NP06/ENUBET

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F. Terranova (Univ. of Milano-Bicocca and INFN) on behalf of the ENUBET Collaboration

ENUBET: ERC Consolidator Grant. Jun 2016 - May ~~2021~~ 2022. PI: A. Longhin.
Since April 2019, ENUBET is also **a CERN Neutrino Platform experiment: NP06/ENUBET**

The ENUBET Collaboration:
60 physicists, 12 institutions
Spokespersons: A. Longhin, F. Terranova
Technical Coordinator: V. Mascagna

The rationale of ENUBET

To extract the most physics from DUNE and Hyper-Kamiokande, a complementary programme of experimentation to determine neutrino cross-sections and fluxes is required. Several experiments aimed at determining neutrino fluxes exist worldwide. The possible implementation and impact of a facility to measure neutrino cross-sections at the percent level should continue to be studied. Other important

European Strategy for Particle Physics Deliberation document (pag. 5)

ENUBET and NUSTORM (see also the European Strategy Physics Briefbook, arXiv:1910.11775)

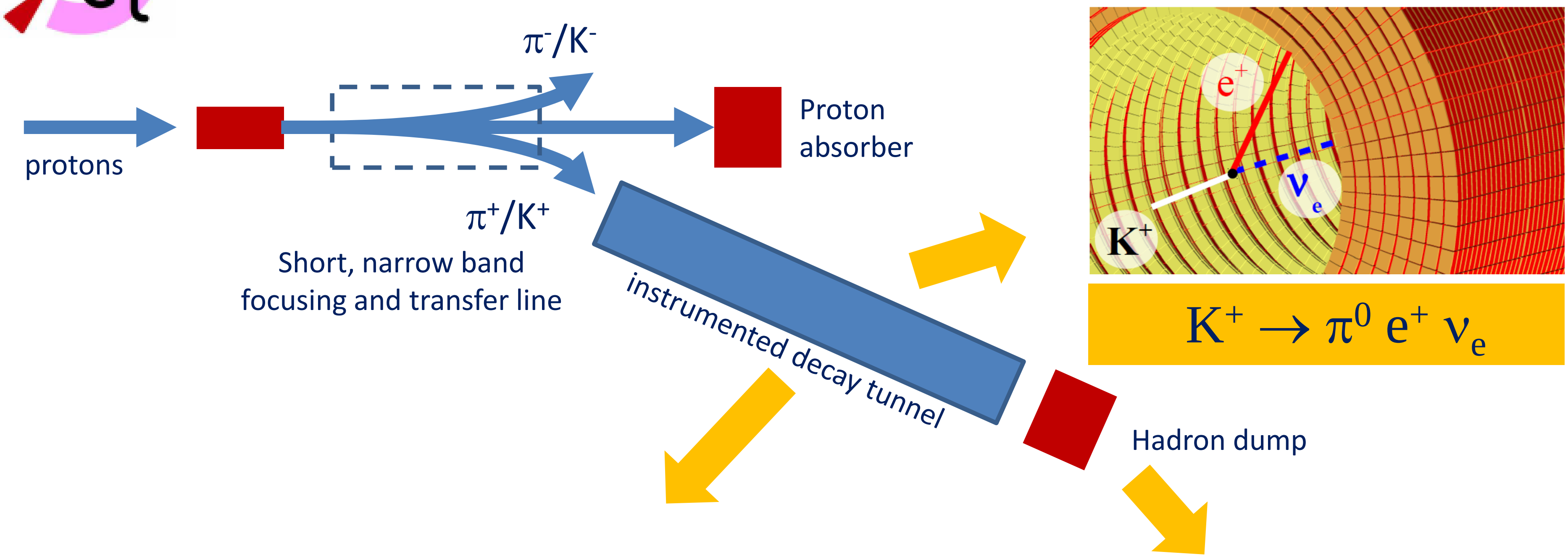
ENUBET is aimed at

- Designing a narrow band neutrino beam at the GeV scale and measure at 1% the **flux, flavor** and (at 10%) the **energy of the neutrinos** produced at source

