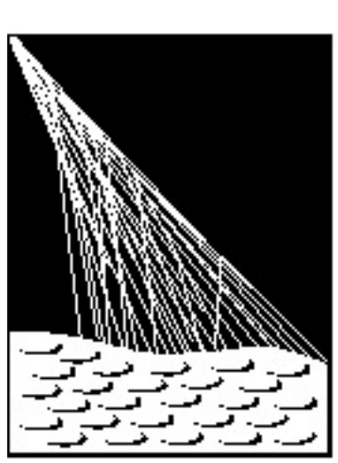
Self-triggered radiodetection of cosmic ray air showers at Auger with the RAuger experiment



CODALEMA

ARENA 2010, Nantes

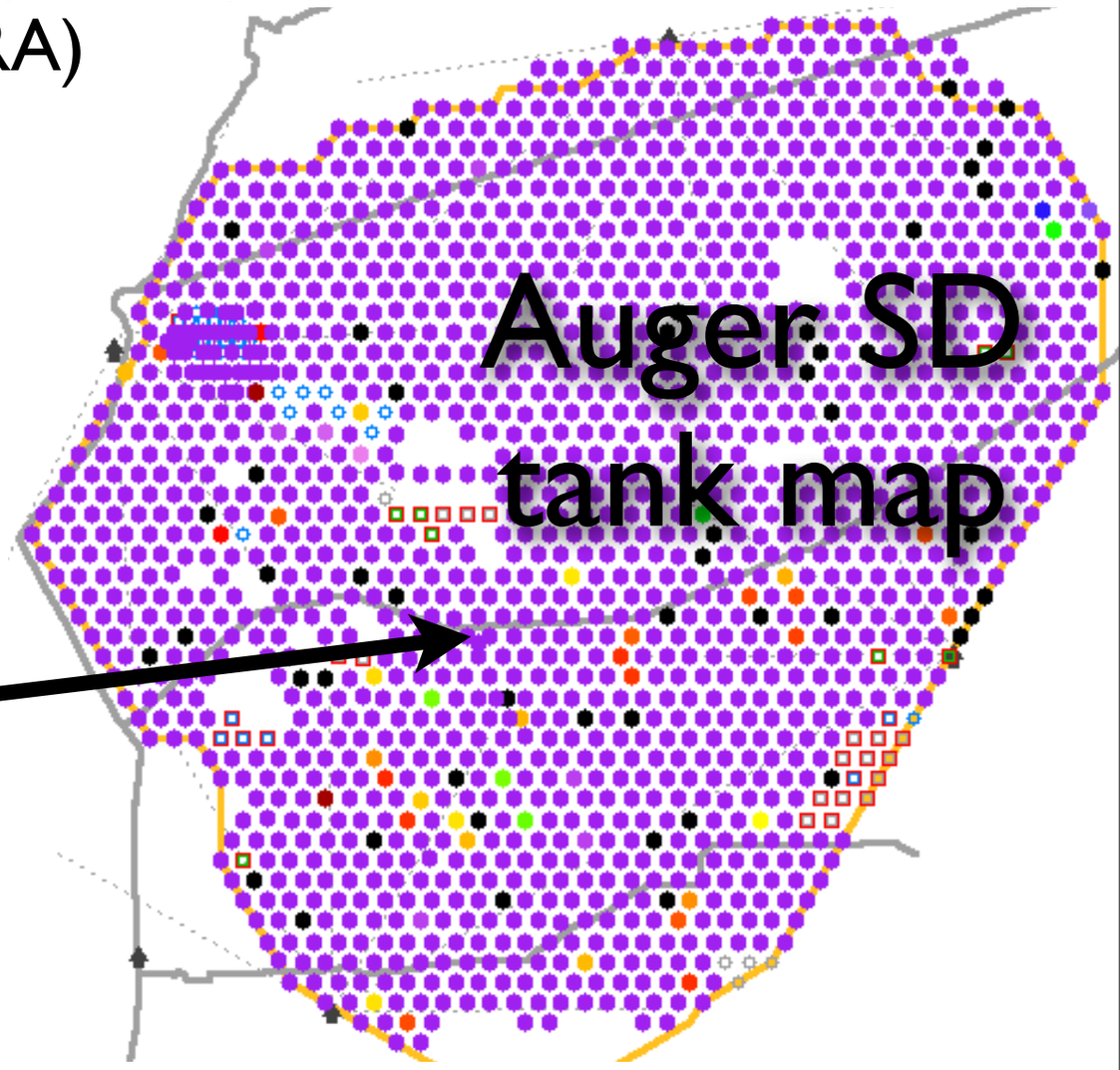
Benoît REVENU
Subatech, Nantes, France

Why ?

- we want to detect EAS with an **autonomous** radio-trigger (no help from any external particle detector)
- try to get coincidences with Auger events at EeV energies
- give input for the study of a larger (20 km^2) autonomous radio-array in deployment in Auger (AERA)

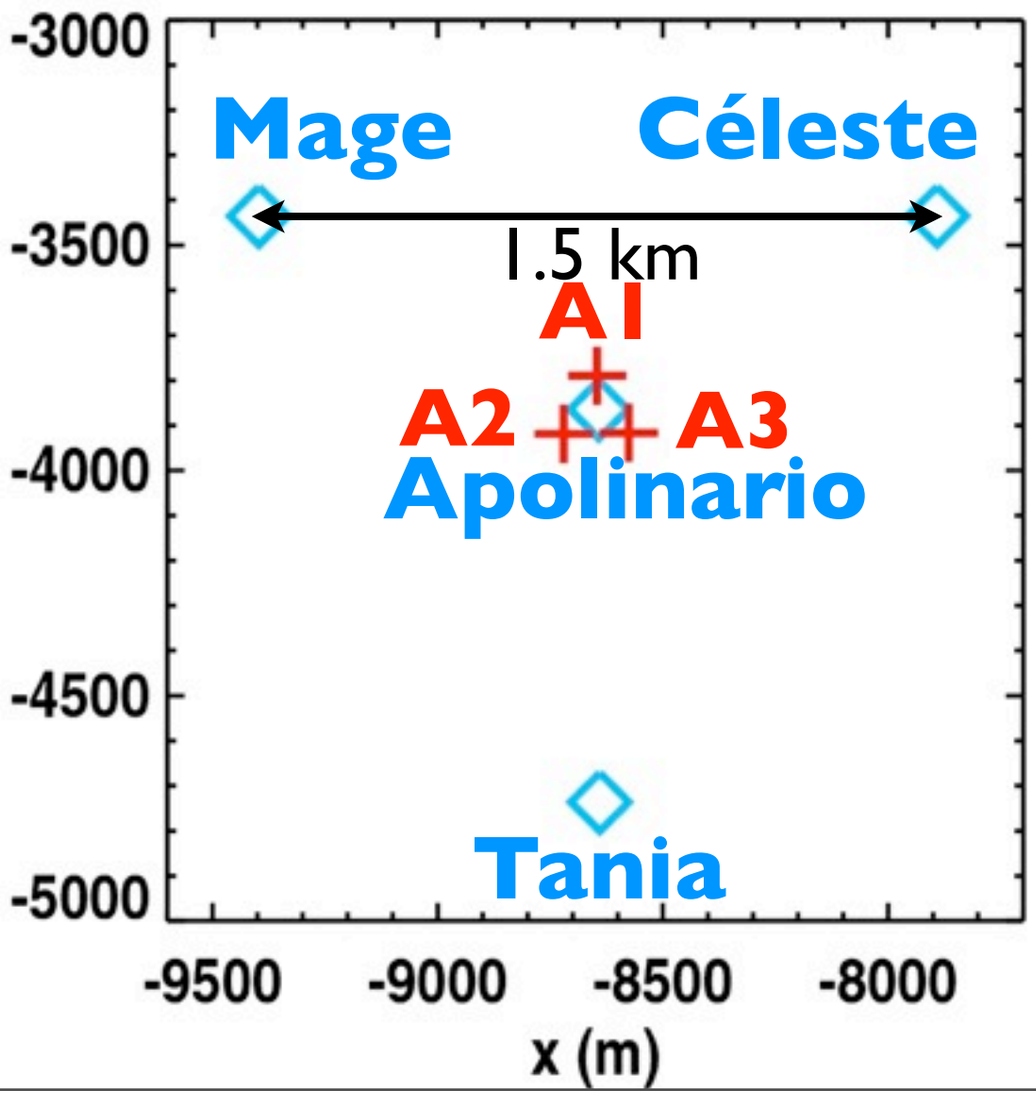
Where ?

