Low Energy Proton Detector for the PENeLOPE Experiment

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

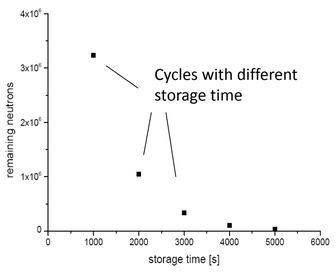
Excellence Cluster Universe

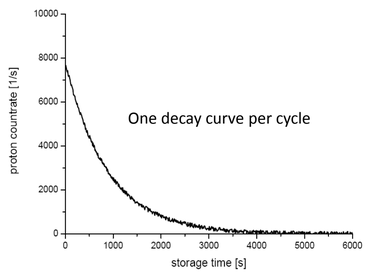
Project Description

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

PENeLOPE
– **P**recision **E**xperiment on **Ne**utron **L**ifetime **O**perating with **P**roton **E**xtraction
– 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)





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

Frontend Communication

Switched Enabling Protocol (SEP)
– time-division multiplexing transport layer protocol
– star like optical network (1:n) or point to point connection (1:1)
– readout in Round-Robin manner
– determined latency for time critical messages
– 98% link utilization efficiency for PENeLOPE

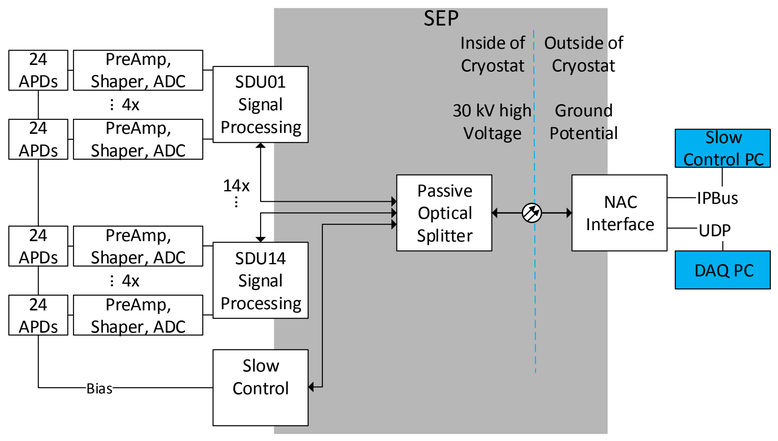
Higher level protocols
– data transmission
– IPBus (control of complete DAQ electronics)
– time distribution
– JTAG interface

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

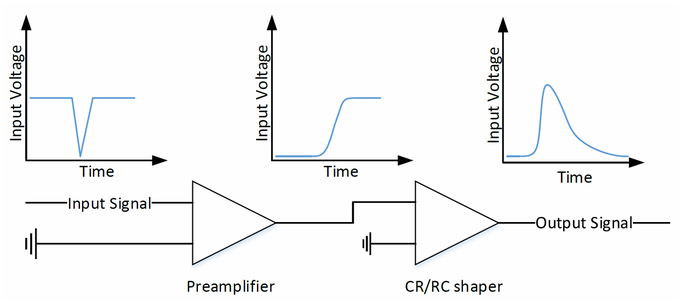
Total link utilization efficiency of SEP for different times a slave can transmit data

PENeLOPE Proton Detector Readout

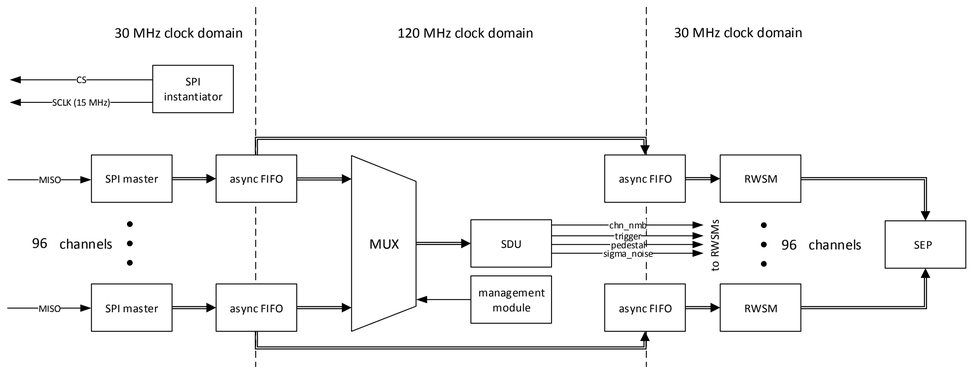
Complete Readout Scheme
– 14 SDU blocks with each 96 channels
– 1:16 passive optical splitter
– slow control card controlling the bias of the APDs
– all electronics inside the cryostat on - 30 kV
– Network Acces Controller (NAC) outside of cryostat to further process data and establish connection to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



