Status of the NP06/ENUBET neutrino beam

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on behalf of the NP06/ENUBET Collaboration

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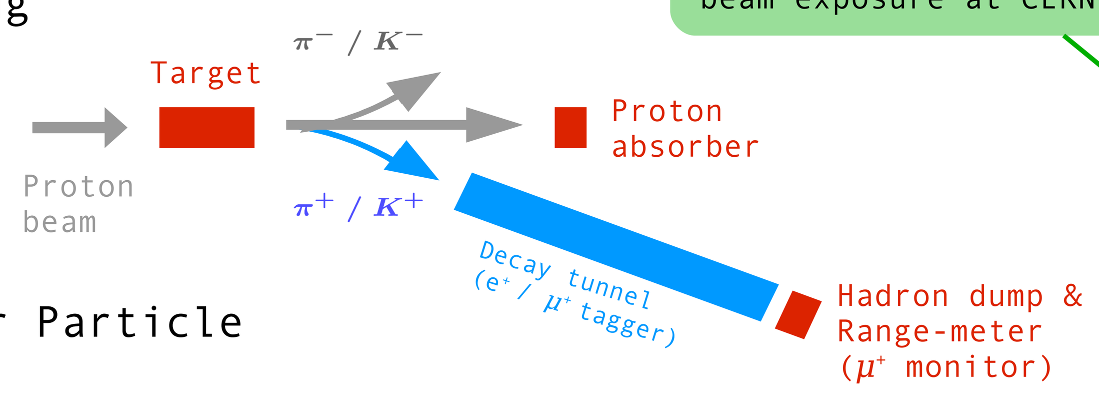
NP06/ENUBET OVERVIEW

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."

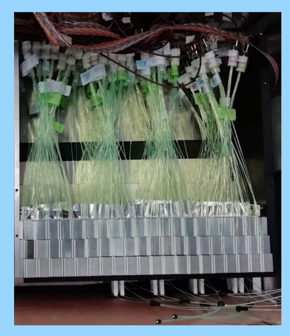


1979 – *"The possibility of using tagged-neutrino beams in high-energy experiments must have occurred to many people."* B. Pontecorvo, Lett. Nuovo Cimento, 25 (1979) 257

2016 – Start of ERC grant & initial shashlik design beam exposure at CERN-PS

2017 – SiPM irradiation campaign at INFN-LNL and beam exposure of irradiated sensors at CERN-PS

2018 – Shashlik to lateral readout design migration for attenuating SiPM radiation damage. Hadronic cal + γveto prototype beam exposure at CERN-PS



2019 – ENUBET becomes a CERN Neutrino Platform experiment

2021 – Systematics budget finalization & demonstrator construction

2022 – Demonstrator beam exposure at CERN-SPS & conceptual design report

THE DECAY TUNNEL

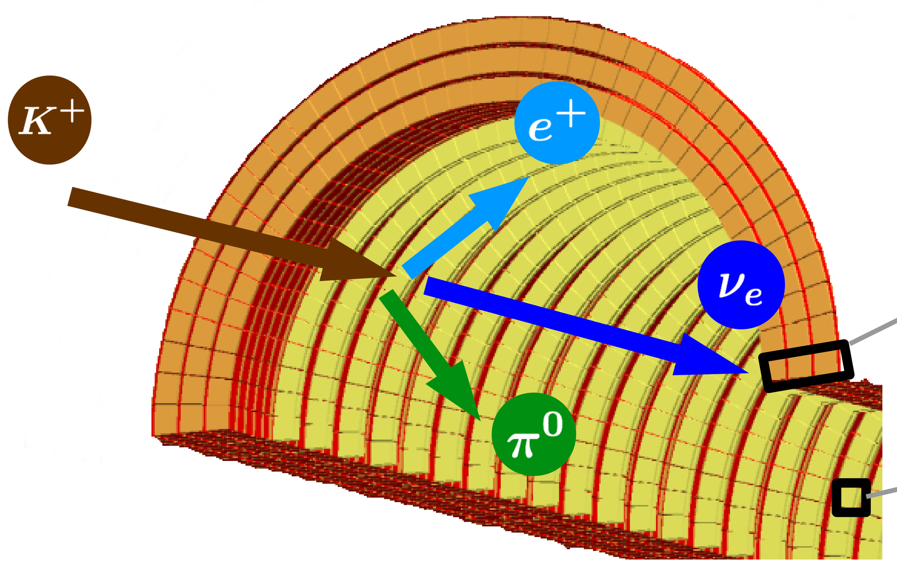
NP06/ENUBET will be the first "monitored neutrino beam":

