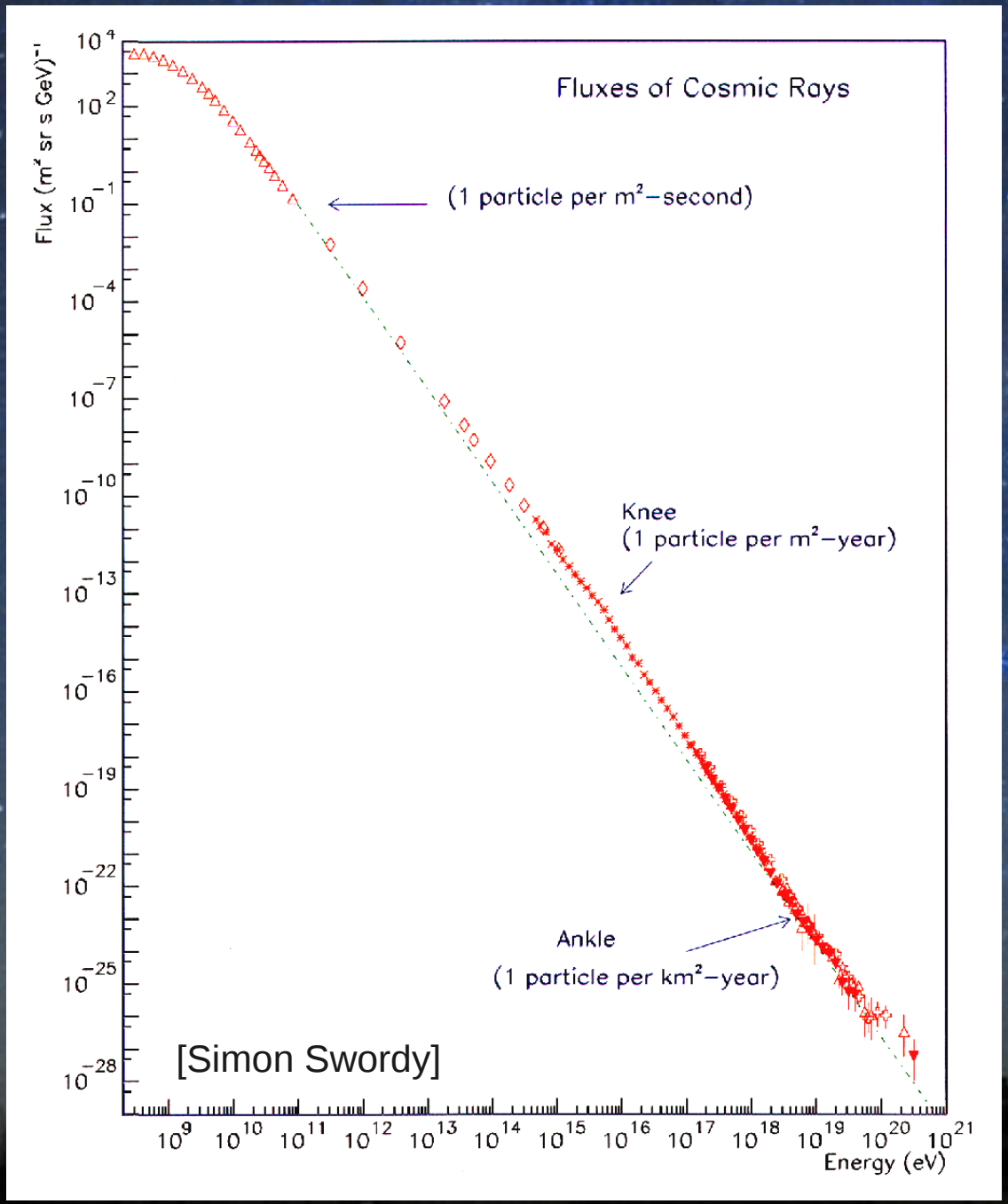
International Cosmic Ray Conference Highlights

Beijing, 11-18 August 2011

Colas Rivière

Cosmic rays context

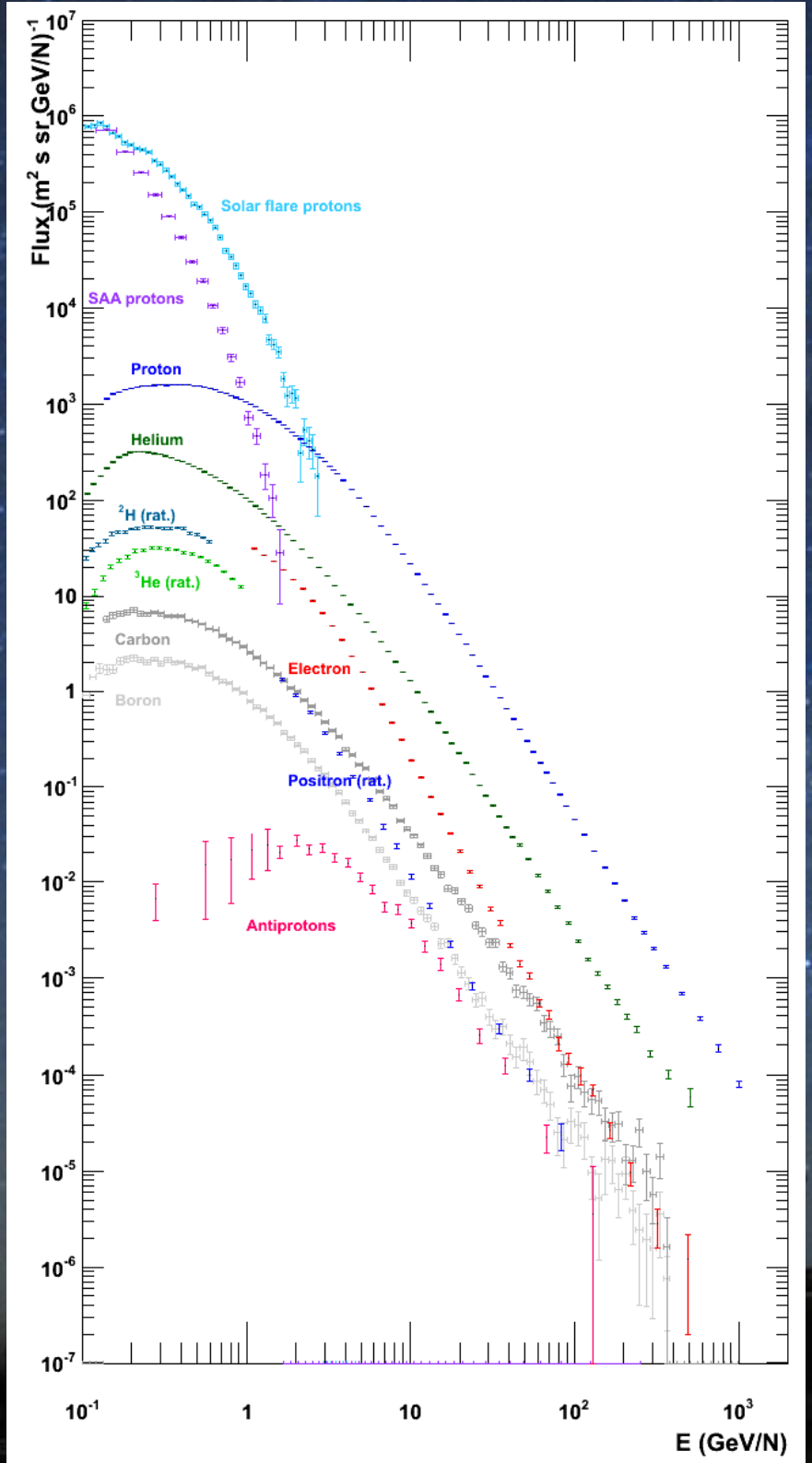


- Simple (broken) power law
- Up to ~knee: SNR
- After: extragalactic

- Closer look:
  - SNR? How?
  - Composition?
  - Sources?
  - Extra-galactic?
  - How?

