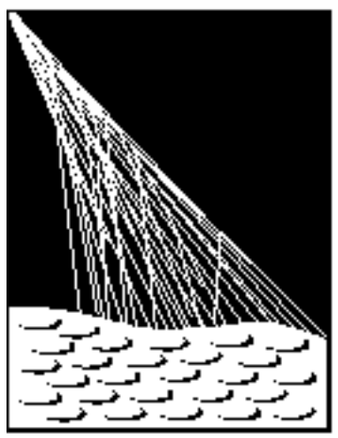
Radiodetection of cosmic air showers with autonomous radio detectors installed at the Pierre Auger Observatory



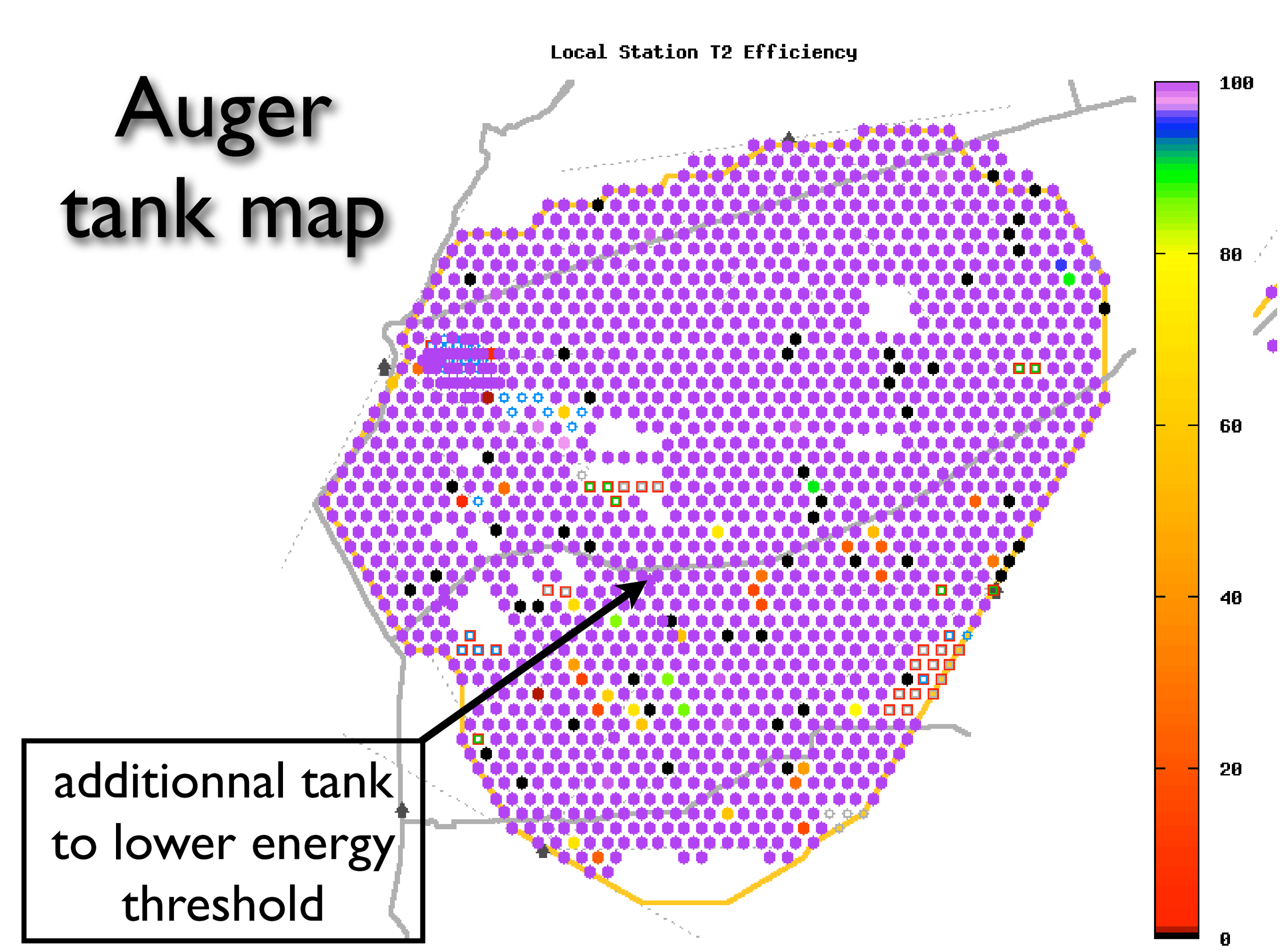
Benoît REVENU
Subatech, Nantes, France

ARENA 2008, Rome

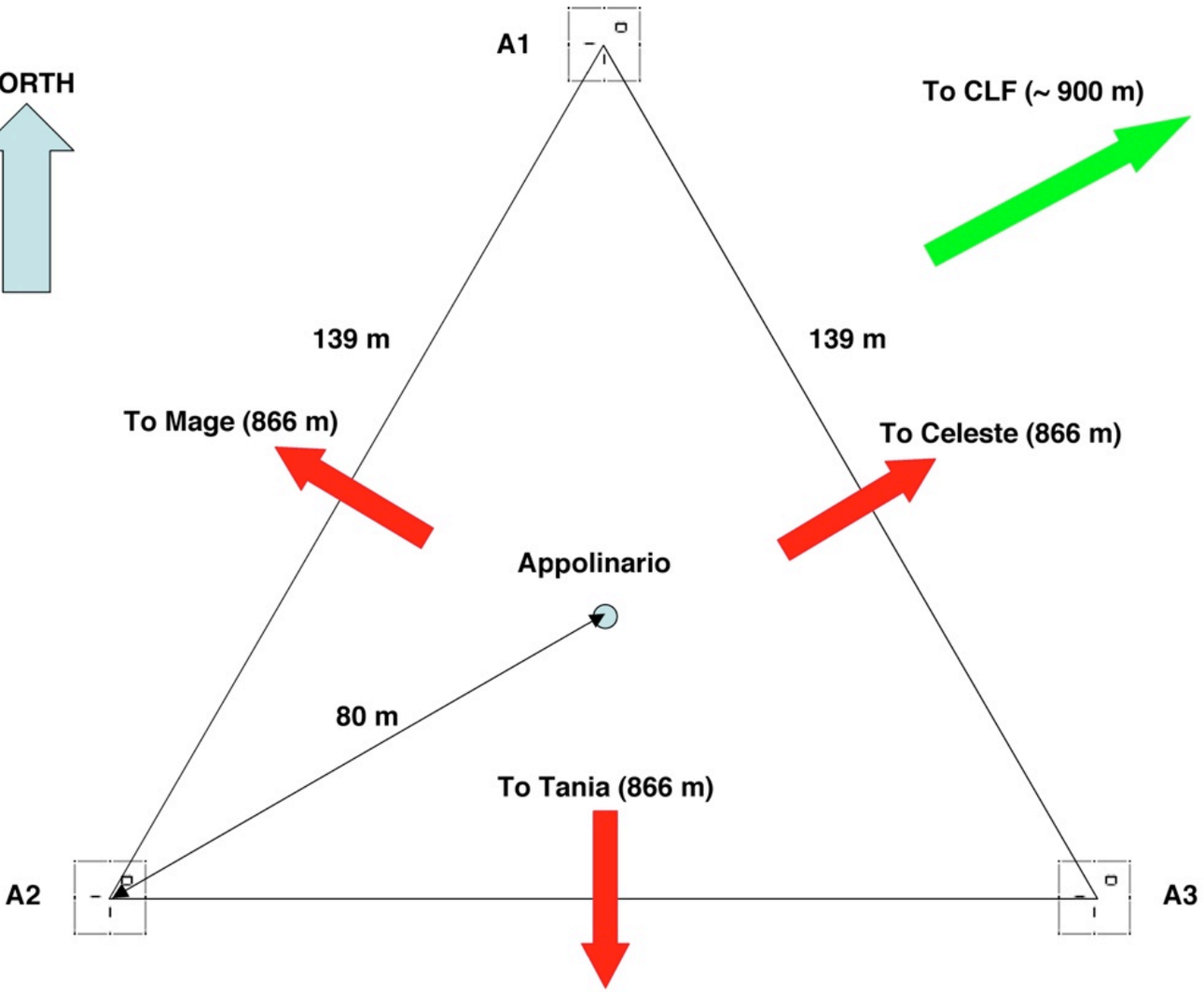
Goals of the prototype

- study the possibility to detect EAS with an autonomous radio-trigger (no help from any external particle detector)
- get coincidences with Auger events at EeV energies
- give input for the study of a larger (20 km^2) autonomous radio-array planned to be installed in Auger

