International Conference “Moon Base: a Challenge for Humanity”

Third workshop “The precursor Age”

Moscow, November 16-17, 2006

First generation particle detectors on the Moon for a lunar cosmic rays observatory *and climate change monitor*

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Preamble

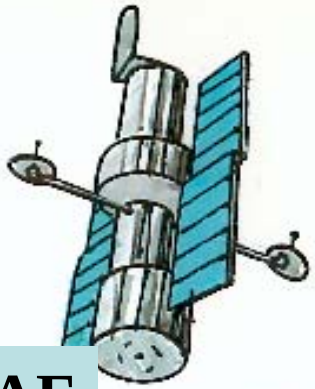
In most of the satellite borne CR experiments, as in general in all satellite borne experiments, the mass and cost of the spacecraft and of its services (altitude and attitude control, power generation and distribution, telemetry, etc.) largely exceed the mass and cost of the experimental device. This fact, as well the increasing concurrence by other field of the science and applications, greatly reduced in last two decades the number of flown satellite born cosmic ray experiments.

As matter of fact the possibility of installing CR experiments on an already organized and serviced lunar habitat can significantly reduce the required investment, as already proven for the many experiments performed on board of the MIR Space Station and of the ISS. This compensates for the cost of the Earth-Moon transportation, that in addition it is anticipated to decrease by a sensible factor in the next decade.----------

As it was the case in the seventies for the Great Observatories (Hubble telescope, CGRO, AXAF, SIRF) in view of the shuttle operations, a complete program at the forefront of space science and technology should include a set of Moon based Observatories to explore any aspect of the Universe.----------

For expanding our knowledge to the extreme Universe at higher energies the Moon based CR observation must be part of this program. --

CGRO

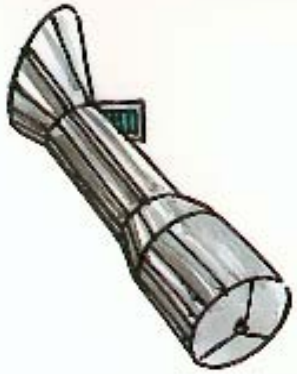


AXAF
(CXO)+
(XMM)

THE GREAT OBSERVATORIES

FOR SPACE ASTROPHYSICS

HST



SIRTF

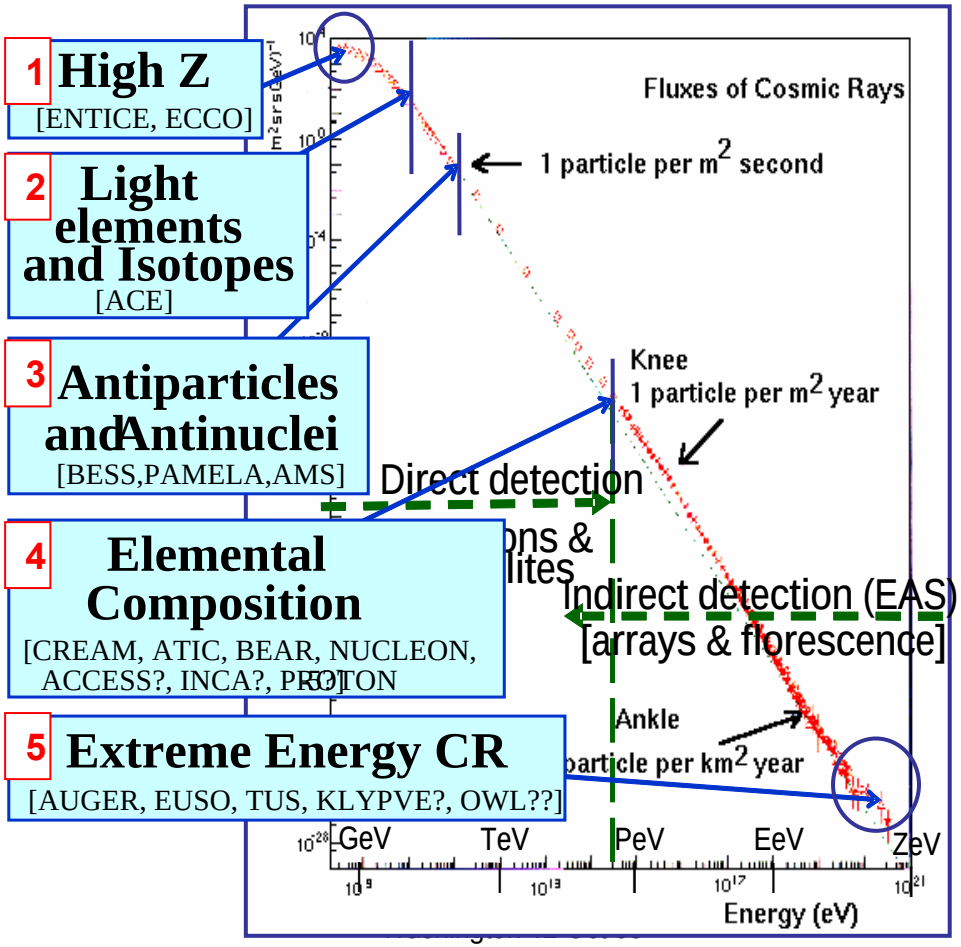
+

Advanced Composition Explorer (ACE)

+ Particle-Antiparticle Superconducting Magnet Facility (ASTROMAG)

+

Very Long Base Interferometer (VLBI)



Washington, Oct. 2005
(first slide)

Washington, Oct. 2005
(last slide)

High Z: 1

HNeXplorer (HNX) [exp. ENTICE + ECCO] in 'stand by'
possible only on the Moon surface

Isotopes (E>GeV/n): 2

on Earth orbit ≈80 are accessible but no plans exist
light isotopes from BESS, PAMELA, AMS in next years
high rate assured on the Moon up to very high E

Rare components: 3

antiN/N up to $<10^{-9}$ (AMS)
antip, e+ up to a >200 GeV (PAMELA ed AMS)
electrons up to >3 TeV (PAMELA, AMS, CALET)
1-10 TeV region on reach on the Moon surface

Elemental composition: 4

up to 100 TeV by ballooning (going on)
up to 1 PeV in orbit (several projects and concepts)
up to 100 PeV (well behind the knee) on the Moon

Ultra High Energies: 5

up to few * 100 EeV on Earth surface (going on)
up to 1000 EeV from orbit (but EUSO in 'stand by')
up to a few 10 ZeV from the Moon surface,
a UHE Neutrino Observatory ($E_\nu > 10^{19}$) is feasible

What detectors for the first CR experiments on the Moon?

***Zero generation experiments*:**

Install on the Moon the experiments planned for satellites or ISS, and that are long time in stand by because too massive and difficult to be operated In LEO:

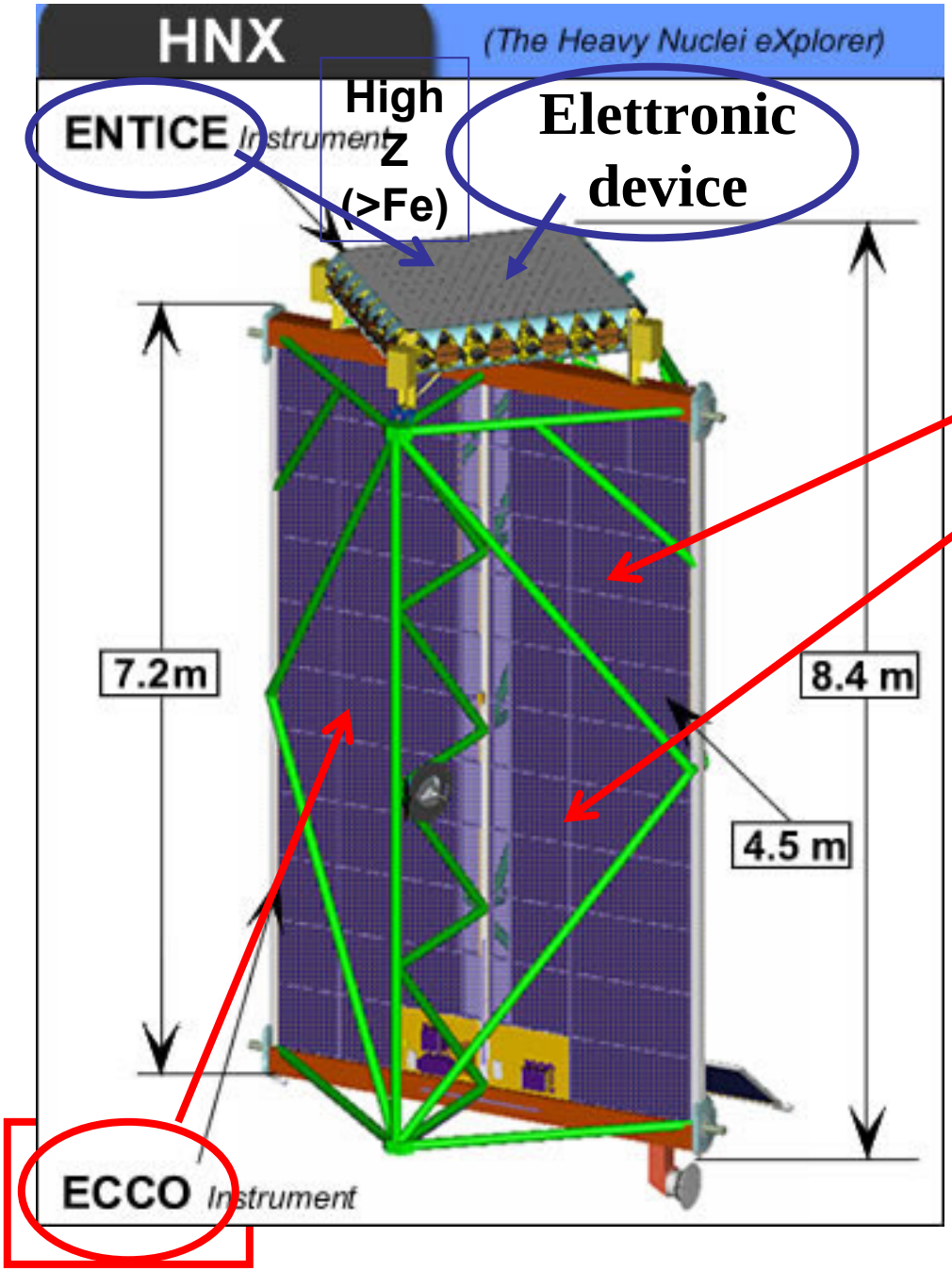
Examples:

1 - ECCO for very high Z (supernovae rate counting) [small changes]

2 - Rare elements, radioattive isotopes [new, ISOMAX-like magnetic spectrometer]

4 - Elemental composition at knee

- [ACCESS class, possibly larger acceptance]
- [CHICAGO EGG spectrometer, but longer exposition]

