The ENUBET narrow band neutrino beam

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ENUBET (Enhanced NeUtrino BEams from kaon Tagging)

New-concept ν_e source based on tagging of large angle e^+ from $K^+ \rightarrow e^+\pi^0\nu_e$ decays in an instrumented decay tunnel (98% ν_e from K^+ decays)

Reduction of the systematic uncertainties on the knowledge of the initial neutrino flux to O(1%) level

Physics programme

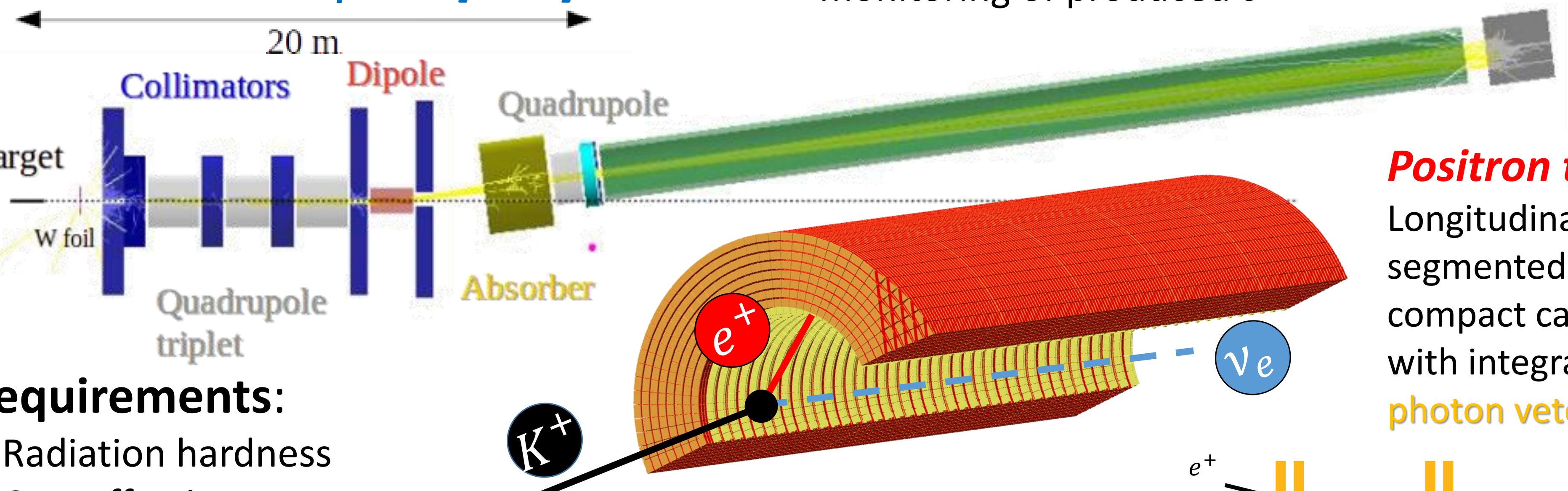
Unprecedented high precision measurement of ν_e **and** $\bar{\nu}_e$ **cross sections**

Highly beneficial for tackling the main open neutrino-related issues: **leptonic CP violation** (mass hierarchy, θ_{23} octant)

First step towards a **time tagged neutrino beam**: direct production/detection correlation

Hadron beamline
collects, focuses, transports K^+
see G. Brunetti's poster [ID 26]

Instrumented decay pipe
real-time, 'inclusive' monitoring of produced e^+

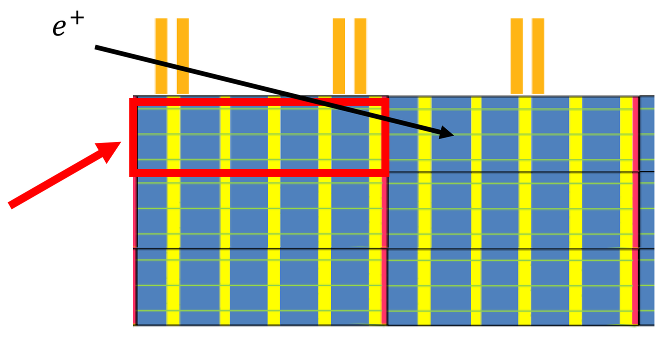


Positron tagger
Longitudinally segmented compact calorimeter with integrated photon veto

