The T2K near detector upgrade

Marco Zito

On behalf of the T2K Near Detector Upgrade Task Force

London, HK open meeting
July 10th 2016

Outline

- The T2K-II project
- The requirements from physics
- Baseline design for the upgraded ND280
  - WAGASCI/3d FGD
  - The TPCs
- Next steps

T2K-II

12

10

8

6

4

2

0

n 1

n 2

n 3

Table 1: Number of events expected to be observed at the far detector for 10×10^{21} POT ν- + 10×10^{21} POT $\bar{\nu}$-mode with a 50% statistical improvement. Assumed relevant oscillation parameters are: $\sin^2 2\theta_{13} = 0.085$, $\sin^2\theta_{23} = 0.5$, $\Delta m^2_{32} = 2.5\times10^{-3}$ eV^2, and normal mass hierarchy (MH).

	True δ_{CP}	Total	Signal $\nu_\mu \to \nu_e$	Signal $\bar{\nu}_\mu \to \bar{\nu}_e$	Beam CC $\nu_e + \bar{\nu}_e$	Beam CC $\nu_\mu + \bar{\nu}_\mu$	NC
ν-mode	0	454.6	346.3	3.8	72.2	1.8	30.5
ν_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 ν_μ	Beam CC $\bar{\nu}_\mu$	Beam CC $\nu_e + \bar{\nu}_e$	$\nu_\mu \to \nu_e +$ $\bar{\nu}_\mu \to \bar{\nu}_e$	NC
ν-mode ν_μ 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

Goal

- The T2K-II phase will accumulate ~20 10**21 POT or 400 nue appearance events at SK
- Require a 2-3% systematic uncertainty on the number of expected events from the near detector
- 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

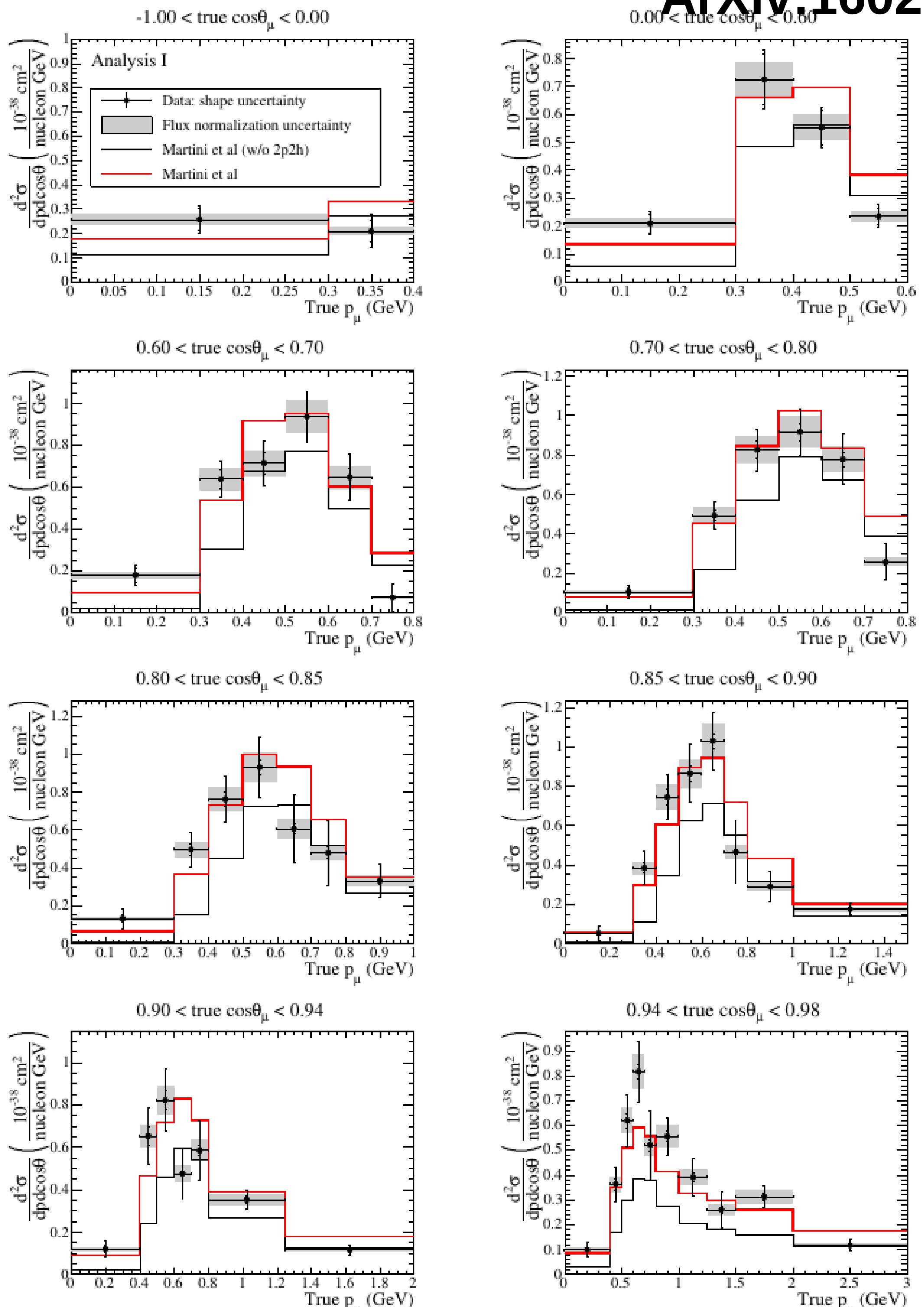
Systematic uncertainties on N_{SK}

Table 7: Error on N_{SK} in the FHC $1R_e$ sample: N_{asimov}(pre-fit) = 26.07, N_{asimov}(post-ND fit) = 26.65.

Systematic	Pre-fit	Pre-fit (no flat priors)	Post-ND fit	Post-SK fit
All errors (incl. osc)	N/A	N/A	N/A	16.8%
All errors	11.7%	11.7%	5.2%	5.2%
Flux only	8.7%	8.8%	3.2%	2.4%
Cross-section (xsec) only	7.1%	7.1%	4.7%	3.9%
Flux and xsec (constrained by ND)	10.8%	10.8%	2.7%	2.1%
Flux and xsec (total)	11.2%	11.2%	3.9%	3.5%
SKdet+FSI+SI+PN	3.5%	3.4%	3.4%	3.6%
SKdet only	2.5%	2.5%	N/A	N/A
FSI+SI+PN only	2.5%	2.5%	N/A	N/A
Osc.	N/A	N/A	N/A	17.7%

Do we have already a sufficient precision on the predicted n of SK events ?

ArXiv:1602.03652 (CC0PI T2K)



The MEC component contributes to the full phase space. However this is a particular model, and we would prefer not too rely on it too much. The conclusion is that we need to measure the full phase space.

