NSTX-U

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Toroidal asymmetry of 2-D divertor heat flux profiles during the ELM and 3-D field application in NSTX

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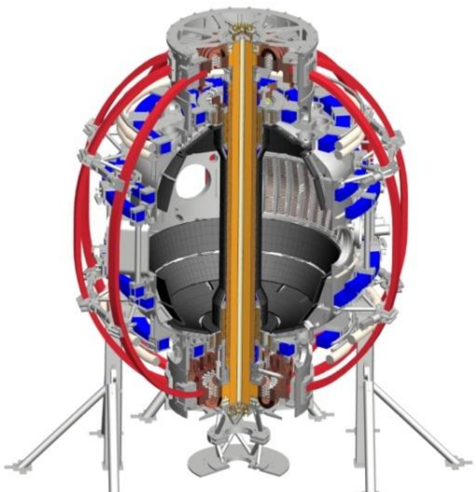

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Motivation

- Toroidally asymmetric heat flux deposition is often observed in various physical phenomena, e.g. ELMs, MHD events, application of 3-D magnetic perturbations, etc

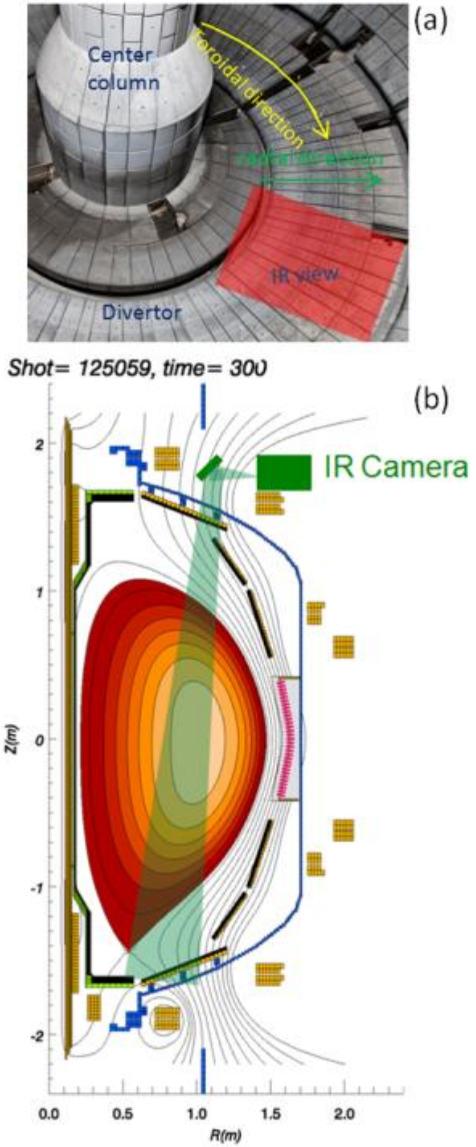
  → can be harmful to the maintenance of divertor tiles as the design is usually based on the assumption of 2-D axisymmetry

- 1-D heat flux profiles in the radial direction at one toroidal location have been widely used in the divertor heat flux study → A full 2-D profile is necessary to study toroidally asymmetric heat deposition

- Conventional heat conduction codes are only able to produce 1-D radial heat flux profiles

  → implemented a novel 2-D heat flux code with incorporation of surface layer effect for more accurate calculation

