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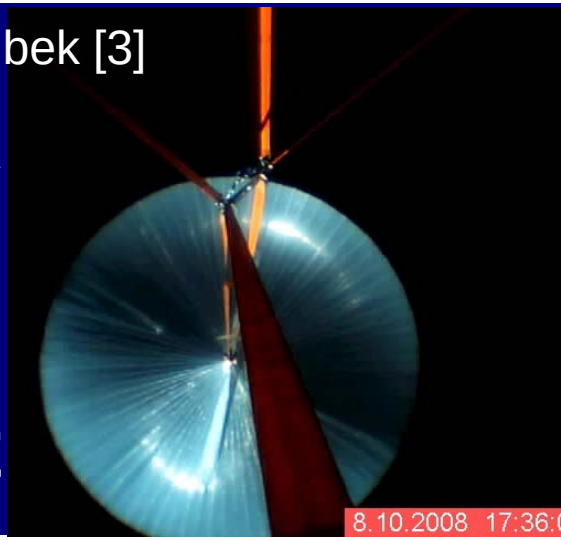
MEDIPIX
CR tracking device flown on ESA BEXUS-7 stratospheric balloon flight

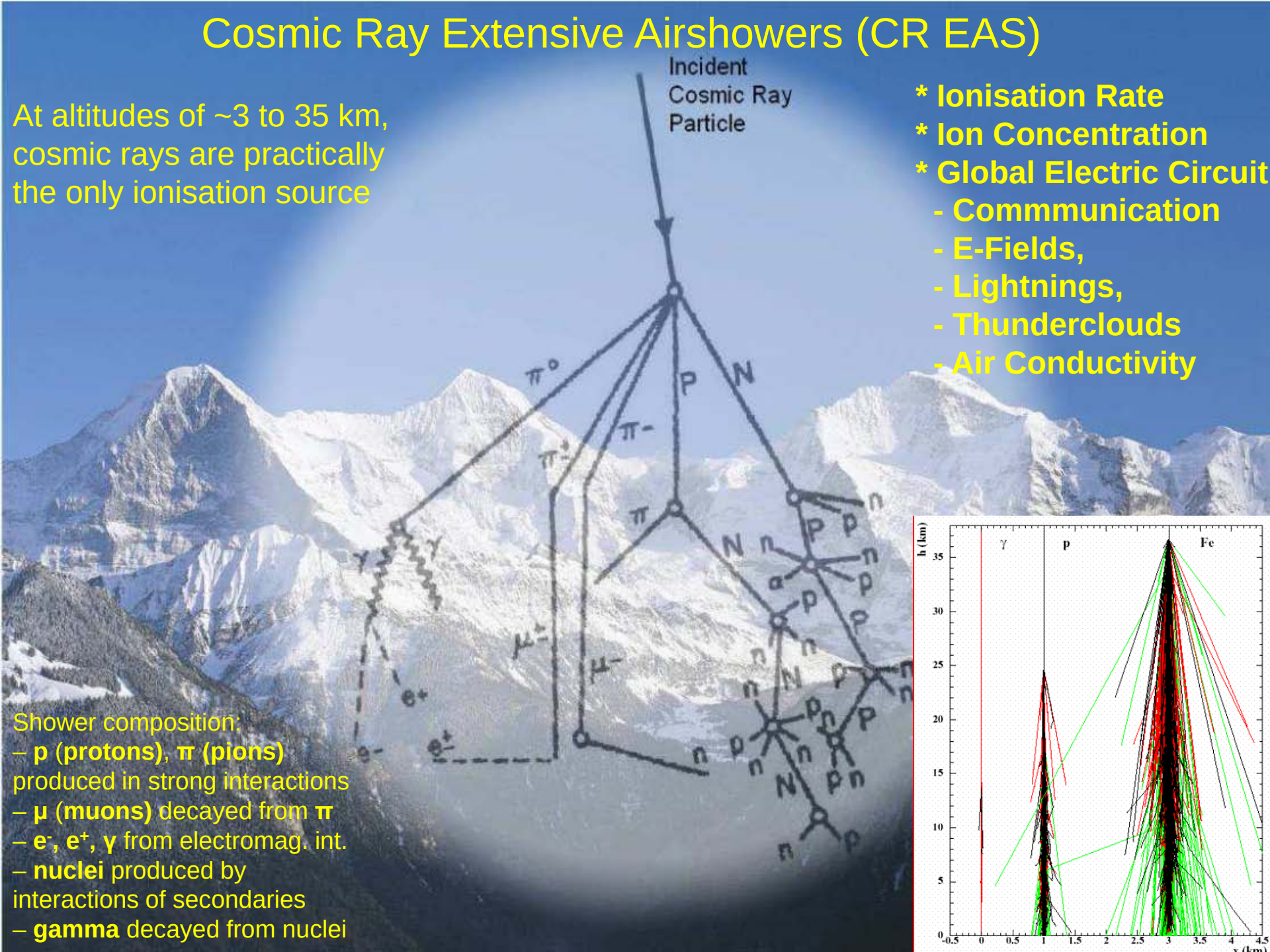


Abstract:

Results of the first student experiment using a MEDIPIX-type detector for CR imaging in stratospheric environment are presented. The detector was used in its tracking mode allowing it to operate as an "active nuclear emulsion". The actual flight time was over 4 hours, with 2 hours at stable floating altitude of 26km. Different types of cosmic ray particles were acquired in the stratospheric radiation environment, sorted and analyzed. Detector performance is evaluated for further design implications of advanced concept focusing on Cosmic Ray Induced Ionization measurement.

Cosmic Ray Extensive Airshowers (CR EAS)

At altitudes of ~3 to 35 km, cosmic rays are practically the only ionisation source



*** Ionisation Rate**
*** Ion Concentration**
*** Global Electric Circuit**
- **Commmunication**
- **E-Fields,**
- **Lightnings,**
- **Thunderclouds**
- **Air Conductivity**

Shower composition:
– **p** (**protons**), **π** (**pions**) produced in strong interactions
– **μ** (**muons**) decayed from **π**
– **e⁻, e⁺, γ** from electromag. int.
– **nuclei** produced by interactions of secondaries
– **gamma** decayed from nuclei

Solid State imaging detector Medipix2

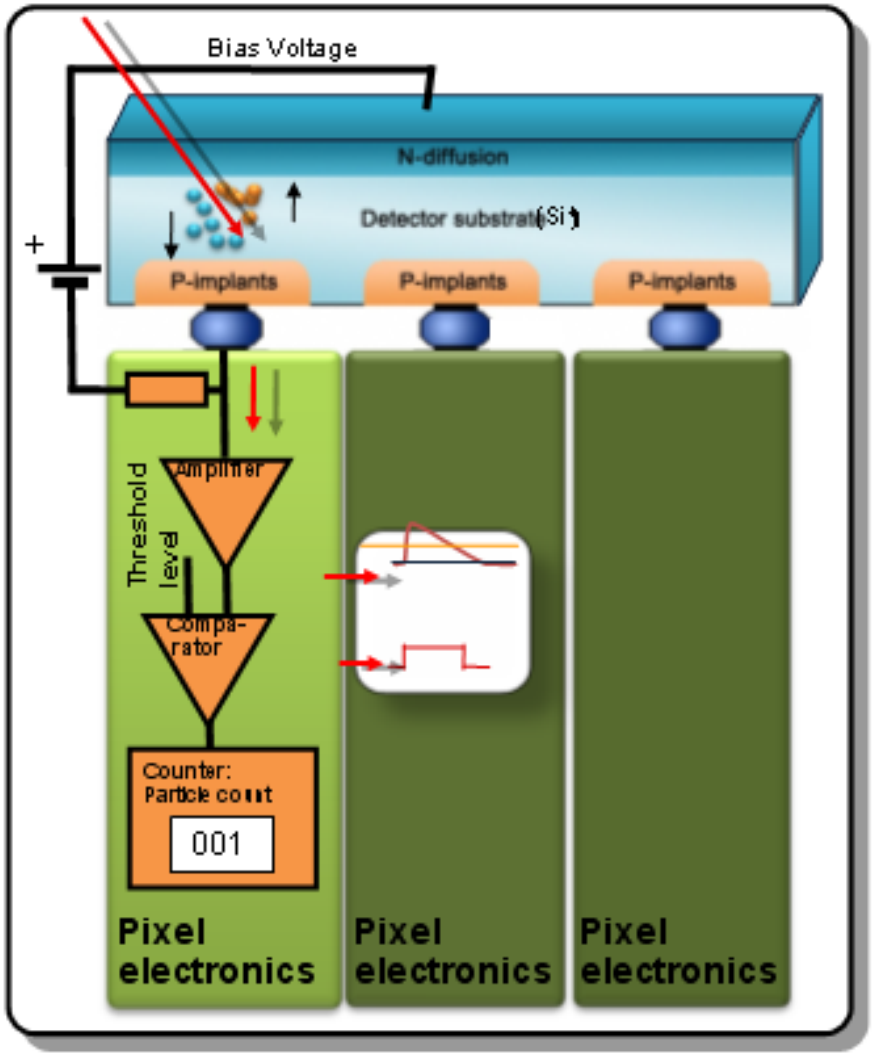
developed at CERN with USB interface developed at IEAP CTU in Prague

Planar pixel detector (700μm Si) bump-bond to read-out chip

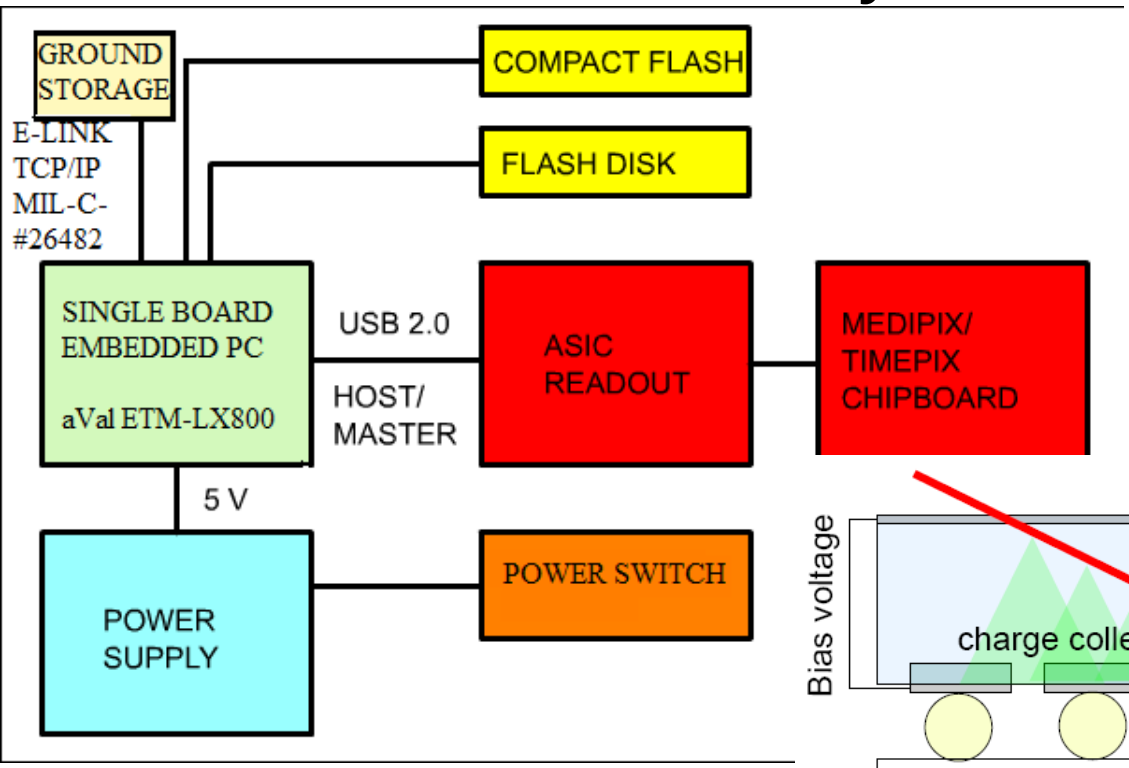
Ionizing particle creates a charge in a sensitive volume