It is the core technology for

- A new generation of short-baseline experiments to achieve a 1% precision on the ν_e **and** ν_μ **cross sections** and **remove all the biases** due the ν energy reconstruction
- It is essential to lower <3% the systematic budget of **DUNE and HyperK** and enhance remarkably their discovery reach (equivalent to doubling the DUNE mass!)
- Is the most natural follow-up of the previous generation of x-sect experiments (including the possibility to upgrade **the ProtoDUNE** or **the SBN physics programme**)

ENUBET



NEW! (2019-20) muon identification and monitoring for

$$K^+ \rightarrow \mu^+ \nu_\mu$$

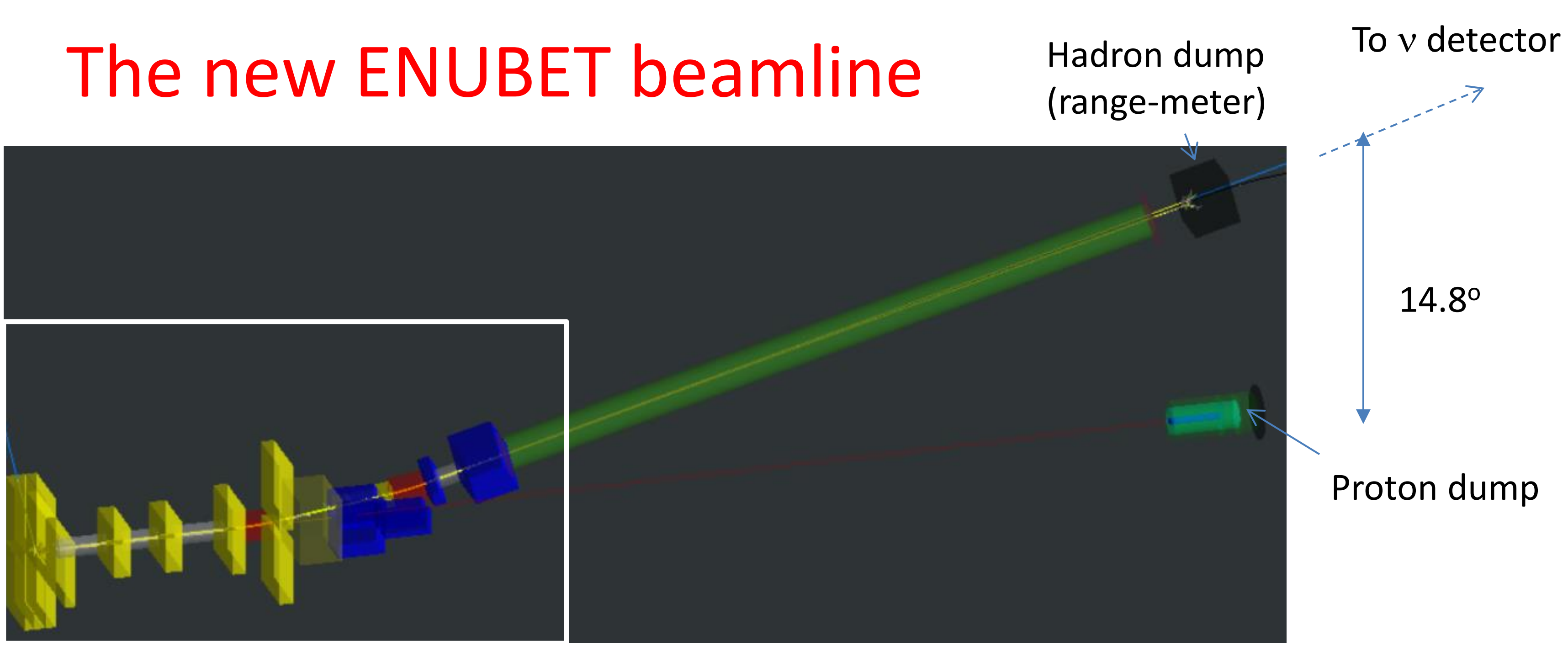
NEW! (2019-20) muon monitoring at single particle level replacing the hadron dump with a real range-meter

