Draft version 03

Wiring of tubes for full scale BIL chamber prototype

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1 Introduction

Below are some results obtained during wiring and testing of 215 tubes produced for construction of full scale BIL chamber prototype intended for DATCHA at CERN.

There were two types of tubes: 'long' - 2554 mm and 'short' - 2194 mm. Short tubes were need to prepare cuts in the chamber for projective alignment RASNIK system. Number of short tubes is 17.

We used tubes produced by METALBA, outer diameter is 30 mm, wall thickness is 0.4 mm. Before wiring tubes were cut and cleaned. Deflection of tubes from straightness was detected. We selected tubes with the deflection less than 1 mm per 2.5 m.

End plugs were constructed and produced in IHEP.

2 Wire stretching

Gold plated tungsten 50μm wire (produced by MELZ of Moscow) was stretched with tension 250 g for 2554 mm long tubes. Free wire distance (distance between locators) is 2 mm shorter. During wire stretching its resonant frequency was controlled. Distribution of the frequency is shown in fig.1. Mean value is 49.86 Hz. $\mathrm{RMS}_f/\mathrm{f}_{mean}$=0.29%. It corresponds to 0.58% spread of tension. Calculated frequency is 49.788 Hz.

Wire stretching was done at temperature 20±1°C (fig.2). During stretching tension was slightly varied (fig.3) to keep constant resonant frequency.

Some increasing of tension (2.7 g) might be caused by change of wire bobbins or by imperfection of stretching tools (e.g. friction). Three wire bobbins were used during wiring. We are not sure that wire diameter did not vary from one bobbin to another but we controlled resonant frequency instead of tension. For constant resonant frequency of wire its sag must be the same independently of variation of its diameter.

For short tubes tension was decreased in such a way that the frequency was the same as for long ones. It means that wire in a short tube will have the same sag as in long one. The calculated sag is 123.7 μm.

Wire is fixed by crimping in copper tube (OD=1.0 mm, ID=0.27 mm).

3 Wire location

Wire locator is a hole in brass disk attached to end plug. We started production of tubes with the hole of 50-70 μm and its eccentricity less than 10 μm with respect to rotation center of end plug. During manufacturing some better parameters were reached: the hole diameter became 55±5 μm and eccentricity less than 5 μm. The figures were presented by hole manufacturer. In principle they show acceptable wire location.

There is a problem caused by imperfection of end plug precise surface. Instead of cycle it has pear-like shape with outstanding from ideal cycle up to ten of microns. We think that we overcame the problem by using balls support during drilling the holes in end plugs similar to stacking balls of assembling jig.

4 X-ray test of wire location in tube

Method is described in ATLAS Note No. . It is based on measurement of wire position in a tube as a function of tube rotation angle. Measured by X-ray ruler wire position will oscillate if there is an off set of wire. Examples of such oscillation curves are shown in fig.4. Fit is a function of $p_1+p_2\cdot\phi+p_3\cdot\cos(\phi+p_4)$, where p_1-p_4 are parameters. The second term describes possible instabilities of X-ray setup during measurement.

After taking into account an angle of X-ray wire position (X,Y) with respect to rotation center of end plug can be found from the fit function parameters p_3 and p_4. We had not time for all tubes measurement, only 30 tubes were tested. Wire position was measured for both sides of tube at distance about 10 cm from locator. Scatter plot of wire positions is shown in fig.5. One of the worst points in fig.5 at x=-4μm and y=28μm corresponds to upper part of fig.4. In fig.6 several distribution are presented. Fig.6a shows wire off set radius distribution. R_{mean} = 12 μm with RMS = 7 μm. Fig.6b and 6c present distributions of X- and Y-coordinate of wires, RMS_X and RMS_Y is about 10μm. Mean value of X is -1.6±1 μm and mean value of Y is 3±1 μm. Mean values are not zero maybe due to contribution from imperfection of end plug surface. Dependence of off set radius versus number of tube in production series is given in fig.6d. The last drawing demonstrates that tubes were taken more or less randomly from production series.

5 Leakage of tubes

For test of leakage a tube was filled by nitrogen at some over pressure and placed in bath with water. In the beginning (the first 40 tubes) we used 6 bars over pressure but then we reduced it to 4 bars. The sensitivity limit 1 bubble of 0.5 mm diameter per 1 minute corresponds to $6\cdot10^{-6}$ torr·l/s.

