EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CERN - LHC DIVISION

LHC-VAC/OBM **Vacuum Technical Note 99-03**
April 1999

Photoelectron current in magnetic field

V.V. Anashin, R. V. Dostovalov, A.A. Krasnov, O.B. Malyshev and E.E. Pyata

1. Introduction

Most of the length of the LHC vacuum chamber will be inside the dipole magnets. High intensity photon flux will stimulate photoelectron emission from the wall of the LHC vacuum chamber. The photoelectrons participate in different processes in the vacuum chamber; more important ones are the gas photodesorption and the beam-induced multipacting. The presence of the magnetic field should have a strong influence on this process. The first question is: How much will the photoelectron current from different samples depend on the magnetic field? This is the aim of present the study.

This note describes the study fulfilled from April to July 1998 within the frame of the collaboration between CERN and the Budker Institute of Nuclear Physics, Novosibirsk, Russia (see item 1.3 in ref. [1]).

2. Set-up and sample preparation

A new experimental set-up was built on the beam line P2 of VEPP-2M to study, at room temperature, the dependence of the photoelectron emission at normal photon incidence on a transverse magnetic field between 0 and 0.6 T. The layout of the installation is shown in Fig. 1.

The experimental volume made of ID46 mm stainless steel tube is ended with a flange with a sample holder and a signal output. The all-metal valve divides the vacuum of the experimental volume and the SR beam line. The distance from the SR source to the collimator is about 11 m. The sample, with dimensions of 44 mm (vert.) by 15 mm (hor.), is fixed with a sample holder normally to SR. The photon flux is collimated by 35mm×10mm into the central part of sample, i.e. the edges of the sample are not irradiated. The irradiated part of the sample shown on the cross-section A-A in Fig. 1 is marked in grey. The increased vertical size of the photon beam and the sample was chosen to avoid the cutting of the part of low energy photons. The sample is isolated from other parts and has the electrical connection to signal output. This output is joined via the ammeter to the voltage source (±300 V). Hence, one can control the potential on the sample and measure the electron current from, or to, the sample.

The dipole magnet was installed outside the experimental volume to have the sample in the centre of the magnet. The magnetic field of 0 to 0.6 T is approximately parallel to the sample surface and along the narrow direction of the sample. The magnet could be pivoted by ±1.5° around the sample. The experimental volume has a close-cut cross-section near the magnet centre to make the magnetic field stronger and more uniform (see Fig. 1).

