COMPASS
INSTITUTE OF PLASMA PHYSICS OF THE CAS

Analysis of tomographical reconstructions obtained from COMPASS tokamak data

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INTRODUCTION

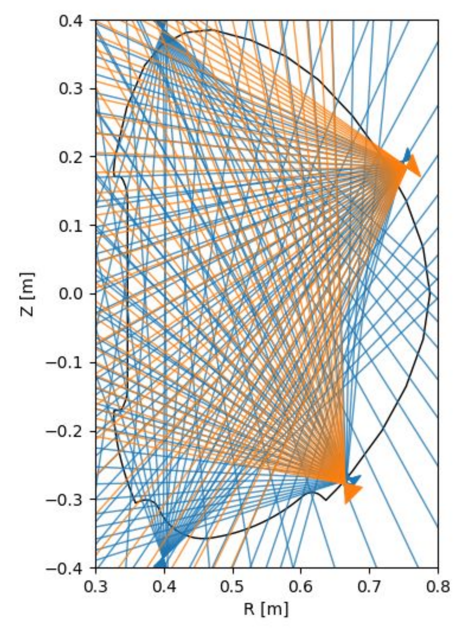
Tomographic inversion uses line integrated measurements of tokamak plasma radiation to provide spatial profiles. The emissivity reconstruction g_j is to be retrieved from line integrals f_i : $f_i = \sum T_{ij} g_j$ where T_{ij} is a geometry matrix. Special inversion algorithm must be used because of limited number of detectors and view angles. At COMPASS and other tokamaks Minimum Fisher Regularization (MFR) has been applied [1] and proved to be robust and reliable compared to other techniques. It contributed e.g. to transport studies [2] and to Runaway Electron studies [3]. Two sets of semiconductor photodiode detectors are used for tomography at COMPASS. Bolometric measurements are obtained using AXUV photodiodes and Soft X-ray (SXR) is measured using LD35-5T with beryllium filters with 10 μm thickness.

Tomography algorithm

Algorithms used for industrial or medical tomography can not be used on tokamaks. The main reason is limited number of observation angles. That is why discretisation and regularisation methods are used for inversion. MFR uses Phillips-Tikhonov regularisation that allows for regularisation that can include a-priori information. The most commonly used informations are requirements for smoothness. Current implementation supports both isotropic smoothness and anisotropic smoothing along flux surface

Comparative analysis and post-processing

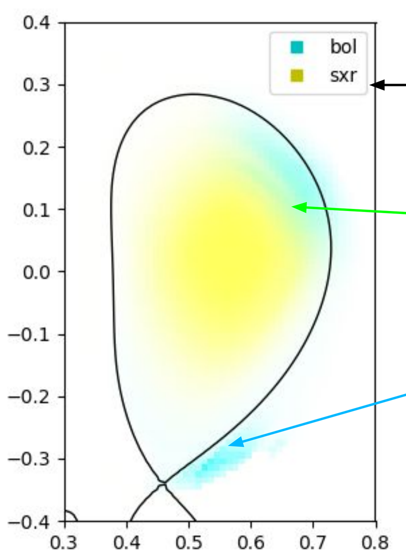
Displaying combined reconstruction or comparing results is for the most part made possible by using the same computation grid for all reconstructions.
These data can be further processed to obtain additional information about profiles or evolution of radiated power. [4]



Current layout of AXUV bolometers and SXR

Combining reconstructions

- Multiple reconstructions can be combined into one image using RGB coding.
- However different diagnostic systems can have varying spectral sensitivity and thus different signal magnitude.
- Therefore normalisation is required for this method.
- These images are then used for identifying regions of interest for further analysis
- Resulting color of each pixel is obtained by mixing basic colors with ratio determined by normalized radiated power



each reconstruction is represented by one of basic CMY colors

green pixels - SXR and bolometer normalized power is approximately the same

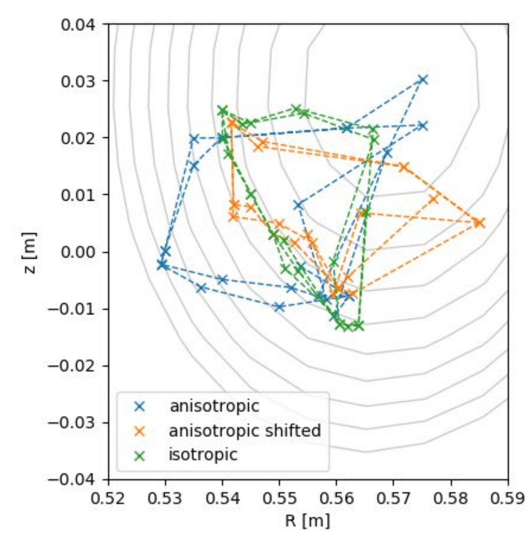
cyan pixels - bolometers are dominant, or others are zero

