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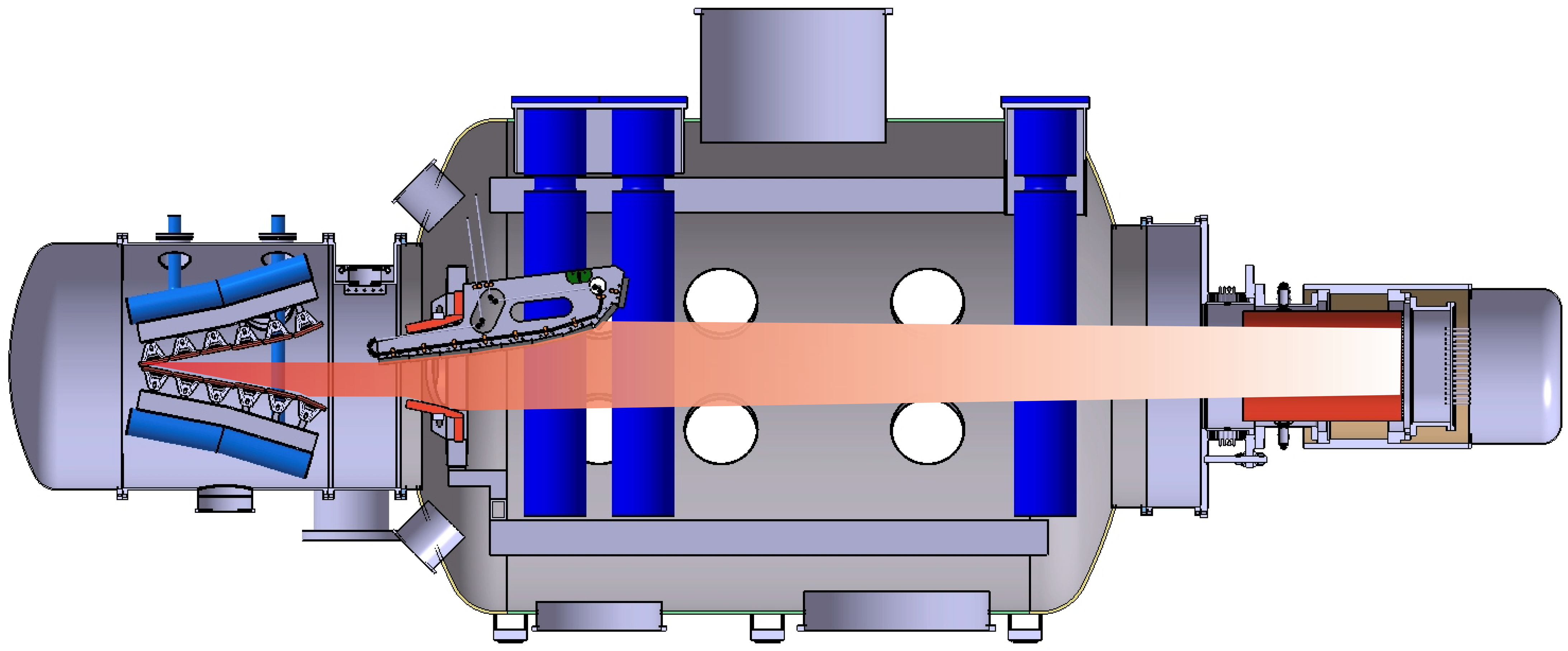
# New options for material testing at the material ion beam test facility MARION

D. Nicolai, P. Chaumet, O. Neubauer, R. Uhlemann

*IEF-4 (Plasma Physics), Forschungszentrum Jülich, Assoc. EURATOM-FZJ, member of Trilateral Euregio Cluster, D-52425 Jülich, Germany*

Within the development of new fusion devices like ITER and DEMO, material testing becomes more and more relevant. The material ion beam test facility MARION which was primarily designed for beam source development and commissioning is also used for high heat flux testing up to 120MW/m². In order to improve this second field of activity the concept of MARION is adapted to material testing. To increase the flexibility and to decrease the costs for material testing operation the vacuum system has been changed by excluding the cryogenic pumps combined with an enhancement of the conventional vacuum pumping part. The reduction in pumping capacity has made a new optimization of the operation parameters necessary.
The experimental results of this optimization can be used as calibration base for future heat load tests. They are shown in this paper, combined with the changes in operation range for this new, additional mode.