The first test of the leakage was performed by technicians immediately after tube production. The most of tubes were O'K. To decrease the limit of leakage sensitivity we tried to use He-based leakage tester. Leakage of all tested tubes was detected. Then we started again the test in water. Results of the 2nd test are shown in fig.7. About 60% of the first 100 tubes were with significant leakage. Most of the leakages took place at the boundaries of epoxy filled cavern of end plug. Then we changed procedure of installation of small O-rings around stainless steel tube in the cavern. All leaky tubes were repaired. For repairing we did follow steps: doing small ditch in epoxy around the end plug cavern boundary; filling the ditch by epoxy paint (UR-231); vacuum pumping of tube for better filling of cracks between Al body of end plug and old epoxy by new epoxy paint. Before installation (1-2 days) of tubes in chamber we performed the 3d test of leakage (fig.8). Only 2 tubes from repaired ones have leakage. Again leaky tubes were repaired. We repaired 107 tubes from 215. But there is not guarantee, that tube leakage will not appear again.

After shipment of the chamber at CERN significant leakage of 27 l/hour at 3 bar pressure was measured. We were able to fix some leakages and eliminate them. The chamber leakage rate was reduced to 0.7 l/hour (in beginning of February 1997).

There was leakage around O-ring between tube and end plug in 11 tubes. Such kind of leakage was eliminated by additional crimping of end plug with slightly larger pressure.

Only 2 tubes were not repaired by such method. Probable explanation of the defect is a bad quality of O-rings.

6 HV test

HV test was performed at atmospheric pressure. The tubes were filled by remnant gas after leakage test that is an uncontrolled mixture of nitrogen and air. Due to time limit we did very simplified test. Current at 3.3 kV was measured. Limit of sensitivity was 2-3 nA. Dependence of the current versus tube number is shown in fig.8. Dashed box in fig.8 marks limit of sensitivity. Two tubes have short circuit under epoxy into end plug cavern. Tubes with current larger then 5 nA were not used in the chamber.

7 Outer diameter test, external view of tubes

We explored 30.1 mm tube pitch in the chamber. Hence the outer diameter of each tube must be less than 30.05 mm. All tubes were pushed through precisely machined hole with internal diameter 30.045 mm and height of 40 mm. About 20 tubes did not go through the hole. There are 3 reasons: 1) deformation of tube wall during cut; 2) deformation of tube wall by O-ring during end plug crimping; 3) misalignment of end plug and tube. The tubes which did not go through the calibrated hole were crimped in the special tool for proper outer diameter.

We don't know well a history of tubes delivered from CERN for our prototype but they have significant deflection from straightness up to 2 mm/m. During cutting, cleaning and wiring we could not conserve perfect surface of tubes. There are scratches and traces of tools.

8 Wire breaking

During X-tomo scan of the chamber at CERN one broken wire was detected. We do not know when the wire was broken, before or after the chamber transportation. It disconnected immediately after HV end plug and could not be detected during the simplified HV test of tubes.

9 Conclusion

We think that we solved satisfactory problems of wire stretching, location and fixation. Control of resonant wire frequency instead of tension force is more promising way to obtain more coherent wires sag in whole chamber because of such way eliminates influence of wire diameter change. As it was shown by our X-ray test we reached 10 μm precision of wire location (RMS for both directions X and Y). Despite of one broken wire we believe that our wire crimping technique is reliable.

Fixation of end plug and providing gas tightness between tube and end plug by gas crimping is also seems reliable. There is a question about crimping of tube over O-ring.

There is an indication that squeezed O-ring (3 mm thickness) deforms tube wall near crimp. For tube pitch less than 30.1 mm it will be crucial.

We have got unsuccessful experience with using of an epoxy for gas tightness purpose. We used small O-rings of bad quality inside our end plug and supposed that combination of bad O-rings with epoxy glue would provide enough gas tightness. But epoxy glue does not work well.

