PRELIMINARY RESULTS OF THE pCT SCANNER TESTING AT CV-28

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ABSTRACT

In the present work the first results obtained with the low energy proton beam of CV-28 at IEN/CNEN and the prototype of a computerized tomography device developed in UFTPR are presented. The system installed in the scatterings chamber of the cyclotron line 3 includes the proton scatter, turntable with translation (1st generation CT scheme), the set of collimators for the secondary proton beam formation and the Si(Li) ORTEC detector. The main parameters of the tomography turntable and the collimators were chosen based on computer simulations with SRIM2006 and GEANT4. A cylindrical glass tube was used as the irradiated sample. On this stage, only the translation of the turntable perpendicular to the proton beam direction was fulfilled. The measured proton energy spectra have, in general, a predicted behavior. However, the experiment revealed some problems with the secondary proton beam formation that should be solved prior to obtain a first pCT image at CV-28.

1. INTRODUCTION

The proposal to use protons in computerized tomographic imaging has practically the same age as the idea of conventional x-ray CT [1]. The first pCT images were obtained in the 70’s in the last century using a high-energy (~200÷300MeV) proton beam [2,3]. In the early 80’s pCT experiments were continued [4,5], and it was shown that due to the better dose utilization the method had some advantages. However, the anticipated extra expense of pCT implementing at that time did not justify it for widespread routine. The only promised pCT used was for special purposes, such as in treatment planning for proton therapy [5].

Starting in the 90’s proton therapy became a hospital-based routine at Loma Linda University Medical Center in the USA [6]. There are currently six proton-therapy facilities under construction worldwide and a further 20 have been proposed [7]. Therefore, the predicted
practical implementation of pCT for treatment planning purposes is now under consideration [8].

The pCT method at low proton energies (~25MeV) had also been tested, but with a specific goal [9]. Such experiments, however, can effectively contribute to the pCT development for high energies. As it was shown recently, the results obtained at low energies can be easily scaled to higher energies, and vice-versa [10].

The pCT measurements at low energies, however, could be done just by using a semiconductor detector, i.e. with very high resolution for proton energies. Particularly, the Si(Li) ORTEC L-035-025-5 detector used in this work has a resolution of 28keV. This factor is essential for the study of pCT method density resolution [10,11]. This work reports the preliminary results of our pCT scanner testing with 23MeV protons.

2. EXPERIMENTAL SETUP

The experimental setup used in this work was reported in details previously [12]. We used the pCT mini scanner installed on the beam line #3 of the cyclotron CV-28 at IEN/CNEN (Rio de Janeiro). The scanner was developed within the 1st generation CT scheme. The tomographic turntable was projected to make the precise movements (translation and rotation) in vacuum, that is, the characteristics of the micron step engines, guides, transmission and lubrication systems were especially adapted to the operation conditions. The standard OPC (OLE for Process Control) server coupled with a logical controller was used for the movement control.

In this stage, only the translation of the turntable perpendicular to the proton beam direction with a 0.2mm step was fulfilled. The precisely measured dimensions of the tube phantom were: 8.23mm – the external tube diameter, 0.52mm – the tube wall width, 2.45mm – the diameter of the central cylindrical polyethylene bar. We did not fill the tube during the reported measurements.

3. RESULTS AND DISCUSSION

The measured proton energy spectra have, in general, the behavior predicted by our preliminary computer simulations [12]. However, the experiment revealed some problems. This is illustrated by Figure1.

The upper spectrum was obtained without the object on the secondary proton beam trajectory. One can see that the noise at the low energy part of the spectrum spreads up to approximately 4MeV. This noise can be due to a high radiation background and/or some harm with used electronics. All necessary procedures to exclude this routine problem are under the way now.

The lower spectrum was measured while the proton beam hits the object tangentially. First, the part of the proton flux was not affected by the object – the "elastic" peak at 23MeV is still on place (as well as the first "inelastic" at somewhat about 18MeV). Another part of the protons crossed the object – a wide peak below 18MeV. The comparison with theoretical predictions [13] and more precise GEANT4 simulations [14] have shown that the width of
this peak is not a reflection of the statistical nature of the proton interaction with matter but is the manifestation of the geometrical factors of our experimental setup.

![Energy Spectra Graph](image)

**Figure 1.** Experimental energy spectra: without the object on the beam (upper spectrum) and while proton beam hits the object tangentially (lower spectrum).

The measurements were done with the $\Theta=0.4\text{mm}$ collimator. Figure 2 shows the expected geometry in the proton beam – object system during the translation. Particularly, the lower spectrum on Figure 1 was measured under the conditions, represented by the left design on Figure 2.

It can be seen that the high variations in the geometry trajectories of protons in the object within the beam diameter are typical. As a result, most of proton energy spectra do not
present a Gaussian form, expected in the theoretically idealized situation. Consequently, the standard procedure of the mean final proton energy determination should be examined.

![Figure 2. The proton beam – object geometry in the translation movement dynamics.](image)

### 4. CONCLUSIONS

The first measurements with our pCT scanner revealed two kinds of problems to be solved. First, the spectrometric tract was found to be quite noisy. The second kind of problems are not connected with experimental routine but due to the specific of our measurements. The maximum object dimensions are limited by the arbitrary low energy of the protons while the minimum collimation of the detector is also limited by the requirement to have a reasonable time on each exposition. Thus, instead of the typical CT (and pCT) situation, our spectra contain a lot of "boundary effects", i.e. a specific structure and energy spread in the registered energy spectra while the proton beam hits tangentially to the external and internal edges of the object. Therefore, an adequate treatment of such proton energy spectra should be developed in the next step of our work.

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### REFERENCES