

SEARCHES FOR COSMIC RAY ANISOTROPIES AT ULTRA-HIGH ENERGIES

OLIVIER DELIGNY (IPN ORSAY),
ON BEHALF THE PIERRE AUGER COLLABORATION



RENCONTRES DE BLOIS 2011

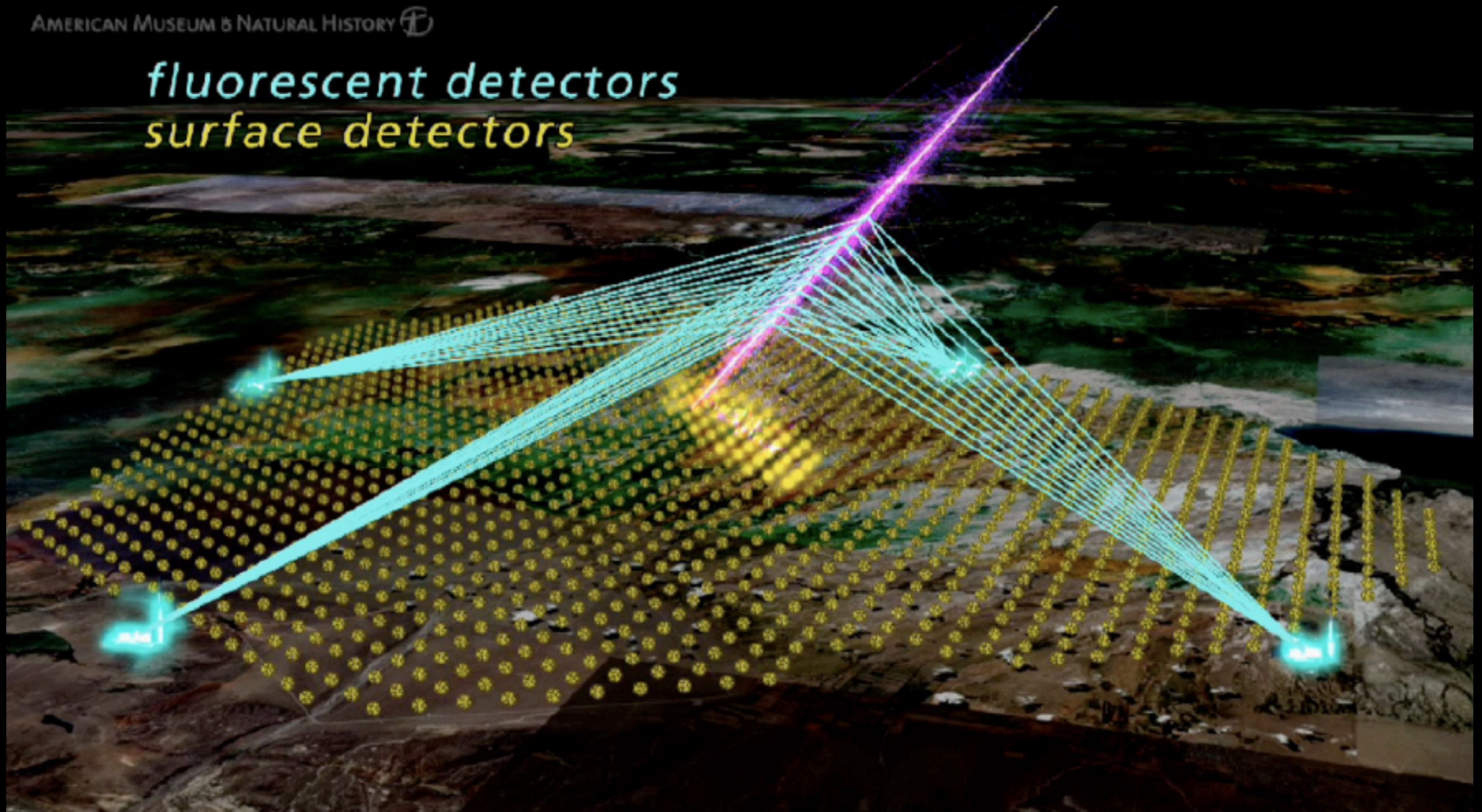
THE PIERRE AUGER OBSERVATORY

LOCATED IN ARGENTINA, MALARGUE, 1400 M A.S.L.

«HYBRID» DETECTOR: 1600 WATER TANKS (CHERENKOV) + 4X6 FLUORESCENCE DETECTORS

AMERICAN MUSEUM OF NATURAL HISTORY

fluorescent detectors
surface detectors

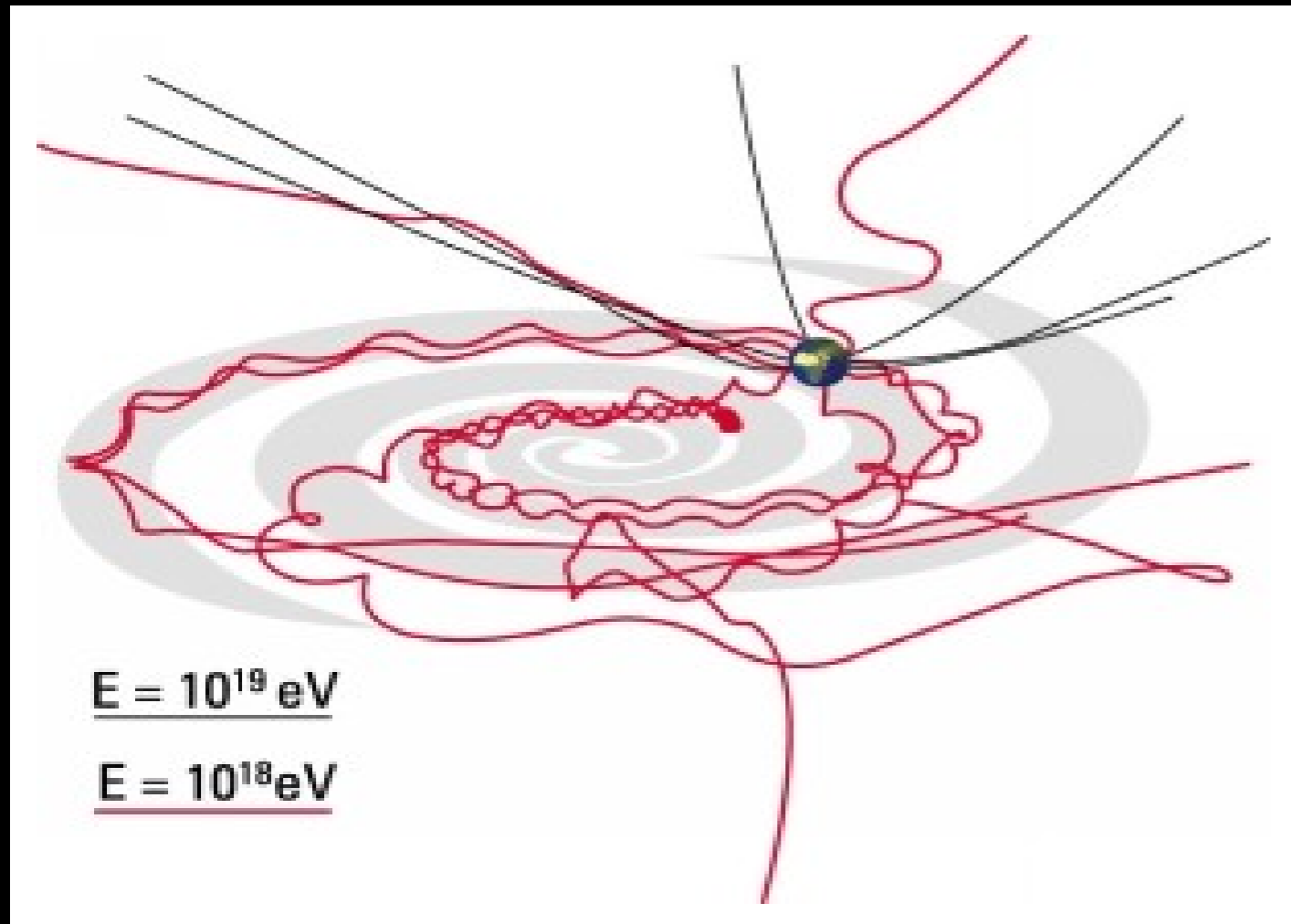


**SEARCHES FOR
LARGE SCALE MODULATIONS IN
RIGHT-ASCENSION**

THE PIERRE AUGER COLL.,
ASTROPART. PHYS. 34 (2011) 627-639

LARGE SCALE ANISOTROPIES AT EeV ENERGIES ?