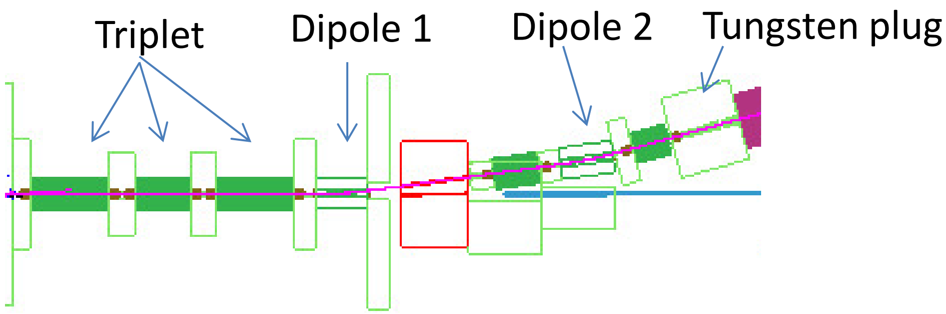
$$\pi^+ \rightarrow \mu^+ \nu_\mu$$

ENUBET will be the first "**monitored neutrino beam**" (*) where nearly all systematics are bypassed monitoring the leptons in the decay tunnel at single particle level

(*) A. Longhin, L. Ludovici, F. Terranova, EPJ C75 (2015) 155

The new ENUBET beamline





Proton dump: **OK** but engineering studies needed
Hadron dump: **OK** (with neutron shieldings NEW!)

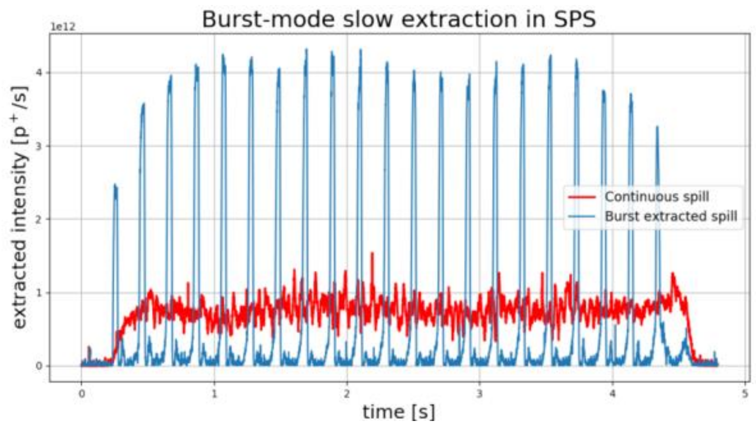
Target simulation: **OK**
Transfer line:
- TRANSPORT/G4Beamline (optics and background shielding **OK**)
- FLUKA (doses and neutron shieldings **~OK**)
- GEANT4 (systematics, **in progress**)

See also: **A. Longhin, Talk @ Neutrino 2020**

Focusing with the Horn

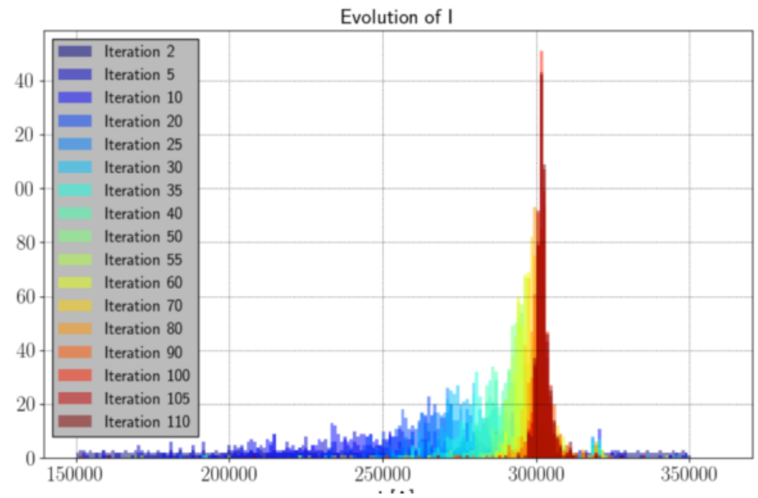
"Slow burst extraction": tested at the SPS in 2018. In 2019 we finalized the simulation with MAD-X to reach 2-10 ms extraction at 10 Hz in the flat top.

