Estimate of the Critical Leakage Current for MDC-II

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1. Introduction

The split high voltage system of MDC-II seems to be a good method to salve the problems of dark current and random noise which caused by the bad manufacture of the feedthroughs. The chamber ran smoothly during the test runs of the R scan in 1997. It's no doubt that some people include few MDC-II group people are still worry about Its life time. Some reasonable questions were asked—How long the feedthroughs can last at the lower high voltage? Could we find a criterion to give a prediction ?

The questions were raised again just before the beginning of the R scan. Will the Chamber suddenly died during the data taking? Should we reduce the high voltage to extend the life time of our chamber? It's extremely a good idea to require the opinions from all collaborators then make a correct decision by the BES leadership.

A strong suggestion was spread out to all collaborators in Nov.24,1999 by a e-mail. It showed some testing results and said." The obvious conclusion is that at +2kv the feedthroughs continue to degrade....we will shortly be having noise and current problems in MDC-II even with the split voltages......MDC-II will not last until the new chamber is ready.....the only way to extend its life time is to reduce all voltages" The situation became very serious. The efficiency will be low and the space and momentum resolutions will be worse if we reduce the high voltages The physics will be spoiled by the low quality data. Showing the current status of MDC-II with three-E-mails in that time I tried to do some calculations. The purpose is to show my opinion and try to convince IHEP and BES leaders running our chamber with existing conditions

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2. Estimate of the critical leakage current on sense wires

According to the measurement of the prototype, The Pules height in average of the Minimum ionizing particles on the input of the preamplifier is

$$V = 3 \text{ mv}$$

The input impedance of the preamplifier is 390 Ω. The peak current is

$$I = 3 \text{ mv}/390\,\Omega = 769 \text{ nA}$$

Suppose the minimum measurable pulse height is 1/10 of the average (very conservative) the minimum measurable current is about 80 nA. (Fig.1)
Suppose the ratio of signal to noise is 10:1 the acceptable noise current will be 80 nA / 10 = 8 nA. This is the criterion when we wiring the chamber.All the dark current of the sense wires except 7 wires is lower than that value when MDC-II

was constructed.

Consider the Noise from the front electronics:
According to the test result of the electronics division the equivalent noise current across the 390 Ω is 40 nA (This value is very close to the level of MARK-II/SLC drift chamber). Since

$$I_{tot} = (I^2_{wire} + I^2_{ele})^{1/2}$$

When $I_{wire} = 8$ nA, $I_{tot} = 40.7$ nA

As we can see, Most of the noise come from the electronics in this condition. If we take

$I_{wire} = 20$ nA , then $I_{tot} = 44.7$ nA

The contribution to the noise current from sense wire is still a small fraction. Taking $I_{wire} = 20$ nA as a critical value for single sense wire we can calculate the maximum acceptable leakage current for every layers of MDC-II as Table 1.
So far, The leakage current of the sense wires at every layer is 0 nA. It's easy to understand because we never put high voltage on the sense wire feedthroughs before The split voltage system to be set-up. According to this calculation we can say that there are no aging effects on the sense wire feedthroughs up-to-now.

3. Calculation for the field wires

The criterion of the leakage current for a single wire should be different between field and sense wires since the noise current is directly connected to the preamplifier on the sense wire but the field wire raw is 14 mm (layer 1) to 26 mm (layers 4 to 10) away from the sense wire raw. The affects of the dark current from field wires should be much smaller than the sense wire one.Taking 40 nA as the maximum acceptable value of the leakage current for a single field wire (It's factor 2 of the sense wire) we can calculate the leakage current for different layers as showing in Table 2.
Table 3 shows the present leakage .It's very clear that the field wire feedthroughs are not going to be died.

