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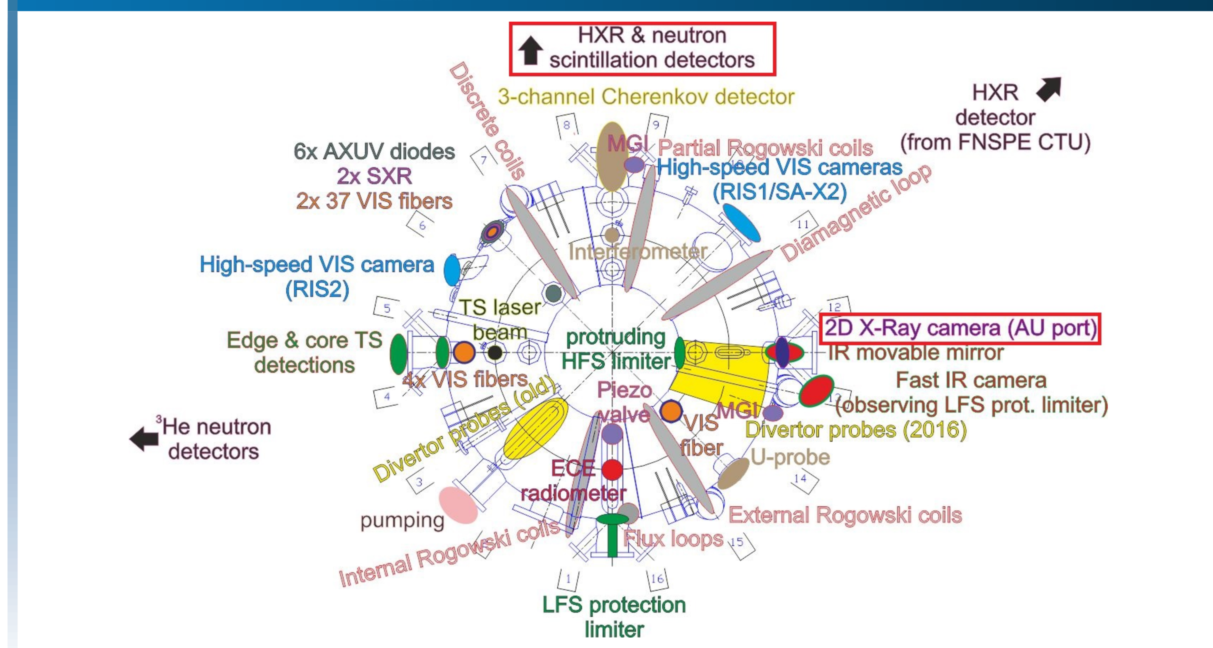
Runaway Electrons Diagnostics Using Segmented Semiconductor Detectors

P. Svihra[1], D. Bren[1], A. Casolari[2], J. Cerovsky[2], P. Dhyani[1], M. Farnik[2], O. Ficker[2], M. Havranek[1], Z. Janoska[1], V. Kafka[1], P. Kulhanek[2], V. Linhart[1], E. Macusova[2], M. Marcisovska[1], M. Marcisovsky[1], J. Mlynar[2], G. Neue[1], L. Novotny[1], V. Svoboda[1], L. Tomasek[1], J. Urban[2], P. Vancura[1], J. Varju[2], V. Vrba[1], V. Weinzettl[2]

Contact: Peter.Svihra@fjfi.cvut.cz

[1] FNSPE CTU, Brehova 78/7, Prague, Czech Republic, [2] IPP ASCR, Za Slovankou 1782/3 Prague, Czech Republic

COMPASS



Runaway electron (RE) measurement campaigns were focused on utilizing Medipix2 detector [1], [2] as X-ray monitoring system outside of vacuum. Diagnostic setup is visualized in left figure, detectors used for measurement are highlighted in red frames. The data taking was started by trigger, acquiring frames during the discharge.

Main setup features:

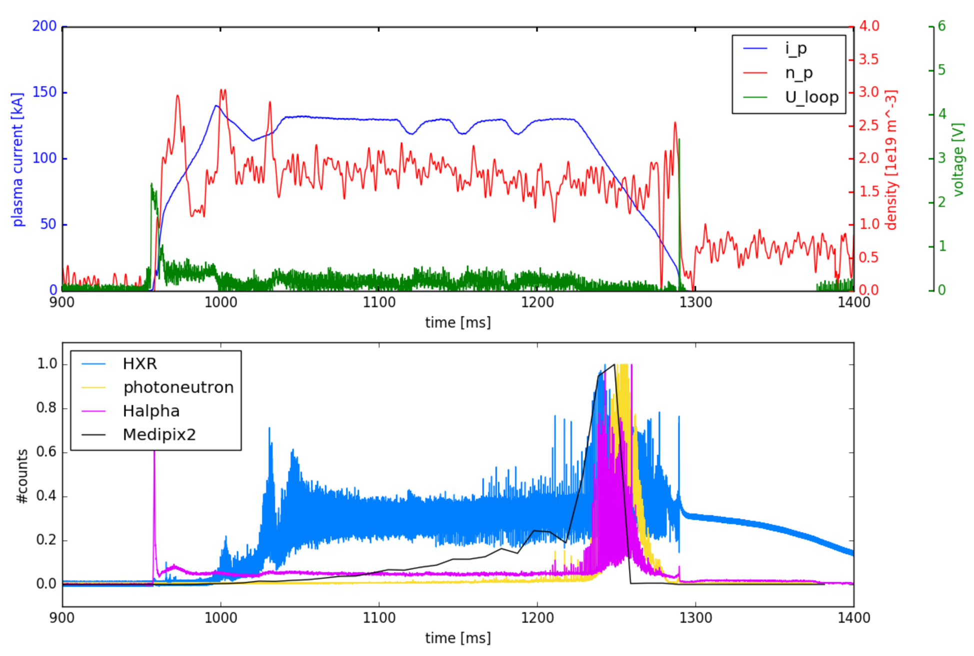
- detection of soft X-ray
- pinhole setup oriented towards inner limiter
- discharge $t \sim 300$ ms, ≈ 30 frames with 1 ms acquisition window

COMPASS measurements

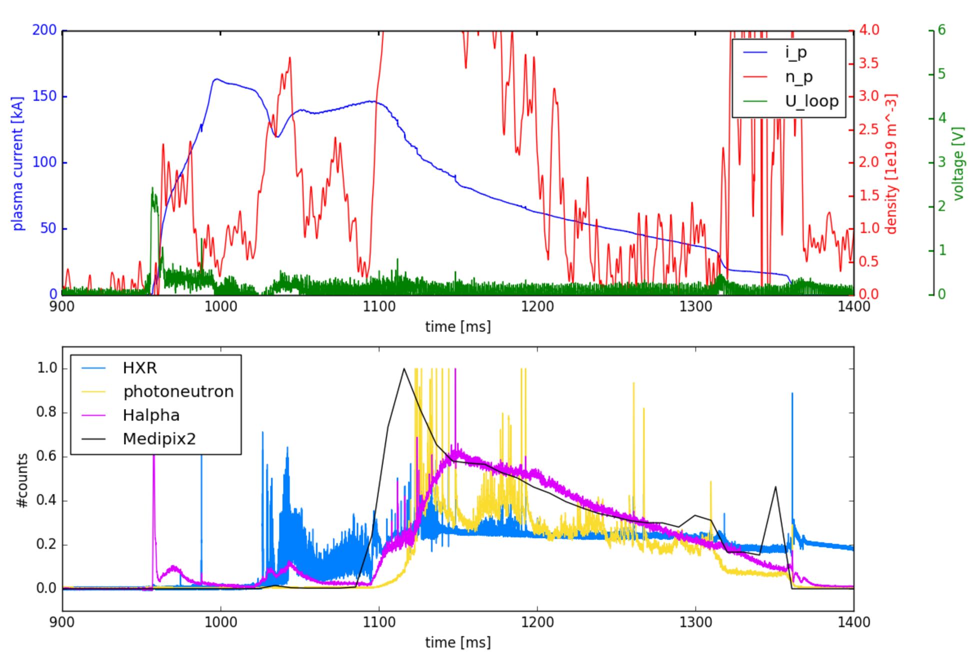
The measured signal from the whole detector correlates well with other X-ray diagnostics applied at tokamak (figures below). Furthermore, effects of the lost configuration of the detector due to rapid changes of electromagnetic field (visible noise after the end of discharge) were not observed.

When collimating the signal from limiter (right figures), vertical shaping of plasma results in visible movement of X-ray hotspot (blue circle in whole frame / orange circle of x-axis histogram) in time.