THE GALACTIC MAGNETIC FIELD «ISOTROPIZES» EeV(/Z) CRS



DIPOLAR ANISOTROPIES AT THE % LEVEL COULD BE LEFT BY DIFFUSION/DRIFT OF GALACTIC CRS

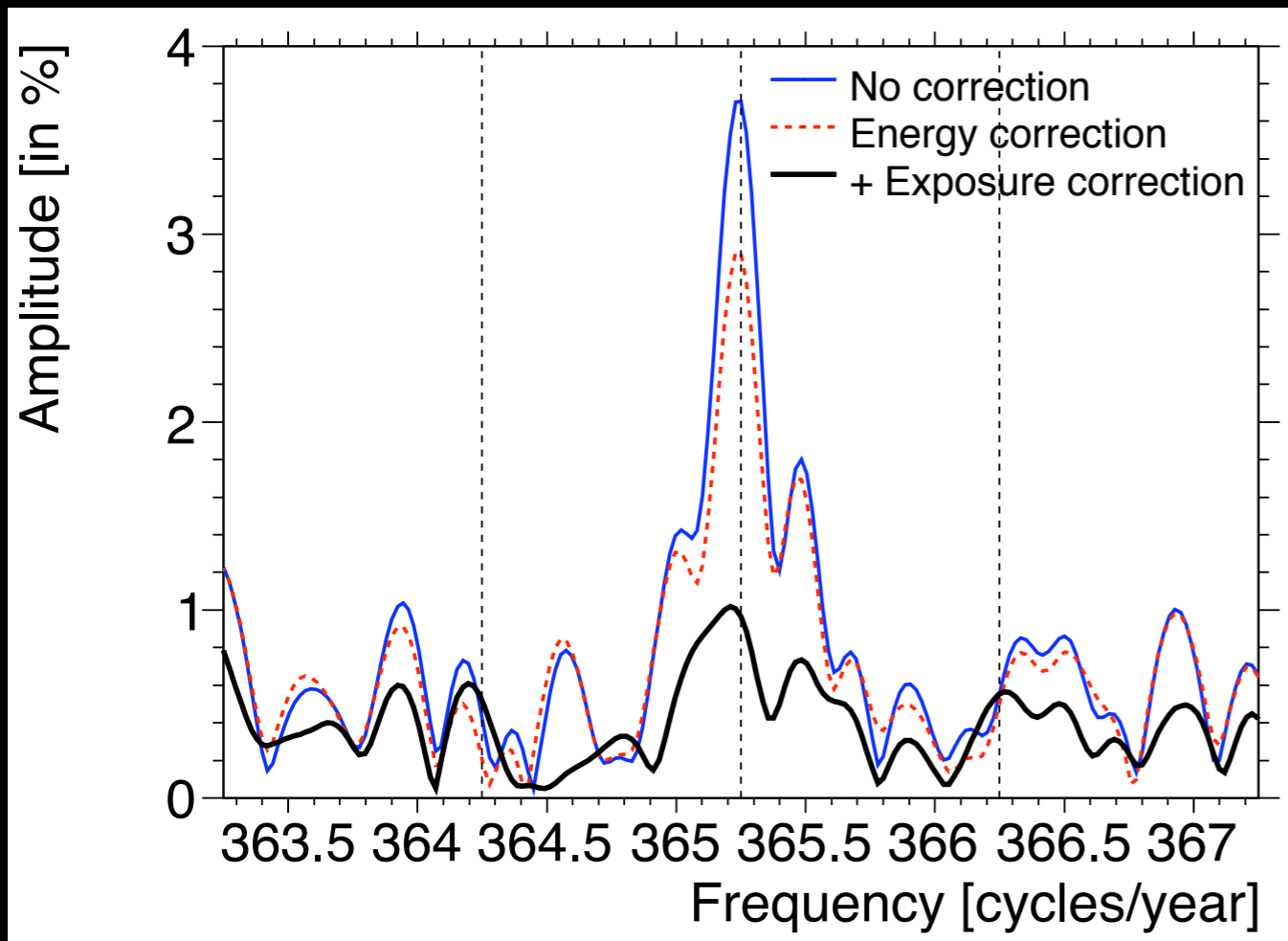
IF EXTRAGALACTIC, A SMALL ANISOTROPY MAY EXIST DUE TO OUR MOTION WITH RESPECT TO THE FRAME OF EXTRAGALACTIC ISOTROPY

=> SEARCHES FOR SMALL EFFECTS

ACCOUNTING FOR EXPERIMENTAL EFFECTS

CHALLENGE: ESTIMATION OF THE EXPOSURE WITH HIGH ACCURACY

- 1- MONITORING OF THE NUMBER OF ELEMENTAR CELLS => GEOMETRICAL EXPOSURE CALCULATION IN EACH DIRECTION
- 2- ENERGY CORRECTIONS AS A FUNCTION OF ATMOSPHERIC PRESSURE AND DENSITY



