Utilizing a visible camera in the first operation phase(s) of a fusion device

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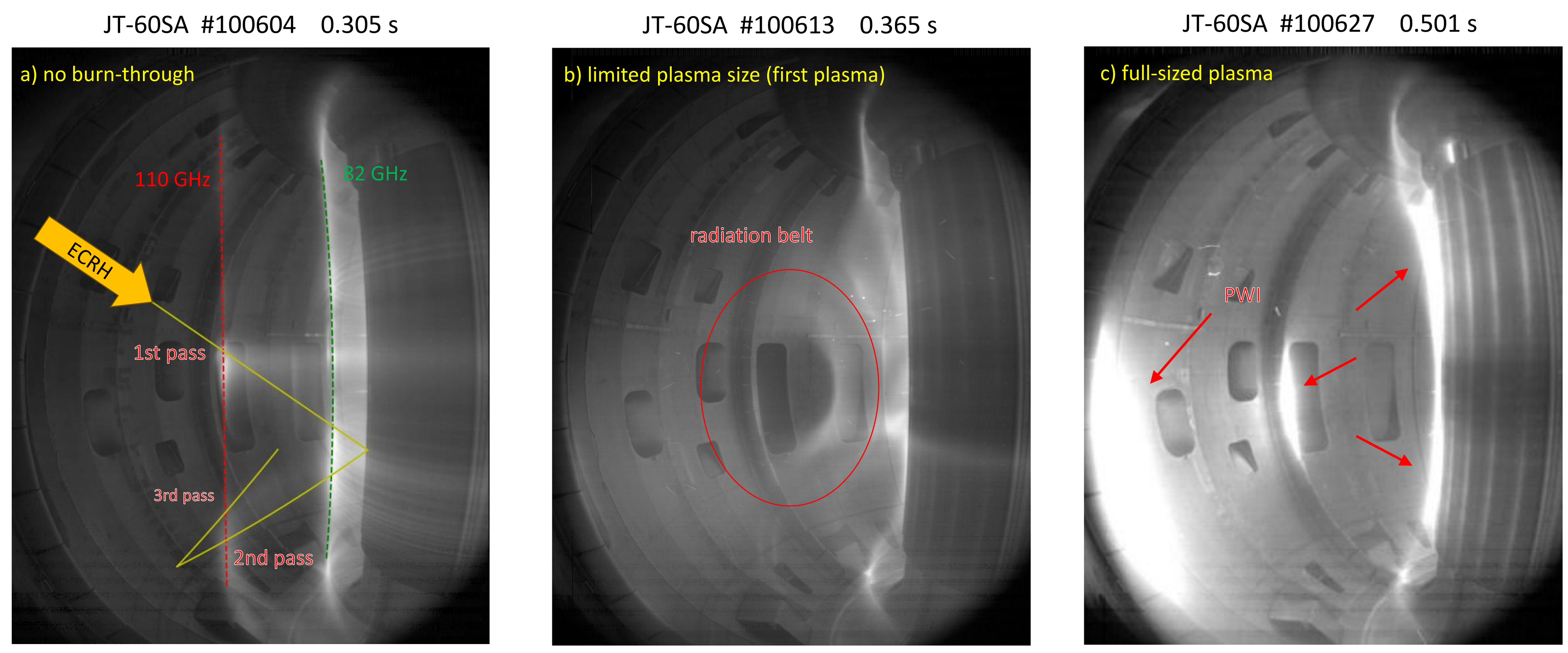
ABSTRACT

