

# The EOI-15/ND280 Upgrade project

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# News since last Workshop

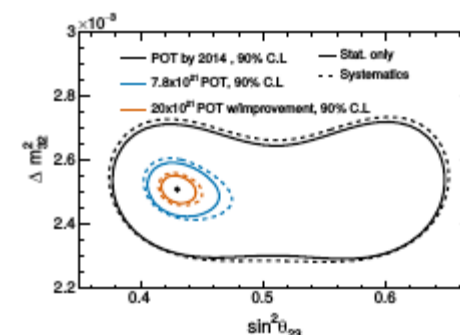
- Addendum to EOI sent to SPSC (end of March)
- The project was discussed at the SPSC April meeting
- Further contacts with SPSC referees, CERN director of research, Neutrino Platform ...
- We have confirmed to CERN our intention to submit a proposal by the end of this year

# ND280 Upgrade: milestones

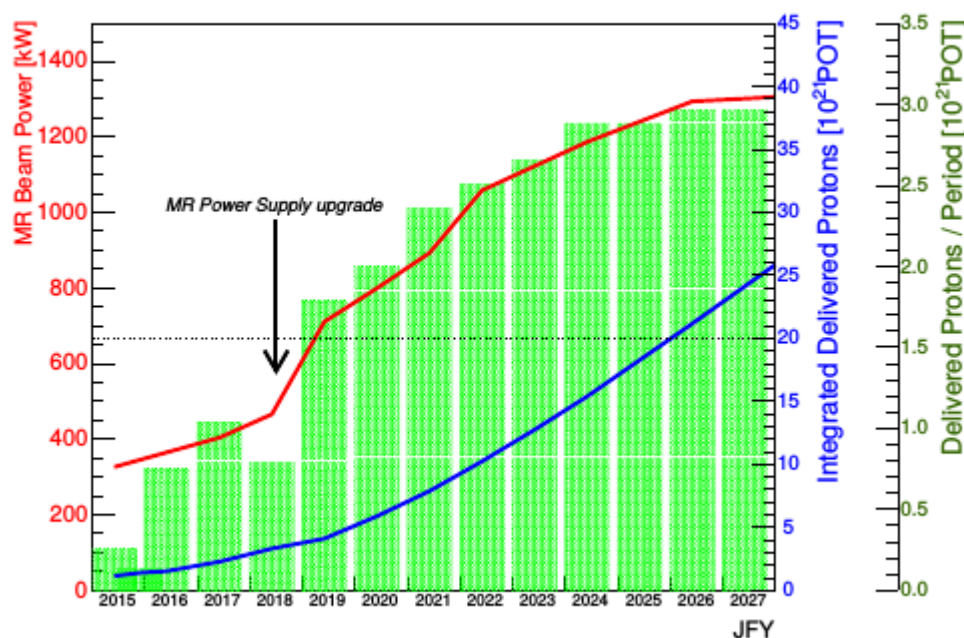
- Task Force: October 2015-December 2016
- TN303 “ND upgrade task force report”
- Workshops: CERN November 2016, CERN March 2017, Tokai May 2017
- Expression of Interest SPSC-EOI-015 (January 2017)

# The T2K-II project

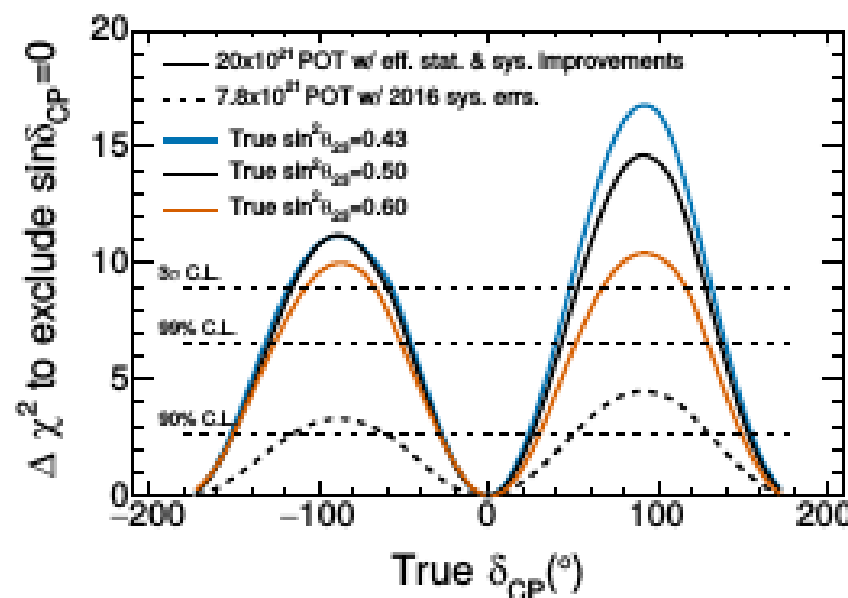
- JPARC Main Ring upgrade approved: beam power up to 1.3 MW
- T2K-II proposal: extend the data taking from 2021 to 2026 with  $20 \times 10^{21}$  POT ( $\sim 3$  times T2K-I)
- 400 nue appearance events, 100 anti-nue
- Reach  $3 \sigma$  for  $\delta_{CP}$



J-PARC MR Expected Performance



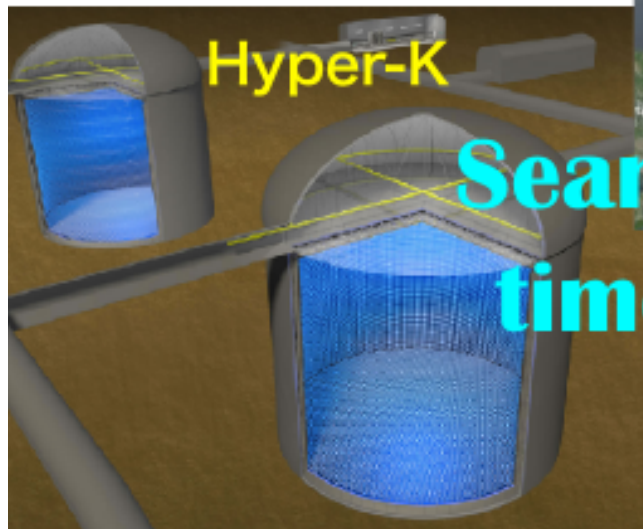
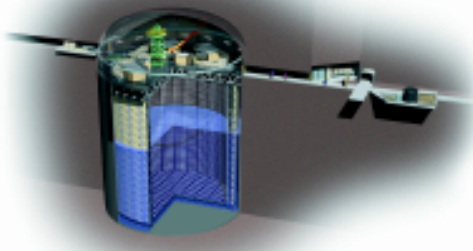
(a) Assuming true  $\sin^2 \theta_{23} = 0.43$ .



