A short report on the electron-positron spectrometer test at HRRL.

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In this experiment we were studying production of the electron-positron pairs via bremsstrahlung photons created by electrons passing through the output window of a HRRL vacuum system (1mil of Ti). This studies will help us to monitor photon flux better than before where a NaI detector was used. It is possible to calibrate the pair spectrometer such that it gives the information about the number of e^-e^+ pairs for the given numbers of photons incident on a pair converter. Detectors spanning small solid angle will allow us to detect e^-e^+ pairs of certain energy and to provide good energy resolution.

Different designs of the experimental setup were used to observe timing spectra giving the information about the counting rate of e^-e^+ pairs for the given beam current, beam energy and rep rate. The main idea lying in the ground of the photon flux monitoring via e^-e^+ pairs detection is production of the pairs in a thin converter which doesn't affect photon flux too much and following separation of the electron and positron in a magnetic field of either a permanent magnet or an electromagnet. Then, using counting rate in a coincidence peak one can recalculate the number of photons which hit the converter. Additional adjustments should be used in order to get rid of e^-e^+ pairs produced in the air by the bremsstrahlung photons before they hit the pair converter.

In the current experiment two kinds of permanent magnets were used as analyzing magnets and two sets of detectors with different acceptances were used for detection of the pairs. One magnet used was a c-shaped "home-made" magnet having a yoke on one side only. Another pair of magnets used were oval-shaped with two yokes.

Electronics used were of NIM-standard. Time-to-amplitude (TAC) converter was used to convert time difference between pulses detected by the detectors to the signal with amplitude proportional to the time difference. In order to see exact coincidences (0 ns between two pulses) an additional delay was introduced by gate-and-delay generator (~640 ns to see the peak in the middle of ADC range provided TAC range was 1000 ns). Calibration (0.11ns/channel) of the TAC was done by introducing different, but known, time delays via passive delay lines (see Fig. 1 below).

