

# ISS OBSERVATIONS OF THE TRAPPED PROTON ANISOTROPIC EFFECT: A COMPARISON WITH MODEL CALCULATIONS

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# Outlook

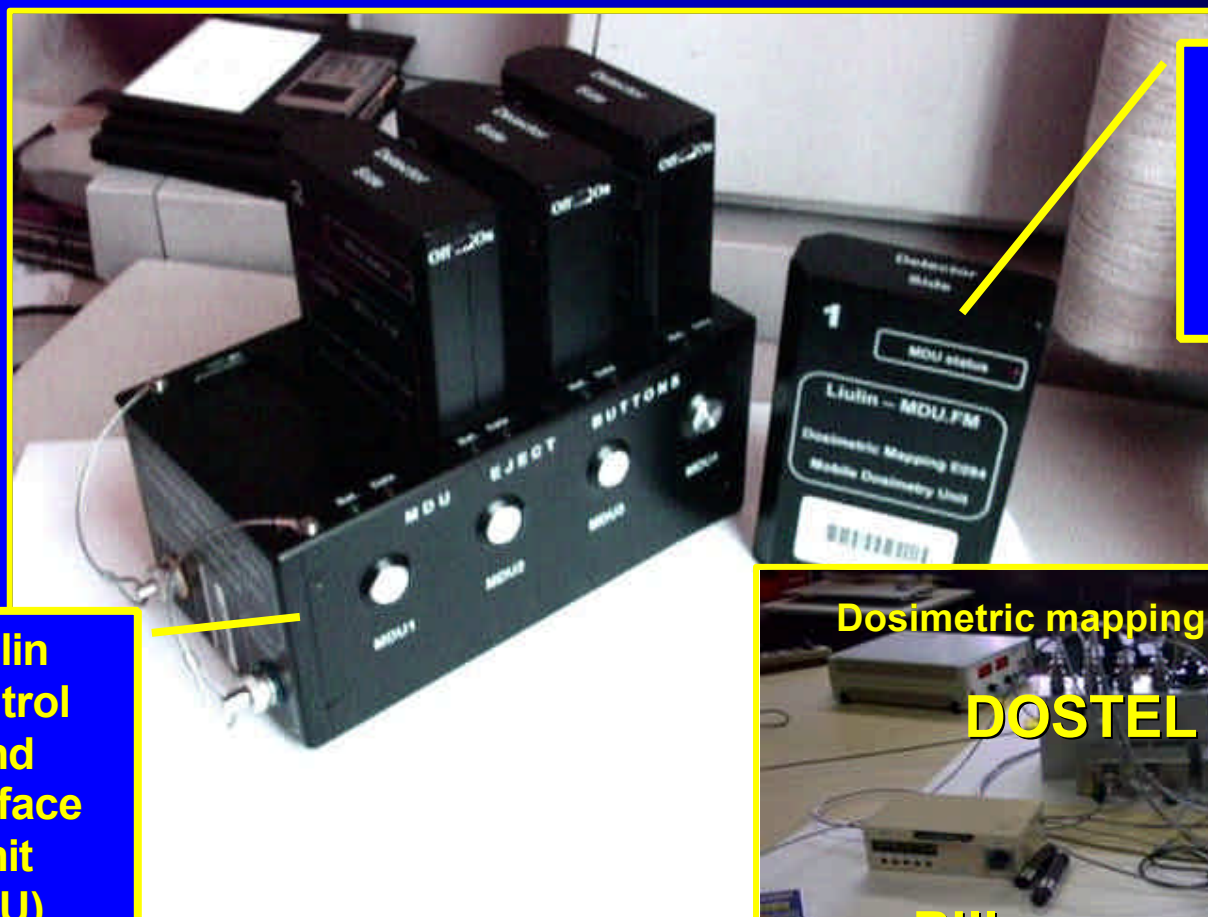
- Instrumentation
- International Space Station Radiation Environment
- Anisotropy in SAA region
- Incident proton spectra inside of ISS
- Comparison of Liulin MDUs data with model calculations
- Conclusions



# Instrumentation

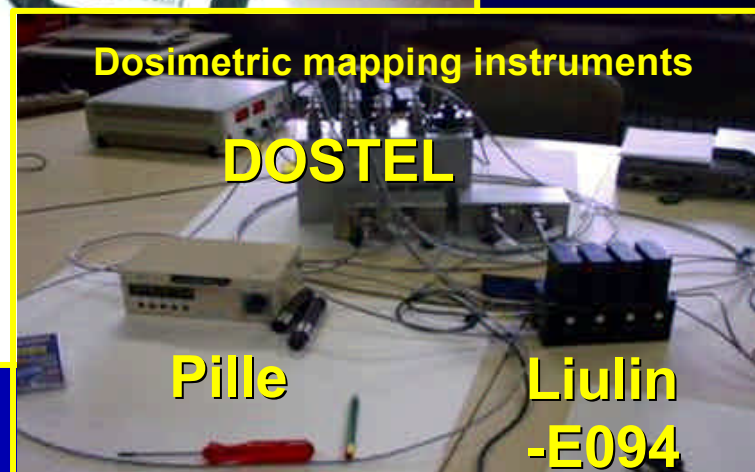


# Liulin-E094 instrument, flown successfully on American Laboratory module May-August 2001 as a part of German lead Dosimetric mapping experiment



Liulin  
Mobile  
Dosimetry  
Unit  
(MDU)

Liulin  
Control  
And  
Interface  
Unit  
(CIU)



Dosimetric mapping instruments

DOSTEL

Pille

Liulin  
-E094

# Liulin-Mobile Dosimetry Unit (MDU)

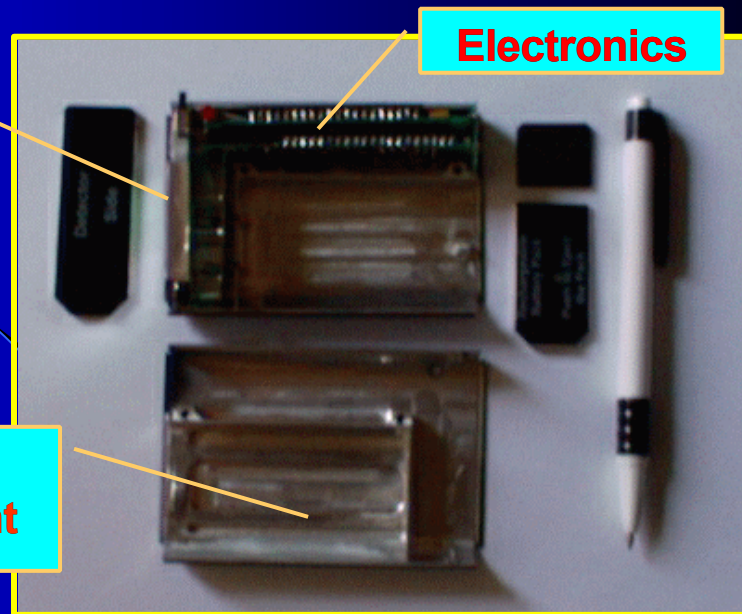
## External view of MDU



**Detector  
+ preamp.**

**Battery  
compartment**

## Internal view of MDU



**Electronics**

## SPECIFICATIONS OF MDU

- Dose range: 0.093 nGy – 1.56 mGy;
- Flux range: - 0.01 - 1250 part/cm<sup>2</sup>s;
- Energy loss range: - 0.0407 – 20.83 MeV;
- Pulse height analysis range: - 19.5 mV – 5.0 V;
- LET range: 0.27- 69.4 keV/m;
- Temperature range: 0°C - +40°C;
- Power consumption: typically 72 mW;

-Size (including 70x38x20 mm battery pack of SONY NP-F550 type): 100x64x24 mm;

-Total mass (including 0.08 kg battery pack): 0.23 kg.

