KASCADE-Grande:
an overview and first results

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KASCADE-Grande
= KArlsruhe Shower Core and Array DEtector + Grande
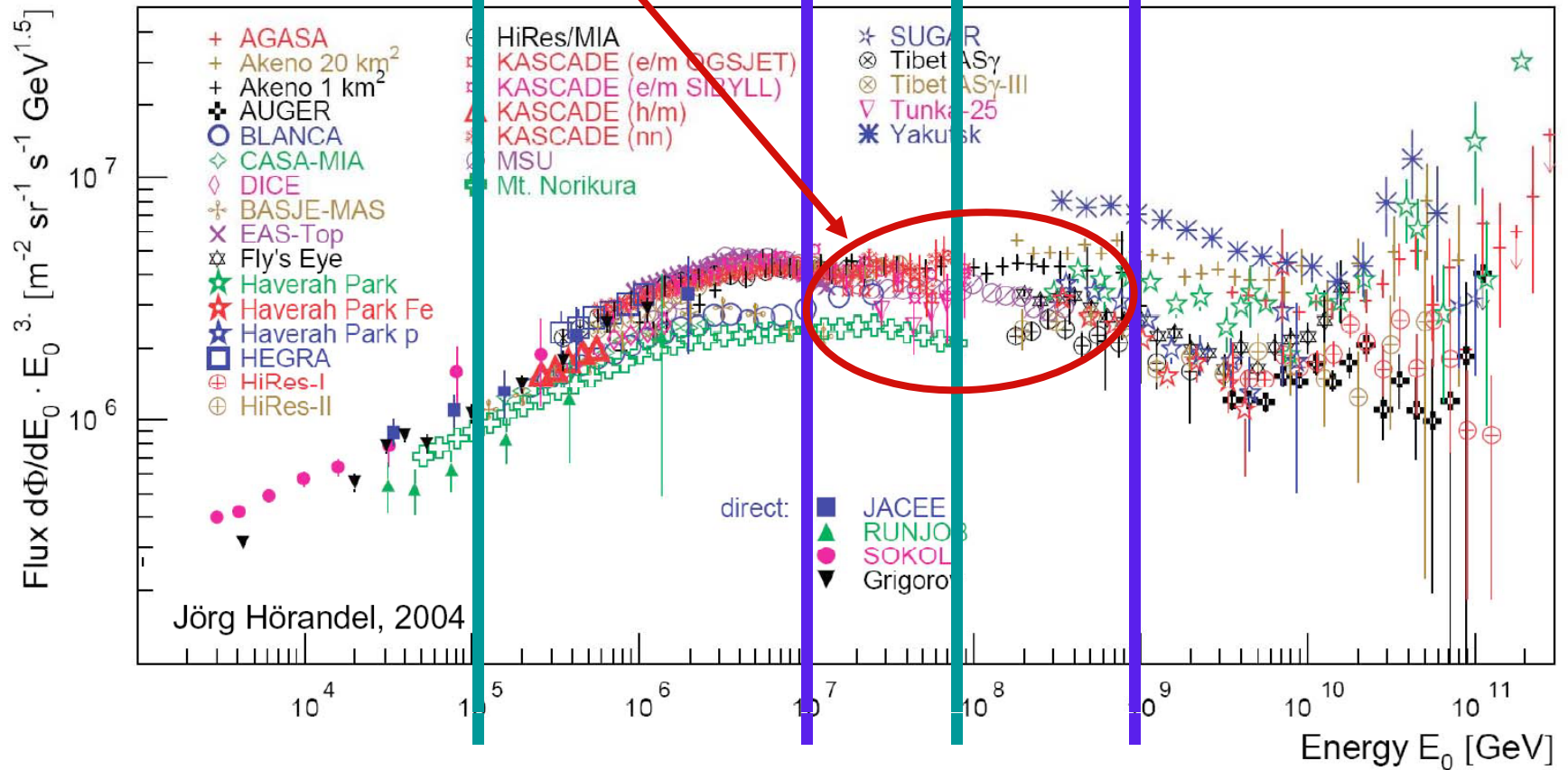# and LOPES

Measurements of air showers in the energy range $E_0 = 100$ TeV - 1 EeV
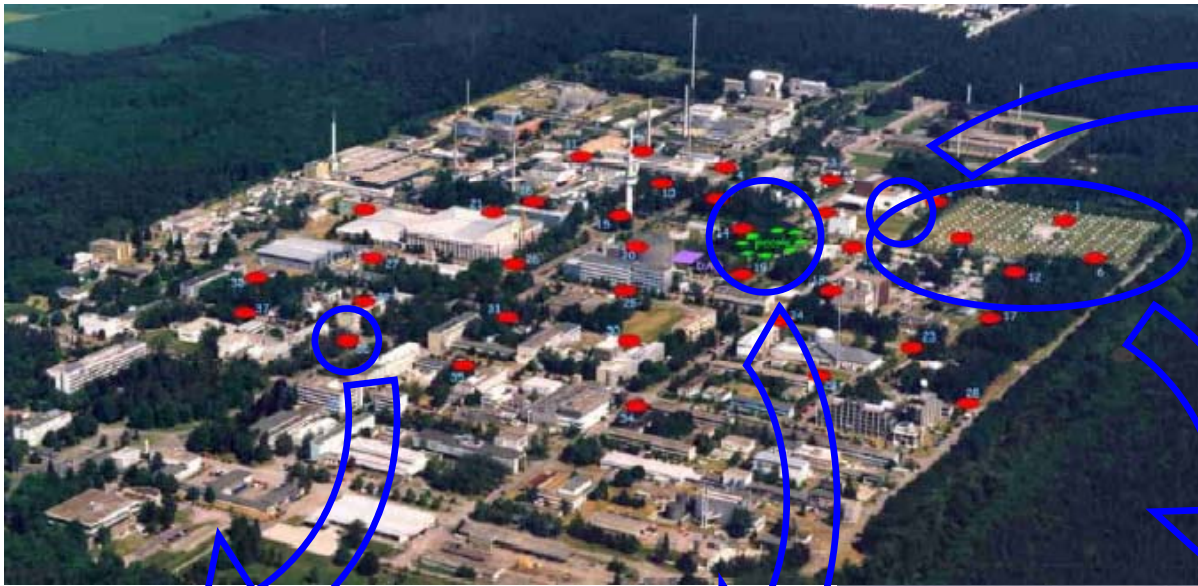
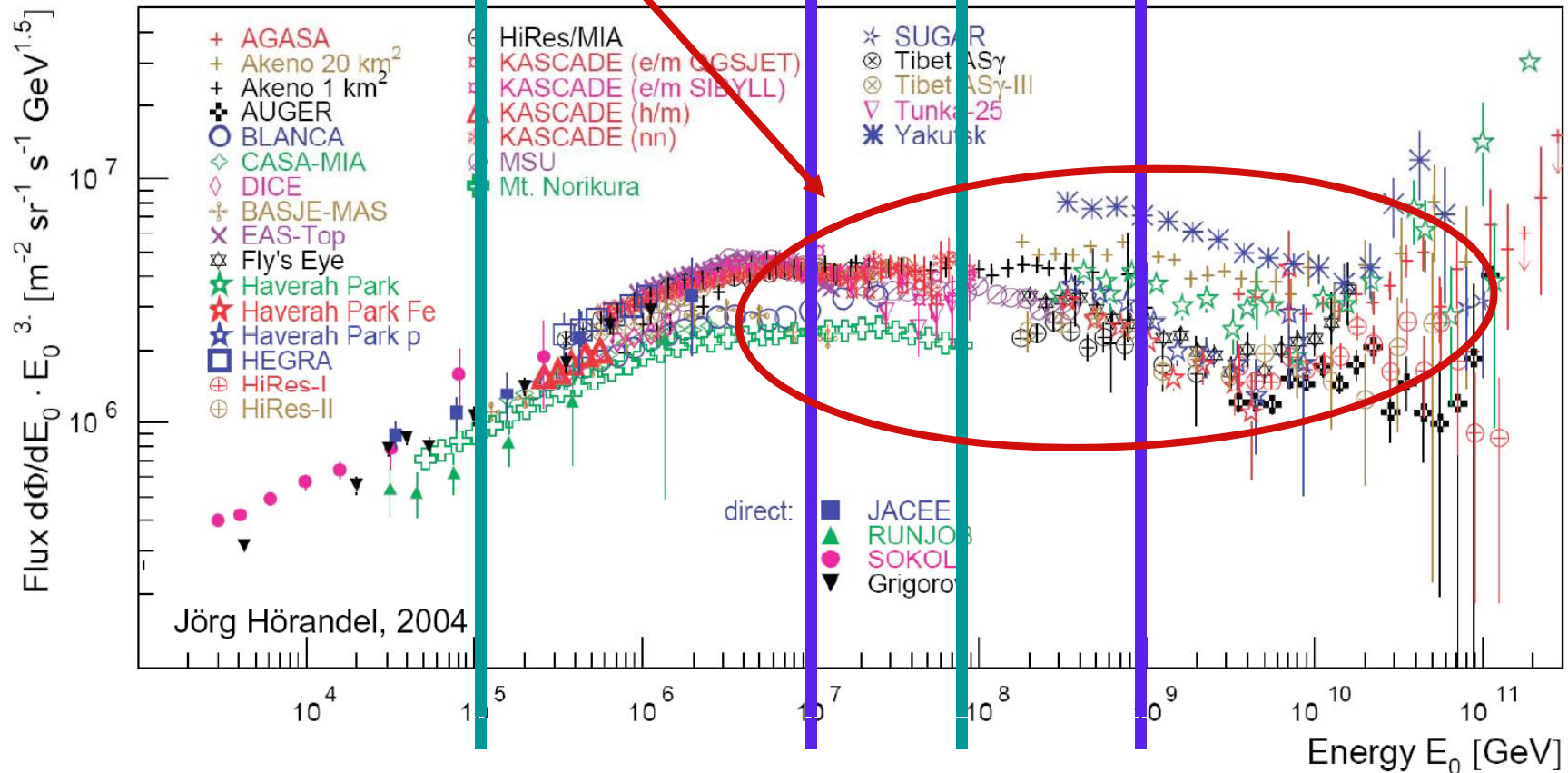# KASCADE: $10^{14} - 8 \cdot 10^{16}$ eV
-Grande: $10^{16} - 10^{18}$ eV

Fe knee? 2nd knee?

