PRODUCTION OF A SLOW POSITRON BEAM AT THE 90 MEV LINAC OF THE GHENT UNIVERSITY.

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Abstract.

The pulsed 90 MeV LINAC of the Ghent University is used to produce electron-positron pairs in a tantalum target. The thus obtained positrons are thermalized. The moderator consists of a set of well annealed tungsten foils set in a venetian blind geometry. The thermalized positrons are then injected into a magnetic transport system leading them to the experimental room which is about 41 m away from the convertor-moderator setup. About $2x10^7$ slow positrons per second are obtained. They are bunched with the frequency of the accelerator, which is 300 Hz. To obtain a more continuous beam, a Penningtrap is installed just before the last bend in the transport system. At the end of the transport system a high vacuum chamber is installed. The beam will mainly be used to do materials research on for example surfaces, interfaces, multilayered samples etc., using equipment and techniques that originate in the domain of nuclear physics.

The positron source.

To be able to produce a high intensity low energy positron beam one needs to have a primary very intense source of positrons. Because of the possibility of obtaining higher slow positron intensities, the option to use a LINAC rather than a positron producing isotope as primary source was taken. In fig.1 one can see a schematic view of the positron source such as it actually exists at the Ghent facility. Electrons are accelerated to energies up to 90 MeV and are then stopped in a tantalum Bremsstrahlungstarget, producing electron-positron pairs. This target is placed in a copper holder which is water cooled. An important factor is the thickness of the target. An optimum has to be found between stopping efficiency for electrons and the possibility for the positrons to emerge from the target. Some experiments where done on this matter by Howell at al. and it seems [1] that for an electron energy of 100 MeV, the optimal thickness of the target is situated at about two radiation lengths. For tantalum this means that the optimal target thickness would be about 0.75 cm for an electron energy of 100 MeV. At present all experiments in Ghent have been performed with an electron energy of 45 MeV and the target thickness was chosen to be 0.5 cm. In a later stage the target thickness will be increased to 0.75 cm and the full power of the LINAC will be used. An advantage of this should be a higher slow positron yield, since it has been shown [1] that the yield increases linearly with the energy of the electrons that hit the Bremsstrahlungstarget. A gain of a factor two or three in slow positron yield is to be expected from this power increase. However some cooling problems might arise at this point and care will have to be taken in increasing the LINAC power.

The moderator.

After the Bremsstrahlungstarget one obtains positrons with a broad energy spectrum. Some simulations were done using the EGS4 software [2]. Fig.2 shows an energy spectrum of positrons emerging from a 5mm thick Ta target with an energy of the impinging electrons of 45 MeV. It is a very broad spectrum that needs to be narrowed down to a very small energy range. Therefore a moderator was used to thermalize the positrons. Our moderator consists of tungsten foils of various thicknesses, in a vane configuration. There are eight tungsten vanes and they are positioned as shown in fig.1. Part of the positrons emerging from the tantalum target are stopped in these foils. It is important to couple the target and the moderator as closely as possible, because the positron beam after the target is rather divergent. Fig.3 shows a simulation of the angular distribution of the positrons after the target for an electron energy of 45 MeV. It shows that the most probable angle is about 20 degrees but much larger angles also occur quite a lot. The positrons are thermalized and start diffusing randomly in the foil. Some of these thermalized positrons are able to diffuse back to the surface of the foils. Tungsten has a negative workfunction (-2.1 eV) for positrons. This means that emission of free positrons at such a surface is possible and these reemitted positrons have an energy which equals about the workfunction of the material. The reemission of positrons depends very much on the surface condition of

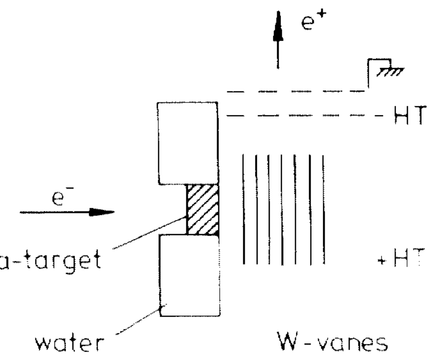

Fig.1 The convertor-moderator setup.