- Operation time 5 days



# International Space Station Radiation Environment



# American astronaut James Voss working with Dosimetric mapping experiment on 26.06.2001

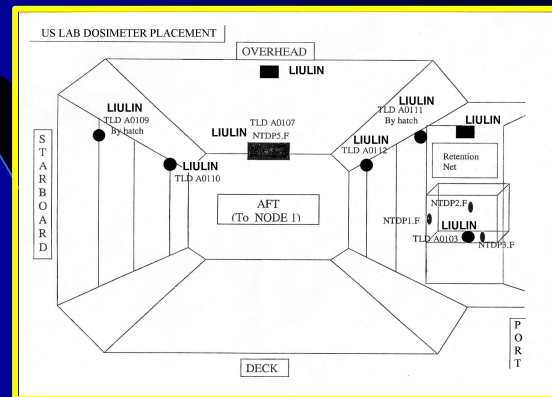
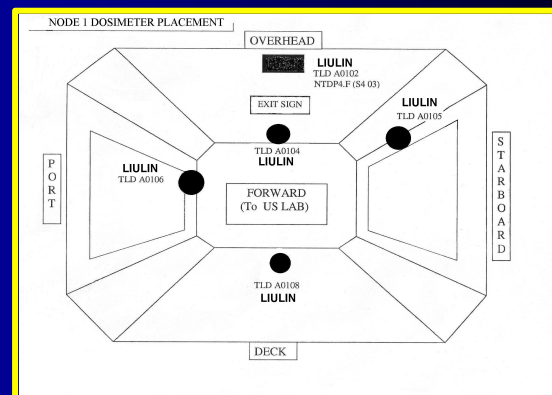
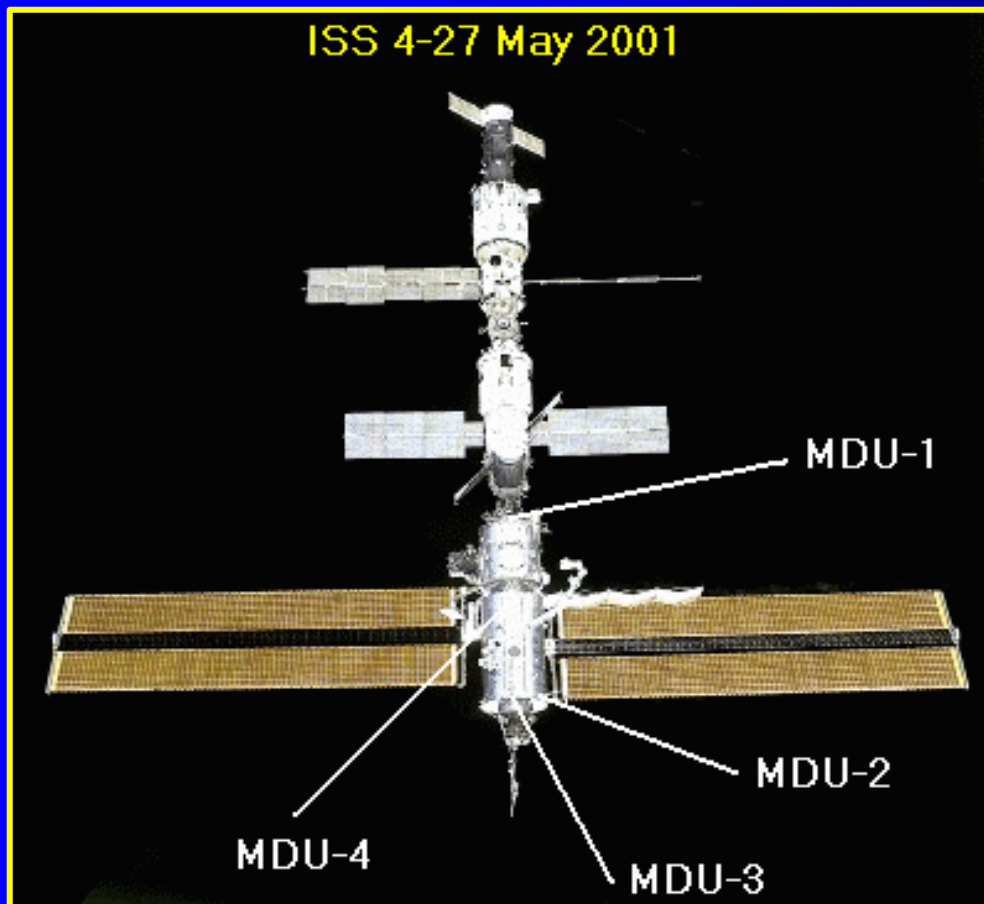


# Usual location of one MDU in ISS





# Locations of MDUs in ISS



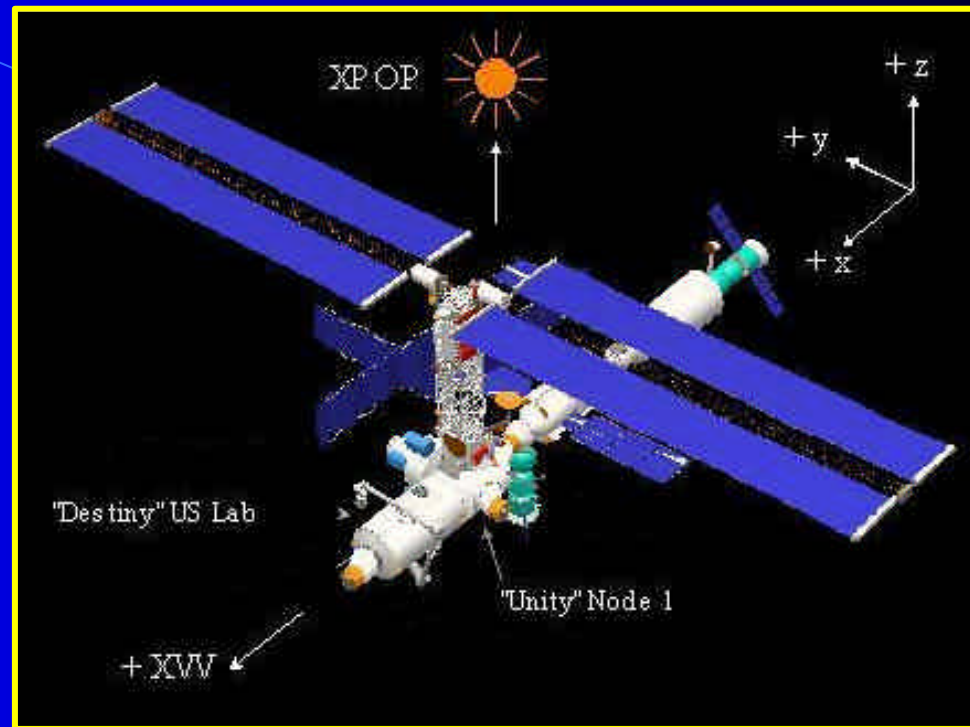
**13 different locations were chosen for MDUs inside US Lab and NODE 1.**

# Orientation of ISS

During the experiments ISS was in one of two attitudes:

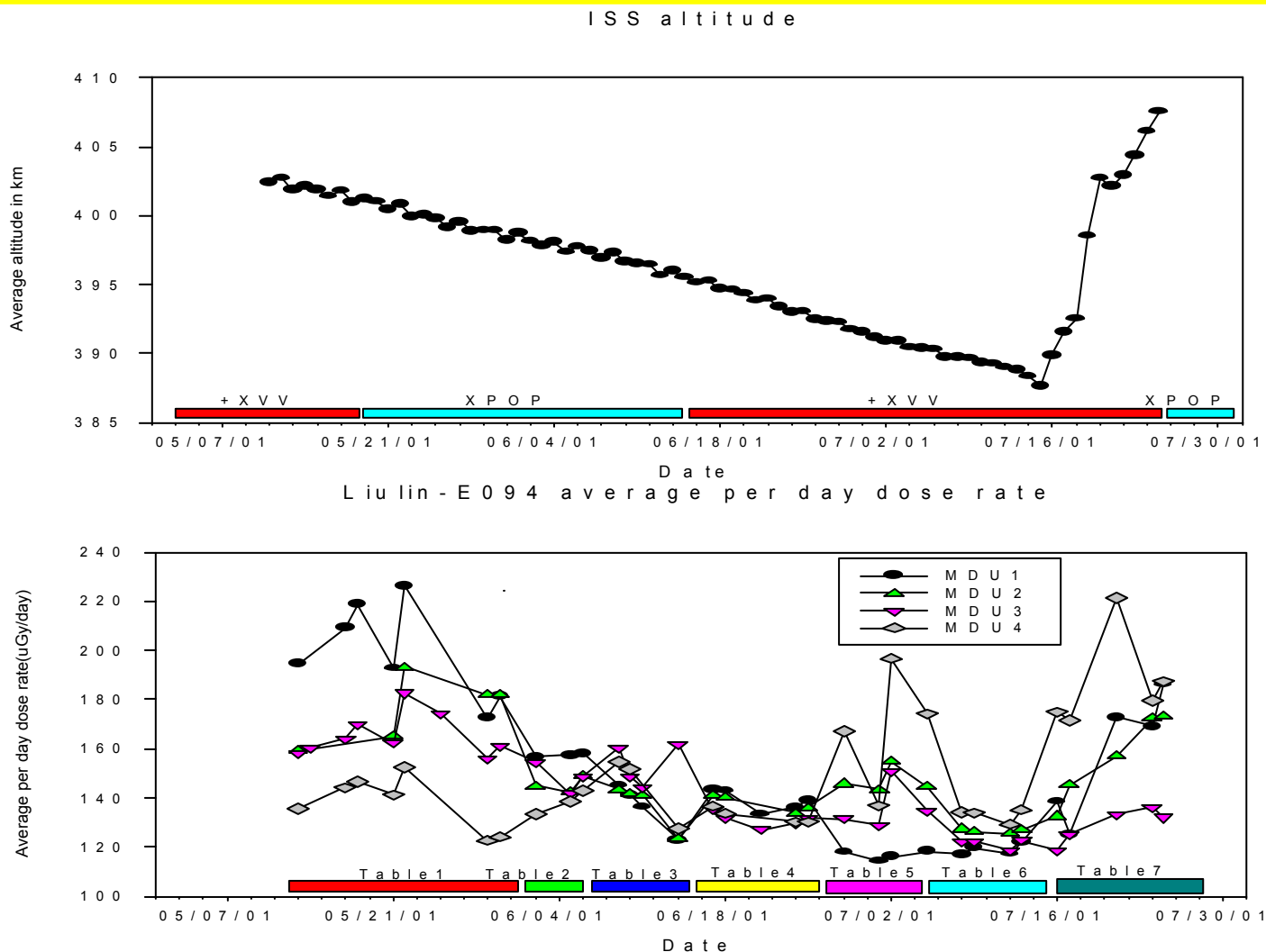
**+XVV** - with the **+x**-axis parallel to the velocity vector

