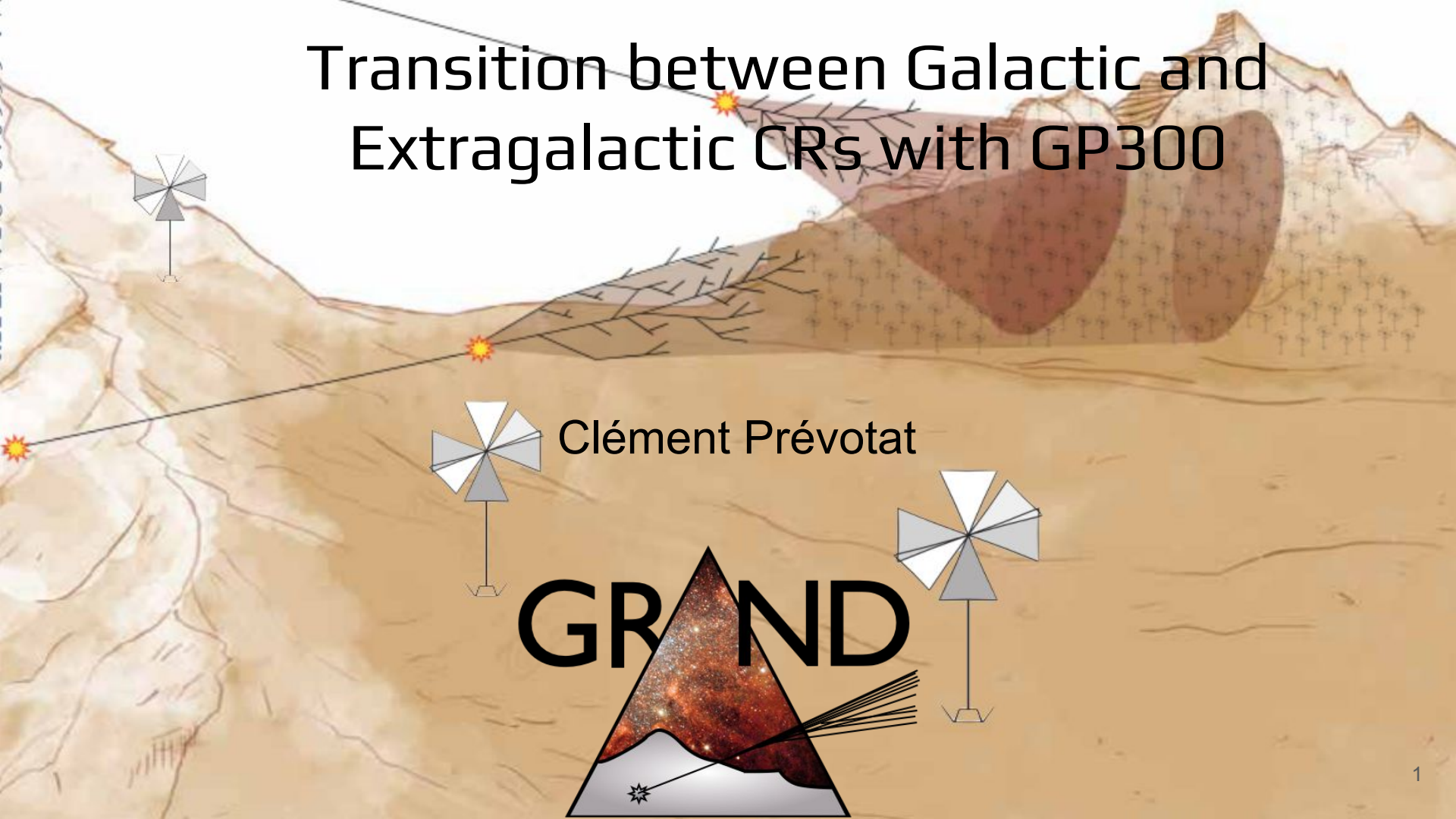


# Transition between Galactic and Extragalactic CRs with GP300



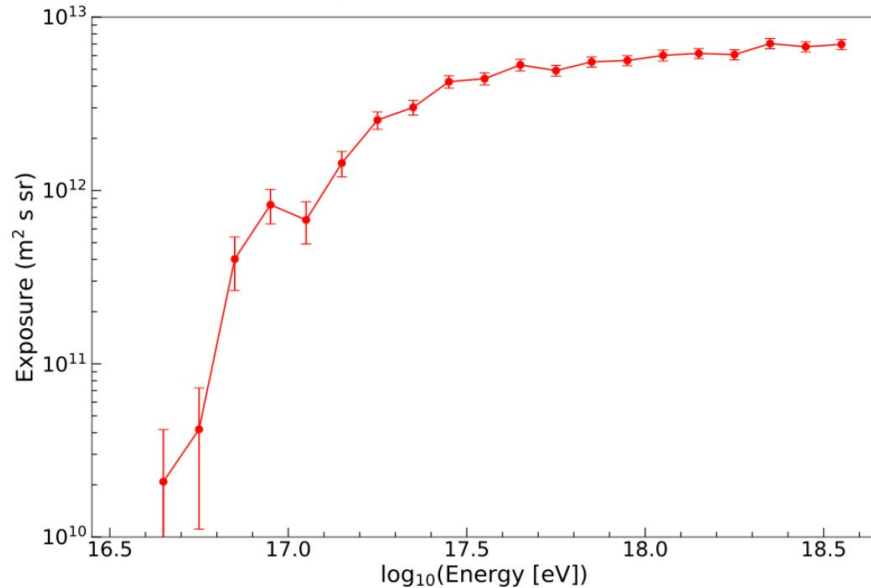
Clément Prévotat

GRAND

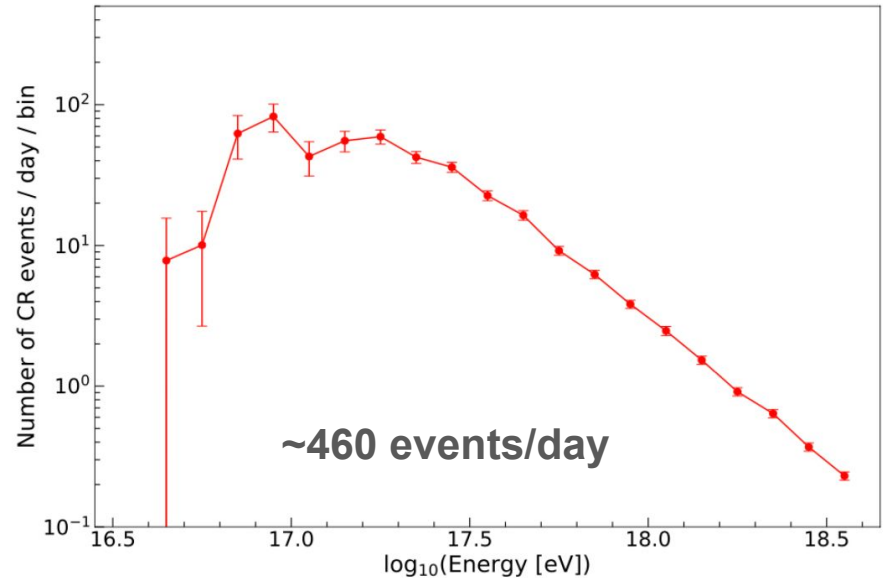
# Exposure as a function of energy

See talk by Sei Kato

One-day exposure ( $\text{m}^2 \text{ s sr}$ )