# *Neutrino oscillation experiments in Japan*

Intense Neutrino Beam for  $(\bar{\nu})_{\mu} \rightarrow (\bar{\nu})_e$  study

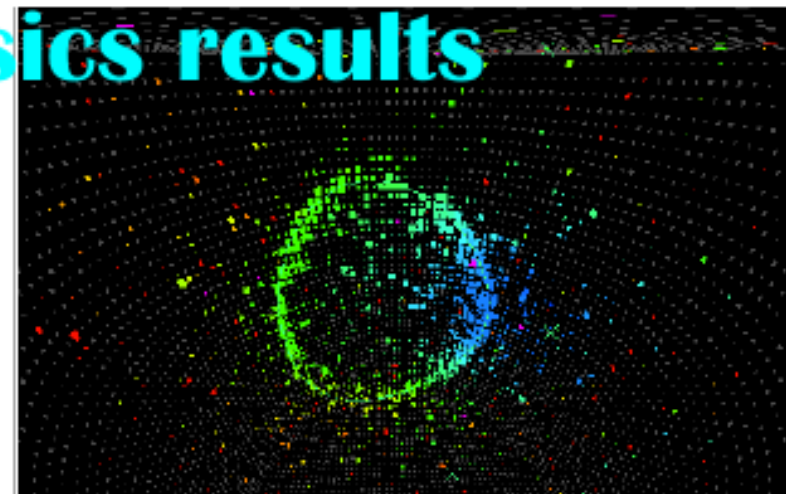
Super-K



Seamless program with  
timely physics results

- 430 kW (today)
- ~1 MW (2020)
- 1.3 MW (2025)

- 22.5 kton (Super-K, ~2026)
- 190(x2) kton (Hyper-K, 2026~)



# T2K-II

Table 1: Number of events expected to be observed at the far detector for  $10 \times 10^{21}$  POT  $\nu$ - +  $10 \times 10^{21}$  POT  $\bar{\nu}$ -mode with a 50% statistical improvement. Assumed relevant oscillation parameters are:  $\sin^2 2\theta_{13} = 0.085$ ,  $\sin^2 \theta_{23} = 0.5$ ,  $\Delta m_{32}^2 = 2.5 \times 10^{-3} \text{ eV}^2$ , and normal mass hierarchy (MH).

	True $\delta_{CP}$	Total	Signal $\nu_\mu \rightarrow \nu_e$	Signal $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	Beam CC $\nu_e + \bar{\nu}_e$	Beam CC $\nu_\mu + \bar{\nu}_\mu$	NC
$\nu$ -mode	0	454.6	346.3	3.8	72.2	1.8	30.5
$\nu_e$ sample	$-\pi/2$	545.6	438.5	2.7	72.2	1.8	30.5
$\bar{\nu}$ -mode	0	129.2	16.1	71.0	28.4	0.4	13.3
$\bar{\nu}_e$ sample	$-\pi/2$	111.8	19.2	50.5	28.4	0.4	13.3

	Total	Beam CC $\nu_\mu$	Beam CC $\bar{\nu}_\mu$	Beam CC $\nu_e + \bar{\nu}_e$	$\nu_\mu \rightarrow \nu_e +$ $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	NC
$\nu$ -mode $\nu_\mu$ sample	2612.2	2290.5	150.0	1.6	7.0	163.1
$\bar{\nu}$ -mode $\bar{\nu}_\mu$ sample	1217.5	482.1	672.5	0.6	1.0	61.3

# Upgrade Task Force: Charge

A second phase of T2K, currently called T2K-II, will extend T2K data taking with the aim of collecting approximately  $20 \times 10^{21}$  POT and reaching a 3 sigma level for the observation of CP violation for a range of delta values around  $3\pi/2$ . This data taking will continue until approximately 2026, and should produce  $\sim 400$  nue appearance events in SK. This level of statistics, and the FSTF studies, motivates a 2-3% systematic uncertainty on the number of expected events, which is predicated on a sufficiently validated neutrino interaction model.

The T2K Executive Committee hereby forms the ND280 upgrade task force, with Masashi Yokoyama and Marco Zito as conveners. The task force is charged to deliver, in Fall 2016, a recommendation document describing the preferred ND280 detector configuration for T2K-II at the level of a conceptual design.

The task force will consider different upgrade options capable of increasing the observable phase space of final state particles and reaching the performance required for CP violation. Some of these options have already been proposed during the ND280 Upgrade sessions over the last two years. The task force will evaluate, in a preliminary but quantitative way, the performance and, if possible, the feasibility and rough cost of the recommended detector configuration. Quantitative performance characterizations should be based on realistic simulations of the proposed detector configurations.

The installation of an upgraded detector should happen around 2020. Budget constraints and other practical and technical considerations limit the upgrade considered by this task force to those inside the NM pit with an assumption that magnetized detectors would reuse the UA1 magnet.

The task force will meet regularly and present progress in T2K open teleconference meetings and at the January 2016 and May 2016 T2K Collaboration meetings. It might organize a workshop in the Summer 2016, to advance progress and also to present T2K-II and the ND280 upgrade project to the community outside T2K.

# Context-Boundaries-Deliverable

- The T2K-II phase will accumulate  $\sim 20 \times 10^{20}$  POT or 400 nue appearance events
- Require a 2-3% systematic uncertainty on the n of exp events
- Goal : CDR-like document describing the preferred configuration for an ND280 upgrade to be delivered Fall 2016
- Based on a quantitative evaluation of the performance
- Boundaries : to be installed around 2020, within the ND280 pit, reusing the magnet facility

# CERN workshop

- Held on Nov 8-9, 2016
  - <https://indico.cern.ch/event/568177/>
- >70 participants from many countries
  - Demonstrate broad interest in community
- Intense discussion on physics study, hardware, cooperation
- Explore the possibility to launch a project in CERN Neutrino Platform with two (synergetic) goals
  - ND280 upgrade
  - HPTPC R&D



# Expression of Interest SPSC-EOI-015

- Signed by ~190 physicists
- From Bulgaria, Canada, France, Italy, Japan, Germany, Poland, Spain, Sweden, Switzerland, UK, USA
- And CERN
- Aims to be part of the CERN neutrino platform
- Next Workshop March 20-21 at CERN
- Proposal by the end of 2017

CERN-SPSC-2017-002 / SPSC-EOI-015  
05/01/2017

## Near Detectors based on gas TPCs for neutrino long baseline experiments<sup>1</sup>

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# Statement by T2K

- On February 11, 2017, the T2K Collaboration launched its Near Detector Upgrade project. The upgrade is targeted at reducing systematic errors in T2K's search for CP violation in the neutrino sector. The current conceptual design will be developed into a technical design, leading to a full proposal, by the end of 2017. The collaboration aims to install the upgraded near detector around 2020, to fully benefit from the foreseen increase of the J-PARC MR beam power.