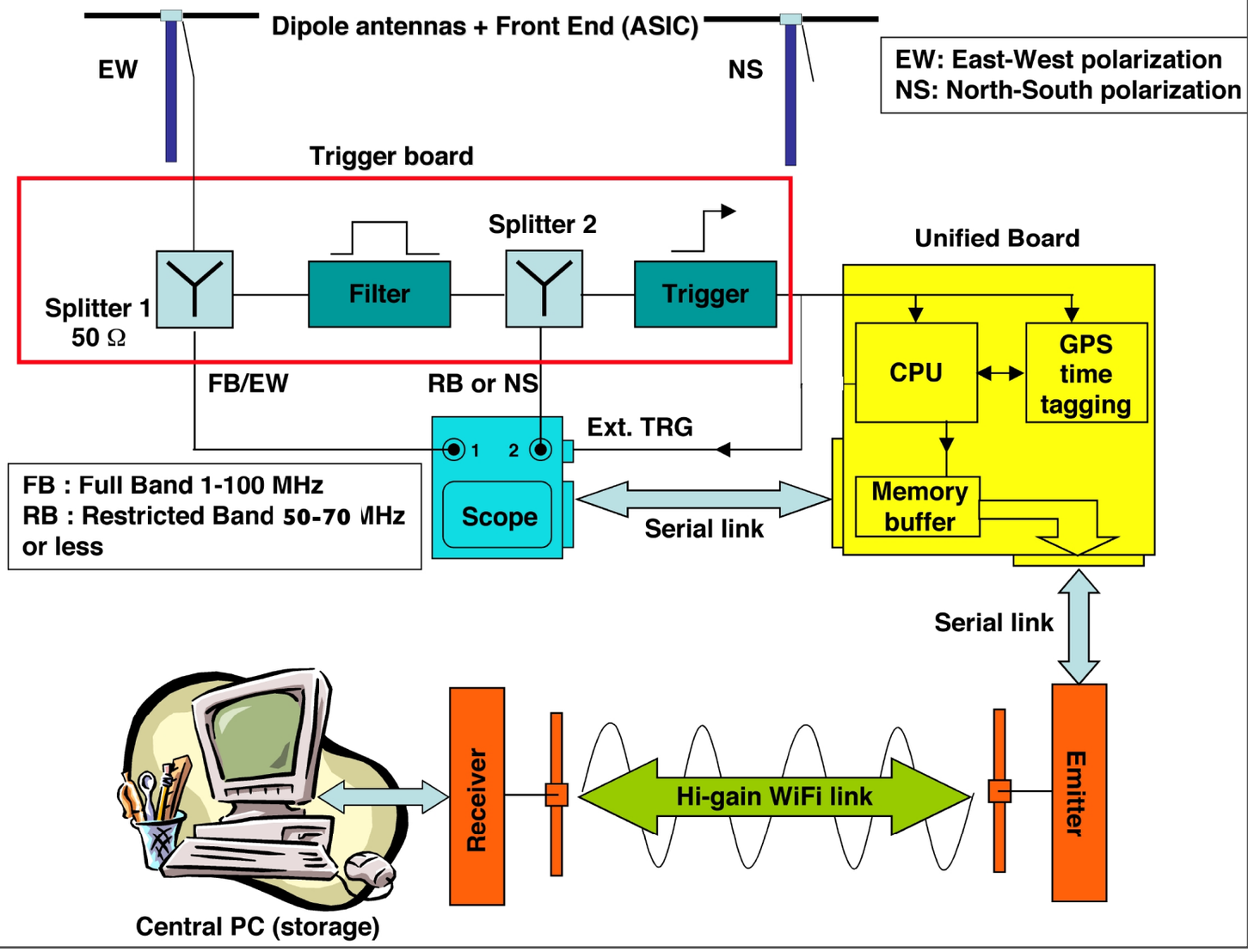
additional tank to lower energy threshold



How ?

- 2 CODALEMA dipolar antennas (EW and NS polarizations)
- trigger with a simple threshold in the 50-70 MHz band, EW polarization (analogic filter)
- send the data by wifi to a distant PC





Strong built-in limitations of these 3 first prototypes

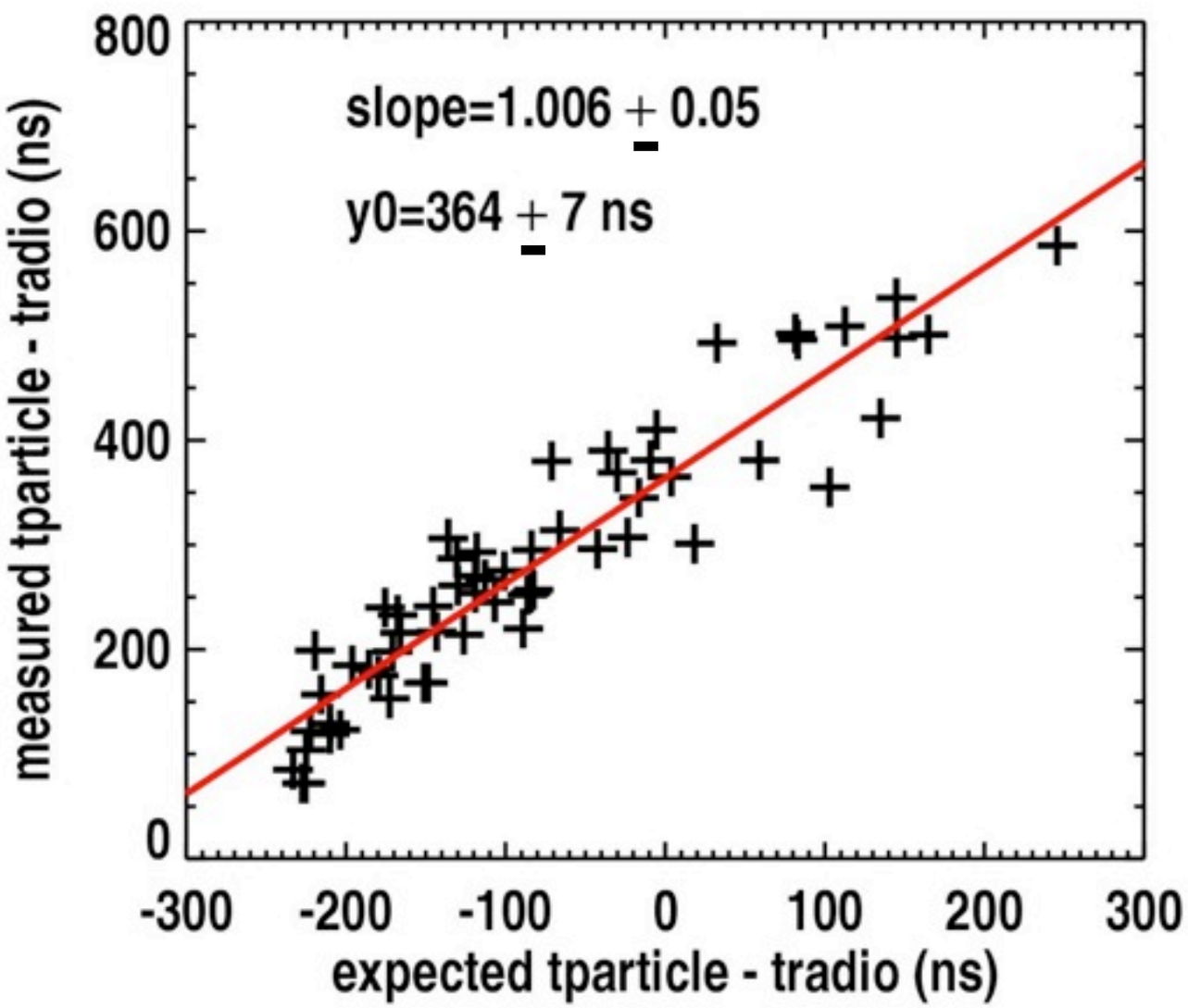
- no dynamic threshold, on-site intervention to modify the levels
- frequent hardware failures on both A2 and A3
- high dead-time of 2.7 s (reading of the trace by serial link)
- consequence: only 1 threefold (the 3 antennas+Auger) coincidence

BUT

- self-triggered cosmic ray detection for the first time, by a FULLY autonomous system (July 2007); May 2010: **65 events** in coincidence with Auger SD
- one complete radio reconstruction in excellent agreement with Auger values
- skymap in good agreement with geomagnetic effect
- detection and follow-up of thunderstorms... (not discussed in this talk)

65 Auger SD events radio-detected

$$t_{\text{Auger tank}} - t_{\text{exp radio}} = -\frac{u\ \delta x + v\ \delta y}{c}$$



measured time differences
between Apolinario trigger time and radio trigger time

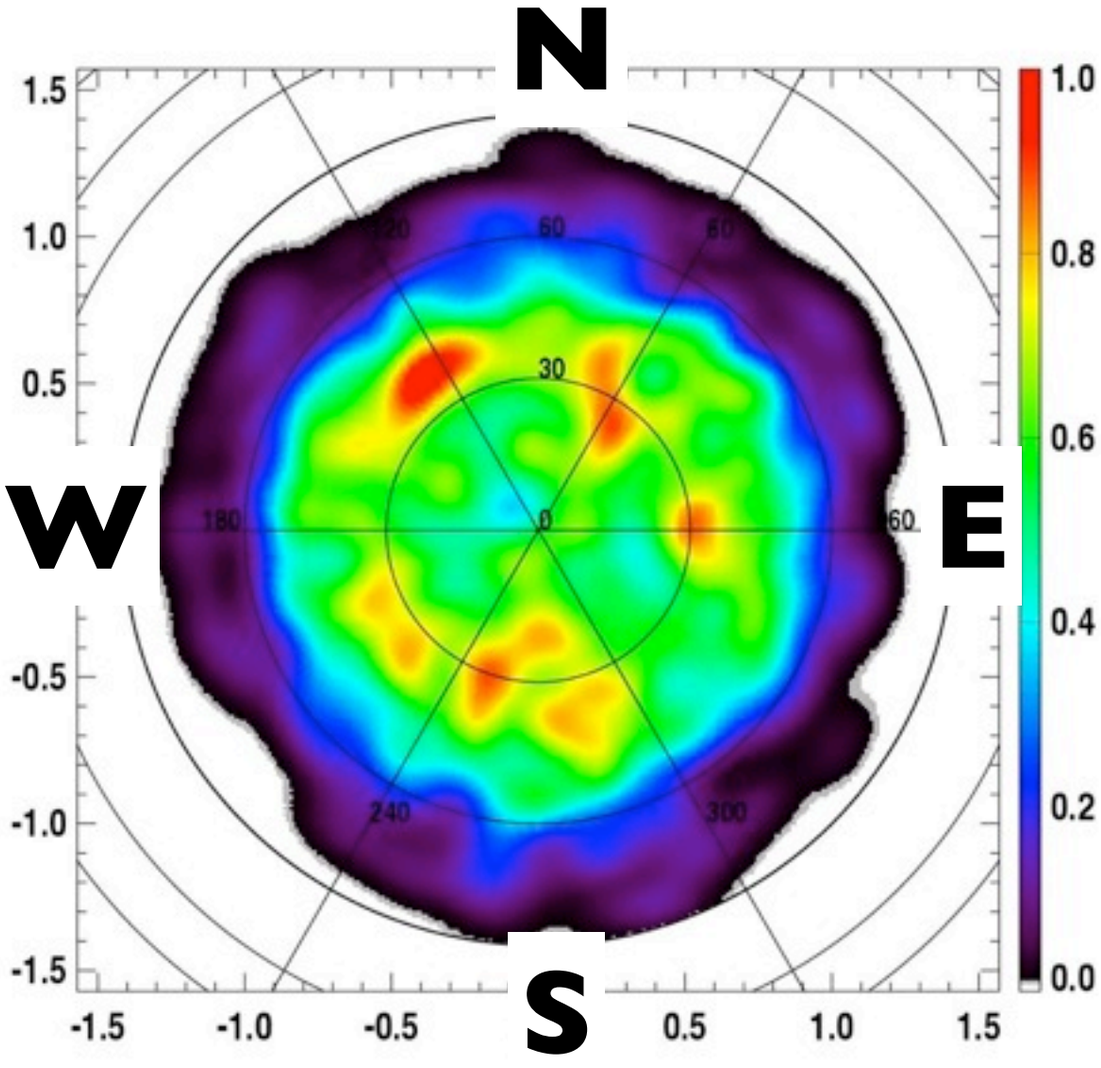
vs

expected time differences
(given the geometry of the shower)

