The Thin-wall Tube Drift chamber Operating in Vacuum

(Prototype)

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This work was initiated by the JINR participation in experiment NA62 planned to be performed at CERN's SPS to study rare decays of K mesons $K^+ \to \pi^+ \nu \bar{\nu}$ and its goal was to design a round shape drift chamber operating in vacuum together with technology of tubes independent assembly.

There are some serious design and technology problems. The main of them are:

Stringent requirements are imposed on the chamber itself as a rigid vacuum-tight structure for operating in vacuum with minimum possible mechanical distortion of the tube geometry.

It is also important to take into account that in vacuum the tubes can uncontrollably increase in length and diameter under the inner pressure of one atm. In this case it is necessary to ensure a minimal deviation of the tubes and anode wires linearity.

Abstract

The goal of this work was to design drift tubes and a drift chamber operating in vacuum, and to develop technologies for tubes independent assembly and for their mounting in the chamber. These design and technology were tested on the prototype.

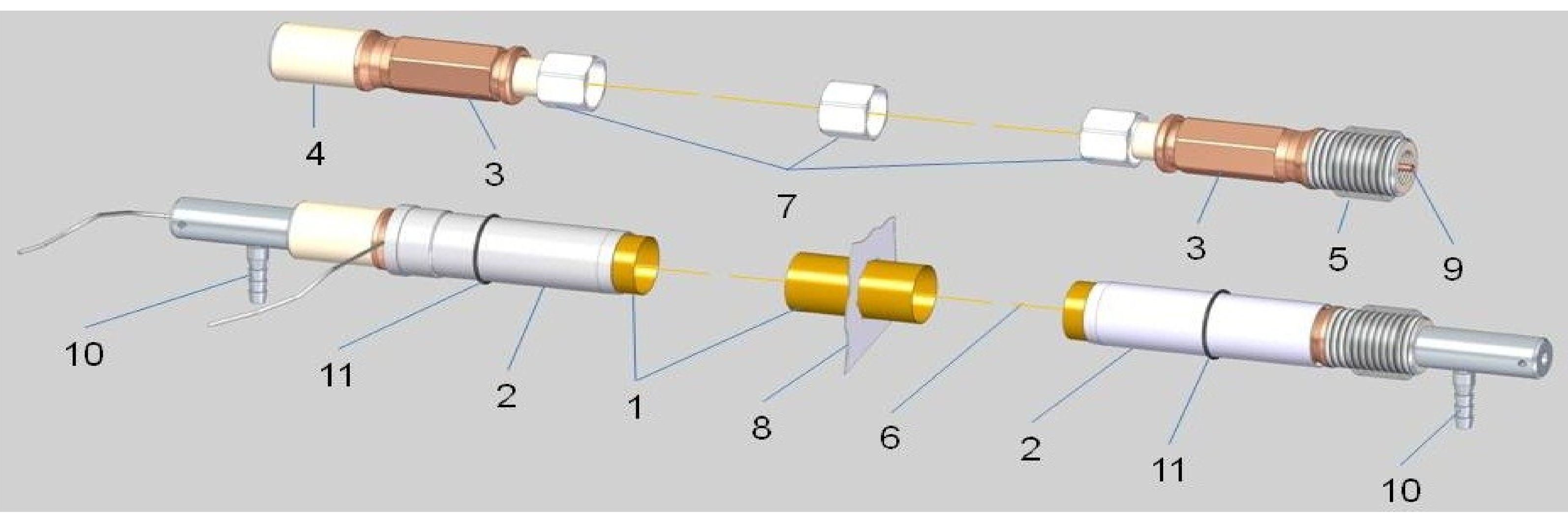
The main features of the chamber are the following:

1. The drift tubes are made of flexible mylar film (wall thickness 36 μm, diameter 9.80 mm, length 2160 mm) using ultrasonic welding along the generatrix; the welding device and welding methods were developed at JINR.
2. Drift tubes with end plugs, anode wires and spacers were completely assembled outside the chamber.
3. "Self-centering" spacers and bushes were used for precise setting of the anode wires and tubes.
4. The assembled tubes were sealed with O-rings in their seats in the load carrying structure of chamber which simplified the chamber assembly and replacement of damaged tubes.
5. The tube assembly and the chamber manufacture can be performed independently and in parallel; this sufficiently reduces its cost and the total time of chamber manufacture and assembly, and allows tubes to be tested outside the chamber which decreases the probability of having damaged tubes.
6. The technology of independent tube assembling is suitable for a chamber of any shape but a round chamber is preferable for operation in vacuum. Its advantages are: high rigidness, absence of dead zones, and lower consumption of expensive drift tubes.
7. Single channel amplifier-discriminator boards which are more stable against cross talks were used for testing the tubes.

Independently assembled tubes were mounted into the chamber prototype for electric tests and measurements of the performance characteristic under the vacuum conditions. The results showed that both the structure and the tubes themselves normally operate. They are suitable for making a full-scale drift chamber operating in vacuum.

Independent assembling of the drift tubes

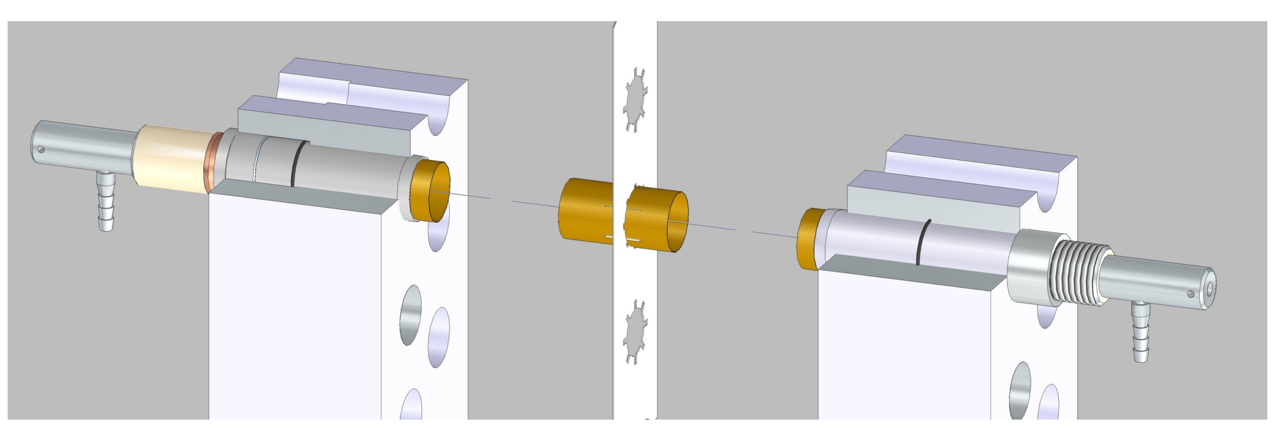
Fig. 2 shows the tube (1) with the end plugs. The end plugs consist of three main details: external (metallic or insulating) sleeves (2), embracing the tube ends from outside and sealed on them with glue. They have exact external dimensions for being set into the holes of the chamber. Their internal diameter corresponds to the maximal external diameter of the tubes (in this work it is 9.80+0.08 mm, where the value 0.08 is the double thickness of the tube walls with a tolerance. When set into the exact holes of the chamber, the sleeves strictly center the end plugs with tubes and are also used for vacuum-tight sealing with O-rings.



