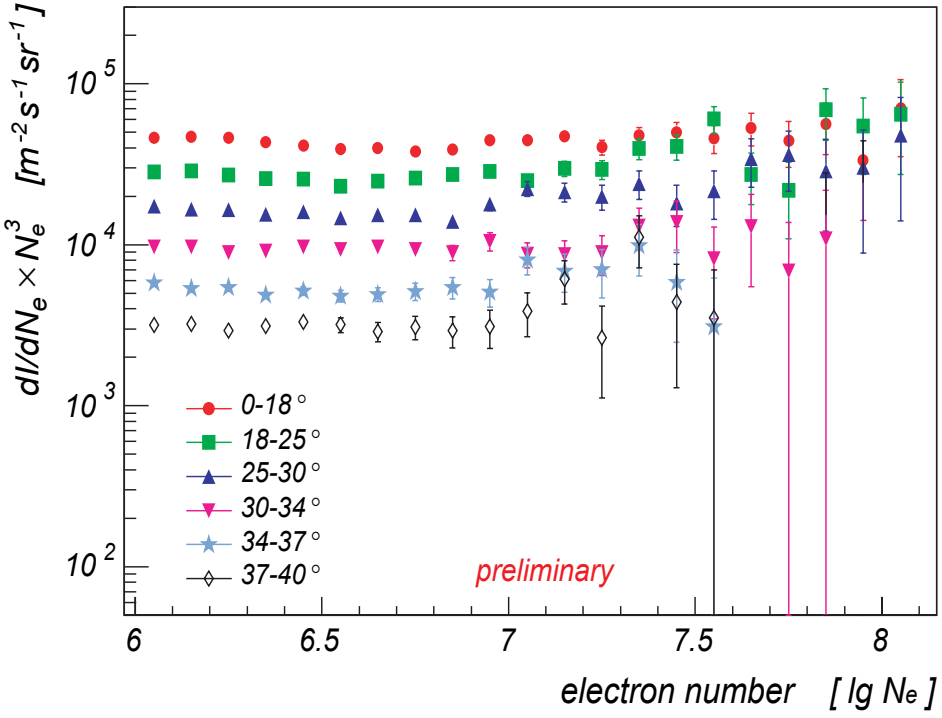
*muon number practically equal*
*RMS reduced because of correlation*
*(SAME data!)*

