Institut "Jožef Stefan", Ljubljana, Slovenija

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.

Task 8.4.1: Innovative SiPMs and future applications in PiD Detectors

Introduction and task overview

Rok Pestotnik for the collaborators of the task

Jožef Stefan Institute, Ljubljana

Task 8.4.1: Innovative SiPMs and future applications in PiD Detectors	*Rok Pestotnik*
Sala Bellini	15:25 - 15:40
Task 8.4.1: Irradiation SiPM tests at Padova	*Ezio Torassa et al.*
Sala Bellini	15:40 - 15:55
Coffee Break	
Sala Bellini	16:00 - 16:20
Task 8.4.1: Subtask multi channel readout and adaptive power supply	*Ivo Polak*
Sala Bellini	16:20 - 16:35

Collaborating institutions

Institut "Jožef Stefan", Ljubljana, Slovenija

Collaborating institutions with contacts and research interests/ projects

Institution	Contact name	Contact e-mail	Projects	
CERN	Carmelo D'Ambrosio	ambrosio@cern.ch	LHCb RICH	single photons
INFN-Padova	Ezio Torassa	ezio.torassa@pd.infn.it	Belle II TOP	
INFN-Torino	Roberto Mussa	Roberto.Mussa@to.infn.it	Belle II TOP	
JSI Ljubljana	Rok Pestotnik (task coordinator)	Rok.Pestotnik@ijs.si	LHCb RICH Belle II ARICH	
FBK Trento RTO	Alberto Gola	gola@fbk.eu	SiPM design	
University of Bergen	Gerald Eigen	gerald.eigen@ift.uib.no	AHCAL	many photons
FOTON Nova Paka Industrial	Jaroslav Moravec	moravec@fotons.cz	AHCAL	
FZU Prague	Jiri Kvasnicka	kvas@fzu.cz	AHCAL	

Goals and Objectives

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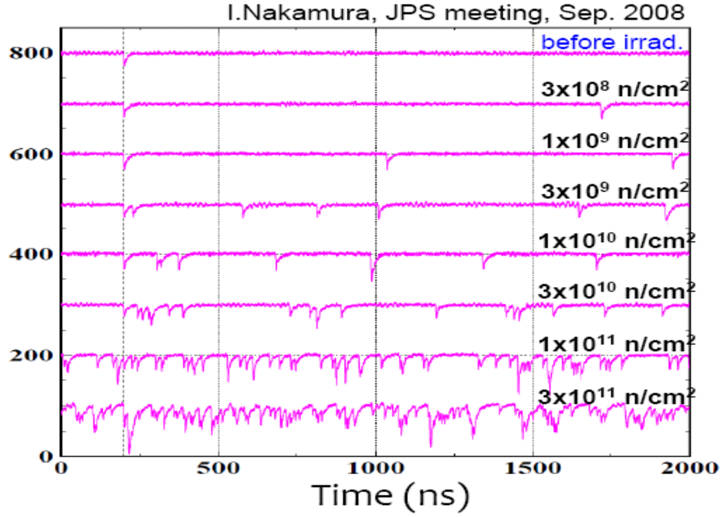
Use of SiPM sensors for a light detection in a new generation of PID detectors

Expected neutron fluence up to 10^{13} neq/cm^2



- ❑ Detection of **single photons** (LHCb RICH, Belle II ARICH + TOP)
  - – Ring Imaging Cherenkov detectors – the use of SiPMs in highly irradiated environments

Improve robustness of SiPMs under neutron irradiation

- – Keep low production cost, high efficiency & good time resolution

- Systematic study of neutron irradiated SiPMs at different temperatures

@ JSI Ljubljana

@ INFN Padova → talk by E.Torrasa

- Beam tests of RICH prototypes with SiPMs @ CERN
- Development of SiPMs with improved radiation resistance @ FBK
- Develop mitigation strategies

- ❑ Detection of **many photons** (CALICE Analog Hadron Calorimeter) @ Bergen, FZU, FOTON
- Multi channel readout and adaptive power supply -→ talk by I. Polak

Milestones & Deliverables

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Milestone MS33, Due Month 18, achieved, Report to StCom → Lead JSI

Definition of SiPM requirements and performance studies with simulations of different use cases.

Deliverable D8.3 **Deadline: 30.11.2024**

Qualification of neutron irradiated SiPMs at different temperatures – Reportv →Lead: JSI

Due to preparation of the clean room delay in the production at FBK : expected Q4 2024

+ time needed for the characterization at labs 6 months

→ move the deliverable for several months or to the end of the AIDAInnova.

