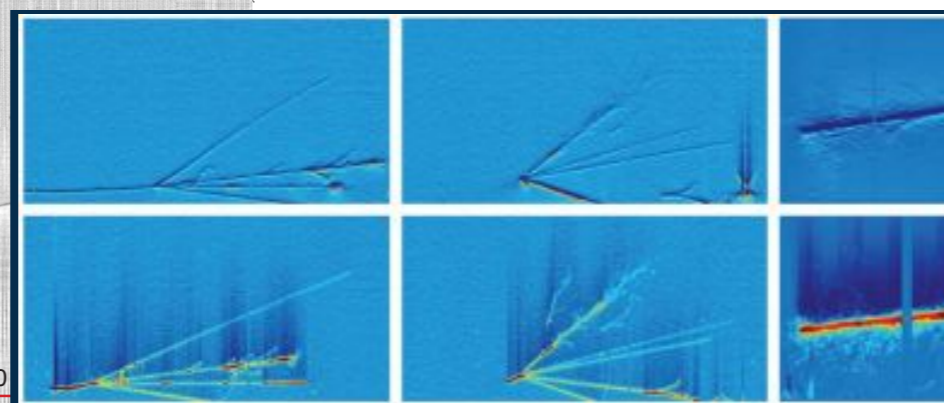
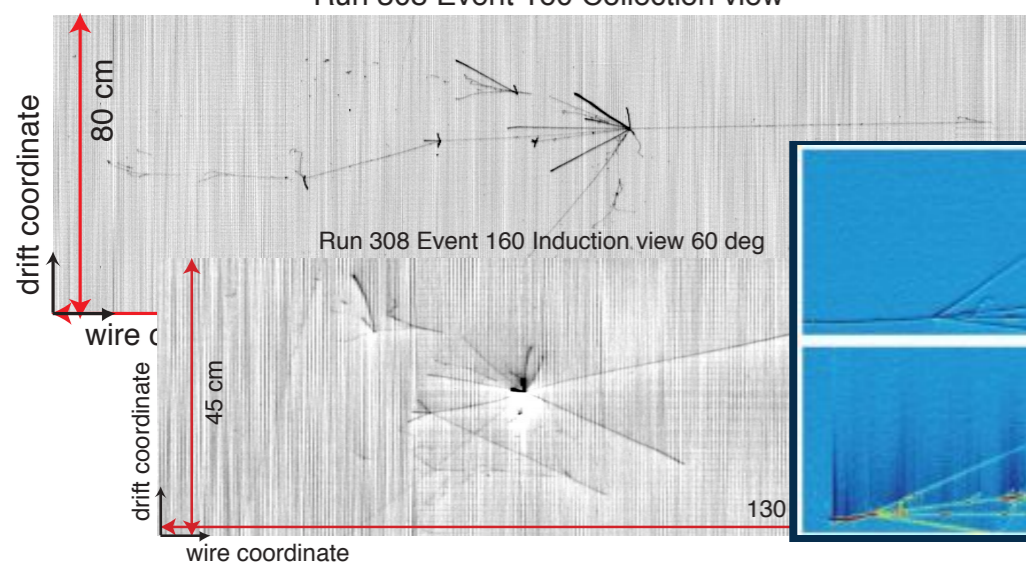


DUNE: Detectors

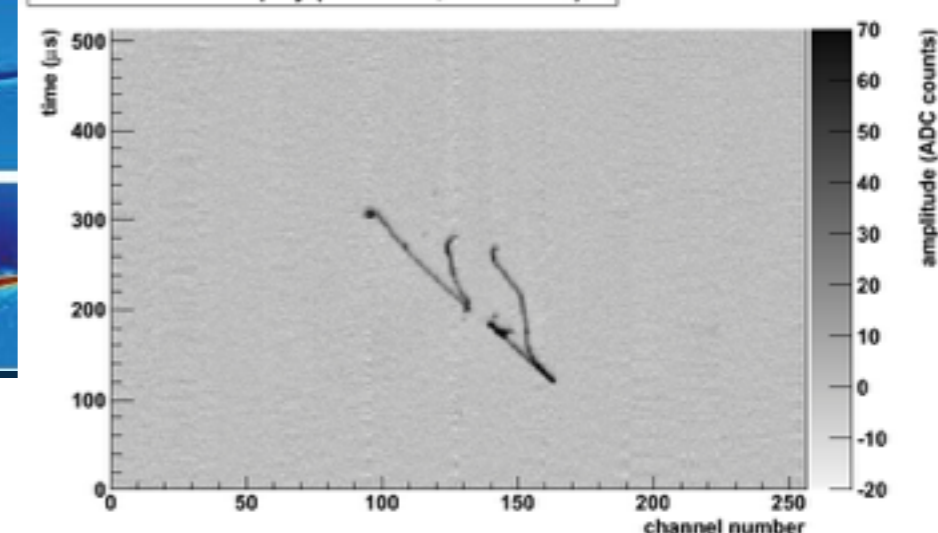
André Rubbia

Run 308 Event 160 Collection view

Run 308 Event 160 Induction view 60 deg



View 0: Event display (run 14456, event 8044)