# T2K Near Detector

ND280

UA1 Magnet Yoke + SMRD

$B = 0.2 \text{ T}$

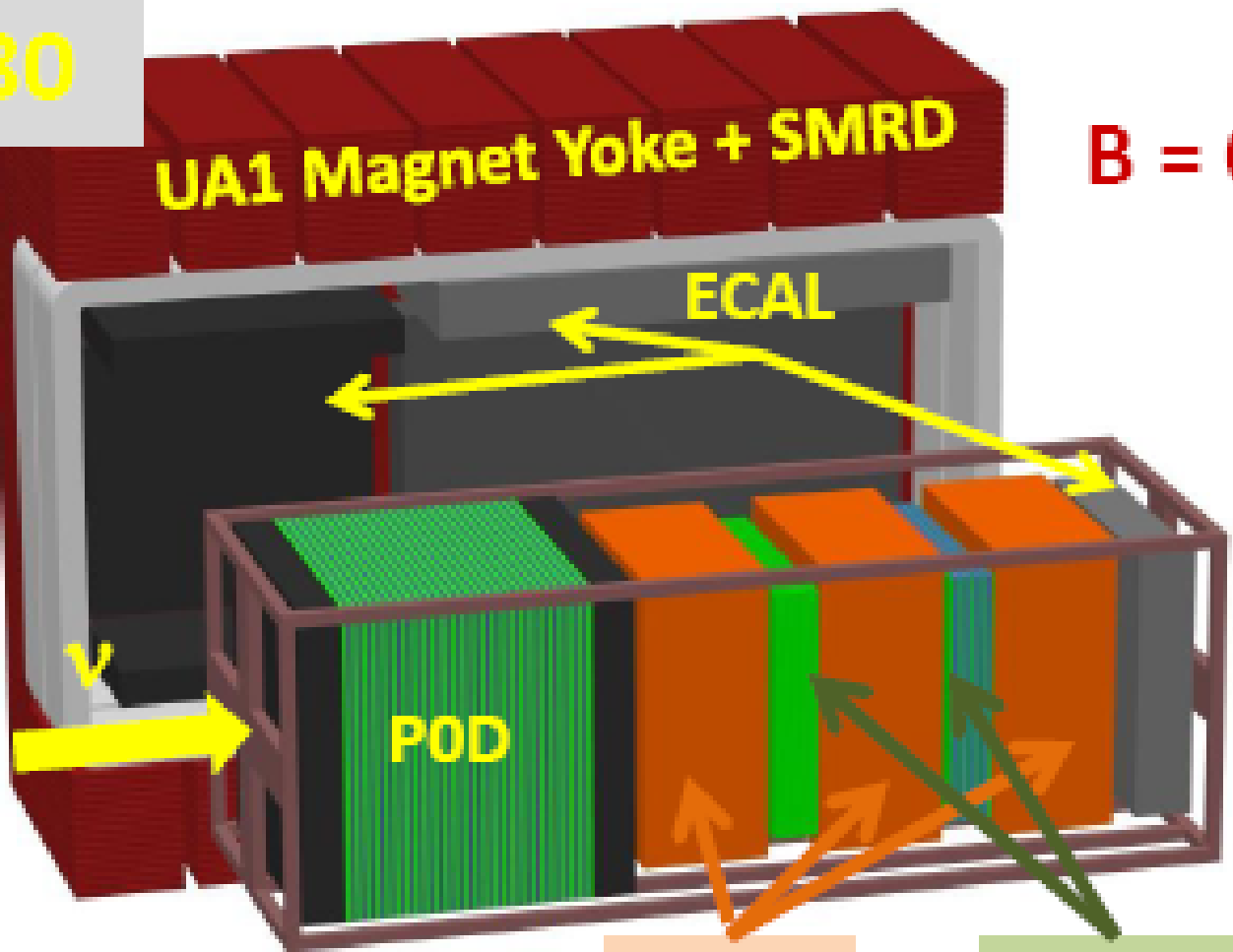
ECAL

POD

TPCs

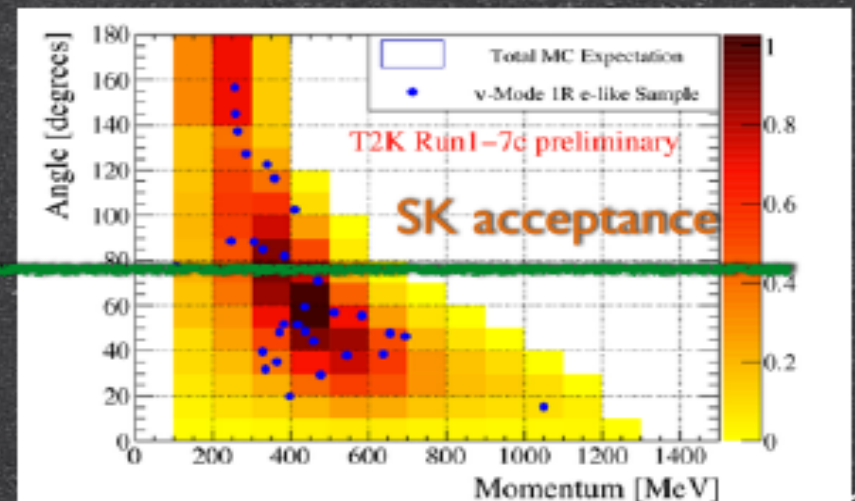
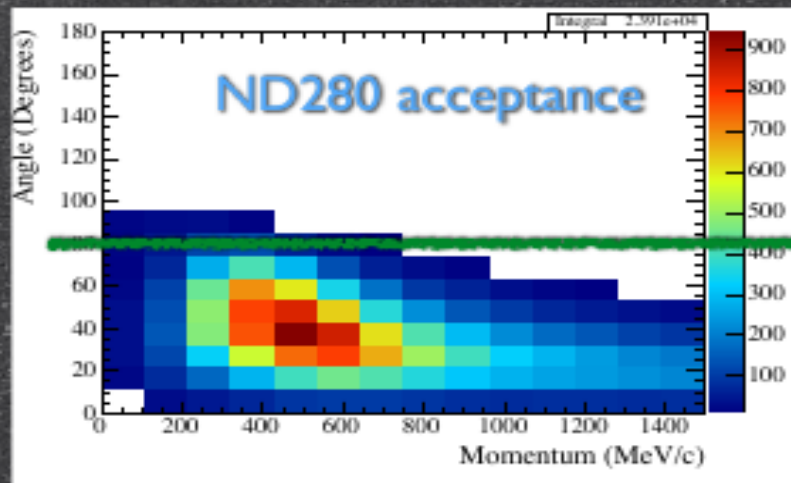
FGDs

