Activities ESR7 (IEAP, CTU in Prague) 4th ARDENT WORKSHOP Prague, Czech Republic

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JUNE 22ND, 2015

What's the motivation?

We have learned a lot from years of experience in the characterization, operation and use of detectors from the Medipix family

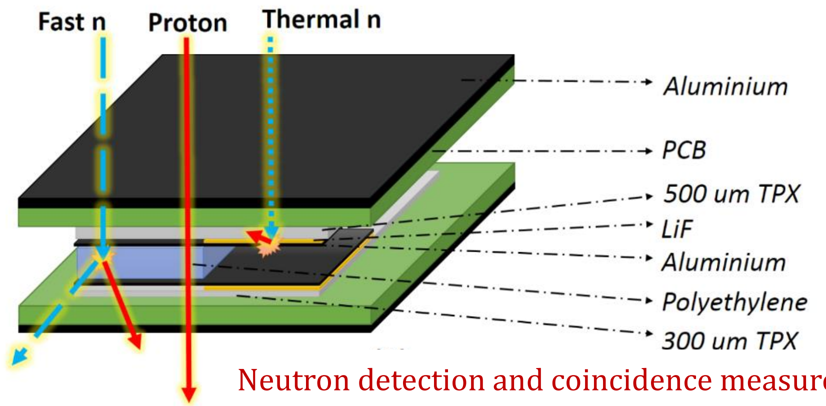
The detection network in the ATLAS experiment at the LHC fulfilled its original expectations and brought new ideas for applications of Medipix detectors in particle physics experiments

ATLAS-MPX as a luminosity monitor

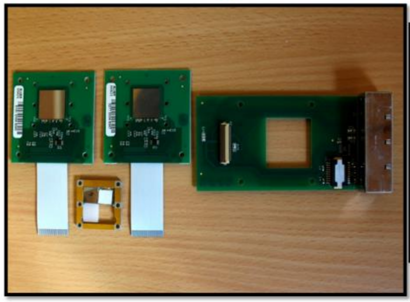
An upgrade of the network was proposed

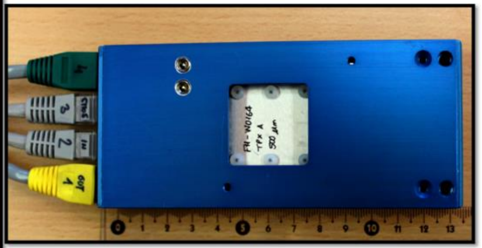
- *Change from Medipix to Timepix: Energy or Time Information available for enhanced discrimination and new features.*
- *Two detectors in each position to enhance particle tracking and neutron signal selection*
- *Improved readout: Up to 2 Frames per second (20 times faster than ATLAS-MPX!)*

The ATLAS-TPX device

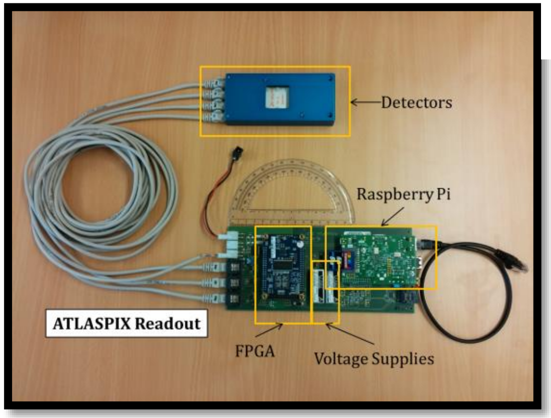


Neutron detection and coincidence measurements



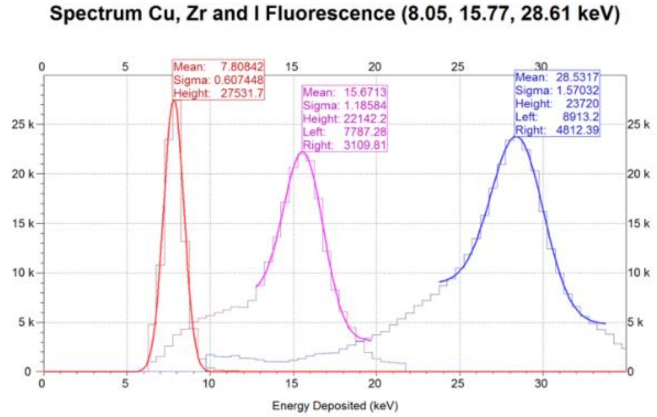


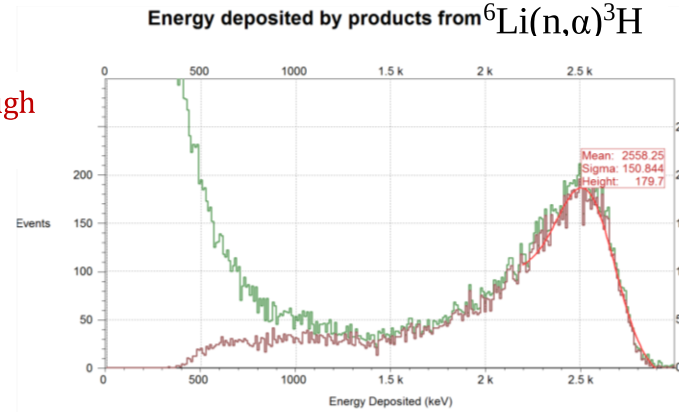
Radiation-resistant and modular assembly.



Remote read-out through Ethernet connections.

Calibrated energy response for every pixel

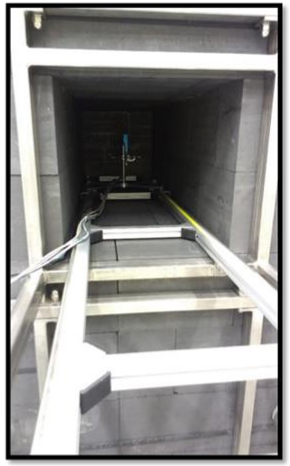




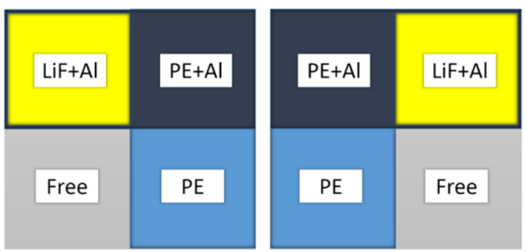
Neutron Eff Calibrations for ATLAS-TPX

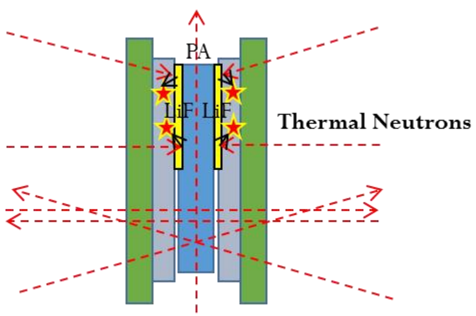
All ATLAS-TPX devices were irradiated with thermal (25 meV) and fast (Cf, AmBe) neutrons from well characterized sources in the Czech Metrological Institute.

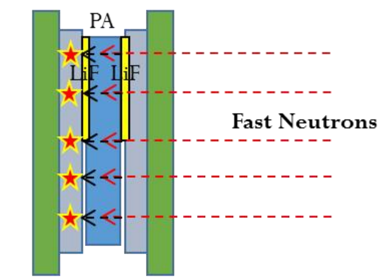
The reference device was also irradiated with fast 17.6 MeV neutrons from D+T reactions in the IEAP VdG accelerator.



Layout of neutron converters



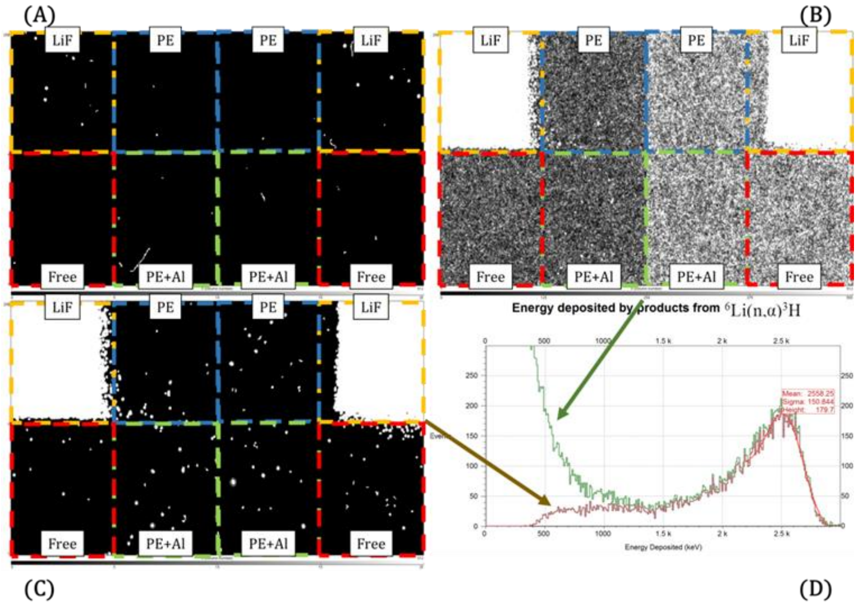




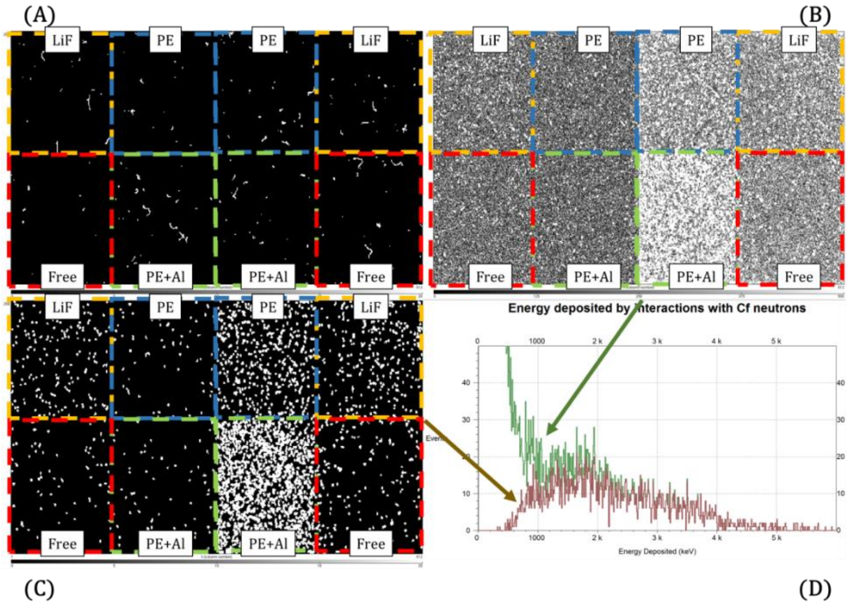
To calculate every converter efficiency:

$$\varepsilon_{C-Si} = \frac{\frac{N_C}{S_C} - \frac{N_{Si}}{S_{Si}}}{\Phi . t}$$

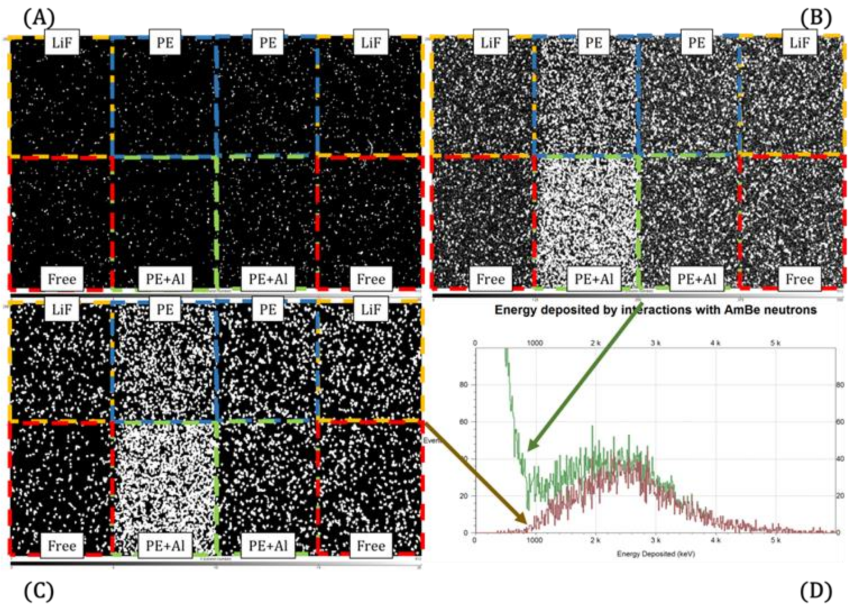
Where N_C and S_C are the number of selected events and area of a given converter "C", respectively; N_{Si} and S_{Si} correspond to those characteristics in the Silicon (Free) area only; Φ is the total flux of neutrons expected in the converter area and t the live time of the detector while measuring.



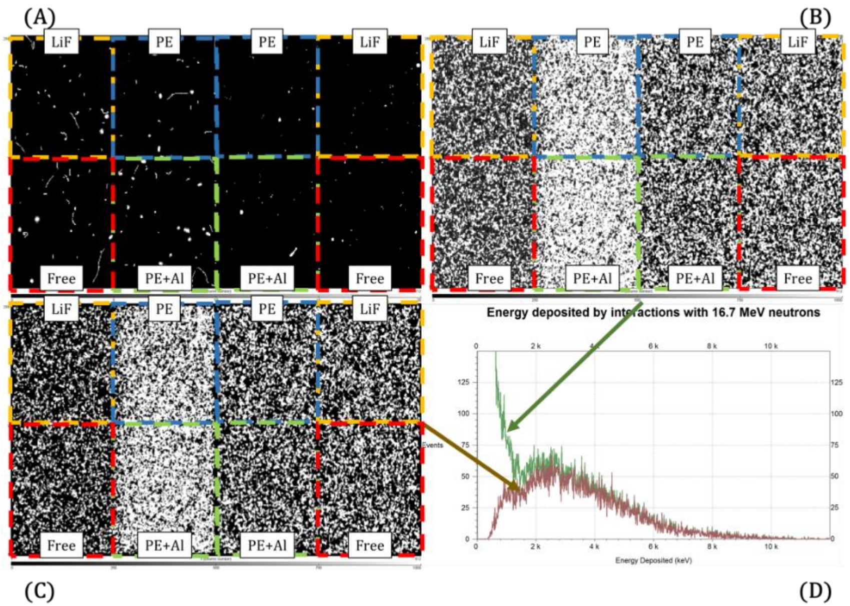
Differentiation of neutron signals from a 25 meV thermal neutron isotropic field. (A): One raw acquisition of 0.06 s; (B): All events after a live time of 8 minutes; (C): Events after energy and geometric discrimination; (D): Energy spectrum of detected events (the green curve corresponds to all events, and the red one to those after discrimination)



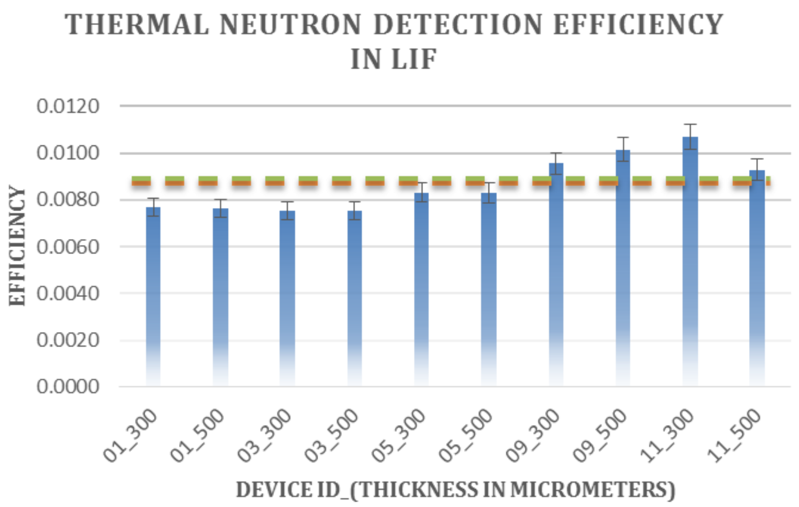
Differentiation of neutron signals from a 252Cf source (2.2 MeV) radiating at 30 cm from the side of the 300 µm thick sensor. (A): One raw acquisition of 0.1 s; (B): All events after a live time of 36 minutes; (C): Events after energy and geometric discrimination; (D): Energy spectrum of detected events (the green curve corresponds to all events, and the red one to those after discrimination).