Neutrino cross-sections and oscillations

- The current largest source of uncertainty on the neutrino-nucleus-cross section for T2K comes from processes contributing to the CC0Pi channel (like 2p-2h and other)
- This has a non-negligible impact on the precision measurement program of T2K
- Short of constraining these processes directly by accessing the low energy hadrons, the best we can do is to precisely measure the CC0Pi reaction in the full phase space of the muons

Physics requirements

- During this first phase of the TF we heard several suggestions from the NIWG, BANFF, NUMU and NUE conveners etc
- The consensus is that to improve ND280 performance we have to

1) Improve the angular acceptance
2) With an oxygen target, as in FGD2 (~50%) or better
3) Lower significantly the threshold on low momentum pions and protons (if possible down to p~100 MeV/c)

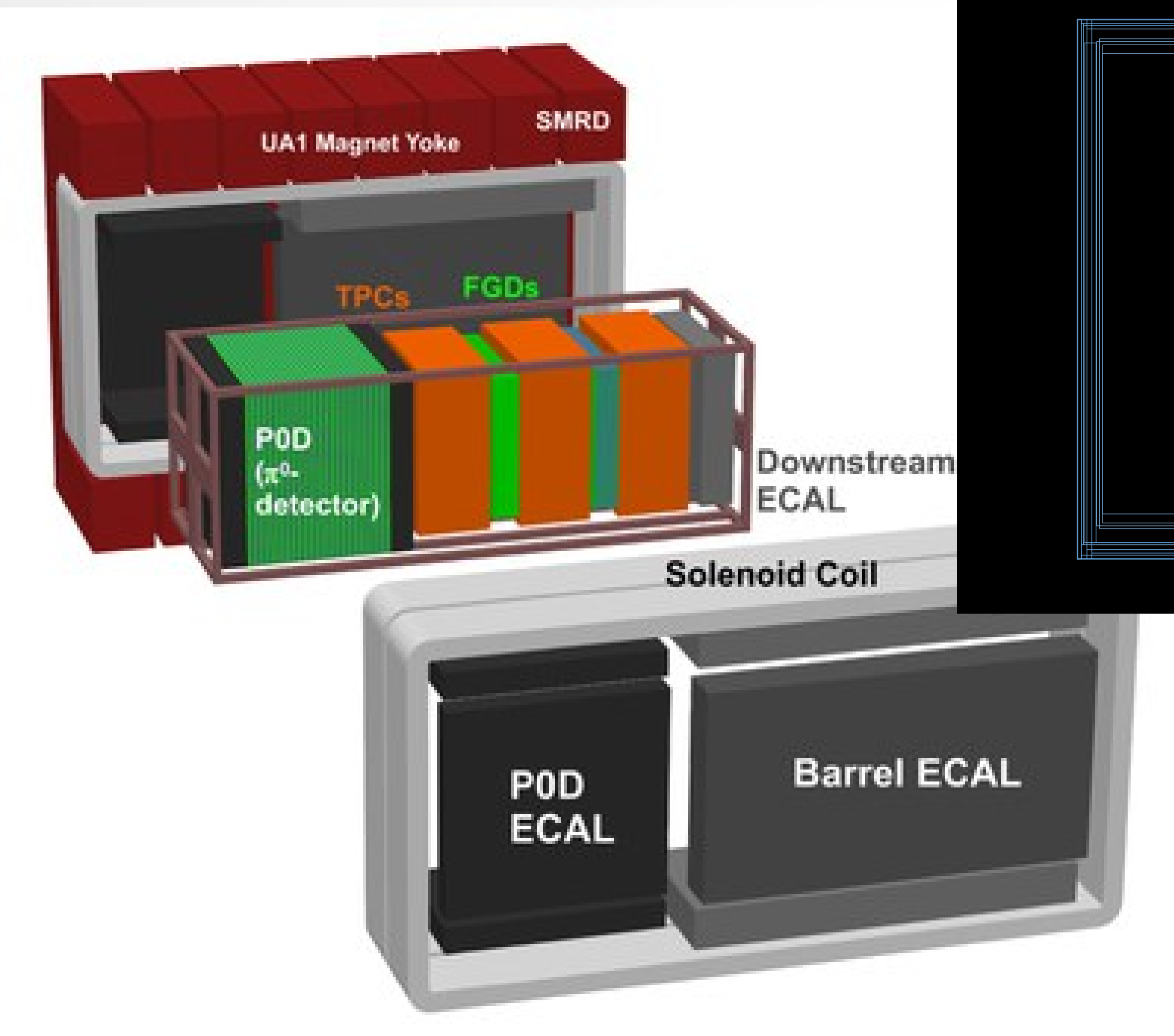
Additional desiderata include

a) Maintain performance for nu_e selection : nue cross-sections measurements
b) If possible, achieve calorimetric energy measurement of nu energy
c) Reduce/measure the incoming photon flux

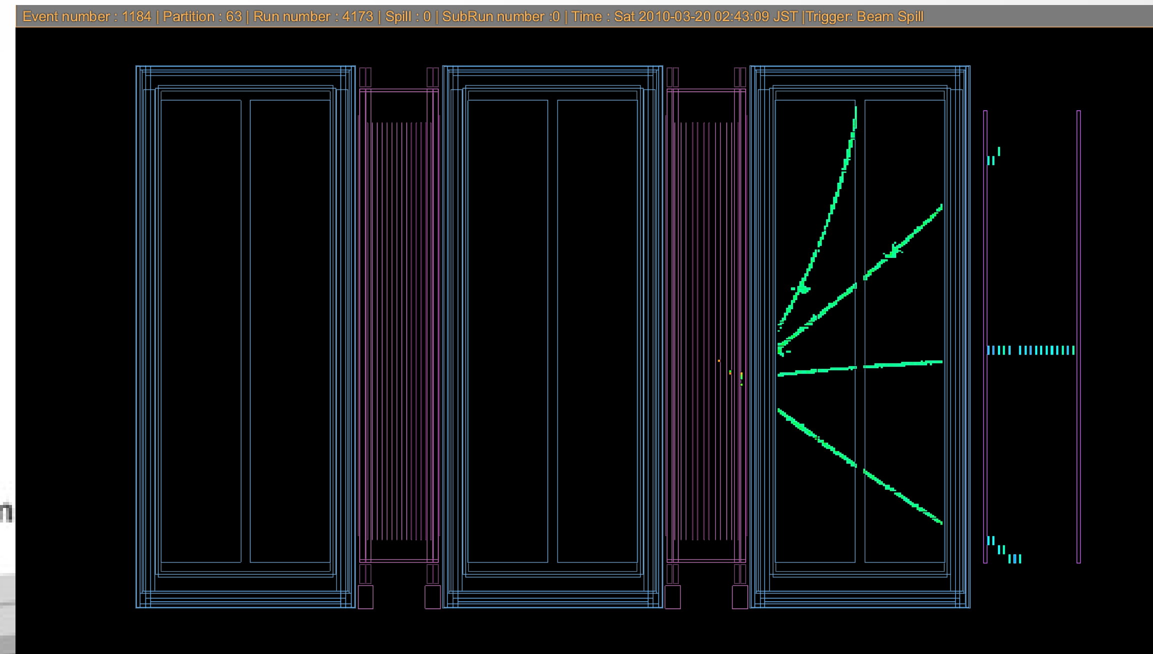
All the proposed detector configuration address several of these requirements.

It is a very difficult task to address all of them simultaneously with the same detector

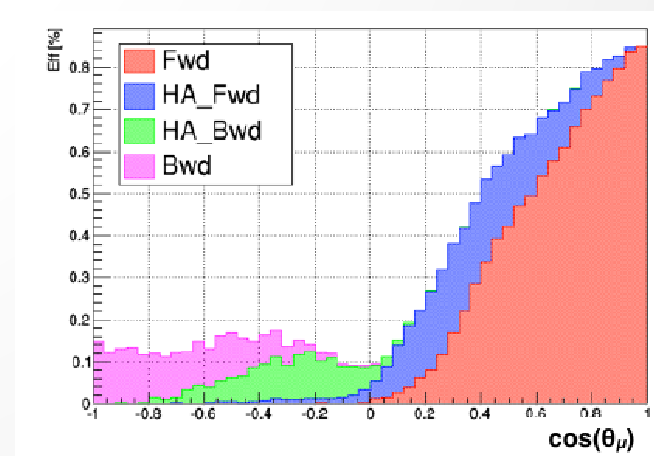
ND280



UA1 Magnet Yoke
SMRD
TPCs
FGDs
P0D
(π⁰-
detector)
Downstream
ECAL
Solenoid Coil
P0D
ECAL
Barrel ECAL



