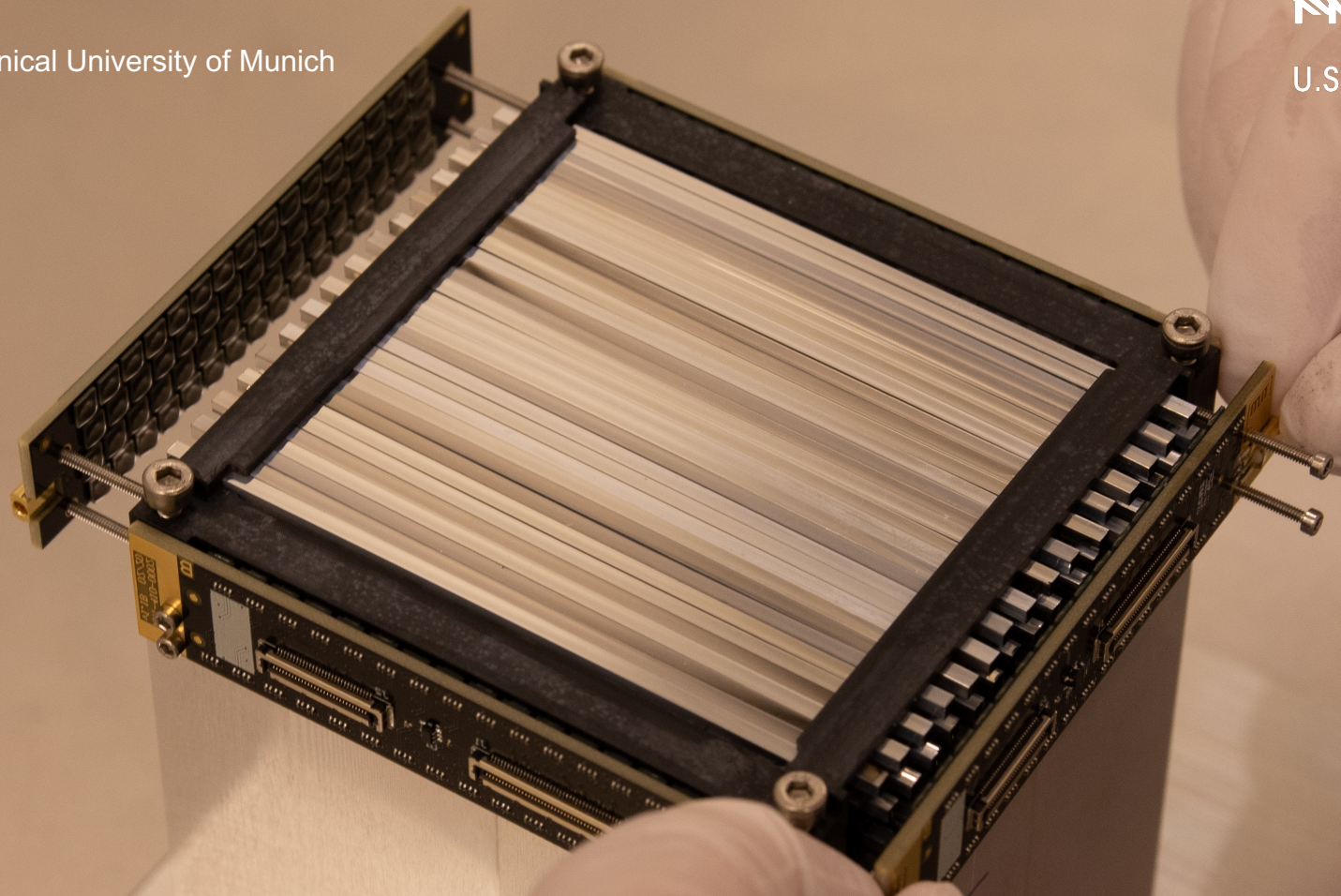
The RadMap Telescope

Updates, Early Results, and Next Steps

Martin J. Losekamm * | Technical University of Munich

3 September 2024



27th WRMISS, 3 – 5 September 2024, Boulder, CO

*For the RadMap Telescope team: Thomas Berger, Peter Hinderberger, Moritz Kaseman, Thomas Kendelbacher, Carl Kuehnel, Karel Marsalek, Daniel Matthiä, Luise Meyer-Hetling, Stephan Paul, Thomas Pöschl, Bartos Przybyla, Markus Rohde, Sebastian Rückerl, Michael Wirtz, Hans J. Zachrau

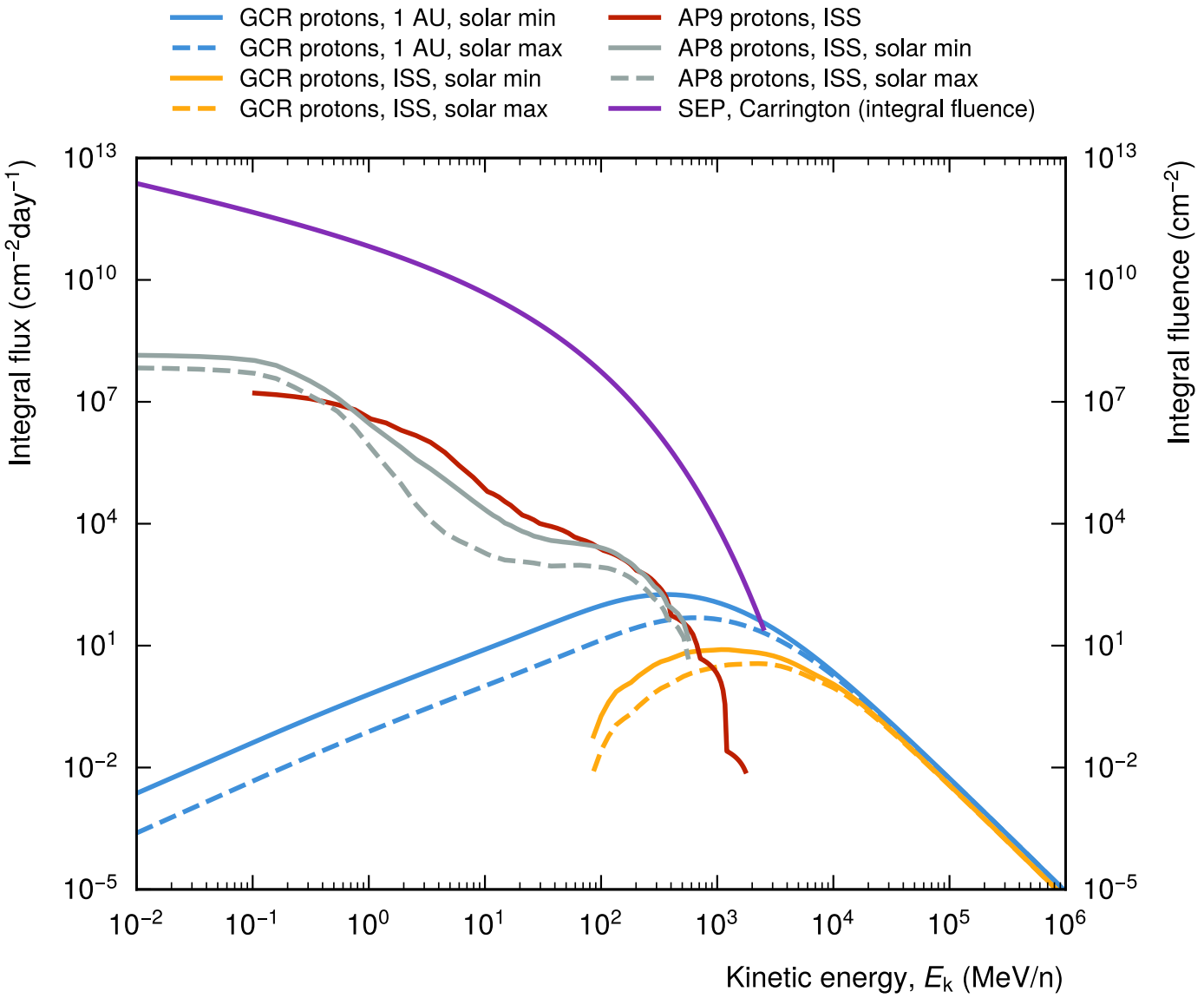
The Space Radiation Environment

Composition and Dosimetry

- Cosmic-ray nuclei
  - Small fluxes
  - Large dose contribution
- Charge-dependence of quality factor and relative biological effectiveness

$$Q_{\mathrm{NASA}} = (1 - P(Z,E)) + \frac{6.24(\Sigma_o/\alpha_\gamma)}{\mathrm{LET}} P(Z,E)$$

$$P(Z,E) = \left(1 - e^{\frac{-(Z^*/\beta)^2}{k}}\right)^m (1 - e^{-(E/0.2)})$$



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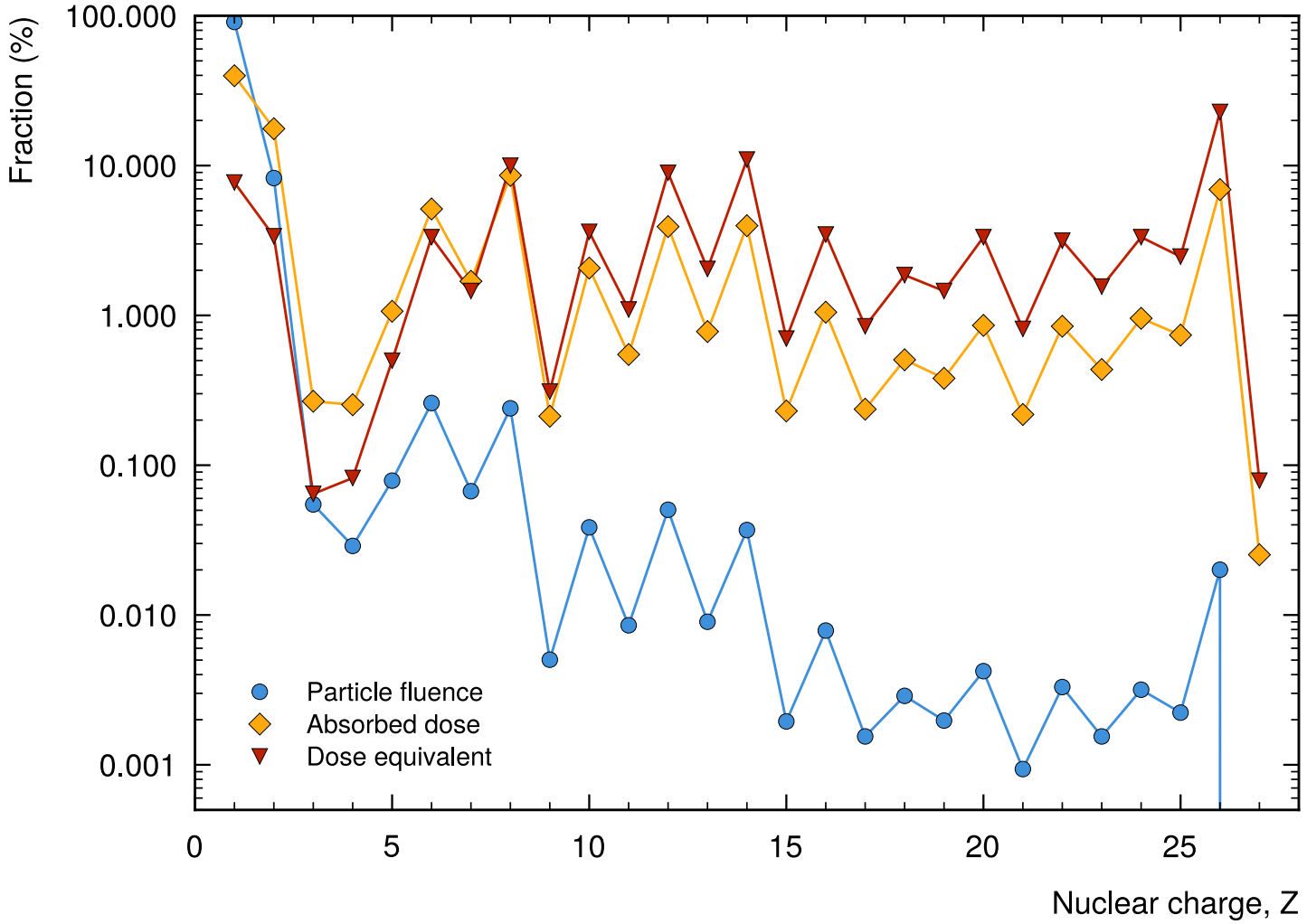


The RadMap Telescope

Instrument Overview

Secondary Sensor: **M-42 Dosimeter**
Real-time dosimetry using 300-µm silicon diode

Primary Sensor: **Active Detection Unit**
Real-time radiation monitoring using tracking calorimeter

- 1024 scintillating fibers + silicon photomultipliers
- Fully parallel readout via 64 IDE3380 ASICs & FPGA

External secondary cooling channels
Ensuring light tightness

Flight Computer
Jetson TX2i with combined CPU / GPU

- Instrument control & housekeeping / telemetry
- Data pre-processing and storage

Electrical Interfaces
100-Mbit Ethernet & 28 VDC power input

Internal primary cooling channel
Large cooling capacity

The RadMap Telescope

Instrument Overview

Secondary Sensor: **M-42 Dosimeter**
Real-time dosimetry using 300-µm silicon diode

Energy Dep. Range:	60 keV to 17.7 MeV
Resolution:	1004 channels, 17.6 keV width
Coverage:	Full solid angle

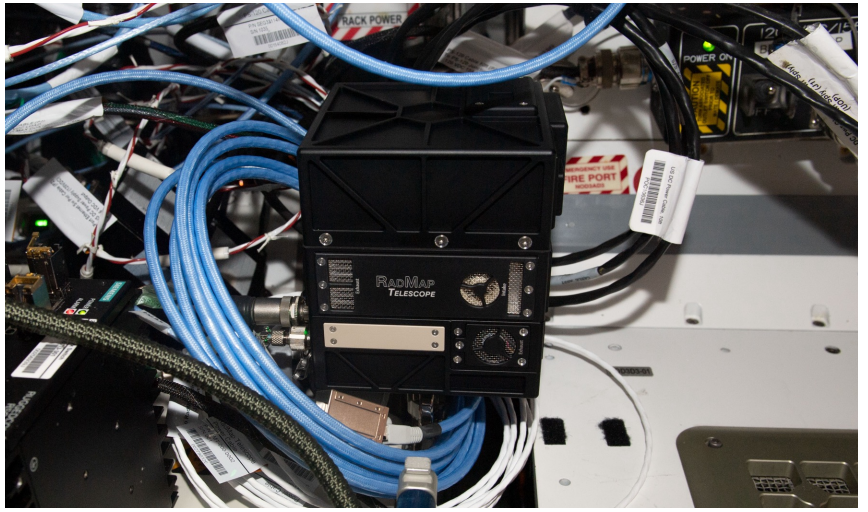
Primary Sensor: **Active Detection Unit**
Real-time radiation monitoring using tracking calorimeter

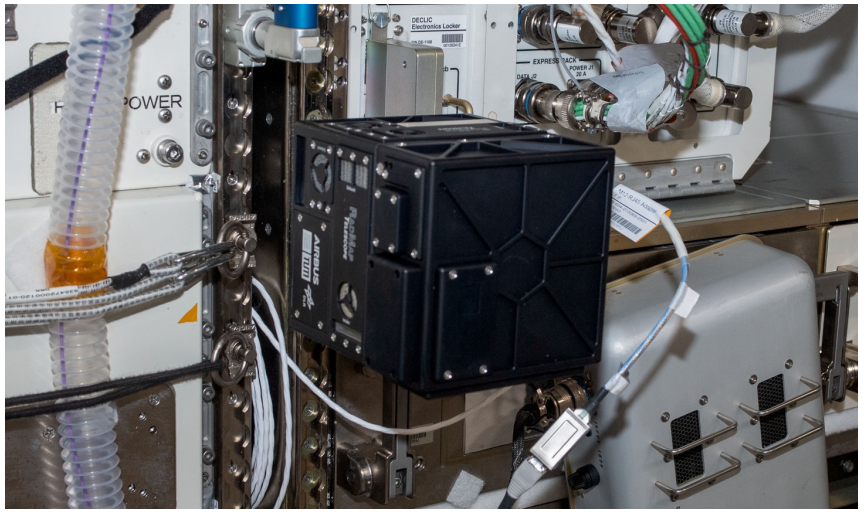
Energy Range:	> ~70 MeV/n
Energy Resolution:	1% for <90 MeV (protons) *non-isotropic 7% for <200 MeV (protons) *isotropic
Angular Resolution:	< 2°
Coverage:	Full solid angle
Geom. Acceptance:	1013 cm^2sr (detection) 925 cm^2sr (reconstruction)

On-Orbit Operations

Operational Concept

- Deployment in various locations throughout the USOS
  - Node 3 → *May 2023*
  - Japanese Experiment Module → *June 2023*
  - US Lab → *October 2023*
  - European Columbus Orbital Facility
- Rotation through these locations in ~~~6 months~~ 16+ months (planned)
- Easy relocation (seat track mounting interface)
- Co-location with operational sensors for cross-validation of measurements (e.g., ISS-Rad and DOSTEL)



