The ESSnuSB Experiment

Leon Halić

Ruđer Bošković Institute

1st Annual MAPS Meeting

What is ESSnuSB?

European Spallation Source neutrino Super Beam

Next-to-next generation long baseline neutrino experiment. Currently in design phase, planned to be situated in Sweden taking advantage of the newly built ESS linear accelerator

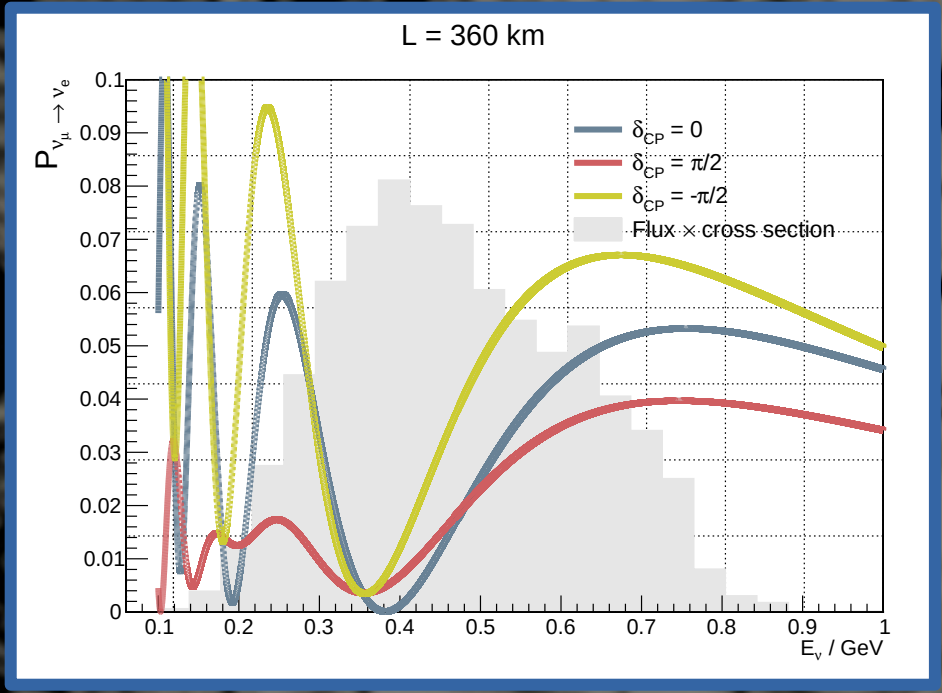
Motivation and purpose

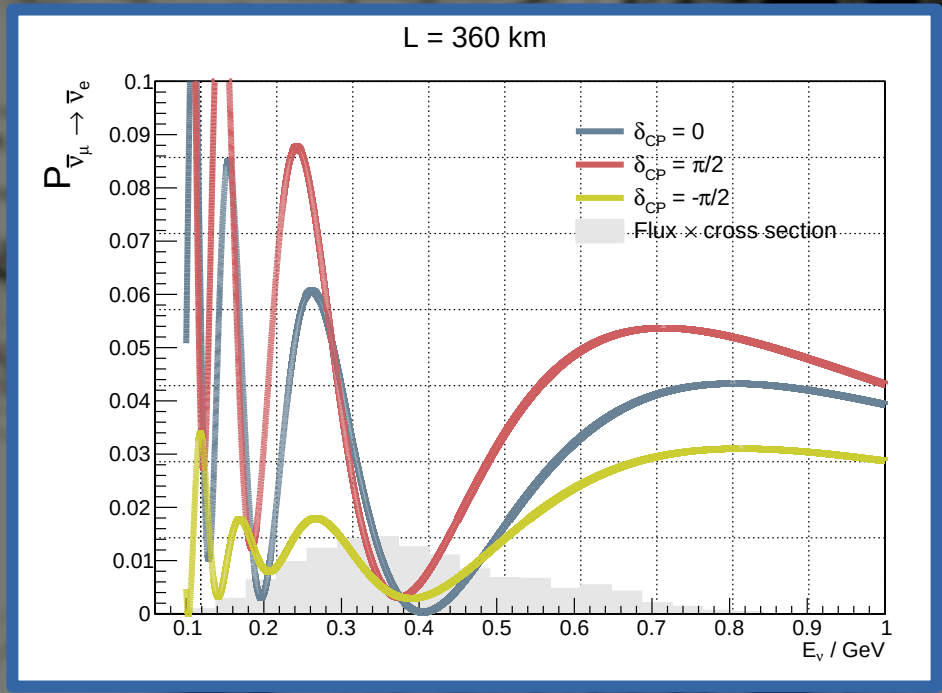
CP violation precision & neutrino cross section measurements, and BSM physics

Main goal of ESSnuSB is the precision measurement of CP violation in neutrino oscillations. To do this, additional neutrino cross section measurements will be needed. The instrumentation needed to achieve these two goals will provide a great opportunity for many BSM physics searches

Experiment parameters

ESSnuSB spectra with relation to the oscillation probability

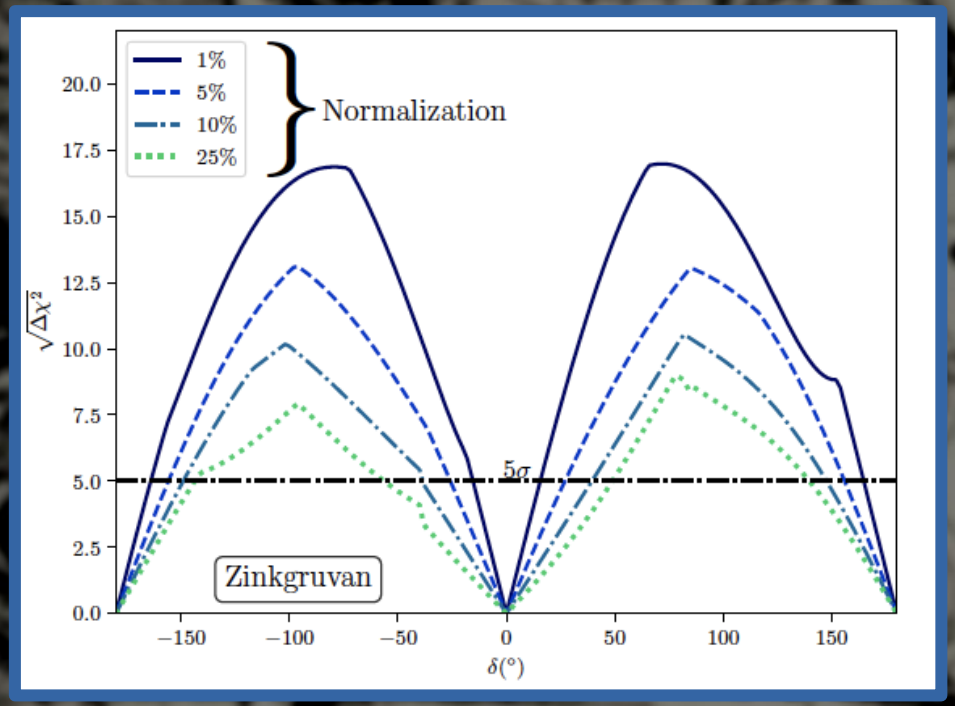


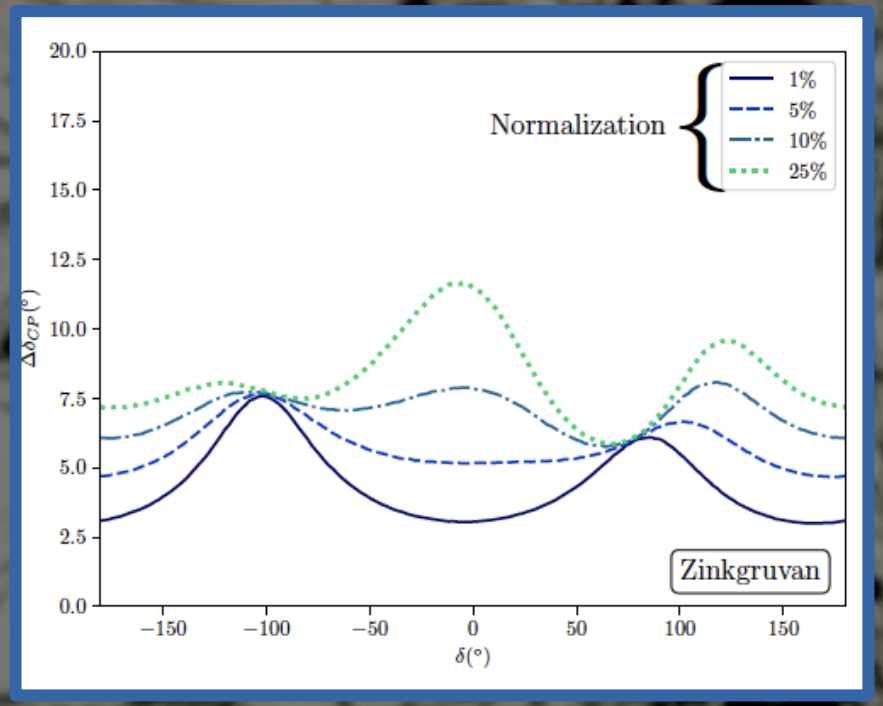


> 2.7x10^{23} protons/year → 768 (116) ν_e appearance events for $\delta_{CP} = 0$

