TALE Composition Methods

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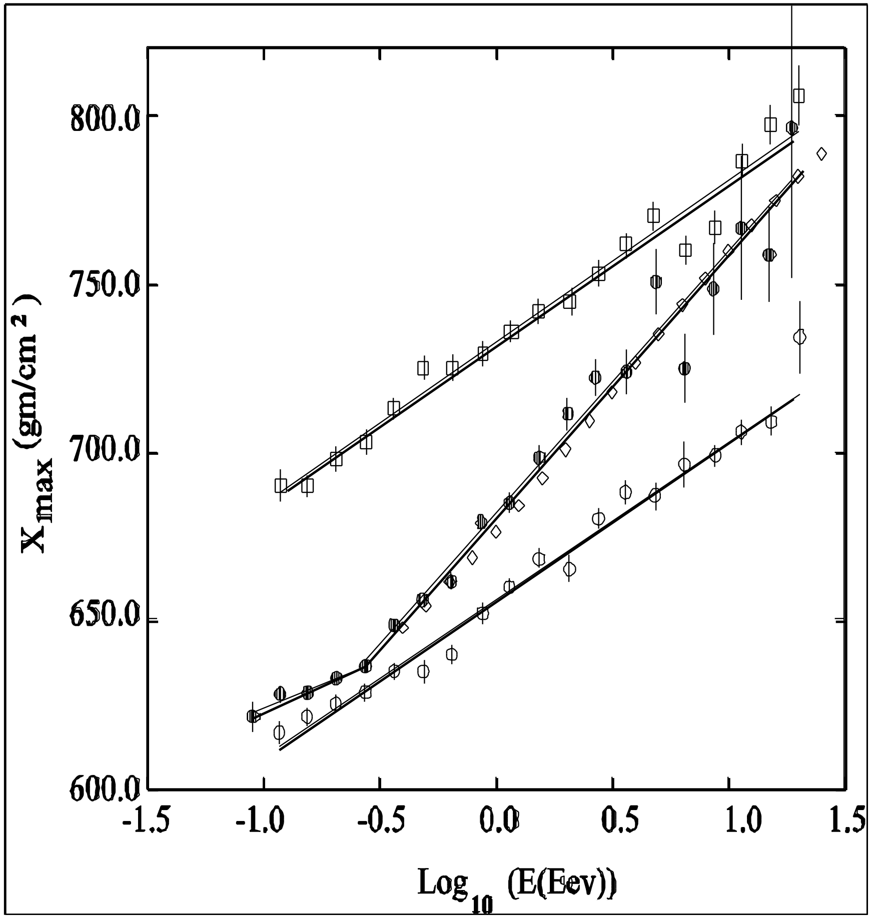
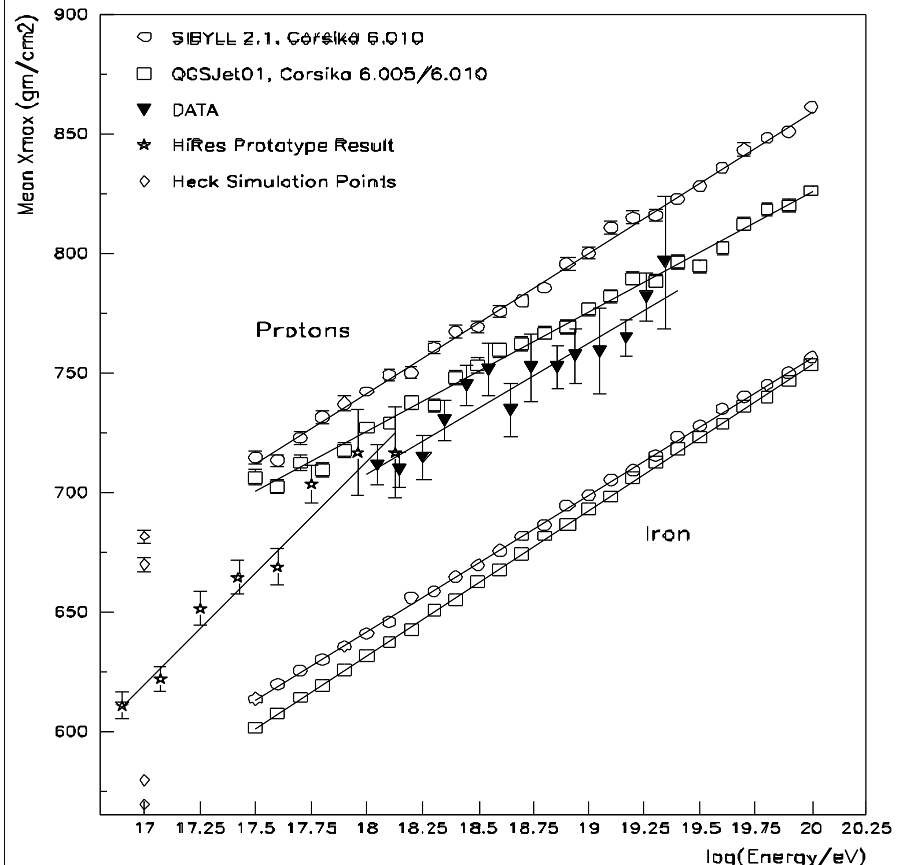
Motivation

- Change of chemical composition a strong indication of a changing source
- Ideally, composition change can be correlated with spectral features to determine transitions within galaxy, or galactic to extragalactic transition
- Experimental information murky...