- 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
π^+	π^0		20.66
π^+	π^+	π^-	5.59
π^0	e^+	ν_e	5.07
π^0	μ^+	ν_μ	3.353
π^+	π^0	π^0	1.761

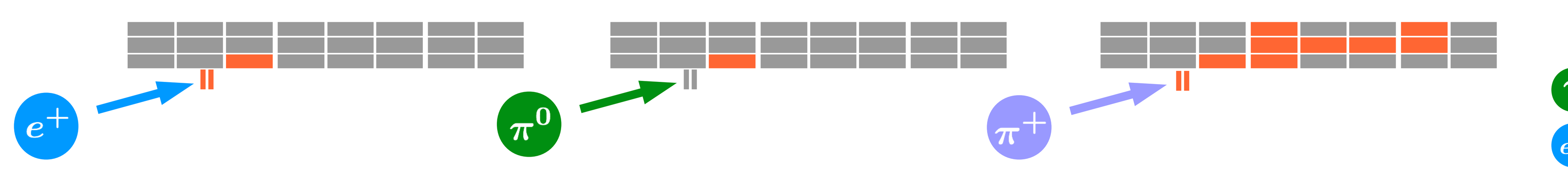
Tagged in decay tunnel ($\mu^+\nu_\mu$; $\pi^0 e^+ \nu_e$; $\pi^0 \mu^+ \nu_\mu$)

$\pi^+ \longrightarrow \mu^+ \ \nu_\mu$ – Tagged in range-meter

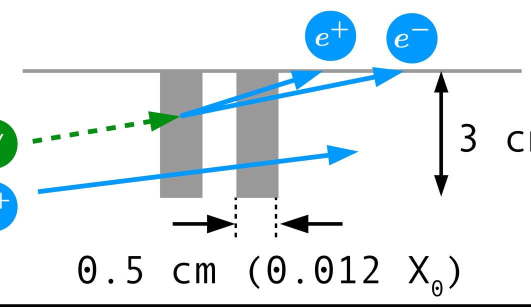


Calorimeter functional block is the LCM:
- LCM = Lateral Compact Module
- LCM dimensions: 3 × 3 × 10 cm³ (4.3 X_0)
- Made of scintillator and iron
- $e^+/\mu^+/\pi^+$ discrimination capabilities

Photon veto rings are made of scintillator doublets:
- Scintillator dimension 3 × 3 × 0.5 cm³ (0.012 X_0)
- Rejects gammas from π^0 decay