**XPOP** - **x**-axis perpendicular to plane of orbit; **+z**-axis constantly pointing toward the Sun

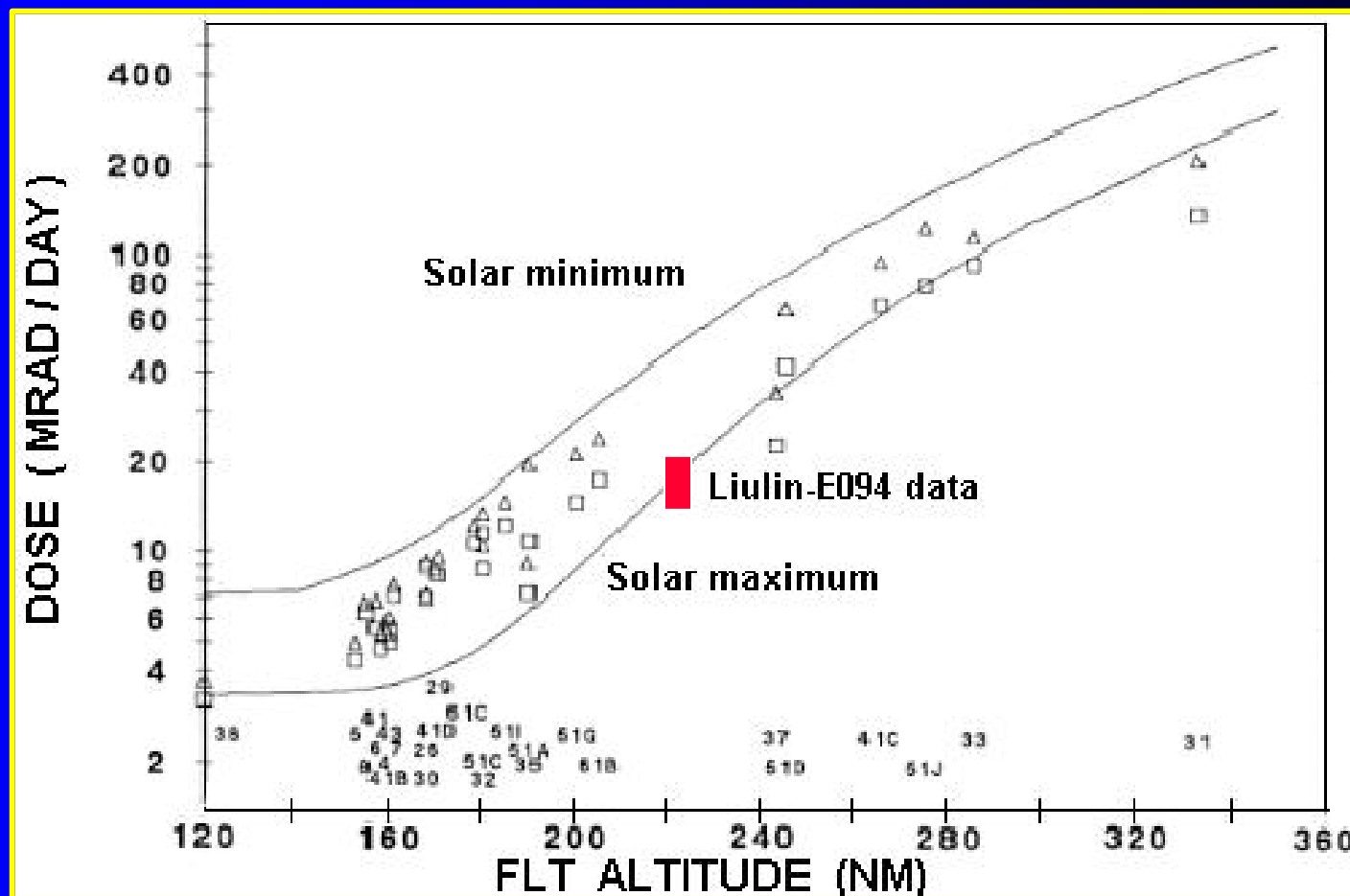




# Overview of the MDUs doses during the whole experiment



## Comparison of the Liulin-E094 mean daily data with (Johnson et al, 1993)



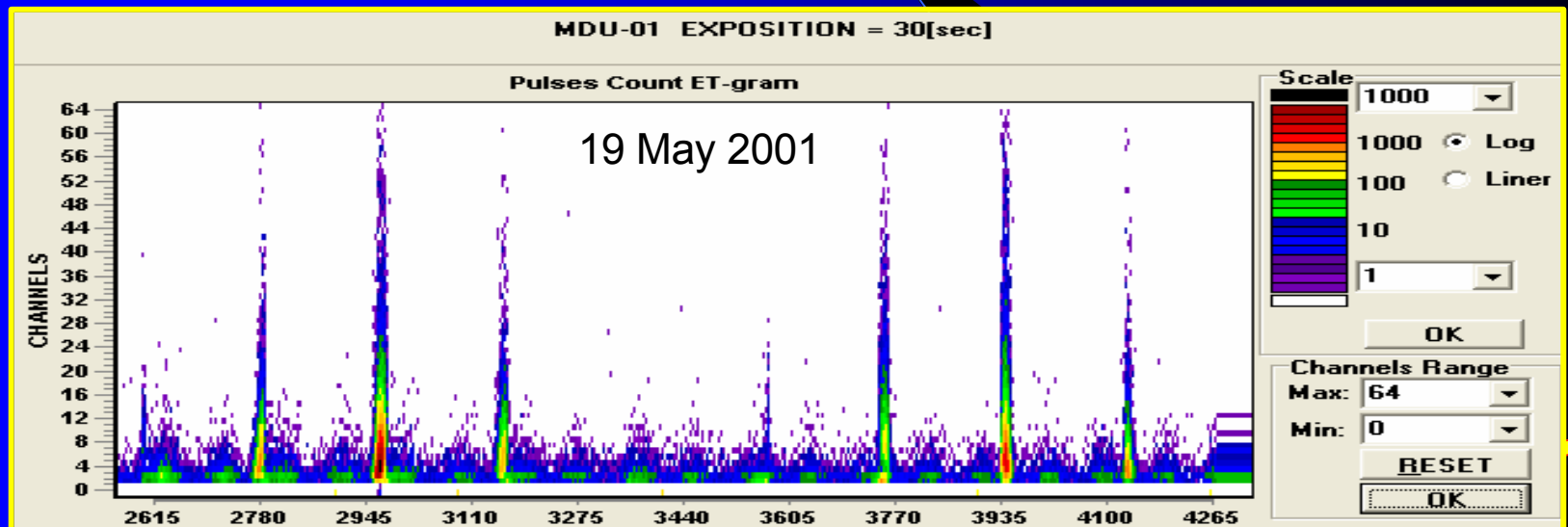
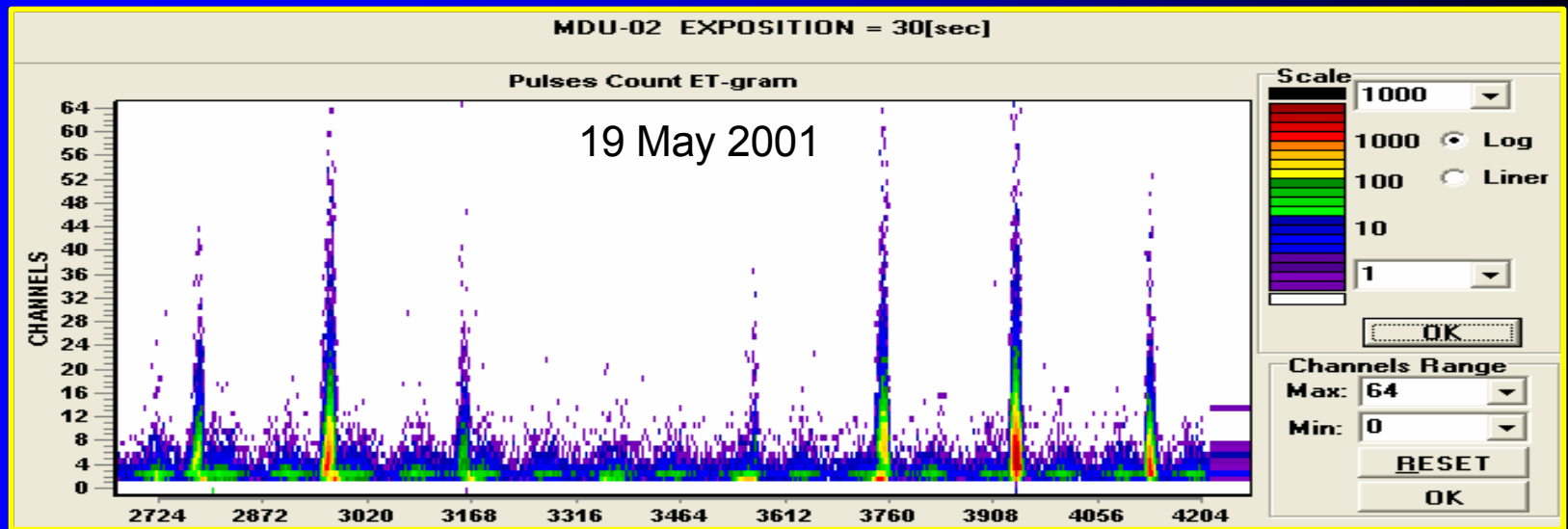


