Monitored beams for high precision measurement of neutrino flux: the ENUBET project

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Outline

- The ENUBET experiment layout
- Detectors
- Focusing system
- G4 simulation & read-out
- ν_μ CC events

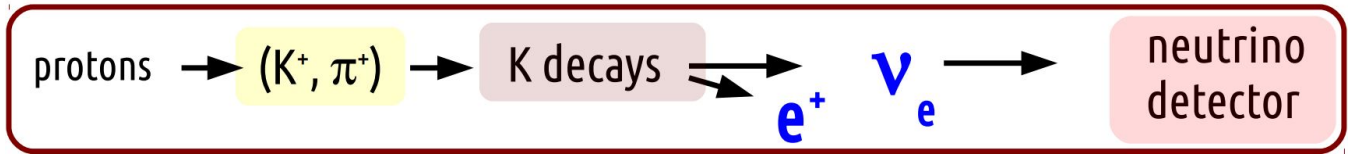
Goal: to demonstrate the technical feasibility and physics performance of a neutrino beam where *lepton production at large angles is monitored at single particle level*

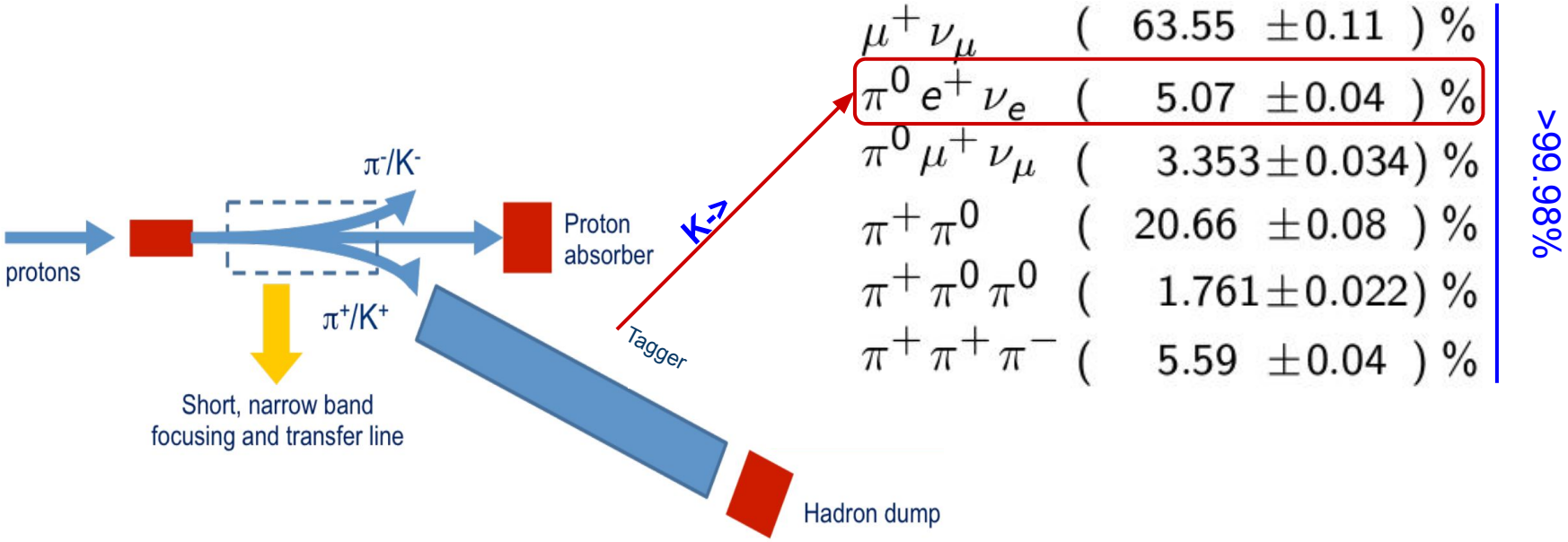
Enhanced NeUtrino BEams from kaon Tagging

ENUBET: 54 physicists, 12 institutions

Monitored beams

The main idea: to obtain a **beam of tagged neutrinos** with well-known parameters.
A new generation of **cross-section** experiment with a **neutrino source controlled at the <1% level**.