KASCADE: 10^{14} - $8 \cdot 10^{16}$ eV
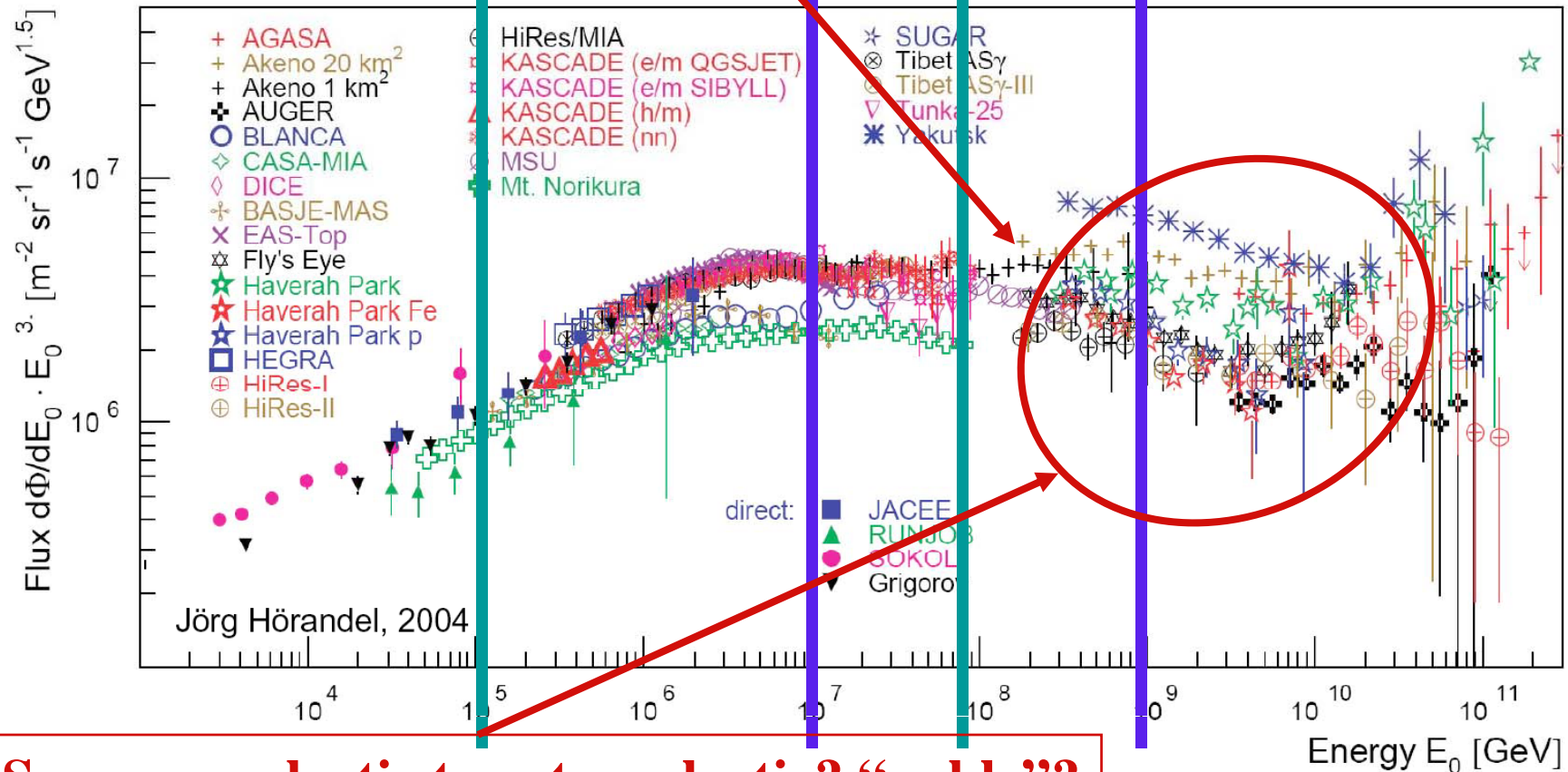## -Grande: 10^{16} - 10^{18} eV

Hadronic interactions

KASCADE: 10^{14} - $8 \cdot 10^{16}$ eV
-Grande: 10^{16} - 10^{18} eV

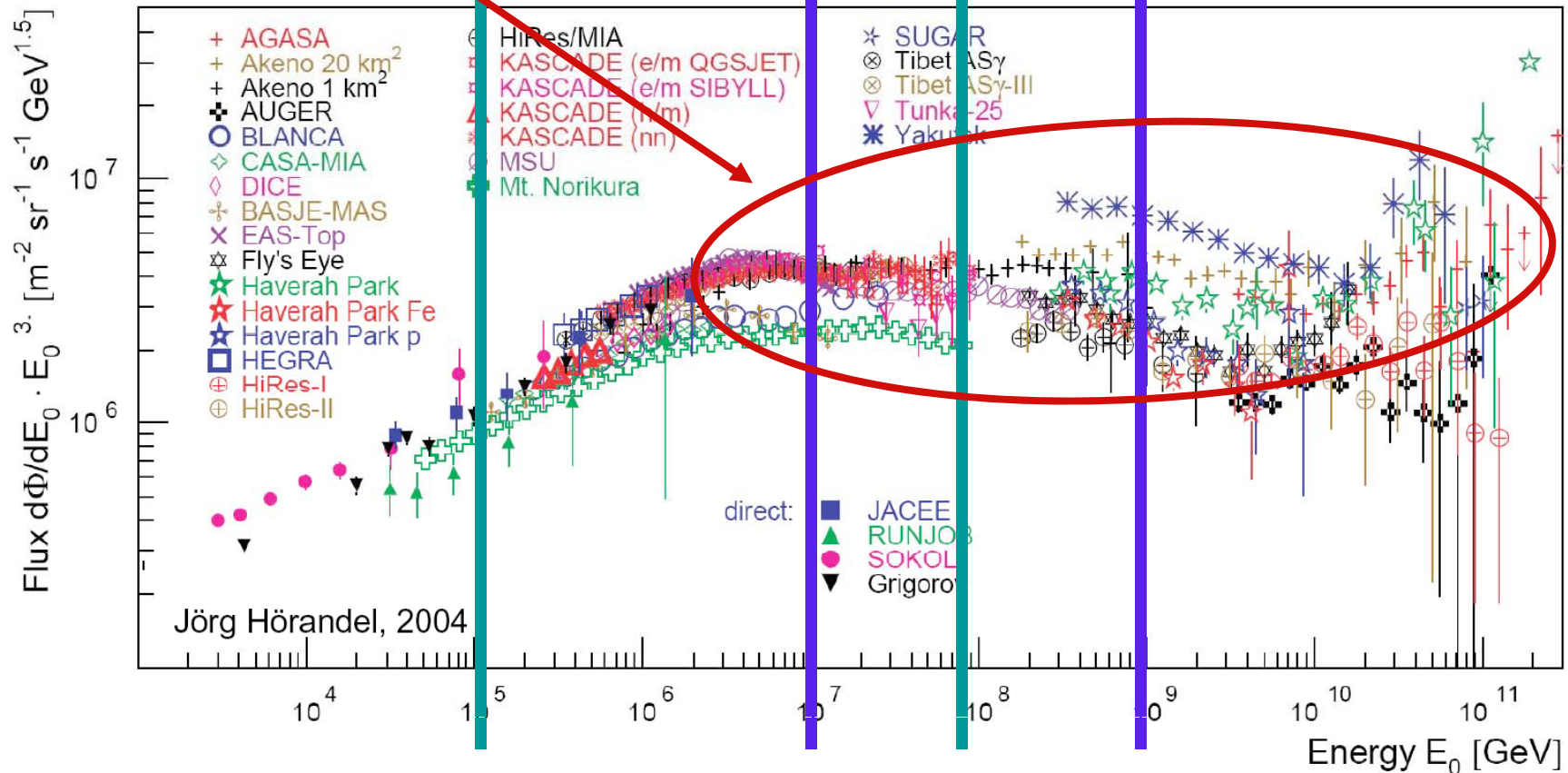**Technical: energy calibration**

Jörg Hörandel, 2004

Sources: galactic to extragalactic? "ankle"?

KASCADE: 10^{14} - $8 \cdot 10^{16}$ eV
## -Grande: 10^{16} - 10^{18} eV

Anisotropies

Jörg Hörandel, 2004

Summary KASCADE and EAS-TOP Results (first knee):

Extrapolation direct measurements

Light comp. breaks off first
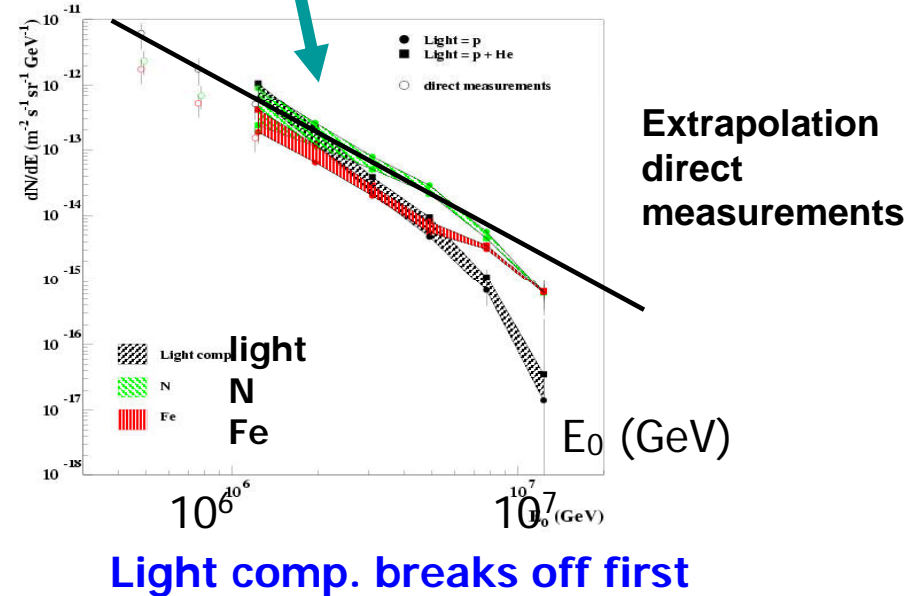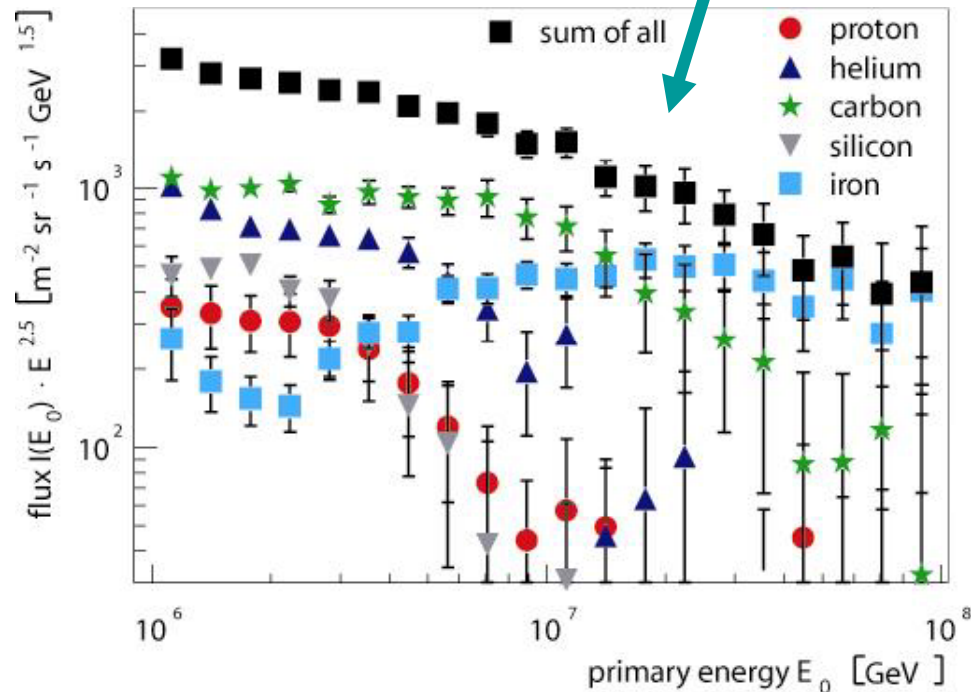
-) **Analysis: Correlation studies are required (➔ multiparameter measurements needed)**