Event number : 1184 | Partition : 63 | Run number : 4173 | Spill : 0 | SubRun number :0 | Time : Sat 2010-03-20 02:43:09 JST |Trigger: Beam Spill



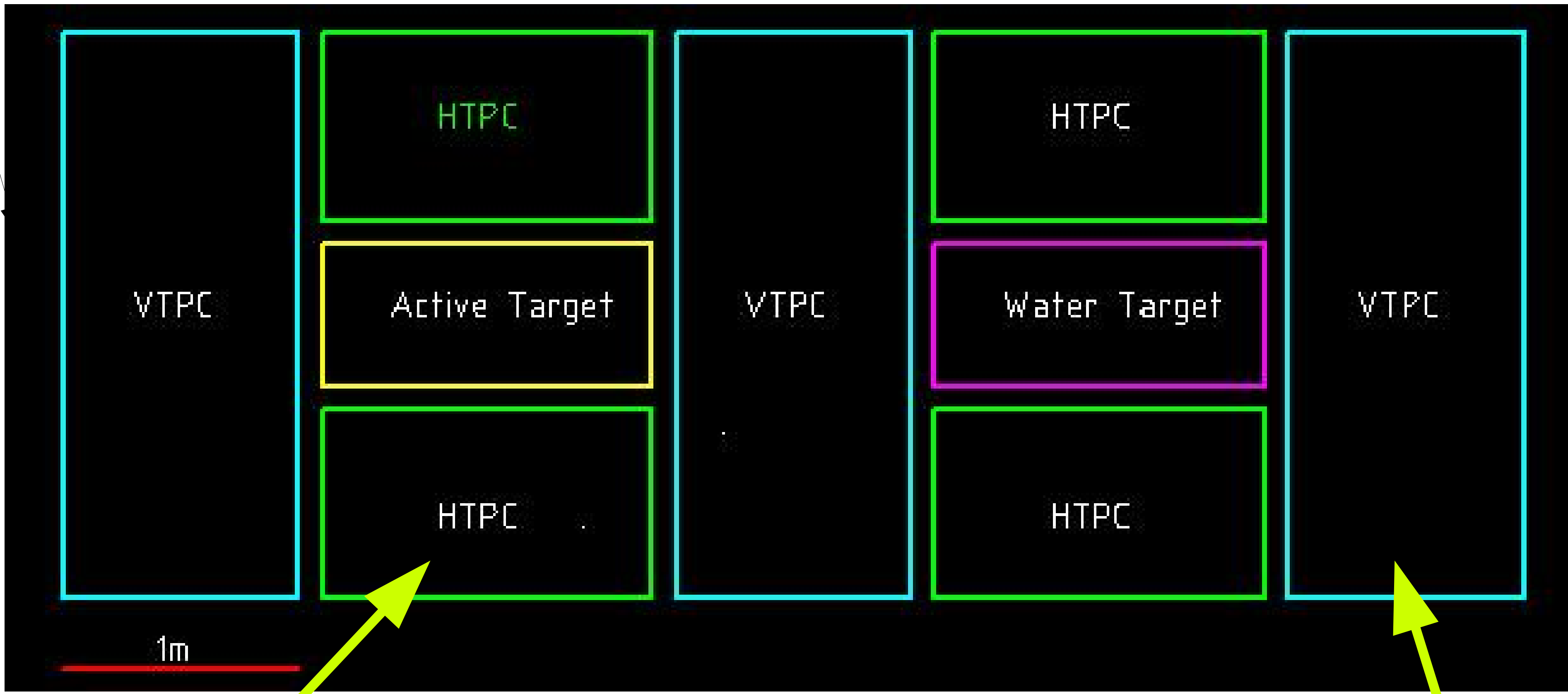
Eff [%]
Fwd
HA_Fwd
HA_Bwd
Bwd
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
cos(θμ)

ND280 strengths and weaknesses

- Strengths: tracker designed for forward tracks, TPC with charge, momentum and PID, calorimeter coverage, symmetry btw carbon and water enriched FGD
- Weaknesses: 90° and backward angles tracking, low momentum hadron tracking
- Reasons: in 2005-2006, theta13 was still unknown, a lot of emphasis was placed on background (like NCpi0 processes) and the forward region was expected to constitute a challenge for the muon momentum at the high end of the spectrum. We also underestimated the need for a redundant T0 determination around the TPC active volume (determination of the sense of the track)

