# T2K Upgrades

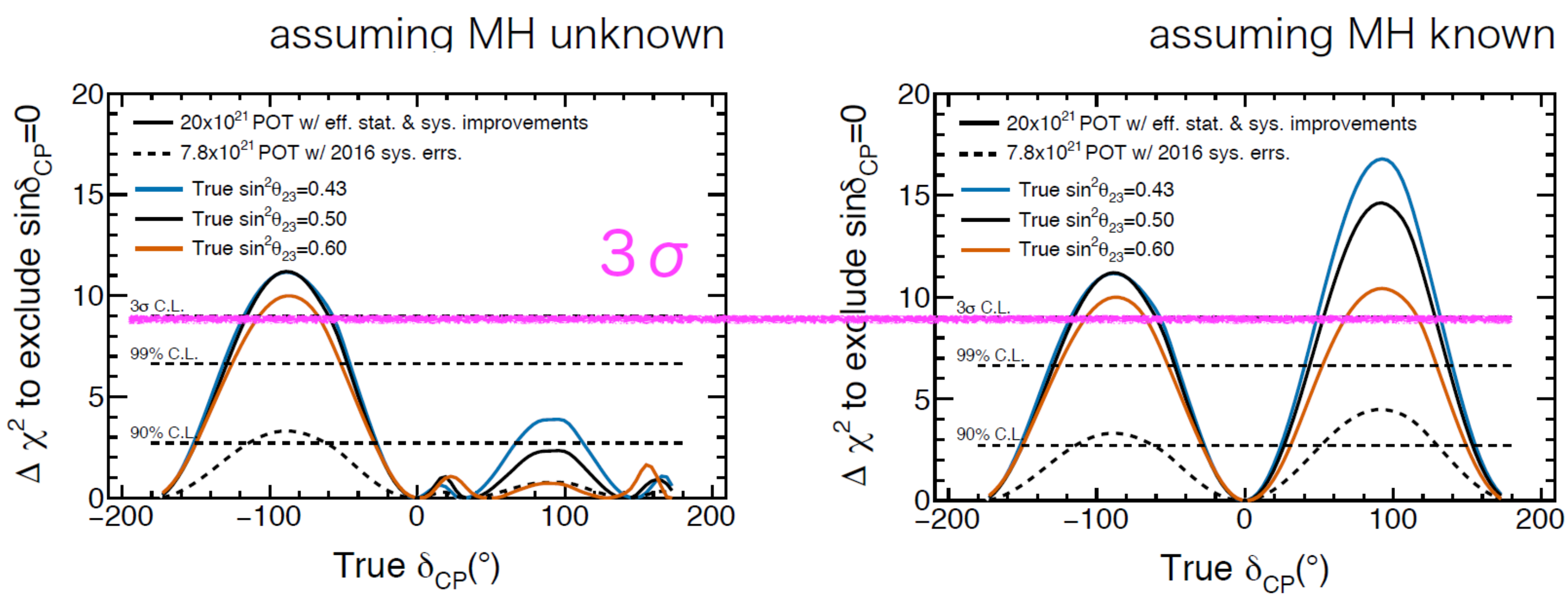
Jennifer Consortium general meeting

KEK

06/10/2017

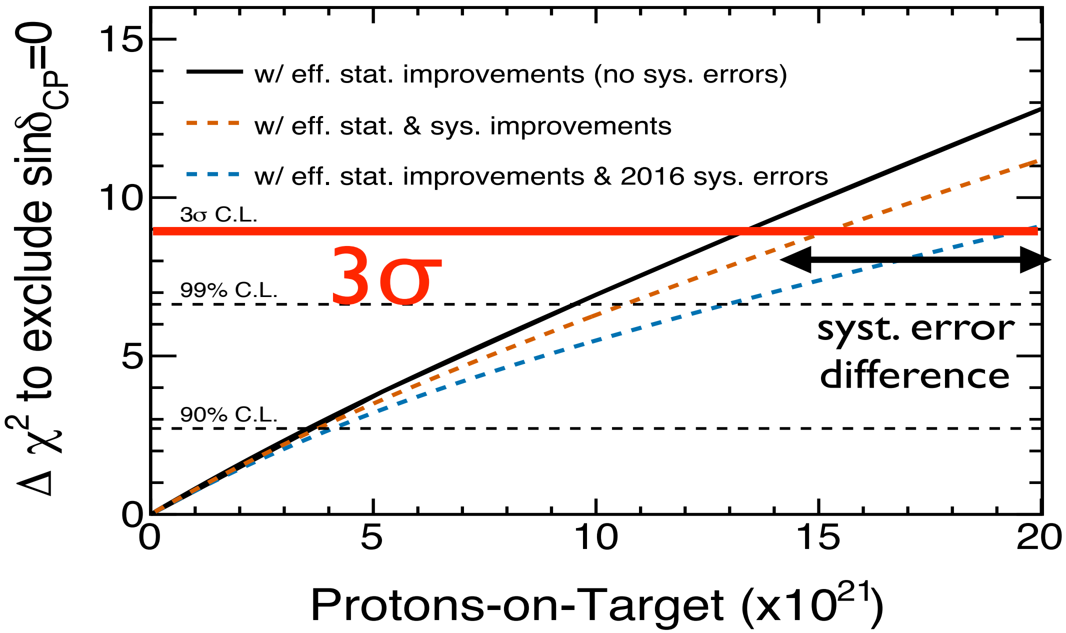
# T2K Phase II (T2K-II)

- T2K-II extension proposal (arXiv:1609.04111)
- Original T2K program is $7.8{\times}10^{21}$ POT
- Plan: Accumulate $2{\times}10^{22}$POT by ~2026 ( 3σ CPV sensitivity for favorable parameters ) => *High Intensity Neutrino beam*



# T2K-II goals

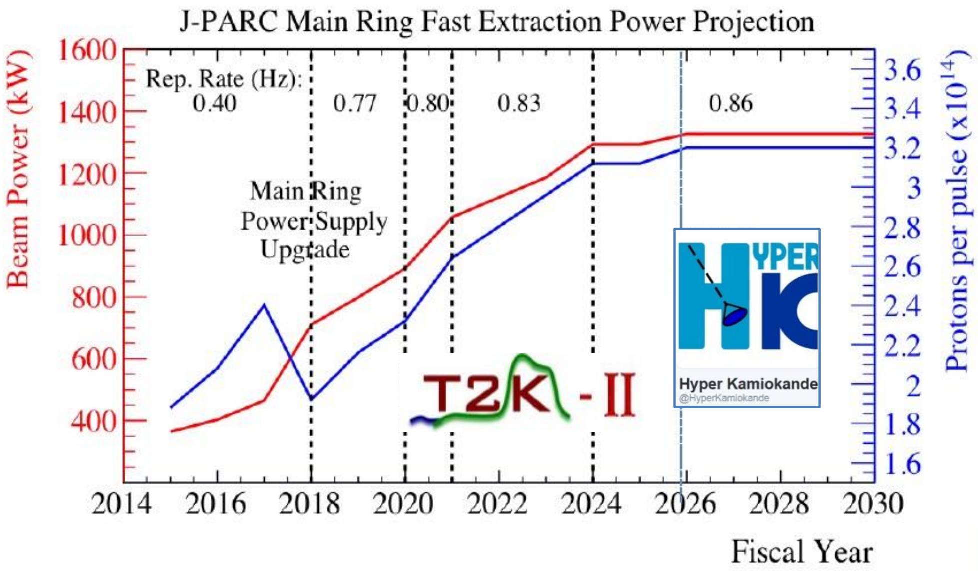
- ~400 events expected for $\nu_e$ appearance signal
  - Analysis improvement to increase statistical significance
- Systematics Error 5.8 => 4% (<3% HyperK/Dune)
  - Near Detectors measurements is a key!
- Approved for the Stage-1 by PAC.
- Technical Design end in 2017 to request for Stage-2 app



# J-PARC neutrino beam upgrade

- Continuous upgrade of neutrino beam up to 2030
- Present beam power ~470 kW
- New MR power supply for 750kW by 2019
  - Repetition rate increase to 0.86 Hz for 1.3MW by 2026

