# The ENUBET Beamline

G. Brunetti
(INFN Padova)
On Behalf of the ENUBET Collaboration

INFN Istituto Nazionale di Fisica Nucleare — erc — HORIZON 2020 — Università degli Studi di Padova

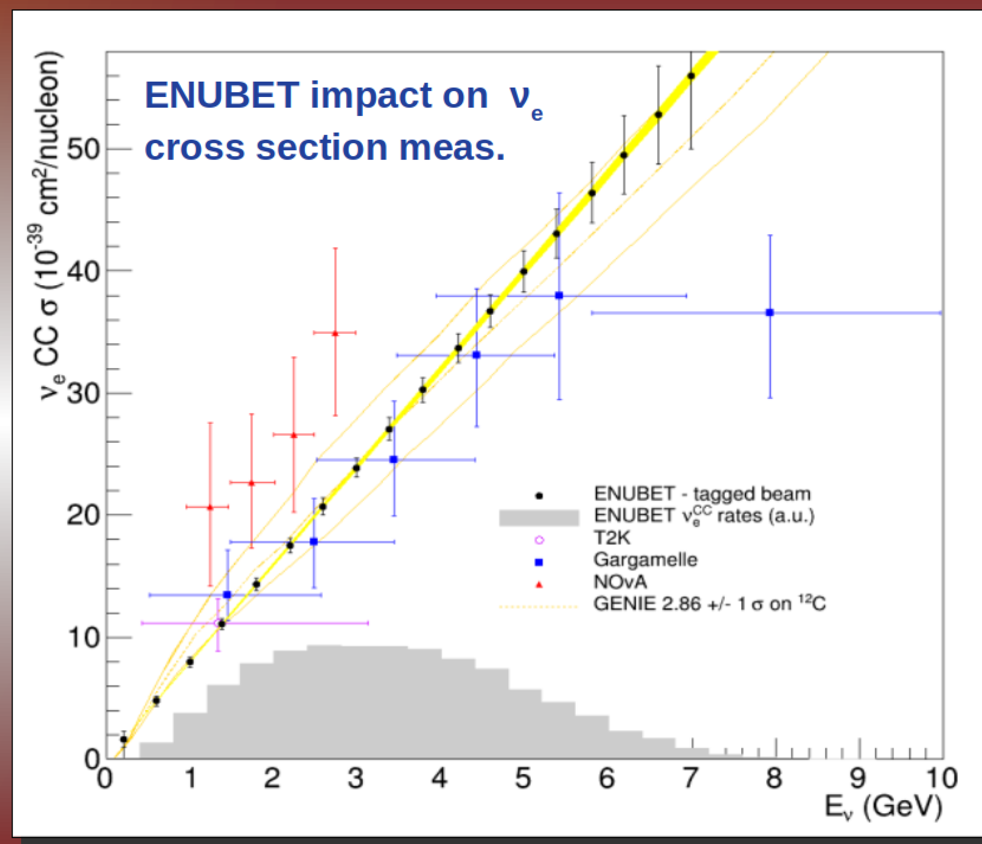
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 681647)

## ENUBET (Enhanced NeUtrino BEams from kaon Tagging)

- A novel $\nu_e$ **source** from $K^+ \to e^+ \pi^0 \nu_e$ decays by **tagging the e+** in an instrumented decay tunnel (See Poster ID61)
- Reduce **systematics on neutrino flux to O(1%) level** by monitoring the positrons produced at large angle in the decay tunnel of **conventional neutrino beams**

**→ Improve by ~ 1 order of magnitude precision on $\nu_\mu$ & $\nu_e$ cross sections**

→ New generation of neutrino cross section experiments with unprecedented control on the flux
→ First step towards time-tagged ν-beam: the ν at the detector is correlated with the lepton in the tunnel
→ Highly beneficial to long baseline $\nu_\mu \to \nu_e$ programs




## A New Facility

**based on conventional accelerators and existing infrastructures**

**3 levels**
- $\nu_\mu$ narrow beams
- $\nu_e$ monitored beams
- Tagged neutrino beams

- **$\nu_\mu$ Cross Section**: high precision scattering measurements with **narrow band beam** where the neutrino energy is known a priori with 10% uncertainty
  Direct measurements of μ from $\pi^+$ at single particle level if **static focusing** → $\nu_\mu$ flux from pions at per-cent level
- **$\nu_e$ Cross Section**: 1% precision measurement with monitored neutrino beam with direct control on $\nu_e$ flux
  **slow proton extraction**: few ms for horn-based transferline, 2s for **static transferline**
  **e⁺ from Ke3 decays monitored at single particle level** by calorimeters of instrumented decay tunnel
- **Tagged neutrino beams**: **Static focusing system** → 1 Ke3 decay every 1.3 ns → **$\nu_e$ interaction in the detector time-linked with lepton observation in the tunnel**