Requirements:
- Radiation hardness
- Cost effectiveness

Harsh environment:
- Particle rate: $< 200\ kHz/cm^2$
- Background: pions from K^+ decays

Ultra-Compact Calorimeter Module (UCM)

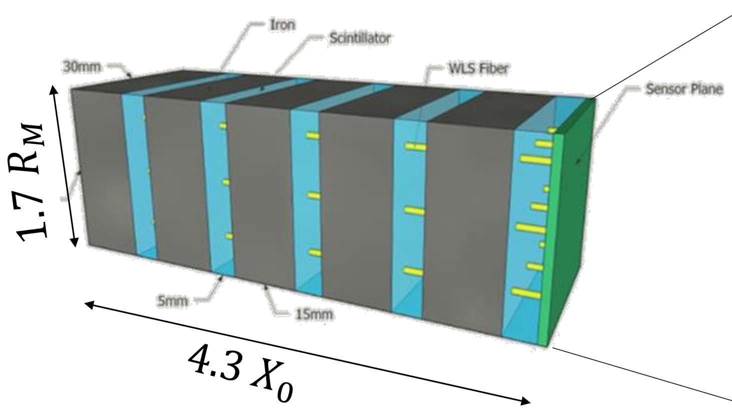


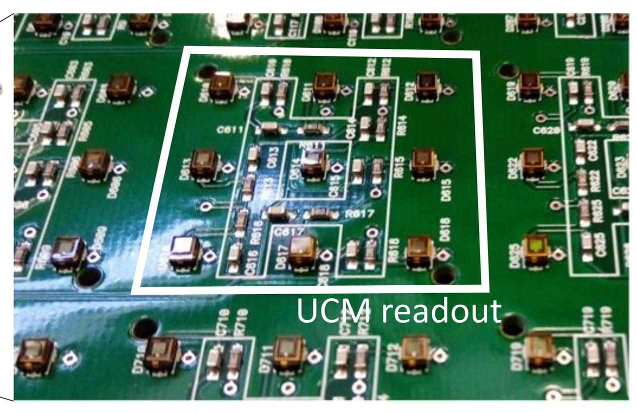
Ultra-Compact Calorimeter Prototypes

Shashlik with integrated readout

Basic shashlik calorimeter: Scintillator / absorber sampling calorimeter, read out by Wavelength Shifter (WLS) optical fibers, routed to PMT

Ultra-Compact shashlik prototype: basic iron/scintillator shashlik where each WLS fiber is read out by one single SiPM. Electronic r/o in the bulk of detector: **compact structure**

