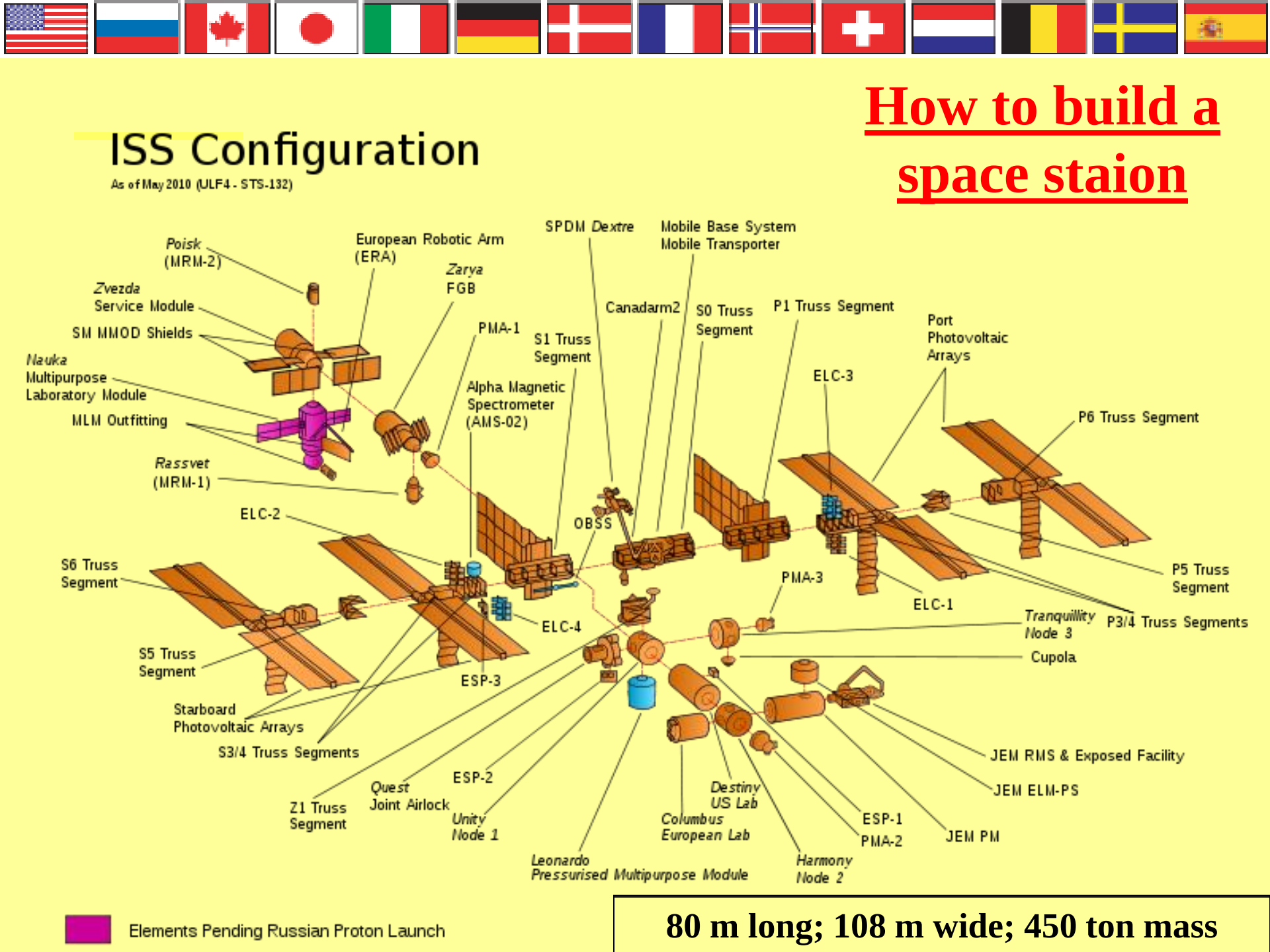
The International Space Station

Christer Fuglesang, KTH & ESA

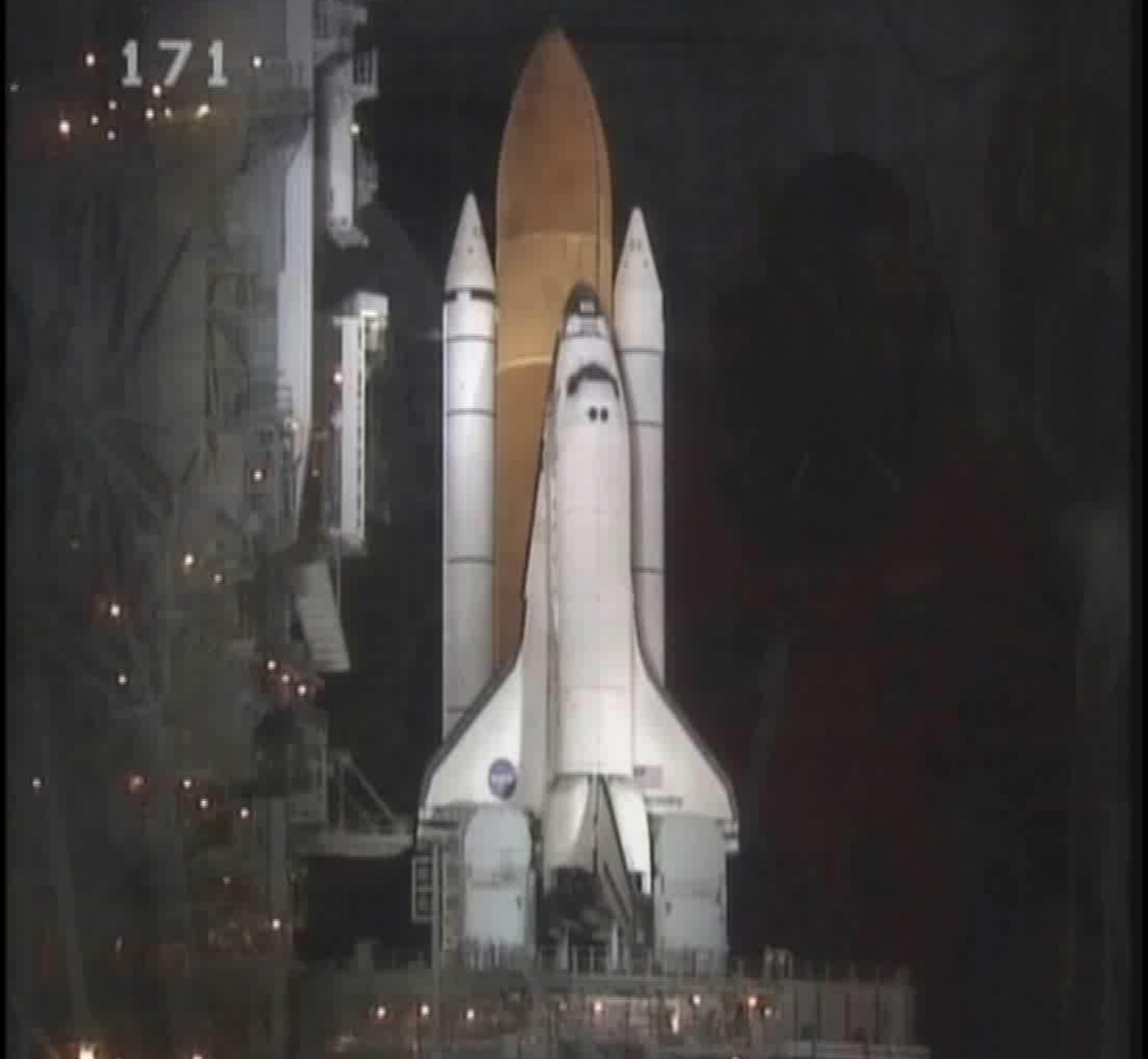
2015: The Spacetime Odyssey Continues

Stockholm 3-6-2015

How to build a space staion



80 m long; 108 m wide; 450 ton mass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”Travel picture of the year 2006”