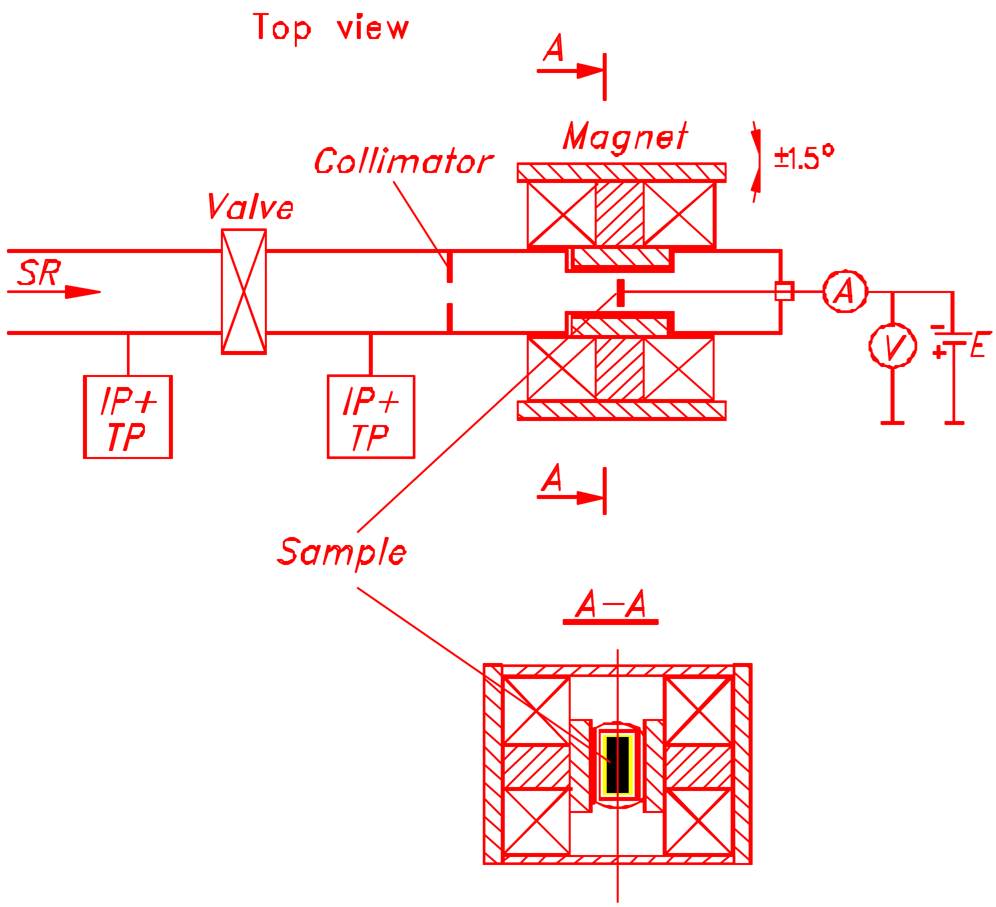

Figure 1. The layout of the installation

A few samples were studied: one made of the stainless steel, four made of copper laminated stainless steel (Cu/SS) from the sheet supplied by CERN and one machined from OFHC. No special treatment was used for the sample before installation, only degreasing, cleaning with benzine and alcohol. Only one sample was oxidated after a 300°C bake-out.

Sample SS. The stainless steel sample made from a rolled sheet, no special treatment.

Sample Cu/SS-1 (≡). The copper laminated stainless steel made from a sheet; the rolling lines are across the sample. No special treatment.

Sample Cu/SS-2 (|||). The copper laminated stainless steel made from a sheet; the rolling lines are along the sample. No special treatment.

Sample Cu/SS-3 (||| ox). The copper laminated stainless steel made from a sheet; the rolling lines are along the sample. Oxidation.

Sample Cu/SS-4 (__/). The copper laminated stainless steel made from a sheet with turned-in, long edges, i.e. 5-mm wide strips at the long edges were turned to 10–15° towards the SR; the rolling lines are along the sample. No special treatment.

Sample OFHC (⊥⊥⊥). The copper sample machined from a bulk OFHC with ribs along the sample. No special treatment. The ribs are 1 mm in height and 0.2 mm in width. The distance between the ribs is 3 mm.

Sample Au/SS. The stainless steel sample electro-deposited with 6-μm Au. No special treatment.

3. Experiment

In all experiments, the photoelectron yield was a measured parameter. It was estimated as a ratio of the measured output current I_{mes} (i.e. electron flux from or to the sample) to photon flux $\dot{\Gamma}$:

$$k\,[e/\tilde{g}] = \frac{I_{mes}[A]}{e[Q]\cdot\dot{\Gamma}[\tilde{g}/\sec]},$$

here e is the electron charge.

1. The photoelectron yield was studied as a function of the different parameters:
2. As a function of the potential on the sample (or bias) from –300 V to +300 V at fixed magnetic field (0, 0.1, 0.2, 0.4, 0.6 T);
3. As a function of the magnetic field from 0 up to 0.6 T at a fixed potential (0, 60, 160, 300 V).
4. As a function of the angle between the magnetic field and the surface sample.
5. As a function of the accumulated photon dose.

In the first experiments these measurements were done in two or three positions: (a) when the magnet is turned maximally clockwise or counter-clockwise (maximal output current); (b) in such a magnet position where the measured output current I_{mes} is minimal. The last position, we believe, as a position with minimal angle between the sample surface and the magnetic field. An additional mechanism for turning the magnet and accurate measurements of the angle was installed before experiment no. 3.

In the experiments, the photoelectron yield was then measured as a function of the potential on the sample (or bias) from –300 V to +300 V. The yield increases rapidly when the bias is changed from 0 to about –100 V, and reaches a saturated value for more negative bias. At a negative potential, the photoelectrons leave the sample. When the potential is positive, the photoelectrons from other parts of vacuum chamber are attracted to the sample. The ratio $\frac{k(+300V)}{k(-300V)}$ without the magnetic field shows how many photons are reflected from the sample.

In the experiments, the photoelectron yield was measured as a function of the magnetic field. The photo-yield rapidly decreases with the magnetic field when the magnetic field changes from 0 to about 0.1÷0.2 T, then decreases slowly, and is practically constant between 0.4 and 0.6 T. It is therefore not very likely that the yield could be changed at a higher magnetic field.

