TIMEPIX DETECTOR NETWORK FOR NEUTRON DETECTION AND CHARACTERIZATION OF THE RADIATION FIELDS IN THE ATLAS CAVERN

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Motivation

- A network of 16 Medipix detectors has proven valuable for the investigation of the ATLAS machine's luminosity, the activation of surrounding material during and after collisions and the composition of the radiation fields at different positions within the cavern [1,2].
- During the 2013-2014 shut-down period this network was upgraded to a two layer Timepix design with a faster readout for an improved particle identification and the investigation of the directionality of the fast neutron component [3].

[1] M. Campbell et al., ATL-GEN-PUB-2013-001 (2013) http://cds.cern.ch/record/1544435
[2] A. Sopczak et al., "MPX Detectors as LHC Luminosity Monitor," in IEEE Transactions on Nuclear Science, vol. 62, no. 6, pp. 3225-3241, Dec. 2015. doi: 10.1109/TNS.2015.2496316
[3] C. Leroy et al., ATL-COM-GEN-2014-005 (2014) http://cds.cern.ch/record/1646970

Hodoscope design

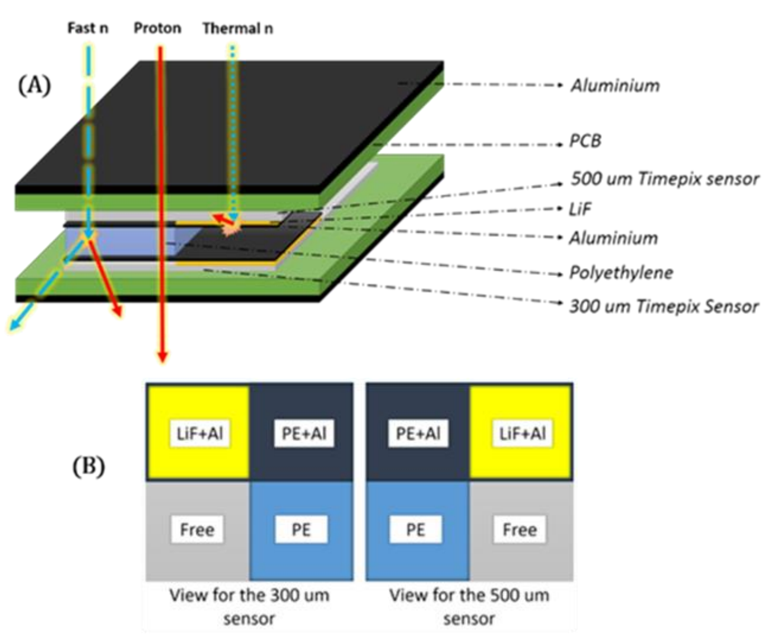


FIG. 1: (A): Schematics of the principle of tracking and neutron detection in the device; (B): Layout of converters as seen by each detector.

Timepix detectors:

- 256 x 256 pixels
- Pixel pitch: 55 µm
- Active area: 1.4 x 1.4 cm²
- Modes of operation (each pixel): Counting (number of hits), Time-over-Threshold (energy mode), Time-of-Arrival (time mode)

Readout speed:

- up to 9 frames/sec (dead time between frames ~120 ms)

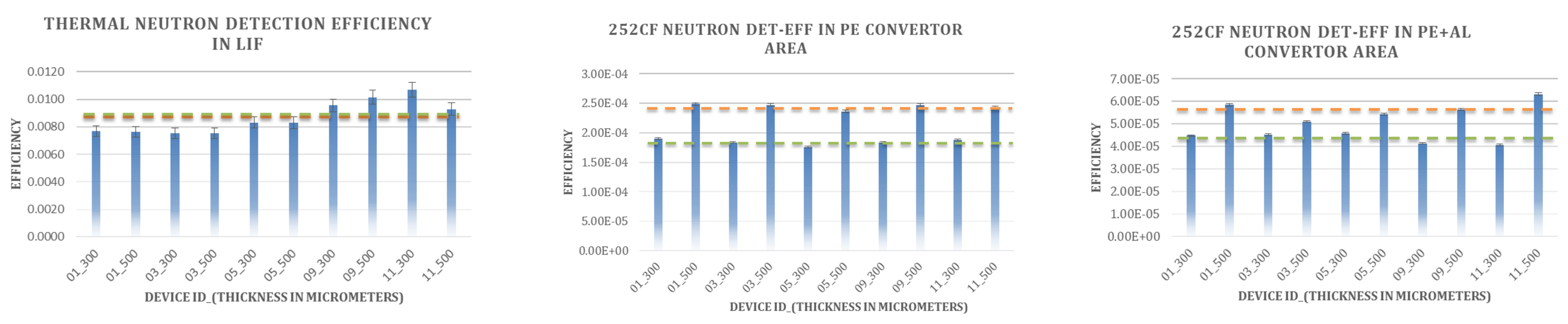
Converter layers:

- Polyethylene (sensitive to fast neutrons via recoil protons)
- Polyethylene with additional aluminum (sensitive to fast neutrons with threshold ~4MeV neutron energy)
- LiF (thermal and epithermal neutrons via tritons and alphas)

Coincidences/anticoincidences for particle discrimination.

Detector calibration measurements and results

- X-ray energy calibration for all sensors.
- **Neutron efficiency** calibration in different neutron fields: AmBe, Cf (Czech Metrology Institute), Van-de-Graaff accelerator in Prague (16.7 MeV), spallation source up to 800 MeV (Los Alamos Neutron Science Center).



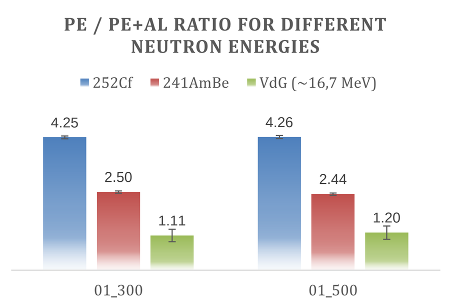


FIG. 2: Detection efficiencies of 5 devices to a Cf-spectrum as an example. The efficiency below the converter i is given by:

$$\varepsilon_i = \frac{N_i/A_i - N_{Si}/A_{Si}}{\Phi_{source} t}$$

Using the ratio of the counts below the PE and the PE+Al regions, neutron fields can be characterized up to ~20 MeV.

- **Charged particles:** protons, alphas, carbon and oxygen ions (Heidelberger Ion Therapy Center), argon ions (SPS CERN) from 50 MeV/A up to 150 GeV/A