(Analyzing mean values of data and simulations appears inadequate)

-) **Knee is due to decrease in flux in light primaries!** (model independent; most experiments)

-) **How precise are the models ?** (no new physics needed, compare proton spectrum)

-) **Distinguishing between astrophysical models** (Investigation of Anisotropy for different primaries)

-) **Knee position dependence: ∝ Z or ∝ A ?**

The experimental set-up
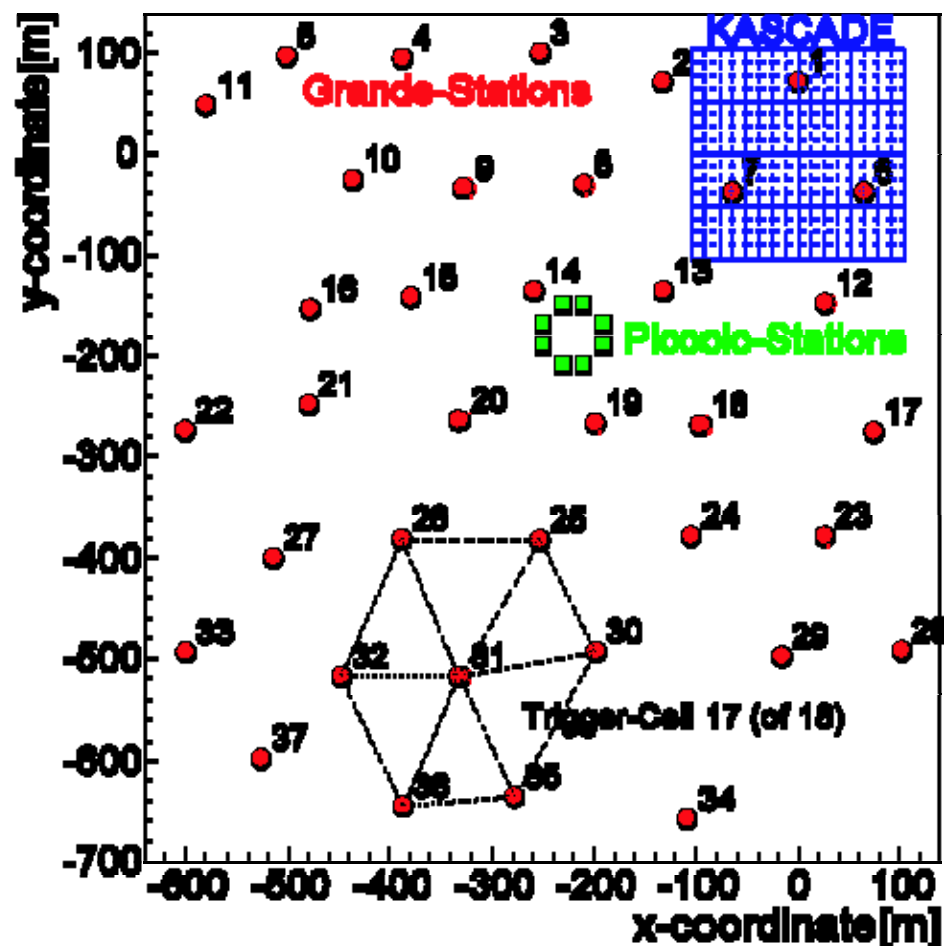
Detector	Detected EAS component	Sensitive area (m2)
Grande	Charged particles	37x10
Piccolo	Charged particles	8x10
KASCADE array e/γ	Electrons, γ	490
KASCADE array μ	Muons ($E\mu^{th}$=230 MeV)	622
MTD	Muons (Tracking) ($E\mu^{th}$=800 MeV)	3x128
MWPCs/LSTs	Muons ($E\mu^{th}$=2.4 GeV)	3x129
LOPES 30	Radio	
Trigger Plane	Muons ($E\mu^{th}$=490 MeV)	208
Calorimeter	Hadrons	9x304

The strength of KASCADE-Grande is the multi observables information
Requirement: keep a good accuracy till 10^{18}eV

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The KASCADE Array

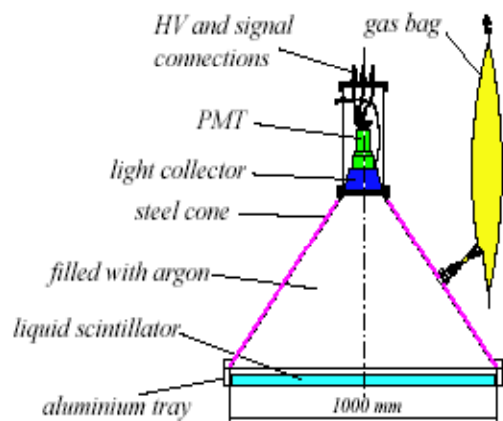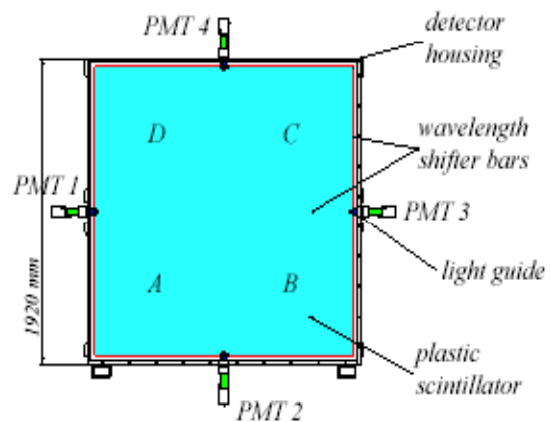

e/γ - detector
(liquid scintillator)

lead/iron absorber

muon detector
(plastic scintillator)

- 252 detectors
- 3.2 m^2 each
- 13 m distant
- 200 x 200 m^2
- **e/γ** : liquid, 48 mm
- **μ** : plastic, 30 mm

HV and signal connections
gas bag
PMT
light collector
steel cone
filled with argon
liquid scintillator
aluminium tray
1000 mm

PMT 4
detector housing
D   C
wavelength shifter bars
PMT 1
PMT 3
light guide
1920 mm
A   B
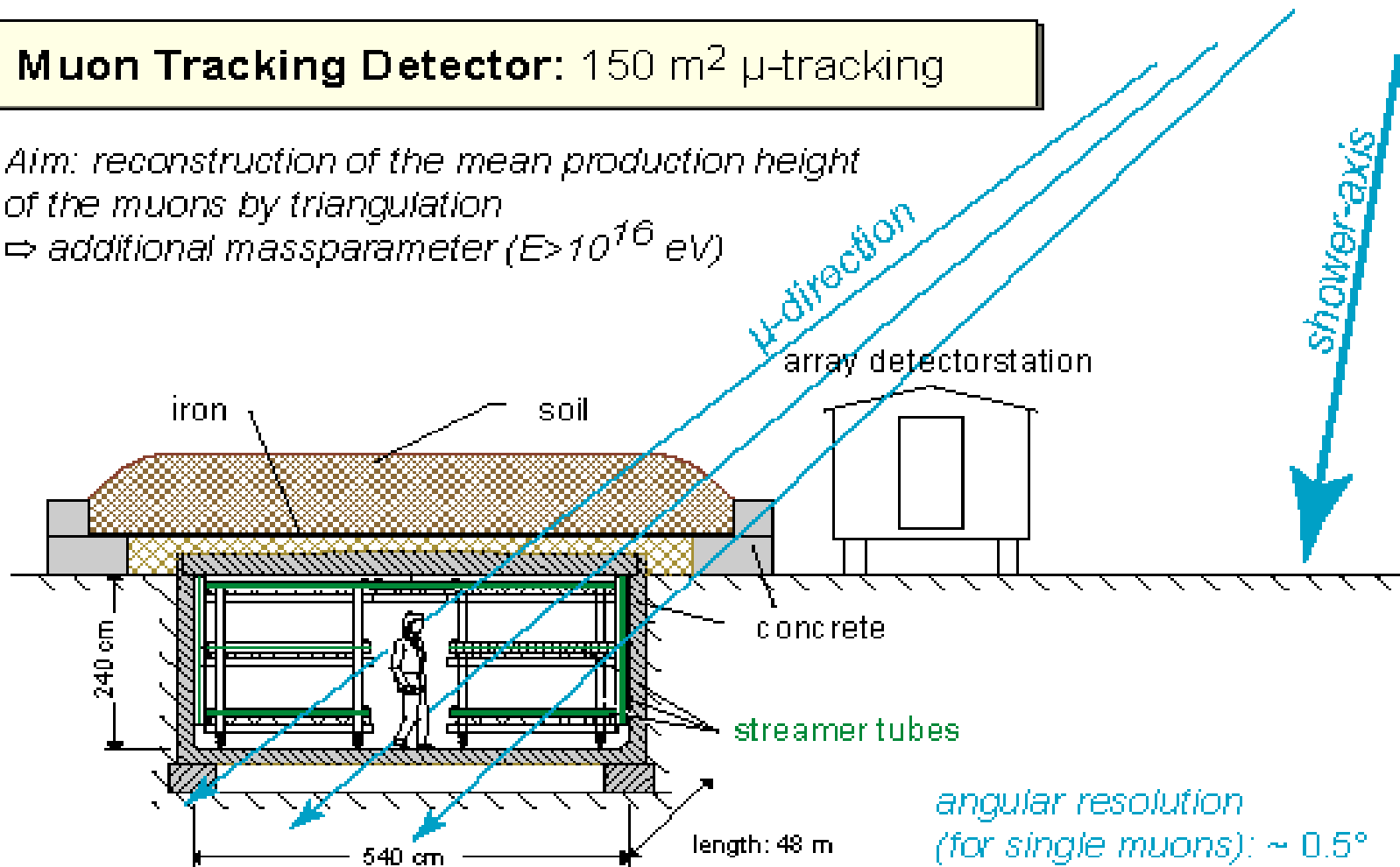plastic scintillator
PMT 2