Continuous beam upgrade @ J-PARC



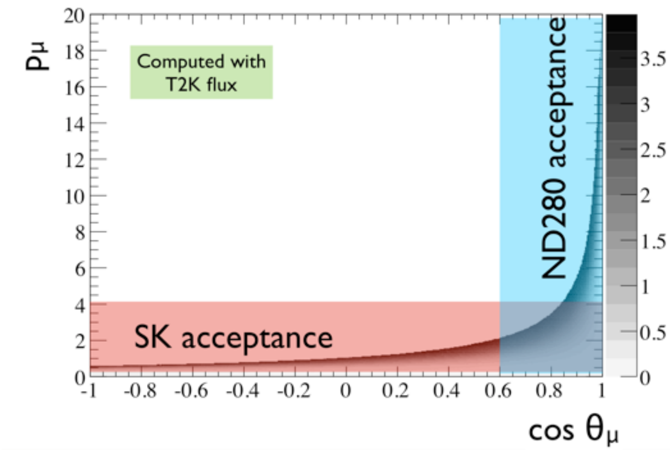

| | Now (achieved) | 2020 | ~2025 |
|---|---|---|---|
| p/spill | $2.4\times10^{14}$ | $2.2\times10^{14}$ | $3.2\times10^{14}$ |
| cycle | 2.48s | 1.3s | 1.16s |
| power | 470kW | 800kW | 1.3MW |

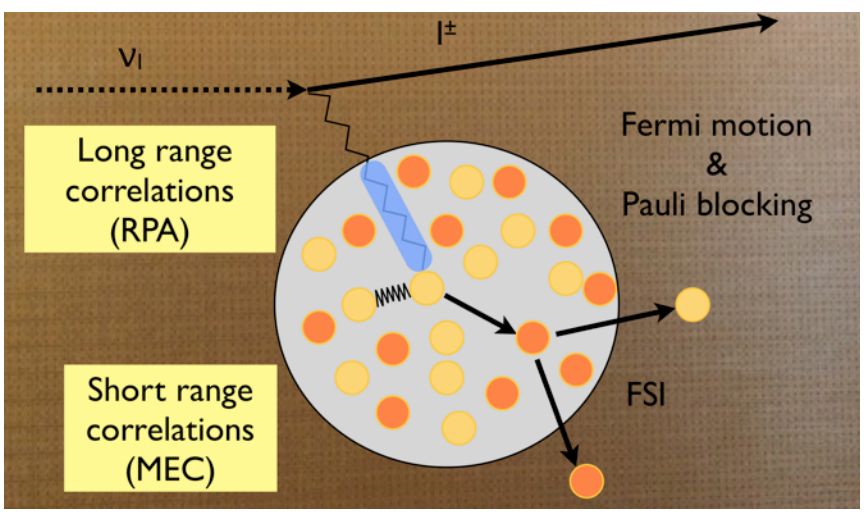
- J-PARC upgrade for Hyper-K is top priority in KEK Project Implementation Plan (KEK-PIP)

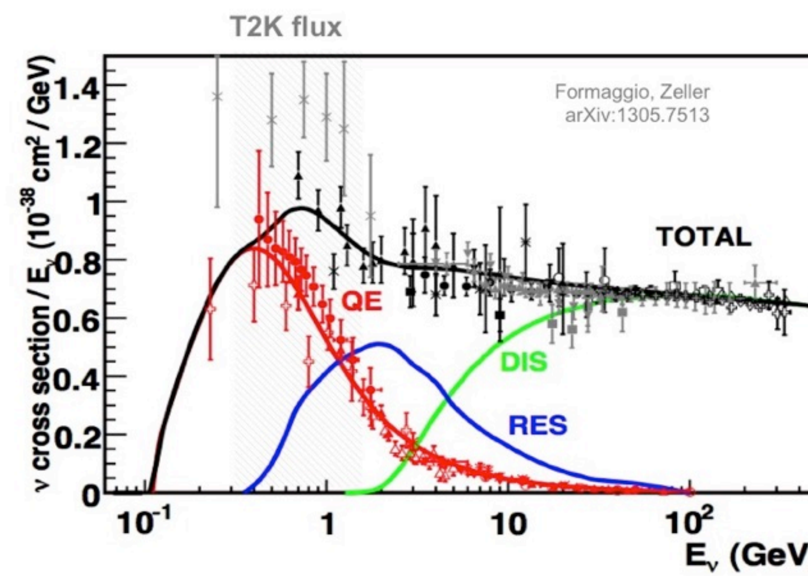
- **Strong commitment for future neutrino program**

# Systematic errors sources

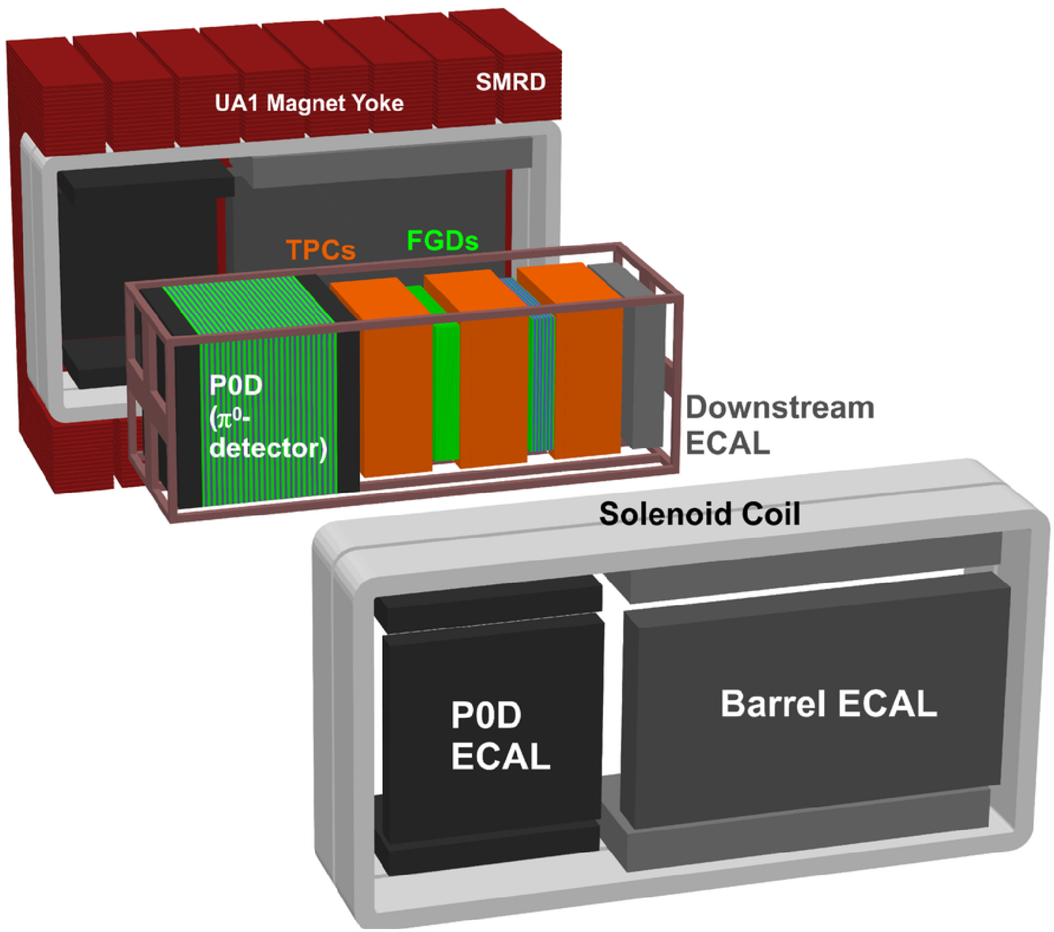
- ✓ Acceptance differences Near/Far detector
- ✓ Different target Near/Far ($CH/H_20$)
- ✓ Low energy Neutrino X-sections
- ✓ Near/Far ratio
- ✓ Theoretical Models