The charge is amplified and compared with a threshold

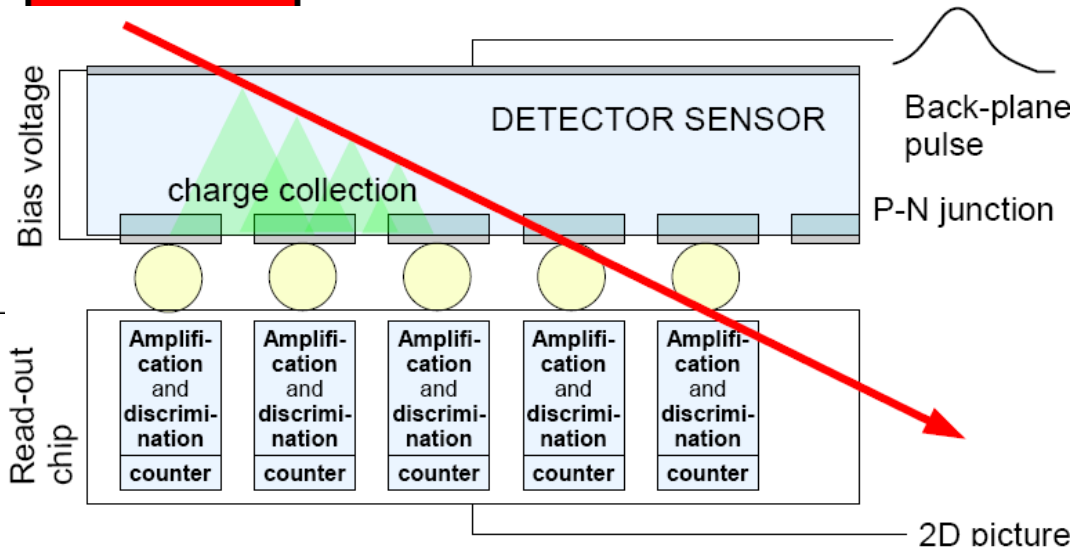
Digital counter is incremented.



TimePiX System Overview



- Single Board computer AMD Geode 500MHz
- Ethernet Interface
- Solid State HDD (Compact Flash)
- Medipix2 Detector

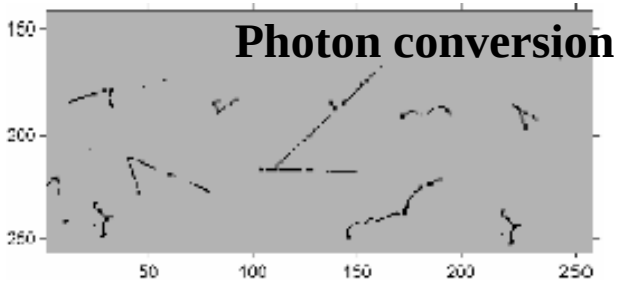


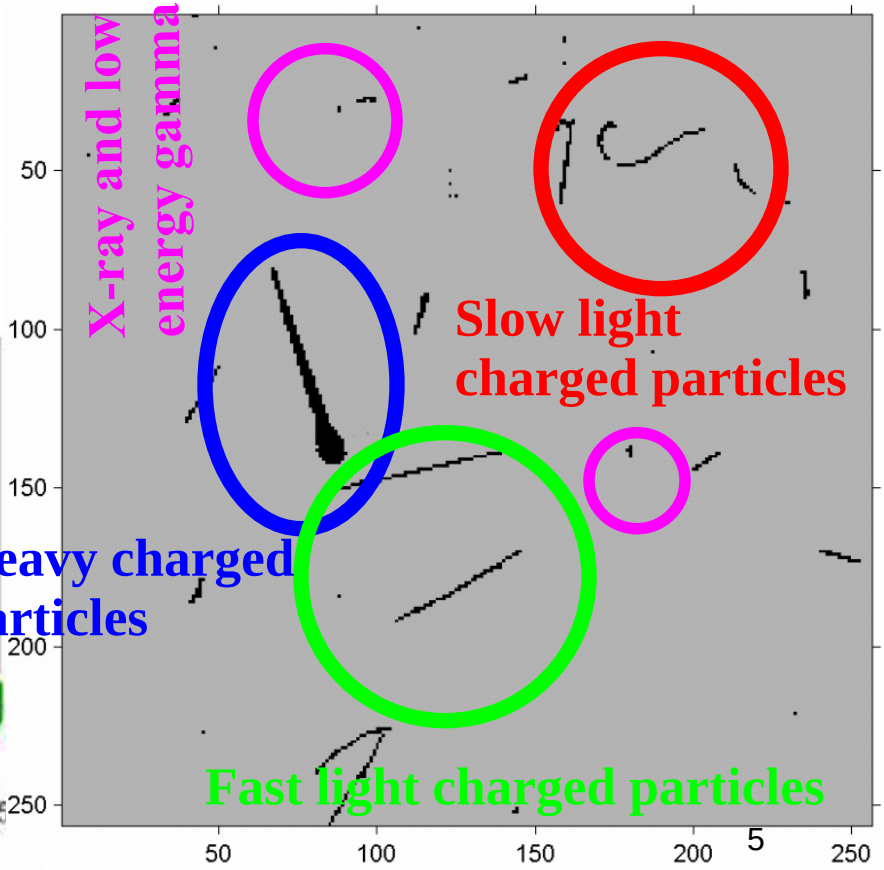
Particle detectors are based on:
Energy deposited in the active material of the detector is transformed into charge (by ionization in gaseous detectors/ by excitation of electron-hole pairs in semiconductor ones). The charge is then collected by read-out electronics.

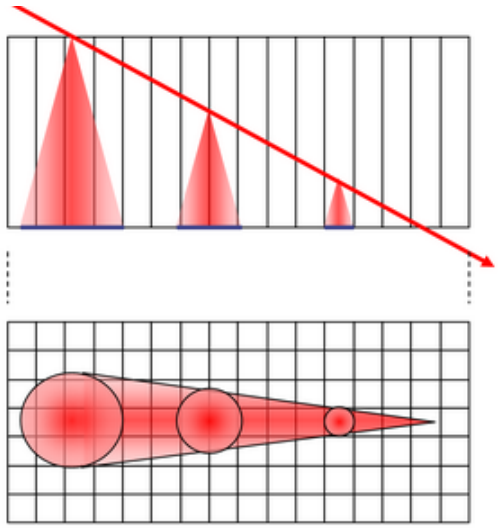
Unique tracking data for particle type identification

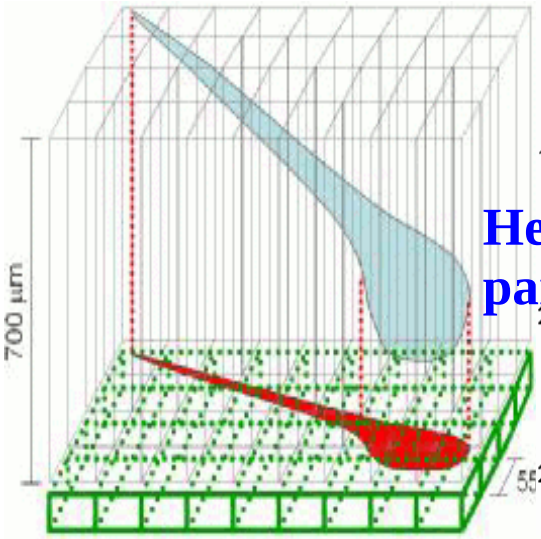
Identification criteria:

- track shape (pattern recognition algorithms: cluster area, linear dimensions, complexity)
- total energy deposited in the sensor (from the amplitude of the back-plane pulse MEDIPIX2)
- Sensitivity range 8keV ~ 100MeV