# Anisotropy in SAA region



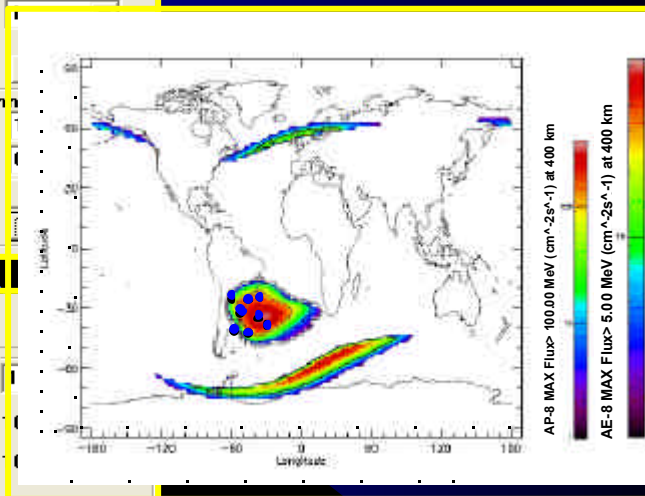
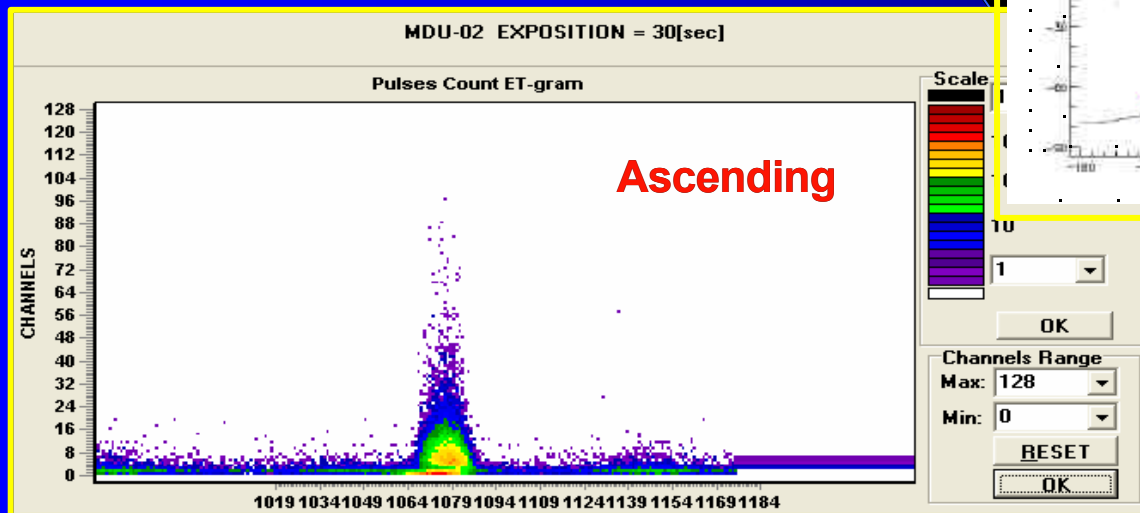
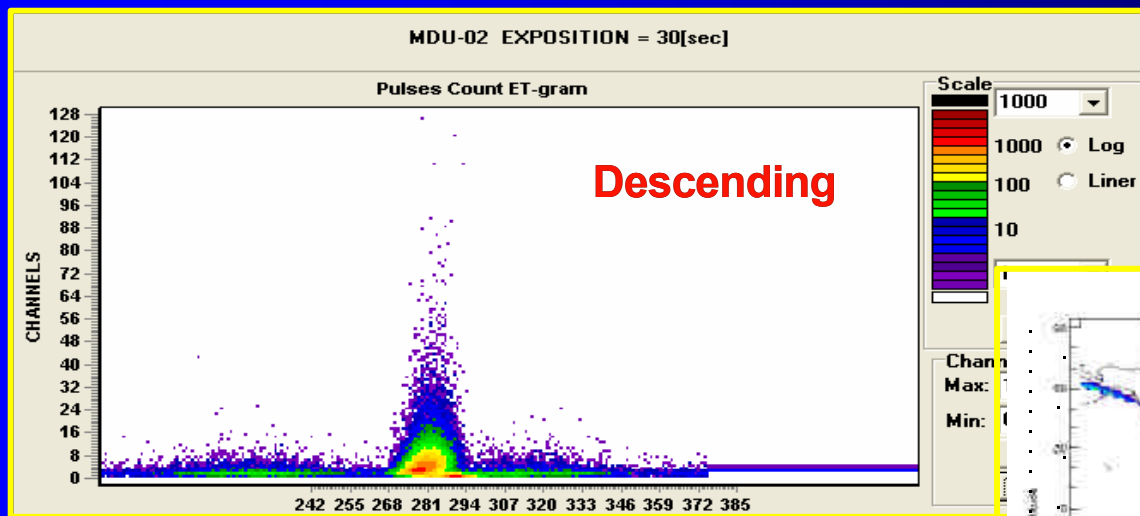


