ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
SWISS PLASMA CENTER

2016 TCV experiments on runaway electrons

within the MST1 TCV15-1.3.5 project

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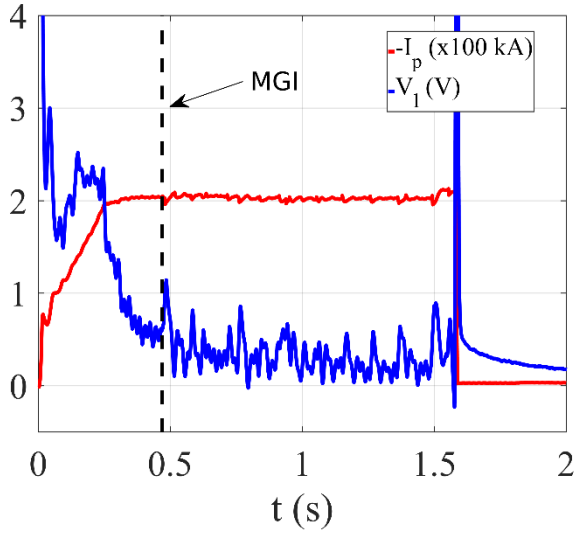
Objectives of TCV15-1.3.5

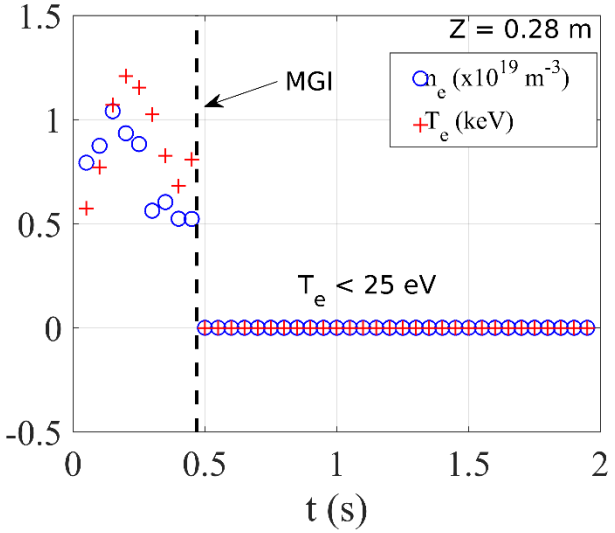
- **Establish reliable scenario for runaway electron plateau formation**
- **Characterize RE generation and mitigation**
- **Determination of the critical field**
- **Effect of plasma shaping on RE generation and mitigation**
- **Effect of MHD instabilities on RE confinement**
- **Control of RE beam position**

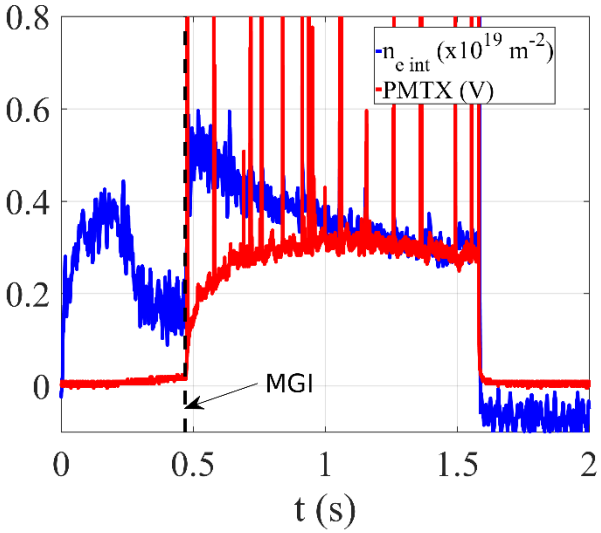
Systems and Diagnostics

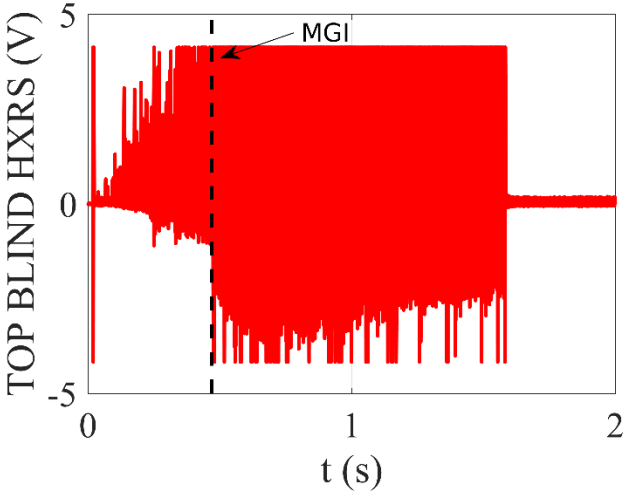
- **TCV : B = 1.45 T, R = 89 cm, a = 25 cm, $\kappa < 2.8$, $|\delta| < 1.0$**
- **MGI via DMV (Ar, Ne, …)**
- **HXRS : HXR tomographic spectrometer**
  - **CdTe detectors, 2 cameras (1 vertical and 1 horizontal)**
- **PMTX : photomultiplier outside the vessel**
- **Usual tokamak diagnostics (magnetics, FIR, TS, SXR, …)**