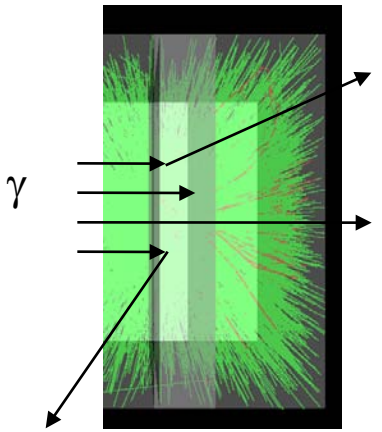


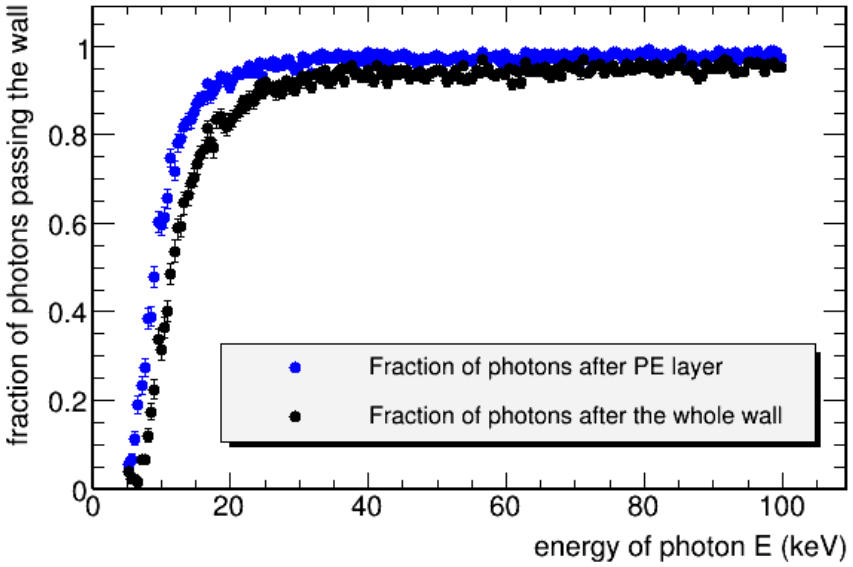


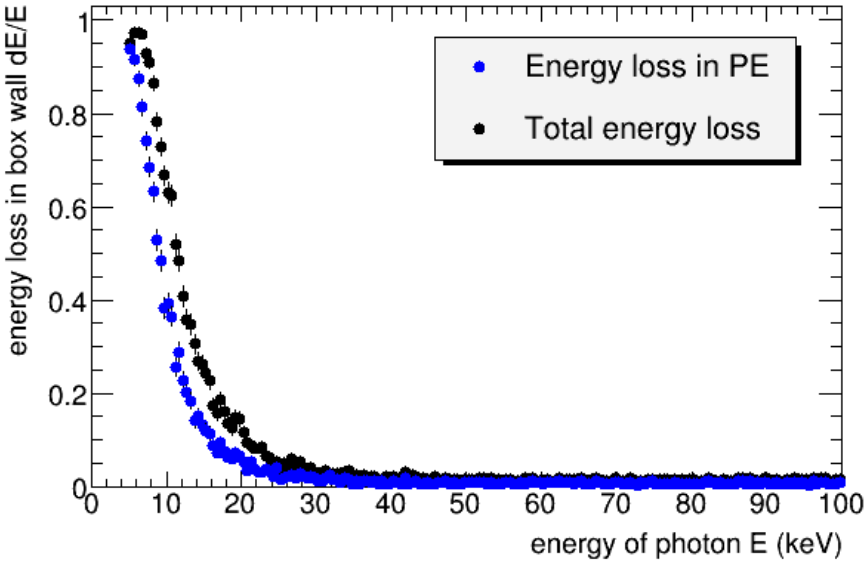
Photon passage through box wall by GEANT4

Photons are absorbed or reflected by box wall.

At 20 keV, 80% photons will pass through. Threshold on collected charge is applied on every pixel for correction of specific deposited charge effect of e-h pair creation (3.65 eV).

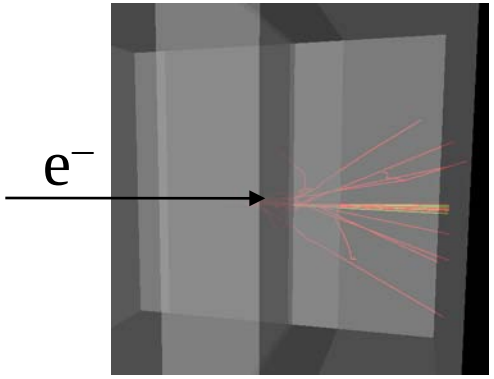


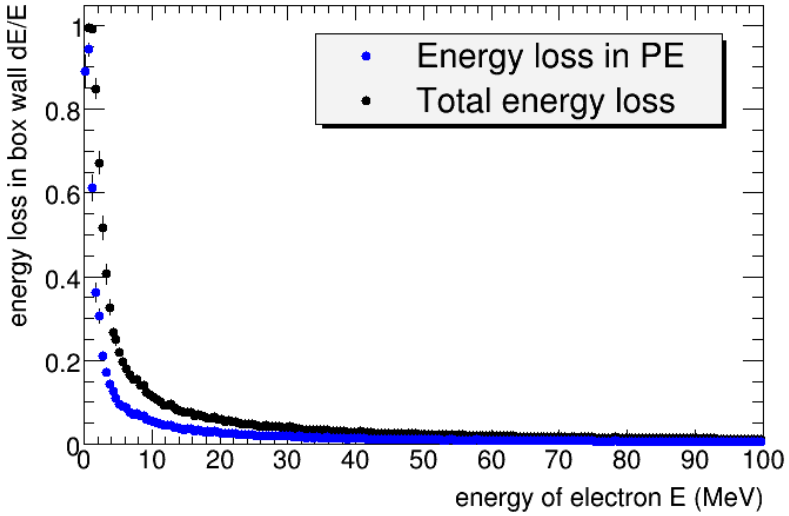


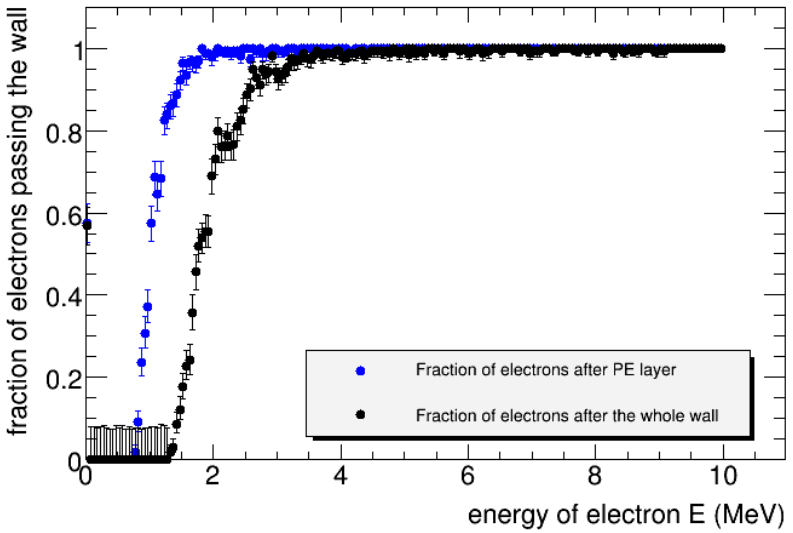


Electron passage through box wall by GEANT4

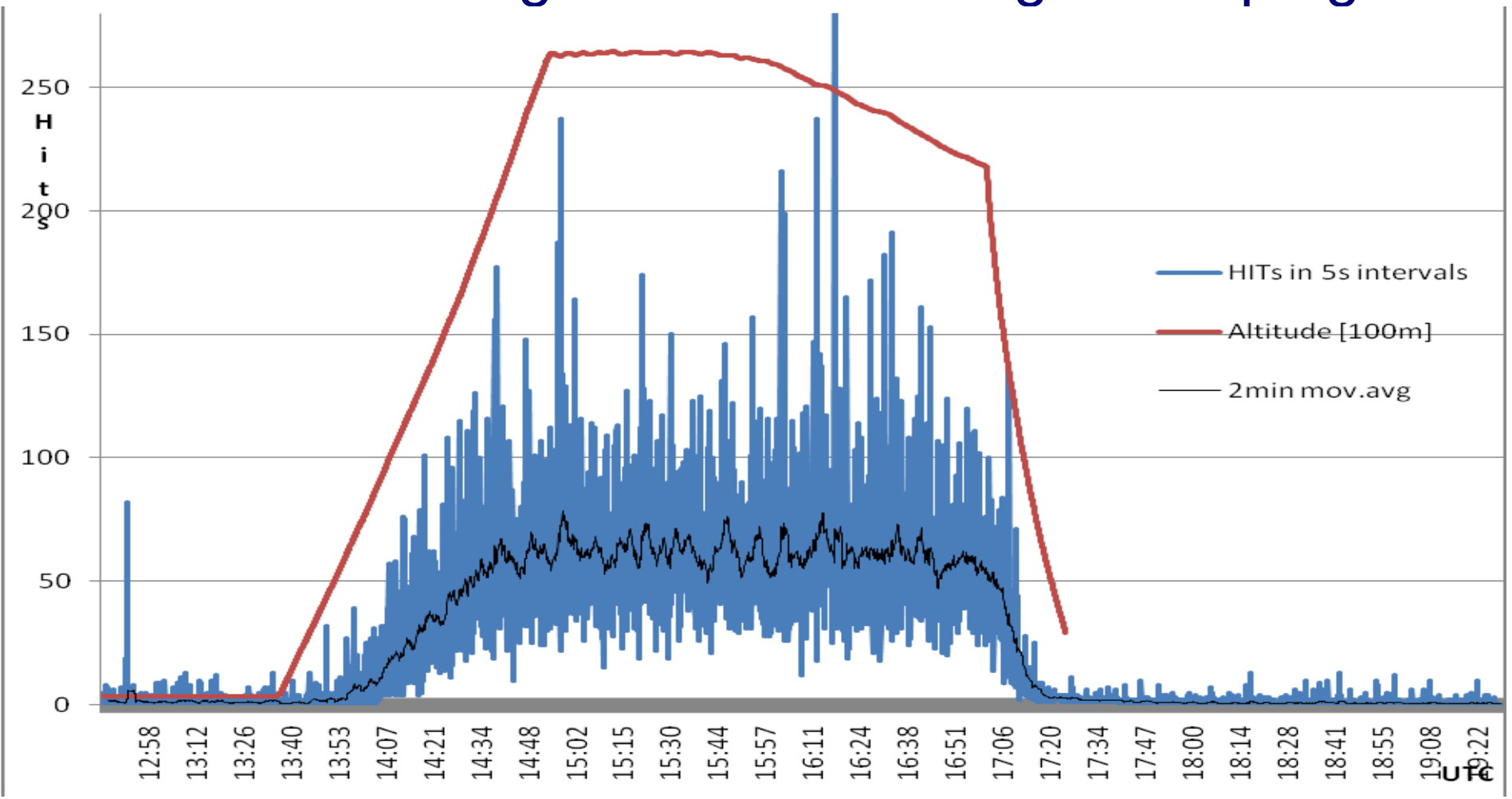
Electrons loose much more energy than photons since they have a charge. From this reason about 50% electrons of 2 MeV will be absorbed in the wall as the simulations demonstrate. PE box enclosing the main detector enables registration of electrons in the MeV range, while converting them to lower energies. Only then they can leave charge passing the detector efficiently enough. Overall charge deposited by electrons sensor >10x larger compared to photons.





