ENUBET

Enabling high precision flux measurements in conventional neutrino beams

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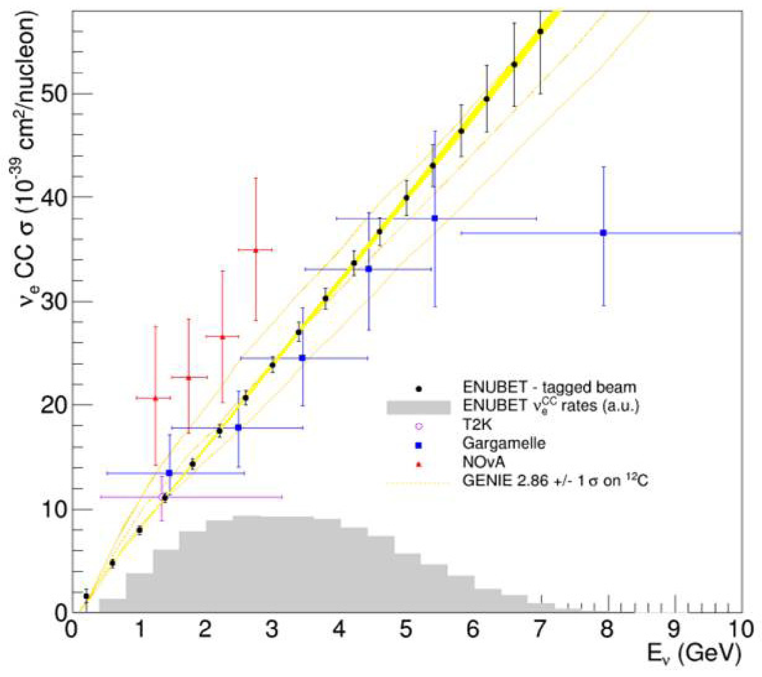
ENUBET (Enhanced NeUtrino BEams from kaon Tagging)

- A new source based on **tagging of large angle e^+ from $K^+ \to e^+ \pi^0 \nu_e$ decays** in an instrumented decay tunnel.
- Reduce systematic uncertainties in the knowledge of the neutrino flux to a **O(1%) level**. [1]
- **ERC** funded **project** (n. 681647, P.I. A. Longhin), **Expression of Interest to CERN-SPSC**. [2]

Physics case and applications

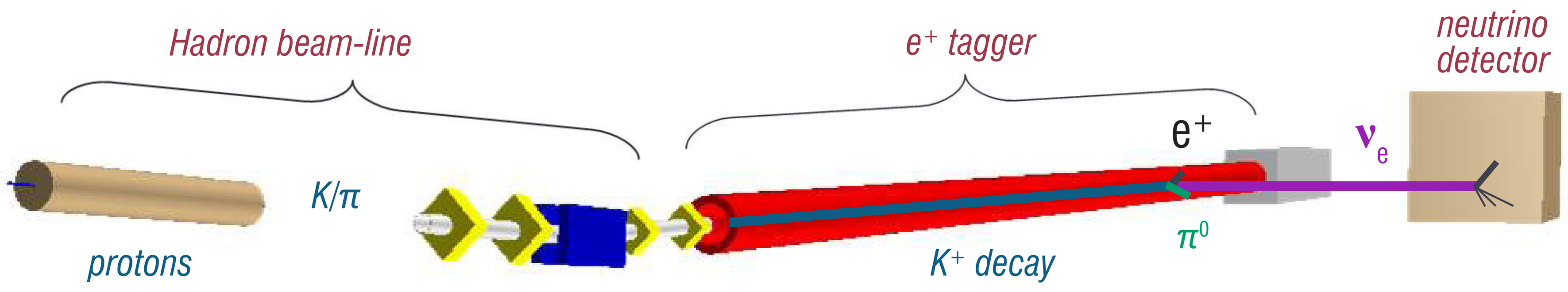
- A new generation of **neutrino cross section** experiments with unprecedented control on the flux.
- The first step toward a **time-tagged ν-beam**, where the ν at the detector is correlated with the lepton in the tunnel.
- A phase-II **sterile neutrino search**, especially in case of a positive signal from the FermiLab SBL program.

Deliverables of ENUBET:
1) conceptual design of the beamline **2)** Construction of a 3m x π section of the instrumented tunnel as a principle demonstrator.



ENUBET impact on ν_e cross section meas.

