The energy dependence and component dependence of large scale anisotropy of CRs

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Outline

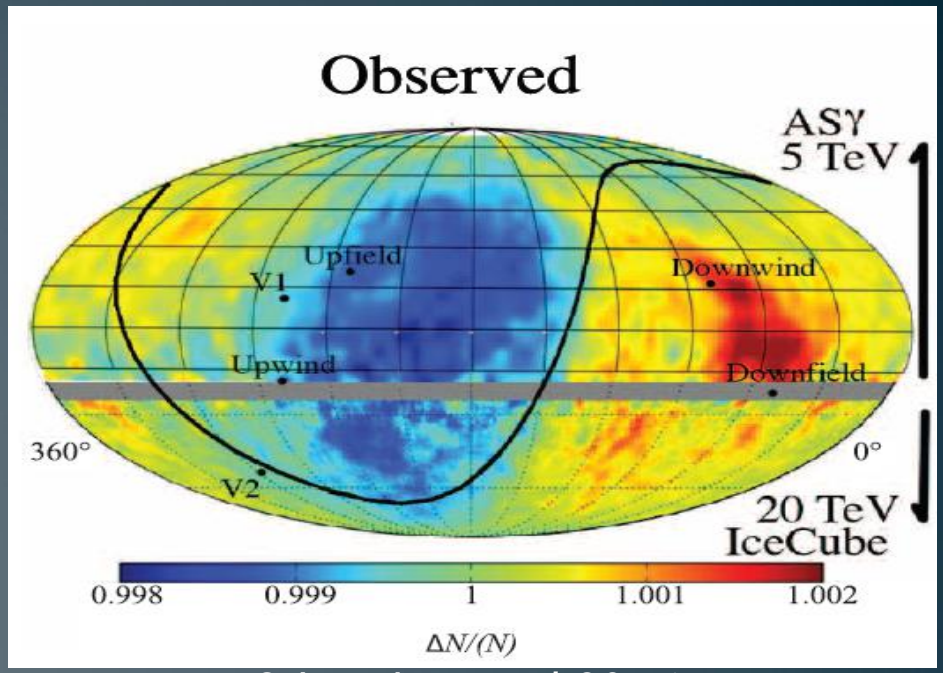
- Introduction
- ARGO-YBJ data
- Energy dependence
- Component dependence
- Conclusion
- Outlook

1.Introduction

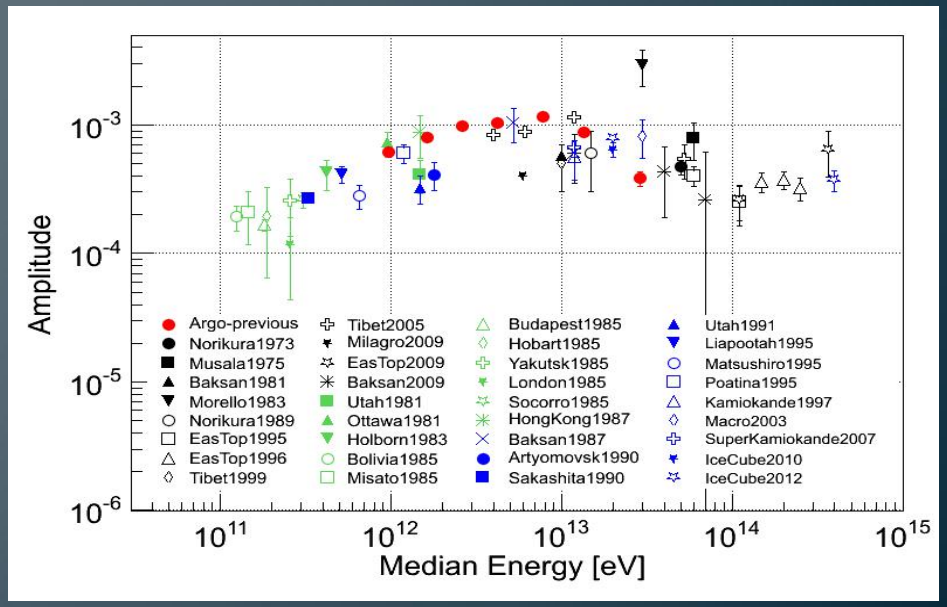
- 0.1 TeV —100TeV

- North sky: Tibet ASr, Milagro, ARGO-YBJ.

- South sky: IceCube.



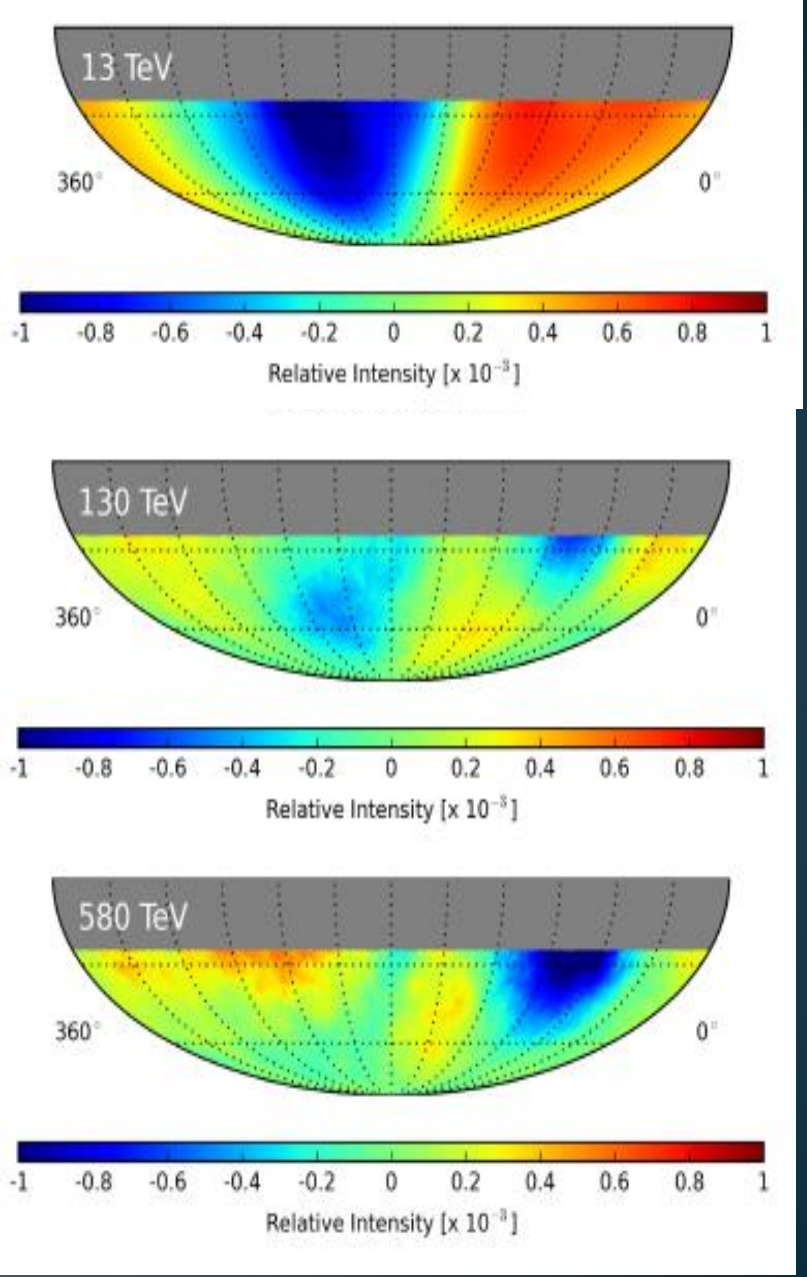
Schwadron *et al 2014*



Bartoli *et al 2015*

➢>100TeV

- The anisotropy is reverse
- North sky: Tibet ASr, EAS-TOP
- South sky: IceCube, IceTop



Aartsen *et al 2016*

The origin of the anisotropy?