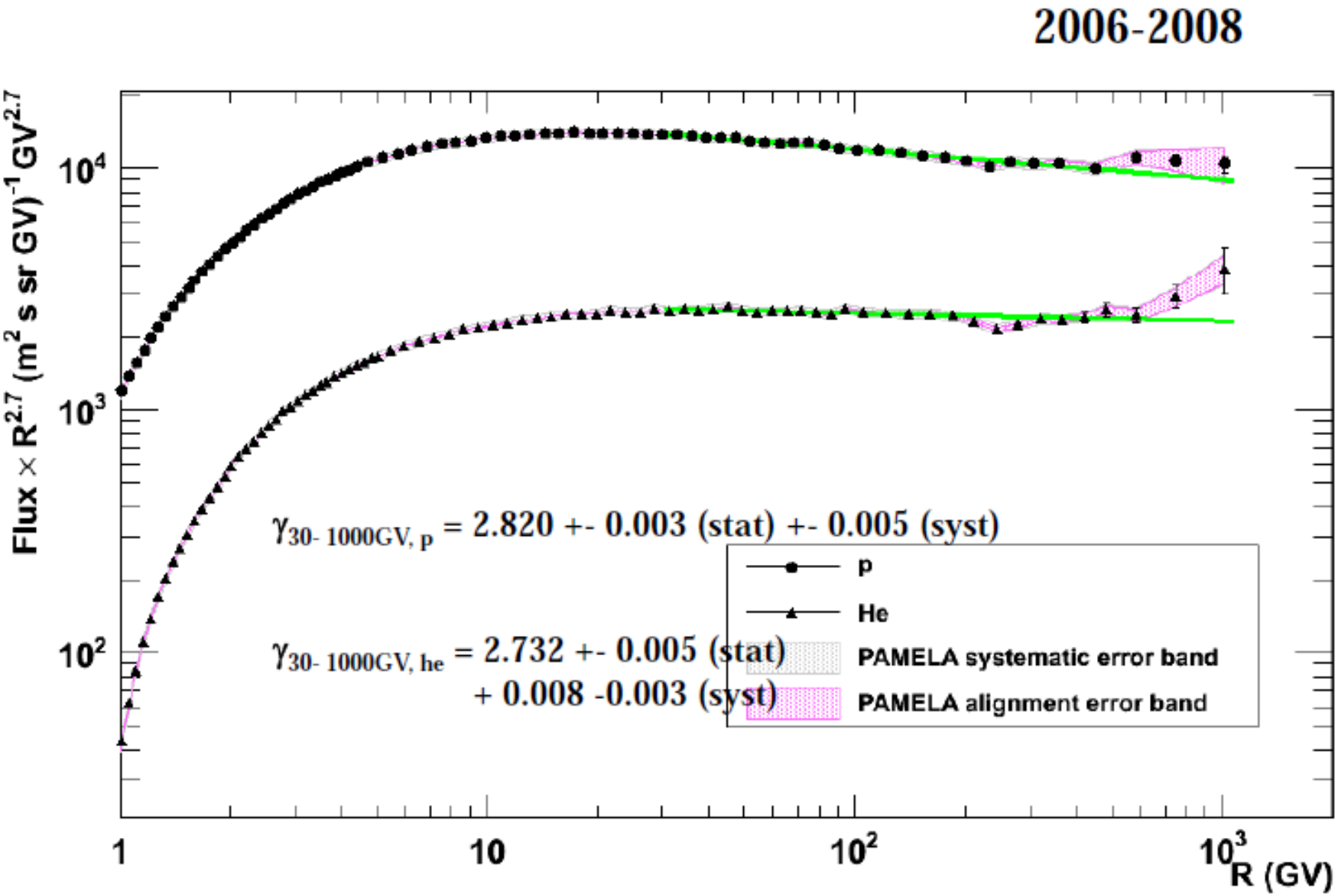
Direct measurement of CRs

- New features
- Challenging interpretation

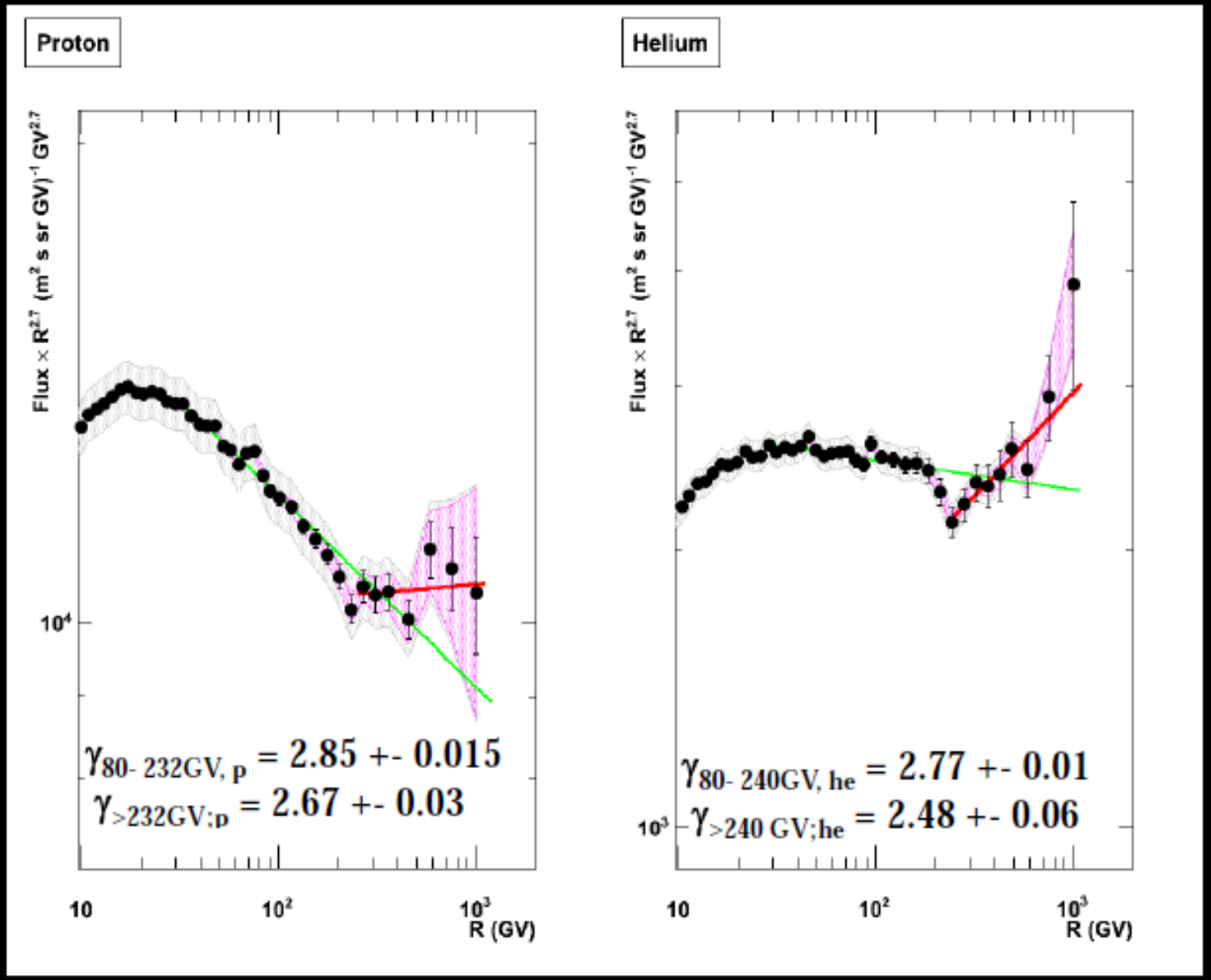


Pamela individual spectra

PAMELA p & He

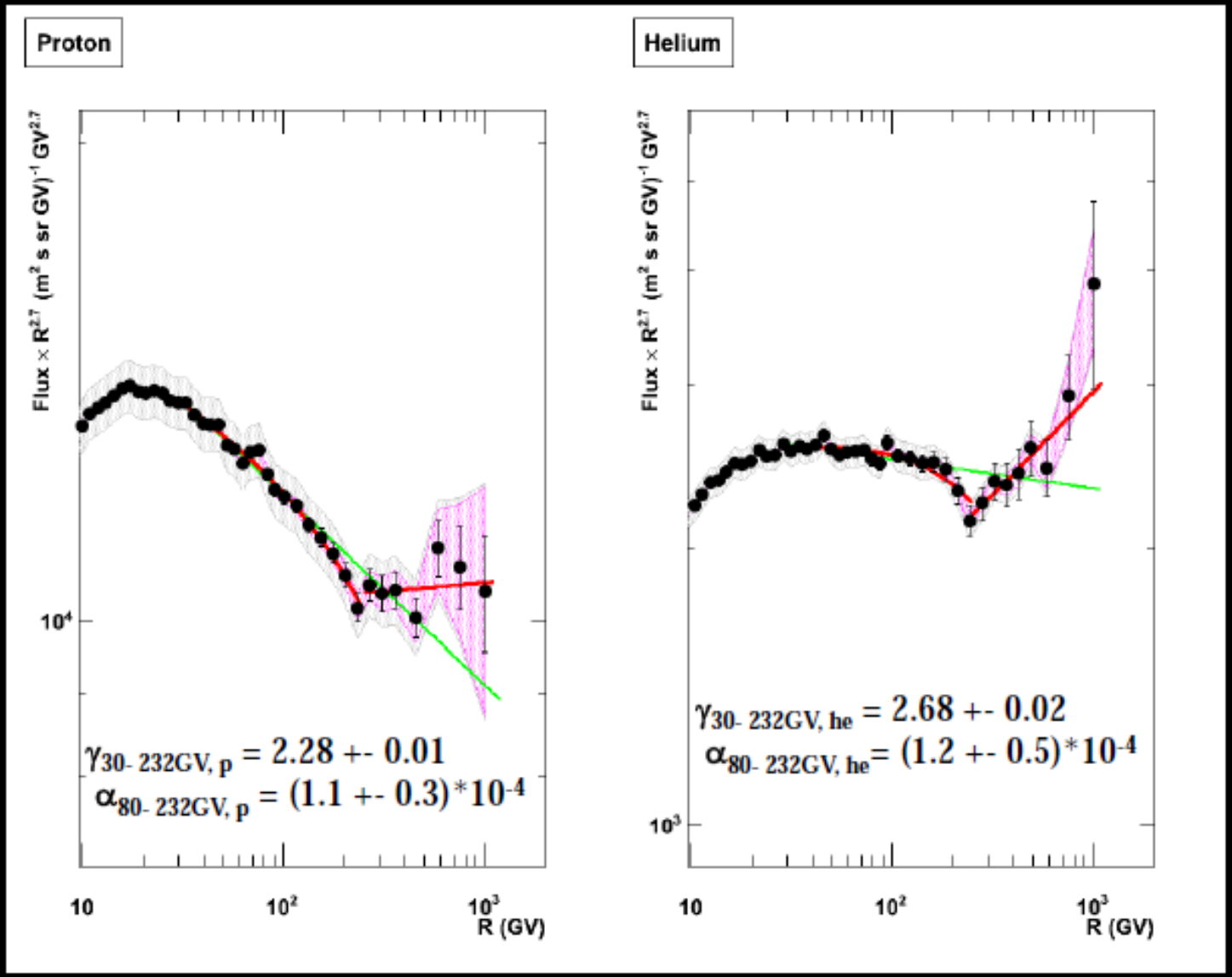


Deviations from power law: a) R>240 GV



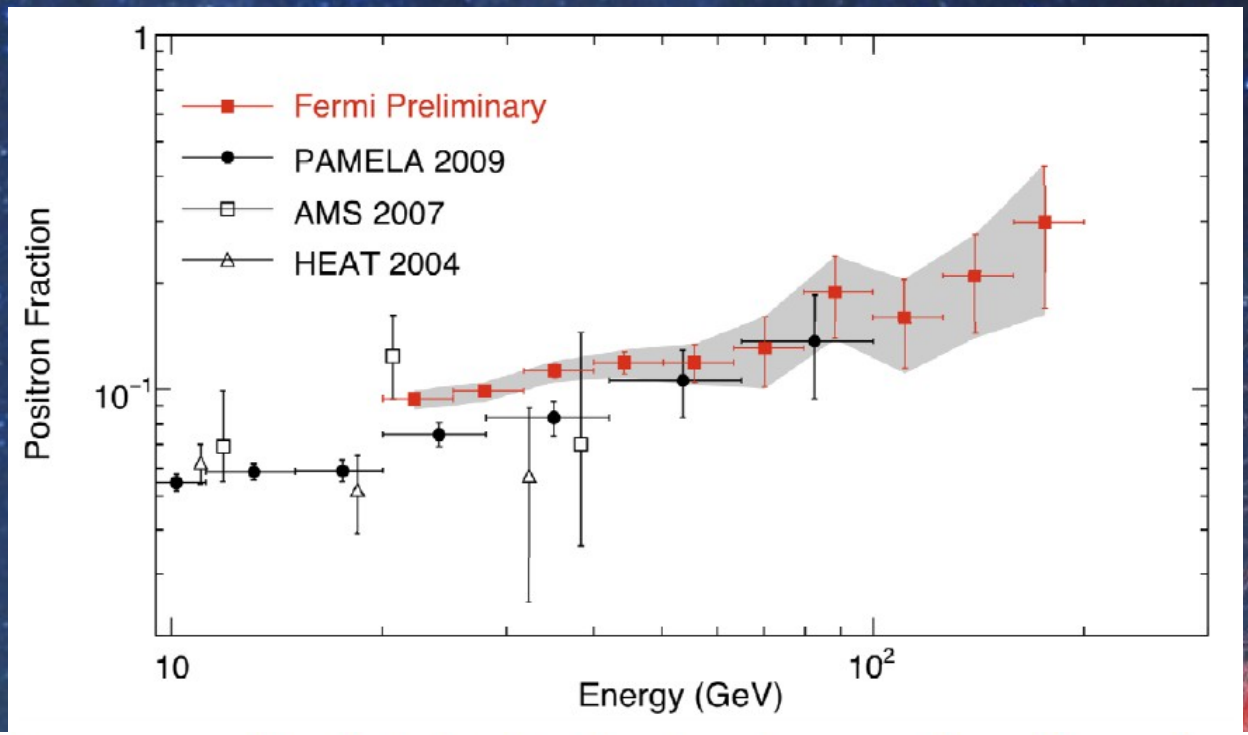
1. Additional source(s) above 240 GV
2. Fisher and T student test reject single power law to better than 99.7 CL

Deviations from power law: a) R<240 GV?



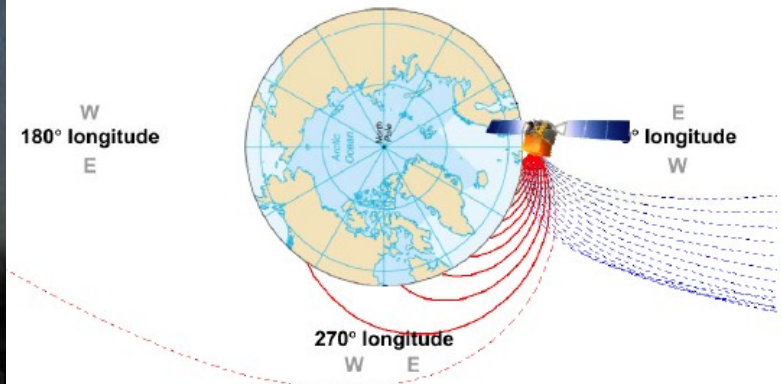
- The spectrum softens at 30-240 GV
- Single power law is also ruled out at lower rigidities

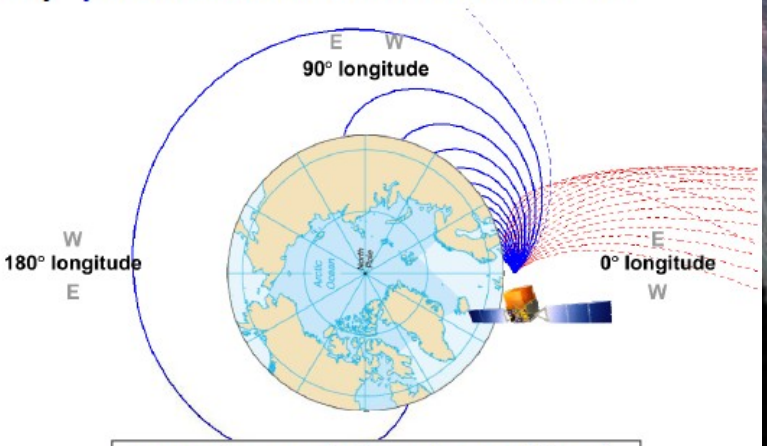
Positron fraction update



Geomagnetic field + Earth shadow = directions from which only electrons or only positrons are allowed

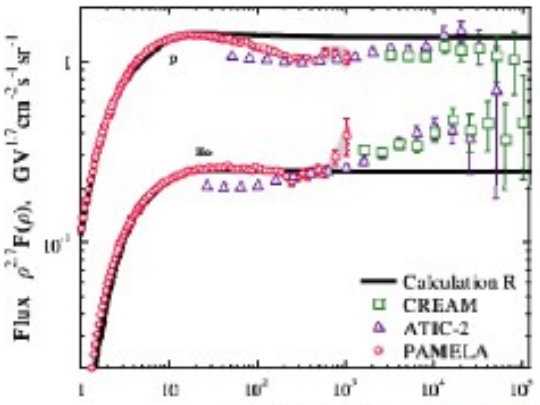
events arriving from West:
e^+ allowed, e^- blocked





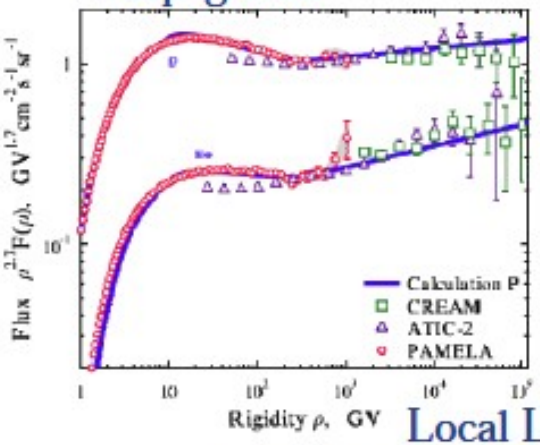
events arriving from East:
e^- allowed, e^+ blocked

Modelization (eg. GALPROP)

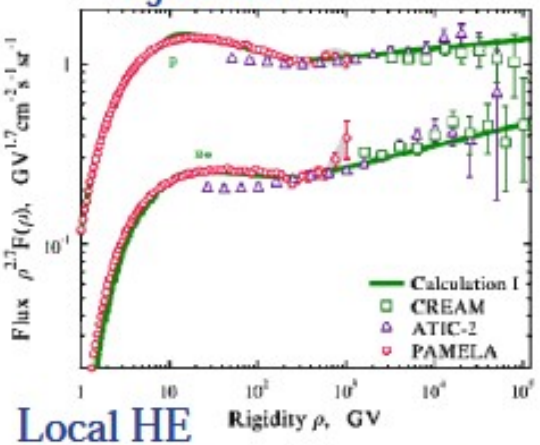


Reference

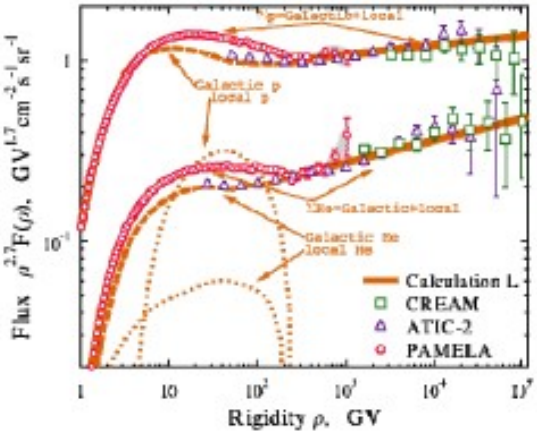
Propagation



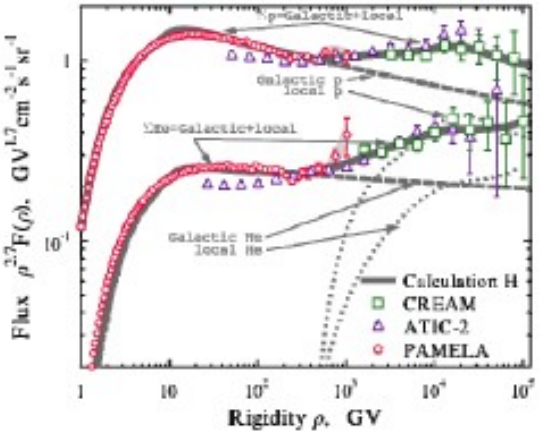
Injection



Local LE



Local HE



P and He spectra in different scenarios

- All scenarios are tuned to the data, except the Reference scenario
- Scenarios L and H: the local source component is calculated by the subtraction of the propagated Galactic spectrum from the data
- The local source is assumed to be close to us, so no propagation; only primary CR species

