Relative nuclear abundances, LET and dose rates at various locations and configurations in ISS from the ALTCRISS experiment.

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On behalf of

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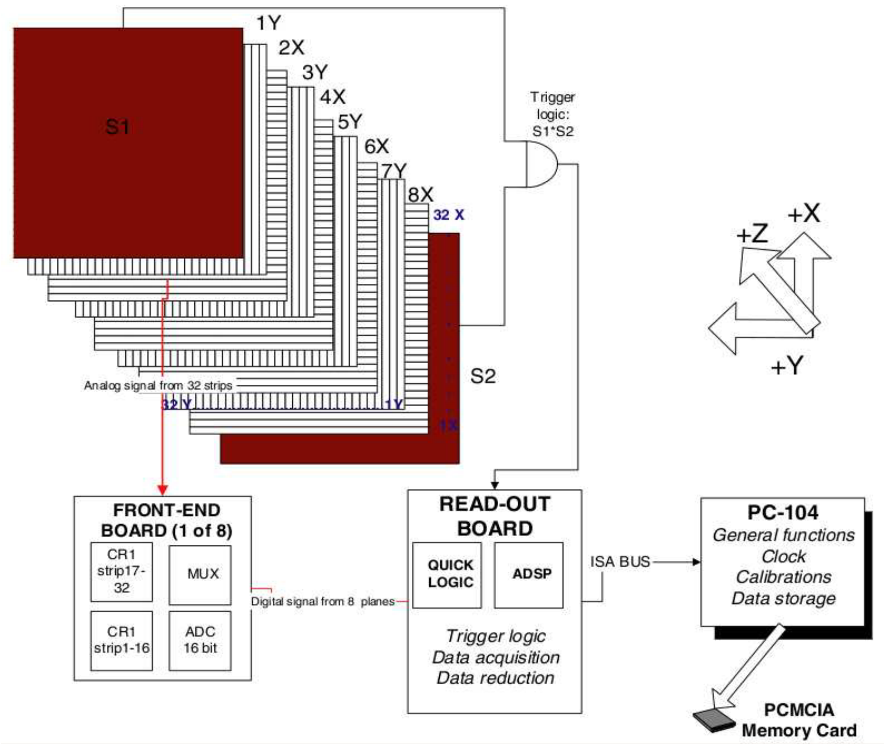
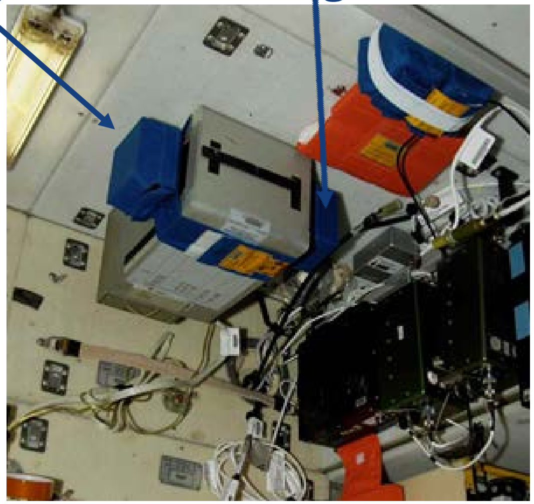
The Alteino / SilEye-3 detector
on ISS between 2002 and 2009



Polyethylene shields 5 g/cm^2



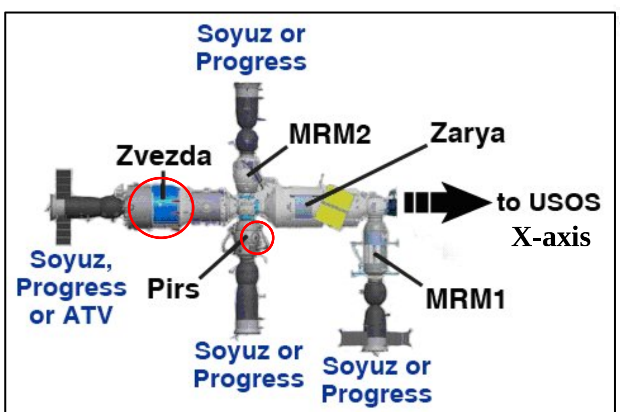
- 8 x 380 µm Si-planes 1.5 cm apart (2.5 between 4&5)
- 32 strips pitch 2.5 mm
- 2 x 1 mm scintillators for trigger (<1 MIP)
- total geometrical factor: 45 cm^{2}sr

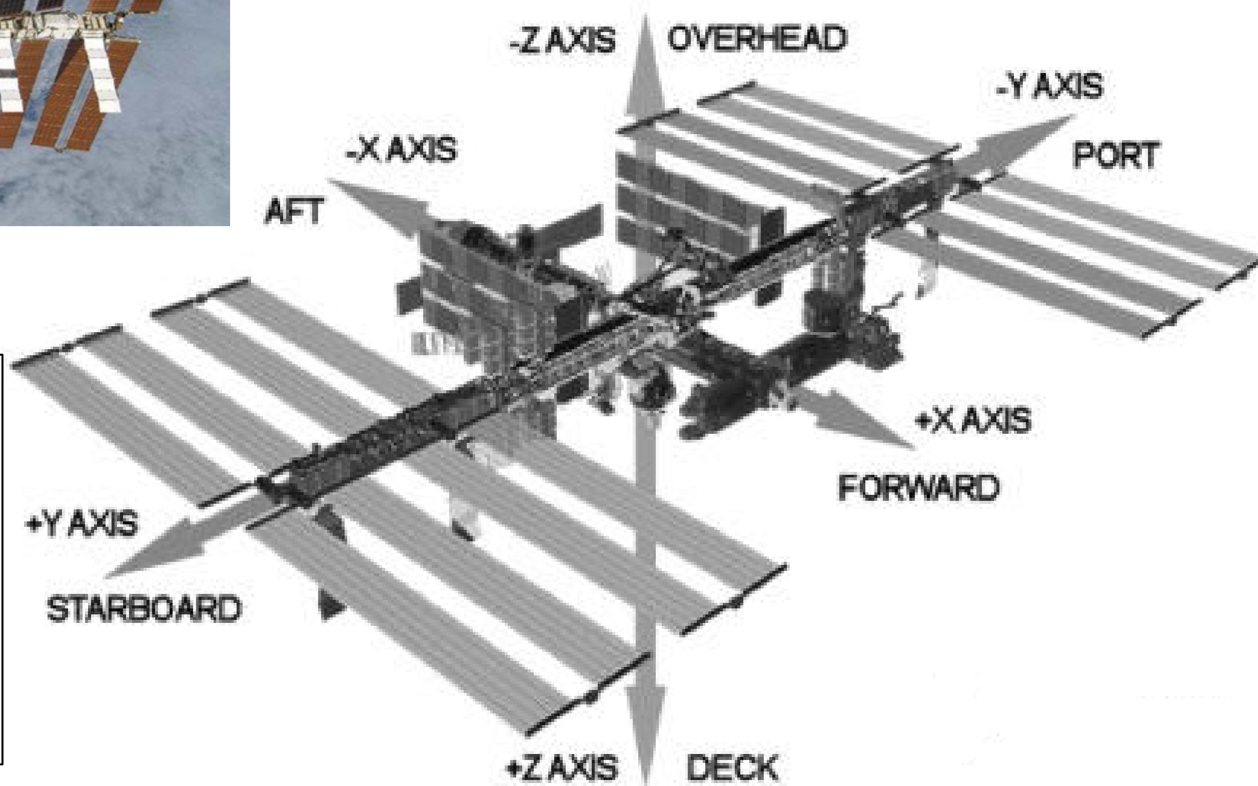
3 Different Data cuts used

1. The **angle ϕ to the detector** xy-plane for the impinging particle is calculated by reconstructing the position of the track in the detector for both x-and y-views.
   If this is possible, **energy is normalised by cos(ϕ),** otherwise the event is rejected.
2. To exclude large shower events in the detector a **maximum number of strip** activations per event was less than **32** (out of 256). An average of 4 strip activations per layer was deemed acceptable for a ”single track” event.
3. The **difference in detected energy in the first and last planes may not differ more than 20%.**
   This selects particles with kinetic energy above $\simeq$ 60 MeV/n.

ISS coordinate system

and Alteino positions

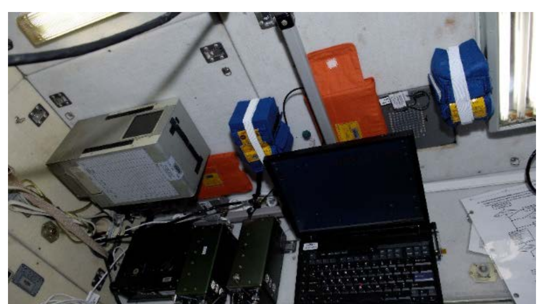




Data sets used for these analyses

Set	Position	Orien-tation	Shiel-ding	Time YYYY-MM-DD+DD	Altitude [km]
902	Pirs	$\hat{X}\hat{Y}$	No	2005-12-26 + 11.2 d	348
903	Pirs	$\hat{X}\hat{Y}$	Yes	2006-01-08 + 15.4 d	347
907	Z-P-CC	$\hat{Y}$	Yes	2006-03-16 + 21.1 d	345
910	Z-P-CC	$\hat{Z}$	Yes	2006-05-17 + 9.31 d	342
925	Z-MC	$\hat{X}$	Yes	2007-05-22 + 17.2 d	335
930	Z-MC	$\hat{X}$	No	2007-06-27 + 21.0 d	333
933	Z-MC	$\hat{Z}$	No	2007-08-07 + 20.6 d	341

