Self-Triggering Readout System for the Neutron Lifetime Experiment PENeLOPE

D. Gaisbauer[a],
F. J. Hartmann[a], I. Konorov[a], S. Paul[a],
R. Picker[b], W. Schreyer[a], D. Steffen[c], R. Stoepler[a], C. Tietze[a]

(a) Technische Universität München, Germany
(b) TRIUMF, Vancouver, Canada
(c) CERN, Genève, Switzerland

SLOW NEUTRONS
DFG SPP 1491
Precision experiments in particle- and astrophysics with cold and ultracold neutrons

MLL

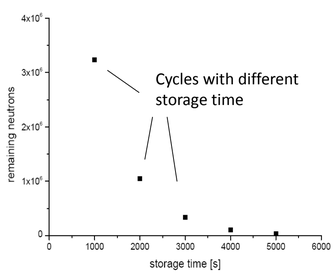
LMU Excellence Cluster Universe

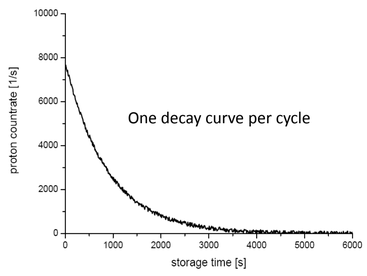
Project Description

Ultra-Cold Neutrons (UCN)
- kinetic energy below 300 neV

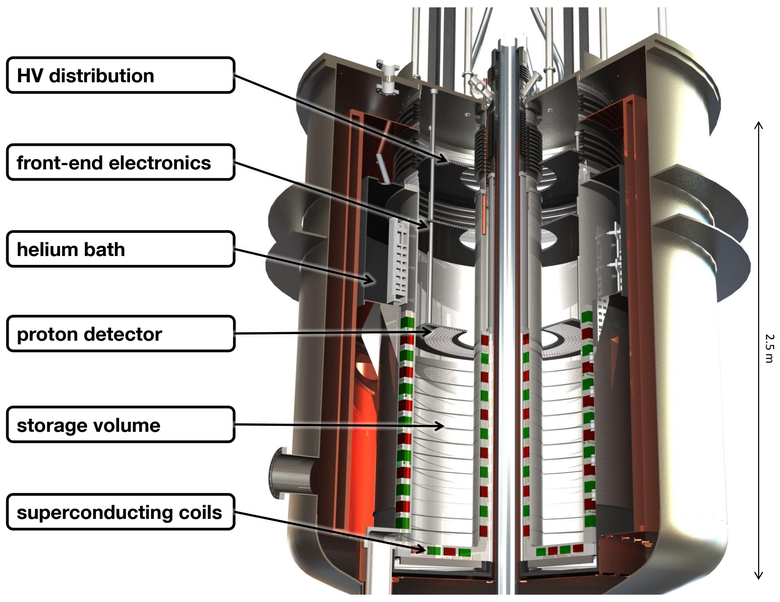
Basic Principles of PENeLOPE
- lossless storage of UCN in magneto-gravitational trap
- neutron lifetime derived from neutron and proton counting
- aspired precision 0.1 s

Proton Detection
- charged decay particle extraction and detection
- extraction efficiency 69% (protons) and 37% (electrons)





PENeLOPE



Detector Requirements

Energy of Protons
- 30 keV

High Voltage Environment
- detector and electronics on -30 kV

Magnetic Field Environment
- 0.6 T

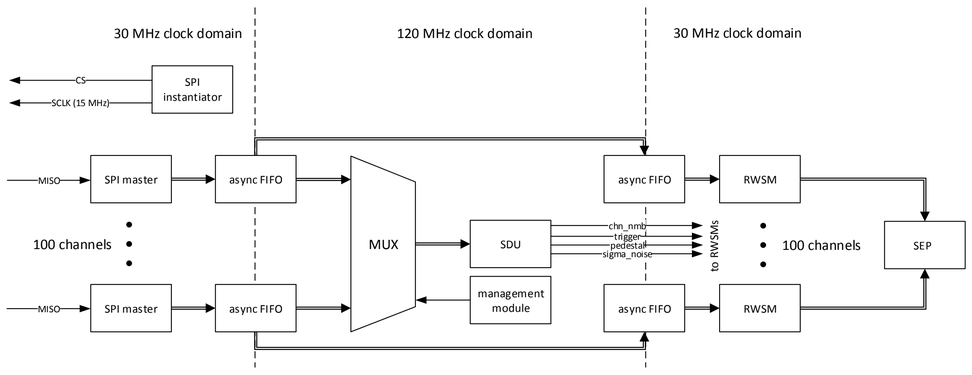
Low Temperature
- 77 Kelvin
- low heat input

Vacuum Compatibility
- 10^{-8} mbar
- low outgassing

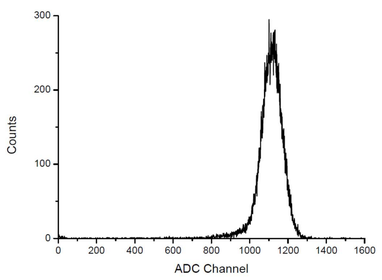
Large Area
- 0.23 m²

PENeLOPE Proton Detector Readout

Signal Detection Unit (SDU)
- Xilinx Spartan 6 LX150T
- detects events and formats the signals provided by the ADCs
- 1 MHz sampling rate
- “Real-time” pedestal calculation
- calculating sigma noise over N_{avg} samples
- signal detection: specified number of consecutive samples must be greater than pedestal + $x_f \cdot \sigma$
- trigger threshold configurable