Observation	*Scenario R/S*	*Scenario P*	*Scenario I (a)*	*Scenario I (b)*	*Scenario L*	*Scenario H*
The break (hardening of p and He spectra at $\rho_{\rm br}$), Figure 3	No	Yes, due to a break in the diffusion coefficient	Yes, due to a break in the injection spectrum	Yes, due to the assumption of a composite source	Yes, due to the assumption of a local low energy source	Yes, due to the assumption of a local high energy source
The 'dip' (softening of CR spectra at $\rho < \rho_{\rm br}$), Figure 3	No	No, unless the diffusion coefficient has a corresponding 'dip'	No	No, but the 'dip' can be explained by assuming that the low-energy Galactic source turns over below $\rho_{\rm br}$.	Yes	No
Difference between p and He spectra, see Figures 3 and 4	Yes, if parameters are tuned to increase grammage and cross sections, as in *Scenario S*.	Yes, phenomenologically introduced	Yes, phenomenologically introduced	Yes, phenomenologically introduced	Yes, phenomenologically introduced	Yes, phenomenologically introduced
Continuity of *p*/He ratio at $\rho_{\rm br}$, Figure 4	Yes, but does not match the value of *p*/He ratio	Yes, no additional assumptions	Yes, no additional assumptions	Yes, but only if the different source classes inject with the same *p*/He ratio at $\rho_{\rm br}$	Yes, but only if the local and Galactic sources classes inject with the same *p*/He ratio at $\rho_{\rm br}$	Yes, but only if the local and Galactic sources classes inject with the same *p*/He ratio at $\rho_{\rm br}$
CR anisotropy due to diffusive escape of CRs above 1 TeV, Figure 6	Overpredicts	Overpredicts, but less than other scenarios	Overpredicts	Overpredicts, but the possibility of different spatial distributions of the two source classes must be considered	Overpredicts	Overpredicts; the local source, if it extends above 1 TeV, may affect anisotropy
B/C ratio above 1 GeV/nuc, Figure 7	Yes	Yes, but differs from other scenarios above $\rho_{\rm br}$; possible discrimination with more accurate data	Yes	Yes	Yes, by construction	Yes
$\bar{p}$ flux (PAMELA), Figure 8	Yes, above a few GeV	Yes, but differs from other scenarios above $\rho_{\rm br}$	Yes, above a few GeV	Yes, above a few GeV	No	Yes, above a few GeV
γ-ray observations of *Fermi*-LAT, Figure 10	Yes	Yes	Yes	Yes	No	Yes

Conclusions

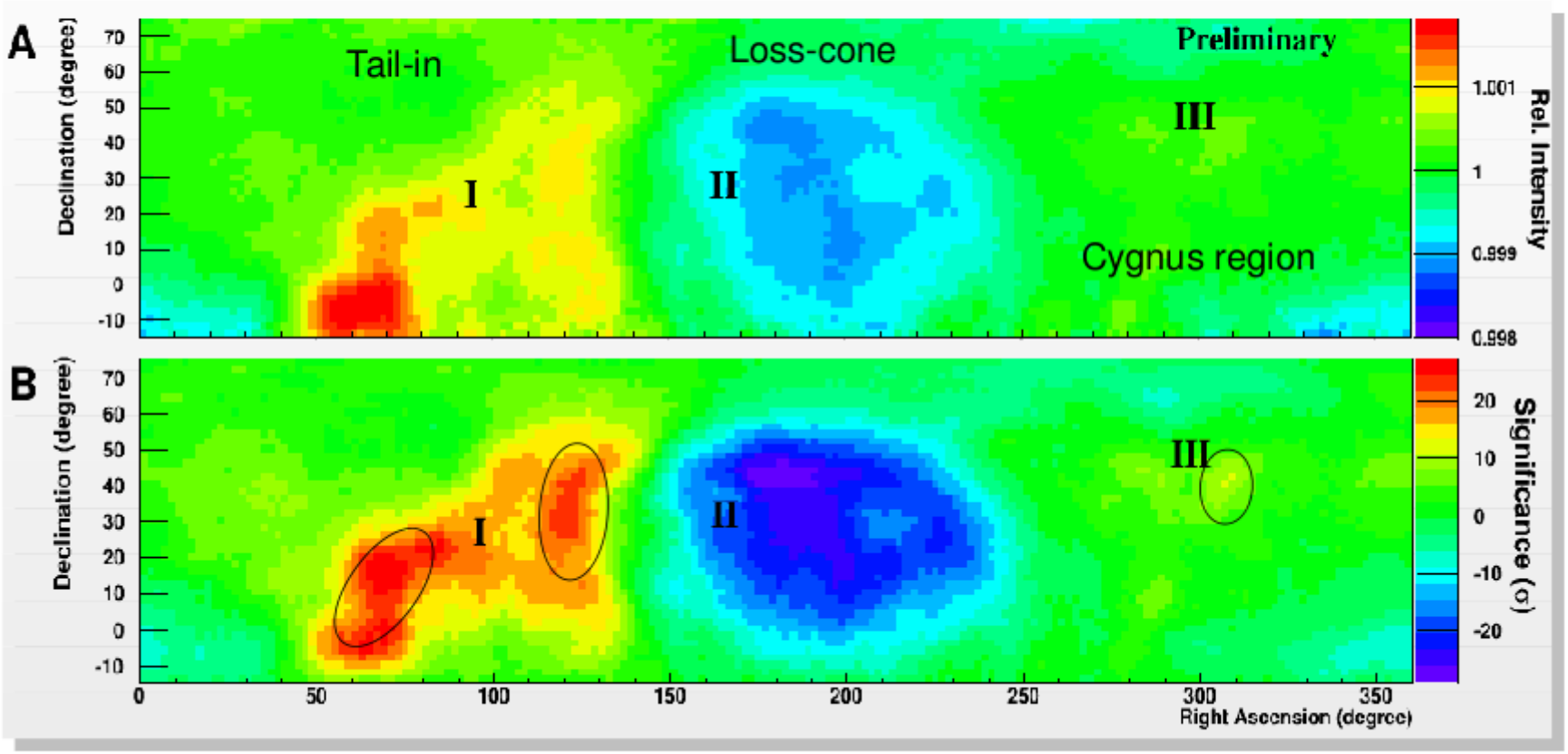
- "Seem to be entering the era where the measurements force us to abandon our simple first-order ideas about acceleration and/or propagation"
  - "Smooth featureless power-laws" no-more?
- Multiple lines of evidence now point to:
  - Different spectral indices for p & He
  - Hardening of spectra above ~200 GV, for p & He
    - Possibly even more complexity (dips?)
  - Possibly this is also happening for heavy elements
- Lots of theoretical work to try to explain…

Conclusions II

- Existing electron spectrum confirmed
  - New Fermi Data
  - PAMELA measurement
  - MAGIC above E ~ 200 GeV
  - Challenge to simplest source/diffusion models
    - New sources? Pulsars? Dark Matter? Conventional Physics?
- Positron fraction confirmed/extended
  - "Excess" beyond ~10 GeV not going away
  - PAMELA reanalysis confirms, pegs lower limit at ~10% beyond 100 GeV
  - Clever analysis from Fermi/LAT in the same ballpark

