Radiation Tolerant Conditioning Electronics for Vacuum Measurements

N. Chatzigeorgiou, G. Pigny, P. Krakowski, V. Rieker, P. Gomes, A. Rocha, R. Ferreira,
J. Gama, J. Fraga, S. Danzeca, R. Garcia Alia

Indico link: https://indico.cern.ch/event/760345/

R2E Annual Meeting

DEC, 11-12TH | CERN, 774/R-013

TWEPP18 poster: https://indico.cern.ch/event/697988/contributions/3056160/

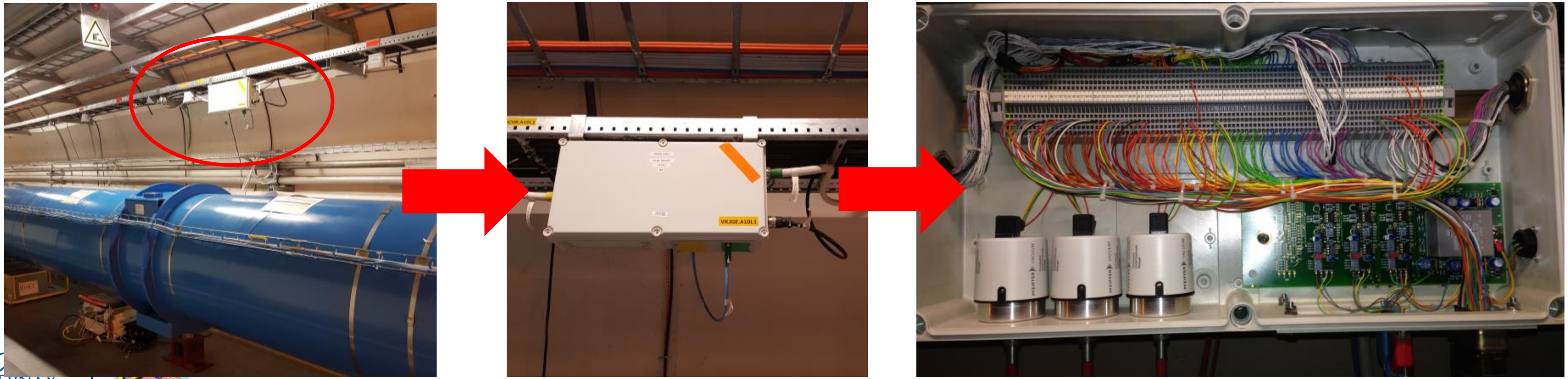
Presentation 11th December "**Radiation tolerant developments: Vacuum**" – G. Pigny

Outline

- Introduction
- Radiation Environment and Motivation
- New System Architecture
- New RadTol Hardware
- Qualifications
  - COTS
  - System-level
- System Installation Timeline
- Conclusions

Introduction

- In the LHC about 24km vacuum chambers in the DS/ARCs
- Thermal insulation vacuum range 10E-8 mbar (High Vacuum)
- Beam vacuum range below 10E-10 mbar (Ultra-High Vacuum)
- 3 sensors with deported electronics to measure pressure: Piezo, Pirani, Penning
- 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



Radiation Environment - Motivation

- By end HL-LHC era doses will reach up to 200Gy in DS and up to 50 Gy in the ARCs

“**Update on the expected radiation levels for HL-LHC**” G. Lerner

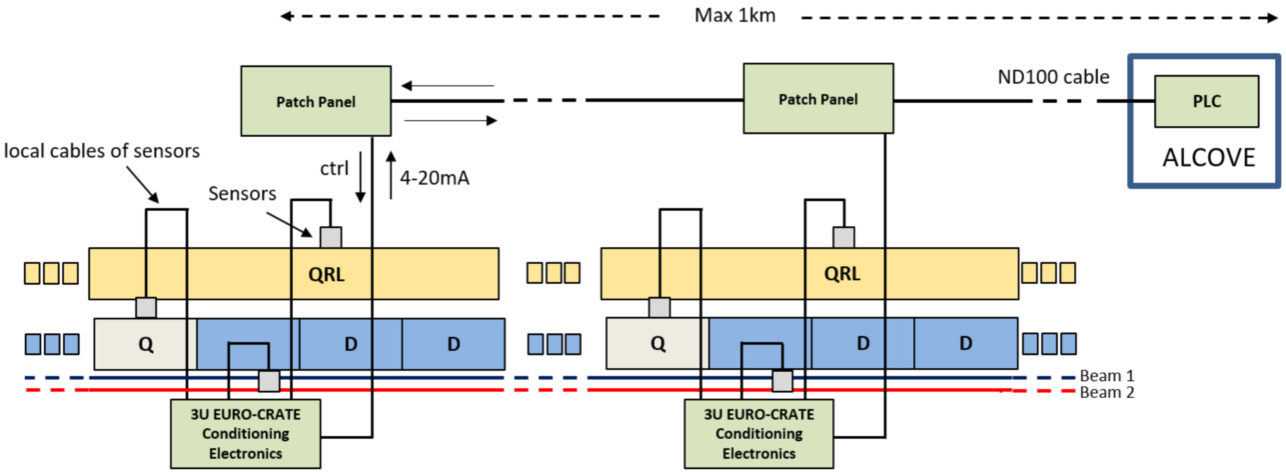
- Present electronics will deteriorate or even destroyed above 15Gy