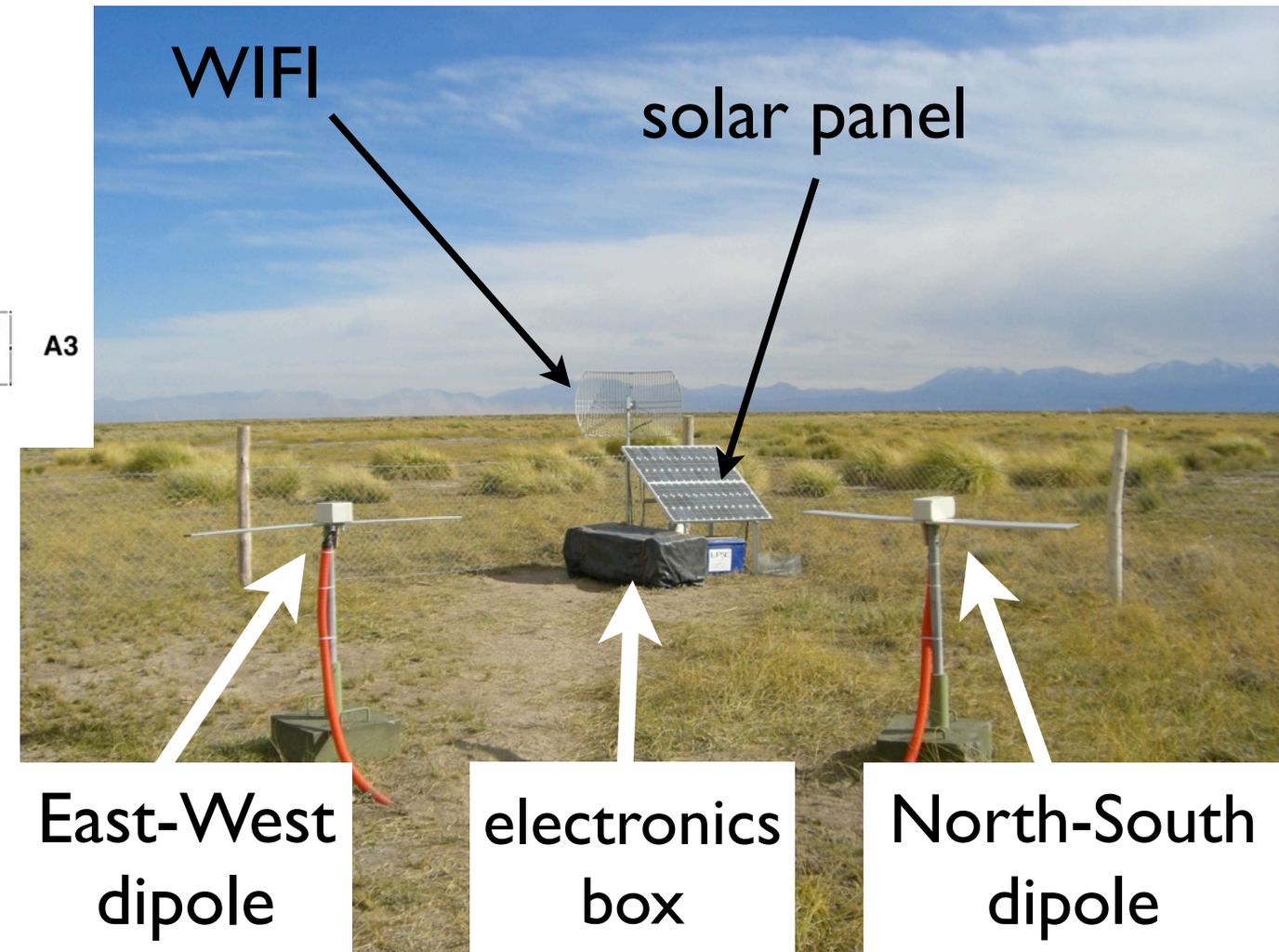
Auger tank map



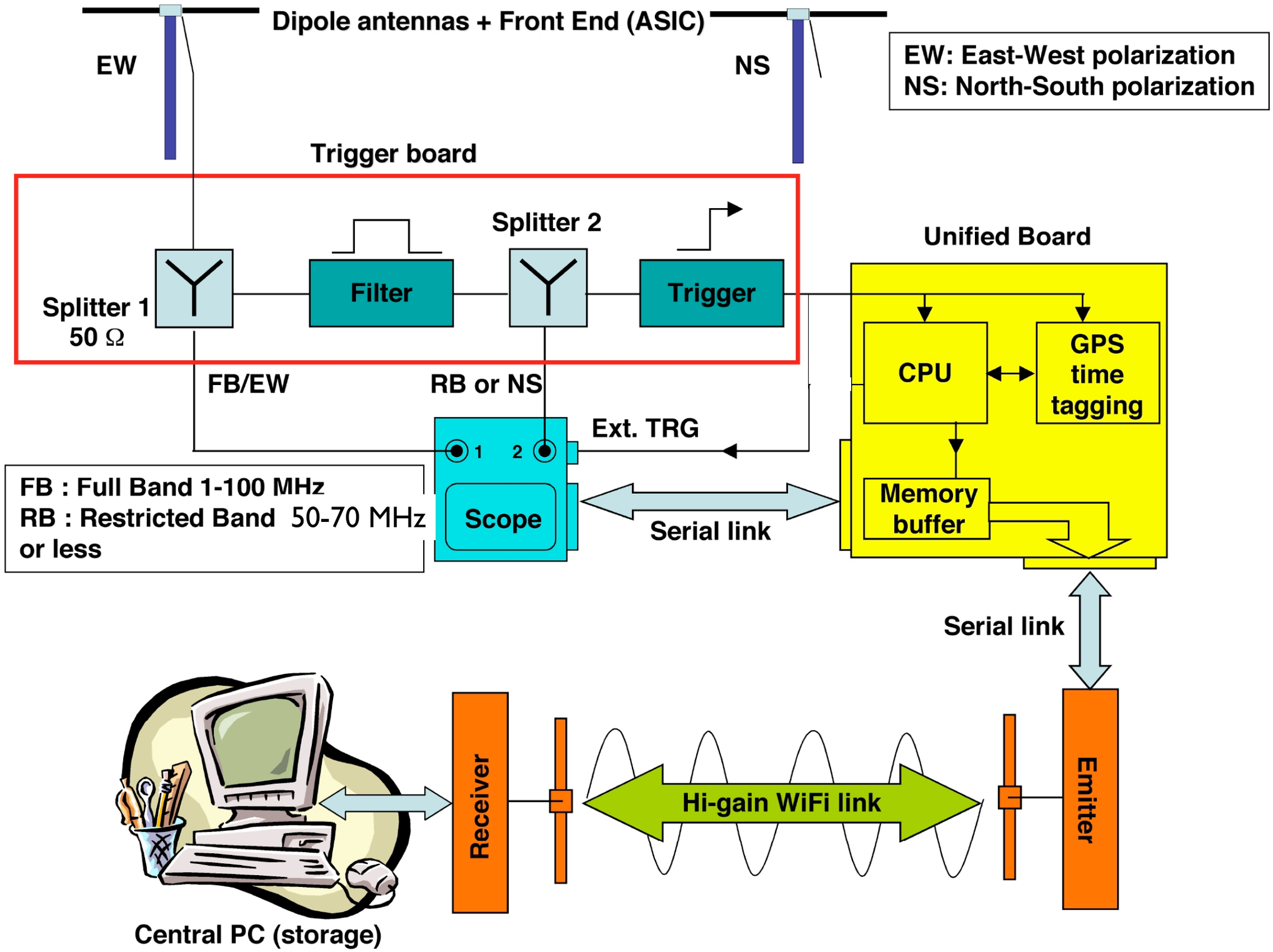
RAuger



Since summer 2007

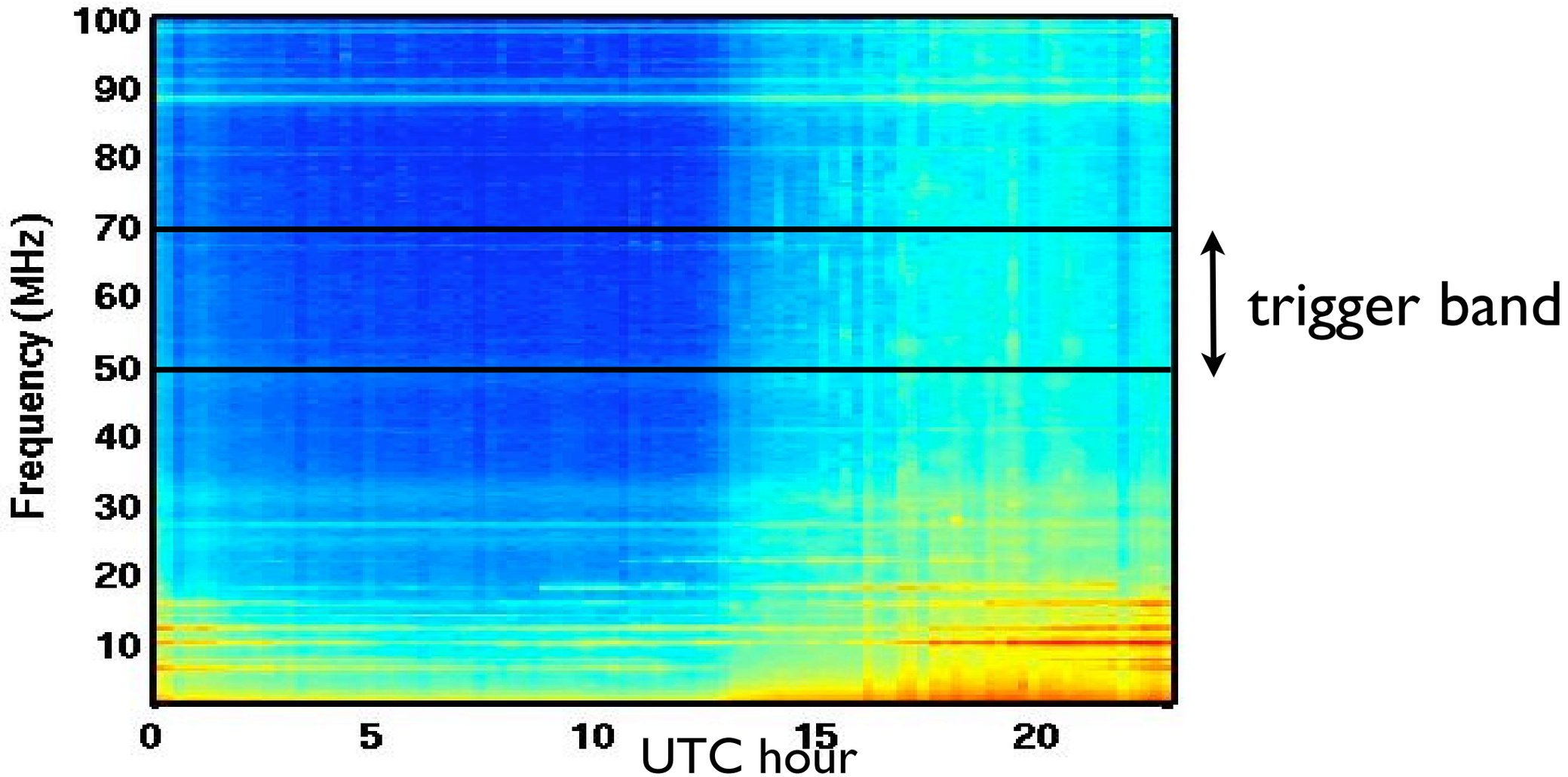


Threshold autonomous trigger



Background

the background is estimated outside the transient :



- observation of the known ionospheric variation
- possibility to lower frequency band down to 20 MHz

