1) Radiation Environment and Dosimetry at FCC

- The effect of radiation on installed equipment is a major issue for LHC experiments.
- Dedicated irradiation testing is required prior installation.
- Constant monitoring of radiation fields during LHC operation is necessary to prevent failures.

2) Irradiation facilities at CERN

- For the characterization in a radiation environment of systems, components, and materials, a complex infrastructure of irradiation facilities is available at CERN.
- During LS1 (2013-2014), many upgrades were performed to fulfill HL-LHC testing requirements, and a similar upgrade will be needed as discussed in the table:

3) Ultra High Fluence Monitor - RDR

- We have focused our research in the design, production and irradiation tests on a novel dosimeter structure targeting Ultra High Fluence Monitoring.
- The proposed sensor, here called Radiation Dependence RDR (RDR) is made of manufacturing and consecutive lithography of thin layers of metals into “serpentine shaped” resistive structures.
- Metals are known to show resistivity variation proportional to fluence due to generation of defects in form of vacancies, interstitials, and also, at higher fluence, of voids and bubbles [316].
- Our work is to prove that the sensitivity to radiation of metal structures can be trimmed and controlled by micro-fabricating µm-thick devices using thin film technology.
- Five wafers were produced with Aluminium, Copper and Chromium, of 500 nm and 1 µm thicknesses.
- Fabrication fully carried out at CMI Centre of Micronanotechnology of EPFL with standard lithography techniques.

4) Irradiation Test with Neutrons

- Several RDRs were measured using a proton beam and selected for this active and passive test.
- Ten PBR sensors were wire-bonded on two FCC-RADMON PCBs for the active test:
  - For each PBR: two Aluminium and two Copper RDRs of 500 nm and 1 µm thicknesses on 500 nm Chromium sample.
  - Each RDR was connected with 4 wires to enable a Kelvin measurement.
- A Ravel-Free substrate was used for the FCC-RADMON to avoid degradation problems at high fluence (fully described in [5] in CLIC.
- The test-bench was assembled using a Kieffer 2410 SMU and an Agilent 34970A switch matrix, controlled via LabVIEW.

5) Results and Discussion

- This irradiation campaign was performed at the TRIGA Reactor of the Joliot-Curie Laboratory in Ljubljana, partially funded by the AIDA-2020 Transnational Access Program.
- During 5 days of reactor time (about 40 h of irradiation), it was possible to obtain a neutron flux of $10^{16}$ n/cm$^2$ for the active samples and $10^{17}$ n/cm$^2$ for the passive ones.
- While all the devices have presented an increase in R due to the increasing neutron flux, only two of the Copper samples (in pink and red) have not shown a big annealing after irradiation, thus integrating a fluence up to $10^{17}$ n/cm$^2$ before experiencing a failure.
- The increased permanent damage of the Copper samples may be explained by the fact that:
  - Copper has the greatest cross section for thermal neutrons ($\sigma_\text{th} = 3.8 \cdot 10^{-24}$ barns/atom) and it is the main source of damage in LHC.
  - Copper (and Al) is face-centered cubic fcc crystal, where the production efficiency of defects is greater, with C is a body-centered cubic fcc [8].

6) Future Work

- Temperature characterization of the irradiated structures, to correct the raw data presented in this poster.
- Further irradiation tests are being scheduled in the CERN Proton Facility IRRAD.
- An online irradiation of two FCC-RADMON in a mixed-field environment is ongoing in the Neutral Beam Absorbers in LHC IP1.
- The study and development of an Ultra High Dose Monitor based on thin-xide and its readout system will soon start.