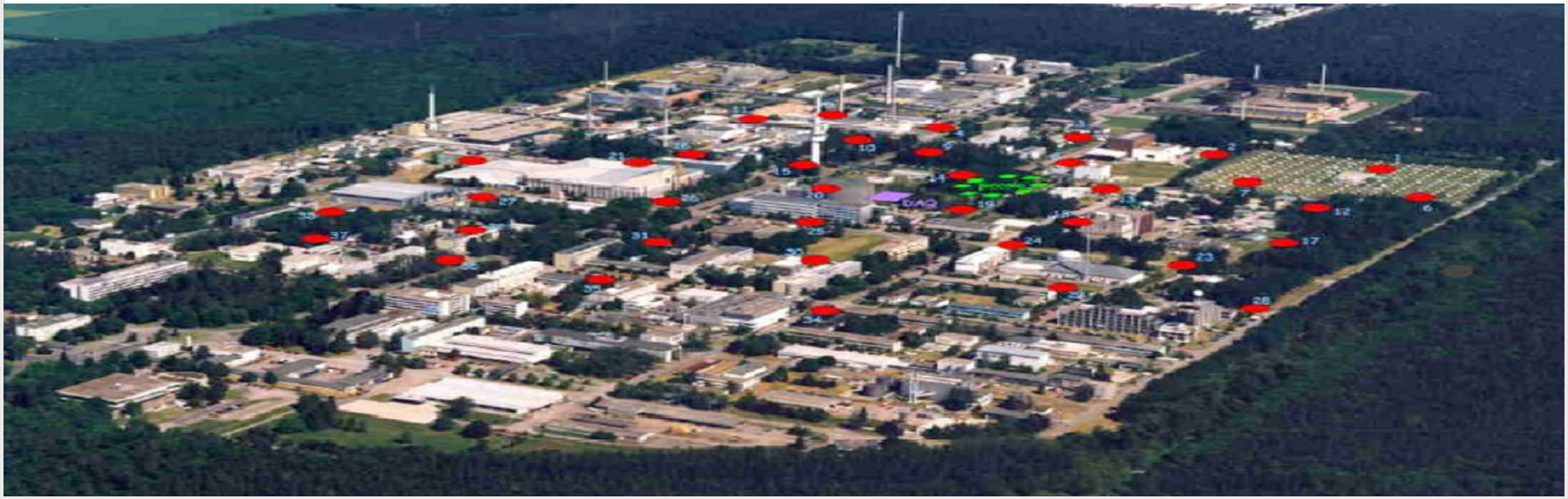
Karlsruhe Institute of Technology

KASCADE-Grande

Cosmic Rays Around the *Knee*



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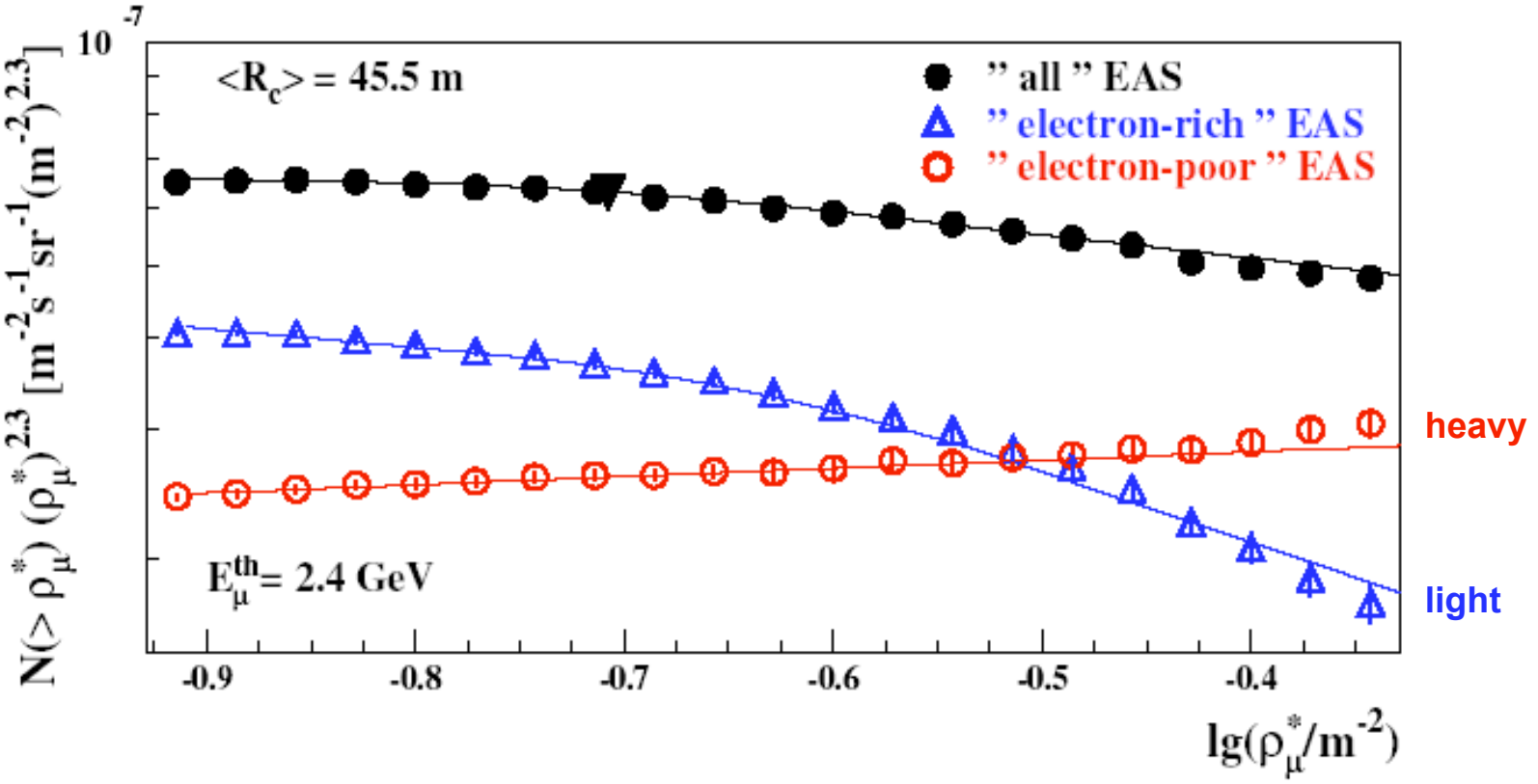
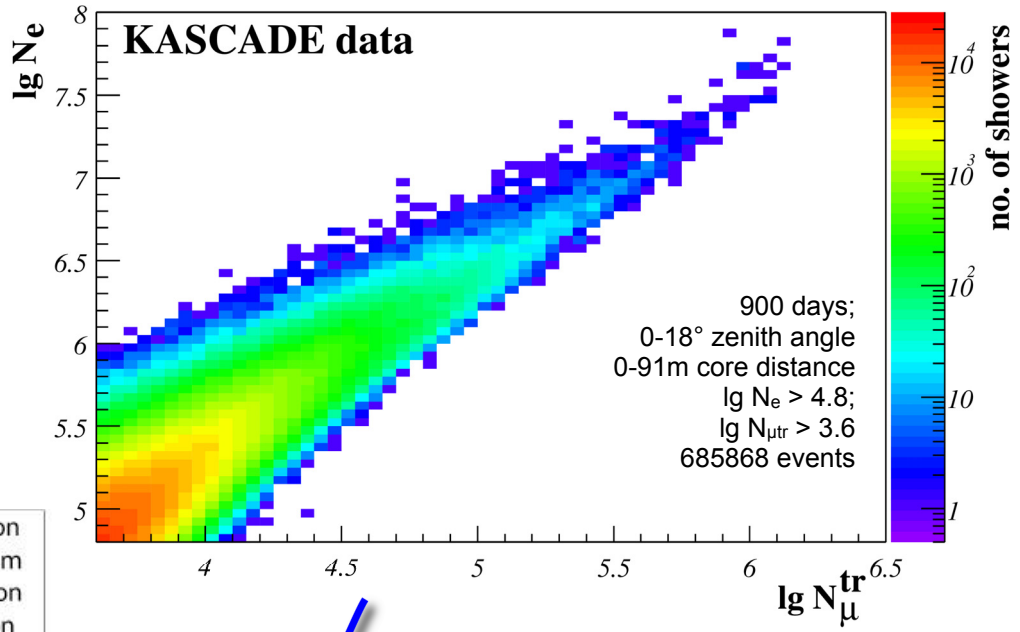
knee = decreasing flux of light component