52716 : full OH->RE conversion

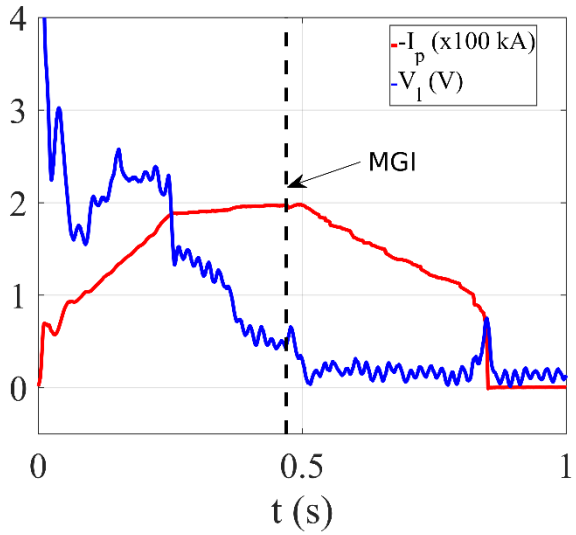


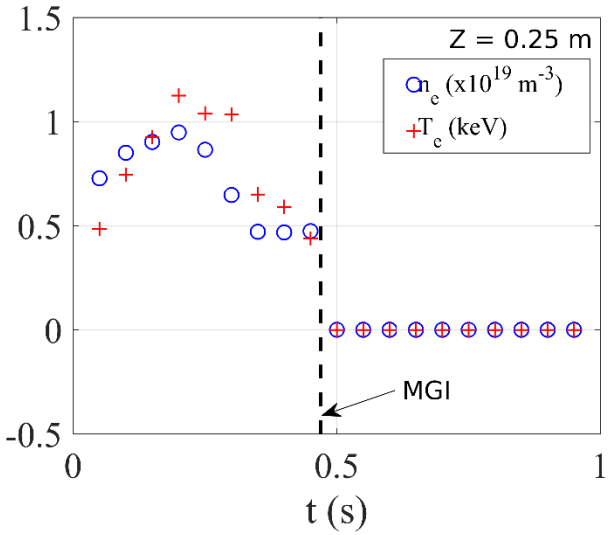


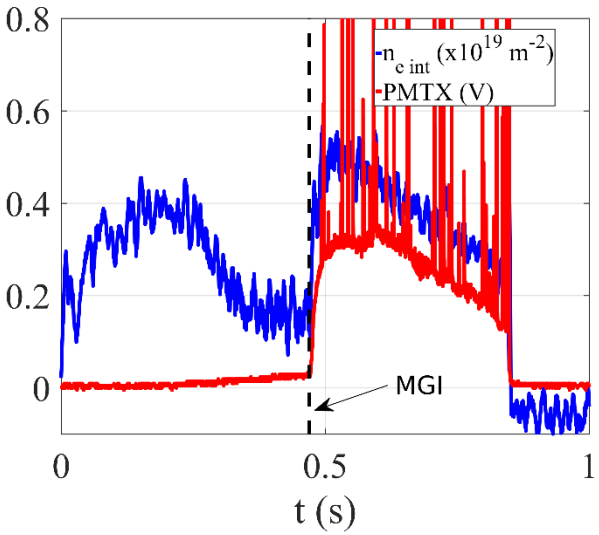


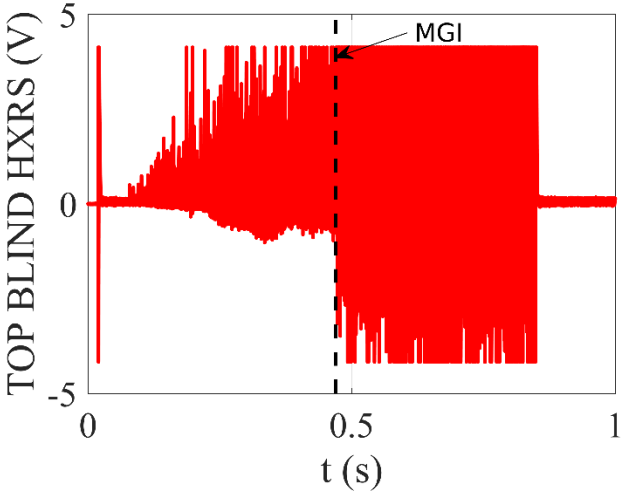


52717: RE beam «natural» decay

