Tore Supra "Fast Particles" Experiments

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LH SOL Generated Fast Particles Meeting

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OUTLINE

Measurements of fluctuating fields

Nonlinear density variations in front of LH launchers

RFA measurements

Fast Particle Generation

Generation of fast electrons in front of lower hybrid frequency (LHF) antennas is known to be caused by Landau damping of high $N_{//}$ components of the launched spectrum. These high $N_{//}$ components ($|N_{//}|>20$) are expected to be absorbed within a very narrow layer (1-2mm) whereas infrared imaging of plasma facing components indicates a much broader (>5mm) heat flux deposition. Moreover this heat flux is found to depend on LHF electric field much more strongly than simulations predict.

A possible explanation of these discrepancies is the theoretically predicted enhancement of fast electron generation by spontaneously arising random fields (fluctuations, LHF wave scattering). In this case a decrease of fluctuation level by absorbtion on fast electrons is expected along flux tubes connected to the antenna. In order to assess this hypothesis, a probe was installed close to the LHF antenna and the fluctuations of the saturation current and floating potential were investigated in the 0.2-500 kHz frequency range.

Physical Mechanism	First observation of damage on Tore Supra	Heat flux location	Density scaling	Protection
Trapped particles (Ripple)	1990	Bottom of the machine (x18)	$\sim 1/n_e^2$	• $n_e > 1.5\ 10^{19}$ • Reinforced areas
Fast electron Diffusion	(?) - 1999	Inner First Wall	$\sim 1/n_e$	• High heat flux PFCs (CIEL)
Acceleration Near the Grills	1994	Grill protection, Bottom limiter, ED neutraliser	$\sim n_e$ (edge)	• Optimization of density at the grill • High heat flux grill protection • High heat flux PFCs (CIEL)

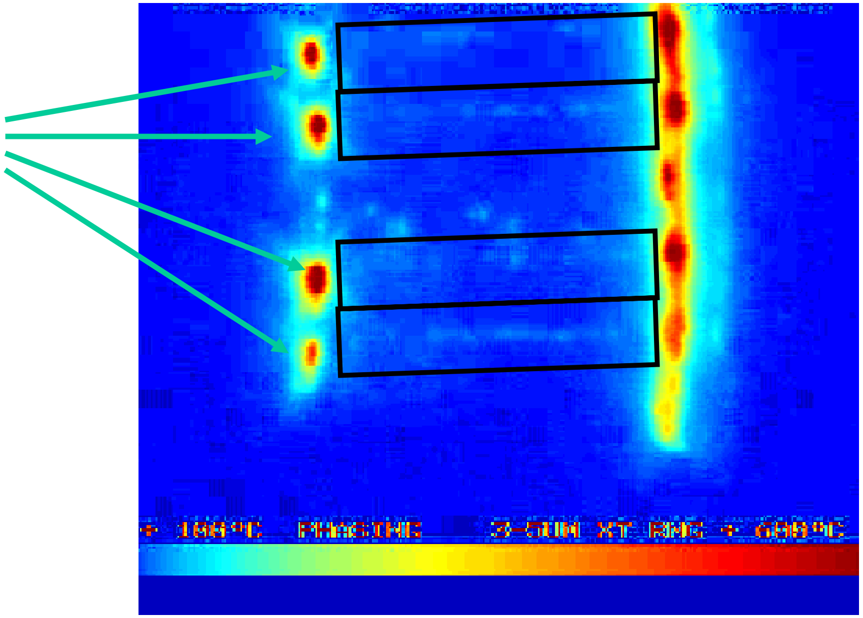
Strong erosion of LH guard limiters (1994)

Strong erosion of ED neutralizer (1996)

Heat flux measurements on the grill guard limiter (1)

- P_{LH} kept constant **(1MW)**
- Number of activated WG varied

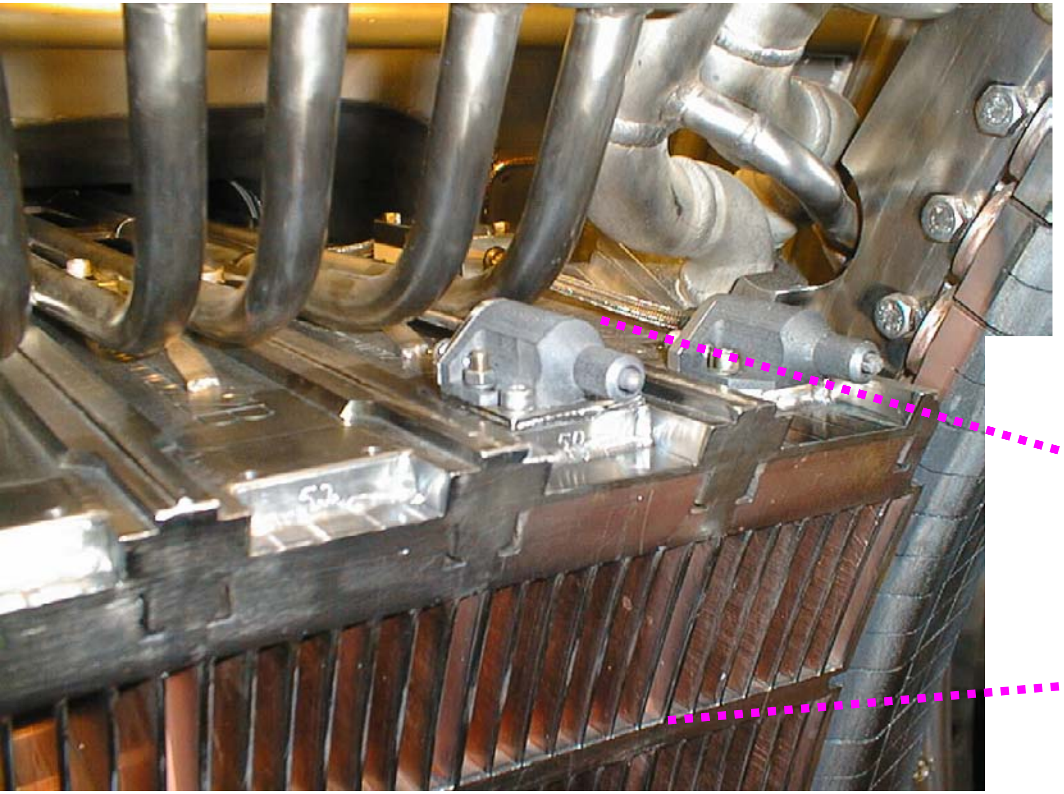
Tore Supra - #30775 – t=16s

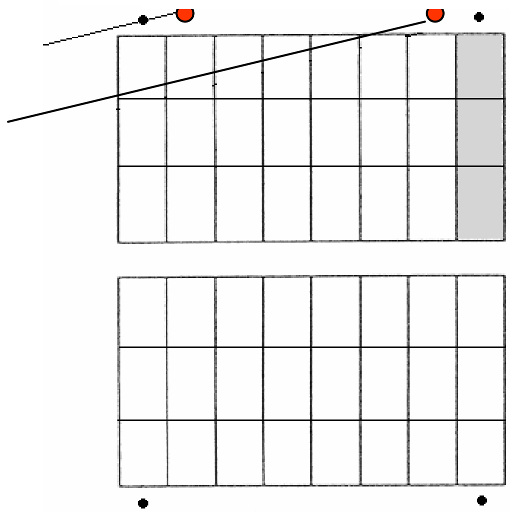


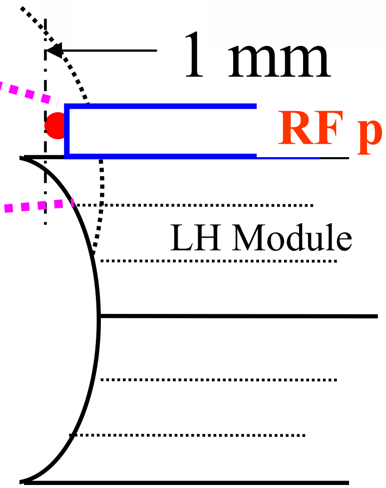
M.Goniche, V. Petrzilka et al., 15th RF Top.Conf, 2003

Fluctuations measurements (1)

RF probe on launcher C3







Fluctuations measurements (2) Tore Supra

DB of 19 shots - 3 triggers /shot (31722-853)

