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A SEALED METAL ARGON IONIZATION CHAMBER (ARGONION)

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Summary

The design, construction and performance of a sealed all metal, transmission type argon ionization chamber (Argonion) and its associated electronics is described. It exhibits a linear response to charged particle density fluxes in the range of 10^5 - 10^{11} cm^{-2} s^{-1} and has very good long term stability. Calibration of the chamber at low fluxes can be made against scintillation counters and at high fluxes against secondary emission chamber and foil activation techniques. Because it bridges the intermediate range, the Argonion is extensively used in high intensity experiments in the CERN PS and SPS secondary beams. It consists of a stainless steel cylinder, two thin end windows (25 μm stainless steel), 21 parallel electrodes (2 μm aluminium) and is filled with pure argon slightly above atmospheric pressure. The chamber introduces a total mass (windows and electrodes) into the beam of ∿ 50 mg cm^{-2} equivalent iron (∿ 0.4% of the iron radiation length). The introduced mass of the argon is ∿ 50 mg cm^{-2} or ∿ 0.25% of the argon radiation length.

Introduction

The argon-ionization chamber hereafter described was built to monitor the intensity of a proton test beam in the CPS East Experimental Hall with the following characteristics.

Proton energy	: 24 GeV
Beam spill	: ∿ 400 ms
Proton flux per CPS cycle	: 10^6 - 10^{10}
Beam diameter at focus	: 0.5 - 1 cm
Time structure	: Presence of both low and high frequencies

These beam characteristics lead to proton flux densities in the range of 10^7 - 10^{11} cm^{-2} s^{-1} without taking into account the presence of high and low frequency components (or time structure) of the beam.

We started the development of the chamber at the explicit request of the users of the above mentioned test proton beam to provide a reliable linear intensity monitoring device with long term stability. This test beam was set up to give the opportunity to users to test their own equipment before installation in the North Area of the SPS. In this area the intensities and generally speaking the fluxes of the secondary charged particle beams will be within the range of intensities of the test beam. The final aim of the development of the argon-ionization chamber was to provide a reliable beam intensity measurer of the SPS secondary beams[1].

The problem of measuring the intensities of the test beam was rather difficult because there was no operational monitor available either of the microscopic type (i.e. scintillation counter telescope) or the macroscopic type (i.e. secondary emission chamber).

G.S. Levine and Swartz[2] developed and built an ionization chamber that gave an upper limit of linear response for a proton flux up to 10^{13} cm^{-2} s^{-1}. It is also known that a relativistic proton produces 100 ion pairs in 1 cm argon path at 1 atm. These facts led us to the conclusion that the best geometry of the ionization chamber to be built was the parallel plate transmission type ionization chamber.

Having experience of building secondary emission chambers the idea came to fill one of these secondary emission chambers with pure argon at slightly above atmospheric pressure and seal it off.

So in this way we made an argon-ionization chamber, hereafter called ARGONION, which we immediately installed in the test beam for performance tests.

Mechanical Construction

The mechanical construction of the chamber is identical to the construction of the Secondary Emission Chambers[3]. Therefore details of the construction can be found in Ref. 3. Figure 1 is a photograph of the Argonion ready to be installed. It consists of a stainless steel cylinder with two thin end windows made of stainless steel foils of 25 μm thickness. Inside are installed 21 flat 5 μm thick aluminium foils. Eleven of them are connected to the bias power supply and ten to the input of the electrometer; they are insulated by ceramic washers having an electric resistance higher than 10^{13} Ω. The gap between the collecting and bias foils connected alternately is 0.5 cm; however the ceramic washers are only 0.3 cm thick. All Argonion parts are made of materials with very high radiation resistance.