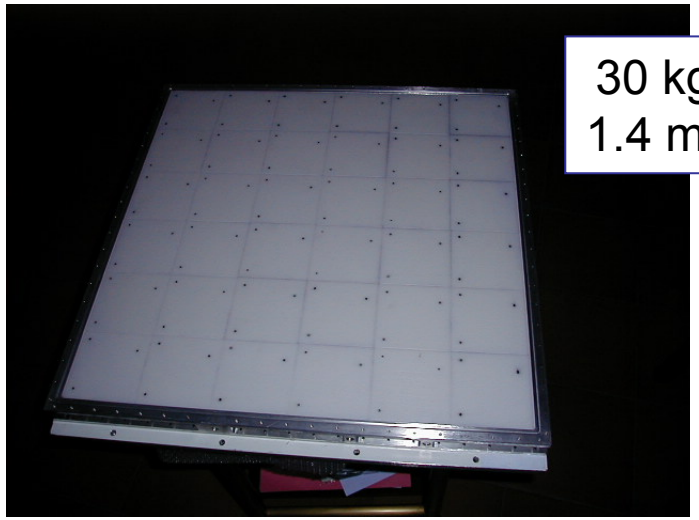


Etching of "charged" glasses

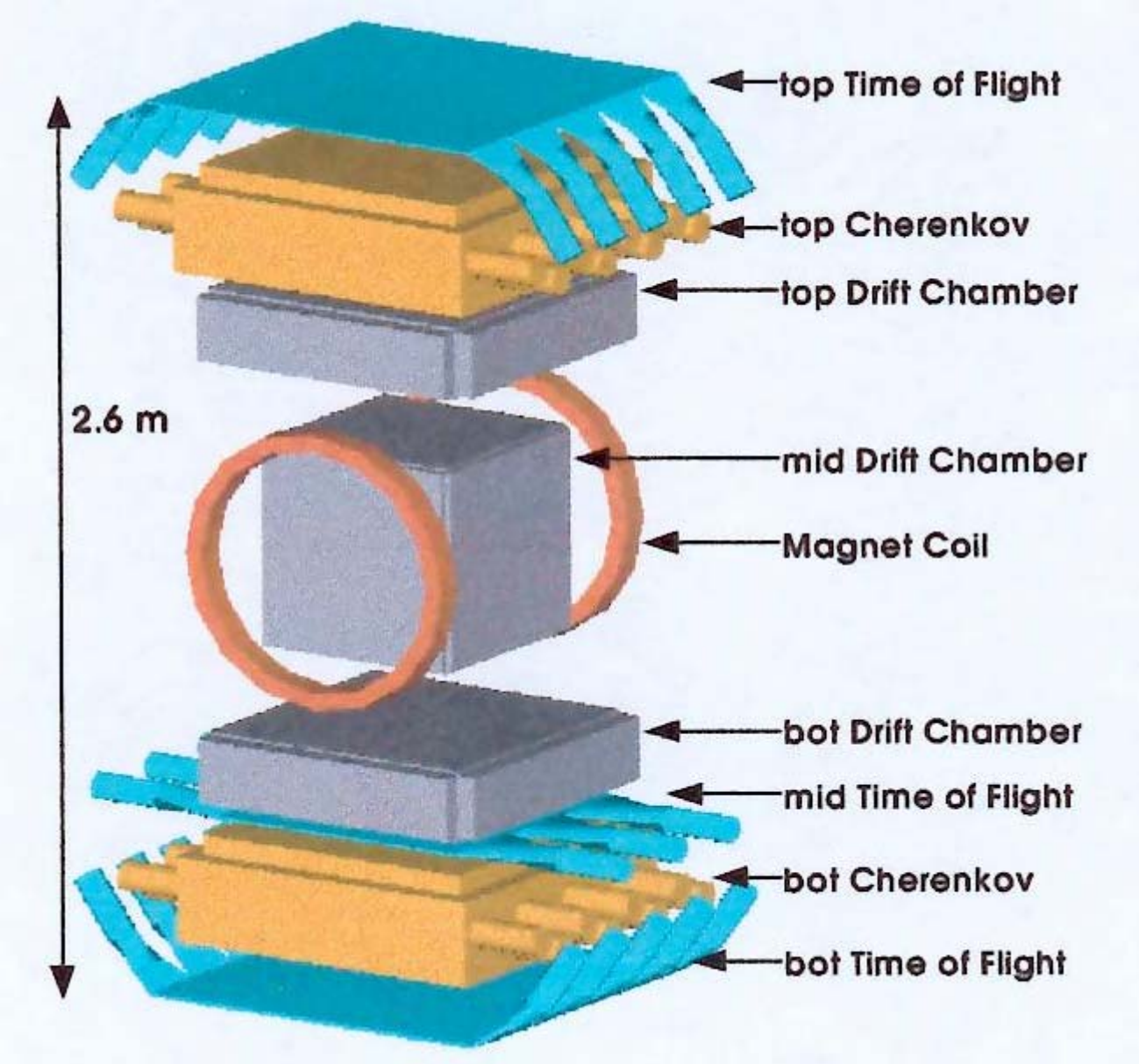
On the Moon:
- no magnetic field
- easy deploied
- easily recovered

Very High Z (actinides)

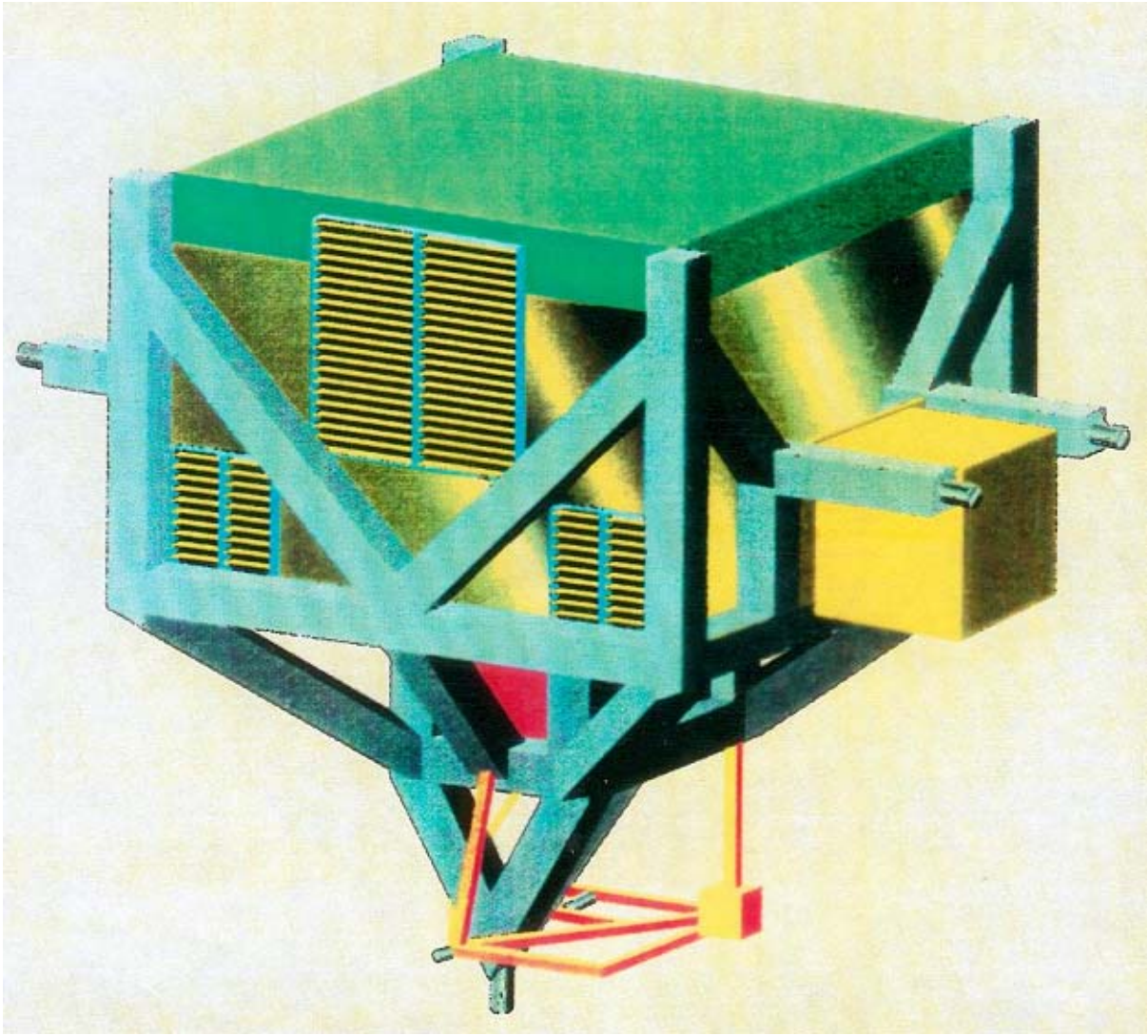
Mass << 100 kg/m2



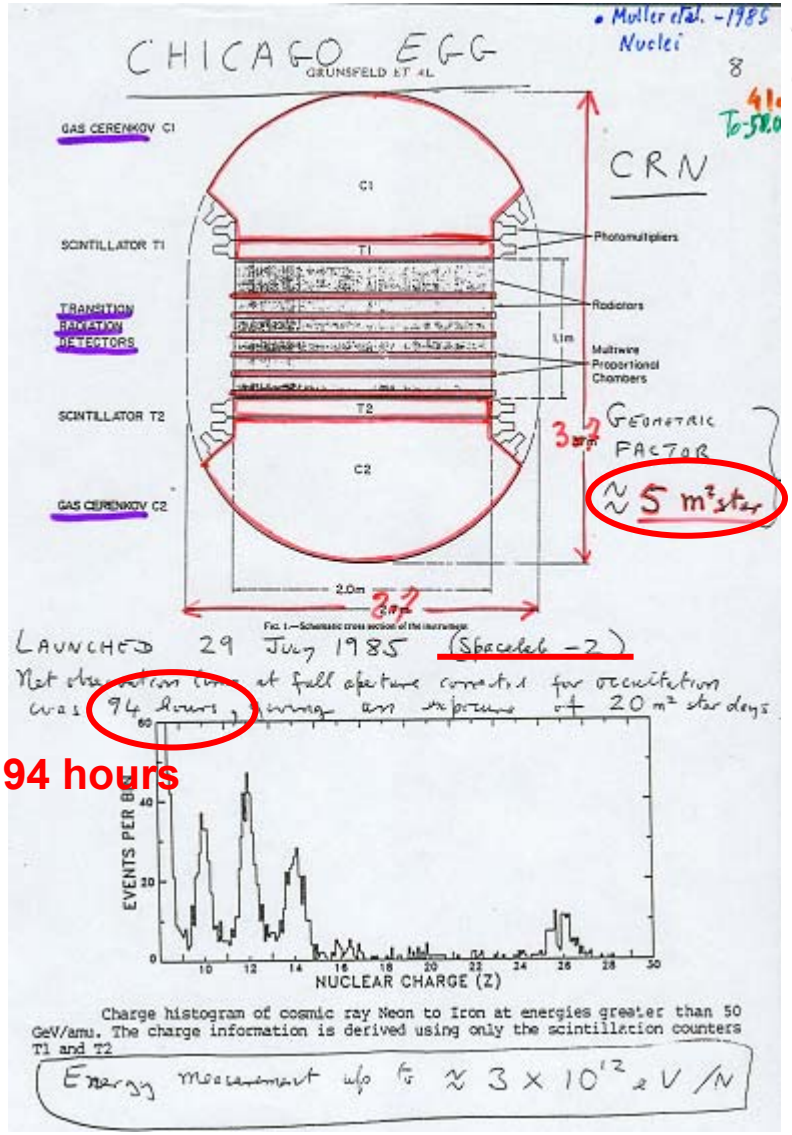
ISOMAX

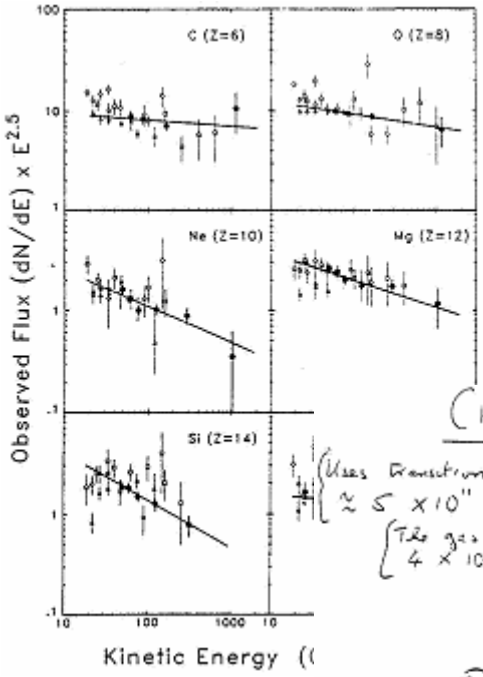

top Time of Flight
top Cherenkov
top Drift Chamber
2.6 m
mid Drift Chamber
Magnet Coil
bot Drift Chamber
mid Time of Flight
bot Cherenkov
bot Time of Flight

ACCESS



CRN (Chicago egg), 1985





CHICAGO EGG

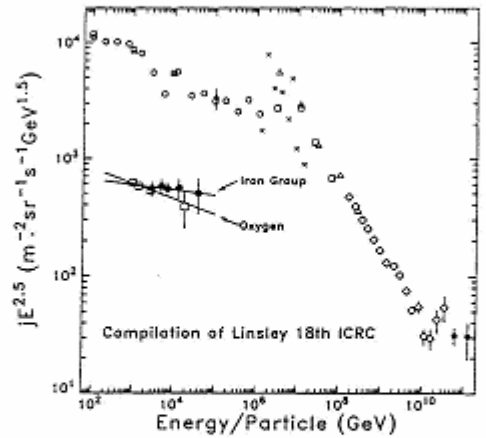
10

4

Uses transition radiation detectors to measure energy from ≈ 5 × 10¹¹ eV/N to ≈ 3 × 10¹² eV/N

