Silicon Photomultipliers and light readout for the Demonstrator of the ENUBET instrumented decay tunnel

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on behalf of the NP06/ENUBET Collaboration

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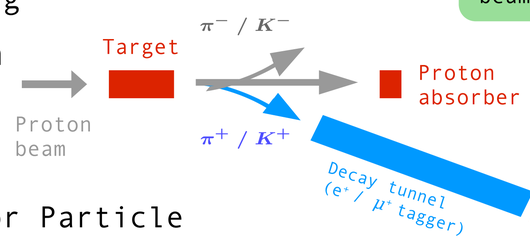
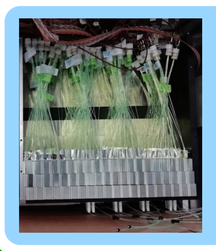
NP06/ENUBET OVERVIEW

NP06: CERN Neutrino Platform experiment number 6
ENUBET: Enhanced NeUtrino BEams from Kaon Tagging

GOAL: developing a new narrow-band neutrino beam in which the flux and flavor composition are known at 1% level, and the energy with O(10%) precision.

MOTIVATION supported by the European Strategy for Particle Physics Deliberation document (page 5):
"To extract the most physics from DUNE and Hyper-Kamiokande, a complementary programme of experimentation to determine neutrino cross-sections and fluxes is required. [...]. The possible implementation and impact of a facility to measure neutrino cross-sections at the percent level should continue to be studied."





Shashlik to lateral readout design migration for attenuating SiPM radiation damage. Hadronic cal + γveto prototype beam exposure at CERN-PS

Start of ERC grant & initial shashlik design beam exposure at CERN-PS

Systematics budget finalization & demonstrator construction

1979 | 2016 | 2017 | 2018 | 2019 | 2021 | 2022

SiPM irradiation campaign at INFN-LNL and beam exposure of irradiated sensors at CERN-PS

Demonstrator beam exposure at CERN-SPS & conceptual design report

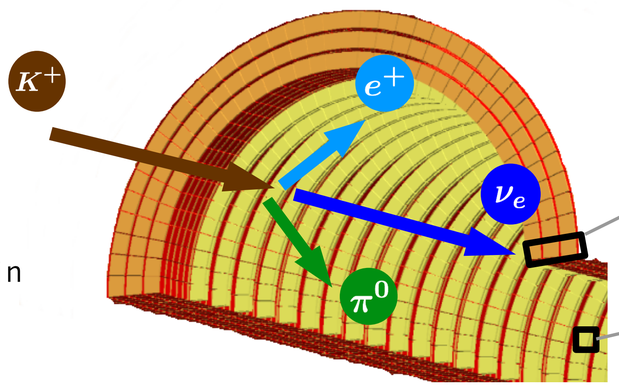
ENUBET becomes a CERN Neutrino Platform experiment

"The possibility of using tagged-neutrino beams in high-energy experiments must have occurred to many people."
B. Pontecorvo, Lett. Nuovo Cimento, 25 (1979) 257

THE DECAY TUNNEL

NP06/ENUBET will be the first "monitored neutrino beam":
- ν_e flux monitored by tagging positrons in instrumented decay channel.
- ν_μ flux monitored by tagging muons in instrumented decay channel and range-meter in the hadron dump.

K^+ decay mode			Branching ratio (%)	
μ^+	ν_μ		63.55	Tagged in decay tunnel
π^+	π^0		20.66	
π^+	π^+	π^-	5.59	
π^0	e^+	ν_e	5.07	Tagged in decay tunnel
π^0	μ^+	ν_μ	3.353	Tagged in decay tunnel
π^+	π^0	π^0	1.761	
$\pi^+ \longrightarrow \mu^+$		ν_μ		Tagged in range-meter

