

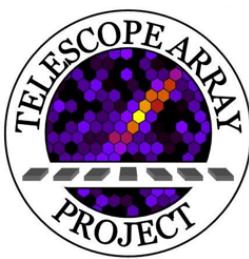
# Ultra-High-Energy Cosmic-Ray Hotspot Observed with the Telescope Array Surface Detectors

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G. B. Thomson, P. Tinyakov, I. Tkachev , H. Tokuno

For the Telescope Array Collaboration



33 institutions, 124 members



# Telescope Array Collaboration

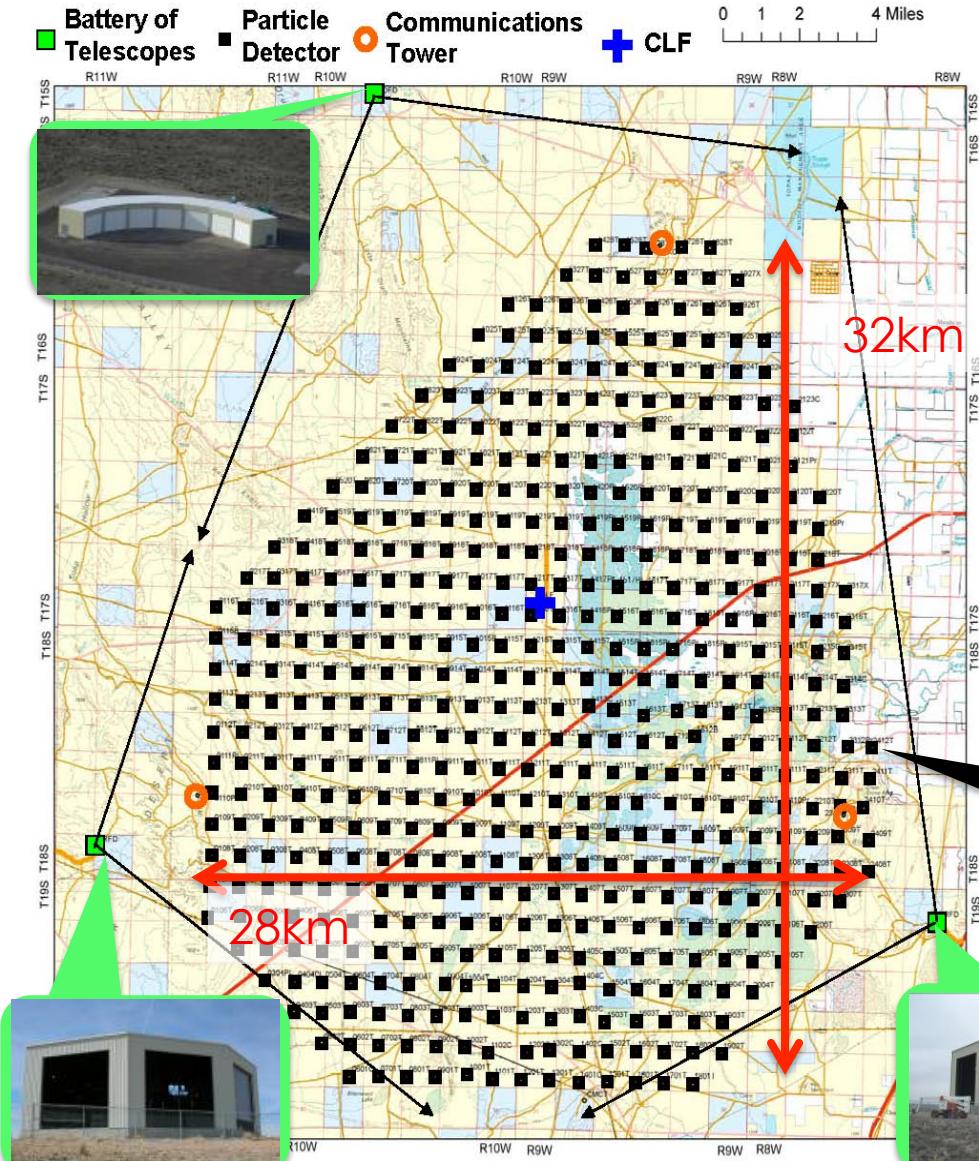
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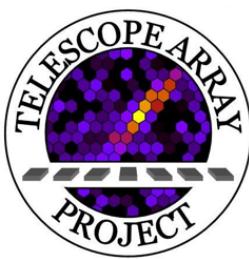