The gas Cerenkovs measure in the range 4 × 10¹⁰ to 1.5 × 10¹¹ eV/N

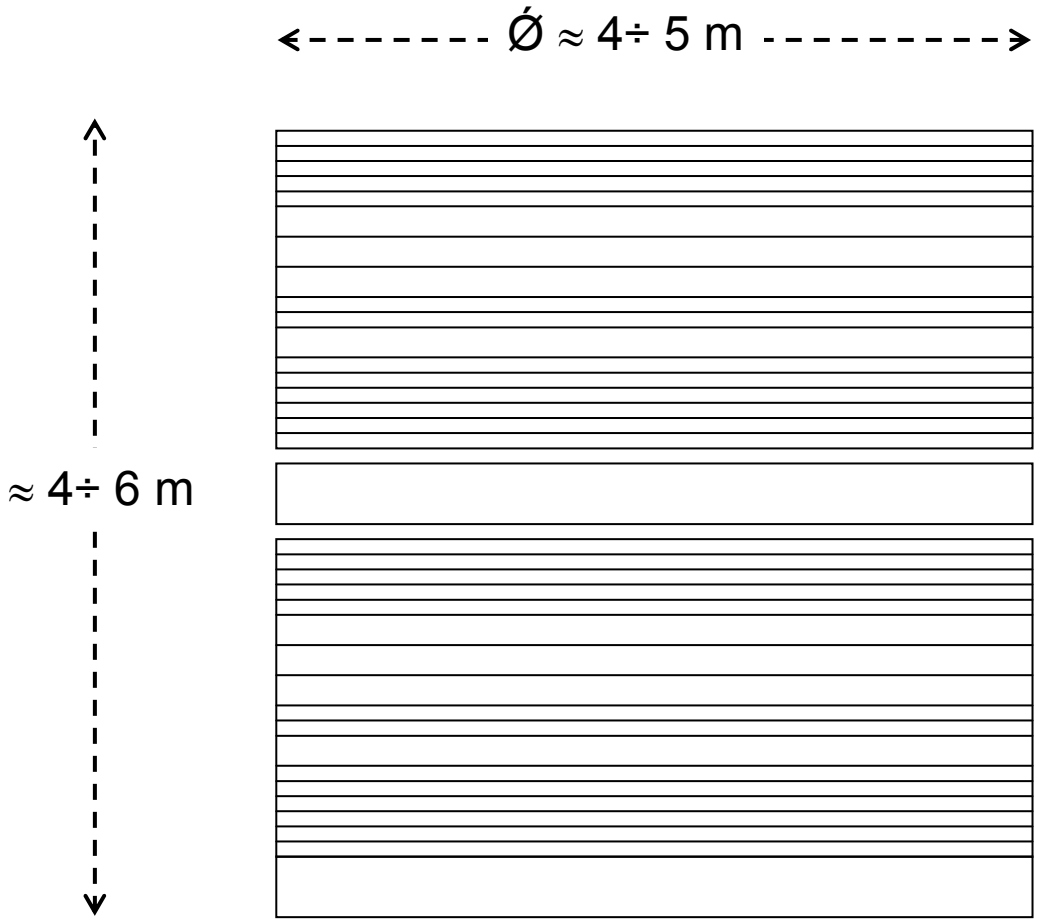
GRUNSFELD ET AL



The all-particle energy spectrum as compiled by Linsley (1983) and the spectra of O and the Fe group (Z = 25, 26, 27) as measured in this experiment. The lines represent the power-law fits to the O and the Fe group data obtained in this experiment. Note that in the absence of absolute fluxes, the normalization of our data is somewhat arbitrary.

Proposed (approved?) for re-flight on MIR-2.

MIR-2 first launch scheduled for 1993 (but not yet approved)



Dimensions compatible with the next future transport systems

TRD's + Cherenkov's Spectrometer

First generation experiments

a) Technical progress on sensors

Examples:

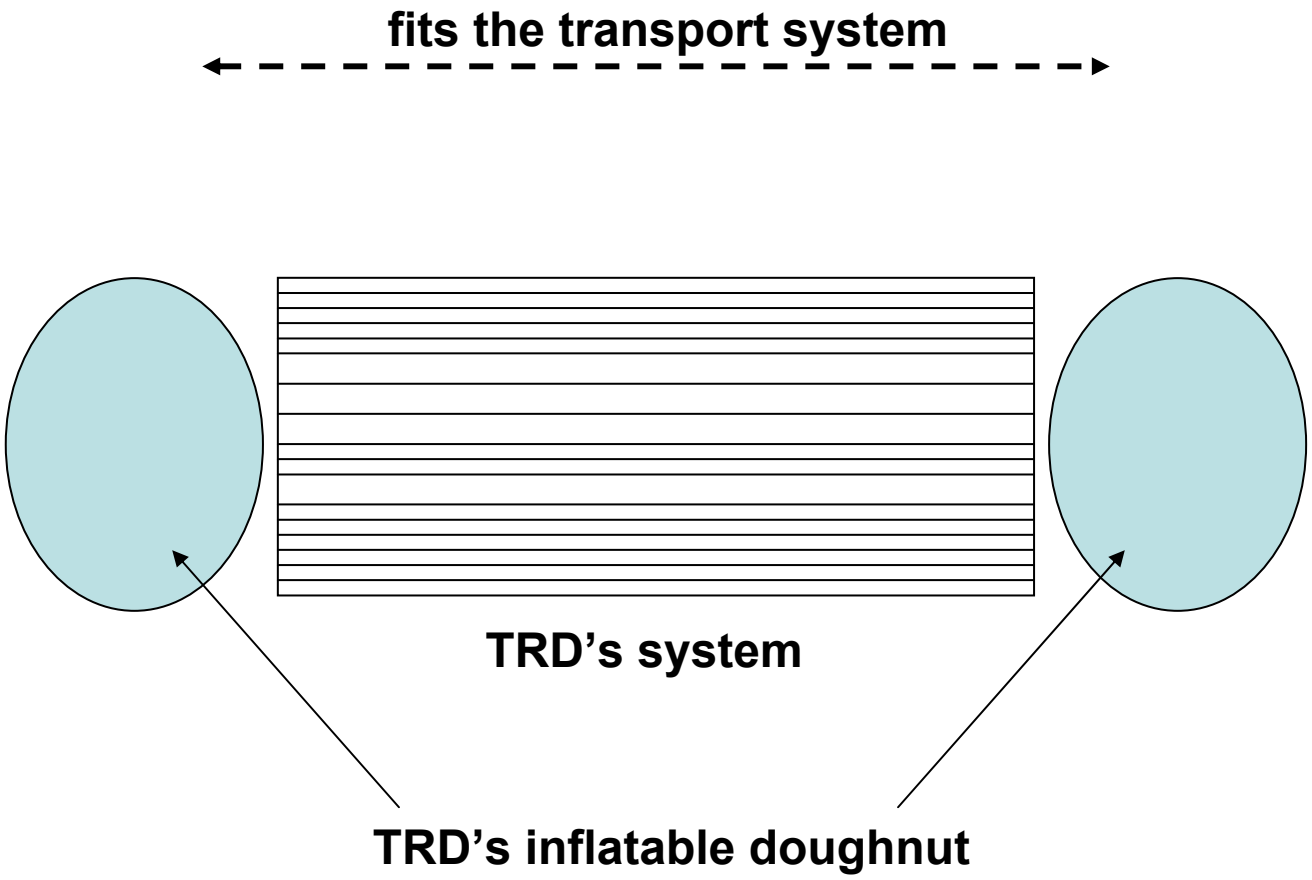
- **High efficiency solid state X-ray sensors** [currently under R&D, essential for TRD's, [cryo] Cherenkov's].
- **Large area covered SIM sytems** [currently under R&D, essential to improve RICH's, trackers]

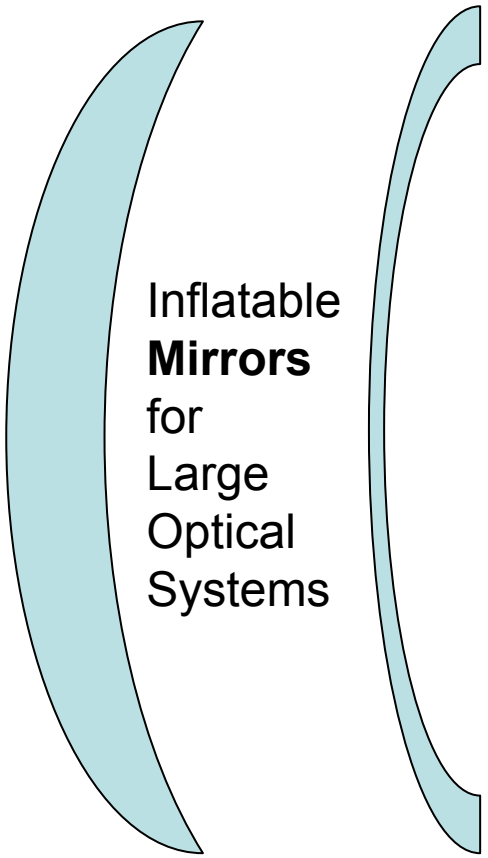
b) Progress on detection systems

- **Inflatable detectors and other elements** (gas counters (?), trusses, stretched membranes, deploied large mirrors, gaseous optical lenses, expandable magnetic lenses,..)
[used in several other fields, important for calorimetry, large structures, etc]

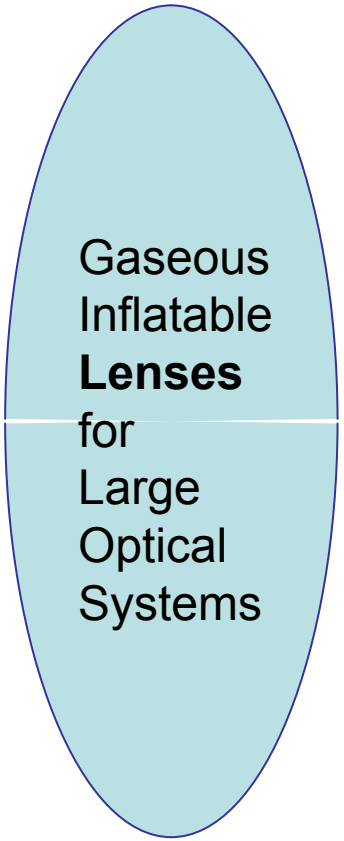
- **Use the terrestrial magnetic field** in magnetic spectrometers (precise direction + energy measurement)
[for antiparticles, hunting for antinuclei, but also for composition]

- **Use calorimetry at high energy** (passive material on the moon, sensor from Earth)


fits the transport system
TRD's system
TRD's inflatable doughnut

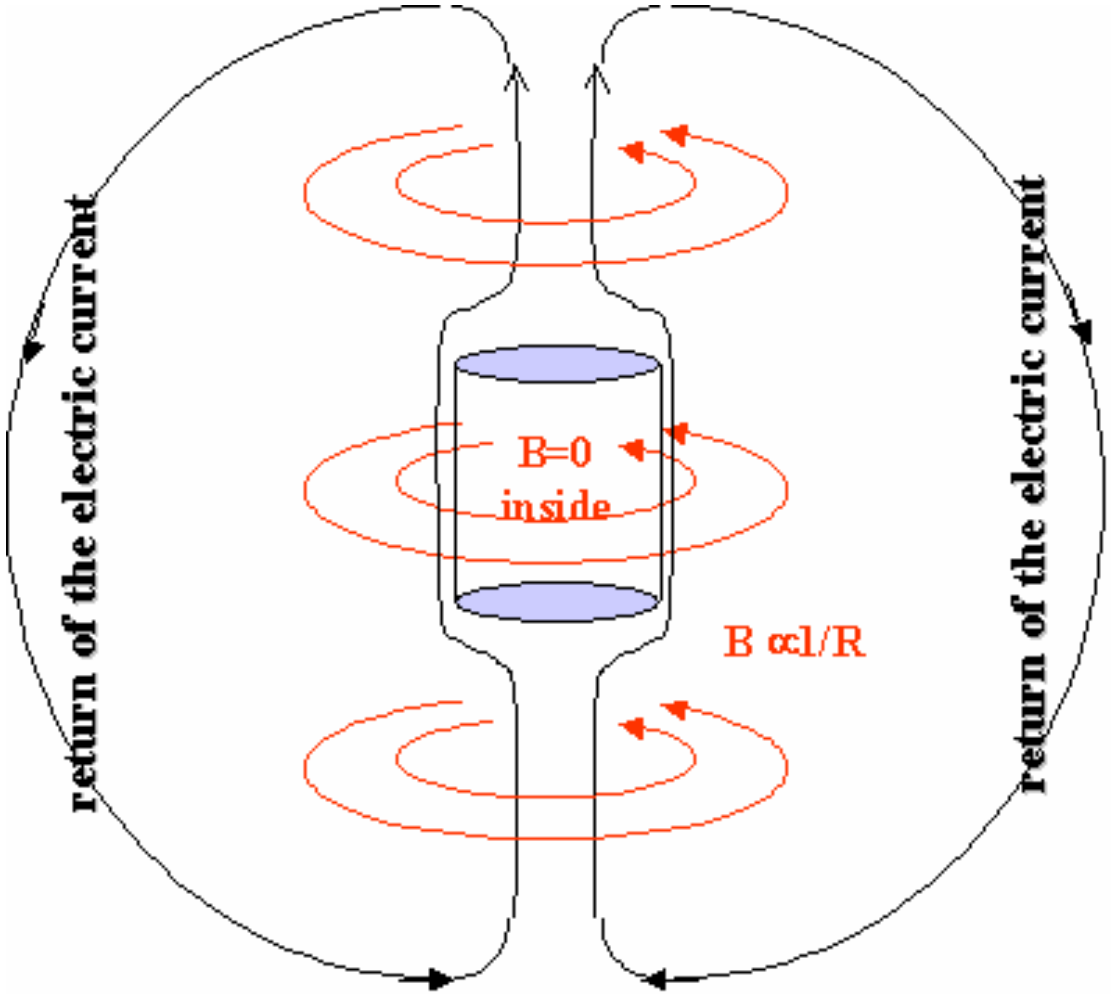


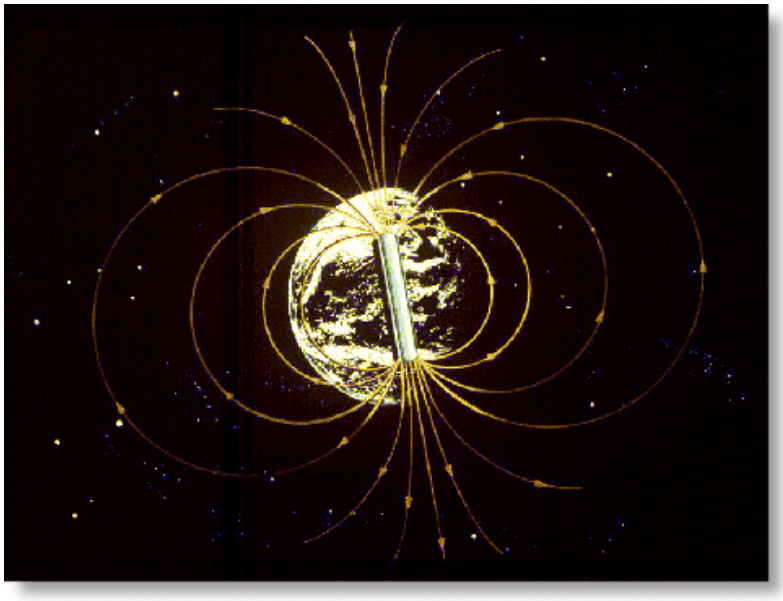
Inflatable
Mirrors
for
Large
Optical
Systems