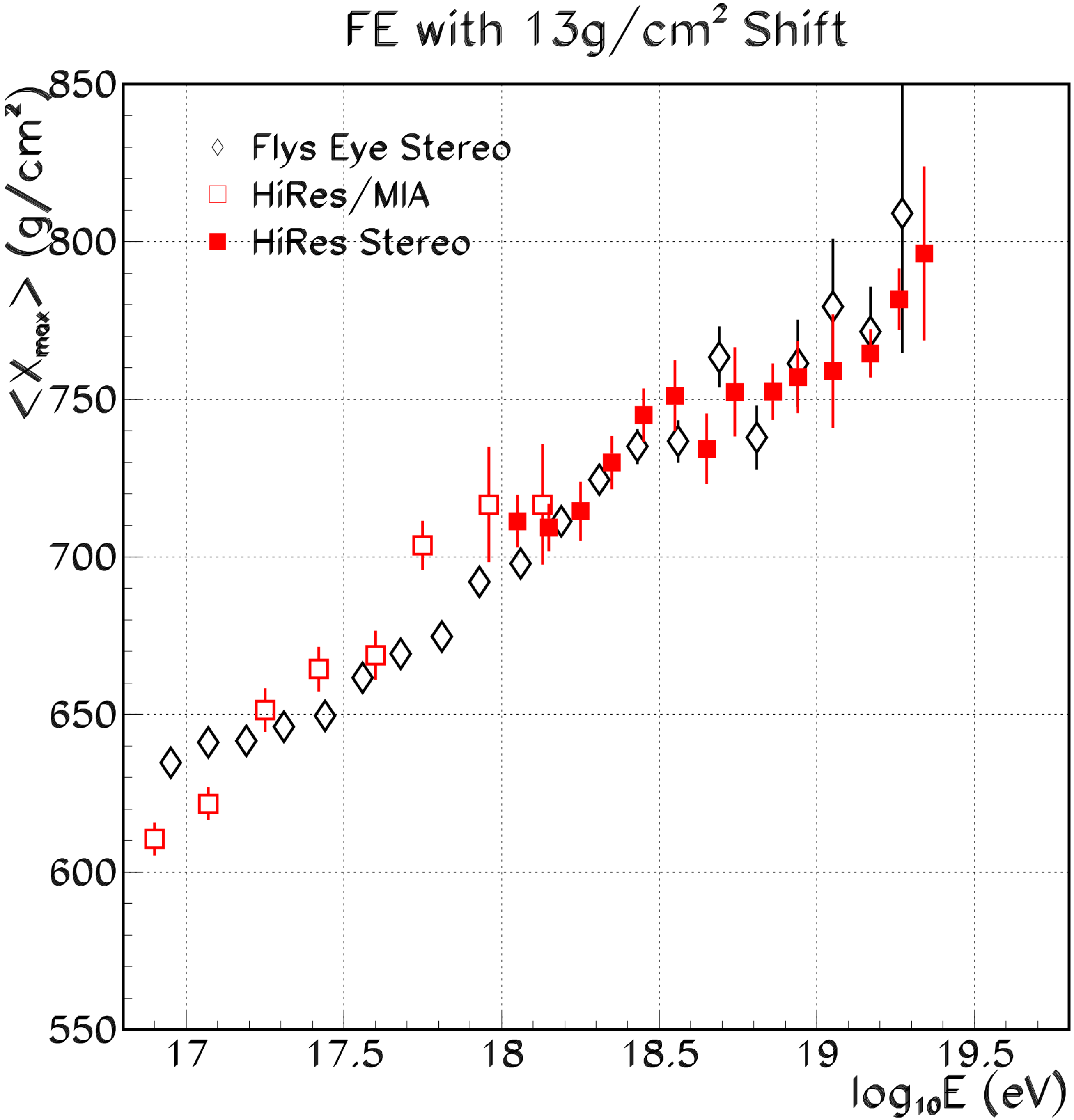
Composition by X_{max} Method



Fly's Eye Stereo

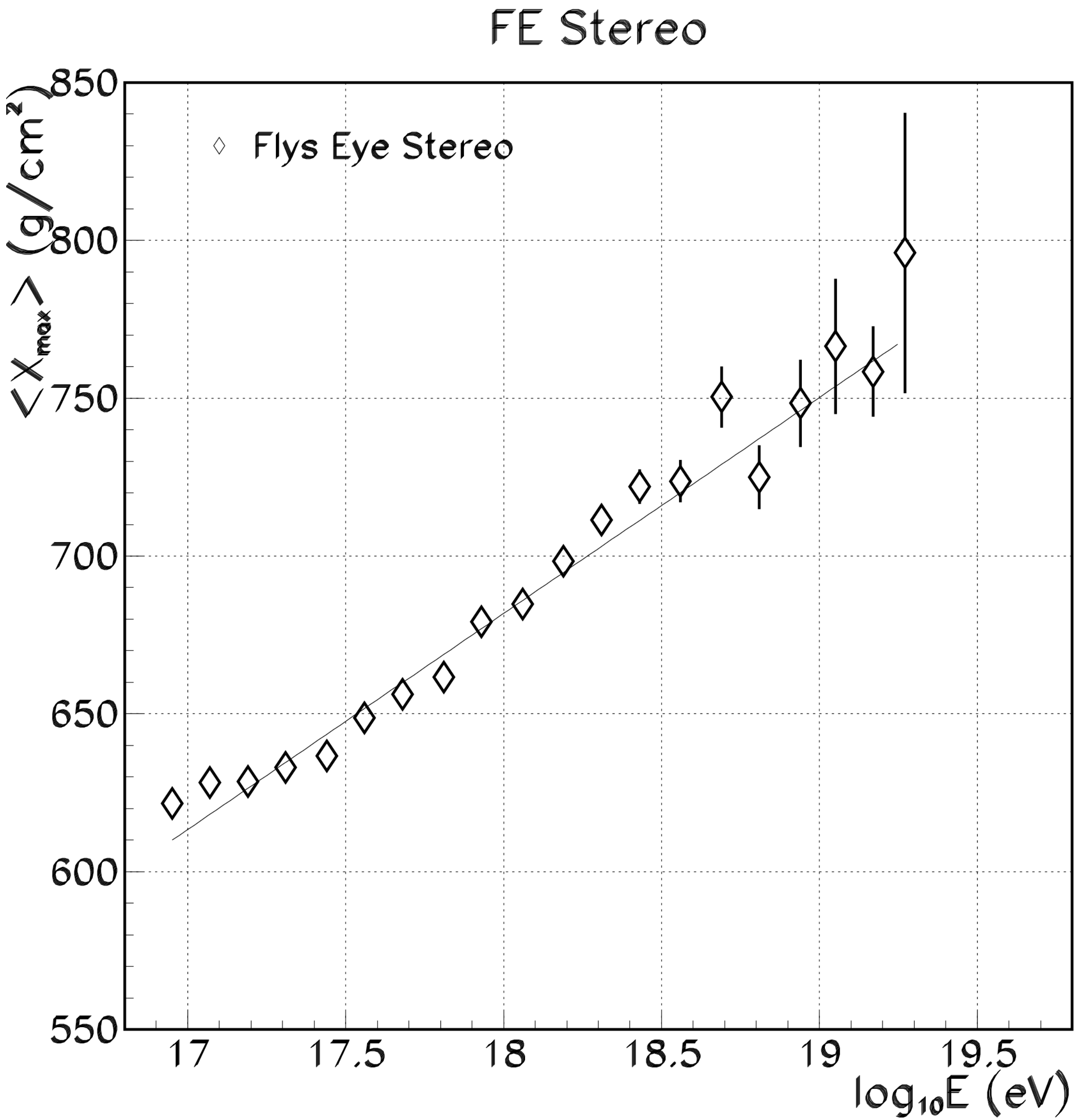


HiRes Prototype w/MIA, and HiRes Stereo



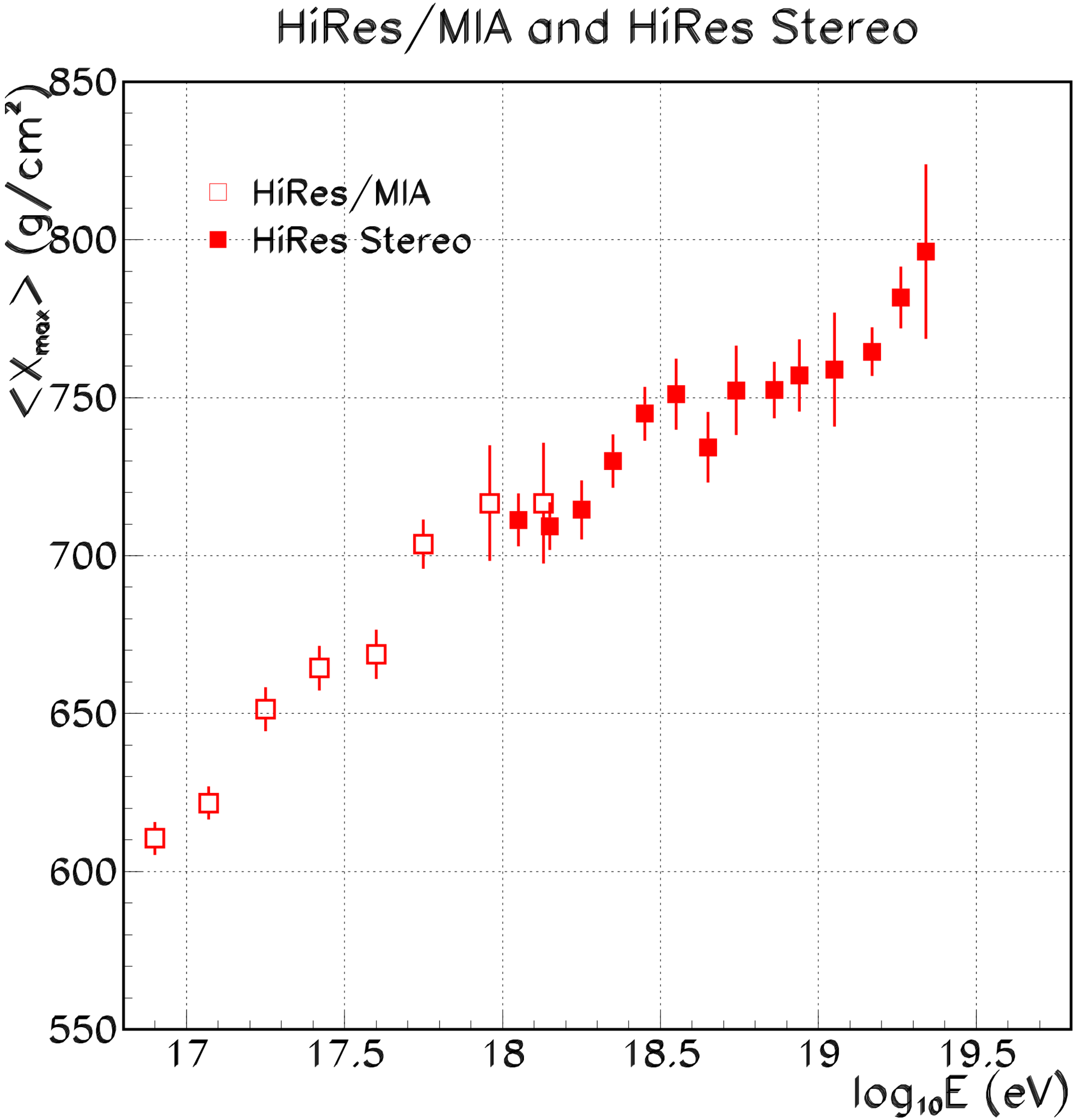
Sokolsky,

2005 ICRC

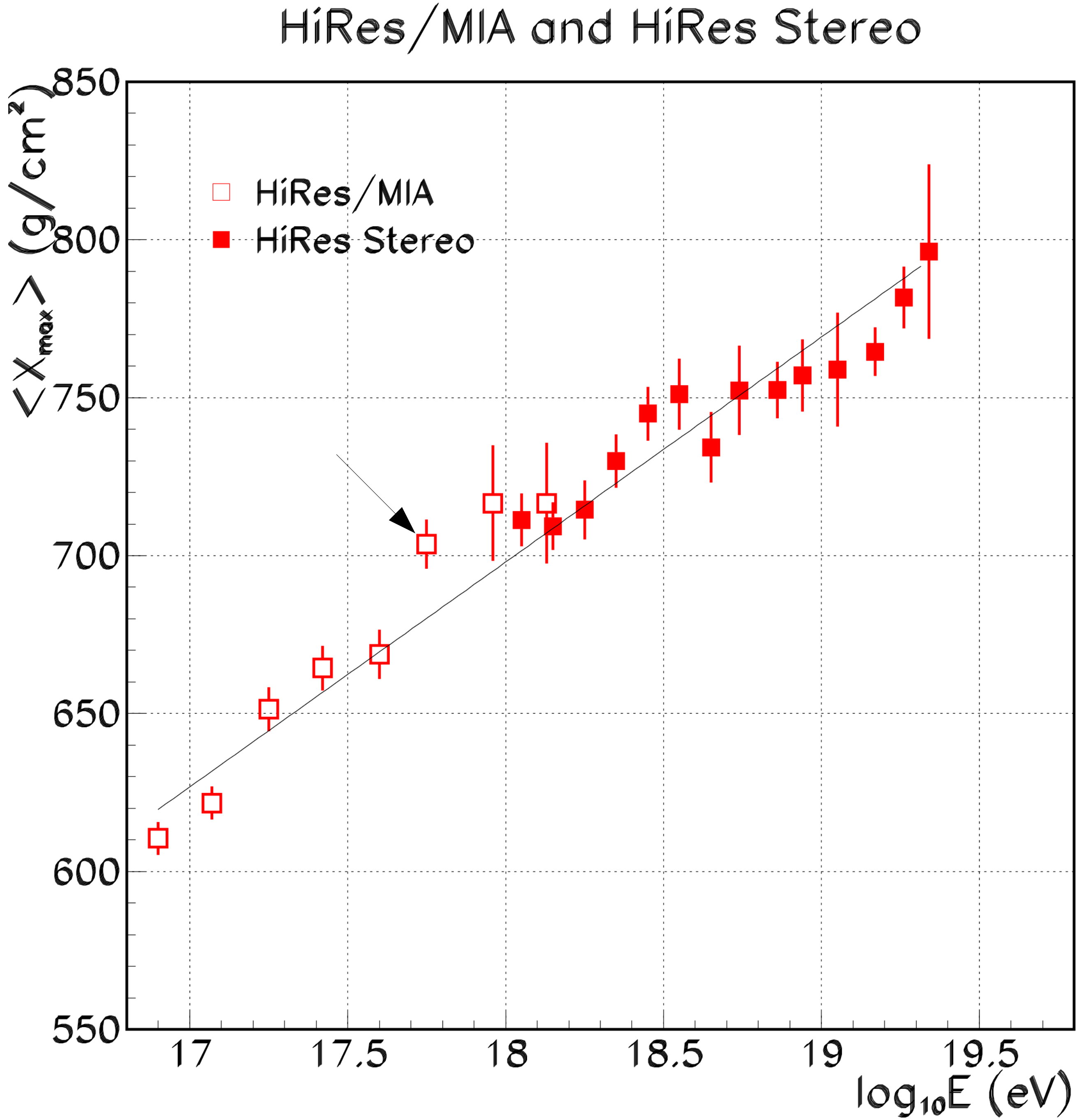


Straight-line fit:

- 68 g/decade
- χ^2/d.o.f = 48/18



Without fits to
"guide the eye"



Straight-line fit:

- 71 g/decade

- χ^2/d.o.f = 34/20

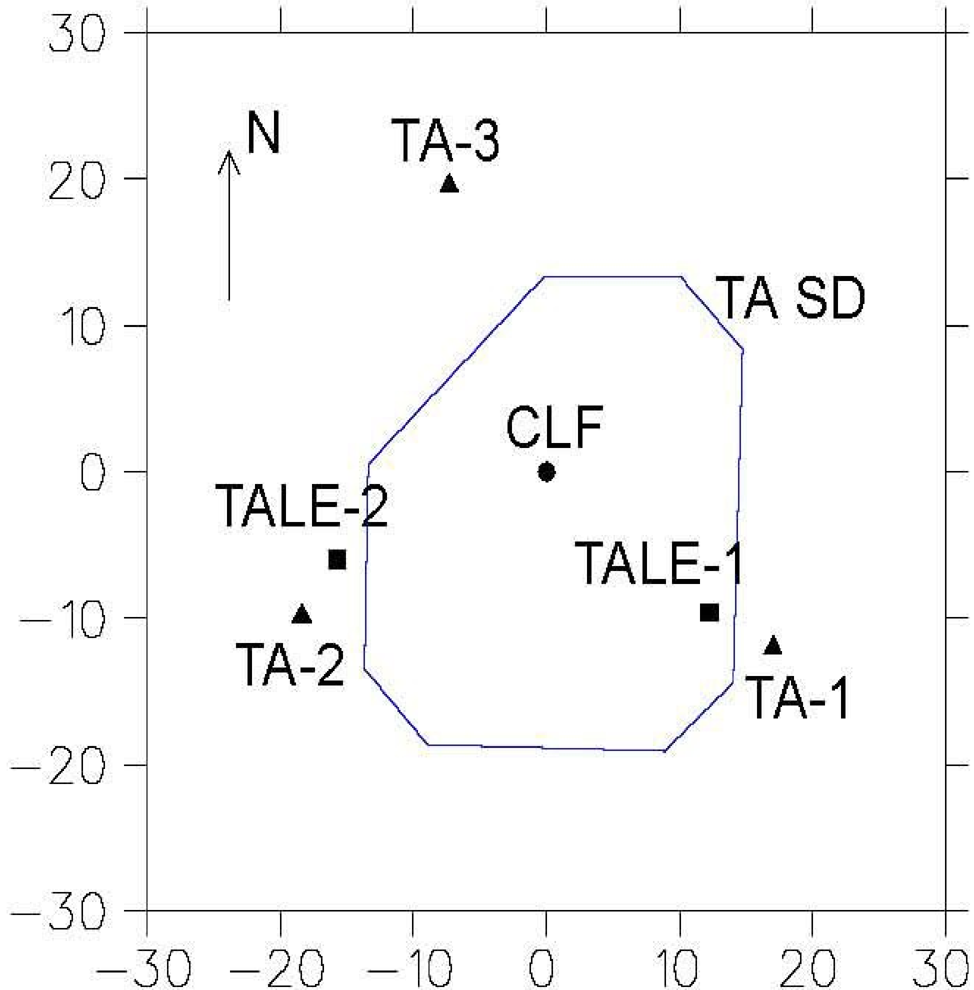
Composition with TALE

- Goal: Extend TA composition measurements to $10^{16.5}$ eV, via...
- X_{max} measurements
  - 6 km stereo fluorescence detectors
  - tower fluorescence detector
  - scintillator infill array
- $\rho(\mu)$ measurements
  - muon sensitive infill detectors

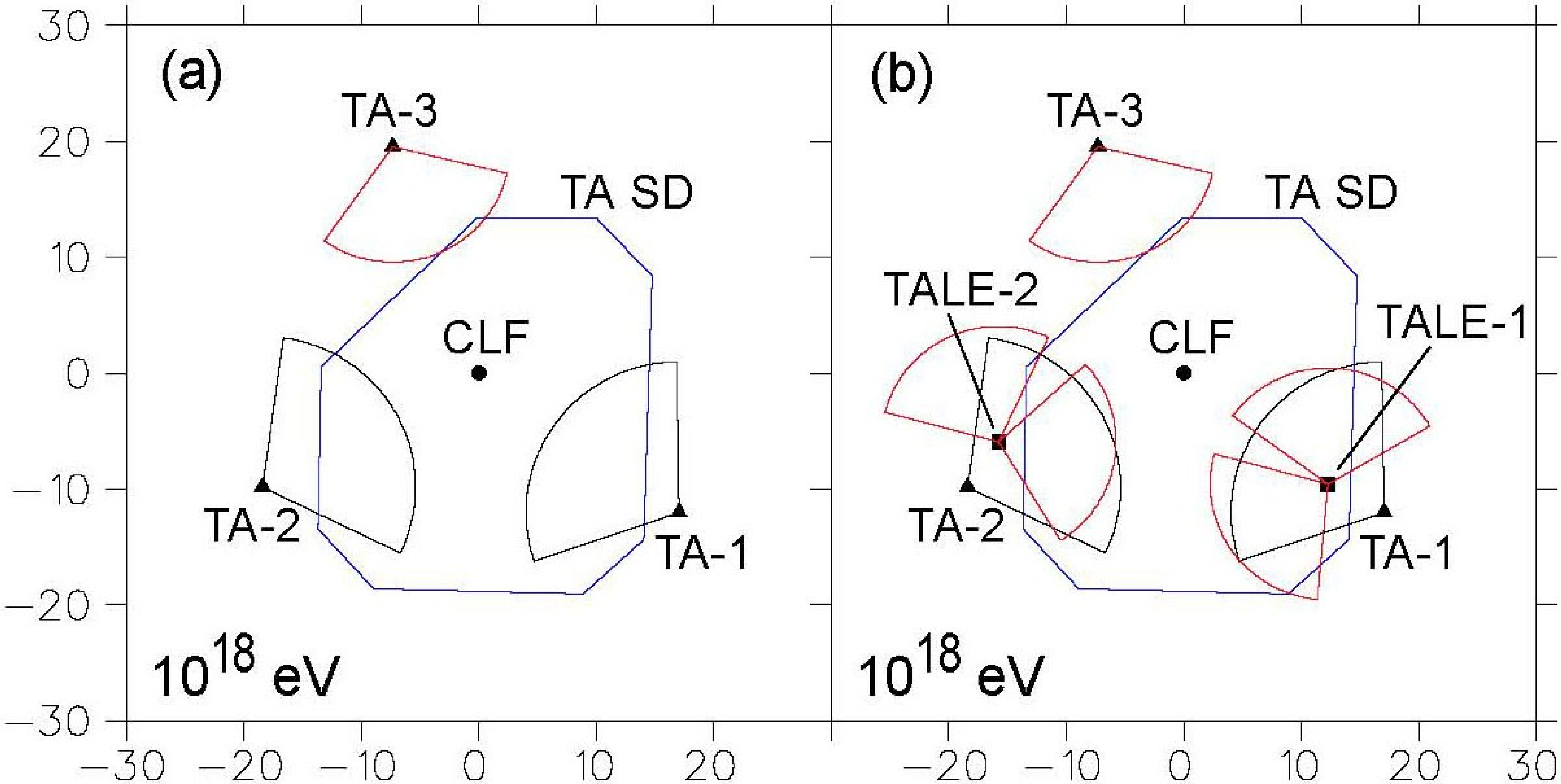
TALE Methods: X_{max}

6 km Stereo Fluorescence Detectors

- Refurbished HiRes mirror units
- Two rings, 3° – 31°
- Positioned to maximize stereo overlap at 10^{18} eV
- Stereo coverage over full SD array at 10^{19}eV