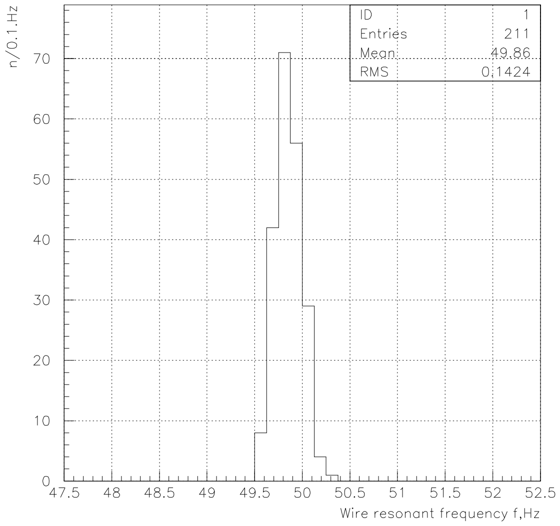

Fig.1. Wire resonant frequency

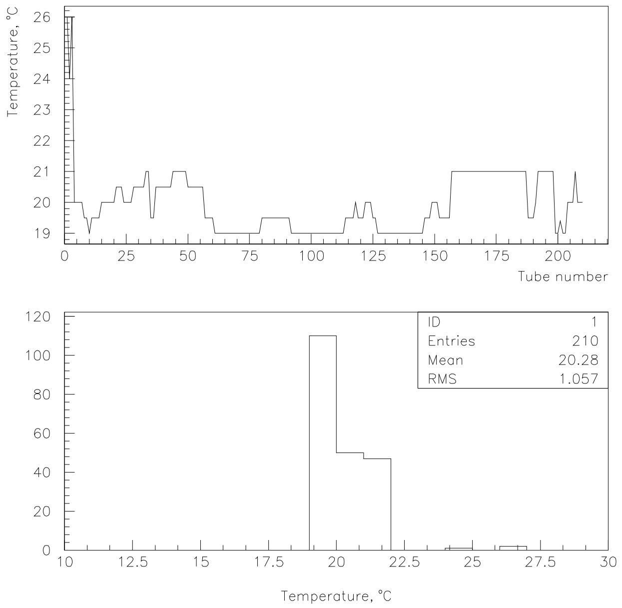

Fig.2. Temperature during wire stretching

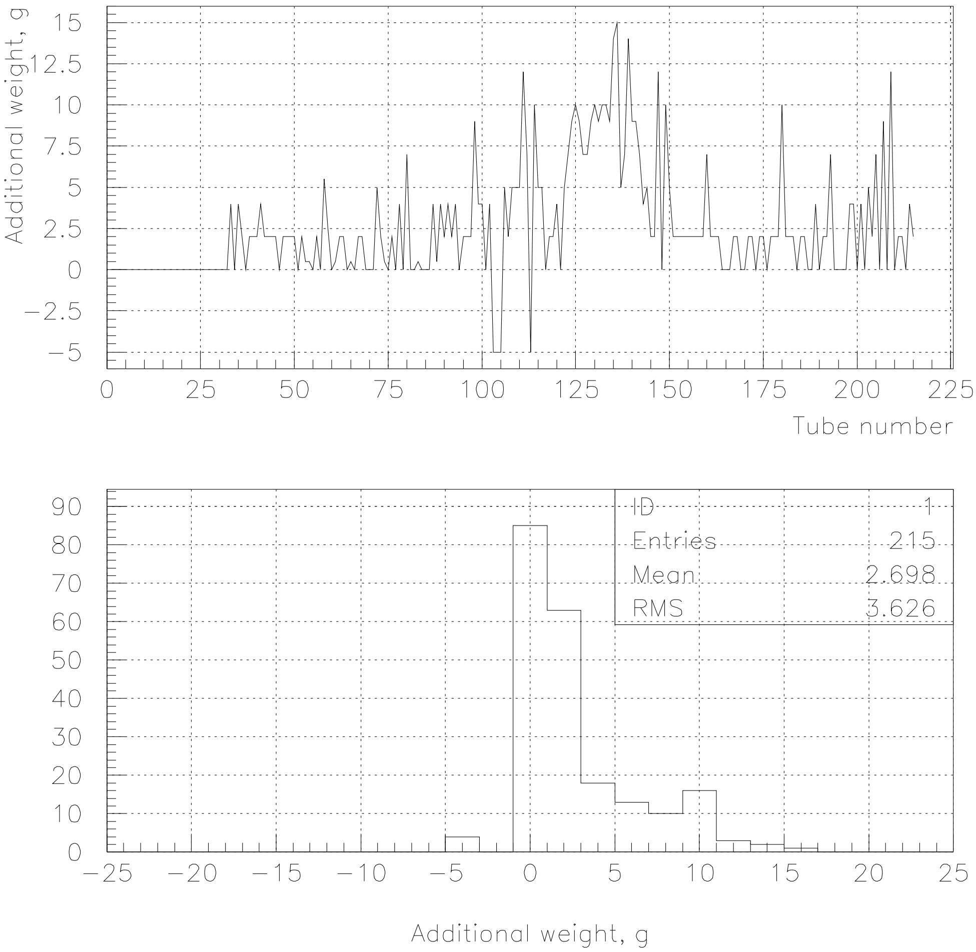

Fig.3. Additional weight applied to wire.