Final test: at SPS in 2022 (post LS2)



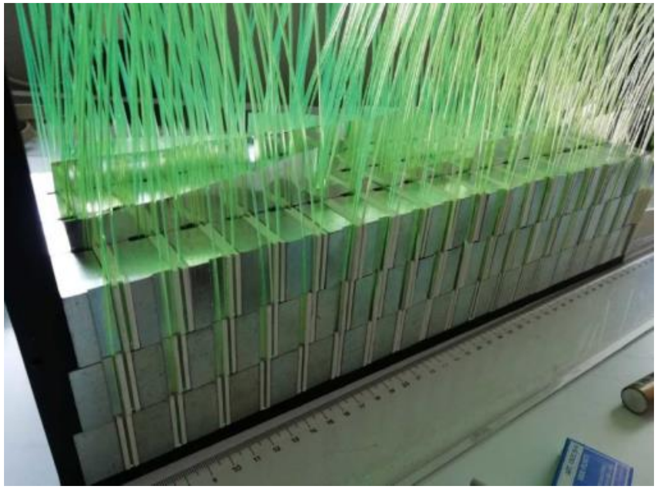
Paper: M. Pari, M. A Fraser et al, IPAC2019

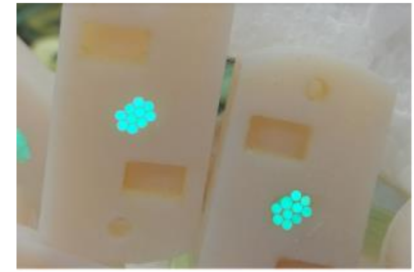
Horn is being re-optimized for the new beamline. We will likely employ a parabolic horn. Current and shape of conductors are chosen in a broad phase space using genetic algorithms. In progress

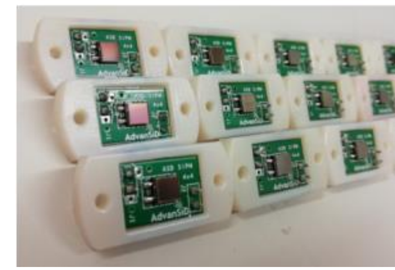


Static focusing (no horn, 2s slow extraction): work carried on in 2017-2019.
Adapt this option to the 2 dipole beamline: in progress

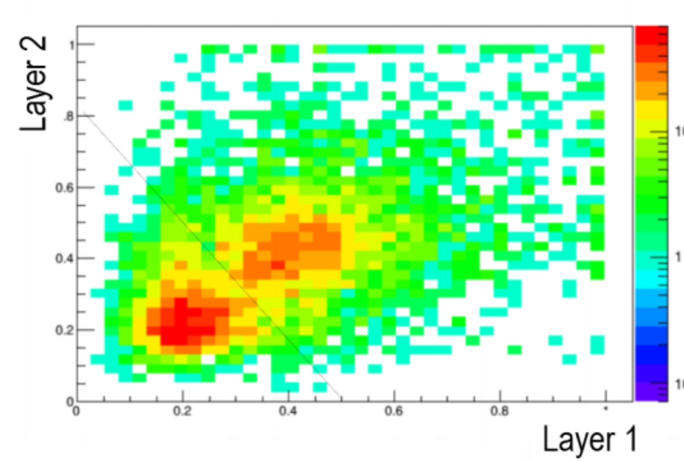
Instrumentation of the decay tunnel







- Longitudinally segmented calorimeter (**OK**)
- SiPMs on top of the calo above a PE borated shield to reduce (x18) radiation damage **OK**
- Test of the photon veto (t0-layer) **OK**
- Custom digitizer: **in progress**



