Detection of Cosmic Rays in Space
(…and not only in Space…)

M. Ricci
INFN Laboratori Nazionali Frascati

LNF mini-workshop series

1st Synergy LNF-OAR Workshop

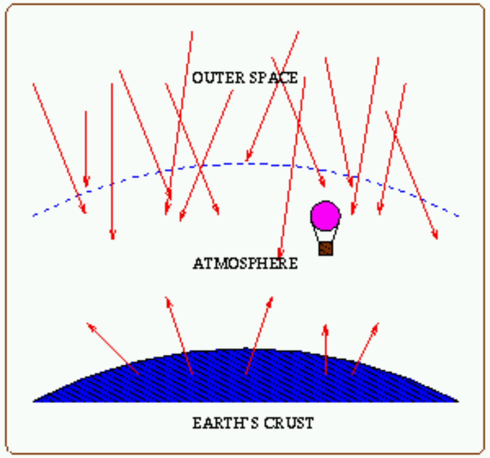
April 16th-17th 2014
Auditorium Bruno Touschek, Laboratori Nazionali di Frascati -INFN

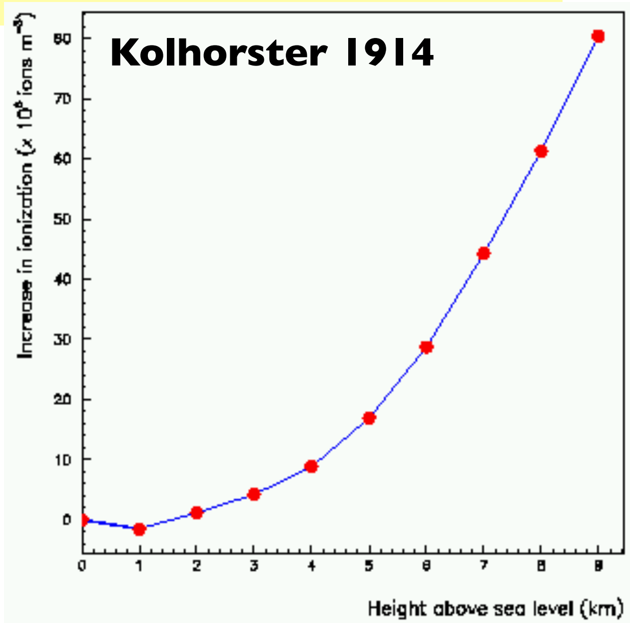
OAR

INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

A Century of Cosmic Rays

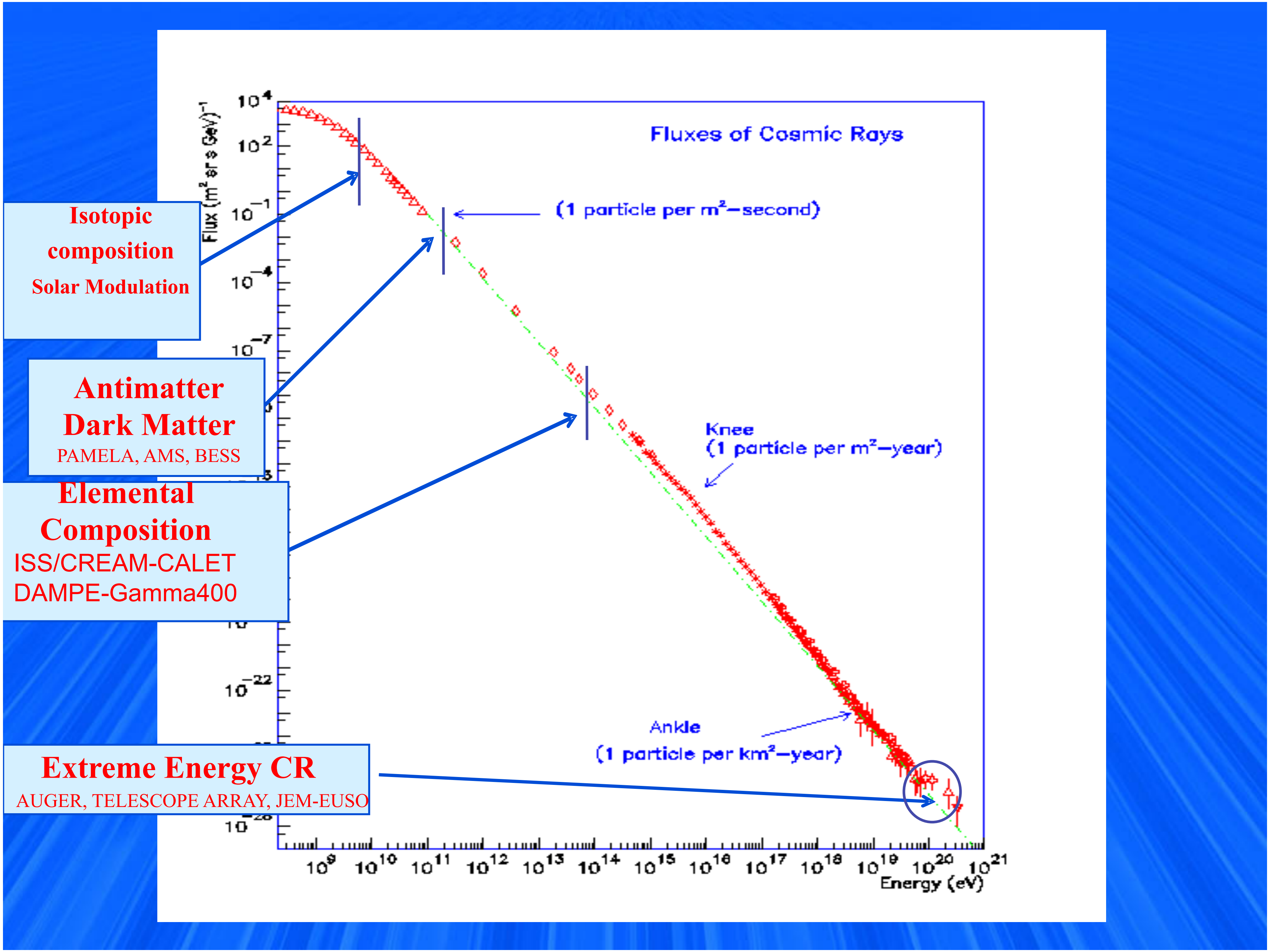
- Victor Hess ascended to 5000 m in a balloon in 1912
- ... and noticed that his electroscope discharged more rapidly as altitude increased
- Not expected, as background radiation was thought to be terrestrial. Extraterrestrial origin, confirming previous hints by Theodore Wulf and Domenico Pacini
- 1934: CR association to SNe proposed on energetic grounds (Baade and Zwicky)
  - Almost 80 years later evidence is still circumstantial
- Late 70's: Diffusive shock accelerations is proposed (Krymskii 77, Bell 78)





Cosmic Rays
main questions

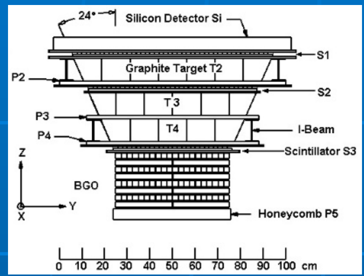
- Where do they come from? → **SOURCES**
- How and where they are getting accelerated? → **ACCELERATION**
- How do they propagate through the interstellar medium? → **PROPAGATION**
- Are they galactic or also extragalactic? → **TRANSITION**
- What kind of interaction do they undergo? → **INTERACTIONS**
- What role do they play in the energy budget of the interstellar medium?
- Do we find hints of the on exotic particles as relic from the early Universe, as antimatter and dark matter?


Fluxes of Cosmic Rays
(1 particle per m²–second)
Knee
(1 particle per m²–year)
Ankle
(1 particle per km²–year)
Flux (m² sr s GeV)⁻¹
Energy (eV)
Isotopic composition
Solar Modulation
Antimatter
Dark Matter
PAMELA, AMS, BESS
Elemental Composition
ISS/CREAM-CALET
DAMPE-Gamma400
Extreme Energy CR
AUGER, TELESCOPE ARRAY, JEM-EUSO

Space Missions and LDBF

PAMELA
2006-

ATIC
2002 – 2007 x3

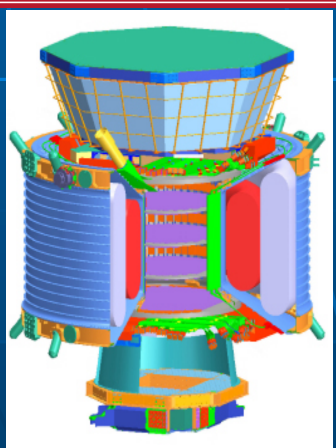


BESS
2004-2007 x3

CREAM
2004-2010 x6

AGILE
2007-

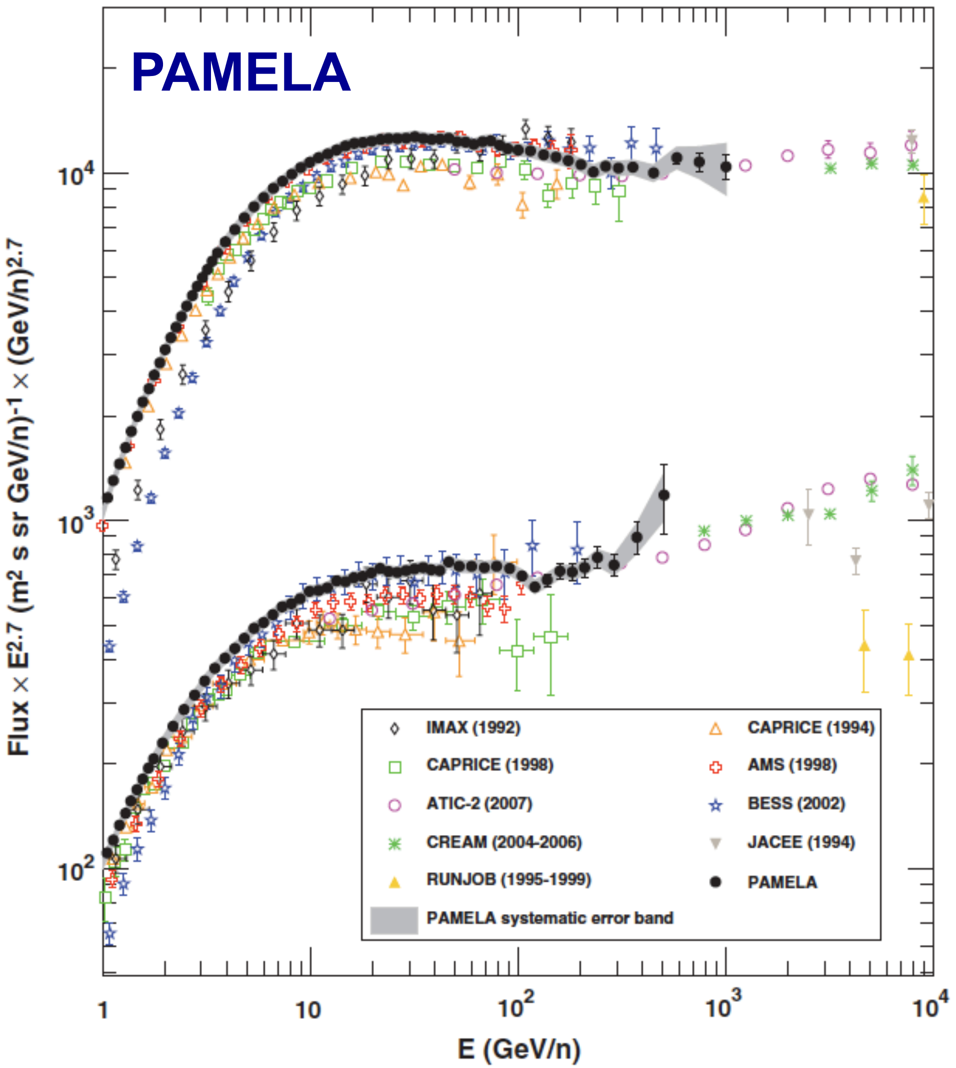
AMS-02
2011-

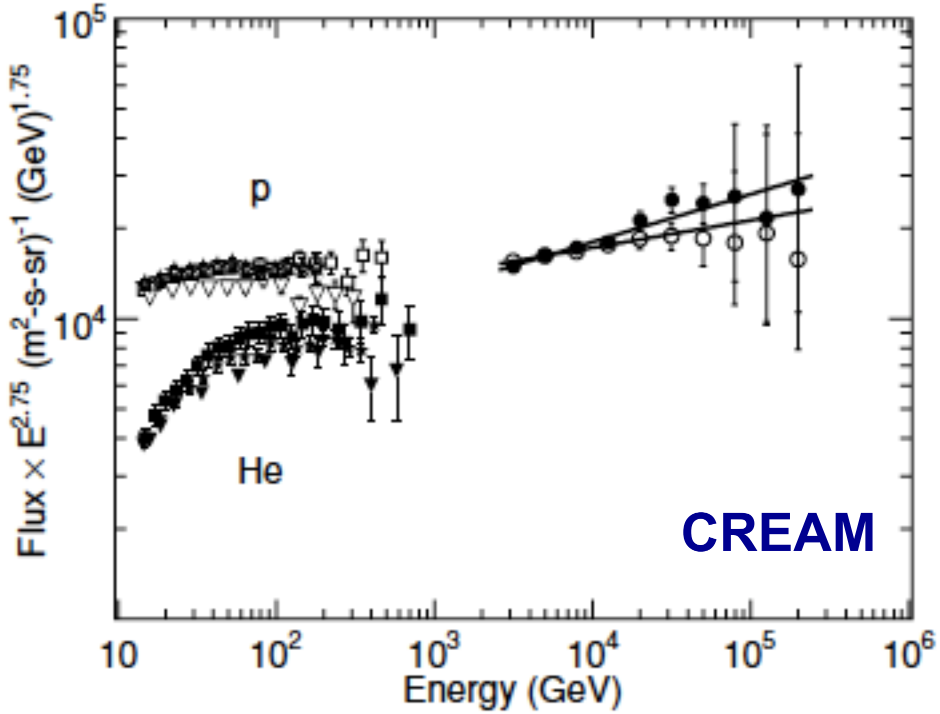


Fermi/GLAST
2008-

- **Cosmic Ray Protons and Helium**

CR HYDROGEN AND HELIUM





SPECTRAL BREAKS AT ~200 GV

SPECTRUM OF He HARDER THAN H

[redacted]

FOR PROTONS:

$$\gamma_{80-232GV} = 2.85 \pm 0.015(stat) \pm 0.004(syst)$$

$$\gamma_{>232GV} = 2.67 \pm 0.03(stat) \pm 0.05(syst)$$

FOR HELIUM:

$$\gamma_{80-240GV} = 2.766 \pm 0.01(stat) \pm 0.027(syst)$$

$$\gamma_{>240GV} = 2.477 \pm 0.06(stat) \pm 0.03(syst)$$

Excellent overlap with previous experiments

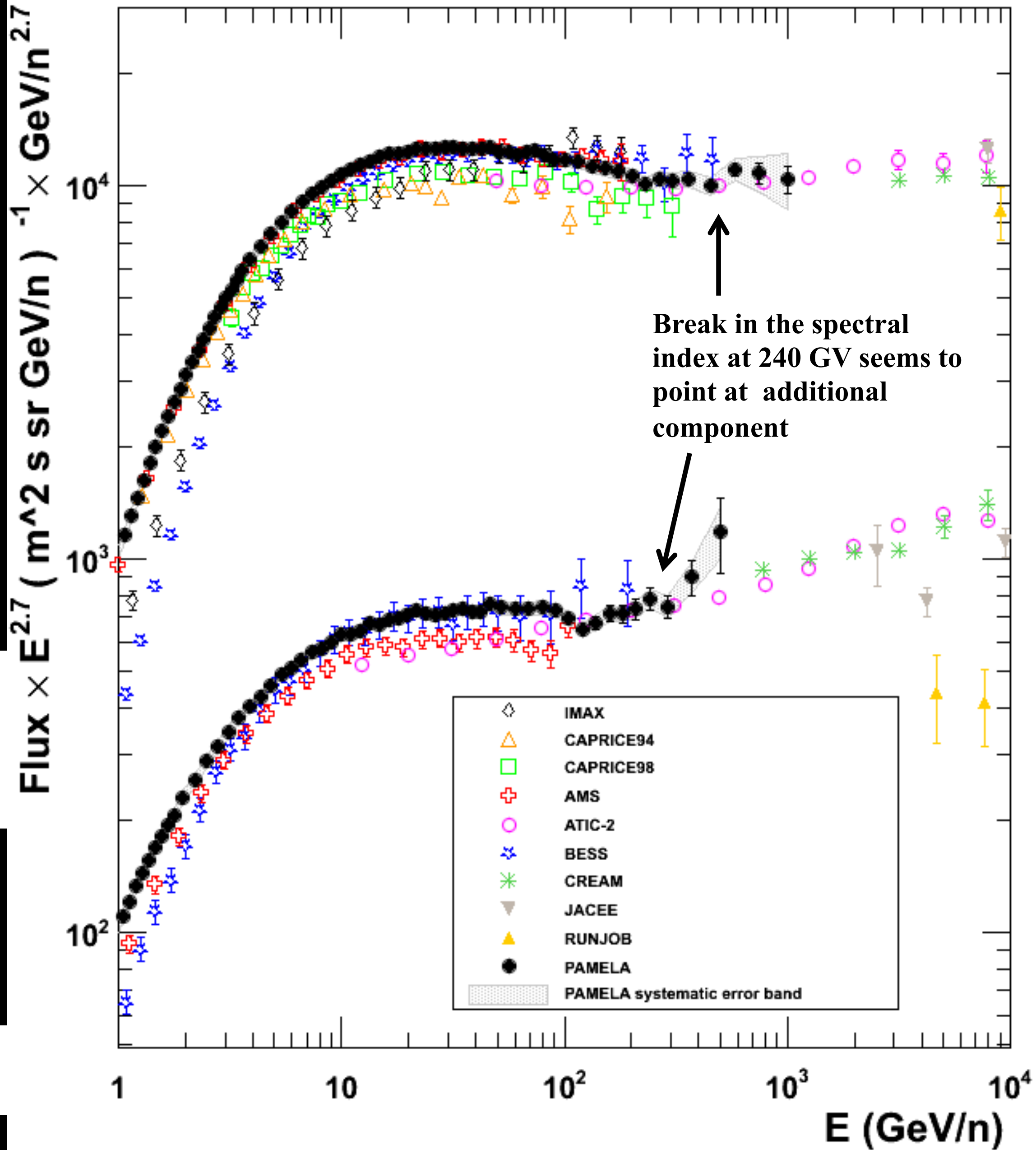
BESS (ICRC974)

Bridge with ATIC & CREAM toward high energy

$\gamma_{30\text{-}1000GeV,\ p} = 2.782 \pm 0.003\ (stat) \pm 0.004\ (syst)$

$\gamma_{15\text{-}600GeV/n,\ he} = 2.71 \pm 0.01\ (stat) \pm 0.007\ (syst)$

$$\gamma_T = \frac{dlog(\phi_T)}{logT} = (\gamma_R - 1)\frac{T^2 + Tmc^2}{T^2 + 2Tmc^2} + \frac{T}{T + mc^2}$$



SPECTRAL ANOMALIES IN GALACTIC COSMIC RAYS

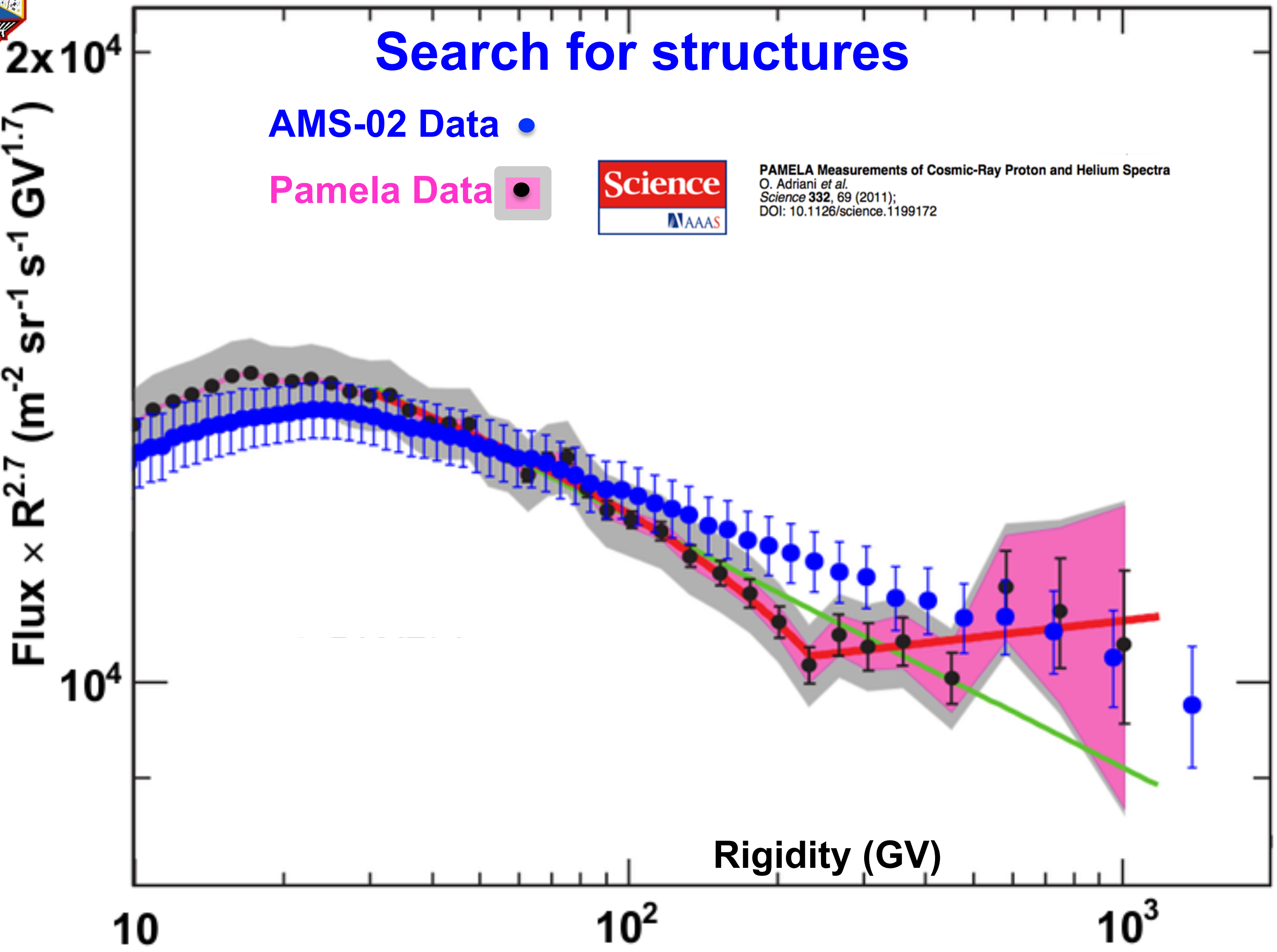
THE HARDENING IN THE SPECTRUM OF PROTONS AND HELIUM NUCLEI AT ~200 GV (AND POSSIBLY OTHER NUCLEI AS WELL) IS PUZZLING AND MAY BE SUGGESTIVE OF SOME INTERESTING PHYSICS:

- **LOCAL ENVIRONMENT**
- **ACCELERATION PHYSICS**
- **ANOMALIES IN THE DIFFUSIVE TRANSPORT**

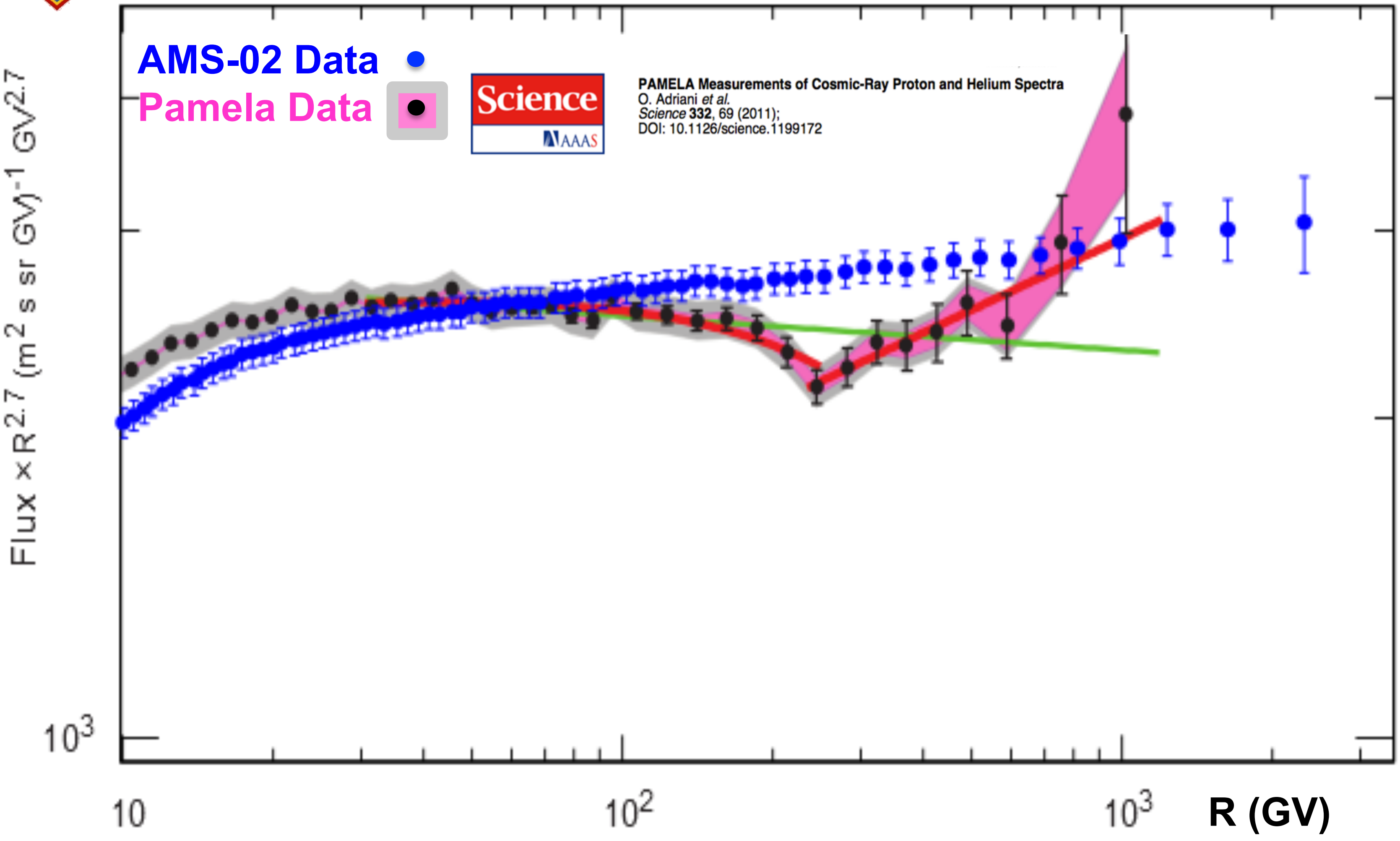
P. Blasi – ICRC 2013

BUT… AMS-02 RAISES A PROBLEM IN THIS SECTOR

Proton flux

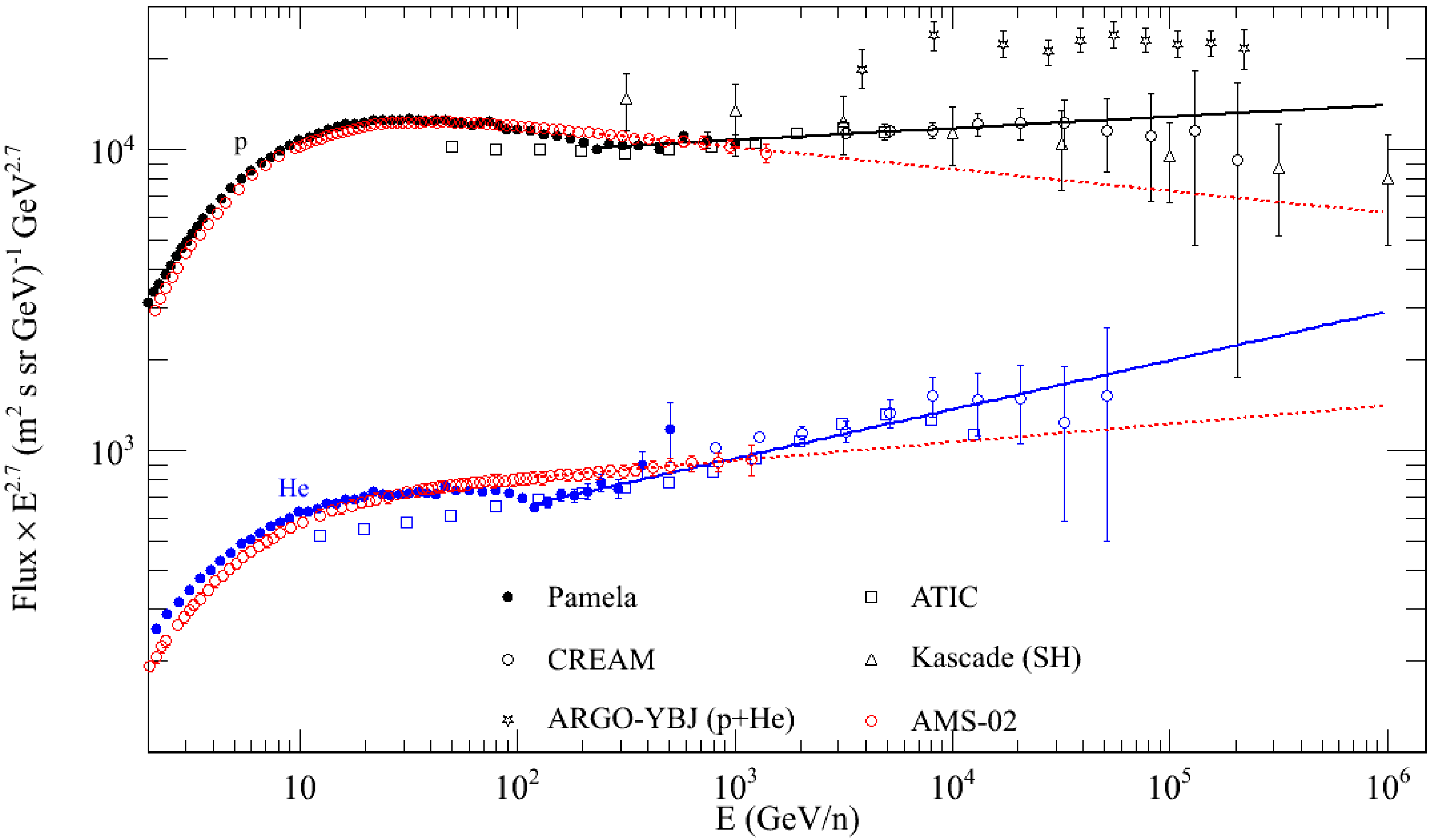

Search for structures
AMS-02 Data
Pamela Data
Science
AAAS
PAMELA Measurements of Cosmic-Ray Proton and Helium Spectra
O. Adriani et al.
Science 332, 69 (2011);
DOI: 10.1126/science.1199172
2x10^4
10^4
Flux × R^2.7 (m^-2 sr^-1 s^-1 GV^1.7)
Rigidity (GV)
10
10^2
10^3

Helium flux
Search for structures



To be presented by V. Choutko (8 July, ICRC)

Proton and Helium Nuclei Spectra



The break of the CR spectrum of p and He

What's happening? Systematics? Statistics?
How to solve this "tension" ?
Not only AMS vs. PAMELA but also vs. other experiments (BESS, CREAM, ATIC etc.)

The game is in progress – Careful review of data

Stay tuned!

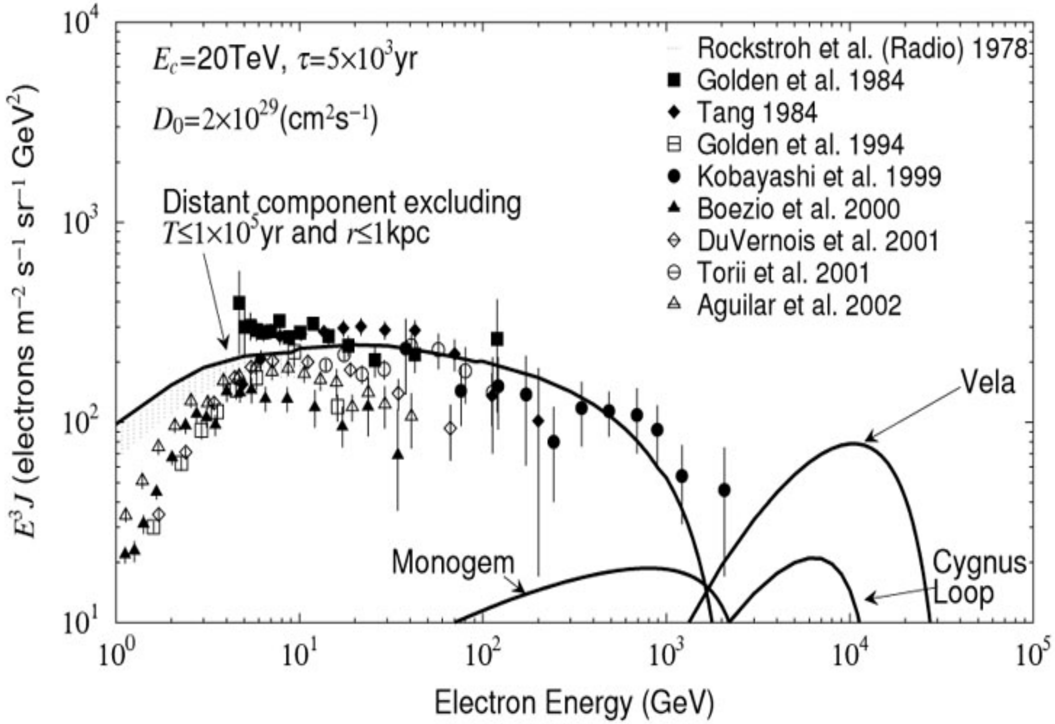
Cosmic Ray Electrons

Electrons can tell us about local GCR sources

- High energy electrons have a high energy loss rate $\propto E^2$
  - Lifetime of $\sim 10^5$ years for >1 TeV electrons
- Transport of GCR through interstellar space is a diffusive process
  - Implies that source of high energy electrons are < 1 kpc away

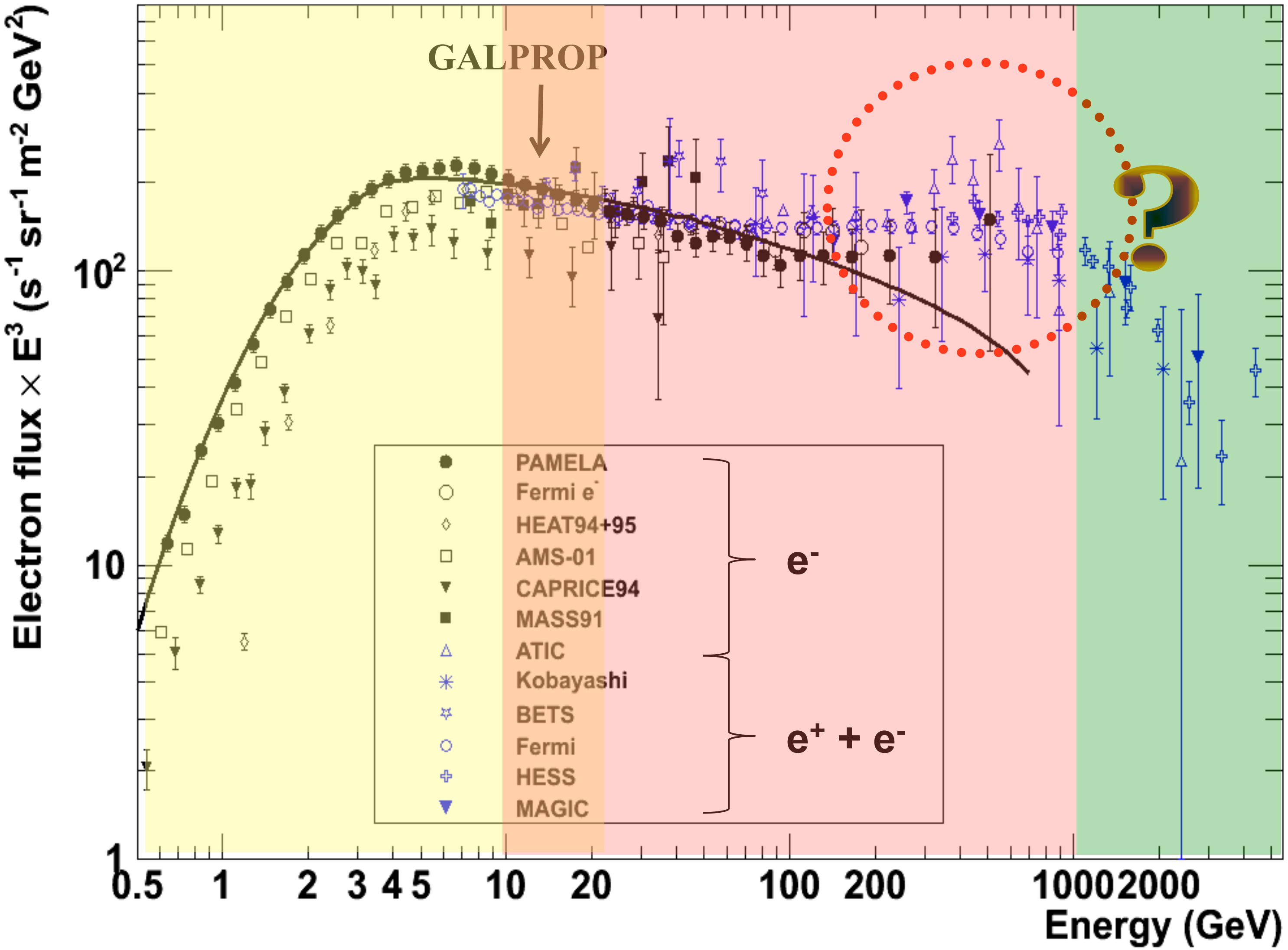
Only a handful of SNR meet the lifetime & distance criteria

Kobayashi et al., ApJ 601 (2004) 340 calculations show structure in electron spectrum at high energy

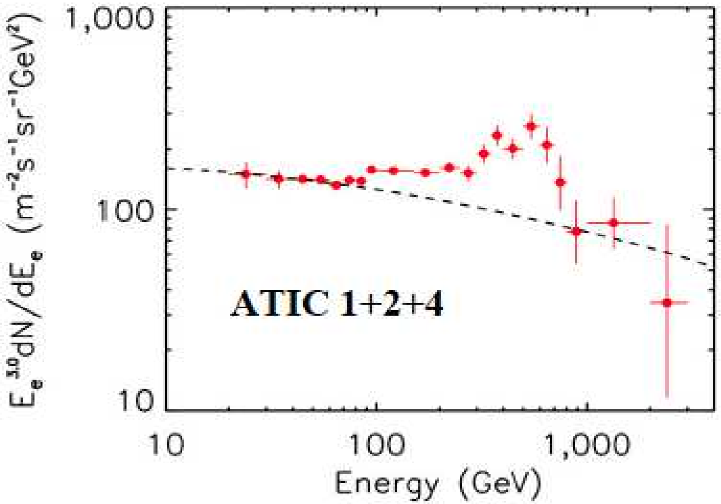


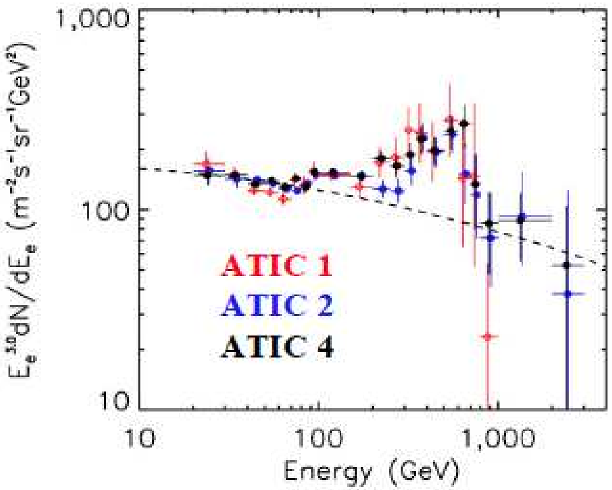
J. P. Wefel, TevPA 2011, Stockholm (2011)

Electron Spectrum



The ATIC “bump” in the all-electron spectrum



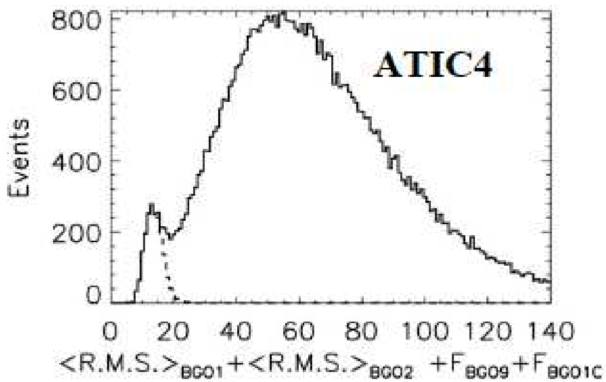


“Source on/source off” significance of bump for ATIC1+2 is about 3.8 sigma

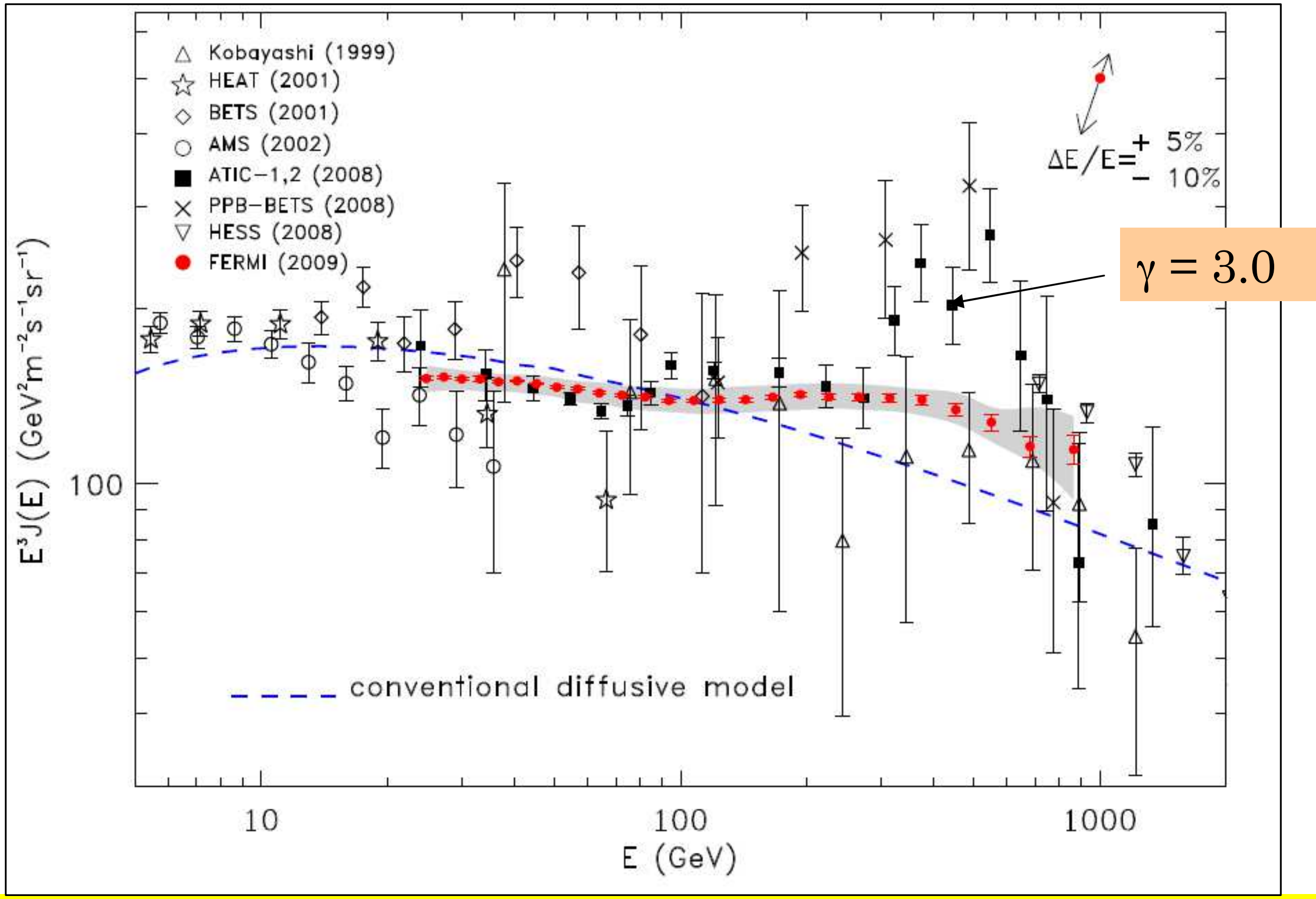
ATIC-4 with 10 BGO layers has improved e , p separation.

“Bump” is seen in all three flights.

Significance for ATIC1+2+4 is 5.1 sigma

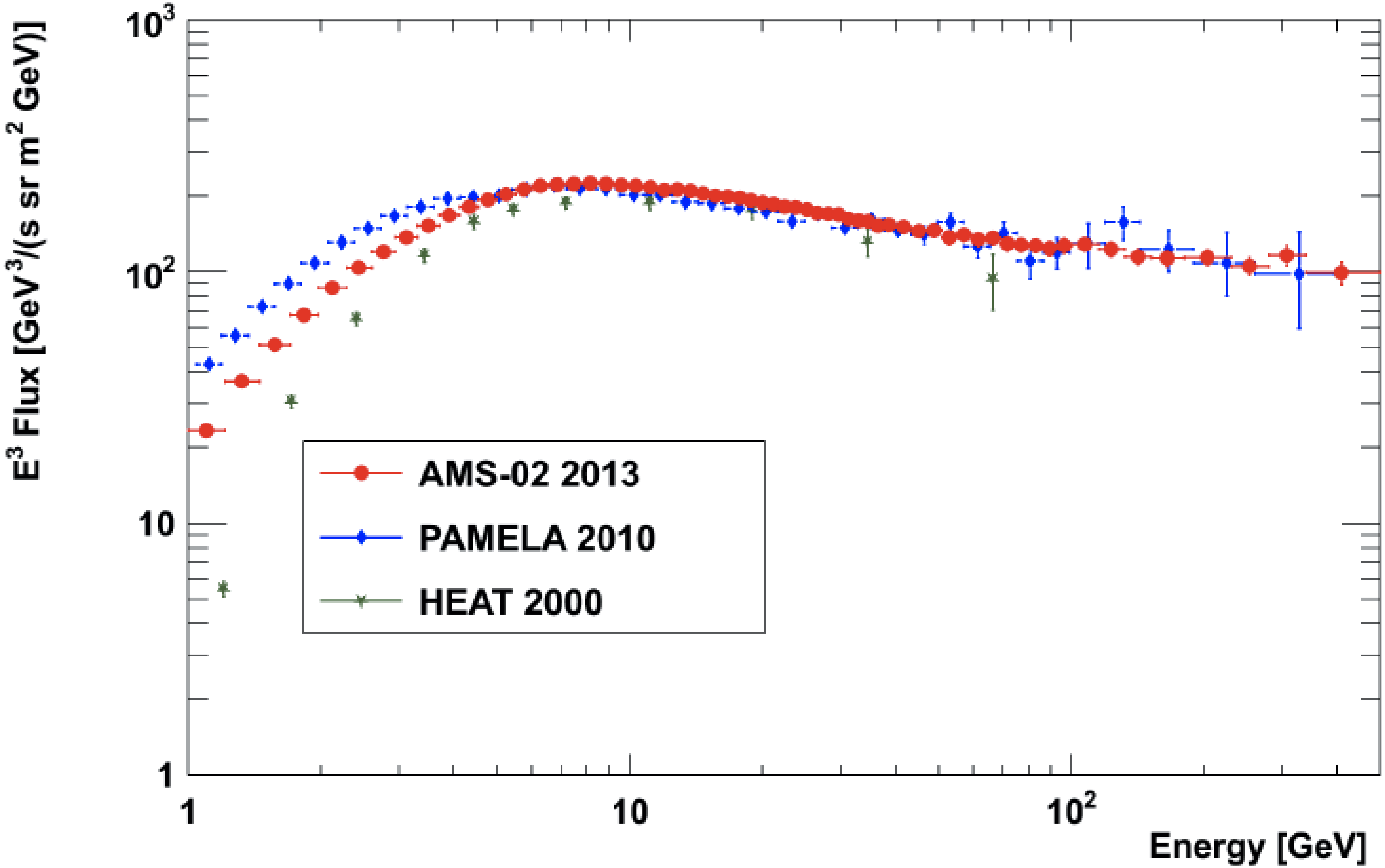


Reply from FERMI

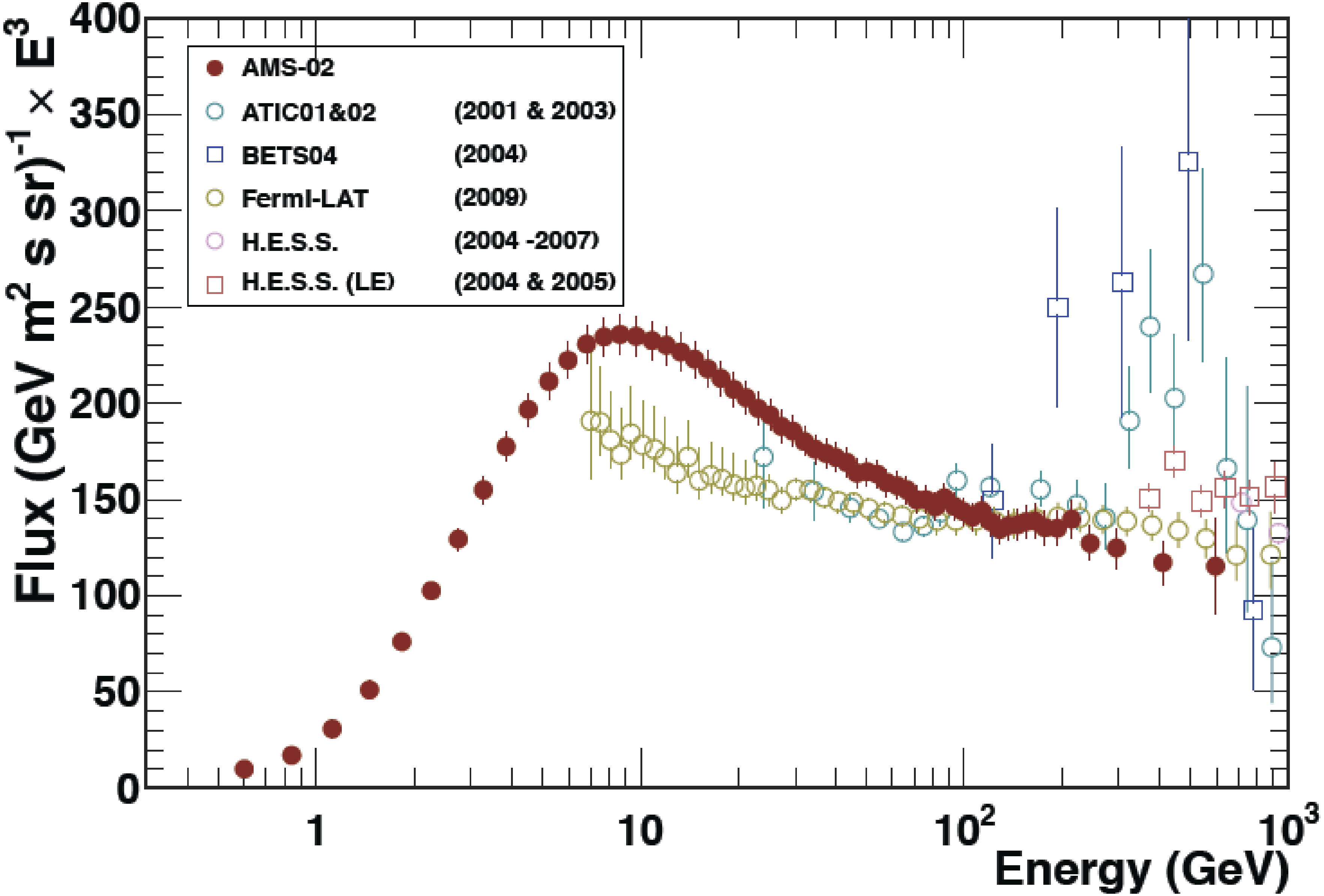


FERMI does not confirm the ATIC bump but finds an excess wrt conventional diffusive models

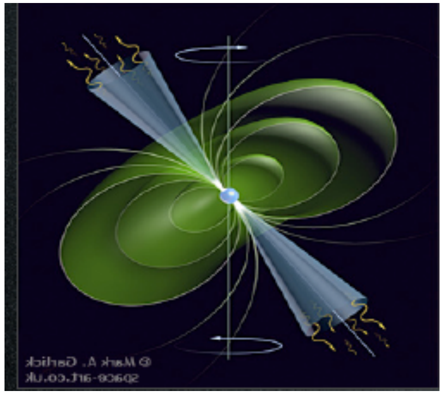
New results from AMS
4) Electron Spectrum



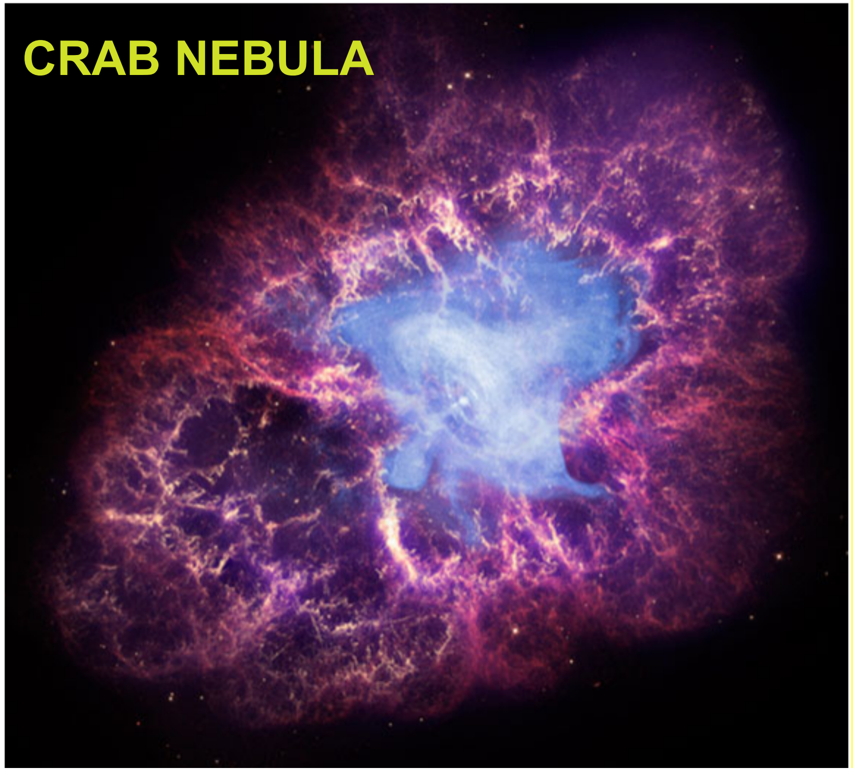
(Electron plus Positron) Spectrum
comparison with recent measurements



Astrophysical Explanation: Pulsars



- Mechanism: the spinning B of the pulsar strips e^- that accelerated in the outer magnetosphere emit γ that produce $e^{\pm}$. But pairs are trapped in the cloud. After $(4\text{-}5)\times10^4$ years pulsars leave remanent and pairs are liberated (e.g. P. Blasi & E. Amato, arXiv:1007.4745).