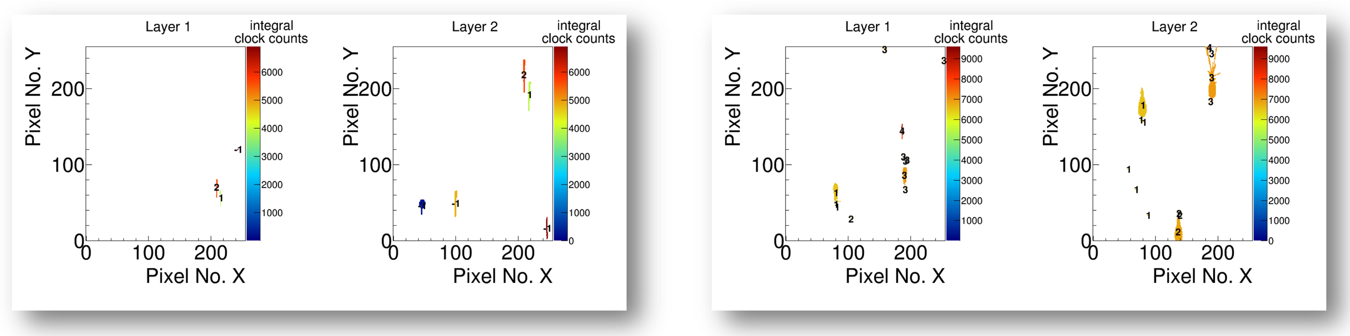
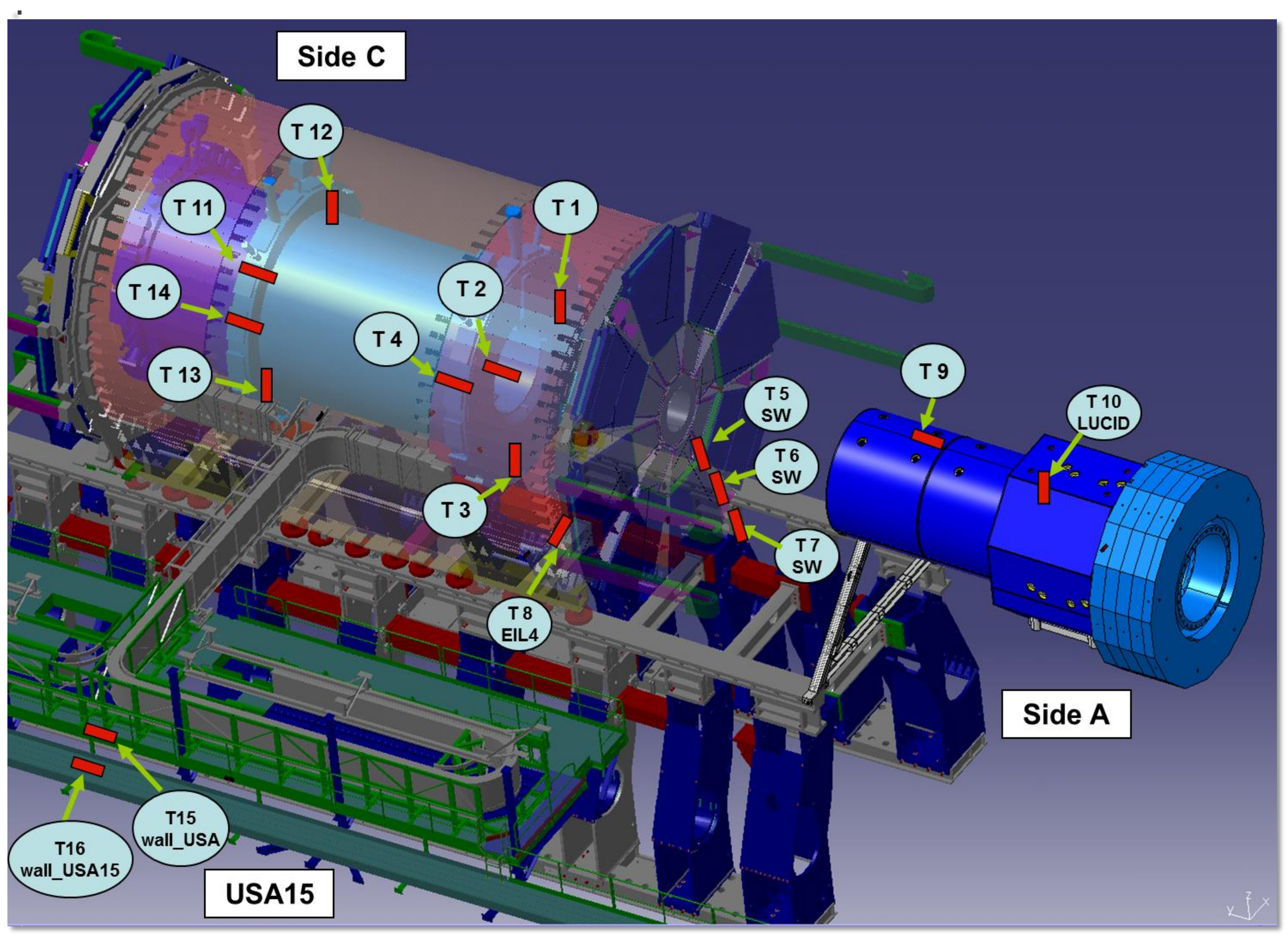


FIG. 3: 100 MeV protons (left) and 250 MeV/A ^{16}O (right) at 75° to the sensor normal. In the time-mode coincident events were identified (numbers > 0). Anticoincident tracks are labelled with -1.

Ions are typically accompanied by secondary particles (delta electrons) created in the sensor and its surroundings. These can be omitted by filtering.

Positions within the ATLAS cavern



ATLAS-TPX Number	Location in ATLAS	X [mm]	Y [mm]	Z [mm]	ρ [mm]	R [mm]
TPX01	Ext. Barrel A	670	880	3540	1106	3709
TPX02	Ext. Barrel A	-1100	180	3540	1115	3711
TPX03	Ext. Barrel A	150	-1130	3540	1140	3719
TPX04	Barrel A side	-3580	970	2830	3709	4665
TPX05	Small Wheel 1	1320	-494	7830	1409	7956
TPX06	Small Wheel 2	2370	-1030	7830	2584	8245
TPX07	Small Wheel 3	3300	-1590	7830	3663	8644
TPX08	ELI4	-6140	0	7220	6140	9478
TPX09	JF Shielding	0	1560	15390	1560	15469
TPX10	LUCID A	230	440	18859	496	18857
TPX11	Ext Barrel C	660	900	-3540	1116	3712
TPX12	Ext Barrel C	-930	670	-3540	1146	3721
TPX13	Ext Barrel C	90	-1100	-3540	1104	3708
TPX14	Barrel C side	-3580	970	-2830	3709	4665
TPX15	Wall UX15	-16690	50	5020	16690	17429
TPX16	USA15	-18900	50	5020	18900	19555

TPX09, TPX10 and TPX13 were not accessible remotely after the closing of the ATLAS cavern. This was most likely caused by damage to the cables during the assembly of detectors nearby.
During a technical shut-down TPX09 was replaced and TPX13 could be recovered. Both are operational since then.

