Comparison between X-ray measurements with the GEM detector and EFIT calculations

Danilo Pacella

Present address: JHU, Baltimore, MD
Permanent address: ENEA, Frascati, Italy

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Abstract

The curvature of the X-ray emissivity surfaces has been measured in the core by means of the X-ray pinhole camera based on Gem detector. These images have been compared with the EFIT calculations of the magnetic surfaces. For shots in L-mode or H-mode with moderate poloidal beta, the agreement is very good. Conversely for a shot in H-mode with high poloidal beta, the EFIT calculations disagree with the X-ray data, predicting a progressive increase of the elongation, while images show clearly an evolution toward circular shape.

Summary

Comparison X-images and EFIT

Shot #108727 L-mode 2MW (excellent agreement)

Shot #108670 H-mode 5MW low βp (excellent agreement)

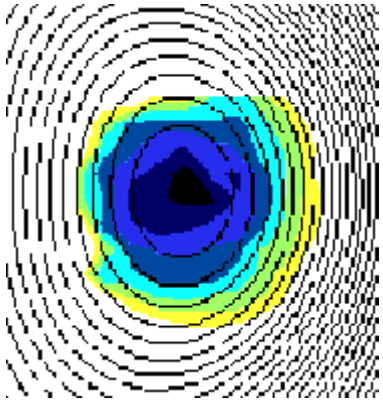
Shot #108729 H-mode 5MW high βp (excellent disagreement)

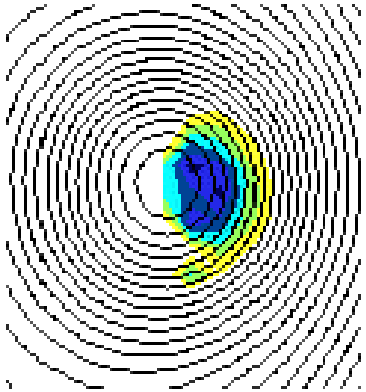
Time evolution of the measured and calculated elongation #108729

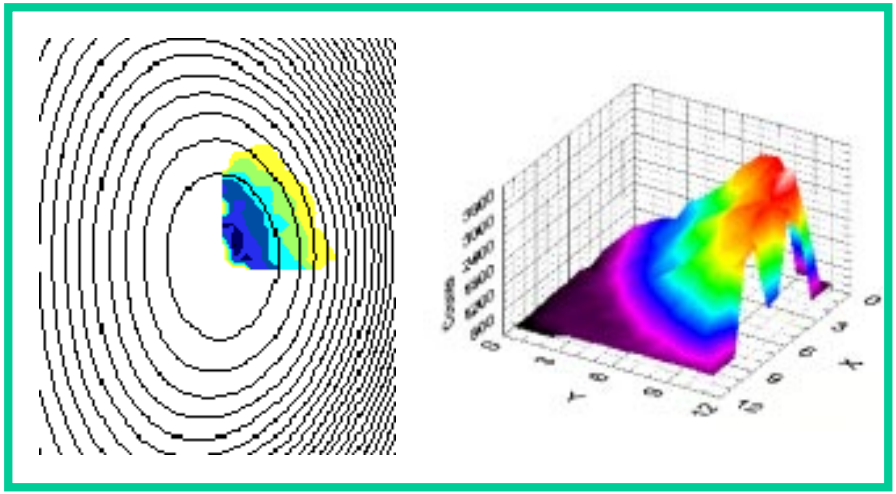
Axis of the X-ray emissivity

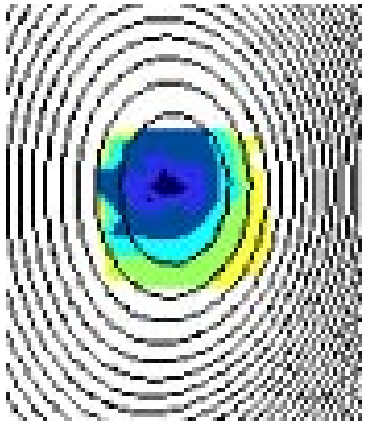
Pictures before the plasma collapse (just as entertainment)

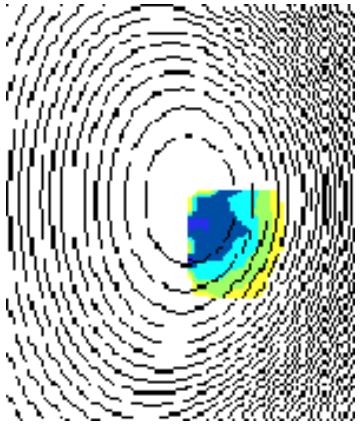
Examples of X-ray images with different magnitudes and views