## Anisotropy as observed in the E-T grams from Liulin MDU#1 and MDU#2

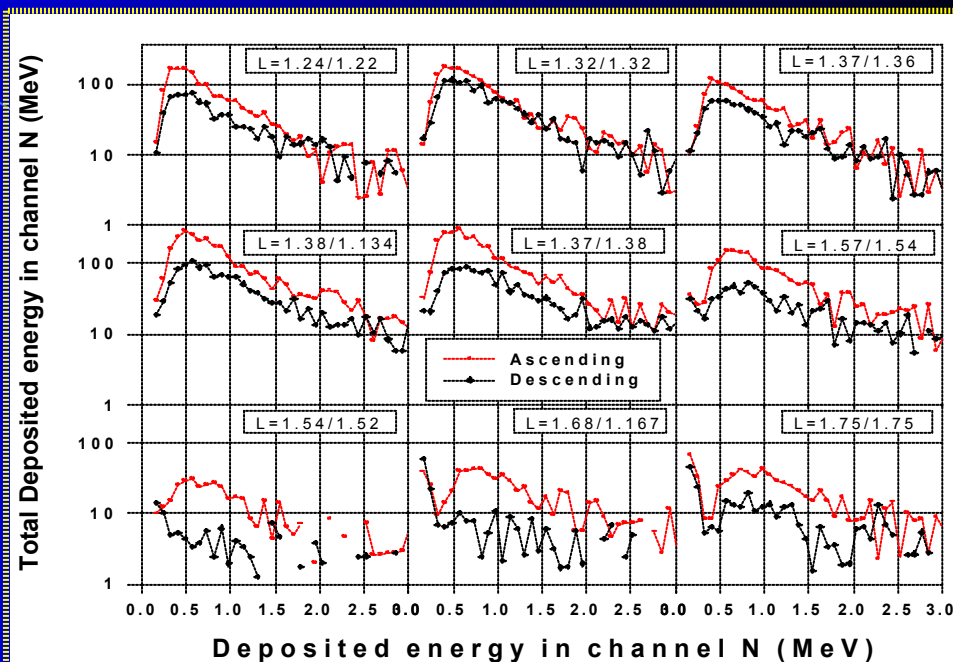
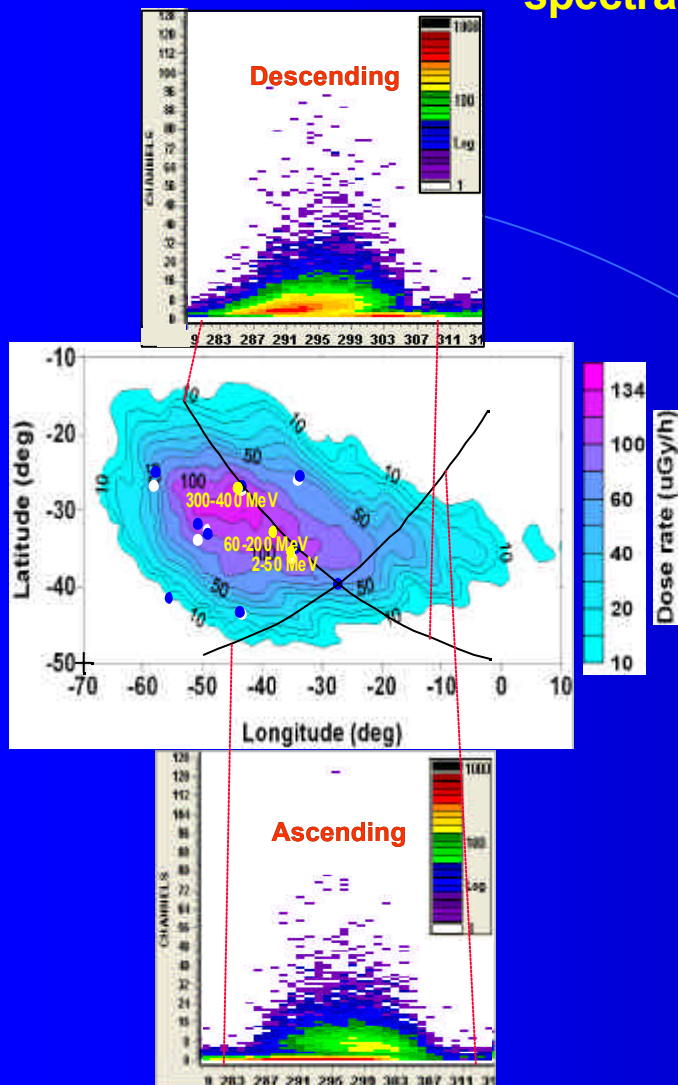




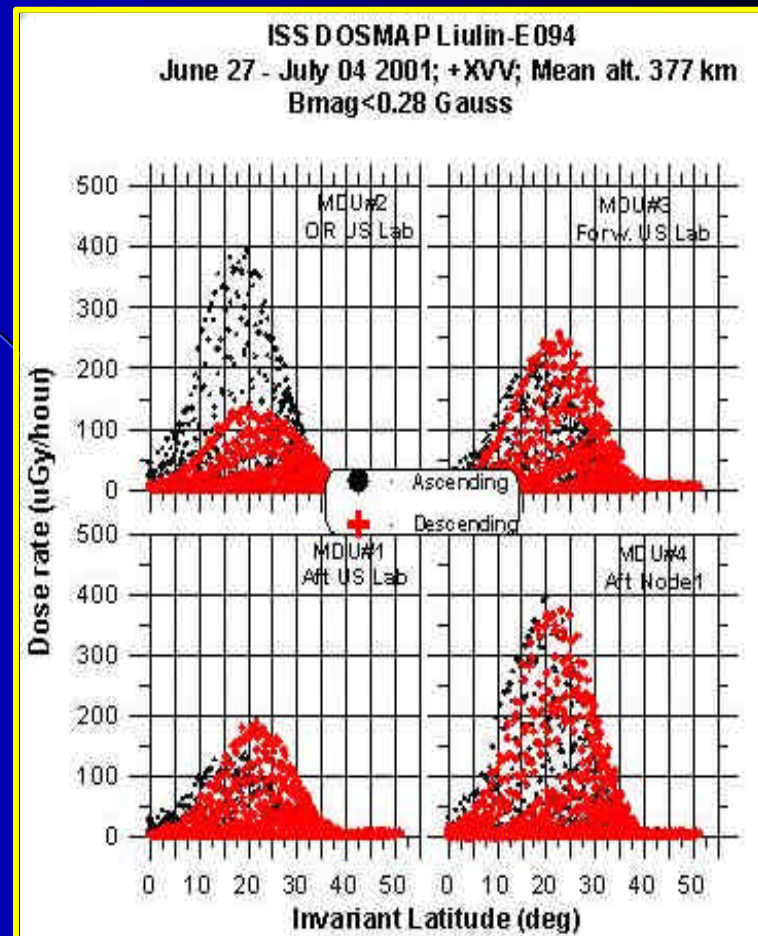
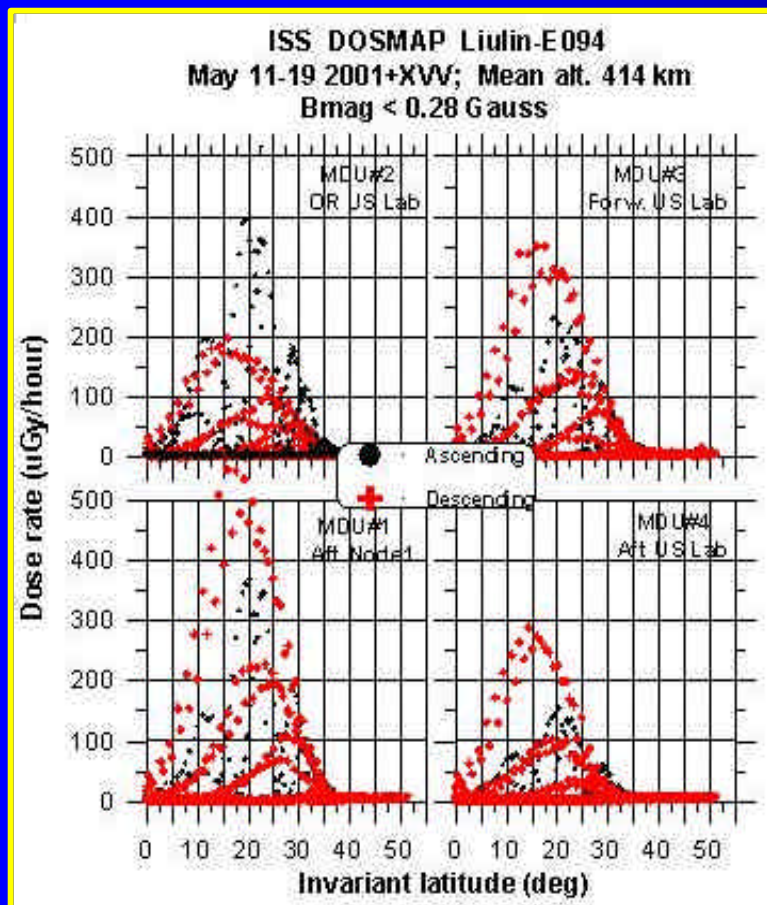
# Spectra anisotropy during SAA crossing at ascending and descending parts of the orbit