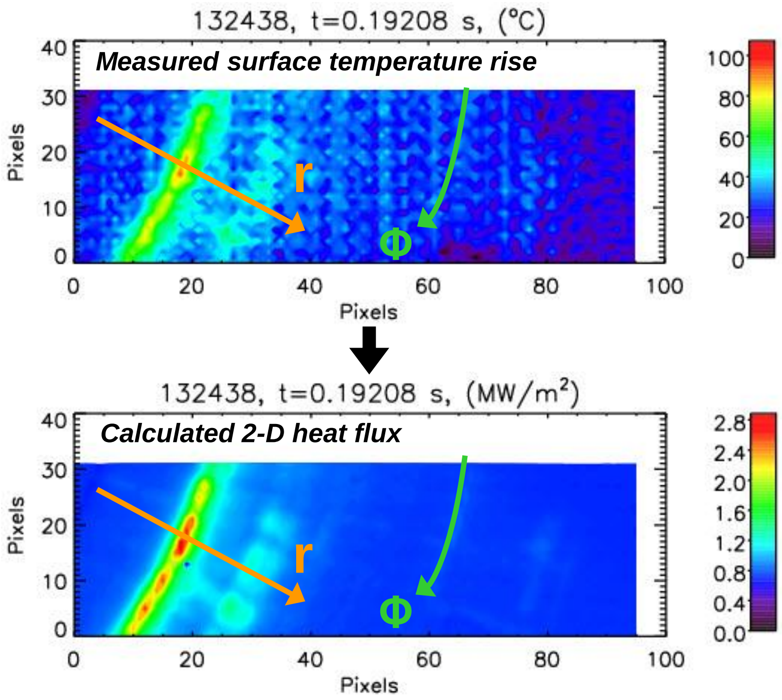
IR camera diagnostics for heat flux measurement



- Lower divertor surface temperature is monitored by fast IR camera
- Long wave length (8-12 μm) fast IR camera in 2009
  - Spatial resolution: 1.7 mm
  - Temporal resolution: 1.6 – 6.3 kHz
- Heat flux calculation from the measured surface temperature
  - 2-D heat flux profile from TACO[1] enables investigation of spatial structure of heat flux profile

[1] In collaboration with Culham, UK

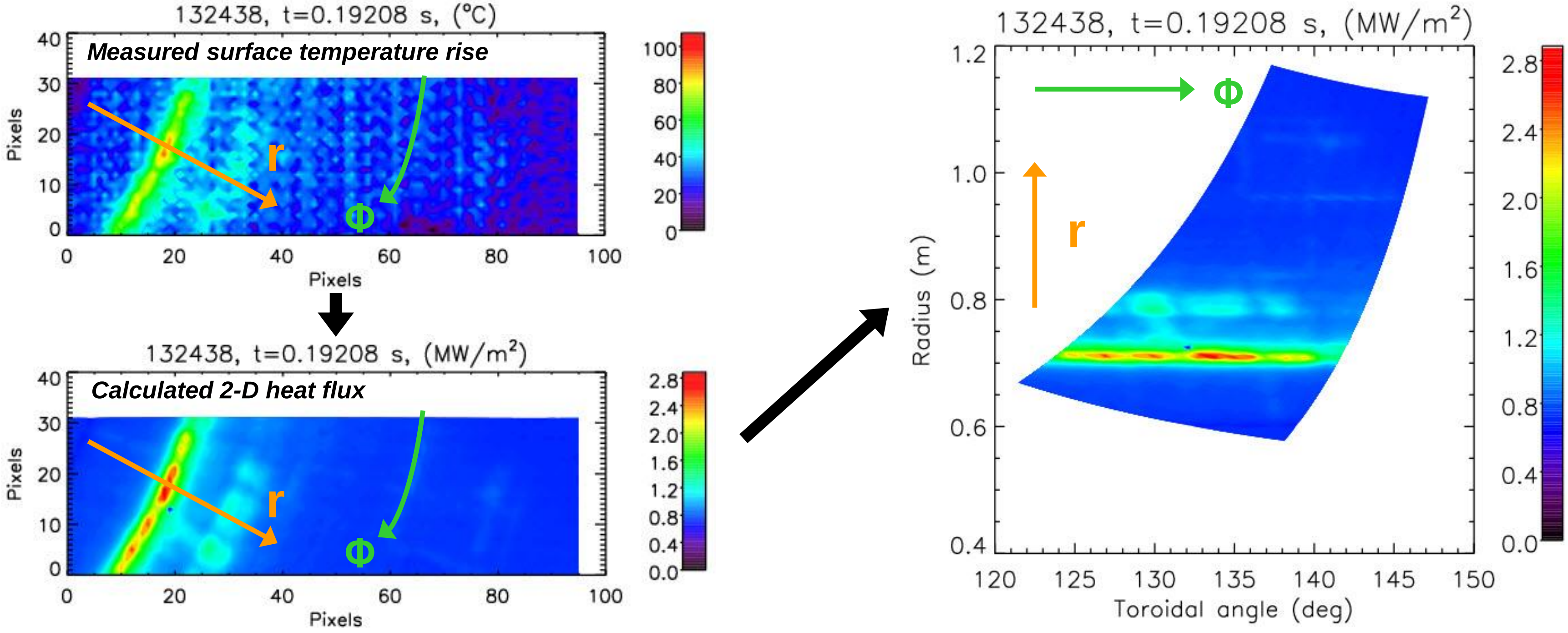
Re-mapping of 2-D heat flux profile from (x, y) to (r, Φ) enables easier investigation of toroidal asymmetry



