IMPROVEMENT OF THE CERN SPS ELECTROSTATIC SEPTA ION TRAPS

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LHC Injectors Upgrade

CERN

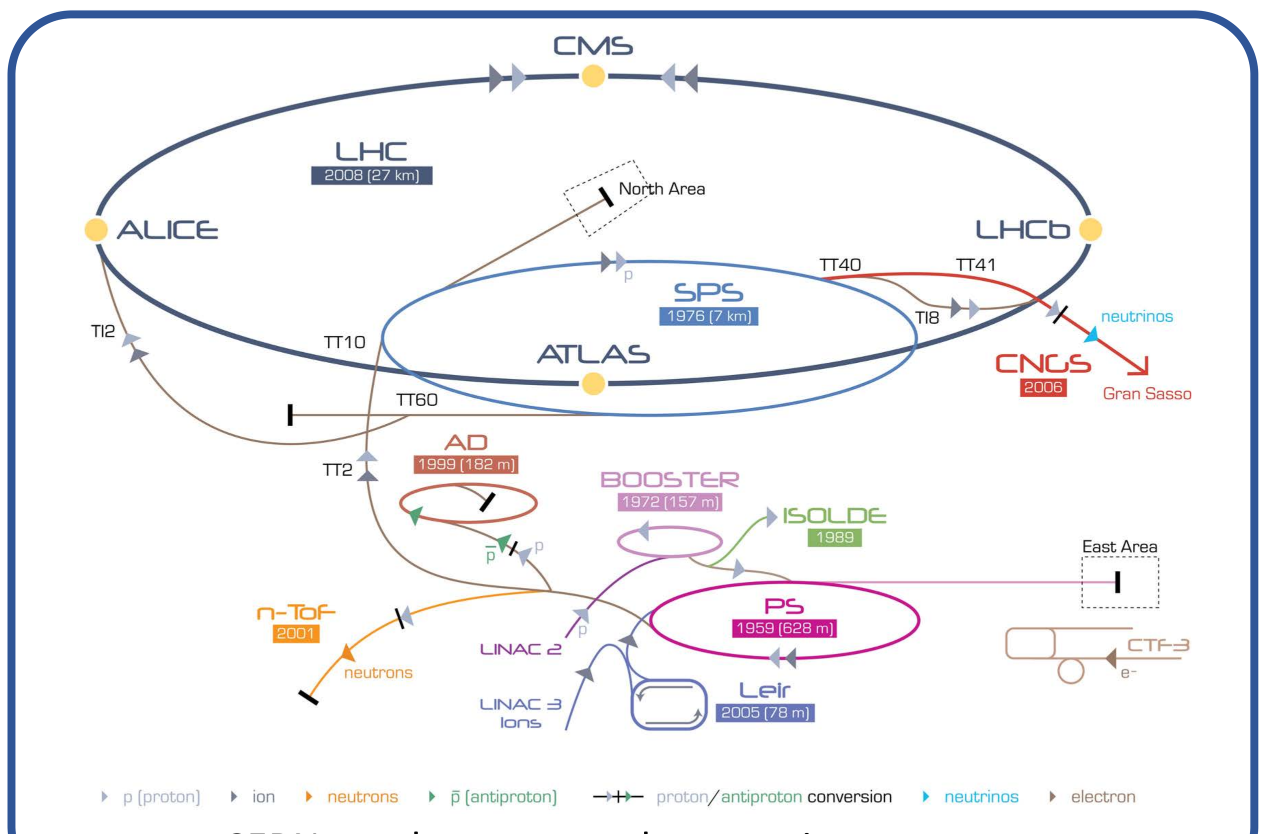
Introduction :

At CERN, the SPS synchrotron is equipped with a slow extraction channel towards the fixed target beam lines in the North Area. This channel includes five consecutive electrostatic septa (ZS), where the field free region and the active high field region are separated by an array of tungsten-rhenium wires. The field-free region provides for the circulating beam, while the high field region is used to deflect the extracted beam. Since the residual gas can be ionized by the orbiting beam, low energy ions could cross the wire array and enter the high field region and cause high voltage breakdown when accelerated onto the cathode. To prevent low energy ions from entering this high electric field region, a vertical field is applied to the orbiting beam using so-called 'ion traps'.

The electrostatic septa suffer from high spark rates and (high) vacuum activity when high intensity beams with 25 ns bunch spacing are accelerated in the SPS for the LHC, despite that these beams are not extracted in this region.