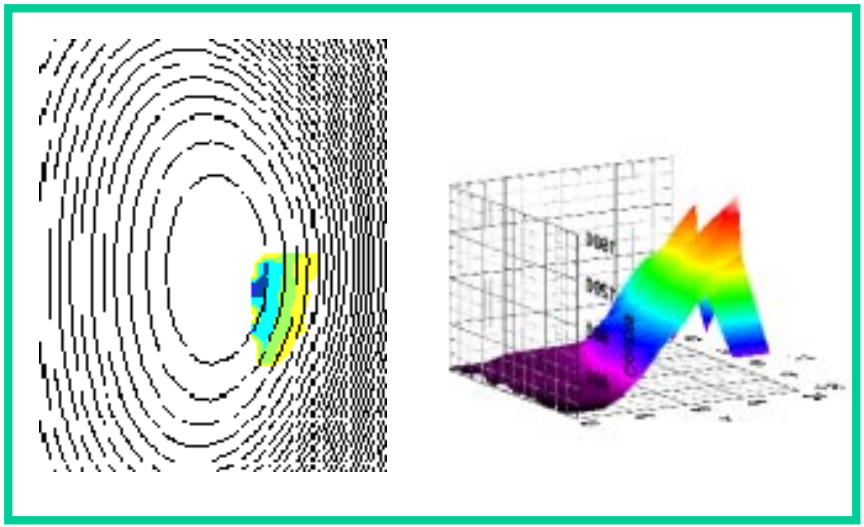




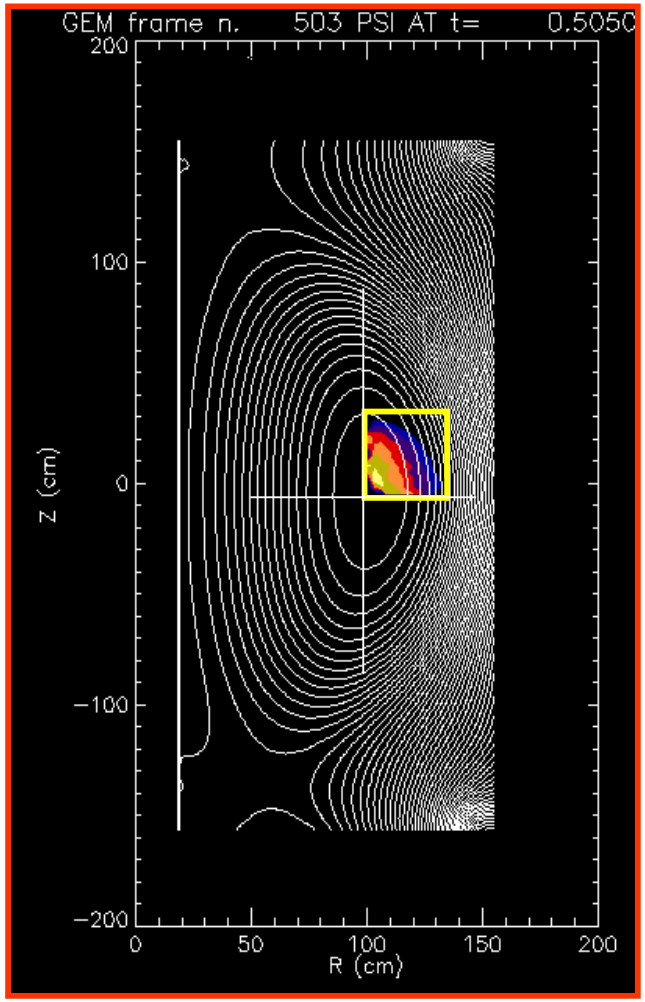








View for the shots #108670 , #108727 , #108729



External quadrant

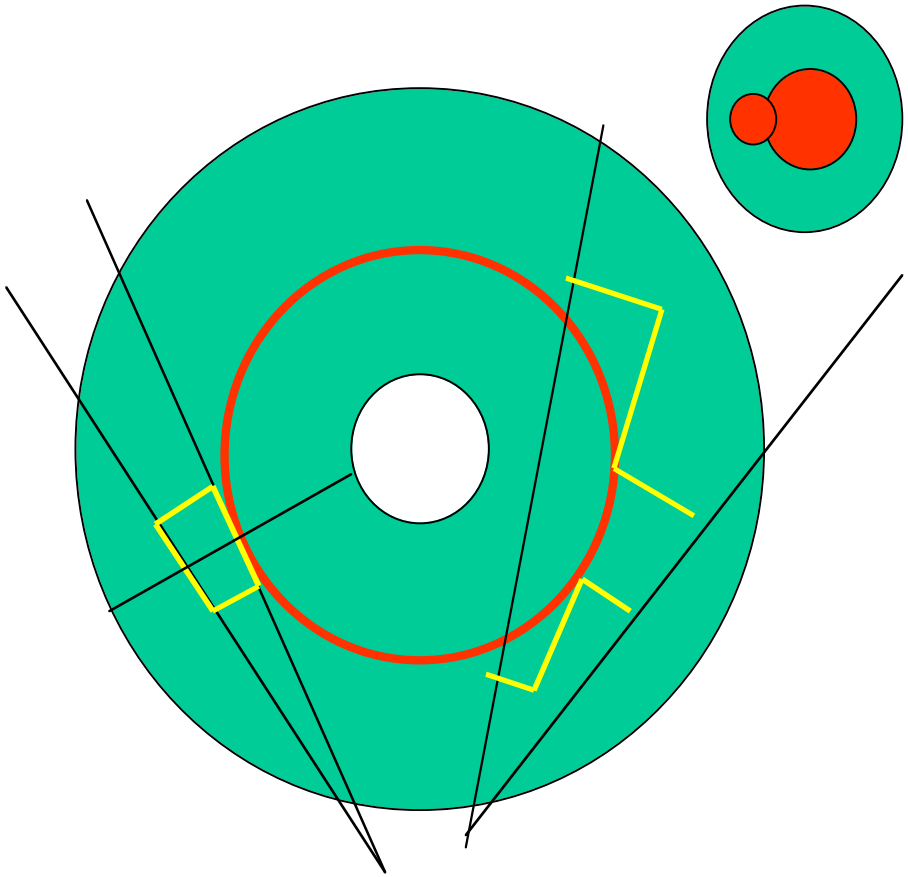
35 cm * 35 cm

100 < R (cm) < 135

-5 < Z (cm) < 30

Geometry and lines of sights

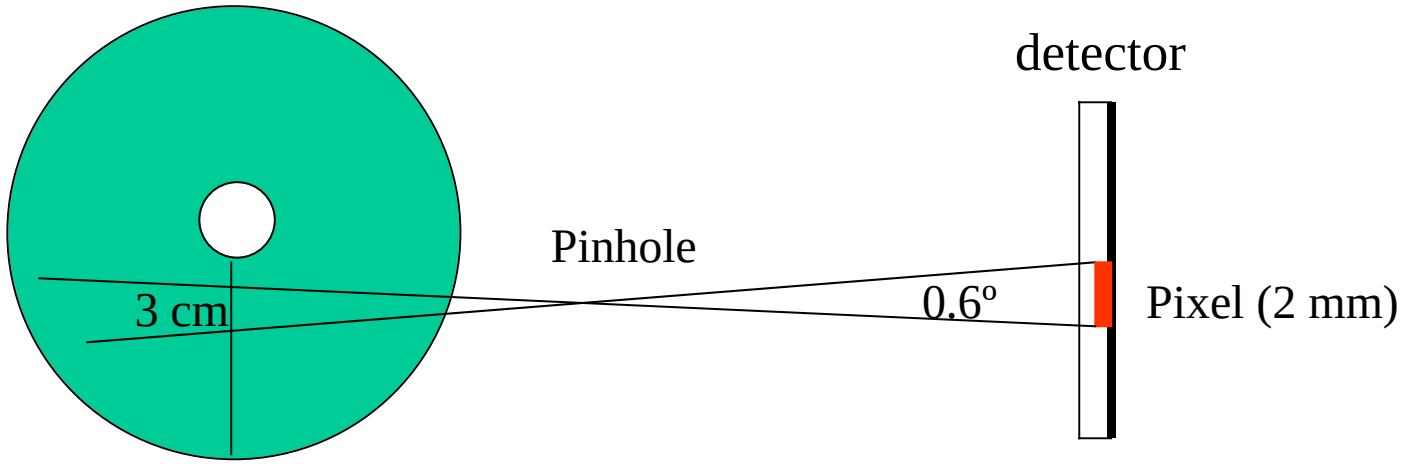
To assess how “thick” is the cross section of the plasma seen by the X-ray camera, a small code is required, taking into account the spectral distribution of the emissivity and the 3-D geometrical effect. (Code is under development)



Evaluation of spatial resolution and errors

- spatial resolution
- statistical fluctuation of the counts
- integration along the line of sight
    - geometric effects
    - strong dependence on the spectrum (Te)
    - weak dependence on Ne, Zeff

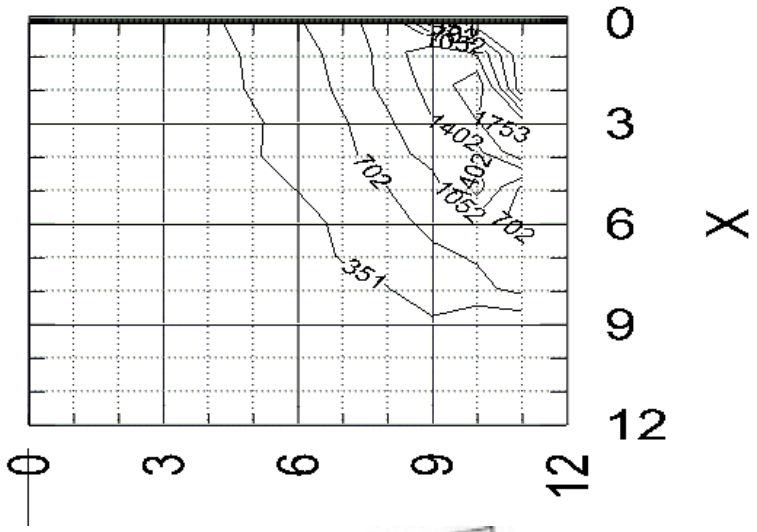
Spatial resolution

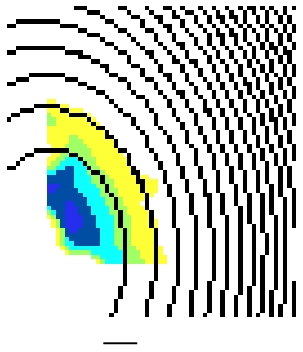


Processes inside the detector (conversion, drift, amplifiers) have a spatial uncertainty of about 100 μm, much smaller than the pixel size 2 mm

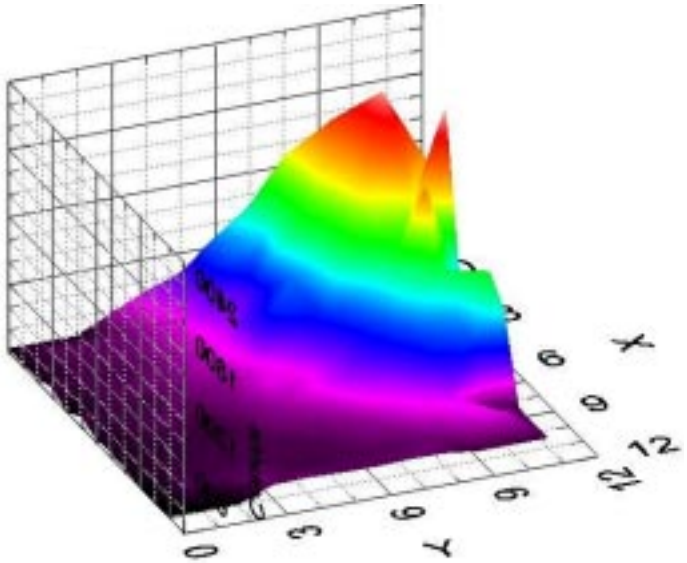
With the magnitude of 1/15 , the spot on the plasma is roughly 3 cm

Statistical fluctuation of the counts





6 cm ➡ 2 pixels



Statistical error

N (Counts/pixel) = 300 - 2000

N ~ 1000 ➡ $\Delta N/N < 3\ \%$

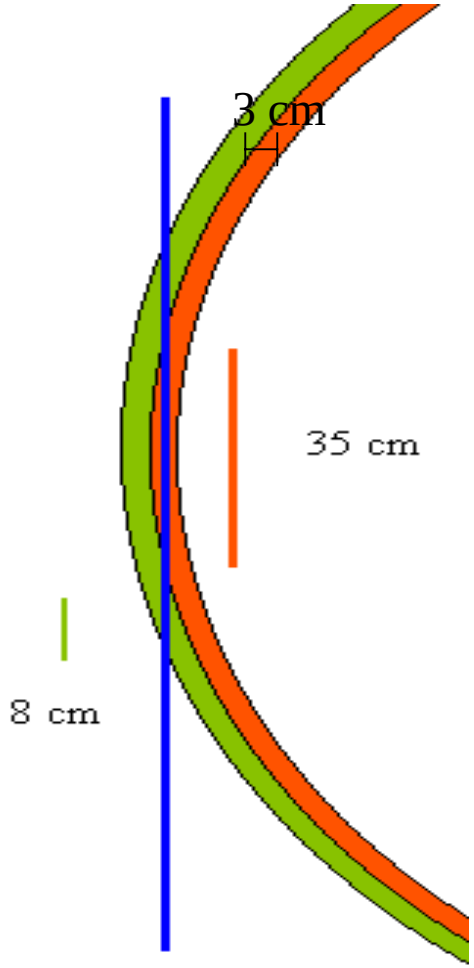
curve ➡ ~ 10 pixels ➡ Err ~ 1 %

Integration along the l.o.s.