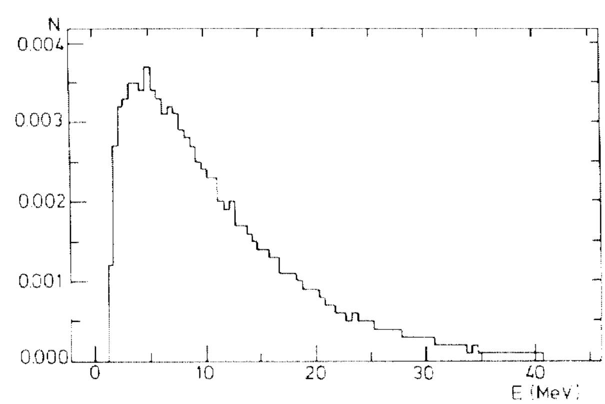

Fig.2 Energy spectrum of positrons emerging from a 5 mm thick Ta target for a primary electron energy of 45 MeV.

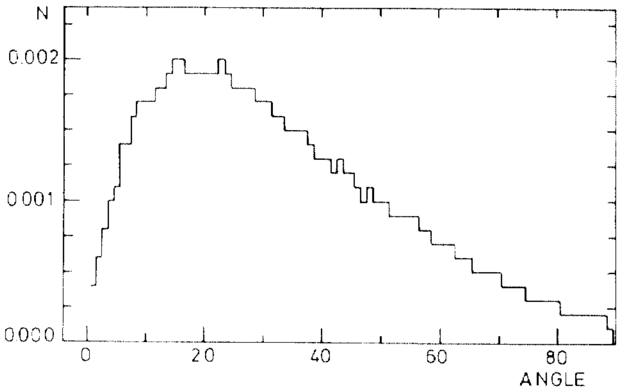

Fig.3 Simulation of the angular distribution of the positrons after the target for an electron energy of 45 MeV.

the moderator. The surface has to be very clean and free from carbon and other contaminants. Therefore the foils are heated up to very high temperatures in vacuum to remove contaminants from the surface. The heating is done with electron beam heating and the vacuum varies between 10^{-3} and 10^{-4} Pa. The color of the foils is brightly white during the annealing stage and the treatment produces a clean shining surface on the foils.

The transport system.

The positrons have to be transported away from the high radiation background that exists at the production site, because it is impossible to perform any measurements in these conditions. Therefore the positrons are accelerated by biasing the moderator foils to 200 V. They move in the axial magnetic field of three large Helmholtz coils towards the first of a series of solenoids. These solenoids are 2 m long vacuum tubes, wound with two layers of copper wire thus being able to produce a homogeneous axial magnetic field of 10 mT. The positrons spiral around the field lines away from the moderator. To transport particles of such low energy over a large distance focussing has to be performed all the way. Therefore a magnetic transport system is to be preferred over an electrostatic one. The whole system is 41 m long and it contains four 90 degree bends. These are in fact quarter toroids with a radius of 0.9 m. All along the transport system compensation for the earth's magnetic field has proven to be necessary. This field which has a magnitude of about 0.048 mT in these regions, always has a component perpendicular to the axis of the transport system. This causes the slow positron beam to drift as much as 5 mm of axis per m of transport. Compensation is achieved by creating an opposite magnetic field all along the beamline. In the curves the gradient in the magnetic field also causes problems of the positron beam drifting away. These are solved by placing two pairs of kick coils perpendicular to one another on each bend. They are able to create small magnetic fields, up to 1.5 mT. The whole system is pumped vacuum with turbomolecular pumps to a vacuum of 10^{-5} Pa and the pumps are bridged with Helmholtz coils to be able to transport the slow positrons past them. A general view of the beamline is shown in fig. **4**. The transport system ends in a high vacuum chamber where the experiments will be performed. For the moment the slow positron intensity in this chamber is about $2x10^{7}$ per second. This was measured for an accelerator current of 85 μA and an electron energy of 45 MeV. This means an overall conversion efficiency of $3.8x10^{-8}$ slow positrons per primary electron. The slow positron beam is pulsed with a frequency of 300 Hz and a maximum pulse length of 3 μs because of the pulsed character of the accelerator. This may cause pile up problems in the detection systems for some kinds of measurements and therefore an attempt was made to fill up the gaps in-between LINAC pulses.

Pulse stretching.

A Penningtrap (fig.5) as was already described by Hulett et al.[2] was installed. It consists of three electrically isolated cylinders, a central one which is 5.6 m long and two 0.2 m long ones at the ends. All three cylinders are placed within a 6 m long vacuum solenoid, constructed out of one piece and which can provide an axial magnetic field of 10 mT. Slow positrons enter the trap with energy determined by V_{mod}, the potential of the moderator, minus the voltage V_2 on the long cylinder. By applying appropriate voltages V_1 and V_3 on the entrance and exit cylinders as shown on fig.5 the Penningtrap is filled with positrons during the accelerator pulse. After several reflections the positrons can then escape because of the linear potential decrease at the exit cylinder. This way it has proven possible to smear out the slow positron pulse up to a width of 1 ms. Further improvements such as for example better alignment of the cylinders in the trap will be necessary to obtain better results. However, first experiments will be started with the Penningtrap in its present form.