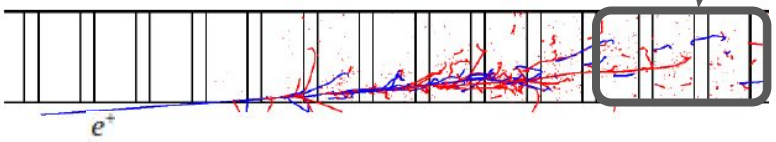


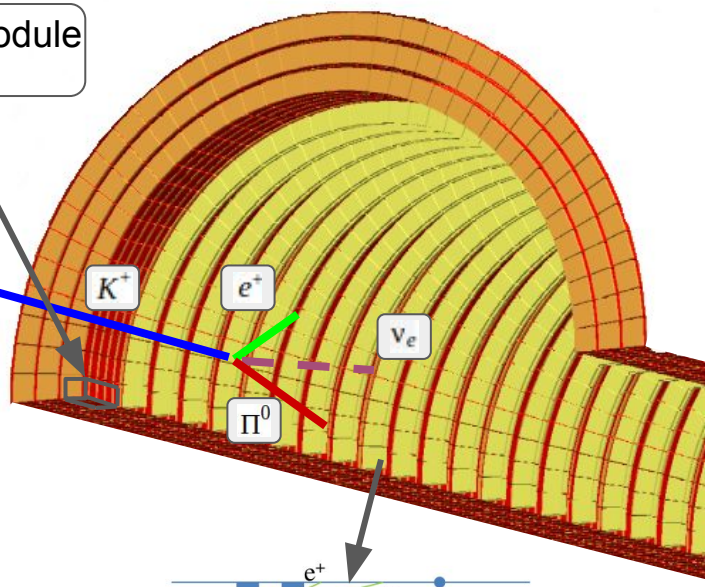
Tagger

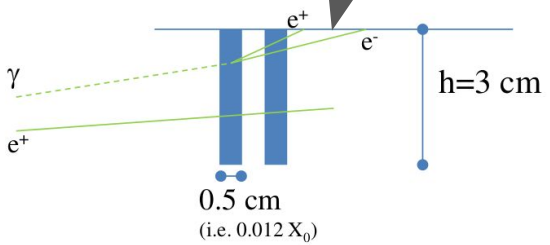
Calorimeter

- Ultra Compact Module (UCM)
- Longitudinal segmentation
- Light readout with SiPM
- e+/Π+ separation

Ultra Compact Module
3x3x10cm 4.3X_0







e^+ (signal) topology

π^0 (background) topology

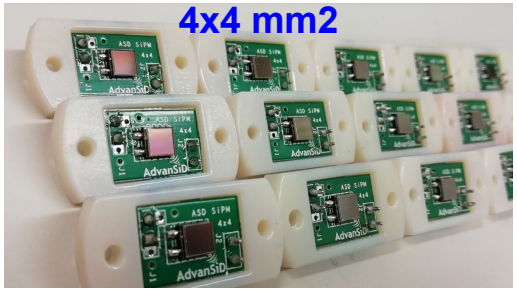
π^+ (background) topology

Integrated Photon-veto

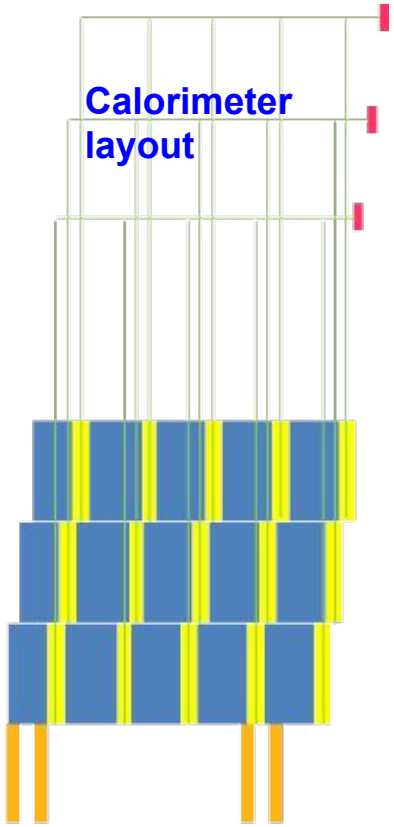
- 3x3 cm2 plastic scintillator pads
- e+/Π0 separation

Detector

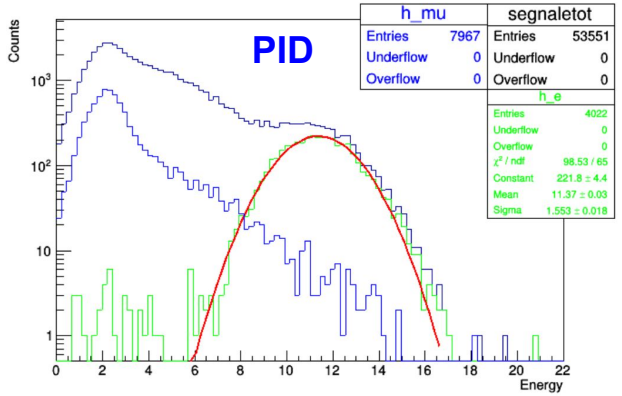
Light collected from scintillator sides and bundled to a **single SiPM reading 10 fibers**

