The GLACIER Double Phase Liquid Argon TPC

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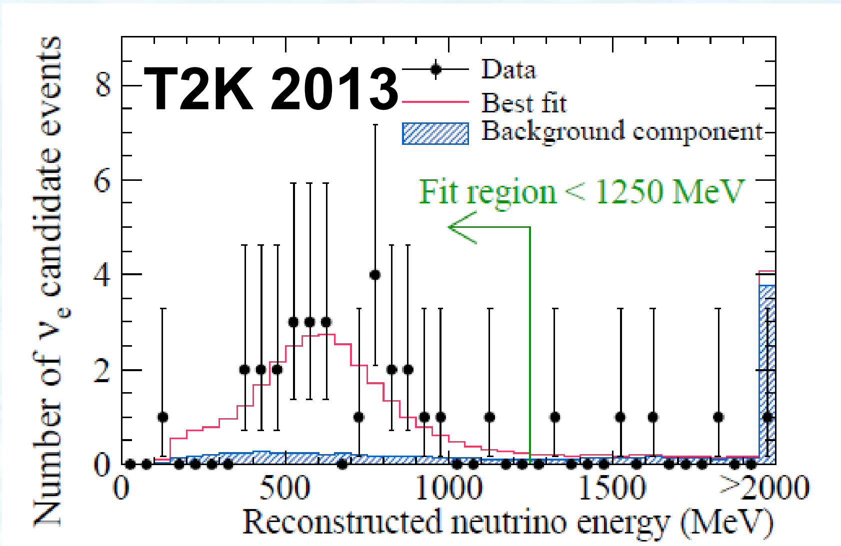
Outline

- Technological challenges of the PMNS study
- The GLACIER concept
- Proof of principle from prototypes
- LAGUNA and LAGUNA-LBNO: engineering studies towards construction plans
- Next steps

See also these related talks: T. Patzak on LBNO and D. Autiero on the WA105 program

The content of the talk is based on the results of the LAGUNA and LAGUNA-LBNO design studies (EU, FP7)

Neutrino oscillation and the study of the PMNS model



28 events (4.9+-0.6 bck)
Conclusive observation of $\nu_\mu \to \nu_e$

Sensitivity to non leading terms, including CPV and MH, requires a larger far detector, higher beam power and improved detection technology

$$P(\nu_\mu \rightarrow \nu_e) \approx \sin^2\theta_{23} \frac{\sin^2 2\theta_{13}}{(\hat{A}-1)^2} \sin^2((\hat{A}-1)\Delta)$$

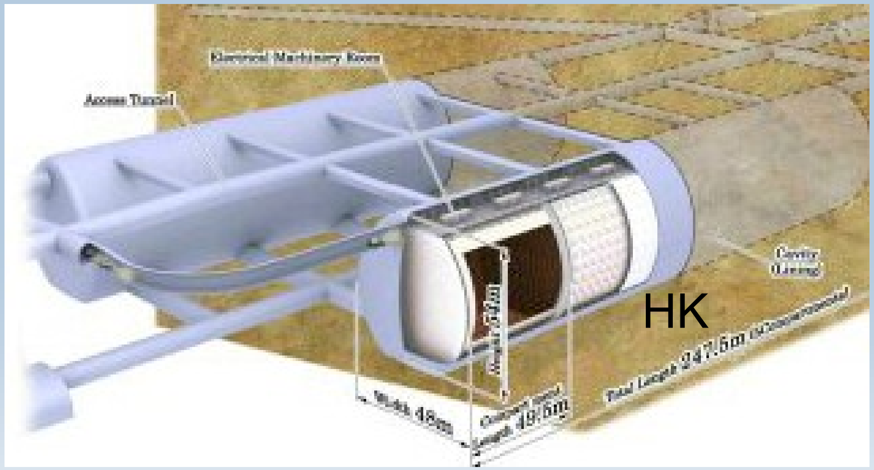
$$+\alpha \frac{8 J_{CP}}{\hat{A}(1-\hat{A})} \sin(\Delta) \sin(\hat{A}\Delta) \sin((1-\hat{A})\Delta)$$

