Towards a high pressure TPC for neutrino long-baseline experiments

Marco Zito
SPP/IRFU CEA Saclay

July 10 2016
London, HK open meeting

Outline

- History-landscape
- Motivations
- The LAGUNA-LBNO Near detector
- Items for R&D
- Next steps

History-landscape

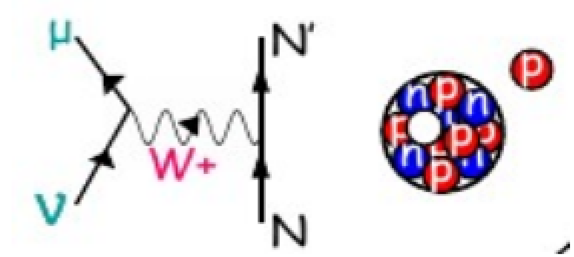
- The first TPC ever built (PEP-4) was a high pressure TPC at 8.5 bar (early proof of feasibility!)
- Today high pressure TPCs are being actively studied for neutrinoless double beta decay searches (NEXT, PANDAX-III)

Features in neutrino interactions

CC0π:

(this talk)

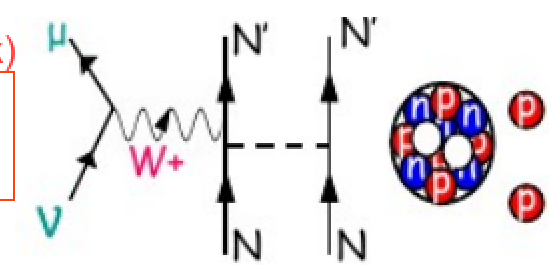
CCQE (aka **1p1h**)
where the nucleons has to be 'extracted' from the nucleus



+

(this talk)