The choice of the technology is now final and it is **extremely cost-effective**

Paper: **F. Acerbi et al, JINST in press** (arXiv:2006.07269)

2020 highlight. First release at ICHEP2020

Lepton monitoring

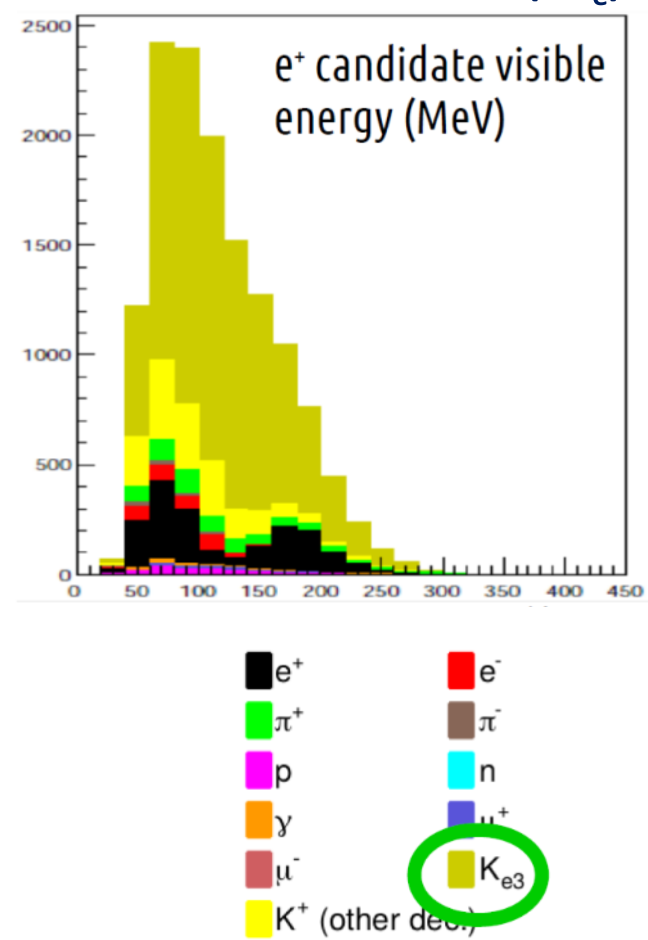
Full simulation: detector response, pile-up, event building, PID algorithms (2016-2020) **OK**

Particle ID for the **positrons** is much better in the new beamline. **OK**

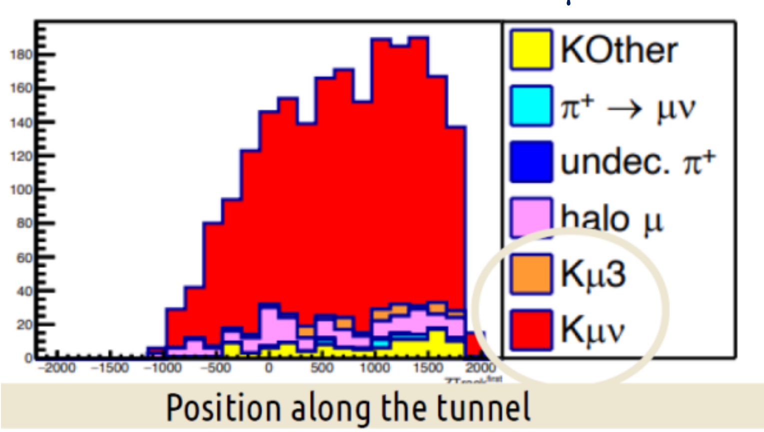
For the first time, we monitor **muons** and the beamline is flexible enough for dedicated runs in the region of interest for HyperK. **In progress**

S/N = 2.1
Efficiency: 24%
(dominated by geometrical eff.)