Tagged neutrino beam concept



- **Hadron beam-line**: collects, focuses, transports K^+ to the **50 m long** e^+ tagger
- **e^+ tagger**: real-time, ''inclusive'' **monitoring** of produced e^+

A traditional beam

- **Passive** decay region
- **ν_e** flux relies on **ab-initio simulations** of the full chain
- **large uncertainties** from hadro-production, k/π ratio, PoT

The tagged beam

- **Fully instrumented** decay region
- $K^+ \to e^+ \nu_e \pi^0 \to$ large angle e^+
- **ν_e flux prediction = e^+ counting**

O(1%) systematic error achievable

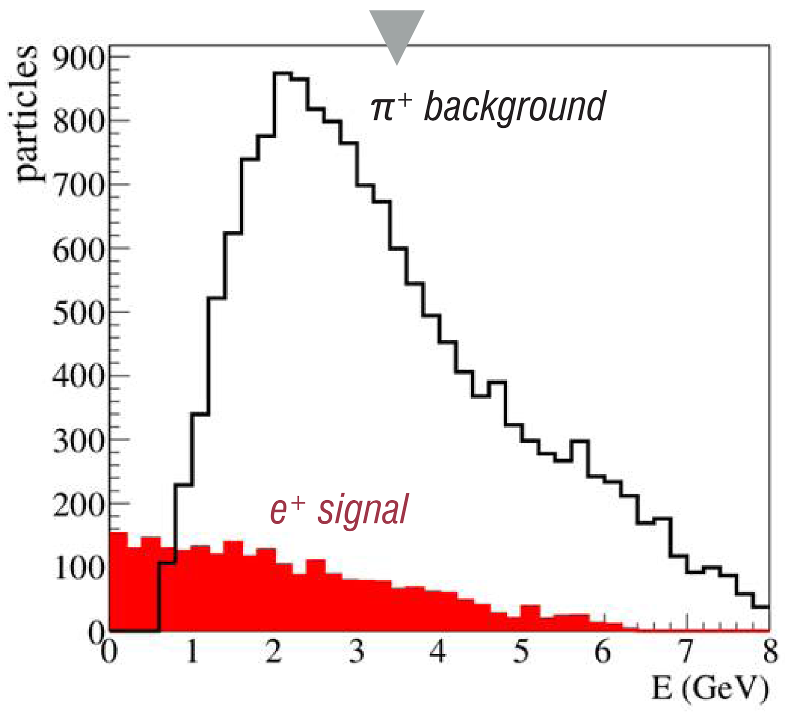
The positron tagger

Challenges

The decay tunnel: a **harsh environment**

- **particle rates**: > 200 kHz/cm^2
- **backgrounds**: pions from K^+ decays
- **extended source of** ~ 50 m
- grazing incidence
- spread in the initial direction