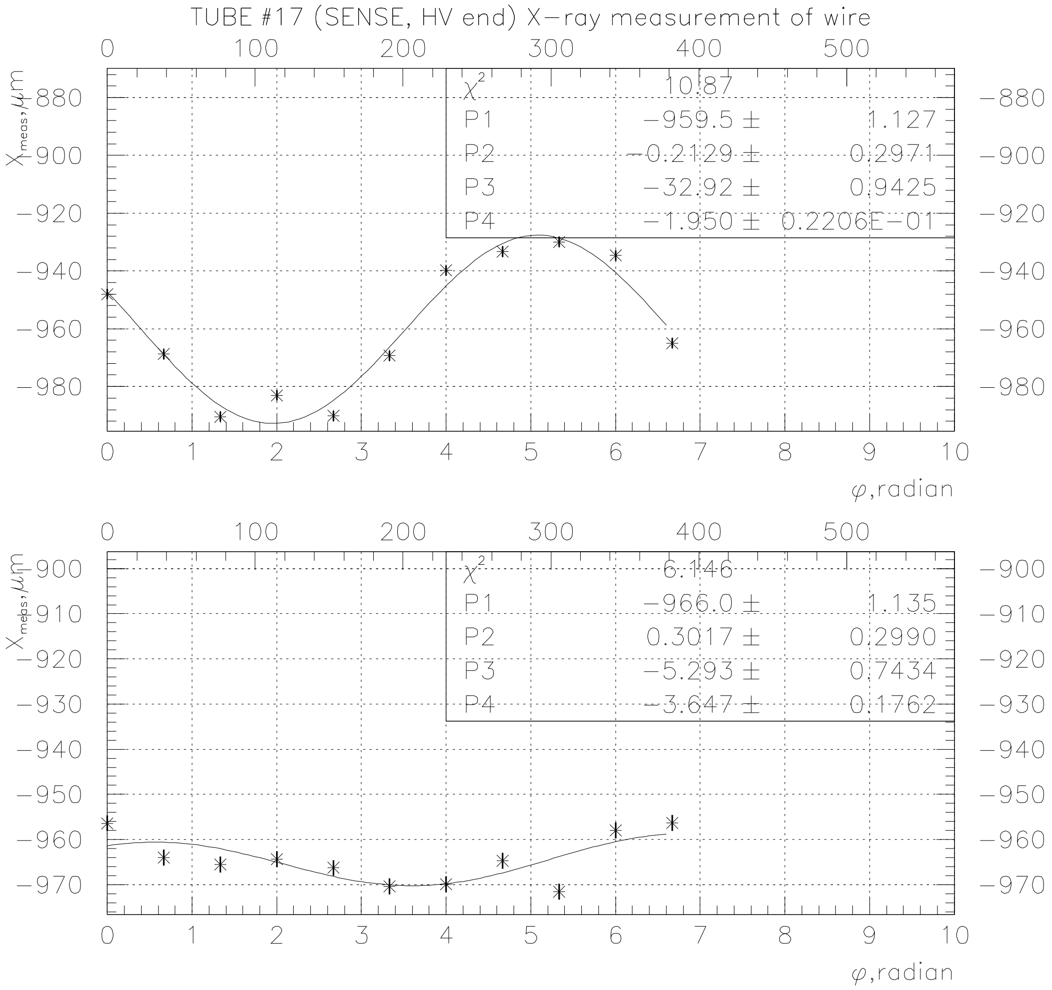

Fig.4. X-ray measured coordinate vs. rotation angle of tube

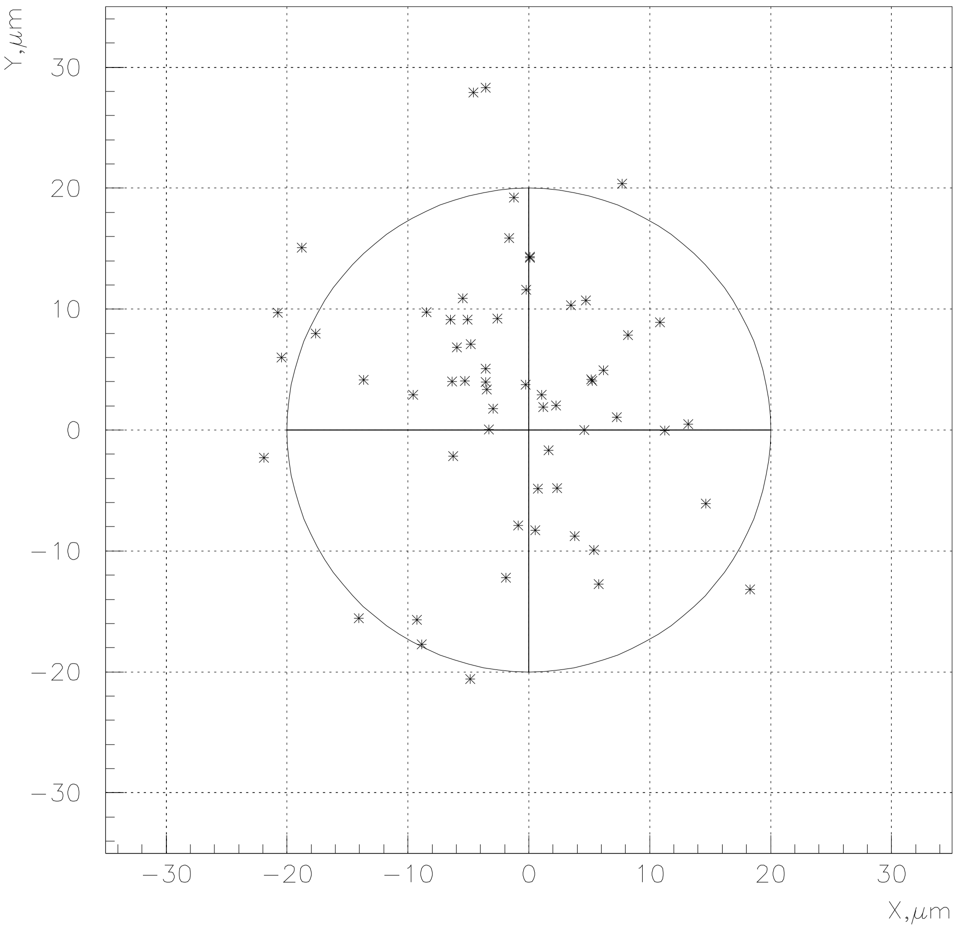

Fig.5. Scatter plot of wires position