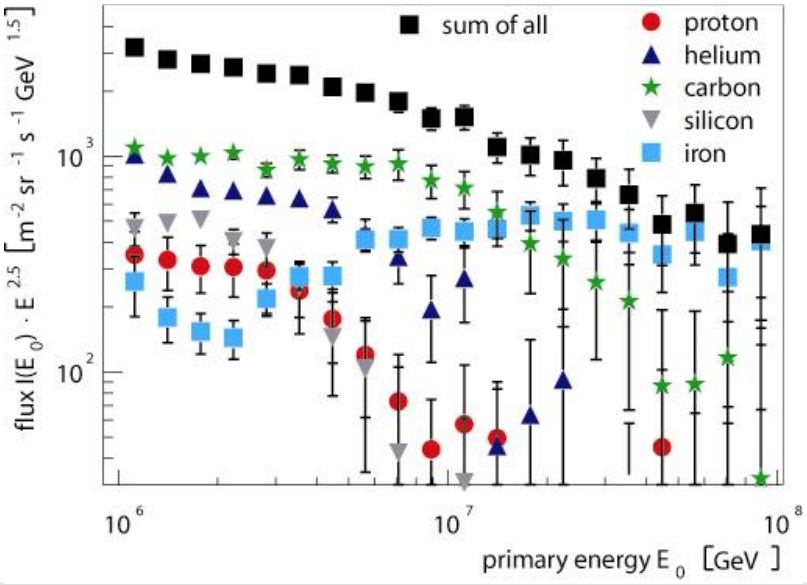
KASCADE : Astroparticle Physics 16 373 2002
need hadronic interaction models for normalization of absolute energy and mass scale

KASCADE : energy spectra of single mass groups



example:

- (at most) 5 representative mass groups
- protons drop off first
- heavier → E_{drop} higher
- abundancies unstable against change of MC codes



Wanted:

E and A of the Cosmic Ray Particles

Given:

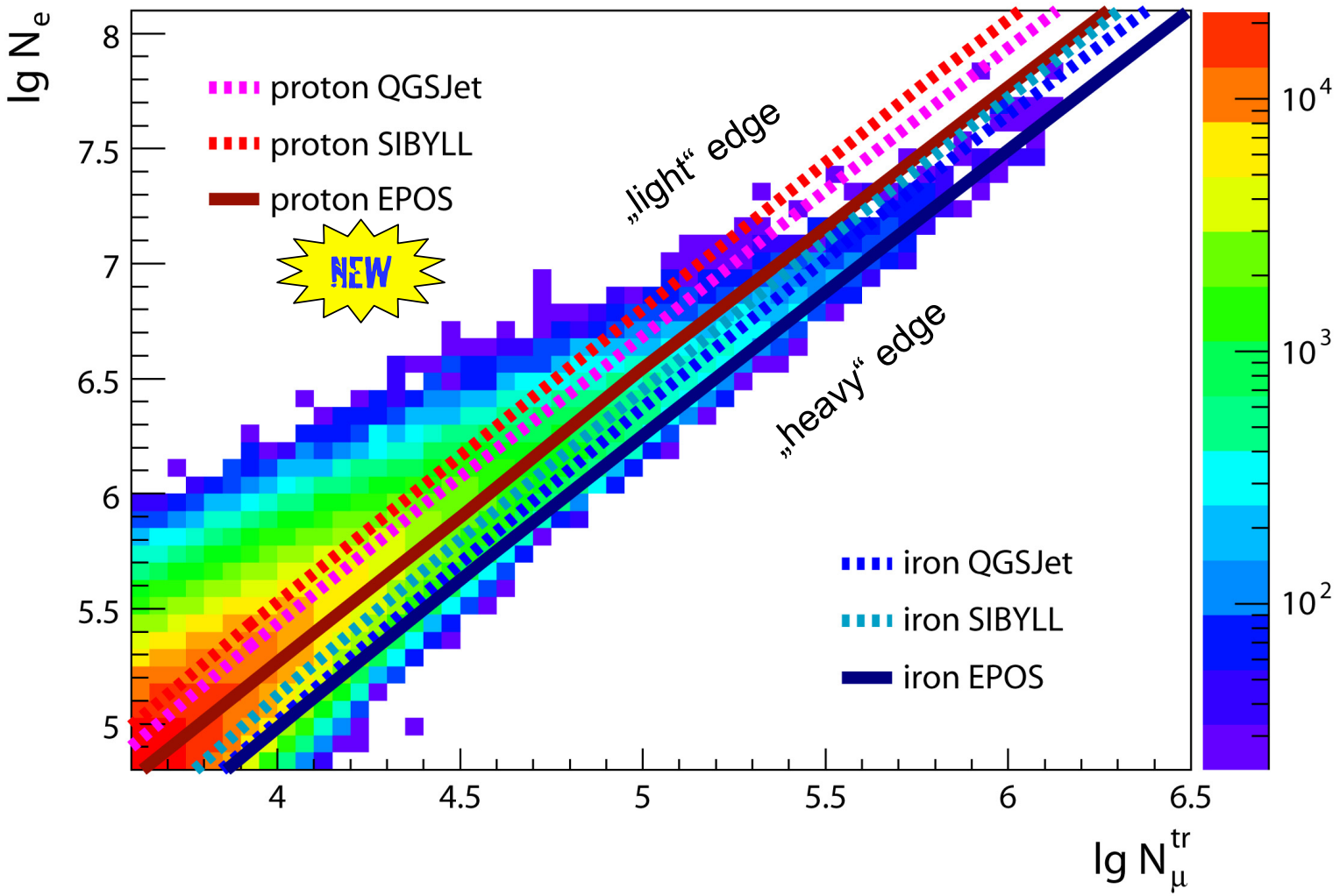
Ne and Nμ for each single event

solve the inverse problem

$$g(y) = \int K(y,x)p(x)dx$$

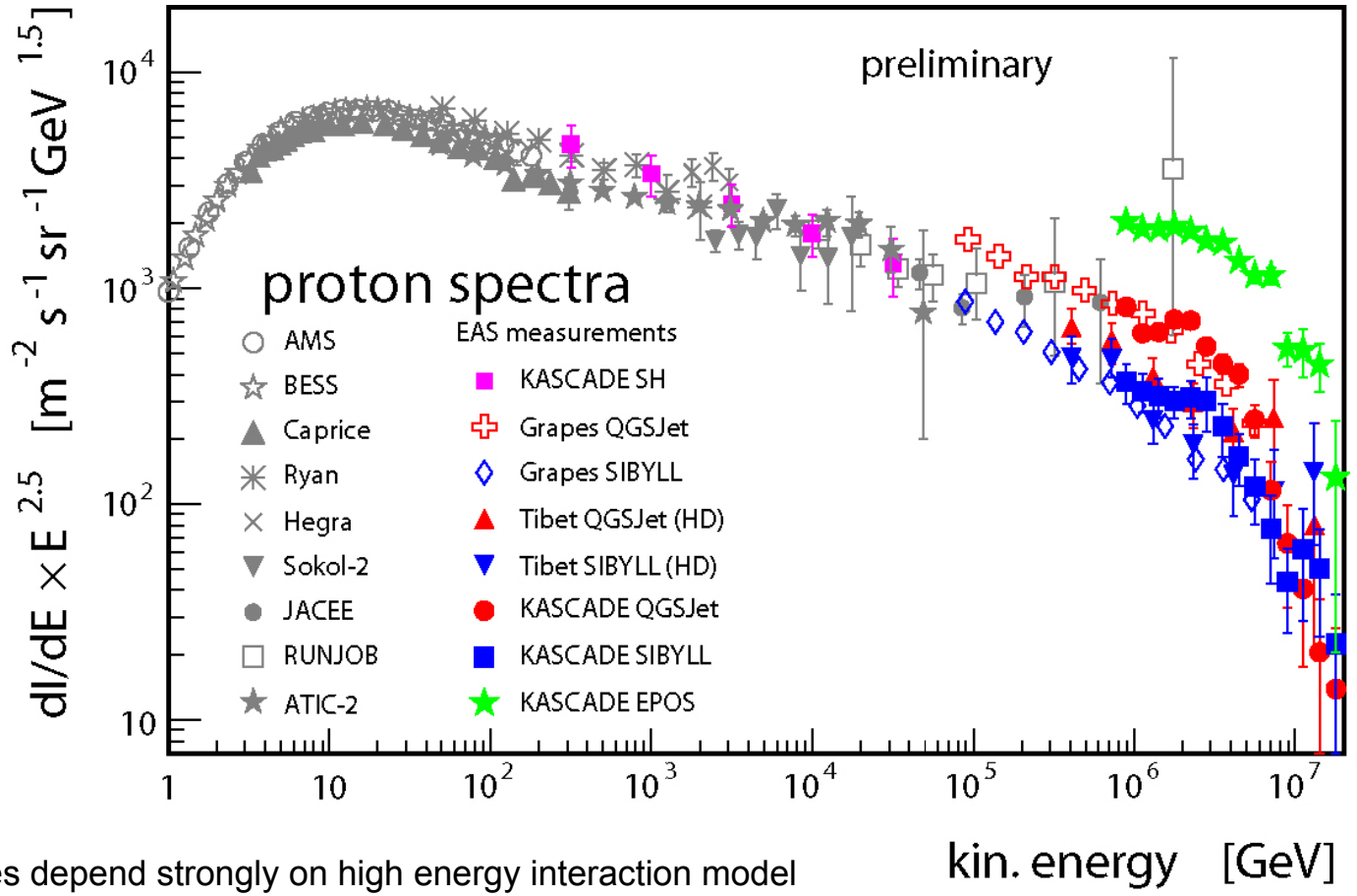
with y=(Ne,Nμtr) and x=(E,A)