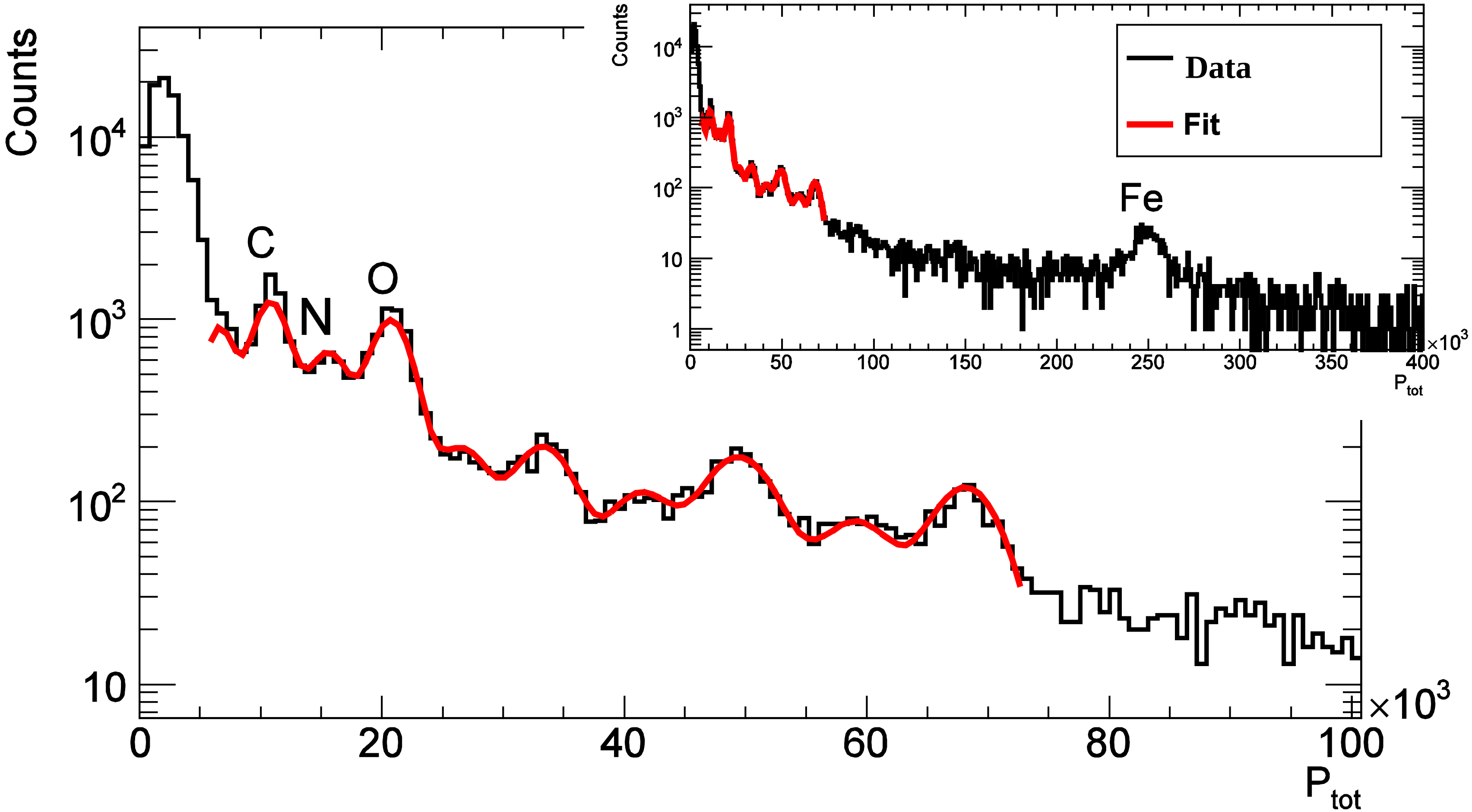
In *Pirs*



Zvezda Medical Cabinet - $\ddot{X}$

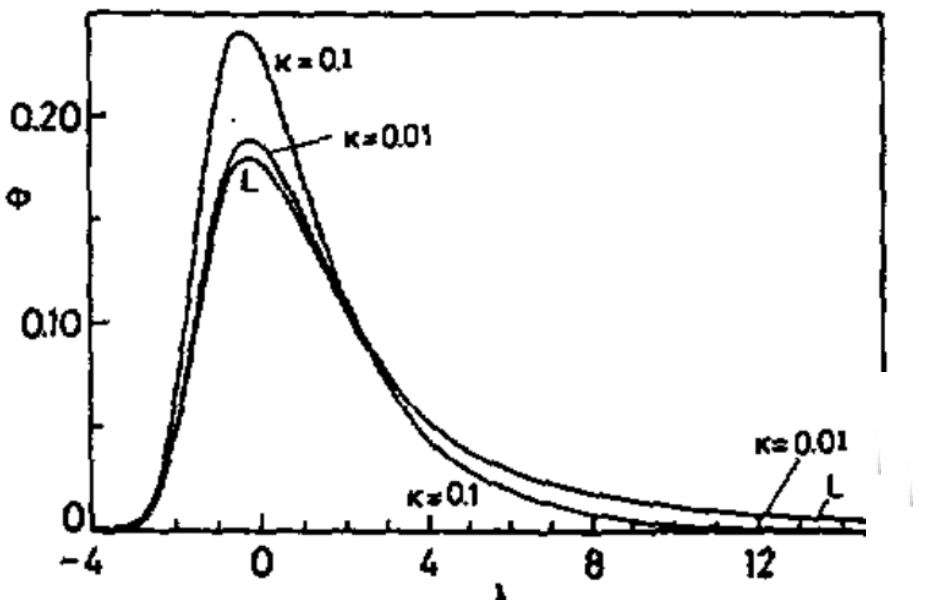
Port Crew Cabin - $\hat{Z}$

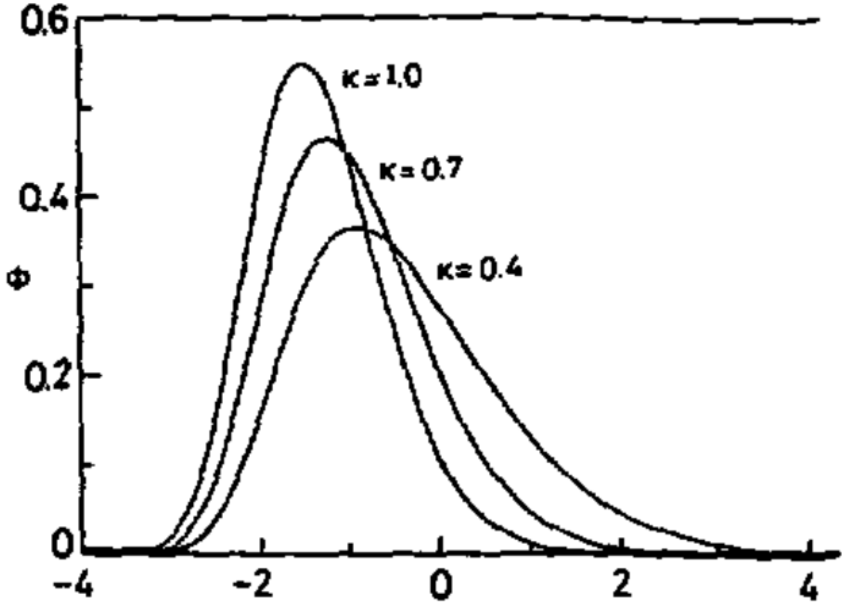
Number of events vs sum of ADC-counts (over all planes)



Fit to multi-Gaussian function

Landau vs Vavilov vs Gauss





of applicability. The distinguishing parameter in all these theories is the ratio

$$\kappa = \bar{\Delta}/W_{\max},$$

$$\bar{\Delta} \simeq \xi = 2\pi N_a r_e^2 m_e c^2 \rho \frac{Z}{A}\left(\frac{z}{\beta}\right)^2 x.$$

that is the the ratio between the mean energy loss and the maximum energy transfer allowable in a single collision. The mean energy loss may be calculated from the Bethe-