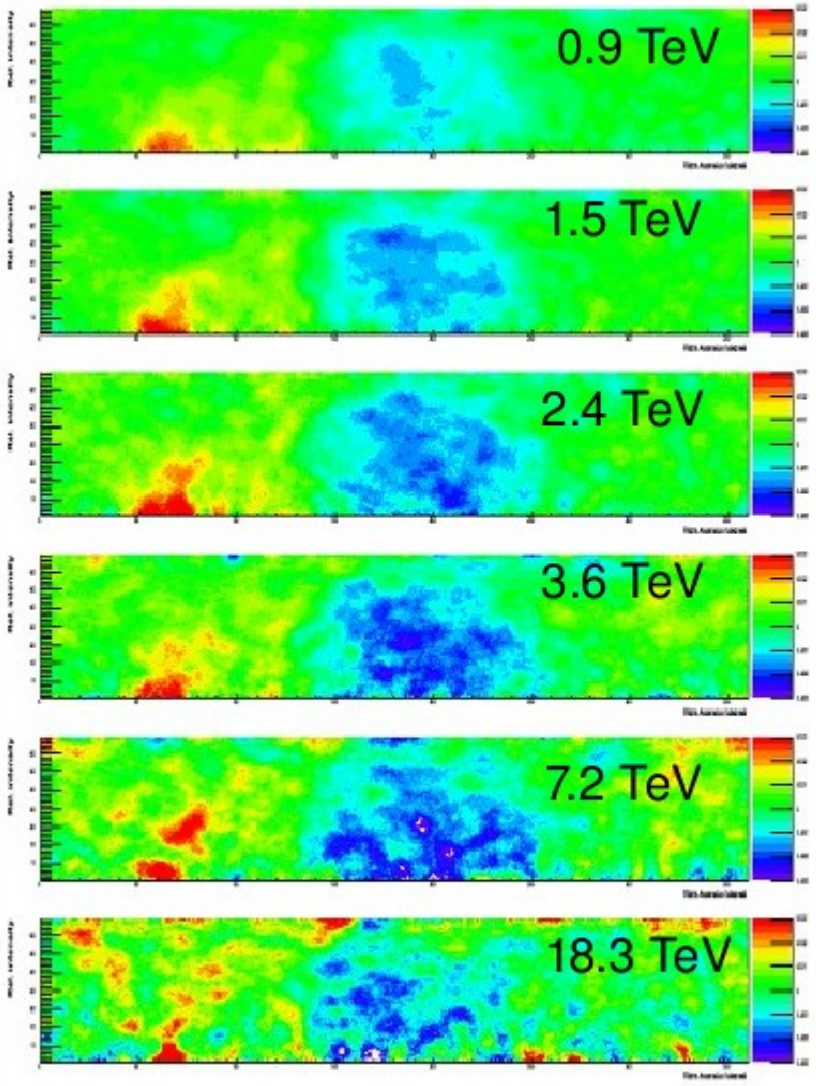
Cosmic rays anisotropies

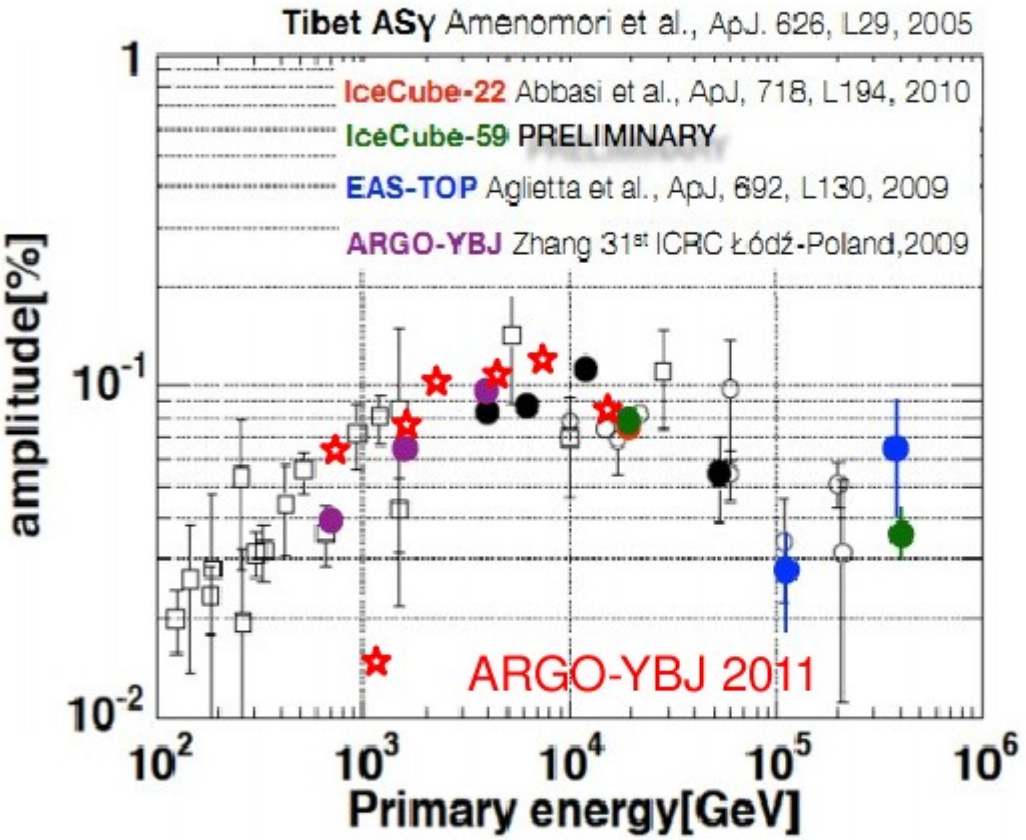
Large scale anisotropy



B. D'Ettorre Piazzoli

Large scale CR anisotropy vs energy

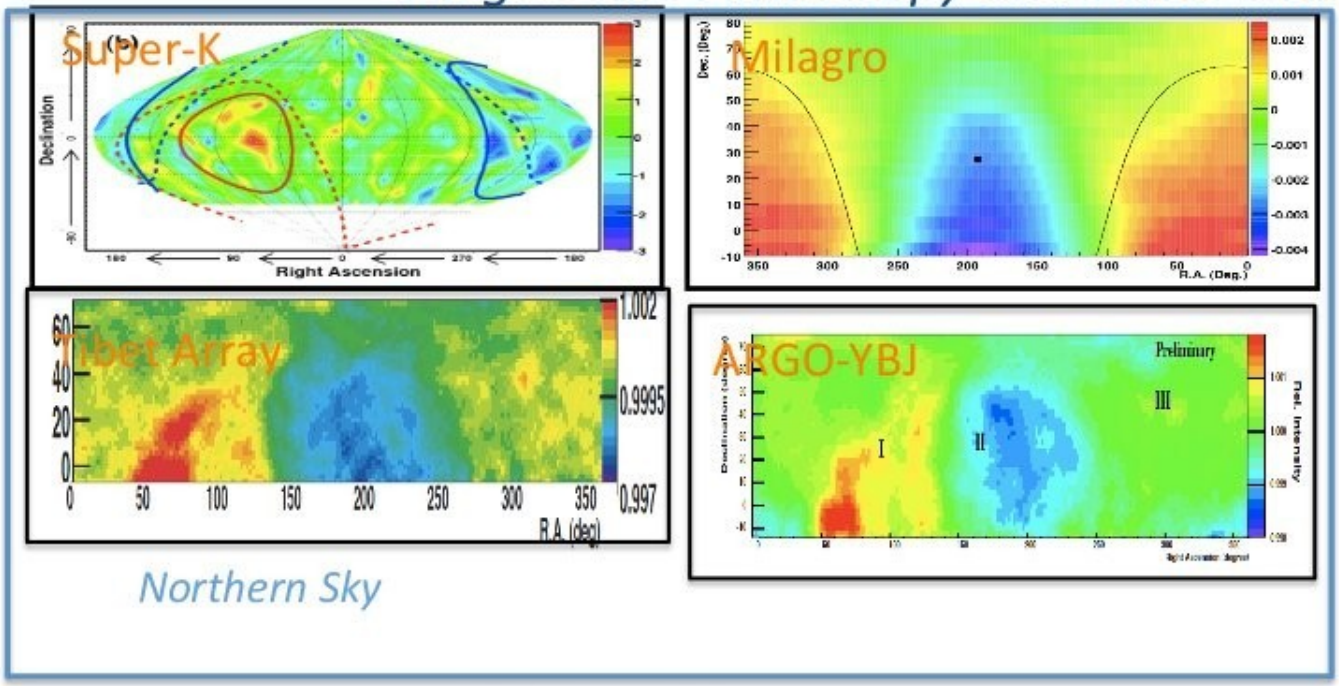


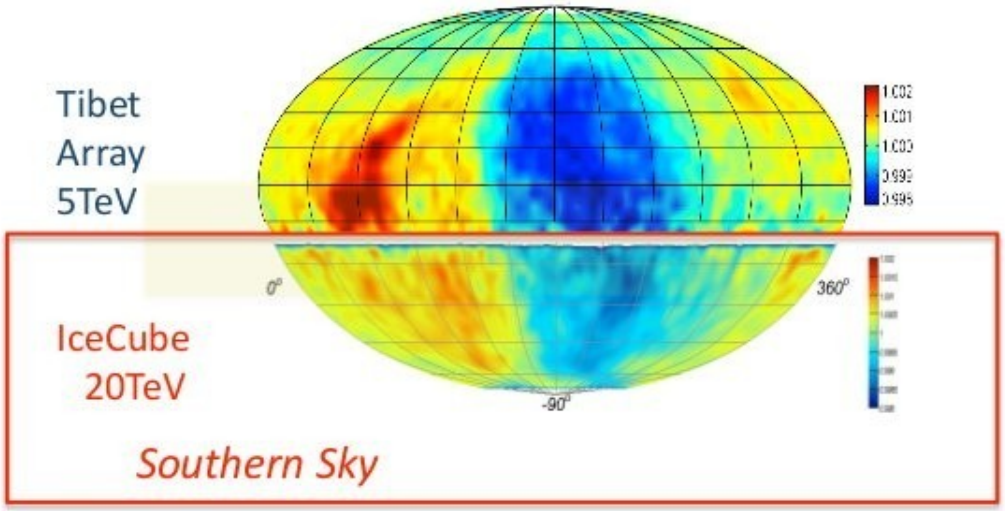


The tail-in broad structure appears to dissolve to smaller angular scale spots.

B. D'Ettorre Piazzoli

Large Scale Anisotropy and Past Results





- IceCube observed a large scale anisotropy at 10^{-3} level for the first time in the Southern Sky.
- *Large Scale Features appear to be a continuation of those observed in the Northern Hemisphere.*

Anisotropies

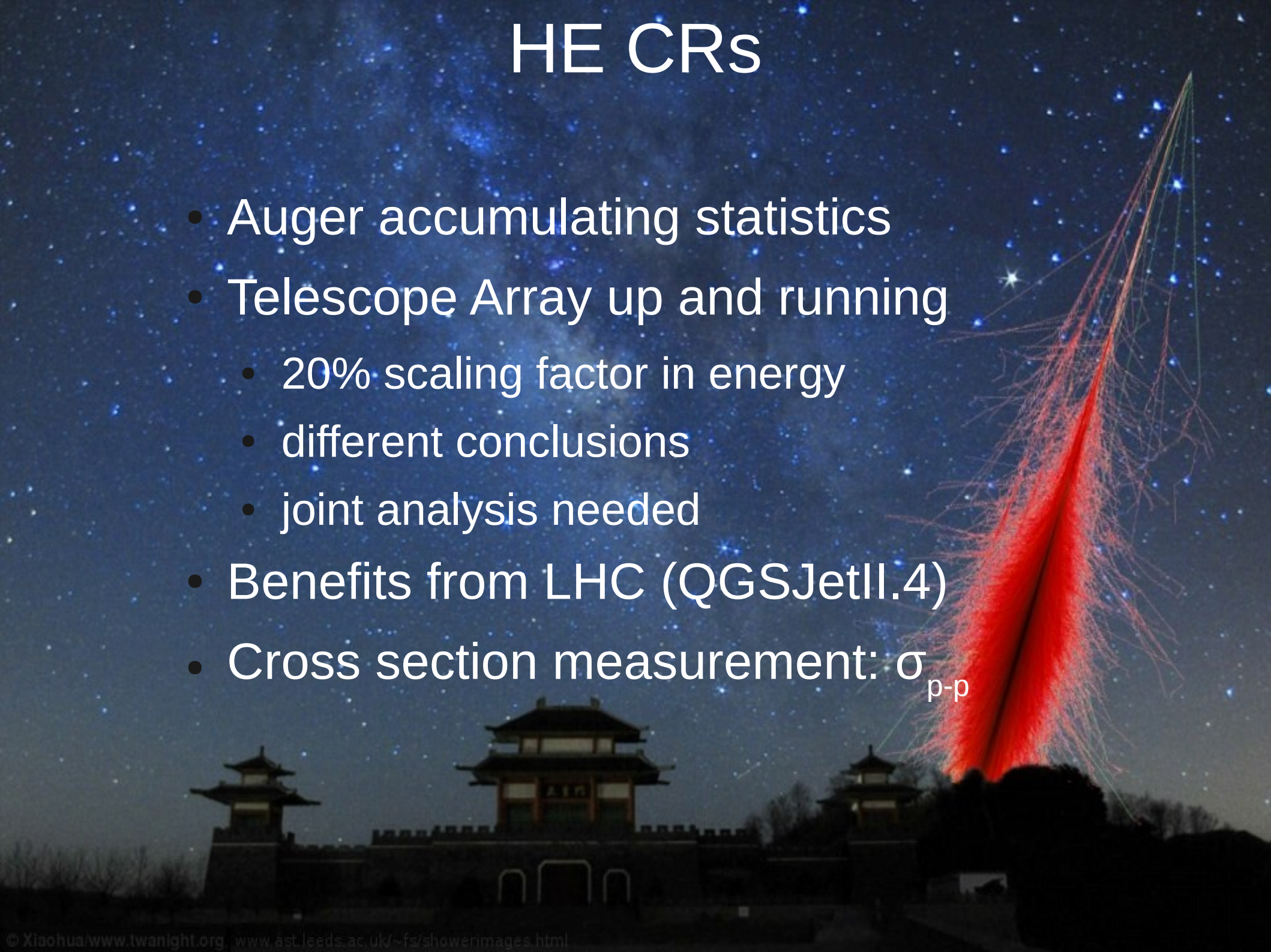
- Several experiments converging: ARGO-YBJ, EAS-TOP, IceCube, Milagro, TIBET Asy

R. Abbasi et al. ICRC-0305 & 0308

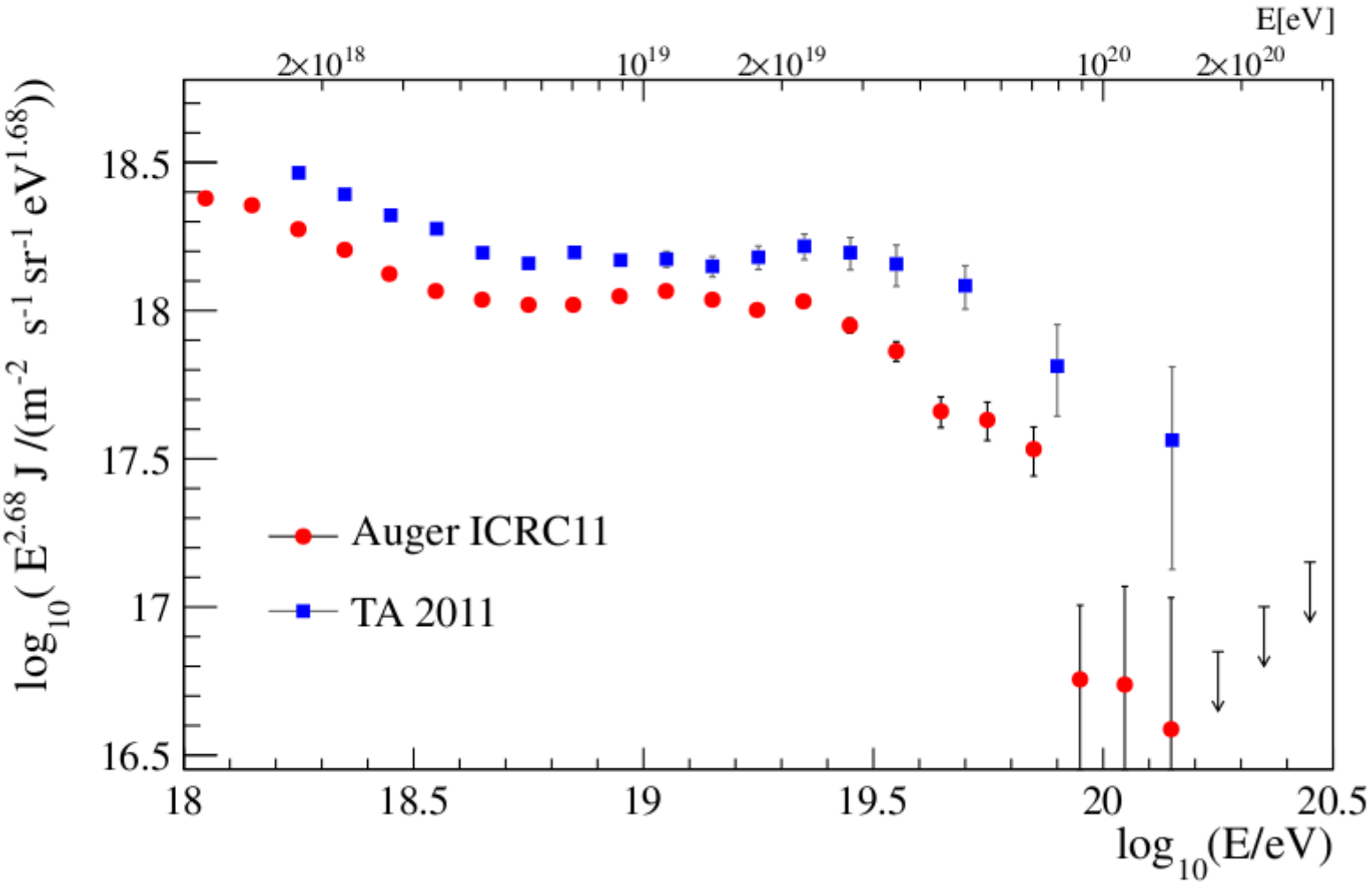
- The origin of the anisotropy is unknown:
  - The result is not consistent with the CG assuming the galactic cosmic rays at rest with the galactic center.
  - Improved theoretical description of the diffusion processes of galactic cosmic rays closer to the knee.
  - Interstellar Magnetic field.
  - This anisotropy reveals a new feature of the Galactic cosmic ray distribution, which must be incorporated into theories of the origin and propagation of cosmic rays.

