Transition from galactic to extragalactic cosmic rays and anisotropy

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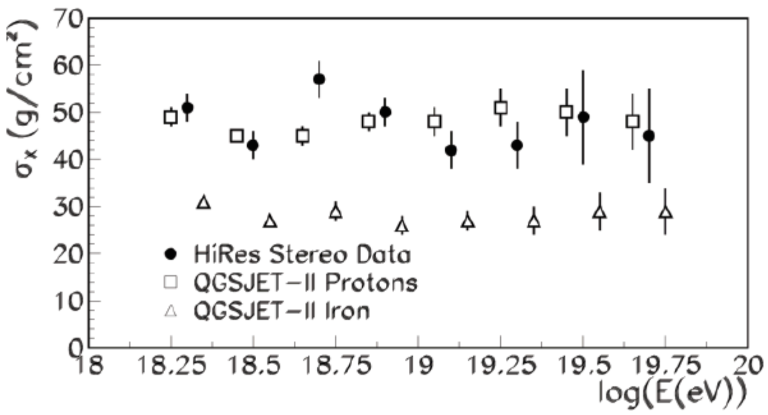
arXiv:1112.5599

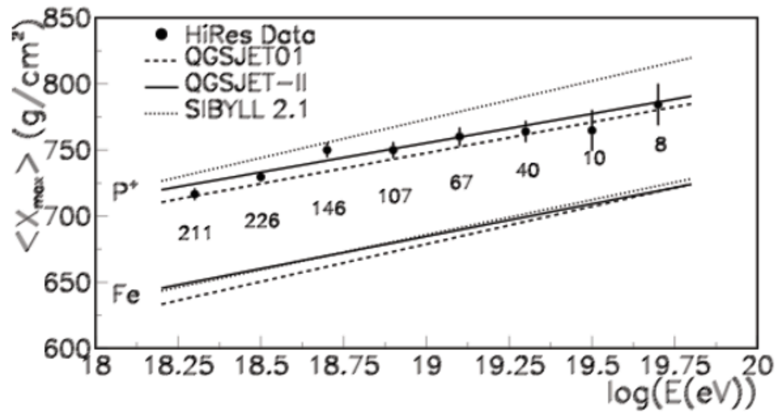
Overview:

- *UHECR composition and anisotropy measurements*
- *Propagation of nuclei in Galactic Magnetic field*
- *What we can learn on galactic component from anisotropy limits?*