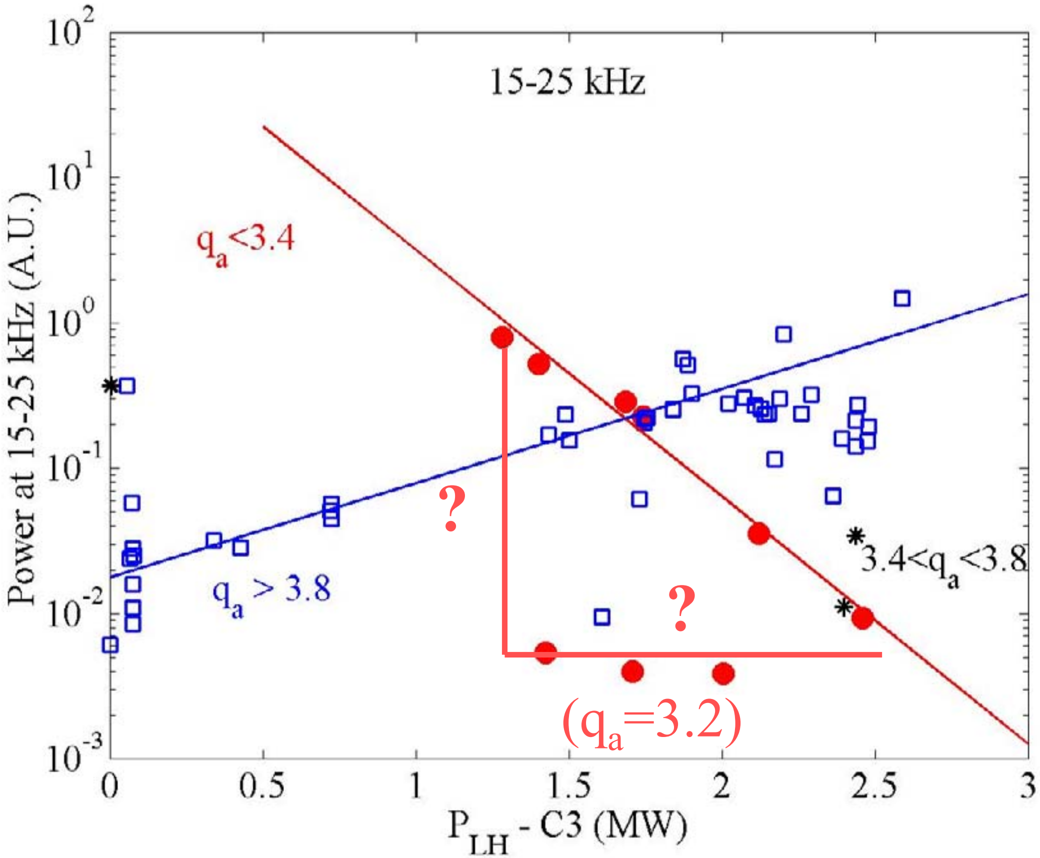
- **Connected (q_a <3.4):**

  Level of fluctuations ↘↘

- **Non-connected (q_a >3.8):**

  Level of fluctuations ↗

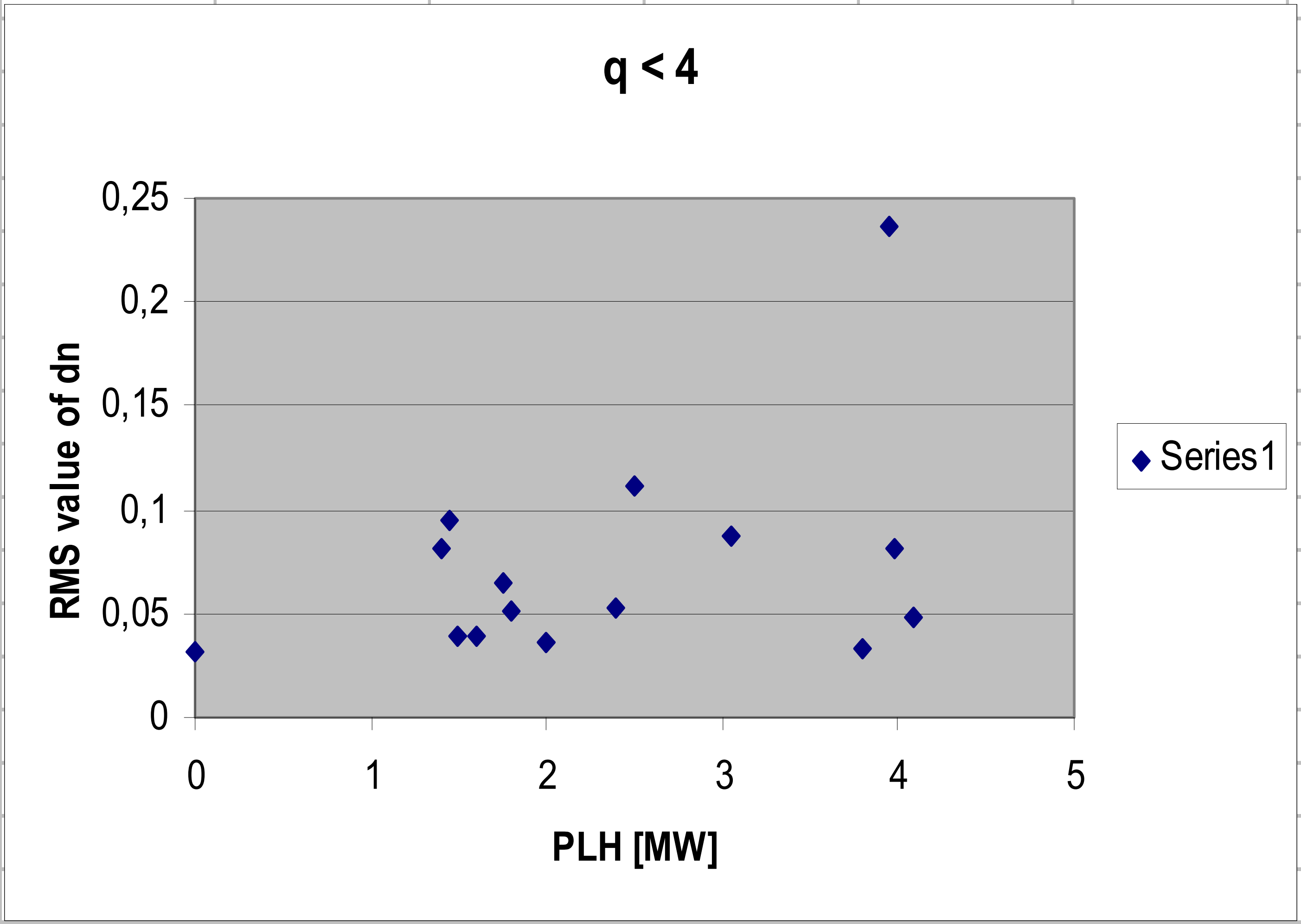
  with LH power



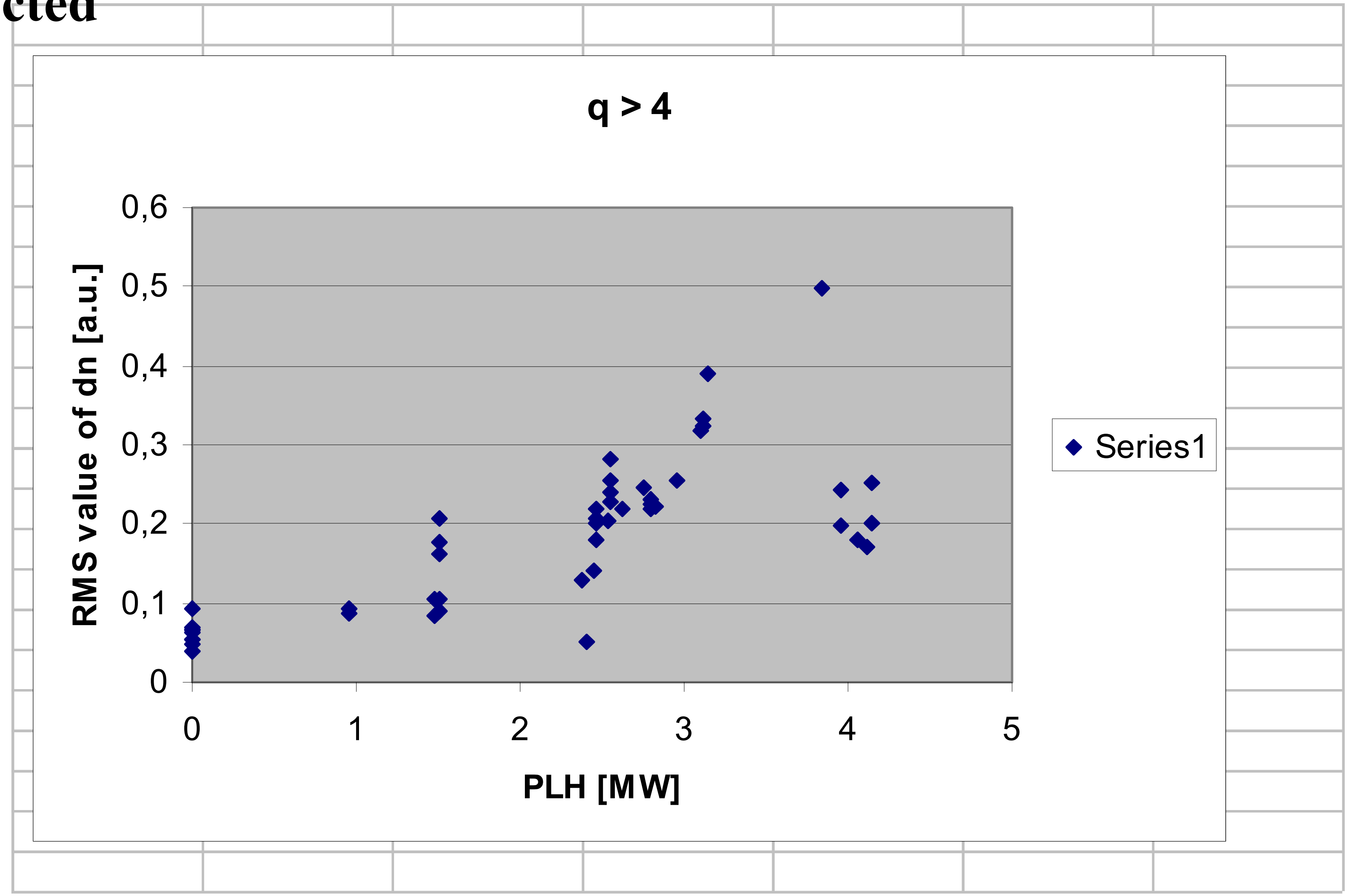
Damping of fluctuations by RF field ?