HE CRs

- Auger accumulating statistics
- Telescope Array up and running
  - 20% scaling factor in energy
  - different conclusions
  - joint analysis needed
- Benefits from LHC (QGSJetII.4)
- Cross section measurement: $\sigma_{p\text{-}p}$



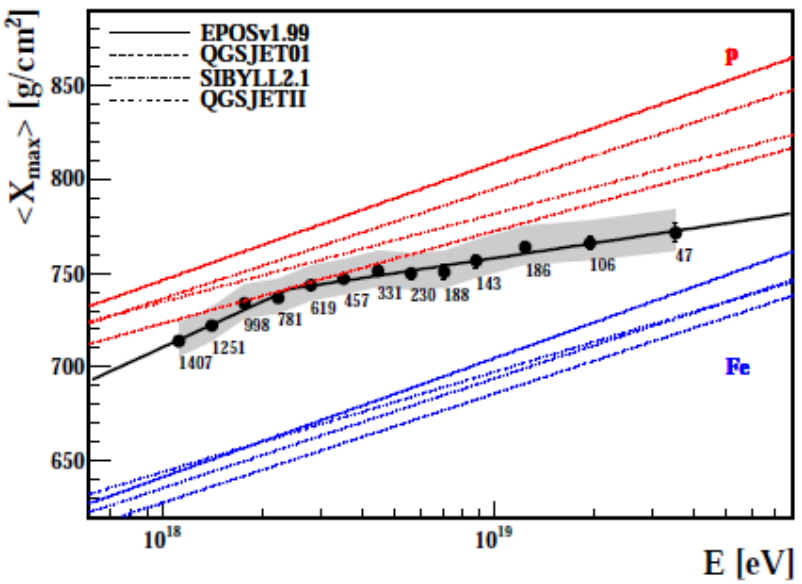
Comparison of Spectra



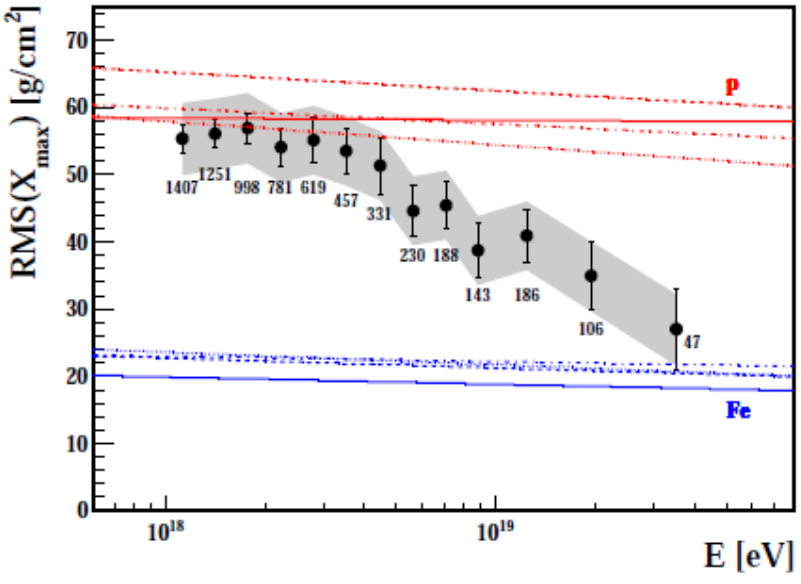
energy scale difference of ~ 20%?

Longitudinal EAS Development with Auger FD

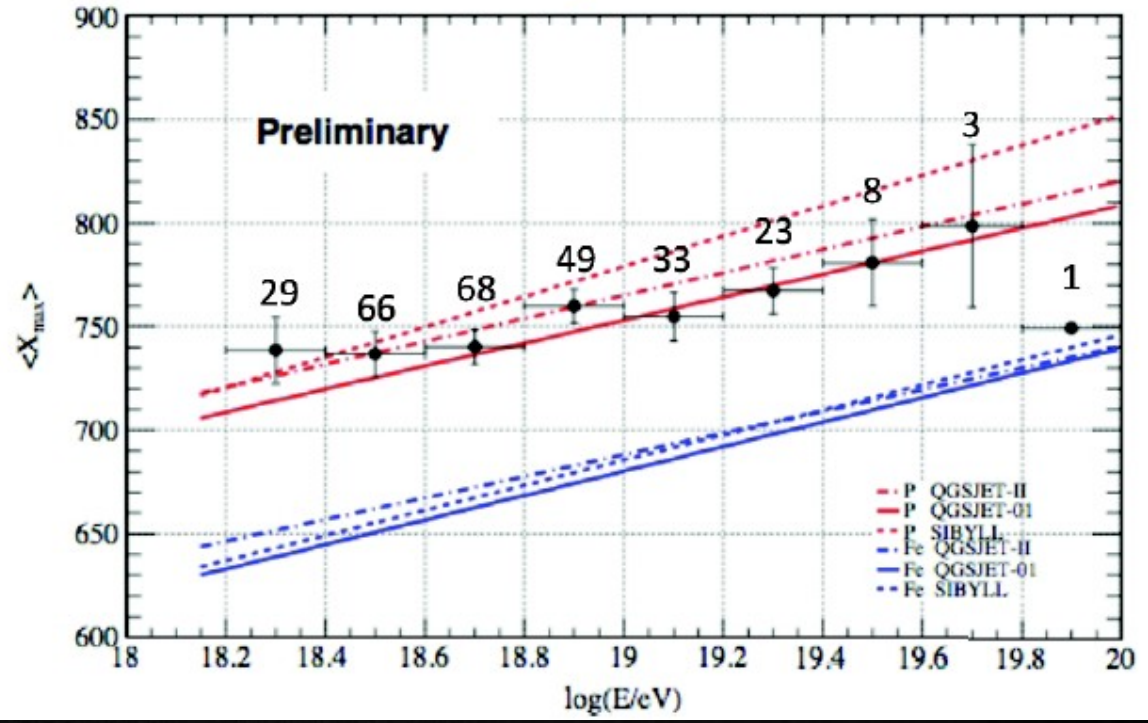
average depth



fluctuations



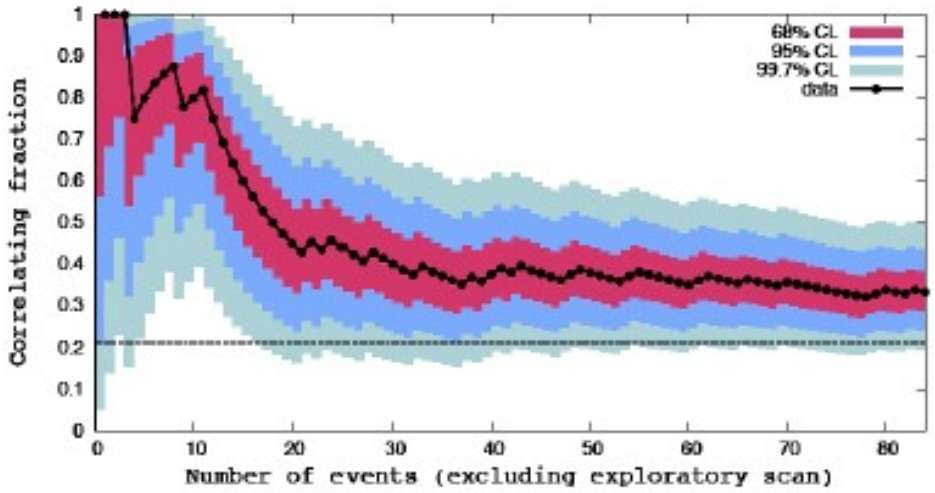
Longitudinal EAS Development with TA Stereo FD



UHE Correlation with AGNs within GZK-sphere?

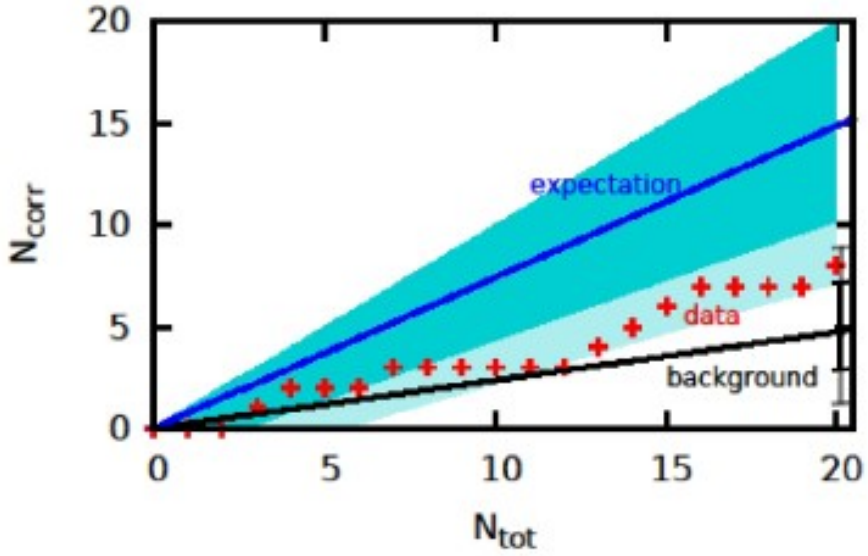
VCV catalogue, E$>$ 57 EeV, z$<$0.018, distance $<$ 3.1 deg.

Auger



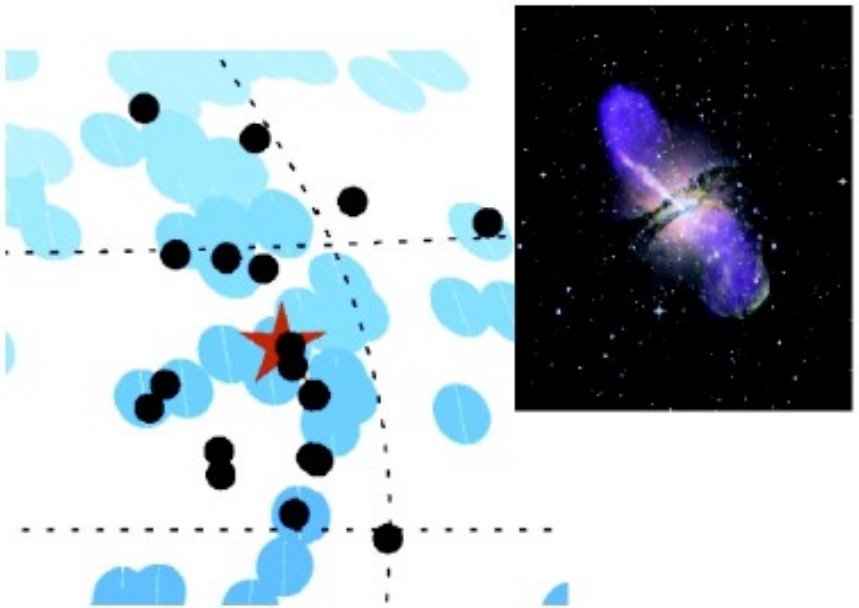
$P = 0.006$, $f = 33 \pm 5\%$

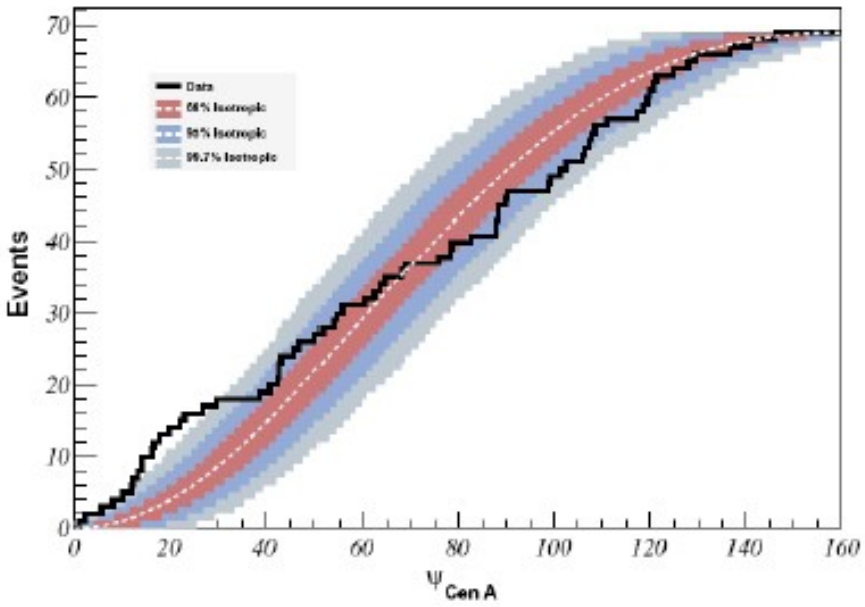
TA



compatible with isotropy and updated (!) Auger

UHERs from CenA?



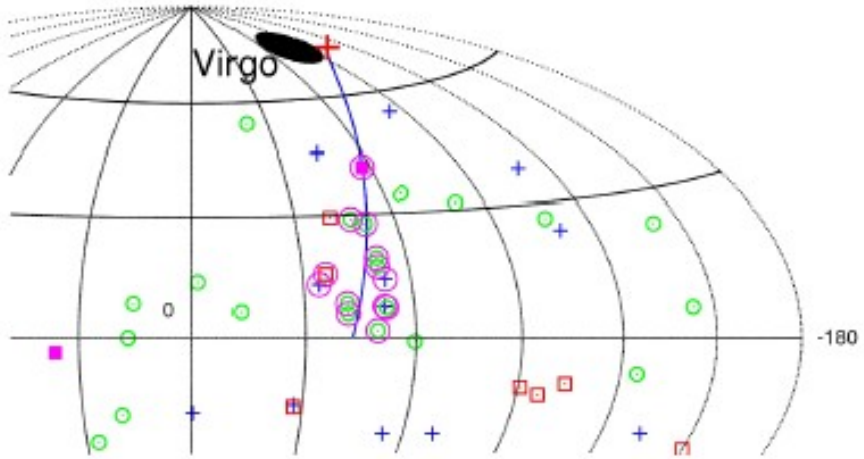


13/62 within 18 deg., expect 3.2

limits on source composition?