Ready to go again: STS-128 crew heading to the launch pad 28/8 2009

ISS - the International Space Station

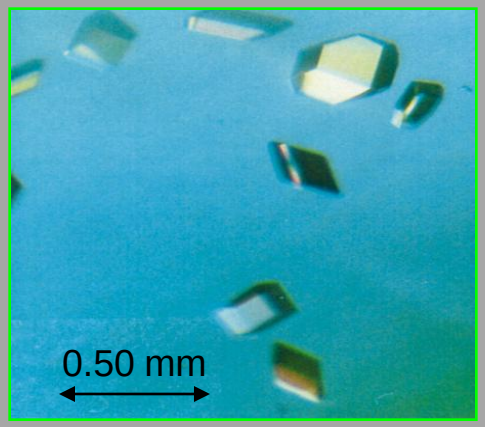
Orbit: 350-400 km altitude / 51.6º inclination

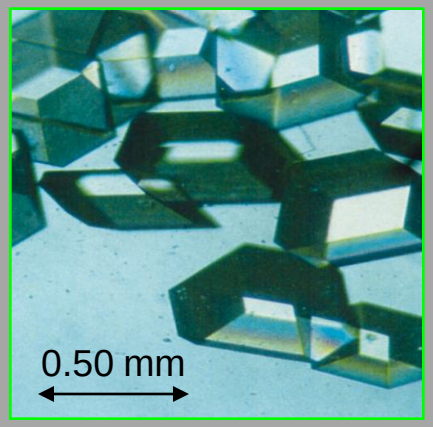
Power: 80 kW
Normal atmosphere
Crew: 6

First part launched 1998

Permanently manned since November 2000

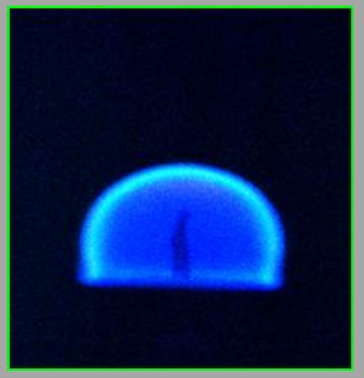
The International Space Station is a fantastic, unique lab, with views up to space, down on Earth and WEIGHTLESSNESS





On Earth

In µG



Weightlessness (0G) is used for inumerable experiments in physics, medicine, biology, technology...

Weigtlessness (μG): Get rid of gravity-driven phenomena

Critical phenomena affected by, or dominant in microgravity:

- Surface wetting & interfacial tension
- Multiphase flow & heat transfer
- Multiphase system dynamics
- Solidification
- Fire phenomena & combustion

Underlying processes on Earth emerge:

- Pressure-driven flows
- Capillary flows
- Diffusion
- Viscosity
- Electromagnetic forces
- Vibration

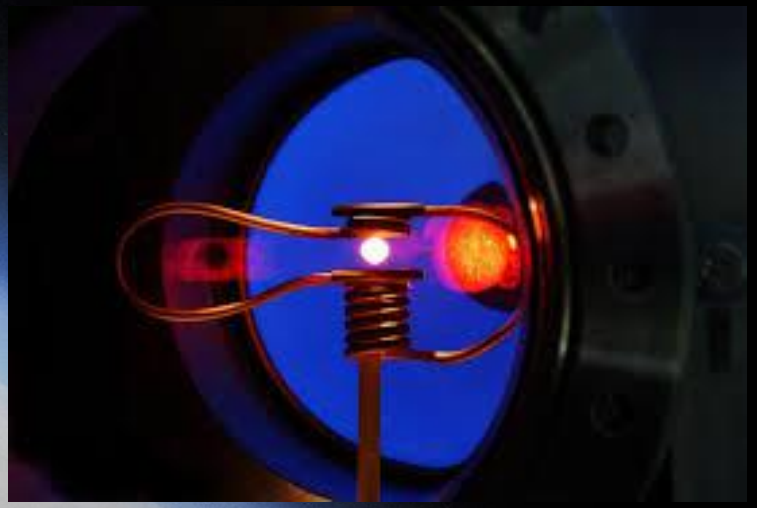
[Stratified flow, 1 g_0]

Multiphase Flow

[Annular flow, microgravity]

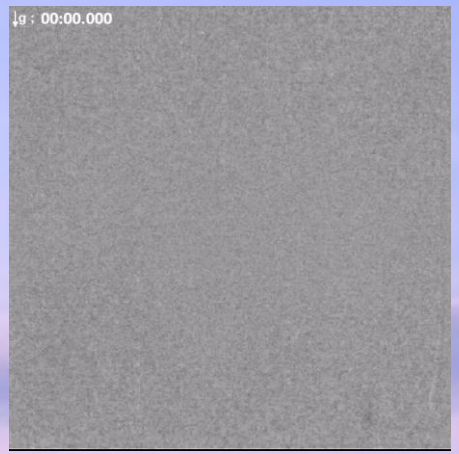
Verify models and calculations

Electro-Magnetic Levitator installed on ISS 21/8/14

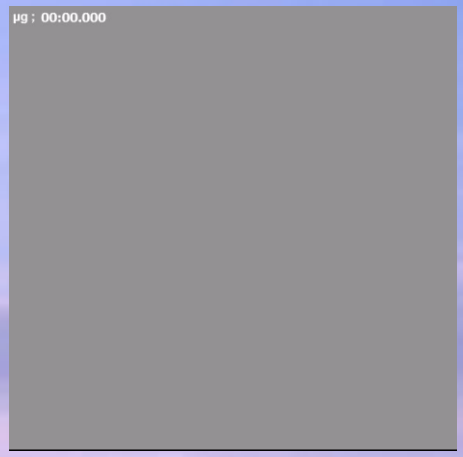


Material Science

In-situ Solidification

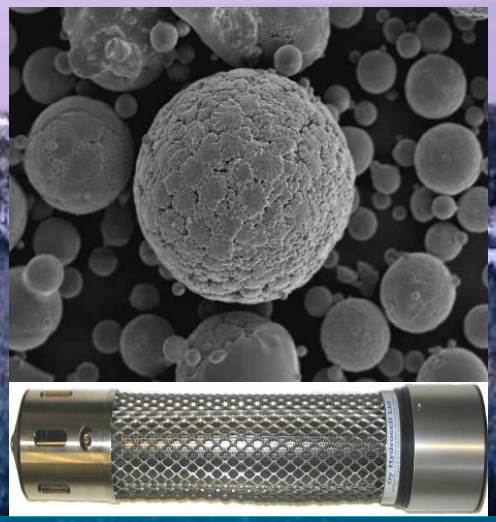


Ground



Space

- New lightweight TiAl turbine blades for jet engines and gas



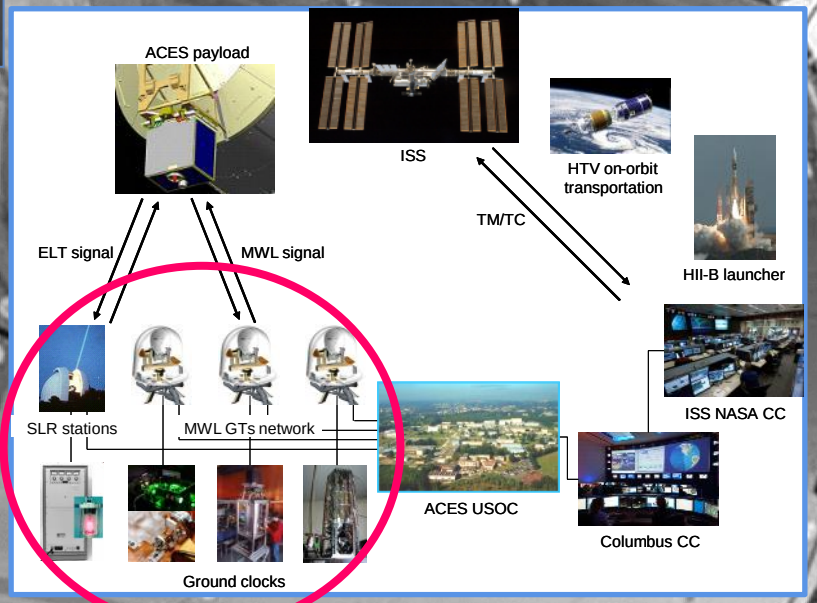
-New NiAl catalytic powders for hydrogen fuel cells and other chemical processes

