Study of runaway electron dynamics at the ASDEX Upgrade tokamak during impurity injection using fast gamma-ray spectrometry
CN-665

A. Shevelev, E. Khilkevitch, M. Iliasova, M. Nocente, G. Pautasso, G. Papp, A. Dal Molin, S. P. Pandya, V. Plyusnin, L. Giacomelli, G. Gorini, E. Panontin, D. Rigamonti, M. Tardocchi, G.Tardini, A. Bogdanov, I. Chugunov, D. Doinikov, V.Naidenov, I. Polunovsky, ASDEX Upgrade Team, EUROfusion MST1 Team

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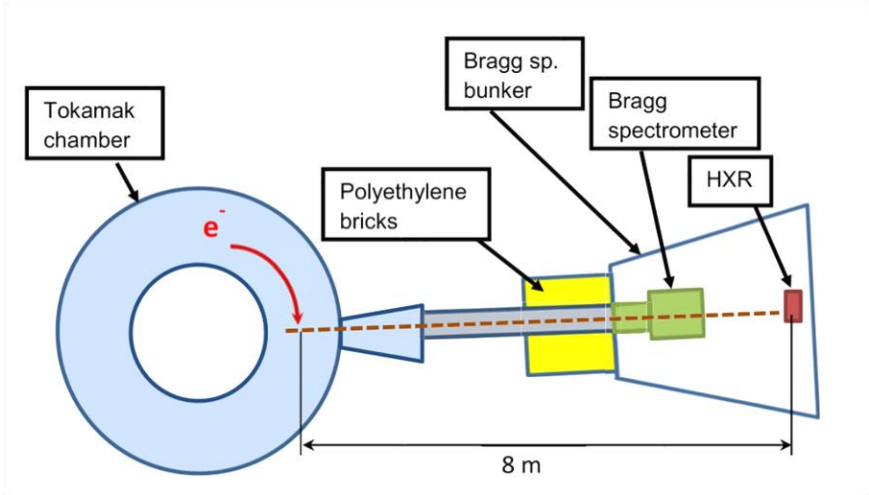
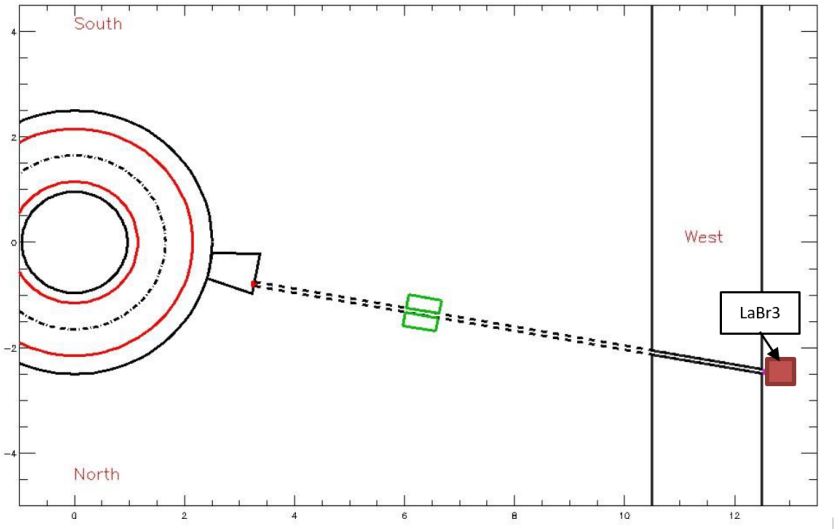
LaBr3(Ce) spectrometers on AUG

Two $LaBr_3(Ce)$ spectrometers are used in the HXR measurements in during experiments at AUG with MGI in deuterium plasmas. They allow conducting γ-ray measurement in the range of 0.1-30 MeV with energy resolution ~3.5% (at 662 keV) and counting rate up to ~10^7 s^{-1}





AUG-HXR spectrometer:

- $LaBr_3(Ce)$ Ø25x17 mm installed in the bunker behind the Bragg spectrometer
- DAQ: 14-bit resolution ADC operating in the segmented mode; 400 MHz sampling rate.

M. Nocente, et al., RSI 89 (2018) 10I124

REGARDS spectrometer

- $LaBr_3(Ce)$ Ø25x25 mm installed behind the bio-shield. Lead collimator Ø10×100 mm
- DAQ: 14-bit resolution ADC recording the **whole signal**; 400 MHz sampling rate.