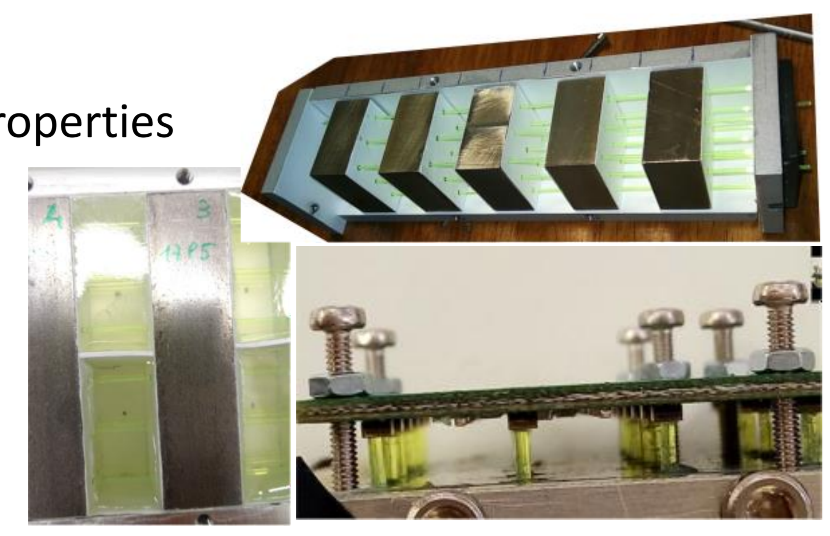




Polysiloxane shashlik calorimeters

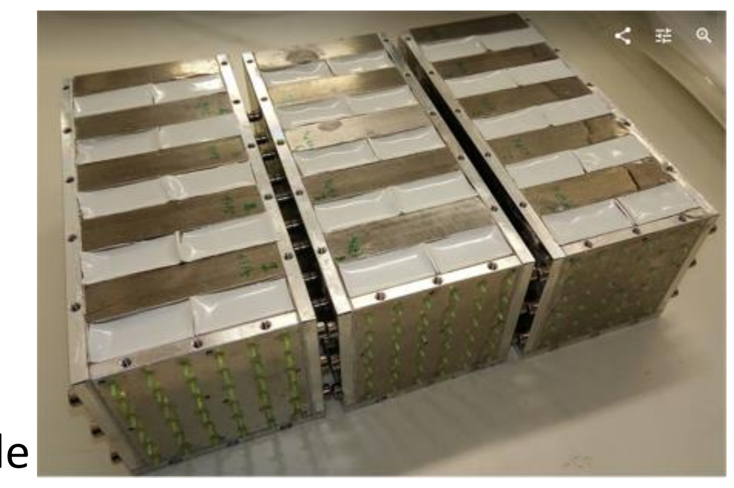
First use in HEP. Elastometric material with interesting properties

- **Superior radiation hardness** (transparent after 10 kGy dose exposure)
- **Easier fabrication** process: initial liquid form. No drilling of the scintillator.
- **Optimal optical contact with fibers**



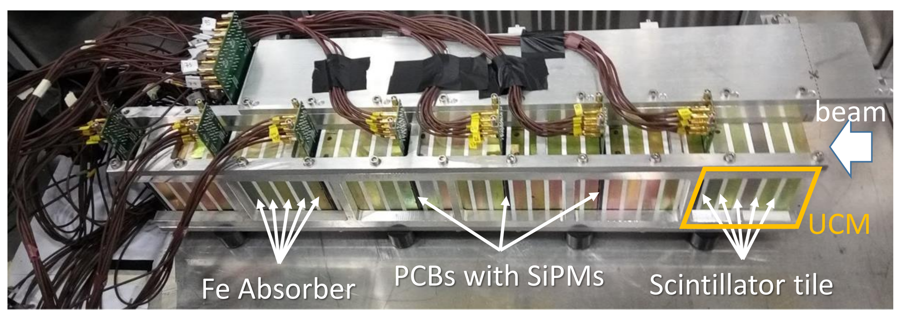
Prototype tested @ CERN (PS-T9)

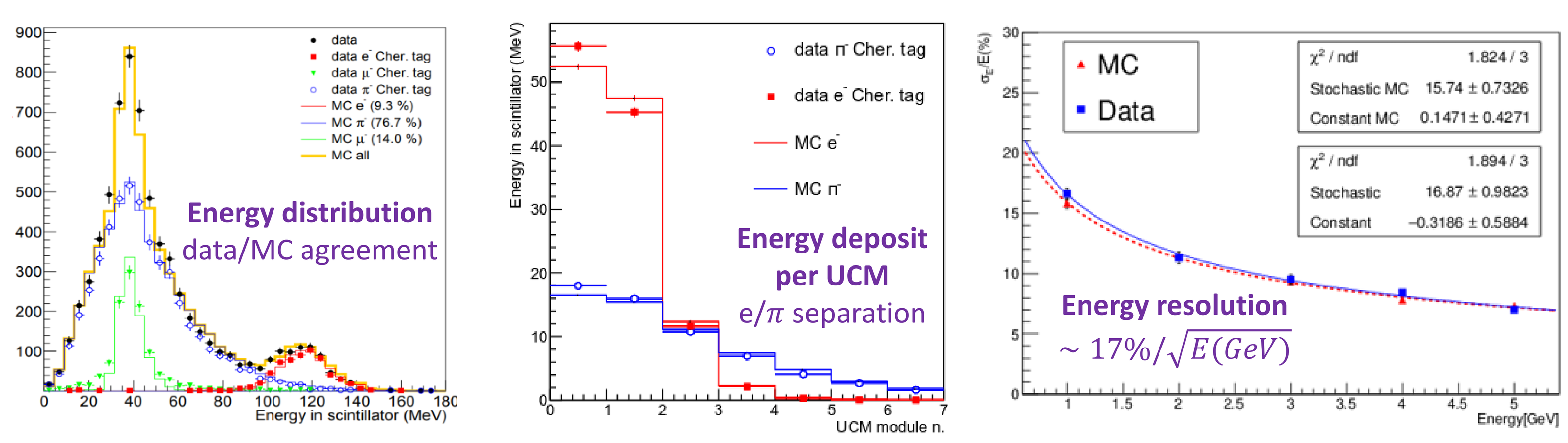
- 12 UCMs: 3 (beam direction) x 2 x 2
- Active layer 3 times thicker: 15 mm compensate 30% lower light yield w.r.t. EJ200
- **Energy resolution: $17\%/\sqrt{E(GeV)}$** comparable with plastic scintillator based prototype
- **Good linearity**: < 3% in the 1-5 GeV
- **Fiber-scintillator coupling** after pouring is comparable to that obtained from injection molding of conventional scintillators