The baseline design for the upgraded ND280

All this inside the EM calorimeter and the UA1 magnet



New horizontal TPC

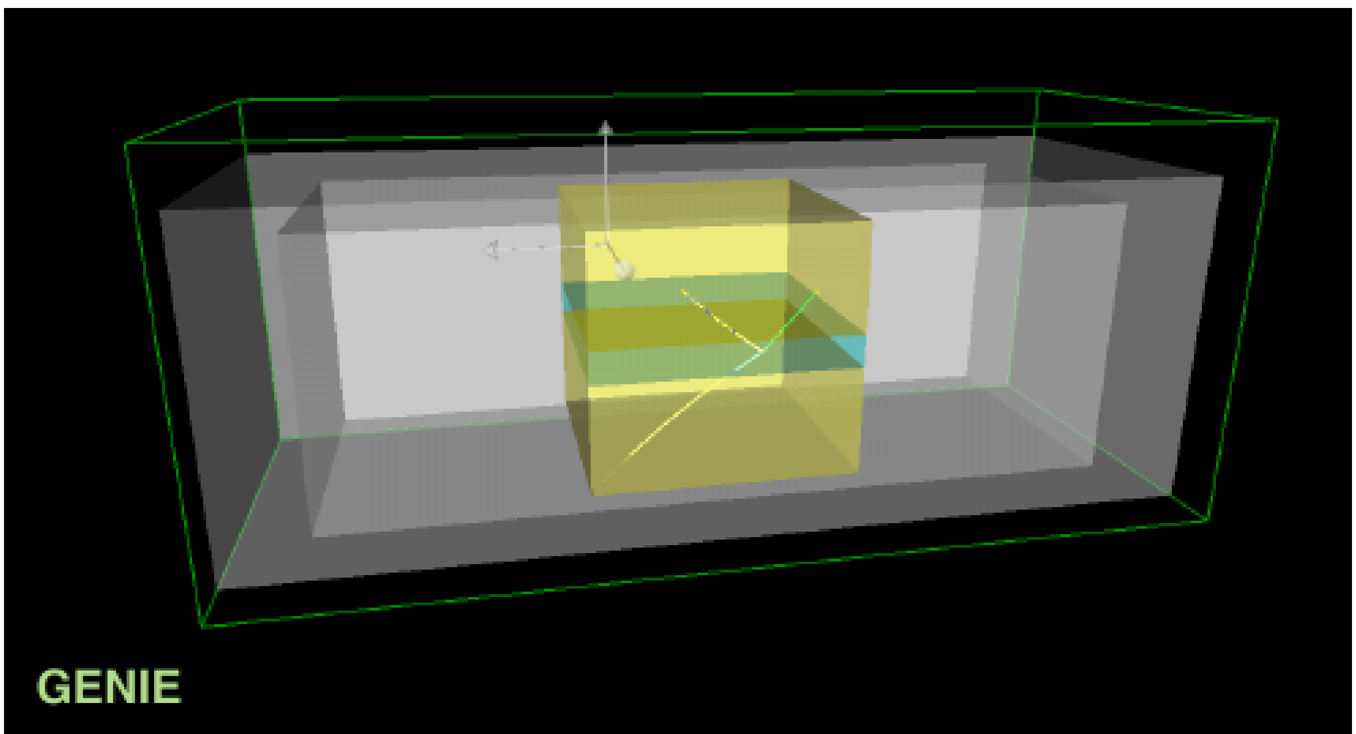
Existing TPC

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

D. Sgalaberna-
B. Quilain

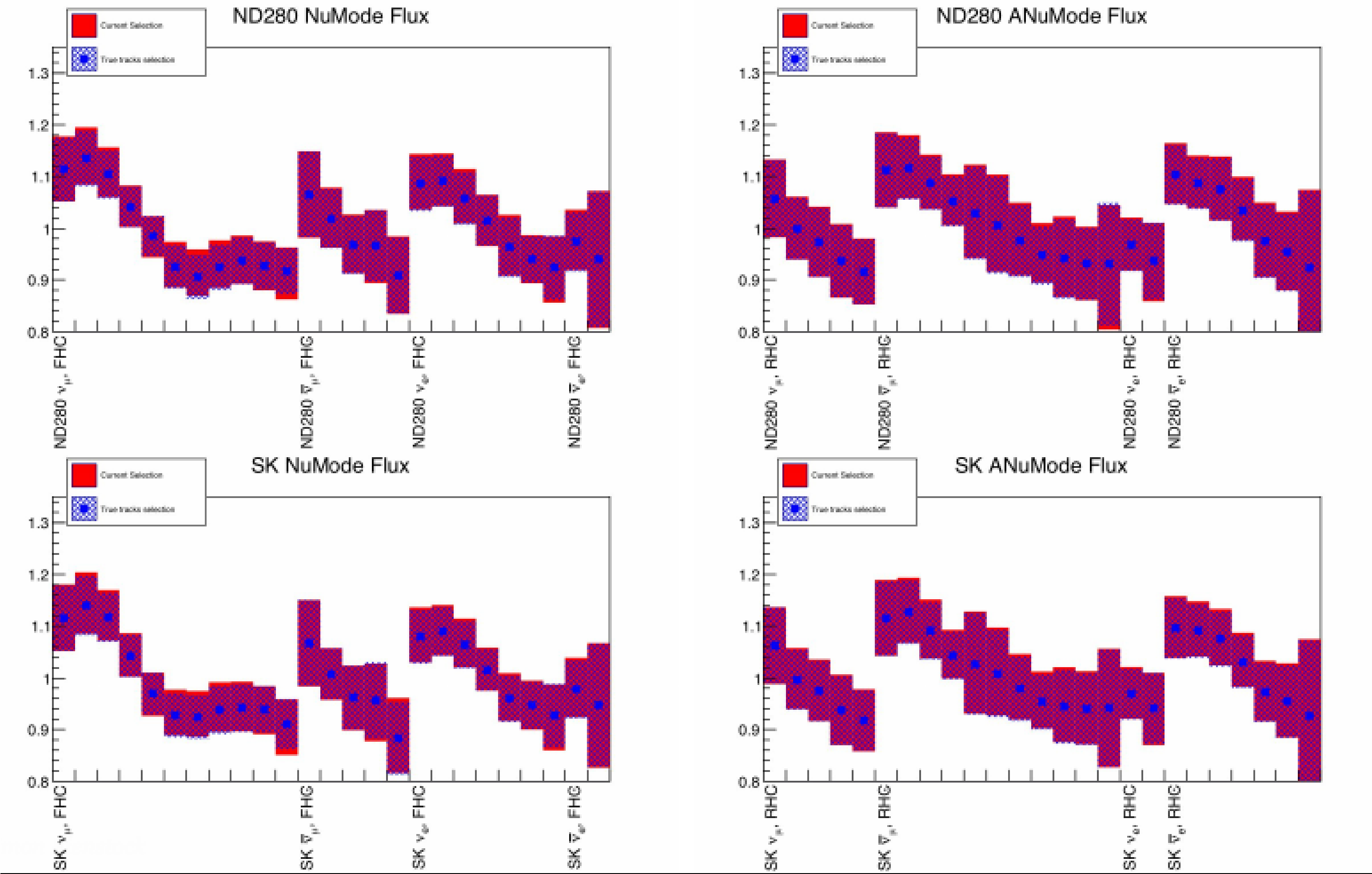
Geant4 framework

- Framework developed to study acceptance and efficiencies issues with a parameterized detector response

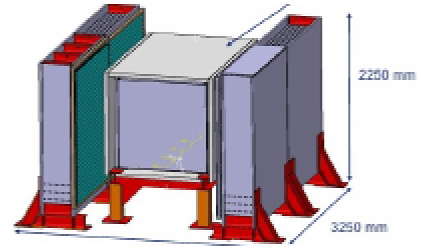


BANFF-like studies

- Comparison of flux constraint with current ND280 data and with a parameterized response

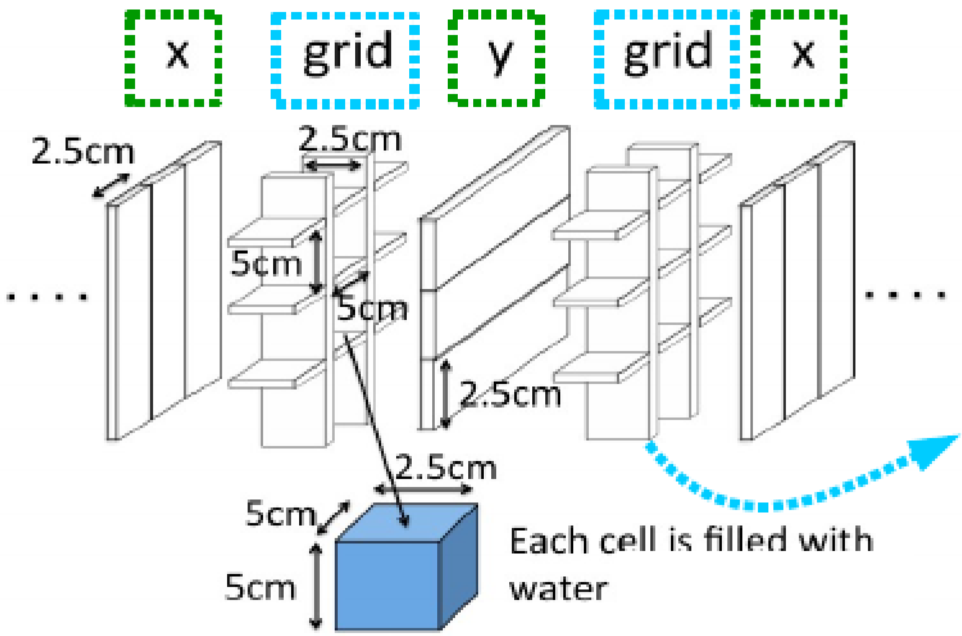


WAGASCI

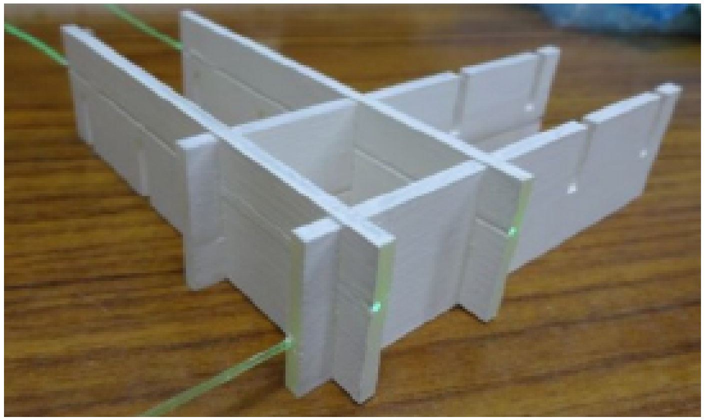


On axis prototype

- Alternance of XY planes & 3D grid scintillators
  → ~4π angular acceptance & high vertex resolution