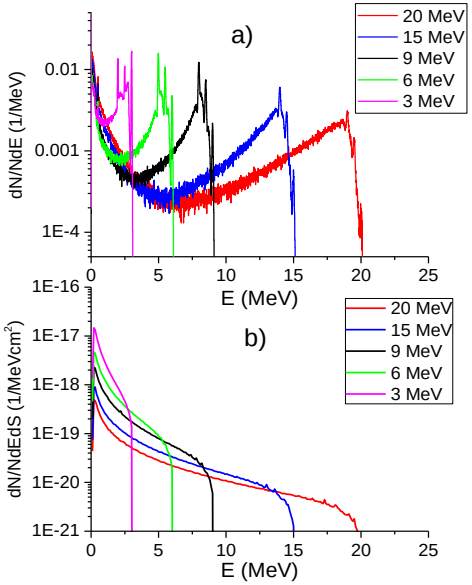
A. Dal Molin, et al., 46th EPS CPP 2019 P1.1015

Reconstruction of REDFs

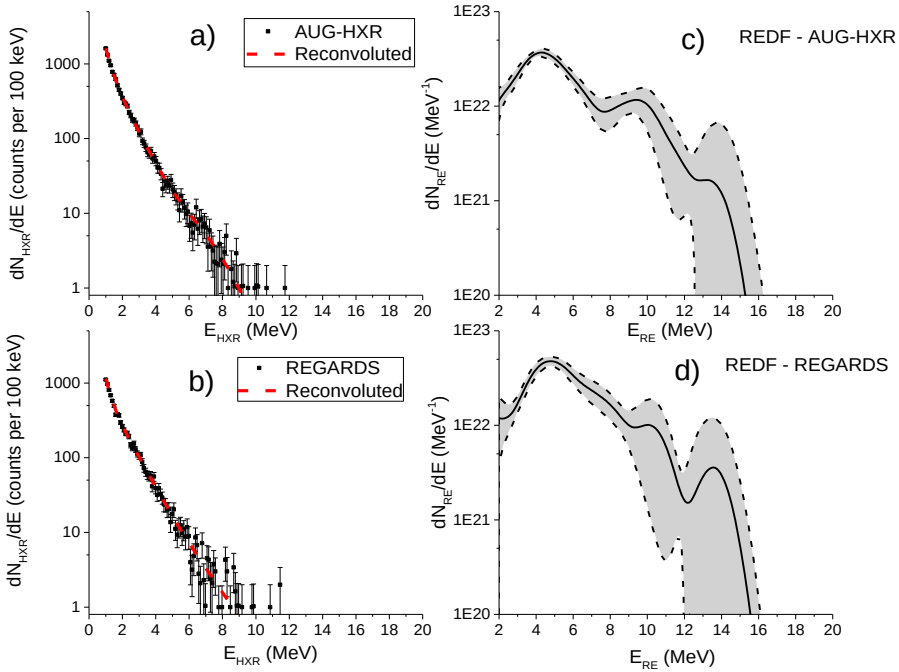
ML-EM (maximum likelihood estimation using expectation maximization) method was realized in the **DeGaSum** code for the RE distribution function (REDF) reconstruction

$$y(\varepsilon) = \int_0^\infty d\varepsilon' \, h_d(\varepsilon, \varepsilon') \int_0^\infty d\varepsilon'' \, h_e(\varepsilon', \varepsilon'') f(\varepsilon'') + n(\varepsilon),$$

y – recorded HXR spectrum; *ε*, *ε'*, *ε"* – energies; *n(ε)* – statistical noise; *f* - runaway electron distribution function; h_d - gamma-ray detector response function; h_e is HXR generation function. h_e and h_d calculated with MCNP code:



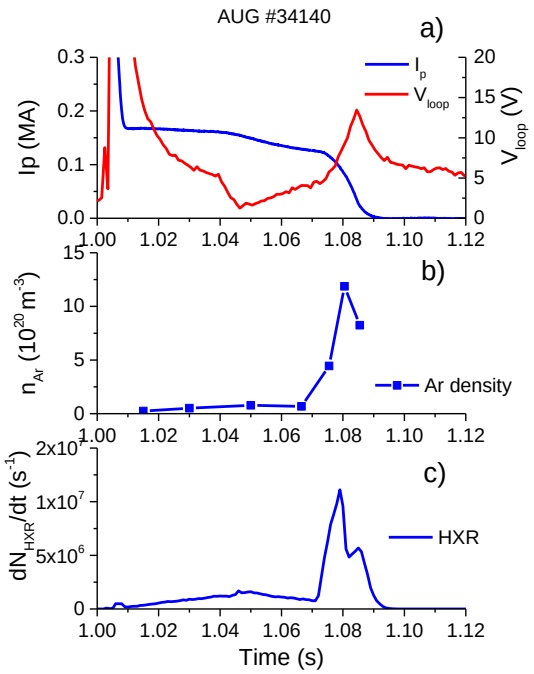
A. Shevelev, et al., NIM A **830** (2016) 102–108