Characterisation setup & protocol @JSI

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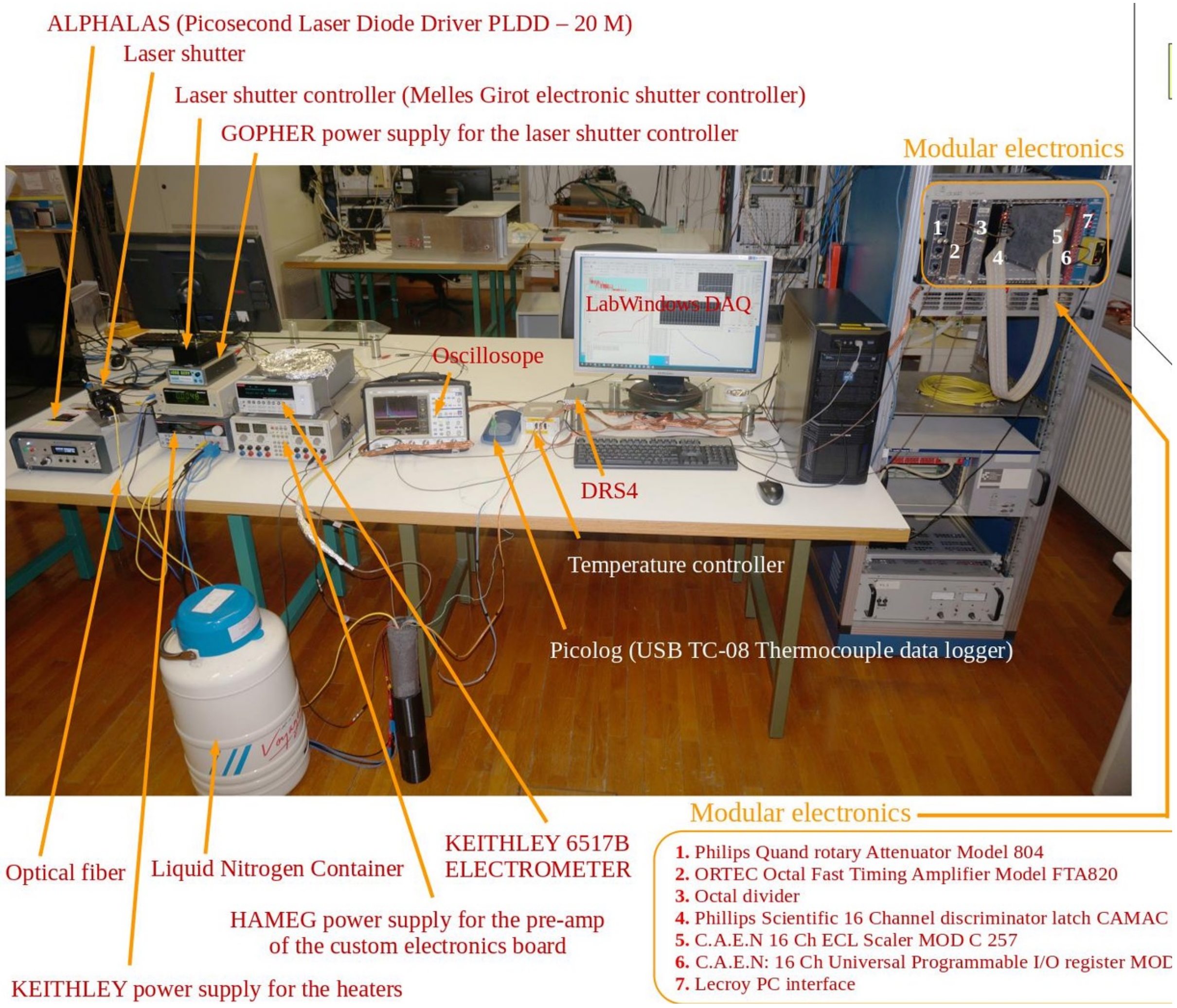
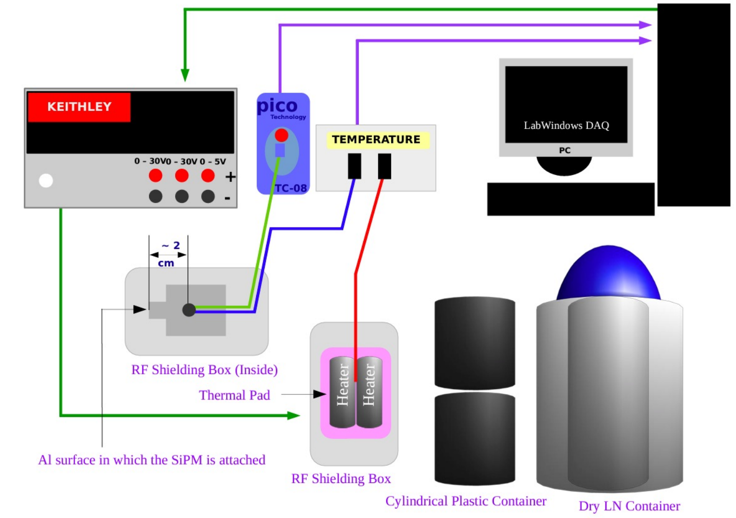
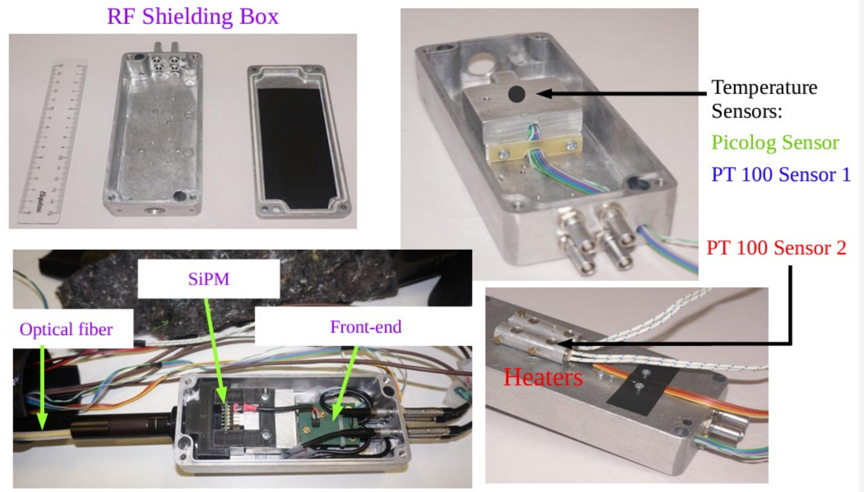
Samples+ electronics enclosed in an insulated box inserted in the cryo- contaeiner and then heated with a resistive heater