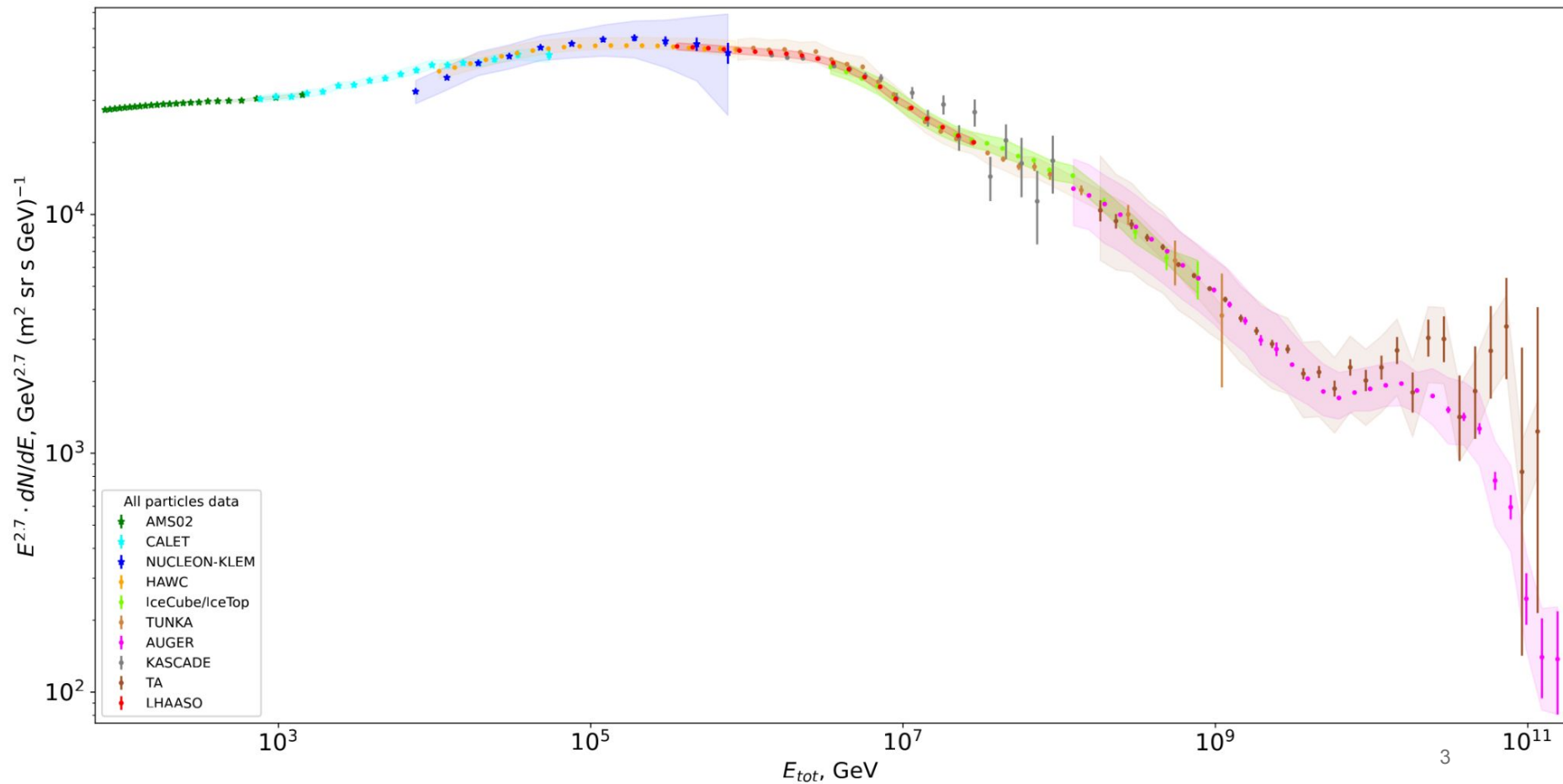
# of CR events/day/bin



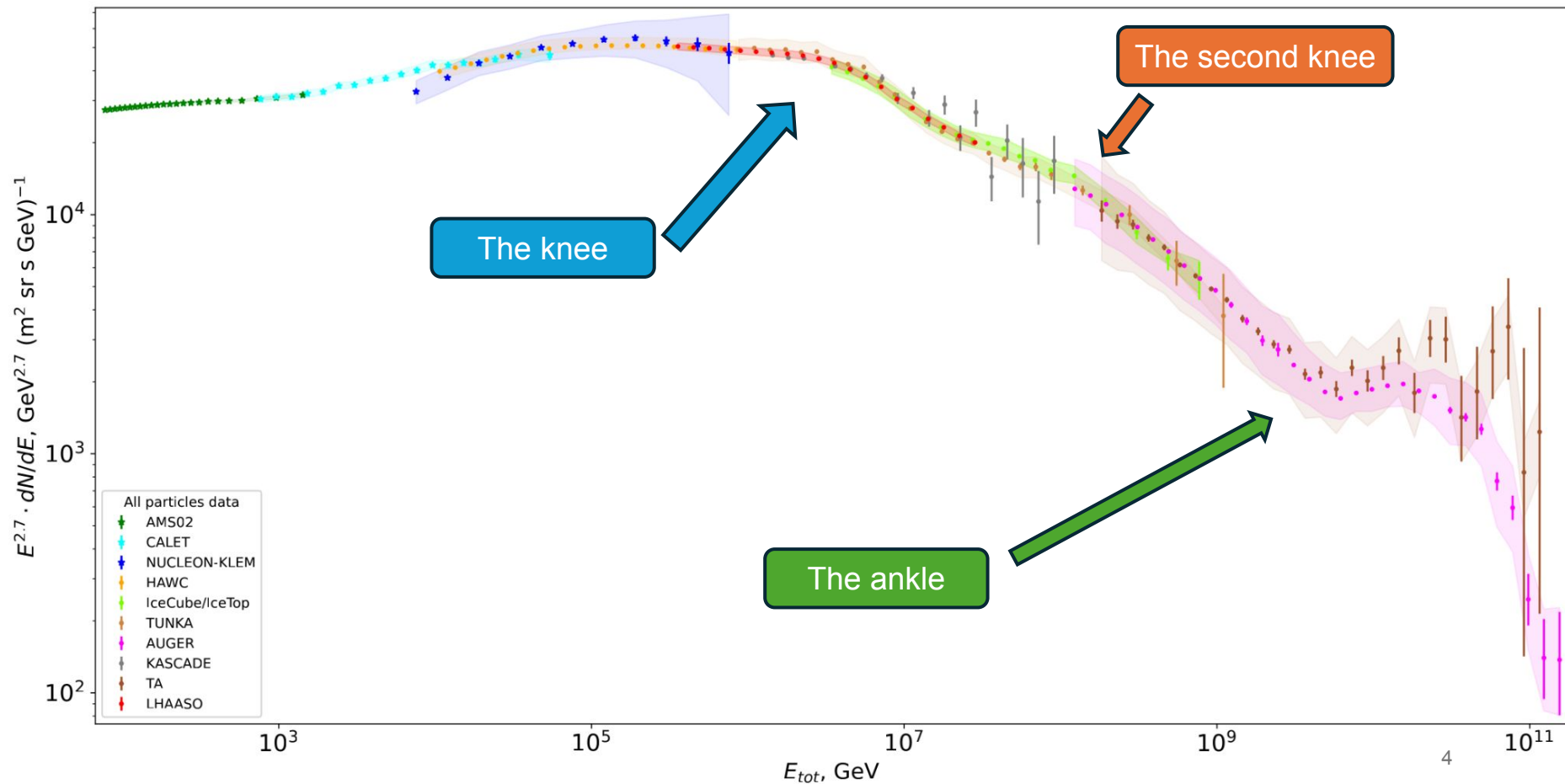
~ 170 000 events per year

Figures by Sei Kato

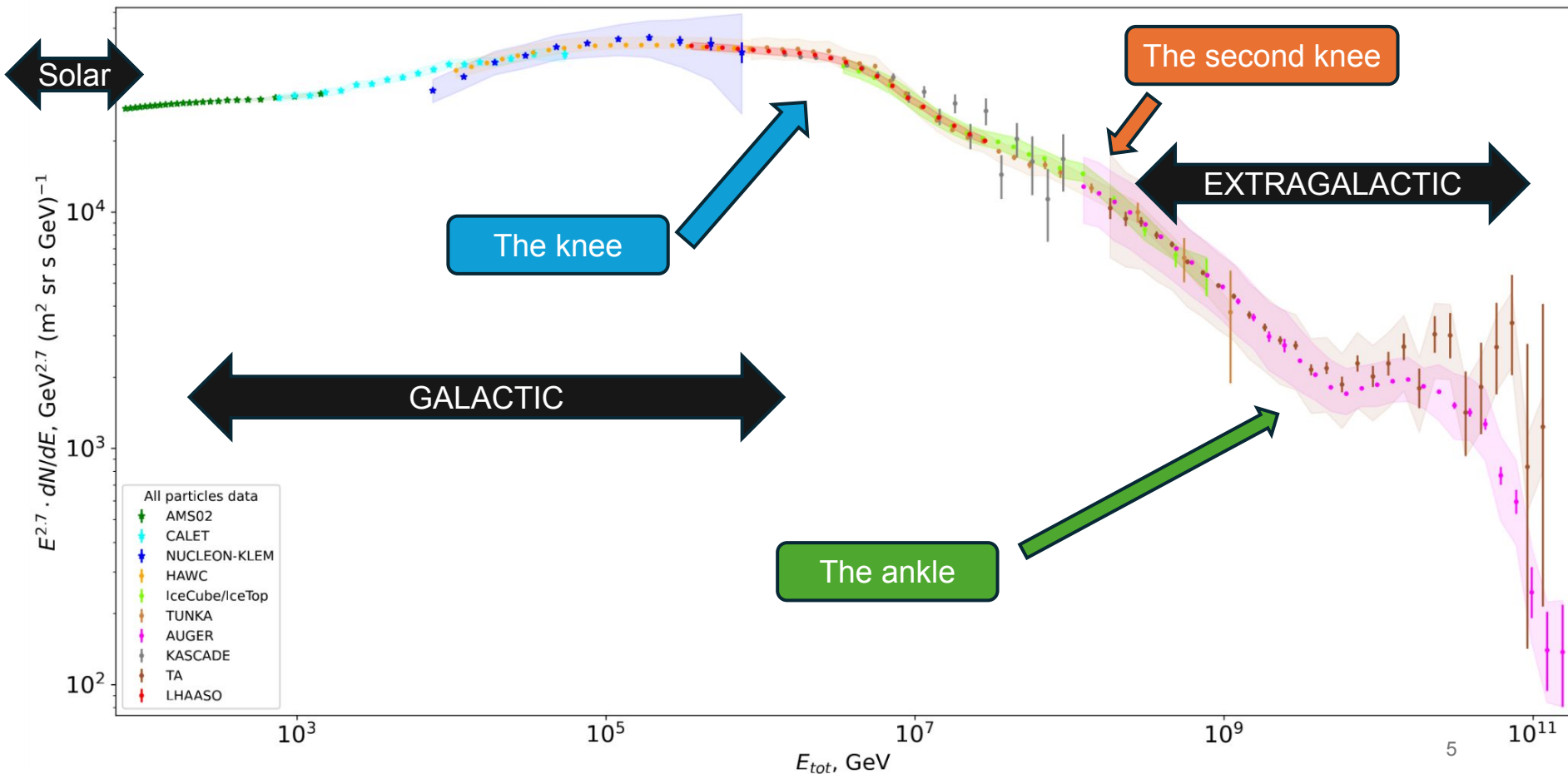
