Status and perspectives of AP in Spain:

Cosmic Rays

Auger
AMS (slides from J. Berdugo)
JEM-EUSO (slides from M.D. Rodriguez Frias)

Fernando Arqueros
Universidad Complutense de Madrid

IV CPAN Days / RENATA meeting (Granada 2012)

Outline

- Where do we come from?
- Where do we stand now?
- What should we do next?

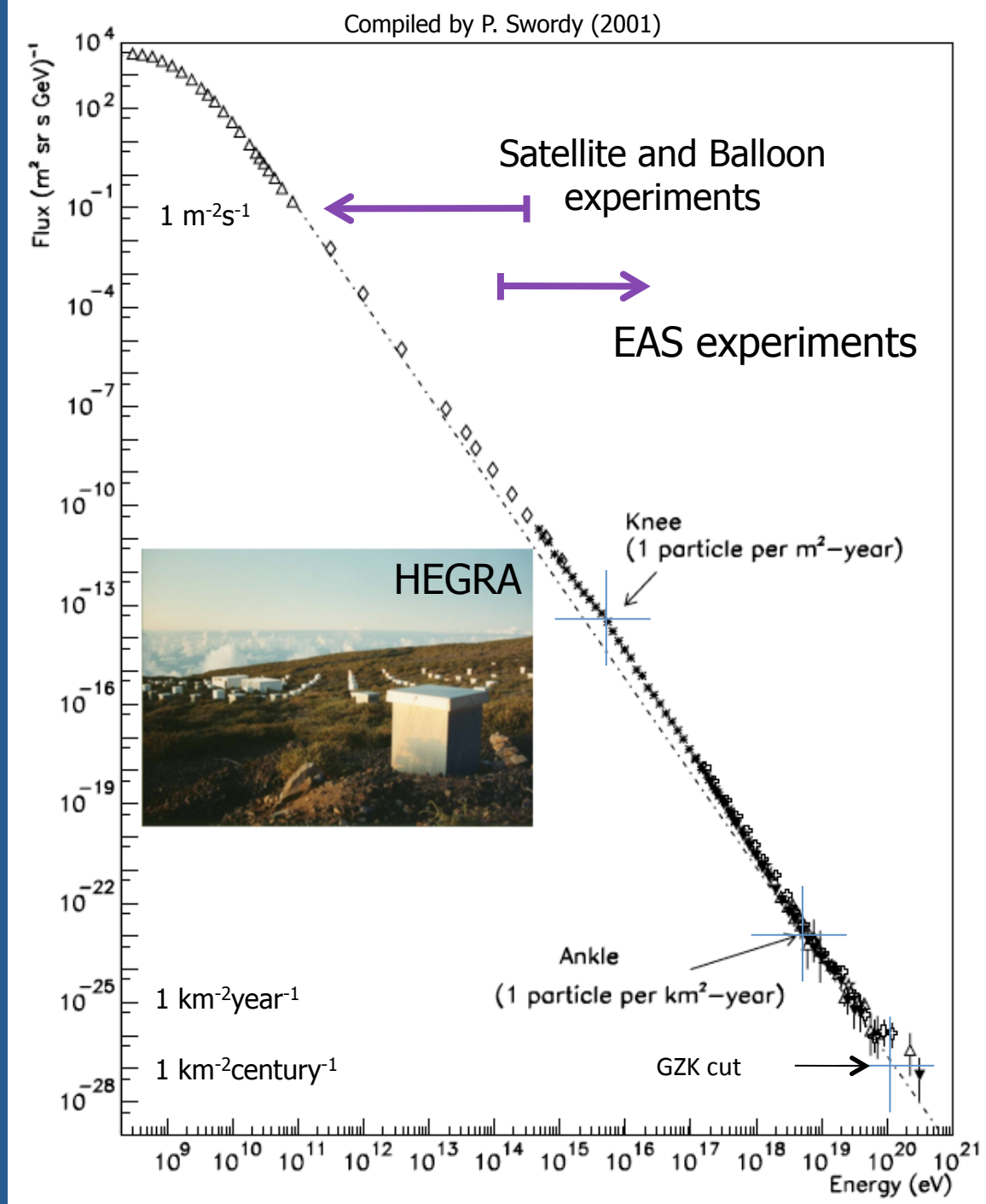
Discovery of cosmic rays

Where do we come from?

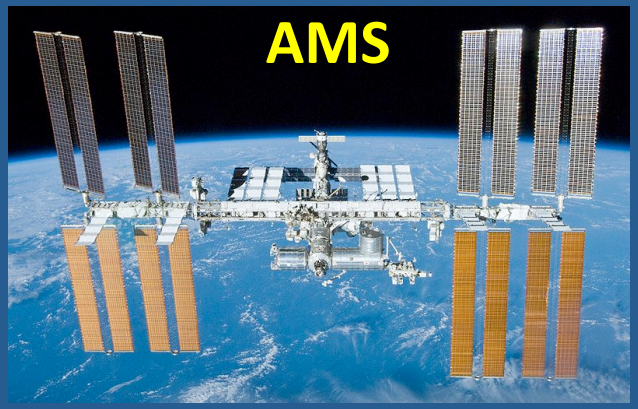
$E < 10^{15}$ eV
JACEE

$E > 10^{14}$ eV
HEGRA (1989)
KASKADE

$E > 10^{18}$ eV
Haverah Park
AGASA
Fly's Eye ➔ HiRes

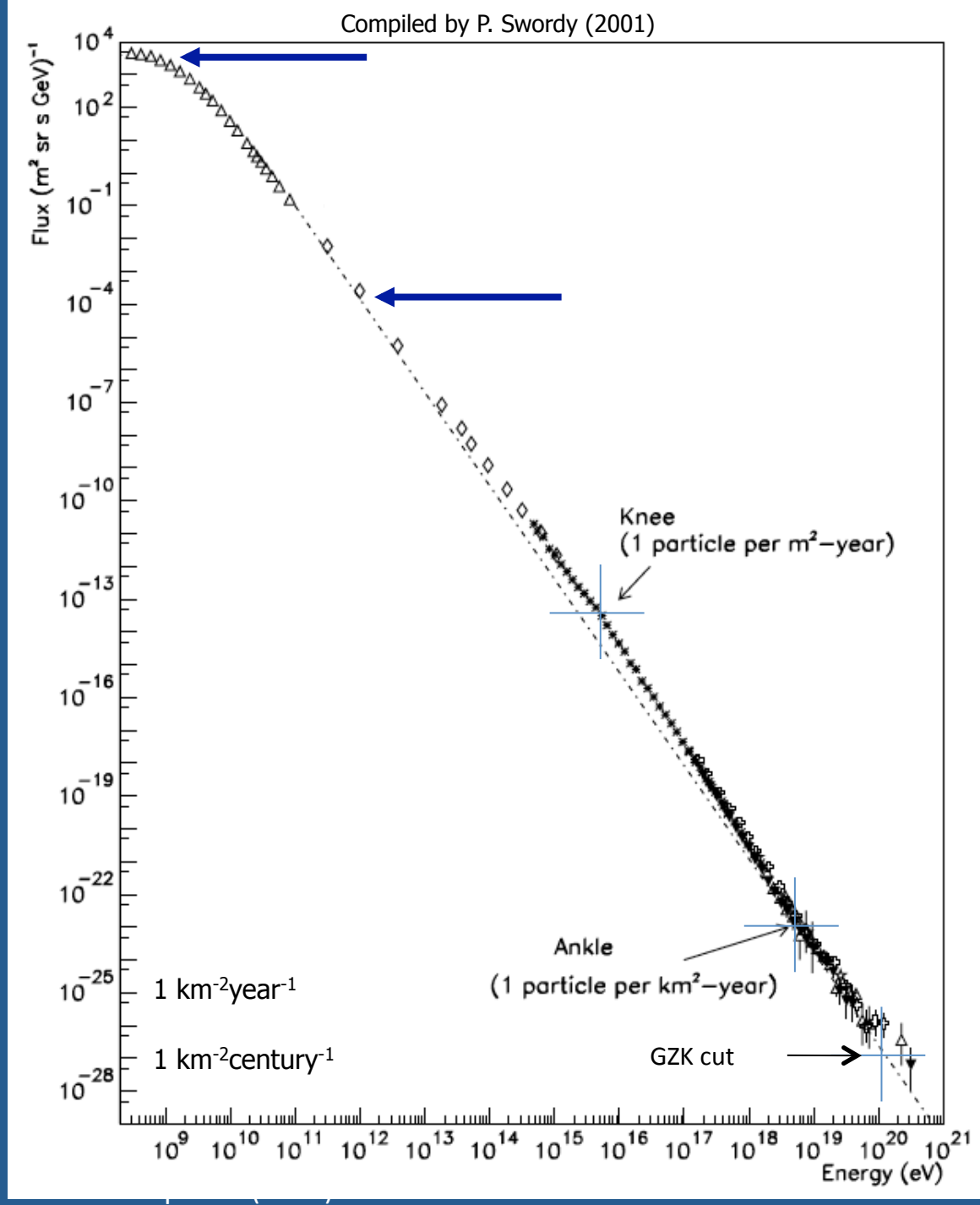


Where do we stand now?

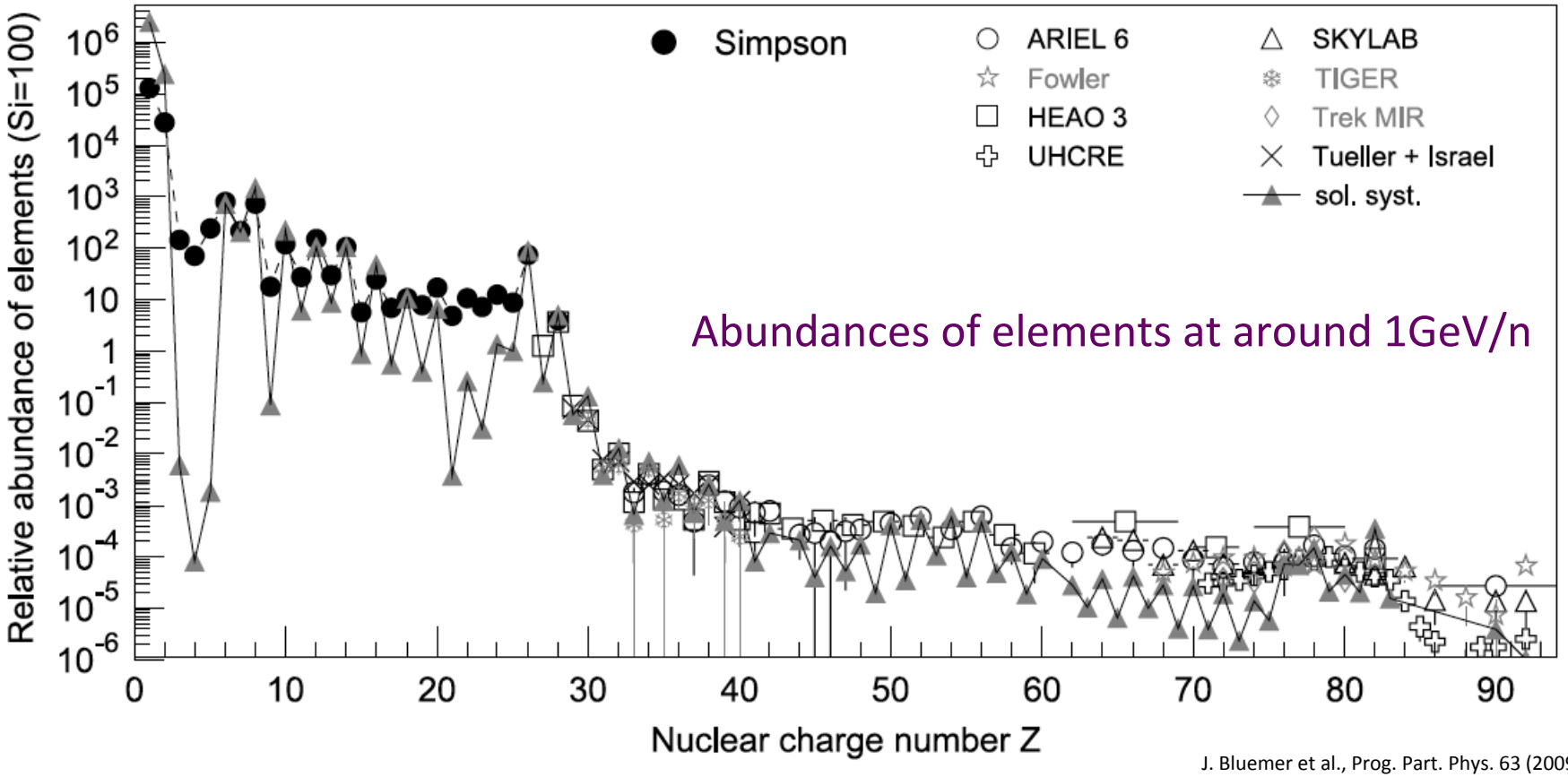


CIEMAT, IAC

AMS is measuring the energy spectrum and composition in the 1GeV – TeV interval with unprecedented accuracy