UHECR composition

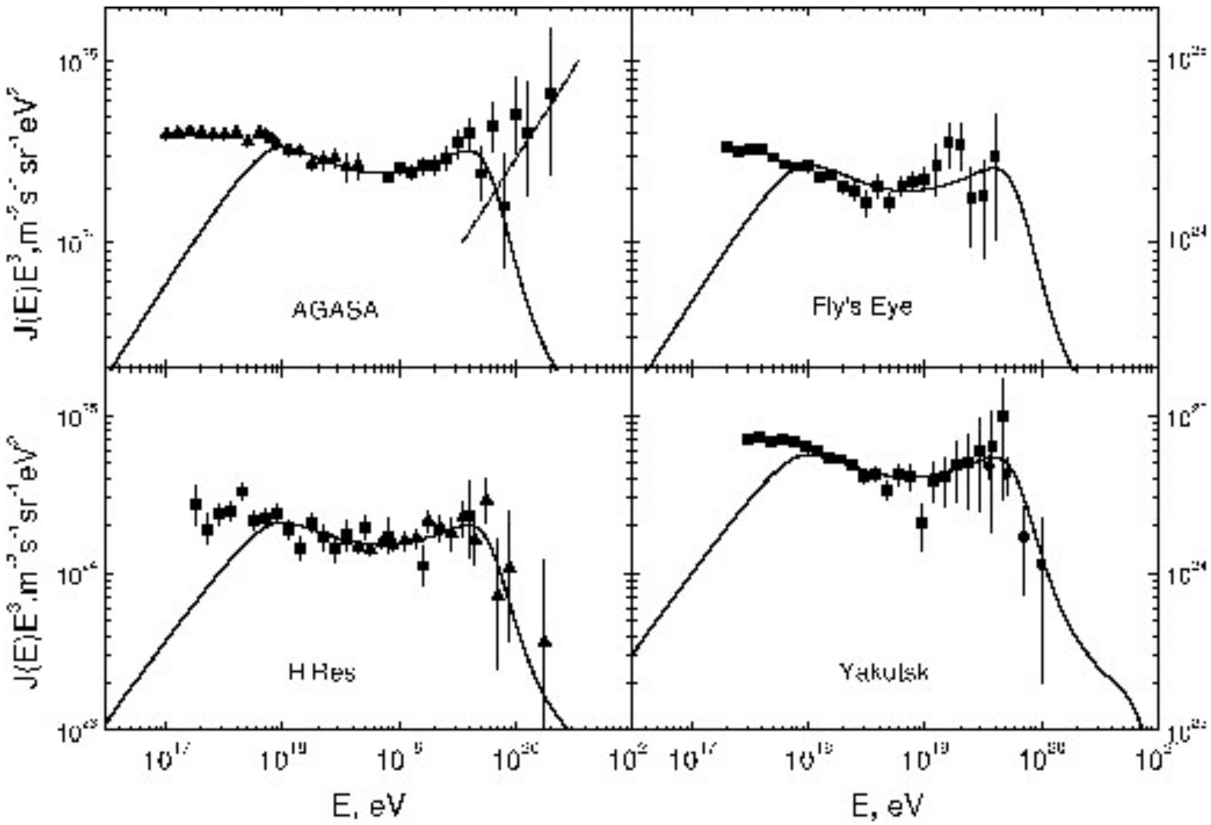
HiRes composition





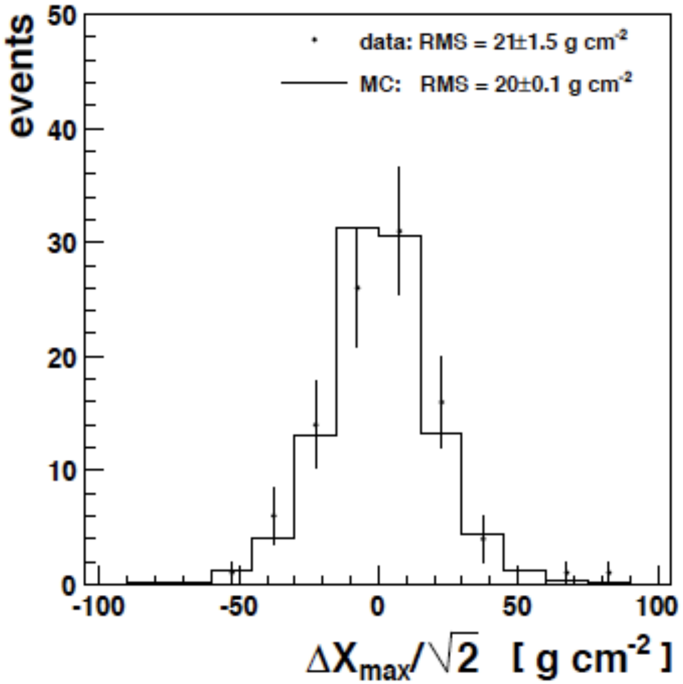
From 1010.2690

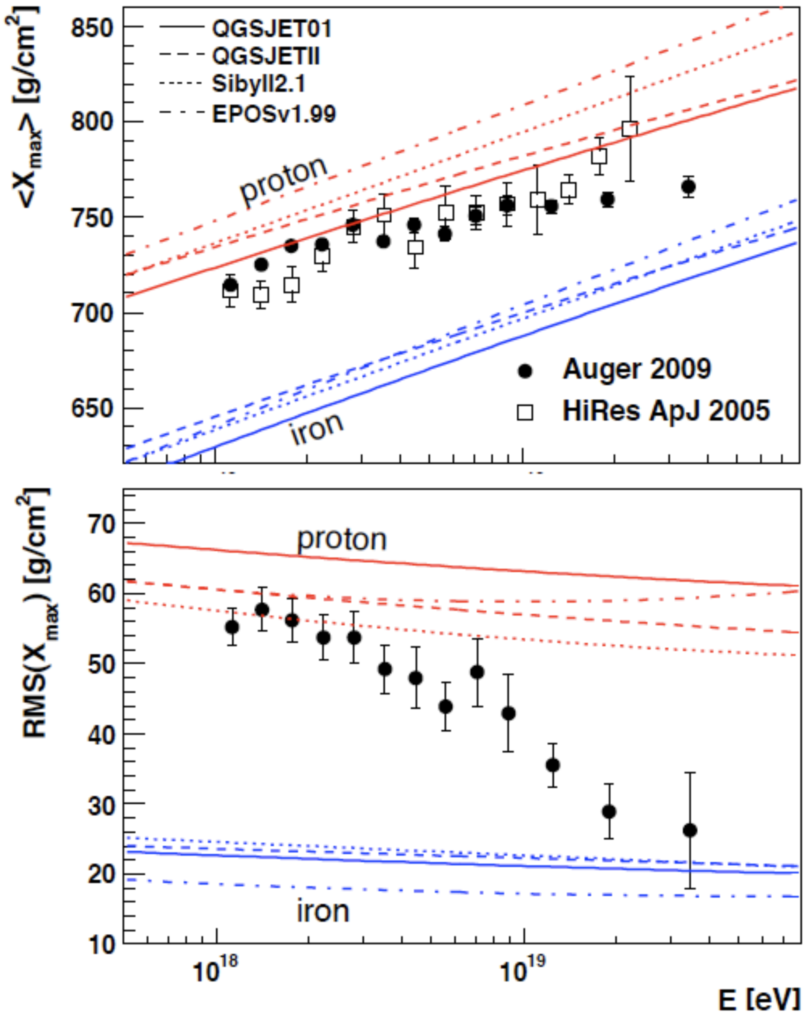
Dip model: Protons can fit UHECR data



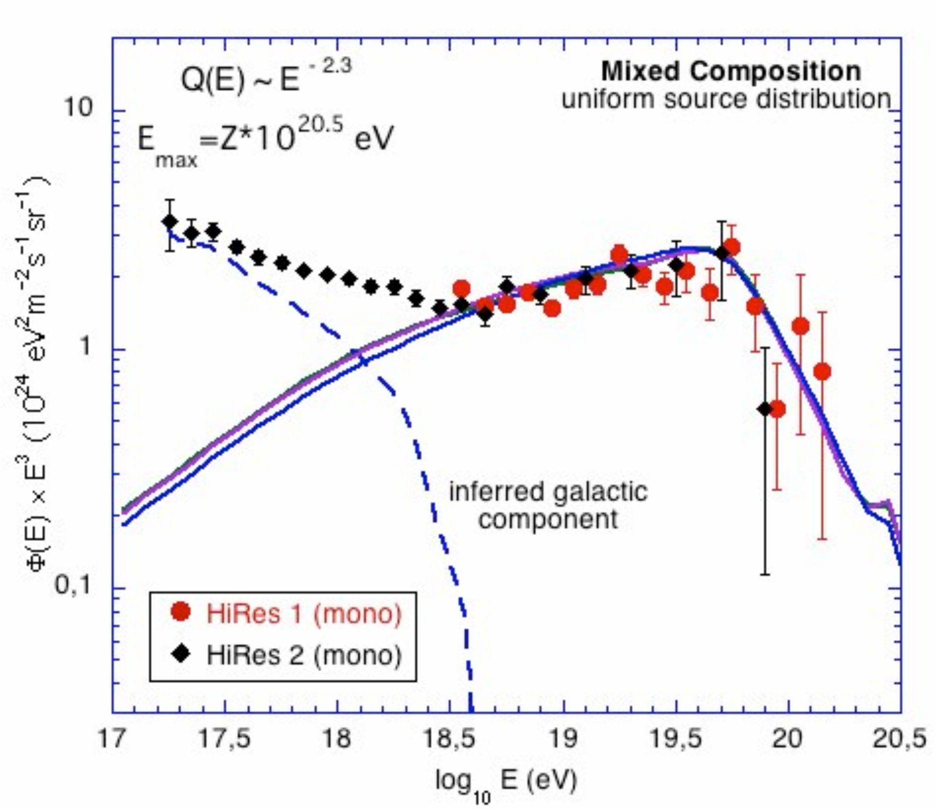
V.Berezinsky , astro-ph/0509069

Auger composition 2009: nuclei





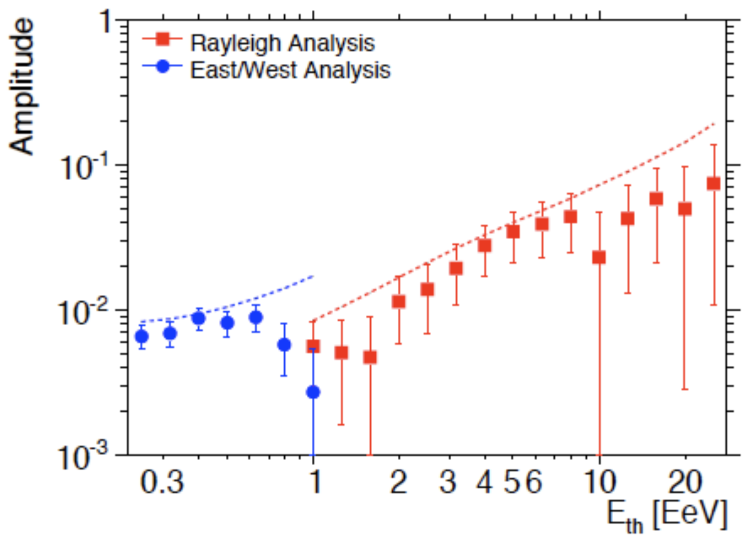
Mixed composition model

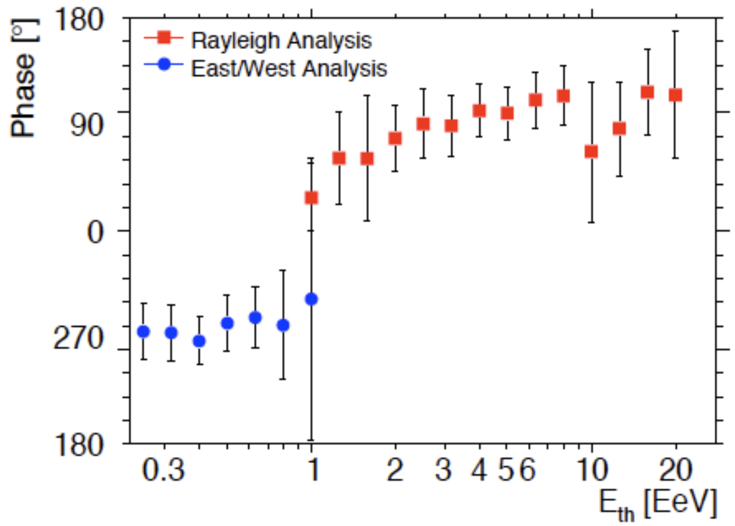


D.Allard, E.Parizot and A.Olinto, astro-ph/0512345

UHECR anisotropy

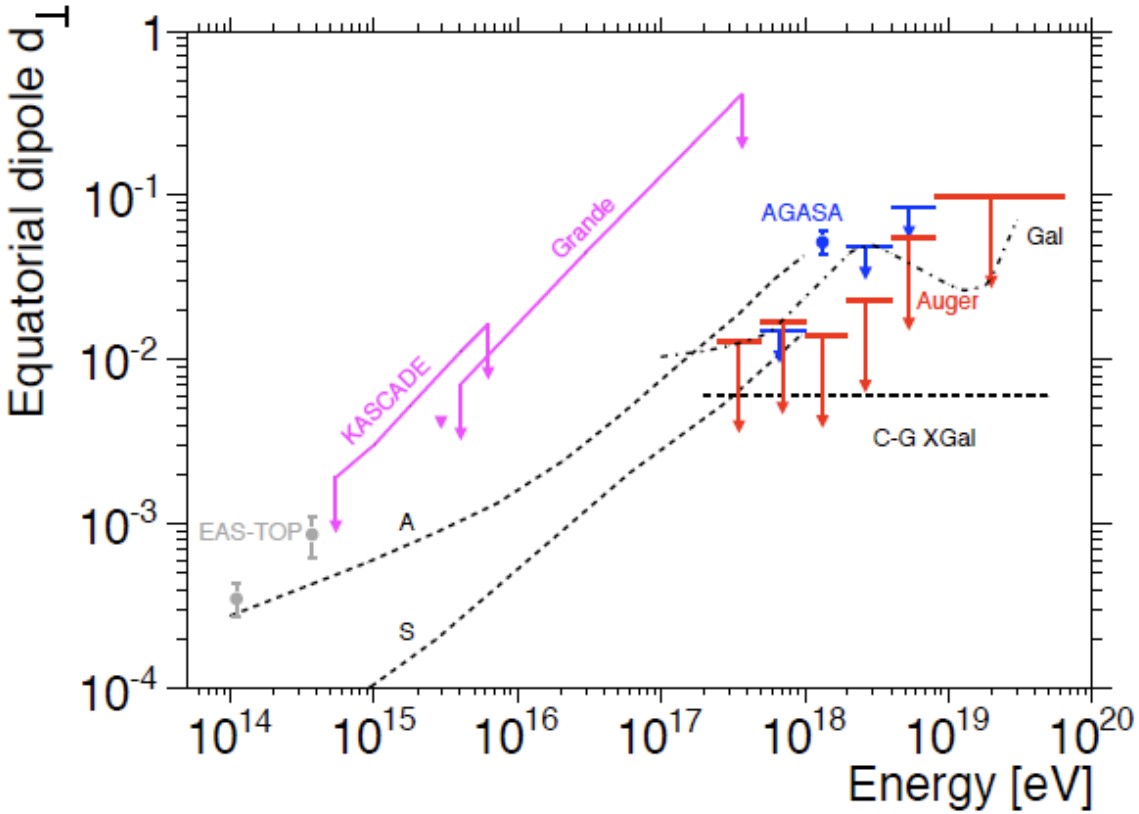
Anisotropy dipole





Pierre Auger Collaboration, arXiv:1103.2721

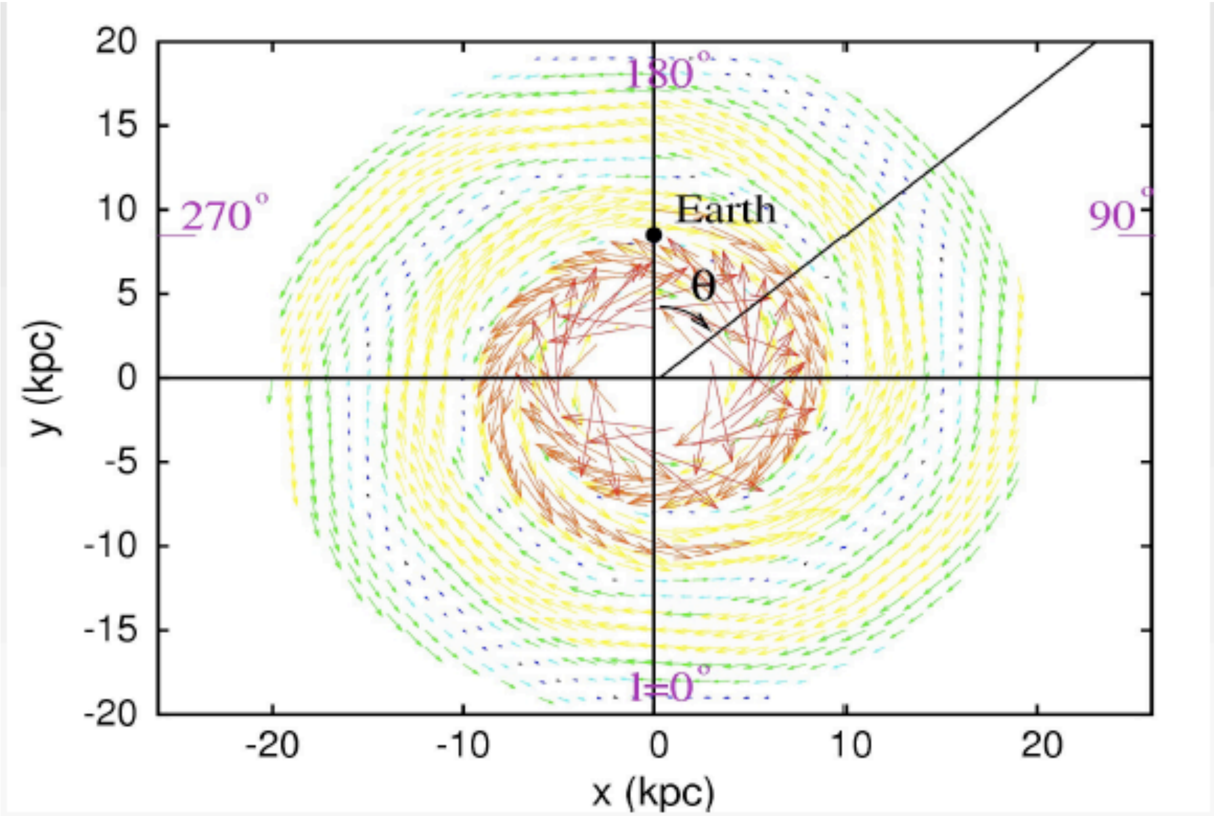
Anisotropy towards Galactic plane



Pierre Auger Collaboration, arXiv:1103.2721

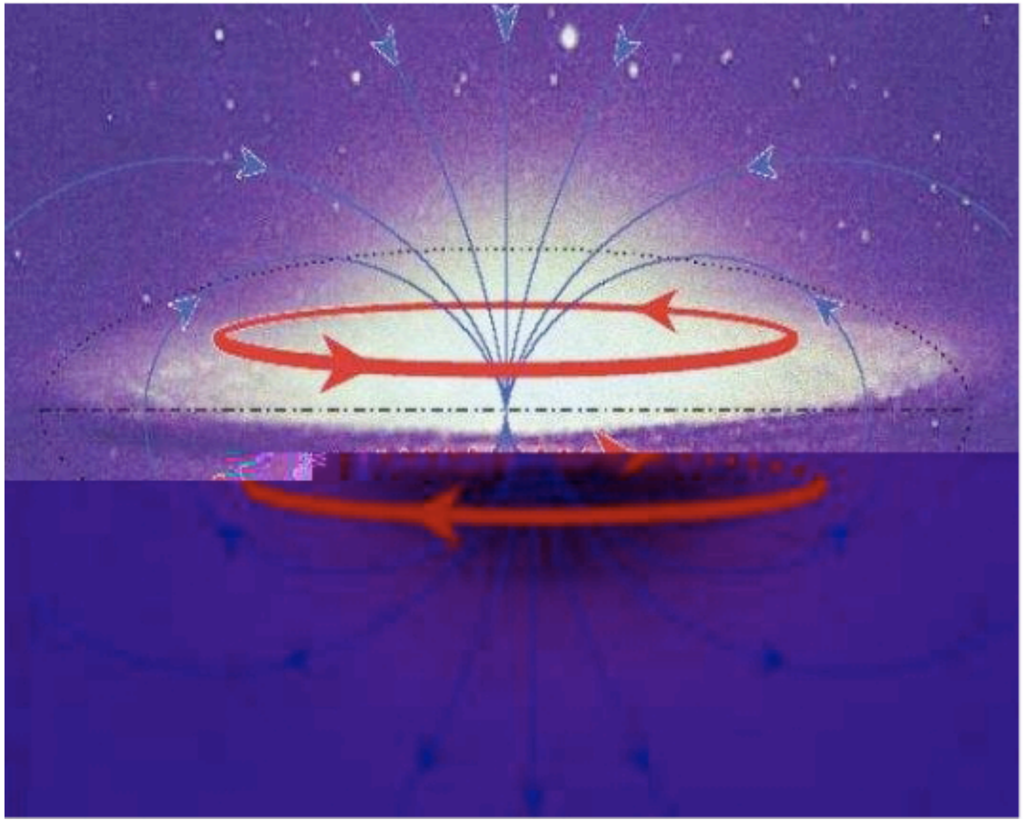
Galactic magnetic field