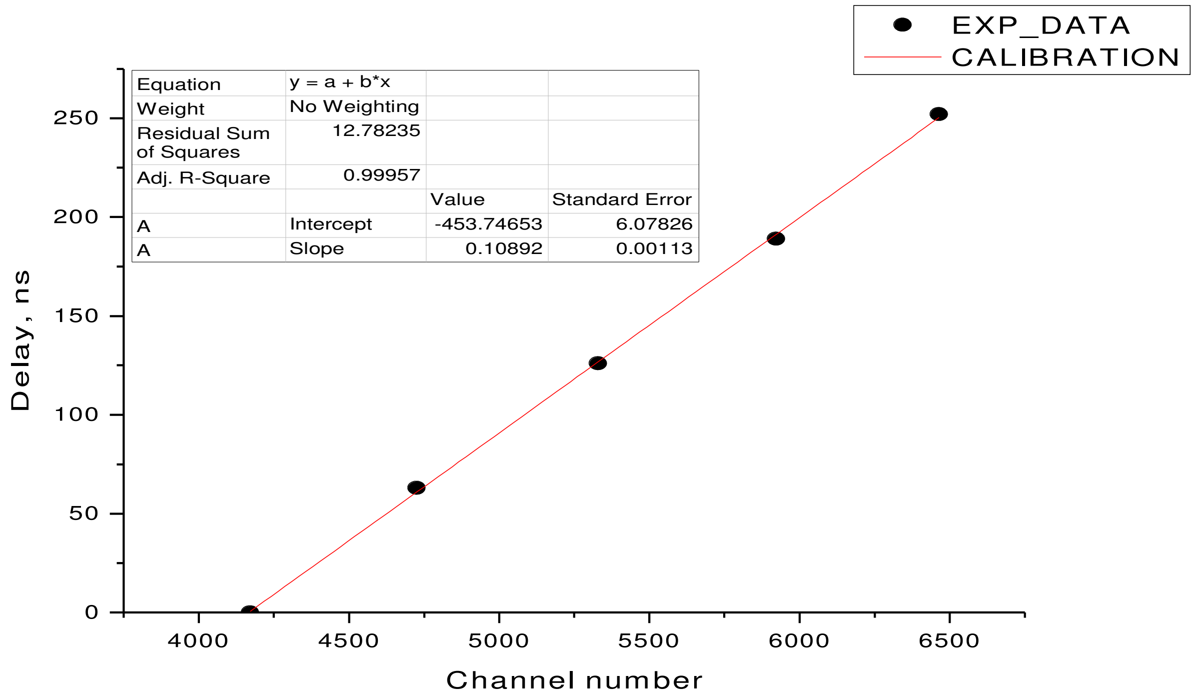

Fig. 1. *Channel-to-time calibration curve. Slope is 0.10892 ns/channel.*

Analog-to-digital converter (ADC) 1B was used to analyze pulses coming from the TAC and to observe timing spectra. MPANT software was used to visualize data and to save the data into files written in .lst(binary), .mpa(ASCII) and .mp formats.

First attempt of e-e^+ pairs observation was made by using c-shaped “silver” magnet and detectors made of L-shaped light-guides+scintillators attached to PMT. The size of plastic scintillators attached to the light-guides was ~5x2x0.7cm. The high voltage on the PMTs was set to ~1200V (negative). Detectors were placed at downstream position (that was calculated before) w.r.t. the magnet and were shielded with lead bricks to reduce room background and cosmic rays. Some neutron shielding and lead collimator (ø2cm) were placed upstream on the setup table.

An iron collimator (2.5x2.6cm) was placed at the output port of a concrete wall. No reasonable data were obtained. Far as I remember, the sweep magnet was on the beam. The beam current was set to ~0.5mA and could not be reproduced precisely. Electron beam energy was set to 10 MeV. A signal taken from the detector detecting positrons was used as a start signal of the TAC.

PICTURE OF THE EXP SETUP

Next try to see the pairs was the O-shaped magnet used as analyzing magnet instead of "home-made" c-shaped one. A sweep magnet was placed on the beam line to clear the beam out of the charged particles produced upstream. PMTs with L-shaped lightguides attached were used as detectors of e^-e^+ pairs. These detectors were placed first symmetrically w.r.t. the beam line downstream the analyzing magnet. All the dimensions of collimators were not changed. A pipe filled with helium was placed on the beam in between the sweep magnet and analyzing magnet in order to reduce background counting rate of e^-e^+ pairs due to e^-e^+ pairs created in the air. Nothing but accidental coincidences were observed. Then one of the detectors was moved upstream and placed behind the analyzing magnet where one can see low energy part of the produced positrons. Nothing but accidental coincidences were observed. Finally, another detector was moved upstream to detect low energy electrons. Again, nothing but accidental coincidences were observed.

After that unsuccessful run we (Dr. Dale, of course) decided to make new detectors which cover larger solid angle and to change the placement of the analyzing magnet to increase Bdl. Indeed, it helped a lot. The holes were drilled in both yokes such that photon beam could pass through w/o interaction with the yokes. An iron collimator (2x0.5mm) was placed at exit of concrete wall. The beam current was set to 5 mA and energy of the electron beam was increased to 14 MeV. We could see the coincidence peak at 456.37 ns in the time spectrum. Pairs were generated on the air.

