Upgrade of the Belle II ARICH detector

**Motivation:** Proximity focusing Aerogel RICH at Belle II

- **Aerogel RICH currently identifies charged particles in the Belle II spectrometer. Cherenkov photons, emitted in the aerogel radiator are detected by single-photon Hybrid Avalanche Photomultipliers (HAPMs) and combining an area of 4.5 m².** By 2020 the Belle II will reach its design goal of 50 ab⁻¹ and the HAPM performance will degrade.

- The upgrade of the spectrometer to extend its operation will thus require replacement of the ARICH photo-sensors. Silicon photomultipliers are one of the candidates. Due to its sizeable dark count rates and their sensitivity to neutrons — we expect fluctuations of up to 5x10⁻¹⁴ m² — such a device requires to read out the signals in a narrow time window of several ns, requiring optimized SiPM design and high integration with the read-out electronics.

**Experimental setup**

- **Irradiated samples**
  - Irradiation at TRIGA nuclear reactor at Jožef Stefan Institute, Ljubljana
  - Fluence: 1.6x10²¹ n/cm²

**Use of irradiated SiPMs at room temperature very challenging.**

In the context of EC Horizon 2020 AADAmoos innovation pilot we are studying the SiPMs with improved radiation resistance.

- **Objectives we are addressing:**
  - SiPM design: Review the production process, change of the design and production
  - Reduction of a cross-talk and after-pulses
  - Use of smaller area SiPMs
  - Integration of the readout electronics with the sensor:
    - TSV interconnects with the ASIC
    - Signal Processing in the front end
  - light collection:
    - Focus light from e.g. 3x3mm² to 1x1mm²
  - Recovery of the operation at lower temperatures — annealing

**Tests at Liquid Nitrogen**

- **T=196 °C**

**SiPM very attractive sensor**

- Its use can be used to extend ARICH capabilities for low momentum region

**Light collection**

- **FASTC current mode ASIC**
  - **8 Inputs:** 2 Single Ended (positive or negative) or 4 differential.
  - 4/8 Outputs: CMOS, LVDS and Analog
  - Summation in clusters of 4 channels.
  - Energy: Linear Time over Threshold with high dynamic range.
  - Different trigger levels and cluster trigger for monolithic crystals.

**Silicon photomultipliers**

- **Advantages:**
  - low operation voltage: 10-100 V
  - gain: up to 10⁸
  - peak PDE up to 65% (@400nm)
  - PDE = QE x e⁻μ x τ
  - τ — decay time between the cells
  - μ — Geiger discharge probability
  - intrinsic time resolution ~100ps
  - can be combined in larger modules in contrary to PMT
  - it works in the magnetic field

- **Disadvantages:**
  - dark counts ~ few 100Hz/mm²
  - radiation damage (uJ)

**Experimental setup**

- **Probe station to measure:**
  - IV-curves
  - Waveform acquisition with DB54
  - DCR with Ni-Counter
  - Temperature controlled sample
  - Peltier with water cooling

**Current mode input**

- **Differential channels**
  - **SE channels w input**
  - **READOUT**

**SiPM 1x1mm² + light guide**

**This work focuses on the use of silicon photomultipliers as a photon detector.**