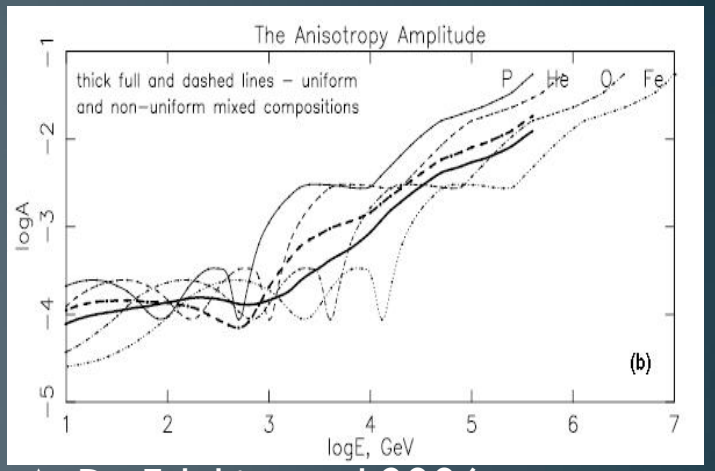
- SNR, diffuse --- $(1/Z)^{a}$
- Magnetic: --- Z^{a}

  galactic,

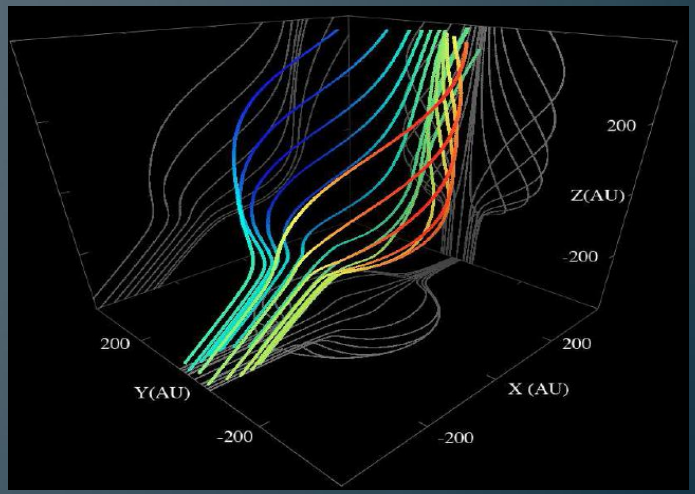
  local interstellar,

  solar

Component dependence could provide more information!



A. D. Erlykin et al.2006



Schwadron et al.2014

Why use ARGO-YBJ?

- Large data sample
- Light component selection

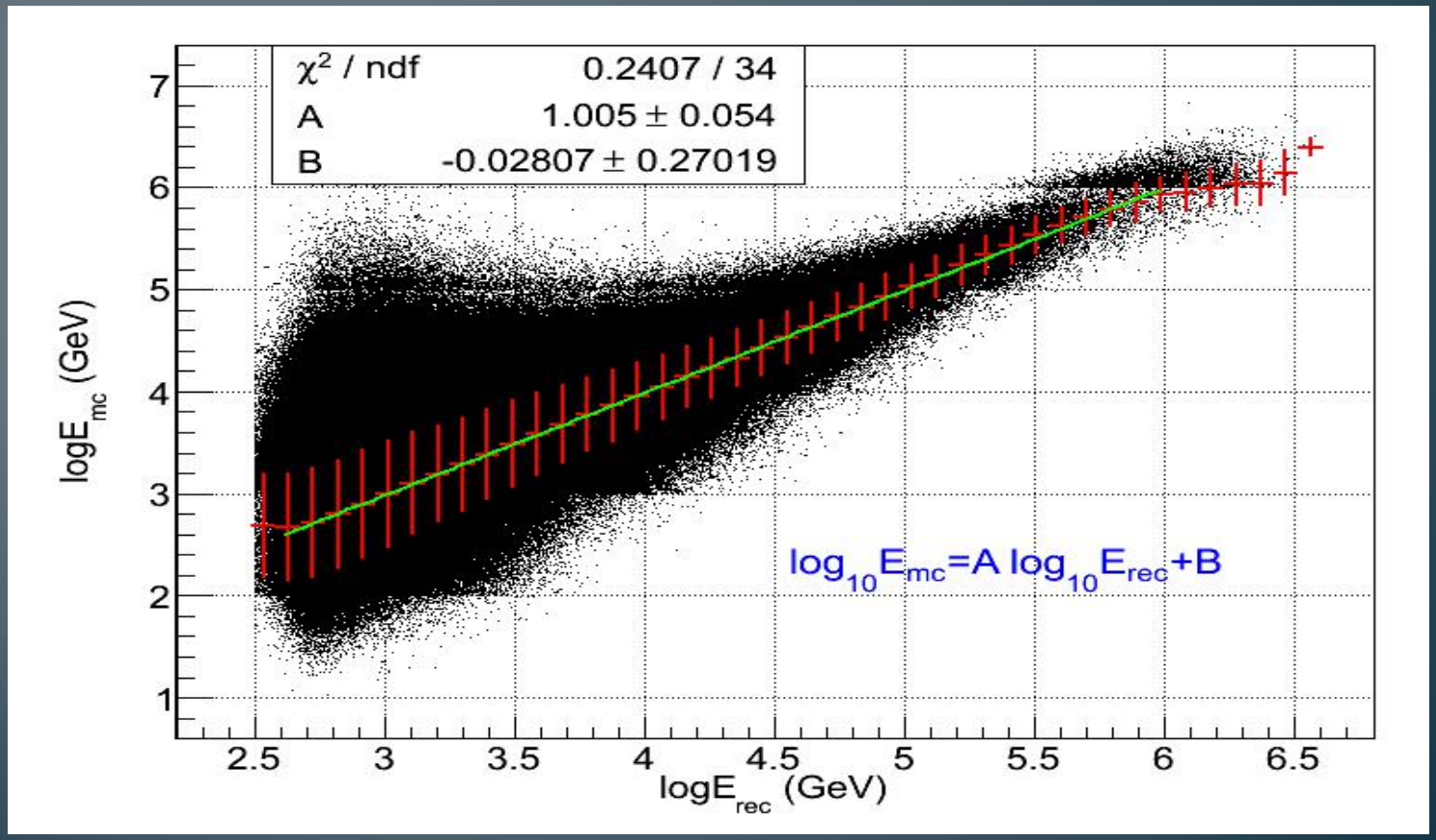
2. ARGO-YBJ data

- The events used in this work were collected by ARGO from 2008 to 2009.