$\longrightarrow$ important for pulse shape studies

Signal : time coincidences with Auger

A2 : both NS and EW in full band and filtered band

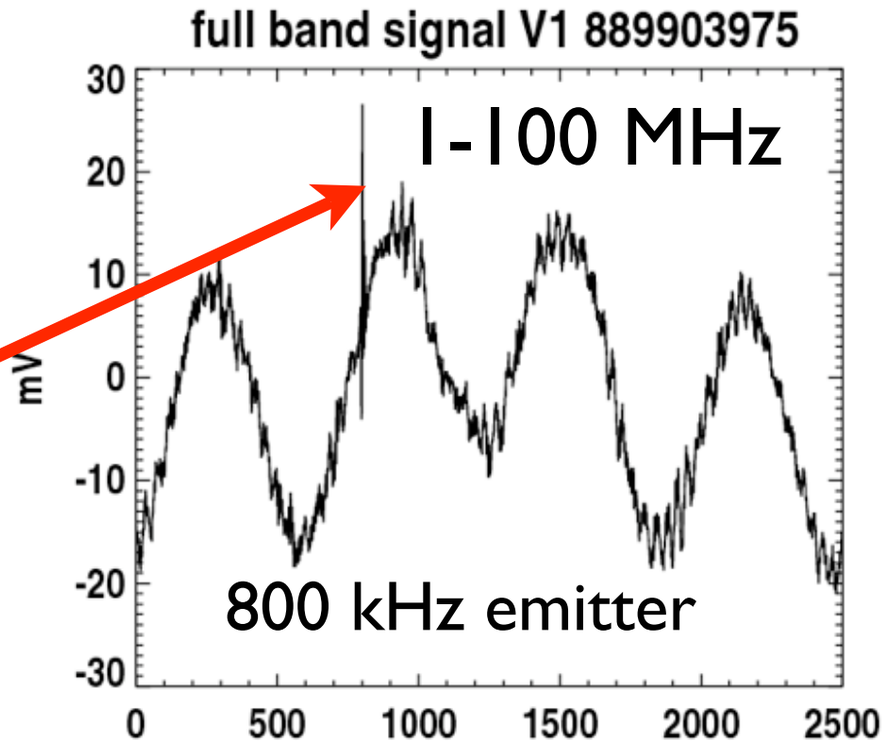
$\theta \sim 4°$

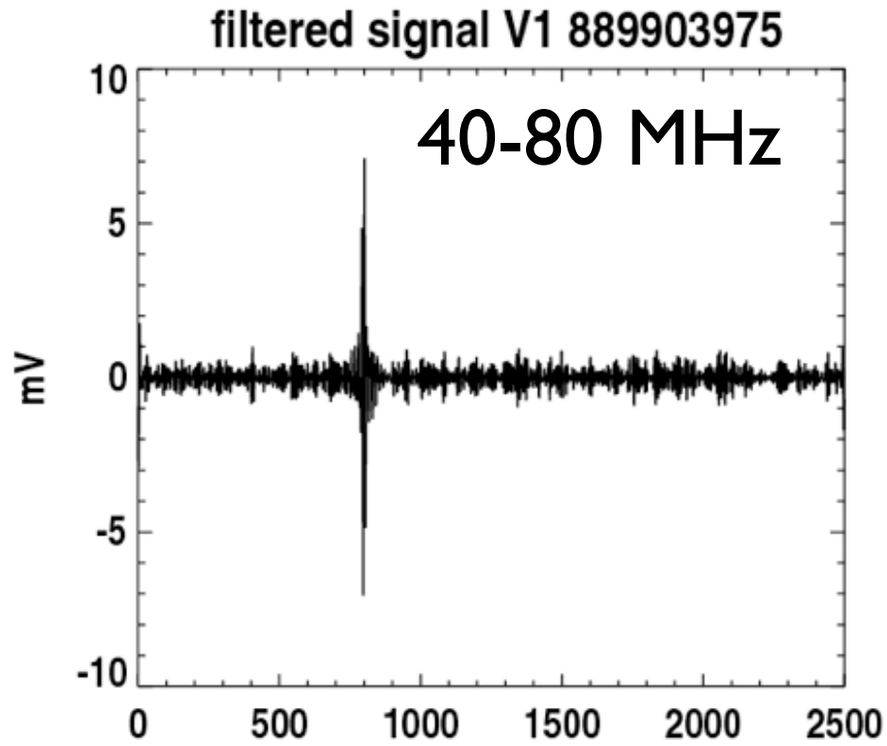
$\phi \sim -7°$

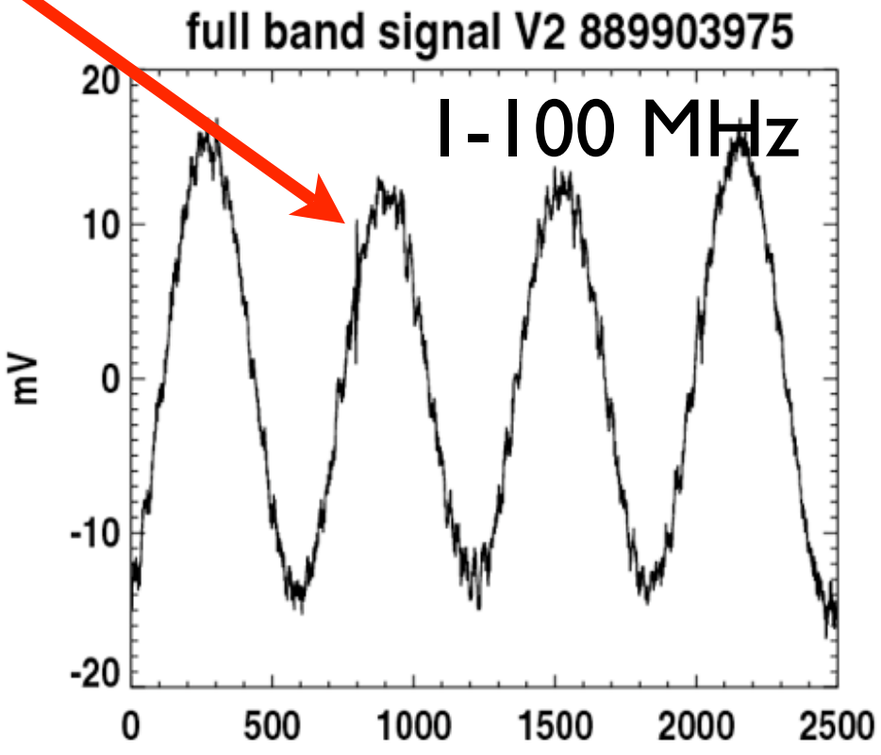
$E \sim 0.5$ EeV

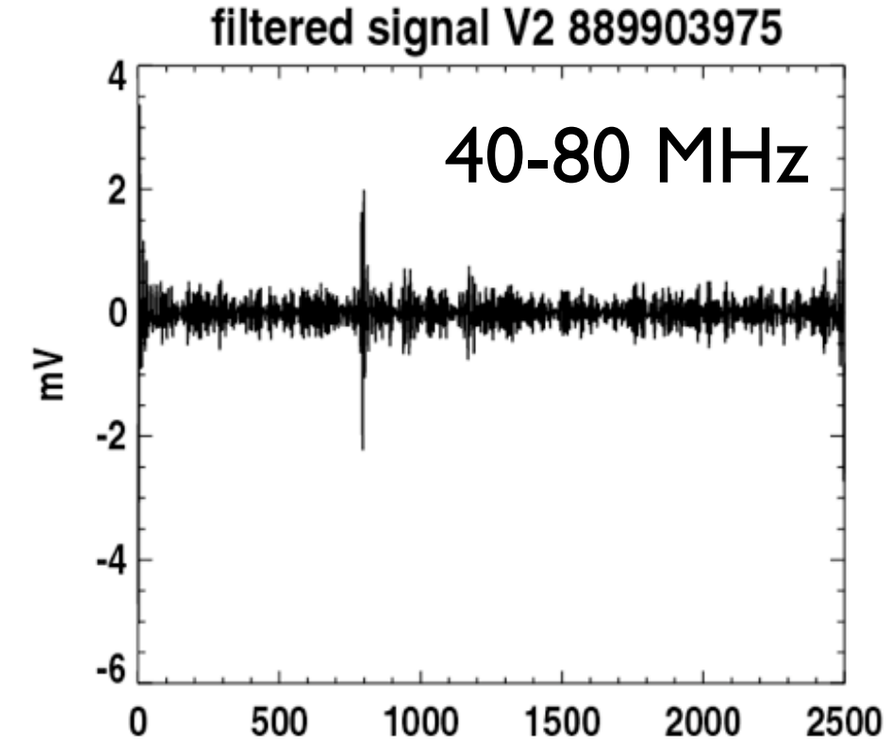
axis at 134 m

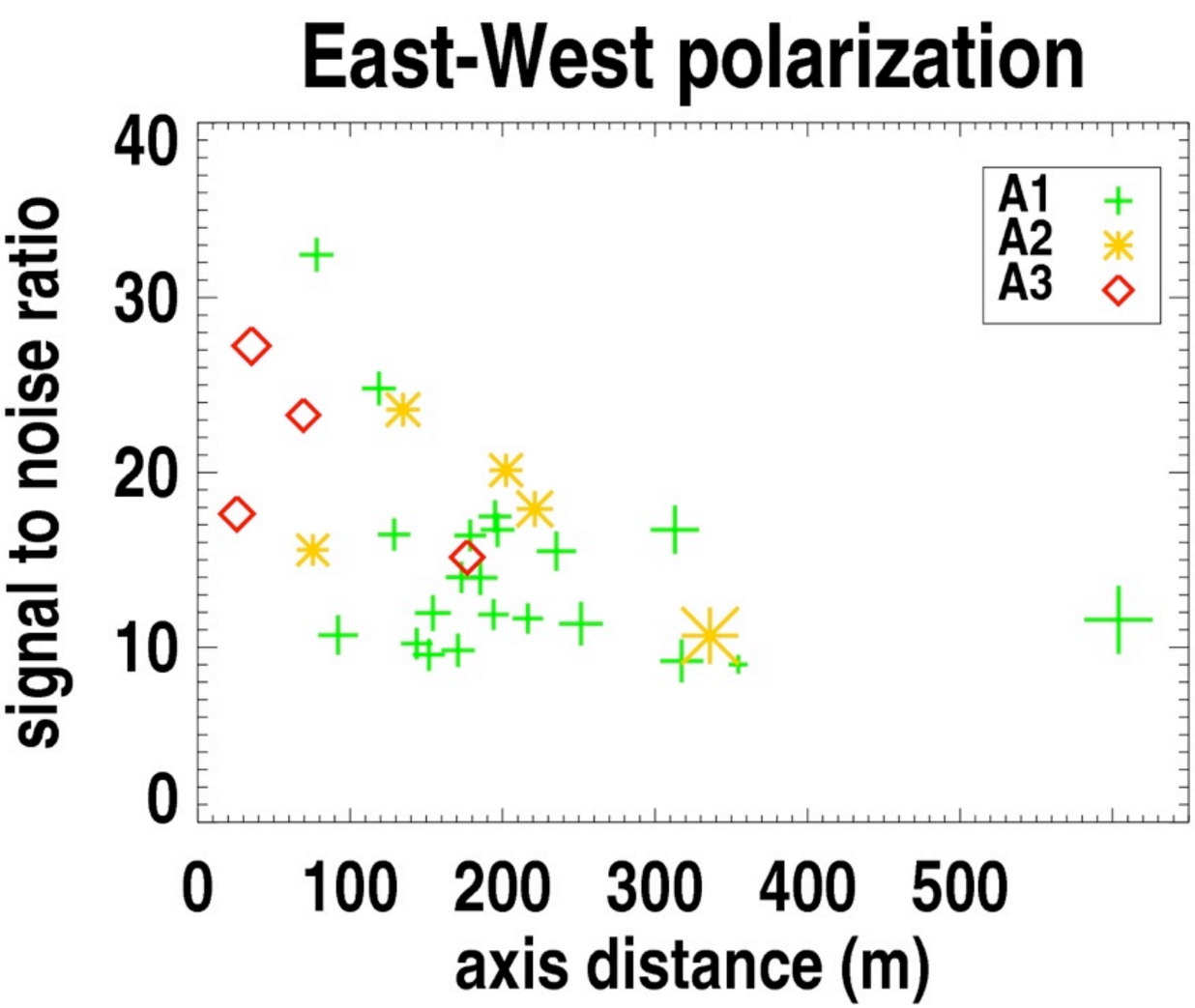
18 march 2008
19h32 UTC









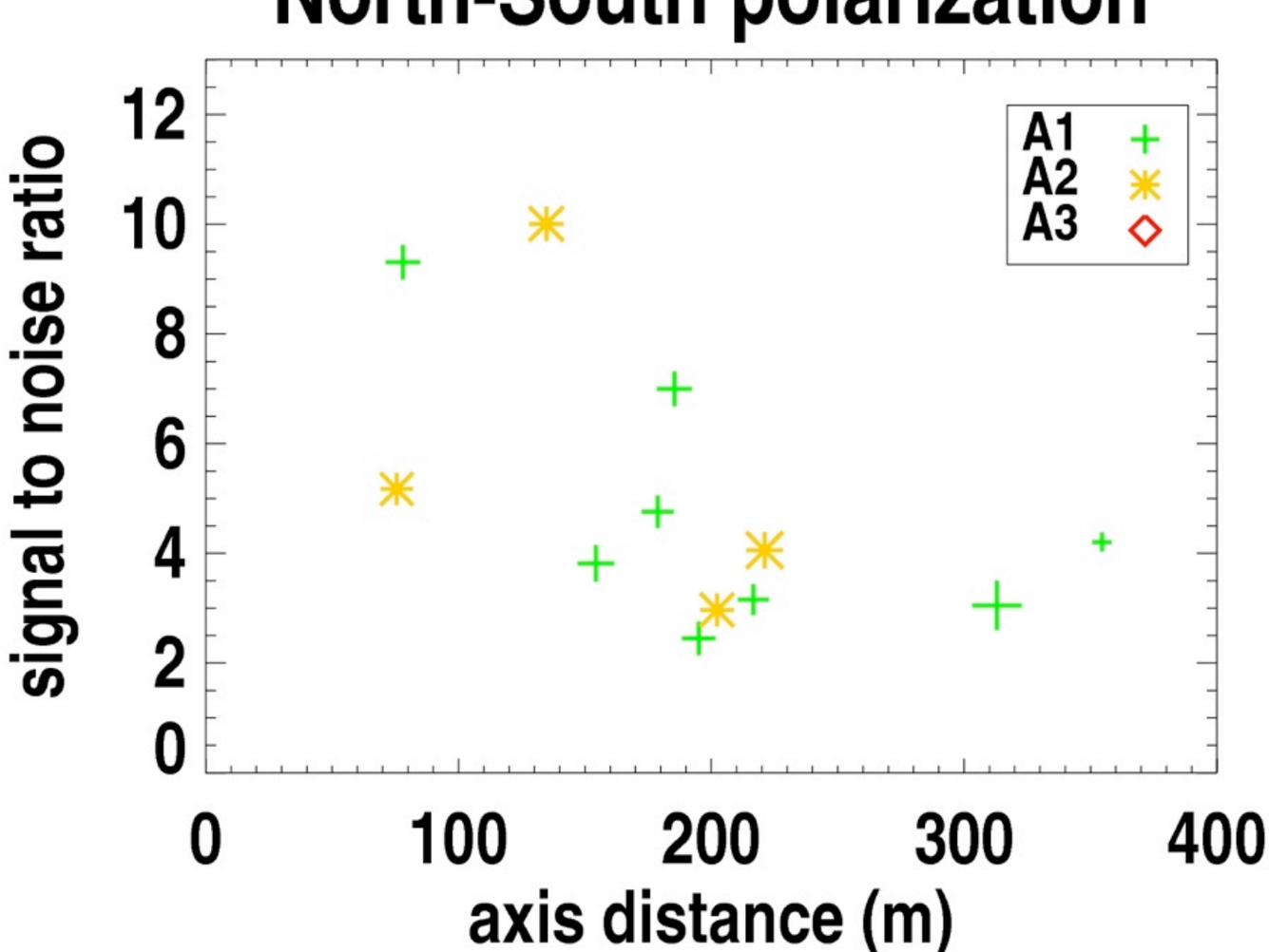


Signal on both EW and NS polarizations

SNR decreases with axis distance as expected

No 3-fold =
no profile for the moment

(since feb. 2008)

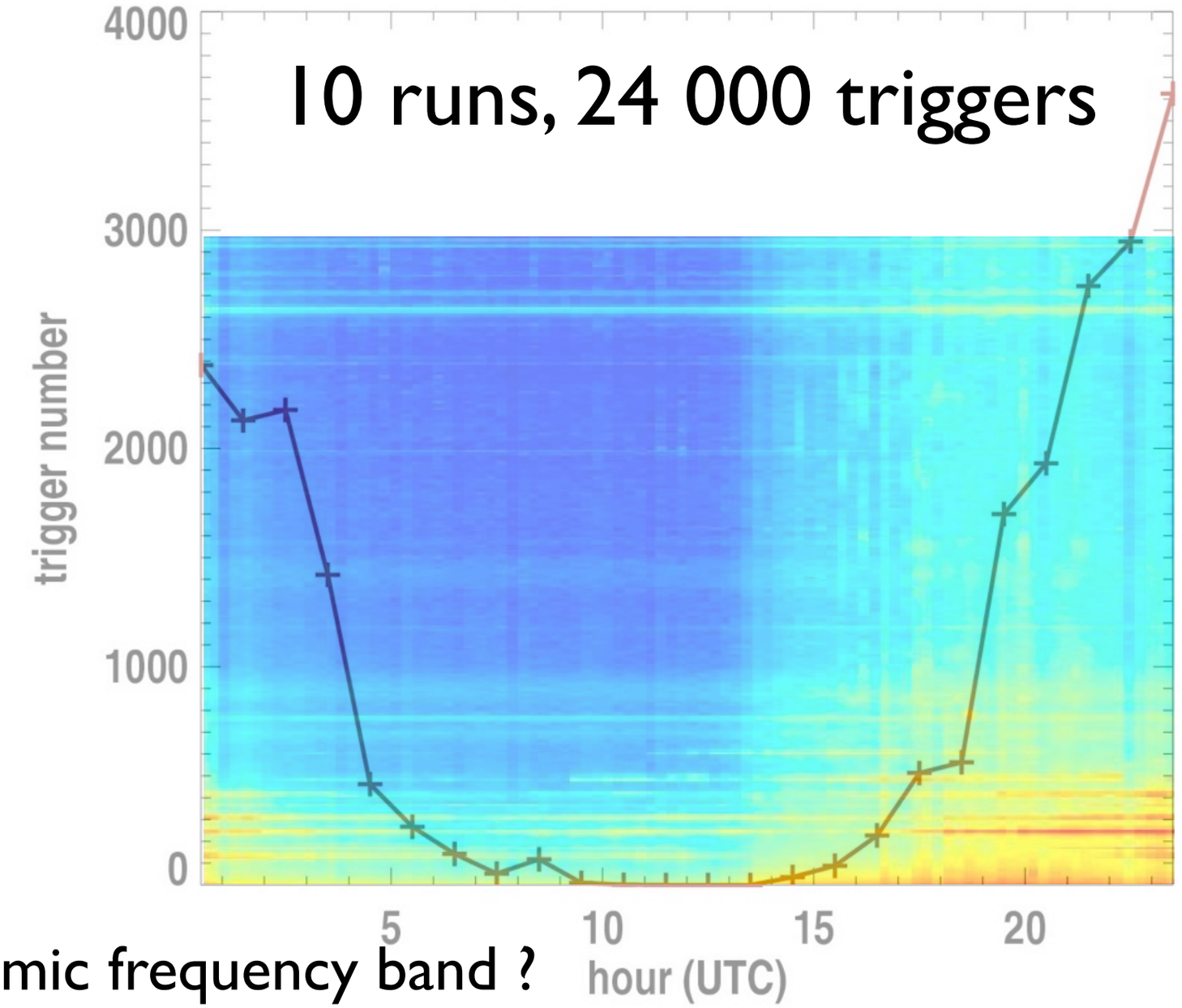


Why no 3-fold yet ?