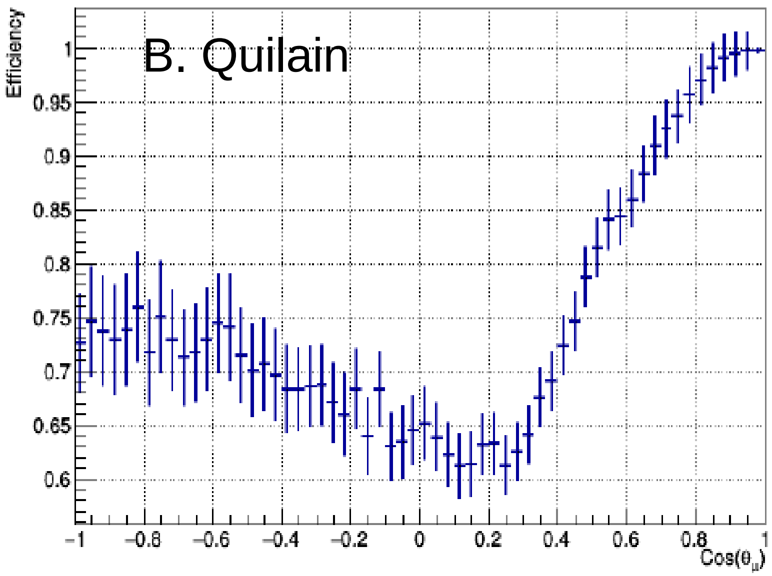


GRID-like scintillators

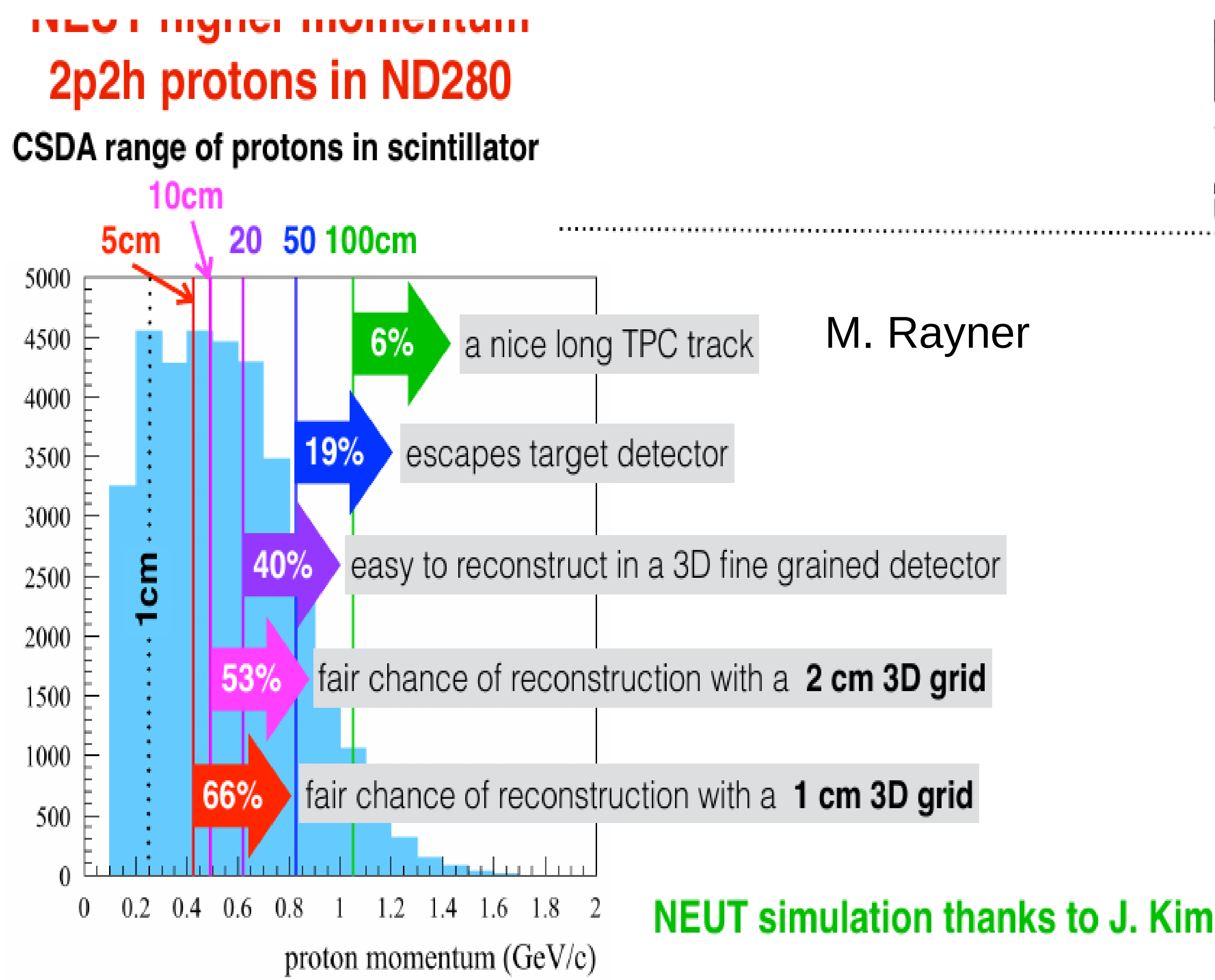


- Main target is H2O (H2O:CH=79:21)

WAGASCI



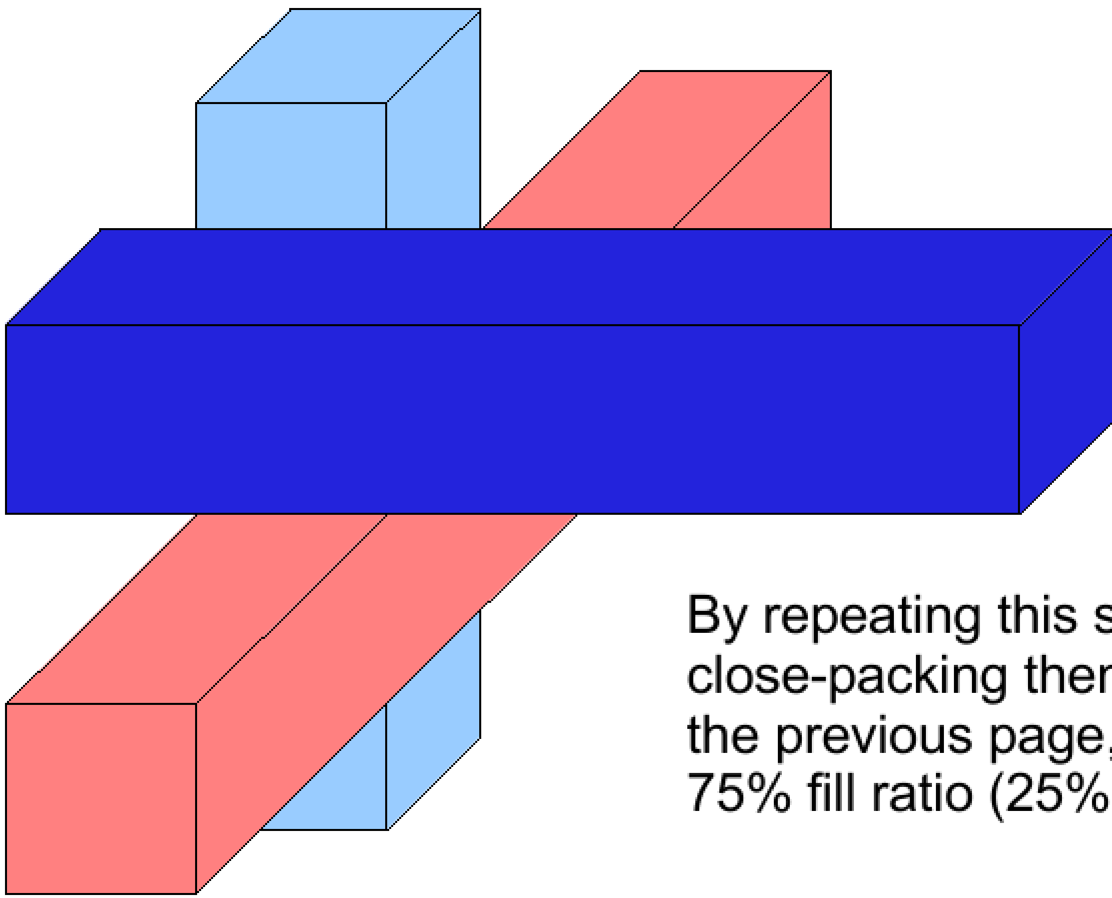
The WAGASCI detector has high tracking efficiency also at high angles.