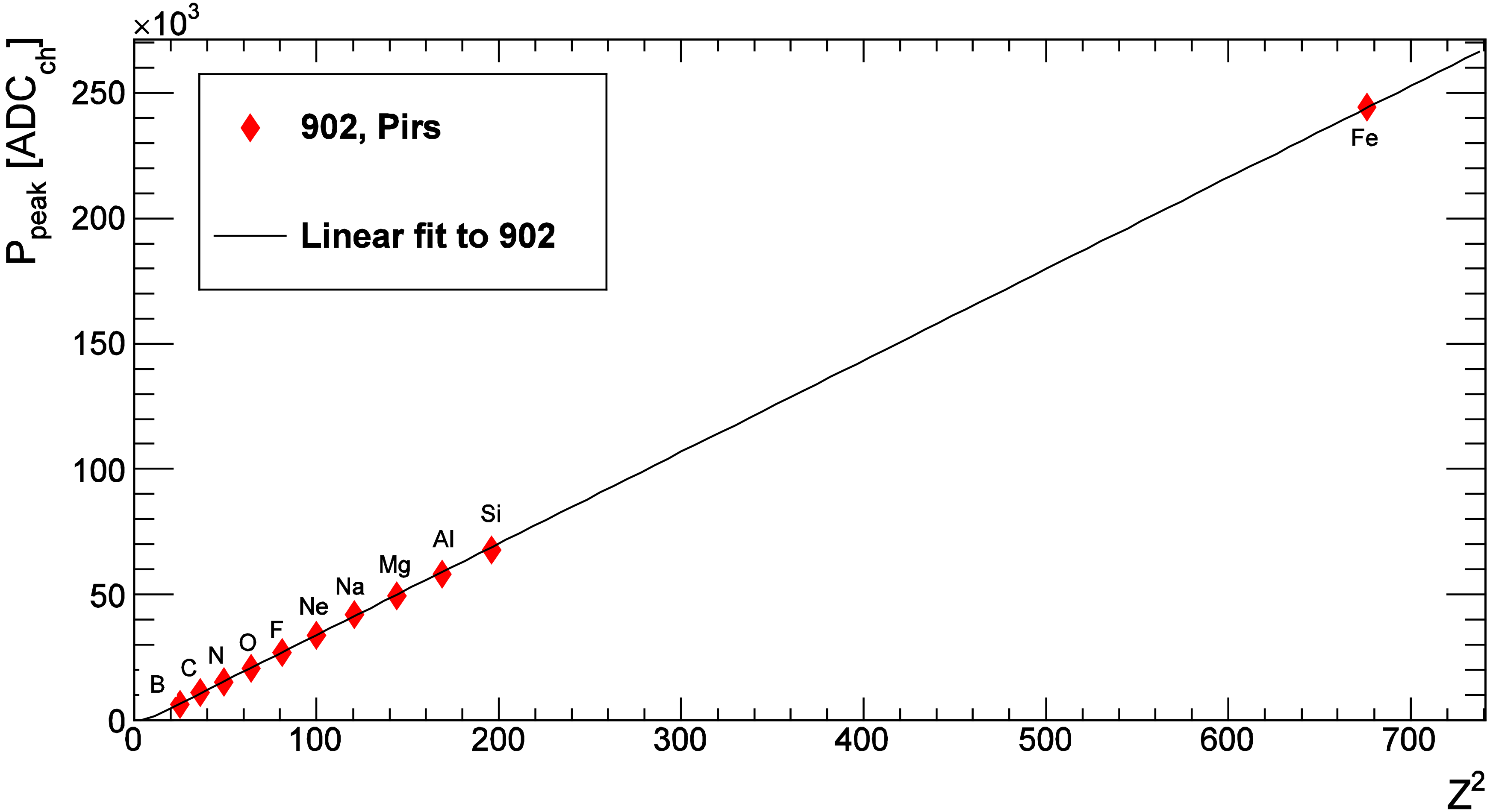
Landau (L) for extremely thin layers (κ<0.01)