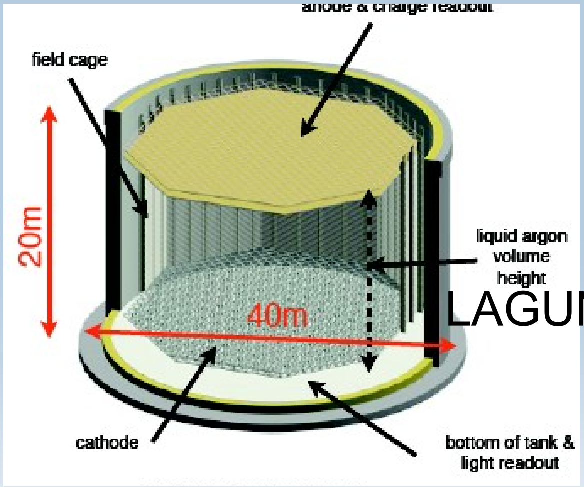
$$+\alpha \frac{8 I_{CP}}{\hat{A}(1-\hat{A})} \cos(\Delta) \sin(\hat{A}\Delta) \sin((1-\hat{A})\Delta)$$

$$+\alpha^2 \frac{\cos^2\theta_{23} \sin^2\theta_{12}}{\hat{A}^2} \sin^2(\hat{A}\Delta)$$

The two strategies towards CP violation

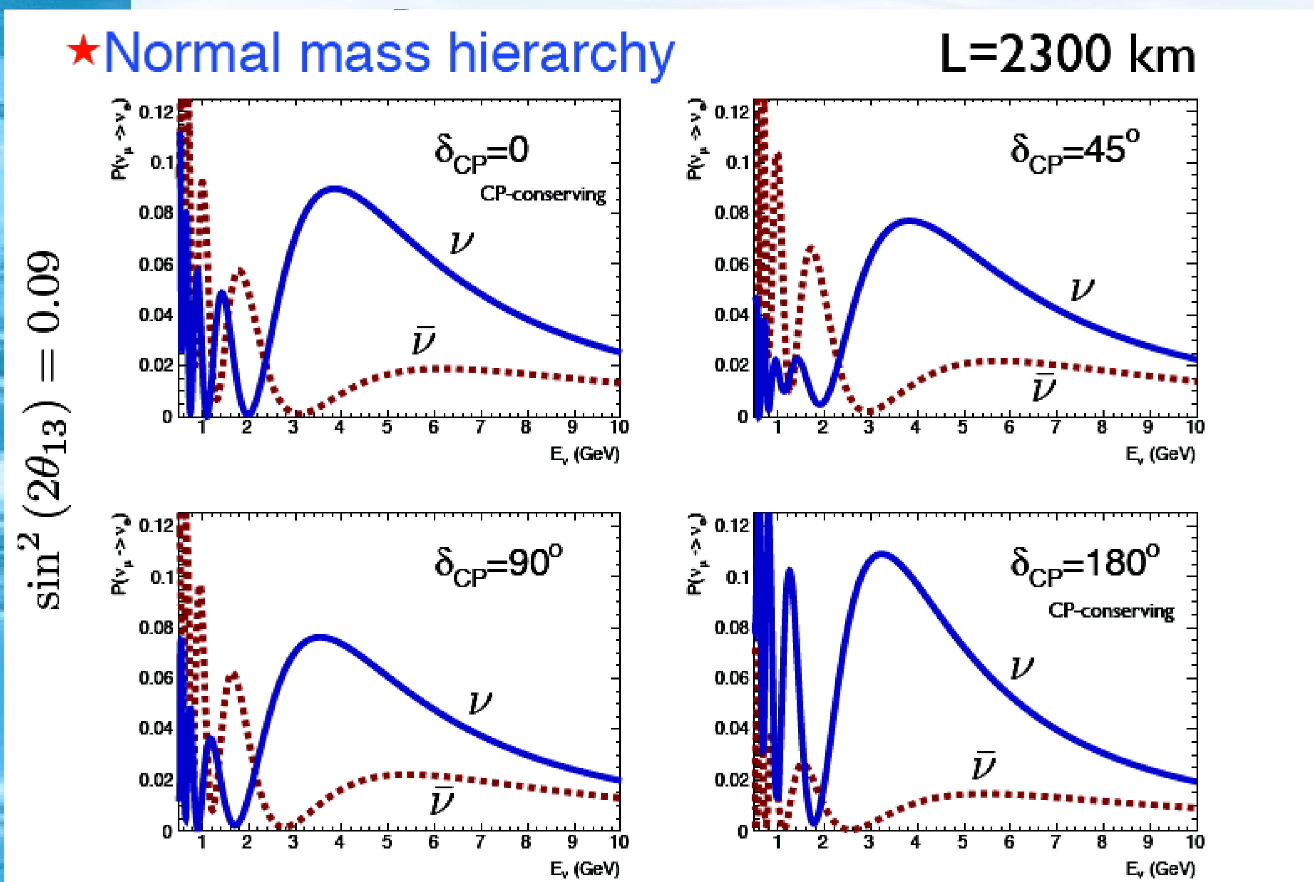
- Short baseline (~100-300 km), lower energy (<1 GeV), narrow beam, large Water Cherenkov (~500 kT). Concentrates on $\nu/\bar{\nu}$ asymmetry, “counting” experiment → HyperKamiokande
- Longer baseline (>2000 km), higher energy (>1 GeV), wide beam, Liquid Argon TPC. All final states accessible, E/L oscillation pattern and second maximum-> LAGUNA-LBNO