This paper describes the 2 approaches to limit the sparking due to vacuum degradation:

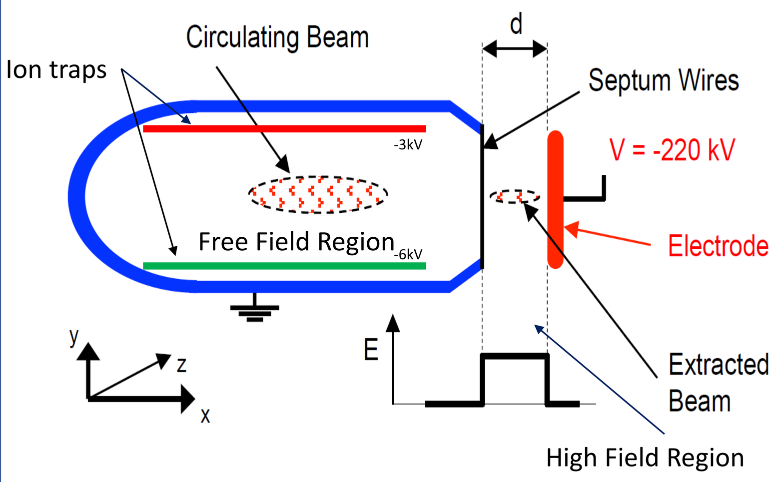
1) limit e-cloud in adjacent sectors by optimising their beam impedance and
2) optimise the electrical circuit to avoid e-cloud being produced inside the ZS



CERN accelerator complex overview

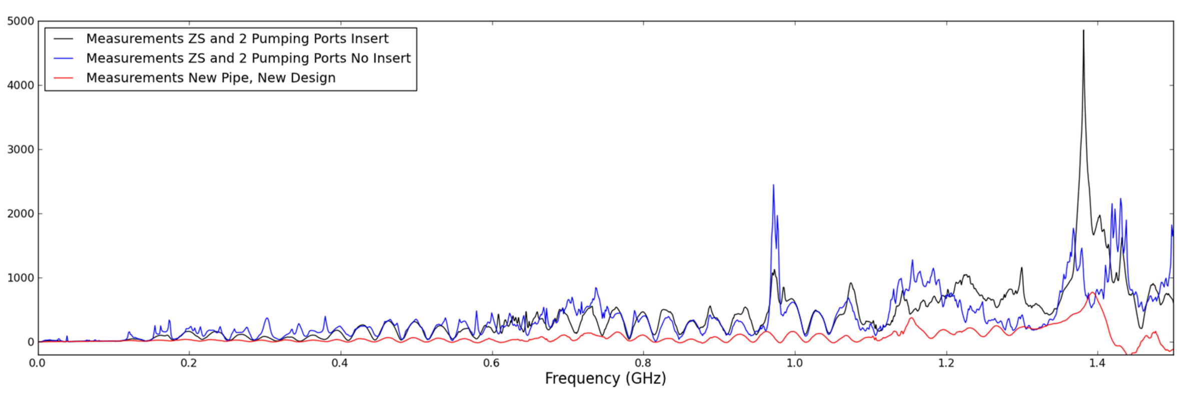
Impedance reduction based on improved layout and vacuum tank pumping :

Additional and modern vacuum pumping systems are being installed on the vacuum vessels of the electrostatic septa themselves.
New interconnects, linking the vacuum vessels have been improved and optimized in terms of beam impedance.