Distances in kilometers

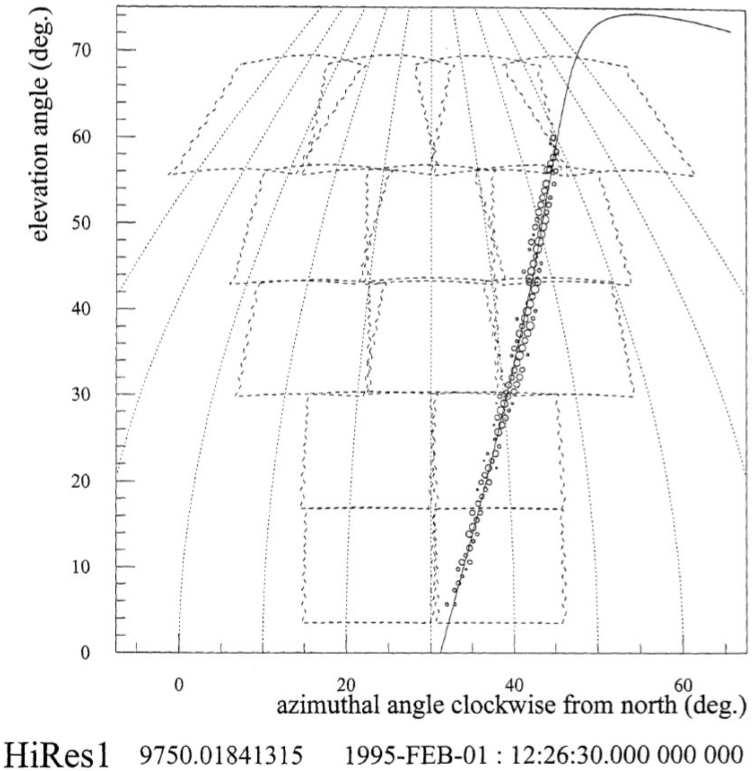


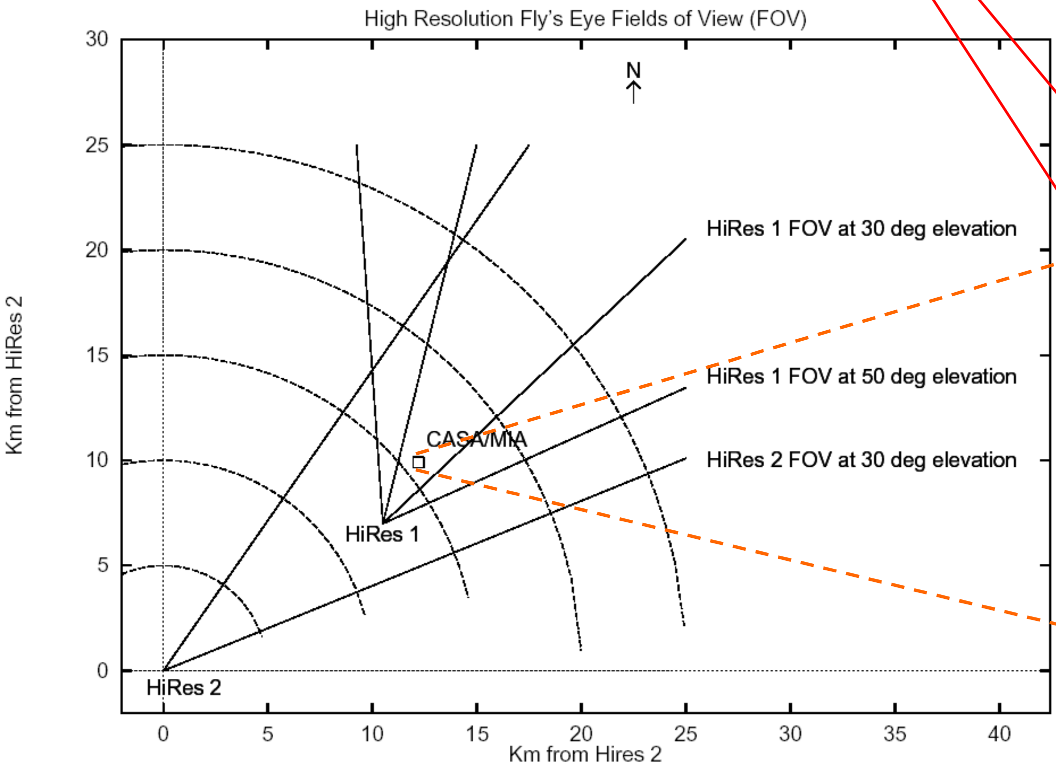
Left: Approximate FOV (pie wedges) for TA fluorescence detectors at 1 EeV

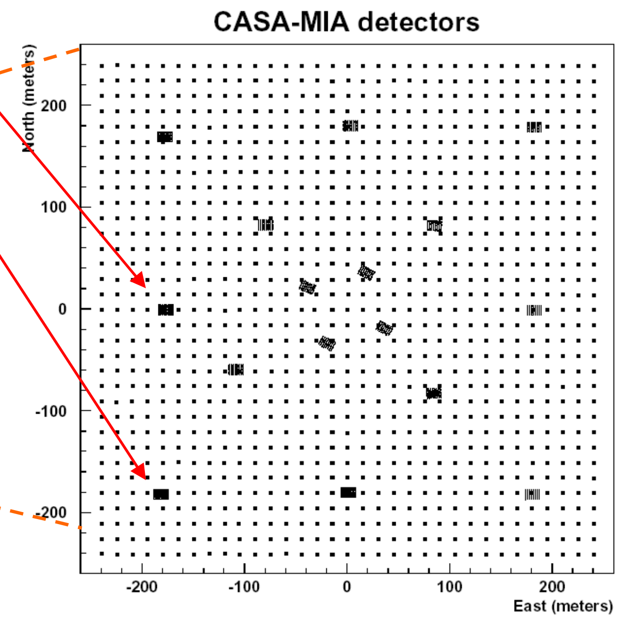
Right: Corresponding FOV for TALE sites, showing optimal stereo overlap at this energy.

1992-96: HiRes Prototype

- 14 (HiRes-1) + 4 (HiRes-2) mirror prototype detector
- HiRes-1 field of view up to ~70°.
- HiRes-1 operated in ***hybrid mode*** with the MIA muon array (16 patches×64 underground scintillation counters each):





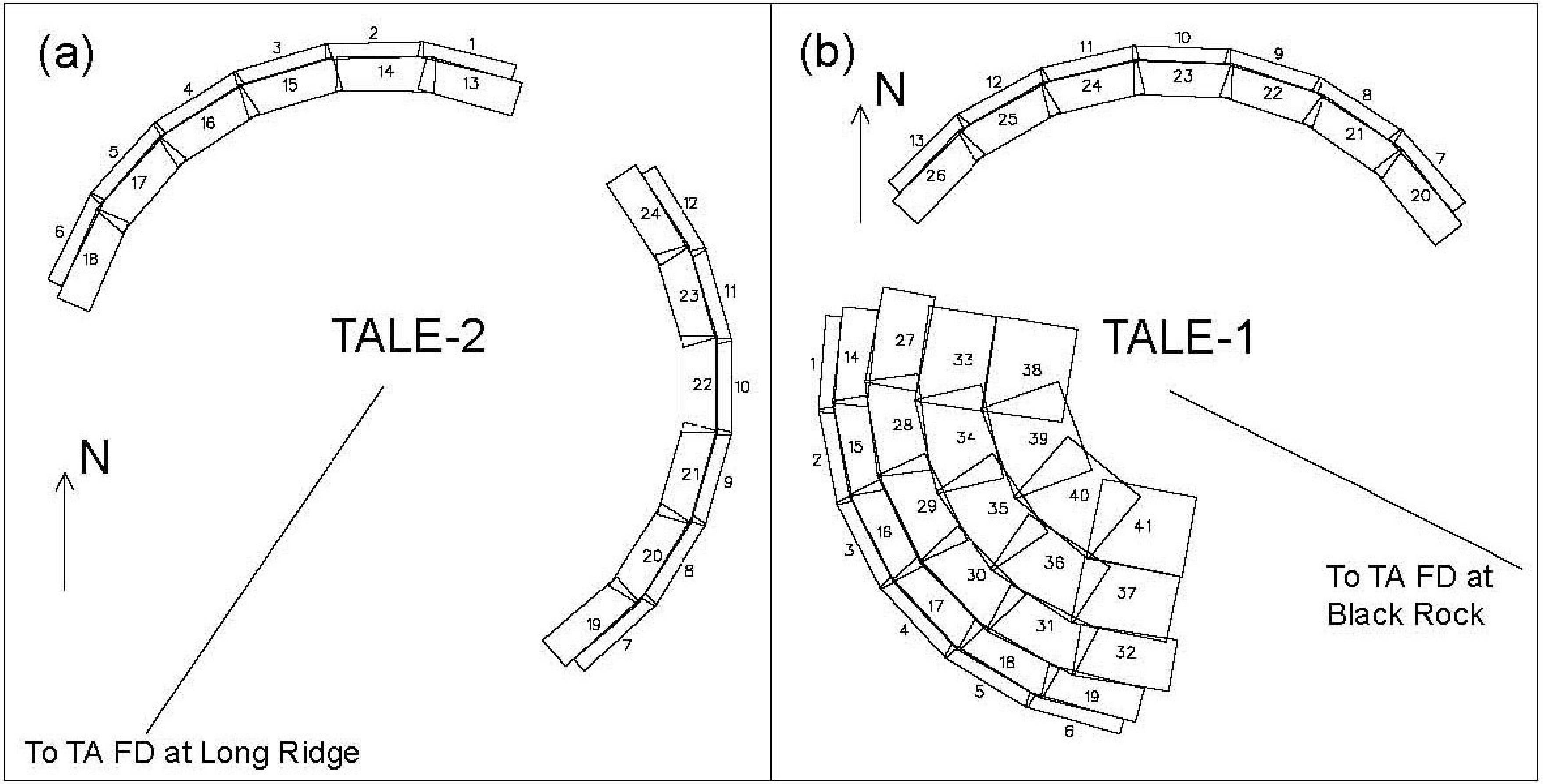


Tower Fluorescence Detector:

- 3 additional rings of mirrors, 31° – 72°
- Each mirror 3x HiRes mirror area

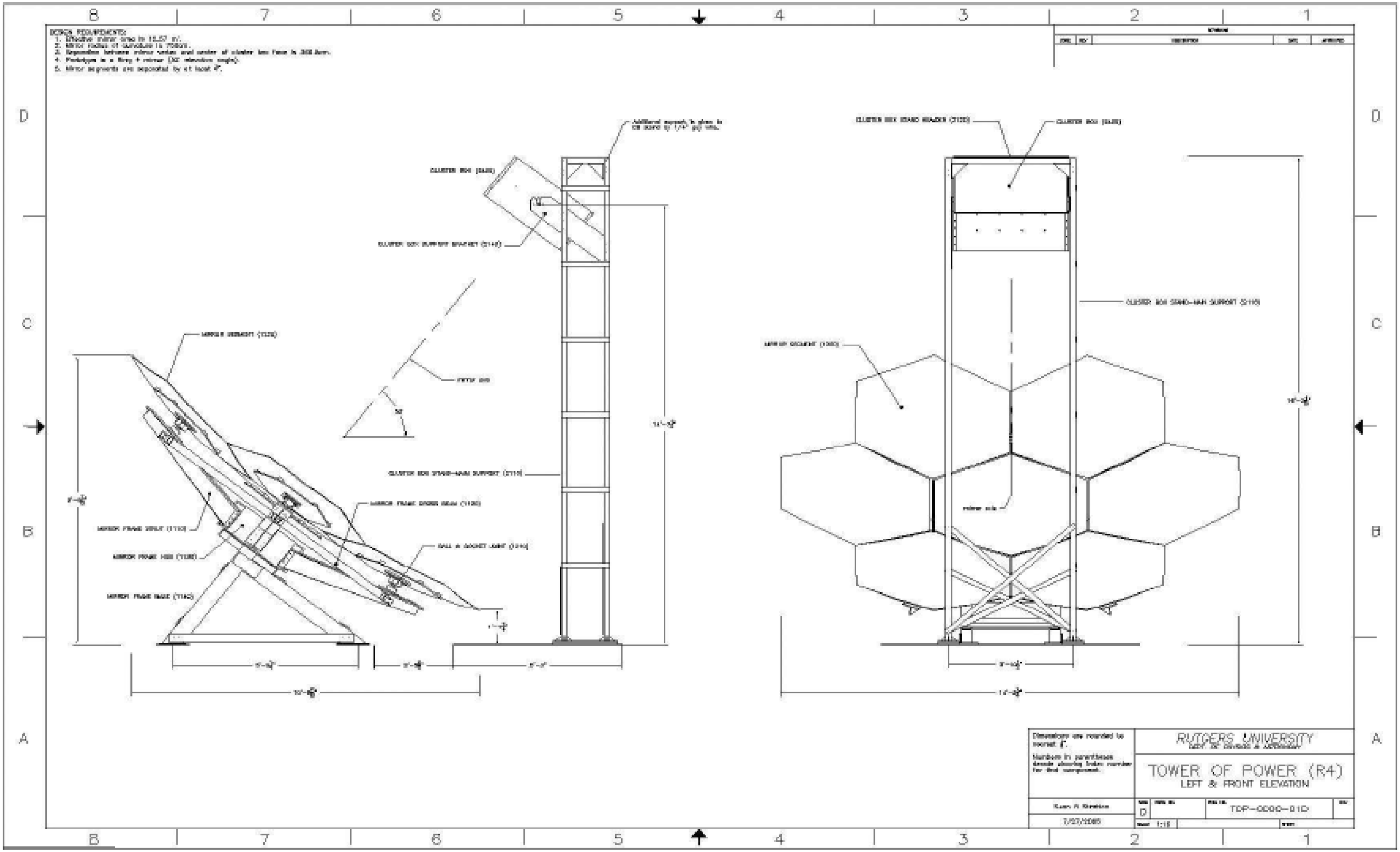
Infill Array:

- 100-150 scintillators on 0.4 (?) km grid
- AGASA detectors, w/ std TA SD electronics



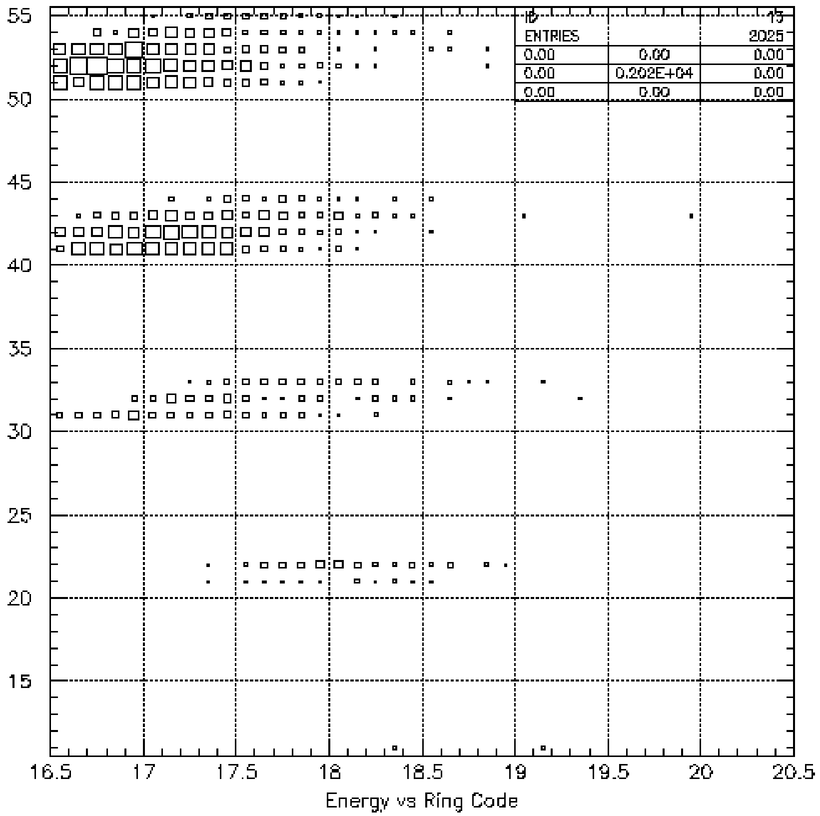
Left: TALE-1 site near Long Ridge (6 km stereo)

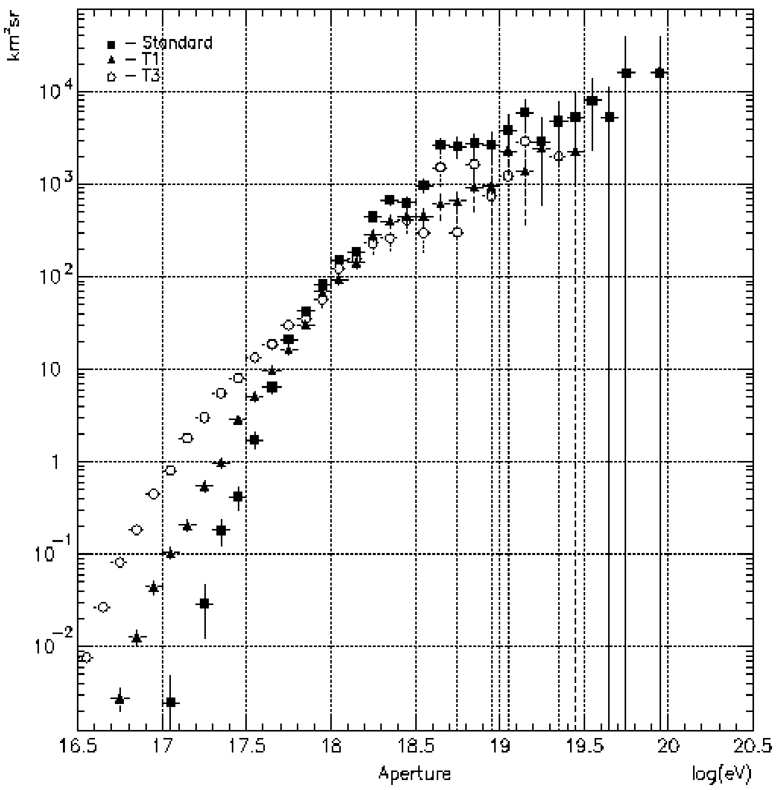
Right TALE-2 site near Black Rock, showing 3rd 4th and 5th rings of "tower"



Prototype tower detector

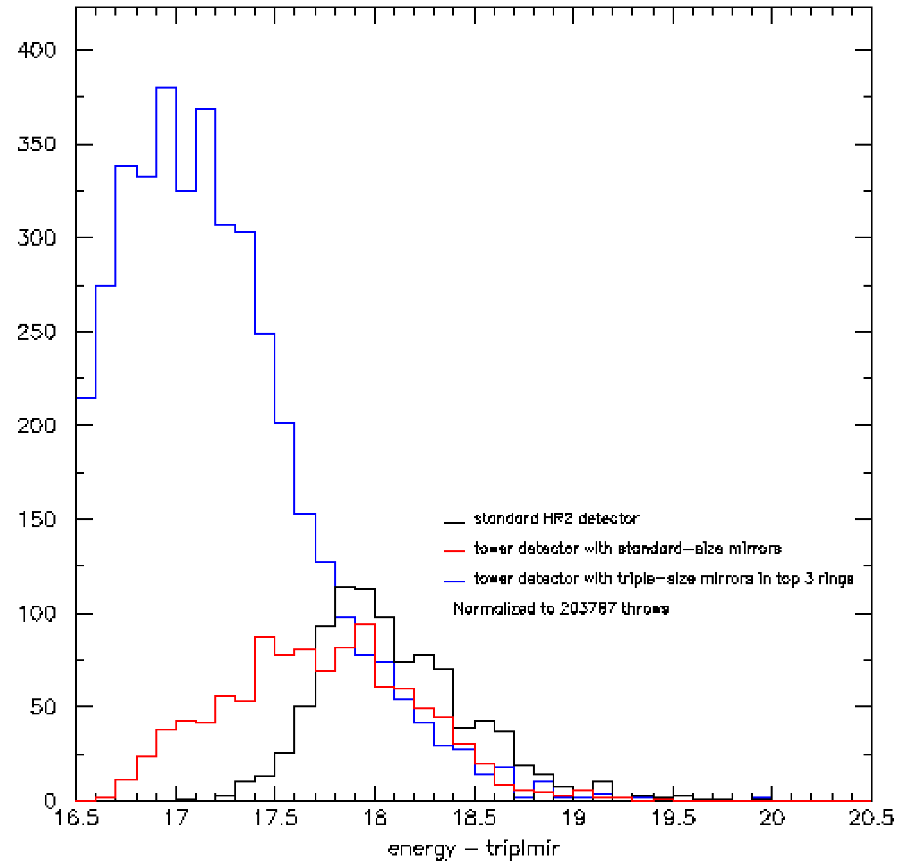
Tower: Ring occupancy and aperture



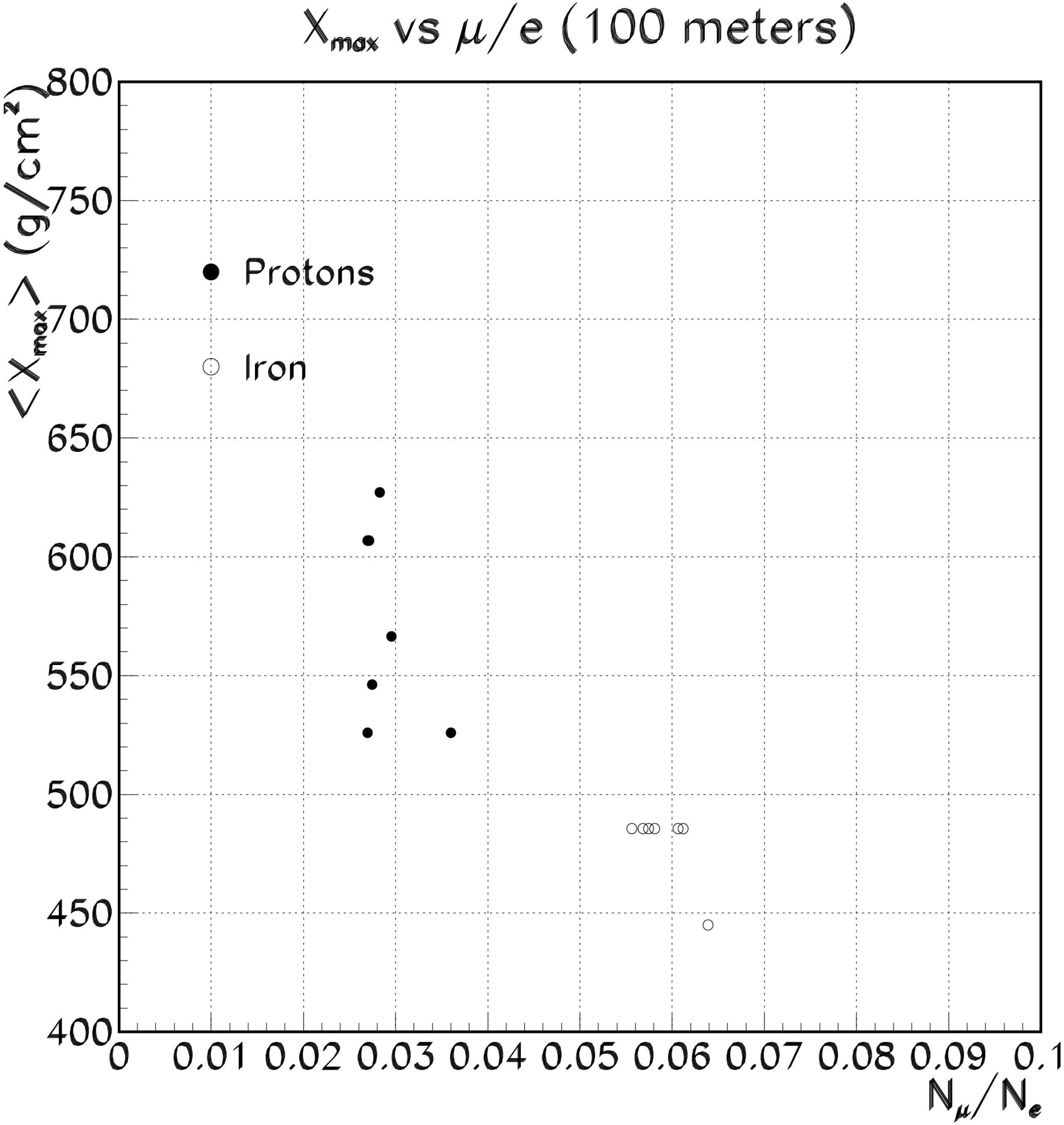


Tower Detector in Monocular Mode: Lower E_{min} by order of magnitude.