Data transfer and storage

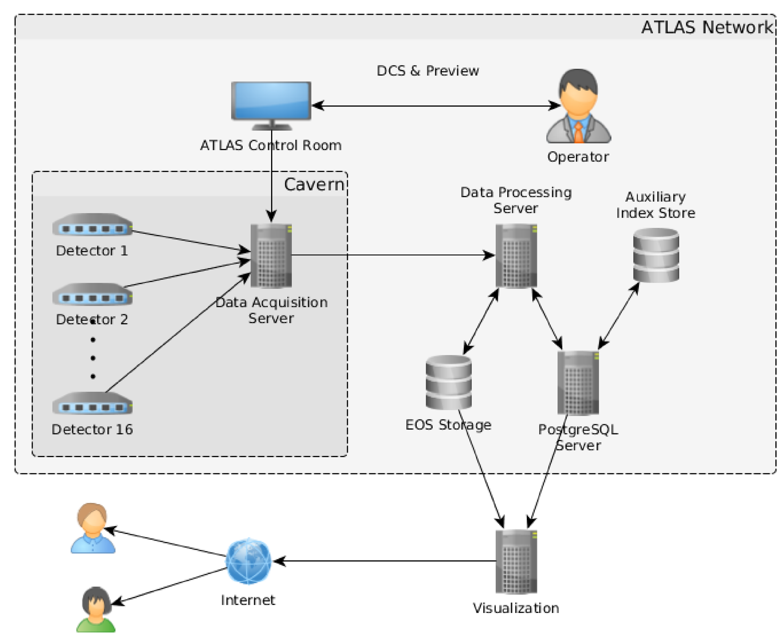


FIG. 4: Scheme of the anticipated detector control and data transfer.

Data are continuously taken and send to the data acquisition server. From there, data will be displayed in real-time through DCS and put to the permanent storage where they are available for visualization and offline evaluation.