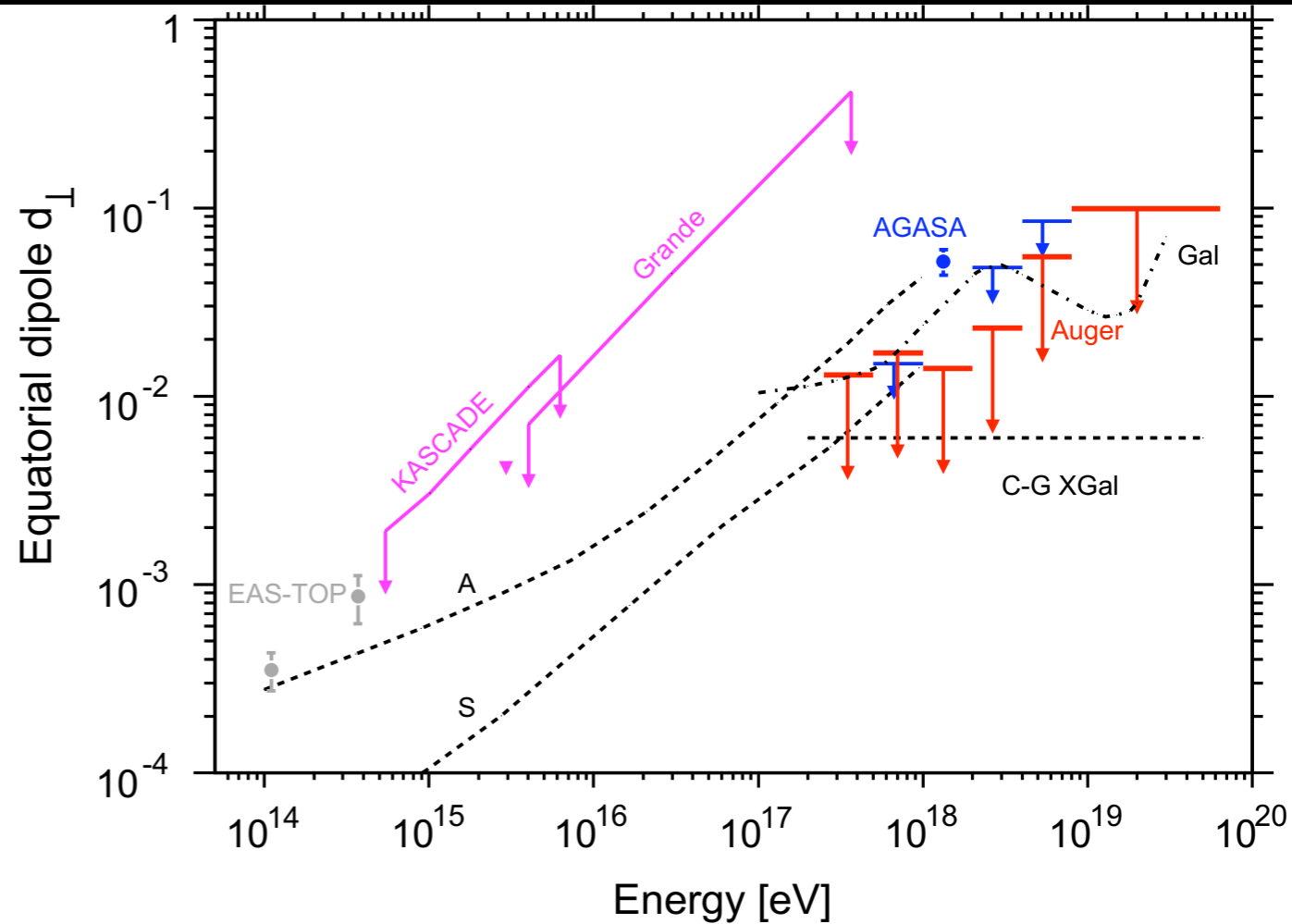
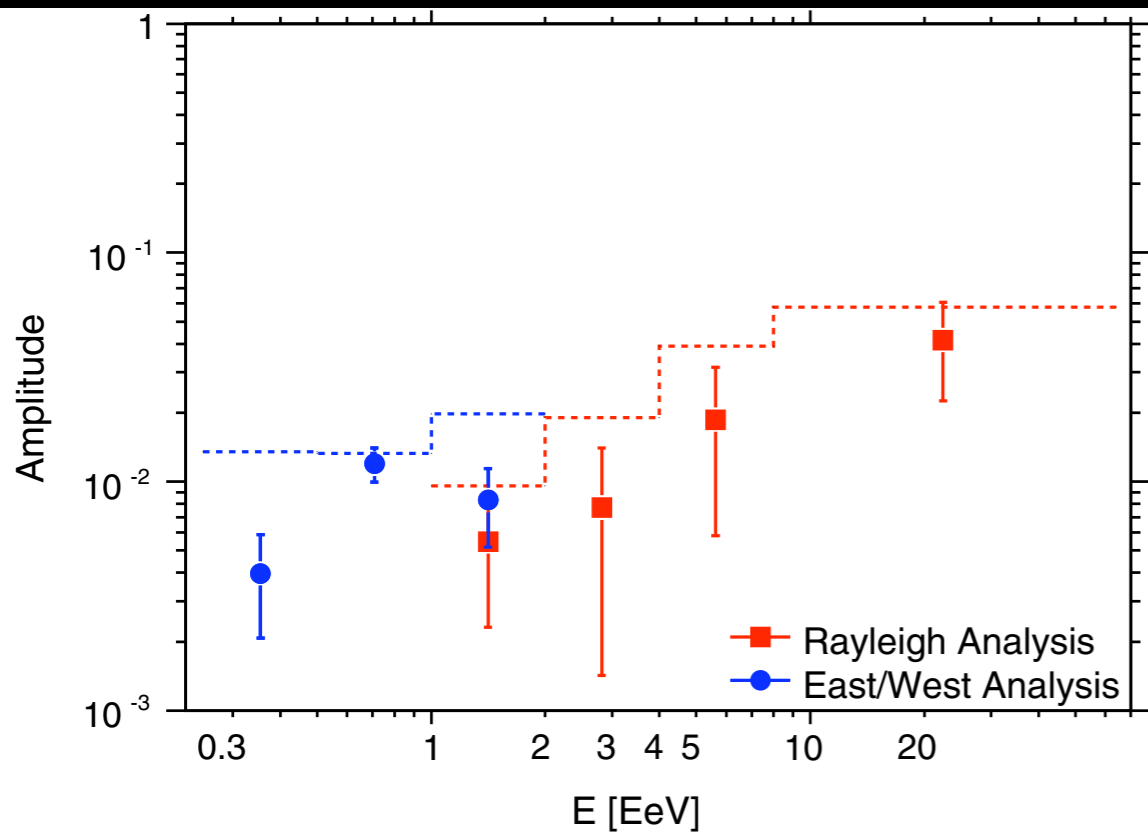
2 POSSIBLE SOURCES OF SPURIOUS MODULATIONS AT THE SIDEREAL FREQUENCY:

- 1- POLLUTION BY THE SOLAR FREQUENCY
(=> CANCELED BY THE 6-YRS EXPOSURE TIME)
- 2- SIDEBAND MECHANISM DUE TO ANY ANNUAL VARIATION OF THE DAILY MODULATION

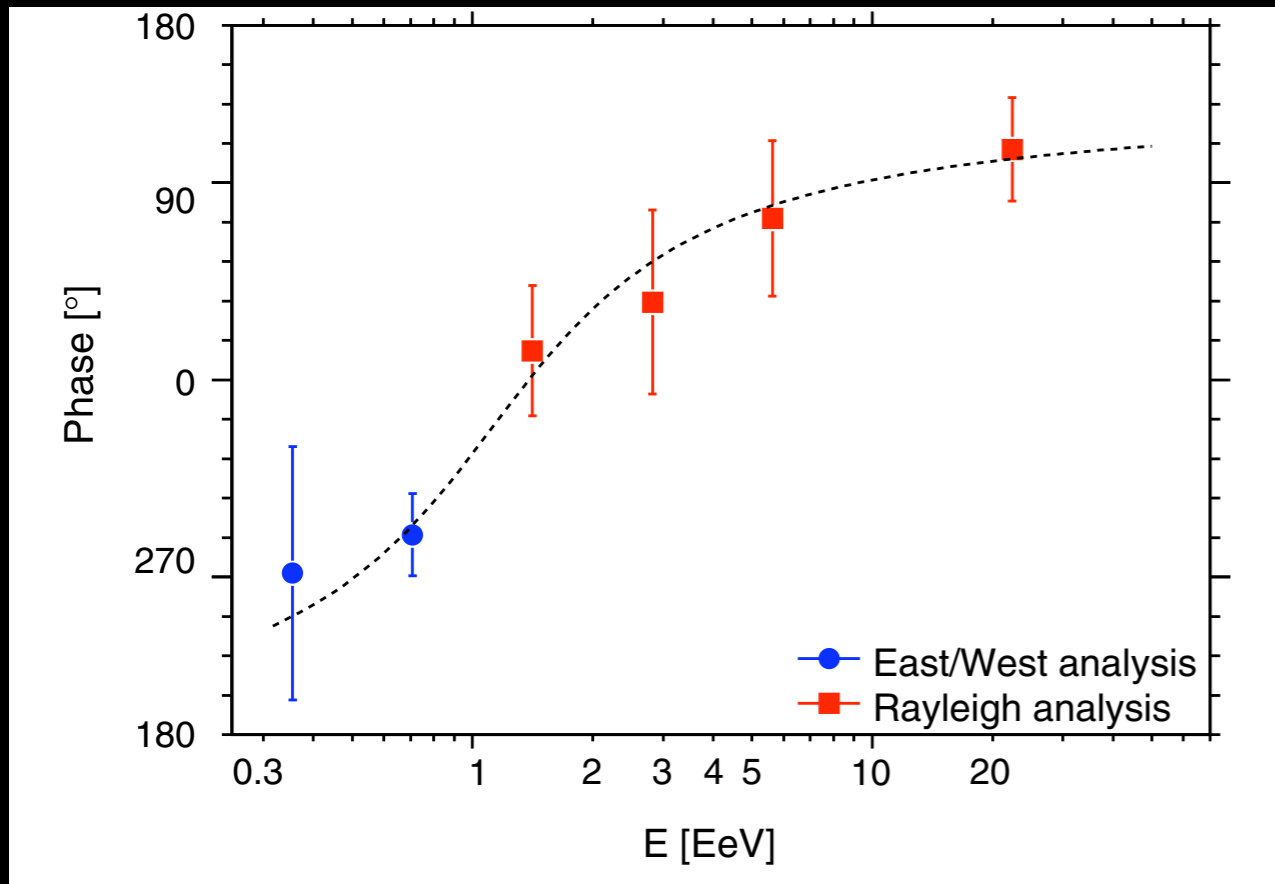
N.B.: WELL BELOW THE ENERGY SATURATION THRESHOLD, USE OF THE «EAST/WEST» METHOD TO REMOVE SPURIOUS EFFECTS [BONINO ET AL., APJ, 2011]