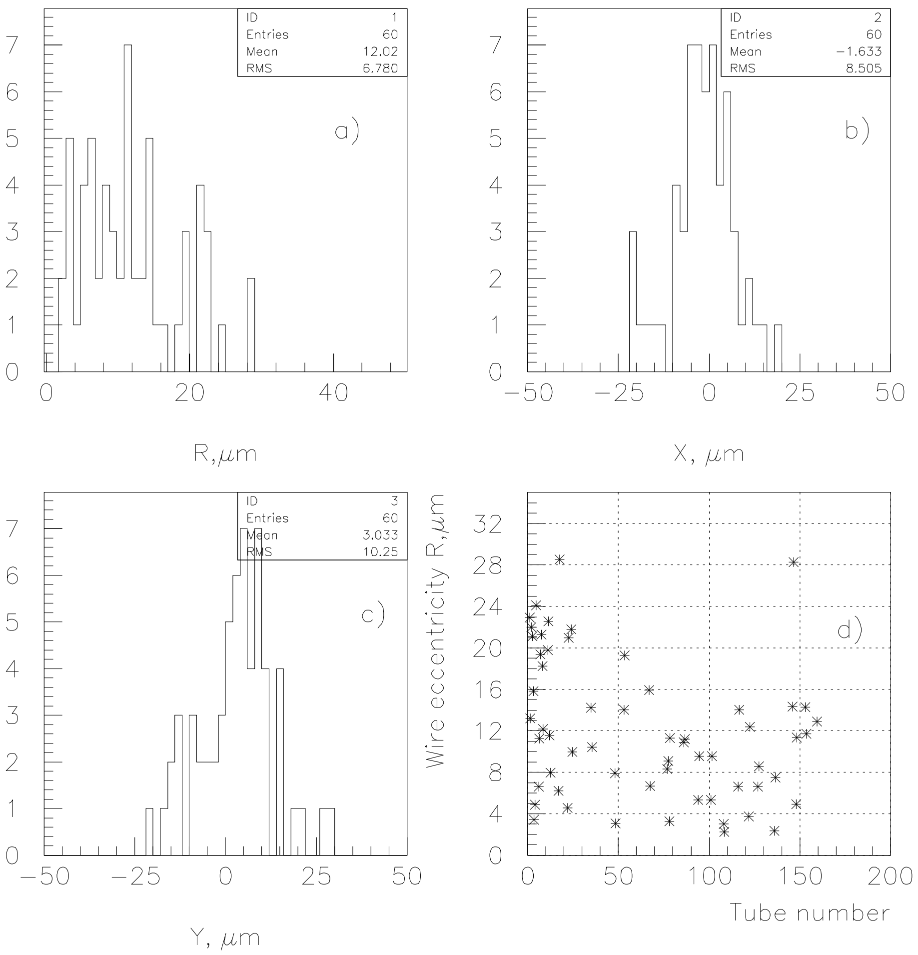

Fig.6. a)-distribution of wire eccentricity radius;
b) X-coordinate distribution; c) Y-coordinate distribution;
d) radius eccentricity vs. tube number in production series

