Karlsruhe Institute of Technology

PIERRE AUGER OBSERVATORY

UHECR2010 Nagoya

AugerNext

Johannes Blümer

KIT-Center Elementary Particle and Astroparticle Physics KCETA

PIERRE
AUGER
OBSERVATORY

A very large ground-based cosmic ray observatory
in the northern hemisphere is required.
A world-wide site search will be conducted.

Conclusions A

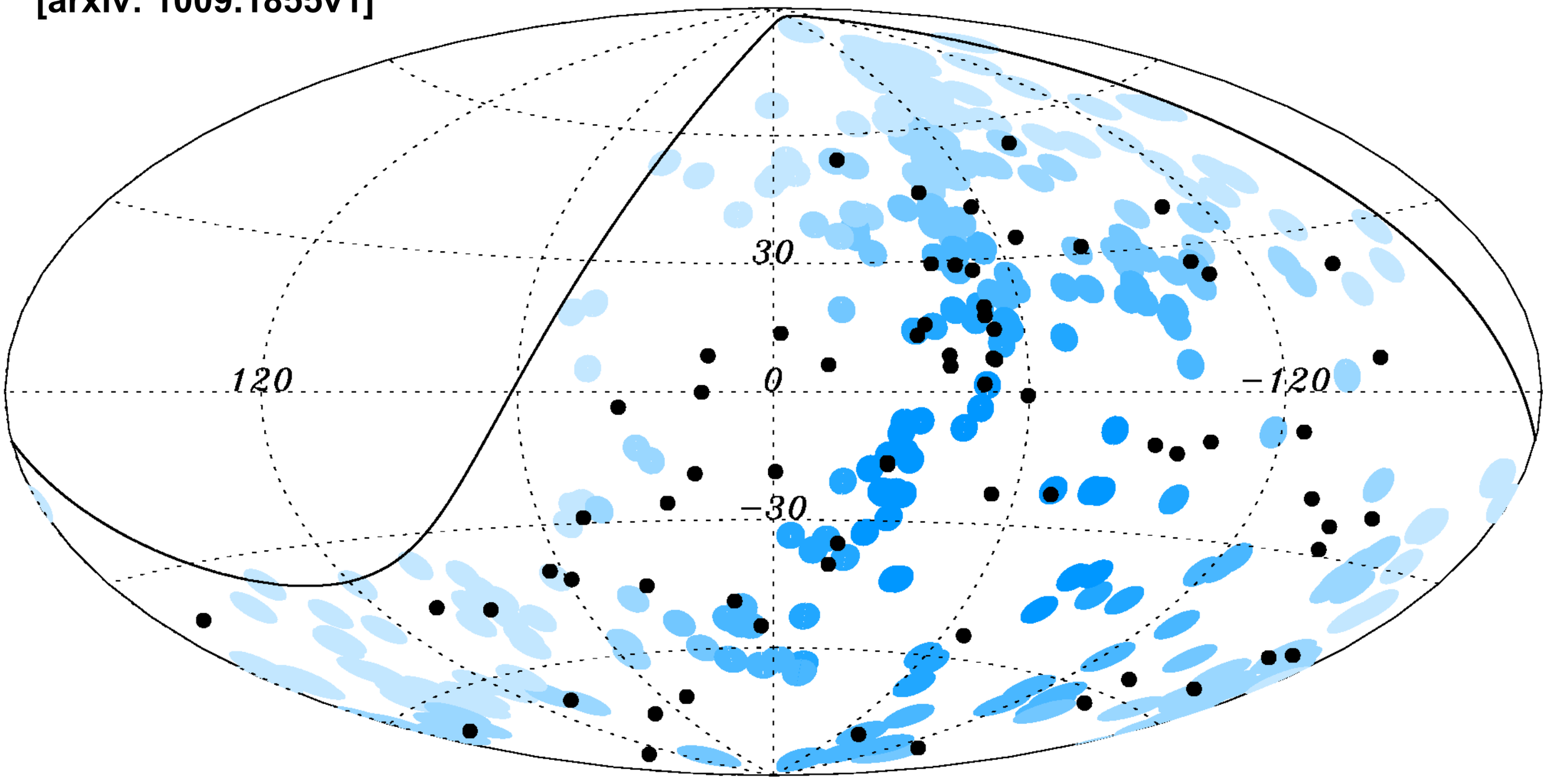
PIERRE AUGER OBSERVATORY

- First precise energy **spectrum** from 1 EeV to above 100 EeV
- Optical fluorescence detection of showers set the **energy scale** to ± 22%,
  - biggest uncertainty from absolute fl. yield; **soon to be much improved**
- **Ankle** at 2-3 EeV: energy cross-calibrator?
- Flux suppression at 50-60 EeV: **GZK effect or maximum accelerator energy?**
- With increasing energy **air showers develop** higher up in the atmosphere and show less fluctuations – **astrophysics and/or particle physics? E.g. heavier particles or higher cross section?**
- arrival directions of cosmic rays become abruptly **anisotropic** above 50-60 EeV, in coincidence with the spectrum being much steeper
- **cosmic ray arrival directions correlate with the distribution of nearby (<75 Mpc) extragalactic objects**; several reference maps are being tested. **The correlating fraction is (38 ± 6)% [was (69+11-13)% initially] -- need more data; interesting to watch the excess from certain regions**

Anisotropy & sources

PIERRE AUGER OBSERVATORY

AGN correlation: update; 69 events E>55 EeV
[arxiv: 1009.1855v1]

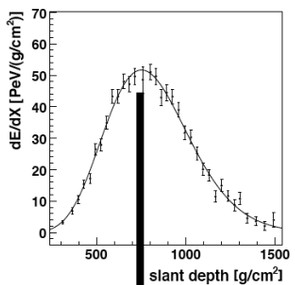


blue: VCV AGNs + 3.1° weighted with exposure, distance less than 75 Mpc
black: 69 events, E>55 EeV, <60° zenith, angular resolution ≤ 0.9°; available as list

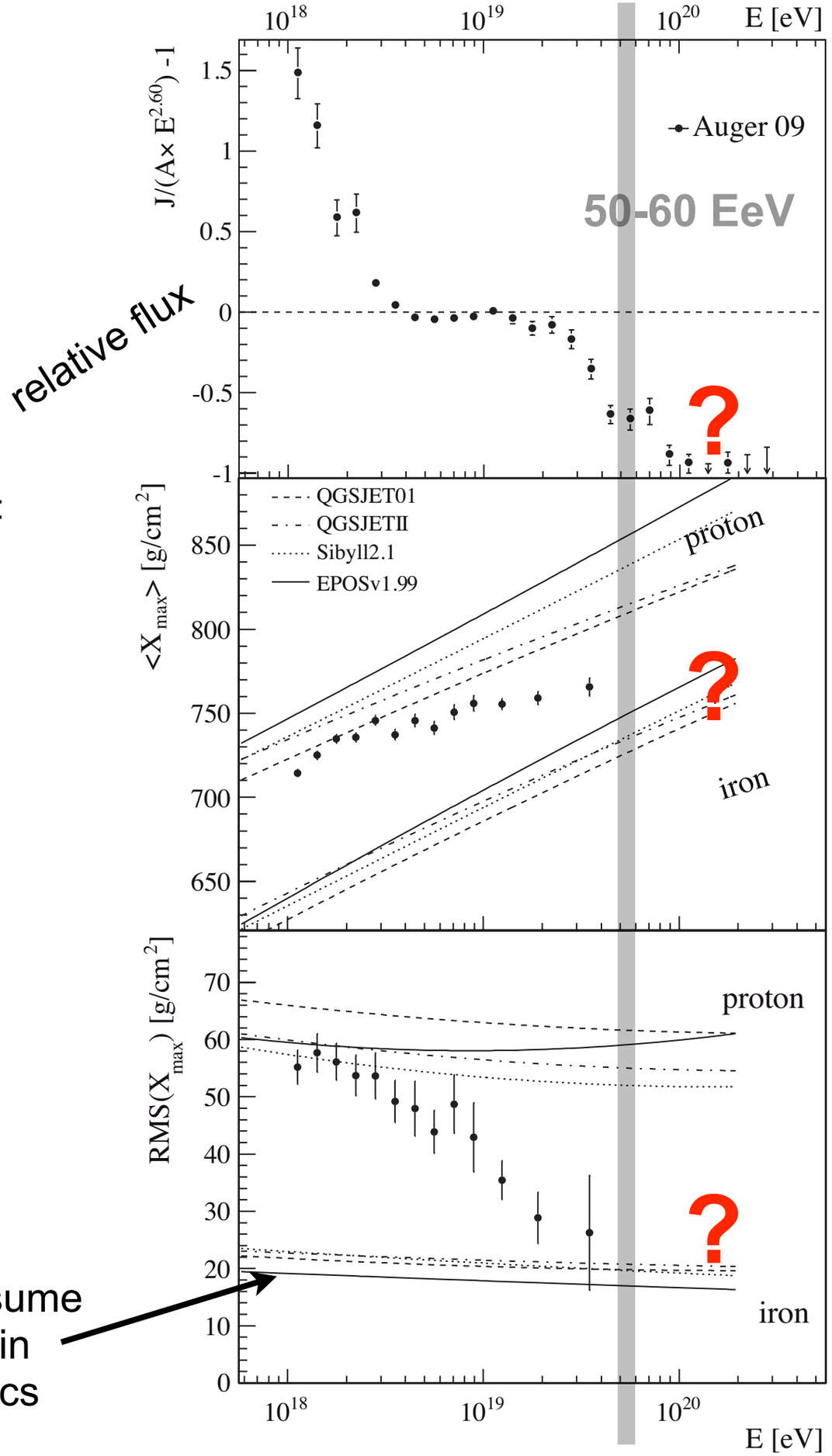
spectrum: convoluted information about sources, particles and propagation

shower profile: independent, best estimator of primary particle mass

de/dX



models assume no change in basic physics



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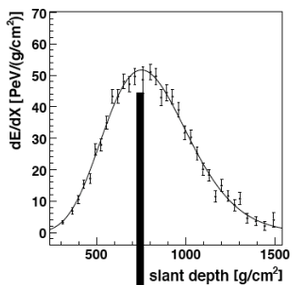

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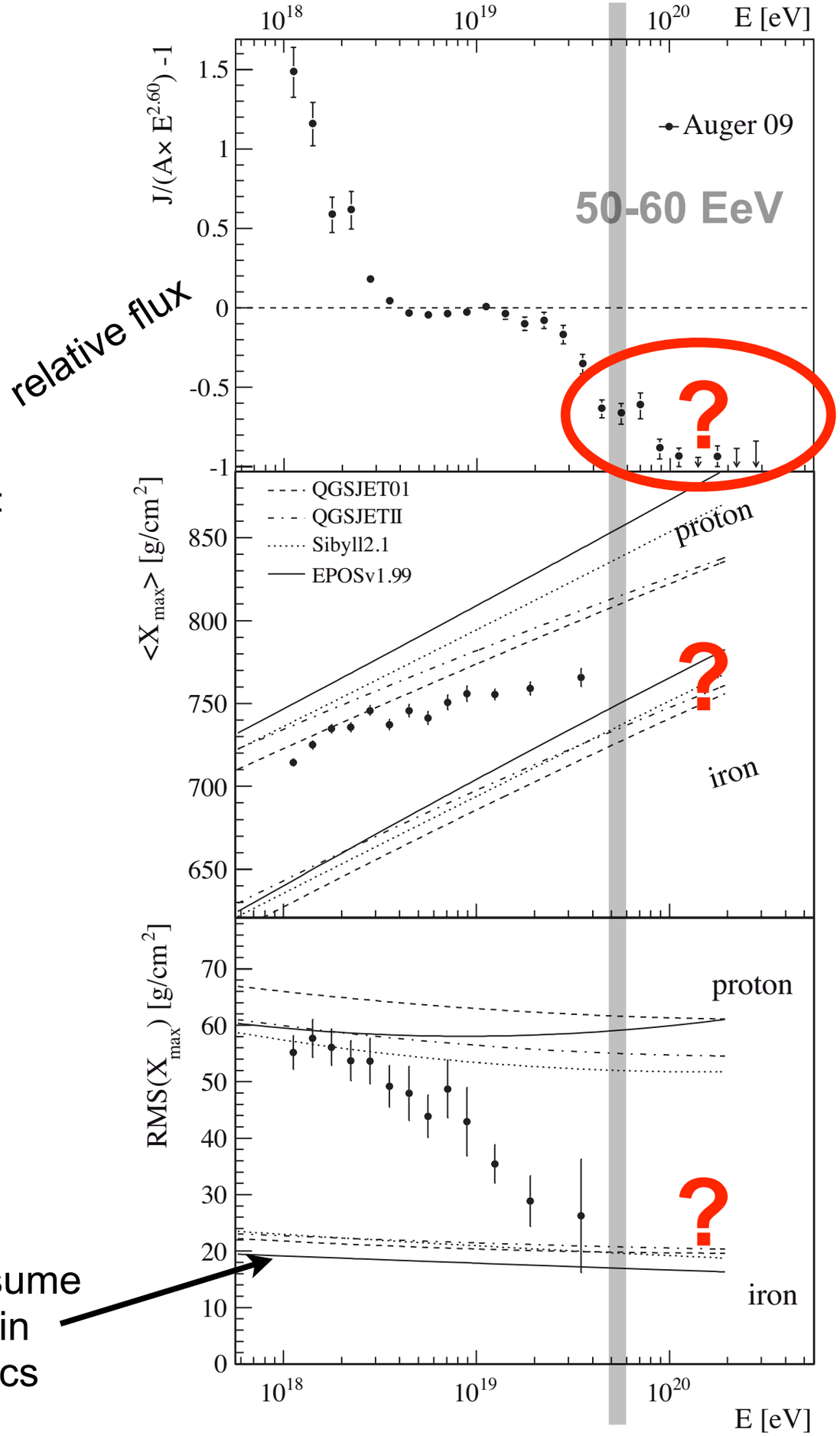