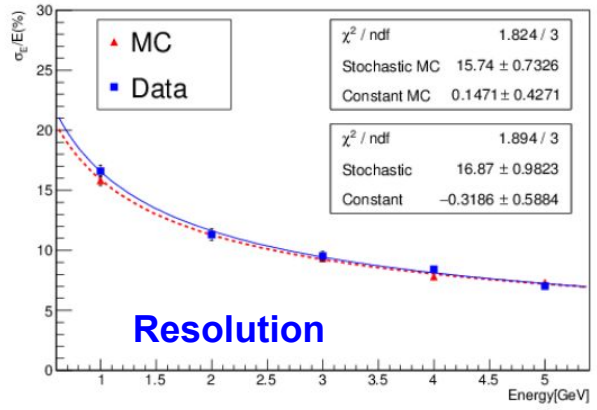


A module with hadronic cal. for pion containment and integrated t0-layer



- Checking good signal amplitude
- Checking the impact of light connection uniformity and reproducibility of WLS-SiPM optical match.



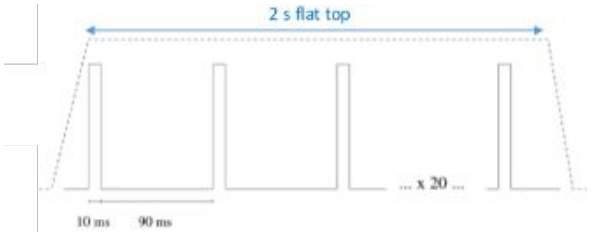


Beam line particle yields

2 possibilities:

HORN-BASED

20x10ms resonant multiple spills



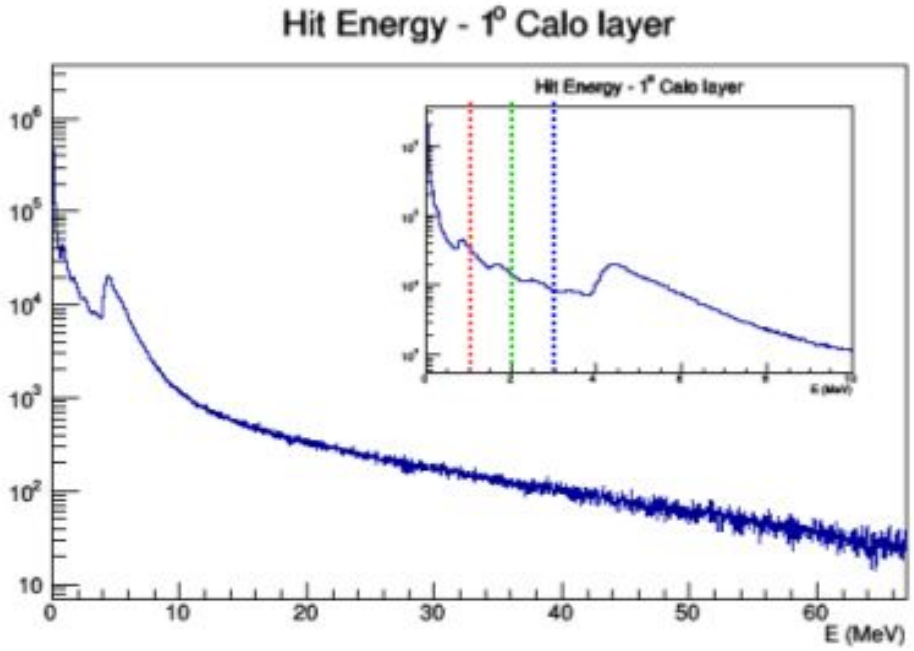
STATIC-FOCUSING

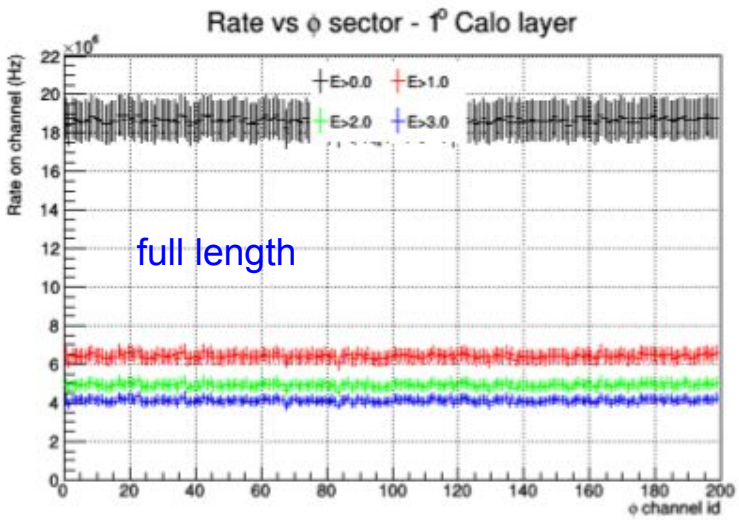
Continuous long spill

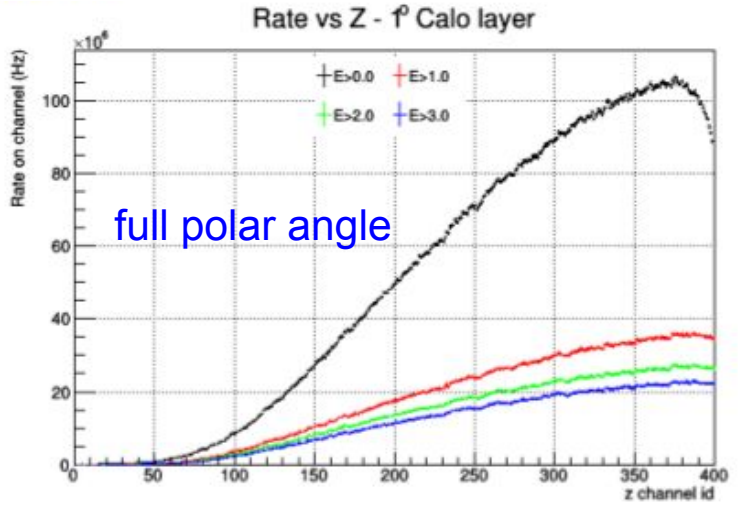
Advantages of the static(slow) extraction:

- No need for fast-cycling horn
- Strong **reduction of the rate** (pile-up) in the instrumented decay tunnel
- **Monitor** the **μ** after the dump at 1% level (**flux of ν_μ from π)** [under evaluation]

GEANT4 Simulation





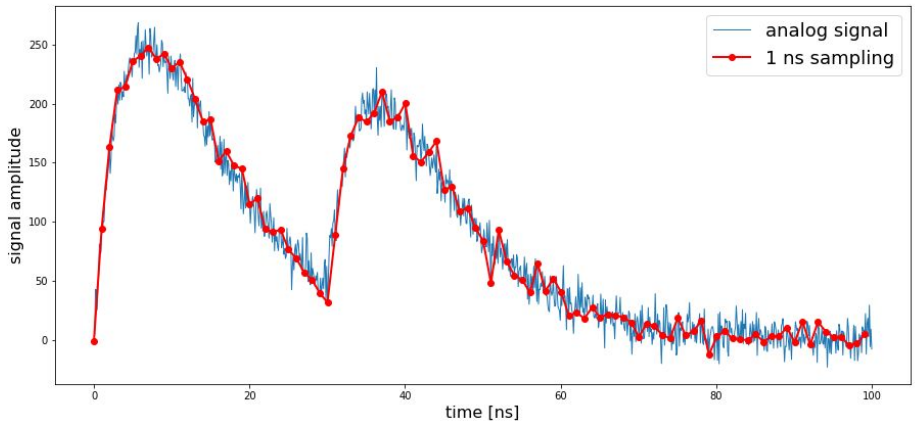


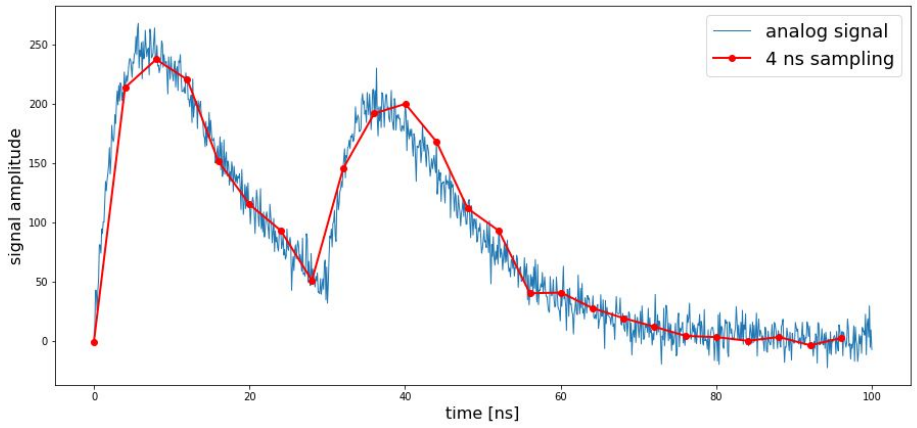
Expected average hit-rate per UCM 1-10MHz

R&D read-out system

Read-out system includes a large number of steps from SiPM to saved signal.
Developed electronics and software for reading the signal from the detector.