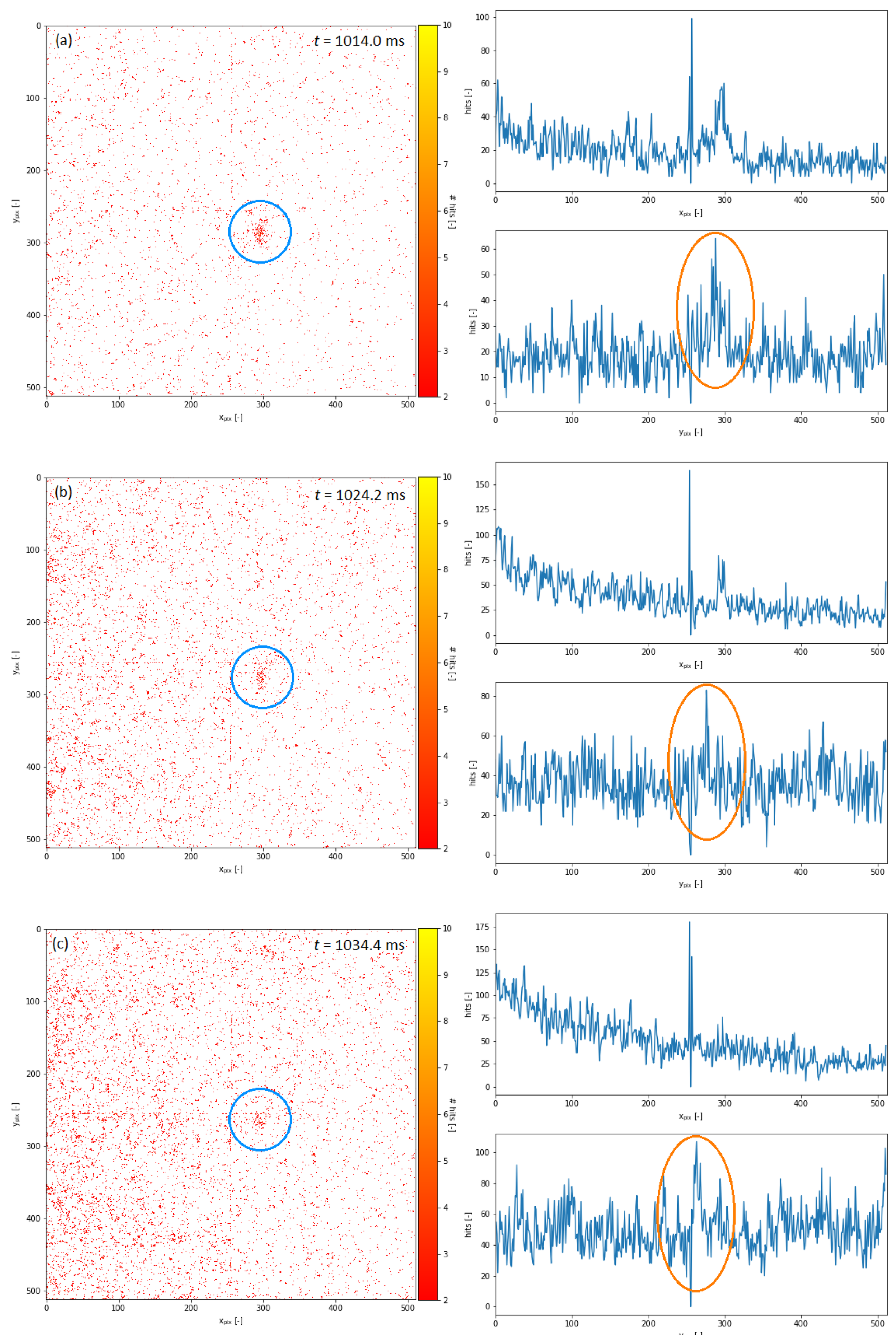
Utilization of detectors performing at higher frame rate with better shielding would significantly enhance measurements.