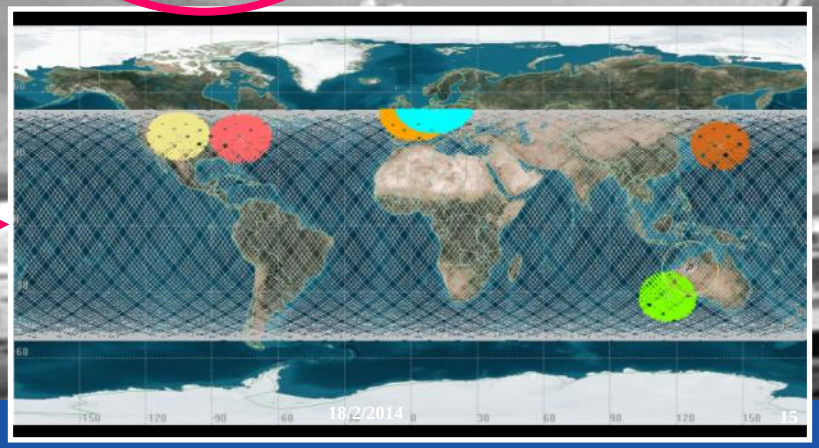
ESRANGE, Kiruna

EXAMPLE FUNDAMENTAL PHYSICS

ACES: The Atomic Clock Ensemble in Space

- Two high-performance atomic clocks for the most precise measurement of time in space. (Stability 10^{-15} - 10^{-16})
- Comparing with high-performance clocks on ground
- Gravitational red-shift
- Potential drift of fundamental physics constant (fine structure constant)
- Search for violation of special relativity





The „Space Optical Clocks“ Project

1) The Earth gravitational potential fluctuations will limit the precision of time on the ground at 10^{-18}-10^{-19} (ie: cm to mm level)
2) The only Solution: set the reference clocks in space where potential fluctuations are vastly reduced
3) Improved Navigation, Earth Monitoring and Geodesy
4) Interesting for fundamental physics Tests

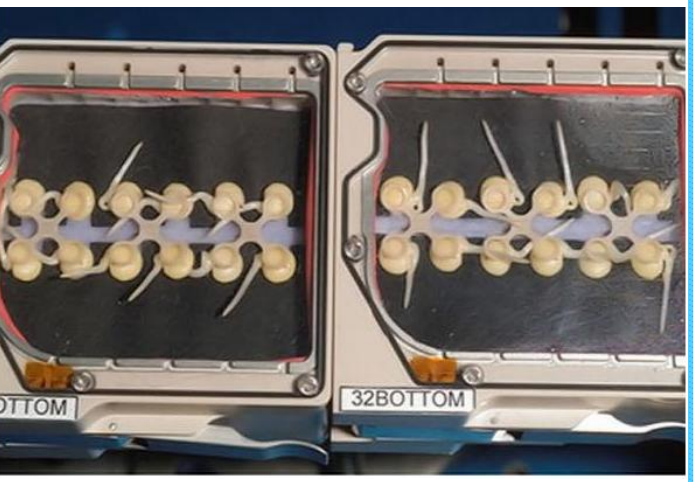
You DO get younger in LEO – or rather you age slower

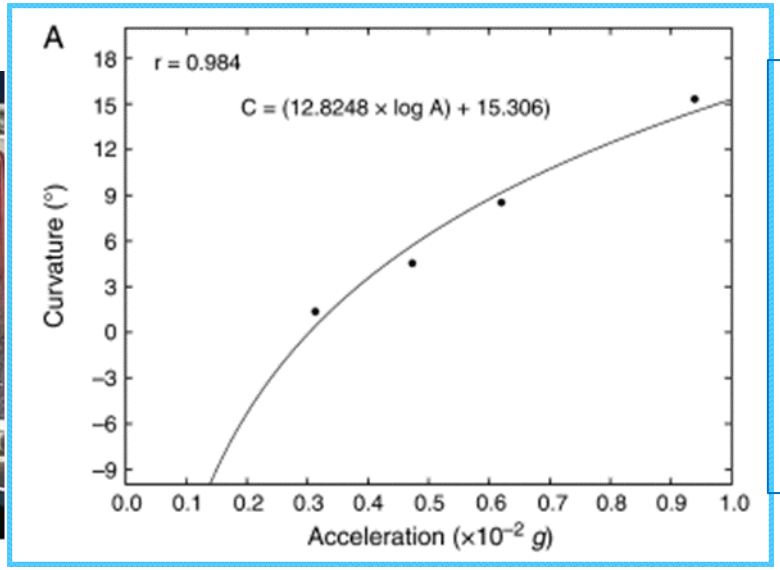
- During my total 26.7 days in LEO I "gained" 0.75 ms from high velocity
- But I "lost" 0.08 ms from the gravitational field being 10% less! ("redshift" effect)

Important effects to correct for in GPS signals – otherwise position error would grow with ≈10 km/day!

Astronaut = guinea pig

EXAMPLES of BIOLOGY EXPERIMENTS





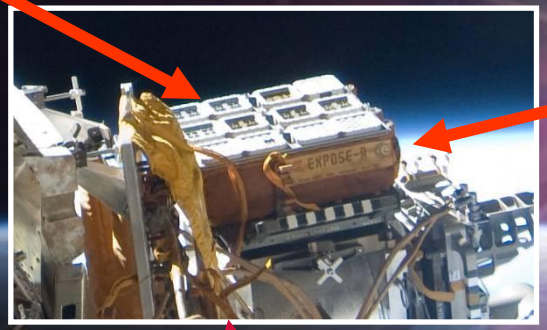
GRAVI-1: Gravity perception thresholds established in Lentil seedlings. “Gravitropism”. The physical processes underlying the detection of the gravity vector by plants

ROALD on ISS in 2008. An enzyme, LOX-5, that regulates life expectancy becomes more active in micro-G.