4. Result of the long-term test

In September 4,1997 we set-up an equipment doing the long term test for the damaged feedththroughs which have tested on -4.0 kv in an experiment and 16 μA leakage current has been observed at 20^0C. The total number of the feedthroughs is 55. They were placed in a clean box and –2.0 kv high voltage was put on. The leakage current and temperature are recorded once a day. This experiment lasted about 600 days (from Sept.4,1997 to April 30,1999). The leakage currents keeps 0 μA except some days in the summer. (see Fig.2).

This is a very important information for us.The goals of this long term test is to monitor the aging effects of the damaged feedthroughs at lower high voltage condition. It's an analog of the split high voltage operation of MDC-II field wire feedthroughs

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This test can give us some warnings::

a). Leakage current:
According to the calculation above the critical leakage current for these 55 testing field wire feedthroughs will be 1.1 μA. This is our cordon.

b).Spark through the plastic
The leakage current will appear and go up very quickly when the feedthrough nearly to be sparked through the plastic. The numbers of sparked feedthrough will be a sign of the degradation of the chamber.

This experiment is our "warning radar" because it was set-up earlier than the split high voltages on MDC-II and we put the H.V. on all the time.

We are very encouraged by this result. Since the net operating time of the drift chamber is about 6 months a year. t means that the feedthroughs of MDC-II can last at least 2 more years.

5. Discussions

A).This estimation is very preliminary because we suppose all feedthroughs have the same leakage current. This may be not true. In fact The leakage current from the field wires is dominated by a small number of feedthroughs which nearly sparked through the plastic. A strong evidence is that we checked every cell of MDC-II before the installation of split high voltages and only found 33 field wires bringing big leakage (see Table 4). The leakage current dramatically dropped down to a negligible value after replaced 16 wires and disconnected the high voltage from other 17 wires.
So, I would say that searching for the bad wires which bring big leakage and replace them or disconnect the h.v. from them is a powerful way to fixe the chamber

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B).The dark current of the feedthrough which have bad crystallization is very sensitive to the temperature as shown in Fig.3 and Fig.4. So, the temperaturecontrol is extremely important for the experiment of leakage current test of the feedthroughs.

C).The humidity may play an important role for the leakage also.A few tens nA current increasing have been seen when blow air from mouth to the testing feedthroughs. It's another interference for the feedthrough testing.

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It's clear that the experiments of leakage current test for the feedthrough should take account on the big background otherwise it will give a wrong result and lead to a wrong prediction.

D). Flushing dry and cold air to the end-cap of the drift chamber is a powerful way to reduce the leakage current. Flushing dry nitrogen is even better. This technique have been successfully used in several experiments in the world such as CLEO,Mark-II etc.

E). The split high voltage system didn't introduce significant noise to MDC-II. The big noise of MDC-II mainly came from the machine, DCCT. The Split high voltage method is a good way to run the drift chamber. It can extend the life time of the feedthroughs.

Table1 Critical Leakage Current on Sense wires

Layers	1	2	3	4	5	6	7	8	9	10
# of cell	48	48	64	56	68	80	92	104	116	128
# of wires	192	192	256	224	272	320	368	416	464	512
Leakage(μ A)	3.84	3.84	5.12	4.48	5.44	6.40	7.36	8.32	9.28	20.48
Real leak(μ A).	0	0	0	0	0	0	0	0	0	0

Table 2 Critical Leakage Current on Field wires

Layers	1	2	3	4	5	6	7	8	9	10
# of cell	48	48	64	56	68	80	92	104	116	128
# of wires	528	528	704	840	1020	1200	1380	1560	1740	1920
Leakage(μ A)	21.12	21.12	28.16	33.60	40.80	48.00	55.20	62.40	69.60	76.80

Table 3 Present Leakage Current on Field wires

Layers	1	2	3	4	5	6	7	8	9	10
# of cell	48	48	64	56	68	80	92	104	116	128
# of wires	528	528	704	840	1020	1200	1380	1560	1740	1920
Leakage(μ A)	5	2	4	6	7	6	6	9	10	18