Gauss when very thick (κ>10) but already κ>1 start appraoch

Our case κ around 4

In addition, electronic noice

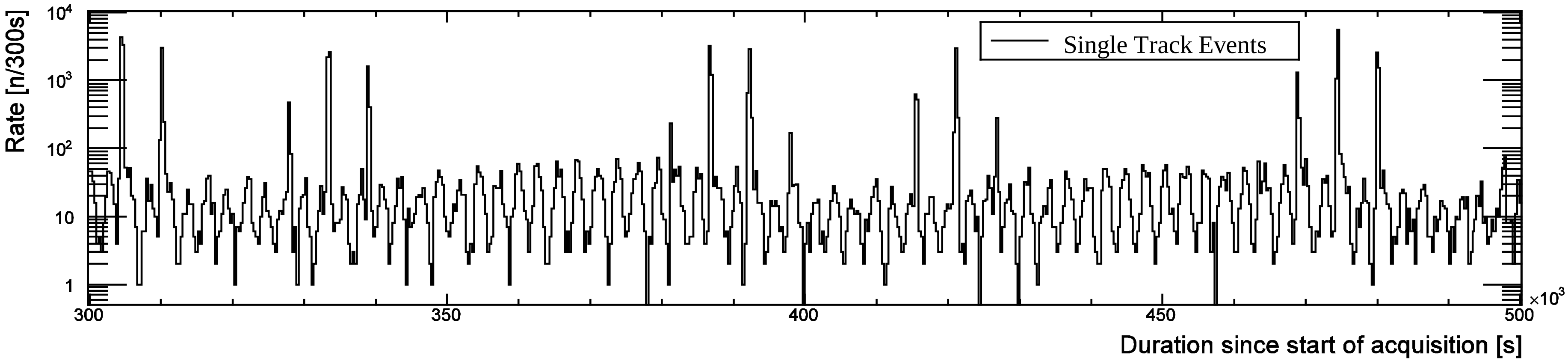
Excellent linearity of the detector

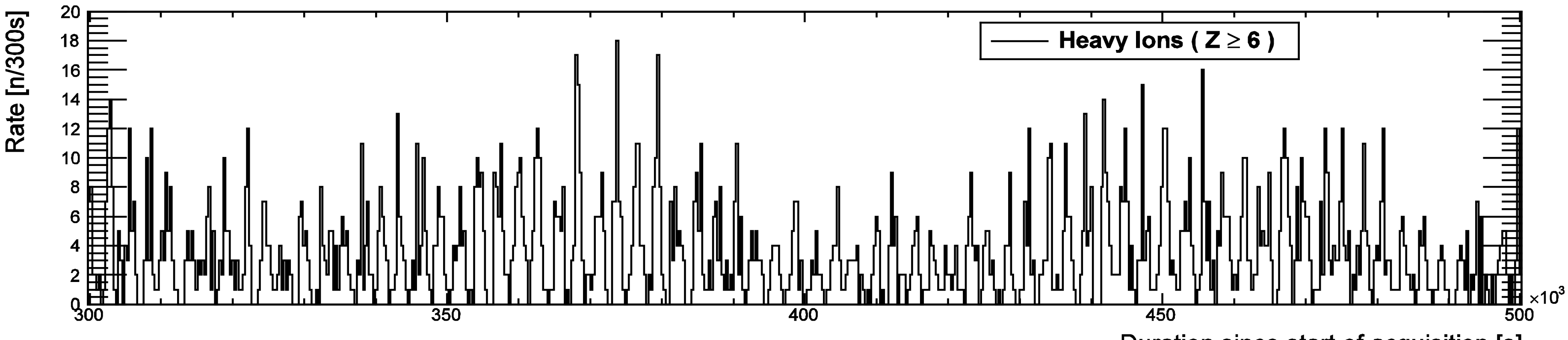


Still excellent after 5 years in space

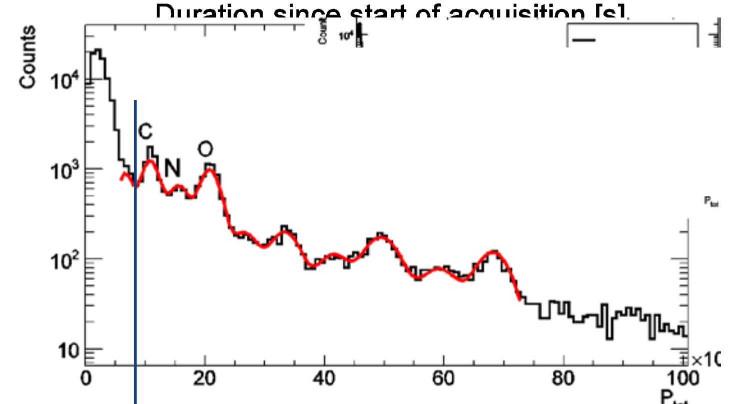
Correlation coefficient R^2=0.99994

Rates of all particles and Z≥6

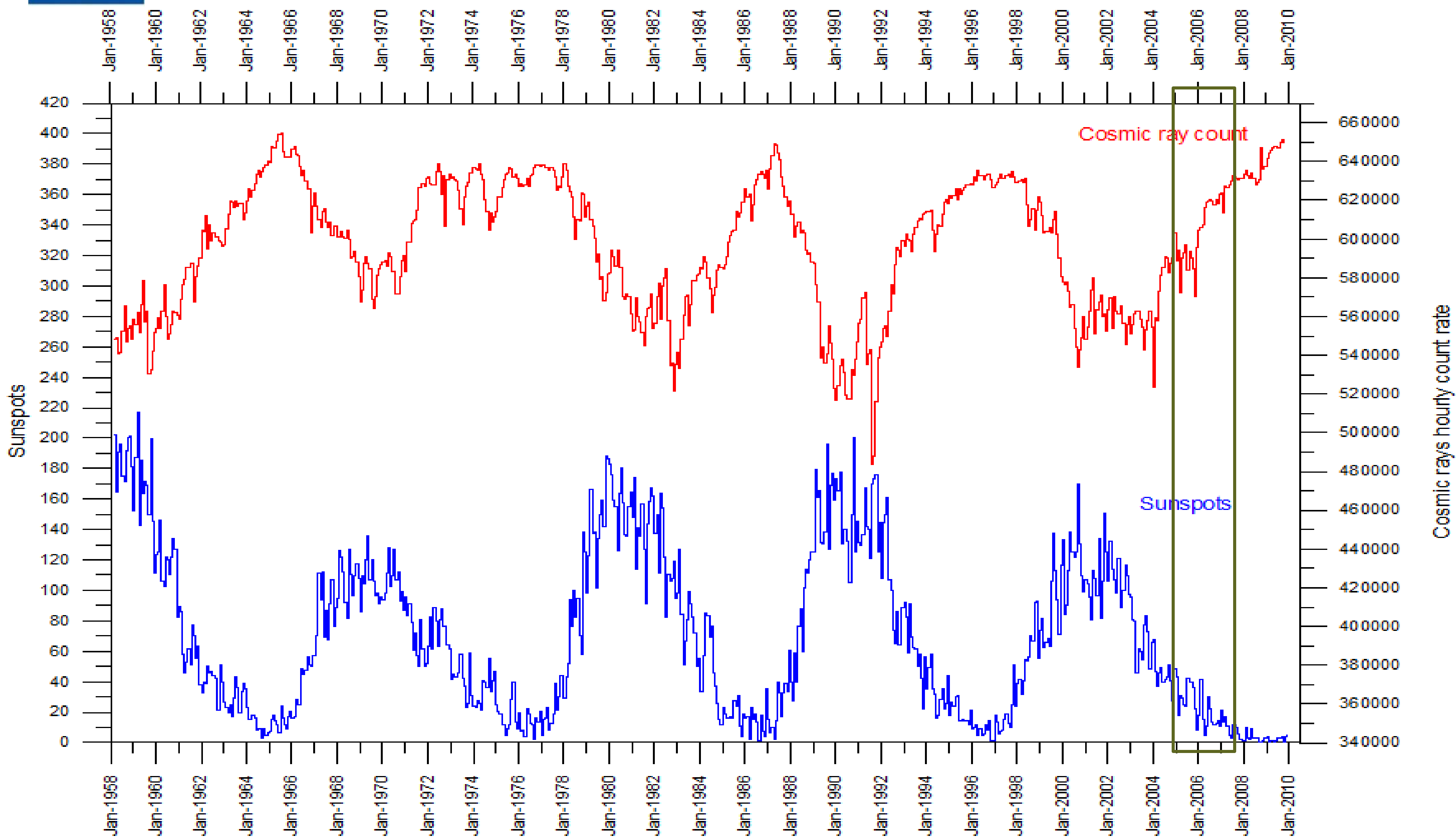




5 min slices during
2.3 days for data set 910

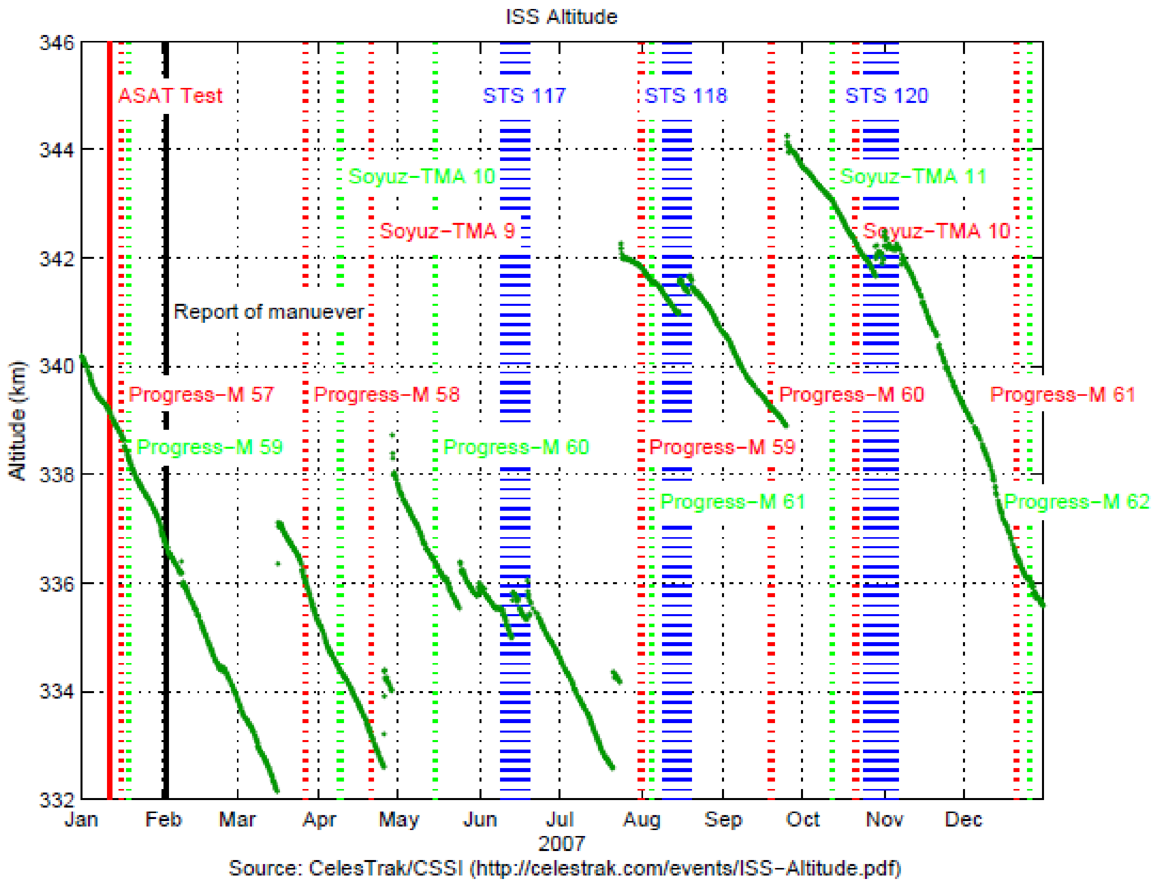


Solar Cycle and Altitude variations



Single particle rates corrected for solar cycle variation

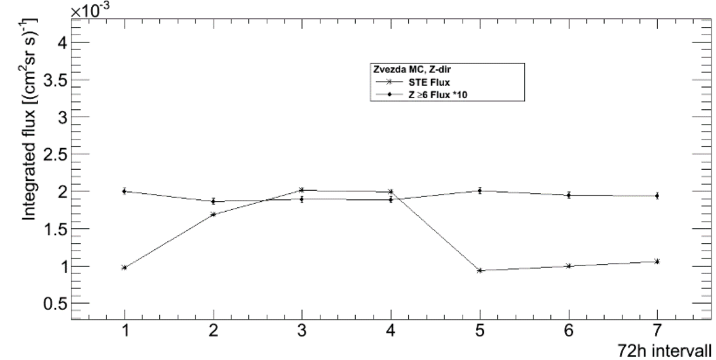
Altitude variation ca 100 m /day



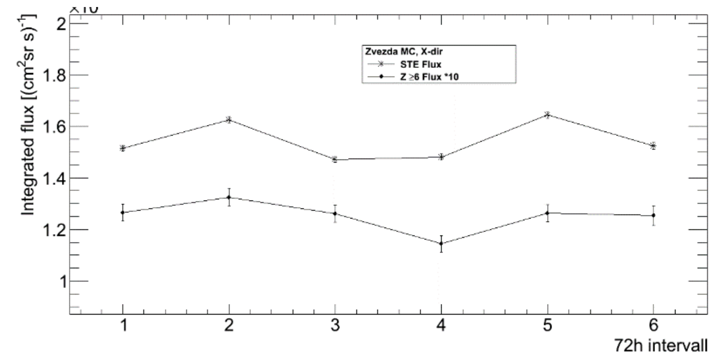
Average altitude for data sets: 333 – 348 km

During a single data set, varies up to 2 km

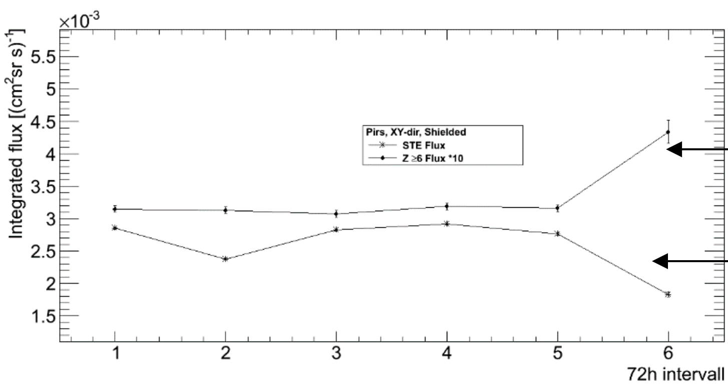
For particle rates, within datasets, see no change with altitude