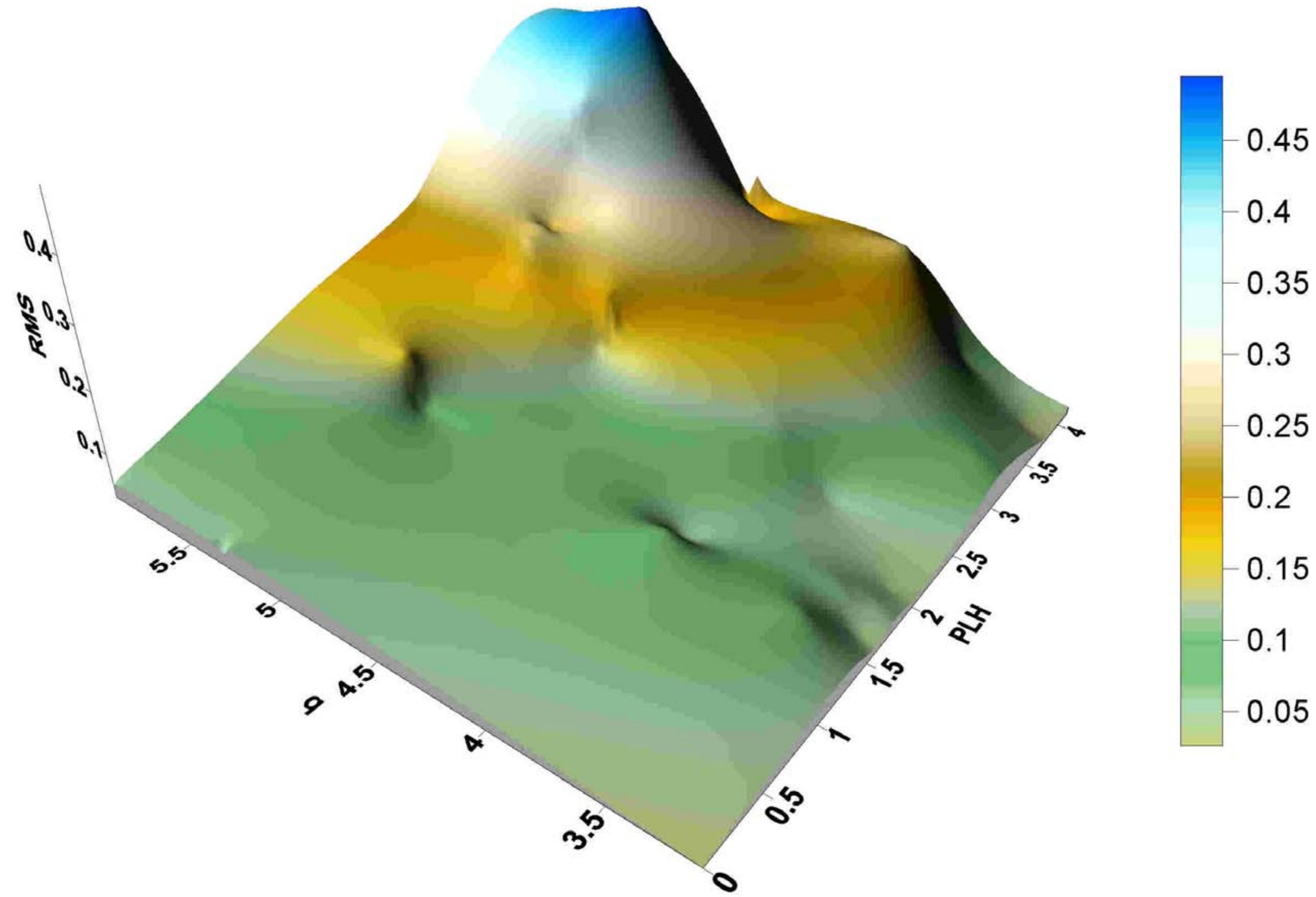
(M. Goniche, V. Petrzilka, et al., presented at the EPS 2004 London conference).

Fluctuations of saturation current (~$\Delta n_e/n_e$) - connected



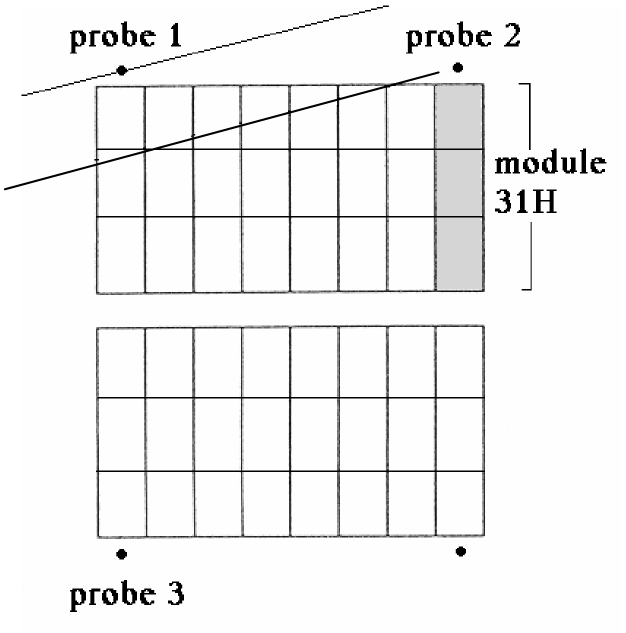
Fluctuations of saturation current (~$\Delta n_e/n_e$) – not connected

