

Design of a Diamond Camera for TCV

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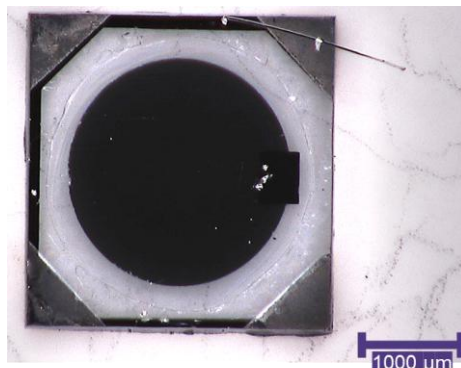
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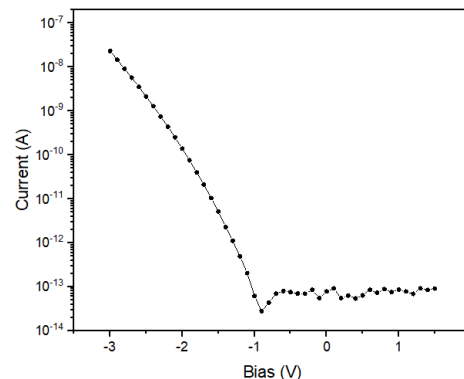
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DIAMOND DETECTORS FOR UV-SX DETECTION

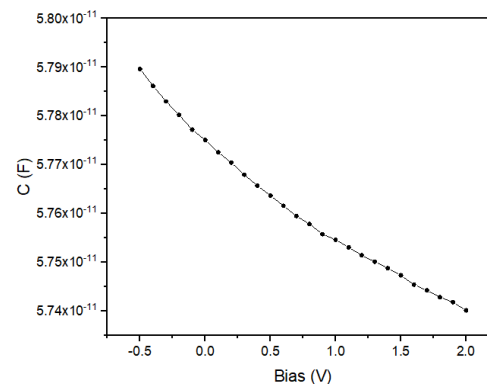
Layer size:
3x3 mm²
Thickness < 20 μm



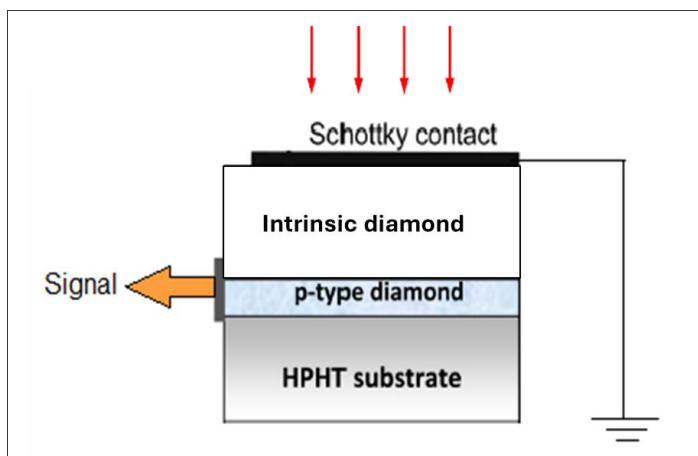
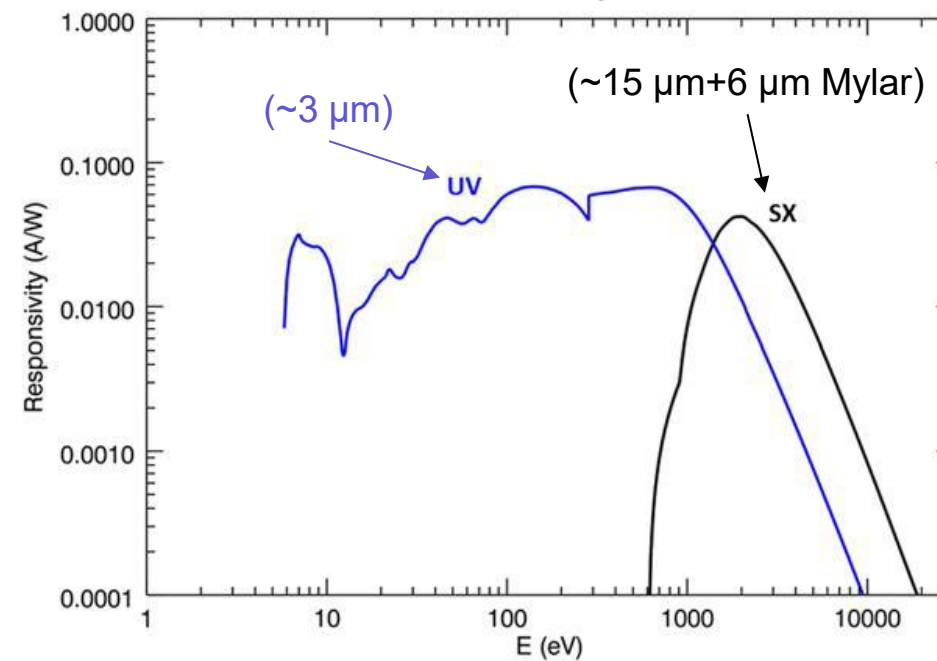
I-V characteristics