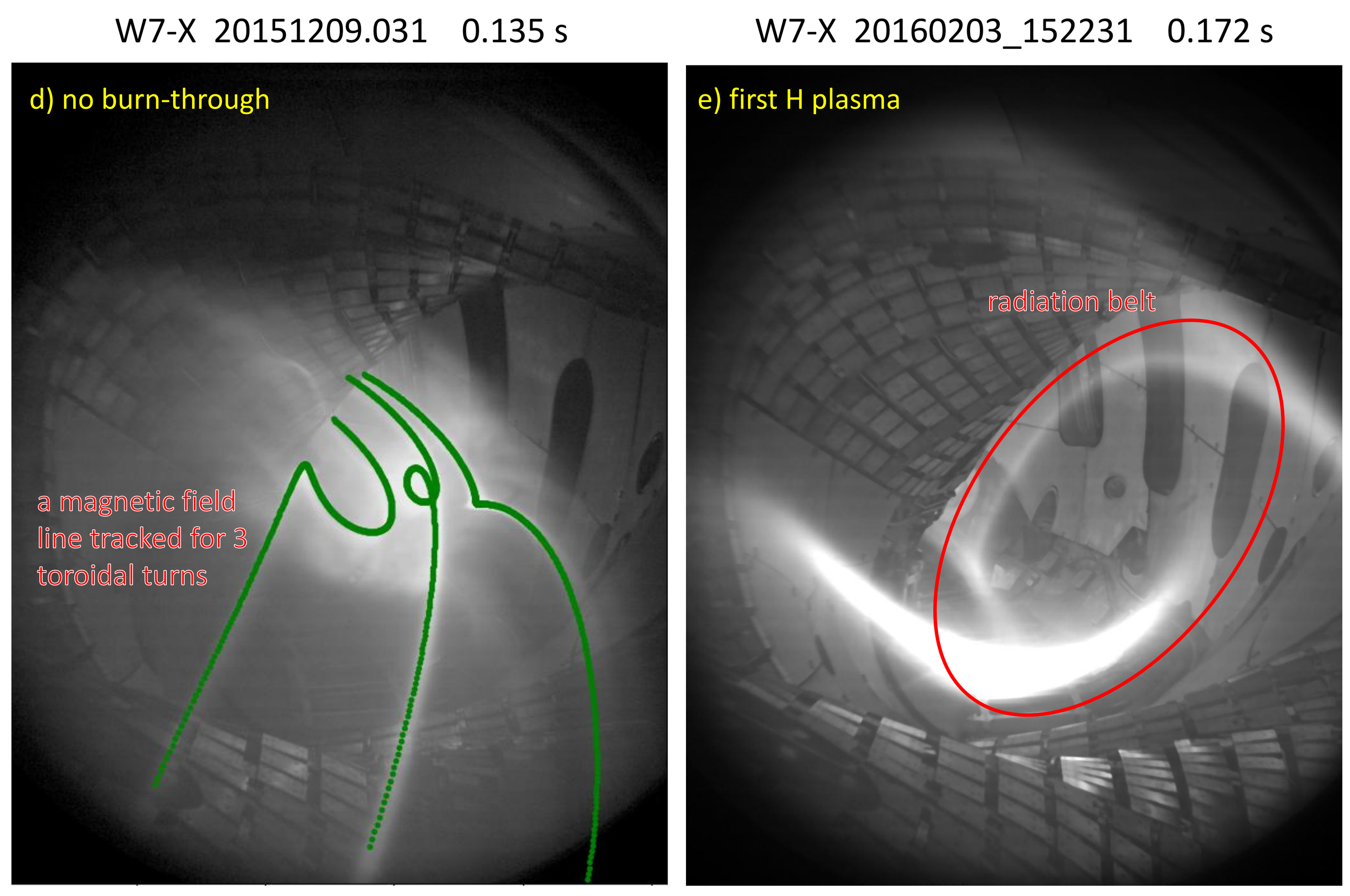
- The paper shows, through examples taken from Wendelstein 7-X and JT-60SA, two recent superconducting nuclear fusion experiments, the "hidden" qualities of video diagnostics.
- In both experiments, the successful achievement of breakdown and burn-through, as well as first plasmas were confirmed by general visible video diagnostic systems.
- At JT-60SA *runaway electron activity* was also observed using the EDICAM camera both via direct detection of synchrotron radiation and indirectly via the increase of pixel noise due to secondary hard X-ray emission.
- At Wendelstein 7-X the successful achievement and sustainment of *divertor detachment* could also be clearly observed by EDICAM cameras.