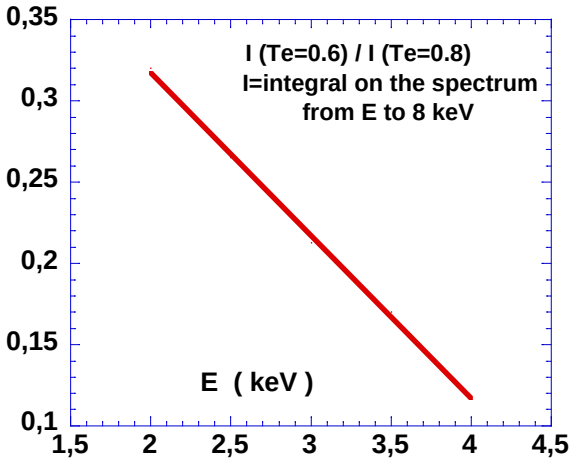
1) geometrical effects: spurious contribution of green layer to the main

2) Strong dependence of the spectrum (3- 8 keV) on Te (< 1 keV)

3) Weak dependence of the X-ray emissivity on Ne, Zeff



Increasing the lower threshold E of integration, the contribution of outer colder layers drops (E >> Te)
Signal also drops, but this device has sensitivity hundreds time higher than other X-ray devices.
This property can be used to increase the contrast of the image



In the present case

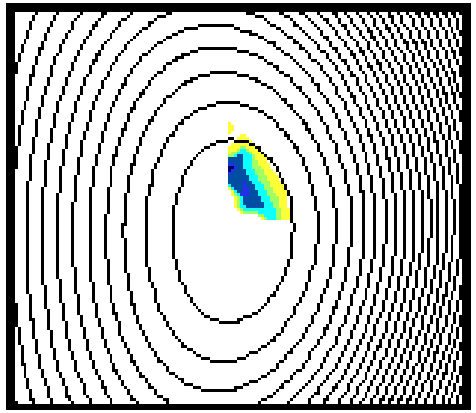
In the **worst conditions** (H-mode), assuming flat profiles for Ne and Zeff, the "geometrical" and the "spectral "effects (Te=800 eV, Te=700 eV) will give a contribution of the green layer of about **10%** and an effective thickness of the "cross section" of about 35 cm
With peaked profile the smearing effect becomes very small (a few %)

Uncertainty for the shaping (elongation) can be estimated of the order of 10 %

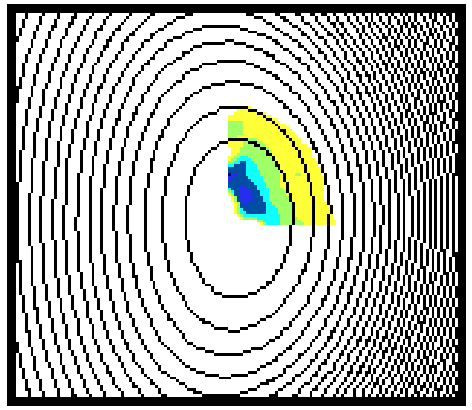
Comparison X-images and EFIT

Shot #108727 L-mode 2MW

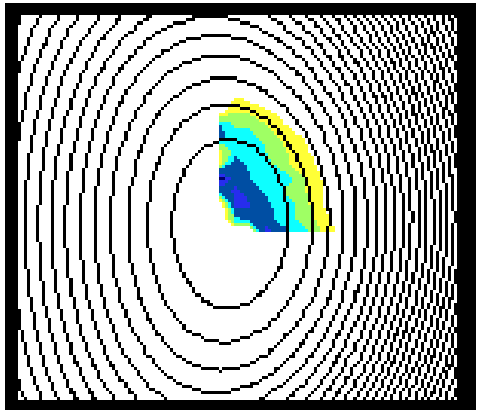
t = 0.25 s



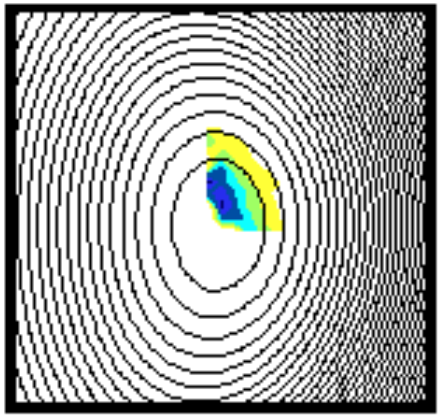
t = 0.30 s



t = 0.35 s

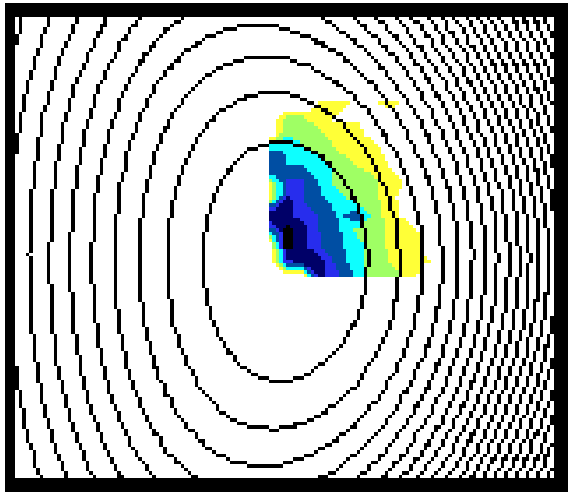


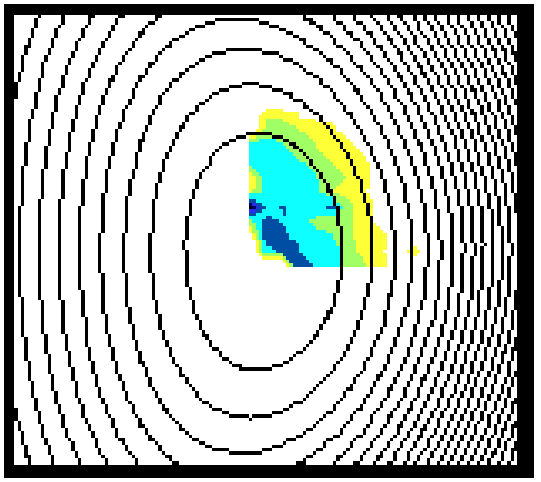
t = 0.45 s



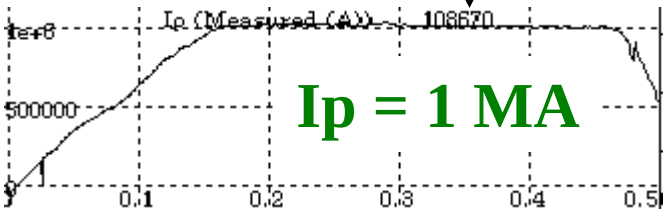
Shot #108670 H-mode 5MW $\beta_p = 0.7$: excellent agreement