Galactic magnetic field: disk



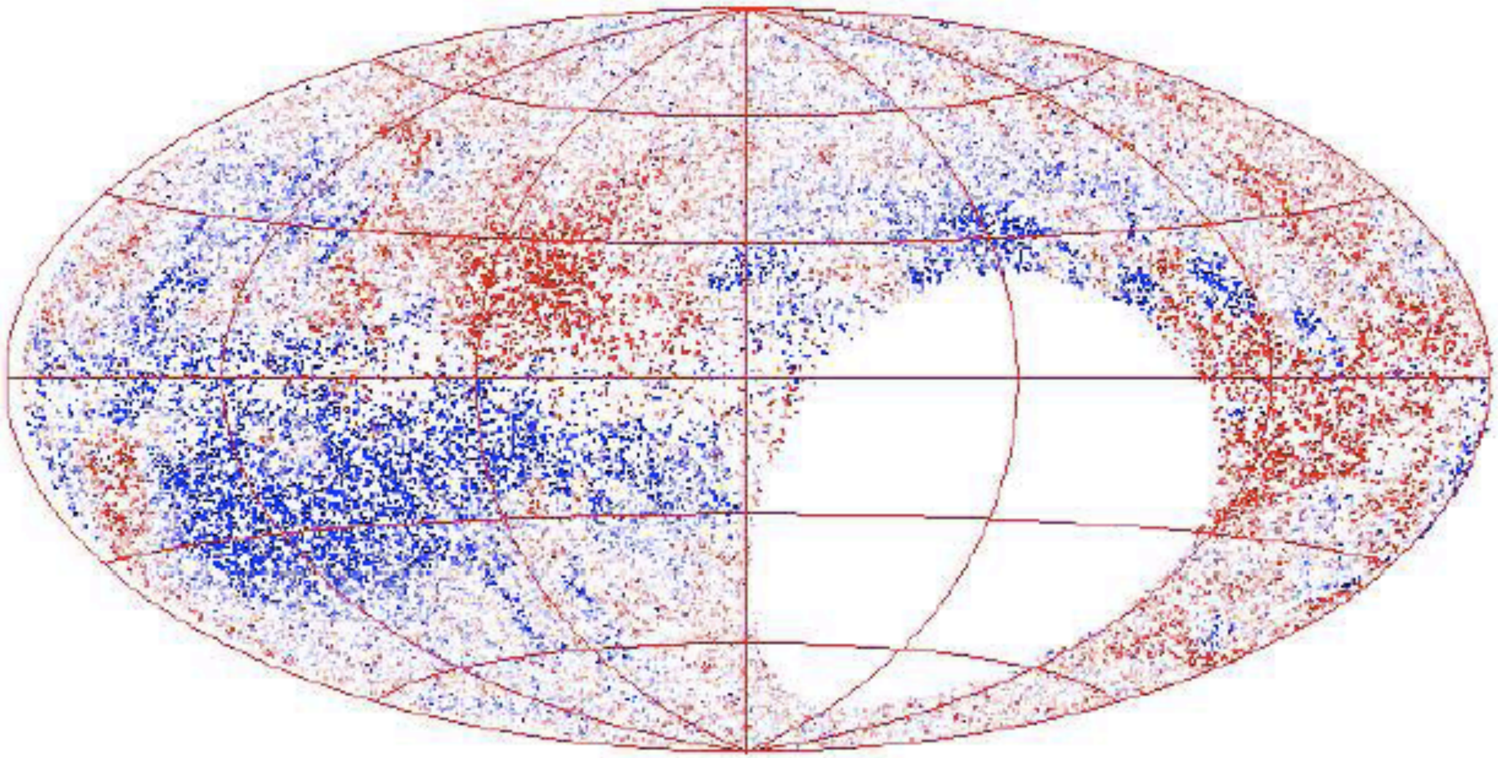
M. Prouza and R. Smida astro-ph/0307165

Galactic magnetic field: halo



J-L. Han et al, **arXiv:0901.0040**

Galactic magnetic field measurement: RM



Pshirkov et al, **arXiv:1103.0814**

Galactic magnetic field: turbulent component

- Field with $\langle B(r)\rangle = 0 \qquad \langle B(r)^2\rangle \equiv B_{\rm rms}^2 > 0.$
- Power spectrum $\mathcal{P}(k) \propto k^{-\alpha}, \qquad |B(k)|^2 \propto k^{-\alpha-2}$
- With index $\alpha = 5/3,\ 3/2$ for Kolmogorov/Kraichnan cases
- Correlation length

$$L_c = \frac{L_{\rm max}}{2}\,\frac{\alpha-1}{\alpha}\,\frac{1-(L_{\rm min}/L_{\rm max})^{\alpha}}{1-(L_{\rm min}/L_{\rm max})^{\alpha-1}}\,.$$

- Where
- $L_{\rm min} = 1\,{\rm AU} \qquad L_{\rm max} = 100 - 300\,{\rm pc}.$