KASCADE: unfolding N_e/N_μ with different models



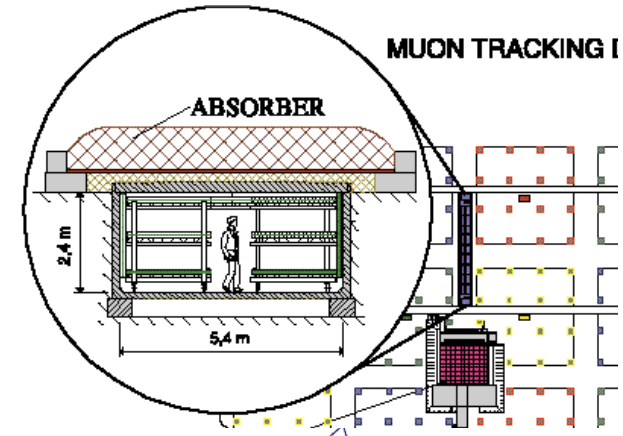
KASCADE: unfolding summary

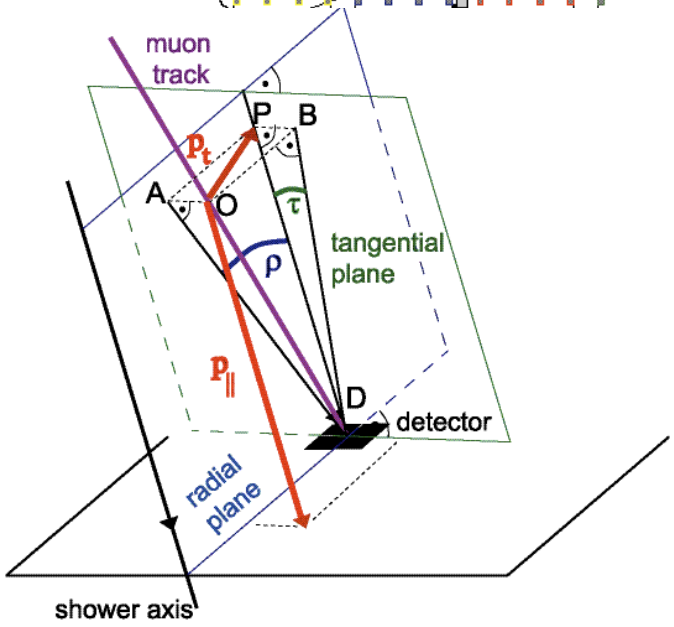
- ☑ knee visible in data structure
- ☑ knee caused by light primaries
- ☑ composition gets heavier across knee
- ☑ positions of knee vary with primary elemental group
- ☑ result consistent for different data sets

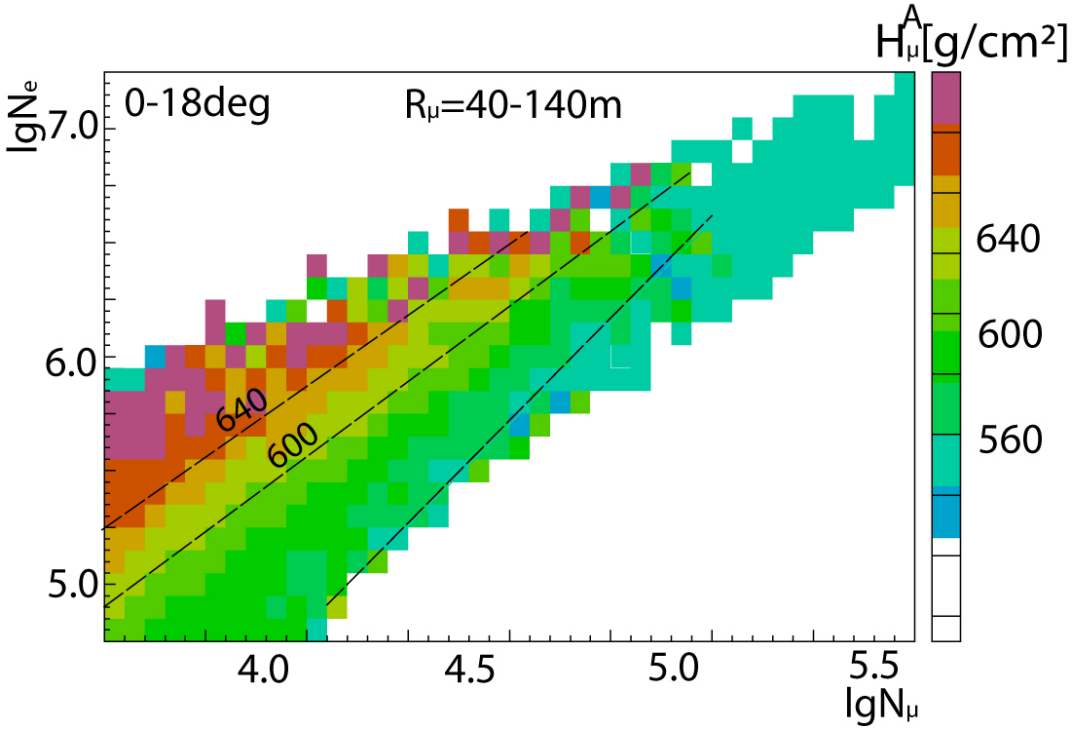


- ✱ relative abundancies depend strongly on high energy interaction model
- ✱ result only weakly dependent on low energy interaction model
- ✱ no (interaction) model can describe the data consistently
- ✱ all-particle spectra agree inside uncertainties (- EPOS)

KASCADE: muon triangulation being added







Sensitivity to composition & models !