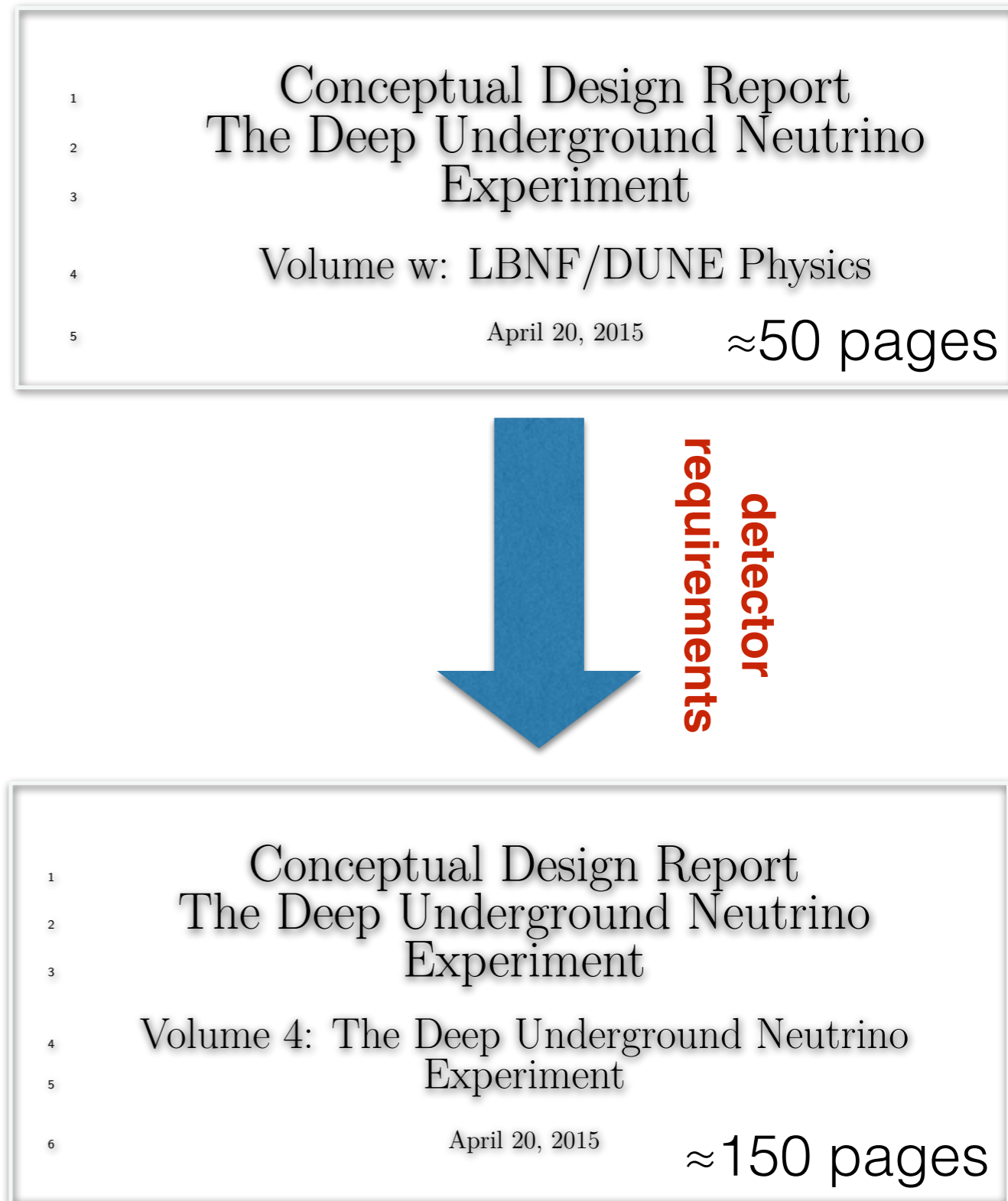
April 20, 2015

Foreword

- **The science of DUNE will require to achieve small systematic errors in order to fully exploit the statistical power that will be available thanks to the huge mass (40 kton) of the far detector and the very intense (MW-scale) neutrino beam.**
- **There will be several sources of systematic errors:**
 - neutrino flux related uncertainties
 - neutrino interactions uncertainties (in the GeV-range)
 - detector related uncertainties
- **The goal is to reach the smallest possible systematic errors, e.g. normalisation of events at the level of 1-2%, including the detector related systematic uncertainties.**
- **These issues will be addressed by dedicated test beams at the CERN Neutrino Platform and the SBN programme (see also next talk on systematic errors).**

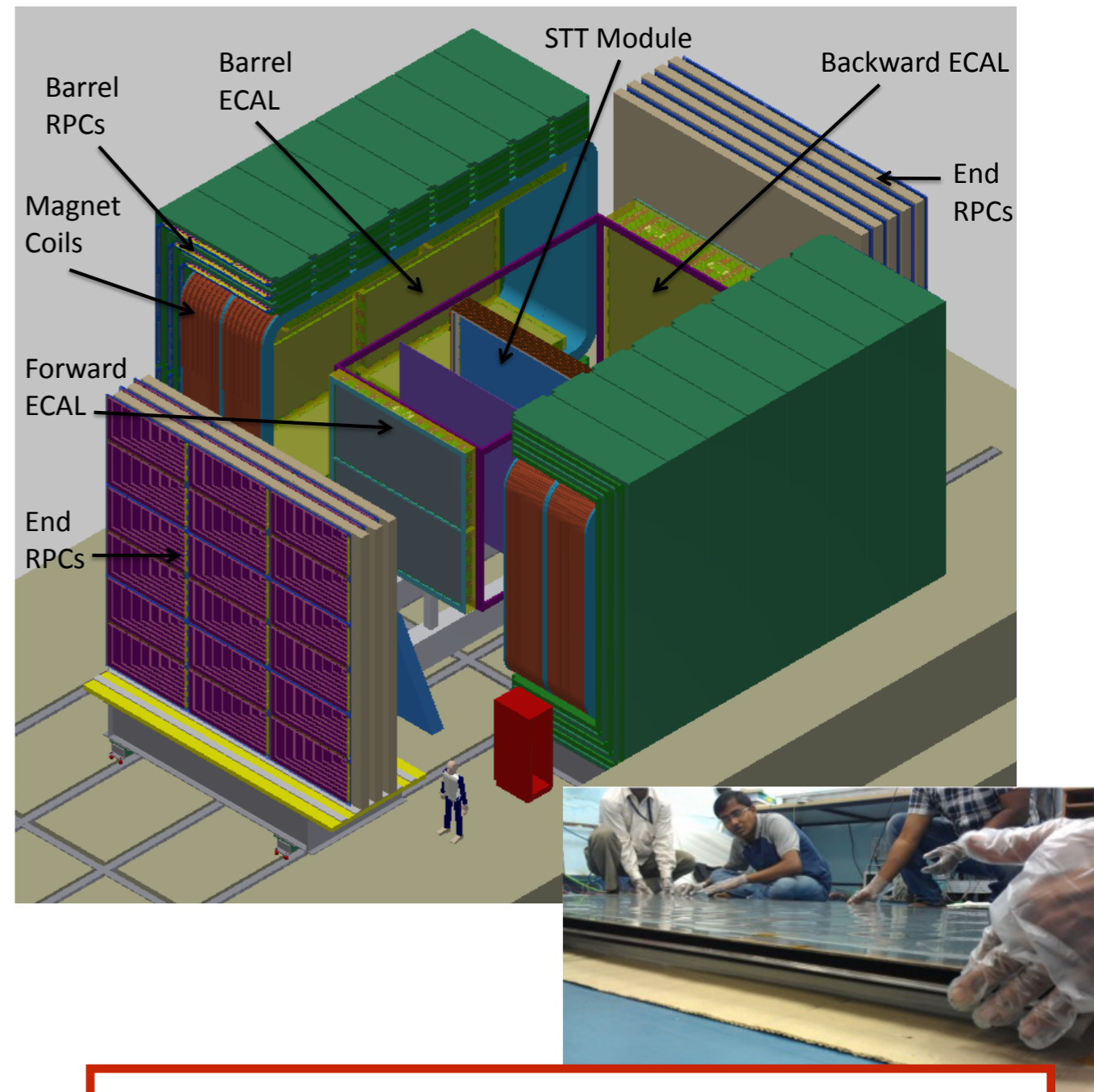
Conceptual Design Report (in preparation)

- **Detector concepts will be described in the LBNF/DUNE Conceptual Design Report is in preparation (Timescale: 07/15)**
- **High-level documentation with reference to existing and/or annexed material**
 - Vol. 1 – Introduction and Executive Summary
 - Vol. 2 – Physics (FD+ND)
 - Vol. 3 – LBNF
 - Vol. 4 – DUNE (FD,ND,prototypes)
- **Science goals drive the detector requirements.**