# Telescope Array Experiment



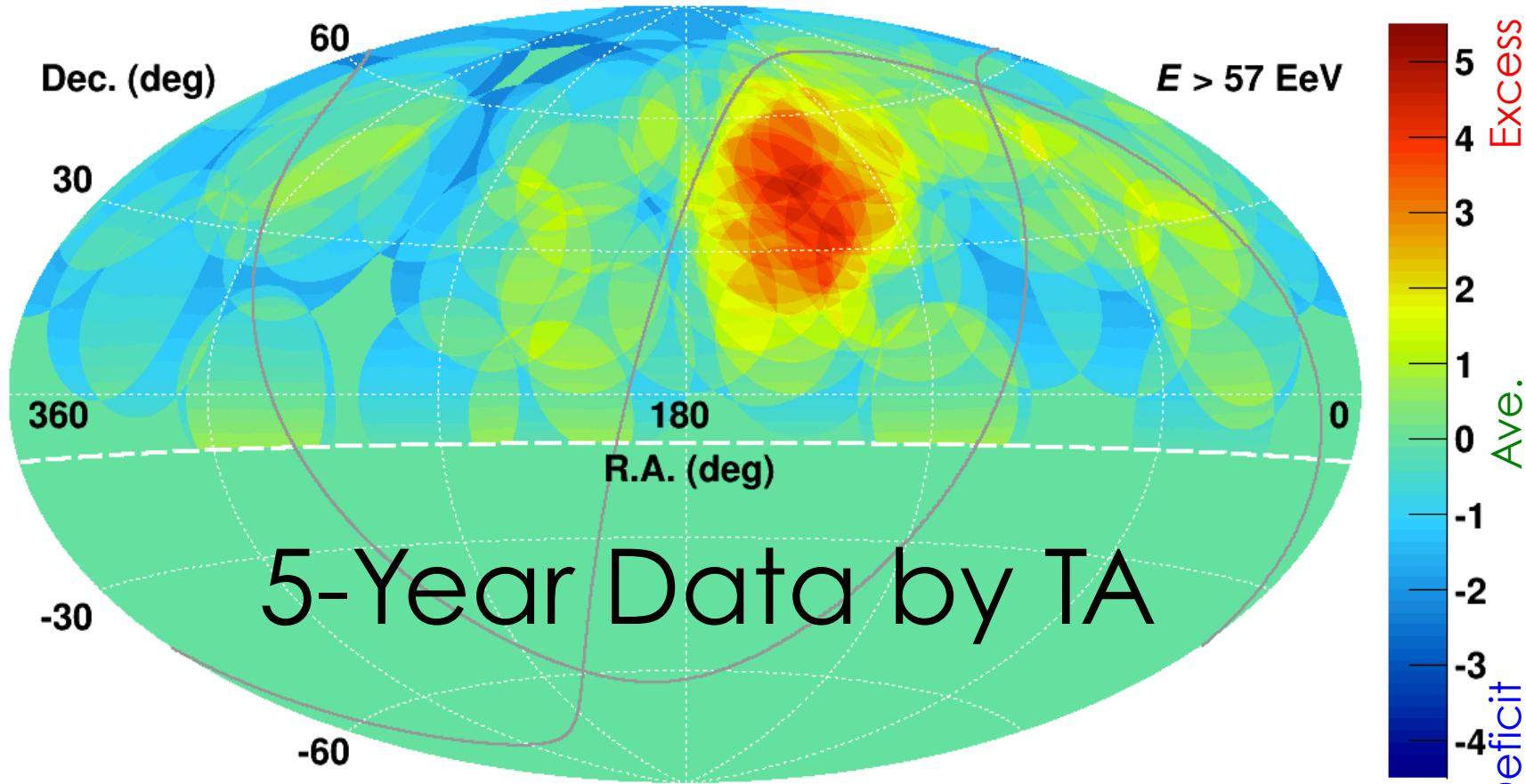
- ❖ Desert in Utah, USA
  - $39.30^{\circ}\text{N}, 112.91^{\circ}\text{W}$ , 1400m a.s.l.
- ❖ Surface Detector (SD)
  - $3\text{m}^2$  Scintillation Detector
  - 507 det. with 1.2km spacing
  - Distributed across **700km<sup>2</sup>**
  - Operating since 2008
- ❖ Fluorescence Detector (FD)
  - 3 stations
  - 12 telescopes / station





# Previous Report (2014)

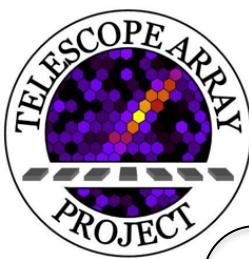
Abassi, R.U., et al., ApJL, 790, L21 (2014)



Indication of the UHECR “hotspot”

Chance prob. from the isotropy :  $3.7 \times 10^{-4}$  ( $3.4\sigma$ )

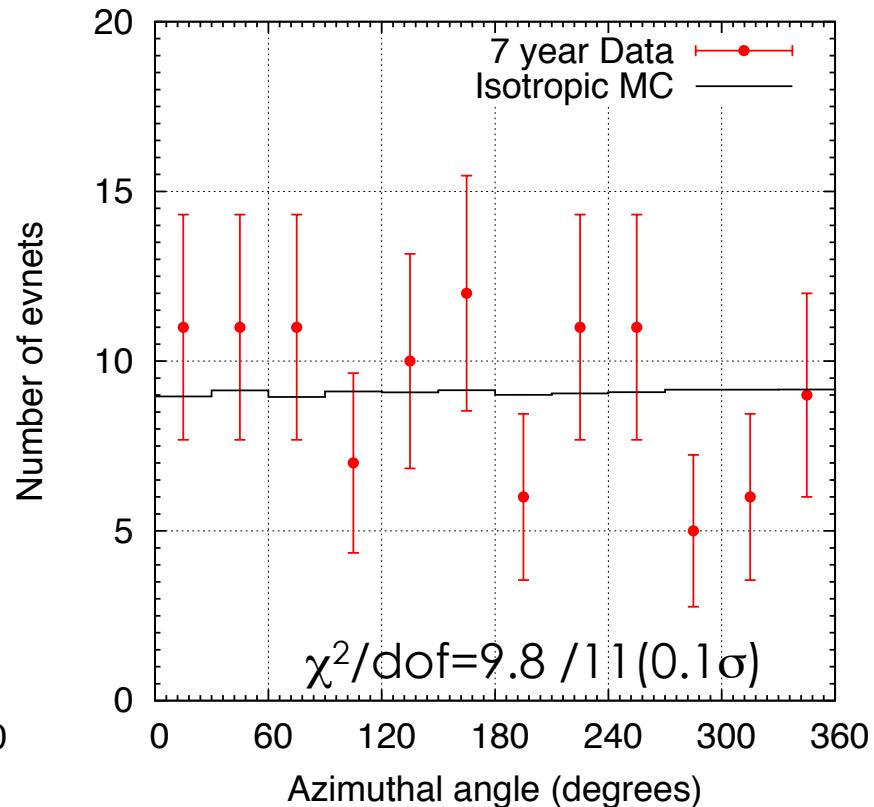
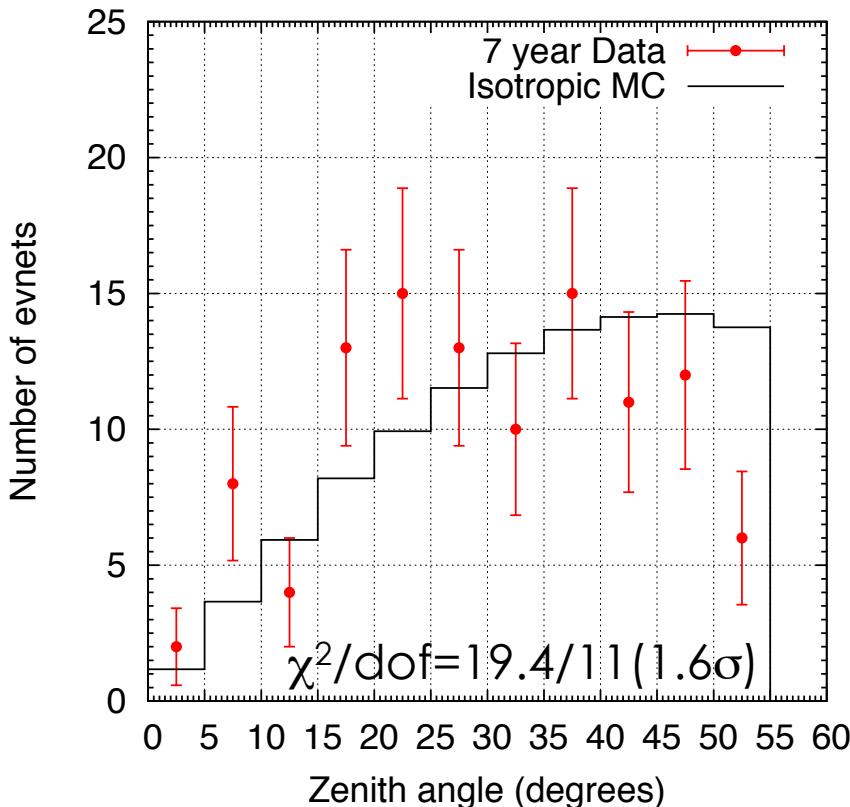
→ We test this result using the latest data