# The cosmic ray spectrum



# The cosmic ray spectrum

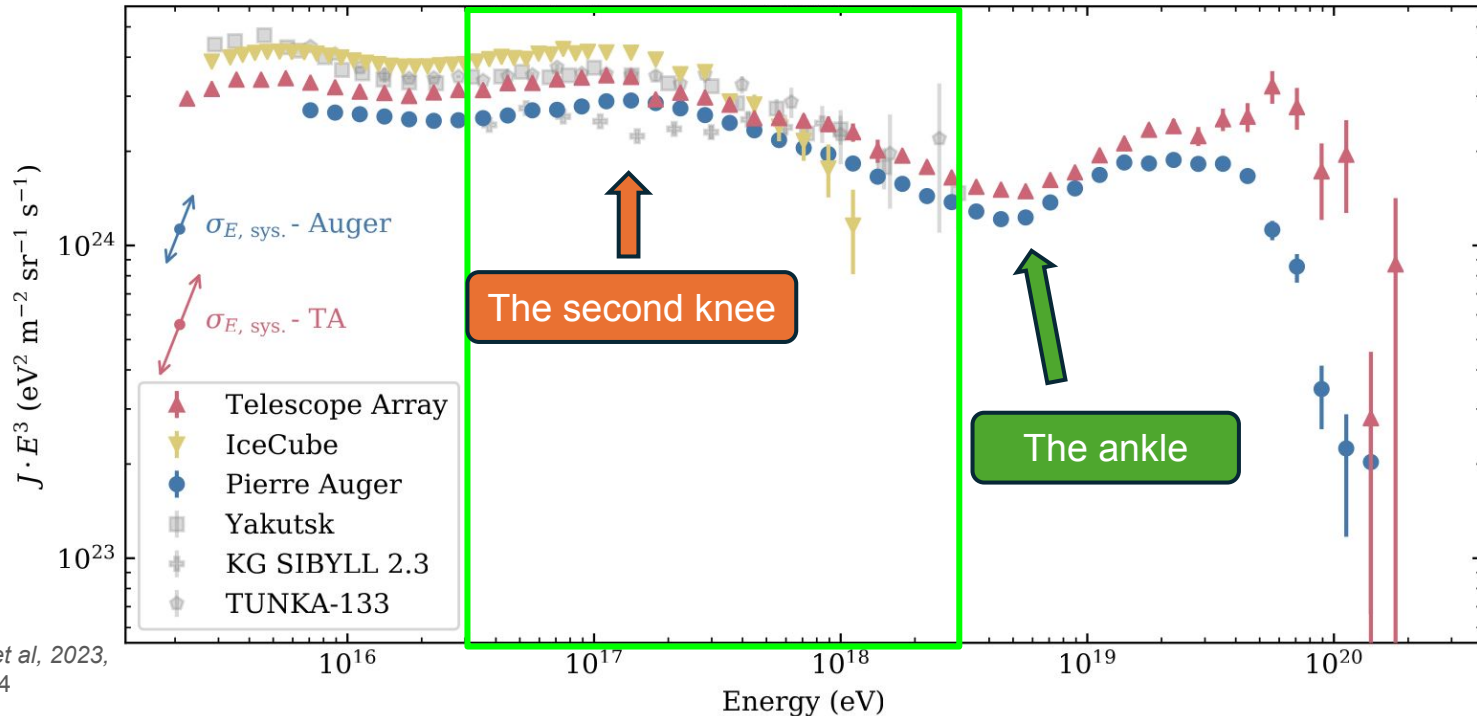


# The cosmic ray spectrum



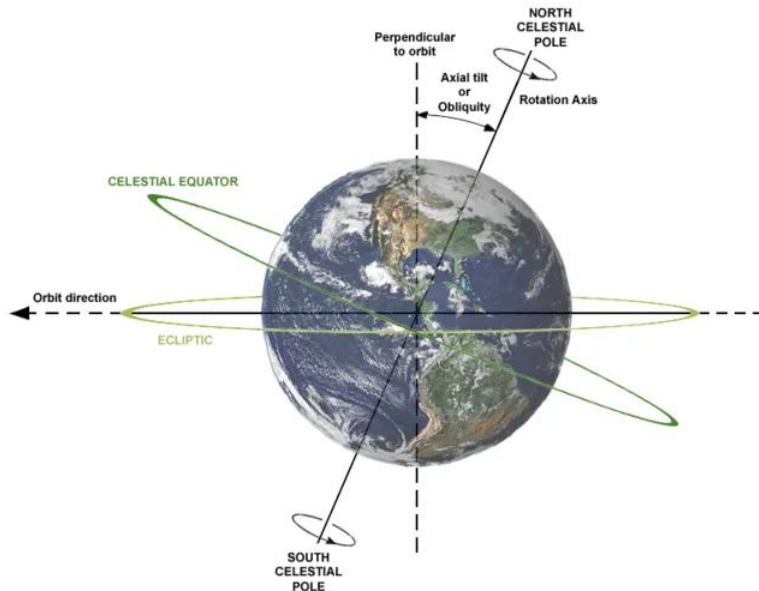
# Target of GRAND Proto 300

- Cosmic rays between  $10^{16.5}$  and  $10^{18.5}$  eV : transition between Galactic and extragalactic CRs

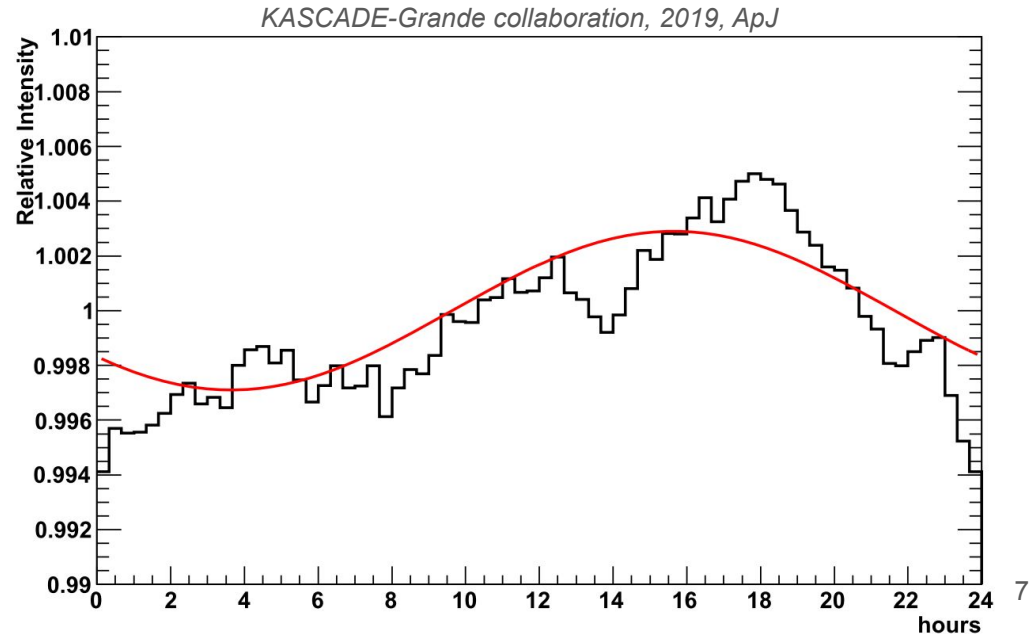


# Dipole anisotropy

- Experiments have only access to a declination band : the dipole is **projected** on the equatorial plane