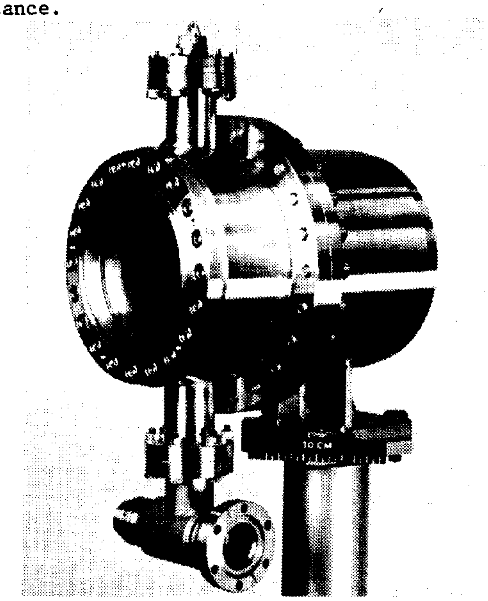

Fig. 1 THE "ARGONION" READY TO BE USED

The Argonion is filled with argon after the chamber has been baked, conditioned and tested for leaks at very high vacuum. We fill the chamber with pure argon at 1.05 atmosphere at 20°C in order to give a convex form to the windows. This ensures a constant mass (∿ 38 mg cm^{-2}) of argon in the path of the proton to be detected; therefore the Argonion is insensitive to temperature changes over a small range. The Argonion is sealed off immediately after being filled with argon. This means we possess a chamber that once having been calibrated will remain so for a long time. The nominal overall amplification factor is 2000 - 2500, in other words each proton will produce 2000 - 2500 ion pairs. For the test beam at the input of the analog integrator we therefore expect to have 2 x 10^9 x 2.5 x 10^{13} electronic charges to be measured. These charges can be measured with good accuracy using the electronic chain which will be described under another heading.

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Performance Tests

Immediately after the chamber had been installed into the test beam in the East Hall we measured its plateau and linearity against the secondary emission chamber (SEC) in the range of 10^9 - 10^{11} protons per burst. We obtained very good plateau for bias varying from ± 500 up to ± 1000 Volts i.e. for applied homogeneous electric fields varying from 1000 - 2000 V/cm. Figure 2 shows an oscilloscope photograph of the proton spill as seen by the Argonion itself. Figure 3 shows the bias curves for both positive and negative applied electric fields.

