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Performance test of the electrostatic septum on 19.11.79

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1. Introduction

Since the beginning of the year a noticeable degradation of the performance of the electrostatic septum in the west extraction channel was observed. The average total sparking rate (sum of sparks in the 4 septum units per hour) which was of the order of 1 to 2 sparks per hour in 1978, increased to some 3 to 4 sparks per hour. In particular during period 5 when a coherent resonant extraction was run for the neutrino beam, the sparking rates of the first septum unit and, to a lesser extent, of the second unit exceeded the limits acceptable for stable and reliable operation. Therefore and because the septum had twice been polluted by water vapour, the complete system was exchanged after the second damage of a thin magnetic septum on 21st October. It turned out, however, that this exchange did not solve the problem. The sparking rate measured on the first unit of the new septum was so high that an attempt to run a two-burst coherent resonant extraction of some 10^{13} protons had to be abandoned. A second undesirable phenomenon was observed during period 3 and later during period 5: the total current through the system which never exceeded 5 to 6 μA in 1978, increased from 3 μA without beam to some 50 μA or more when a fast resonant spill was run.

Recently, the performance of the first septum unit in the north extraction channel also started to degrade. In this unit the average sparking rate has gone up to some 5 sparks per hour for an extraction of 8×10^{12} protons.

For all these reasons it seemed necessary to investigate more systematically the present limits of the electrostatic septum.

2. Short description of the electrostatic septum

The electrostatic septum consists of 4 identical units, 3 m long each. The main components of each unit, mounted in an ultra-high vacuum are (compare Figs. 1 and 2):

- a cathode made of an oxydized aluminium alloy. This cathode can be brought to a negative potential of a peak value of - 300 kV via a high voltage feedthrough. The insulation in the feedthrough is obtained by a special fluorocarbon liquid ("3M-FC75").

- an anode assembly essentially consisting of an U-shaped stainless steel body which supports a row of tungsten-rhenium wires with a diameter of 0.1 mm, spaced at 1.5 mm intervals. These wires form the beam splitting plane (septum) separating the "field free" region of the circulating beam from the high field region in which the extracted beam is deflected.

  The anode is electrically insulated and grounded through a measuring circuit.

- two clearing electrodes placed in the U of the anode close to its upper and lower surfaces which they cover entirely. Without these electrodes the electrical field leaking through the wire curtain drains the ions, which are created by the circulating beam in the residual gas, into the high field region. The ions are accelerated towards the cathode and their impact provokes sparking between anode and cathode. The role of the clearing electrodes is to compensate the leakage field and to act as an ion collector.

It can be shown (1) that the field leaking through the wire screen is the same as if the wires were at a "grid potential" of - 3.73 kV (assuming a field strength in the gap of 100 kV/cm). To compensate this effect the potential of the clearing electrodes must therefore be of the order of - 4 kV.

It should be noted that the upper and lower clearing electrodes have independent HT supplies thus permitting different potentials on the two electrodes. These supplies are, however, common to the 4 septum units.

3. Obervations during the performance test

A 12 hour test of the west electrostatic septum was made immmediately after the physics run of period 6A. During the run the following extraction had been in operation:

- a slow extraction of about 4.5×10^{12} protons to the west area at 250 GeV/c
- two 25 ms spills of a few times 10^{11} protons on T7 at 220 GeV/c and 270 GeV/c respectively.
- a slow extraction of some 6 to 8×10^{12} protons to the north area at 400 GeV/c.
- a fast extraction on T11 at 400 GeV/c.

During the septum test the slow extractions to the west area and on T7 were maintained at their initial intensity. The fast extraction on T11 was replaced by a fast resonant extraction of 1 ms duration. Its intensity was varied between 6×10^{12} and 1.6×10^{13} ppp by adjusting the amount of protons extracted to the north area. Throughout the 12 hours the SPS intensity at 200 GeV/c was about 2×10^{13} ppp. The field strength in the electrostatic septum was 101 kV/cm, 95 kV/cm, 106 kV/cm and 107 kV/cm in the first, second, third and fourth unit respectively. The observations made during the test can be summarized as follows:

- For a fast resonant extraction of 6×10^{12} protons the electrostatic septum remained stable. The total sparking rate increased, however, from 0.5 sparks/h during the physics run to some 10 sparks/h.

