A NEW SPARK DETECTION SYSTEM FOR THE ELECTROSTATIC SEPTA OF THE SPS NORTH (EXPERIMENTAL) AREA

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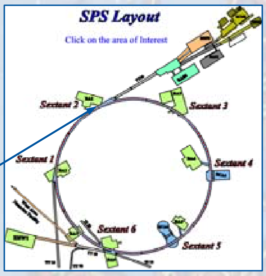
ABSTRACT

Electrostatic septa (ZS) are used in the extraction of the particle beams from the CERN SPS to the North Area experimental zone. These septa employ high electric fields, generated from a 300 kV power supply, and are particularly prone to internal sparking around the cathode structure. This sparking degrades the electric field quality, consequently affecting the extracted beam, vacuum and equipment performance. To mitigate these effects, a **Spark Detection System** (SDS) has been realised, which is based on an industrial SIEMENS S7-400 programmable logic controller and deported Boolean processors modules interfaced through a PROFINET fieldbus. The SDS interlock logic uses a moving average spark rate count to determine if the ZS performance is acceptable. Below a certain spark rate it is probable that the ZS septa tank vacuum can recover, thus avoiding transition into a state where rapid degradation would occur. Above this level an interlock is raised and the high voltage is switched off. Additionally, all spark signals acquired by the SDS are sent to a front-end computer to allow further analysis such as calculation of spark rates and production of statistical data.

MOTIVATION for a SDS system

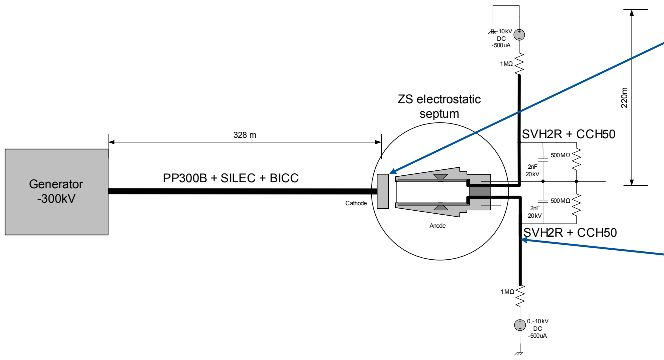
The main objective of the SDS system is machine protection and is an aid in optimising losses at extraction. **Assuring longevity of the electrostatic septa chain (5 of)** of the extraction channel. Avoiding repetitive sparking from and to same spark centres that can damage the spark electrodes. Without the SDS, the septum magnet could potentially suffer damage, specially on the thin wall structures that forms the septum electrode.

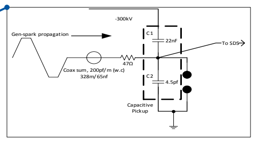
Super
Proton
Synchrotron



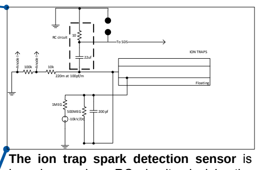
ZS BA2 North extraction area for Fixed target physics

SYSTEM OVERVIEW





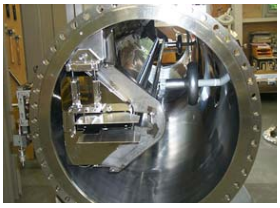
The capacitive divider pickup is housed inside a small metallic box which acts as a screen, the components are welded inside, one side has a HV Lemo connector (15kV) and on the other side is a standard BNC



The ion trap spark detection sensor is based around an RC circuit principle, the components are housed inside a metallic enclosure and acts as a feed through between the electrostatic septum and cabling and controls electronics

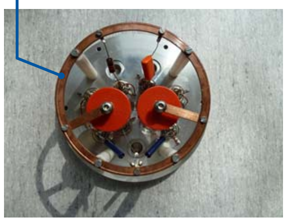
The five ZS tanks per extraction channel are powered in parallel by a single high-voltage supply located in the auxiliary surface building. A 328 m long cable feeds the high-voltage to a 'fan-out' via two 1.4 MΩ series resistors; from this the connections to the individual tanks are made via 420 MΩ series resistors. In addition each feed through contains a 300 Ω resistance to dampen reflections in cabling. Both the cathode and ion traps can spark internally causing disruption to the electric fields inside the tank, affecting circulating beam and vacuum. To help alleviate these effects, a cathode HV generator interlock is based over the acceptance of several sparks during a set time window to allow the ZS septa tank vacuum to recover. In the case of the BA2 North extraction septa's, **no more than 5 sparks within a 10s time frame is tolerated.**

ZS SEPTUM AND COMPONENTS



Transversal side view of the electrostatic septum magnet

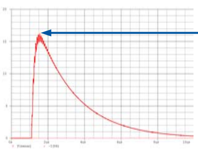
Each of the **electrostatic septa ZS** provides three meters of field length. The cathode is planar, made from an aluminum alloy PRE30,oxidised on the surface to form an **alumina (Al2O3) coating** some 8μm thick. The anode is formed by an array of about 2000 W.75Re.25 wires, of 60-70μm diameter in the first (upstream) tanks, and 100μm diameter for the subsequent tanks. **The wires, stretched over a 'C' shaped stainless steel or invar former**, are spaced at 1.5 mm intervals. This structure separates the high-field region from a field-free region containing the circulating beam.