First crop of lettuce in space. Steve Swanson, June 2014

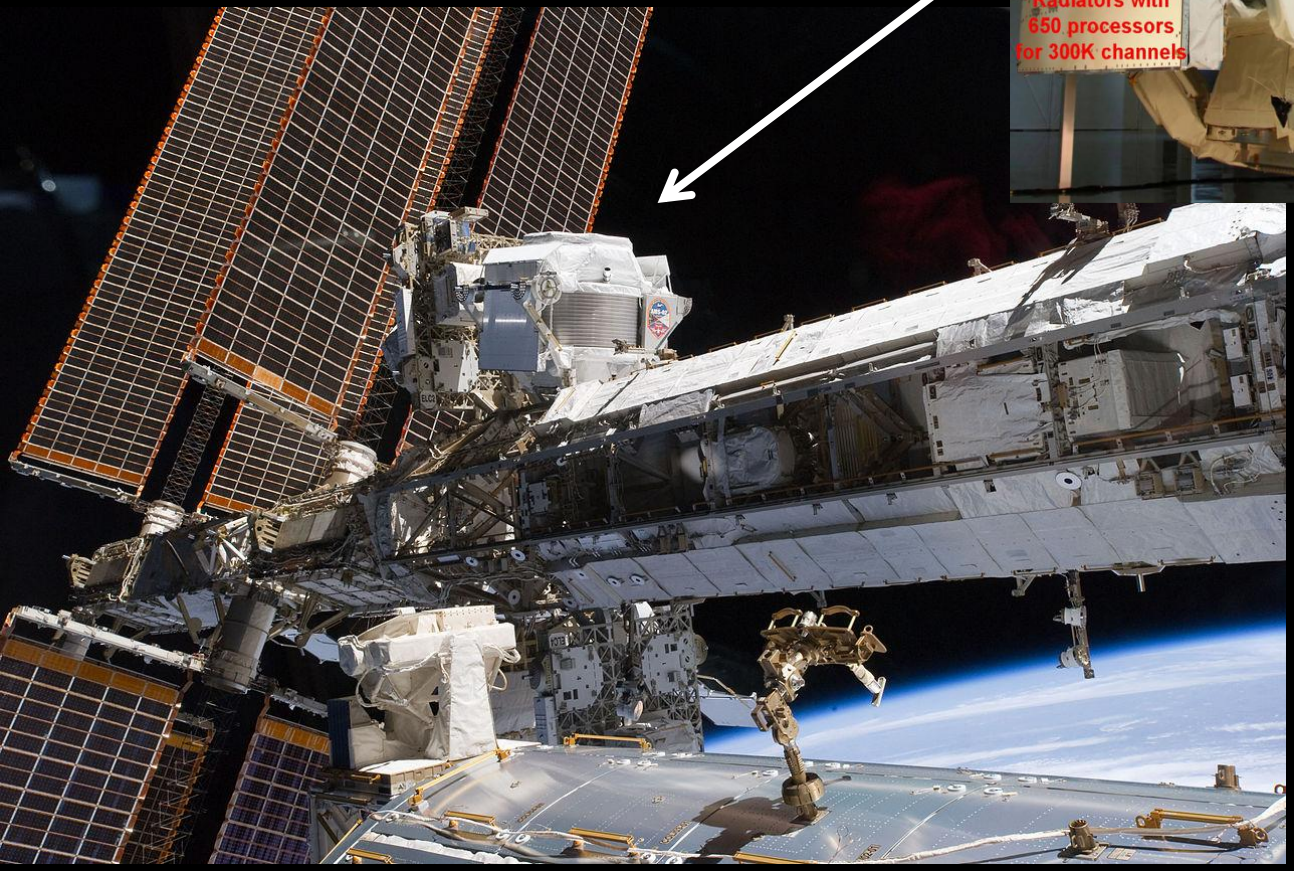
"Space Survivors"

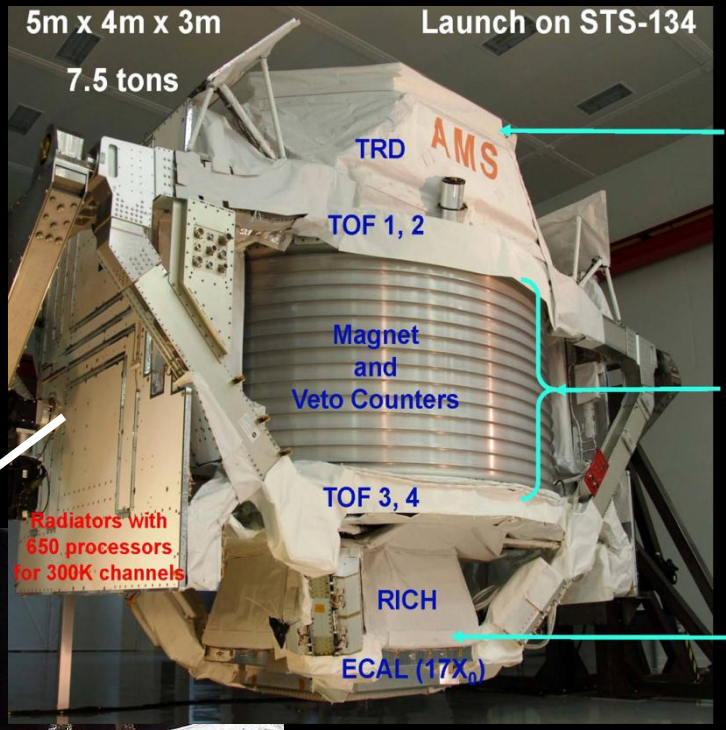
Cyanobacteri
Lichens
Tardigrades
Plant seeds



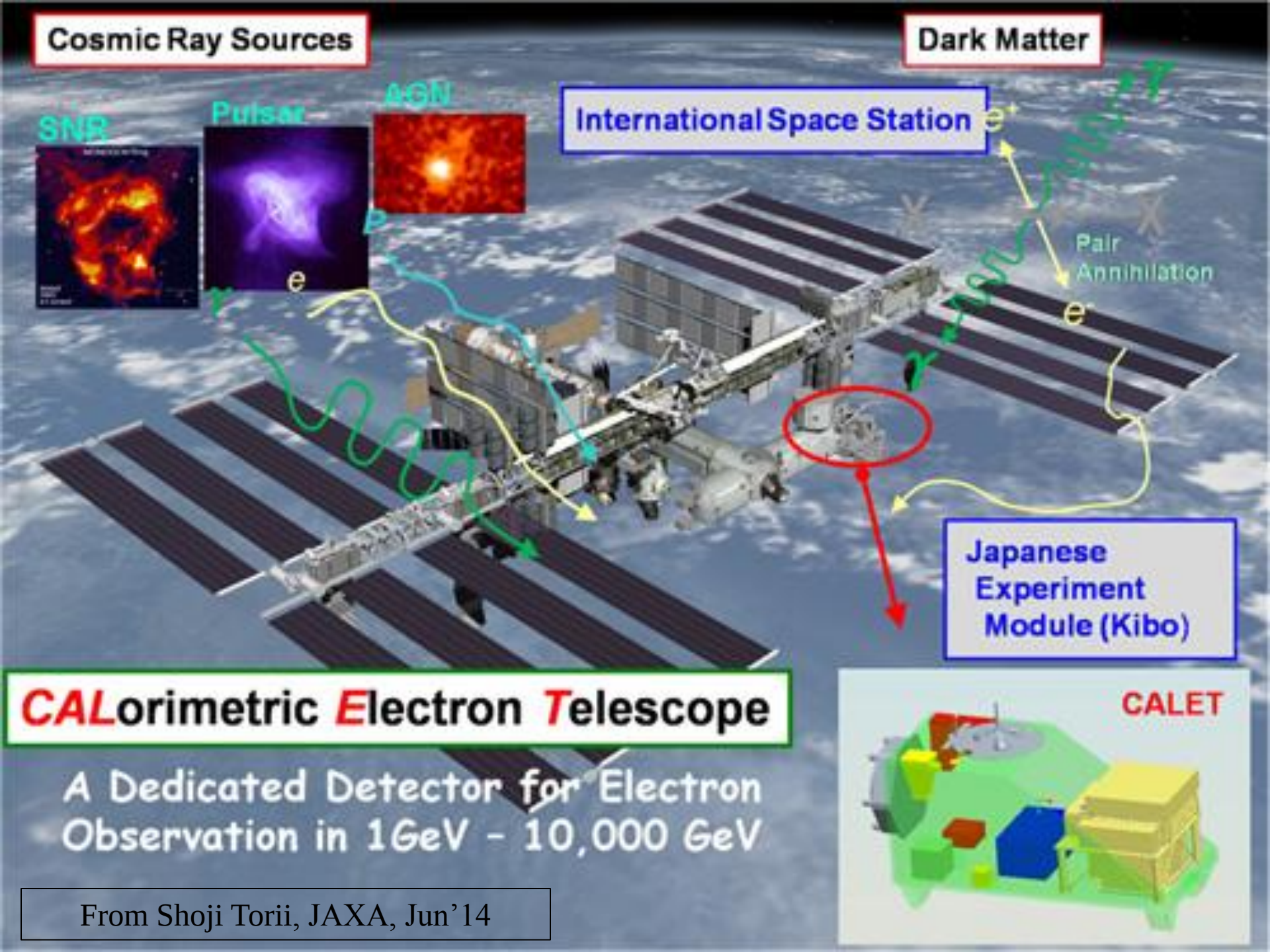
The Alpha Magnetic Spectrometer on ISS

> 60 billion cosmic ray events (e-, e+, p, antiproton, He, Li, B/C ...) up to TeV energies since 2011





