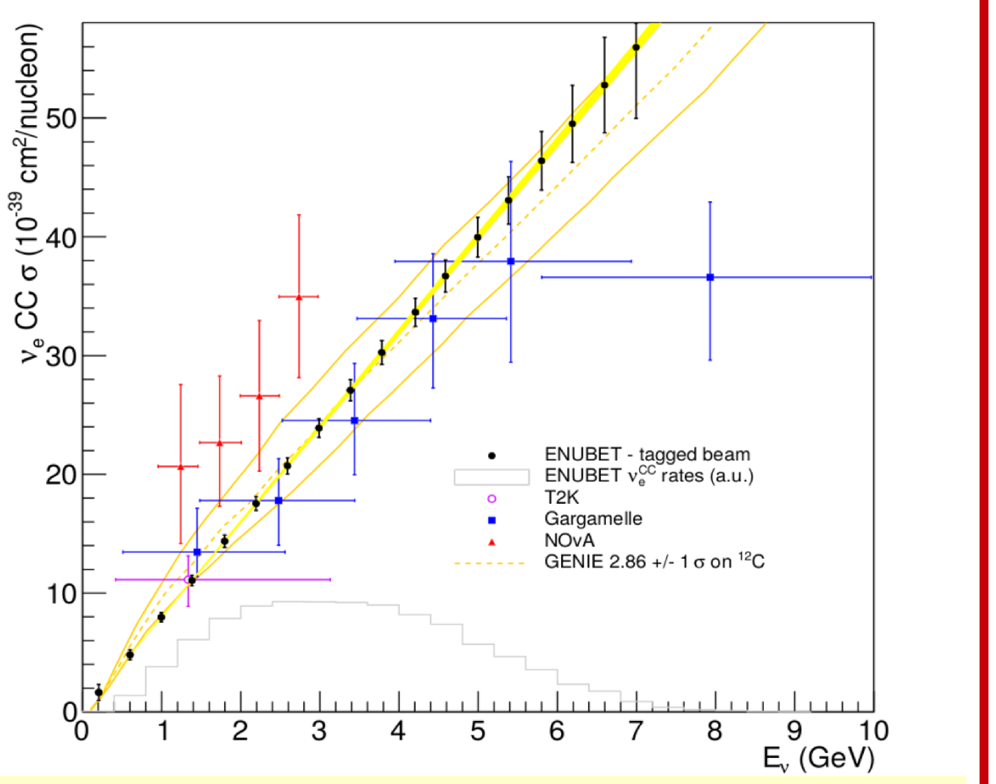
The ERC ENUBET Project: high precision neutrino flux measurements in conventional neutrino beams

F. Pupilli (INFN-Padova) on behalf of the ENUBET collaboration

ENUBET (Enhanced NeUtrino BEams from kaon Tagging)

O(10^4) ν_e^{CC} in a few years of run at existing proton drivers with a 500 t scale detector [1]



A new-concept ν_e source based on tagging of e^+ from $K^+ \to e^+\pi^0\nu_e$ decays

- The goal of the project is to demonstrate the **feasibility of real time monitoring of the positrons produced at high angle in the decay tunnel of conventional neutrino beam** to obtain a 10x reduction in the systematics on the neutrino flux → Highly beneficial for the **leptonic CP violation** international program at long baselines ($\nu_\mu \to \nu_e$).
- ENUBET is a **ERC Consolidator Grant-2015** project (n. 681647, P.I. A. Longhin) with a **2 MEUR** funding **started on 01/06/2016** with a **5 years duration**.
- An **Expression of Interest** was recently submitted to **CERN-SPSC** [2]