Characterisation

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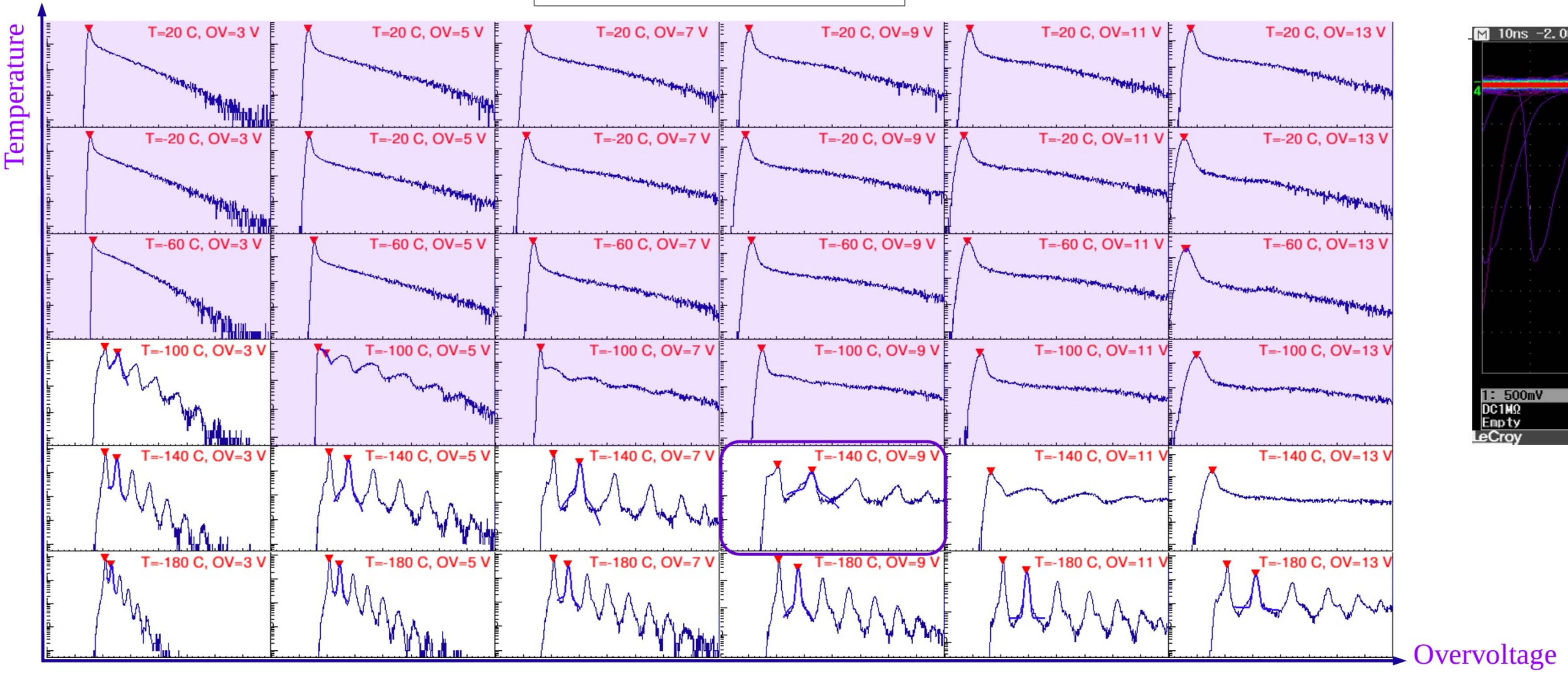
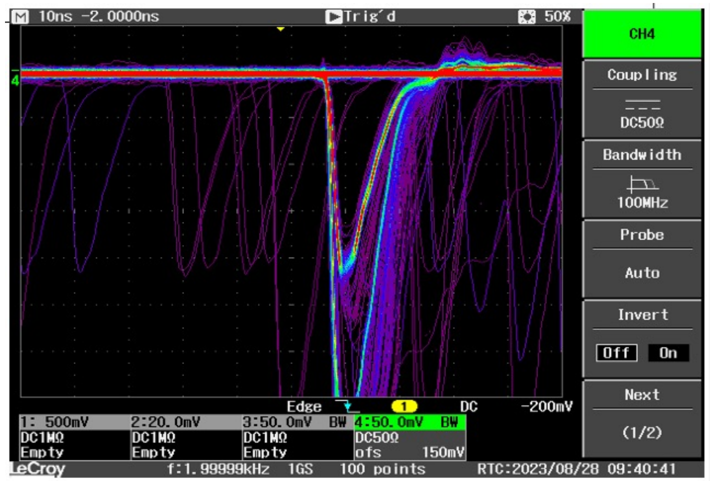
Characterizaton of irradiated SiPMs at different temperatures

- I-V dependance
- Dark Count Rate (DCR)
- Waveform acquisition:
  - Single Photon Time Resolution (SPTR)
  - Pulse height distributions

After Irradiation

QDC, 10^{12} neq/cm^2





stable operation: **Single photons at 9 V Over Voltage can be resolved after irradiation**

Works at -140 ^{0}C

Characterisation of Neutron irradiated SiPMs @JSI

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AidaInnova has received funding from the EU Horizon 2020 RIA programme under Grant No 101004761

Co-funded by Slovenian Research and Innovation Agency project - J1-4358

EU grant n.822070
Jennifer 2 is an MSCA-RISE project funded by EU under grant n.822070

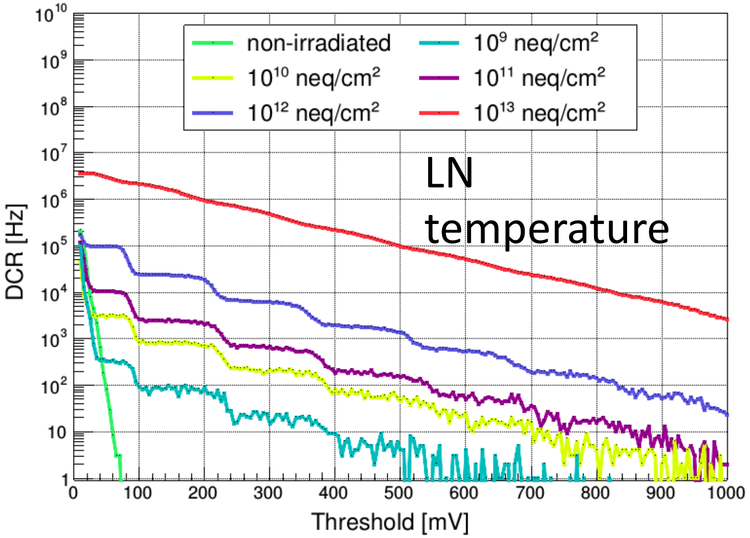
Evaluation of SiPMs :

