APPEC – Town Meeting

Roadmap ("Considerations") Discussion

(High-Energy) Cosmic Rays

Paris, 6-7 April 2016

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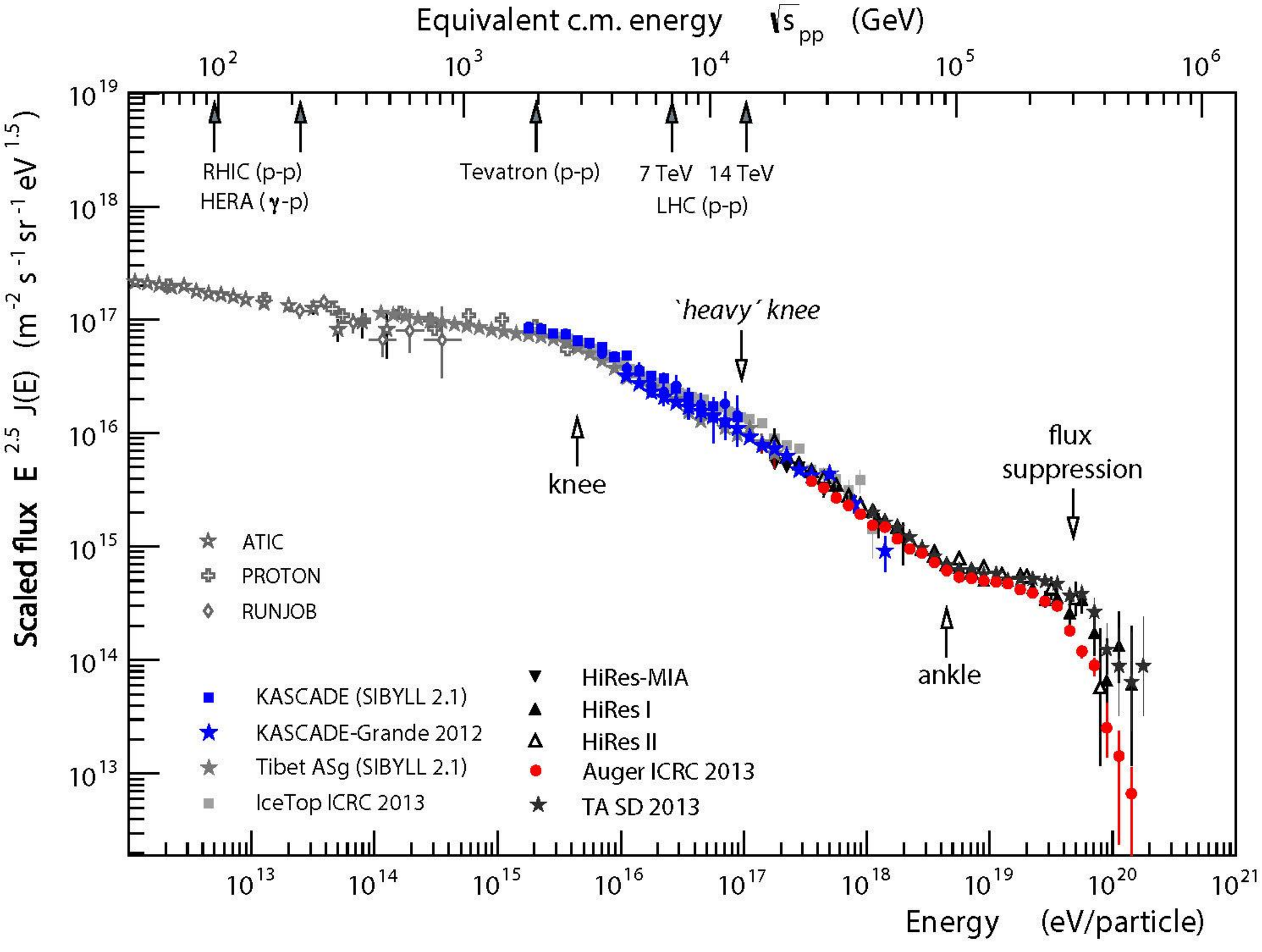
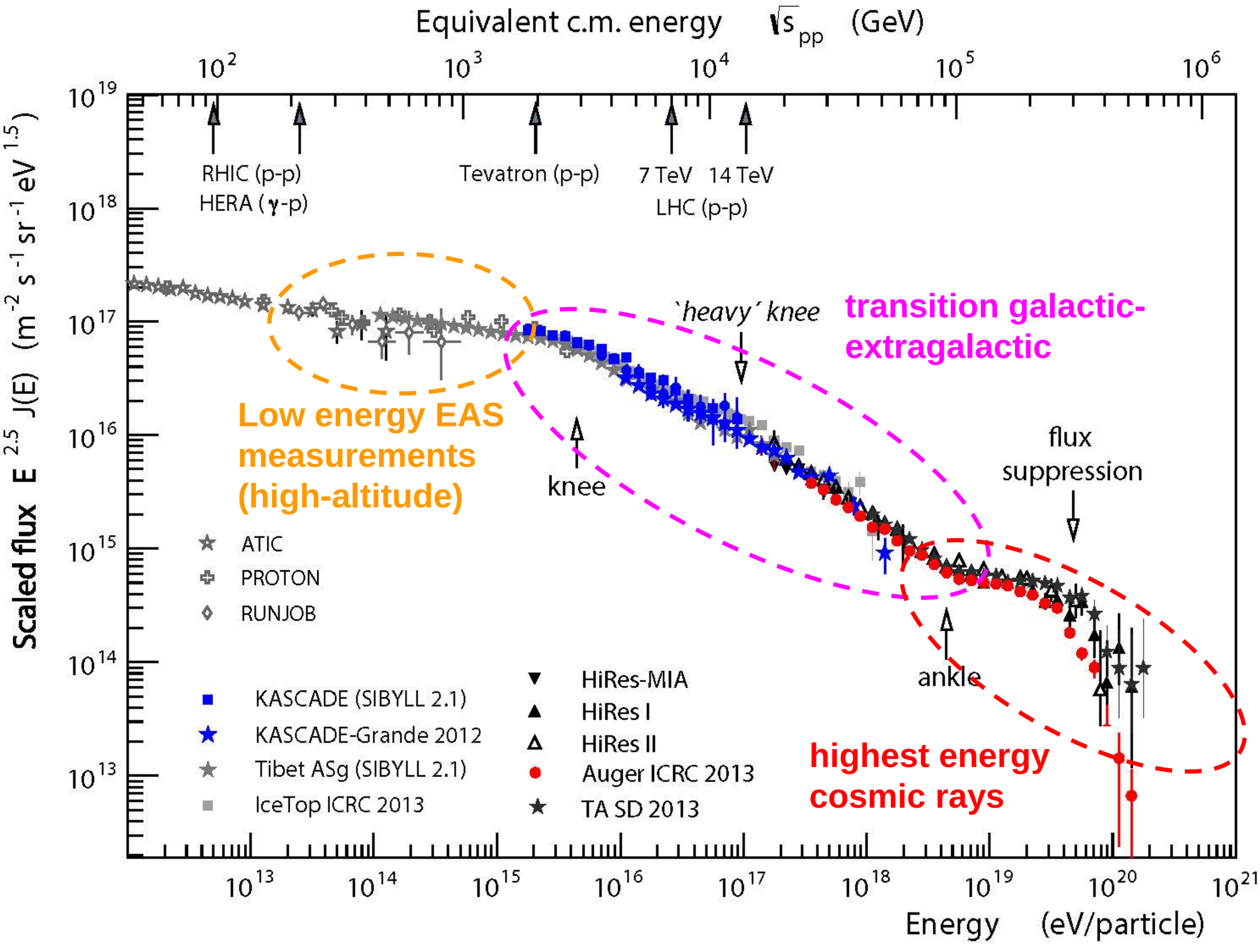
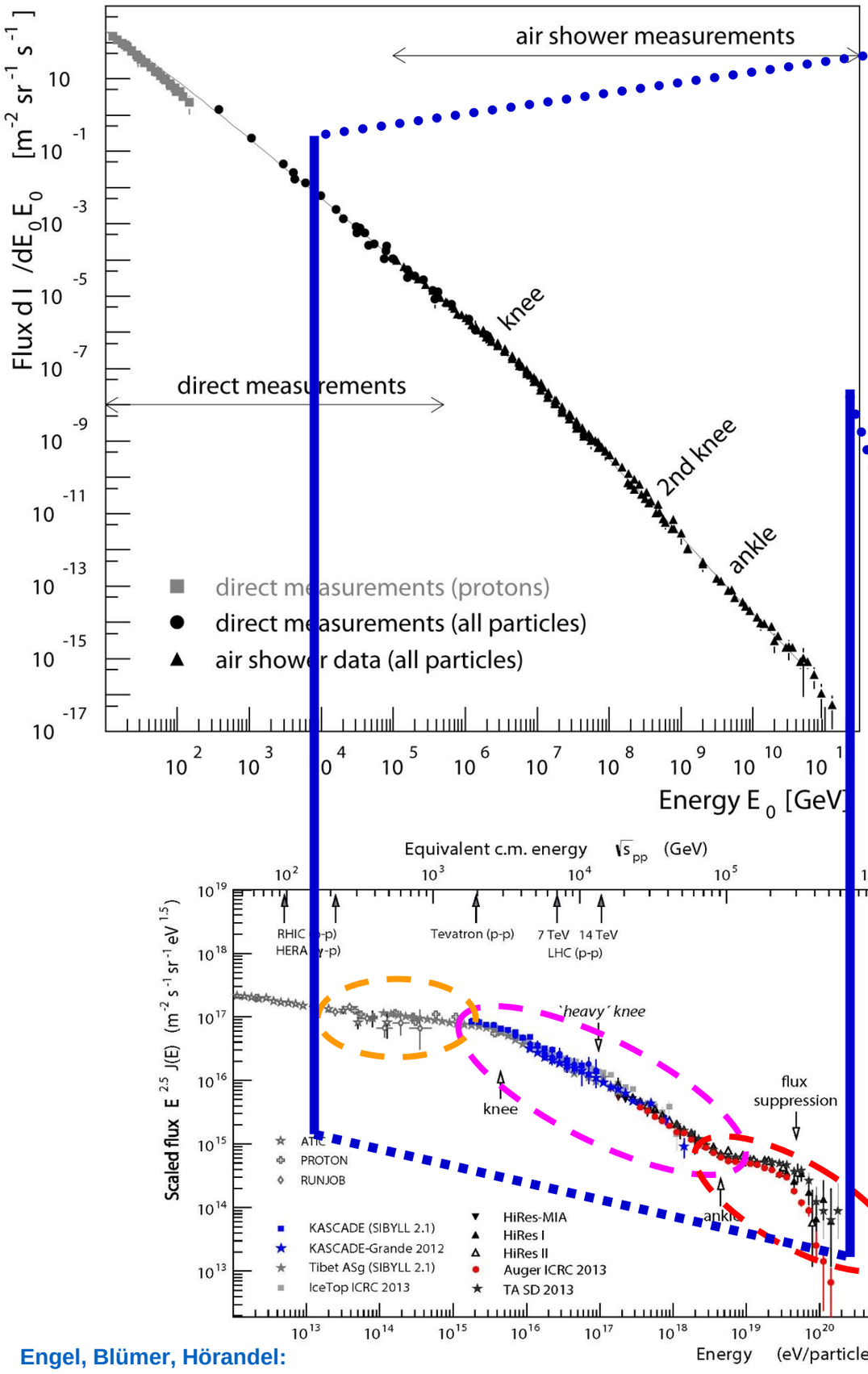
Energy spectrum