Near detector - reference design

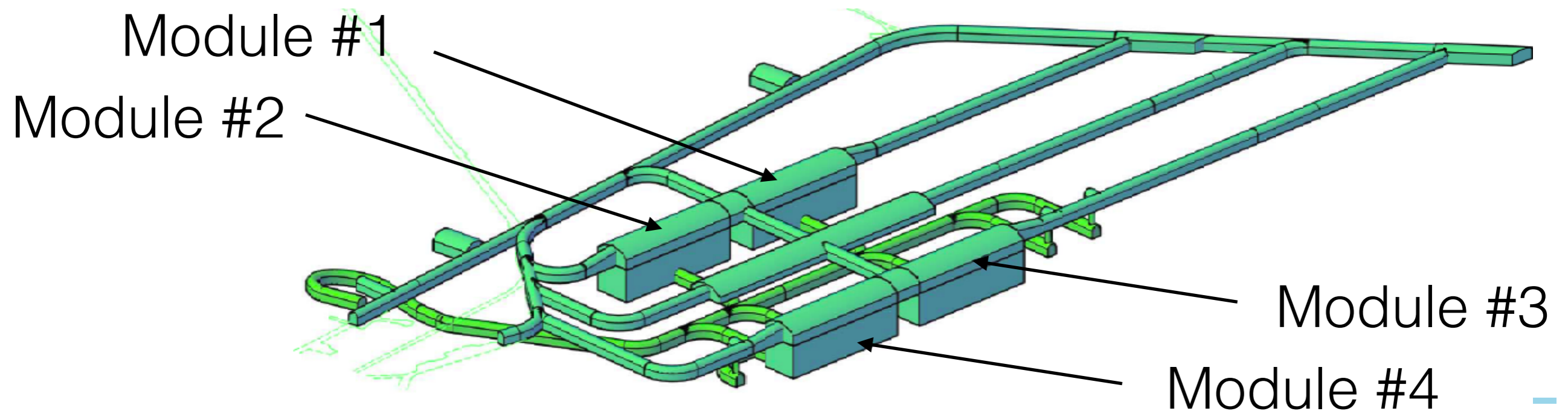
- A **highly-capable neutrino detector** which provides the **required information for LBL goals** and a **rich physics program on its own**.
- **Fine-grained tracker (FGT) magnetised neutrino near detector**.
- A **LAr TPC target** may be added for comparison with FD [need measures for event pileup at high beam power].
- May be advantages of deploying a **high-pressure gaseous argon TPC** [upgrade of the FGT tracker]
- **Complete design ongoing**.



A very complete magnetised neutrino detector (magnet +tracker+calorimeter+ μ catcher)

Far detector - the path towards 40 kton

- **Four independent 10 kton fiducial modules:**
 - ◆ Target date for instrumenting the first cryostat is 2021/2022.
 - ◆ The cryostat for the second detector should be available when the first cryostat is filled (sloshing / risk mitigation).
 - ◆ The aim is to install third and fourth cryostats beyond that as rapidly as funding will allow, instructed by the gained experience.
- **Road to first 10 kton by 2021 is challenging → success of large-scale demonstrators at CERN Platform and SBN are critical.**



R&D path towards large cryostats



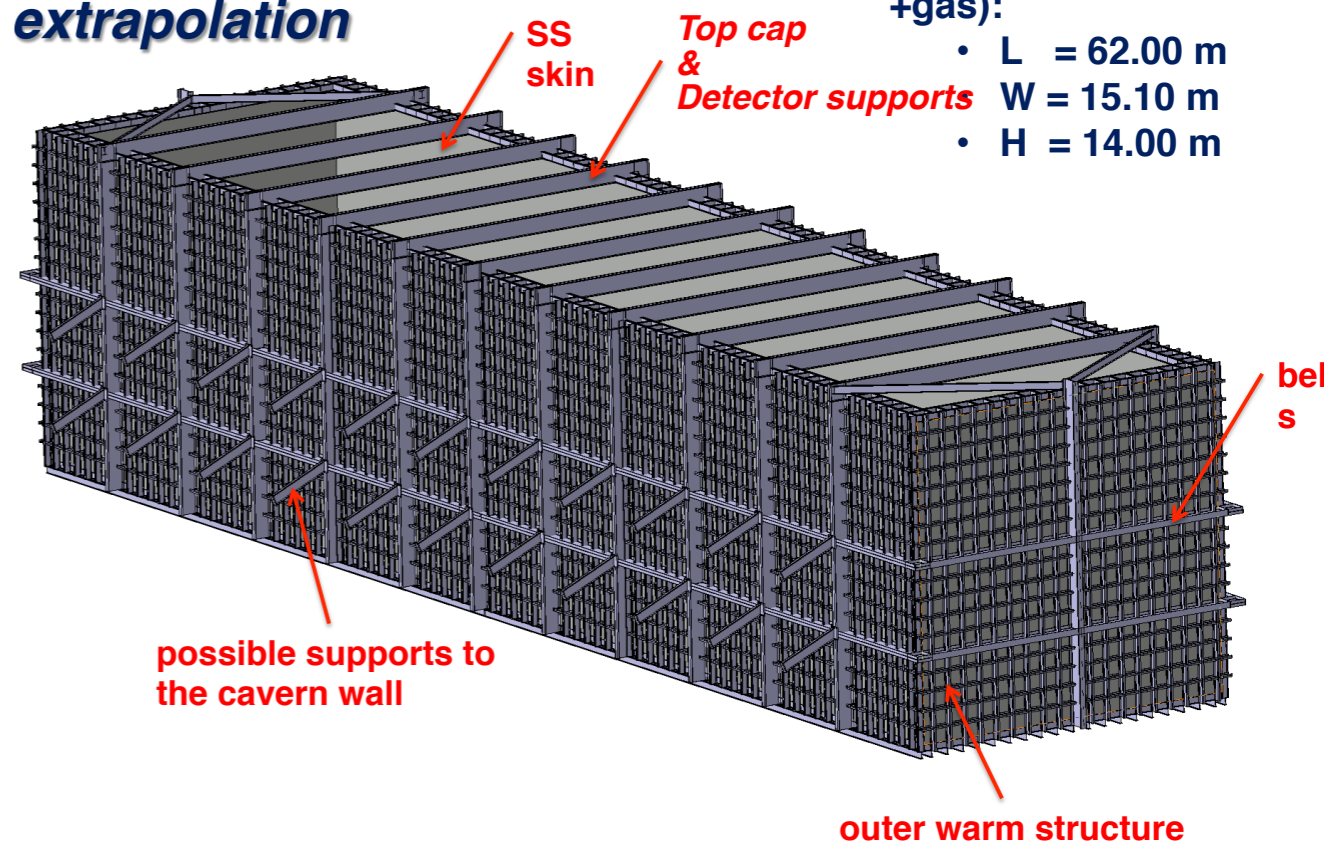
x 700



**4 LBNF Cryostats
extrapolation**

Inner dimension (liquid
+gas):