The Cut Condition	No cut	$\theta < 50°$	$nStr\_ca \geq 20$	$R \leq 100m$	$\chi^2 < 100$
NUM ($\times 10^{11}$)	1.8597	1.7521	1.7516	1.1248	1.0068
Retaining Ratio	--------	94.21%	94.19%	60.48%	54.14%

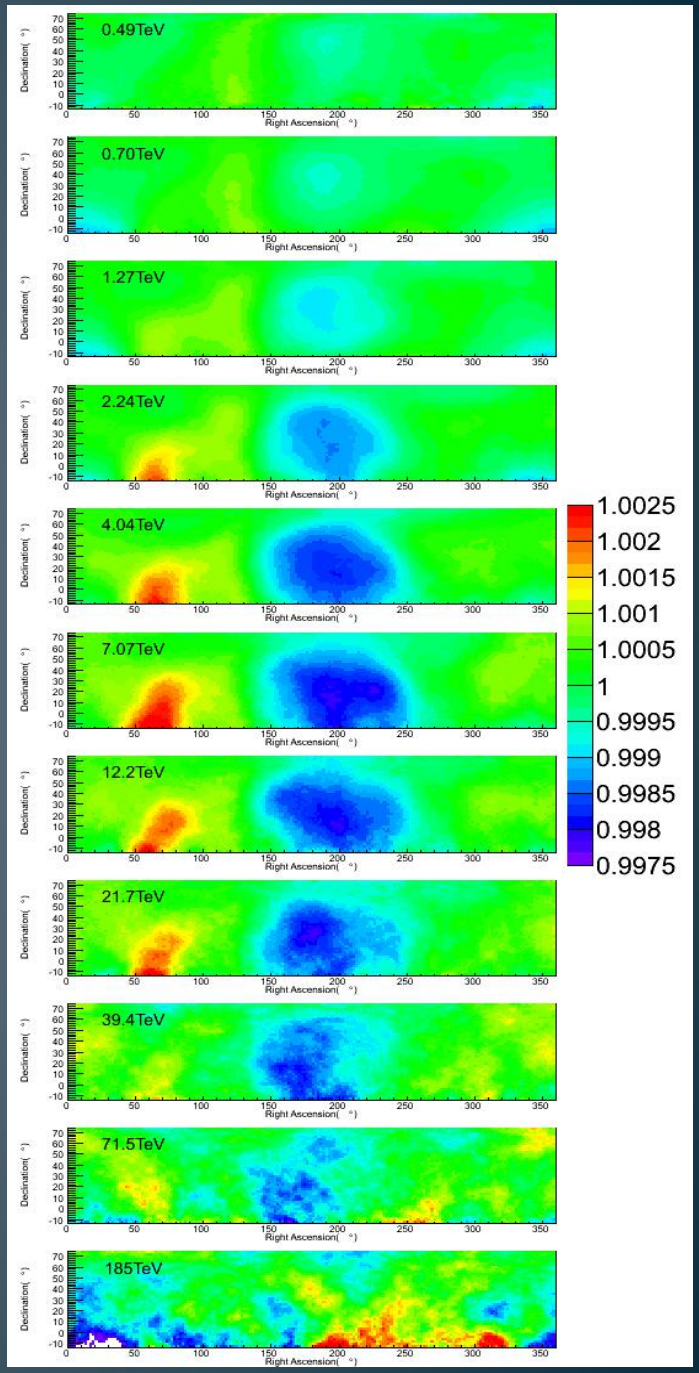
3.Energy dependence

- Median true energy as a function of θ, nStr_ca and R.

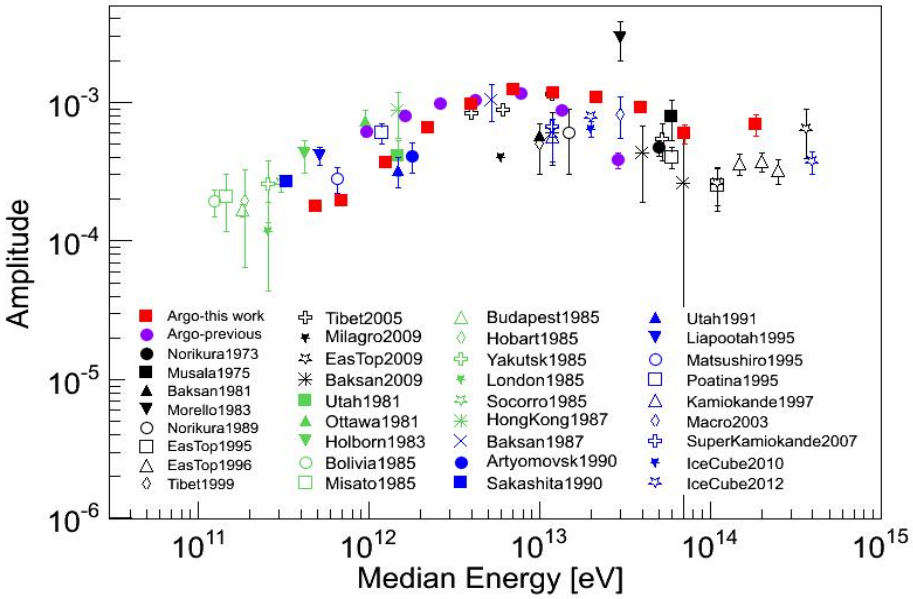


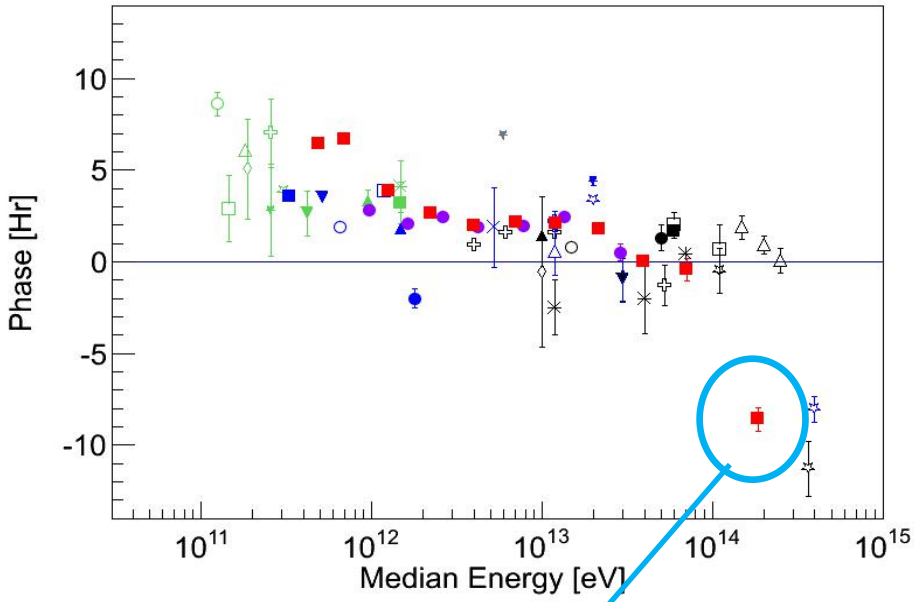
Energy dependence

N	$\log_{10}$E(GeV)	E(TeV)	NUM$\times 10^8$
1	2.50-2.75	0.49	130.0
2	2.75-3.00	0.70	370.0
3	3.00-3.25	1.27	220.0
4	3.25-3.50	2.24	130.0
5	3.50-3.75	4.04	71.0
6	3.75-4.00	7.07	38.0
7	4.00-4.25	12.2	20.0
8	4.25-4.50	21.7	10.0
9	4.50-4.75	39.4	5.0
10	4.75-5.00	71.5	2.2
11	>5.0	185	1.5



