A pellet cloud database to investigate isotope effects for ASDEX Upgrade

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Cryogenic pellet injection is one of the most promising methods to fuel fusion plasmas and to control Edge Localized Modes (ELMs). The next step device, ITER will start operation with hydrogen or helium plasmas, thus it is important to know, how the ablation is changing at these conditions. In order to investigate the pellet ablation, a pellet cloud database [1] has been developed at ASDEX Upgrade. Using this database the pellet clouds' distribution detected by fast cameras is investigated with particular attention devoted to the cloud shape, size and radiation distribution along the pellet path and the magnetic field lines. The dynamical investigation of the pellet cloud evolution can be found in [2]. The analysis of the clouds radiation distribution at different radial positions with different plasma parameters gives us a better understanding of the ablation process.

In recent experiments at ASDEX Upgrade beside the usual deuterium pellets in deuterium plasma, hydrogen pellets were injected into helium and hydrogen plasmas. Accordingly the above described pellet cloud database was substantially upgraded with the data derived from these new plasma discharges. The pellet clouds were observed from a radial view. Snapshots with the exposure time of a few microseconds were taken by fast cameras, the individual pellet clouds were selected from these snapshots. Then the radiation distributions were determined in two directions: along the field line crossing the centre of the pellet and the direction perpendicular to it. With the usage of the measured electron temperature and density profiles, the local ablation rate was calculated from an NGS model at the centre of the cloud. The calculation of the ablation rate is necessary for the comparison of different pellet and plasma types to avoid the implicit parameter dependency (pellet mass and velocity, electron temperature etc.). The database was created from all of this data to make the statistical analysis possible.

Having the upgraded pellet cloud database first it was investigated, whether the hydrogen pellet clouds' radiation distribution is similar to the cloud types we determined earlier for deuterium pellet clouds [1]. All of the three cases (hydrogen pellet in hydrogen plasma, hydrogen pellet in helium plasma and deuterium pellet in deuterium plasma) were found the most frequently observed characteristic radiation distribution, which is a “cigar” shaped distribution with one maximum along the field line, and also one in the perpendicular direction (see figure 1). The other, earlier observed cloud types were also found in the new dataset. This is also a “cigar” shaped cloud with a radiation distribution, that contains two maxima along the field line, but it has only one maxima in the perpendicular direction (see figure 2). The other formerly observed data types, which was found in the new dataset are two “cigar” shaped clouds with one- or two radiation maxima.