# 3-D presentation of the ascending and descending spectra in the Region of SAA



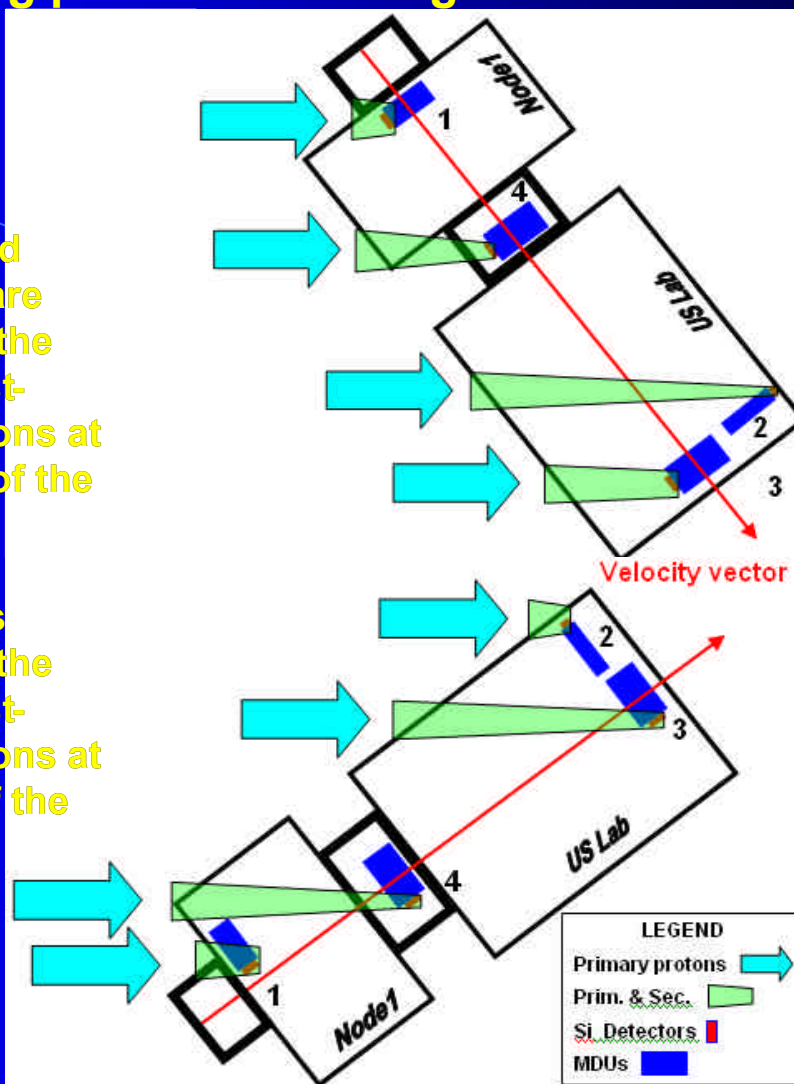
# Dose rate distribution in SAA for 2 different +XVV orientation time span



# Geometry of the MDUs exposition against the eastward drifting protons in the region of SAA

MDU#1, MDU#3 and MDU#4 detectors are orientated toward the predominating east-down drifting protons at descending parts of the orbit

MDU#2 detector is orientated toward the predominating east-down drifting protons at ascending parts of the orbit

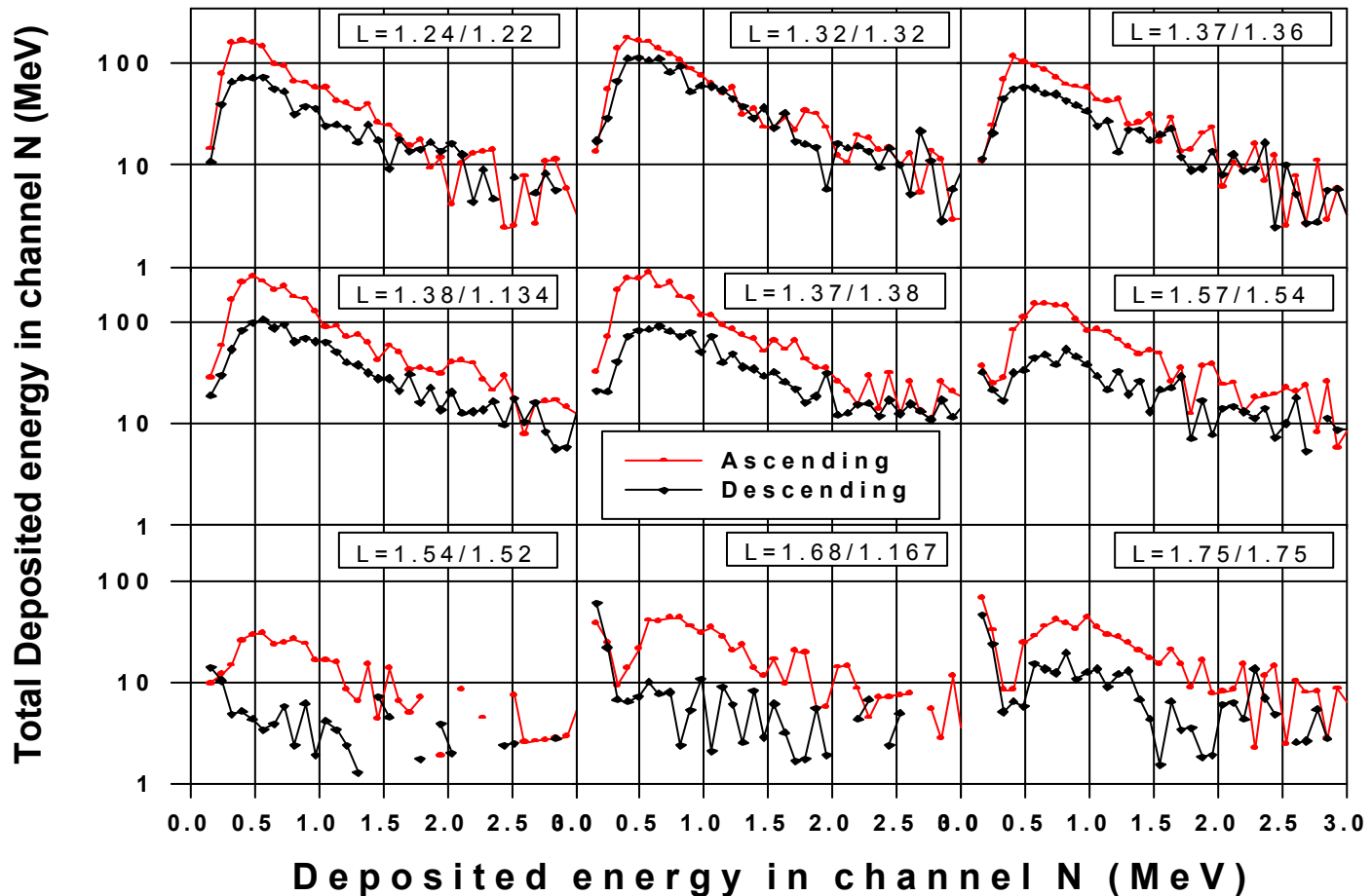




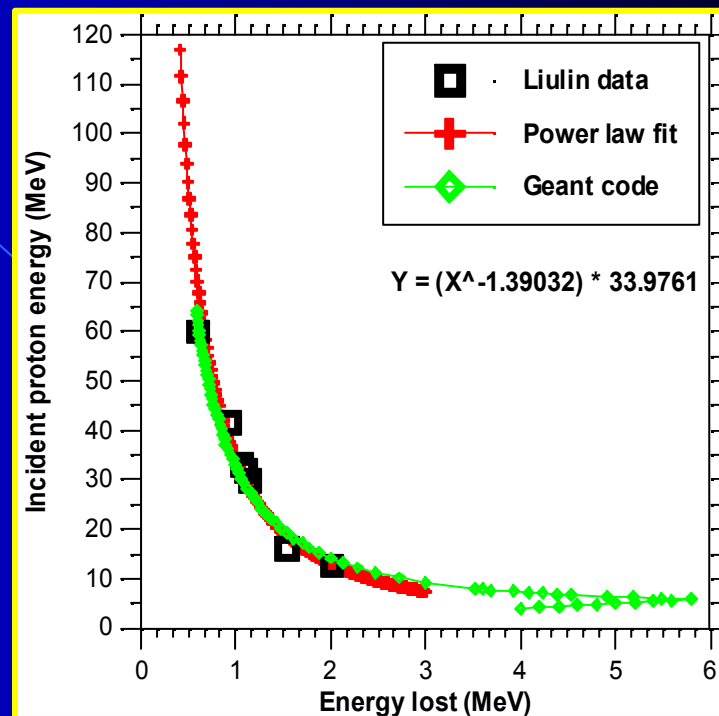
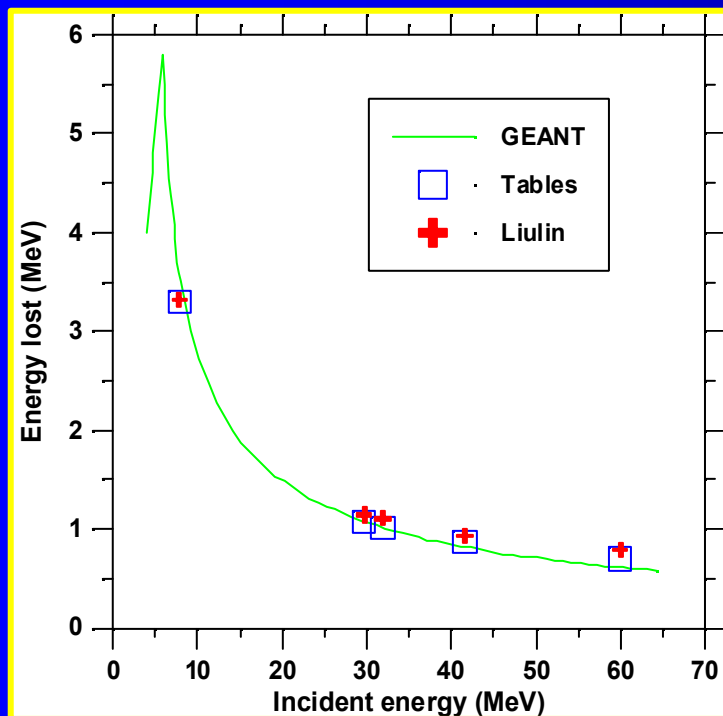