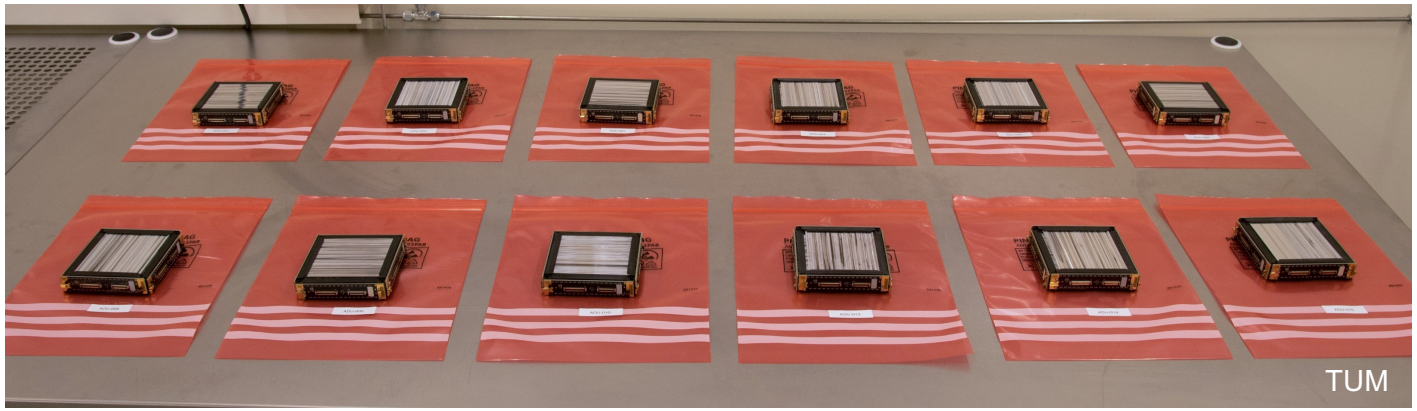


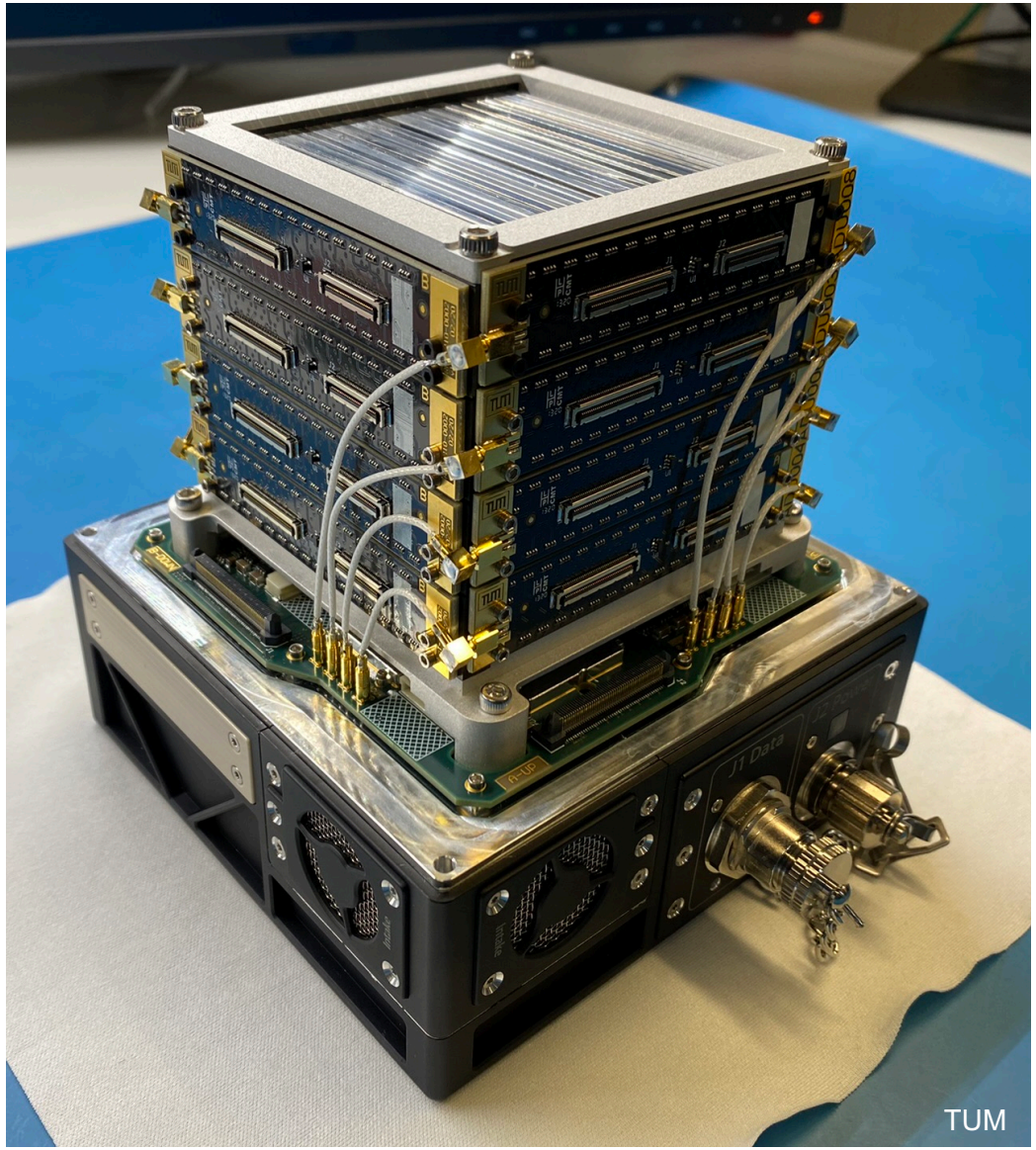
Primary Sensor

Active Detection Unit (ADU)

- 1024 sensor channels in four 256-channel modules (8 layers with 32 fibers each per module)
  - Kuraray SCSF-78 scintillating-plastic fibers
  - KETEK PM3325-WB-D0 silicon photomultipliers (SiPMs)
- Active tracking volume of ~ 8 x 8 x 8 cm^3
- Custom SiPM arrays
- Individual bias-voltage filtering for each channel

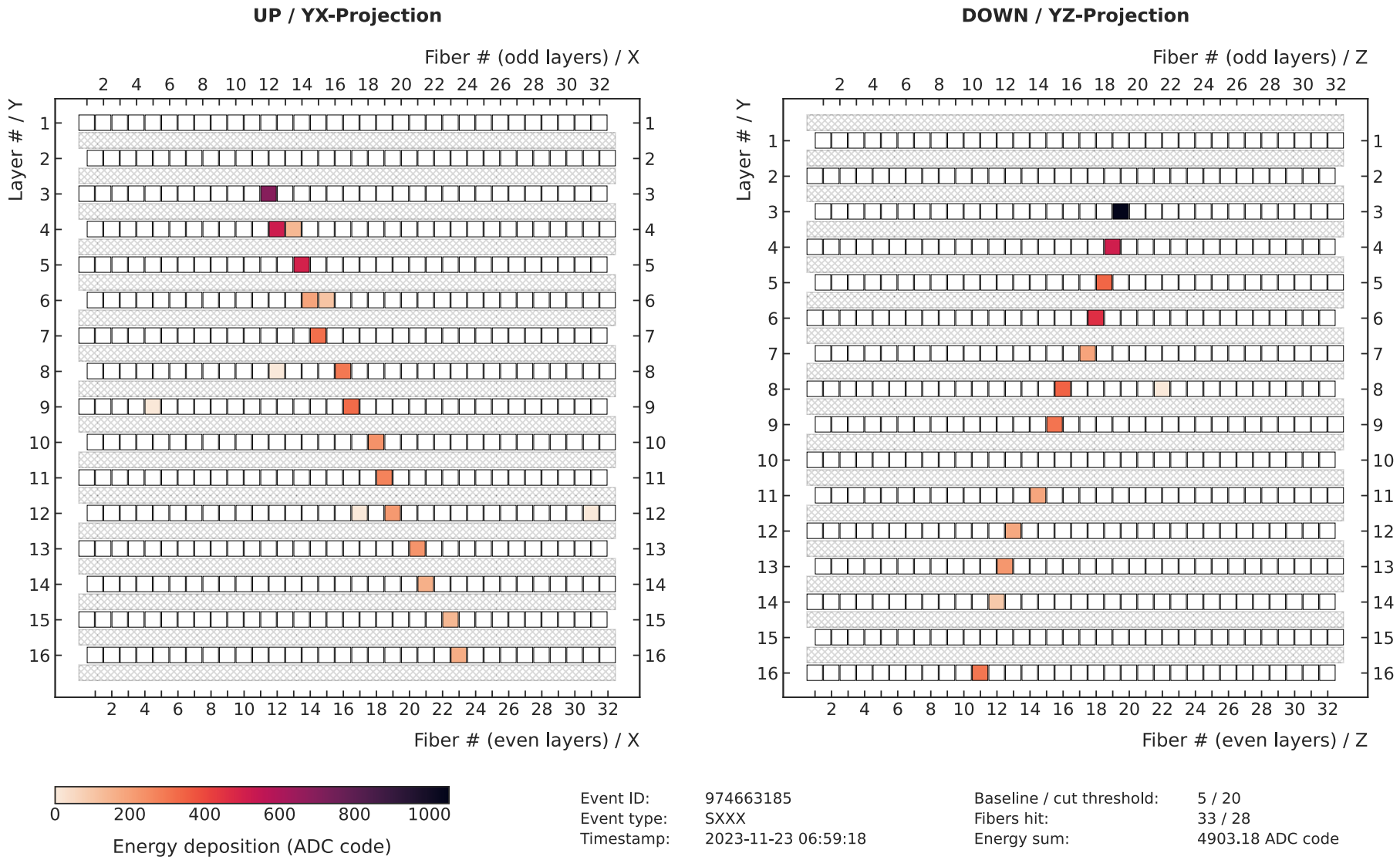
- Calibration at piM1 beamline of Paul Scherrer Institute





Example ADU Events

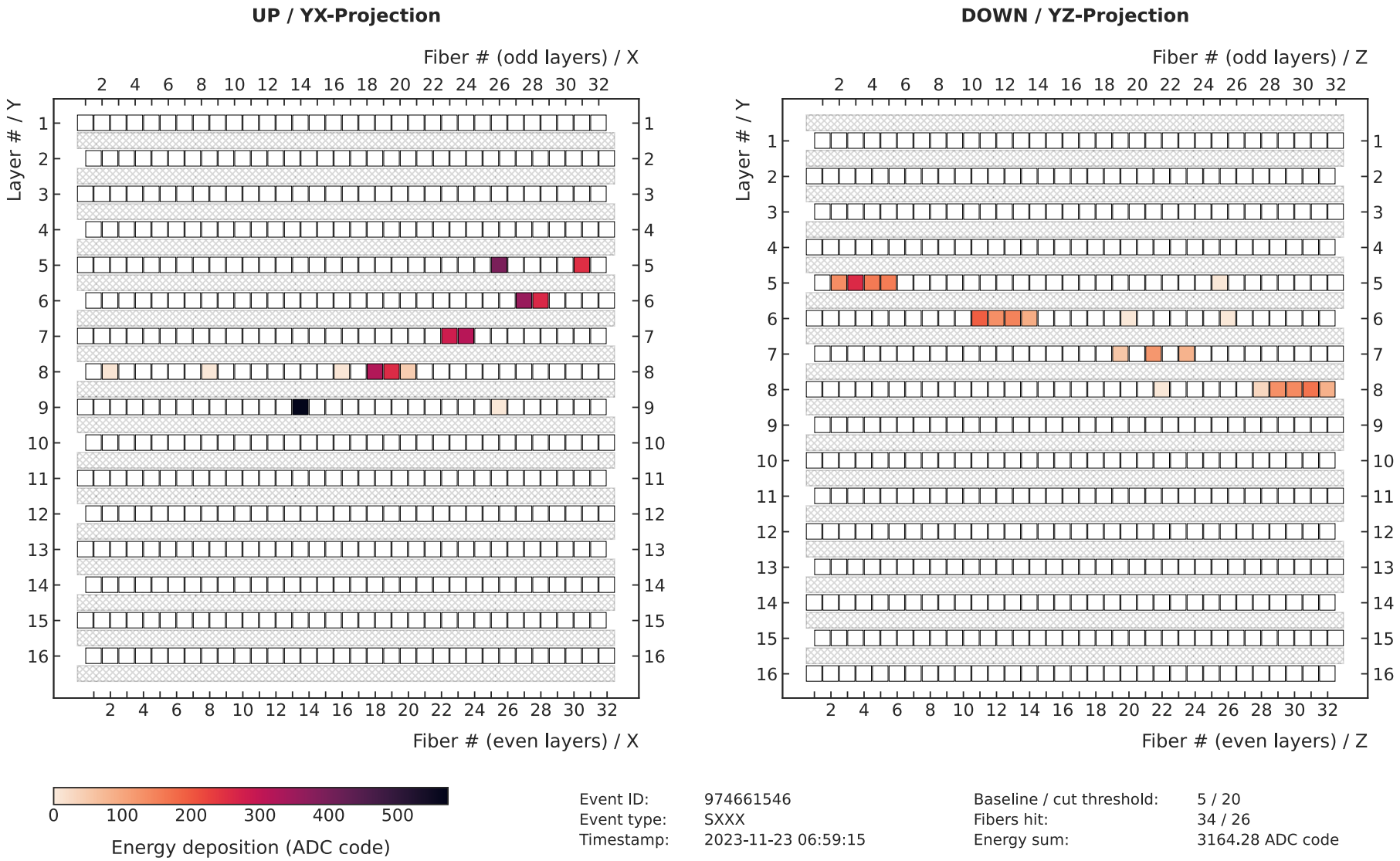
Uncalibrated



Event ID:	974663185	Baseline / cut threshold:	5 / 20
Event type:	SXXX	Fibers hit:	33 / 28
Timestamp:	2023-11-23 06:59:18	Energy sum:	4903.18 ADC code

Example ADU Events

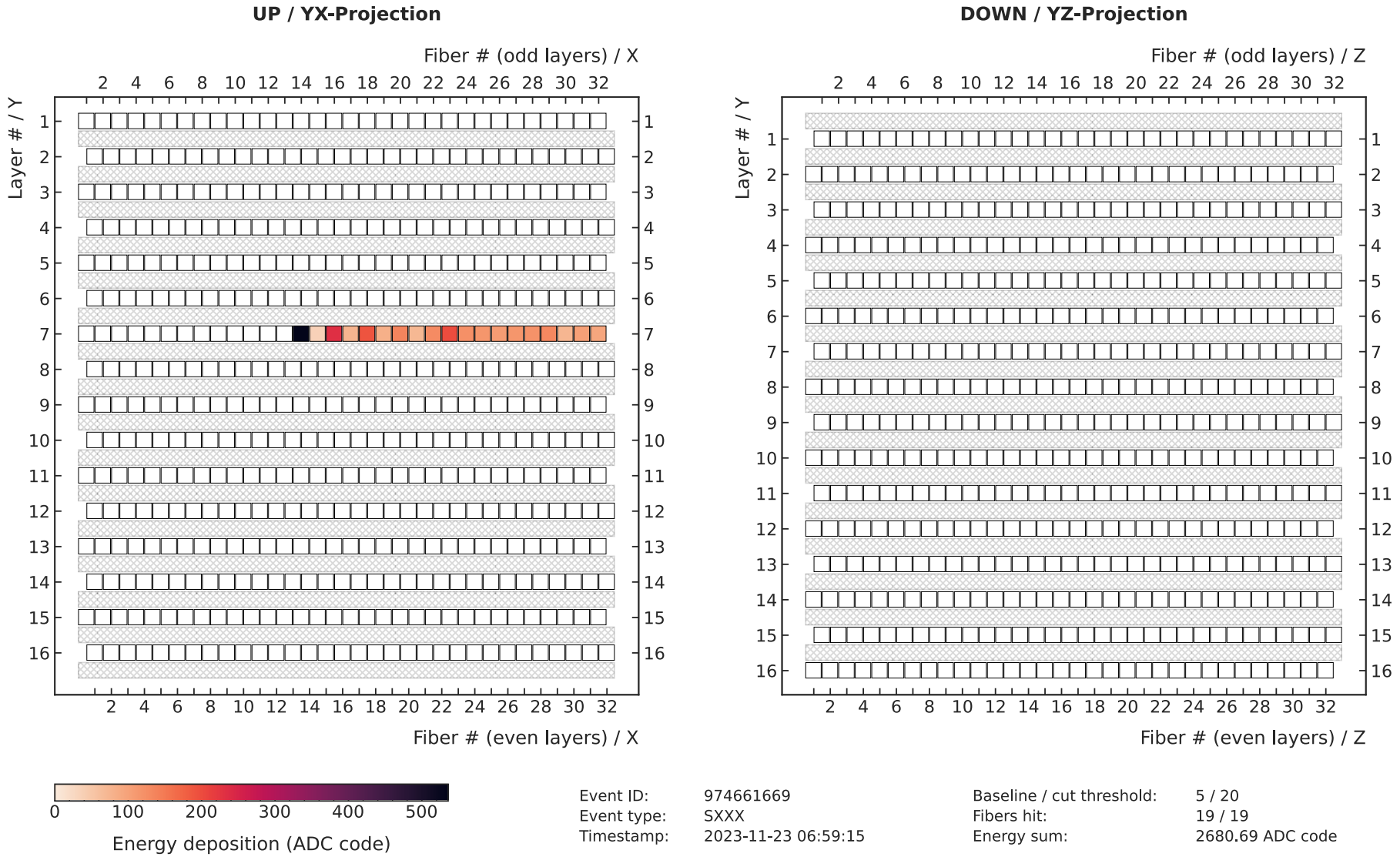
Uncalibrated



Event ID:	974661546	Baseline / cut threshold:	5 / 20
Event type:	SXXX	Fibers hit:	34 / 26
Timestamp:	2023-11-23 06:59:15	Energy sum:	3164.28 ADC code

Example ADU Events

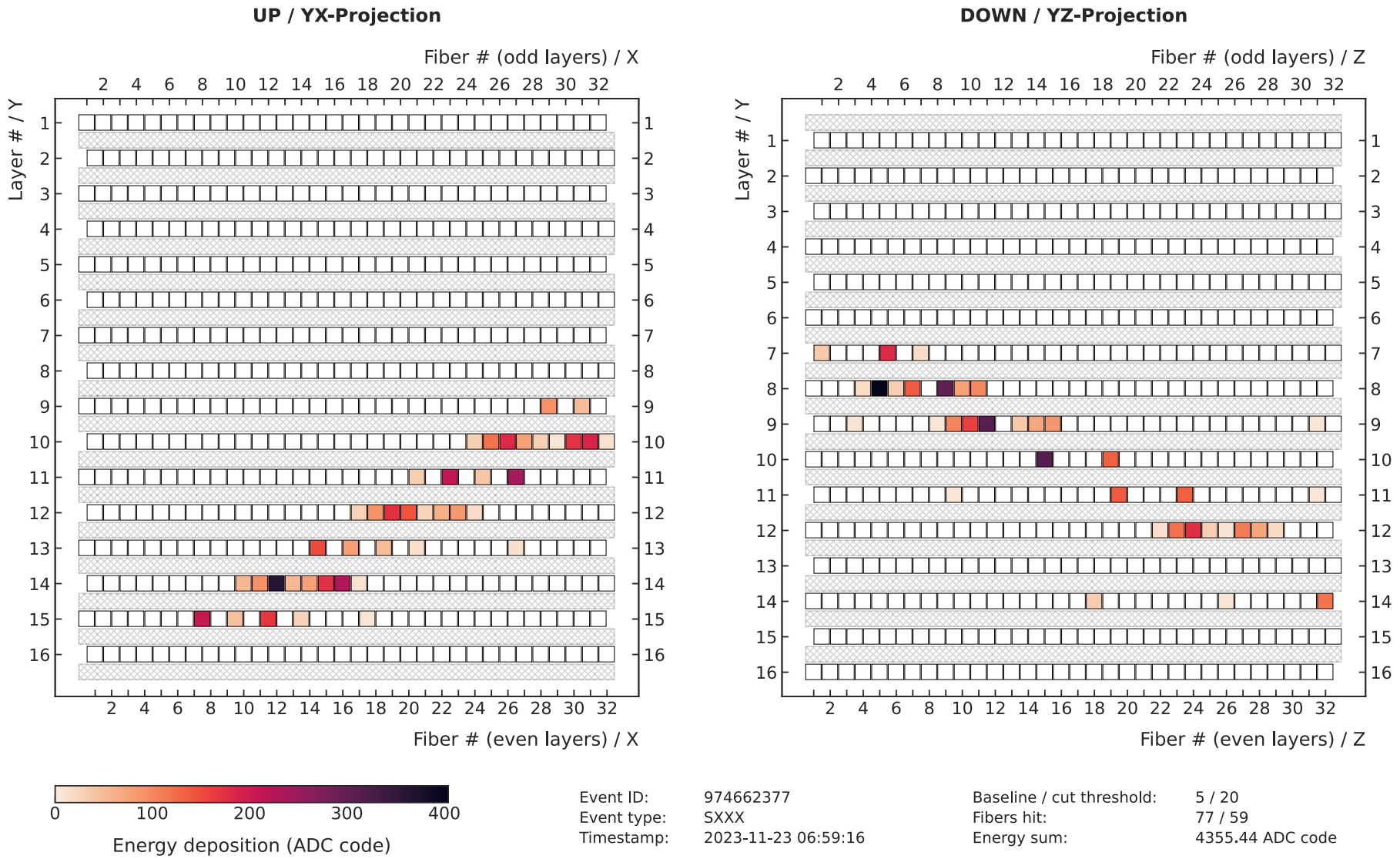
Uncalibrated



Event ID:	974661669	Baseline / cut threshold:	5 / 20
Event type:	SXXX	Fibers hit:	19 / 19
Timestamp:	2023-11-23 06:59:15	Energy sum:	2680.69 ADC code