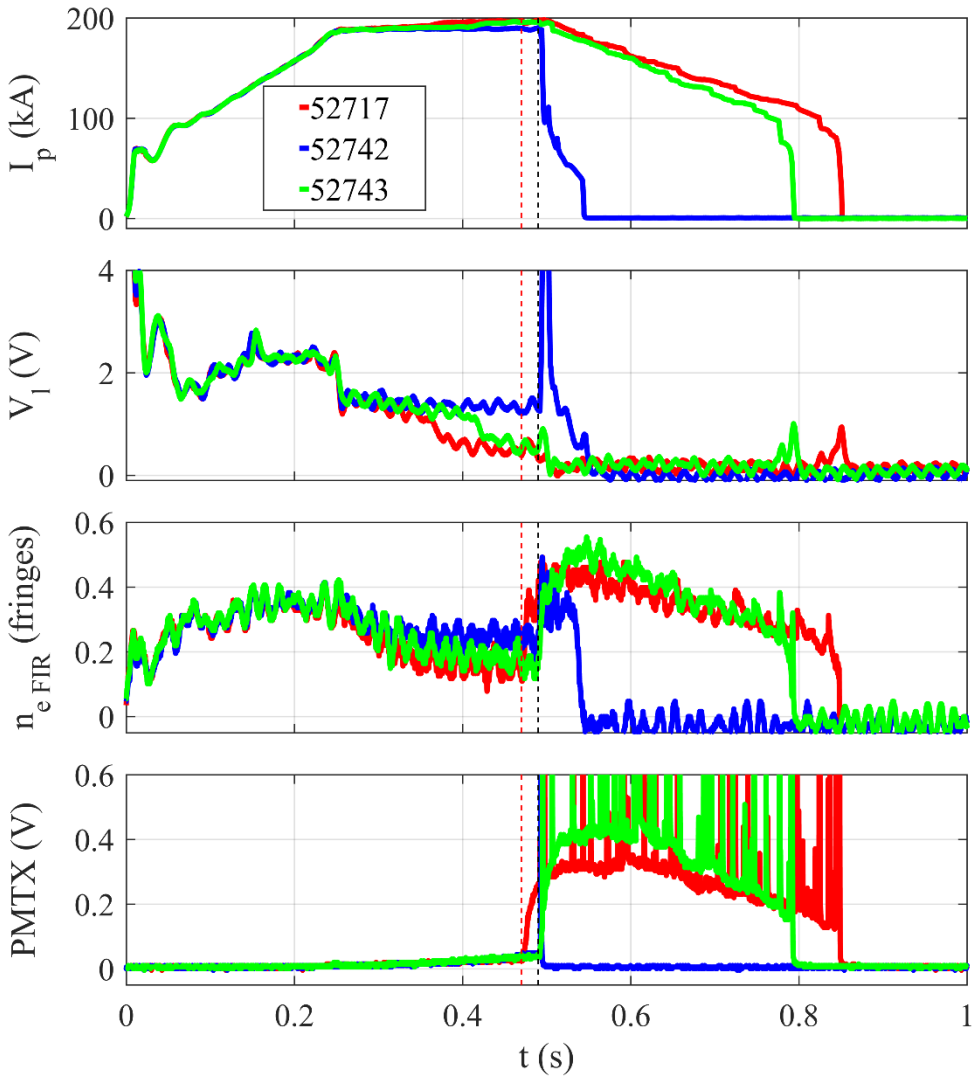








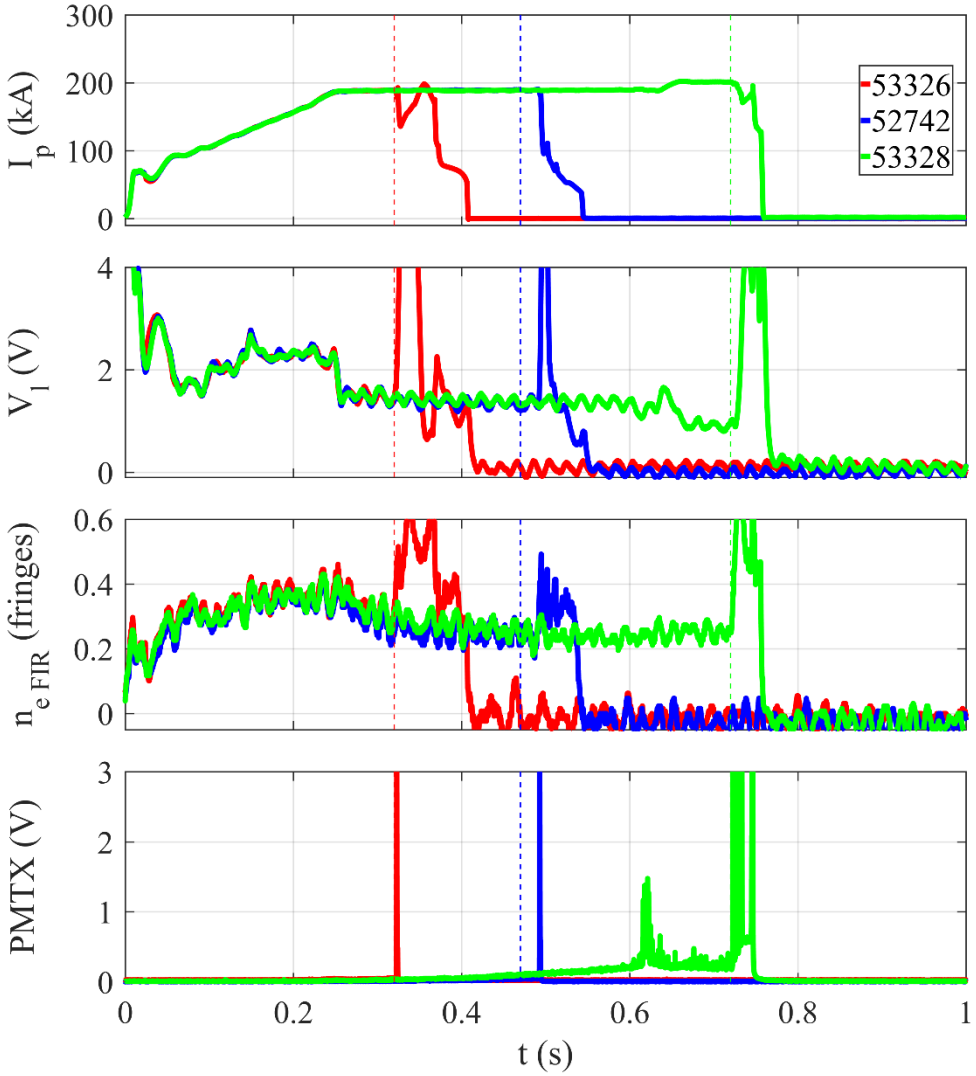
Effect of pre-MGI density



- 52717 : ne = 1.5×10^{18} m^{-2}
- 52743 : ne = 2.0×10^{18} m^{-2}
- 52742 : ne = 2.5×10^{18} m^{-2}

- Importance of pre-MGI RE fraction?