C-V characteristics



Responsivity



Current mode operation

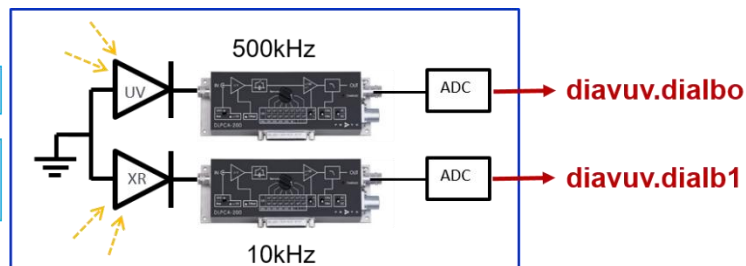
CVD diamond detectors for fast VUV and SX-ray diagnostics on FTU, F. Bombarda, M. Angelone, G. Apruzzese, C. Centioli, S. Cesaroni, L. Gabellieri, A. Grosso, M. Marinelli, E. Milani, S. Palomba, V. Piergotti, G. Pucella, G. Rocchi, A. Romano, A. Sibio, B. Tilia, C. Verona, G. Verona-Rinati, Nucl. Fusion 61 (2021)

PREVIOUS INSTALLATION ON FTU TOKAMAK

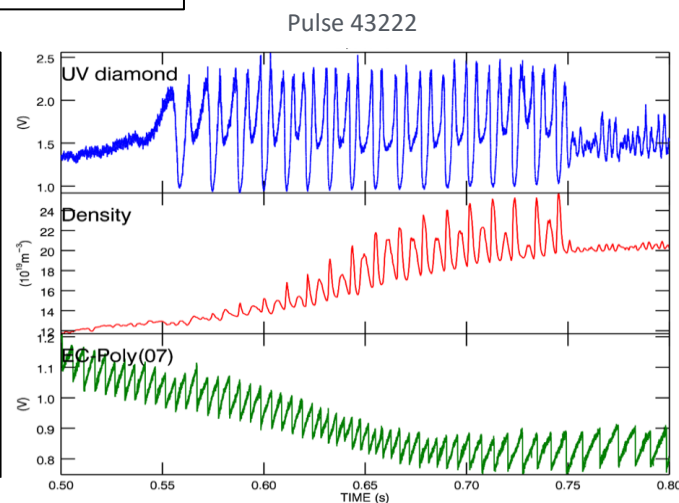
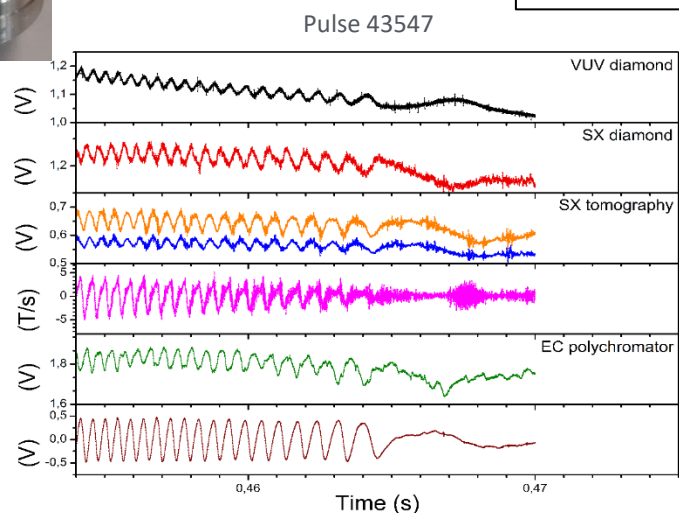


UV: 2 μ m, 5nm of Pt

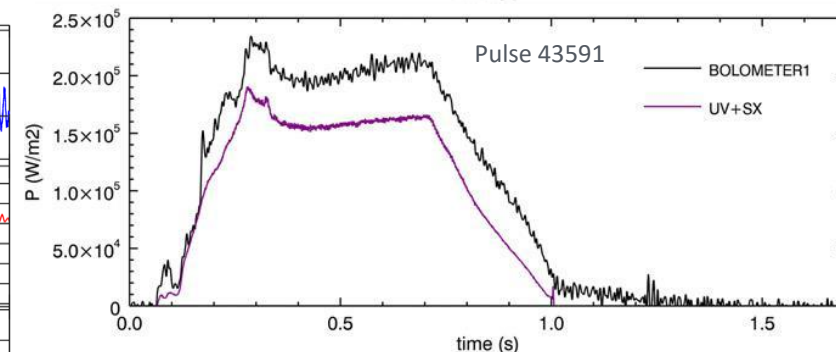
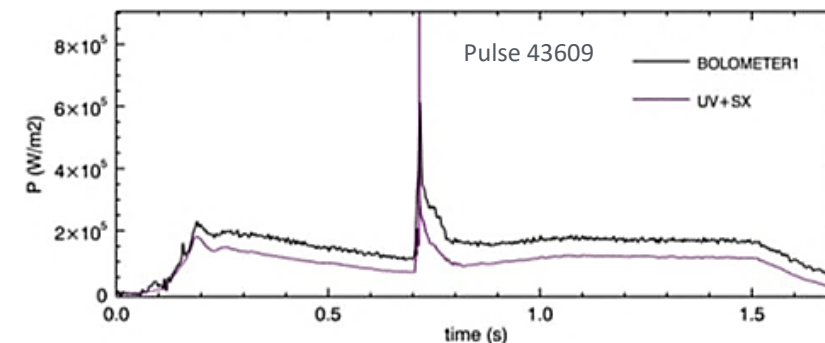
SX: 15 μ m, 5nm of Cr
+ 6 μ m of Mylar filter