With 1D fit parameter

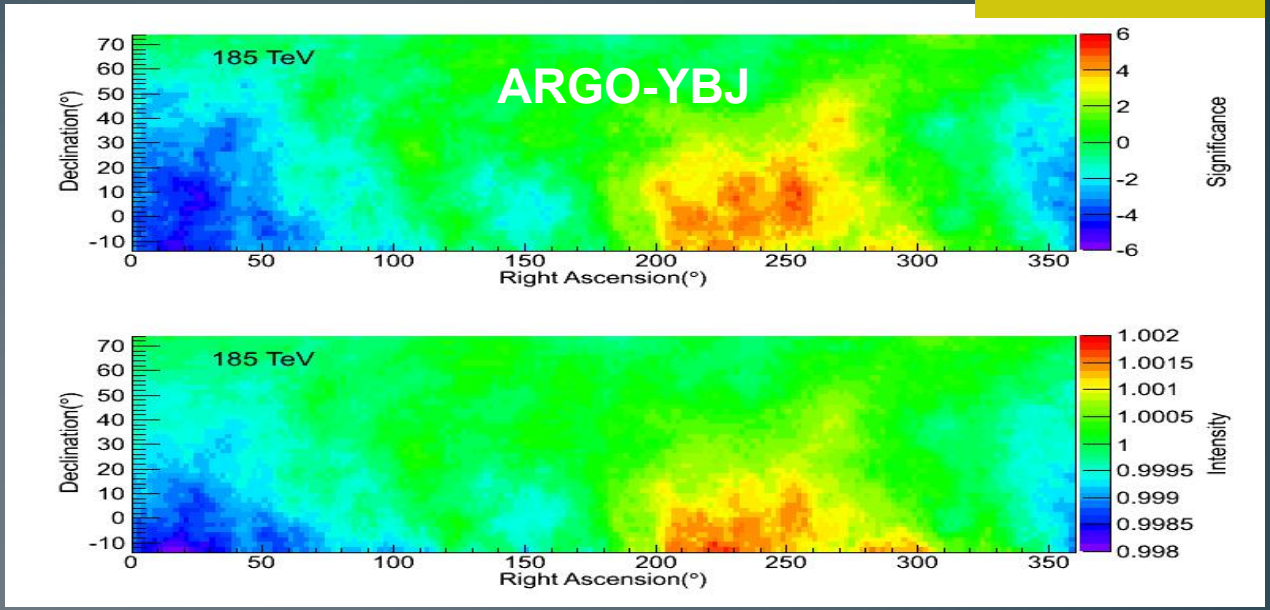




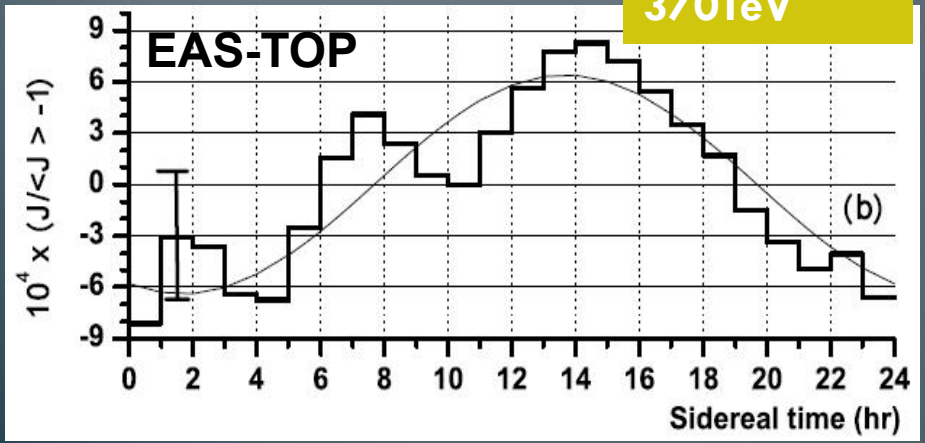
- Old: 1—30 TeV
- New: 0.5—185 TeV

The phase change at 185TeV

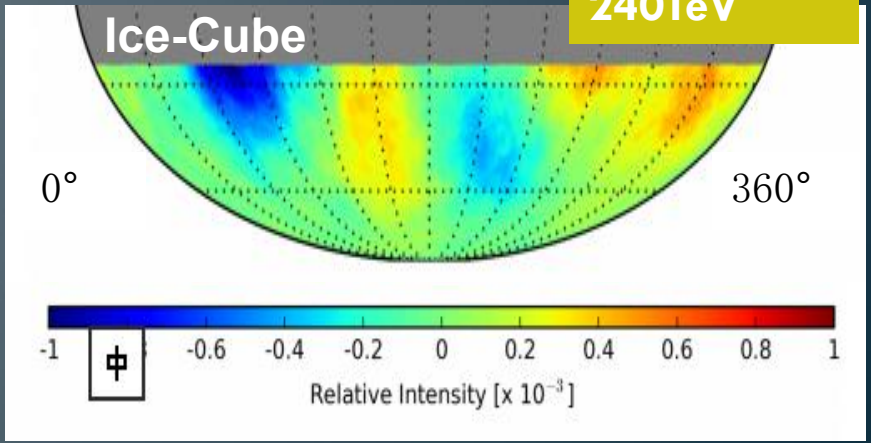
185TeV



370TeV



240TeV

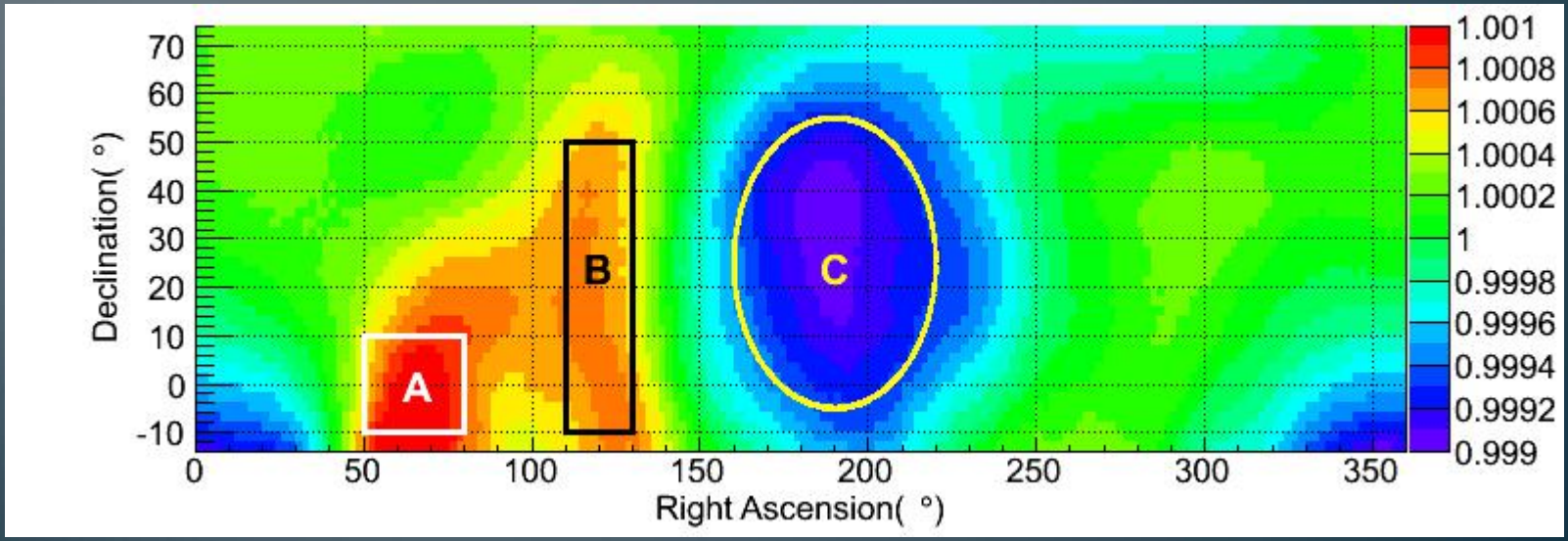