A possibility for the scintillator only target is to use an empty WAGASCI. This has the advantage of a proton threshold at ~250 MeV/c (to be checked), to be compared to 500 MeV/c for FGD

Alternative configuration for the target

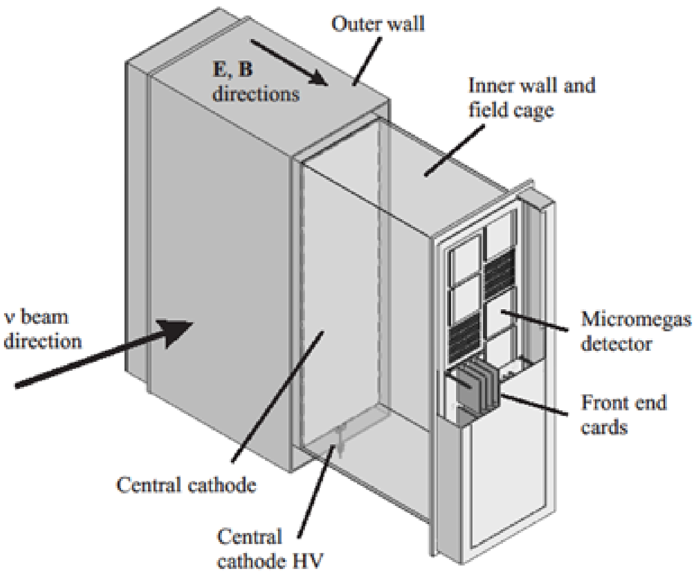
The 3-axis structure

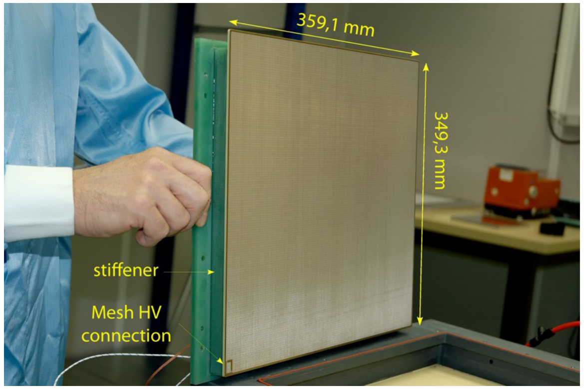


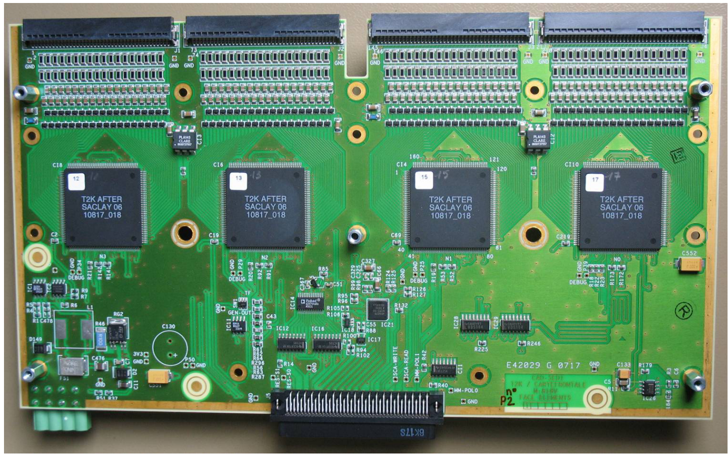
By repeating this structure and close-packing them as shown on the previous page, you can get 75% fill ratio (25% of volume is air)

The T2K TPC

- The existing TPC are operating succesfully with a very low failure rate
- They provide a baseline design and several components (Micromegas, front and back end electronics) practically ready to use