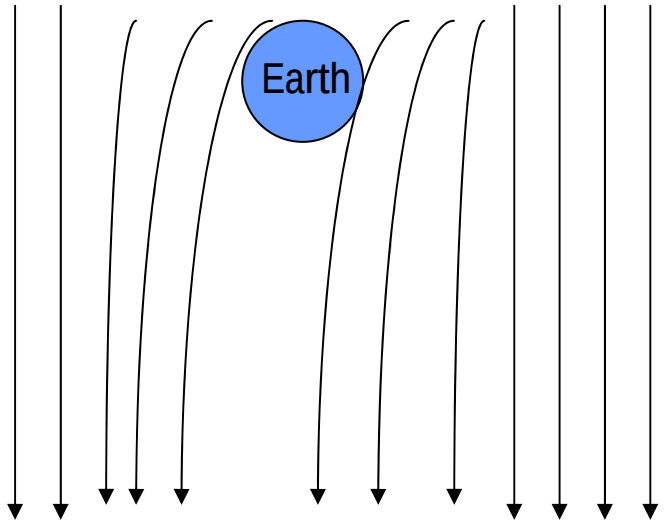
Gaseous
Inflatable
Lenses
for
Large
Optical
Systems

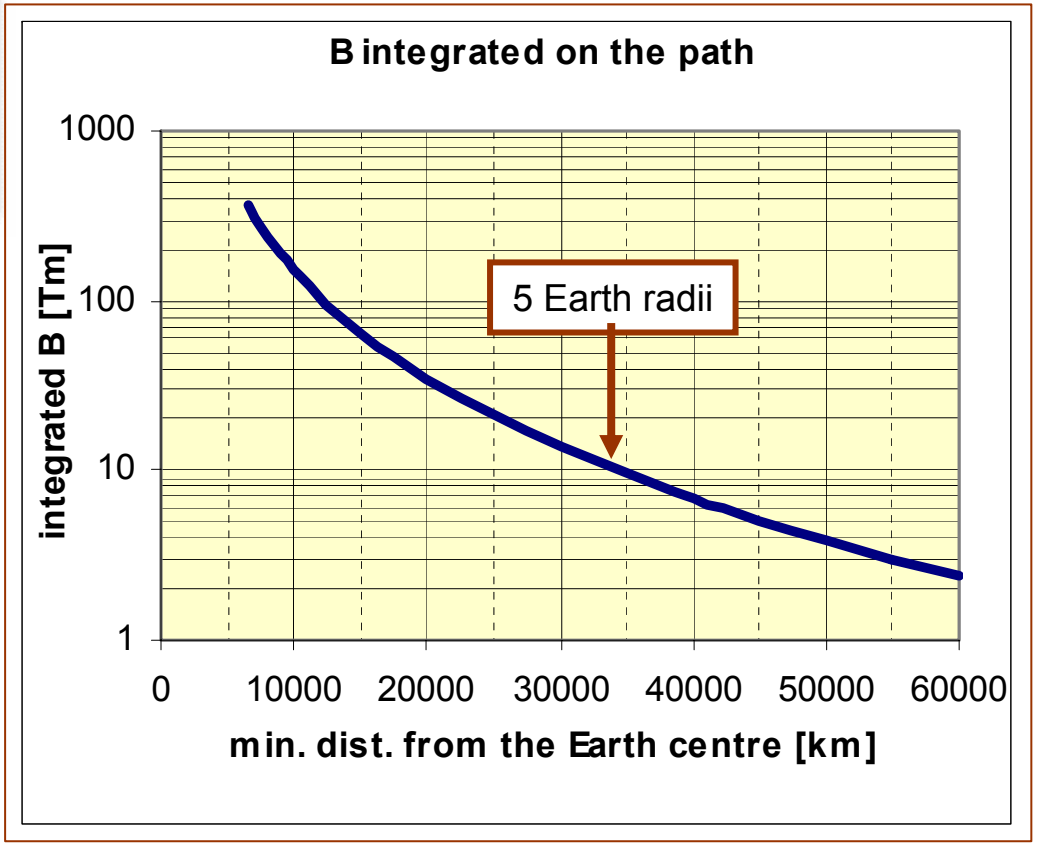
Deployable external conductor for returning the current of the toroid





