OFF-NORMAL AND FAILURE CONDITION ANALYSIS OF THE MITICA NEGATIVE-ION ACCELERATOR

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MITICA Goal:

P = 16 *MW*
I = 40 *A*
V = 1 *MV*
t = 3600 *s*

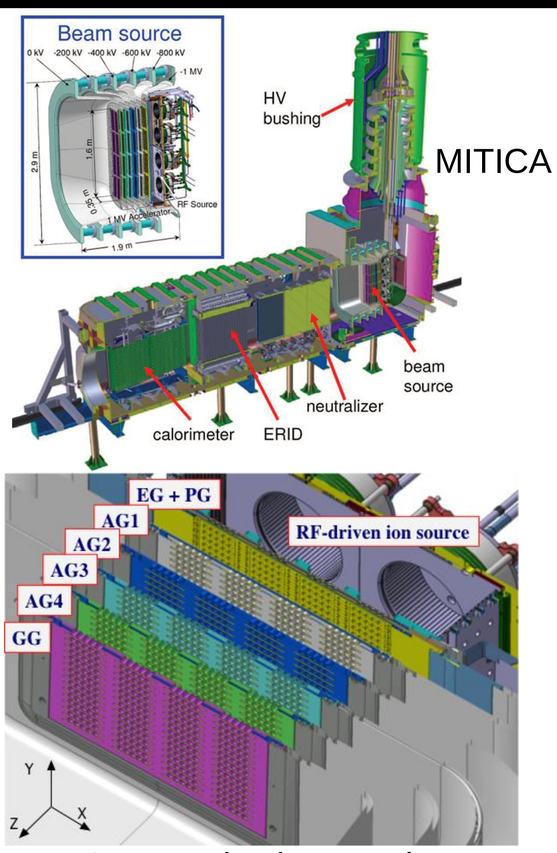
MITICA (Megavolt ITER Injector & Concept Advancement) is the full-scale prototype of ITER NBI

The negative ion (D^-) accelerator design is based on Multi Aperture Multi Gap concept (7 grids,1280 apertures)

Main design issue: keep the thermo-mechanical stresses in the materials below the tolerable limit for the required pulse duration and fatigue life

Achieved by: (a) reducing and uniforming heat loads caused by electrons and secondary particles
(b) improving heat removal capability of the water cooling channels inside the grids

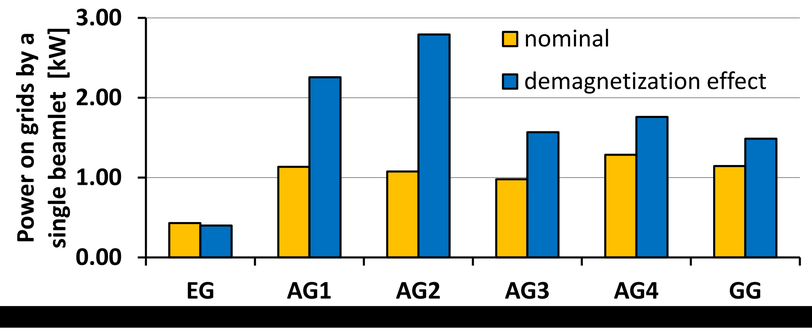
Aim of this work: analyse and identify the "off-normal" operating conditions of MITICA accelerator



MITICA negative ion accelerator

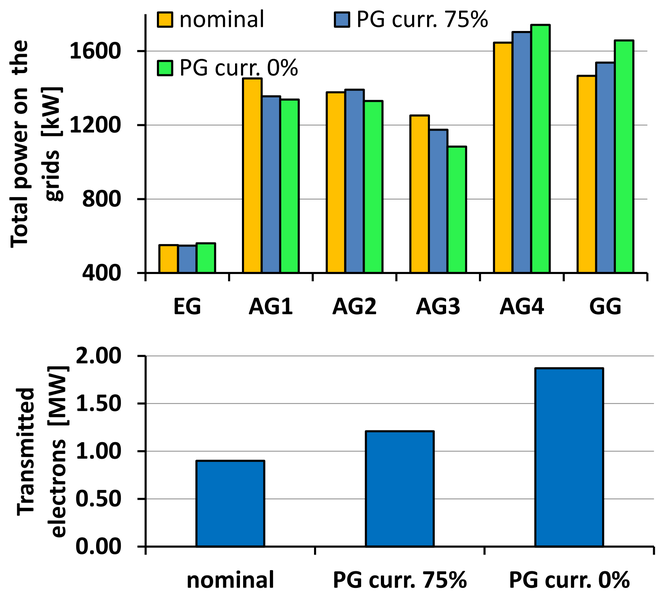
Condition #1: demagnetization of permanent magnets

- B_R reduced from 1.1 T to 0.5 T for all the magnets contiguous to one beamlet
- Heat load increased by a factor of 2.5 on AG2 (due to co-extracted e^-)
- Could lead to damages if a large area (tens of beamlets) is affected