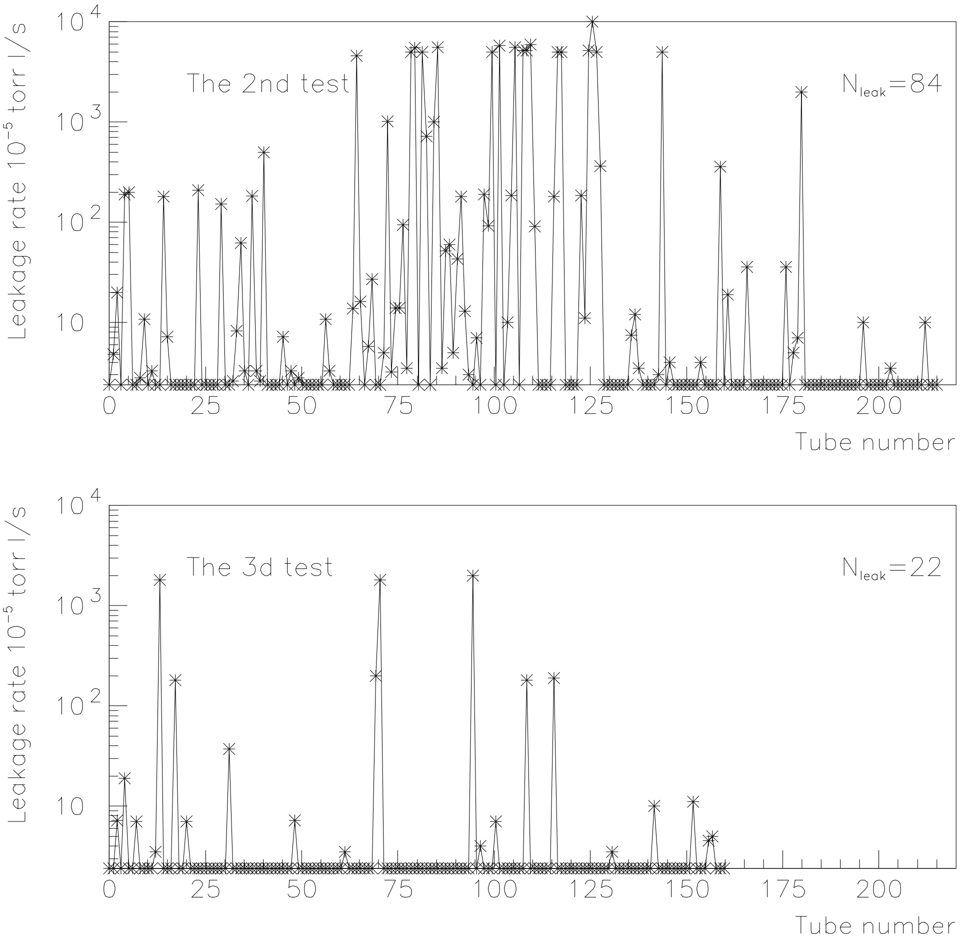

Fig.7. Leakage rate vs. tube number