time interval distribution is Poissonnian with a constant of 12 days

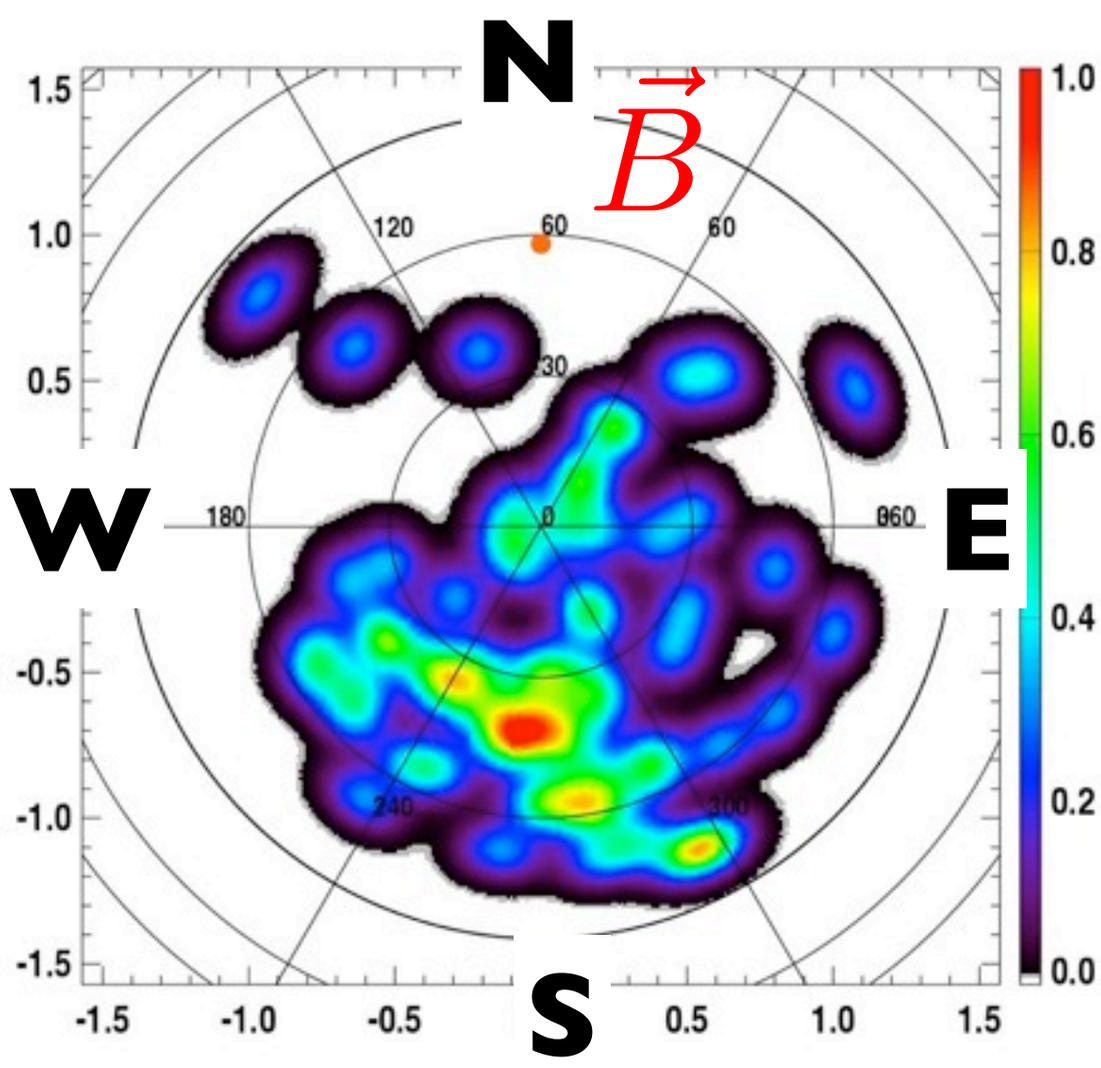
Events sky map

Auger events around Apolinario
(same time period,
axis distance < 1 km)



~uniform in azimut

Auger events seen by RAuger
53/65 from South (81.5 %)



evidence of the geomagnetic effect
in the electric field emission

Events sky map

Auger events around Apolinario
(same time period,
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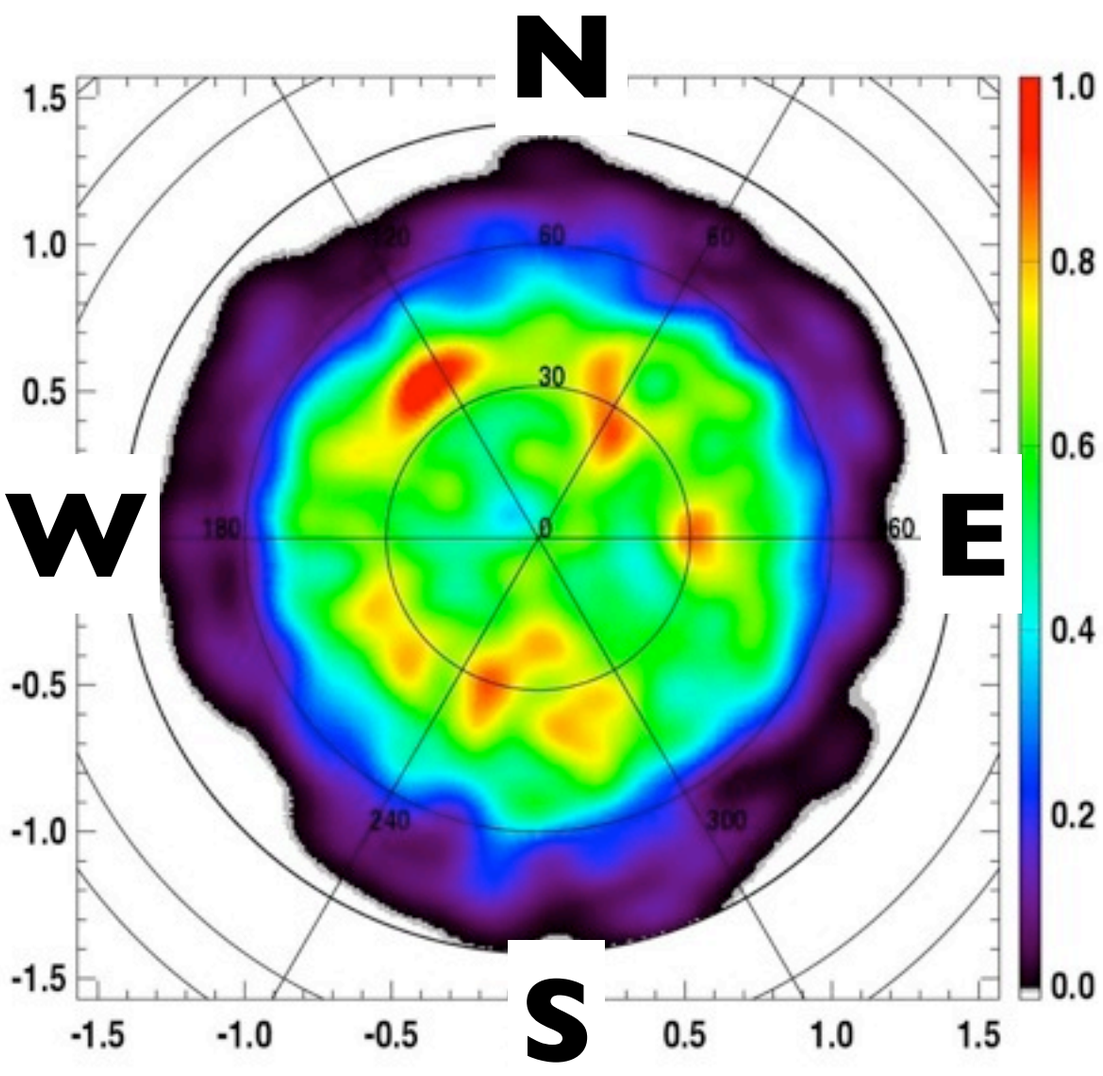
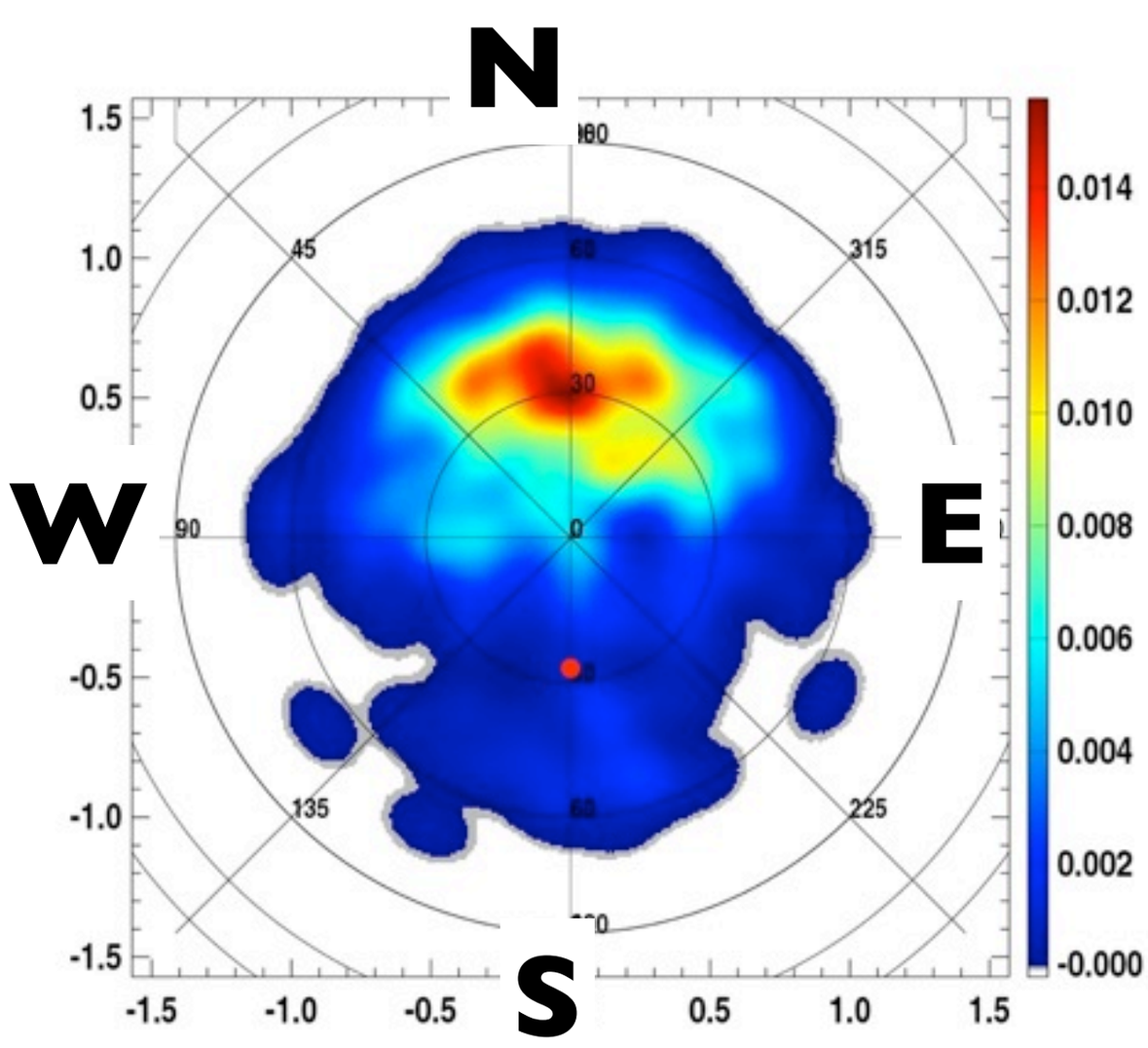


