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Results and lessons learned from calibration measurements of the TRITEL 3D silicon detector telescope at the HIMAC accelerator facility

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22nd Workshop on Radiation Monitoring for the ISS, 5-7 September 2017, Torino, Italy

Outline

- Brief overview of the TRITEL system
- TRITEL history in space
- Calibration setup
- MC simulations with GRAS
- Comparison of on ground measurements with the results of the simulations
- Conclusion

Brief overview of the TRITEL system

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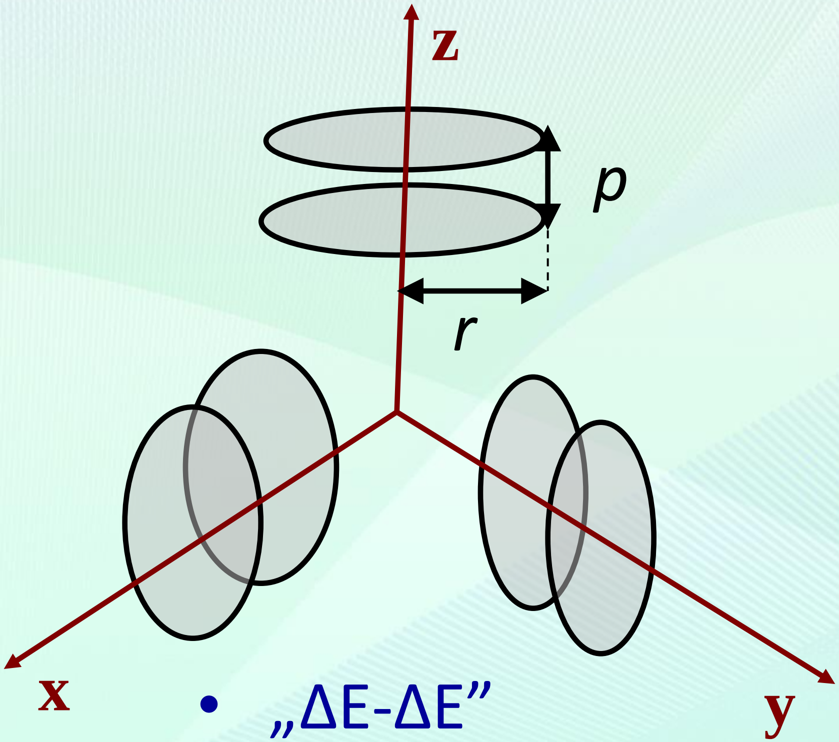
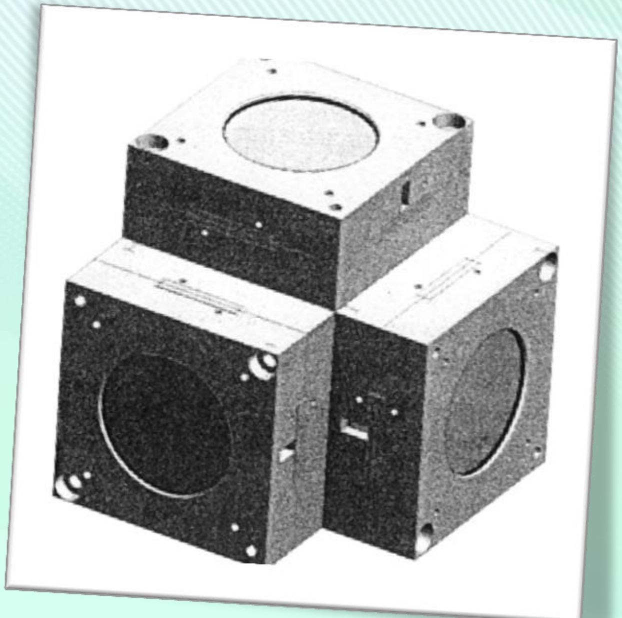
TRITEL – 3D silicon detector telescope

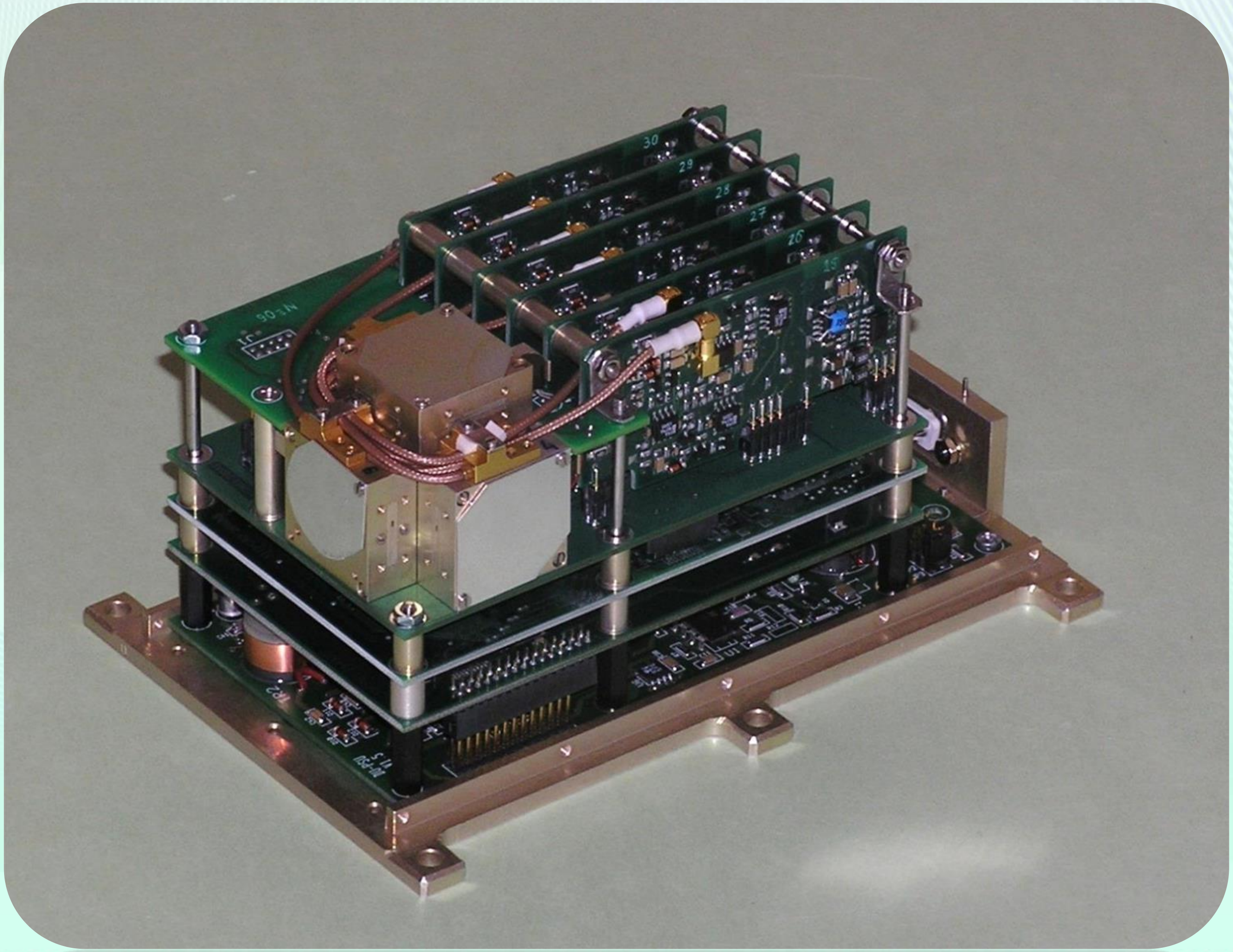


- „ΔE-ΔE" detector
- Σ ΔE → ~D
- $\Delta E / x_{avg} \approx LET_{Si}$

- *3 x 2 Canberra FD PIPS det.*
- *r* = 8.4 mm
- *p* = 8.9 mm
- *w* = 300 µm



TRITEL – 3D silicon detector telescope



Data products

- ΔE measurements: 60 keV – 83 MeV
  (quasi logarithmic spectra; total and coincidence)
  → LET: 0.2 keV/μm – 120 keV/μm in water
- ΔE spectra every 10 minutes
  → 90-min and daily spectra are stored
- Time spectra (total and coincidence); 1-min resolution
- Contribution from SAA crossings →collected separately

TRITEL history in space

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TRITEL on board Columbus

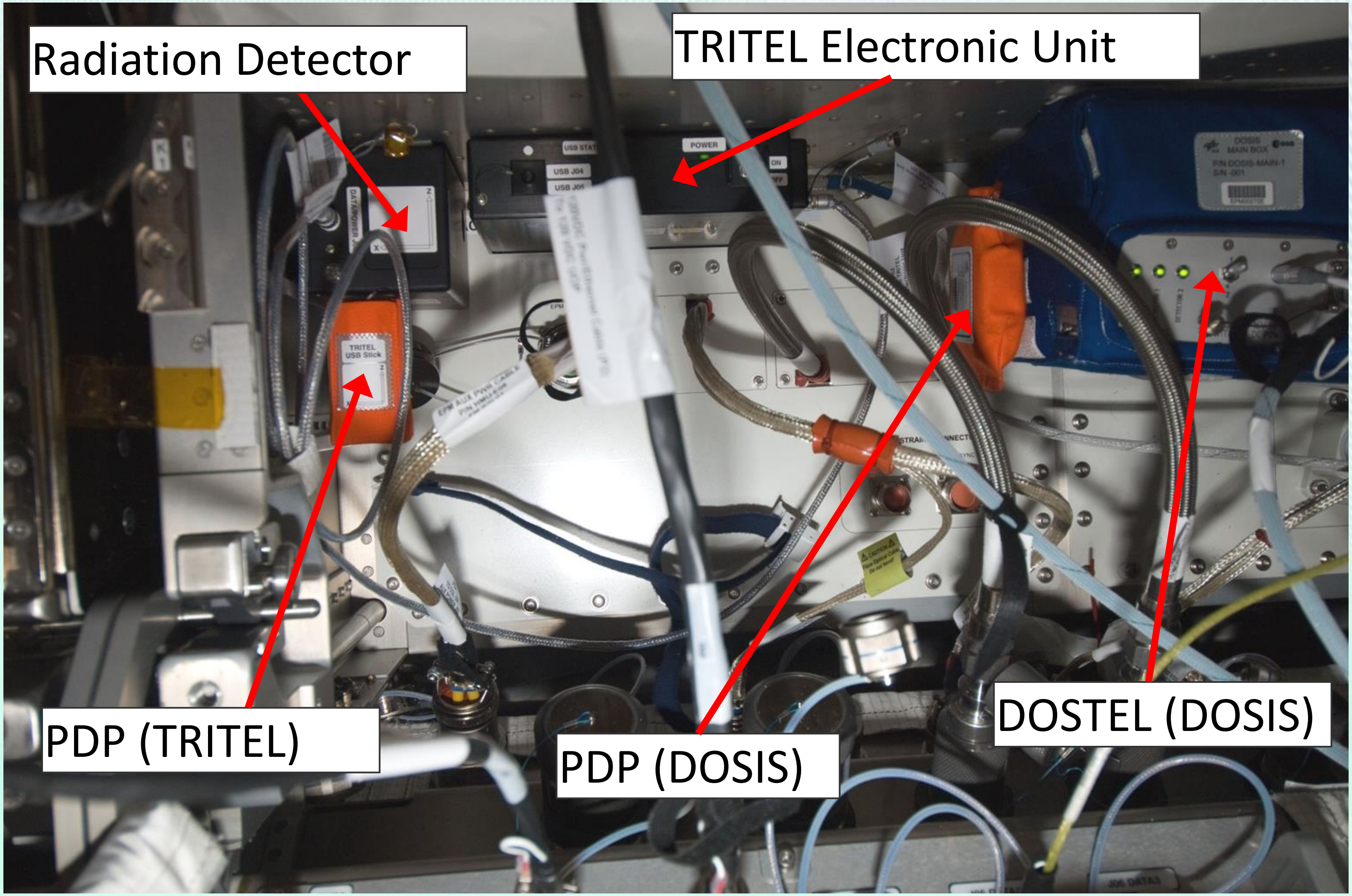

Photo: ESA/NASA

TRITEL on board Columbus

The *TRITEL-SURE experiment* was co-funded by the EC project SURE, contract number RITA-CT-2006-026069 and by the Government of Hungary through ESA Contracts 98057 and 4000108072/13/NL/KML under the PECS (Plan for European Cooperating States).

External CoIs: Sönke Burmeister, Günther Reitz

Acknowledgements for S. Burmeister for sharing DOSTEL data, experiences, etc.

TRITEL in the Russian SM

TRITEL-RS (in the frame of Matroshka-R) was developed in cooperation with the Institute of Biomedical Problems, Moscow and with the former financial support of the Hungarian Space Office.