25 events in coincidence

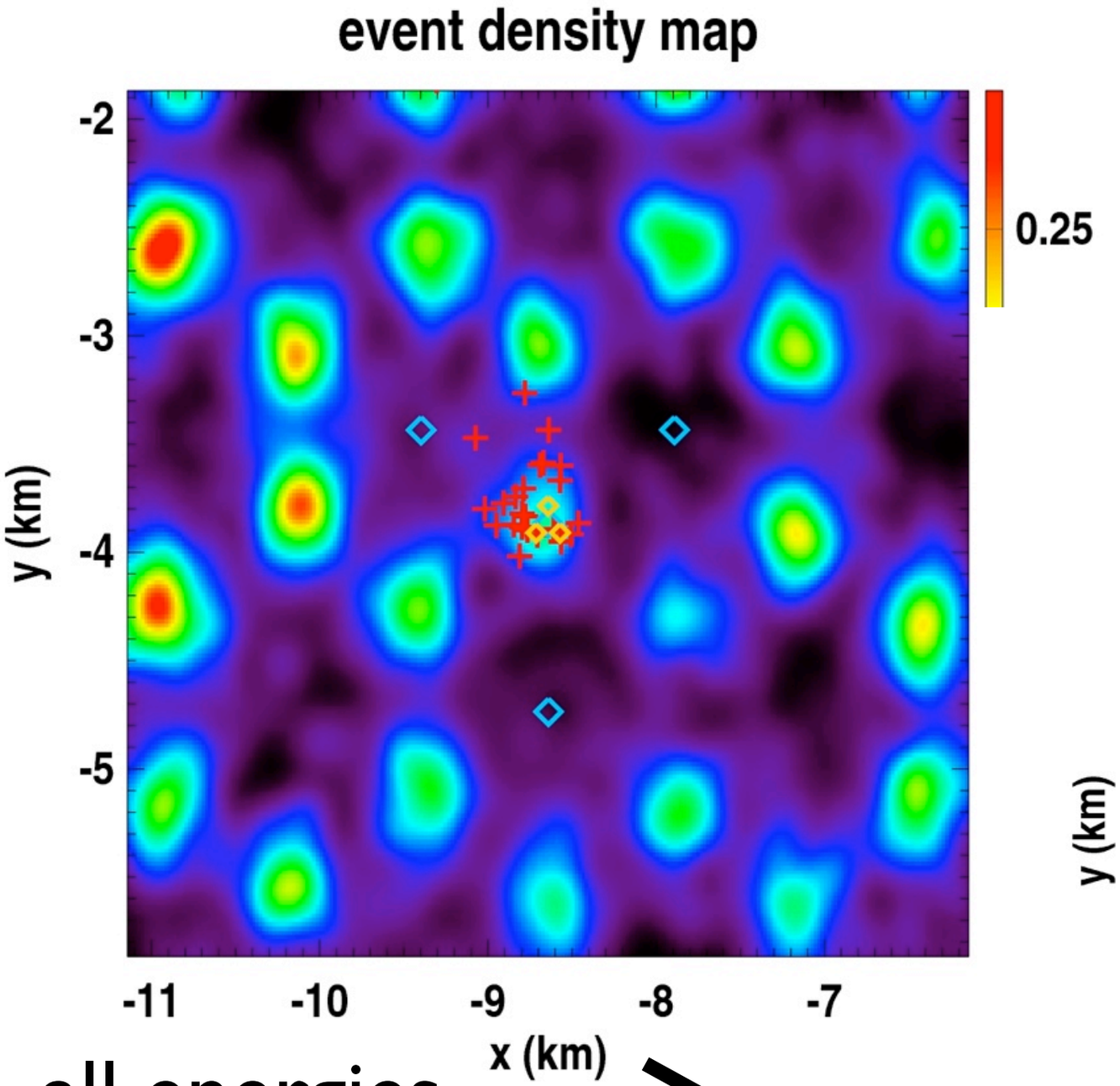
6 of them only (24%) could have been 3-fold

- A2 failure (50%)
- A3 saturating (25%)
- high dead time, around 3 s (serial link to send the 5 kb event)
- highly variable trigger rate



dynamic frequency band ?

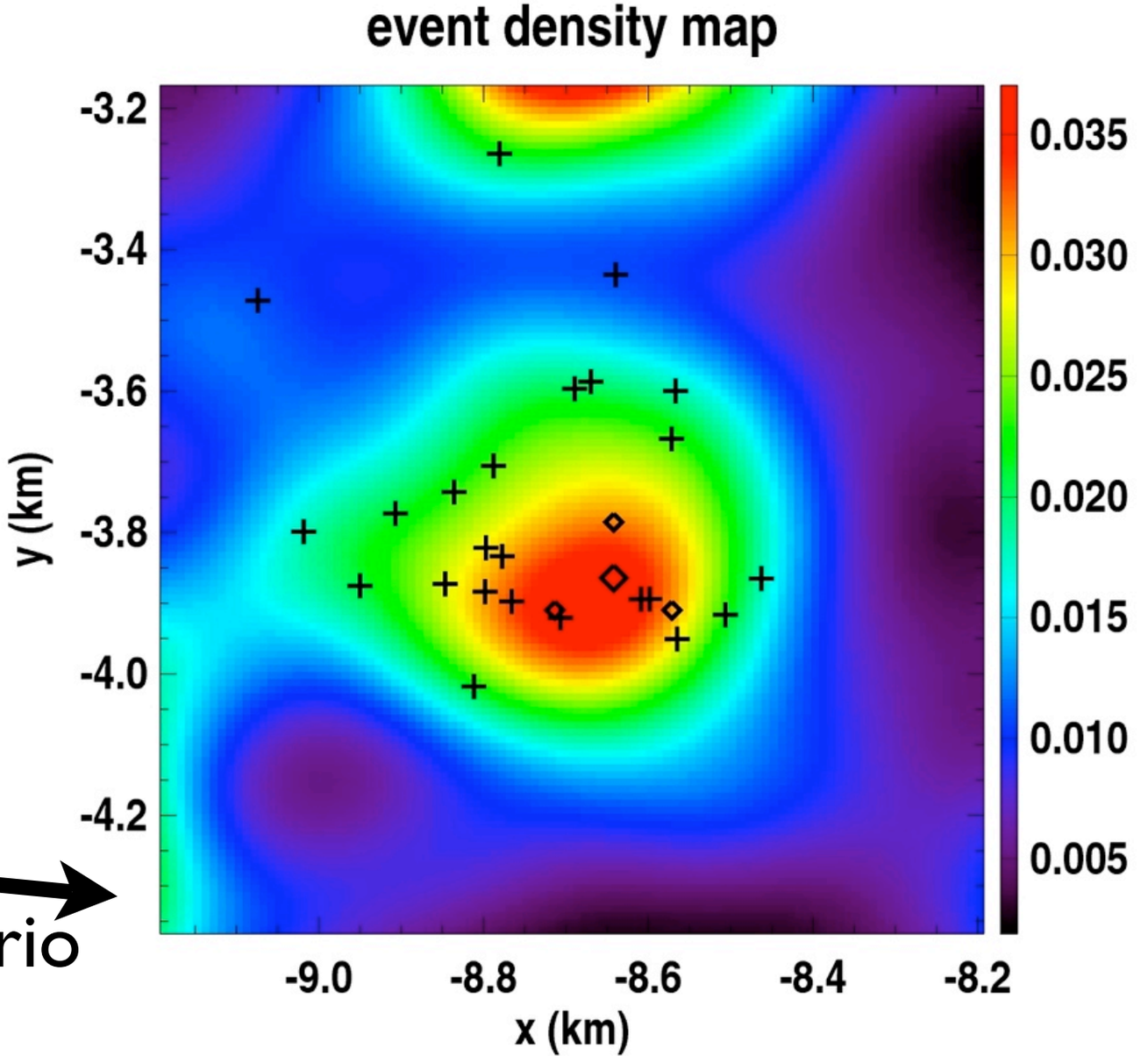
Coincidences with Auger



all energies

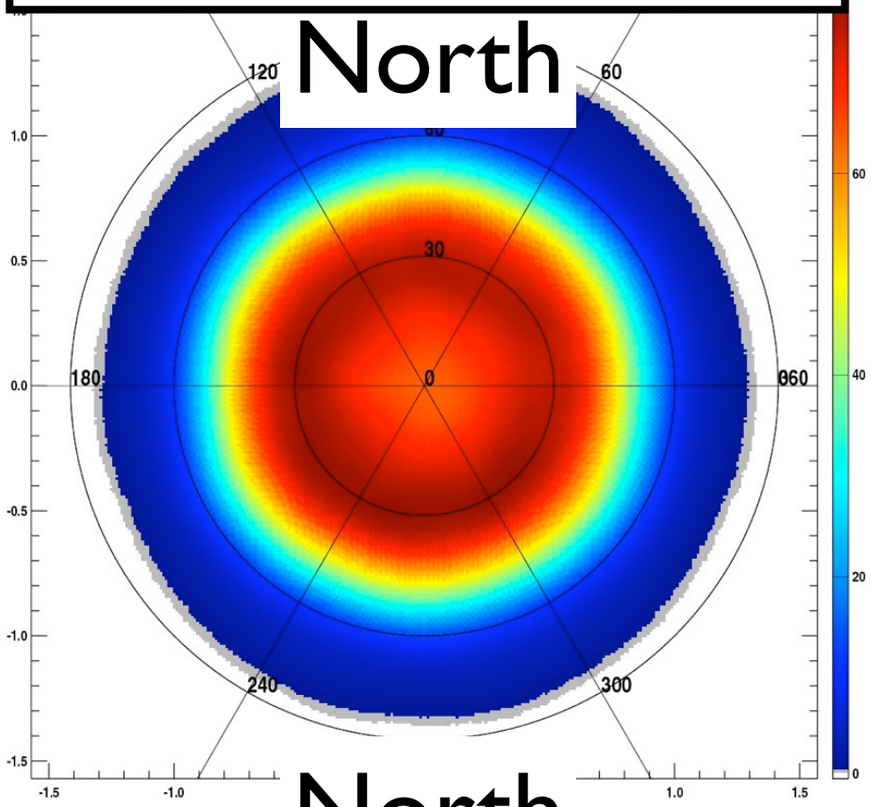
the 25 events in coincidence follow Auger SD events distribution