- Early during the test the septum still seemed to remain stable for an extraction of 9×10^{12} protons with a sparking rate of about 20 to 25 sparks/h. The extracted intensity was then increased to 1.2×10^{13} protons. After about 15 minutes of stable operation with only a few occasional sparks, the instantaneous sparking rate suddenly became extremely high. Many sparks per SPS cycle were observed in the first septum unit. At the same time some of the other units also sparked once or twice. The sparking rate exceeded the preset limit of 8 sparks per 10 sec with the result that the HT generator of the electrostatic septum was switched off and the trigger of the extraction quadrupole was inhibited (HT interlock). Putting both, the septum and the quadrupole back into operation took about 5 minutes. Thereafter stable operation was again possible for 15 to 20 minutes before another "multi-spark" event stopped the system once more. A stable interval of 15 to 20 minutes between successive stops turned out to be characteristic; a considerably shorter or longer interval could not be observed.

Occasionally it happened that the high sparking rate just remained below the preset limit for several SPS cycles before the HT generator of the electrostatic septum was finally switched off. When the septum became unstable, many sparks per SPS cycle were always counted in the first septum unit, but not in the other units which sometimes did not spark at all.

As mentioned before it took about 5 minutes to put everything back into operation after a stop. Thus, no extraction was possible during 25% to 30% of the time.

When the number of extracted protons was lowered to 8×10^{12} the above phenomenon persisted and even at this intensity the septum was not operational any more.

- A more careful observation of the total septum current and the current of the clearing electrodes revealed that in case of a "multi-spark event" most sparks occurred between the anode and the clearing electrodes of the first septum unit. In such an event a few sparks between anode and cathode of one or more of the 4 septa could often also be observed. (Unfortunately, the present spark counters which can be read from the MCR, do not distinguish between the different types of sparks in a unit, but simply add them up).

- Occasionally the clearing electrodes kept sparking for a while after the beam had been inhibited. Even when the beam was off since a few minutes, the clearing electrodes would still spark at a negative potential of - 5.5 kV. This potential is fairly close to the -4 to -5 kV needed in operation and it is far below the -8 kV which the electrodes stand when no beam has been extracted for a longer period. (The day after the septum test and after the extractions had been off for more than 12 hours, the -8 kV were easily maintained in a stable way).

- The observations described above were all made with one clearing electrode at -3.5 kV and the other one at -4 kV. When the potential of the second electrode was also lowered to - 3.5 kV, sparks between anode and cathode of one or more septum units occurred almost every SPS cycle. When this potential was raised to -4.5 kV, the "single spark" rate seemed to be smaller than at -4 kV. The potential difference between the two clearing electrodes should therefore be 1 kV at least, rather than 0.5 kV as used during the last months.

- During the 12 hours of the test the total current drawn from the 300 kV generator increased from 11 μA to 32 μA.

4. Comments on the above observations

- It seems that the intensity which can be extracted through the west extraction channel is essentially limited by sparks between the anode and the clearing electrodes of the first septum unit. In the event of such a spark the negative potential of one of the clearing electrodes breaks down in all 4 septa. (Remember that the upper and lower clearing electrodes have independent HT supplies, but that these supplies are common to the 4 septa). Therefore, the clearing effect is reduced in all septum units during about 10 ms, the time it takes after a spark before the electrode is again at 90% of its nominal potential. In general, once the clearing electrodes in the first unit became unstable, a whole series of sparks at a high sequence was observed. The reduced protection against ions invading the high field region then considerably increased the probability of a spark between anode and cathode in all units. This explains why multi-sparking in the first septum was often accompanied by sparks in the others.

- There seemed to be some delay between the time when the high intensity resonant extraction was put back into operation after a stop and the time when multi-sparking started. The clearing electrodes also seemed to remember for quite a while that there had been a beam after it was off. This may lead to the following tentative explanation: By the high extraction losses, in particular occurring on the first septum, the ceramic washers, which insulate the clearing electrodes from the anode are electrically charged until they can no longer hold the high voltage and sparks develop along them.

- As mentioned above the "single spark" rate was apparently reduced when the potential difference between the two clearing electrodes was increased to 1 kV. A difference of 1 kV had indeed been used in operation throughout 1978. At the beginning of 1979 the potential difference was lowered to a value between 0.5 and 0.7 kV. This together with the increased SPS intensity may have led to the degradation of the septum performance observed since period 1.