e/γ - detector   muon detector

The muon tunnel
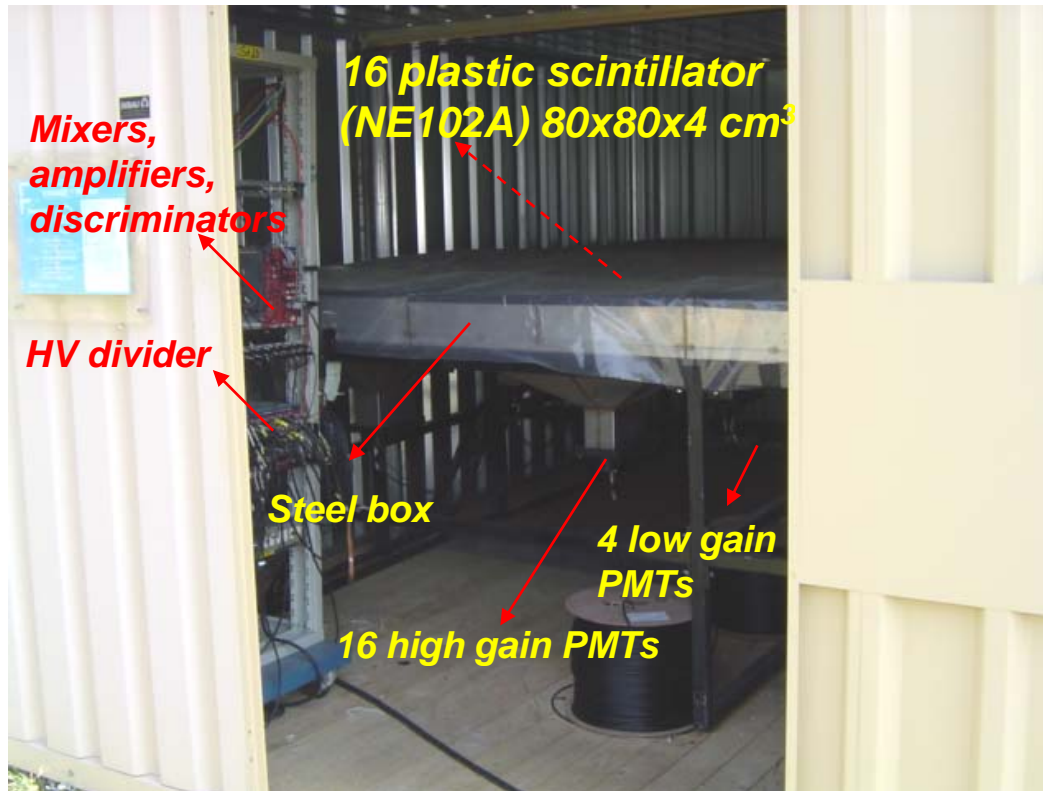
Muon Tracking Detector: 150 m^2 μ-tracking

Aim: reconstruction of the mean production height
of the muons by triangulation
⇒ additional massparameter (E>10^{16} eV)

μ-direction
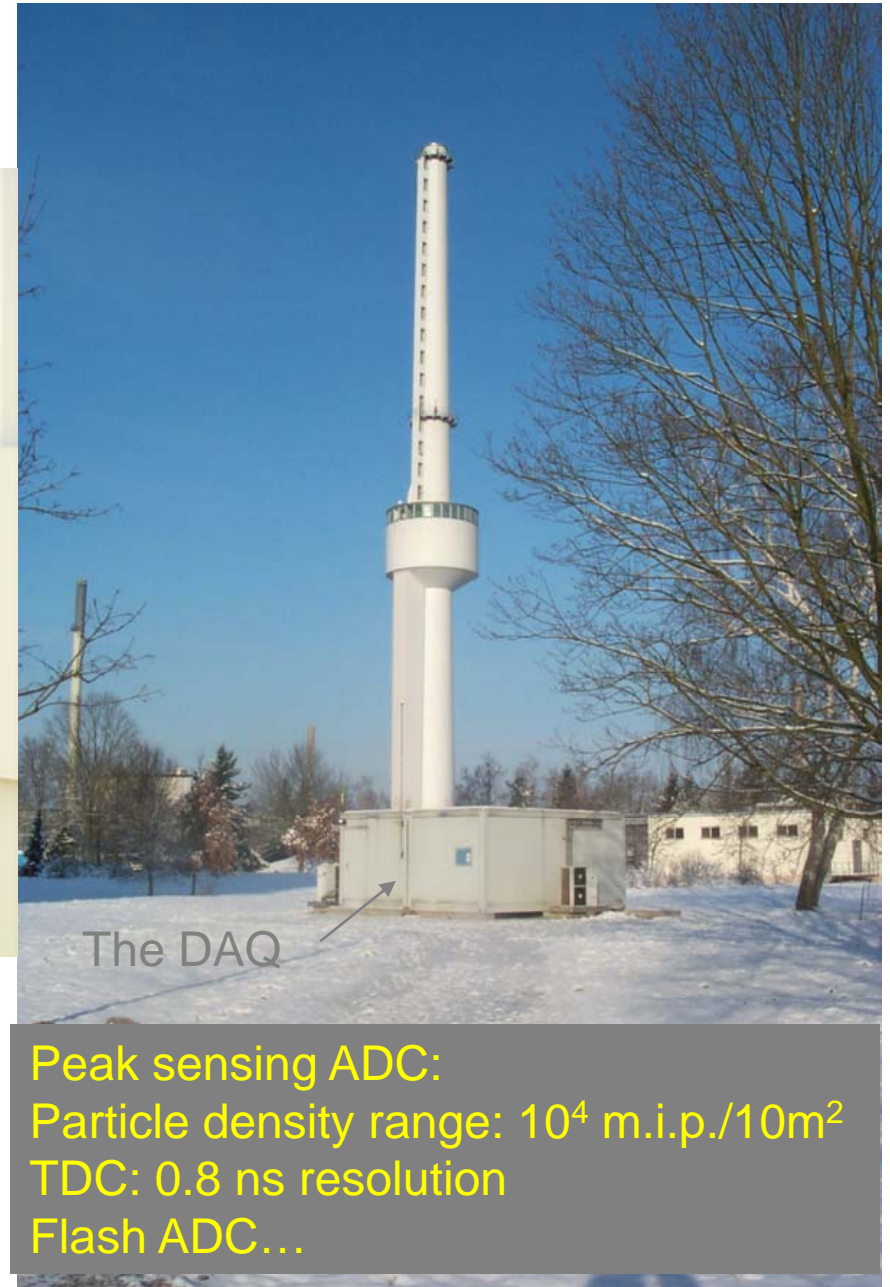
shower-axis

array detectorstation

iron   soil

concrete

240 cm

streamer tubes

540 cm   length: 48 m

angular resolution
(for single muons): ~ 0.5°

The GRANDE Array

The detector station

Mixers, amplifiers, discriminators

HV divider

16 plastic scintillator (NE102A) 80x80x4 cm³

Steel box

4 low gain PMTs

16 high gain PMTs

The DAQ

37 Stations of plastic scintillators 10 m²
140 m average distance
0.5 km² total surface

Peak sensing ADC:
Particle density range: 10^4 m.i.p./10m²
TDC: 0.8 ns resolution
Flash ADC…

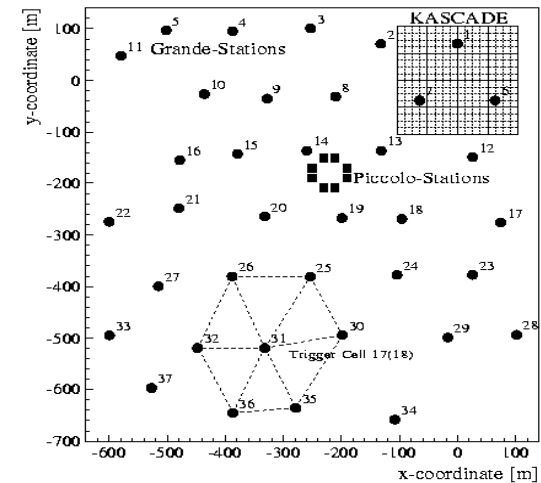# KASCADE-Grande : Reconstruction steps

1) **core position and angle-of-incidence**
   from Grande array data

2a) **shower size (charged particles)**
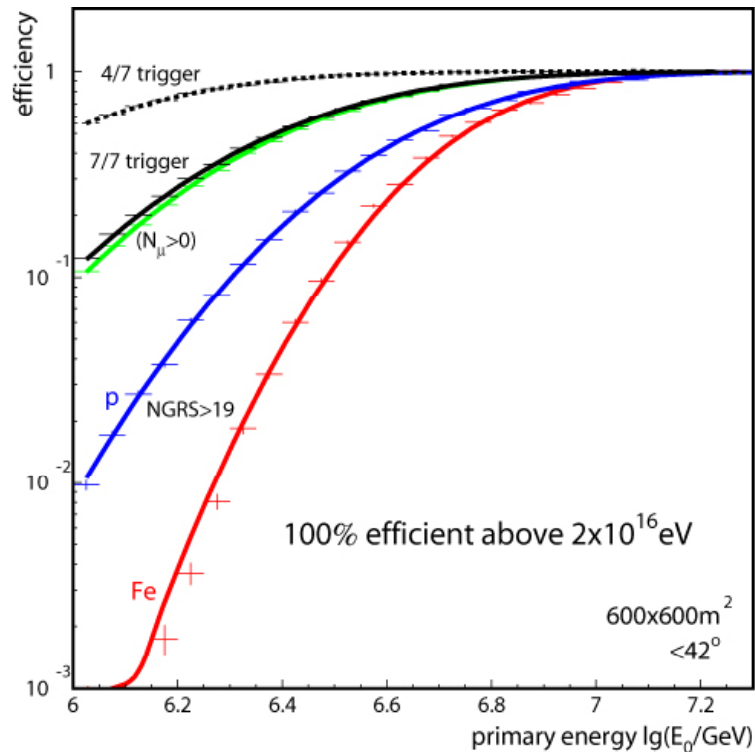   from Grande array data