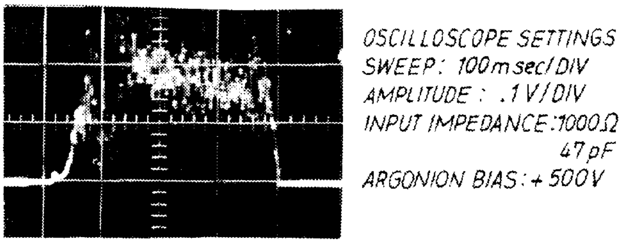

Fig. 2 THE PROTON BURST OF THE TEST BEAM AS SEEN BY THE ARGONION

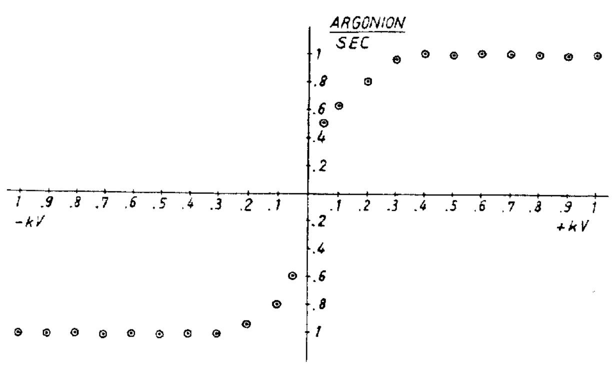

Fig. 3 BIAS CURVE OF THE ARGONION OBTAINED WITH BEAM INT. ~10^{11} PROTONS PER BURST

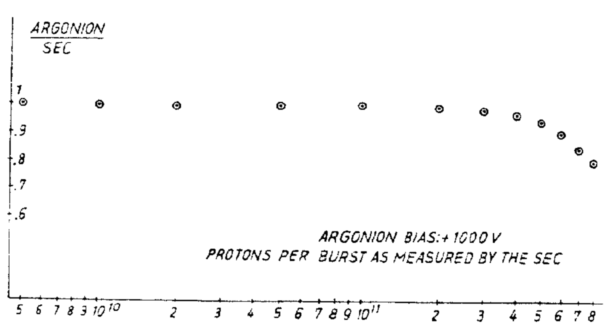

Fig. 4 LINEARITY OF THE ARGONION

Figure 4 gives the linearity of the Argonion against the secondary emission chamber also installed in the same beam. From this plot we calculate that one proton at 24 GeV traversing the chamber produces 2375 ± 5% ion pairs. George Matthiae[4], user of the test beam, calibrated by an indirect method with a counter/telescope looking at his own target through a large angle to give 2400 ± 5% ion pairs per 24 GeV proton traversing the chamber, which agrees with our figure. There are about 20 Argonions built up to now and three of them have been in beams since 1978. Nineteen of them have a useful diameter of 12 cm and one has a useful diameter of 20 cms. Up to now the users of these chambers have not seen any detectable change of the calibration of the chambers[5].

Electronics

Figure 5 shows the simplified diagram of the Argonion and its interconnections with the associated electronics. Here also we use the same electronic chain that we built for the measurement of the secondary emission chamber signals[6]. This chain is bipolar and consists of four discreet NIM plug-in units.

Briefly the main unit of the chain consists of an electrometer type analog integrator, an amplifier with variable gain 1 - 11, an analog to digital converter and a test signal generator.

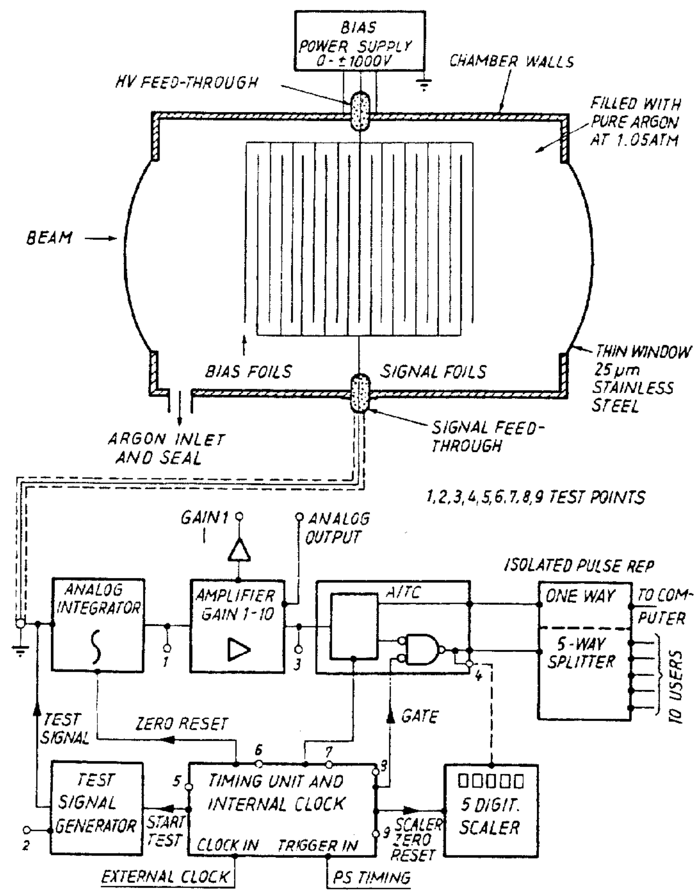

Fig. 5 SIMPLIFIED DIAGRAM OF THE ARGONION AND ITS INTERCONNECTIONS WITH THE ASSOCIATED ELECTRONICS

The gain of this chain is adapted to cover the Argonion signal range.

Due to its long term stability it is not necessary to recalibrate the chamber or its electronics. However for different charged particle fluxes and or different energies the number of ion pairs produced per traversing particle has to be measured. Generally this is done by the users themselves. The calibration of the Argonion at its lower range is done with reference to a transmission type counter telescope and of its upper range with reference to secondary emission chambers.

Conclusion

The stability and long life of the Argonion have led to its extensive use for the measurement of proton or other charged particle fluxes in the range between $10^6 - 10^{11}$ particles per burst. The Argonion therefore bridges the gap between the microscopic and macroscopic methods of beam intensity measurements.

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