- Test tower detector design: MC ~ 2 mos. running.
  - cover 90^o azimuthally, 3^o -71^o in elevation.
  - 15 mirrors in rings 3-5.
  - HiRes-size mirrors reach down ½ order of magnitude.
  - 3x larger mirrors reach down full order of magnitude.
- **Big difference** in statistics below $10^{17.7}$ eV.



TALE Methods: $\rho(\mu)$



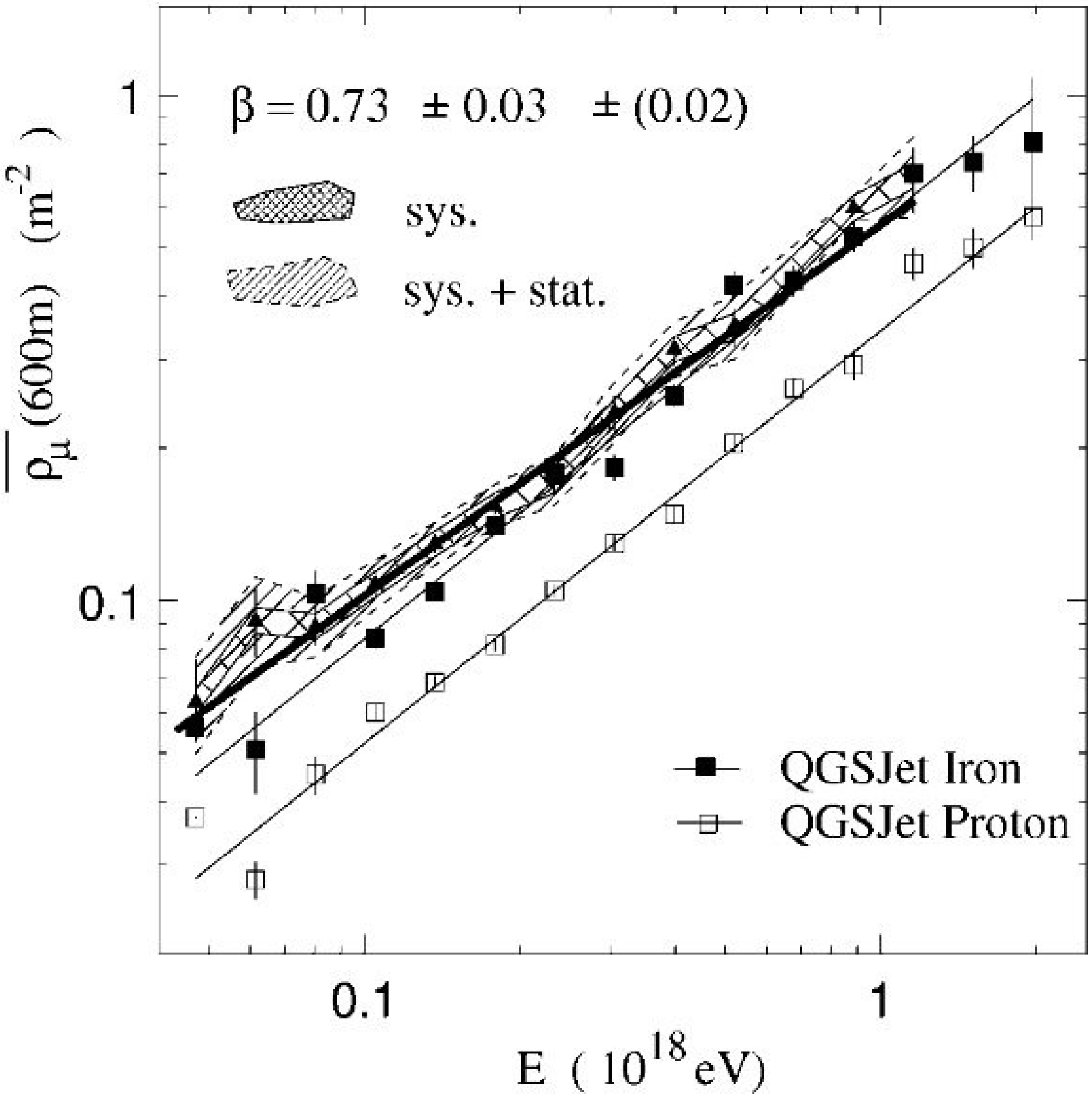
Unthinned showers

10^{17} eV, 30° zenith

QGSJET01

>3 MeV EM

>300 MeV μ

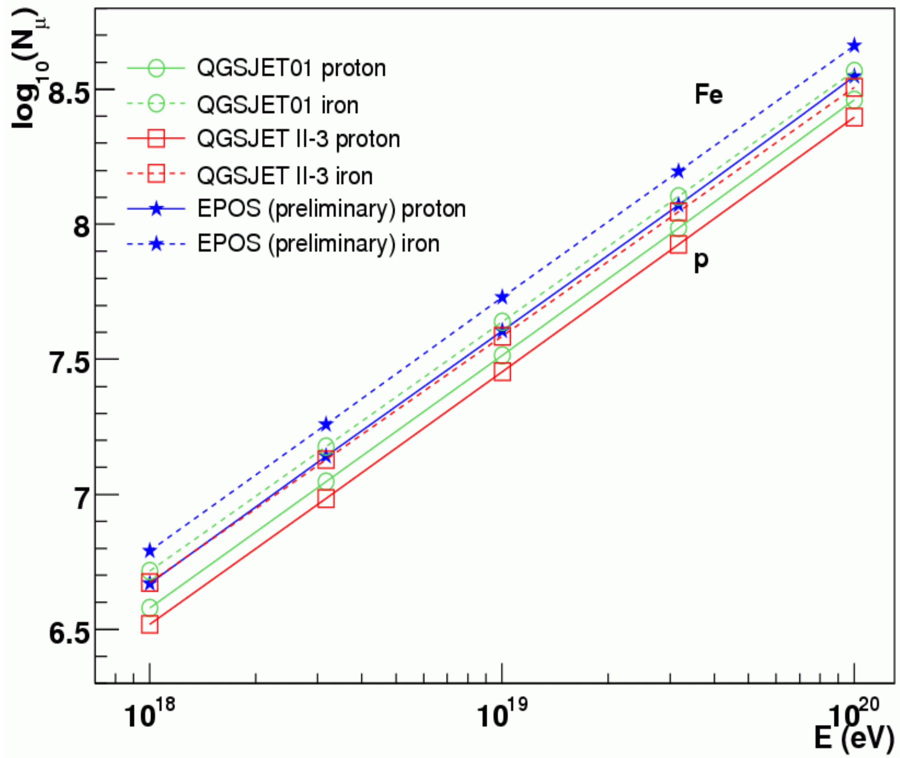


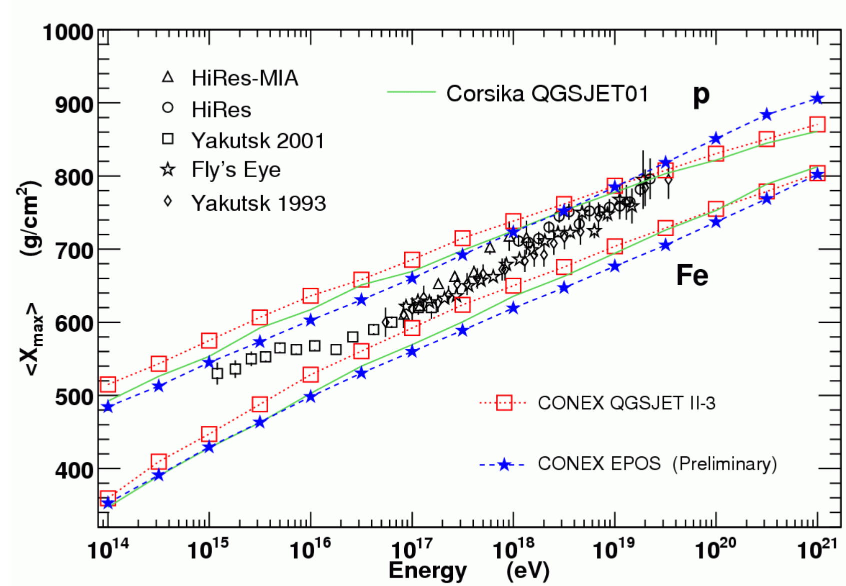
HiRes-MIA Result:

- slope consistent with composition change
- Overall densities outside QGSJet range. (EPOS)?

New hadronic model (EPOS):

- Large increase in N_μ
- Larger elongation rate (protons)
- 10x slower :-(
- (T. Pierog, 20th ECRS, Lisbon 2006)





