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"LCDC" IN TOKAMAKS

THE LOCAL COLD AND DENSE COMPRESS

FORMED BY THE INJECTED PELLETS INTO TOKAMAKS

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Pellet Injection

The fusion reactor experiment should allow bulk densities close to the Greenwald value with retaining a high energy confinement. It seems that only pellet injection technique fulfils this requirement so far. However we should remember that this technique inherently forms extra-natural hydrogen plasmoid in virtual Local Thermodynamic Equilibrium (LTE) in the order of eV in temperature and 10^{24} / m^3 in density. Hydrogen atoms are continuously supplied by frozen SOLID hydrogen as a hard core with further four orders of magnitude lower temperature and higher density. Many research works have been conducted especially in EU countries. Quite a few theoretical works as well as the experimental works are has been done and proposed up to now as shown in the famous review paper [1].

Plasmoid phase (Boundary condition of LCDC)

Pellet injection diagnostics are mainly conducted to find out the "striated" plasmoid formation process from the frozen pellet. In this phase, extremely strong spectral radiation helps measurements even though it requires special high speed cameras requires faster than

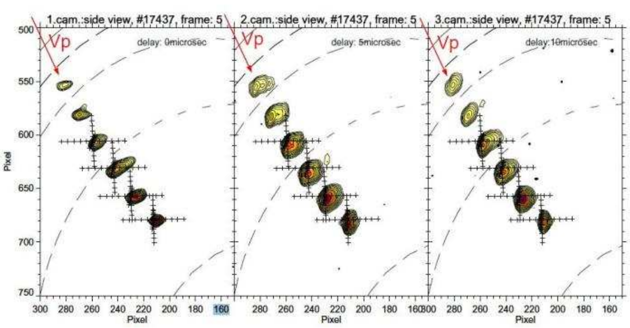

Fig.1. Plasmoid formation and decay in ASDEX Upgrade

S.Kalvin et.al. " Investigation of cryogenic pellet cloud dynamics", CP52 EPS20004

1M fps and more than 10 k frame capacity ideally which is not in the market now. As had been demonstrated, the evaporated cloud/plasmoid should be in plorate spheroid with longer axis in parallel and shorter axis in perpendicular to the local magnetic field. In the lower Fourier mode, the density distribution can be assumed to be controlled by the stationary diffusion equation with a general solution expressed by Gaussian distribution. This agrees with the observed results from the intense H-alpha emission spectra. In Fig.1, we would like to introduce the beautiful result obtained in ASDEX Upgrade published in EPS 2004. In this paper Kalvin et al. detected clear striation. Inspecting their data we can see that the plasmoid can be assumed to be prorate spheroid in shape. The simulation code by Nakamura et al. [3] explains the actual experimental results well in this stage.

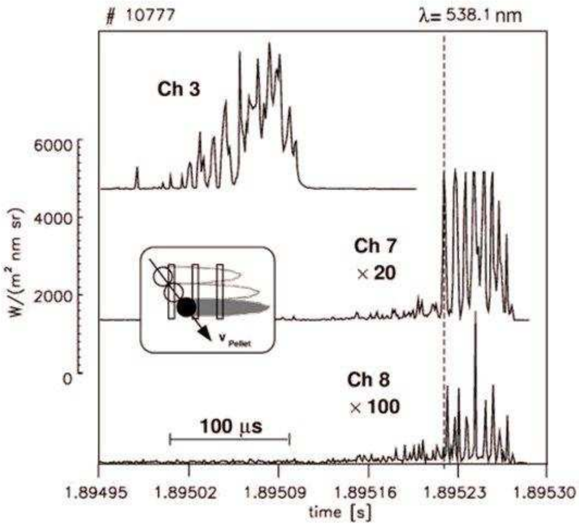

Fig.2. High density plasma drift and continuum radiation
H.W. Muller et al. 1999

In the highly ionized regime, we can find a remarkable paper by ASDEX team with H.W. Muller et al. in 1999 on the continuum spectra [4] dealing with the gradient-B drift of the High-Fild-Side pellet injection. This technique should be applied to our experiment.