Chemical Composition



J. Bluemer et al., Prog. Part. Phys. 63 (2009) 293

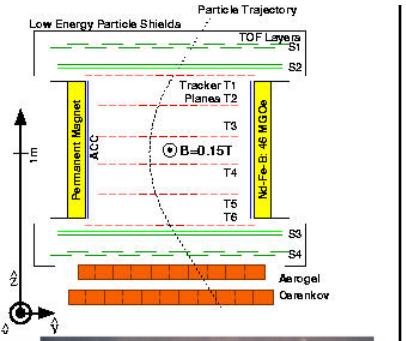
- Well known at low energies
- By groups (H, He, CNO, …) at the knee region
- Very difficult at the highest energies

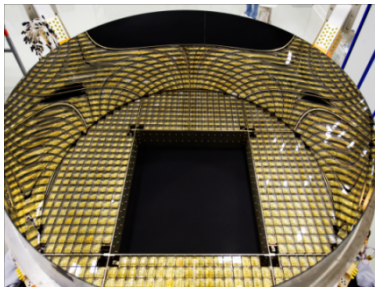
Instalación de AMS en la ISS
19 de mayo de 2011

J. Berdugo

Grupos españoles participando en AMS:
CIEMAT (9 seniors + 3 becarios)
IAC (3 seniors + 1 becario)
Financiación: AYA (Subprograma Espacio) – Proyecto coordinado
CPAN: 1 Post-doc (CIEMAT)

AMS: Participación española





Participación en AMS01 (1997-2000) (CIEMAT)

Actividades:

- ❑ Desarrollo de software y análisis de datos
  - Integración en el ETH (Zurich) y test funcionales en el KSC (NASA)
  - Toma de datos en el JSC (NASA)
  - Calibración del detector con Test Beam (GSI & CERN)
  - Análisis de datos (CERN & CIEMAT)

Participación en AMS02 (2000-2012) (CIEMAT, IAC)

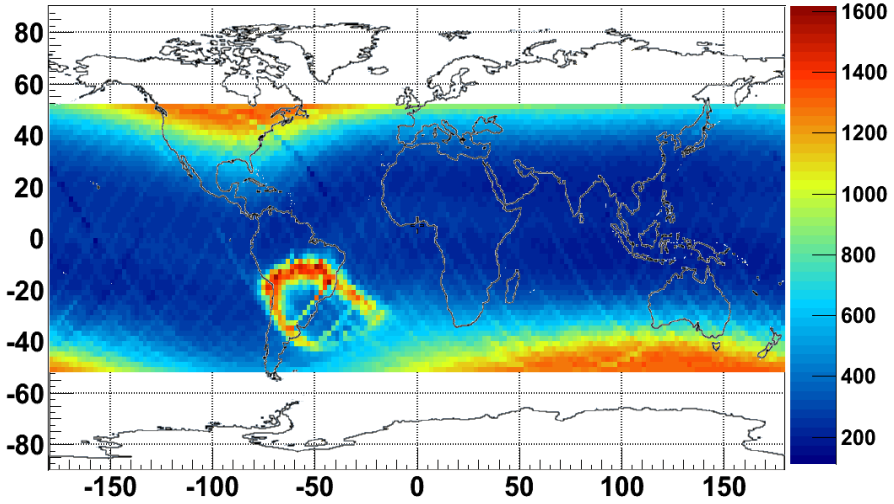
Actividades

- ❑ Construcción del detector
  - Cherennkov Radiation Detector (RICH)
  - Electrónica del imán Superconductor
- ❑ Desarrollo de software de reconstrucción
- ❑ Operación y mantenimiento del detector RICH
- ❑ Análisis de datos

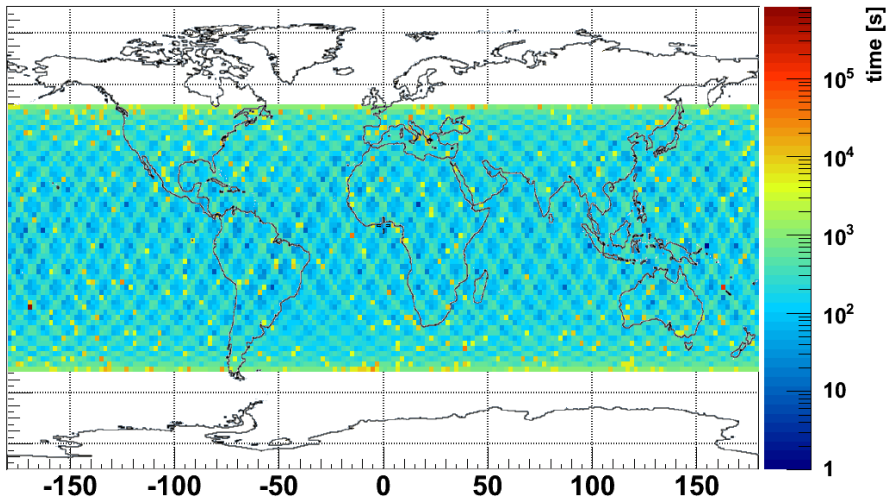
J. Berdugo

AMS DAQ: Toma de datos ininterrumpida desde el 19 de mayo de 2011

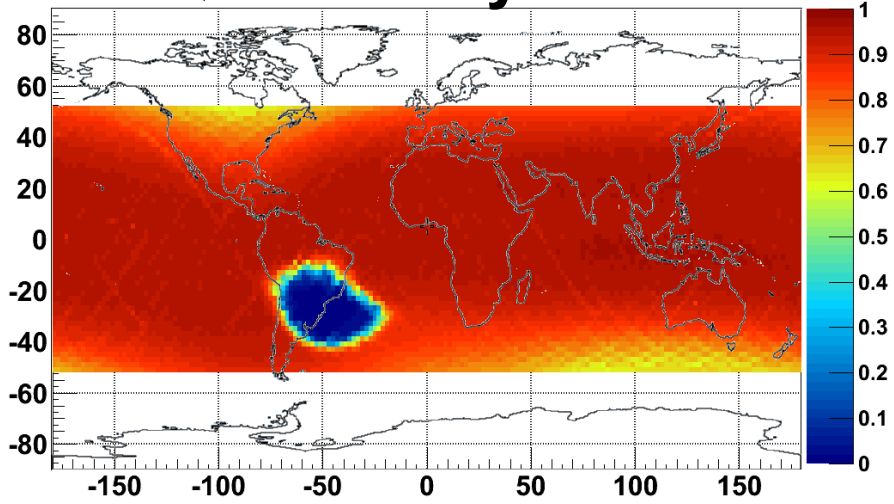
Acquisition rate [Hz]



Time at location [s]



DAQ efficiency



<Frecuencia> ~ 600Hz

<Eficiencia> ~ 85%

~ 1.3 * 10^9 sucesos/mes

J. Berdugo

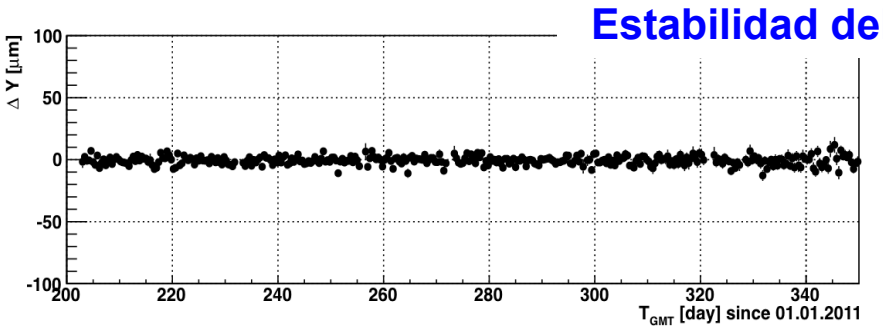
AMS: Primer año de toma de datos

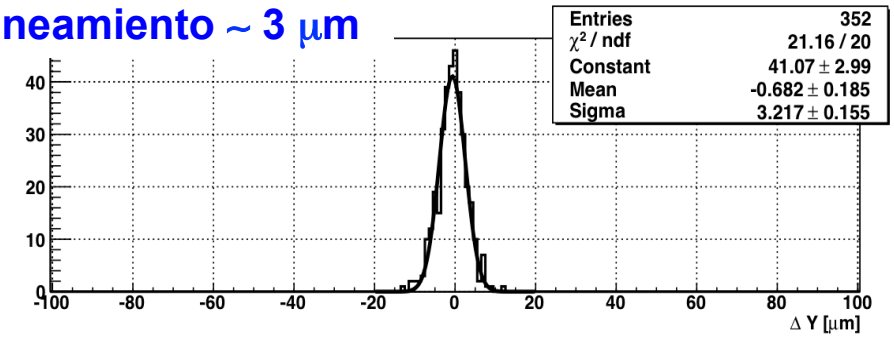
J. Berdugo

- **Operación y mantenimiento del detector**

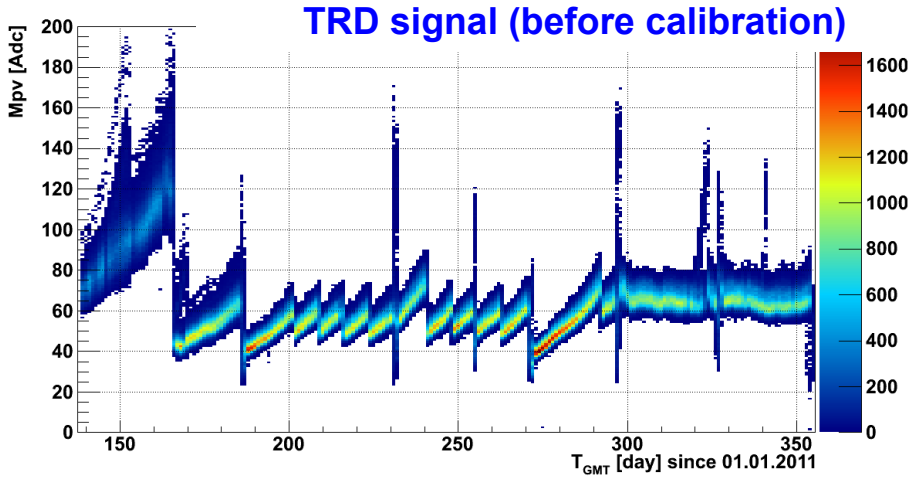
  AMS ha estado operando initerrumpidamente desde el inicio de la toma de datos

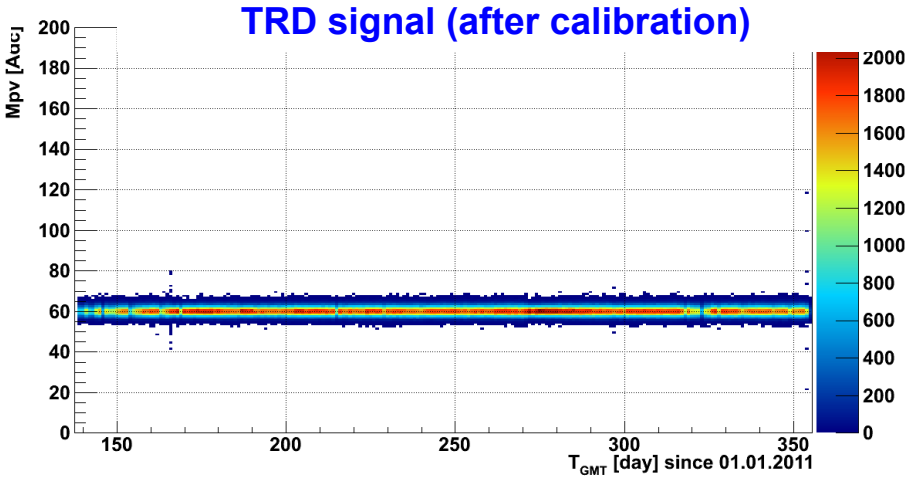
- **Alineamiento del detector de trazas**