Photon veto working principle

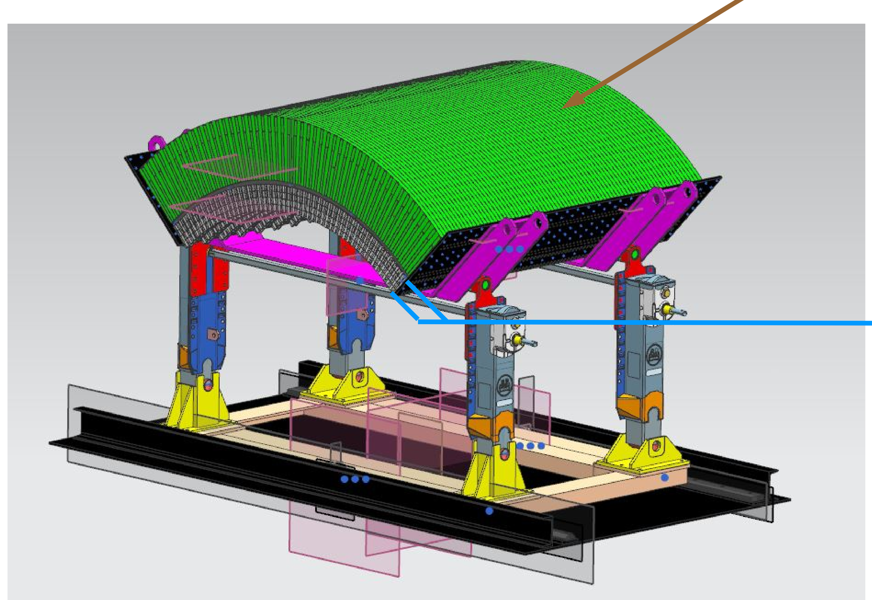


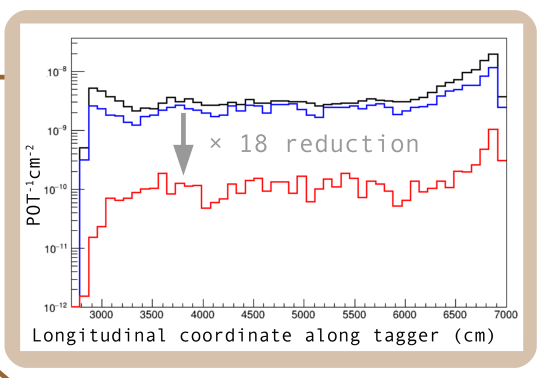
THE DEMONSTRATOR

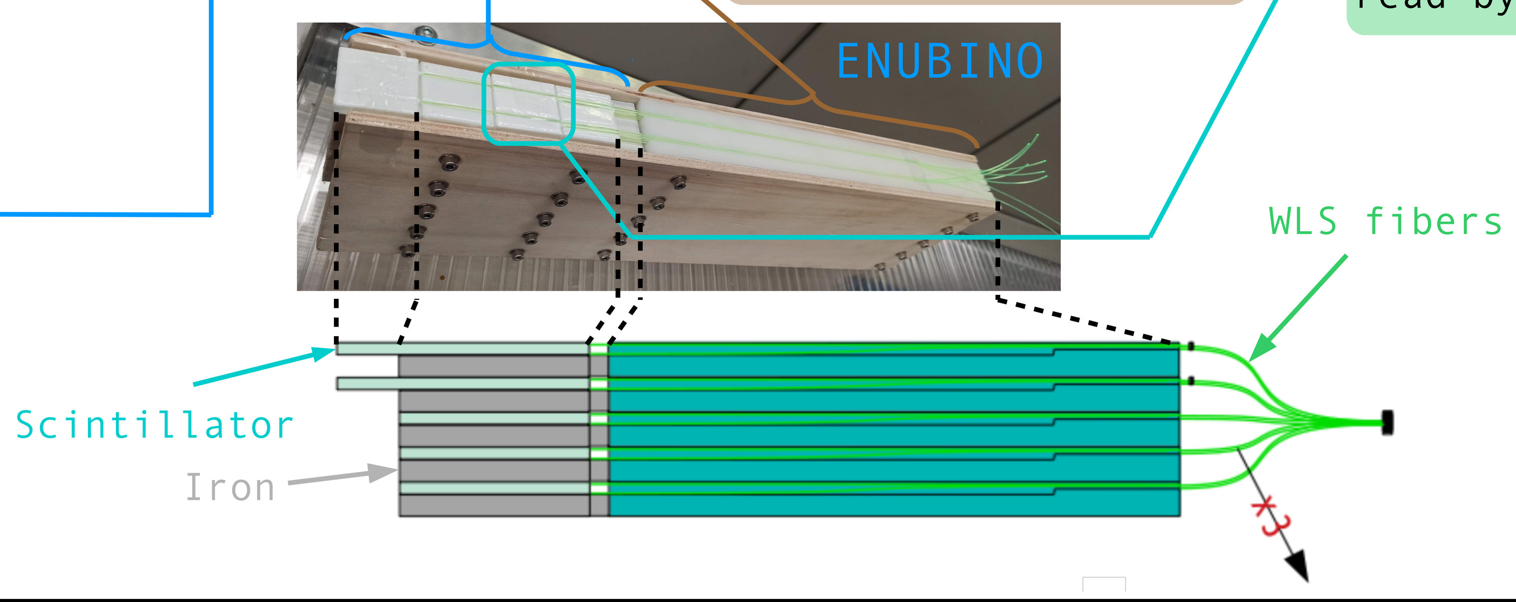
Deliverable of the ENUBET ERC project is the tagger demonstrator, a portion of the instrumented decay tunnel:
- Under construction, to be finished in 2022 for beam exposure at CERN.
- Dimensions: azimuthal quarter-of-circle, length 1.65 m.
- Instrumented with electronics in central 45 degrees.

