HIGHT VOLTAGE ELECTRIC DIPOLE CONDITIONING FOR THE SUPER SPECTROMETER SEPARATOR AT GANIL/SPIRAL2

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Abstract

The "Super Separator Spectrometer" project S^3 is under technical commissioning at the GANIL facility (Caen-France). It is a new research installation designed for fundamental physics experiments with high intensity heavy ions beams produced from the SPIRAL2 linear accelerator. This spectrometer will open new horizons for nuclear physics. The S^3 spectrometer is made of 77 Superconducting magnets, 12 room temperature magnets and one electric dipole to guide and focalize the beam and select the particles of interest.

This paper presents technology of the Electric Dipole and the first operation of its conditioning before the commissioning of S^3 project.

S^3 SUPER SEPARATOR SPECTROMETER

S^3 Project [1] [2] aims to push the boundaries of nuclear physics by enabling the study of unstable nuclei and super heavy elements, particularly those beyond 104 in the periodic table (Fig.1). The design of the primary target is optimized for fusion-evaporation production. S^3 is a two-stage optical structure combining a large acceptance momentum achromat and a high-resolution mass separator. Each stage includes 2 dipoles and 4 multipoles triplets. 77 superconducting magnets, 3 room temperature dipoles, 3 open quadrupoles and 1 electric field dipole will allow S^3 to achieve high transmission and high resolution in mass to charge ratio for scientists [3].

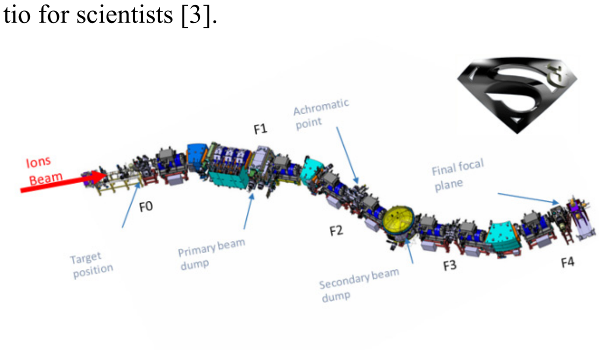

Figure 1: S3 spectrometer.

An electric dipole and a magnetic dipole are used in concert to provide an achromatic image at the final focal plane that is dispersive in m/q (Fig.2). The electric dipole separates the particles based on their kinetic energy so they exiting this dipole with the same mass but different charge states. In second stage, the magnetic dipole does a charge states separation to perform a mass resolution power about 500.

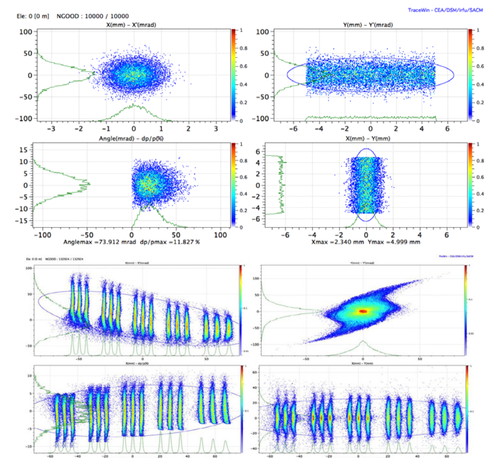

Figure 2: Input and final focal point emittance for different mass SN like distribution with 22+ to 26+ charge state.

ELECTRIC DIPOLE

The electric dipole consists of two titanium electrodes placed in a vacuum chamber (Table 1). Titanium was chosen for its good dielectric rigidity.

Table 1: Electric Dipole Dimensions

Vessel diameter [m]	Total height [m]	Total weight [kg]	Bending angle [°]	Bending radius [m]	Beam axis height [m]
1.9	2.4	2500	22	4	1.5

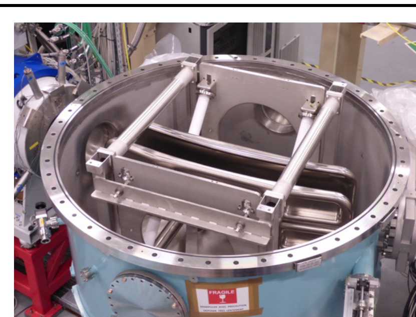

Figure 3: Electric dipole (IJClab).

The electrodes are held in place by a frame and ceramic insulators sized for the high voltages (Fig.3). Two ceramic insulated feedthroughs equipped with anti-corona protection are designed for connecting the 300kVcables.

The height of electrodes are optimized to ensure maximum homogeneity of the electric field experienced by the particles. An electrochemical mirror polishing Ra0.02µm was applied to the edges of the electrodes to eliminate roughness and improve the surface condition, thus enabling very high voltages to be achieved. The anode end is slotted to allow dumping of the primary beam (Fig.4).

