Measurement of threshold electric field for runaway electron generation

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1st experimental day: 31/10/2013

Contribution to ITPA MDC-16

B. Esposito – 28/10/2013

Backround

- ITER discharges could generate **~10 MA of** 10-20 MeV **runaway electrons (RE)** through an avalanche growth process (near-head-on collisions with background thermal electron)
- Necessary condition for avalanche growth:

  → **acceleration due to the toroidal electric field** > **collisional drag on the background particles** ($E>E_{crit}$)
- Preliminary experimental results (FTU, TEXTOR, DIII-D and Alcator C-mod) and theoretical predictions indicate that there are **other RE energy loss mechanisms** (such as **synchrotron radiation losses**)

  → possibly **lower density to achieve runaway avalanche suppression** ($<n_{Rosenbluth}$)

  → large impact on the design of the ITER Disruption Mitigaton System (based on Gas Massive Injection)

Aim

Evaluate the threshold electric field for runaway generation during the flat-top of ohmic discharges in FTU

Compare the classical collisional threshold:
*(J.W. Connor and R.J. Hastie, Nucl. Fusion **15** (1975) 415)*

$$E_R = \frac{n_e e^3 \ln\Lambda}{4\pi\varepsilon_0^2 m_e c^2}$$

Dependence on n_e only

…with the radiation threshold:
*(J.R. Martín-Solís et al., Phys. Rev. Lett. **105** (2010) 185002)*

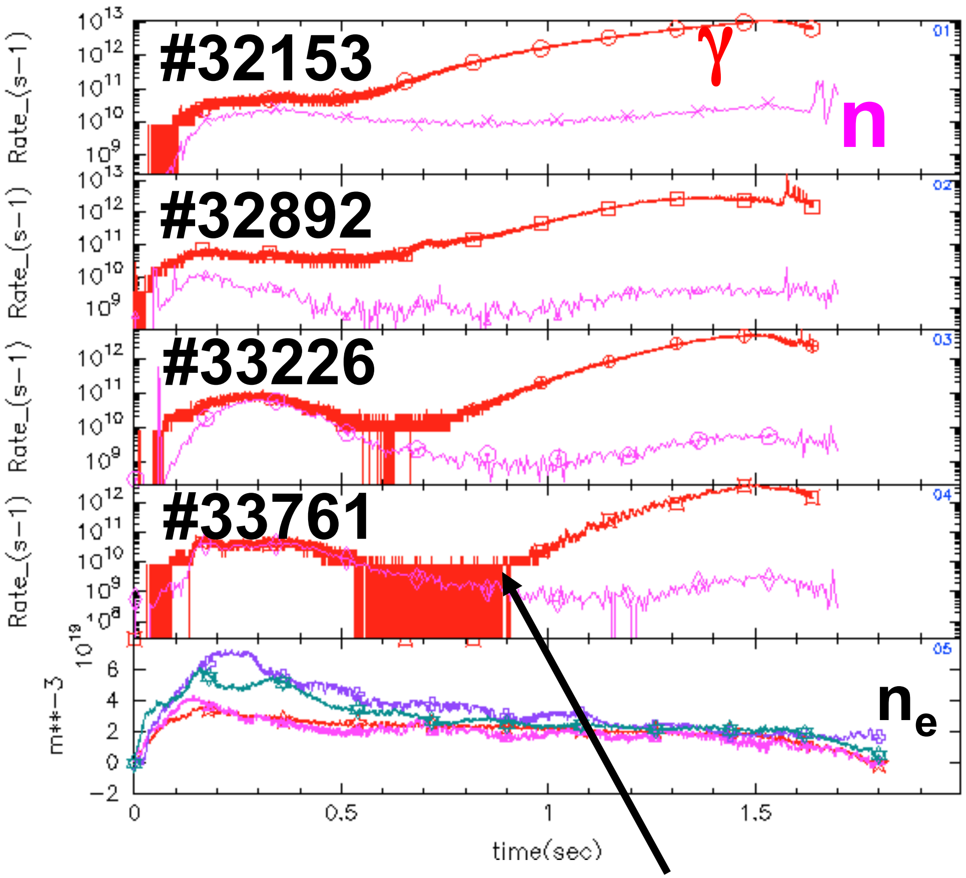
$$\frac{E_R^{rad}}{E_R} \cong 1 + C(Z_{eff})\, F_{gy}^{\alpha}$$