$e^-$



# Angular acceptance

- ▶ One of the main limitation of current ND280 analyses is that it only select forward-going muons
- ▶ In SK the acceptance is flat with respect to the lepton angle and events with backward leptons are also selected
- ▶ Currently we constraint the models in the forward region and we let the model constraint the backward region → model dependent

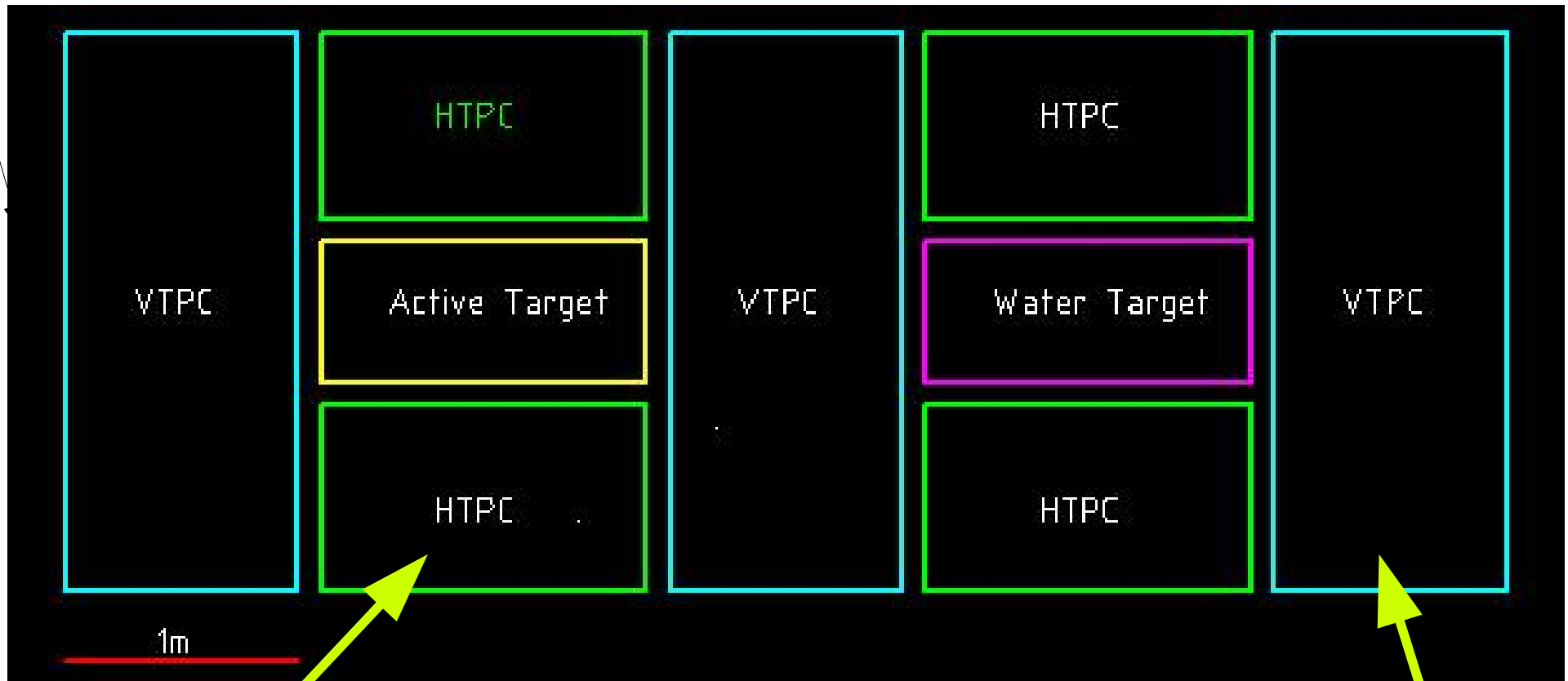


# Criteria for the design

- Cover the full muon polar angular domain
- With carbon and water targets
- Increase the efficiency low momentum protons
- Improve the nue sample