- 2-D heat flux data are calculated from TACO
- Naturally forming thin surface layer on the divertor surface is incorporated in the heat flux calculation[1] by introducing a heat transmission coefficient, α

[1] K.F. Gan, submitted to RSI (2012)

Re-mapping of 2-D heat flux profile from (x, y) to (r, Φ) enables easier investigation of toroidal asymmetry



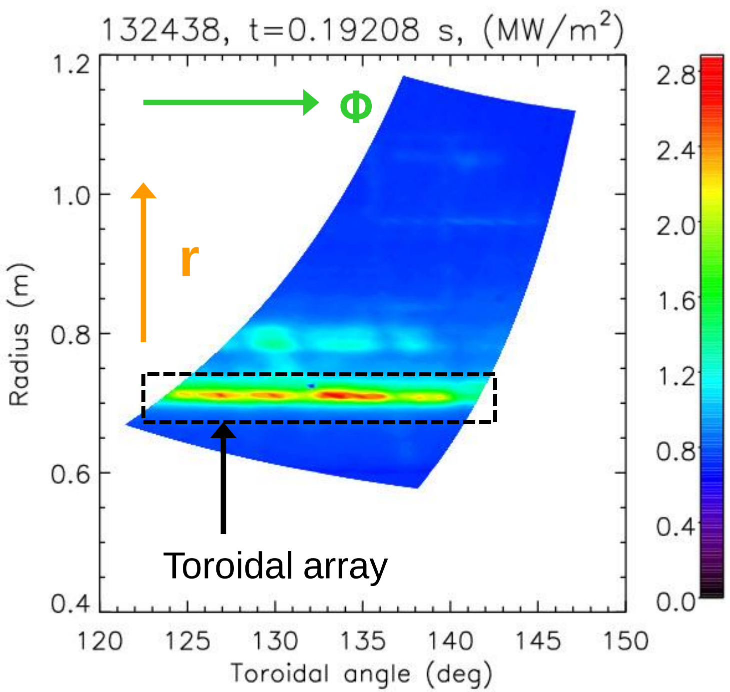
- 2-D heat flux data are calculated from TACO
- Naturally forming thin surface layer on the divertor surface is incorporated in the heat flux calculation[1] by introducing a heat transmission coefficient, α
- 2-D heat flux profile in (x, y) plane is re-mapped to the (r, Φ) plane → useful technique in the study of toroidally non-axisymmetric heat flux deposition → particularly important during the ELMs and 3-D fields application

[1] K.F. Gan, submitted to RSI (2012)

Toroidal peaking factor is obtained as an indicative for asymmetric heat flux distribution