Energy spectrum



Questions / Challenges of the experiments



Engel, Blümer, Hörandel:
Progress in Particle and Nuclear Physics 63 (2009) 293

Spectral indices?

Antimatter?

Composition / Isotopes?

Overlap direct-indirect measurements?

Hadronic interaction models?

Fine-structures in spectrum?

End of Galactic Spectrum?

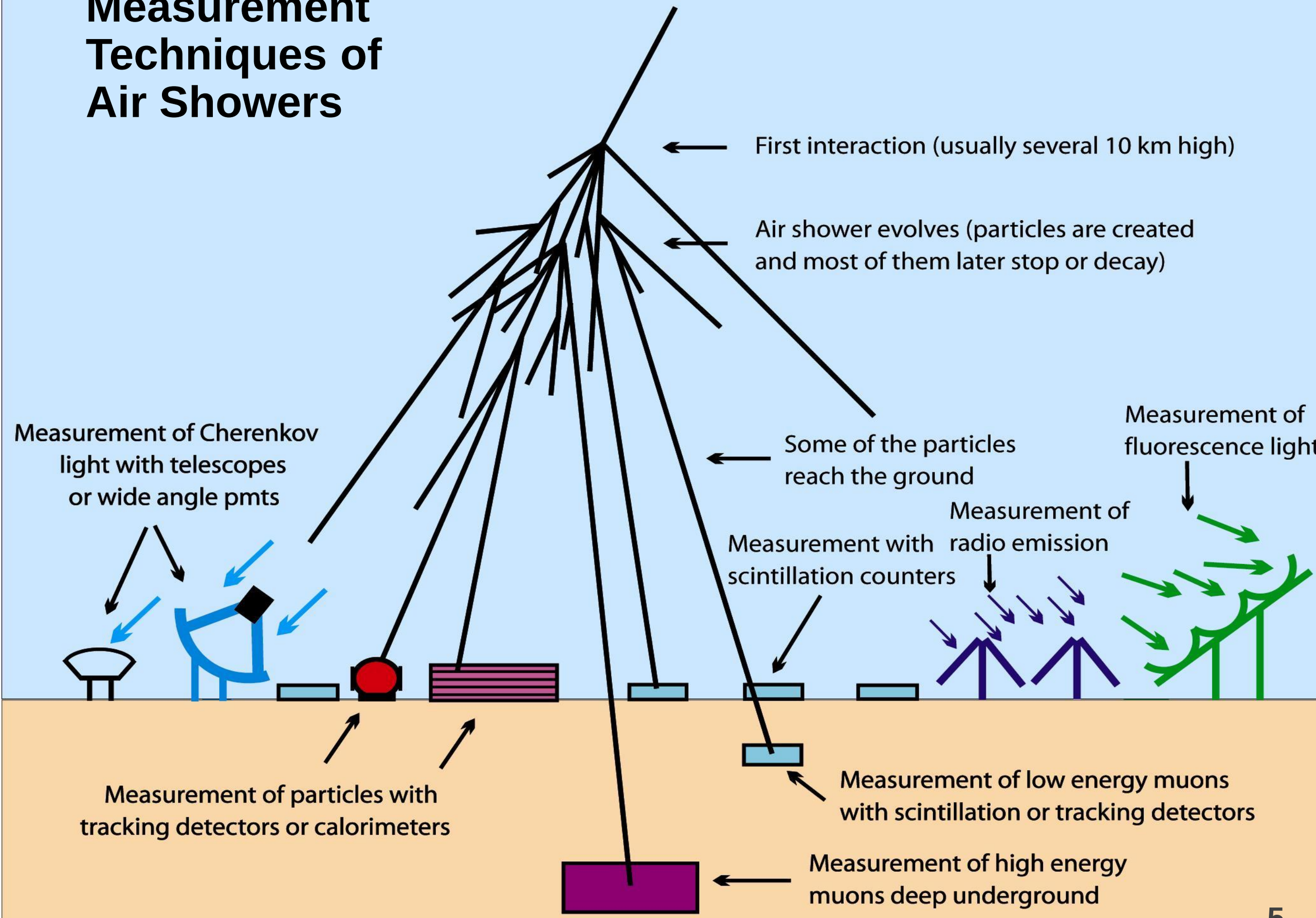
Composition?

GZK / maximum acceleration?

Anisotropy?

…and many more!