# The baseline design for the upgraded ND280

All this inside the EM calorimeter and the UA1 magnet



New horizontal TPC

Existing TPC

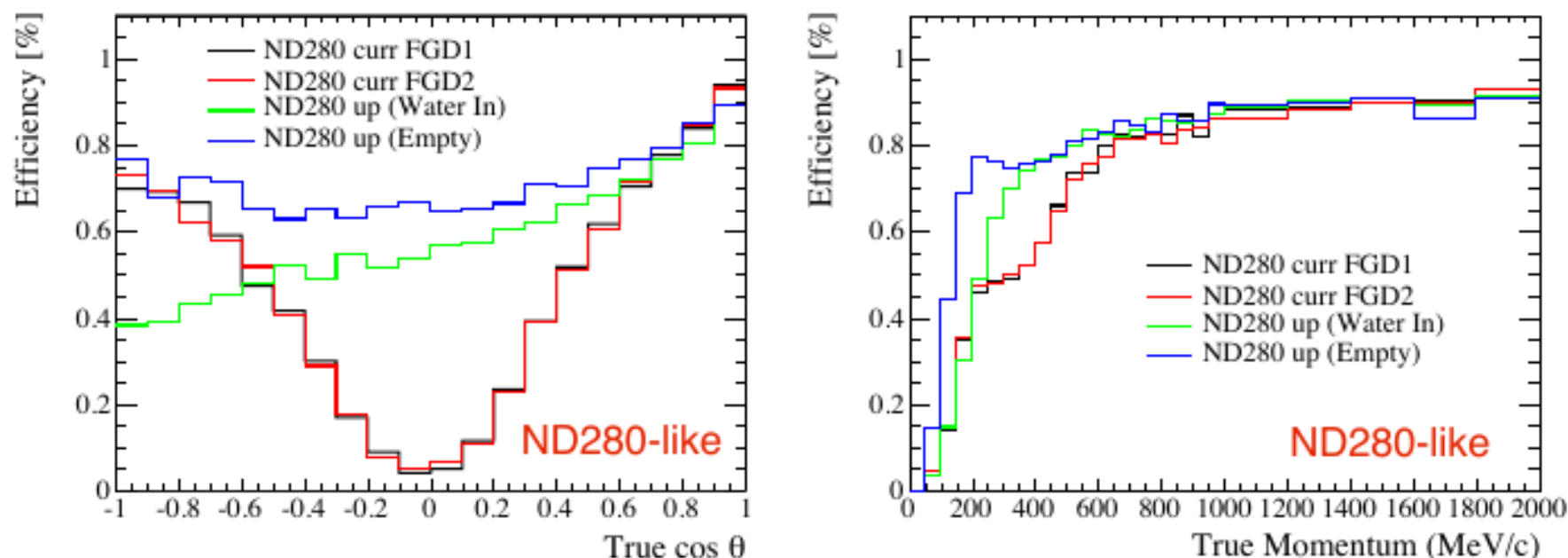
July 2016

Marco Zito

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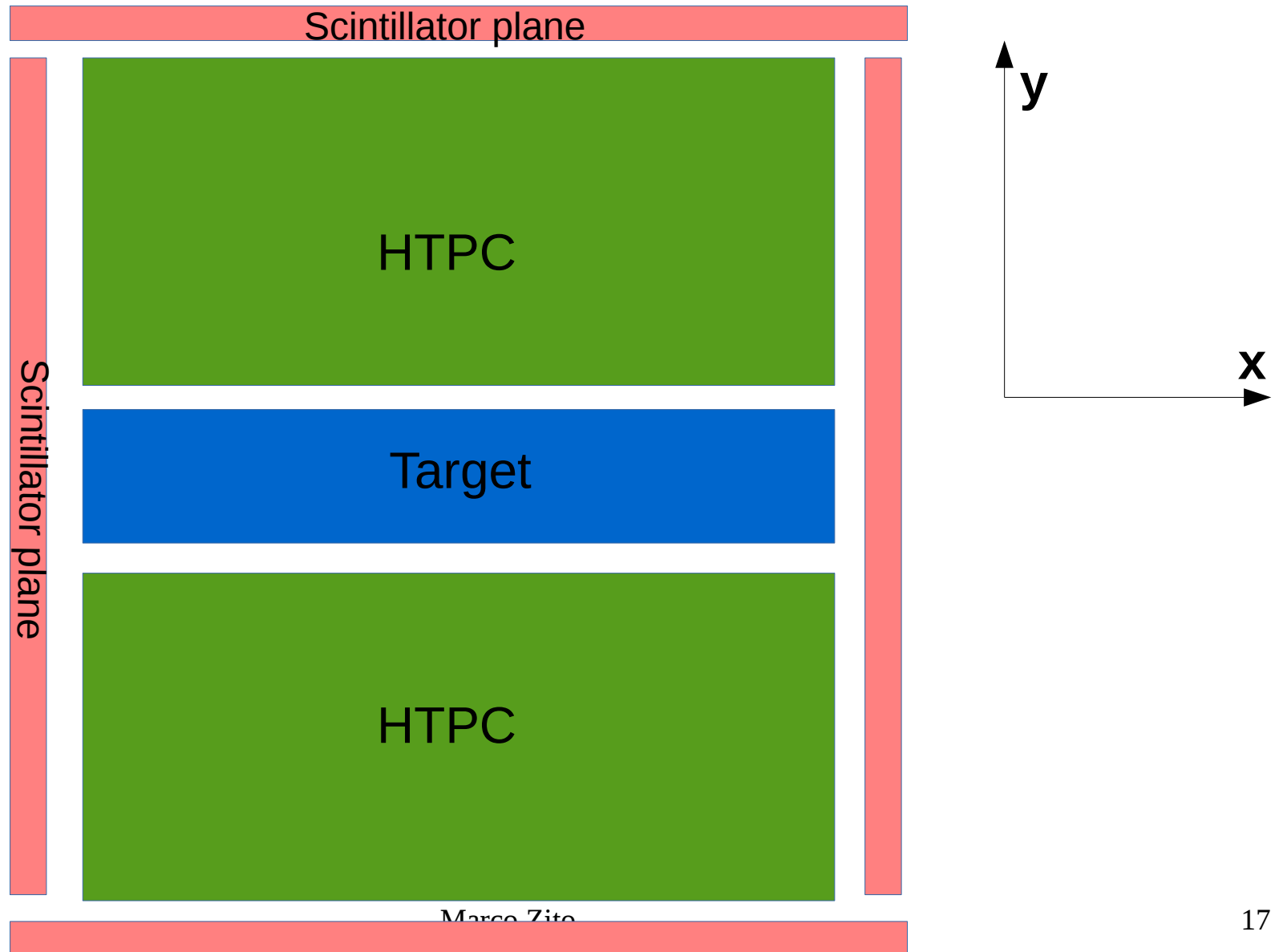
We plan to surround the TPC by scintillator planes for T0 and TOF determination. Still to be studied.

## ND280 upgrade performance



- Horizontal targets and new TPCs can measure very well the high angle region both for Water-in and Water-out WAGASCI targets
- At  $\cos\theta \sim 0$  the efficiency is improved to  $>50\%$  for water-in,  $\sim 70\%$  for water-out
- Also momentum threshold is lower with the new configuration

# T0 determination



# Main sub-detectors/WP

- Atmospheric pressure TPCs (HTPC for Horizontal TPC)
- Active targets
- TOF detectors
- POD Ecal
- other ND280 detectors and systems
- R&D for a High Pressure TPC

# Interest expressed by institutes

- WP1 Mechanical design and integration: groups CERN(?), Geneva, Krakow, Liverpool, LLR(later)
- WP2 TPC field cage and gas vessel: INFN
- WP3 TPC Readout technology: Saclay CERN
- WP4 TPC electronics and DAQ: Saclay, Warsaw, LPNHE
- WP5 Gas system and calibration: Winnipeg, CERN
- WP6 Scintillator-based trackers: Japan+LLR, Sofia
- WP7 TOF system: INR, Geneva
- WP8 Test beam measurements: IFAE, CERN
- WP9 High Pressure TPC: UK, IFAE ...
- WP10 Simulation and optimization studies: many groups
- WP11 Physics studies: many groups
- WP12 DAQ: UK
- WP13 Software: UK