Need to veto 98-99 % of pions

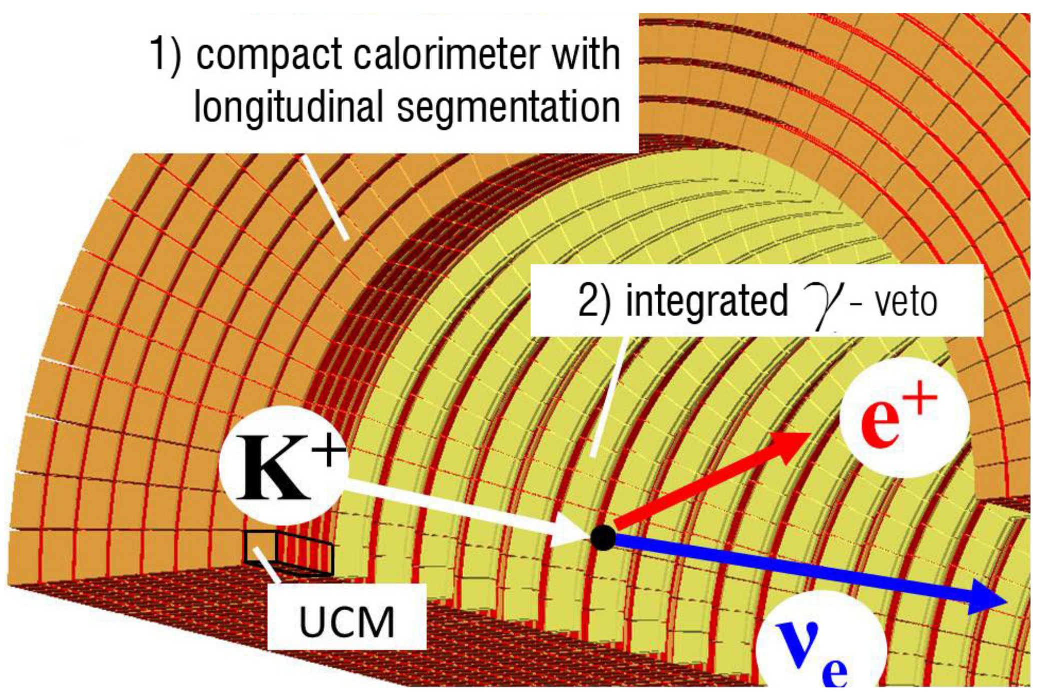


Adopted solution

Conventional beam-pipe replaced by **active instrumentation**

Key points:

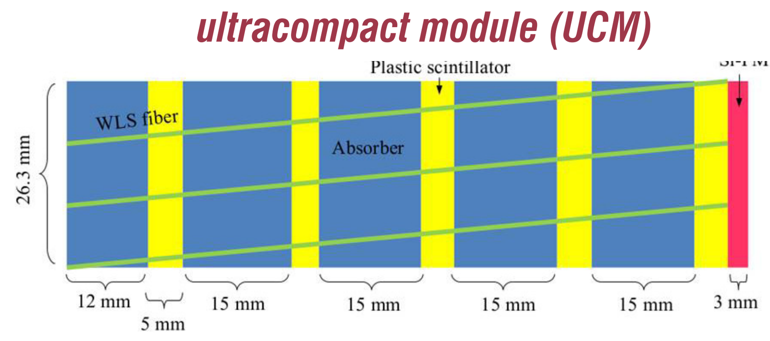
- longitudinal sampling
- perfect homogeneity
- radiation hardness
- cost effectivness



1) Calorimeter ("shashlik") $\to \pi^\pm$ rejection

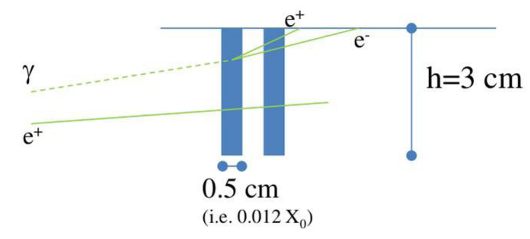
- UCM (4 X_0 thick) read-out by **SiPMs directly coupled to WLS**
- nearly perfect homogeneity of the longitudinal sampling
- cheap, fast (<10 ns), rad. hard

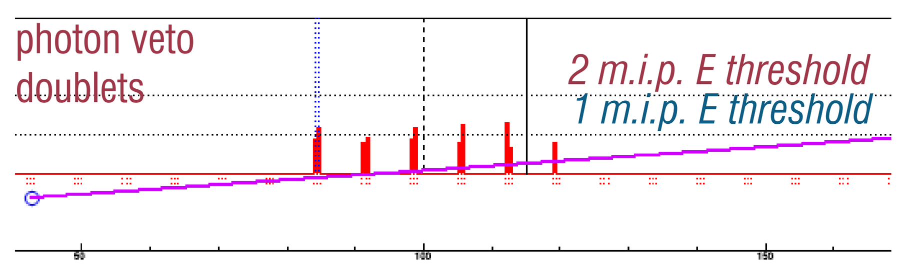
ultracompact module (UCM)



2) Integrated γ – veto $\to \pi^0$ rejection

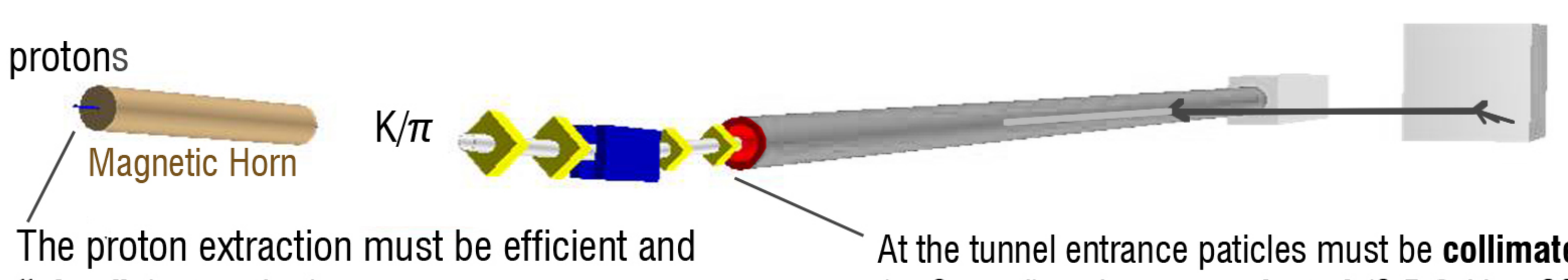
- rings of 3x3 cm^2 **pads of plastic scintillator** doublets
- exploit 1 m.i.p./2 m.i.p. separation