SIDEREAL ANALYSIS

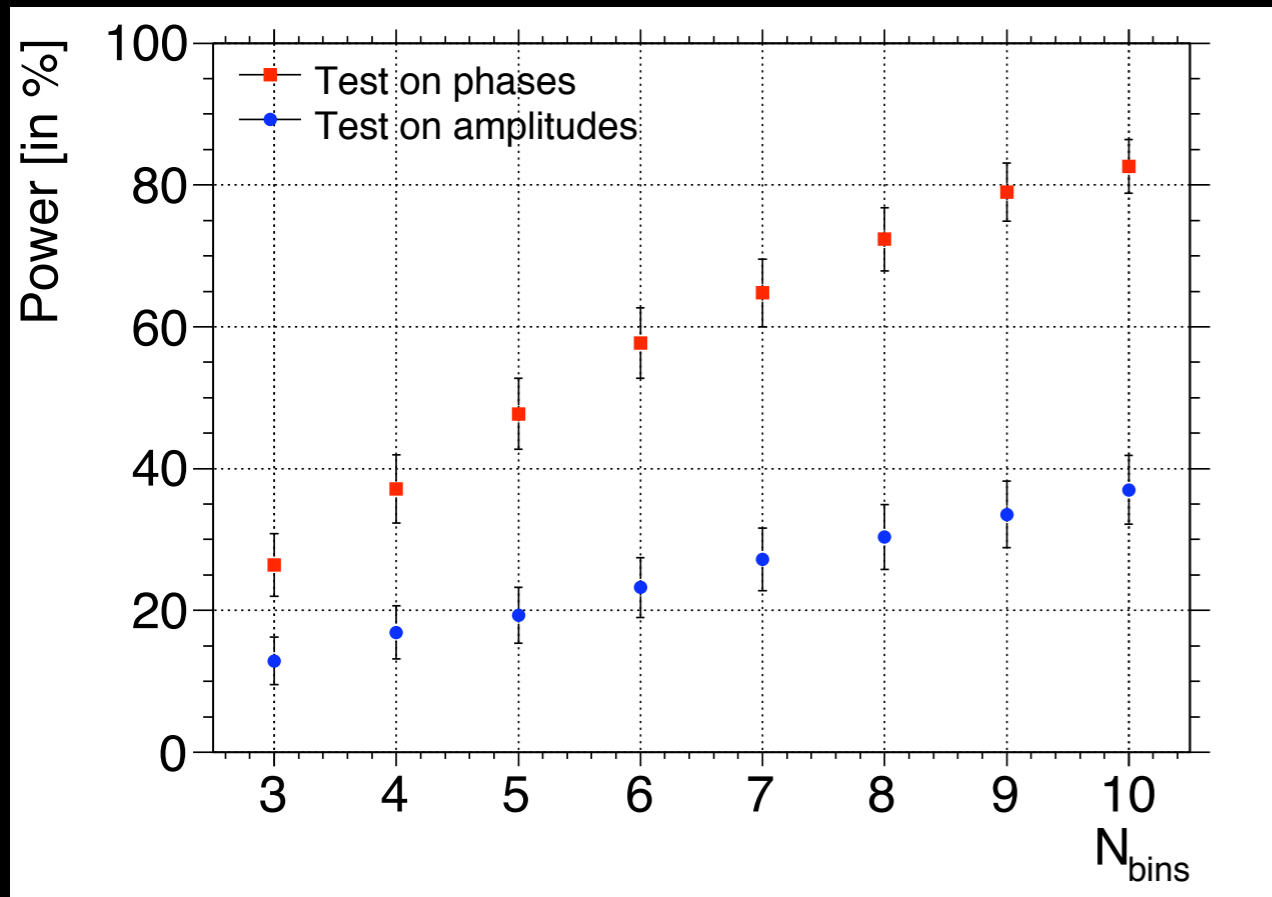
NO SIGNIFICANT AMPLITUDES => UPPER LIMITS



WHAT ABOUT THE PHASES ?