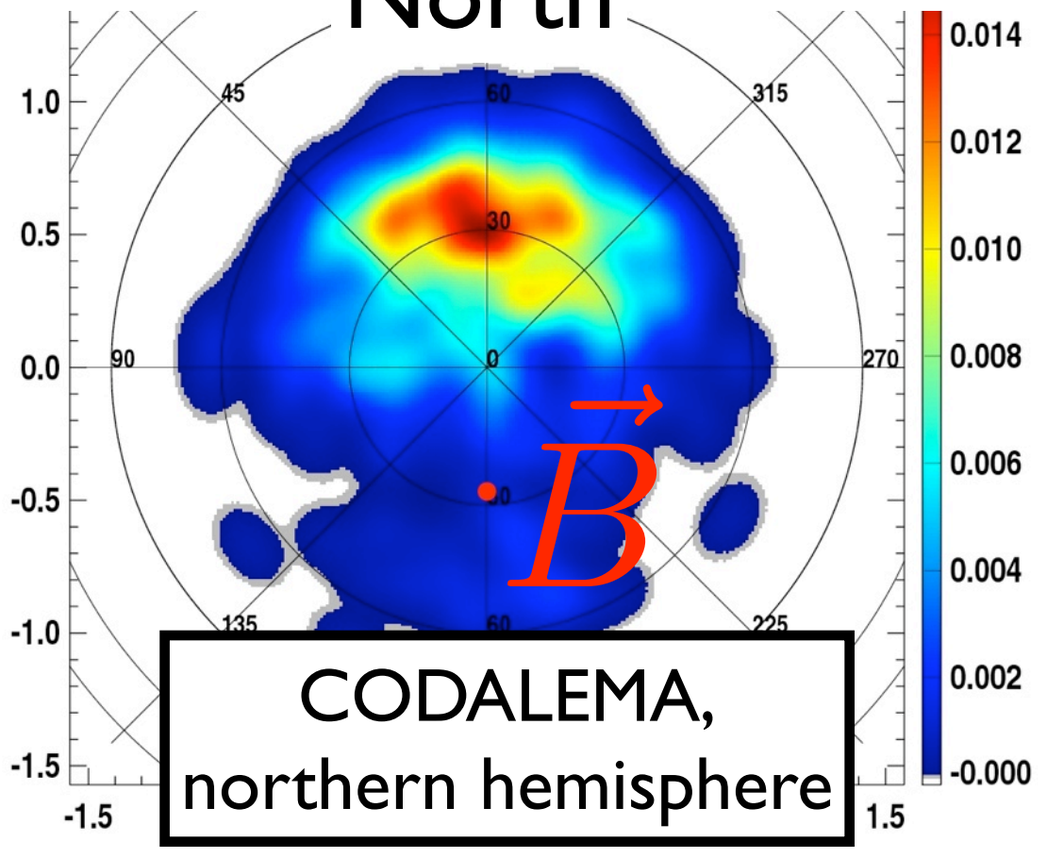
zoom on Apolinario



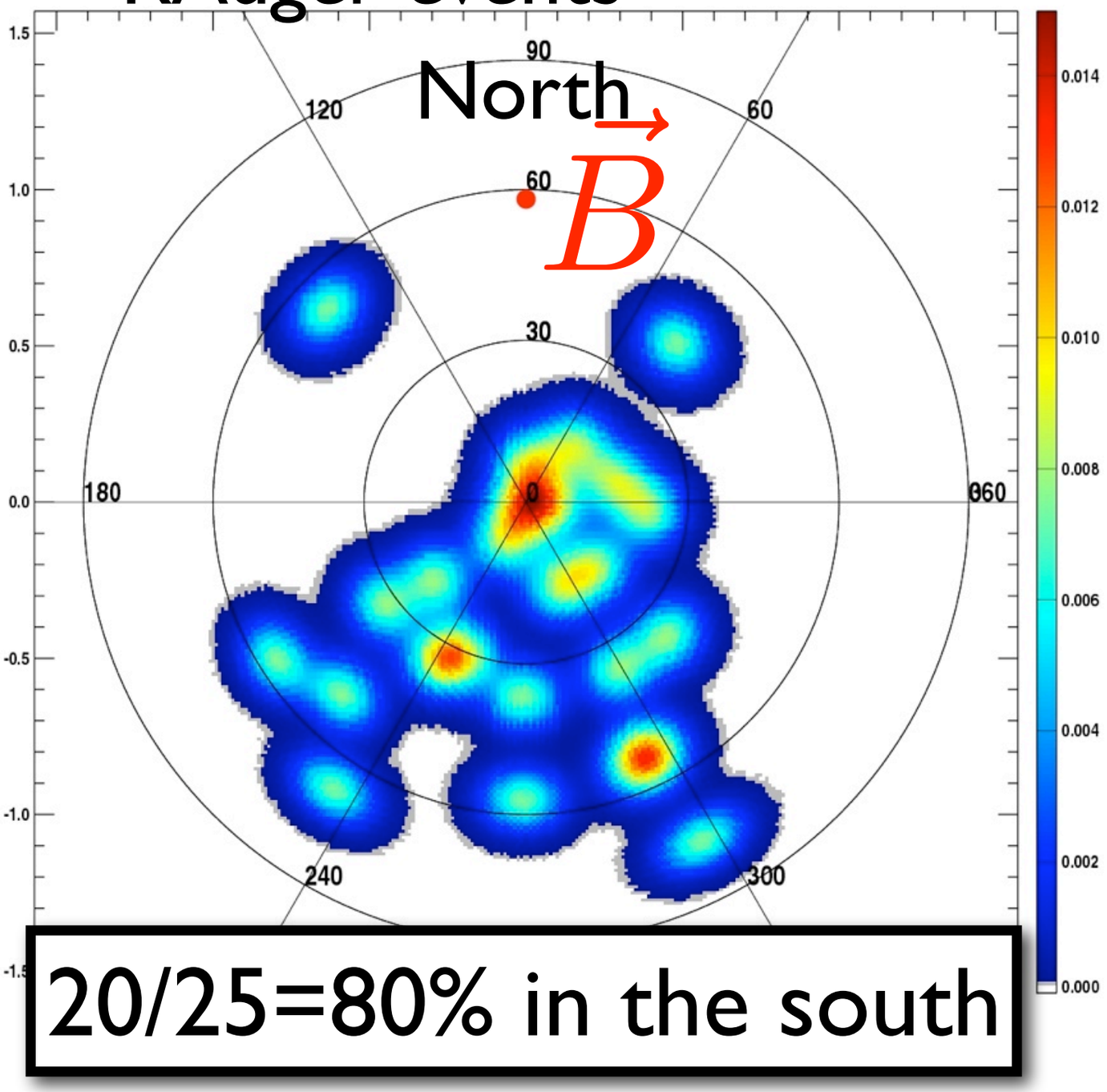
Coincidences sky map (local coordinates)

