# T2K-II and the upgrade of the T2K near detector N280

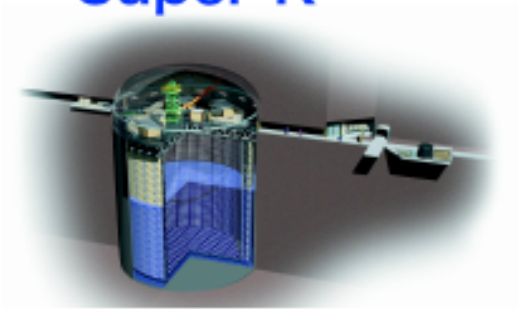
Marco Zito
IRFU/SPP CEA Saclay

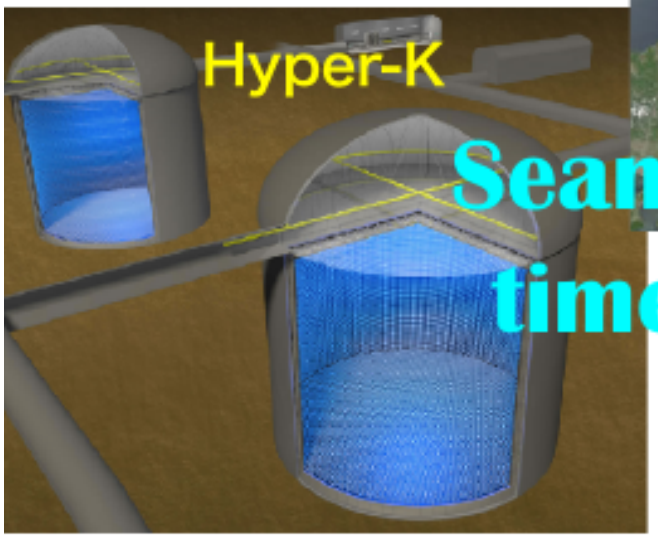
GDR
June 11 2018


# *Neutrino oscillation experiments in Japan*

Intense Neutrino Beam for $\overset{(-)}{\nu}_{\mu} \rightarrow \overset{(-)}{\nu}_{e}$ study

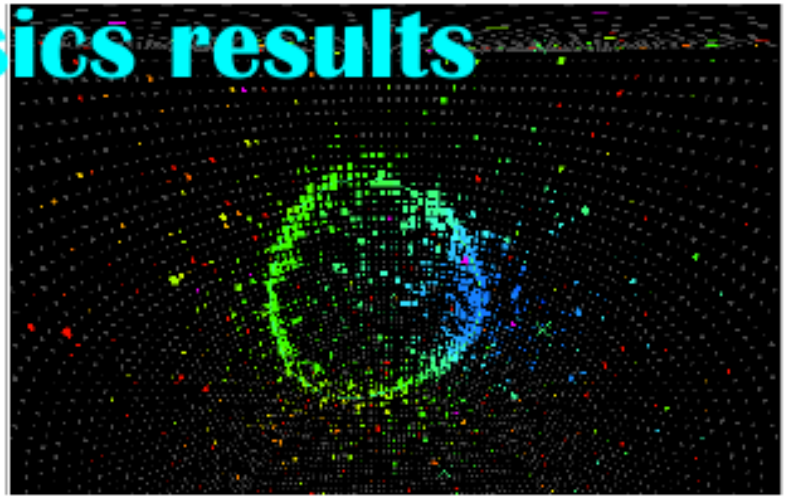
Super-K




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

**Seamless program with timely physics results**



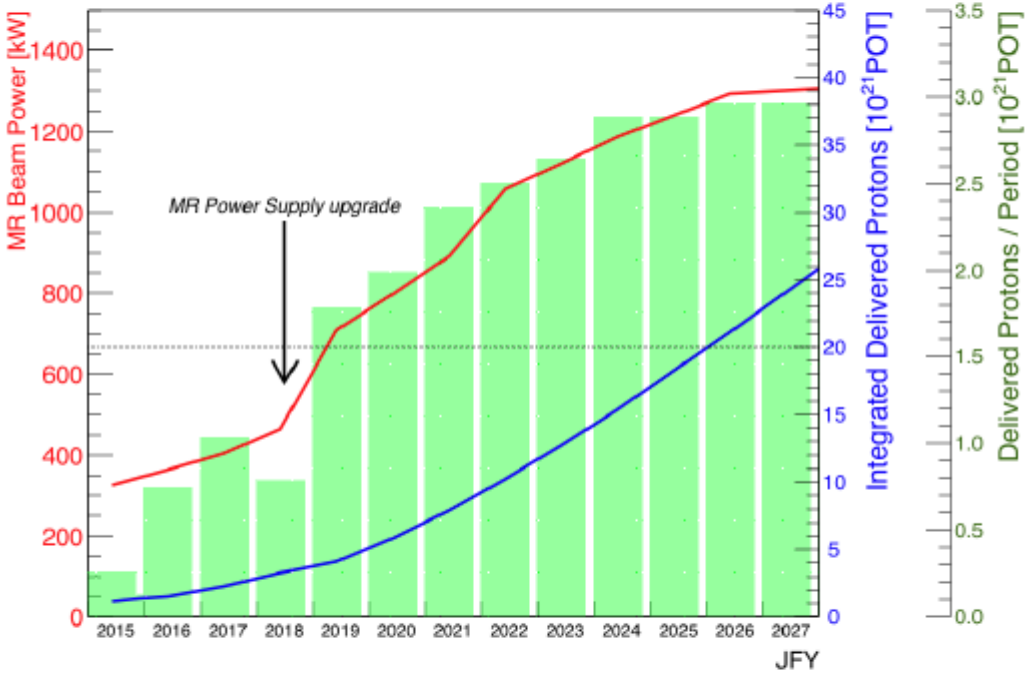
- 22.5 kton (Super-K, ~2026)
- 190(×2) kton (Hyper-K, 2026~)

arxiv:1607.08004

# T2K phase2 target statistics and systematics

- Target Beam power 1.3 MW
- 20E21 POT by 2025~2026
- Increase effective statistics by up to 50%
  - horn current, SK fiducial volume, new event samples
- Reduce systematic error ~6% → ~4%

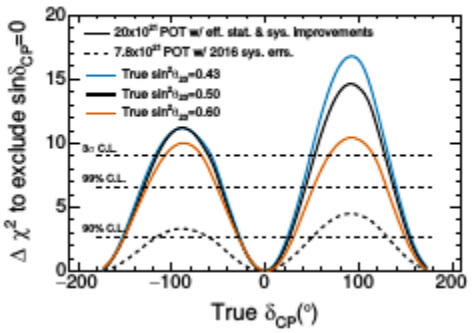
J-PARC MR expected performance and T2K-2 POT accumulation scenario




Expected number of events (1:1 $\nu$: $\bar{\nu}$ running case)

$\nu_e$ sample : 468 evts ± 20% change depending

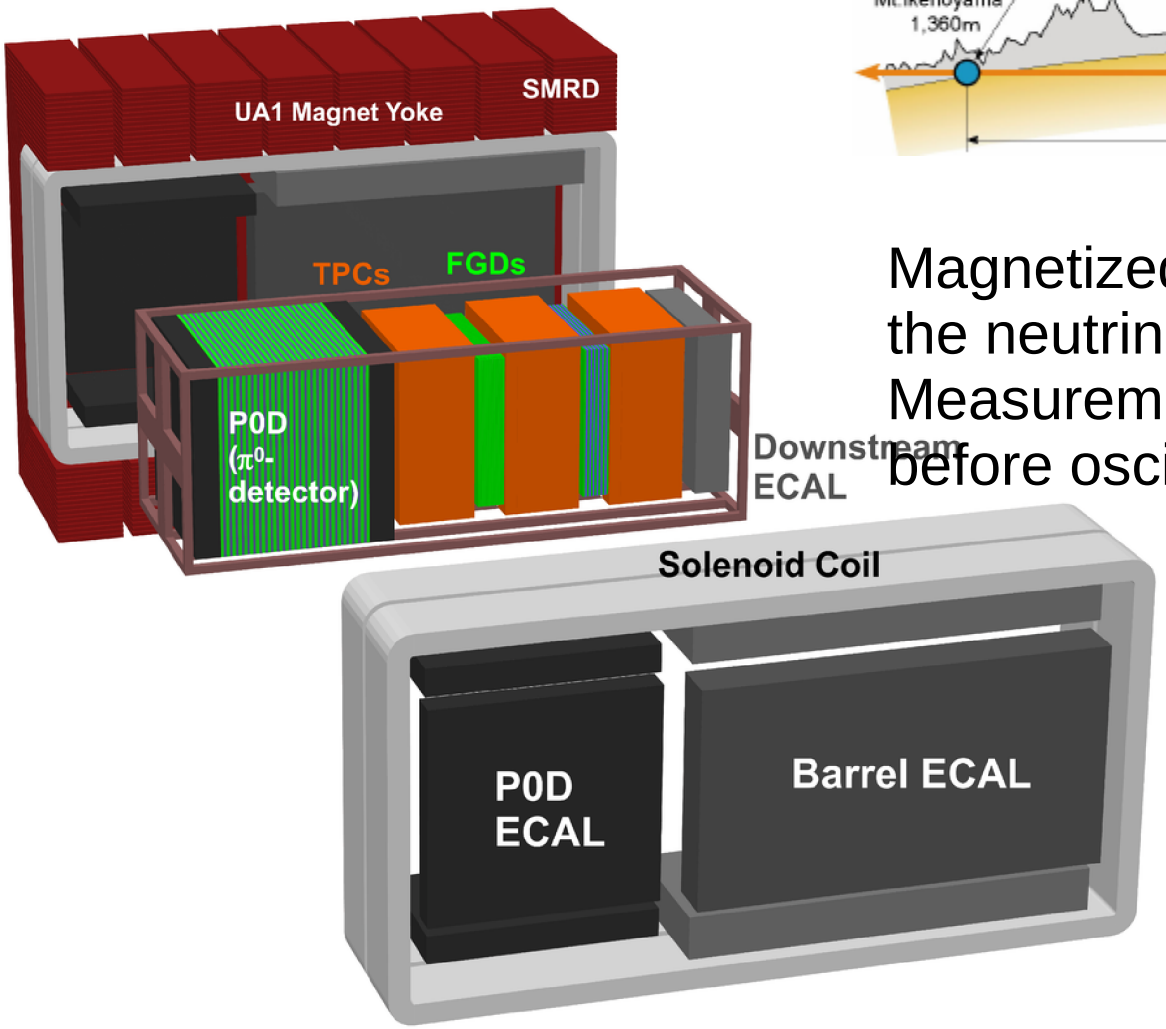
$\bar{\nu}_e$ sample : 134 evts ± 13% change depending