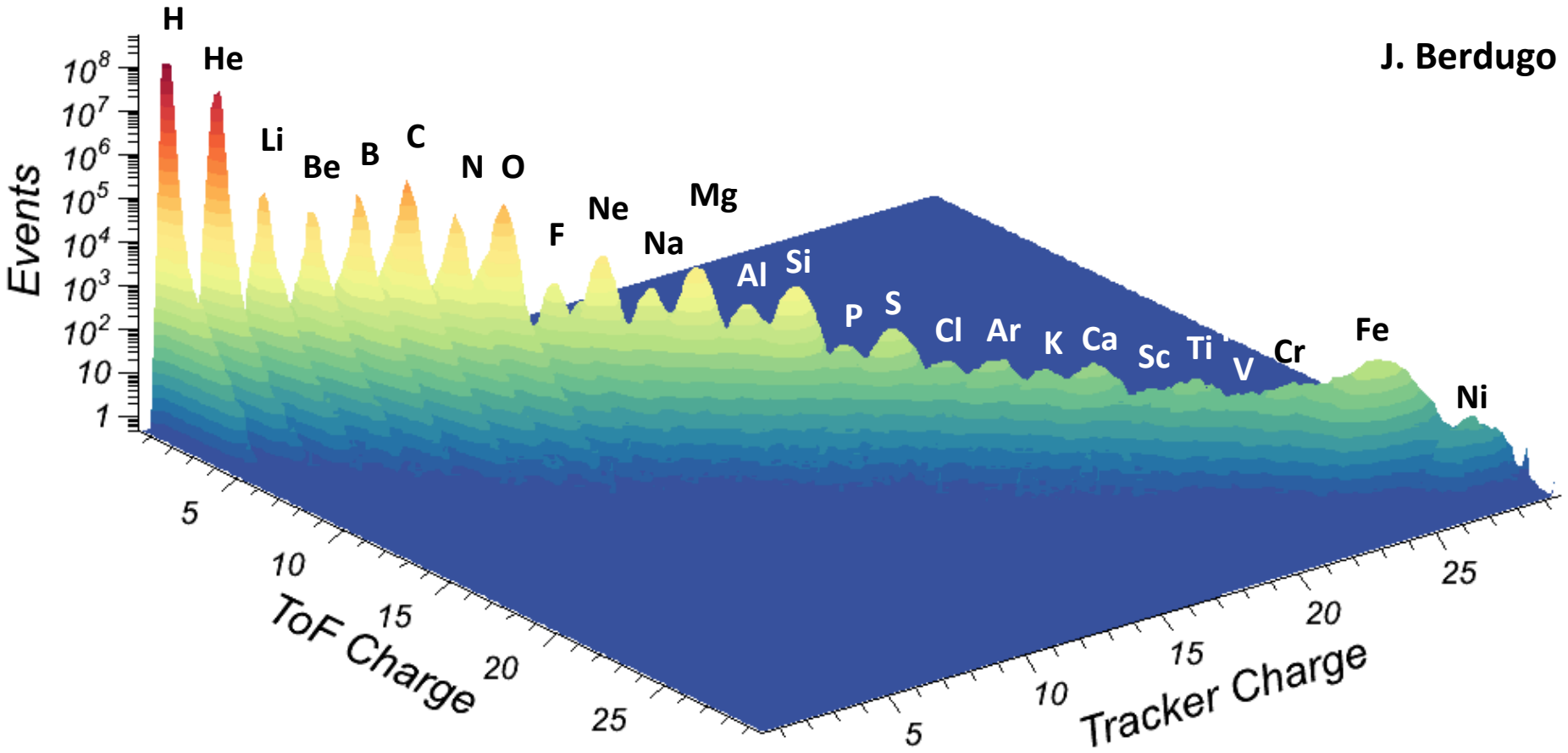


- **Calibraciones de los subdetectores**





AMS-Objetivos científicos:
Detección y medida de rayos cósmicos con Z≤26 (1GeV-1TeV)



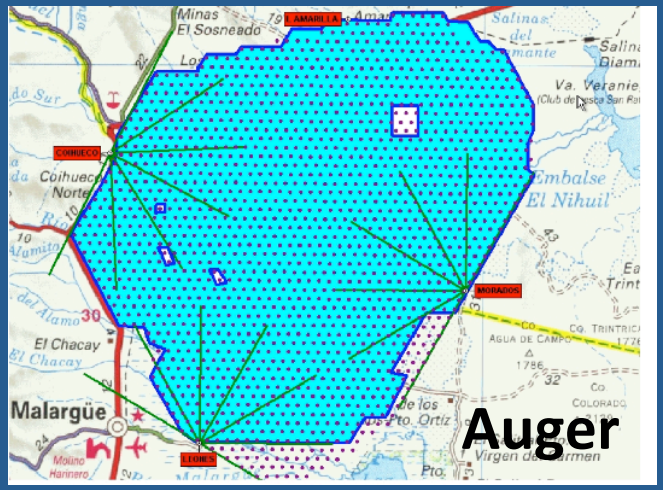
Temas de análisis prioritarios (2012-2013):

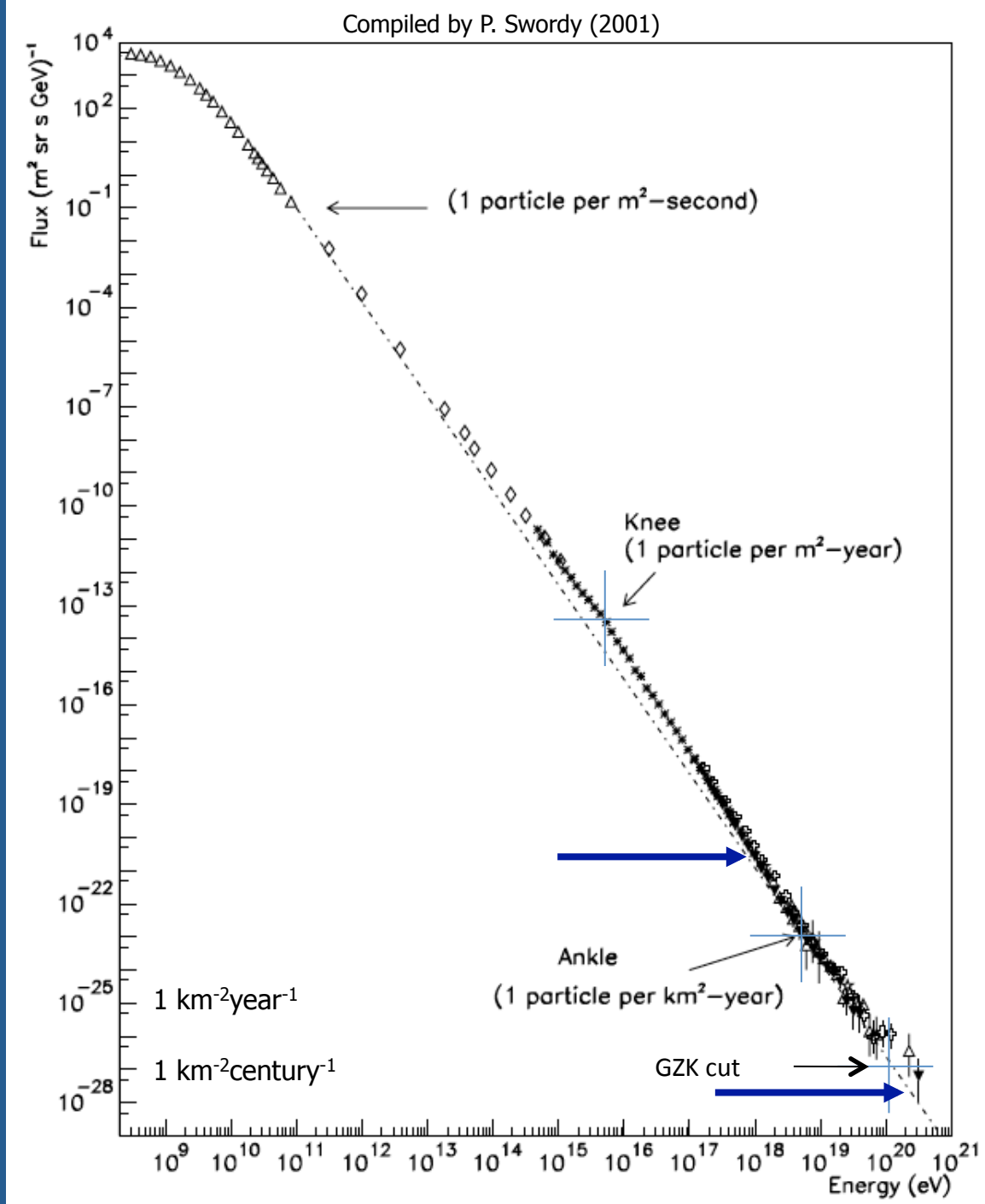
- Medida de la fracción de $e^+ / (e^+ + e^-)$
- Medida de la fracción de secundarios a primarios (B/C)
- Medida del flujo de diferentes especies: (electrones, protones, helio, ...)
- Búsquedas: (antimateria, strangelets,...)

Where do we stand now?

The Pierre Auger Observatory studies the end of the cosmic ray spectrum (E>10^{18} eV) with unprecedented accuracy.

UAH, UCM, UGR, USC





Spanish participation in the Pierre Auger collaboration

USC/IGFAE (2002)
UCM (2004)
UAH (2004)
UGR (2006)
IFIC (2006) associated to USC/IGFAE

} **FPA program**

Hardware contribution:
≈ 1 M€ in solar panels for SD + Auger Access + CLF + muon detector prototypes

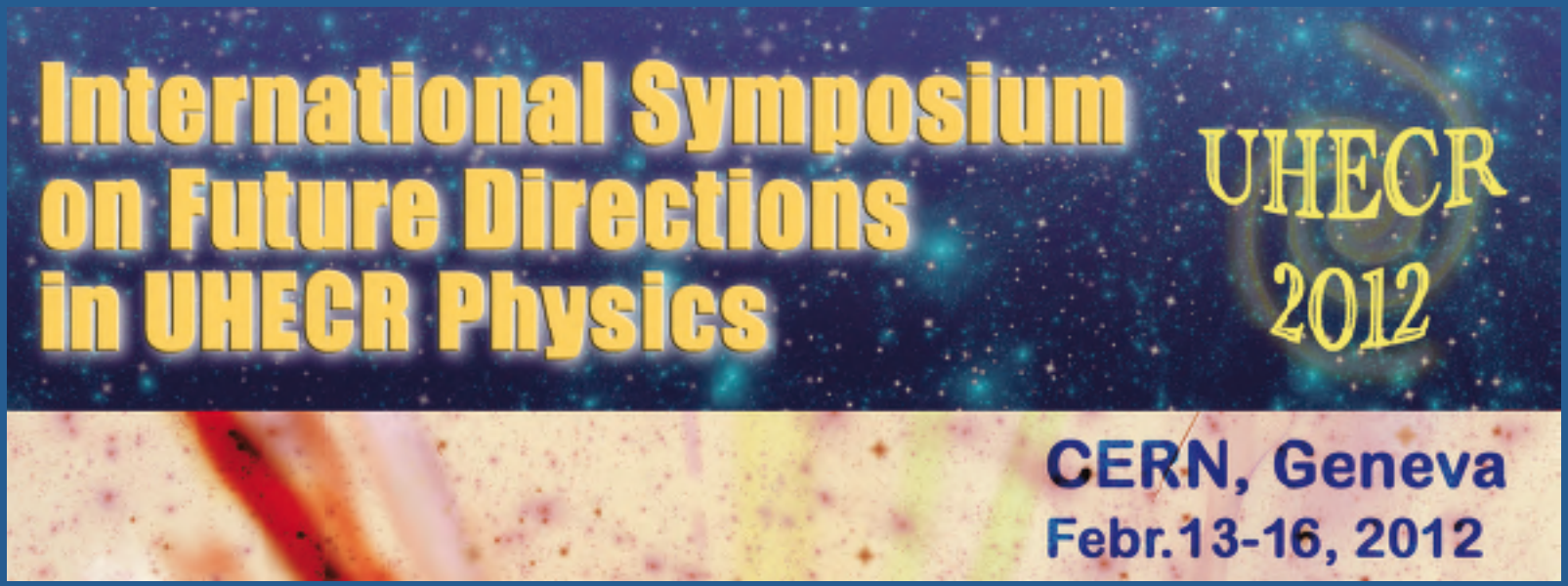
Computing: MC production

Scientific contributions: Inclined events, Mass composition, Neutrinos, Fluorescence Yield

R&D: AERA, MIDAS, PMTs, SiPMT, BATATA, RPCs

Where do we stand now?