- When the total current through the system had gone up to unacceptable values during period 3, it could be brought back to its normal value by a renewal of the insulating liquid in the HT feedthroughs. We, therefore, believe that effects in this liquid are the reason for the undesirable current increase. It is, indeed, known that under radiation fluoric acid is formed in the liquid, bubbles develop and the liquid loses some of its resistivity. Since about 2 years the liquid in the feedthroughs of the first two units was regularly renewed after each period, whereas the liquid in the other feedthroughs was renewed after every second period.

5. Short term improvements

The following improvements of the west electrostatic septum are foreseen during the January shutdown:

- Independent HT supplies will be installed for the clearing electrodes of all 4 septum units. It will then be possible to optimize the parameters of each unit individually, for instance to run the first septum at a considerably lower field and at a lower potential of the clearing electrodes. Moreover, sparks between the anode and the clearing electrodes of the first unit will no longer have any influence on the performance of the other units.

- Additional spark counters will be installed which permit to measure the sparks between the HT cathode of each septum and the ground (mostly sparks between anode and cathode). This information (instead of the sum of all sparks) may then be used in the interlock system which inhibits the fast extraction elements in case of a spark and which stops these elements and the HT generator of the electrostatic septum when the spark rate exceeds a preset limit.

- On each HT feedthrough a system will be mounted which regularly circulates and regenerates the insulating liquid.

6. Conclusions

The electrostatic septum which was originally designed for an extraction of a maximum of 10^{13} protons per cycle seems to approach its operational limits. The above short term modifications may well turn out to be insufficient and more fundamental improvements may become necessary, such as a re-design of the clearing electrodes and of their support or the design of a dry feedthrough.

7. Acknowledgements

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Reported by K.H. Kissler

References

(1) Champ de fuite des septa électrostatiaques à fils; A. Durand, P. Tanguy and D. Thouroude, Nuclear Instruments and Methods 165 (1979), p. 361-370.

