I. INTRODUCTION

We have recently developed a proposal for a new radiotherapy technique based on a single convergent photons beam (RTHC: Radioterapia de Haz Convergente) by means of a device capable to generate a single beam of convergent X photons. Previous studies have shown that a primary beam of these characteristics provides excellent dosimetric results with a dose peak close to the isocenter, similar those used for hadron therapy treatment. Objectives: To determine the physical and dosimetric characteristics of a device convergent X photons beam and its potential to be used in clinical treatments.

II. MATERIAL AND METHOD

Analytical developments plus software that allows determining the necessary fields (electrostatic and/or magnetic fields) for electrons trajectory control are used. Also Monte Carlo simulation code (PENELOPE) was applied to a specially designed anode geometry for the generation of a convergent photons beam. This data were considered different energies and thicknesses and materials and W and Pb as possible materials for the anode.

III. RESULTS Y DISCUSSIONS

We determined the values of the magnetic and/or electric fields to handle the convergent beam device for an electrons’ energy range from 0.1 to 20 MeV. The achieved results show that it is possible to develop a convergent beam prototype of low and high energy as a single unit or to be adapted to an existing radiation-therapy LINAC, so this might be used either in the conventional mode or in the conventional one, depending on the case.

Table 1: Electric field $E$ values and magnetic field values $B$ for various electron kinetic energies for three turning radius (10, 20 and 30 cm) of the curved trajectories of the electrons.

<table>
<thead>
<tr>
<th>Electron Energy (MeV)</th>
<th>$E$ (KV/cm)</th>
<th>$B$ (Tesla)</th>
<th>$E$ (KV/cm)</th>
<th>$B$ (Tesla)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn radius 10 cm</td>
<td>Turn radius 20 cm</td>
<td>Turn radius 30 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>18.5</td>
<td>0.010</td>
<td>9.2</td>
<td>0.006</td>
</tr>
<tr>
<td>0.3</td>
<td>49.2</td>
<td>0.020</td>
<td>24.6</td>
<td>0.011</td>
</tr>
<tr>
<td>0.5</td>
<td>75.7</td>
<td>0.030</td>
<td>37.9</td>
<td>0.015</td>
</tr>
<tr>
<td>1</td>
<td>134.7</td>
<td>0.050</td>
<td>67.3</td>
<td>0.024</td>
</tr>
<tr>
<td>2</td>
<td>345.8</td>
<td>0.120</td>
<td>172.9</td>
<td>0.058</td>
</tr>
<tr>
<td>3</td>
<td>651.1</td>
<td>0.220</td>
<td>325.6</td>
<td>0.109</td>
</tr>
<tr>
<td>4</td>
<td>1055.2</td>
<td>0.350</td>
<td>527.6</td>
<td>0.176</td>
</tr>
<tr>
<td>5</td>
<td>2062.6</td>
<td>0.600</td>
<td>1031.3</td>
<td>0.344</td>
</tr>
</tbody>
</table>
We can see that the requirement of electrostatic fields required is much more difficult to be achieved technically energy above 3 MeV for any of the three curvature radii indicated. On the other hand we note that the magnetic field values are much more accessible than electrostatic practically the entire energy range considered.

Angular distribution curves of the bremsstrahlung were determined for different thicknesses and incident electrons energies (0.4 to 6.0 MeV), plus the respective doses distribution in each case, characterized by a high dose concentration, close to the isocenter. Figure 1 shows the angular distribution for different energies for a foil W of 1 \( \mu \text{m} \) thickness. Note that almost 80% of bremsstrahlung is directed forward in a cone of 2\( ^\circ \) angular opening. In Figure 2 shows two curves for thicker sheets W of 0.1 and 1 mm thick for the same set of energies.

In this case there is a greater opening angle with respect to the previous case, but with a significant increase in the production of bremsstrahlung.

In the sheet 1 mm, which bremsstrahlung shown right, there is a greater production of this and a significant increase in the angular, which is in line with expectations. Note bremsstrahlung production energy remarkably falls below 1 MeV. Of the three cases we see that the choice of 0.1 mm sheet presents the best trade-off between openness and bremsstrahlung production.

The Figure 3 we see the images of depth dose distributions for openings of 30\( ^\circ \) and 60\( ^\circ \) (left) and corresponding dose profiles (right).

Below in Figure 4 we can see a comparison of images of the depth dose distribution of experimental and one achieved by Monte Carlo Simulation.

To the left is an image recorded on a radiographic plate plates for a convergent beam experimentally simulated angular scans 30\( ^\circ \) by describing a cone. This was performed by a phantom Octavius allowing the placement of the plate therein. On the right the corresponding image achieved Monte Carlo simulation. Note the great similarity between them and a few small differences in peak area due to the difference collimation used in each case.
Figure 4: Images of the dose distribution, experimental (A), Monte Carlo Simulation (B) to 30° angular opening.

Figure 5: convergent beam device adapted to a LINAC (Pat Pending). To RTHC applied technical proposal.

Finally in Figure 5 shows a generic model of how it should be a converging beam device Converay®, adapted to clinical use LINAC which is soon to be built.

IV. CONCLUSIONS
The physical and dosimetric characteristics of convergent beam device radiotherapy have been determined. The achieved results show that it is possible to develop a convergent beam prototype of low and high energy as a single unit or to be adapted to an existing radiation-therapy LINAC, so this might be used either in the conventional mode or in the conventional one, depending on the case.

V. ACKNOWLEDGMENTS
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VI. REFERENCES

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