- L = 62.00 m
- W = 15.10 m
- H = 14.00 m

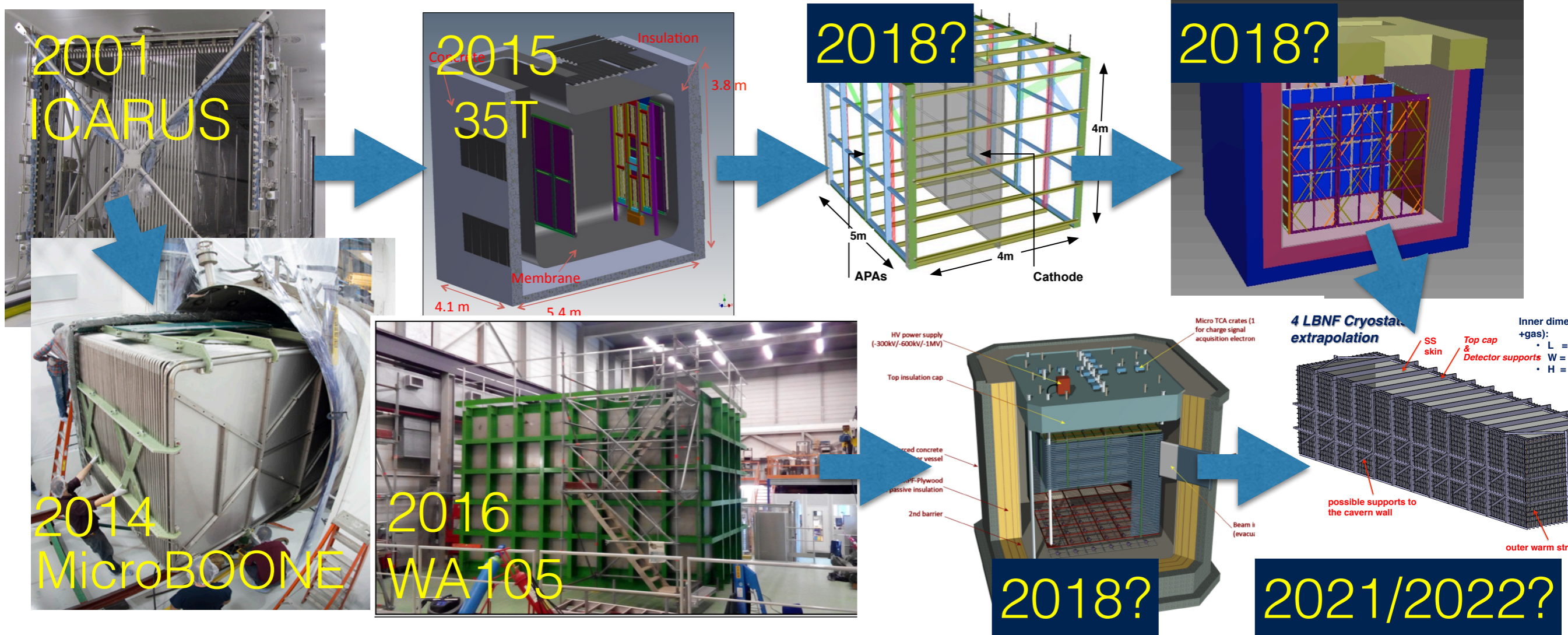


LAr = 17'432 tons (95% liquid)

- **GTT membrane technology for effective underground storage of ultra pure liquid argon** → many years of studies now materialising
- **Today: WA105 prototype**
 - ◆ Inner dimensions: 3x3x2 m³
- **Next steps:**
 - ◆ SBN ND, single phase proto
 - ◆ WA105 8x8x8 m³
- **DUNE 10 kton:**
 - ◆ 15.1(W)x14.0(H)x62m(L)

Far detector - the path towards 10 kton

- Ever growing number of LAr TPC's with ever evolving designs and performance, and of growing sizes...
- **CERN Neutrino Platform and FNAL SBN provide the necessary development and prototyping for the DUNE FD reference and alternative designs.**



10 kton detector designs (in CDR)

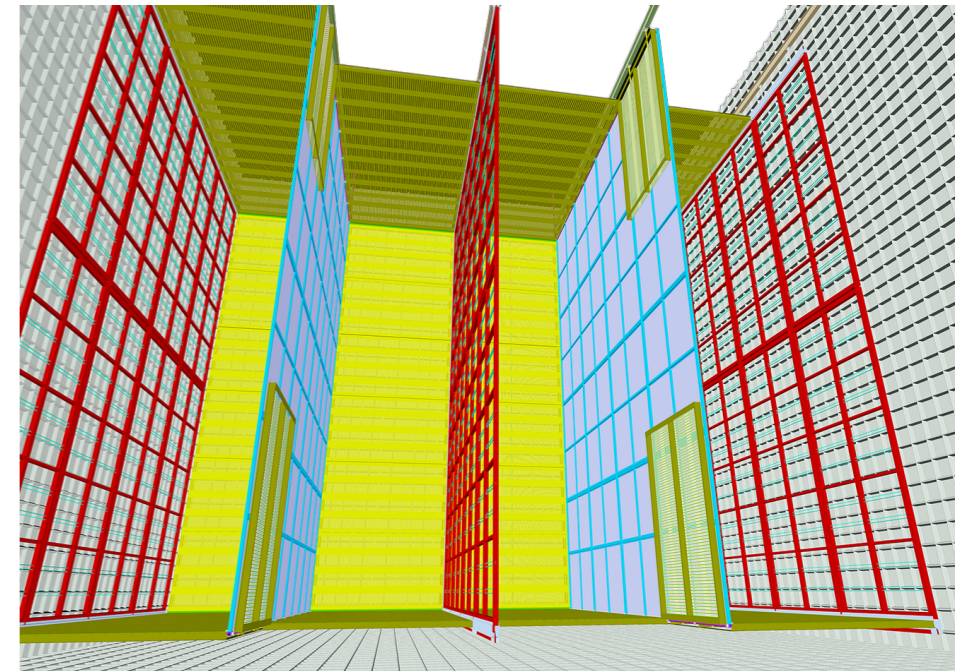
• Reference design

- ◆ Alternating CPA/APA assemblies, 2.3m(w)x6.3m(h) modules
- ◆ 4 wires planes (1 grid + 1 collection + 2 inductions), 4.8mm readout pitch
- ◆ **150 APAs** and **200 CPAs** / 10 kton
- ◆ **384,000** ionisation readout channels
- ◆ Embedded PD
- ◆ Active mass **14'128 tons**, fiducial **10'200 tons**