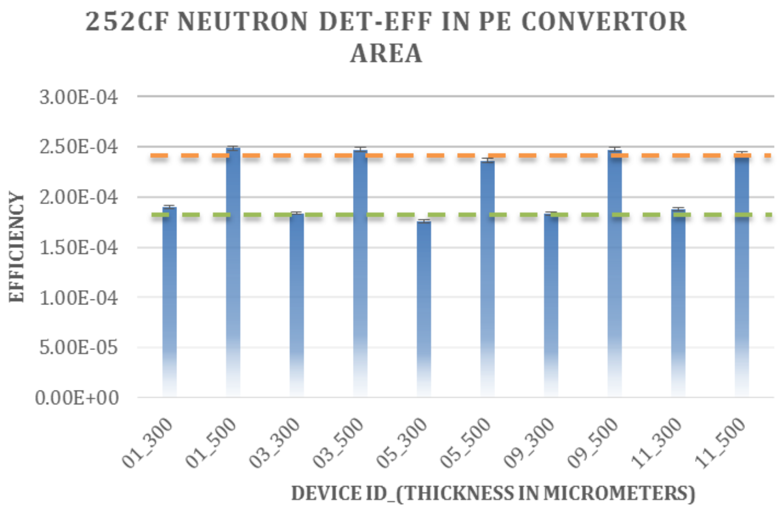


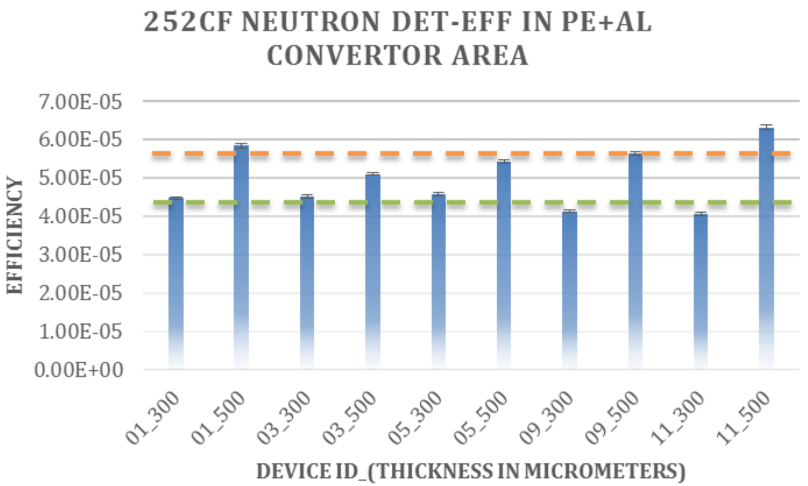
Differentiation of neutron signals from a 241AmBe source (4.1 MeV) radiating at 30 cm from the side of the 500 µm thick sensor (A): One raw acquisition of 0.07 s; (B): All events after a live time of 66 minutes; (C): Events after energy and geometric discrimination; (D): Energy spectrum of detected events (the green curve corresponds to all events, and the red one to those after discrimination).

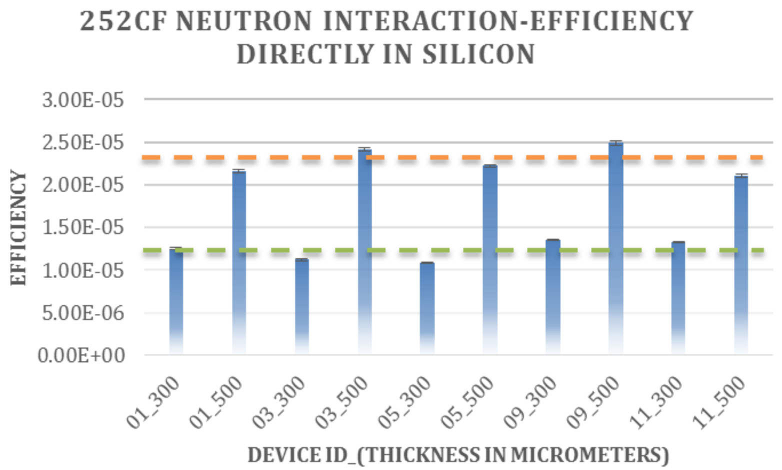


Differentiation of 16.7 MeV neutron signals from D-T reactions at 22 cm from the target in a Van de Graaff accelerator. (A): One raw acquisition of 1 s; (B): All events after a live time of 8 minutes; (C): Events after energy and geometric discrimination; (D): Energy spectrum of detected events (the green curve corresponds to all events, and the red one to those after discrimination).


THERMAL NEUTRON DETECTION EFFICIENCY IN LIF
EFFICIENCY
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
01_300
01_500
03_300
03_500
05_300
05_500
09_300
09_500
11_300
11_500
DEVICE ID_(THICKNESS IN MICROMETERS)


252CF NEUTRON DET-EFF IN PE CONVERTOR AREA
EFFICIENCY
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
01_300
01_500
03_300
03_500
05_300
05_500
09_300
09_500
11_300
11_500
DEVICE ID_(THICKNESS IN MICROMETERS)


252CF NEUTRON DET-EFF IN PE+AL CONVERTOR AREA
EFFICIENCY
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
01_300
01_500
03_300
03_500
05_300
05_500
09_300
09_500
11_300
11_500
DEVICE ID_(THICKNESS IN MICROMETERS)


252CF NEUTRON INTERACTION-EFFICIENCY DIRECTLY IN SILICON
EFFICIENCY
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
01_300
01_500
03_300
03_500
05_300
05_500
09_300
09_500
11_300
11_500
DEVICE ID_(THICKNESS IN MICROMETERS)

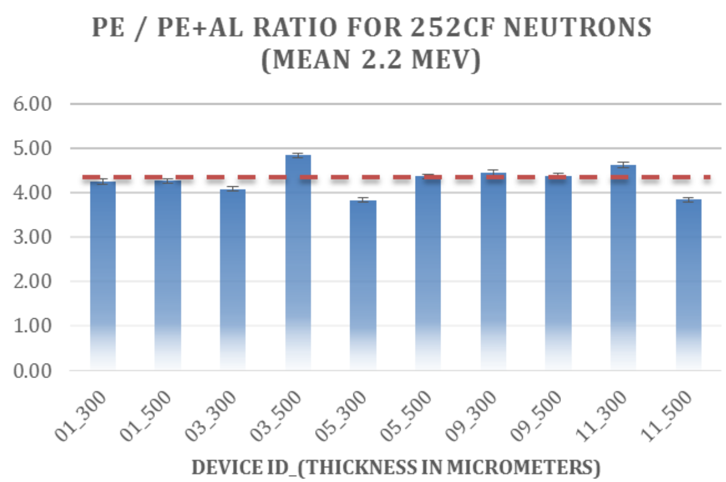
NEUTRON DETECTION EFFICIENCIES IN THE 300UM SENSOR

Source / Converter	Average Det. Eff.	Tolerance
Thermal N / LiF	8.76×10^{-3}	13.71 %
^{252}Cf / PE	1.84×10^{-4}	2.67 %
^{252}Cf / PE+Al	4.35×10^{-5}	4.92 %
^{252}Cf / Si	1.23×10^{-5}	8.81 %
^{241}AmBe / PE	5.49×10^{-4}	N/A
^{241}AmBe / PE+Al	2.19×10^{-4}	N/A
^{241}AmBe / Si	7.54×10^{-5}	N/A
17.6 MeV N / PE	1.61×10^{-3}	N/A
17.6 MeV N / PE+Al	1.45×10^{-3}	N/A
17.6 MeV N / Si	8.58×10^{-4}	N/A

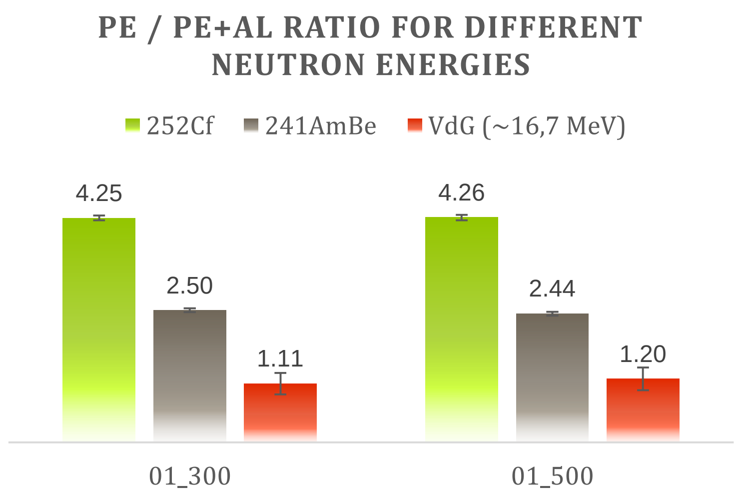
NEUTRON DETECTION EFFICIENCIES IN THE 500UM SENSOR

Source / Converter	Average Det. Eff.	Tolerance
Thermal N / LiF	8.58×10^{-3}	11.60 %
^{252}Cf / PE	2.44×10^{-4}	1.87 %
^{252}Cf / PE+Al	5.67×10^{-5}	7.18 %
^{252}Cf / Si	2.28×10^{-5}	6.49 %
^{241}AmBe / PE	7.12×10^{-4}	N/A
^{241}AmBe / PE+Al	2.93×10^{-4}	N/A
^{241}AmBe / Si	1.40×10^{-4}	N/A
17.6 MeV N / PE	1.63×10^{-3}	N/A
17.6 MeV N / PE+Al	1.36×10^{-3}	N/A
17.6 MeV N / Si	1.52×10^{-3}	N/A

In the case of fast neutrons, the efficiencies vary for the same converter area in different detector thickness. But, if we look at the ratio between the PE and PE+Al sections:



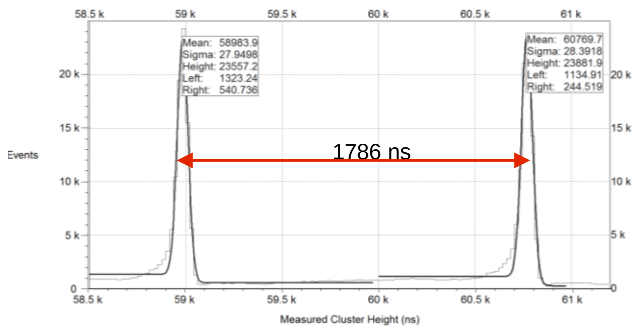
4.3 ± 0.3 for Californium (Mean energy of 2.2 MeV)

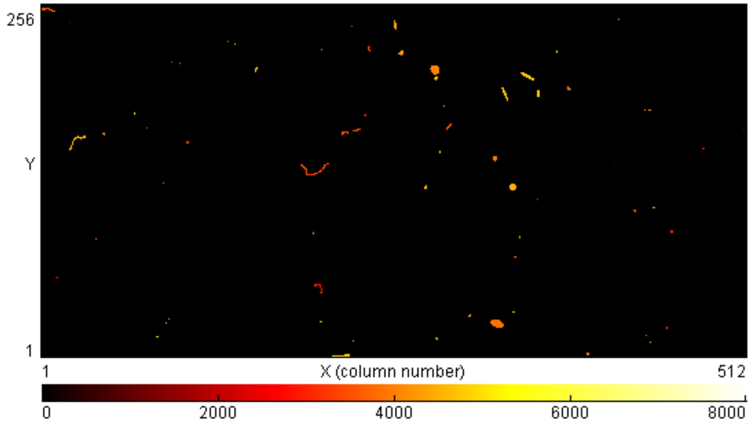


We can estimate the mean energy for fast neutrons up to ~20 MeV

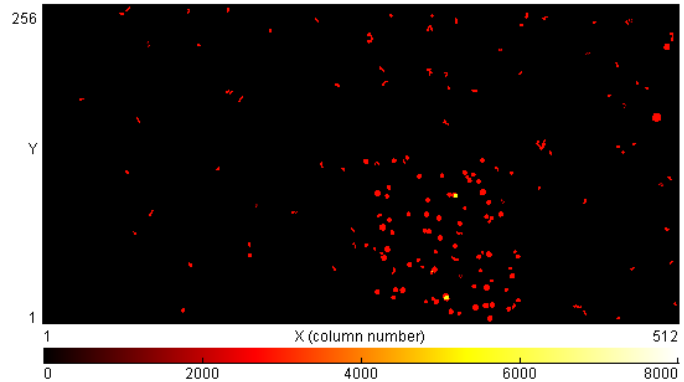
The efficiencies will be corroborated with reference measurements from a pulsed 1-800 MeV neutron beam (LANSCE, by ESR9 and ESR2) using the ToF technique

Cluster Height Spectrum ATLAS-TPX ToF

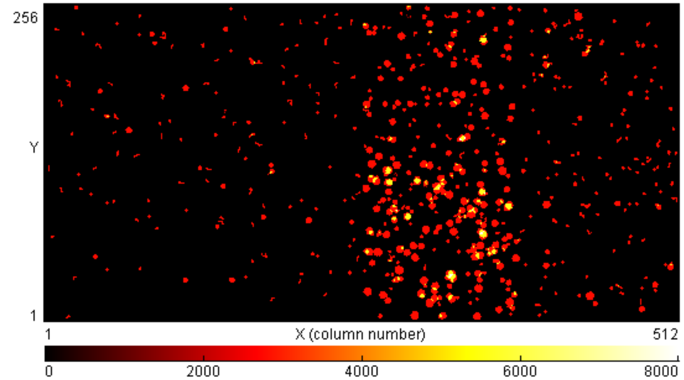




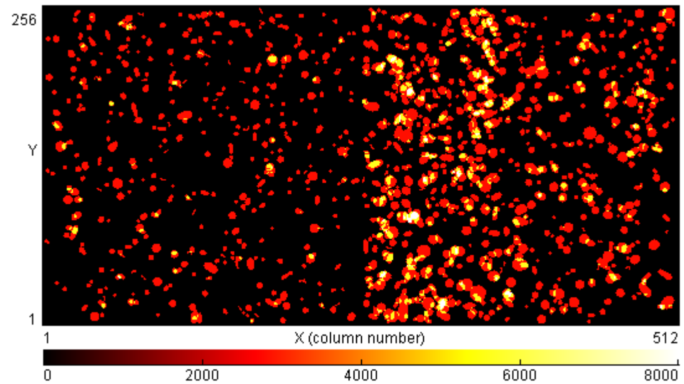
Single Acquisition Frame
0,2 ms



2 - 2,5 MeV (~252Cf)



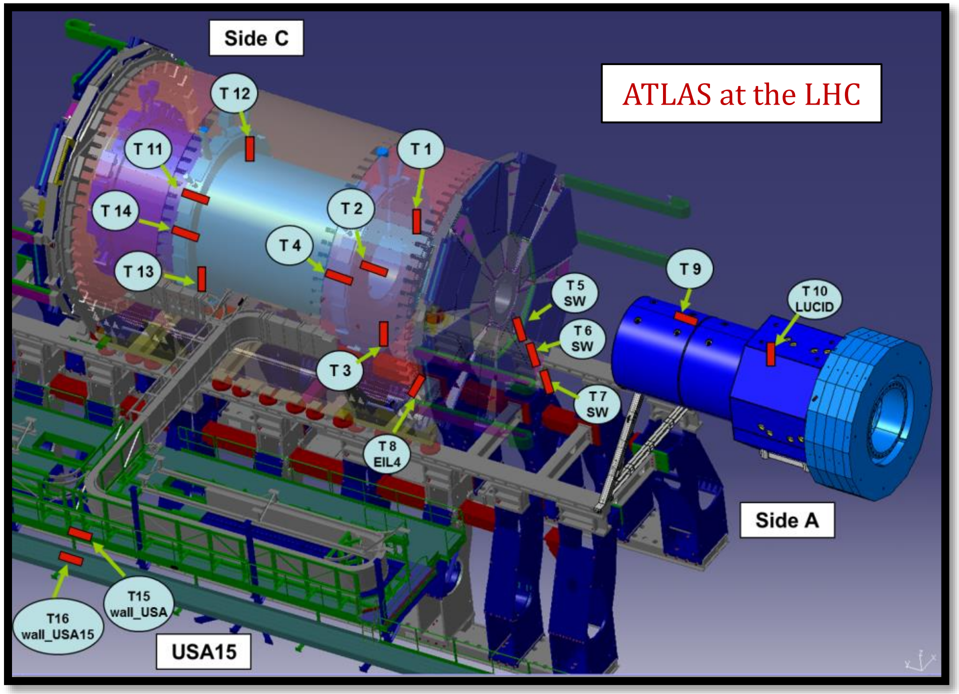
3,5 - 4,5 MeV (~241AmBe)



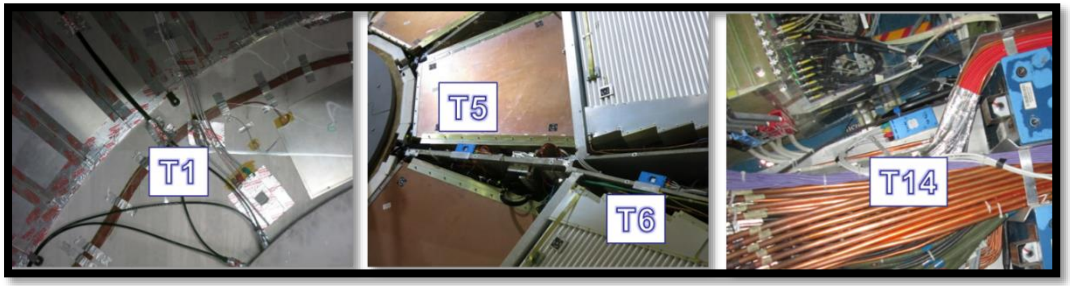
15 – 17,5 MeV (~VdG N)

The ATLAS-TPX Network

A network of fourteen Timepix-based hodoscopes has been installed inside the detector volume and surroundings of the ATLAS detector during the LHC shut-down period in 2014. These devices are managed through a readout system (ATLASPIX) specifically designed for remote measurements in a network configuration.