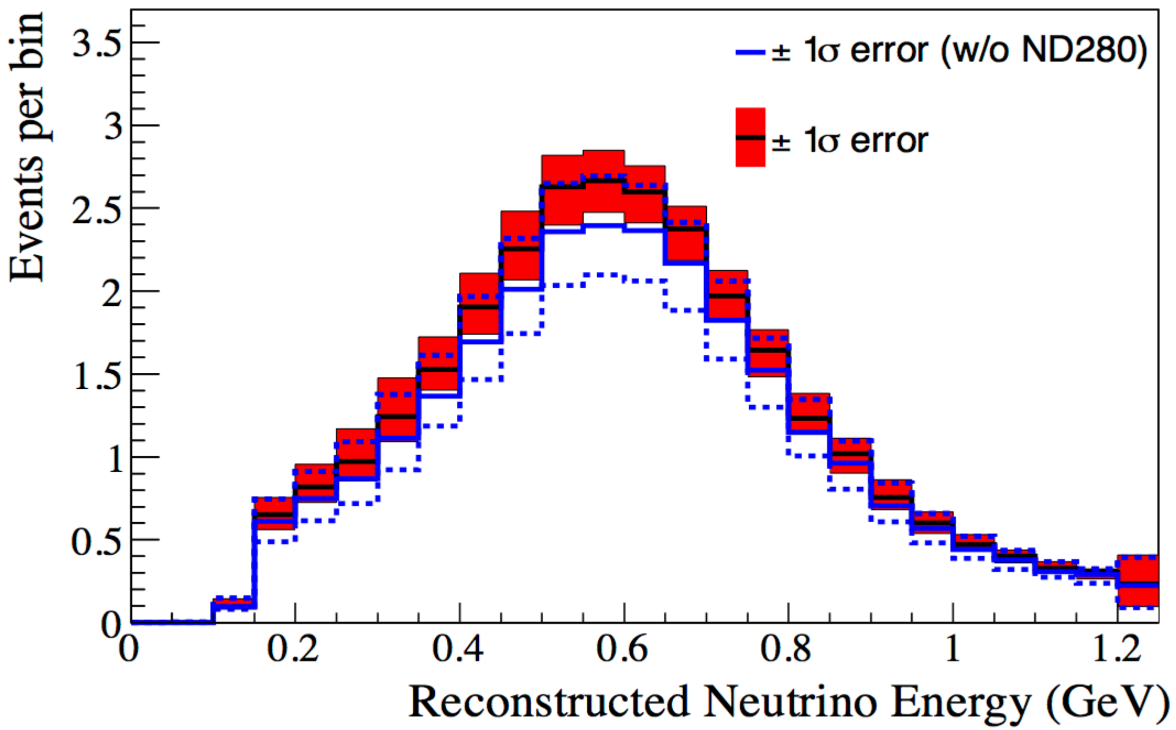



# The T2K ND280 Near Detector



# Role of the ND280 near detector

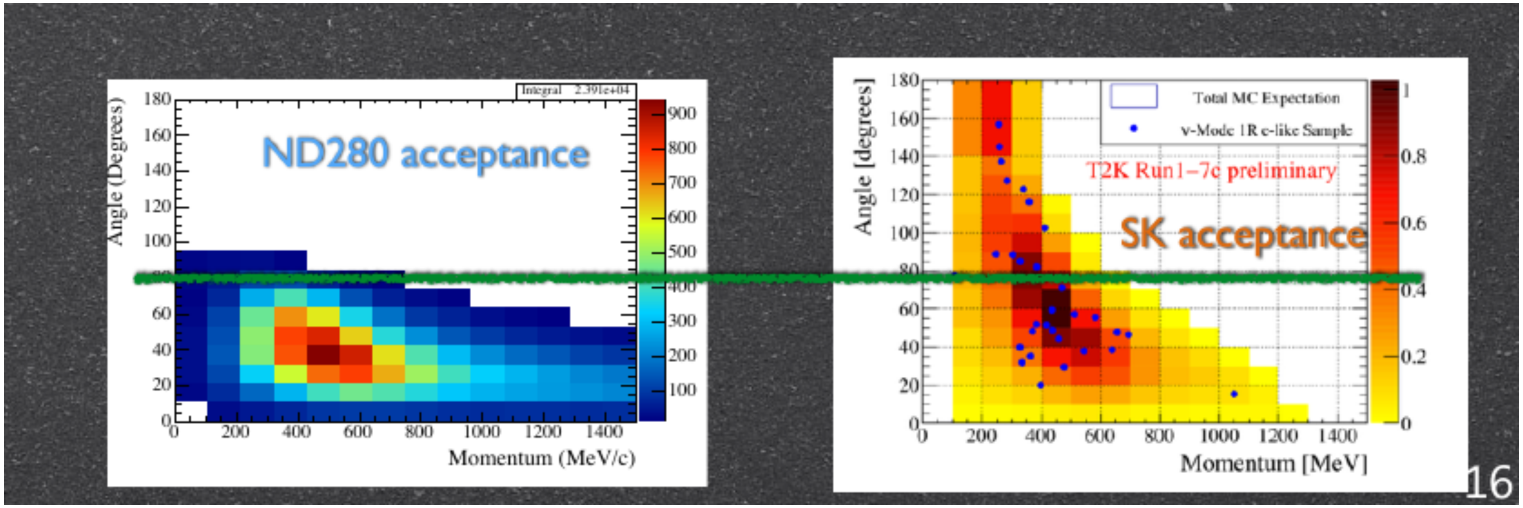
Expected electron neutrino appearance signal




- Measure the neutrino interaction rates (flux • cross-section) in various channels
- Strongly constrain the expected rates at SuperKamiokande for precision oscillation analyses
- Measure neutrino nucleus cross-sections in several channels

# ND280 limitations

- One of the main limitations of the ND280 data used for the oscillation analyses is that they mainly cover the forward region while SK has a 4π acceptance
- Model dependence when extrapolating to the full phase space
- The neutrino-nucleus cross-section is not well known, an upgrade is necessary to reduce the systematic errors for T2K-II



# The ND280 Upgrade project

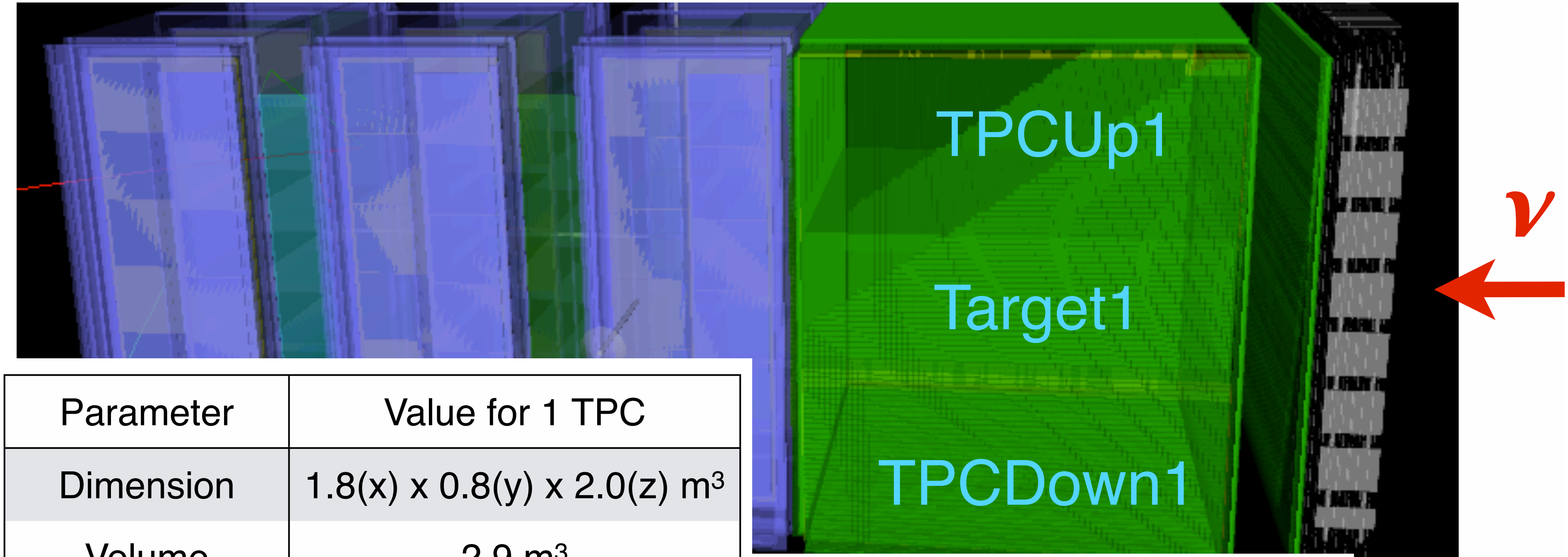
### Recent activity

- 2015-2016 ND280 Upgrade Task Force
- November 2016 Open Workshop at CERN
- January 2017 Expression of Interest submitted to CERN SPSC (towards a project in the framework of the CERN Neutrino Platform)
- February 2017: the ND280 project is formally approved by T2K
- March-Aug 2017 workshops at CERN and Tokai