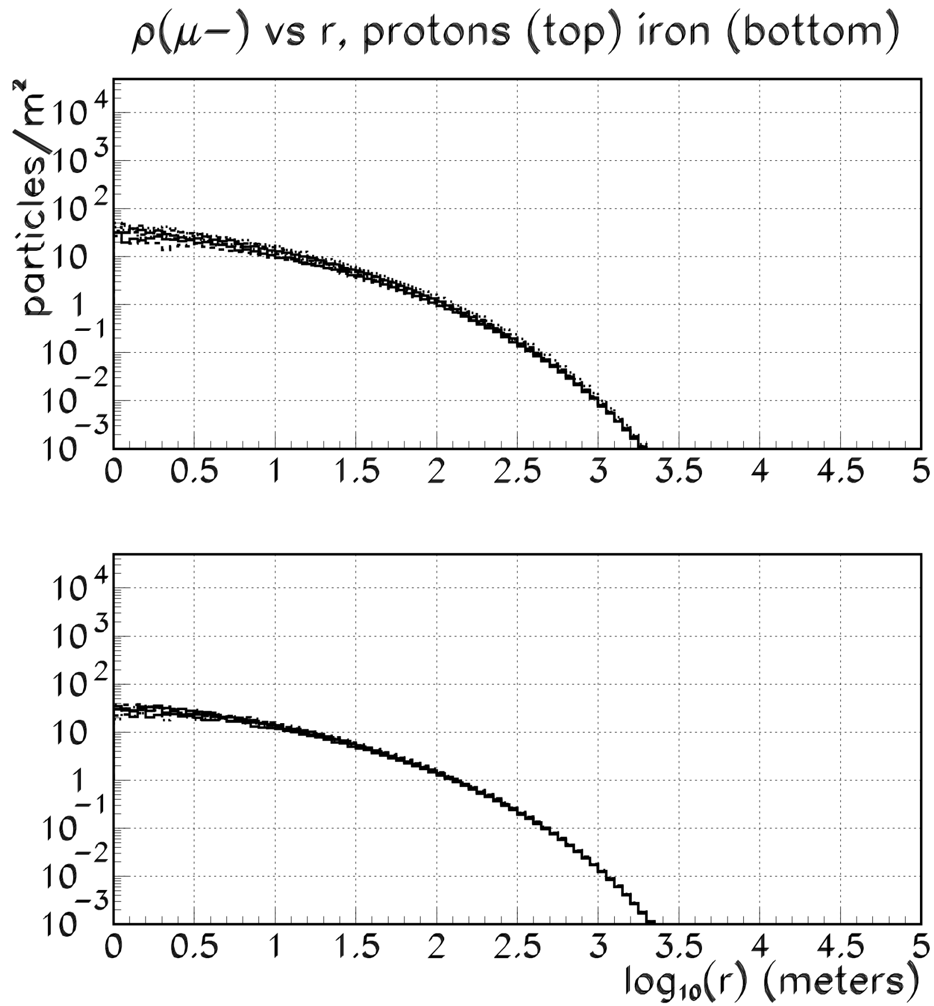
TALE Muon Detector Options

Unthinned showers

10^{17} eV, 30 degree zenith

CORSIKA/QGSJET01

3 MeV EM Cutoff, 300 MeV μ



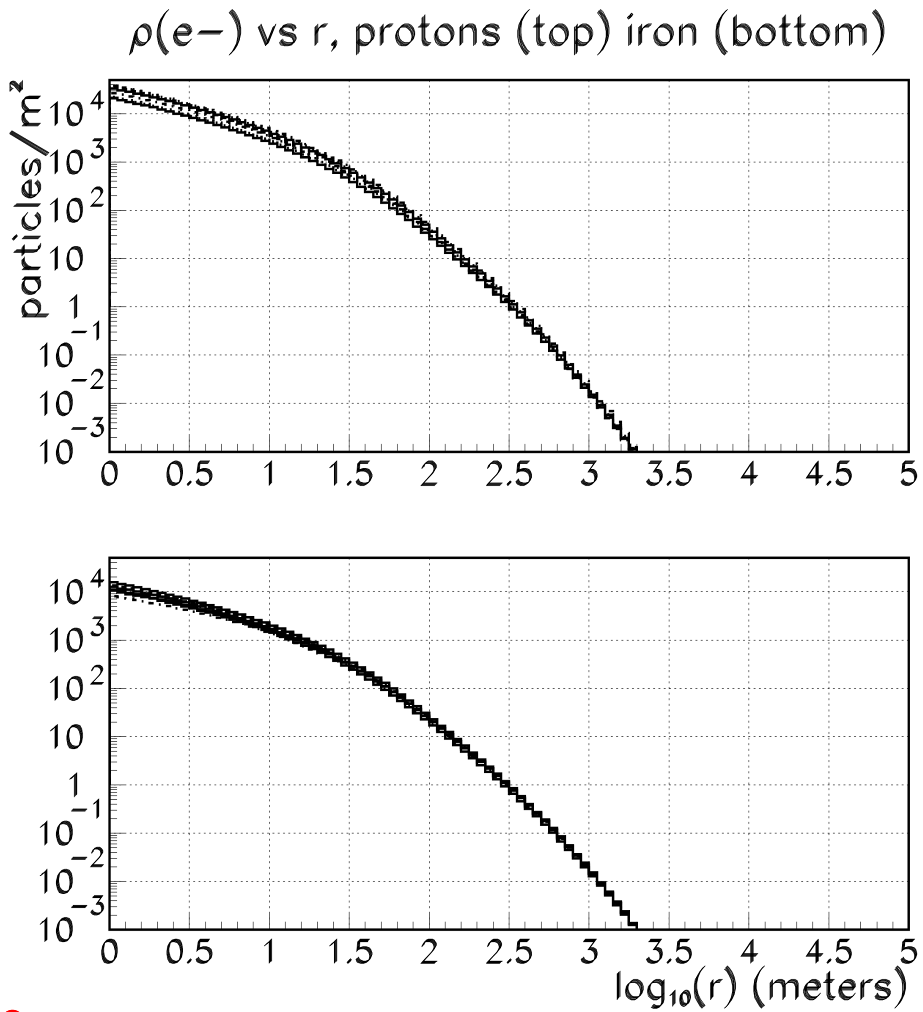
~1 muon/m^2 at 100 meters from core

Unthinned showers

10^{17} eV, 30 degree zenith

CORSIKA/QGSJET01

3 MeV EM Cutoff, 300 MeV μ

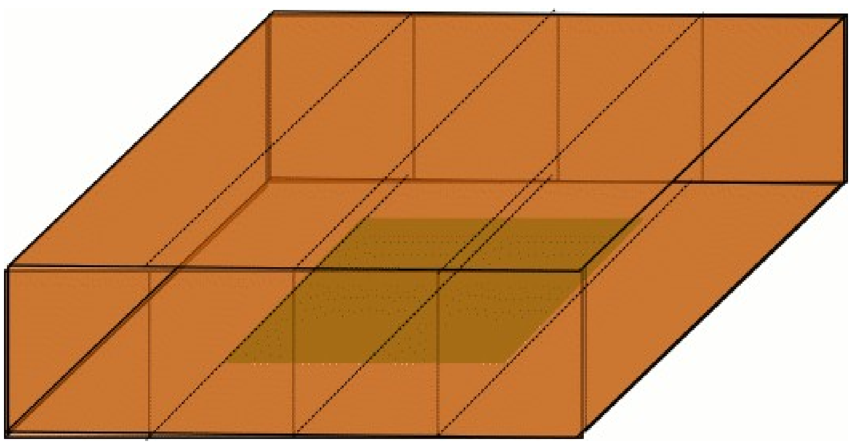


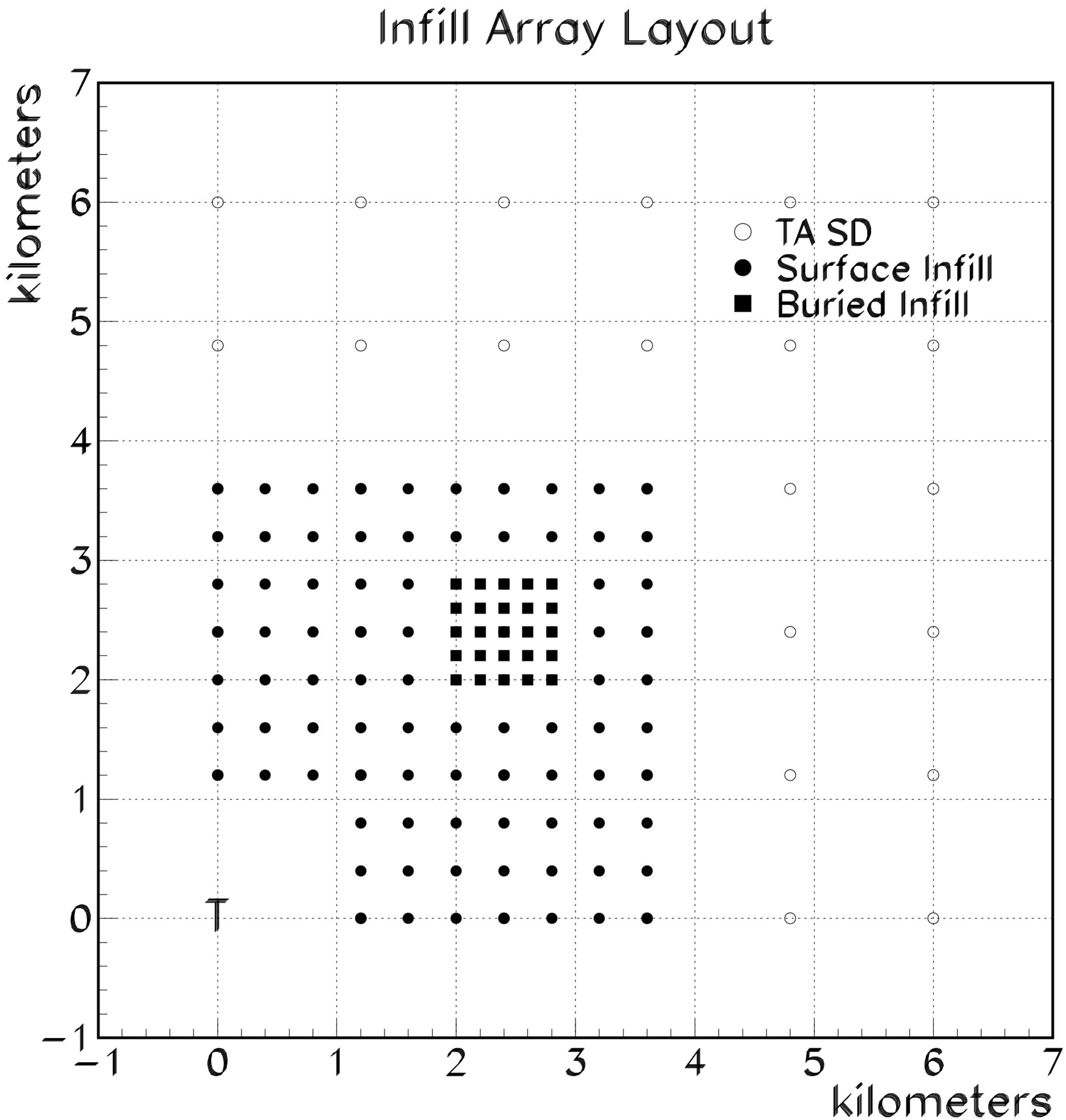
>10 electrons/m^2 at 100 meters from core

(gammas another order of magnitude)

- Water Cherenkov (Milagro)
  - Signal dominated by EM
  - Muon counting difficult
  - Small area

- “Sand Box”
  - 4x40' Connex boxes
  - 25 m^2 scintillator
  - Sand filters EM
  - Better option!



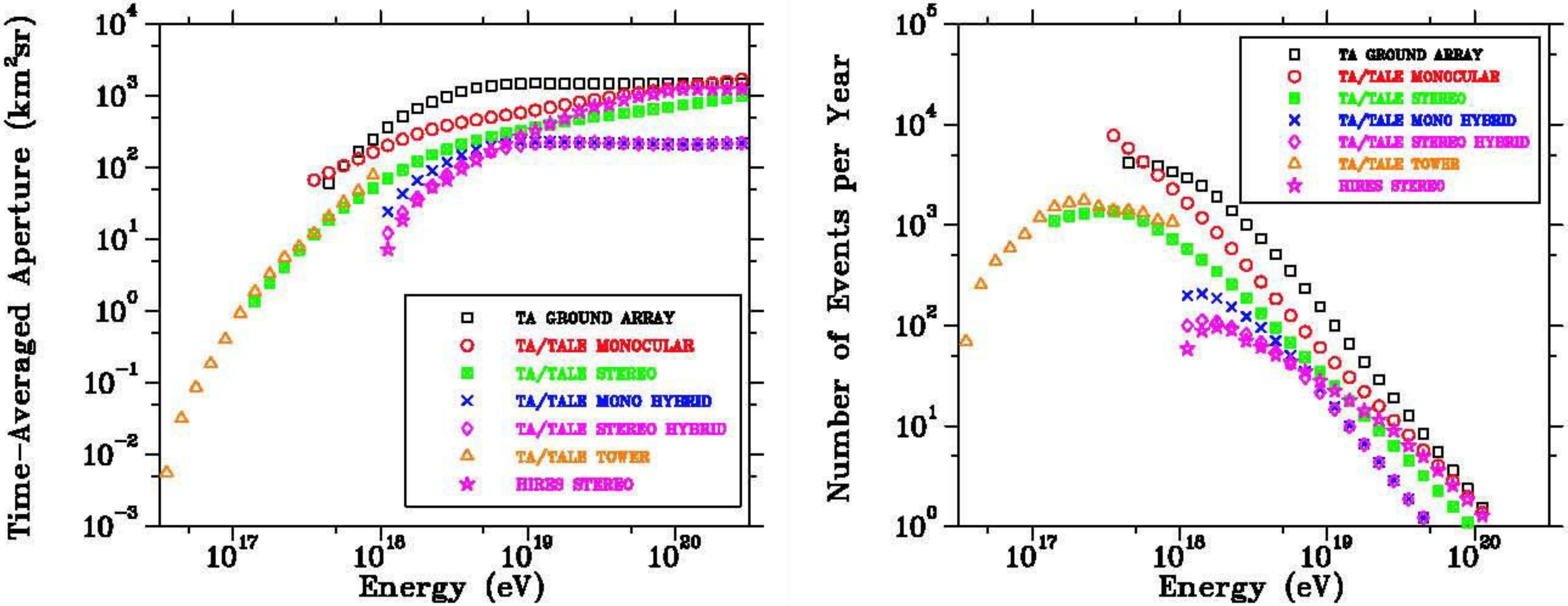


Infill Array Layout
kilometers
kilometers
TA SD
Surface Infill
Buried Infill
T
−1
0
1
2
3
4
5
6
7

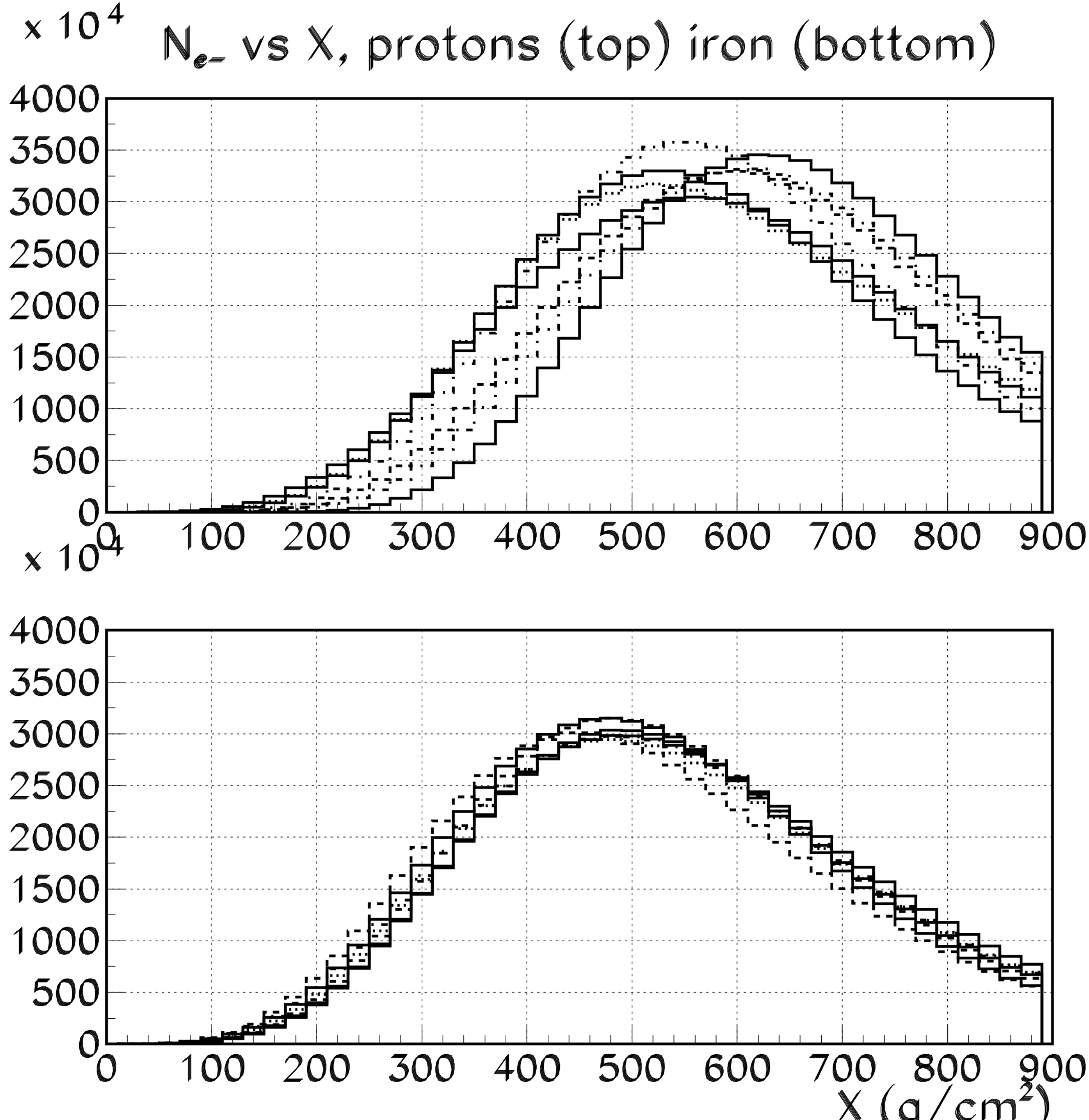
Summary

- Composition studies are vital to TALE physics objectives.
- Tower Detector, infill array will be main tool for composition studies at the knee.
- Sandbox detectors will provide complementary $\rho(\mu)$ measurements