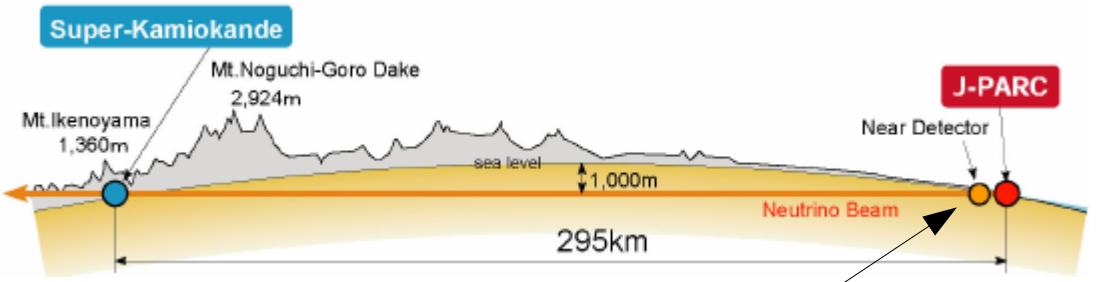


# Motivations

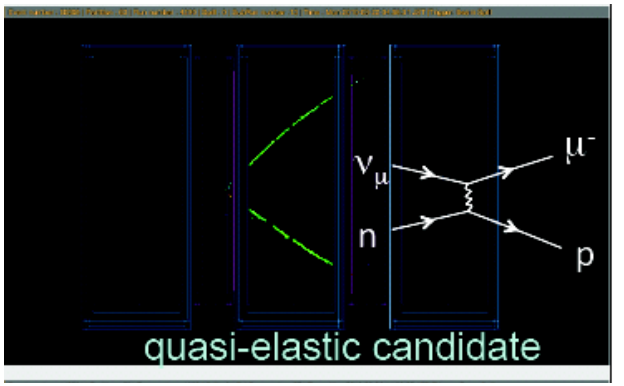
- T2K together with NOVA will be the leading experiment in long baseline domain (precision disappearance measurements, CP search) for the next 8-10 years
- T2K-II, ND Upgrade: innovative R&D and detectors for precision flux and cross-section measurements
- Crucial know-how for future long baseline projects : analyses, tools, PhD thesis etc

# The T2K ND280 Near Detector

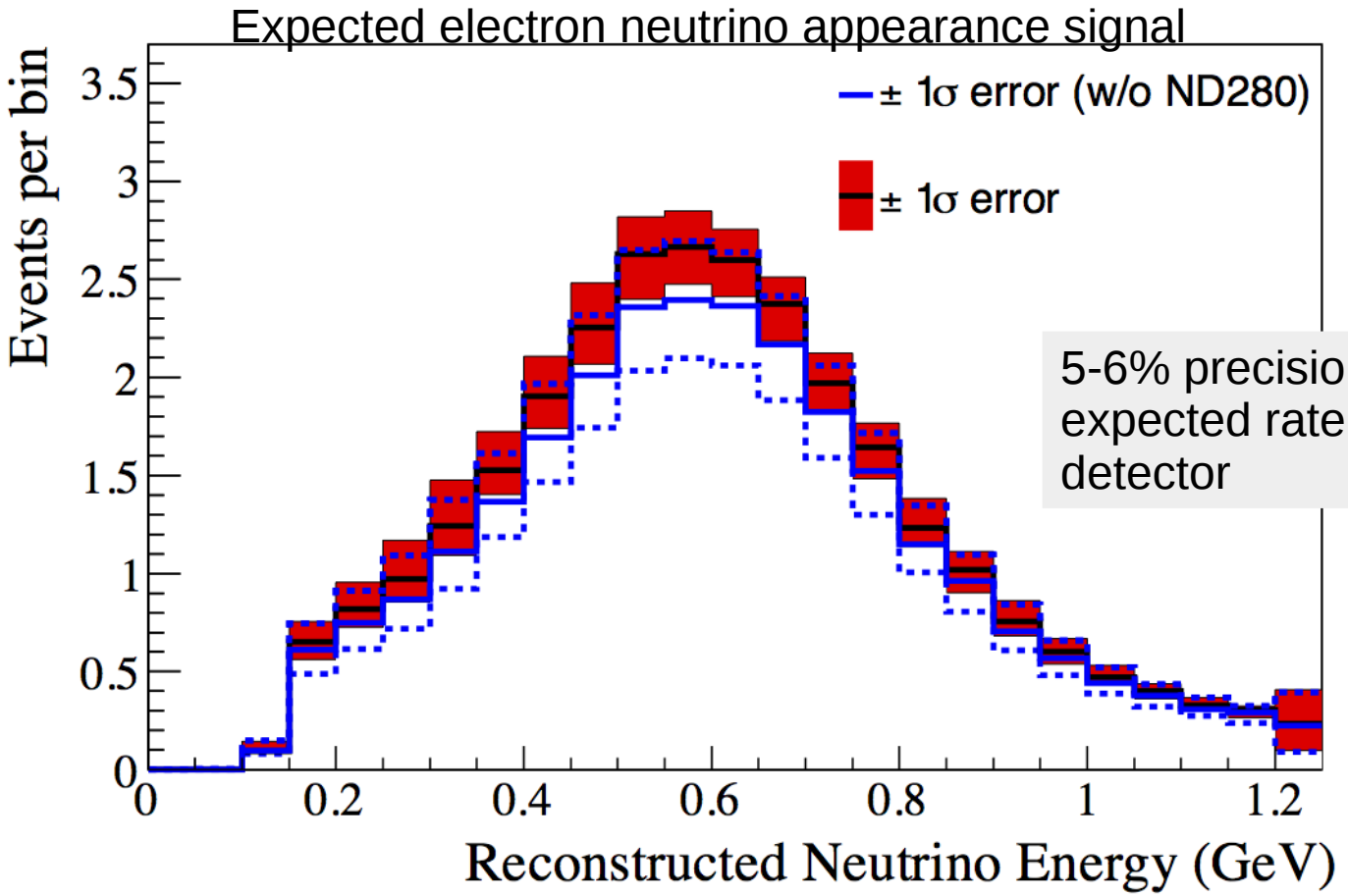



Magnetized near detector at 280m from the neutrino production point (target). Measurement of the interaction rates before oscillation.