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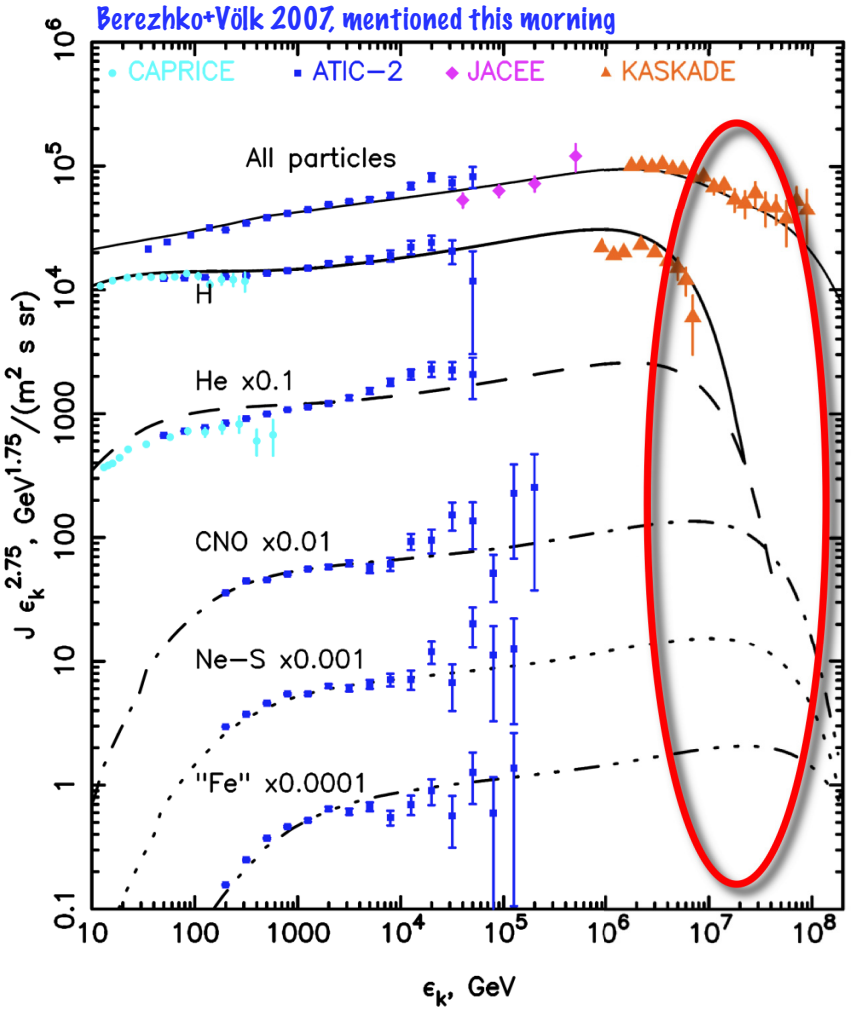
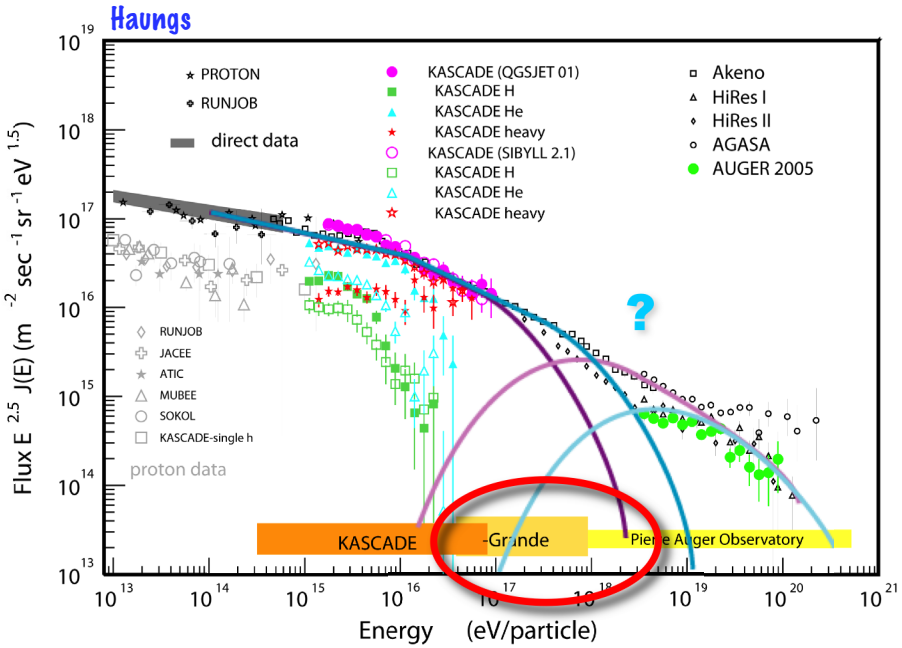
KASCADE-Grande: motivation





extend the energy range & improve composition measurements

KASCADE-Grande

instrumented area:
0.04 → 0.5 km^2
▶ measurements of air showers in the energy range 100 TeV - 1 EeV

scintillators from previous EAS-TOP expt.

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KASCADE-Grande Collaboration

Institut für Kernphysik
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Universität Wuppertal
Fachbereich Physik
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IFSI, INAF
and University of Torino
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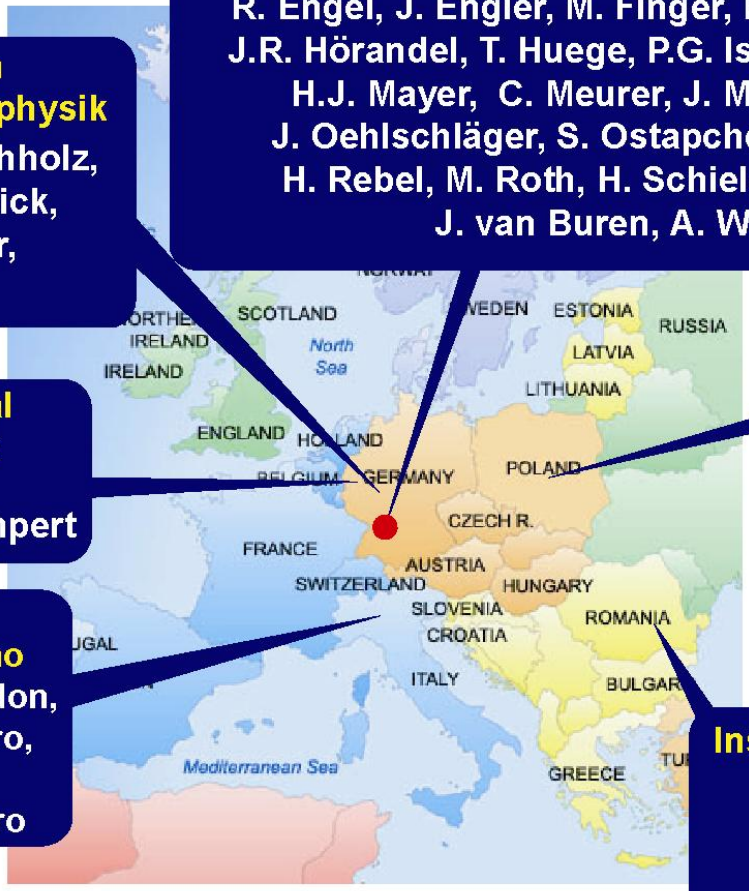

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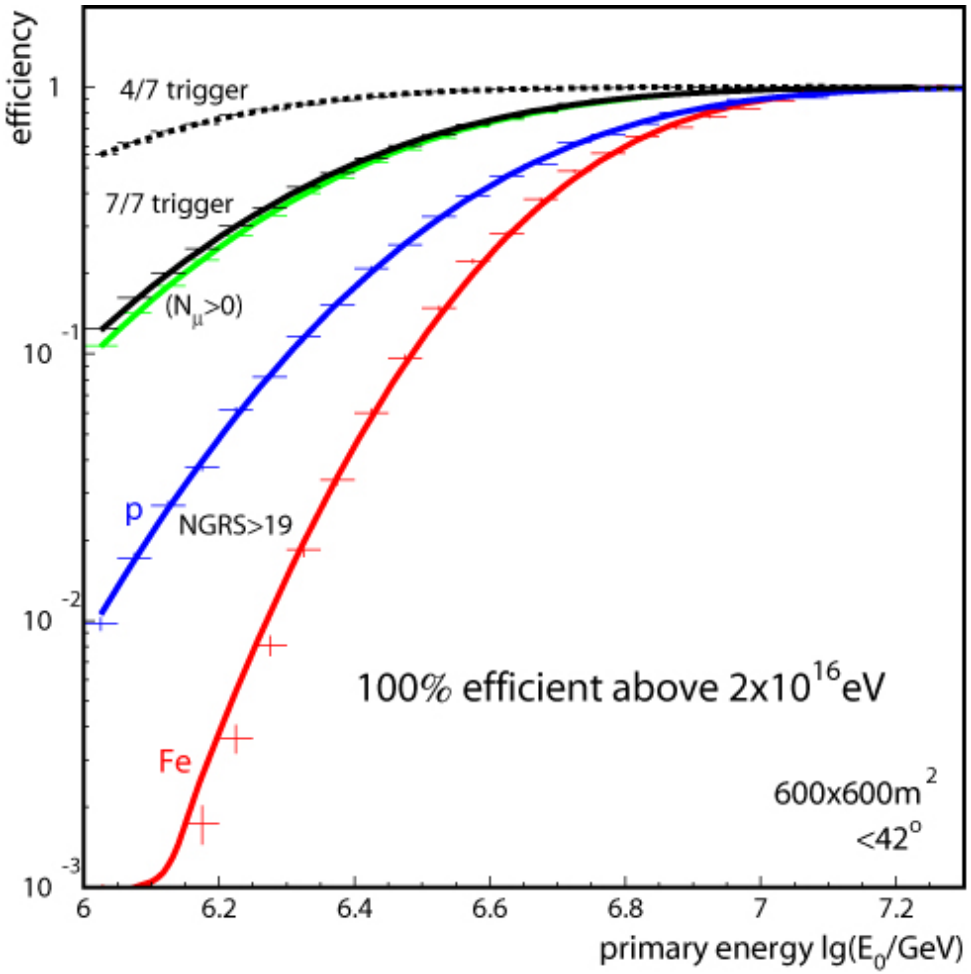
P. Luczak, J. Zabierowski