t_{MGI} vs pre-MGI RE density

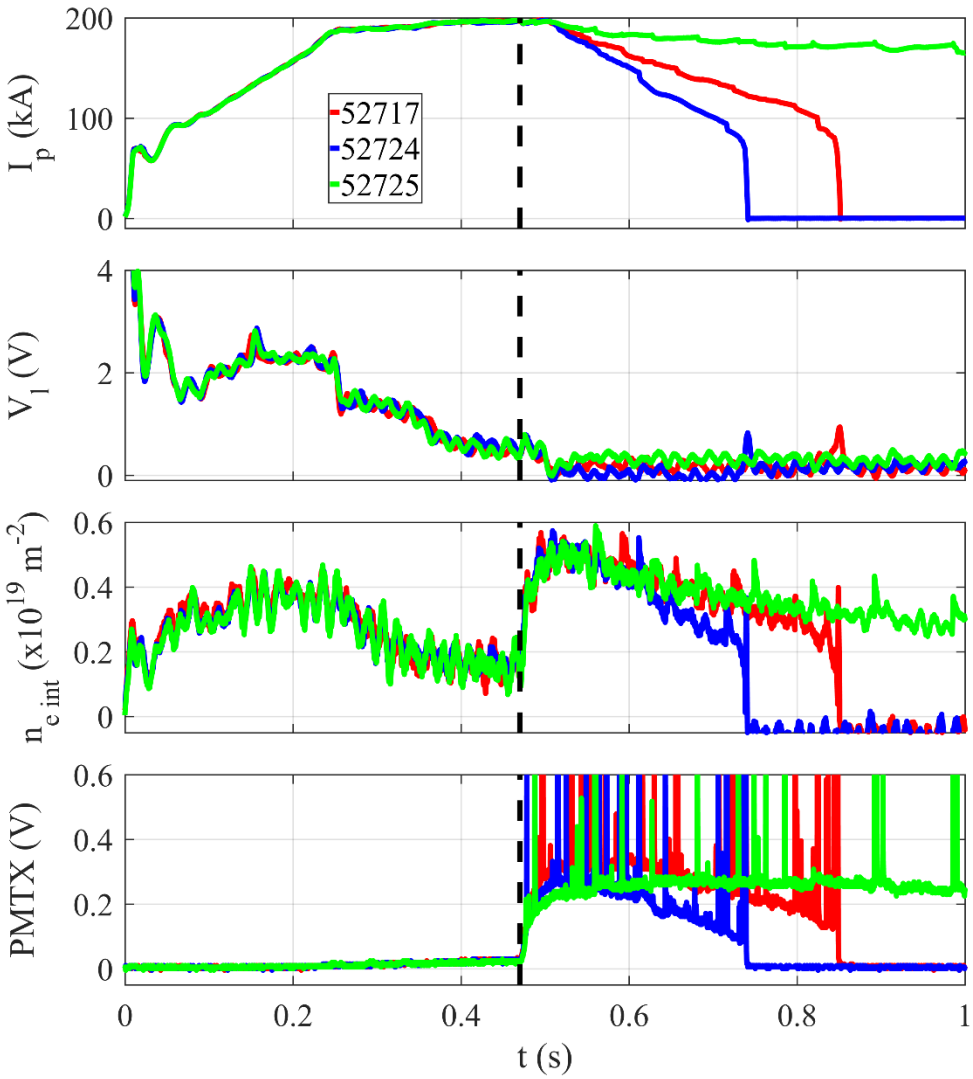


n_{eFIR} = 0.25 f.