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

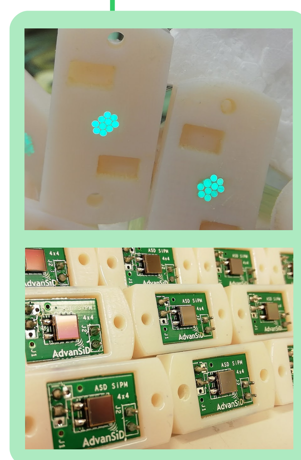
Calorimeter + γ-veto (11 cm radial iron part)





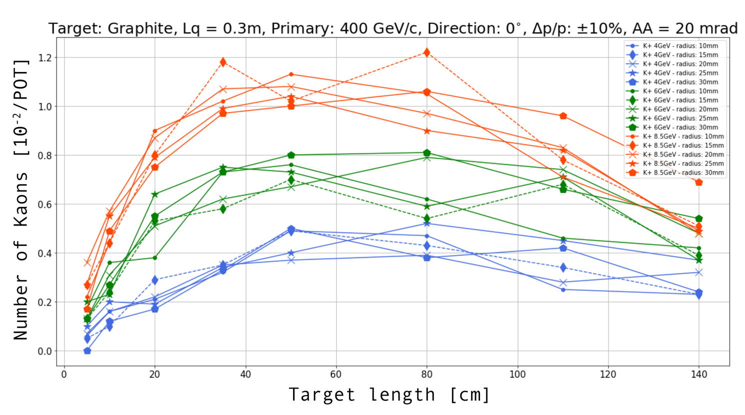


The ENUBINO prototype is a single azimuthal portion (3 radial LCM) of the demonstrator:
- Scintillator tiles frontally coupled to WLS-fibers.
- 10-fibers bundle (1 LCM) read by a 4 x 4 mm² RGB SiPM.



THE PROTON TARGET

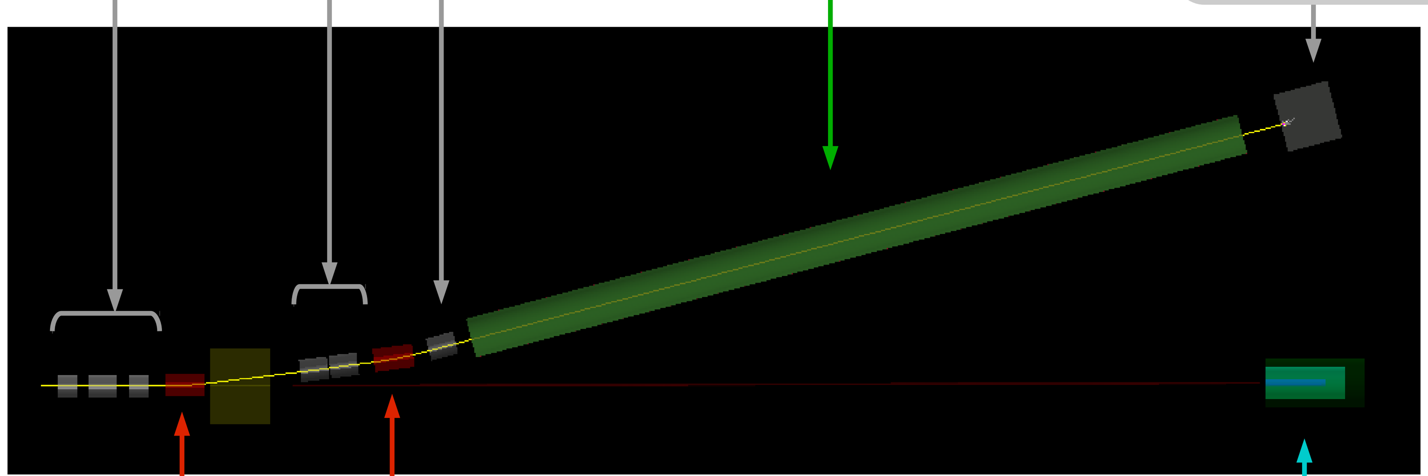
The design of the cylindrical target has been studied to optimize the challenging trade-off between heat dissipation and yield loss due to re-interactions in the target.
The final output of the optimization is:
- Best size: 3 cm radius, 70 cm length.
- Most robust material choice is graphite thanks to its heat endurance and production yield.