Auger SD events



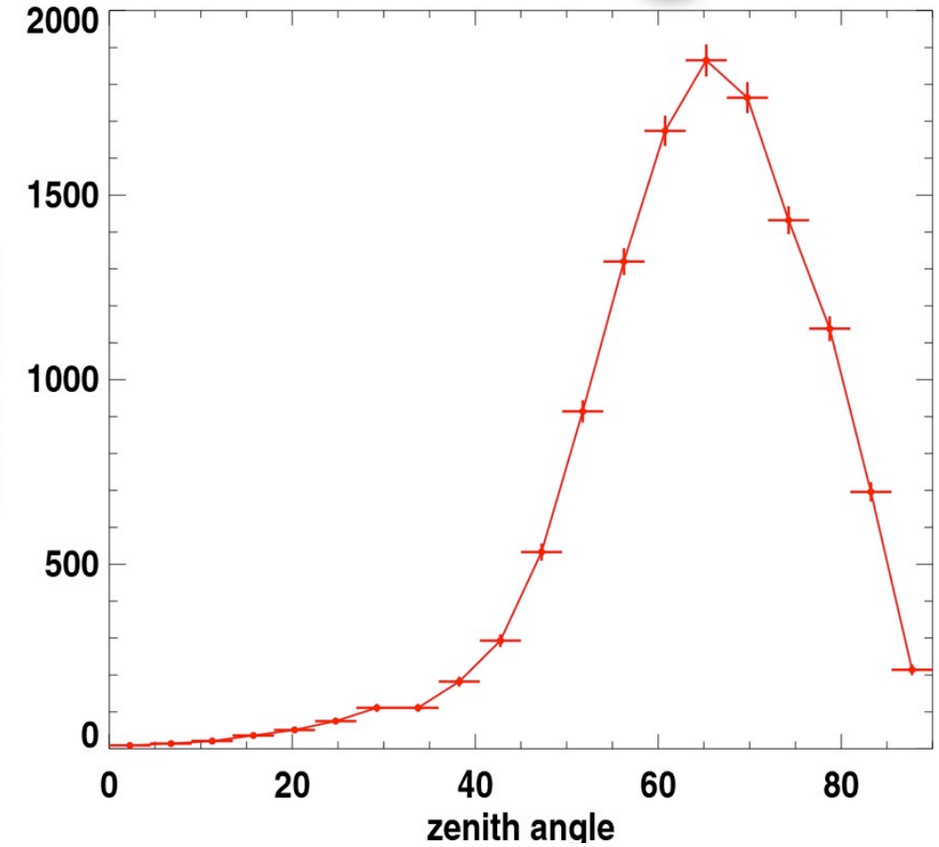


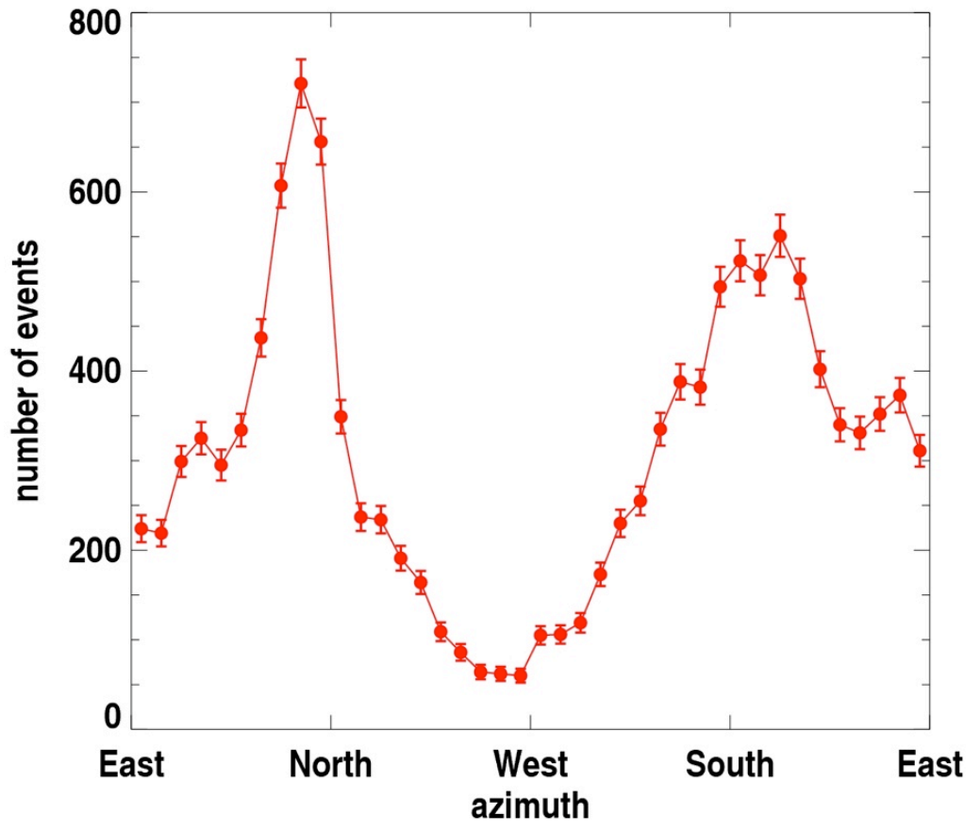
RAuger events

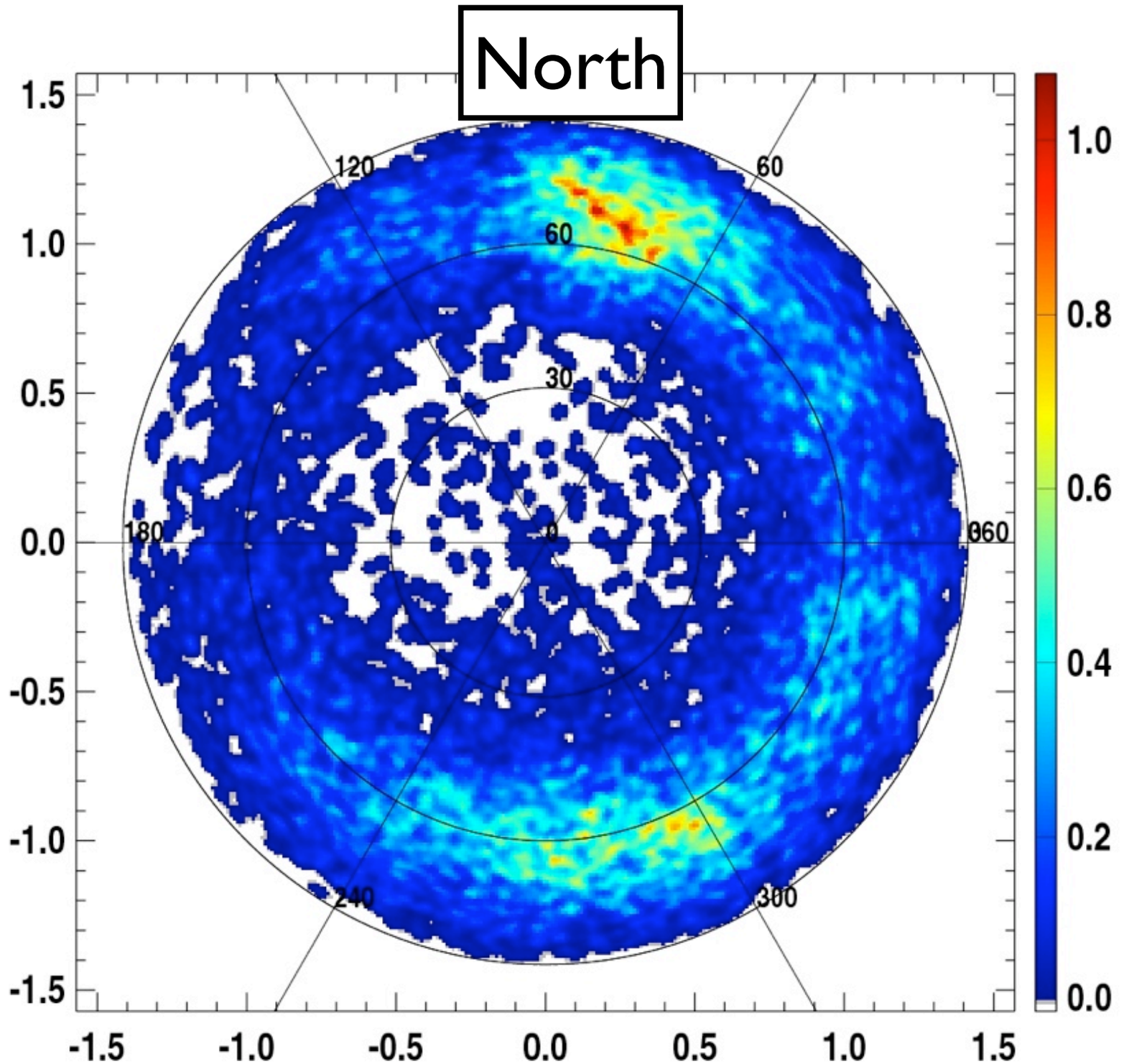


Triangulation with 3-fold radio events

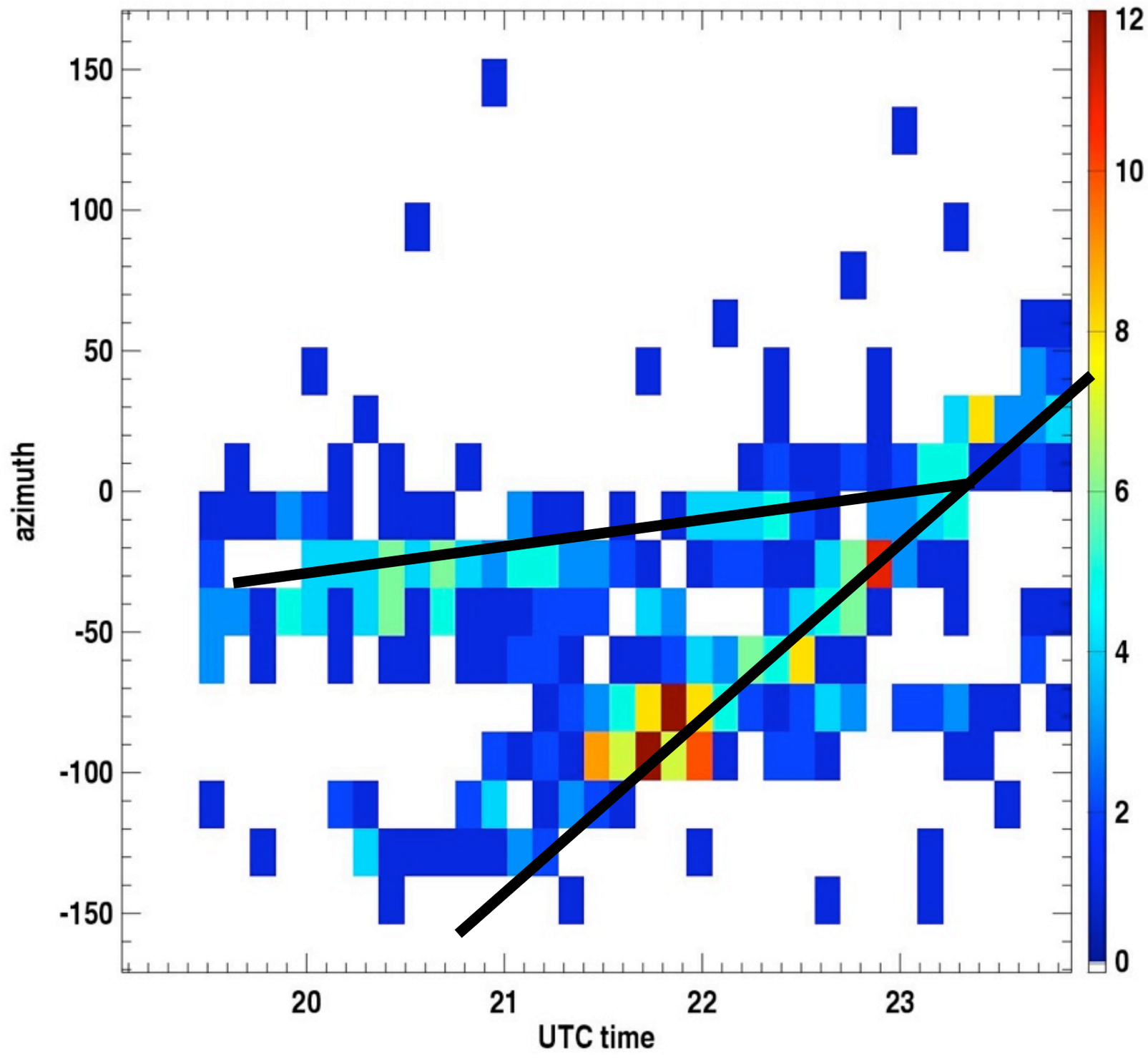
12 400 events 11/2007-05/2008







Triangulation



some remarquable causal events to follow : 2 merging clouds ?

this kind of event bursts are frequent (thunderstorms ?)

Conclusion

- for the first time, an autonomous radio detector is able to trigger on EAS
- triangulation works well for anthropic and thunderstorm signals
- trigger : need a dynamic threshold in a dynamic frequency band to fine tune the trigger rate

↓

installation of the next generation of autonomous detectors (same as CODALEMA's) in late 2008-start 2009, at the BLS before the 20 km^2 array

illustration : horizontal event

Sd Event Display | FD Event Display | Hybrid Event Display | Help

Events list

854) 200801201635, 4 stations, TOT2C1&3C2
855) 200801201636, 3 stations, TOT2C1&3C2
856) 200801201639, 7 stations, 2C1&3C2&4C4
857) 200801201640, 4 stations, TOT2C1&3C2
858) 200801201641, 15 stations, 2C1&3C2&4C4
859) 200801201643, 4 stations, TOT2C1&3C2
860) 200801201644, 4 stations, TOT2C1&3C2
861) 200801201645, 3 stations, TOT2C1&3C2
862) 200801201646, 7 stations, TOT2C1&3C2
863) 200801201649, 4 stations, TOT2C1&3C2
864) 200801201650, 6 stations, TOT2C1&3C2
865) 200801201651, 5 stations, TOT2C1&3C2
866) 200801201652, 6 stations, TOT2C1&3C2

Stations list

01) 0107 (0 ns, 3.0 VEM)
02) 0117 (2056 ns, 5.0 VEM)
03) 0110 (4323 ns, 6.3 VEM)
04) 0116 (6626 ns, 7.5 VEM)
05) 0118 (9132 ns, 3.6 VEM)
06) 0203 (11709 ns, 10.6 VEM)
07) 0205 (13969 ns, 10.1 VEM)
08) 0548 (16541 ns, 26.6 VEM)
09) 0582 (18539 ns, 6.6 VEM)
10) 0542 (21359 ns, 19.1 VEM)
11) 0537 (23645 ns, 8.1 VEM)
12) 0798 (26203 ns, 14.4 VEM)
13) 0134 station deleted

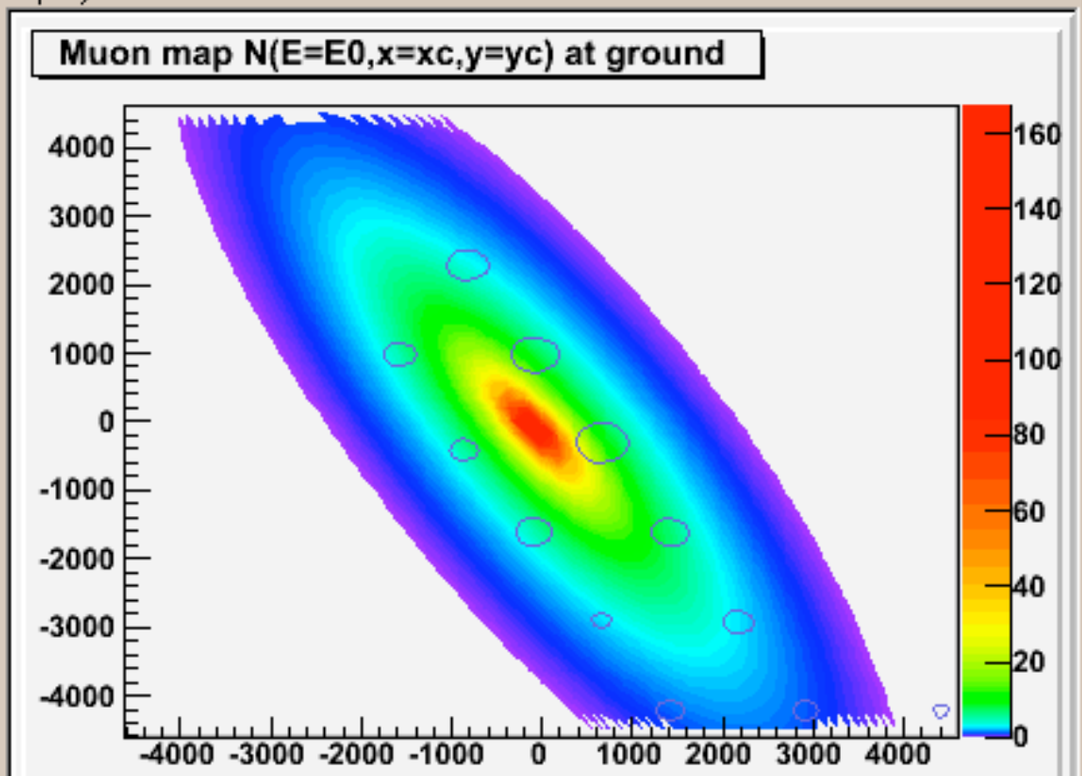
Array

Apolinario

Status

```
selected file: /Users/revenu/sdt4_v0r4_2008_01_12_12h00.root
Minimum number of triggered stations: 1
Trigger selected: all of them, 1761 events.
Date of this event: Sat Jan 12 23:44:10 2008 (GPS 884216650)
```

Display



Sat Jan 12 23:44:10 2008
X = -9305 ± 238m
Y = -1821 ± 395m
Δt = 61.5ns

θ = 75.7 ± 0.2 deg
φ = -62.3 ± 0.1/sin(θ) deg

R = 33.9 ± 4.0 km

Ra 161.7 deg -- Dec -57.5 deg

E= 7.8 EeV ± 18% (statistical)

illustration : horizontal event

- seen by A1, 604 m from the shower axis
- A2 was OFF
- unfortunately, A3 was in acquisition at this time

Check the timing between radio and SD by comparing the offset between A1 and each of the 13 tanks of the event :

$$\text{offset} = -\frac{u(x_{\text{ant}} - x_{\text{tank}}) + v(y_{\text{ant}} - y_{\text{tank}})}{c} - (\text{nano}_{\text{ant}} - \text{nano}_{\text{tank}})$$

$\text{offset} \neq 0$

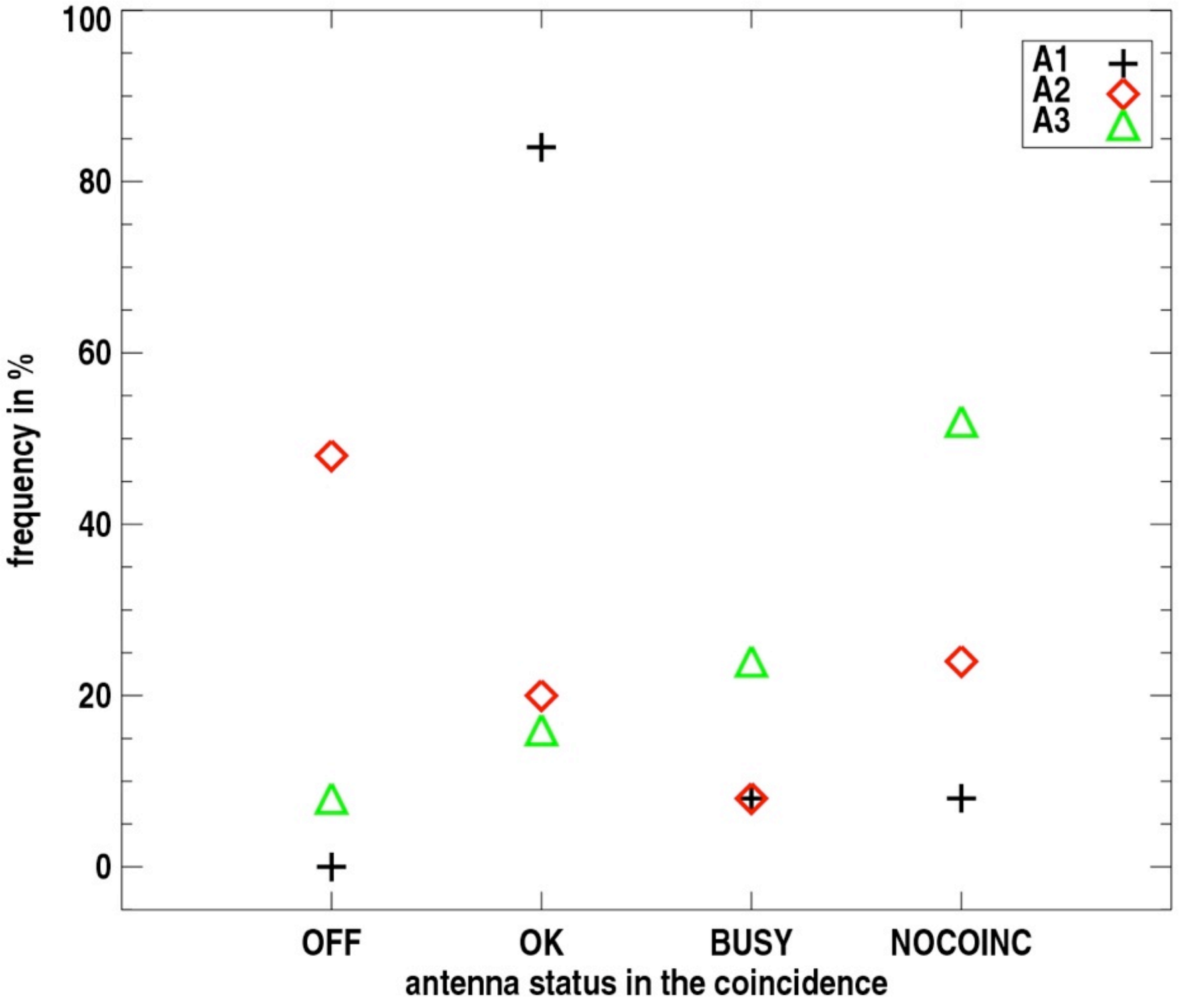
this offset measures cable and electronics delays, and the intrinsic time difference between radio and particles fronts for this event