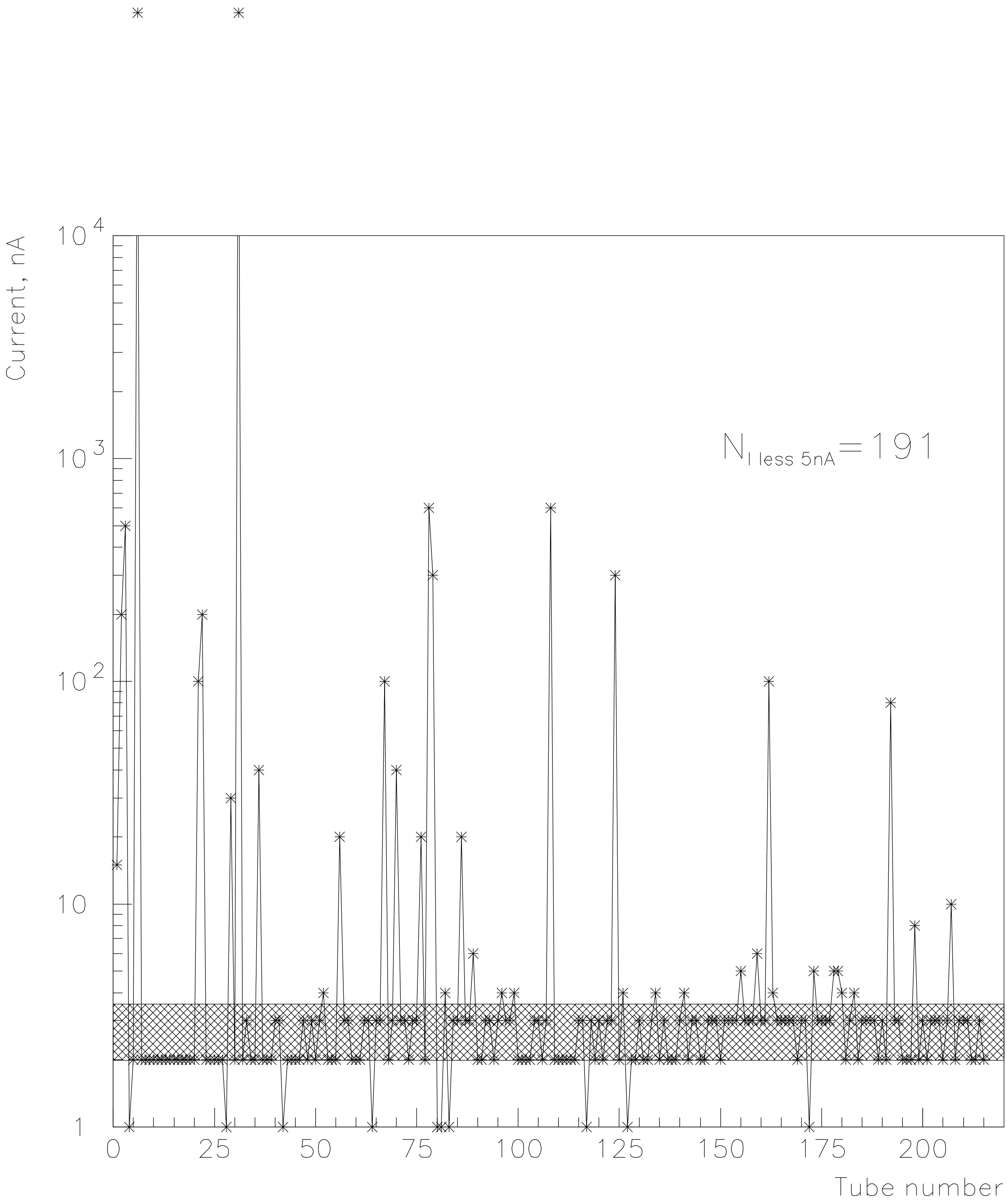

Fig.8. Tube current at 3.3 kV and atmospheric pressure.