Soon to appear on ISS…

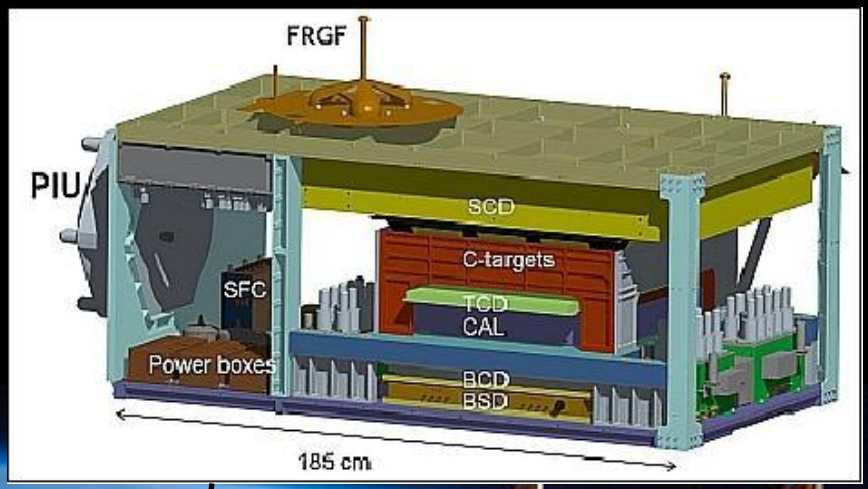


From Shoji Torii, JAXA, Jun'14

ISS-CREAM

Cosmic Ray Energetics And Mass
for the International Space Station

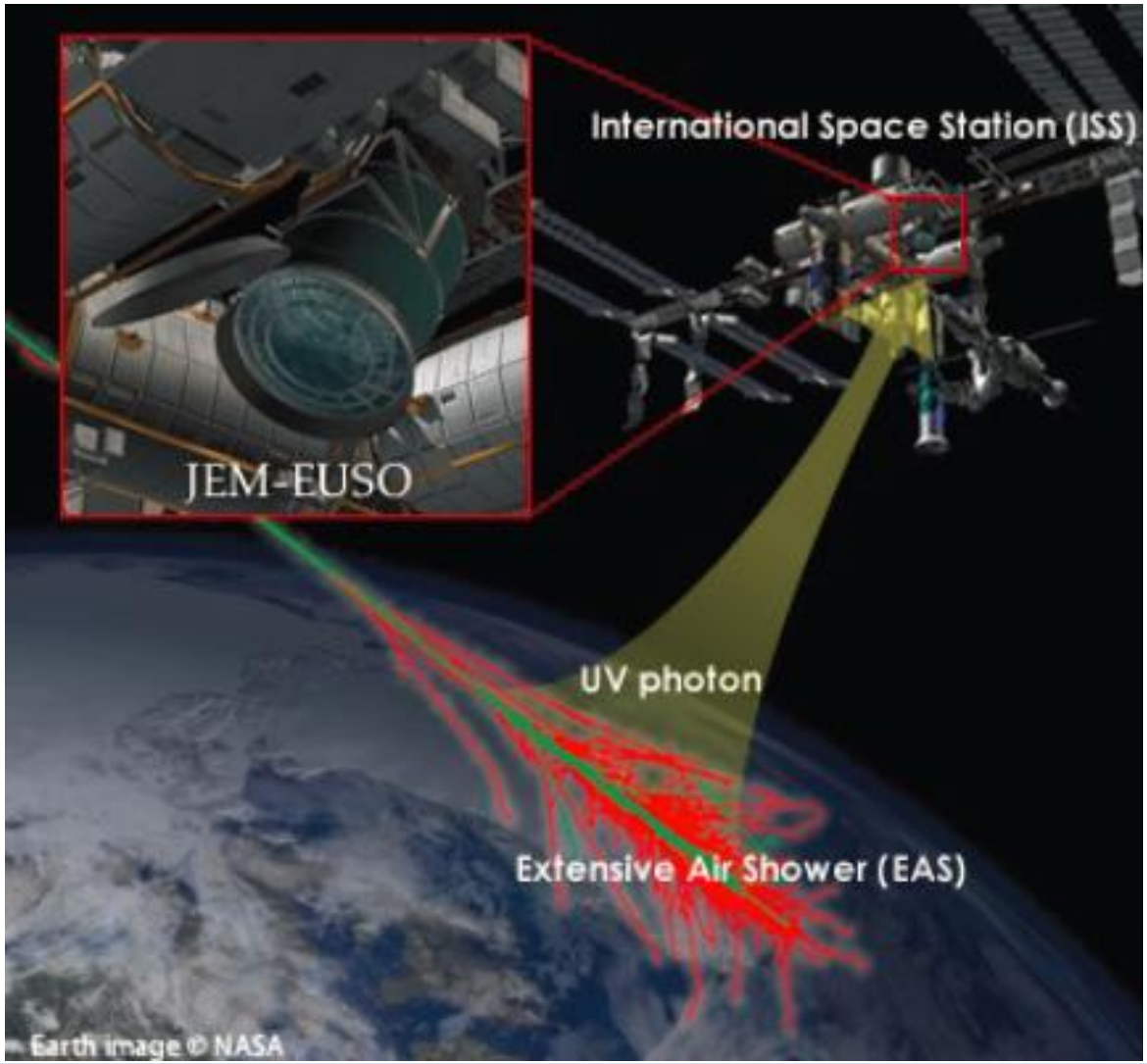
Measure elemental spectra of Z = 1–26 nuclei over the energy range 10^{10} to 10^{15} eV