MHD and MARFE

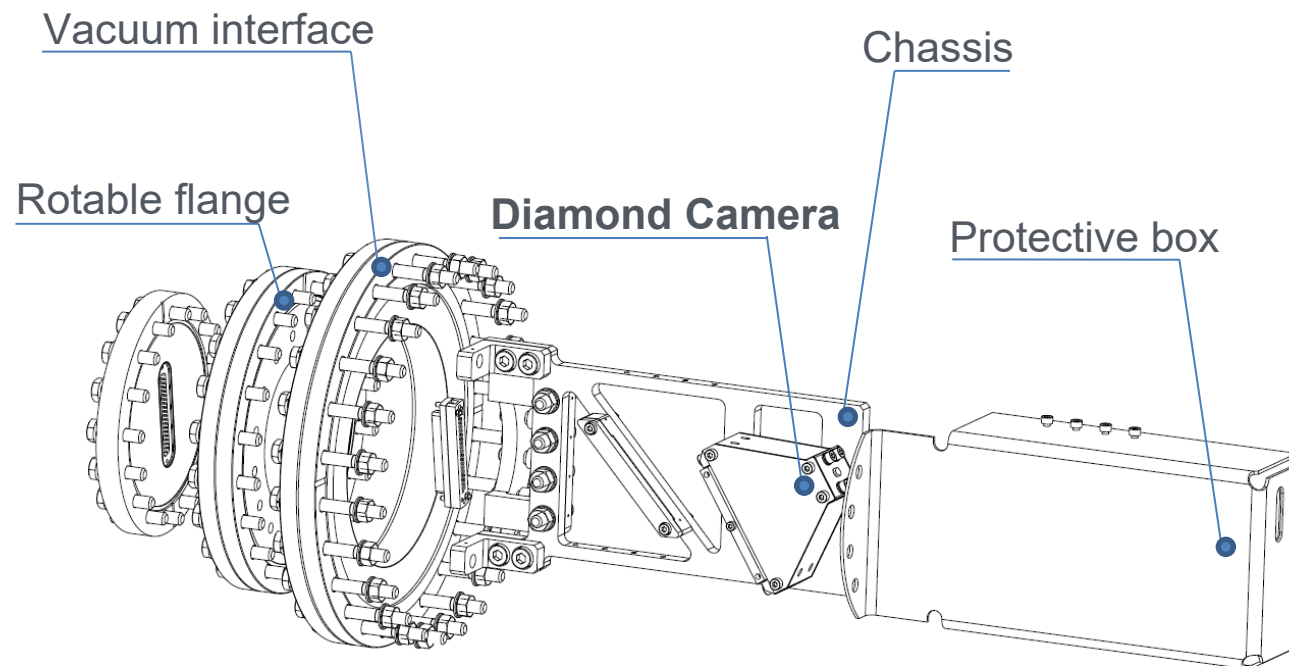
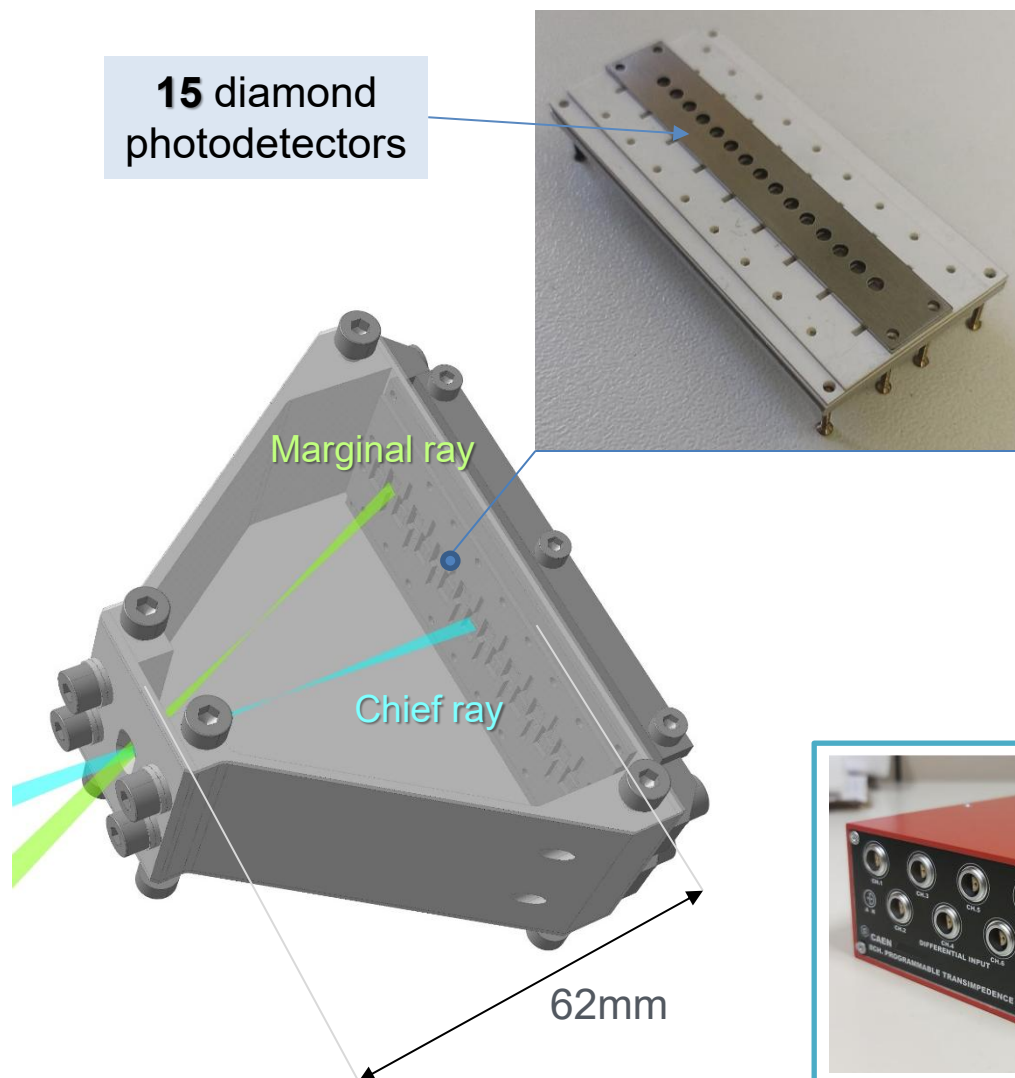