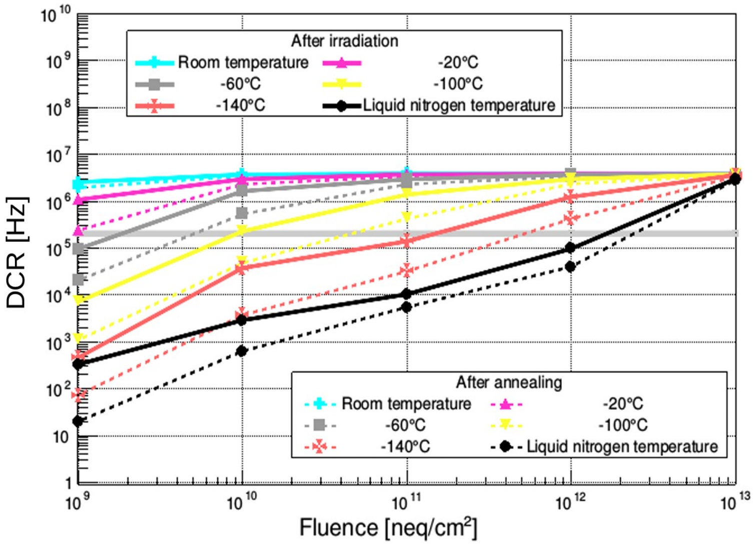
- 1x1 mm2 FBK NUV-HD-RH samples
- **HF high power cryogenic readout**

Irradiated with neutrons : 10^9 … 10^{13} n_{eq}/cm^2 and later annealed at 80 deg. for 24h

Cooled down to -196 deg. in steps of 40 deg.

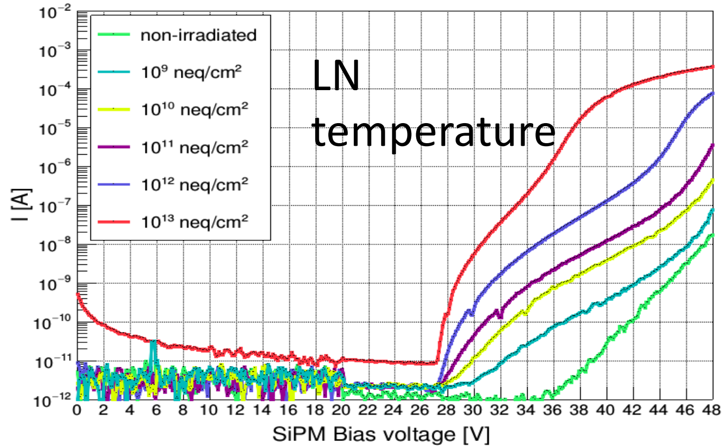
Dark count rate





I-V dependance

Damage visible already at LN



Temperature of stable operation

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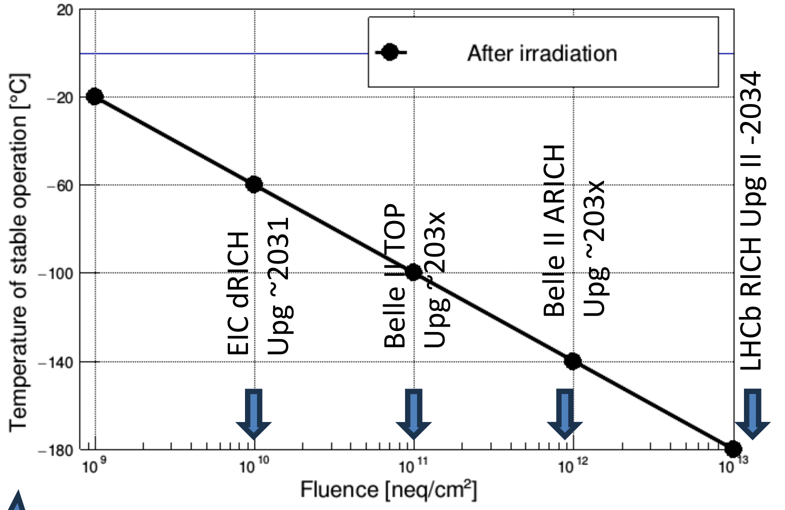
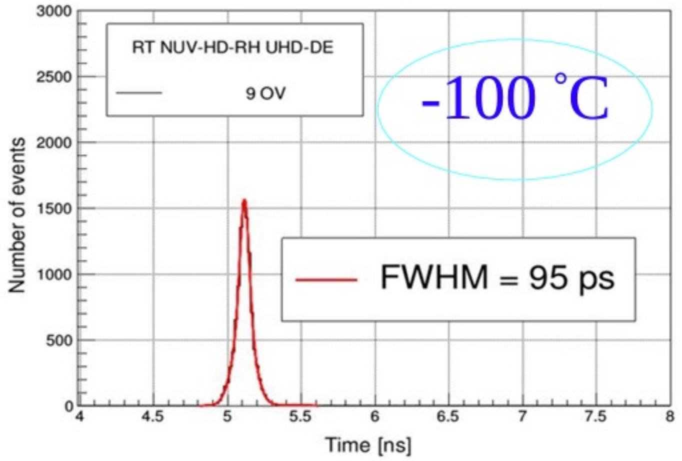
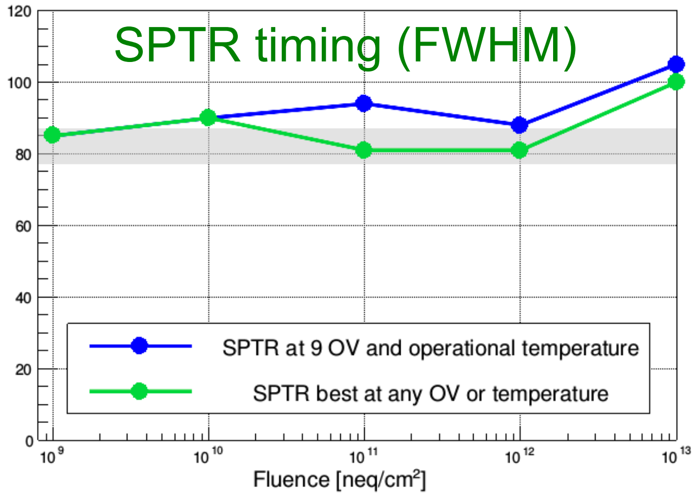
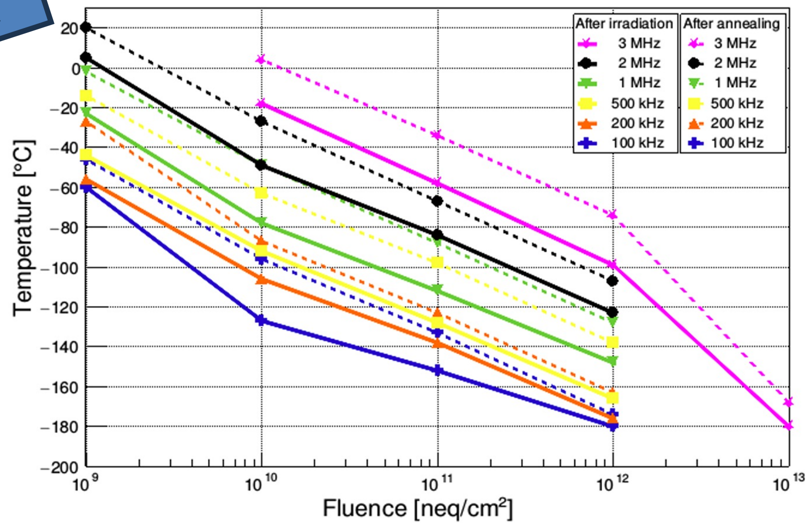
- Temperature at which the SiPM are "usable", i.e. where the single photo electron peak @ 9V Over Voltage is separated from the background.
- Temperature below which the Dark Count rate falls below certain value.
- Depends on the readout electronics