Focusing quadrupoles
- Aperture radius 15 cm

Instrumented decay line

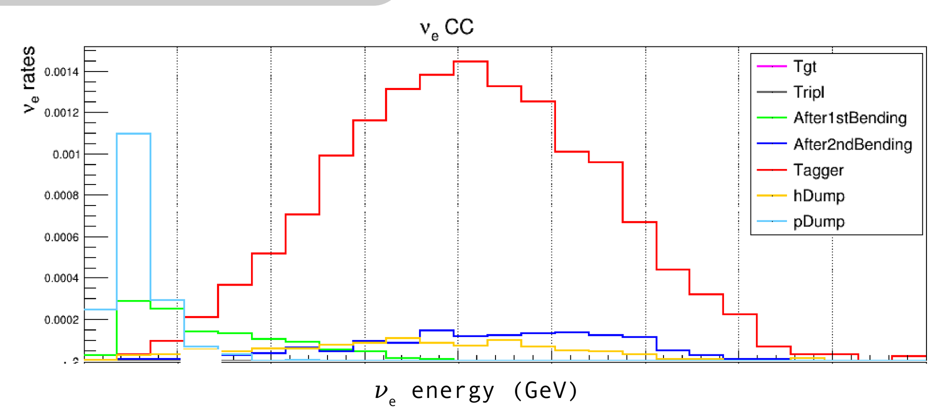
Hadron dump
- 3 radial layers: graphite core, iron coating, and outer borated concrete
- Neutron backscattering attenuation of 0.2



Bending dipoles
- Normal conducting
- 1.5 T field
- 14.8° total bend from proton beam-line

Proton dump

THE MESON TRANSFER LINE



Assuming a realistic operation at CERN-SPS corresponding to 4.5 × 10^{19} POT/year, the newly simulated transfer line TLR6 would ensure, in a far detector displaced 50 m downstream its end, the occurrence of 10^4 ν_e-CC interactions in about 2 years.

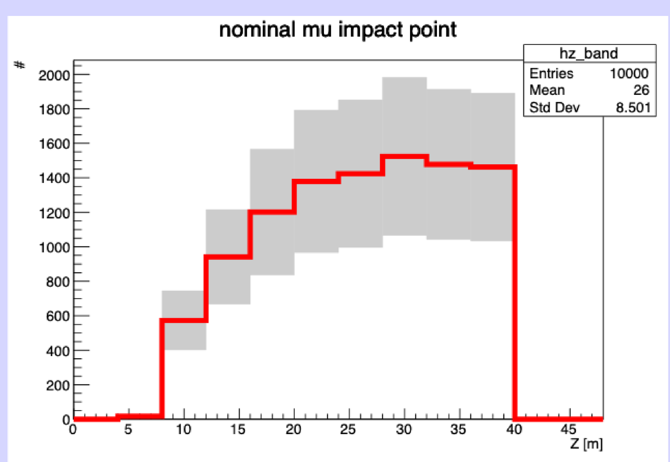
ν-FLUX SYSTEMATICS

Lepton monitoring data coming from the calorimeter and range-meter can constrain the hadro-production and beamline parameters, implying a reduction of the systematic uncertainty on the neutrino flux.

EXAMPLE: consider as observable the position Z along the calorimeter of the muons from K-decays.

1. Construct from MC simulation the PDF of Z, and store it as a histogram

$$PDF(Z;\vec{\alpha})$$

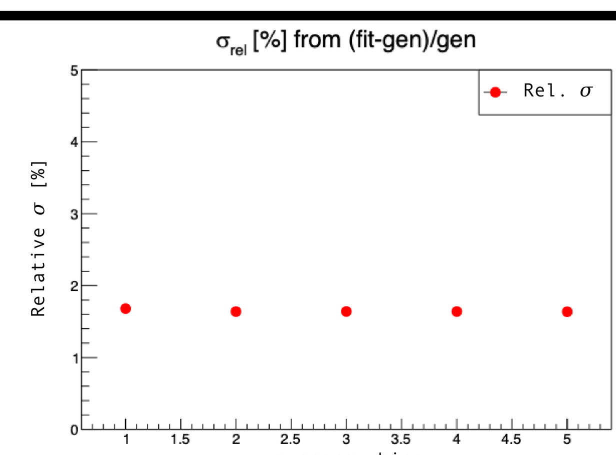


2. Given the lepton monitoring data-set $\{Z\}_i$ compute the likelihood for various values of the hadro-production parameters α

$$\log \mathcal{L}(\vec{\alpha}) = \sum_{i \in \{DATA\}} \log PDF(Z_i;\vec{\alpha})$$

3. The hadro-production parameters are constrained to the values maximizing the likelihood

$$\max\left(\log \mathcal{L}(\vec{\alpha})\right) \Longrightarrow \text{constrained } \vec{\alpha}$$



Simplified hadro-production toy model shows systematic uncertainty reduction from initial 15% down to 1.8%. Complete study of systematics budget ongoing.

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