The WA105-3x1x1 m3 dual phase LAr-TPC demonstrator

Sebastien Murphy ETH Zurich

on behalf of WA105
DUNE Far detector R&D

Large scale LAr TPC for LB neutrino oscillation physics, astrophysics, and nucleon decay search (GUT physics). (See talk Elizabeth Worcester).

- Single cryo-tank based on industrial LNG solution to house $O(10)$ kton of LAr mass. Envisaged options for single and dual phase TPCs. (See talk Alexander Himmel).
- R&D for double-phase for charge readout with amplification yields
  - **One drift distance** (bottom to top) for cost effective large scale detectors
  - **Low energy detection thresholds** as needed for physics
  - **High reconstruction efficiency** thanks to collection only readouts planes. Maximise active LAr volume whilst minimising the number of channels.
  - **Robustness of signal-to-noise** with respect to environmental sources thanks to tunable amplification.
  - 3x3 m² PCB based modular charge readout plane (no extensive wiring) allow for easy industrial procurement, off site assembly and shipping.
Outcome of 10 years of R&D

10x10cm²: LEM/anode R&D

40x80cm²: stable operation of large area readouts

Max Gain 180 = MIP S/N ~900!

Stable Gain 20 = MIP S/N 100

Operating with amplification of about a factor 20

X pitch: 3 mm
Y pitch: 3 mm

Anode requirements for large area readout

ϕ

\[
dC/dl \sim 120 \text{ pF/m}
\]
Dual phase readout

View 0: Event display (run 15937, event 22)

View 0: Signals (run 15937, event 22)

Real events on 250 liter LAr dual phase TPC

Raw waveform no software filtering

Literature
NIM A617 (2010) p188-192
NIM A641 (2011) p 48-57
JINST 7 (2012) P08026
JINST 8 (2013) P04012
JINST 9 (2014) P03017
JINST 10 (2015) P03017
More events

**cosmic muon**

**HADR shower**

**EM shower**
From R&D to large scale

- CERN b. 182
- CERN EHN1
- SURF SD
- 3x1x1 5 ton active - cosmics-
- ProtoDUNE Dual phase 300 ton active - test beam-
- DUNE Dual phase FD 10 kton active
Thanks to the CERN Neutrino platform the technology has evolved from the R&D stage to the construction of detectors with relevant size for neutrino physics.
The WA105 collaboration

demonstrate the capabilities of the dual phase technology at the kton scale

21 institutes 138 physicists
Construction of the 3x1x1 dual phase LAr TPC at CERN.
Operational this fall.
First step towards the realisation of 10 kton dual phase LAr TPCs.
3m3 Dual phase LAr TPC

Drift cage

Photomultiplier tubes

Muon
3m3 Dual phase LAr TPC

Charge Readout Plane

- Multilayer PCB anode
- Vapor
- Extraction grid
- Liquid

Drift cage

Photomultiplier tubes

CRP
3x1x1 detector and cryostat

**Top-cap:** 1.2 m passive insulating lid with all feedthroughs and services.

**Membrane cryostat:** corrugated stainless steel panels and 1 m passive insulation. Technology used in LNG transportation.

**3x1x1 detector:** suspended under the top cap.
3x1x1 detector and cryostat

top-cap

corrugated stainless steel panels and 1 m passive insulation. Technology used in LNG transportation.
High voltage feedthrough: this one up to 300 kV.

GND protection grid

Cryogenic cameras

Drift cage: fixed to top-cap

Charge Readout plane (CRP): extraction of charge readout and amplification in one module adjustable to LAr level

Signal feedthroughs: front end cards for amplification in cold. Can be removed without accessing main LAr volume

5 coated Photomultiplier tubes
3x1x1 detector

- sensors (LEM, anode)
- top-cap
- installation & safety
- light readout
- cryogenics (in & out)
- purity monitors
- chimneys & feedthroughs
- cryostat insulation & membrane
- drift cage & cathode
- very high voltage
- cryo cameras
- Fe & DAQ
- slow control & PVSS

Sebastien Murphy ETHZ
CRP for large area readouts

- fully active 3x1 m² amplification and readout adjustable to LAr level.
- All components industrially fabricated with most of the QA/QC performed by the companies.
- Mechanical tolerances validated in warm but also at LAr temperature in open cryogenic baths.
- Assembly is straightforward and quick (~2 people, 2 days)
purchasing and QA/QC aspects for both are now well under control. The construction of the 311 has been fundamental in defining this.

**LEMs**

- extensive experience on handling, cleaning, testing based on series of 20 (pilot) + 20 (final design) LEMs.

**Anodes**

- 4-layer 3.4 mm thick PCB
- Rather standard to manufacture
- Electrical continuity tested by company
- Minimal QC needed on our side.

Years of R&D devoted to design and testing of those crucial components.

C. Cantini et al 2015 JINST 10 P03017
C. Cantini et al 2014 JINST 9 P03017
purchasing and QA/QC aspects for both are now well under control. The construction of the 311 has been fundamental in defining this.