*Paper under preparation

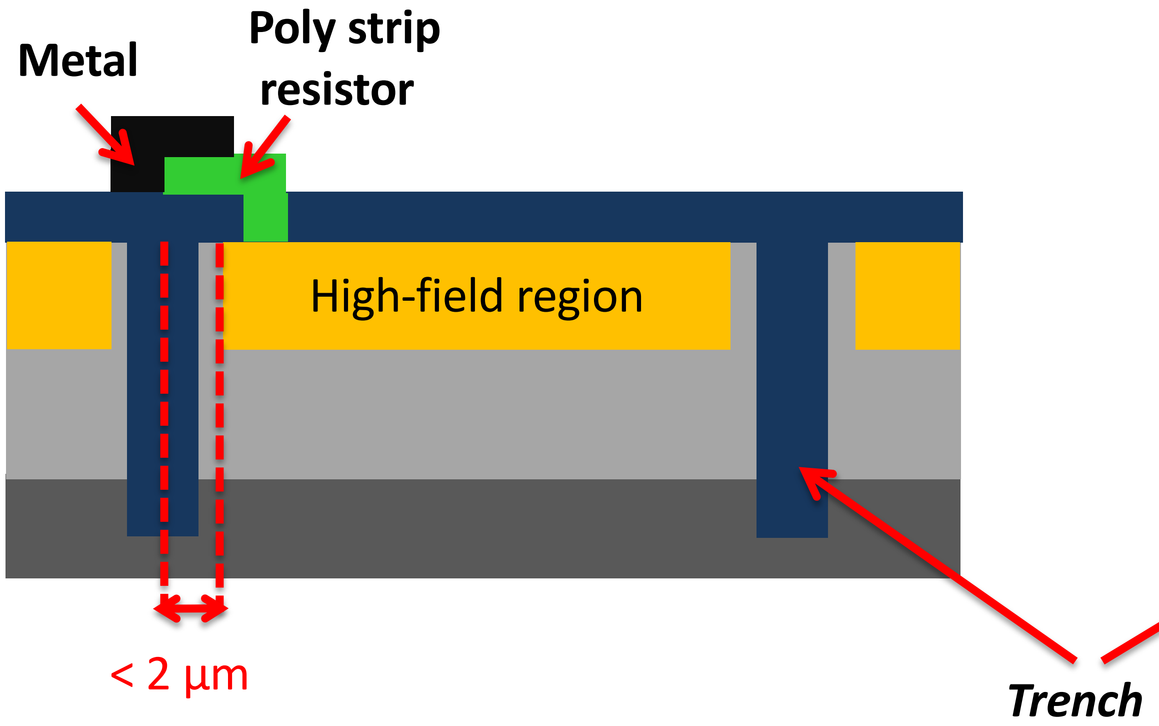
FONDAZIONE BRUNO KESSLER

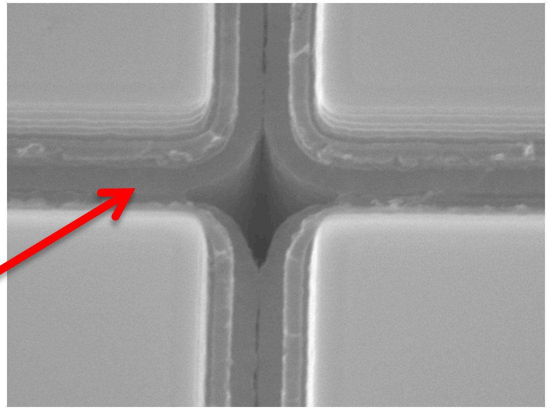
FUTURE BUILT ON KNOWLEDGE

AIDAinnova
Production of new samples at FBK
Layout and splits

NUV-HD for AIDAInnova

Design of new rad hard design with low field is under way –
Production start: Q1 2024, finished Aug, 2024





Trenches between cells filled with highly doped polysilicon as light absorbing material

Sensors **2019**, *19*(2), 308

Advantages:
- Lower cross-talk

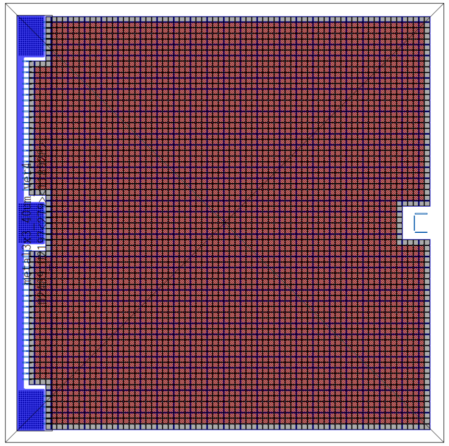
NUV-HD for AIDAInnova

3x3 mm²

2x2 array of 1x1 mm² and mini-SiPM

The test structures will include several different SiPM and pixel sizes

- Aim: timing tests
- Die size: 3.15 mmx3.15mm
- Cell pitch: 15um, 25um, 40um, 75um
- Metal grid
- 3 bonding pads