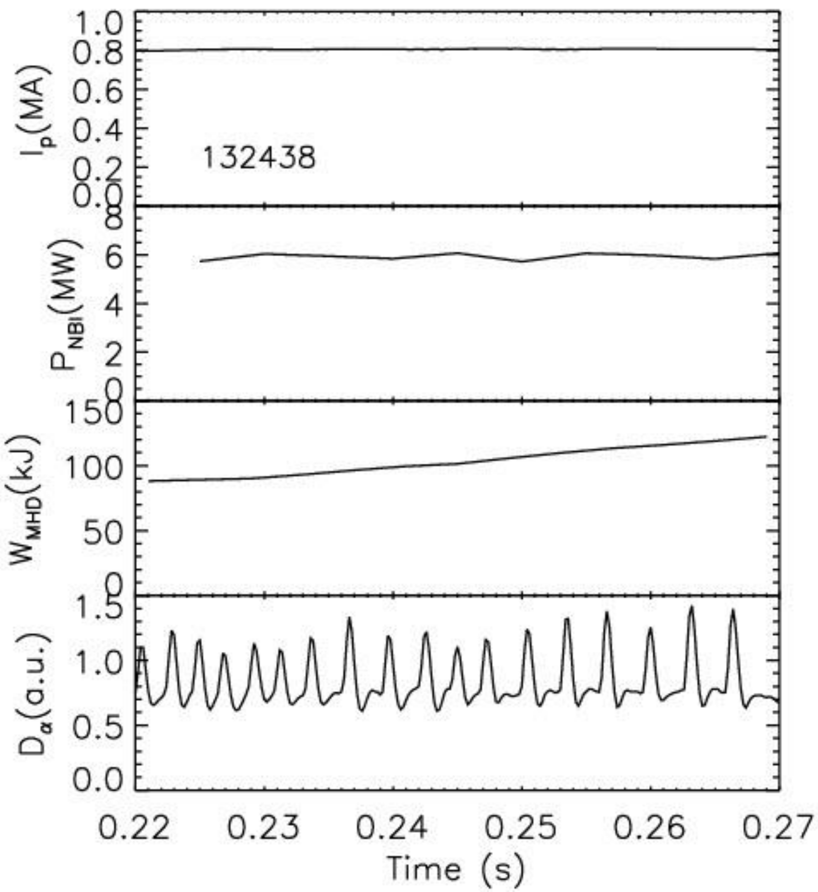
- Define toroidal peaking factor (PF) of peak heat flux as an indicative of asymmetric distribution of peak heat flux

  $PF(q_{peak}) = max(q_{peak})/mean(q_{peak})$

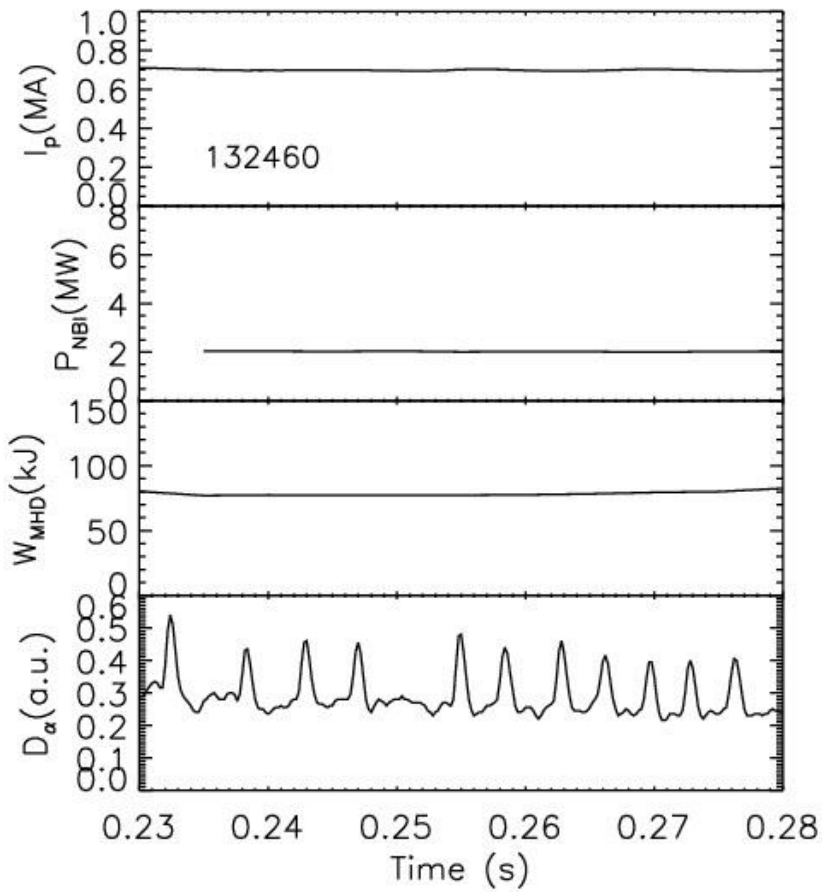


Type-I and III ELMs have been analyzed for toroidal asymmetry in peak heat flux

Type-I ELMy



Type-III ELMy



- Type-I and high power type-III ELMs: heat flux width decreases during ELM
- Low power type-III ELMs: heat flux width increases during ELM[1]