2p2h : interaction with correlated nucleons



+

RPA : screening effect due to whole nucleus

+

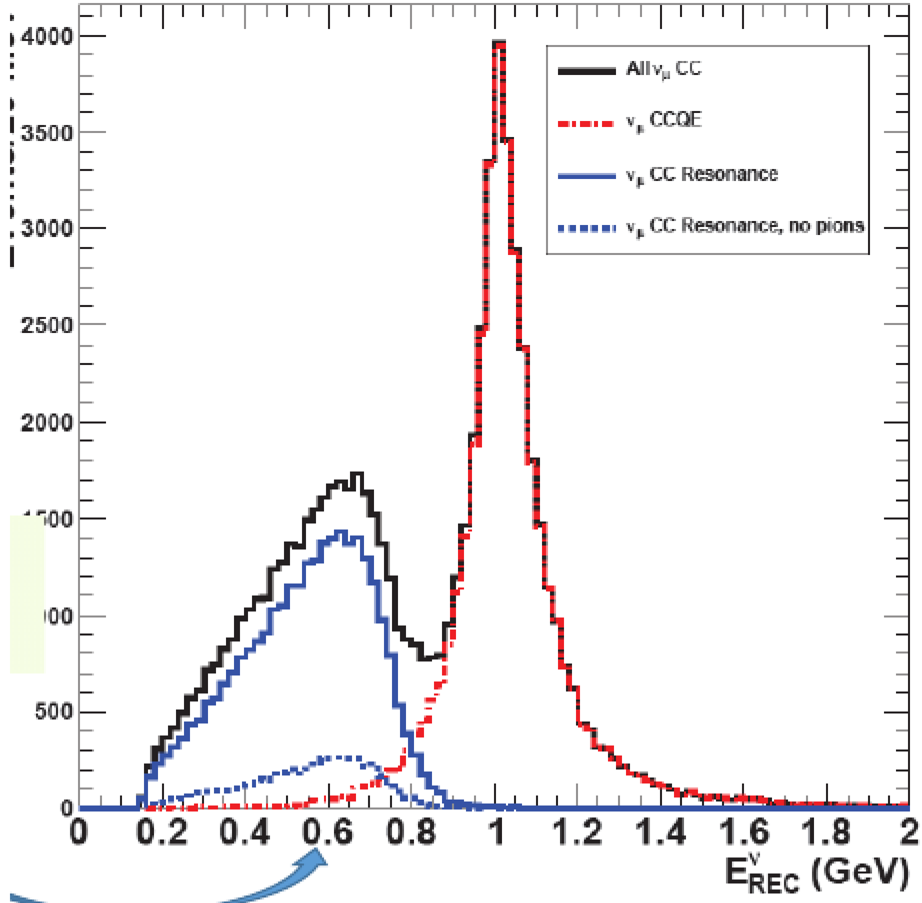
Final state interactions

- outogoing nucleon re-interact with nucleus
- CC1π events with pion absorption

S. Bolognesi

Distortion of reconstructed neutrino energy

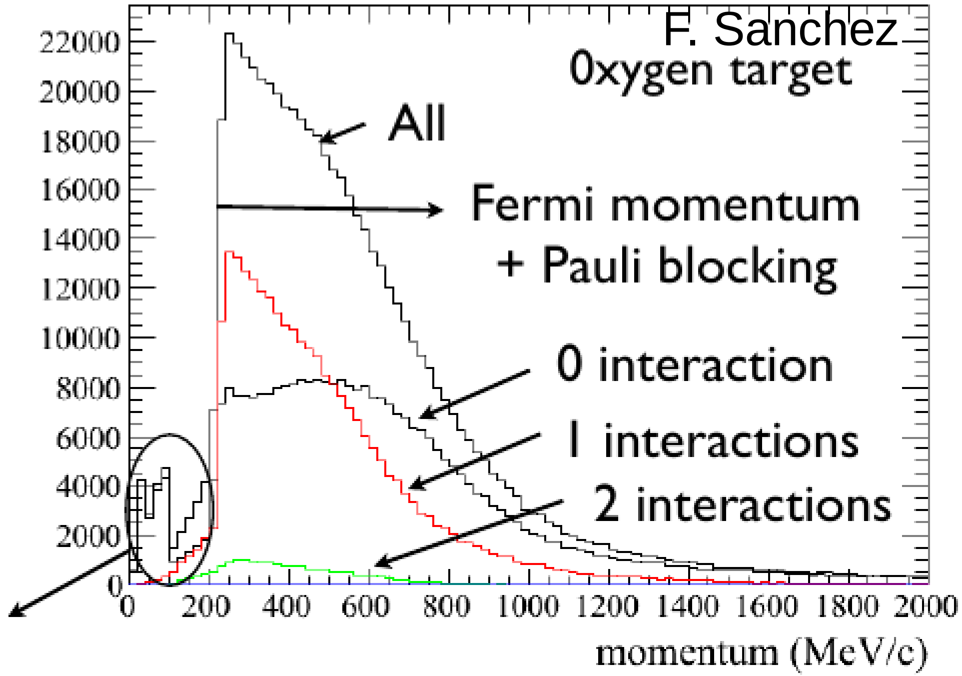
GENIE E_ν = 1 GeV



Nieves@Neutrino2016

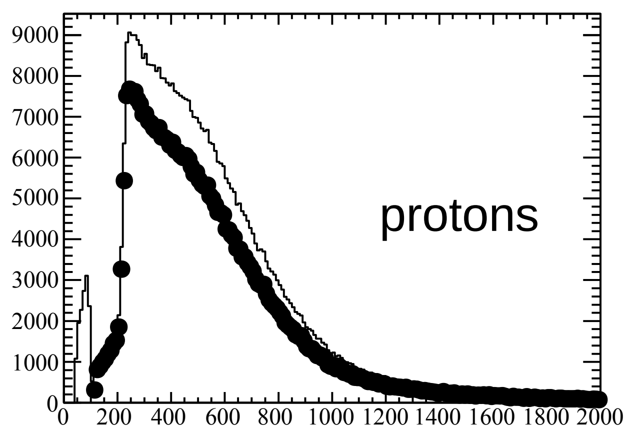