$E > 10^{18}$ eV



Working groups with members of UHECR experiments met to compare results and solve differences among them

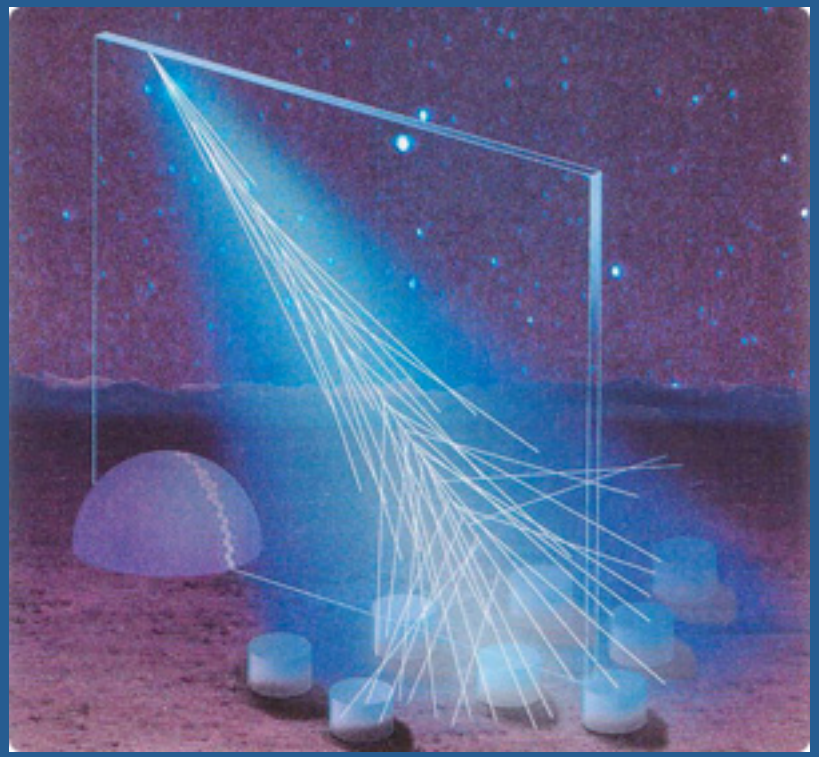
Auger
HiRes
TA
Yakutsk

Currently operative

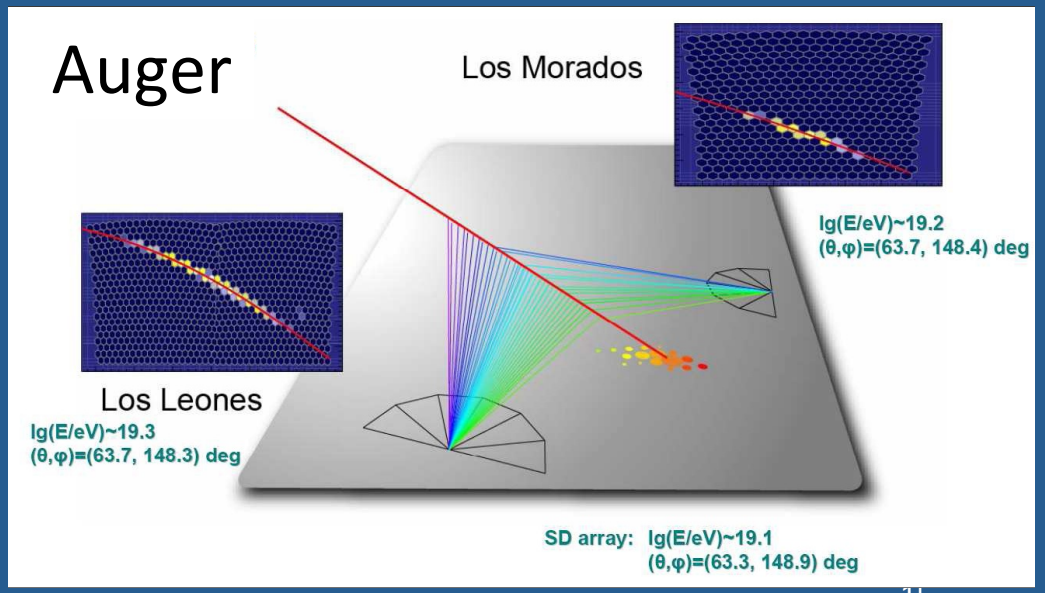
$E > 10^{18}$ eV

Pierre Auger Observatory

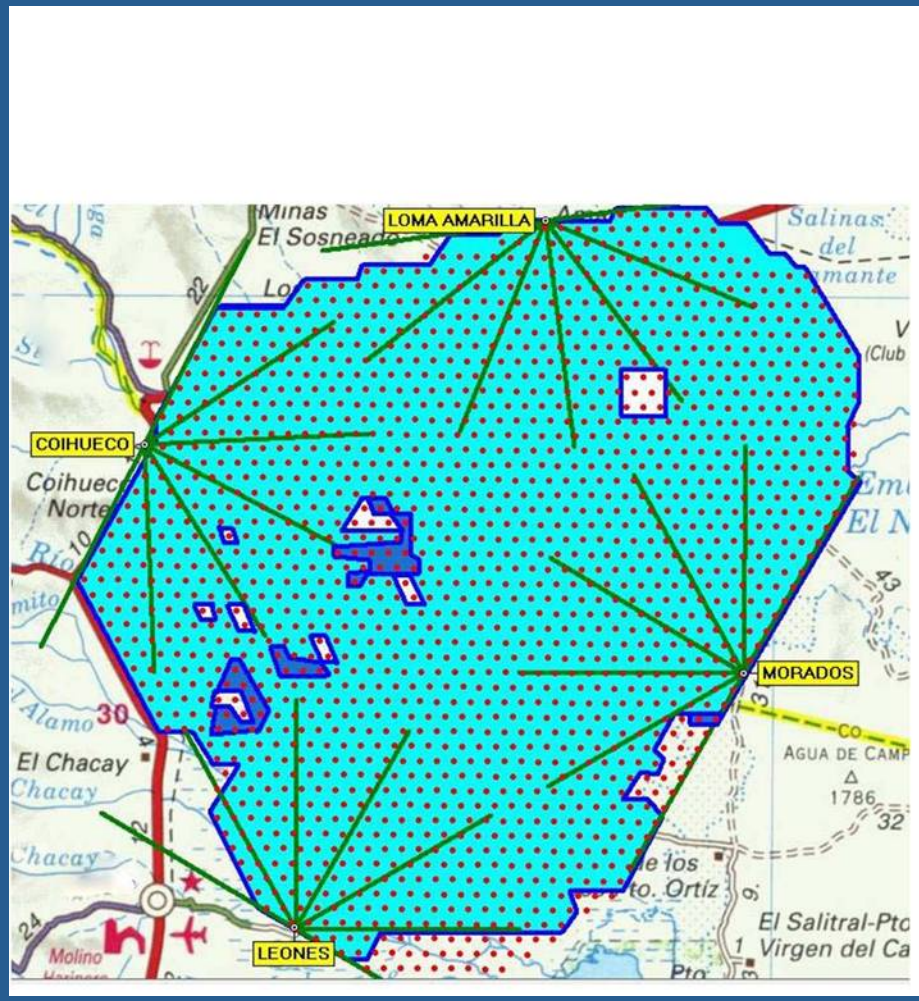
South Hemisphere: Mendoza (Argentina)
1660 water-Č tanks / 3000 km^2
24 Fluorescence telescopes

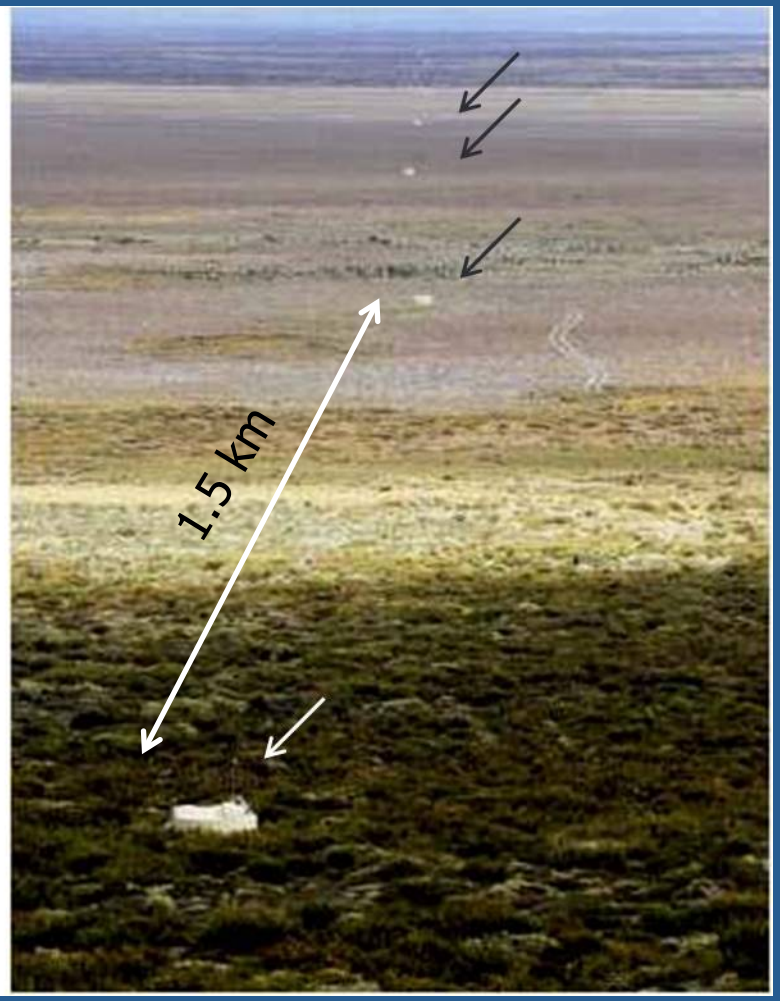


Hybrid detector

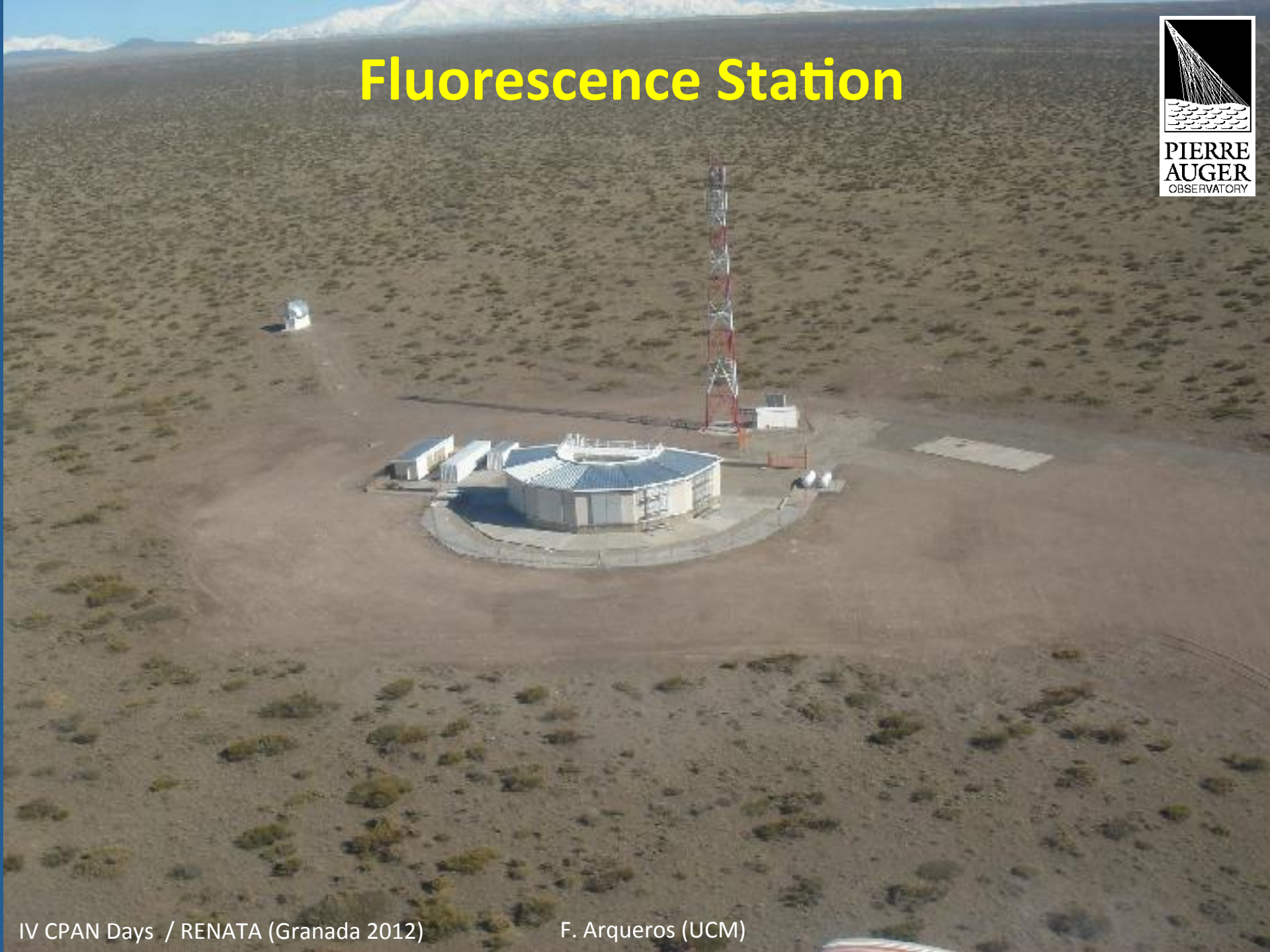


Pierre Auger Observatory (Surface Array)