**NOT RANDOM... SUGGESTIVE OF A SMOOTH TRANSITION AROUND 1 EeV
- POSTERIOR PROBABILITY: ~0.002**



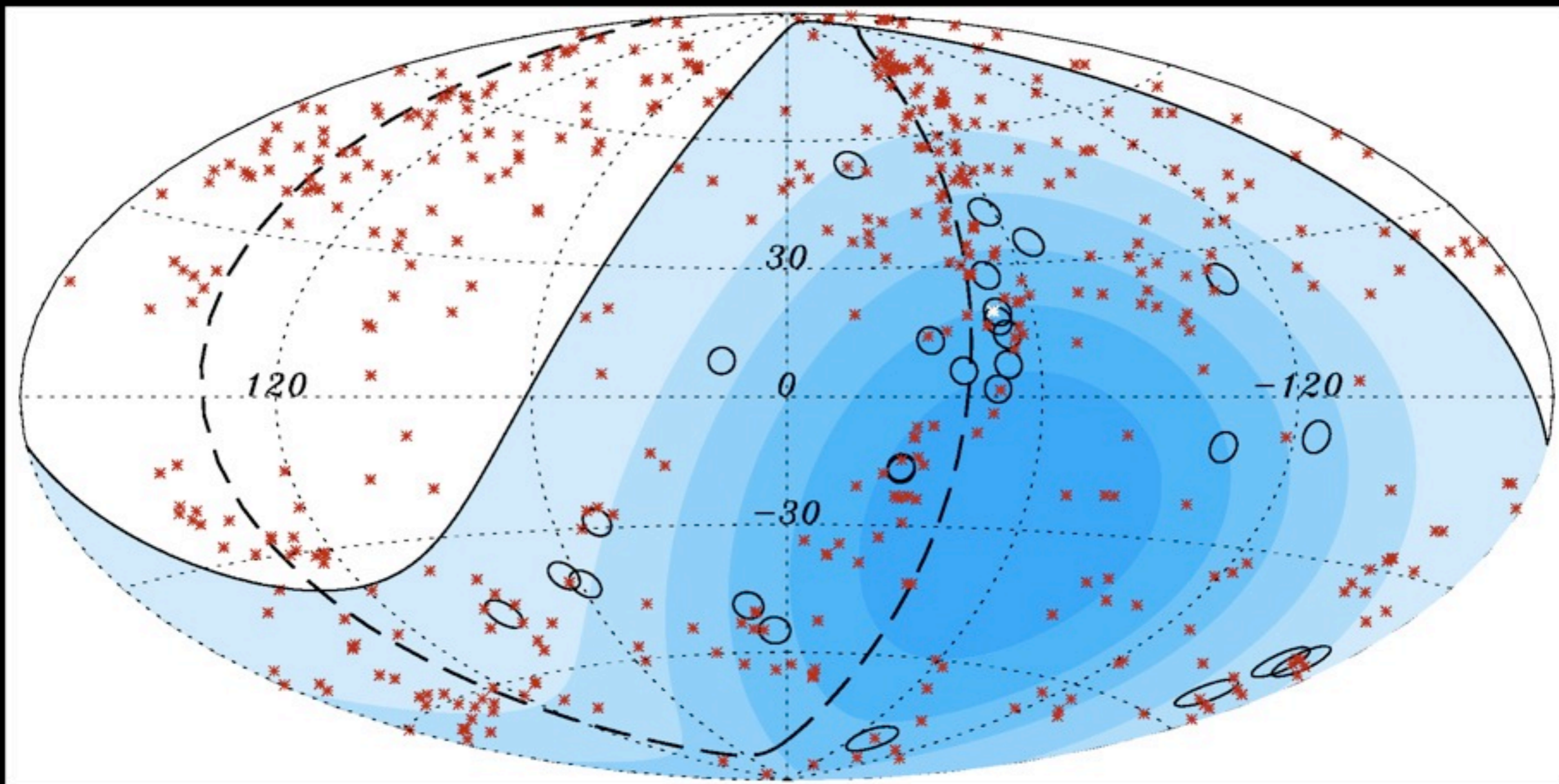
THE PHASE TEST IS ~2.5 MORE SENSITIVE THAN THE AMPLITUDE ONE TO A GENUINE SIGNAL DILUTED WITHIN THE BACKGROUND NOISE

FUTURE WORK WILL PROFIT FROM THE LOWER ENERGY THRESHOLD THANKS TO THE LOW ENERGY EXTENSION OF THE OBSERVATORY

SEARCHES FOR POINT SOURCES AT UHE

REFERENCE PAPERS:
THE PIERRE AUGER COLL.,
SCIENCE 318 938 (2007),
ASTROPART. PHYS. 29 (2008) 188-204,
ASTROPART. PHYS. 34 (2010) 314-326

ANGULAR DISTRIBUTIONS AT UHE



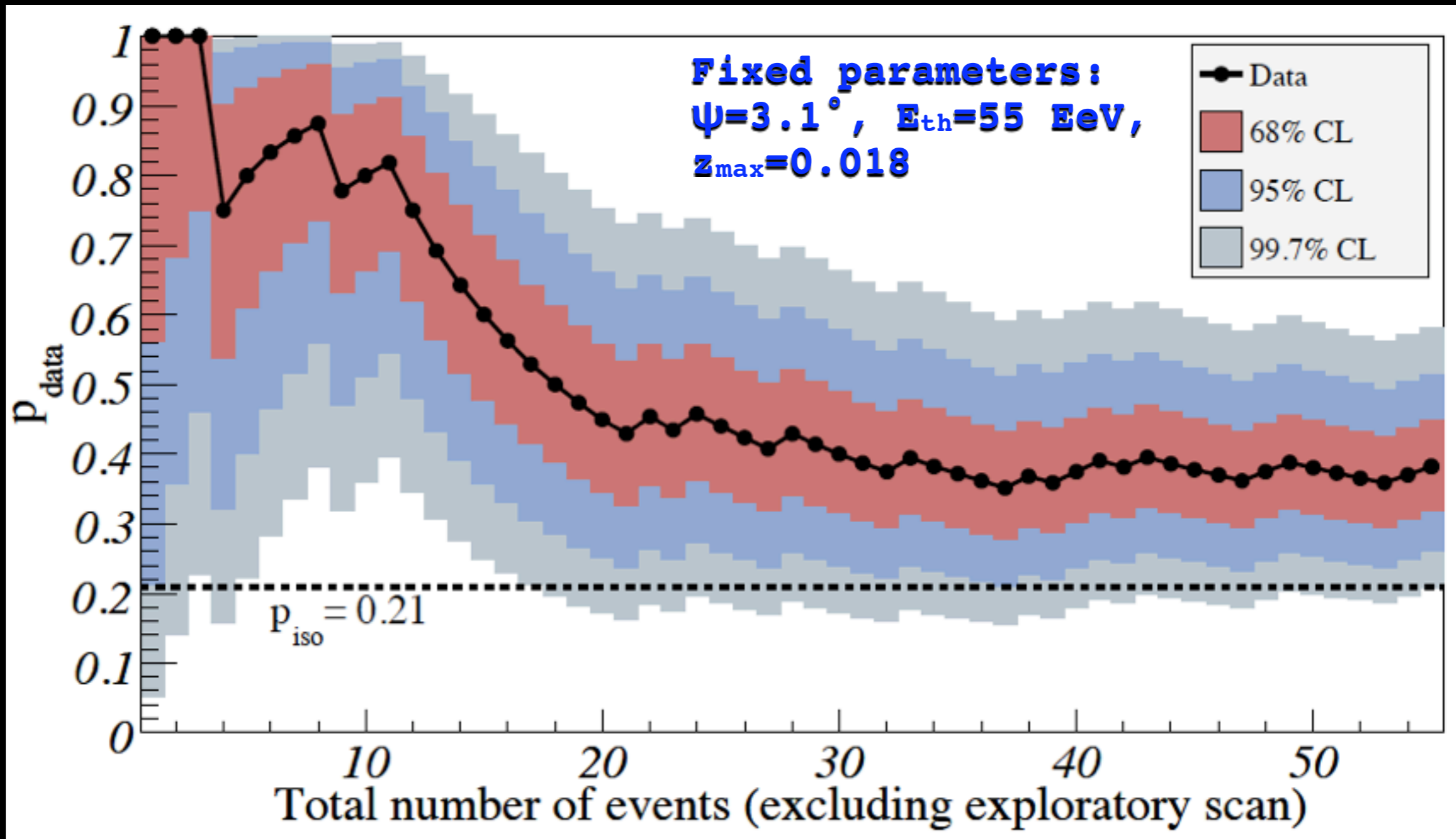
USING 27 CR ABOVE 56 EeV COLLECTED THROUGH 31 AUGUST 2007 -> CORRELATION WITH THE POSITIONS OF NEARBY EXTRAGALACTIC OBJECTS (12TH VCV)

CORRELATION PARAMETERS: ENERGY (55 EeV), ANGULAR SEPARATION (3.1°), DISTANCE (75 MPC) FIXED WITH EARLY DATA

TEST WITH LATER DATA, BUILT TO REJECT ISOTROPY WITH 1% CHANCE PROBABILITY:
TEST PASSED WITH 6 CORRELATED EVENTS OUT OF 8

--> ISOTROPY REJECTED AT 99% C.L.