Timing problem is solved

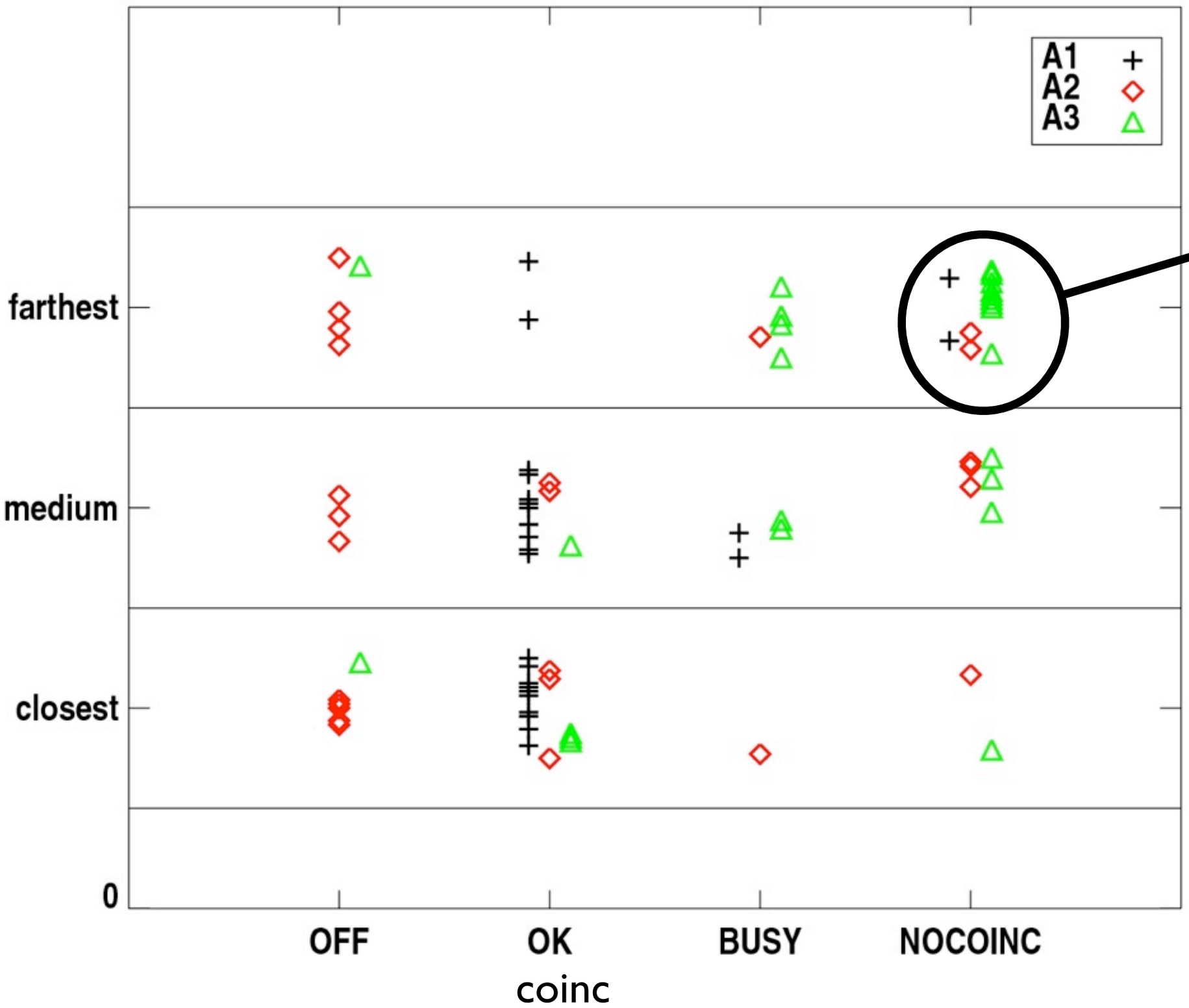
LsID	ED status	dt (in ns)
548	ok	430
542	ok	437
798	ok	414
1351	ok	418
203	ok	458
537	ok	443
116	ok but with 2 pulses	271
110	ok	496
582	ok	459
205	ok	482
117	ok	494
118	ok	481
107	additionnal station	720

$$\text{offset} = 456 \pm 29 \text{ ns}$$ for this event

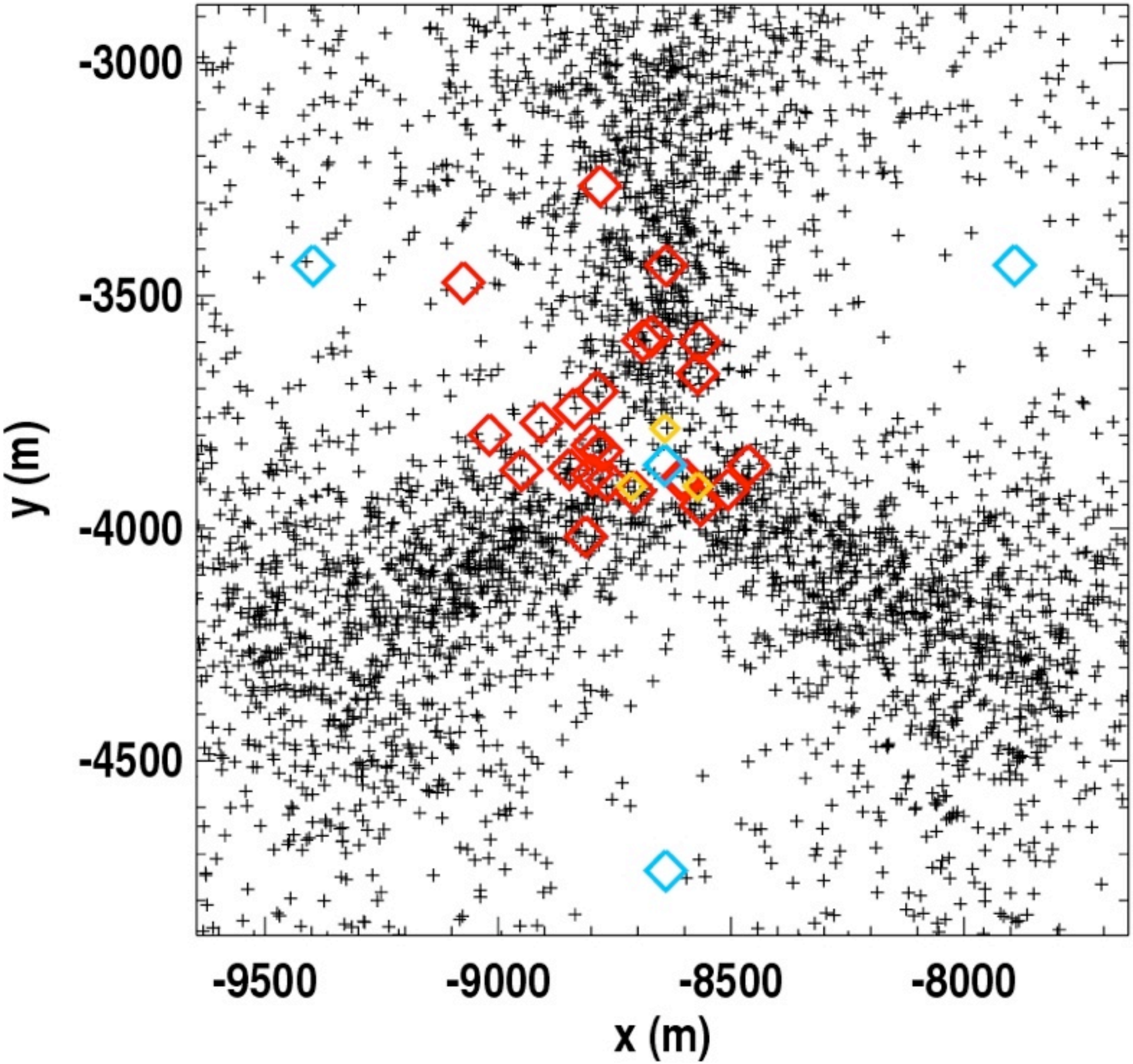
Why no 3-fold yet ?

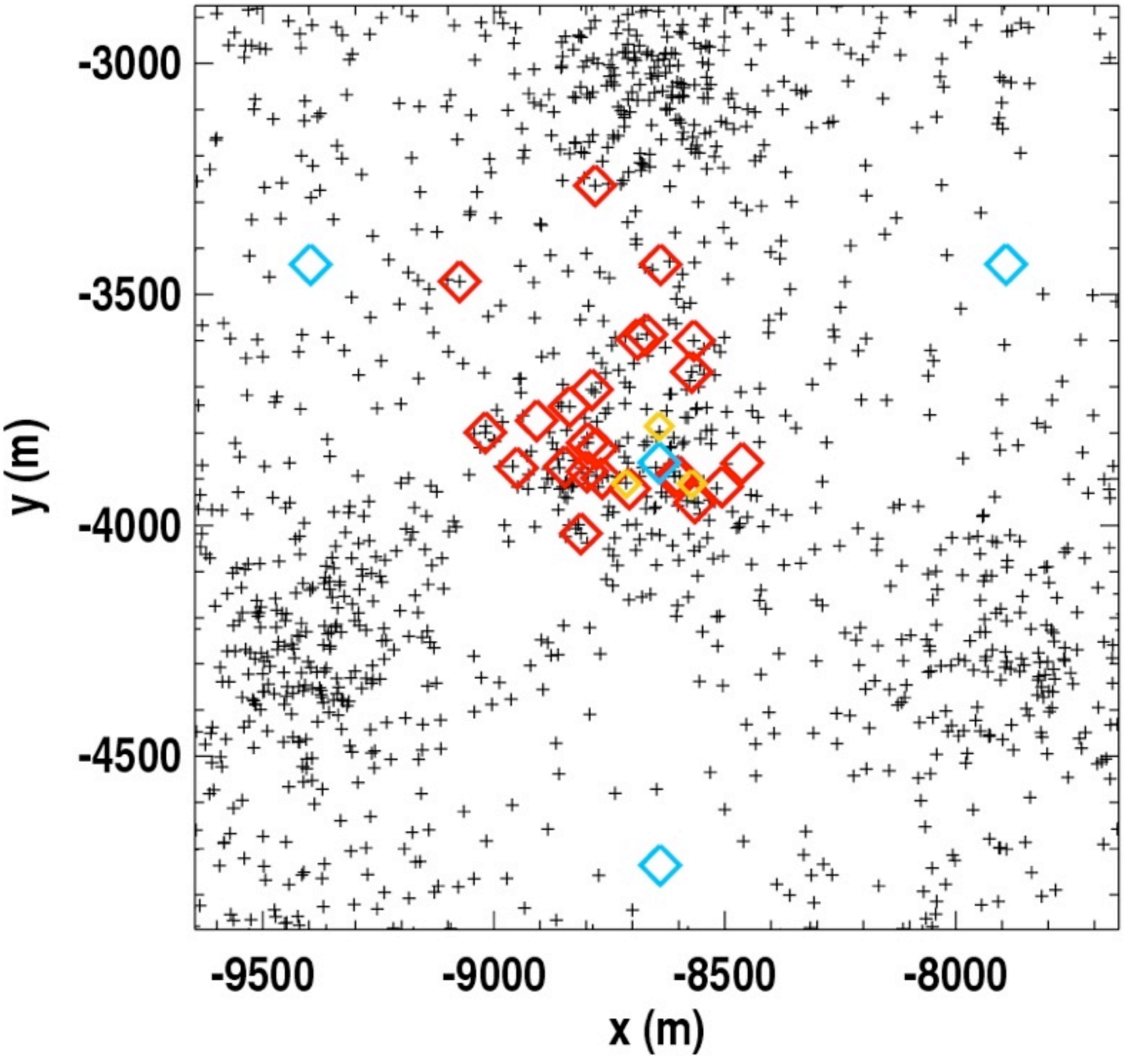


Why no 3-fold yet ?

