Runaway electron beam stability and decay in COMPASS

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MOTIVATION AND INTRODUCTION

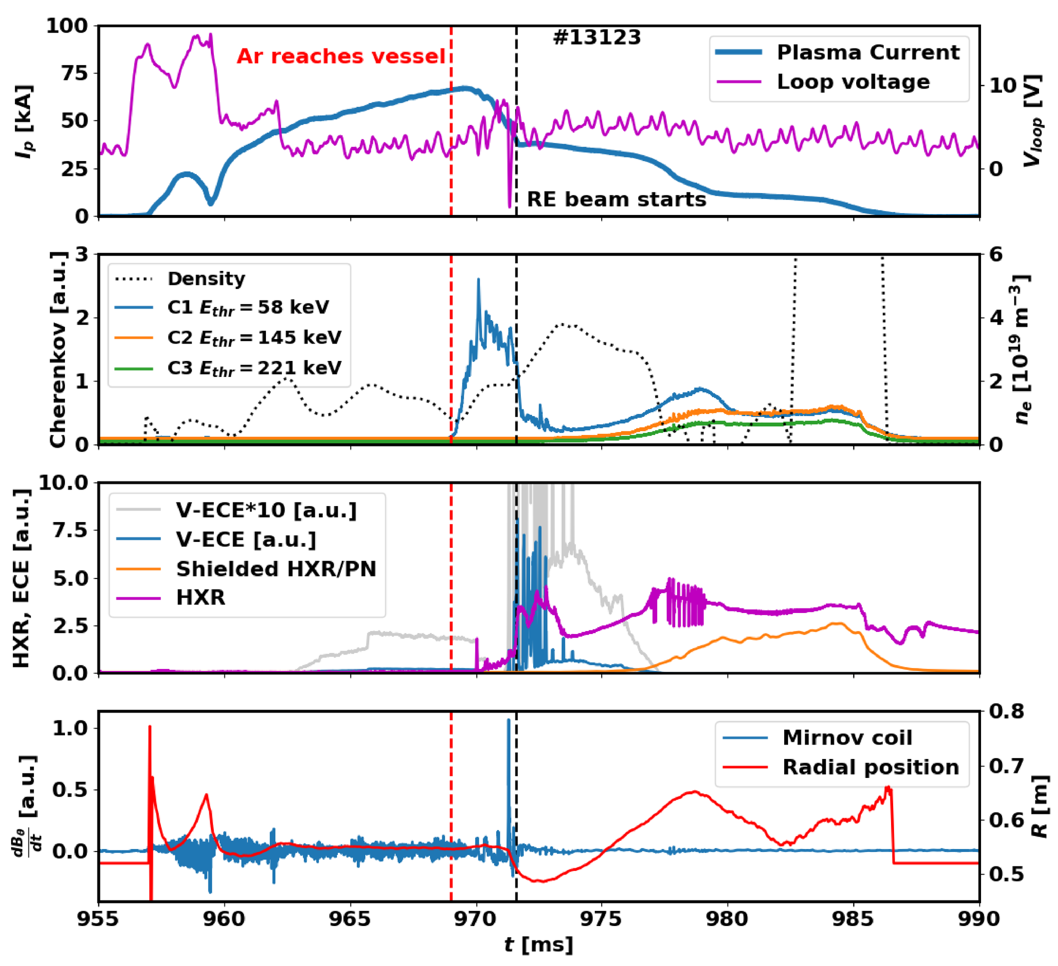
- Runaway electrons (RE) = a significant threat for the safe operation of ITER
- RE in tokamaks appear in low density plasmas or during disruptions
- Massive gas injection (MGI) mitigated disruptions with and without RE beam generation studied in most medium size and large machines, e.g. [1]
- MGI and gas puff disruptions studied in many machines including COMPASS
- Similarities to plasma betatrons and plasma-assisted modified betatrons ($+B_t$) [2]
- Optimised current drive waveform to study spontaneous decay and gas influence
- RE beam needs special radial position feedback with energy dependence