Aglietta et. al. 2009

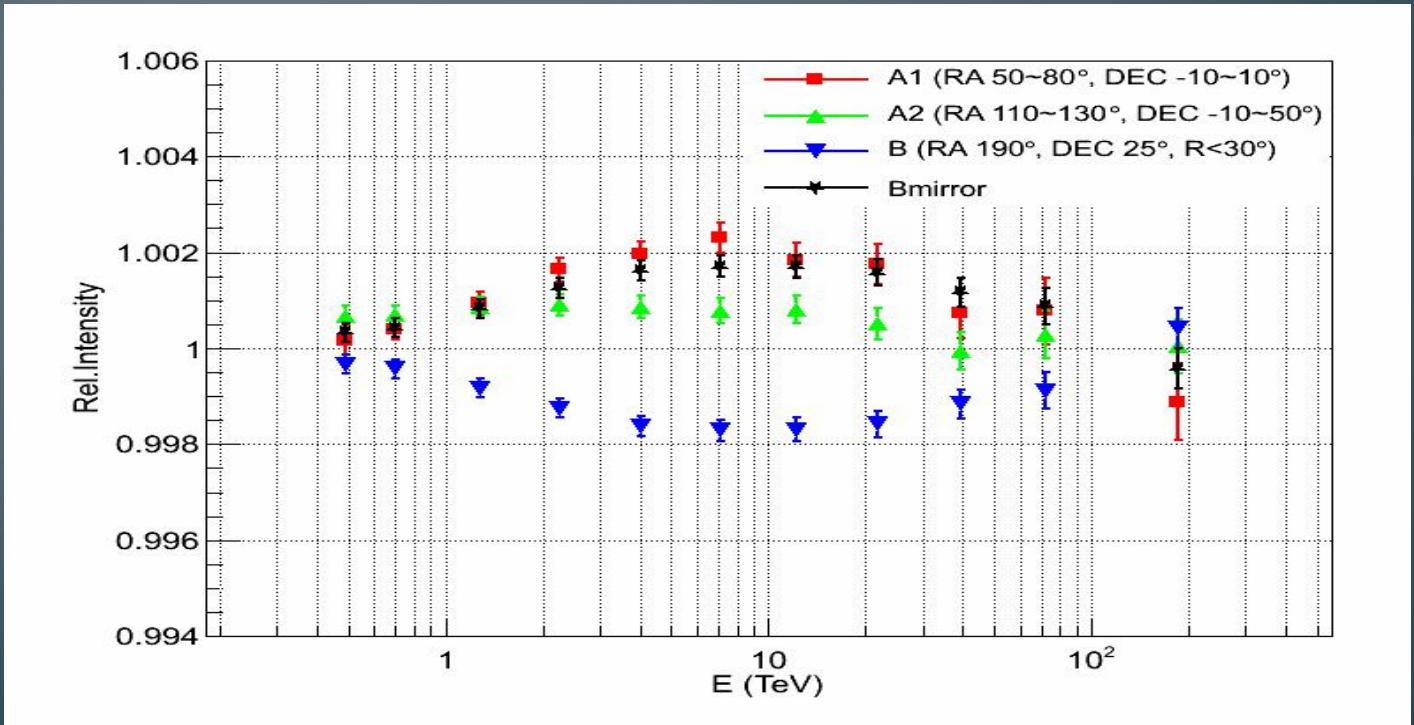
Aartsen et al 2016

Select three area

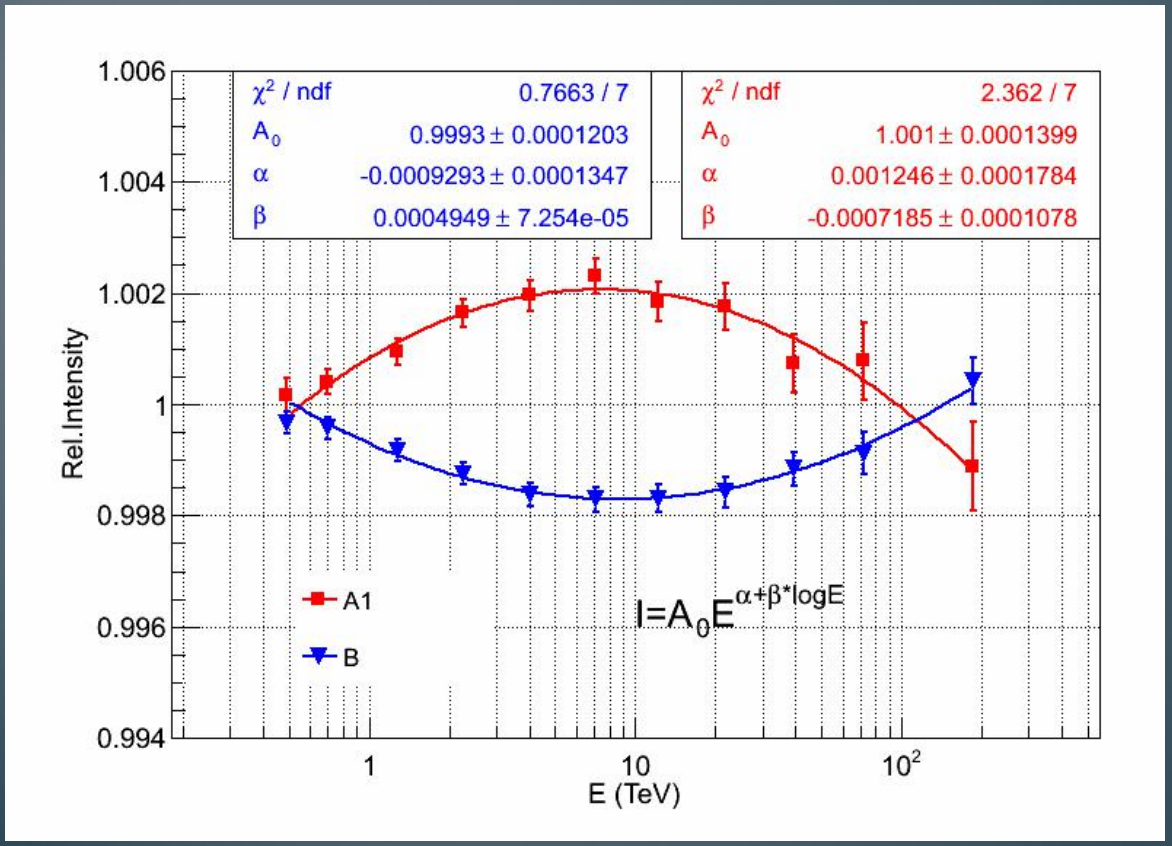
Area	RA	DEC	Radius
A1	50°~80°	-10°~10°	--
A2	110°~130°	-10°~50°	--
B	190°	25°	30°



- A1 and B, same origin?
- A2 is different from A1 and B, different origin?