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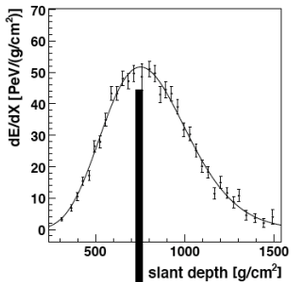
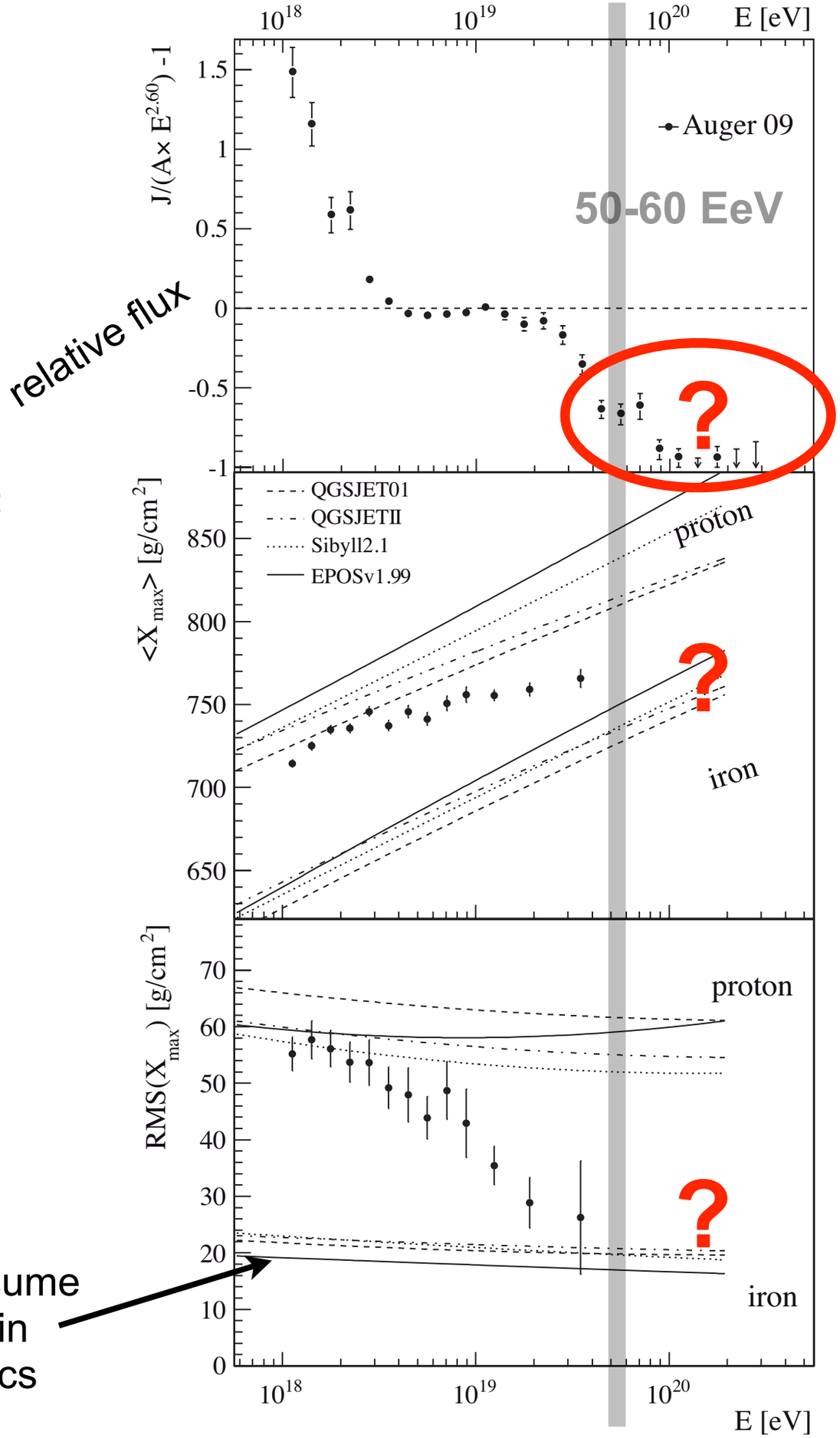
de/dX





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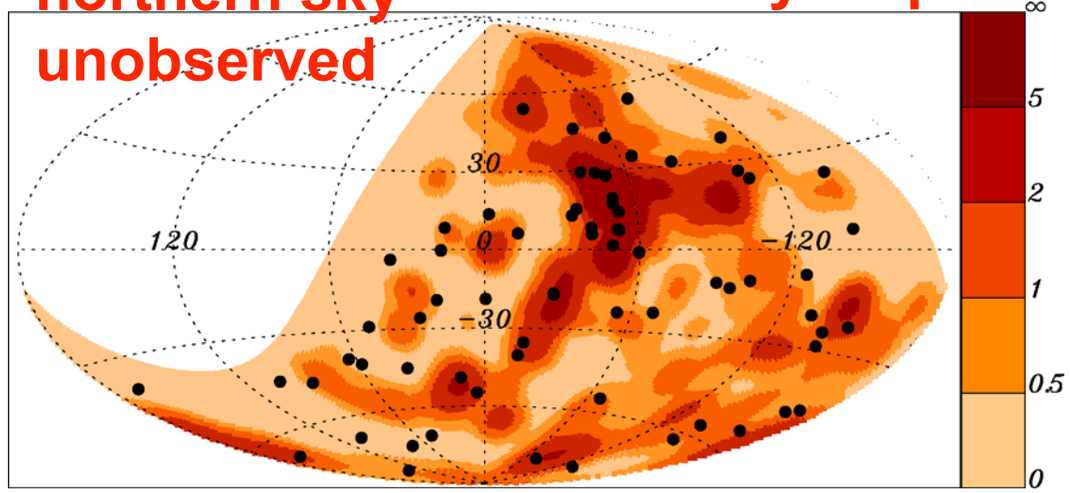
northern sky unobserved

few events in sky map



http://arxiv.org/abs/1009.1855 as of Sep 10, 2010

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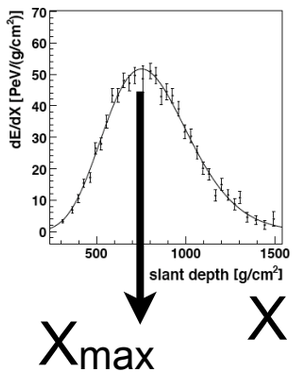
de/dX



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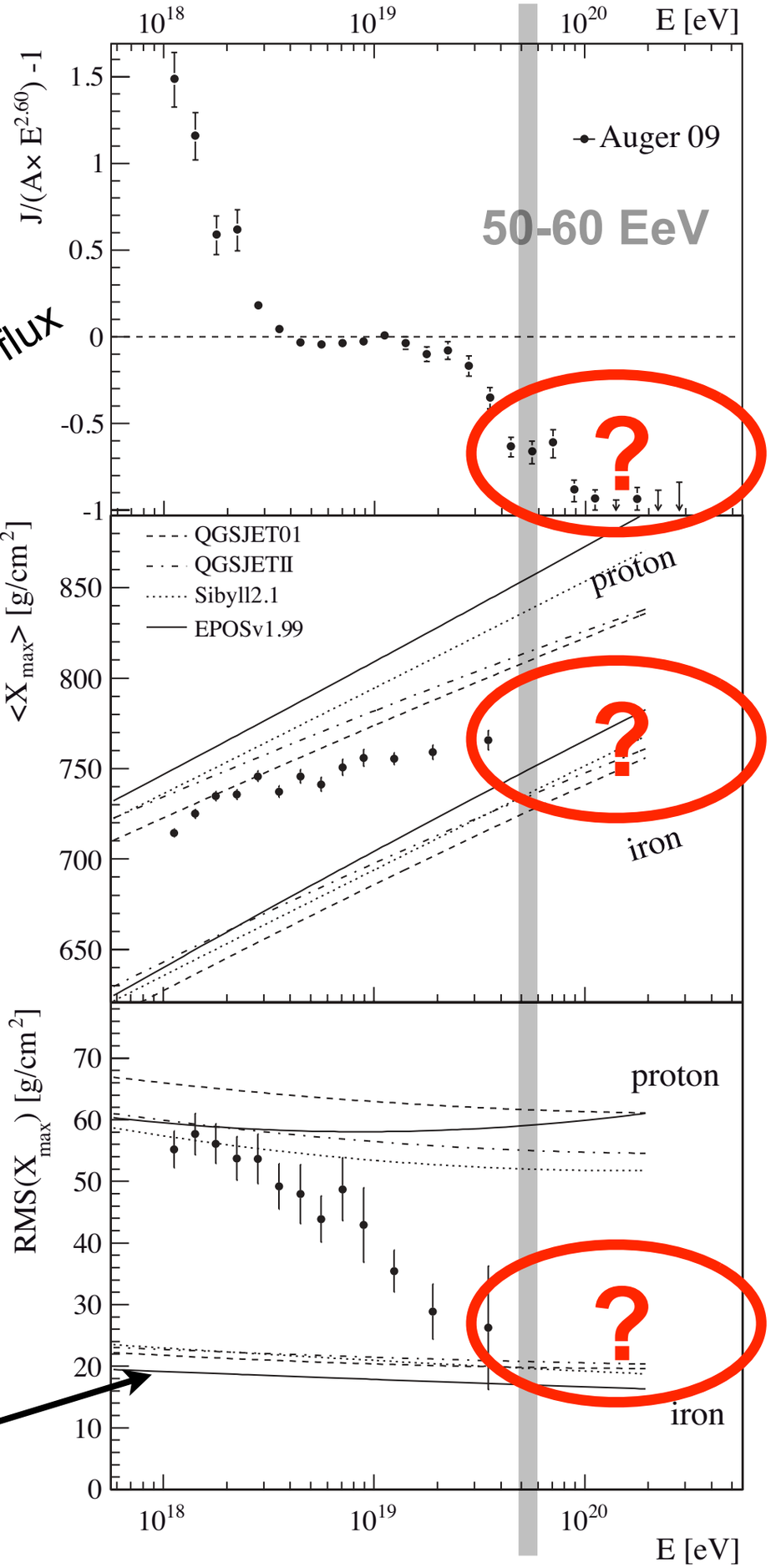

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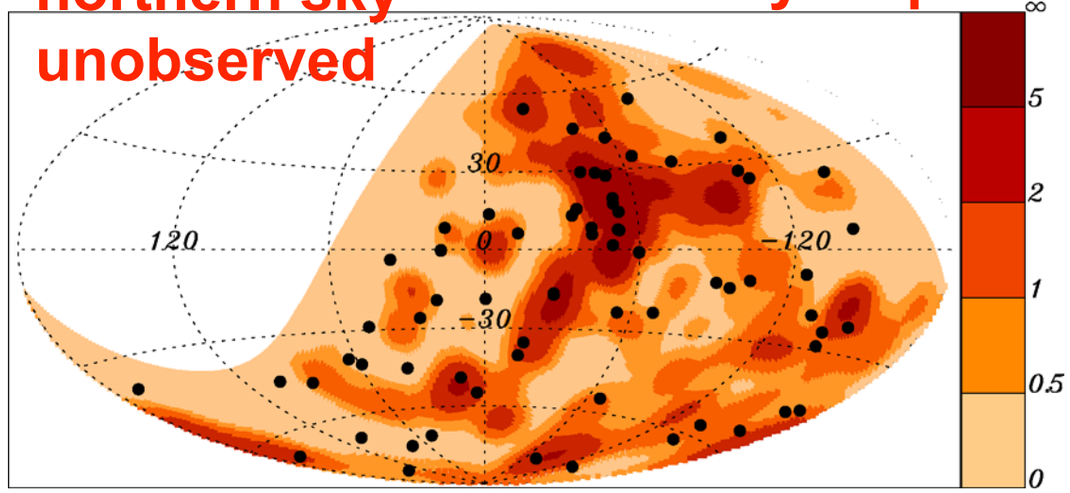

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composition at and above the GZK threshold?

alternative explanations like increasing cross section?

particle physics at √s > 350 TeV

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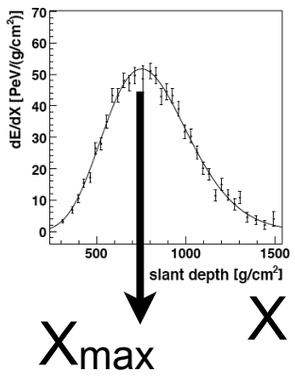
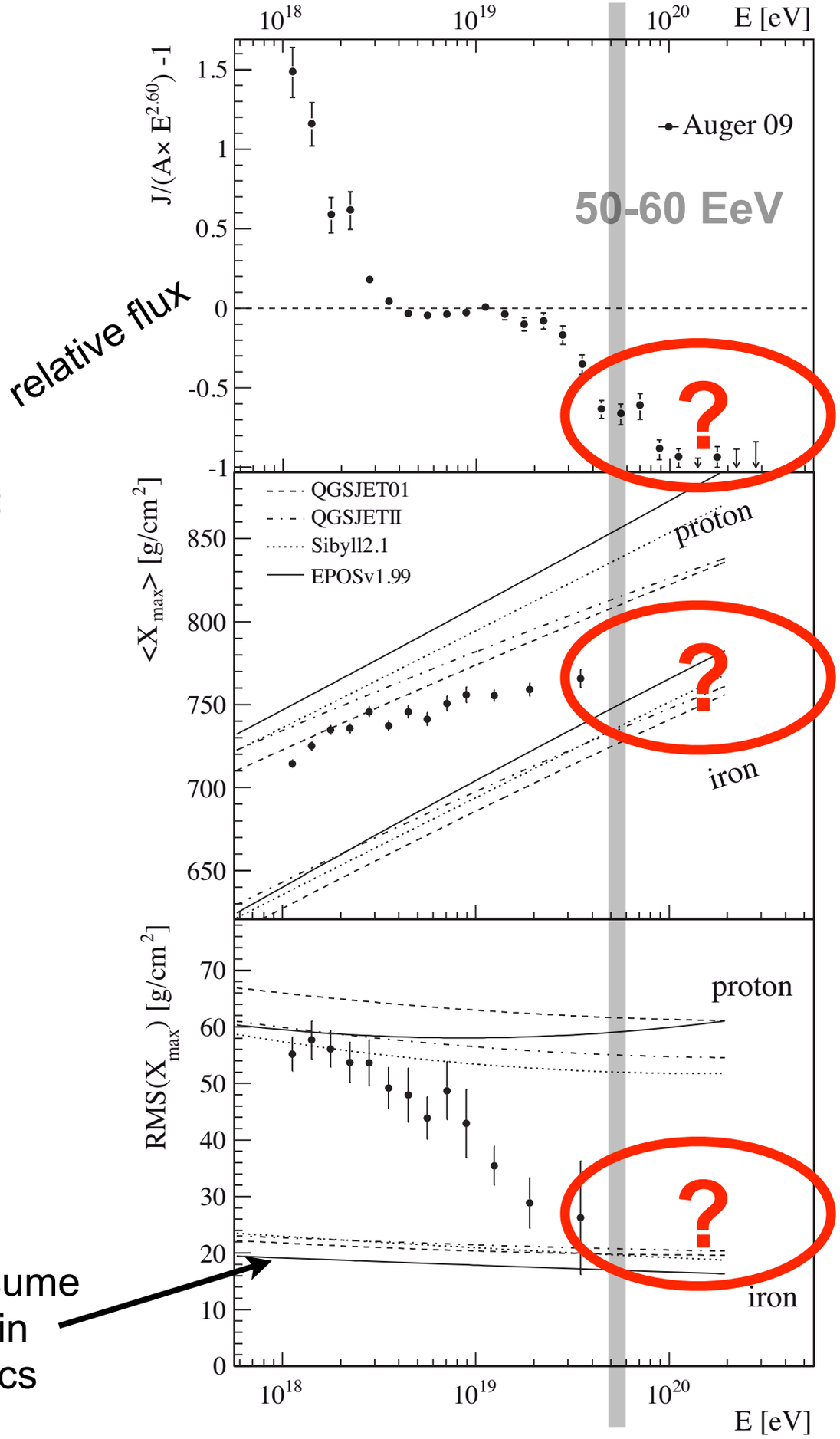
shower profile: independent, best estimator of primary particle mass

de/dX



models assume no change in basic physics



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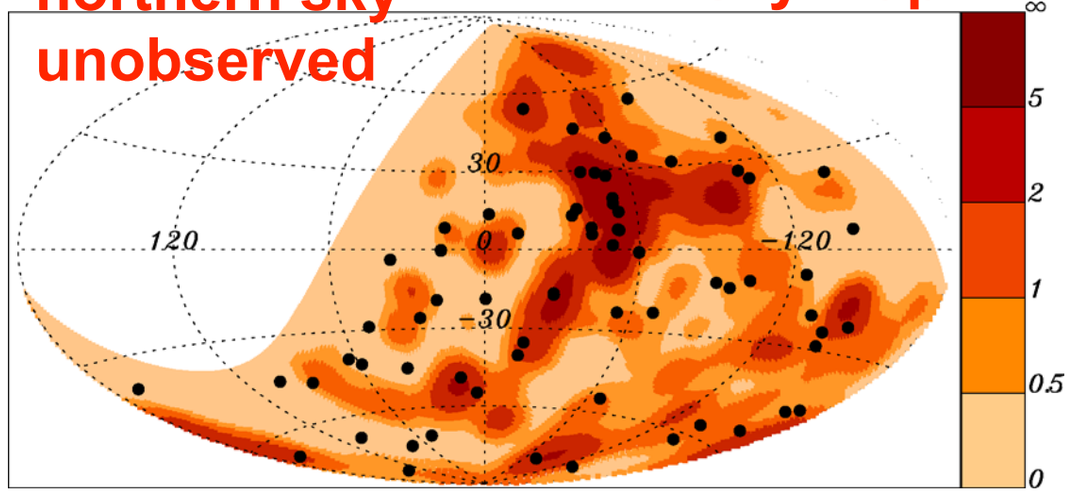

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composition at and above the GZK threshold?