Dependence on B and z_{eff}

$$\left(\alpha = 0.45 \pm 0.03; \quad F_{gy} \equiv \frac{2\varepsilon_0 B_0^2}{3 n_e \ln\Lambda m_e}; \quad C(Z_{eff}) \cong 1.64 + 0.53\, Z_{eff} - 0.015\, Z_{eff}^2 \right)$$

Method

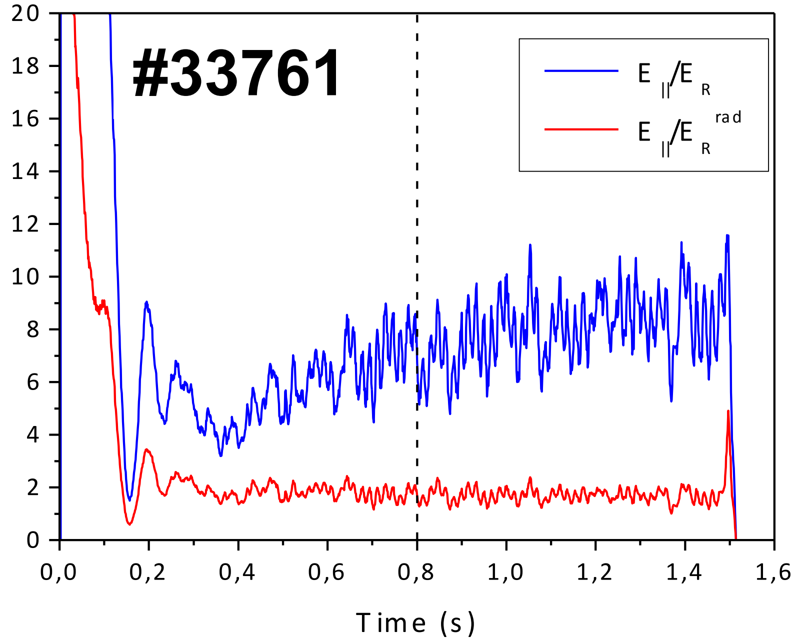
In discharges with no runaways, ramp down the density until runaway electrons are observed