Physics potential

ESSnuSB sensitivity and precision on measuring δ_{CP}



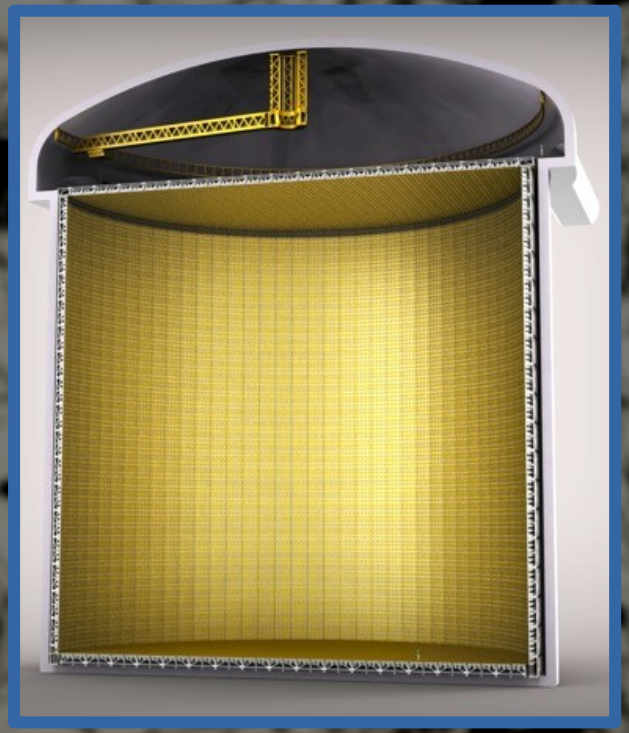


Far detector

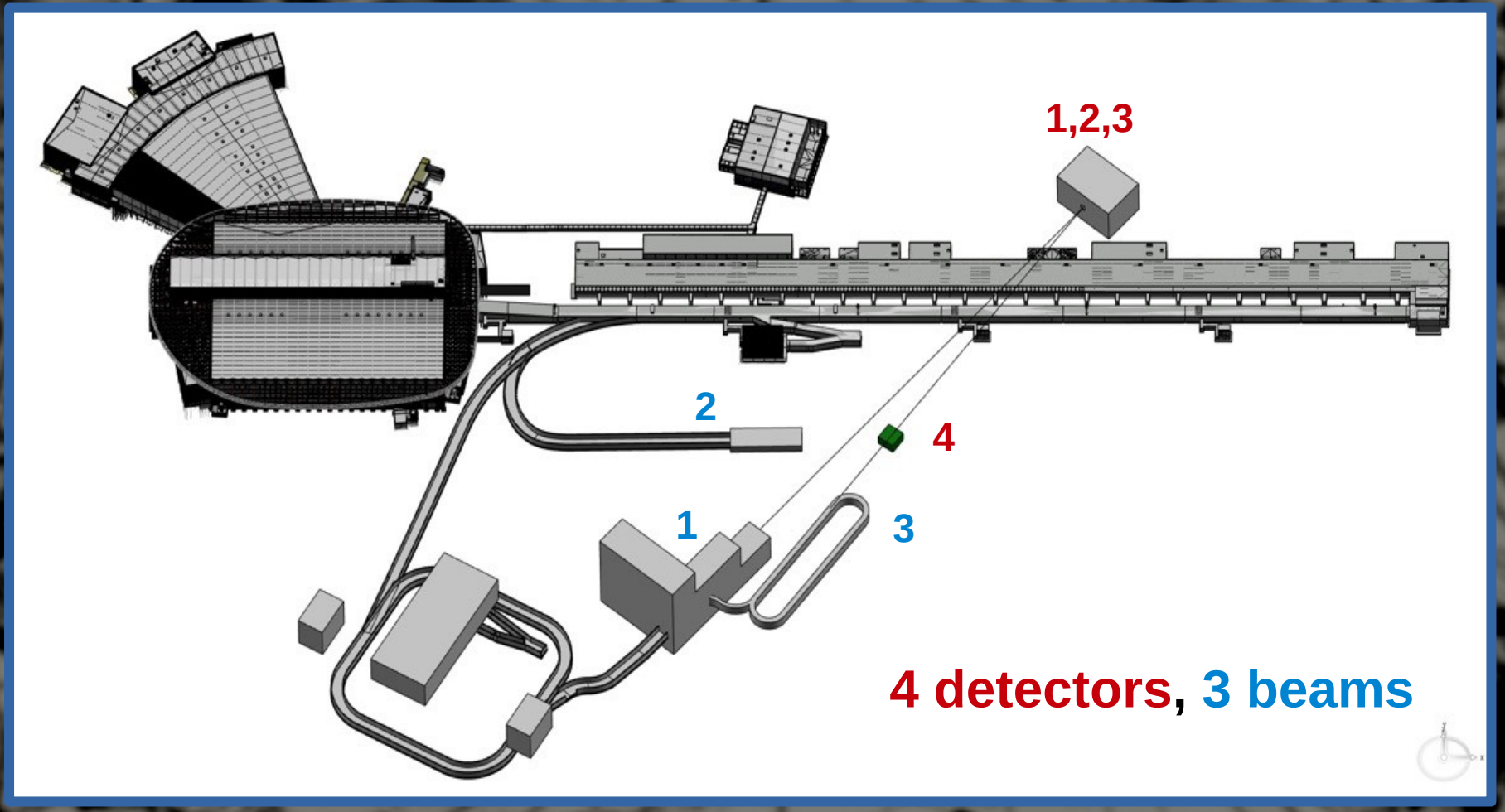
2 huge water Čerenkov detectors 360 km away from the beam source

Total fiducial volume of 538 kt

Non-beam physics – Atmospheric, solar, supernova…..



Near detector facility

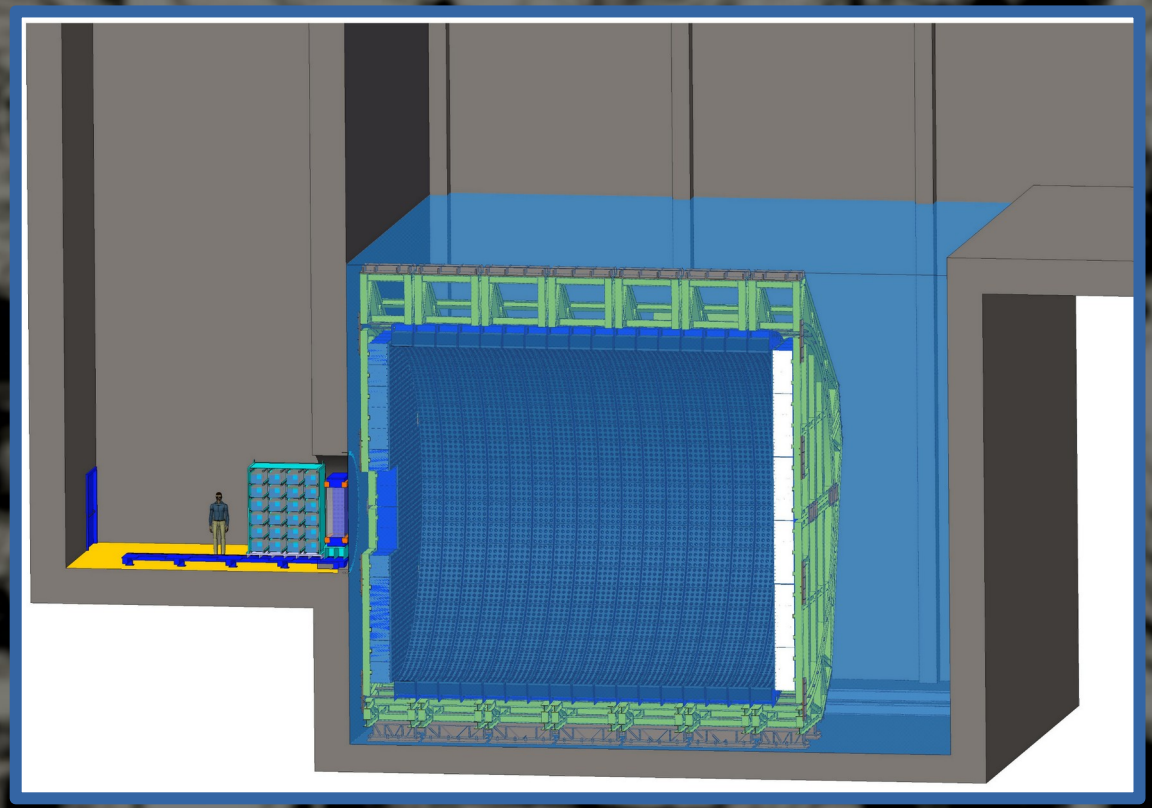


Main ESSnuSB beam

Water-Čerenkov detector for event rate measurement and flux normalization

Super Fine-Grained Detector (plastic scintillator) for cross section measurements