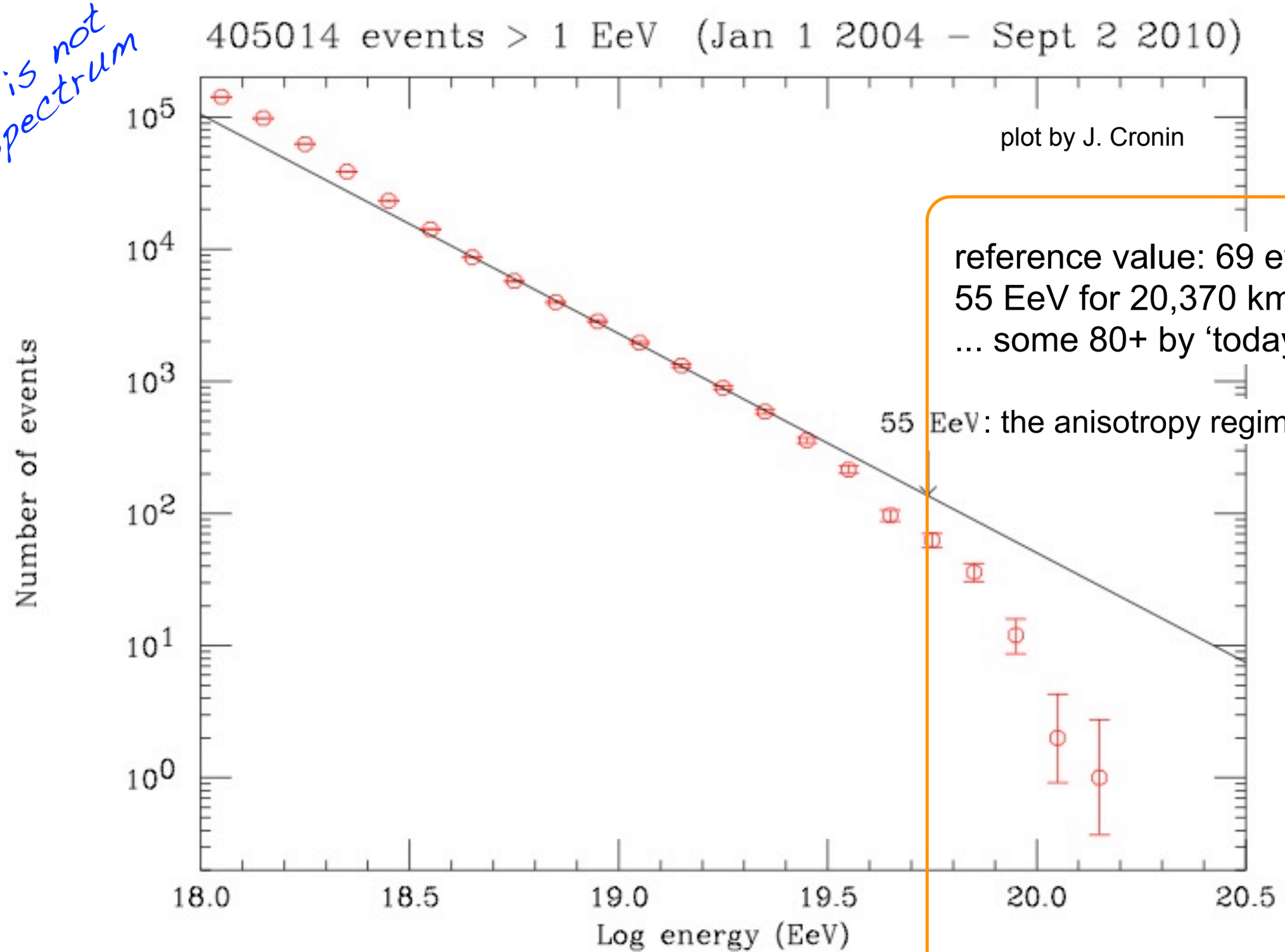
alternative explanations like increasing cross section?

particle physics at √s > 350 TeV

Addressing these questions needs much more statistics at the highest energies, i.e. a much larger area

Statistics

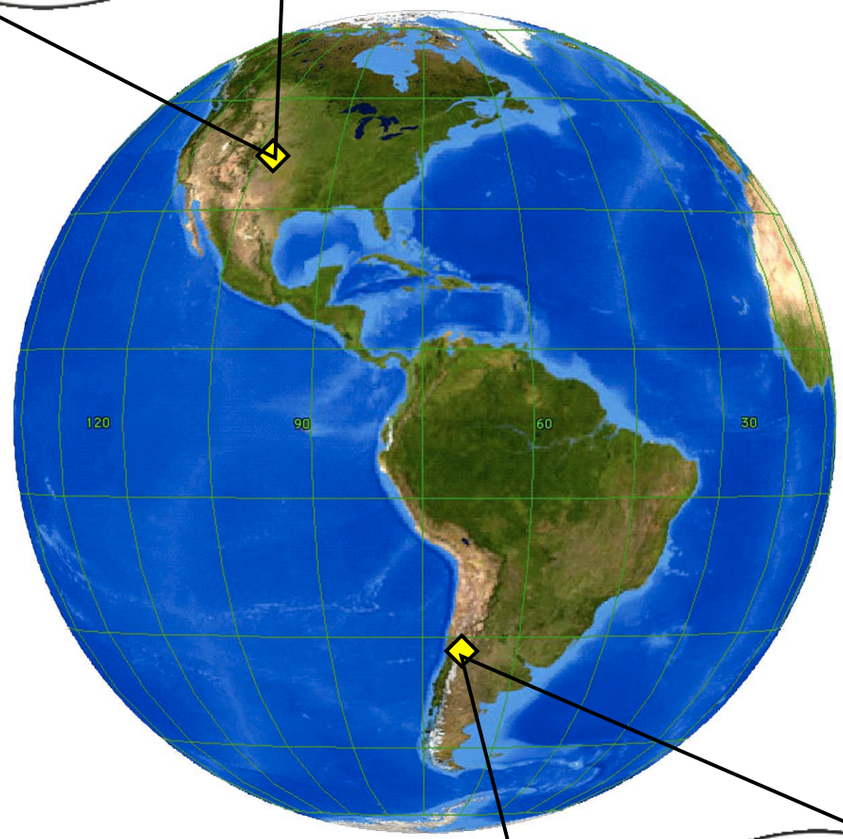
this is not a spectrum



reference value: 69 events above 55 EeV for 20,370 km^2 sr yr;
... some 80+ by 'today'...

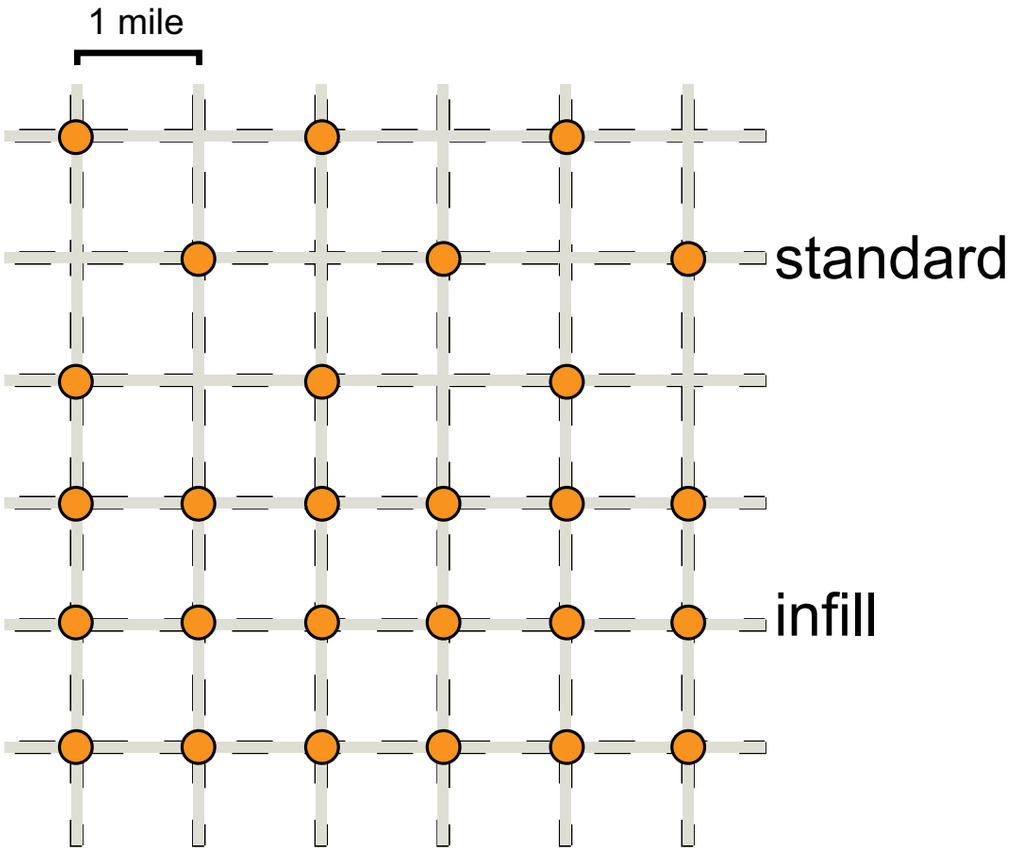
55 EeV: the anisotropy regime

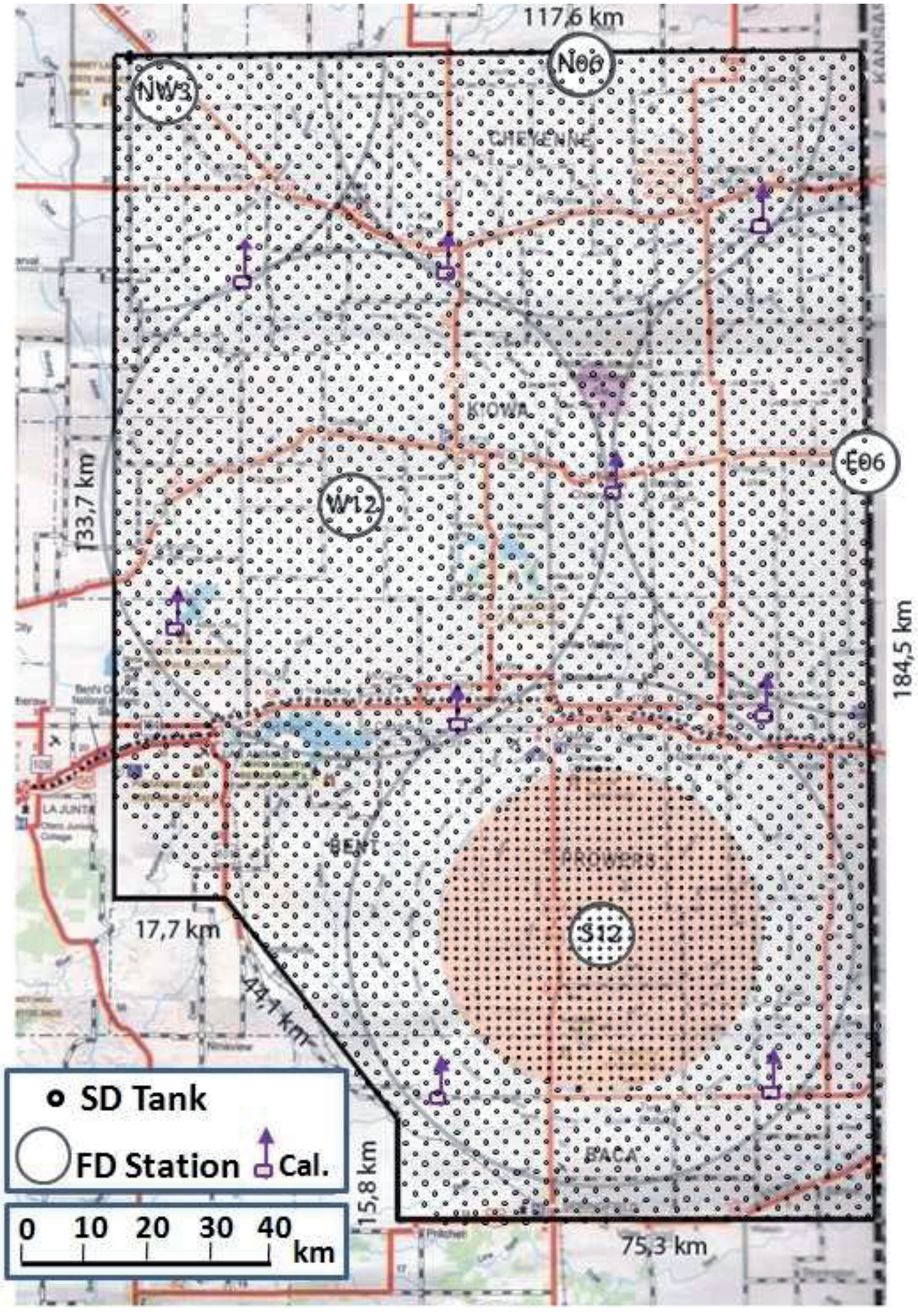
Auger had always been designed as a two-instrument, full-sky coverage cosmic ray observatory