- Young ($T < 10^5$ years) and nearby (< 1kpc)
- If not: too much diffusion, low energy, too low flux.

- Geminga: 157 parsecs from Earth and 370,000 years old
- B0656+14: 290 parsecs from Earth and 110,000 years old.

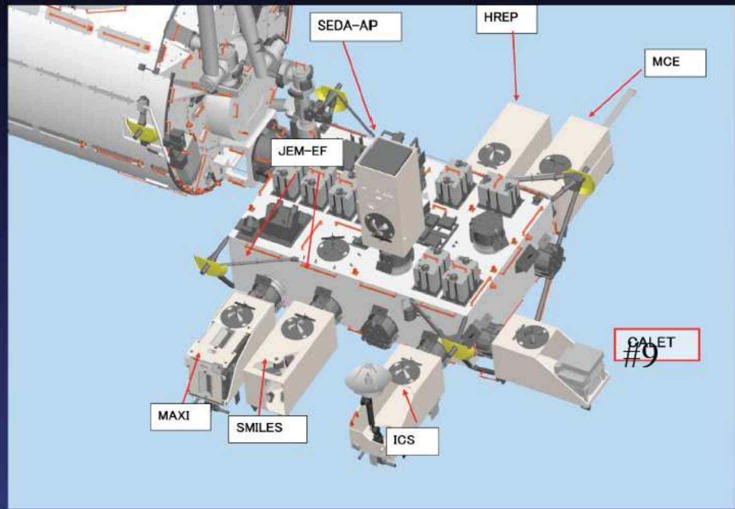
- Not a new idea, e.g.: Harding & Ramaty, ICRC 2 (1987), Boulares, ApJ 342 (1989), Atoyan et al. PRD 52 (1995)

Need of measurements above 1 TeV for electrons

Planned missions →

CALorimetric Electron Telescope (CALET)

- **Instrument:**
  High Energy Electron and Gamma-Ray Telescope
- **Carrier:**
  HTV: H-IIA Transfer Vehicle
- **Attach Point on the JEM-EF: #9**
  for heavy (< 2000 kg) payloads
- **Nominal Orbit:**
  407 km, 51.6° inclination
- **Launch plan:**
  FY 2013
- **Life Time:**
  ≥ 5 years



1 GeV ~ 20 TeV for electrons

20 MeV ~ TeV for gamma-rays

Weight: 500 kg

GF (fiducial volume): ~ 0.12 m^2sr

Power Consumption: 640 W

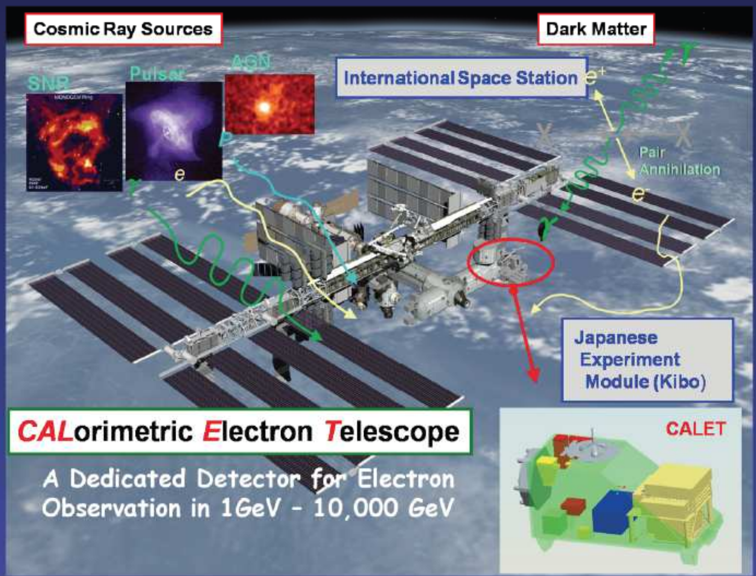
Data Rate: 300 kbps

Firenze
Pisa
Siena
Roma Tor Vergata

CALET Overview

□ Observation

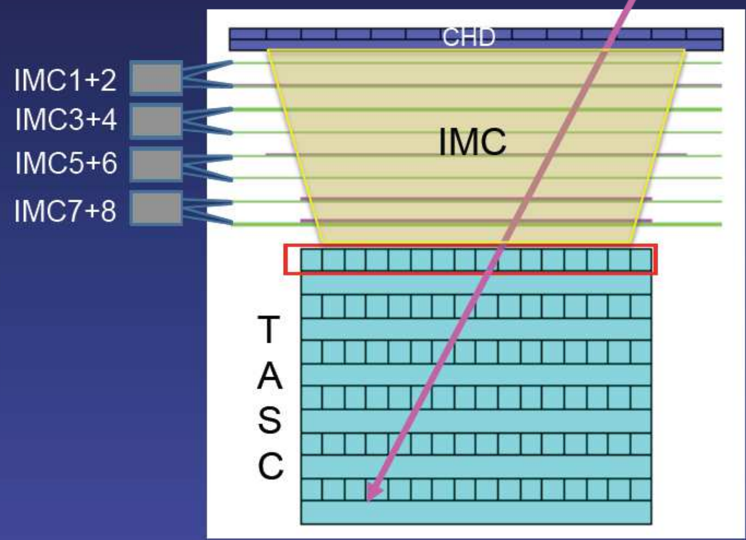
- **Electrons** : 1 GeV - 10 TeV
- **Gamma-rays** : 10 GeV-10 TeV (GRB > 1 GeV)
  + Gamma-ray Bursts : 7 keV-20 MeV
- **Protons, Heavy Nuclei**:
  several 10 GeV- 1000 TeV (per particle)
- **Solar Particles and Modulated Particles in Solar System**: 1 GeV-10 GeV (Electrons)

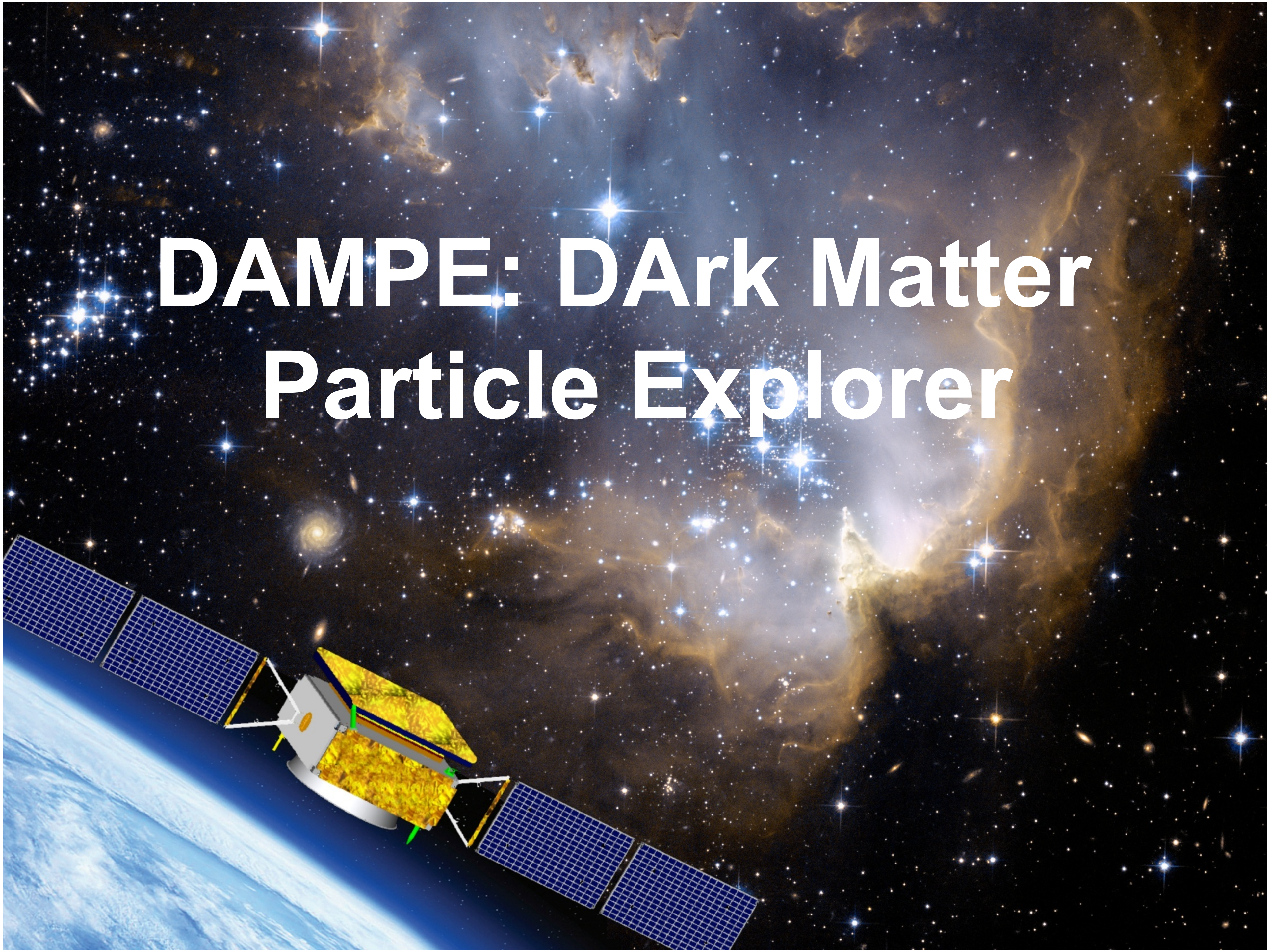


Instrument

High Energy Electron and Gamma-Ray Telescope:

- **CHarge Detector (CHD)**
  (Charge Measurement in Z=1-40)
- **Imaging Calorimeter (IMC)**
  (Particle ID, Direction)
  Total Thickness of Tungsten (W): 3 X_0 $0.11\ \lambda_I$
  Layer Number of Scifi Belts: 8 Layers × 2(X,Y)
- **Total Absorption Calorimeter (TASC)**
  (Energy Measurement, Particle ID)
  PWO 20mm x 20mm x 320mm
  Total Depth of PWO: 27 X_0 (24cm) , $1.35\ \lambda_I$




DAMPE: DArk Matter
Particle Explorer

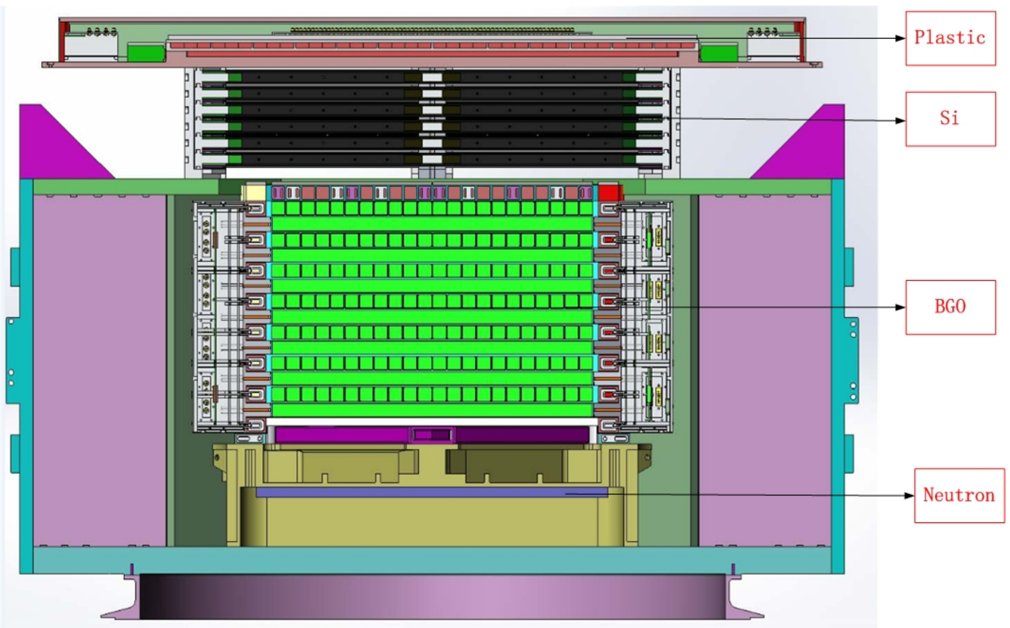
DAMPE: One of the Five Approved Satellite Missions of the Chinese Academy of Sciences

- Hard X-ray Modulation Telescope (HXMT)
- Quantum Science Experimental Satellite
- Dark Matter Particle Detection Satellite (DAMPE)
- Retrievable Scientific Experimental Satellite
- Kuafu Space Weather Project (3 satellite)

DArk Matter Particle Explorer (DAMPE) satellite

Energy range: 1 GeV-10 TeV
Particle type: electron, gamma-ray, heavy ions
Energy resolution: 1.5%@800GeV
Spatial resolution: 0.1degree@500GeV
Background level: 1%@800GeV
p/e separation: <1%
GF: $0.5m^2$.sr

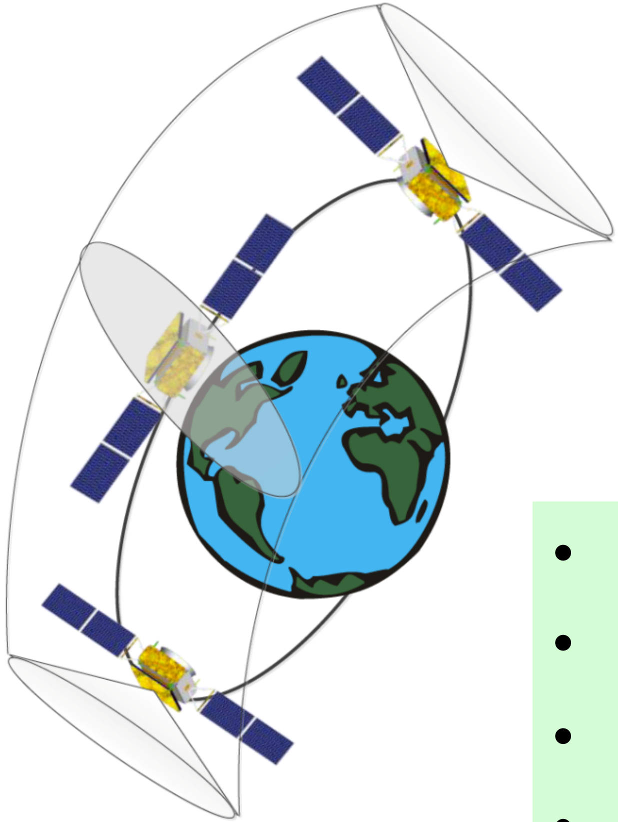
Top scintillators
Si tracker (5 layers)
BGO calorimeter
Neutron detector

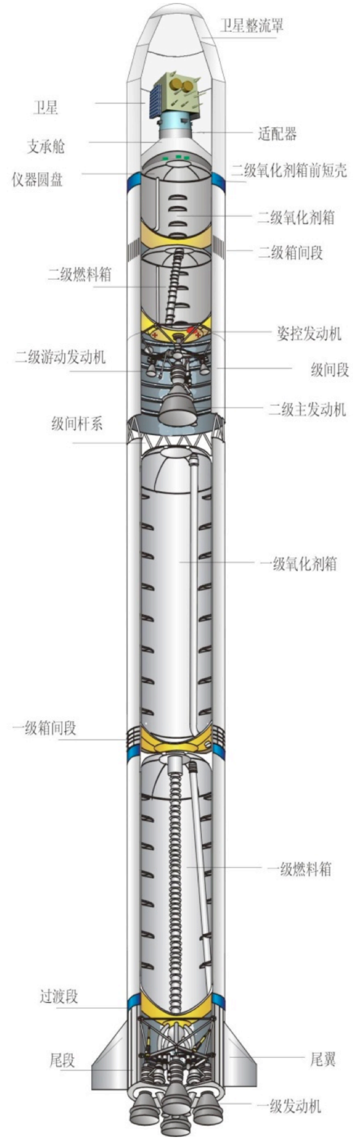


- Satellite < 1900 kg
- Payload ~1340kg
- Power: 840W
- Lifetime > 3 years

DAMPE Mission

- Approved for construction (phase C/D) in Dec. 2011
- Scheduled launch date 2015
- **To be Launched by CZ-2D rockets**



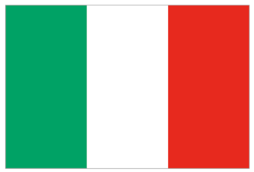


- Altitude 500 km
- Inclination 97.4065°
- Period 90 minutes
- sun-synchronous orbit

The DAMPE Collaboration

- Purple Mountain Observatory, CAS, Nanjing
- Institute of High Energy Physics, CAS, Beijing
- National Space Science Center, CAS, Beijing
- University of Science and Technology of China, Hefei
- Institute of Modern Physics, CAS, Lanzhou
- University of Geneva, Switzerland
- INFN Perugia, Italy
- INFN Bari, Italy

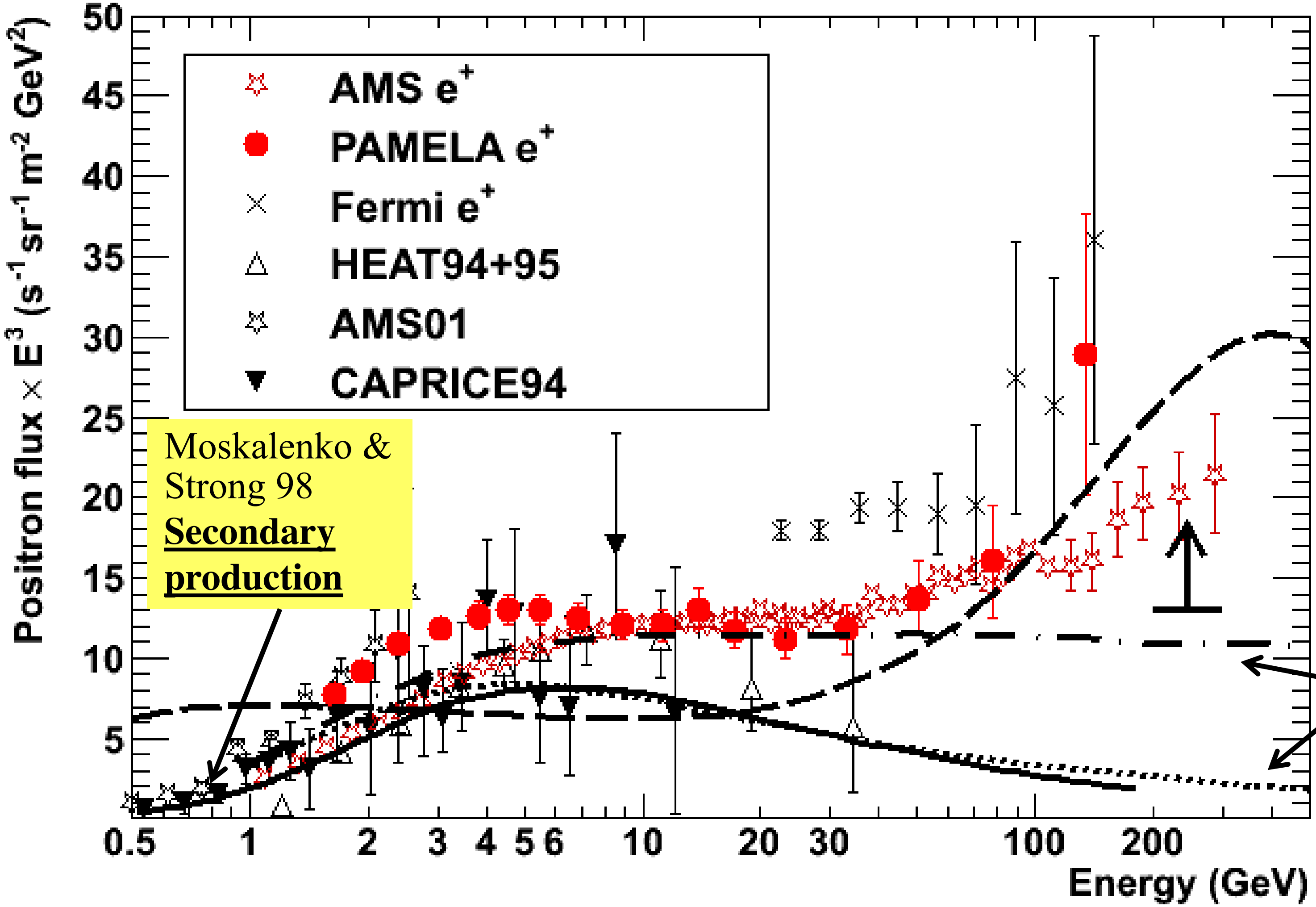




Cosmic Ray Antimatter (antiparticles)