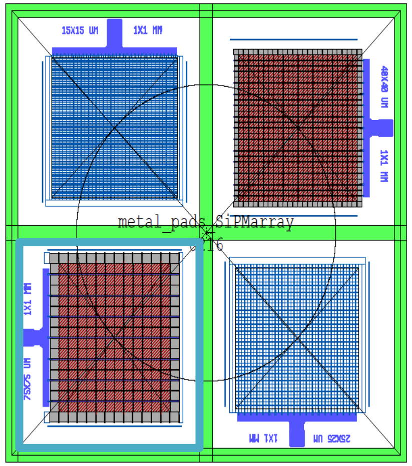
- Die size: 3.15 mmx3.15mm
- Cell size: 15um, 25um, 40um, 75um
- Array of 2x2 with active area:

~ 1x1 mm2, ~ 0.75x0.75 mm2, ~ 0.5x0.5 mm2, ~ 0.25x0.25 mm2

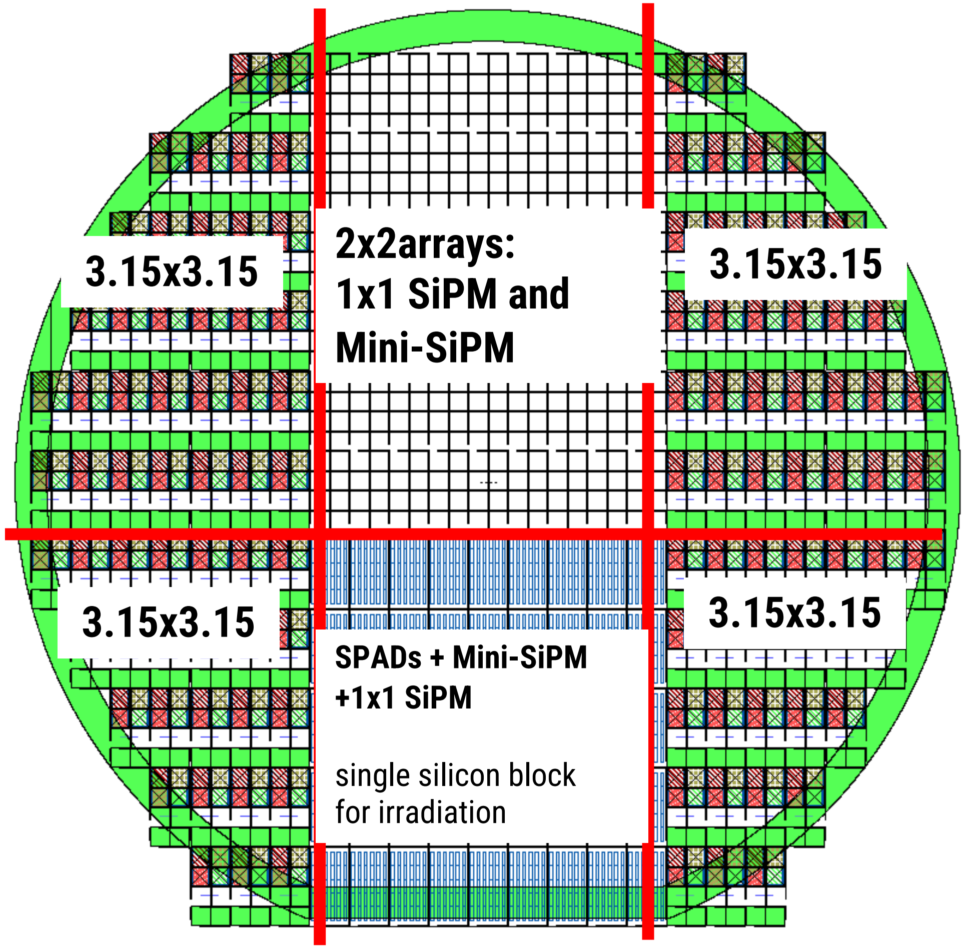
- Same bonding PADs
- Same center of active areas
- The 2x2 array variants can be sub-singulated in 4 individual pieces of 1.57x1.57mm

Variants of 2x2 arrays:

1) 2x2 array of SiPM 1x1mm2 with 15um-25um-40um-75um cell size
2) 2x2 array of SiPM 0.75x0.75mm2 with 15um-25um-40um-75um cell size
3) 2x2 array of SiPM 0.5x0.5mm2 with 15um-25um-40um-75um cell size
4) 2x2 array of SiPM 0.25x0.25mm2 with 15um-25um-40um-75um cell size
5) 2x1 array of SiPM 1.5x1.5mm2 with 15um+25um cell size - (or slightly less, so that they still fit in the 3.15x3.15mm2 die)
6) 2x1 array of SiPM 1.5x1.5mm2 with 40um+75um cell size - (or slightly less, so that they still fit in the 3.15x3.15mm2 die)
7) single SiPM 2x2mm2 with 15um cell size
8) single SiPM 2x2mm2 with 40um cell size



NUV-HD for AIDAInnova
Wafer composition



Chip size 3.15x3.15mm2.
The 2x2 array variants can be sub-singulated in 4 individual pieces of 1.57x1.57mm2

Additional test structures will include a SiPM with isolated SPADs to quantify the distribution of damaged cells and determine the main cause of dark pulses

Characterisation of SiPM and electronics readout for LHCb RICH LS3 enhancements at CERN

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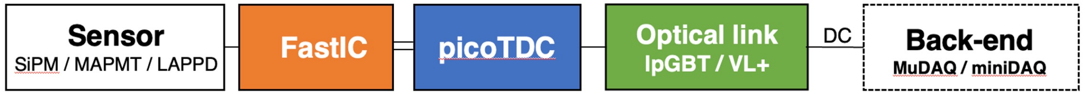
2023 front-end readout chain designed and tested at the CERN SPS testbeam.