UPDATED DEGREE OF CORRELATION (31/12/2009)



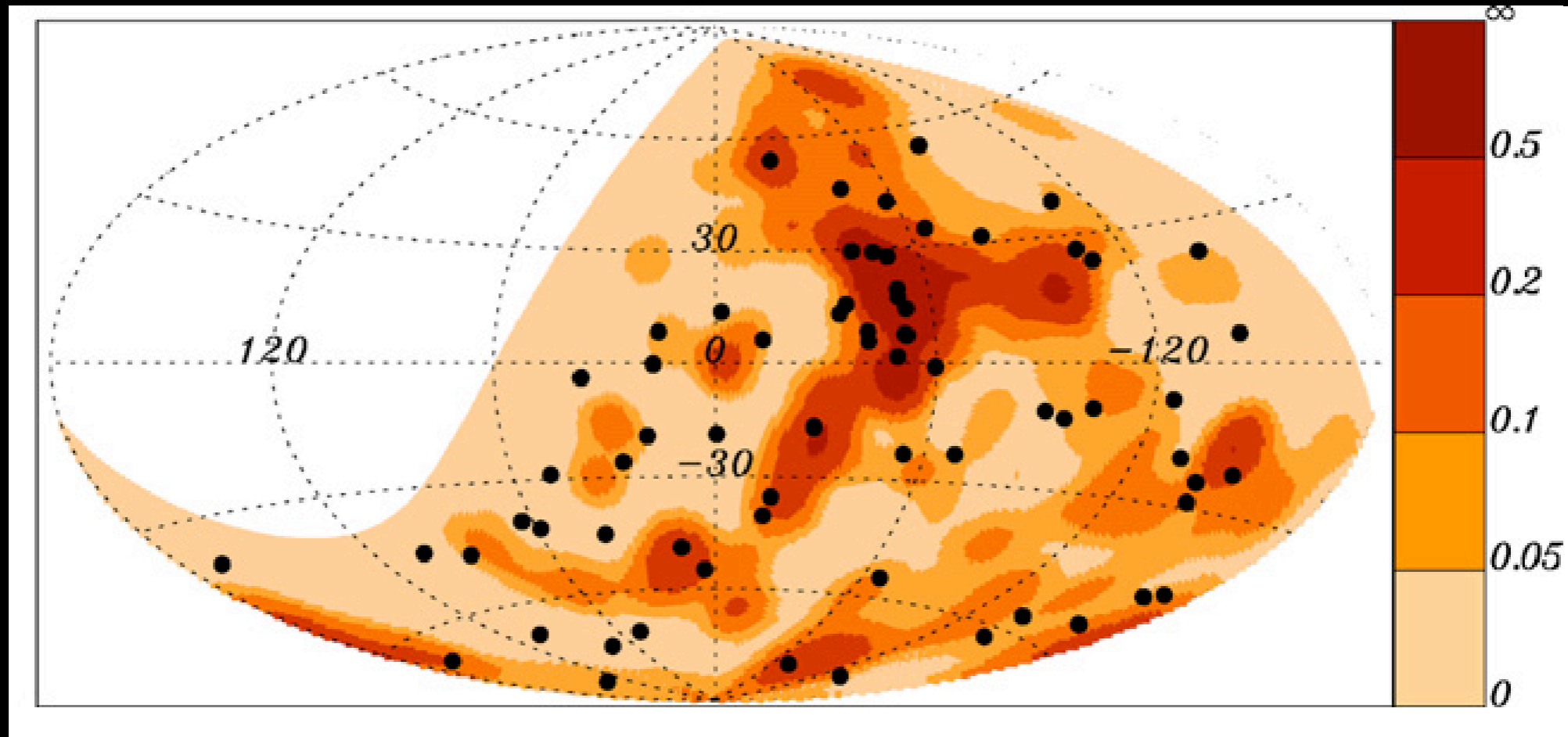
CORRELATION DOWN: FROM $(69 \pm 12)\%$ TO $(38 \pm 7)\%$

(21% OF RANDOM CORRELATION FROM ISOTROPIC EXPECTATIONS)

ANGULAR DISTRIBUTIONS AT UHE

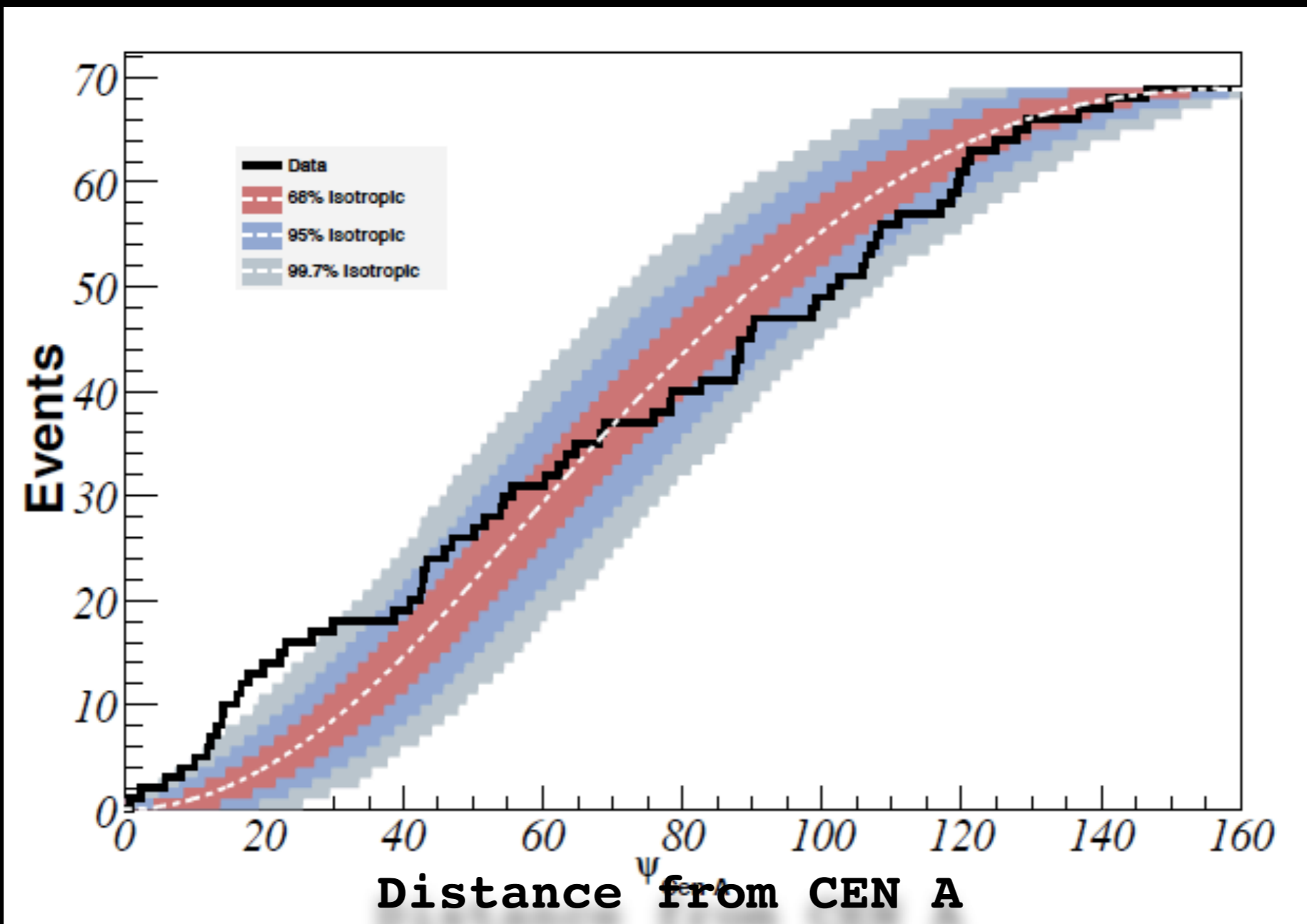
SEARCH FOR CORRELATIONS WITH OTHER (MORE COMPLETE)
CATALOGS OF EXTRA-GALACTIC OBJECTS

FITTING THE 69 EVENTS ON MAP DENSITIES BUILT FROM SOURCE MODELS BASED ON
2MRS AND SWIFT-BAT CATALOGS AND INCLUDING THE GZK EFFECT
2 FREE PARAMETERS : DEFLECTION ANGLE (MAGNETIC FIELD) AND «ISOTROPIC
FRACTION» (INCOMPLETENESS, HEAVIER ELEMENTS, ...)