The neutrino energy reconstructed in the CCQE kinematic hypothesis. T2K studies indicate that precision measurements (most notably theta23) will be affected by these features.

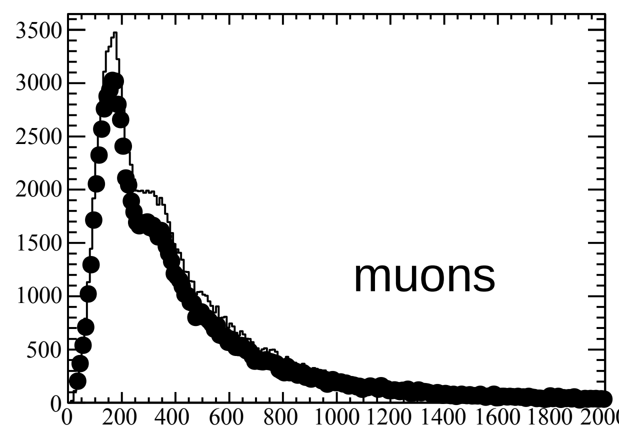
Particle spectrum in neutrino interactions



Observation of low energy protons below the Fermi momentum would be the signature of phenomena beyond CCQE.
Extraction of physical information would need to disentangle FSI, 2p2h and other effect

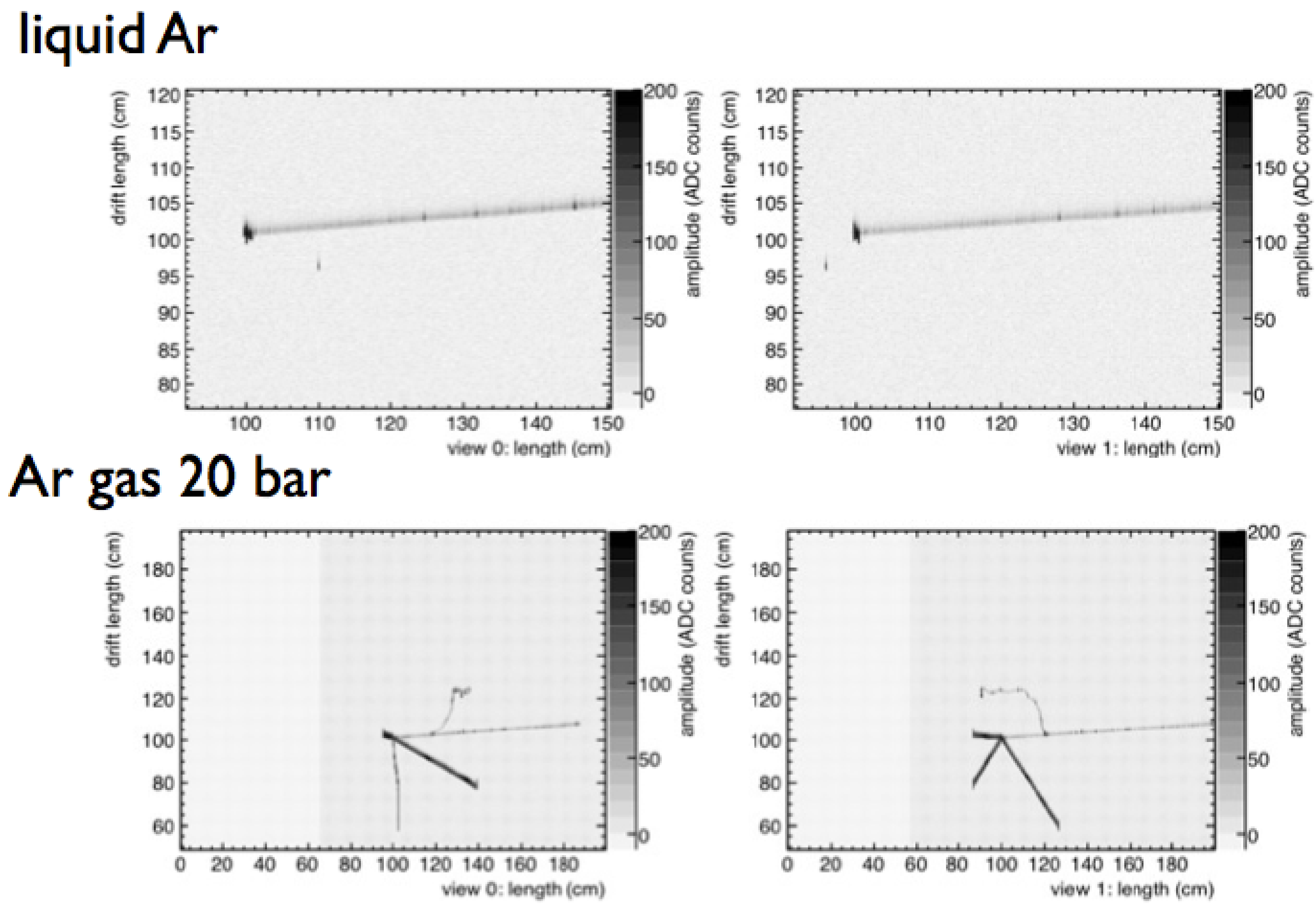
Black dots:particle measured in a high pressure TPC