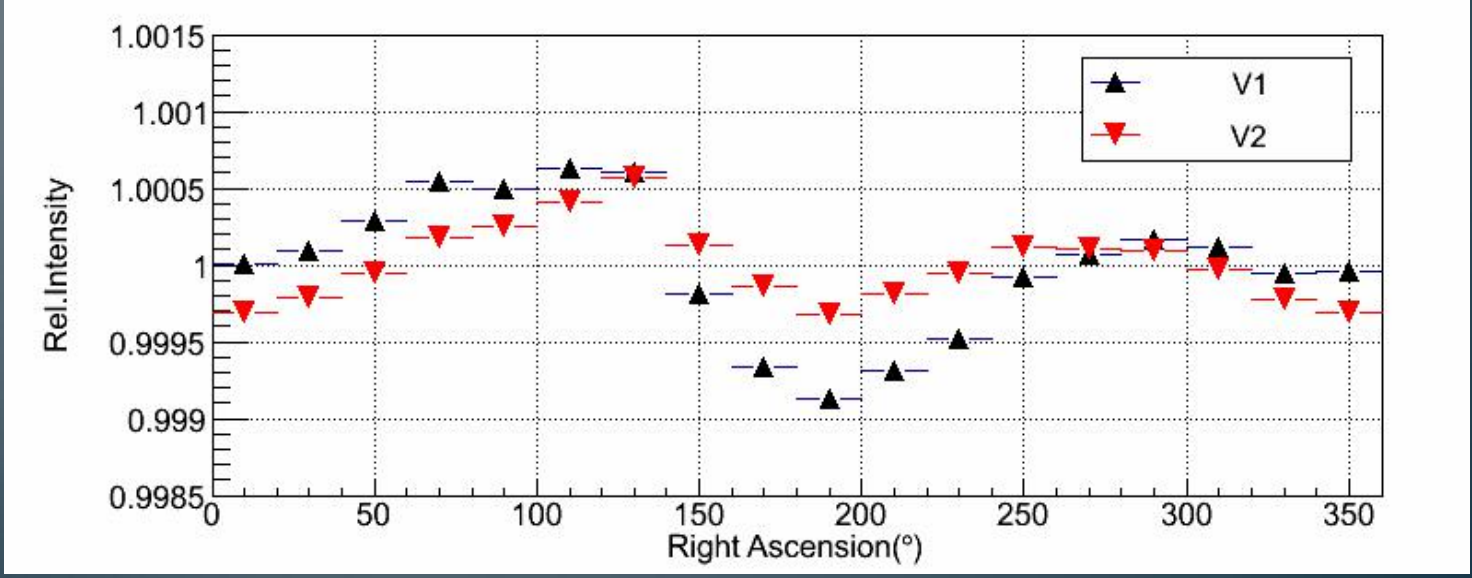
- A1 and B



The peak at:
A1: 7.4 TeV
B: 8.7 TeV

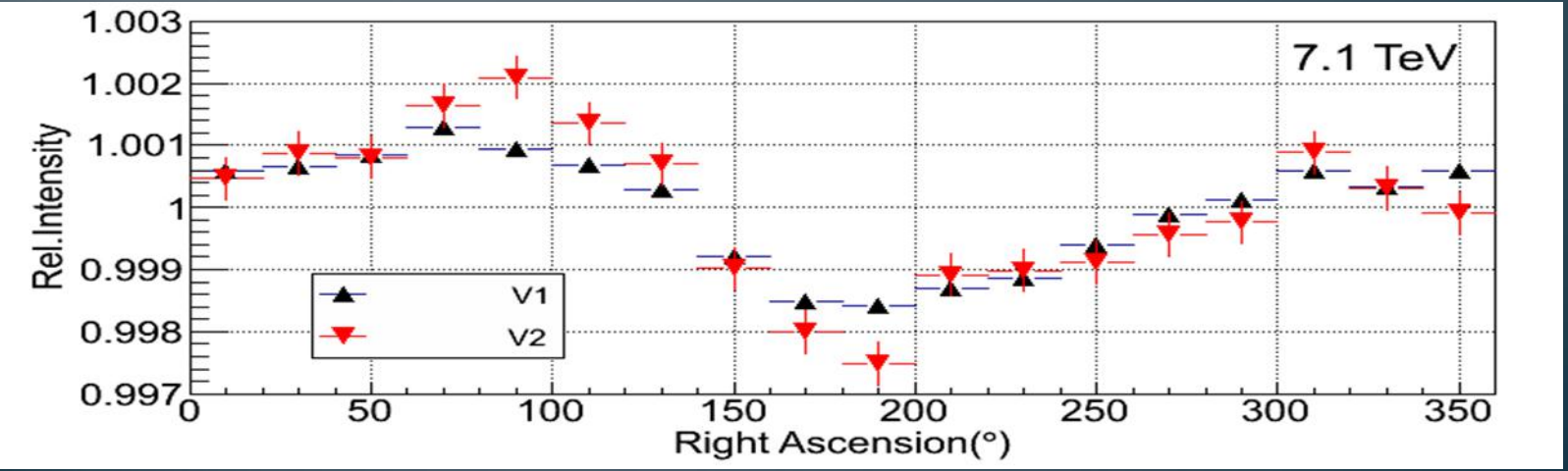
4.Component dependence

Component	P(%)	He(%)	CNO(%)	MgAlSi(%)	Fe(%)	E(TeV)
V1	72.6	22.1	3.3	0.9	1.0	1.27
V2	77.6	18.9	2.3	0.6	0.5	0.68