- alternative solutions allowing superior timing under study (large area fast APD, LAPPD with Cherenkov radiator)

The hadron beamline



The proton extraction must be efficient and **"slow"** (saturation)

At the tunnel entrance paticles must be **collimated** (< 3 mrad) and **energy selected** (8.5 GeV ± 20%)

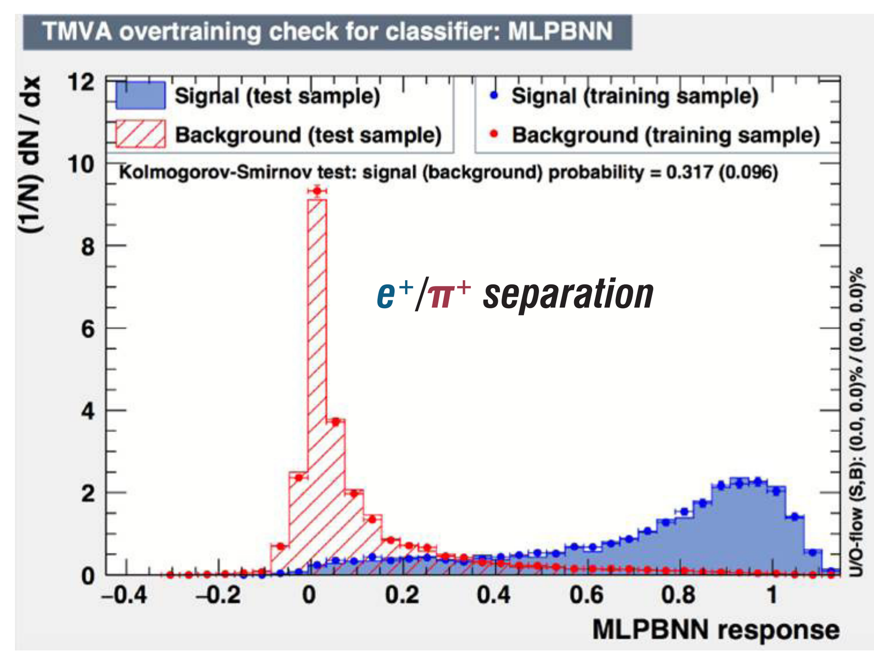
Scenarios	Focusing system	Proton extraction from accelerator
	A: **pulsed device** (magnetic horn)	**Unconventional:** many (10^8), short (2-10 ms) pulses with few protons (< 3×10^{11})
	B: **static devices** (DC magnets)	**O(1s) long slow extractions**

Scenario B is the way to **a "time-tagged" ν beam**:
proton "time-dilution" $\to$ t-coincidences between e^+ and ν_e at the detector

Reconstruction: full tagger GEANT4 simulation

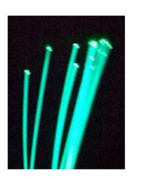
- Event building and clustering of neighboring UCM to avoid pile-up effects
- Artificial NN with 5 variables employing the pattern of deposited energy in the calorimeter (e^+/π^+ separation)
- Sequential cuts exploiting info from γ-veto

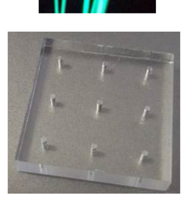
e^+ efficiency: ~ 49%
π^+ rejection: ~ 97%
π^0 rejection: ~ 99%