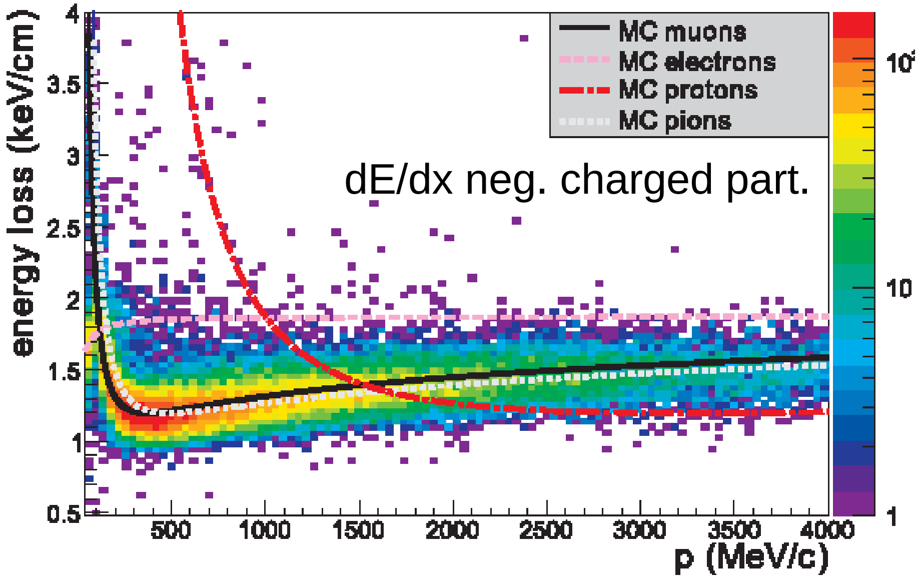


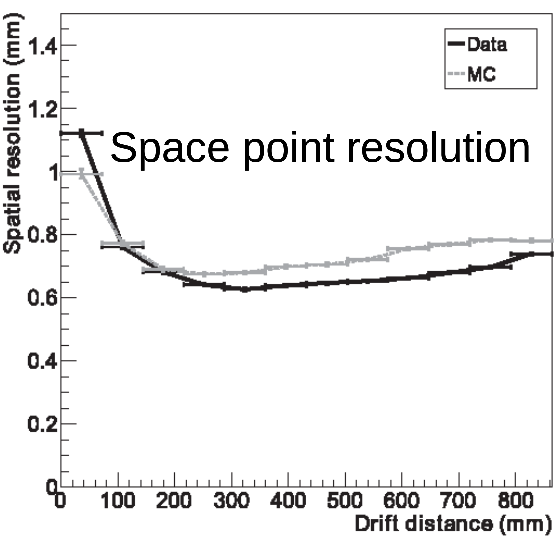


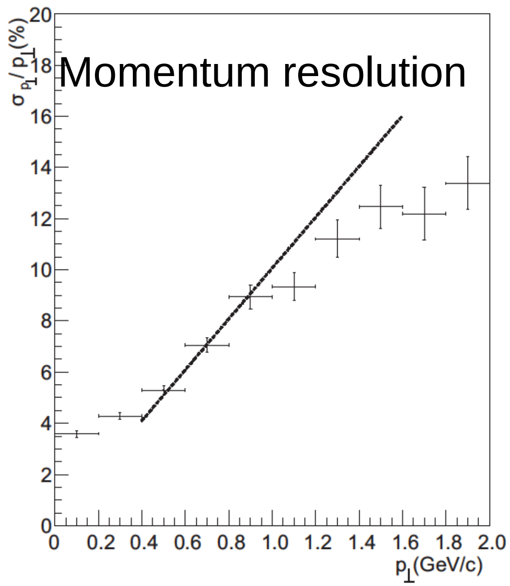


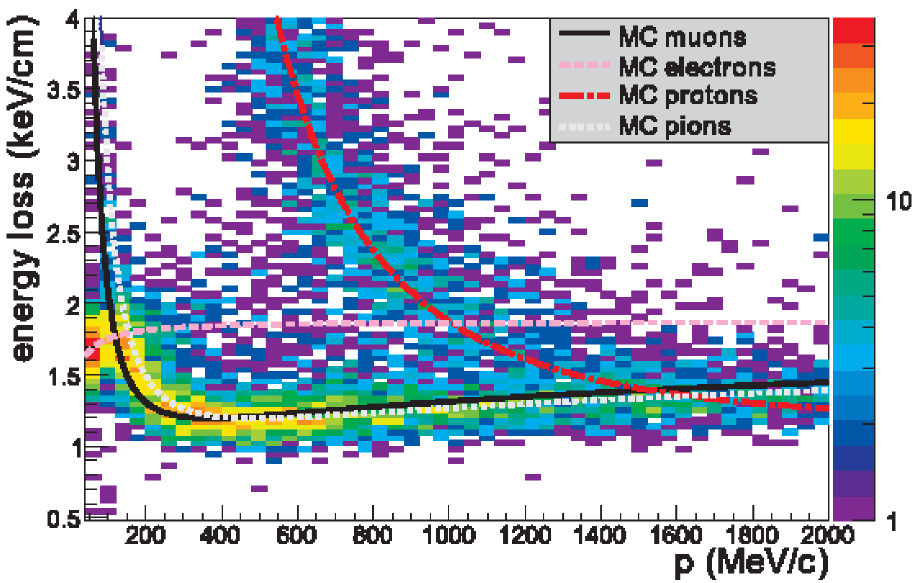
TPC performances

- 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 PIL
- Space resolution : 0.6 mm
- Momentum res. 9% at 1 GeV
- dE/dx: 7.8 % (MIP)







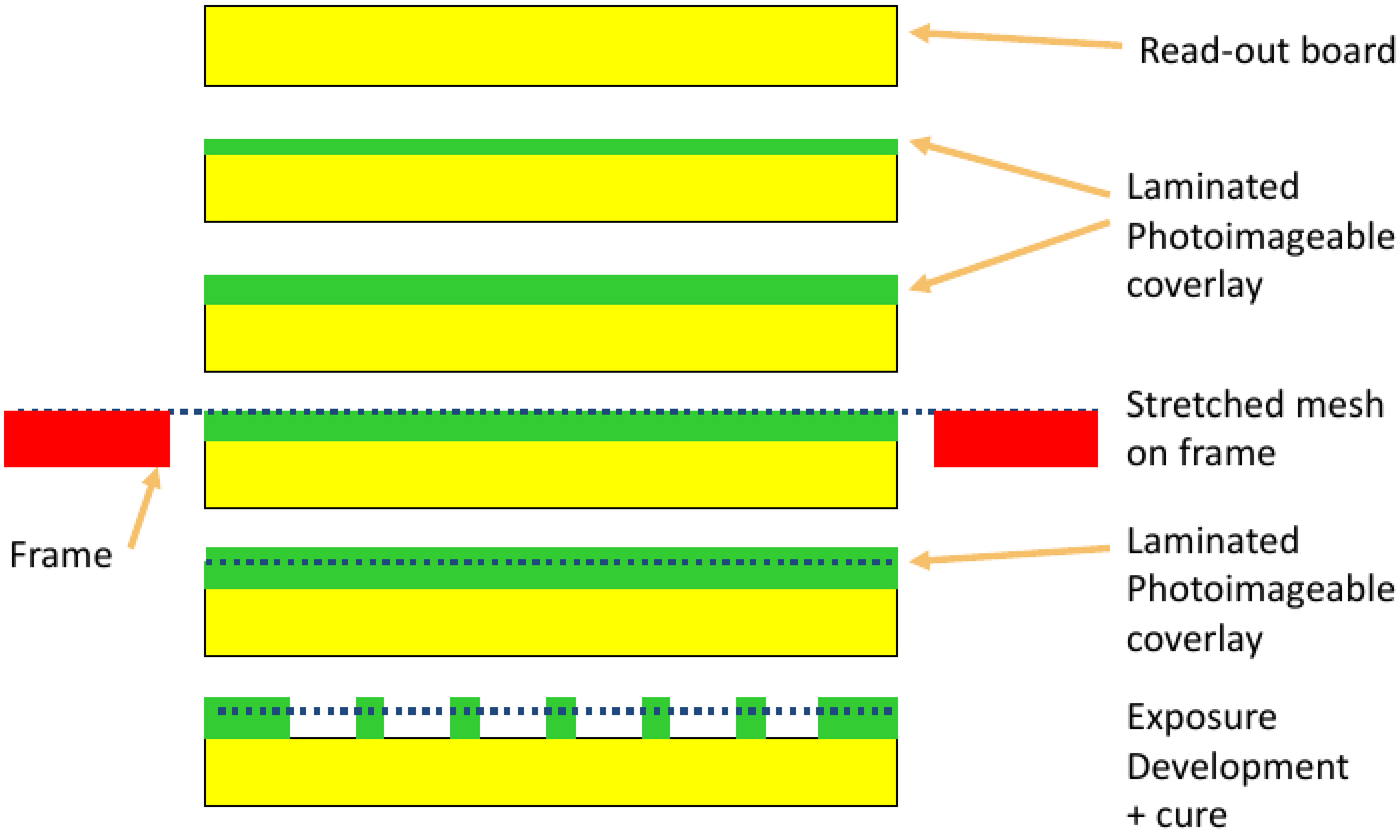


dE/dx pos. charged part.

The new TPC

- The additional TPCs are similar in size to the existing VTPC (planned to be re-used)
- We plan to use a thin (a few cm) field cage following what was done for the Aleph and Delphi TPCs
- Several technological innovation developed by the ILC-TPC and RD51 could also be considered: resistive anode Micromegas, readout electronics on the back of the MM, low mass cooling ...

