Performance Optimization of a Short-Baseline Neutrino Beamline at CERN

M.A. Jebramcik[1]*, A. Baratto-Roldan[1] , N. Charitonidis[1], E. Parozzi[1], M. Perrin-Terrin[2], F. Terranova[3]

[1]: CERN; [2]:Aix-Marseille Université, CNRS/IN2P3, CPPM; [3]: INFN, University of Milano-Bicocca

*marc.andre.jebramcik@cern.ch

ENUBET

see Talk by G. Brunetti

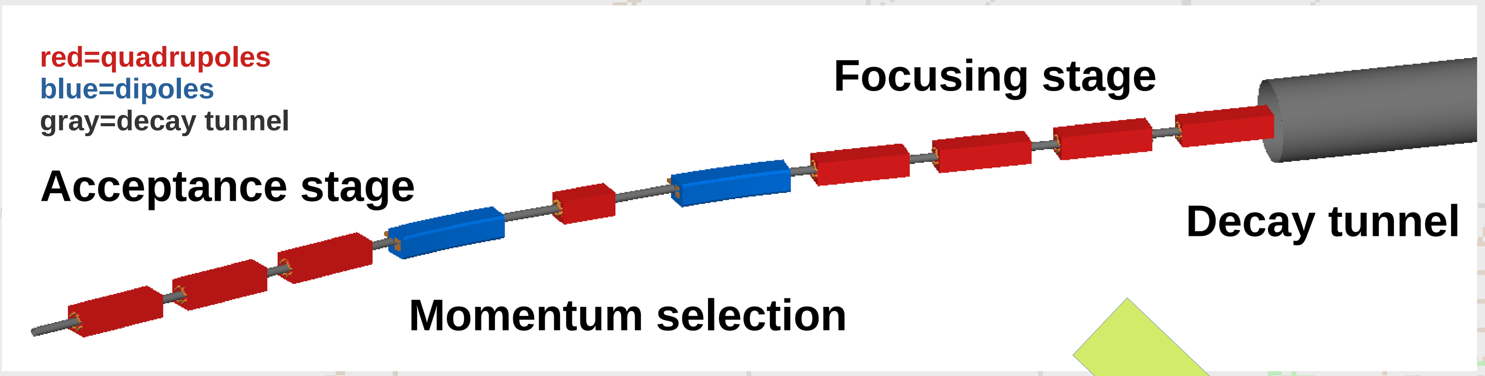
The ENUBET beamline aims to achieve a *monitored* neutrino beam (flux determined to the 1% level).To do so, the ENUBET beamline has the following key features:

→ A set of dipoles to perform a **momentum selection**

→ A **fully instrumented 40 m long decay tunnel** that measures the lepton coming out of the K^+ and π^+ decays using special calorimeters.

→ A liquid-argon near detector comparable to the ProtoDUNEs in size and resolution

The ENUBET collaboration had an initial/baseline design. Within the **Physics Beyond Colliders Initiative (PBC)**, a new design has been developed.



NuTag

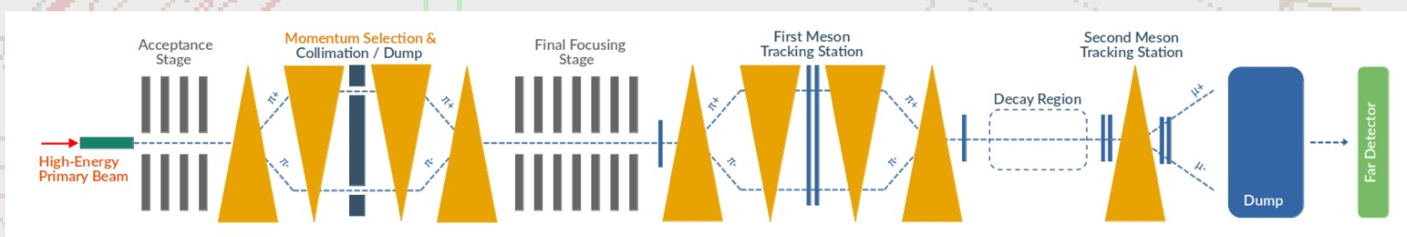
NuTag is a beamline proposal that that tries to achieve a *fully-tagged* neutrino beam (**see Poster 175 by L. Petit**). The beamline features:

→ **Two achromats featuring silicon pixel detectors** to achieve a momentum reconstruction of the **parent meson** (K^+ and π^+) and the μ produced in the respective two-body decay.

→ A drift space between the achromats that particles have sufficient time/space to decay. In consequence, the neutrino properties are fully determined.

→ Either a near or far neutrino detector (depending on the physics case)

The application of the NuTag technique is vast. The **Physics Beyond Colliders Initiative** at CERN has studied a long-baseline application.