G.Giacinti et al, arXiv:1112.5599

Galactic magnetic field: turbulent component

- Profile 1

$$B_{\rm rms}(r,z) = B(r)\exp\left(-\frac{|z|}{z_0}\right)$$

$$B(r) = \begin{cases} B_0\ \exp\left(\frac{5.5}{8.5}\right) & \text{, if } r \leq 3\,\text{kpc (bulge)} \\ B_0\ \exp\left(\frac{-(r-8.5\,\text{kpc})}{8.5\,\text{kpc}}\right) & \text{, if } r > 3\,\text{kpc} \end{cases}$$

- Profile 2

$$B_{\rm rms}(r,z) = \begin{cases} B_0 & \text{, if } r \leq 20\,\text{kpc and } |z| \leq z_0 \\ 0 & \text{, if } r > 20\,\text{kpc or } |z| > z_0 \end{cases}$$

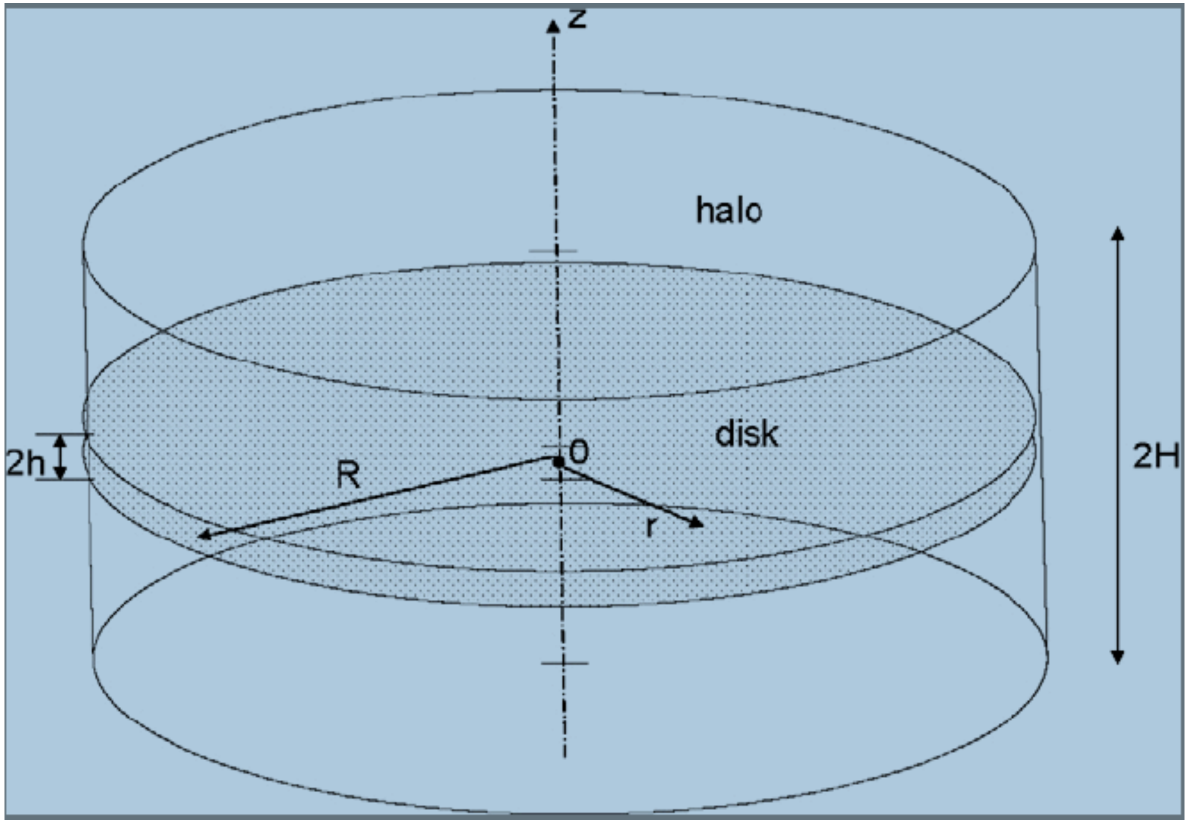
G.Giacinti et al, arXiv:1112.5599

Propagation of nuclei in the Galactic magnetic field

Model:

- *Sources are uniformly distributed distributed in the galactic disk of the width h=200-500 pc with radius up to 15-20 kpc*