Viking – a nuclear emulsion detector for cross section measurements

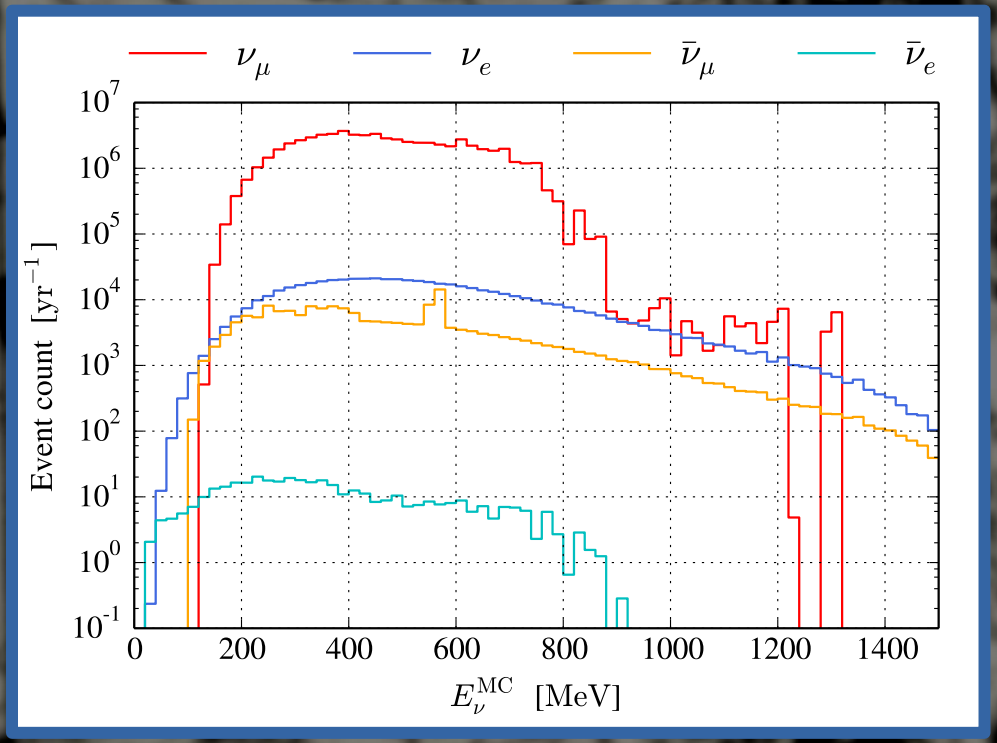


Near detector Water-Čerenkov

10.96 m length and 9.44 m diameter (~500 t fiducial volume)