Measurement Techniques of Air Showers



Pierre Auger Observatory

Pierre Auger Observatory: Results

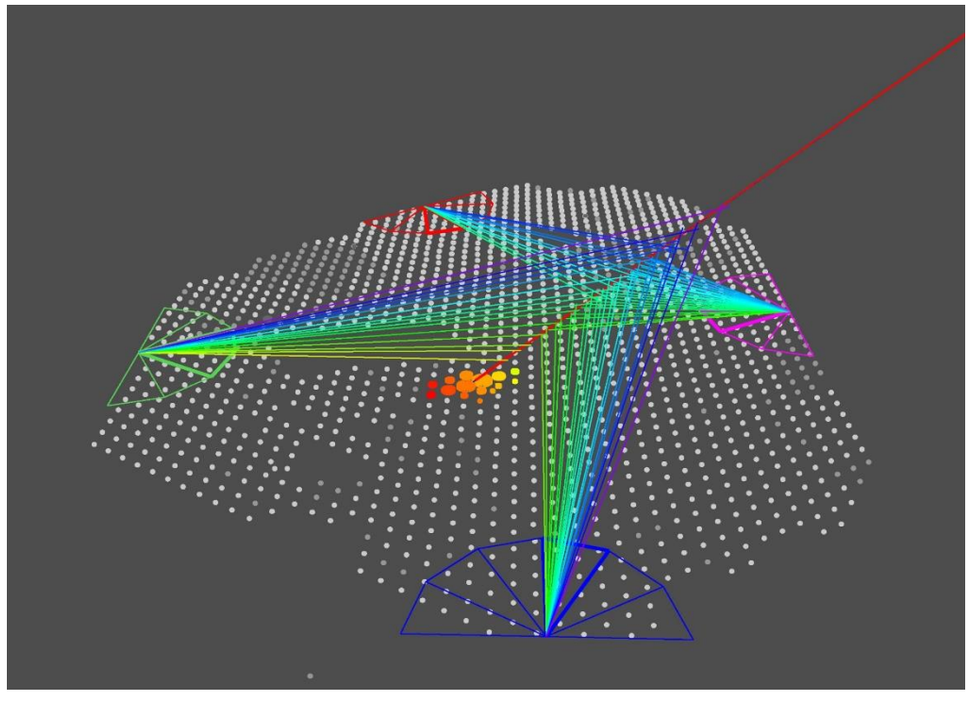
one decade ago:

→ not known whether flux suppression exists
→ composition expected to be protons
→ no anisotropies observed

~450 collaborators; 92 institutions, 17 countries

today:

→ flux suppression (50 EeV) beyond any doubt
→ anisotropies (large scale) seen
→ evidence to become heavier
→ cosmogenic γ and ν are constrained
→ particle physics performed σ(pp)@57TeV cms
→ atmospheric effects, LIV studies, ….
→ ….

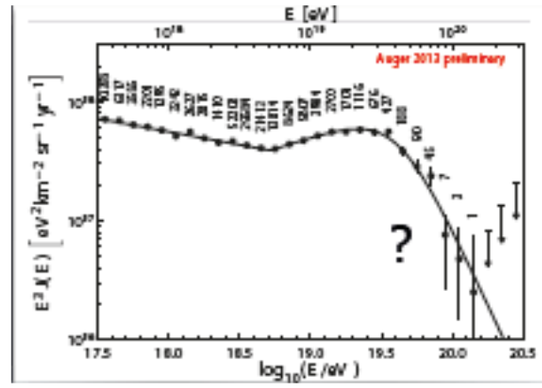


➔ but, flux suppression mechanism unclear
➔ but, no sources of UHECR identified - yet

Auger-upgrade (AugerPrime) Science Goals

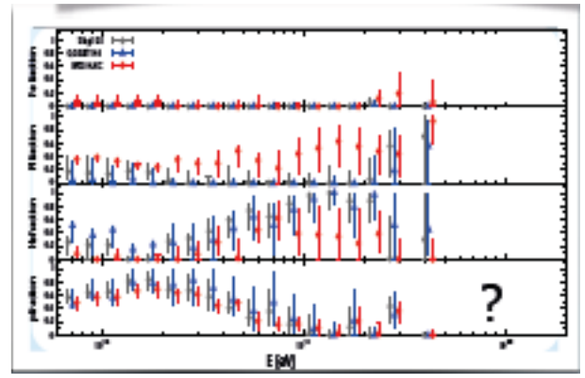
1. Elucidate the origin of the flux suppression, i.e. GZK vs. maximum energy scenario

→ fundamental constraints on UHECR sources
→ galactic vs extragalactic origin
→ reliable predictions of GZK ν- and γ-fluxes



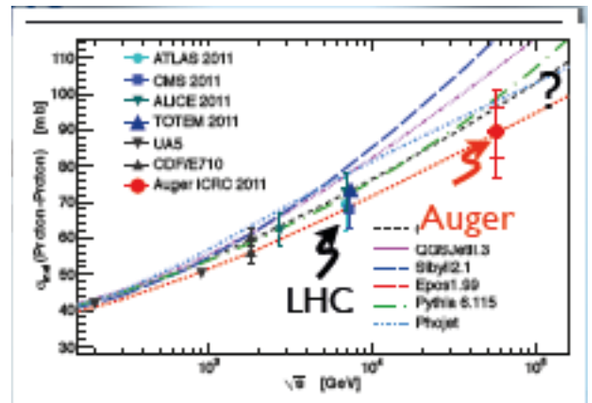
2. Search for a flux contribution of protons up to the highest energies at a level of ~ 10%

→ proton astronomy up to highest energies
→ prospects of future UHECR experiments



3. Study of extensive air showers and hadronic multi-particle production above $\sqrt{s}$=70 TeV

→ particle physics beyond man-made accelerators
→ derivation of constraints on new physics phenomena



Pierre Auger Observatory is in place to address all these questions now

Auger upgrade (AugerPrime)