Comparison with Bolometry



CVD diamond photodetectors for FTU plasma diagnostics, **S. Cesaroni**, M. Angelone, G. Apruzzese, F. Bombarda, L. Gabellieri, M. Marinelli, E. Milani, S. Palomba, G. Pucella, A. Romano, C. Verona, G. Verona-Rinati, C. Centioli, A. Grosso, V. Piergotti, G. Rocchi, A. Sibio, B. Tilia, Fusion Eng. Des. 166, 112323 (2021)

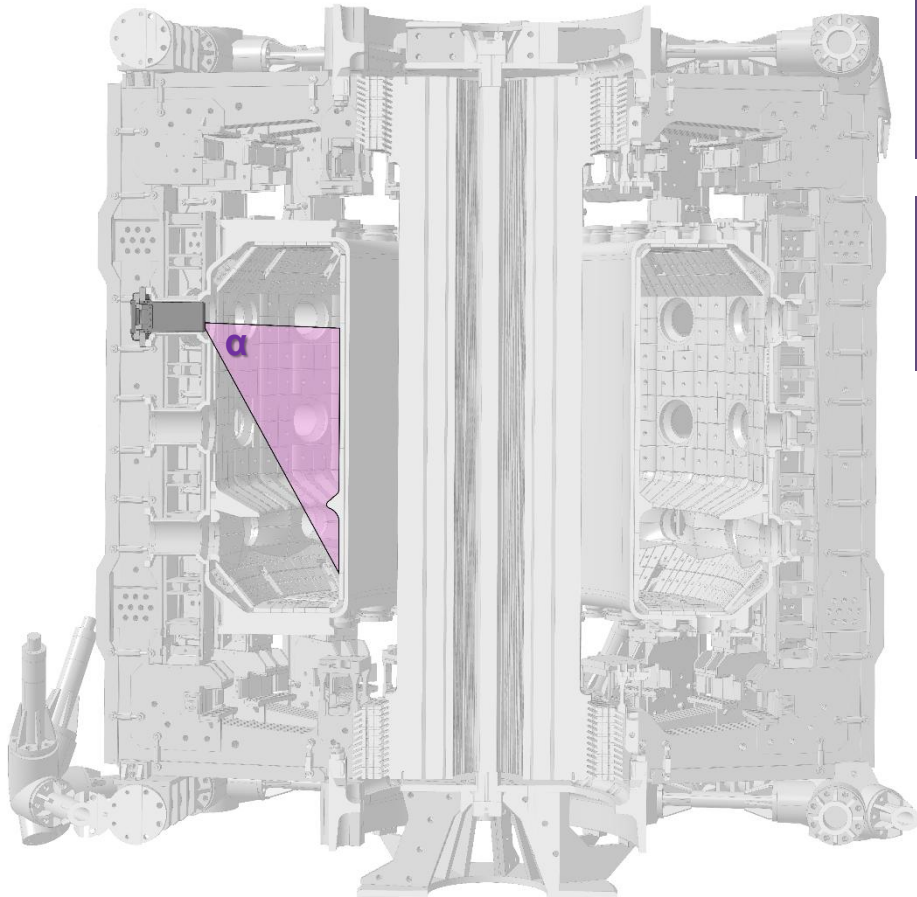
THE DIAMOND CAMERA FOR TCV



Front-end electronics:
8-channel CAEN amplifier
+ single FEMTO modules

THE DIAMOND CAMERA FOR TCV

Poloidal Geometry

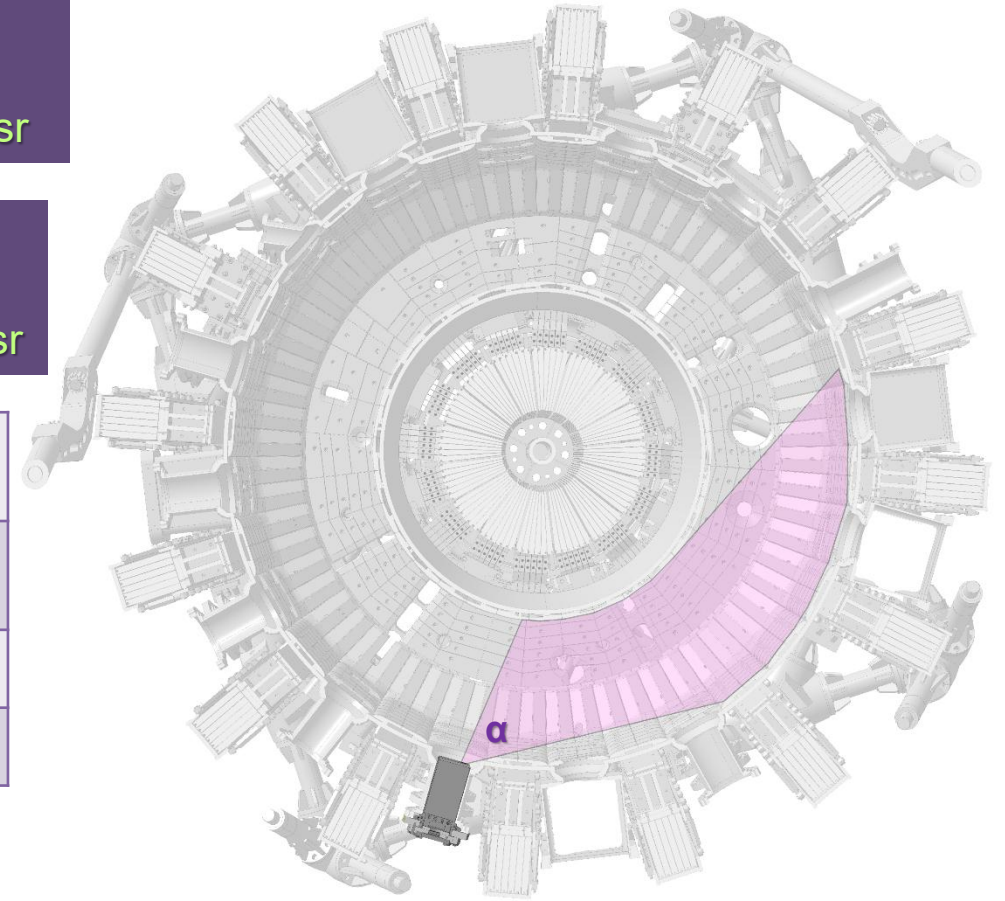


Single solid angle:
Chief ray 0.08×0.14 sr
Marginal ray 0.06×0.14 sr

Etendue:
Chief ray $0.021 \text{ mm}^2\text{sr}$