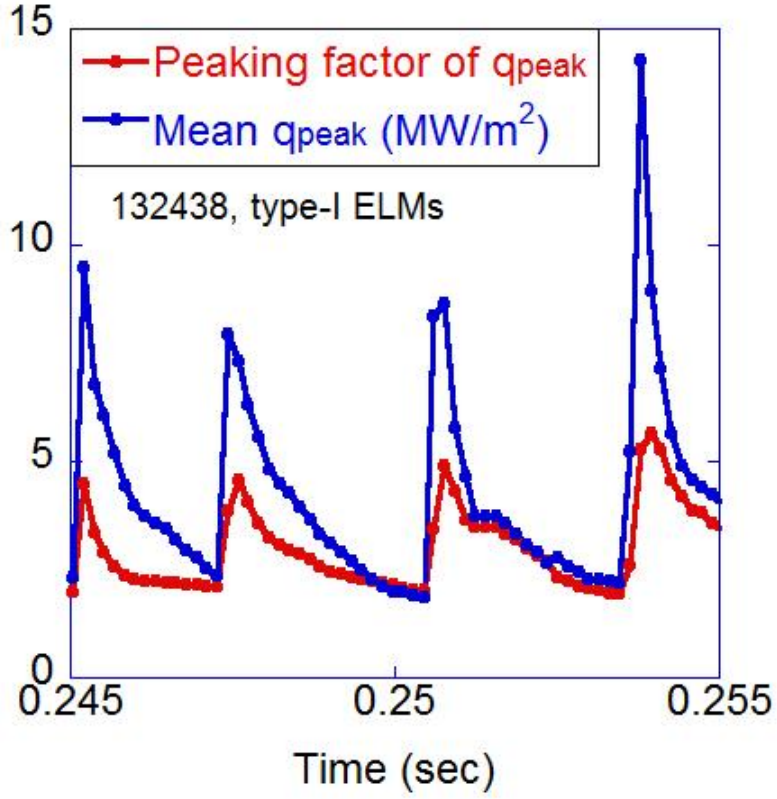
[1] K.F. Gan, submitted to NF (2012)

Toroidal peaking factor increases as the peak heat flux rises during the ELM

- Define toroidal peaking factor (PF) of peak heat flux as an indicative of asymmetric distribution of peak heat flux

  $PF(q_{peak}) = max(q_{peak})/mean(q_{peak})$

- Peaking factor goes up during the ELM → Toroidal distribution of peak heat flux becomes rapidly asymmetric during the ELM