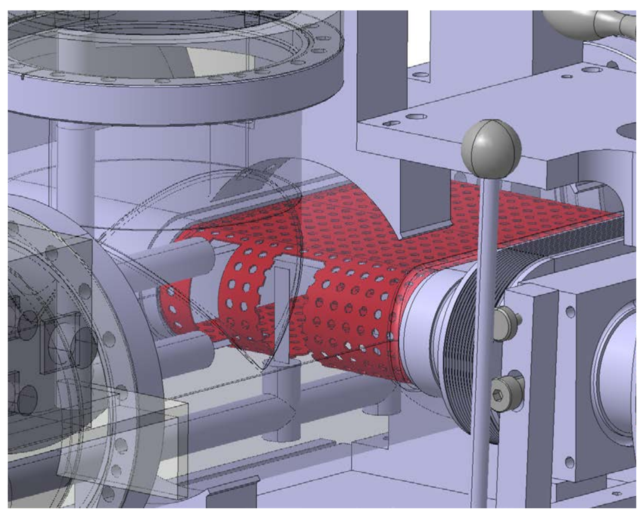


Electrostatic septa principle

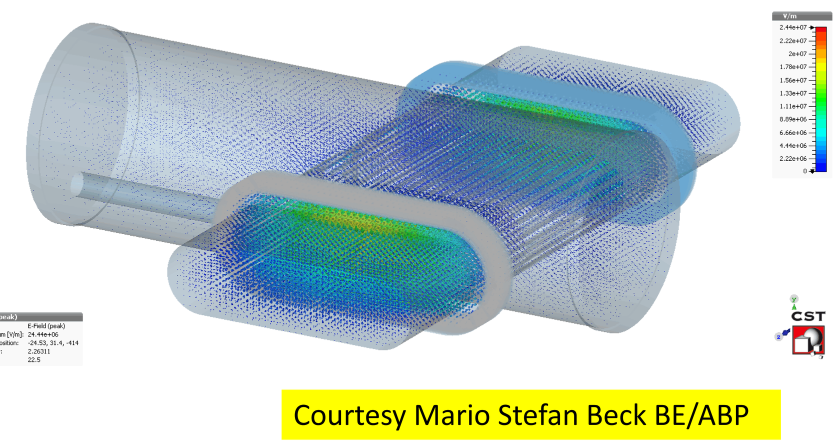
Longitudinal modes below 1.2 GHz supressed with the new design, achieving much better impedance performance longitudinally



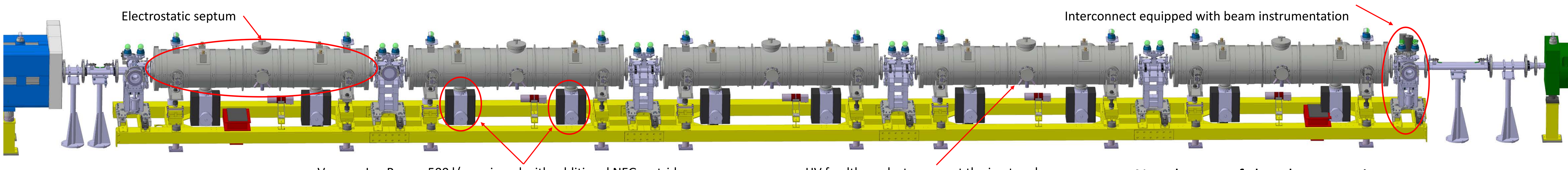
Beam impedance measurement using wire installed on a spare ZS with simplified elliptical beam pipes (both ends)



Beam instrumentation RF shielding



Results of a bellow resonance frequency analysis used to design the bellow and shielding



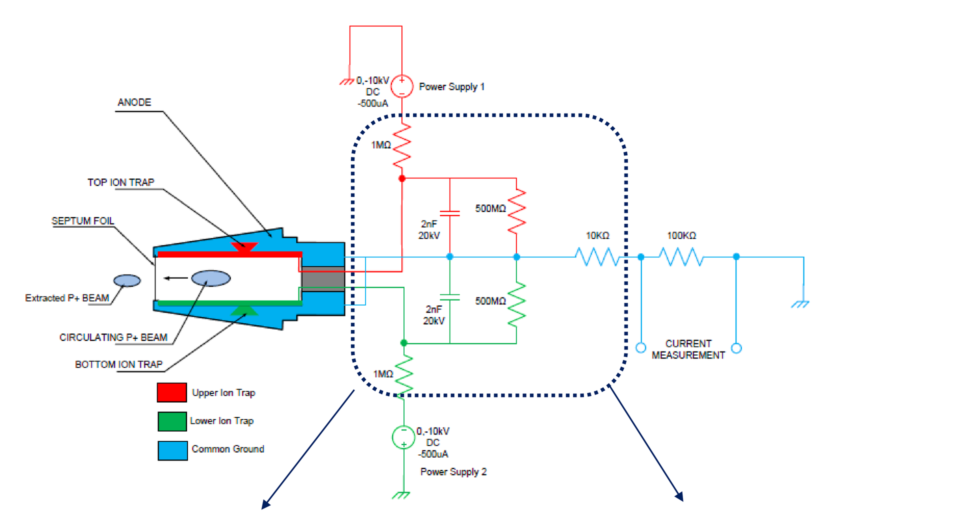
New layout of the electrostatic septa

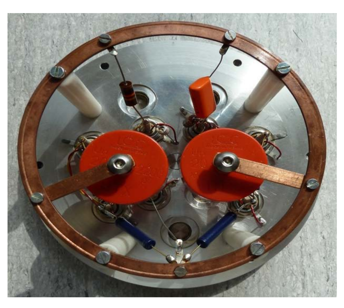
Ion trap readout box upgrade :

Constraints requiring upgrades were based on the fact that the ion trap electrodes lose their voltage bias due to beam-induced coupling to the high impedance external electrical circuit. The studies performed and the measurements collected have proven the existence of a capacitive coupling between the ZS cathode and the ion traps electrodes during sparking without beam.