The Pierre Auger Observatory Upgrade

Preliminary Design Report

April 10, 2015

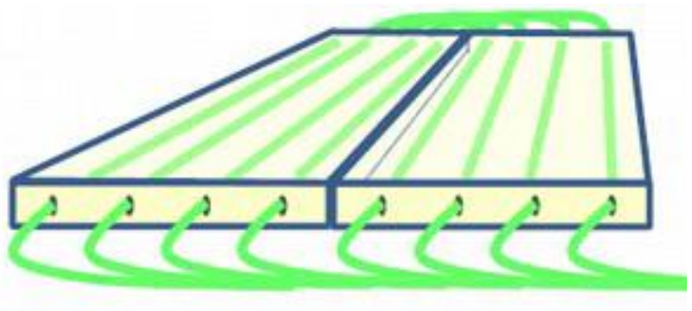
Organization: Pierre Auger Collaboration
Observatorio Pierre Auger,
Av. San Martín Norte 304,
5613 Malargüe, Argentina

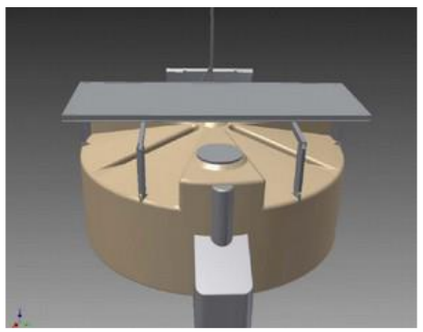
PIERRE AUGER

194 pages

Status:

- positively evaluated by International Advisory Committee
- endorsed by International Finance Board
- R&D well advanced, prototypes running
- 11/2015: International Agreement
- signed for operation into 2025
- engineering array 08/2016
- construction 01/2017 - 2018
- data taking into 2025
- costs: 12.5 M€
- funding: ~50% already committed