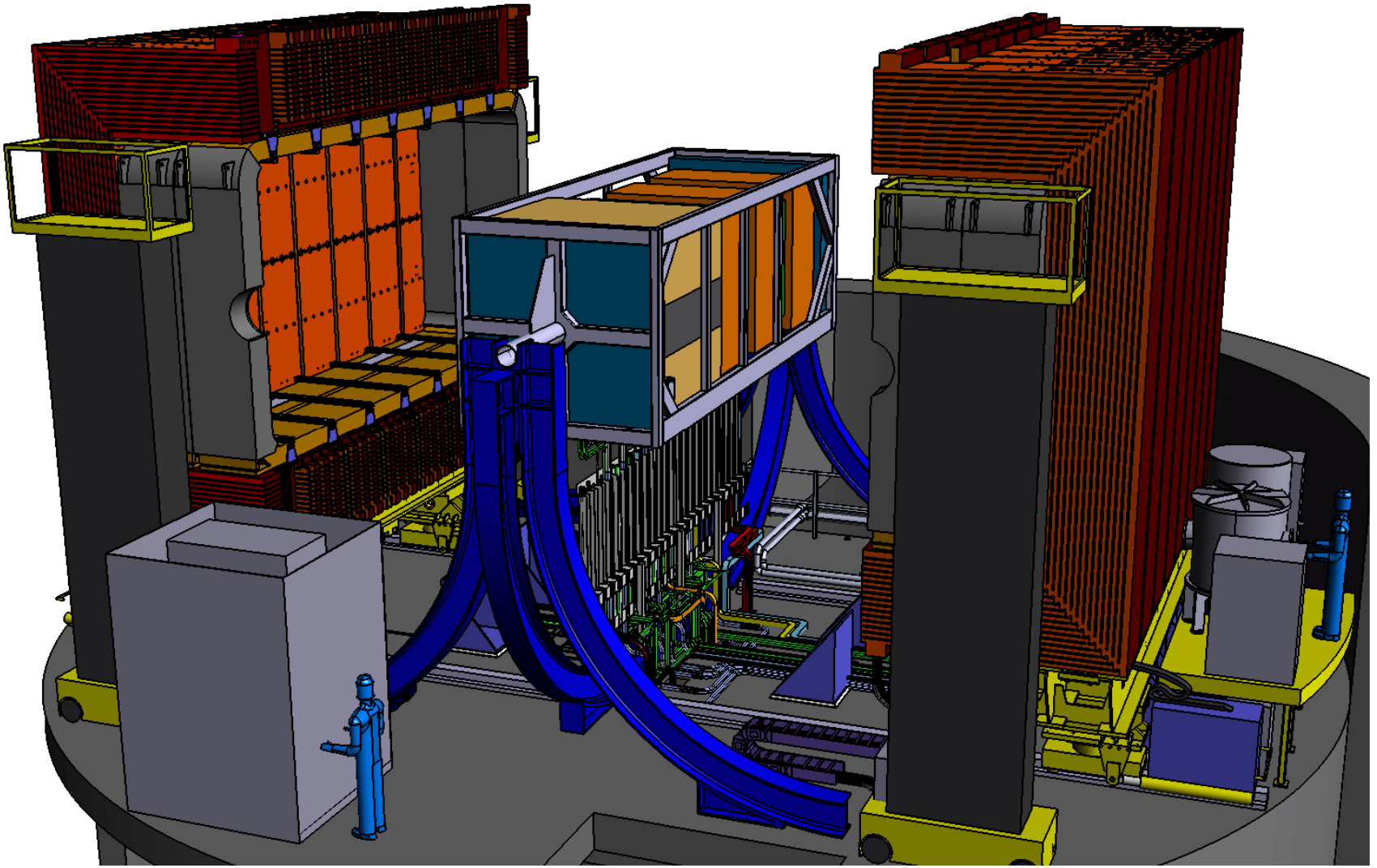
# Role of the ND280 near detector




5-6% precision on the expected rate at the far detector

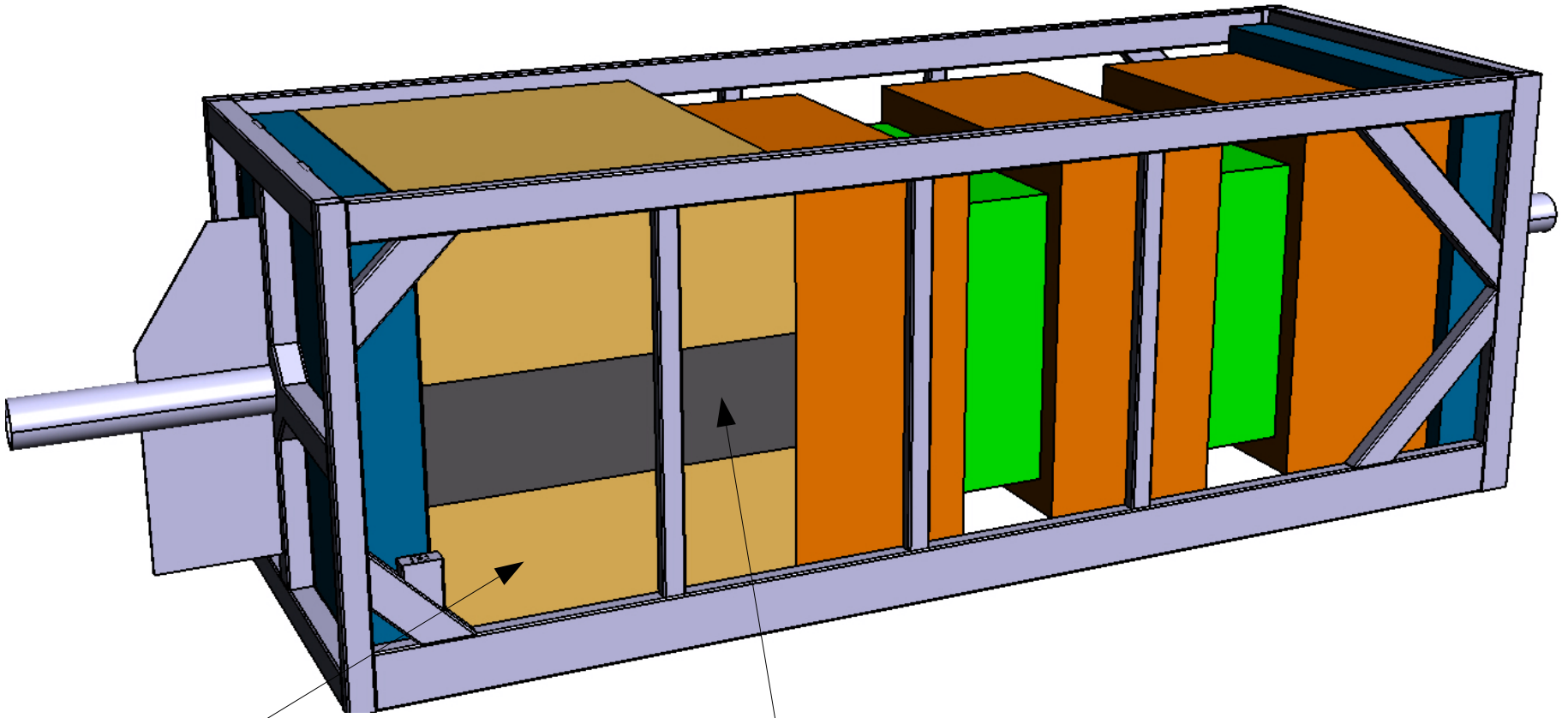
- Measure the neutrino interaction rates (flux.times.cross-section) in various channels
- Strongly constrain the expected rates at SuperKamiokande for precision oscillation analyses
- Measure neutrino nucleus cross-sections in several channels
- Searches for exotic phenomena

# ND280 within B1



CAD model by Franck Cadoux

# The ND280 upgrade detector



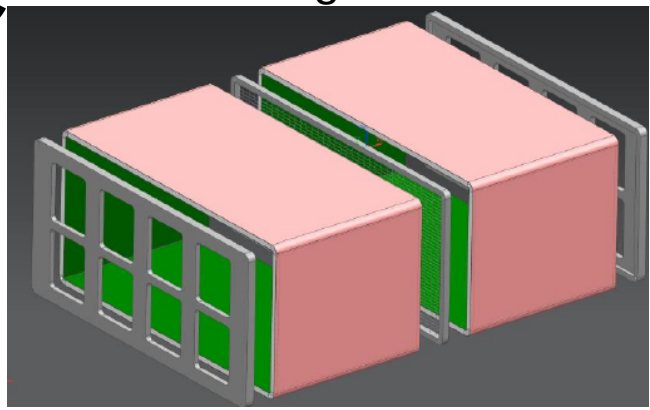
Two new High-Angle TPCs
A highly segmented Scintillator Detector (SuperFGD is the baseline technology)
TOF planes all around
No changes to the downstream detectors, nor the Ecal

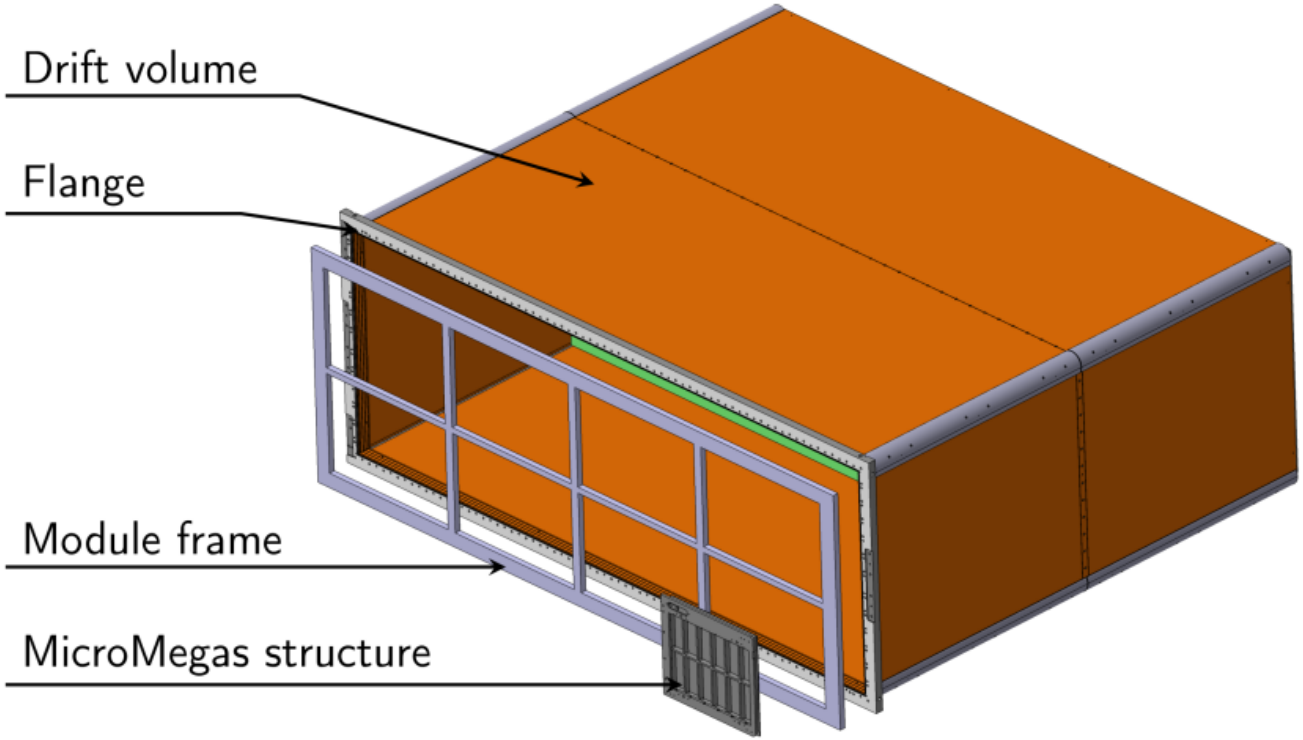
# ND280 Upgrade: sub-detectors

- Atmospheric pressure TPCs (Horizontal TPC)
  2 detectors (~2m x 2m x 0.8 m)
- Active targets (SuperFGD, ~2tons)
- TOF detectors