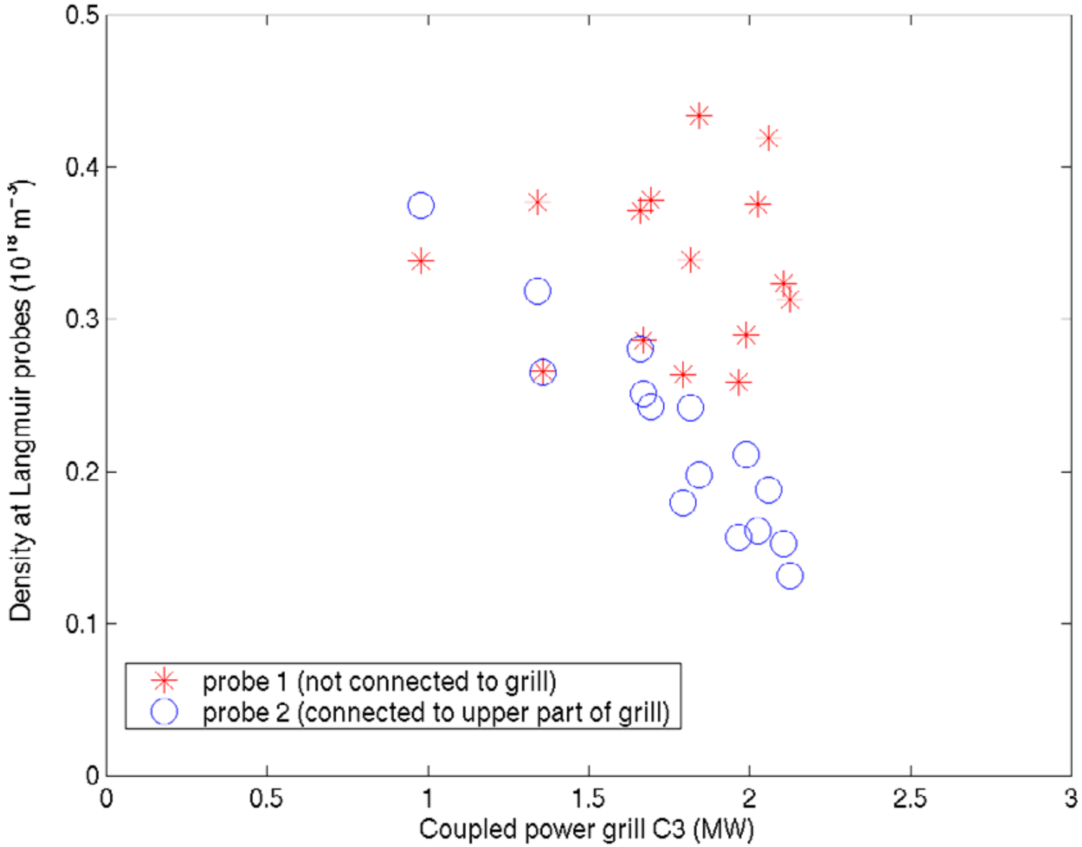



RMS
0.1
0.2
0.3
0.4
q
3.5
4
4.5
5
5.5
PLH
0
0.5
1
1.5
2
2.5
3
3.5
4
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45

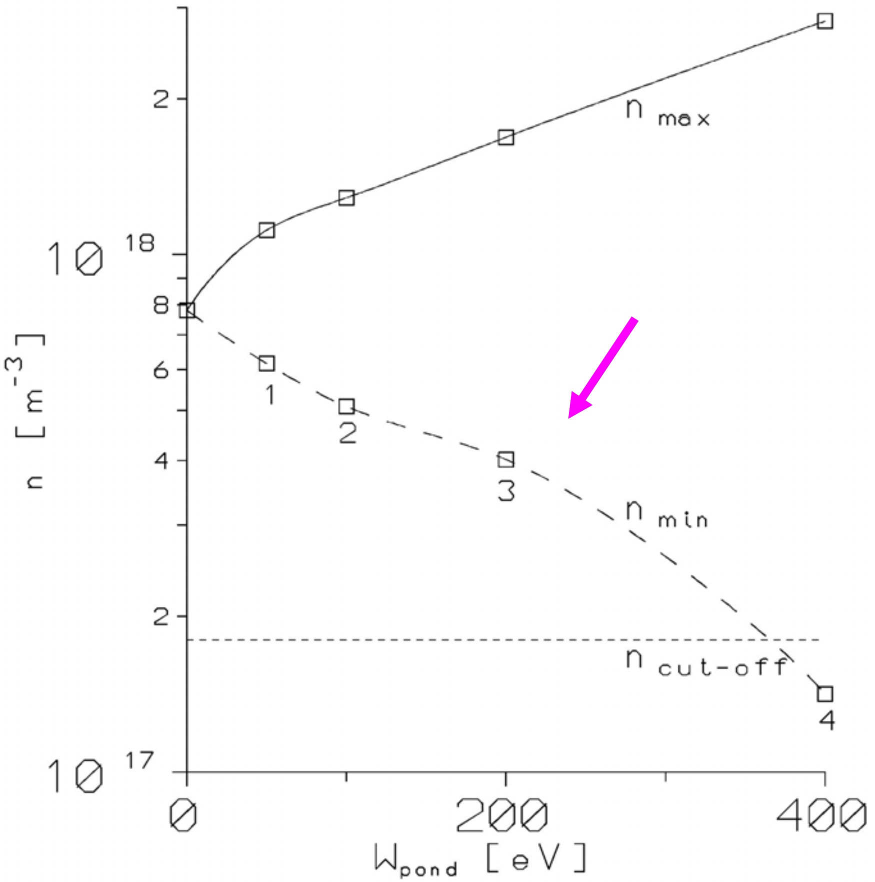
Langmuir probe data on C3 Tore Supra launcher: density at grill vs coupled power on C3

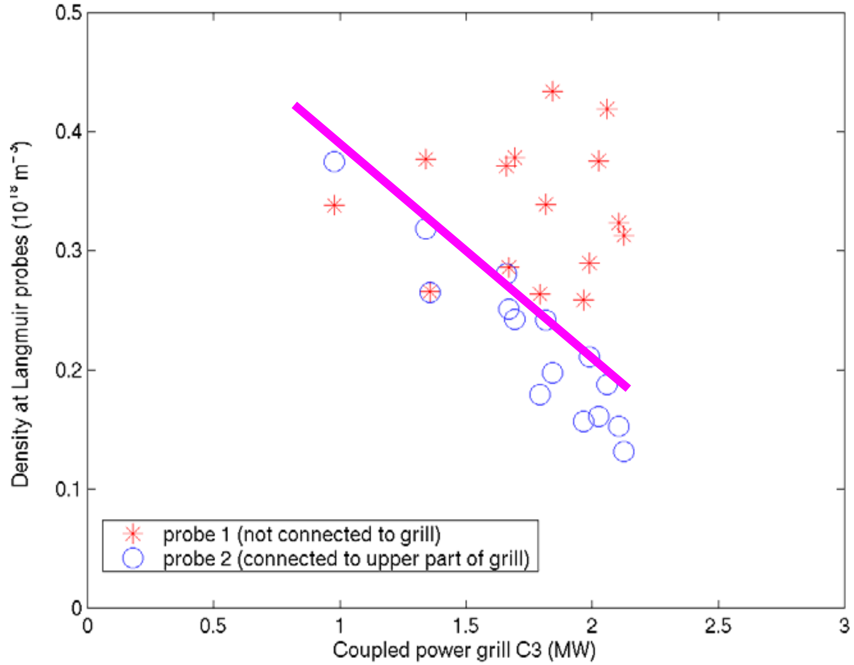
Density on probe 1 is independent of power (not connected to grill)
Density on probe 2 decreases with power (connected to grill)