Telescope Array

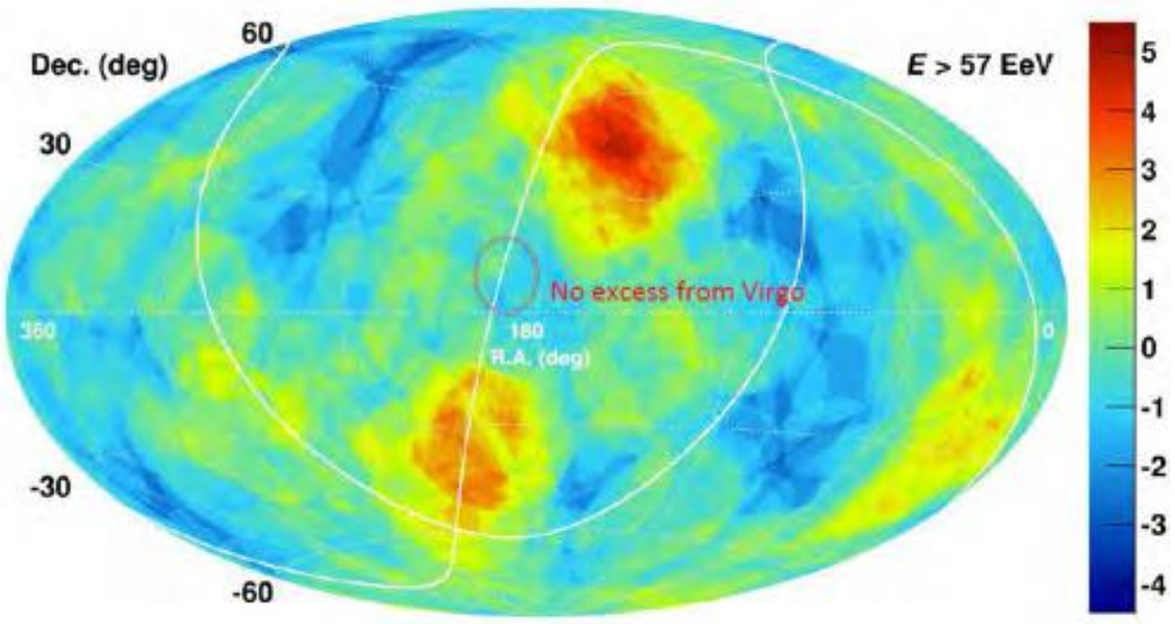
Telescope Array

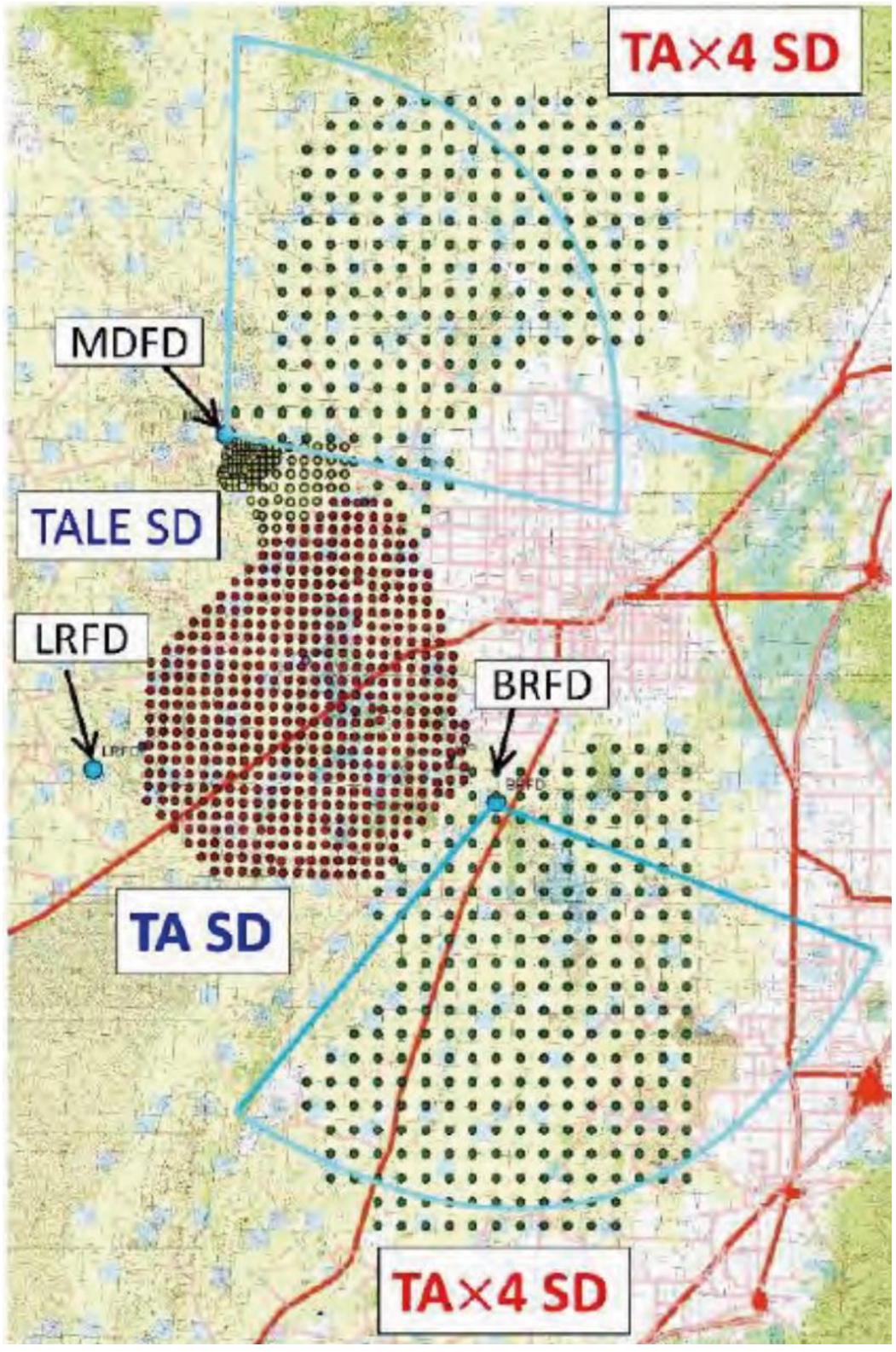
TAx4:

- **SD: 700 ➔ 2800 km²**
- **Hybrid: x3 acceptance**
- **Optimized for above ~50 EeV**

Goal:

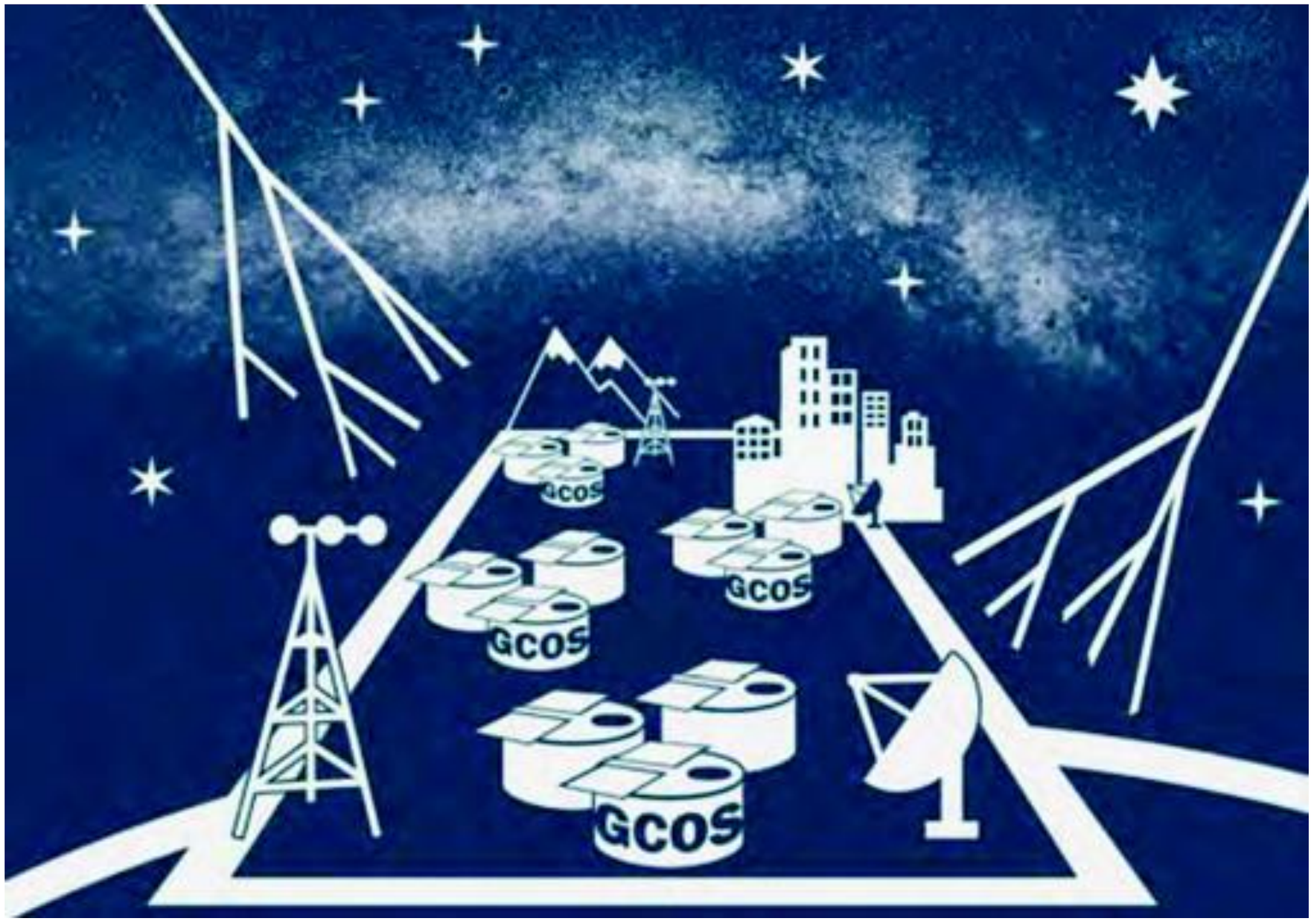
Get 20 TA-years by 2019
to look for structure within hotspot!