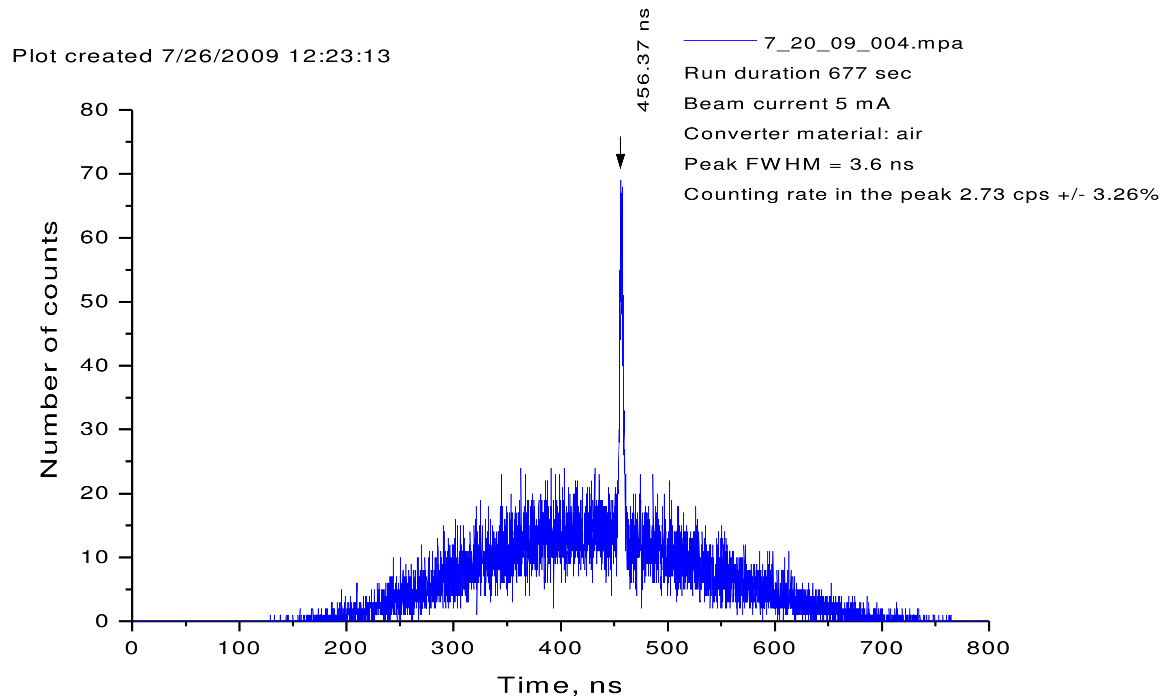

Fig. 2. *Timing spectrum. Pairs produced in the air.*

Then we changed the experimental setup placing Al converters of different thickness and moving around the graphite collimator and sweep magnet. For instance, for 10 mA beam current and 70 layers of Al foil we got 3.63cps$\pm$3.46% in coincidence peak (cps stands for counts per second). For no target we got 2.71cps$\pm$3.61%. Signal-to-noise (S/N) ratio was observed to be ~3. In the end of this run we did the “Dr. Forest's test”, namely, we placed lead brick on the beam path and, as a result, we got almost nothing in the time spectrum which was a good sign.

The next improvement in the experimental setup was a lead collimator 3x3mm placed in front of the sweep magnet. In order to get a reasonable counting rate the value of the beam current was increased from 10 mA up to 100 mA. This value of the beam current can be reproduced with relatively small error. In this case we obtained very good S/N ratio ~6. The timing spectrum obtained at the beam current 40 mA, electron energy 14 MeV and Al target thickness ~2 mm is shown in Fig. 3 below.