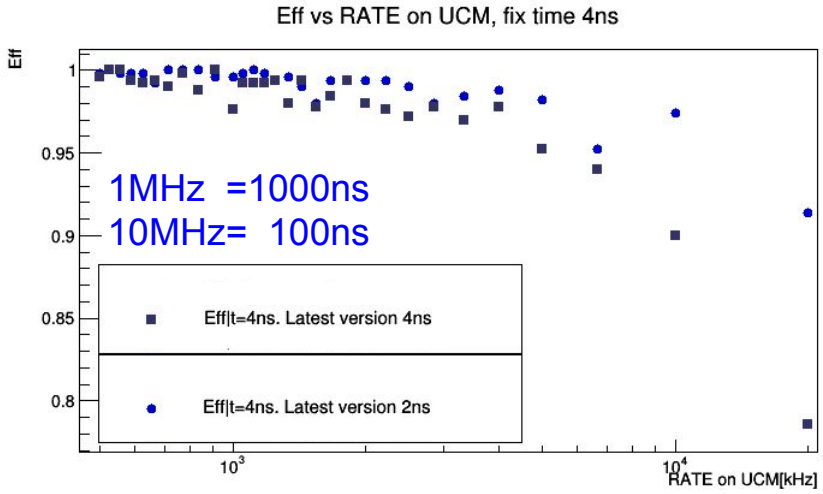
Possible digitizer sampling time:1ns, **2ns, 4ns**





Challenges:

- Develop an algorithm for finding the amplitude and absolute time of a signal.
- Develop a digitizer with a minimum sampling time and a price of ~100€/ch.



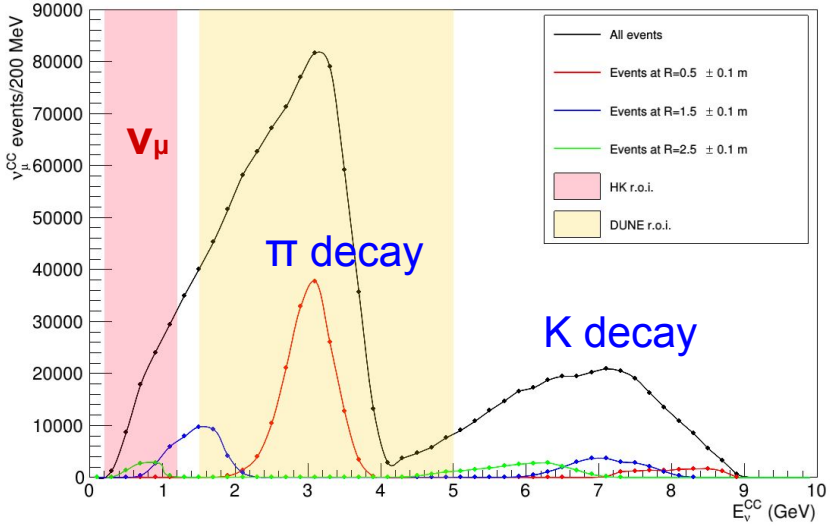
5MHz	2ns	4ns
t|4ns	0.982	0.952
t|8ns	0.994	0.974

ν events per year at the detector

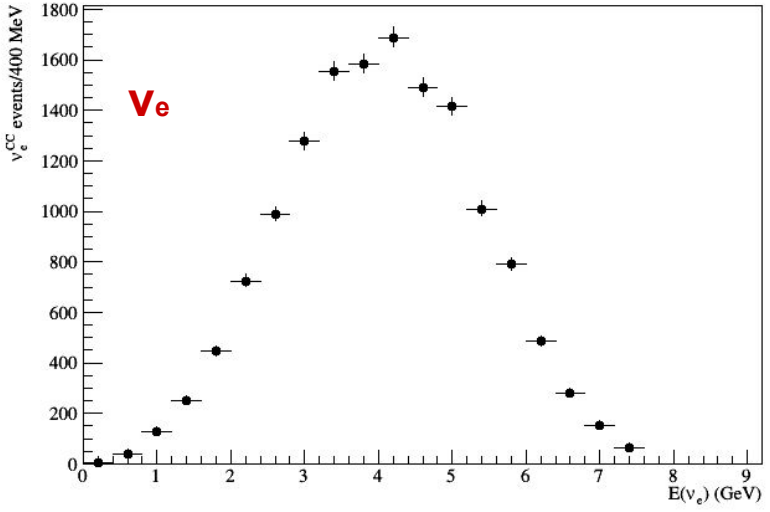
- **Detector mass: 500 t** (e.g. Protodune-SP or DP @ **CERN**, ICARUS @ **Fermilab**);
- **Baseline** (i.e. distance between the detector and the beam dump) : **50 m**;
- Integrated pot: **4.5x10^19 pot** at SPS (6 months in **dedicated mode**, ~1 year in **shared mode**) or, equivalently, **1.5x10^20 pot** at the Fermilab Main Ring.