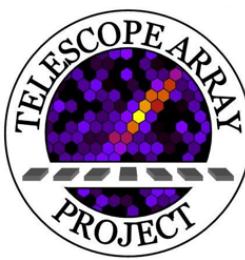


# TA SD Data Set

- ❖ Period :  
2008 May – 2015 May (**7 years**)
- ❖ Angular resolution :  $\sim 1^\circ$   
**= 109 events**

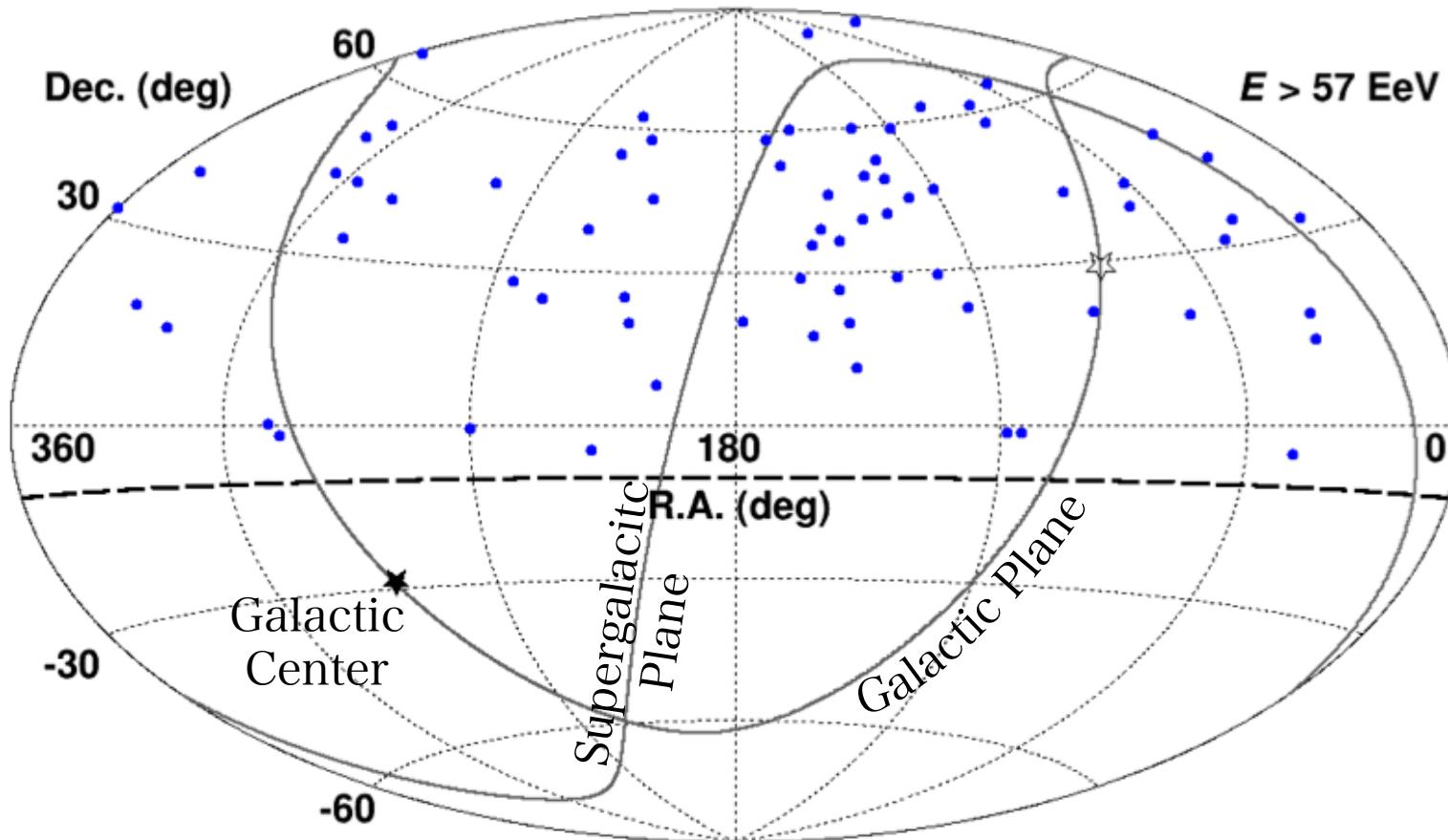
- ❖ Cut conditions :
  - # of used detectors  $\geq 4$
  - Zenith angle  $< 55^\circ$
  - Energy  $> 57\text{EeV}$
  - No boundary cut





# Initial 5-Year Data by TA

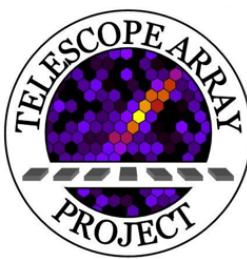
*Abbasi, R.U., et al., ApJL, 790, L21 (2014)*