Main purpose is to measure the non-oscillated neutrino flux

Measurement of the ν cross section on water



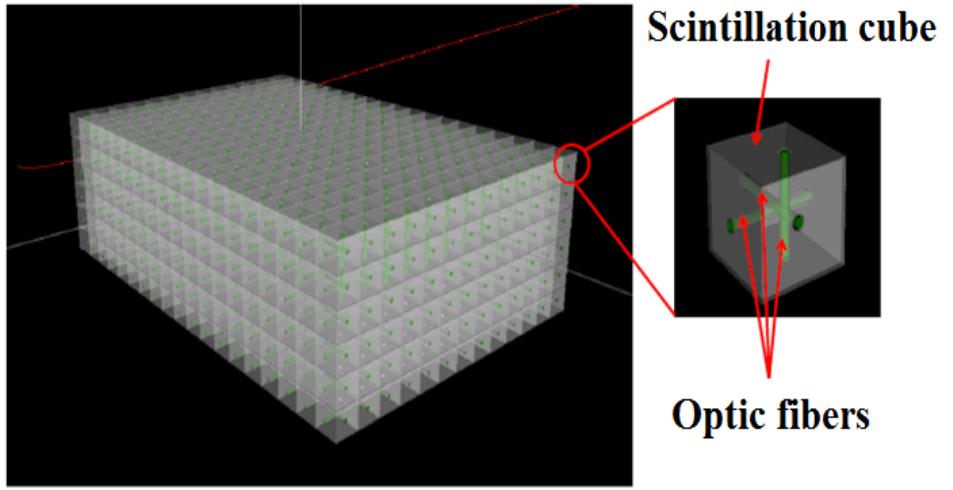
Super Fine-Grained Detector

Similar design to the T2K ND280, consists of plastic scintillator cubes

1.4 m × 1.4 m × 0.5 m → 10^6 cubes

Magnetic field of 1 T perpendicular to the beam

Lower energy threshold than WC detector



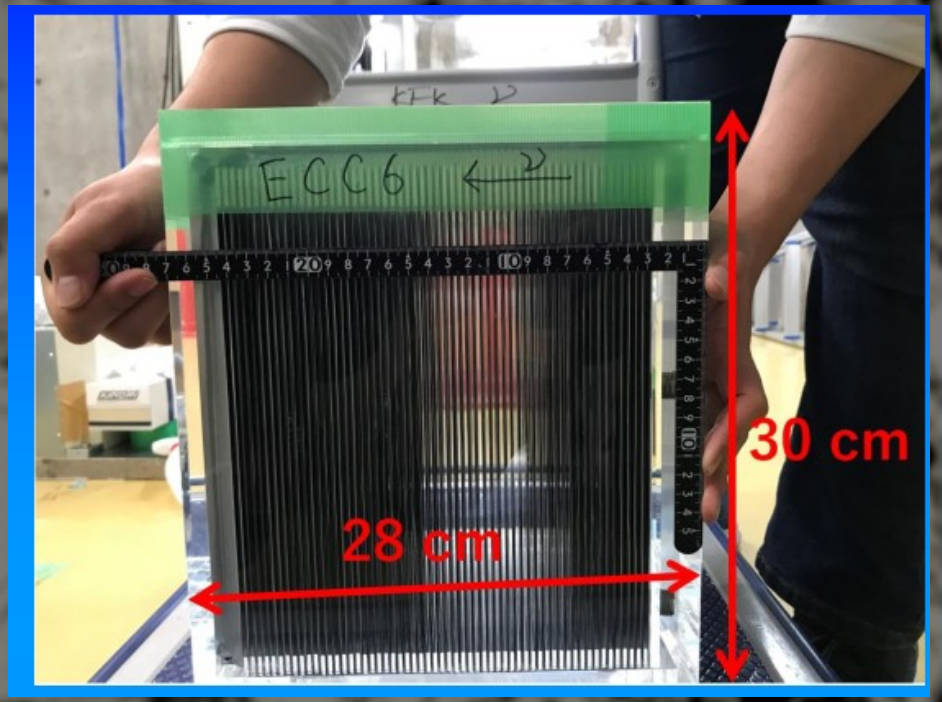
Viking – a nuclear emulsion detector

Nuclear emulsion detector inspire by NINJA

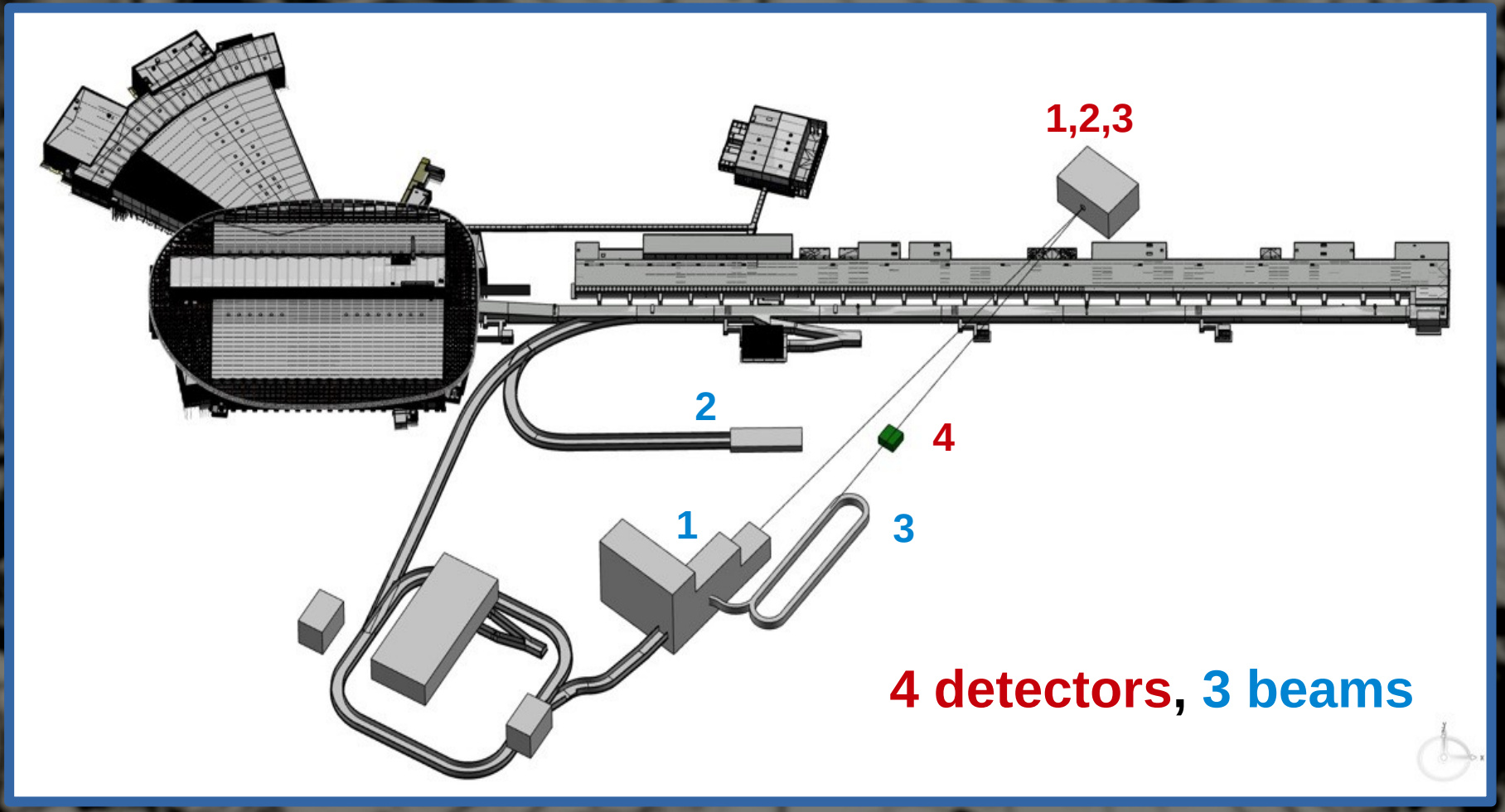
130 Emulsion cloud chambers → 1 t water mass

Unparallel spatial resolution and a very low energy threshold → perfect for double differential cross section measurements

No timing resolution



Near detector facility



LEMMOND

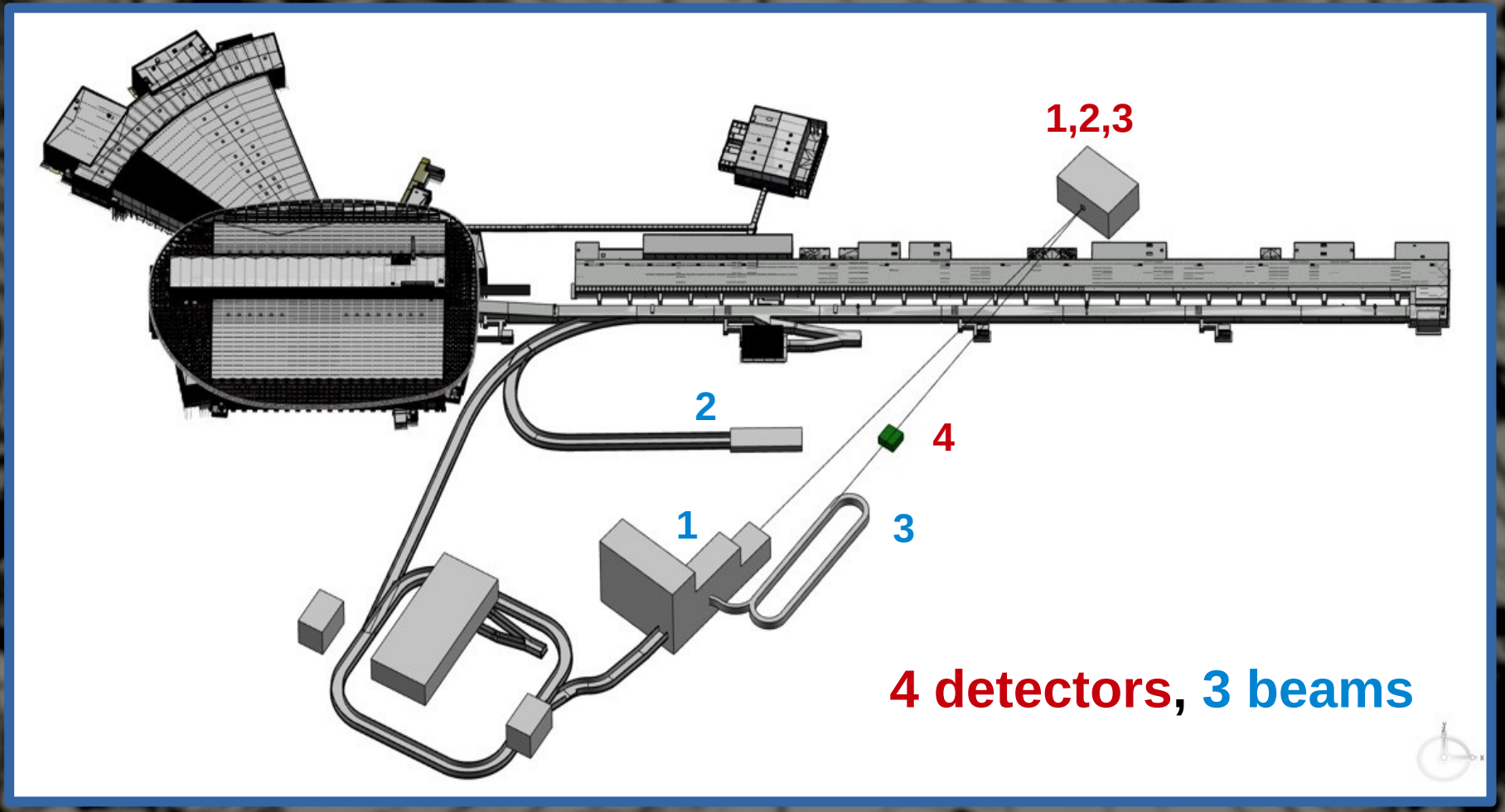
Low Energy neutrinos from stored Muons and low energy Monitored Neutrino beam Detector

A dedicated water-Čerenkov detector for precise measurements of neutrino interaction cross section