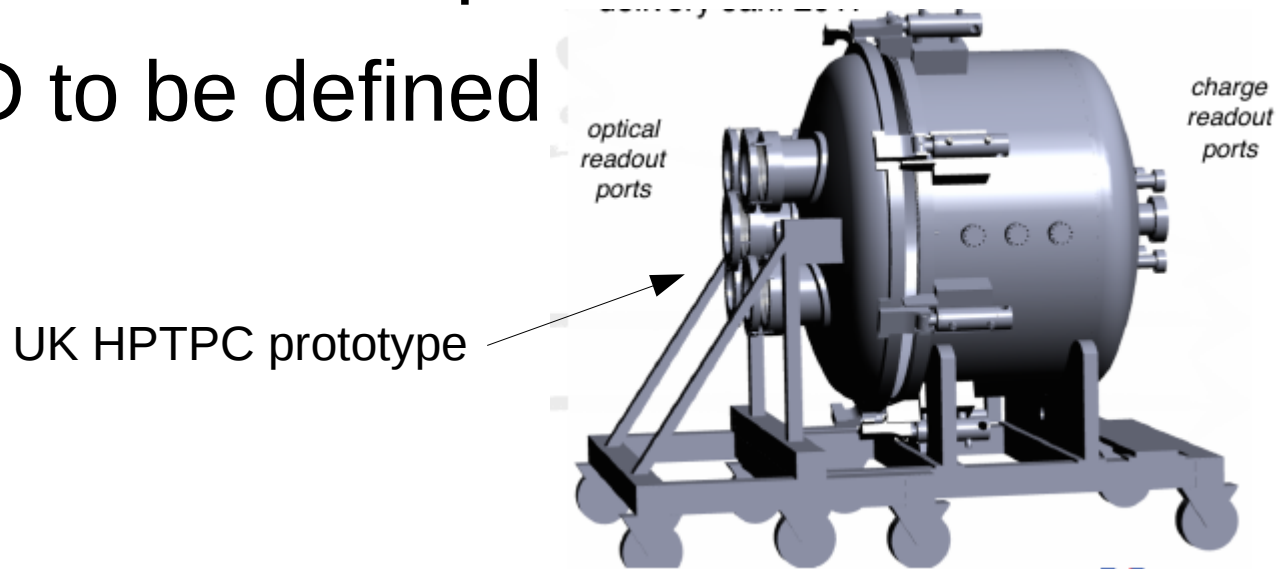
We welcome the participation of Swedish groups and will integrate them in the project structure

# Work Packages and Contact persons

- WP1 Mechanical design and integration (Marcela, Davide)
- WP2 TPC field cage and gas vessel (Gabriella, Emilio) → (Emilio, Gianmaria Collazuol)
- WP3 TPC Readout technology (A. Delbart, CERN)
- WP4 TPC electronics and DAQ (D. Calvet, Andrzej Rychter)
- WP5 Gas system and calibration (Blair, CERN)
- WP6 Scintillator-based trackers (Japan+LLR)
- WP7 TOF system (Yury)
- WP8 Test beam measurements (Federico, Stefania)
- WP9 High Pressure TPC (Asher, Morgan)
- WP10 Simulation and optimization studies (Davide)
- WP11 Physics studies (Sara, Claudio)
- WP12 DAQ (G. Barr)
- WP13 Software( Y. Uchida)

# High Pressure TPC

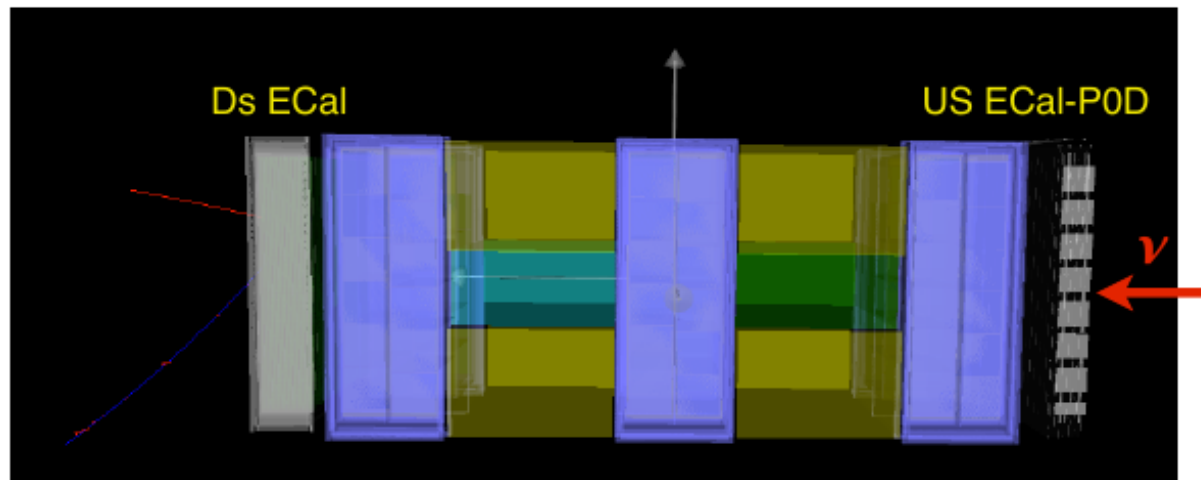
- Interest expressed by several ND280 groups for a High Pressure TPC as neutrino detector
- Several synergies with the ND280 Upgrade project
- We have decided to have an R&D on a High Pressure TPC for neutrino as part of the EOI
- Scope of this R&D to be defined



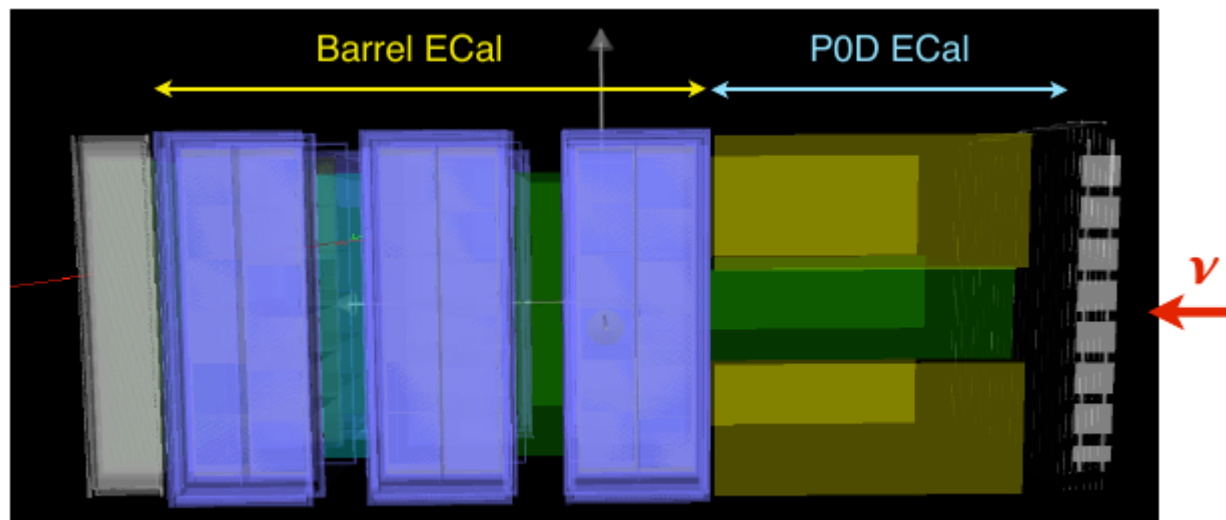
# Proposal document

- We have set the goal to produce a proposal document by the end of the year (to be approved by T2K, then submitted to CERN SPSC)
- The aim is to have the content of the proposal ready for the October CM
- This would be a ~50 pages document, we need the active participation of the WP contact persons to define the structure and provide the content
- We would like to make progress during this workshop on the main questions to be addressed in the next months
- One important questions is to provide an approximate cost estimate for the prototype and the detector