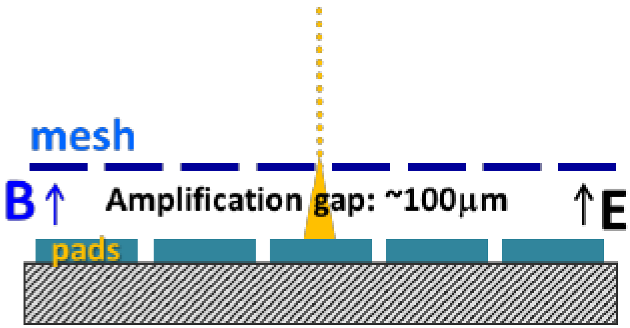
Bulk Micromegas

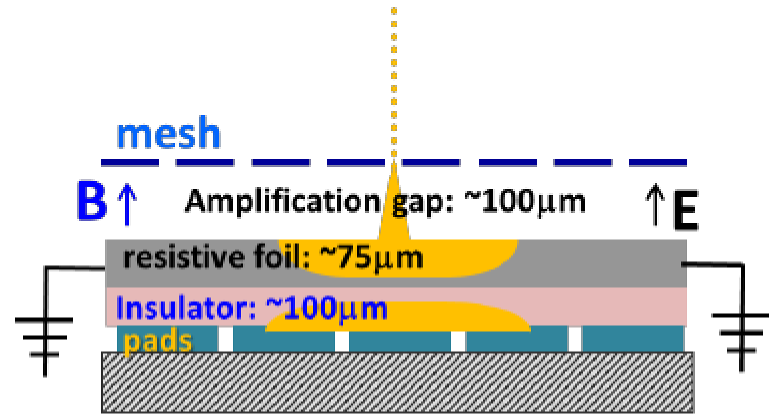


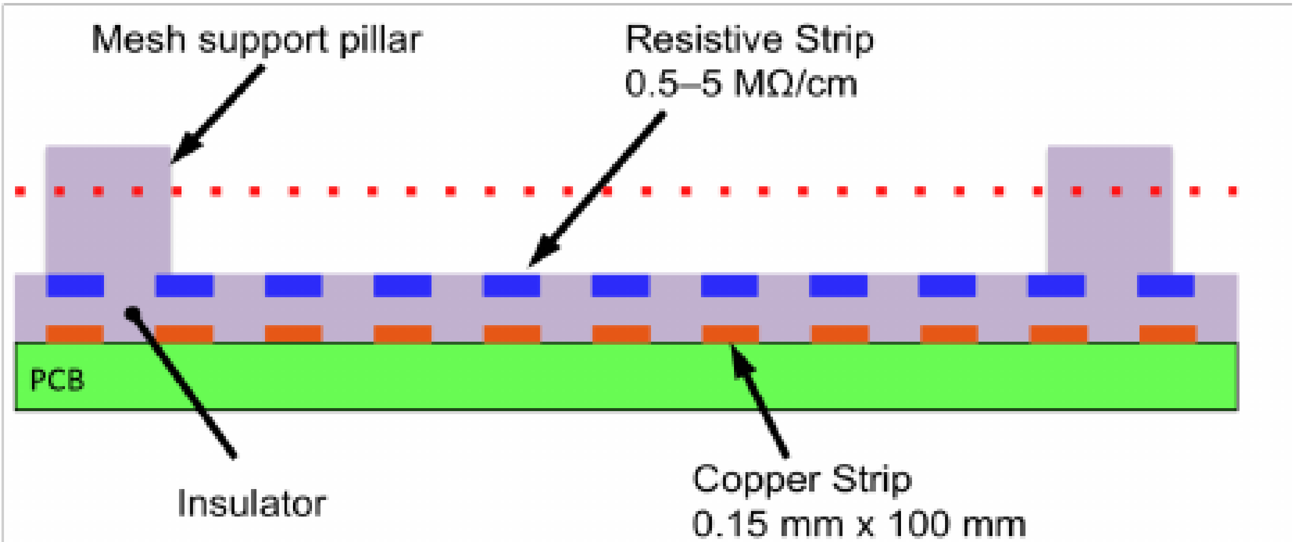
Proven technology. Saclay equipped with a new production line. Micromegas technology succesfully transferred to industry as part of the ATLAS New Small Wheel Phase I upgrade. Can also count with CERN (R. De Oliveira) workshop

Resistive Bulk Micromegas

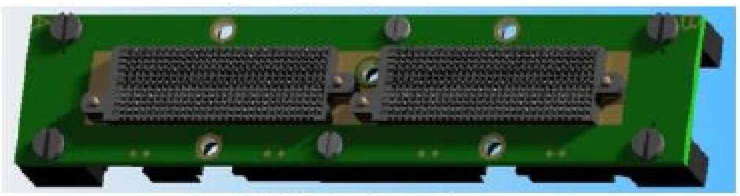
- Several advantages (charge spread, intrinsic spark protection)
-



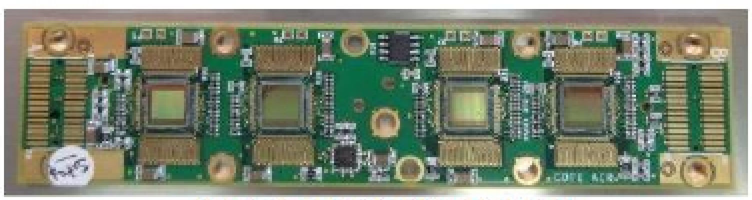




ILC TPC R/O electronics



(a) FECi Detector side connectors

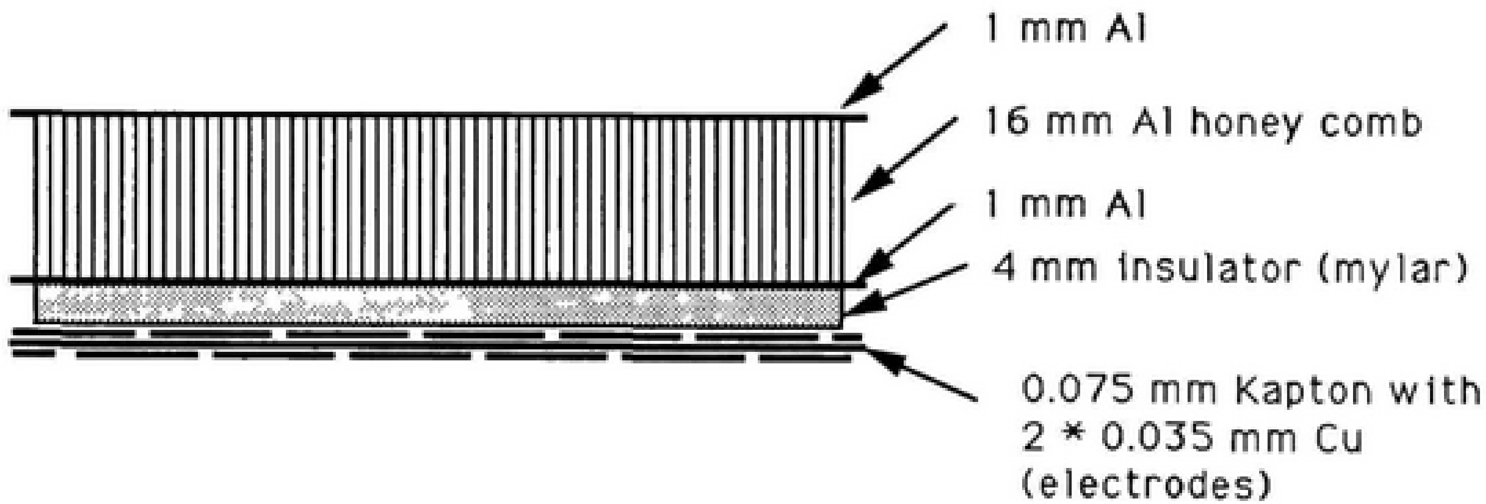


(b) Component side of a FECi

(c) A FECi with its heat sink

Size: 1/10 of a T2K TPC FEC, for the same number of channels. Flat readout achieved for a pad size of 3x7 mm**2. We plan to use a pad size ~~100 mm*2

The Aleph TPC field cage



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

Next steps

- We plan to finalize a Conceptual Design Report of the ND280 upgrade by the end of the year
- 2017: detailed design of the detectors/setting up the project and the funding
- 2018-2020 construction/installation
- New groups are very welcome ! Please contact us
- Collaborative aspects in Europe: see A. Blondel talk and HPTPC talk later