~50 m from both LEMNB and LEnuSTORM

10.4 m length and 5.4 m diameter → ~200 t volume

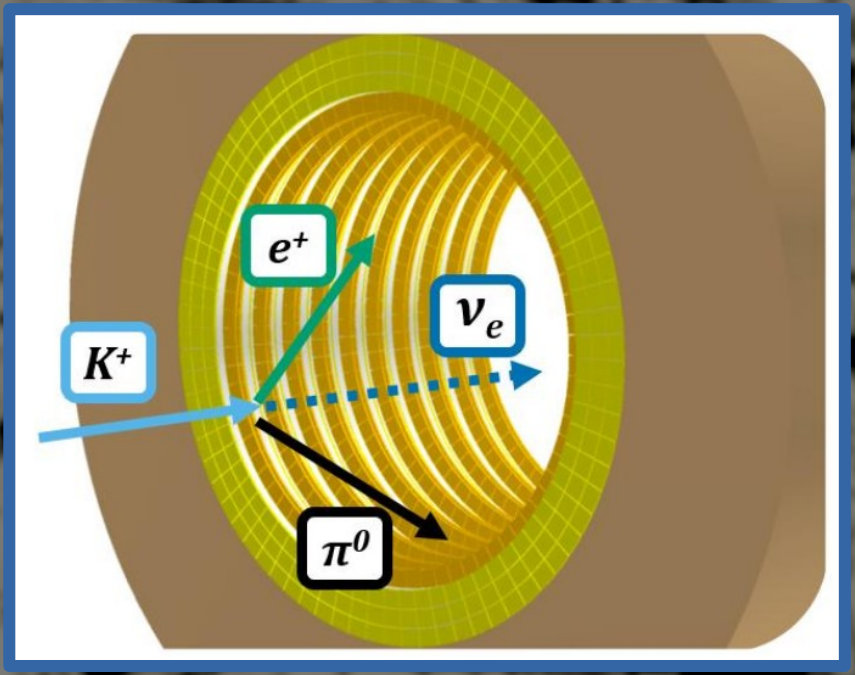
Near detector facility



Low Energy Monitored Neutrino Beam

Monitored neutrino beam inspired by ENUBET but modified for low energies

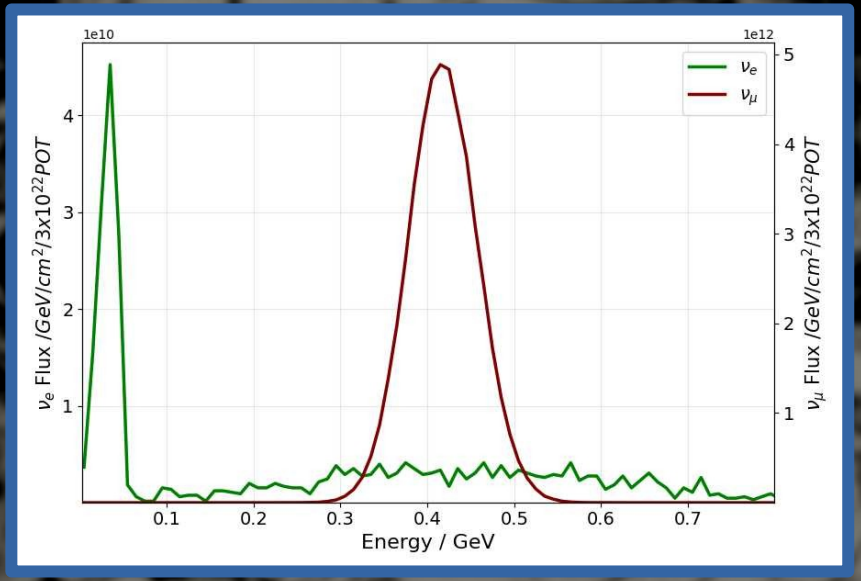
- A simple idea that is very difficult to implement
- Observe the charged lepton created in Kaon and Pion decays
- Reducing the total flux systematic to <1%
- Trickier to do at lower (ESSnuSB) energies

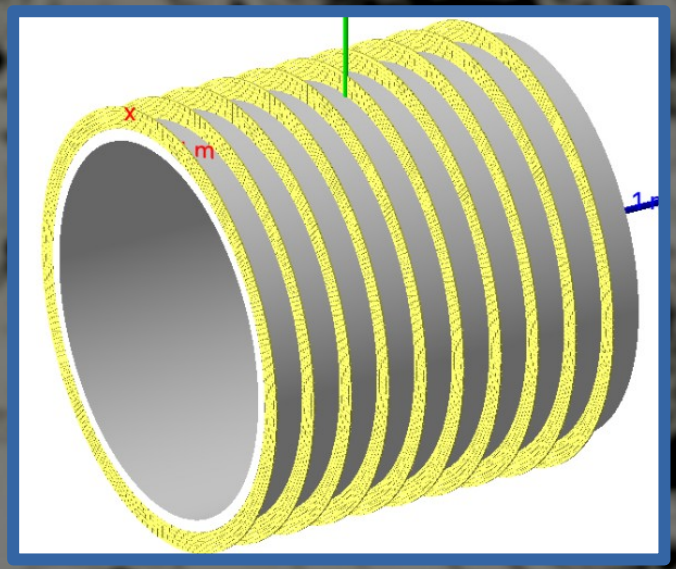


Low Energy Monitored Neutrino Beam

Due to lower energies and higher intensity, ESSnuSB implementation is different than ENUBET

At lower energies, only pions are present, which mostly decay via $\pi_{\mu\nu}$ - 40% of the muons exit the tunnel without hitting the wall ("straight")