Sources of galactic cosmic rays



Ptuskin, **Astropart. Phys. 2011**

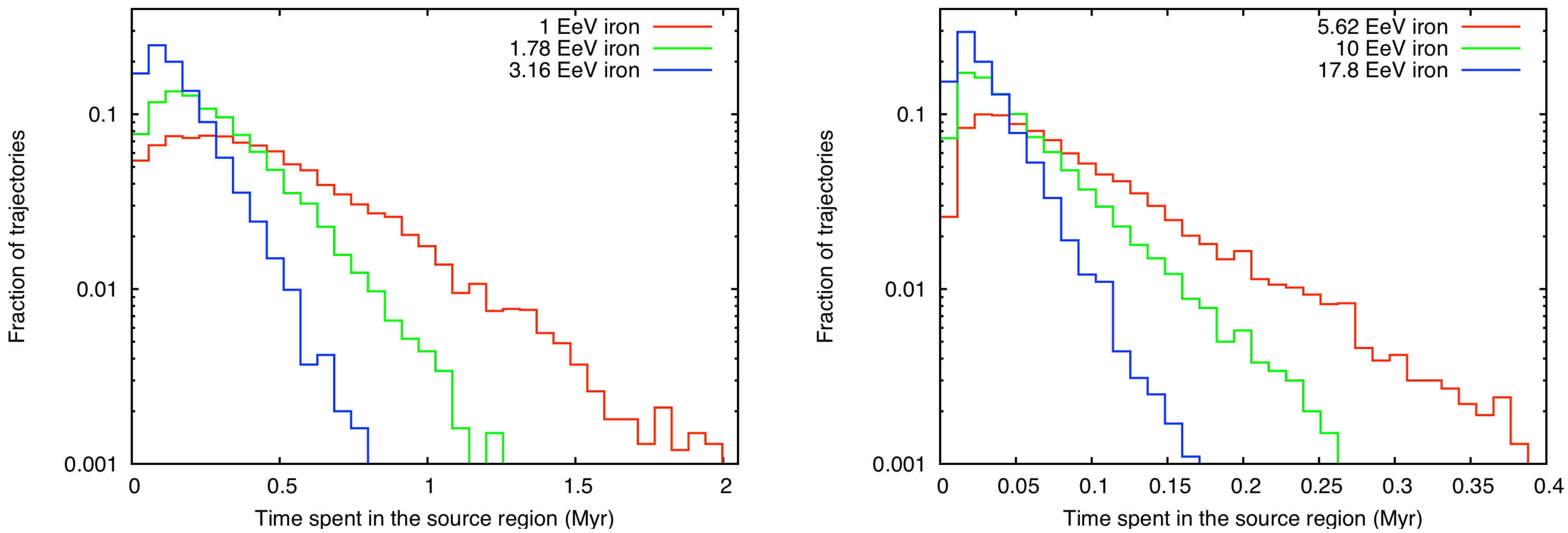
Model:

- *Sources are uniformly distributed in the galactic disk of the width h=200-500 pc with radius up to 15-20 kpc*
- *Dipole calculated in continues homogeneous source distribution approximation*
- *Method of* S K Karakula *et al* 1972 *J. Phys. A: Gen. Phys.* **5** 904. Later studied in A A Lee and R W Clay 1995 *J. Phys. G: Nucl. Part. Phys.* **21** 1743

Questions:

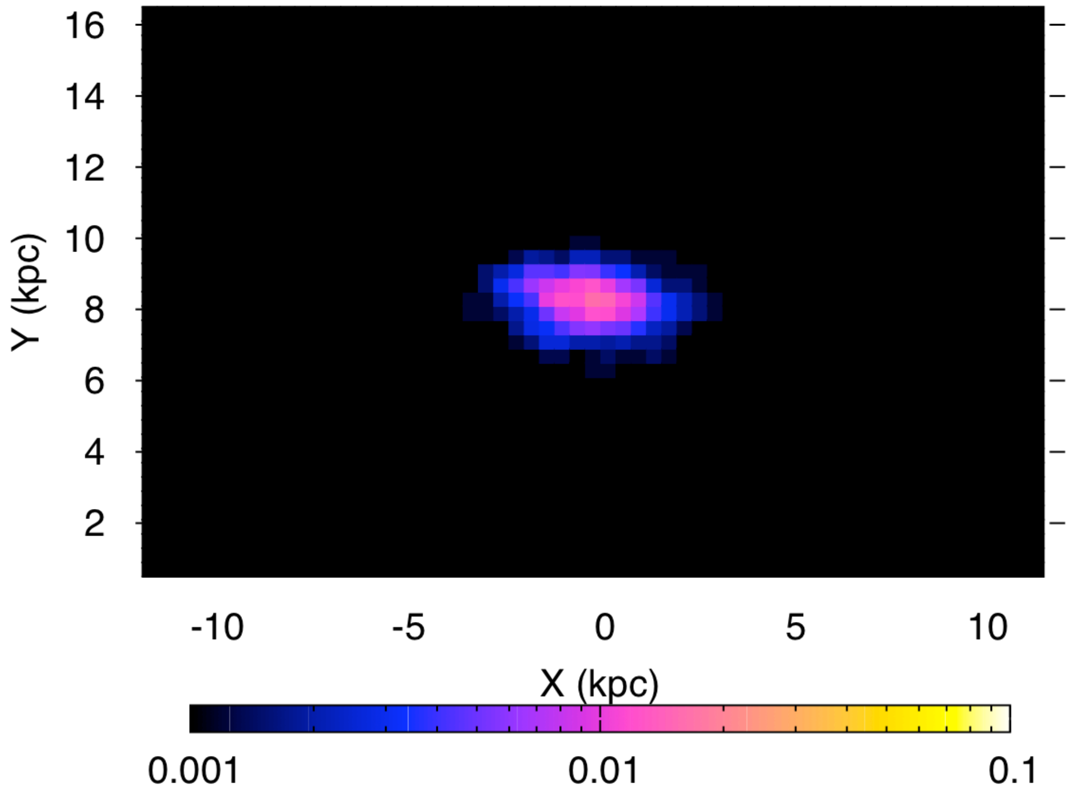
- *Can iron from galactic sources be isotropic up ankle and above?*
- *Can light component around 1 EeV be of Galactic origin?*