- 53326 : t_{MGI} = 0.32s
- 52742: t_{MGI} = 0.47s
- 53328: t_{MGI} = 0.72s

- RE beam generation if pre-MGI RE density is sufficient

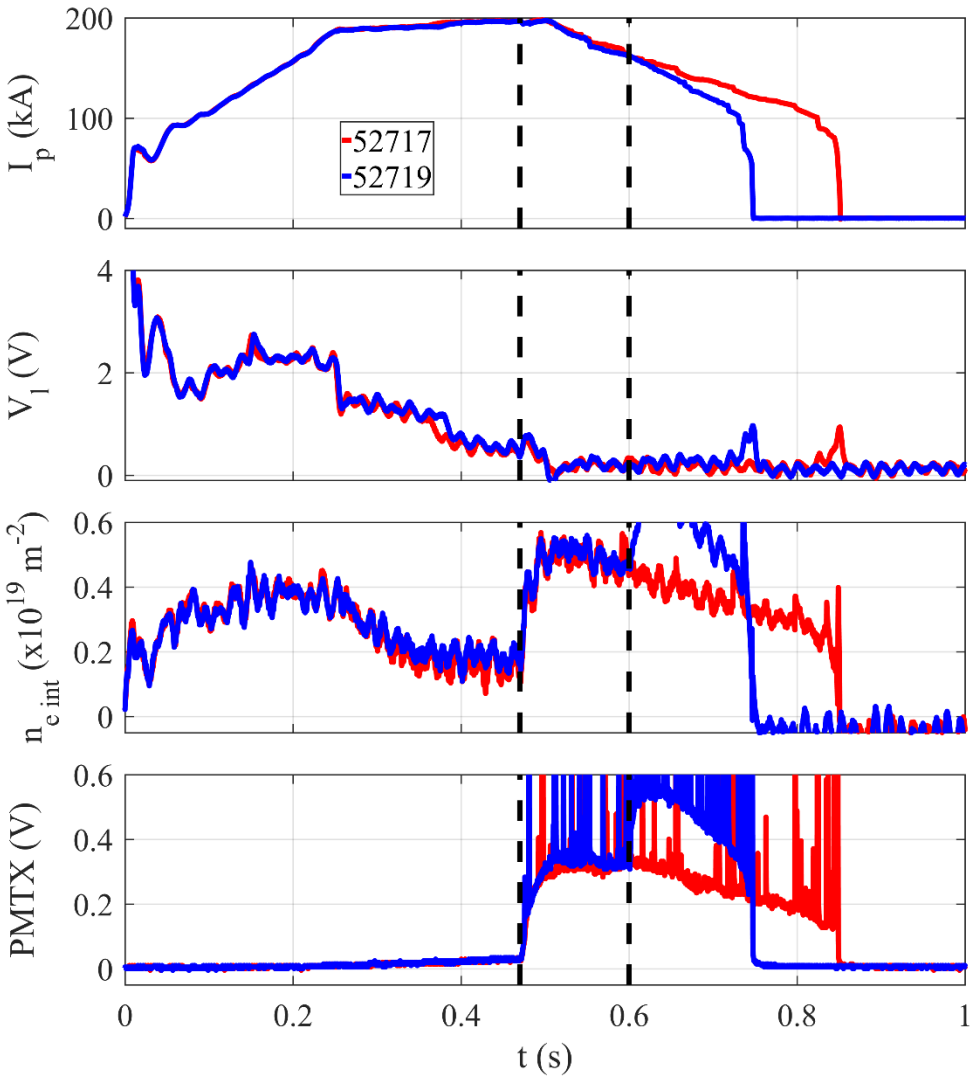
I_{OH} control



- 52717 : $dI_{OH}/dt = 0$
- 52724 : $dI_{OH}/dt < 0$
- 52725 : $dI_{OH}/dt > 0$

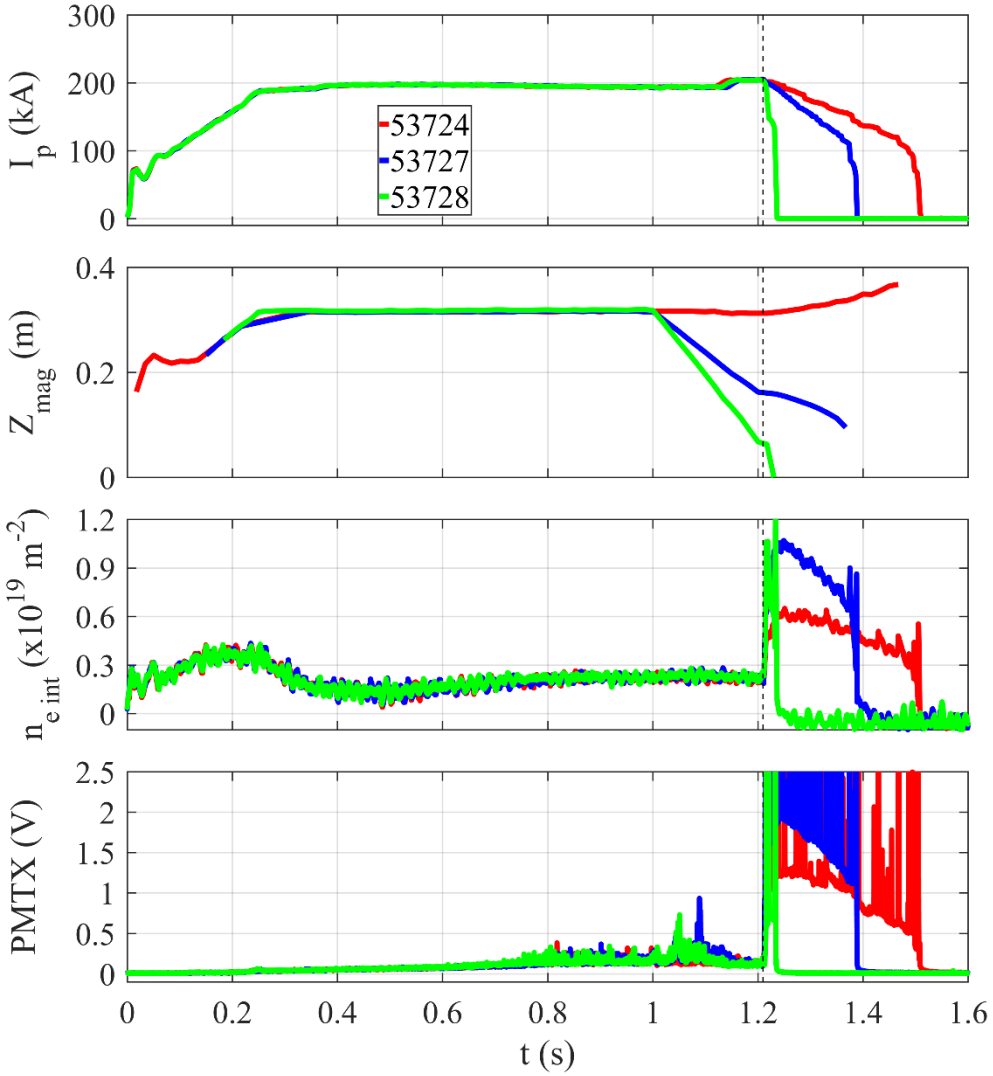
- Reliable RE beam scenario
- RE plateau current control

Second MGI – Ne injection



- 1st injection :
  - Ne 7.2 bar
  - 5 ms @ 0.47 s
- 2nd injection : 52719
  - 80ms @ 0.6 s
- Density, HXR increase
- Faster ramp-down

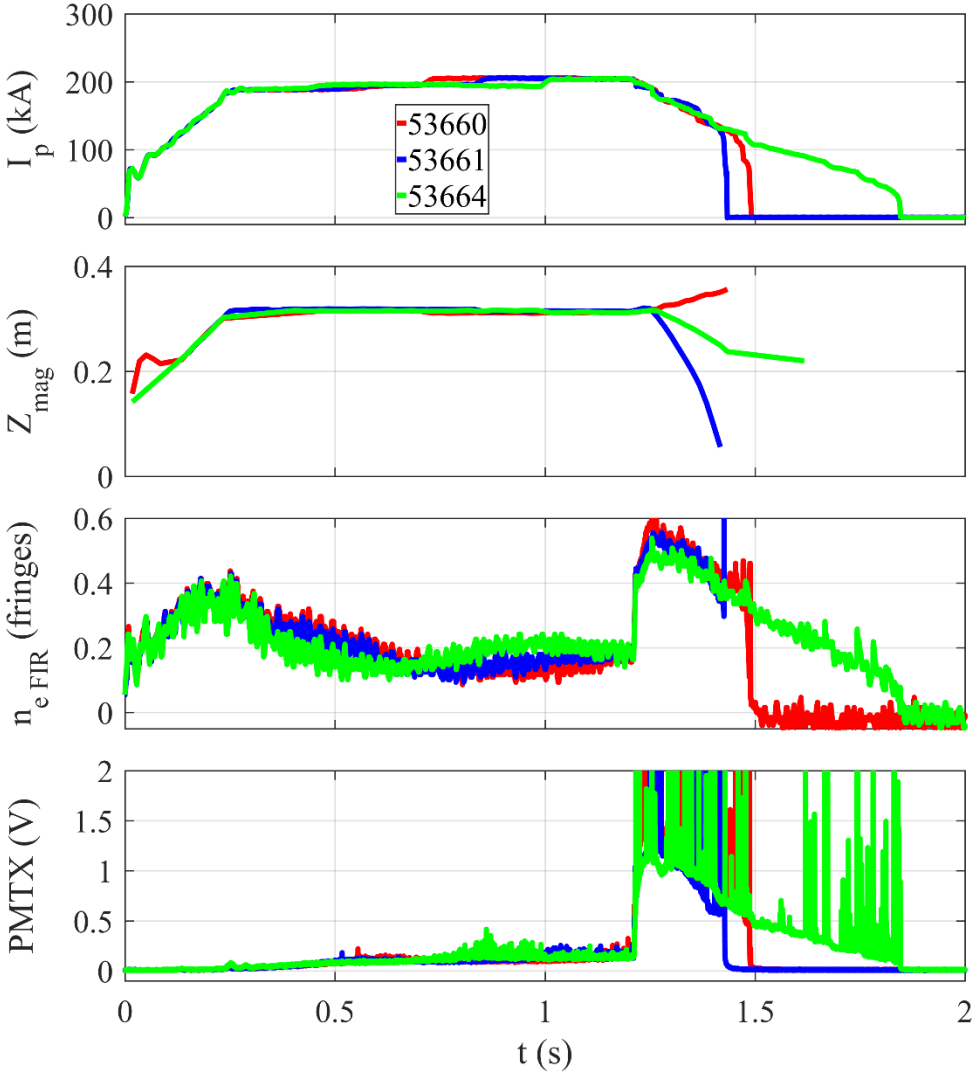
pre-MGI vertical position



- 53724: Z = 0.32m
  midplane inj.
- 53727: Z = 0.16m
  top inj.
- 53728: Z = 0.08m
  inj. above plasma