runaway onset

E = 0.17 V/m

n_e = 0.25 x 10^{20} m^{-3}



$$E_{crit} \sim 7\ E_R$$
$$E_{crit} \sim 2\ E_R^{rad}$$

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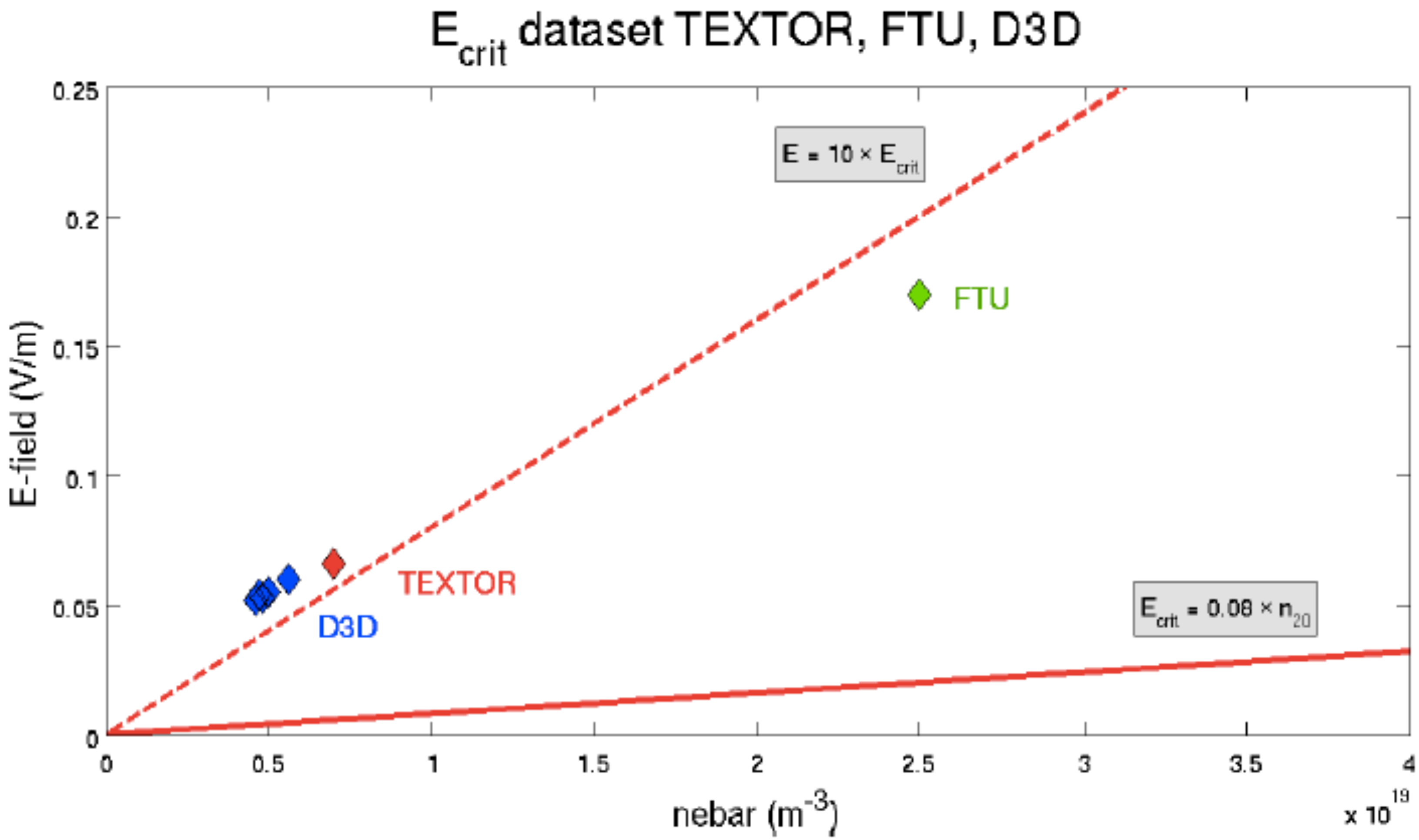
Inter-machine comparison



from R. Granetz, invited talk at forthcoming APS (November 2013)

Program 1st FTU experimental day

Investigate systematically dependence of E_{crit} on B, z_{eff}, V_{loop}

Pulse List

1. *Discharges (**500 kA, 6T**) to optimize the scenario: get the right low density (**2-3x10^{20} m^{-3}**) with **NO runaways at the beginning** (this is important)*
   → ***4 shots***

2. *Do a scan of the same discharge at **other B_{tor} values** (**3T, 4.5T, 5.3T, 7.2T**)*
   4 discharges + 5 magnetic field references
   → ***8 shots***

3. *Do a **scan in I_p** at fixed field (6T): 350 and 700 kA (V_{loop} variation)*
   → ***2 shots***

- *Try to **vary Z_{eff} by Ne injection** → in **2nd day***
- *Raise density after RE onset and hold constant to reach new steady-state to see suppression (alternative measurement of E_{crit} from growth rates) → in **2nd day***

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Required Diagnostics

Neutron/gamma

FEB

Soft-X

Scanning Interferometer

Fast ECE

Mirnov