- They are **standard industry components**. A large part of the QA is done by the companies.
- Anode & LEM Modularity of 50x50 cm2 allows for ➡ practical shipping to assembly point.
  ➡ easy and rapid check of the individual components
- the assembly is **straightforward and quick** (~2 people, 2 days for the 3x1m2).
- The entire frame can be **dipped in LAr to check mechanical integrity** and fulfilment of tolerances in cold.
CRP resting on optical table - for flatness measurements
Charge Readout Plane

- Fully assembled CRP, partly instrumented and dipped in LAr with photogrammetric targets
- check resistance to thermal shock and planarity at cold as well as signal continuity.

3x1 m² CRP suspended in an LN2 bath for flatness measurements (photogrammetry) and contacts in cold
The access to electronics without emptying/contaminating inner detector volume is critical for long term operation.

Proximity of pre-amplifiers to the readout is also an important aspect.

Limit noise due to cable capacitance

Front-end electronics is housed in “chimneys” which are physically isolated from cryostat / ambient environment with vacuum tight feedthroughs.

Could be accessed/replaced without opening cryostat.
Signal feedthrough

parts of FE plugged in - measurements of noise ongoing
High voltage Feedthrough

As detectors get larger so does the required HV. Developing feedthroughs that can transport several hundreds of kV through gas and liquid argon. Very important topic for the field. Lot’s of ongoing R&D.

lab-tank interface: high voltage feedthrough
transport (3 cm diameter coax cable)
generation (very high voltage PSU)
As detectors get larger so does the required HV. Developing feedthroughs that can transport several hundreds of kV through gas and liquid argon. Very important topic for the field. Lot’s of ongoing R&D.
High voltage Feedthrough

Successful design of ICARUS 150 kV Feedthrough has been scaled up to 300 kV, designed for the protoDUNE dual phase (6 m drift).

Feedthrough designed for 300 kV is installed on the 311. Currently under test.
Crucial part of the experiment is all the slow control. Large development and new types of sensors and acquisition system has been developed. ->same system will be used on protoDUNE & DUNE Dual Phase.
The plan

2015
Feb ... May ... Aug ...
CRP frame delivered

2016
Feb Jan Mar Apr May June July Aug Sept Oct Nov Dec
CRP 1st cryogenic bat test
CRP installed under top-cap
all FE boards inserted

cryostat constructed
LEMs & anode delivered
drift cage delivered
top-cap delivered
weld top-cap

Front Ends inserted in first chimney and tested
noise testing with detector in cryostat
cryogenics installation complete
full detector lifted in cryostat

System ready for commissioning
The detector was fully assembled and tested outside the cryostat suspended from the top cap. On July 4th 2016 the detector was lifted and inserted inside the cryostat.
Detector inside the cryostat
**Conclusion**

After a decade of R&D on smaller prototypes, the first large scale dual phase detector is now constructed. Data taking is about to begin.

This milestone is a first step towards the cost effective realisation of giant liquid argon TPCs.

The dual phase design is considered for the second and subsequent modules of the DUNE far detector, providing several benefits compared to the baseline design.

Although of much larger volumes the protoDUNE 6x6x6 m$^3$ and DUNE 12x12x60 m$^3$ dual phase TPCs are constructed following a modular approach. Most of those components are identical to those already successfully installed in the 3x1x1.

First results from the 3x1x1 expected by the end of the year.
CRP: adjustable to LAr level

Suspended by 3 ropes coupled to motors on top-cap. Precision of motors 100 um over 4 cm.

8 capacitive level meters readout the LAr level with similar precision.
LEM thickness measurements

Mean Thickness

FR4 + copper

20 um

15 um

1σ Thickness deviation

Thickness [mm]

1
1.05
1.1
1.15
1.2
1.25
20 um
15 um

FR4 + copper

LEM thickness measurements
Detector installation
Detector installation
Complete detector assembled in TAS

Clean room

Cryostat

CRP assembled in clean room

Detector assembly structure
And from TAS to cryostat
The cryostat itself is an important part of the R&D. GTT (France) licence. Corrugated membrane steel panels used for storage and transport of Liquified Natural Gas.
Purification monitor

- Design follows ICARUS PrM design
- Hamamatsu Xenon lamp
- Photocathode:
  - fused silica window (λ/4 quality surface at 632 nm, i.e. < 0.1 μm surface irregularities)
  - 500 nm Al coating (at London Centre of Nanotechnology)
  - photoelectric effect: Al work function 4.08 eV (~300 nm)
- 600 μm Cu cladded UV fibre guides the light onto the PHC
- SS fields shaping rings
- Nickel mesh
- Al Faraday cage
- Amptek charge amplifier
Wiring and testing the chimneys

1. prepare 1.5 m blade with a fake FE card (to test continuity)

2. insert the blades

3. test the connections

4. insert on top-cap
Top-cap

- Gas purging and cooling down
- Pure liquid argon return
- 3 slow control feedthroughs
- 1 HV FT
- Liquid argon for cooling down
- 3 anode suspension FT
- 1 Cryo-pump Chimney
- Vent
- Signal feedthroughs
- 1 Manhole
- Boil off gas purification