**72 TA SD events on the equatorial coordinate**

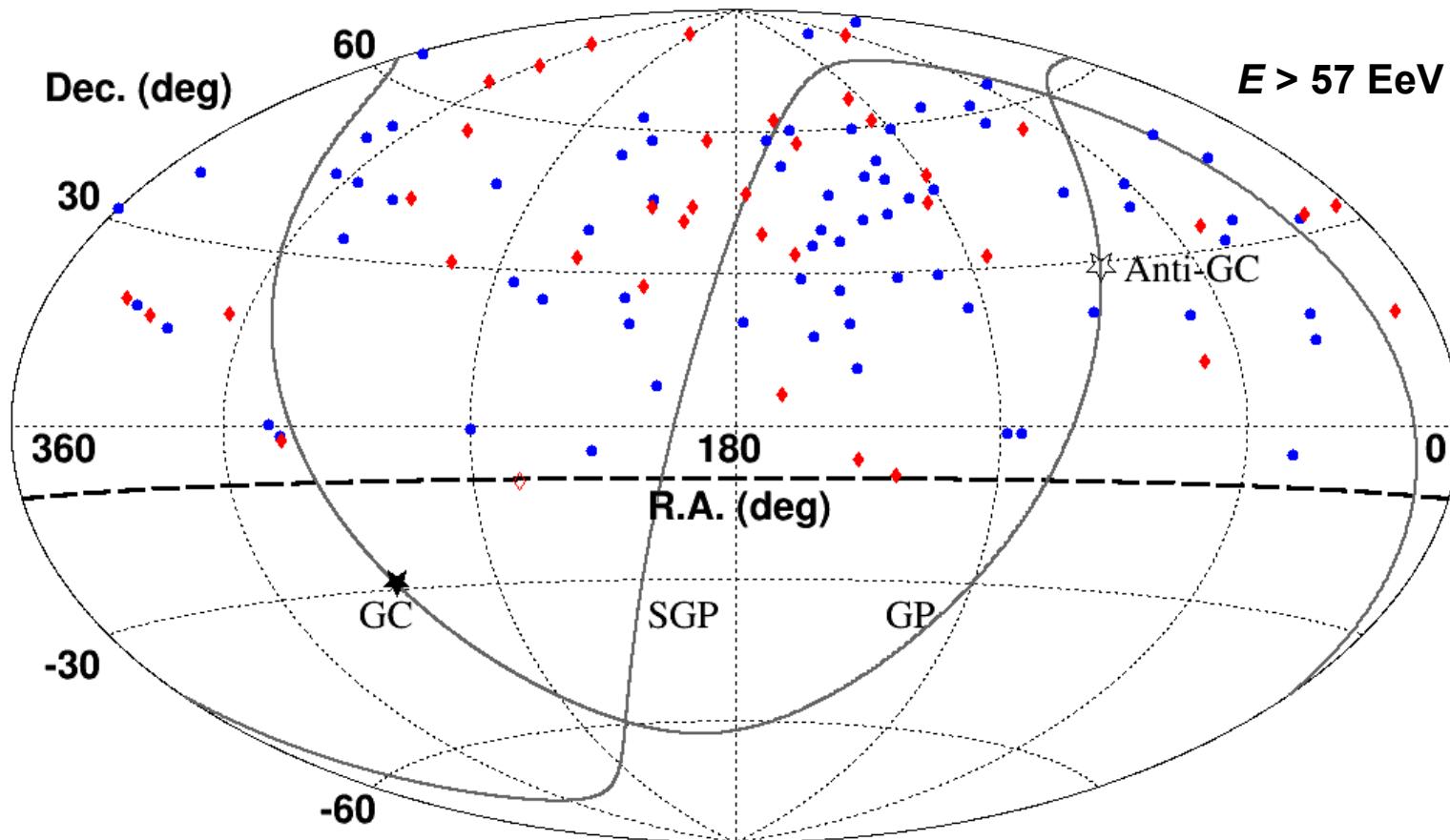
Full event table is available in the ApJL online journal :

[http://iopscience.iop.org/2041-8205/790/2/L21/suppdata/apjl498370t1\\_mrt.txt](http://iopscience.iop.org/2041-8205/790/2/L21/suppdata/apjl498370t1_mrt.txt)



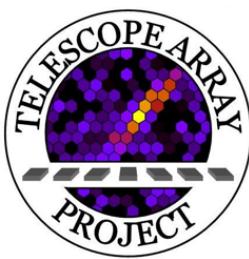
# 7-Year Data by TA

New!



First 5-year data  
New 2-year data

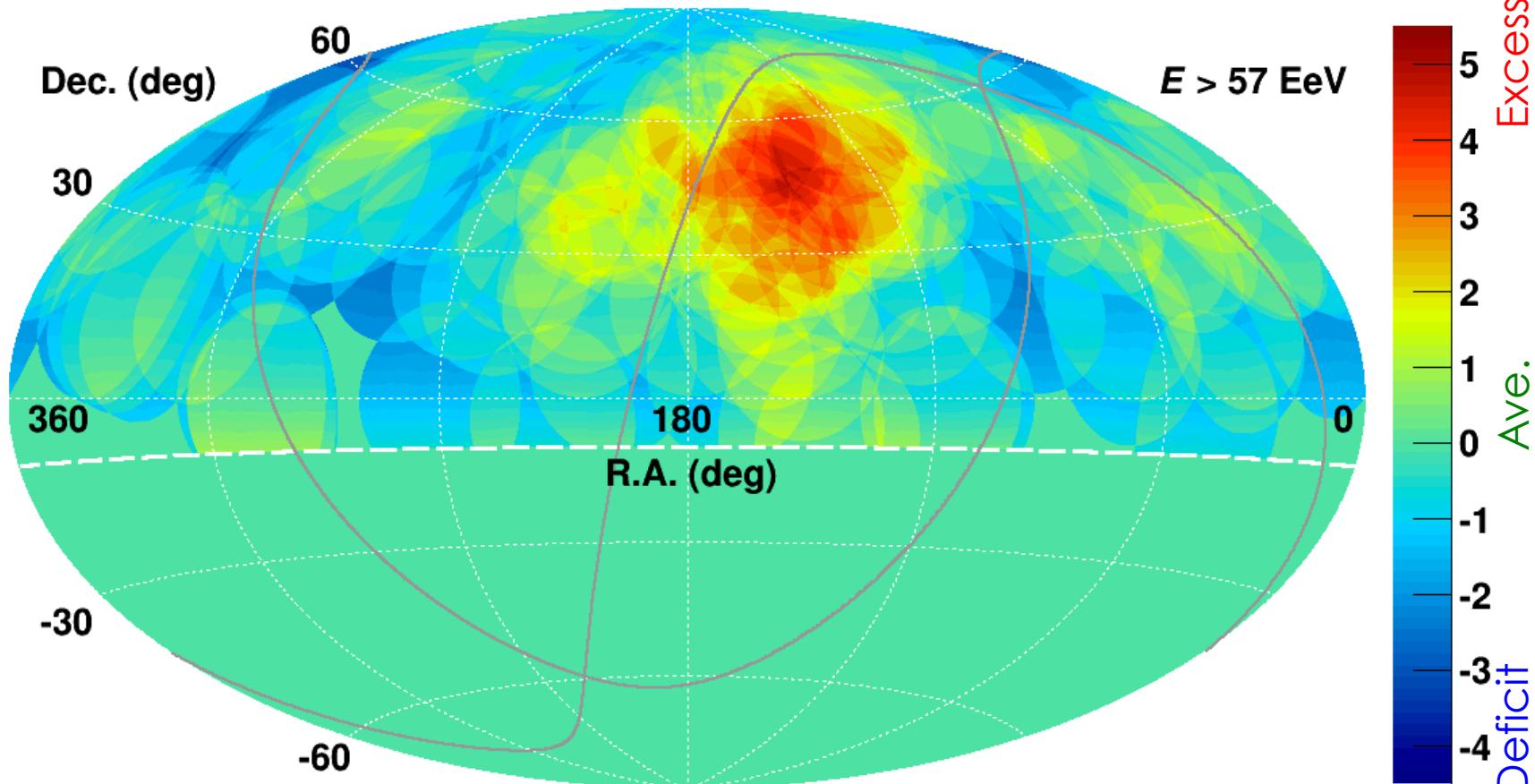
Period:  
2008 May 11 – 2015 May 11 : 109 events