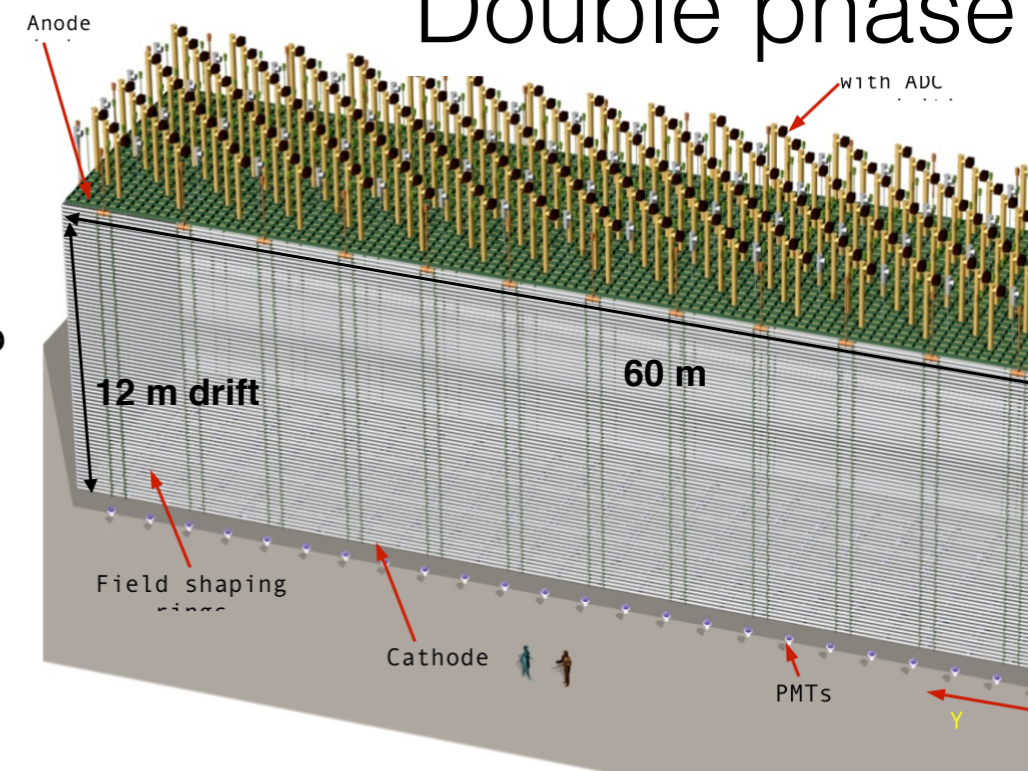
• Alternate design

- ◆ $3 \times 3 \text{ m}^2$ CRP modules placed at the gas-liquid interface
- ◆ 2 perpendicular “collection” views, 3mm readout pitch
- ◆ **45 CRPs** / 10 kton
- ◆ **153,600** ionisation readout channels
- ◆ Hanging field cage and cathode - decoupled from CRP plane
- ◆ Decoupled PD (w/ no. 720 8” PMT)
- ◆ Active mass **12'096 tons** (**10'643 fiducial**) for 12m drift
[15'120 tons (13'444 fiducial) for 15m drift]

Single phase



Double phase

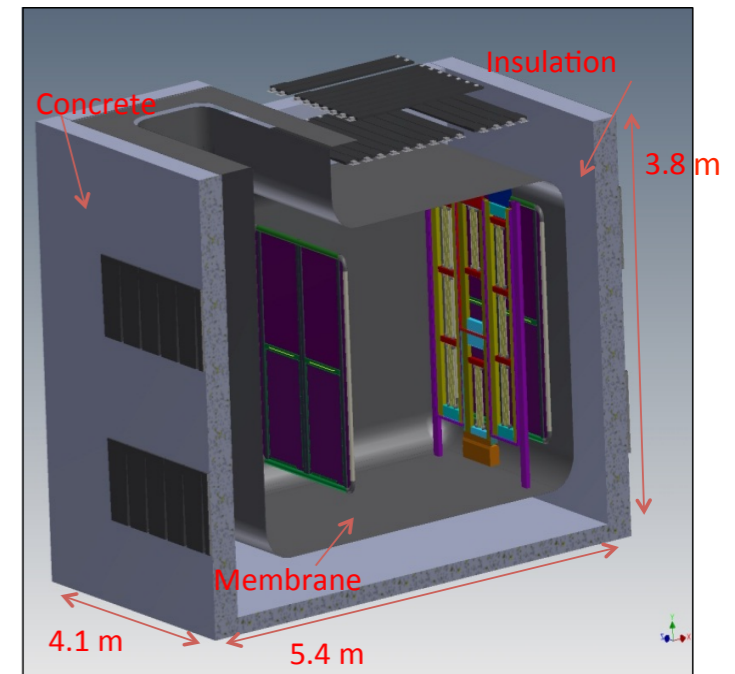


Far detector - from concept to reality

- **Reference design**

- ◆ **35 ton installed at Fermilab**

- Crucial test of concept
- 2.5m x 1.5m x 2m single phase TPC
- Two drift volumes (long/short)
- 4 APA modules (8 sets of wires)
- **Operation in 2015**