Positrons from K ($\sim\nu_e$)



Muoni from K ($\sim\nu_\mu$)



S/N = 6.1
Efficiency: 34%
(dominated by geometrical eff.)

Physics performance

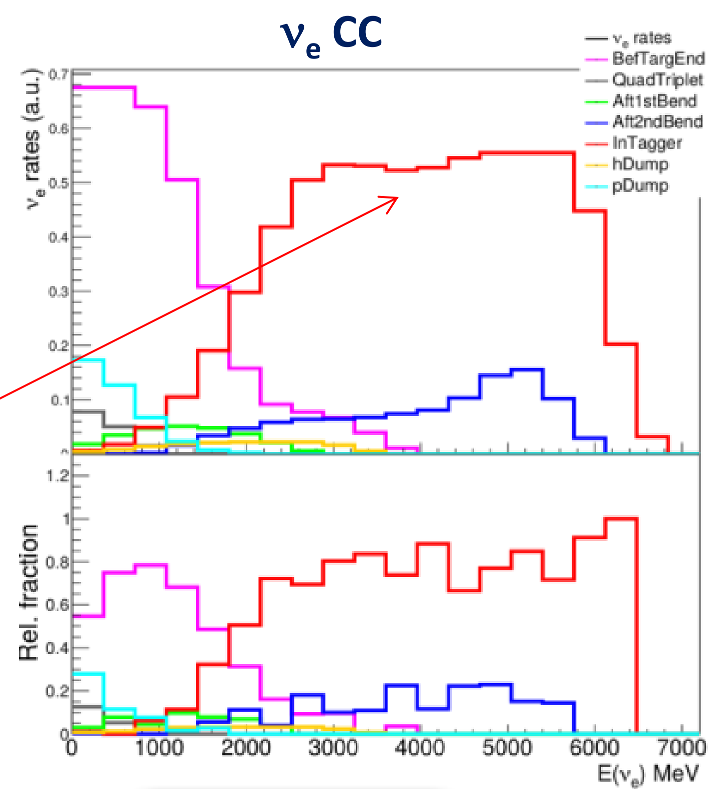
Focusing system	π/pot (10^{-3})	K/pot (10^{-3})	Extraction length	π/cycle (10^{10})	K/cycle (10^{10})	Proposal [c]
Horn	**97**	7.9	2 ms [a]	438	36	x 2
"static"	**19**	1.4	2 s	85	6.2	**x 4**

To be updated with the new beamline In progress

The following results are given under the assumption of a **500 t neutrino detector** located 50 m from the hadron dump

10^4 fully reconstructed ν_e CC in about 1.5 y of data taking (TBC)

80% of the events directly monitored (positron in the decay tunnel)
10% from decay in the transfer line
10% low energy events from K^0_L et al.



Beamline optimized for DUNE

Muon neutrinos

Flux:

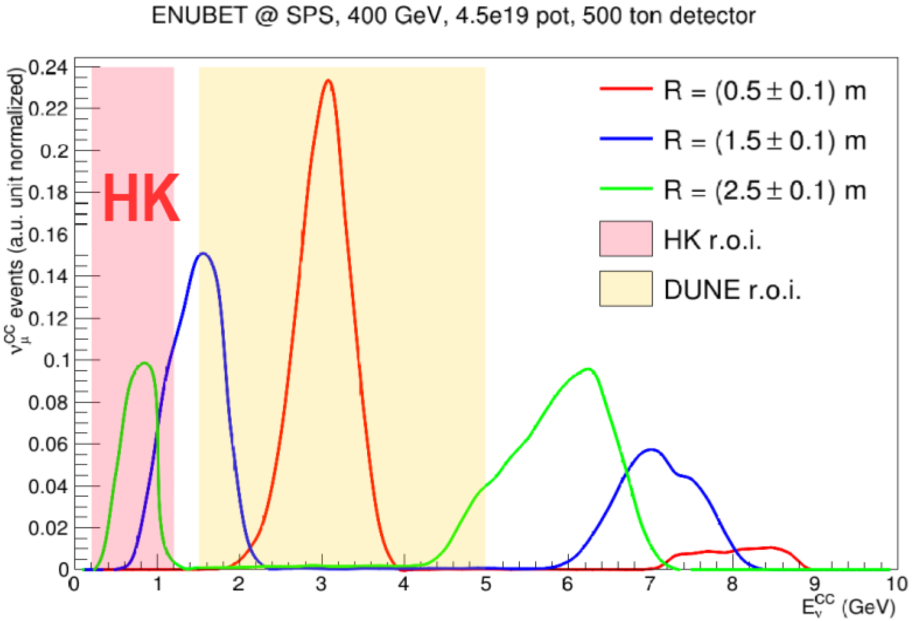
- Muons from π monitored by the range-meter (useful for DUNE and HyperK)
- High energy muons monitored by $K_{2\mu}$ (useful for x-sect modeling and DUNE “tau runs”)