# Significance Map 7 years

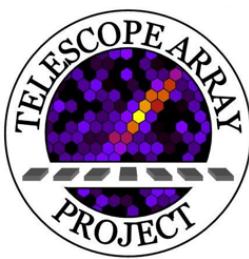
New!

Oversampling with 20°-radius circle



Max significance  $5.1\sigma$  ( $N_{\text{on}} = 24$ ,  $N_{\text{bg}} = 6.88$ ) for 7 years

Centered at R.A.=148.4°, Dec.=44.5° (shifted from SGP by 17°)



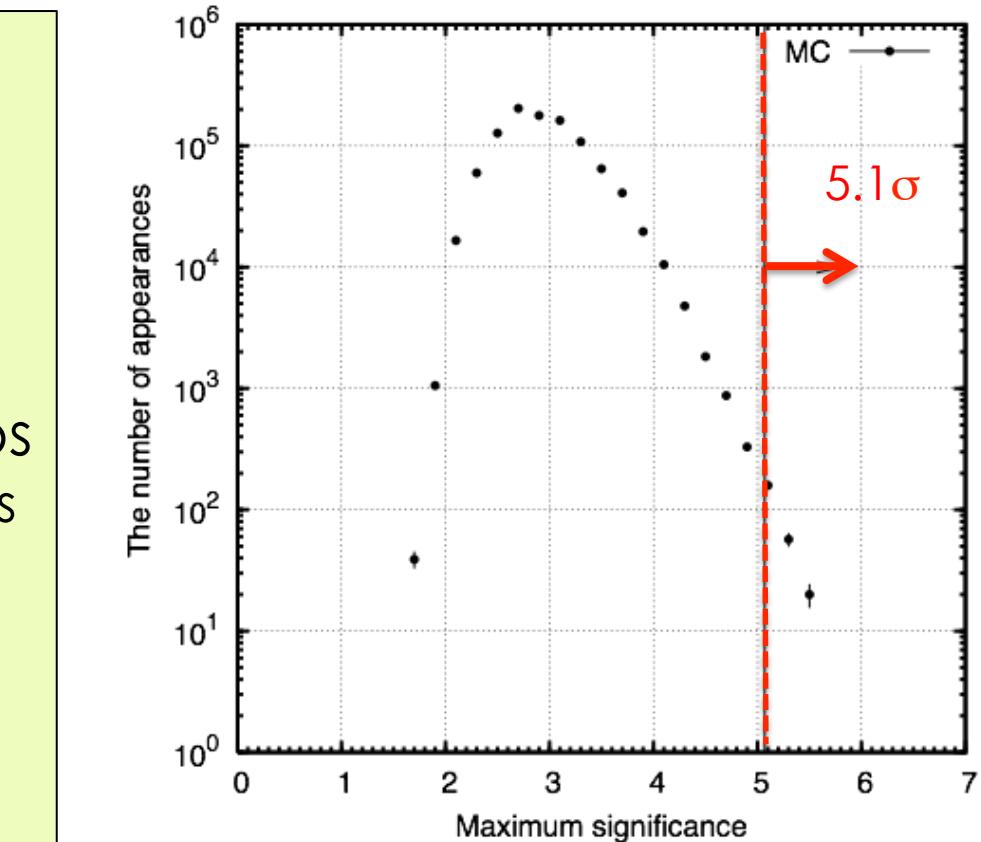
# Chance Probability

Random 109 events  
assuming isotropy  
(TA geometrical exposure)

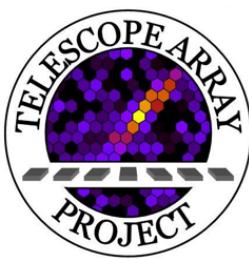
Adopt same analysis &  
create significance maps  
(by five oversampling radius  
: 15, 20, 25, 30, 35 deg.)

Search for maximum  
significance in the FoV

Repeat 1 million times  
How many  $>5.1\sigma$  ?