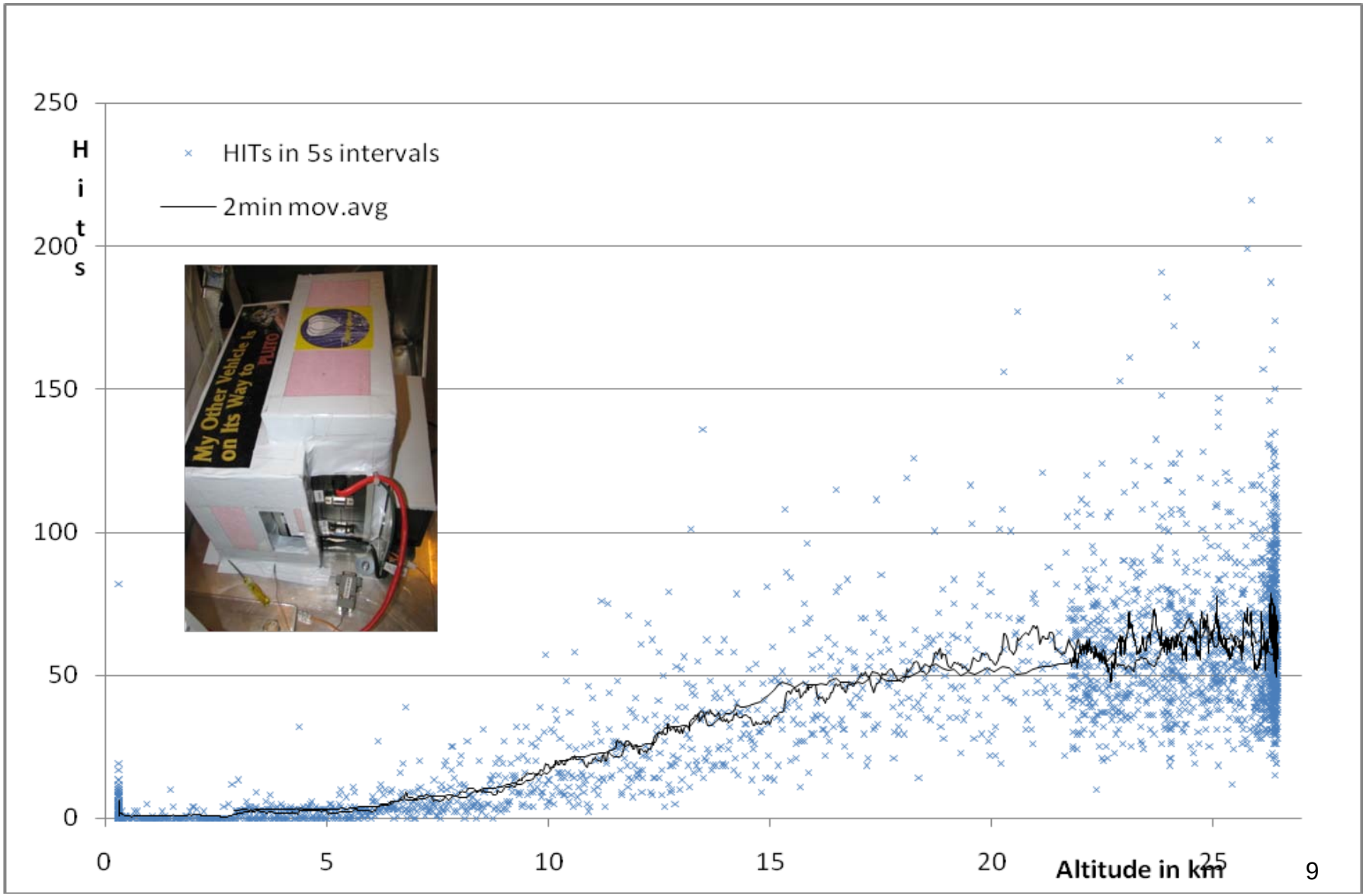


Flight profile HITs (pixels with signal in 5sec) as measured during the BEXUS-7 flight campaign

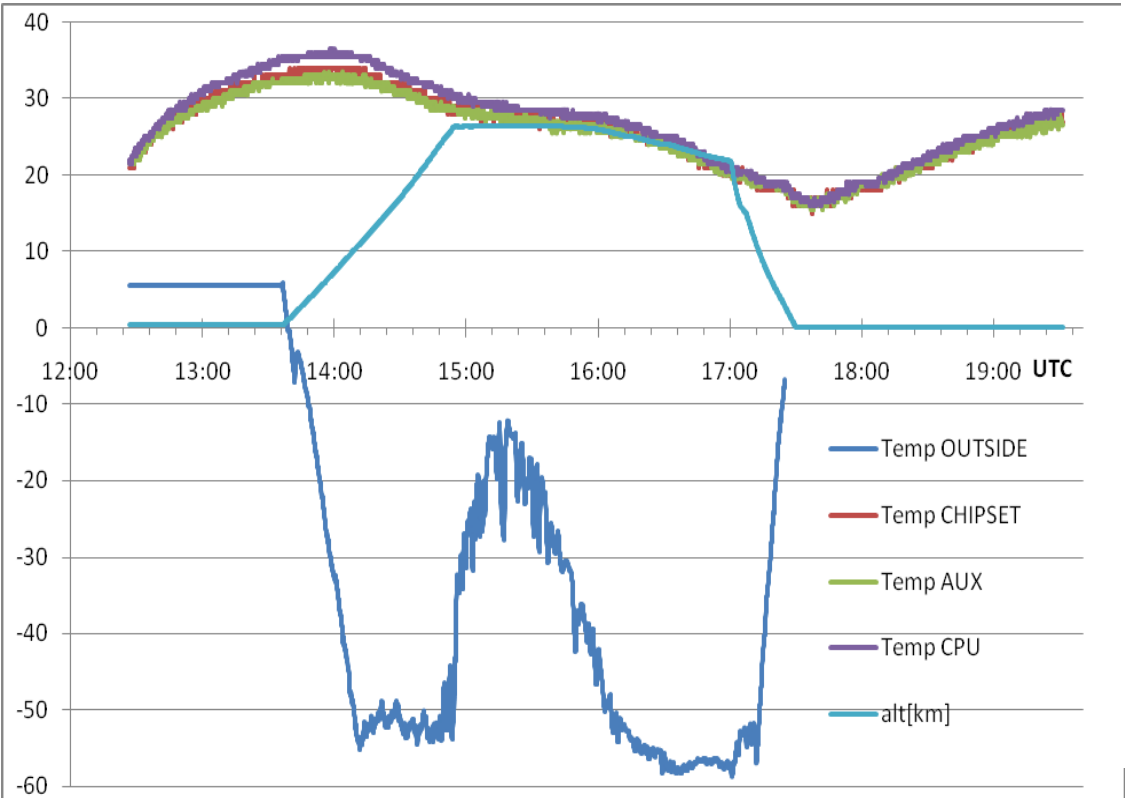


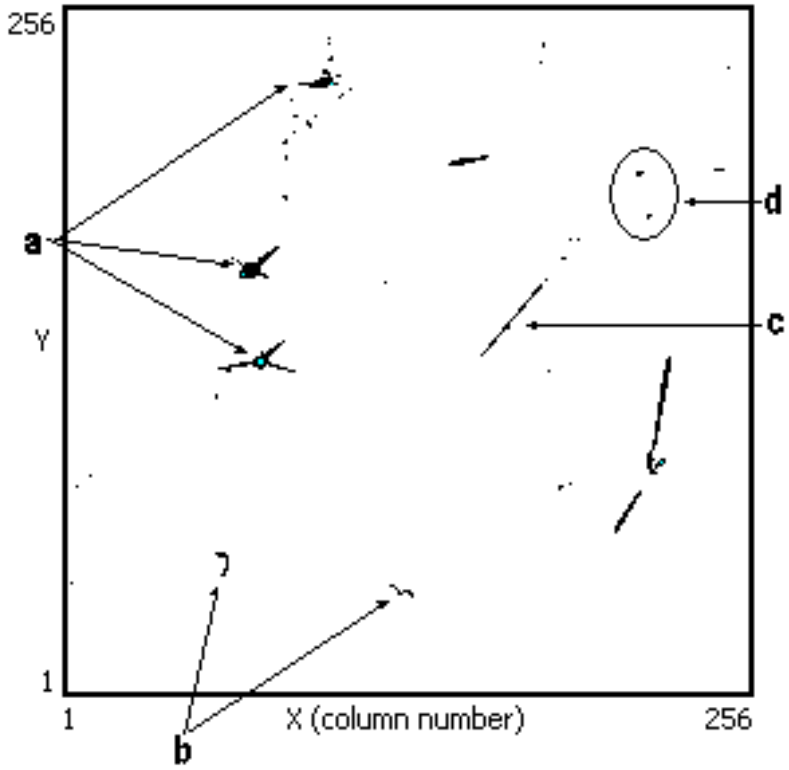
Experiment took place in arctic stratosphere, associated with high-geomagnetic latitude, corresponding to geomagnetic cut-off rigidity of 280 MV. That, along with ongoing Solar MINima, providing relat. high CR flux WITH *PARTICLE TYPES* AND *ENERGY* data.

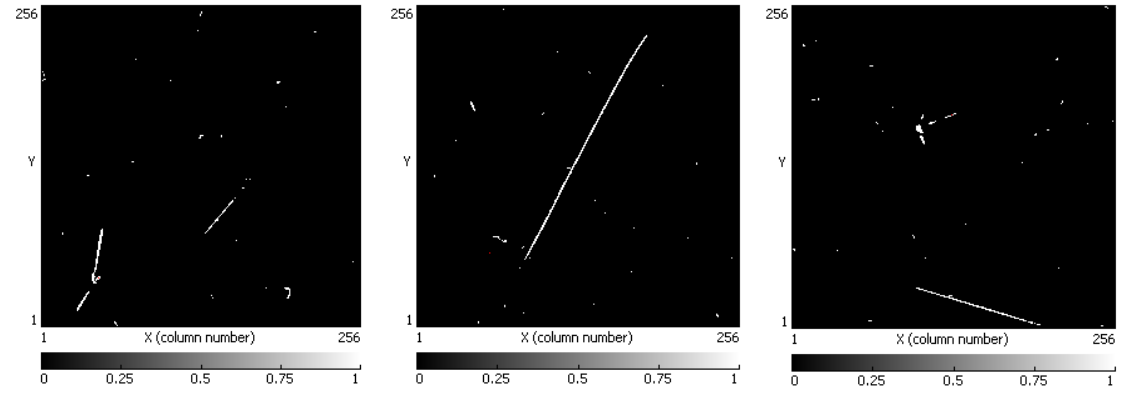
Altitude dependent ionization rate in Medipix2



Medipix systems' flight performance







Ionizing radiation tracks acquired in stratosphere, particle pattern identification-by-track concept:
a- Heavy charged particles,
b- Slow light charged particles,
c- Fast light charged particles,
d- X-rays, low energy gamma

CRindIons team

Novel concept of parallel in-situ measurement of the CosmicRay Induced Ionization rate by SSD with the ion concentration by means of:

Ionization-vetoed breakdown Voltage =>
Formation of ions in Earth Atmosphere

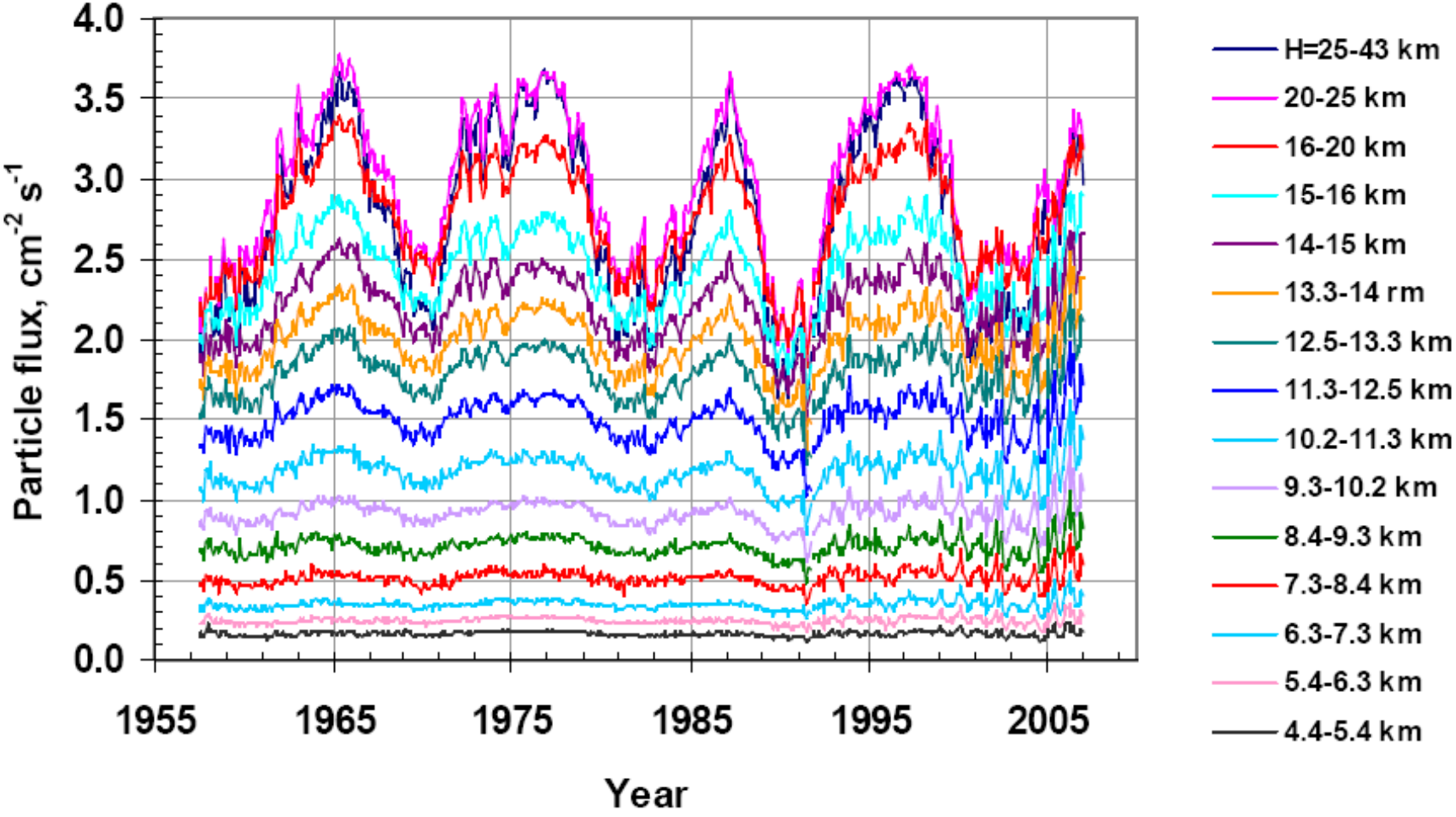
Ongoing STUDENT project on BEXUS8/9 with launch campaign Oct 2009

Luleå University of Technology, Sweden
Czech Technical University in Prague,
Charles University in Prague, Czech Republic

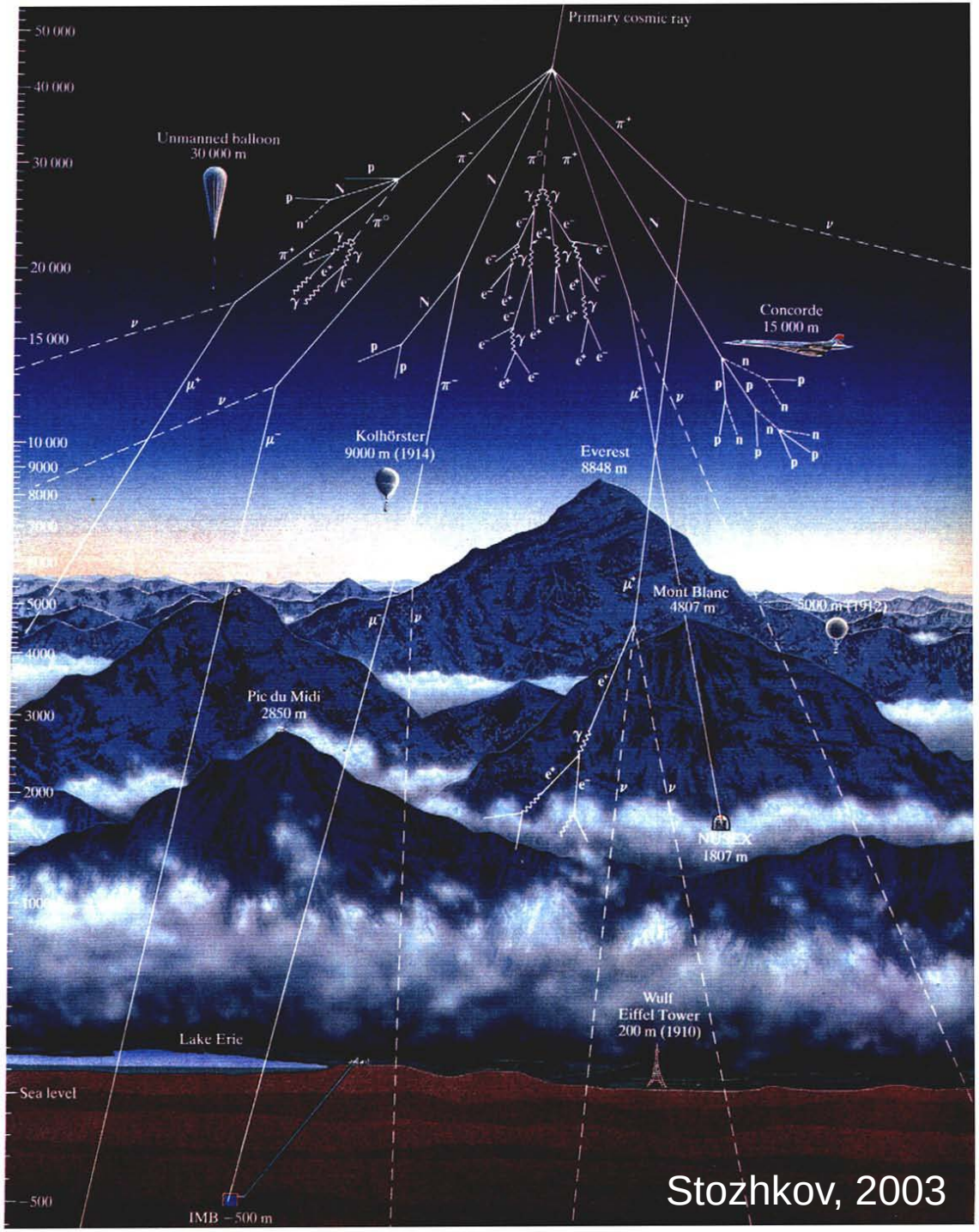
CRIndIons: Multiple Objectives

- On-flight comparison between TWO Medipix2 detectors – one with fast NEUTRON converter (PE)
- Intercalibration of multiple SSDs – Medipix2 with STANDARD RAS sonde Geiger tube (on-ground)
- Ionization rate measurement ~ Medipix2 pixel HITs
- Breakdown voltage measured by 2 IONIZ. TUBEs
- Particle energy estimation from backside pulse
- Coinc. Medipix HW trigger⇔shower arrival direction
- 2 IONIZ. Tubes w.diff.shield ⇔CR-induced/ambient
- Aerosol conditions (estimate by ESRANGE LIDAR)

Ionizing particle FLUXes – BUT w/o particle types...



Monthly averaged fluxes of ionizing particles in the atmosphere over Murmansk region as measured by omnidir. Geiger counter (Bazilevskaya, 2007)



Cosmic ray-induced Ion Production rate and Ion Concentration in the Earth's Atmosphere

At altitudes of ~3 to 35 km, cosmic rays are practically the only ionisation source