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TRITEL on board ISS

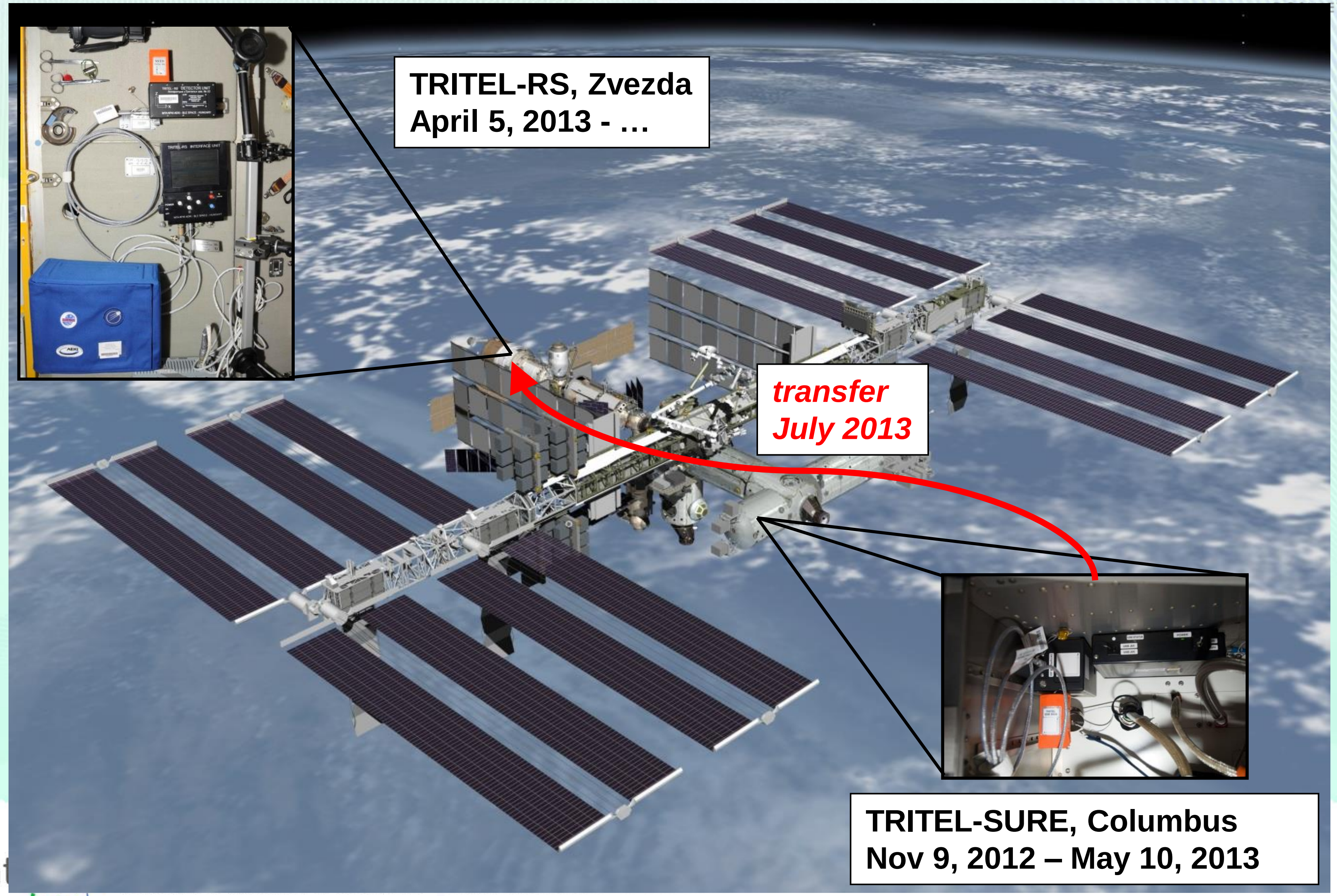
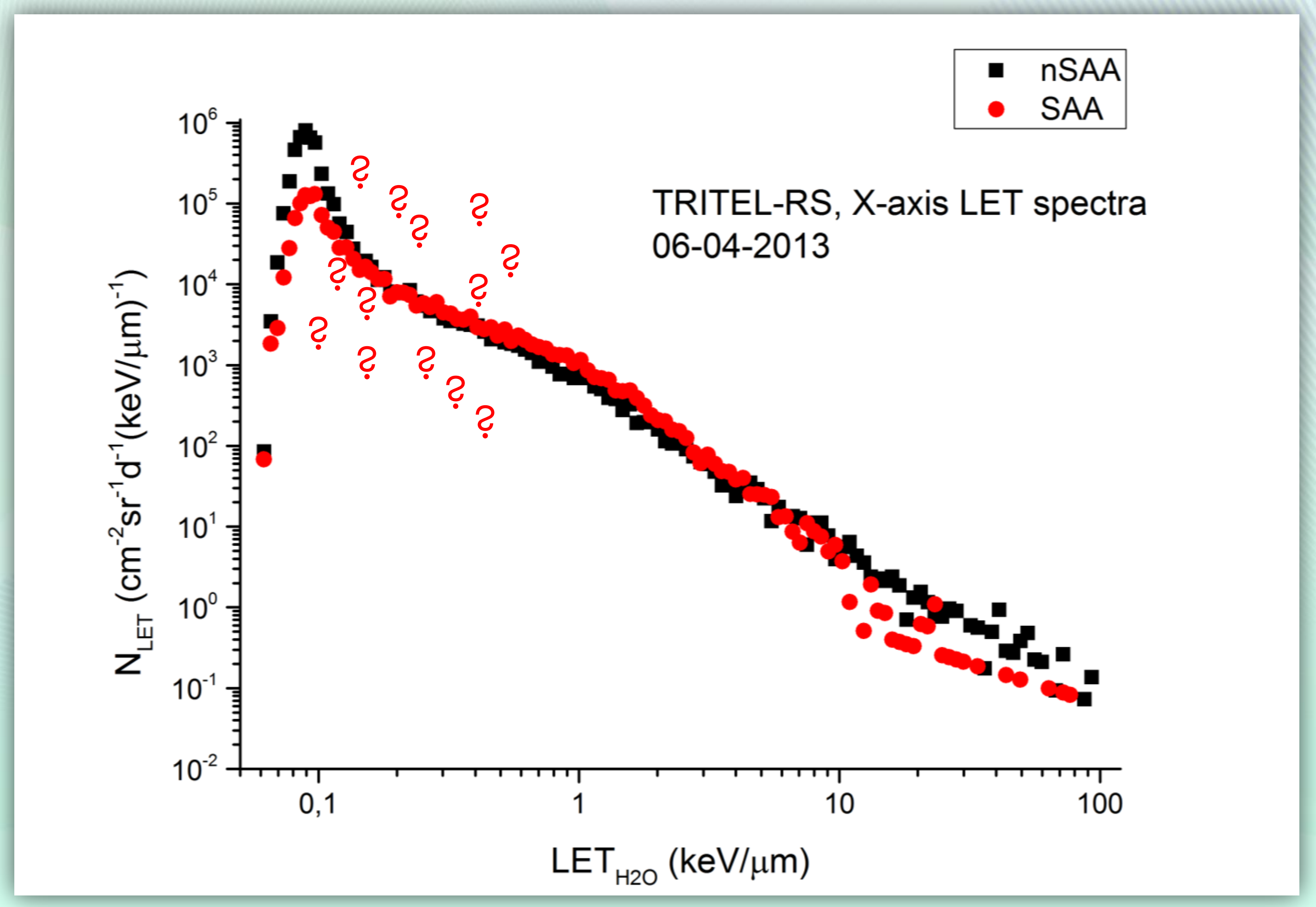
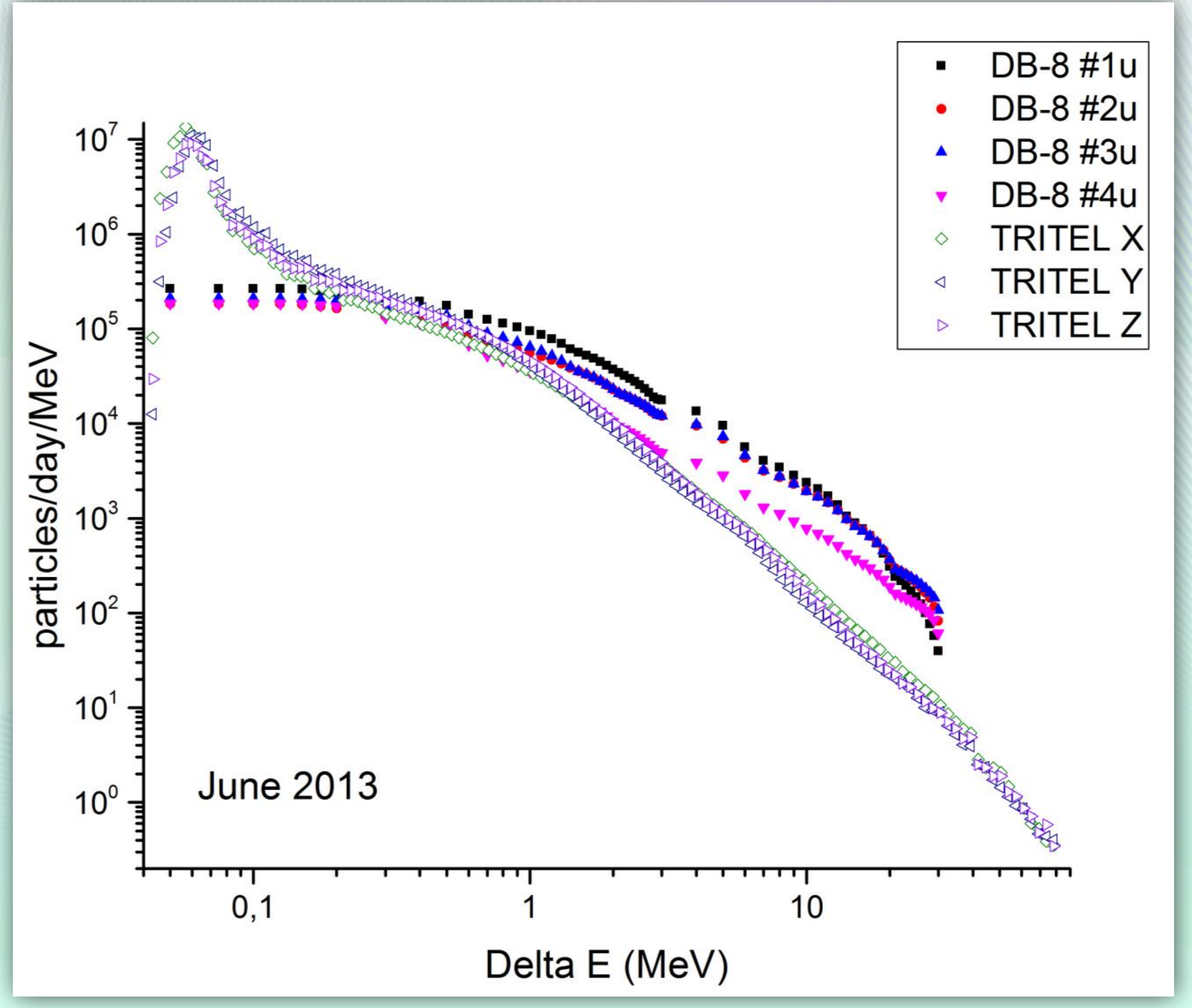