# High Angle-TPC

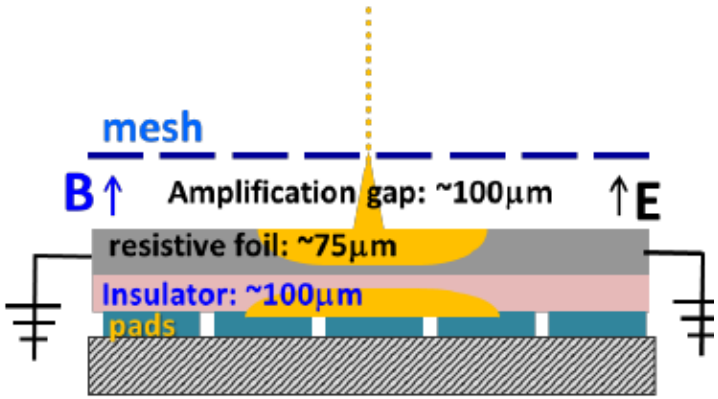
Field cage: INFN-IFAE





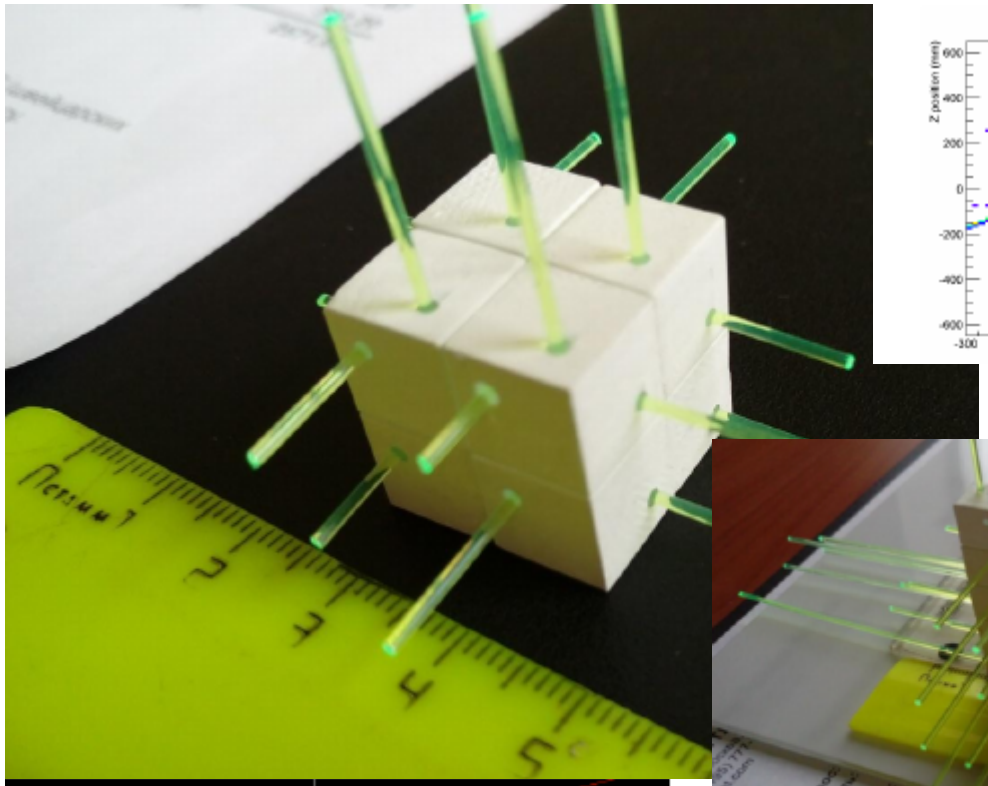

Saclay test bench

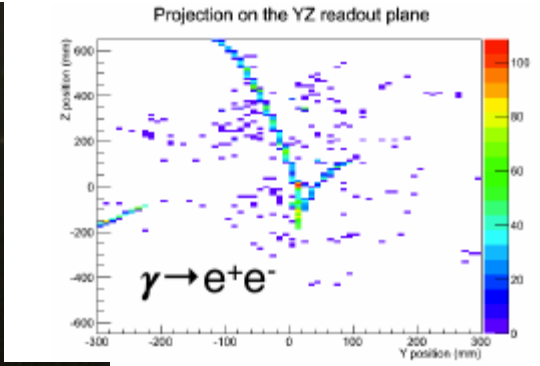
Resistive Micromegas
(ILC TPC R&D)

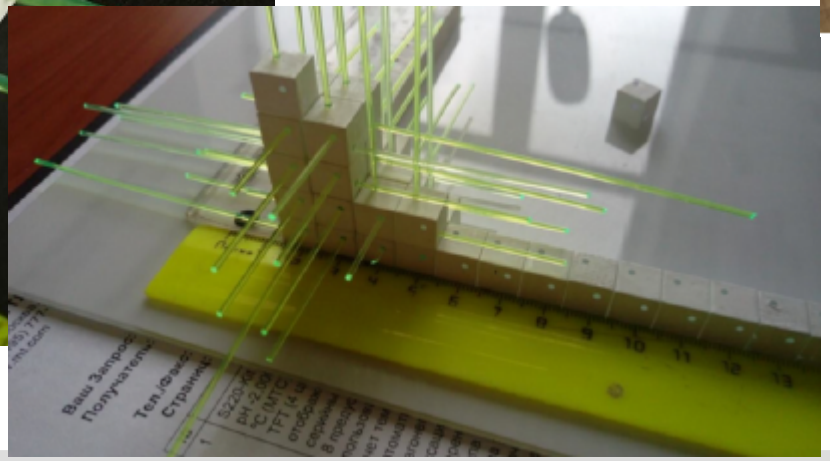


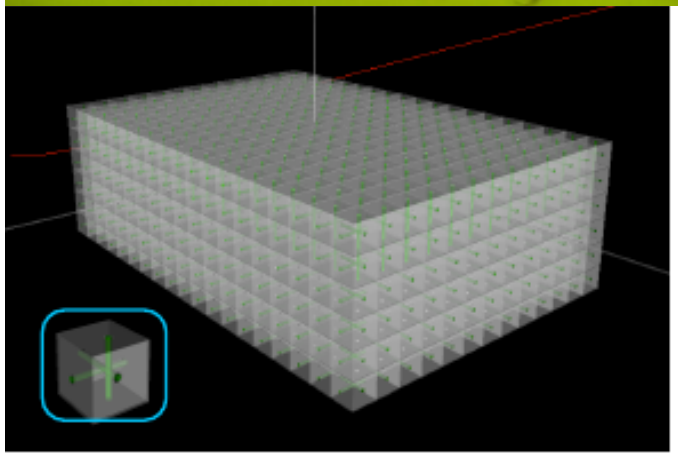
# Super-FGD

arXiv:1707.01785

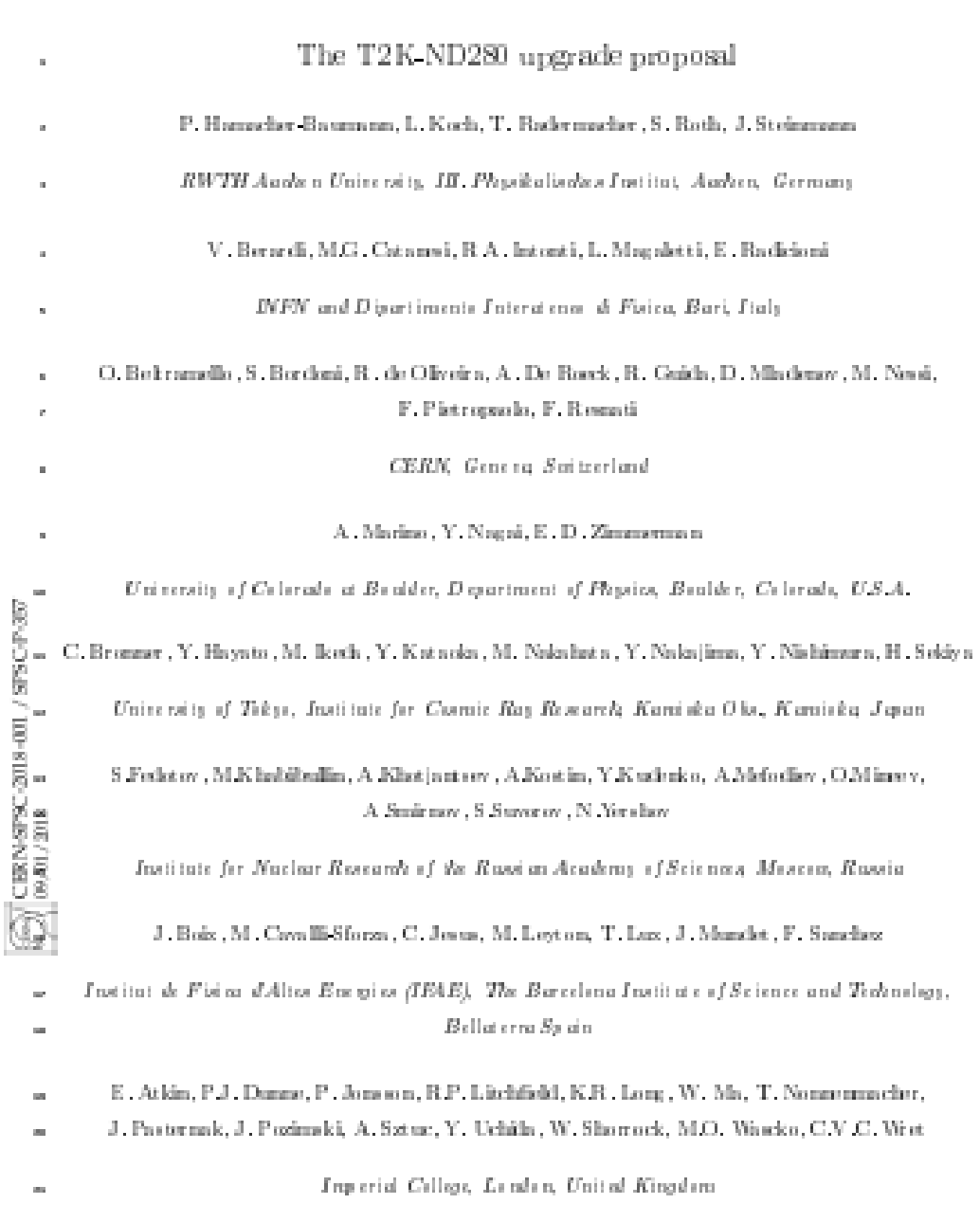






1x1x1 $cm^3$ plastic scintillator cubes with 3 fibers readout
R&D started, with 5x5x5 cubes & 75 channels (INR/UNIGE/Japan)



