# STEPS Students Report

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*For a one month I had a great opportunity to participate in short-term internship of program STEPS. I want to express big appreciation for this to facilitators and also to all members of my laboratory, especially Takase-sensei and Ejiri-sensei. It was really useful scientific experience.*

*Further I present the information about research that I have done.*

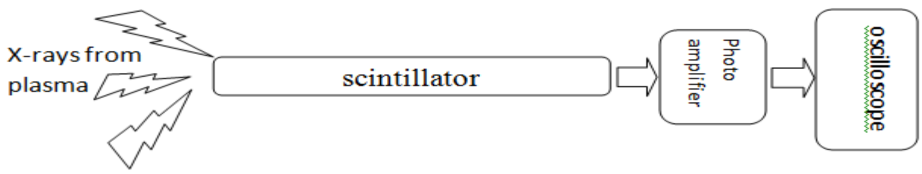
**Introduction(i)**

All researches that are carrying our nowadays in tokamaks are devoted to optimization of the process of fusion: time of plasma existence, cost etc.

In this research hard X-rays (HXR) from plasma are investigated in order to compare two types of high temperature plasma in TST-2 spherical tokamak driven by two different ways : by top and outboard launch antenna. In tokamaks one originally uses central solenoid to drive the plasma (inductively ) but the solenoid should be huge and consequently expensive. Also in spherical tokamaks plasma is more stable (compared to convectional one). But there is a problem: there is a tiny space in the centre, so there is no enough place for putting solenoid. That is why scientists created another way to drive plasma in tokamak, by waves. In Takase-Enjiri laboratory one has analyzed several kinds of antenna that produce LHW(low hybrid waves) and these days the best position for the best one is considering. According to hard X-ray spectrum(energy of HXR ~10-200keV) obtained from plasma one can get information about behavior of accelerated electrons by LHW. From the spectrum of HXR it is possible to obtain the effective temperature of plasma(in high temperature plasma electrons have the same temperature as the rest components).

**Diagnostic of X-rays. Calibration**

For detection of X-ray scintillators are used. Scintillators are materials that can luminescence exiting by radiation. Further light is collected on photo device, sent to amplifier and visible on oscilloscope. On oscilloscope one can see voltage, but in order to find out the photon's energy exactly, calibration is demanded. To find correspondence between voltage (in Volts, on oscilloscope) and energy of photon(in keV) we use isotope Ba133, which spectrum is well-known.

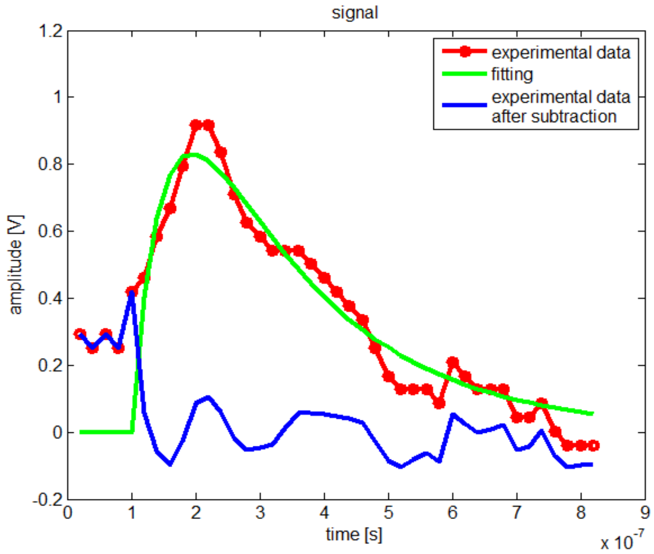



***1.1 The block scheme of measurements***

**Analysis of signals. Approximation**

Any signal that we get from detector consists of noise. Another problem during analysis is existence of overlapped pulses(photon emission).So the right way to distinguish pulse is to approximate the part of signal with known beforehand function and look if it appropriate pulse or not.