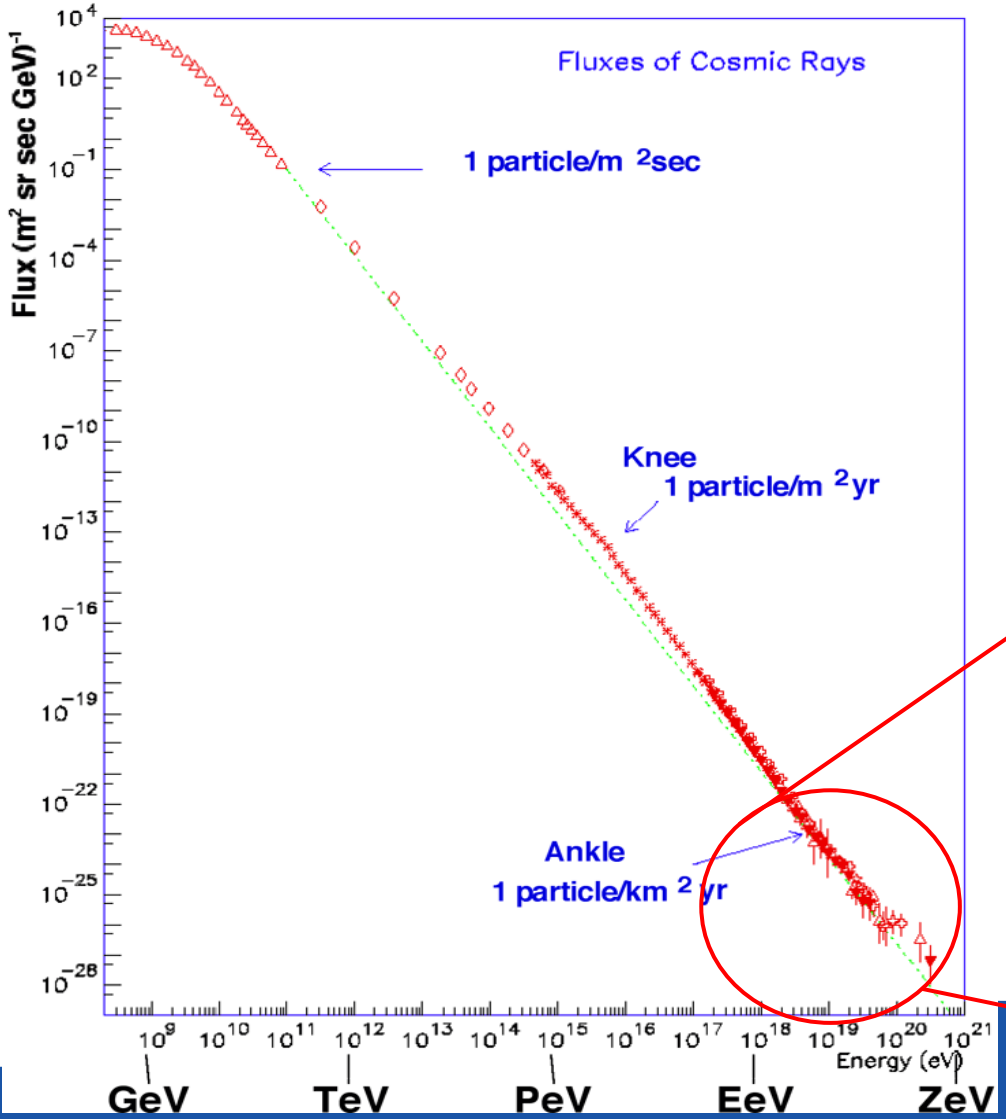
JEM-EF

Extreme Universe Space Observatory

- Ultra-high energy Cosmic Rays E: > 3×10^{19} eV
- Earth atmoshere as detector
- Measure produced UV and Chrenkov light from ISS



UHECR: Ultra-High Energy Cosmic Rays

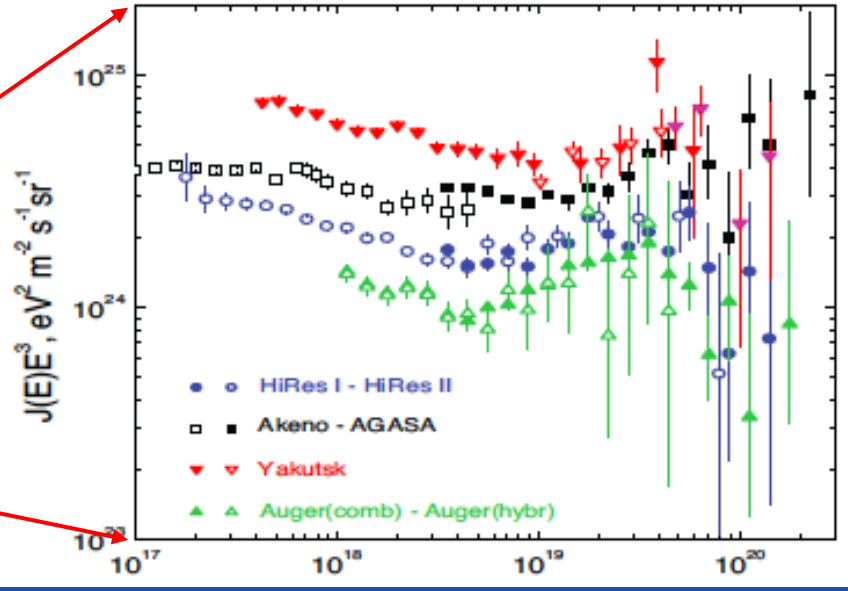


Several joules = macroscopic energy!

Lorentz factor: 10^{11}

$v \approx 0{,}99999999999999999995 \times c$

Existence of UHECRs is very challenging for astrophysics → very interesting and informative!



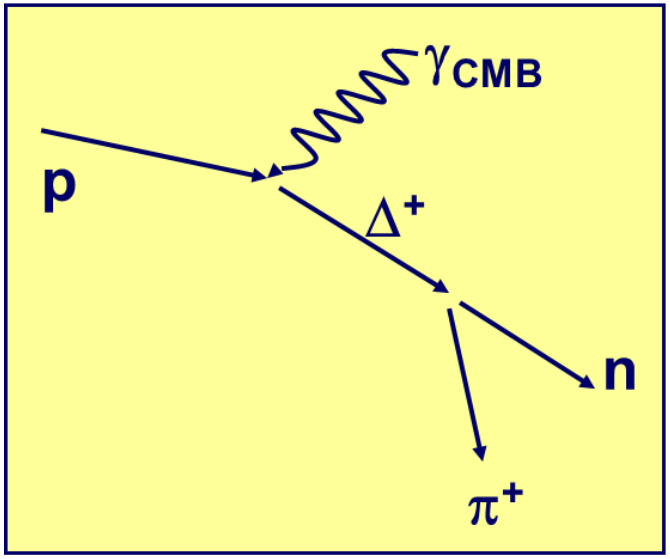
Main physics objectives

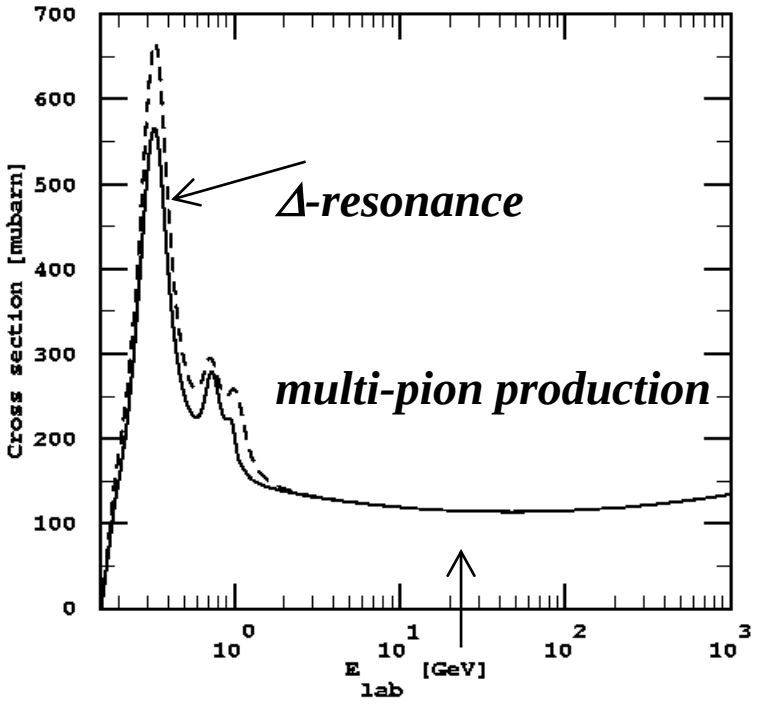
- Identification of Sources by Arrival Direction
- Studies of Acceleration Mechanisms
- Separation of Gamma Rays from Nuclei
- Testing of Super Heavy Particle Models of the source particles
- Clarification of the trans-GZK intensity profile