The T2K-ND280 upgrade proposal

P. Hamacher-Baumann, L. Koch, T. Radermacher, S. Roth, J. Steinmann

*RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany*

V. Berardi, M.G. Catanesi, R.A. Intonti, L. Magaletti, E. Radicioni

*INFN and Dipartimento Interateneo di Fisica, Bari, Italy*

O. Bekrandella, S. Bordoni, R. de Oliveira, A. De Roeck, R. Guida, D. Mladenov, M. Nessi, F. Pietropaolo, F. Resnati

*CERN, Geneva, Switzerland*

A. Marino, Y. Nagai, E.D. Zimmerman

*University of Colorado at Boulder, Department of Physics, Boulder, Colorado, U.S.A.*

C. Bronner, Y. Hayato, M. Ikeda, Y. Kataoka, M. Nakahata, Y. Nakajima, Y. Nishimura, H. Sekiya

*University of Tokyo, Institute for Cosmic Ray Research, Kamioka Obs., Kamioka, Japan*

S. Fedotov, M. Khabibullin, A. Khotjantsev, A. Kostin, Y. Kudenko, A. Mefodiev, O. Mineev, A. Smirnov, S. Suvorov, N. Yershov

*Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia*

J. Bolz, M. Cavalli-Sforza, C. Jesus, M. Leyton, T. Lux, J. Muraleet, F. Sanchez

*Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Bellaterra, Spain*

E. Atkin, P.J. Dunne, P. Jonsson, R.P. Litchfield, K.R. Long, W. Ma, T. Nonnenmacher, J. Pasternak, J. Prouimski, A. Sztuc, Y. Uchida, W. Shorrock, M.O. Wascko, C.V.C. Wret

*Imperial College, London, United Kingdom*

CERN-SPSC-2018-001 / SPSC-P-357
09/01/2018



# Proposal

- CERN-SPSC-P357
- ~214 authors (more than EOI)
- New institutes: Stonybrook Rochester Louisiana Michigan State Legnaro Kobe Tokyo IT Tokyo US
- Strengthened CERN group (10)
- Support from Sofia and Uppsala for the test beam

# Participation of French Institutes

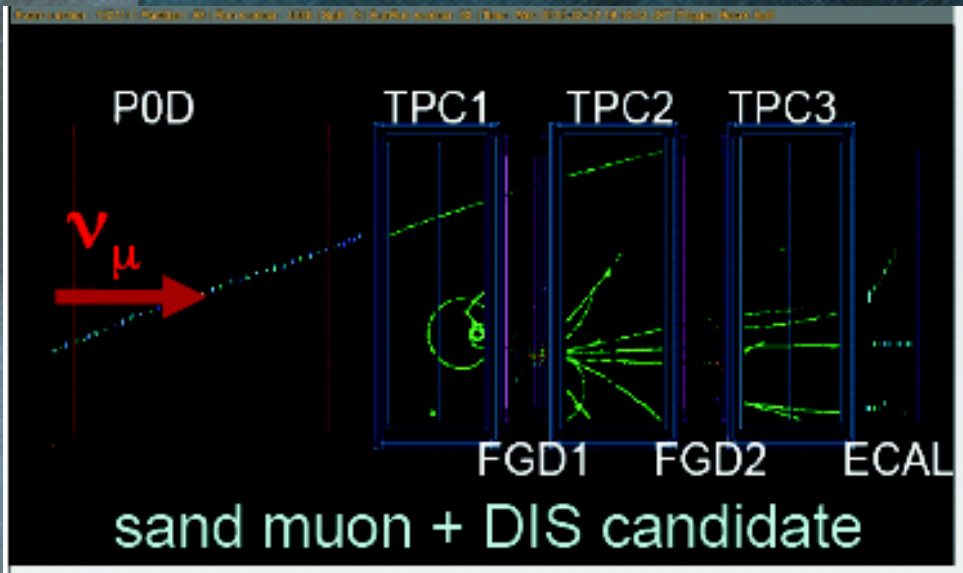
- IRFU: TPC charge readout (resistive Micromegas), TPC mezzanine card and backend electronics
- LLR: proposal to build the SuperFGD front end electronics based on the Calice design (Omega Spiroc chip)
- LPNHE: TPC FE boards, mechanics
- IN2P3 contributions to be discussed at June CS

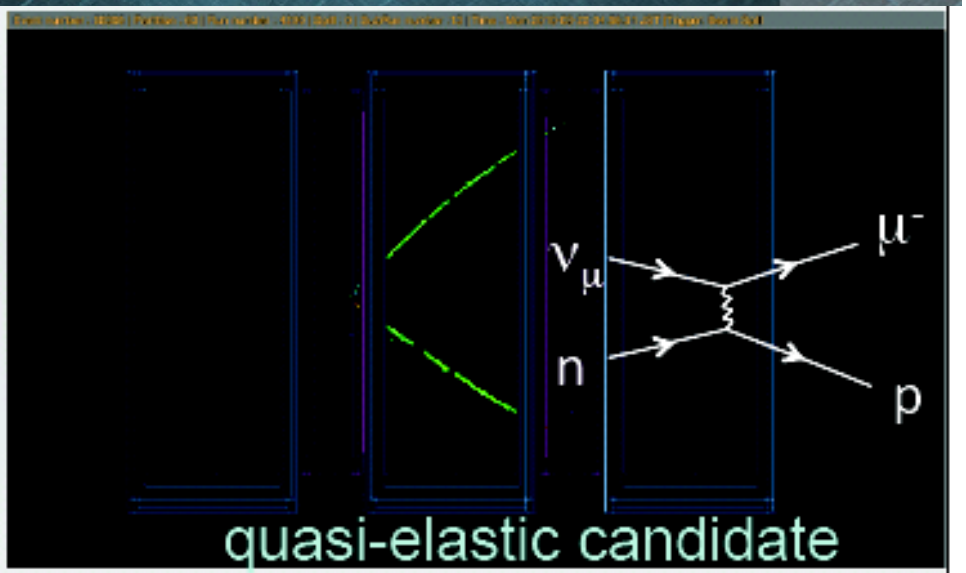
# Conclusions

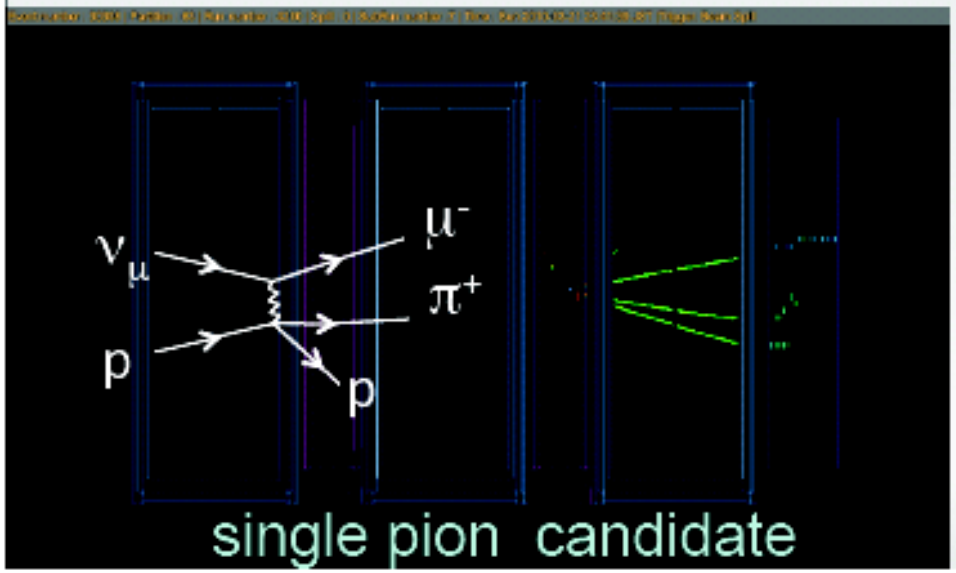
- LBL physics with T2K-II: ~3sigma on delta_CP
- A realistic and optimized ND280 upgrade configuration to match the statistical improvement
- Prototypes and test beam this year
- Preparation of TDR (end of the year)
- Next open workshop at CERN July 25-26