SNET

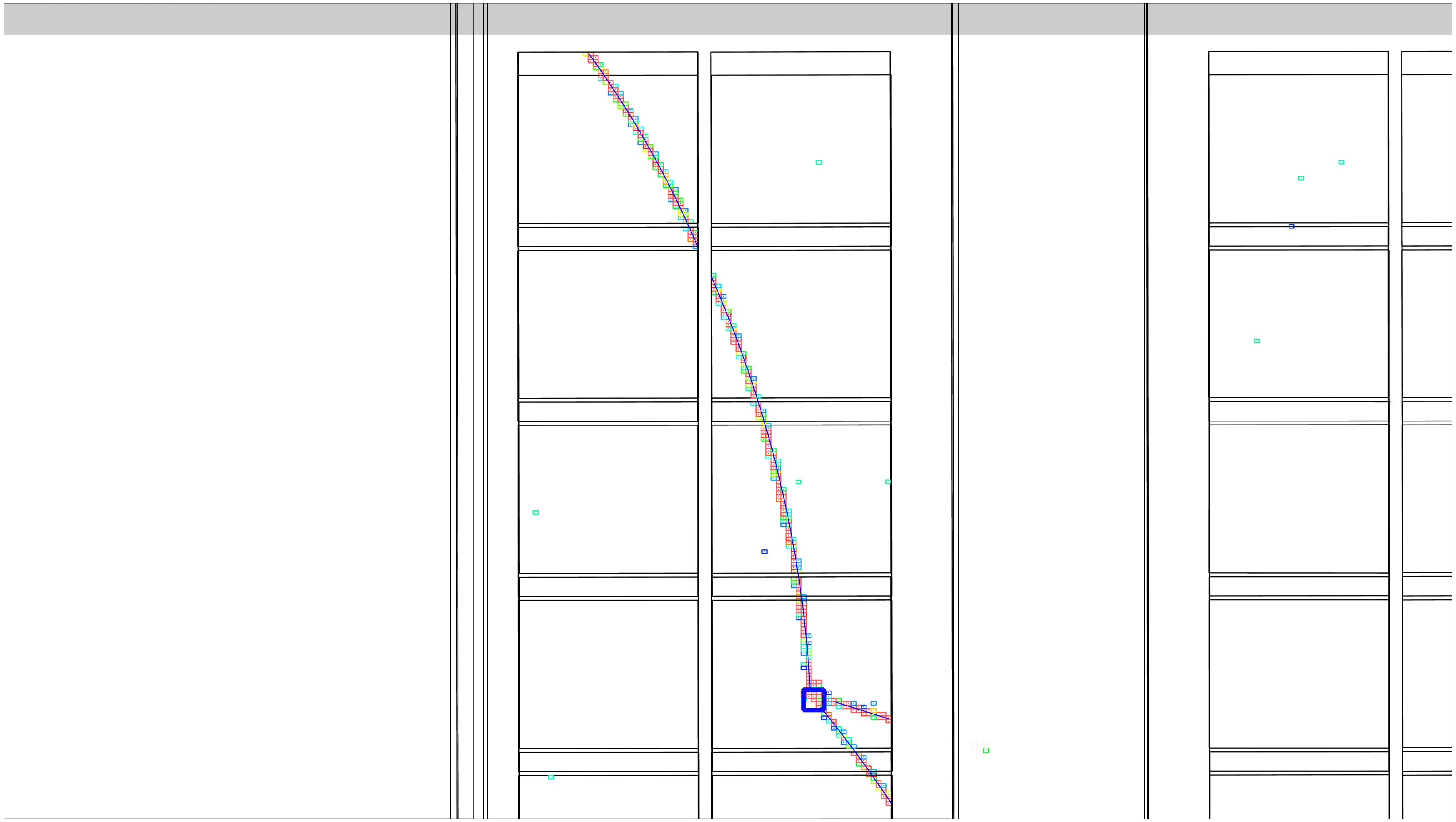
Gas versus liquid argon



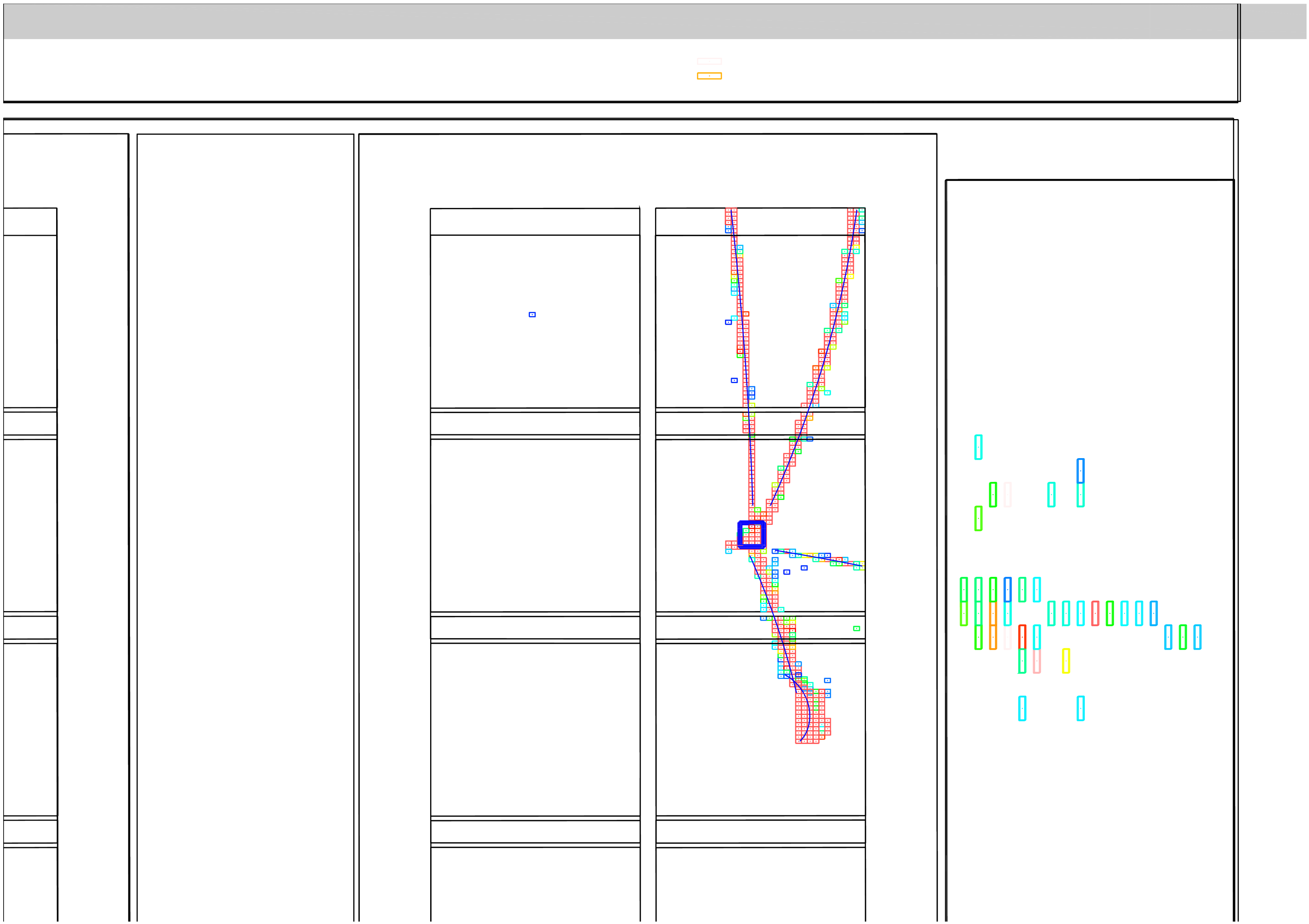
A. Curioni

A high pressure TPC is uniquely sensitive to very low momentum protons: more complete picture of the dynamics of the neutrino interaction with a nucleus

T2K TPC: interaction in the gas



T2K TPC: interaction in the gas



Motivations-considerations

- A high pressure TPC would be a unique detector to precisely reconstruct the low momentum charged hadrons emitted at the neutrino vertex
- Need to be surrounded by a calorimeter
- Despite early ideas/dreams, it will be very difficult to have oxygen nuclei in the target: oxygen, high pressure and long drifts are in conflict
- In my opinion, it will also be difficult to operate the device with a wide variety of gases, but argon and neon based mixtures are possible
- For Hyper-Kamiokande, it should considered as a very valuable associated experiment, rather than a near detector. It does not even need to sit on the same beamline
- On the other hand, it is ideally suited as a near detector for an argon-based long baseline project like DUNE

LAGUNA-LBNO near detector

- The most advanced study of a high pressure TPC was conducted in the framework of the LAGUNA-LBNO (2011-2014) design study
- HPTPC considered as a near detector
- Full simulation studies conducted