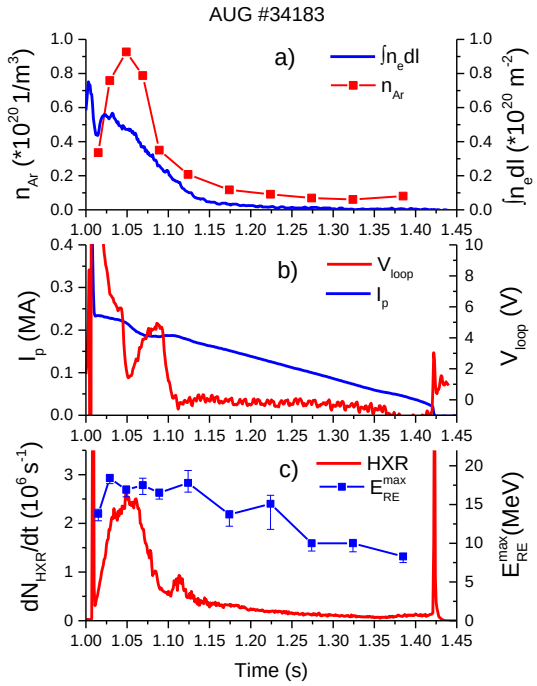


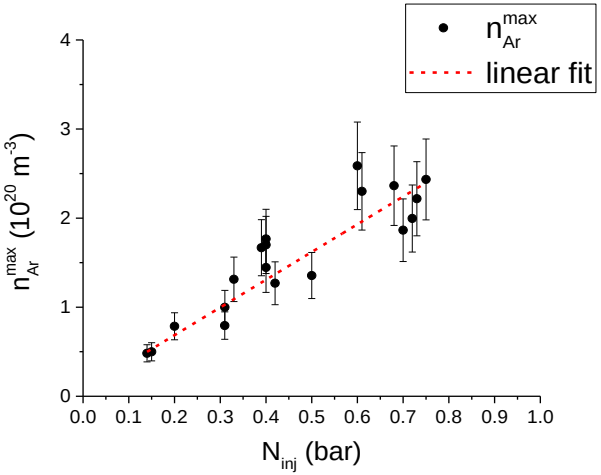
1.03-1.06 s of the AUG discharge #36431: a) HXR spectrum measured by AUG-HXR (black dots); b) HXR spectrum measured by REGARDS (black dots); c) REDF reconstructed from the AUG-HXR spectrum; d) REDF reconstructed from the REGARDS spectrum

Argon density evaluation

The analysis of the obtained runaway electron distributions provided the assessments of the gas target's density and the RE beam fraction visible for spectrometers. Assessed argon density coincides with argon fueling efficiency after the first injection, 60 ± 20%, provided in [Pautasso, G., et al., Nucl. Fusion 60 (2020) 086011]







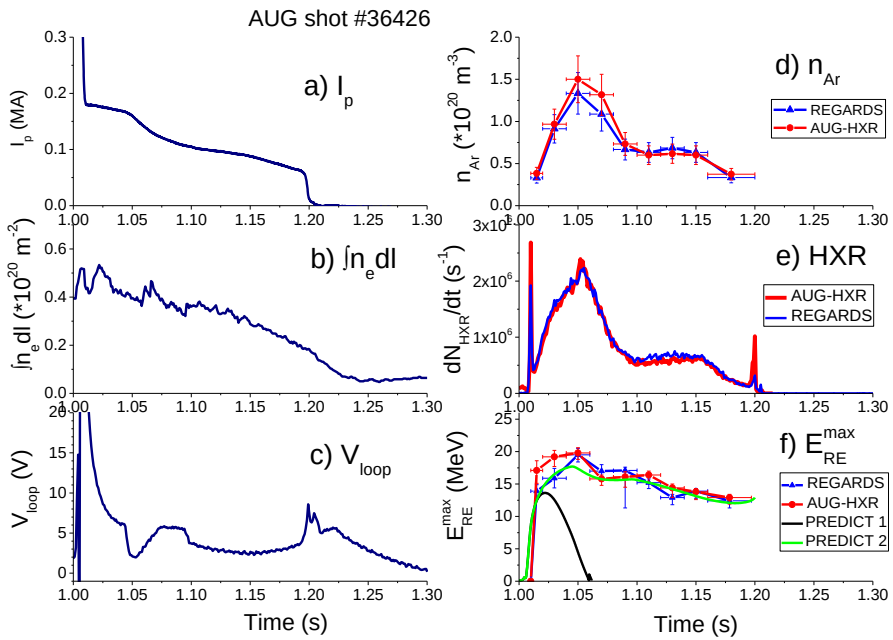
#34140 with the second argon injection: a) I_p and V_{loop}; b) argon density reconstructed from HXR measurements; c) AUG-HXR spectrometer count rate