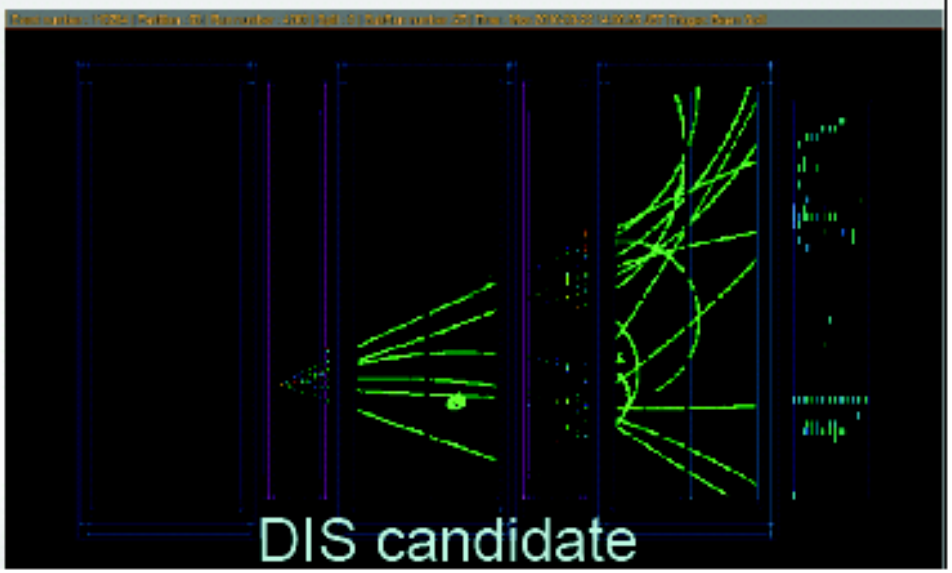
| 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Proposal | TDR, prototypes | Construction | Construction | Installation |