2b) **muon number**
   from KASCADE muon detectors

3) **electron number**
   from Grande by subtraction of muon content
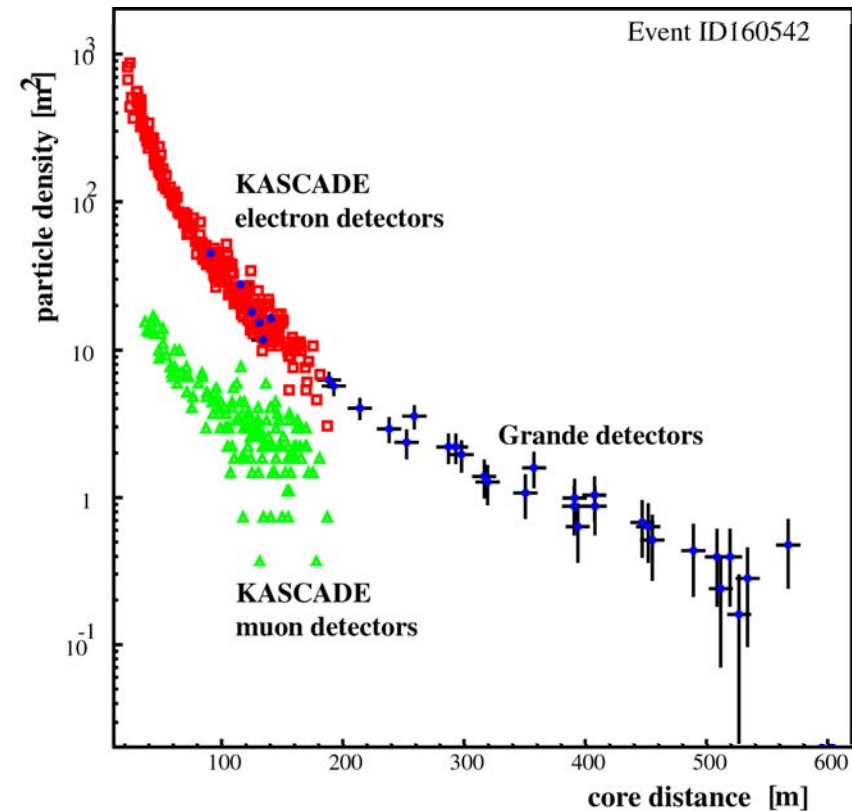
4) **two dimensional size spectrum for the analysis**

KASCADE-Grande : Efficiency

KASCADE-Grande : Single event measurement

**100% efficient above 2×10^{16} eV**

$600 \times 600 \, m^2$
$< 42°$

lateral distribution of a single event measured by KASCADE-Grande:
$E_0 \approx 2 \cdot 10^{17}$ eV, $\Theta = 33°$

- **Common events (all detector components) measured since December 2003**
- **Trigger: 7 of 7 stations at one of 18 hexagons**

Reconstruction : comparison Grande – KASCADE array

Event Selection:

At least 10 out of 32 pmt

inside a KASCADE cluster

7/7 coincindence in Grande

ΔE_{max} in Grande Station 7

0 m < r_{KA} < 90 m

Log Ne_{KA} > 6.0

0.4<s_{Grande}<1.4

Grande Station 7
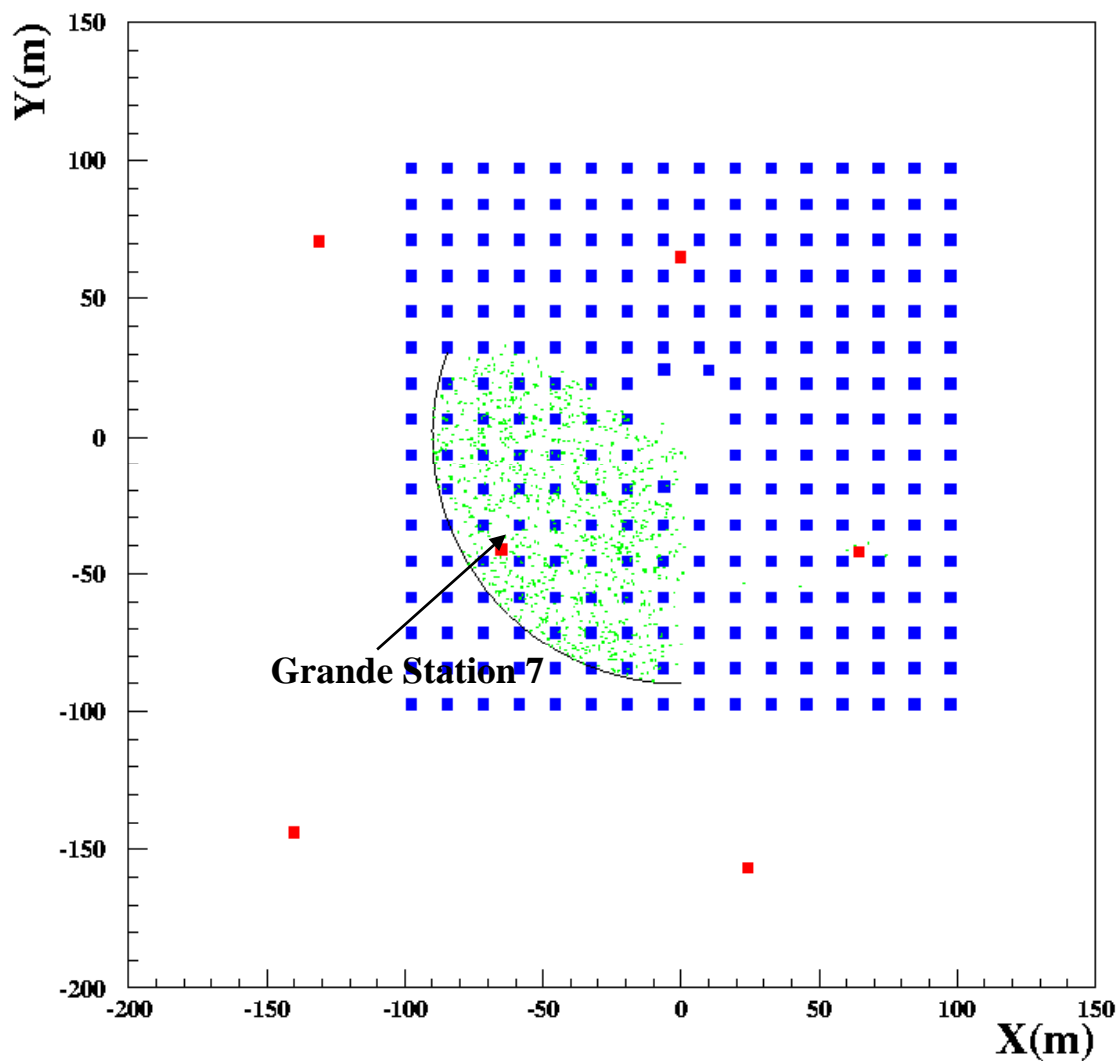
Reconstruction : comparison Grande – KASCADE array

Arrival direction

Core position

mode: 0.58 deg

mode: 6.4 m
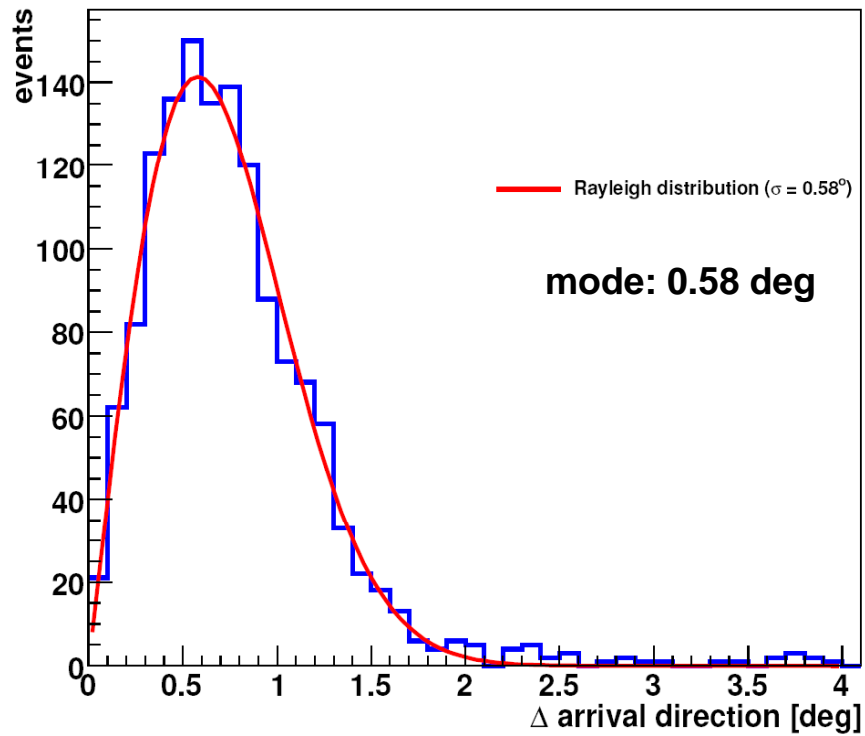
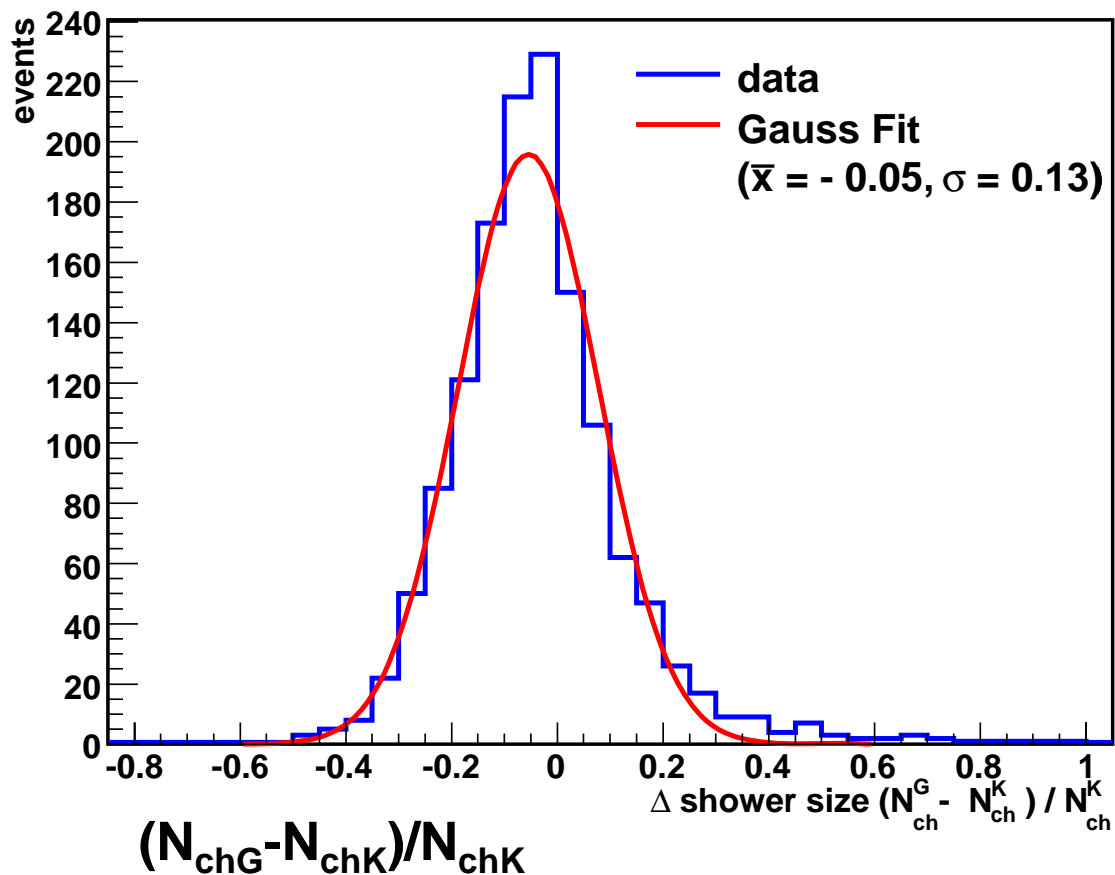$\omega_k - \omega_g$ (deg)
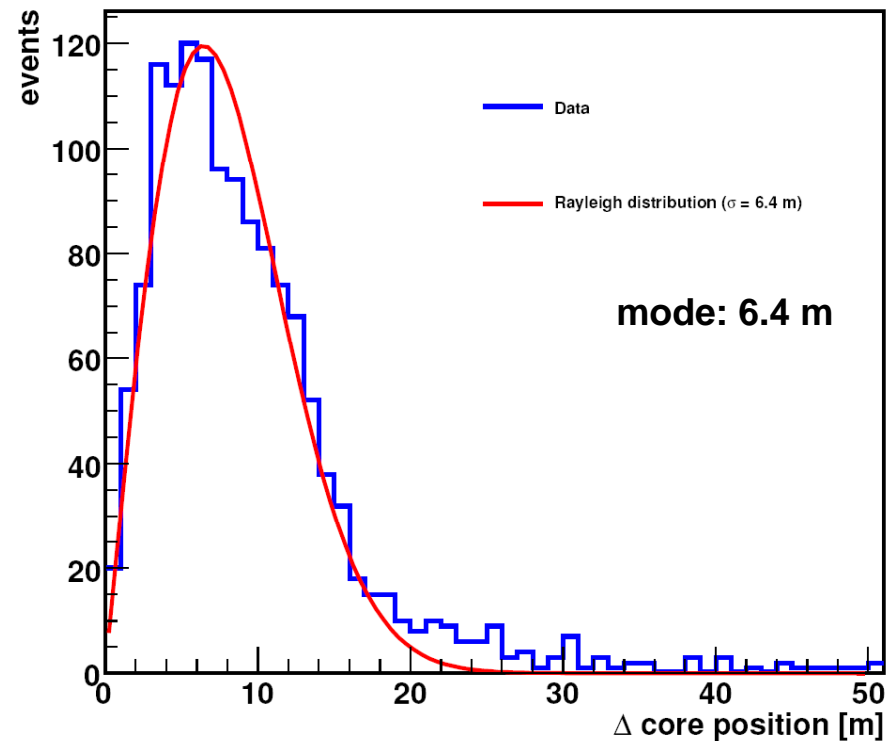
Δr (core position)