t = 0.35 s

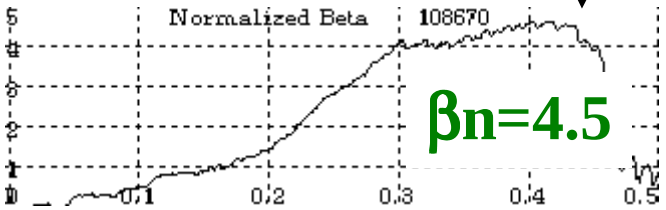




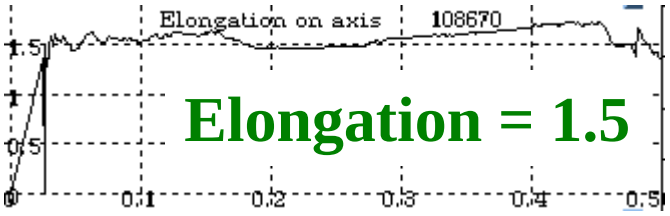
t = 0.45 s



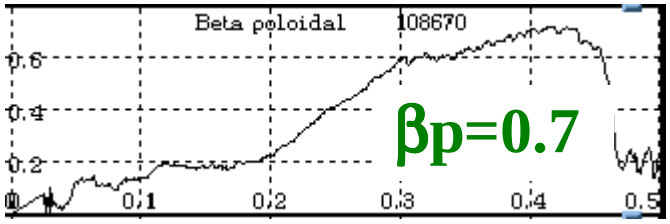
Ip = 1 MA



βn=4.5



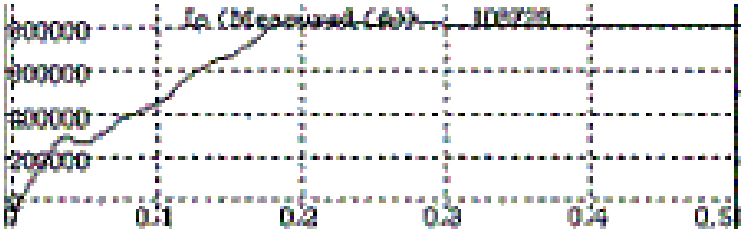
Elongation = 1.5



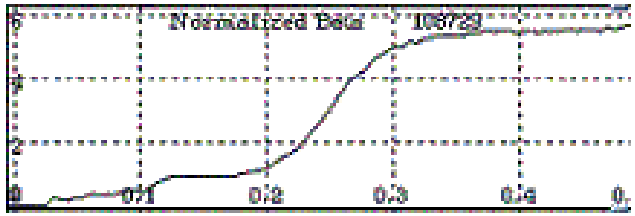
βp=0.7

Shot #108729 H-mode 5MW $\beta_p = 1.2$

EFIT predicts negative shear

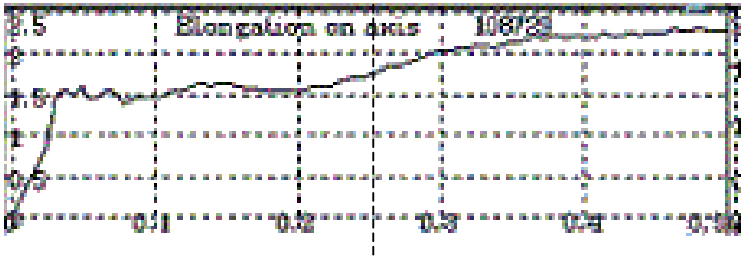


Ip = 0.8 MA



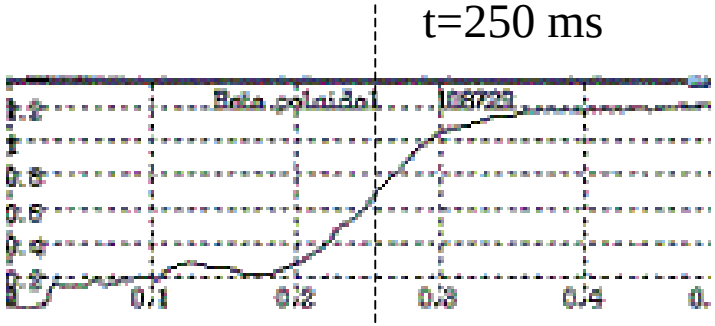
βn = 5.5

t=250 ms



Elongation = 1.5 - 2.3

t=250 ms

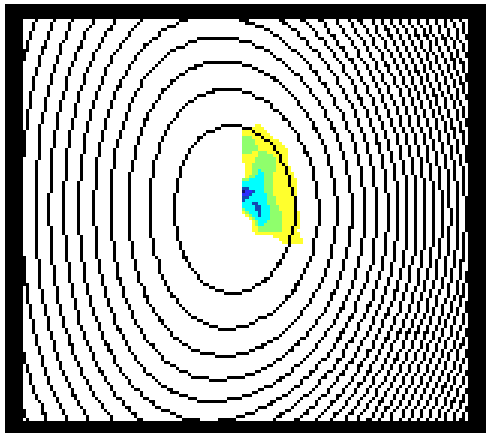


0.6

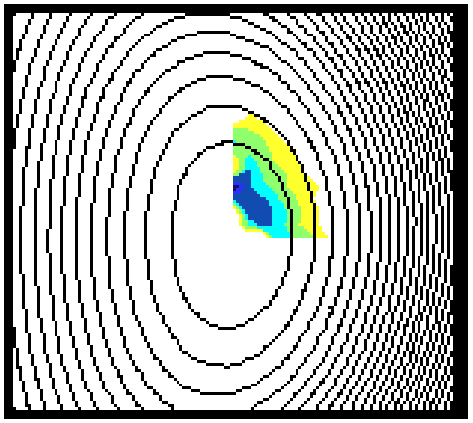
βp = 1.2

Shot #108729 H-mode 5MW $\beta_p = 1.2$: excellent disagreement

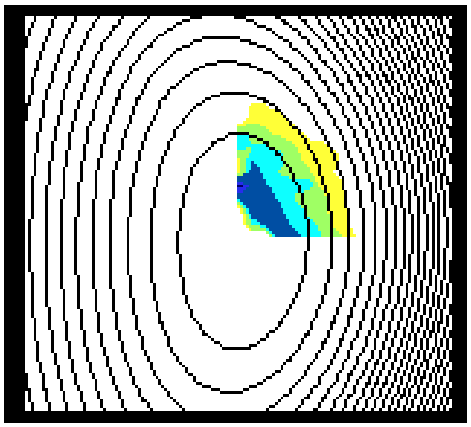
t = 0.20 s



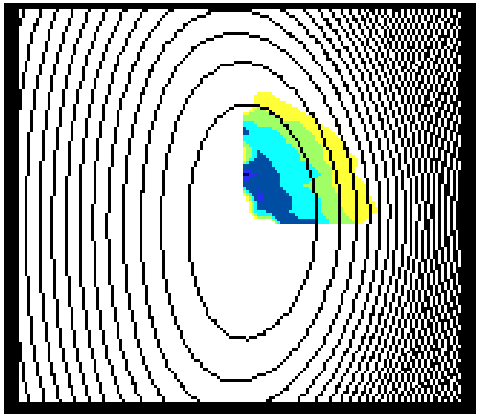
t = 0.23 s



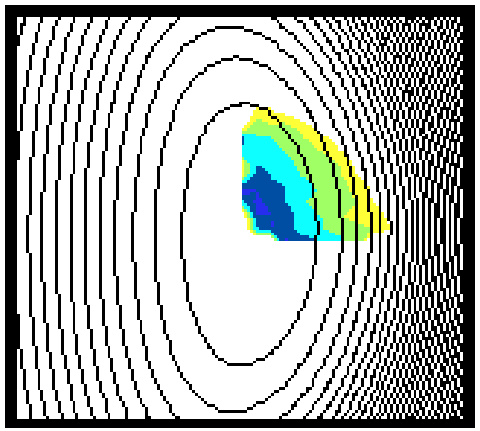
t = 0.27 s



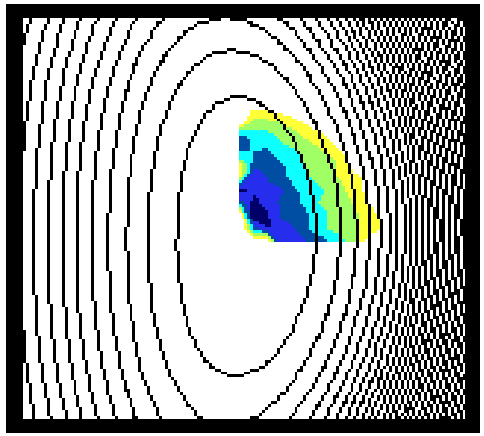
t = 0.31 s



t = 0.40 s

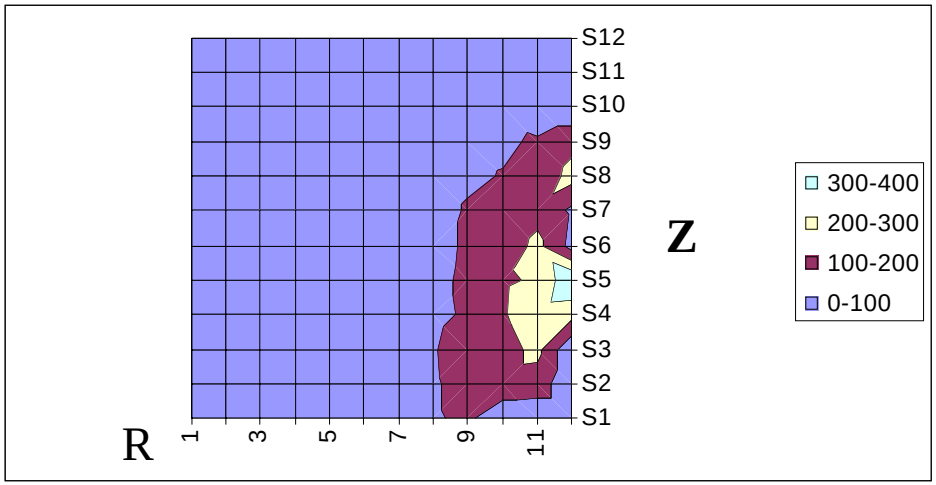


t = 0.50 s

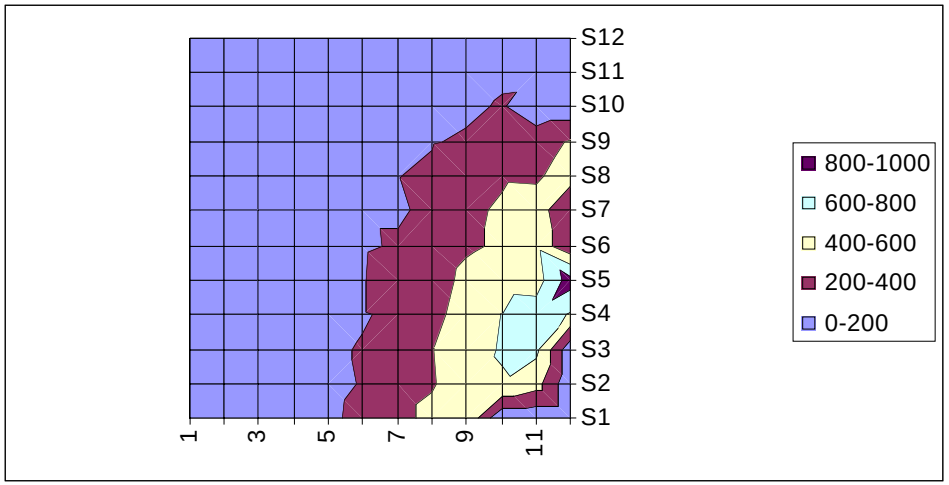


Time evolution of the elongation (#108729)