Completely assembled drift tube with end plugs: Drift tube, 2. sleeve, 3. hexagonal bushes, 4. insulating inserts, 5. nut, 6. anode wire, 7. hexagonal spacers, 8. film strip support, 9. copper pin, 10. gas connections, 11. O-rings

Internal hexagonal "self-centering" copper bushes (3) are fixed with current-conducting glue from inside of the tube ends. The vertices of the hexagon with the diameter of the circumscribed circle $d_{mean}+\Delta d$, they are against the sleeve from inside and are used for precise centering of tubes. That is why the tube fits into the sleeve coaxially. At the same time the bushes ground the cathodes with this glue. The ground is taken out to the by flexible outlets welded into it. Inside the copper bushes there are insulating inserts (4) with thread for stretching the tubes with nuts (5); at the centre of the insert there are holes for the anode wire and gas mixture. The anode wire (6) going through the tubes is centered by hexagonal spacers (7) relatively to tube. Two spacers are located at the tube ends and their vertices are also the sleeves from inside. One spacer in each tube is placed in the middle. Here in the chamber they will be supported by the film strips (8) stretched across the tubes and reinforced with tungsten wire. The anode wire is fixed on both ends of the tube by copper pins (9), to which wires are welded for high voltage supply and pulse output. The gas mixture is supplied through connections (10). O-rings (11) for vacuum tighten.

It should be noted that complete assembly of one tube takes about 30-20 minutes (without taking into account the time for glue hardening which depends on the glue used). Presumably it will take less time during mass production and it takes about 3-5 minutes to set one tube into the chamber.



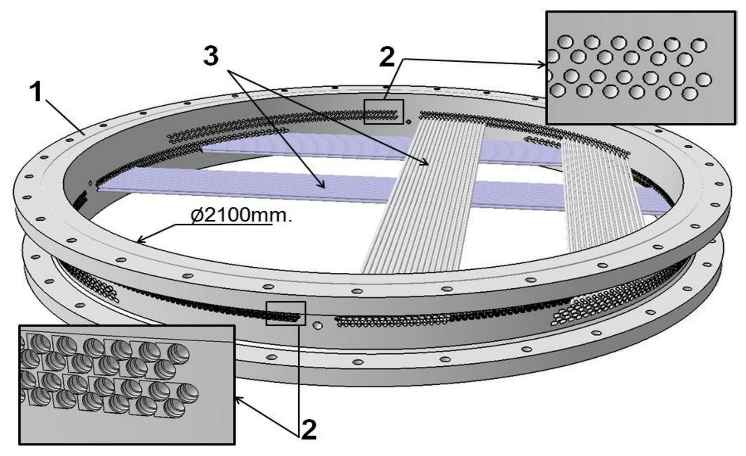
Tube in chamber

Design of the full-scale chamber

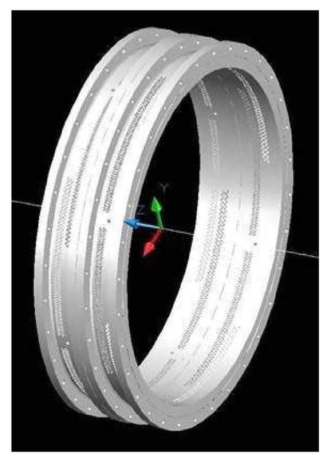
The precision of the coaxial holes for the tubes in the chamber should meet the requirements of the experiment (≤0.1 мм). The assembled tubes will be inserted into the chamber and sealed with end plugs and O-rings. When inserted and sealed the tubes will be stretched using nuts. Then the anode wires will be stretched. This procedure was properly developed during the assembling of the prototype.

Whatever its shape the chamber should be capable of operating in vacuum, thus, its deformations after it is mounted for operation at the experimental setup should not exceed the design values. The tubes should not deviate from their geometrical position within the given precision. Only if these conditions are fulfilled, it is hoped that the anode wires and tubes will be as straight as possible. It is evident that these conditions are better fulfilled in the round chamber because the ring is the simplest and lightest of all possible forms. This is not the only advantage. Here are some others:

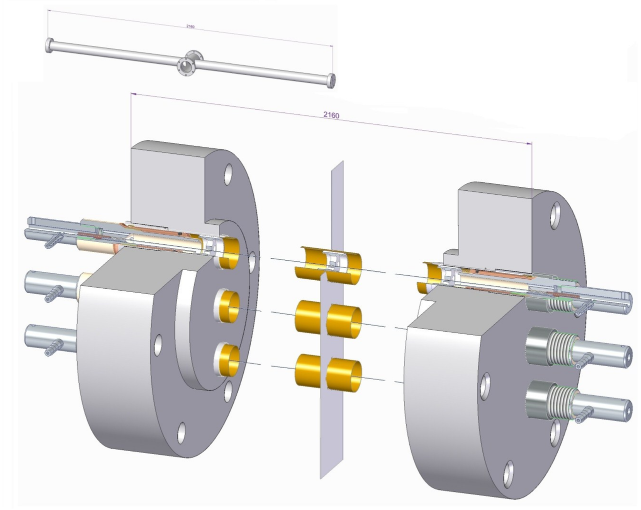
* Integrity of the design and relatively simple machining are important;
* There is no necessity of an additional load carrying structure which is unavoidable for rectangular frames;
* Mechanical deviations in vacuum conditions are smaller;
* There are no dead zones in corners;
* Consumption of expensive tubes reduces by approximately 25% in comparison with the rectangular chamber.



The two-coordinate round chamber design. (1) Chamber, (2) holes for end plugs, (3) drift



Round for 4^x coordinates chamber



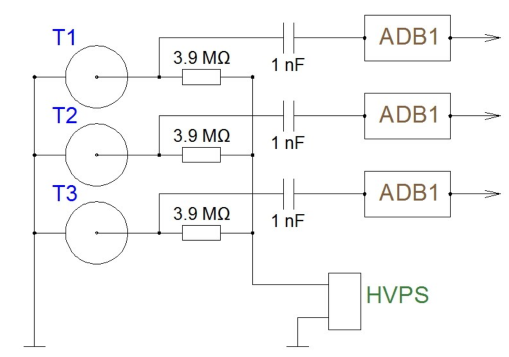
3D view of the chamber prototype

The prototype and tubes working characteristics

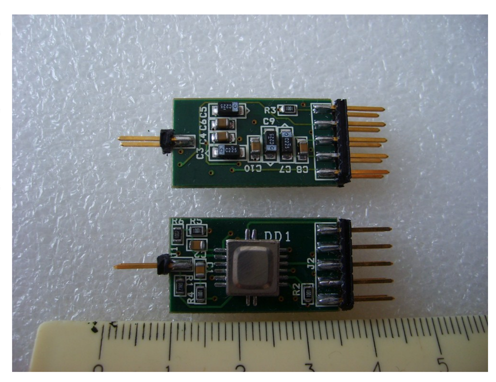
The working characteristics measurements were carried out in vacuum of $2x\ 10^{-5}$ bar with the gas mixture (70% Ar + 30% CO_2), using cosmic rays and radioactive sources. All three tubes were arranged vertically one above another along with two scintillation counters connected in coincidence.

The connection of the tube to the electronic equipment is shown in Fig. (3a). The signals from the tube were recorded via the high-voltage capacity by one-channel amplifier-discriminators of the ADB-1 type [10]. These circuits are less sensitive to cross-talks. In addition, the small sizes of these boards see Fig. (3b), allow it to be inserted into the end plug of each drift tube. Fig. (3c) presents oscillogram of the amplified signal of one of the tubes for the radioactive source ^{60}Co. Fig. (3d) shows Volt-Ampere characteristics of the tubes. Fig. (3e) shows the counting rate curves averaged for three tubes obtained with radioactive ^{55}Fe source for different thresholds. The efficiency of the tubes was measured with cosmic rays. Fig. (3f) shows the efficiencies averaged over three tubes. Fig. (3g) illustrates the TDC spectrum and Fig. (3h) - the charge spectrum from ^{55}Fe.