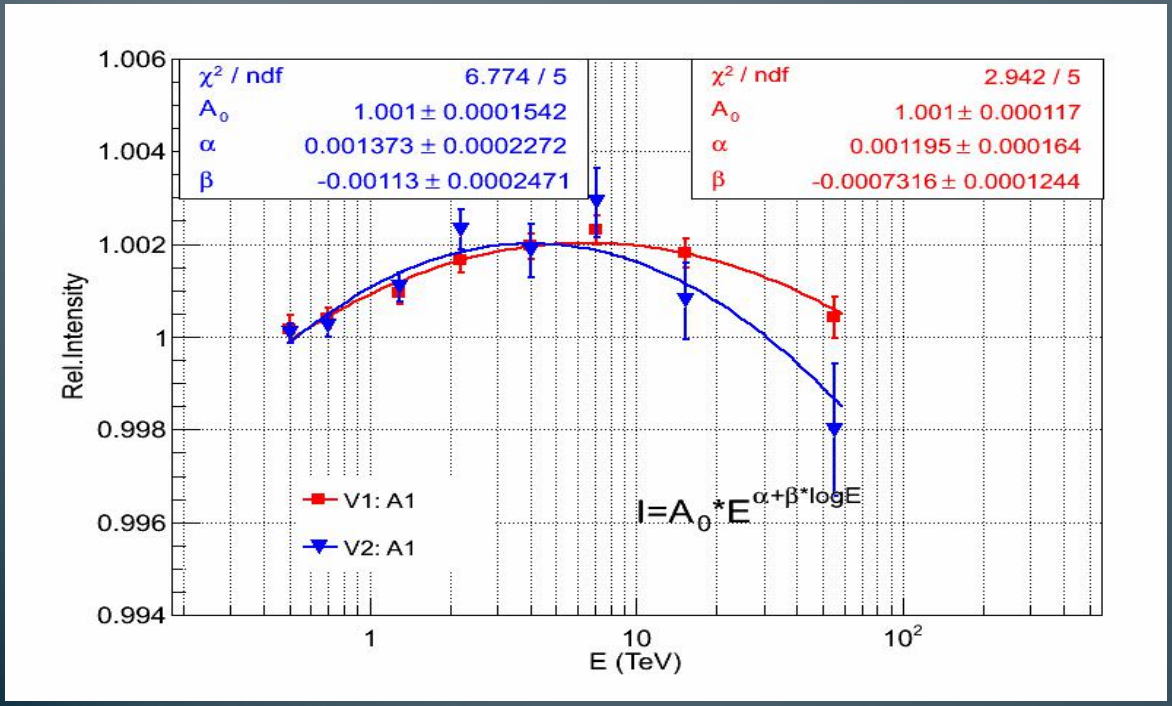
At same energy

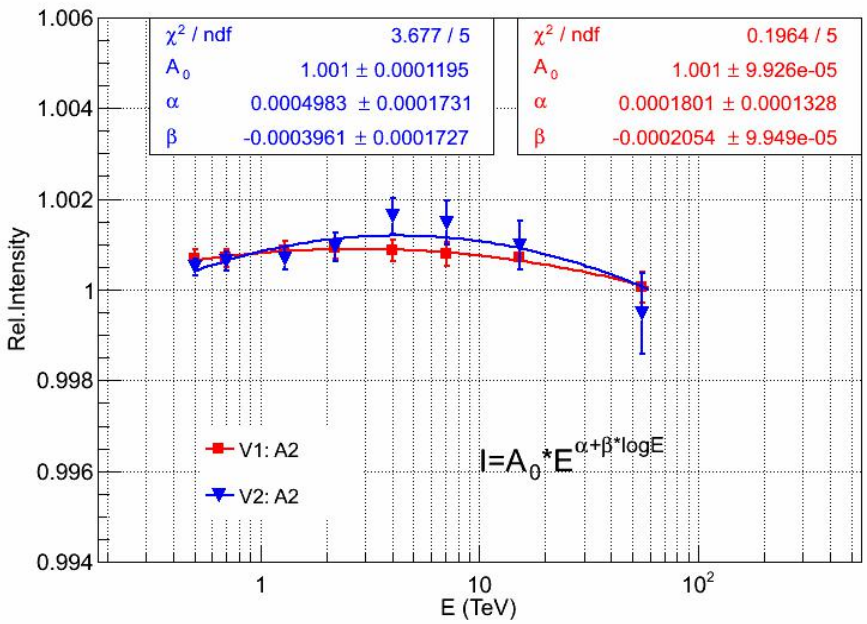
Energy(TeV)		7.1	
Sample		V1	V2
component Ratio (%)	H	68.4	83.8
	He	28.7	15.5
	CNO	4.4	0.6
	MgAlSi	1.1	0.1
	Fe	1.0	0.0

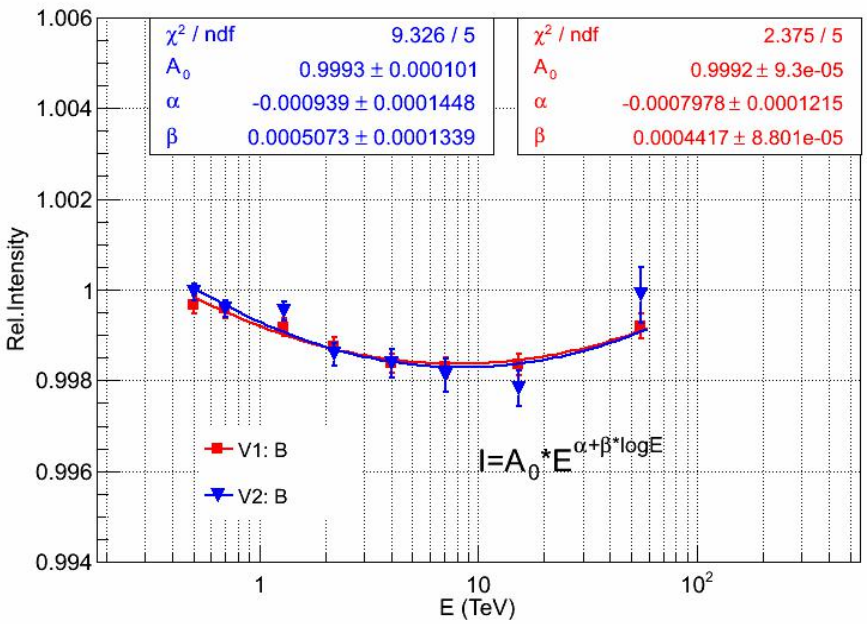


The energy dependence of V1 and V2

E	0.5TeV	0.7TeV	1.3TeV	2.2TeV	4.0TeV	7.1TeV	15.3TeV	55.0TeV
lgE (GeV)	2.5~2.75	2.75~3.0	3.0~3.25	3.25~3.5	3.5~3.75	3.75~4.0	4.0~4.5	>4.5
V1	1.3e10	3.7e10	2.2e10	1.3e10	7.1e9	3.8e9	3.0e9	8.7e8
V2	1.7e10	8.1e9	2.2e9	7.9e8	3.7e8	1.9e8	1.5e8	3.9e7




χ² / ndf 3.677 / 5
A0 1.001 ± 0.0001195
α 0.0004983 ± 0.0001731
β -0.0003961 ± 0.0001727
χ² / ndf 0.1964 / 5
A0 1.001 ± 9.926e-05
α 0.0001801 ± 0.0001328
β -0.0002054 ± 9.949e-05
Rel.Intensity
E (TeV)
V1: A2
V2: A2
I=A0*E^(α+β*logE)


χ² / ndf 9.326 / 5
A0 0.9993 ± 0.000101
α -0.000939 ± 0.0001448
β 0.0005073 ± 0.0001339
χ² / ndf 2.375 / 5
A0 0.9992 ± 9.3e-05
α -0.0007978 ± 0.0001215
β 0.0004417 ± 8.801e-05
Rel.Intensity
E (TeV)
V1: B
V2: B
I=A0*E^(α+β*logE)

Simple model for component dependence

- Set two models to get the expect E dependence of V2 :

  The first model: assuming ΔI is Z dependence;

  The other one: assuming ΔI is $1/Z$ dependence.