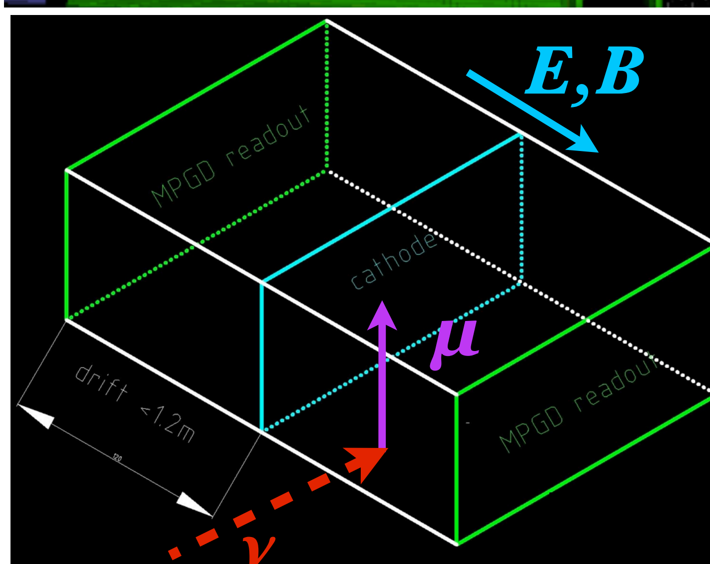
### Involved sub-detectors

- Atmospheric pressure TPCs (Horizontal TPC) 2 detectors (~2m x 2m x 0.8 m)
- Active targets (one, ~2tons)
- TOF detectors
- other ND280 detectors and systems (ECAL, DAQ, ...)
- R&D for a High Pressure TPC

# New “horizontal” TPCs




| Parameter | Value for 1 TPC |
|---|---|
| Dimension | 1.8(x) x 0.8(y) x 2.0(z) $m^3$ |
| Volume | 2.9 $m^3$ |
| Drift Length | 90 cm |
| Pad area | ~1 $cm^2$<br>(~2 $cm^2$ resistive MM) |
| Sensitive area | 3.2 $m^4$ |
| # MM | 16<br>(50x50 $cm^2$ each MM) |
| # channels | $3.2 \times 10^4$ |

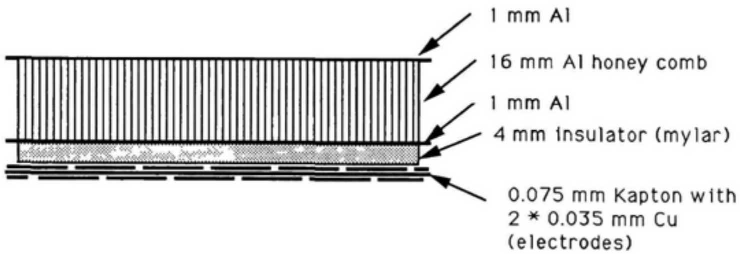


# “new” field-cages

- no outer volume: one structure must do:
  - Electrostatic insulation
  - gas tightness
  - overpressure
- with minimal wasted volume
  - thin
  - light
  - multiple strip layers
- Optimized for low-energy secondaries at large angles
- light + thin + single panel → challenging design

# Design and optimization of the field-cage

**Aleph / ILC scheme:**
Strip layers glued / embedded in the mechanical structure (typically: composite materials)




Insulator from a thin Mylar foil winded around many times using a higly resistive glue

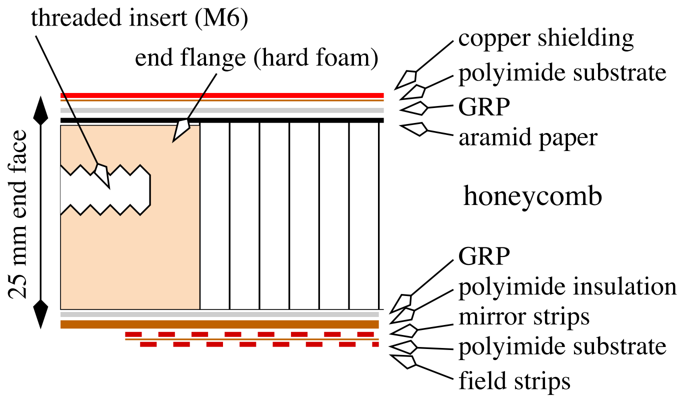
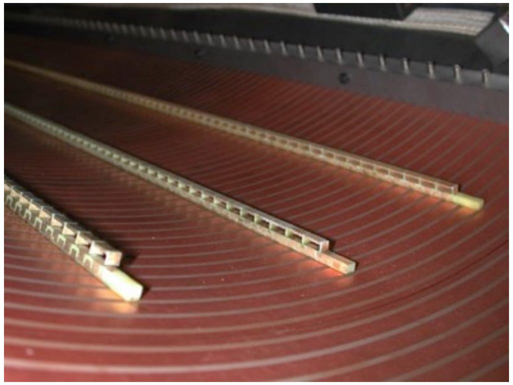
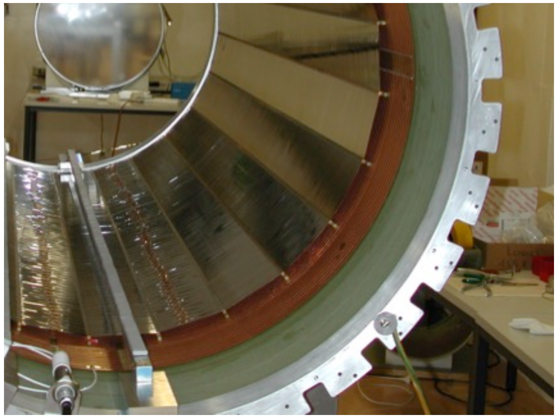



**Figure 7:** *Cross section of the Large Prototype field cage wall.*

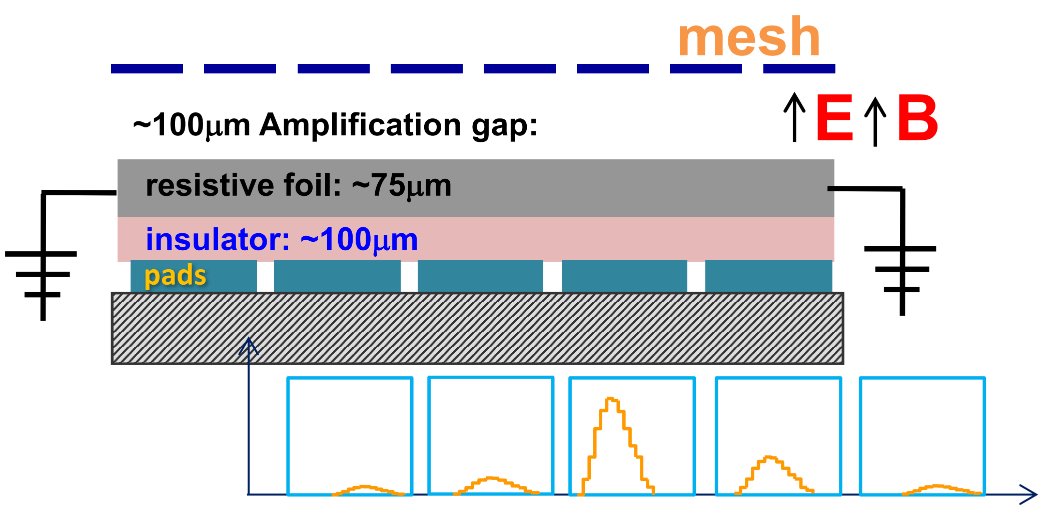
**HARP scheme:**
One strip layer is glued to the mechanical structure, additional layers as mylar strips stretched on light supports