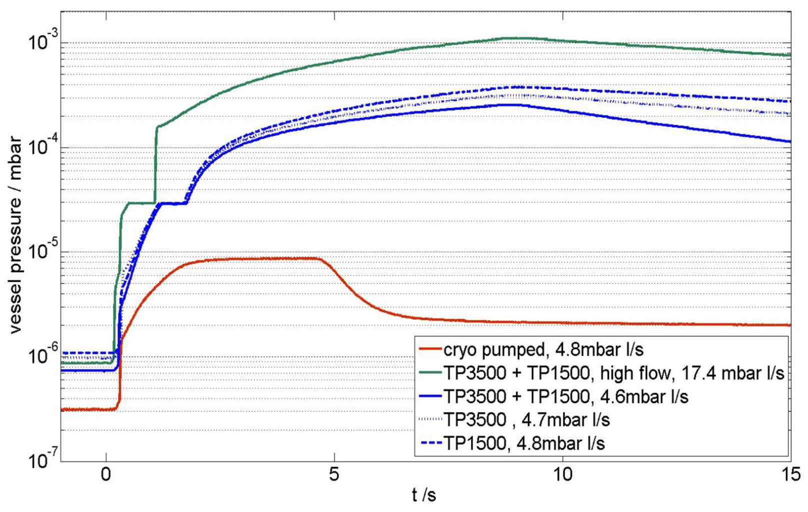


| MARION design parameter | |
|---|---|
| Acceleration voltage | 15 kV – 60 kV |
| Beam current | ≤100A |
| Total Beam Power | 70 kW – 6 MW |
| Power density | ≤120 MW/m² |
| Beam area | 1300 cm²: w 32 cm, h 40 cm |
| Pulse length | 10 ms – 30 s, above 30 kV: t ≤ 10 s |
| Pulse repetition | 1 min – 5 min |
| Operation gas | $H_2$, He |

**Step1:**
*Measurement of pumping capacity without beam*

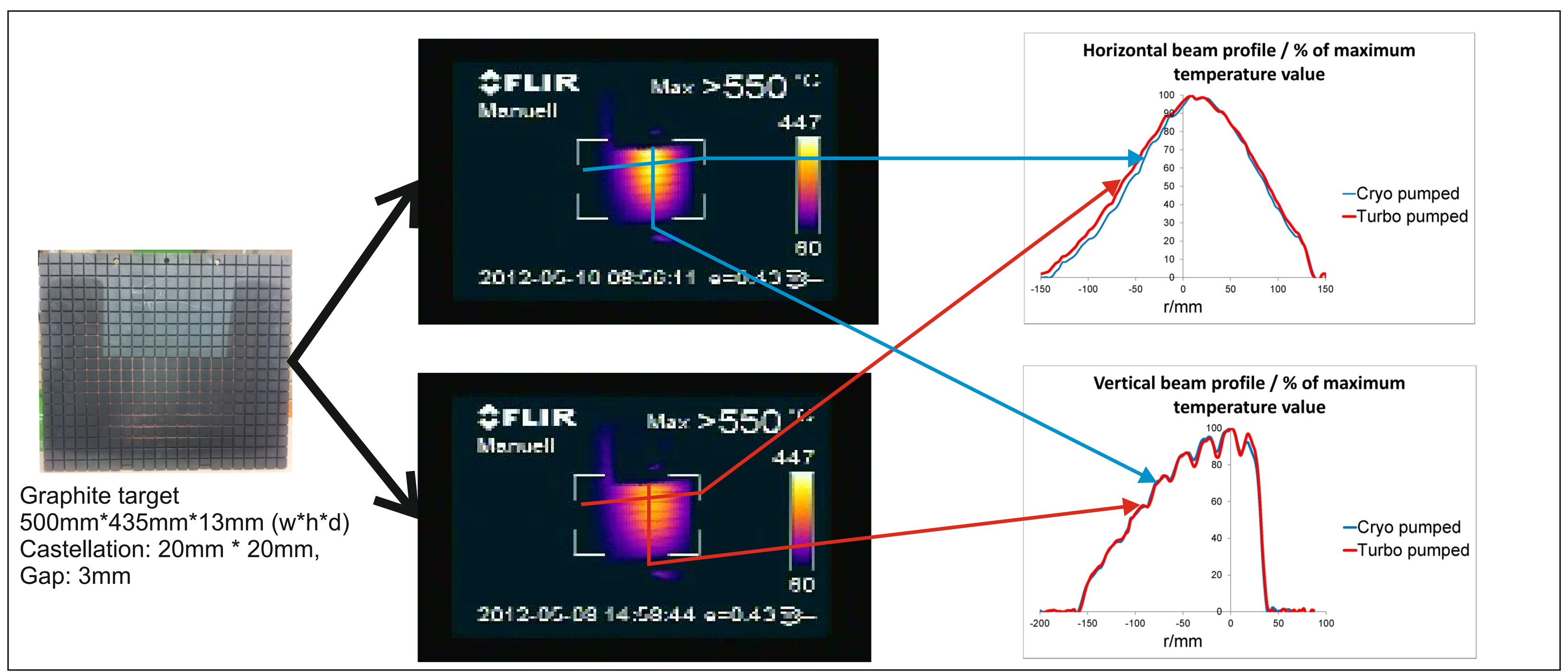
- Effect of aditional turbomolecular pumping system is shown
- maximum Level of 1*10$^{-3}$ mbar is reached after 8s with high source gas flow corresponding to 55kV beam cryo pumped parameters