Ion production rate q

$$q = I \rho \sigma / M$$

$I = I(h, R_c, \Phi)$ cosmic ray flux

ρ air density

σ eff. ionisation cross section

$\approx 2 \times 10^{-18}$ cm^2 at $h \leq 20$ km

M average mass of air atom

Ion concentration n

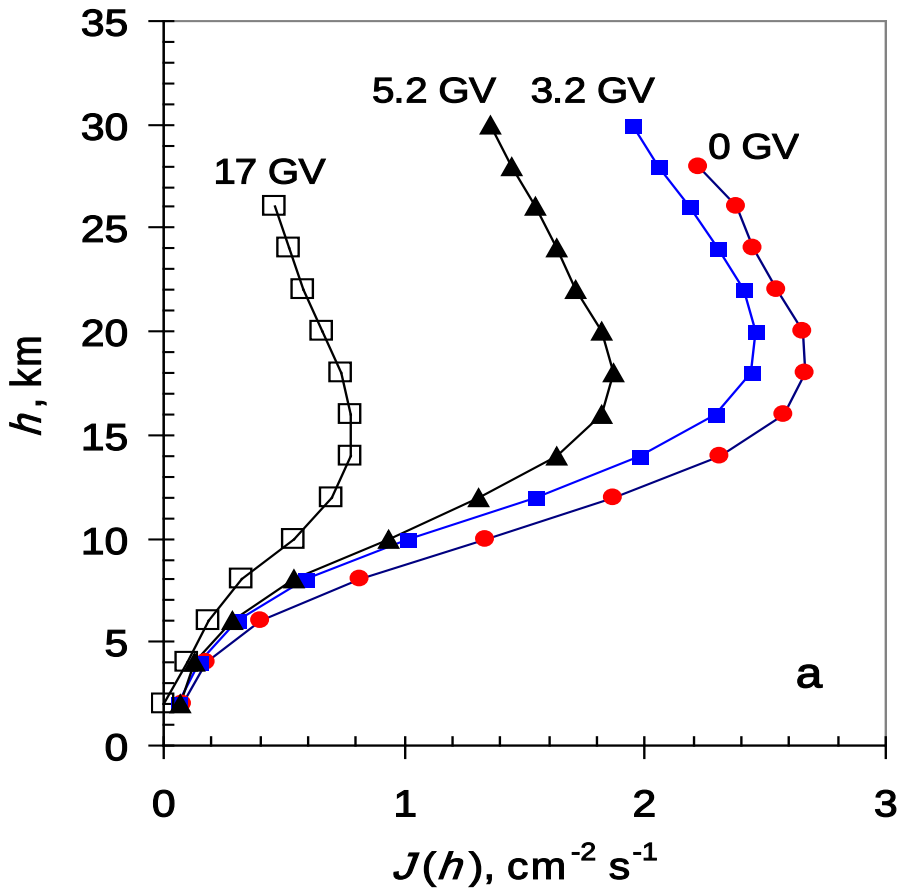
$$q = \alpha n^2$$

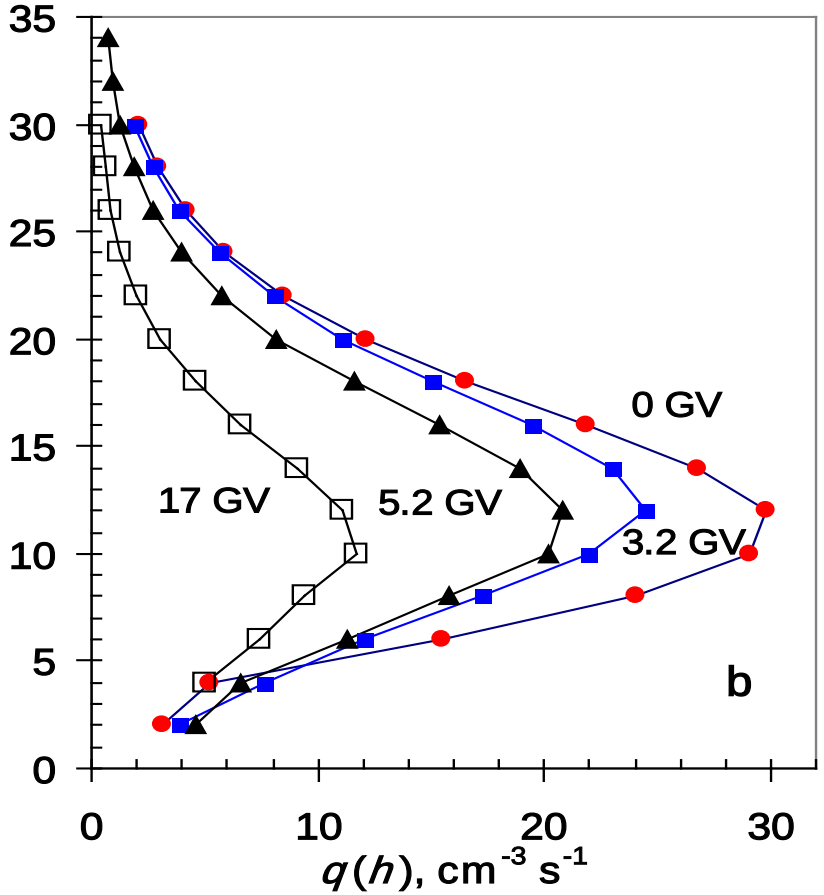
α 3D recombination coefficient

$$q(h) = \beta(h)\, n(h)$$

$\beta(h)$ linear recombination coeff

Modeled CR fluxes vs. Ion production rates (Stozhkov, 2008)

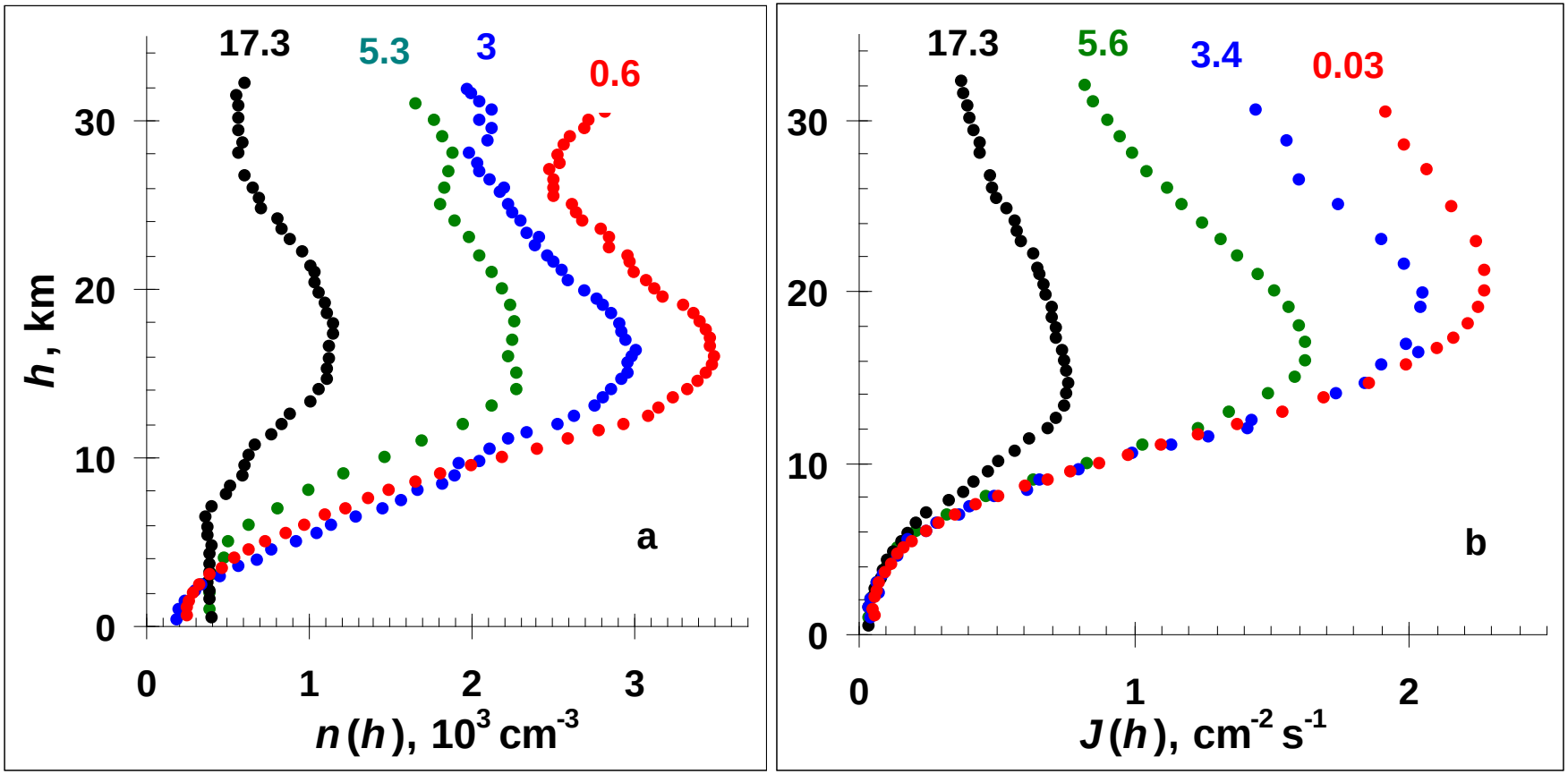




Left: altitudinal profiles of CR fluxes *J*(*h*), Right: ion production rate q(*h*)

The values of *J*(*h*) and *q*(*h*) were measured and calculated at the latitudes with different values of R_c (shown near each curve) and correspond to the period of high solar activity level (Stozkhov, 2008)

MEASURED Ion concentrat. vs. CR FLUXes (Stozhkov, 2008)