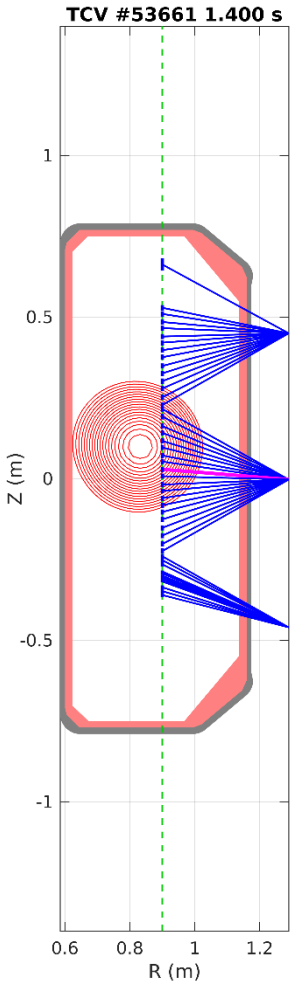
- Better Ne penetration with MGI above midplane?

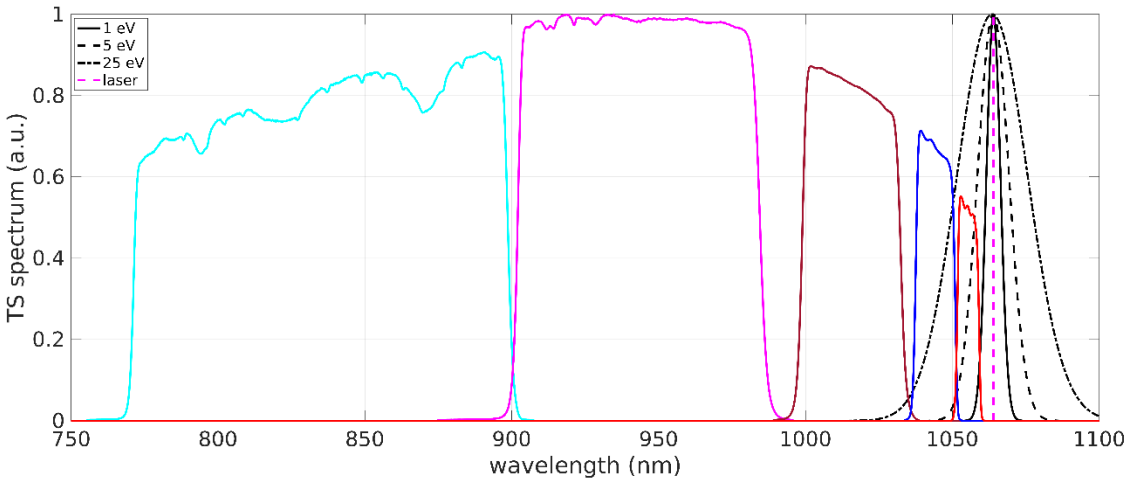
RE beam vertical position control



- **RE beam position control**
  Z_{mag} = 32cm -> Z_{mag} = 6cm
- **Better vertical control at Z_{mag} = 23cm**
  - RE beam maintained to I_p=20 kA
  - Record RE beam duration t_{RE} = 650 ms

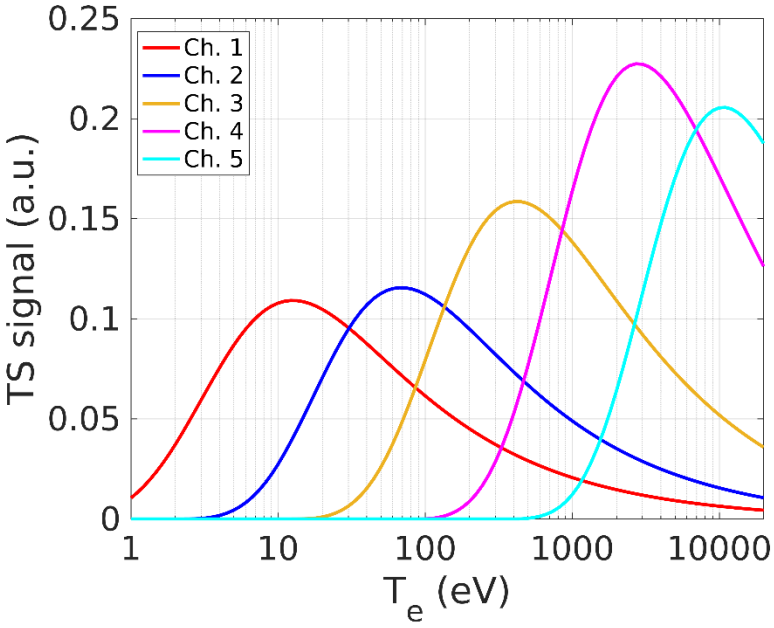
Thomson Scattering System

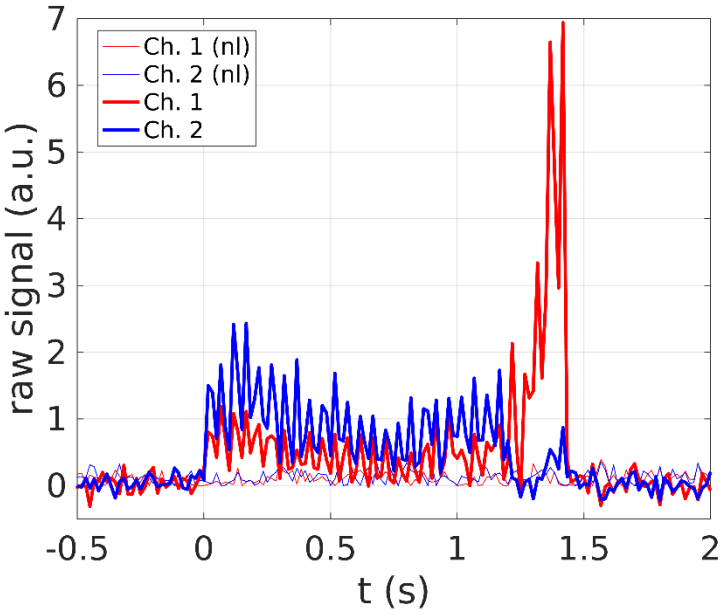




- **Central region covered by new 5-channel spectrometers**
  - T_e measurements down to 5 eV
- **Top half of chamber covered by old 4-channel spectrometers**
  - $T_e < 25$ eV