“R2E of critical vacuum controls in the LHC” P. Krakowski – RADECS16

- RadTol version is not supported by industry
- 500Gy development goal, safety factor x2.5 for DS

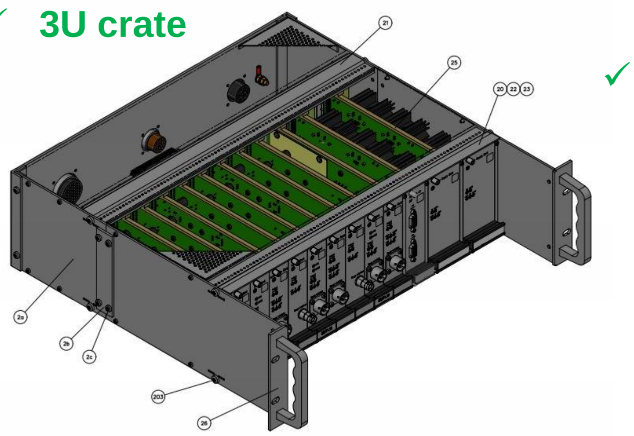
New System Architecture

- 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



New RadTol Hardware based on COTS

✓ **3U crate**



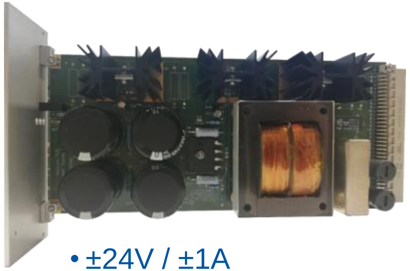
✓ **Penning**

- 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**

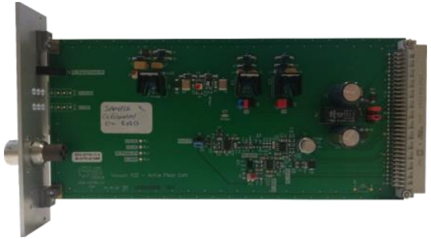
- Pressure range from 10^{-3} to 10^{2} mbar
- Filament bias current from 3mA to 40mA
- On-board calibration and linearization
- 4-20mA signal transmission

✓ **Power Supply**



- ±24V / ±1A
- Redundant (2 units per euro-crate)
- Can supply up to 9 conditioning electronics