Luminosity calibration with van der Meer scans

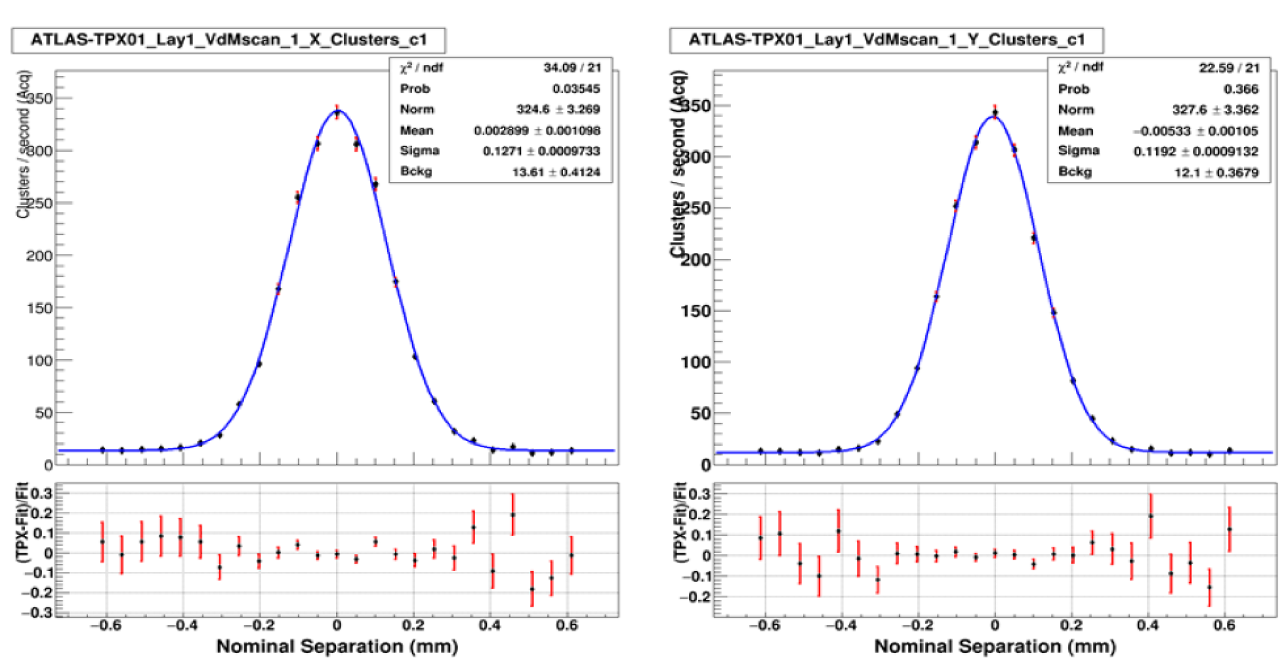


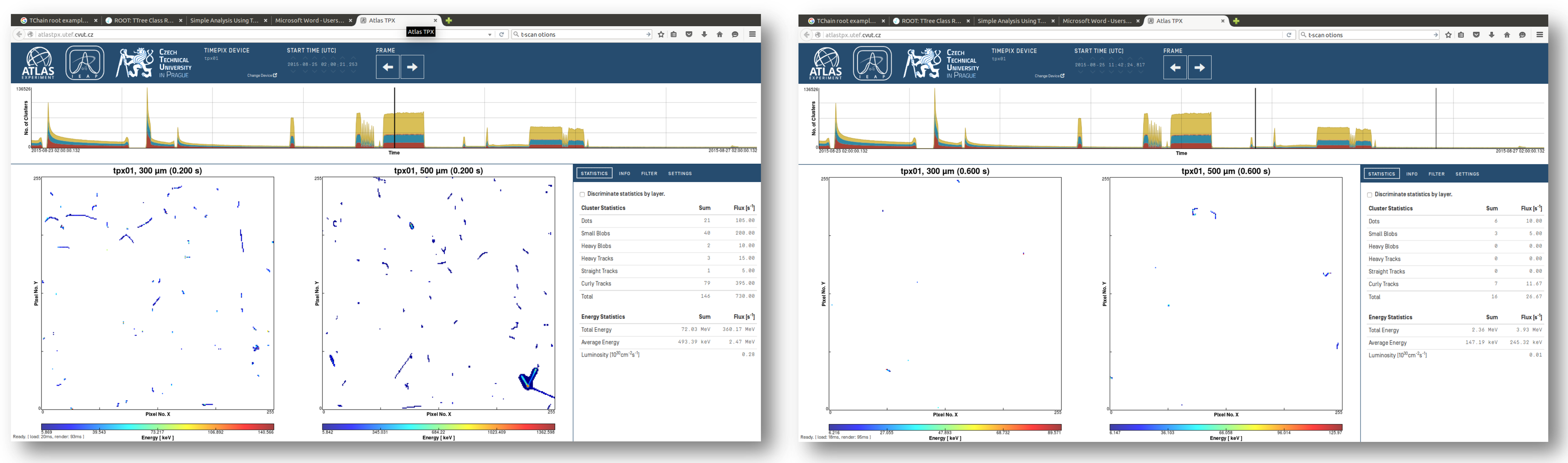
FIG. 5: Number of clusters per second vs. nominal beam separation for the first vdM scan from Aug. 24, 2015 in X and Y axes. A Gaussian with a constant background is fitted to the data points.

Correlating the count rate measured at the peak position of the Gaussians with the luminosity at 0 beam separation given by

$$\mathcal{L} = \frac{N n_1 n_2 f}{2\pi \Sigma_x \Sigma_y},$$

the calibration coefficient to convert count rate into luminosity is obtained.

Online data visualization and examples of frames (TPX 01)



Conclusion

- During the recent long shut-down the ATLAS-MPX detector network was upgraded to the ATLAS-TPX network consisting of 15 operational two layer Timepix detectors.
- The detection efficiencies to neutral and charged particles were determined and the capability of applying the coincidence/anticoincidence technique was tested.
- The devices were able to monitor luminosity in the range from 10^{29} to 10^{33} events per cm² and second using hit and cluster counting methods after calibration with van der Meer scans.
- Typical frames during and after collisions were shown to demonstrate the difference in the radiation fields. They can be displayed through a web application from atlastpx.utef.cvut.cz.

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