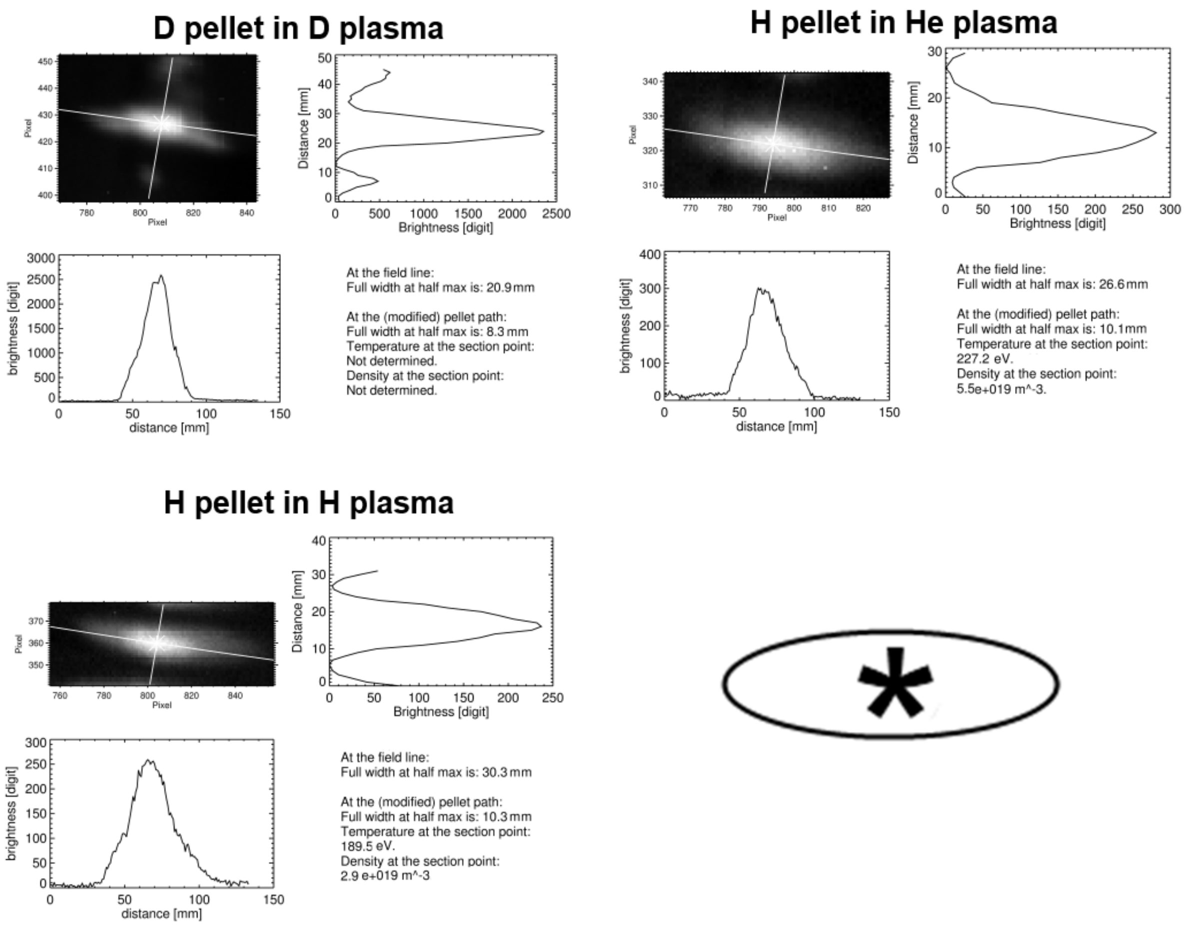

Figure 1. The most frequent, “cigar” shaped cloud type from the old and new cloud databases. The upper left corner shows a D pellet in D plasma with the radiation distribution along the field line and the perpendicular direction at the centre of the cloud. In the text box there are further information about the cloud (FWHM-s in both directions, electron temperature and density at the centre of the cloud). In the upper right corner there is an image about an H pellet in H plasma, the bottom left corner shows the same image for H pellet in H plasma, and in the lower right corner there is the schematic figure of the “cigar” type pellet with one maximum. The almost horizontal white line shows the field line crossing the centre of the cloud, the other line shows the perpendicular direction.

In the next step, the radiation distribution of the clouds was investigated statistically along the magnetic field line crossing the centre of the cloud, and perpendicular to the above mentioned field line as the function of the pellet ablation rate calculated from an NGS model (see figure 3 – upper line). It is seen, that perpendicular to the magnetic field lines, there is no change in the width of the cloud although the ablation rate of the pellet is changing with at least one order of magnitude.