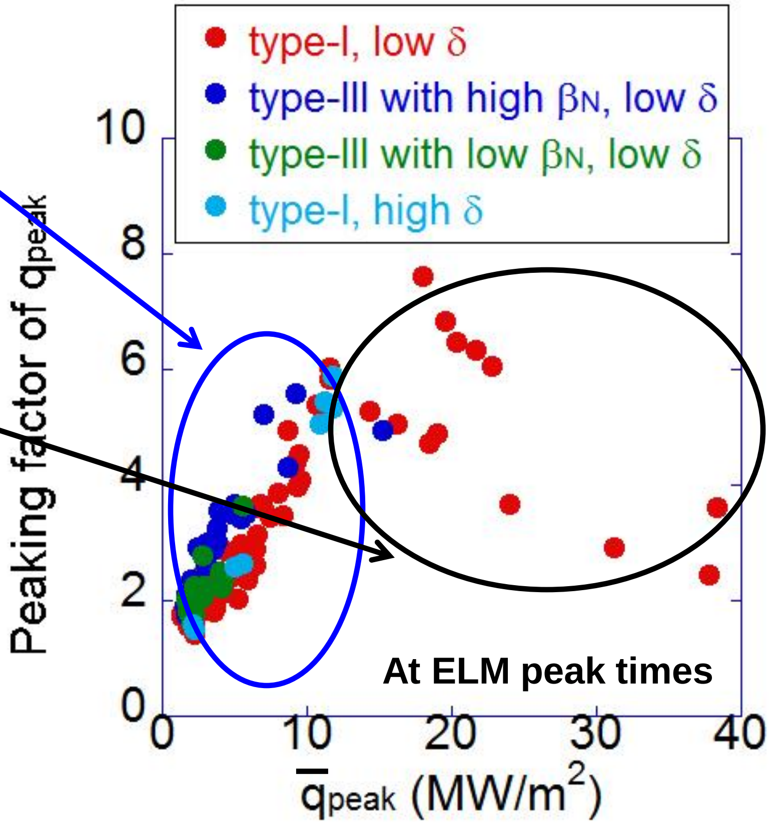


Peaking factor at ELM peak times is strongly dependent on peak heat flux, independent of ELM types

- Peaking factor at ELM peak times increases with increasing q_{peak} up to 10 - 15MW/m^2 for all ELM types

- It decreases with peak heat flux higher than 10 - 15MW/m2

  → Temperature deviation from the calibration becomes larger, making the heat flux data more uncertain



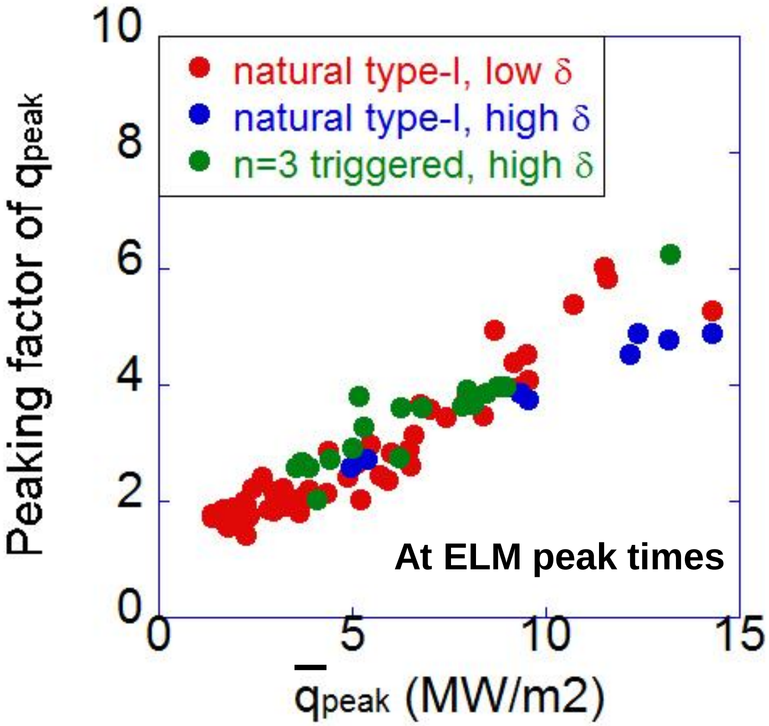
Dependence of peaking factor on peak heat flux is well aligned for both natural and triggered ELMs

- Peaking factor at ELM peak times increases with increasing q_{peak} up to 10 - 15MW/m^2 for all ELM types

- It decreases with peak heat flux higher than 10 - 15MW/m2

  → Temperature deviation from the calibration becomes larger, making the heat flux data more uncertain

- Triggered ELMs show similar trend, and are aligned well with the natural type-I ELMs



Caveats for the study of 2-D toroidal asymmetry in heat flux

- Irregular surface films possible
  → only constant alpha is used at the moment
- Tile misalignment, gaps
- Intrinsic error field
  → Baseline toroidal asymmetry

Summary and Conclusions

- 2-D heat flux profiles are obtained from the TACO heat flux code, enabling to study toroidal asymmetry in heat flux
- The toroidal peaking factor of peak heat flux is used as an indicative of how asymmetrically the toroidal peak heat flux is distributed
  → peaking factor increases during the ELM
  → strong positive dependence on peak heat flux up to 10 – 15 MW/m^2 regardless of ELM types, 3-D field triggered ELMs also follow the same trend and the peaking factor data are well aligned with naturally occurring type-I ELMs
  → peaking factor decreases with heat flux higher than 10 – 15 MW/m^2 (bigger uncertainty due to the temperature calibration issue)
- Irregular distribution of thin surface layer can add uncertainties in the estimation of toroidal asymmetry