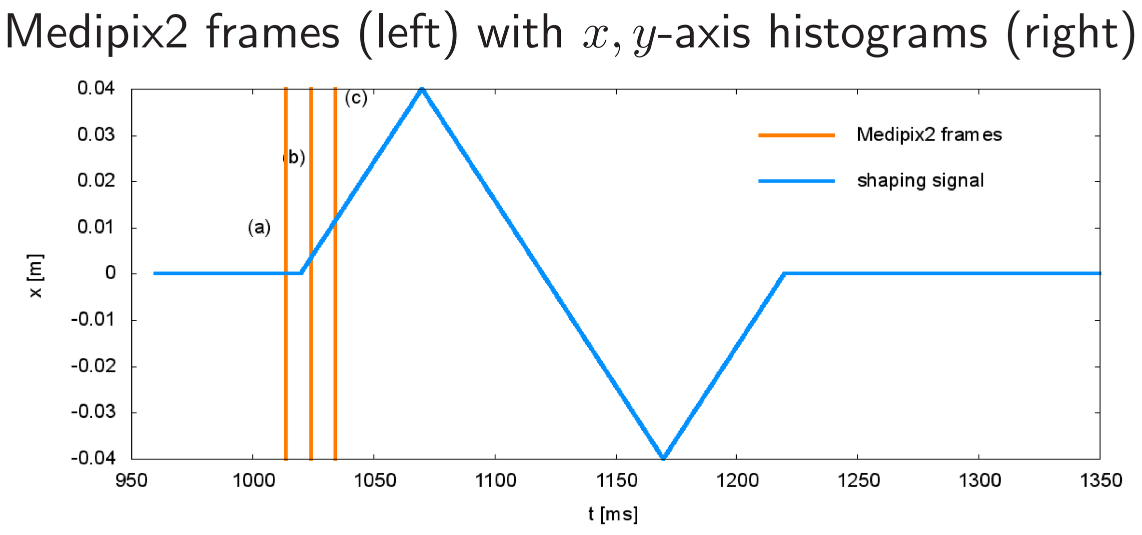
Comparison of diagnostics from discharge 14513.



Comparison of diagnostics from discharge 14601.



Medipix2 frames (left) with x, y-axis histograms (right).



Vertical shaping of the plasma during discharge 14555.

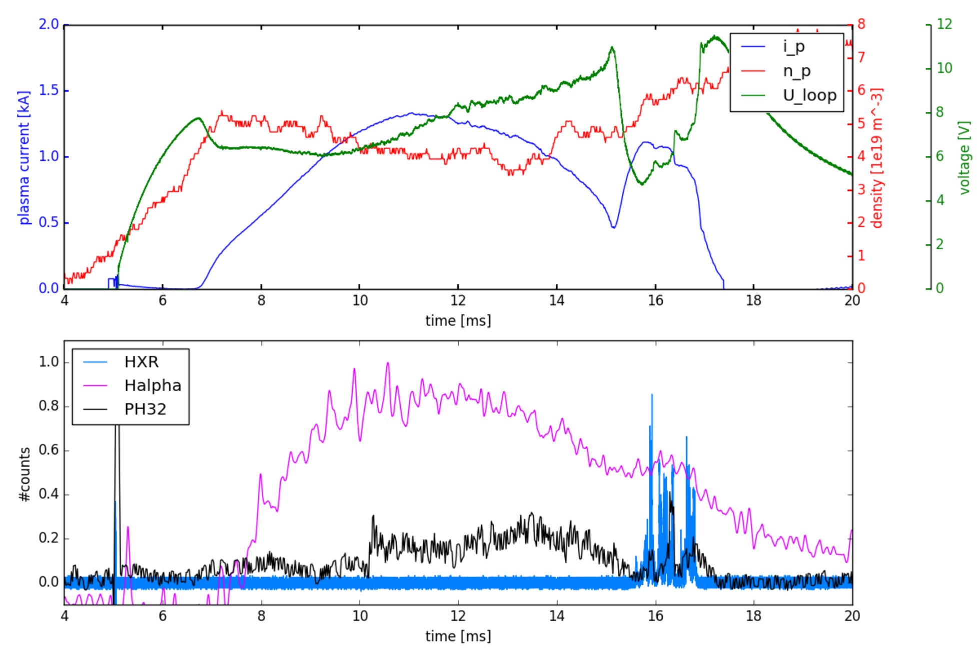
For better interpretation of results a simulation of interaction of RE population with tokamak geometry should be performed. The main reason is generation of Compton electrons in the shielding of detector and other tokamak components, since such signal is stronger in contrast with low detection efficiency of high energy X-ray and gamma photons in the silicon sensor.

GOLEM

Advances of detector development enabled utilizing more promising detector PH32 [3], which is being tested at tokamak GOLEM. Measuring setup is still being enhanced, work oriented towards triggering and shielding. Preliminary results show potential of such application, providing more information than standard diagnostics.