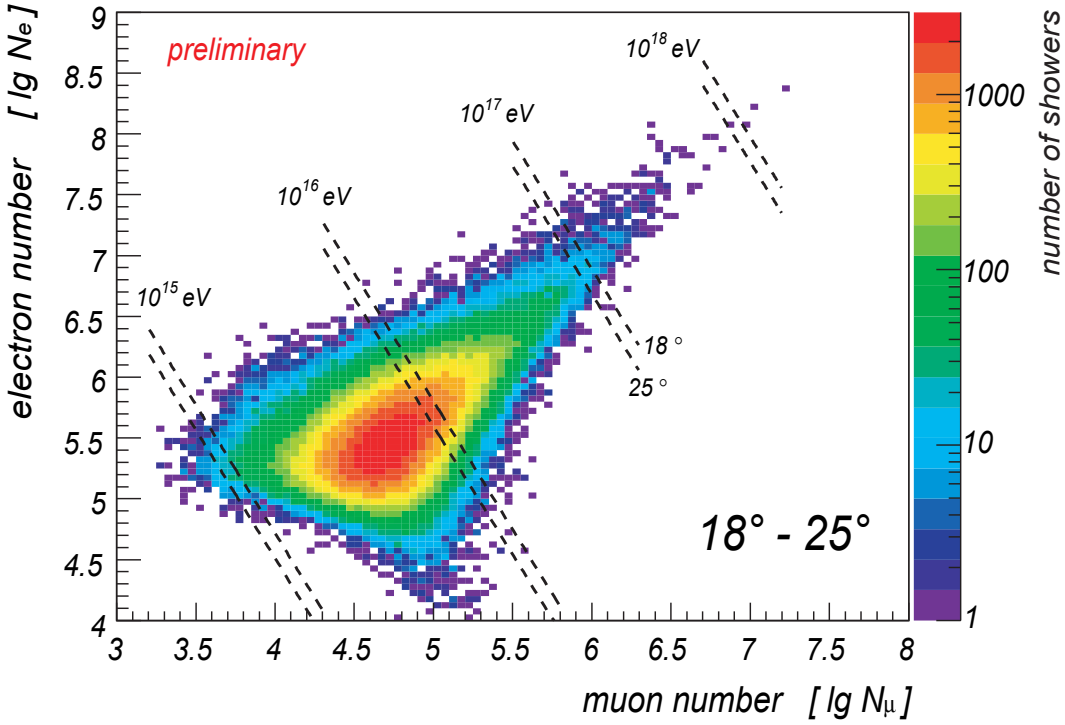


# Shower size spectra

*frequency distribution of showers dependent on electron or/and muon number*




*already some events around $10^{18}$ eV*

*next step:*
*unfolding analysis for determination of energy spectra of mass groups*

*... but not yet done!*

## *Conclusions and outlook ...*

### *KASCADE-Grande*

*continous data taking*

*shower reconstruction well understood*

*anisotropy studies: no deviations from isotropy found*

*above $10^{17}$ eV already more data than KASCADE*

*also some events around $10^{18}$ eV*

*analysis of shower size spectra has begun* → *energy spectra to come!*

# *KASCADE-Grande collaboration*

**Institut für Kernphysik**
**Forschungszentrum and University of Karlsruhe**

W.D. Apel, J.C. Arteaga, F. Badea, K. Bekk, H. Blümer, H. Bozdog, F. Cossavella, K. Daumiller, V. de Souza, P. Doll, R. Engel, J. Engler, M. Finger, H.J. Gils, A. Haungs, D. Heck, J.R. Hörandel, T.Huege, P.G. Isar, H.O. Klages, H.J. Mathes, H.J. Mayer, C. Meurer, J. Milke, A. Morales, S. Nehls, R. Obenland, J. Oehlschläger, S. Ostapchenko, T. Pierog, S. Plewnia, H. Rebel, M. Roth, H. Schieler, M. Stümpert, H. Ulrich, J. van Buren, A. Weindl, J. Wochele

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**Soltan Institute for Nuclear Studies, Lodz**

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**IFSI, INAF and University of Torino**

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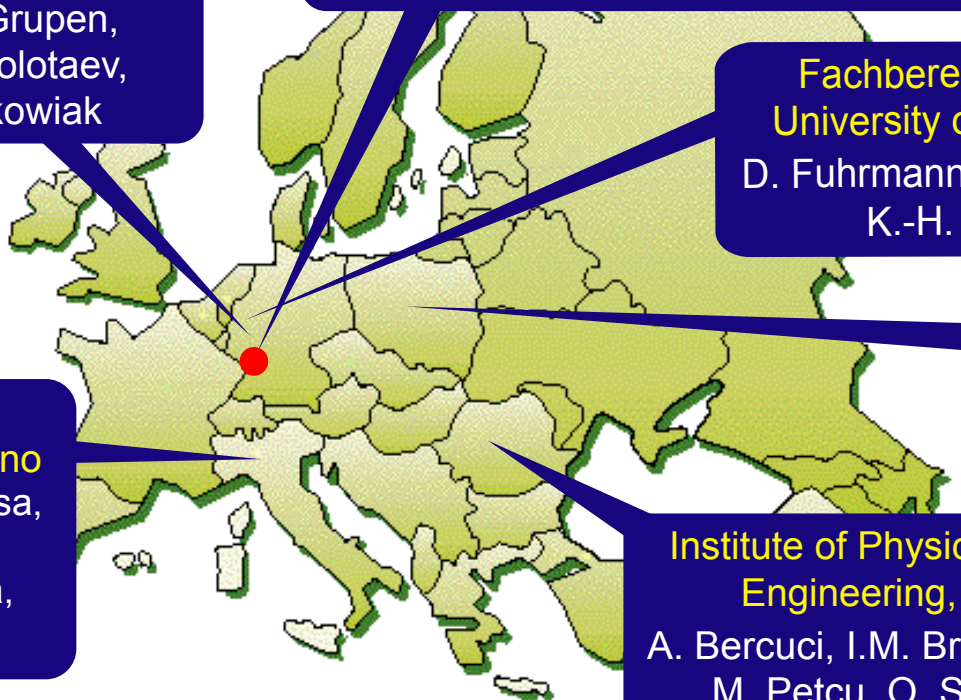

*http://www-ik.fzk.de/KASCADE_home_g.html*