BACKGROUND

- In the early life of fusion devices, the available diagnostics are usually limited to a few line-integrated or point-like measurements. **Visible cameras**, on the other hand, provide *spatio-temporally* resolved results, even in 3D for some special cases.
- Visible video is usually among the first diagnostics BUT their full potential is rarely utilized.
- Visible cameras provide essential information for plasma operators, contributing to the success of *start-up campaigns*.
- Beyond these, visible camera recordings **alone** can deliver sophisticated results on various phenomena.

BREAKDOWN, BURN-THROUGH and FIRST PLASMAs

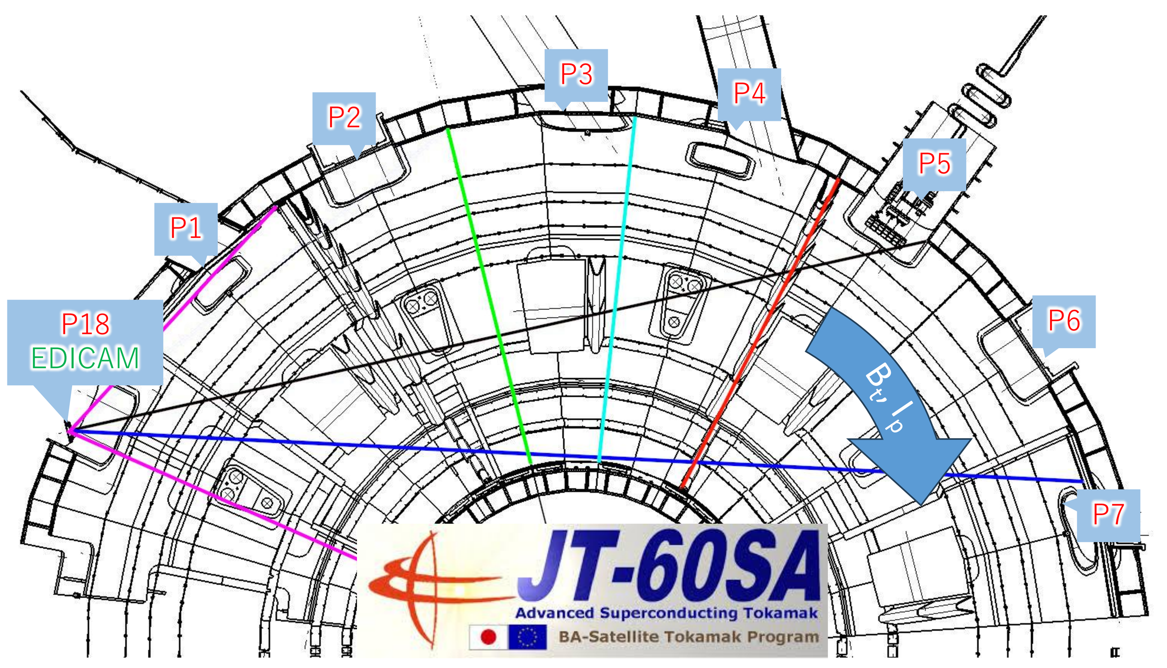


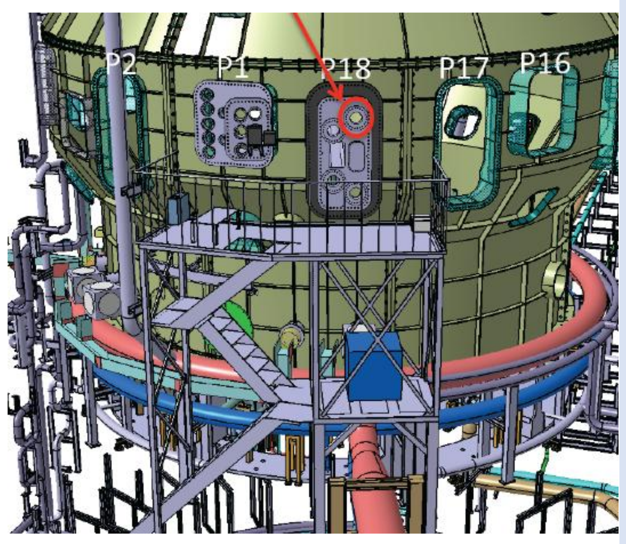


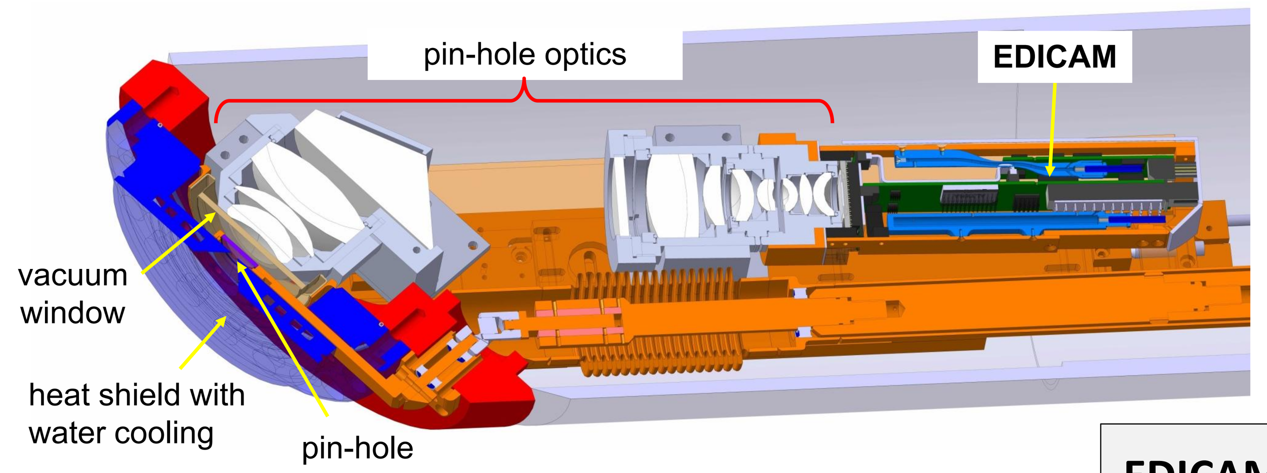
BREAKDOWN without burn-though
- no bulk plasma but localized regions
- emission follows vacuum magnetic field → unexpected patterns

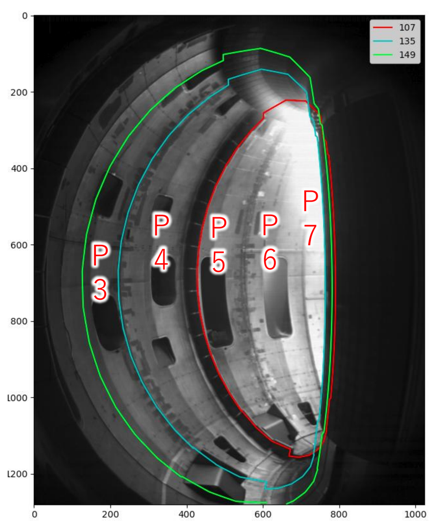
SUCCESSFUL burn-through
- significantly large bulk plasma
- small plasma → radiation belt
- ➢ confirm the formation of a plasma current channel w/ closed flux surfaces
- ➢ plasma size can be inferred
- full-sized plasma → PWI dominates