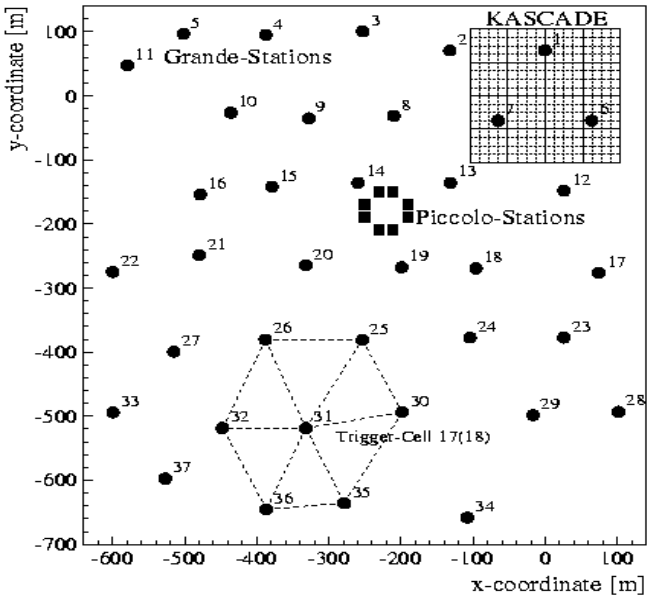
Institute of Physics and Nuclear Engeneering, Bucharest
I.M. Brancus, B. Mitrica, M. Petcu, O.Sima, G.Toma

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

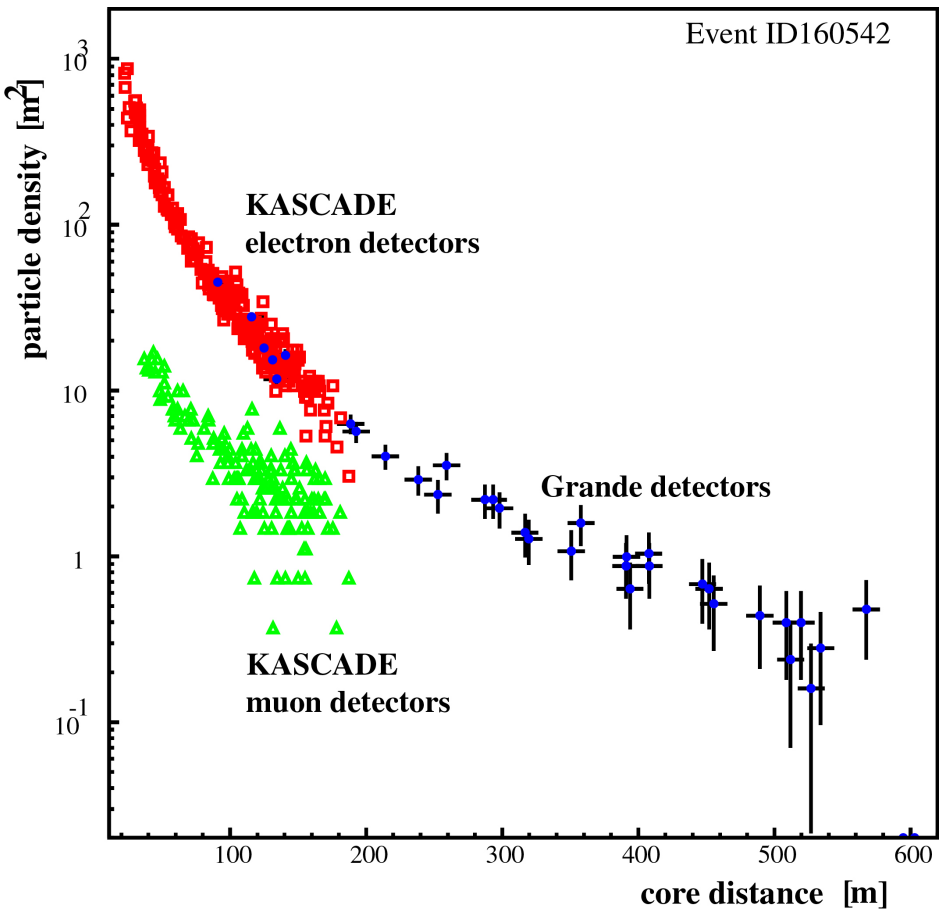
KASCADE-Grande: efficiency



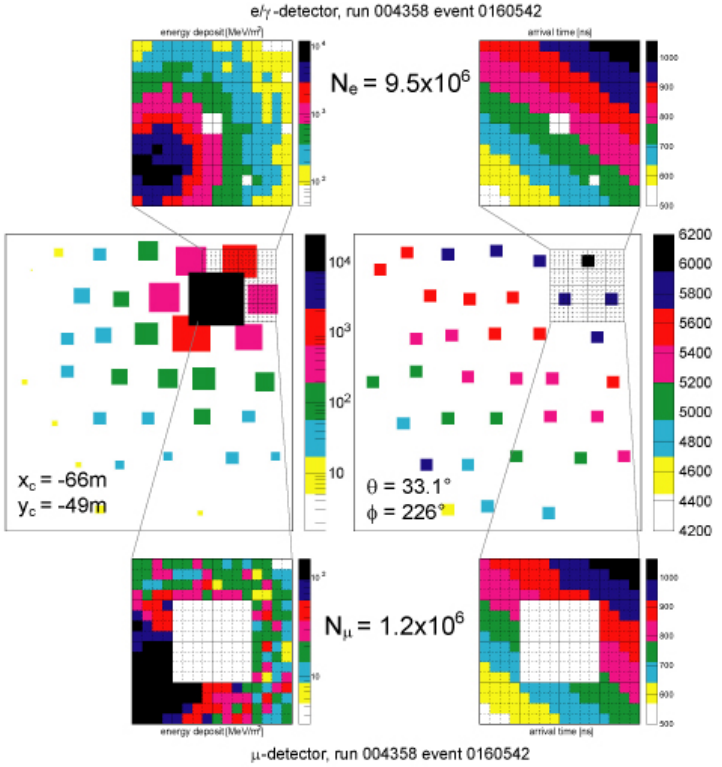
Common events
(all detector components)
measured since December 2003
Trigger: 7of 7 stations at one
of 18 hexagons



