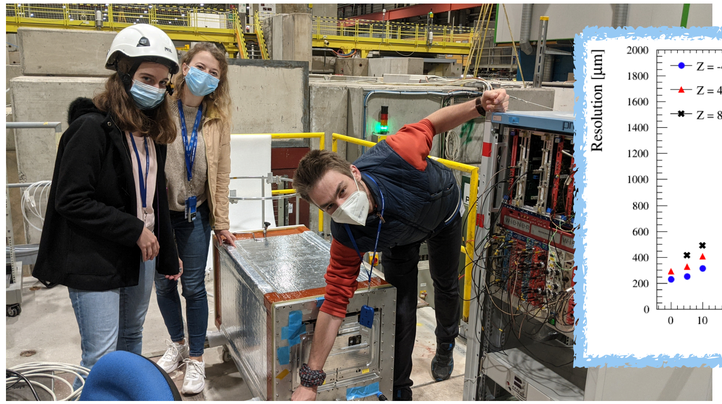
T2K-II and ND280 Upgrade

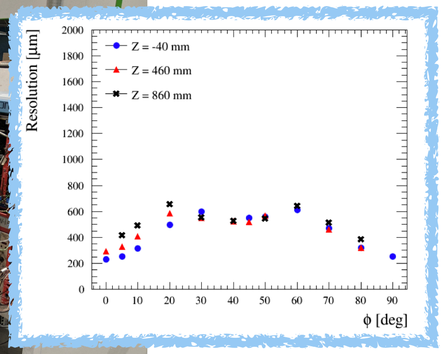
LPNHE group activities

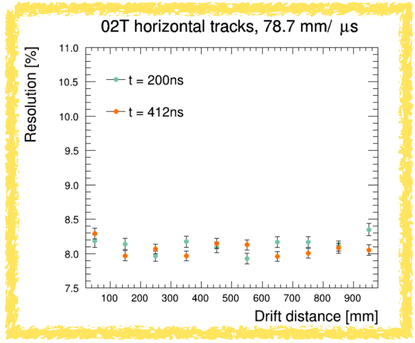
- Strong contribution of LPNHE group on T2K-II and the Near Detector upgrade
  - CG → coordinator of ND upgrade and member of the T2K Executive Committee
  - MG → convener of the reconstruction group
  - BP → coordinator of NA61 analyses for T2K
- Our goal is to install the ND280 upgrade at J-PARC in 2022 and prepare the tools to exploit the first ND upgrade data
- These activities are only possible thanks to the invaluable help of 2 ANR postdocs (Adrien Blanchet, Sergey Suvorov) and 3 PhD students (Viet and Vlada mostly on ND upgrade, Lucile on T2K Oscillation Analysis and HK)
  - Postdocs of Adrien and Sergey will finish at the end of 2022
  - Viet will also finish his thesis in 2022, Lucile and Vlada in 2023
  - Need to reinforce the LPNHE neutrino group to fully exploit T2K-II (and HK!)

HA-TPC performances and reconstruction

- Results from 2018 CERN test beam and 2019 DESY test beam both published on PRD → Sergey corresponding author for both papers
- Another test beam with the Field Cage prototype was done at DESY in 2021
  - Allow to test ERAM performances for long drift distances
- Preliminary analysis show performances better than our requirements:
  - Spatial resolution between 200 and 600 μm (depending on angle and drift distance)
  - dE/dx resolution ~8% for tracks crossing one ERAM module
  - Paper in preparation → Vlada and Sergey

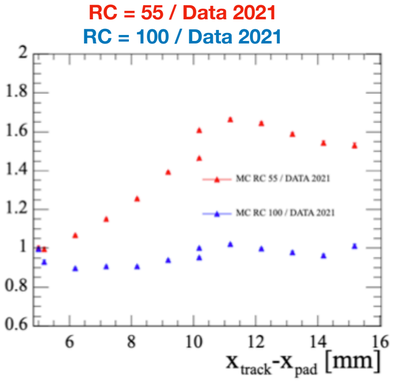


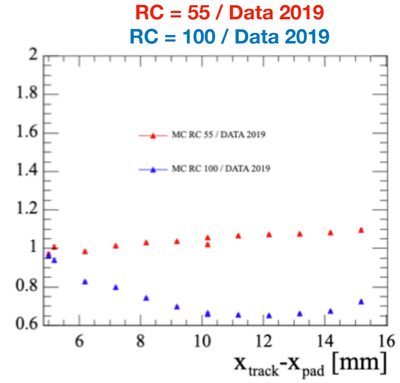


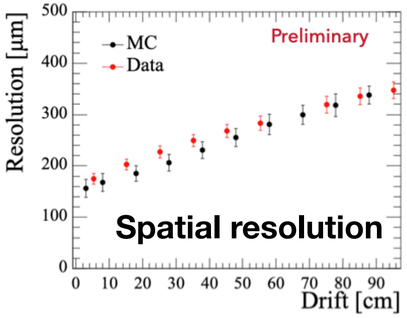


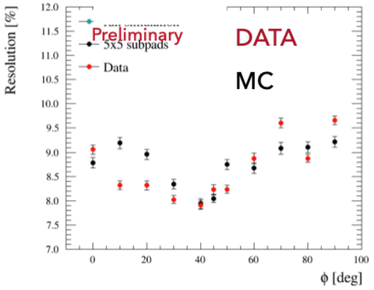
DAQ: Adrien
Test beam analysis: Vlada and Sergey
TPC simu and reco: Sergey

Sergey developed the ERAM simulation and implemented it in the ND280 Software
Currently finalizing the HA-TPC reconstruction