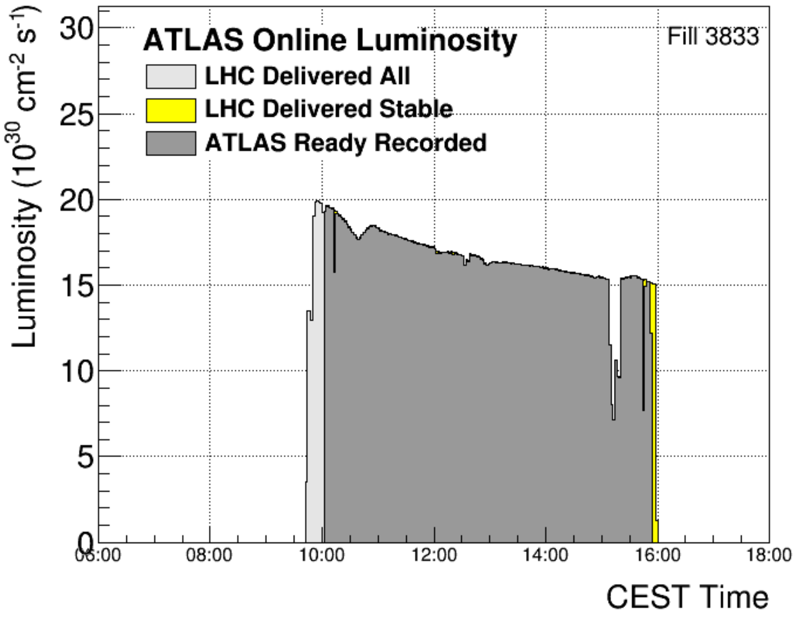
ATLAS-TPX devices inside the ATLAS experiment

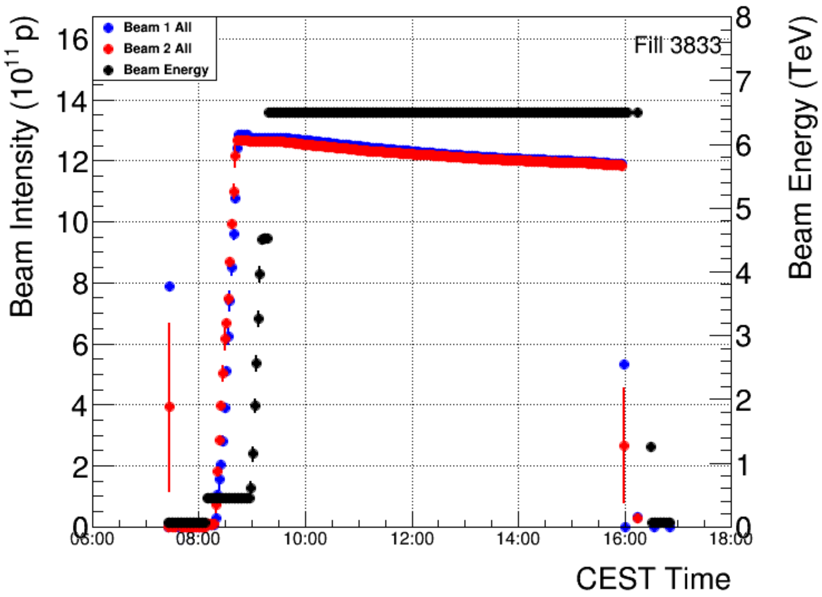


Devices in ATLAS

ATLAS-TPX Number	Original Unit Number	Cable Length (m)	Position	Calibration Threshold Chip 0 -300um, IKRUM5- (THL/keV)		Calibration Threshold Chip 1 -500um, IKRUM5- (THL/keV)	
Reference IEAP	**Unit 01**	-	-	718	6.5	746	6.5
TPX01	**Unit 10**	81	Ext. Barrel A	689	6.5	776	6.5
TPX02	**Unit 11**	73	Ext. Barrel A	773	6.5	704	6.5
TPX03	**Unit 12**	74	Ext. Barrel A	750	7.1	699	6.5
TPX04	**Unit 05**	47	Barrel A side	636	6.5	765	6.5
TPX05	**Unit 04**	82	Small Wheel 1	846	8.5	743	8
TPX06	**Unit 06**	81	Small Wheel 2	710	7	728	6.9
TPX07	**Unit 03**	80	Small Wheel 3	783	6.5	820	6.5
TPX08	**Unit 13**	51	ELI4	718	6.5	673	6.5
TPX09	**Unit 07**	90	JF Shielding	698	7.9	708	6.5
TPX10	**Unit 09**	LVDS Conn. Error	LUCID A	719	6.5	763	6.5
TPX11	**Unit 15**	84	Ext Barrel C	768	7.9	641	6.5
TPX12	**Unit 08**	77	Ext Barrel C	738	7	665	7.4
TPX13	**Unit 16**	Pwr Ln Short Circuit	Ext Barrel C	757	8.6	708	7.5
TPX14	**Unit 02**	49	Barrel C side	691	9.2	748	7.1
TPX15	**Unit 14**	40	Wall UX15	715	6.5	760	6.5
TPX16	**Unit 07**	-	USA15	713	8.7	787	7.3

First look: Fill 3833 (2015/06/07) from ATLAS Data Summary

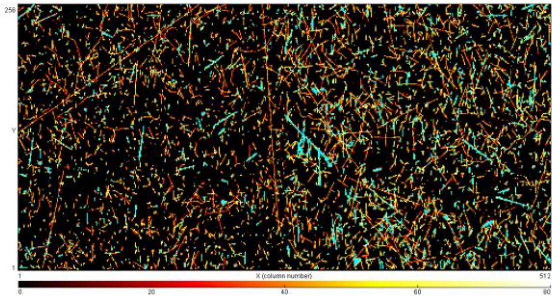




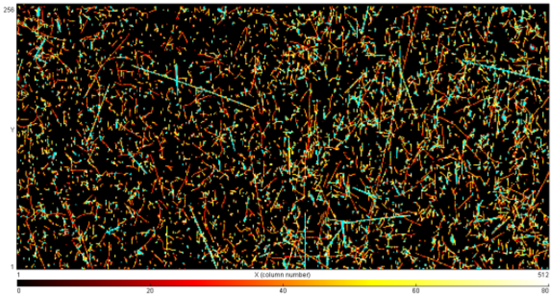
First measurements from the network (Fill 3833)

Occupation per 1s. frame at ~16E30 (cm-2 s-1)

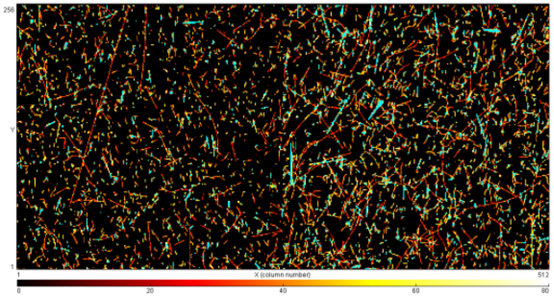
TPX-01



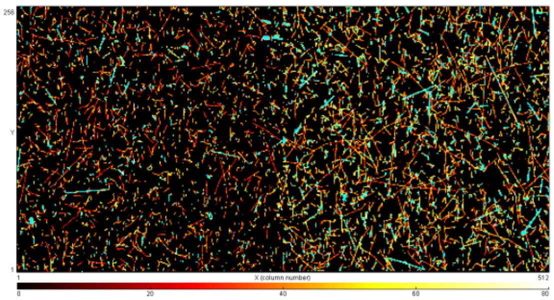
TPX-02



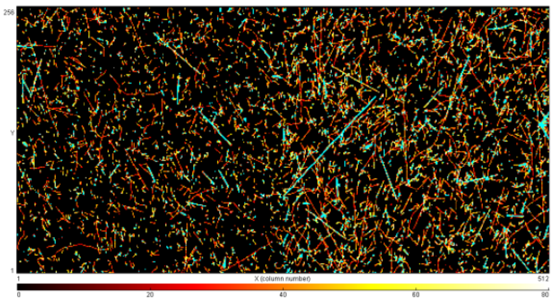
TPX-03



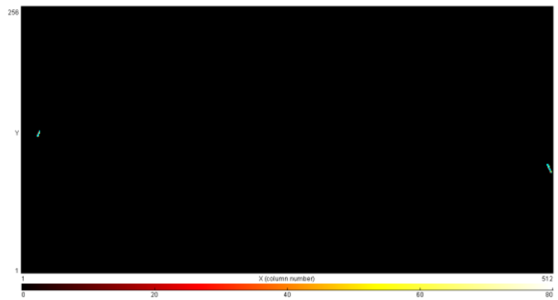
TPX-11



TPX-12



TPX-04

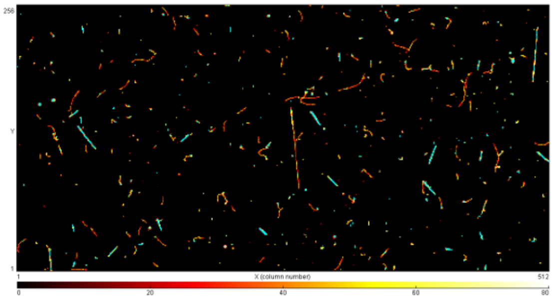


The occupation is too high for 1s frames at this intensity in the External Barrel

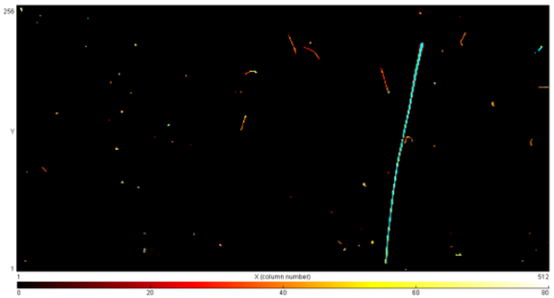
First measurements from the network (Fill 3833)

Occupation per 60s. frame at ~16E30 (cm-2 s-1)

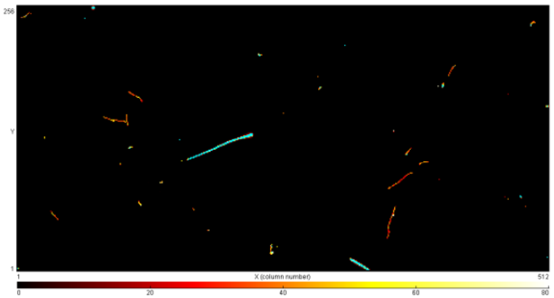
TPX-05



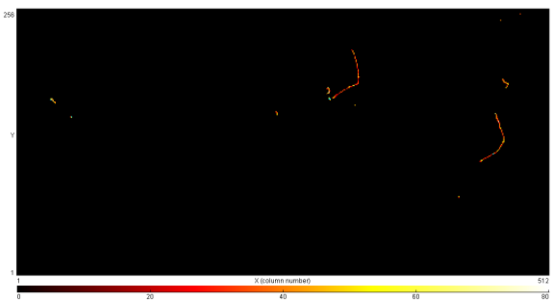
TPX-06



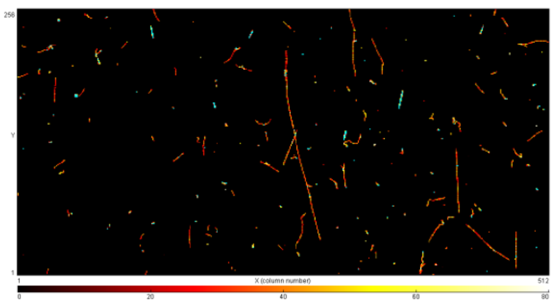
TPX-07



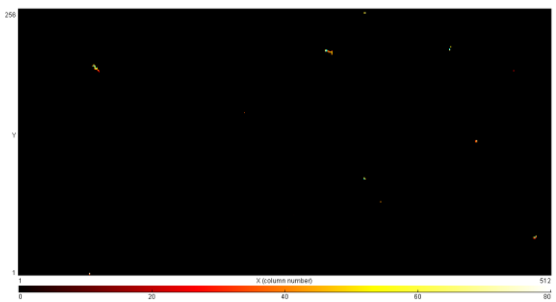
TPX-08



TPX-14

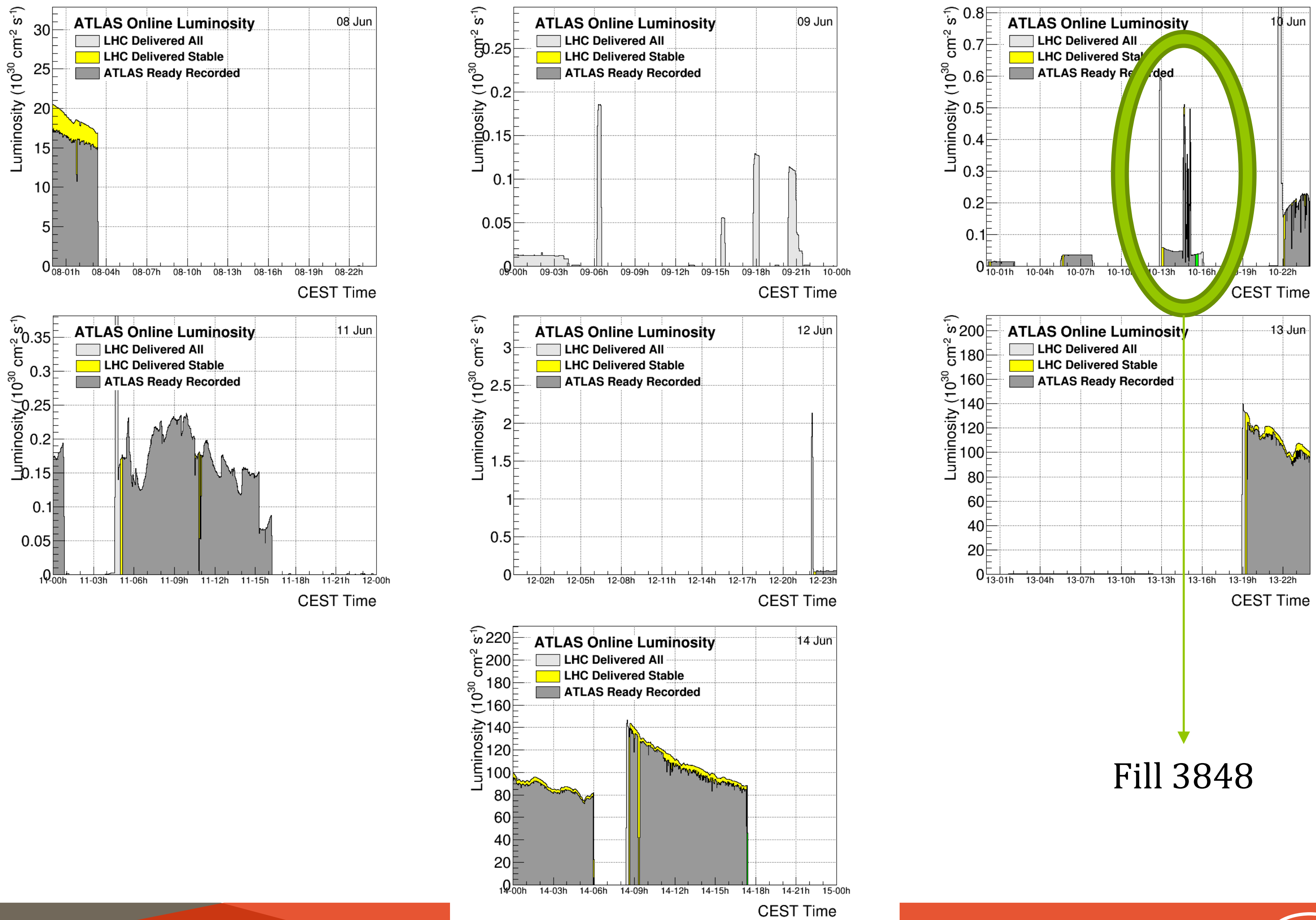


TPX-15



On the other hand, 60s frames are OK for other devices at this intensity

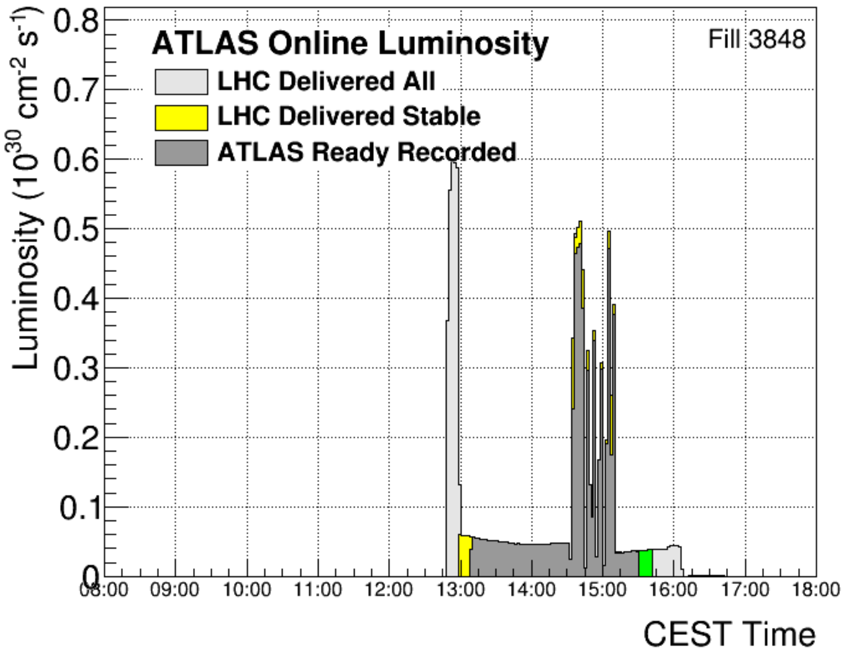
ATLAS status during Week 24 (June 8th to 14th)

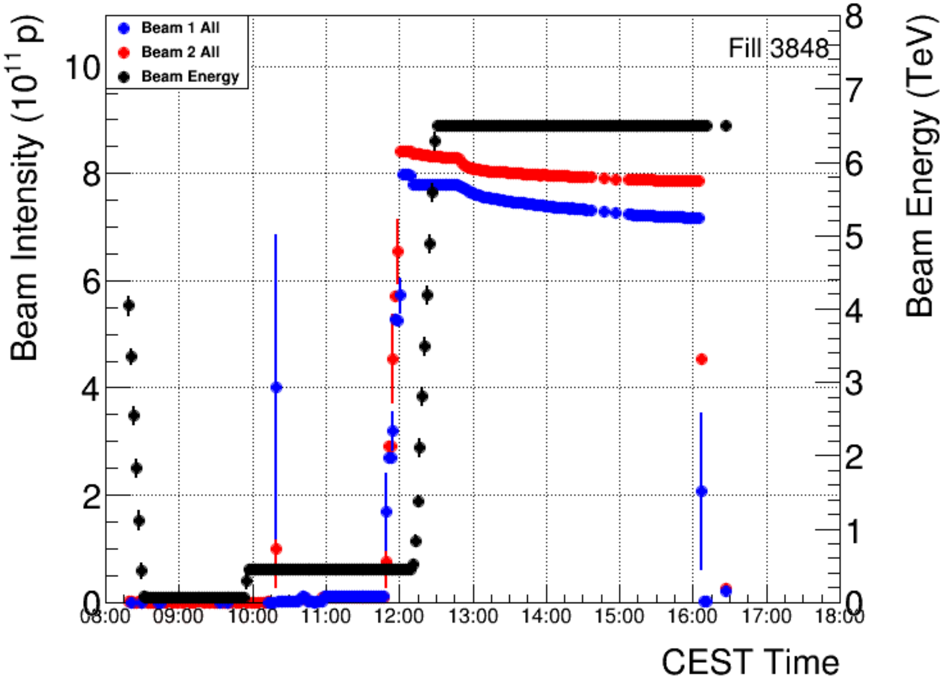


Measurement settings for Week 24(June 8th to 14th)