"LCDC: THE LOCAL COLD AND DENSE COMPRESS"

In few tens of micro seconds after the pellet injection, the bulk tokomak plasma suffers multi-layer rapping up with the stripes of "LCDC: THE LOCAL COLD AND DENSE COMPRESS" expanding on the magnetic surfaces. This phase fills in the long path between the pellet ablation phase and the density shoot up phase in the bulk plasma. We are interested in this plasmoid / ultra-cold and ultra high density “plasma” expansion process and its effect to the fusion plasma. This might cause unique MHD instabilities. Conventional large tokamaks are extremely robust against this LCDC, even though they are fragile to the bulk density limit.

The key scheme we are trying to apply in this path has been taken in different category by ASDEX team with H.W. Muller et al. in 1999 on the continuum spectra [4].
We can expect to trace the "the Rise and the Fall" of the LCDC following their track. If we give up getting irreproducible information, in other word, if we can be satisfied by getting only lower order Fourier components, we can get them in this striated clouds by stepping into "the out of focus photography". We also can extend the diagnosis down to very low signal to noise ratio and
with few orders of magnitude darker emission than the spectral radiation. The key to open the door is the existence of the extremely localized hypothetical stripes of LCDC on the rational surfaces in TOKAMAKS.

The injection speed of a pellet from the low field side is required to attain few 1000 m/s in velocity to reach in the centre of the tokamak. In this case, the solid pellet life is less than 10ms. In this flight duration, even the low temperature thermal electrons impinged from the plasmoid can travel around the torus main axis far more than 10 times in the magnetic flux tube. The trace of flux tubes for 10 rotations inside the torus is shown in Fig.3.

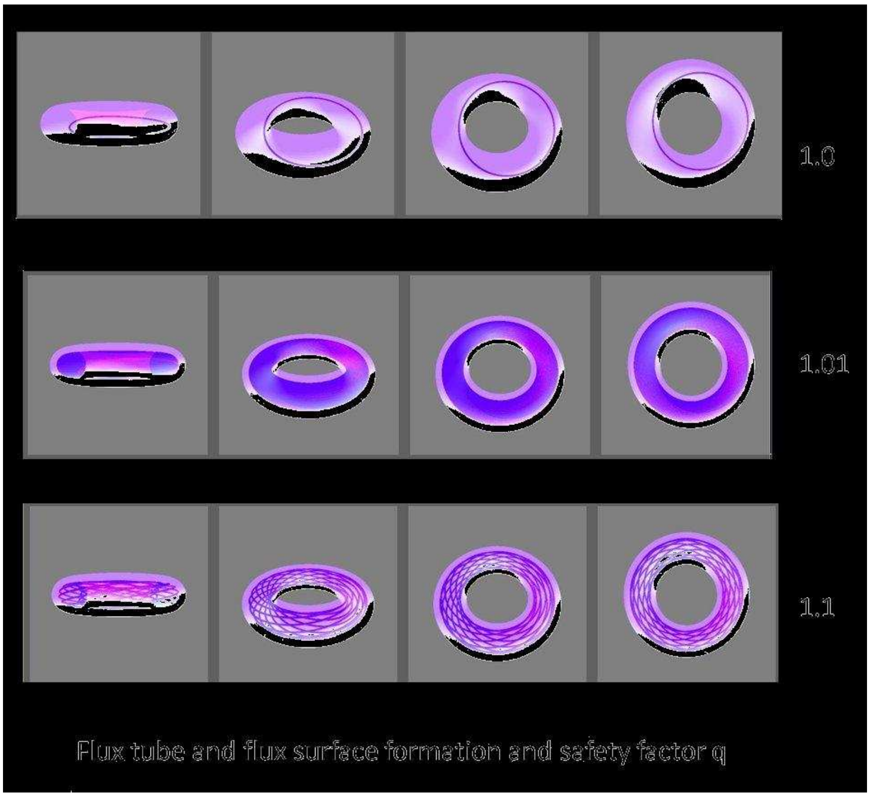

Fig.3 Flux tube inside a tokamak and the effective volume normalized to the q=1 tube.