In case we detect pulse, we should subtract fitting function from the data, this way we can detect overlapped pulses too while we are looking for pulses again among renew data.




$$y = Am \quad \vartheta(x - tau)\left(1 - e^{-\frac{x-tau}{a}}\right) \, e^{-\frac{x-tau}{b}}$$

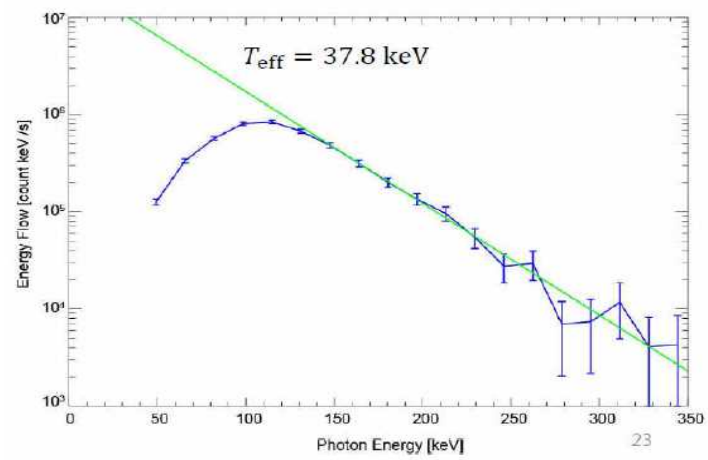
***1.2 The explanation how to the signals of photon pulses have been analyzed with following function. The found coefficient of the shape of pulses a=6.75e-8 b=2.075e-7***

**Obtaining parameters of plasma**

After collecting the amplitudes of pulses one can plot the spectrum of photon energy. Exactly we need the dependence energy flux on photon energy. Exponential approximation of the right part of line (on the right from maximum) can be used for getting parameters of plasma such as effective temperature, energy flux.

$$P\left[keV\,\frac{counts}{s}\right] = A\left[\frac{count}{s}\right] T_{eff}[keV]\exp\left(-\frac{E\,[keV]}{T_{\,eff}\,[keV]}\right)$$

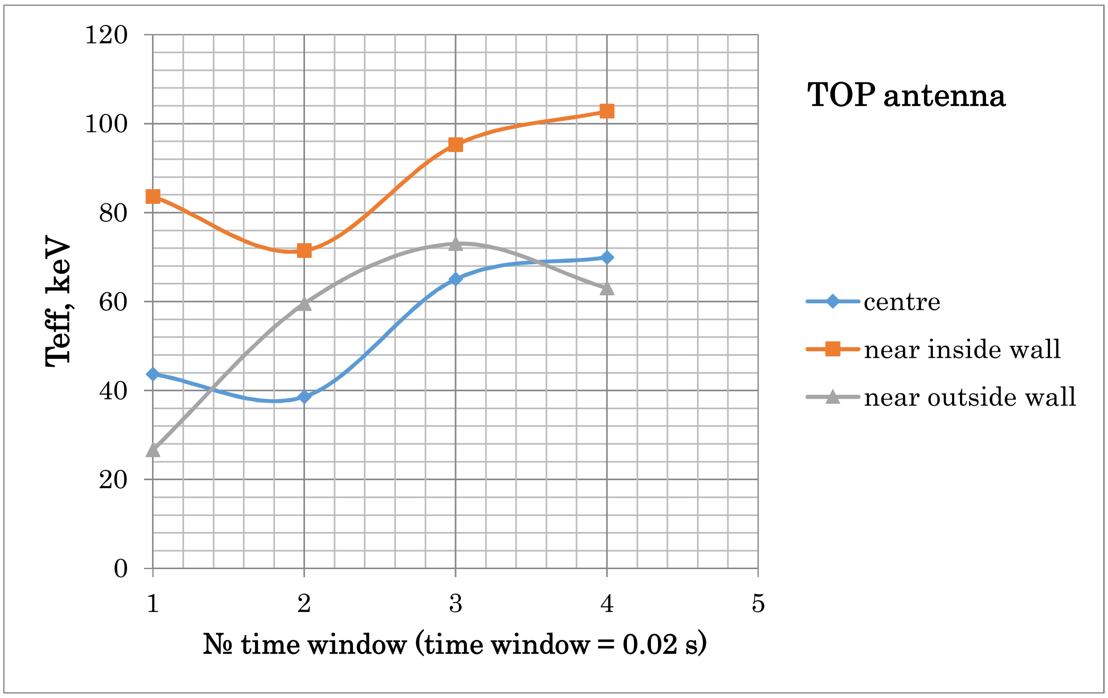
***1.3 The formula that connects the power of photon's flux and parameters plasma like temperatures***




*1.4 The illustration how to get parameters of plasma from oscilloscope data according to formula 1.3*

**Results and conclusions(ii)**

As a results the plots of parameters of plasma were obtained for different period of time, different location in plasma and for both cases of top and outboard antenna using method described above.




***1.5 The example of taken results: radiation flux during the discharge for different location in tokamak plasma driven top launch antenna***

It was noticed that plasma driven by top antenna, all in all, reaches the higher temperature than the one driven by outboard antenna in the end of discharge. Also in top case shape of dependence of flux on time is similar to shape of current discharge and reaches higher value comparing with outboard case.