# RADIATION TOLERANT CONDITIONING ELECTRONICS FOR VACUUM MEASUREMENTS

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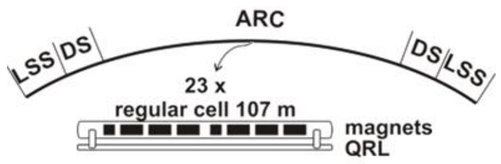
**Abstract**

Vacuum in the ARCs of the LHC is crucial to minimize beam – gas interactions and to assure thermal insulation of cryostats and helium distribution lines. Several hundred of sensors with their associated conditioning electronics are installed across the DS/ARCs for both beam and insulation vacuum measurements. Calculations predict that radiation levels will greatly increase during HL-LHC era.

New radiation tolerant conditioning electronics for vacuum measurements are required to withstand such conditions. This poster presents the design of these new electronics, their qualification tests and implementation within the vacuum controls architecture foreseen during the long-shutdowns of the LHC.

## 1. Introduction and Motivation




*DS = Dispersion Suppressor

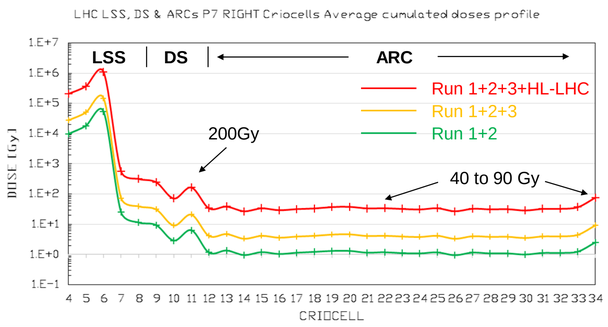
### Introduction

In the LHC, about 24km of vacuum chambers are located in the DS*/ARCs. They serve as thermal insulators for cryogenic magnets and helium distribution lines, with a pressure range from $10^{-6}$ to $10^{-8}$ mbar (High-Vacuum). In order to minimize the interaction between the particle beam and any residual air molecules, pressure in the beam pipes is kept below $10^{-10}$ mbar (Ultra-High-Vacuum) by means of cryogenic pumping.

Three types of pressure sensors with their dedicated conditioning electronics are used to cover the whole pressure range: the membrane, the Pirani and the Penning sensor. Calculations predict that the Total-Ionization-Dose (TID) in the LHC DS/ARCs will reach 40 to 200 Gy by the end of HL-LHC era. The present system is not designed to withstand such doses. New radiation tolerant electronics have been developed, based on Commercial Off-The-Self components (COTS), aiming to withstand 500 Gy.

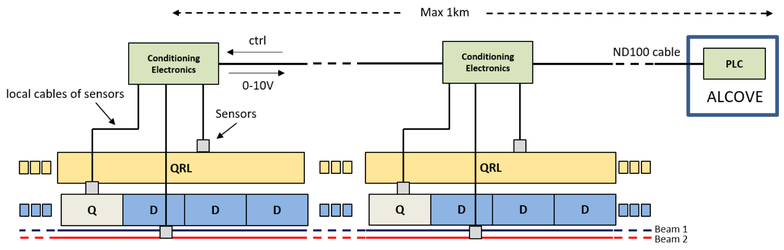
### Radiation Environment:

- LHC environment is changing (beam energy, operation, luminosity)
- By end HL-LHC era doses will reach 200 Gy in DS and 90 Gy ARCs
- Present electronics will deteriorate or even destroyed above 15 Gy
- Radiation tolerant version is not supported by industry
- 500 Gy development goal, safety factor x2.5 for DS



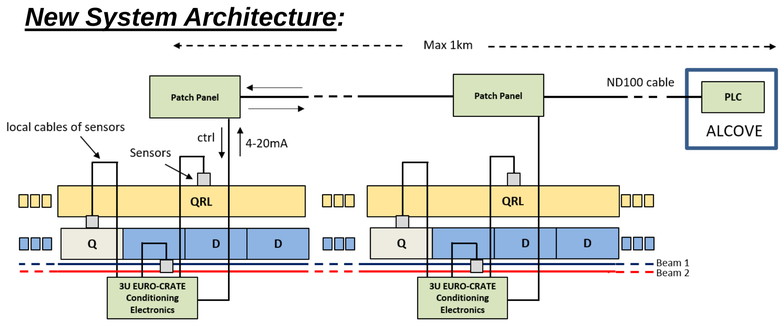

## 2. System Architecture & Hardware

### *Present System Architecture:*




- All runs will deteriorate or destroy electronics
- Electronics fixed above dipole magnet – difficult access
- Non-modular resulting to long interventions and commissioning campaigns
- 0-10V signal transmission resulting to signal losses and noise coupling