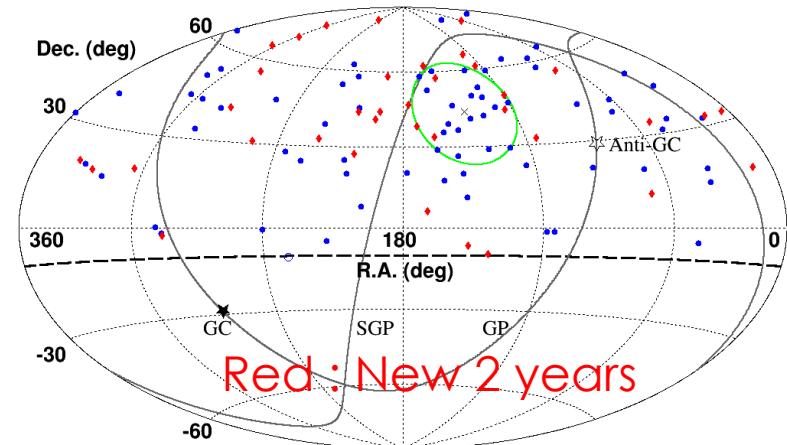


$$\begin{aligned} P &= 367 / 1,000,000 \text{ trials} \\ &= \underline{\underline{3.7 \times 10^{-4} (3.4\sigma)}} \end{aligned}$$

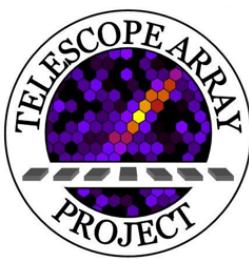


# Independent Search Using New 2-year Data

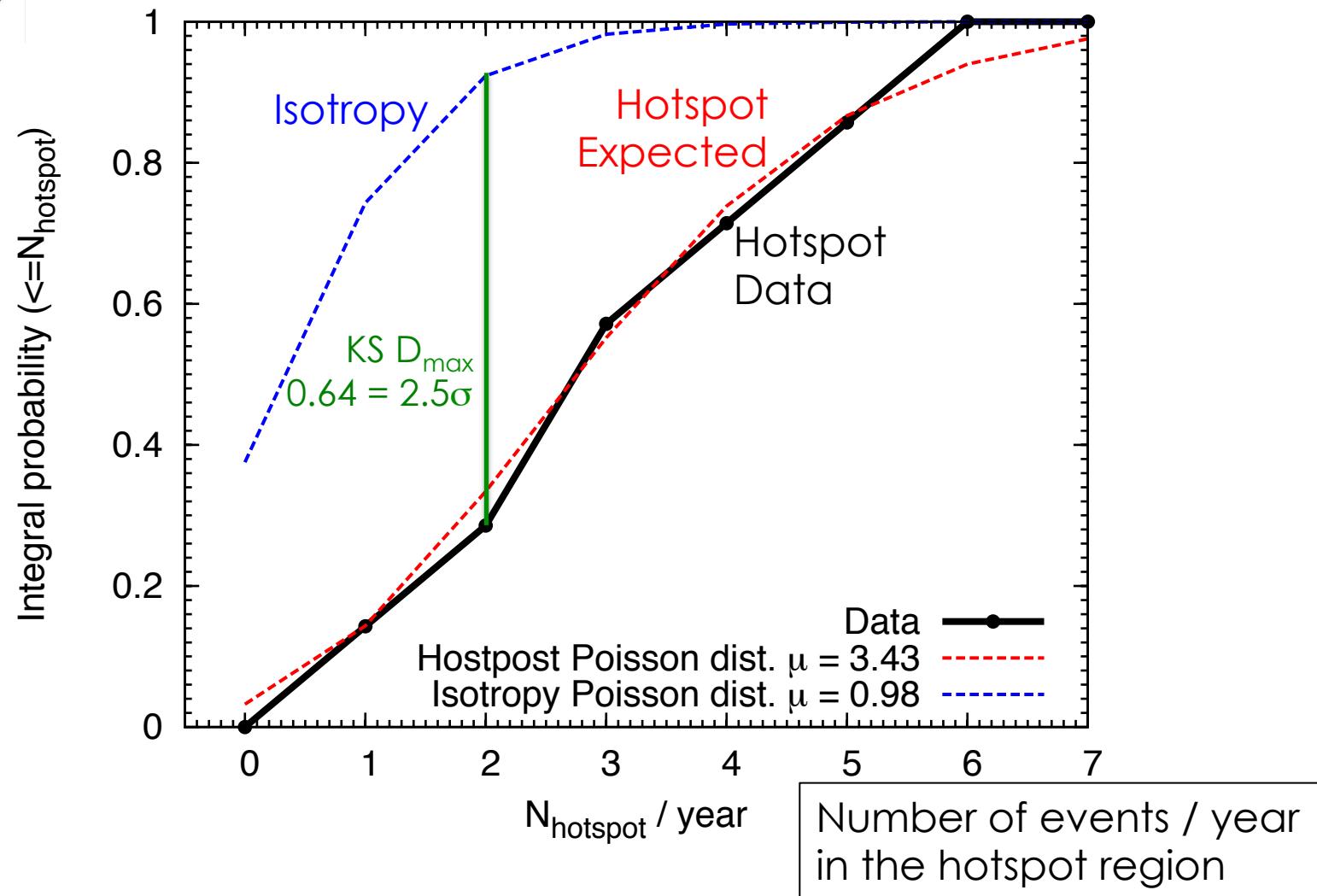
- Search for excess in the **Hotspot Circle** with 20°-radius circle centered at previous max position in new 2-year data.



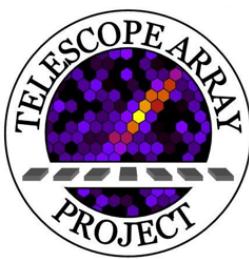
Period	Total (>57EeV)	Hotspot Signals	B.G.	Chance Prob.	Center position (RA., Dec.)
6-th year	15	3	0.94	7%	146.7°, 43.2°
7-th year	22	1	1.37	74%	146.7°, 43.2°
6 & 7-th year	37	4	2.31	20%	146.7°, 43.2°