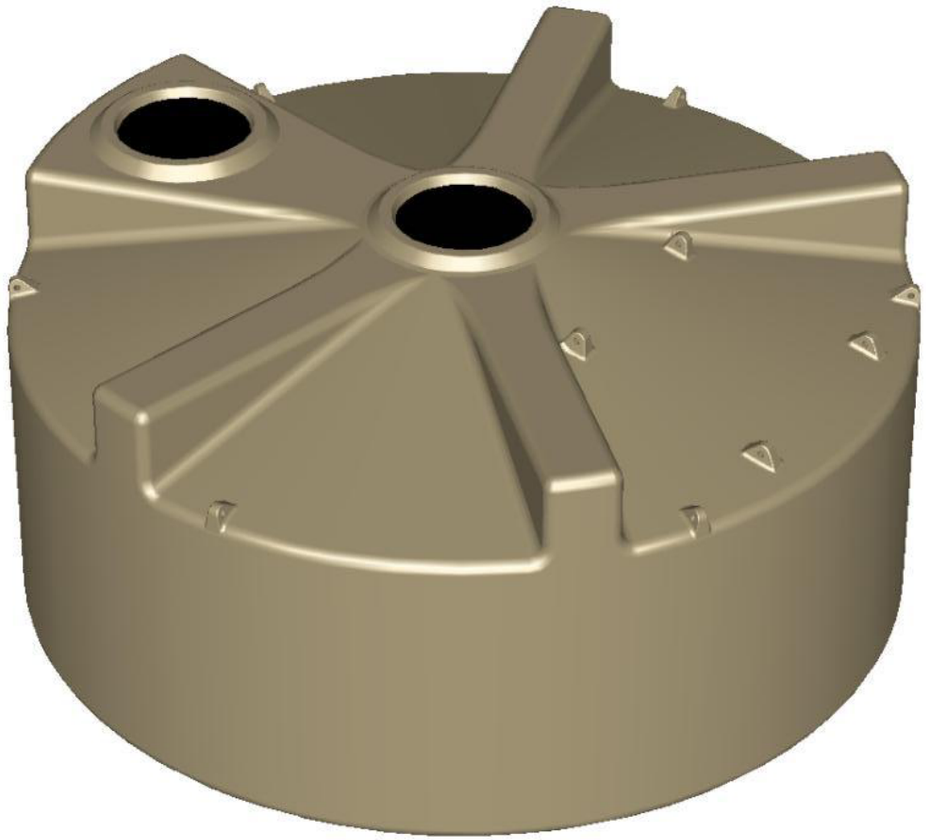


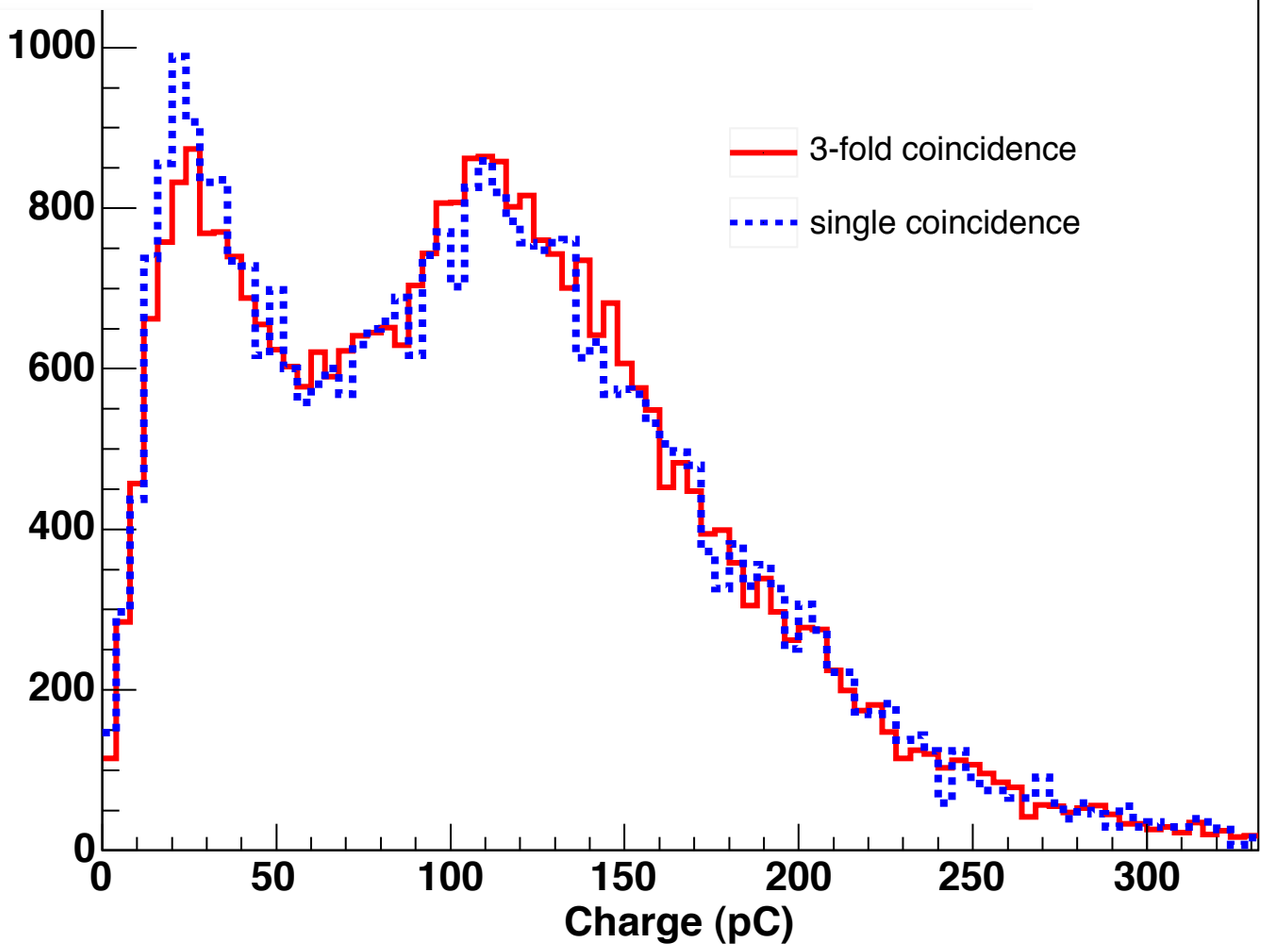
see e.g. JBL & Auger Coll.,
New Journal of Physics 12 (2010) 035001

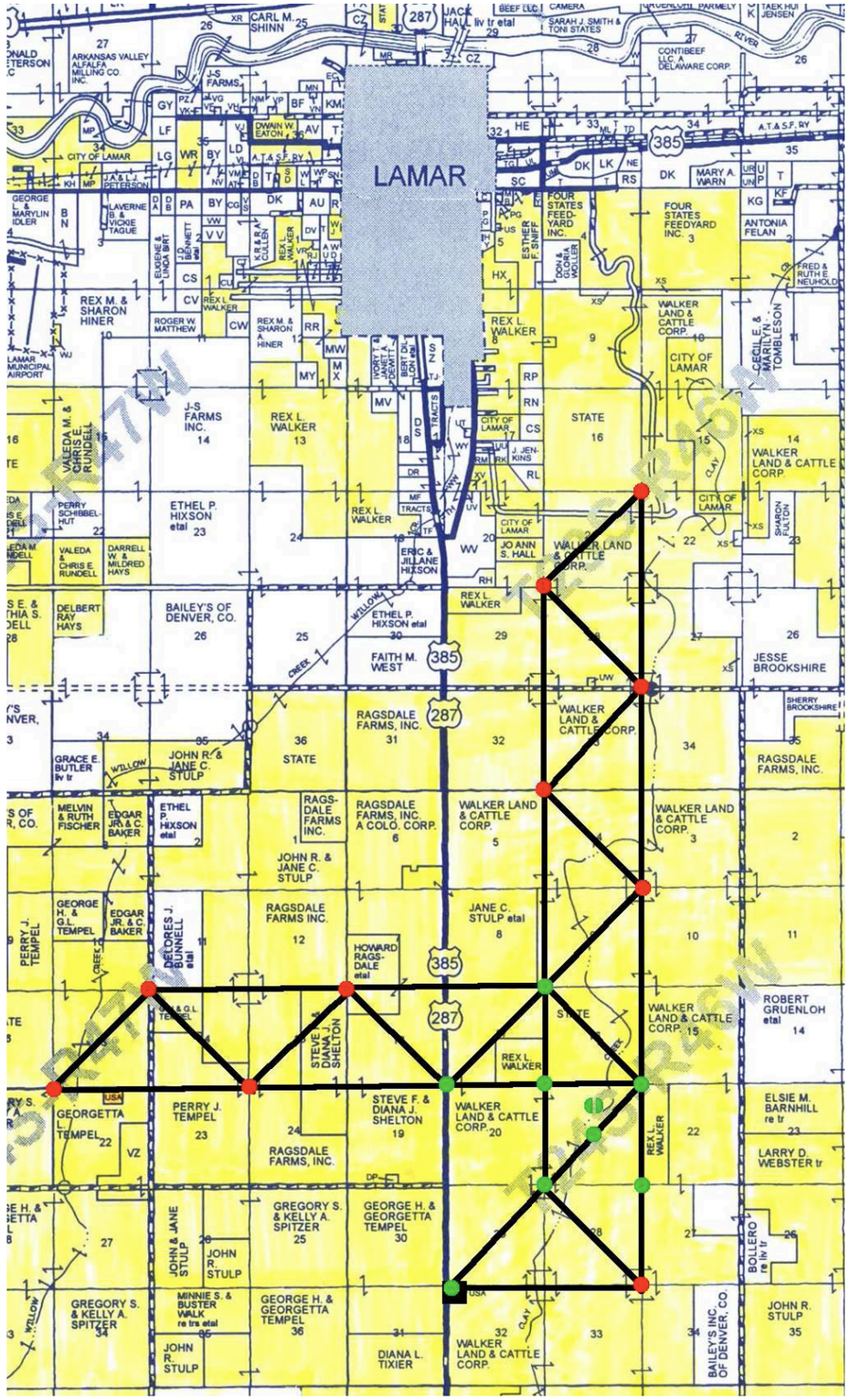

Fort Collins
Boulder
Denver
Aurora
Colorado
Colorado Springs
Pueblo

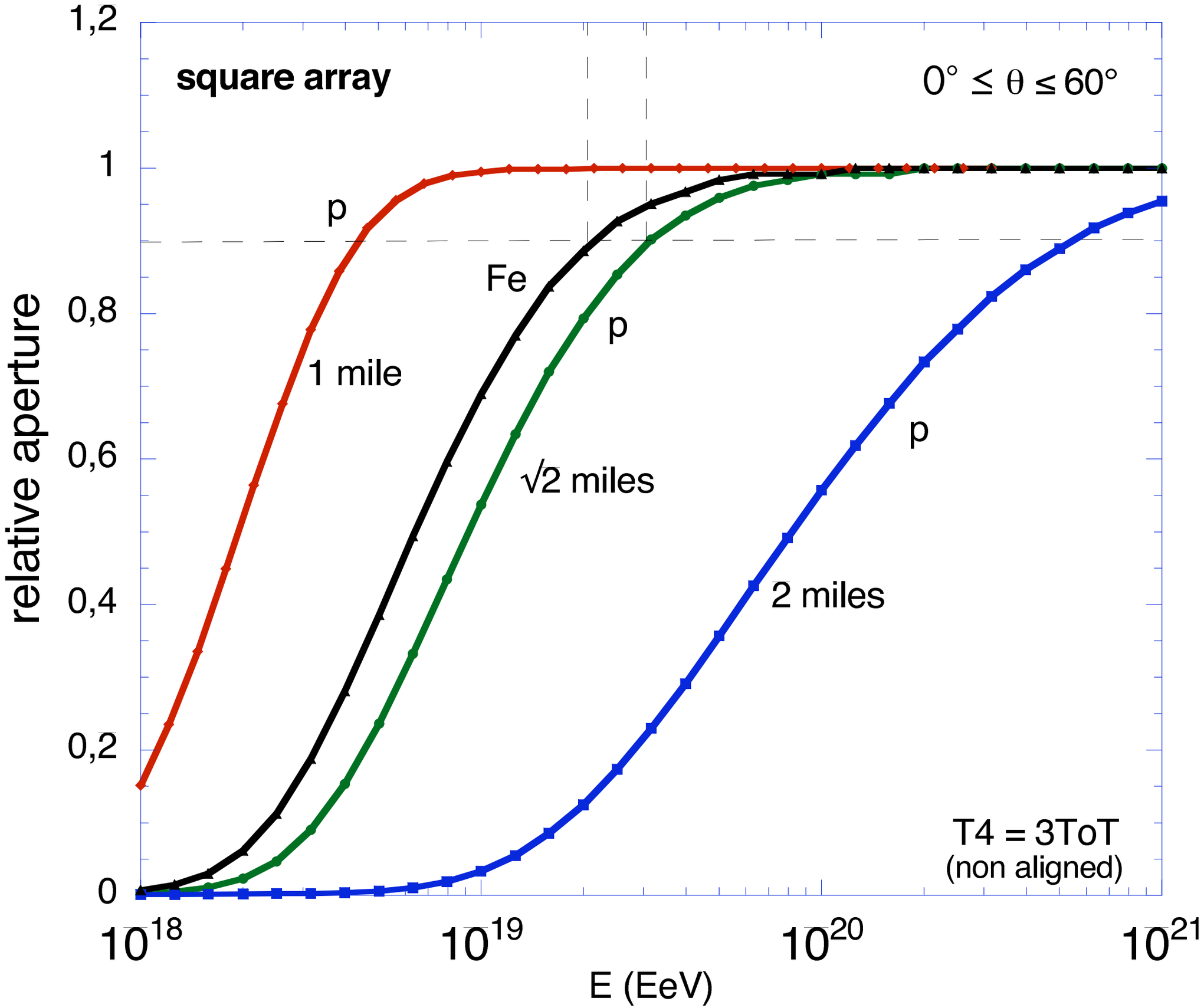

1 mile
standard
infill


117,6 km
N06
NW3
W12
133,7 km
E06
S12
17,7 km
44,1 km
15,8 km
75,3 km
184,5 km
SD Tank
FD Station
Cal.
0 10 20 30 40 km




1000
800
600
400
200
0
0
50
100
150
200
250
300
Charge (pC)
3-fold coincidence
single coincidence