Greisen-Zatsepin-Kuzmin – GZK effect

Interaction of UHECR with cosmic background radiation

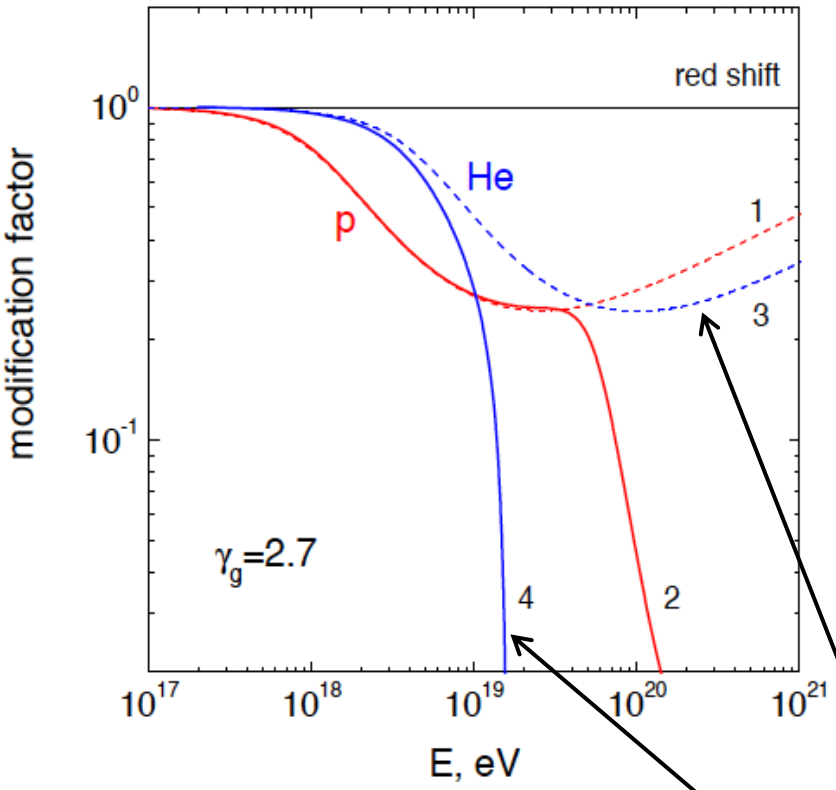
=> An effective attenuation length of 50 Mpc for a proton of 10^{20}eV

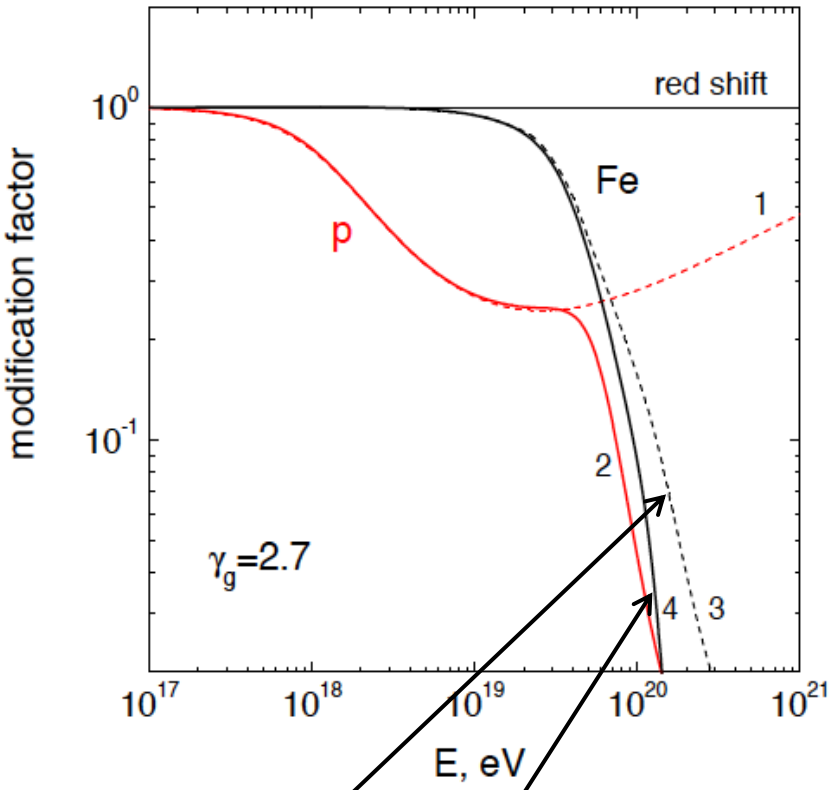




Modification factor of nuclei vs. protons

Berezinsky: astro-ph:0509069v2





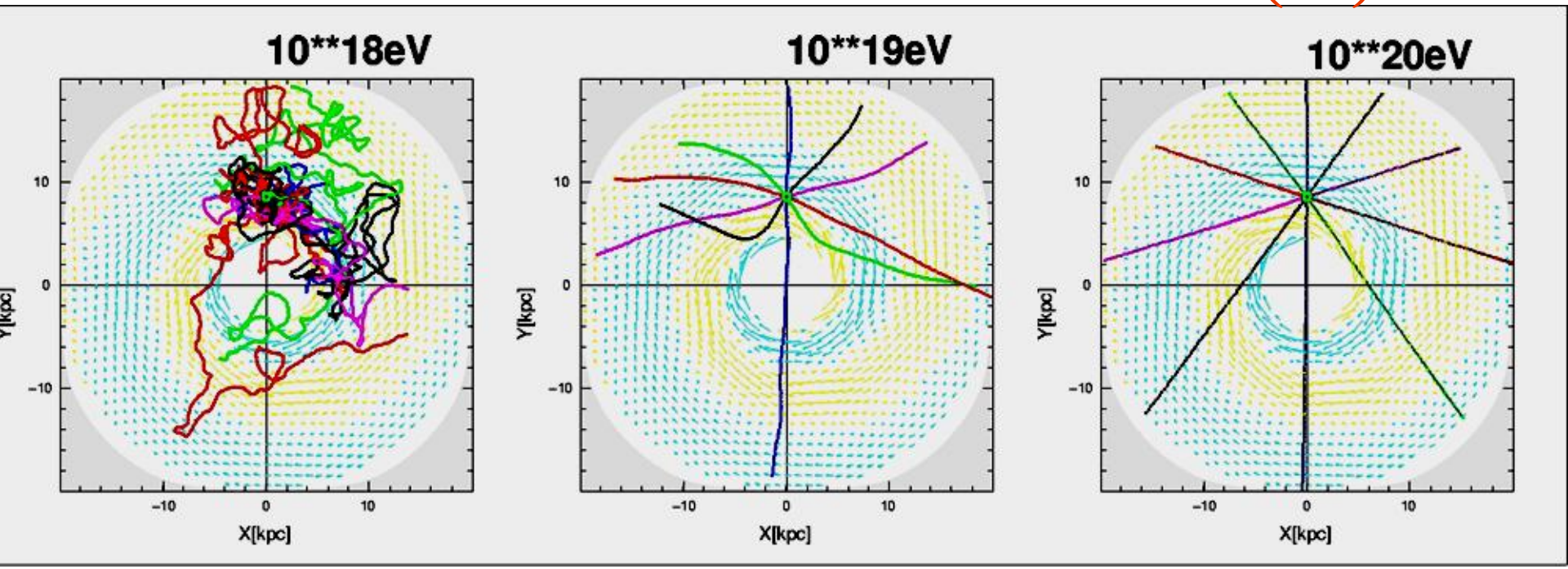
pair production

pair production + photo-disintegration

$$s_i = s_i\left(E_{nuc}\right) = s_i\left(E_{Tot} / A\right)$$

Cosmic Ray propagation in our Galaxy

$$r = \frac{\gamma m_0 v \sin\theta}{ZeB} = \left(\frac{pc}{Ze}\right)\frac{\sin\theta}{Bc}$$