From LAGUNA-LBNO final report

LAGUNA-LBNO Near Detector

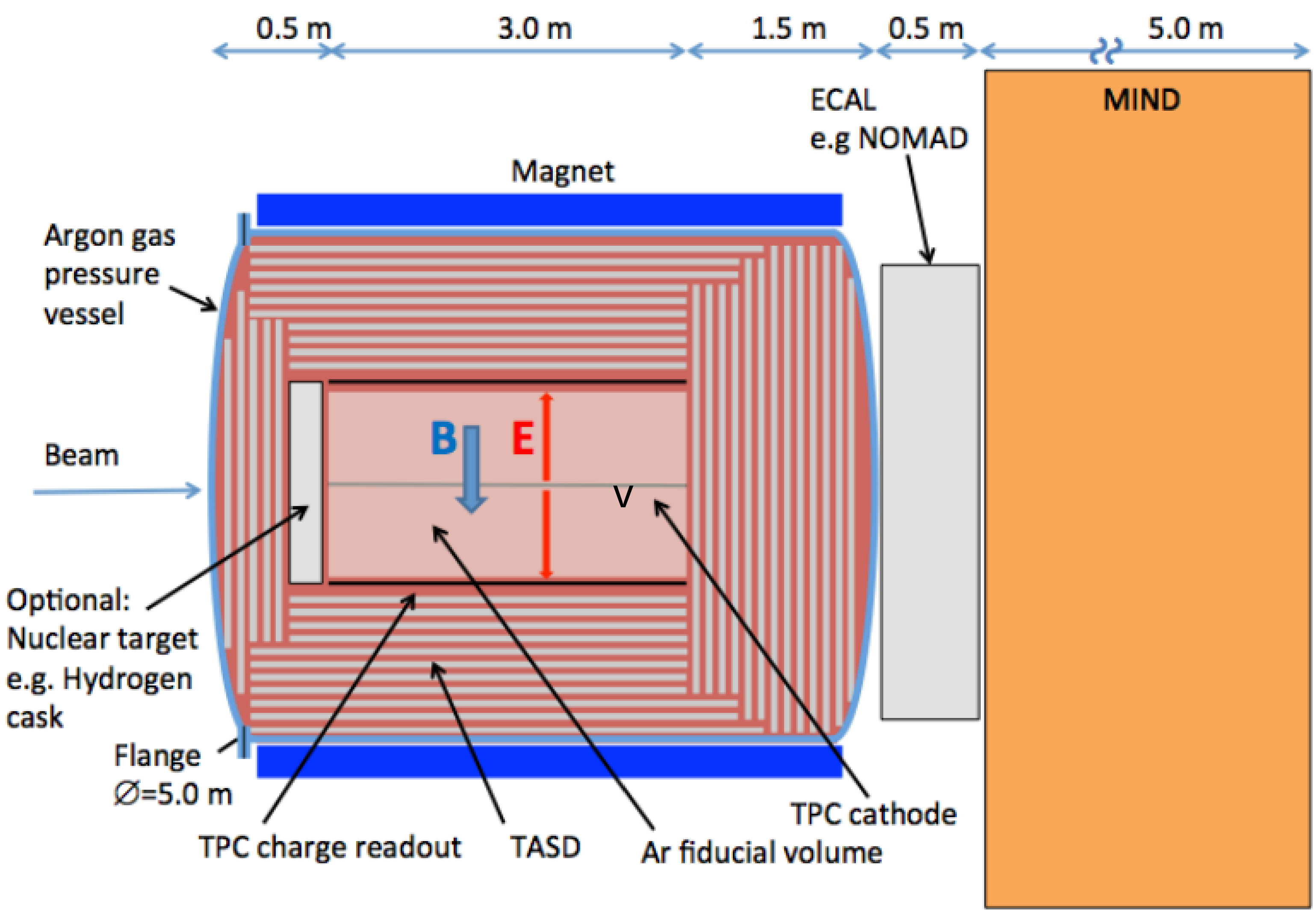


Figure 7.4: *Schematic layout of the LBNO ND.*

Table 7.1: Geometrical preliminary parameters for the detector layers.

Item description	Number	Thickness [mm]	Width [m]	Height (radi.) [m]	Depth [m]	Mass [t]
Air magnet inner volume						
Air magnet	1	1000	-	(3.5 outer)	5.0	440
Argon gas TPC						
TPC	1	-	2.4	2.4	3.0	0.6
Anode/Cathode plates	3	13.2	2.3	2.3	-	-
Pressure vessel						
Barrel	1	20	-	(2.5)	5	-
Ends (semi-hemis.)	2	20	-	(1.5)	-	-
Fiducial volume	1	-	-	(0.5)	5	-
Steel envelope	1	10	-	-	-	-
TASD						
Scintillator bars	150000	7	0.03	-	-	162
Plane (X or Y or U or V)	200	7.5	-	-	-	-
Module (X+Y)	100	15	-	-	-	-
ECAL						
Lead (or steel) plates	50	10	-	-	-	160
Scintillator bars	20000	7	0.03	-	-	23
Module (X+Y)	50	15	-	-	-	-
Structure (Pb + Scint)	50	25	-	-	-	-
MIND						
Iron plates	150	30	10	10	-	3600
Scintillator bars	100000	7	0.03	-	-	245
Module (X+Y)	150	15	10	10	-	-
Structure (Fe + Scint)	150	45	-	-	-	-

From LAGUNA-LBNO final report

- Exposure 3.3×10^{19} p.o.t
- 94614 gas events (94% ν_μ)
- 6.5 particles per neutrino event on average

Primaries from entire gas volume

particle	count
p	178013 (28.9%)
n	146258 (23.7%)
π^+	76696 (12.5%)
π^0	73132 (11.9%)
μ^-	66390 (10.8%)
π^-	40679 (6.6%)
γ	6572 (1.1%)
μ^+	3253 (0.5%)
e^-	823 (0.1%)
e^+	108 (<0.1%)
other	23913 (3.9%)
Total	**615837** (excluding ν)

Interaction Types

type	CC	NC
QEL	9012 (9.5%)	2776 (2.9%)
RES	13017 (13.8%)	5139 (5.4%)
DIS	47994 (50.7%)	16000 (16.9%)
COH	467 (0.5%)	209 (0.2%)
MEC	not enabled	not enabled
Total	**70490**	**24124**