Marginal ray $\sim 0.016 \text{ mm}^2\text{sr}$

Total field of view (α)	$\sim 52,3$ deg
Slit – Detector plane	62 mm
Slit aperture	$7,7 \text{ mm}^2$
Detector area	$10,8 \text{ mm}^2$

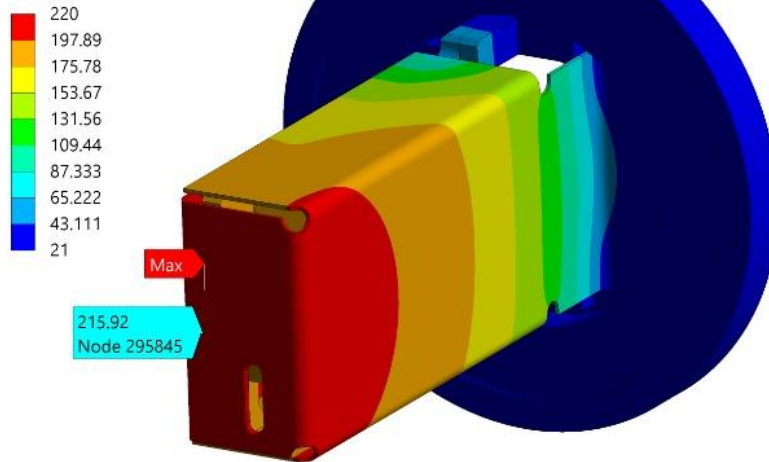
Toroidal Geometry



THERMAL ANALYSIS – BAKING @250 °C

A: Baking

Temperature
Type: Temperature
Unit: °C
Time: 1 s
Max: 216.85
Min: 21.988



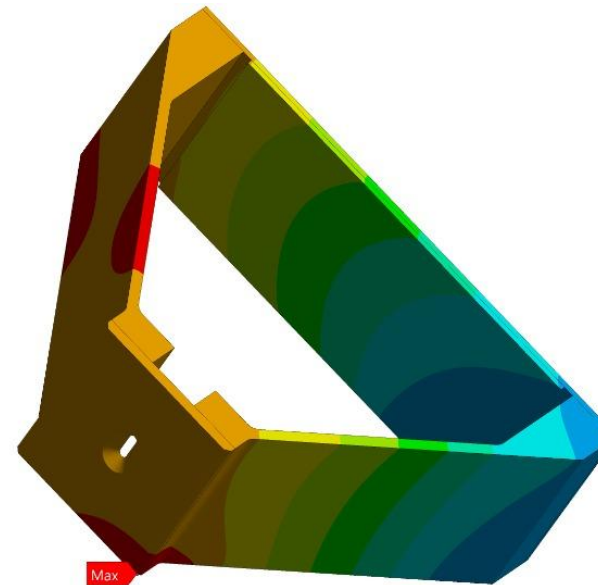
Calculations performed
with $T_{\text{baking}} = 250 \text{ }^{\circ}\text{C}$.

Baking for TCV
machine is performed
at $230 \text{ }^{\circ}\text{C}$.

A: Baking

Temperature 6
Type: Temperature
Unit: °C
Time: 1 s
Max: 179.35
Min: 174.47

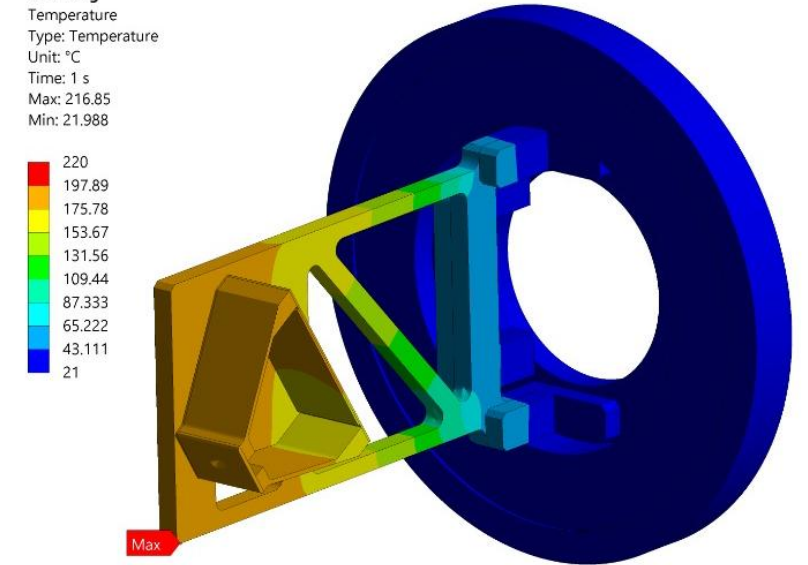
179.4
178.8
178.2
177.6
177
176.4
175.8
175.2
174.6
174