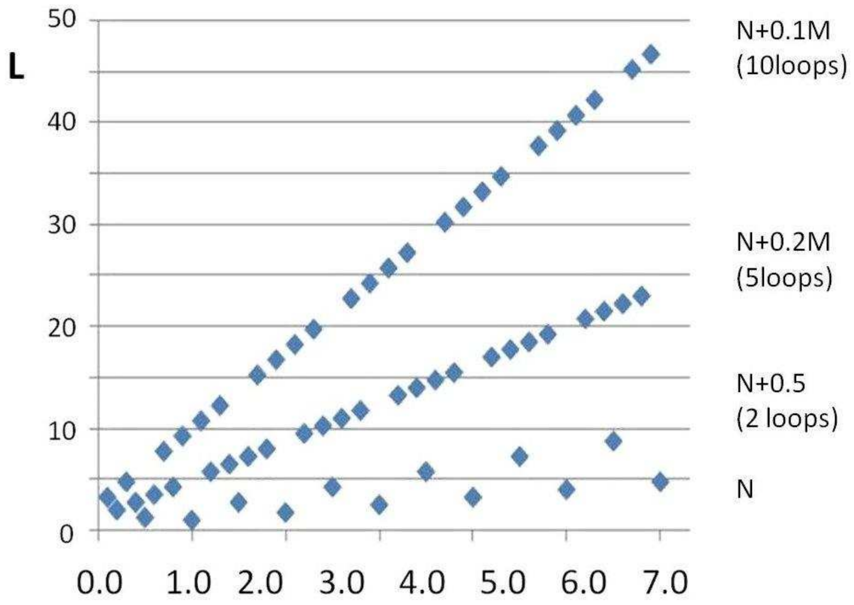

Fig.4. Field loop and safety factor

On the rational "surfaces" where the magnetic flux tube is closed, the electron diffusion along the field line is suppressed efficiently. In fig.4. On the rationa surface mod (q,n)=0 the flux tube is discontinius and local minimum. Which means this flux tube is very efficiently protected from LCDC smearing out.

The drastic progress of the computer performance and CCD/NMOS detectors are changing the information acquisition system mainly in the medical diagnostics and in the next generation information processing. Here we would like to discuss the application of these system to the sophisticated diagnostic techniques. The fundamental algorithm was originally developed i nuclear fusion research as a Soft X-ray Tomography. It is now developing in medical field, CXT (Constrained X-ray Tomography), as well as a biological field, CEBT (Constrained Electron Beam Tomography) for 3D image reconstruction in our laboratory [5].

The fundamental survey was conducted with the help of Profs. R. Sakamoto and H. Yamada in NIFS Japan and is still underway. The survey experiment in a Tokamak was planned and authorized to start in JT60 with Dr. H. Takenaga in Japan Atomic Energy Agency in 2006 but the experiment itself was cancelled for upgrading the pellet injector and ITER Broader Approach JT60SA. We are looking forward to the collaboration with EU high temperature Tokamaks.

References

[1] S.L. Milora, W.A. Houlberg, L.L. Lengyel and V. Mertens, Nuclear Fusion 35,6(1995)
[2] Kalvin et.al. " Investigation of cryogenic pellet cloud dynamics", CP52 EPS20004
[3] Y.Nakamura, H.Nishighara and M.Wakatani, Nuclear Fusion 26,907(1986)
[4] H.W. Muller et al. Phys. Rev. Lett. 83,2201 (1999) References

[5] Irie M, Kubo-Irie.M and Mohri.H., Plasma and Fusion Research 2, S1028 (2007)