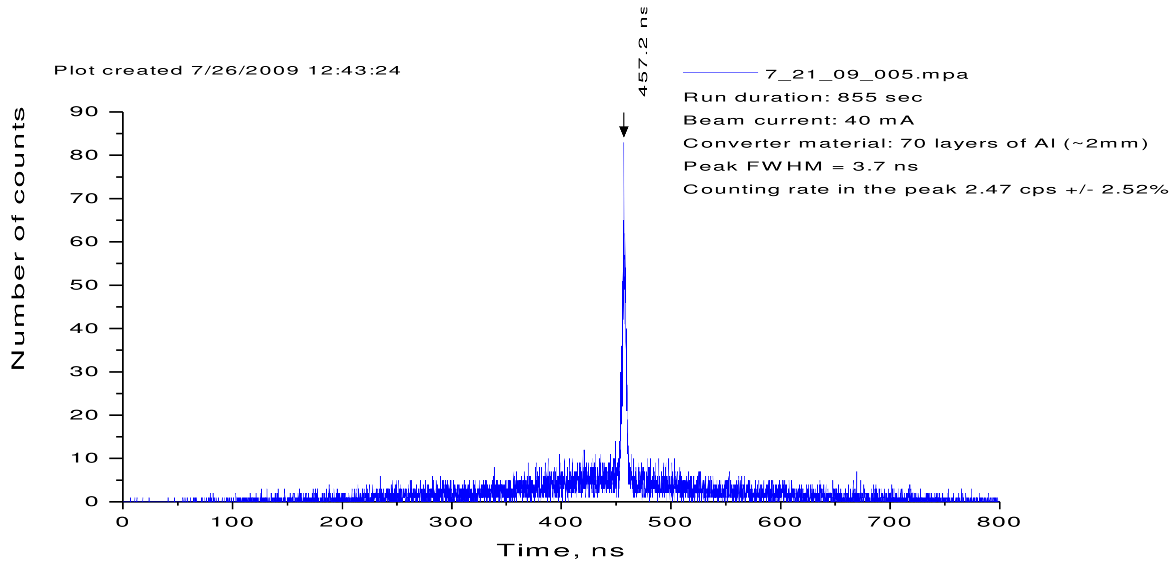

Fig. 3. *Timing spectrum. Improved collimator in use.*

For instance, for 100 mA beam current and 70 layers of Al foil we got 3.08cps±2.45% in coincidence peak. For no target we got 0.58cps±4.5%. It should be noted that leading edge discriminator (LED) had different thresholds for the two detectors. The values of thresholds were set to 56 mV and 150 mV.

In the end of the experiment we did what we should have done in the very beginning, we obtained the dependence of the counting rate vs. discriminator threshold under fixed high voltage applied to PMTs.

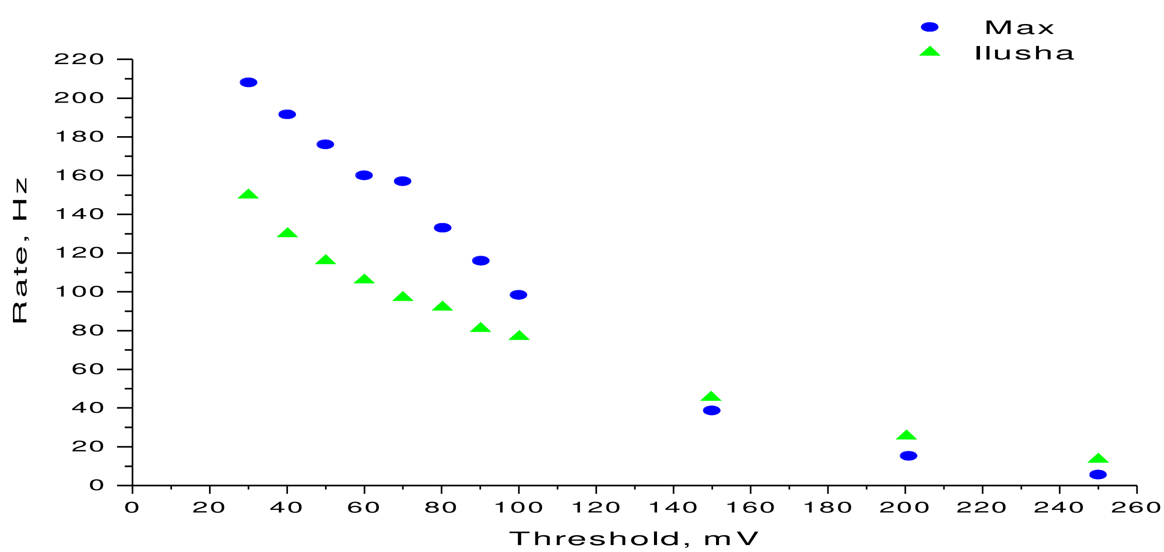

Fig. 4. *Dependence of the counting rate vs. threshold value.*

No clear plateau was observed for both detectors. An additional investigation of the appropriate thresholds that should be set was done in the following way. We fixed the threshold value in the one channel of the LED and observed the dependence of counting rate vs. different threshold values set in the second channel of the LED.