A: Baking

Temperature
Type: Temperature
Unit: °C
Time: 1 s
Max: 216.85
Min: 21.988

220
197.89
175.78
153.67
131.56
109.44
87.333
65.222
43.111
21

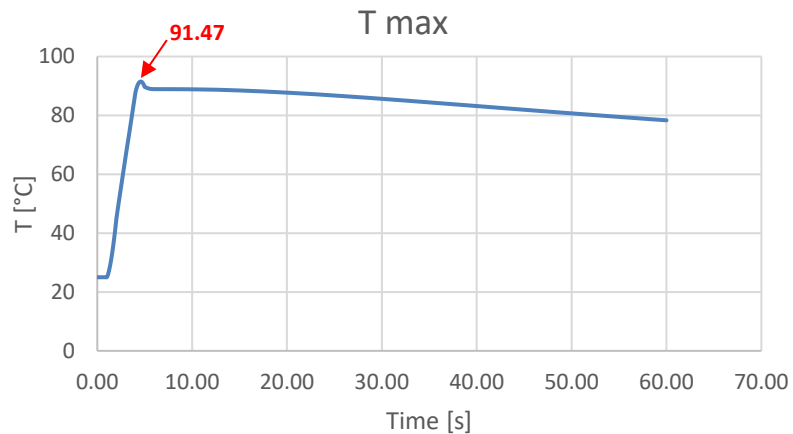
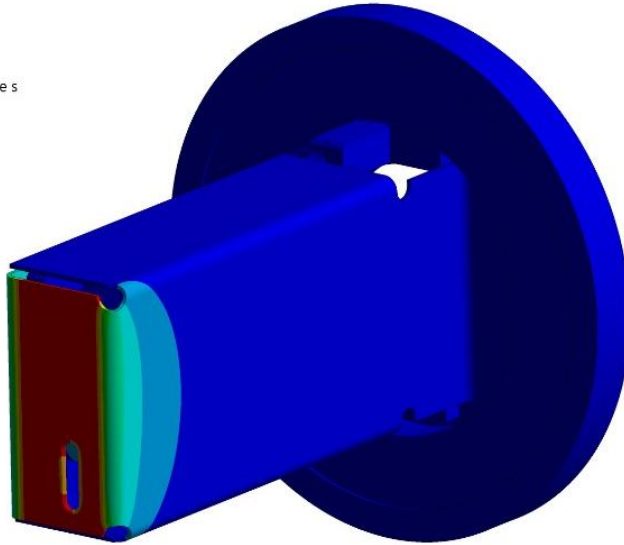


THERMAL ANALYSIS – NBI+ECRH

B: Load

Temperature
Type: Temperature
Unit: °C
Maximum Over Time s
Max: 91.47
Min: 25

91.47
84.084
76.699
69.313
61.928
54.542
47.157
39.771
32.386
25

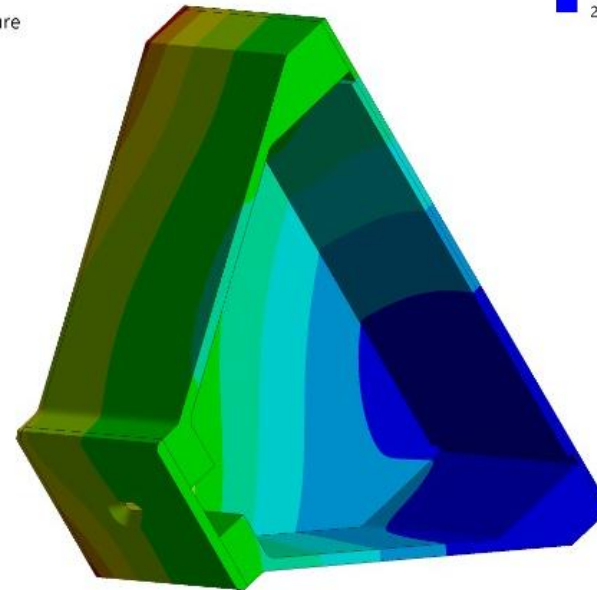


Calculations performed with
a thermal load of 0.17 W/mm^2

B: Load

Temperature 3
Type: Temperature
Unit: °C
Time: 1200 s
Max: 26.037
Min: 25.473

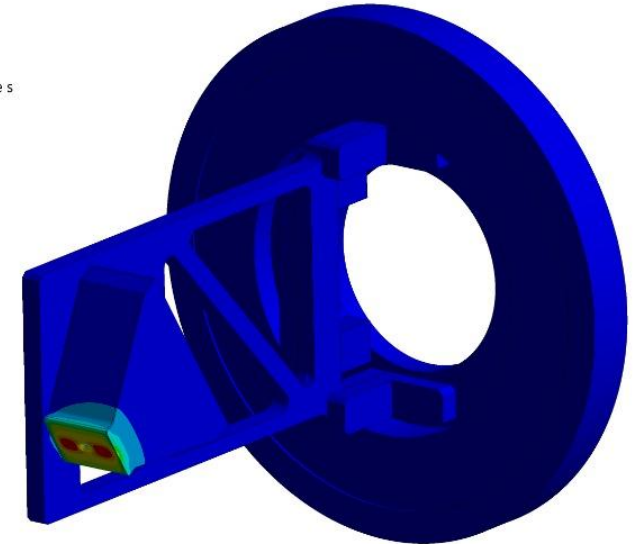
26.037
25.974
25.912
25.849
25.786
25.724
25.661
25.598
25.536
25.473