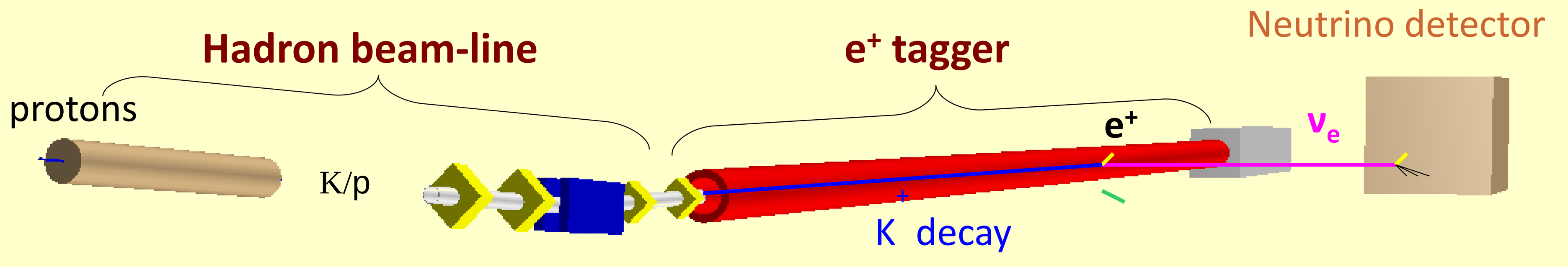
A traditional beam

- **Passive** decay region
- ν_e flux relies on **ab-initio** simulations of the full chain
- **large uncertainties** from model dependency

↔

The tagged beam

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



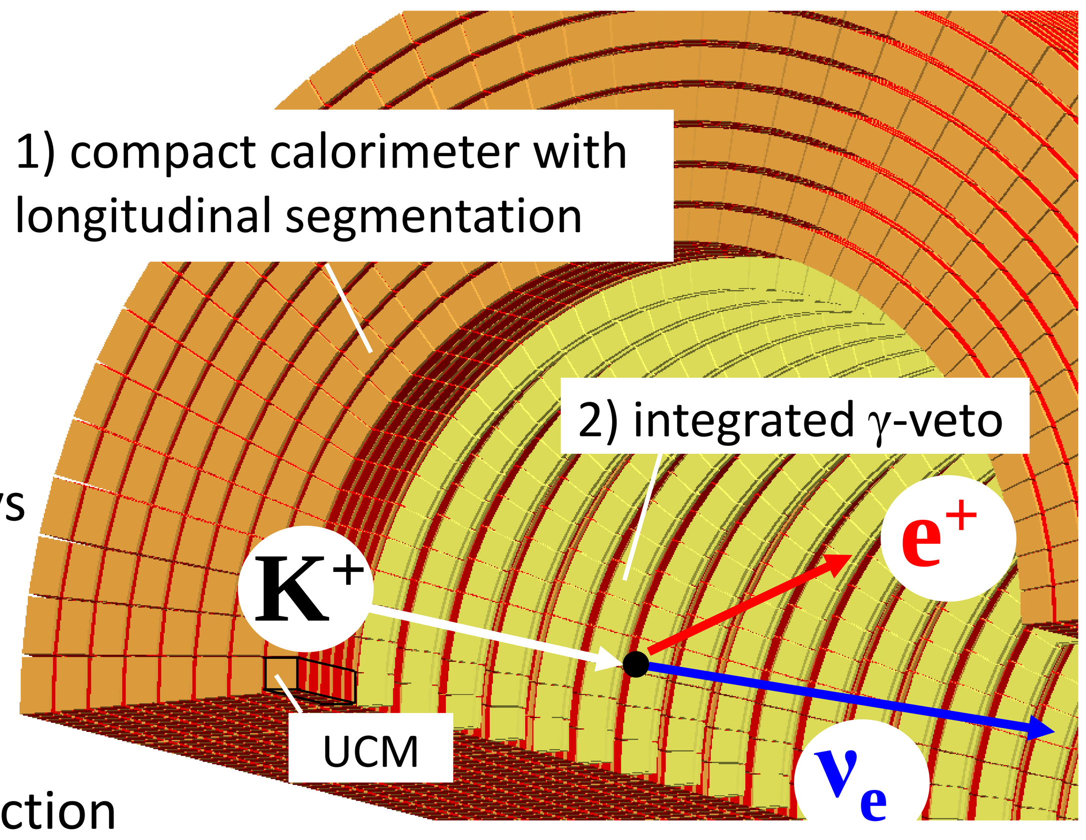
- **Hadron beam-line:** collects, focuses, transports K^+ to the e^+ tagger
- **e^+ tagger:** real-time, "inclusive" **monitoring** of produced **e^+**

The positron tagger

➢ Challenges

The decay tunnel: a **harsh environment**

- **particle rates: > 200 kHz/cm²**
- **backgrounds:** pions from K^+ decays
  Need to veto 98-99 % of them
- **extended source of ~ 50 m**
- grazing incidence
- significant spread in the initial direction