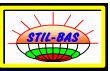
# Incident proton spectra inside of ISS

# Shielding and proton anisotropic effects for various L-shells as a function of ascending and descending orbital passes through the SAA.

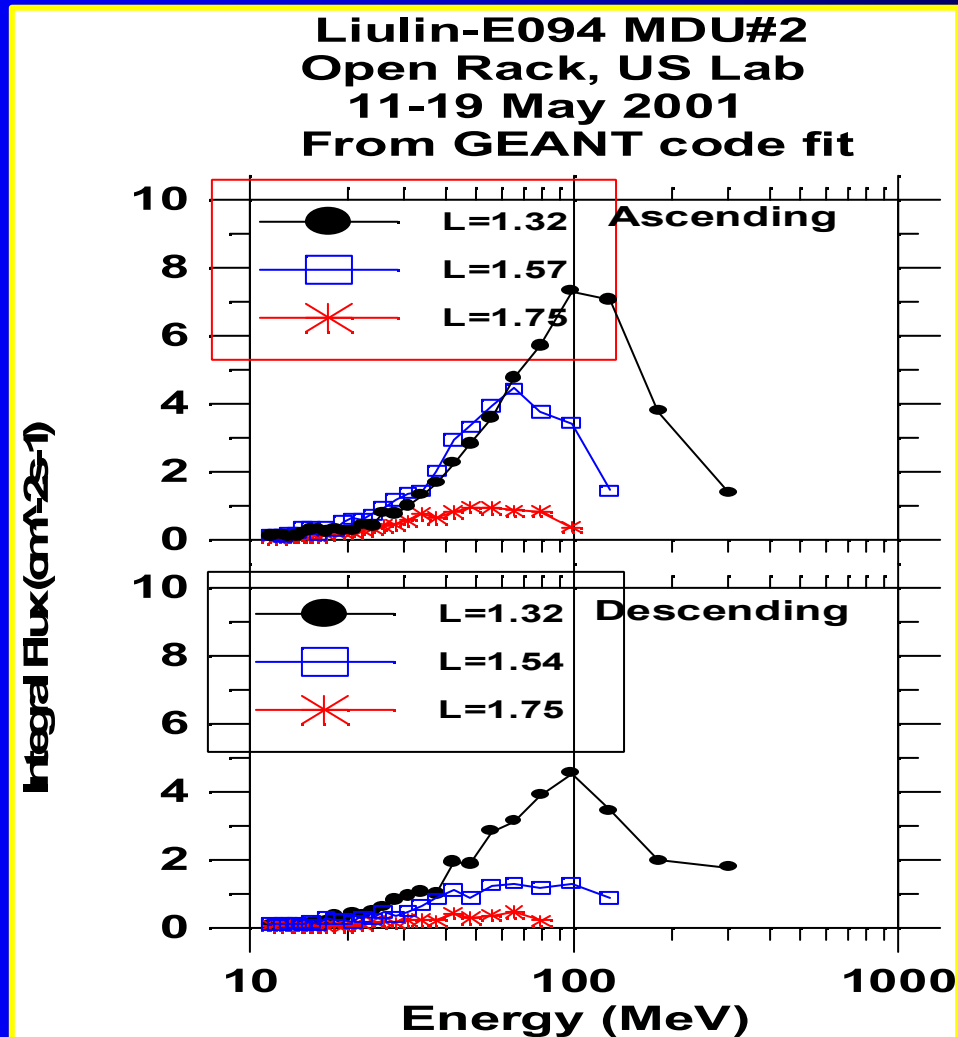


# Calibration curves of MDUs obtained with protons at the Universite Catholique de Louvain, Belgique



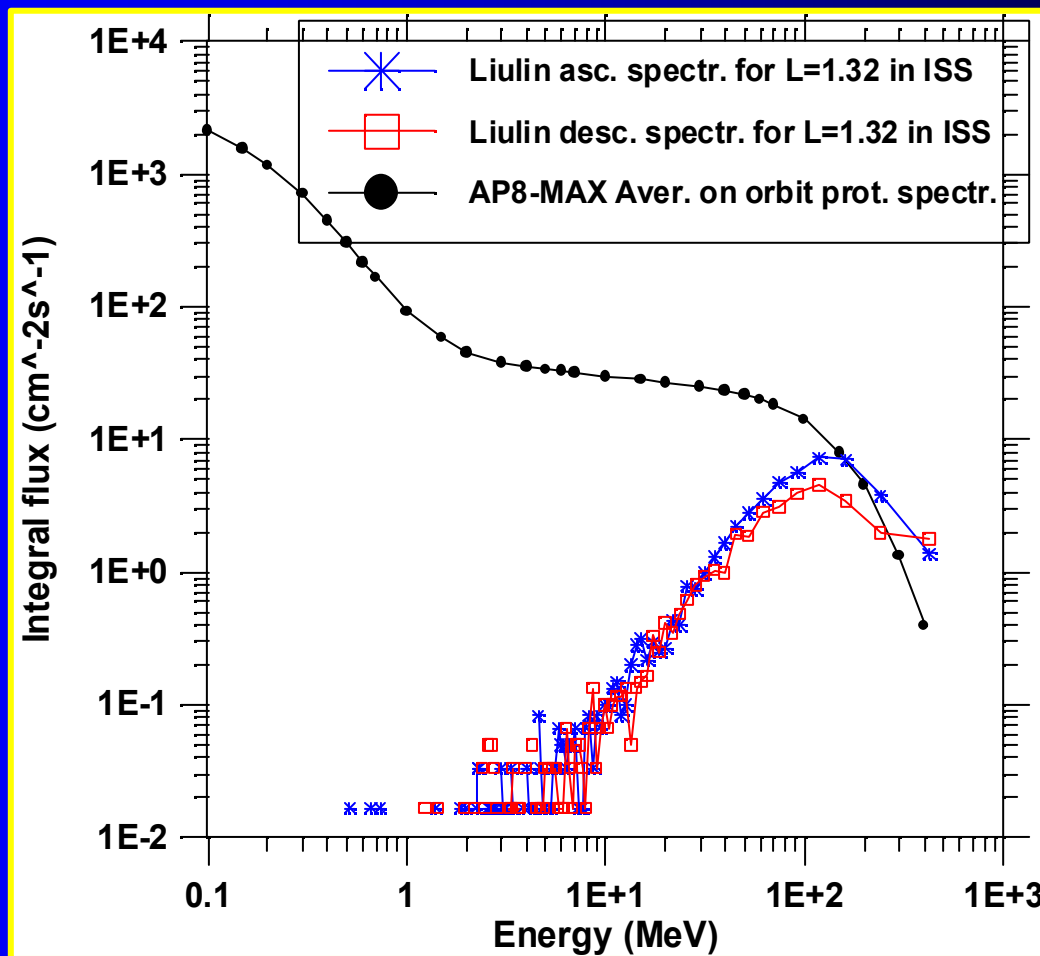


# MDU#2 incident proton spectra inside of US Lab module recalculated from GEANT code fit of the Liulin calibration data





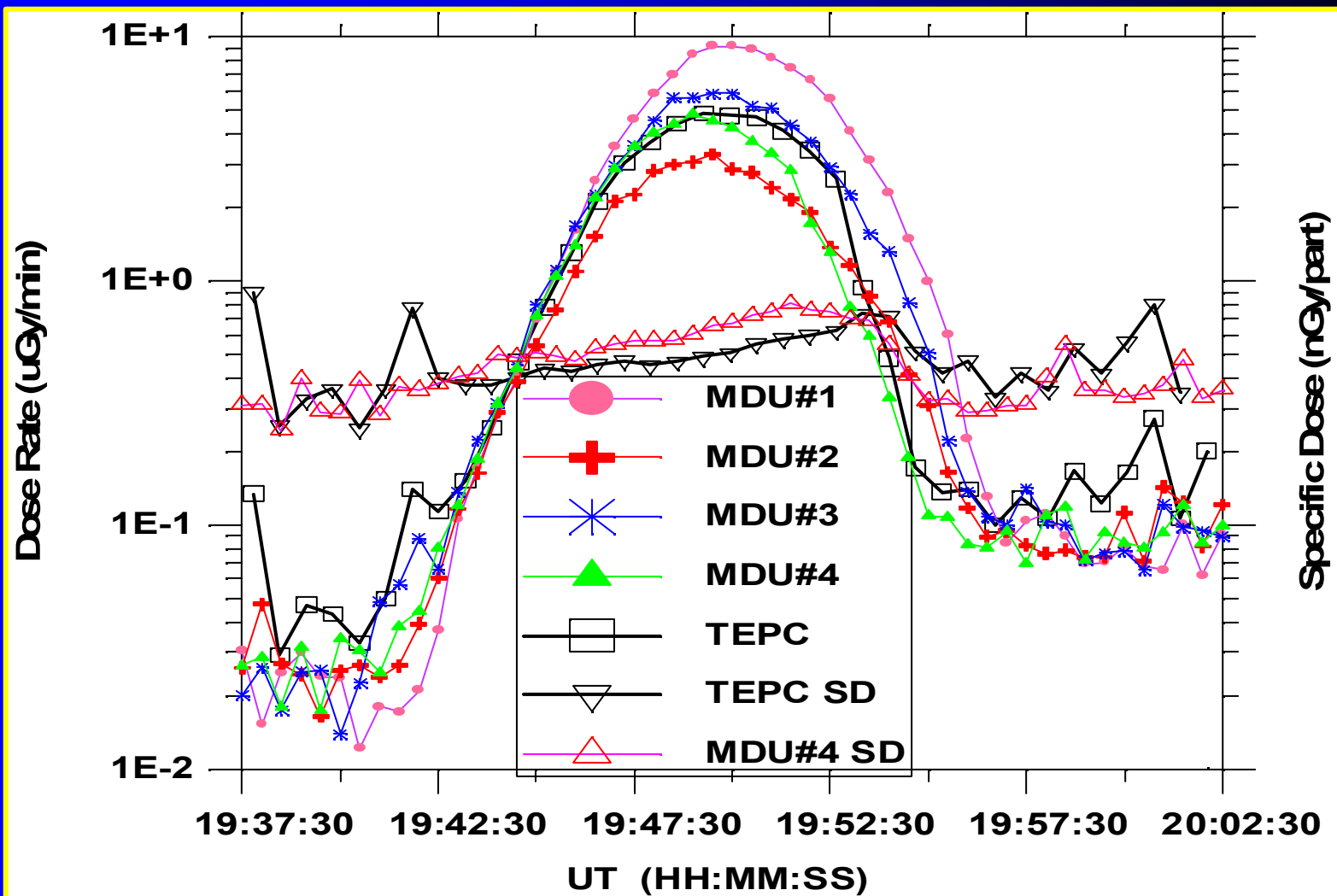
# Comparison of AP-8 MAX averaged along the orbit proton spectrum with the calculated inside ISS Liulin spectra for L=1.32







# Comparison between Liulin MDUs and TEPC data

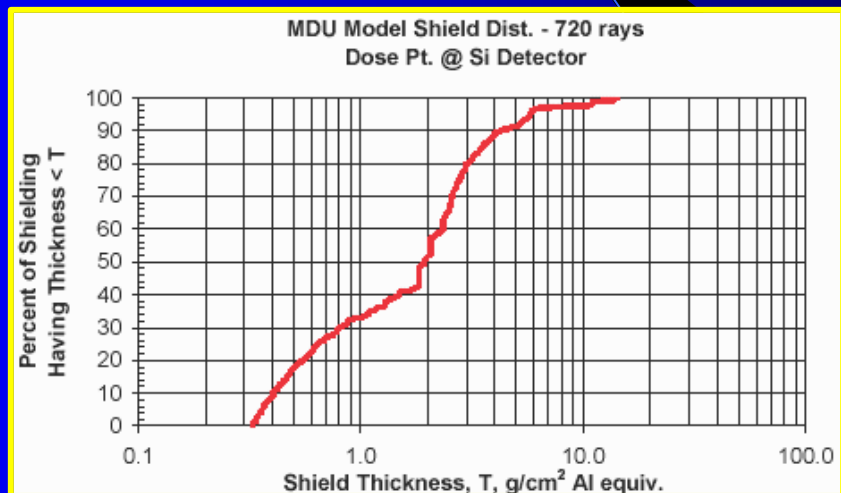
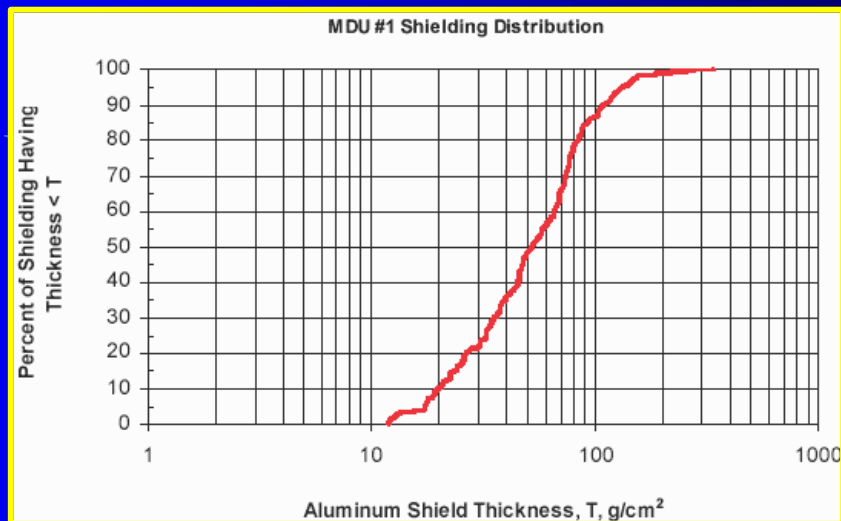




# Comparison of Liulin MDUs data with model calculations



# Shielding Distribution for the MDU for the MDU #1 location in the ISS.





# Comparison of MDU Measurements with Model Calculations, performed by W. Atwell from Boeing company, NASA Systems for May 11-12, 2001

MDU number and Location	MDU#1 Node-1 (Aft)	MDU#2 HRF	MDU#3 Fvd. Lab	MDU#4 Aft Lab
Measured dose (mrad/day)	18.84	15.31	15.22	12.97
Calculated dose (mrad/day)	19.97	16.95	16.90	15.00
Difference (%)	6.00	10.71	11.04	15.65



# Conclusions

- Liulin-E094 doses in ISS in May 2001 at altitude about 400 km close correspondent with the data published in the NASA "Spaceflight radiation health program" (Johnson et al., 1993) and with AP8MAX predictions