Example ADU Events

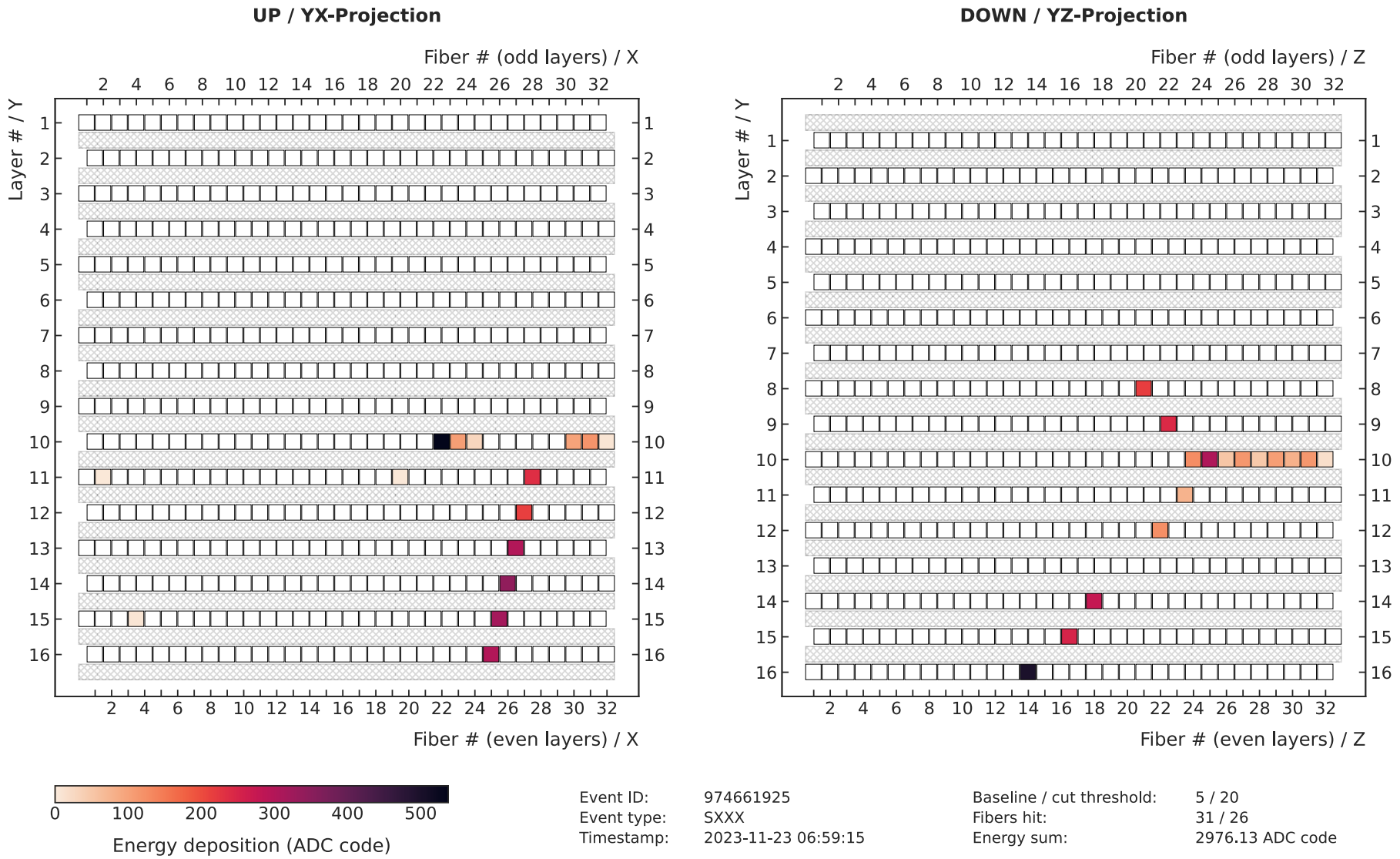
Uncalibrated



Event ID:	974662377	Baseline / cut threshold:	5 / 20
Event type:	SXXX	Fibers hit:	77 / 59
Timestamp:	2023-11-23 06:59:16	Energy sum:	4355.44 ADC code

Example ADU Events

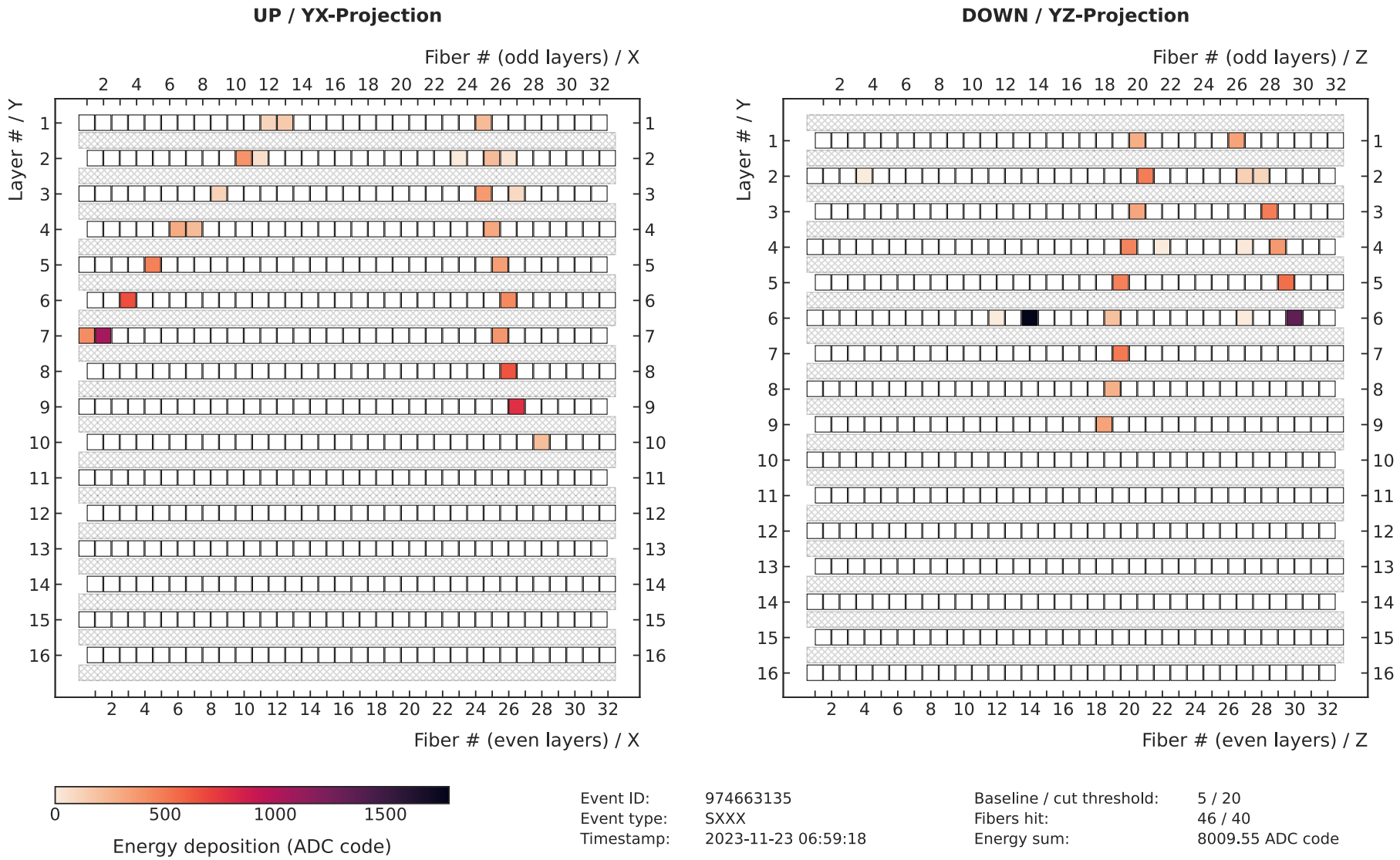
Uncalibrated



Event ID:	974661925	Baseline / cut threshold:	5 / 20
Event type:	SXXX	Fibers hit:	31 / 26
Timestamp:	2023-11-23 06:59:15	Energy sum:	2976.13 ADC code

Example ADU Events

Uncalibrated



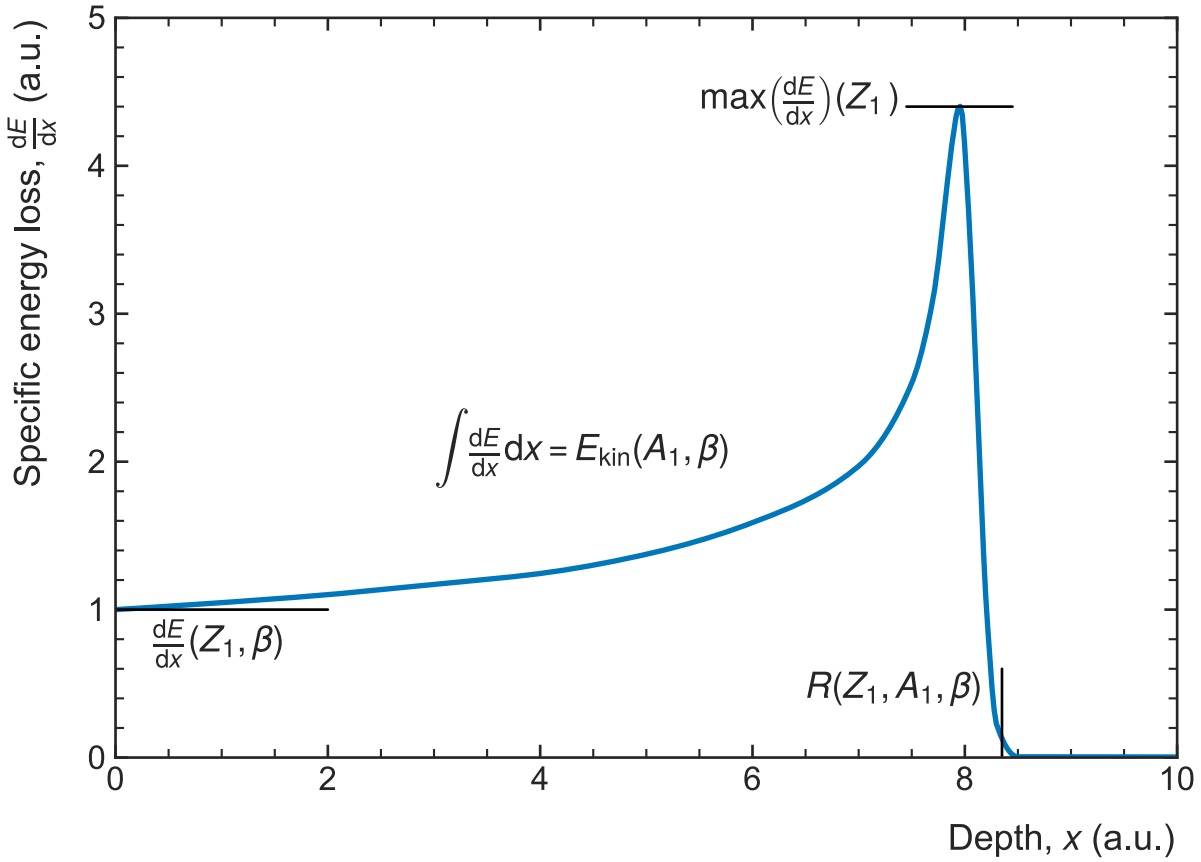
Event ID:	974663135	Baseline / cut threshold:	5 / 20
Event type:	SXXX	Fibers hit:	46 / 40
Timestamp:	2023-11-23 06:59:18	Energy sum:	8009.55 ADC code