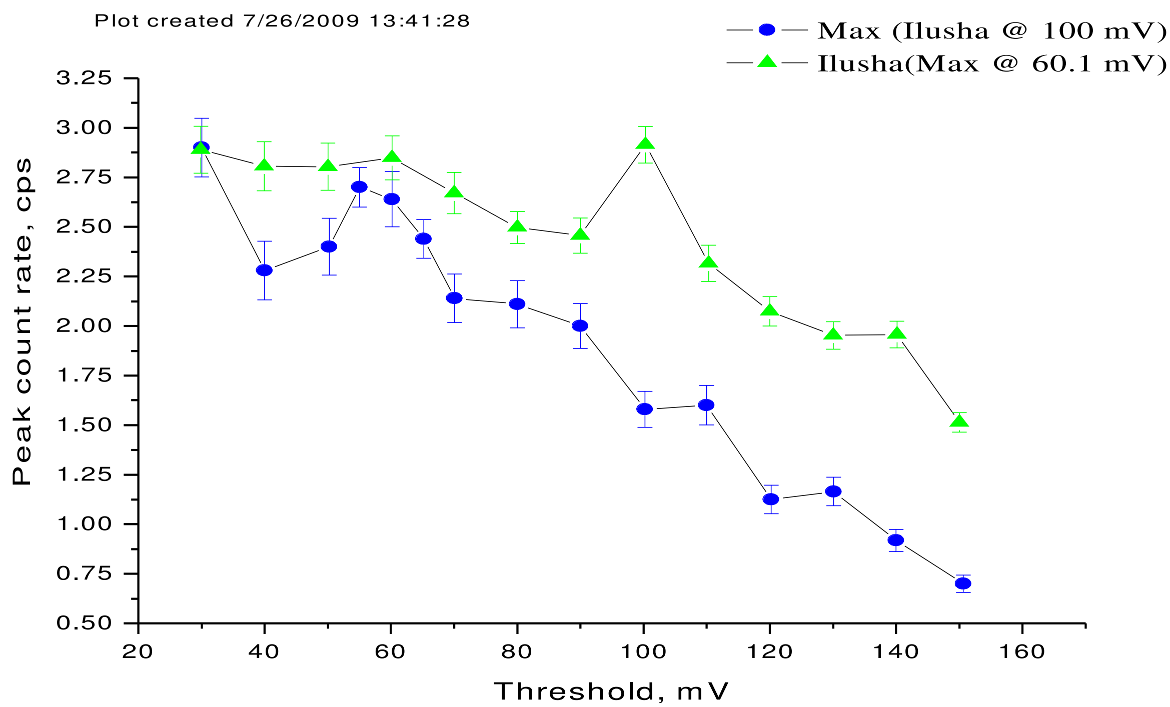

Fig. 5. *Dependence of the counting rate in the coincidence peak vs. threshold value.*

We found that the value of the threshold for "Ilusha" should be set to 60 mV. Then using this value of the threshold fixed we observed the dependence of counting rate vs. different threshold values set for "Max". Again, it was obtained that threshold value should be set to 60 mV. At these values of the thresholds the counting rate of single events was equal to 65.6Hz ("Max") and 67.7Hz ("Ilusha") in the case when analyzing magnet was removed from the beam line (Roman's test). In the case when the analyzing magnet was removed from the beam line we observed no peaks in the timing spectrum which proved that we observed e-e^{+} pairs created in the Al converter and air gap and which were swept by analyzing magnet towards the detectors.

As a conclusion it can be said that the studies of photon flux based on the detection of e^-e^+ pairs described above were successful as a first attempt. In the future we will try to quantify observed counting rate in the coincidence peak and to relate it to the real beam current, i.e. to relate it to the number of photons which hit the converter.