LAMAR
CITY OF LAMAR
REX M. & SHARON HINER
REX L. WALKER
J-S FARMS INC.
ETHEL P. HIXSON etal
BAILEY'S OF DENVER, CO.
DELBERT RAY HAYS
FAITH M. WEST
RAGSDALE FARMS, INC.
WALKER LAND & CATTLE CORP.
JESSE BROOKSHIRE
JOHN R. & JANE C. STULP
GRACE E. BUTLER liv tr
MELVIN & RUTH FISCHER
EDGAR JR. & C. BAKER
RAGS-DALE FARMS INC.
RAGSDALE FARMS, INC. A COLO. CORP.
JANE C. STULP etal
HOWARD RAGS-DALE etal
STEVE F. & DIANA J. SHELTON
GEORGETTA L. TEMPEL
PERRY J. TEMPEL
GREGORY S. & KELLY A. SPITZER
GEORGE H. & GEORGETTA TEMPEL
DIANA L. TIXIER
ROBERT GRUENLOH etal
ELSIE M. BARNHILL
LARRY D. WEBSTER tr
JOHN R. STULP
BAILEY'S INC. OF DENVER, CO
FOUR STATES FEEDYARD INC.
ANTONIA FELAN
MARY A. WARN
CONTIBEEF LLC A DELAWARE CORP.
CARL M. SHINN
ARKANSAS VALLEY ALFALFA MILLING CO INC.
LAMAR MUNICIPAL AIRPORT
STATE
CITY OF LAMAR
WALKER LAND & CATTLE CORP.
385
287


square array
0° ≤ θ ≤ 60°
relative aperture
1,2
1
0,8
0,6
0,4
0,2
0
p
Fe
p
p
1 mile
√2 miles
2 miles
T4 = 3ToT
(non aligned)
10^18
10^19
10^20
10^21
E (EeV)

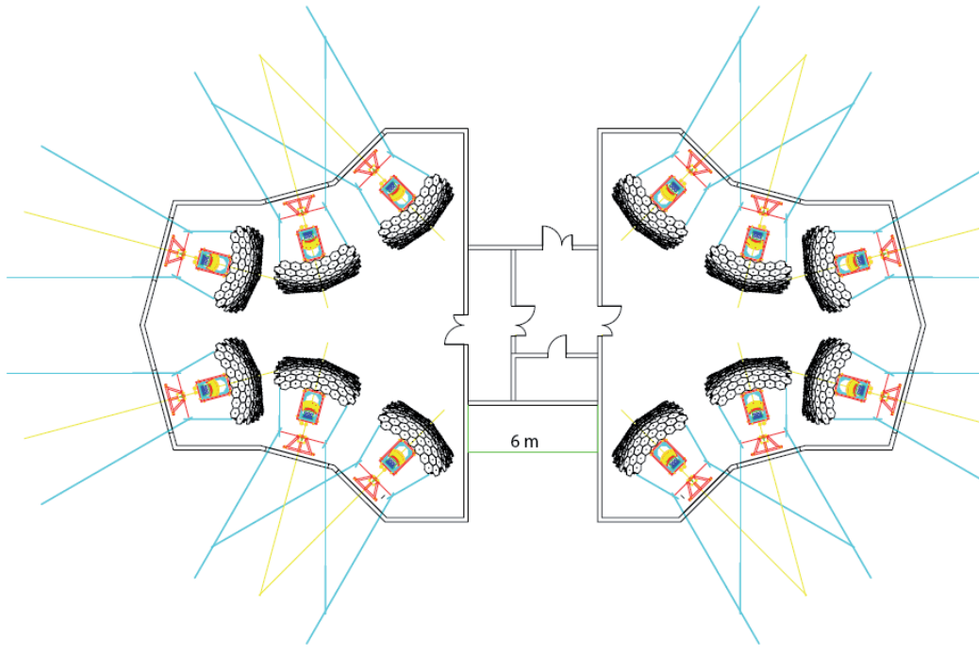
clear(1)
clear(2)
hazy(1)
hazy(2)

acceptance [km^2 sr]

40000
35000
30000
25000
20000
15000
10000
5000

18
18.5
19
19.5
20
20.5

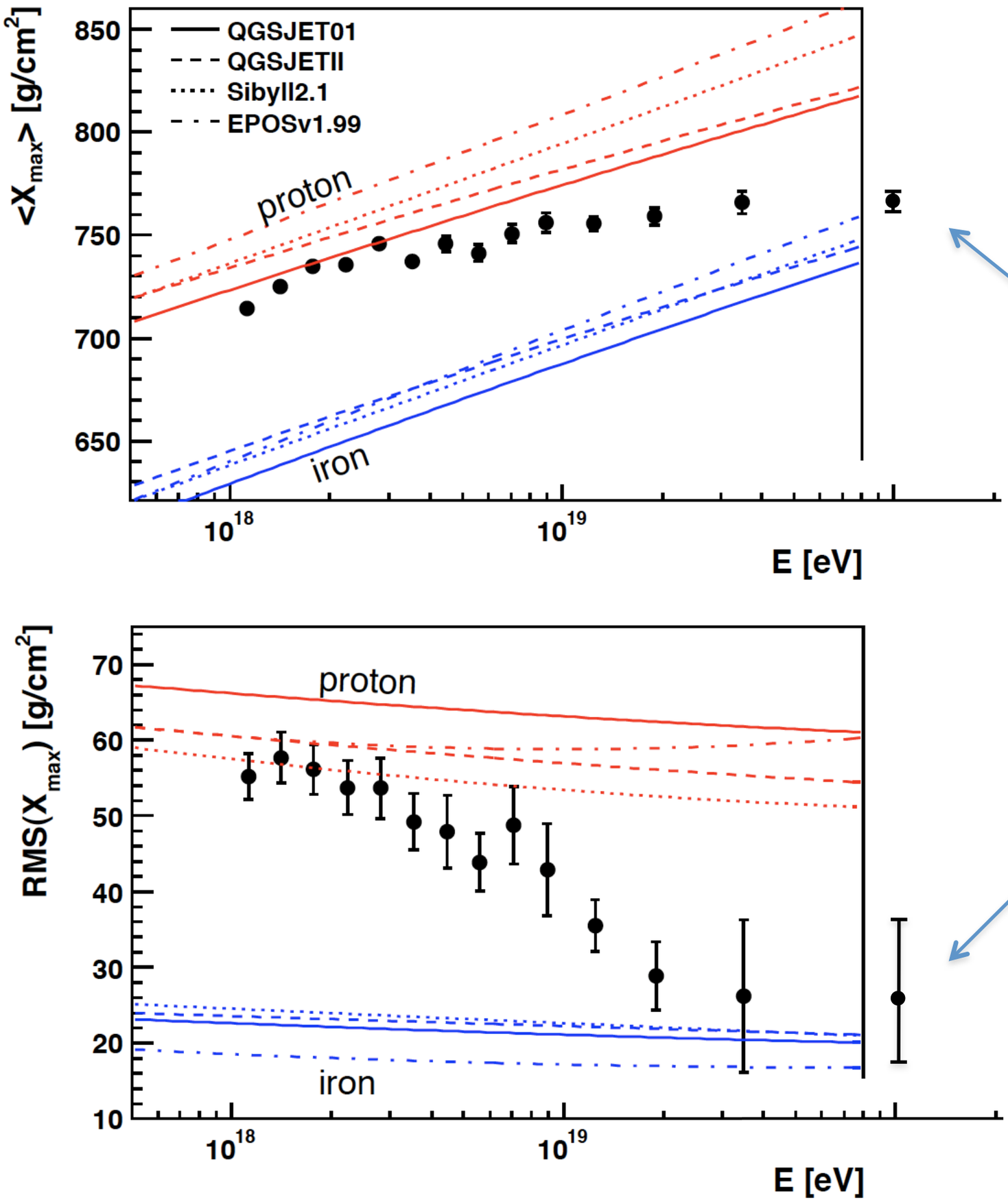
lg(E/eV)



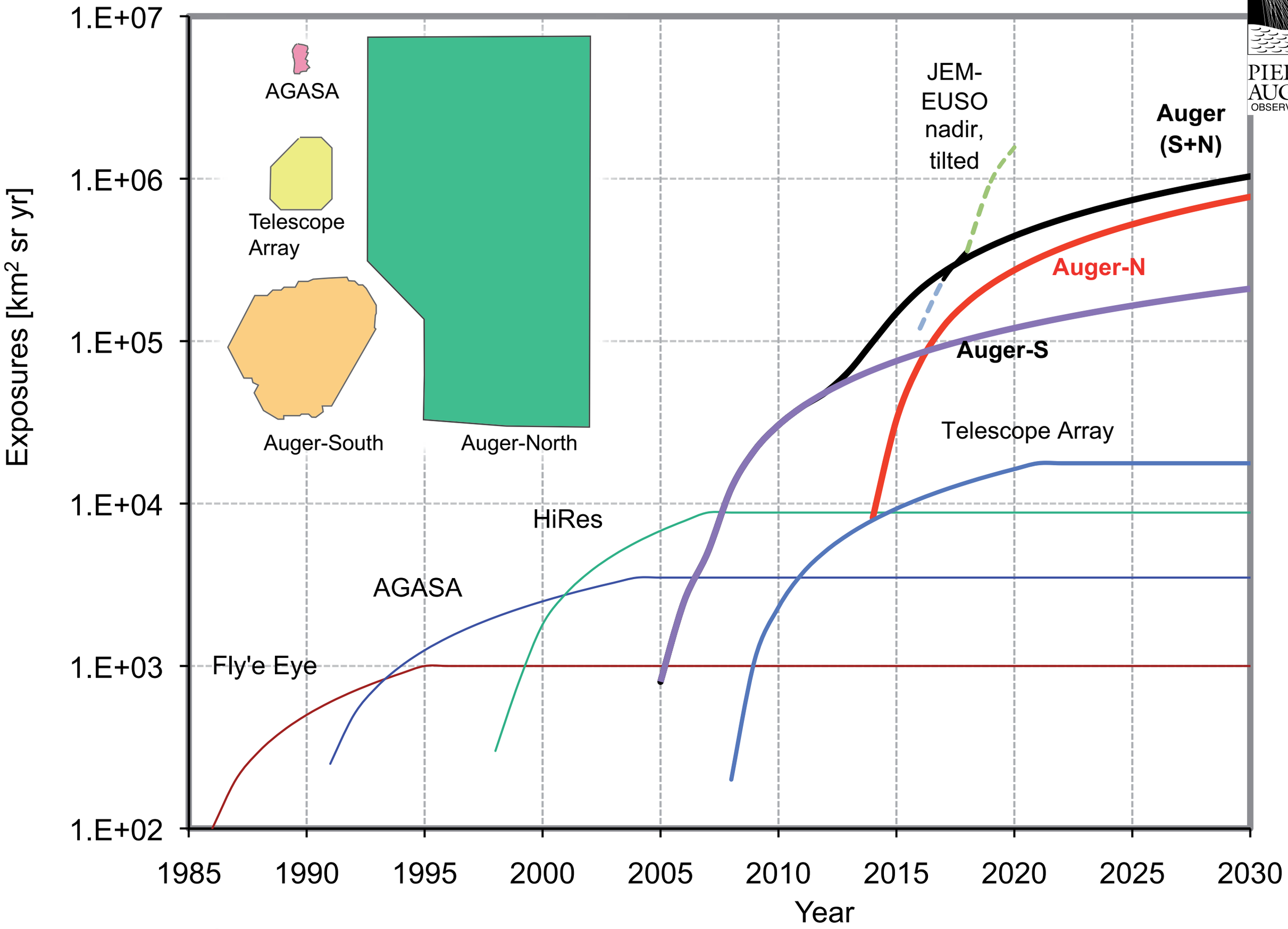
Comparison of Auger South and Auger North in SE Colorado

PIERRE AUGER OBSERVATORY

	Auger South	Auger North
Location	35° S, 69° W	38° N, 102° W
Altitude	1,300 - 1,500 [m a.s.l.	1,300 [m a.s.l.]
Area	3,000 km^2	20,000 km^2
Number of SD stations (infill)	1,600	4,000 (400)
SD spacing (infill)	1,500 m	2,300 m (1,600 m)
PMT sensors / SD station	3	1
Communications network	SD-tower radio	peer-to-peer
SD array 50% efficient at	0.7-1 EeV	8-10 EeV
SD array 100% efficient at	3 EeV	80 EeV
FD stations	4	5
FD telescopes	24 (4×6)	39 ($2 \times 12 + 2 \times 6 + 1 \times 3$)
Begin construction	1999	2012
End construction	2008	2016



After 10 years of AN we can measure X_{max} (avg., rms) at 10^19.95 with the same quality as ‘now’


Exposures [km² sr yr]
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
AGASA
Telescope Array
Auger-South
Auger-North
JEM-EUSO nadir, tilted
Auger (S+N)
Auger-N
Auger-S
Telescope Array
HiRes
AGASA
Fly'e Eye

Auger South in Argentina: very successful

SOUTH:	half of the sky	✔
FLAT:	communications	✔
WARM:	no water freezing	✔
CLEAR:	fluorescence	✔
LARGE:	statistics	low

Auger North 2010		Colorado
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WARM:	no water freezing	✔
CLEAR:	fluorescence	✔
NORTH:	half of the sky	✔
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Auger South in Argentina: very successful

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Auger North 2010 Colorado

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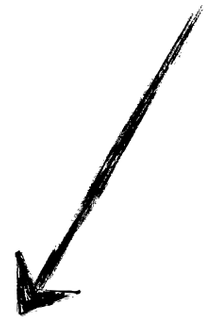
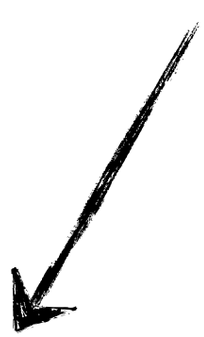


Auger North 2010		Colorado	**other site**
FLAT:	communications	✔	develop, ok
WARM:	no water freezing	✔	develop, ok
CLEAR:	fluorescence	✔	radio? difficult
NORTH:	half of the sky	✔	**ughh** (= don’t wanna give it up”)
LARGE:	statistics	✔	**mandatory**

Auger South in Argentina: very successful

SOUTH: half of the sky ✔
FLAT: communications ✔
WARM: no water freezing ✔
CLEAR: fluorescence ✔
LARGE: statistics low