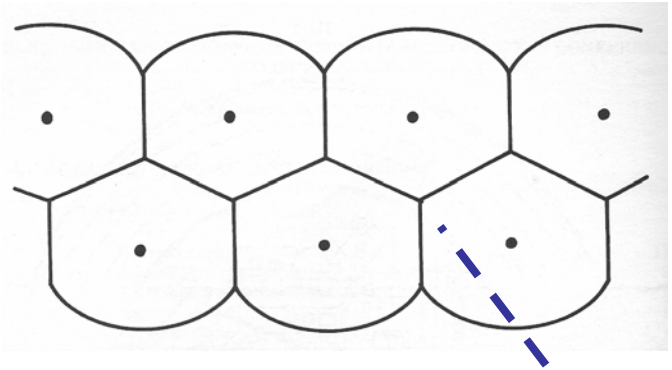
Max bending power ≈ 360 Tm

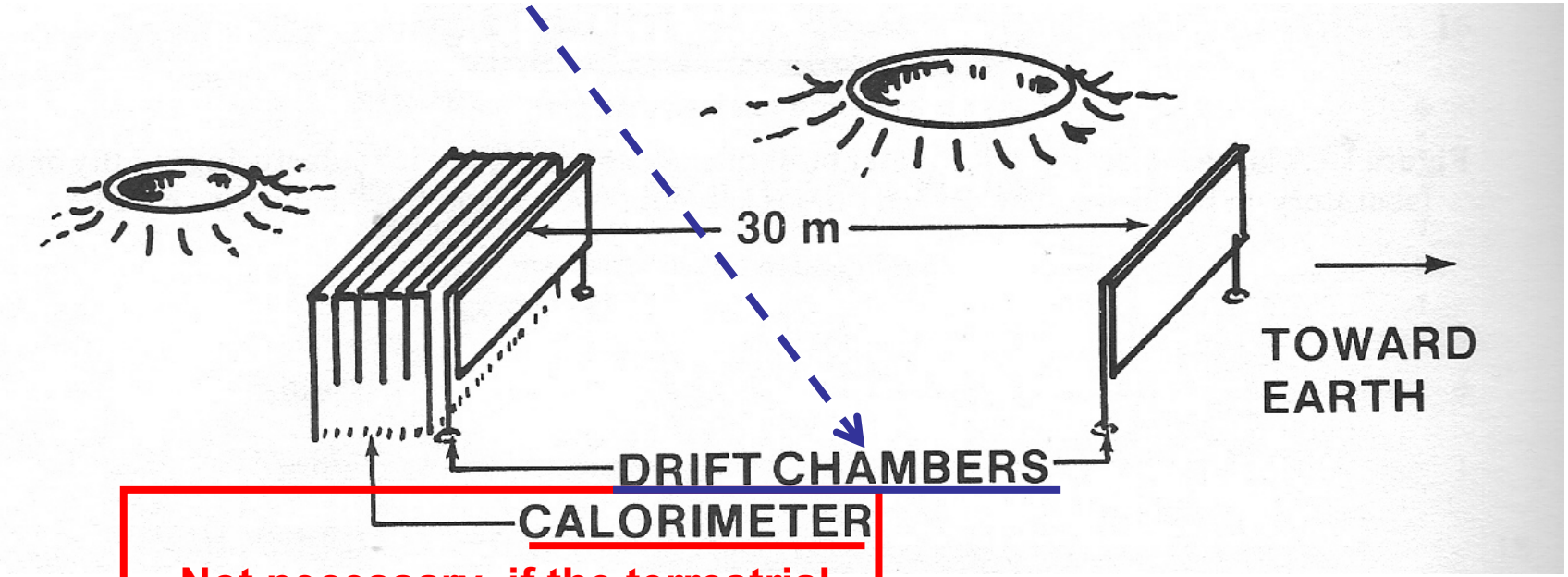




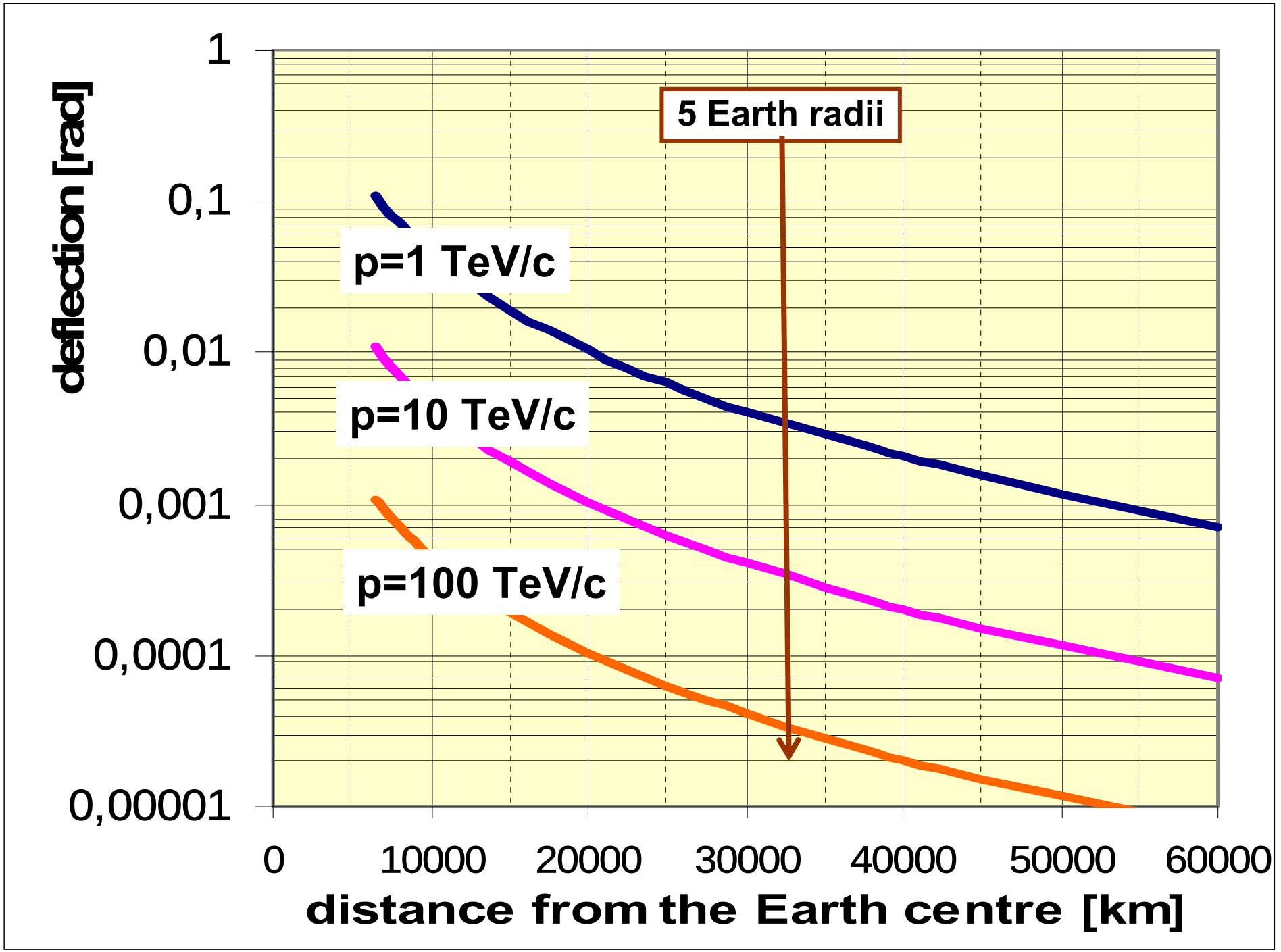
Tracker to be up-dated

John Linsley 1986



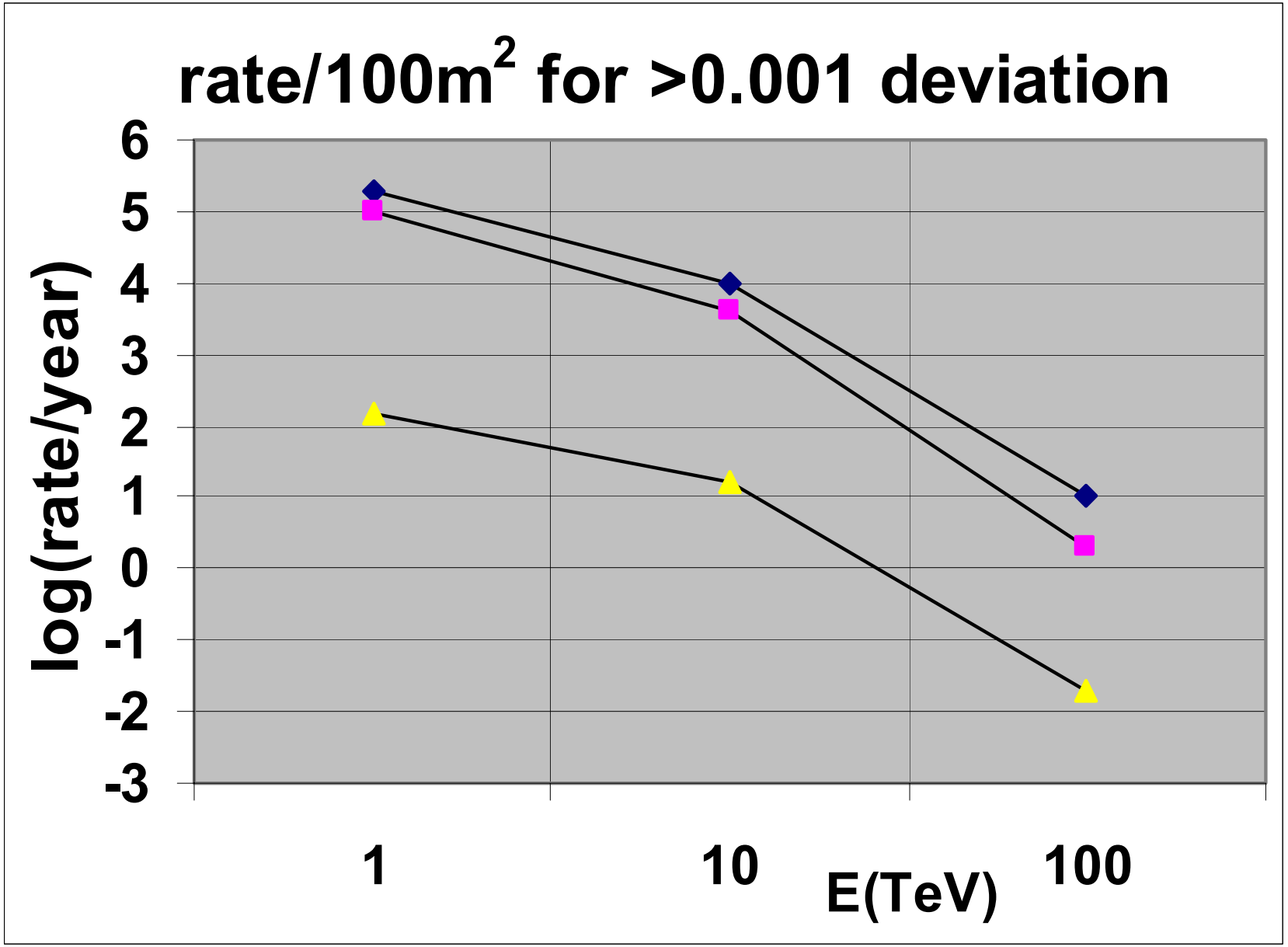


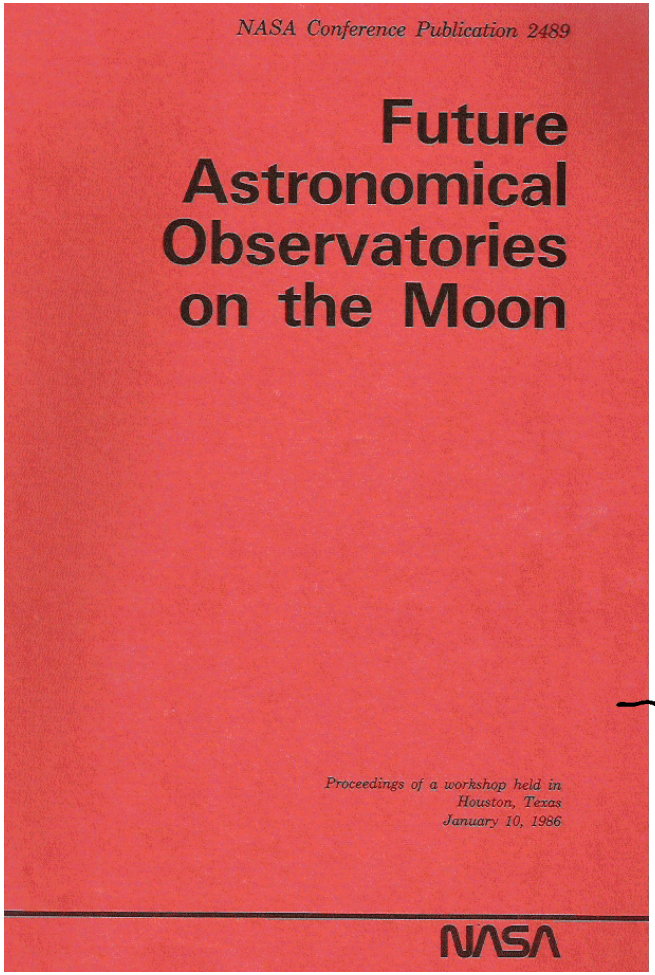
Not necessary, if the terrestrial magnetic field is properly used


deflection [rad]
1
0,1
0,01
0,001
0,0001
0,00001
5 Earth radii
p=1 TeV/c
p=10 TeV/c
p=100 TeV/c
0
10000
20000
30000
40000
50000
60000
distance from the Earth centre [km]

3 Antiparticles and Antinuclei

[BESS,PAMELA,AMS]





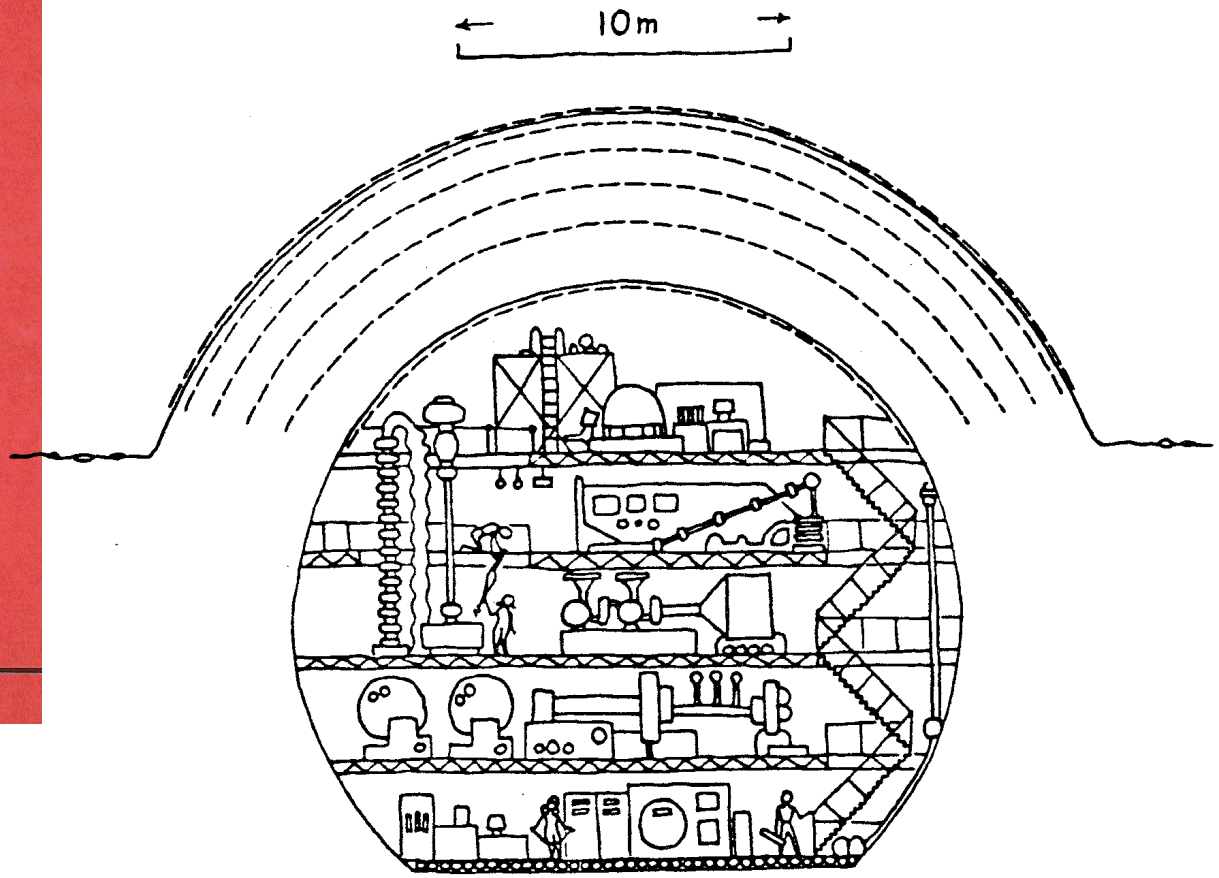
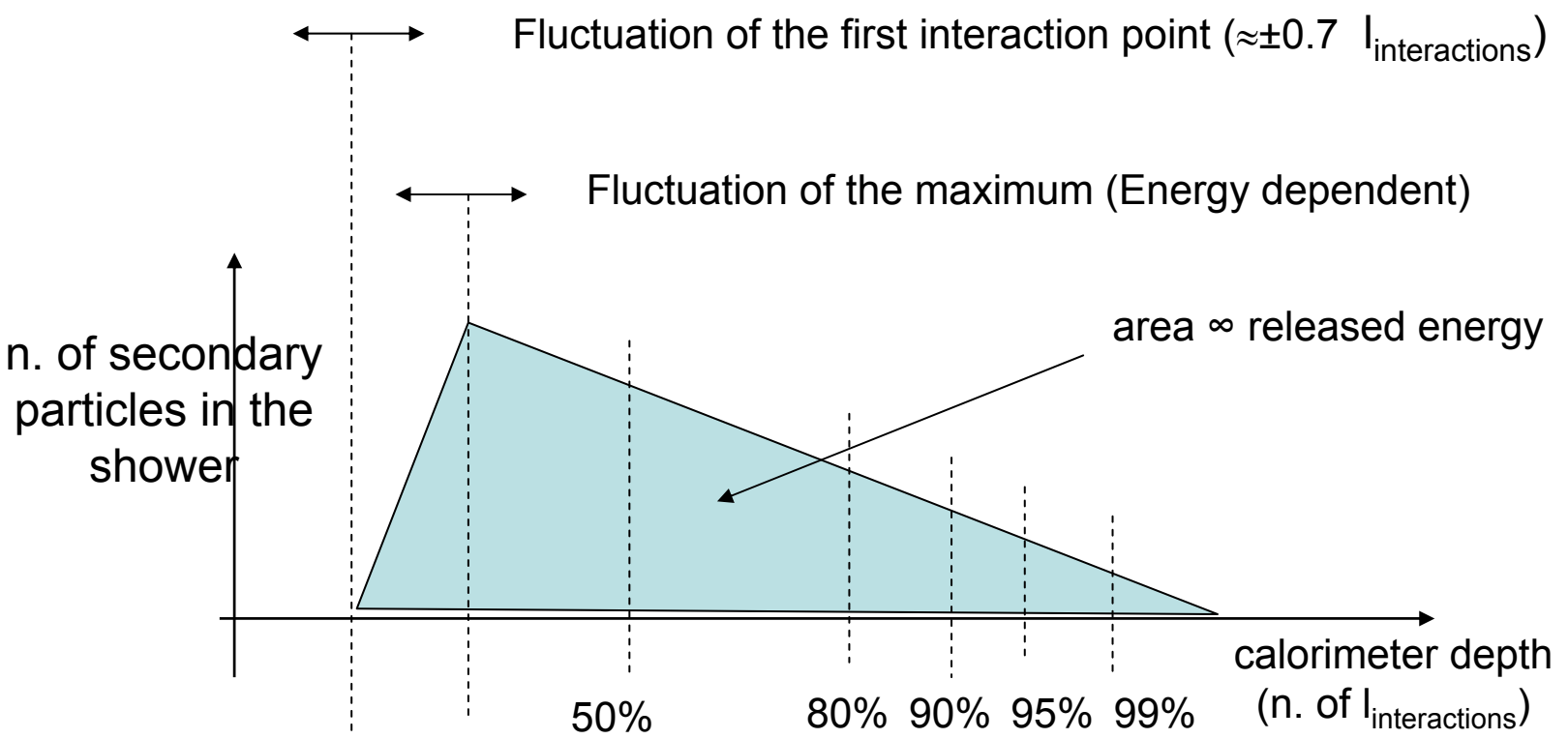
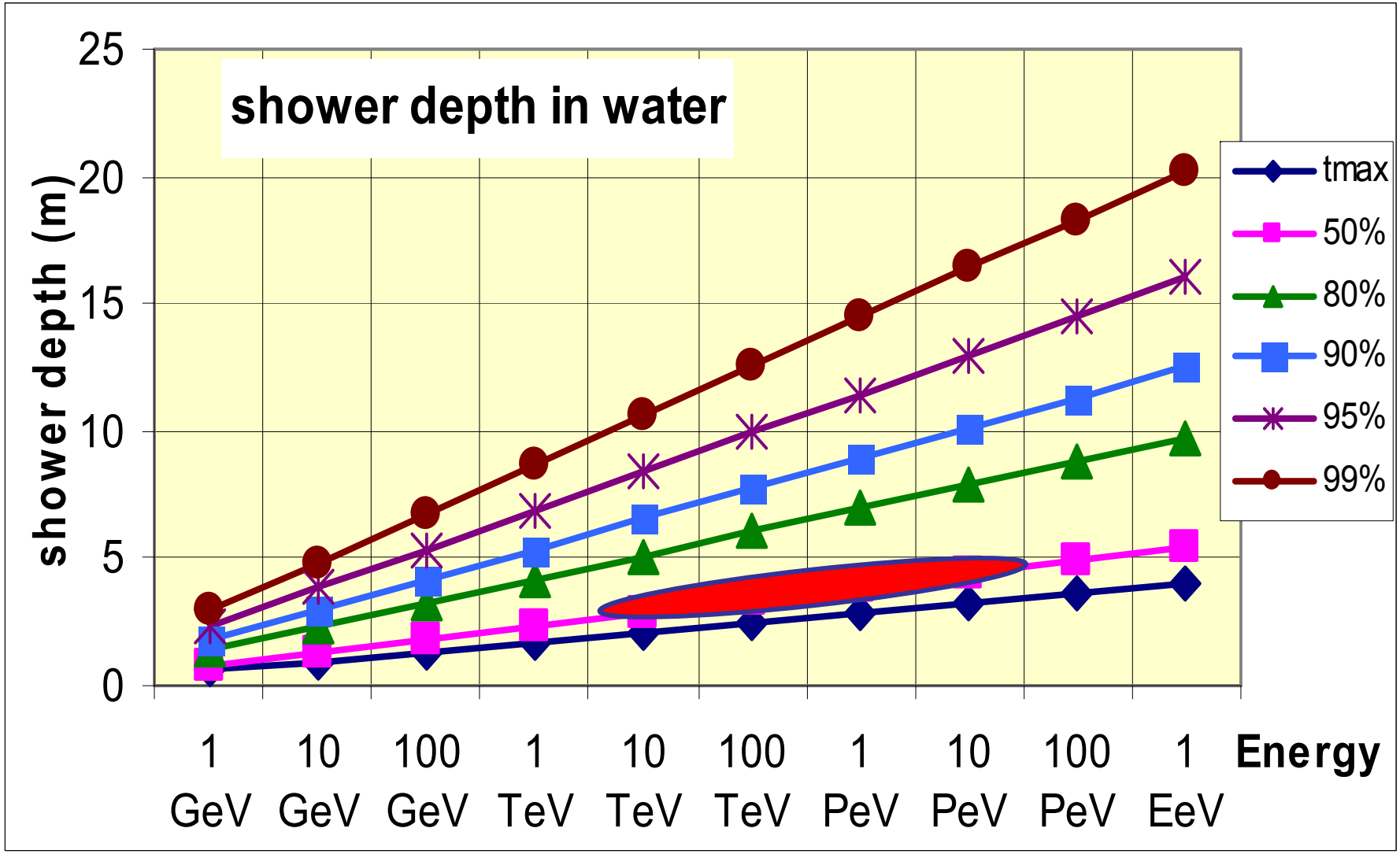