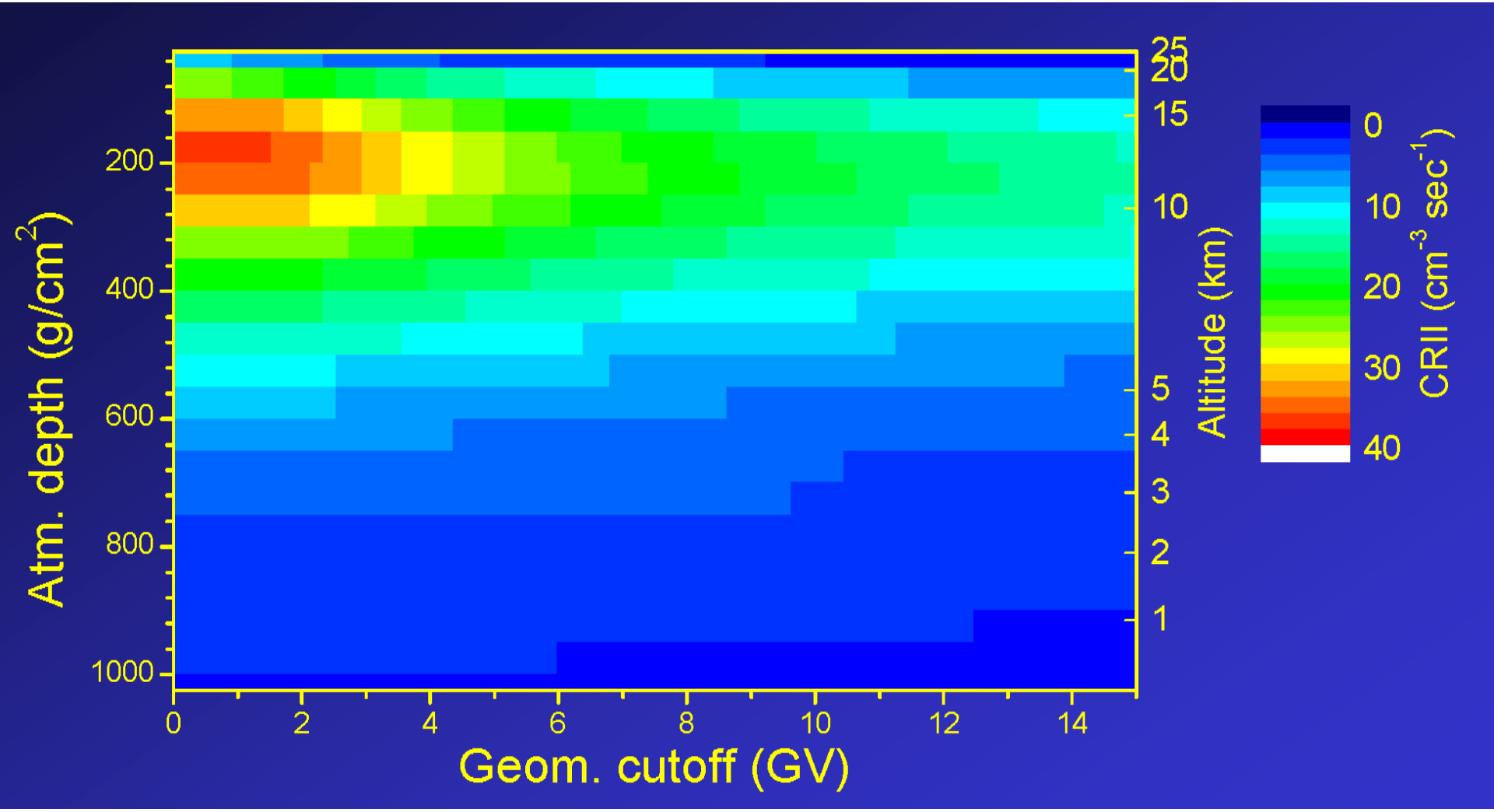


Left: Altitudinal profiles of light ion concentrations $n(h)$

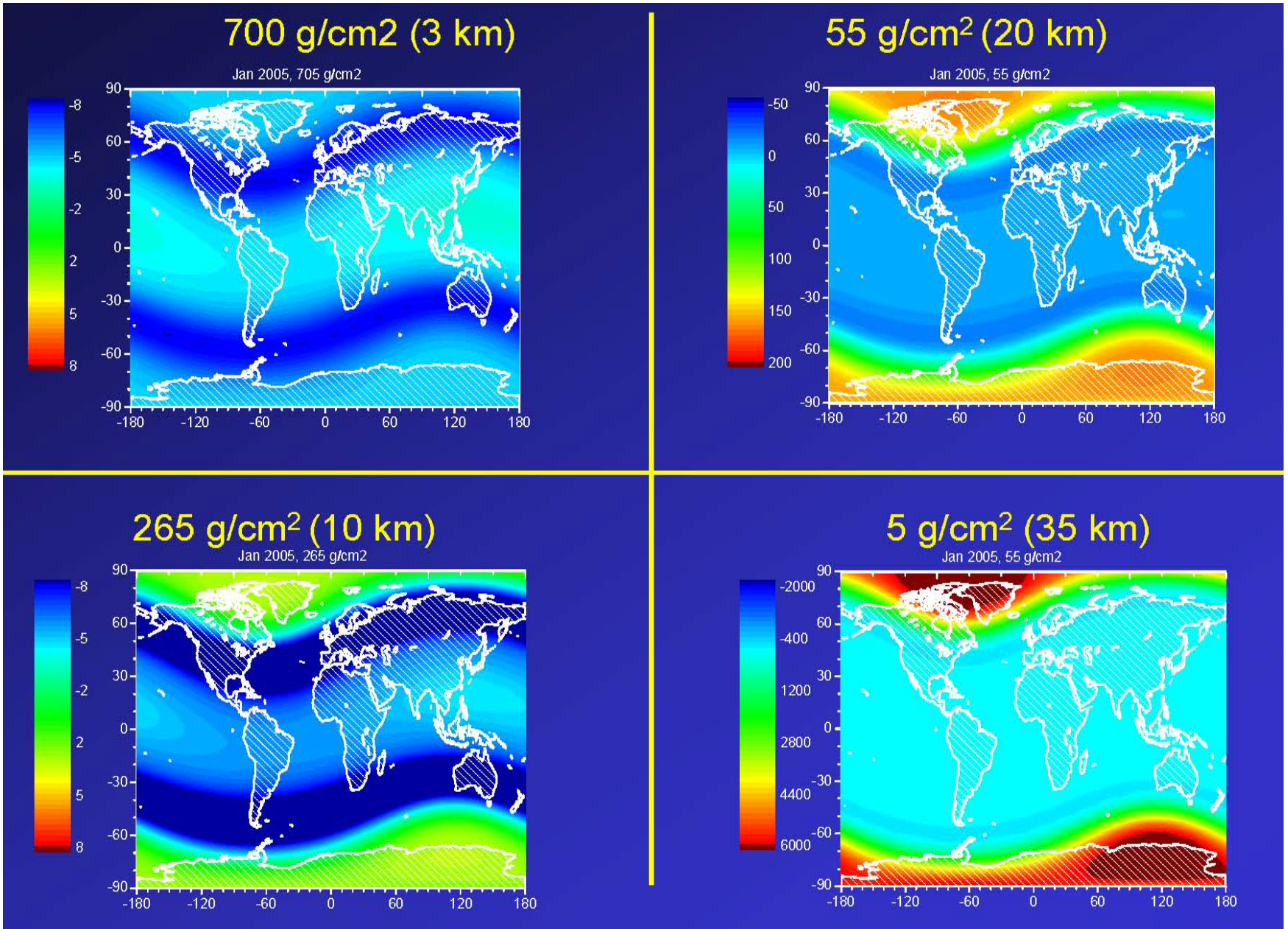
Right: Altitudinal profiles of CR fluxes $J(h)$

These data were obtained during solar activity maximum at the latitudes with different values of R_c (labels near curves) (by Stozkhov, 2008)

OuluCRAC model for Cosmic Ray Induced Ionization: Altitude on geomag. latitude dependence (Usoskin,2004)

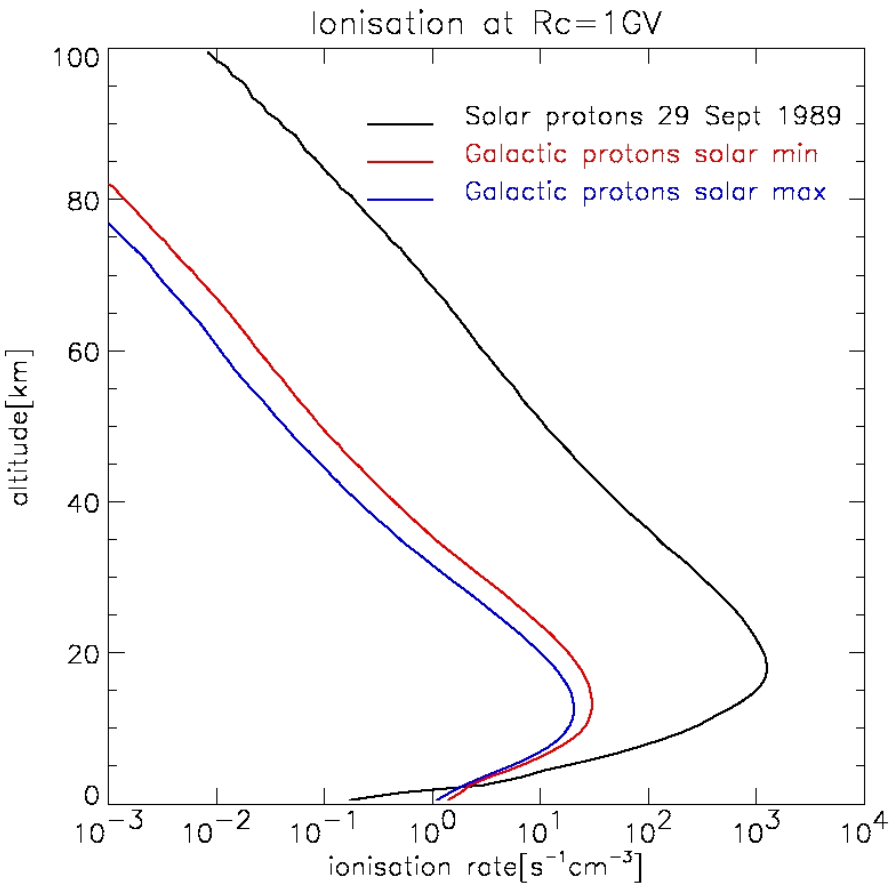


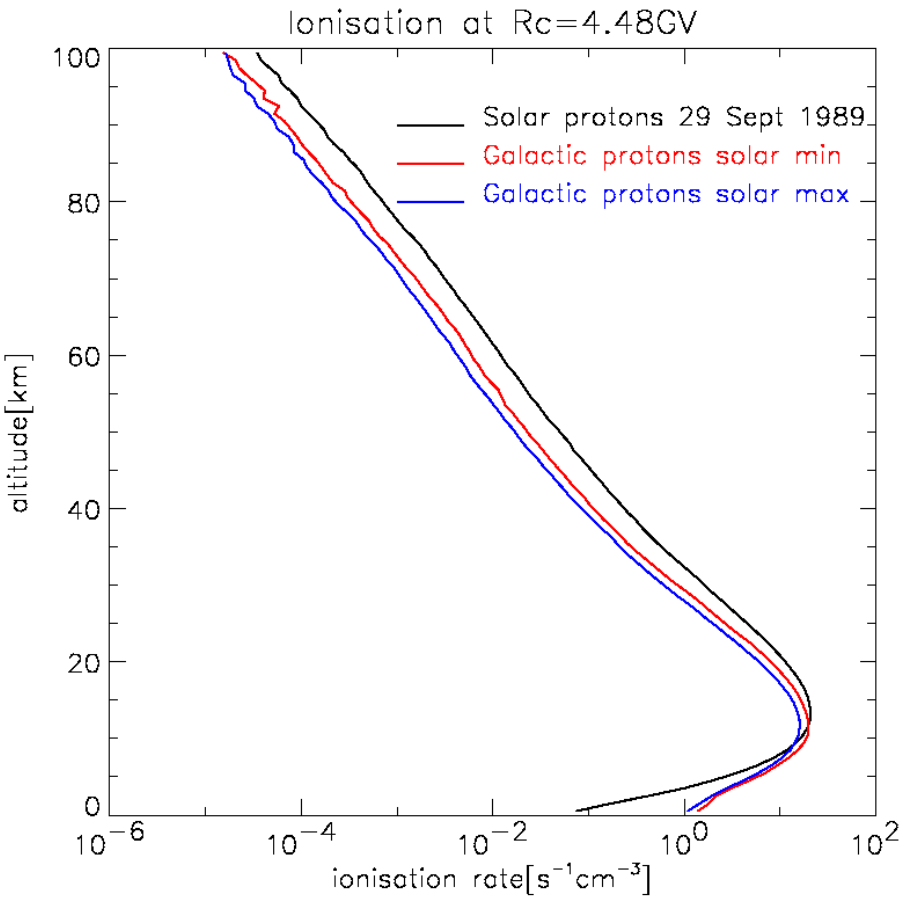
Modeled combined ionization effect of GCR (Usoskin, 2007)