Auger North 2010 Colorado **other site**
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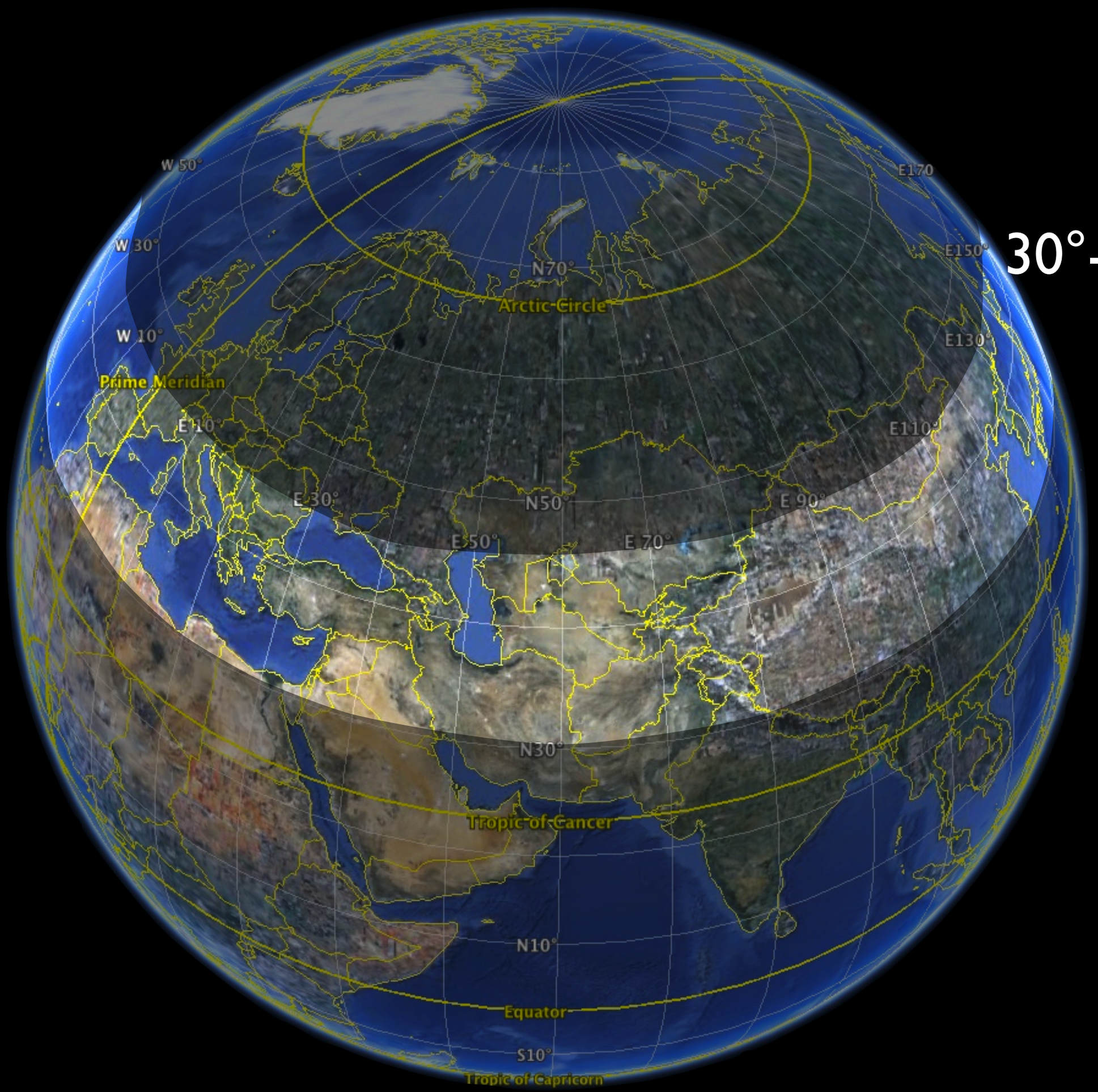
WARM: no water freezing ✔ develop, ok
CLEAR: fluorescence ✔ radio? difficult
NORTH: half of the sky ✔ **ughh** (= don't wanna give it up")
LARGE: statistics ✔ **mandatory**

} next specific proposal in 3-5 years


W 50°
W 30°
W 10°
Prime Meridian
E 10°
E 30°
E 50°
E 70°
E 90°
E110°
E130°
E150°
E170
N70°
Arctic Circle
N50°
N30°
Tropic of Cancer
N10°
Equator
S10°
Tropic of Capricorn


W 50°
E170
W 30°
E150°
N70°
Arctic Circle
W 10°
E130°
Prime Meridian
E 10°
E110°
E 30°
N50°
E 90°
E 50°
E 70°
N30°
Tropic of Cancer
N10°
Equator
S10°
Tropic of Capricorn

30°-45° N

Conclusions B

- First precise energy **spectrum** from 1 EeV to above 100 EeV
- Optical fluorescence detection of showers set the **energy scale** to ± 22%,
  - biggest uncertainty from absolute fl. yield; **soon to be much improved**
- **Ankle** at 2-3 EeV: transition from galactic to extragalactic cosmic particles
- Flux suppression at 50-60 EeV: **GZK effect or maximum accelerator energy?**
- With increasing energy **air showers develop** higher up in the atmosphere and show less fluctuations – **astrophysics and/or particle physics? E.g. heavier particles or higher cross section?**
- arrival directions of cosmic rays become abruptly **anisotropic** above 50-60 EeV, in coincidence with the spectrum being much steeper
- **cosmic ray arrival directions correlate with the distribution of nearby (<75 Mpc) extragalactic objects**; several reference maps are being tested. **The correlating fraction is (38 ± 6)% [was (69+11-13)% initially] -- need more data; interesting to watch the excess from certain regions**
- Many open important questions remain to be answered – **a very large ground-based array in the northern hemisphere** is needed: Auger North → **AugerNext**
- A complementary approach (detection from space, ~less precise, even larger statistics) is **JEM-EUSO**, a mandatory step towards SUPER-EUSO

What are we talking about: the future, the unknown, the challenge...