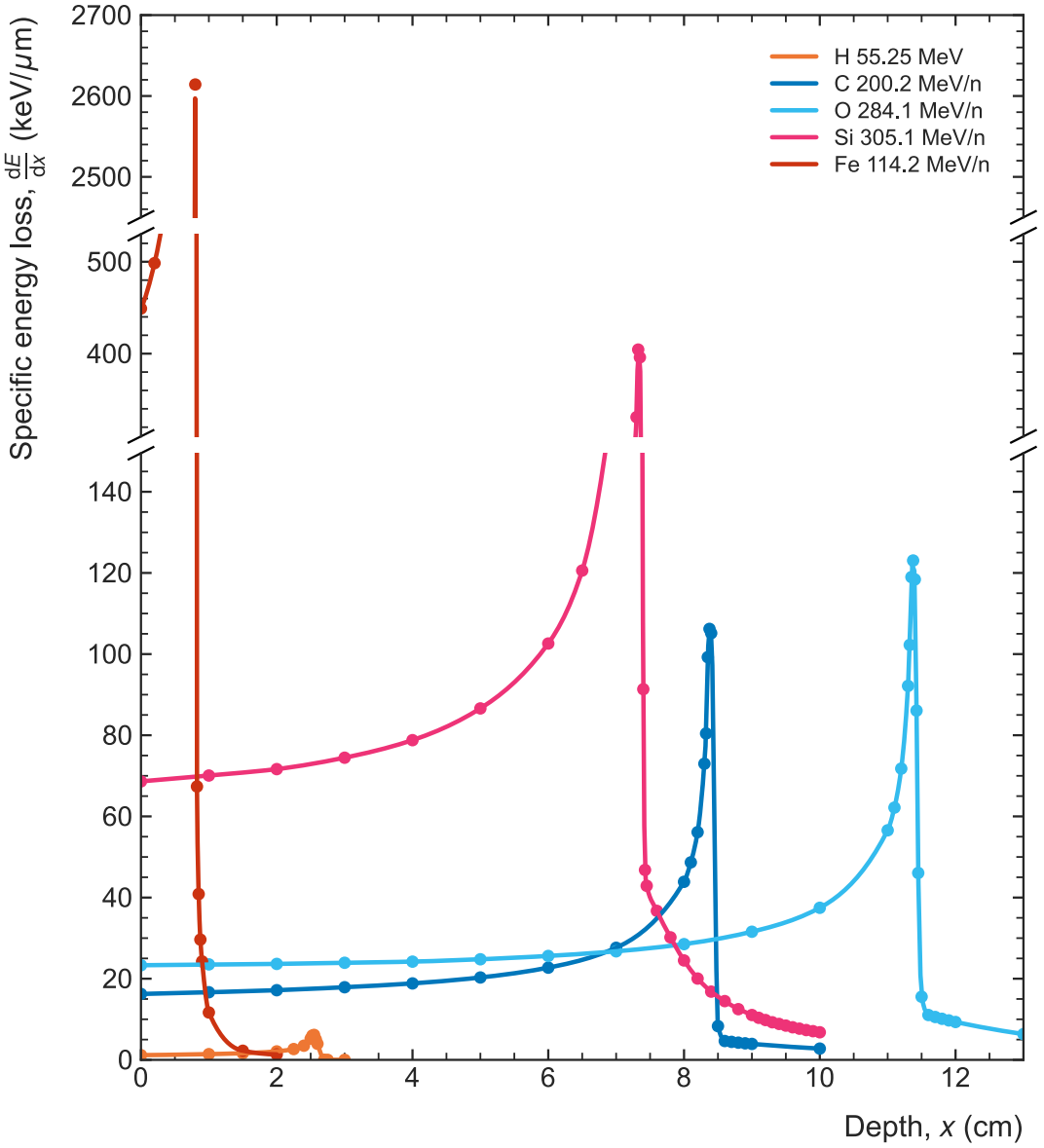
Projected Performance

ADU Working Principle

Bragg Curve Spectroscopy

- Determination of E/β, Z, A from energy-deposition profile

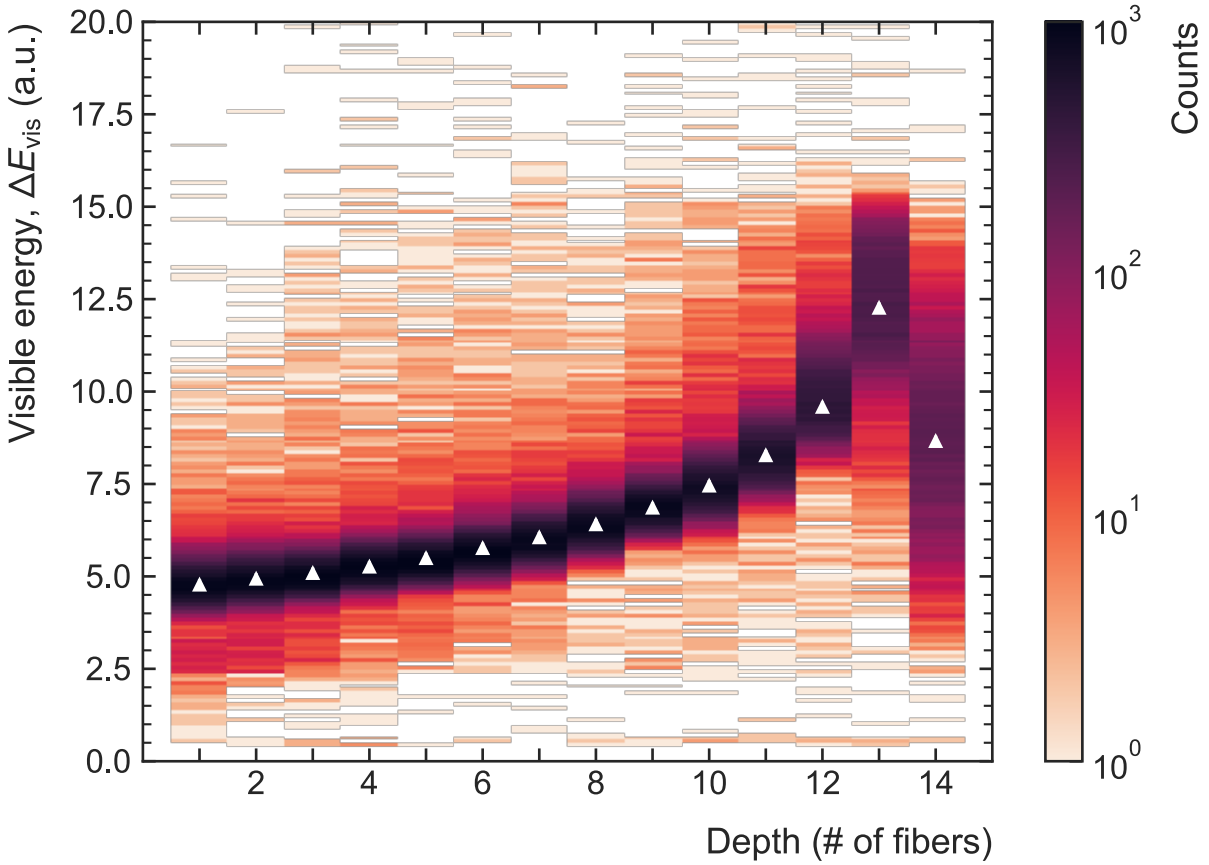


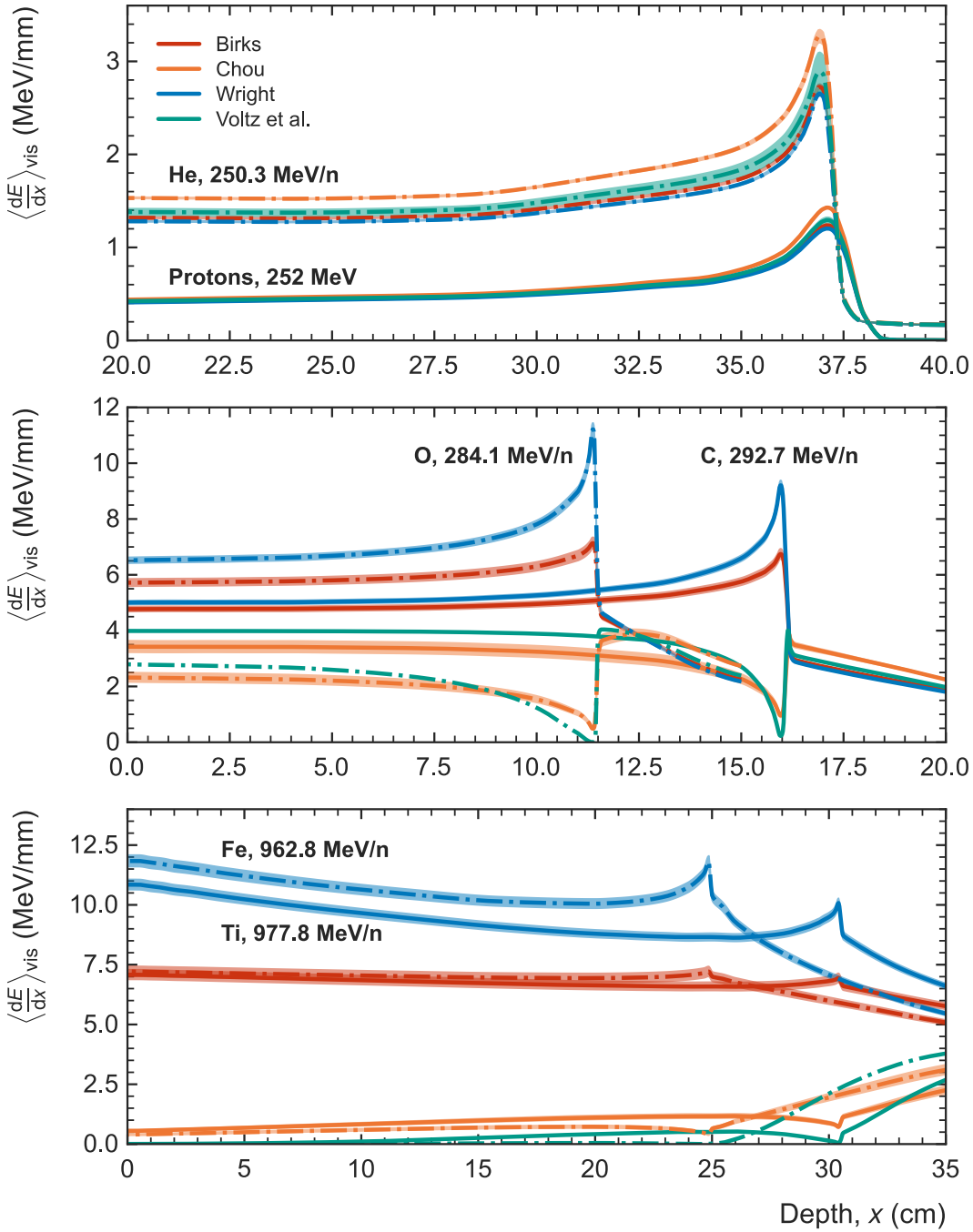


ADU Working Principle

Challenges

1. Energy-loss straggling
2. Fragmentation
3. Ionization quenching

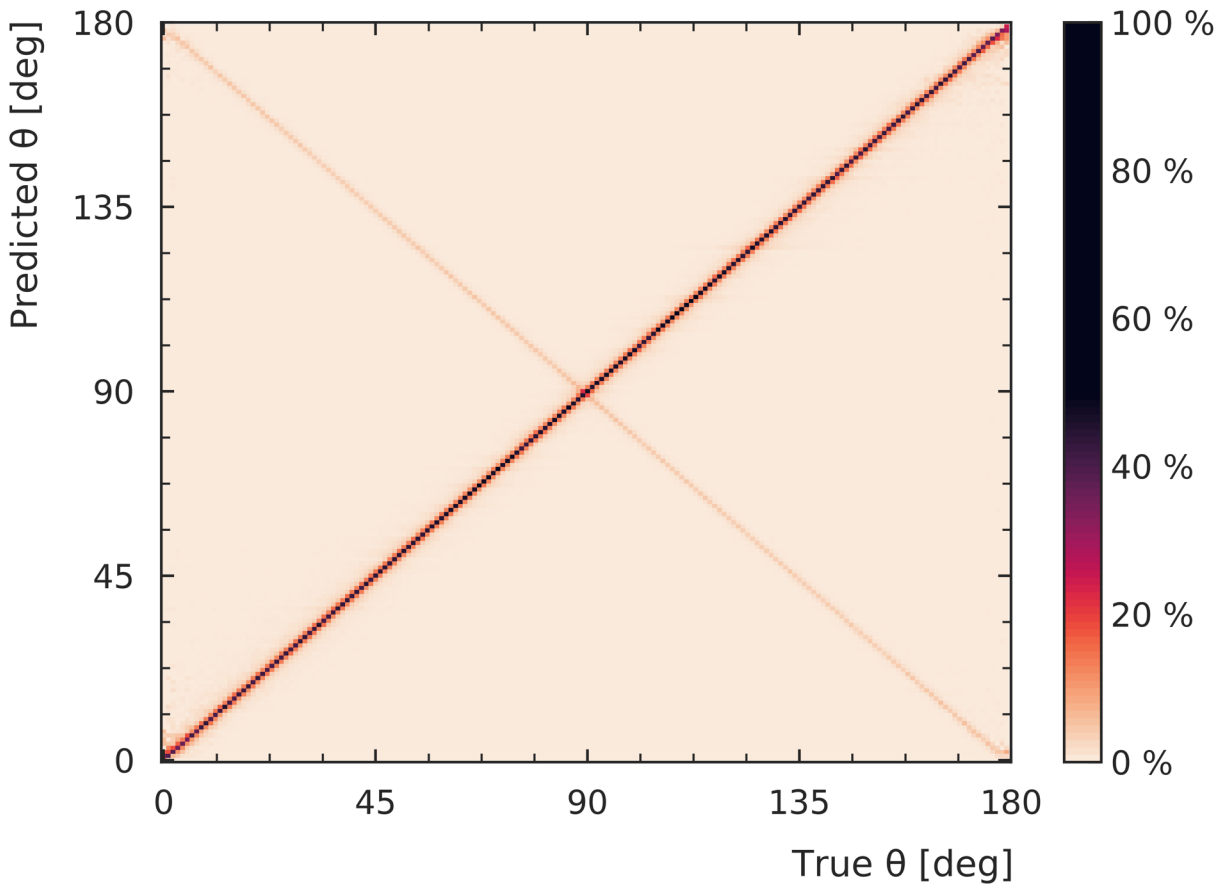




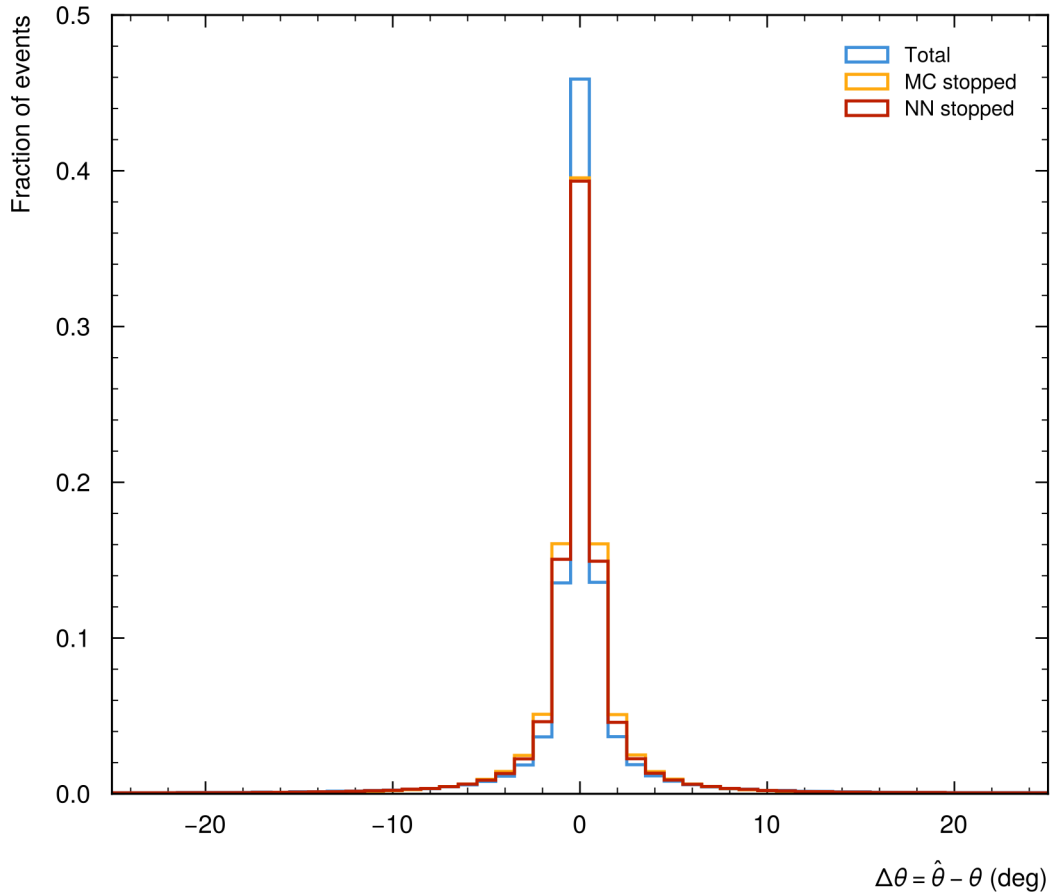
NN-Based Event Reconstruction

Track Angles

- Geant4 simulation data, fully isotropic distribution from H to Fe, 70 MeV to 5 TeV, 10^7 events



$\sigma_\theta = 1.15$ deg



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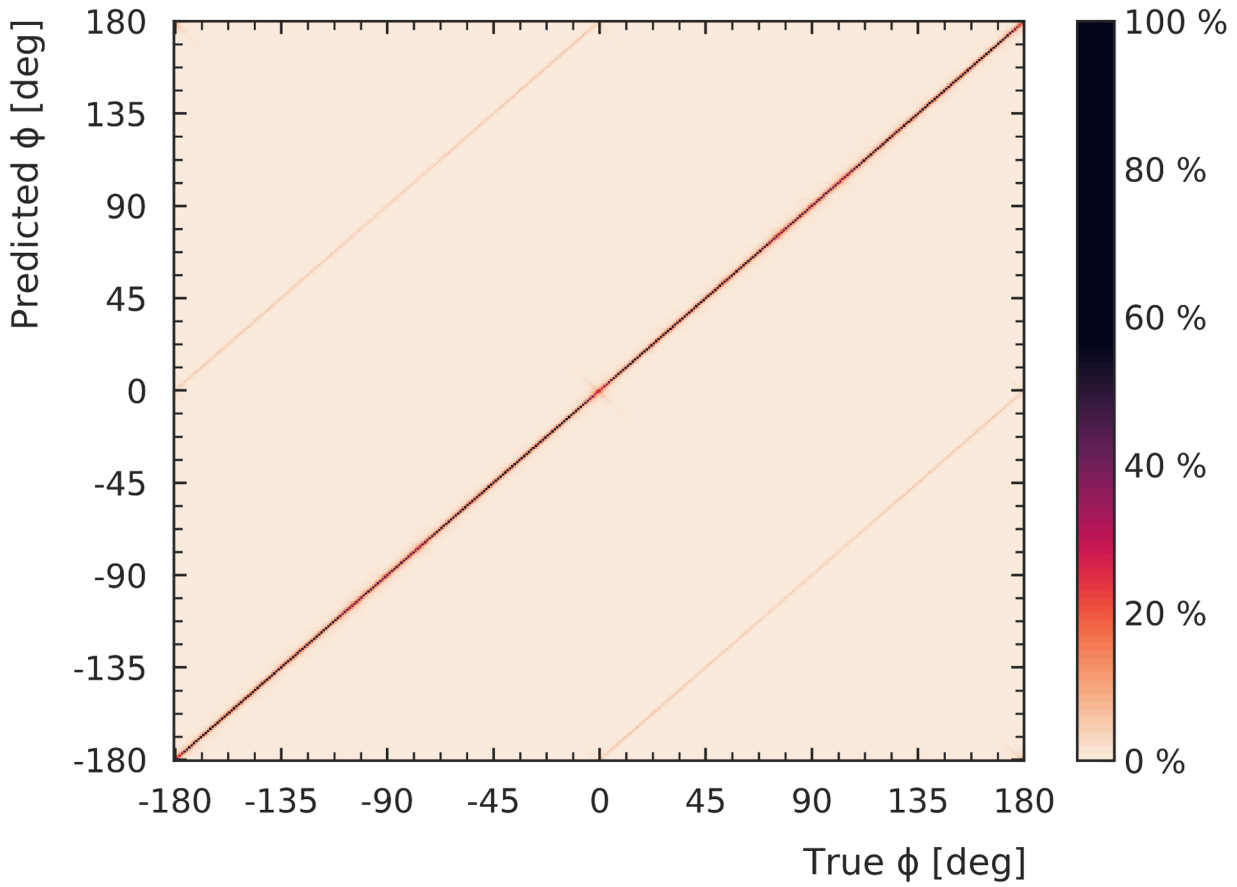
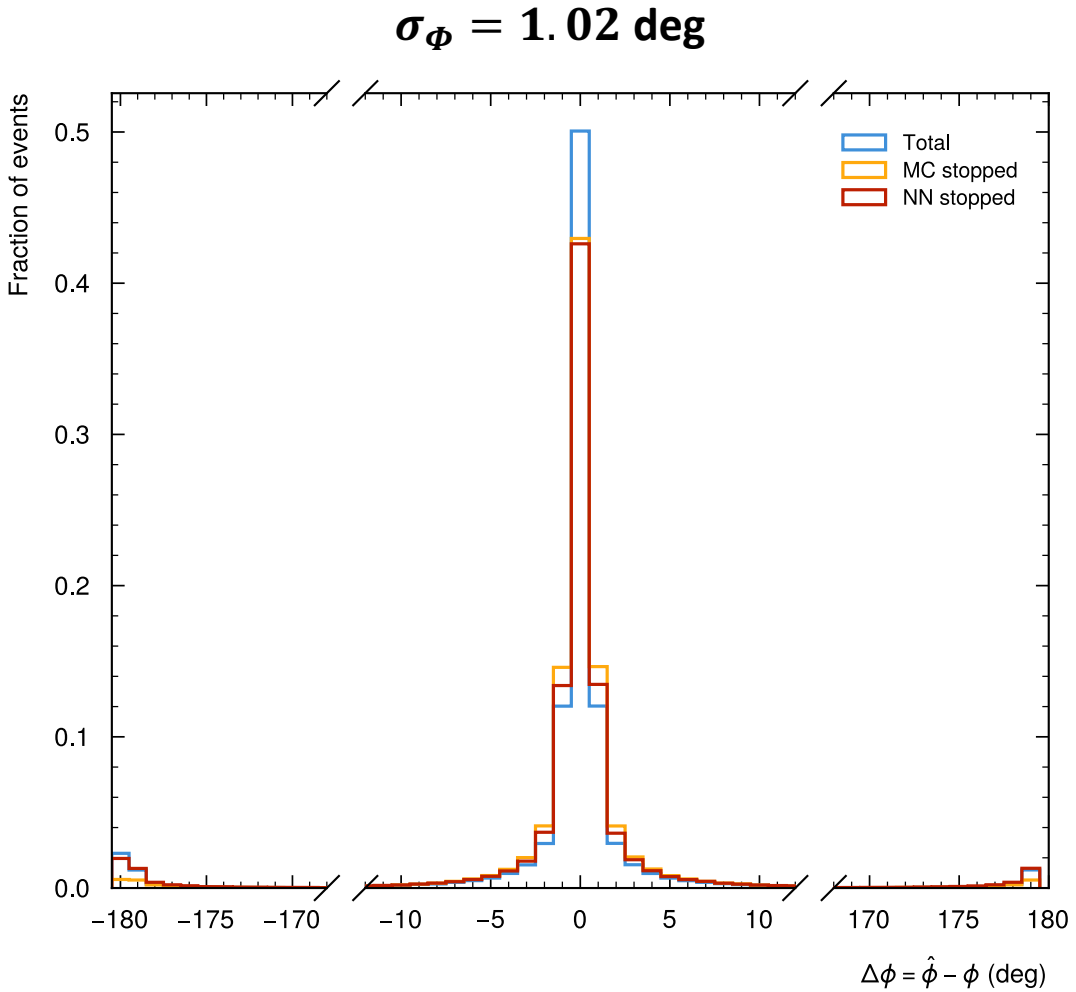


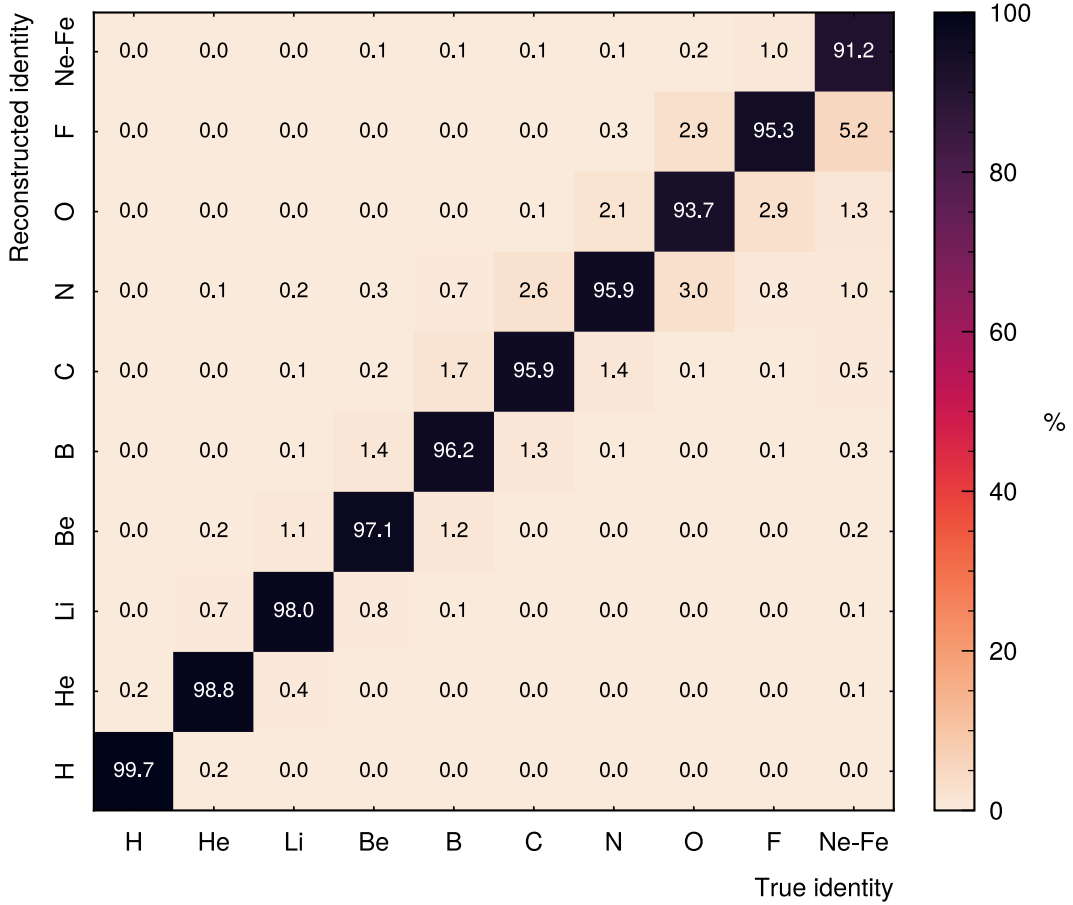


NN-Based Event Reconstruction

Particle / Ion Identification

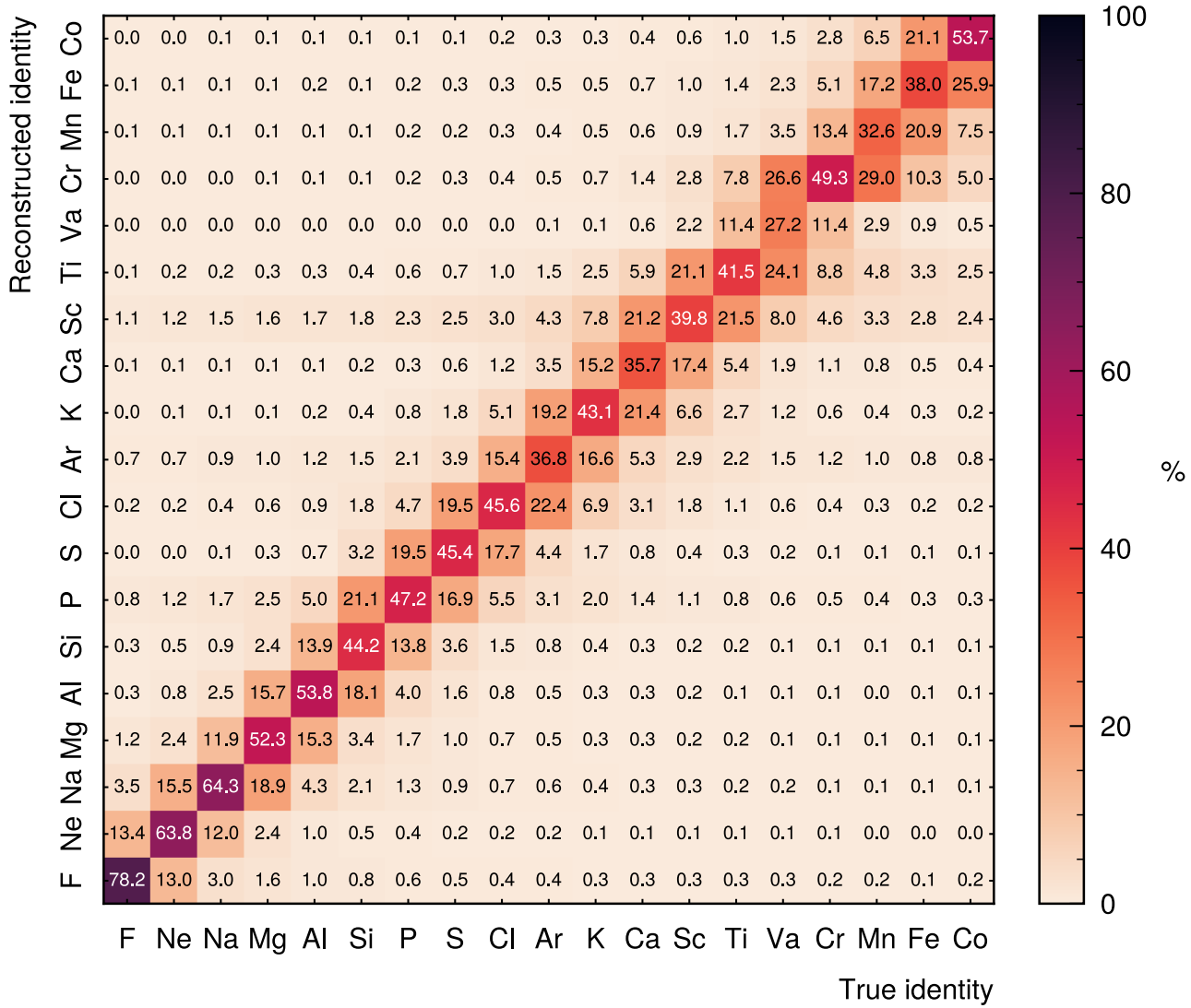
- Geant4 simulation data, fully isotropic distribution from H to Co, 70 MeV to 5 TeV, 10^7 events