-> Operation without cryogenic pump reachable




**Step2:**
*Short pulse operation without neutralization gas, profile compare between cryo-pumped and turbo-pumped beam, protection scraper mounted*
- Target: castellated graphite plate
- Analysys: Infrared camera, intensity normalized on maximum value
- First beam set with up to 1s beam on-time and up to 41kV acceleration voltage

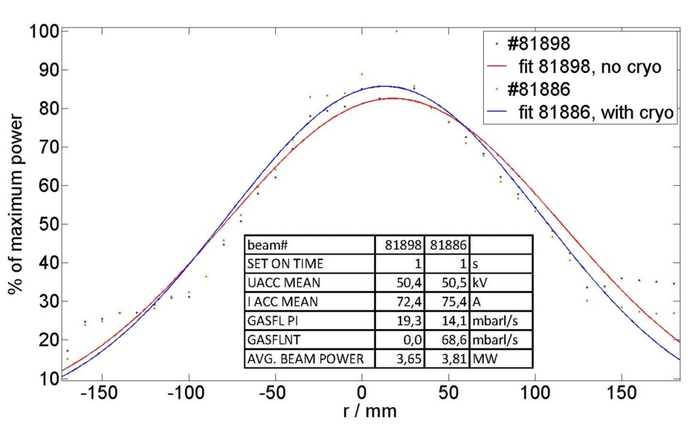
-> No significant change in the power distribution on the plate could be recognized using the same beam parameters. With the results of this first profile check the operation of MARION with long time pulses was allowed.

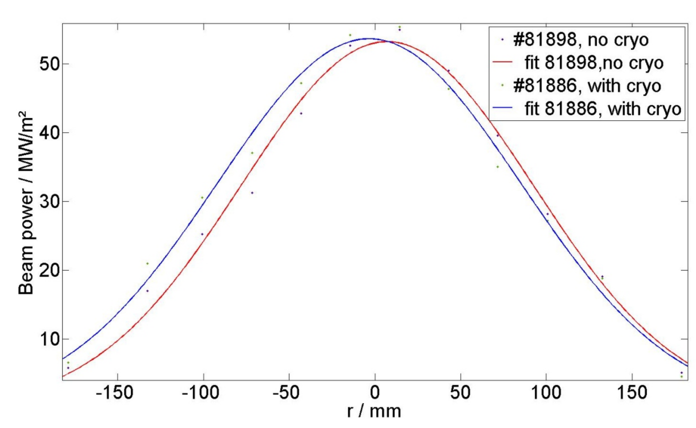



**Step 3:**
*Long pulse operation without neutralization gas, profile measurement by horizontal and vertical calorimeter, scraper dismounted*

- Horizontal calorimeter: Resolution of 39*1cm
- Vertical calorimeter: Six upper and six lower V-target plates (6MW beam power for 10s)
- Comparison of beams in both pumping regimes with up to 50kV acceleration voltage and beam on-time from 1s to 5s.

->Good accordance between the profiles on both calorimeters
Gaussian fit shows a slightly drift of the beam to the upper half of the target (10mm) and to the right side of the horizontal calorimeter (4mm).
Peak power calculated by the calometric data of the V-Target is related to the electrical measurement which shows a smaller overall beam power for the non cryo pumped beam.