✓ Adopted solution

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

Key point:
- longitudinal sampling
- perfect homogeneity
→ integrated light-readout

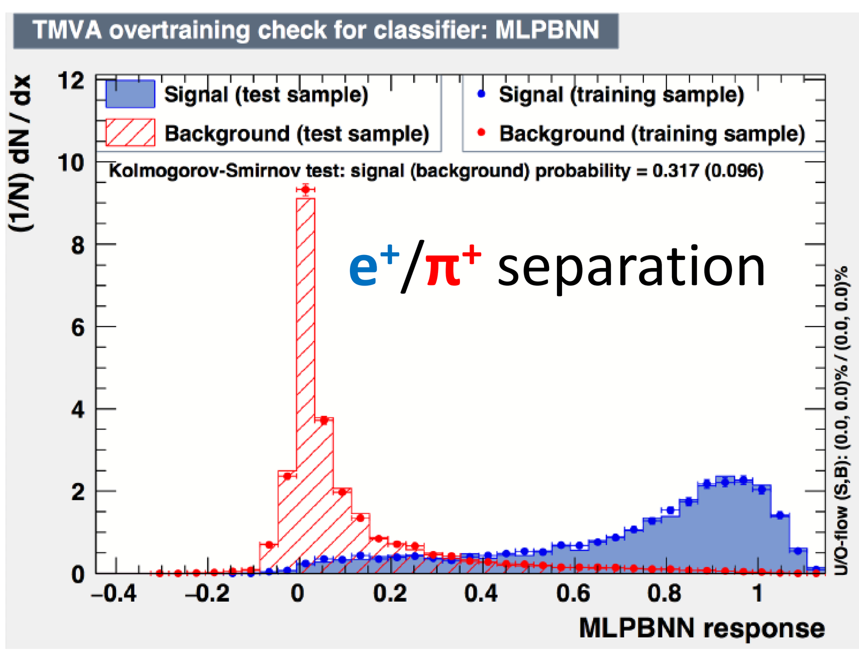
1) Calorimeter ("shashlik") → $\pi^\pm$ rejection
- Ultra-Compact Module (UCM) read-out by SiPM directly coupled to WLS fibers

2) Integrated γ -veto → π^0 rejection
- plastic scintillators or
- large-area fast avalanche photodiodes

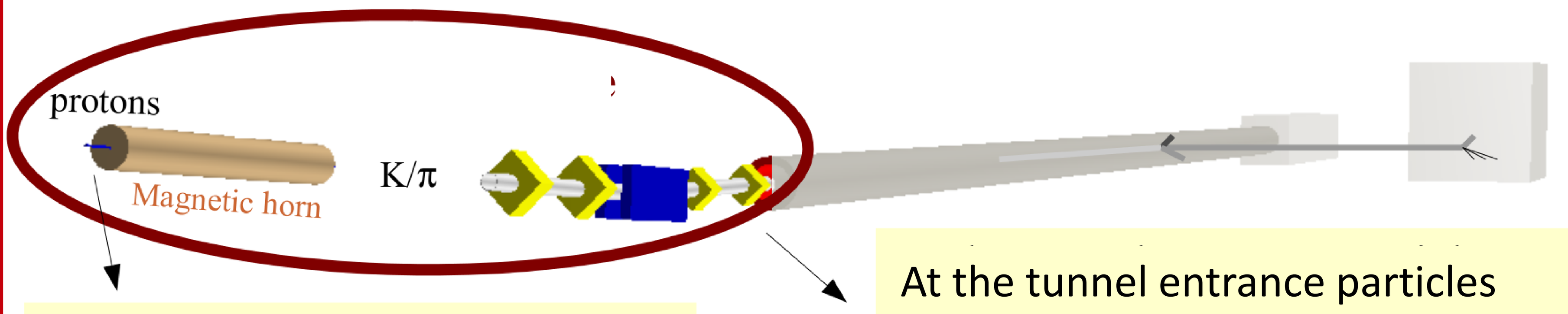
Full tagger GEANT4 simulation

Preliminary results:

- e^+ efficiency: **~ 49%**
- π^+ rejection: **~ 97%** **(Neural Network)**
- π^0 rejection: **~ 99%** **(Sequential cuts)**