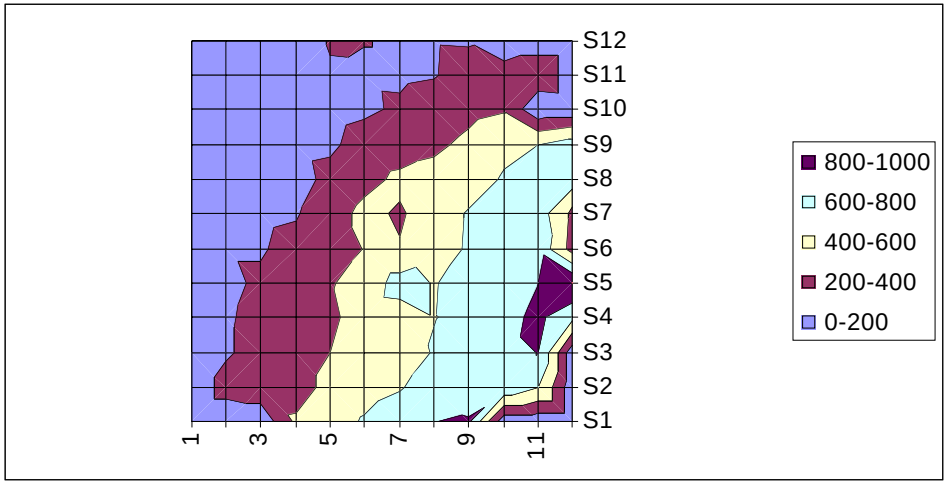
t = 0.2 s



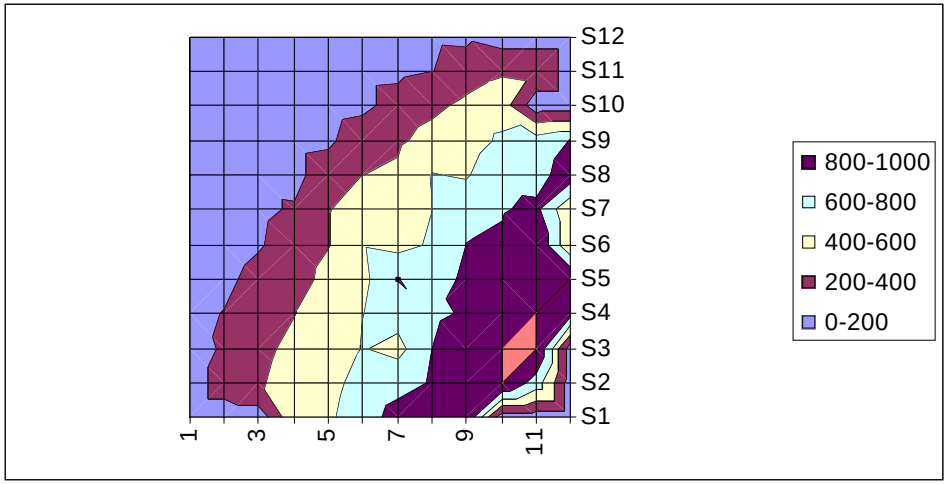
t = 0.23 s



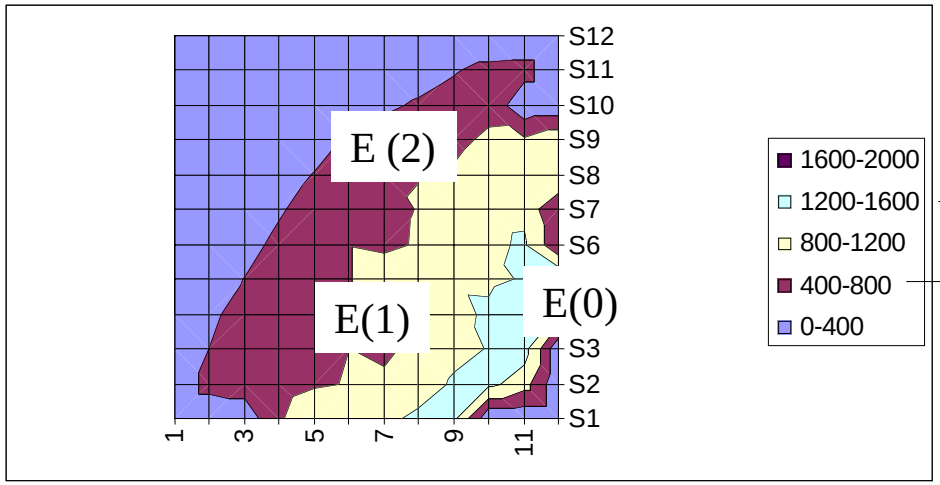
t = 0.27 s



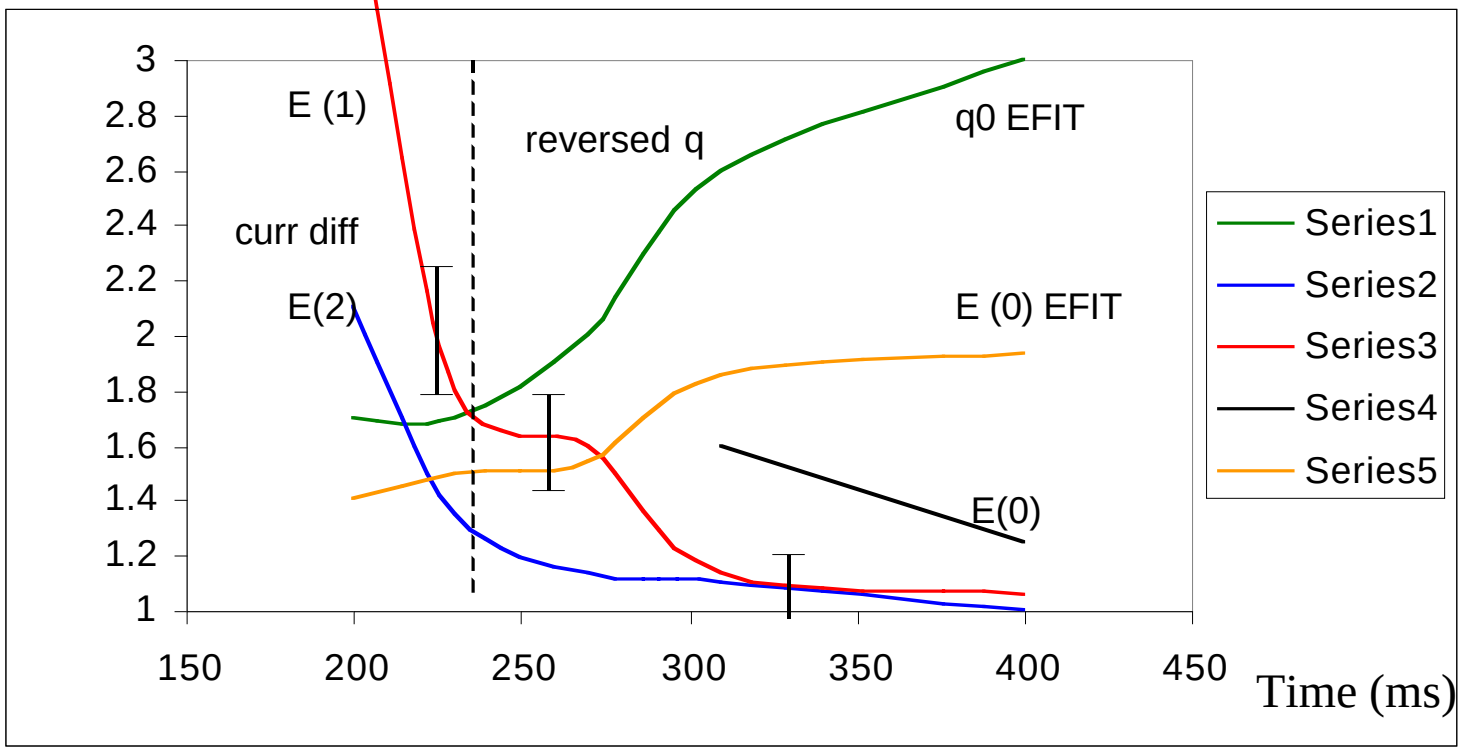
t = 0.31s



t = 0.4 s



Elongation (E), q



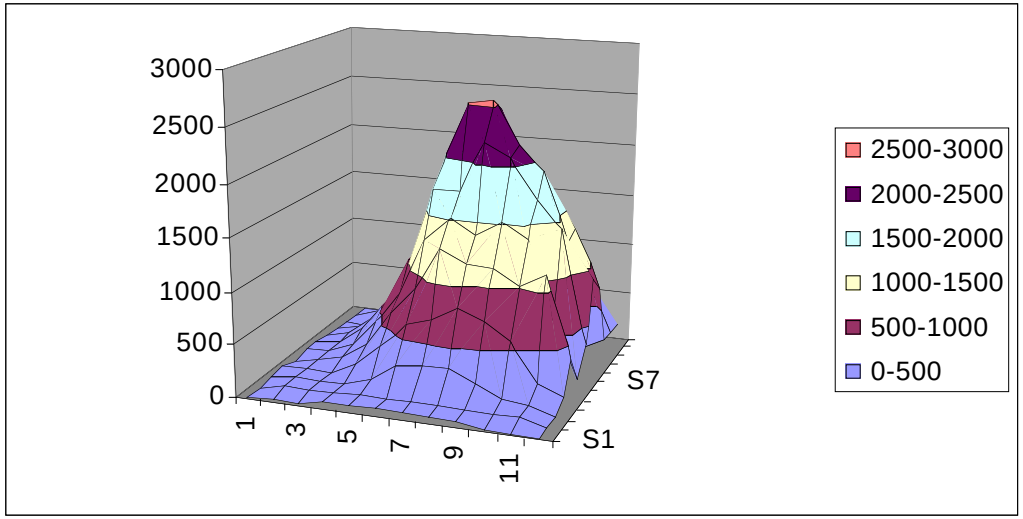
Δ (pixel) = 2 – 7 %

Comments

- Contour-plot of the X-ray emissivity surfaces can be extracted by the images
- Elongations of the different surfaces can be assessed
- Images can be acquired at 1 khz and used as constraint for EFIT calculations

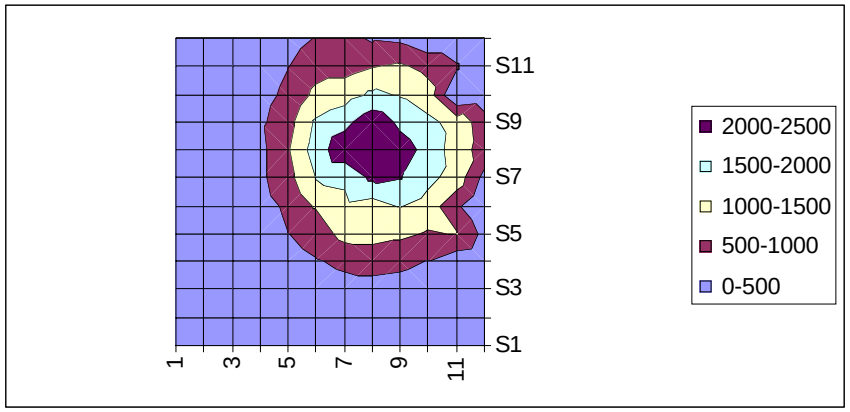
- **N.B. All the presented images are pure raw data**

Axis of the X-ray emissivity

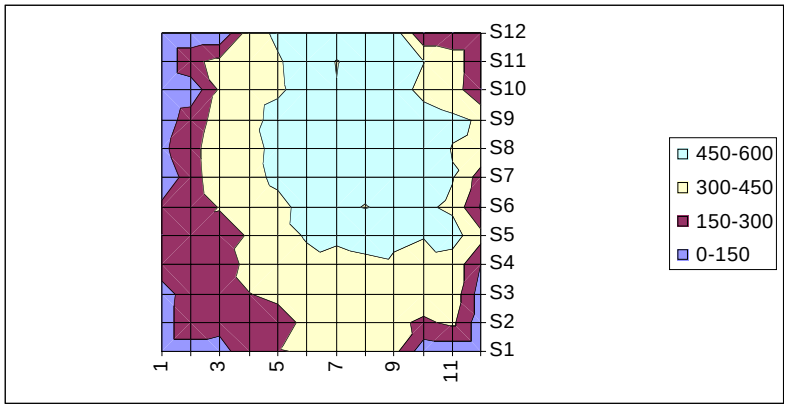


The position Zc, Rc of the center of the emissivity (magnetic axis) has been calculated and studied vs time for two shots