KASCADE-Grande: single event measurement

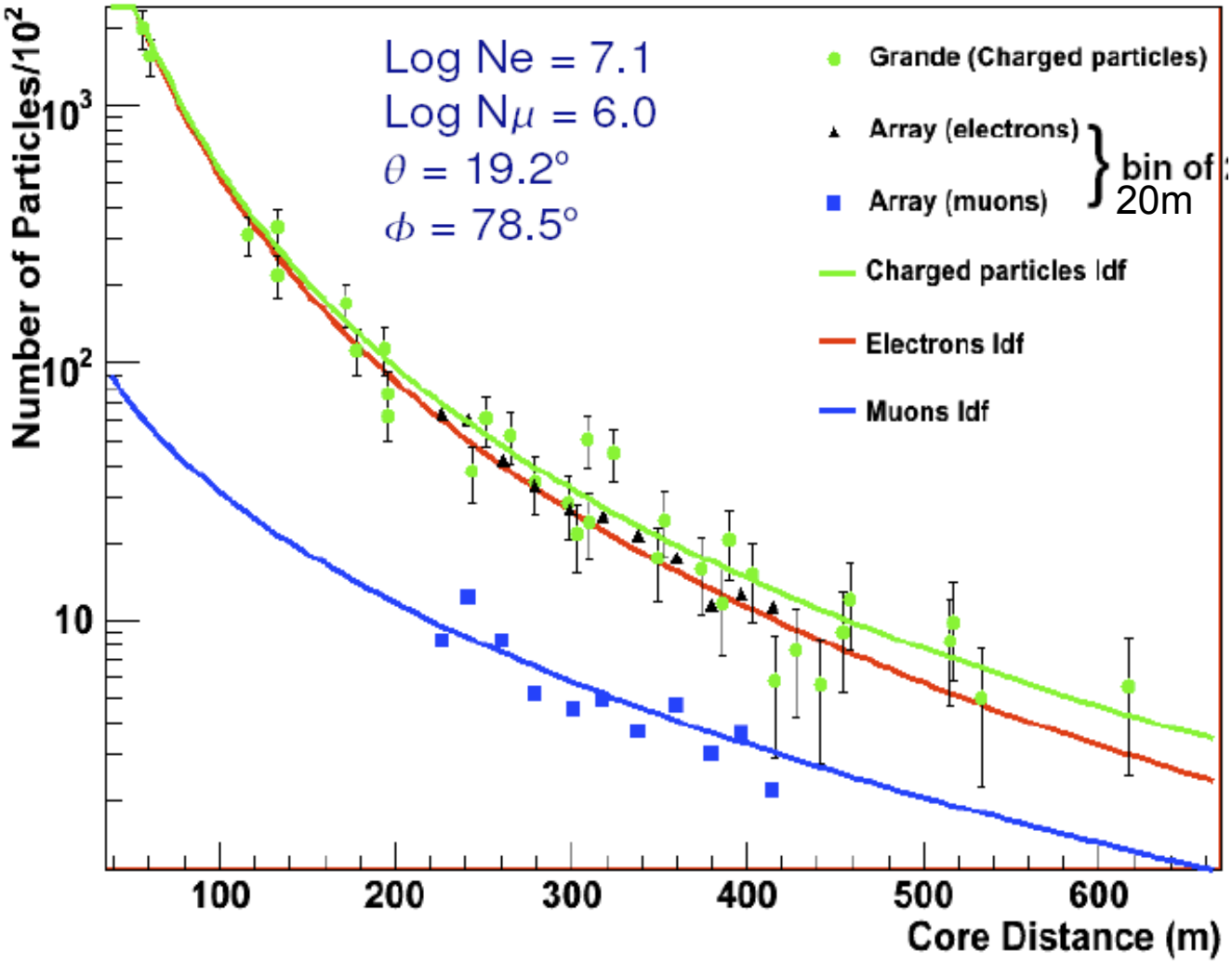


lateral distribution of a single event measured by KASCADE-Grande:
$E \approx 2 \cdot 10^{17}$eV, $\Theta = 33°$



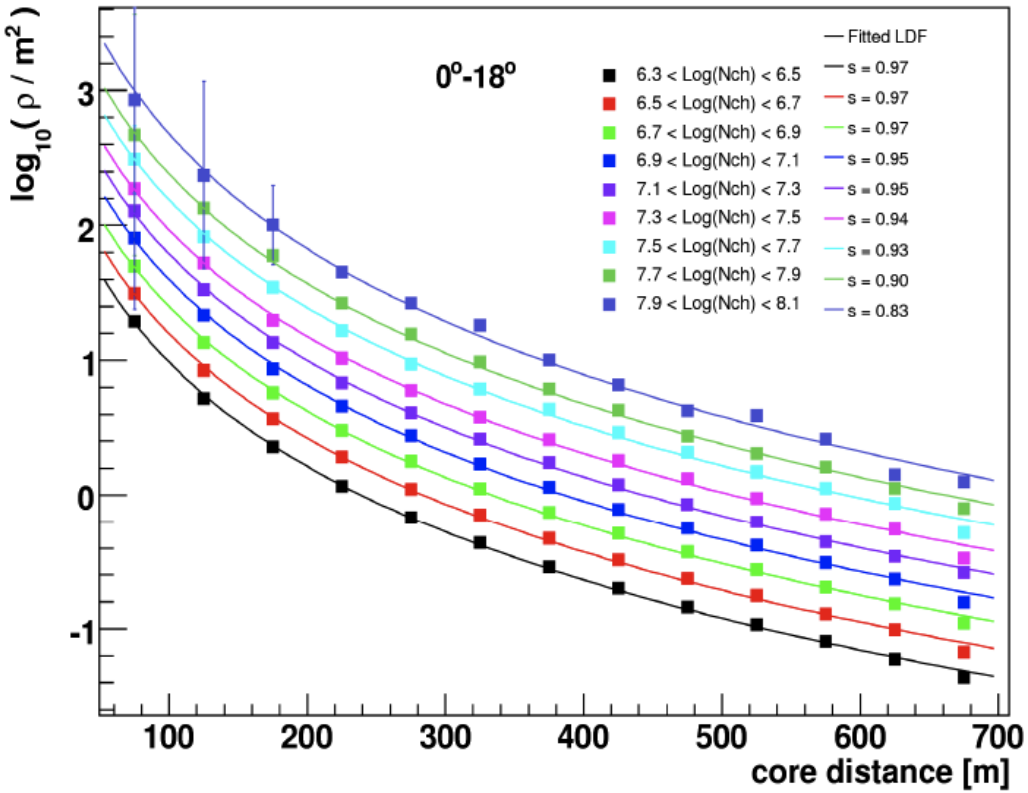
deposited energy [MeV/m^2] arrival time [ns]

KASCADE-Grande: single event lateral distribution



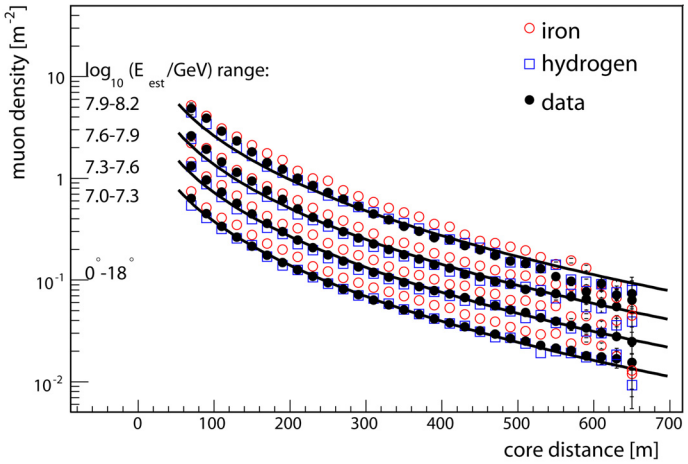
KASCADE-Grande: lateral distributions

$$(1)\quad \rho_{ch} = N_{ch} \cdot C(s) \cdot \left(\frac{r}{40\text{m}}\right)^{s-1.5} \left(1 + \frac{r}{40\text{m}}\right)^{s-3.6}$$