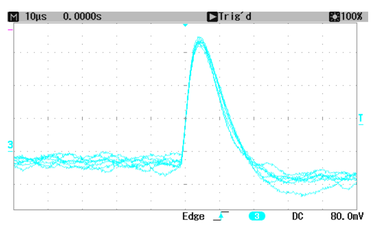


Preamplifier, Shaper and ADC
- Analog Devices AD8011 used as preamplifier and shaper
- ADC card for 24 channels each using Analog Devices AD7450
- 4 ADC cards per SDU

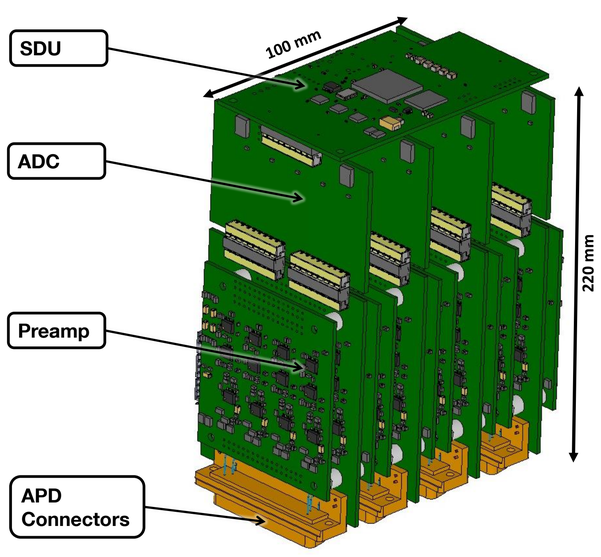


Proton spectrum collected with ADC

APD Proton Detector
- approx. 1200 APDs with active area of 7x14 mm² each
- cooled by liquid nitrogen to 77 K

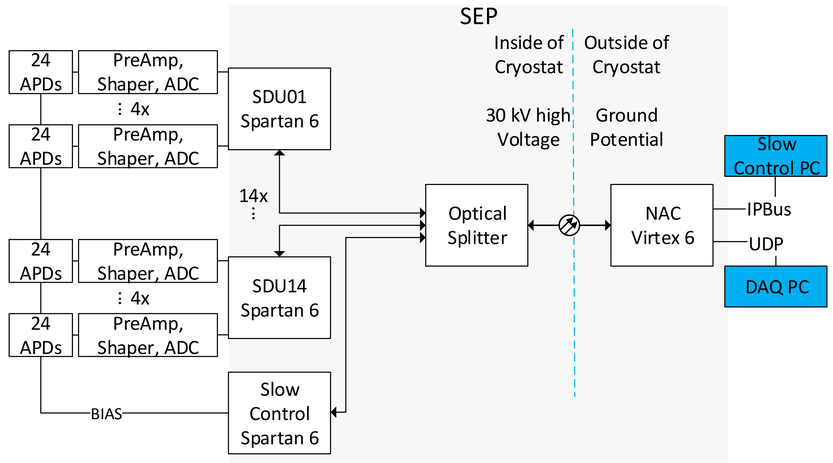


Proton signal before ADC



Full readout stack for 96 Channels

Complete Readout Scheme
- 14 SDU blocks with each 96 channels
- 96 channels divided to four ADC boards holding 24 channels each
- 1:16 optical splitter
- slow control card controlling the bias of the APDs
- all electronics inside the cryostat on - 30 kV
- Network Acces Controller (NAC) outside of cryostat to further process data and establish connection to PCs



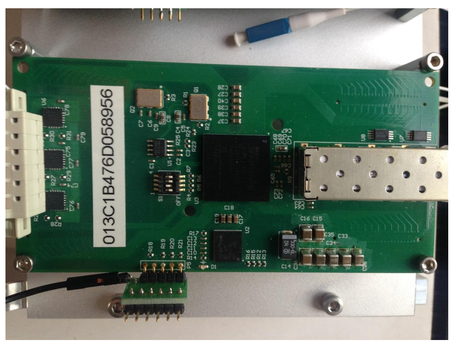
Switched Enabling Protocol

Switched Enabling Protocol (SEP)
- time-division multiplexing transport layer protocol
- star like optical network (1:n)
- readout in Round-Robin manner
- 98% link utilization efficiency for PENeLOPE

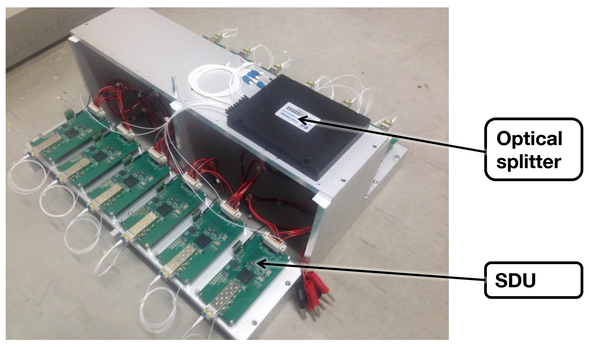
Higher level protocols
- data transmission
- IPBus (control of complete DAQ electronics)
- time distribution
- JTAG interface

Transmission Time [µs]	Efficiency [%]
25000	99,93
10000	99,84
1000	98,42
500	96,90
100	86,20

Total link utilization efficiency of SEP for different times a slave can transmit data



Close up photo of a SDU card



Picture of test set-up for all SDU cards

Outlook

Switched Enabling Protocol (SEP)
- further extensive test phase including performance, usability and stability
- extending the protocol to a multipurpose framework

PENeLOPE
- integrating hardware and software into a fully functional test set-up of the proton detector
- development of the slow control software

Related Talks

Talk by Dominik Steffen (CERN) on Thursday 14:50 in Sala 02.1: “Overview and Future Developments of the FPGA-based DAQ of COMPASS”