Dose rates much more sensitive to altitude, due to SAA dependence

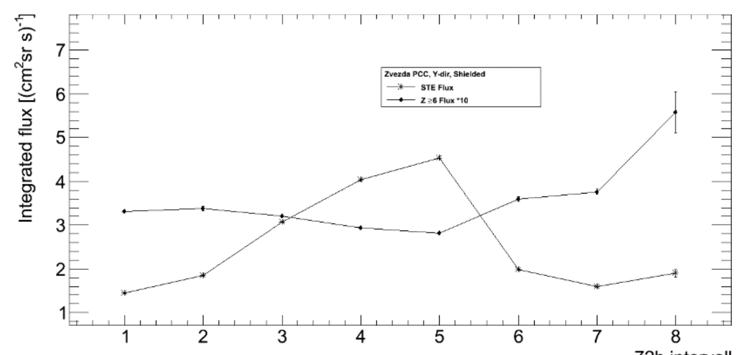


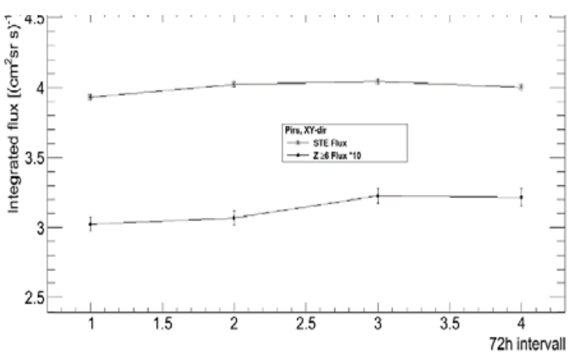
No correction for altitude made

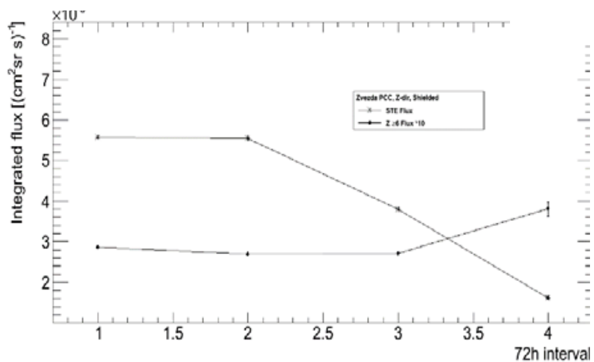


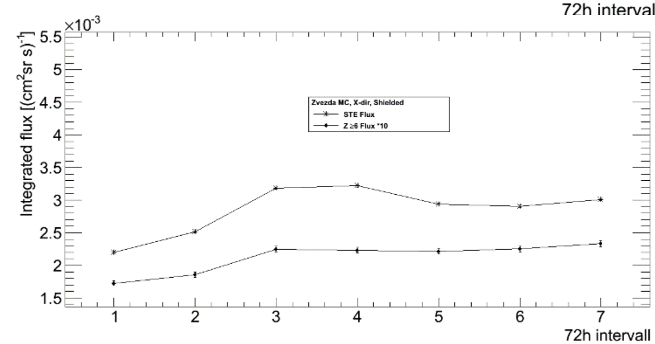
Z≥6 times 10

All particles



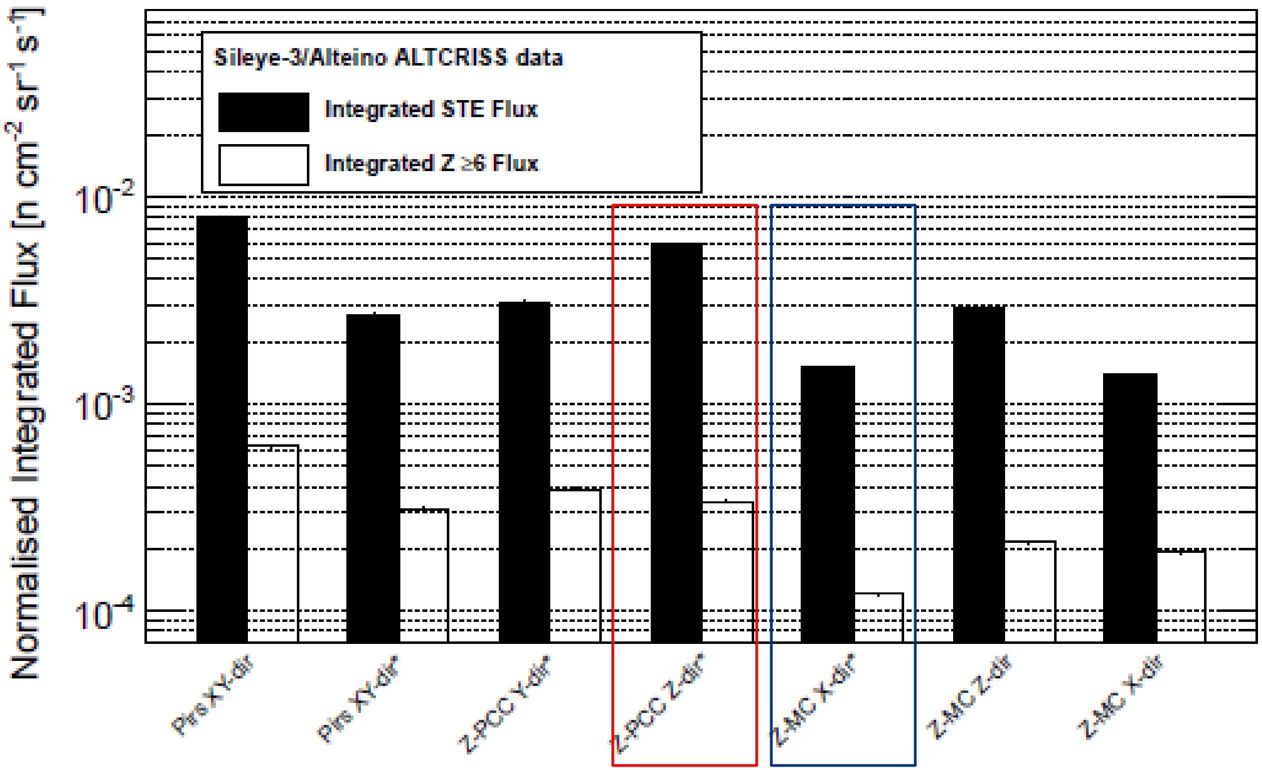






Flux rates for all data sets

STE = Singel Track Event, i.e. all particels



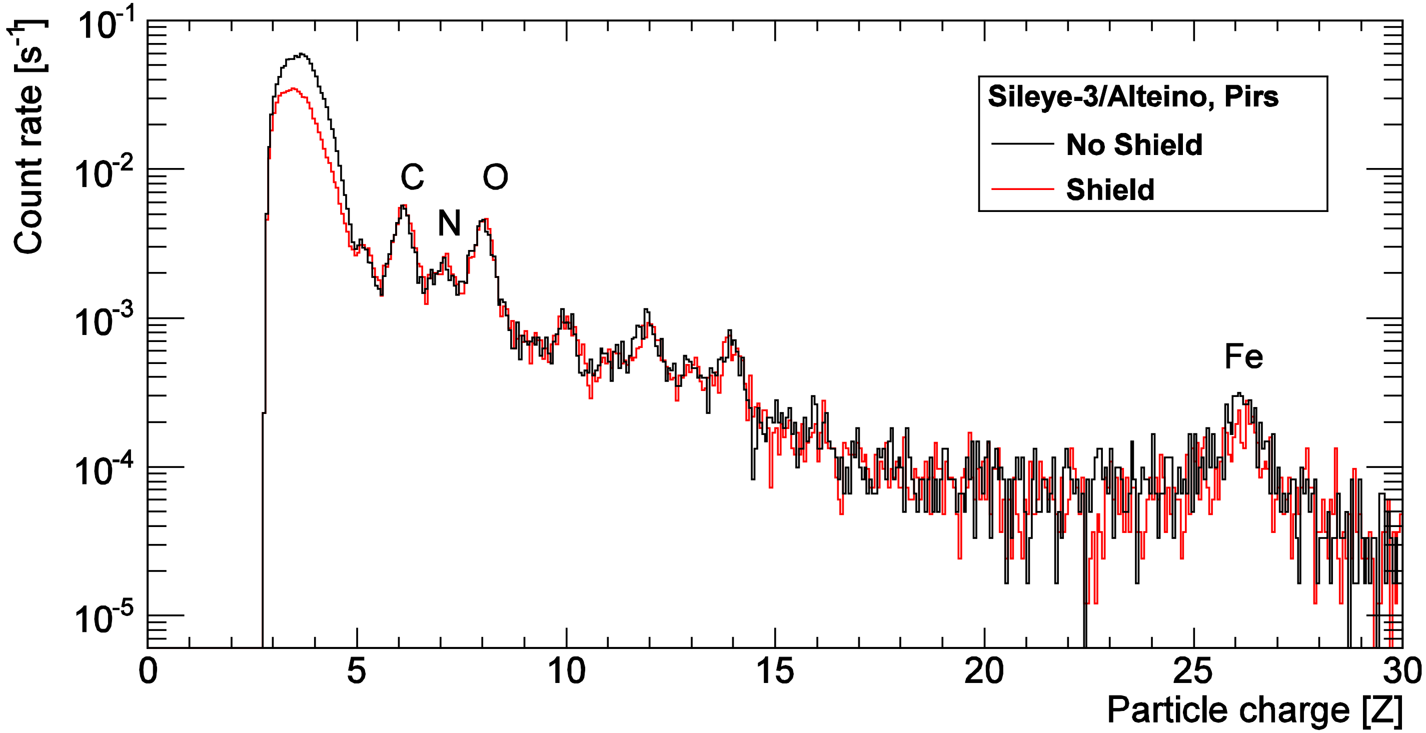
910 probably lowest amount of material in front of detector of the Zvezda sets

925 most material in front

Set	Position	Orientation	Shielding	Time YYYY-MM-DD+DD	STE Flux [(s cm^2 sr)$^{-1}$]	STE Flux normalised	Altitude [km]
902	Pirs	$\hat{XY}$	No	2005-12-26 + 11.2 d	$4.0 \cdot 10^{-3}$	$8.0 \cdot 10^{-3}$	348
903	Pirs	$\hat{XY}$	Yes	2006-01-08 + 15.4 d	$2.7 \cdot 10^{-3}$	$4.1 \cdot 10^{-3}$	347
907	Z-P-CC	$\hat{Y}$	Yes	2006-03-16 + 21.1 d	$2.6 \cdot 10^{-3}$	$3.1 \cdot 10^{-3}$	345
910	Z-P-CC	$\hat{Z}$	Yes	2006-05-17 + 9.31 d	$4.9 \cdot 10^{-3}$	$5.9 \cdot 10^{-3}$	342
925	Z-MC	$\hat{X}$	Yes	2007-05-22 + 17.2 d	$1.5 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	335
930	Z-MC	$\hat{X}$	No	2007-06-27 + 21.0 d	$2.9 \cdot 10^{-3}$	$2.9 \cdot 10^{-3}$	333
933	Z-MC	$\hat{Z}$	No	2007-08-07 + 20.6 d	$1.4 \cdot 10^{-3}$	$1.4 \cdot 10^{-3}$	341

