New Beam Position Detectors for NA61/SHINE experiment

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Objectives

- The NA61/SHINE experiment at the CERN SPS is undergoing a major upgrade during the LHC Long Shutdown 2 period (2019-2021). The upgrade is essential to fulfill the requirements of the new open charm and neutrino programs. In these programs the NA61/SHINE will operate with the data acquisition rate increased by a factor of 10, which requires an upgrade of current Beam Position Detectors (BPDs). New BPDs should monitor beam particle positions with a frequency up to $\mathbf{10^5}Hz$.

Introduction

- NA61/SHINE is a fixed-target experiment located in the H2 beam line in the North Area of the CERN Super Proton Synchrotron (SPS). The multi-purpose detector is optimized to study hadron production in hadron-proton, hadron-nucleus and nucleus-nucleus collisions.
- The main purpose of beam position detectors is measurement of beam particle trajectory on event-by-event basis (particle-by-particle). New BPDs should monitor lead and proton beams at $\mathbf{13}A - \mathbf{150}AGeV/c$ momentum with rates up to $\mathbf{10^5}Hz$and operate in vacuum.

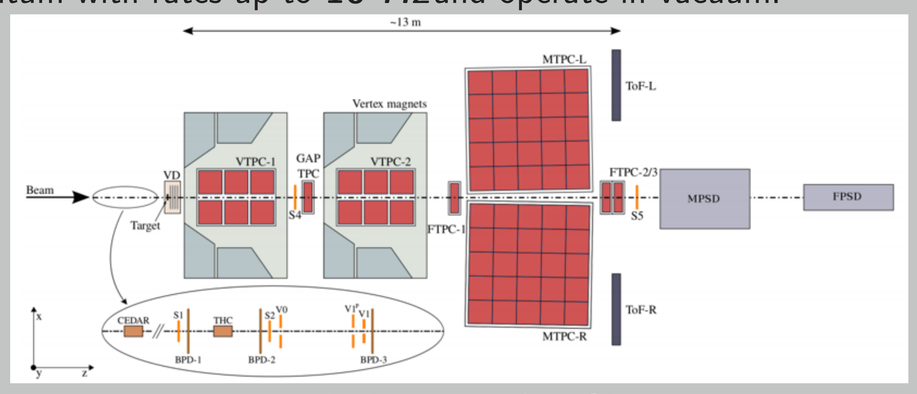

Figure: NA61 scheme after LS2 upgrades

Beam Position Detector requirements

- Detector should work with p and Pb beams
- The planned beam intensity is on the level of 100 kHz of Pb or p ions at momentum $\mathbf{13}A - \mathbf{150}AGeV/c$
- For this purpose detector should be able to determine without doubts the position in X and Y plane of each beam particle (probability of pileup should be minimised)
- The accuracy of the position measurement is expected to be on the level of $\mathbf{250}\mu m$
- Detector should be installed in the vacuum $\mathbf{10^{-3}}mbar$
- Material on the beam line should be minimised

Overall design

- Trajectory of the beam in NA61/SHINE is measured by a telescope, consisting out of 3 separate detectors with two sensitive elements each, together providing 2-coordinate determination of the particle hit position at 3 positions on the beam, along 25 meters downstream from the target.
- A Hamamatsu S13804 silicon strip detector has been chosen
  - The only off-the-shelf component meeting the spacial resolution criteria
  - 9x9 cm Silicon wafer with 1024 diodes etched into it
  - Only the 200 inner ones are planned to be used.
  - Such detectors have been already used for similar task at BM@N, LHC, J-PARC and other experiments

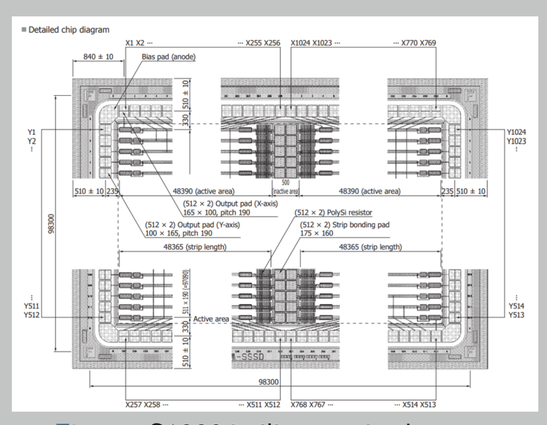

Figure: S13804 silicon strip detector

- Strip detector is connected to a front-end charge-sensitive amplifier with a differential output, which transmits pulses to an ADC through HDMI cables.