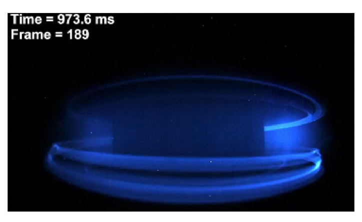
COMPASS [3] AND RELEVANT DIAGNOSTICS

- $R_0 = 0.56$ m, $a = 0.21$ m , B_T: 0.9 - 1.5 T, $I_p = 80-400$ kA,
- $t_{disch} < 0.5$ s, $n_e = 10^{19}$ - 10^{20} m^{-3} (RE at $n_e < 2\cdot10^{19}$ m^{-3})
- Details on COMPASS diagnostics in [4]
- AXUV system (bottom camera reliable during RE beam phase) - rough radiated power
- HXR NaI(Tl) and HXR/Photoneutron shielded scintillator, ^{3}He neutron detectors
- Cameras: 2x Photron Mini UX-100, 4,5,8 or 40 kfps, Photron SA-X2 at 100 kfps.

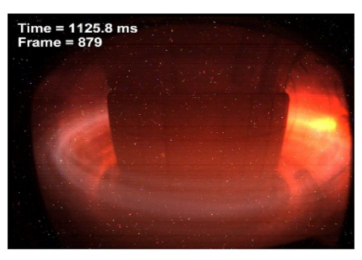
RAMP-UP SCENARIO

- I_p ramp-up, 10-25 ms after breakdown, $I_p = 60-90$kA, $q_{95} > 4$, $n_e < 2\cdot10^{19}\mathrm{m}^{-3}$, circular cross-section, HFS limited, classical disruption with CQ
- Solenoid MGI valve, open for 15 ms, Ar, $p = 0.8-3.0$ bar, $N_{Ar} = 1-5\cdot10^{20}$