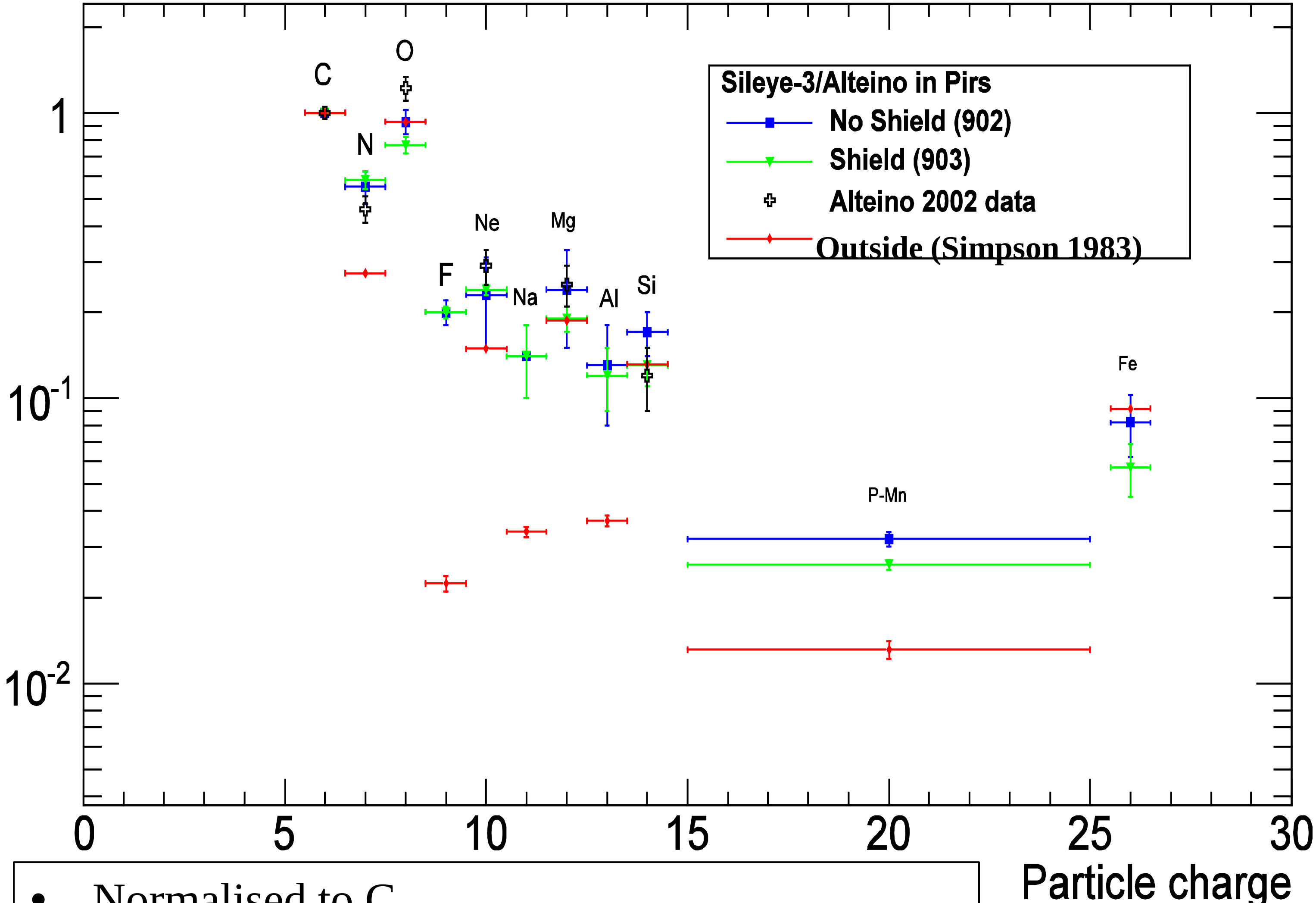
”Normalised” is to solar cycle data set 933

No Shield vs. Shield (Polyethylene 5 g/cm^2)



Set	Position	Orien-tation	Shiel-ding	Time YYYY-MM-DD+DD	Altitude [km]
902	Pirs	$X\hat{Y}$	No	2005-12-26 + 11.2 d	348
903	Pirs	$X\hat{Y}$	Yes	2006-01-08 + 15.4 d	347

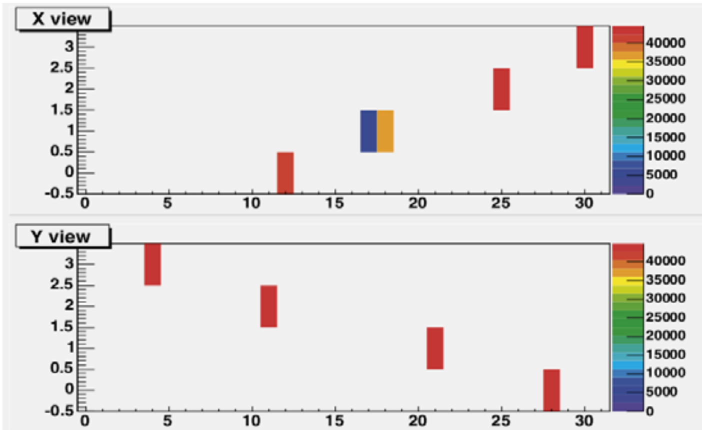
Relative abundances of nuclei speices

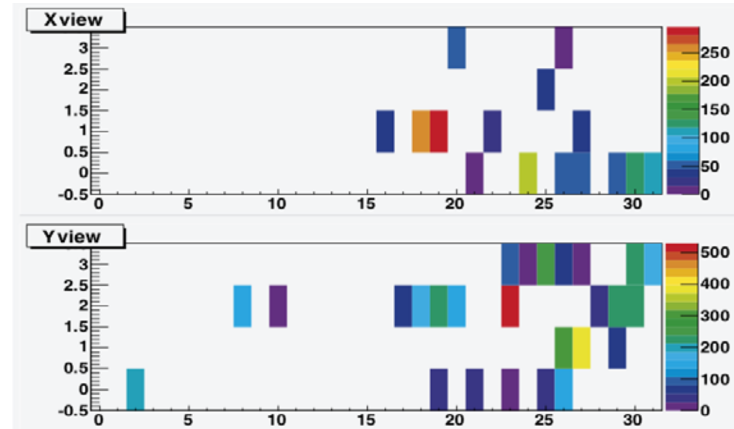


- Normalised to C
- More odd Z inside, due to fragmentation
- Reduction of Fe (as also seen by ALTEA)
- Reduction of C and O ??

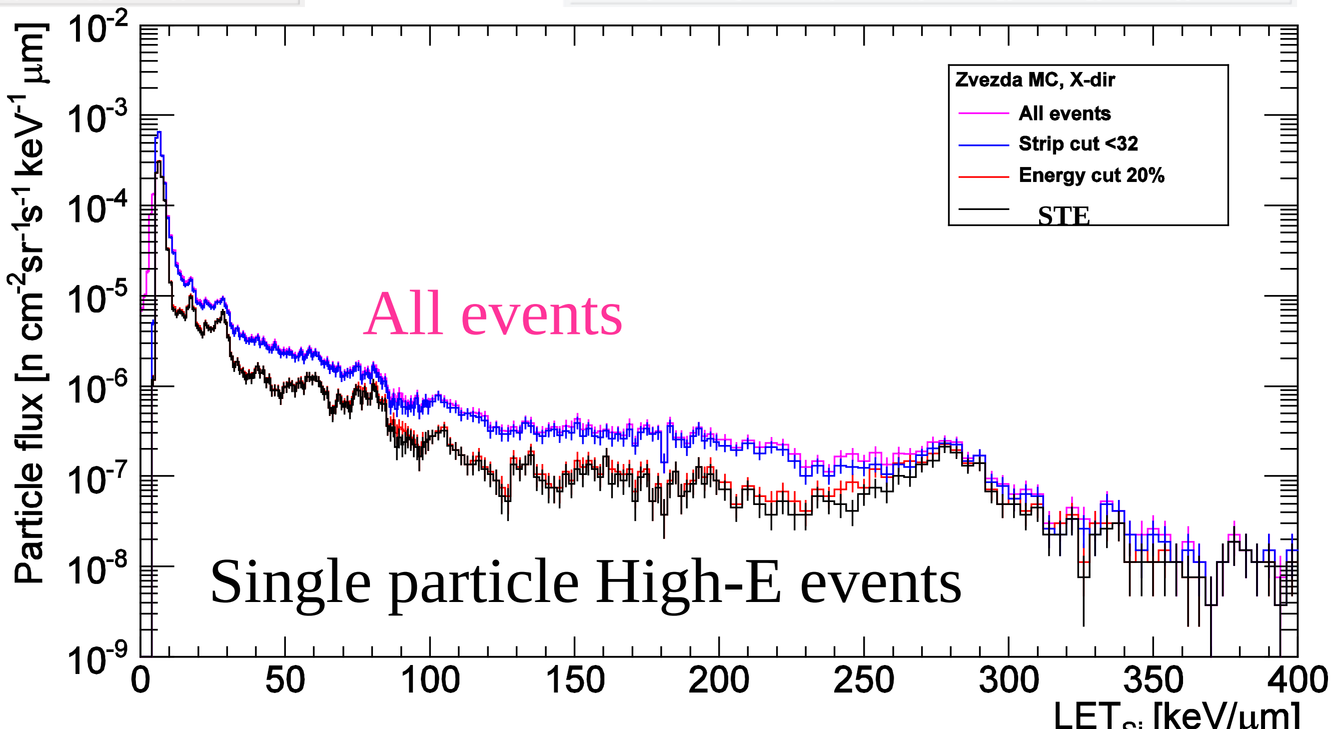
LET – spectra (prelimnary)

(Alteino collab + T. Berger, A. Nagamatsu, G. Reitz)