Time spent in the galactic disk

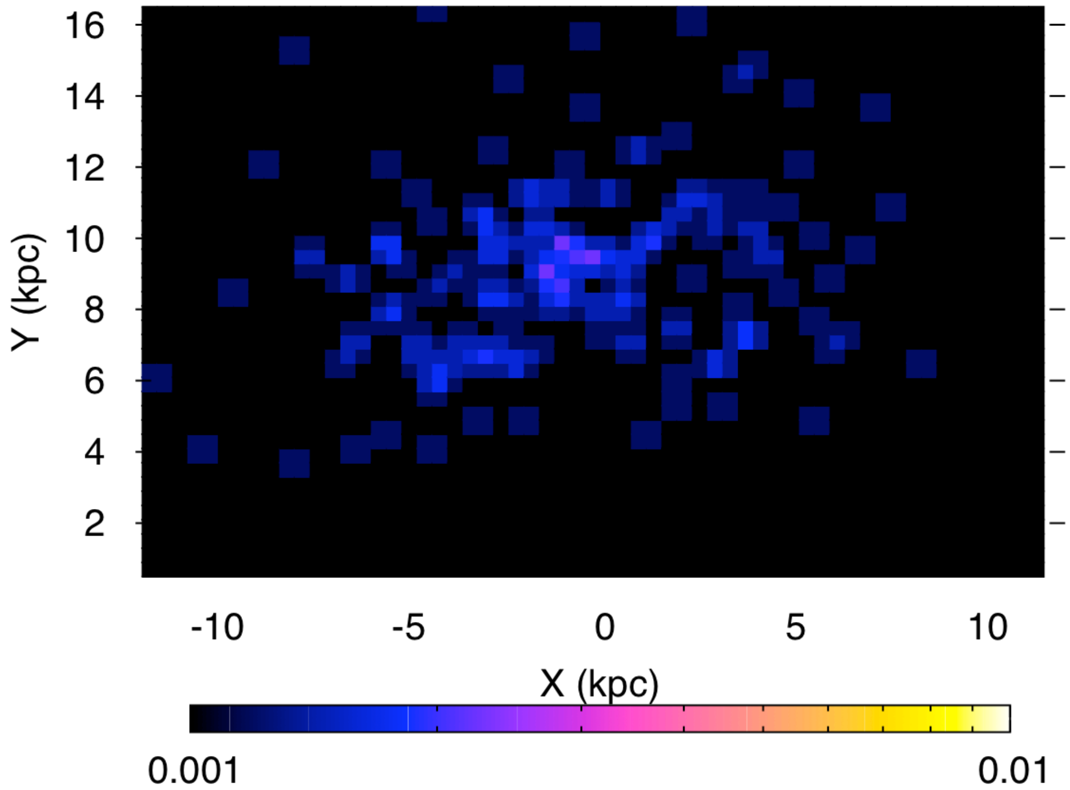


G.Giacinti et al, arXiv:1112.5599

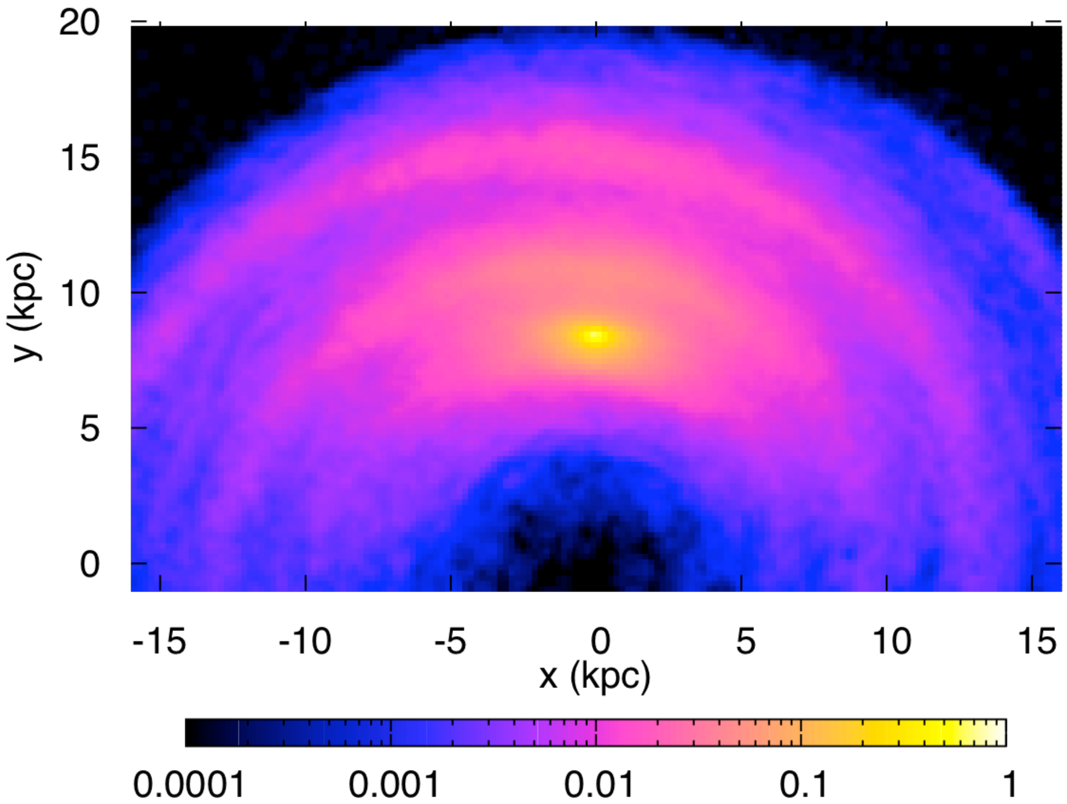
1 EeV iron from single source: 100 kyr (33%)