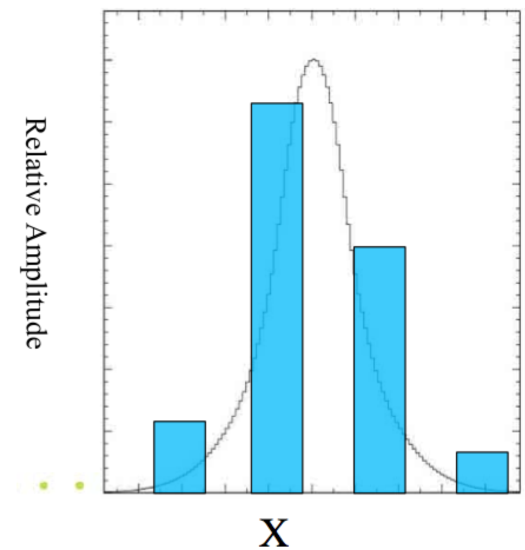




# New resistive-anode Micromegas

- Try a new configuration: ‘encapsulated resistive anode with grounded mesh’
  - Charge spreading allows space point resolution improvement with less electronics channels
  - The protection provided by the resistive foil allows lighter Font End  Cards
  - Less track distortions due to field homogeneity
  - Less sensitive to noise

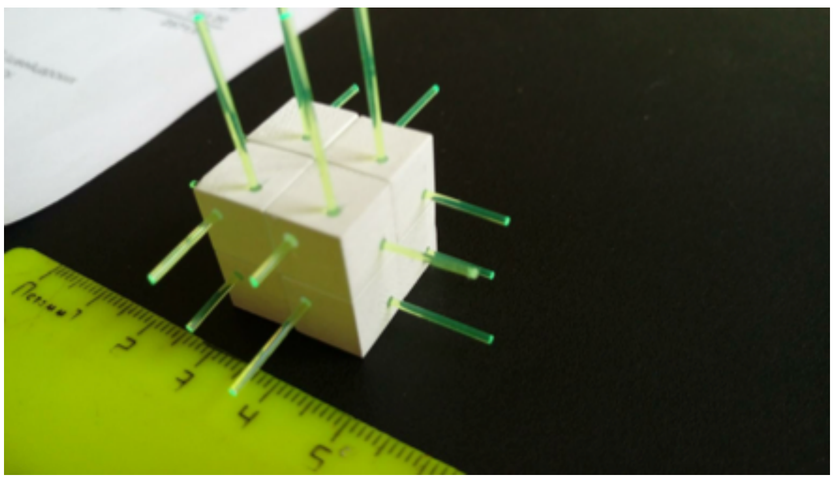


# a target option: SuperFGD

- Need a target detector that can detect the particles produced by neutrino neutrino interactions with a 4pi acceptance and momentum threshold lower than the currents state-of-the-art of plastic scintillators

- Instead of XZ plastic scintillator bars, use plastic scintillator cubes coated with chemical reflector and 3 WLS fibers in the 3 orthogonal directions that provides 3 views (XY, XZ, YZ) **arXiv:1707.01785**



| | |
|---|---|
| Size detector | 1.8 x 0.6 x 2.0 $m^3$ |
| Size cube | 1 $cm^3$ |
| # of channels | ~59k |
| # of cubes | ~2.16M |
| fiber length | ~59km |

**Cubes: 10x10x10 $mm^3$**
**Material: extruded polystyrene + p-terphenyl**
**White chemical reflector, thickness ~ 50 mkm**
**3 holes: each of 1.5 mm diameter**
**WLS fibers: Kuraray Y11**

| Parameter | Value |
|---|---|
| Coating thickness | 50 $\mu m$ |
| Hole diameter | 1.5 mm |
| WLS fiber diameter | 1.0 mm |

# Motivations for WAGASCI tracker

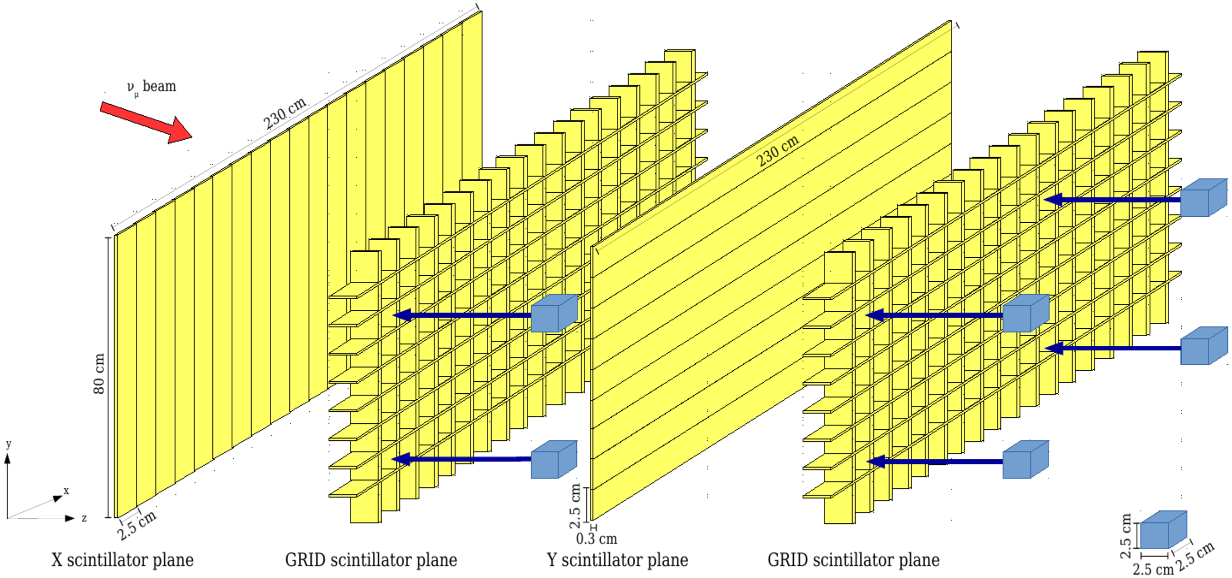
*Benjamin Quilain*

**<u>Proposal :</u>** WAGASCI, a high granularity 2π scintillator tracker.

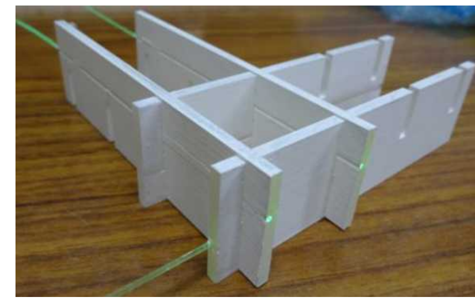
**<u>→ WAGASCI tracker:</u>** Alternance of XY planes & 3D grid scintillators.

→ ~2π angular acceptance

→ Good vertex resolution (even for large angle tracks)




<u>GRID-like scintillators</u>



↓

High angle efficiency !

**<u>2 targets :</u>** 1 $H_2O$ (& 1 plastic module → End of the talk).

<u>$H_2O$ Module ID card :</u>

<u>Module size :</u> 230 x 60 x 130 cm³ **~ 1.8 tons** (FGD ~ 2t).