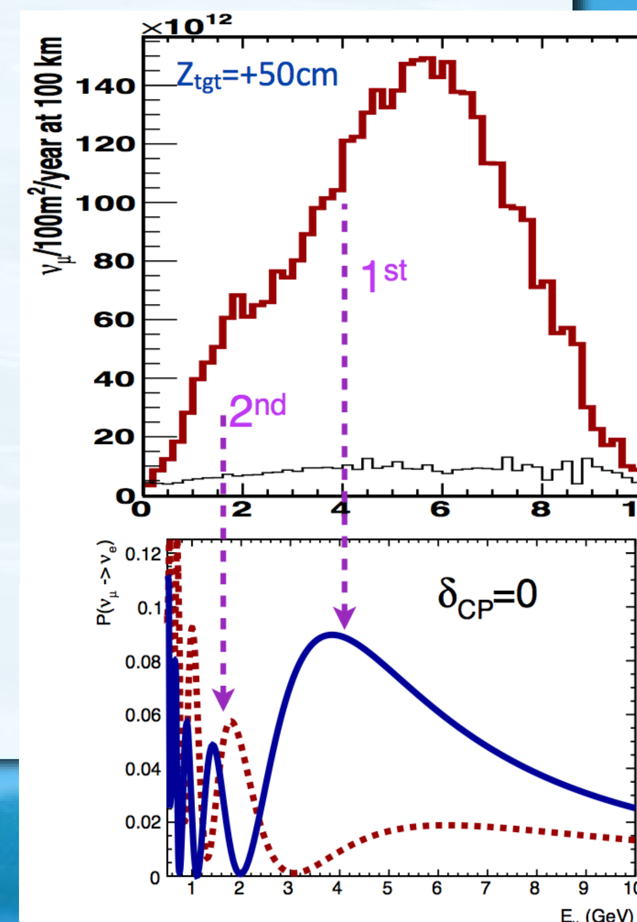




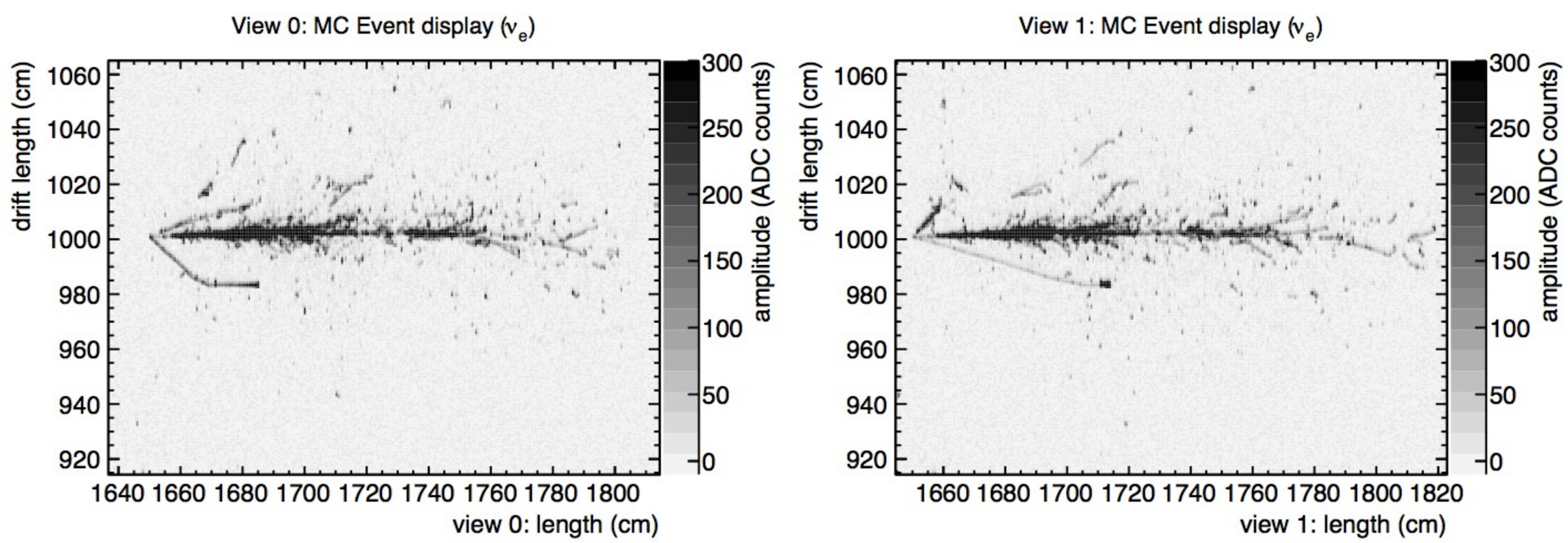
Probing the PMNS model

To fully probe the PMNS paradigm, a new detector technology capable of covering the 0.1-10 GeV range, with sensitivity to the three neutrino flavors is required