PBC-SBN

The ENUBET-NuTag Merger

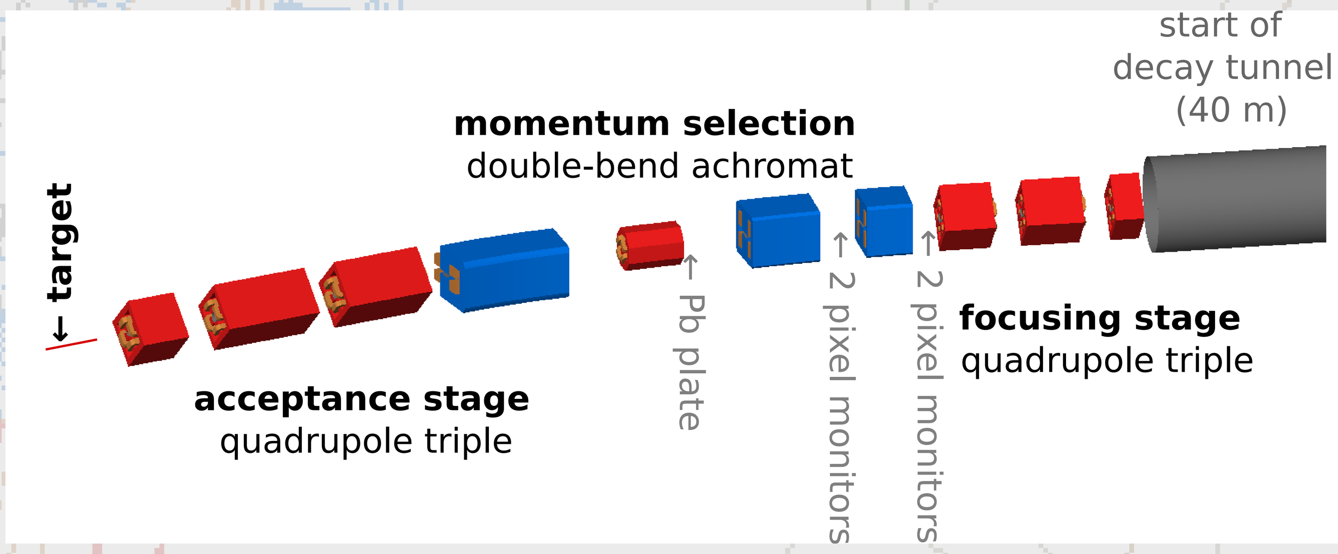
The **Physics Beyond Colliders Short-Baseline Neutrino beamline (PBC-SBN)** is meant to be able to serve both the ENUBET and NuTag physics cases. As a consequence, the PBC-SBN line features:

→ A double-bend achromat acting as a momentum selection section

→ A 40m long decay tunnel that is fully instrumented

→ two momentum measurements, i.e. twice 4 silicon pixel enclosing a bending magnet

→ A dedicated setup for the removal of positrons: A Pb plate combined with a dipole



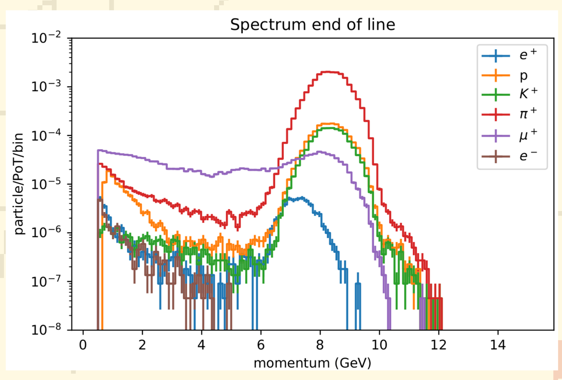
The beamline will be capable of measuring the ν_e and ν_μ cross section to a 1% level precision; however, the physics case is not limited to that and is evolving!

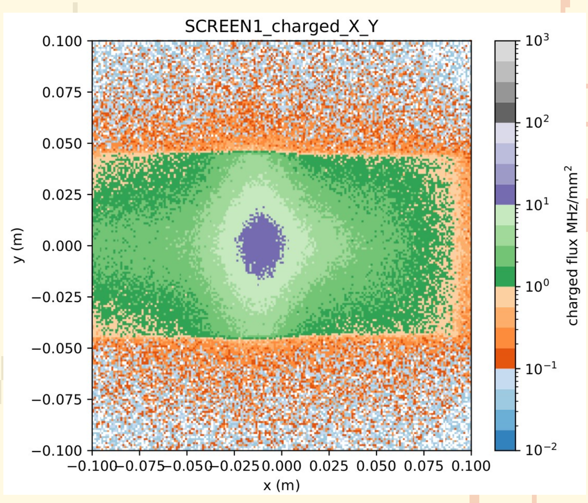
Positron Background

The silicon pixel detectors proposed by NuTag are comparable to those used in NA62 (GTK). They are expected to have a pile-up limit of O(10 MHz/mm²) up to O(100 MHz/mm²).