Conclusion.

A 41 m long, intense slow positron beam has successfully been installed at the 90 MeV LINAC of the Ghent university. It is only the sixth beam of its kind in the world. It will be used to do depth resolved materials research. Further improvements on the installation will be made such as remoderation to obtain higher brightness of the beam and bunching of the slow positron pulses to be able to measure lifetimes in the ns range.

Acknowledgements.

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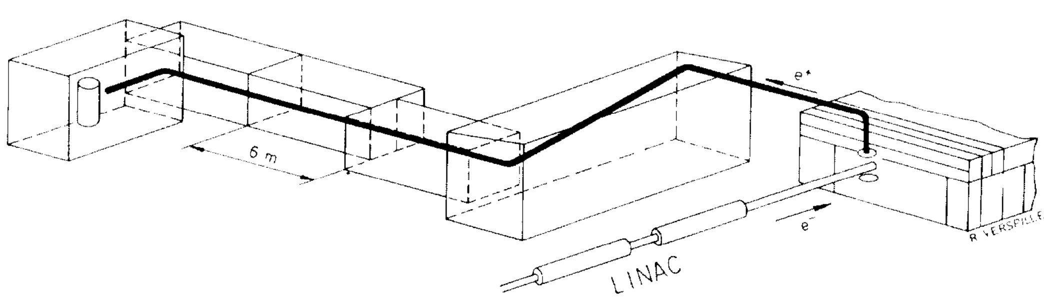

Fig.4 General view of the slow positron facility.

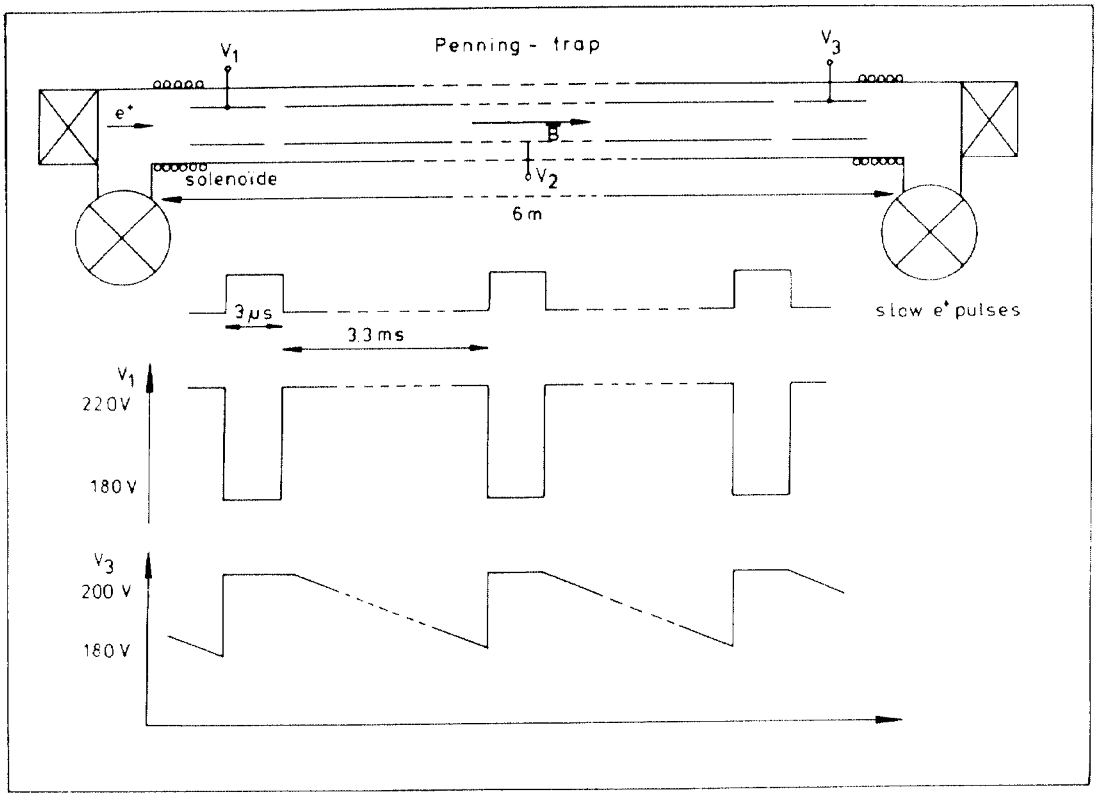

Fig.5 Schematic view of the Penningtrap.

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