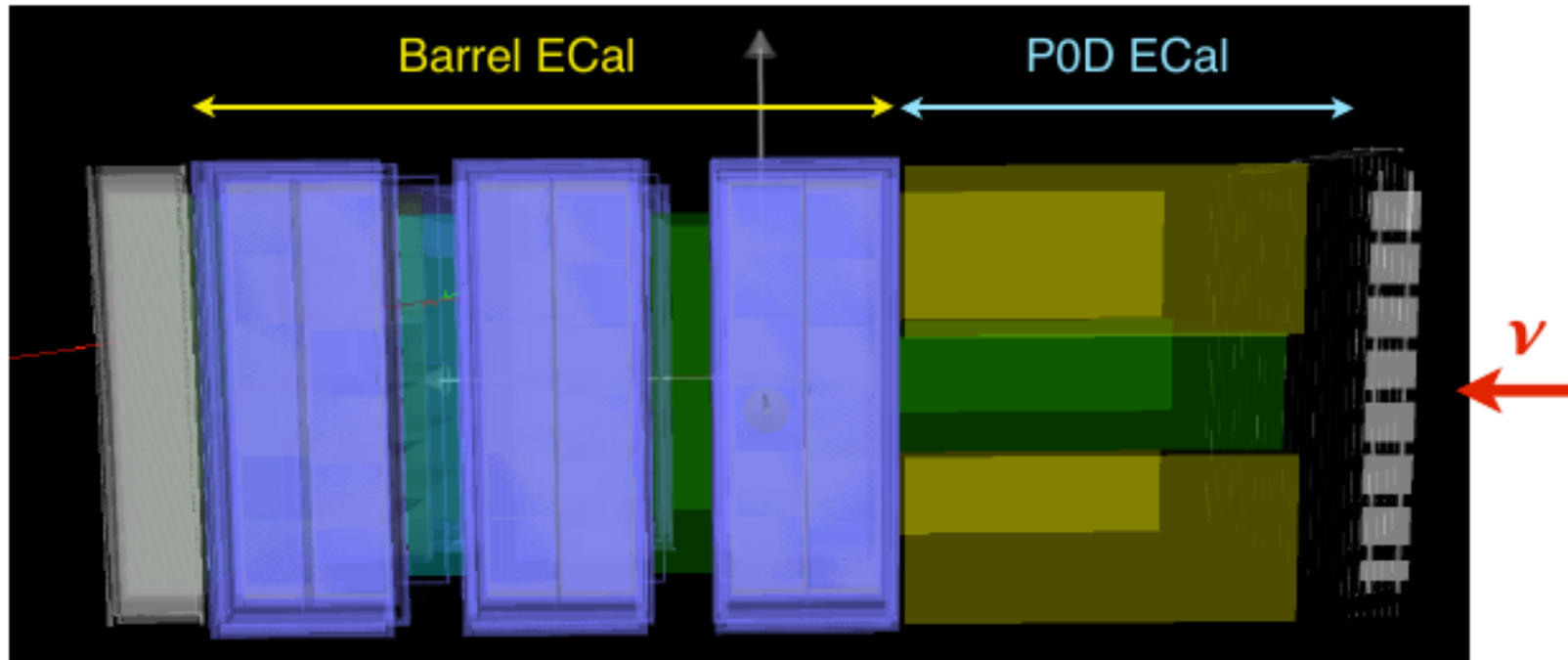
# Important design choices-1



or



# Alternative configuration



## Advantages:

- Keeps present ND280 tracker in place (comparison possible) including FGD2 (water)
- Less challenging (areas, n of channels etc) for target/TPC/TOF
- Adds significant target mass (total~1+1+2 ton)
- Superior results observed in BANFF like fit
- Advantages foreseen for  $\bar{\nu}_e$  studies

# Important design choices: 2

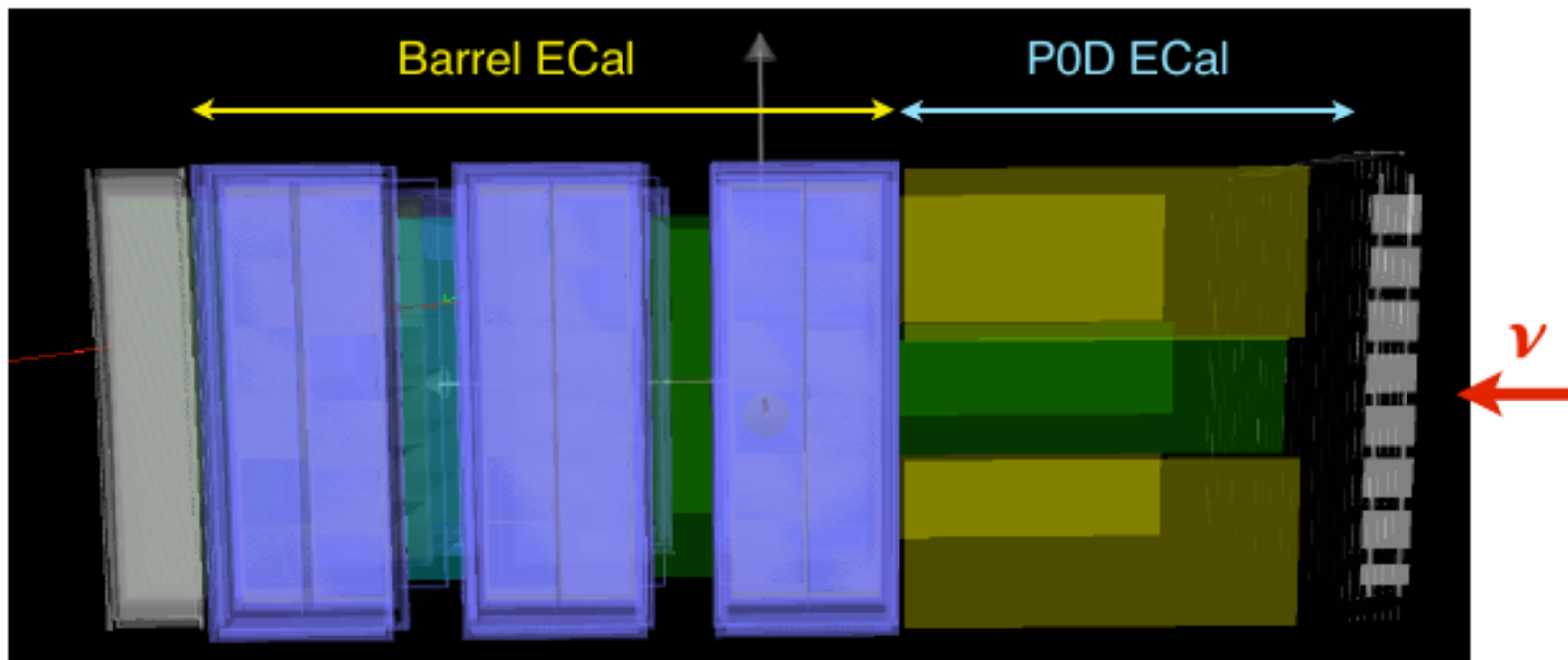
- 6 scintillator-based detectors considered for the active target(s): FGD-like, 3D FGD, Super-FGD, Wagasci-like, Empty Wagasci, Scintillating fibers
- For the alternative configuration, the horizontal target could be totally active (Carbon only)
- Apart from the technology, other design choices for the target (granularity, bars geometry etc) need to be addressed
- Performances should include: efficiency for short hadronic tracks (includes high angle tracks), PID, gamma/nue, Michel electrons