# Neutrino interactions in ND280

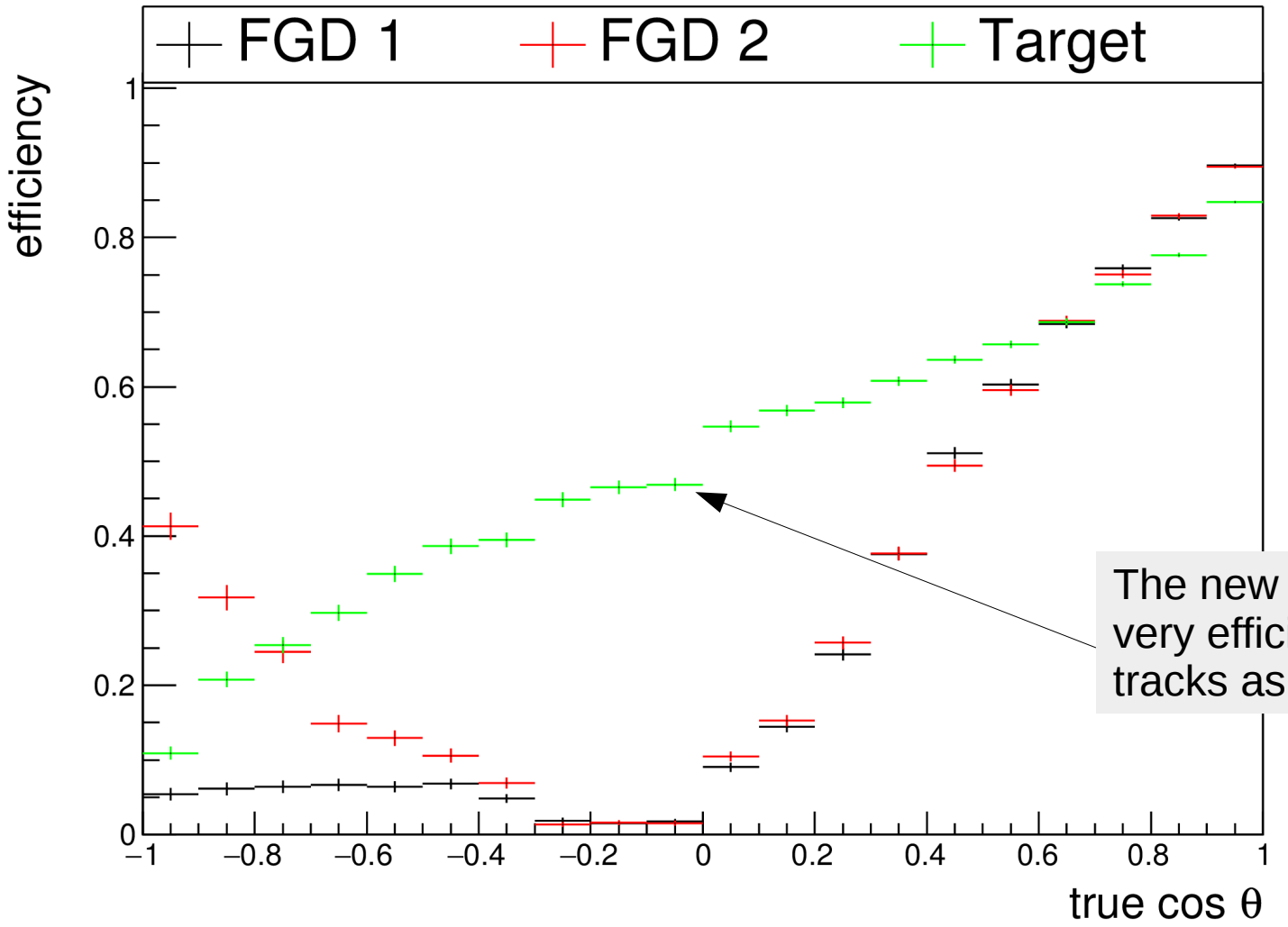


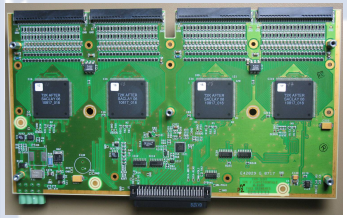



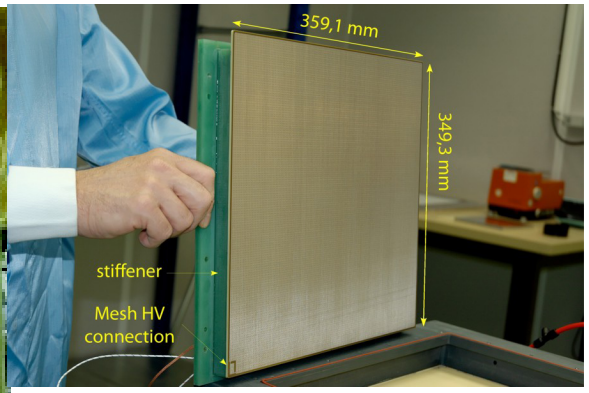
# Muon tracking efficiency

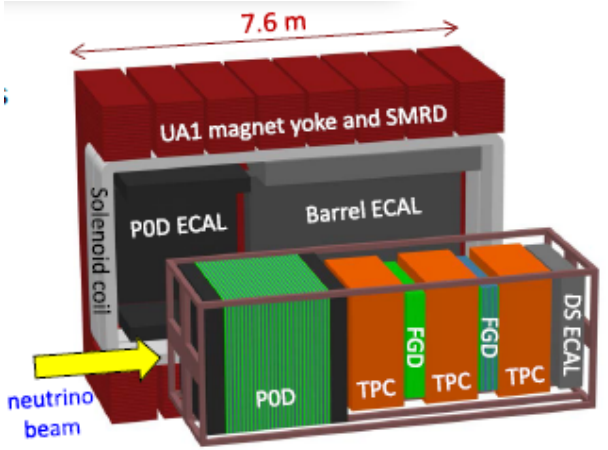



Studies with full GEANT4 simulation

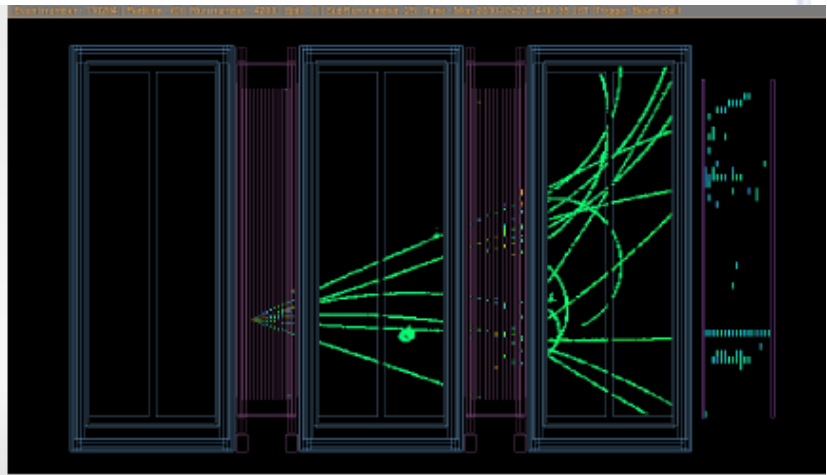


# The T2K near detector TPC

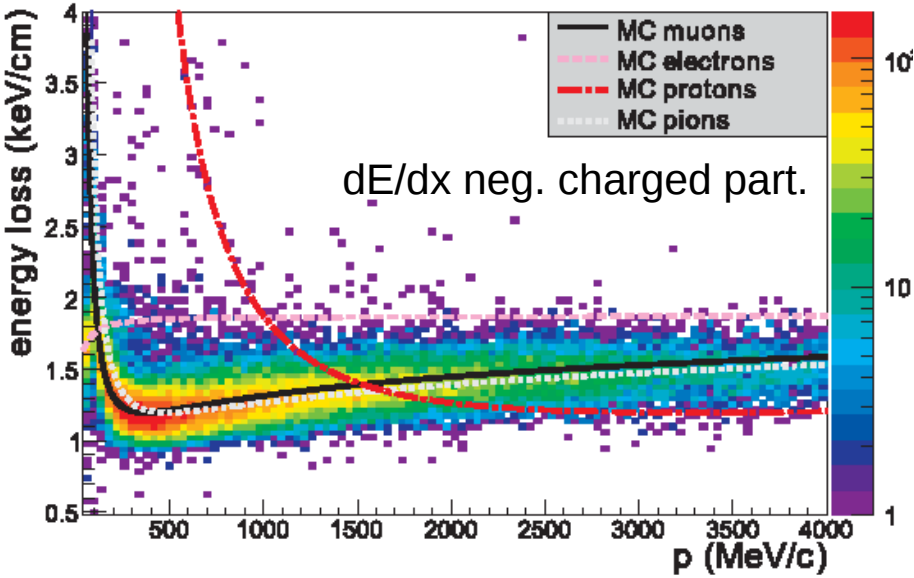

- Three large TPC for the T2K near detector
- The first large TPC using MPGD
- ~9 m**2 equipped with bulk Micromegas detectors
- Playing a key role in the study of the neutrino flux and interactions (charge, momentum and dE/dx PID)
- Space resolution : 0.6 mm
- Momentum res. 9% at 1 GeV
- dE/dx: 7.8 % (MIP)

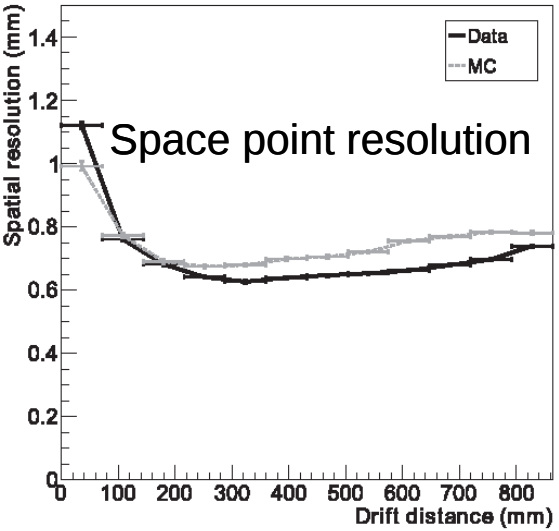


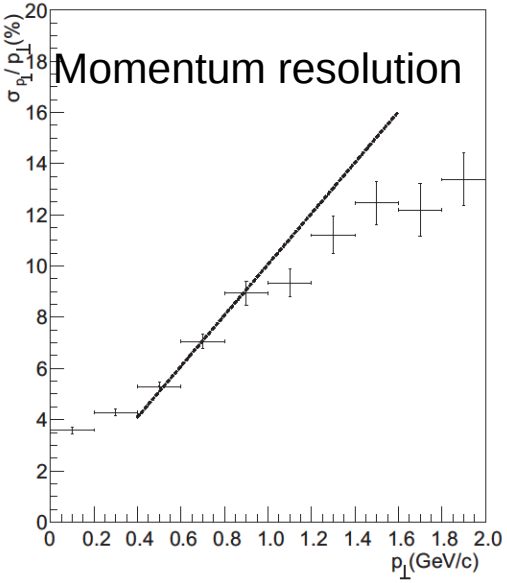
72 Micromegas and 120k channels functioning flawlessly since 2009 (dead channels 144/124272)

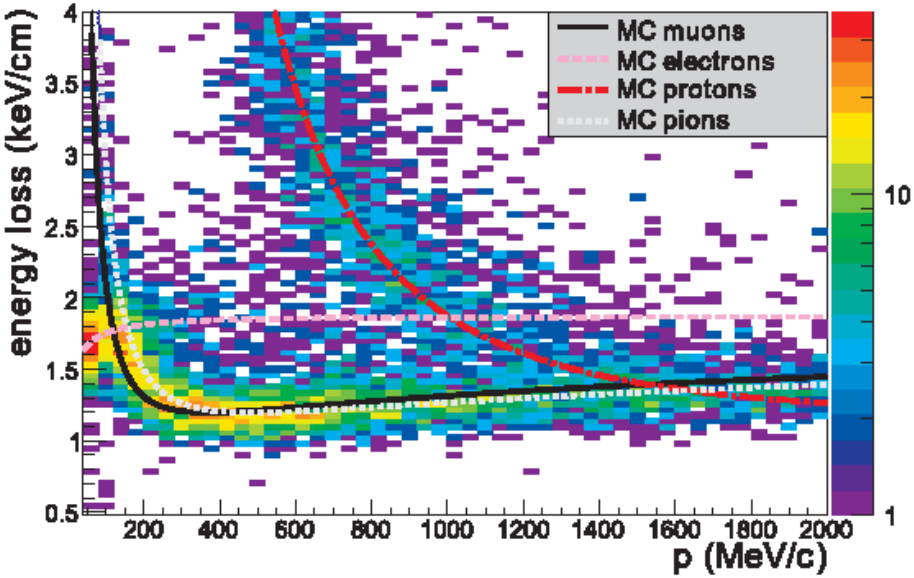
# TPC performances

- Three large TPC for the T2K near detector
- The first large TPC using MPGD
- ~9 m**2 equipped with bulk Micromegas detect
- Playing a key role in the study of the neutrino fl
  interactions (charge, momentum and dE/dx PID
- Space resolution : 0.6 mm
- Momentum res. 9% at 1 GeV
- dE/dx: 7.8 % (MIP)




dE/dx pos. charged part.

# 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
- 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**[1]

*P. Hamacher-Baumann, L. Koch, T. Radermacher, S. Roth, J. Steinmann*
RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany

*V. Berardi, M.G. Catanesi, R.A. Intonti, L. Magaletti, E. Radicioni*
INFN and Dipartimento Interateneo di Fisica, Bari, Italy

*S. Bordoni, A. De Roeck, D. Mladenov, M. Nessi, F. Resnati*
CERN, Geneva, Switzerland

*Z. Liptak, J. Lopez, A. Marino, Y. Nagai, E. D. Zimmerman*
University of Colorado at Boulder, Department of Physics, Boulder, Colorado, U.S.A.

*Y.Hayato, M. Ikeda, M. Nakahata, Y. Nakajima, Y. Nishimura*
University of Tokyo, Institute for Cosmic Ray Research, Kamioka Obs., Kamioka, Japan

*M. Antonova, A. Izmaylov , A. Kostin, M. Khabibullin, A. Khotjantsev, Y. Kudenko, A. Mefodiev, O. Mineev , T. Ovsiannikova, S. Suvorov, N. Yershov*
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia

*F. Sanchez, M. Cavalli-Sforza, T. Lux, B. Bourguille, M. Leyton*
Institut de Fisica d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Campus UAB, Bellaterra (Barcelona) Spain

*J. Amey, P.J. Dunne , P. Jonsson, R.P. Litchfield, W. Ma, L. Pickering*
*M. A. Uchida, Y. Uchida, M.O. Wascko,C.V.C. Wret*
Imperial College, London, United Kingdom

*C. Bronner, M. Hartz, M. Vagins*
Kavli Institute for the Physics and Mathematics of the Universe (WPI), University of Tokyo, Kashiwa, Chiba, Japan

*S. Bolognesi , D. Calvet, P. Colas, A. Delbart, S. Emery, F. Gizzarelli, M. Lamoureux, M. Martini, E. Mazzucato, G. Vasseur, M. Zito*
IRFU, CEA Saclay, Gif-sur-Yvette, France

1 Corresponding authors: Alain Blondel (alain.blondel@cern.ch), Marco Zito (marco.zito@cea.fr)

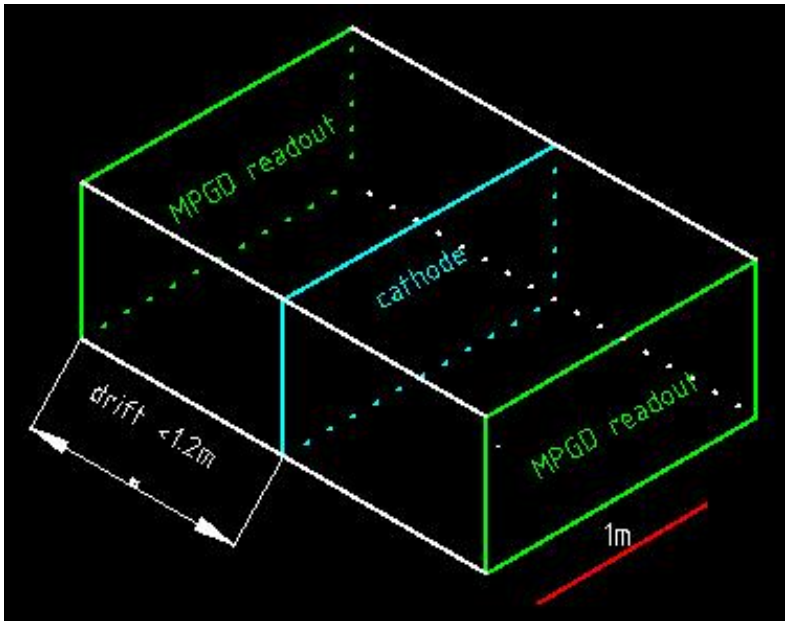
# Horizontal TPCs

Similar in size and technology to the existing TPC.

Resistive Micromegas for spreading the charge and spark protection (ILC TPC R&D).