The initial density was just above 10^{17} m^{-3}



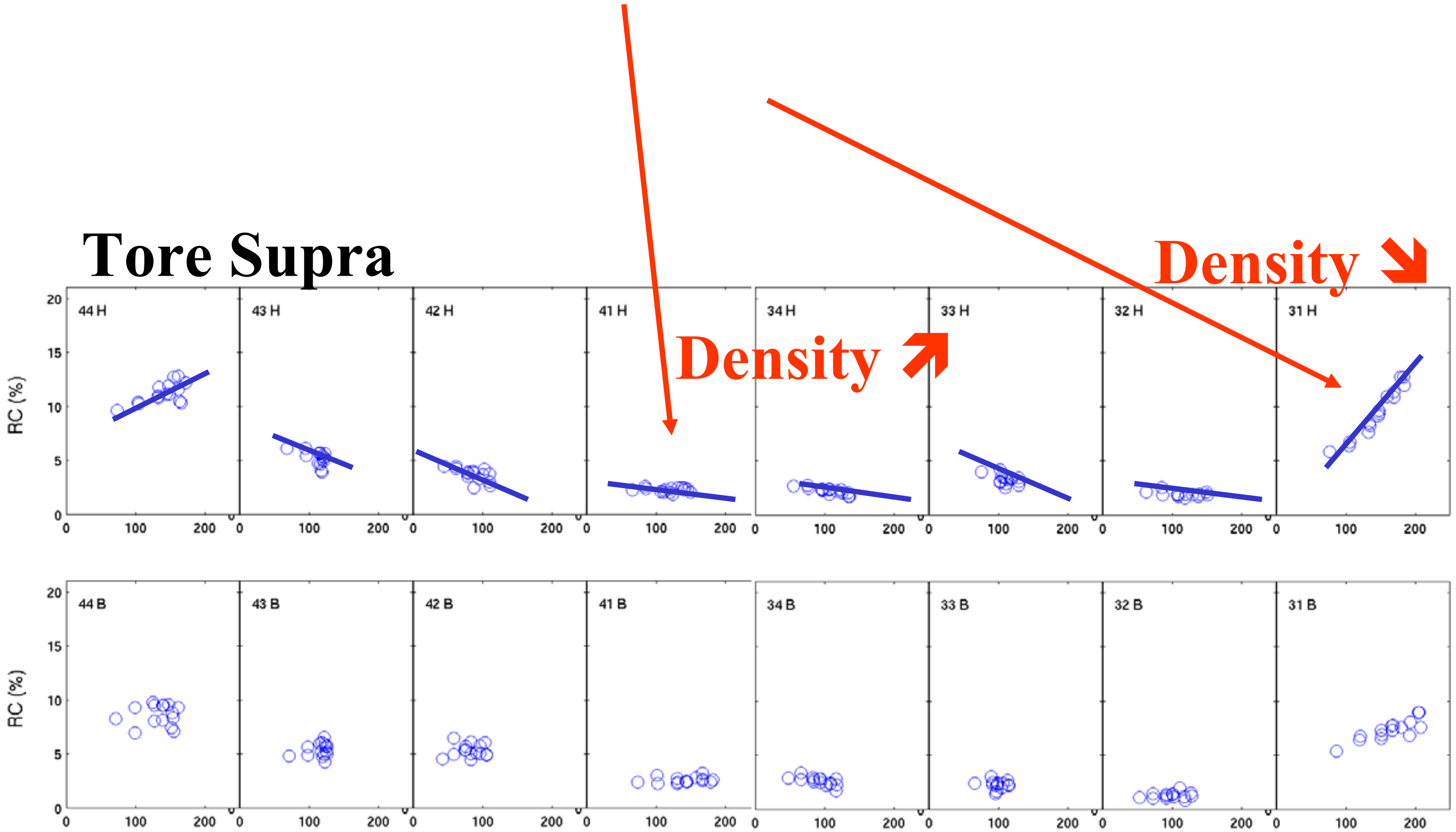


Computed dependence of the plasma density at the wave-guide row center (n_{max}) and at its toroidal boundary (n_{min}) on W_{pond}. The value W_{pond} = 400 eV (case 4) corresponds to the LH field electric field intensity E at the grill mouth of about E = 3 kV/cm.

Measured dependence of the plasma density at the wave-guide row toroidal boundary

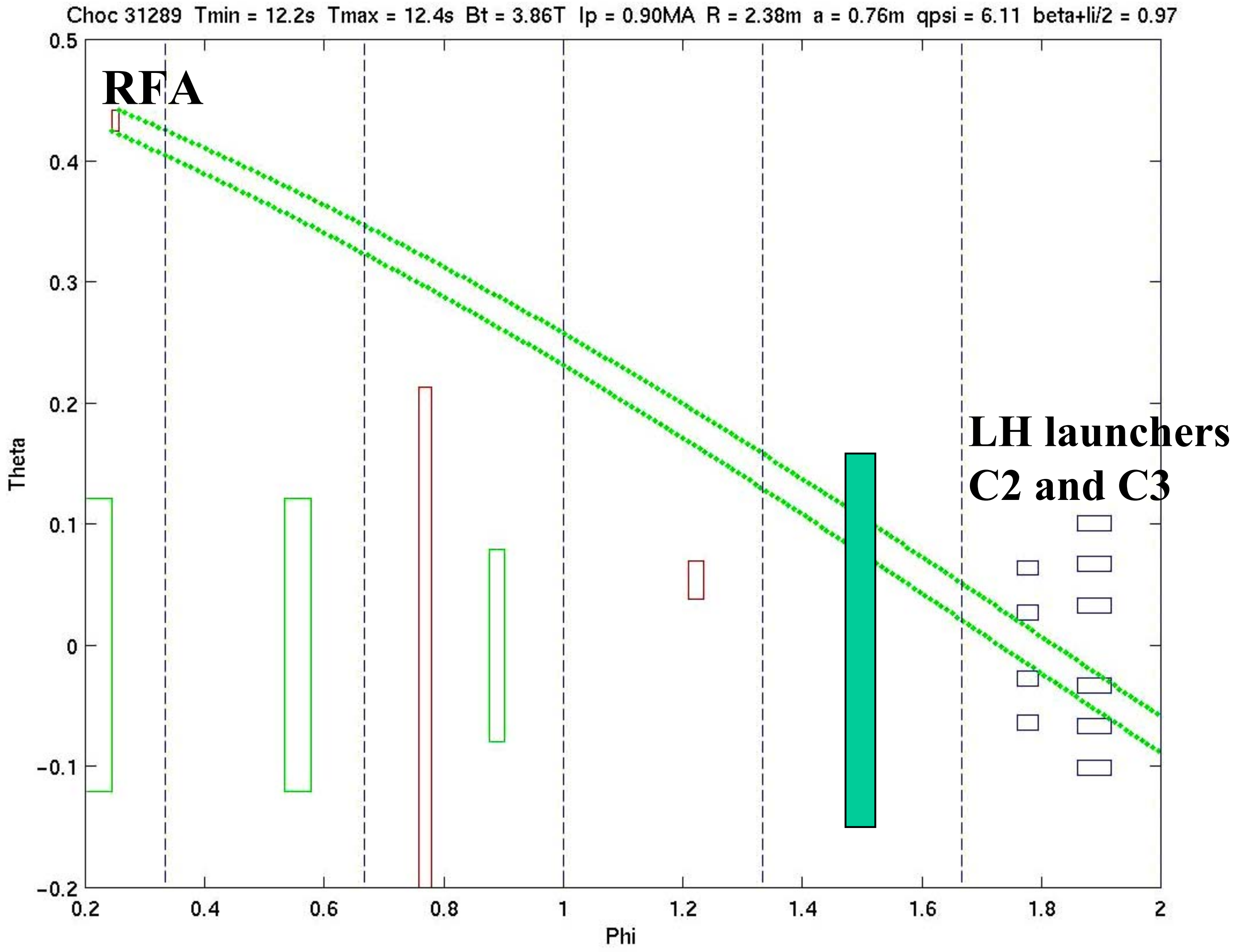
Plasma fluxes and density inhomogeneities

Modeling



V. Petrzilka, A. Ekedahl et al., 30th EPS 2003 Conference

Magnetic field connections between RFA and LH launchers



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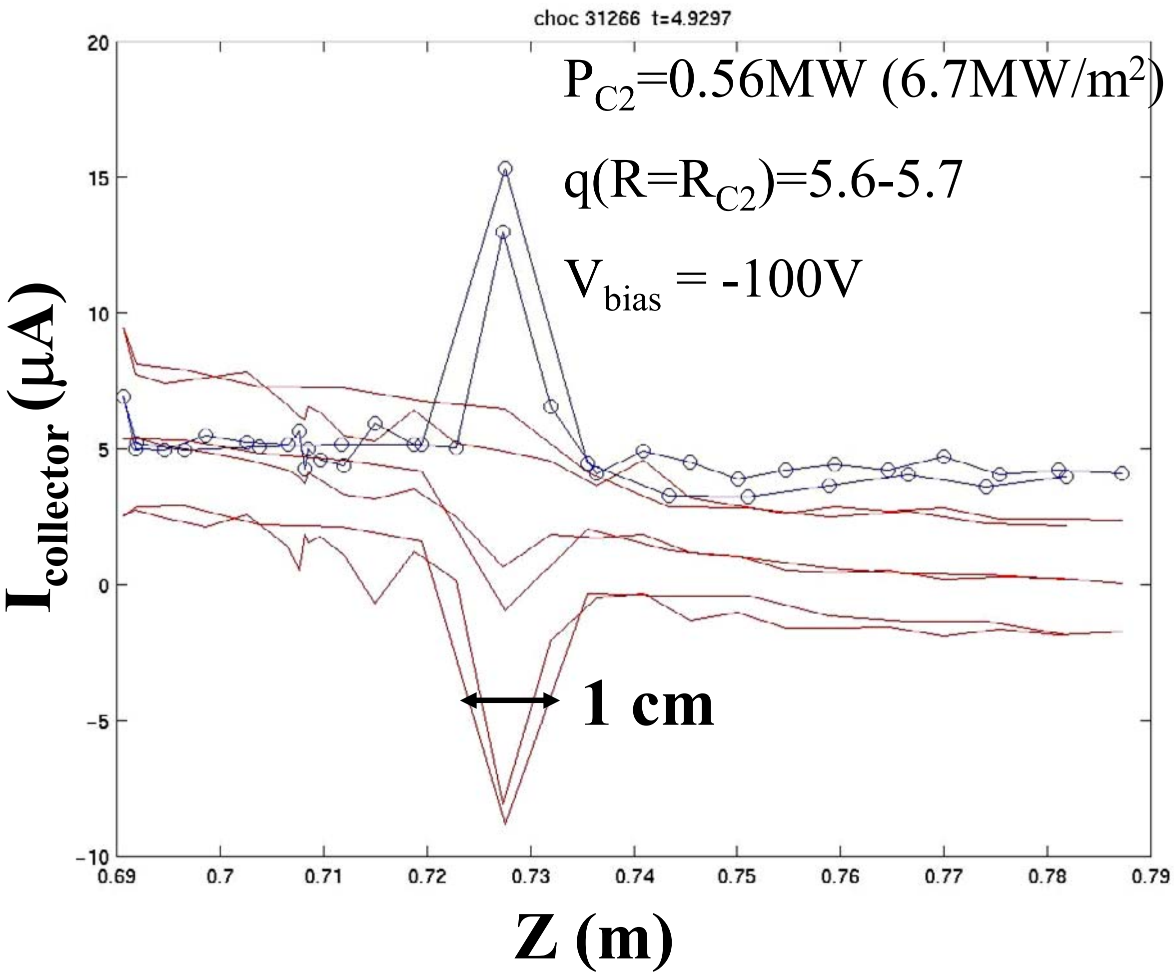
TORE SUPRA