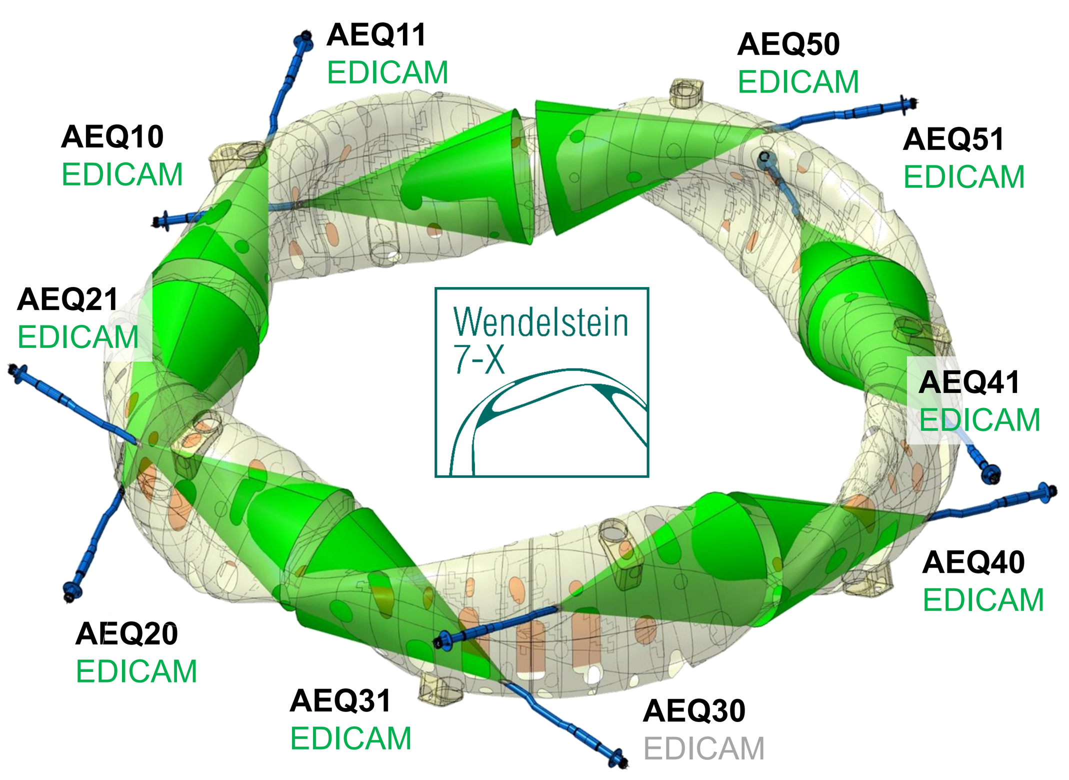
EXPERIMENTAL SET-UP at JT-60SA [1] and W7-X [2]