Indirect search for Dark Matter

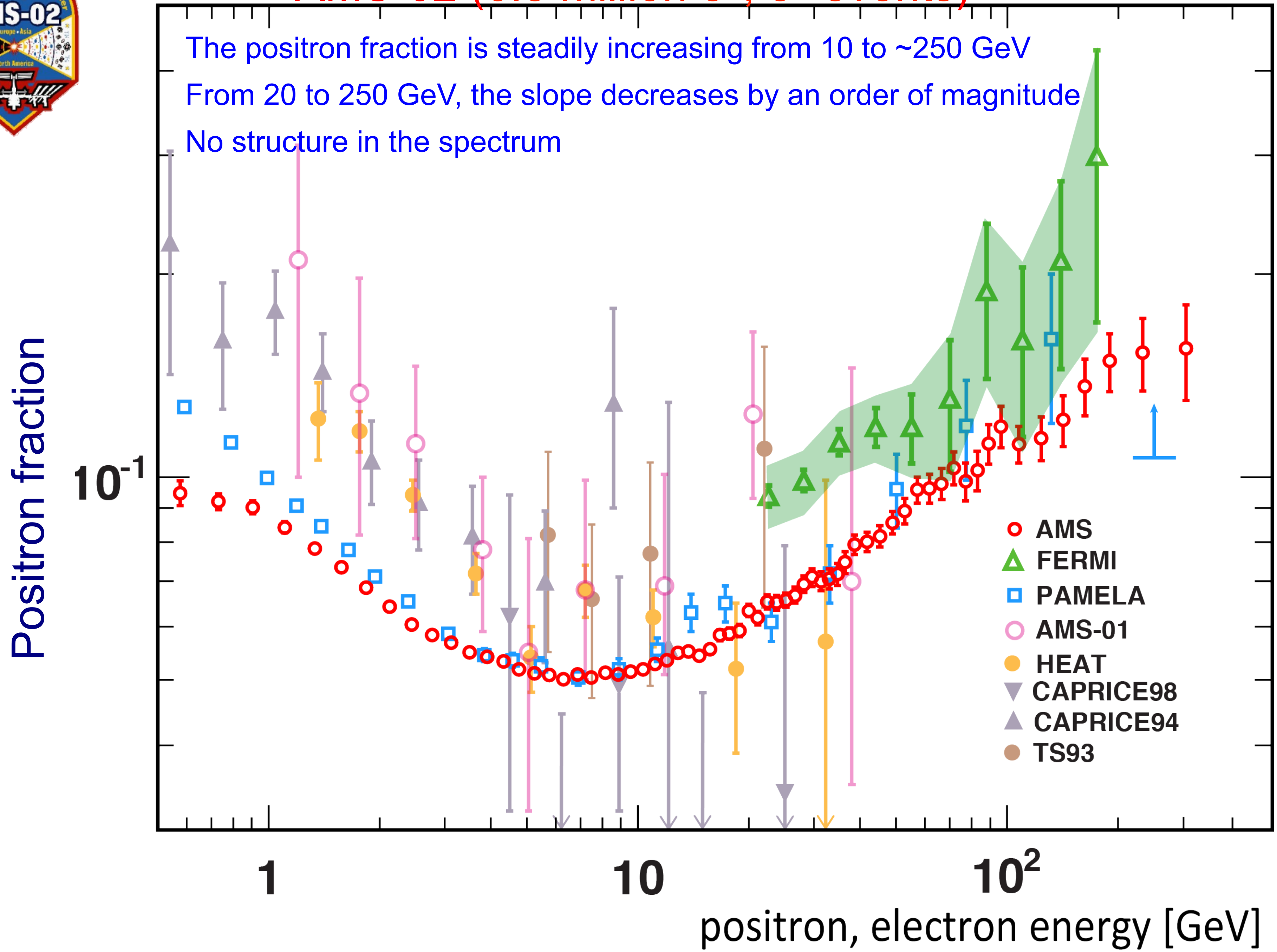
Positron Energy Spectrum



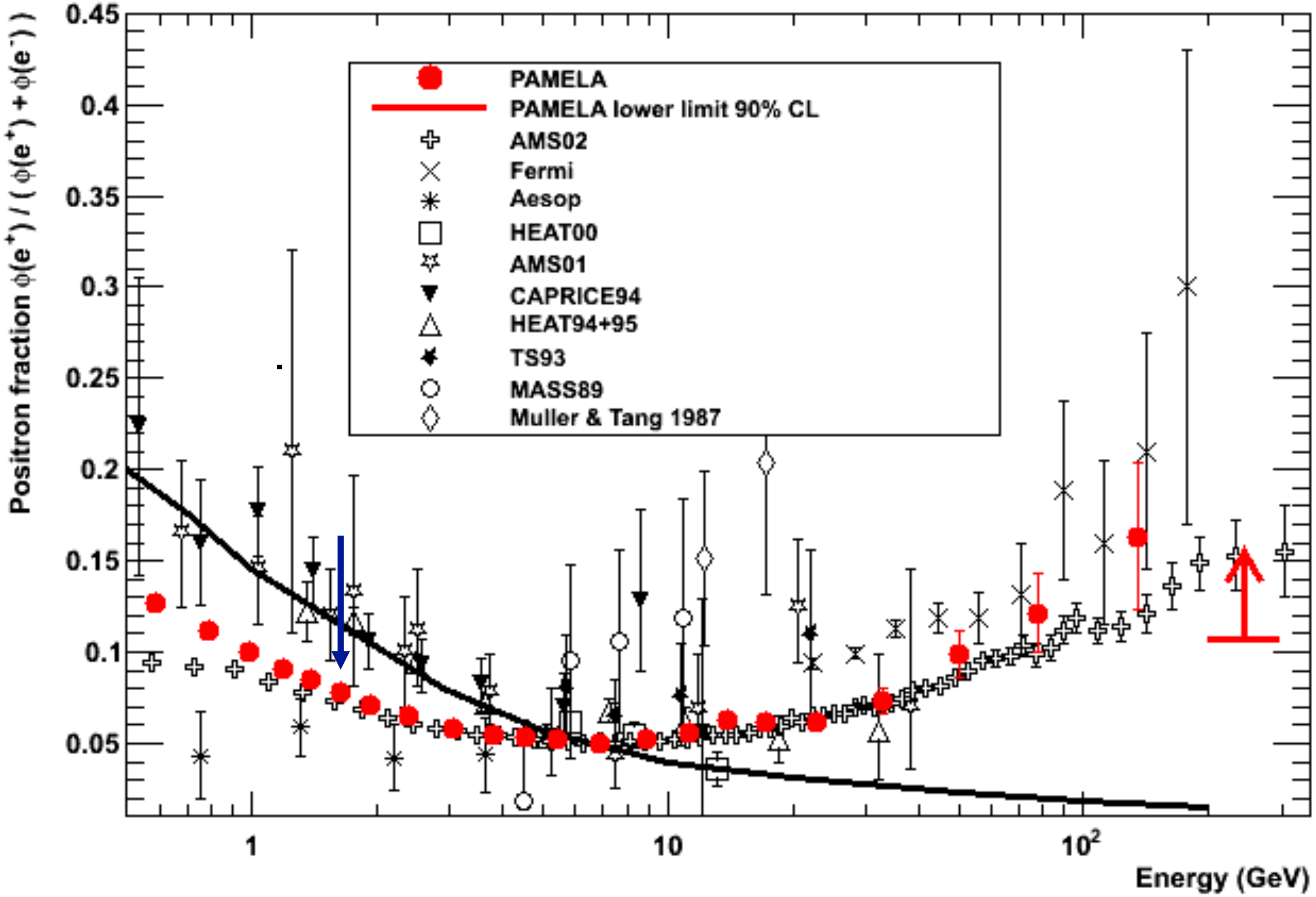
D. P. Finkbeiner et al., JCAP 1105, 002 (2011).
Secondary+ primary production (from dark matter annihilation

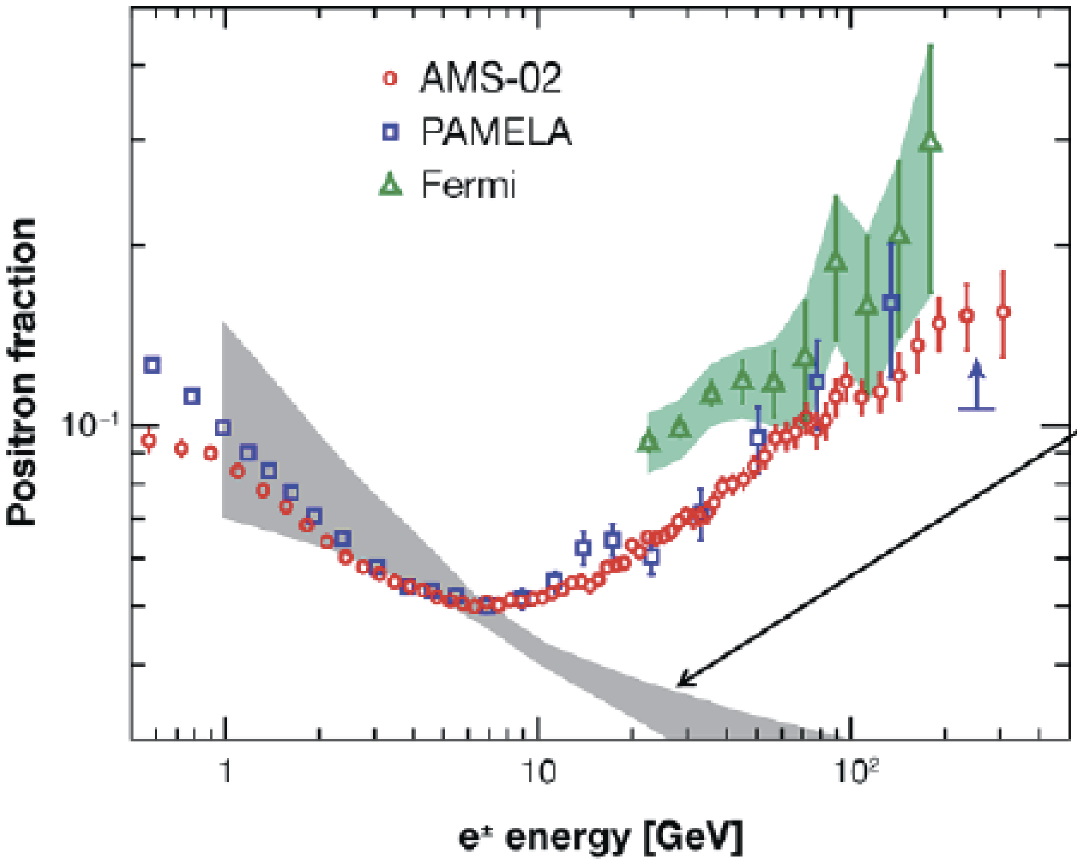
T. Delahaye et al., A&A 524 (2010) A51
Secondary & Seconday+Primary productions (from Astrophysical Sources)

AMS-02 (6.8 million e^+, e^- events)



PAMELA, AMS and FERMI Positron Fraction Compared to Expectation





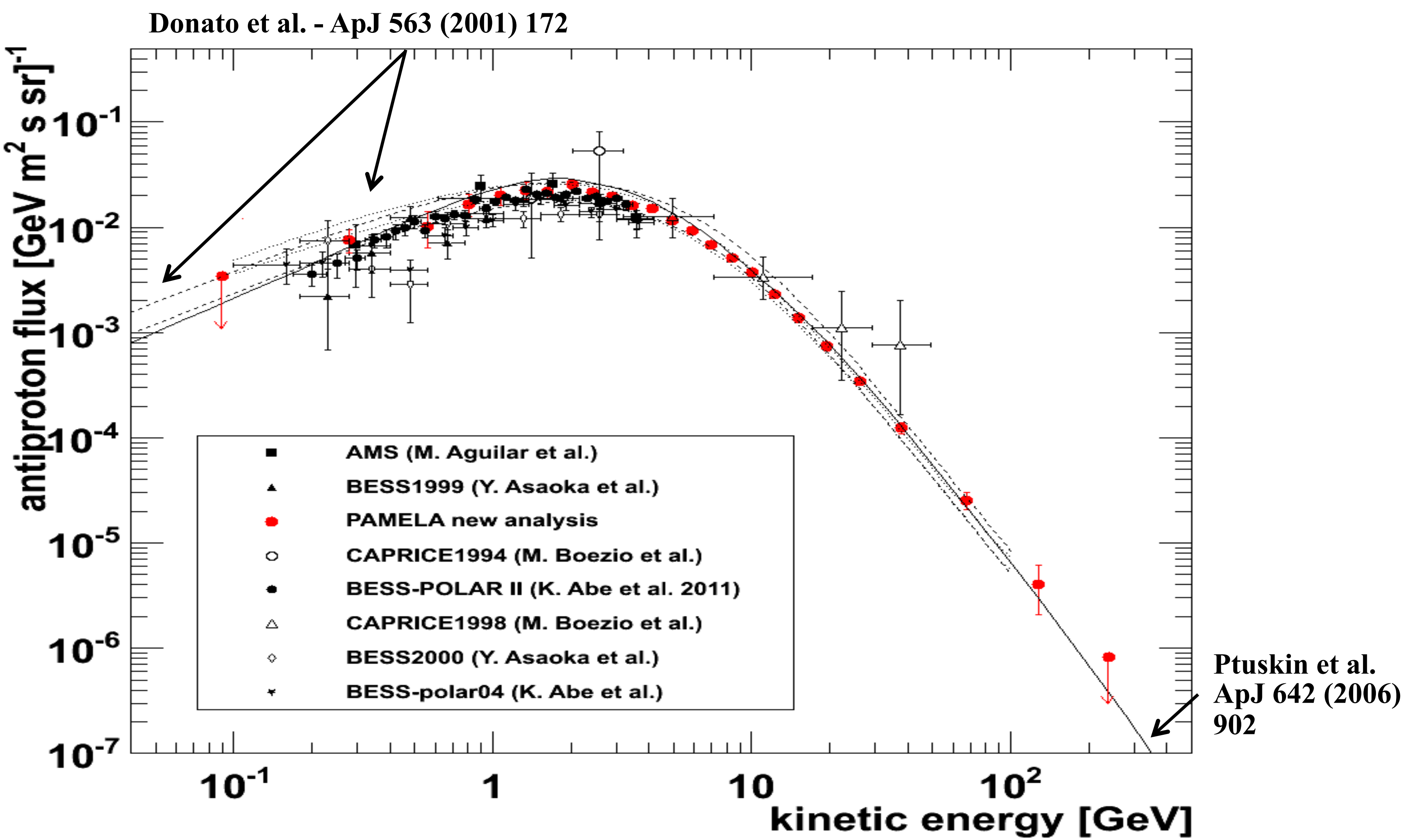
Range of predictions of secondary positrons from widely used model of CR propagation.

S. Coutu, Viewpoint *Physics* **6** 40 (2013)

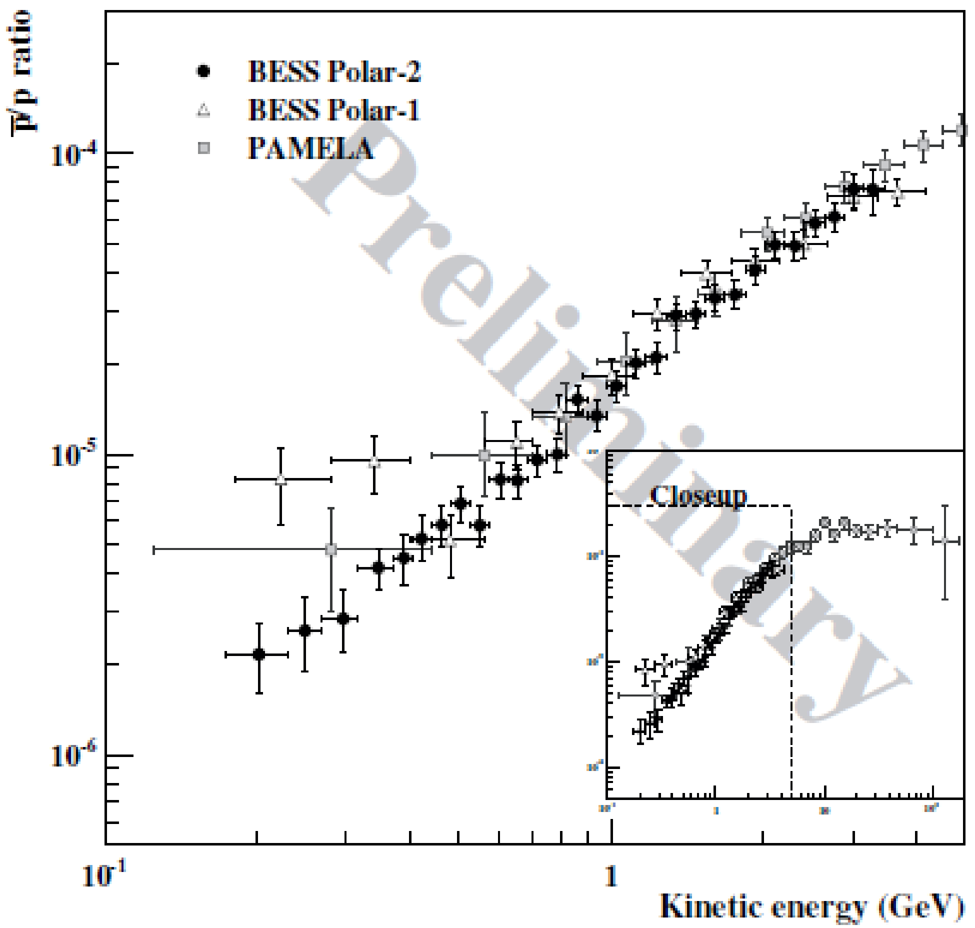
Two approaches to understanding this difference between data and predictions:

1. Look for new primary sources of positrons.
   - Annihilation of dark matter
   - Positron production and acceleration by pulsars
2. Look at modifications of Galactic cosmic-ray propagation models.
   - Three kinds of modification have been presented in recent publications.

PAMELA Antiproton energy spectrum

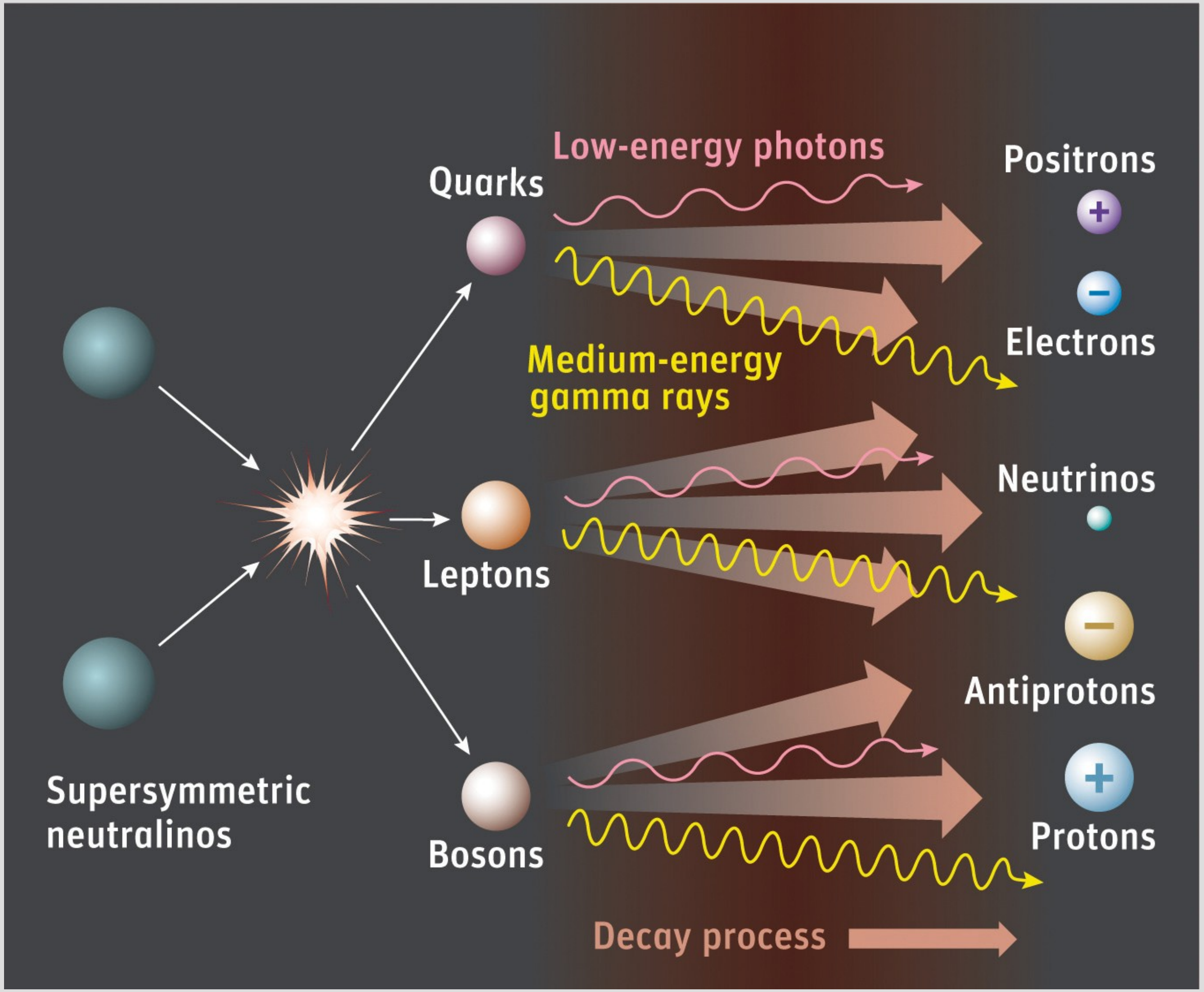


Antiproton/Proton Ratio

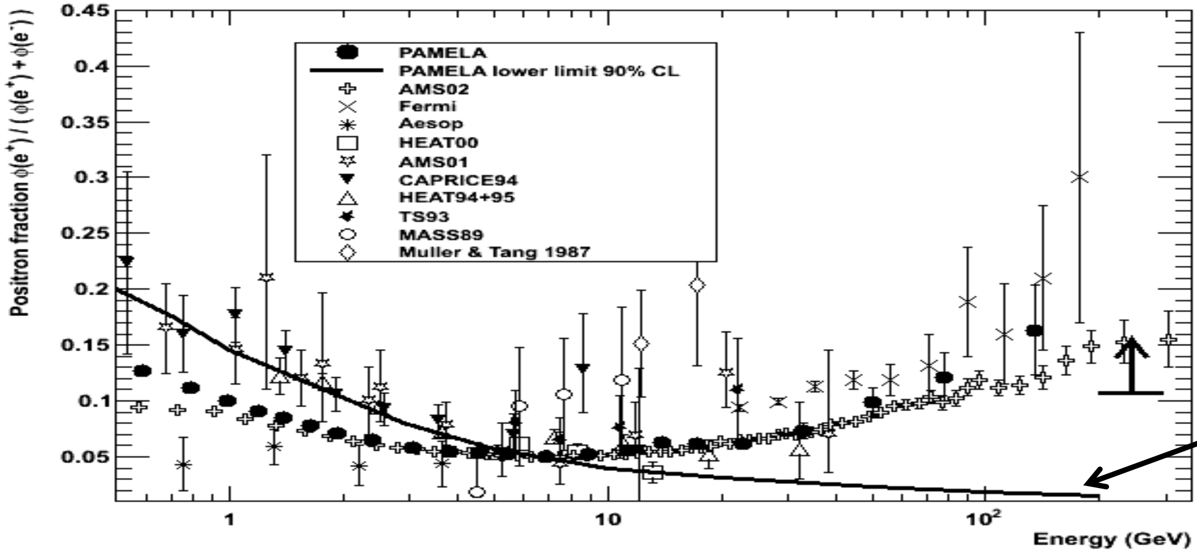


- Excellent agreement between BESS-Polar II and PAMELA in common energy range
- BESS-Polar I ratio flatter at low energy than BESS-Polar II or PAMELA due to solar modulation

Indirect Detection



A Challenging Puzzle for CR Physics

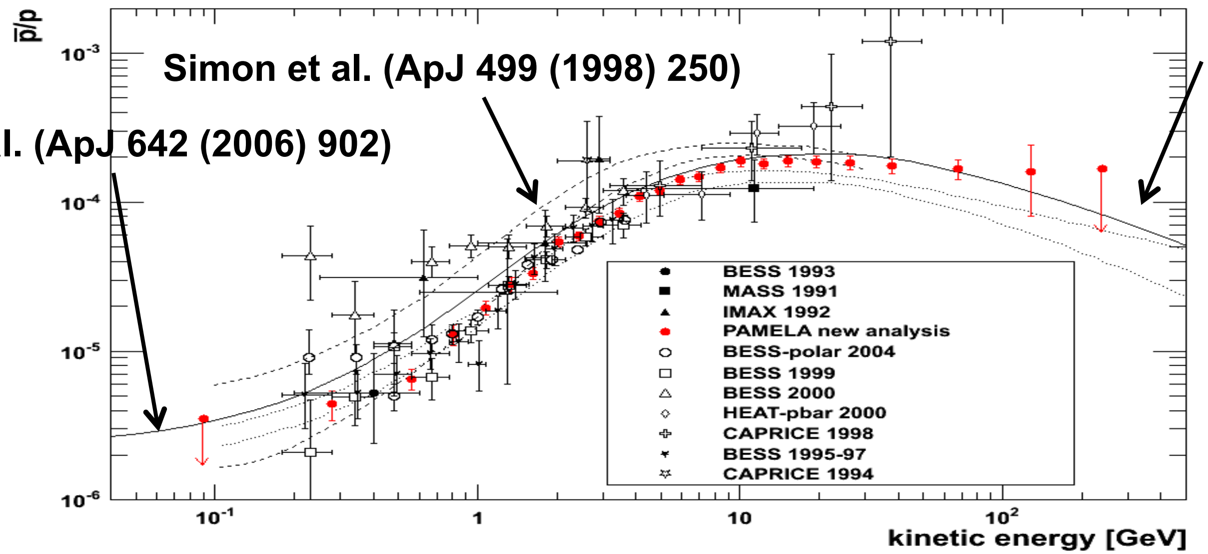


CR Positron spectrum significantly harder than expectations from secondary production Moskalenko & Strong 98

Simon et al. (ApJ 499 (1998) 250)

Ptuskin et al. (ApJ 642 (2006) 902)

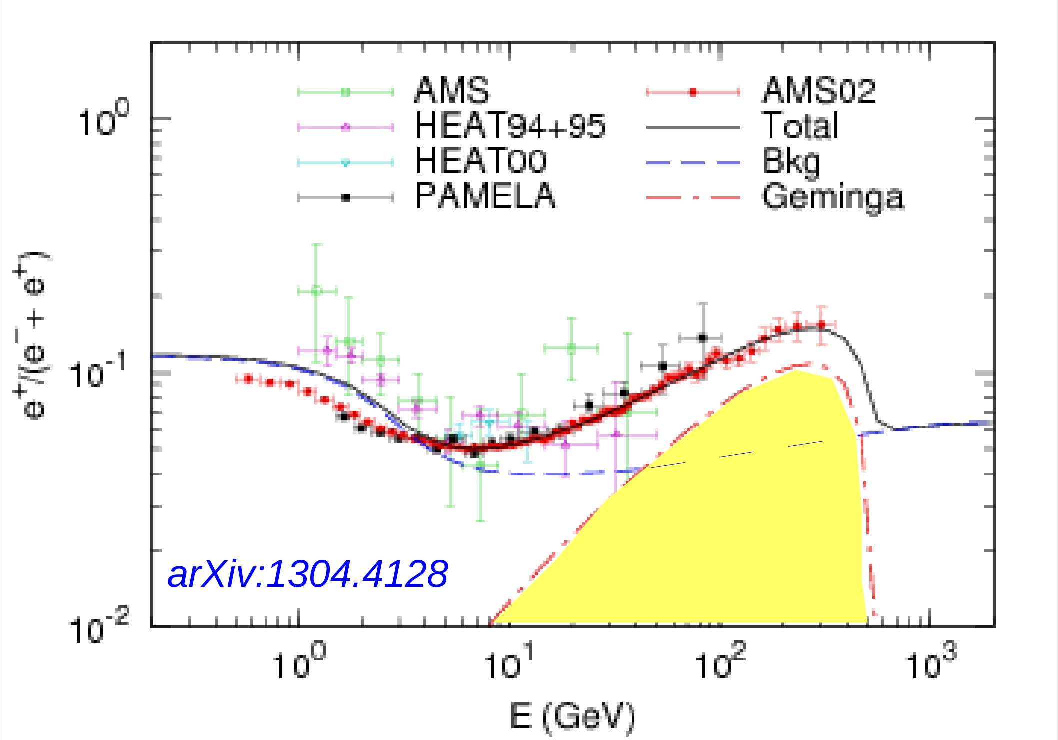
Donato et al. (PRL 102 (2009) 071301)



But antiprotons in CRs are in agreement with secondary production

Review: CR Antiparticles

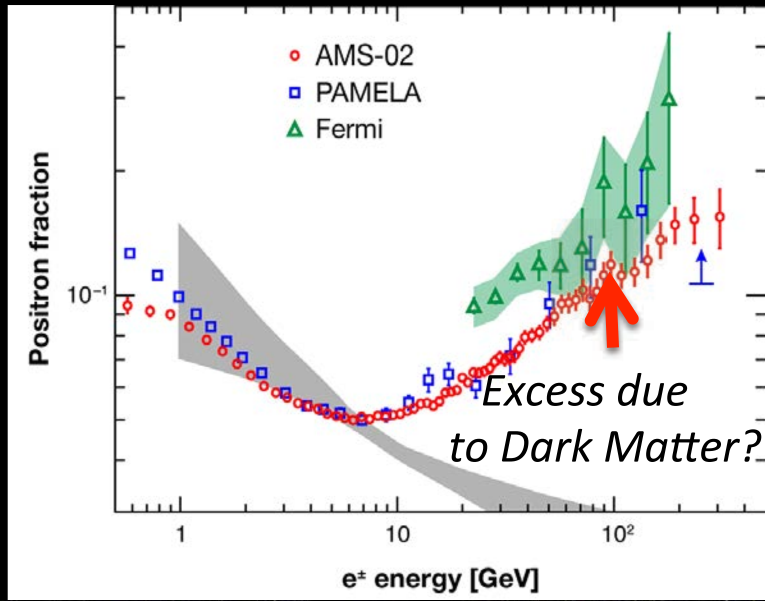
1284: Mirko Boezio

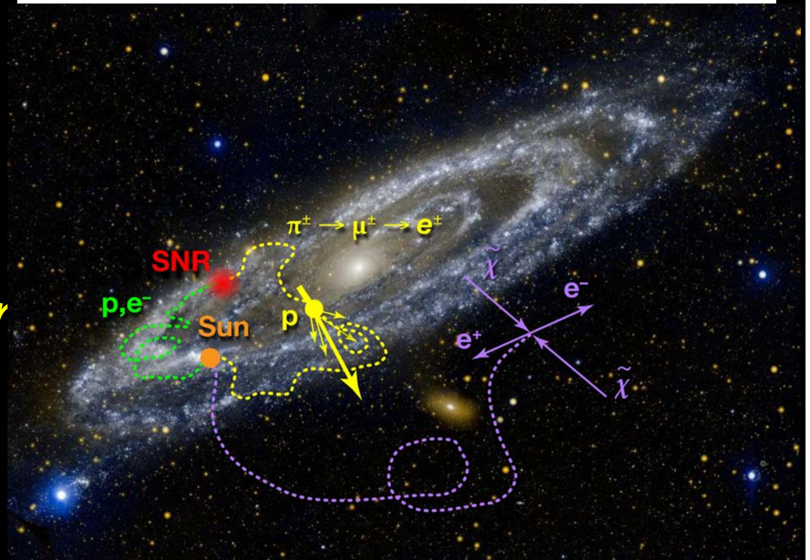


- Dark matter interpretation of the positron excess is possible
- In conflict with the non-observation of an excess in anti-proton data
  → would need leptophilic dark matter
- Pulsars might be the better explanation at the moment