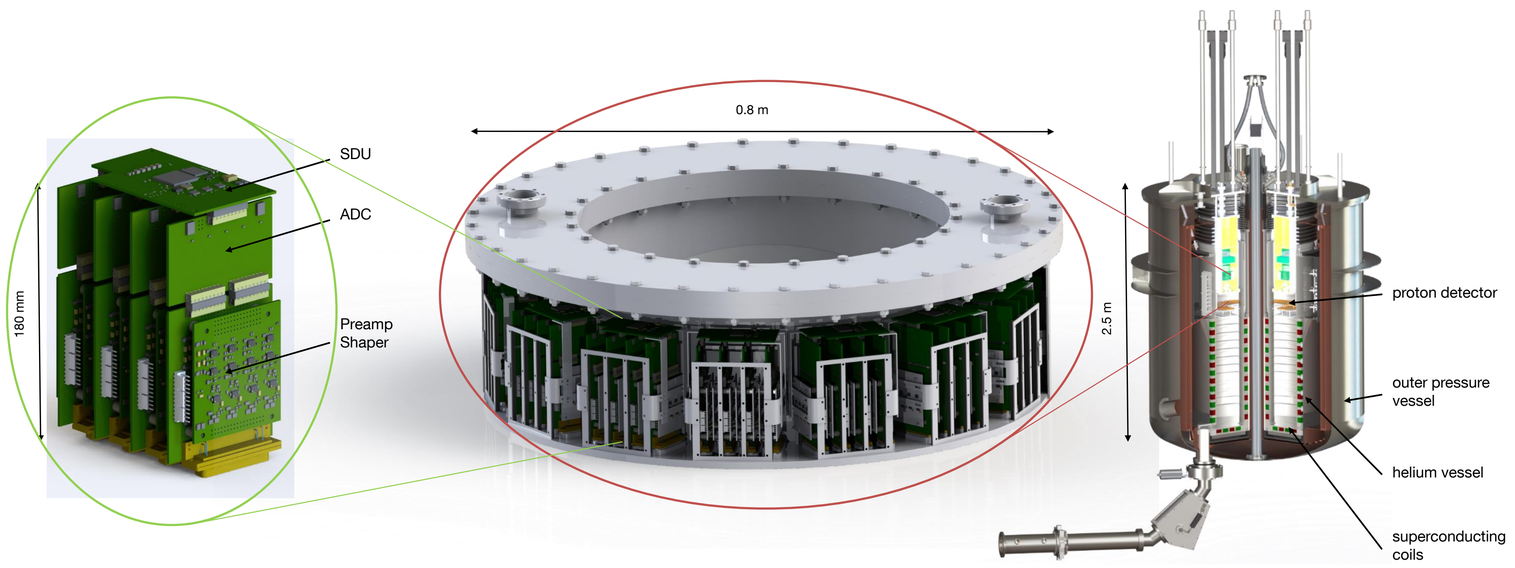
Avalanche Photodiodes
– Hamamatsu S11048
– 6.8 x 14 mm² active area
– 9 x 18 mm² size
– terminal capacitance of 220 pF
– no epoxy cover
– operational voltage of 240 to 270 V
– liquid nitrogen cooled to 77 K



Preamplifier, Shaper and ADC
– CR/RC shaper architecture with 1 µs time constant
– long time constant possible due to low trigger rate
– ADC card for 24 channels each using a 12 bit SAR ADC

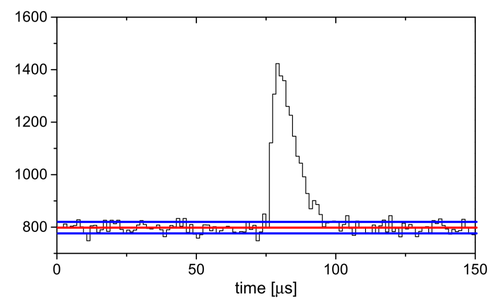


Signal Detection Unit (SDU)
– 1 MHz sampling rate
– Xilinx Spartan 6 LX150T
– detects events and formats the signals provided by the ADCs



Trigger Algorithm

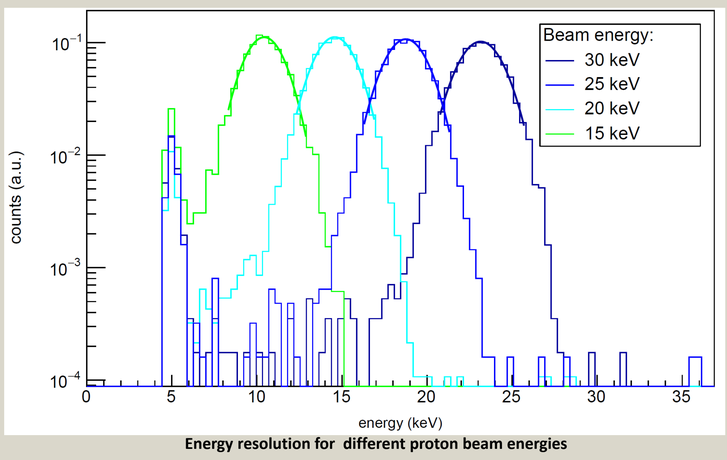
FPGA Signal Detection Algorithm
– "Real-time" pedestal calculation: Averaging over N_{avg} samples
– calculating sigma noise over N_{avg} samples: calculating quadratic deviation from mean value
– signal detection: If n_s consecutive samples > pedestal $+ x_f \cdot \sigma$
– trigger threshold configurable to exactly defined signal/noise ratio
– each channel is treated by itself



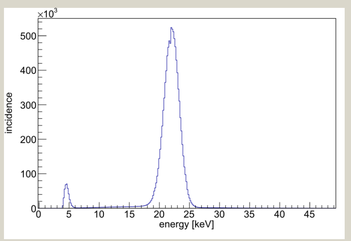
Proton signal with pedestal (red) and plus/minus sigma (blue)

Test Results

Beam results
– proton beam test at the paff accelerator
– 1.29 keV energy resolution at 300 K
– usable with proton energies downto about 15 keV



Energy resolution for different proton beam energies



30 keV proton event

Picture of the test set-up with 12 SDUs and 1 NAC