TS raw data analysis





- TCV Shot 53661 @ 1.4s
  - $T_e \approx 5$ eV

Conclusions

- **Reliable RE beam generation scenario**
  - MGI in very-low density plasma
  - **Full conversion of ohmic current to RE current**
  - I_{OH} control during RE beam phase
- **RE beam formation requires a significant amount of pre-MGI RE**
- **Secondary MGI increases HXR and -dI/dt**
- **Better Ne penetration with DMV aligned with plasma upper position**
- **RE beam vertical control demonstrated**
  - **Better control at Z=23cm**
  - **RE beam maintained for 650ms without external drive (to I_p = 20kA)**

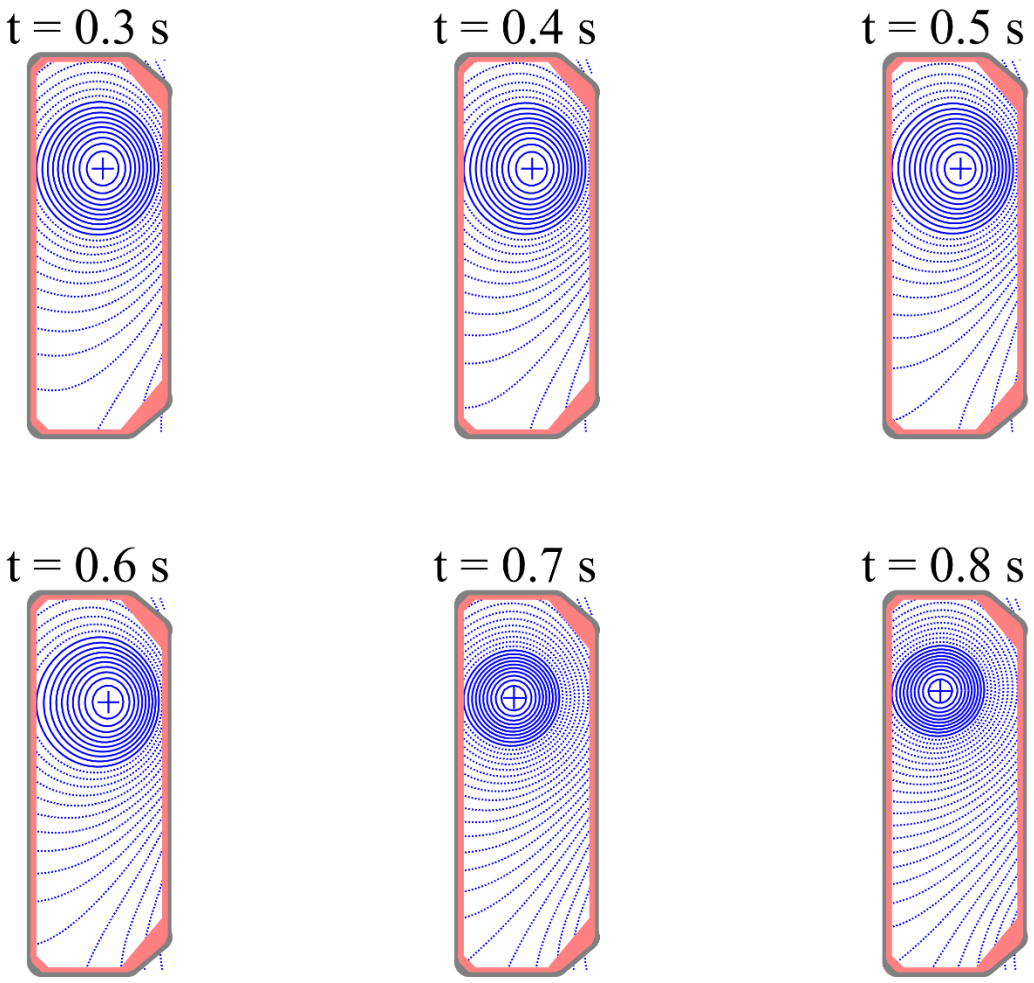
2017 TCV RE experiment