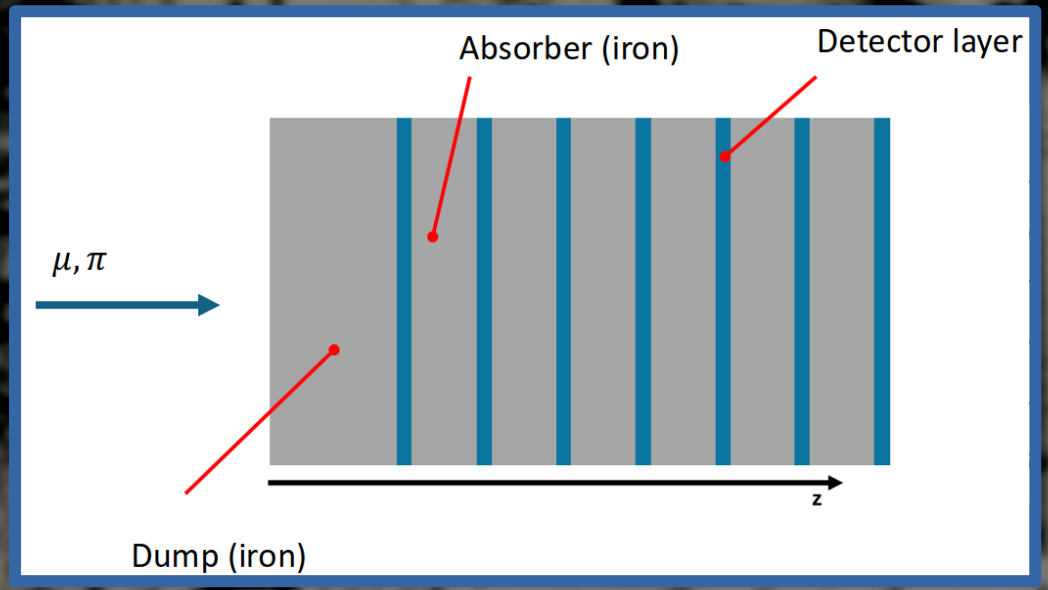


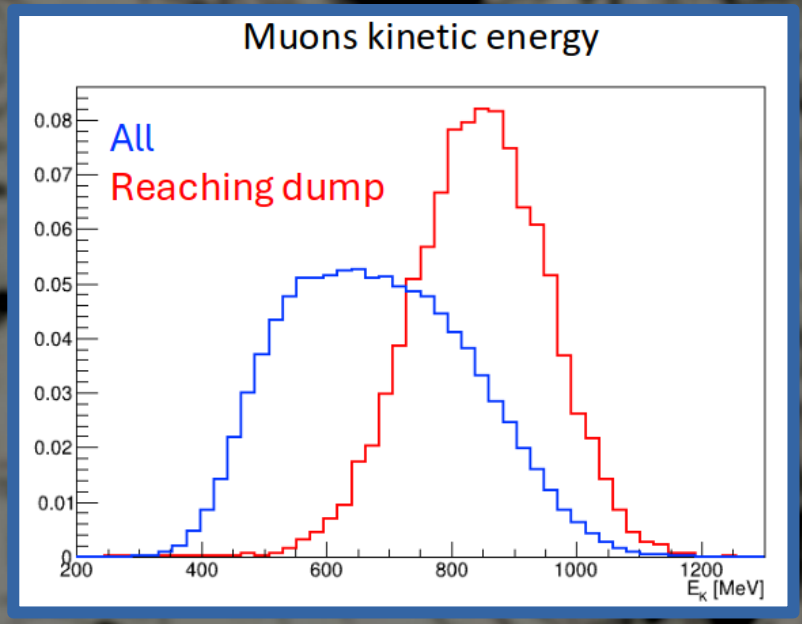


Low Energy Monitored Neutrino Beam

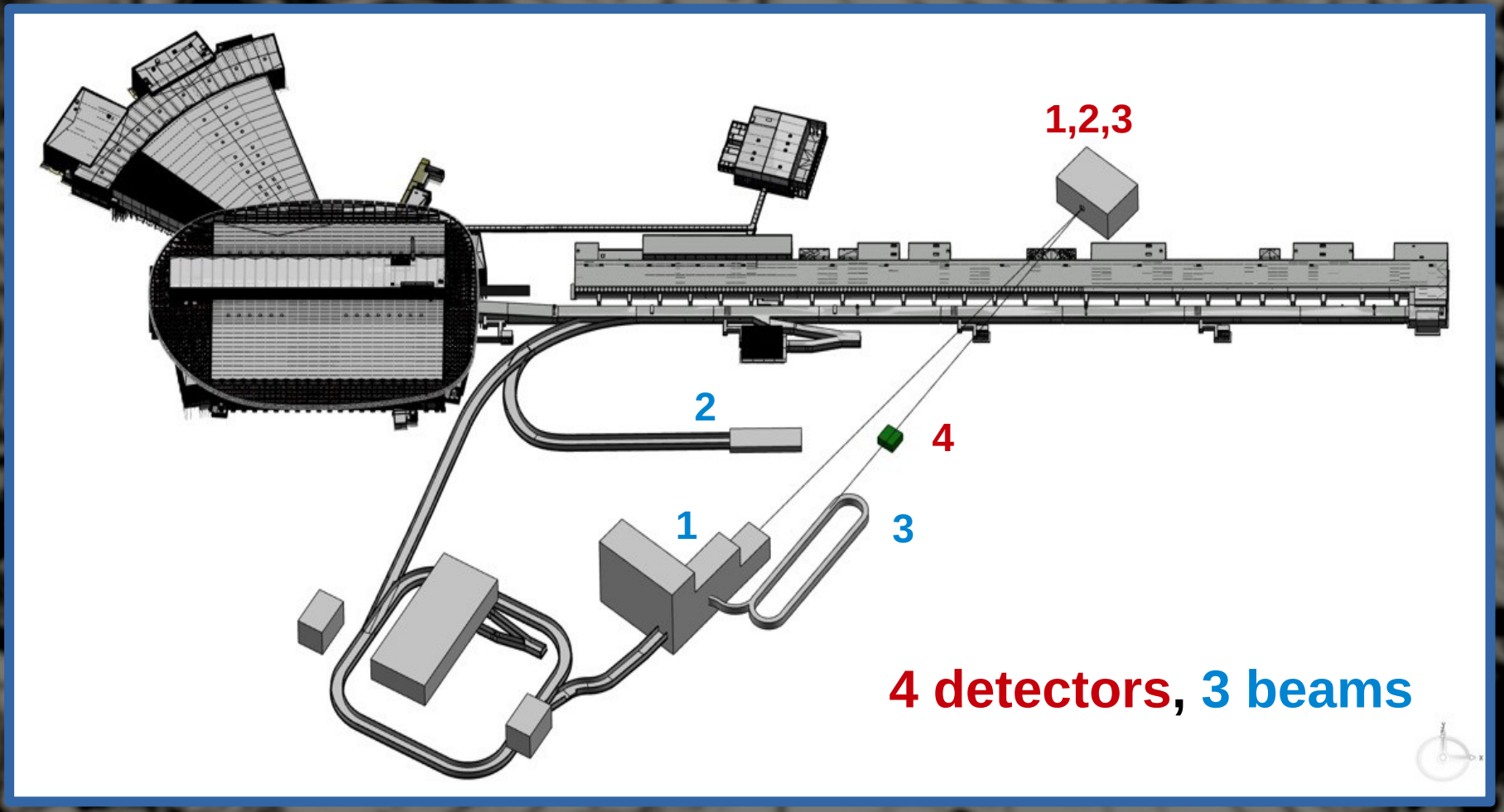
To catch the escaping muons, we also instrument the hadron dump