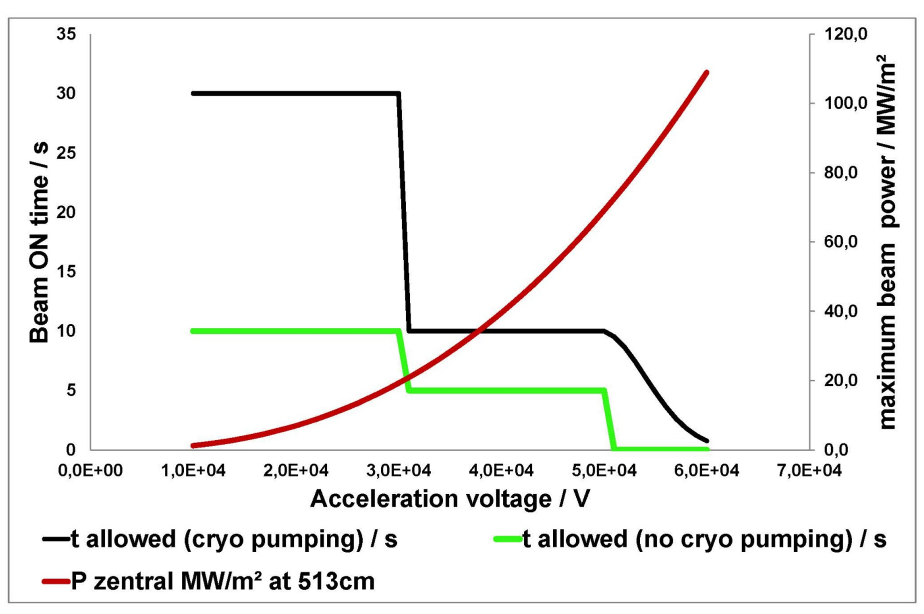

**Step 4:**
*Control of beamline structures:*
- Measurement of thermal load on components along the beam line
- Comparison of three beams of different length at nominal beam power for each pumping mode.
- Single values, exceeding the mean value, are marked in red.
- Shift of the beam to the upper right position is shown at the magnet liner and the scraper data as already seen in the fit.
- Grid 3, the last grid to the vacuum chamber, with reduced load.
- Neutraliser 2 shows a small increase during two beams and should be controlled at higher beam power.

| Energy deposition on beamline parts in % of total beam energy | | | | | | | |
|---|---|---|---|---|---|---|---|
| | mean value | no cryo pumping | | | with cryo pumping | | |
| beam # | | 81898 | 81907 | 81905 | 81886 | 81882 | 81885 |
| duration / s | | 1 | 2 | 4 | 1 | 2 | 4 |
| grid 1 | 3,0 | 3,7 | 2,8 | 2,3 | 3,6 | 2,9 | 2,4 |
| grid 2 | 0,6 | 0,6 | 0,5 | 0,4 | 0,7 | 0,6 | 0,5 |
| grid 3 | 0,6 | 0,6 | 0,5 | 0,6 | 0,8 | 0,7 | 0,7 |
| neutralisor 1 | 0,5 | 0,6 | 0,7 | 0,5 | 0,4 | 0,5 | 0,4 |
| neutralisor 2 | 1,7 | 2,3 | 2,0 | 1,7 | 1,4 | 1,5 | 1,6 |
| magn.liner left | 1,2 | 1,4 | 1,6 | 1,1 | 1,4 | 0,9 | 0,9 |
| magn.liner right | 1,4 | 1,7 | 2,0 | 1,4 | 0,8 | 1,0 | 1,3 |
| H- dump | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| scraper lower | 4,8 | 4,2 | 4,7 | 4,6 | 5,0 | 5,1 | 5,1 |
| scraper upper | 2,9 | 2,5 | 3,1 | 3,0 | 2,8 | 3,0 | 3,1 |
| VT outer stripes | 4,7 | 4,6 | 4,9 | 4,8 | 4,9 | 4,3 | 4,8 |
| VT outer plates | 0,5 | 0,5 | 0,4 | 0,5 | 0,5 | 0,5 | 0,5 |
| VT upper | 39,4 | 40,6 | 40,8 | 41,8 | 37,6 | 37,9 | 37,9 |
| VT lower | 38,6 | 36,5 | 35,9 | 37,2 | 39,9 | 40,9 | 40,9 |
| VT total | 78,0 | 77,1 | 76,7 | 79,0 | 77,5 | 78,8 | 78,8 |

-> Operation without cryogenic pump leads to no critical heat load for the components. The shift of the beam could be easily compensated by the mechanical source adjustment.

**Step 5:**
*Definition of new operation ranges*

- Operation without restriction up to 5s beam on-time, up to nominal acceleration voltage of 50kV (69MW/m² at Target position)
- below 30kV (19MW/m² at Target position) the beam on-time is limited to 10s




-> Large parts of operation area work without cryo pumping
High pumping capacity needed for:
- Long time beams >10s up to 30kV and >5s above 30kV
- High power beams >50kV

Enhancement of the „no cryo"-area is possible by upgrading the source gas inlet for higher values and increasing the pumping capacity of the turbo molecular systems

**Conclusion:**
- Successful test operation of the high heat flux test facility MARION.
- Large areas of operation range could be done without using the cryo pumps.
- Much higher flexibility for the test operation could be offered.
- Change of prototypes will be possible within some hours instead of three days.
- By the abandonment of cryogenic gases operation costs of about 40% of the total amount are saved.
- Higher reliability by leaving thermal cycles.
- Risk of damages within the cooling water system by freezing water near the cryogenic parts will be avoided.
- Operation with cryogenic technology is still an option to reach highest loads above 60MW/m², for long operation times up to 30s or to increase the pumping capability for special specimens.