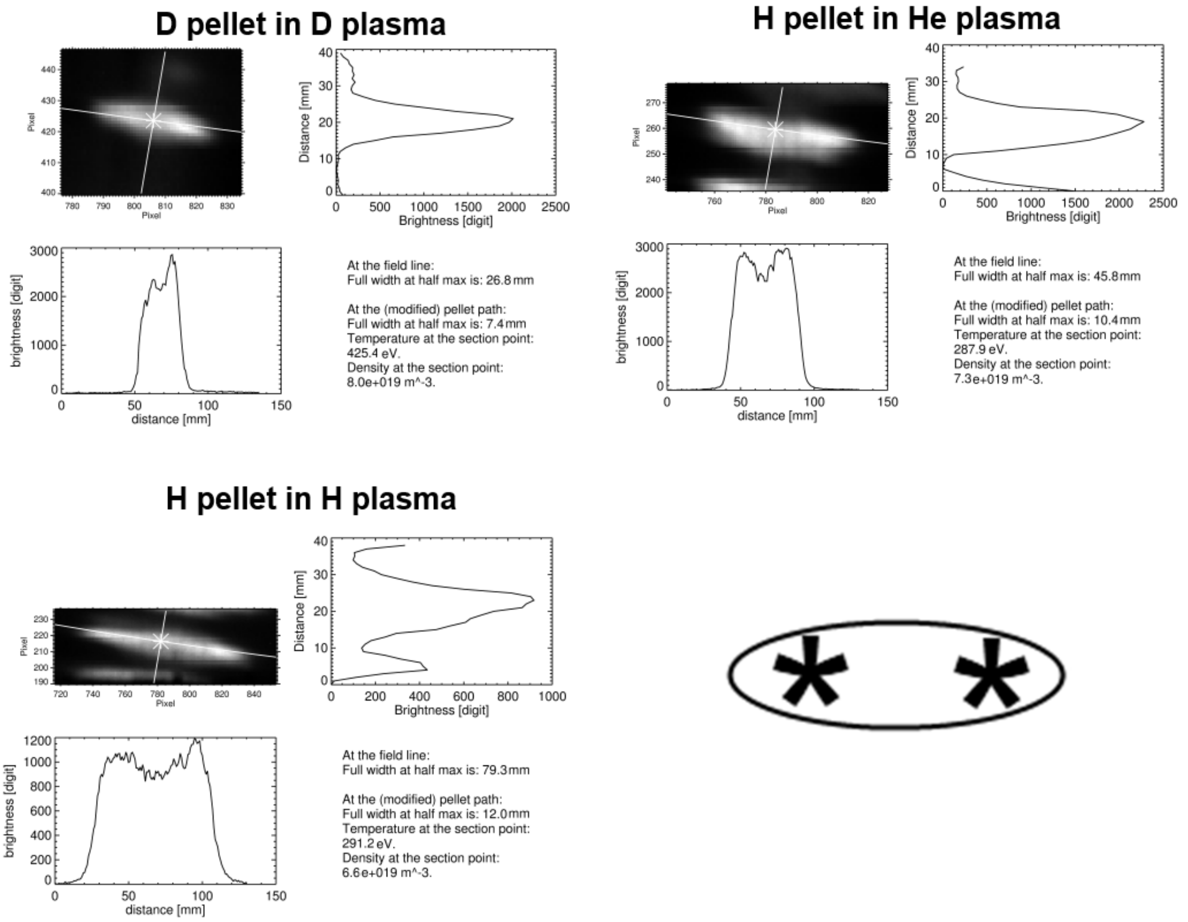

Figure 2."Cigar" shaped cloud type with two radiation maxima. The structure of the figure is the same as in figure 1.

However, along the magnetic field lines the width of the radiation distribution slightly increases as the ablation rate grows.

To clarify, whether there is a separation between the different pellet/plasma materials, there is a plot about the box averaged version on figure 3 (bottom line). The plot also shows the error bars (error of the mean) both in x and y direction. As a consequence, we can say, that beside that we observed the same cloud shapes, no significant difference in the pellet cloud width as a function of ablation rate was observed for different pellet- and plasma materials.