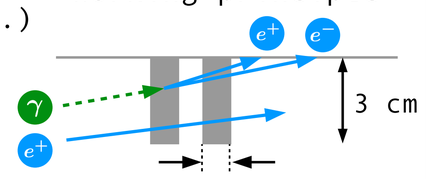


Calorimeter functional block is the LCM:
- LCM = Lateral Compact Module
- LCM dimensions: 3 × 3 × 10 cm³ (4.3 X_0)
- Made of scintillator and iron
- $e^+/\mu^+/\pi^+$ discrimination capabilities

Photon veto rings are made of scintillator doublets:
- Scintillator dimension 3 × 3 × 0.7 cm³ (0.012 X_0)
- Rejects gammas from π^0 decay

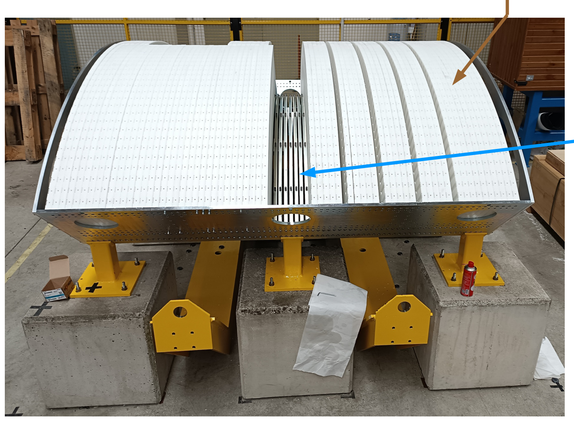
e^+ topology (signal) | π^0 topology (backgr.) | π^+ topology (backgr.)

Photon veto working principle



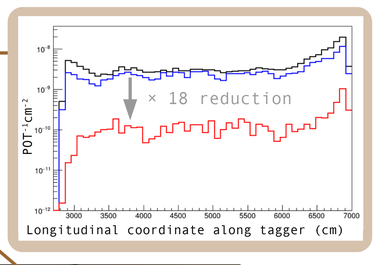
THE DEMONSTRATOR

Deliverable of the ENUBET ERC project is the tagger demonstrator, a portion of the instrumented decay tunnel:
- Under construction, to be finished in 2022 for beam exposure at CERN.
- Dimensions: azimuthal quarter-of-circle, length 1.65 m.
- Instrumented with electronics in central 45 degrees: 1875 SiPMs total

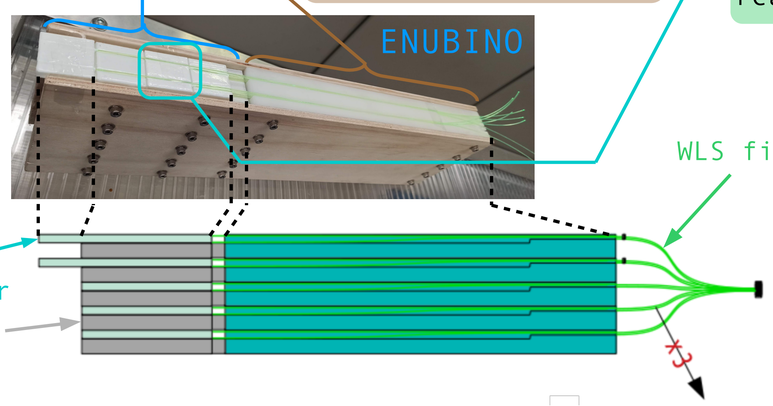


The DEMONSTRATOR while under construction

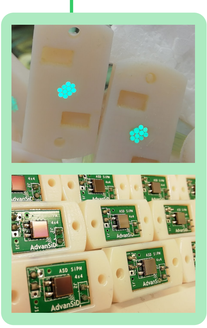
Neutron shield (30 cm 5% borated polyethylene)
- Neutron reduction factor = 18



Calorimeter + γ-veto (11 cm radial iron part)

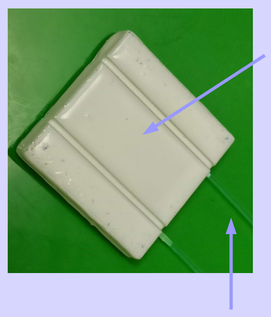


The ENUBINO prototype is a single azimuthal portion (3 radial LCM) of the demonstrator:
- Scintillator tiles frontally coupled to WLS-fibers.
- 10-fibers bundle (1 LCM) read by a 4 x 4 mm² RGB SiPM.