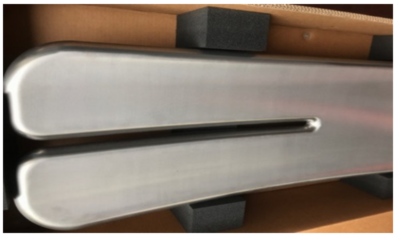

Figure 4: Anode end slotted.

The maximum electric field is present for each electrode at the rounded ends of the slit opposite the cathode (Table 2). It is 7.7 MV/m at the anode and 7.4 MV/m at the cathode. The central electric field between the two electrodes is 3 MV/m.

Table 2: Electrode Characteristics

Length [m]	**Height [m]**	**weight [kg]**	**Gap between electrode [cm]**	**Average Electric field between electrodes [MV/m]**	**Maximum electric field on electrode [MV/m]**
A 1.5 C 1.6	0.470	110	20	3	7.7

HIGH VOLTAGE POWER SUPPLIES

The voltages applied to the two electrodes are supplied by two HEINZINGER PNC-300kV-1mA power supplies: +300 kV and -300 kV (Fig.5). Stability of 100 ppm, ripple of 100 ppm at nominal voltage. They are connected to the electrodes via high-voltage feedthroughs and 300 kV cables. Due to the lengths and capacity, a high level of energy is stored in the cables (Cathode: 27, 6 J; Anode: 18.4 J).

Figure 5: High voltage power supplies.

The power supplies are remote controlled by a dedicated HMI developed by IJCLAB and based on a Cypress microcontroller based rack (Fig.6). This HMI ensures analog control and communication with a computer via the Ethernet protocol. A specific LabVIEW program allow to control the voltage and current parameters to condition the electrodes.

Figure 6: IJClab rack.

Arcs detection, vacuum level and speed variation as well as electrodes voltages and currents are taken in account by the conditioning algorithm to manage the voltage increase safely (Fig. 7). This program also allows data recording for analysis purposes.

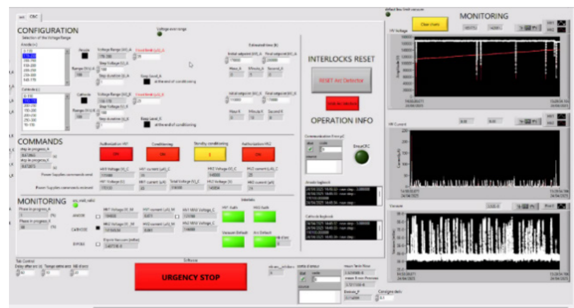

Figure 7: IJClab HMI.

VACUUM SYSTEM

The vacuum system is composed of one turbo-molecular pump Edwards STP1603 and two cryogenic pumps Leybold Coolvac 1500 (Fig.8). The optimal level achieved with the two electrodes in a steady state is 3.5 10-8 mbar. The pressure rises to1.10-7 mbar when a current appears (35µA)

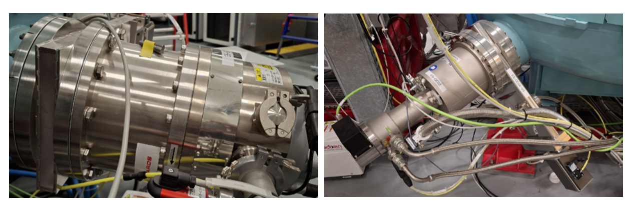

Figure 8: Turbo-molecular and cryogenic pumps.

The pumping dynamic is very fast and the resting level returns in less than a second after current is cancelled

CONDITIONNING

The conditioning of the electrical dipole is necessary to achieve nominal voltages. This involves eliminating electron emission sites caused by impurities or surface conditions, using currents (direct or arc-based) and thermal effect. The conditioning process took place in several phase during two month. The anode and the cathode are conditioned alternately up to 130kV and then up to 200kV with respect to ground. Once the voltage are reached, they are conditioned in parallel at +/-170kV and then at +/-200kV. The phenomena and electrode response are very different between anode and cathode. Due to the rapid effect of electron and his negative polarity, the cathode is conditioned with multiple voltage breakdowns (Fig.9).

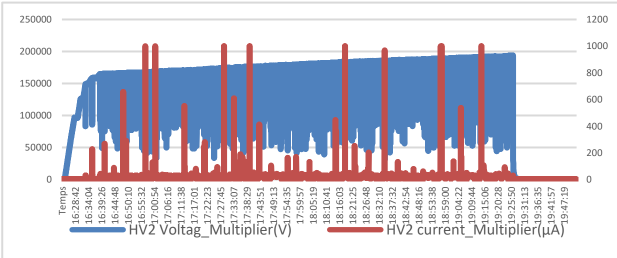

Figure 9: Cathode conditioning at 195kV.

The anode, on the other hand, can be conditioned at constant current with very few arcs, and the rate of voltage rise depend of the current limitation level (Fig10).