~uniform in azimut

CODALEMA, northern
hemisphere



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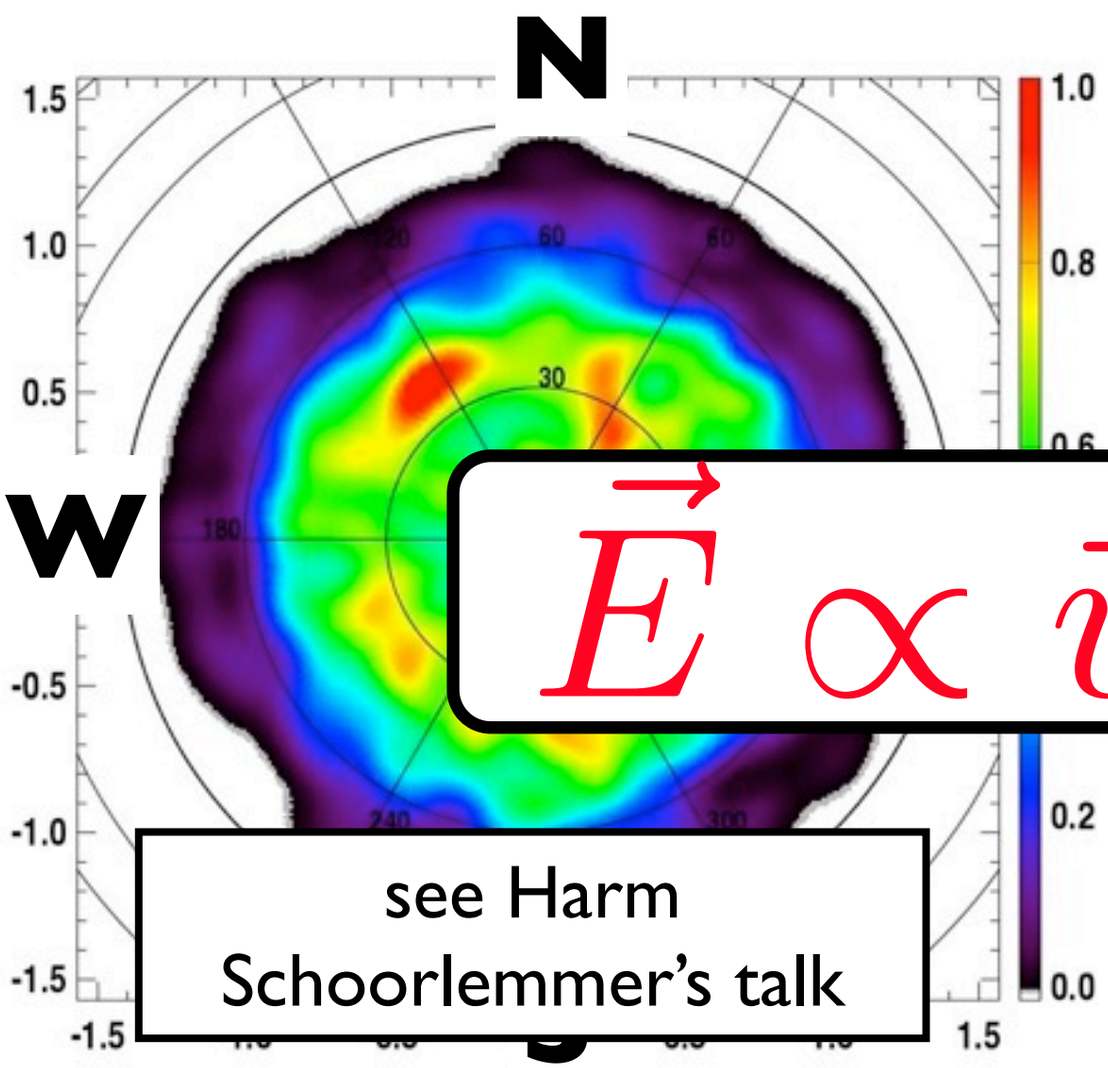
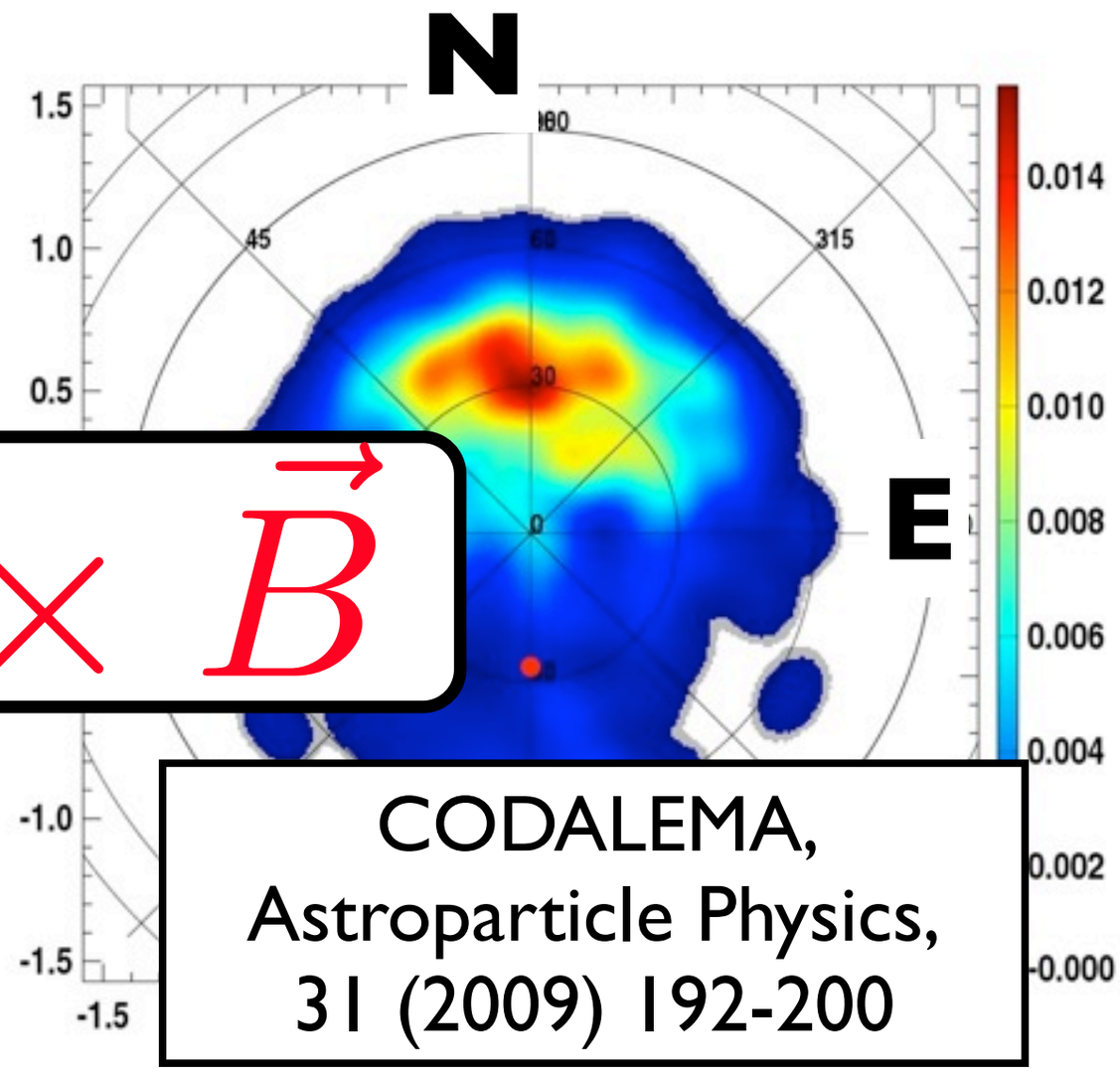