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

KASCADE-Grande decommissioning *(BTW: public data)*

AS3 operation

science case

Auger Next site survey

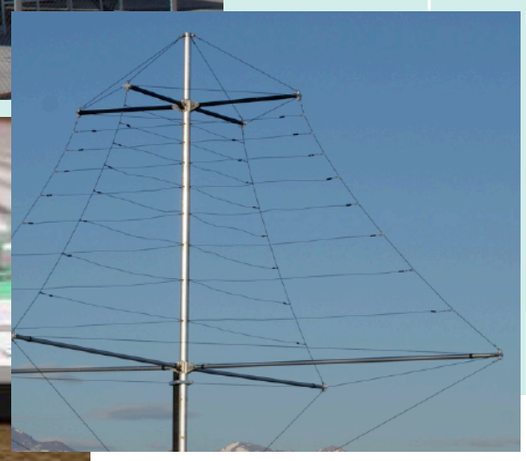
design report

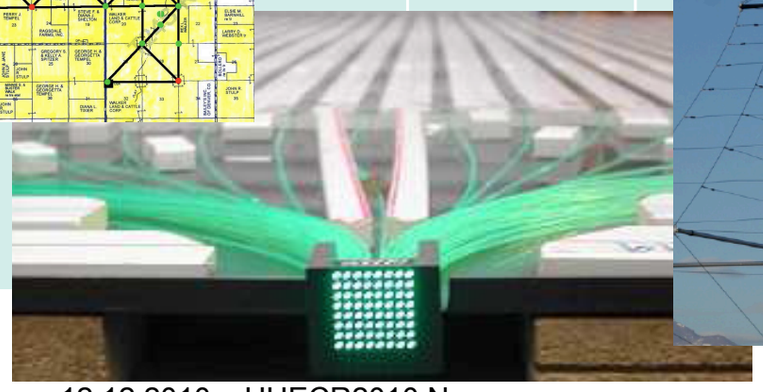
proposals

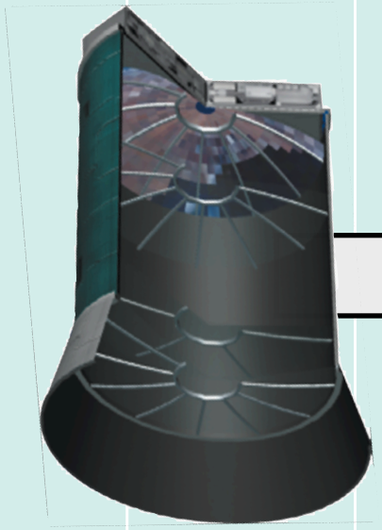
AN30 construction

AN30 operation

Auger technologies++



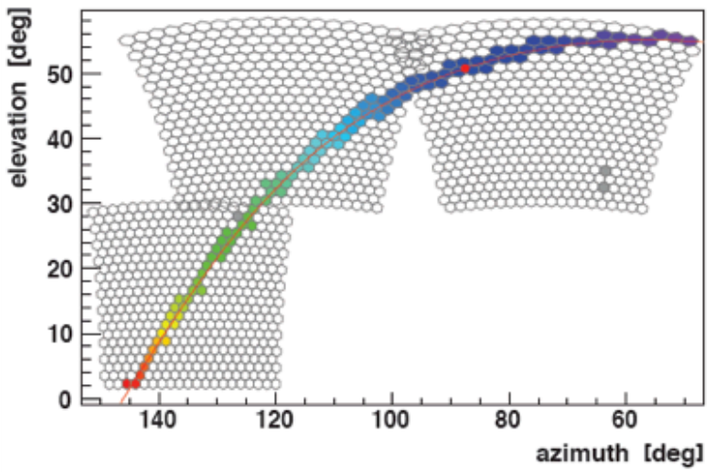


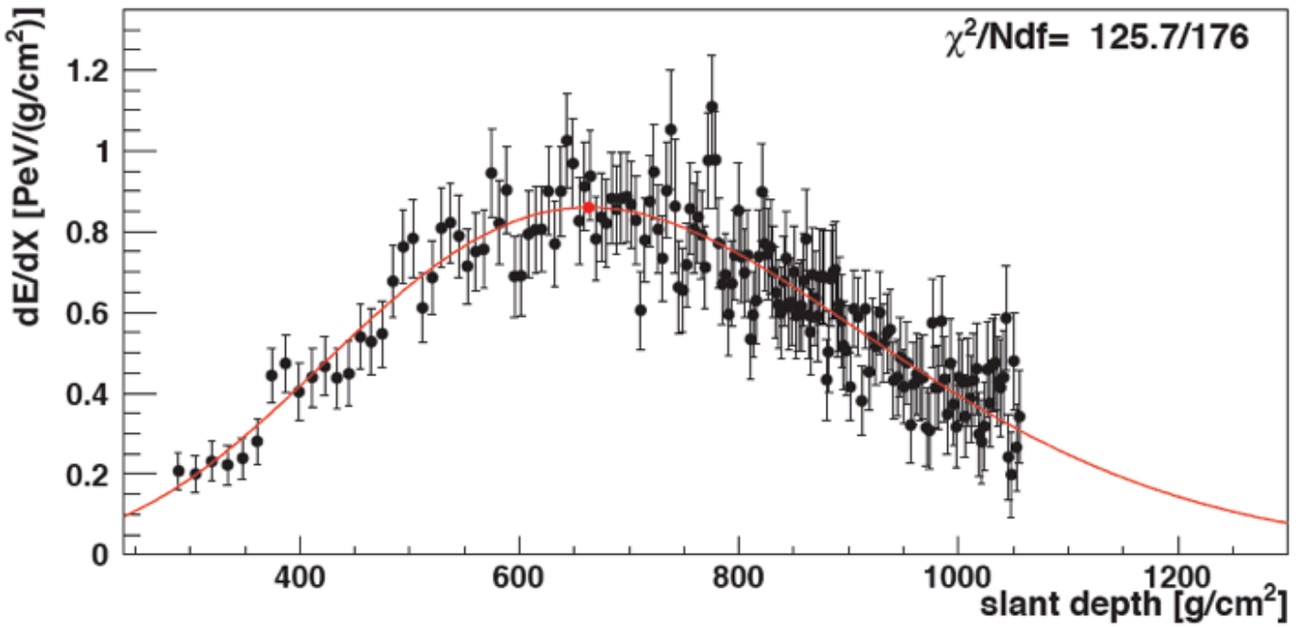


JEM-EUSO operation

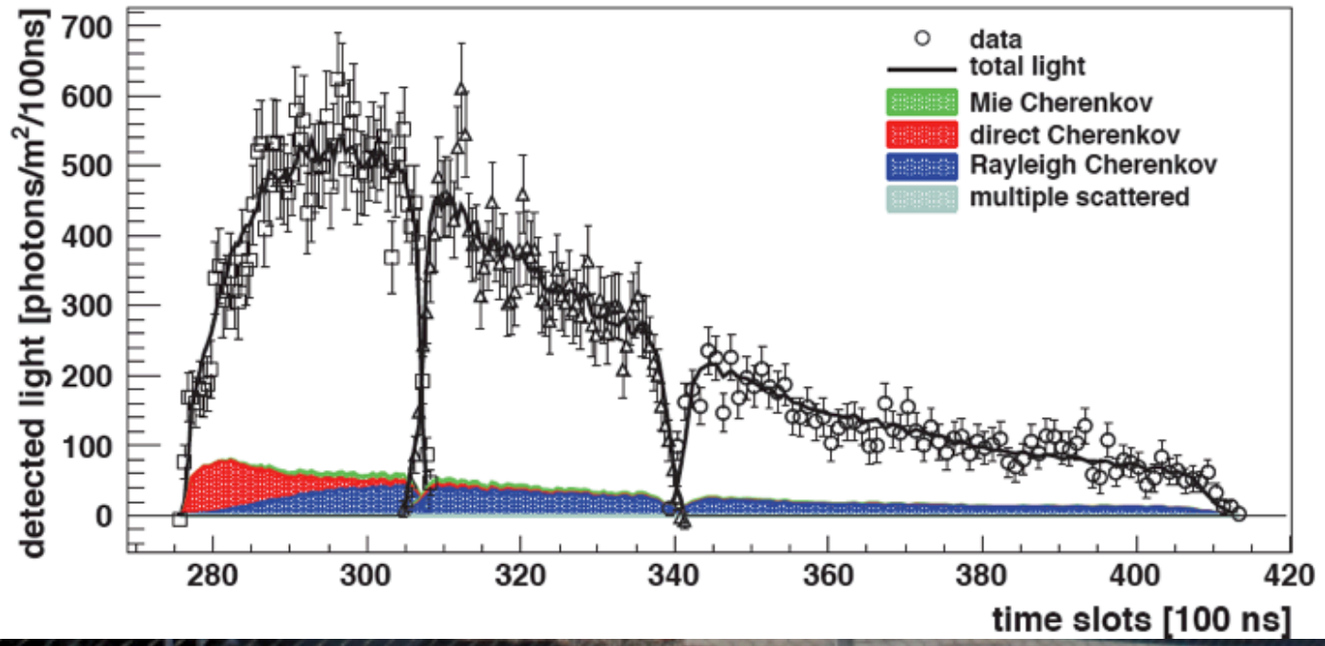
HEAT

HEAT

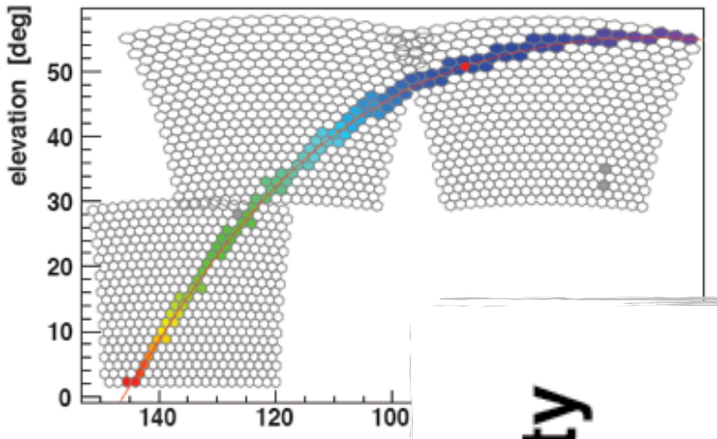


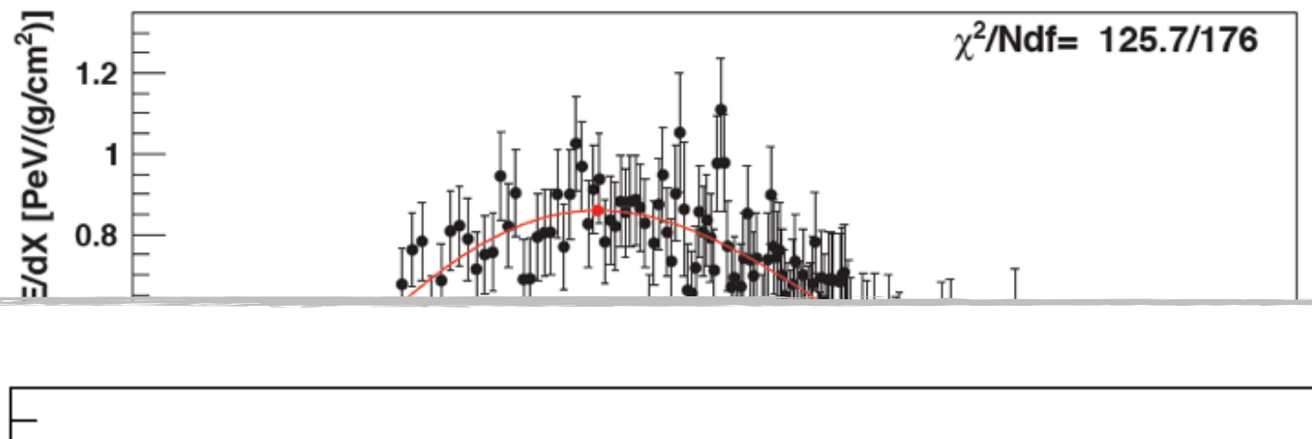


Run 127, Event 9296

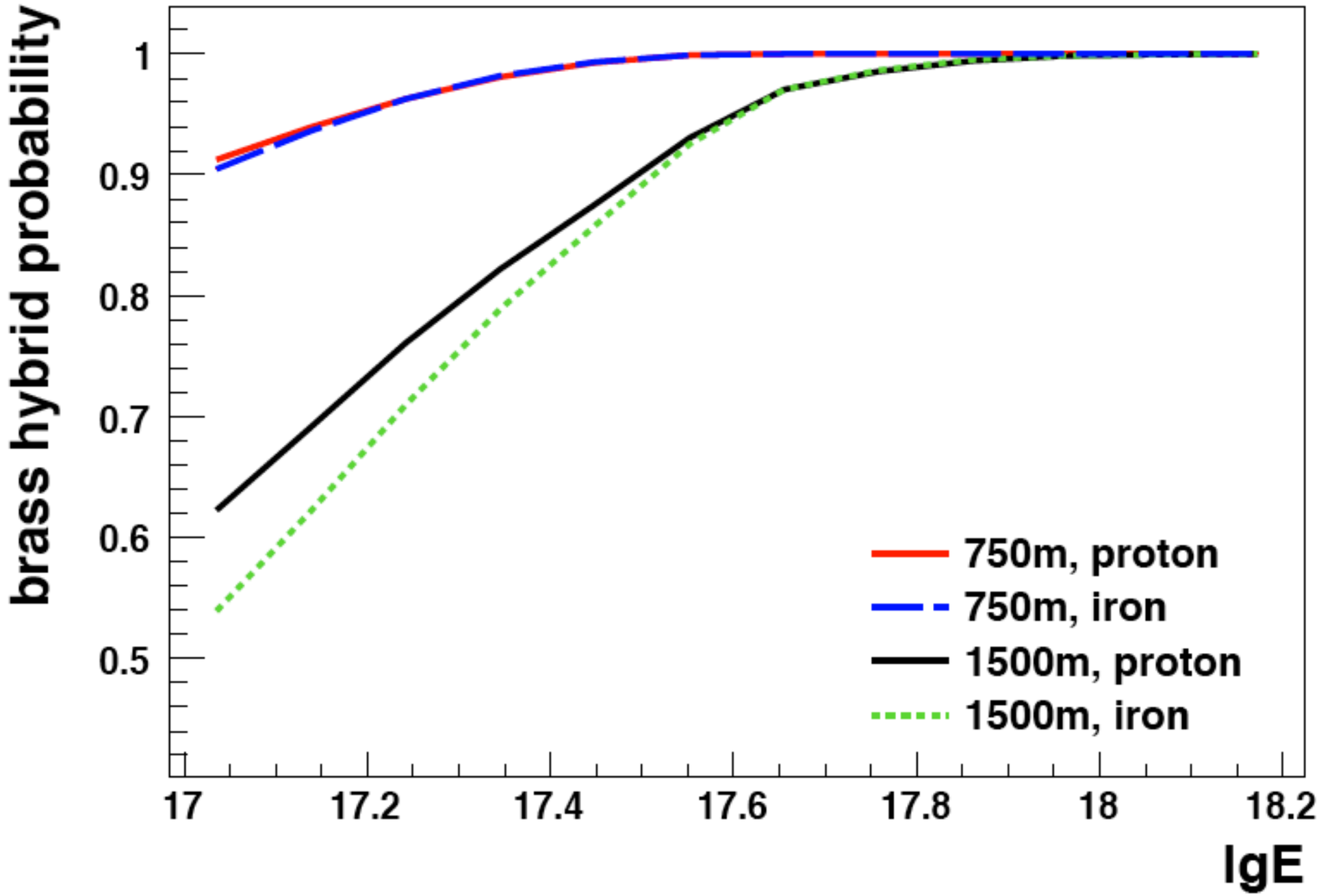


HEAT



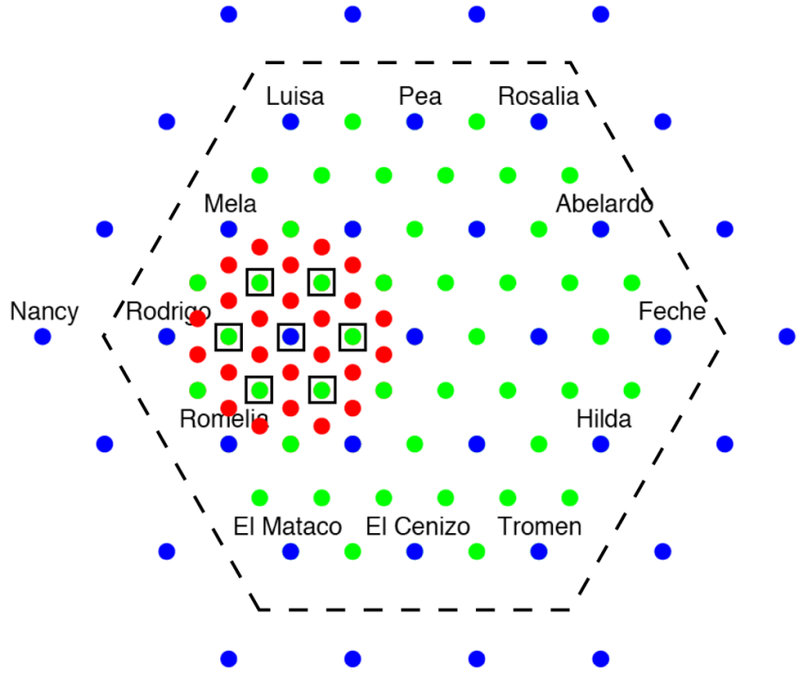


Run 127, Ev



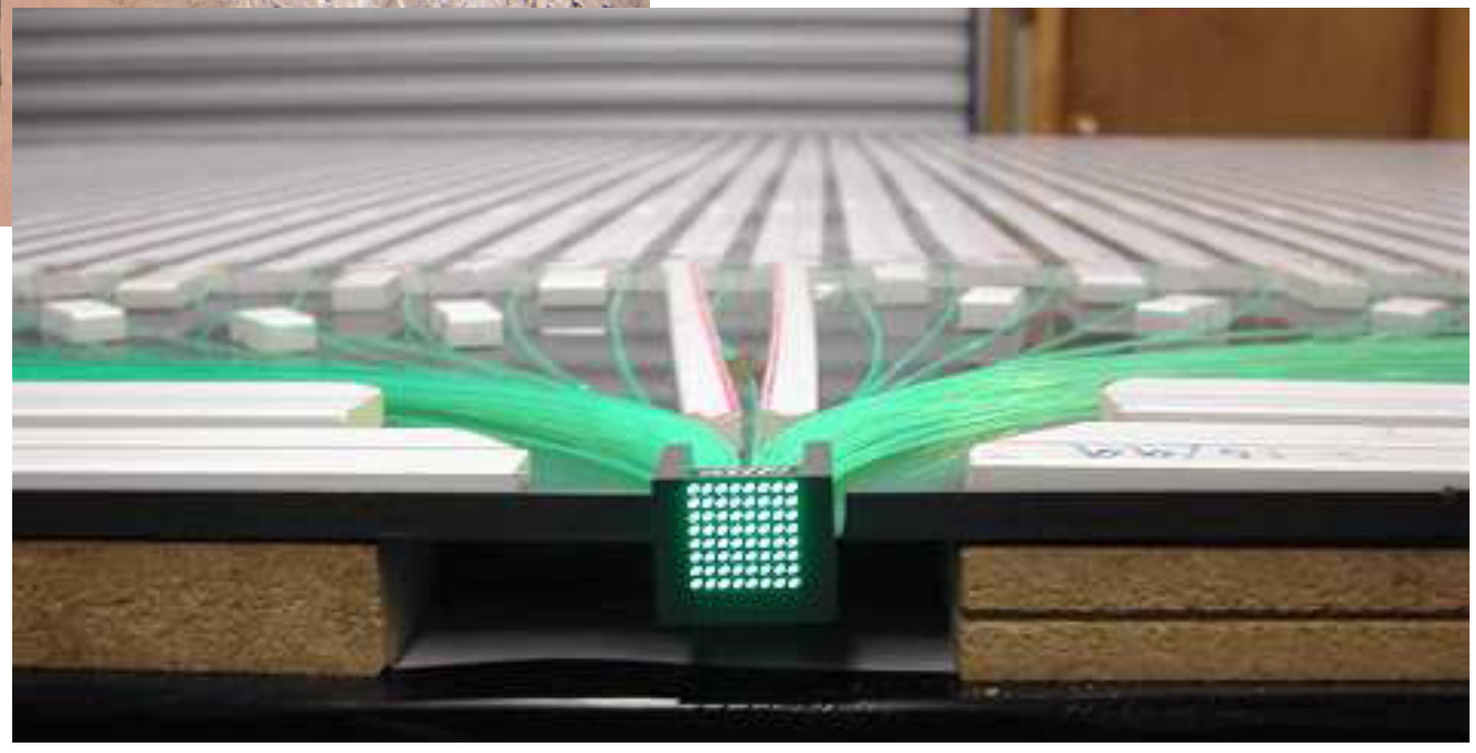
AMIGA

PIERRE AUGER OBSERVATORY



unitary-7 muon counter (example, merging Fig. 7.1 with Fig. 6.1)

all blue and green tanks within the dashed line are to be accompanied with muon counters