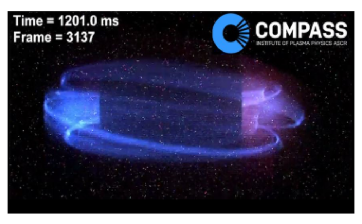




#13123 Ramp-up Ar MGI



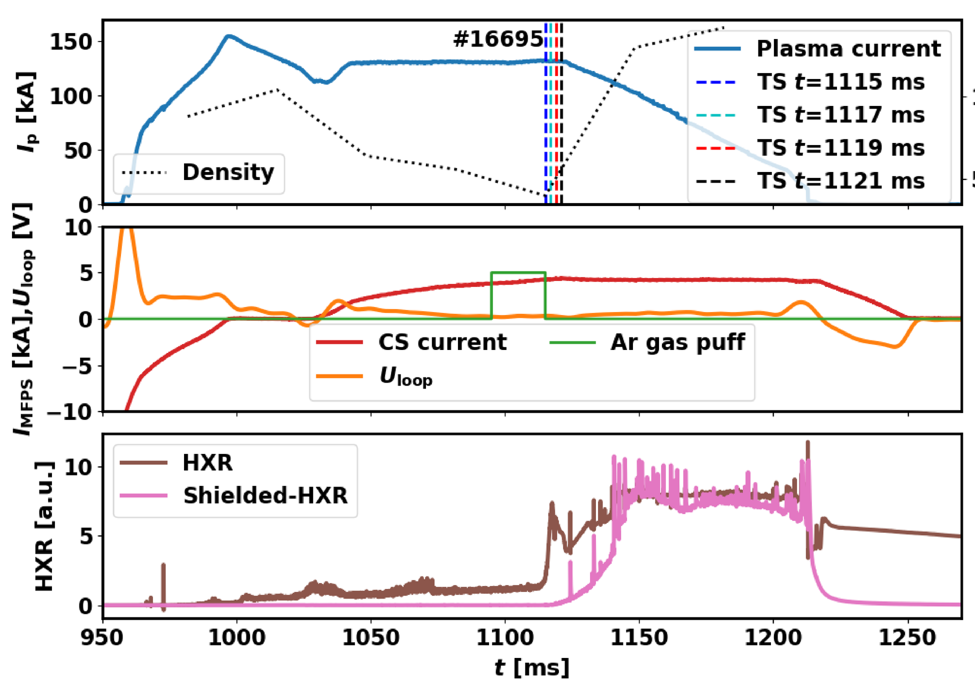
#16664 flattop Ne MGI

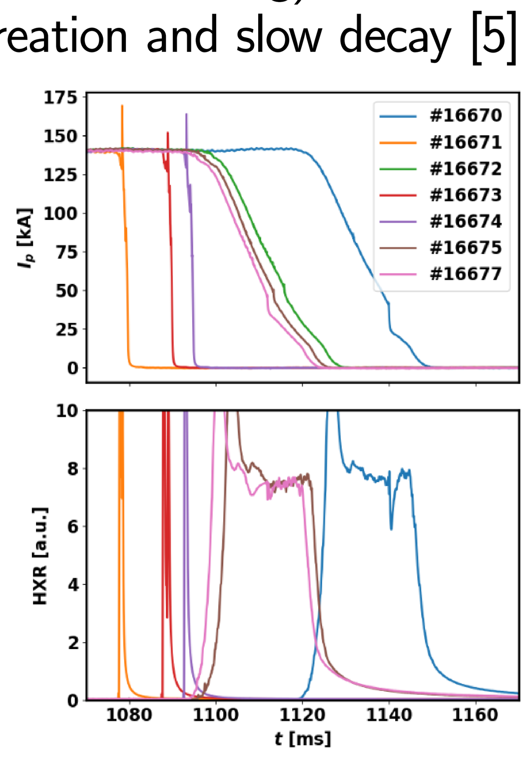


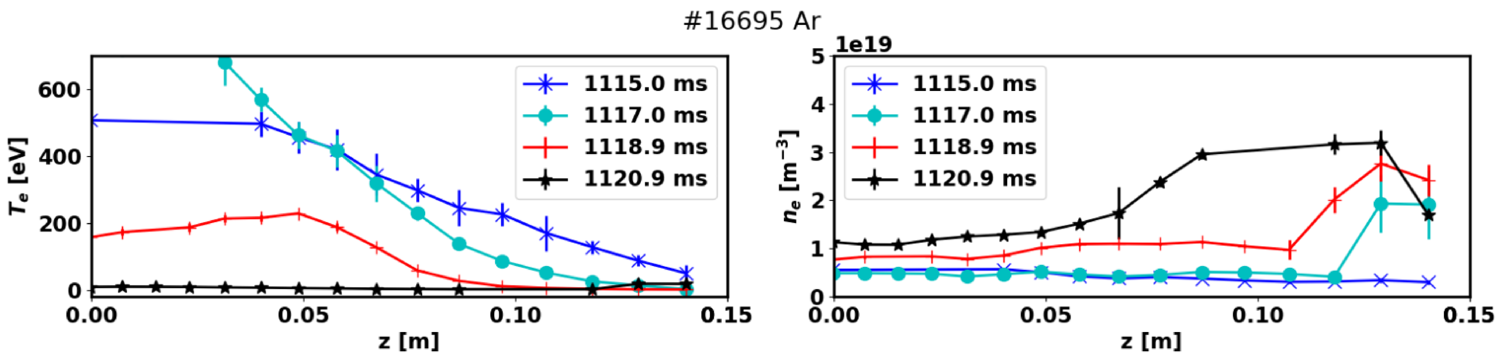
#14598 flattop Ar and D piezo vlave injection, Ip feedback