3.7 M$US approved by Japan for 500 SD
funding fro FD is seeked fo in the US
minor European contribution

GCOS = Global COSmic ray observatory



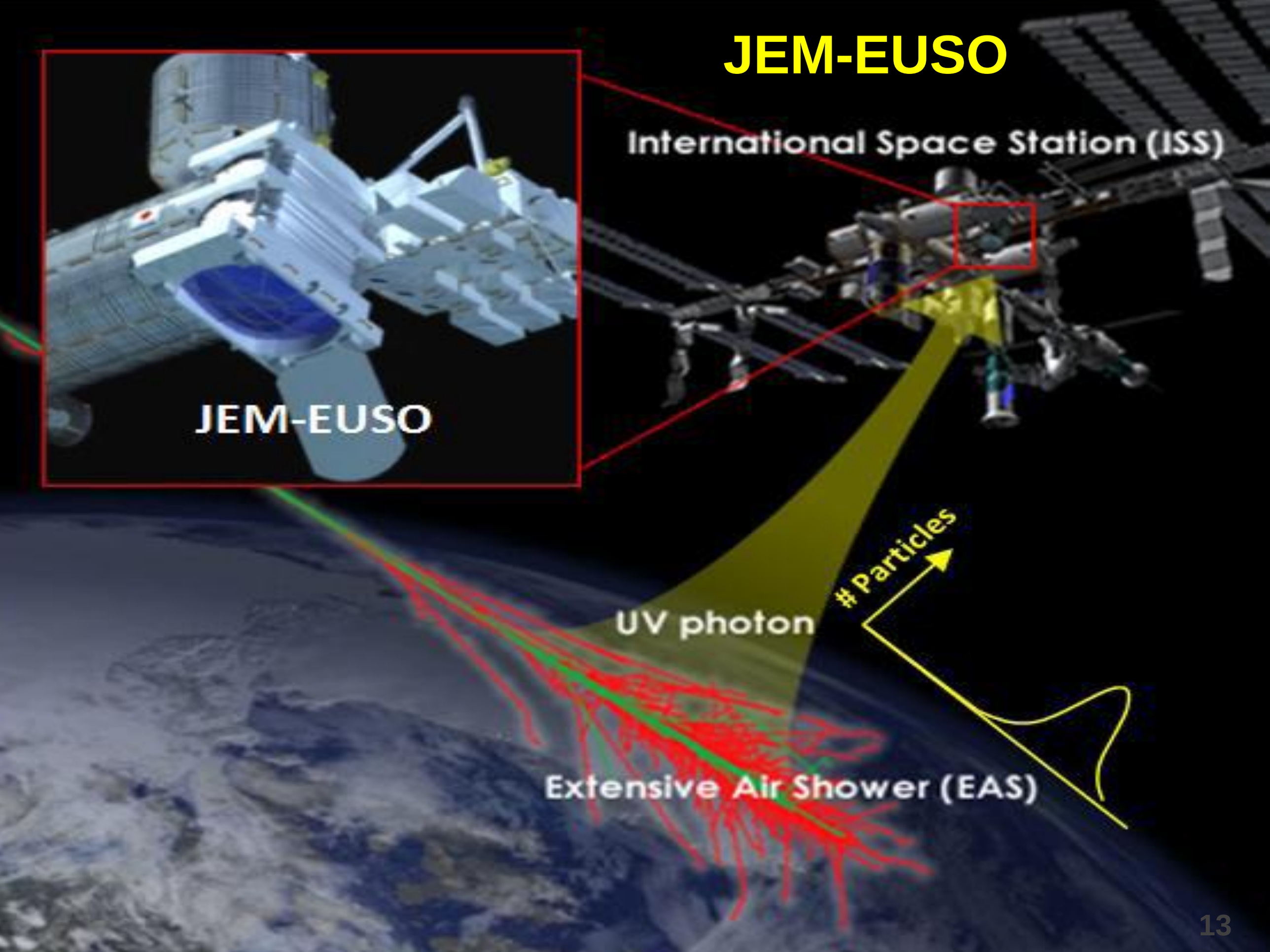
Helmholtz (D) large infrastructure Roadmap

p-astronomy with sources

- Global, few sites, N+S
- ca. 90,000 km^2 (x30 Auger)
- Optimal detector for composition-sensitivity

- Design in 2020-25
- Operation 2025-2050
- Cost 390 M€ (120 M€ European contr.)
- Operation cost 6 M€/y

JEM-EUSO


JEM-EUSO
International Space Station (ISS)
JEM-EUSO
UV photon
Particles
Extensive Air Shower (EAS)

Air Shower Observations from Space

2014 — 2017 — 2020 — 2023

TA-EUSO
Continuous operation

EUSO-Balloon
1st flight 2014

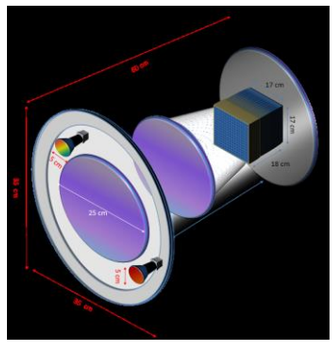
EUSO-SPB
Preparation in work
(including small SiPM-camera)
Launch spring 2017

JEM-EUSO

?