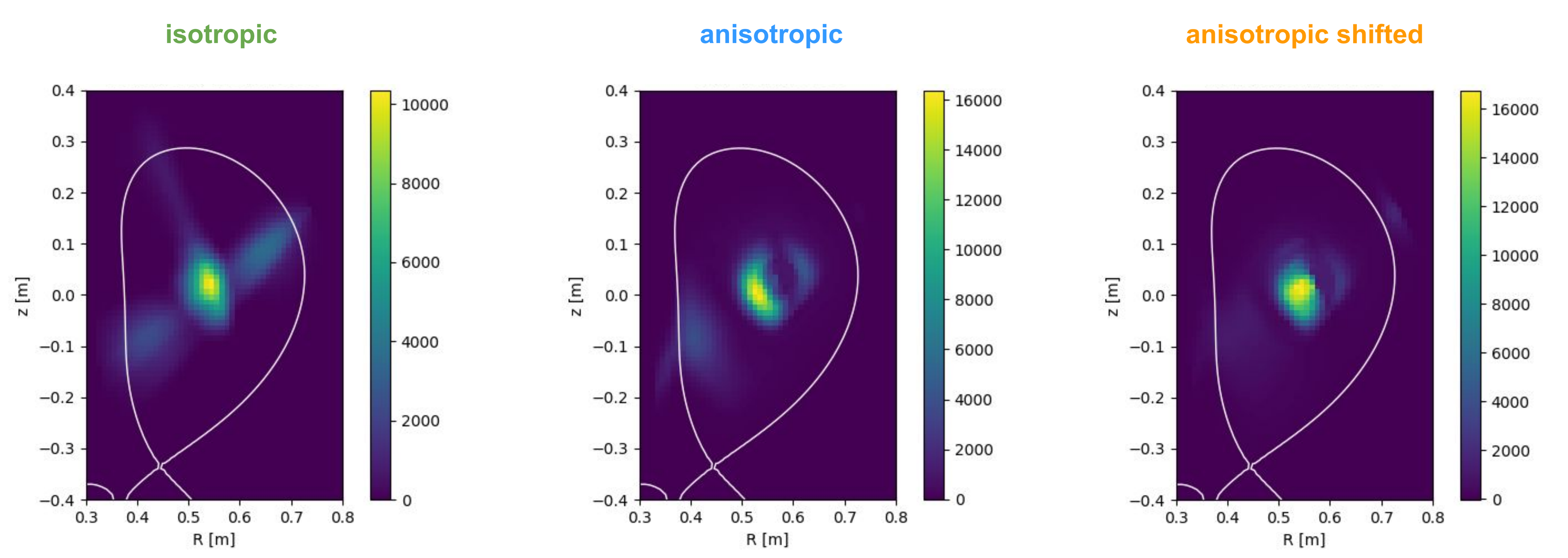
white pixels - reconstructions are zero or negligible