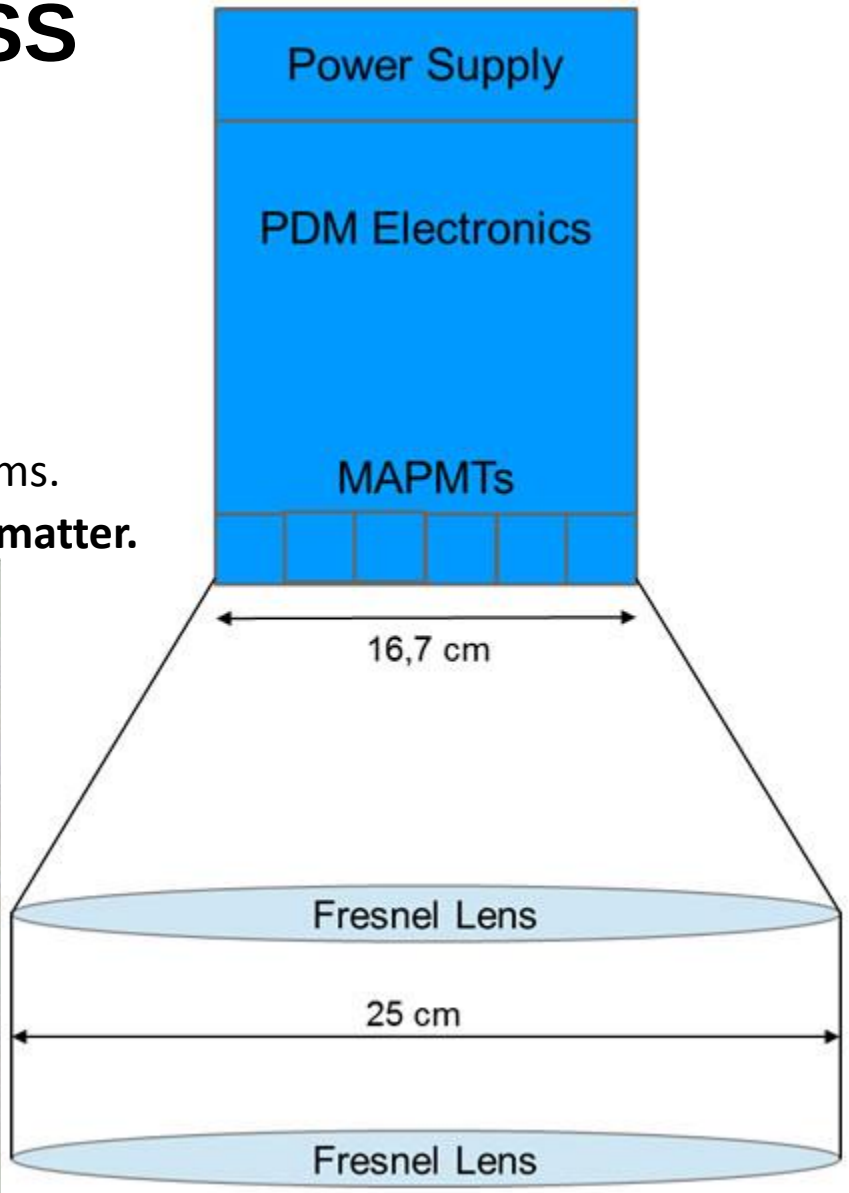
Largely unknown local extragalactic and galactic magnetic field limits proton astronomy to higher energies

Mini-EUSO inside ISS

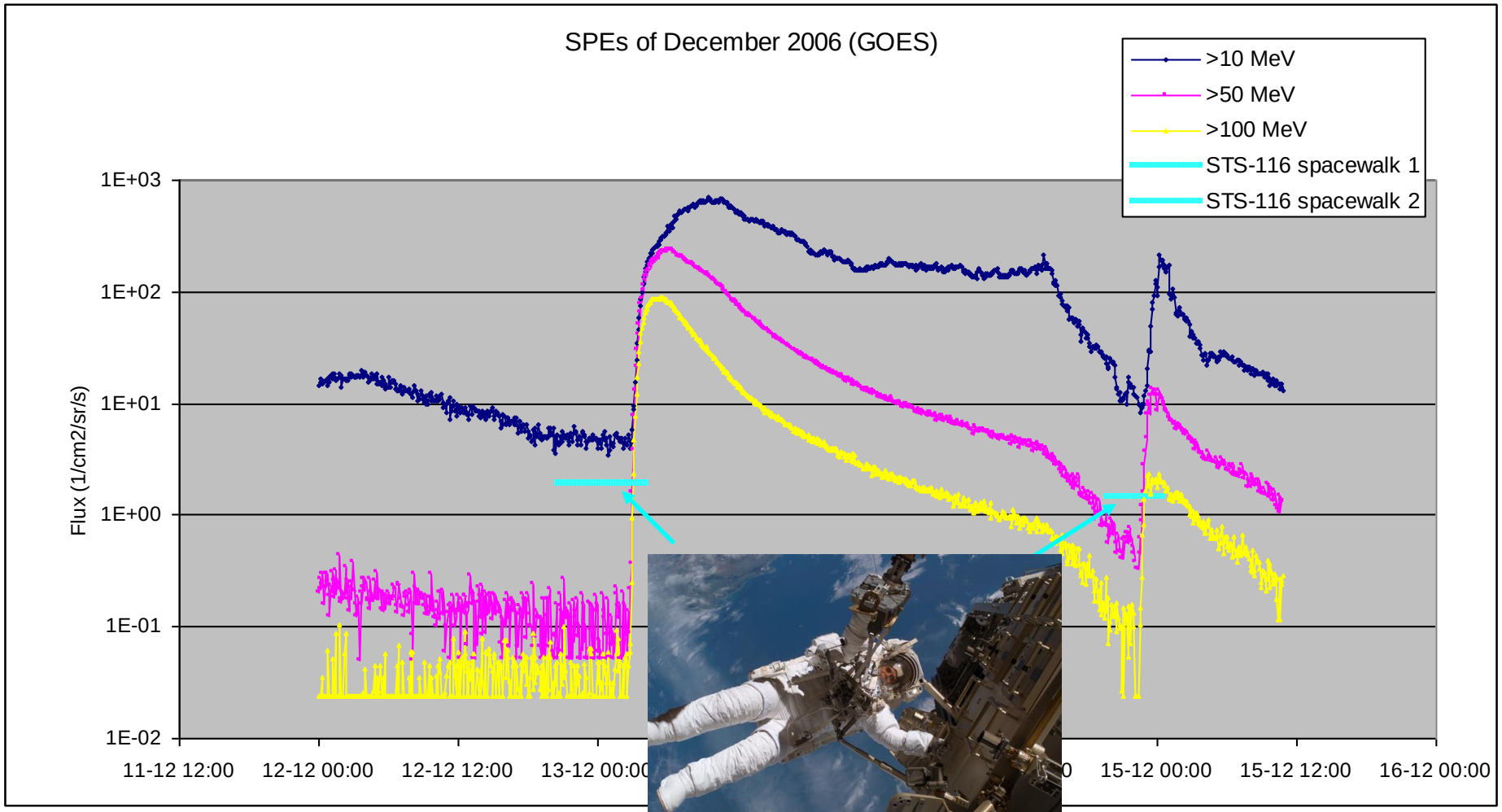
- Test new technology and operations
- Measure UV-background
- First UV-map of the Earth
- Some additional science:

  - Atmospheric phenomena, like lightning, and bioluminescence of Animal and vegetal organisms.

  - Meteors from space & look for **strange quark matter.**



Particle flux from the sun during spacewalks of STS-116



December: | 12 | 13 | 14 | 15 |