Mechanical design

- For mounting the detector, a special fixture has been developed. It consists out of:
  - A vacuum-sealed cap with two electrical feed-troughs with 104 channels each
  - An aluminium backplate mounted with optical brackets to ensure the detector position
  - A flexible PCB with the detector glued and bonded to it
- Each of the 3 detectors will be fitted with two such fixtures, mounted perpendicularly
- On the atmosphere side of the detector, two PCBs with the front-end electronics will be mounted, each consisting out of a motherboard and a mezzanine board, together carrying 100 discrete amplifiers

Figure: Mechanical fixture assembled

Electronics design

- Front-end amplifiers are implemented with discrete components, simplifying and lowering the cost of production (a.e. no ASICs are used)
- Each amplifier consists out of a charge-sensitive front-end, an intermediate amplifier and on output differential line driver
- Each amplifier provides its own power regulation through a linear stabilizer
- Output signal is transmitted through HDMI cables to a differential-to-singe-ended converter connected to an ADC
- Front-end electronics are implemented with a scale-changing feature, allowing operation on both proton and heavy ion beams without altering the setup.

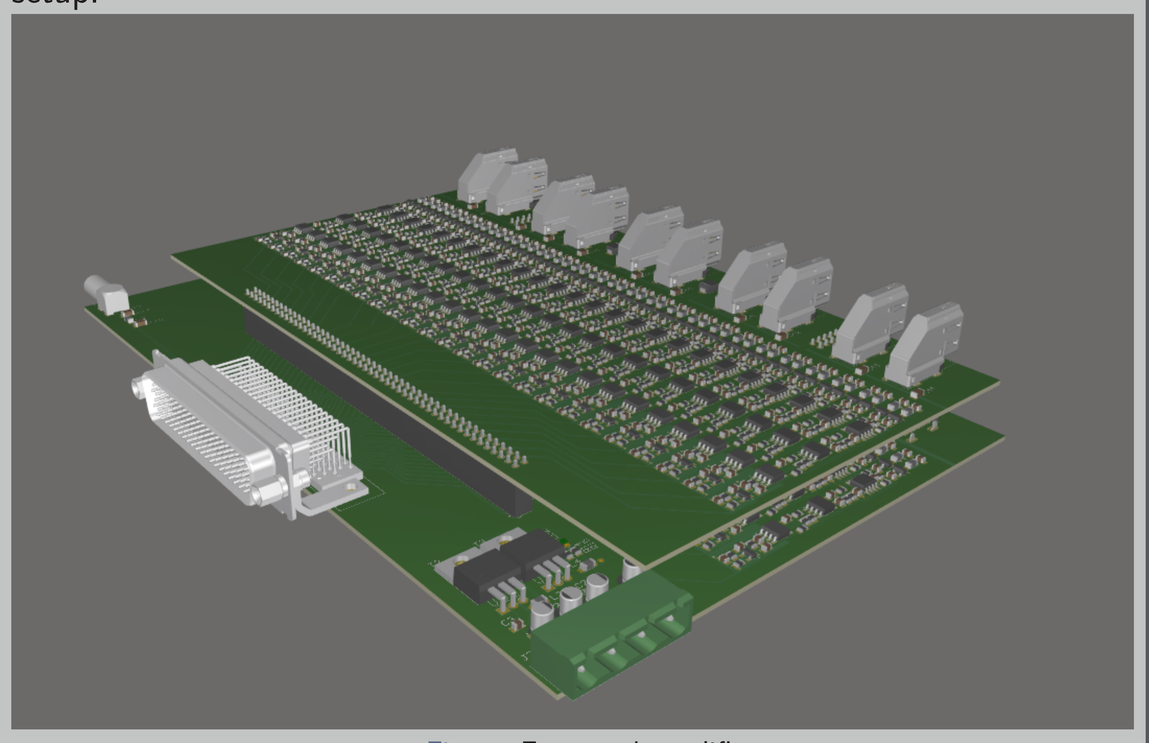

Figure: Front-end amplifiers

- Amplifier functionality has been tested with both a one-channel prototype and a multichannel assembly

Conclusion

- Development of the new Silicon Strip BPD, which will be able to operate with beam intensities up to $\mathbf{10^5}Hz$ is presented. At the moment, mechanical design and electronics design are completed.

Acknowledgements

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