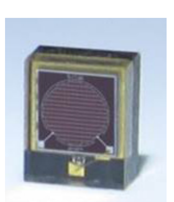


Tagger detector R&D

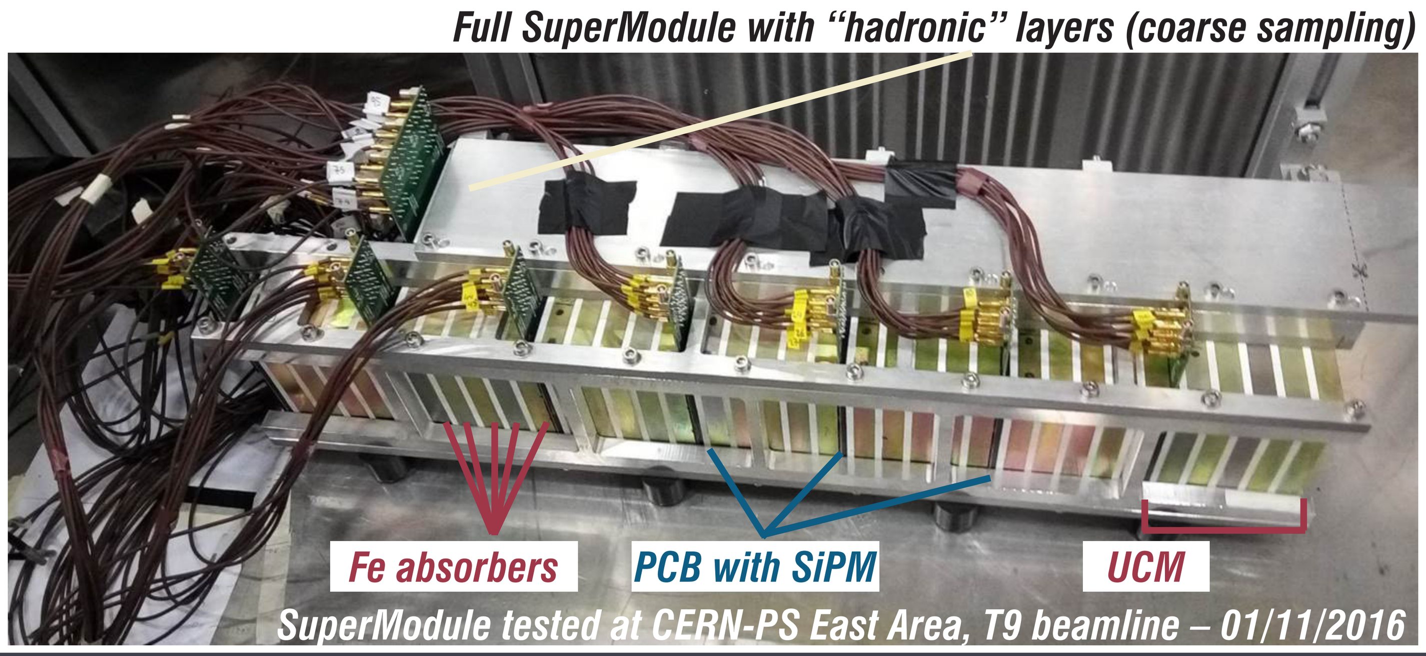
Activity already started in the INFN-CSN5 SCENTT project [3]







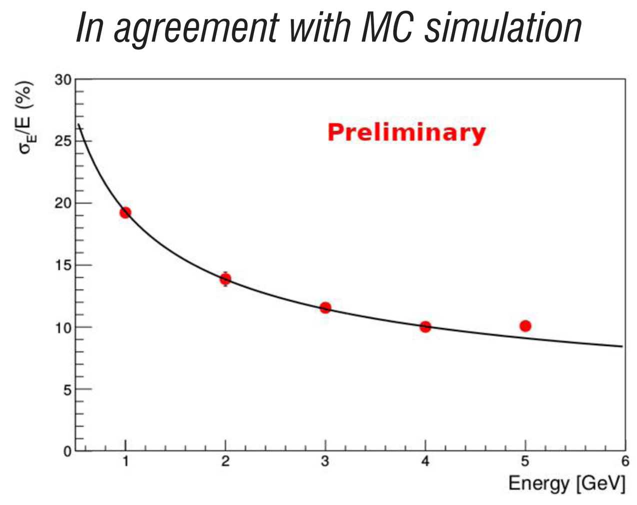
Full SuperModule with ''hadronic'' layers (coarse sampling)



SuperModule tested at CERN-PS East Area, T9 beamline – 01/11/2016

Energy resolution for electrons

In agreement with MC simulation



3 UCM - T9 beamline, 29/06/2016

References, additional info

http://enubet.pd.infn.it

[1] **Eur. Phys. J. C (2015) 75:155**
A novel technique for the measurement of the electron neutrino cross section.
A. Longhin, L. Ludovici, F. Terranova

[2] **CERN-SPSC-2016-036; SPSC-EOI-014**
Enabling precise measurements of flux in accelerator neutrino beams: the ENUBET project
ENUBET Collaboration

[3] **N.I.M. A, 2016.05.123 arXiv:1605:09630**
A compact light readout system for longitudinally segmented shashlik calorimeters