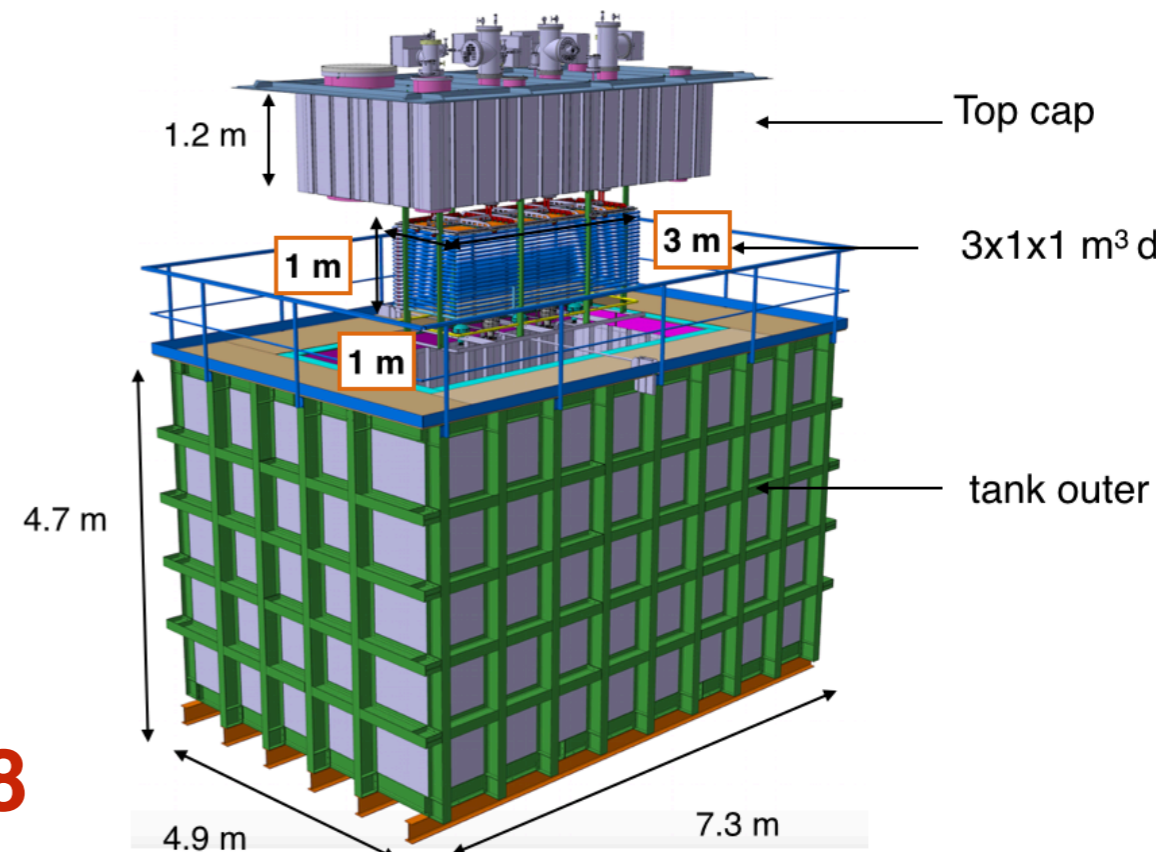
- **Alternate design**

- ◆ **WA105 3x1x1m³ at CERN**

- Crucial test of concept
- 3mx1mx1m double phase TPC
- **Operation in 2016**

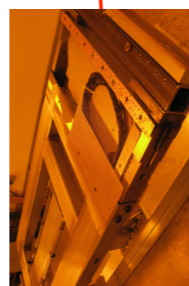
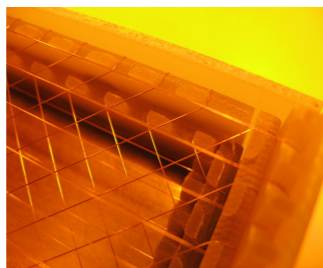
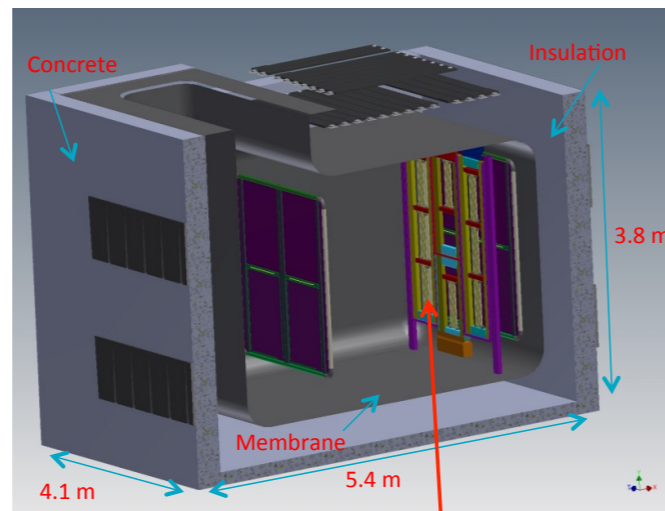
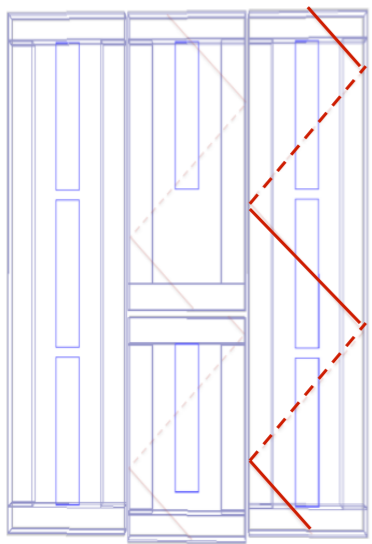
- **Synergies with SBN**

- ◆ MicroBoone **is cooling soon**
- ◆ LAr1-ND/ICARUS **operating in 2018**

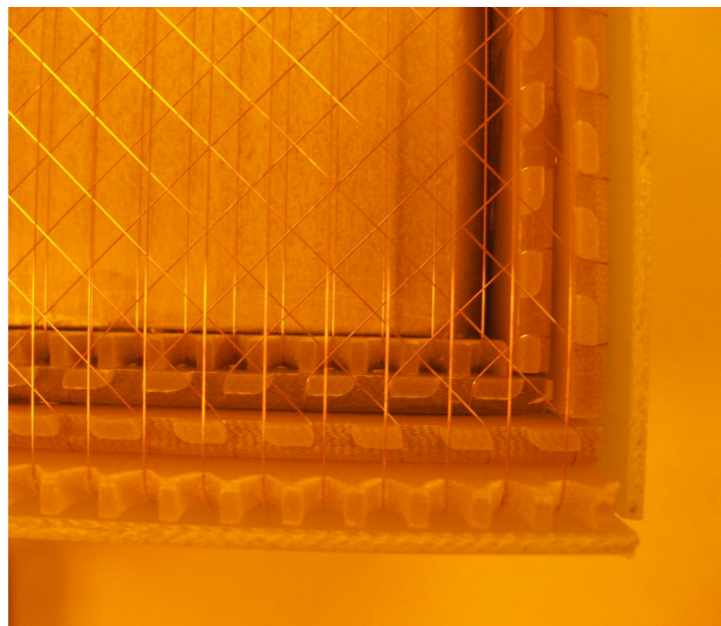
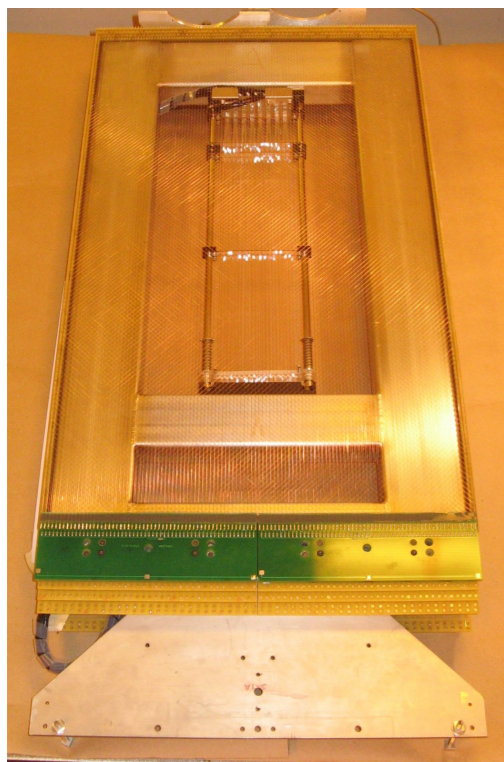


35 ton @ FNAL phase 2

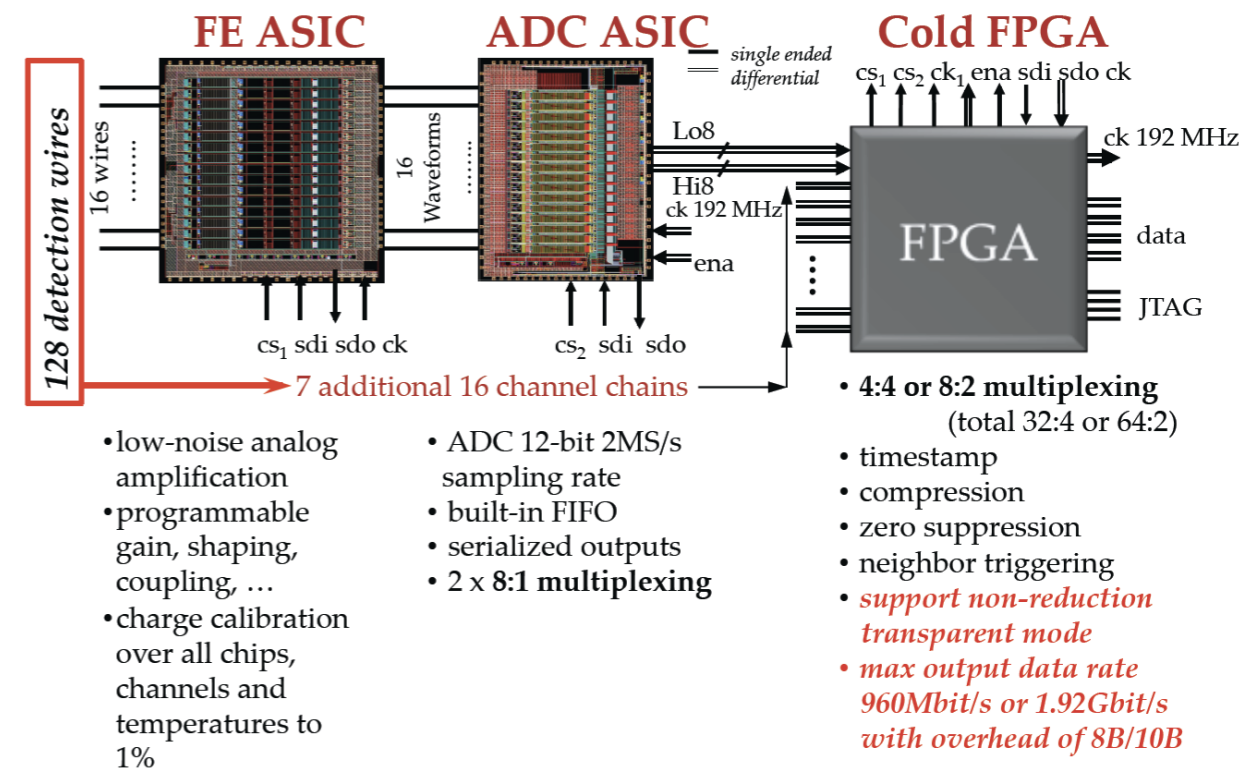
- 2.5m x 1.5m x 2m active volume
- Two drift volumes (long/short)
- 4 APA modules (8 sets of wires)



...