Figure: NASA; Photos: Energia/Roscosmos/IMBP and ESA/NASA

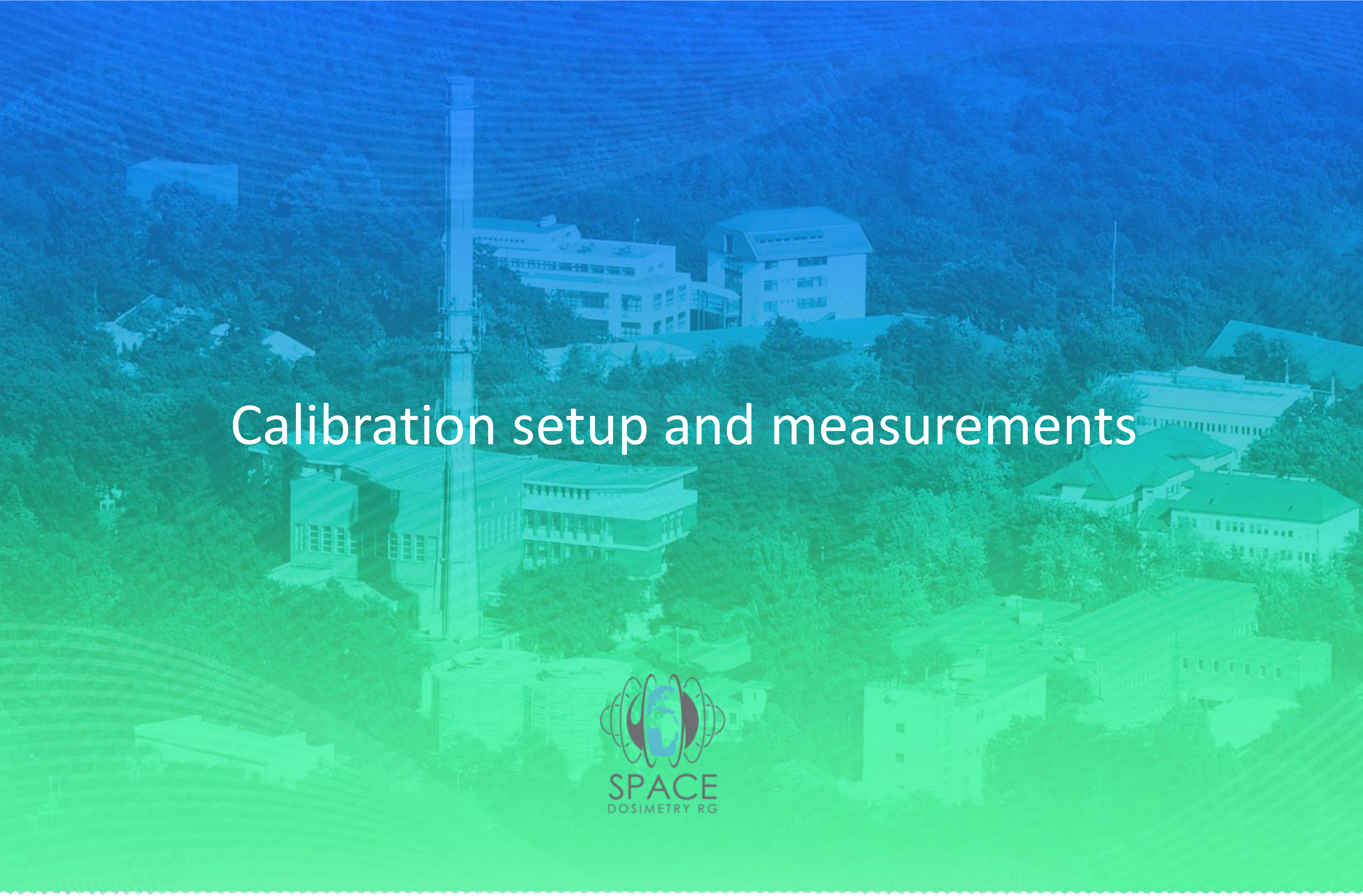
Weird shape of LET spectra

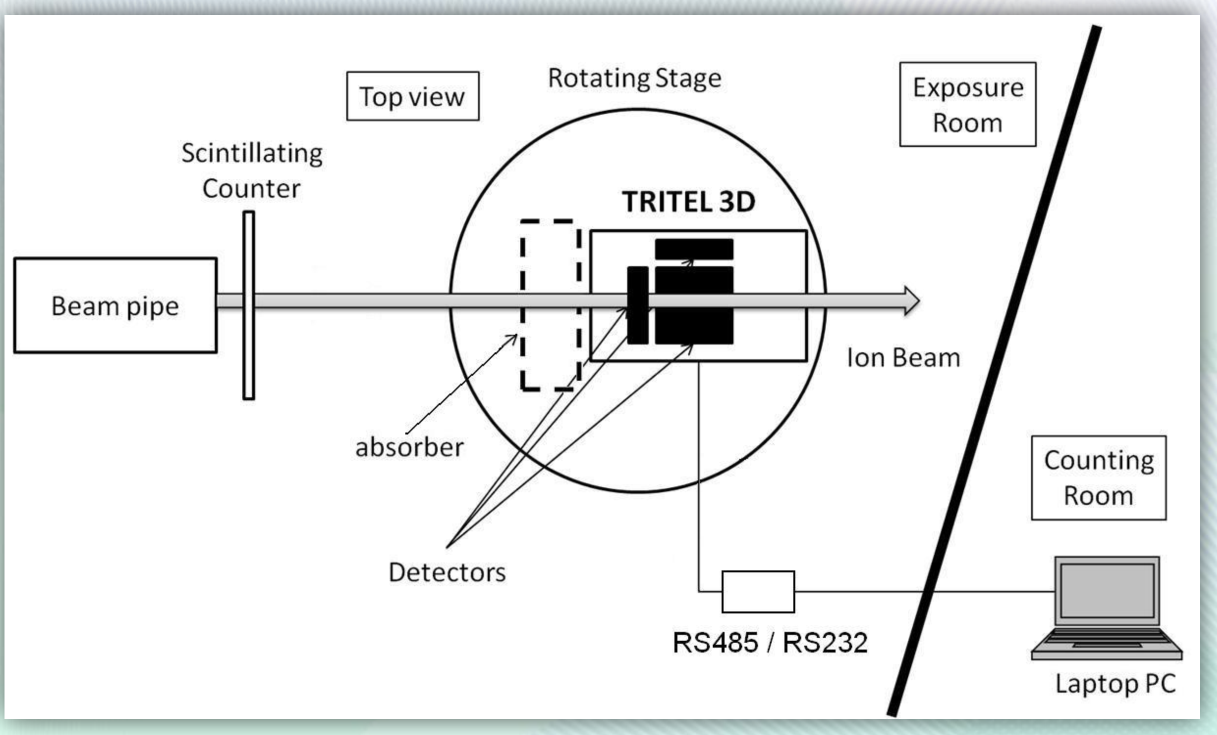


Credits (DB8 data): Andrei Lishnevskii



Calibration setup and measurements

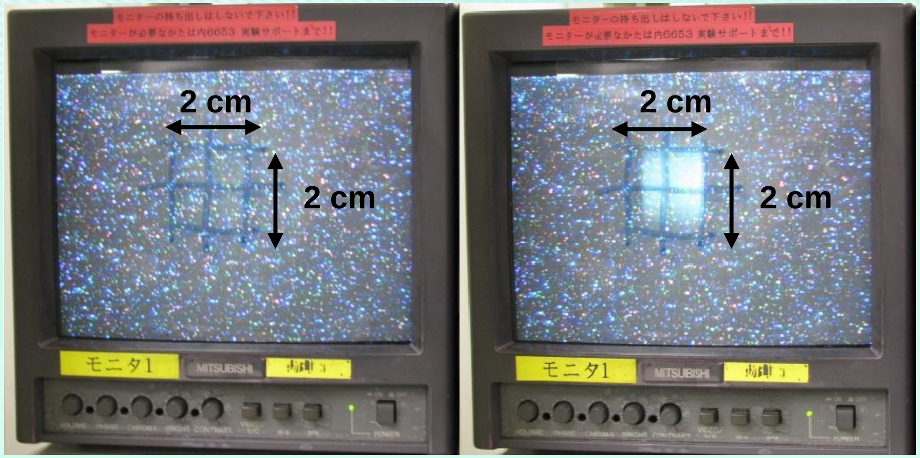


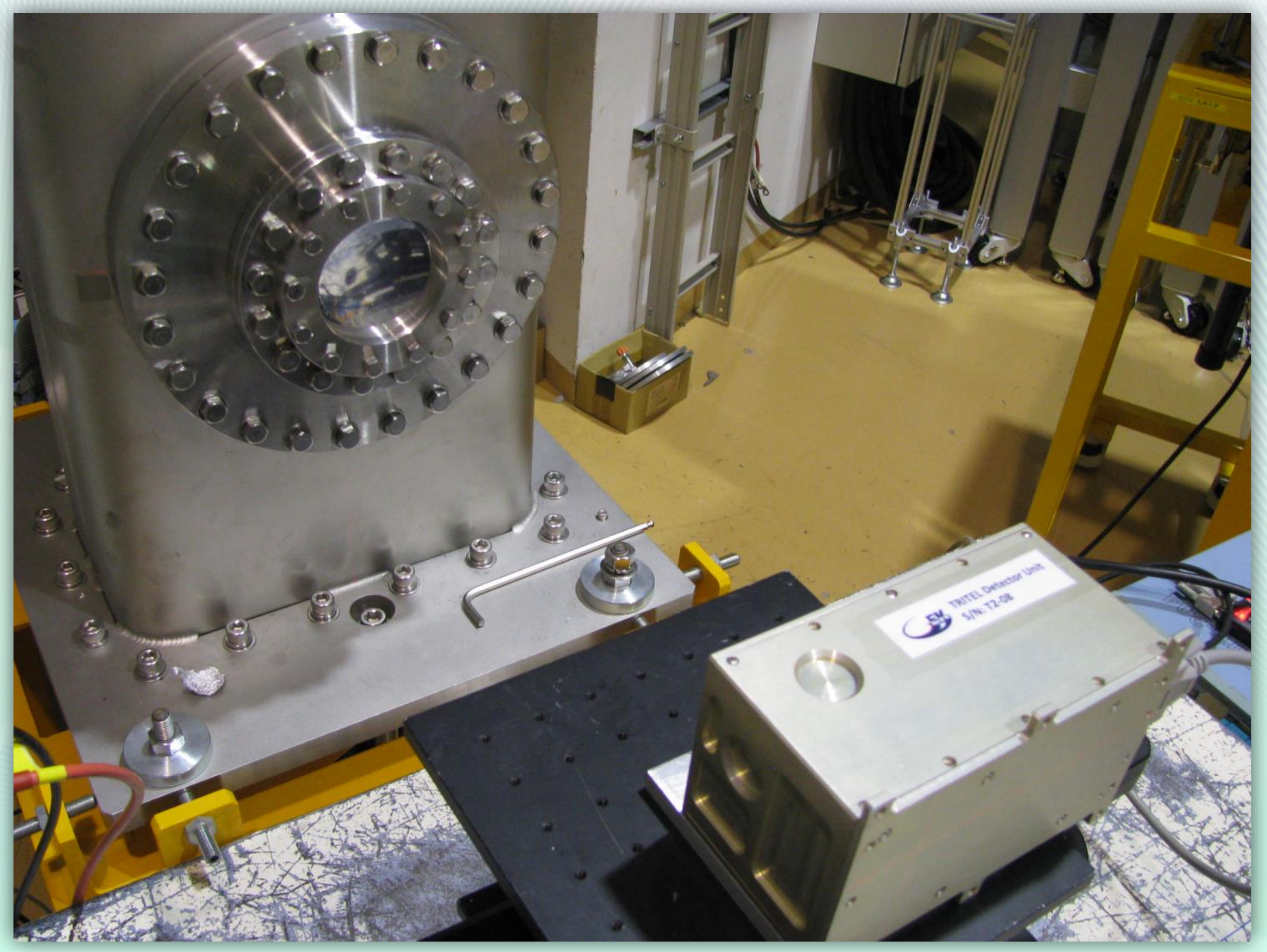


Heavy Ion Medical Accelerator
NIRS, Japan

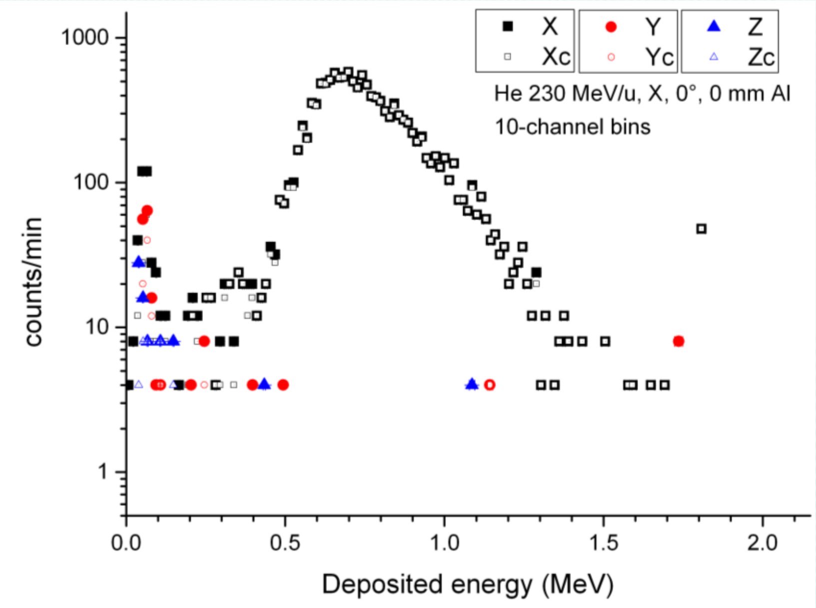
Beams:

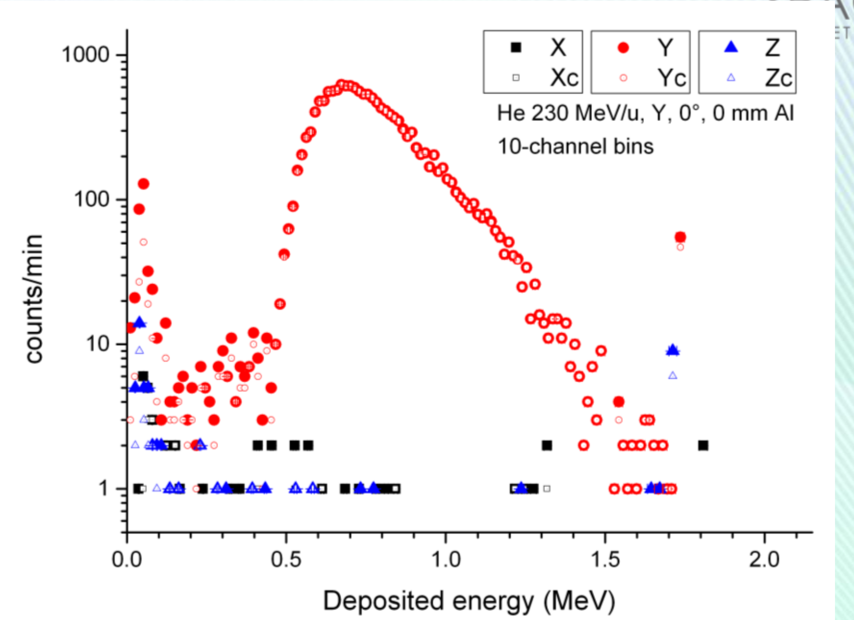
- He, 230 MeV/u (1.66 keV/µm)
- C, 400 MeV/u (10.7 keV/µm)
- Ar, 290 MeV/u (121 keV/µm)