H to F



F to Co

WORK IN PROGRESS



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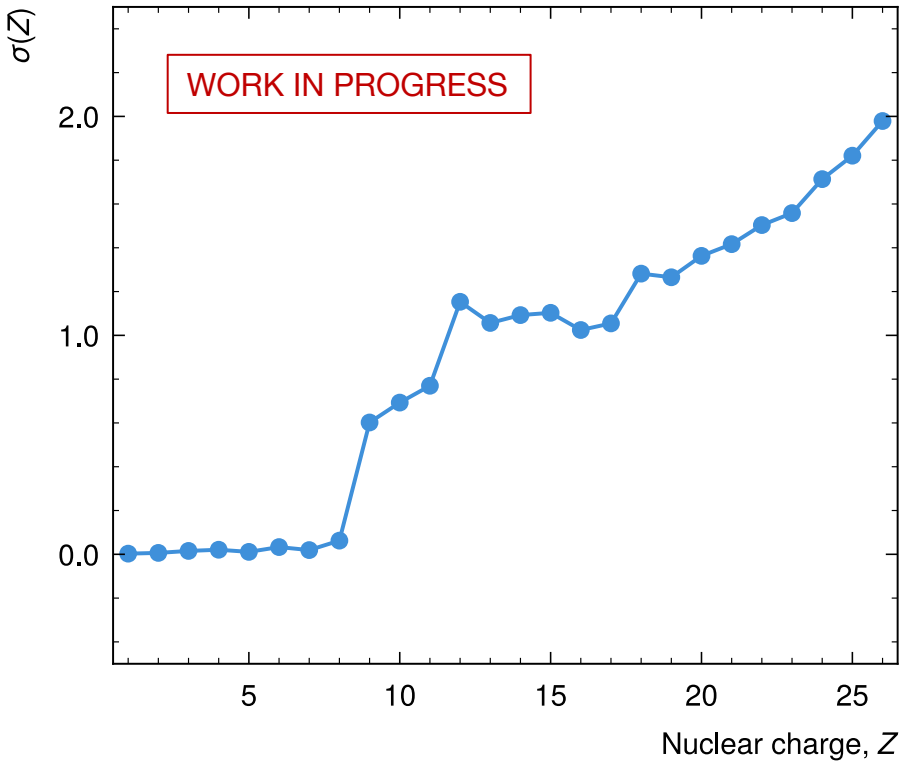
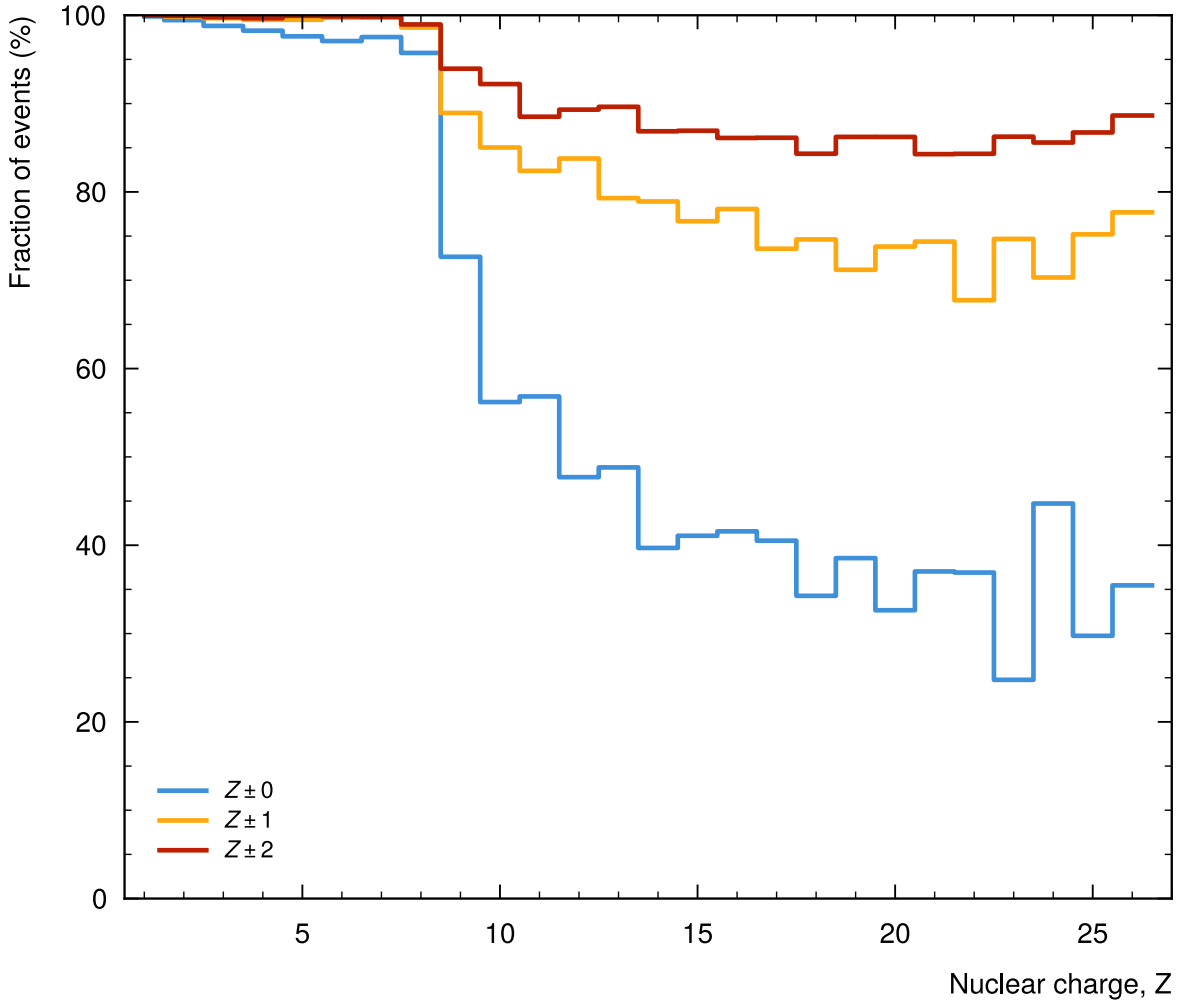
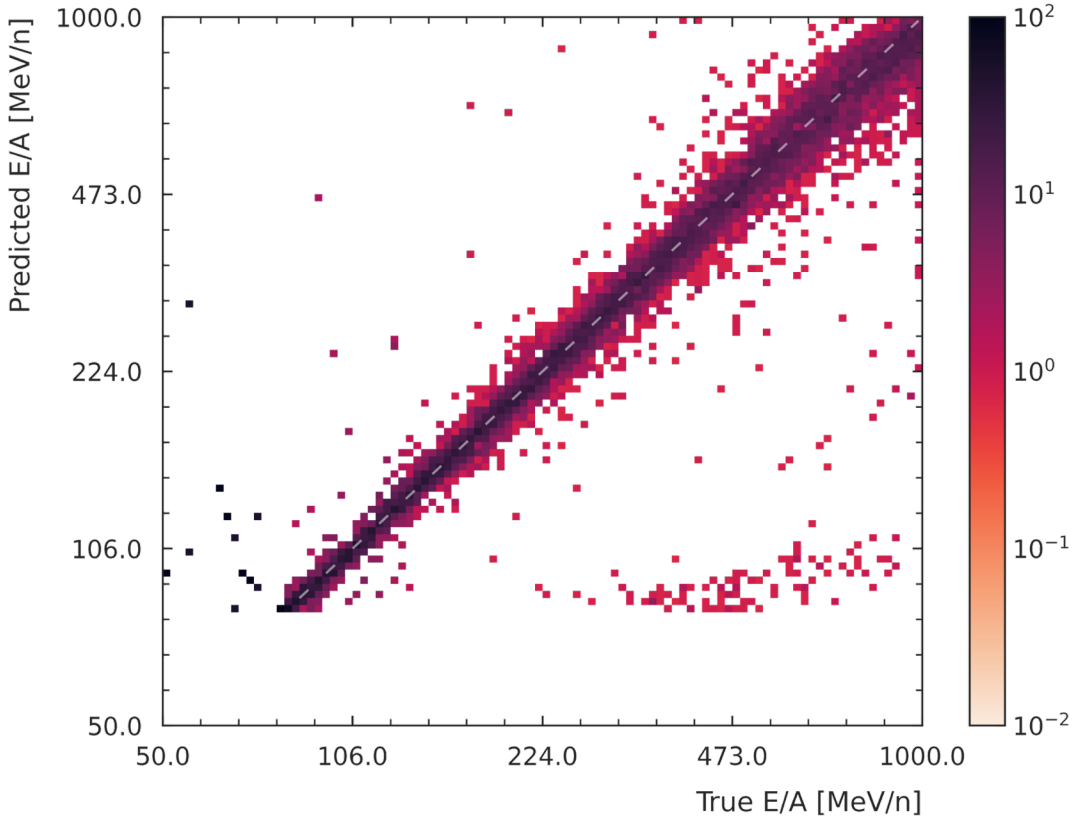




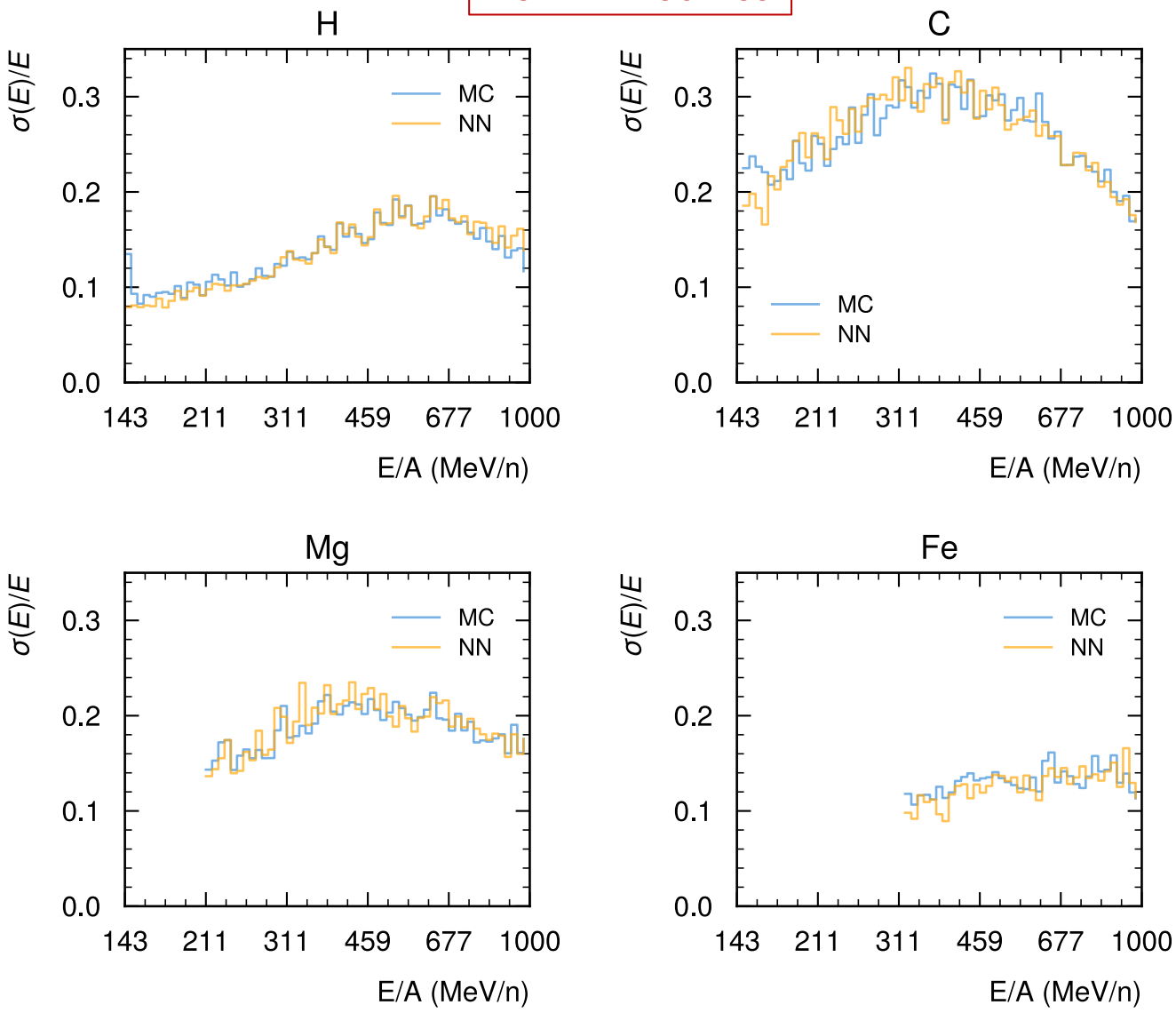
NN-Based Event Reconstruction

Energy

- Geant4 simulation data, fully isotropic distribution, 70 MeV to 1 GeV, 10^7 events
- **NN- vs. MC-selected particles**



WORK IN PROGRESS



NN-Based Event Reconstruction

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WORK IN PROGRESS

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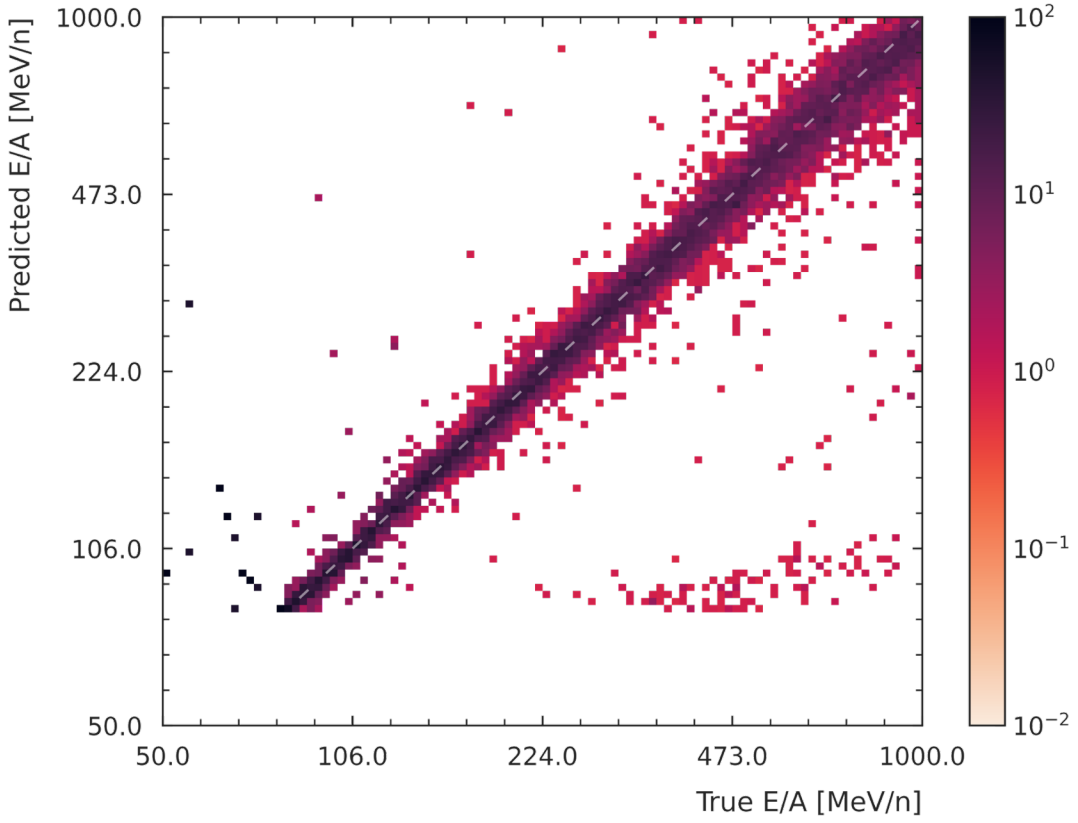
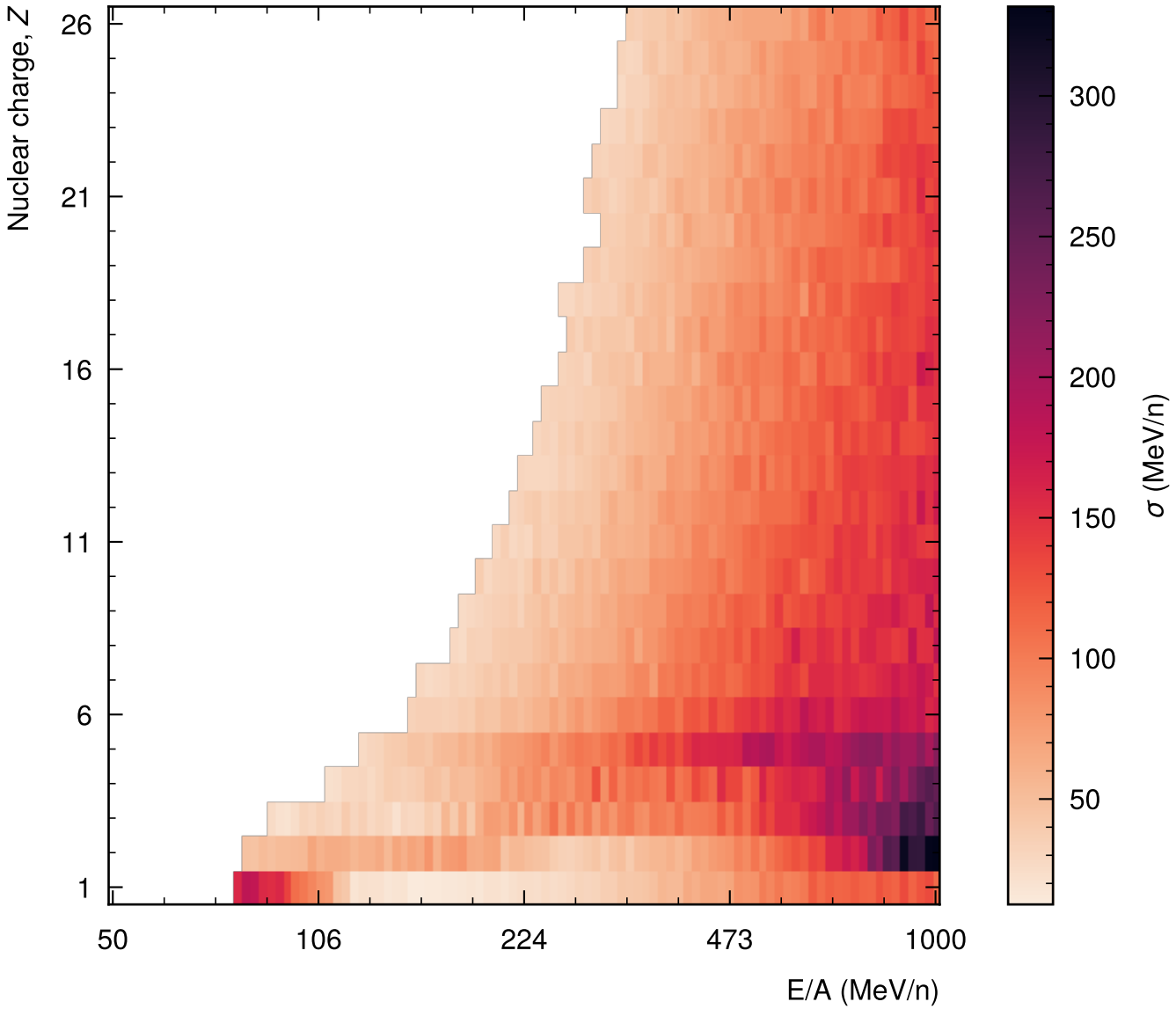