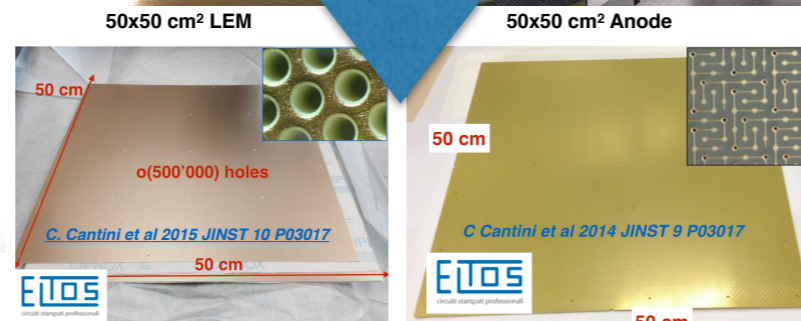
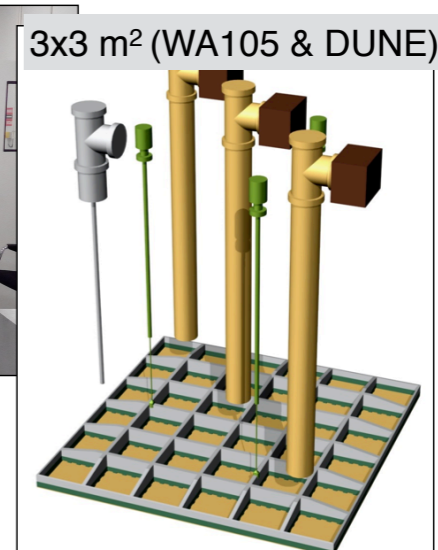
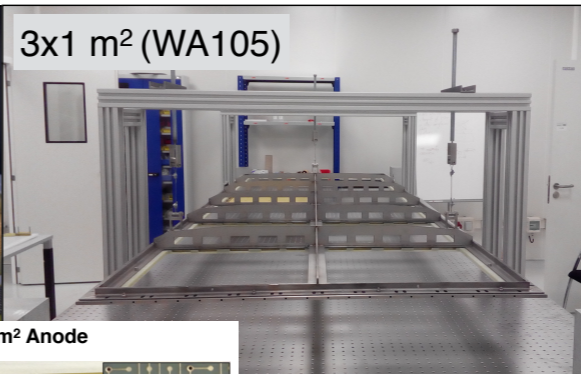
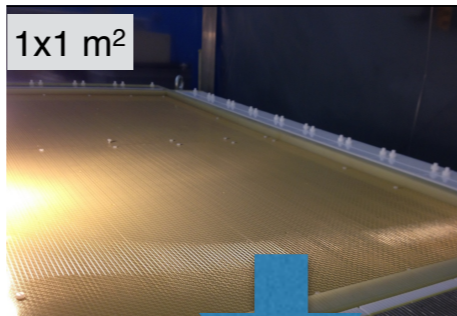
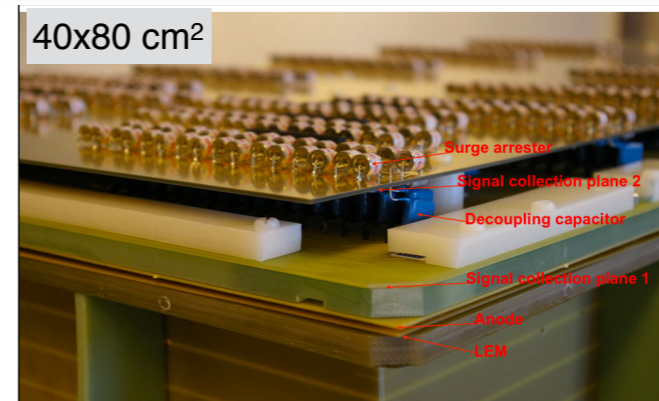
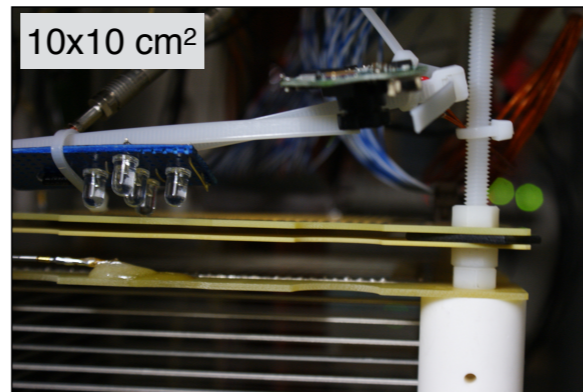
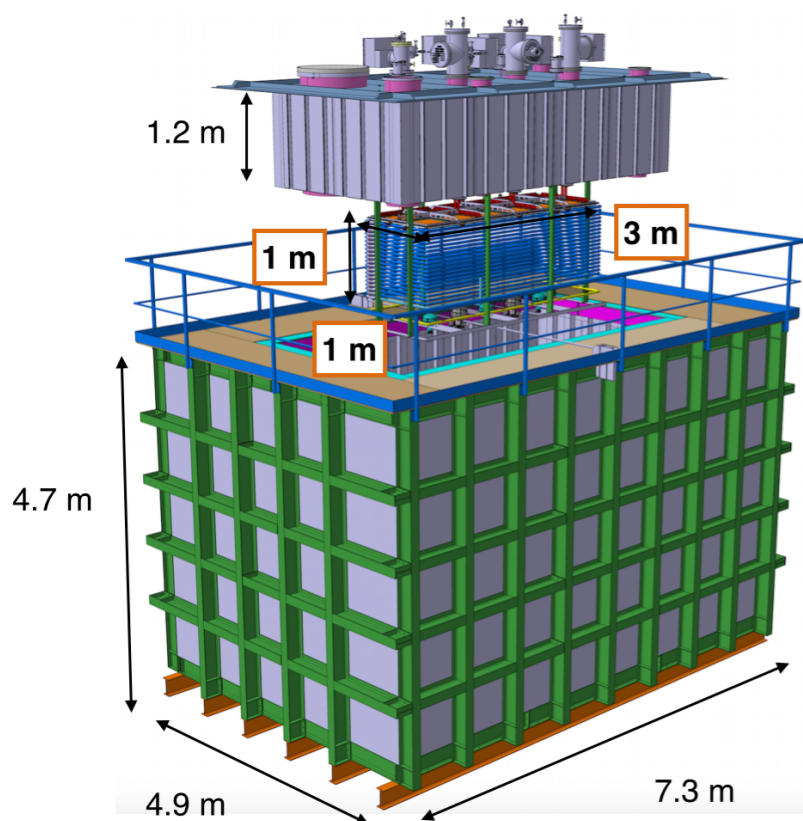