1 EeV iron from single source: 1 Myr (12%)

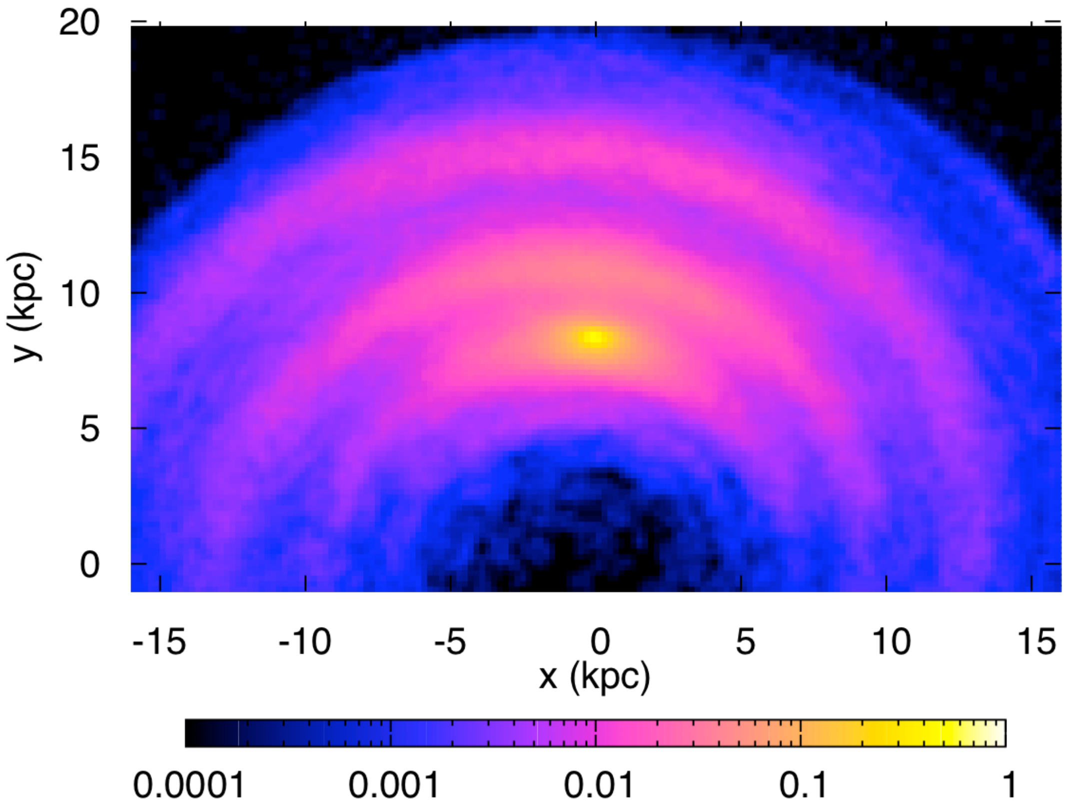


Iron 1 EeV



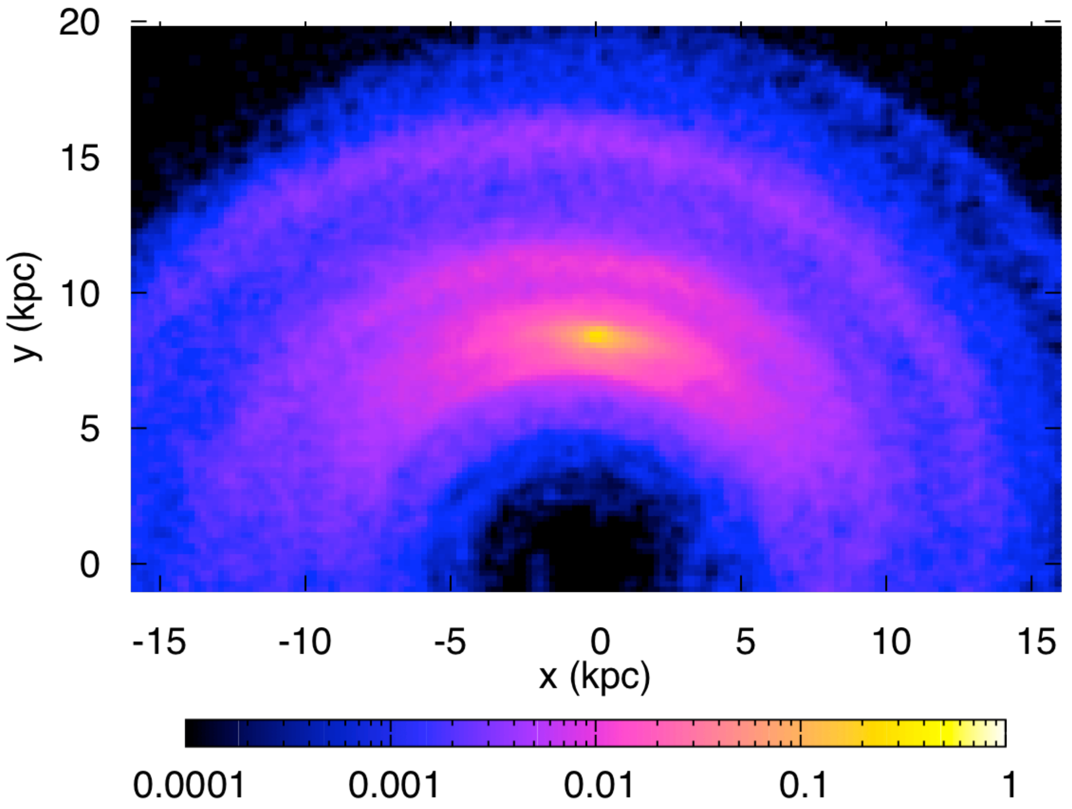
G.Giacinti et al, arXiv:1112.5599

Iron 3 EeV



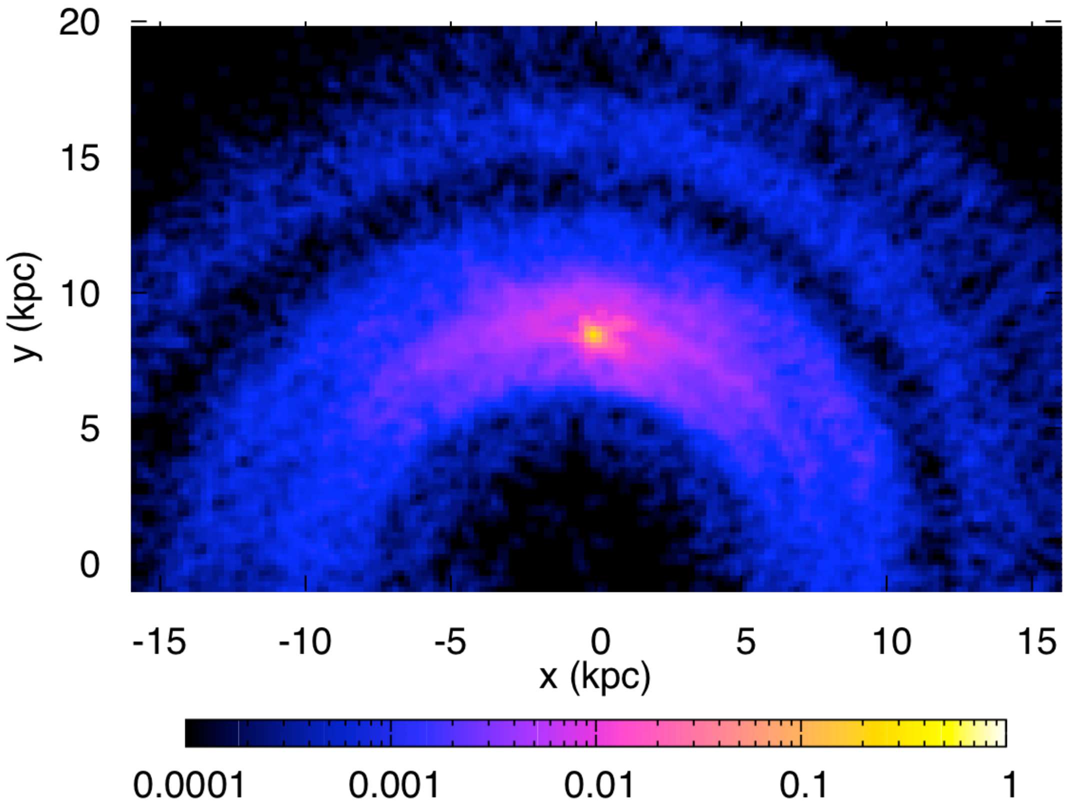
G.Giacinti et al, arXiv:1112.5599

Iron 10 EeV



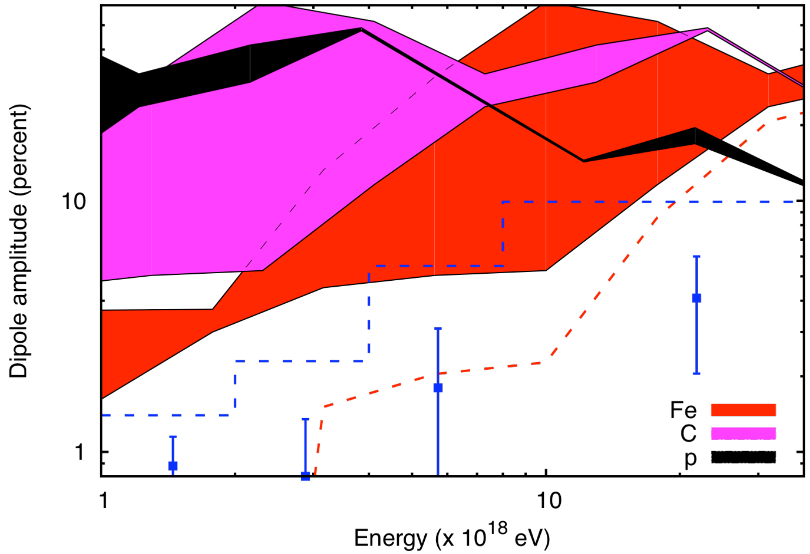
G.Giacinti et al, arXiv:1112.5599

Iron 30 EeV

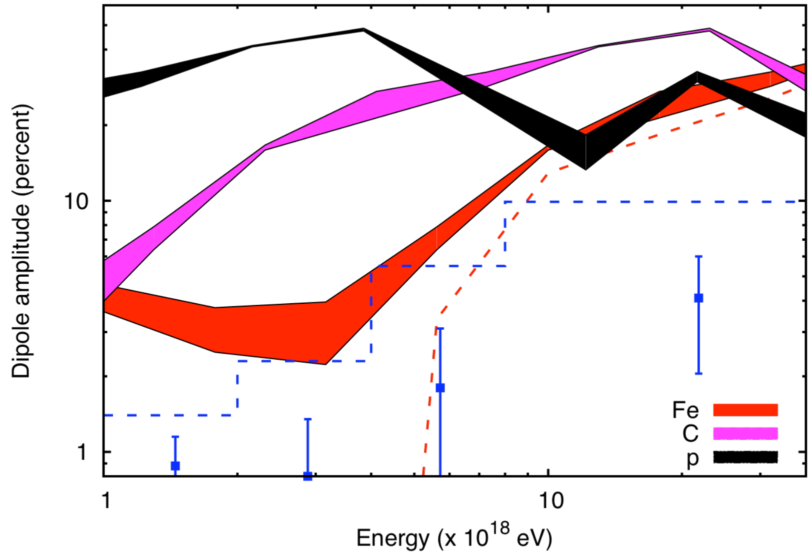


G.Giacinti et al, arXiv:1112.5599

Dependence on parameters



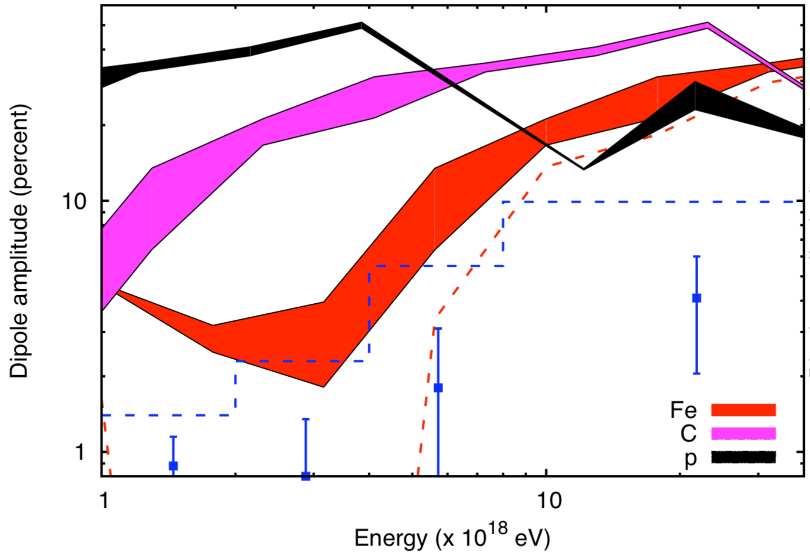
Magnetic field strength 2-8 muG



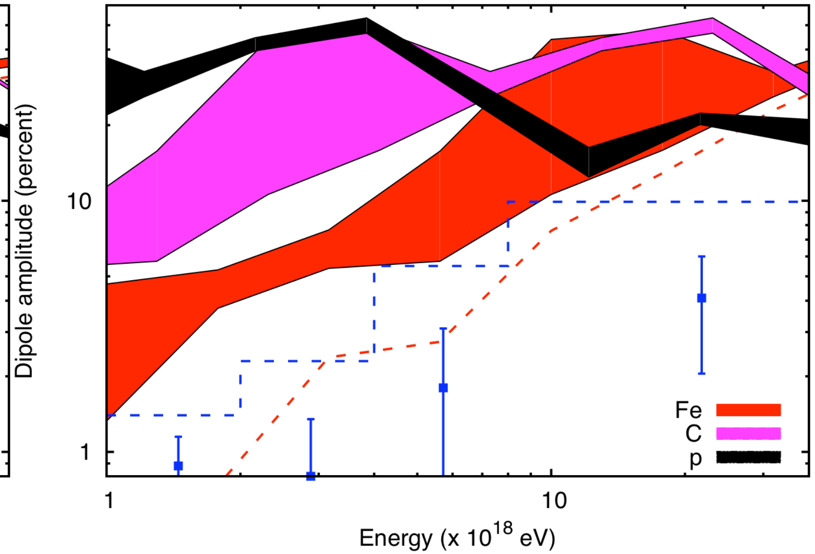
Halo width z0 = 1-8 kpc

G.Giacinti et al, arXiv:1112.5599

Dependence on parameters



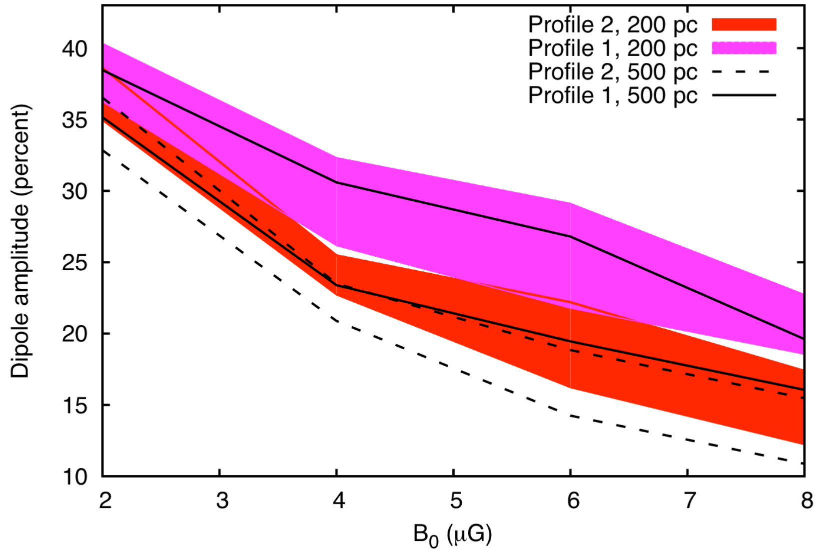
Turb. Magn. Field spectrum
Kolmogorov/Kraichnan