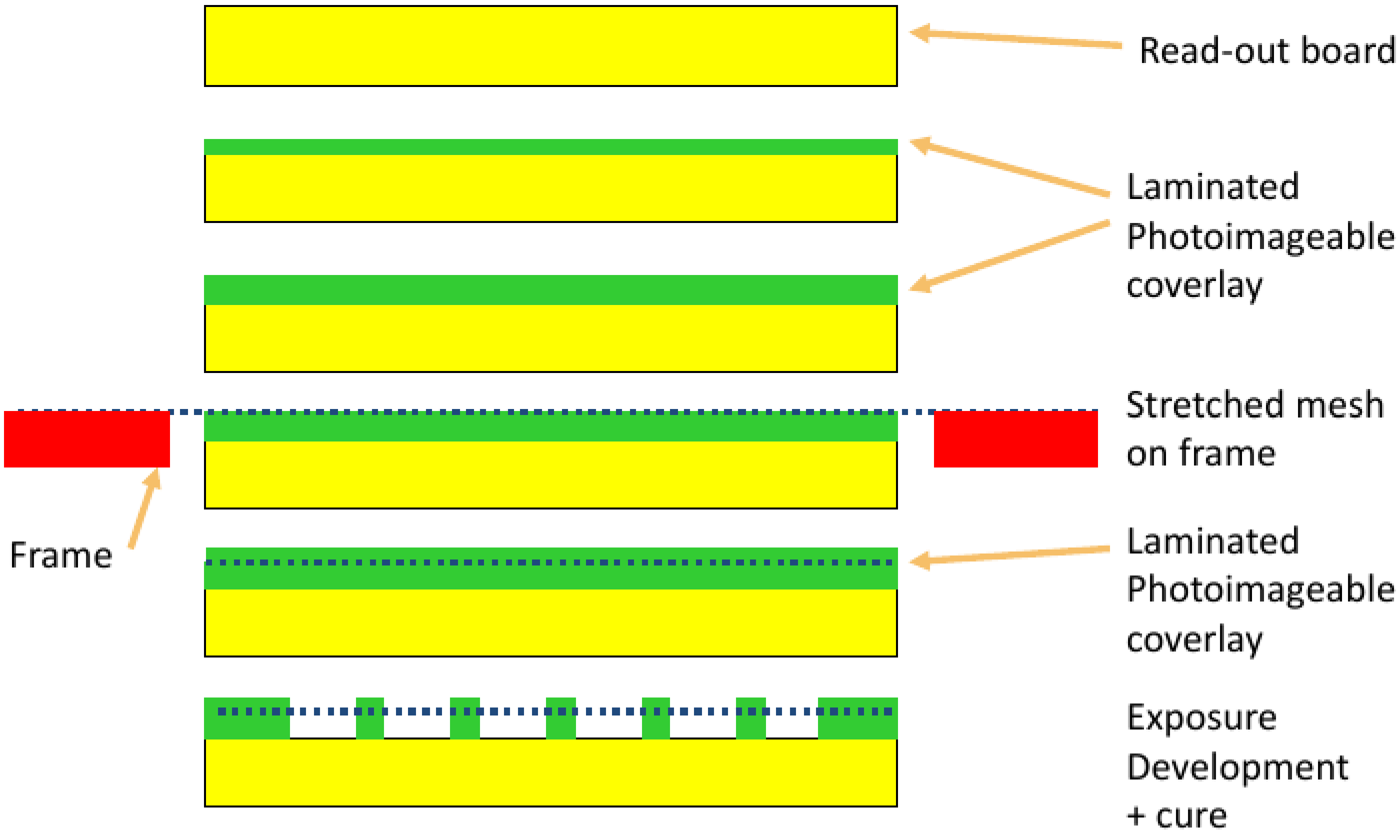
Items for R&D

- Overall design and optimization of the detector
- Pressure vessel
- Gas mixture
- Gas amplification devices

Notice possibility to adopt innovative features developed by the ILC-TPC collaboration including resistive micromegas (charge spreading), readout electronics mounted directly on the Micromegas back plane, low mass cooling …