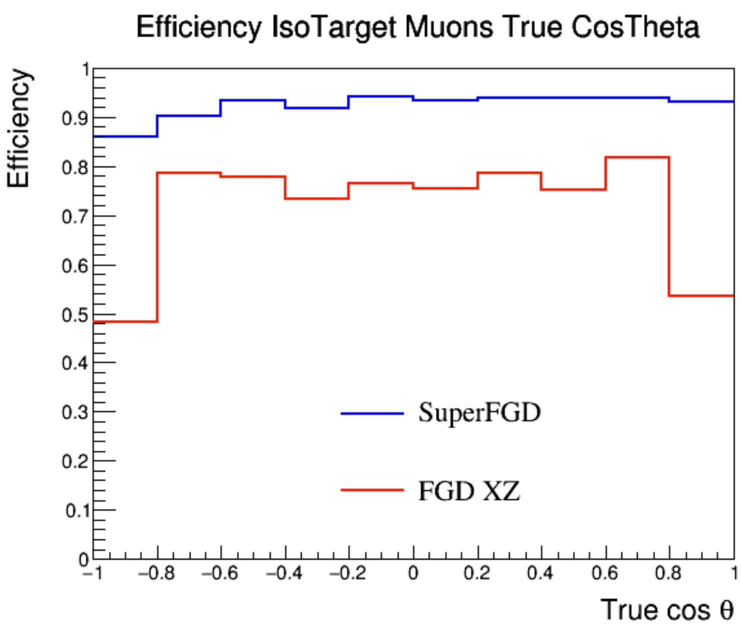
<u>Cell size (resolution) :</u> 2.5x2.5x2.5 cm³ cells

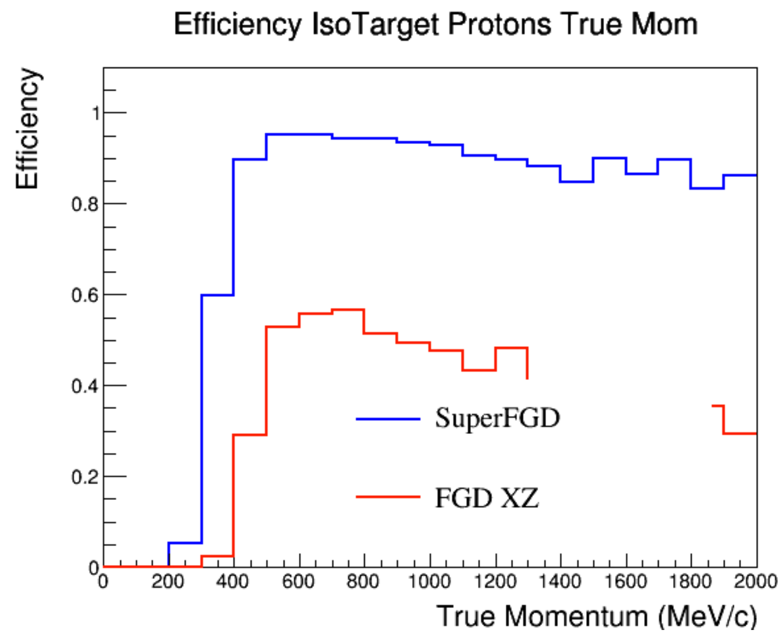
<u>Plastic background substraction :</u> **$H_2O$:CH(Plastic)=7:3** in $H_2O$ module (FGD2 is 4:6)

# Simulated performance

- The goal of SuperFGD is to detect particles with a 4pi acceptance
- The momentum threshold is also reduced:

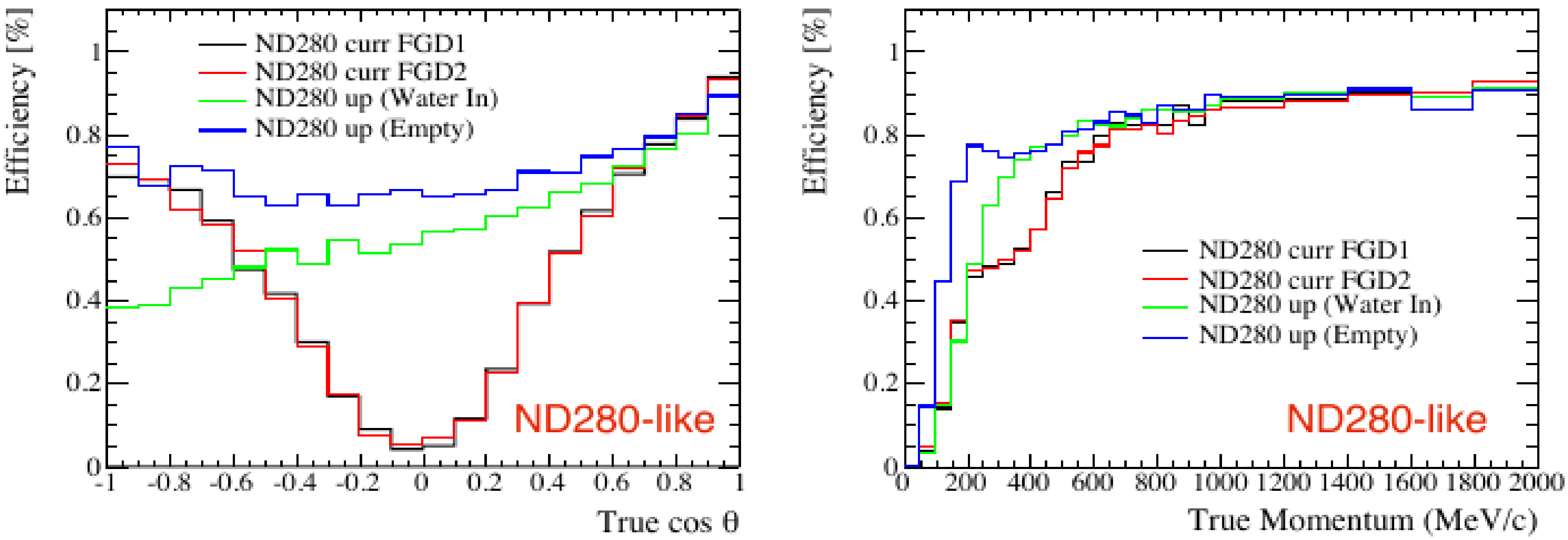
- 1 particle hit enough to obtain a XYZ point
- in standard plast. scint. detectors. 2 hits are needed to obtain XY




- Proton momentum threshold ~300 MeV/c (SuperFGD) Vs ~450 MeV/c (FGD)
- Expect ~8% probability to misidentify a muon or a pion as a proton
- Expect to reject $\gamma \rightarrow e^+e^-$ with efficiency up to 90% only by light yield