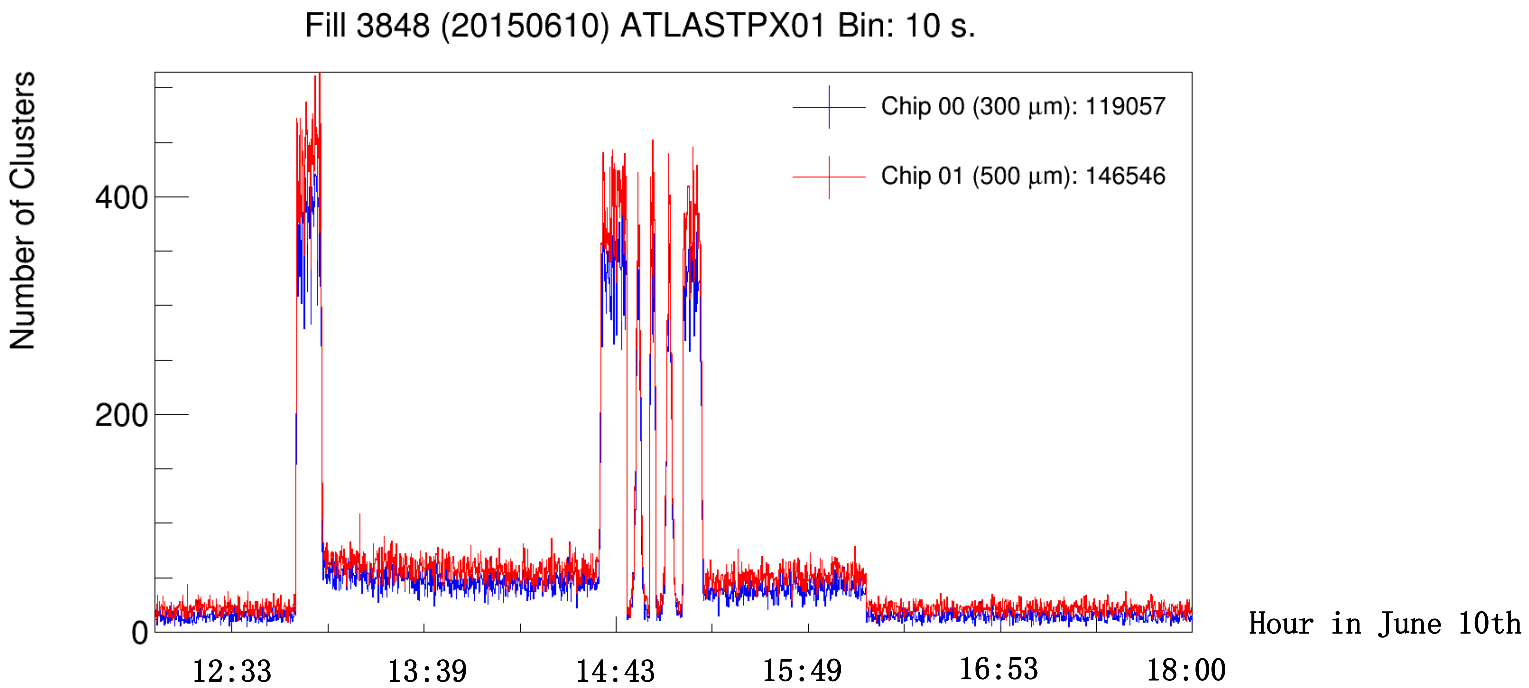
- Data saved in a provisional local PC (The server is installed but CERN still needs to allow access) from Monday 8th of June in the early morning.
- 12 Devices Available
- Measurement Frequency (Clock): 33.3 MHz
- Deadtime between frames: 700 ms (To be improved to 400 ms) ~ 2100 1s frames per hour.
- ATLAS-TPX **2, 12 and 3**: Counting (Medipix) mode, no energy information available. 1 second acquisition time.
- ATLAS-TPX **1 and 11**: Time Over Threshold mode. 1 second acquisition time.
- ATLAS-TPX **4, 5, 6, 7, 8, 14, 15**: Time Over Threshold mode. 60 seconds acquisition time.
- NOT COINCIDENT START YET, but it will be implemented.

Look at events: Fill 3848 (2015/06/10) from ATLAS Data Summary

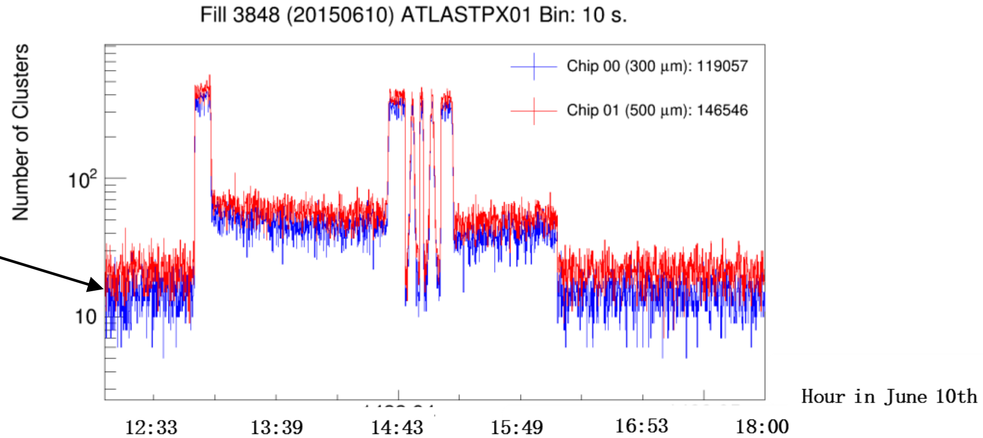


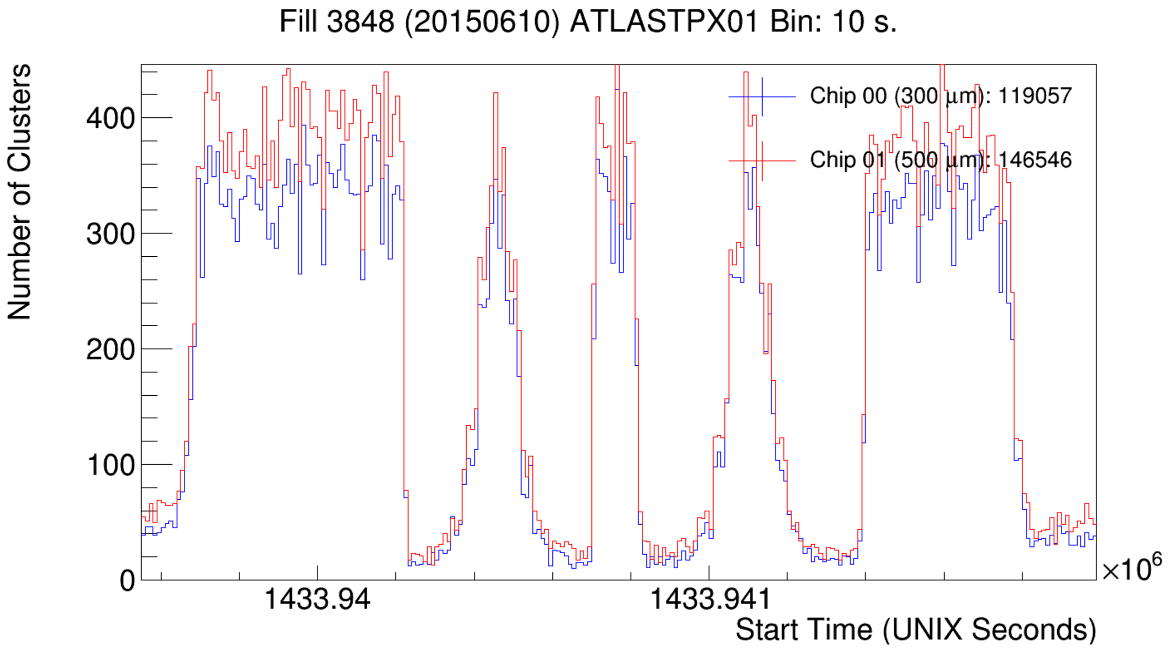


Fill 3848 (2015/06/10) 12:00 to 18:00 data as seen by ATLAS-TPX 01

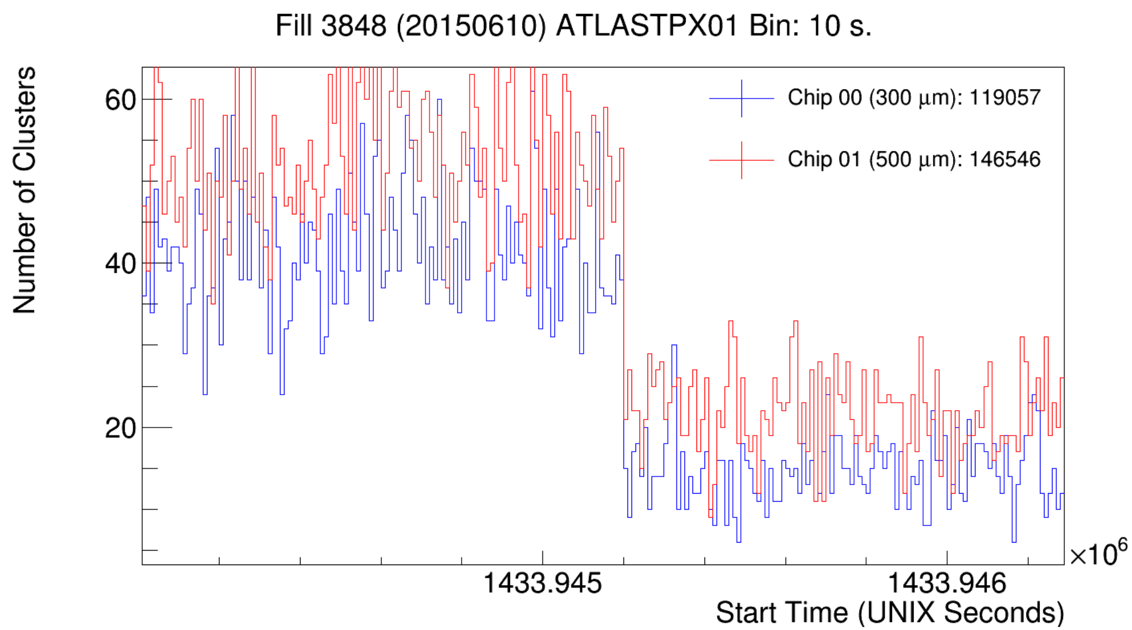


Studying the background before and after collisions allows to estimate the activation of materials

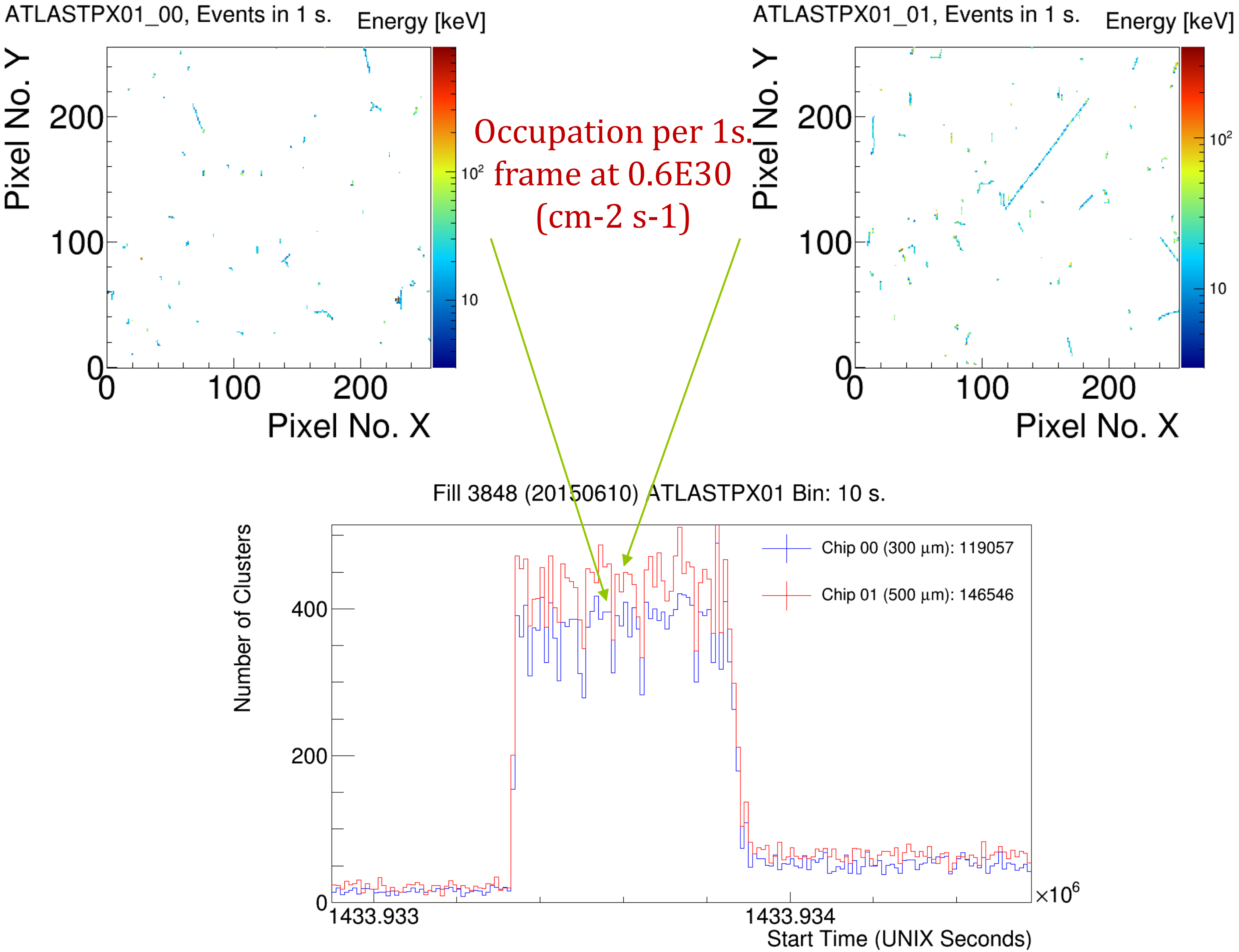


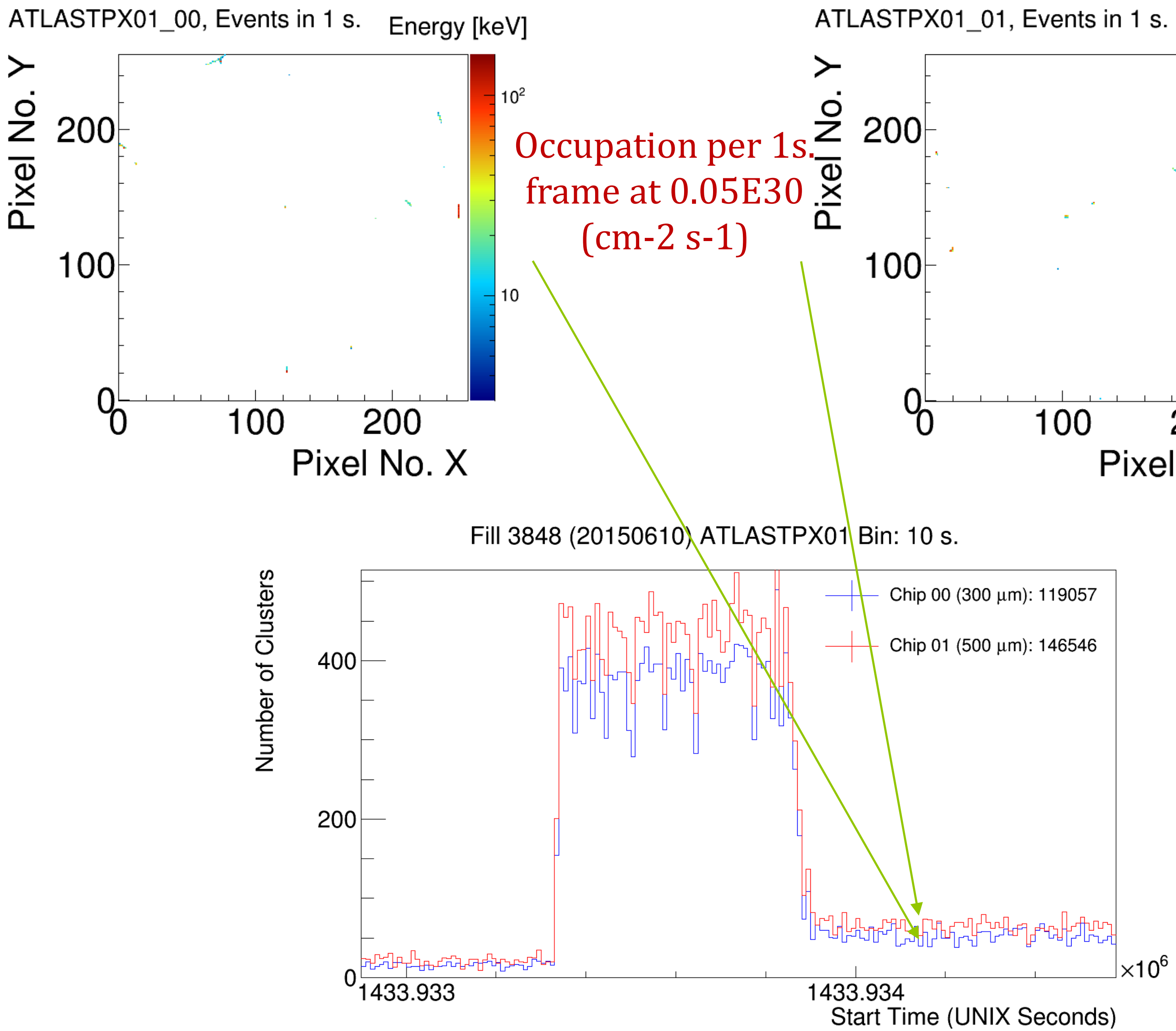


Fill 3848 (20150610) ATLASTPX01 Bin: 10 s.
Chip 00 (300 µm): 119057
Chip 01 (500 µm): 146546
Number of Clusters
0
100
200
300
400
1433.94
1433.941
×10^6
Start Time (UNIX Seconds)