### *New System Architecture:*

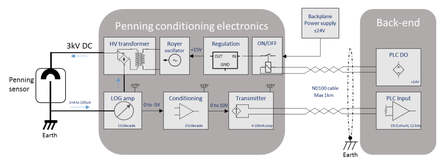



- Radiation tolerant electronics and power supplies
- Mini-rack with 3U euro-crate beneath dipole magnet – easy access
- Modular electronics reducing intervention times and commissioning campaigns
- 4-20mA transmission resulting to no signal losses and reduced noise coupling
- Fail-safe signal readout in case of power cut

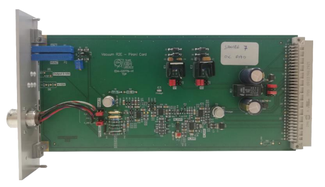
### *3U Euro-Crate:*

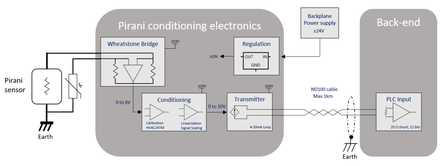
- Fits 2 redundant Power Supplies
- Can house up to 9 conditioning electronics
- Incorporates PCB backplane and back-plate connectors

### *New Hardware:*

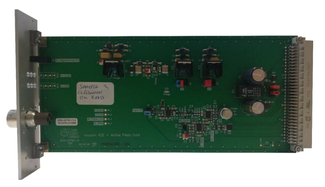


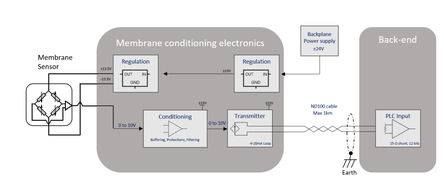

**Penning:**
- Pressure range from $10^{-9}$ to $10^{-5}$ mbar
- Current range from 1nA to 100uA
- High voltage generation (3kV DC)
- One-time calibration (for Air or Nitrogen)
- 4-20mA signal transmission



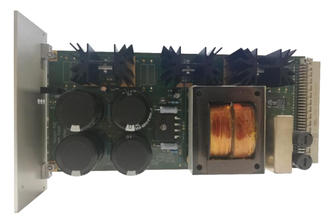



**Pirani:**
- Pressure range from $10^{-3}$ to $10^{+2}$ mbar
- Filament bias current from 3mA to 40mA
- On-board calibration and linearization
- 4-20mA signal transmission





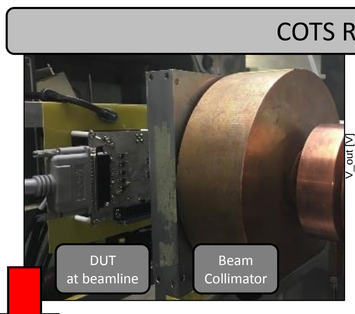

**Membrane:**
- Pressure range from $10^{+0}$ to $10^{+3}$ mbar
- Sensor regulated supply ±13.5V
- 4-20mA signal transmission

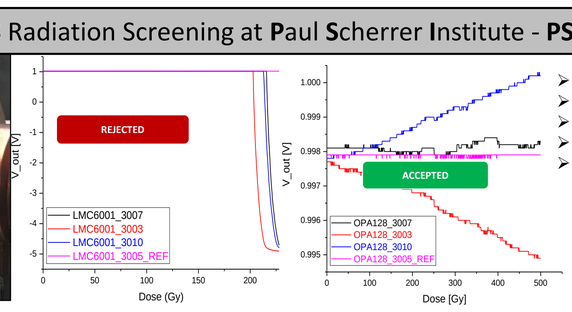


**Power Supply:**
- Linear and robust provides ±24V to the backplane of the crate
- Redundant (2 power supplies per euro-crate)
- Can supply up to 9 conditioning electronics

## 3. Qualifications

### COTS Radiation Screening at **P**aul **S**cherrer **I**nstitute - **PSI**







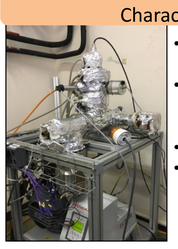
- 18 COTS tested
- 15 accepted for 500 Gy certification
- 200 MeV proton beam at 350 Gy/h
- HEH fluence $10^{12}$ cm$^{-2}$
- Batch procurements