Requirement for the new HV box design

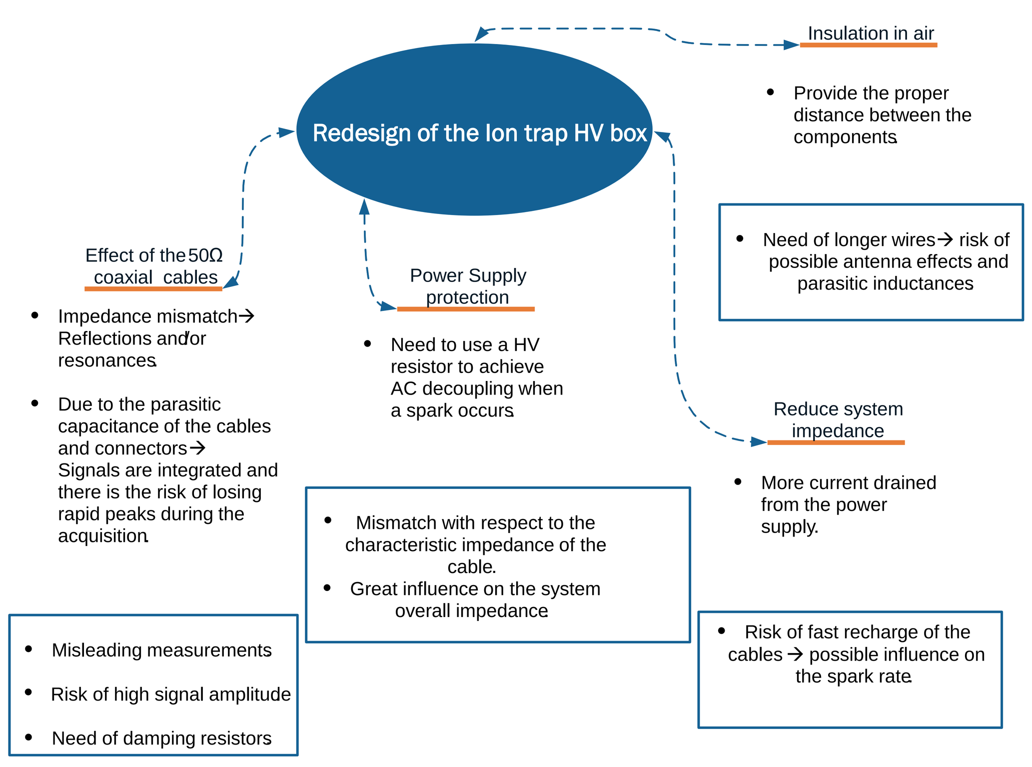
- Act as a feedthrough to provide the ion trap plates with the expected voltage.
- Behaviour of the plates deduced from the acquisition of *anode current* and *anode spark* signals.

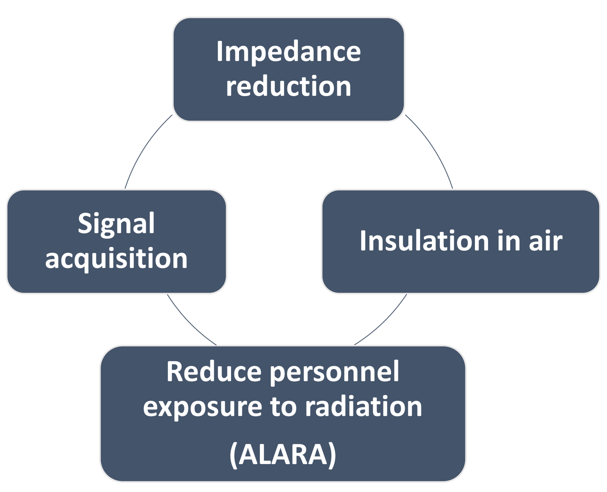




Upgrades required	
Oil suppression	Reliability for connectors
Ion trap Umon acquisition	Acquisition of new signals, U monitoring Top and Bottom
Ion trap spark acquisition	Acquisition of additional monitoring signal Spark Anode
Anode grounding	Optional feature
Impedance reduction between power supply and ion trap plate	Reduced 'Z' seen by beam