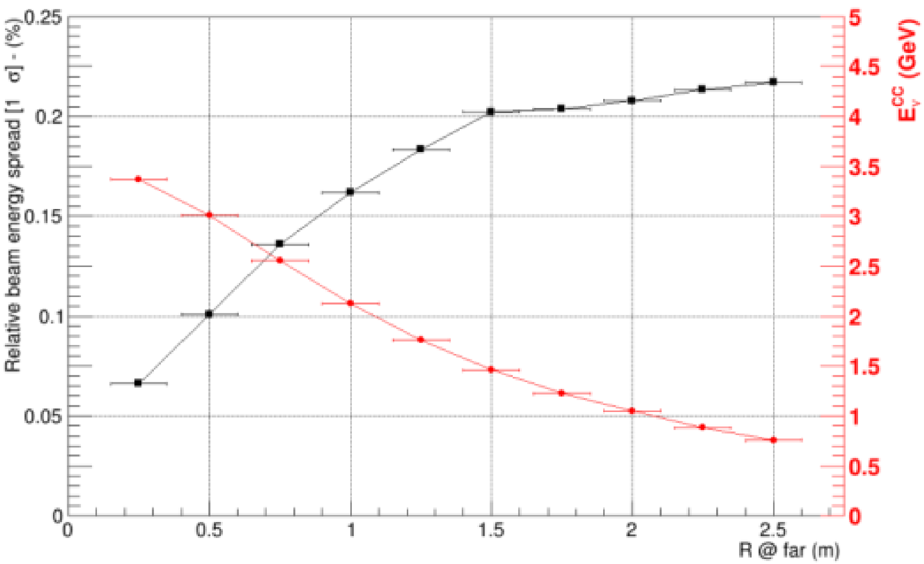
Energy:

- Since the momentum bite is <10% and the detector distance is small, strong correlation between the position of the neutrino vertex and its energy.
- We dubbed this technique “narrow-band off-axis technique” (*)
- **We provide the ν energy on a event-by-event basis without relying on final state particles in ν_μ CC**