- **ν_μ** from **K** and **π** are **well separated** in energy (narrow band);
- **ν_e** and **ν_μ** from **K** are **constrained** by the tagger measurement (Ke3, mainly Km2);
- **ν_μ** from **π**: **μ detectors downstream** of the hadron dump ? (under study)

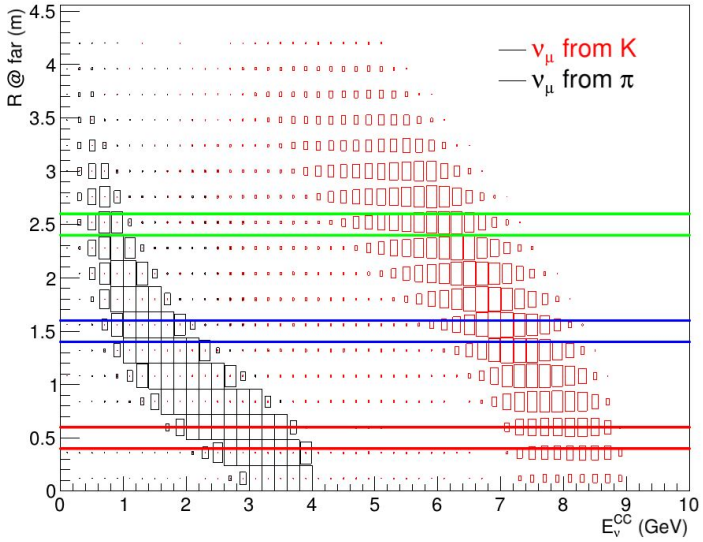
1.2 million ν_μ Charged Current per year