2MRS -> (1.5°, 64%); SWIFT -> (7.8°, 56%)

ANGULAR DISTRIBUTIONS AT UHE



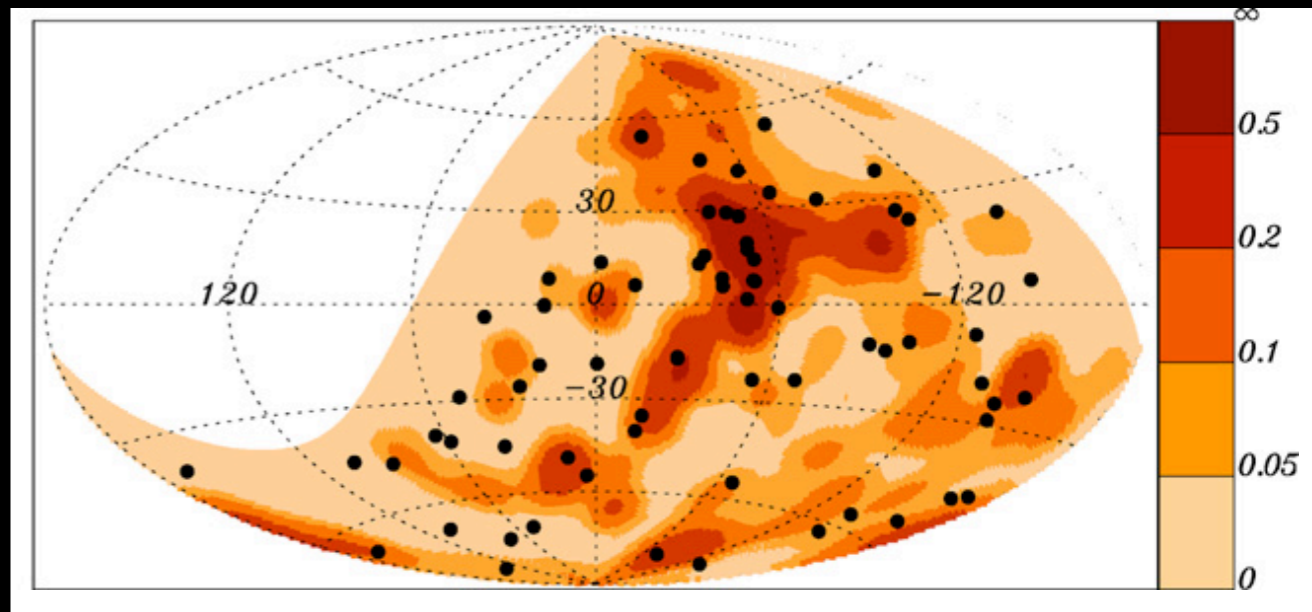
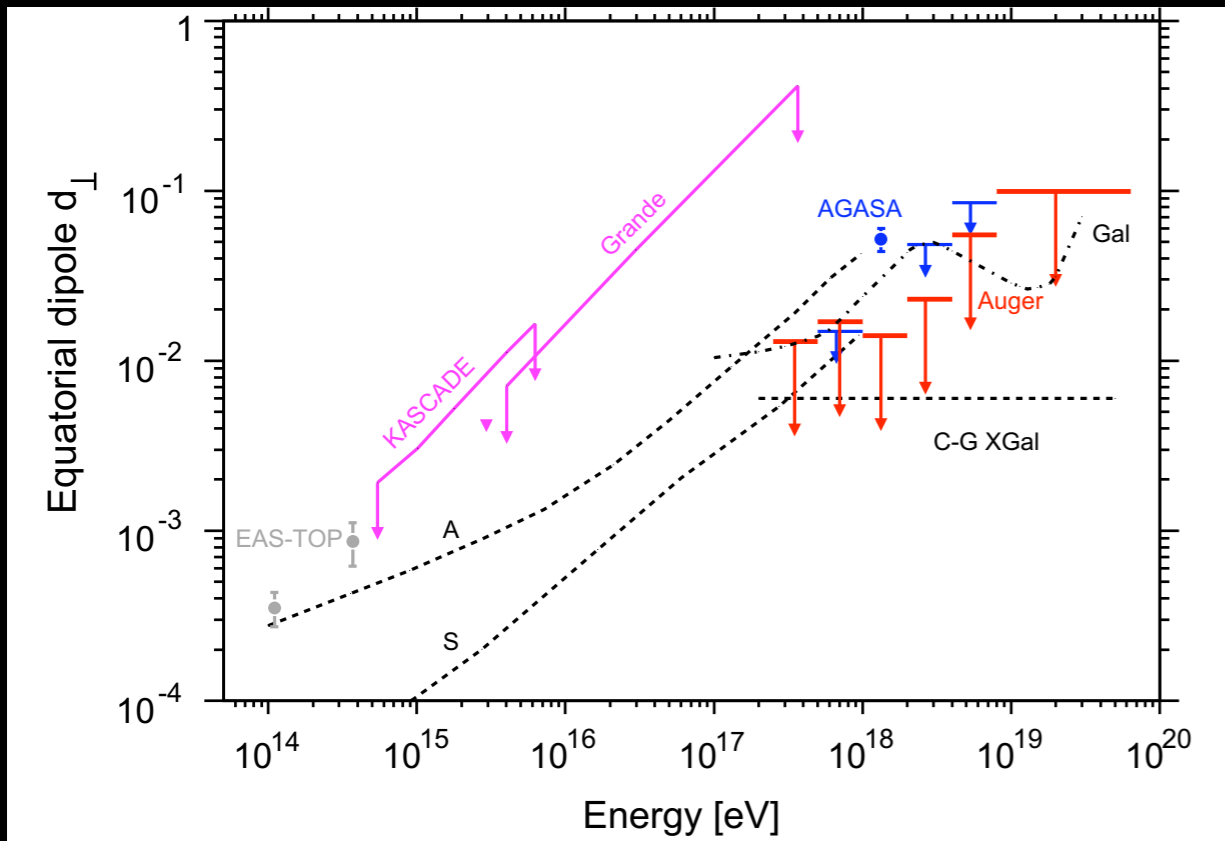
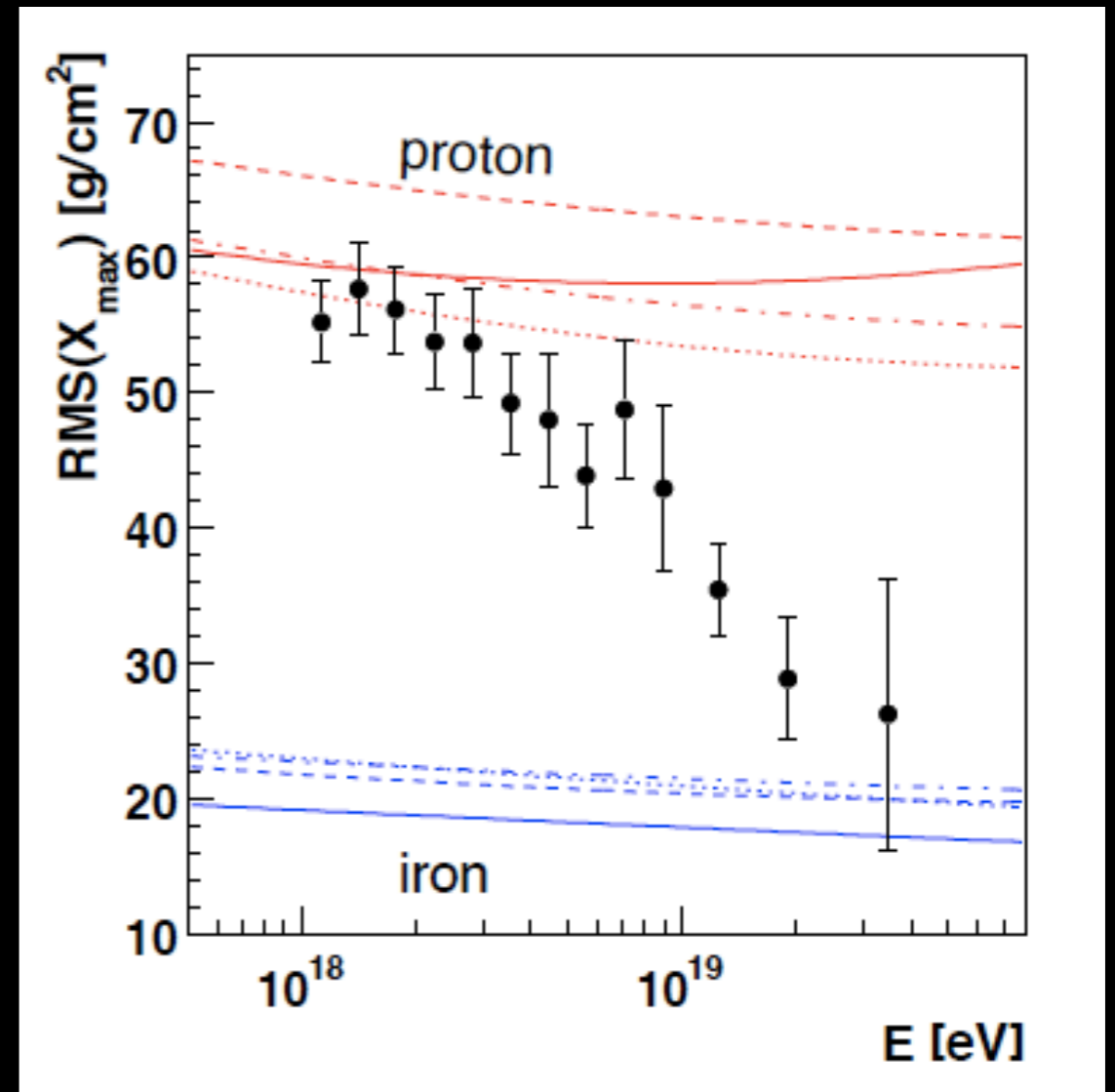
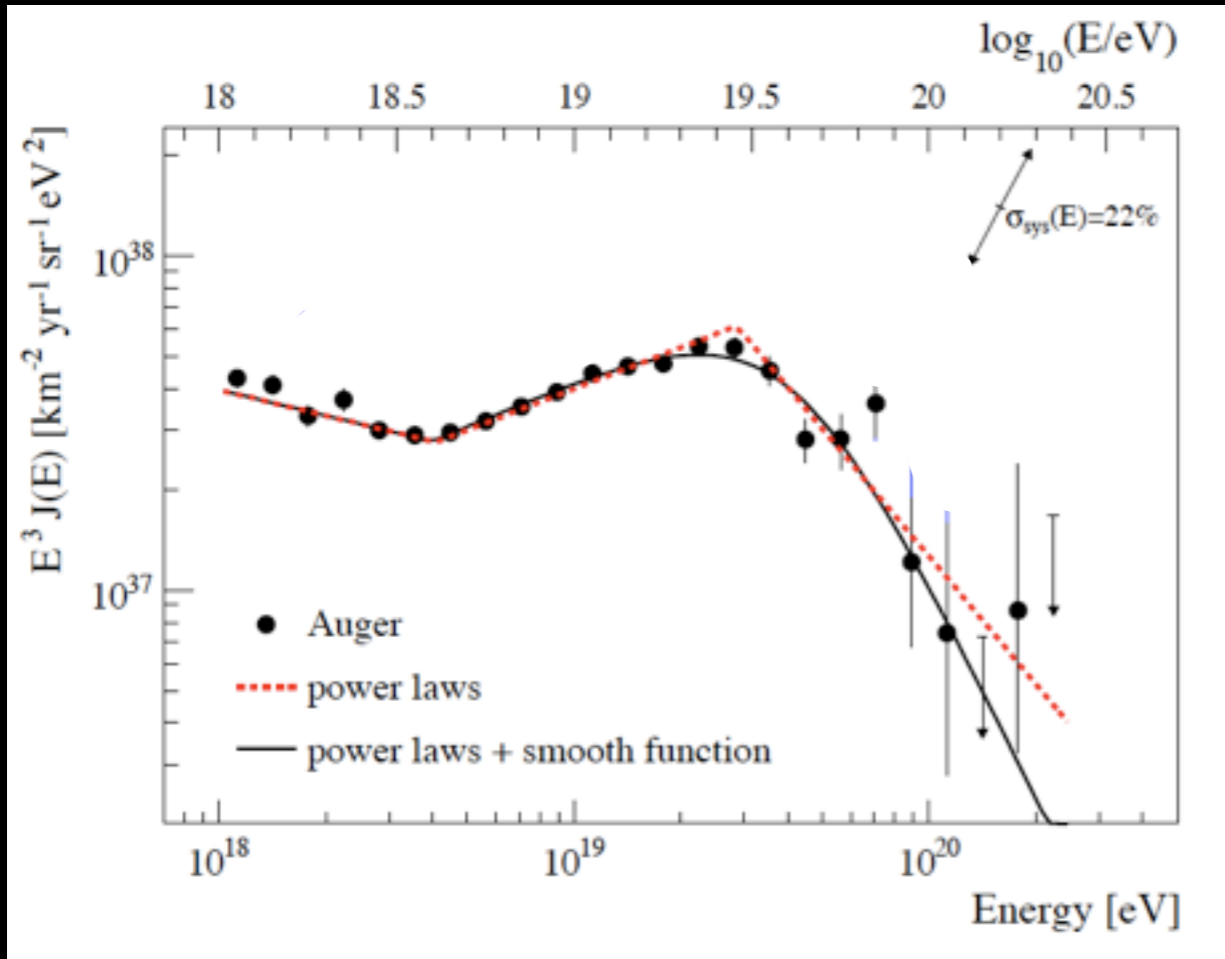
SEARCH FOR THE LARGEST EXCESS (ABOVE 57 EeV):

12 EVENTS IN A 13° CELL (1.7 EXPECTED): IT LIES AT 4° FROM CEN A

CENTERING ON CEN A: LARGEST EXCESS WITHIN 18° (13 EVENTS VS 3.2 EXPECTED)

CONCLUSIONS

THE OBSERVABLES



A GLOBAL PICTURE ?

The ankle as the gal/Xgal transition ? (Linsley 1963)

Sharpness of the ankle unnatural with a gal/Xgal transition (fine tuning needed)

Presence of light elements around 1 EeV ?

The ankle as the dip ? (Hillas 1967, Berezhinsky et al. 2006)

Should see only protons > 1 EeV (increase of the average mass above ~ 1.5 EeV - but quid of the hadronic interaction models ?)

Extragalactic UHECRs ?

Origin of the flux suppression at UHE still uncertain (propagation or source cut-off ?)

Correlations at UHE, but large isotropic component (mixing of masses a/o components ?, ...)

Suggestion of a dipolar modulation over a large energy range through the phase alignment

The ankle as a transition from light to heavy CRs of *galactic* origin ?

But : upper limits on anisotropies at the 2% level at EeV energies...