- Highly integrated chain of FastIC, picoTDC, lpGBT and VTRX+,
- 25 ps timing resolution,
- 10 Gbps output data throughput.
- coupled to : SiPM, MAPMT and LAPPD.
- Important step for 2024 beam and lab tests

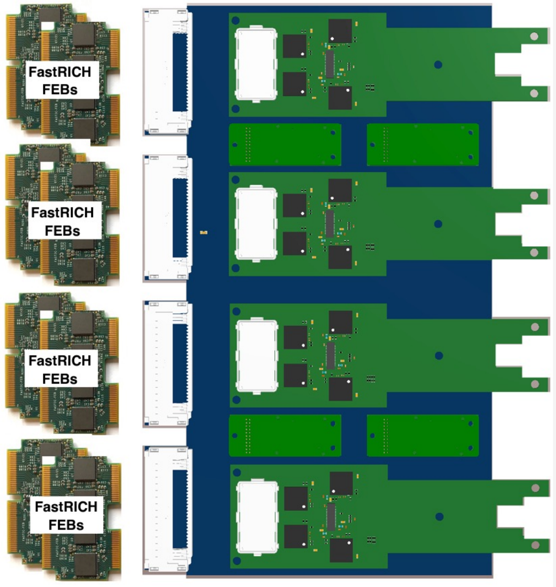


Design of the front-end ASIC FastRICH – production first samples in Q3 2024

Many added features:

- fast-timing,
- improved data throughput and
- radiation hardness.

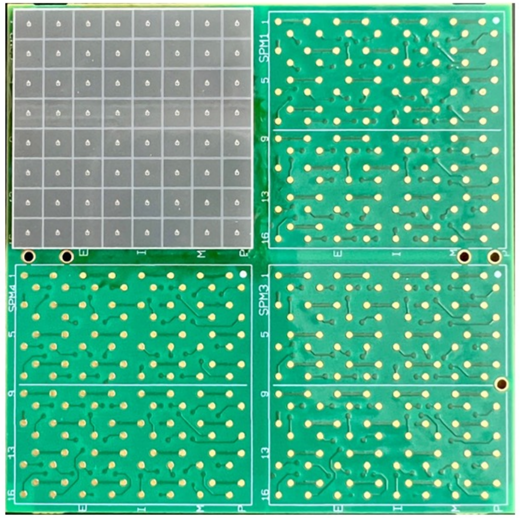
- Time resolution: TDC with ~ 25 ps time bins and ~ 30 ps RMS jitter.
- Power consumption: ~ 8 mW per channel (analogue + digital).
- Radiation hardness: ASIC solution for ~ 2 x 10^{13} n_{eq}/cm^2 and ~ 12 kGy.
- Dynamic range: 30 μA to few mA for coupling to MAPMT / SiPM / MCP.
- LHCb compatibility: direct compatibility with lpGBT / VTRX+ chipset.
- Readout rate: 40 MHz (LHC).
- Number of channels: 16.
- Hardware shutter (configurable) to limit timestamp range to ~ 1 ns.
- Constant-fraction discrimination (CFD).
- Zero-suppressed output, with typically ~ 12 bits per hit.



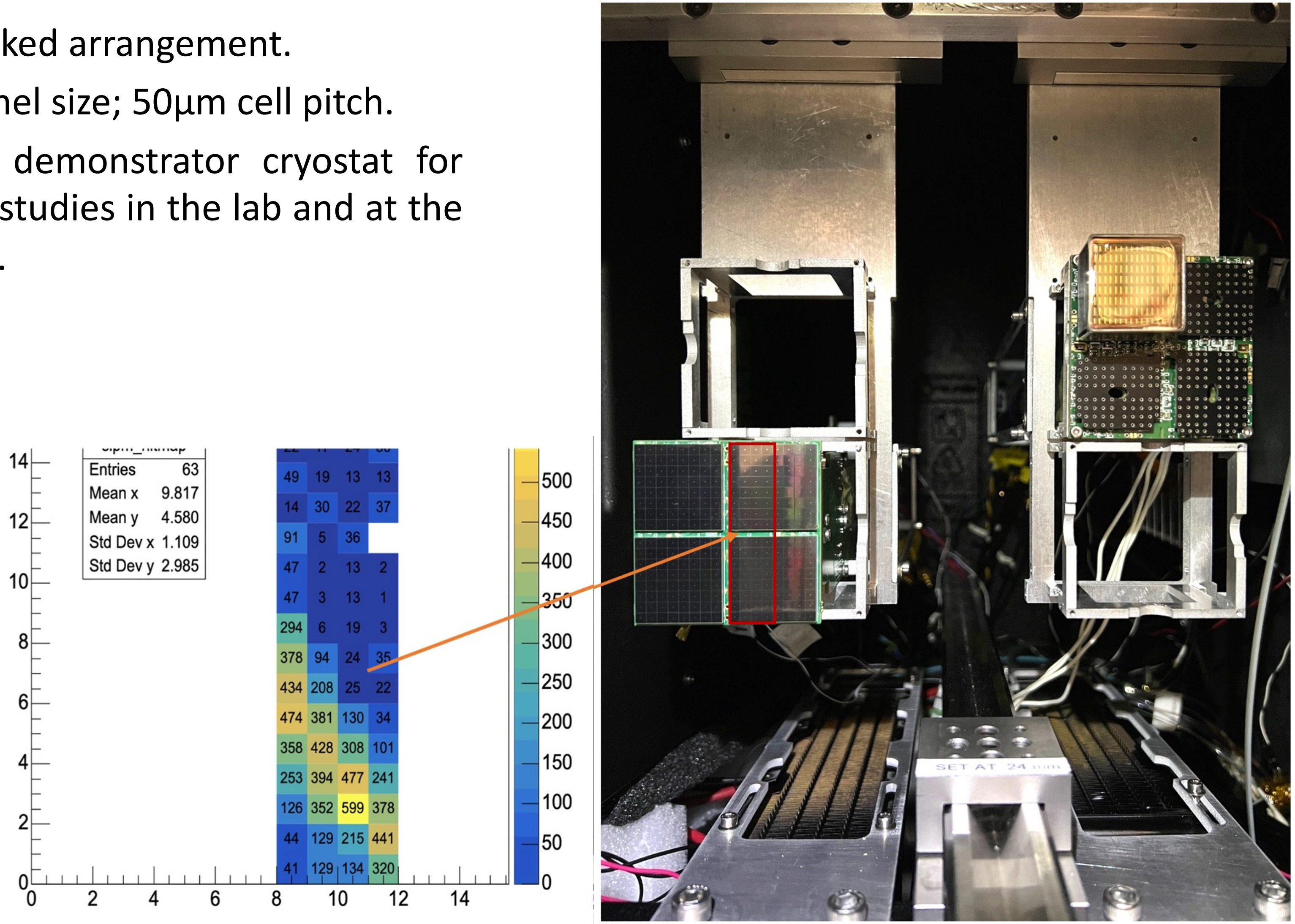
Note: Sketch for illustrative purposes. The numbers and placement of components will be subject to R&D and optimisation.