The main results are shown in Table 1.

Table 1

Experiment No. and	Beams		Measurements without magnetic field			Magnetic field efficiency:	
Sample	E_{e-e+}, [MeV]	E_c, [eV])	k, [e^-/γ] U=-300V	$\frac{k(0V)}{k(-300V)}$	Reflectivity $\frac{k(+300V)}{k(-300V)}$	U = 0 $\frac{k(0.6T)}{k(0T)}$	U = -300V $\frac{k(0.6T)}{k(0T)}$
Exp. 1, SS	518	259	0.016	0.036	0.024	0.023	0.028
Exp. 2, Cu/SS-1 (≡)	514	253	0.015	0.15	0.044	0.010	0.029
Exp. 3, Cu/SS-2 (|||)	470	194	0.014	0.11	0.015	0.021	0.030
Exp. 4, Cu/SS-3 (||| ox)	392	112	0.014	0.052	0.033	0.018	0.015
Exp. 5, OFHC (⊥⊥⊥)	380	102	0.0084	0.055	0.023	0.024	0.013
Exp. 6, Cu/SS-4 (__/)	220	20	0.014	0.07	—	0.02	0.06
Exp. 7, Cu/SS-4 (__/)	560	319	0.018	0.05	0.180	0.01	0.08
Exp. 8, Au/SS	580	356	0.027	0.06	0.045	0.028	0.042

The most interesting experimental dependencies are presented below in a number of figures for each sample.

Experiment No. 1

Sample SS. The stainless steel sample made from a piece of rolled sheet. No special treatment.

Comments:

- The dependence of the photoelectron emission on the photon dose was found in comparing the data without the magnetic field at the beginning of the measurements. After some doses, and after a dose of 10^{22} photons at the end of measurements.

Experiment No. 2

Sample Cu/SS-1 (≡). The copper laminated stainless steel made from a piece of rolled sheet; the rolling lines across the sample. No special treatment.

Experiment No.3

Sample Cu/SS-2 (|||). The copper laminated stainless steel made from a piece of the rolled sheet, the rolling lines along the sample, no special treatment.

Comments:

- The dependence of photoelectron emission on photon dose was specially studied on that sample with dose in range 10^{16} to 10^{21} photons.
- The dependence of photoelectron emission on the angle between the magnetic field and the sample surfaces is presented for the bias potential of –300 V in the magnetic field of 0.6 T.

Experiment No. 4

Sample Cu/SS-3 (||| ox). The copper laminated stainless steel made from a piece of rolled sheet; the rolling lines along the sample. Oxidation.

Comments:

- The dependencies of photoelectron emission on the angle between the magnetic field and the sample surface are presented for the bias potential of –60 V and –300 V in the magnetic field of 0.6 T.

Experiment No.5

Sample OFHC (⊥⊥⊥). The copper sample machined from a bulk OFHC with ribs along the sample. No special treatment.

Comments:

- The dependence of photoelectron emission on the angle between the magnetic field and the sample surface was very weak on this sample.

Experiments No. 6 and No. 7

Experiments No. 7 and 8 are fulfilled with the same sample at a different critical photon energy.

Sample Cu/SS-4 (__/). The copper laminated stainless steel made from a piece of rolled sheet with turned-in long edges, the rolling lines along the sample. No special treatment.

Comments:

- There is no dependence of photoelectron emission on the angle between the magnetic field and the sample surface.

Experiment No. 8

Sample Au/SS-4. The Au electro-deposited stainless steel sample (6-µm Au layer). No special treatment.

4. Conclusion

1) Although the value of the photoelectron yield is different for studied samples at zero potential, they are the same at the accelerating potential of 300V, $k \approx (1.5 \pm 0.3) \cdot 10^{-2}$ electron/photon. The photoelectron yield from the layer of gold is about two times higher.

2) The magnetic field could strongly suppress the photoelectron yield up to 30–100 times when the surface is parallel to the magnetic field, but this effect is much less at the angle of 1.5° (5–10 times).

3) The photoelectron yield decreases with the accumulated photon dose: the photoelectron yield reduced 2–3 times at the accumulated photon dose of about 10^{22} photons/cm^2 compared to the initial value.

References

1. Addendum No. A3 to the Protocol dated 14 June 1996 to the 1993 Co-operation Agreement between CERN and the Government of the Russian Federation concerning the Russian participation in the Large Hadron Collider project (LHC). CERN-BINP, 1997.