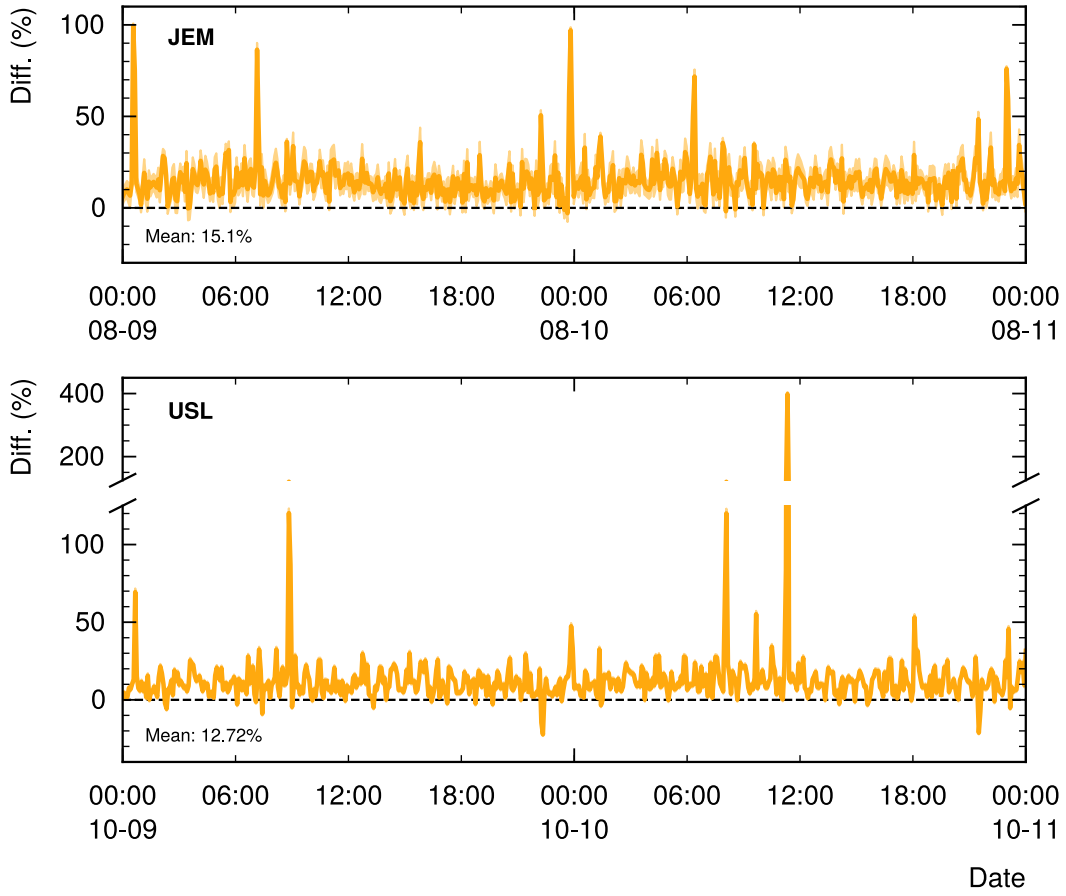
AIRBUS Technical University of Munich

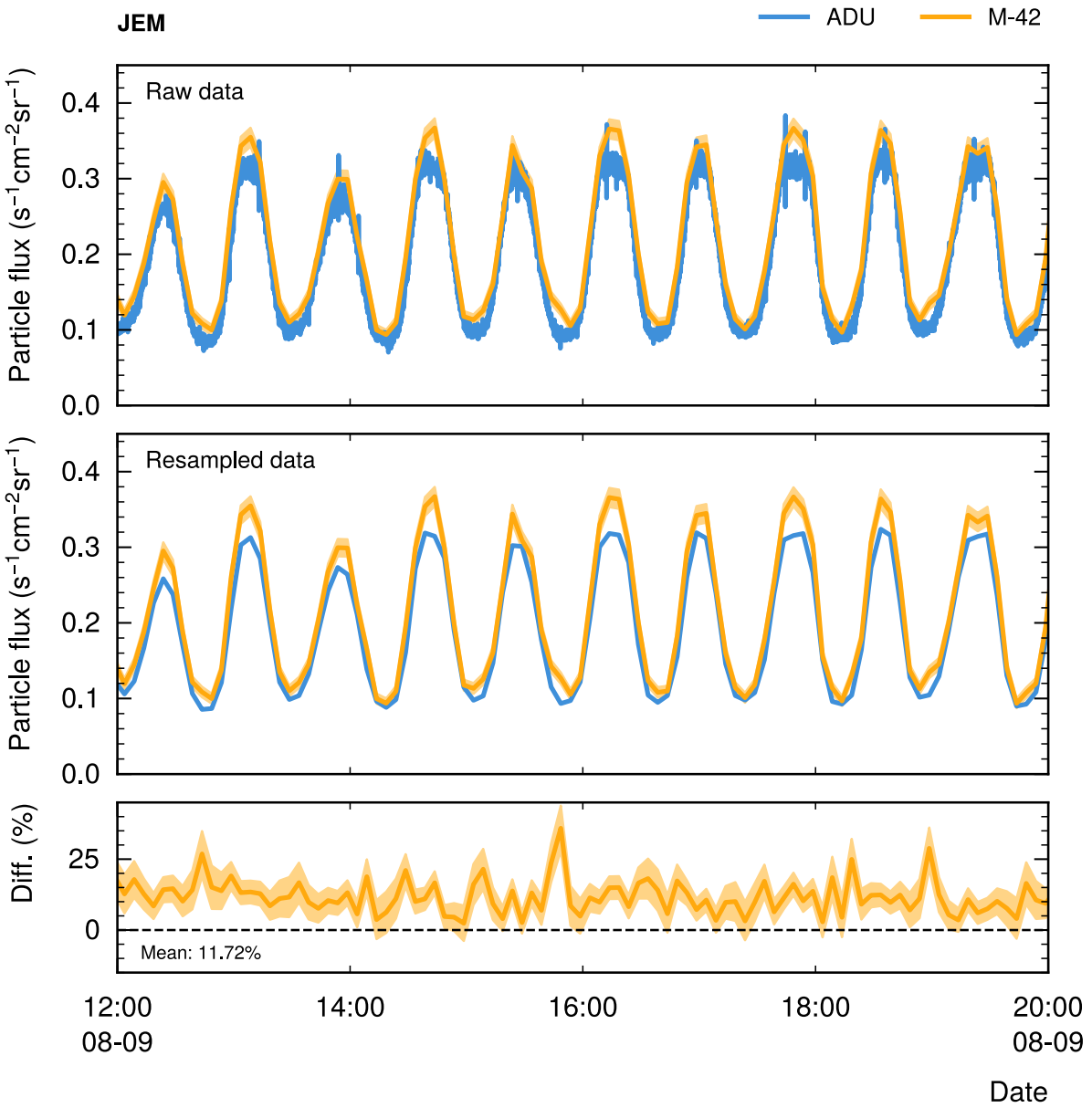
On-Orbit Data

Count Rates

Comparison Between ADU & M-42

- Scaling of ADU and M-42 count rates with
  $GF_{ADU} = 1013\ cm^2sr$
  $GF_{M\text{-}42} = 7.61\ cm^2sr$





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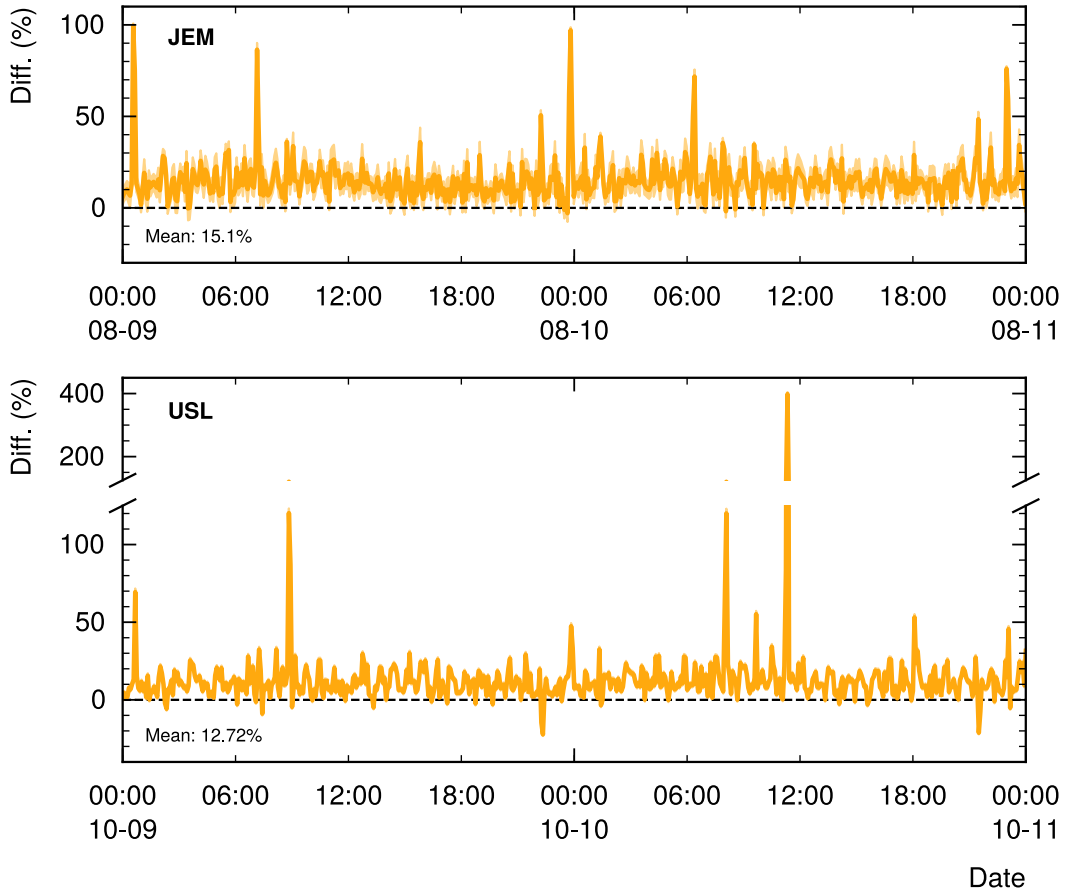
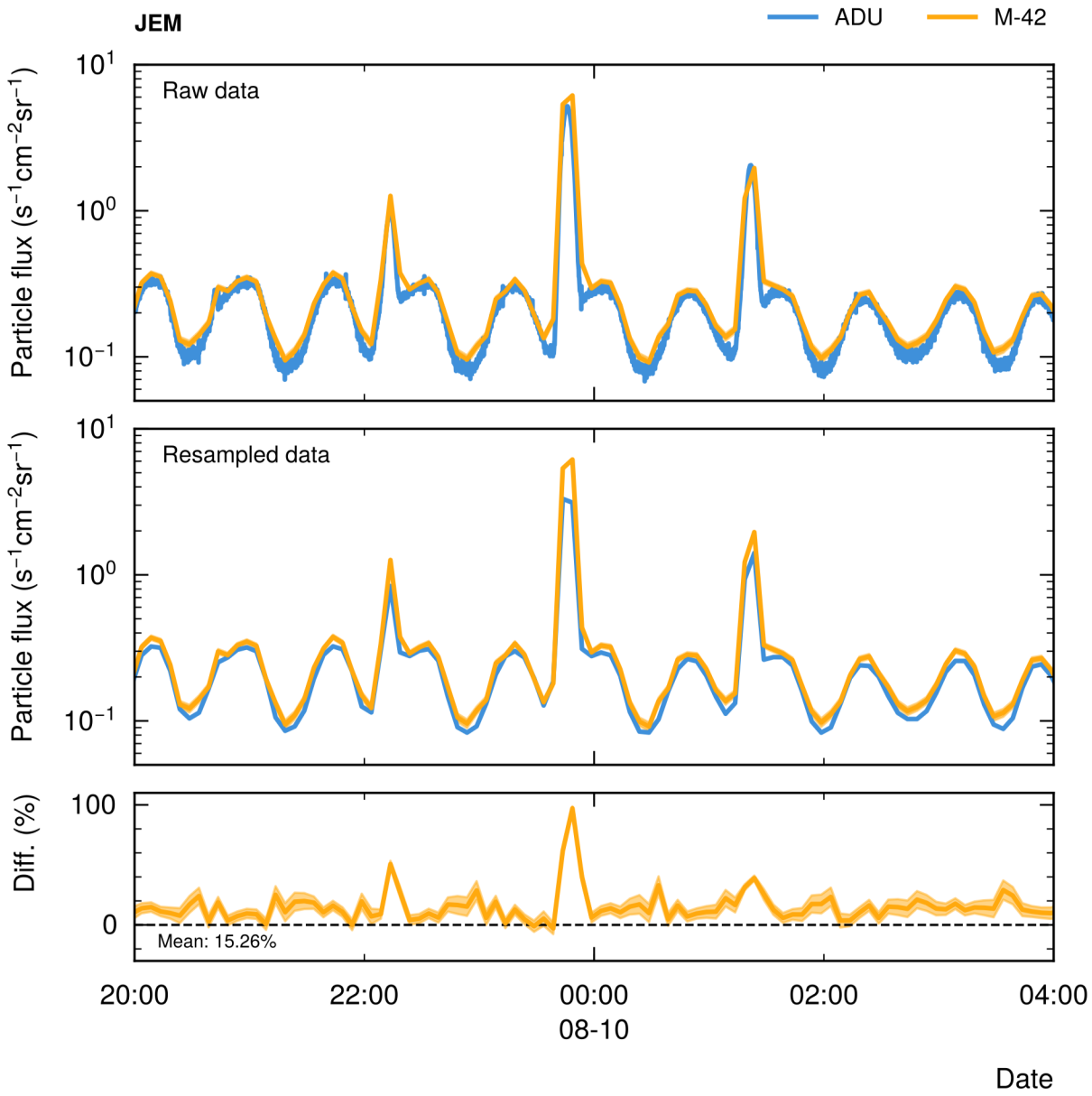