Ionization by GCR & SCR as simulated by PLANETOCOSMICS

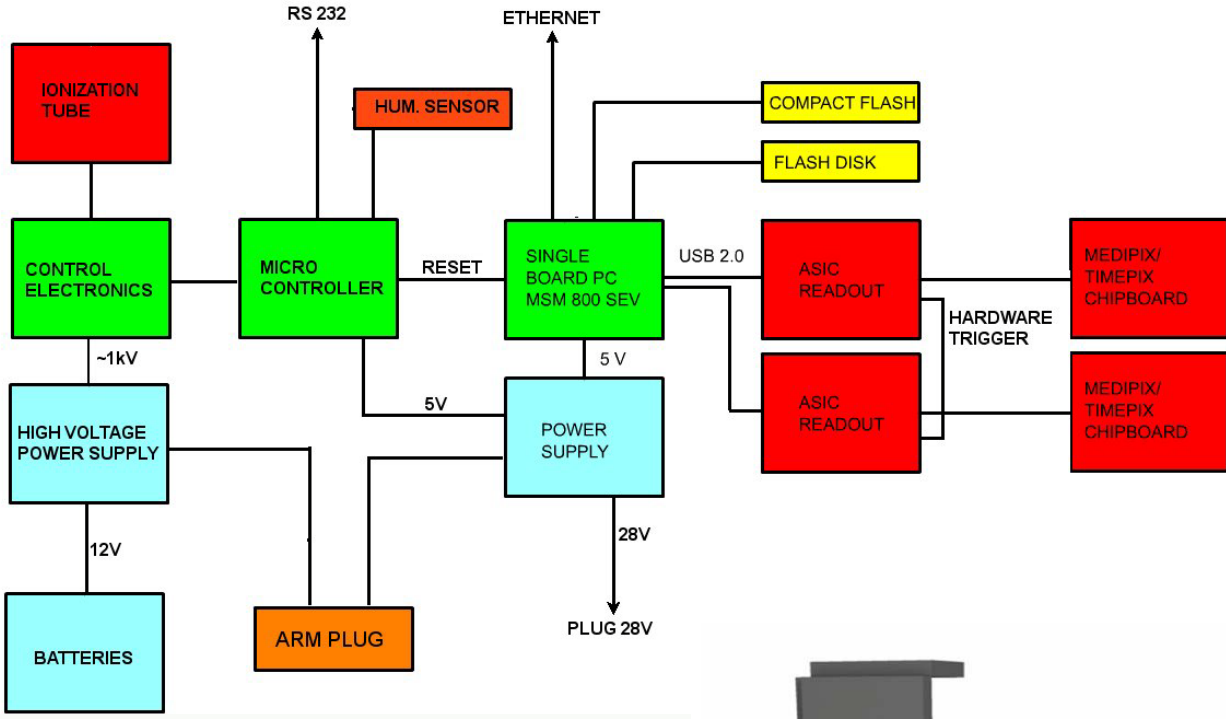
Bern Model, using GEANT4 CERN MC package:
http://cosray.unibe.ch/~laurent/planetocosmics
(Desorgher et al., AOGS 2004)

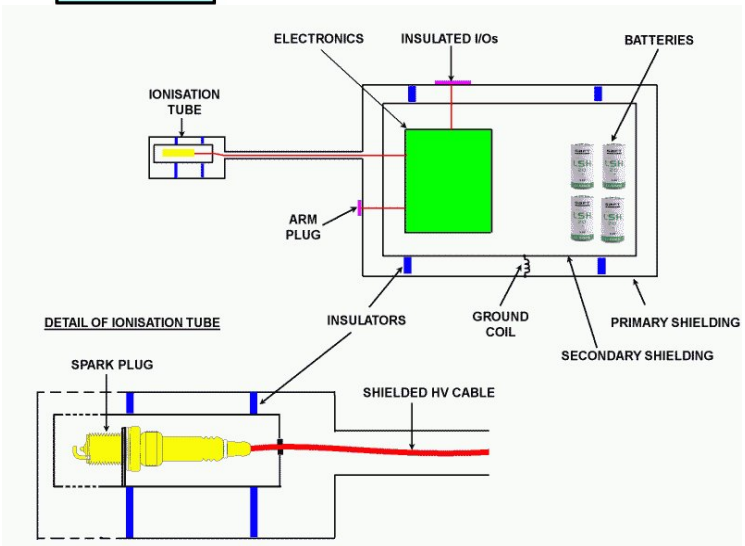


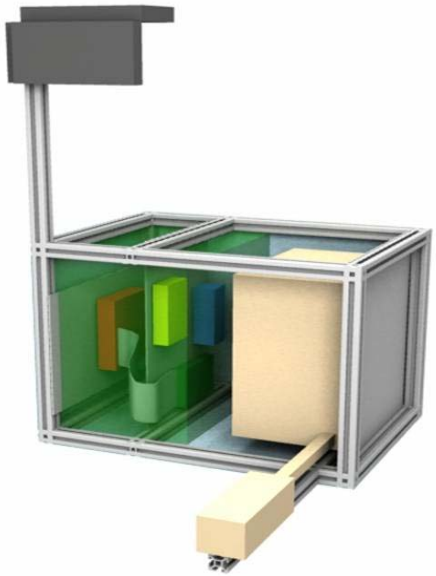


CRIndIons System Overview

- 2 Medipix2 detectors
- Ionization Tube module
- Single Board Industrial Computer AMD 500MHz
- Single-chip MicroController (Ionization time measurements)
- Ethernet, RS 232
- Solid State HDD (CF) backup flash memory



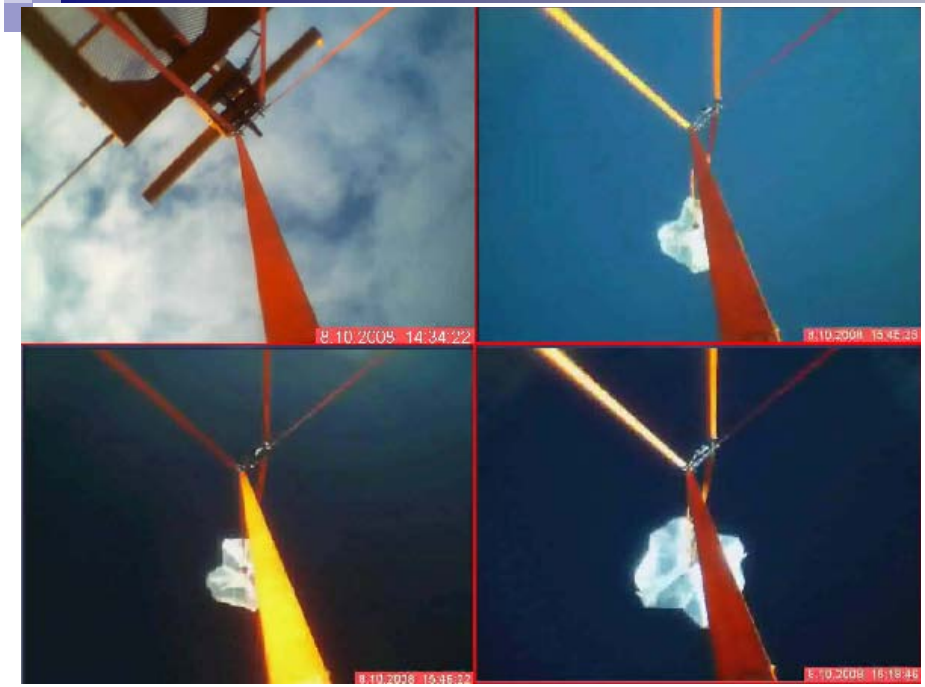


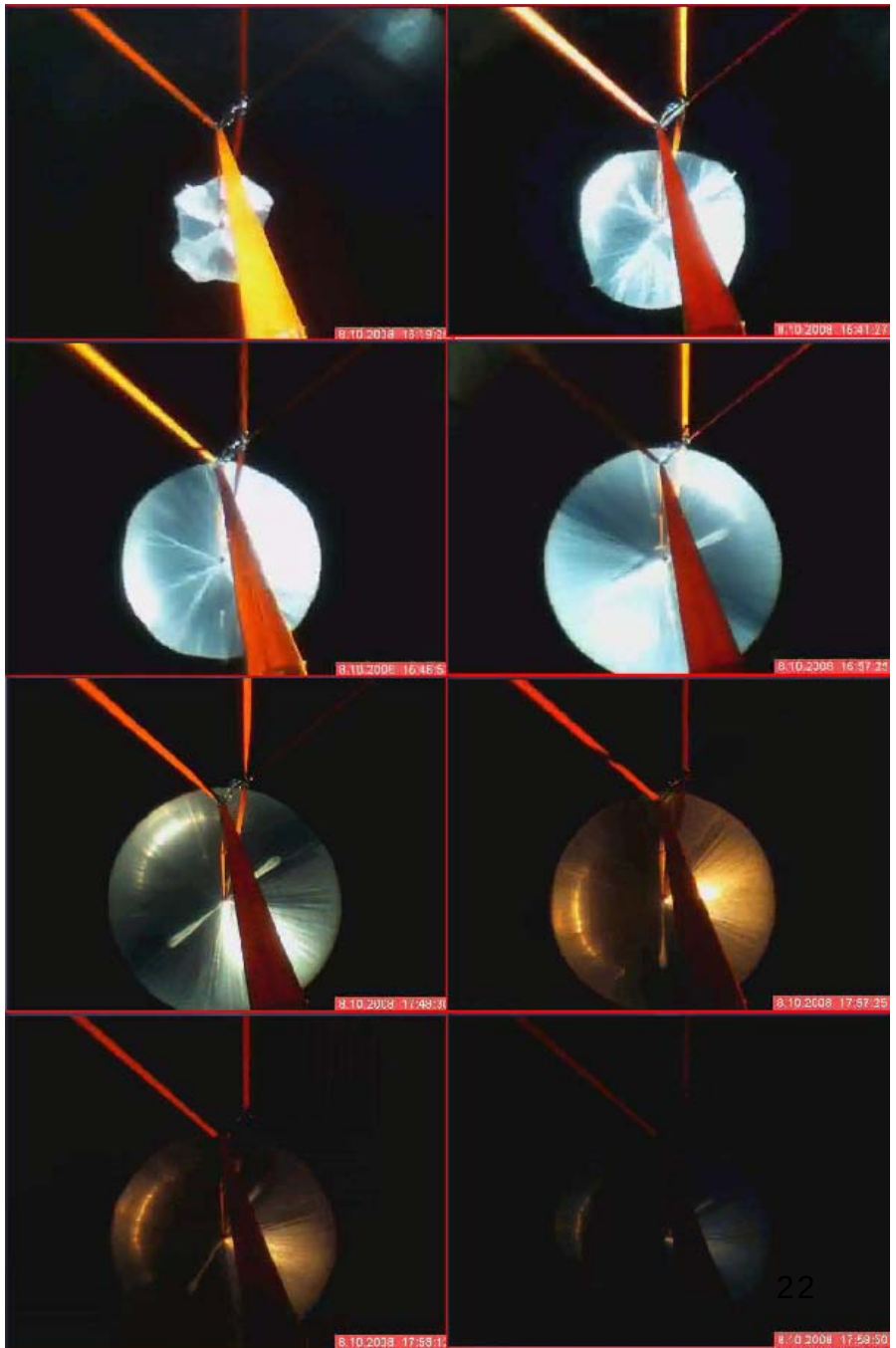


Acknowledgments

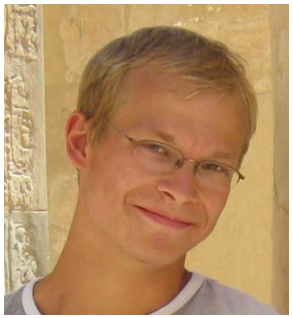
Detector providers

Launch opportunity





Any Suggestions?



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