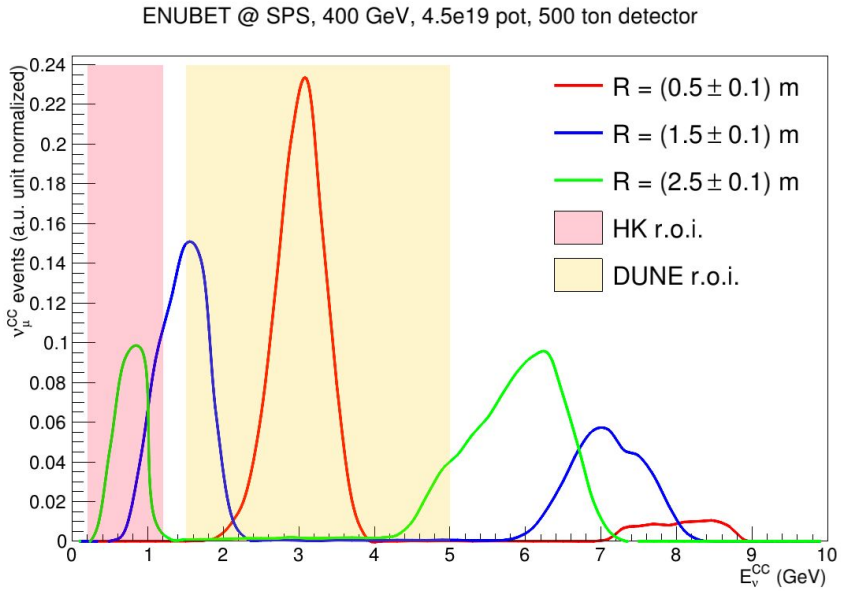


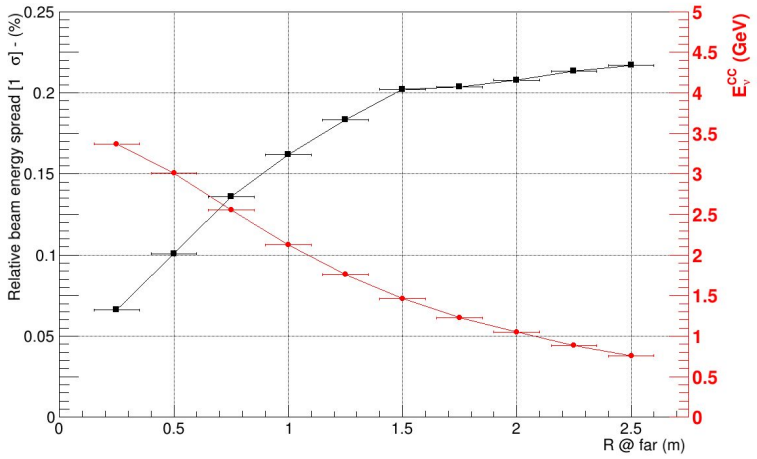
14000 ν_e Charged Current per year



ν_μ CC events. Narrow band beam







The neutrino E is a function of the distance of the neutrino vertex from the beam axis.

The beam width at fixed R (≡ ν energy resolution for π component) is:

- 8 % for r ~ 50 cm, <E_ν>~ 3 GeV
- 22% for r ~ 250 cm, <E_ν> ~ 0.7 GeV

Conclusions

ENUBET is a narrow band beam with a high precision monitoring of the flux at source (1%) and neutrino energy

At the last 3 years:

- first end-to-end simulation of the beamline
- Tested the “burst” slow extraction scheme at the CERN-SPS
- proved the feasibility of a purely static focusing system (10 6 ν_μ CC per year, 10 4 ν_e CC per year with a 500 ton detector)
- completed the full simulation of the positron reconstruction: single particle level monitoring
- identified the best options for the instrumentation of the decay tunnel: lateral readout of the sampling calorimeter.

Thank you for your attention!


e+
nu
be
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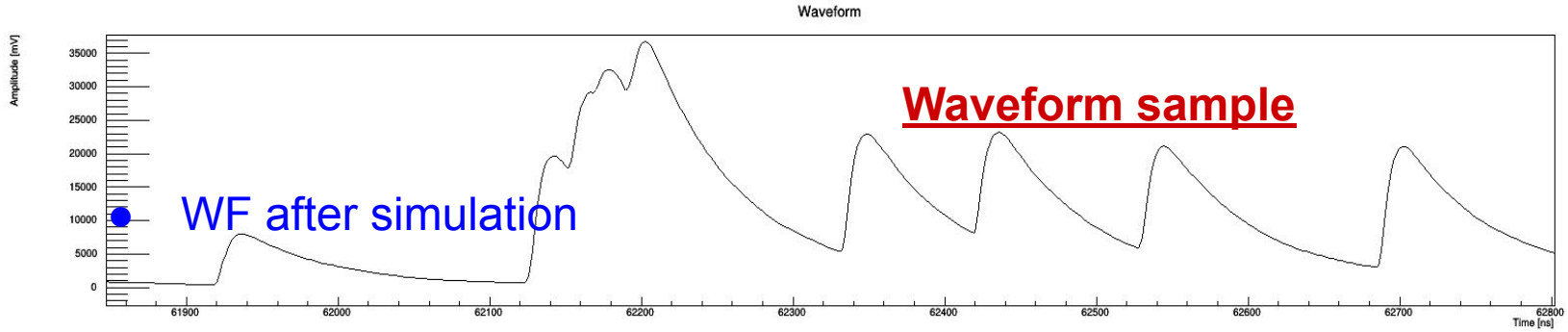
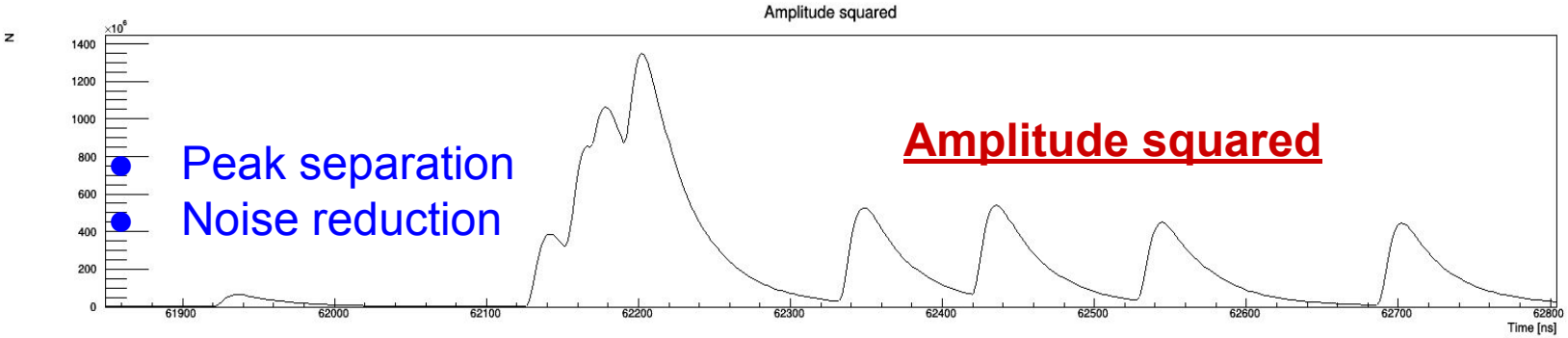
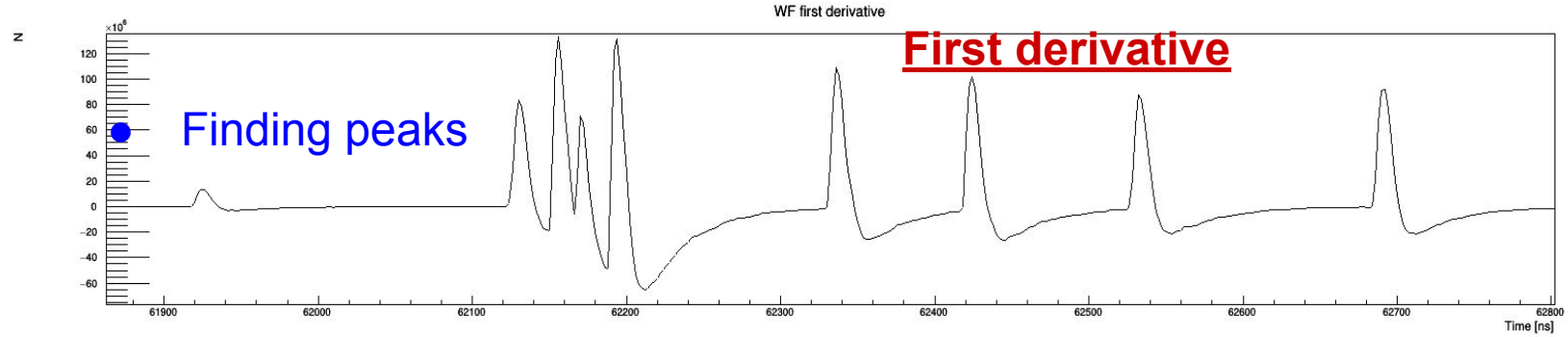
WF conversion