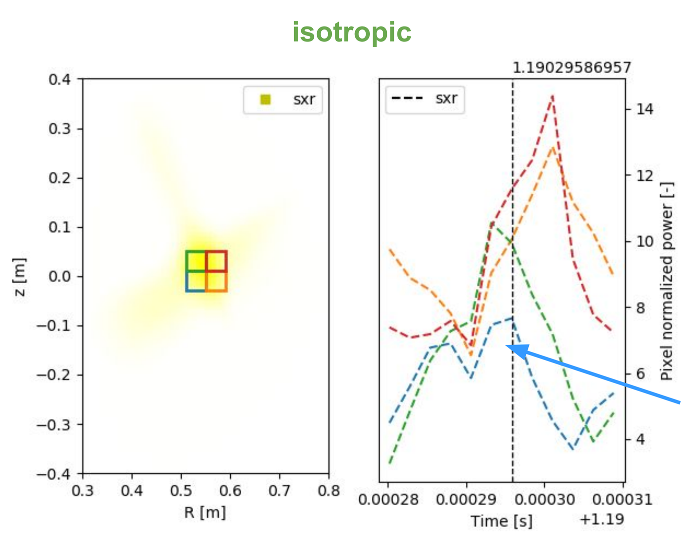
STABLE MAGNETOHYDRODYNAMIC MODE

 # 6071 observed by SXR diagnostic

- Stable magnetohydrodynamic (MHD) mode occurred during pulse 6071
- Data reconstructed using different regularisation methods
- Anisotropic smoothing that is routinely used (depends on EFIT)
- Verified by isotropic smoothing (independent of EFIT)
- Emissivity maximums rotated differently
- Magnetic axis from EFIT results seemed to be out of rotational center
- EFIT results were shifted and used for anisotropic regularisation



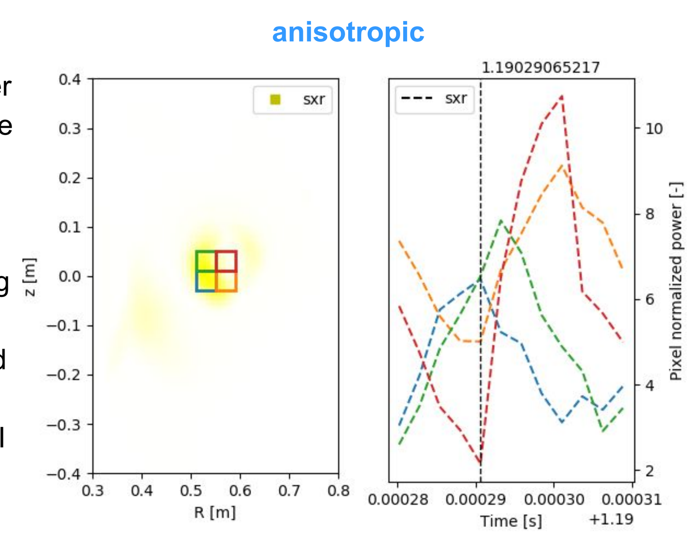




evolutions of radiated power from rectangular regions are shown on these graphs

rotation of mode can be observed by shifted peaking

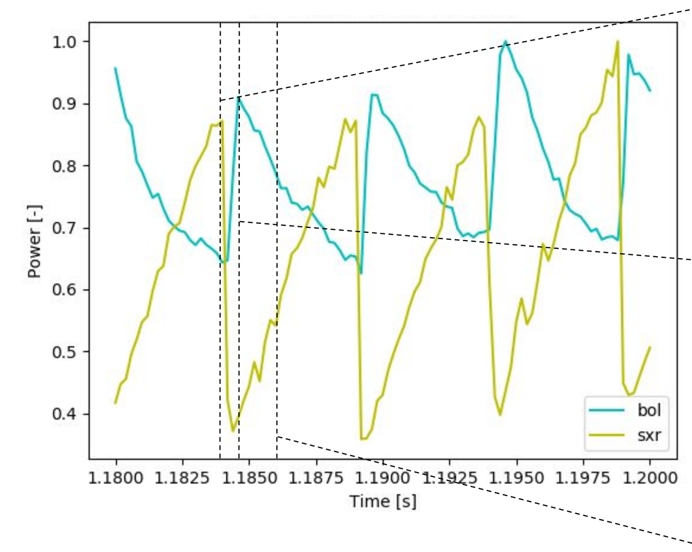
the second peak is believed to be caused by increased radiation from whole central region of plasma