B: Load

Temperature 2
Type: Temperature
Unit: °C
Maximum Over Time s
Max: 39.496
Min: 25

39.496
37.886
36.275
34.664
33.054
31.443
29.832
28.221
26.611
25



CONCLUSIONS

- Studies have suggested the use of diamond photodetectors in diagnostic systems located close to the plasma as replacements for other semiconductors, particularly Si diodes, owing to their material properties and extremely fast response.
- An array of 15 diamond photodetectors has been designed, and its manufacturing is nearing completion. Installation is planned for 2027, in line with the TCV machine timeline.
- Data from the TCV Diamond Camera will be benchmarked against measurements from other diagnostics available on the machine to exploit the capability of diamond photodetectors of providing complementary information on the observed plasma phenomena.

THANK YOU!

Acknowledgements to:

Dr. Andrea Belpane

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Prof. Stefano Coda

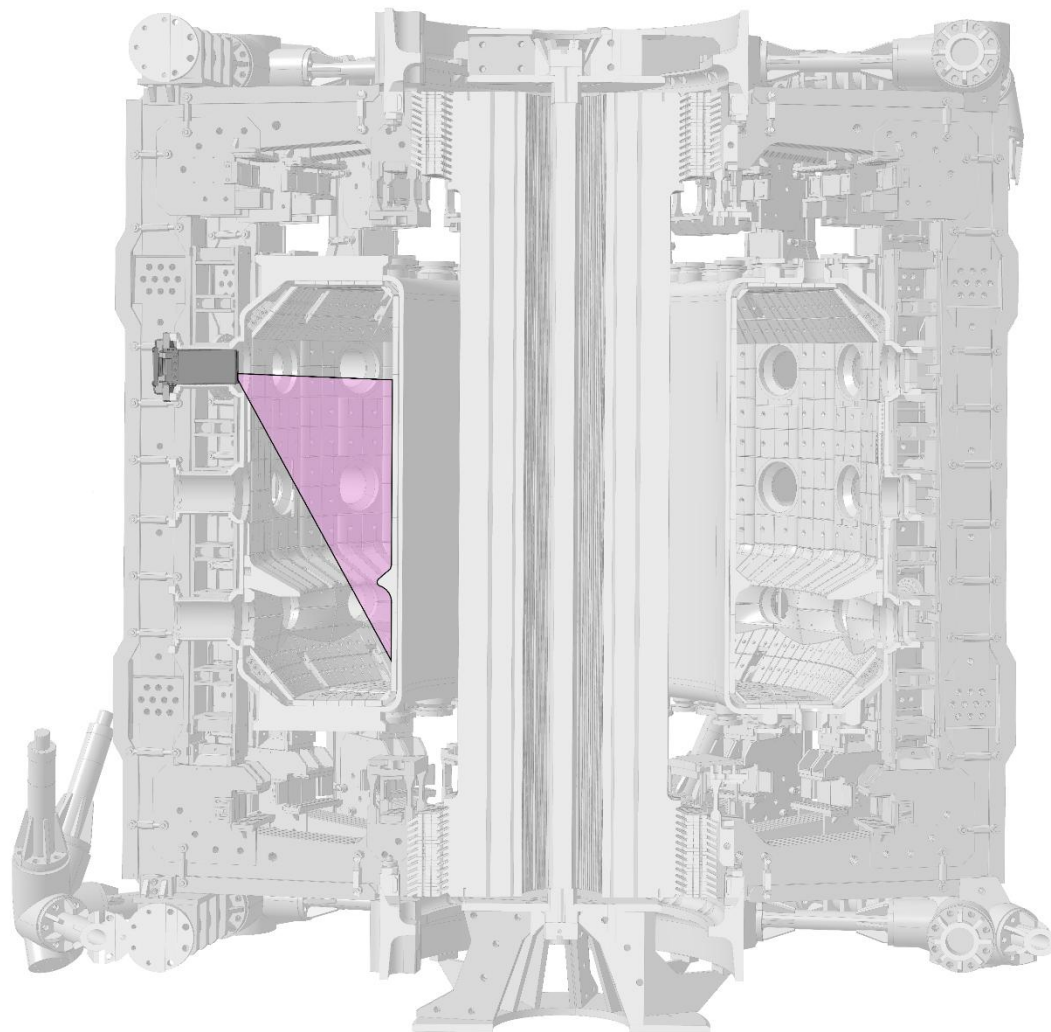
Dr. Umar Sheikh

Prof. Claudio Verona

Prof. Gianluca Verona Rinati