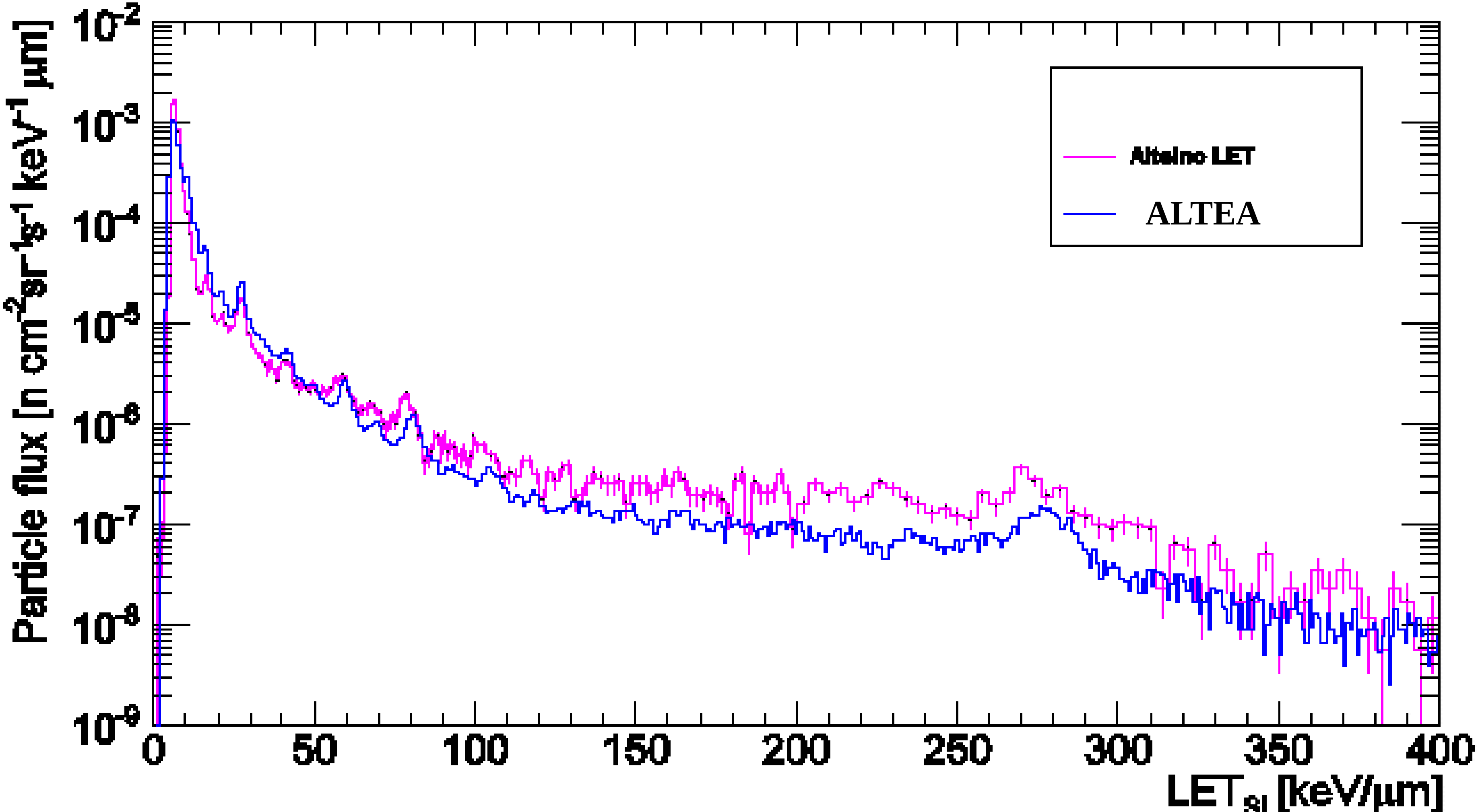


Drop single track requirement and convert to LET



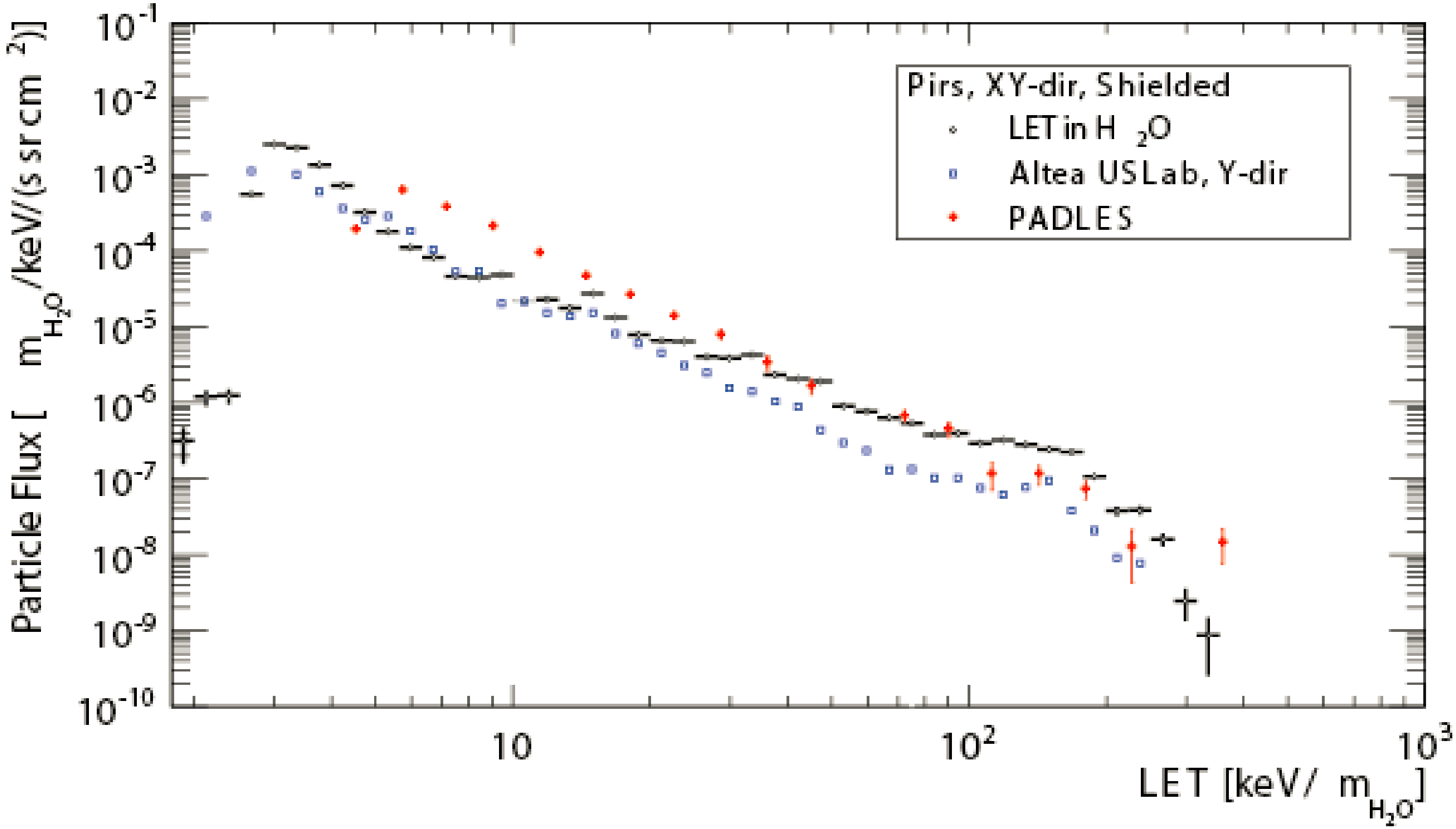
LET events in Si

Alteino in *Pirs* vs ALTEA in *Destiny* Ŷ-dir



- Position of Ion peaks agree well
- More material around ALTEA than Alteino (in this positon)

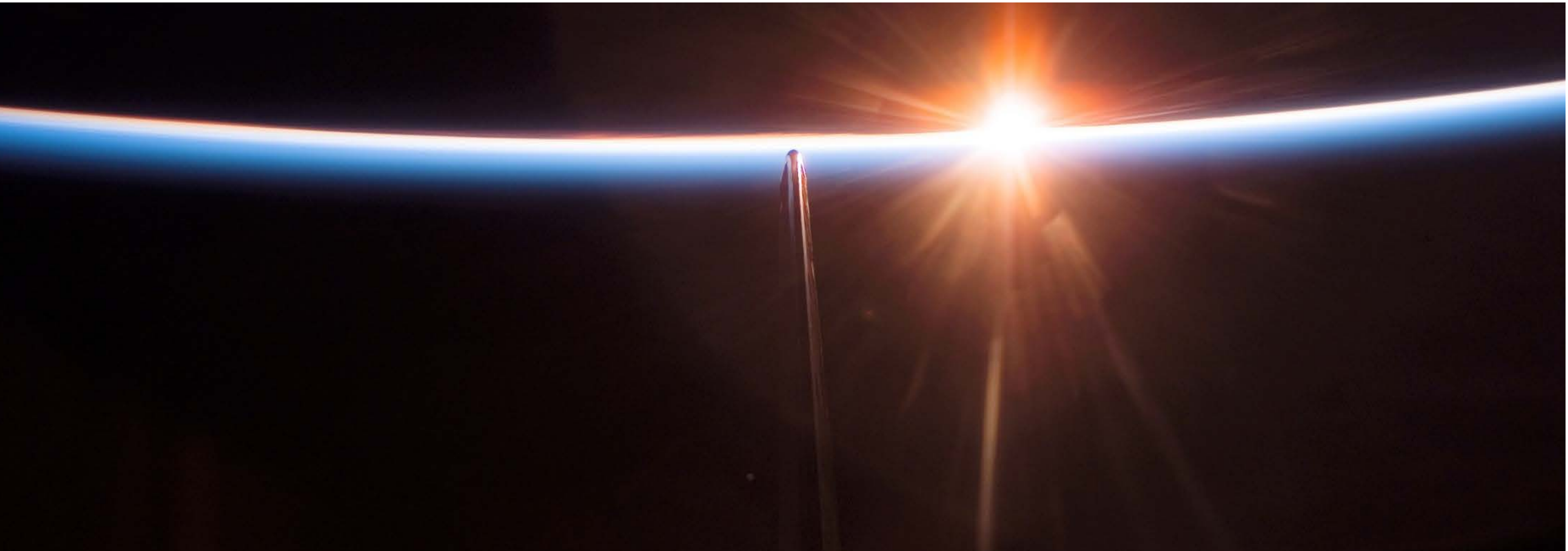
LET in H_20 distribution (preliminary)



- PADLES (CR-39 & TLD – here only CR-39 used) placed with Alteino
- Alteino and ALTEA require higher min energy of particle for read-out