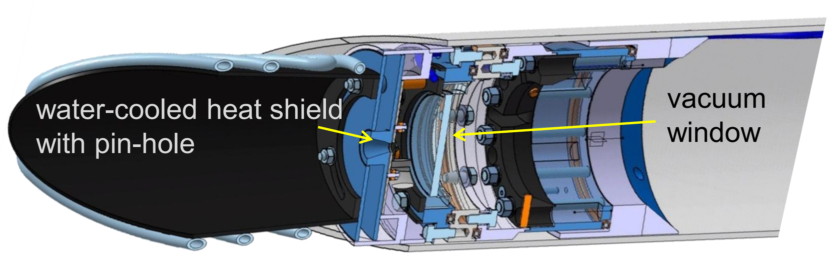




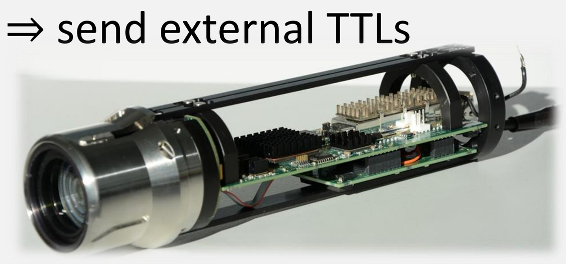






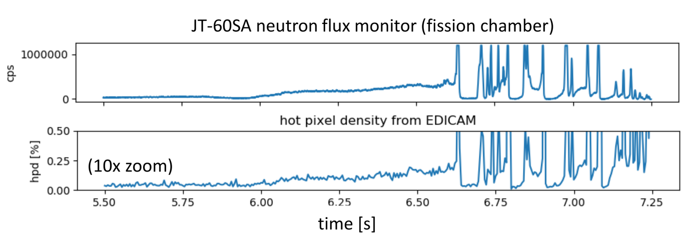


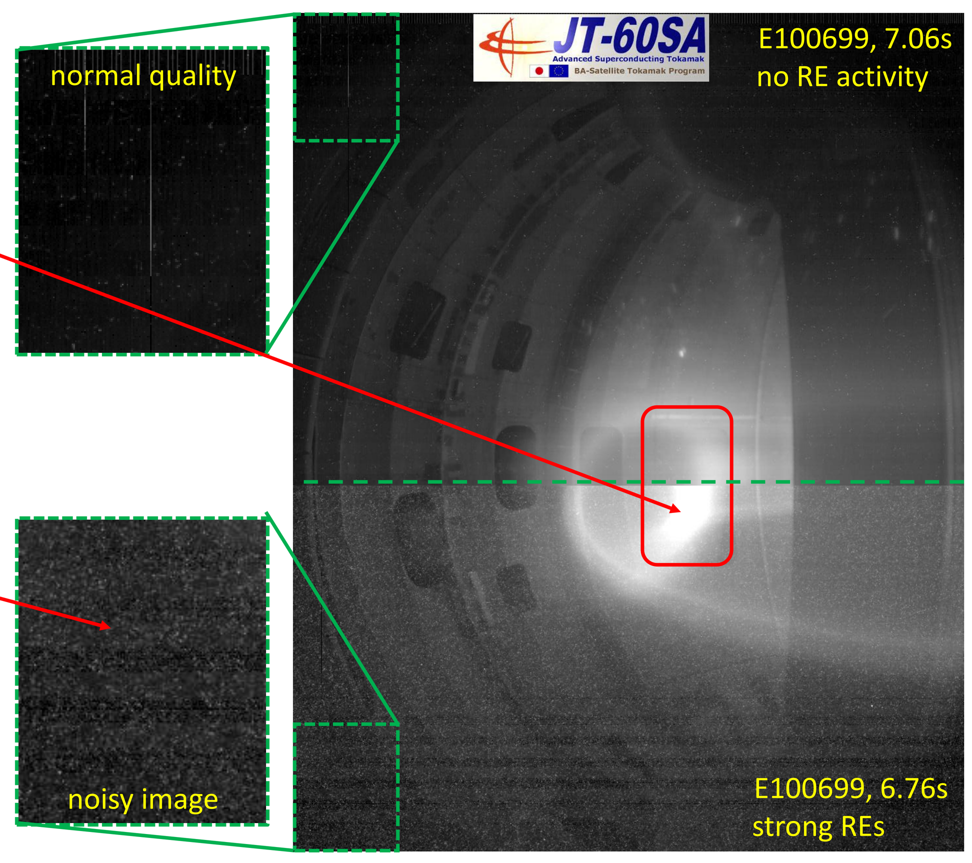
EDICAM [3] video diagnostics
- ➢ 10 EDICAMs @ W7-X [2]
- ➢ 1 EDICAM @ JT-60SA [1]
- 1280×1024 pixel CMOS
- Plasma overview: 50-400 Hz
- Fast monitoring (in parallel)
  - ⇒ up to 5 additional ROIs
  - ⇒ max. 50 kHz
- Real-time data processing
  - ⇒ start/stop ROIs
  - ⇒ manage storage
  - ⇒ send external TTLs