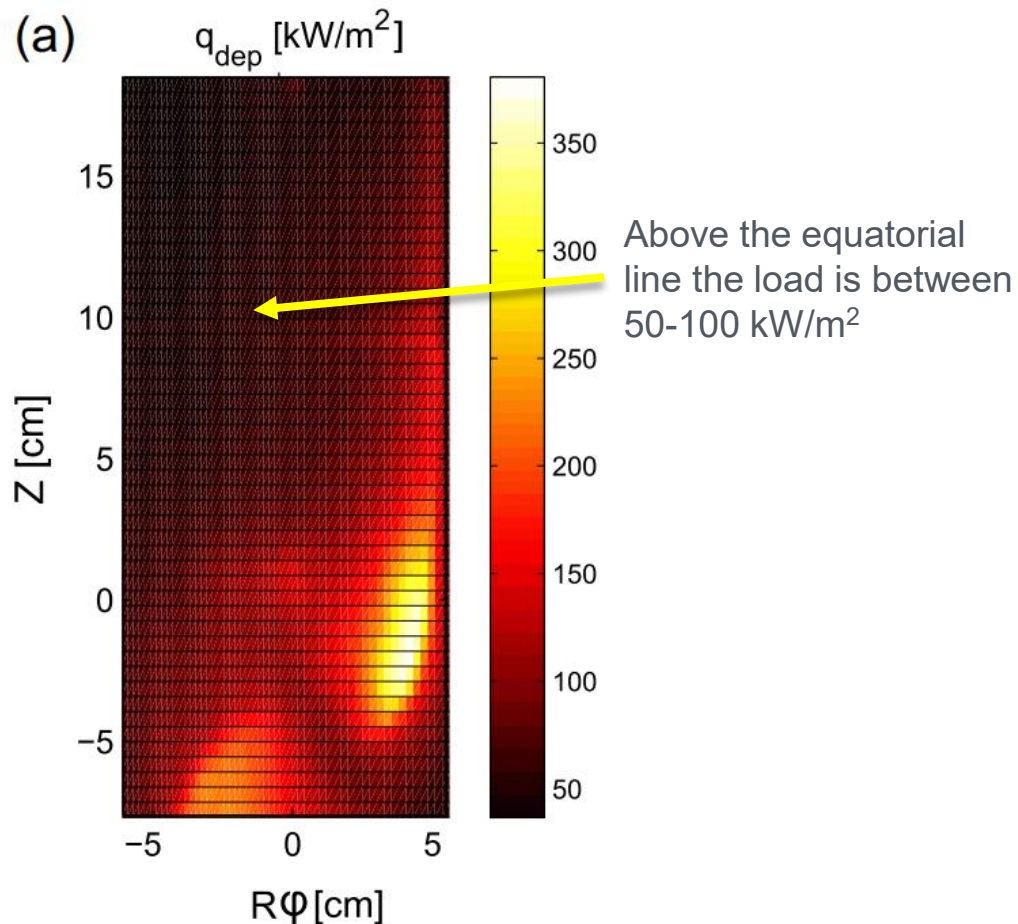
& NUC-FUSEN-DIA team

DETECTOR SOLID ANGLE CALCULATION



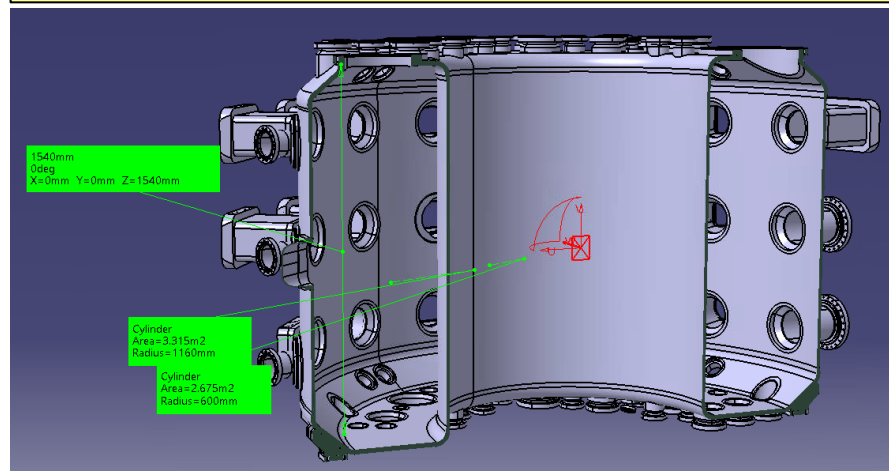
Number of detectors	15
Poloidal field of view single	- Chief ray: ~ 4,5 deg - Marginal ray: ~ 3,6 deg
Toroidal field of view single	~ 8,0 deg
Total poloidal field of view	~ 52,3 deg
Slit – Detector plane	62 mm
Slit aperture	7,7 mm ²
Detector area	10,8 mm ²
Solid angle slit	2 E-3 srd
Etendue	- Chief ray: 0,021 mm²sr - Marginal ray: ~ 0,016 mm²sr

THERMAL ANALYSIS – NBI+ECRH



Nespoli, F. et al(2015). Heat loads in inboard limited L-mode plasmas in TCV. Journal of Nuclear Materials, 463, 393–396.
<https://doi.org/10.1016/j.jnucmat.2014.11.137>

Labit, B et al (2019). Dependence on plasma shape and plasma fueling for small edge-localized mode regimes in TCV and ASDEX Upgrade. Nuclear Fusion, 59(8), 086020.
<https://doi.org/10.1088/1741-4326/ab2211>



NBI → 1 MW
ECRH → 1,4 + 0,9 = 2,3 MW
→ **4 MW**

Area:
LFS = 11218592 mm²
HFS = 5802720 mm²
Top = Bottom = 3094784mm²
Area = 23210880 mm² = **23,2 m²**
Q = P/A = 4MW/23,2m² = 0,17 MW/m²
Q = 170 kW/m² = **0,17 W/mm²**