$$\vec{E} \propto \vec{v} \times \vec{B}$$

see Harm
Schoorlemmer's talk

~uniform in azimut

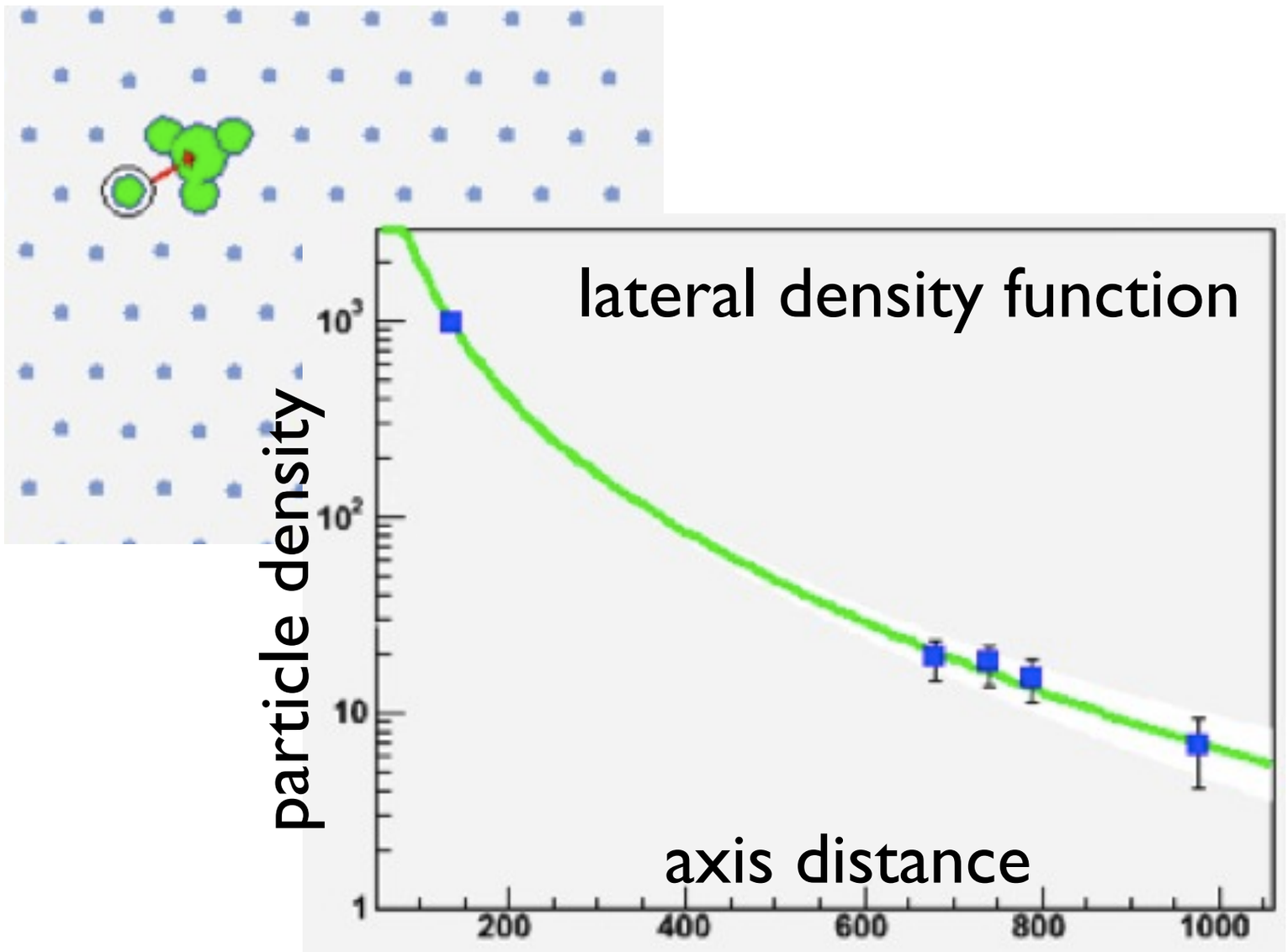
CODALEMA, northern
hemisphere



CODALEMA,
Astroparticle Physics,
31 (2009) 192-200

evidence of the geomagnetic effect
in the electric field emission

The threefold coincidence



xcore = -8838 ± 23 m

ycore = -3953 ± 47 m

energy = 1.43 EeV (< 20%)

axdist-A1 ~ 160 m

axdist-A2 ~ 80 m

axdist-A3 ~ 180 m

hybrid time fit: (radio signal arrives first, direct estimation, not a simple t_{0radio}-$t_{0particle}$)

$$\delta t_{\mathrm{hybrid}} \sim -34 \text{ ns}$$

radio

θ = **51.33°**

Φ = **209.74°**

Auger SD

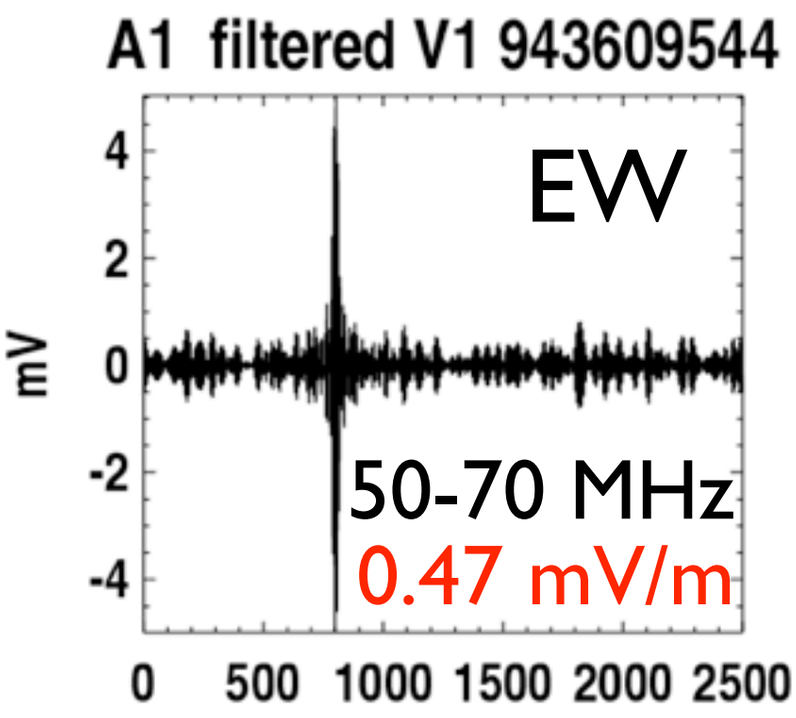
θ = **51.02°**

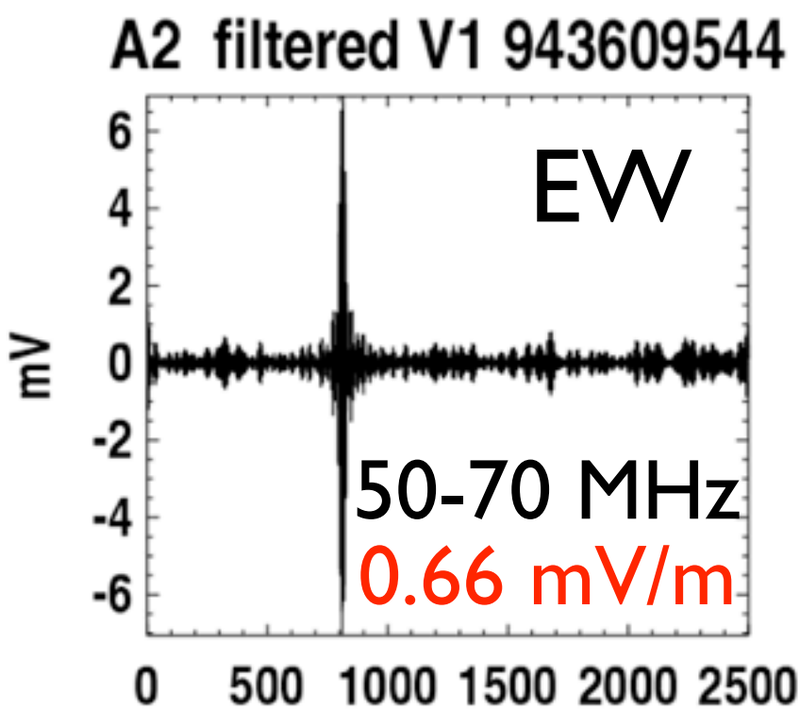
Φ = **209.53°**

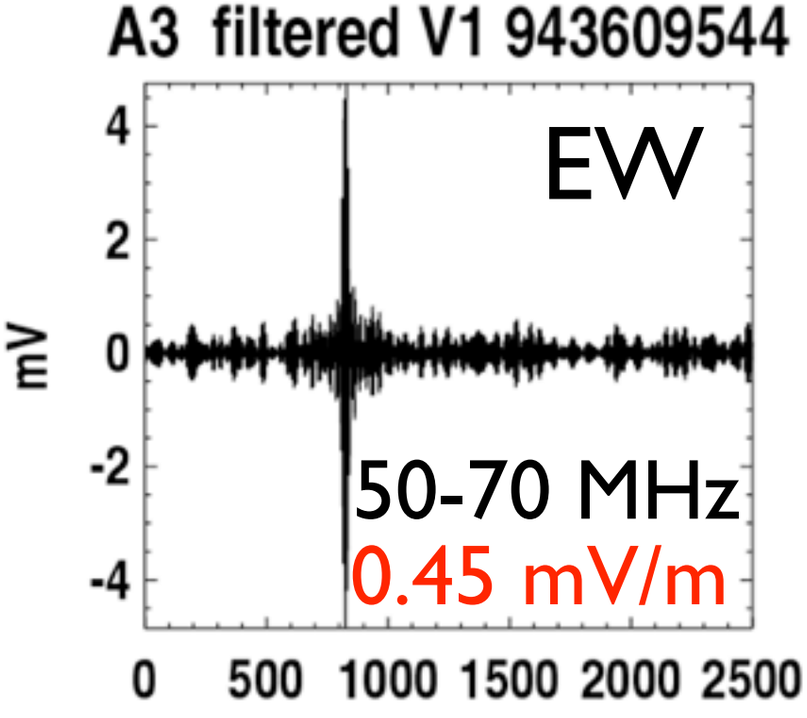
angular difference radio/SD : **0.36°**

Auger angular resolution for this θ and multiplicity : **above 1°**

Radio reconstruction







Use the Auger core position, direction is known: compute the profile

$$E_i^{\mathrm{EW}} = E_0^{\mathrm{EW}} \exp(-d_i/d_0) \longrightarrow E_0^{\mathrm{EW}} \sim 900\ \mu\mathrm{V/m}$$