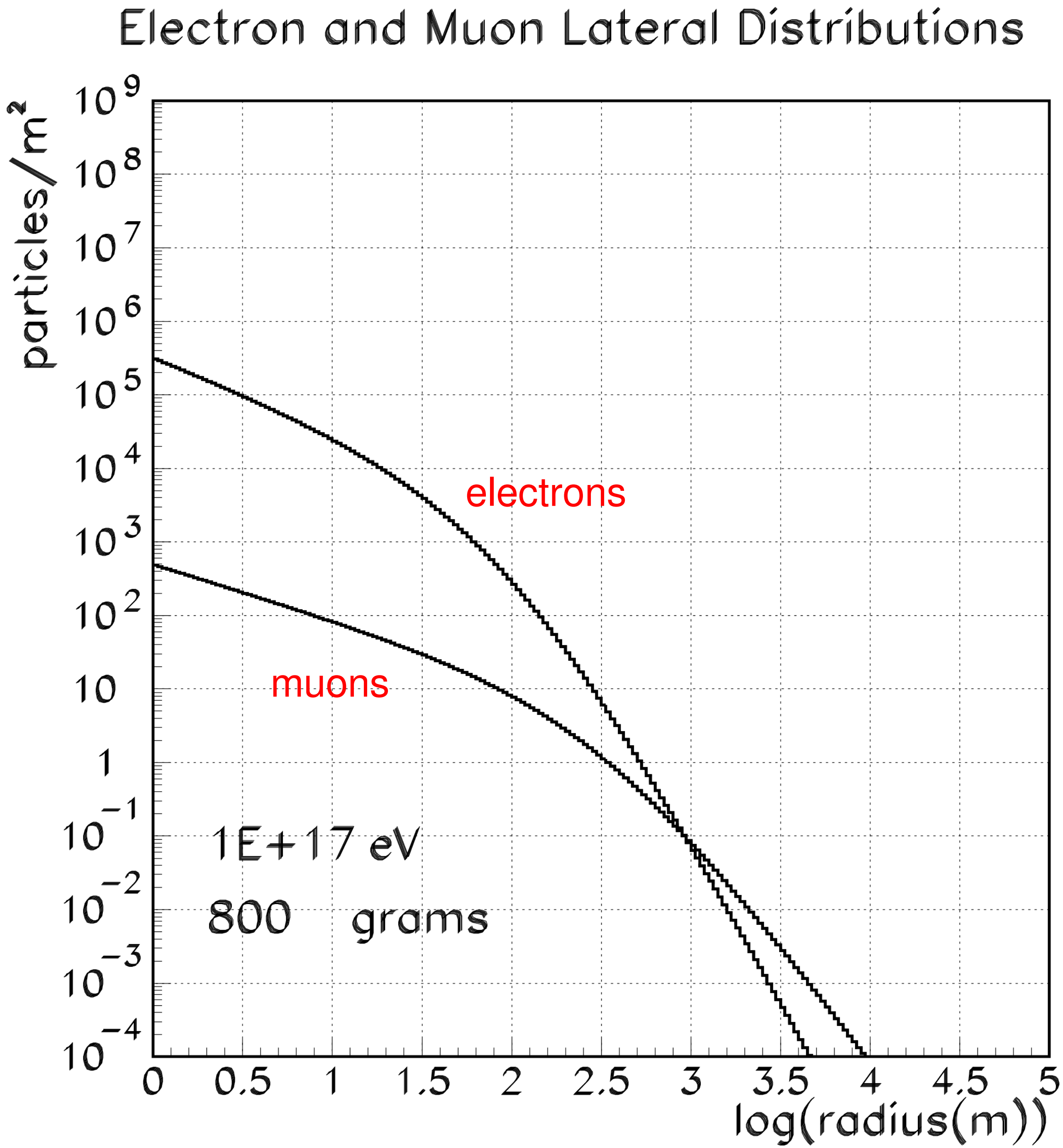
Extras



- Left: Aperture of TA/TALE Experiment, vs HiRes Stereo
- Right: Events collected per year by TA/TALE

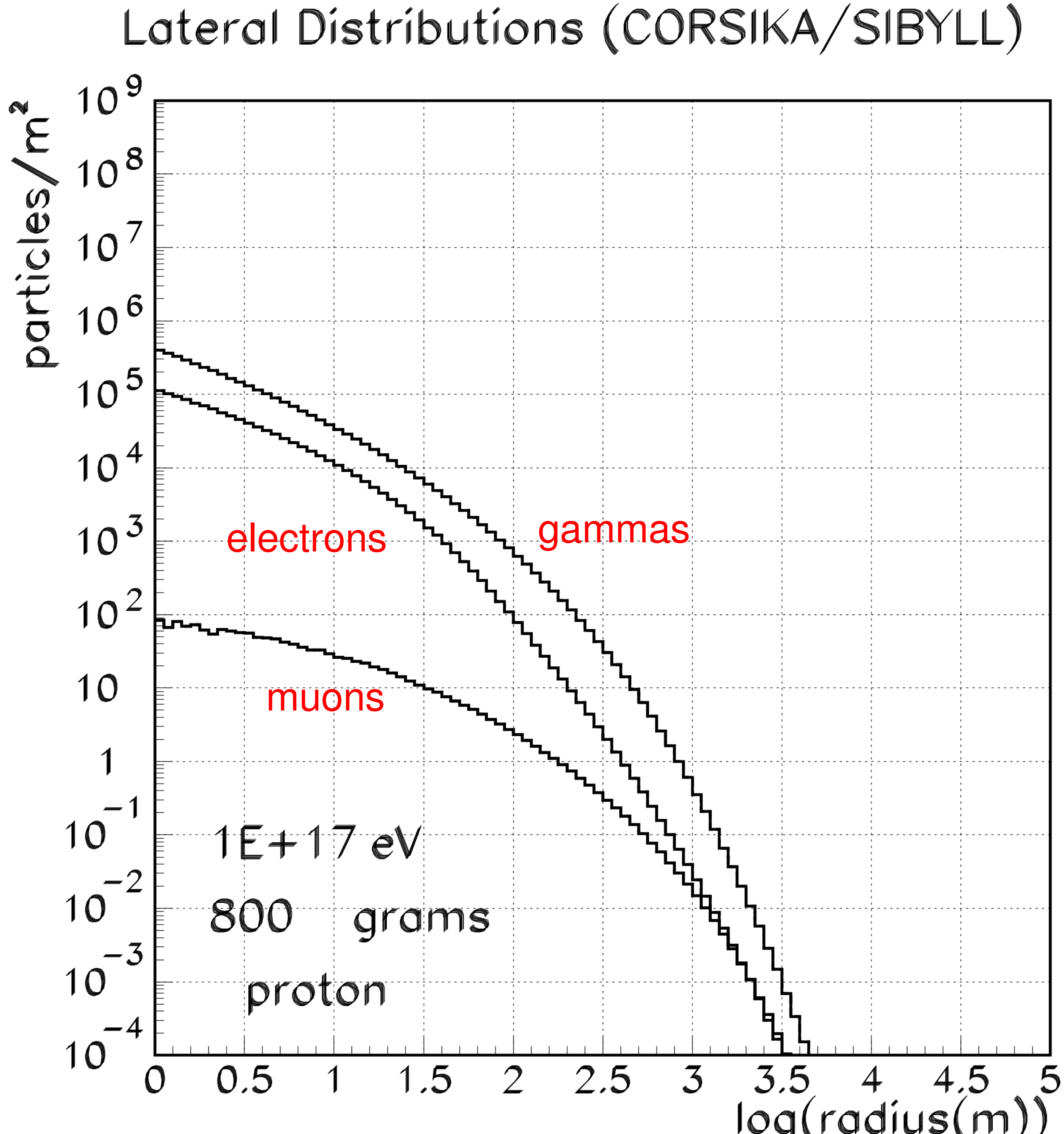


x 10^4
N_e- vs X, protons (top) iron (bottom)
4000
3500
3000
2500
2000
1500
1000
500
0
0 100 200 300 400 500 600 700 800 900
x 10^4
4000
3500
3000
2500
2000
1500
1000
500
0
0 100 200 300 400 500 600 700 800 900
X (g/cm^2)