Towards a “bubble chamber” for neutrino interactions



Excellent energy resolution and tracking performance. Efficient background rejection

High granularity: ~0.05 cm in drift direction, 3mm in transverse direction

Very high signal-to-noise (>100) thanks to amplification in gas.

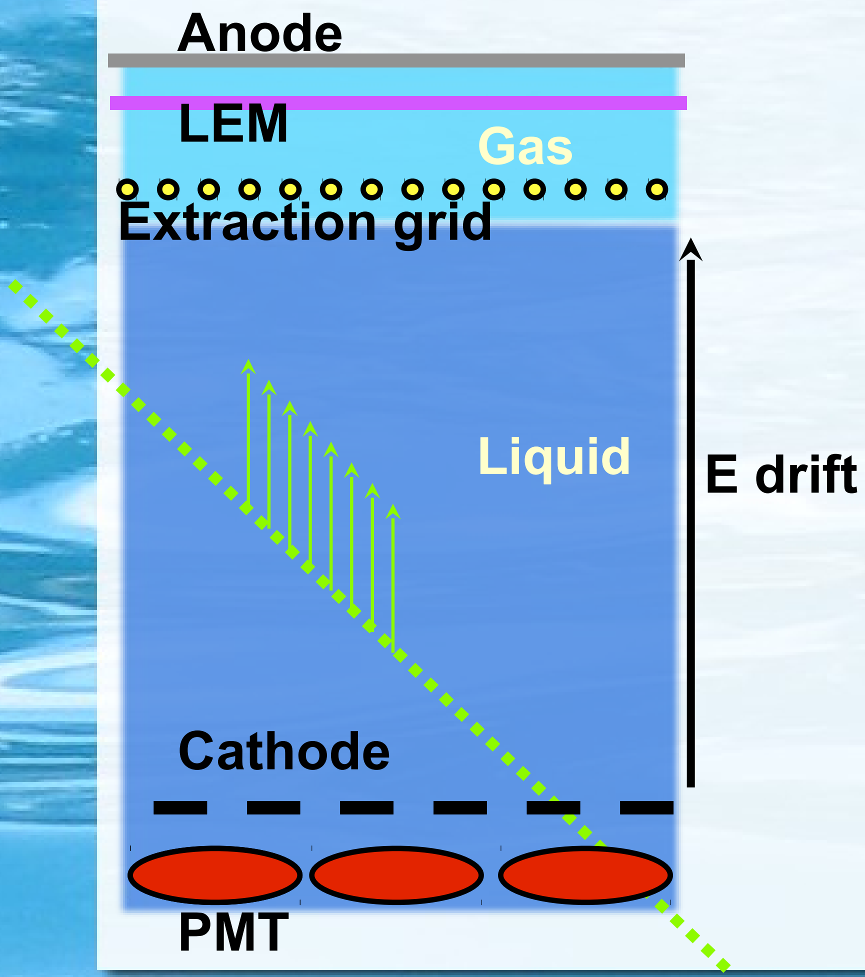
Adjustable energy threshold=>sensitivity from sub-GeV to multi-GeV

The GLACIER concept

*G*iant *L*iquid *A*rgon *C*harge *I*maging exp*ER*iment

1) Large single vessel for the Liquid Argon containment using industrial standards
2) Double phase TPC
3) Long drift distance
4) With amplification in the gaseous phase
5) Using Micro Pattern Gas Detectors