 # 107314

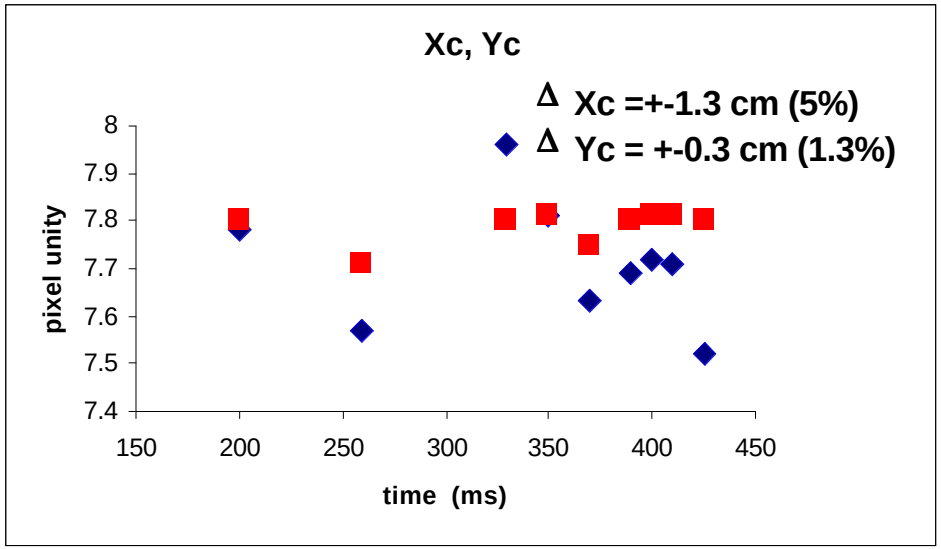


 # 107390



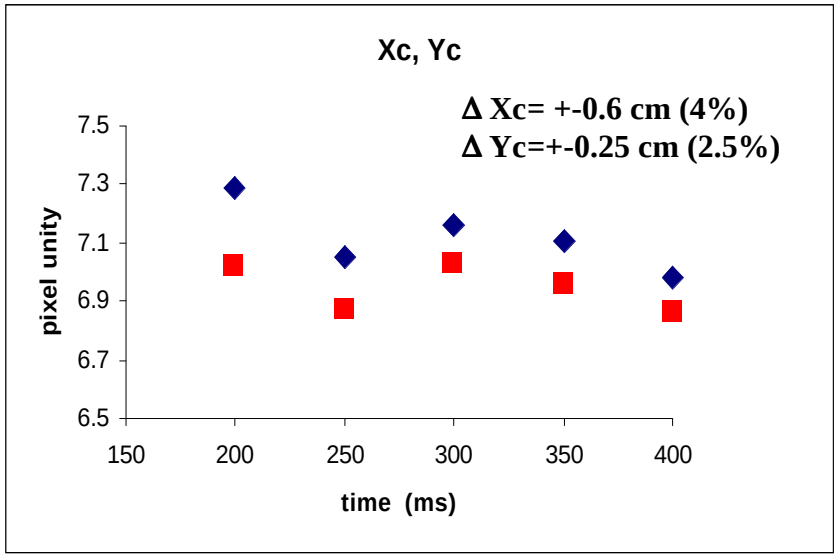
 # 107314

Ip=900 kA 5 MW NBI (350-500ms)
βn=5 βp=0.8



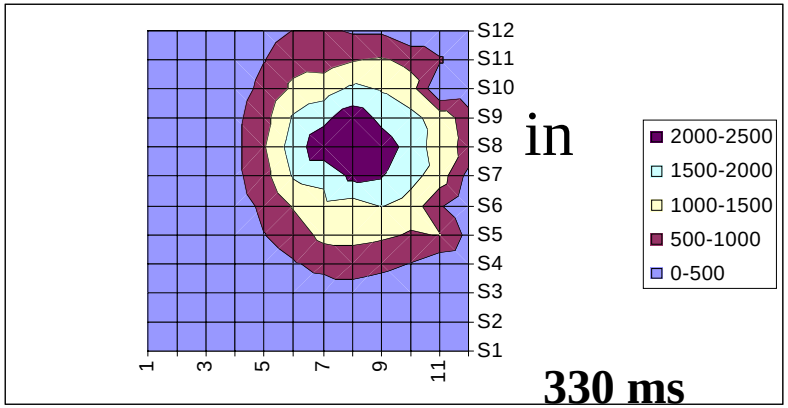
 # 107390

Ip=900 kA 2 MW NBI
βn=3 βp=0.5

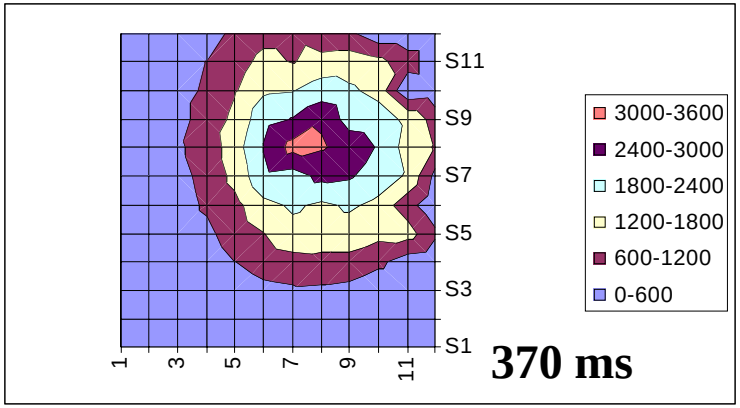


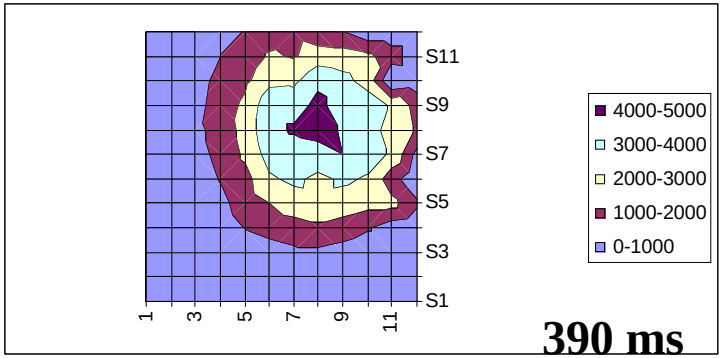
Fluctuations of the position of the ”magnetic axis” are less than +-1.3 cm (5%) for these two shots
(Statistical uncertainty less than 1%)

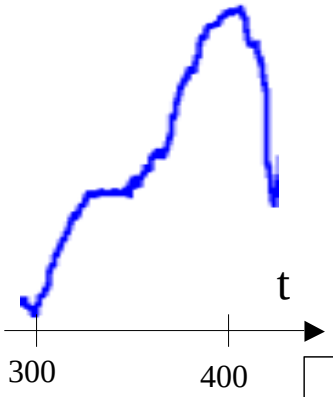
Final Entertainment: # 107314 0.9 MA 5 MW NBI