Notice also the synergy with the T2K near detector upgrade plans

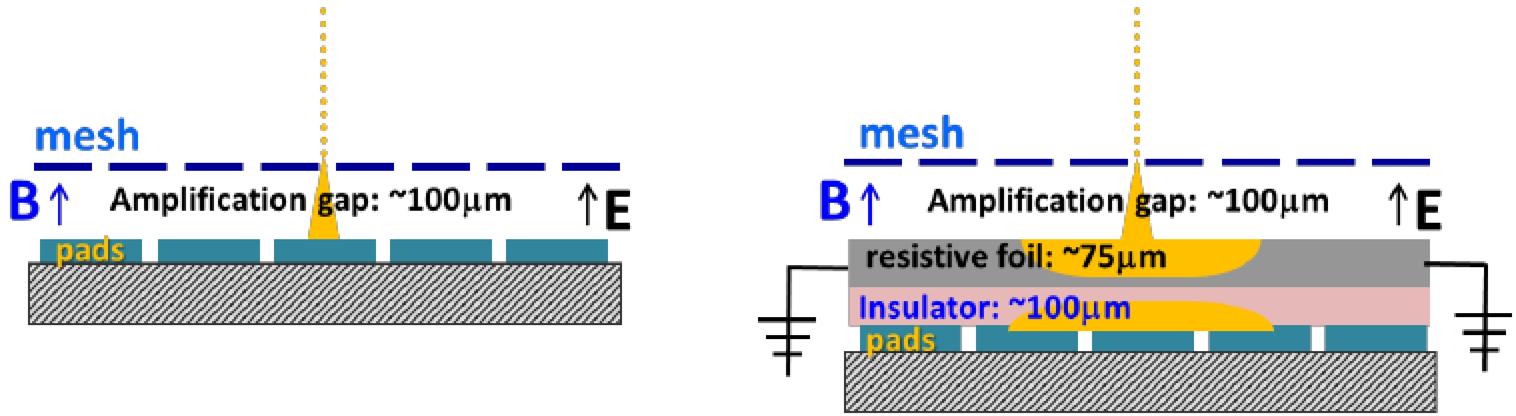
Bulk Micromegas

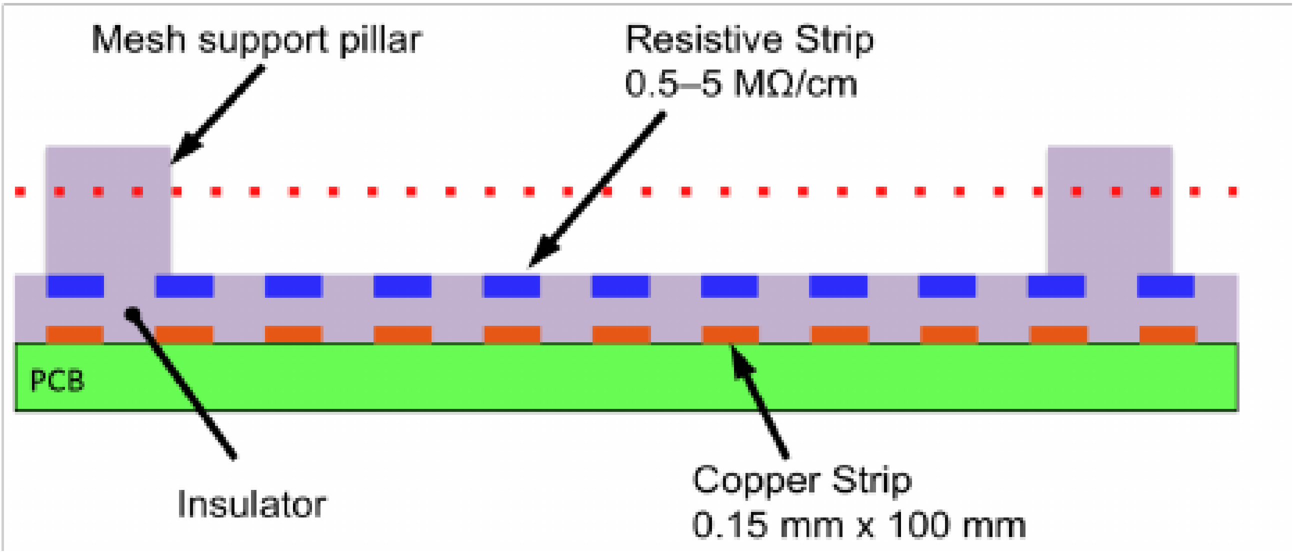


Proven technology. Saclay equipped with a new production line. Micromegas technology succesfully transferred to industry as part of the ATLAS New Small Wheel Phase I upgrade. Can also count with CERN (R. De Oliveira) workshop

Resistive Bulk Micromegas

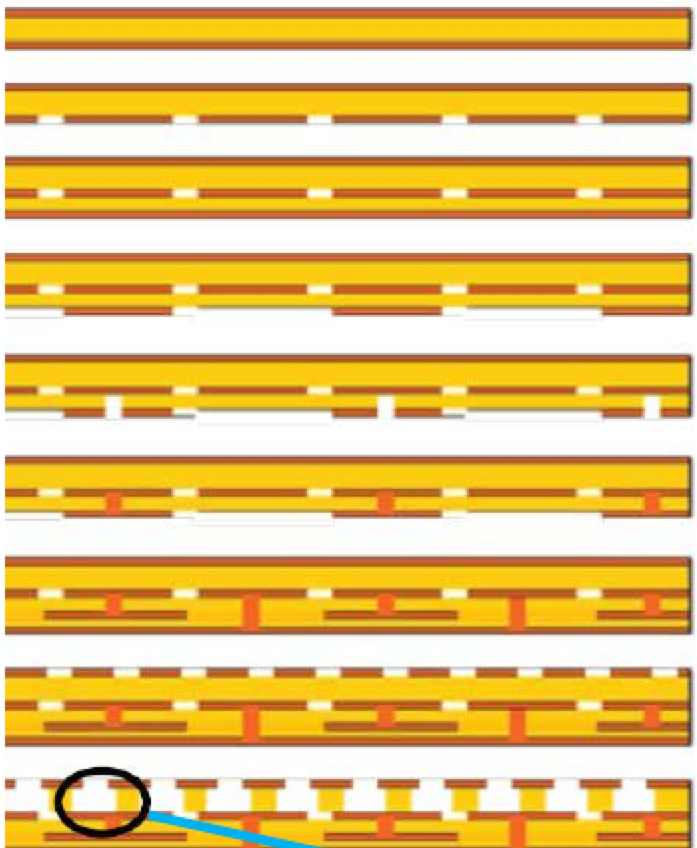
- Several advantages (charge spread, intrinsic spark protection)
-





R. De Oliveira
+R&D by Zaragoza group

Microbulk technique



Double side Cu-coated (5 μm) Kapton foil (50 μm),

Construction of readout strips/pads (photolithography)

Attachment of a single-side Cu-coated kapton foil (25/5 μm)