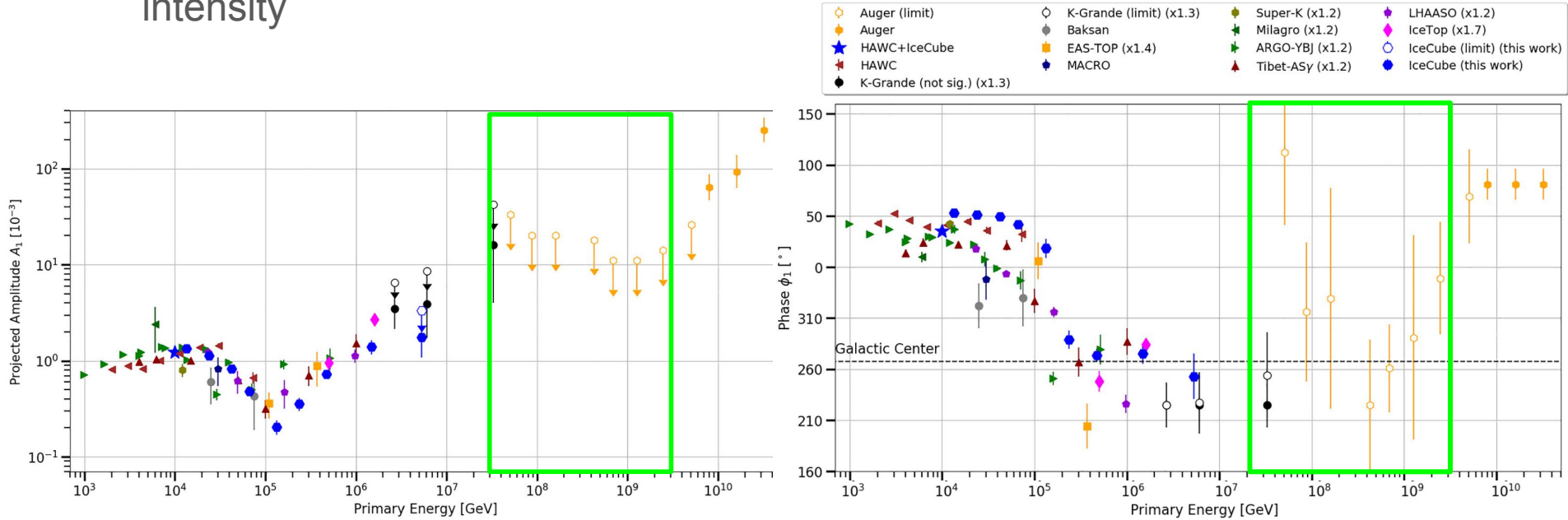


Amplitude : 
$$\delta \equiv \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$



# Dipole anisotropy

Phase : Direction of maximal intensity





# Number of events used in the analyses

**Table 2**  
First Harmonic Amplitude and Phase in Different Intervals of  $N_{\text{ch}}$

$\text{Log}(N_{\text{ch}})$	Median Energy (eV)	$A \times 10^{-2}$	Phase (deg)	$P$	Number of Events	U.L. (99% c.l.)
5.2–5.6	$2.7 \times 10^{15}$	$0.26 \pm 0.10$	$225 \pm 22$	3%	$1.42 \times 10^7$	$0.49 \times 10^{-2}$
5.6–6.4	$6.1 \times 10^{15}$	$0.29 \pm 0.16$	$227 \pm 30$	19%	$6.27 \times 10^6$	$0.64 \times 10^{-2}$
$\geq 6.4$	$3.3 \times 10^{16}$	$1.2 \pm 0.9$	$254 \pm 42$	41%	$1.97 \times 10^5$	$3.15 \times 10^{-2}$

Kascade-Grande

KASCADE-Grande  
collaboration, 2019, ApJ

	$E$ [EeV]	$E_{\text{med}}$ [EeV]	$N$	$d_{\perp}$ [%]	$\sigma_{x,y}$ [%]	$\alpha_d$ [°]	$P(\geq d_{\perp})$	$d_{\perp}^{\text{UL}}$ [%]
East-West (SD750)	1/32 - 1/16	0.051	432,155	$1.0^{+1.0}_{-0.4}$	0.91	$112 \pm 71$	0.54	3.3
	1/16 - 1/8	0.088	924,856	$0.6^{+0.6}_{-0.3}$	0.52	$-44 \pm 68$	0.50	2.0
	1/8 - 1/4	0.161	488,752	$0.2^{+0.8}_{-0.2}$	0.63	$-31 \pm 108$	0.94	2.0
East-West (SD1500)	1/4 - 1/2	0.43	770,316	$0.6^{+0.5}_{-0.3}$	0.48	$-135 \pm 64$	0.45	1.8
	1/2 - 1	0.70	2,388,467	$0.5^{+0.3}_{-0.2}$	0.27	$-99 \pm 43$	0.20	1.1
	1 - 2	1.28	1,243,103	$0.18^{+0.47}_{-0.02}$	0.35	$-69 \pm 100$	0.87	1.1