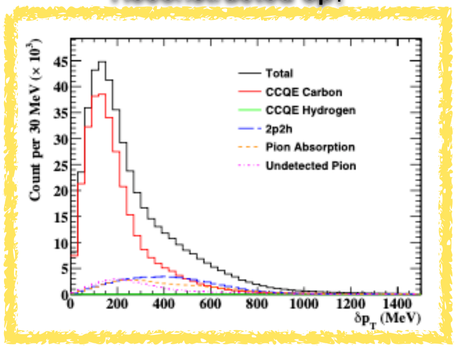


σ(dE/dx)/dE/dx < 9%

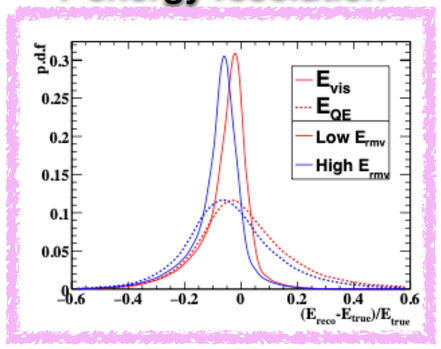
ND280 upgrade performances

Exploiting hadronic informations

Reconstructed δp_T

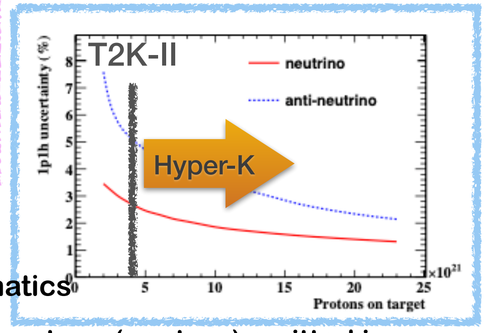


ν energy resolution



arXiv:2108.11779
Accepted for publication on PRD
Viet corresponding author!

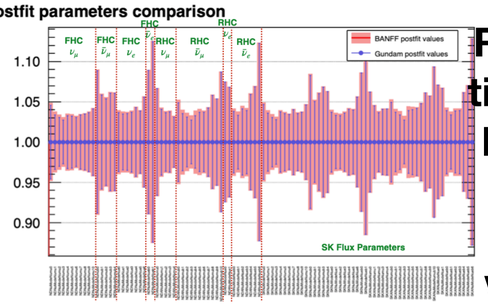
Uncertainty on 1p1h vs POT



- Analyses done so far by ND280 mostly exploited the μ kinematics
- With the upgrade we will be able to reconstruct muons and protons (neutron) emitted in ν ($\bar{\nu}$) QE interactions
  - Reconstruct variables in the transverse plane → more sensitive to nuclear effects → $\delta p_T = |p_T^{\mu} - p_T^{p(n)}|$
  - $E_{vis} = E_{\mu} + T_{p(n)}$ → where T is the kinetic energy
    - Evis better estimator of the neutrino energy than QE formula
- ND280 Upgrade will exploit these variables to better constraint cross-section systematics
  - Benefit of the upgrade for T2K-II but also for Hyper-K

Adrien developed a new fitter for ND280
Designed to be easily extendable to ND Upgrade samples and to fit different variables (currently we only use lepton kinematics in ND fits)

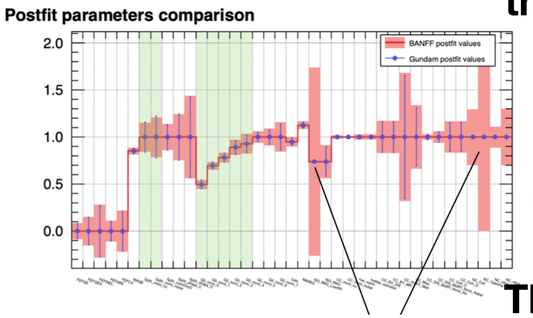
Postfit parameters comparison



Reproduce current results but 3 times faster → 6h to do the 2020 ND280 fit (~20 hours for official ND fitter)

Vlada is using this fitter for the the new T2K Oscillation Analysis

Postfit parameters comparison



LLR group (Jafaar and Margherita) have added the expected super-FGD samples

The tool is ready to contribute to T2K OA

Installation of ND280 Upgrade

- LPNHE contributions to TPC FEC finalized → see Jean-Marc slides
- Some delays in the fabrication of the first HA-TPC field cage at Nexus → received it at CERN only this week (TBC!!)
- Commissioning of ERAM detectors and of field cage at CERN on-going
  - Test Beam at CERN PS in April
- Shipment and installation of first HA-TPC at J-PARC in Fall 2022
- Second TPC will be ready at CERN by the end of 2022 → installation at J-PARC by March 2023
- We hope to have ~4 months of data with ND upgrade by Summer 2023

Longer term

- Once the ND280 upgrade will be installed we will exploit its data to:
  - Reduce systematic uncertainties in T2K-II
    - CPV at ~3σ by 2027 for maximal CP violation
  - Prepare the early discovery of CP violation with Hyper-K
    - CPV at >5σ by 2029 for large values of CPV
    - Discovery of CPV requires an excellent control of systematics uncertainties and ND280 will have a central role for this
- With the lessons learned from the first few years of data taking with ND280 Upgrade we might want to consider further upgrade of ND280 for Hyper-K
  - Add water target?
  - Larger sFGD for ν_e measurements?
  - Excellent opportunity for additional contributions to HK bringing our expertise from T2K → several European groups are participating to the brain-storming for ND280 Upgrades for HK
- Request to IN2P3: one CR position to contribute to T2K-II and prepare Hyper-Kamiokande