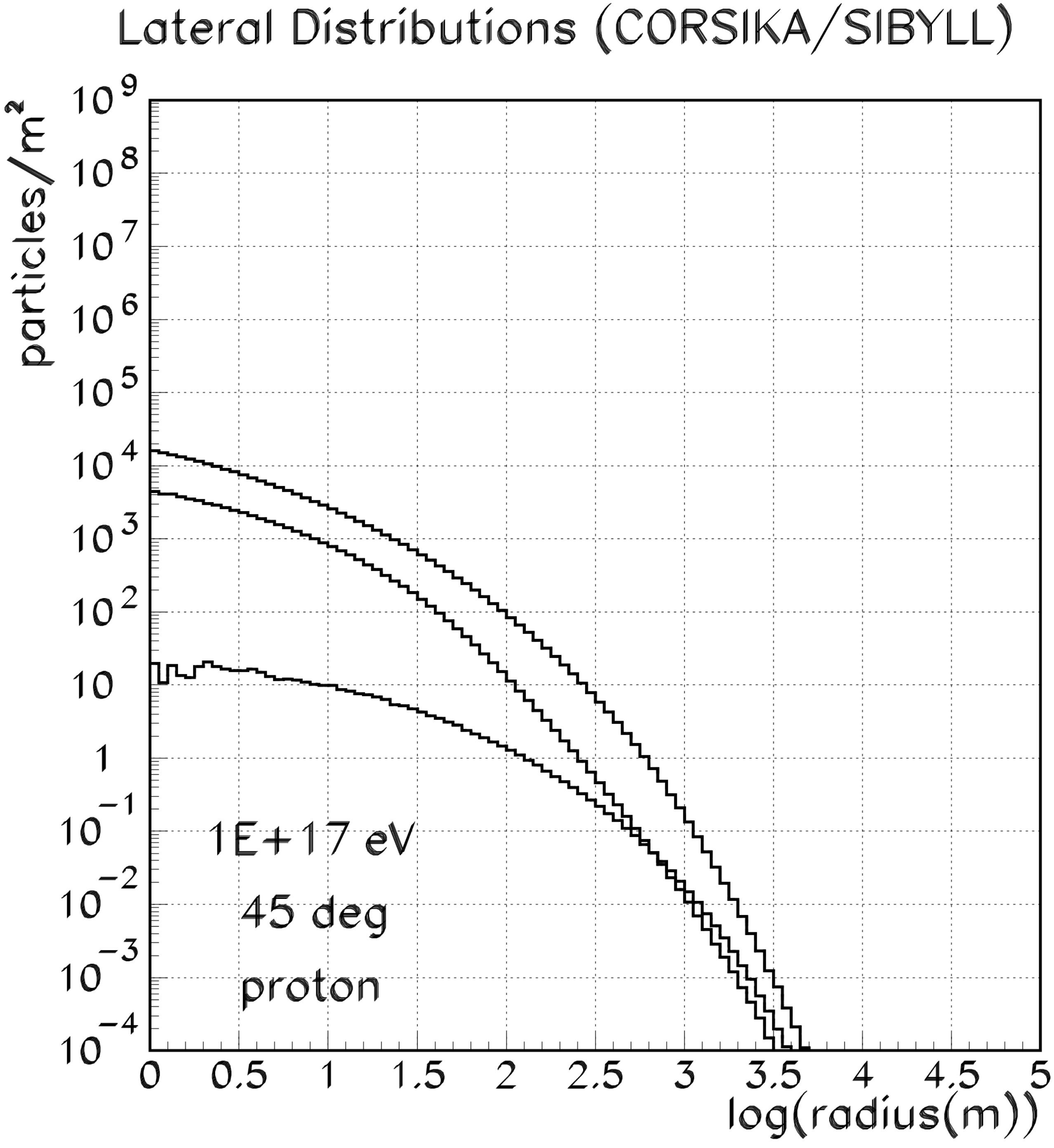


analytic functions

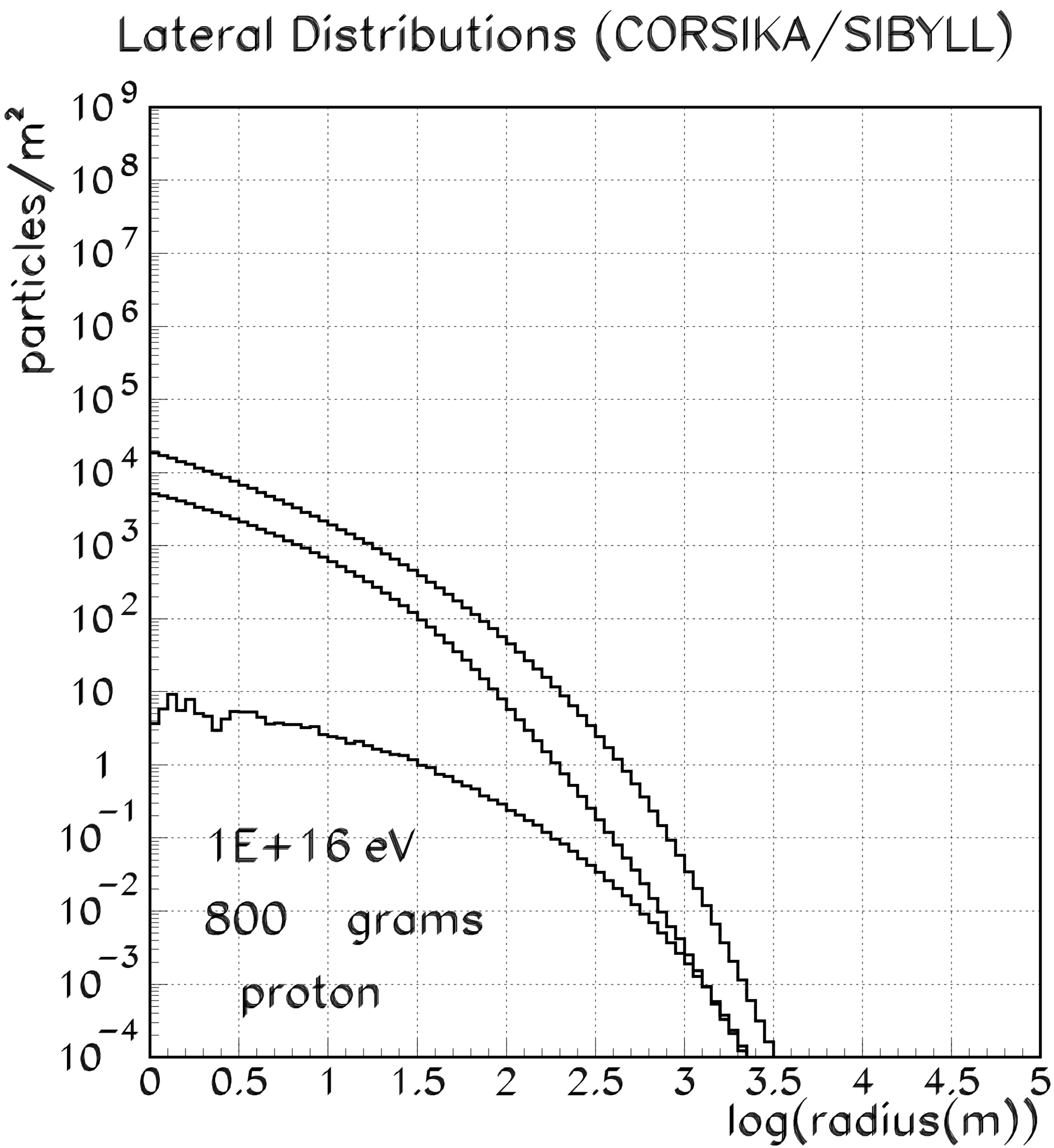
(PVS book)



Lateral Distributions (CORSIKA/SIBYLL)
particles/m²
log(radius(m))
electrons
gammas
muons
1E+17 eV
800 grams
proton



Lateral Distributions (CORSIKA/SIBYLL)
particles/m²
10⁹
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
1E+17 eV
45 deg
proton
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
log(radius(m))



Lateral Distributions (CORSIKA/SIBYLL)
particles/m²
10⁹
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
log(radius(m))
1E+16 eV
800 grams
proton

How does a water tank respond to electrons?

- S. Ranchon, M. Urban, Auger GAP 2004-014

The spectrometer has been built and calibrated at the IRES laboratory in Strasbourg by J. L. Guyonnet, J. Cailleret and R. Igersheim. It is described in the figures 1 and 2.

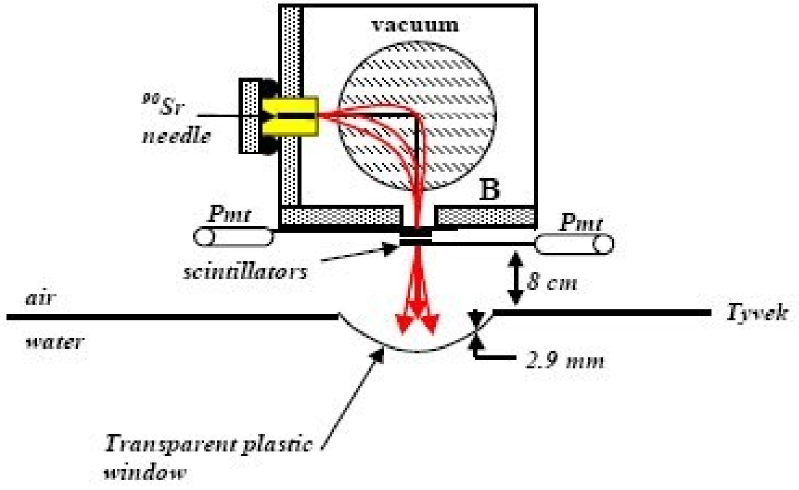
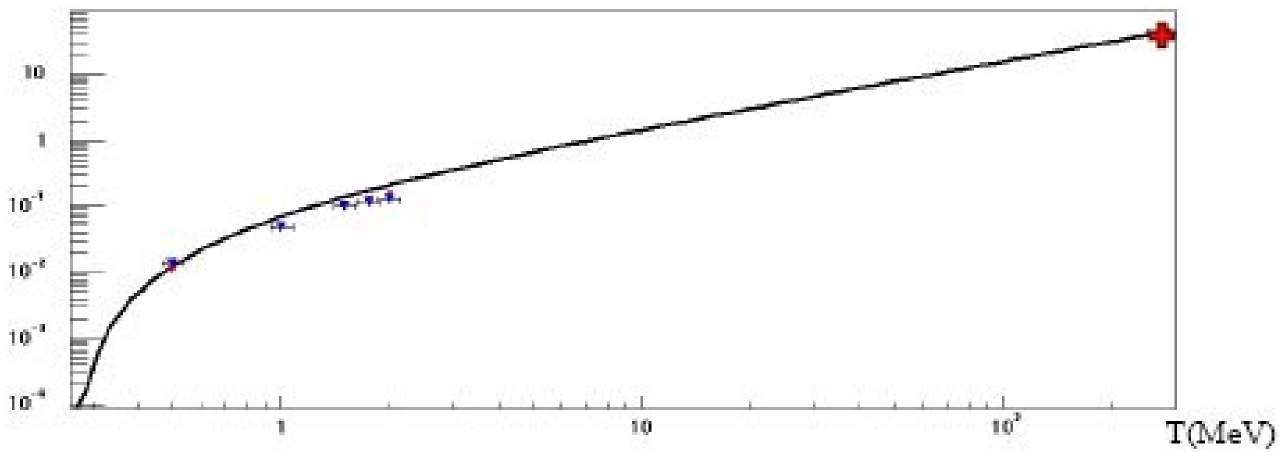
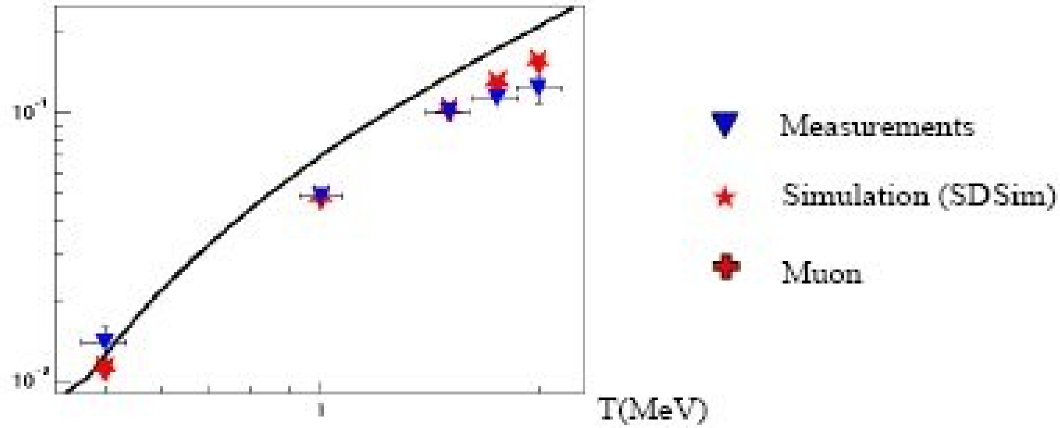
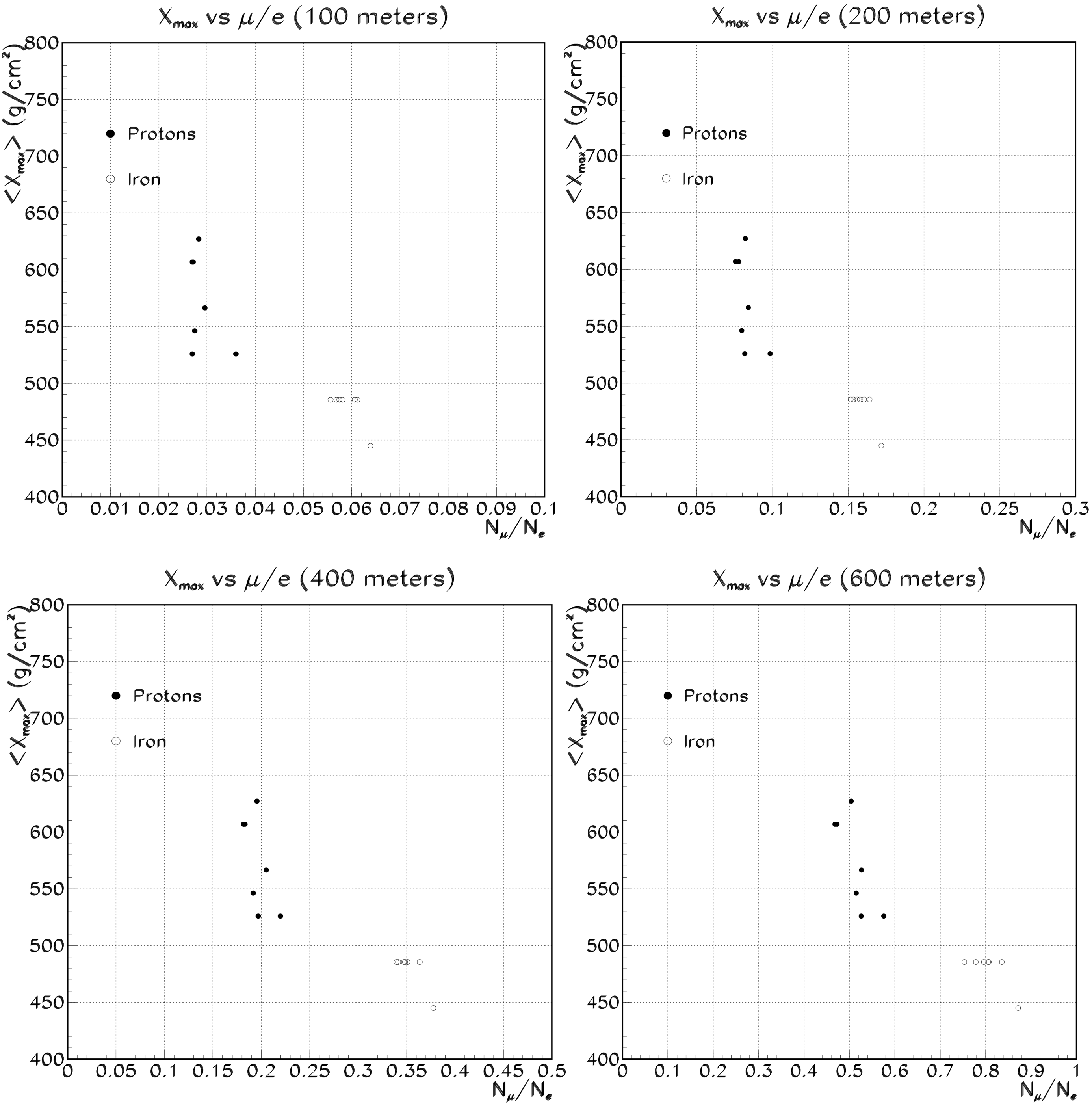


Fig. 1. Description of the spectrometer on top of the window of pmt 2 in the Orsay tank.

- Orsay results: a parametrization of response to electrons
- Need shower simulations to tell us about electron energies







Unthinned showers

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QGSJET01

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Shower Footprints