RFA measurements on a magnetic line passing in front of the TS LH grill

- Fast elec. (E>100V) are collected when the RFA is (θ,φ) connected to the grill

- Width of the beam is >5mm

- Beam is drifted radially by **3±-1** cm **INWARDS** along the field lines (L_c= 14m)



(M. Goniche, V. Petrzilka, J. Gunn et al., presented at the EPS 2004 London conference).

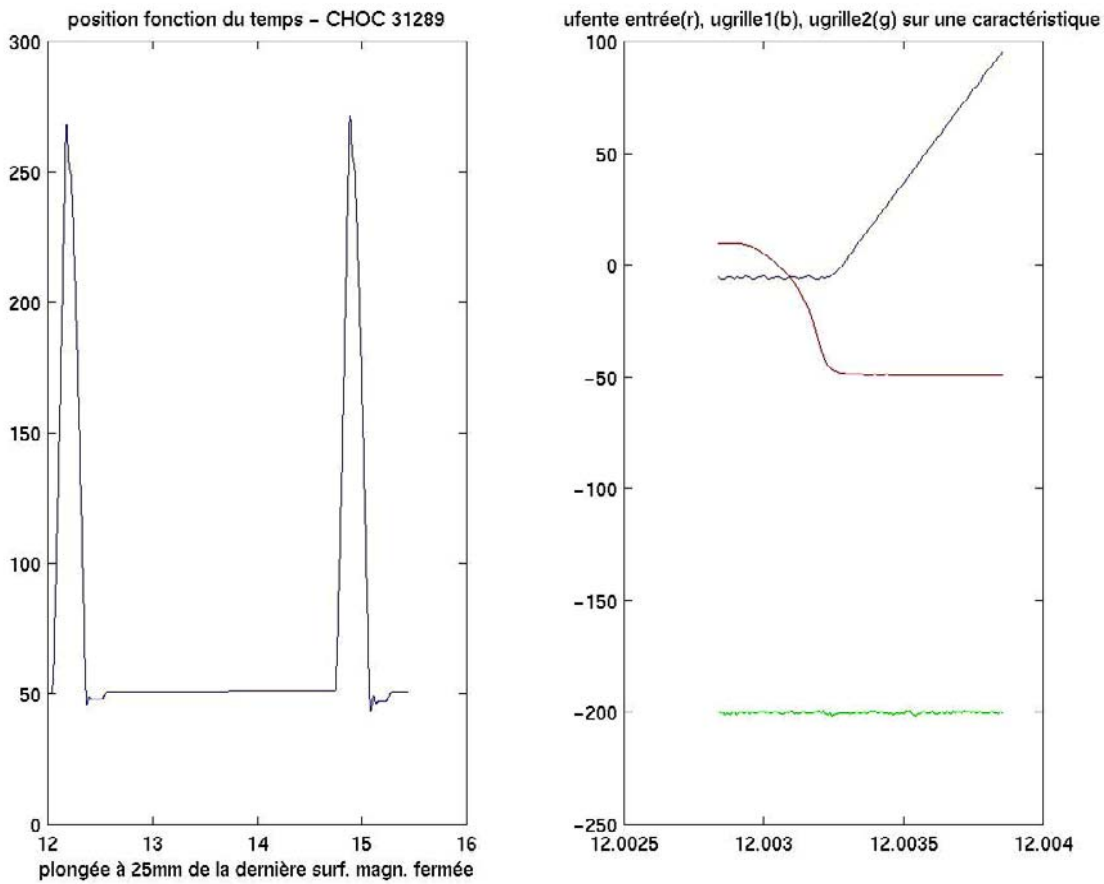


Fig. 1. Timing of the RFA triggers (left) and voltage on the RFA entrance slit (red), 1st grid (blue) and 2nd grid (green) for the shot #31289.

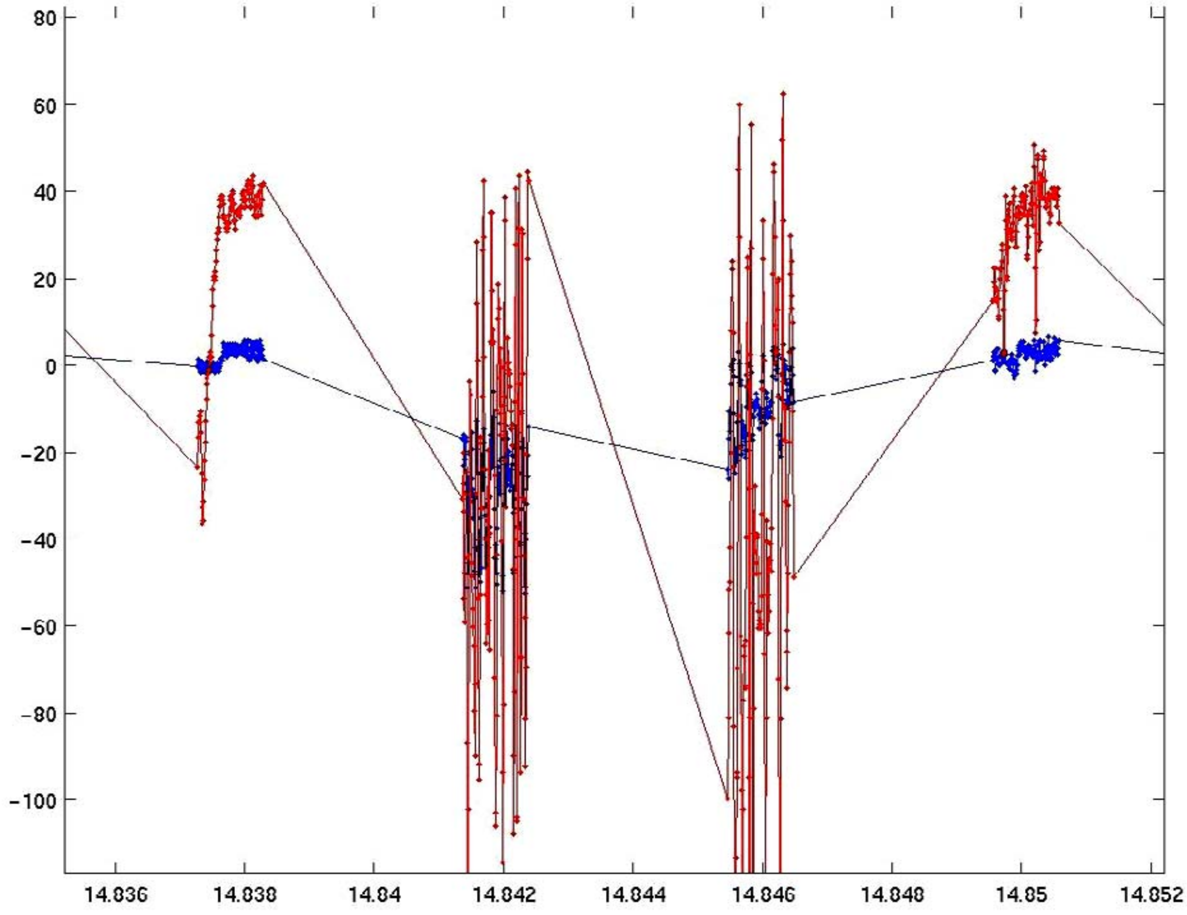


Fig. 2. Variations of the collector (blue) and the entrance slit (red) signal, when the RFA head goes through the fast electro beam, shot #31289.