(*) F. Acerbi et al., CERN-SPSC-2018-034

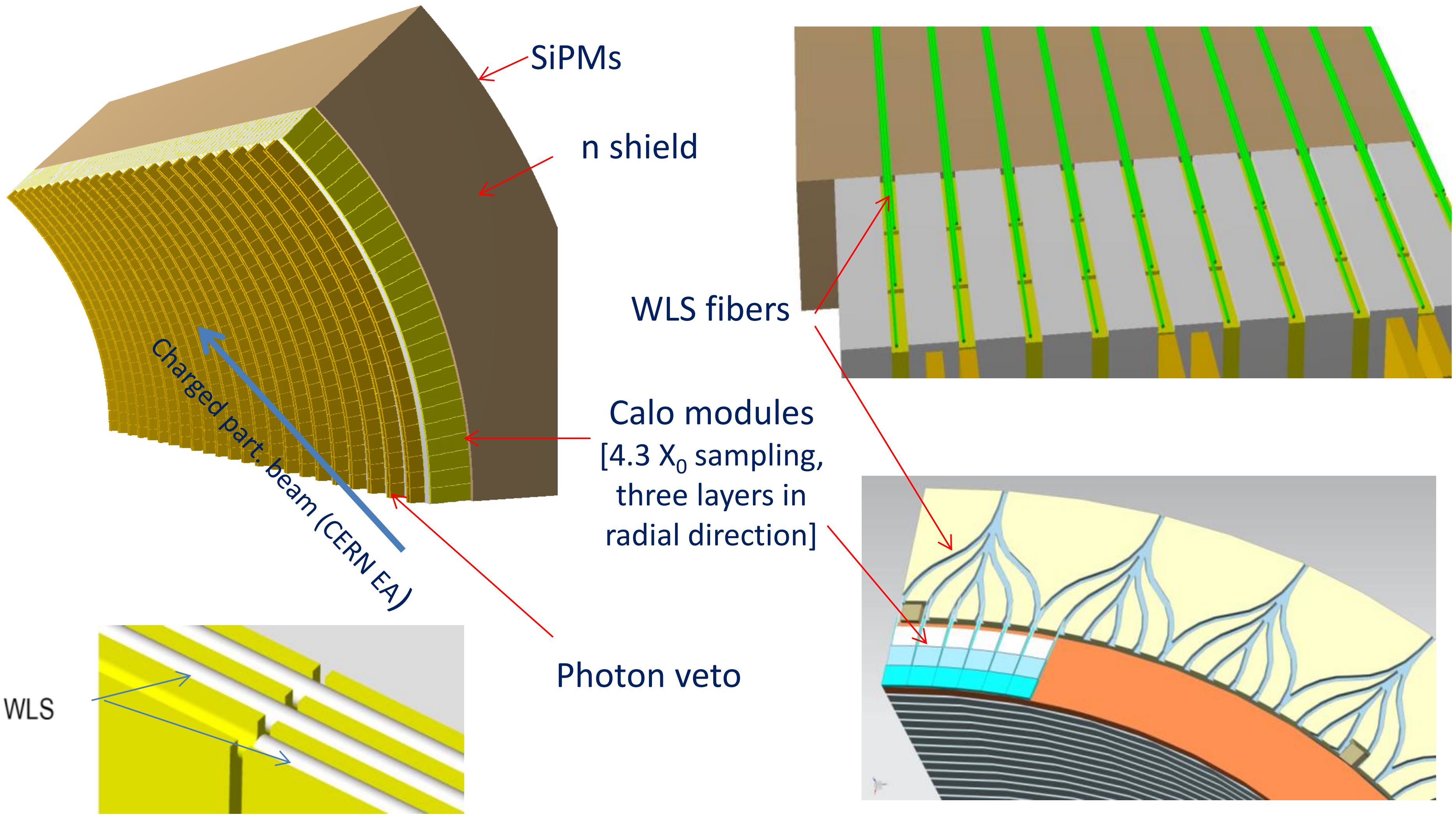
About **O(10^6)** fully reconstructed ν_μ CC per year





The ENUBET Demonstrator

A realistic 2m long instrumented decay tunnel to be tested with beams of charged particles



Conclusions and next steps

- **ENUBET is on schedule**: the design phase is over, the simulation are nearly completed and we are going to build the final demonstrator
- The physics performance are extremely appealing but we have to go through the complete study:
  - Optimization of the horn
  - Update of flux and spectra with the final beamline
  - Establish the final systematic budget for ν_e and ν_μ: **in progress** using the same techniques currently employed by T2K. We **add the ENUBET observables as additional priors** to defeat the flux systematics. We use the information on the **initial energy** to reduce the FSI systematics on cross section measurements
- The main tasks for 2021 are the construction of the **demonstrator** and the **full assessment of systematics**
- Beam-tests and machine studies are postponed to 2022 due to the COVID lockdown of the facilities (the ERC Project will be extended by one year, too)
- We aim at the final **Conceptual Design Report** by 2022

We look forward to seeing ENUBET up and running in the DUNE/HyperK era!