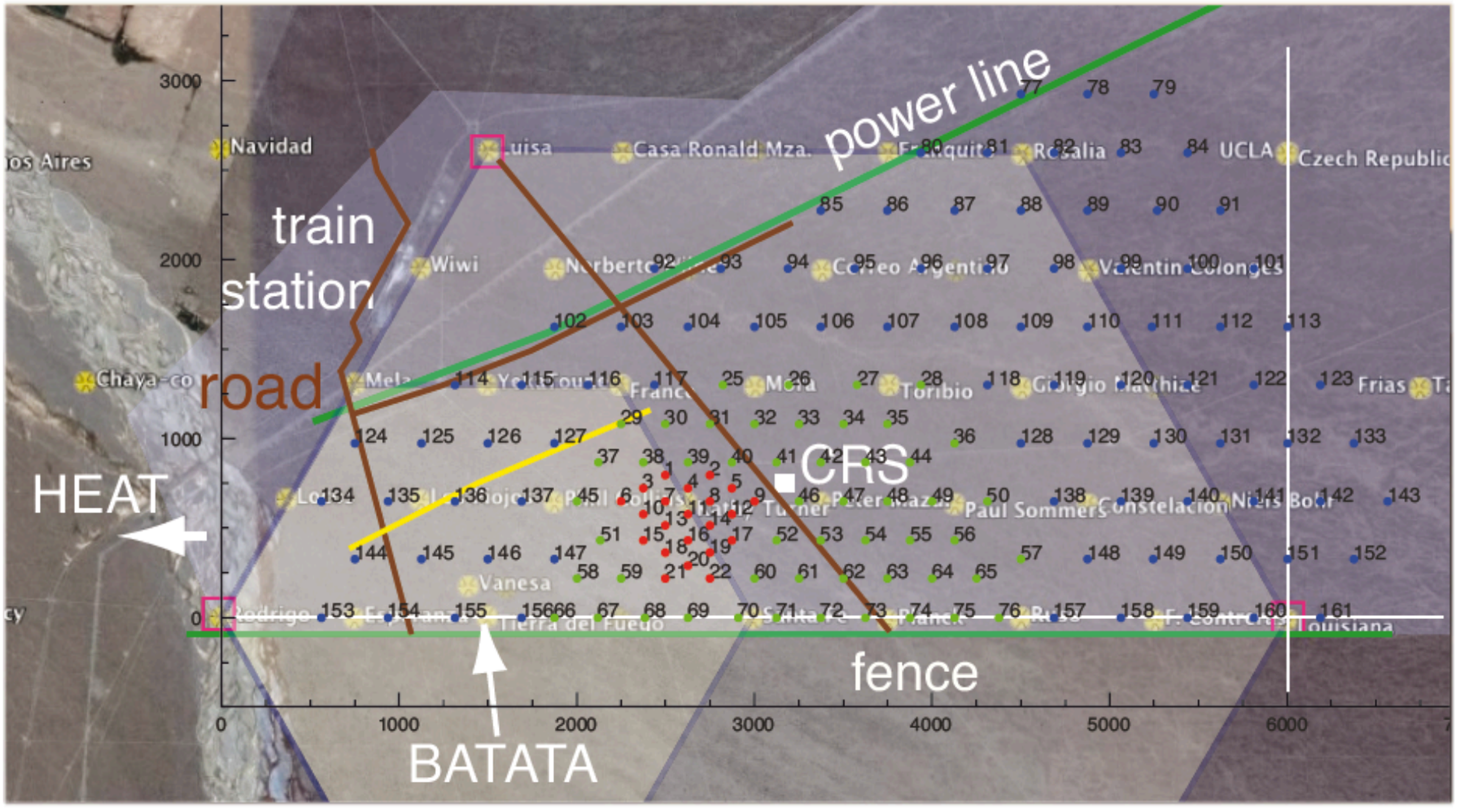


AERA: Auger Engineering Radio Array

PIERRE AUGER OBSERVATORY

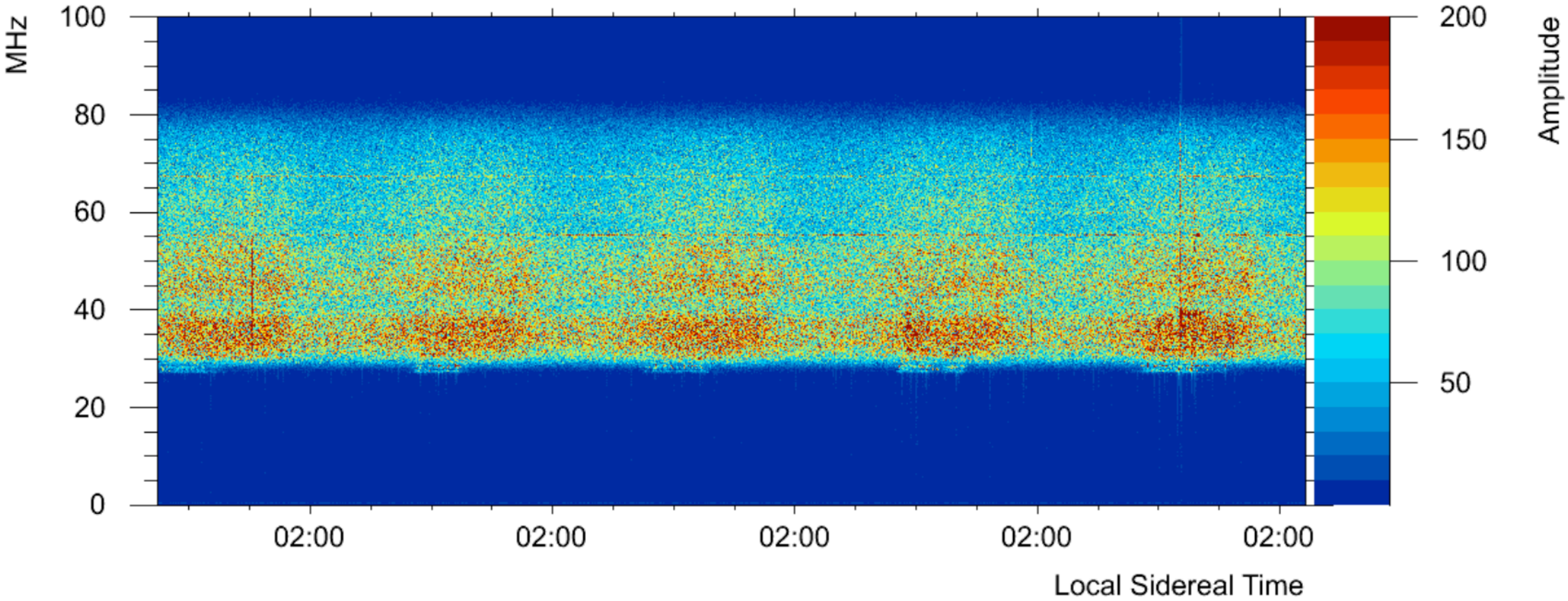
Objective:

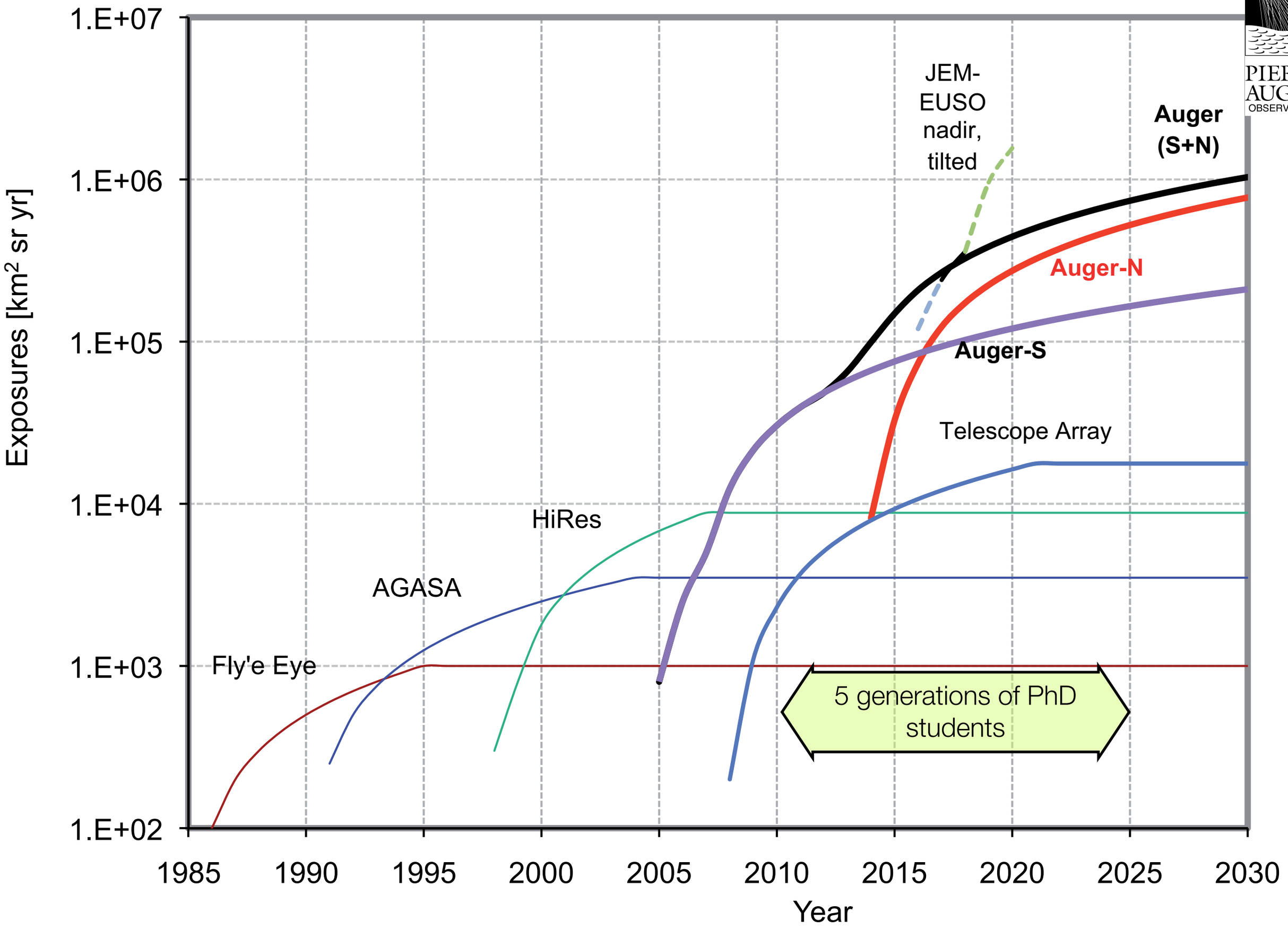
- measure radio emission from EAS in frequency range 30 MHz - 80 MHz
- electrons emit synchrotron radiation in Earth‘s magnetic field
- ~20 km2 array with ~160 antennas
- operation together with infill/HEAT/AMIGA
- three antenna spacings to cover efficiently 17.2 < lg E/eV < 19.0
- measure composition of cosmic rays in energy region of transition from galactic to extragalactic cosmic rays

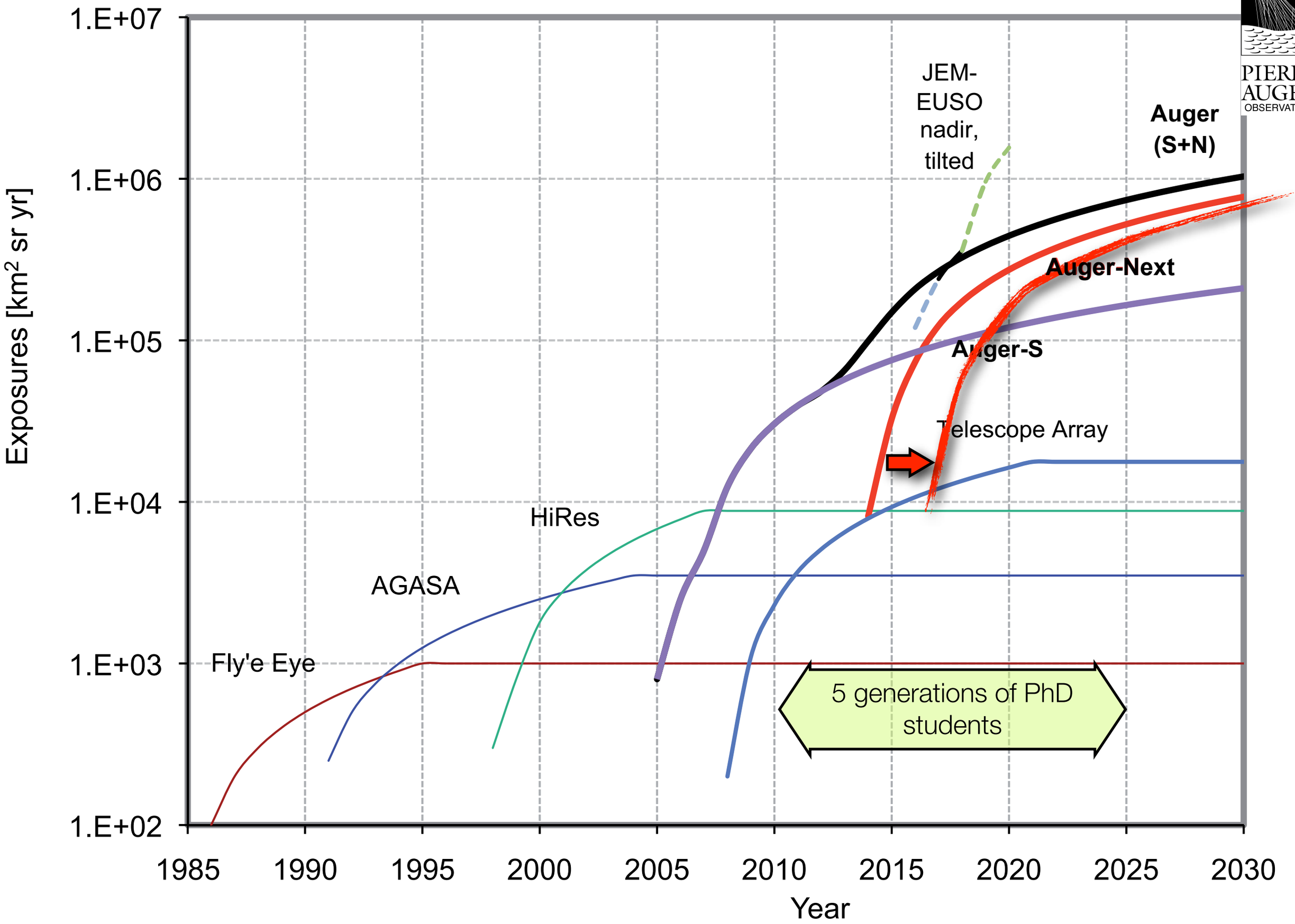


AERA: Auger Engineering Radio Array

PIERRE AUGER OBSERVATORY




1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
Exposures [km² sr yr]
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
JEM-EUSO nadir, tilted
Auger (S+N)
Auger-N
Auger-S
Telescope Array
HiRes
AGASA
Fly'e Eye
5 generations of PhD students
PIERRE AUGER OBSERVATORY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1.E+06
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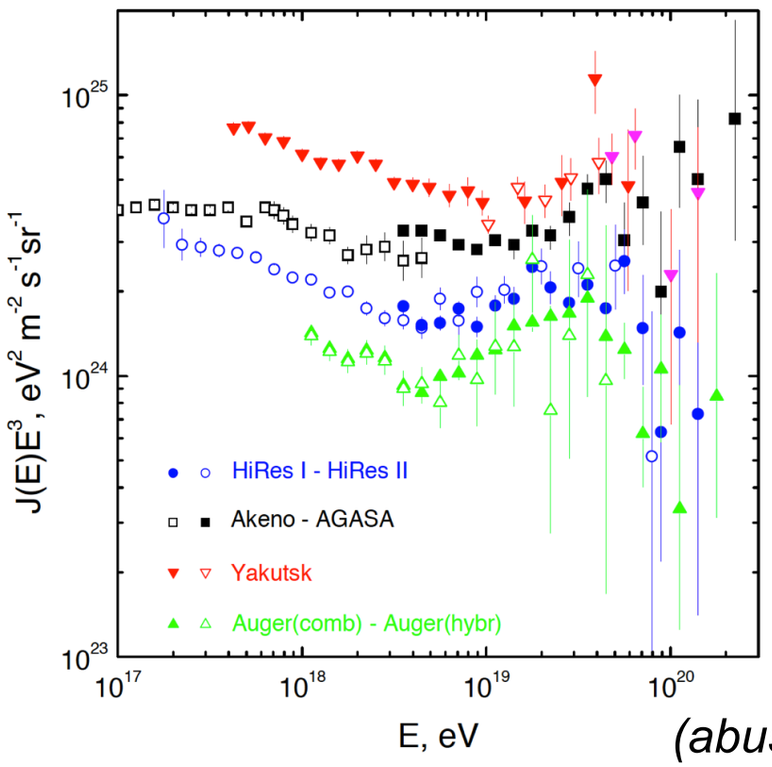
PIERRE AUGER OBSERVATORY

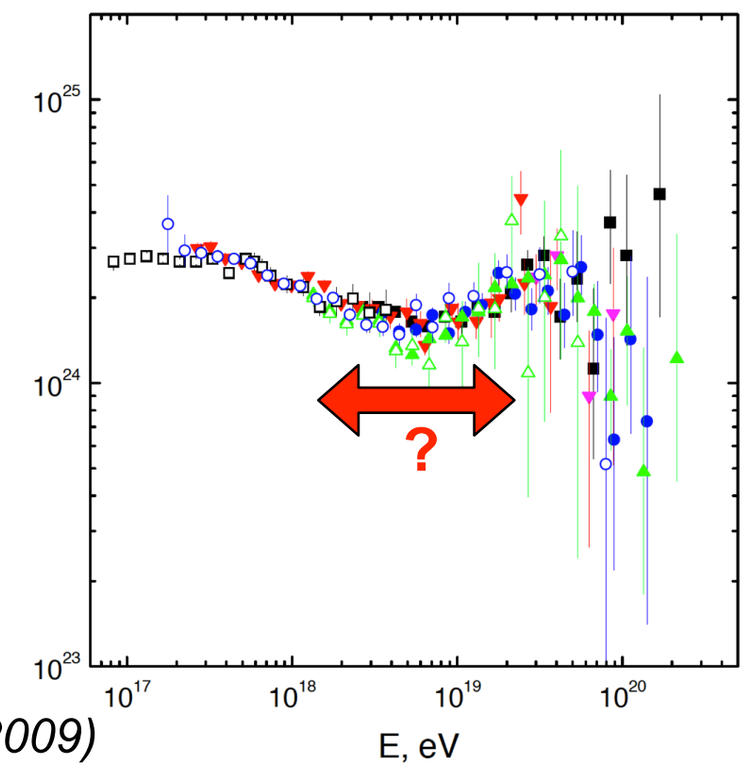
PIERRE
AUGER
OBSERVATORY

A very large ground-based cosmic ray observatory
in the northern hemisphere is required.
A world-wide site search will be conducted.

before



some time after...



(abusing plots from Berezinsky 2009)