- Comparison of the Liulin-E094 and TEPC doses shows differences, which are in the range of few to 50% in dependence of the differences of their shielding
- Liulin-E094 trapped proton anisotropy in SAA is shown by strong differences in the doses and fluxes on ascending and descending parts of orbits for the location of MDU#2 in ISS. The enhanced doses at ascending parts of the orbits are explained by different shielding generated by the different geometry against the predominating eastward drifting protons in SAA region
- The analysis of the spectra in the SAA region shows existence of two types of predominating incident radiation inside ISS. In the core of SAA protons are predominating, while at the south-east bound bremsstrahlung, generated by the outside electrons;
- Using the Liulin MDUs calibration curves we were able to calculate the incident proton spectra inside of US Lab. Calculated spectra maximum moves from about 100 MeV at low L values toward 50-60 MeV at higher L values. This behavior was approved by simultaneous analysis of the Liulin and TEPC specific doses distribution
- We developed a 3-D shielding model of the MDU unit and located it at the four locations in the ISS shielding model. Using the trapped proton differential spectra generated from the SPENVIS on-line capability for calculation of AP8 trapped proton spectra and the high-energy proton transport code PDOSE we were able to calculate the doses at each locations of MDUs. The differences between the observed Liulin-E094 MDUs doses and calculated do not exceed 15%





**Thank you for your attention**