Tagger prototype tested @ CERN (PS-T9)

- 56 UCMs: 7 (beam direction) x 4 x 2 equivlent to 30.1 X_0 and 3.09 λ
- UCM:
  - ✓ EJ200 plastic scintillator
  - ✓ Y11 & BCF92 WLS fibers
  - ✓ FBK 20 μm SiPMs



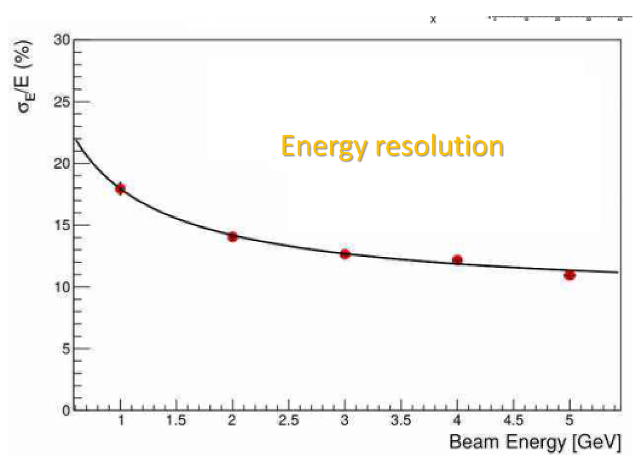


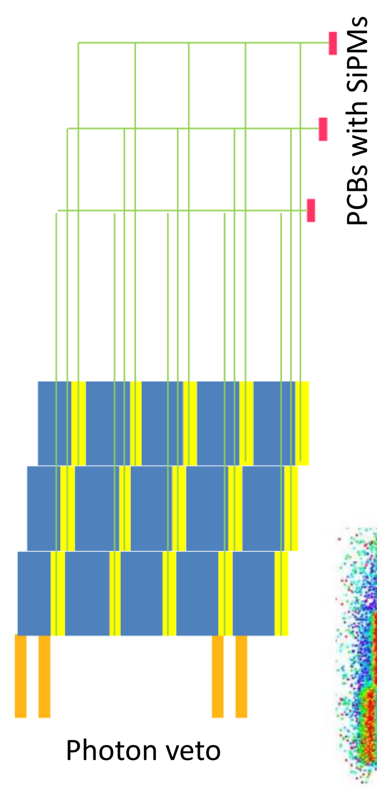
- Measures repeated with different tilt angle (from 0 to 200 mrad)
- Data compared with **Geant4 simulation** of the detector (photon generation and transport not included)
- **Good e/π separation** based on longitudinal segmentation (mis-id. < 3%)