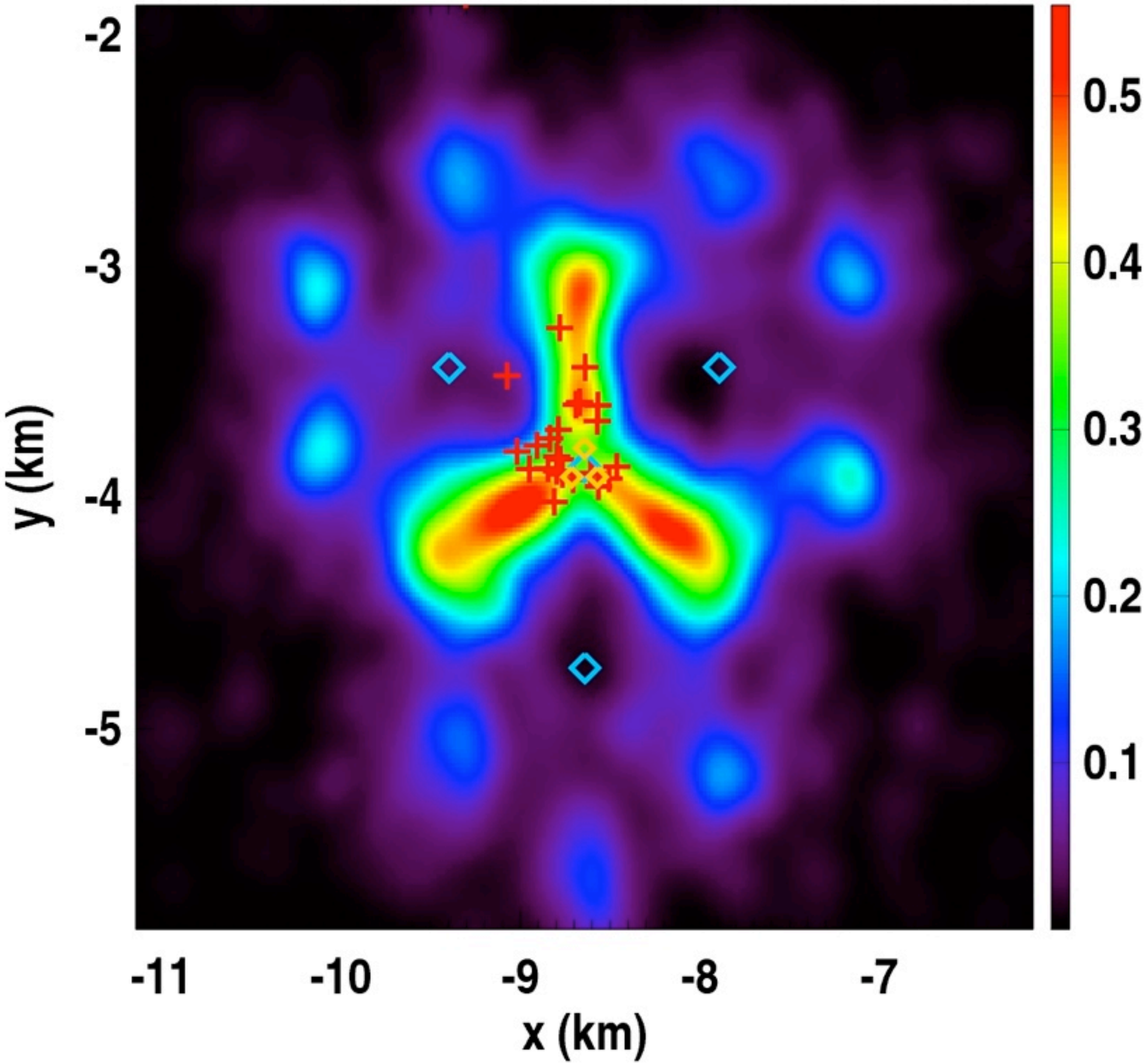


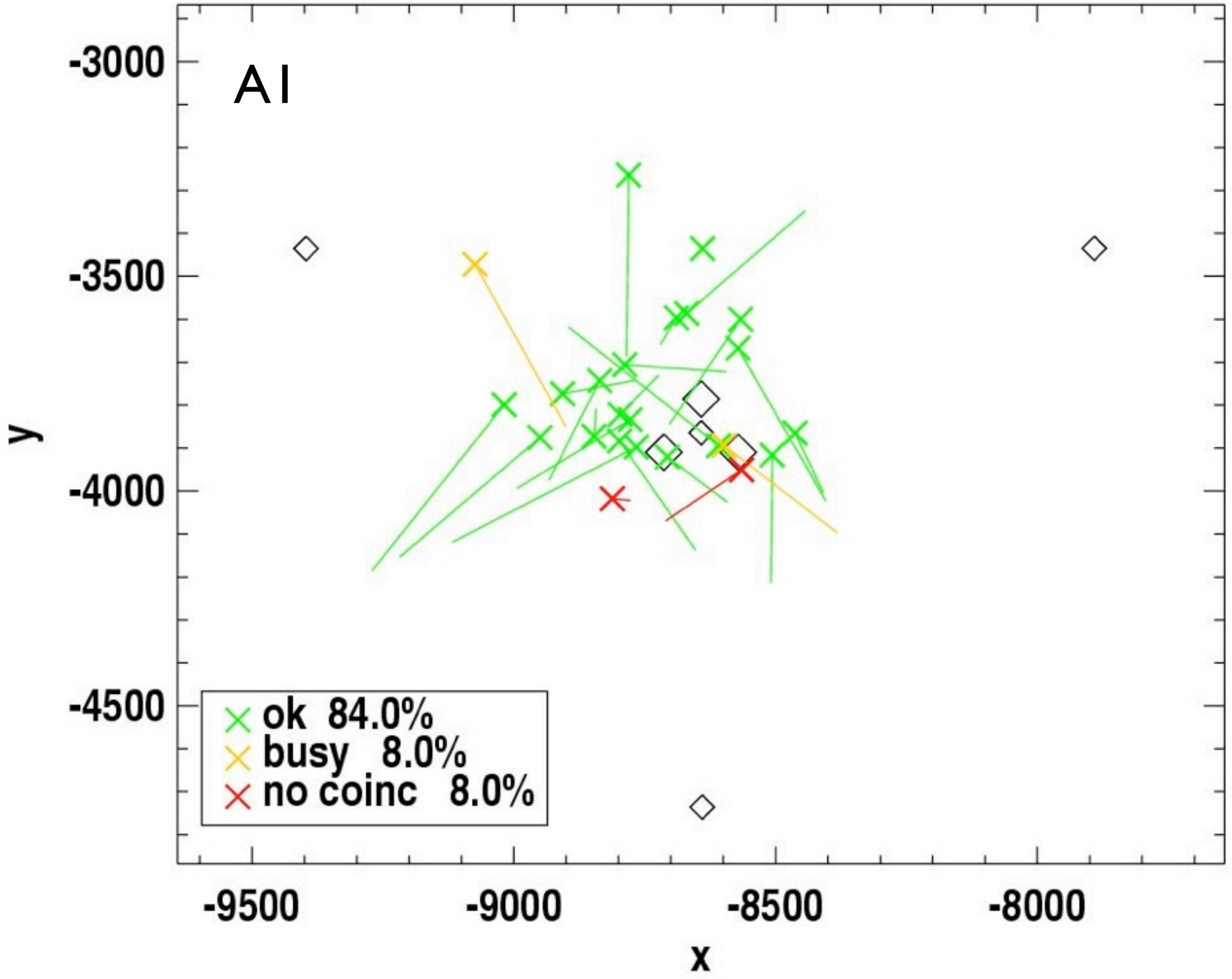
antennas that did not see the coincidence are the most distant from the axis in 62% of the cases


-3000
-3500
-4000
-4500
y (m)
-9500
-9000
-8500
-8000
x (m)


-3000
-3500
-4000
-4500
y (m)
-9500
-9000
-8500
-8000
x (m)

event density map




Al
-3000
-3500
-4000
-4500
y
ok 84.0%
busy 8.0%
no coinc 8.0%
-9500
-9000
-8500
-8000
x

A2

-3000
-3500
-4000
-4500

y

off 48.0%
ok 20.0%
busy 8.0%
no coinc 24.0%

-9500
-9000
-8500
-8000

x

A3

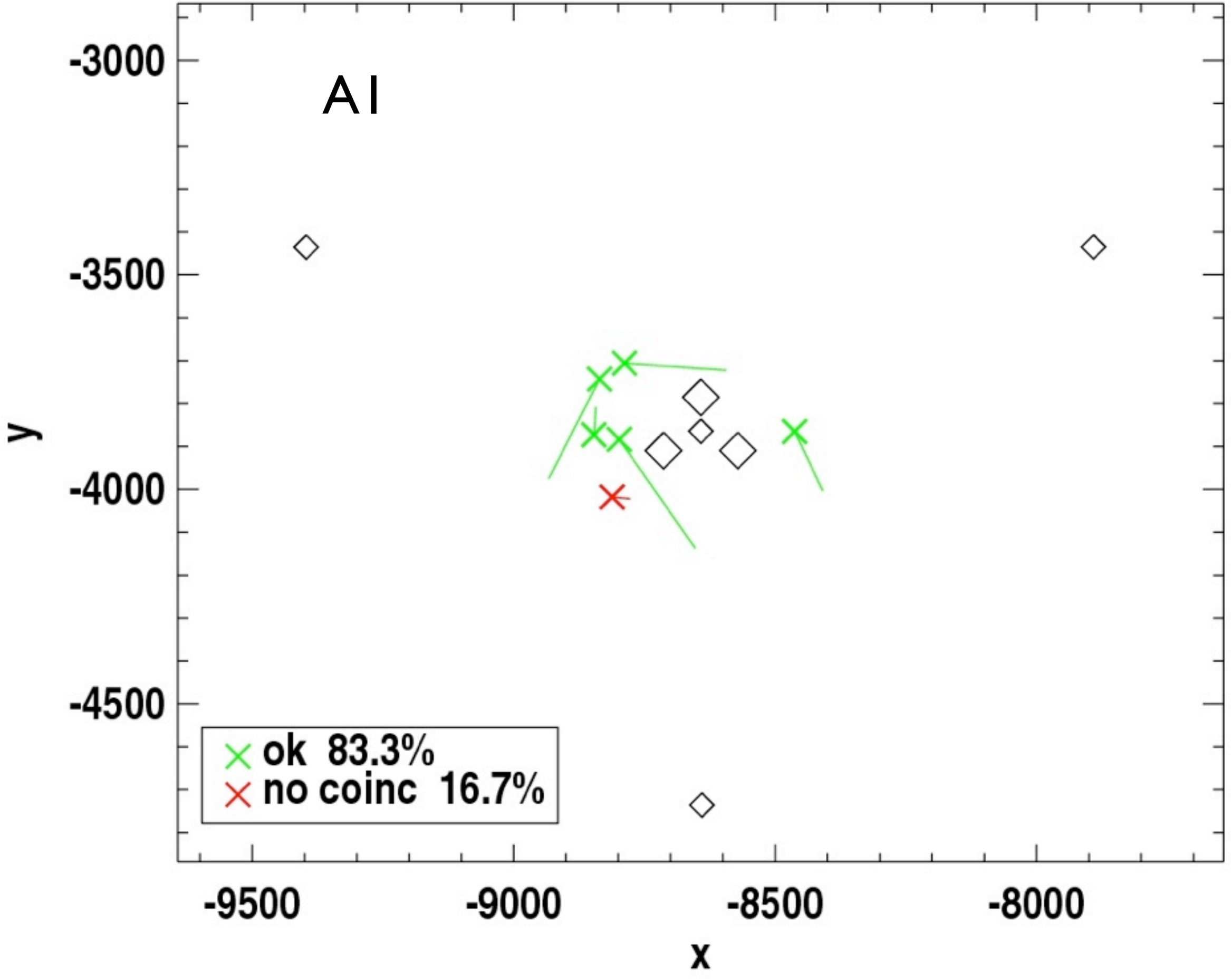
-3000
-3500
-4000
-4500

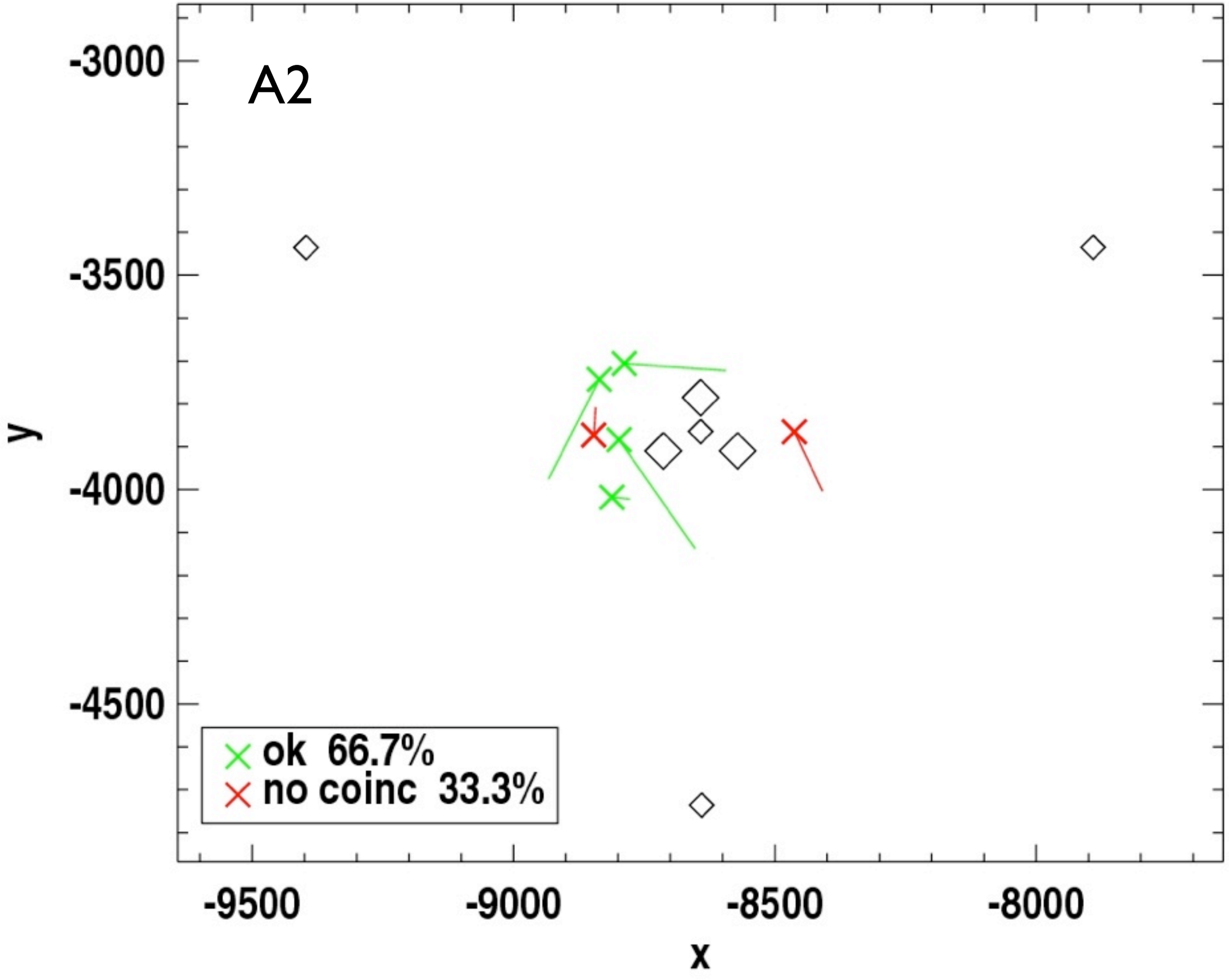
y

off 8.0%
ok 16.0%
busy 24.0%
no coinc 52.0%

-9500
-9000
-8500
-8000

x


Al
-3000
-3500
-4000
-4500
y
ok 83.3%
no coinc 16.7%
-9500
-9000
-8500
-8000
x


A2
-3000
-3500
-4000
-4500
y
ok 66.7%
no coinc 33.3%
-9500
-9000
-8500
-8000
x

A3

-3000
-3500
-4000
-4500

y

-9500
-9000
-8500
-8000

x

no coinc 100.0%

Triangulation