E.M. Santos [Auger Coll.], icrc868

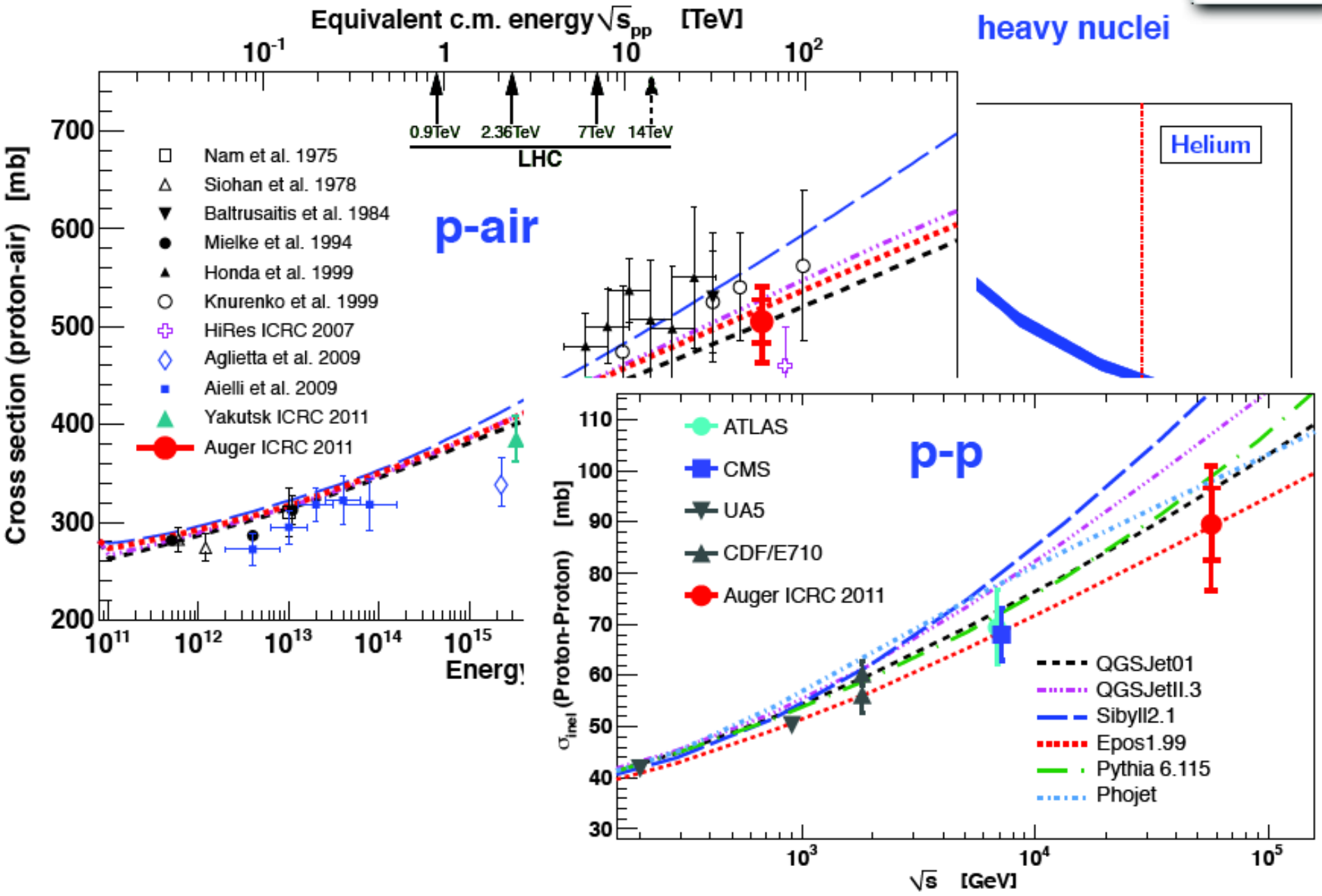
... or Virgo?



Giacinti&Semikoz, icrc171

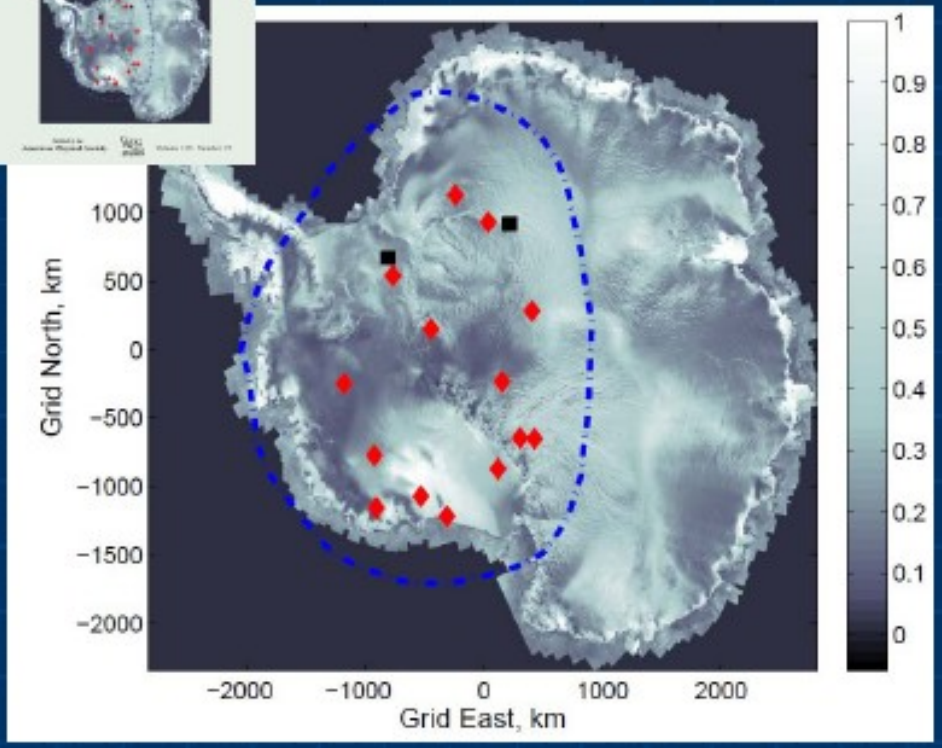
Estimation of the proton-air cross section with the Pierre Auger Observatory

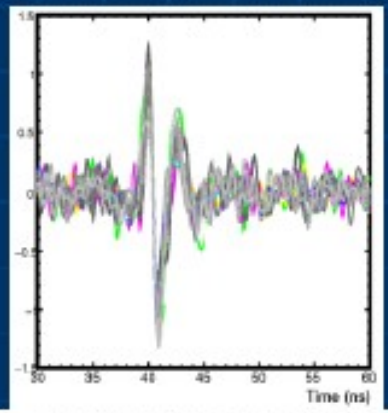
#946
Ulrich

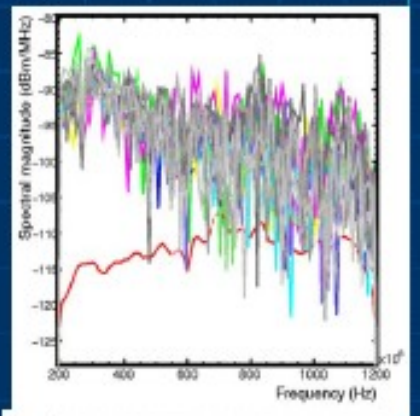


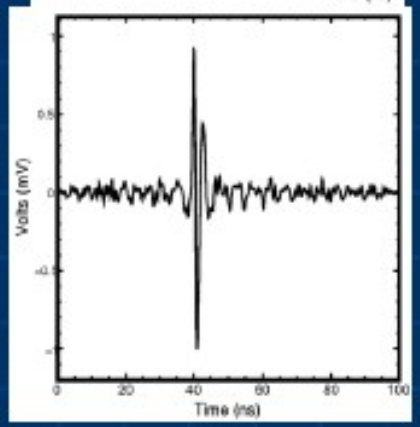
Radio detection

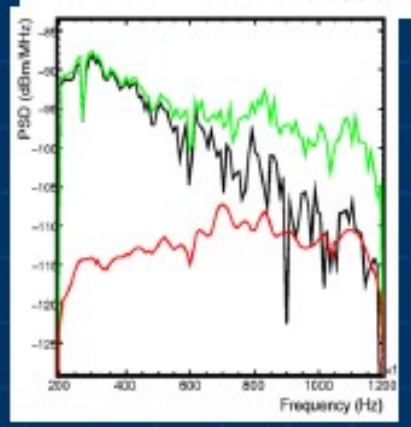
ANITA-1 deep Hpol analysis











- Independent deeper analysis done at UCLA
- **Still no neutrino candidates**
- BUT: all of original 6 Hpol events, **+10 more**
- Hpol events: impulsive, broadband, coherent, not like anthropogenic signals
  - Spread out randomly over the flight path coverage, not clustered with any camps