Indirect Dark Matter Searches

- *No Evidence in the data for dark matter in the antiproton flux measurement by AMS, PAMELA ,etc*
- *But there was excitement about the positron excess seen by PAMELA, FERMI-LAT etc*
  - *The shape of the energy spectrum is consistent with eg KK- WIMPs → but the flux is a factor of 100-1000 too big for a thermal relic*
- *NEW: This positron excess has been seen with high precision by AMS*
- *At this point, pulsars are a more likely explanation*





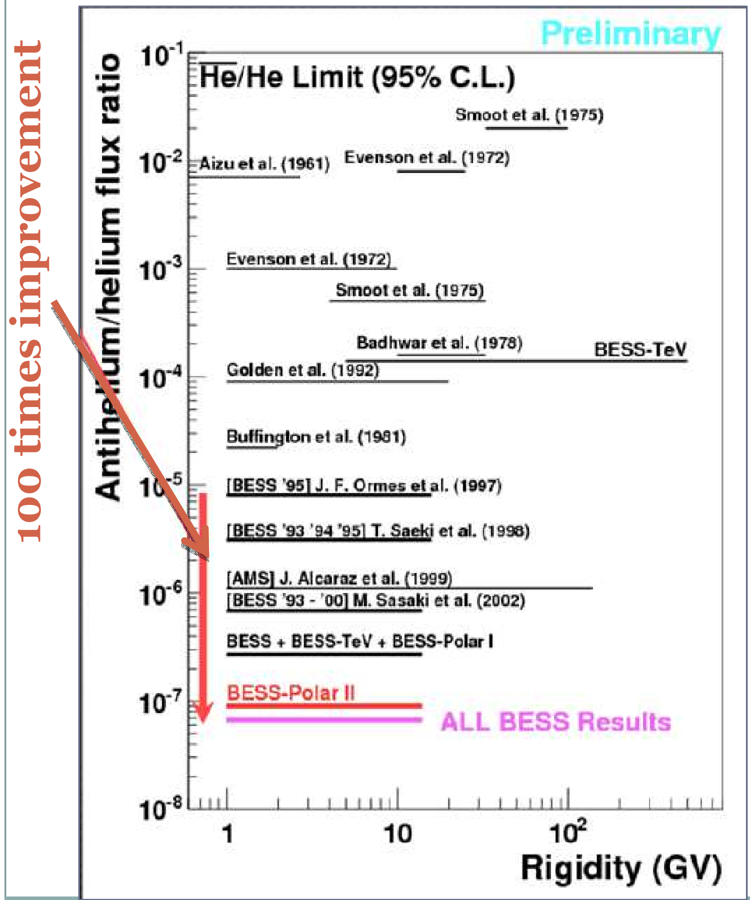
What about heavy antinuclei?

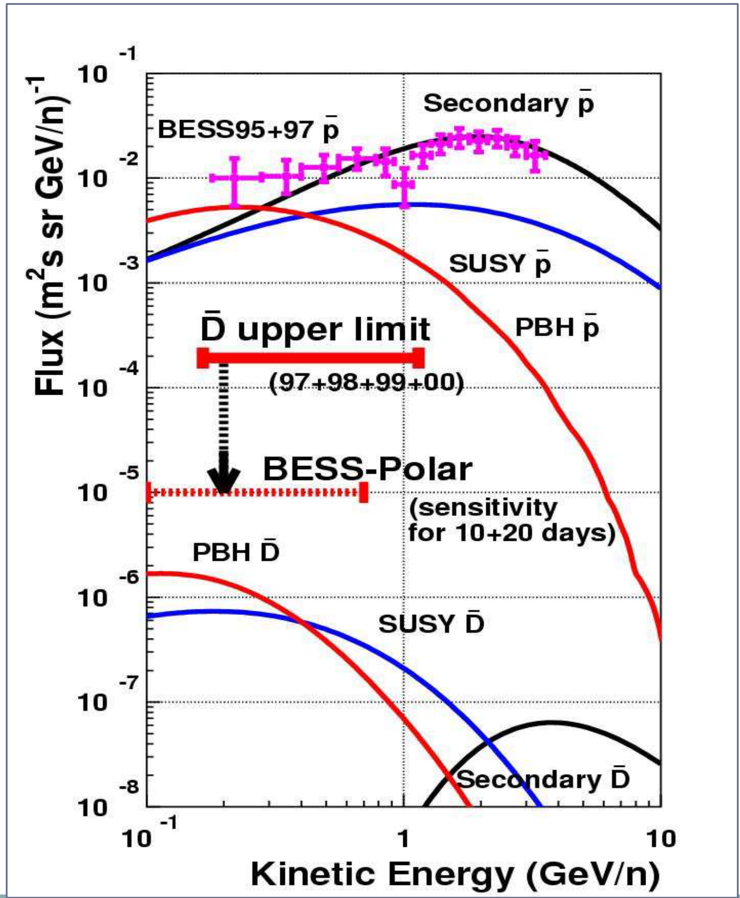
- The discovery of one nucleus of antimatter ($Z \geq 2$) in the cosmic rays would have profound implications for both particle physics and astrophysics.

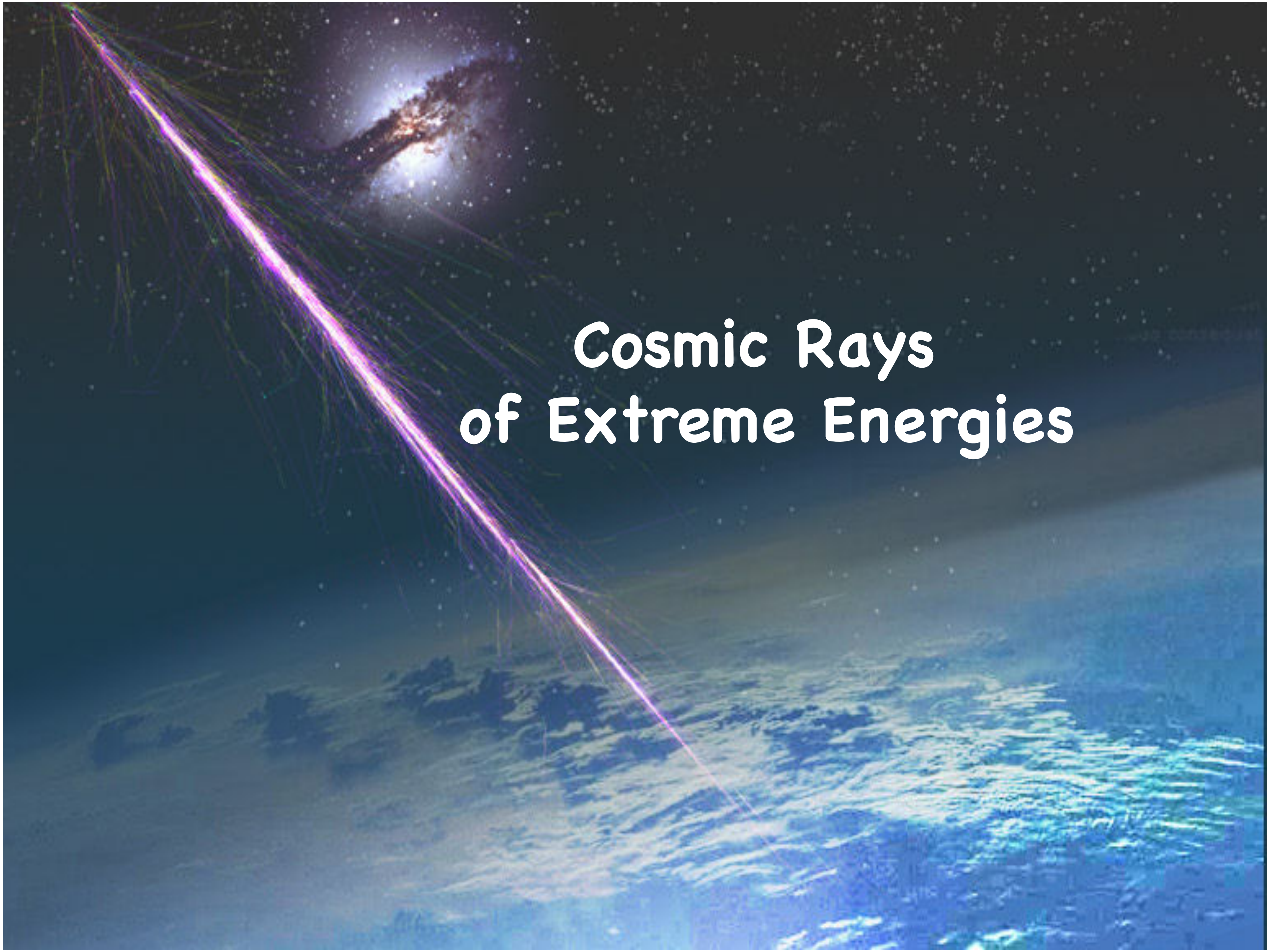
  - For a Baryon Symmetric Universe Gamma rays limits put any domain of antimatter more than 100 Mpc away

    (Steigman (1976) Ann Rev. Astr. Astrophys., 14, 339; Dudarerwicz and Wolfendale (1994) M.N.R.A. 268, 609, A.G. Cohen, A. De Rujula and S.L. Glashow, Astrophys. J. 495, 539, 1998)

Limits on antimatter (antiHe and antiD)



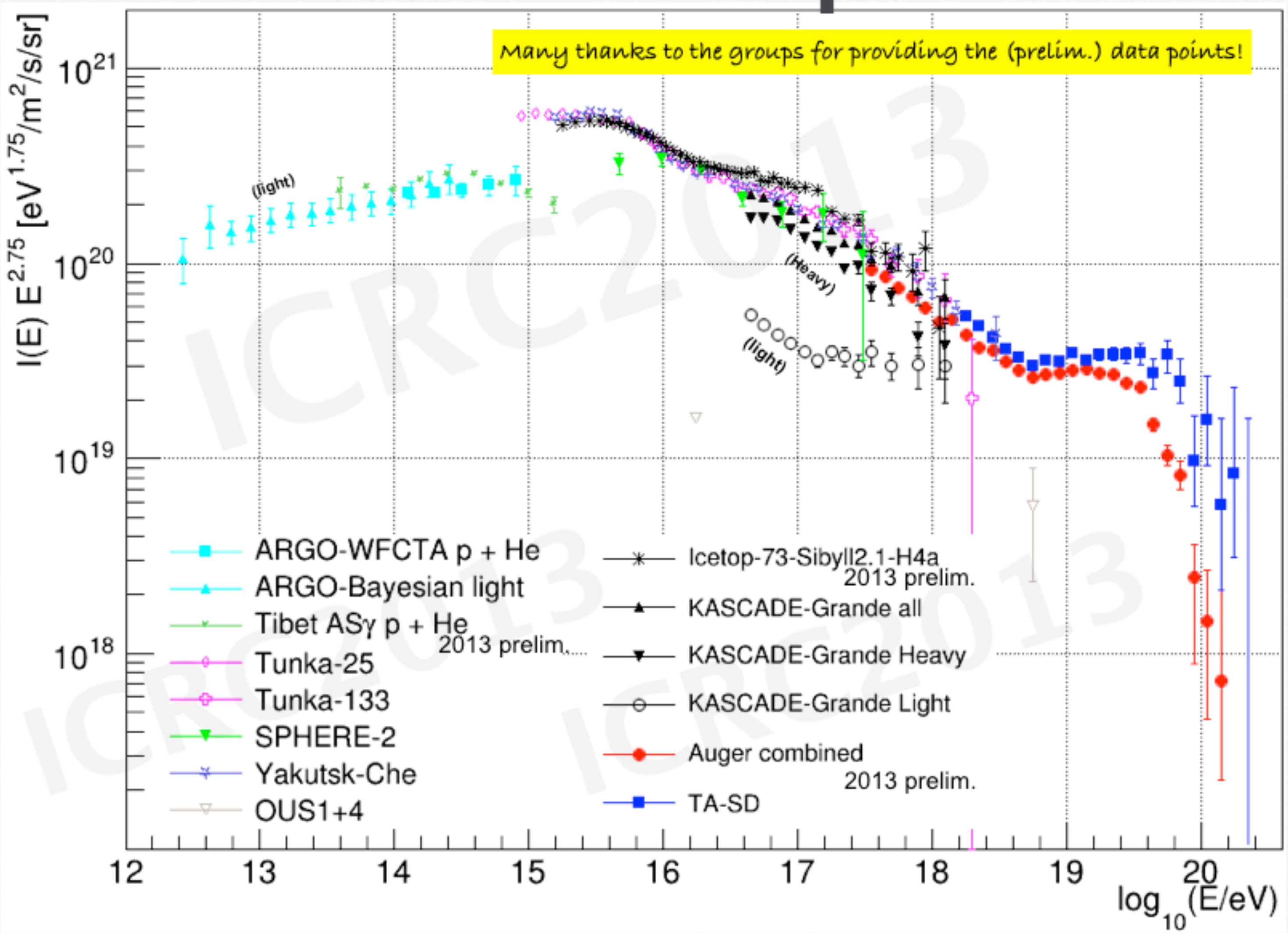



Cosmic Rays
of Extreme Energies

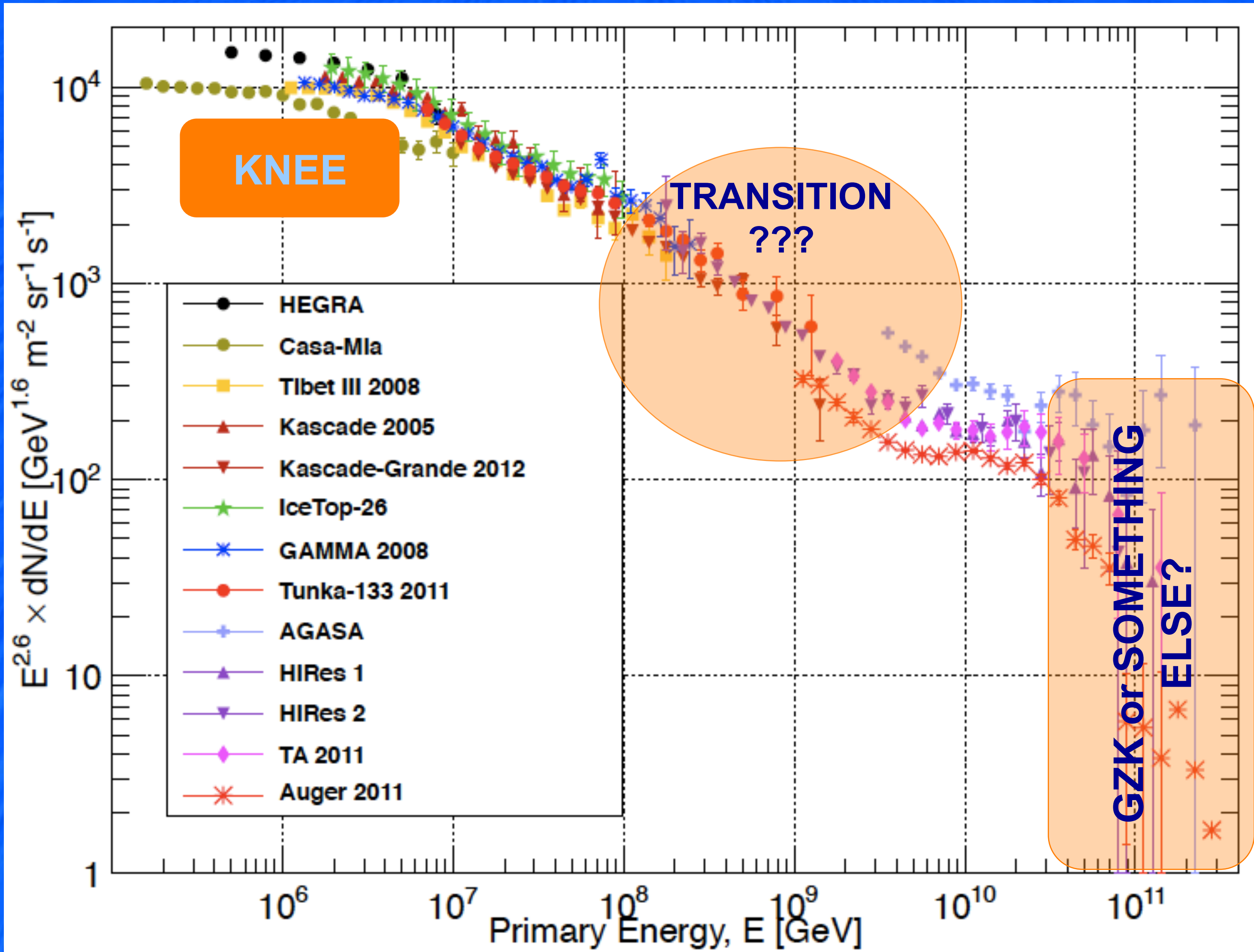
The main topics of UHE Cosmic Rays

- Anisotropies
- Composition
- Interaction Processes on Cosmic backgrounds
- Magnetic Fields
- Galactic to Extragalactic Transition
- Acceleration Mechanisms
- Sources

HE-CR: ICRC2013 Spectra



THE SPECTRUM OF COSMIC RAYS



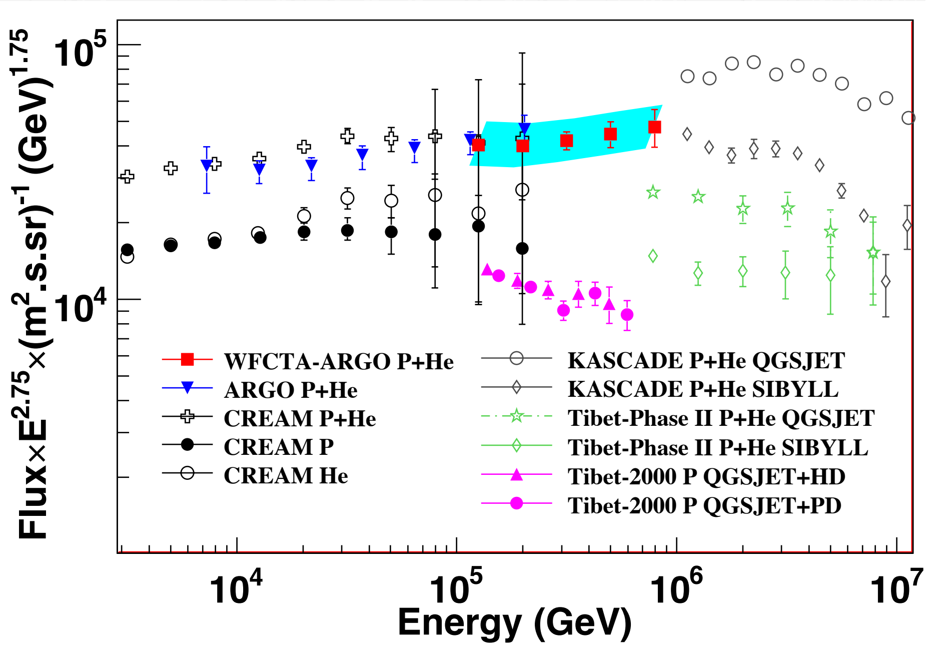
From Gaisser et al. 2013

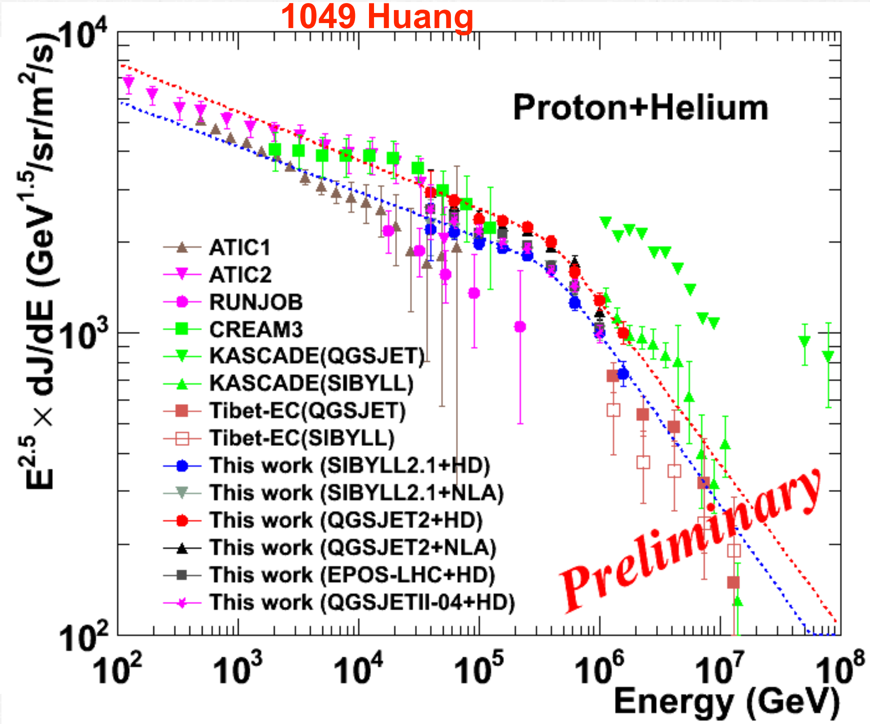
[redacted]

Spectrum around the Knee

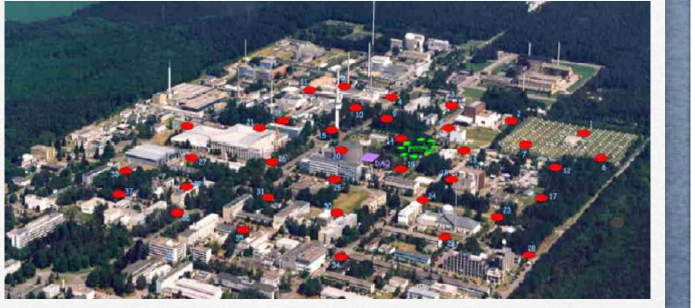
0603 Zhang, ARGO+WFCTA
0866 Mari, ARGO, Beyesian approach

1047 Huang, YAC+Tibet-III, p + He
1049 Huang

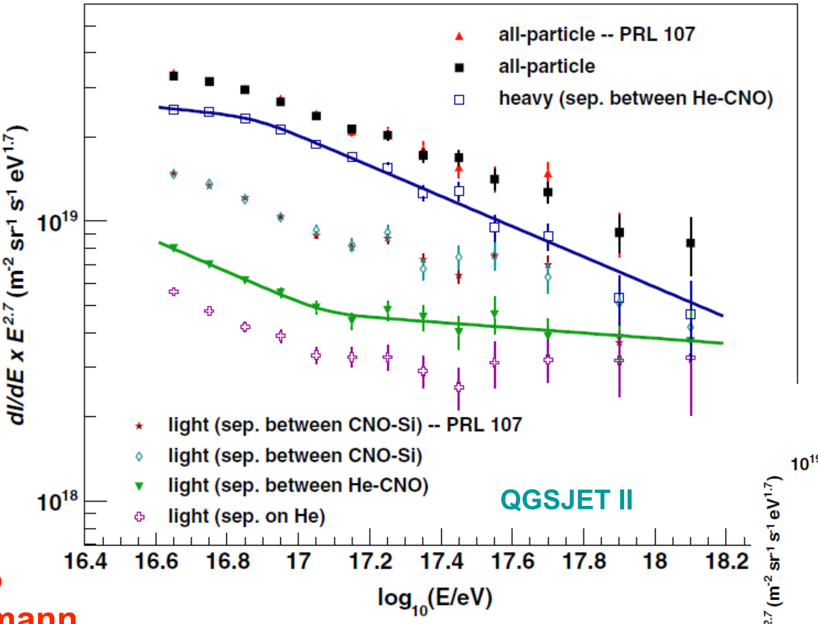




KASCADE-Grande

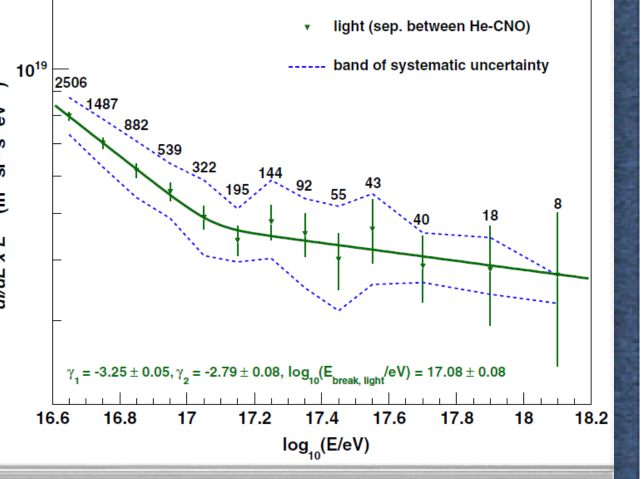


- Mass group separation by N_{ch}, N_{μ}
- *Heavy knee*
- *Light ankle*



➔ hardening at $10^{17.08}$ eV (5.8σ) in light spectrum

➔ slope change from γ = -3.25 to γ = -2.79!