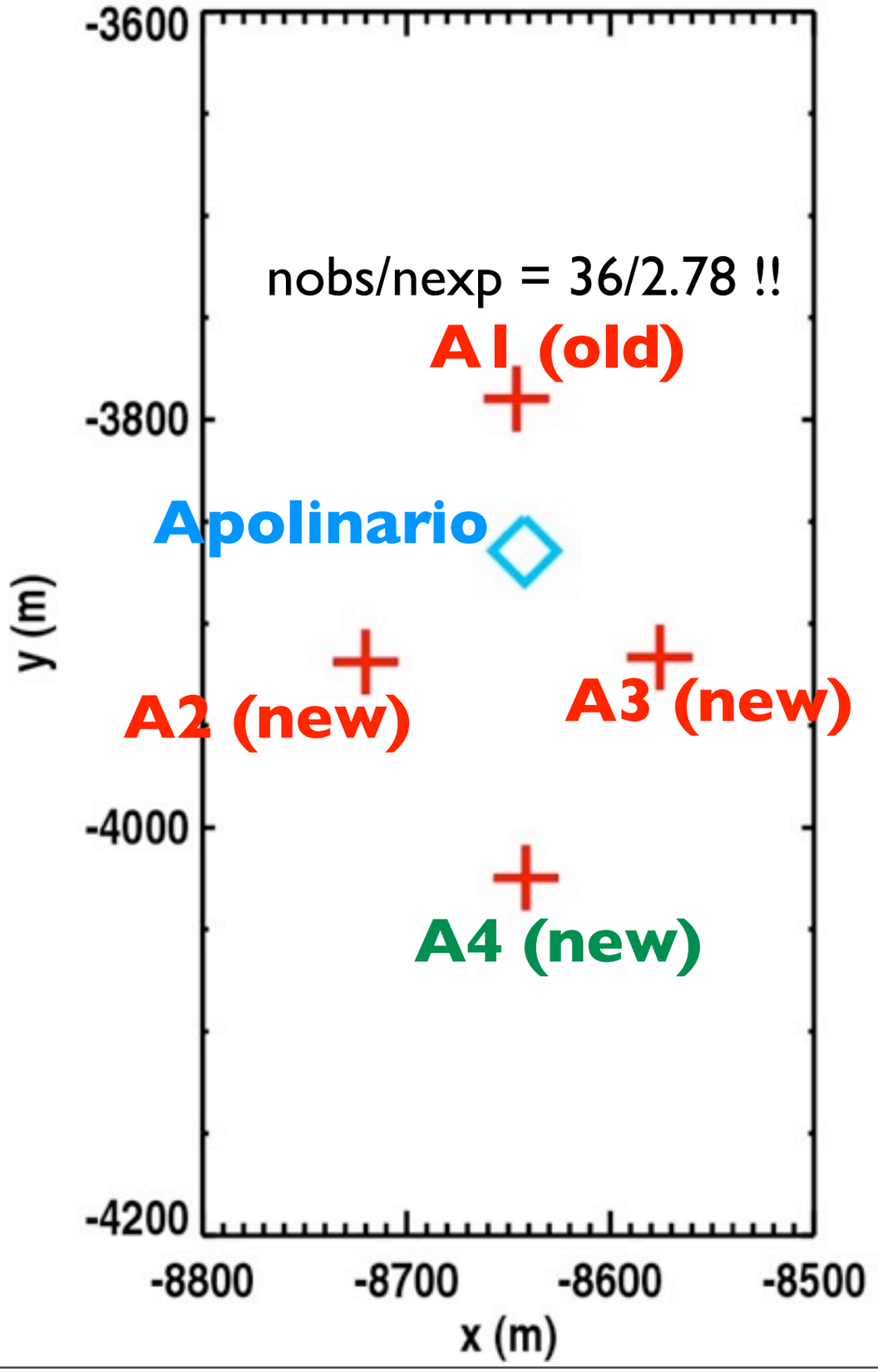
then, geomagnetic correction: $E_0^{\mathrm{EW}}/|(\vec{v}\times\vec{B}).\overrightarrow{\mathrm{EW}}| \sim 1220\ \mu\mathrm{V/m}$

finally use the CODALEMA calibration:

$$E_0^{\mathrm{EW}}/|(\vec{v}\times\vec{B}).\overrightarrow{\mathrm{EW}}| = 10^b {E_{\mathrm{CIC}}}^a,\ b=-15.93,\ a=1.05$$

leads to: $E_{\mathrm{CIC}} = 1.29\ \mathrm{EeV}$ Auger finds: 1.43 EeV OK !!!!

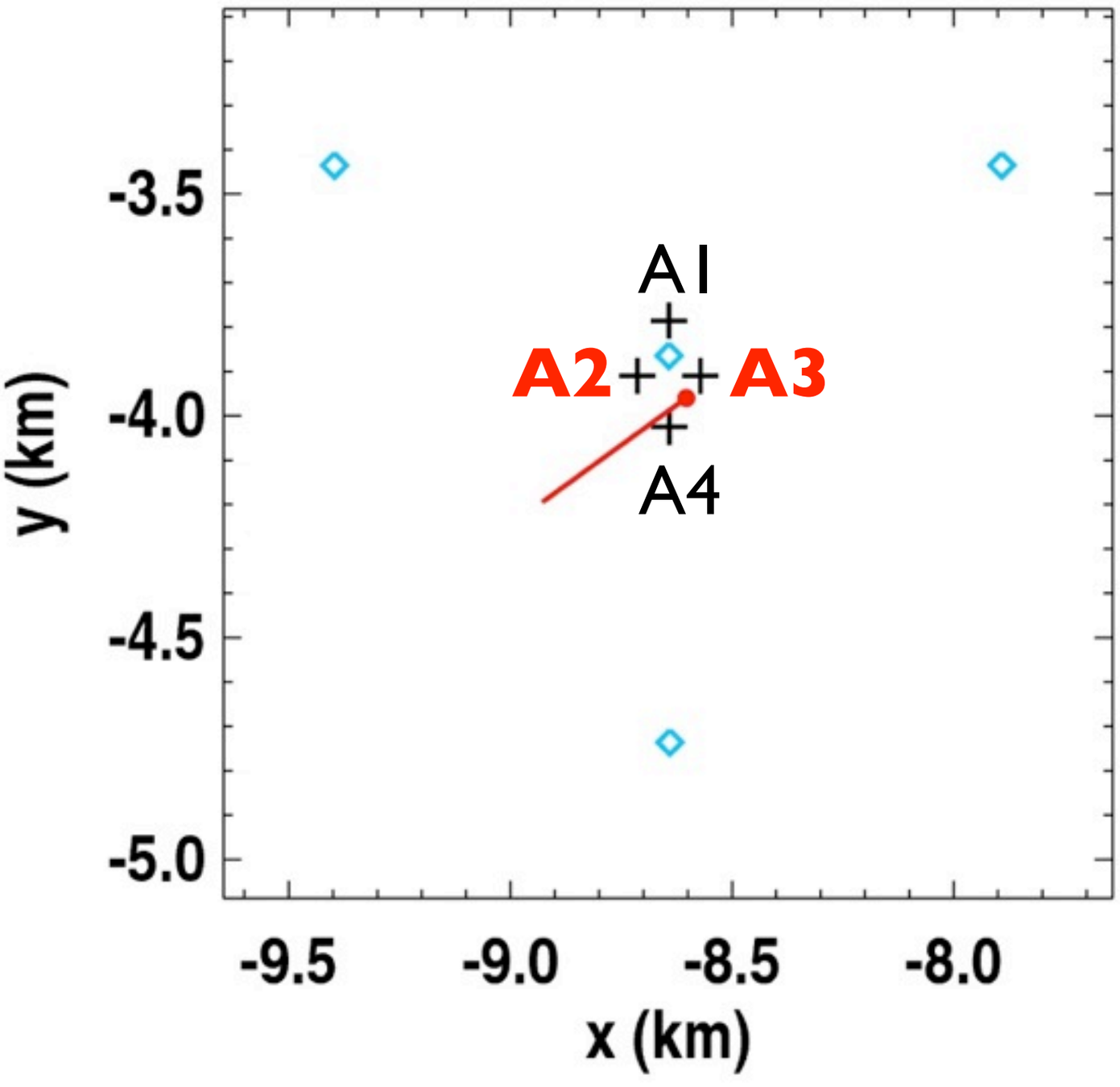
RAuger new setup



(already described yesterday in T. Garçon's talk, antenna described in D. Charrier's talk)

- upgraded antennas and electronics
- still fully autonomous with a simple threshold trigger
- first switched ON, on May 10th, first coincidence with Auger on May 13th!