# ND280 upgrade performance studies




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

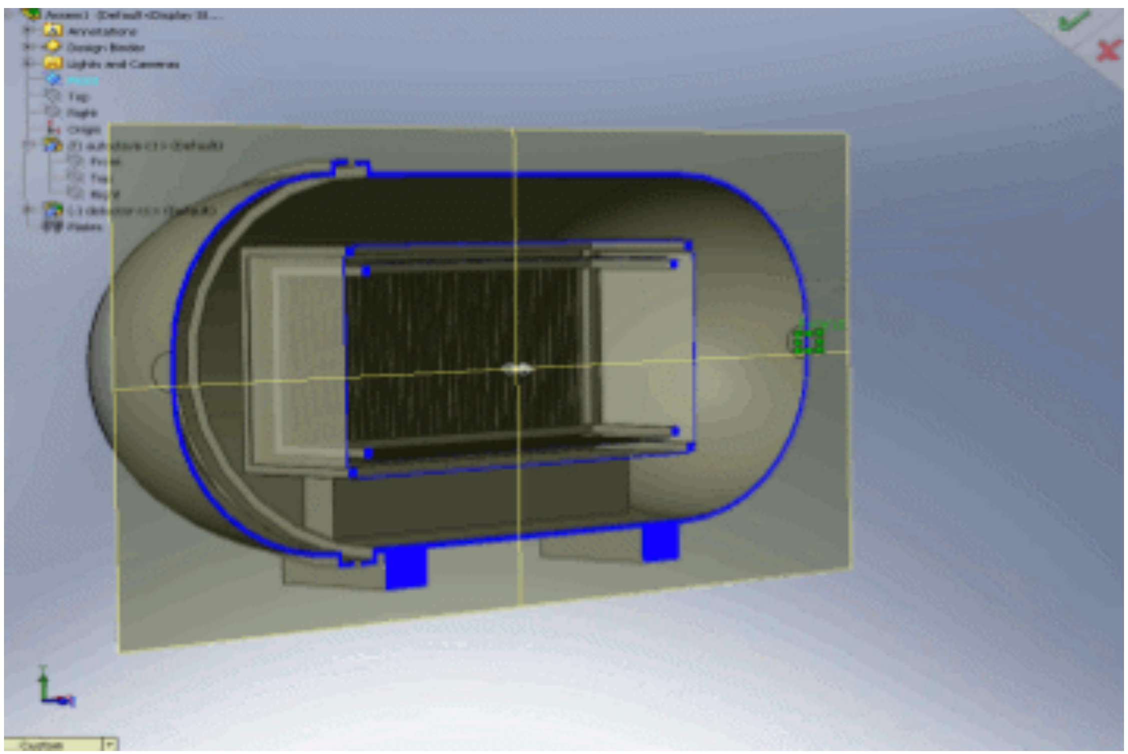
# Near Detectors (High Pressure TPC)

- ➢ Need low momentum thresholds to reduce xsec systematics
- ➢ Important difference lie below threshold for liquid detectors

Concept:

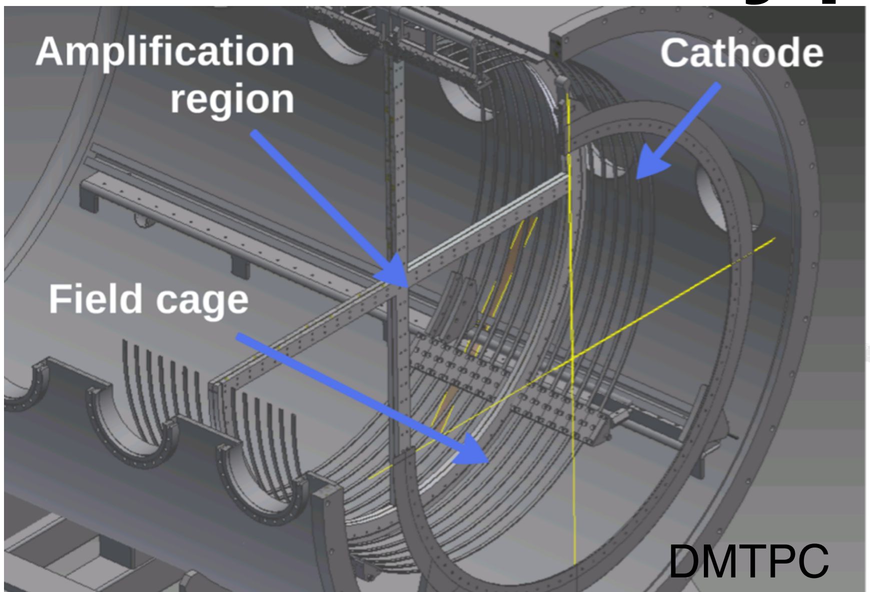
- high pressure TPC to increase the mass 10x w.r.t. standard TPC → enough events by interaction in gas
- Study low momentum final state particles and in particular resolve vertex

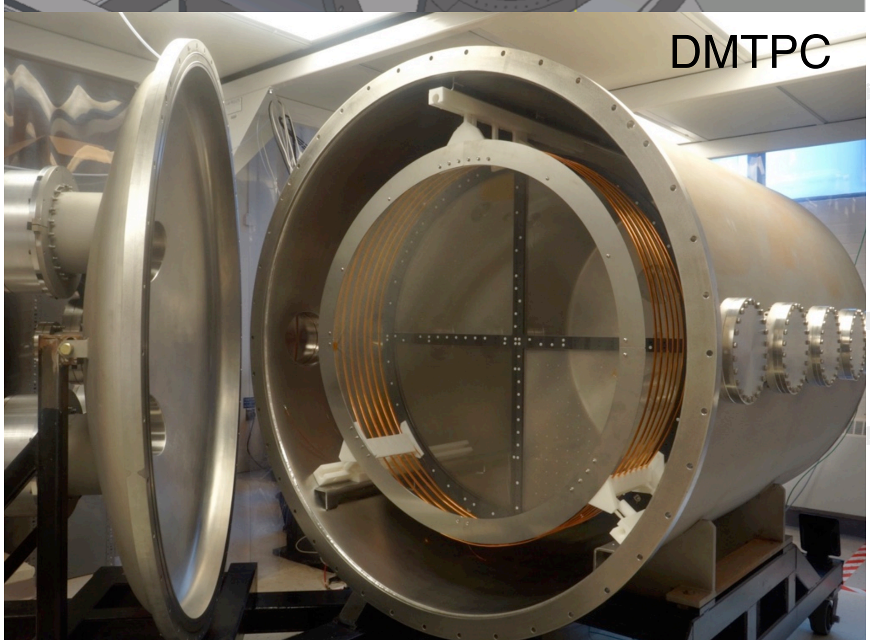
→ HPTPC detectors to reduce xsec systematics on different targets (mostly He, Ne, Ar)



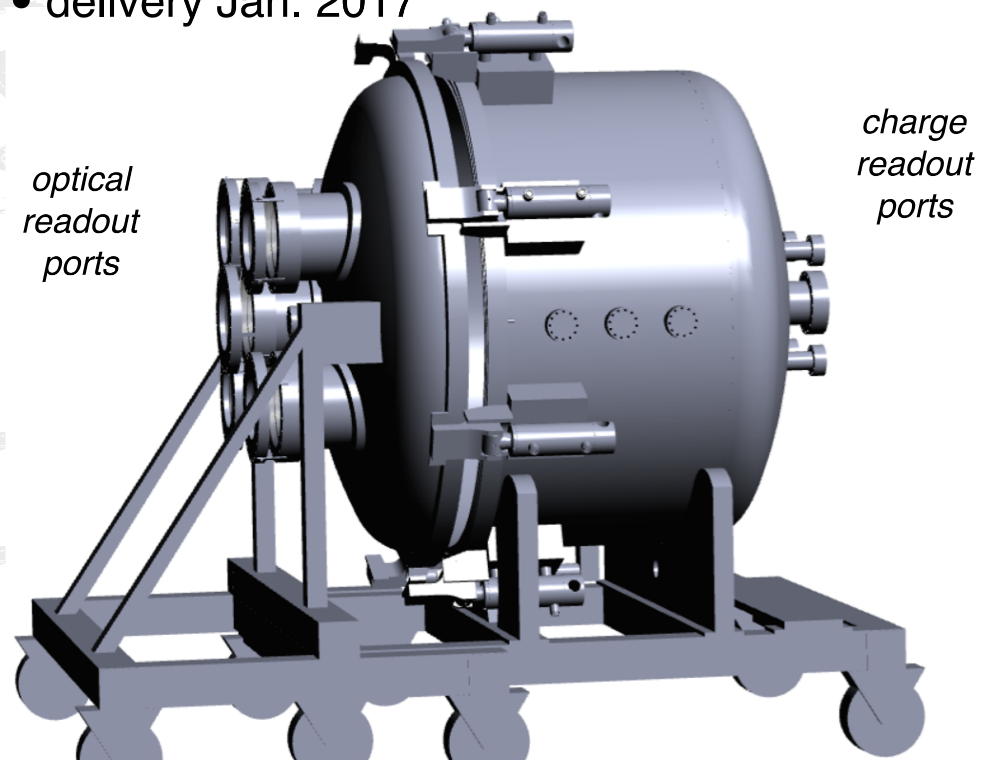
- T2K has pioneered (~1 bar) gas TPCs for accelerator neutrinos
- Need a path to high pressures for sufficient statistics
- Generic to next generation LBL experiments