FLATTOP SCENARIO

- I_p flattop (130-160 kA), no fuelling after ramp-up
- $n_e < 1.5\cdot10^{19}$ m^{-3}, circular cross-section, HFS limited
- Ar/Ne injection: piezo valve 20 ms opening $N < 1\cdot10^{19}$, or MGI valve, op. 7-15 ms, $p = 0.8-3.0$ bar, $N = 1-5\cdot10^{20}$ [5]
- Top left - scenario with basic plasma parameters and control signals
- Bottom - profiles of temperature and density (Thomson scattering)
- Top right - MGI timing scan - threshold for beam creation and slow decay [5]

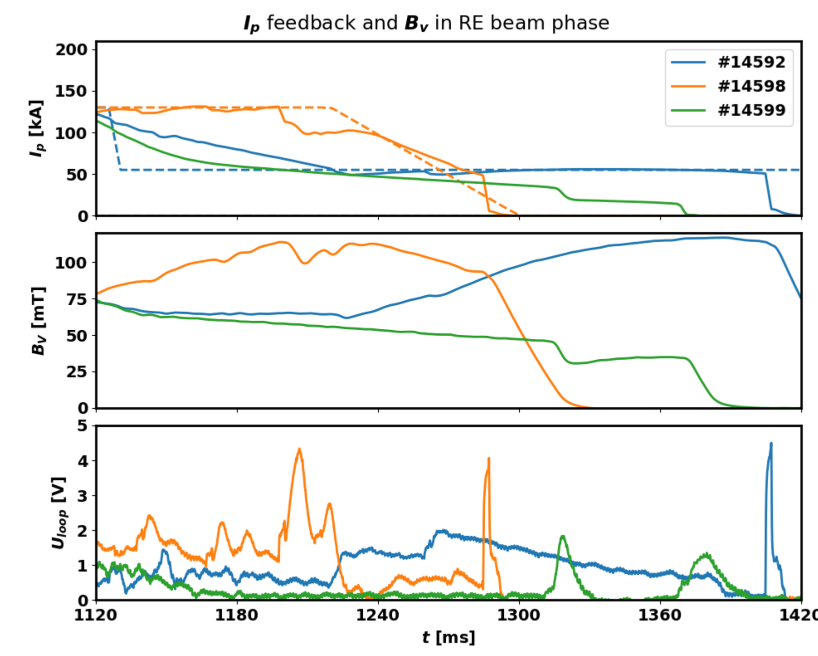


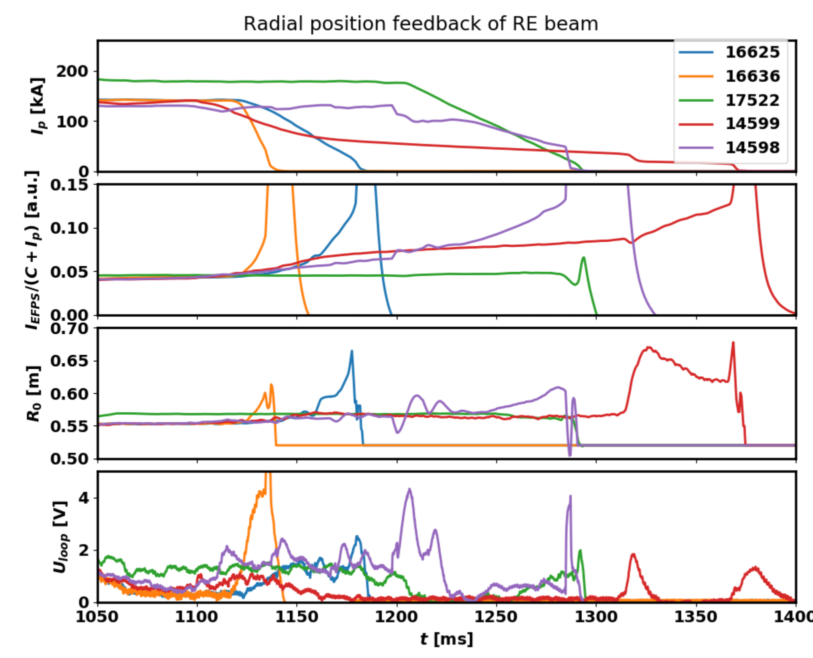