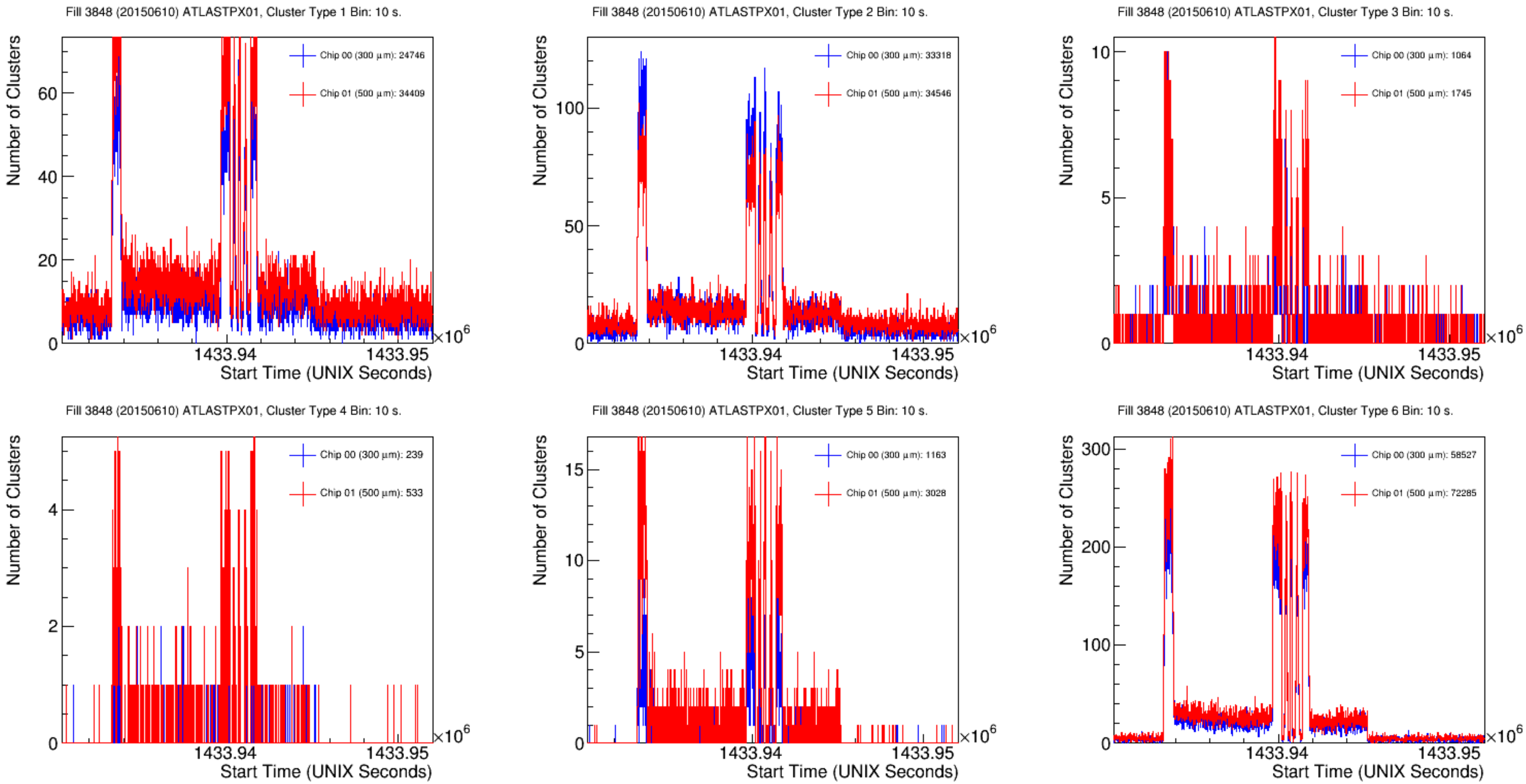


Fill 3848 (20150610) ATLASTPX01 Bin: 10 s.
Chip 00 (300 µm): 119057
Chip 01 (500 µm): 146546
Number of Clusters
20
40
60
1433.945
1433.946
×10^6
Start Time (UNIX Seconds)

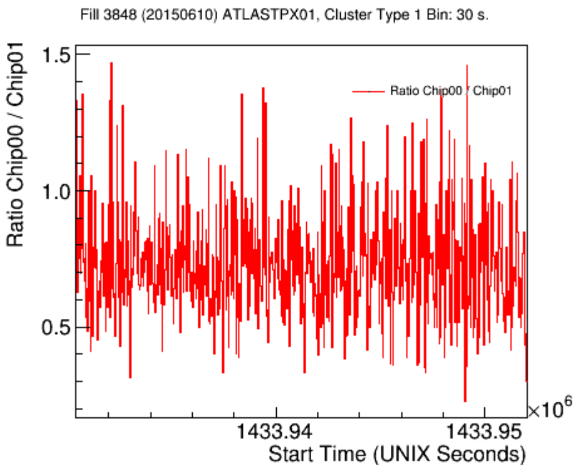

ATLASTPX01_00, Events in 1 s.
Energy [keV]
Pixel No. Y
Pixel No. X
ATLASTPX01_01, Events in 1 s.
Energy [keV]
Pixel No. Y
Pixel No. X
Occupation per 1s. frame at 0.6E30 (cm-2 s-1)
Fill 3848 (20150610) ATLASTPX01 Bin: 10 s.
Number of Clusters
Chip 00 (300 μm): 119057
Chip 01 (500 μm): 146546
Start Time (UNIX Seconds)
×10^6

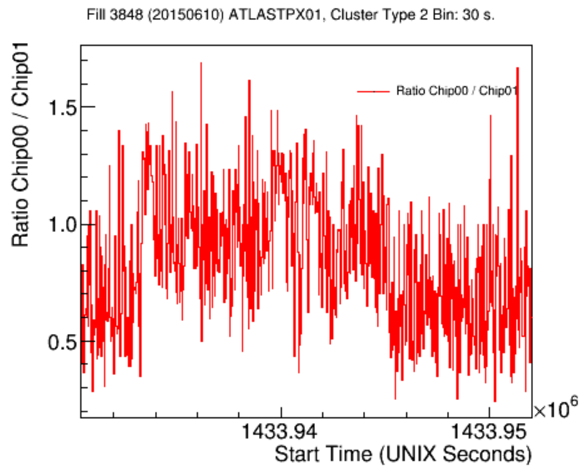

ATLASTPX01_00, Events in 1 s.
Energy [keV]
Pixel No. Y
Pixel No. X
ATLASTPX01_01, Events in 1 s.
Energy [keV]
Pixel No. Y
Pixel No. X
Occupation per 1s. frame at 0.05E30 (cm-2 s-1)
Fill 3848 (20150610) ATLASTPX01 Bin: 10 s.
Number of Clusters
Start Time (UNIX Seconds)
Chip 00 (300 μm): 119057
Chip 01 (500 μm): 146546

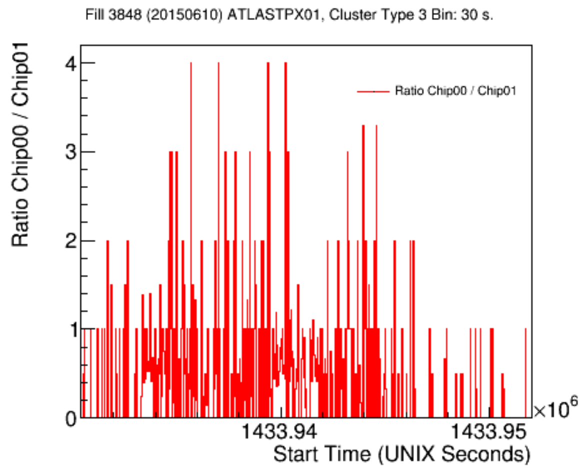
Cluster counts in each detector for different particle types:

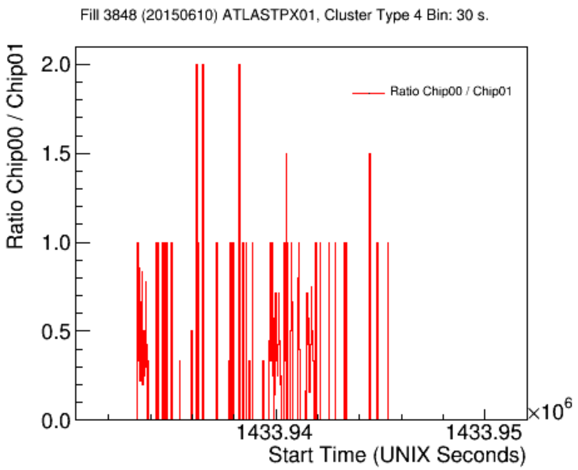


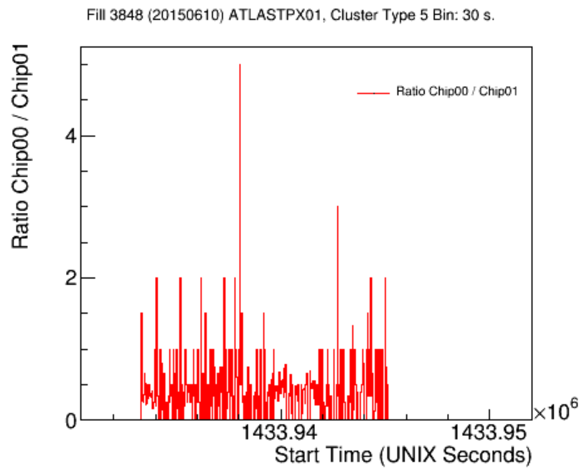
Ratio of cluster counts between Chips 00 and Chip 01:

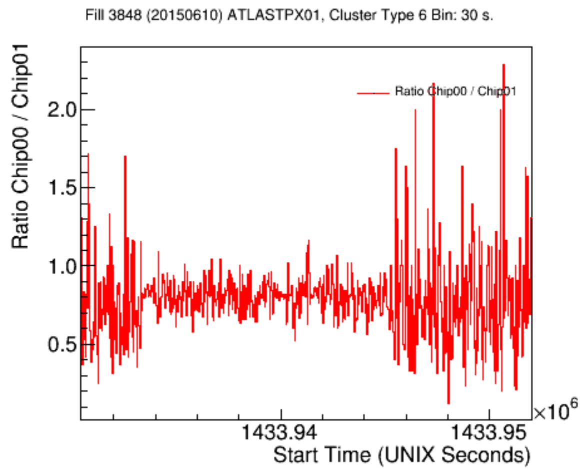




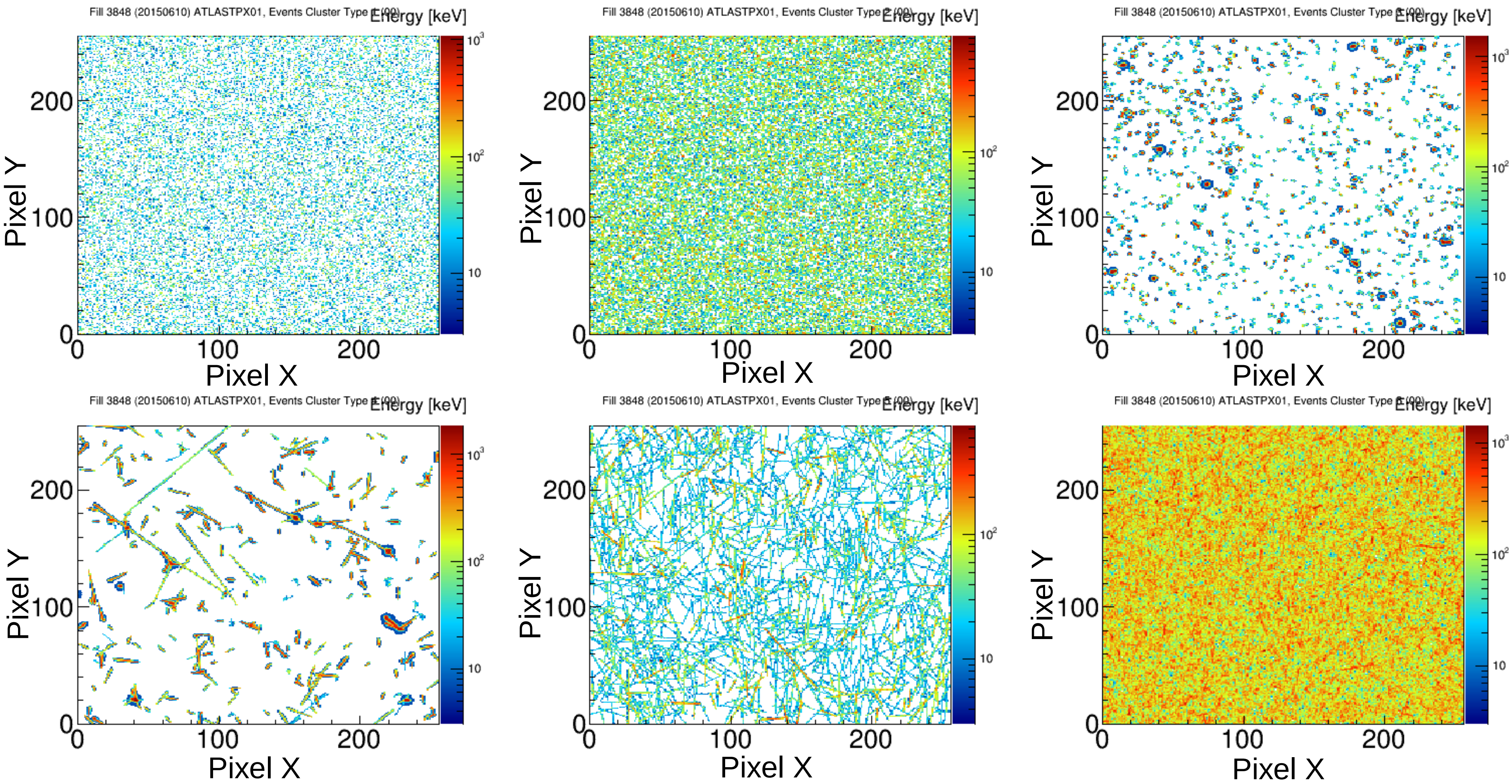




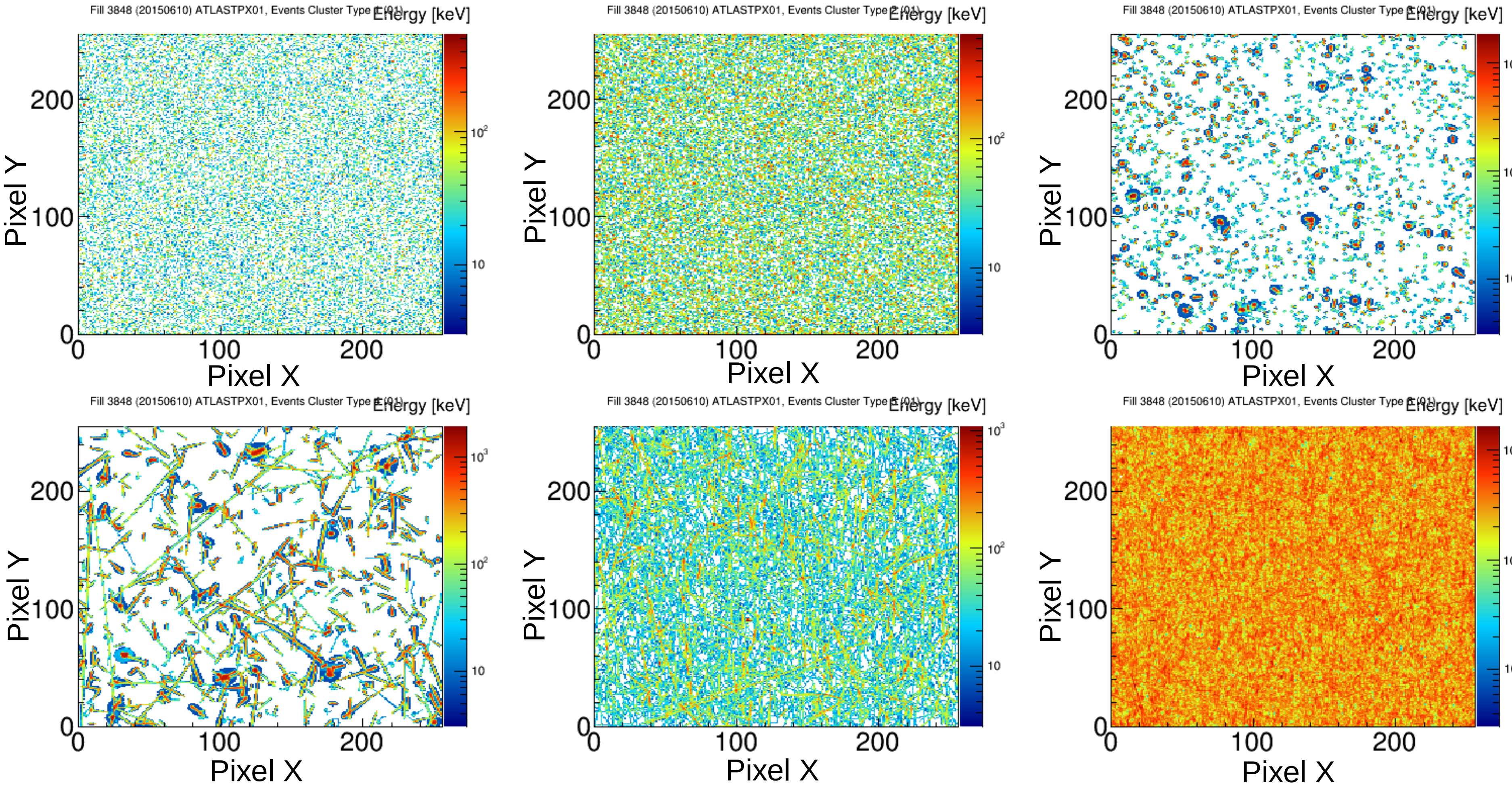


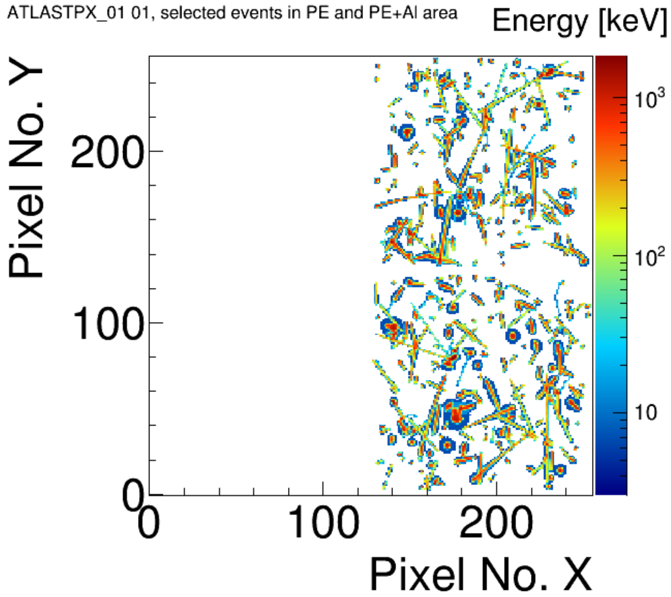


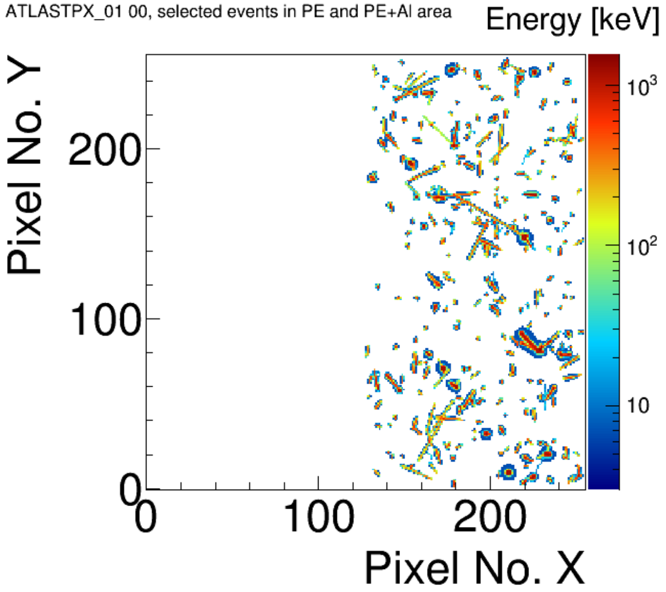
Sum of all clusters in the Fill for Chip 007:



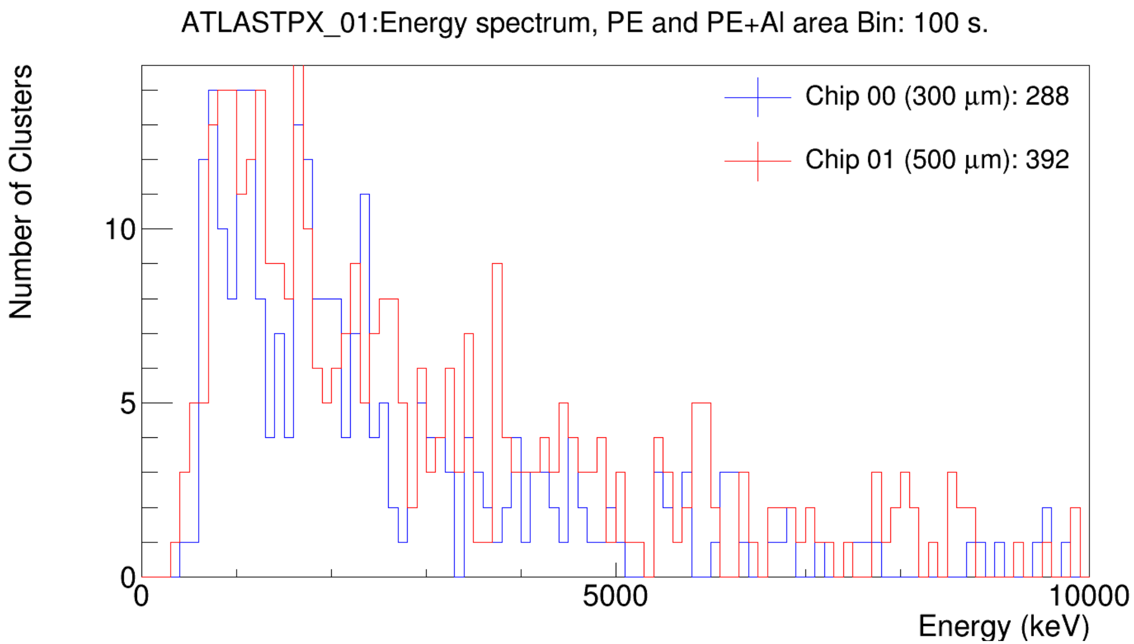
Sum of all clusters in the Fill for Chip 01:

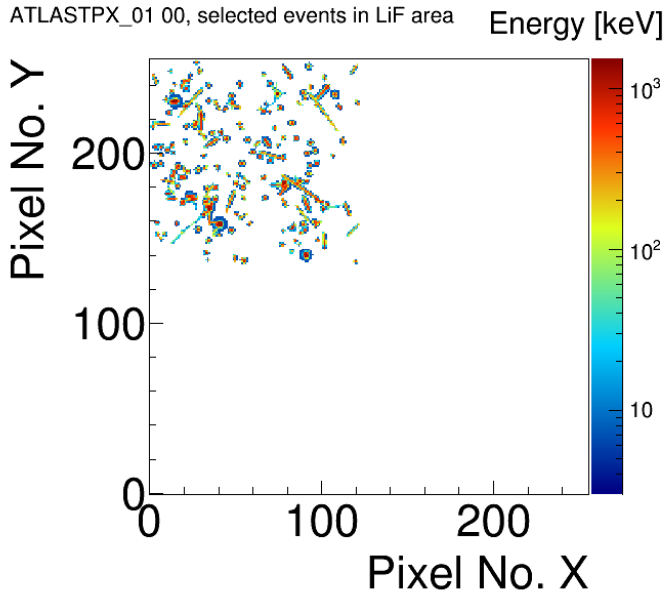


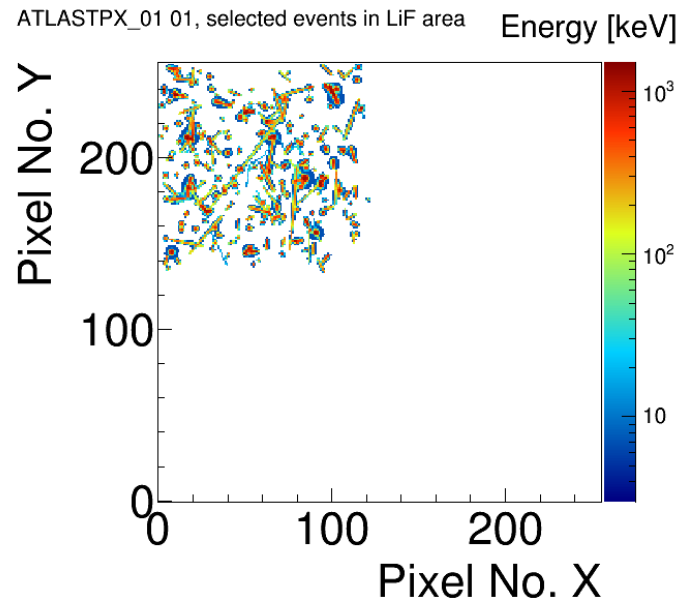




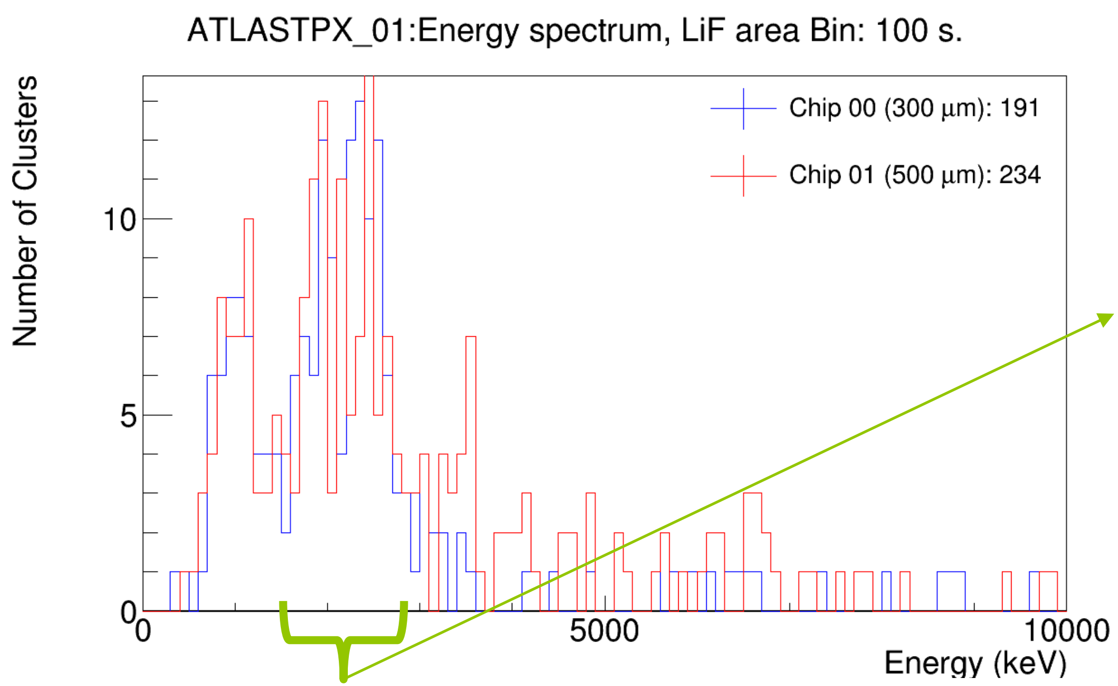
Heavy tracks and blobs with a cluster height >200 keV in the PE and PE+Al area:





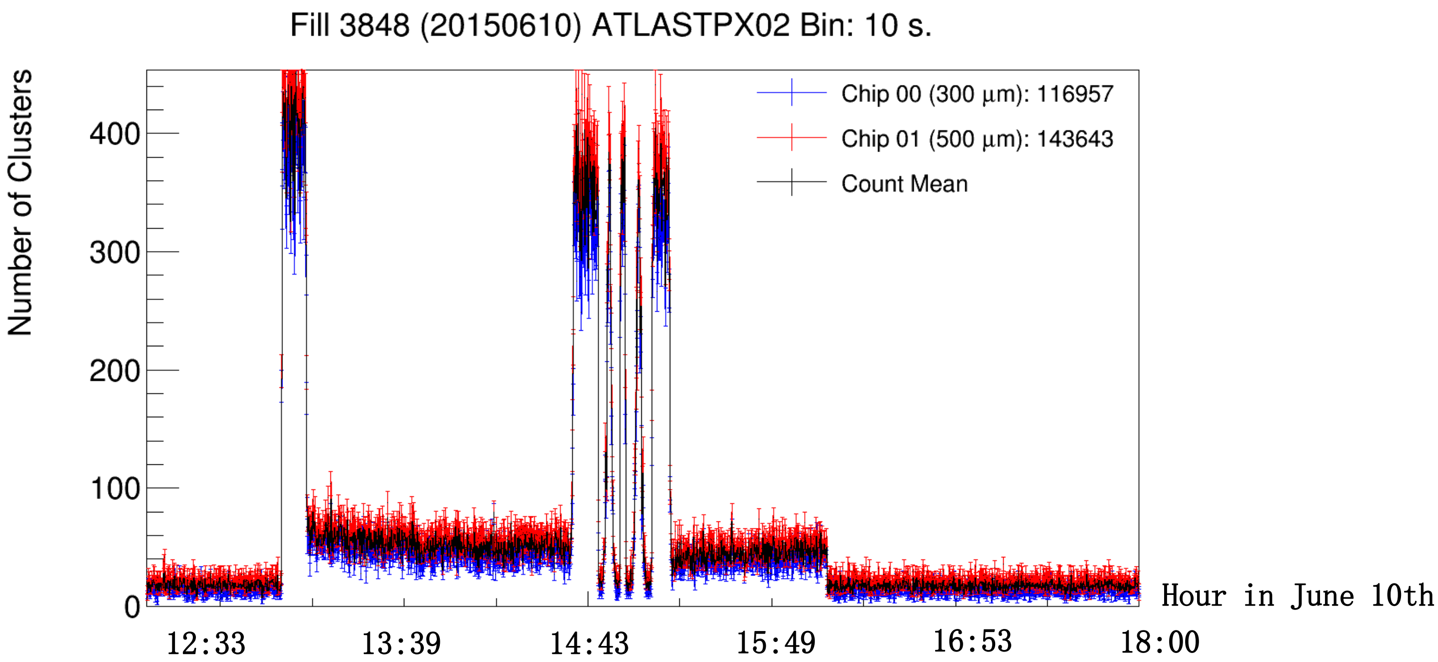


Heavy tracks and blobs with a cluster height >200 keV in the LiF area:

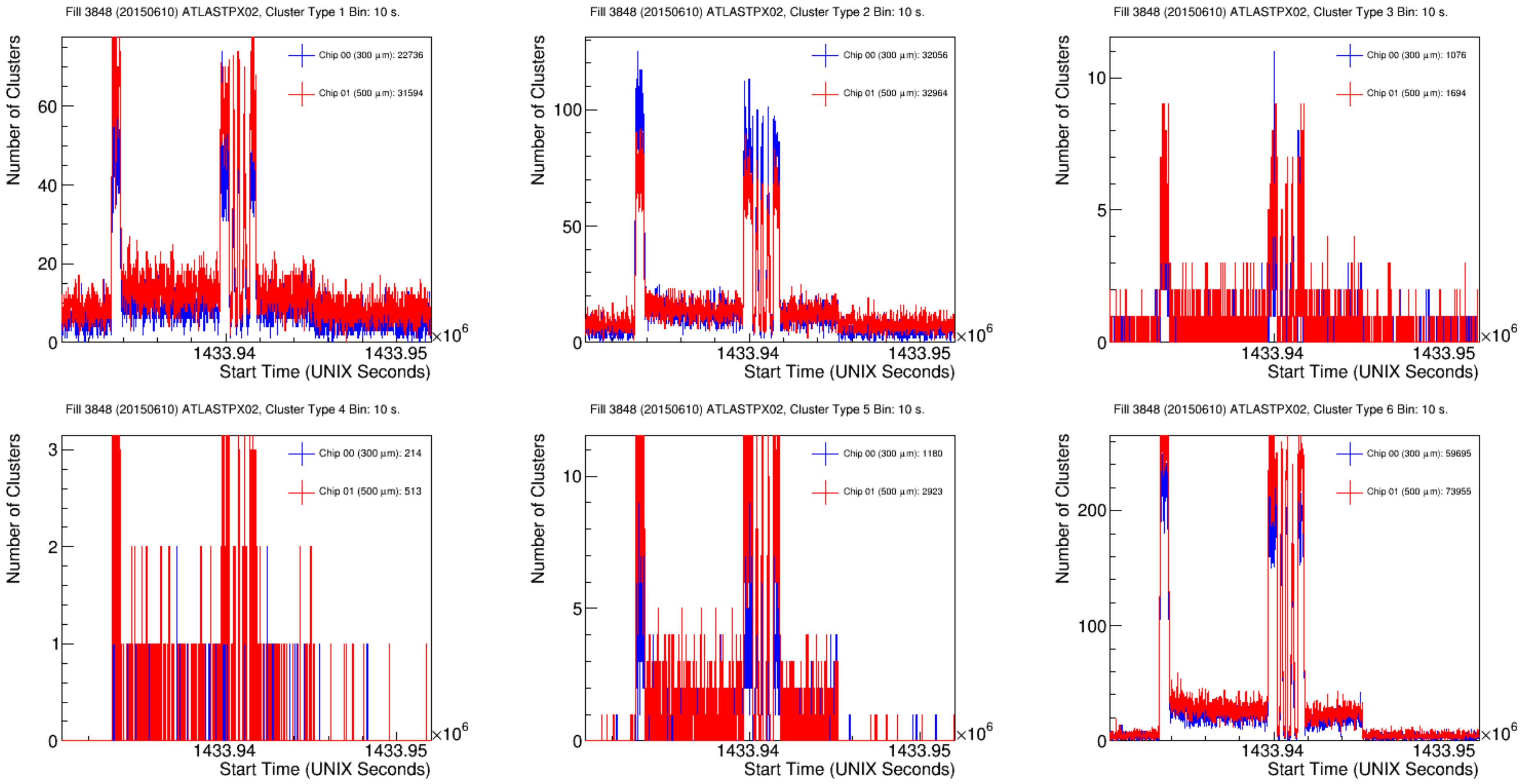


Tritium and alpha products from $^{6}Li(n,\alpha)^{3}H$

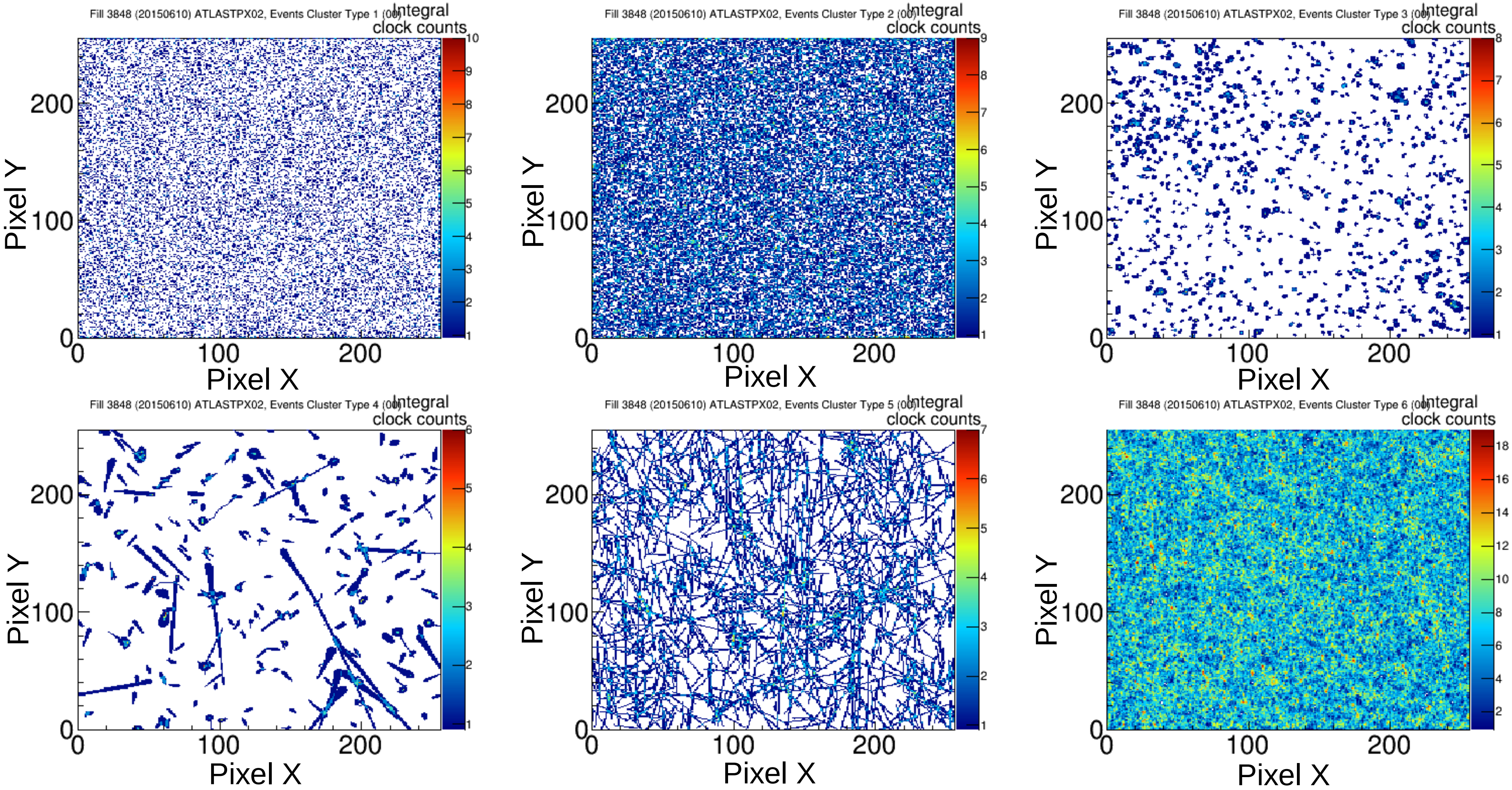
Fill 3848 (2015/06/10) 12:00 to 18:00 data as seen by ATLAS-TPX 02 (Medipix Mode)



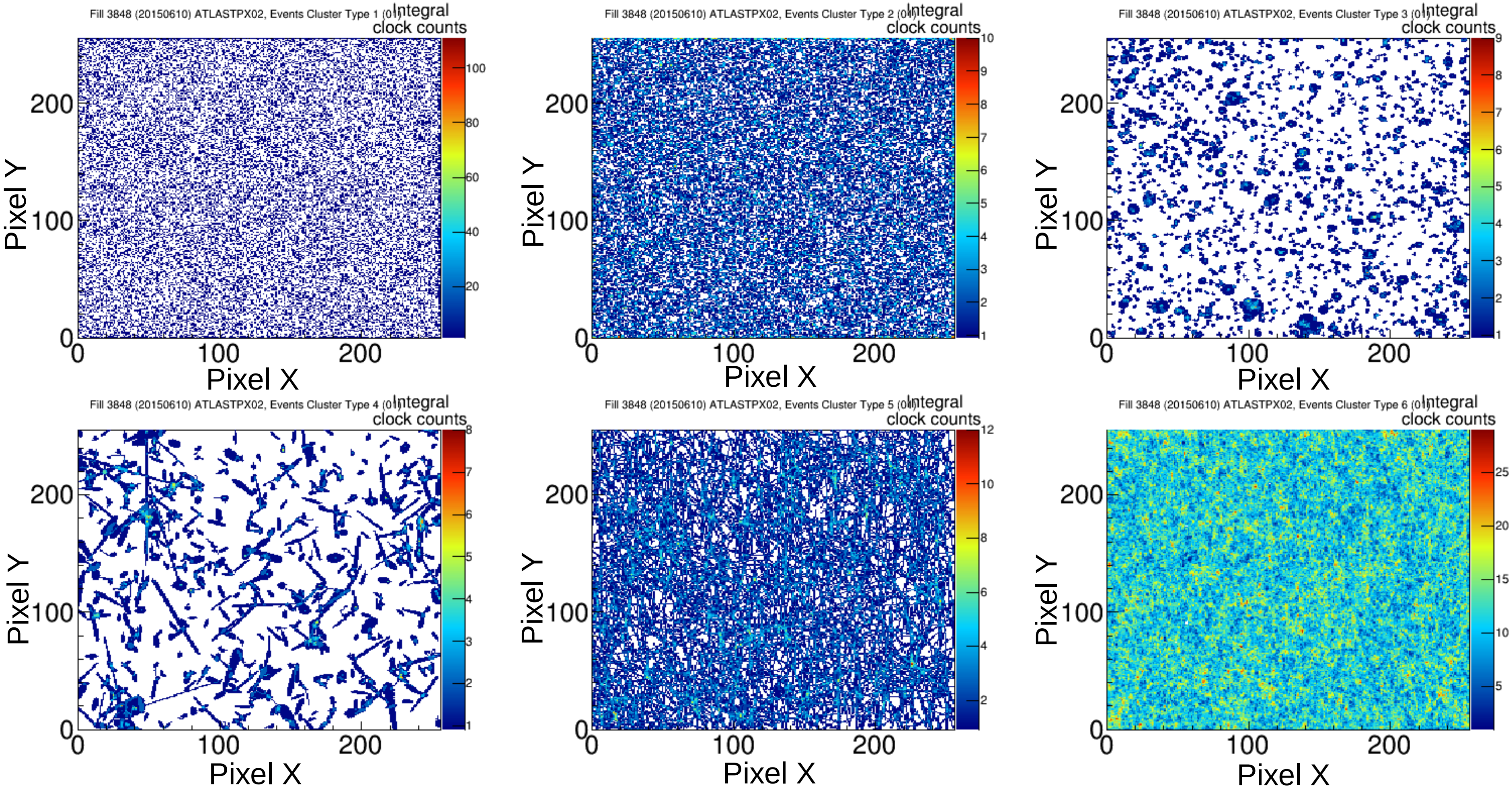
Cluster counts in each detector for different particle types:



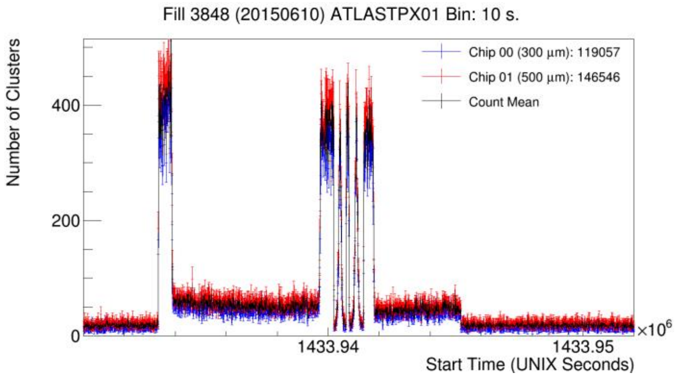
Sum of all clusters in the Fill for Chip 00:

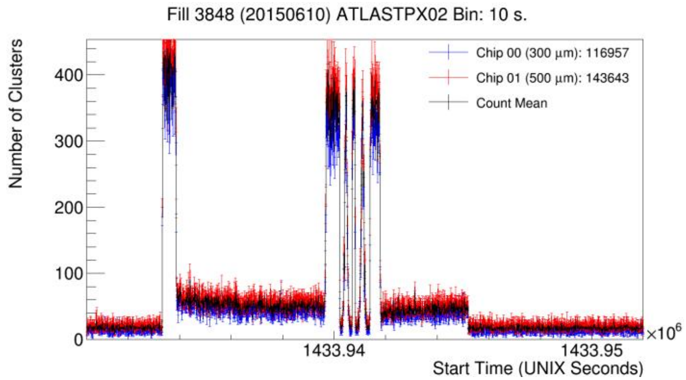


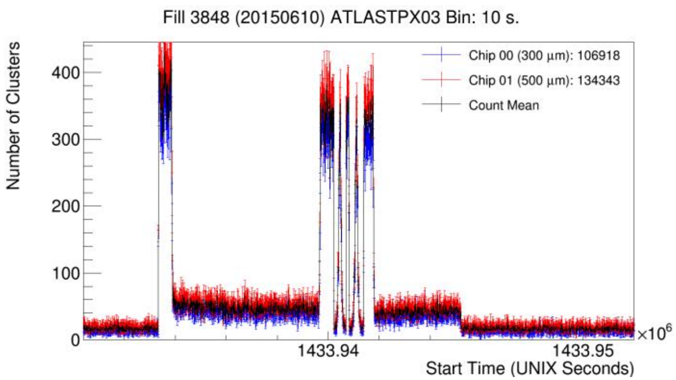
Sum of all clusters in the Fill for Chip 01:

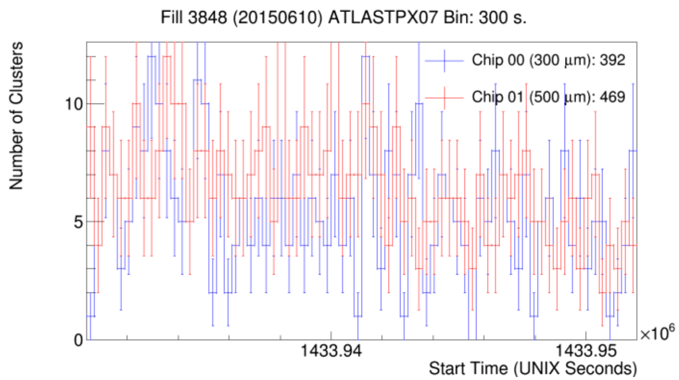


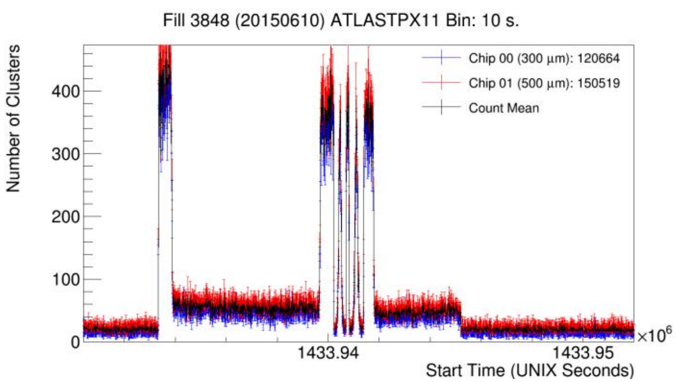
What about the other devices?

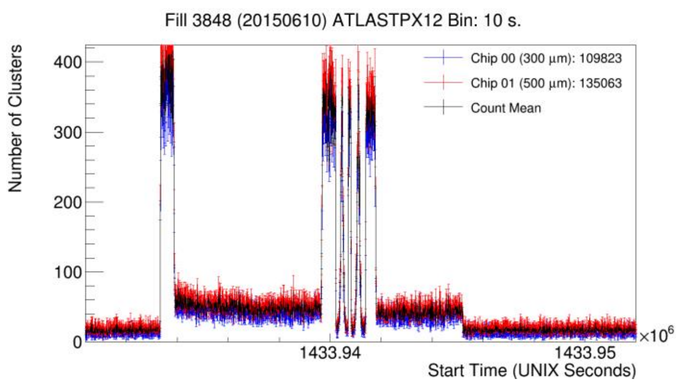






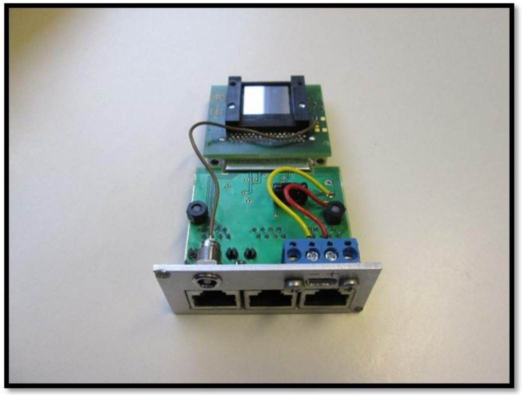


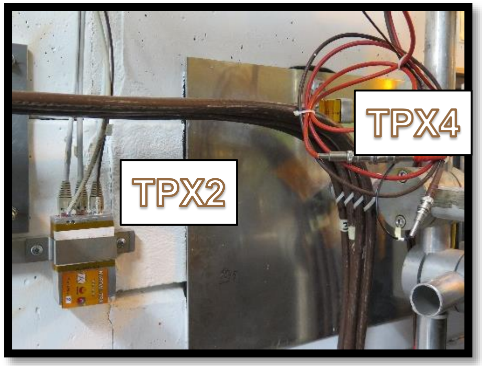


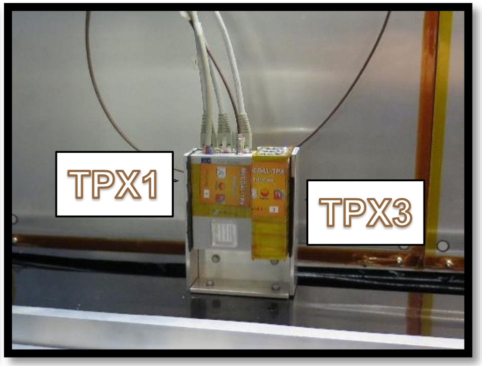


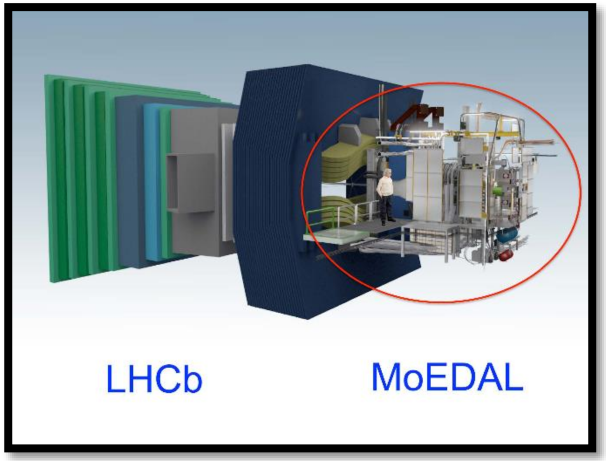
A Network for MOeDAL

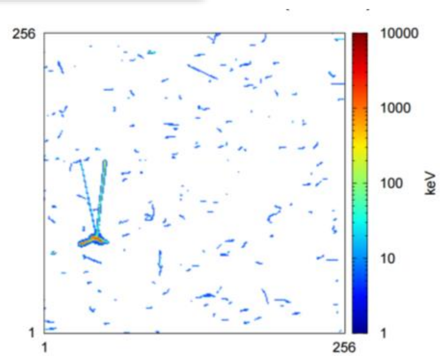
5 radiation tolerant single Timepix detectors of different thicknesses (1 of them equipped with neutron converters) were installed in the MoEDAL experiment at the LHC. They operate as a network and they will record the tracks of highly ionizing events, contributing to the search for new and exotic particles.