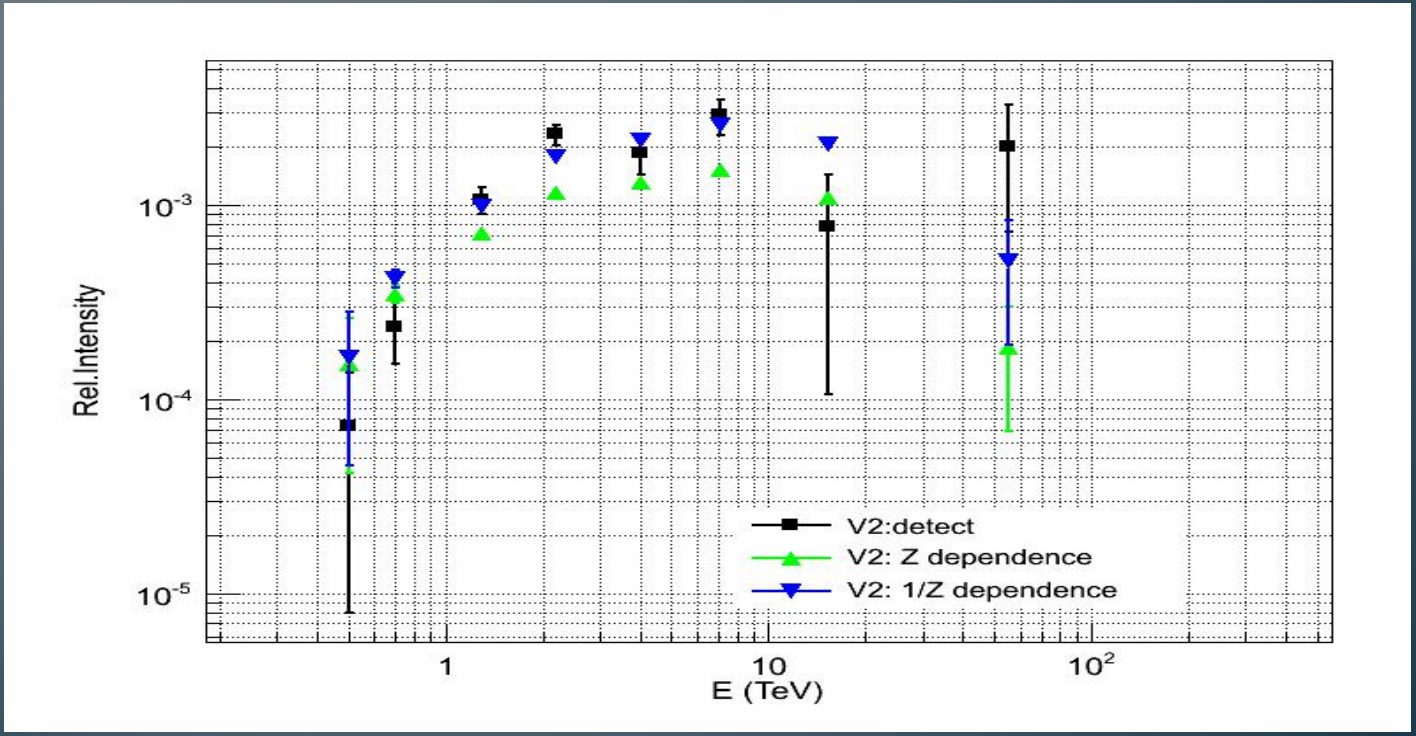
- For each energy range, the anisotropy is calculate as below:

$$\Delta I_{totall} = \sum_j \alpha_j \cdot Z_j \cdot I_0 \quad \text{or} \quad \Delta I_{totall} = \sum_j \alpha_j \cdot \frac{1}{Z_j} \cdot I_0$$

- Table I shows the component ratio of V1 and V2, table II shows the expect anisotropy of V2.

Data vs expected

1/Z or Z dependence ?



6.Conclusion

- Energy dependence of the LSA of CRs:

  Extend the energy to 0.5~185TeV, the peak at 8.7TeV.

  A1 and B maybe have same origin, A2 is different.

  The phase of LSA at 185TeV changed, same as ICECUBE at 240TeV.

- Component dependence

  >1TeV: 1/Z or Z dependence ?

  The models are need more studying.

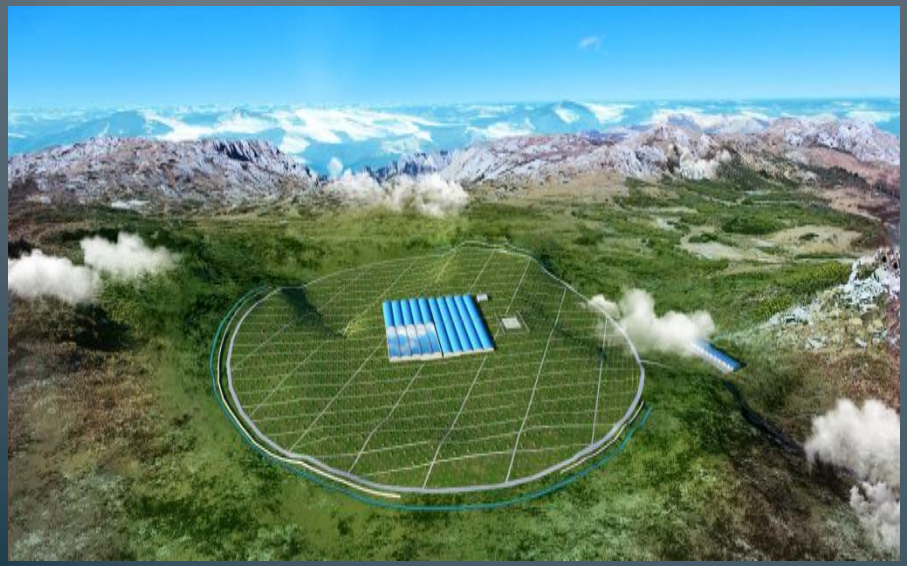
Out look

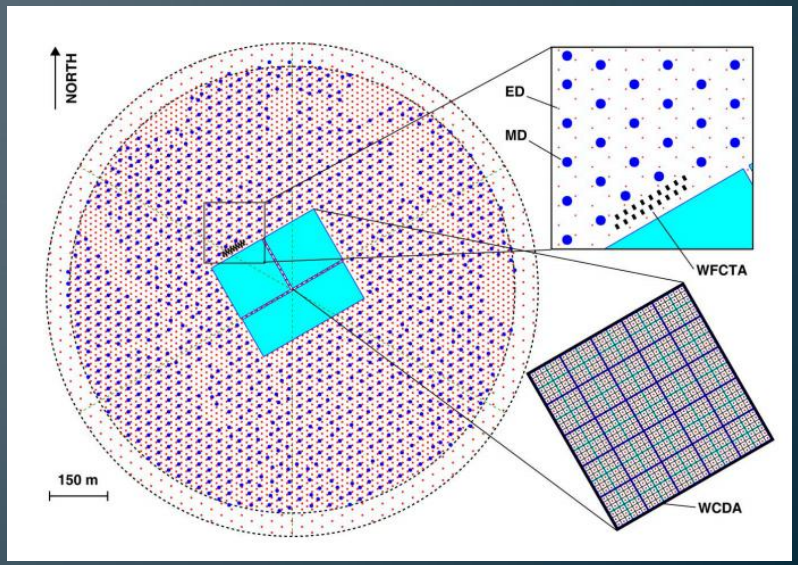
- LHAASO:

  Very broad energy range;

  High statistics;

  Better component discrimination.





Back up

- Table I: The component ratio α_j:

E(TeV)		0.5	0.7	1.3	2.2	4.0	7.1	15.3	55.0
V1	P	0.745	0.736	0.735	0.722	0.709	0.684	0.632	0.523
	He	0.207	0.212	0.215	0.226	0.238	0.260	0.296	0.348
	CNO	0.031	0.032	0.032	0.033	0.035	0.037	0.048	0.074
	Mg-Si	0.009	0.009	0.009	0.009	0.009	0.009	0.013	0.025
	Fe	0.008	0.010	0.010	0.010	0.009	0.009	0.011	0.030
V2	P	0.766	0.779	0.808	0.839	0.842	0.838	0.816	0.765
	He	0.196	0.187	0.170	0.146	0.149	0.155	0.178	0.230
	CNO	0.026	0.023	0.017	0.011	0.007	0.006	0.006	0.005
	Mg-Si	0.007	0.006	0.003	0.002	0.001	0.001	0.001	0.000
	Fe	0.006	0.005	0.002	0.001	0.000	0.000	0.000	0.000

- Table II: The expect anisotropy of V2:

E(TeV)	0.5	0.7	1.3	2.2	4.0	7.1	15.3	55.0
Z	0.000151	0.000349	0.000718	0.001162	0.001317	0.001529	0.001100	0.000184
1/Z	0.000165	0.000418	0.000986	0.001787	0.002146	0.002575	0.002076	0.000516

- The simple model with Z and 1/Z dependence.