## ENUBET Hadronic Transferline

**a short (~20m) tranferline followed by 40m long decay tunnel**

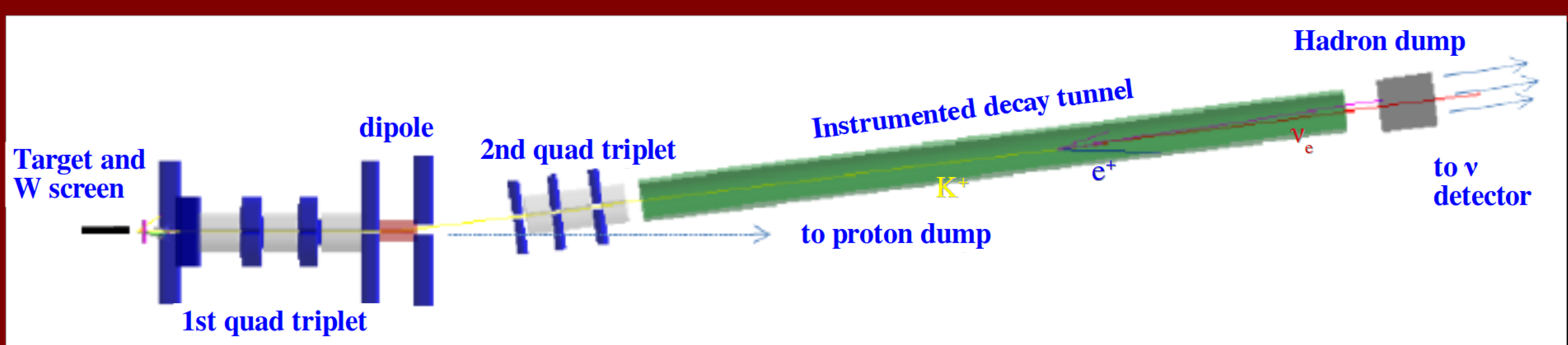
- Primary proton interactions in the Target simulated with **FLUKA.** Various proton drivers considered: **400 GeV, 120 GeV, 30 GeV protons**
- Optics optimized with **TRANSPORT** → results implemented in **G4Beamline** for full transport and interaction simulation. **Reference momentum: 8.5 GeV ±10%**
  → Best configuration achieved:
  **quadrupole triplet – bending dipole – quadrupole triplet**
  magnet apertures 15 cm, **dipole field 1.8 T → 7.4° bending,** quad fields in the range 5-11 kG
- Optimization performed with regards to:

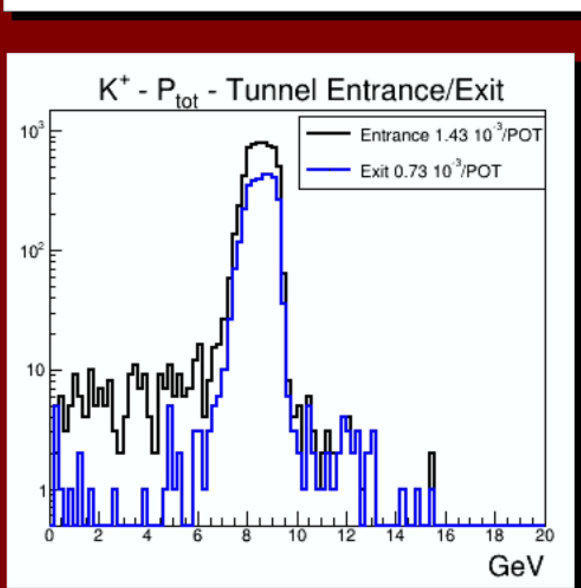
✓ **Number of K⁺ and π⁺** at tunnel entrance in the momentum range of interest
✓ **Total Length of the Transfer Line** → minimized to reduce kaon decay losses
✓ **Beam Size** → non decaying particles should exit the decay tunnel without hitting the tunnel walls
✓ **Magnet Field and Apertures** → use of normal conducting, conventional magnets
✓ **Level of Background** transported to the tunnel → affects S/N of identified e⁺