To remove positrons from the beam, a Pb plate at a location at which the primary beam cannot interact with it was inserted into the beamline.
The Pb plate energy modulates the positrons

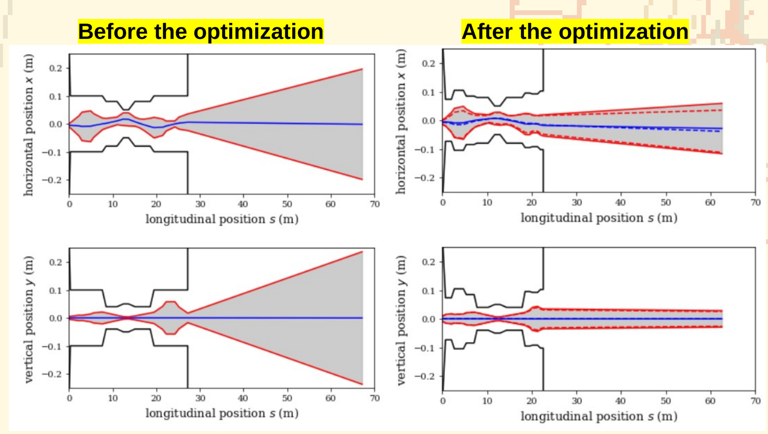
The first pixel detector (highest flux) measures a flux in the 10 MHz/mm² range with a reasonable spill intensity of 5e12 protons from the SPS





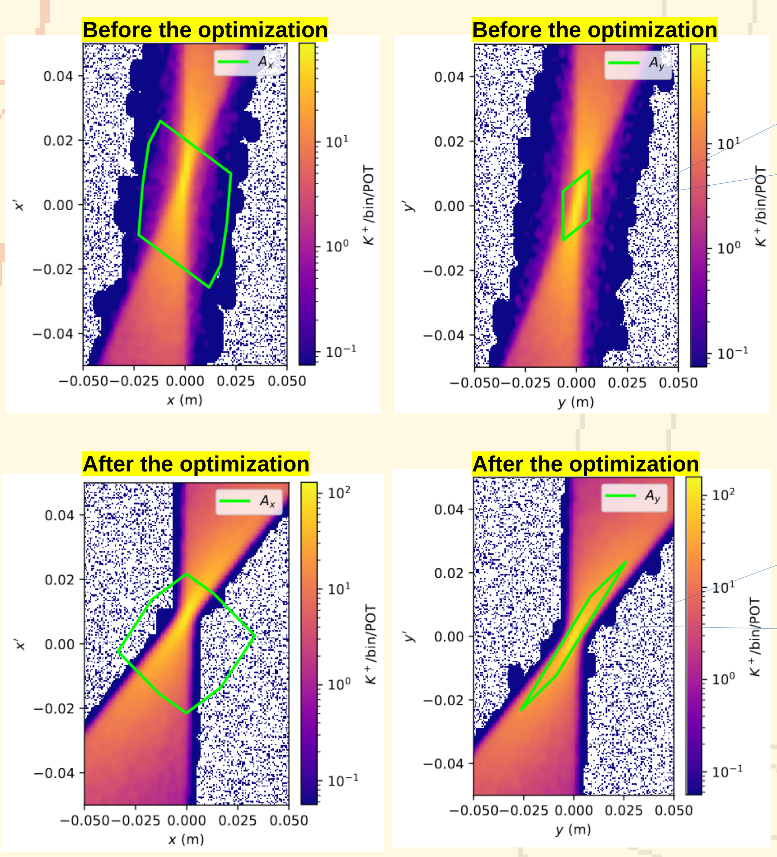
Improved optics

The beam remains small throughout the decay tunnel.



Improved Acceptance-Target Overlap

The optimization has improved the overlap of the transverse acceptance with the target histogram. The y-y' acceptance follows the stark diagonal correlation after the optimization



Parts of the distribution cannot be accepted by the beamline.

The optimized target appears more "clean"
The acceptance follows nicely the y-y' correlation.

Transmission Optimization

A state-of-the art multi-objective genetic algorithm (MOGA) framework was setup to improve the beamline transmission

26 free parameters:
Target, 6 quadrupoles (length, aperture, gradient), 7 drift spaces

3 objectives:
Maximum K^+ and π^+ transmission, minimum beam size in the decay tunnel and at the Pb plate

Design	K^+/PoT	π^+/PoT
baseline	3.6×10^{-4}	4.0×10^{-3}
PBC Version	7.0×10^{-4}	1.1×10^{-2}
PBC-SBN	12.7×10^{-4}	1.8×10^{-2}

The transmission was improved by additional ~80% compared to the previous design

Summary and outlook

- ENUBET and NuTag designs have been successfully merged into a single beamline

- An optimization of the initial beamline was very successful

- A start-to-end BDSIM simulation reproduced the improvement achieved by the optimizer (based on accelerator concepts)

We continue the optimization of the beamline in the future and will focus on the potential implementation of the line at CERN.

Exciting times to come!