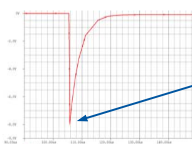
Ion trap HV entrance boxes

SPARK DETECTION PICKUPS

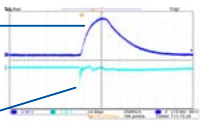
The ZS HV transmission path between generator and septum was studied prior with **Pspice modelling** to further aid the understanding of the inner workings and effects of internal sparking inside the electrostatic septa tank and coupling effects within the HV generator, HV lines and ion traps generators. A simplified model approach was chosen. The model includes all the following elements, power source, HV transmission lines, line resistances, spark breakdown model, connectors capacitance and spark detection circuitry. The aim is **to understand the embedded characteristics** of the complete HV path and the overhaul system including the effects coming to and from the ion traps, septum anode and cathode structures. Furthermore the model was then reinforced by the following inclusions of parameters, improved source modelling (Ureg and Ireg monitoring), HV transmission line lumped parameters including **(R,L,C and G)** and lengths, monitoring of cathode and ion trap sensing circuit outputs, improved spark breakdown model, system coupling effects and their study (ex. effect of an ion trap spark with respect to the cathode HV power supply), spark shaping through sense circuitry, **model matching to real world measures**. The main outcome of the Pspice was to understand the shape of the electrical breakdown, its transient behaviours (T_r & T_f) and amplitude once it has propagated through approx. 328 m of HV coaxial cable.



Simulated spark shape of cathode from cable to SDS



Simulated spark shape of anode from cable to SDS

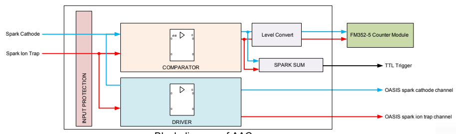


Real measure of spark shape from cathode and anode structure

SDS ELECTRONICS

The SDS is based on a custom made electronic **Analogue Acquisition Card (AAC)** which interfaces the different types of spark sensing circuit with the digital counting system. One **AAC** can acquire and condition simultaneously 2 channels, one for the septum cathode and one for the ion trap. Its principal characteristics are:

- **Galvanic isolation** through a wide bandwidth pulse transformer between generator high-voltage circuit and electronic;
- Passive front-end circuit for spark signal acquisition;
- Generation of clean pulse from spark edges through adjustable fast comparators;
- Isolated low impedance and wide bandwidth analogue outputs of the spark input signals;
- **Level conversion of comparator** output pulses to industrial standards (typically +24 V);
- Production of a trigger pulse train synchronised to any spark event in the system.



Block diagram of AAC

Altium designer 3D view of spark acquisition card (AAC)

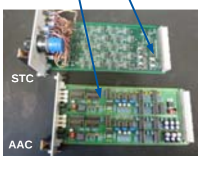
ELECTRONICS HARDWARE & CONTROL

The SDS is housed in a 19 inch rack chassis that contains 5 analogue acquisition cards (one per septum), 1 self-test card and a set of **SIEMENS S7-300 PLC modules for data acquisition.**

- **1 power supply, PS307, 5A**
- **1 Profinet coupler, IM153-4**
- **2 Boolean processors, FM352-5**
- **3 Digital Inputs, SM321**

The high-voltage inputs which receive the spark signals from the septum are located on the rear side of the unit. These signals are internally transferred onto a backplane for distribution to the analogue acquisition layer. The signals are then conditioned in order to be compliant with industrial signal levels for connection to off-the-shelf SIEMENS modules.

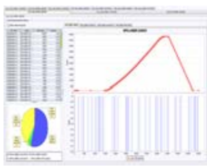
The spark sensor high-voltage input connectors (15 kV LEMO) are fitted onto a thick epoxy resin plate for a proper galvanic isolation between the generator high-voltage and the electronic grounds.



Each card treats one septum tank; hence 5 **AAC** cards (10 channels) are necessary for the complete ZS system. A Spark Test Card (**STC**) is incorporated in the **SDS** for the monitoring of an on board self-test facility. It emulates spark events **for all 10 channels** with variable spark amplitude and spark rate in order to check whether the system is functioning correctly.

SCADA INTERFACE

To read and interpret the data from the **SDS system**, an operator panel in-situ contains all the information for the specialist. This interface was designed with **WinCC flexible**. Added to this is a WebNaviguator version of WinCC for remote viewing



The SDS is controlled and monitored from the CERN Control Centre **(CCC)** using the standard communication protocols developed at CERN with a **JAVA based interface**. This allows the remote control of the SDS through generic Java application and the continuous publication of the various SDS data to the SPS logging database for off-line analysis or to fixed displays in the CCC for **real time visualisation of the spark rates during machine performance optimisation**

Another important feature of the WinCC interface is the trending of the spark counts. **These are recorded on a chart and overlaid with all three vacuum gauges reading from the electrostatic septa's,** this shows the close relation between HV breakdown and its effect on the vacuum and vacuum recovery inside the ZS tanks