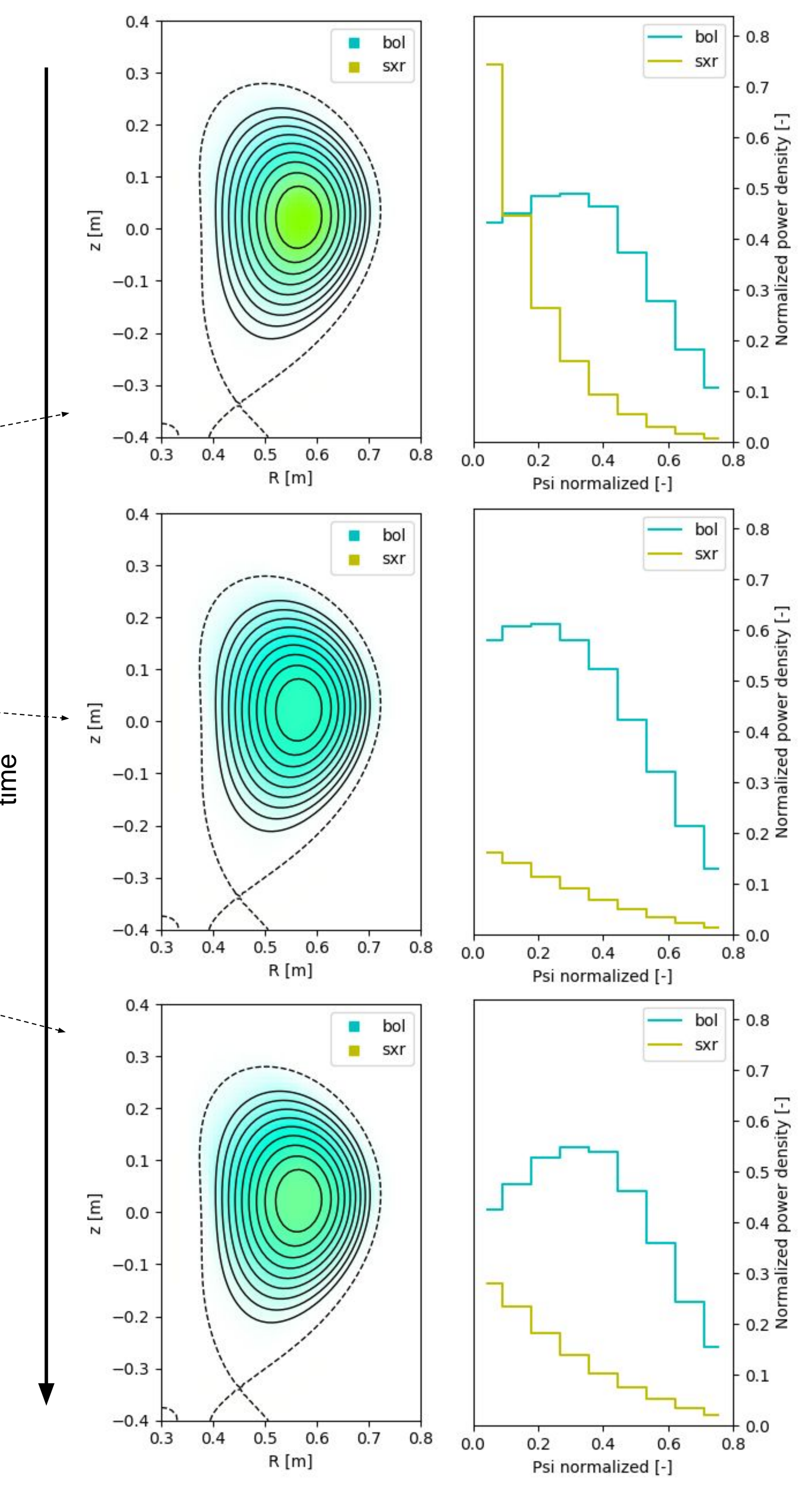


SAWTOOTH INSTABILITY

#19092 observed by both SXR and AXUV bolometers

- Sawtooth is a common instability occurring in tokamak plasma
- Named after characteristic shape of SXR radiation evolution [5]
- Below we can see normalized radiated power reconstructed by both axuv and sxr
- Vertical lines are located at approximate time when profiles shown on the right were created