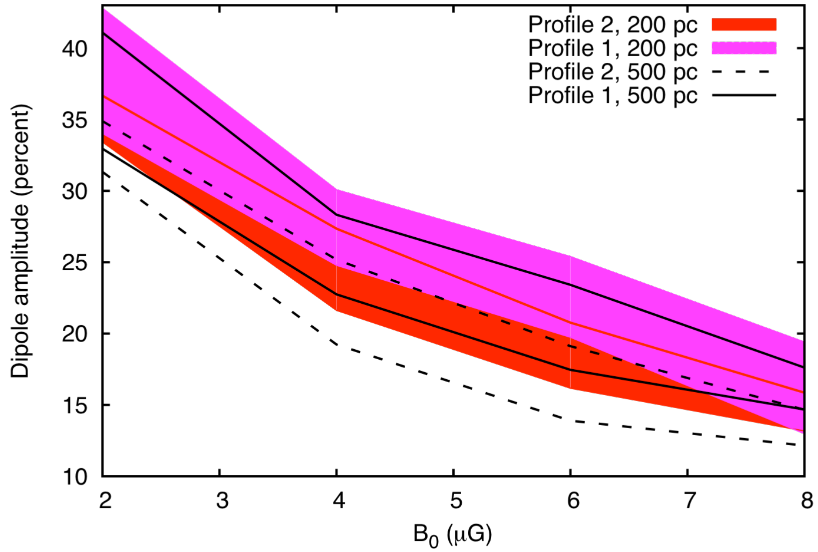


Lmax = 100-300 pc

G.Giacinti et al, arXiv:1112.5599

1 EeV protons from galactic sources



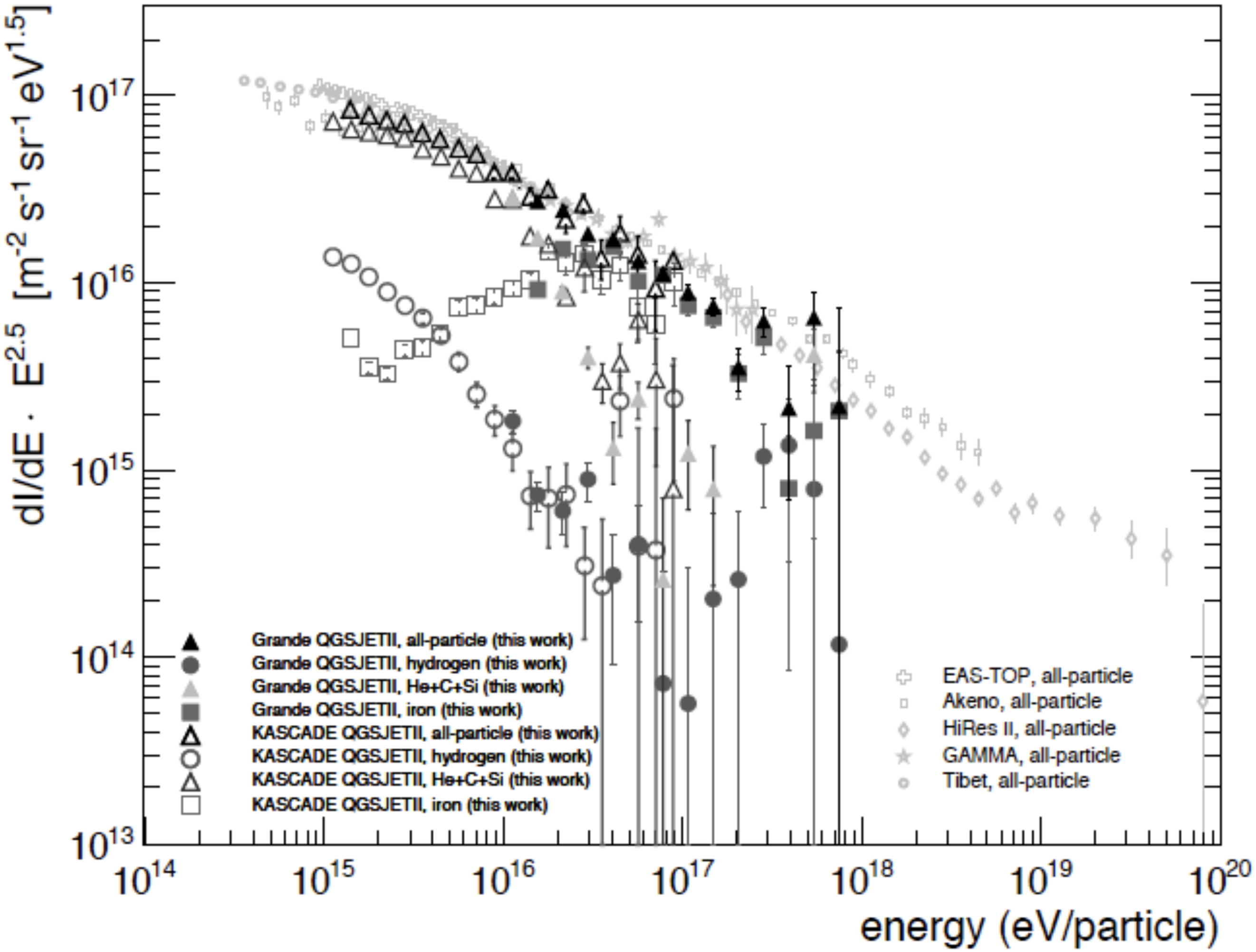


Turb. Magn. Field spectrum
Kraichnan

Turb. Magn. Field spectrum
Kolmogorov

G.Giacinti et al, arXiv:1112.5599

KASCADE-Grande protons



ICRC 2011 arXiv: 1111.5436

Conclusions

- Auger limits on the anisotropy of UHECR does not restrict existence of galactic iron component up to ankle or even up to 10^19 eV, depending on parameters of galactic magnetic fields.

- Existing limits on anisotropy forbid large (conservatively 10% or more) fraction of Galactic protons around 1 EeV. This mean that quickly rising up to 50% proton fraction below 1 EeV in KASCADE-Grande has extragalactic origin.