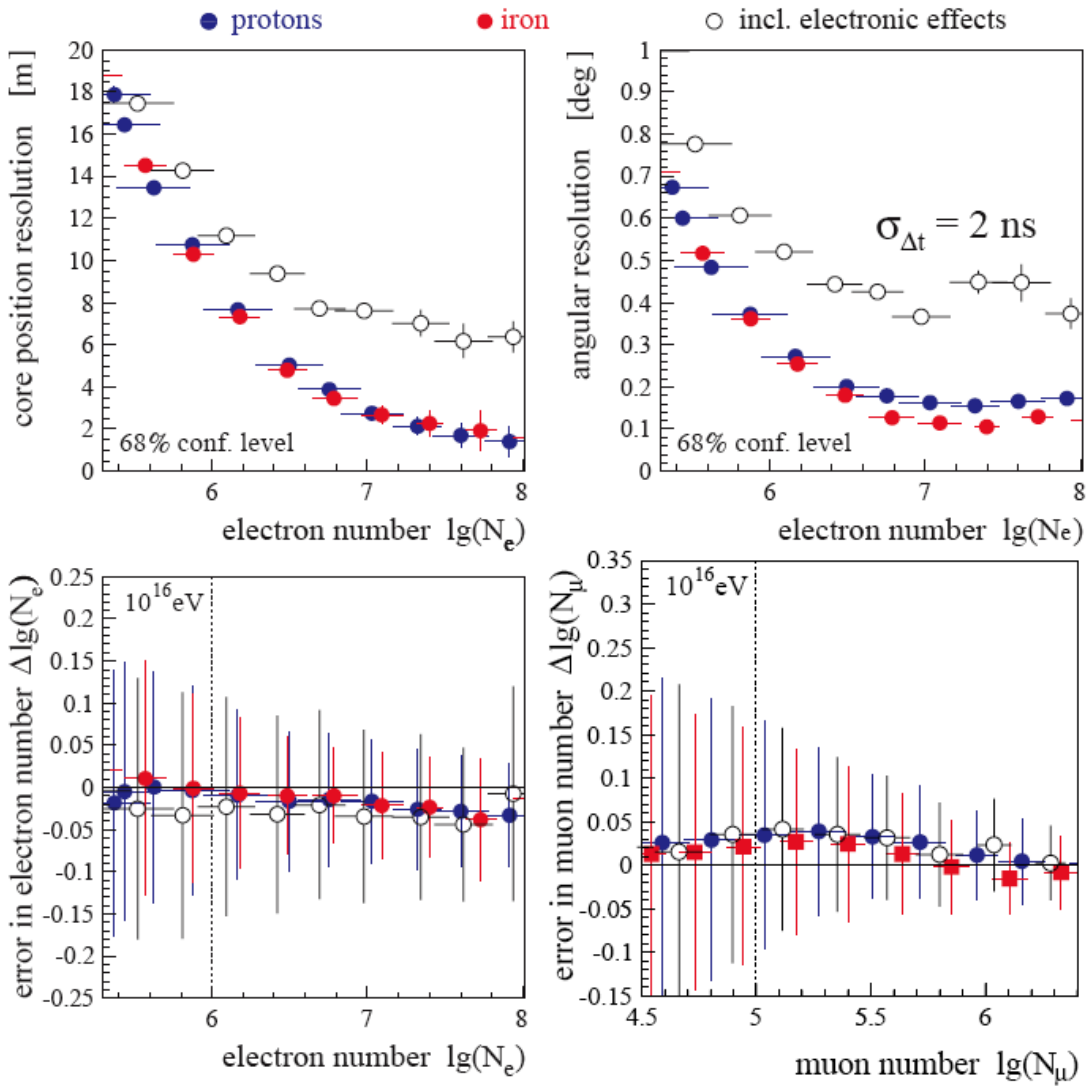
charged particles LDF

- vertical showers
- mean lateral distributions in shower size (Nch) bins
- fitted with the LDF (1)



LDF for muons only -- mass sensitive

KASCADE-Grande: reconstruction



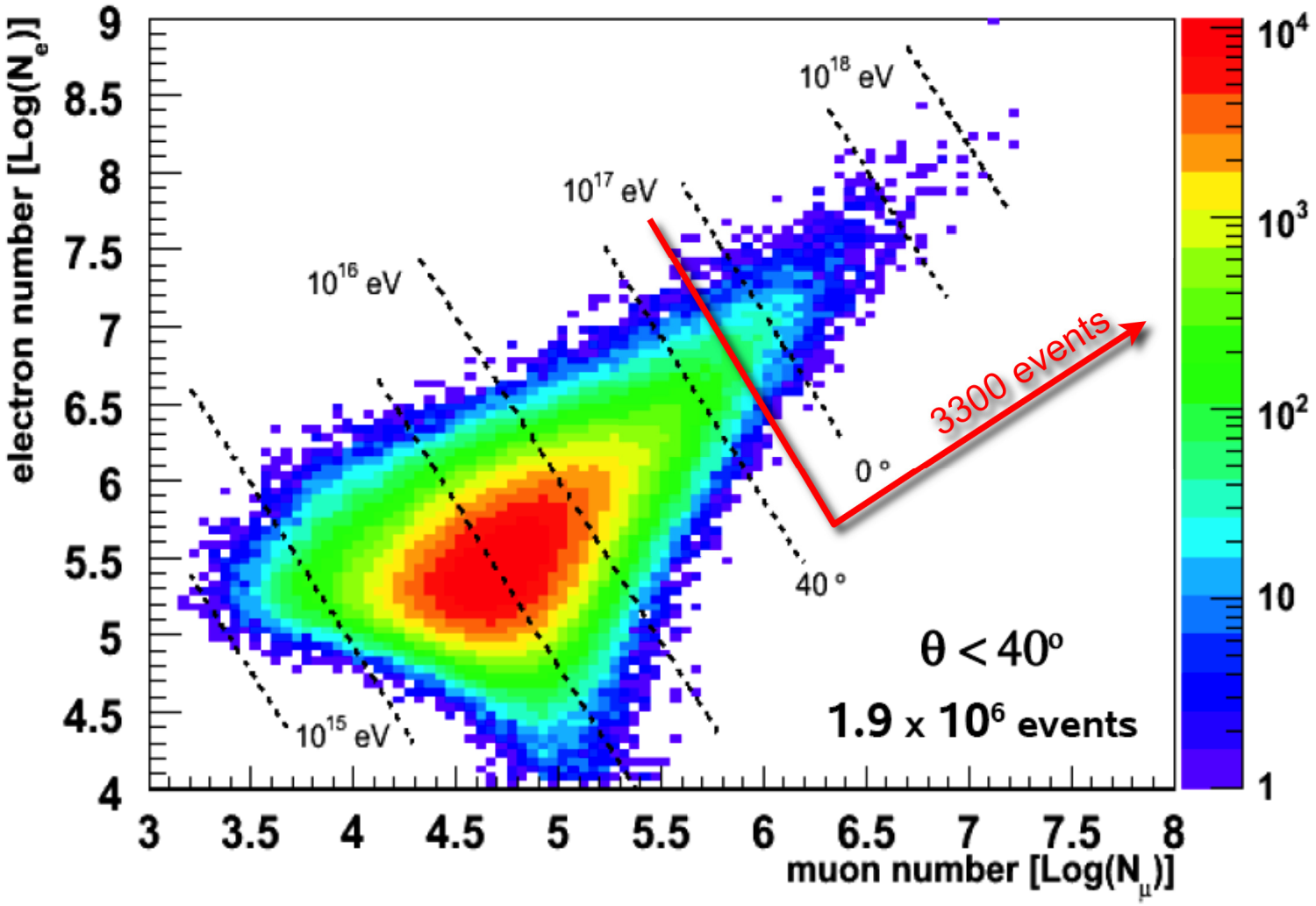
Accuracies/correlation KASCADE./. K-G:

particle density: ~15%

core positions: 6 m

angle: 0.6°

KASCADE-Grande: towards N_e/N_μ unfolding



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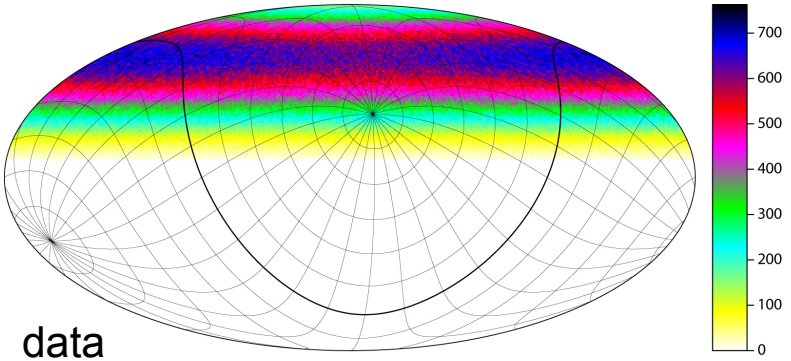
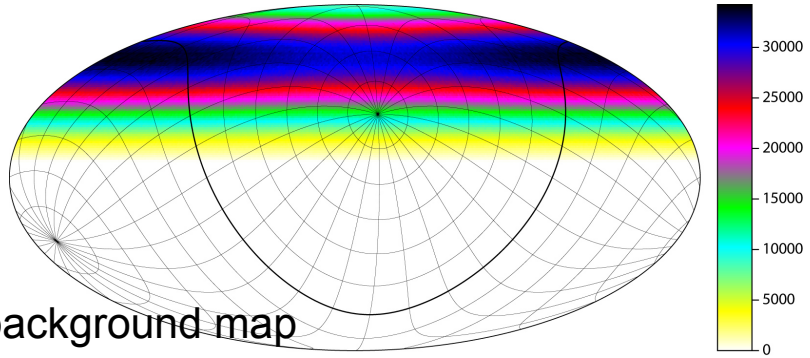
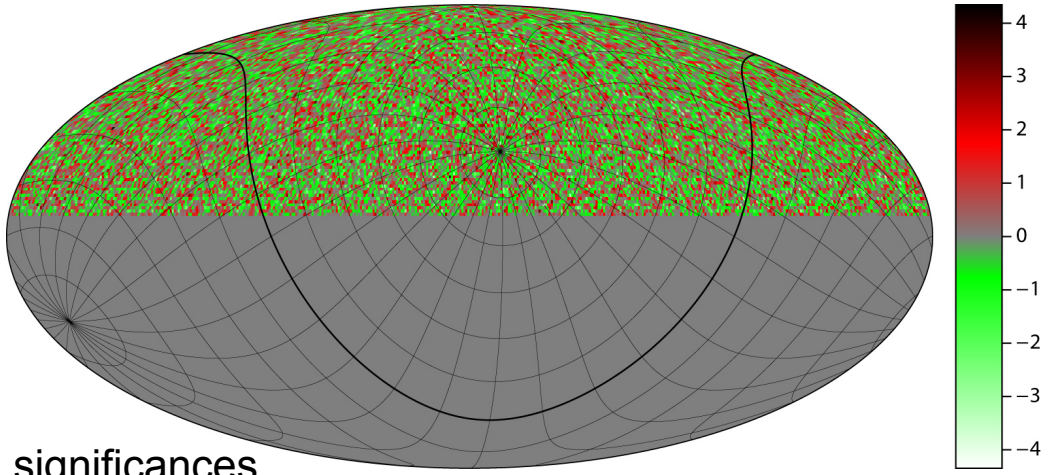
KASCADE-Grande: source distribution



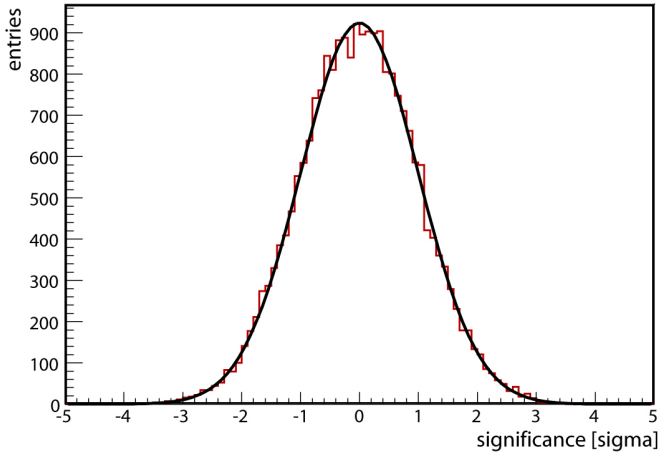
data



background map



significances



Significance distribution: no hint to distinct sources

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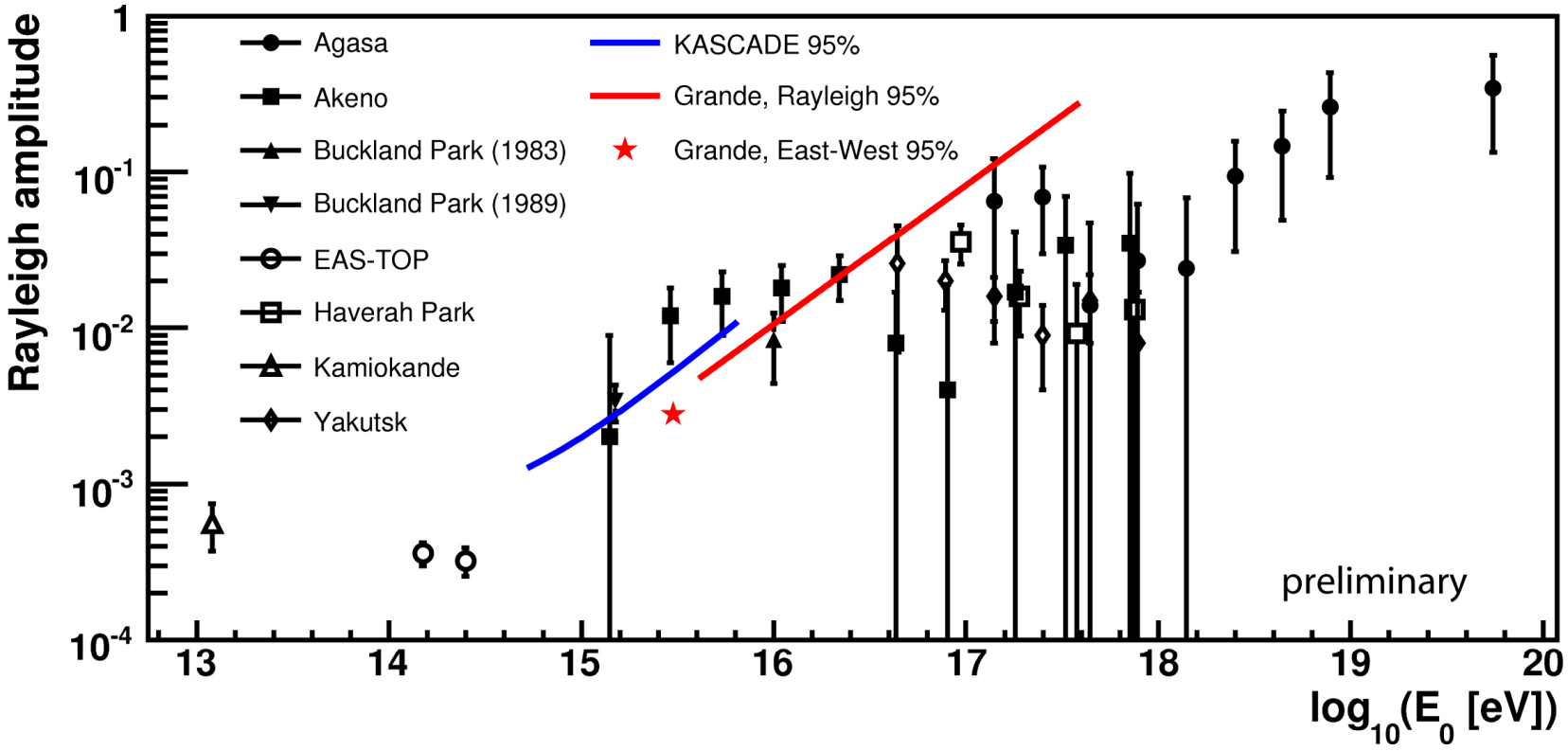
KASCADE-Grande: large-scale (an)isotropy



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Summary

- knee is caused by light primary elements
- CR arrival directions are isotropic around the knee
- need better shower models
  - sophisticated experiments and analyses needed
  - data are not consistent with Monte Carlo
  - work on interaction models
  - work on *forward physics* at accelerators, e.g. HARP, NA61 (=NA49*) @ CERN
- KASCADE-Grande will cover whole „knee“ range
  - close the gap to Auger, TA(LE) from the low-E side
  - promising status and first data
    - 100% efficiency above 2×10^{16} eV
    - event reconstruction
    - accuracies: particles:15%, core: 6 m, angle 0.6°
    - extended lateral distribution, use S(500)
    - 2-dim unfolding should work
    - no sources, no large-scale anisotropy
- facility for radio detection with LOPES

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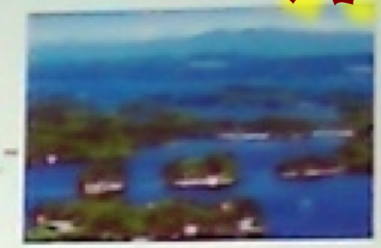
THANK YOU

concluding haiku

「松島や　ああ松島や　松島や」
松尾芭蕉（?）

"Matsushima, ah Matsushima, Matsushima."
- Matsuo Basho (?)



宇宙線　ああガンマ線　ニュートリノ

"Cosmic rays, ah Gamma-rays, Neutrinos."

The real beauty will be in the combination of the techniques!