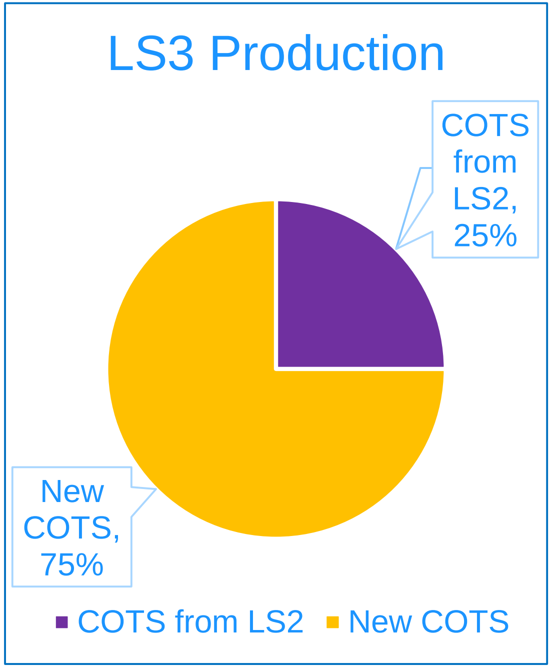
✓ **Piezo**

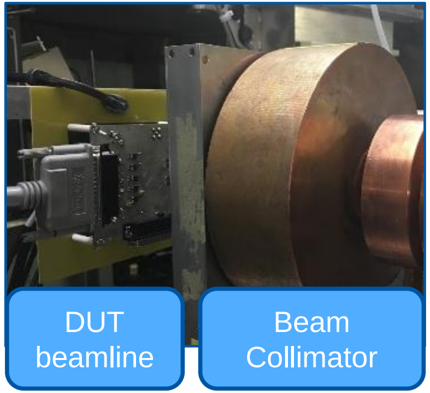


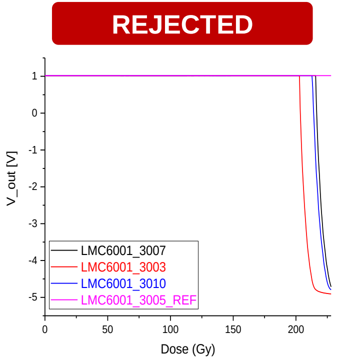
- Pressure range from 10^{0} to 10^{3} mbar
- Sensor regulated supply ±13.5V
- 4-20mA signal transmission

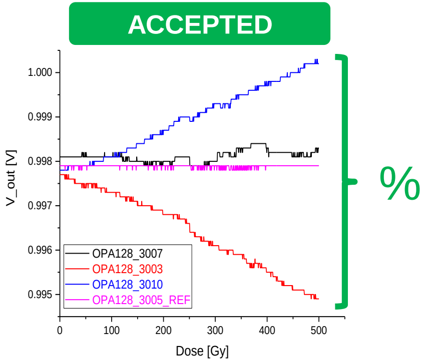
Qualifications – COTS screening at PSI

- 18 COTS tested
  - 200 MeV proton beam at 350 Gy/h – fluence 8E+11 [n/cm2]
  - TID, DD (many bipolar devices), SETs
- 15 accepted for 500 Gy
- Batch procurements for tests and LS2 production
  - Same batches with PSI whenever possible
  - New batches shorted with date codes / factory
  - Tested at system level at CHARM – batch acceptance at PSI

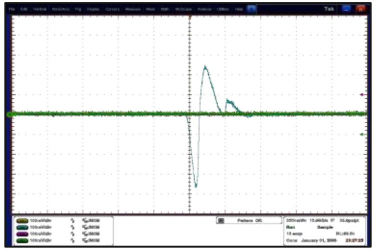








Example of competitive ultra-low bias current amplifiers for measuring ion current of Penning design

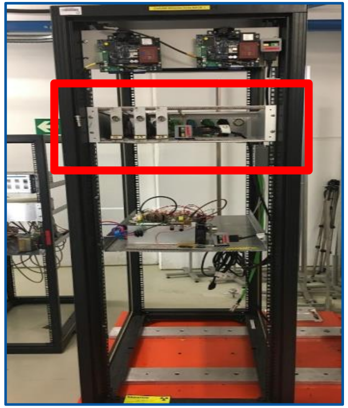


σ-section:
3.7E-11 [cm2]
For DS cell 12:
3 SET/y
For ARC:
3E-3 SET/y

Qualifications – System Level tests at CHARM

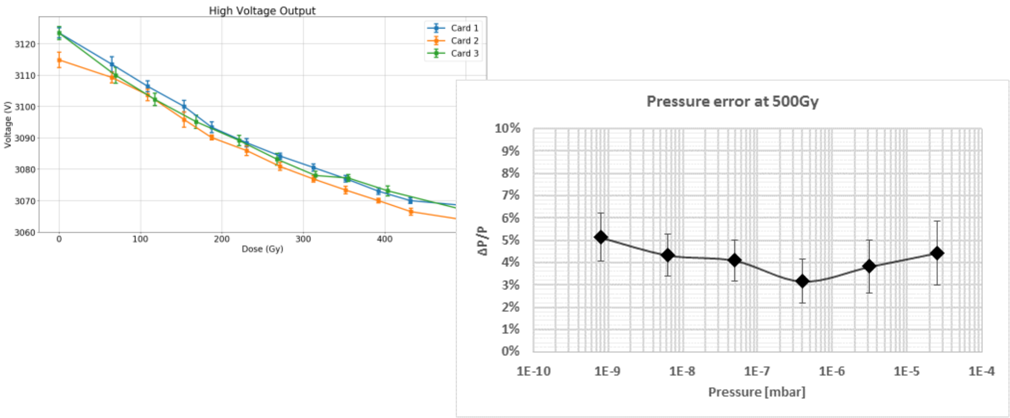
- Secondary particles with wide energy spectra, up to 24 GeV
- 4 irradiation campaigns – 1 per system development
- 1 extra irradiation campaign for revised Penning electronics
- 2 weeks duration of each campaign with 2 Gy/h dose rate – total 10 weeks at CHARM
- All conditioning electronics accumulated more than 500 Gy successfully
- Measurement errors at 500 Gy within tolerable margins

Irradiation rack



Control room

Penning most important graphs



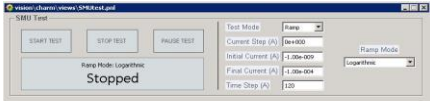
Dedicated control system for irradiation campaigns

- Based on Siemens PLC and WinCCOA
- 100 analog channels, 16 DOs
- Controls external SMU instruments
- Programmable Linear/Logarithmic sequences
- Archives data in a database
- Sends notification alarms in case of system failure

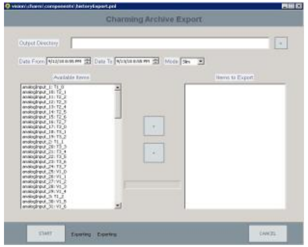
12U for external instruments (PS, SMU..)