# Prototype HPTPC



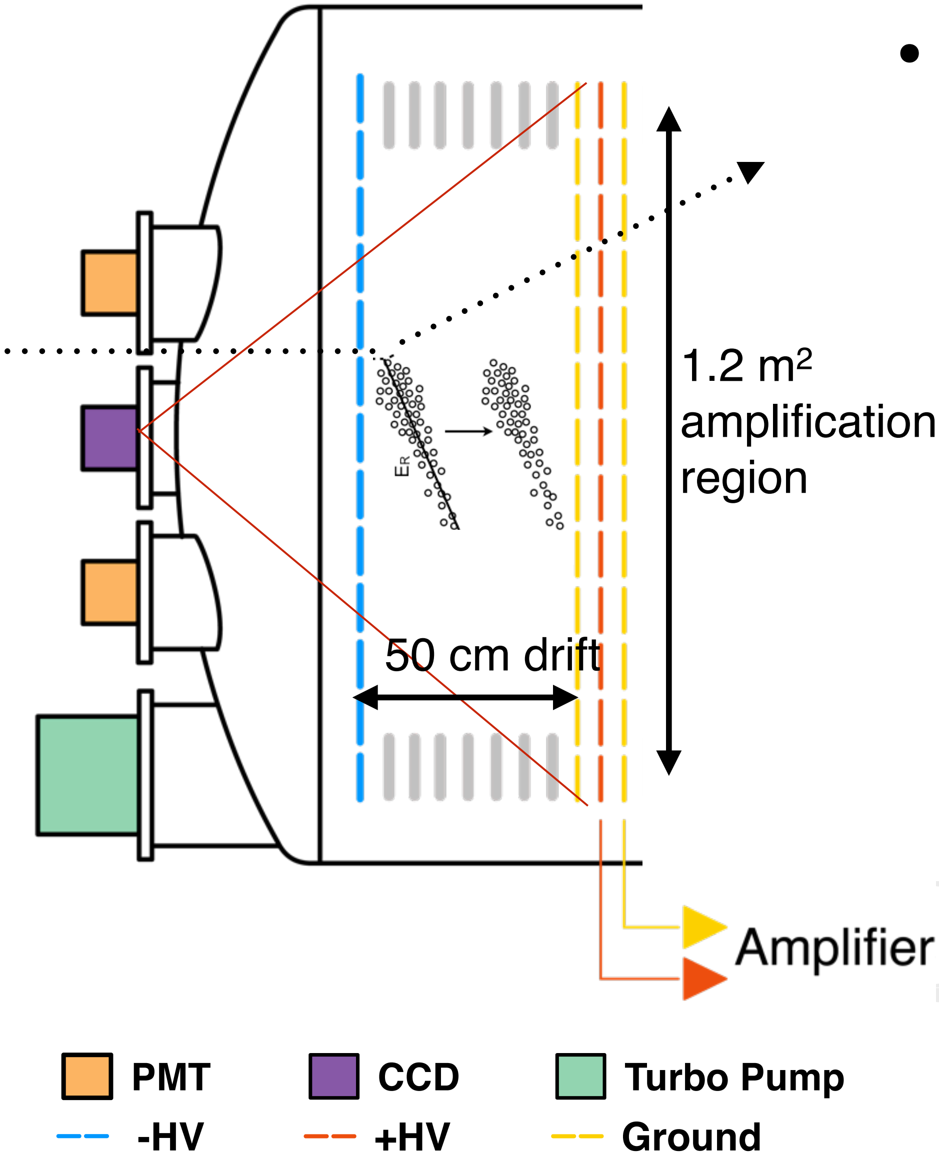



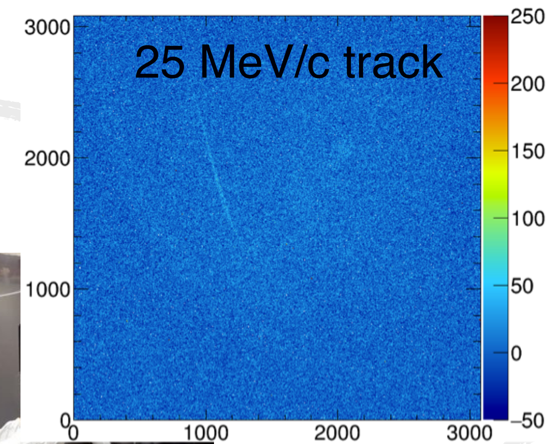

- UK HPTPC proto design based on DMTPC 1m3 detector
  - mesh amplification region, could be replaced with MPGD
- HPTPC vessel and gas system under construction by Cryovac (ES)
  - delivery Jan. 2017

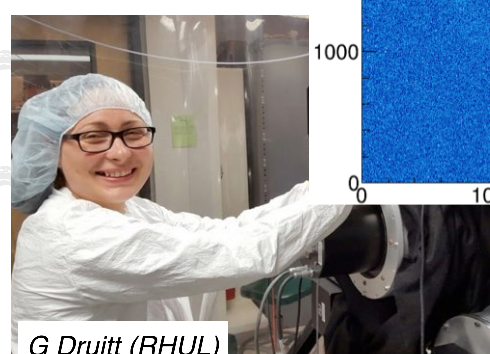


# Optical Readout

- CCD images scintillation produced in the amplification region
  - Fairchild 386 16 MPix CCD + lens outside pressure vessel
  - 90 cm object distance
  - results in 1 mm readout pitch with 4x4 readout binning



# Expression of Interest (EOI) SPSC-EOI-15

- Decision taken at the November workshop
- Signed by 190 people (including a CERN group)
  Submitted to SPSC early January
- First contact with referees and questions received
- Addendum submitted  April 4-5


Expression of Interest for the January 2017 SPSC

**Near Detectors based on gas TPCs for neutrino long baseline experiments**[1]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## One project, two goals

- Study, optimize, design and build an upgrade of the ND280 near detector capable of improved and model-independent precision below ~4% in line with T2K-II physics needs
- Study, optimize, design a High Pressure TPC that could serve as base for a detector aimed at exploring the details of neutrino interactions. Demonstrate the concept with prototypes on a test beam.

We identified synergies and strong overlaps in the interests expressed by the participating groups. Associating the two projects will strengthen the collaboration.

## Main Detector Sub-systems

- TPC
  - Field cage
  - Other mechanical structures
  - Micromegas
  - Electronics
  - Gas system
- TOF
- Active targets
- HPTPC prototype

## Work Packages

WP1 Mechanical design and integration
WP2 TPC field cage and gas vessel
WP3 TPC Readout technology
WP4 TPC electronics and DAQ
WP5 Scintillator-based trackers
WP6 TOF system
WP7 Gas system and calibration
WP8 Test beam measurements
WP9 High Pressure TPC
WP9 Simulation and optimization studies
WP10 Physics studies
WP11 DAQ
WP12 Software

# preliminary Timeline

- To benefit from the MR upgrade the upgraded detector should be installed around 2020 (data taking until ~2026)
- The installation must happen during the Summer shutdown to limit the downtime
- It seems reasonable to aim for the 2021 Summer shutdown as the target for the installation of the upgraded detector
- The schedule needs to be prepared taking into account the technical and budgetary constraints for the various detectors.

- **2017**: pursue optimization studies, define preferred configuration, finalize WP structure and responsibilities, prepare and submit proposal for SPSC
- **2018** Prototype of TPC (field cage, micromegas) in a testbeam. Define the detector options (granularity etc). Prepare for production. NB similar milestones for the other detectors
- **2019-2020** Production, integration at CERN. System test (cosmics?).
- **2021** Shipment to Japan, installation, commissioning.

# conclusions

- A realistic and optimized ND280 upgrade configuration is proposed
- This will be part of a proposal to be finalized by the end of this year (January 2018 SPSC)
- In parallel making progress with the technical design
- Short-term goal: test beams in 2018, before LHC LS2

| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| Design proposal | TDR prototypes | Construction | Construction Integration | Installation | Commissioning Operation | Operation |