Liquid Argon TPC: the double phase concept



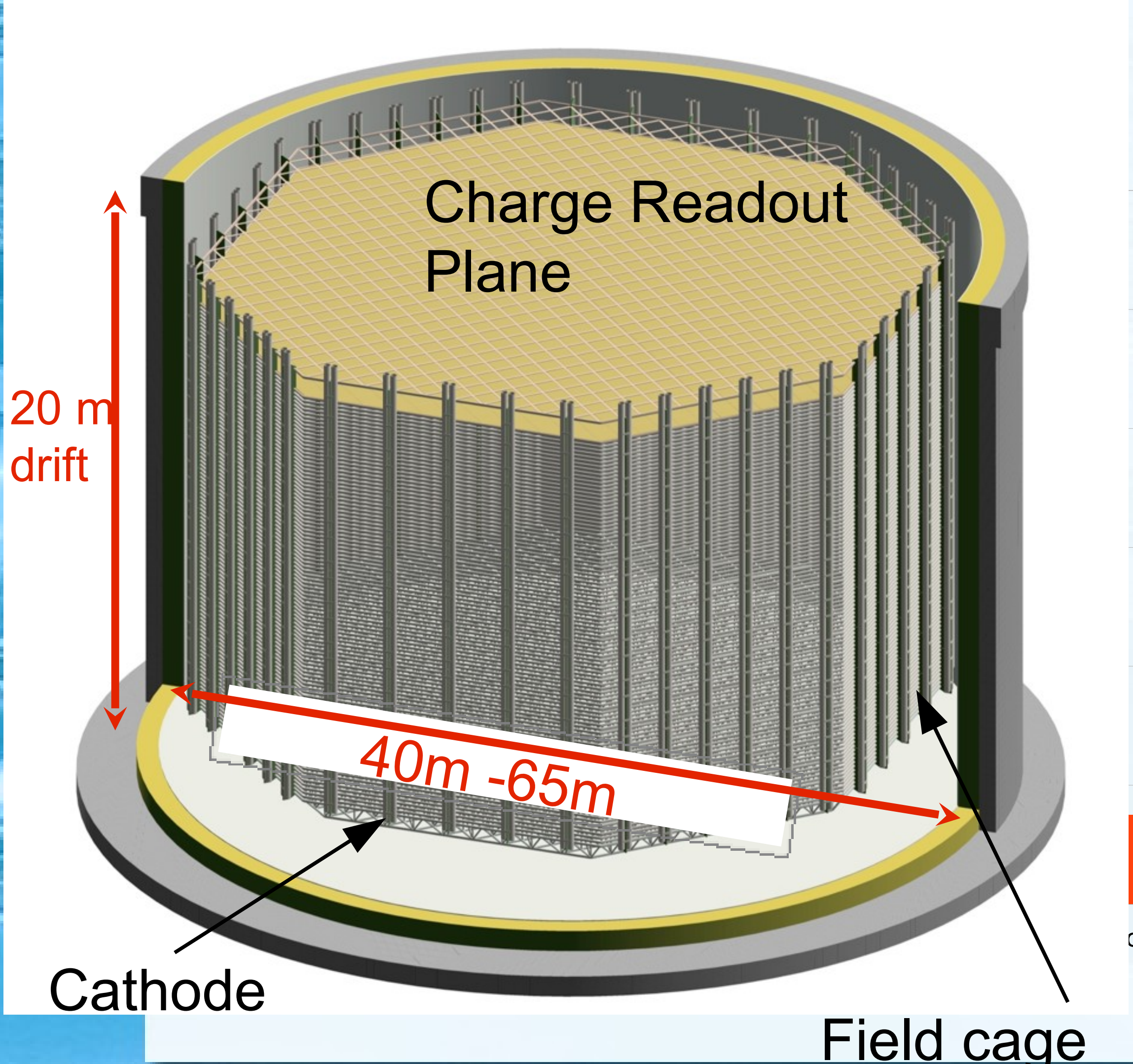
Charge collection on 2D anode

Charge amplification in the gaseous phase using LEM

Target for neutrino interactions: 20-50 kt

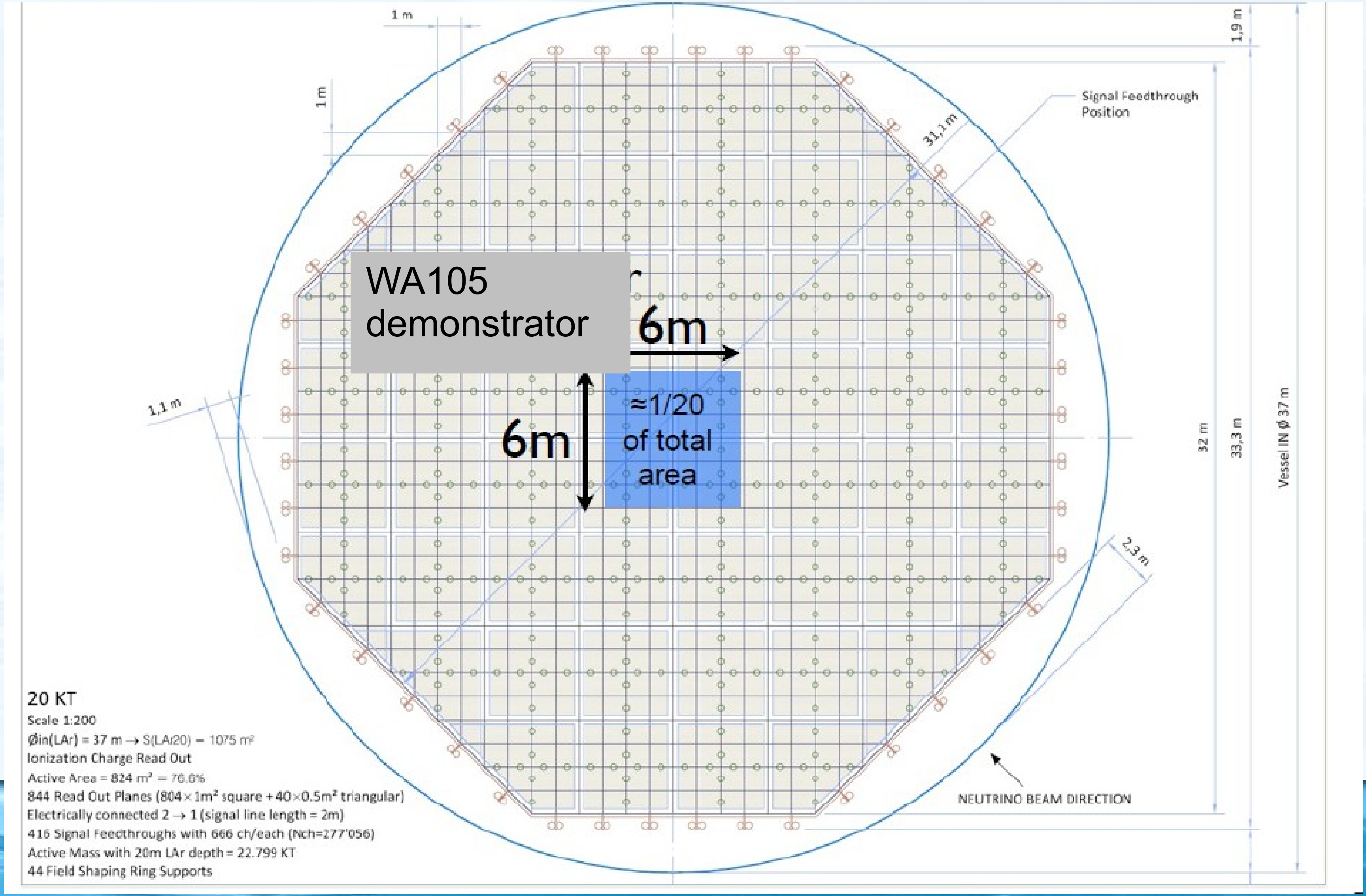
PMT for T0 determination

The GLACIER detector



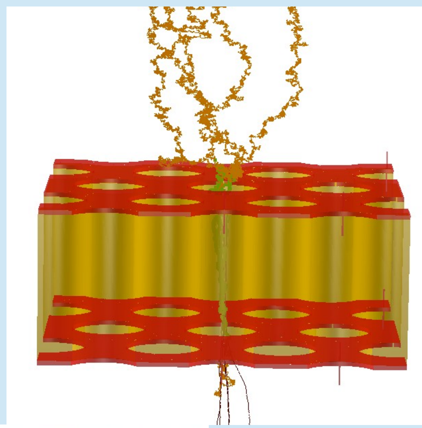
	20KT	50KT
Liquid argon density at 1.2 bar [T/m3]	1.38346	
Full LAr height [m]	22	
Instrumented LAr height [m]	20	
Pressure on the bottom due to LAr [T/m2]	30.4 (= 0.3 MPa = 3 bar)	
Vessel diameter [m]	37	55 76
Vessel base surface [m2]	1'075.2	2'375.8 4'536.5
Instrumented LAr area (percentage) [m2]	824 (77%) (76.6%)	1'845 (78%) 3'634 (80.1%)
Liquid argon volume [m3]	23'654.6	52'268.2 99'802.1
Instrumented LAr mass [KT]	22.799	51.299 100.550
Charge readout square panels (1m×1m option)	804	1'824 14'456
Charge readout triangular panels (0.5m2)	40	60
Charge readout square panels (4m×4m option)	40	104
Charge readout triangular panels (2m2)	20	16
Number of signal feed-throughs (666 ch/FT)	416	1'028 1'872
Number of PMTs (1m × 1m option)	~800	~1'850 909
Number of PMTs (1.2m × 1.2m option)		~1'288
Number of PMTs (2m × 2m option)	~200	~450
Number of field shaping rings	100	
Vertical spacing (heart to heart distance) of field shaping rings [mm]	200	