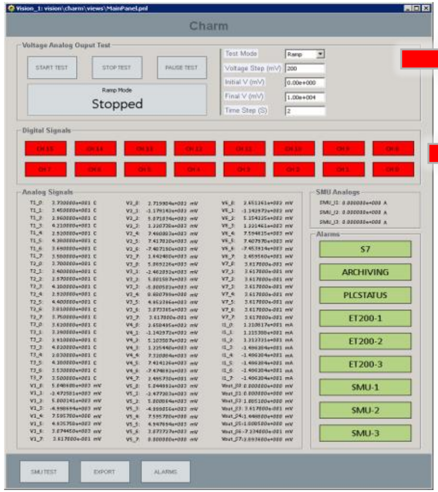
12U PLC hardware

SMU panel



Export panel





Voltage Source

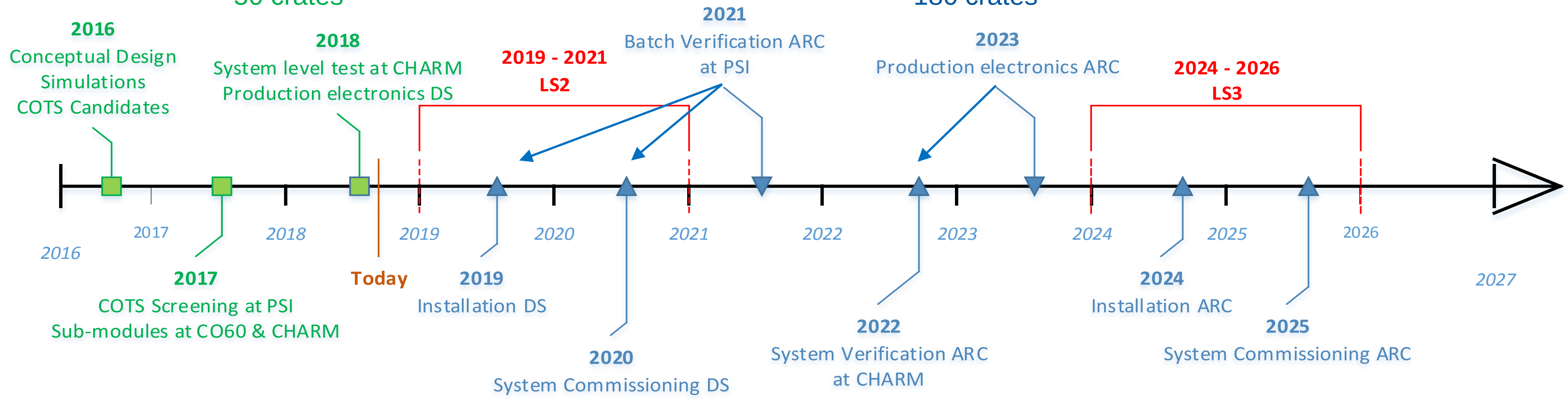
DO

Alarms

System Installation Timeline

LS2 production:
~180 electronics
~50 crates

LS3 production:
~1300 electronics
~180 crates



Conclusions

- New system architecture will greatly reduce maintenance and commissioning times
- Current loop transmission will enhance signal integrity and provide smooth integration within the vacuum controls architecture
- The characterization of electronics meets the required specifications under the different non radiative test environments
- The electronics can withstand doses up to 500Gy with satisfying performance degradation

Development in 2019

- Cost reduction of LOG stage by 40% by designing a version only for E-9 mbar gauges (replacement of OPA128 with OPA121)

Thank you! Any questions?

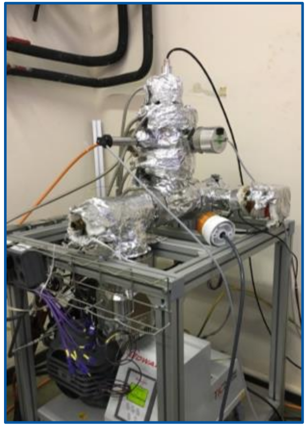
Backup

Qualifications – System Level 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