Made so it is possible to range out muons, for basic muon energy reconstruction





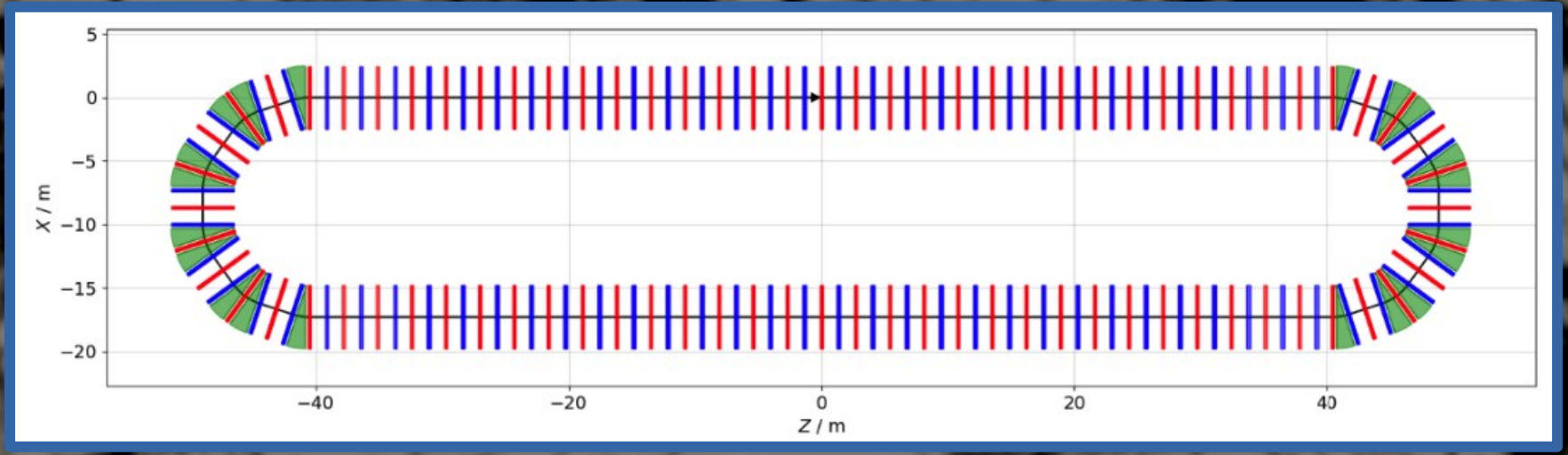
Near detector facility



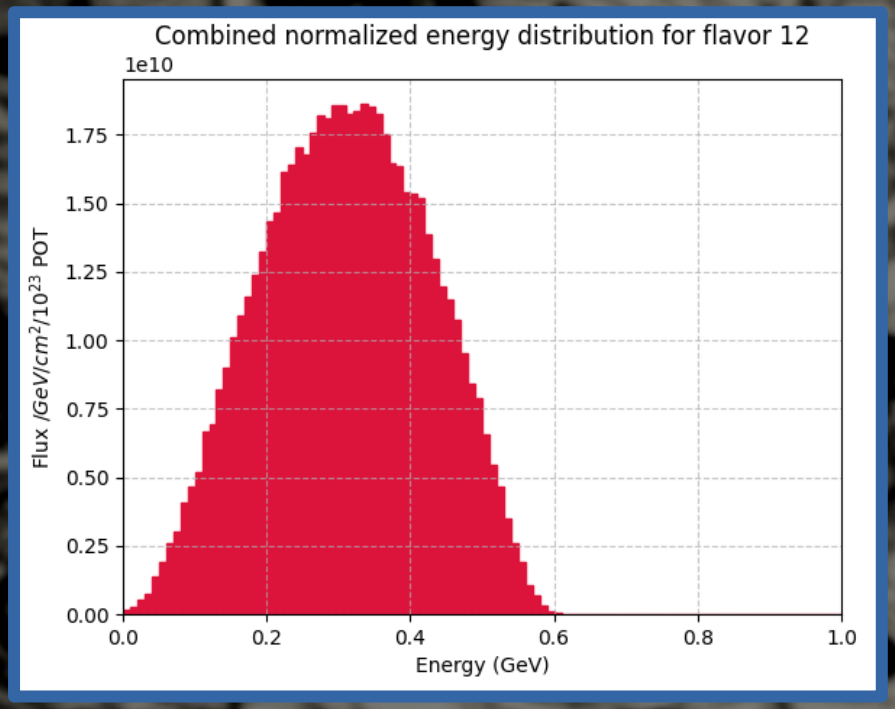
Low Energy neutrinos from stored muons

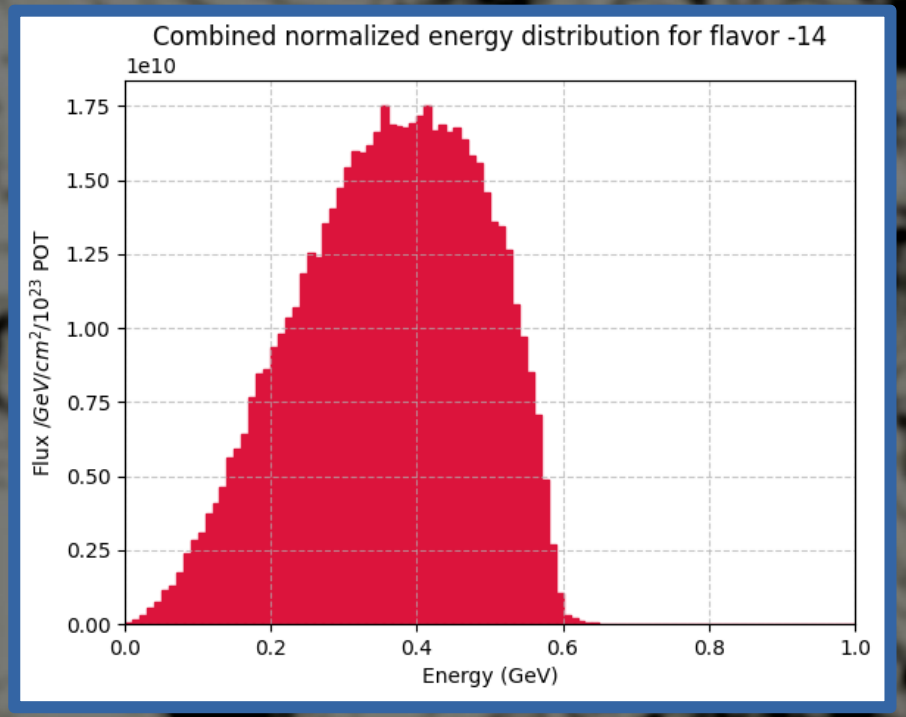
The “purest” source of electron neutrinos – neutrinos coming from muons decays

Beam will go both through the LEMMOND and the main WC



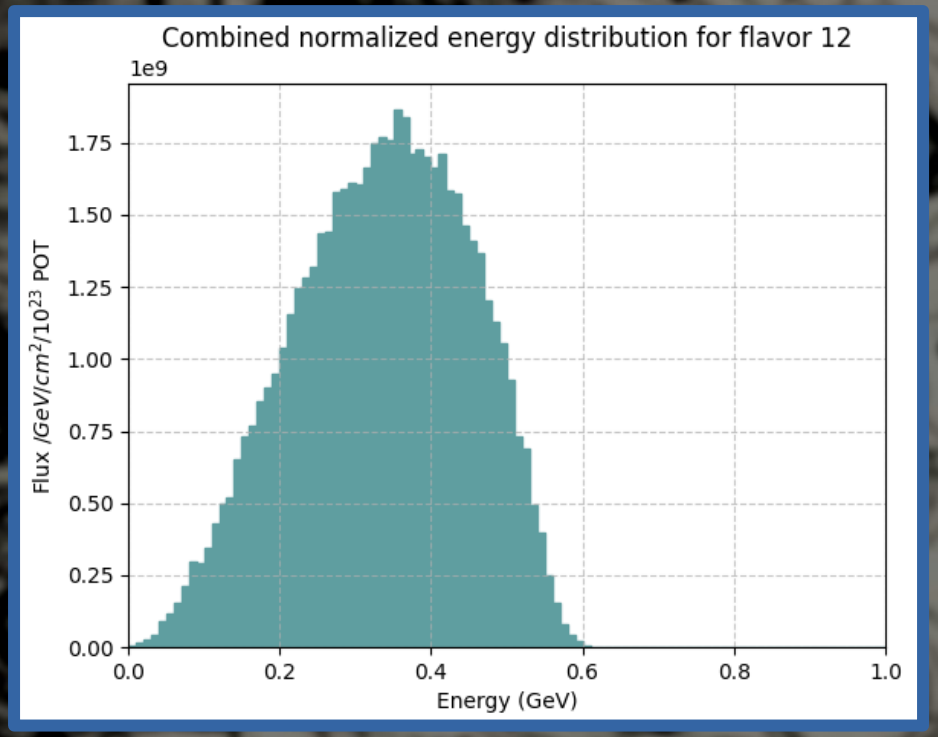
Low Energy neutrinos from stored muons

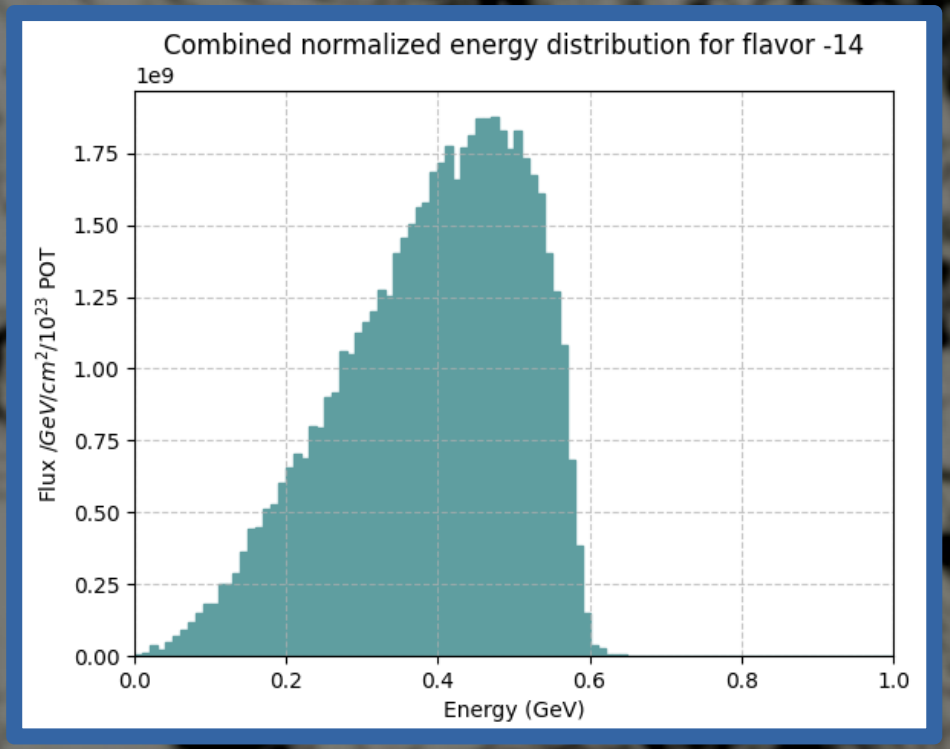




Flux at LEMMOND (~50m)

Low Energy neutrinos from stored muons

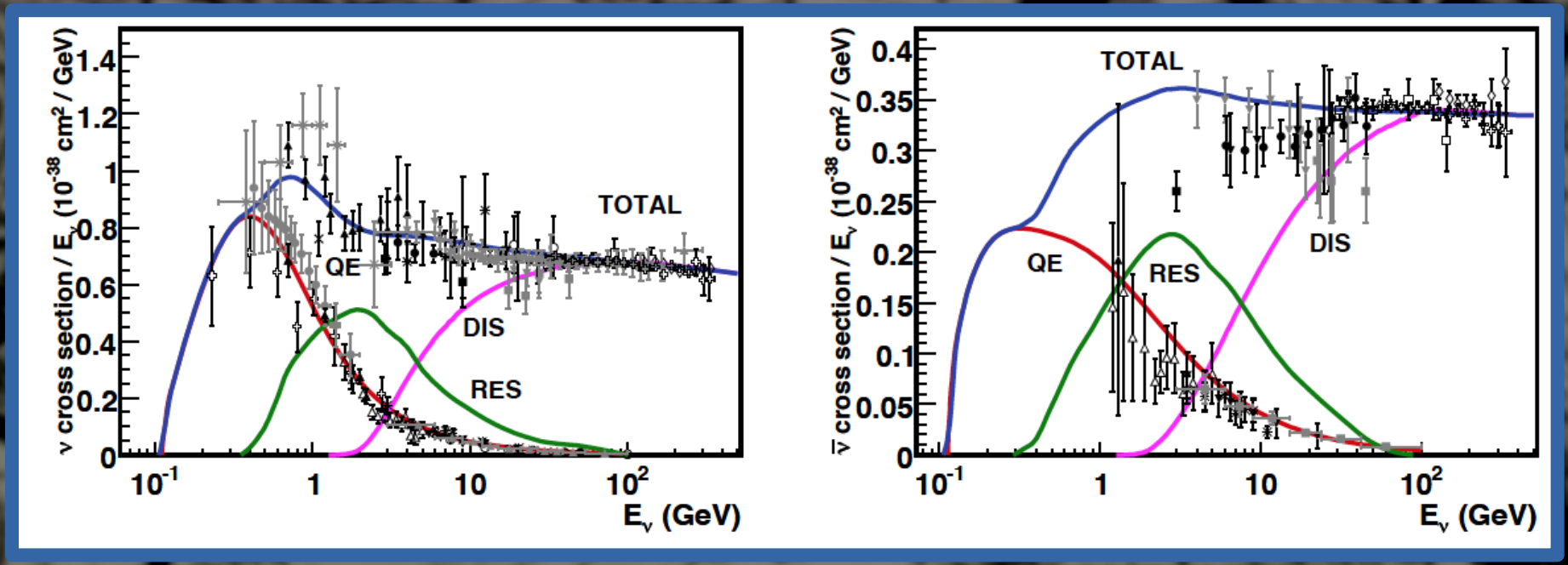




Flux at the main WC (~250m)