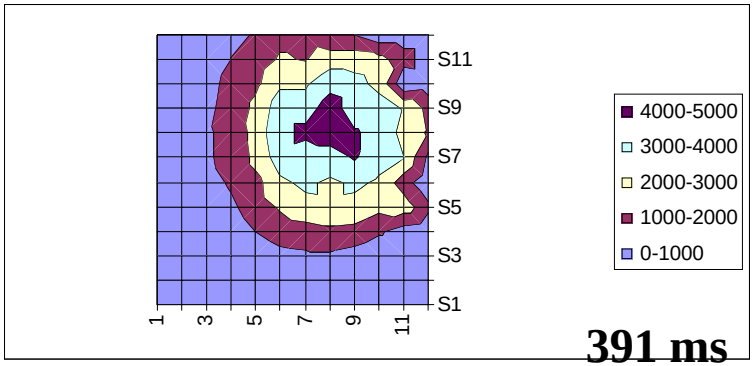


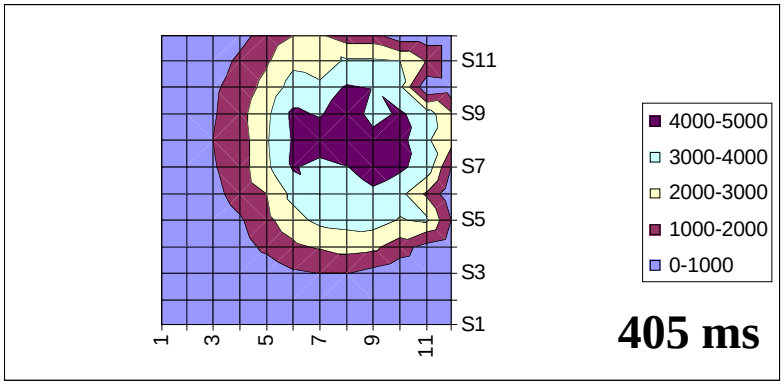
in

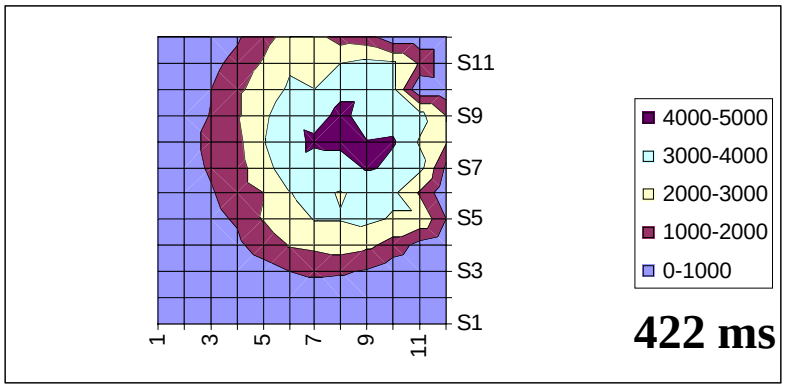




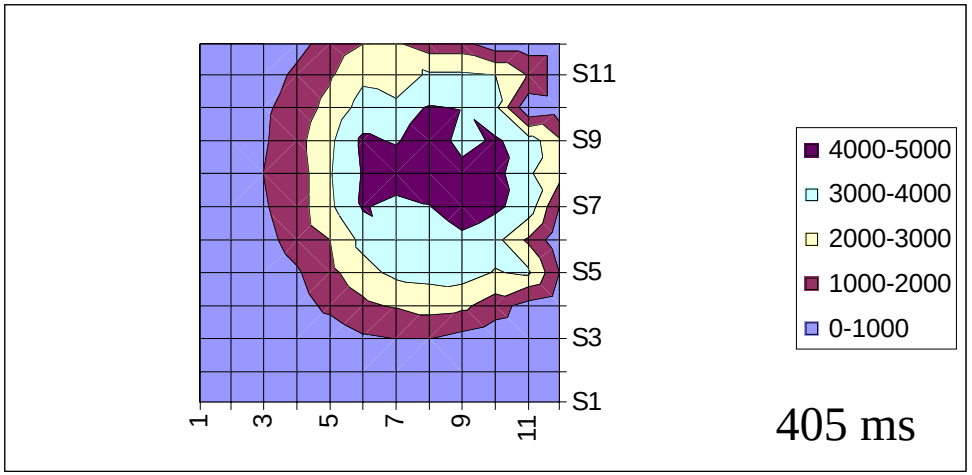




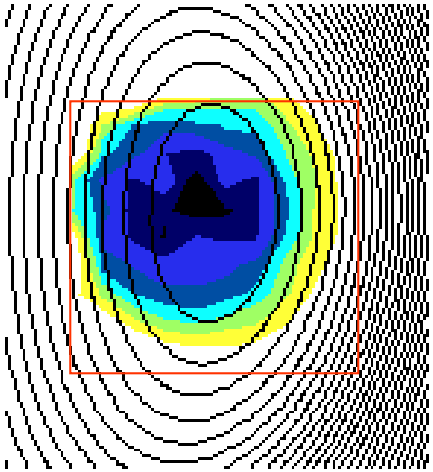




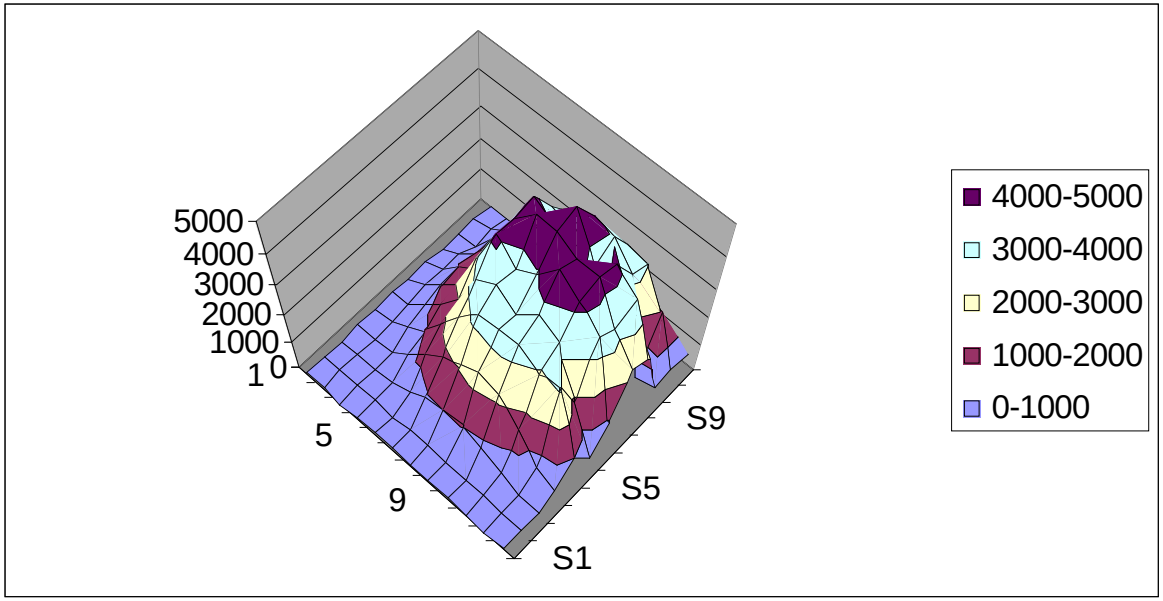
107314



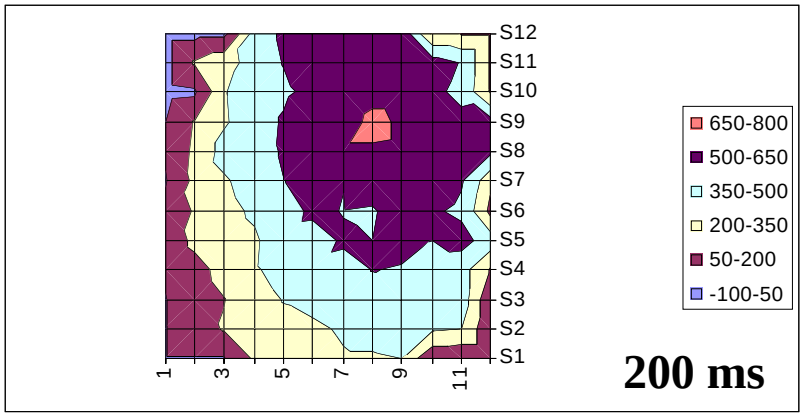
in

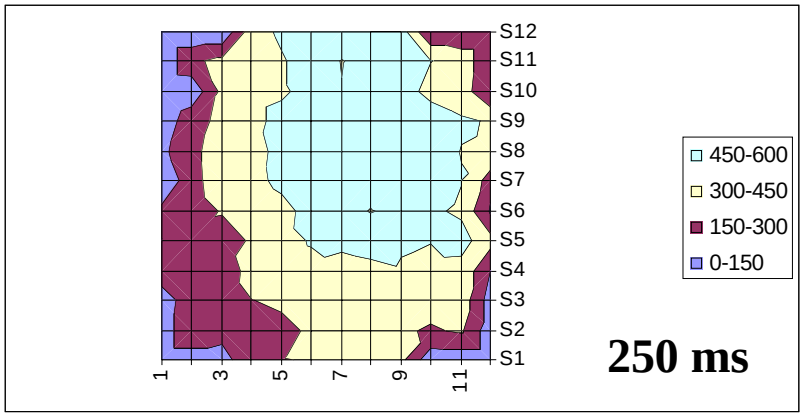


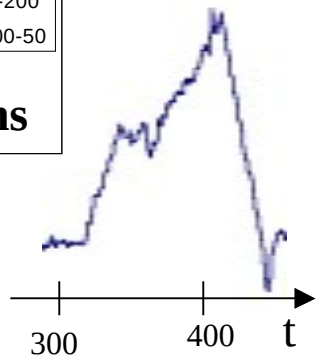
410 ms

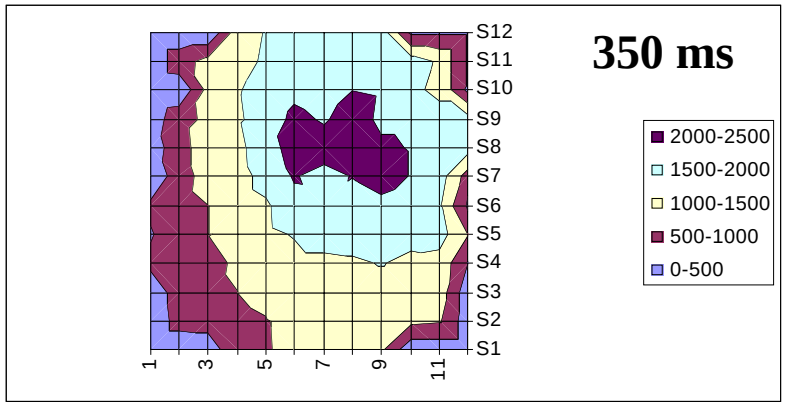


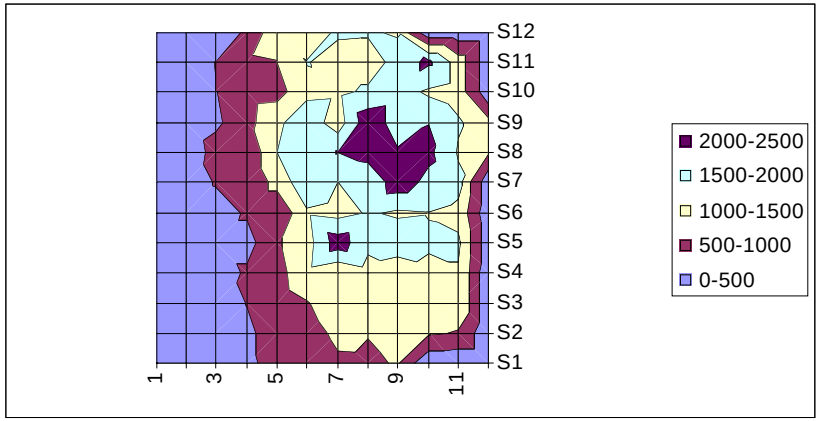
107390 0.9 MA 2 MW NBI











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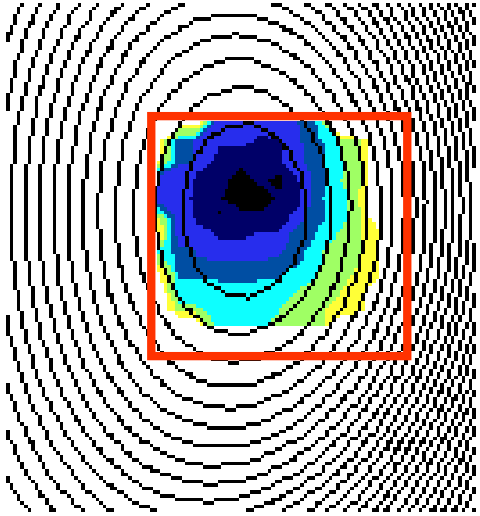
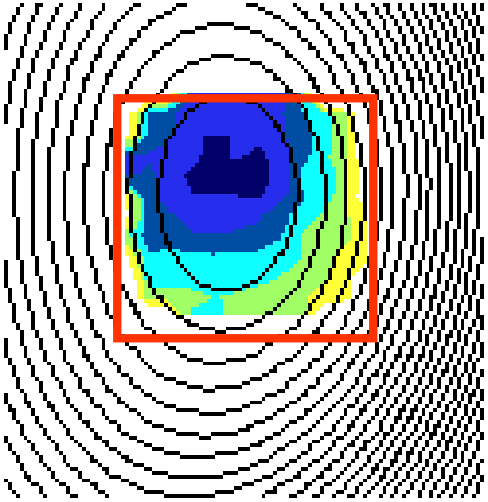
Before the collapse

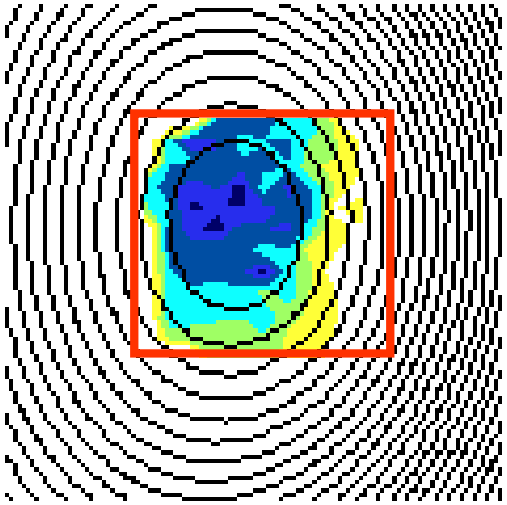
During the collapse



t = 350 ms



t = 370 ms



t = 420 ms

CONCLUSIONS

- Curvature and elongation of the X-ray emissivity surfaces has been measured with sampling at 1kHz
- Shots at moderate poloidal beta show a good agreement between X-ray images and EFIT calculations, while at high poloidal beta EFIT reconstruction is wrong
- These X-ray images can be used to constrain EFIT
- “Magnetic axis” inferred by the X-ray emissivity for two shots, shows fluctuations in its position less than 1.3 cm. In general it can be monitored at tens of Khz;
- A few pictures, just before and during the phase of confinement loss, show complex core patterns

..and now is time to…….. give a name to this system

Plasma Imaging X CounterS

Happy Birthday PIXCS

Please, don’t call me GEM anymore !!!!!!!!