The hadron beamline

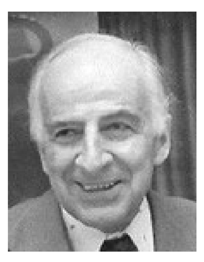


The proton extraction must be efficient and **"slow"** (saturation)

At the tunnel entrance particles must be **collimated** (< 3 mrad) and **energy selected** (20% spread)

Scenarios	Focusing system		Proton extraction from accelerator
	A: **pulsed device** (magnetic horn)	⟶	**Unconventional:** many (10^8), short (2 ms) pulses with few protons (< 3 x 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" → t-coincidences between e^+ and ν_e at the detector



Bruno Pontecorvo

ENUBET final results:

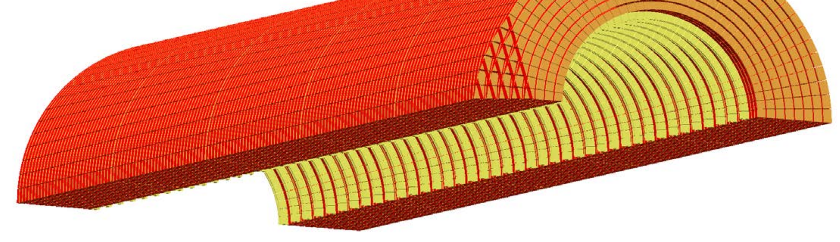
- 1) **e^+ tagger** validated with **particle beams data**
- 2) a detailed design for the **hadron beam-line**

The complete picture to move to a full scale experiment

By-products and cross-fertilization:

- **calorimetry** → new low-cost, ultra-compact detectors
- **accelerator physics solutions** → novel proton extraction schemes for fixed-target and beam-dump experiments

Prototype dimensions:
3 m x π
60 cm outer radius



Tagger detector R&D: SCENTT

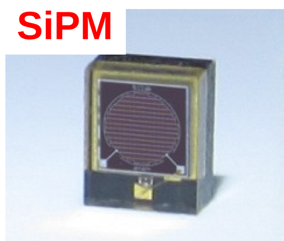
INFN-CSN5 activity (PI F. Terranova) [3]