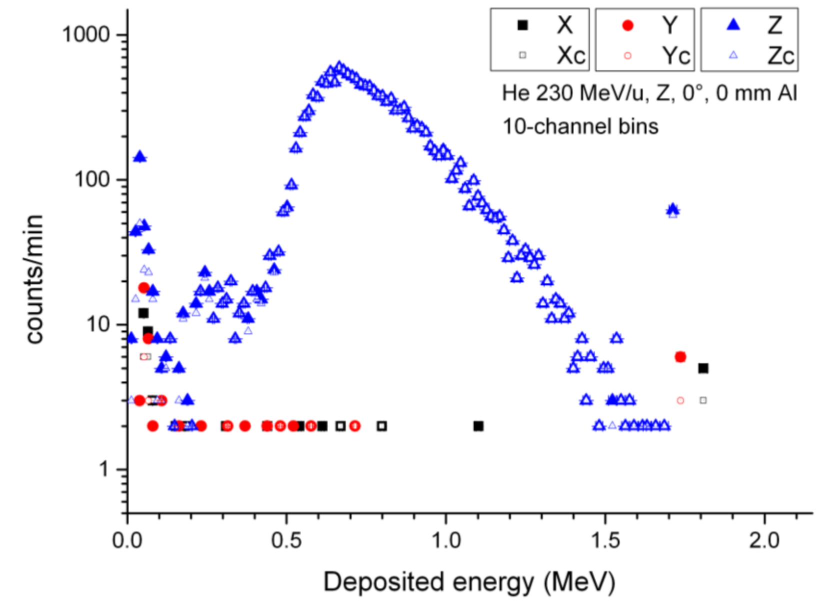



TRITEL Detector Unit
S/N: T2-08

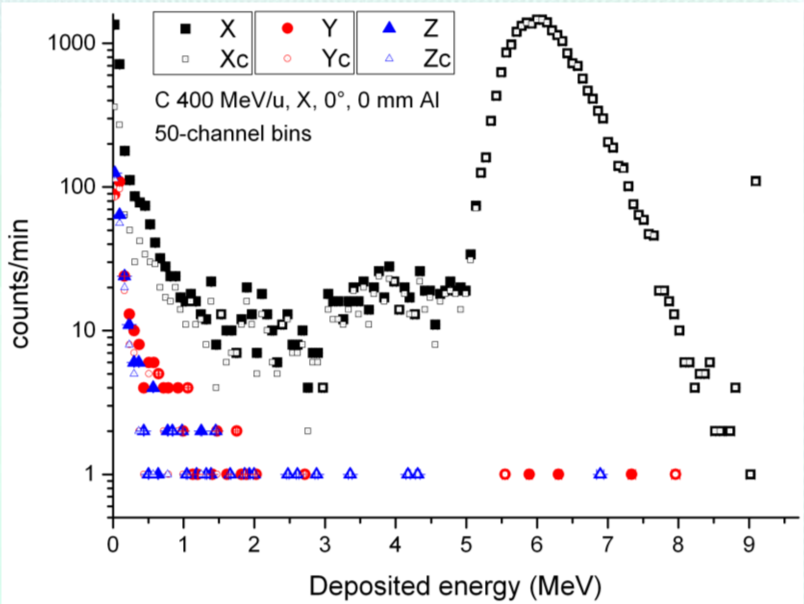
He 230 MeV/u, 0°, 0 mm Al

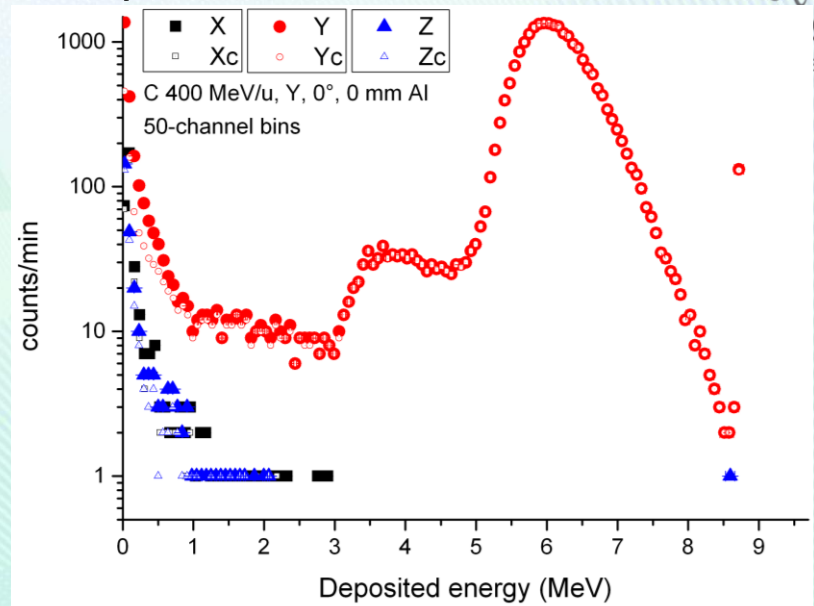


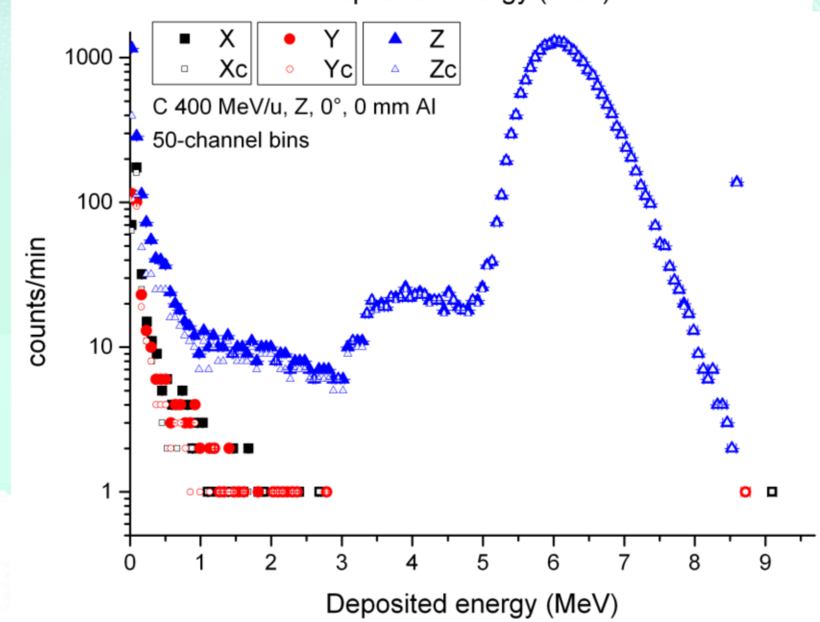




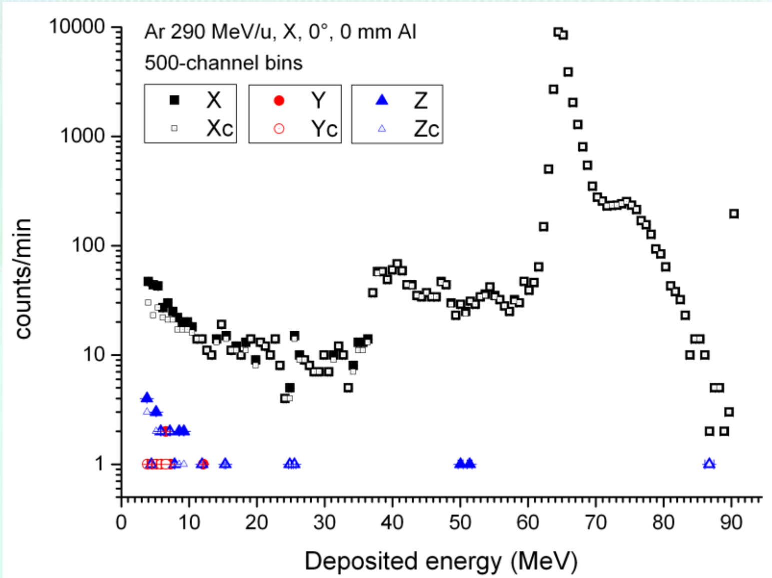
C 400 MeV/u, 0°, 0 mm Al

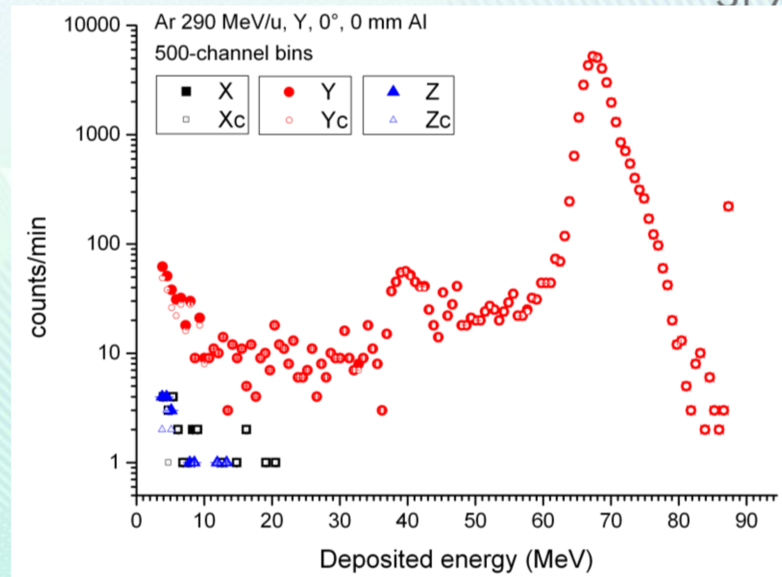


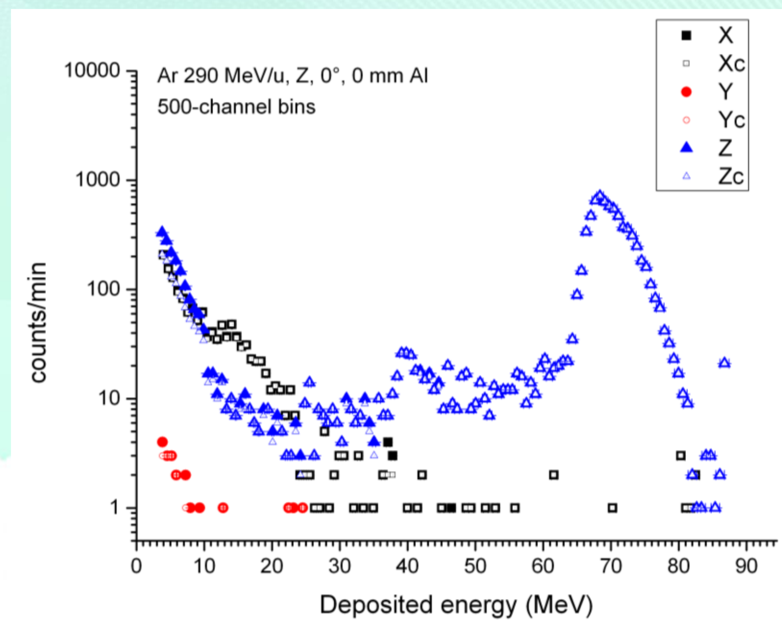


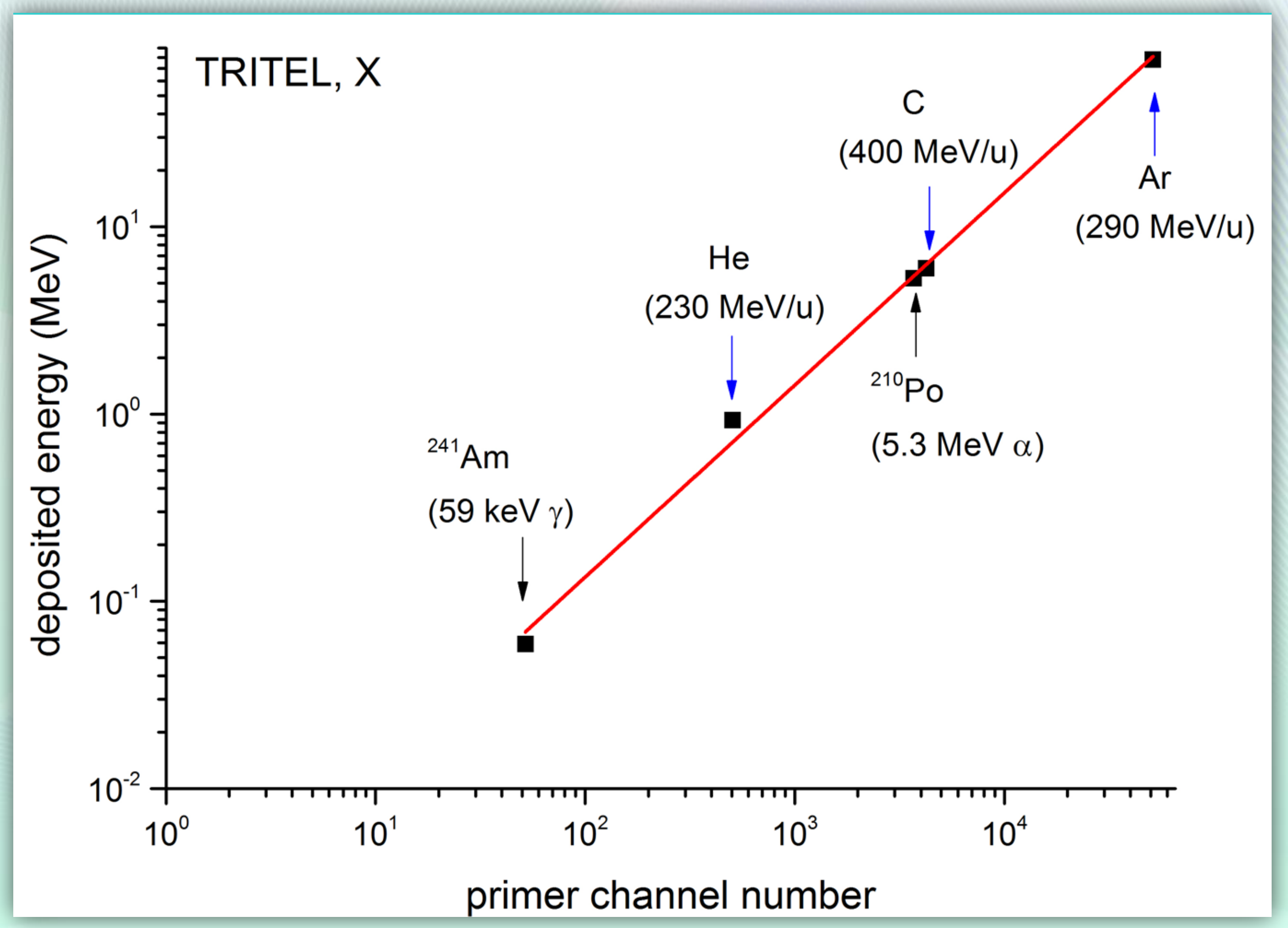


Ar 290 MeV/u, 0°, 0 mm Al









TRITEL, X
deposited energy (MeV)
primer channel number
C
(400 MeV/u)
Ar
(290 MeV/u)
He
(230 MeV/u)
210Po
(5.3 MeV α)
241Am
(59 keV γ)
10-2
10-1
100
101
100
101
102
103
104