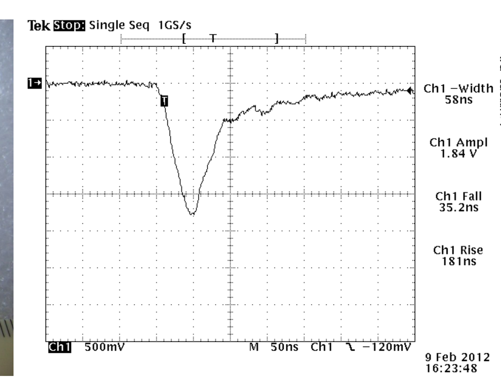
(a) Output electronics scheme



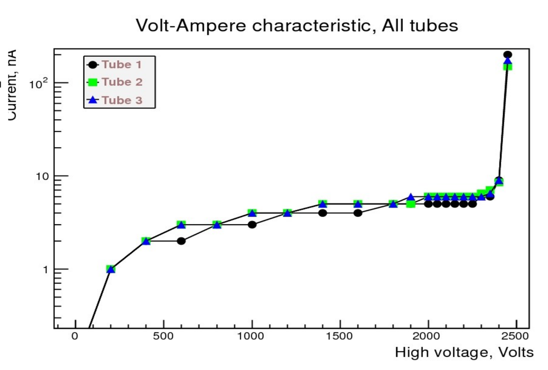
(b) Electronics card ADB-1



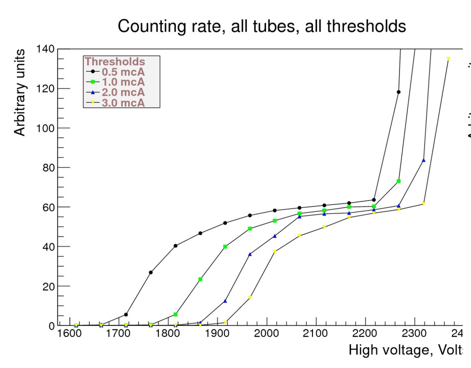
(c) Oscillogram of the amplified signal



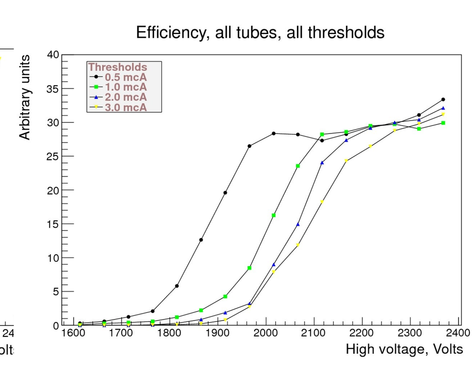
(d) Tubes Volt-Ampere characteristic



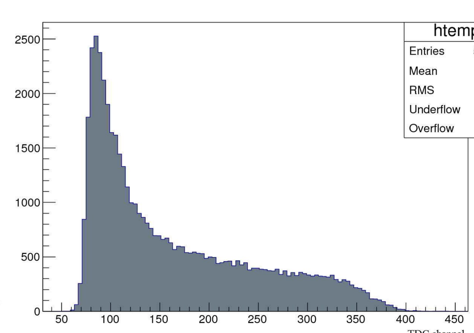
(e) Counting rate



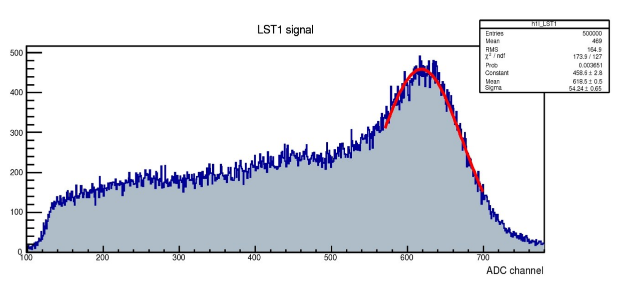
(f) Tube efficiency



(g) TDC spectrum



(h) Charge spectrum



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Conclusion

The results obtained with the prototype have shown that the developed design of the tubes and the technology of their independent assembly outside the chamber are justified. Preliminary working characteristics have shown good operation of the tubes. As mentioned above, these results apply to a chamber of any shape, but for the flat chamber it is more preferable to use a round design. The experience gained in construction and tests of the prototype is enough to construct a first full-scale chamber.