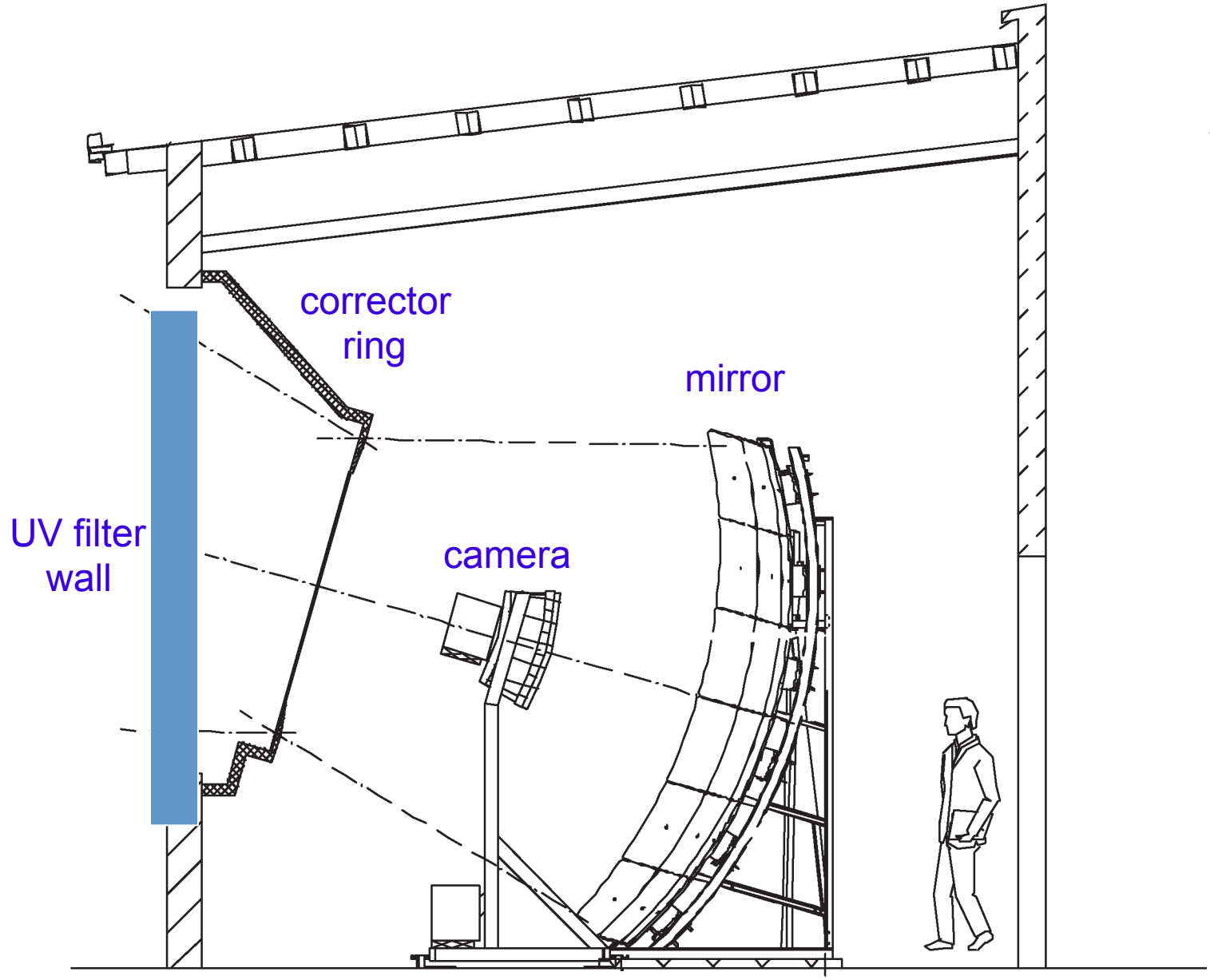


Fluorescence Station



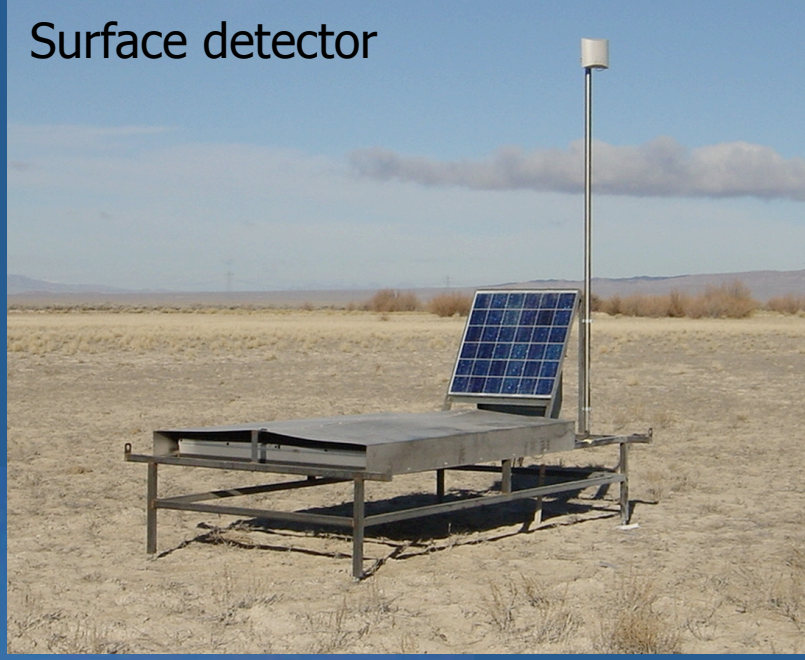

PIERRE
AUGER
OBSERVATORY

Fluorescence Telescope



Telescope Array

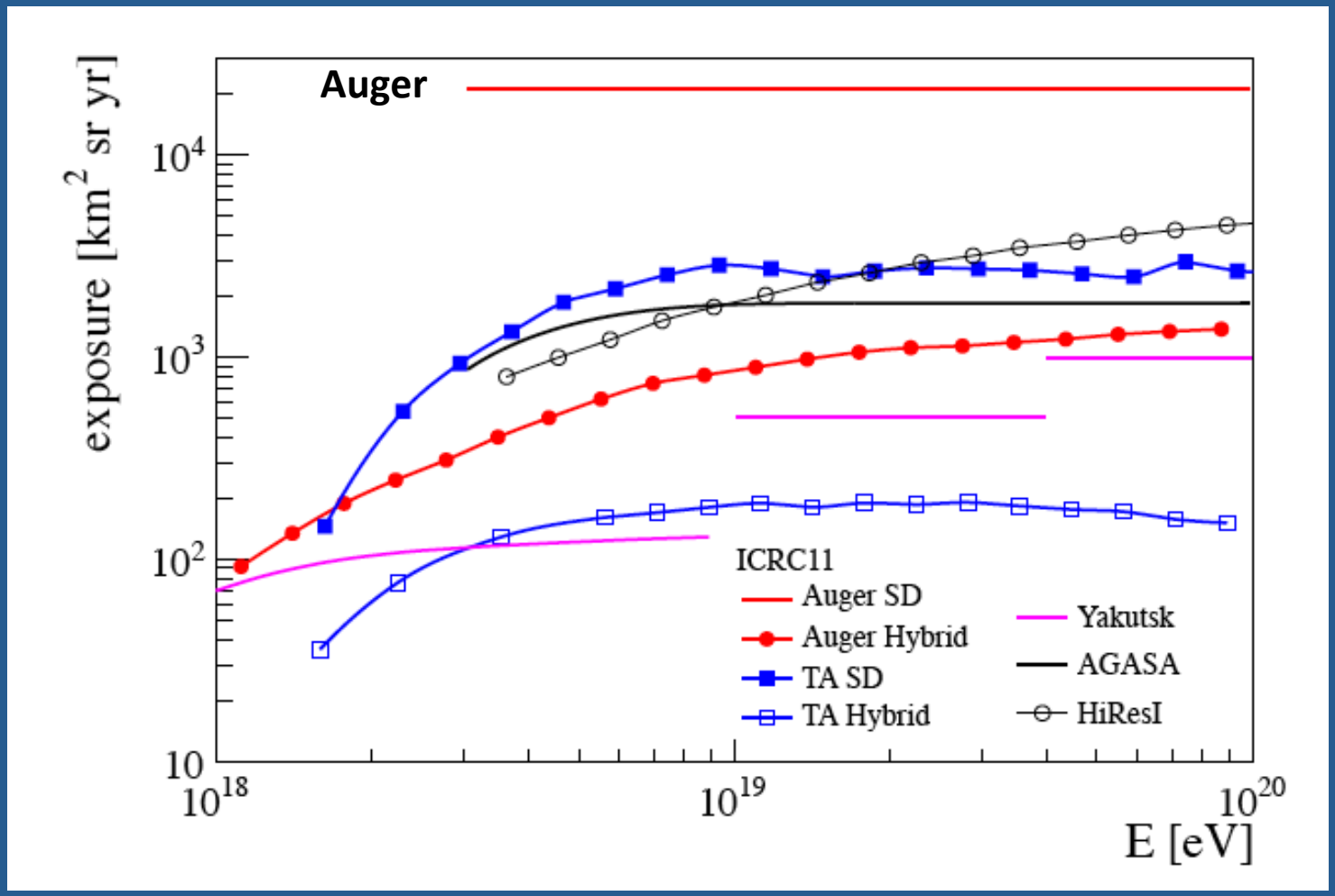
North Hemisphere: Utah (USA)
507 scintillators / 680 km^2
38 Fluorescence telescopes



Fluorescence telescopes

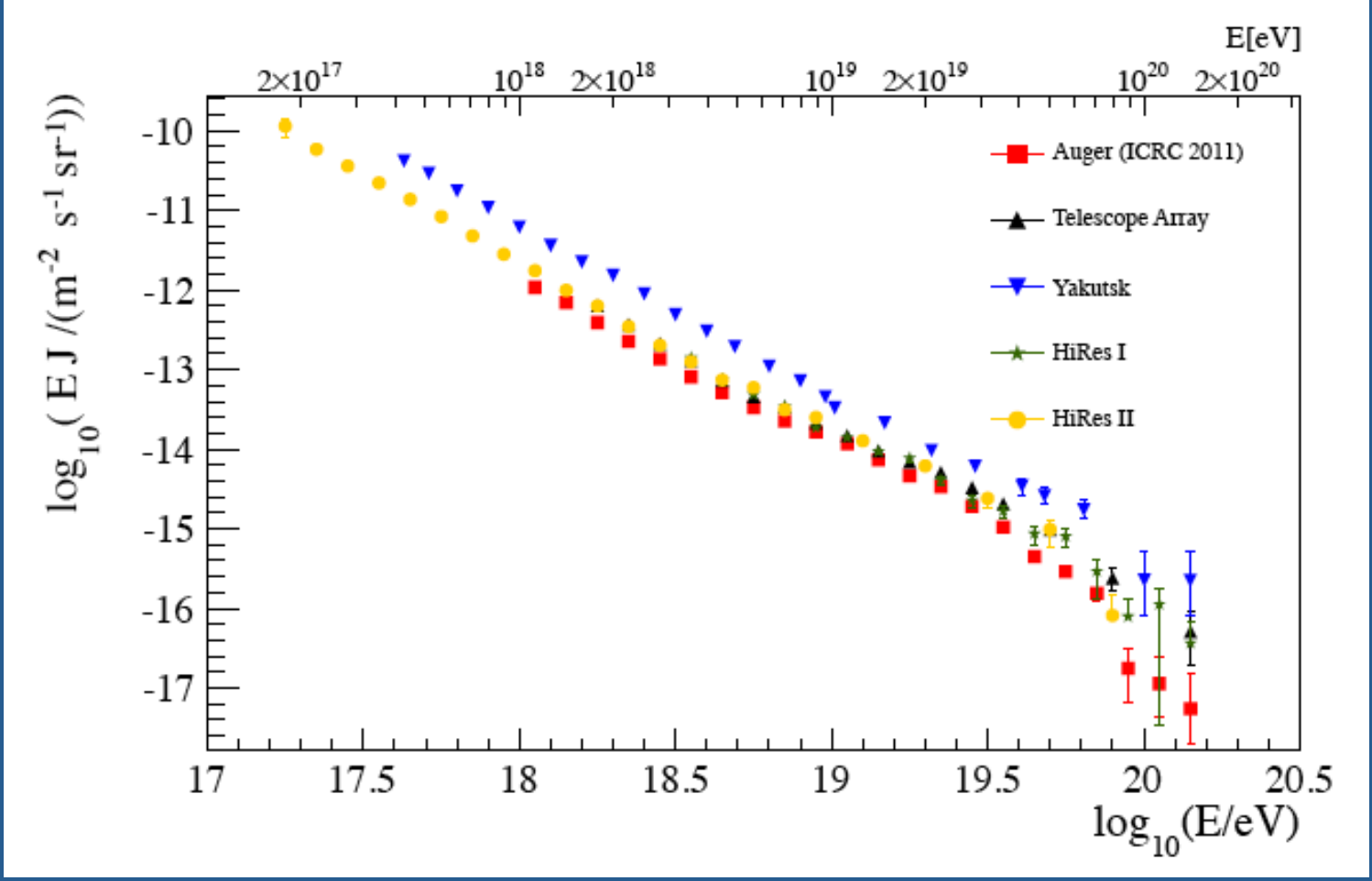
$E > 10^{18}$ eV

Current Exposure (ICRC11)