THE PHOTODETECTION CHAIN

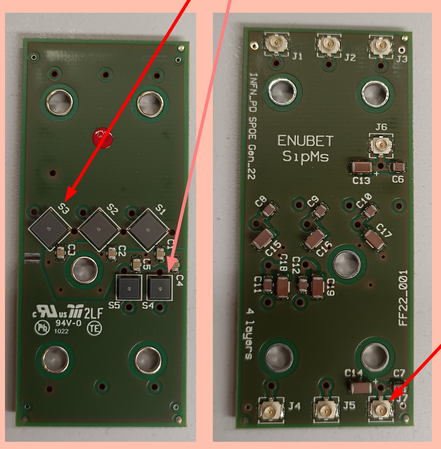
SCINTILLATOR



Plastic scintillator tile
Dimensions = 3x3x0.7 cm³
Yield = 10 400 ph / 1 MeV e^-
Attenuation length = 160 cm
Emission peak = 408 nm

Blue-to-green wavelength shifting (WLS) optical fibers
Kuraray Y11
Emission peak = 476 nm

SiPM BOARD



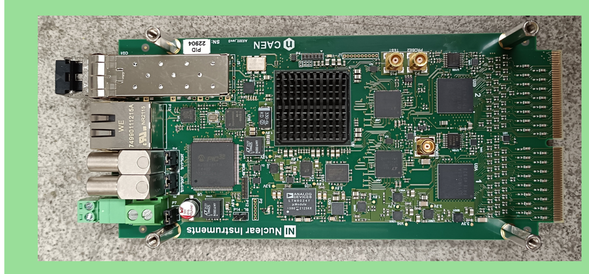
Front | Back

Hamamatsu 14160-4050HS (-3050HS)
4x4 mm² (3x3 mm²) active surface SiPM
Breakdown voltage 38 V
Pixel pitch 50 μm
Max photosensitivity 50% at 450 nm

Compact Hirose U.FL connectors for high-density cabling

Each board mounts 3 SiPMs for calorimetric measurements and 2 SiPMs for photon vetos

READOUT BOARD



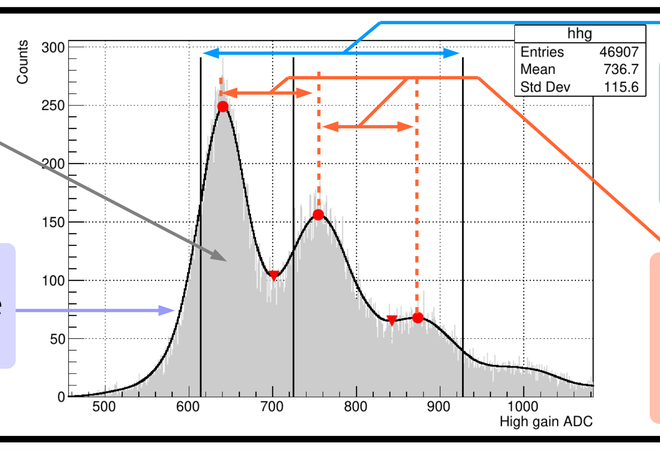
Signal processing and digitization through CAEN A5202 boards hosting two 32-channels CITIROC-1A ASICs.

AUTOMATIZED CALIBRATION

The number of SiPM firing cells corresponding to an event is used to reconstruct the energy.

Assigning the number of firing cells to an event requires a calibration. Since the demonstrator mounts 1875 SiPMs, the calibration procedure has been automatized.

1. The spectrum is acquired triggering with a low threshold
2. A moving average filter with centred window is applied twice for smoothing the spectrum
3. The 10th and 90th percentiles define the region of interest (ROI), the median is also shown for reference
4. Peaks and valleys are searched in the ROI. The average of the peak inter-distances defines the firing cell in ADC units.



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