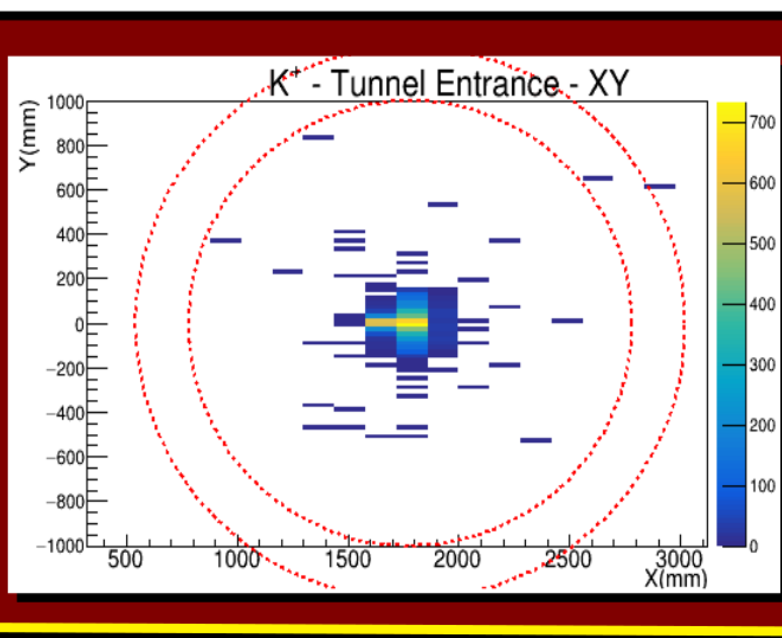
- Constrain on sources of systematics provided by distribution of particles in the decay tunnel, their energy and polar angle → **no info is needed from particle production in the target**

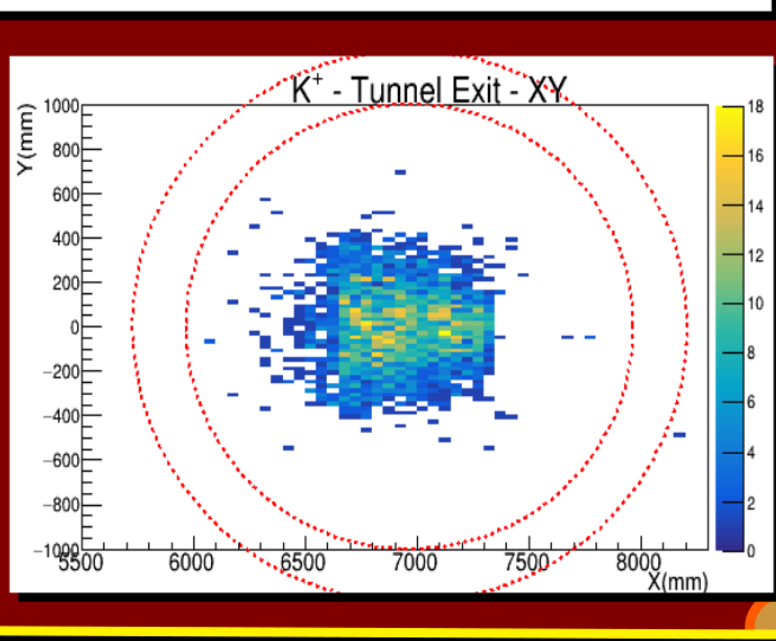
## Static Transferline

- Performance significantly better than proposal estimates [1] → K yield 4 times larger as result of optic optimization
- several advantages: cost, technical implementation and performance of particle ID. First step towards tagged beams!
- ~50% of K⁺ decay in the 40m long instrumented decay tunnel