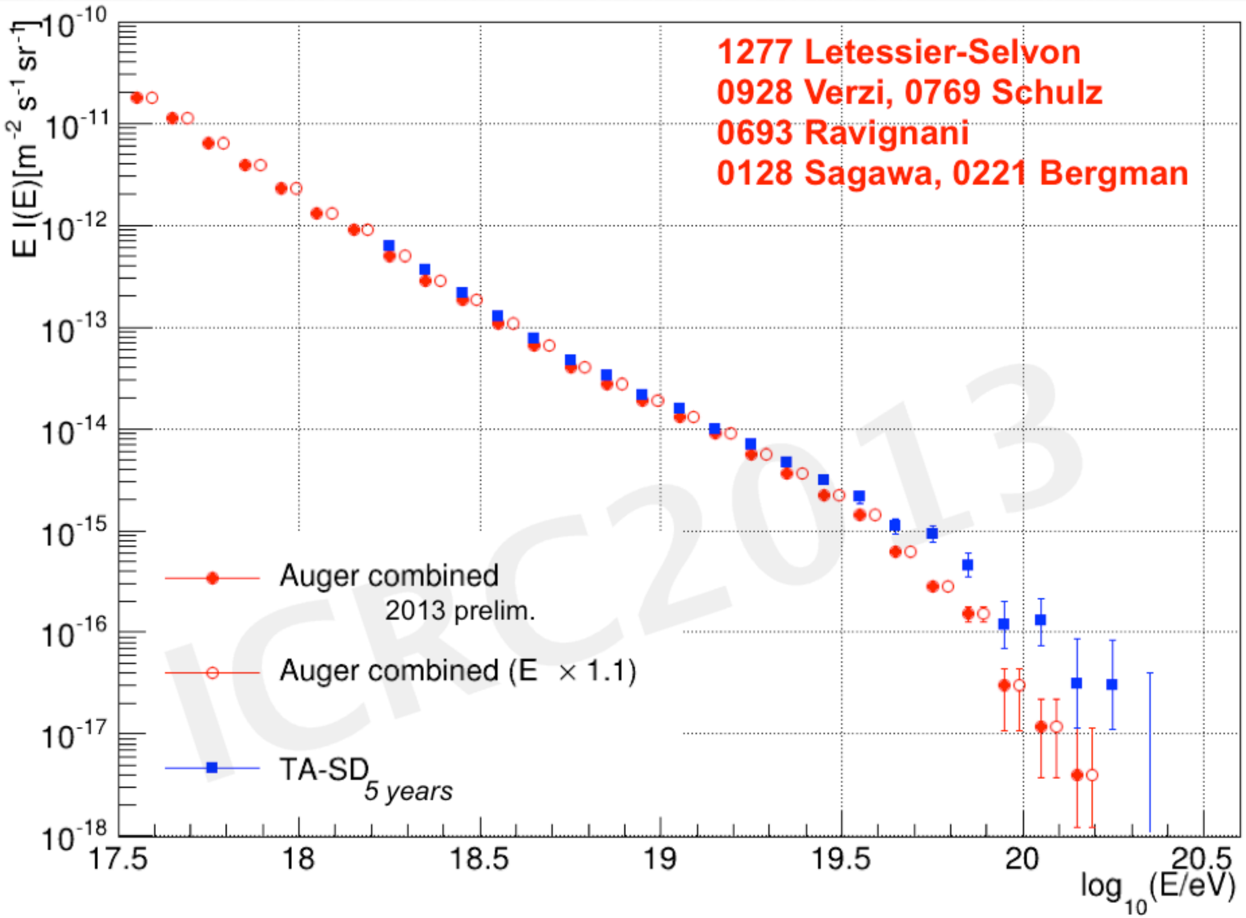


0300 Haungs, 0527 Schoo
0196 Bertaina, 0531 Fuhrmann,
0517 Toma, 0521 Kang,
0092 Chiavassa

Phys.Rev.D (R) 87 (2013) 081101
S.Schoo ICRC2013 4/7

Energy Spectrum $E > 10^{17.5}$ eV

- TA 4-year spectrum published ---> updated to 5 years
- Auger energy scale updated by 16~10%, energy dependent, within prev. uncertainties.
- Auger energy uncertainty improved from 22% to 14%.

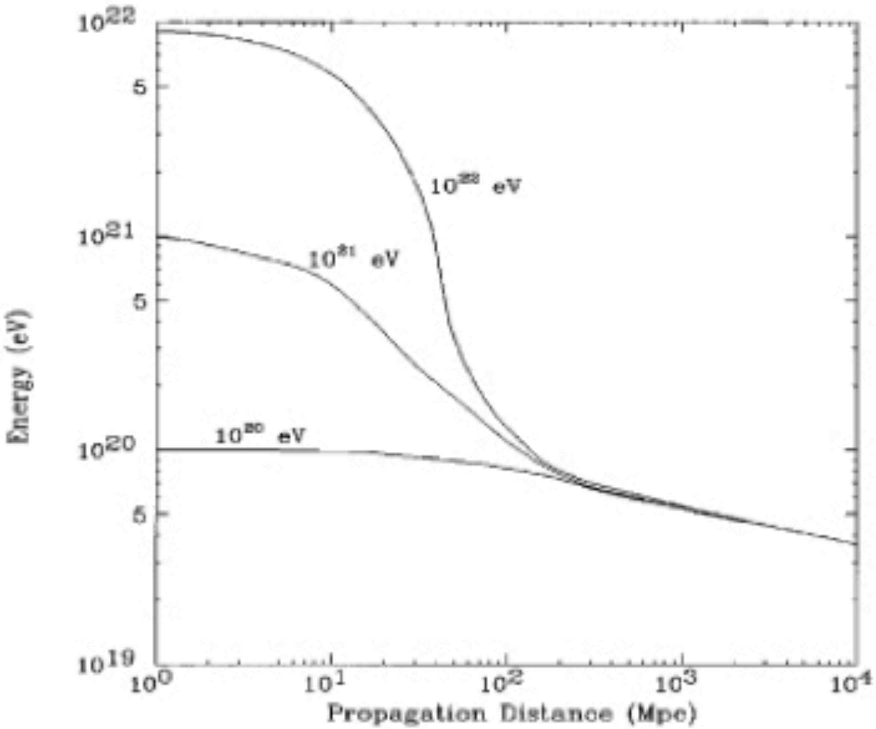


UHECR Physics – The main questions

- *Spectrum features - GZK effect?*
- *Sources?*
- *Mass composition?*
- *Anisotropy?*

The GZK (Greisen Zatsepin Kuzmin) Limit

$$\boxed{\begin{aligned} p+\gamma_{cmb} &\rightarrow \Delta^{+} \rightarrow p+\pi^{0} \\ &\rightarrow \Delta^{+} \rightarrow n+\pi^{+} \end{aligned}}$$



- When this process is energetically allowed (~ 5 x 10^{19} eV), space becomes <u>opaque</u> to cosmic rays
- Sources of CR with energies above the GZK limit must be 'close', < 100 Mpc
- ie: within the well known local galactic cluster...
- No known acceleration sites for such high energies...

Current Observatories of Ultrahigh Energy Cosmic Rays

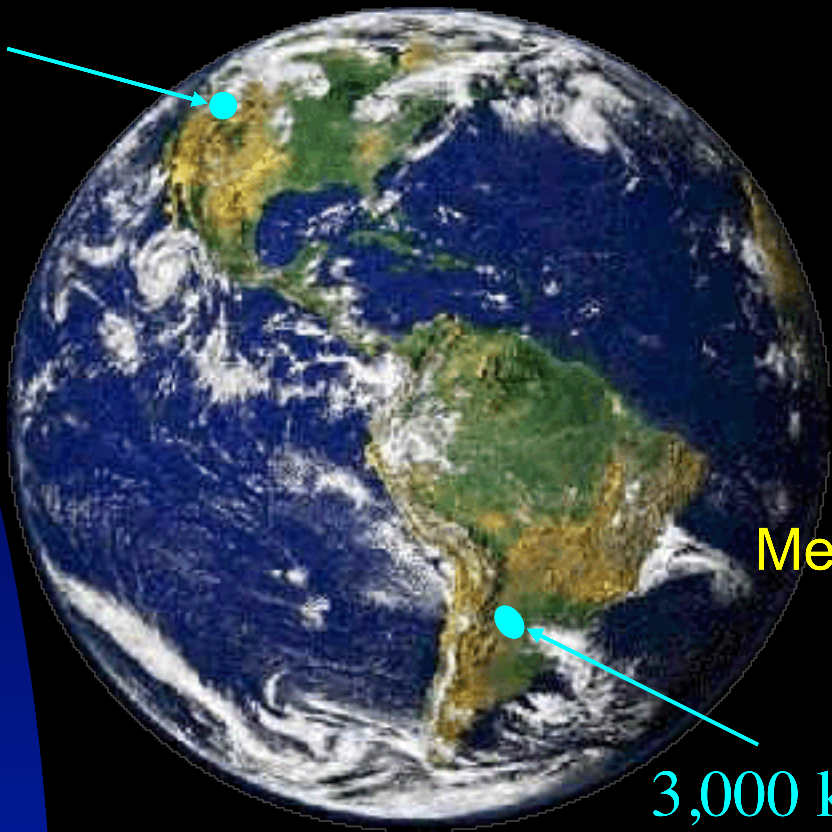
Telescope Array

Utah, USA

(5 country collaboration)

700 km^2 array

3 fluorescence telescopes



Pierre Auger Observatory

Mendoza, Argentina

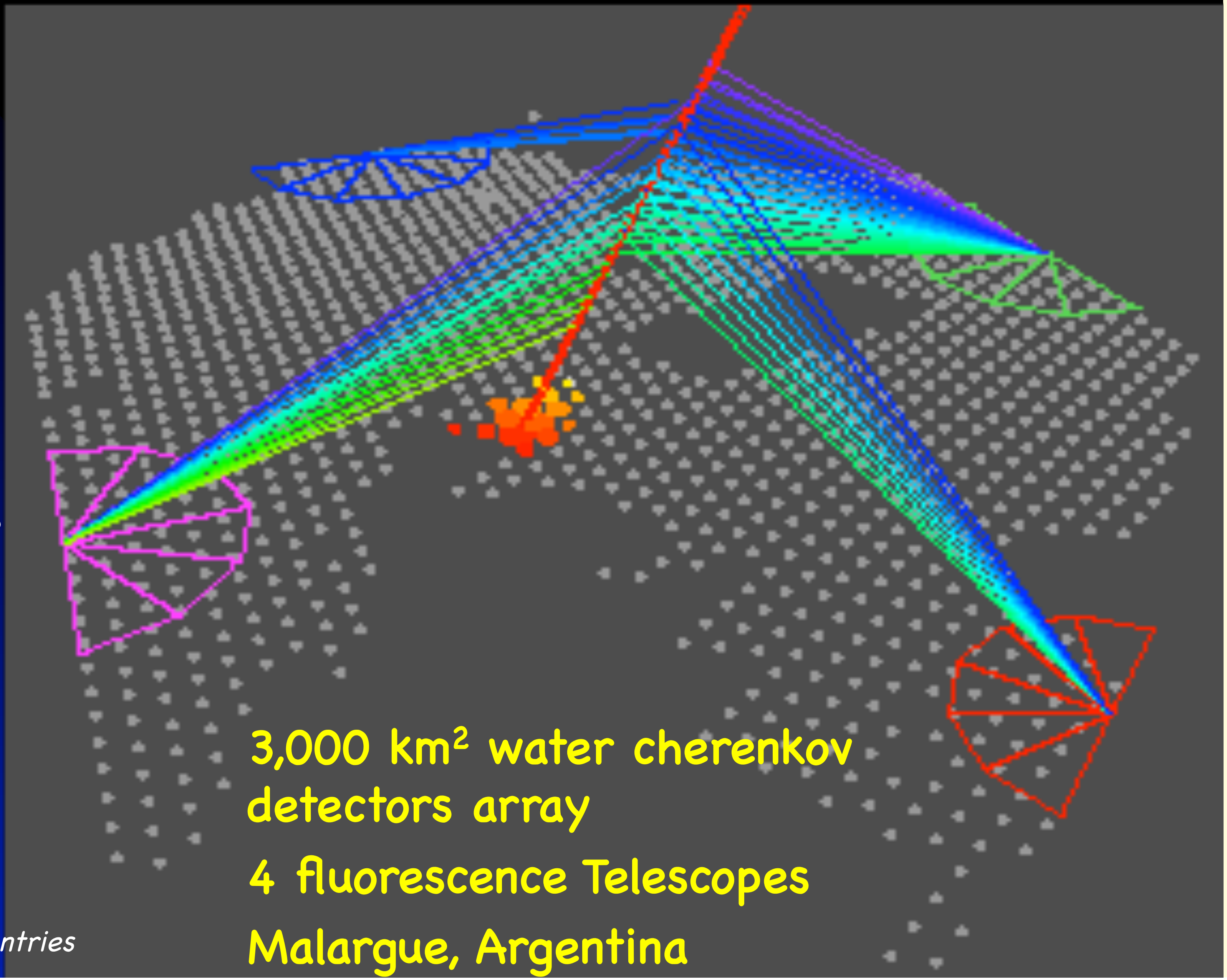
(19 country collaboration)

3,000 km^2 array

4 fluorescence telescopes

The Pierre Auger Observatory

Argentina
Australia
Brasil
Bolivia*
Croatia
Czech Rep.
France
Germany
Italy
Mexico
Netherlands
Poland
Portugal
Romania*
Slovenia
Spain
UK
USA
Vietnam*
*Associate Countries



3,000 km² water cherenkov detectors array

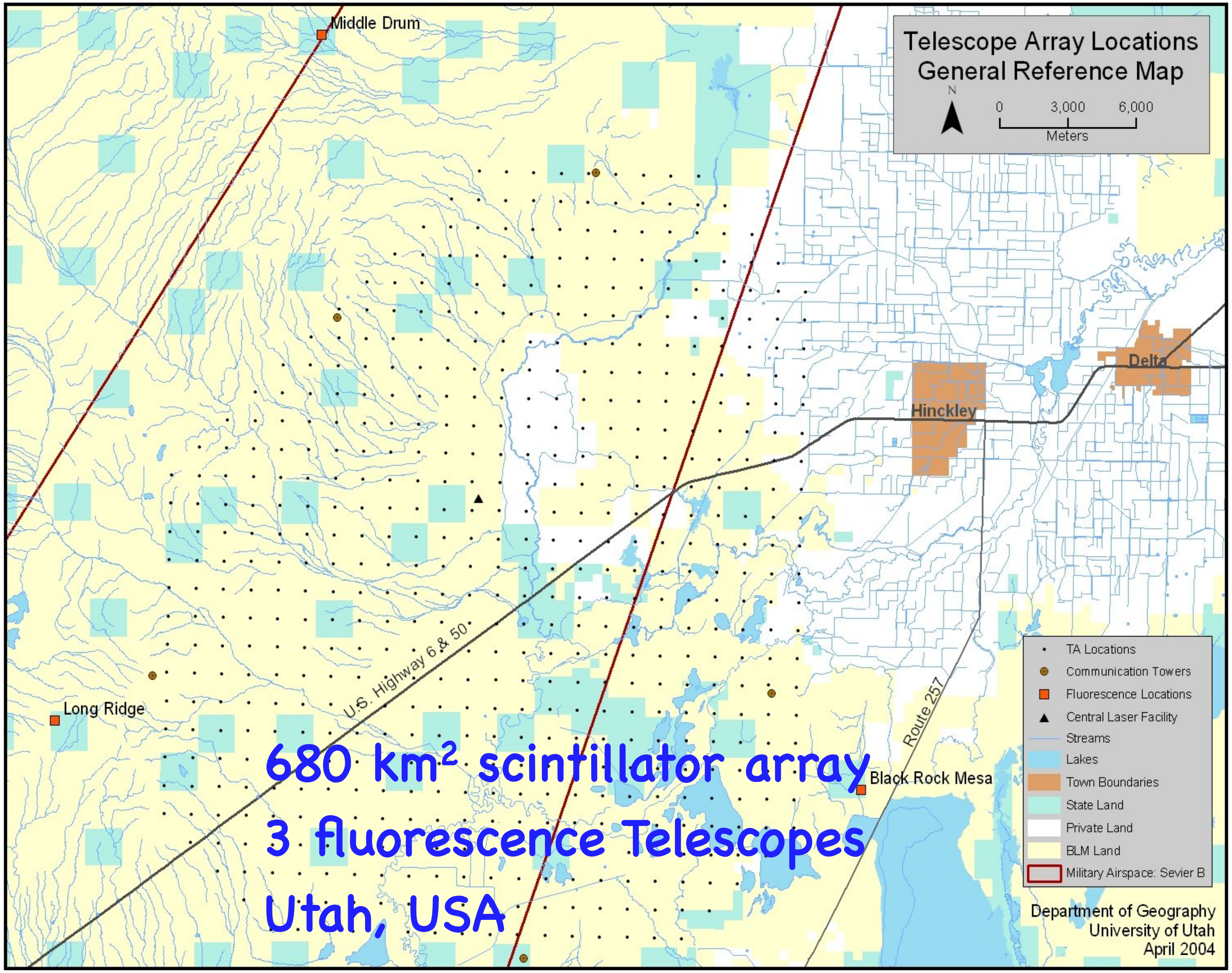
4 fluorescence Telescopes

Malargue, Argentina

The Telescope Array

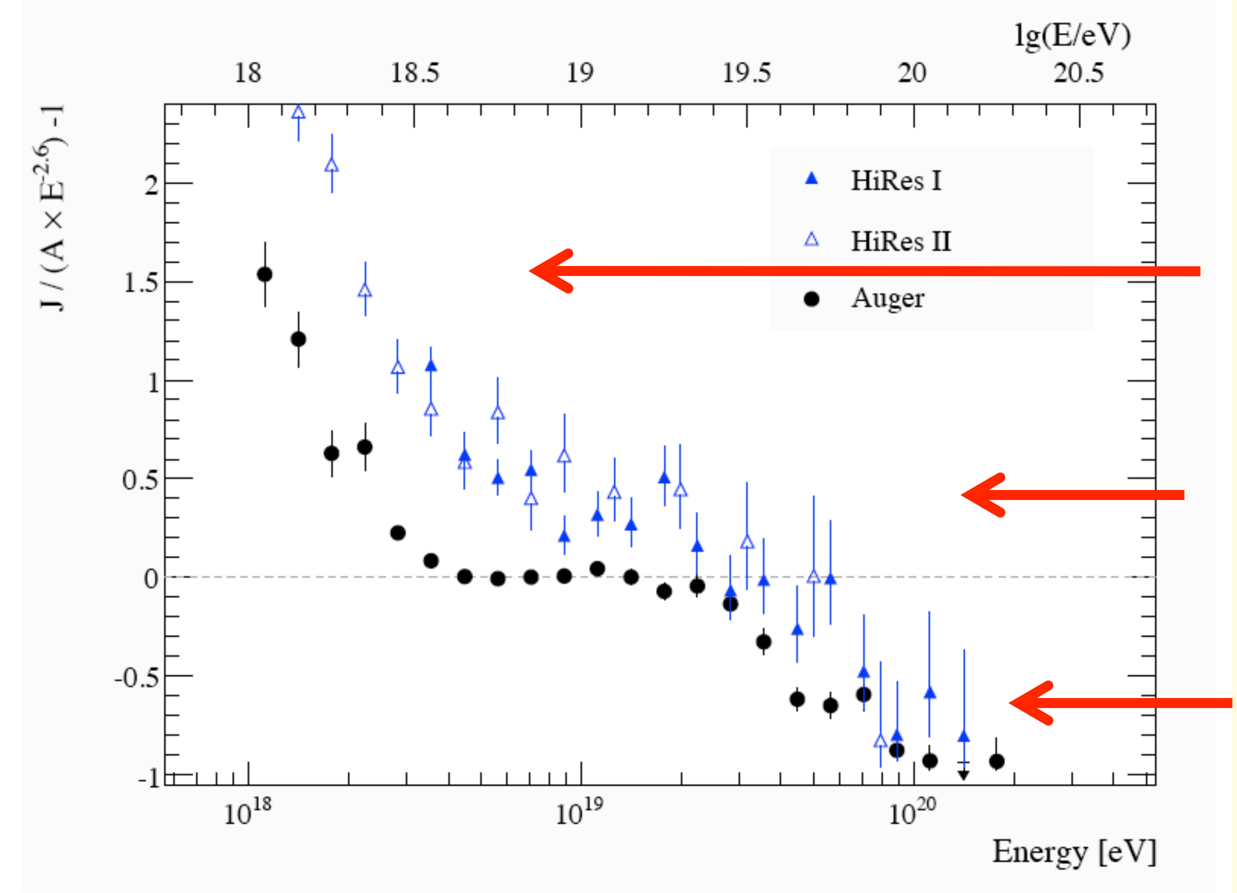
(Evolution of Hi-Res)

Belgium
Japan
Korea
Russia
USA



A key result of Auger South and HiRes

The Auger Collaboration (2008a), Abbasi et al. (2008), Bergman (2008), Fukushima (2011)



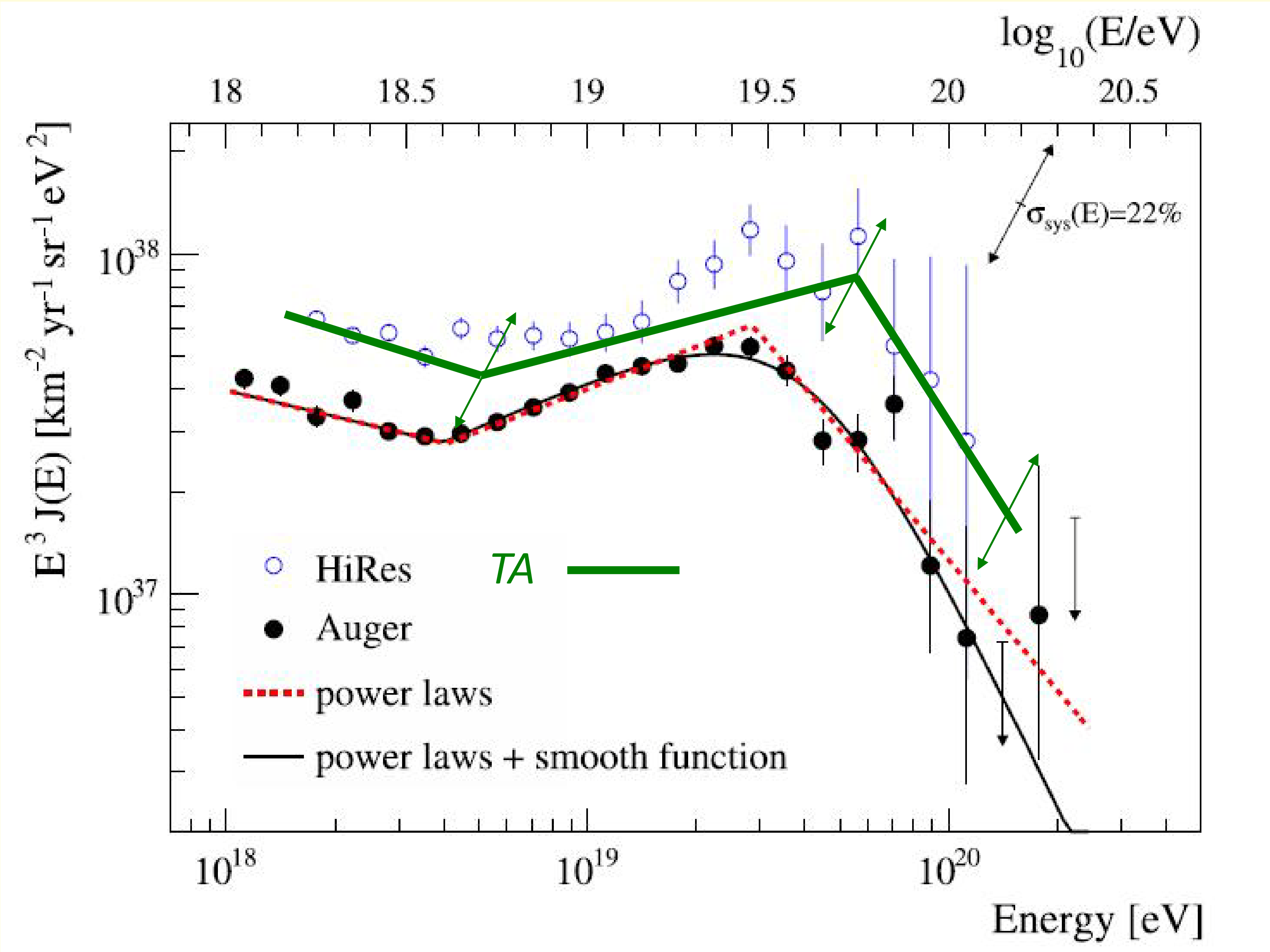
$$\gamma_1 = 3.26 \pm 0.04$$

$$\gamma_2 = 2.59 \pm 0.02$$

$$\gamma_3 = 4.3 \pm 0.2$$

Observation of a "flux suppression" in the spectrum: GZK feature (?)

Recently confirmed by Telescope Array



How to find the Sources?

GET A LOT MORE DATA above 60 EeV
OVER THE WHOLE SKY

Auger + TA ~30 events/yr

1 EeV = 10^{18} eV

UHECR status in just one word

Previous to Auger/HiRes/TA

$$\frac{1\ \text{particle}}{100\ km^2\ yr\ sr}$$

After Auger/HiRes/TA

$$\frac{1\ \text{particle}}{\underset{1000}{\cancel{100}}\ km^2\ yr\ sr}$$

A quantitative jump in exposure

(orders of magnitude: e.g., $10^3 \rightarrow 10^6$ km^2 yr sr)

is needed to effectively open such an astronomical window @ $E > 10^{20}$ eV

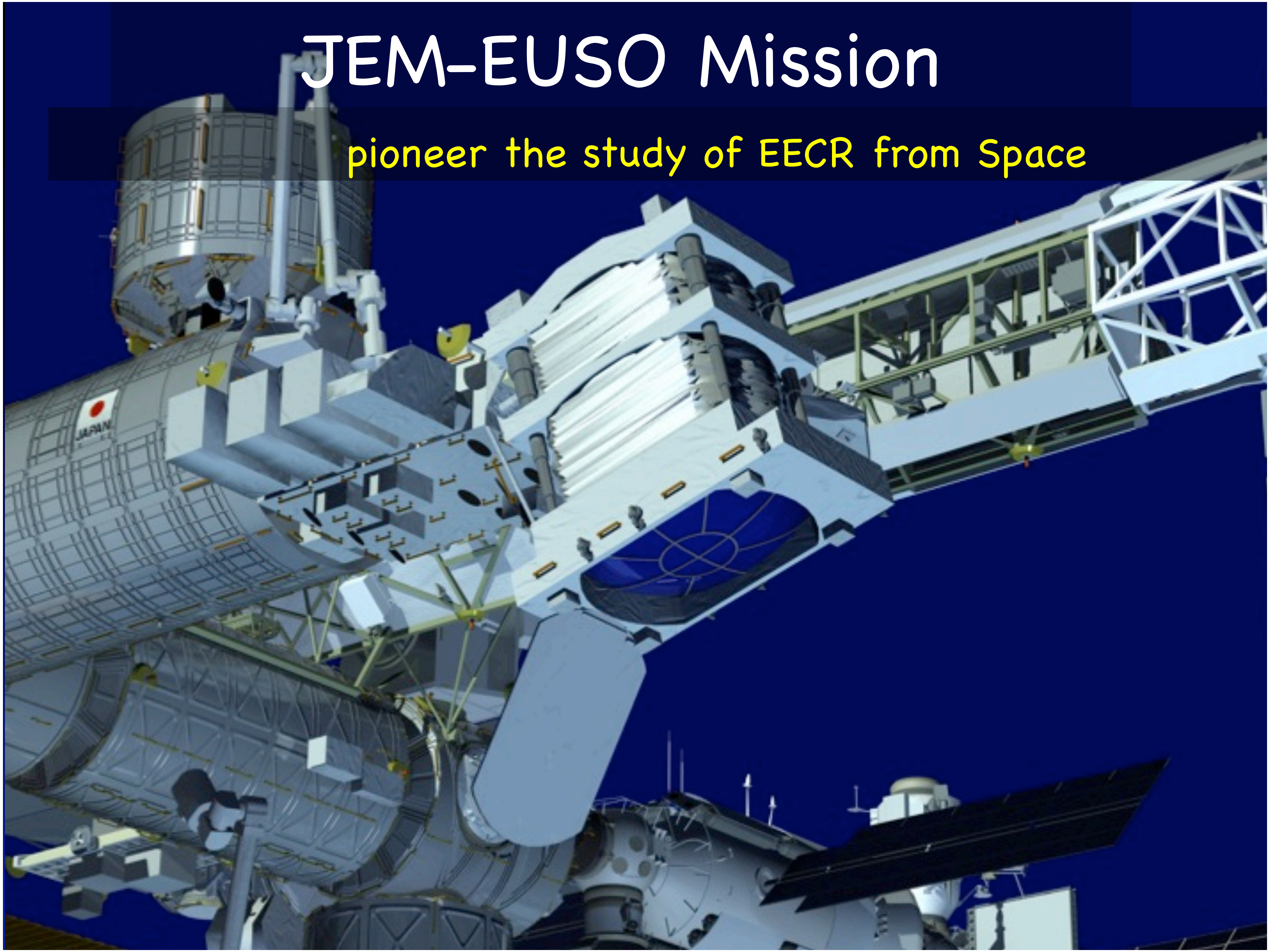
Go to SPACE!