LET rate (prel) vs Single Track Flux for the various data sets

Set	Position	Orien-tation	Shiel-ding	Time YYYY-MM-DD+DD	STE Flux $[(s\ cm^2\ sr)^{-1}]$	LET rate $[keV/(cm^2 sr\ s\ \mu m)]$
902	Pirs	$\hat{X}\hat{Y}$	No	2005-12-26 + 11.2 d	$4.0 \cdot 10^{-3}$	$2.18{\cdot}10^{-1}$
903	Pirs	$\hat{X}\hat{Y}$	Yes	2006-01-08 + 15.4 d	$2.7 \cdot 10^{-3}$	$1.76{\cdot}10^{-1}$
						$5.03{\cdot}10^{-2}$
907	Z-P-CC	$\hat{Y}$	Yes	2006-03-16 + 21.1 d	$2.6 \cdot 10^{-3}$	$1.60{\cdot}10^{-1}$
910	Z-P-CC	$\hat{Z}$	Yes	2006-05-17 + 9.31 d	$4.9 \cdot 10^{-3}$	$1.03{\cdot}10^{-1}$
925	Z-MC	$\hat{X}$	Yes	2007-05-22 + 17.2 d	$1.5 \cdot 10^{-3}$	$1.20{\cdot}10^{-1}$
930	Z-MC	$\hat{X}$	No	2007-06-27 + 21.0 d	$2.9 \cdot 10^{-3}$	$1.98{\cdot}10^{-1}$
933	Z-MC	$\hat{Z}$	No	2007-08-07 + 20.6 d	$1.4 \cdot 10^{-3}$	



Dose rates (preliminary)

For Dose rate (D_r) and Equivalent Dose rate (H_r) the LET spectrum in Silicon (LET_{Si}) has been recalculated to LET in water (LET_{H_2O}) by equation (1), according to [3].

$$Log(LET_{H_2O}) = -0.2902 + (1.025 \cdot Log(LET_{Si})) \tag{1}$$

It then follows the D_r in $[Gy/s]$ is calculates as:

$$D_r = 1.6 \cdot 10^{-9} \cdot 4\pi \cdot \int LET_{H_2O}(E) \cdot E \cdot dE \tag{2}$$

and the H_r, in $[Sv/s]$, by multiplying the LET-value with a quality factor Q, according to:

$$H_r = 1.6 \cdot 10^{-9} \cdot 4\pi \cdot \int LET_{H_2O}(E) \cdot E \cdot Q(E) \cdot dE \tag{3}$$

Location	Orientation	Panel	Shielding	D_r $[\mu Gy/day]$	H_r $[\mu Sv/day]$	Q-average
Pirs	$\hat{X}\hat{Y}$	401	No	33.1	211	1.40
Pirs	$\hat{X}\hat{Y}$	401	Yes	26.5	197	1.56
Z-PCC	$\hat{Y}$	239	Yes	27.9	231	1.66
Z-PCC	$\hat{Z}$	333	Yes	37.3	209	1.32
Z-MC	$\hat{X}$	326	No	19.9	184	1.81
Z-MC	$\hat{X}$	326	Yes	22.1	154	1.46
Z-MC	$\hat{Z}$	326	No	22.6	240	2.12
ALTEA	$\hat{X}$	-	No	28	68.2	1.2
ALTEA	$\hat{Y}$	-	No	30.0	125	1.3
ALTEA	$\hat{Z}$	-	No	27	110	1.3
PADLES	-	-	Yes	250	480	1.9
PADLES	-	-	No	260	500	1.8
CR-39 only	-	-	Yes	33	170	?
TLD600	-	-	Yes	230	-	-
TLD700	-	-	Yes	210	-	-
TLD600	-	-	No	250	-	-
TLD700	-	-	No	230	-	-

Multiplicity and dose rates

Table 3. Contribution count rate depending on event multiplicity. Datasets with an * have additional 5 g/cm^2 polyethylene. Values in % of LET events.

Multip.	Pirs	Pirs*	Z-PCC $\hat{Y}$*	Z-PCC $\hat{Z}$*	Z-MC $\hat{X}$	Z-MC $\hat{X}$*	Z-MC $\hat{Z}$*
5-10	98.0	96.3	96.3	97.6	85.4	96.1	84.2
11-15	1.16	2.24	2.18	1.44	3.19	2.46	4.02
16-20	0.377	0.717	0.728	0.451	0.967	0.807	1.31
> 20	0.371	0.659	0.644	0.404	0.896	0.610	1.11

Table 4. Contribution to dose rate depending on event multiplicity. Datasets with an * have additional 5 g/cm^2 polyethylene. Values in % of LET events.

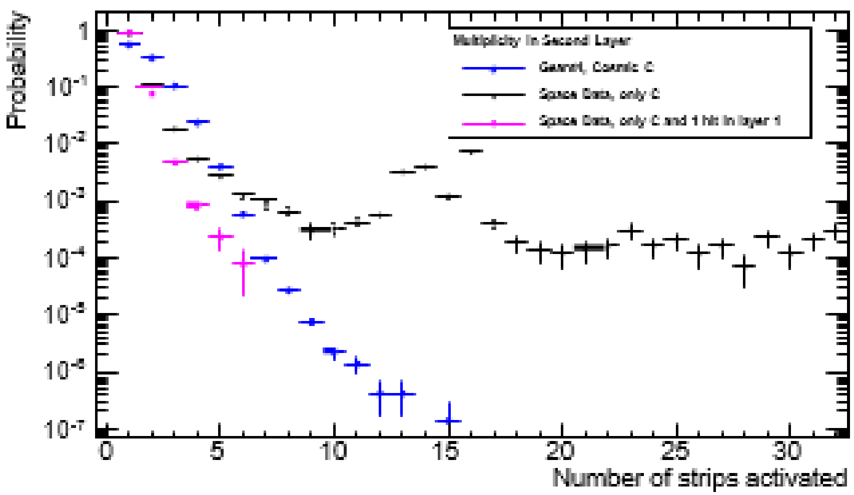
Multip.	Pirs	Pirs*	Z-PCC$\hat{Y}$*	Z-PCC$\hat{Z}$*	Z-MC$\hat{X}$	Z-MC$\hat{X}$*	Z-MC$\hat{Z}$*
5-10	91.8	88.4	87.8	90.8	81.3	85.8	78.7
11-15	4.77	6.94	7.28	5.65	9.99	8.86	11.1
16-20	1.56	2.00	2.18	1.64	3.10	2.71	3.78
> 20	1.81	2.54	2.66	1.83	3.10	2.59	4.54

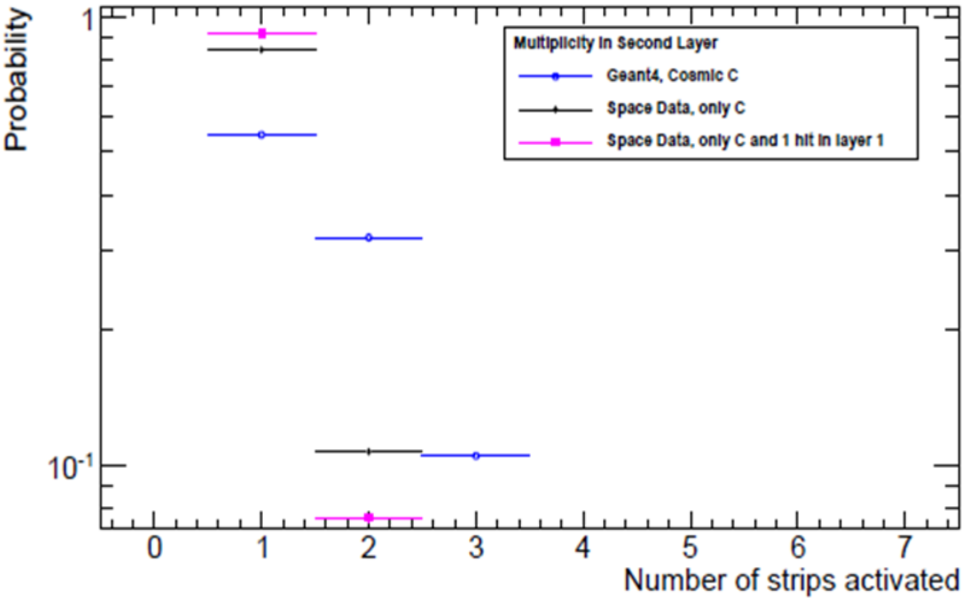
Table 5. Contribution to dose equivalent rate depending on event multiplicity. Datasets with an * have additional 5 g/cm^2 polyethylene. Values in % of LET events.

Multip.	Pirs	Pirs*	Z-PCC$\hat{Y}$*	Z-PCC$\hat{Z}$*	Z-MC$\hat{X}$	Z-MC$\hat{X}$*	Z-MC$\hat{Z}$*
5-10	78.3	75.9	75.0	74.5	70.6	68.0	67.7
11-15	12.3	14.2	14.6	15.6	18.3	19.9	17.9
16-20	4.43	4.12	4.54	4.73	5.71	6.04	6.23
> 20	4.96	5.75	5.74	5.18	5.20	6.04	7.91

Simulation of detector on-going, but persistent problem with GEANT4 for δ-electrons

Probability distribution for multiplicity in layer 2, simulated data compared with space data.





Summary

- Alteino (”small Altea”) took data at several locations and orientations in the Russian Segment of ISS between 2002 and 2007
- 7 data sets from 2005, 2006 and 2007 analysed, with and without polyethylene shields of 5 g/cm2
- Nuclei identified between C and Fe
- Fragmentation in ISS material seen by increased odd, low-Z nuclei; Fe relative abundance seems lower
- Rates of $Z \geq 6$ decrease with shielding
- Preliminary LET spectra agree as expected with other data
- Large relative contribution to LET from high-multiplicity events

Acknowledgement: This experiment was supported in various ways by ESA, ASI, INFN and RSA