# Poisson Distribution of Events / Year

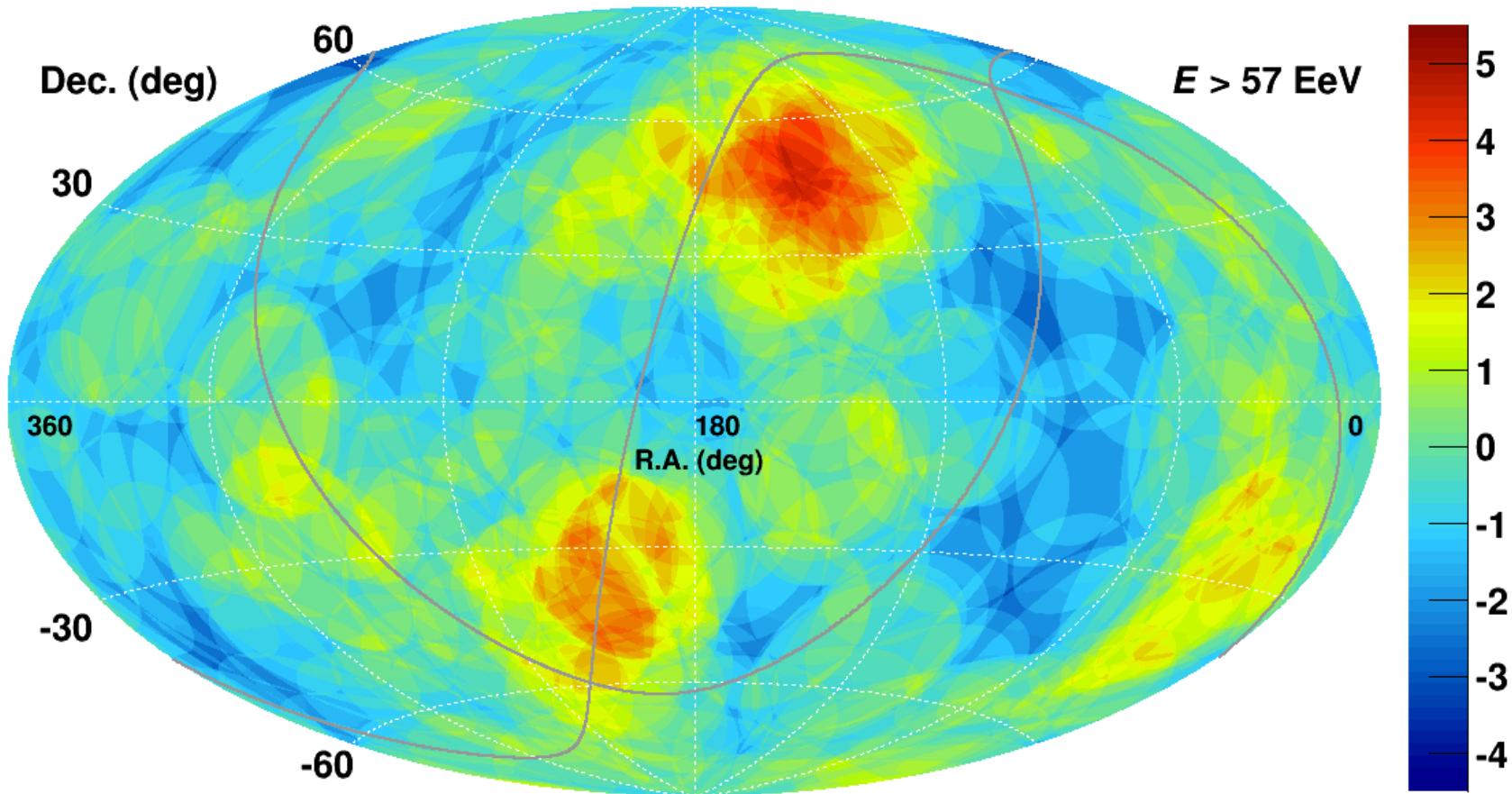


K.S. Test shows data is consistent with hotspot (No time variation),  
but inconsistent with isotropy at  $2.5\sigma$



# All Sky Survey with TA&PAO

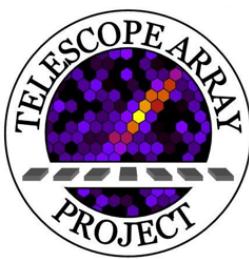
Oversampling with 20°-radius circle



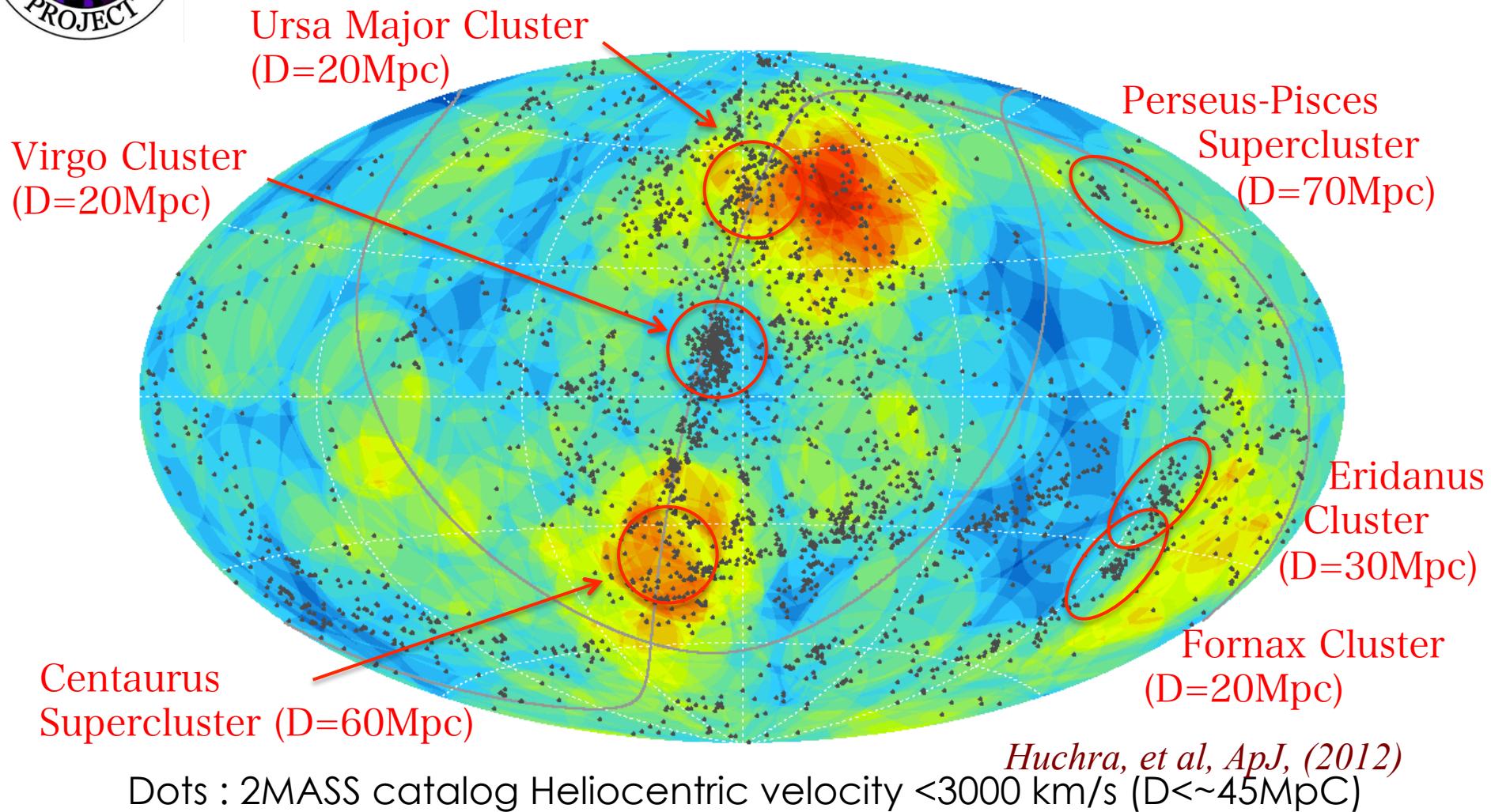
No correction for  
E scale difference  
b/w TA and PAO !!