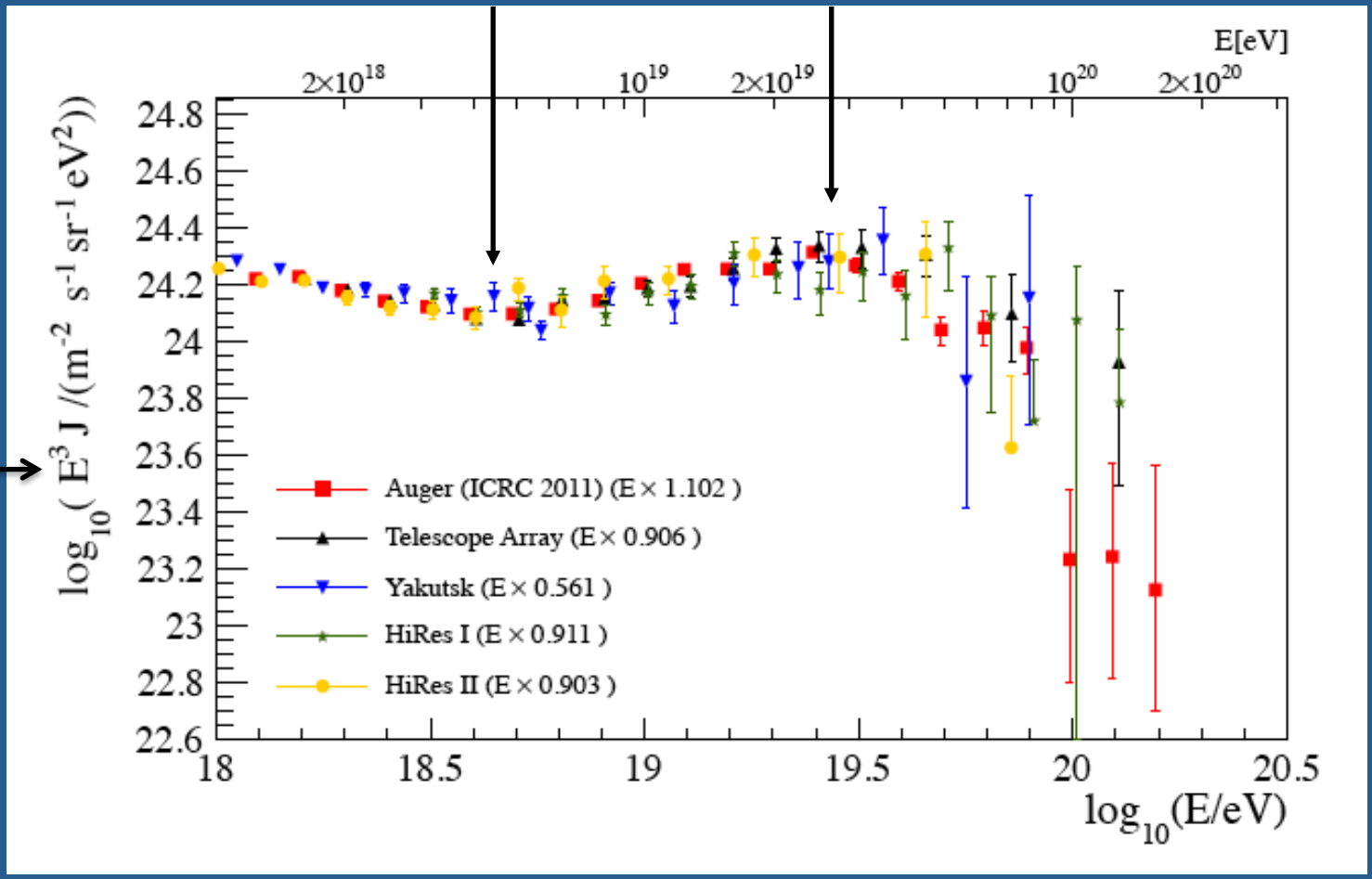
$E > 10^{18}$ eV

Energy Spectrum



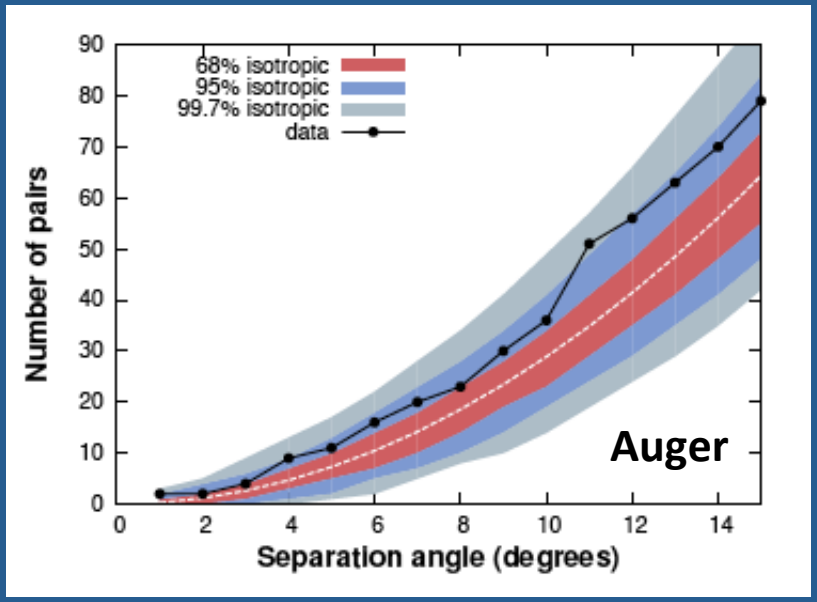
$E > 10^{18}$ eV

Energy Spectrum (E re-scaled)

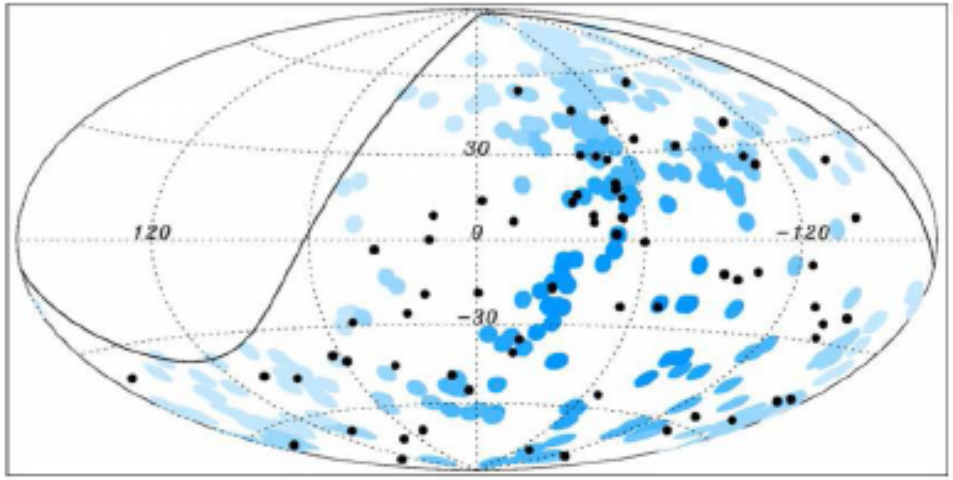


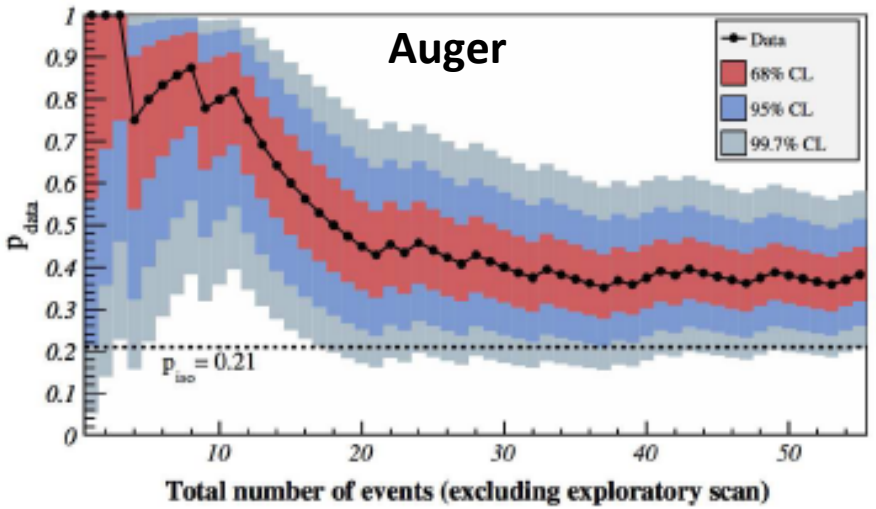
Anisotropies

E > 55 EeV



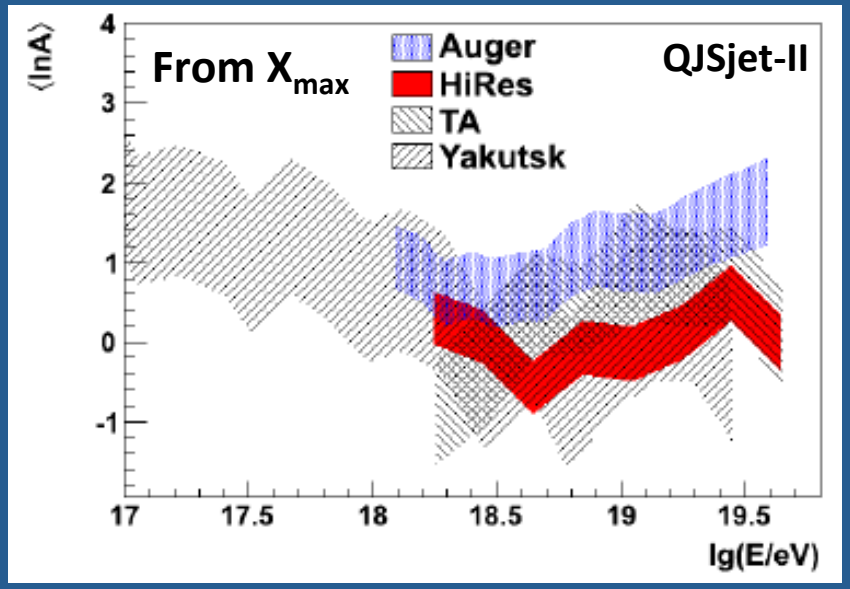
- Clear hints of anisotropies
- The correlation with AGNs has weakened
- Clustering around CenA