#34183 with D_2 pellet injections: a) Line integrated n_e and argon density assessed from HXR measurements; b) I_p and V_{loop}; c) AUG-HXR detector count rate and obtained E_{RE}^{max}

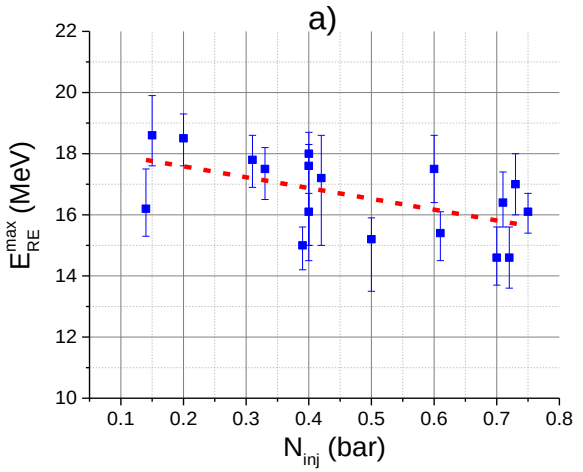
Dependence of the maximum Ar density estimated using DeGaSum calculations vs injected argon value

Evolution of RE maximum energy

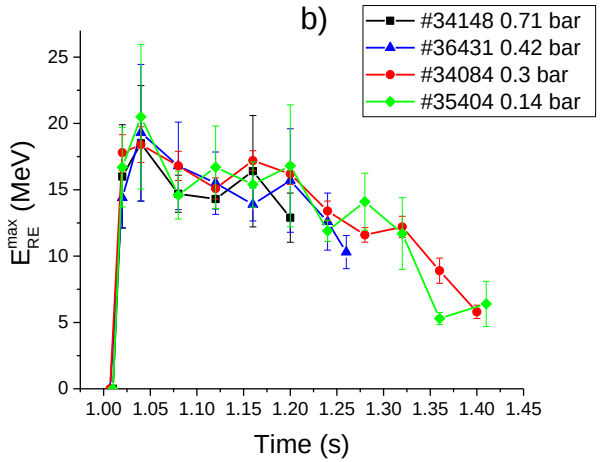
- REs attain their maximum energies of about 20 MeV within 50-100 ms after the gas injection. After that it gradually decreases
- Test particle calculations with the PREDICT code demonstrated that E_{RE}^{max} to correspond to the measured values, the argon density must be by order of magnitude lower than the values provided by HXR measurements.
- E_{RE}^{max} value decreases from about 18 to 16 MeV when N_{inj} rises from 0.14 to 0.75 bar
- The similarity in the E_{RE}^{max} evolution dynamics for discharges with different amounts of injected argon



AUG discharge #36426



E_{RE}^{max} dependence on the amount of injected argon.



E_{RE}^{max} evolution in discharges with different argon injections

Conclusions

- Two high-performance $LaBr_3(Ce)$ spectrometers have been developed, installed on ASDEX Upgrade and used in experiments with RE beam generation.
- RE distributions were reconstructed from measured HXR spectra using deconvolution methods.
- Two spectrometers with small scintillators made it possible to analyze gamma radiation caused by runaway electrons in the energy range up to 30 MeV.
- We studied the evolution of E_{RE}^{max} in various MGI regimes.
- The realized system allowed testing the technical solutions and data processing algorithms for ITER runaway diagnostics.

Acknowledgements

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Thanks for your attention!