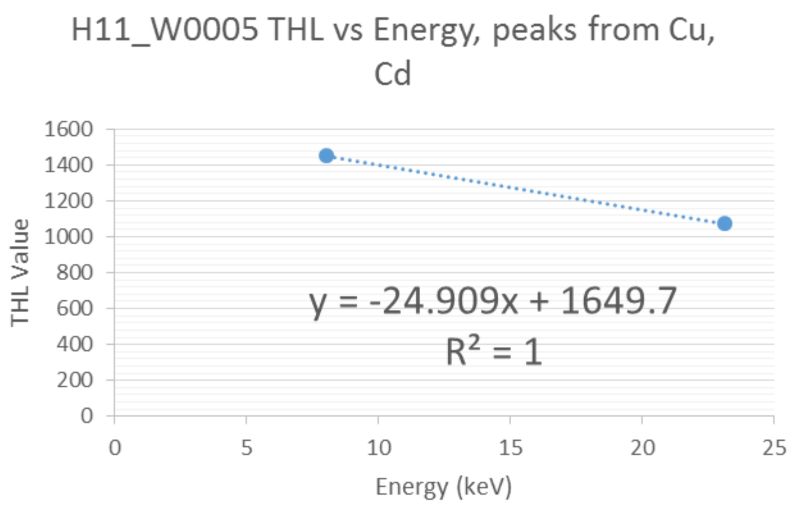


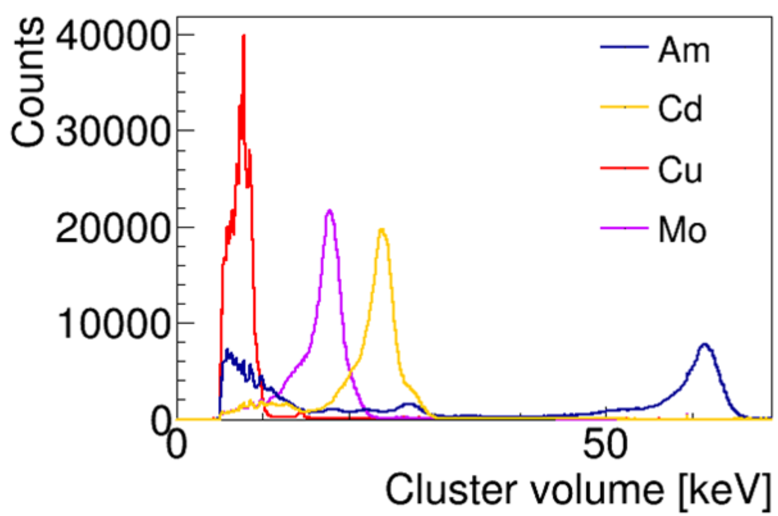
Timepix devices in the MoEDAL experiment

Irradiation of TPX and TPX3 detectors

Together with ESR 9, ESR 2, colleagues from the IEAP CTU and the CERN Medipix Group, we participated of three beam times (2 at SPS and 1 in the Dubna Nuclotron) granted in the framework of the SATRAM (Proba-V) Project of the IEAP.

Timepix and Timepix3 detectors of different thickness were characterized and irradiated under different angles and parameters (Bias, PreAmp, IKRUM, Polarity).





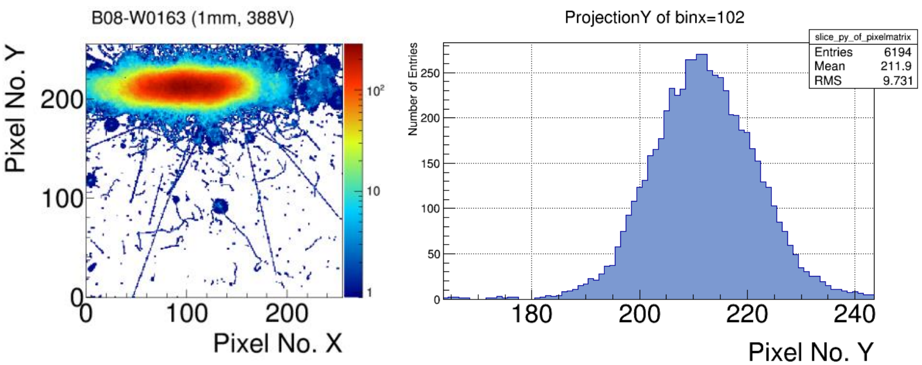
THL scan and energy calibrated spectra measured with a 300um TPX3

SPS 1 and 2:

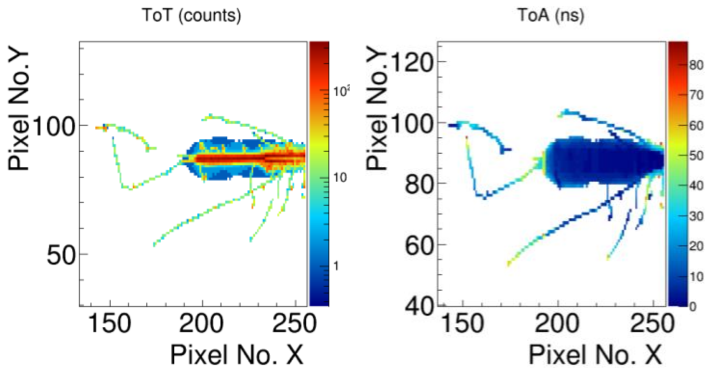
Beam: Argon ions. 13, 75 and 150 GeV.

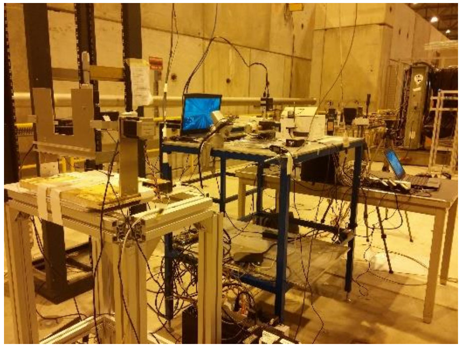
Irradiated detectors: Timepix (Si: 150, 300, 1000, 1500 / CdTe: 300 um), Timepix3 (Si: 300, 500, 675 um), GEM (Fabrizio Murtas).

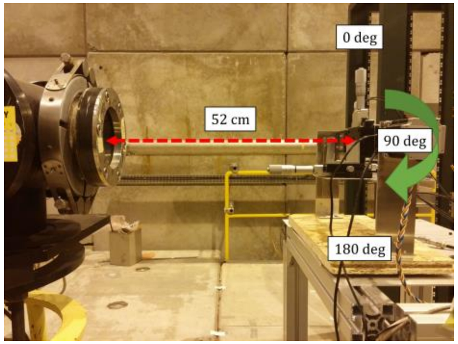
Beam Profile with a 1000 um (Si) Timepix



150 GeV/c Ar ion measured with a 500 um (Si) Timepix3



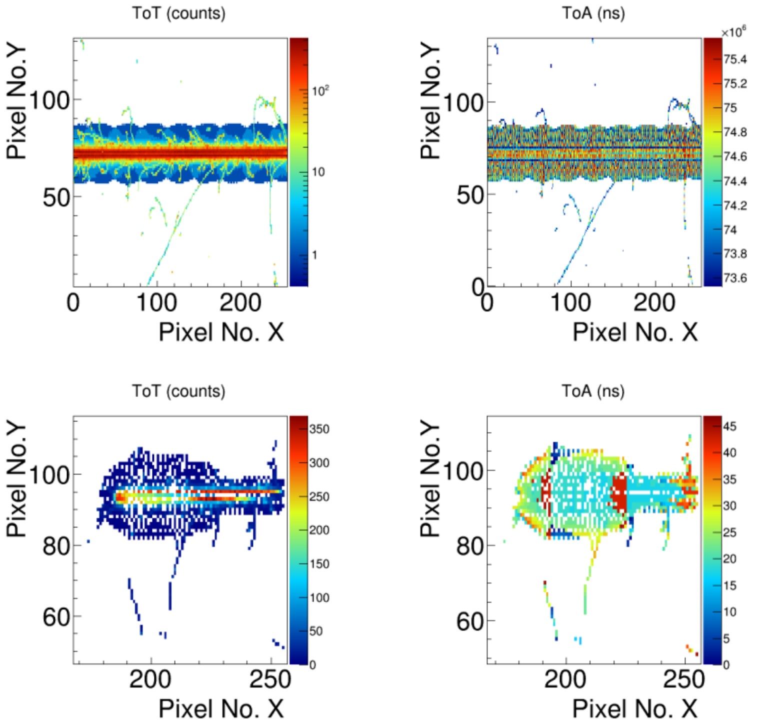




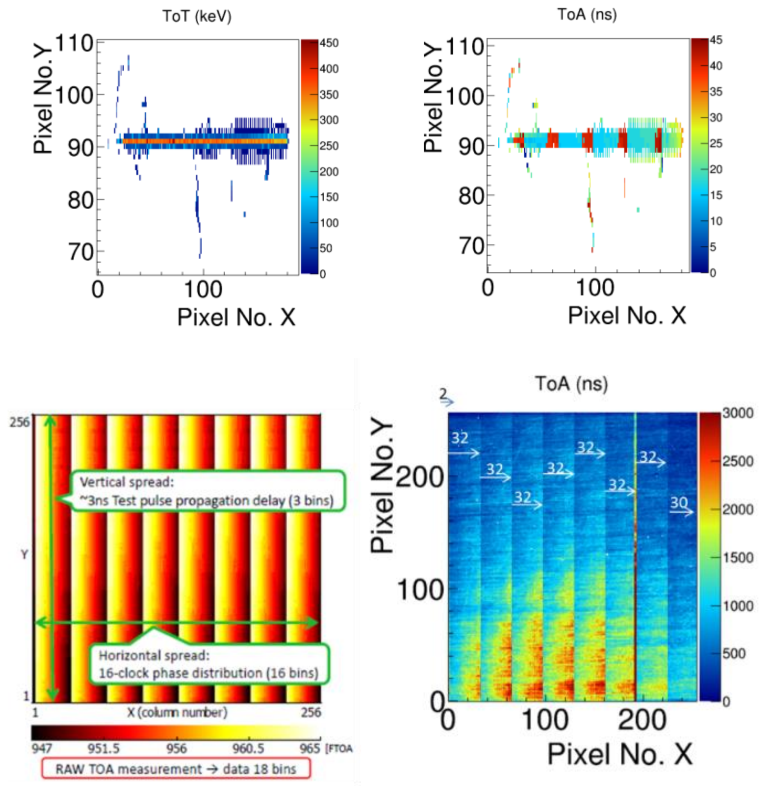
And well… Timepix3 is young, and so are its readout and Software.

We also gave some feedback about issues from these measurements:

Data loss or miscounting due to a big number of simultaneously activated pixels



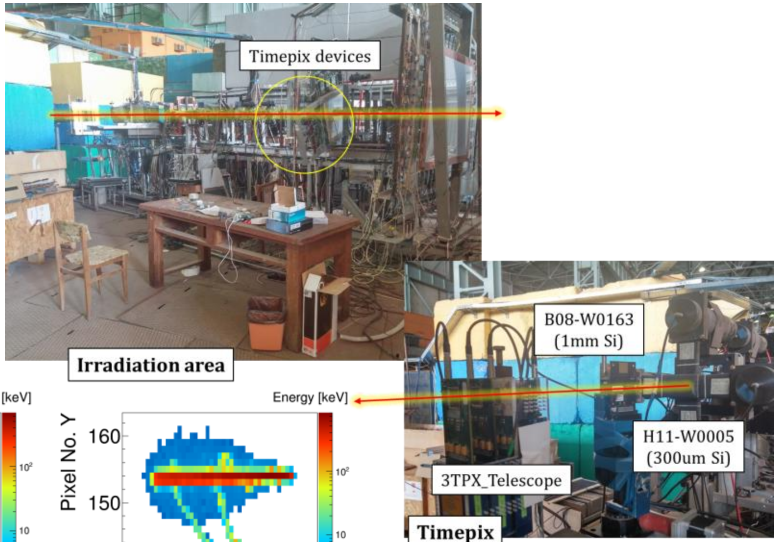
Miscounting in ToA correlated with the way how timing information is read from the chip

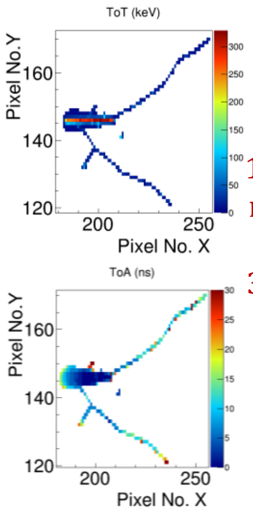


JINR Dubna Nuclotron:

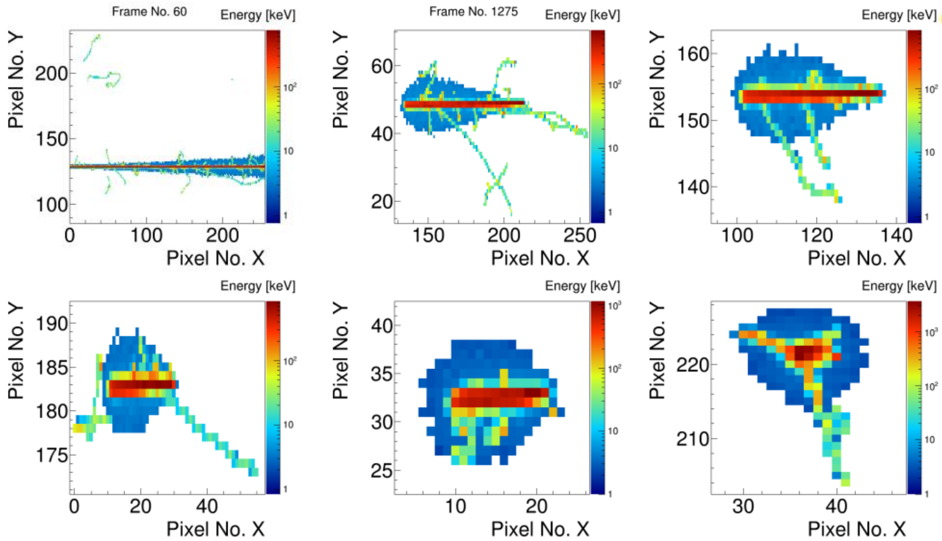
Beam: Carbon ions, 1 GeV/U.

Irradiated detectors: Timepix telescope (Synchronized, 3 300um layers), Timepix (Si 1000um), Timepix3 (Si 300um), CR39 (MoEDAL).





12C: 1 GeV/A measured by a Timepix3, 300 um, with 90V Bias



Timepix, 1000 um, with 400V Bias. 12C ions at 90°, 75°, 60°, 45°, 30° and 0°

Conferences, presentations, deliverables

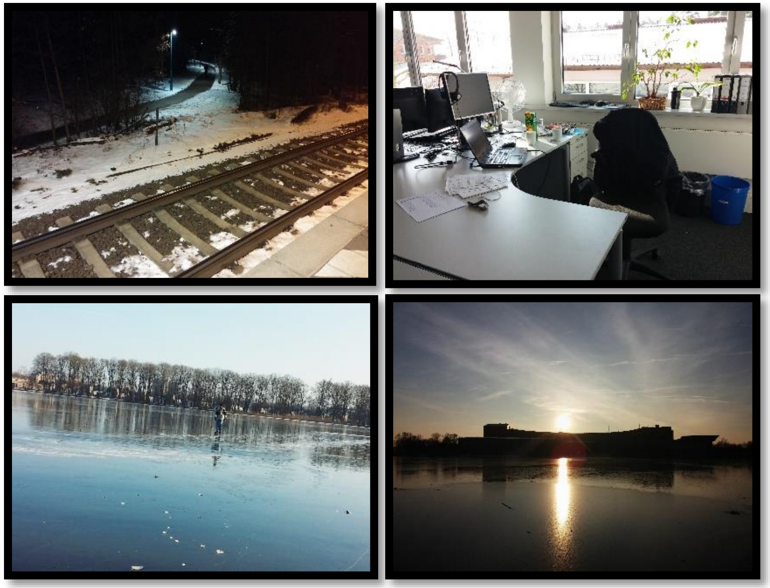
- **2014 IEEE Nuclear Science Symposium and Medical Image Conference -21st Symposium on room-temperature semiconductor x-ray and gamma ray detectors. (7-17 November 2014, Seattle).** I attended this conference and presented the contribution "Radiation-Hard Timepix Detector-Based Hodoscope for the Characterization of Harsh Mixed Radiation Environments" in the "Radiation Damage Effects and Radiation Hard devices" poster session of the event. An article based on it was sent for the Conference Records (Still not published).

- **Presentations and contributions in the ATLAS-TPX. ATLAS Luminosity and Board meetings of the IEAP.**

- **ARDENT Deliverable Report D.2.12:** "Interim report on a radiation-hard device and interface for environmental radiation monitoring"

Training

- **Interdisciplinary Symposium "Precision, speed and flexibility: New radiation methods for ion beam radiotherapy"(22-25 October 2014, Heidelberg).** Expert talks regarding detection techniques for quality assurance of ion beams in ion therapy, visualization of moving organs, beam monitoring in the patient and spectroscopy of secondary ions for radiobiology (Including work carried out using Timepix devices, and a poster contribution).
- **Medipix Meeting (18 February 2015, CERN)**
- **2015 CERN School of Computing (Accepted for September 2015)**



Secondments

- **Business and Administration secondment in IBA Dosimetry (2-13 February 2015, Schwarzenbruck).** Two weeks as an intern for the Program Management Department, supervised by Dr. Marcus Mueller. I learned about the characteristics and workflow structure of the projects carried out by IBA. Furthermore, I worked using the prototype of a PM Software (ACCOLADE) and learned basics of SQL to provide some required queries.

Conclusions

- The calibration of the response to neutrons for ATLAS-TPX agrees with the expected detection efficiencies and energy range discrimination based on the response in different converter areas.

- The ATLAS-TPX devices are operational, measuring particle fluxes and characterizing mixed radiation fields at different positions inside the ATLAS experiment. The network is ready to measure VdM scans.

- Based on the experience with ATLAS-TPX, a five-single detector network is under installation at MoEDAL.

- Timepix data for ions in a wide energy range was collected. These measurements will be processed and provide valuable information about the response of the detector in highly energetic radiation environments (e.g. Particle Physics experiments, space, ion therapy).

- Conference contributions, technical training and the B&A secondment were carried out successfully in the last nine months.

Thank you all!
Thank you ARDENT and IEAP of the CTU!

My best wishes for all your future projects!

This research project has been partially supported by the Marie Curie Initial Training Network Fellowship of the European Community's Seventh Framework Programme under Grant Agreement PITN-GA-4 2011-289198-ARDENT