X-EUSO-X

Announcement of Opportunity from NASA in 2016 for ISS 2021-24?



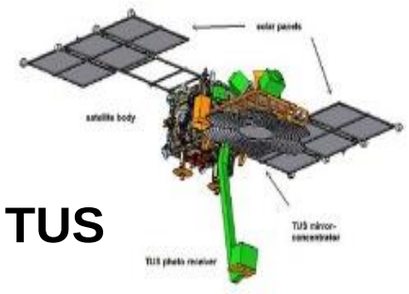
Mini-EUSO on ISS
(approved for 2018)

Baseline design change to SiPM-PDM?

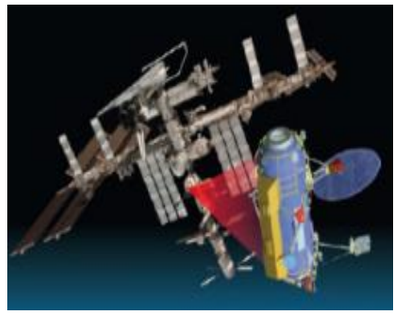
M5 mission
Free flyer?

Proposal 201?

Russian line



TUS



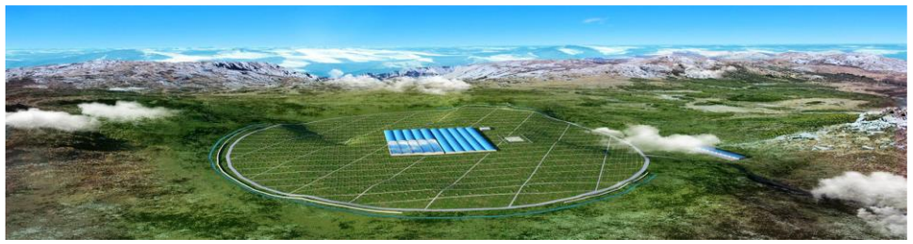
K-EUSO

JEM-EUSO collaboration — 358 authors; 95 institutions; 16 countries

Further experiments with possible strategic relevance

- **LHAASO**

  CR around knee with multi-detector installation
  China - with participation of France, Italy



- **TAIGA/ Tunka/HiSCORE/Tunka-Taiga-Rex**

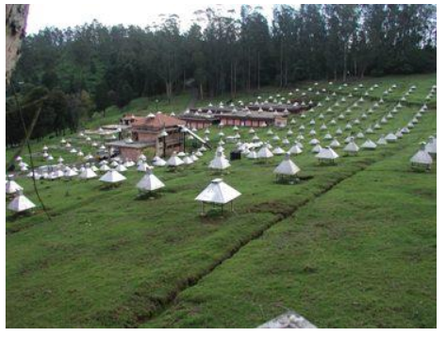
  CR around knee and up to ankle with multi-detector installation
  Russia - with participation of Germany, more?

- **IceCube/IceTop – (Gen2)**

  Ice-Cherenkov array on top of IceCube
  USA – with important European contribution
  Advanced plans for Gen2-surface (veto) array

- **GRAPES**

  KASCADE-like operating array at 2300m altitude
  India - with participation from Japan



- **KCDC**

  KASCADE Cosmic ray Data Centre for public use
  Extension to other experiments foreseen (Auger?)

LHAASO

Tunka / Tunka-Rex / HiScore

IceCube / IceTop (-Gen2)

GRAPES

https://kcdc.ikp.kit.edu

AMS

SWOT: AugerPrime

Strength

- environmental infrastructure exist
- clear science task
- part of multi-messenger program
- cost efficient
- collaboration (funding agencies) exist
- working groups with TA exist

Weakness

- small statistics at highest energies

Opportunities

- European leadership
- definition of science questions for GCOS
- R&D for next generation experiment

Threats

- uncertainty due to hadronic interaction models

SWOT: all CR

Strength

- global program for all energies
- ready for multi-messenger
- Global use of new large infrastructures
- complementary with LHC
- close community (for air-shower observations)

Weakness

- mostly non-European dominated
- small visibility

Opportunities

- cost effective European contribution
- Participation / driving hardware R&D
- ready / preparing public data dissemination

Threats

- excluded from R&D
- missing visible European participation

APPEC Roadmap for high-energy cosmic-rays

Pierre Auger Observatory is key experiment

➔Full support of Upgrade Strategy (AugerPrime)

→ cost estimation is rational

→ R&D for GCOS

JEM-EUSO like detector: situation unclear, test experiments running!

➔ Support of further design and R&D studies

→ if, than funding by space agencies (?)

Other experiments with small European contribution

➔Mentioning and support of continuation of R&D

➔Support usage of Infrastructures

Low energy (space/balloon) cosmic ray investigation?

→ AMS analysis / ISS-CREAM? Funding by space agencies?

Data dissemination (open access to scientific data)

➔Need more room and efforts in next decade

→ common funding?