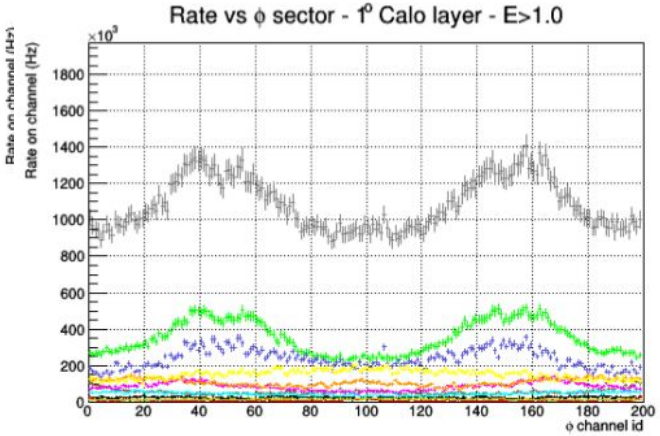


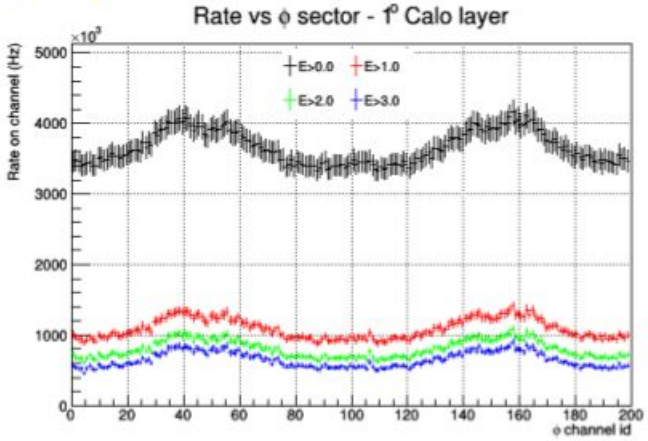
Other GEANT4 simulation

TL_r4 ["static focusing option" - single dipole]

(assuming 4.5×10^{13} pot/spill and a 2s spill → Rate of particles entering the tunnel: 2.65×10^{11} Hz)

[profiling on z]





1MHz