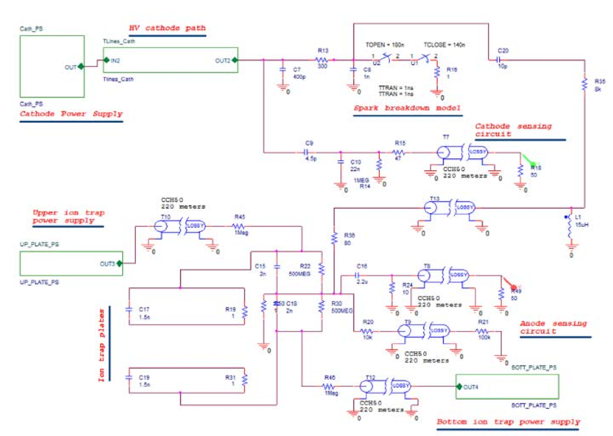
Design path breakdown



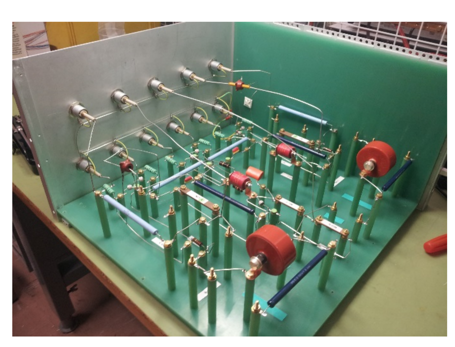


Technical progress realised during study

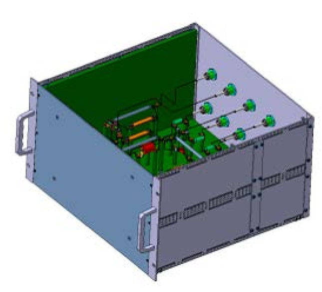
Tasks accomplished	Comment
• New ion trap HV box prototype designed and fabricated	Optimal circuit topology and candidate components identified, 3D model available
• Spark measurements collected during 1st long shutdown	Referenced in EDMS 1487194, CERN
• Spice model for anode coupling when a cathode spark occurs (with no beam)	Not fully understood yet …
• Oscilloscope connected in BA6 to ZS ion trap UP	Evidence of beam coupling and voltage drop on the ion trap plates
• Spice model for the beam coupling to the ion trap plate	Correlation with 'real world' data
• Effect of the length of the cables in the 867 understood	Tests with 20 m/200 m of CCH50 cable
• New feedthrough planned to replace obsolete LEYBOLD® connector	Improved reliability



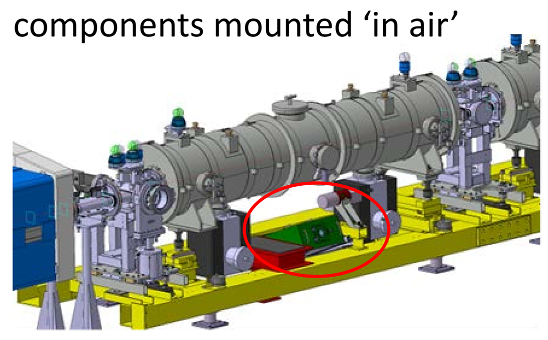
Pspice® studies of coupling effects



ZS ion trap box prototype, internal components mounted 'in air'



Catia® 3D model of new ion trap box



New ion trap box implantation

Conclusion:

The SPS electrostatic septa remain an important system for the CERN accelerator complex and the slow extraction towards the North Area in particular.
Upgrades are needed to ensure their continuing good performance in the HL-LHC era.
To avoid electron cloud being produced in the neighbouring sections of the electrostatic septa, new interconnects have been designed with reduced beam impedance.
In parallel, an improved version of the electrical circuit powering the ion traps has been developed. The improved electrical circuit (ion trap box) will be tested both in the laboratory as well as in a test facility installed in the accelerator to assess the circuit's behaviour while having beam in the in electrostatic septa.
These modifications will be implemented during the long shutdown (LS2) of the accelerator complex, which is scheduled 2019-2020.