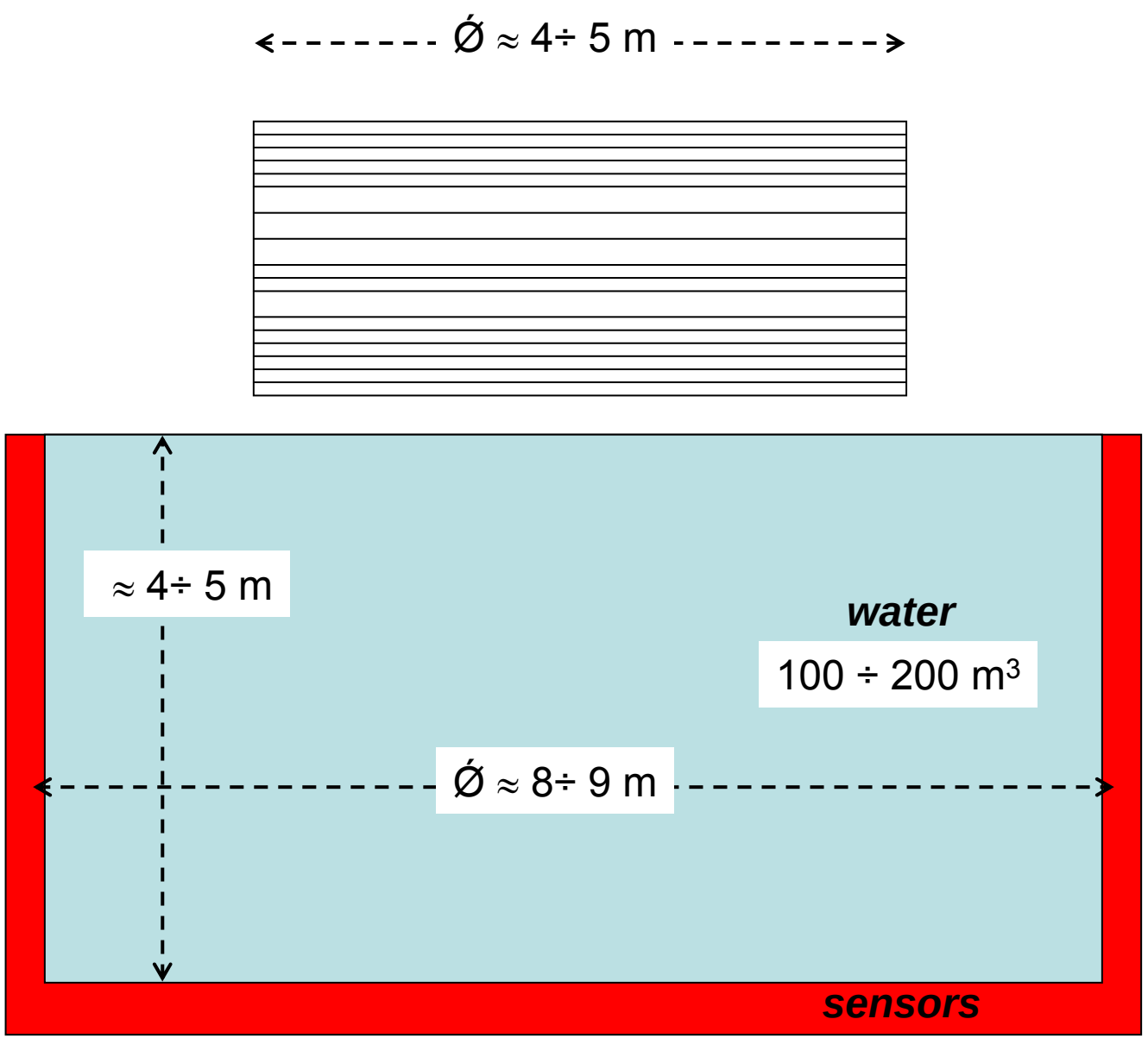
Figure 1.- A large ionization calorimeter built into the shielding of a manufacturing facility or a laboratory on the Moon. The dashed lines represent layers of gas-filled ionization counters.



Poor containement
Poor Sampling
No compensating
CALORIMETER
<150%/sqrt(E(GeV)) + (few)%

100 GeV	(15+few)%
1 TeV	(5+few)%
10 TeV	(few)%
100 TeV	(few)%
1 PeV	(few)%
10 PeV	(few)%


shower depth in water
shower depth (m)
25
20
15
10
5
0
1 GeV
10 GeV
100 GeV
1 TeV
10 TeV
100 TeV
1 PeV
10 PeV
100 PeV
1 EeV
Energy
tmax
50%
80%
90%
95%
99%



TRD's + Calorimeter Spectrometer

Water on the Moon???

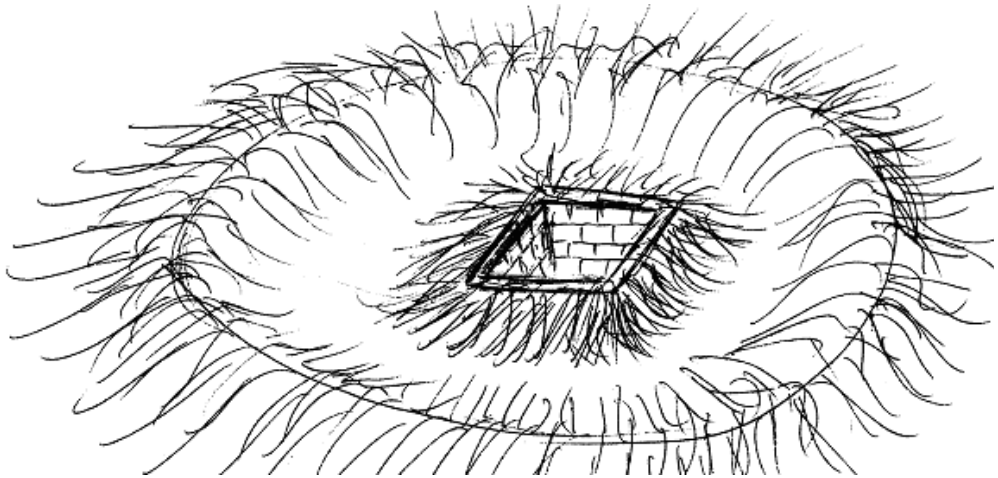
- Perequisite for the establishement of a permanently inhabited Moon base

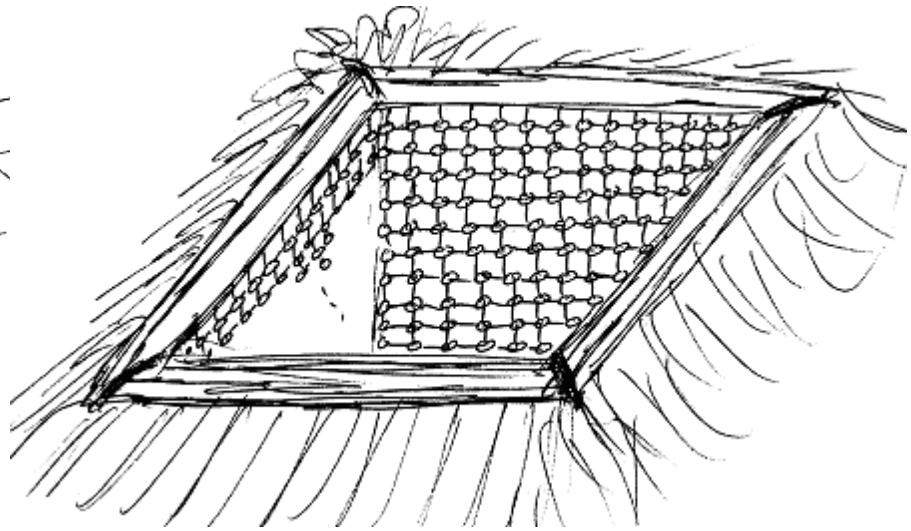
- We now believe that water is present:
  1%÷10% concentration in the regolith in polar craters
  (H signature of the Clementine mission)

-extraction:
  - mechanically
  - thermodinamically
    >200 t/year employing 120 kw
    (Jamestwon Group LCC study, Feb. 2006,
    Heiss et al., June 2006)