### System-Level Characterization (non-radiative)

**Simulated Pressure Measurement Characterization**

- Specific test-bench for each card
- SMU simulates pressure
- Long-term stability tests
- Room temperature
- First performance evaluation and mitigations

**Real Pressure Measurement Characterization**

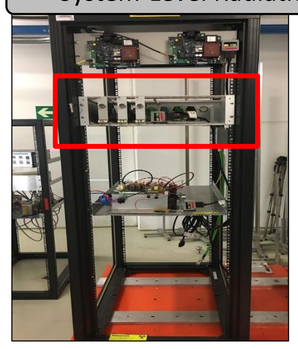


- Pressure range depending on sensor
- Electronics readout compared to reference pressure system
- Room temperature
- Optimizations to exploit full potential of the sensor

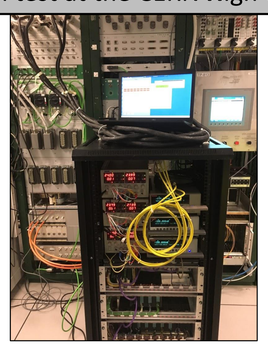
**Thermal Characterization**
simulated pressure

- Test of thermal effects in climatic chamber
- Cycles from 5°C to 70°C
- 5°C step upwards-downwards
- Mitigations for optimum thermal response

### System-Level Radiation test at the **C**ERN **H**igh energy **A**ccele**R**ator **M**ixed field facility – **CHARM**



Irradiation Rack



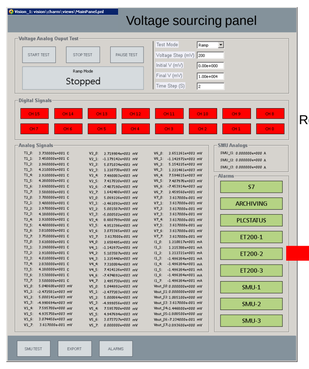
Control Room

- Secondary particles with wide energy spectra, up to 24 GeV
- HEH fluence 1.10$^{12}$ cm$^{-2}$ and 1MeV fluence 2.10$^{12}$ cm$^{-2}$
- 4 irradiation campaigns – 1 per system development
- 1 extra irradiation campaign for revised Penning electronics
- 2 weeks duration of each campaign with 2 Gy/h dose rate
- All conditioning electronics accumulated more than 500 Gy successfully
- Measurement errors at 500 Gy within tolerable margins

### *Dedicated Control System:*

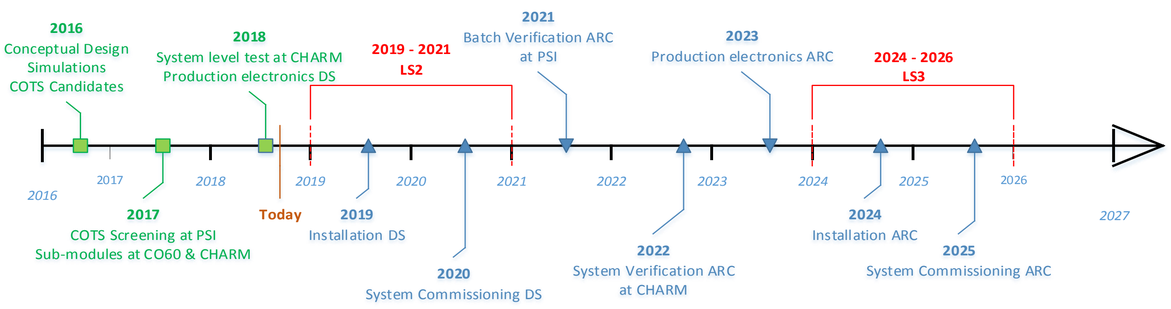
- Designed to tackle all characterization and irradiation campaigns
- Based on PLC and WinCCOA
- Can sample up to 100 analog channels
- Controls external instruments (SMU) through RS232
- Programmable Linear or Logarithmic sequences
- Archives data in server database
- Sends notification alarms in case of system failure
- Movable rack

SMU panel




Export panel

## 4. System Installation Timeline




## Conclusion

The new system architecture will greatly decrease maintenance and commissioning times, while it will enhance signal integrity and provide smooth integration within the vacuum controls architecture. The characterization of the conditioning electronics meets the required specifications under the different test environments. Regarding the tolerance to radiation, the new conditioning electronics can withstand doses up to 500 Gy with satisfying performance degradation. They will be replacing the present electronics in the DS areas during the second long-shutdown (LS2) and in the ARCs during the third long-shutdown (LS3).

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