To look down on the Atmosphere!

- increase exposure to EECR at least by 1 order of magnitude
- discover the nearby sources of UHECRs

JEM-EUSO Mission

pioneer the study of EECR from Space



Science Objectives

- **Main Objectives**:

Astronomy and astrophysics through particle channel with extreme energies > 10^{20} eV

  - Identification of individual **sources** with high statistics
  - Measurement of the **energy spectrum** of individual sources
  - Understanding of the **acceleration processes** and source dynamics

- **Exploratory objectives**:
  - Detection of extreme energy **neutrinos**
  - Measurement of extreme energy **gamma rays**
  - Study the intensity and topology of Galactic and extragalactic magnetic fields
  - Global observation of **atmospheric** phenomena: nightglows, lightning and plasma discharges

JEM-EUSO Collaboration

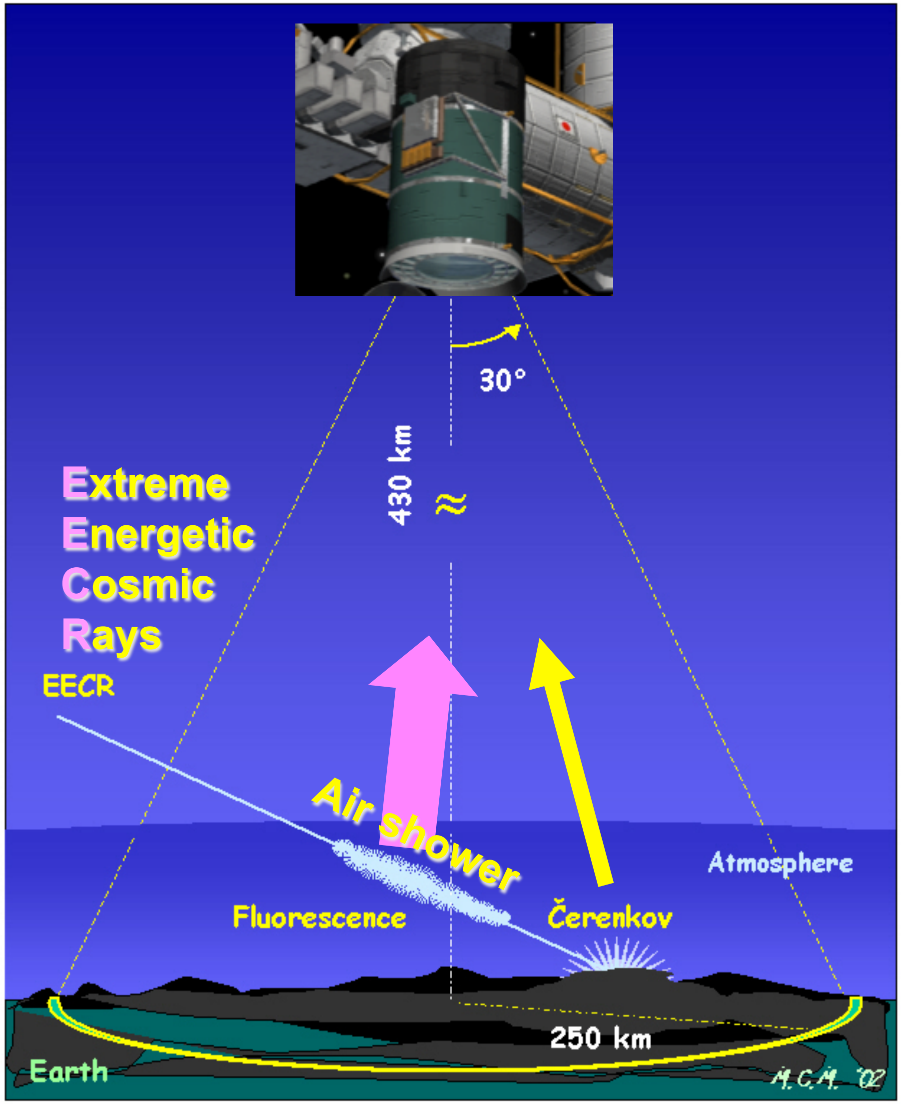
- Japan, USA, Korea, Mexico, Russia

- Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Sweden, Switzerland
- Africa: Algeria

- 15 Countries, 75 Institutions, about 300 researchers

- RIKEN, Tokyo: Leading institution

JEM-EUSO Observational Principle



JEM-EUSO is a new type of observatory on board the International Space Station (ISS), which observes transient luminous phenomena occurring in the Earth's atmosphere.

The telescope has a super wide field-of-view (60°) and a large diameter (2.5 m) and can operate in two modes: nadir and tilted

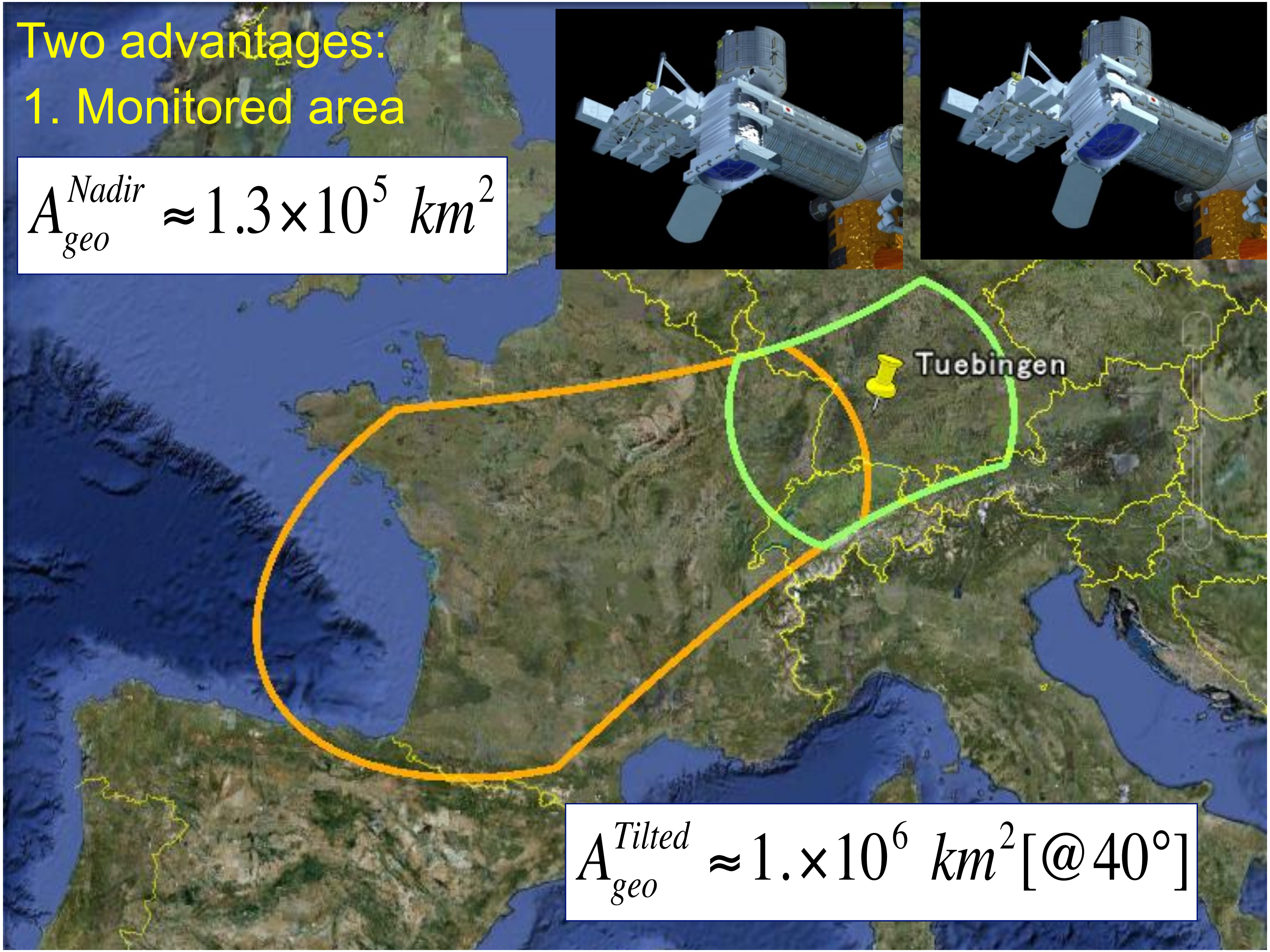
JEM-EUSO mission will initiate particle astronomy at ~10^{20}eV.

JEM-EUSO telescope observes fluorescence and Cherenkov photons generated by air showers created by extreme energetic cosmic rays

Two advantages:

1. Monitored area

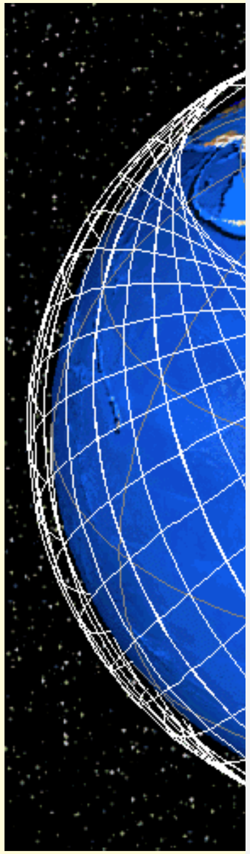
$$A_{geo}^{Nadir} \approx 1.3 \times 10^{5}\ km^{2}$$

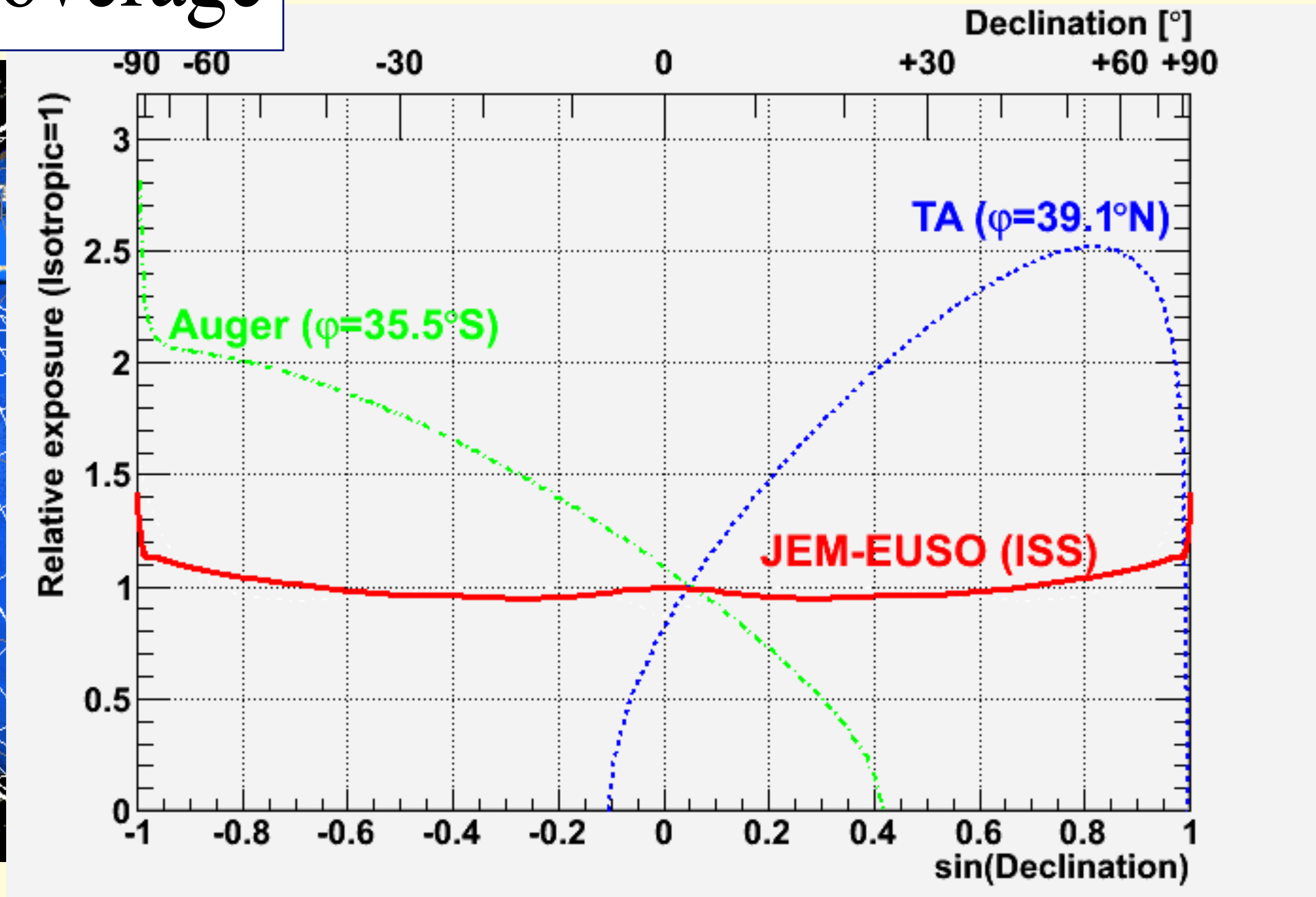


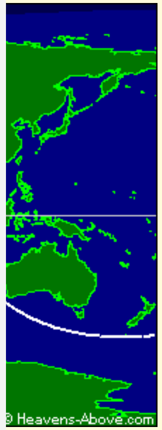
$$A_{geo}^{Tilted} \approx 1. \times 10^{6}\ km^{2} [@40°]$$

2. ISS Orbit→ Full sky Coverage…

4π coverage

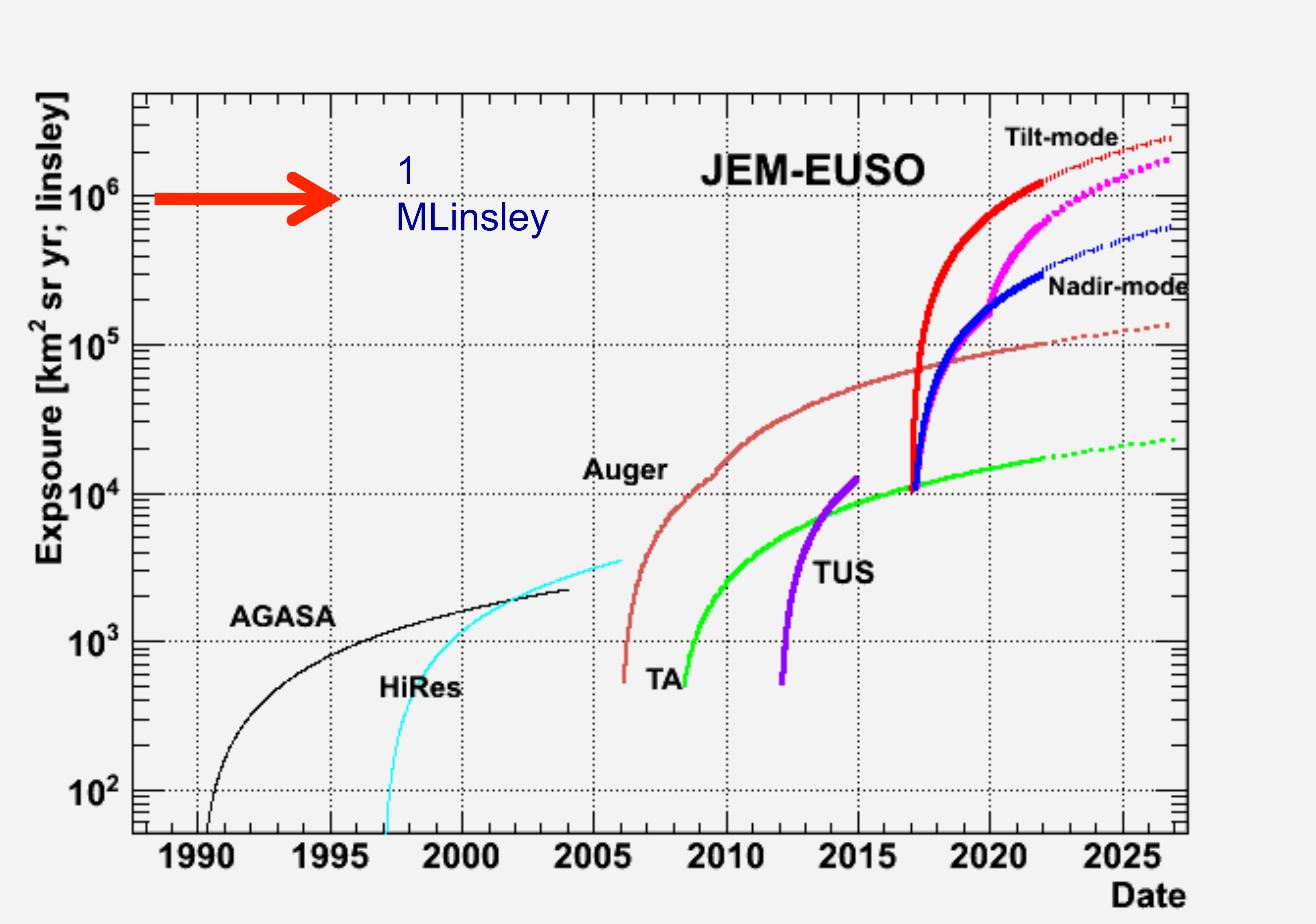


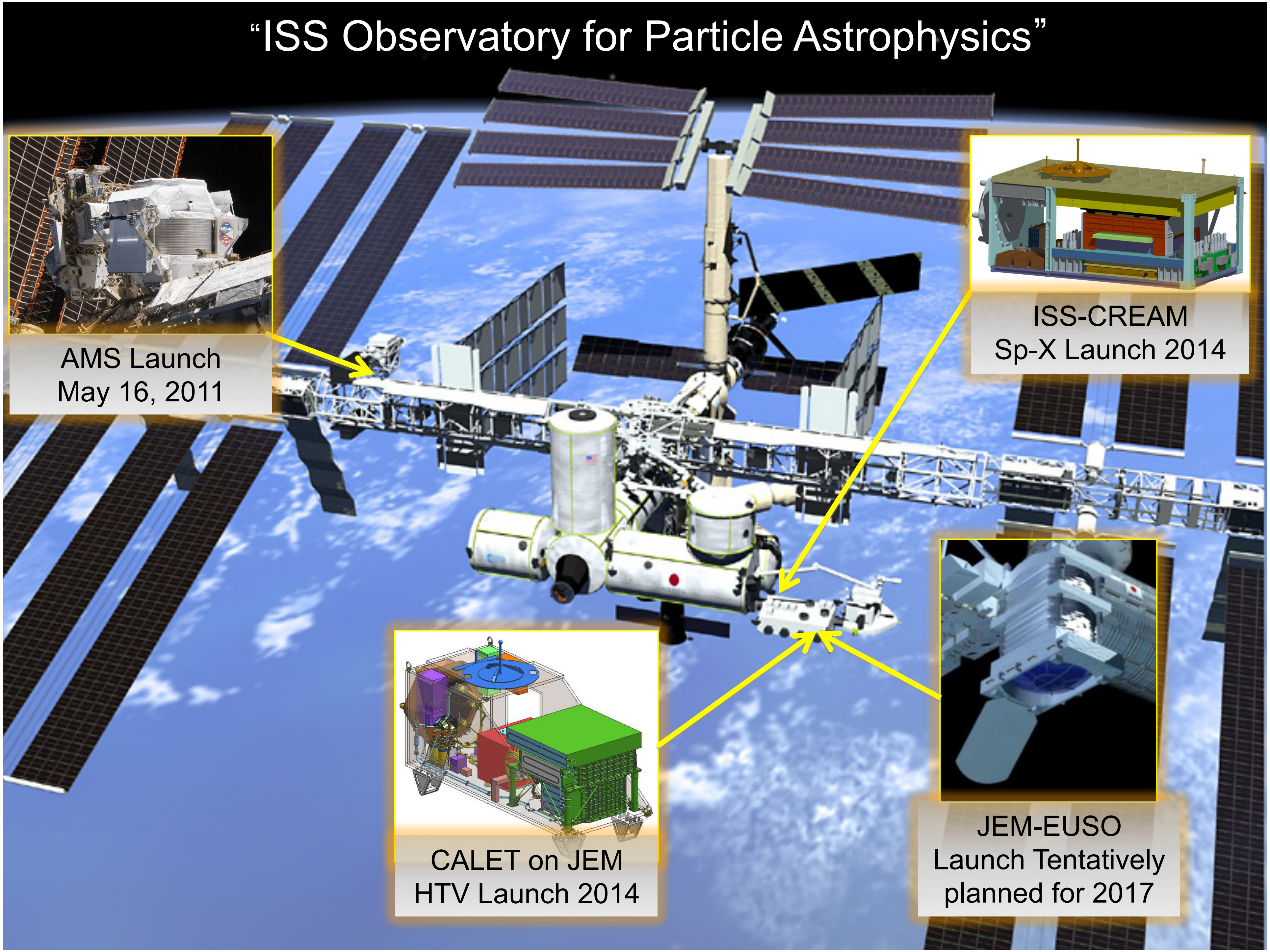




… and uniform exposure

Why JEM-EUSO? Large exposure + Full sky coverage

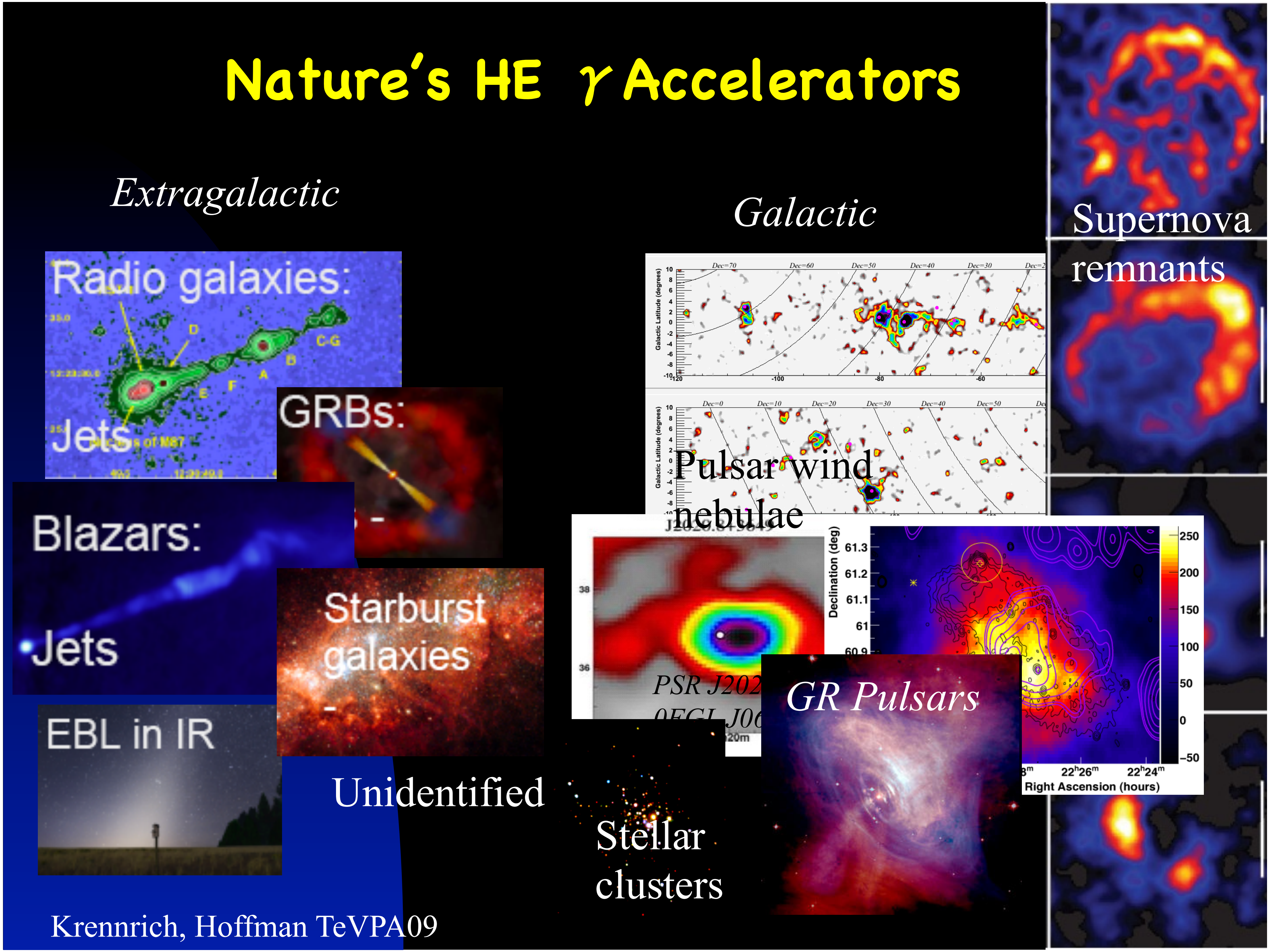




"ISS Observatory for Particle Astrophysics"
AMS Launch
May 16, 2011
ISS-CREAM
Sp-X Launch 2014
CALET on JEM
HTV Launch 2014
JEM-EUSO
Launch Tentatively
planned for 2017