Auger

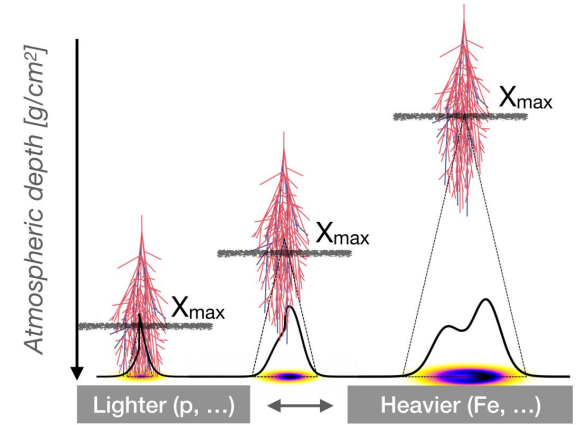
A. Aab, 2020, ApJ

Low significance : no strong result yet

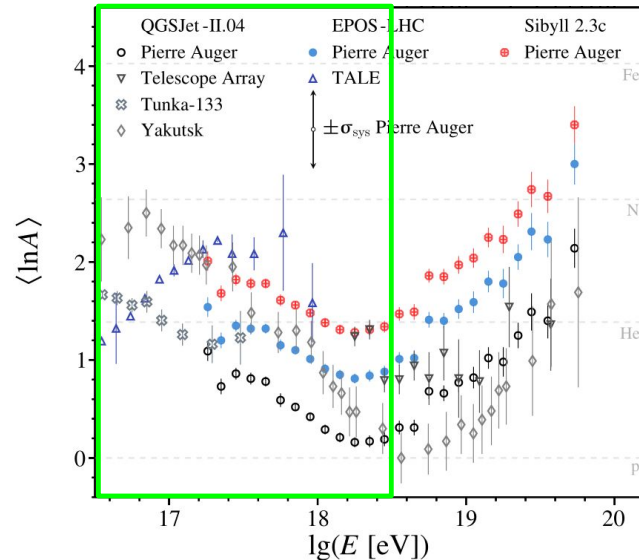
+ GP300 won't get as many events within the few next years....

# Mass composition

- Measured from the  $X_{max}$  distribution
- Constraints on the sources and acceleration scenarios
- Constraints on propagation
- Improvements of magnetic fields models



*C. Glaser et al, 2019,  
1806.03620v2*



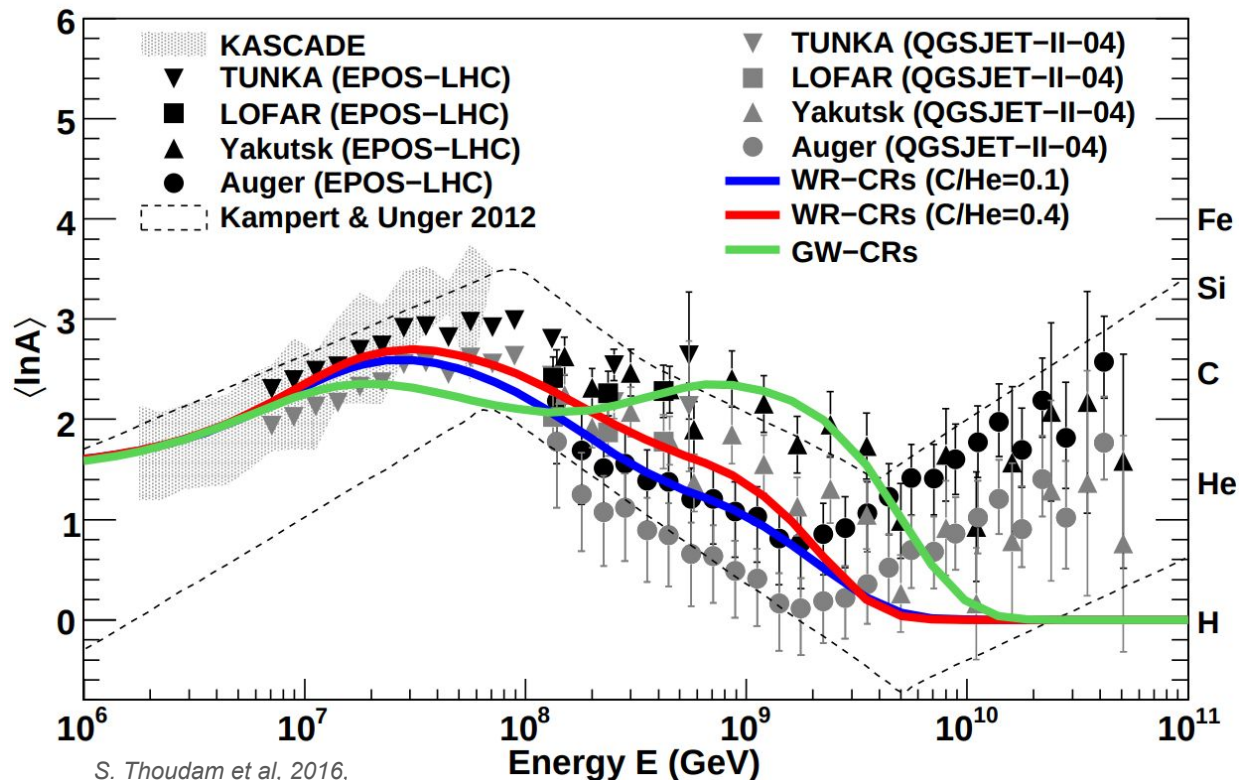
A : Atomic mass

*A. Coleman et al, 2023,  
2205.05845v4*

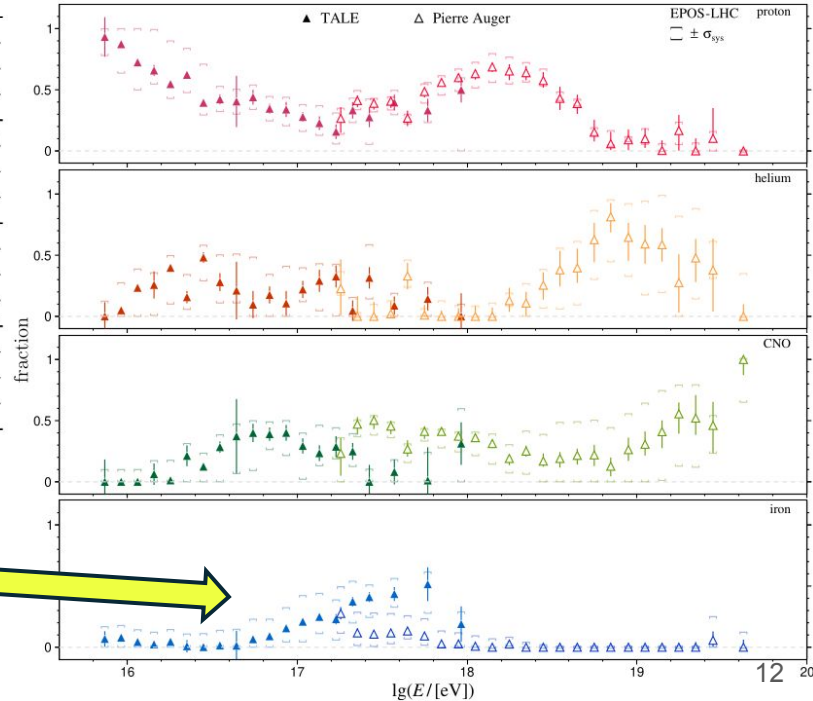
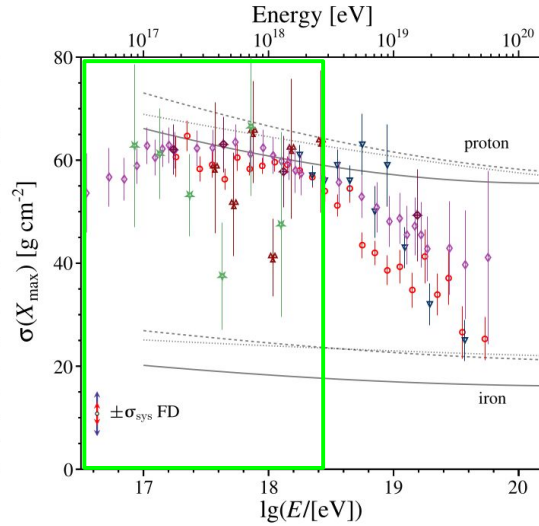
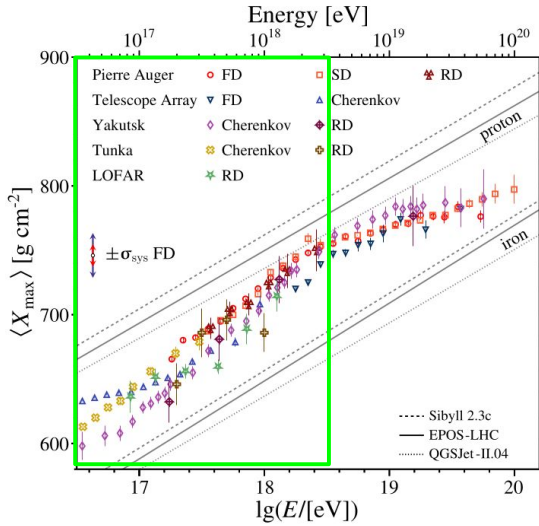
# Example of composition constraints