- Modular TPC performance:
 - wrapped wires
 - gaps between modules
 - tracks crossing APAs
- Bar+SiPM photon detectors
- Field Cage: FR4 printed circuit board
- Electronics/DAQ
 - cold pre-amp and ADC
 - triggerless operation (continuous readout)
 - zero suppression development



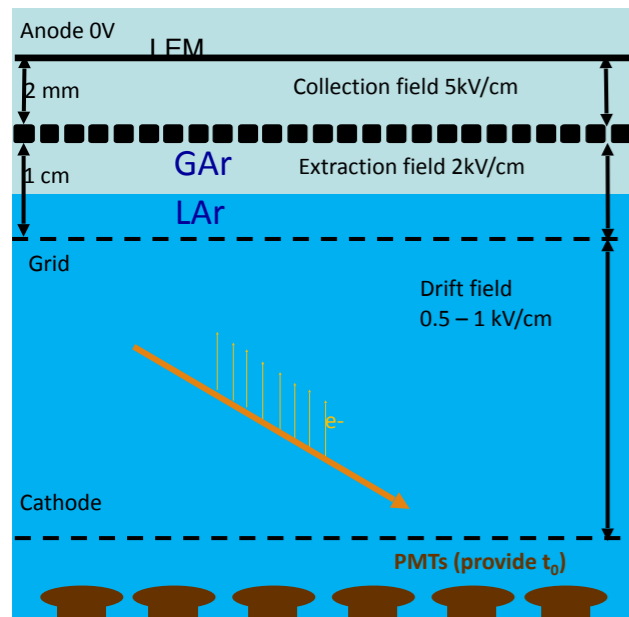
3x1x1m³ @ CERN Blg 182

LAr-Proto
(3x1x1 m³ active 24 ton LAr total)

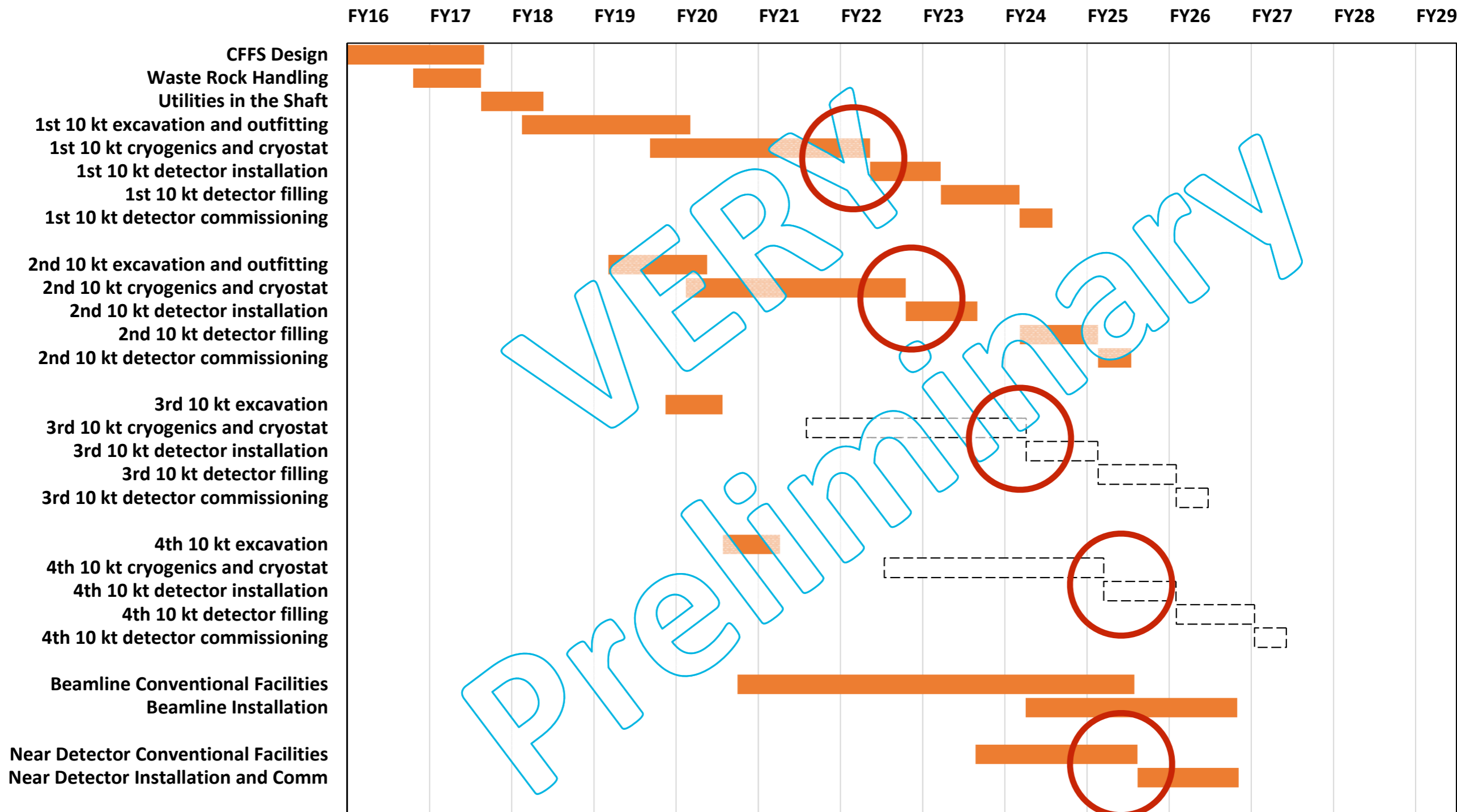


80 units for DUNE 10kton

- **Double phase ionisation readout (several years of R&D on small prototypes), field cage, PMT based light readout**
 - ◆ Extraction, amplification in holes (GEM-concept), segmented anode 3mm pitch, 2 x-y collection views
- **Accessible cold F/E electronics (lower risk than immersed electronics)**
- **17m³ cryostat under construction at CERN Blg 182**
- **Detector in procurement phase → integration in 2015**
- **Gas purging ≈ 2015?; Cryogenic operation ≈ 2016?**
- **Performance demonstration with cosmic rays**



Possible schedule



Conclusion

- DUNE strategy has evolved very rapidly. Starting from basic assumptions outlined in the LOI, we are developing **a solid strategy** – being described in the CDR.
- Conceptual designs for detector have been defined and provide the basis for cost estimations.
- A critical item is the success of the **now on-going prototyping efforts** such as 35ton @ FNAL and WA105 photo (3x1x1m³) @ CERN, to be followed by the large-scale final engineering demonstrators at the CERN neutrino platform on a timescale of ~2018.
- Target date for first far detector installation is ~2021/2022 with reference technology. Additional modules will be installed and commissioning subsequently.