Federico Di Pierro et al. – KASCADE-Grande coll., ICRC (2007)
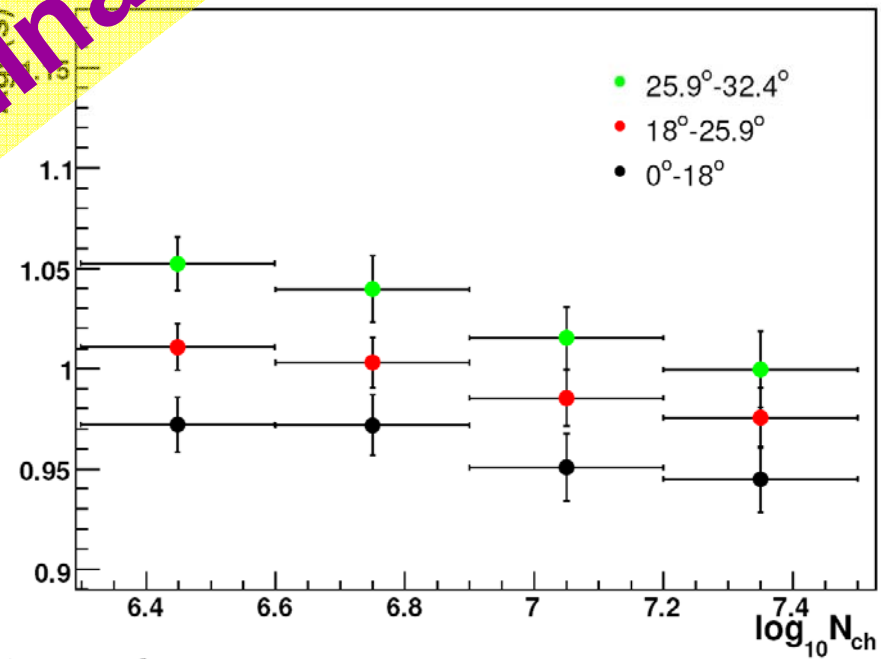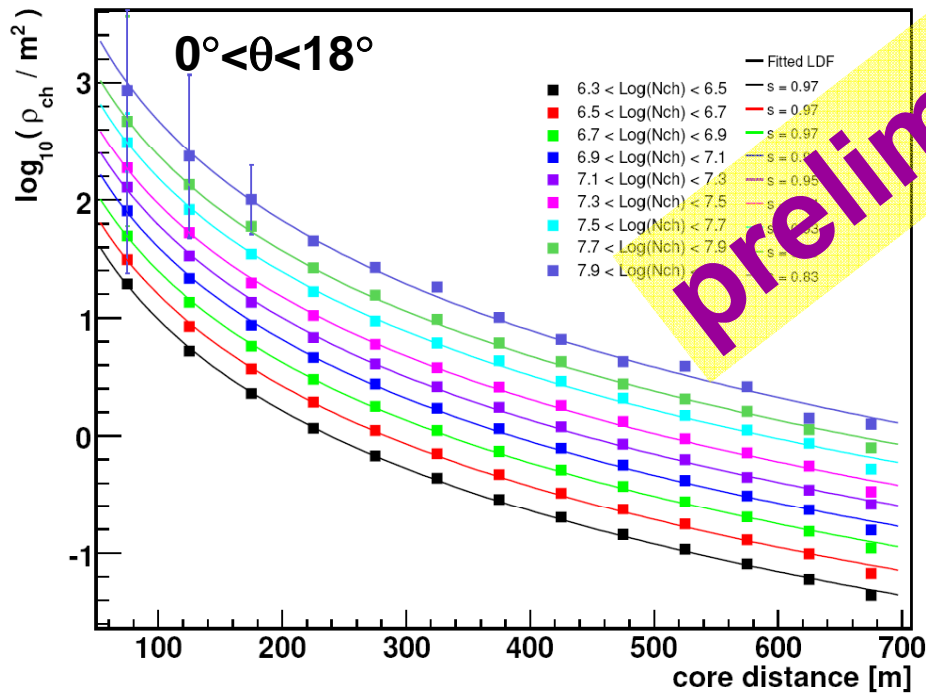
Reconstruction : comparison Grande – KASCADE array

Size

Cross-check between EAS-TOP and KASCADE

Legend: data (blue), Gauss Fit ($\bar{x} = -0.05$, $\sigma = 0.13$) (red)

x-axis: Δ shower size $(N_{ch}^{G} - N_{ch}^{K}) / N_{ch}^{K}$

$(N_{chG} - N_{chK})/N_{chK}$

KASCADE-Grande : lateral distributions

charged particle lateral distribution

s parameter

2-year data, core inside Grande array

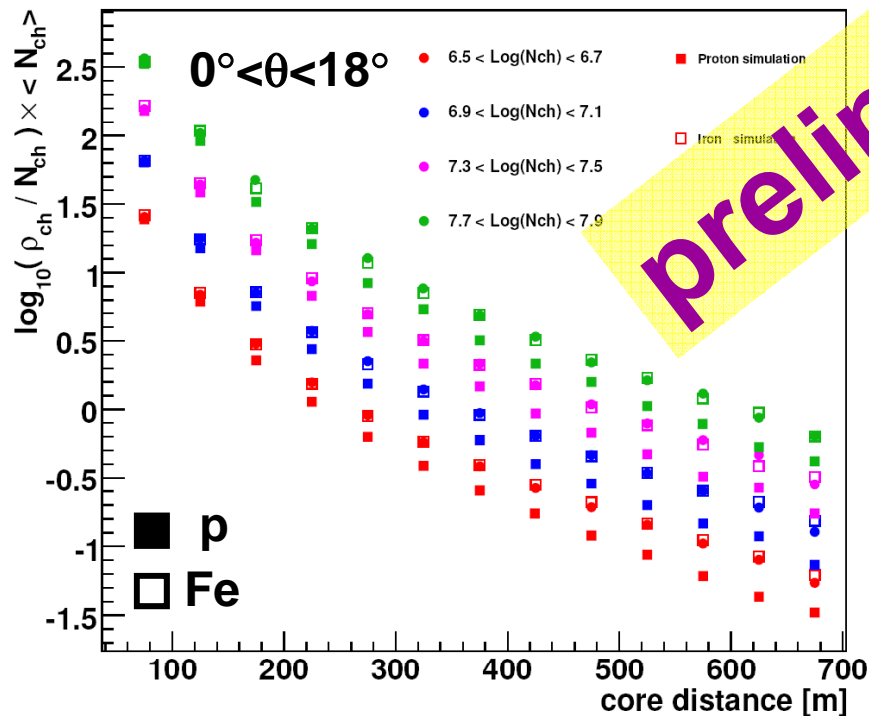$$\rho_{ch} = N_{ch} \cdot C(s) \cdot (r/r_0)^{s-\alpha} \cdot (1+r/r_0)^{s-\beta}$$

$\alpha = 1.5$, $\beta = 3.6$, $r_0 = 40m$

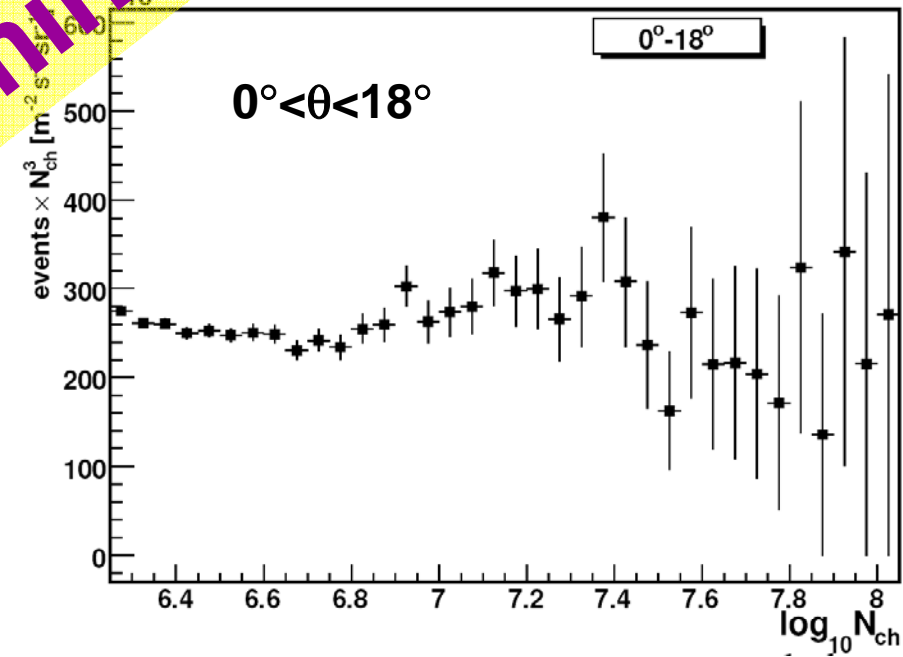**Federico Di Pierro et al. – KASCADE-Grande coll., ICRC (2007)**