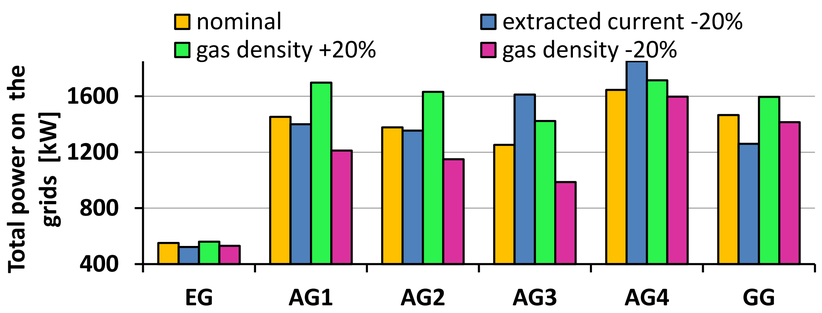
Condition #2: PG current failure

- PG current is necessary for generating long-range magnetic field for electron deflection
- Partial (75%) and total (0%) failure considered
- Major effect: increase of transmitted electrons



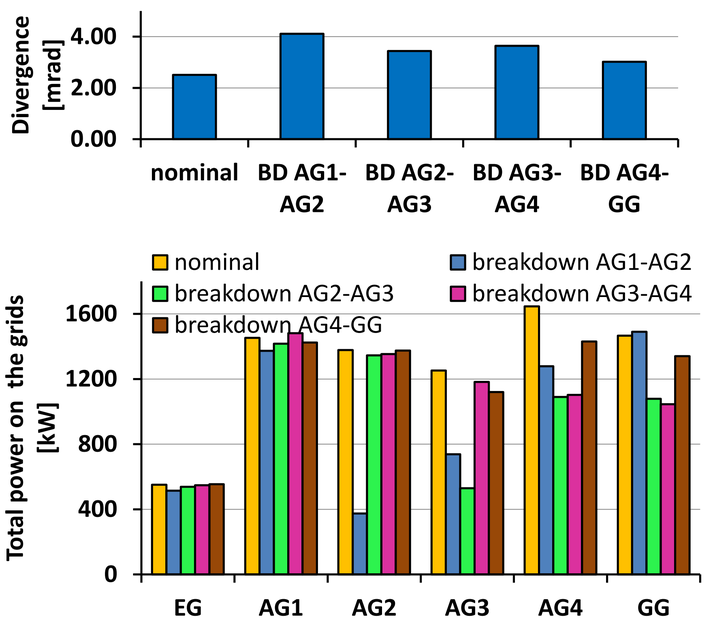
Condition #3: non uniform extracted current/gas density

- Non uniform extraction observed in large ion sources
- Both reduced extracted current (-20%) and increased gas density (+20%) lead to higher heat loads on the grids
- Heat load on last grids probably underestimated due to lack of realiable model of halo region



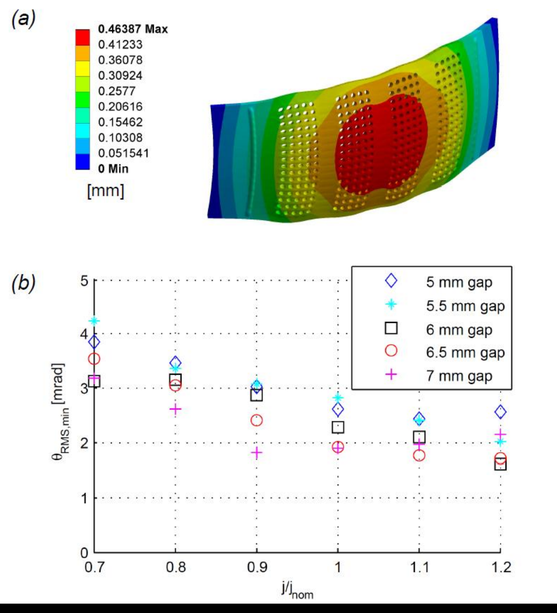
Condition #4: breakdown between grids

- Modeled considering zero voltage across one of the acceleration gaps, and the voltage on the other gaps unchanged
- Breakdown PG-EG and EG-AG1 not considered as the accelerator operation would be interrupted
- Optics quality deteriorated, total beam energy decreased by 200 kV



Condition #5: variation of extraction gap

- Heat loads lead to out-of-plane grid deformation
- Variation of extraction gap between 5 and 7 mm has been investigated
- Resulting divergence of ± 0.5 mrad has been obtained (acceptable)



Condition #6: effect of grid misplacement

- Misplacement due to grid deformation caused by heat loads, wrong mechanical tolerances and over-constrained thermal expansion
- Final deflection range [-1.6, 2.4] is slightly larger than the requirement on beamlet alignment (±2mrad)

Cause of Beamlet deflection	deflection (mrad)
Grid offset in plane (±50% Power Load)	[-0.15, 0.25]
Grid offset in plane (Positioning tolerance)	±0.7
Grid offset out of plane (Thermal deformation)	+0.3
Grid offset out of plane (±50% Power Load)	±0.1
Grid offset out of plane (Positioning tolerance)	[-0.5, +0.6]
Magnetic non uniformity	±0.35
Tolerance on magnet position	±0.1
Total Beamlet Deflection (range)	**[-1.6, 2.4]**

Detection and protection strategies

- Faults having purely electric nature: easy detection
- Other faults: temperature measure of cooling water combined with other diagnostics:
  - Beam Emission Spectroscopy (BES)
  - Beam tomography
  - Secondary emission imaging on the calorimeter
- Data cross-checking could be complex and time-consuming

Conclusions

- Off-normal operating conditions cause a degradation of performances but do not constitute immediate risk
- detection requires processing and cross-checking data from different diagnostic systems

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