WR : Wolf-Rayet  
GW : Galactic Wind

- Environments and  
processes yield  
different compositions



# Measurements as of today



No iron knee ?



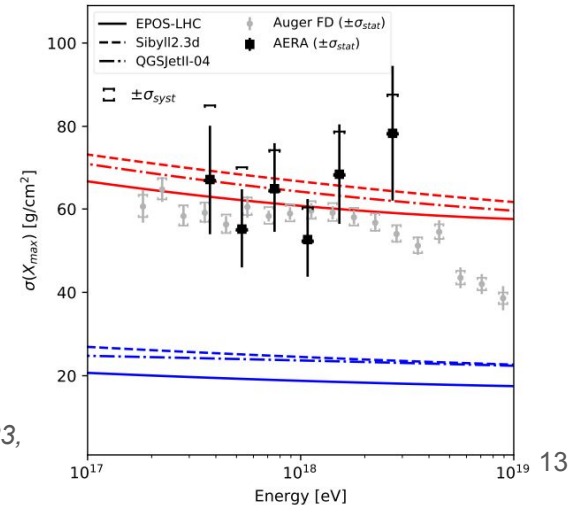
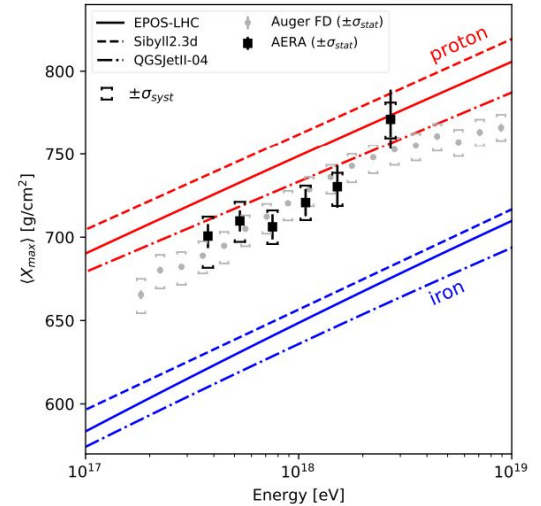
# Assets of GP300

Discrepancy among all measurements, could GP300 help ?

- GP300 : **autonomous radio detection**
- Sensible only to the EM part of the showers (don't use muons)
- Systematics are different

AERA : for now, only used events triggered by the SD

Large exposure of GP300

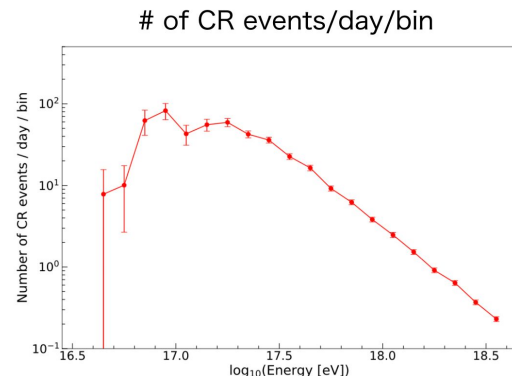
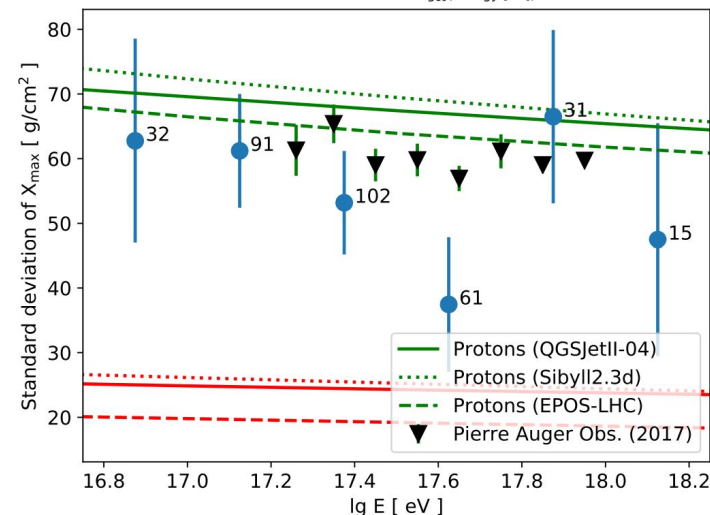
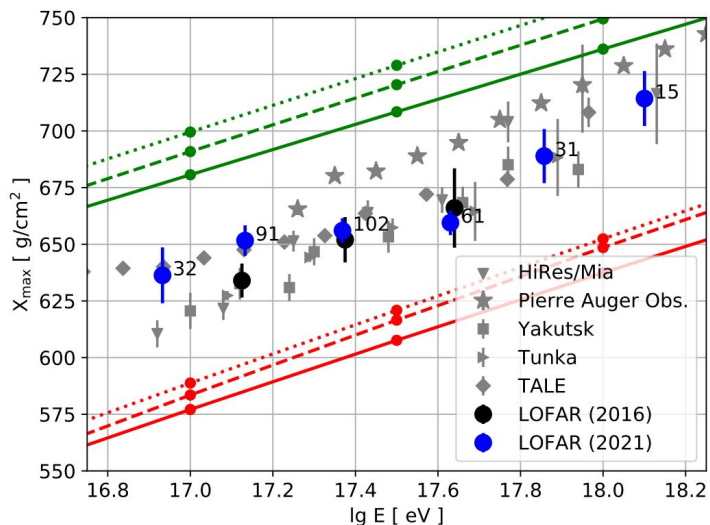