KASCADE-Grande :
lateral distributions and size spectrum

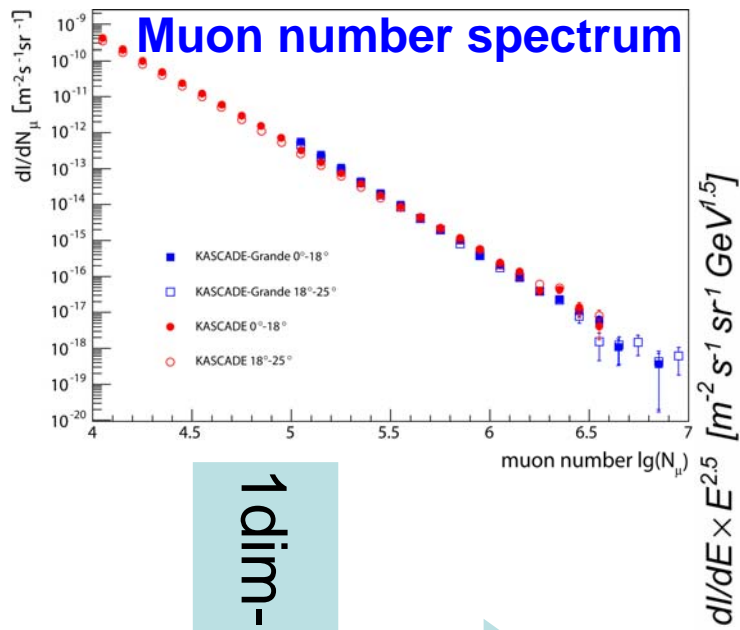**charged particle lateral distribution**

size spectrum parameter

2-year data, core inside Grande array

reconstruction gives reasonable spectra
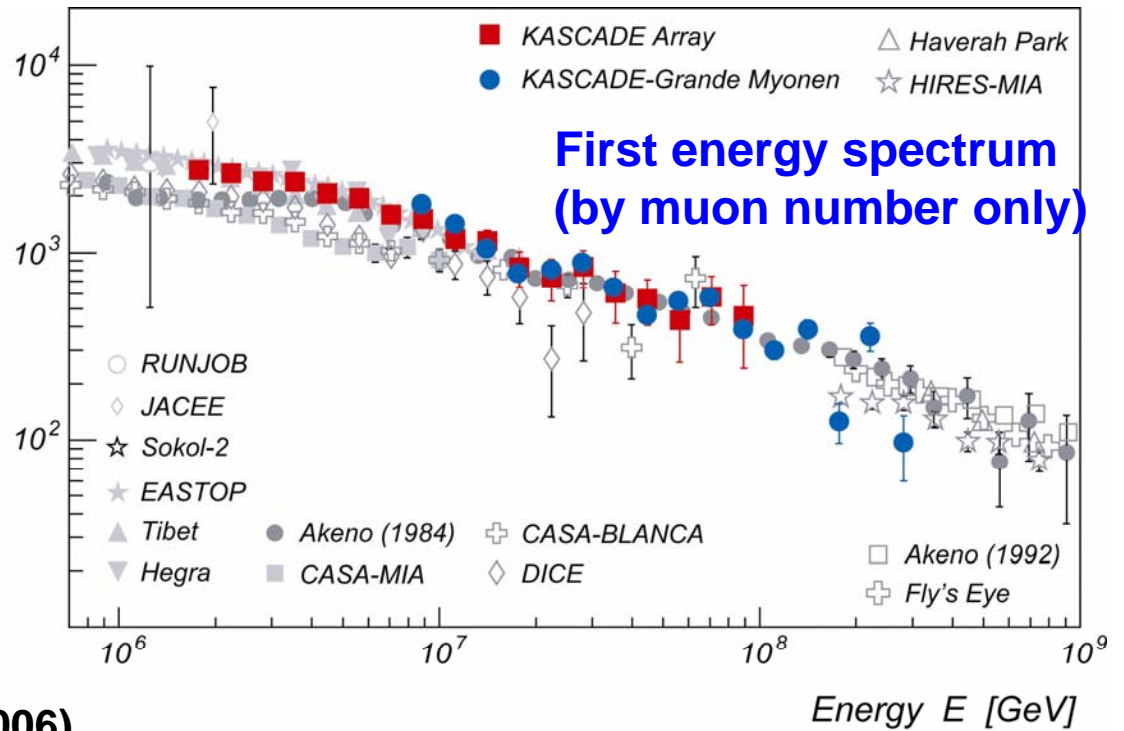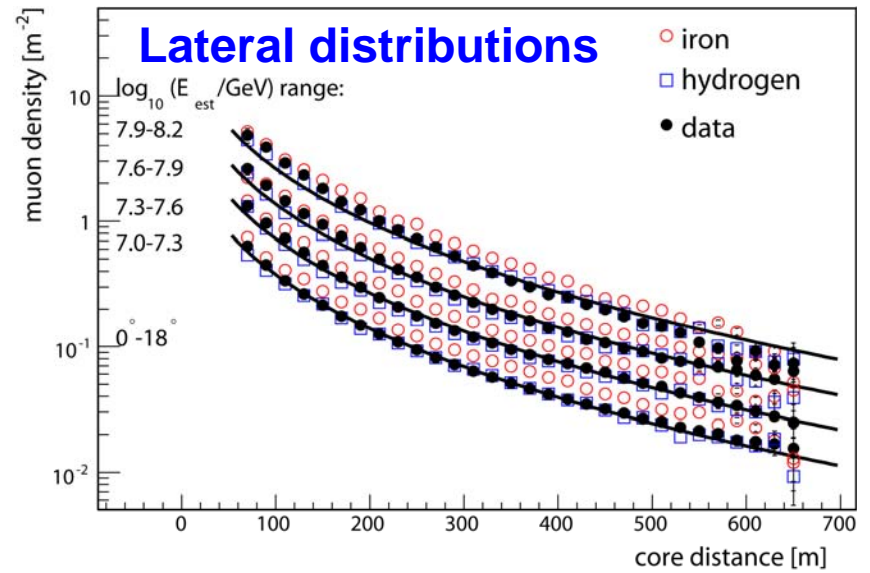**careful checks of systematic effects in work**

Muon
lateral distribution
number spectrum
and 1-dim unfolding

Lateral distributions

Muon number spectrum

1dim- unfolding

First energy spectrum (by muon number only)

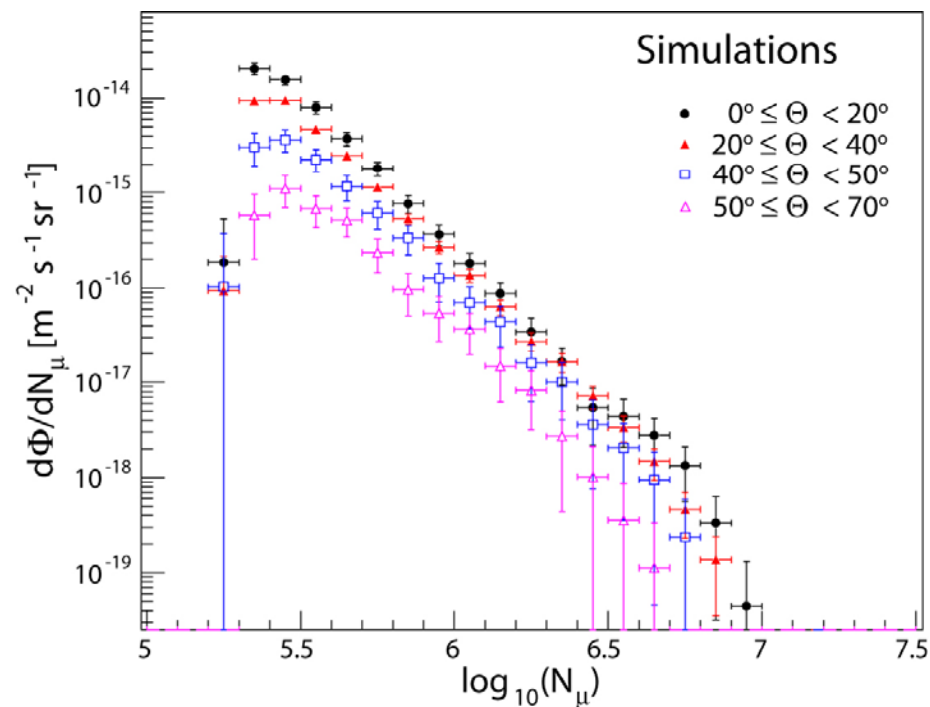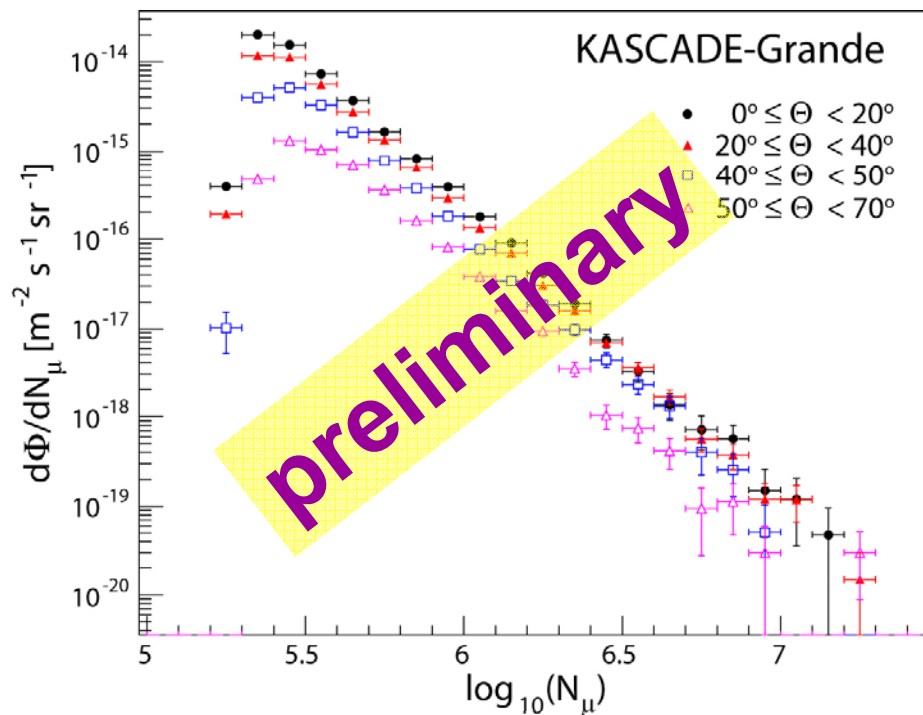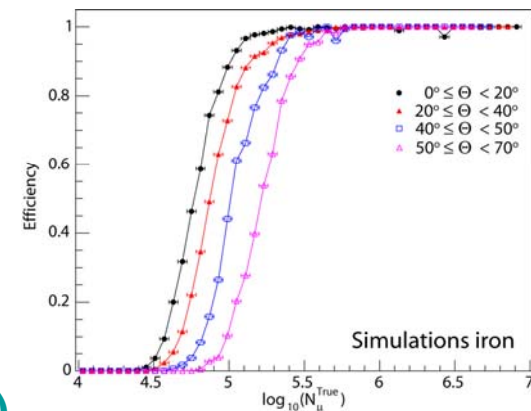**Jurriaan van Buren, PhD thesis (2006)**