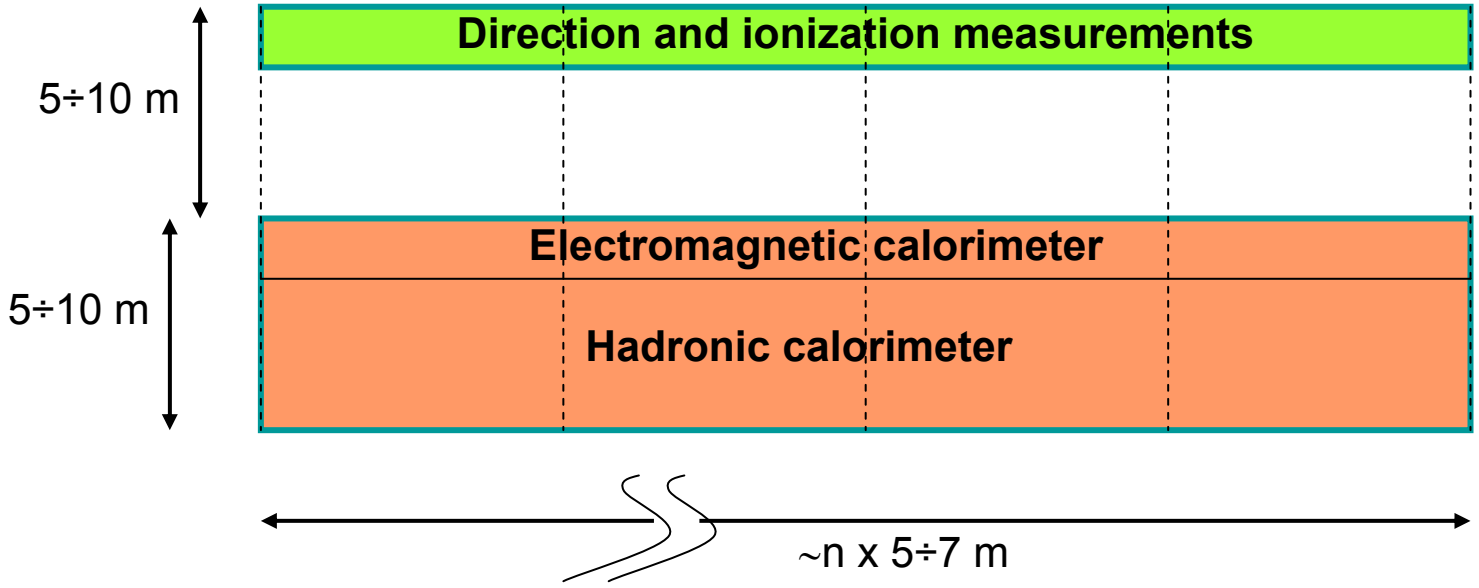
ISRU Scenario for Lunar-Based Water Observatories

- Identify Nearby Smaller Crater to House Water Observatory
  - ~30 – 50 m diameter crater – use central low lying portion
  - Form observatory with regolith 'bricks' and regolith pile-up (regolith moving)
  - Line with pre-fabricated, hermetic detector-array 'vinyl' liner



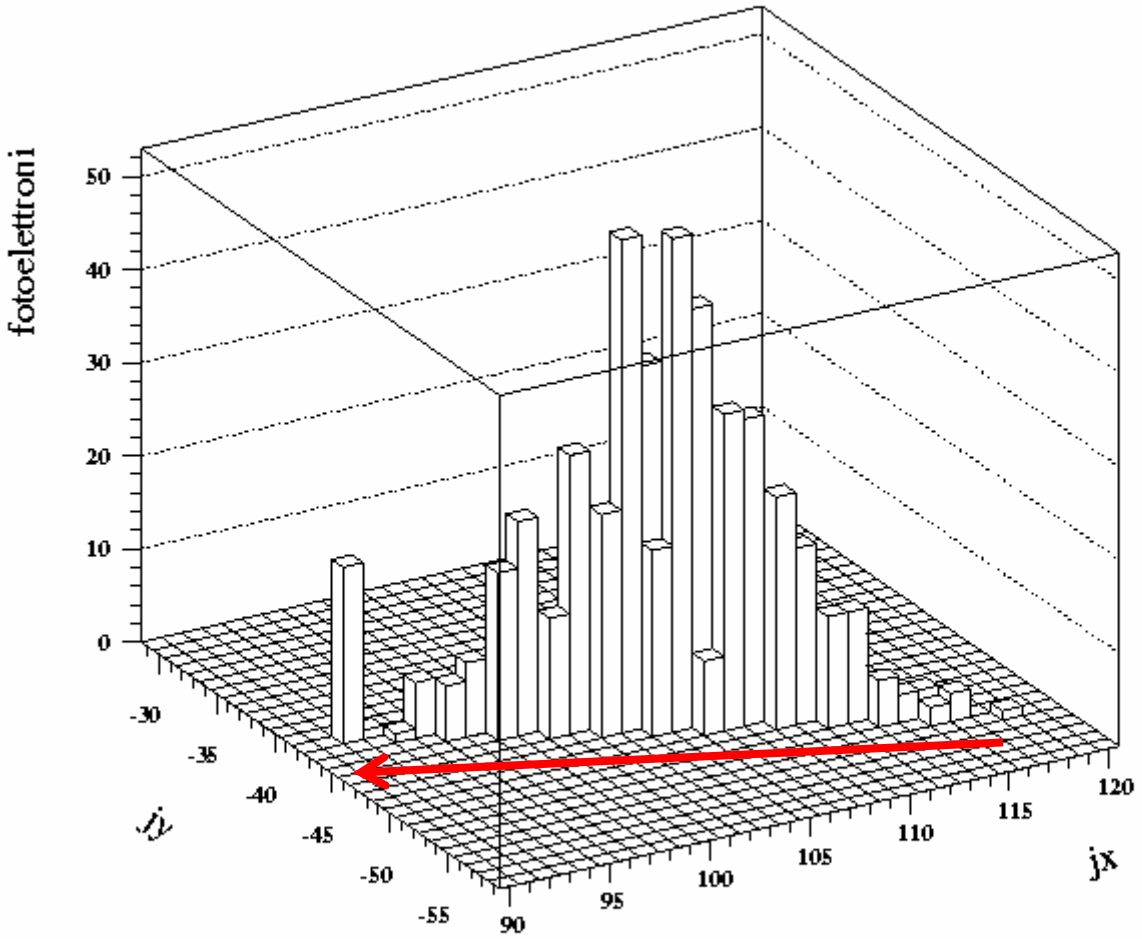


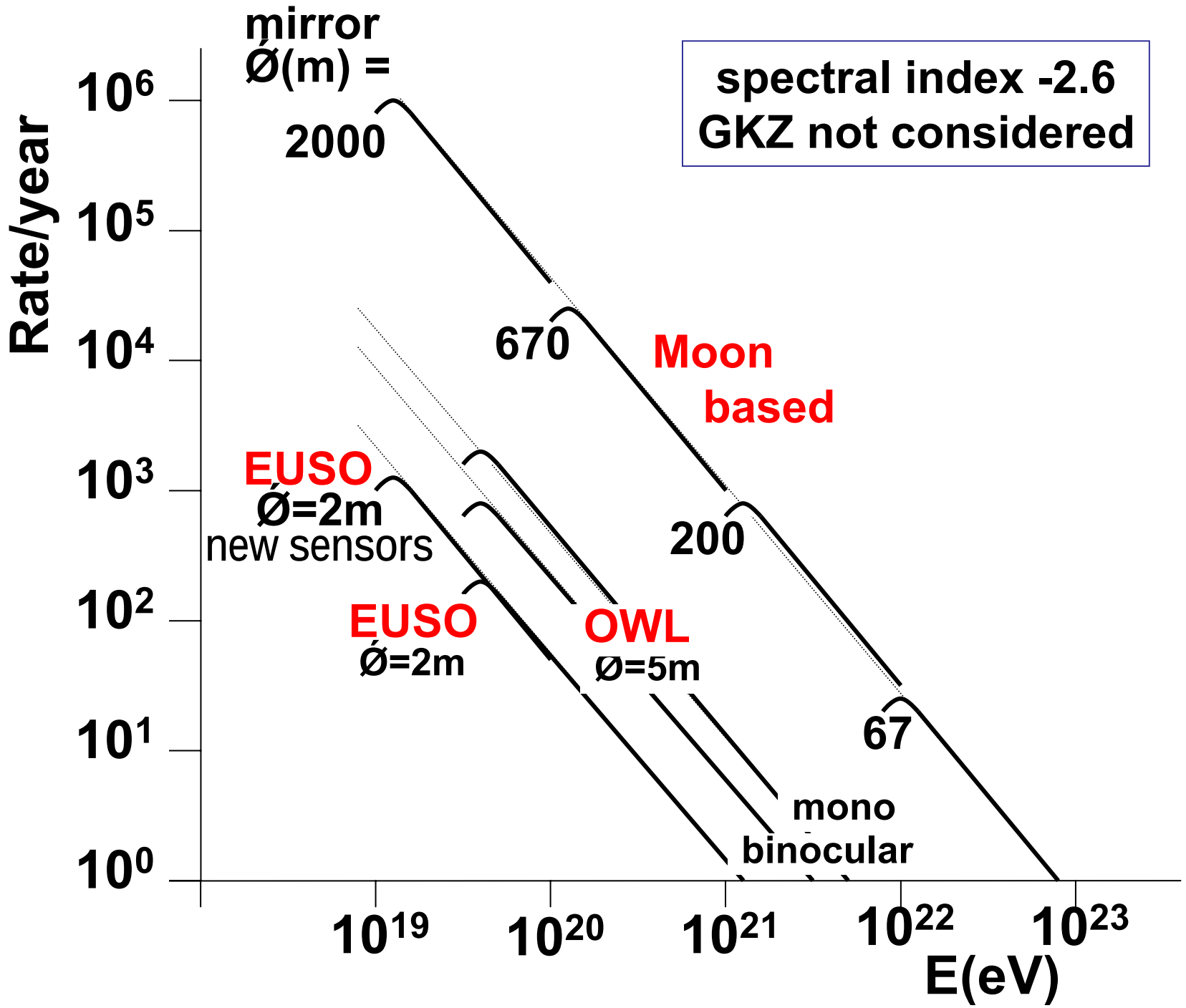
Lunar facility for UHE gamma rays and UHE Cosmic Rays (several ~100 m²sr modules)

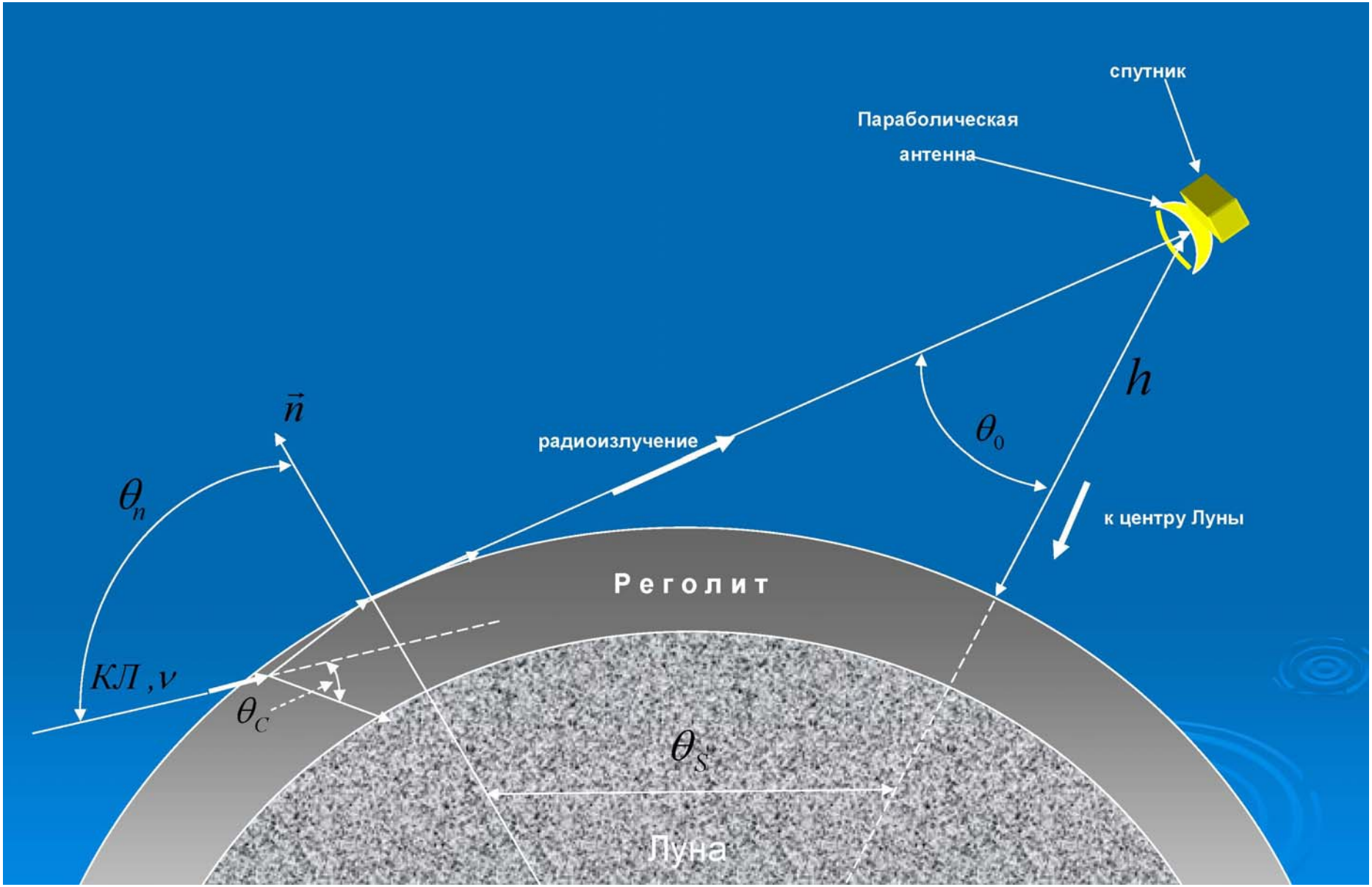


5 Extreme Energy CR

[AUGER, EUSO, TUS, KLYPVE?, OWL??]