- **New DMV above the plasma**
- **REIS diagnostic for synchrotron radiation**

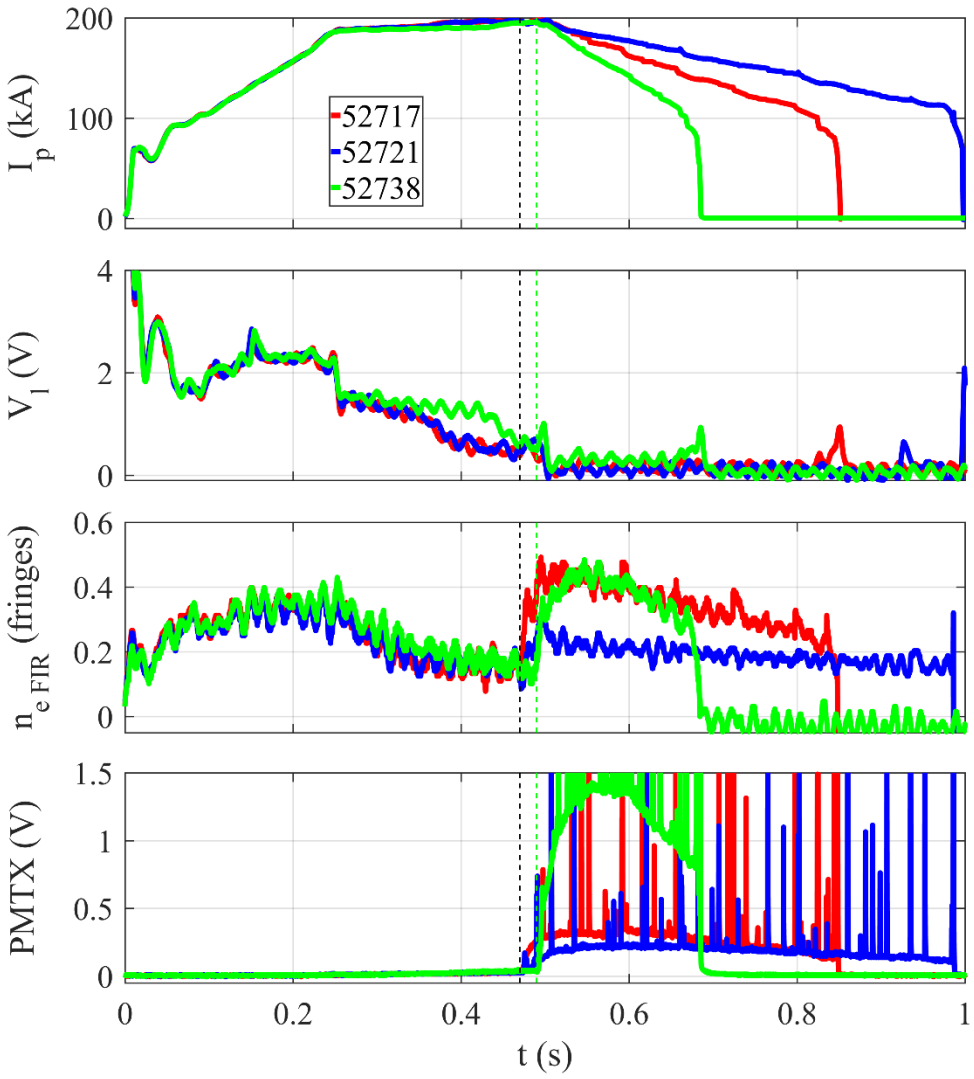
- **Effect of plasma shaping on RE generation and mitigation**
- **Feedback control of RE beam position and current**
- **Effect of MGI composition, quantity, and position vs plasma**
- **B_t scan**

Extra slides

52717: Equil. reconstruction

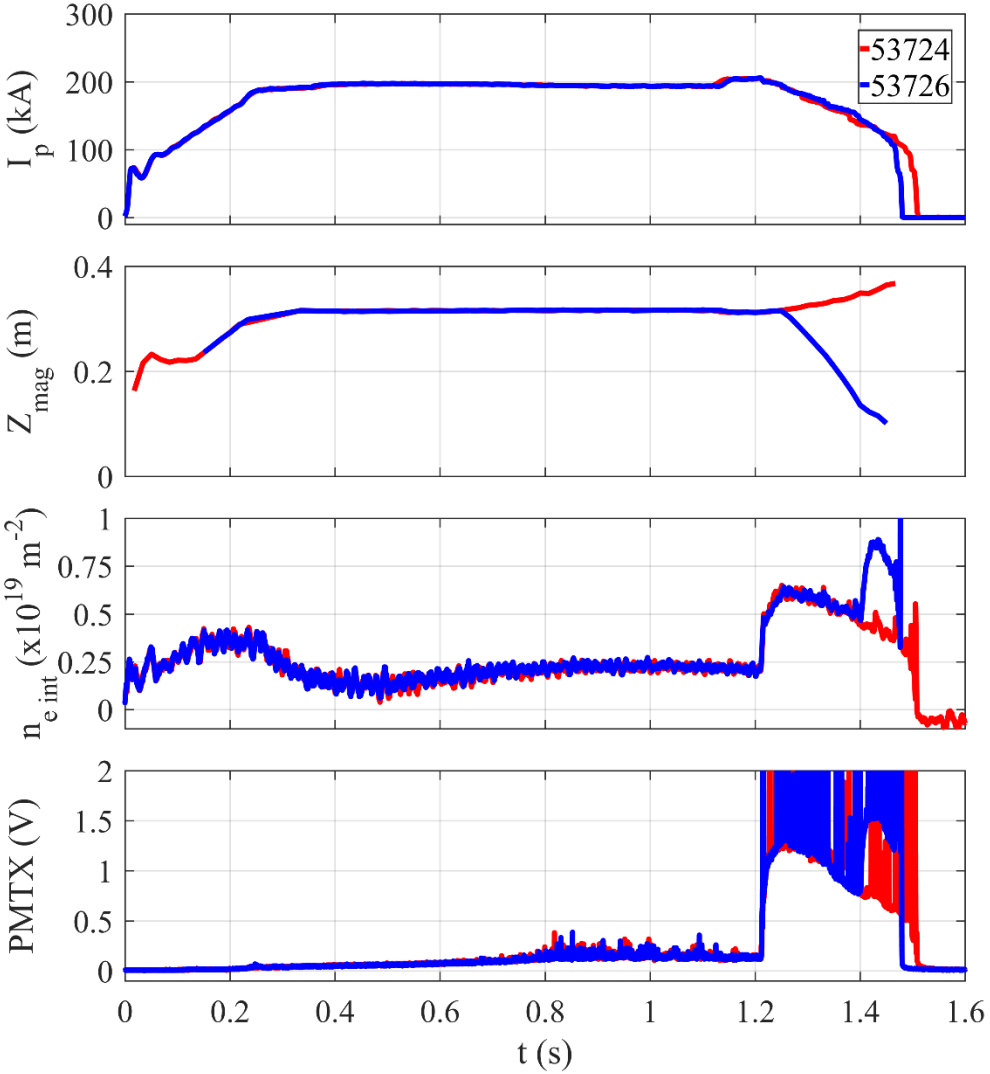


MGI : effect of gas type



- 52717 : Ne 7.2 bar
  - 5 ms @ 0.47 s
- 52721 : Ar 2.0 bar
  - 20 ms @ 0.47 s
- 52738 : Ar 17.7 bar
  - 2.5 ms @ 0.47 s

Second MGI – Ne injection (2)



- Z=0.16 m for 2nd injection
- Slightly better gas penetration?

52716 : RE loss events