Stephen Hoover UCLA

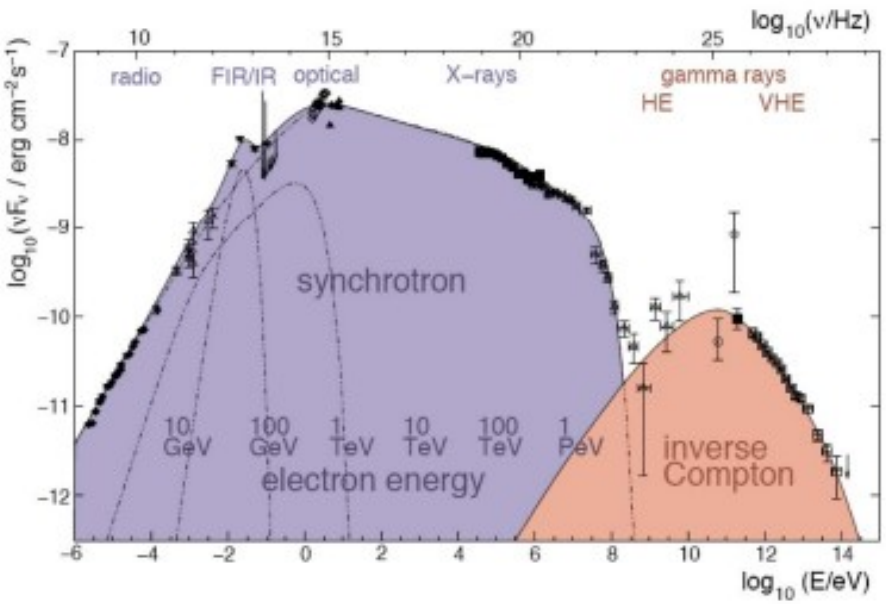
Gammas

- Source lists increasing
- Sensitivity improving
- Joint efforts ongoing

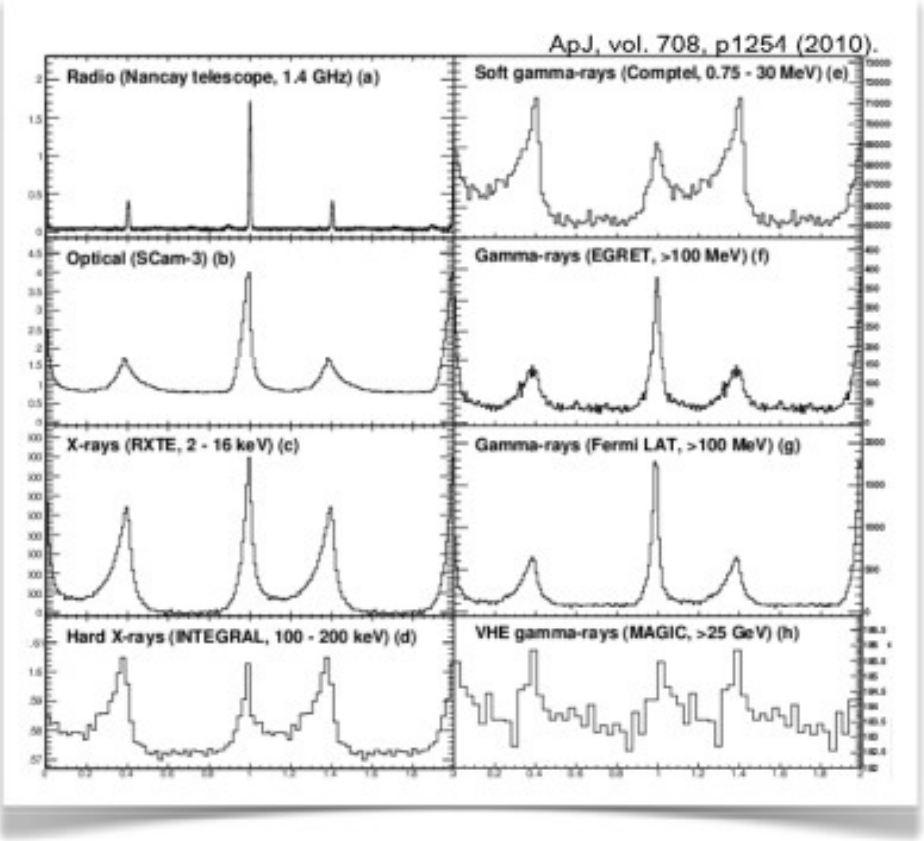
The case of the Crab

The Crab

Nebula

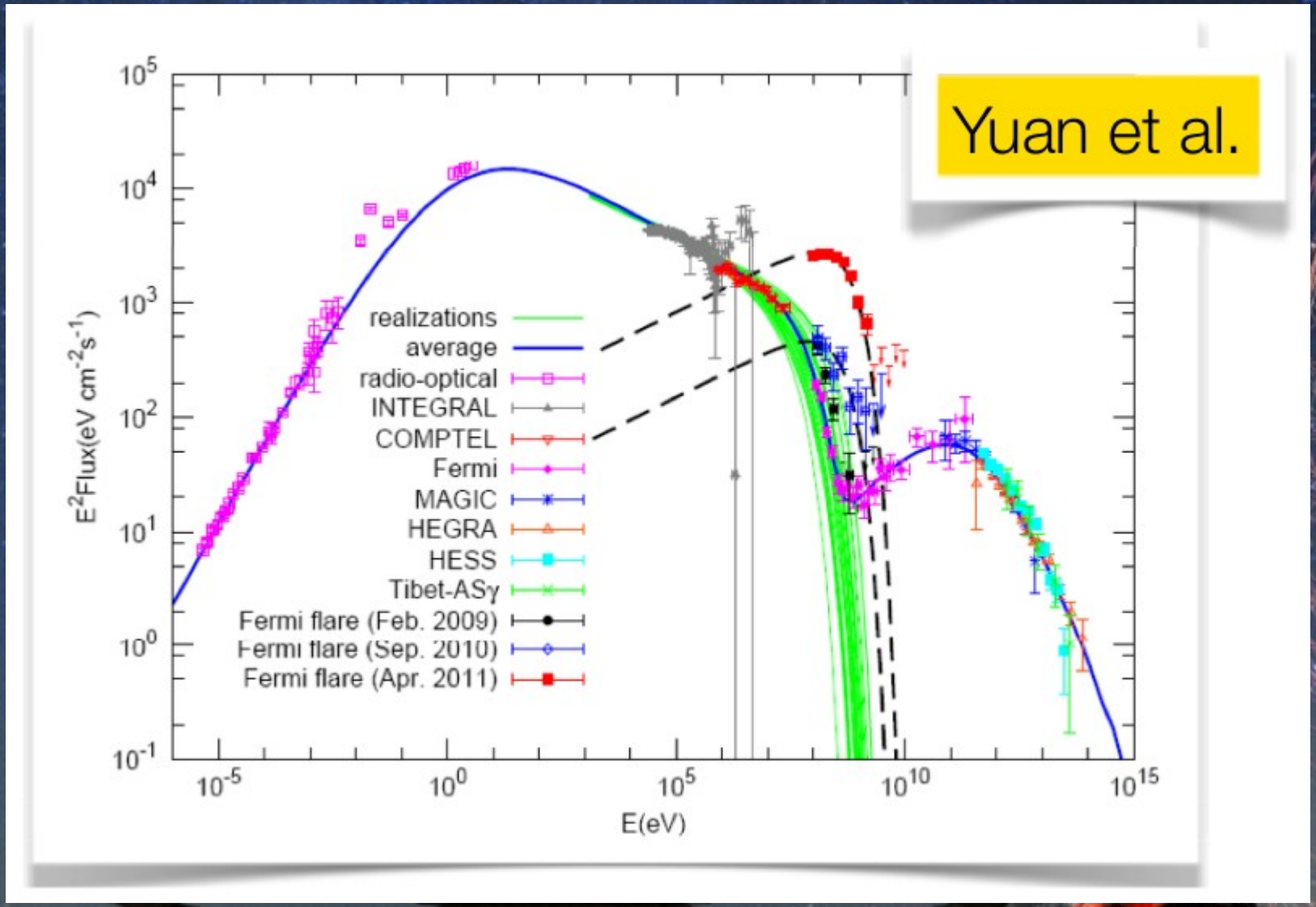


Pulsar



- In late 2009, we were reasonably confident that we understand the Crab rather well.
- Nebula: Synchrotron + IC emission. e^- up to PeV, accelerated at termination shock. Pulsed emission: curvature radiation in outer gap of neutron star

The case of the Crab



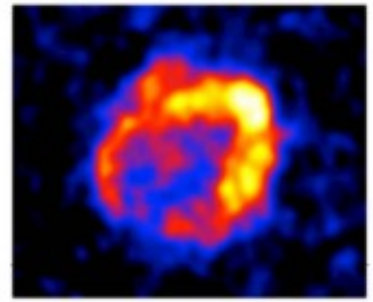
Flux *30, April 2011, hour timescale

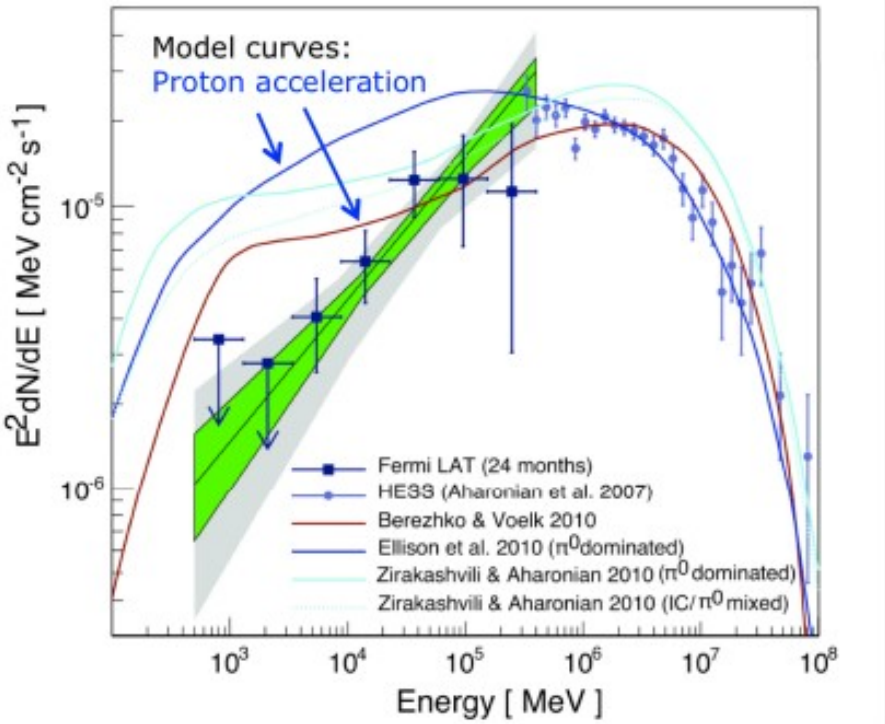
Standard diffusive shock acceleration not possible

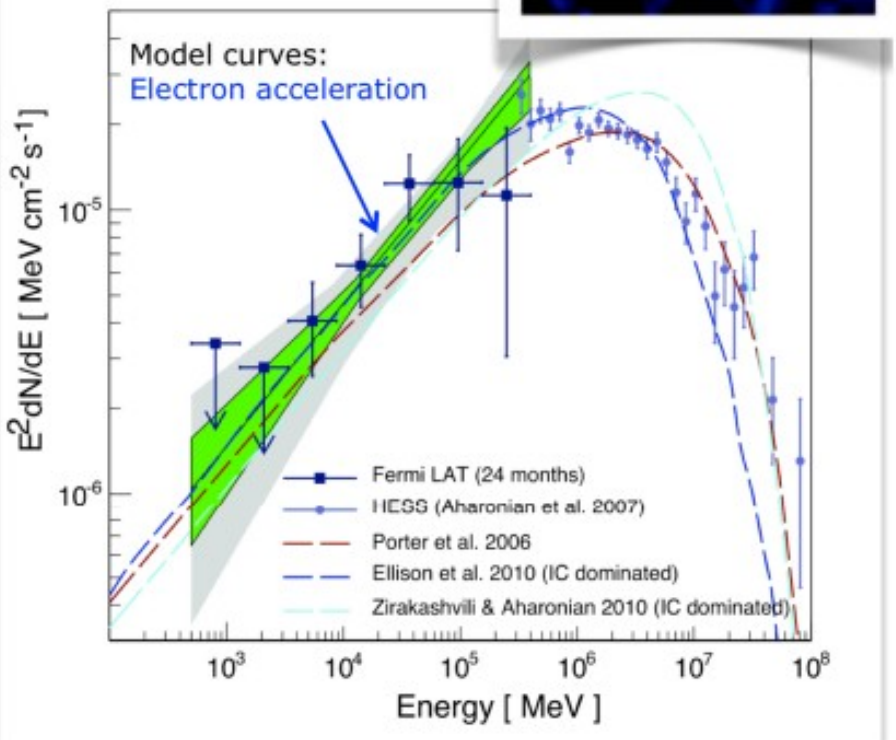
=> See lecture next week

Hadronic candidates?

The best candidate? RX J1713.7-3946







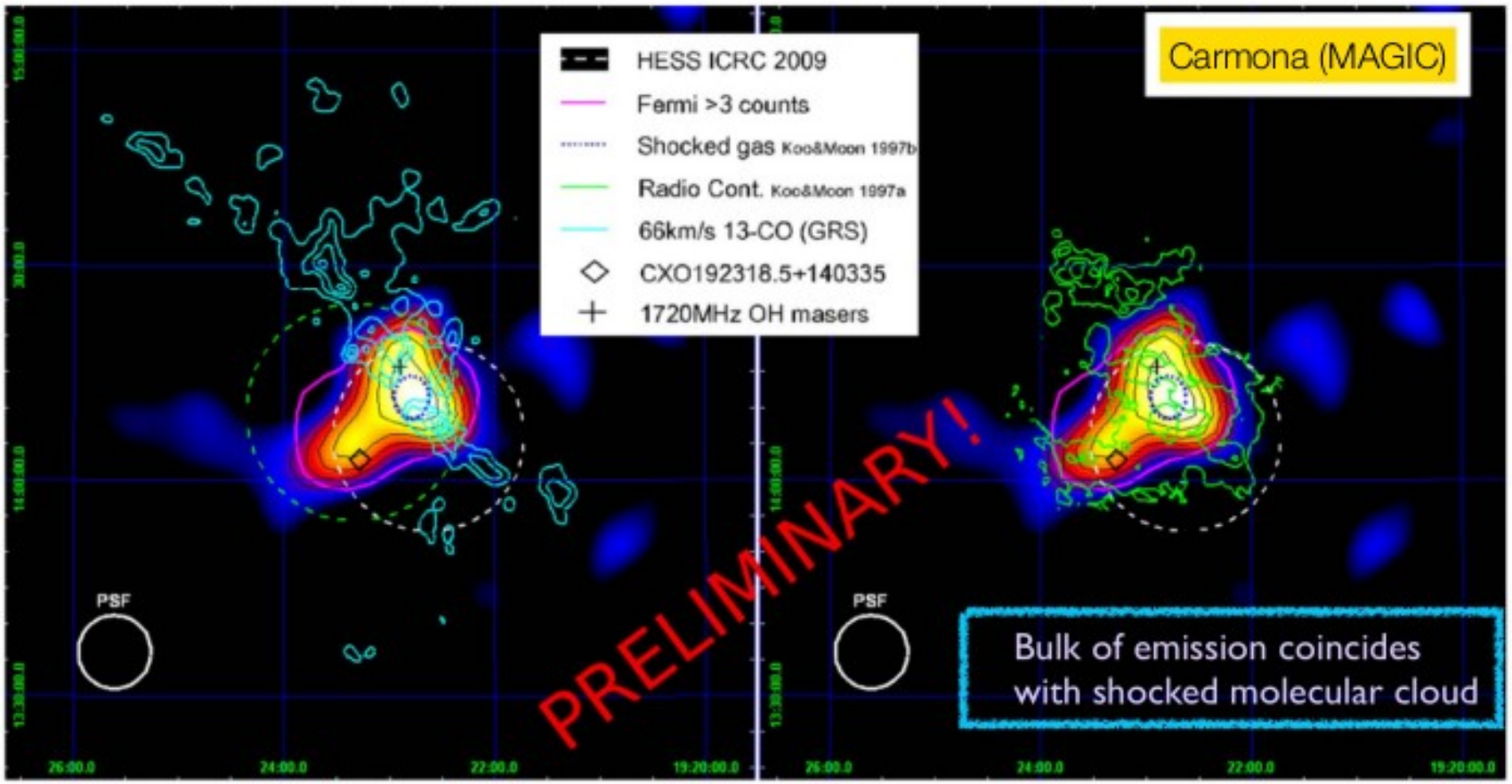
- It seems that the lepton-dominated case is favored, given the Fermi-LAT measurement and the low ambient gas density.
- F. Aharonian: "Life might be more complicated"

Aharonian

Hadronic candidates?

Life might get even more complicated

- W 51C. One of the best cases for hadronic acceleration in the Fermi-LAT data (mid-aged remnant, interacting with dense molecular material)



Stefan Funk, August 18th 2011, 32nd ICRC Beijing

Hadronic candidates?

