Detectors for the ENUBET instrumented decay tunnel

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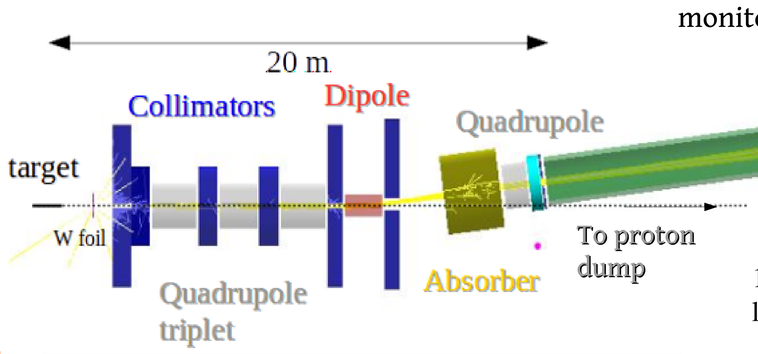
ENUBET (Enanched NeUtrino BEams from kaon Tagging)

- This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 681647).
- 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.

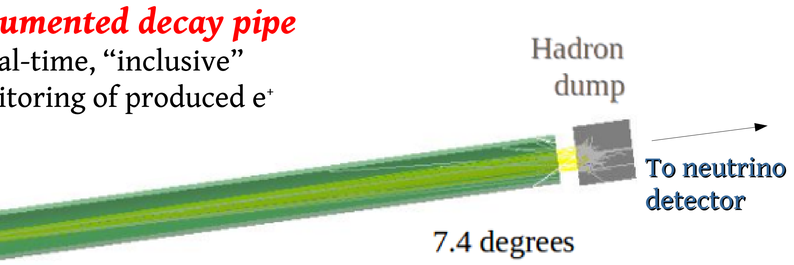
Physics programme

- Unprecedented high precision measurement of ν_e and $\bar{\nu}_e$ cross sections.
- Highly beneficial for tackling the main open neutrino-related issues: mass hierarchy, θ_{23} octant, leptonic CP violation.
- First step towards a **time tagged neutrino beam:** direct ν production/detection correlation.

Hadron beamline
collects, focuses, transports K^+

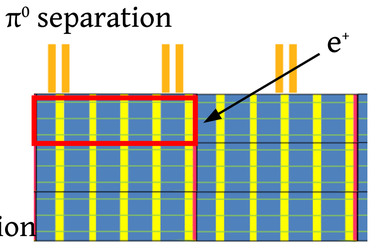


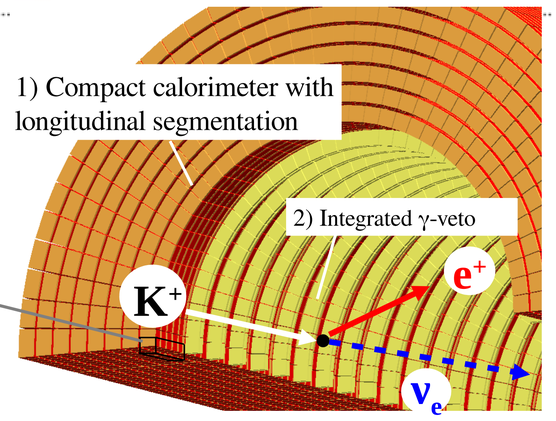
Instrumented decay pipe
real-time, "inclusive" monitoring of produced e^+



Photon veto: e^+, π^0 separation (π^0 rejection)

Ultra Compact Module (UCM): e^+, $\pi^\pm$, $\mu^\pm$ separation





Positron tagger
Longitudinally segmented compact calorimeter with integrated photon veto

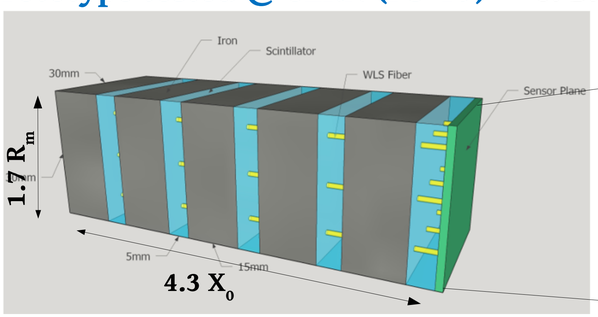
Ultra-Compact Calorimeter prototypes

Shashlik with integrated readout

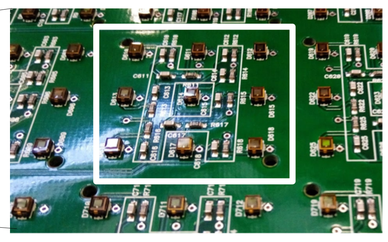
Basic shashlik calorimeter: Scintillator / absorber sampling calorimeter, read out by Wavelength Shifter (WLS) optical fibers, routed to PMT

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**

Prototype tested @ CERN (PS-T9) → ***G. Ballerini et al. JINST 13 (2018) P01028***



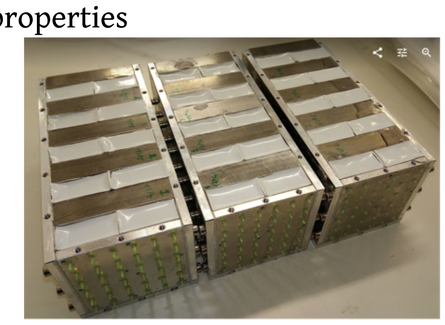
UCM readout



Polysiloxane shashlik calorimeters

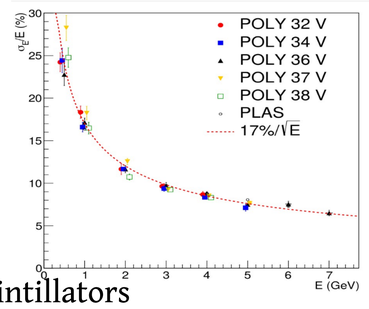
First use in HEP. Elastometric material with interesting properties