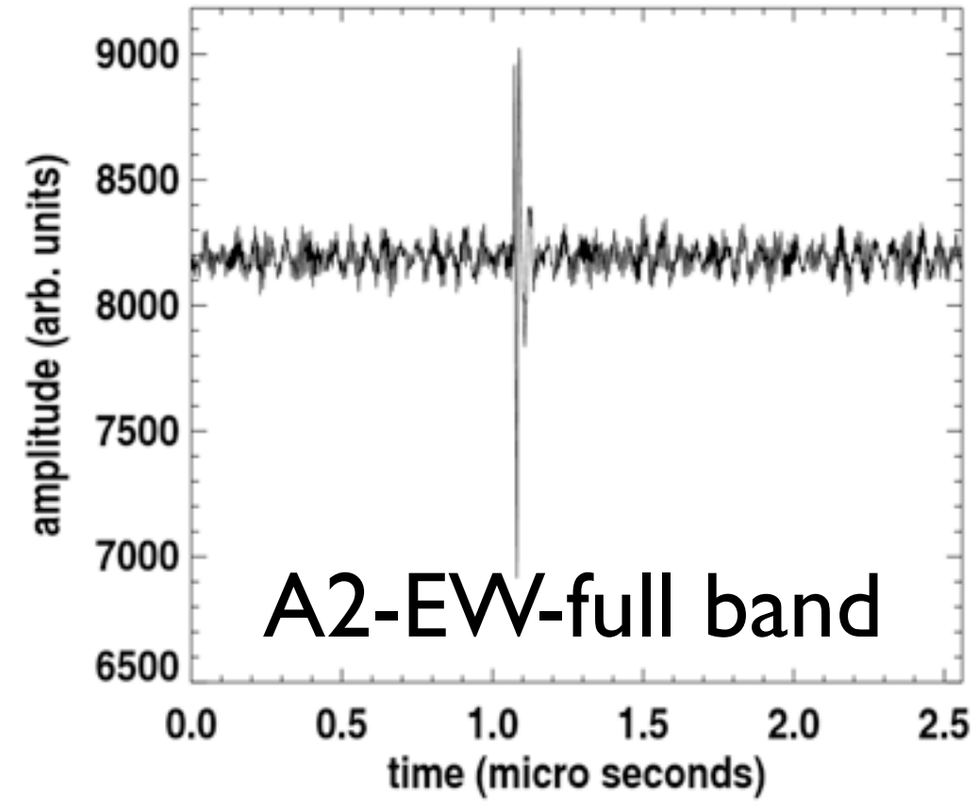
RAuger new setup: Auger coincidence

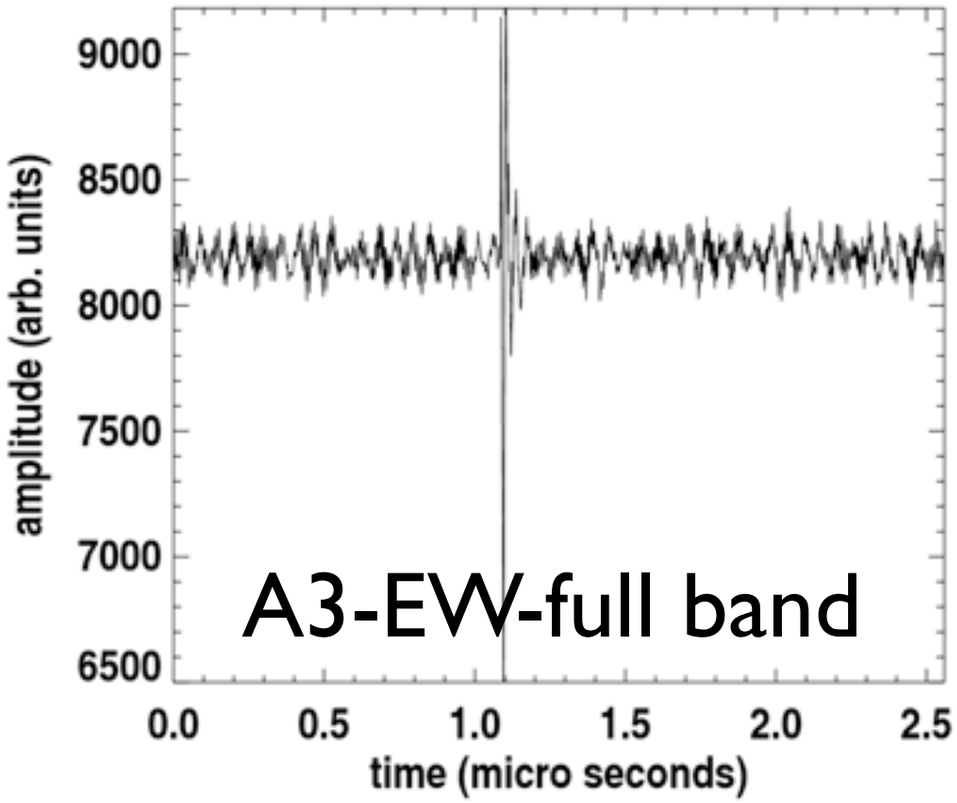


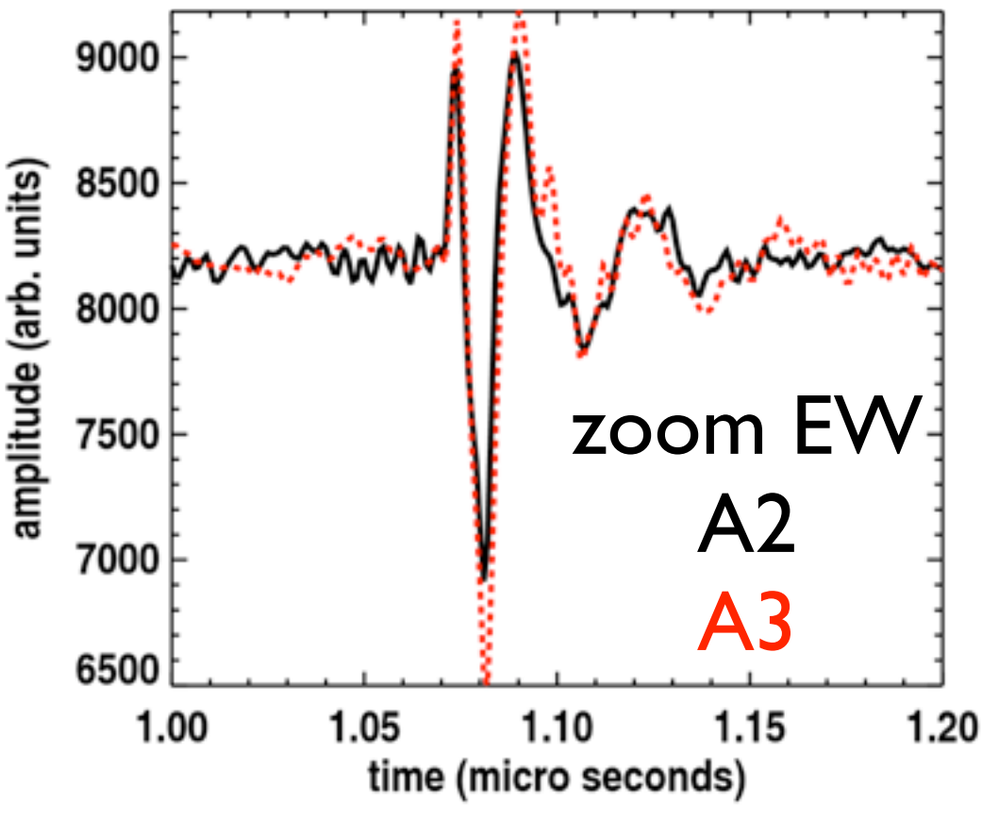
UTC	1273782927
NTanks	4
GPS	957818142
NANO	90779870
TS	2010-05-13 20:35:27
THETA	40.0
PHI	-144.2
ENERGY (EeV)	1.2
XC (m)	-8603.4
YC (m)	-3959.8
axdist(A1)	170 m
axdist(A2)	**115 m**
axdist(A3)	**40 m**