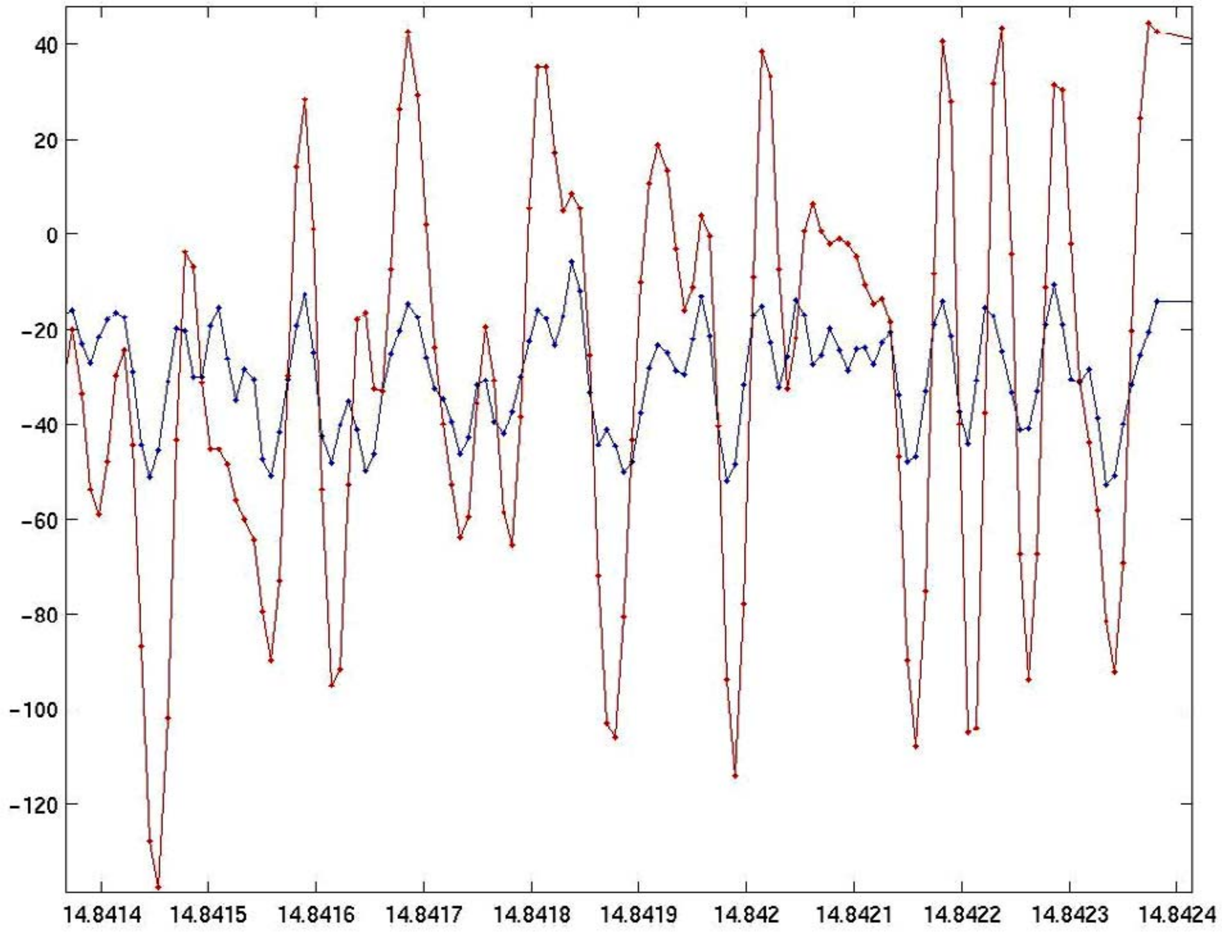
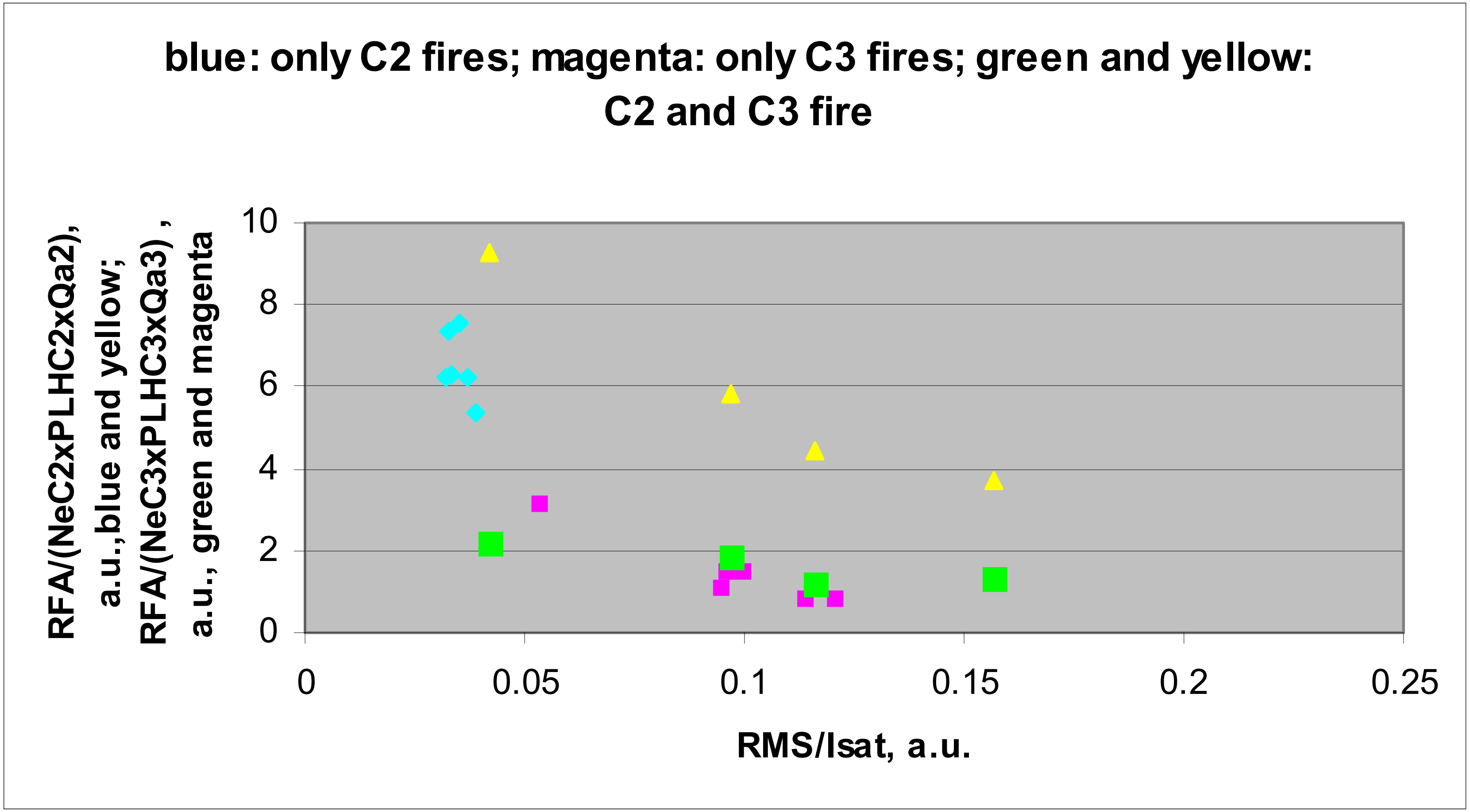
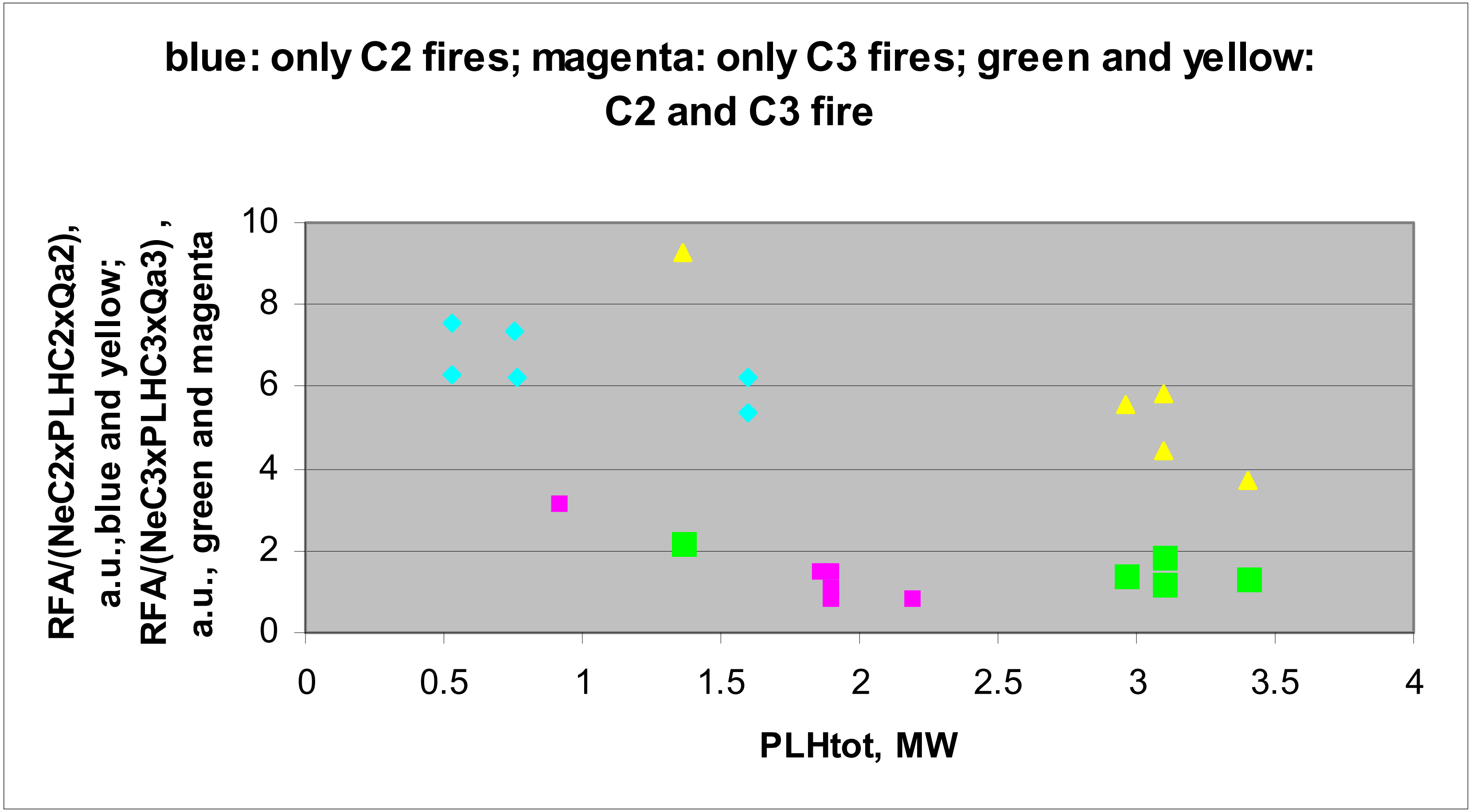