# Radio measurements by LOFAR and AERA

AERA : 9336 preselected  
events between  $10^{17.5}$   
and  $10^{18.8}$  eV (7 years)

N events in AERA :

$\langle \lg(E[\text{eV}]) \rangle$	$N$
17.6	167
17.7	150
17.9	127
18.0	74
18.2	43
18.4	33



# Outlook

- ❖ GP300 will study the transition region, where many questions are still raised : sources, end of galactic components ?
- ❖ Dipole anisotropy :
  - No clear detection yet (in this energy range)
  - Complement the few measurements/constraints we have in this region
- ❖ Composition
  - key information for understanding the CR spectrum
  - Autonomous radio detection : different systematics
  - Larger exposure than LOFAR or AERA

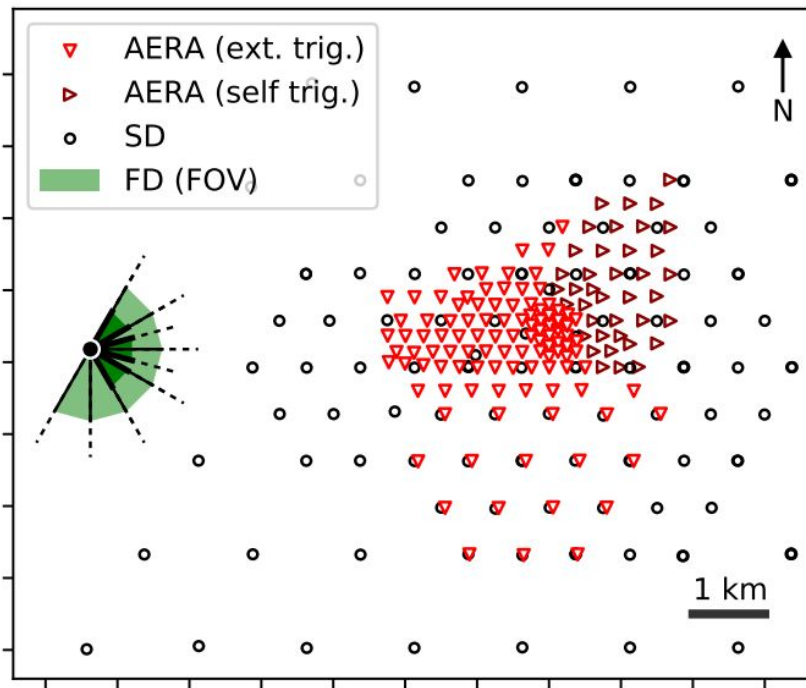
Thanks for your  
attention !





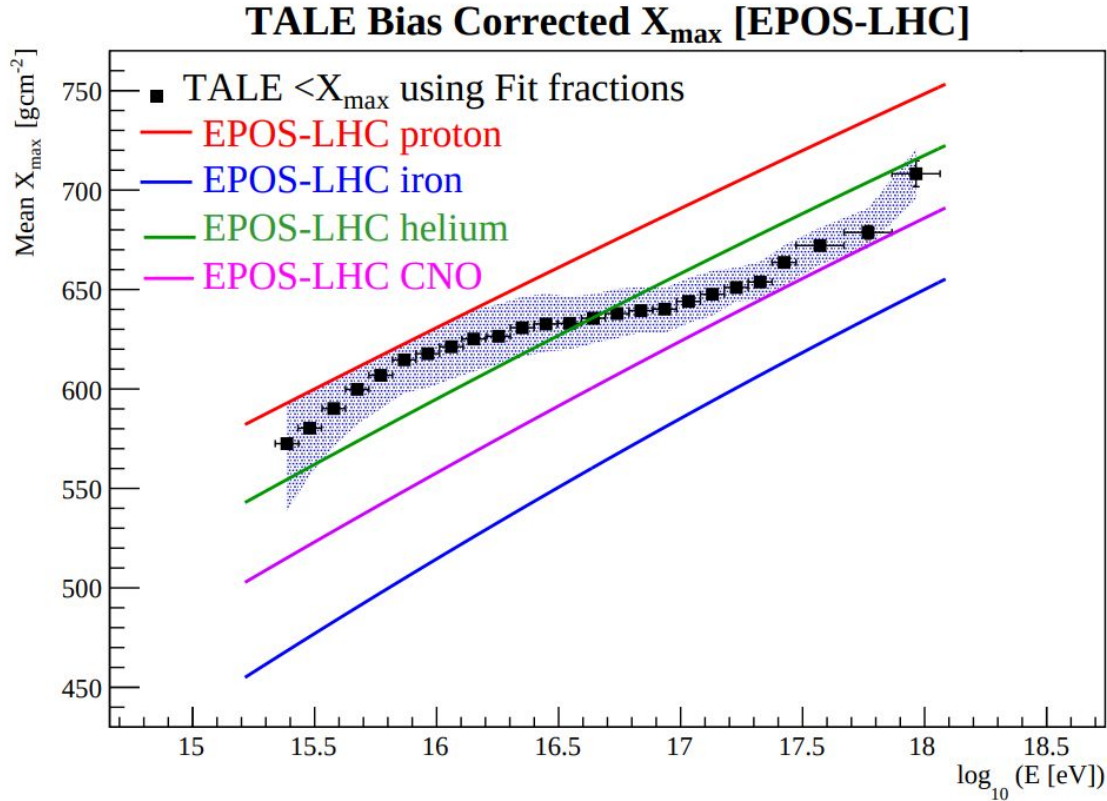
# Backup slides

# AERA (Auger Engineering Radio Array)



153 radio stations  
30 - 80 MHz

# TALE : X<sub>max</sub>



TA collaboration, 2023,  
arXiv:2012.10372v2

# Compton-Getting Effect

$$A_{\text{CCG}} \equiv \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}} = \left( 2 - \frac{d \ln I}{d \ln E} \right) u$$

*M. Kachelrieß and P.D. Serpico, 2006, 0605462v2*