Shashlik Calorimeters for Electron Neutrino Tagging and Tracing

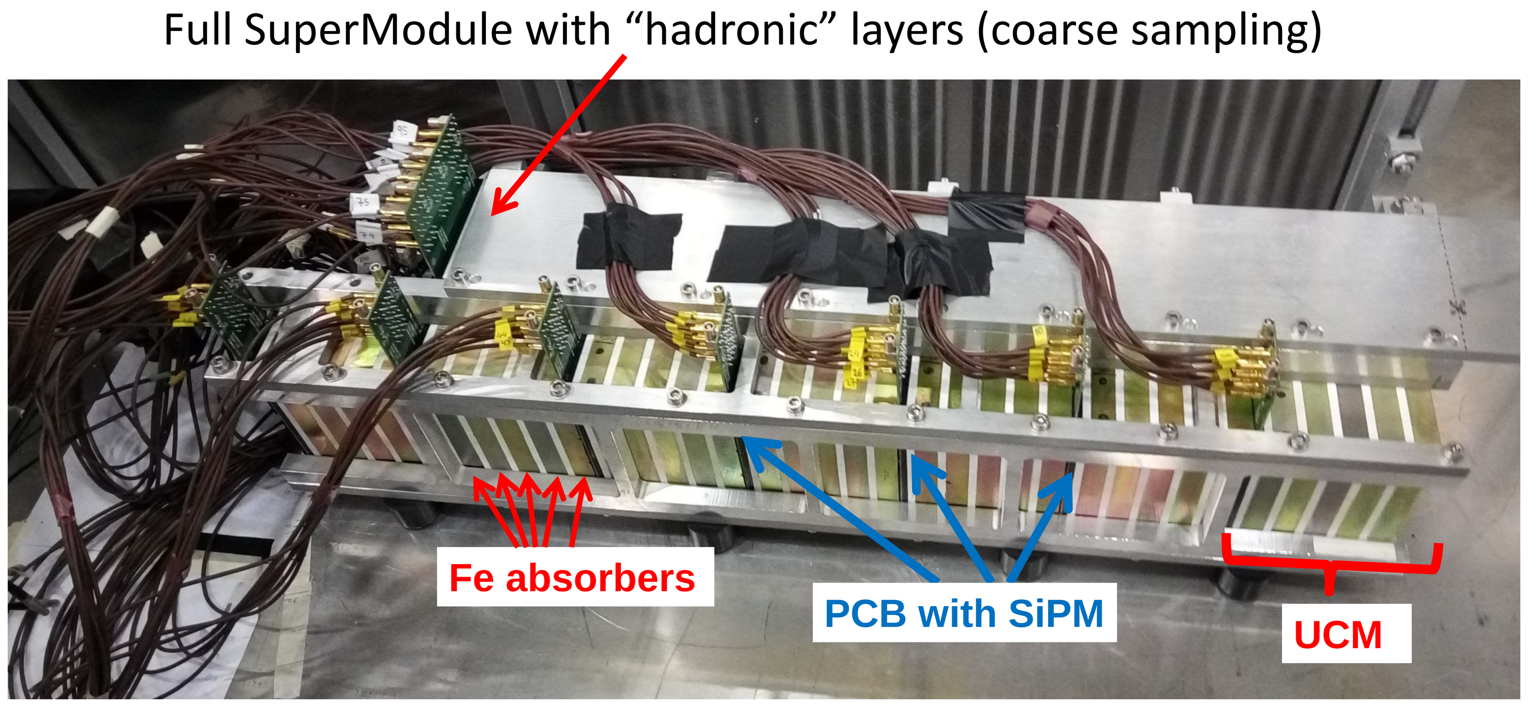
WLS

Scintillator

SiPM



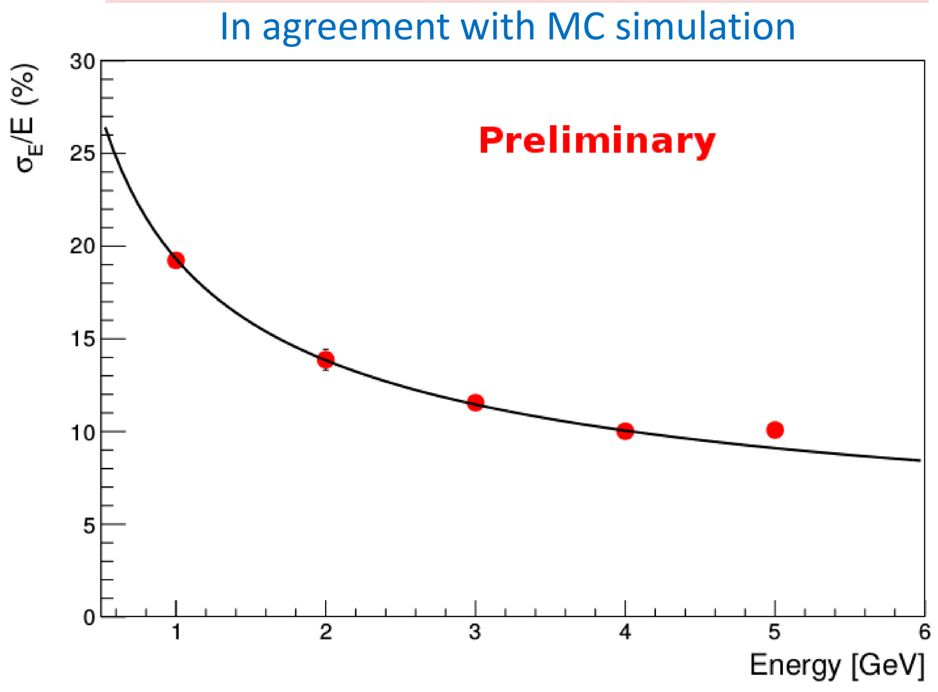
Full SuperModule with "hadronic" layers (coarse sampling)



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
A. Berra[a,b,*], C. Brizzolari[a,b], S. Cecchini[c], F. Cindolo[c], C. Jollet[d], A. Longhin[e], L. Ludovici[f], G. Mandrioli[c], N. Mauri[c], A. Meregaglia[d], A. Paoloni[e], L. Pasqualini[c,g], L. Patrizii[c], M. Pozzato[c], F. Pupilli[e], M. Prest[a,b], G. Sirri[c], F. Terranova[b,h], E. Vallazza[i], L. Votano[e]