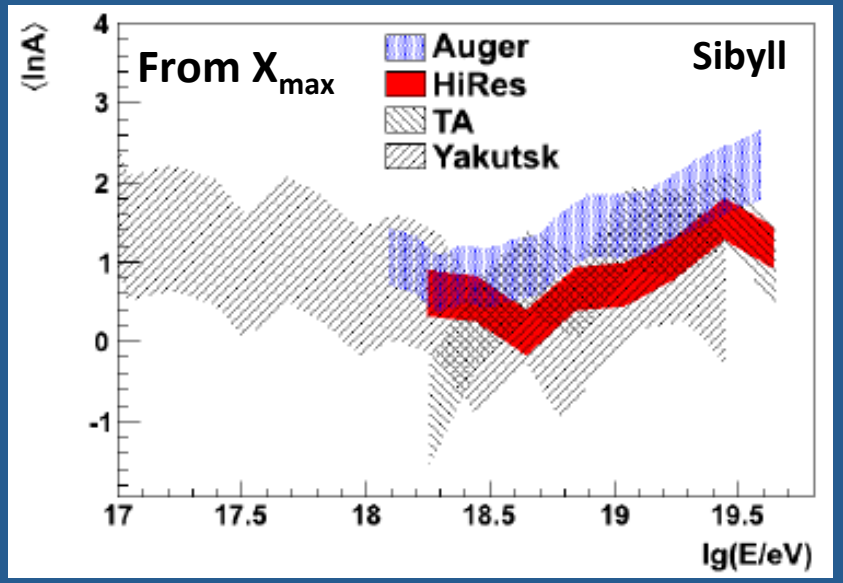


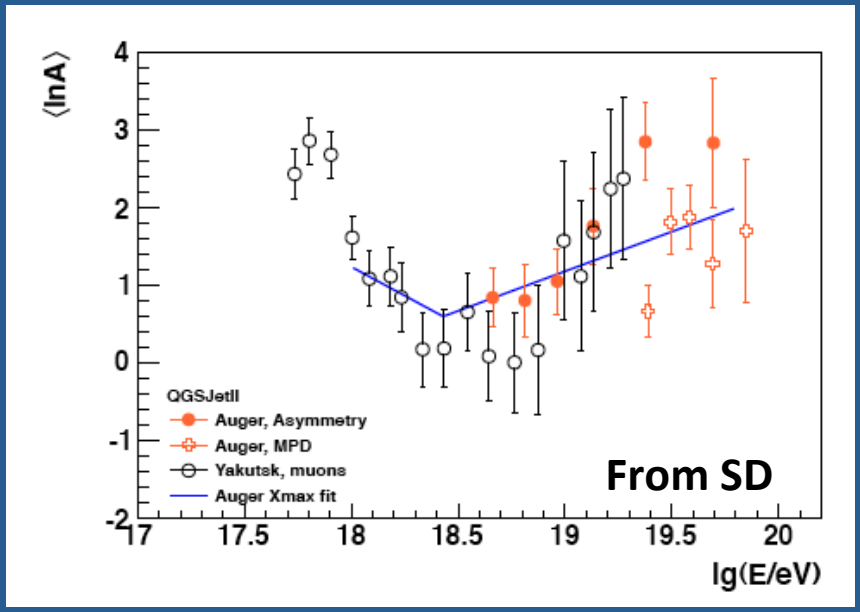


Where do we stand now?

Mass composition $E > 10^{18}$ eV







Results on mass composition:

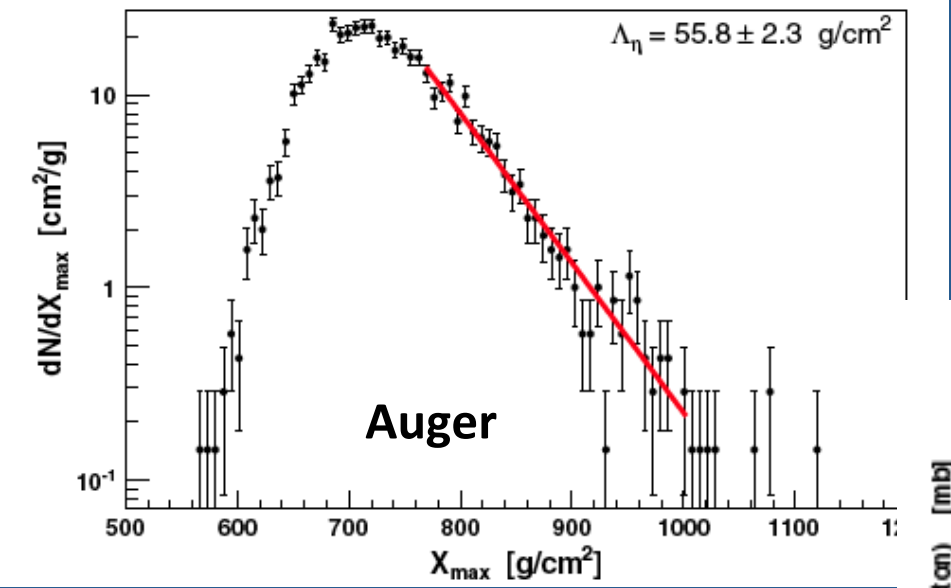
- depends on hadronic interaction model
- have strong implication in the interpretation of anisotropies and spectrum

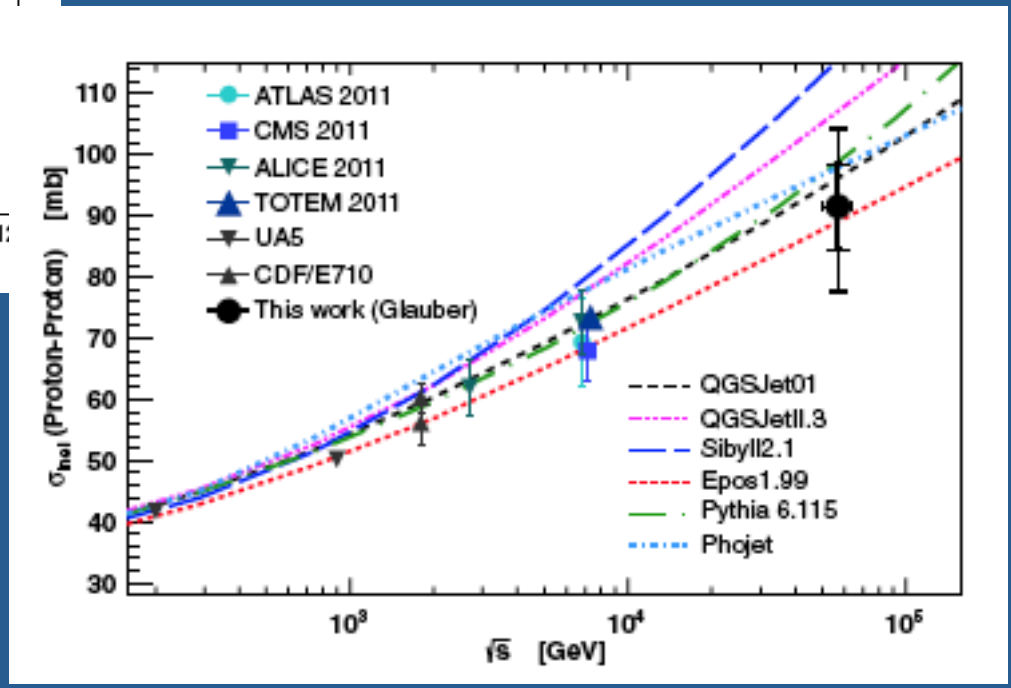
HiRes → protons

Auger → heavier at the largest Energies

Where do we stand now?

Hadronic Physics





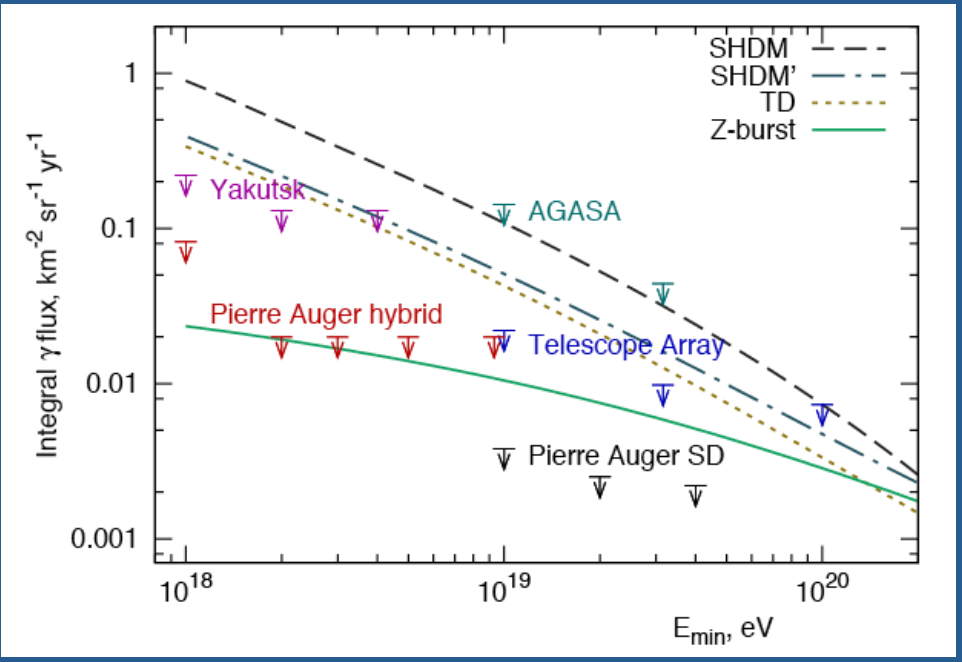
Cross section for p-p collisions at 57 TeV (c.m. energy) =

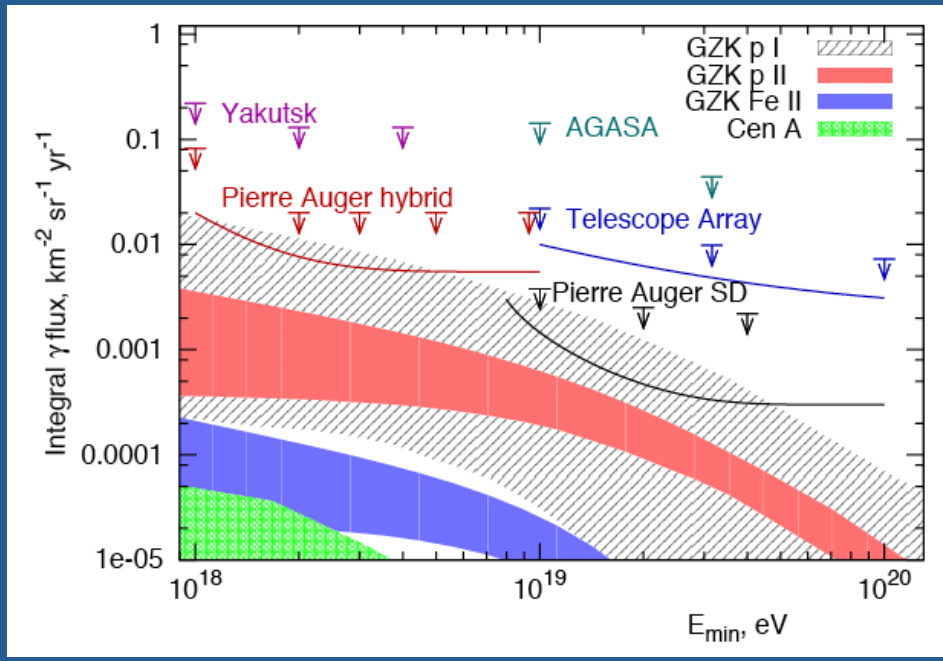
$$\sigma_{pp}^{\text{inel}} = [92 \pm 7(\text{stat})^{+9}_{-11}(\text{syst}) \pm 7(\text{Glauber})] \text{ mb},$$

Where do we stand now?

UHE Photons

$E > 10^{18}$ eV





Constraints in top-down models

UHE limits and estimates of sensitivity in 2015

The present status $E > 10^{18}$ eV

Energy Spectrum

Excellent agreement within scale factors in Energy compatible with systematics.

Ankle at log(E/eV) = 18.6

Flux suppression at log(E/eV) = 19.4

Mass composition

Auger: increasingly heavier above $\approx 3 \times 10^{18}$ eV.

HiRes / TA: compatible with pure proton.

Difficult to understand the cause of the disagreement (different analysis techniques). HiRes/TA need increasing data (about $\times 4$).