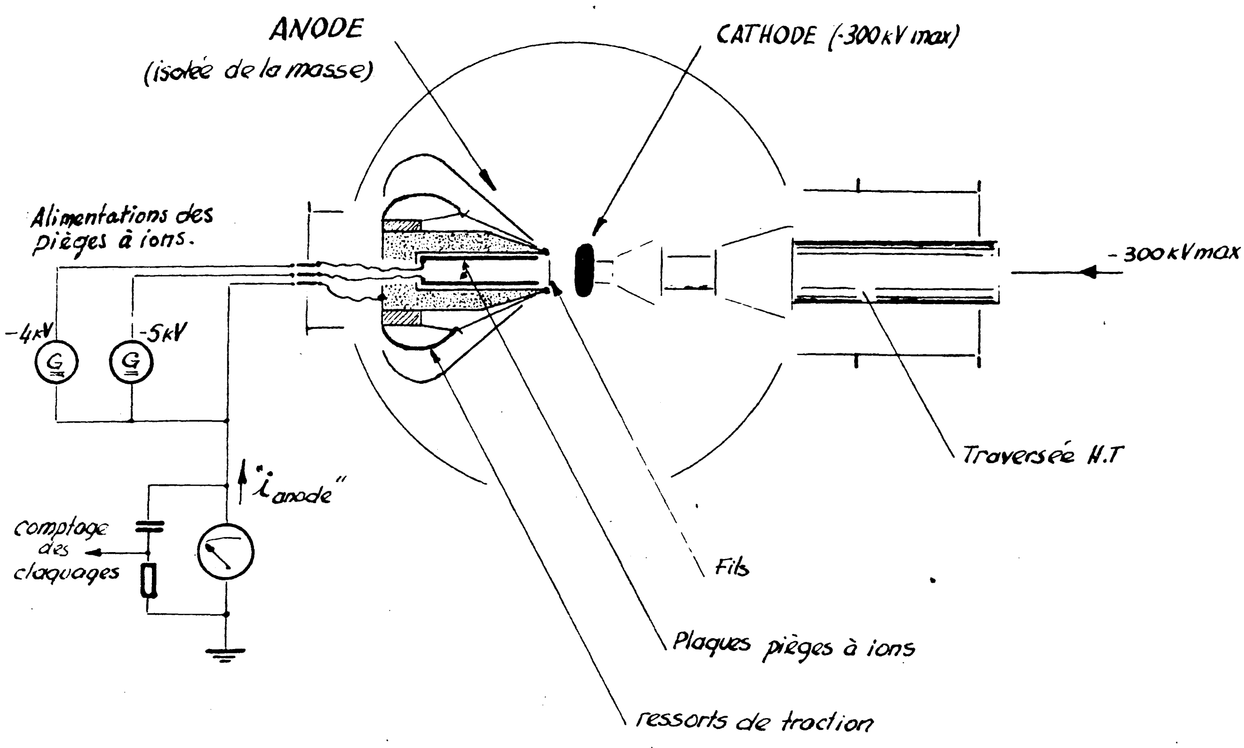

Fig. 1 - Schematic description of the electrostatic septum

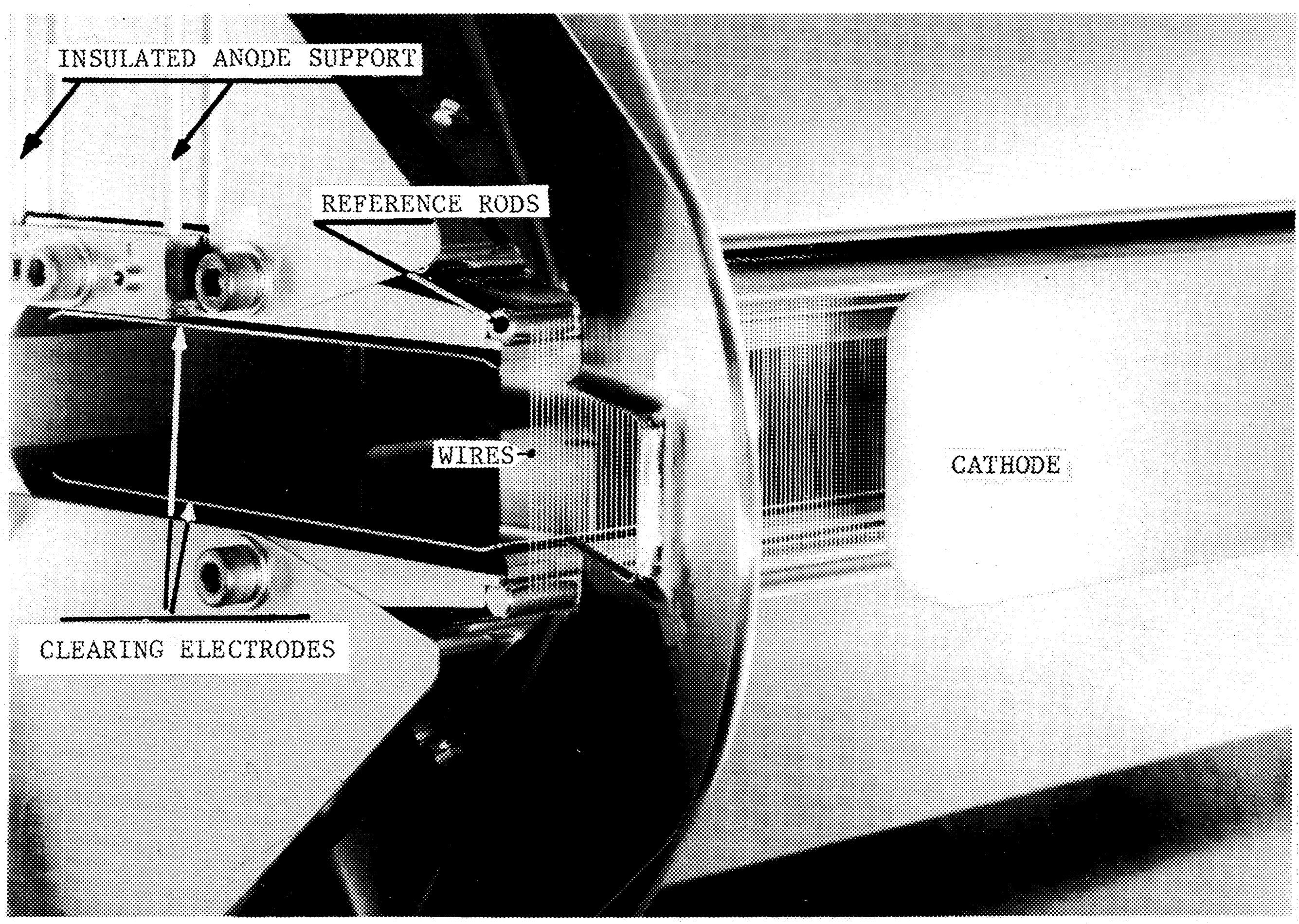

Fig. 2 - Photograph showing some of the main components of the electrostatic septum