MC simulations with GRAS

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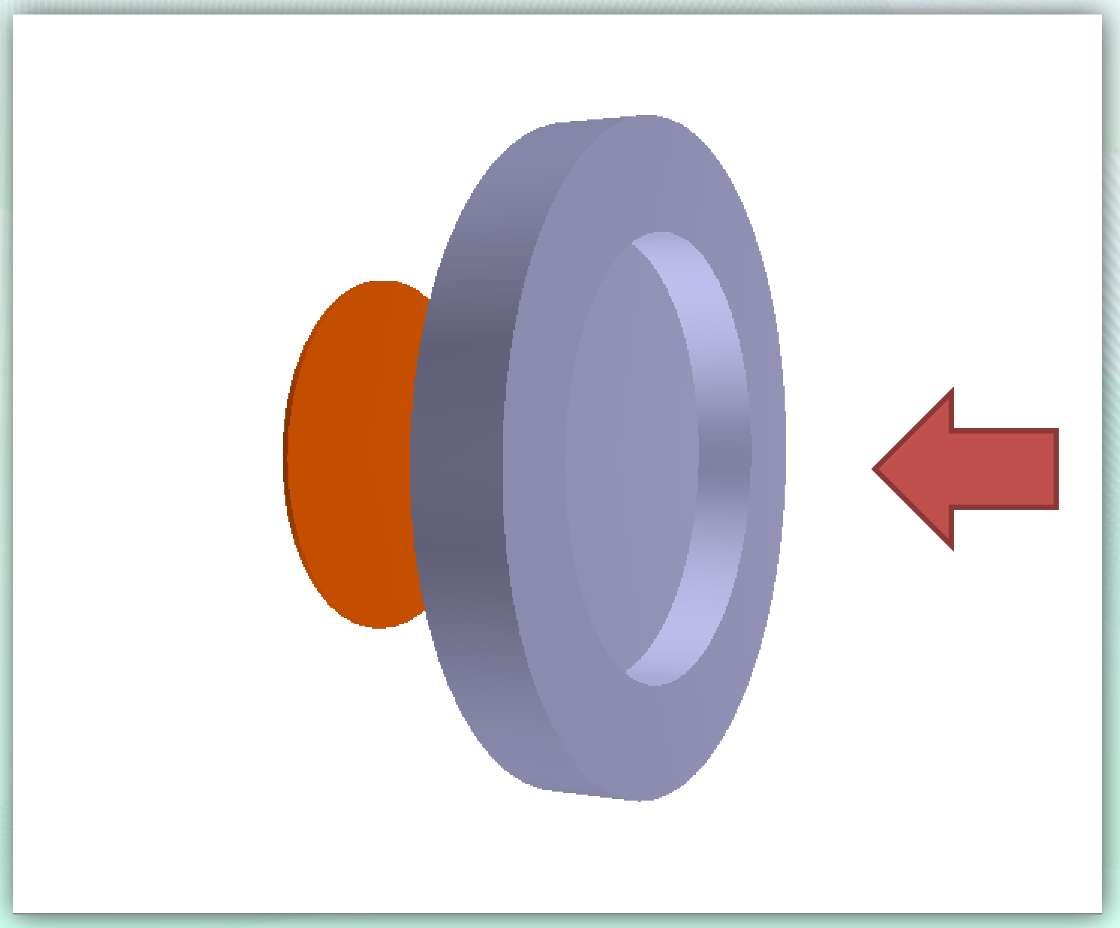
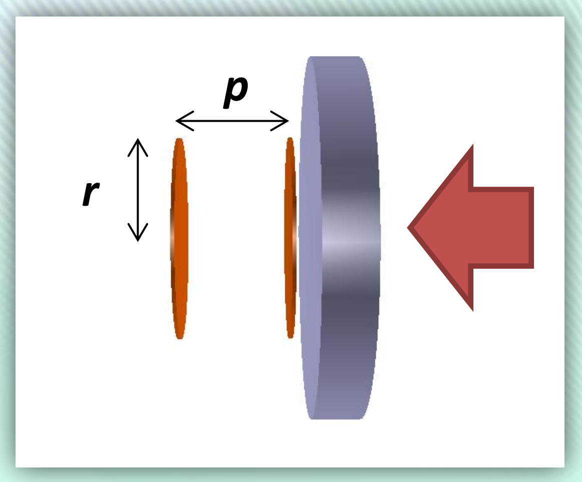
Geant4 – Geant4 Radiation Analysis for Space

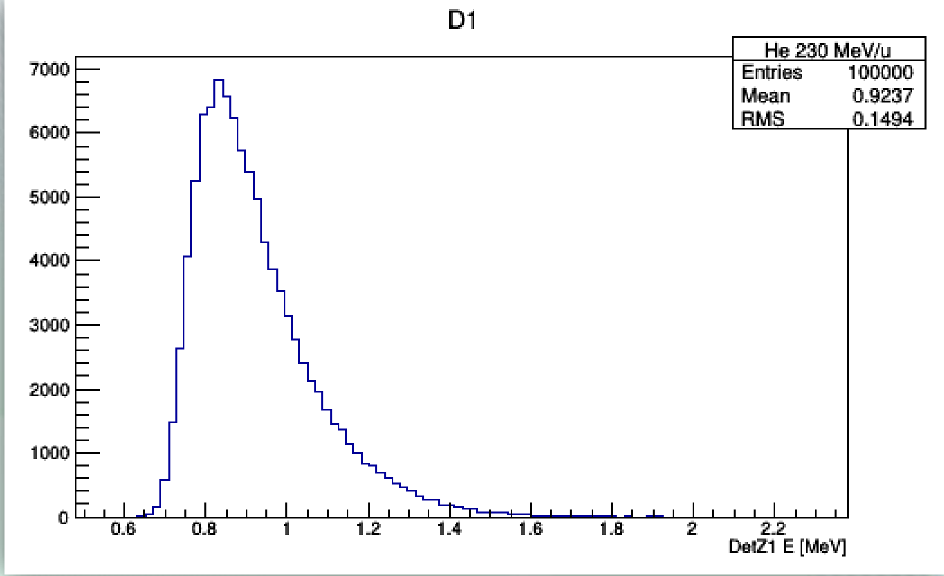
- GRAS v3.4: ESA developed tool based on Geant4 10.1
  G. Santin, V. Ivanchenko, H. Evans, P. Nieminen, E. Daly, *GRAS: A general-purpose 3-D modular simulation tool for space environment effects analysis*, IEEE Trans. Nucl. Sci. 52, Issue 6, 2005, pp 2294 - 2299
- Physics model: em_standard_opt3 (advanced EM physics for non-LHC applications providing maximum precision)
- Cuts: 0.01 mm
- Simplified geometry
- 10^6 events for each run