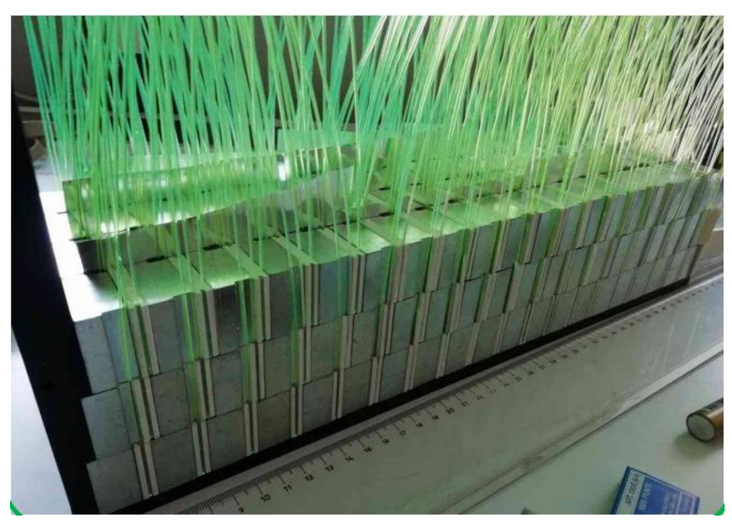
Lateral scintillation light readout

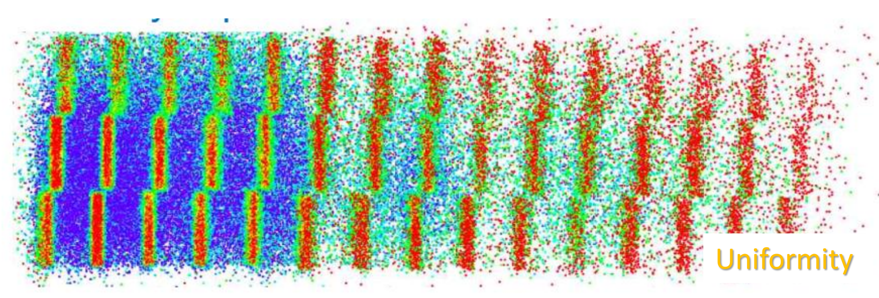
Light collected from scintillator sides and bundled to a single SiPM reading 10 fibers
SiPM are not immersed anymore in the hadronic shower less compact but ..

- Much **reduced neutron damage** (larger safety margins)
- **Better accessibility**
- **Safer WLS-SiPM coupling**.
- Resolution, light yield, uniformity, optical coupling to photo-sensors, e/π separation. In progress



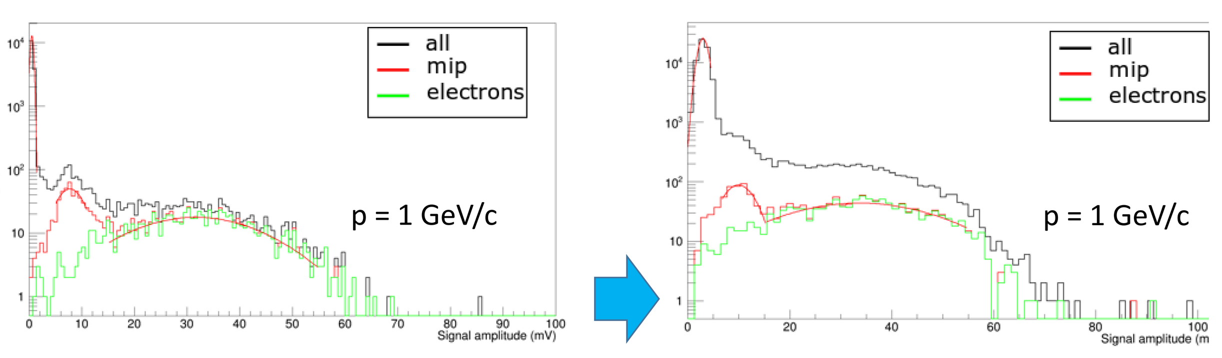






Test of SiPM radiation-hardness

- Van de Graaff CN accelerator at Laboratori Nazionali di Legnaro p (5 MeV) + ^{9}Be $\rightarrow$ n + X (p currents < 1 μA, n ~ 1-3 MeV)
- Test beam @CERN PS-T9
- **Loss of single p.e sensitivity** after $3 \cdot 10^{9}$1 MeV-eq n/cm^2
- **Constant MIP peak/e peak** Equalization can be achieved with overvoltage



Irradiation: 10^{11} 1 MeV-eq n/cm^2

More information: enubet.pd.infn.it

- 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*
- CERN-SPSC-2016-036; SPSC-EOI-014, **Enabling precise measurements of flux in accelerator neutrino beams: the ENUBET project**. *ENUBET Collaboration*
- IEEE Trans. Nucl. Sci. 64 (2017) 1056, **Shashlik Calorimeters With Embedded SiPMs for Longitudinal Segmentation**. *A. Berra et al.*
- JINST 13 (2018) P01028 arXiv:1801.06167, **Testbeam performance of a shashlik calorimeter with fine-grained longitudinal segmentation**. *G. Ballerini et al.*