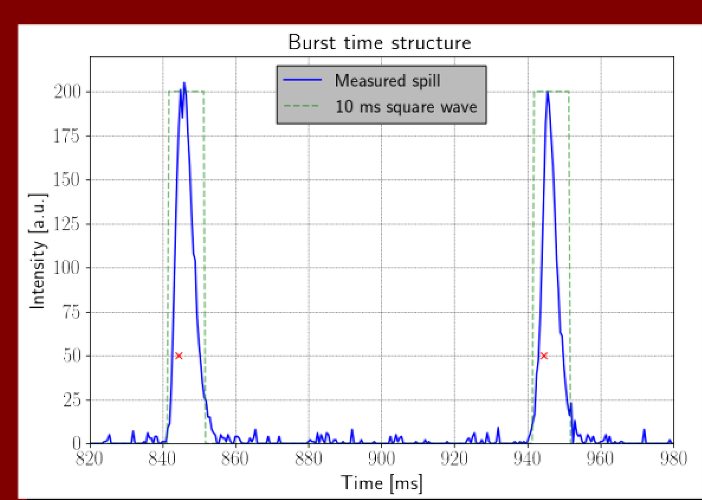



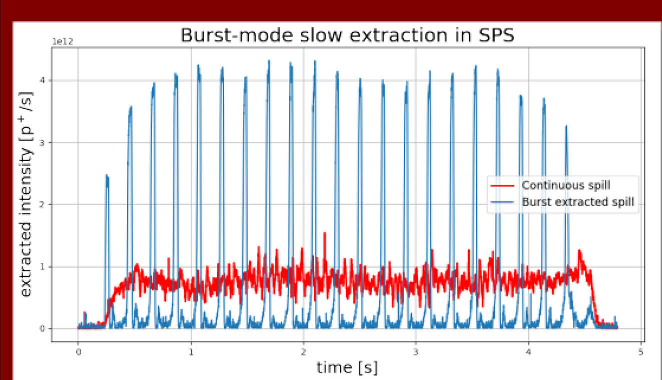



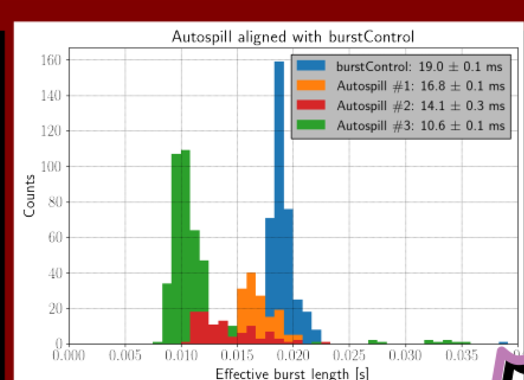

## Horn-based Transferline

A narrow band transfer-line based on
**ENUBET slow proton extraction (few ms) + horn pulsed for 2-10 ms**
On-going studies at CERN to implement the **synchronization of a slow-extracted spill with a pulsed strong focusing system → enhance output of neutrino flux keeping a reasonable pile-up threshold**

- Recent test results @ CERN confirmed the proof-of concept of feed-forward burst spill optimization: **Autospill-Burst** leads to a burst length optimization from 20 → **10(.6) ms**
- From this benchmark more degrees of freedom to explore full simulation and address remaining issues towards full operability




CERN-BE-OP-SPS, F.Velotti, M.Pari, V.Kain, B.Goddard

## Expected rates of π⁺ and K⁺ in [6.5÷10.5 GeV/c] range at the decay tunnel entrance for the 2 possible focusing schemes

| Focusing | $\pi^+$/POT [$10^{-3}$] | $K^+$/POT [$10^{-3}$] | Extraction Length | Factor w.r.t. [1] |
|---|---|---|---|---|
| Horn-based | 77 | 7.9 | 2 ms | × 2 |
| Static | 19 | 1.4 | 2 s | × 4 |

- Proven Static focusing feasibility
- Assuming 4.5 $10^{19}$ POT (~1 year of SPS operations in 50% shared mode with 200 days of live time) and a 2 s extraction per supercycle → about **1.13 $10^6$ $\nu_\mu$ CC and 1.4×$10^4$ $\nu_e$ CC interactions at the neutrino detector**

νPhys 2018 — Prospects in Neutrino Physics, 19-21 December 2018 Cavendish Centre

**ENUBET**
**Enabling high precision flux measurements in conventional neutrino beams**

## References

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] NIM A, 2016.05.123 arXiv:1605:09630
**A compact light readout system for longitudinally segmented shashlik calorimeters.** A. Berra et al

[4] IEEE Trans.Nucl.Sci. 64 (2017) no.4, 1056-1061
**Shashlik Calorimeters with embedded SiPM for Longitudinal Segmentation**, ENUBET Collaboration.

[5] JINST 13 (2018) P01028
**Testbeam performance of a shashlik calorimeter with fine-grained longitudinal segmentation**, Ballerini et al.