Life might get even more complicated

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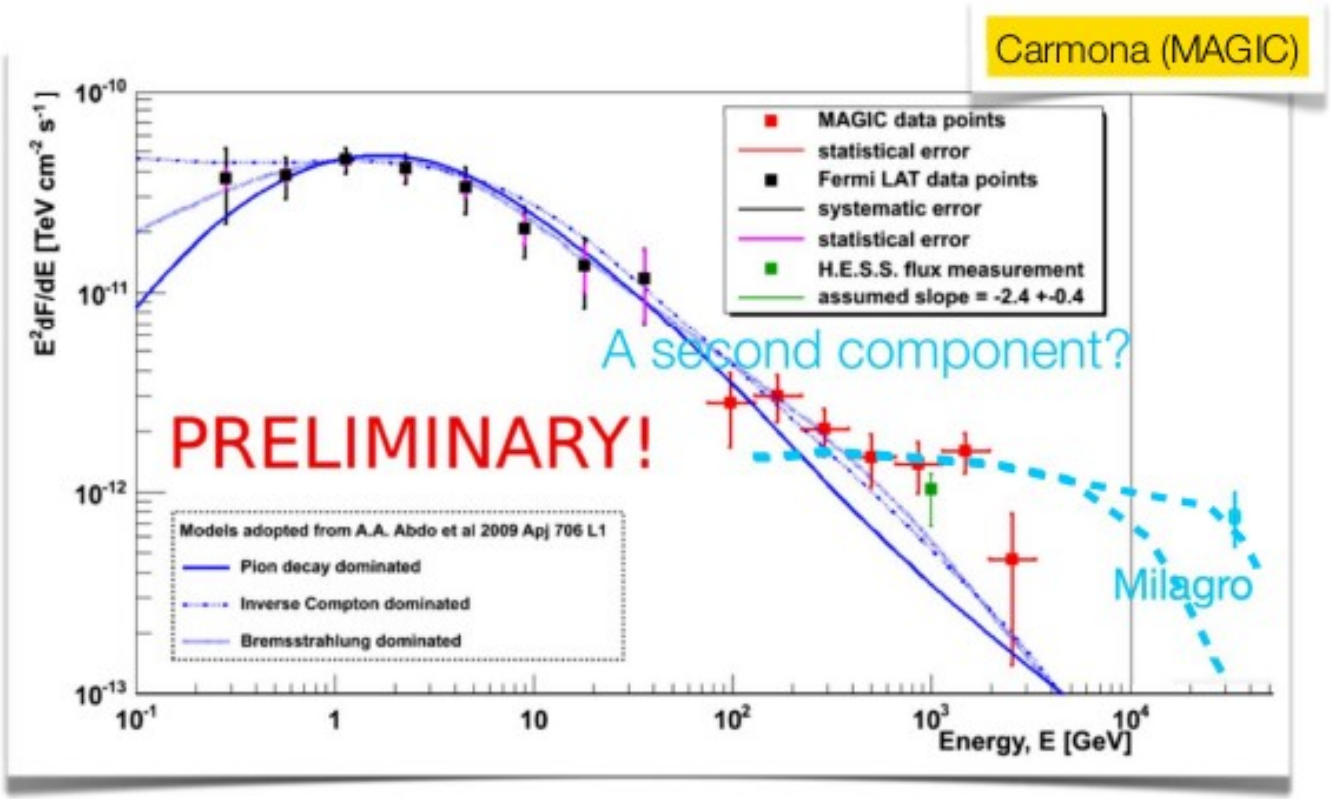
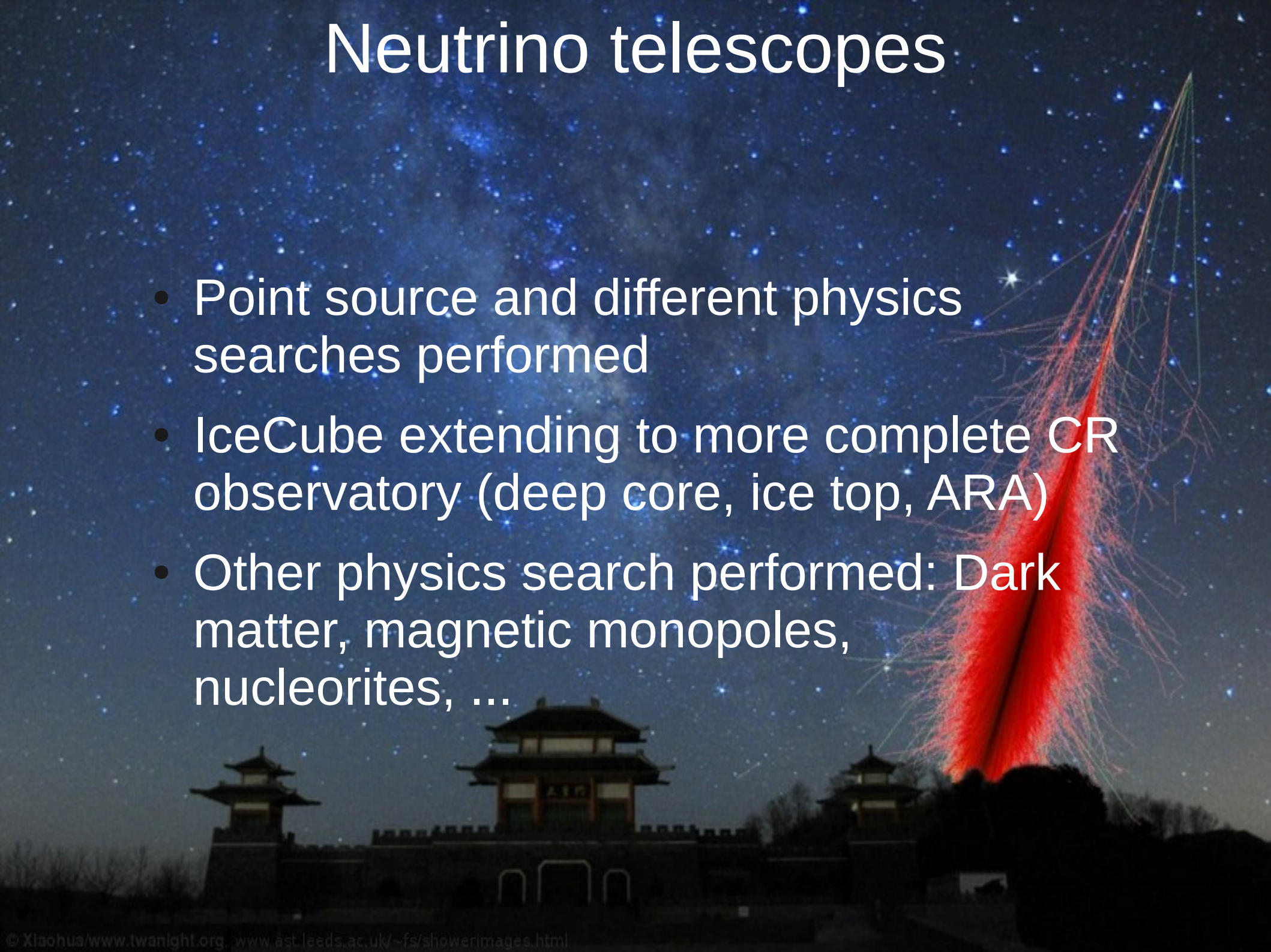


Neutrino telescopes



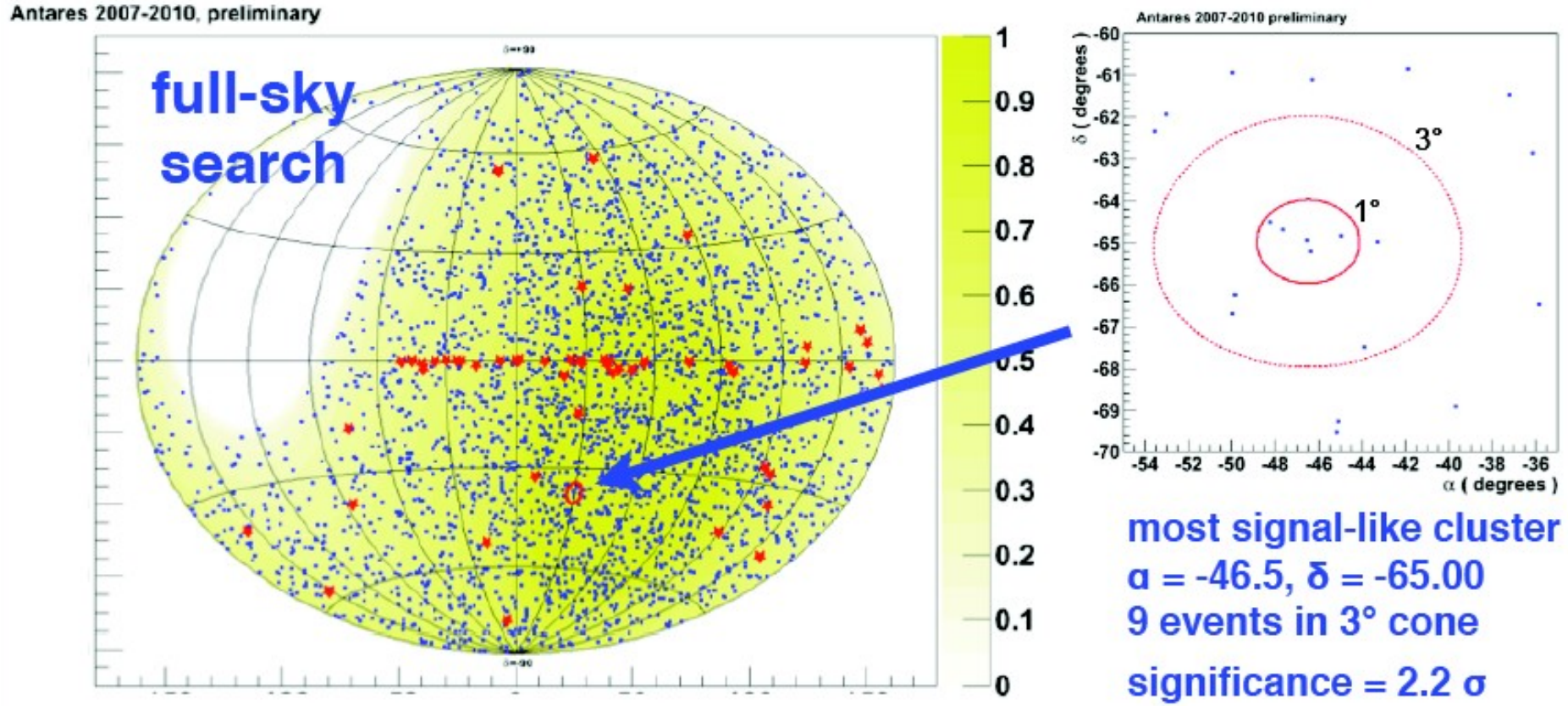
- Point source and different physics searches performed
- IceCube extending to more complete CR observatory (deep core, ice top, ARA)
- Other physics search performed: Dark matter, magnetic monopoles, nucleorites, ...

Searching for point sources of high-energy cosmic neutrinos with the ANTARES telescope

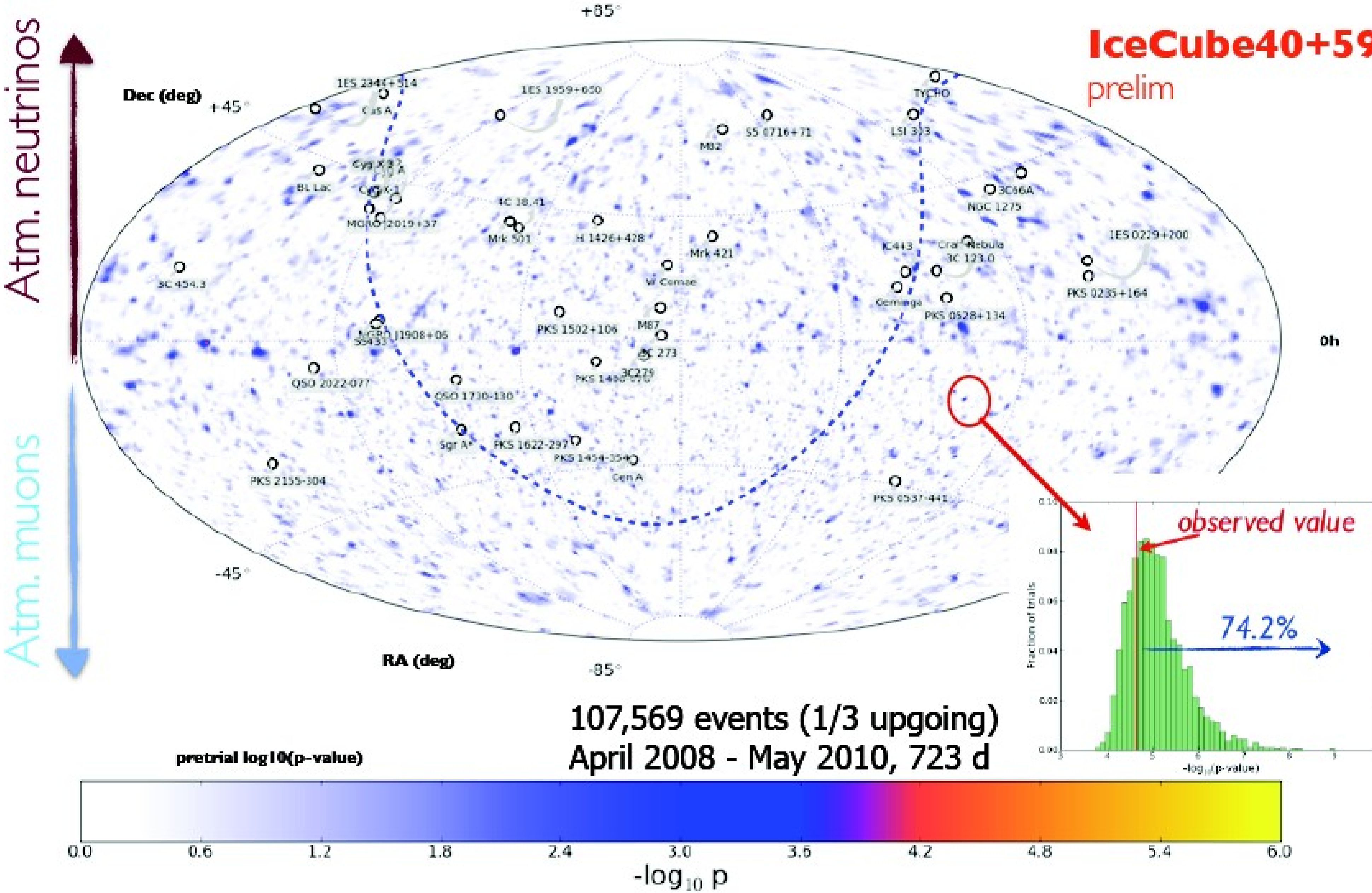
#295
Bogazzi

51 candidate sources

name	ra	decl	Nsigfit	Q	p-value	nsigma	lim_Nsig	lim_flux
HESS J1023-575	155.83	-57.76	1.97	2.35	0.41	0.82	5.62	6.6e-08
3C 279	-165.95	-5.79	1.11	2.15	0.48	0.71	5.35	1.0e-07
GX 339-4	-104.30	-48.79	1.26	1.49	0.72	0.36	5.10	5.8e-08
Cir X-1	-129.83	-57.17	1.52	1.31	0.79	0.27	5.00	5.8e-08



Point-source search: All sky and Selected Sources



No significant fluctuation: best pre-trial p-value = 0.14 pretrial in a list of 43 sources => 95% post-trial for PKS_1454-354

Conclusion

- First order description not sufficient anymore
- Injection and propagation models investigated
- Hadronic sources still mysterious
- At highest energies, correlation with AGN ~1/3, debate on composition

- Did not speak about incoming experiments (AMS-2, HAWK, CTA, ...)