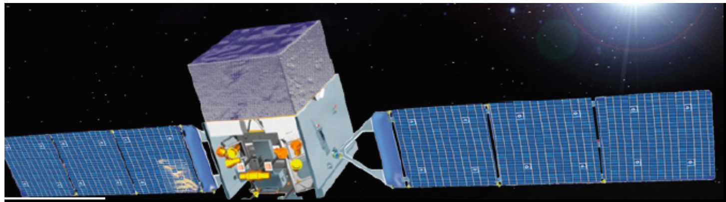
Contribution of gamma-ray experiments to Cosmic Ray research

(quick look)

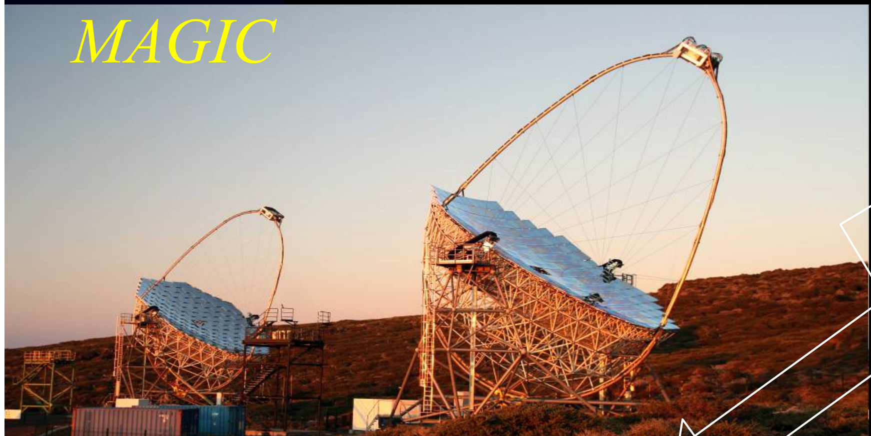


Nature's HE γ Accelerators
Extragalactic
Galactic
Supernova remnants
Radio galaxies:
Jets
GRBs:
Blazars:
Jets
Starburst galaxies
EBL in IR
Unidentified
Pulsar wind nebulae
GR Pulsars
Stellar clusters
Declination (deg)
Right Ascension (hours)
Krennrich, Hoffman TeVPA09

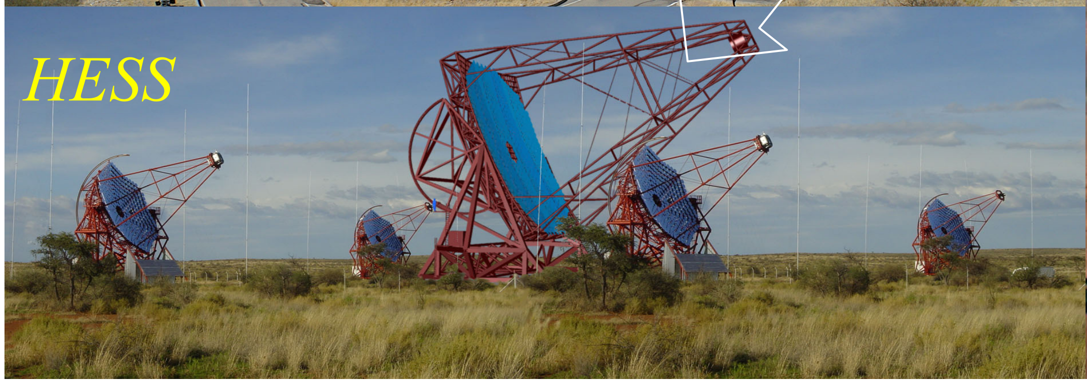
Gamma-Rays Eyes

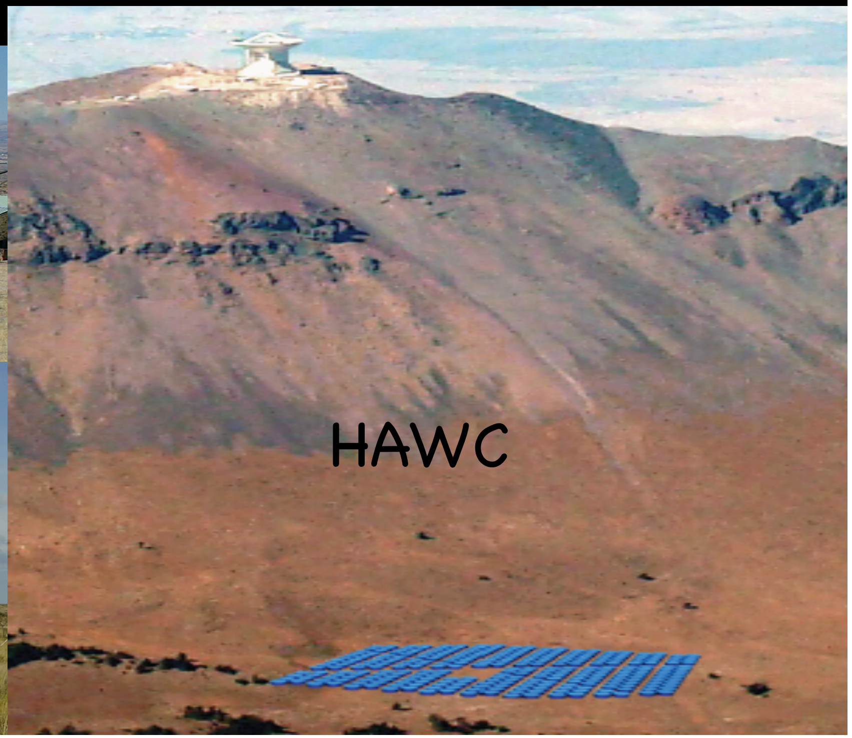


Fermi



IACT –
Imaging Atmospheric Cherenkov Telescopes
~10^{10} to <10^{14} eV





First evidence of proton acceleration in the Supernova Remnant W44 with AGILE

A. Giuliani et al.[AGILE Coll.], ApJ 742, 2011

SNR W44

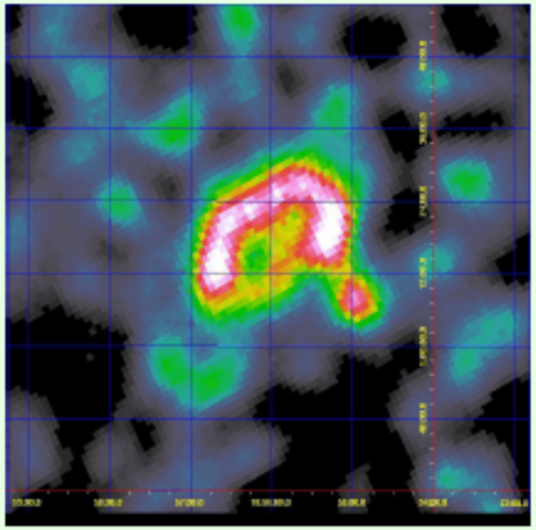


Fig 1 : SNR W44 as seen by AGILE for energies greater than 400 MeV

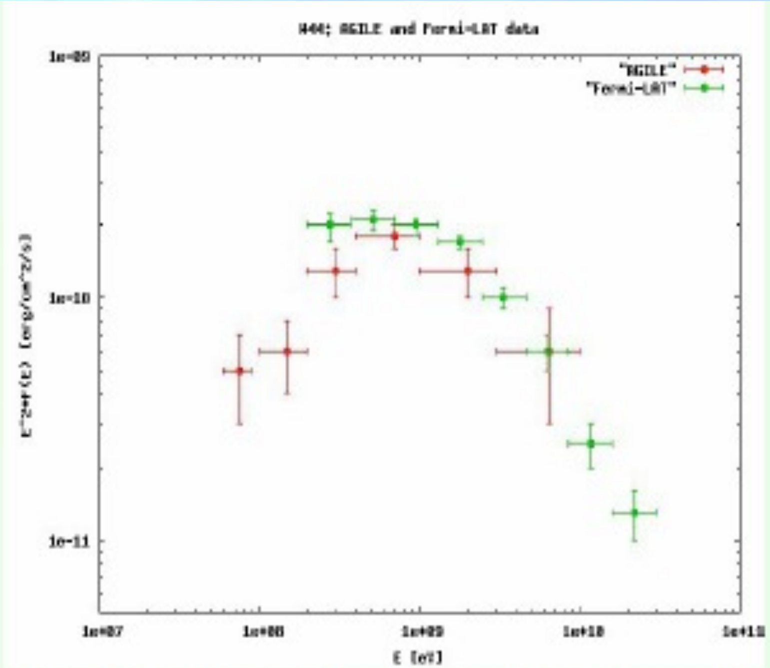
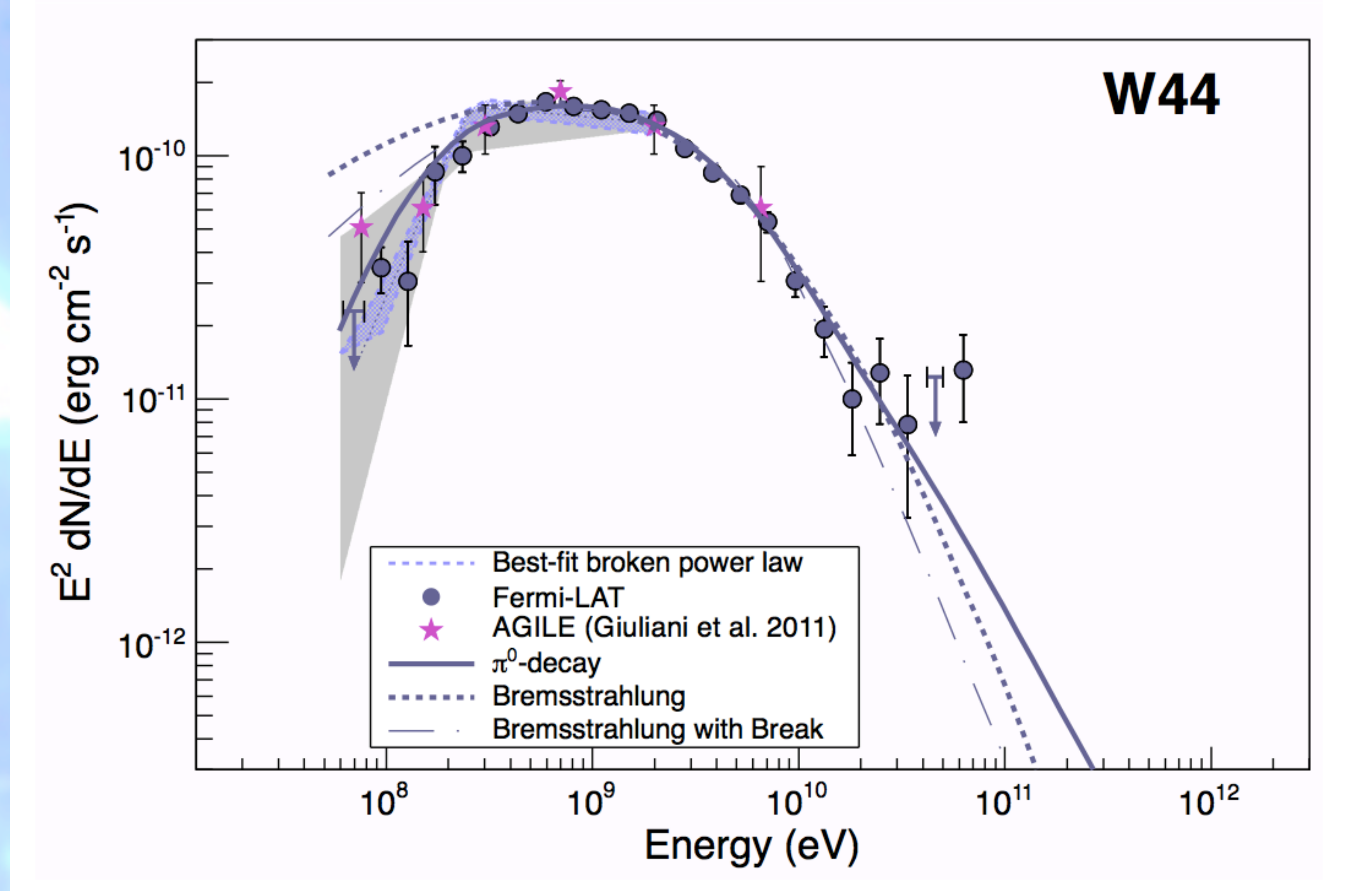


Fig 3 :combined AGILE (red) and Fermi/LAT (green) spectra energy distribution (SED) for SNR W44. AGILE points are in the range 50 MeV- 10 GeV divided in six energy intervals. Fermi/LAT data span the energy range 0,2-30GeV (from Abdo et al, 2010)

Detection of the Characteristic Pion-decay Signature in Supernova Remnants
Direct evidence that cosmic-ray protons are accelerated in SNR

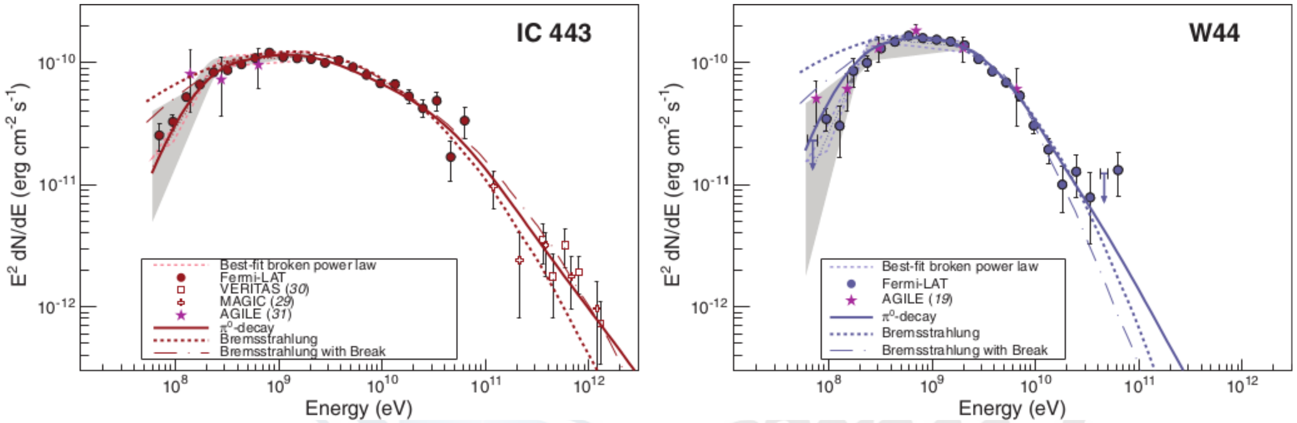


M.Ackermann et al.[Fermi Coll.],Science 339 (2013) 80 [arXiv:1302.3307]

FERMI

Supernova Remnants Produce Cosmic Rays

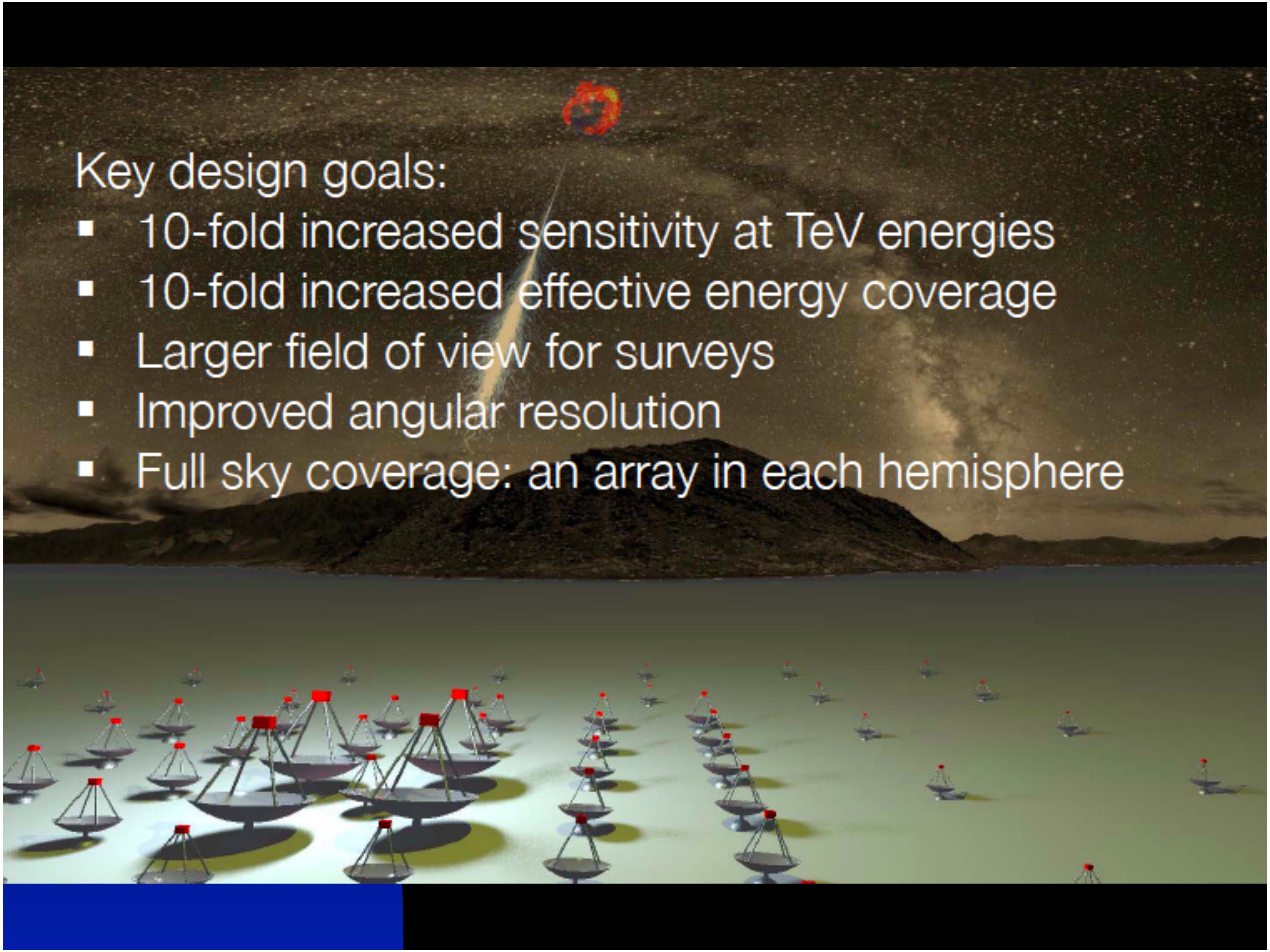
http://www.nasa.gov/mission_pages/GLAST/news/supernova-cosmic-rays.html (02.14.13)



- "SNR paradigm": Galactic Cosmic Rays accelerated in SNRs:
  - provide environment for diffusive shock acceleration, energetics ok;
  - smoking gun: "pion bump" in gamma-ray emission.
- Fermi observations strongly disfavoring leptonic scenarios.
- Most of the gamma-ray emission must be of hadronic origin.
- (Difficult measurement involving the study of extended sources at low energies.)

Next Generation Gamma-ray Detectors

CTA: Cherenkov Telescope Array


Key design goals:
10-fold increased sensitivity at TeV energies
10-fold increased effective energy coverage
Larger field of view for surveys
Improved angular resolution
Full sky coverage: an array in each hemisphere

HAWC:
High Altitude Water Cherenkov

USA: 

16 institutions,

57 people

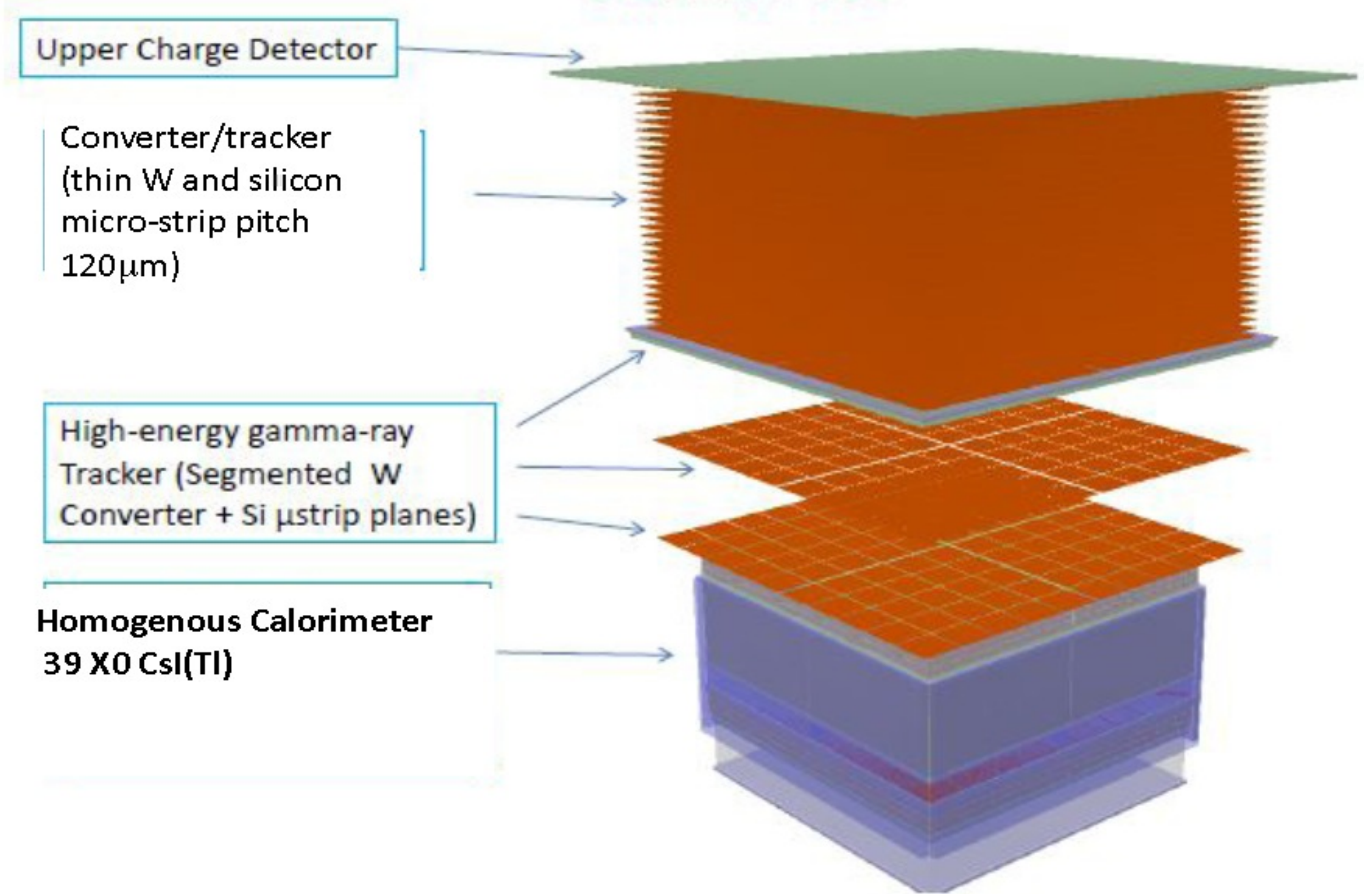
Mexico: 

15 institutions

54 people

to be completed in Aug 2014

Gamma-400 Satellite



- *Launch foreseen by end 2018*
- gamma-rays from 30 MeV up to 300GeV energies
- electrons/positrons in the TeV energy range and beyond
- proton/ion cosmic-rays up to the "knee"

GAMMA-400

- Mission approved by ROSCOSMOS (launch currently scheduled by November 2018)
- GAMMA-400 will be installed onboard the platform “Navigator” manufactured by Lavochkin
  - Scientific payload mass 4100 kg (rocket changed from Zenith to Proton-M)
  - Power budget 2000 W (like previously)
  - Telemetry downlink capability 100 GB/day
  - Lifetime $\sim$ 10 yrs

Activities in INFN Laboratori Nazionali di Frascati and Roma Tor Vergata on Cosmic Rays Research in Space and related

- **Running Missions**
  - PAMELA
  - FERMI (+INAF)
  - AGILE (+INAF)

- **Planned Missions**
  - CALET (ready to launch 2014)
  - GAMMA 400
  - JEM-EUSO (+INAF)
  - CSES/LIMADOU


asdc
ASI Science Data Center
ASI Science Data Center
agenzia spaziale italiana
Home
About ASDC
Public Outreach
Quick Look
Missions
Multimission Archive
Catalogs
Tools
Links
Bibliographic services
Helpdesk
AGILE
SWIFT
FERMI
HERSCHEL
PLANCK
BeppoSAX
NUSTAR
Gaia
Astrophysics and Cosmology
Exploration of the Solar System
Astroparticle Physics
NuSTAR 44Ti map of Cassiopeia A
TOP RESULTS/PRESS RELEASES
Mar 26, 2014: AGILE mission operations extended by ASI for another year
Feb 21, 2014: PLATO selected by ESA!
Feb 20, 2014: NuSTAR creates the first map of 44Ti emission in Cassiopeia A
ASDC Sky EXPLORER
web tools
Time SED tool V 3.0
web tools
ASDC Newsletter
SCIENTIFIC NEWS
Feb 12, 2014: AGILE gamma-ray detection of a new unidentified source in 2010 has led to the discovery of the first ever known Be-BH binary system.
Feb 06, 2014: NuSTAR 3rd Data Release at ASDC
Jan 21, 2014: Fermi-LAT Detection of Delayed Gamma-ray Flares from Gravitational Lens B0218+357
EVENTS
TORINO 19 DICEMBRE 2013
ALTEC
NuSTAR Archive Research Opportunity (NARO)
NOTTE EUROPEA DEI RICERCATORI
27 SETTEMBRE 2013
[WANTED]
frascati scienza
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If your research benefits from the use of ASDC, we would appreciate the following acknowledgement in your paper:
Part of this work is based on archival data, software or on-line services provided by the ASI Science Data Center (ASDC).
Best viewed with:
(3.5+)
(8+)
(3+)
(1+)

What Next

7-8 April 2014 *Angelicum - Roma*

Europe/Rome timezone

Informazioni

Programma

L' INFN si interroga alla vigilia di importanti input sperimentali (LHC14, 1-ton DM), test-chiave nella decennale ricerca di una fisica nuova, oltre il Modello Standard, alla scala di energia del TeV.

Conclusions

- Cosmic-Ray/Astroparticle physics from space (and not only …) is a fascinating field, fertile and rich of scientific potentials.
- Several important esperiments are, or going to, directly measuring cosmic-ray energy spectra, their composition and their antimatter component.
- Important results have already been published and soon more will come.

Stay tuned, interesting times ahead!