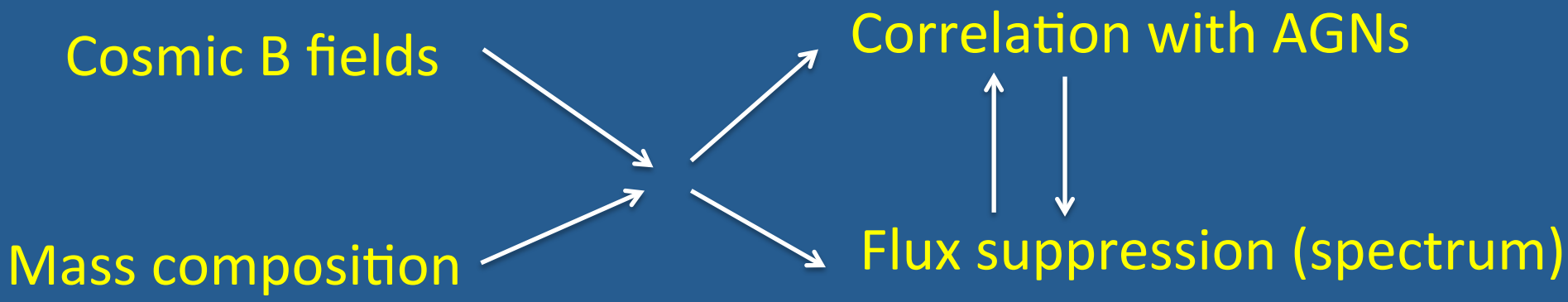
Arrival directions

Auger: anisotropy (99% confidence level). Correlation with AGNs weakened 69% -> 38%.

HiRes / TA: no significant deviation from isotropy.

Present status

E > 50 EeV



- Heavy composition (Auger) inconsistent with AGNs correlation (< 10 deg.). Protons are favored

- Flux suppression consistent with GZK cut if protons.
  Other models of mixed composition compatible with suppression

The Future

E > 50 EeV

- Increase the aperture (> 30.000 km ^{2}) without reducing data qualit (angular resolution about 1° and energy resolution < 20%).
  - Sparse array of water-Č tanks
  - Low-cost single pixel fluorescence telescopes
  - wide field air-Č detectors

- Increasing duty cycle of detector of EM shower development
  - FD working with partial moon
  - Microwave detection (molecular bremsstrahlung)

- Accurate muon densities at ground
  - RPC's
  - Faster FACDs + black top in current water-Č tanks
  - Segmented water-Č tanks

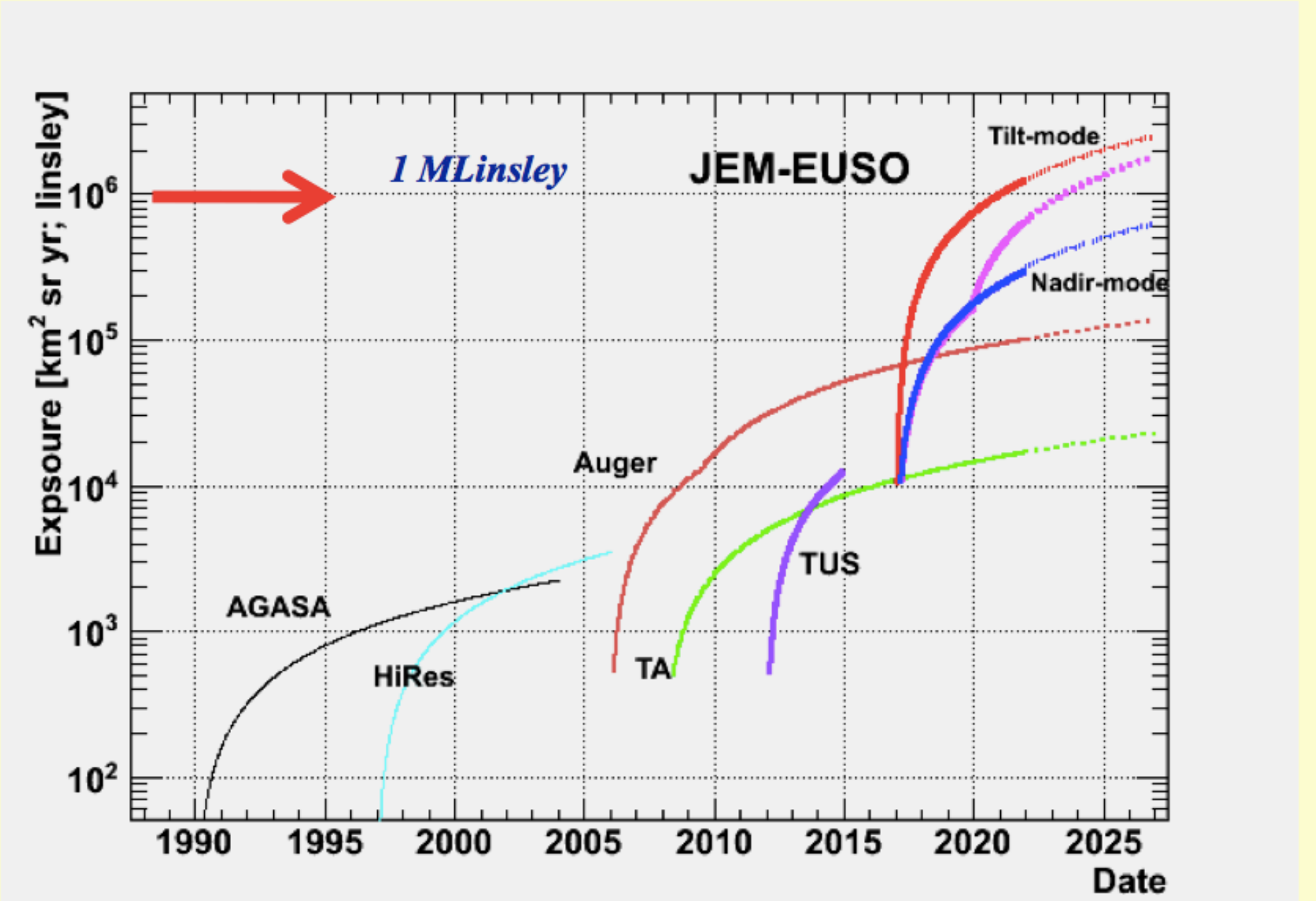
Extreme Universe Space Observatory

Internal IR-camera SRR, Madrid, 23/11/2011

The JEM-EUSO Space Mission: Spanish Scientific & Technological Contribution

M. D. Rodríguez Frías
for JEM-EUSO-Spain
spas.uah.es

Why JEM-EUSO? Large exposure + Full sky coverage



JEM-EUSO: Status & Schedule

- Phase A: 2007-mid 2009.
- Phase B1: SRR. mid 2009-2011.
- Phase B2: PDR+BBM 2012-2013. ONGOING…
- JEM-EUSO pathfinder: EUSO-Balloon @ French Space Agency (CNES) 2013. Phase B scheduled on Dec 18, 2012. More than 200 pg to be delivered to CNES by Dec 3, we are in a rush… to arrive on time ! Launch: 2013 @ Timmins, Canada.
- Phase C: CDR 2014-2015.
- Construction, Assembly & Verification: 2015-2016.
- Launch by HIIB-HTV & Commissioning: 2016-2017.
- Operation period: 2017-2018 (Nadir mode). 2018- … (Title mode).
- Resources: 90.000 k€-26.000 k€ Europe (33% Europe, 66% Others).

ESA committees positive reviews

- 2010: ESA: “Fundamental Physics Roadmap Advisory Team (FPR-AT)”
- 2010: ESA “Astronomical Working Group (AWG)”.
- 2010: Program ELIPS (European programme for Life and Physical sciences and applications): JEM-EUSO approved by the ESA committee for “Human Spaceflight, Microgravity and Exploration”.
- 2010: The Science Unit of The European Space Foundation (ESF) has informed positively the JEM-EUSO space mission.
- April 2011: :ESA has funded the European partners of JEM-EUSO with the project “ESA topical team for Coordination of the european involvement in JEM-EUSO ” to reinforce the coordination and contribution of Europe to this mission.
- Nov 2011: JEM-EUSO has been included in the updated version of the ASPERA ApP Roadmap.

JEM-EUSO Collaboration

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Involvement & Role of Spain in JEM-EUSO

"Construyendo la Ciencia del siglo XXI. Estrategia española para la participación en infraestructuras científicas y organismos internacionales". MICINN, 2010.

Mision	Tipo	Intensidad	Organismos Líderes
IMAX	CoIP	Muy Alta	INTA, IAC, IAA, UV, NASA, DLR
AMS_ISS	CoIP	Alta	NASA, Ciemat, IAC
Rover Environmental Monitoring Station (REMS)	IP	Alta	NASA, CAB, UPC, INM (Sevilla)
WSO-UV	IP	Alta	Rusia, UCM
Phobos_METNET	IP	Alta	Rusia, INTA, UCM, UC3M, UPC, IAA
JEM-EUSO	IP	Alta	JAXA, UAH, INTA, UC3M

The involvement of Spain in JEM-EUSO is at the level of PI of one of the instruments of the mission: the infrared camera and the intensity is high due to the involvement of research groups from Univ. OPI & Space companies.

Since 2011 Spain is involved in the Executive Committee of JEM-EUSO (M. D. Rodriguez Frias).

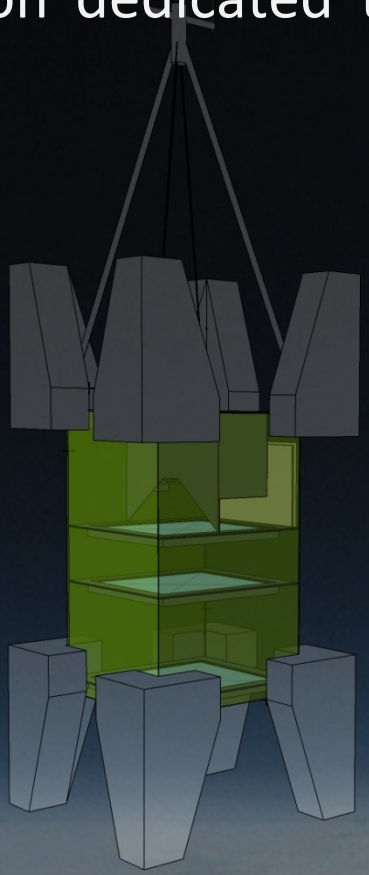
JEM-EUSO_SPAIN Consortium @ Present

- Spanish contribution since 2007 (MOU: UAH-RIKEN).
- JEM-EUSO funded in Spain (2009-2013) from
- MICINN+CAM+MULTIDARK+UAH: O(2) M€ for the Feasibility Study delivered to Japan in Dec 2009 & Phase A delivered to Japan in Aug 2010. Phase B1 & SRR delivered to Japan by Dec 2011.
- Spain is involved in the Executive Committee of the Space Mission since Oct2011.
- Since a coordinated MICINN project for Phase B2 (BBM & PDR) to be delivered to Japan by Dec 2012.

- 5 research centers: UAH, INTA, UC3M, IAC & USC.
- 4 Space companies: SENER, LIDAX, SENSIA & ORBITAL-AEROSPACE.

EUSO-BALLOON pathfinder @ JEM-EUSO

A pathfinder mission for the JEM-EUSO Extreme Universe Space Observatory on-board the Japanese Experiment Module mission, and any future mission dedicated to observing Ultra-High Energy Cosmic-Rays from space



- ✓ Spain is involved in the JEM-EUSO Space Mission since 2007:

  5 research groups + 4 space companies + O(2) M€ (2009-2013).

  Since 2012 we are funded as a coordinated MICINN project:

  UAH+IAC+UC3M+INTA. USC joined June 2012.

- ✓ The Spanish contribution is at the highest level of involvement: Role as IP of one of the instrument of the Mission (IR camera payload). Spain is in charge of the full design, prototype, construction & AIV of the IR camera. The IR camera is a high complexity and challenging camera with very high space & temporal resolution and with a wide 48º FoV in the track of the ISS. This will be the first mid-infrared camera fully designed and constructed in Spain under space qualifications.Phase B2 of the JEM-EUSO IR Camera ongoing…
- ✓ Phase B of the EUSO-BALLOON IR Camera ongoing… MULTIDARK+UAH +ORBITAL-AEROSPACE has funded up to the BBM, Phase B, to be accomplised by Dec 18, 2012. This pathfinder will be stopped in Phase B: no funds to continue so far.
- ✓ Since 2011 Spain is member of the Executive Committee of the Mission.
- ✓ Spain is deeply involved in the UHECR Science & software of the Mission as well: ESAF simulation code + cloudy conditions & IR camera E2E simulation.

Conclusions

- Spain is involved in the best experiments of cosmic rays:
  - **AMS**: low energy cosmic rays (apart from antimatter).
    New exciting results are foreseen in a near future.
  - **Auger**: the highest energies (particle physics, astrophysics).
    Many challenging proposals to solve the current limitations.
  - **JEM-EUSO**: a possible way to enlarge statistics at the highest energies.