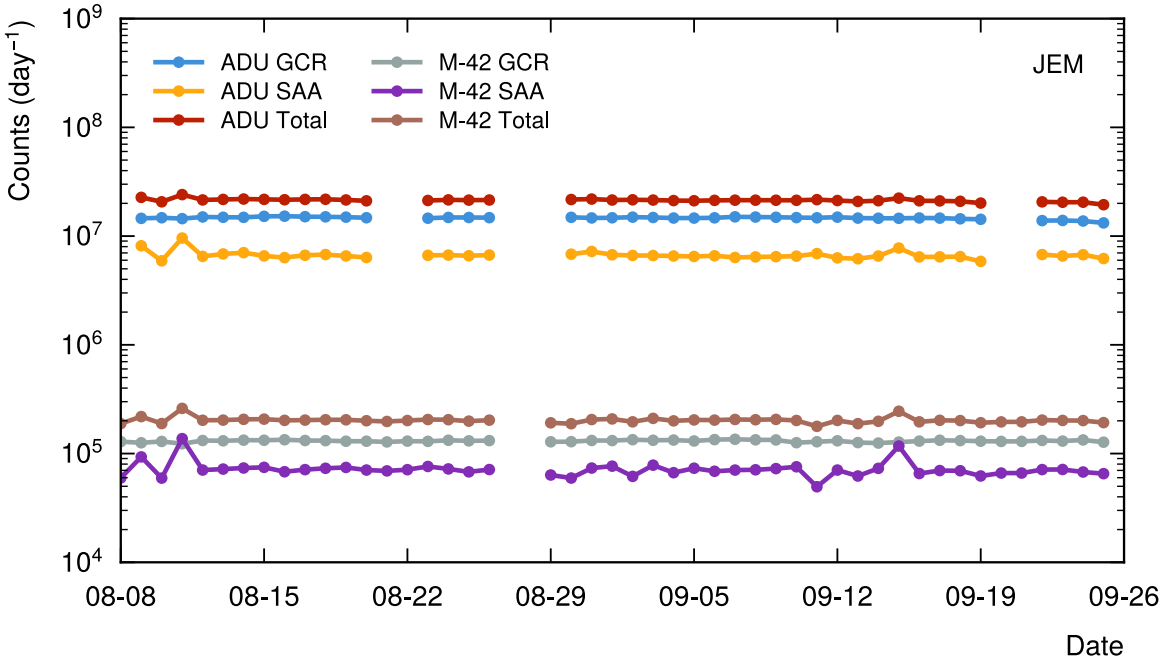


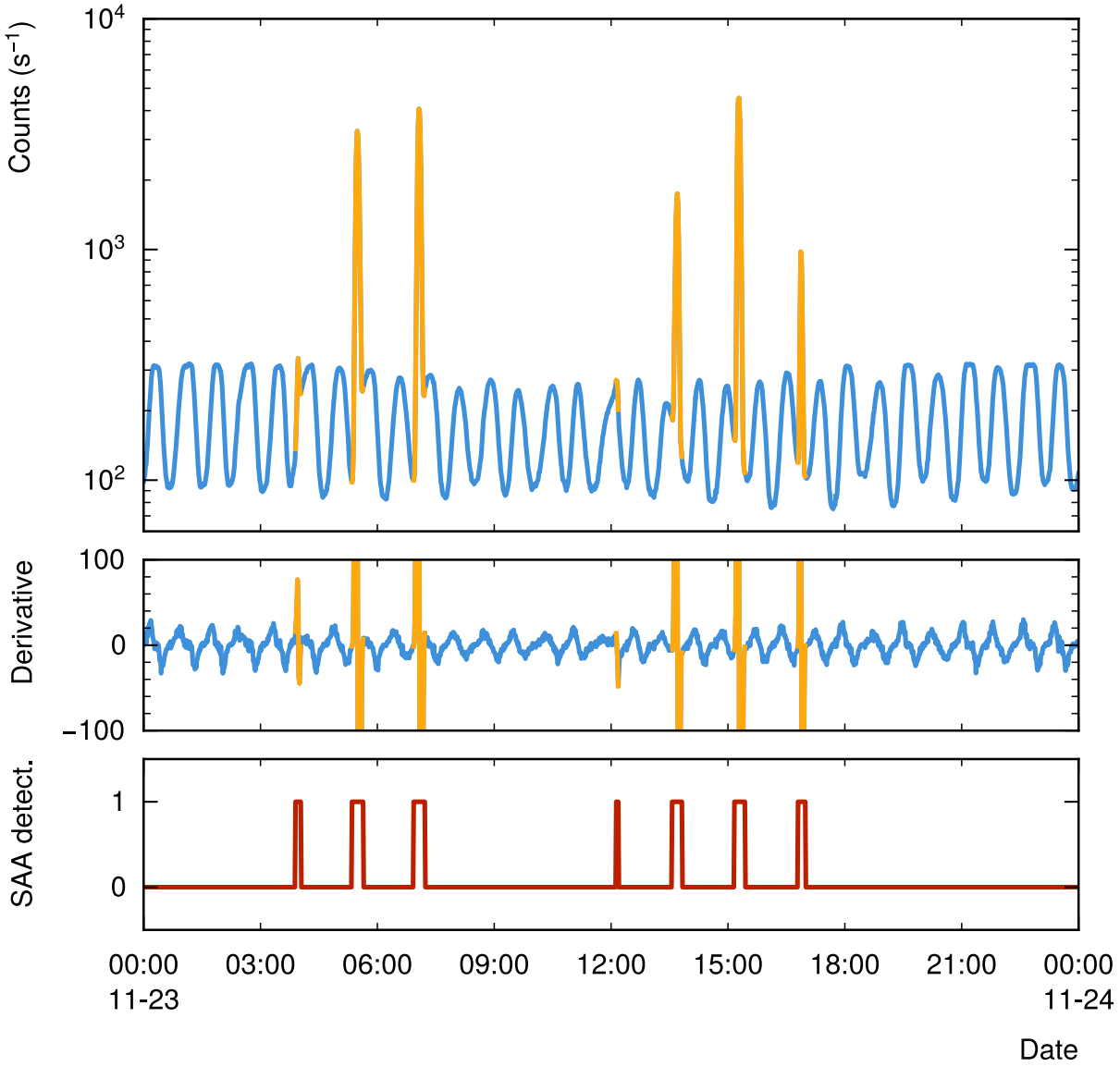
GCR—SAA Separation

Based on Count Rates

WORK IN PROGRESS

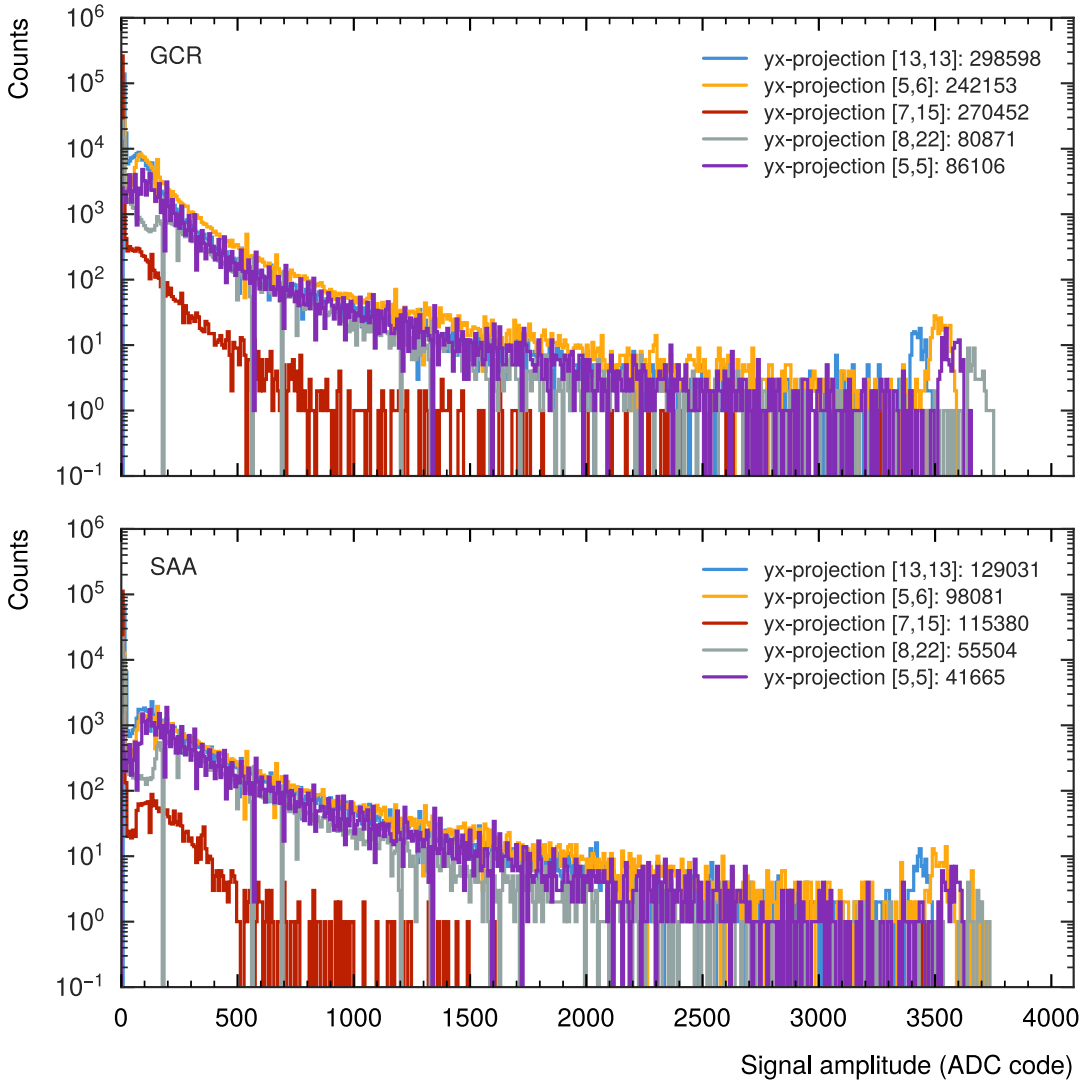
- Automatic detection via
  - Count rate
  - Derivative of count rate

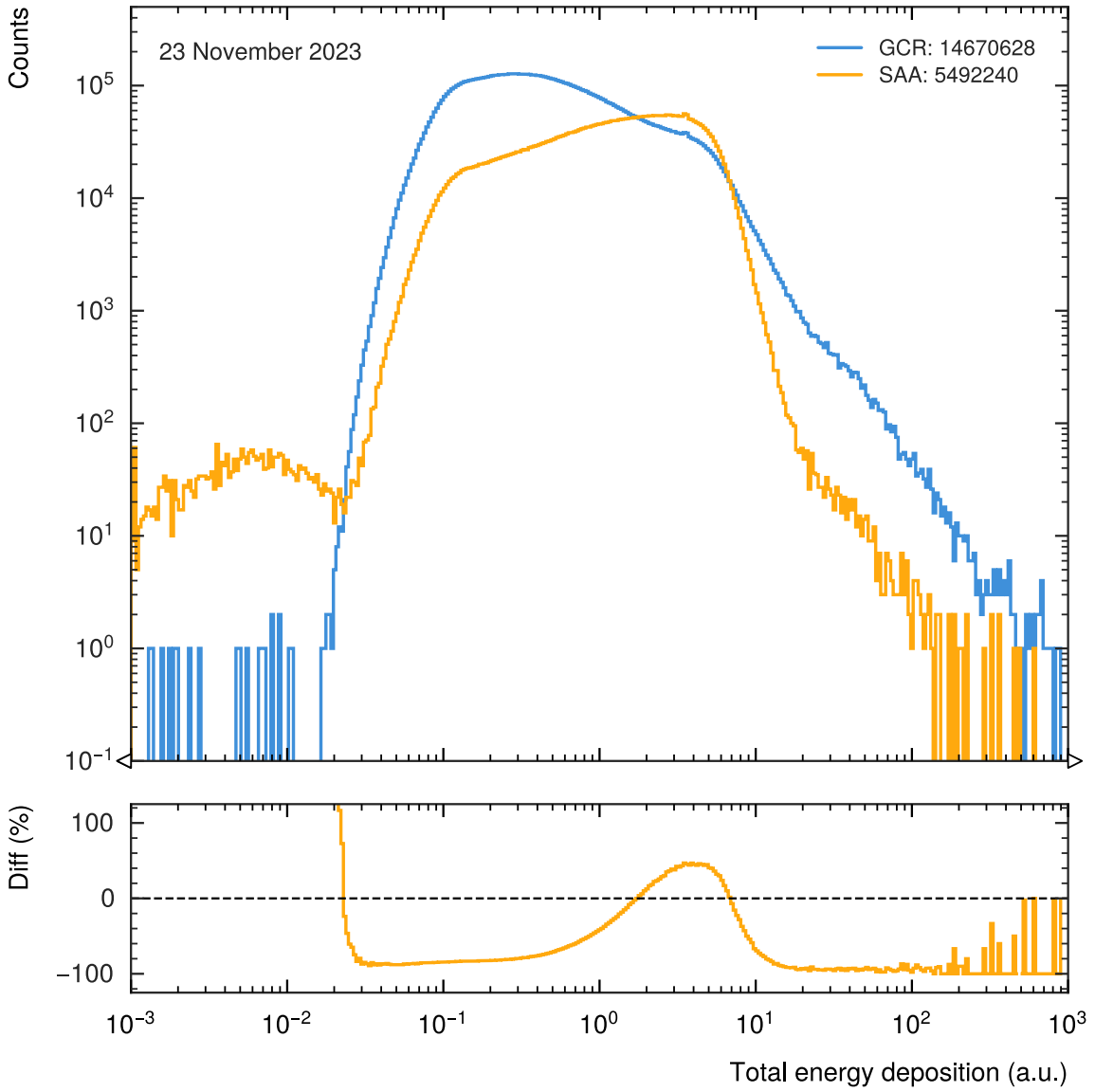




Energy Deposition

Single Channels vs. Full Detector (Uncalibrated)

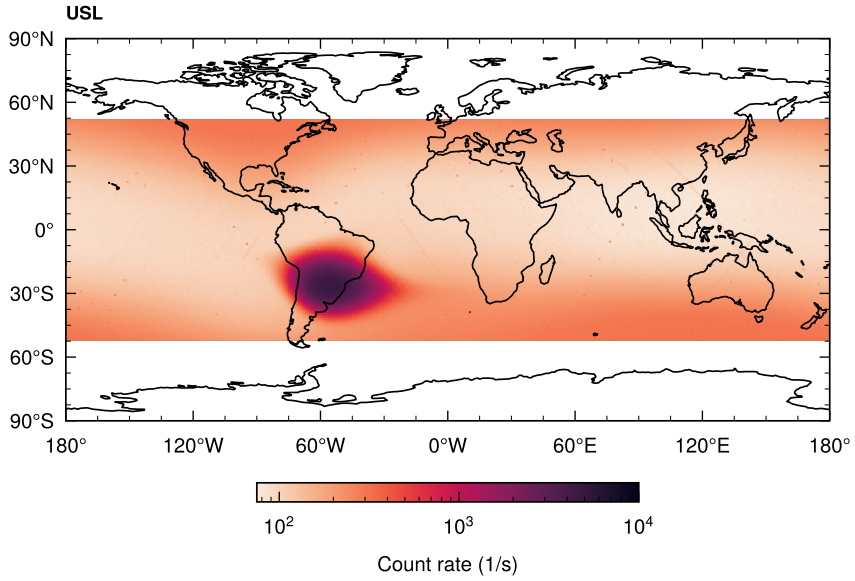


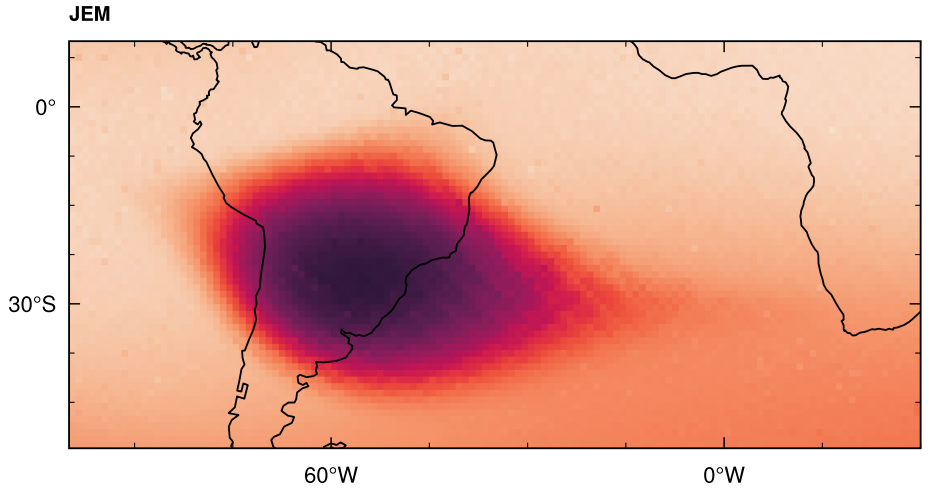


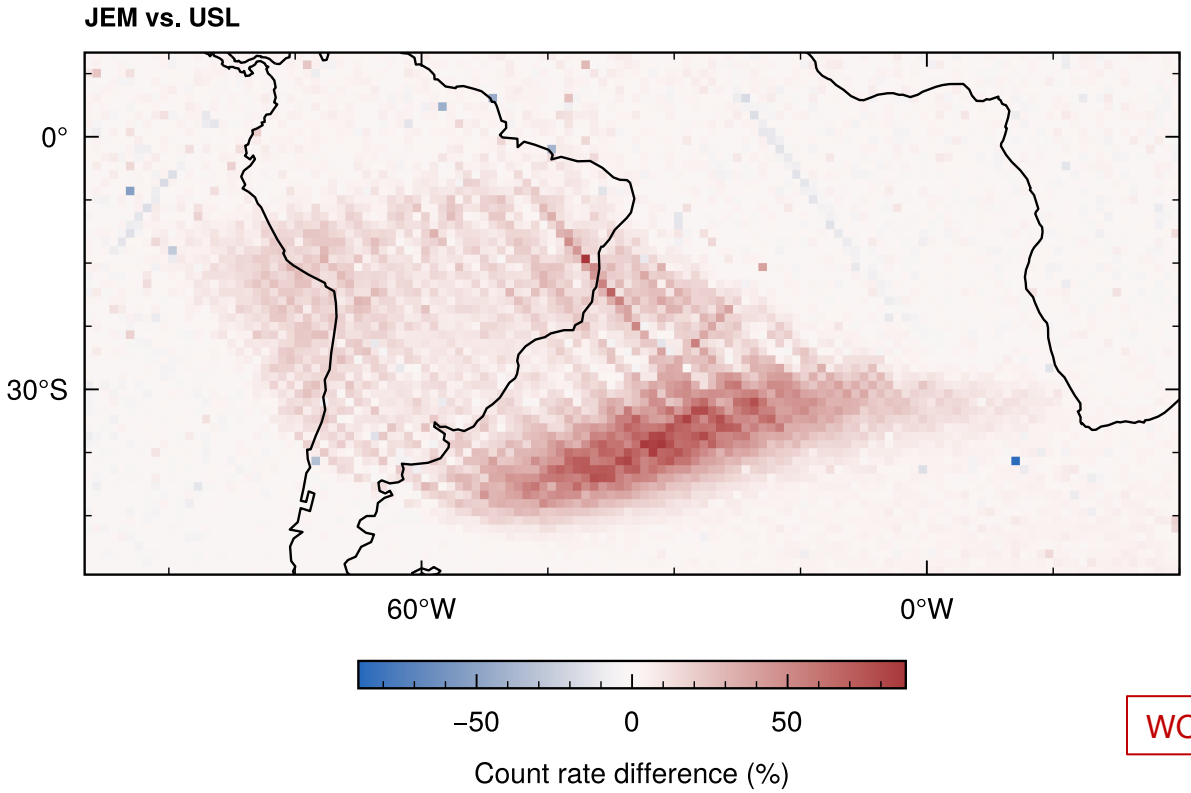
Orbit Correlation

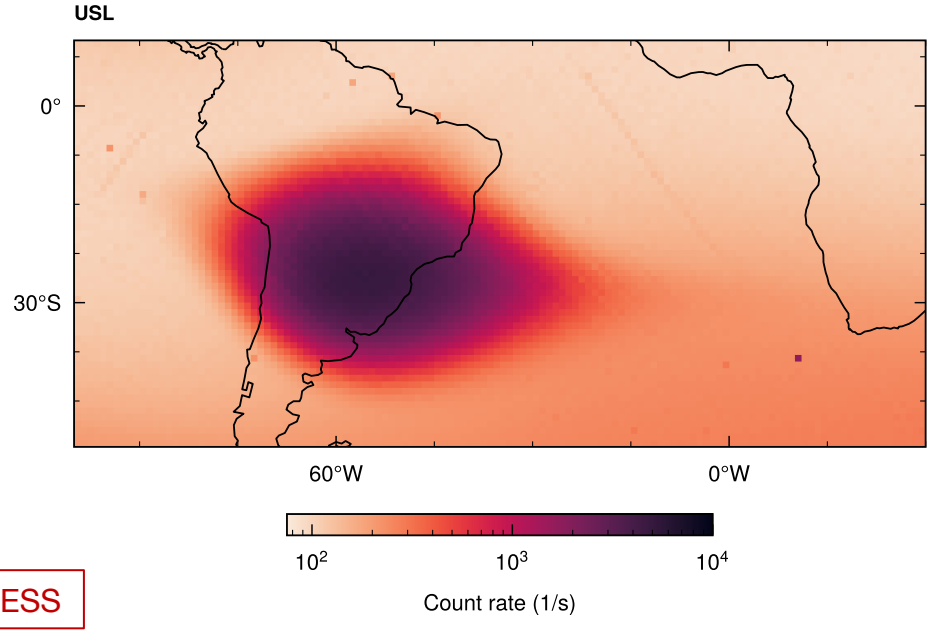
JEM vs. USL

- Raw count rates, no cleanup whatsoever
- 1 x 1 deg bins







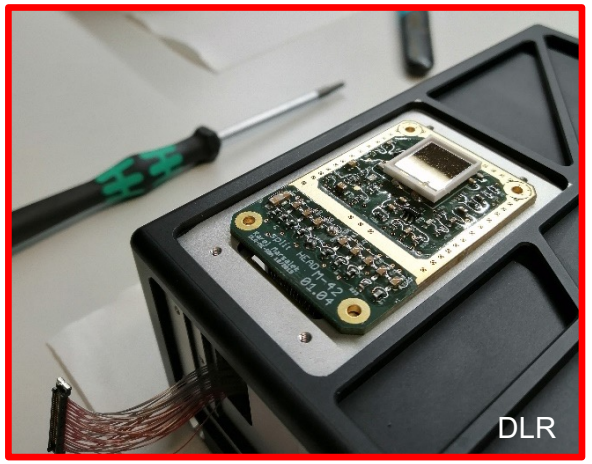


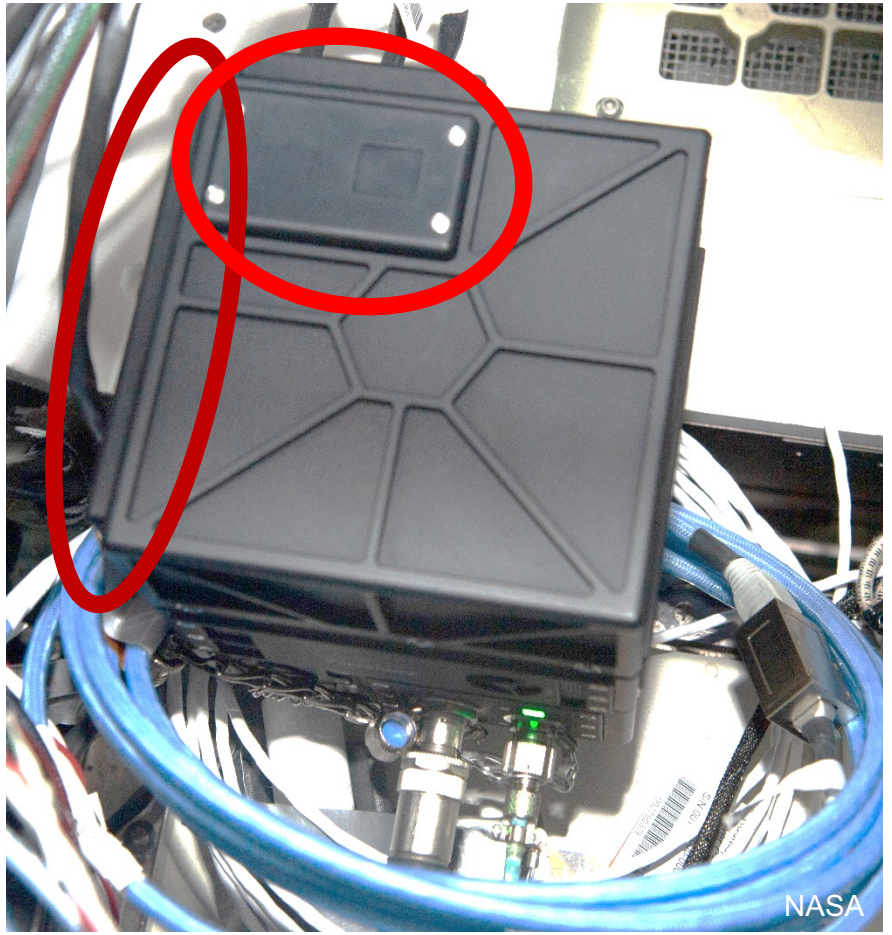
WORK IN PROGRESS

Secondary Sensor

M-42 Dosimeter

- Planar silicon detector
- 300 µm thickness, 1.23 cm^2 area
- E_{dep}: 60 keV – 17.7 MeV in Si
- 1004 channels, 17.6 keV width
- Interfaces: power, data (UART)