- **Superior radiation hardness** (transparent after 10 kGy dose exposure)
- **Easier fabrication** process: initial liquid form poured at 60° . No drilling of the scintillator.
- **Good optical contact with fibers**



Prototype tested @ CERN (PS-T9)

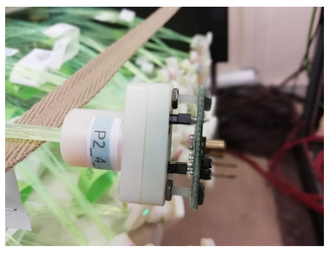
- 12 UCMs: 3 (beam direction) x 2 x 2
- Active layer 3 times thicker: 15 mm compensate 30% lower light yield w.r.t. EJ200
- **Energy resolution:** 17% / √E(GeV) comparable with plastic scintillator based prototype
- **Good linearity**: < 3% in the 1-5 GeV
- **Fiber-scintillator coupling** after pouring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

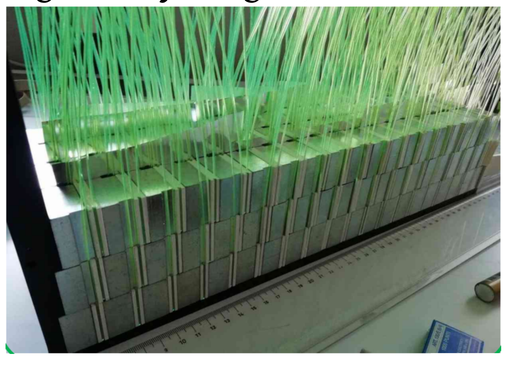


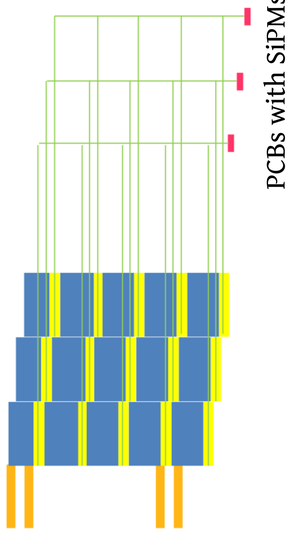
Lateral scintillation light readout

Light collected from scintillator sides and bundled to a single SiPM reading 10 fibers (5 scintillators)
SiPM are not immersed anymore in the hadronic shower thus less compact but ..

- Much **reduced neutron damage** (larger safety margins)
- **Better accessibility**
- **Safer WLS-SiPM coupling**

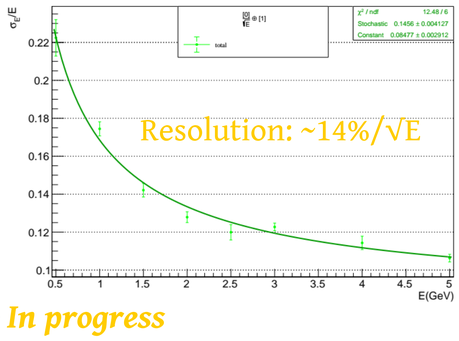






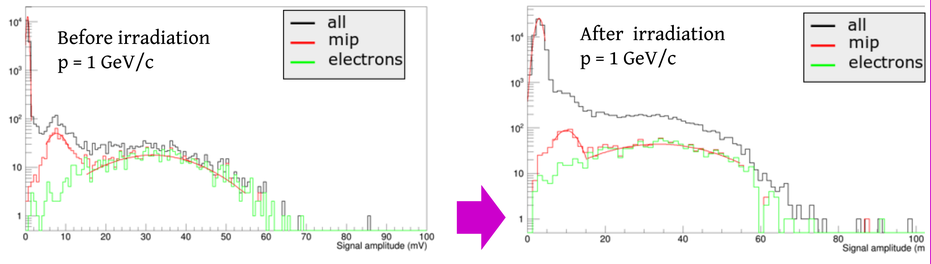
Tagger prototype tested @ CERN (PS-T9)

- 84 UCM :
  - ✔ EJ204 plastic scintillator
  - ✔ Y11 & BCF92 WLS fibers
  - ✔ FBK 4x4 mm² SiPMs
- Measures repeated with different tilt angle (from 0 to 200 mrad)
- Uniformity, optical coupling to photo-sensors, e/π separation → ***In progress***
- Comparison with Geant4 simulation of the detector → ***In progress***



Test of SiPM radiation-hardness

- Van de Graaf CN accelerator at Laboratori Nazionali di Legnaro p (5 MeV) + ^{9}Be n + X (p currents < 1 μA, n ~ 1-3 MeV)
- **Test beam @CERN (PS-T9)**
- **Loss of single p.e sensitivity** after $3 \cdot 10^9$ n/cm²
- **Constant mip peak/e peak**



Irradiation: 10^{11} 1 MeV- eq n/cm²

F. Acerbi et al. JINST 14 (2019) P02029

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-2018-034 ; SPSC-I-248,* ***The ENUBET project****. ENUBET Collaboration*
- IEEE Trans. Nucl. Sci. 64 (2017) 1056, **Shashlik Calorimeters With Embedded SiPMs for Longitudinal Segmentation**. *A. Berra et al.*