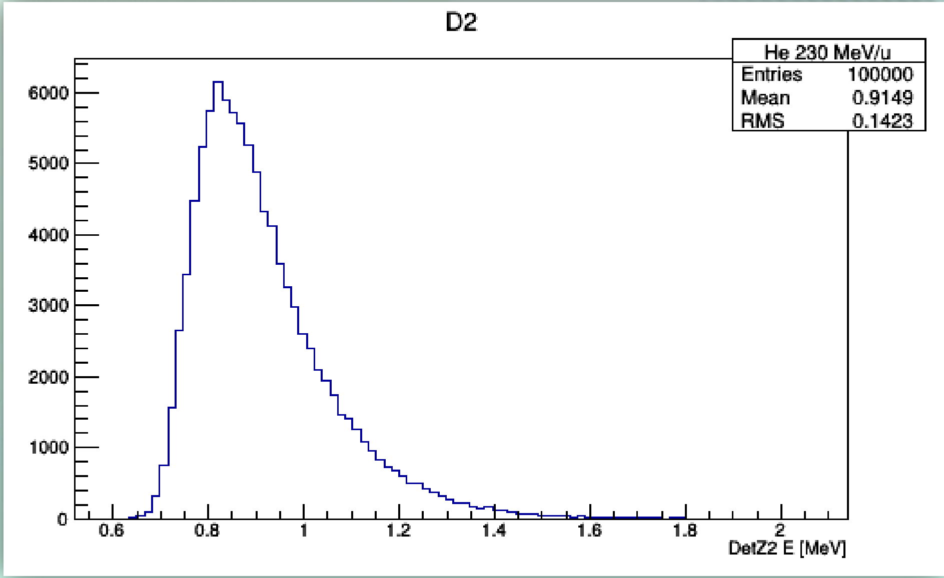
Geometry model – for 1 telescope axis

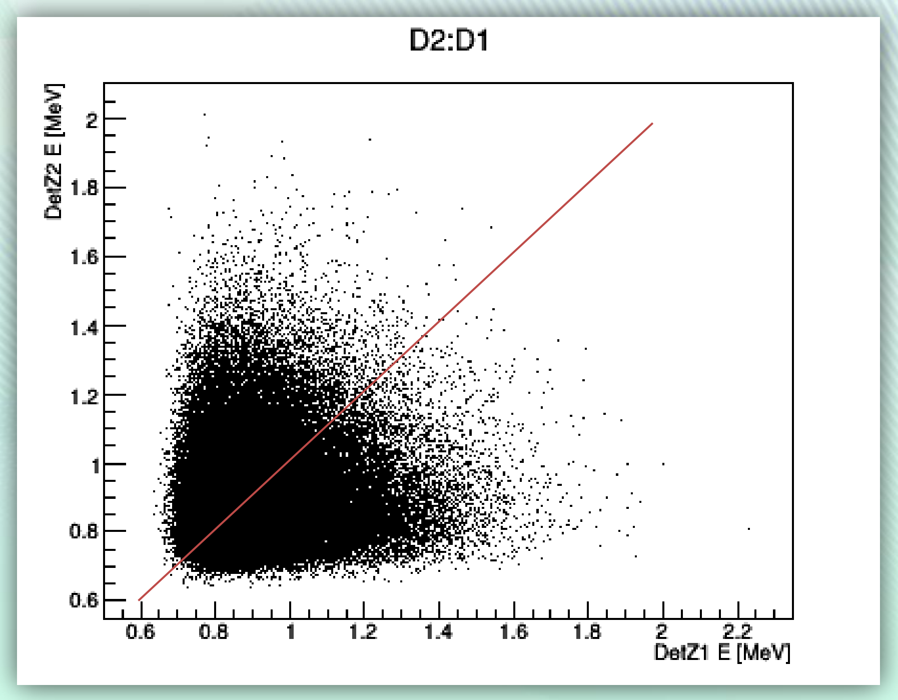




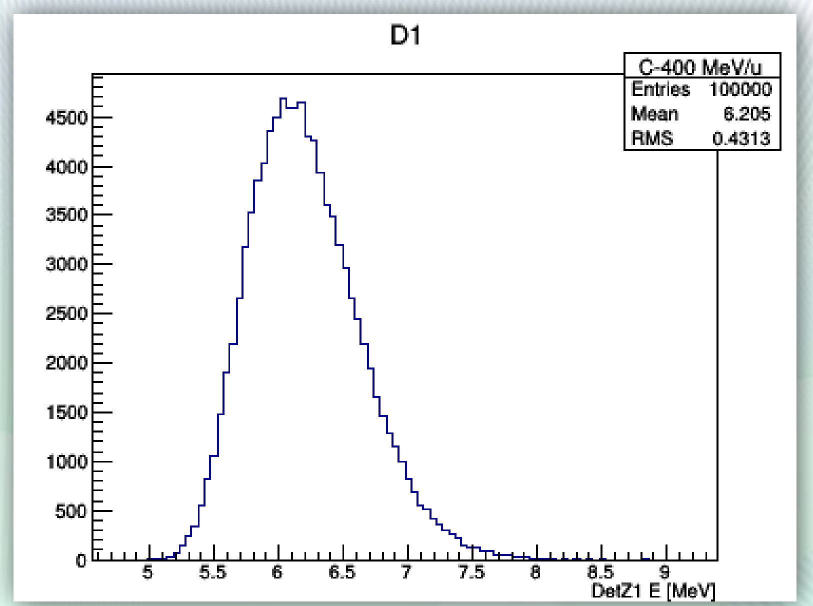
230 MeV/u He ions

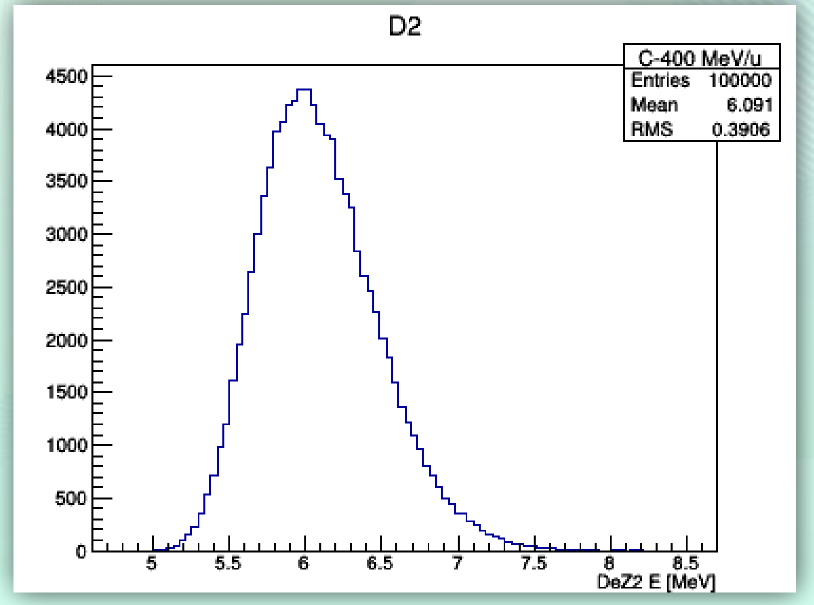


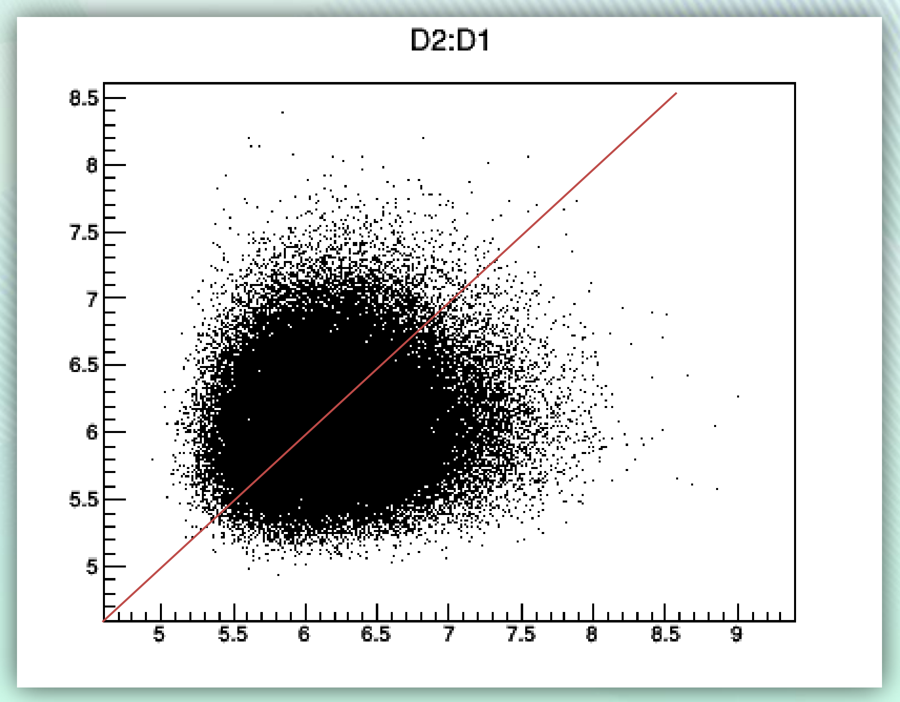




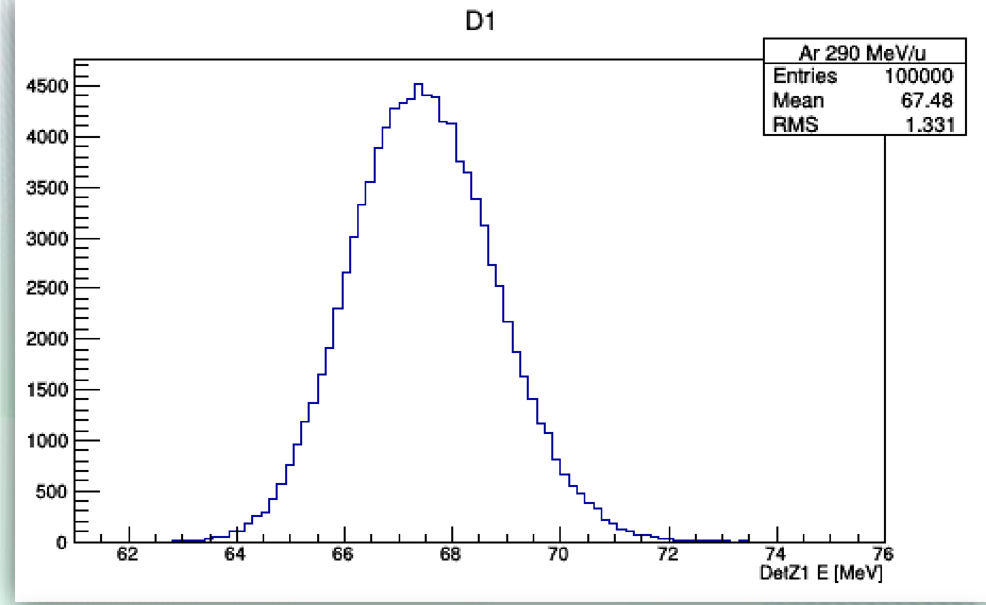
400 MeV/u C ions

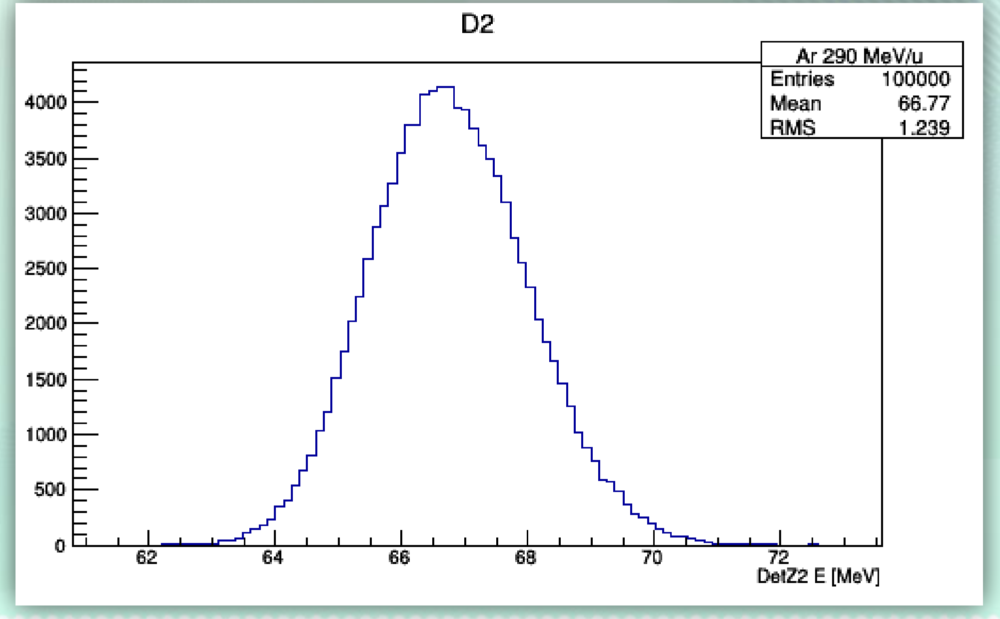


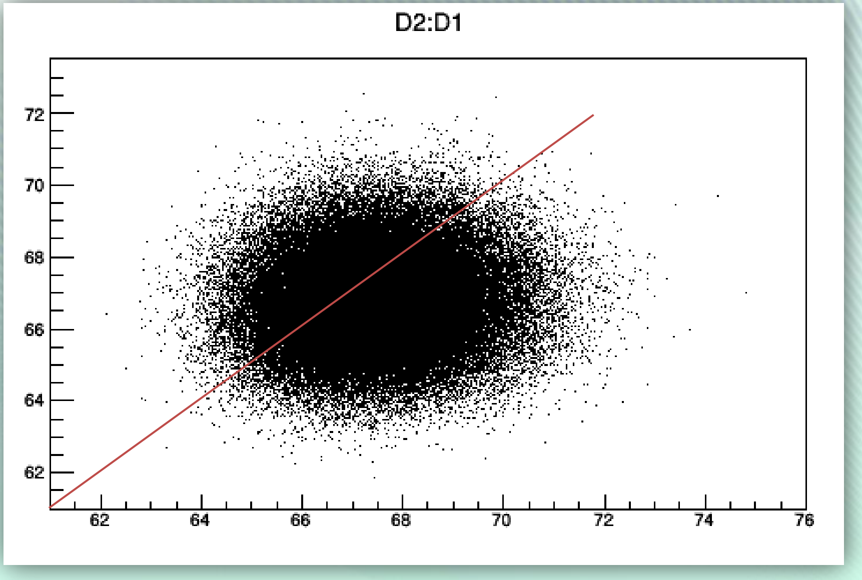




290 MeV/u Ar ions







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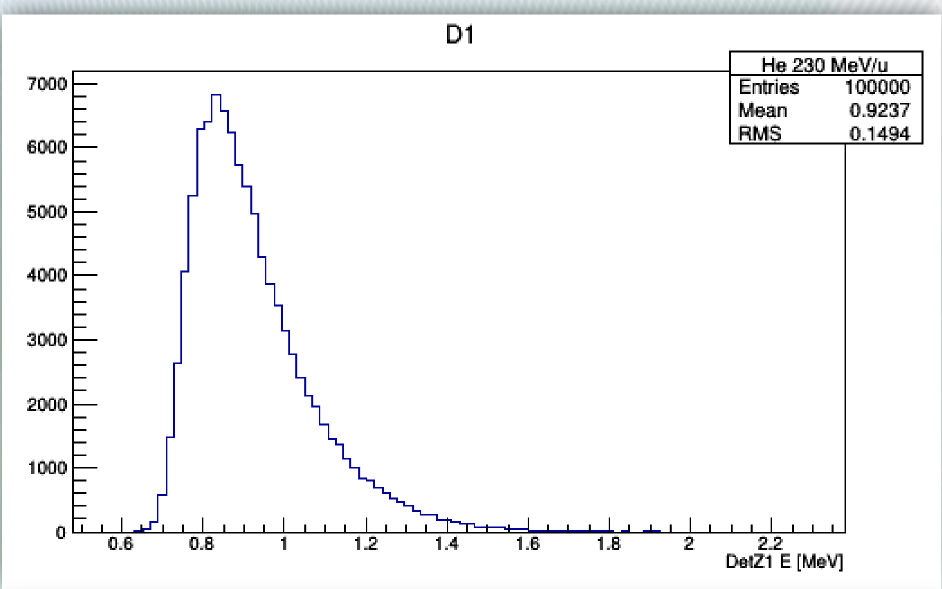
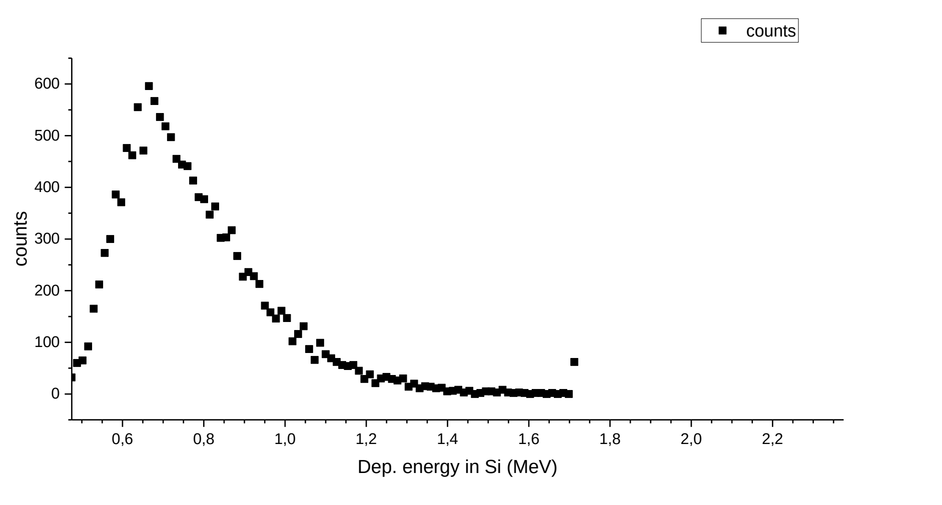
Comparison of data