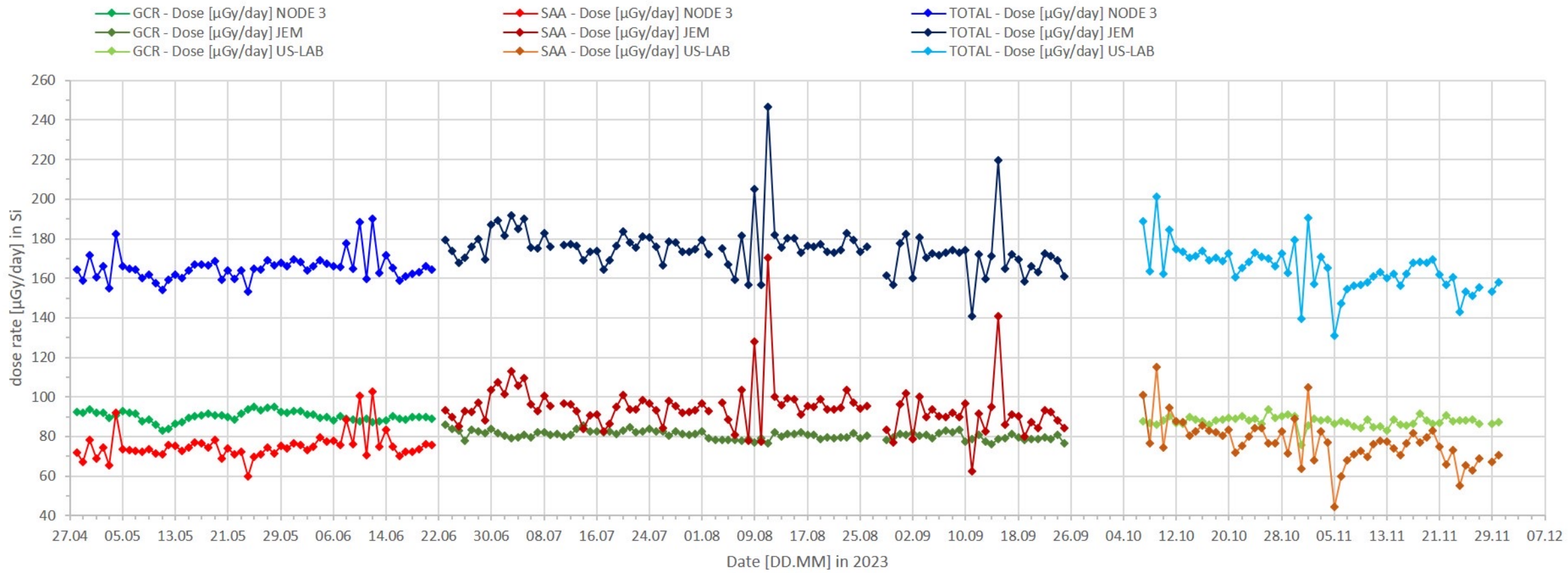




Berger, T., Marsalek, K., Aeckerlein, J., Hauslage, J., Matthiä, D., Przybyla, B., Rohde, M., Wirtz, M. (2019). The German Aerospace Center M-42 radiation detector – a new development for applications in mixed radiation fields. Review of Scientific Instruments, 90, 125115. https://doi.org/10.1063/1.5122301

M-42 Dosimeter

Daily Dose



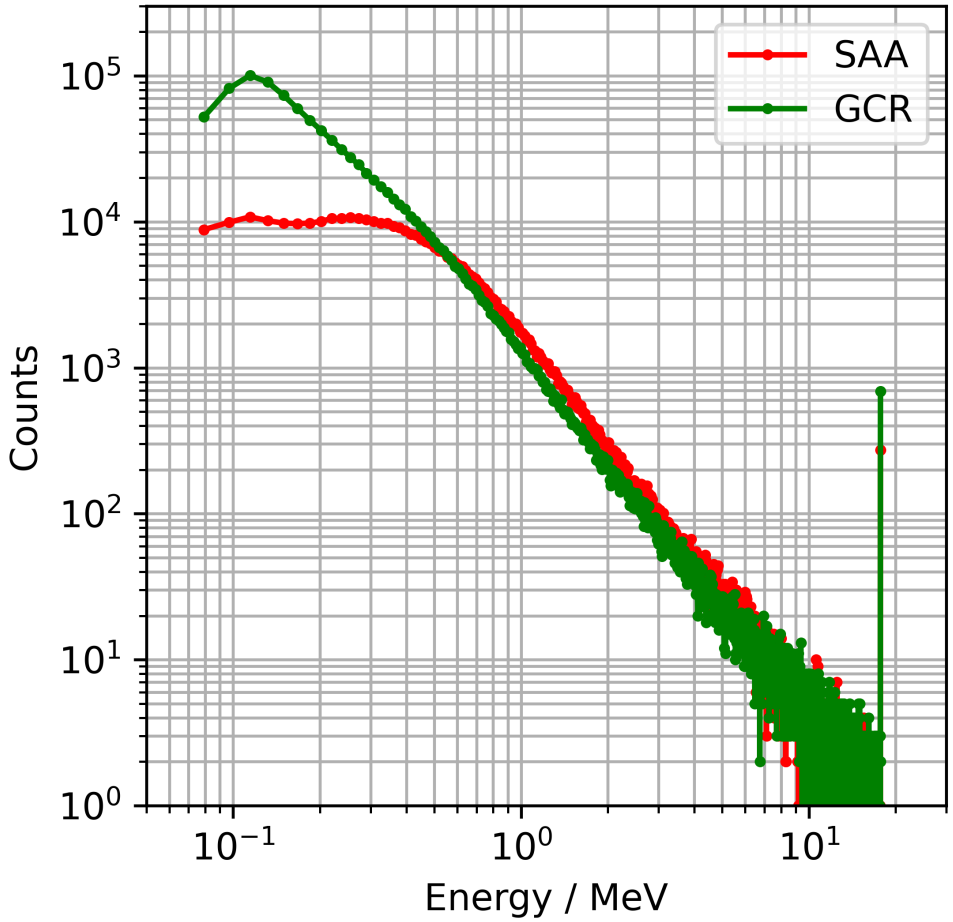
NODE 3 | JEM | US-LAB

M-42 Dosimeter

Energy-Deposition Spectra

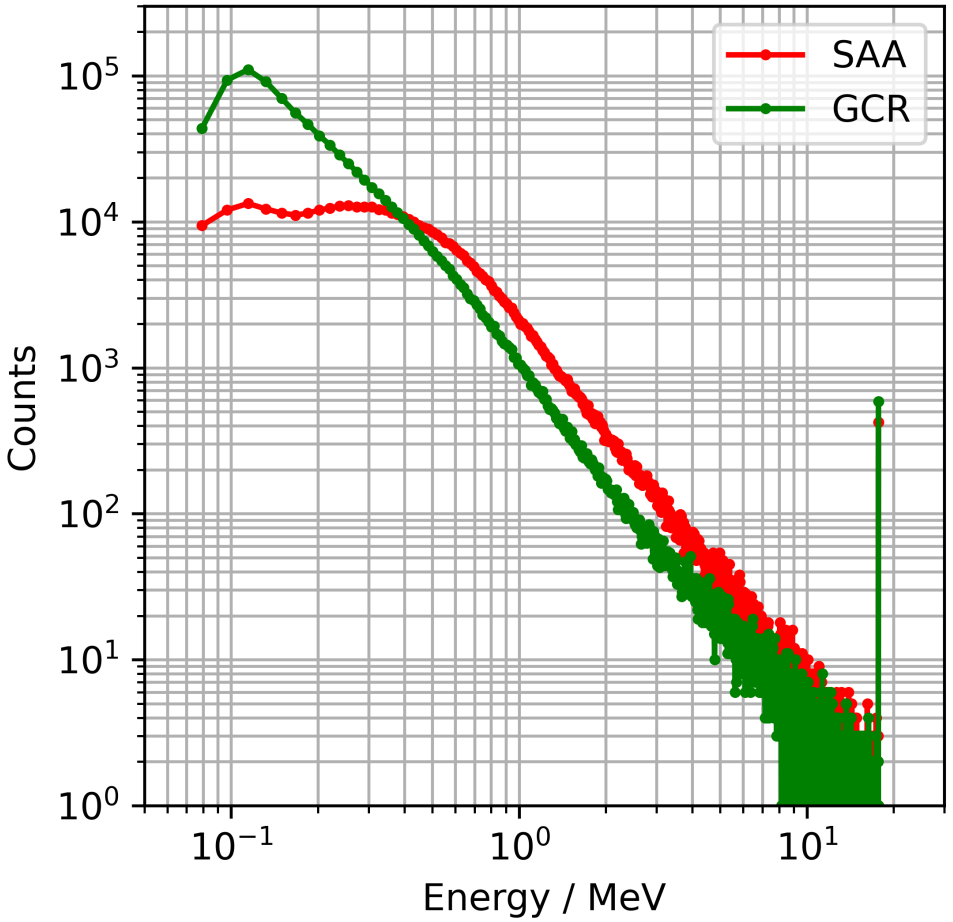
NODE 3

29-05-2023 to 05-06-2023



JEM

24-07-2023 to 31-07-2023



Summary & Outlook

- RadMap Telescope deployed to ISS in April 2023; measurements in
  - Node 3 → *May 2023*
  - Japanese Experiment Module → *June 2023*
  - US Lab → *October 2023*
- Co-location with ISS-Rad in US Lab → data comparison pending

- Analysis of ADU data ongoing
  - Clearly identifiable track candidates in ~30% of events → identify nature of rest
  - Baseline subtraction, crosstalk identification, and noise suppression work
  - Tracking works, automatic correction of position-dependent light yield in verification
  - Energy / gain calibration ongoing
  - ➢ Start `physics' analysis

Unfortunately: Communication problems with the instrument

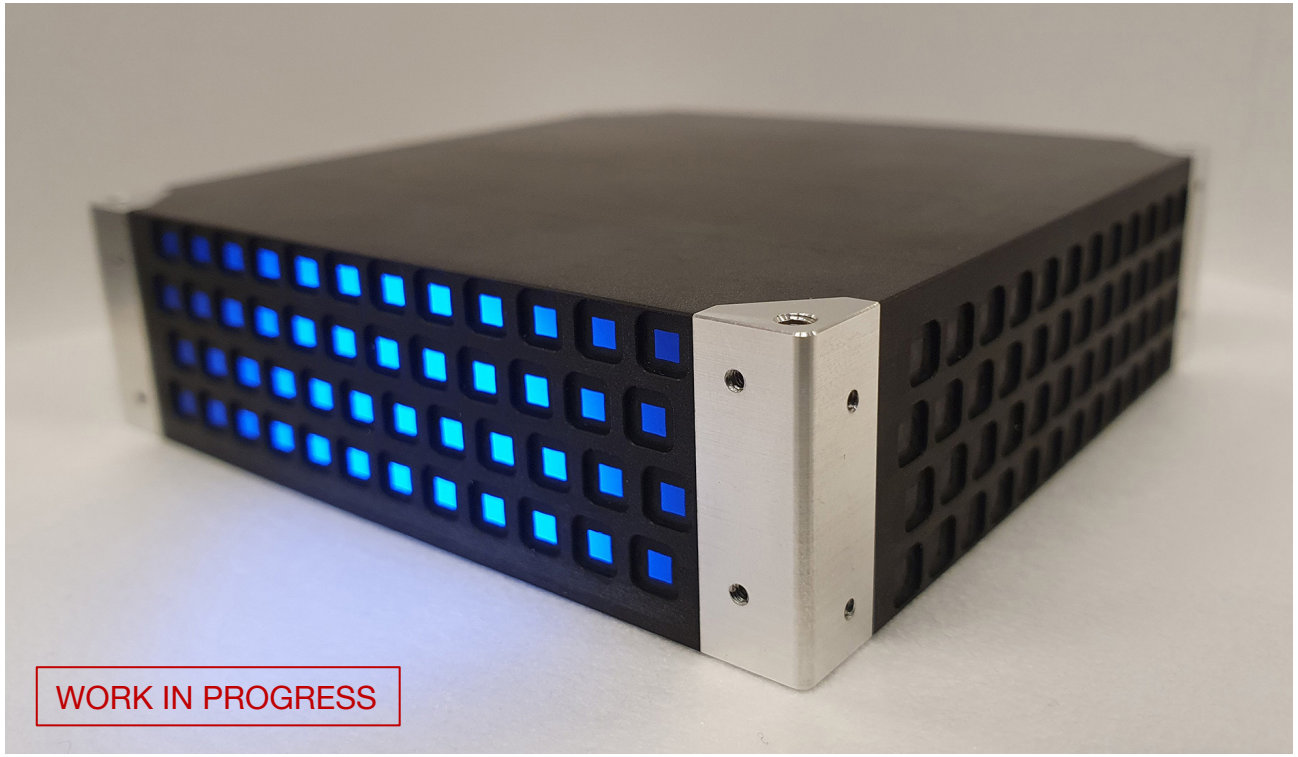
- On-orbit troubleshooting not successful
- Return & re-flight in planning

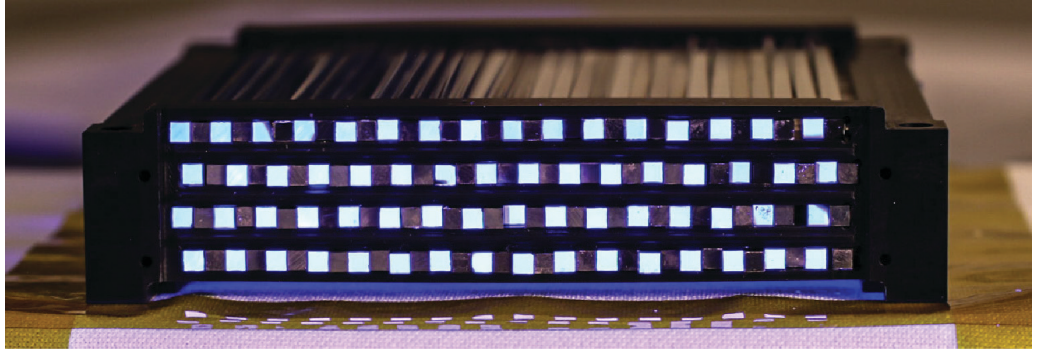
Outlook

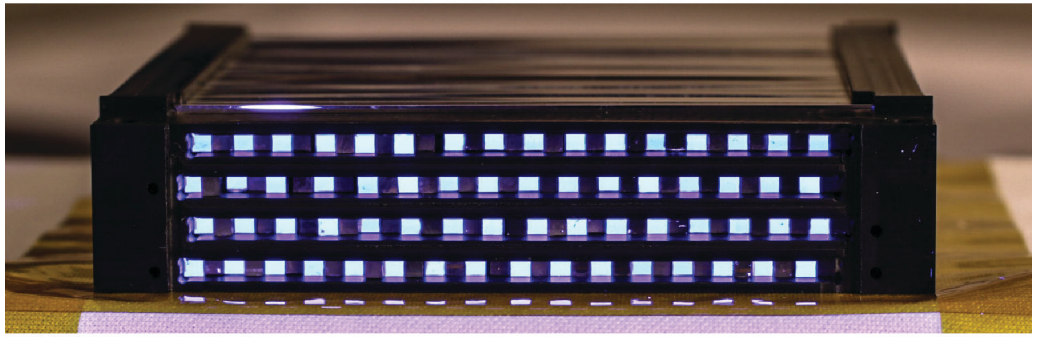
- Quality issues during RadMap ADU production
- New approach: pot fibers in epoxy

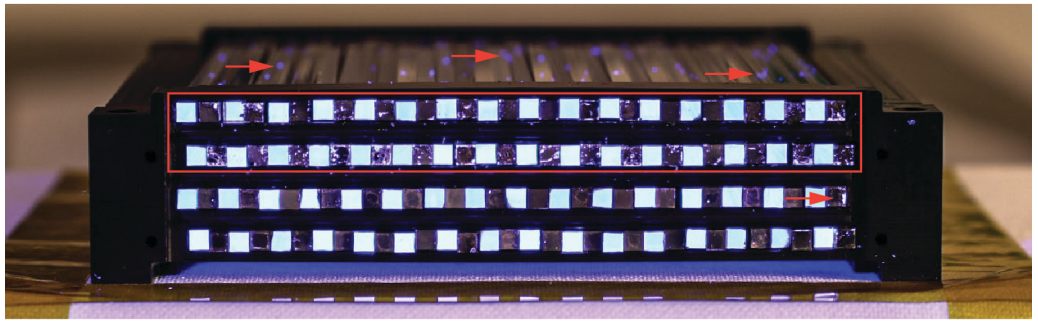
➢ Insensitive material, MC correction required to reconstruct particle energies

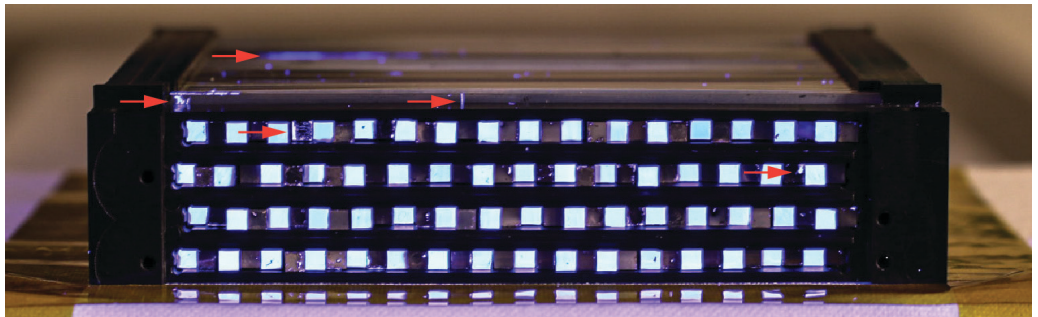
➢ Total suppression of optical cross-talk; more robust











Thank you for listening!

For questions, contact

Martin J. Losekamm
m.losekamm@tum.de

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DLR

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