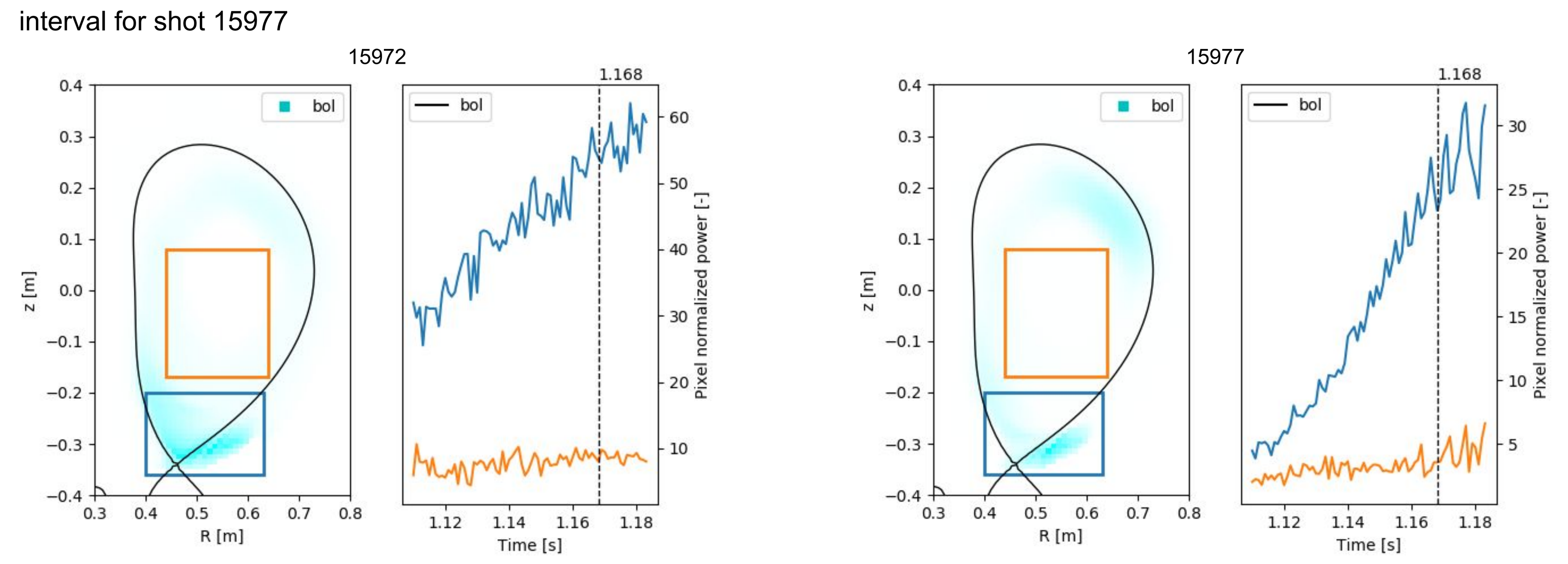


- Profiles measured by AXUV and SXR radiation are on the right
- The first profile is taken right before collapse of SXR profile, that is significantly peaking in the plasma centre
- The second one is taken immediately after the collapse when increase in AXUV recorded power can be observed
- The third one is taken after several milliseconds when SXR profile started to peak again, the AXUV profile is shifted more towards the plasma edge

PLASMA DETACHMENT

 # 15972 and 15977 observed by AXUV photodiodes

- Plasma detachment is a regime with substantial power dissipation in the edge plasma.
- Particles leaving plasma interact with injected impurity (nitrogen) before reaching PFCs
- This helps to significantly reduce heat fluxes on the divertor PFCs. [6]
- As a result of this interaction a strong emission occurs in divertor area, its evolution is of interest
- Saturation of undamaged camera occurred during pulse 15977 before disruption preventing reconstruction of emissivity immediately prior disruption
- Evolution of normalised radiation after impurity seeding can be seen in graphs below, impurity seeding rate used in 15972 was approximately half of that used in 15977, total radiated power was approximately 5 times larger at the end of observed interval for shot 15977



SUMMARY

- Post-processing tools were successfully implemented to tomographic reconstruction of COMPASS tokamak data
- Anisotropic smoothing using EFIT results can improve general shape of emissivity on whole poloidal section especially for reconstructions of hollow profile, as seen in sawtooth example
- However its accuracy has to be considered when examining small scale phenomena as demonstrated by MHD example
- Steeper increase of divertor radiation was observed for shot with greater seeding rate
- Normalisation required by universal nature of post-processing tools is limiting for phenomena requiring absolutely calibrated data. Development of tools for only one reconstruction series with absolutely calibrated data is planned.

Acknowledgement

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References

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