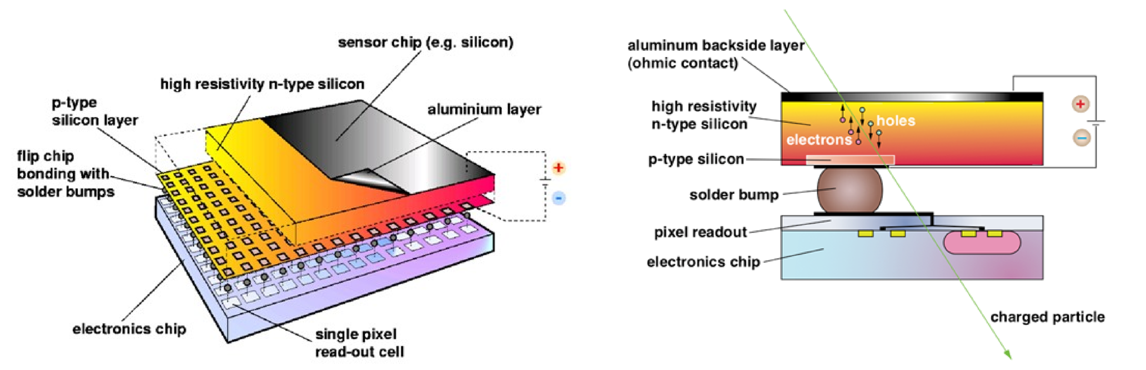
Main setup features:

- proof of concept utilization of semiconductor detectors inside tokamak vacuum for RE discharge
- enhanced results by directly measuring electron energy
- discharge $t \sim 15$ ms, ≈ 150 frames with $40\,\mu$s acquisition window, analog output of one channel



Comparison of diagnostics from discharge 27487.

Semiconductor detectors

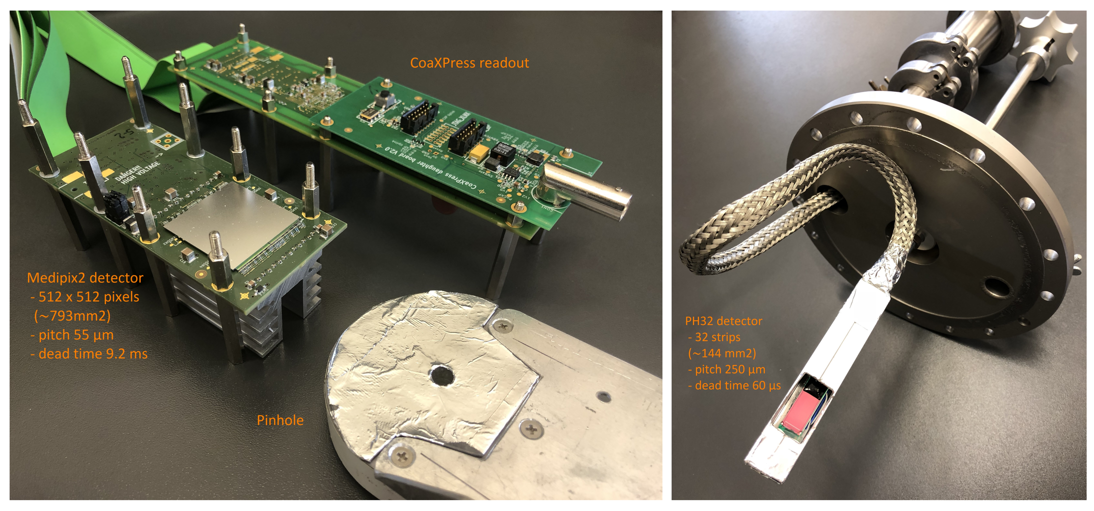


Interaction of both charged (direct radiation) and neutral (indirect radiation) particles in sensor results in generation of electron-hole pairs ($3.6\,\mathrm{eV}$ per pair), which can be detected by readout electronic chip. The quantity of read-out electric signal corresponds to the deposited energy, its collection is regulated by applied bias field.

Detection features of Si sensor:

- Efficient detection of soft X-rays up to tens of keV,
- charged particles up to units of MeV.

Detector setup



- Medipix2 [1],[2]
  - developed by CERN collaboration
  - hit counting mode
  - indirect RE measurement via X-rays
  - pinhole setup outside of vacuum
- PH32 [3]
  - hit counting, energy mode
  - low/high gain of ADC
  - direct RE measurement inside vacuum
  - analog output to oscilloscope

Conclusions

Semiconductor pixel detectors were demonstrated to be a functional new addition to the RE diagnostic methods at tokamaks. Recorded secondary photon hit data correlate well with other used diagnostic methods. Since the full potential of semiconductor pixel detectors in this field of research is not yet fully exploited, their application should be studied further. A novel segmented semiconductor detection system is being developed as a new method of diagnostics, providing both spatial and temporal resolution throughout the plasma discharge.

References

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[2] G. Neue et al. Flexible DAQ card for detector systems utilizing the CoaXPress communication standard. *Journal of Instrumentation, 10 (2015)*, C04013.

[3] Z. Janoska et al. The PH32 readout integrated circuit. *Proceedings of the 10th International Conference on Measurement, (2015)*, 207-211.

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