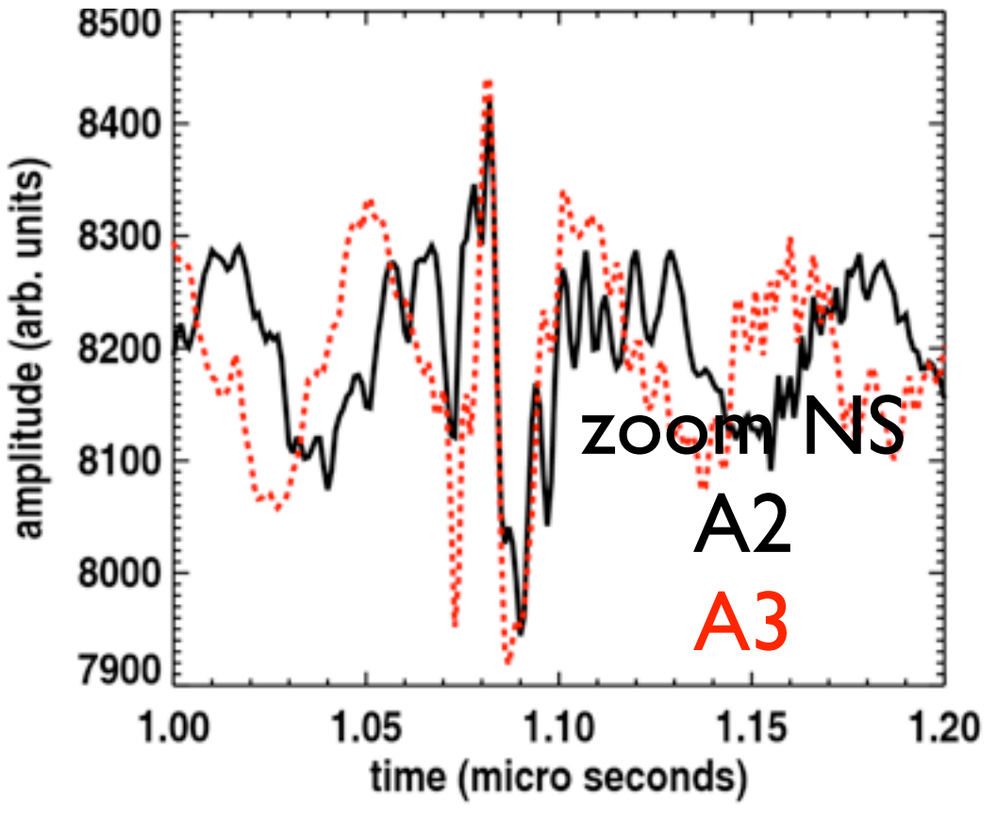
A1 and A4 were OFF

RAuger new setup: Auger coincidence

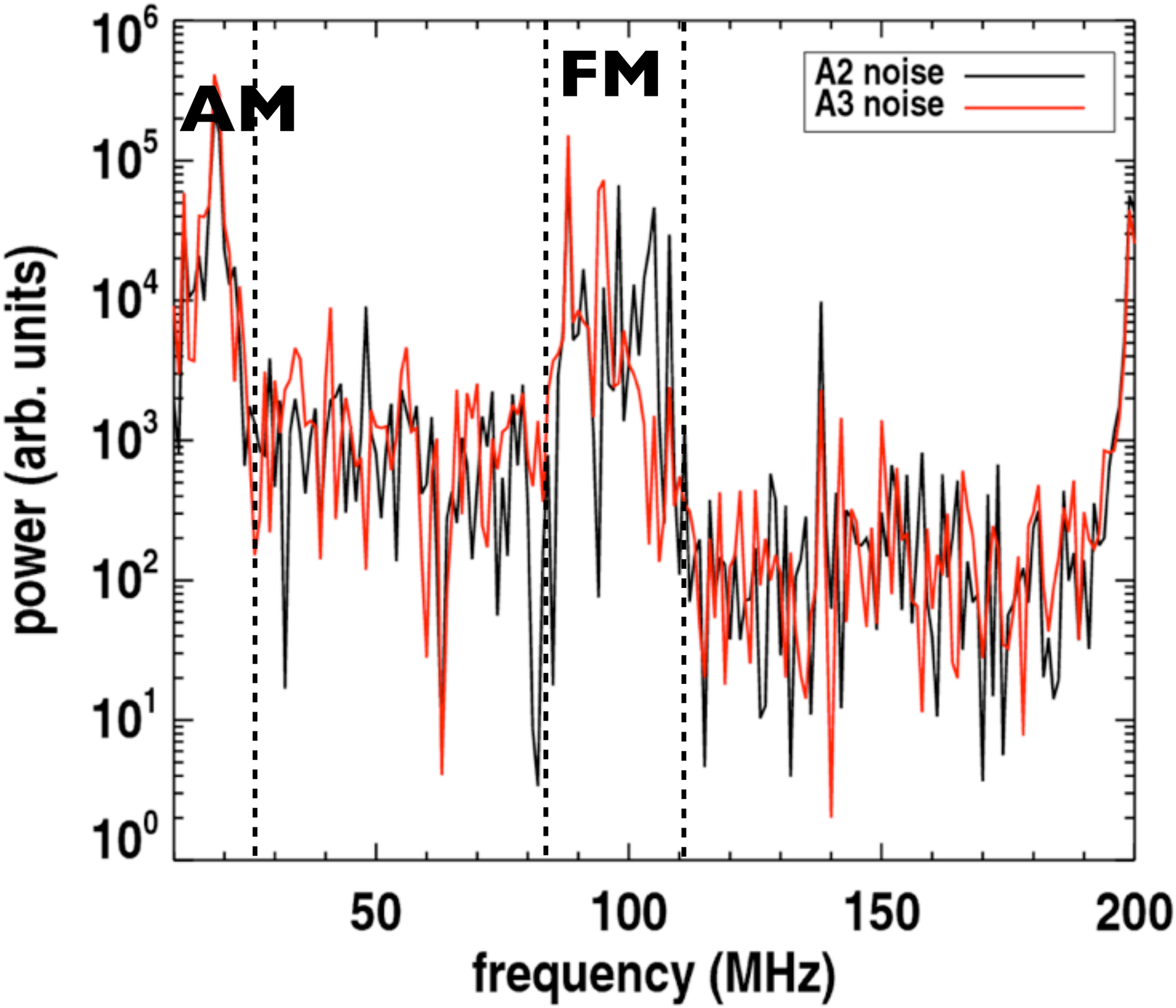




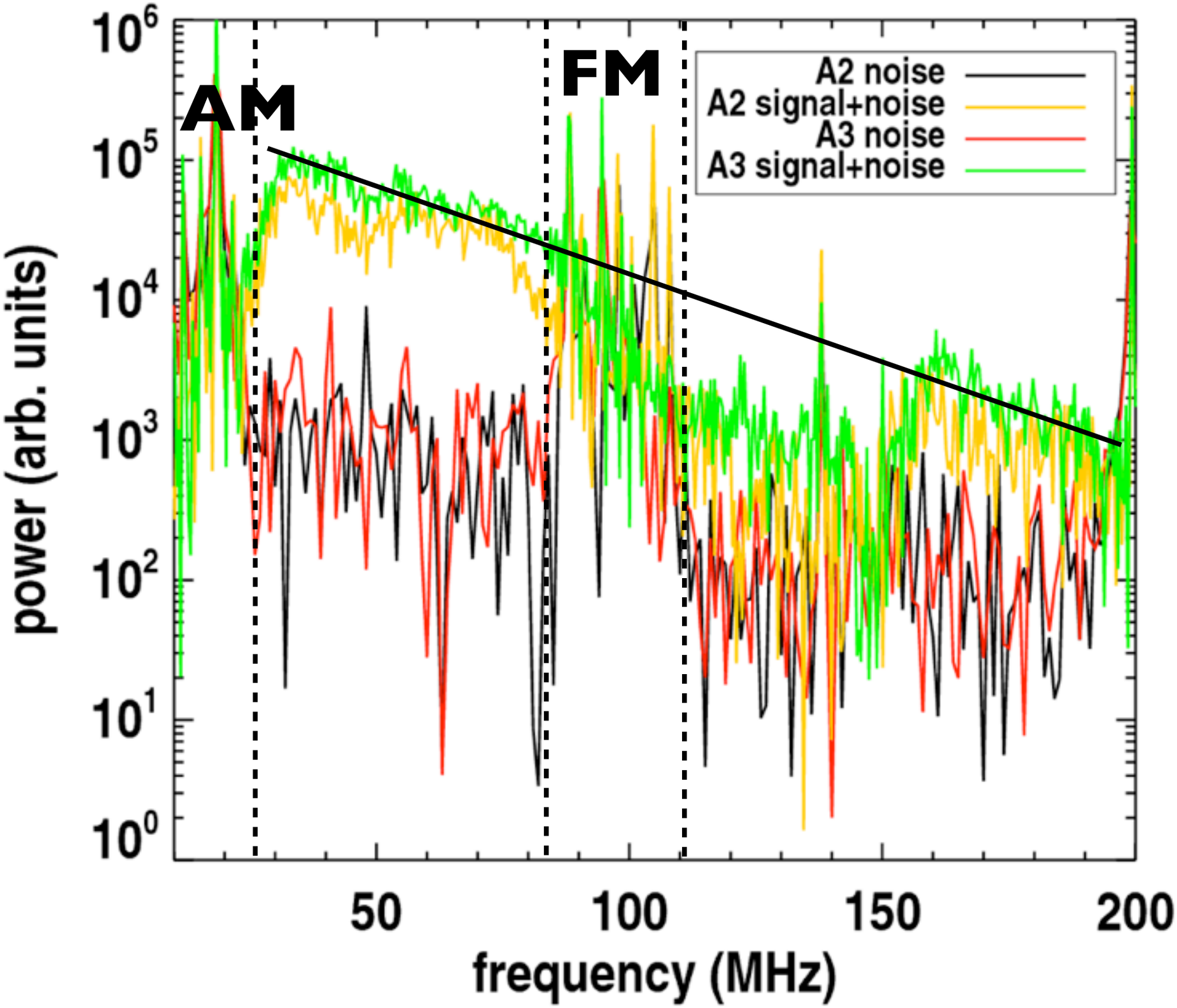




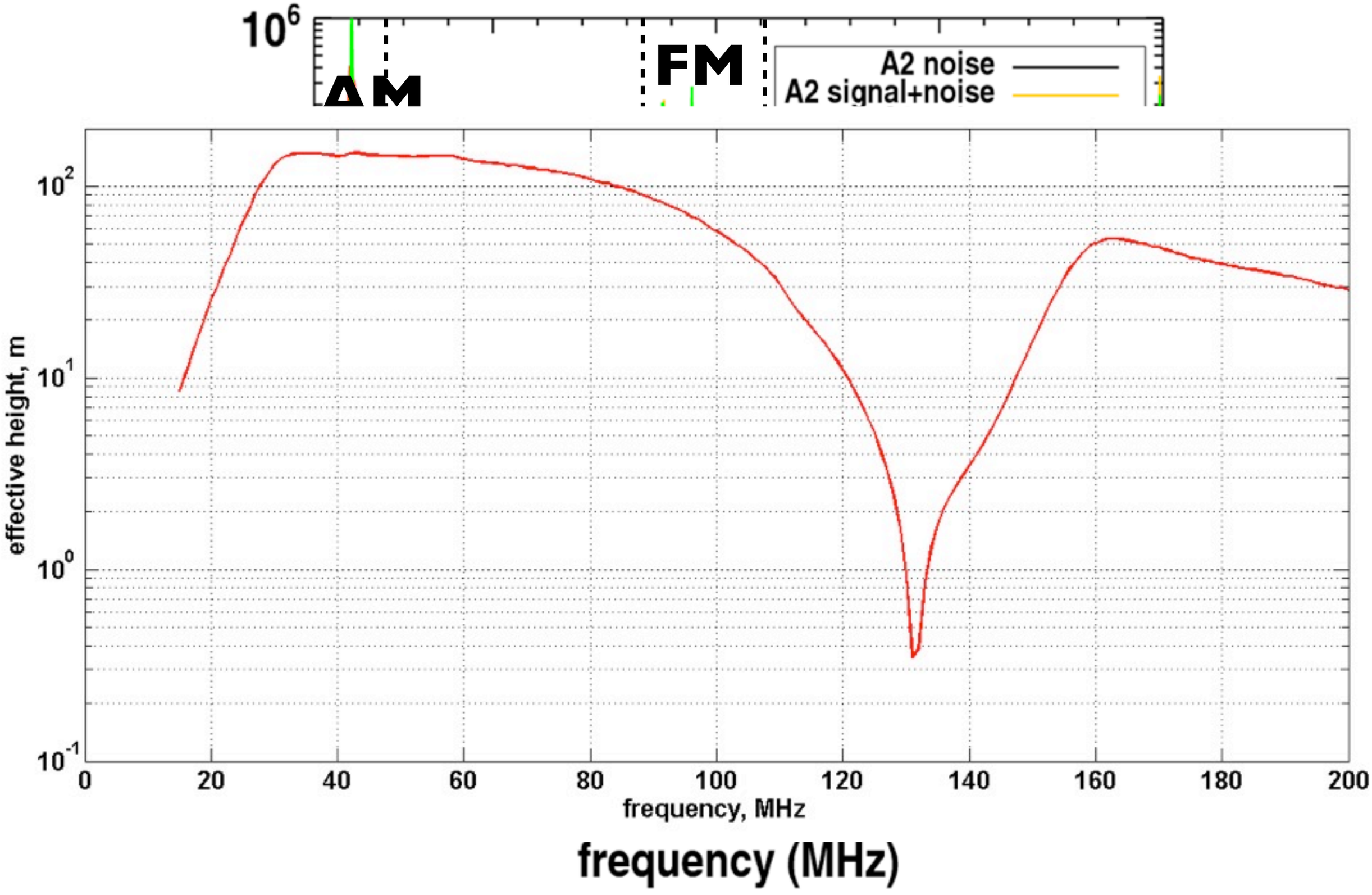
RAuger new setup: Auger coincidence



RAuger new setup: Auger coincidence



RAuger new setup: Auger coincidence



Conclusion

- for the first time, self-triggered radiodetection of showers! Running in Auger since 3 years and continuing

- confirmation of the geomagnetic effect observed by CODALEMA

- 3-fold event: reconstruction is in excellent agreement with Auger

- detect showers up to 80° in zenith angle and up to 1 km

- we also obtained coincidences with Auger in a very wide band [2-75] MHz (not presented here)

- new RAuger setup installed in May 2010 is very promising (part of the AERA effort on the Pierre Auger Observatory)