mirror
Ø(m) =
2000
670
200
67
Moon
based
EUSO
Ø=2m
new sensors
EUSO
Ø=2m
OWL
Ø=5m
mono
binocular
spectral index -2.6
GKZ not considered
Rate/year
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{19}
10^{20}
10^{21}
10^{22}
10^{23}
E(eV)


спутник
Параболическая
антенна
радиоизлучение
$\vec{n}$
θ_n
θ_0
h
к центру Луны
Реголит
КЛ , ν
θ_C
θ_S
Луна

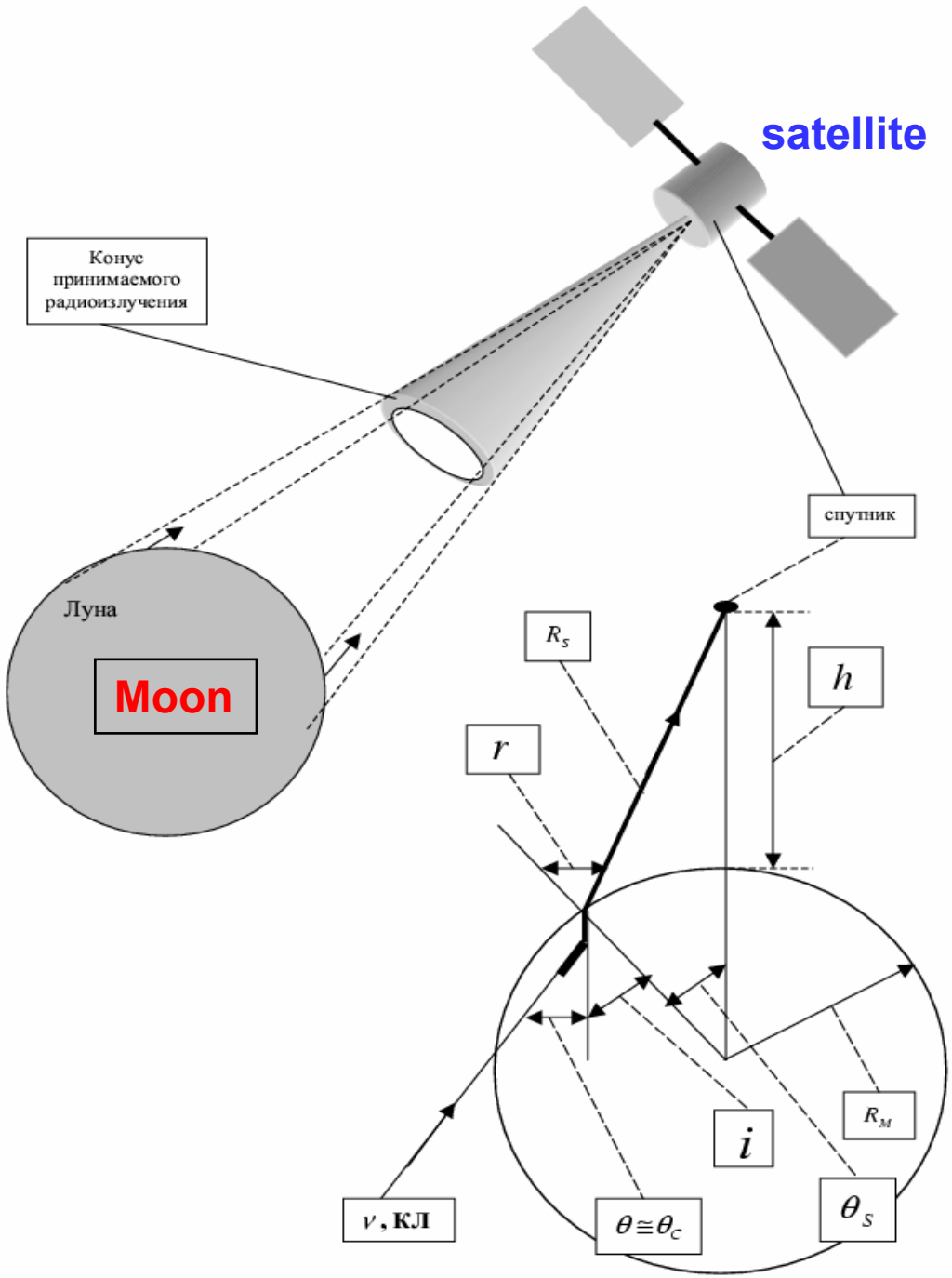
Geometry

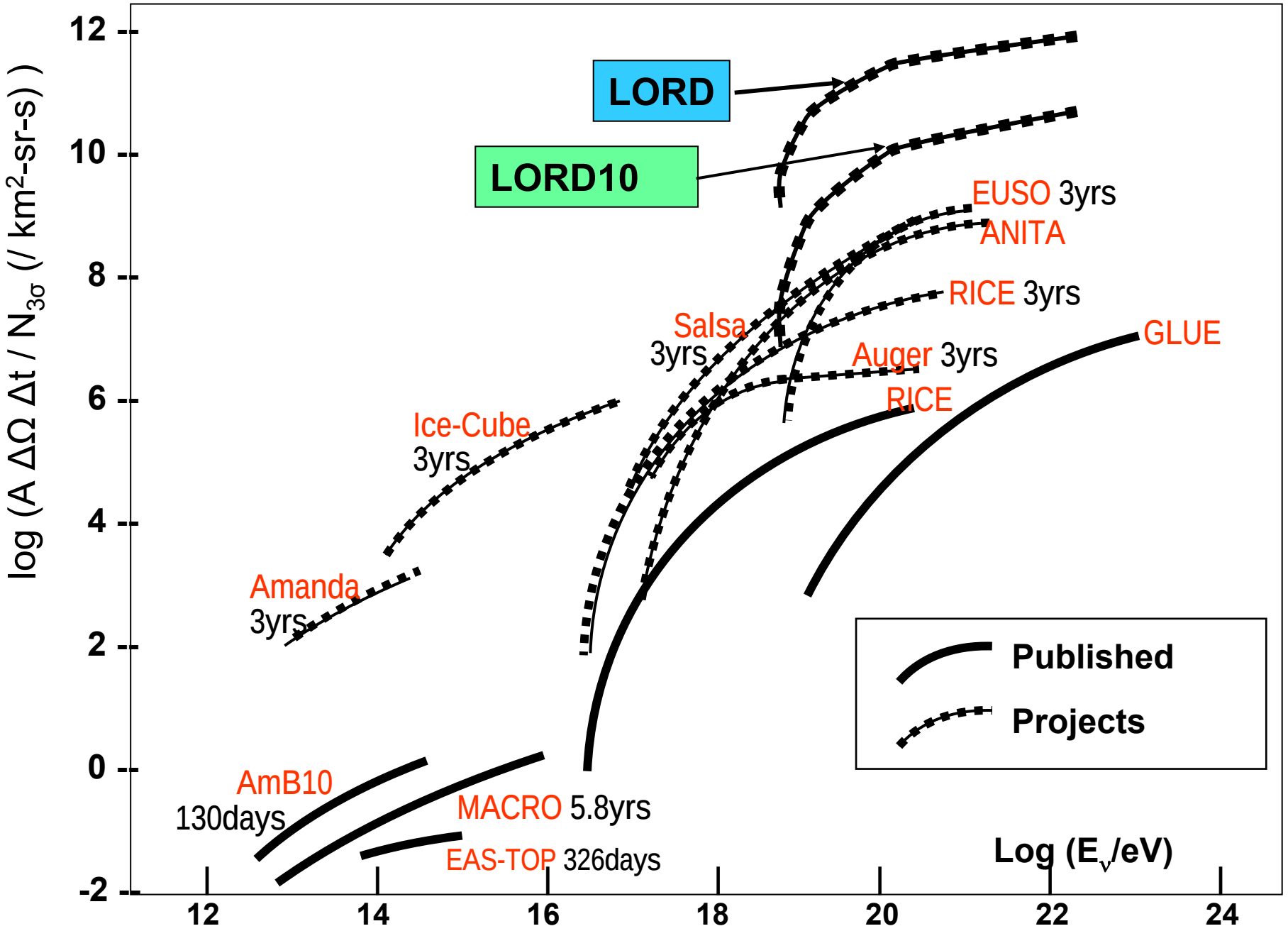
of the LORD

experiment

h: from a few tens to a few thousands of km

R_m ~ 1740 km




LORD
LORD10
EUSO 3yrs
ANITA
RICE 3yrs
Salsa
3yrs
Auger 3yrs
RICE
GLUE
Ice-Cube
3yrs
Amanda
3yrs
AmB10
130days
MACRO 5.8yrs
EAS-TOP 326days
Published
Projects
log (A ΔΩ Δt / N3σ (/ km2-sr-s))
Log (Eν/eV)
12
10
8
6
4
2
0
-2
12
14
16
18
20
22
24

A new actor on the scene of CR from space?

neutrino

new instrument for
Astrophysics,
Cosmology,
Particle Physics

By products (or basic services, or (zero -1) generation experiments)

Monitor of **sun activity** (em, charged particle (identified), neutrons)

Direction of **high energy SCR** from CME (for radiation protection)

Unbiased **monitor of GCR flux and composition** (climate long range change)

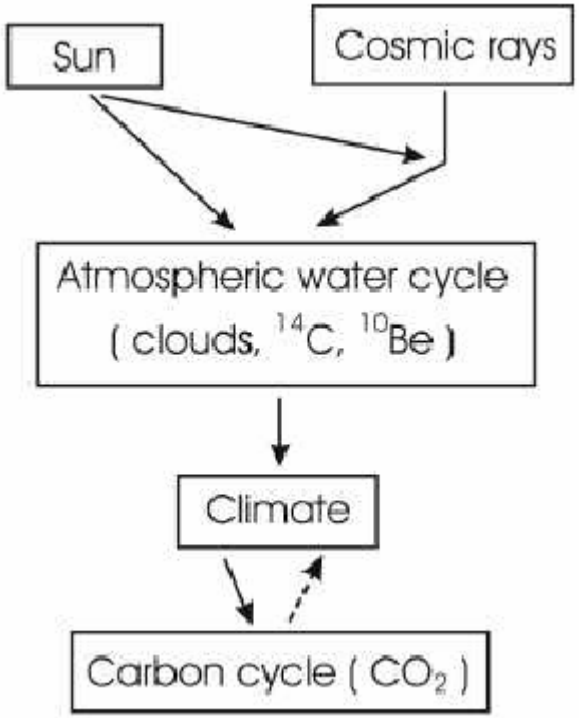
Global **Earth scanning** (pixel < 50x50 km^2 possible) in UV, optical, infrared (many uses, including continuous forecasting of fast phenomena formation)

Cosmic Rays and Climate Change:

Some new Hypotheses/Data

"The Chicken (CR) or the Egg (CO2, CH4)"

Model of Celestial Forcing of Climate Change



Sun activity filters the Galactic CR flux
GCR interact with the atmosphere and
- affect CO2 cicle
- affect climate

climate long range change conclusion:

- The **Lunar Cosmic Rays Water Observatory** may be the single most important scientific facility for answering this most fundamental of all questions: **the role of cosmic radiation on climate change**
- Other climate related observations from the Moon
  - Direct measurement of **Luminescence** variations of the Earth
  - Direct, continuous, multispectral **Observations of the Sun**
  - Direct observations of the **Sun-Earth Interactions** (magnetic fields, cosmic rays impacts, cloud formation, irradiance …)
  - **Global Continuous Observations of Earth**
- Vision: **A Lunar Climate Observations Condominium** combining long dwell times, global views, large distributed apertures, stable observation platforms, condominium services (energy, data processing, storage, maintenance, refurbishment …

Спасибо за внимание