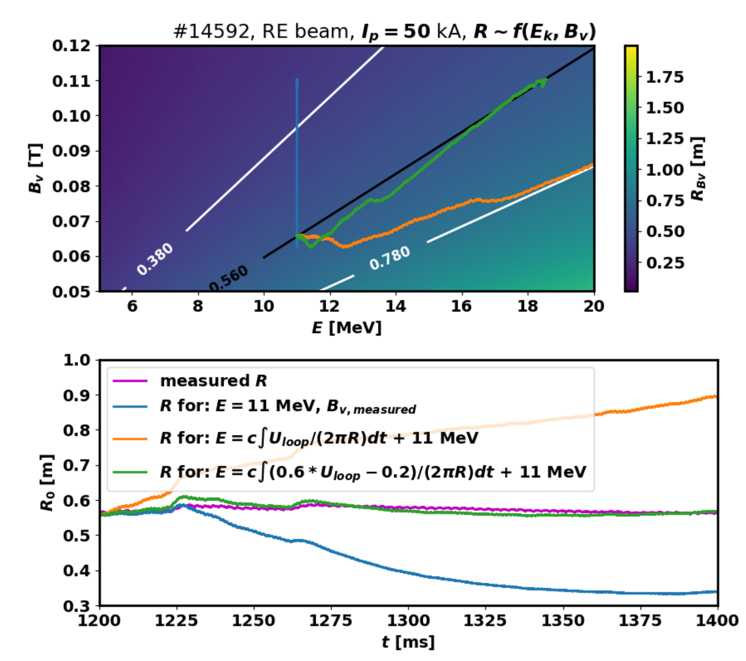


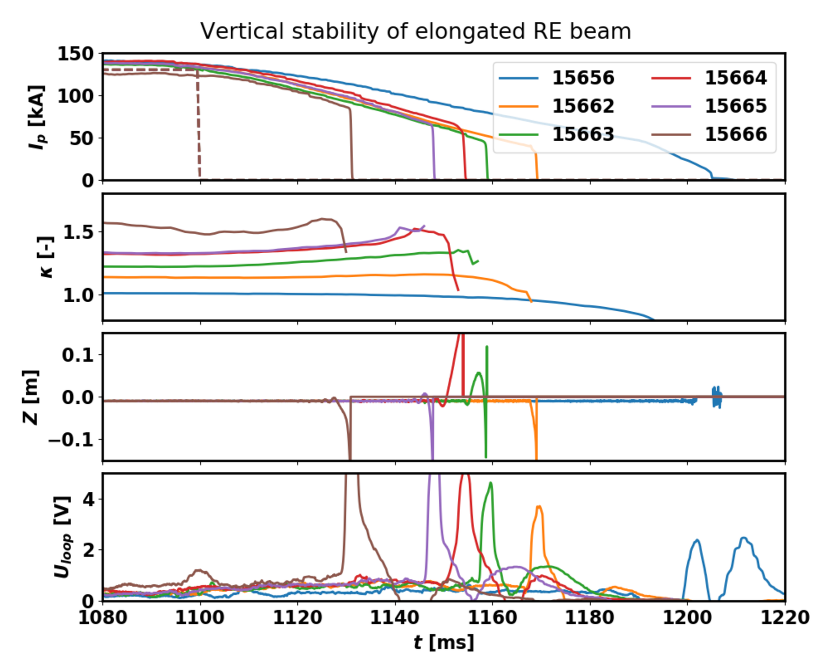
RE BEAM CURRENT AND POSITON

- I_p policy - $U_{loop} = 0$ V or I_p feedback (FB) - in Ar requires high U_{loop} (top left)
- Radial position FB (B_v) - slow system ($\sim I_p, \sim\Delta R + \int\Delta R dt$), fast system ($\sim\Delta R + \int\Delta R dt$)
- $\sim I_p$ dependence seems to degrade the performance in case of RE beam (top r.)
- Betatrons: $B_v = f(E_{k,e^-})$ - the case for RE beam in tokamak as well? (bot. l.)
- Elongated RE beams - can be generated, stable up to a critically low I_p (bot. r.)