Northern TA : 7 years 109 events ( $>57\text{EeV}$ )  
Southern PAO : 10 years 157 events ( $>57\text{EeV}$ )

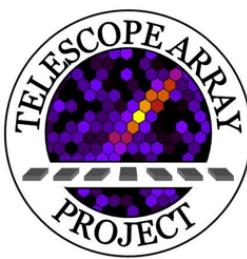
Southern hotspot is seen at Cen A(Pre-trial  $\sim 3.6\sigma$ )



# Nearby Galaxy Clusters

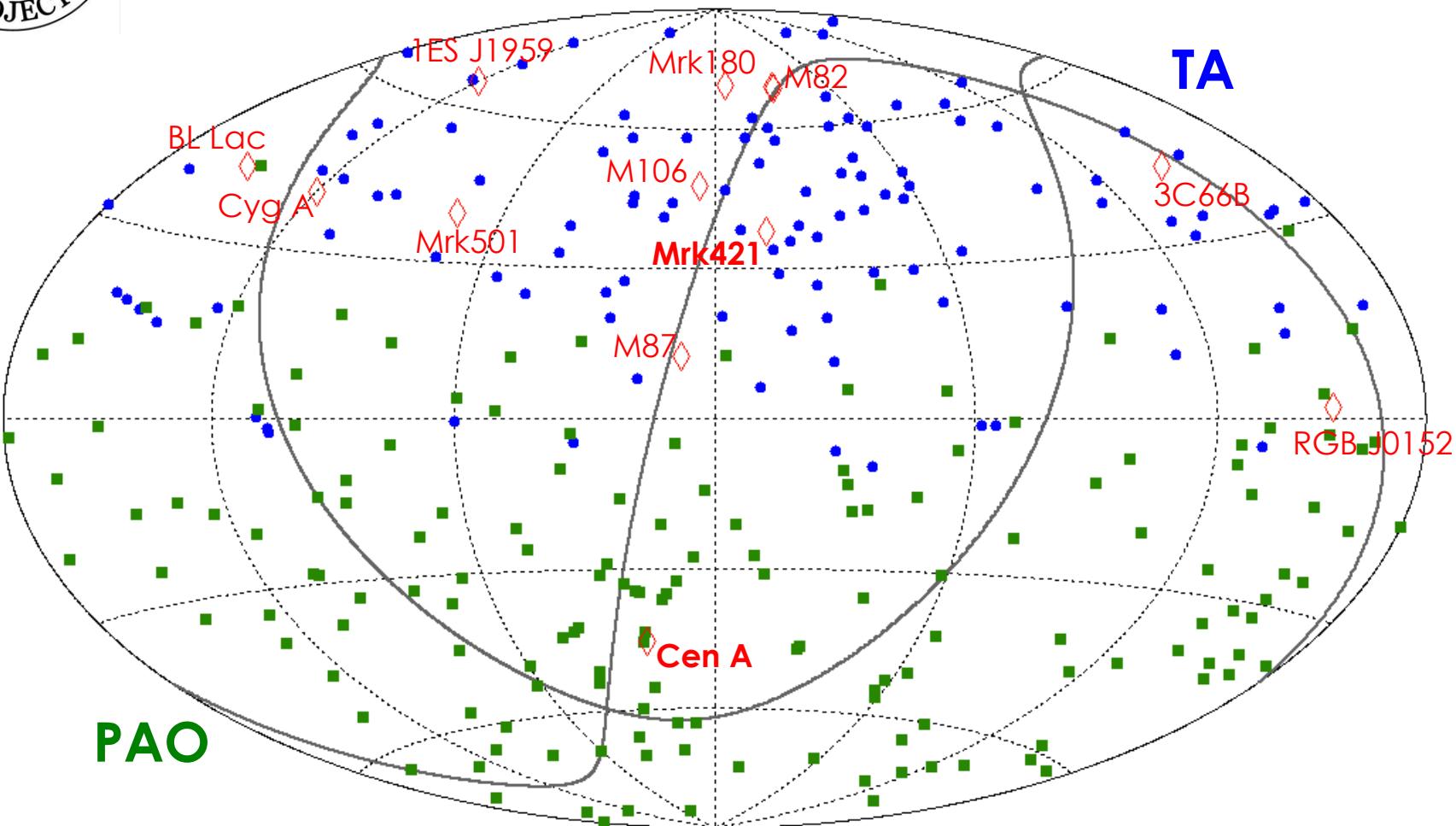


TA hotspot is found near the Ursa Major Cluster  
TA & PAO found no excess in the direction of Virgo.



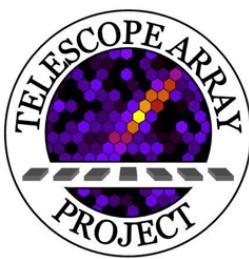
# Nearby Prominent Sources

*Dermer, et al, New J. Phys., (2007)*



The blazar Mrk421, Mrk180 and starburst galaxy M82 are candidates?

*K. Fang, et al., ApJ, 794, 126 (2014)*  
*H.-N. He, et al., arXiv:1411.5273 (2014)*



# Summary

- Aims
  - We reported an indication of the **UHECR hotspot** near the Ursa Major cluster using initial 5-year data.
  - We tested this result using total **7-year data (109 events)**.
- Results
  - Number of events in the hotspot increases to 24 events (6.88 background events) with additional 2-year data.
  - **Chance probability** of the hotspot for 7 years remains at the same level of  **$3.4\sigma$**  as for 5-year initial sample.
- Future Prospects
  - We will promote the **TAX4** project (extend the size of the TA SD by a factor of 4) to collect data faster.