Fig. 3. Details of the signal shown in Fig. 2.

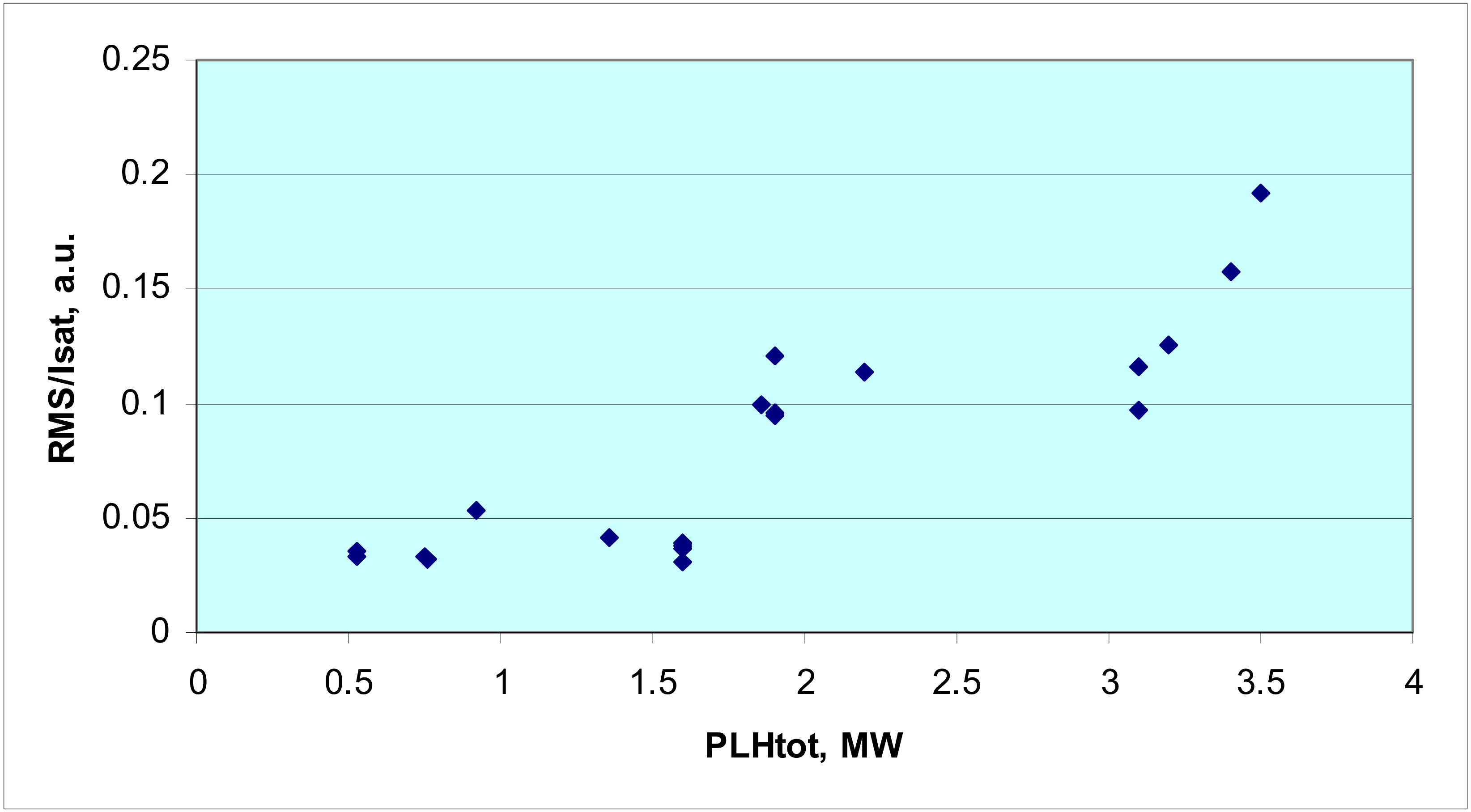
Normalized RFA signal as a function of normalized RMS of fluctuations



Normalized RFA signal as a function of total launched LH power



Normalized RMS of fluctuations signal as a function of the total launched LH power



Conclusions (1)

• ITER antenna design is expected to be favorable as far as there is no enhancement by additional physics

➔ to be checked on Tore Supra C4 PAM launcher (2005)

•Effect of additional physics (random fields) is suggested by the following experimental results:

- ambiguous effect (TdeV) or no effect (Tore Supra) of septa roundings on dissipated power

- Strong electric field dependence (E_{RF}^4) not explained by calculations

- Strong local reduction of density fluctuations at high power

➔ More studies on CASTOR and TS (V_f fluctuation meas.)

Conclusions (2)

- Parasitic LH power absorption may have 2 deleterious effects:
  - **Heat flux** => documented
  - **Sputtering** if ions are accelerated => **unknown** !

    ➔RFA measurement of fast ions is difficult in case of el. and ions

    ➔To be attempted on Tore Supra (and JET ?)

    ➔Preliminary CASTOR results (emissive probe) show POSITIVE plasma potential in front of the grill!

- Knowledge of the parallel heat flux and grazing angle of the field lines is basic

    ➔ Grazing angle is small on JET , $F_{//}$ is unknown (IR meas. needed!)

    ➔ Field line tracing is required for ITER

    ➔ Inwards drift has to be understood