Studies of SiPM arrays @ CERN

- Studies of SiPM arrays in close-packed arrangement.
- S14161-3050HS-08 - 3.0 mm channel size; 50µm cell pitch.
- Next step: transition towards a demonstrator cryostat for SiPM-based opto-electronic chain studies in the lab and at the SPS beam tests (expected in 2025).



Baseboard design Genova INFN

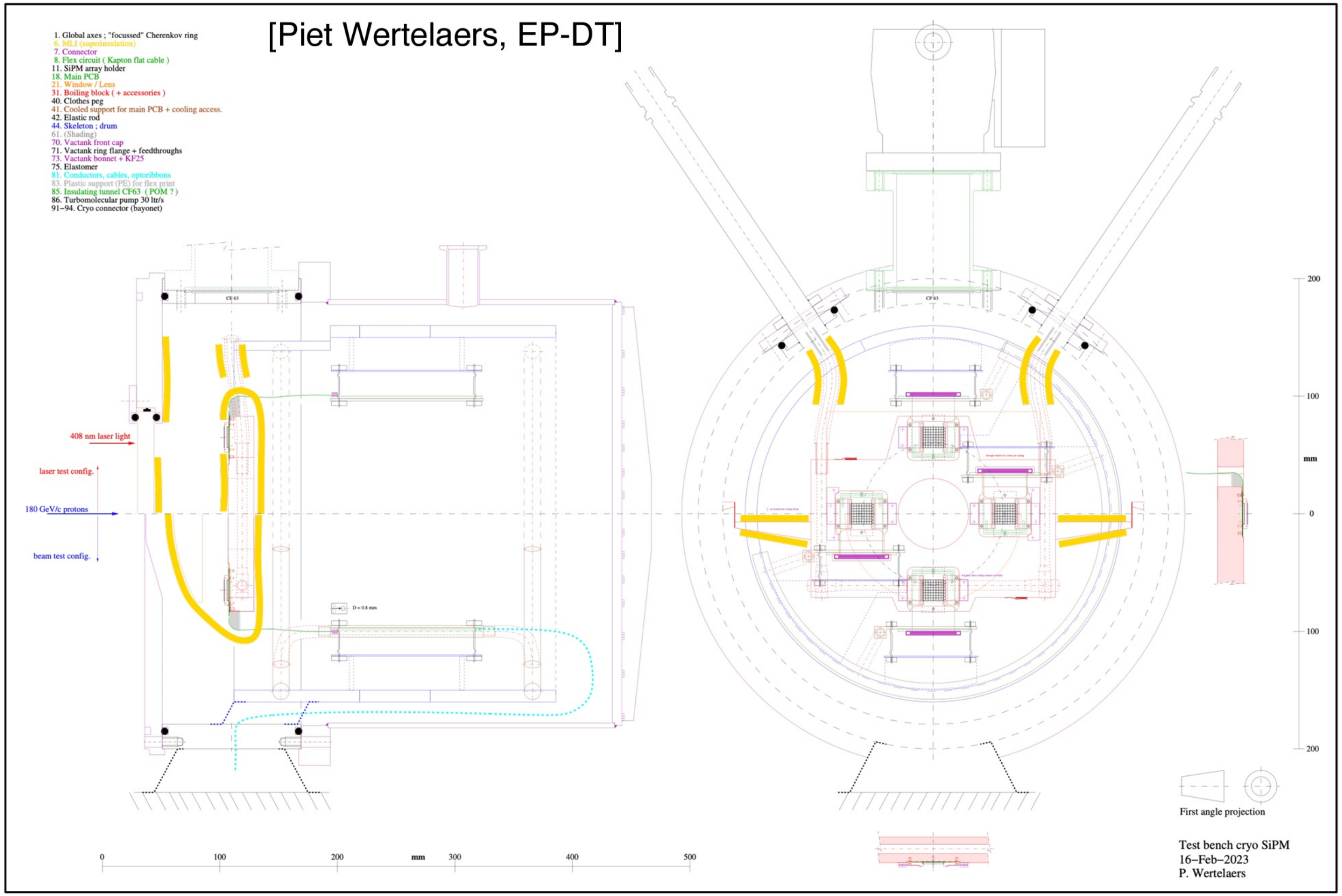


Infrastructure @CERN

Institut "Jožef Stefan", Ljubljana, Slovenija

Design and development:

Test bench design for cryogenic cooling of SiPMs and evaluation o the RICH prototypes with SiPM photo sensors



18.01.24 LHCb RICH Testbeams - F.Keizer

Summary

Different mitigation strategies will be needed to enable the operation of SiPMs in single photon regime in highly irradiated environments:

- Operation at low temperatures
- Operation at lower bias
- Use of macro or micro lenses to collect photons from larger area
- Annealing (by forward biasing?)
- Gating in the electronics to limit the acquisition to a narrow time window

- Temperature of operation impacts the mechanical and opto-electronical design
- New samples will be produced to better understand different performance parameters