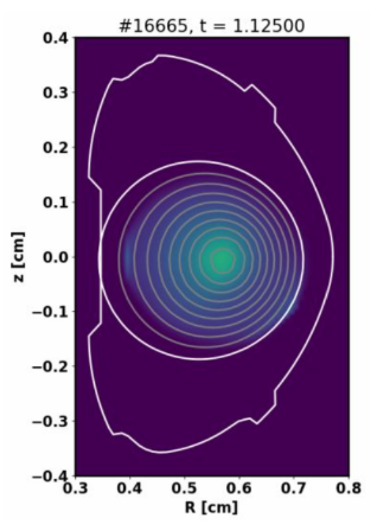


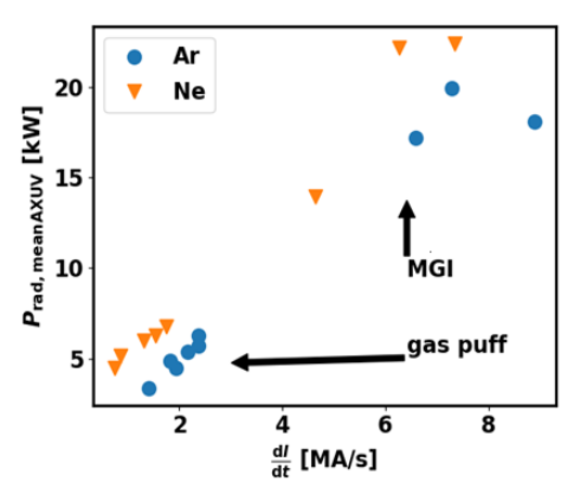


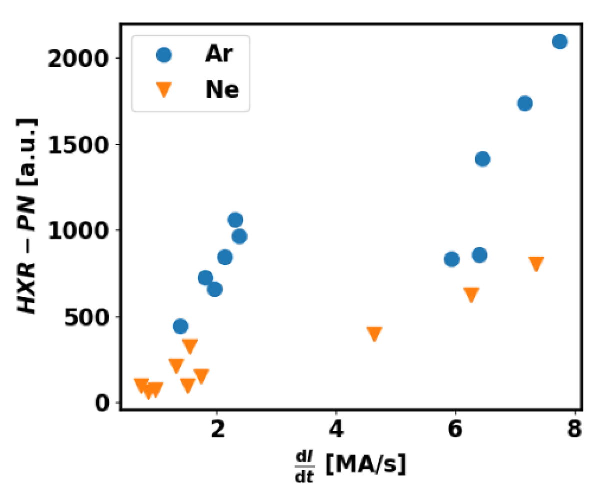


RADIATED POWER and HXR

- Gas amount scan in flattop (no CQ, $U_{loop} = 0$) - MGI($\sim10^{20}$),piezo v.($< 10^{19}$)
- Slightly slower current decay for Ne, radiated power comparable
  - for given $\mathrm{d}I/\mathrm{d}t$ neon radiates more in the AXUV spectral region
- HXRs and photo-neutrons - larger flux for Ar than for Ne







SUMMARY

- Two different scenarios utilised for RE beam experiments on COMPASS
  - MGI into I_p ramp-up and gas-puff or MGI into low density I_p flattop
- RE beam decay with no external loop voltage may be studied or I_p can be stabilised using a large loop voltage
- The plasma assisted modified betatron and plasma betatron research may be a source of useful information for RE beam issue
- **Stabilising radial position of the RE beam requires special feedback policy with dependence on kinetic energy rather than on current**
- **Neon seems to radiate more energy of the beam in UV-VIS while argon causes stronger hard radiation**

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