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KASCADE-Grande : first analyses
muon reconstruction at inclined showers

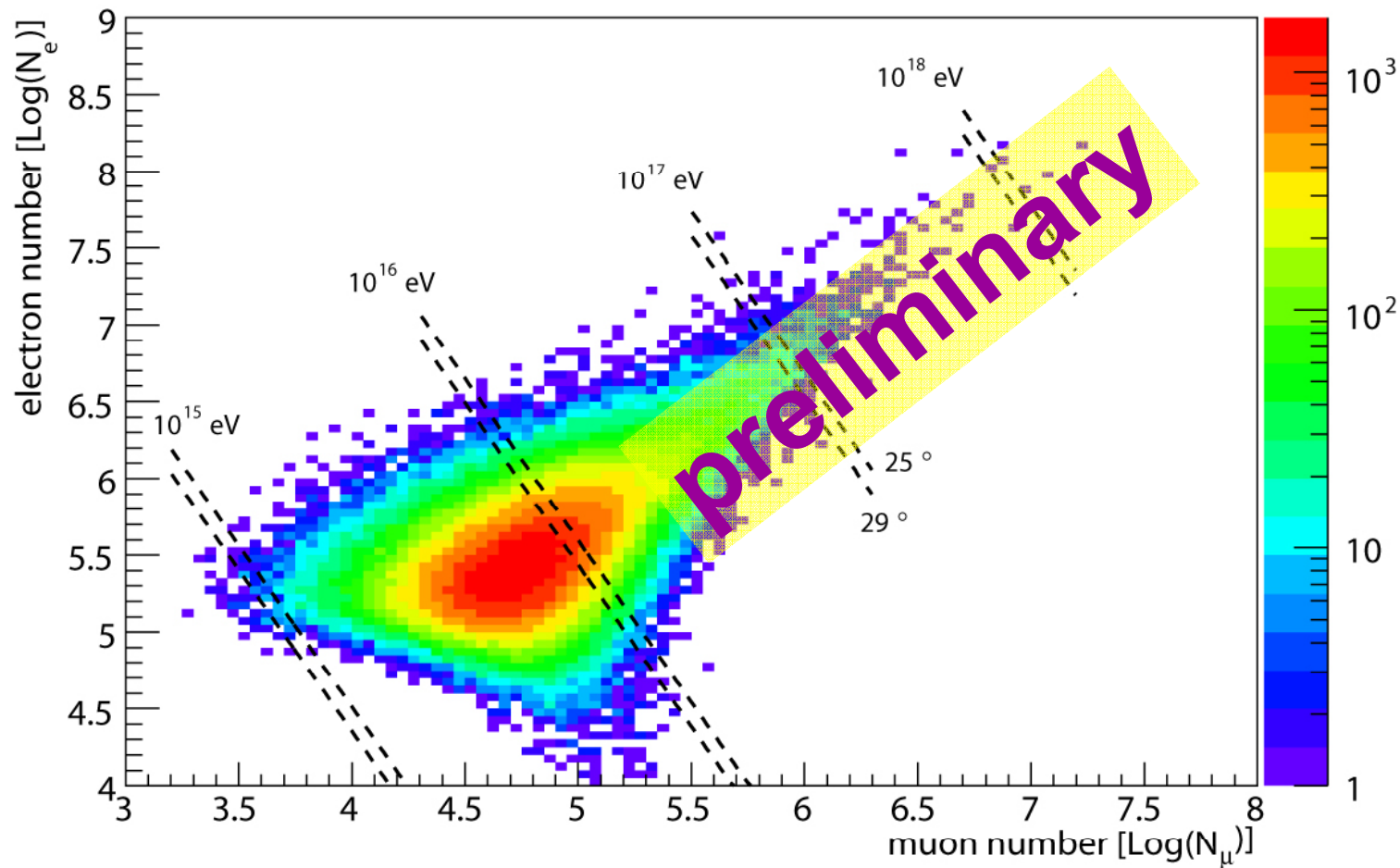
-muon number reconstruction possible up to 70°
-investigation of attenuation of muon component
➔model tests
➔Increasing of KASCADE-Grande statistics

Juan Carlos Arteaga et al. – KASCADE-Grande coll., ICRC (2007)
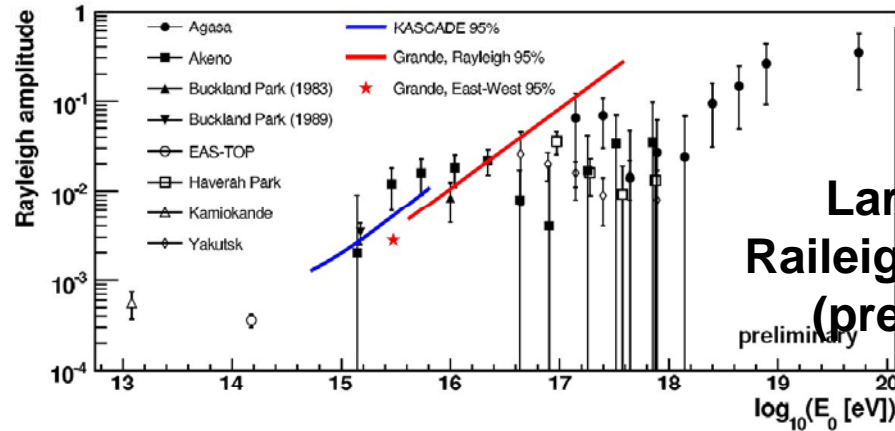
2-dimensional analysis (Ne-Nμ)

Unfolding of 2-dimensional shower size spectrum possible
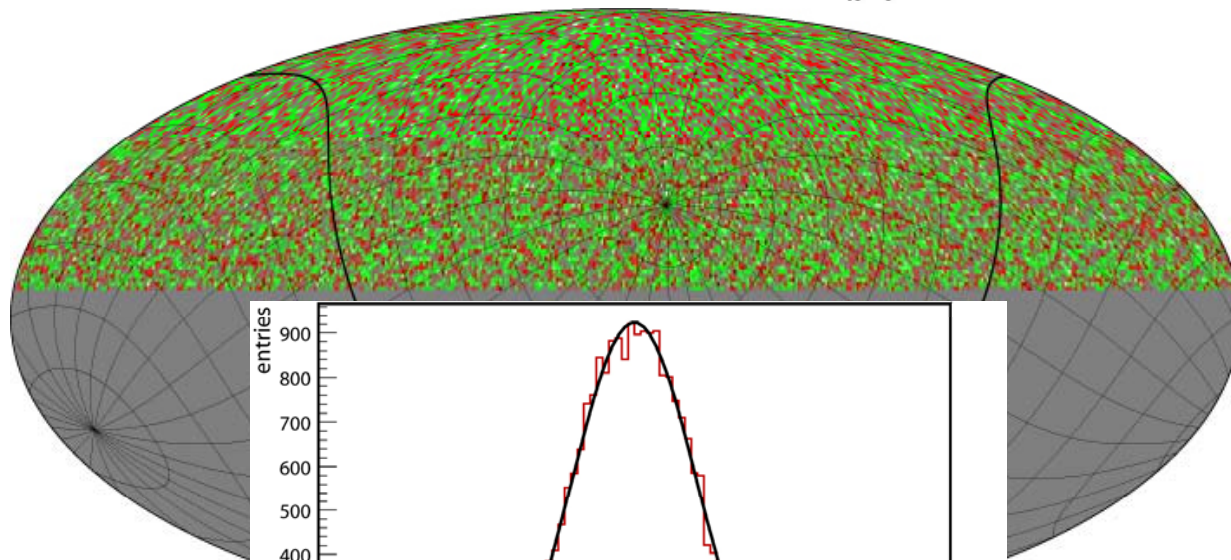➔ **energy & composition, but still improvements in systematics needed**

Fabiana Cossavella et al. – KASCADE-Grande coll., ICRC (2007)

Anisotropies: first analyses

**Large scale
Raileigh amplitude
(preliminary)**

**Until now no hint
for point source
(very preliminary)**
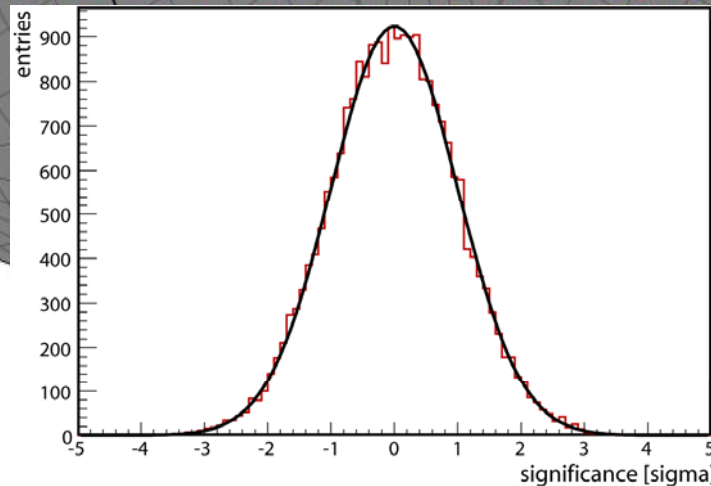
**Sven Over et al. –
KASCADE-Grande coll., ICRC (2007)**

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Conclusions

- **KASCADE-Grande is in continuous and stable data taking since 2004**
- **The detector has been studied and understood**
- **The performance of the detector looks promising**
- **First analysis show reasonable preliminary results**
- **Lot of physics to be explored…**

THANK YOU for your attention!

KASCADE-Grande Collaboration

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Forschungszentrum and University of Karlsruhe

W.D. Apel, J.C. Arteaga, F. Badea, K. Bekk, J. 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, 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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http://www-ik.fzk.de/KASCADE-Grande/

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