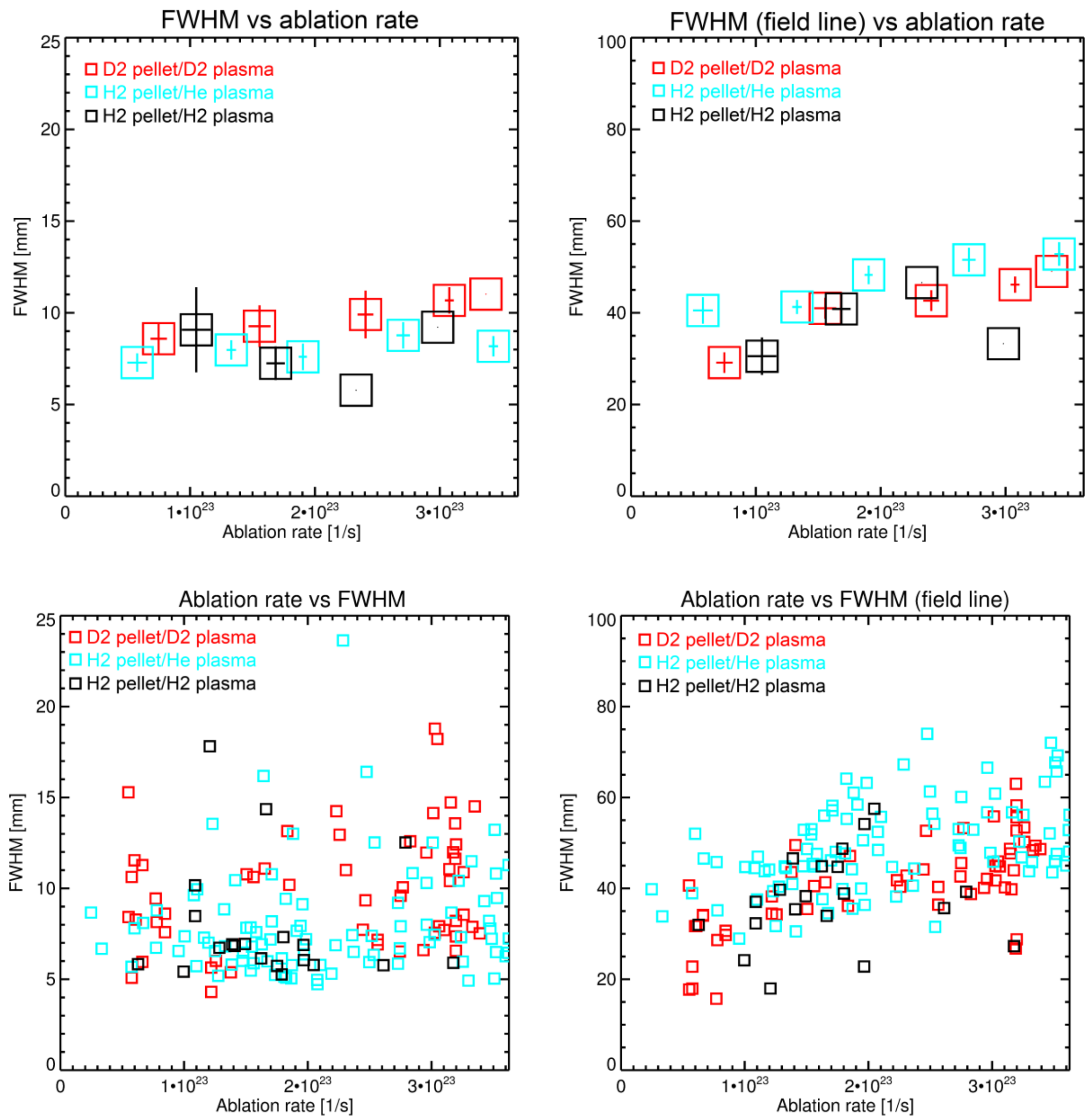

Figure 3. The full width at half maximum of the pellet clouds' radiation distribution along the magnetic field line (right) and perpendicular to the field line (left). The upper two figures show all of the data points, the lower two figures are an averaged plot of the upper ones.

[1] G. Cseh et al., Frühjahrstagung der DPG, Hannover, 2010
[2] G. Kocsis et al., P1.146, 40th EPS Conference, Espoo, 2013