230 MeV/u He ions





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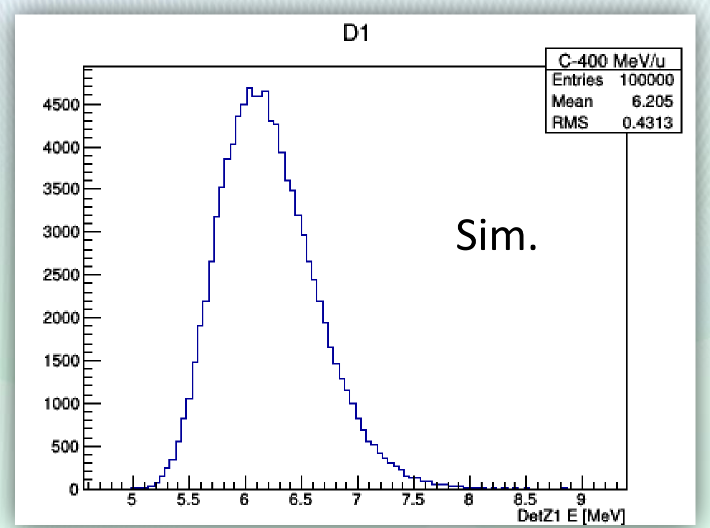
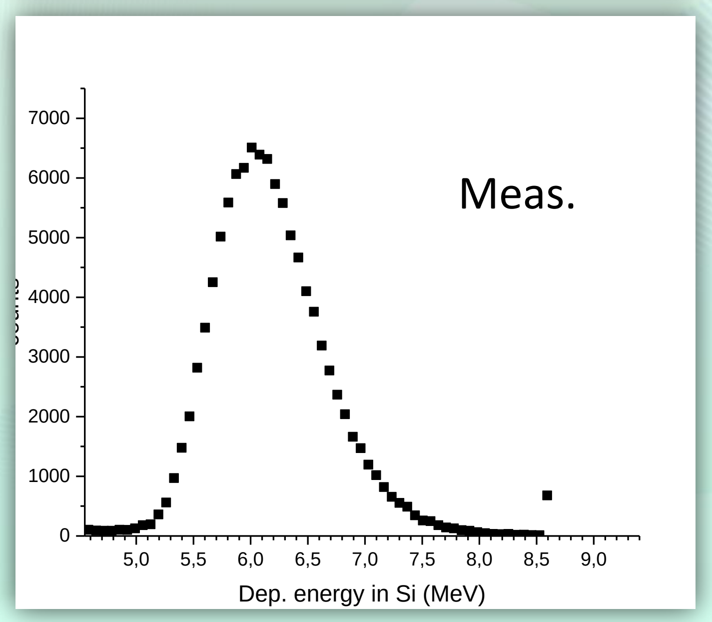
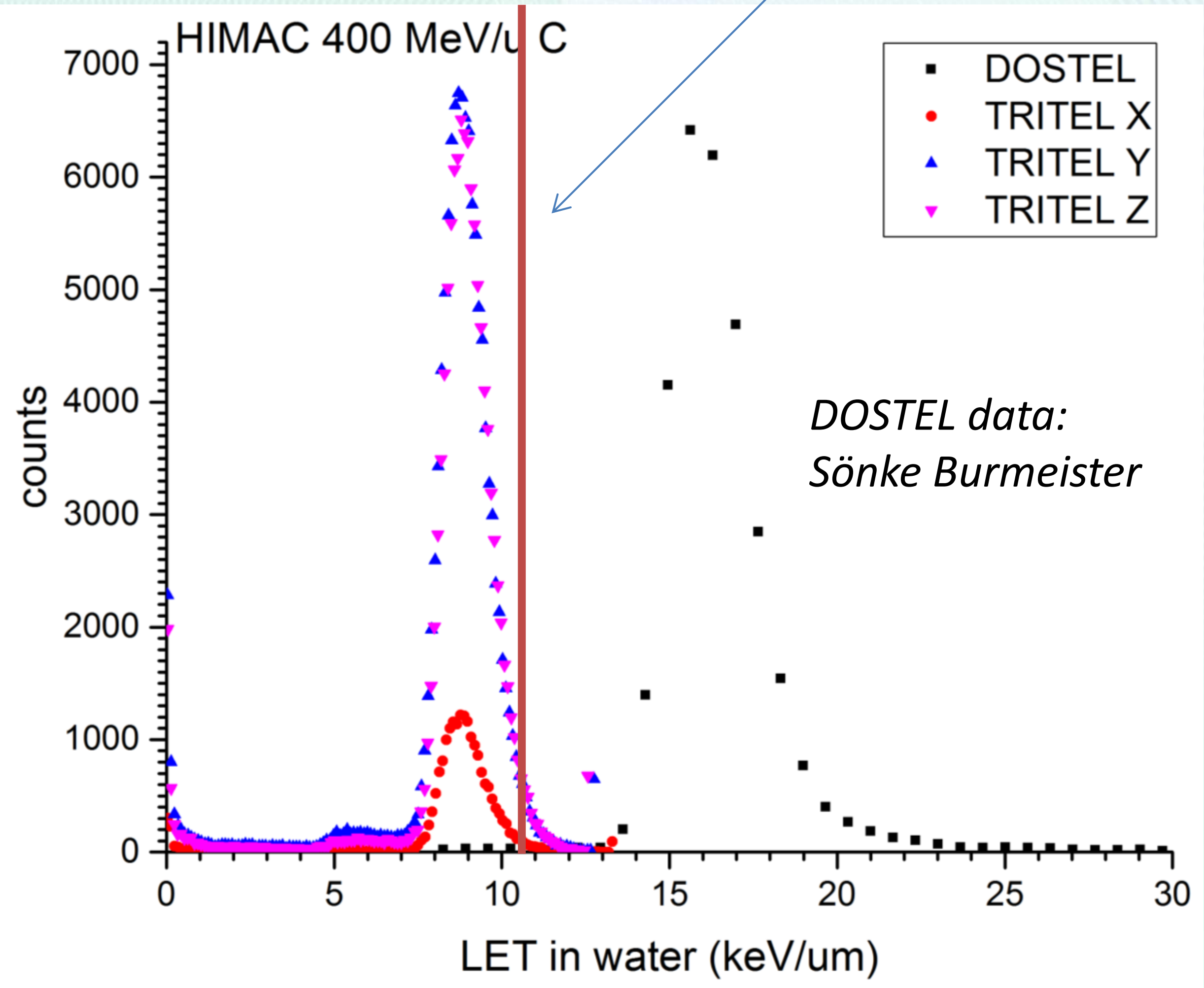
400 MeV/u C ions





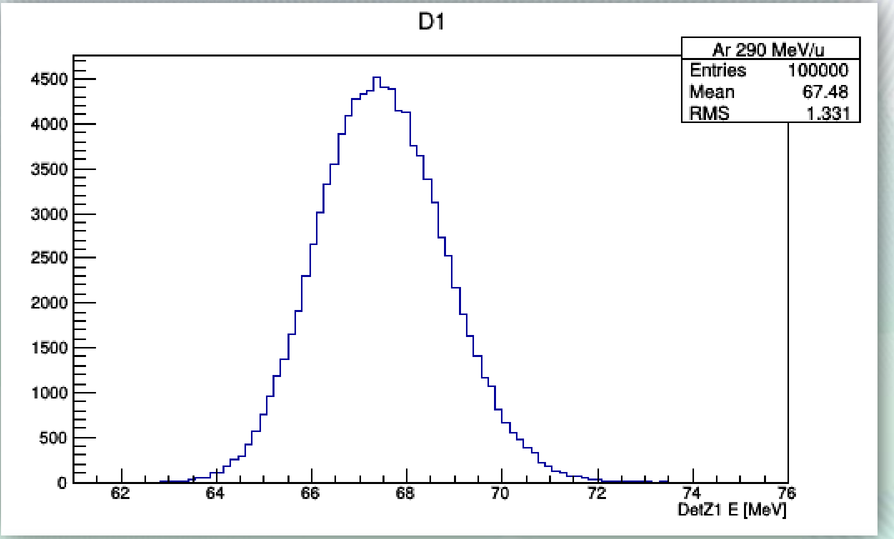
Measurements at HIMAC

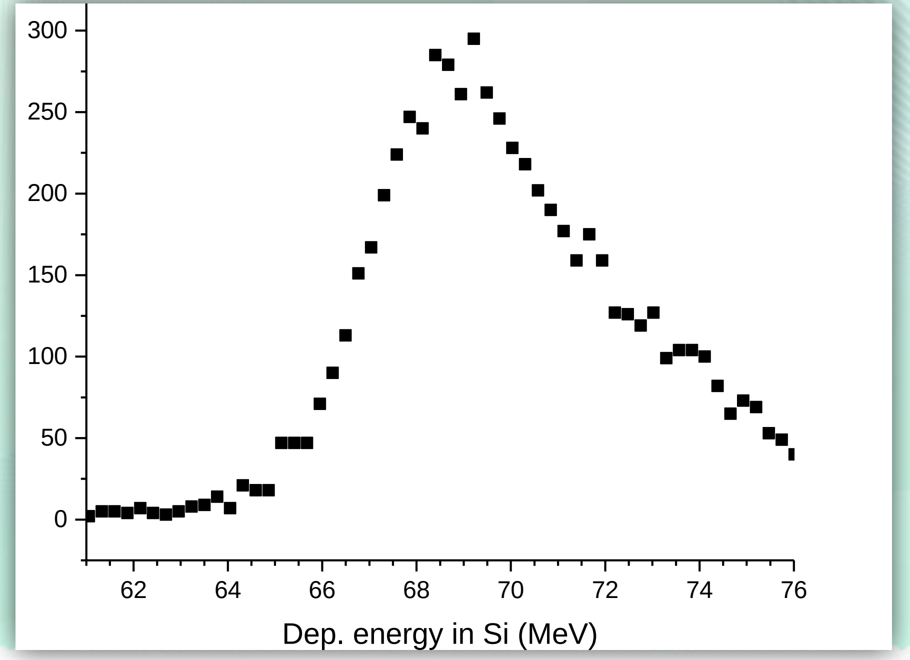
Stopping power
[SRIM2013]



DOSTEL data:
Sönke Burmeister

290 MeV/u Ar ions





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Conclusion

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- Shift towards lower energies at lower LET values
- Comparison of calibration data with Si detector systems and diff. ions would be useful
- Necessary to carry out calibrations/performance tests with low-LET protons (e.g. @PSI)

Acknowledgement

TRITEL calibration measurements were performed in the frame of the research project No. 13H322 at HIMAC/NIRS.

We wish to thank our Japanese colleagues for their precious help.

Additional slides

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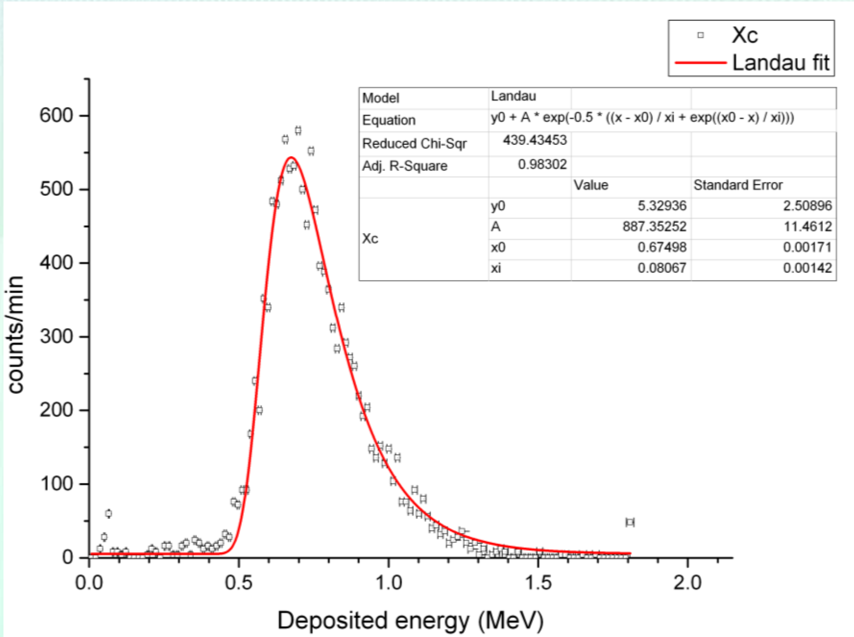
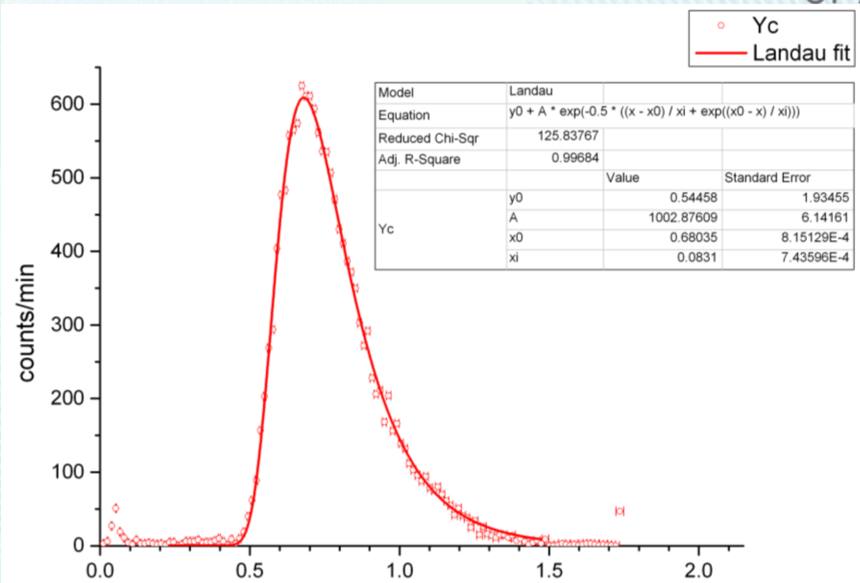
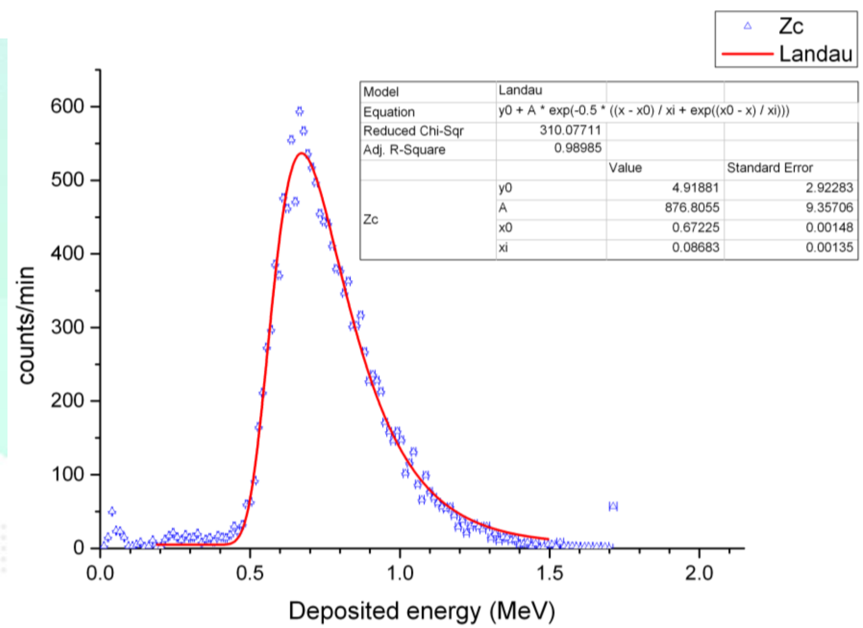
He 230 MeV/u, 0°, 0 mm Al