# Important design choices: 3

- Type and geometry of TOF detectors
- The minimum performance is to distinguish forward/backward tracks (inward/outward) over a distance of  $\sim 1\text{m}$  with  $\sim 1\text{ns}$  resolution or better
- Some PID ( $e^+$  vs  $p$ ,  $e$  vs  $\mu$ ) might be possible for  $\sim 100\text{ps}$  resolution
- Cost/benefit to be understood

# Important design choices: 4

- Is POD Ecal enough for photons tagging, electrons PID ? ( $4.3^\circ$ , only z-bars)
- Do we need to complete it with a pre-shower ?



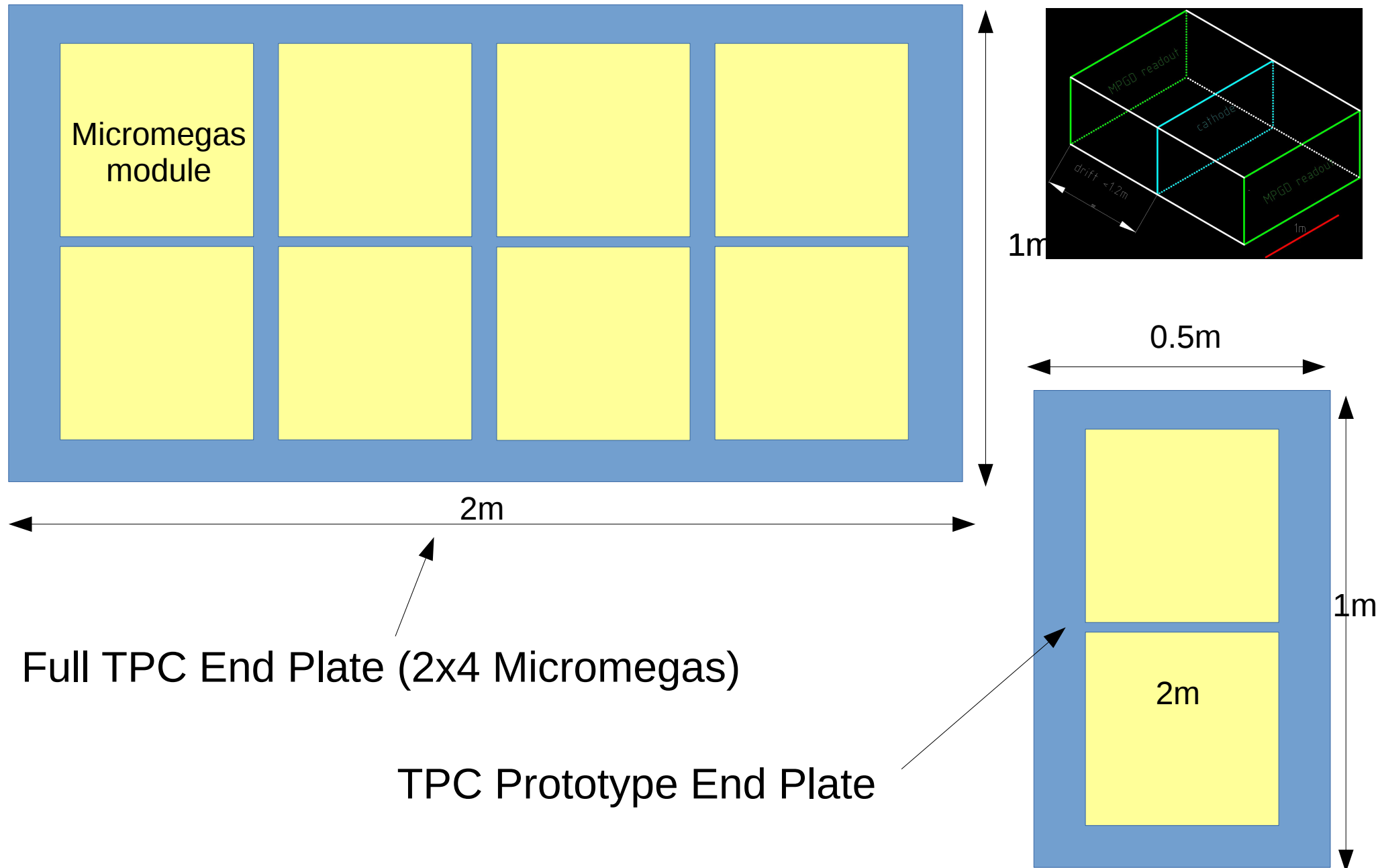
# Other questions

- Other urgent questions to be addressed concern the feasibility of the proposed configurations and the boundary conditions
- For instance, we need to design the mechanical support structure, the service routing, the cabling from the SS level etc

# Prototyping

- For the atmospheric pressure TPC, we aim to build and test a prototype at CERN next year (before October 2018)
- Approximate dimensions : 1m (drift) x 0.5 m x1 m (two Micromegas modules on the readout end plate)
- Other prototypes might be needed for the target and the TOF
- All this should be part of a detailed plan of beam tests, including appropriate requests to CERN

# TPC end plate and prototype



# Conclusions

- The Upgrade Project is at an important turning point
- We have succeeded in attracting attention beyond T2K
- We need to make progress on the design to move towards the construction phase
- Simulation and physics studies (please join this effort!) will provide a crucial input towards major choices