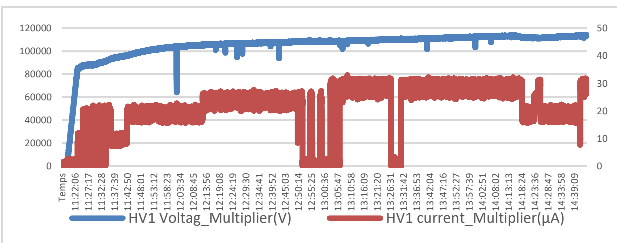

Figure 10: Anode conditioning at 120kV.

During the simultaneous conditioning of the 2 electrodes, the limiting current of the anode is set slightly higher than that of the cathode so that the conditioning regime is carried out with a current acceptable for the cathode (Fig11).

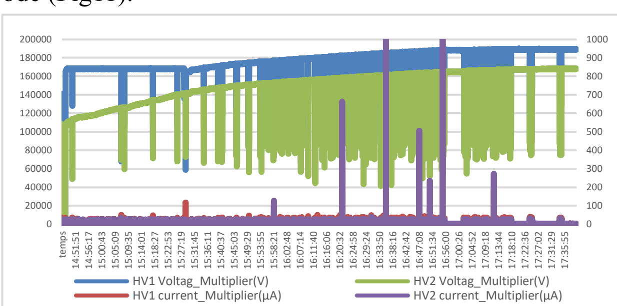

Figure 11: Anode & Cathode conditioning.

RESIDUAL GAS ACQUISITION

A RGA is performed during the conditioning to draw conclusions about the effects of current and breakdown. Some peaks of the spectrum show desorbing by electron impact (Fig12).

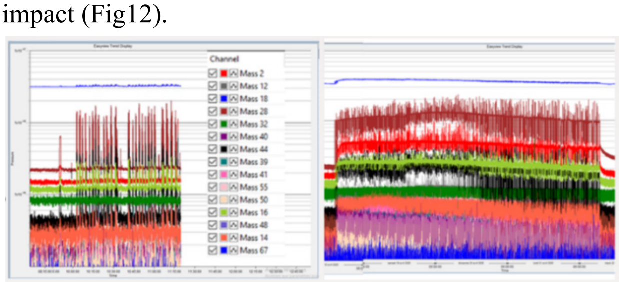

Figure 12: Cathode and anode RGA.

This RGA show active degassing of H2, H2O, CO and CO2 from desorption of the tank and electrodes. (Fig.13).

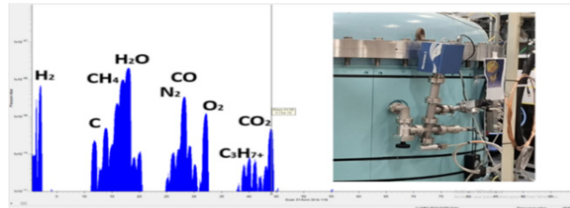

Figure 13: RGA spectrum measurement.

The two different conditioning regimes, with breakdown on the cathode and direct current for the anode, are clearly visible in the vacuum and RGA measurements.

X-RAY DOSE RATE

The X-ray dose rate is measured using a calibrated ionizing chamber dosimeter BERTHOLD placed at 1 meter from dipole on the anode side. The most unfavourable case was when only cathode was conditioned (1000µSv/H at 200kV) and that numerous arcs were generated (Fig.14).

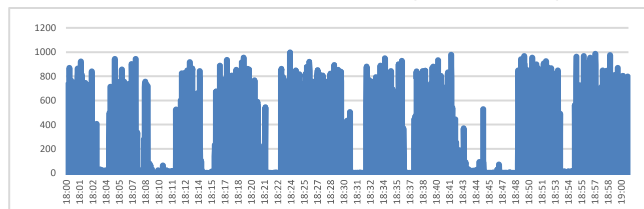

Figure 14: Dose rate (µSv/H).

In the case of the anode alone or the 2 electrodes in parallel, the highest measured rate was 40µSv/H

EXTERNAL X-RAY ENERGY

The external X-ray energy is measured using a BaF2 scintillation detectors placed at 1 meter from the dipole on the cathode side.

The maximum energy of 1 Kev was measured during the conditioning of the cathode to the maximum voltage reached of 200kV (Fig.15).

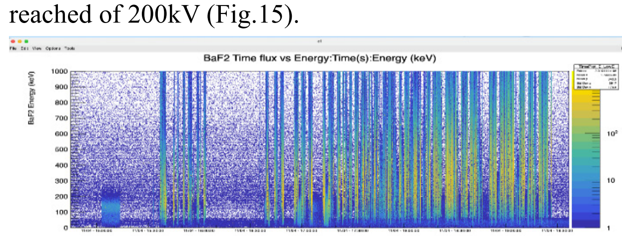

Figure 15: x ray energy during cathode conditioning.

This measurement is in line with the expected level given the attenuation achieved through the thickness of the steel tank and the added lead shielding for this voltage level.

NEXT STEP

Next step will require modification of the electrical circuit in order to minimize breakdown effect at higher voltages and to safely reach +/-300kV.

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