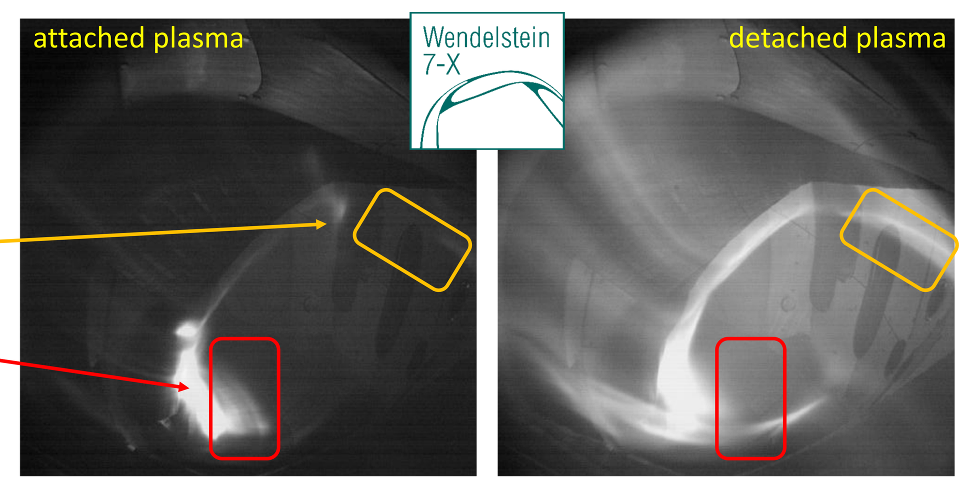
ADVANCED studies using (only) visible camera data

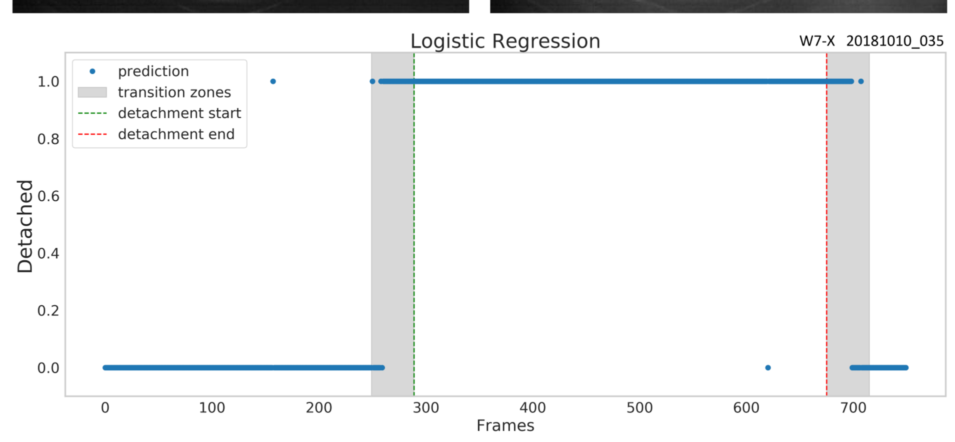
RUNAWAY electron detection
- direct observation (synchrotron)
  - ➢ crescent-shaped emission (not present during normal plasma)
- indirect observation (image quality)
  - ➢ RE impact → (H)XR emission
  - ➢ hot pixel density = fission chamber signal





DETACHMENT detection
- overall intensity increase
- additional localized emission
- fading of divertor strike-lines
- simple machine learning analysis [4]
  - ➢ logistic regression
  - ➢ fast method, real-time OK
  - ➢ F1 = $\frac{TP}{TP+0.5(FP+FN)}$ = 0.933
  - ➢ robust against magnetic configuration effects
- ✓ automatic detection of detachment





ACKNOWLEDGEMENTS / REFERENCES

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This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.