Model	Landau		
Equation	y0 + A * exp(-0.5 * ((x - x0) / xi + exp((x0 - x) / xi)))		
Reduced Chi-Sqr	439.43453		
Adj. R-Square	0.98302		
		Value	Standard Error
Xc	y0	5.32936	2.50896
	A	887.35252	11.4612
	x0	0.67498	0.00171
	xi	0.08067	0.00142



Model	Landau		
Equation	y0 + A * exp(-0.5 * ((x - x0) / xi + exp((x0 - x) / xi)))		
Reduced Chi-Sqr	125.83767		
Adj. R-Square	0.99684		
		Value	Standard Error
Yc	y0	0.54458	1.93455
	A	1002.87609	6.14161
	x0	0.68035	8.15129E-4
	xi	0.0831	7.43596E-4



Model	Landau		
Equation	y0 + A * exp(-0.5 * ((x - x0) / xi + exp((x0 - x) / xi)))		
Reduced Chi-Sqr	310.07711		
Adj. R-Square	0.98985		
		Value	Standard Error
Zc	y0	4.91881	2.92283
	A	876.8055	9.35706
	x0	0.67225	0.00148
	xi	0.08683	0.00135

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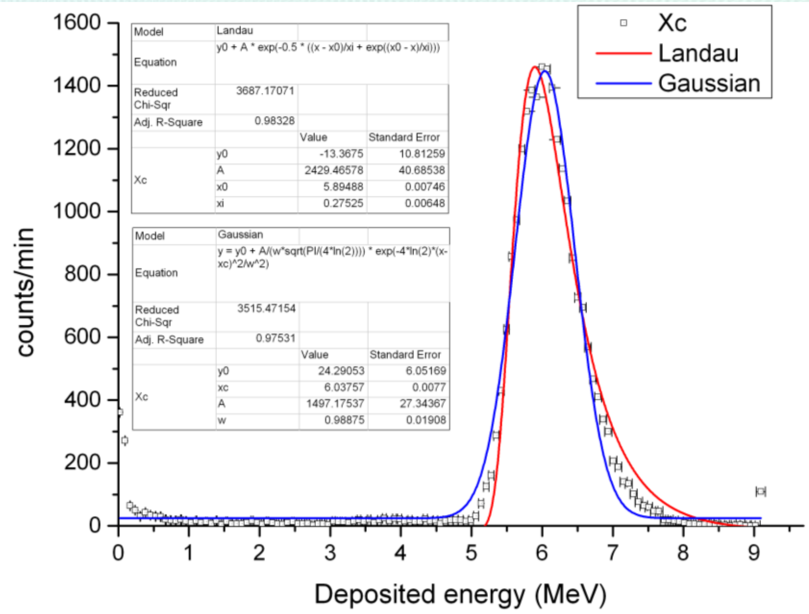
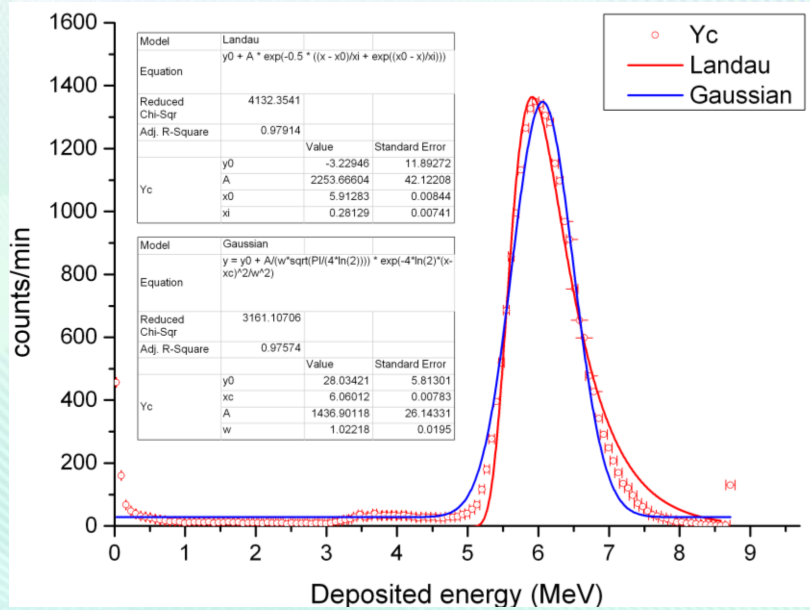
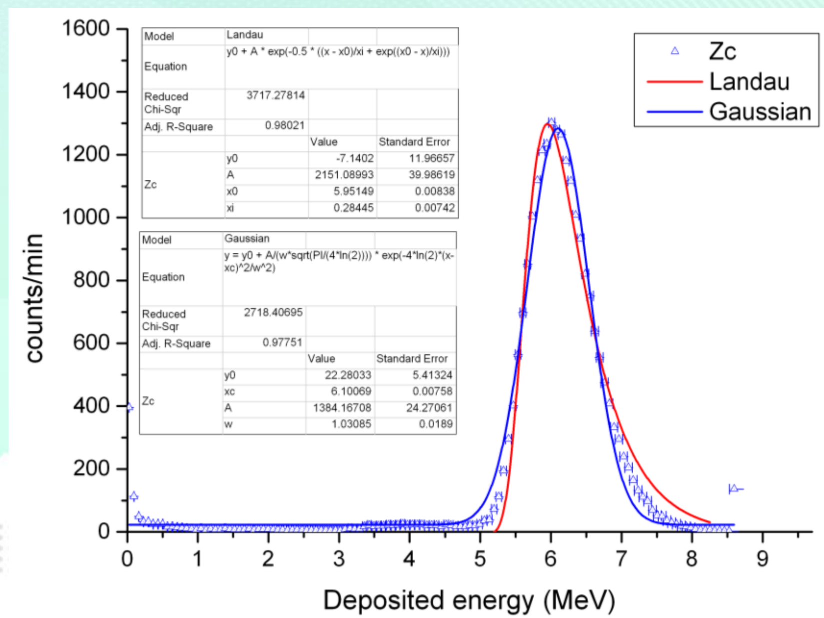
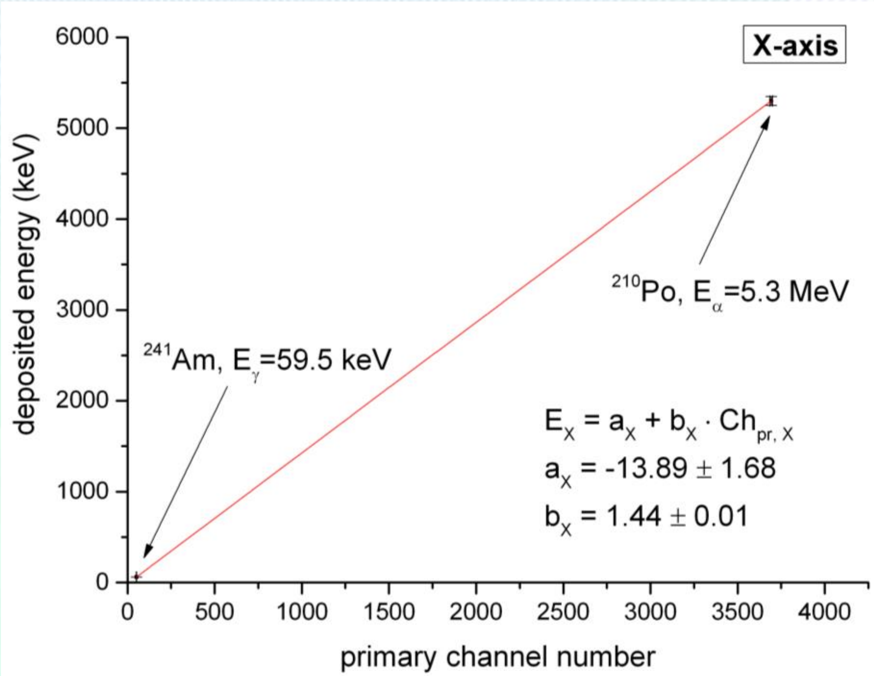
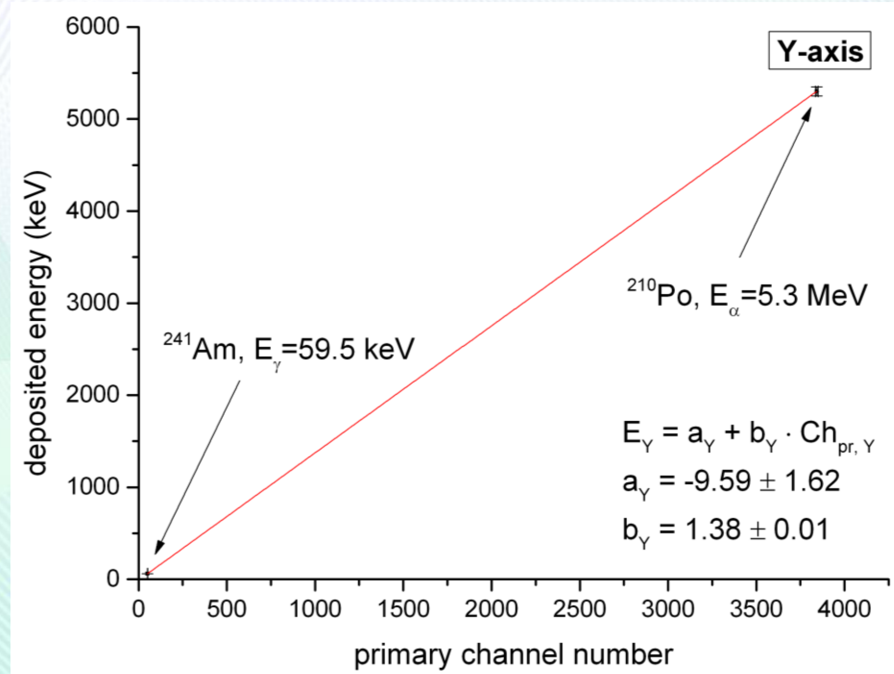
C 400 MeV/u, 0°, 0 mm Al

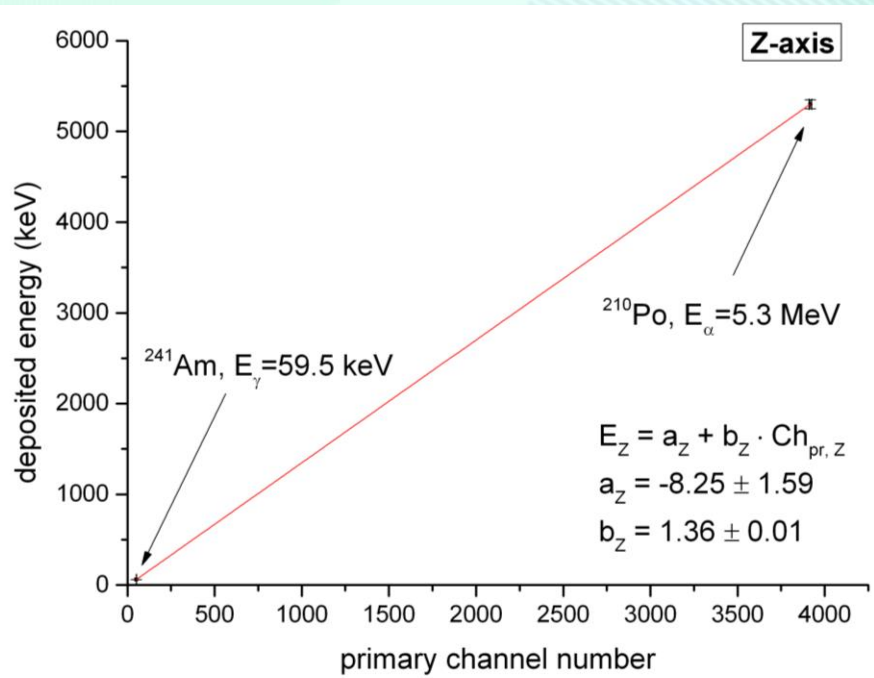












	X	Y	Z
a	-13.89 ± 1.68	-9.59 ± 1.62	-8.25 ± 1.59
b	1.44 ± 0.01	1.38 ± 0.01	1.36 ± 0.01