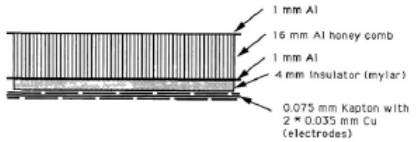
Thin field cage along the lines of the Aleph TPC.

~1cm pad size, ~30-50k channels




G. Catanesi

**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

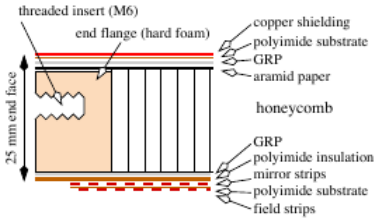
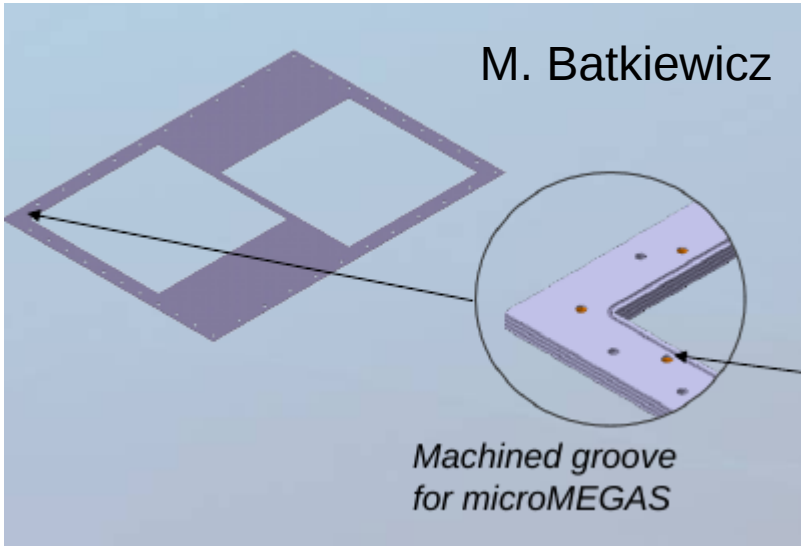
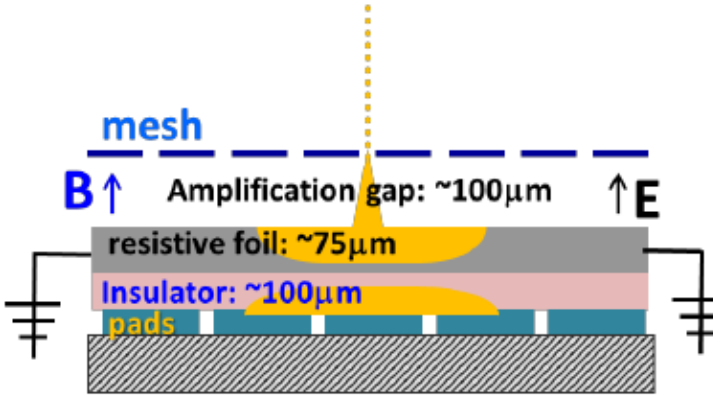



**Figure 7:** *Cross section of the Large Prototype field cage wall.*

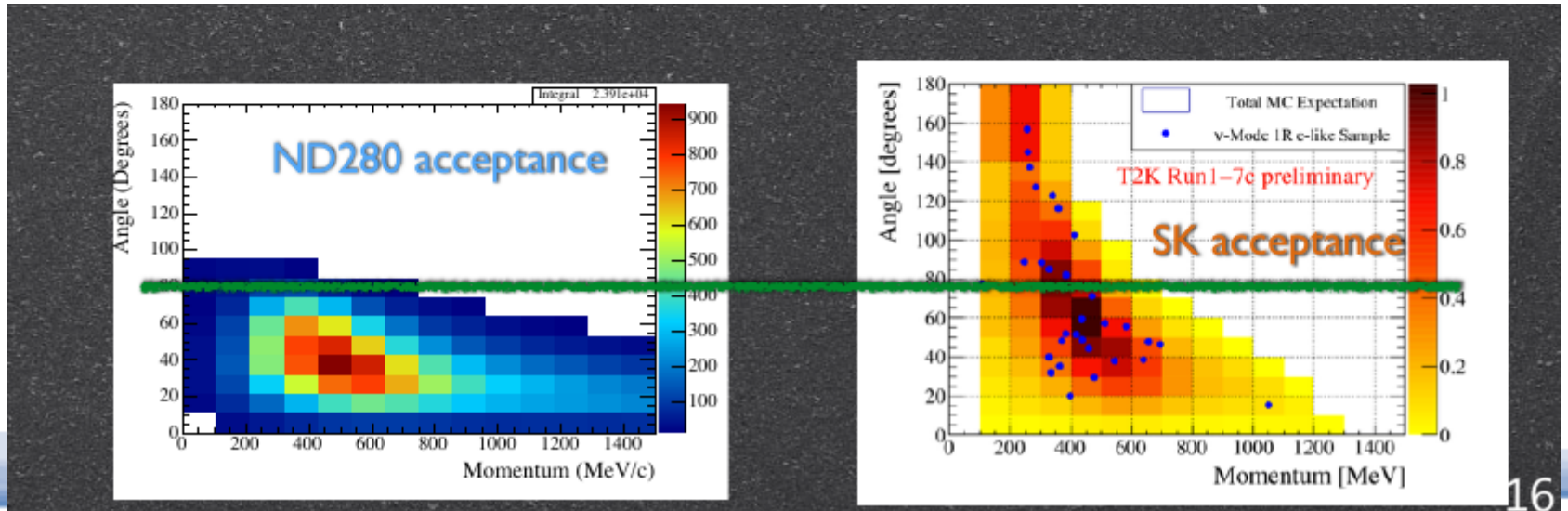
M. Batkiewicz



# ND280 limitations

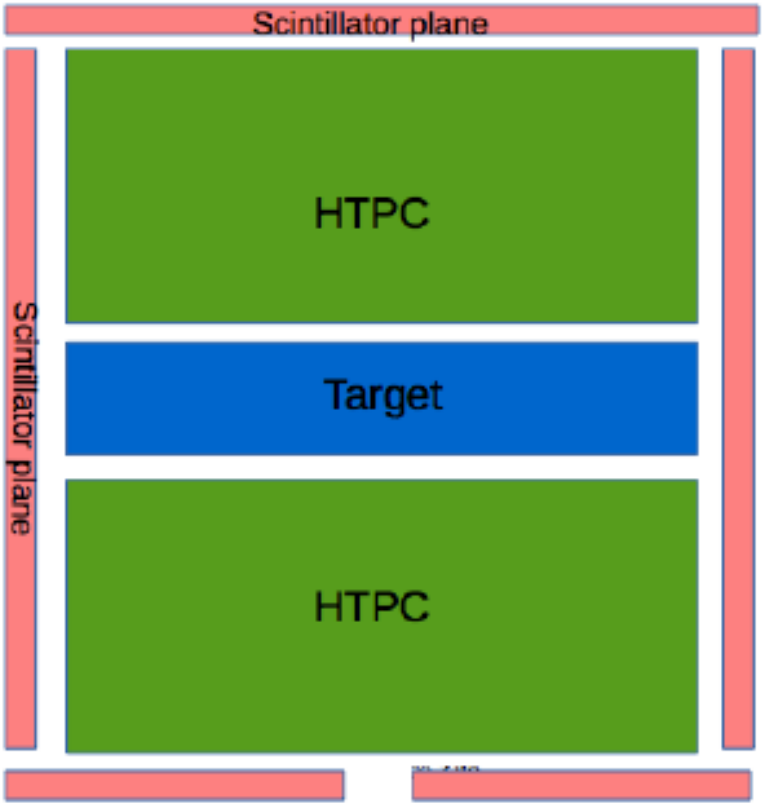
- One of the main limitations of the ND280 data used for the oscillation analyses is that they mainly cover the forward region while SK has a 4π acceptance
- Model dependence when extrapolating to the full phase space
- The neutrino-nucleus cross-section is not well known, an upgrade is necessary to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

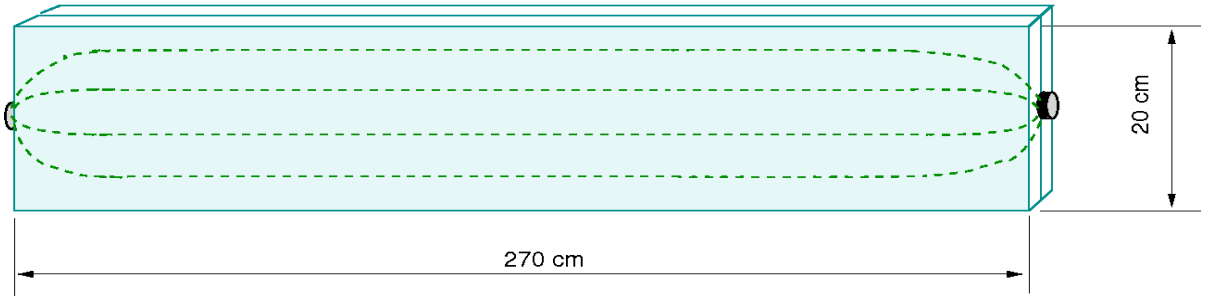


# Time of Flight detector

Purpose:
- determine the sense of the tracks
- improve particle Identification

Extruded plastic scintillator
- WLS Kuraray 1mm fibers (glued), single connector, 3x3mm2 MPPC, double-end
- Time resolution  630-650 ps
- R&D studies at INR (Moscow)




Cast plastic scintillator
- about 4m attenuation length
- 8 sensors of 6x6 mm2
- Time resolution is 120-140 ps
- R&D at University of Geneva (SHiP)