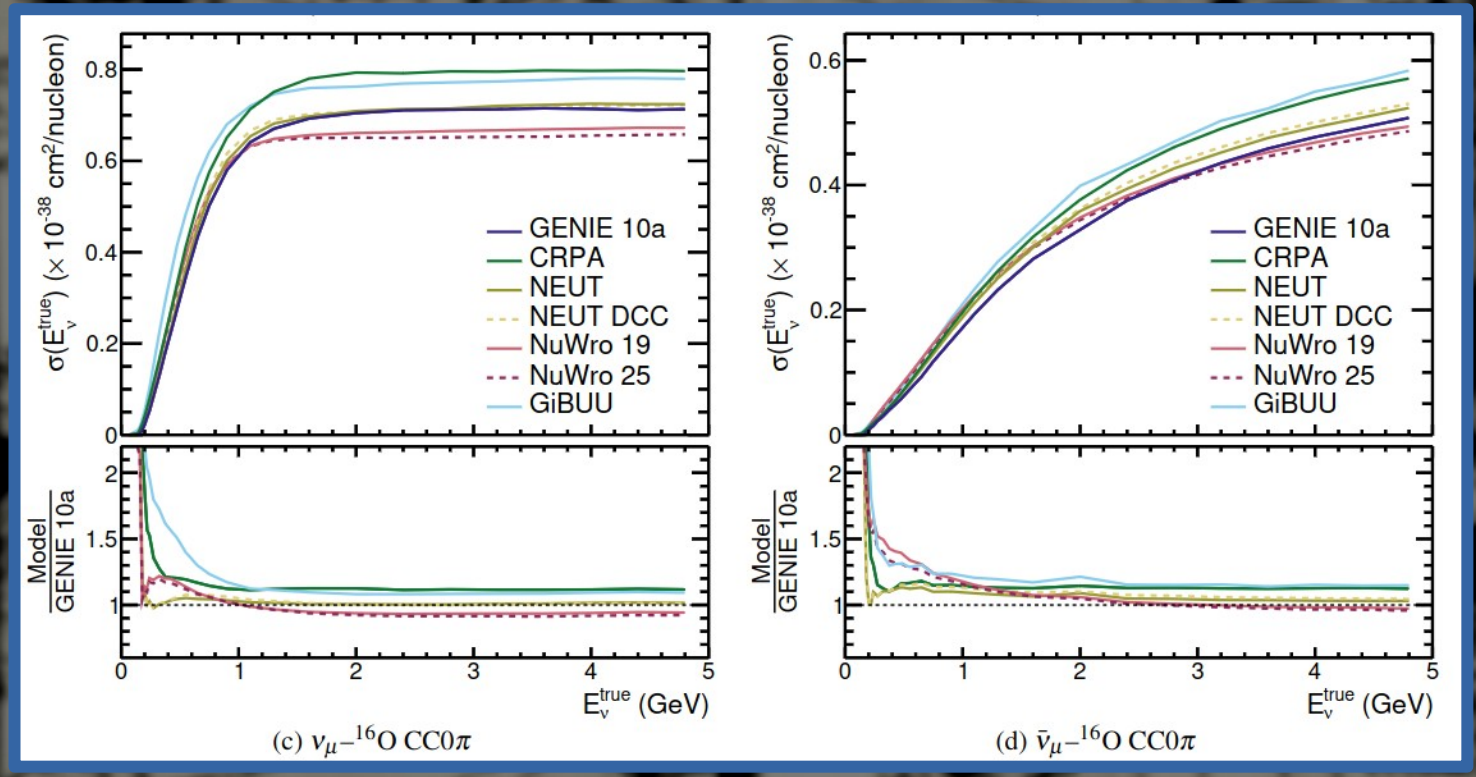
Why we need to measure cross section?

Neutrino interaction cross section is relatively well known for higher energies, but at sub-GeV level there are many unknowns



Why we need to measure cross section?

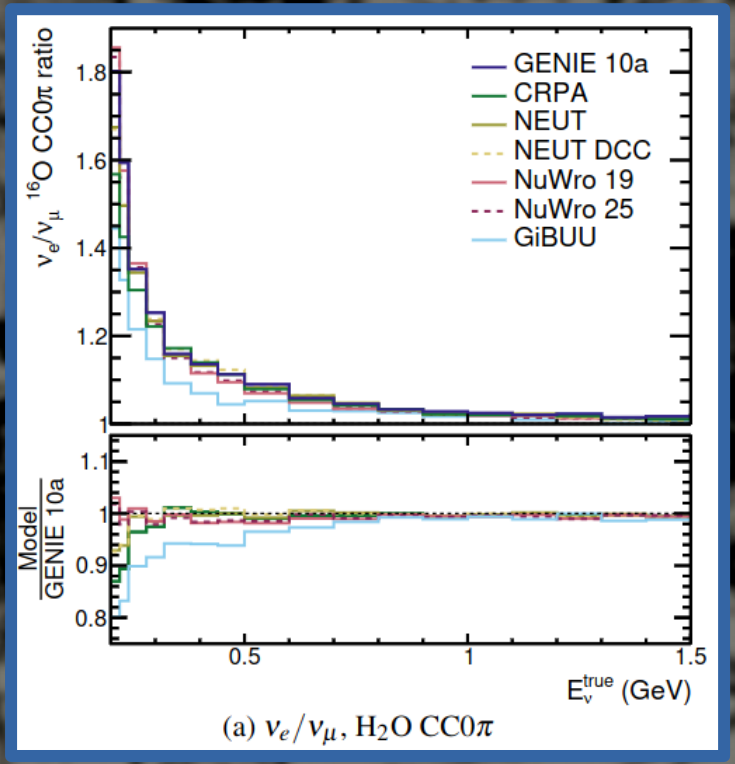
Different event generators and their models do not agree at those energies



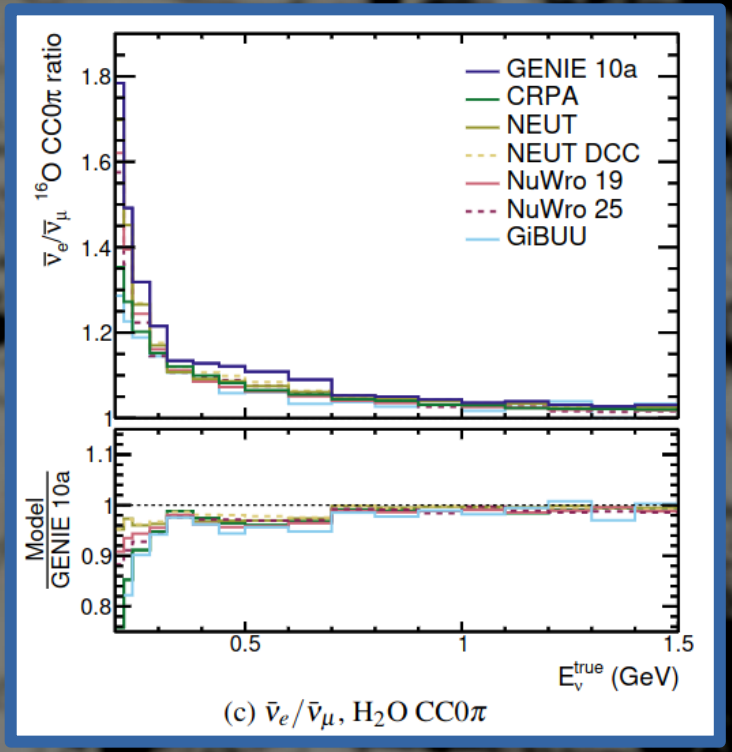
CCINC (CC0π) neutrino cross section

Why we need to measure cross section?

Cross section ratios are a key component of all LB experiments



(a) ν_e/ν_μ, H_2O CC0π



(c) $\bar{\nu}_e/\bar{\nu}_\mu$, H_2O CC0π

Significant disagreements at energies <0.5 GeV

Summary

Major issues in neutrino interaction cross section knowledge in sub-GeV regions

ESSnuSB – a next-to-next generation long-baseline neutrino oscillation experiment for precision physics

Significant neutrino interaction cross section measurement program within ESSnuSB

Unique neutrino beams for high precision xsec measurements – LEMNB and LEnuSTORM