Construction of readout lines

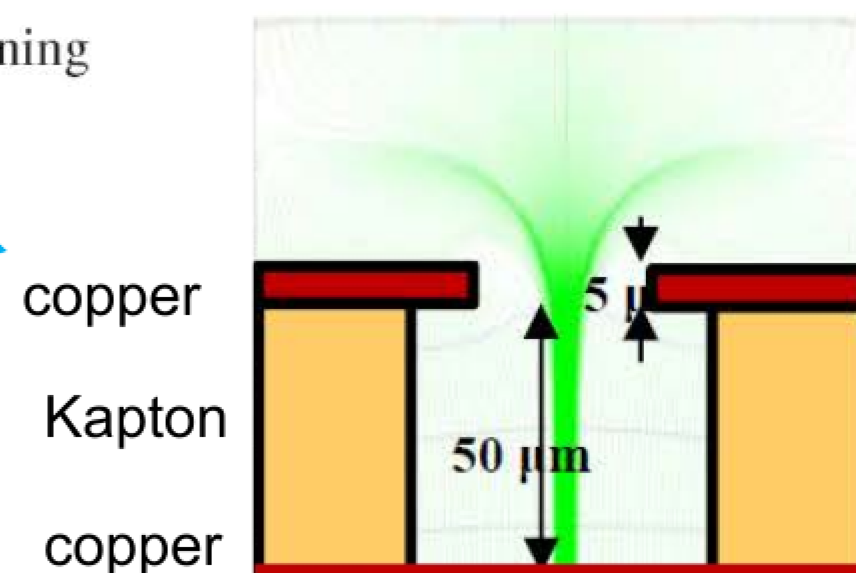
Etching of kapton

Vias construction

2^{nd} Layer of Cu-coated kapton

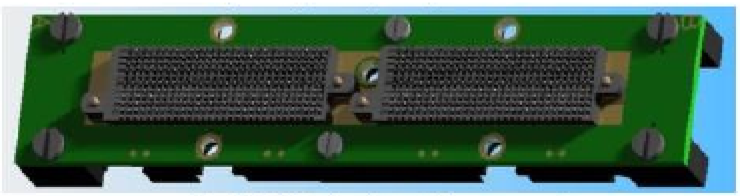
Photochemical production of mesh holes

Kapton etching / Cleaning

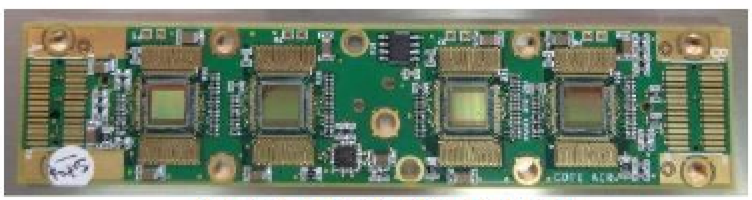


Single Amplification Cell

ILC TPC R/O electronics



(a) FECi Detector side connectors

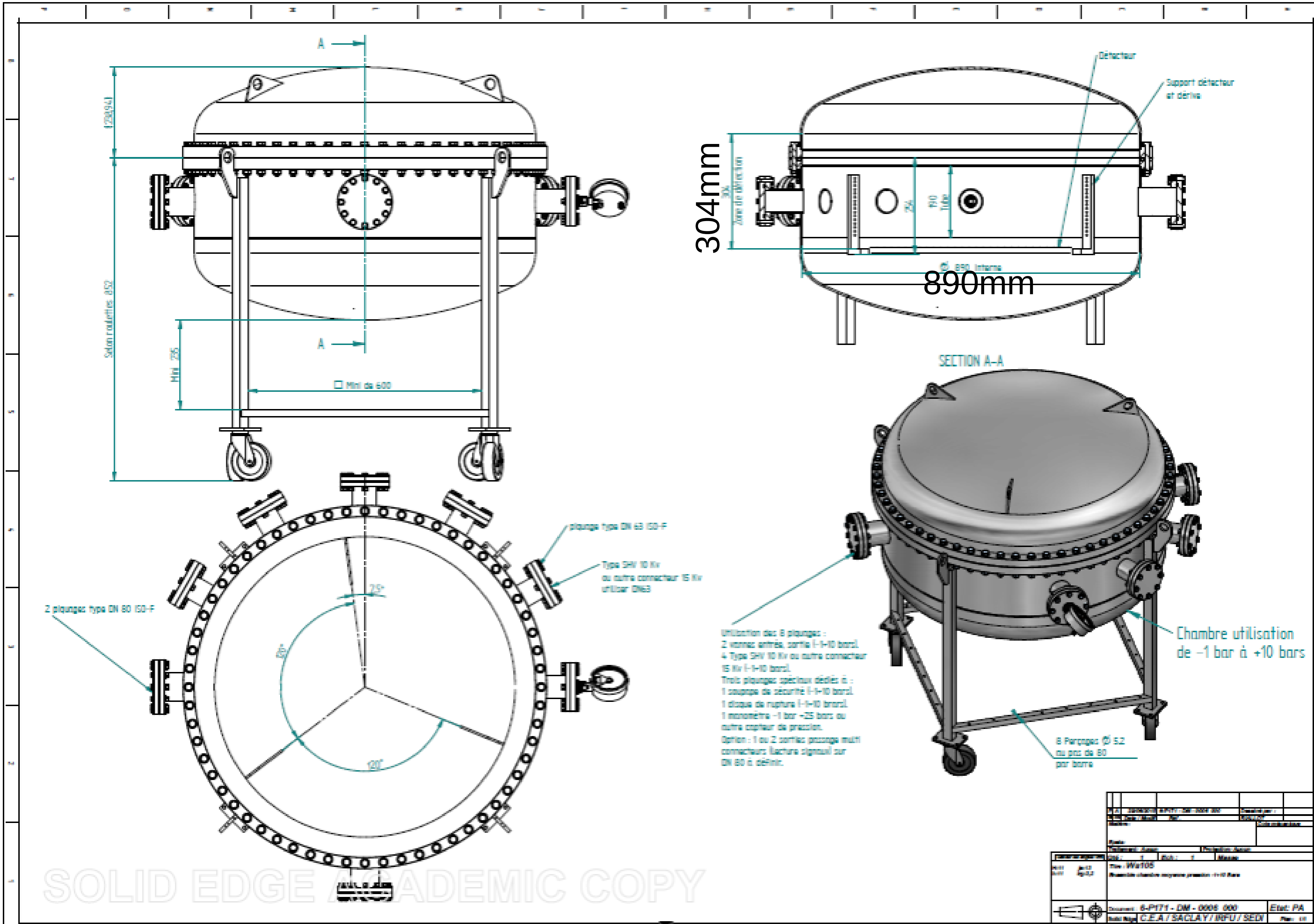


(b) Component side of a FECi

(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

Saclay high pressure test vessel



High pressure vessel at Saclay

- We have designed a high pressure vessel (12 bar) now in the phase of procurement (at Saclay in September)
- It is aimed at testing 50x50 cm**2 LEM (thick GEM) for the WA105 project and will be used until mid-2017
- It can host a small TPC setup (50x50 cm**2 for the readout, 20 cm drift)
- Possible items that can be studied: gas amplification devices (bulk Micromegas, microbulk …), gas mixtures, readout electronics

Next steps

- In July 2015 a workshop on HPTPC took place at IFAE and F. Sanchez coordinated a European ITN proposal (unfortunately not approved by EU)
- The group of people interested (France, Switzerland, UK, Spain, Poland, Italy …) is practically the same as those interested in atmospheric pressure TPC for the T2K-II near detector upgrade
- Moreover a HPTPC is also a very appealing option for the DUNE near detector
- We aim to submit in the autumn an EOI to SPSC for the development of TPCs for neutrino experiments

Conclusions

- The HPTPC is a very powerful detector to shed light on neutrino interactions
- Several preliminary studies have already taken place
- But the time has come to plan a more systematic R&D and prototyping effort
- We should build on the existing tools and platforms, like the Cern neutrino platform and the EU funded projects to facilitate the next steps
- Based on the strong collaboration already active in HK, T2K, the T2K TPC and the T2K ND upgrade project