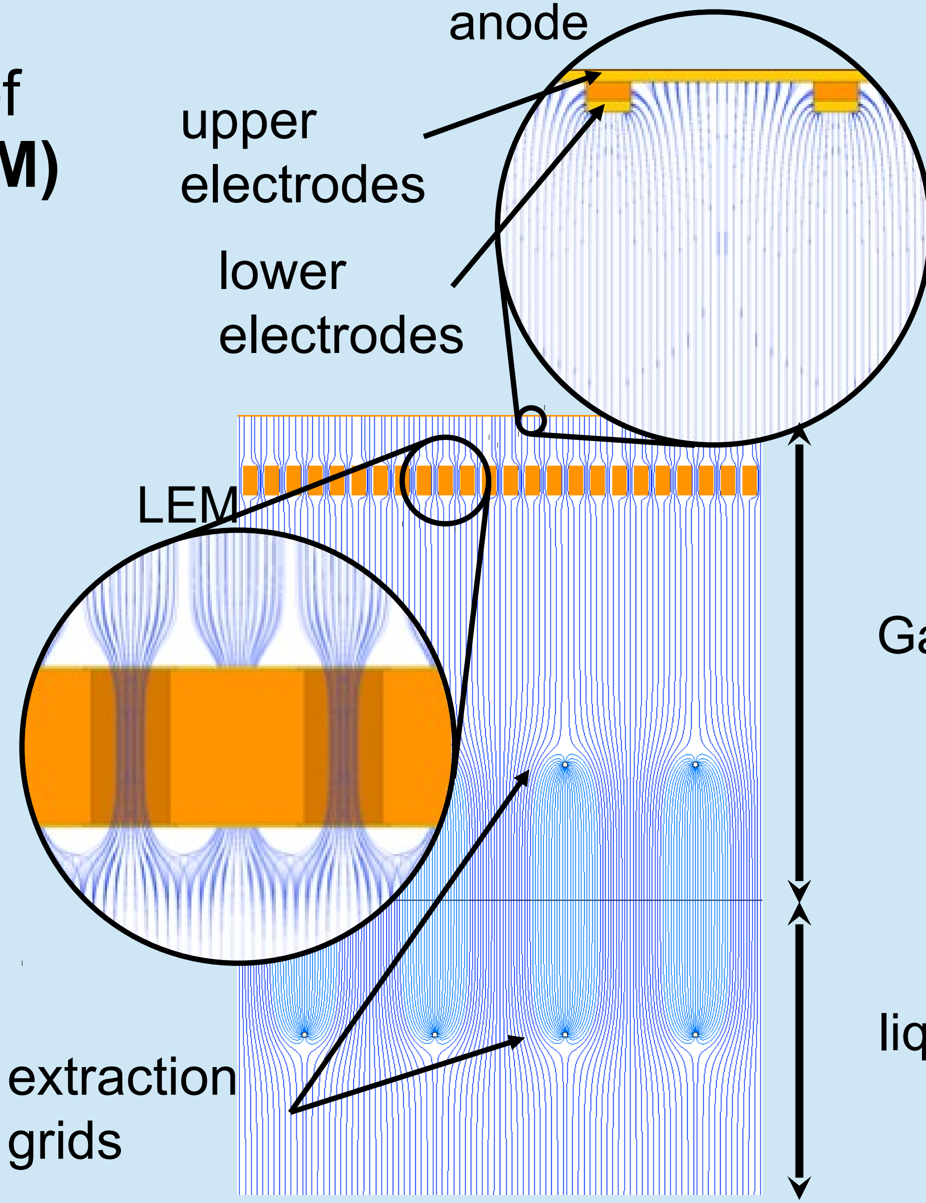
Anode modular structure



Gas amplification

Charge multiplication in the holes of the **Large Electron Multiplier (LEM)**

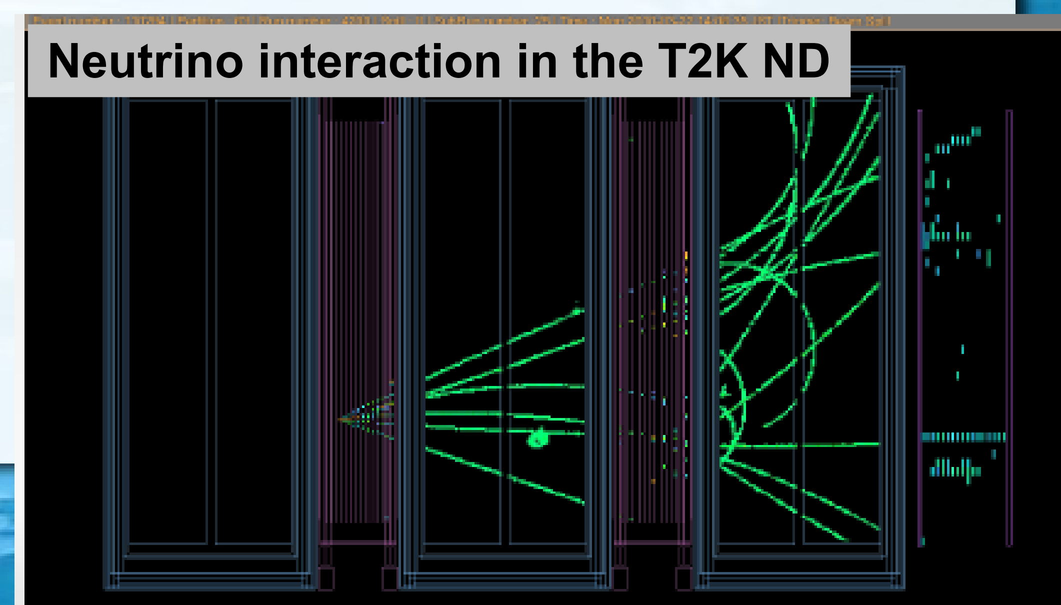




Progress with MicroPattern Gas Detectors (MPGD)

The GLACIER concept is fully supported by the recent progress in the MPGD technology:

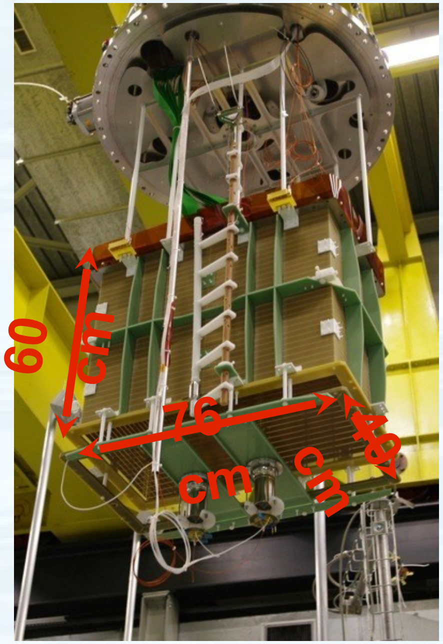
- T2K near detector TPC, 10m**2 paved with Micromegas
- Large MPGD (2m**2) (Rui De Oliveira workshop at CERN, RD51)
- ATLAS new Small wheel (~1000 m**2)



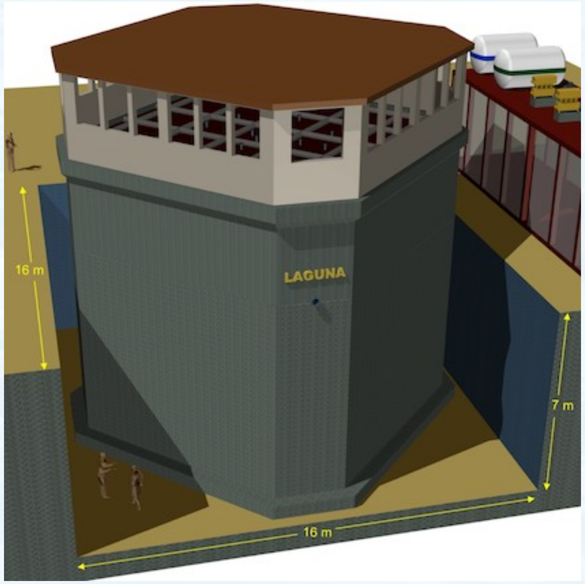
The path toward GLACIER

5kg

1t

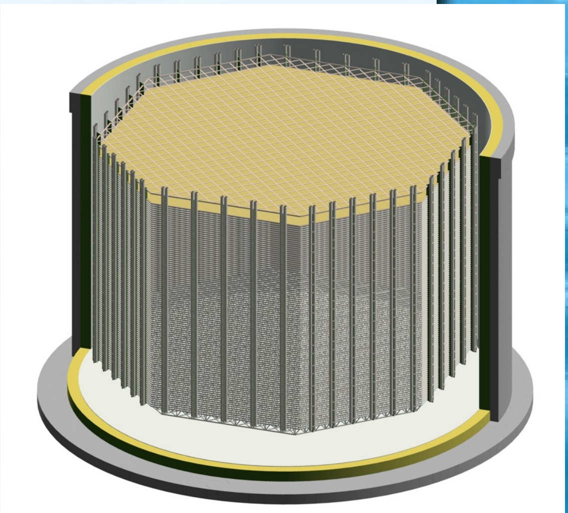


300t

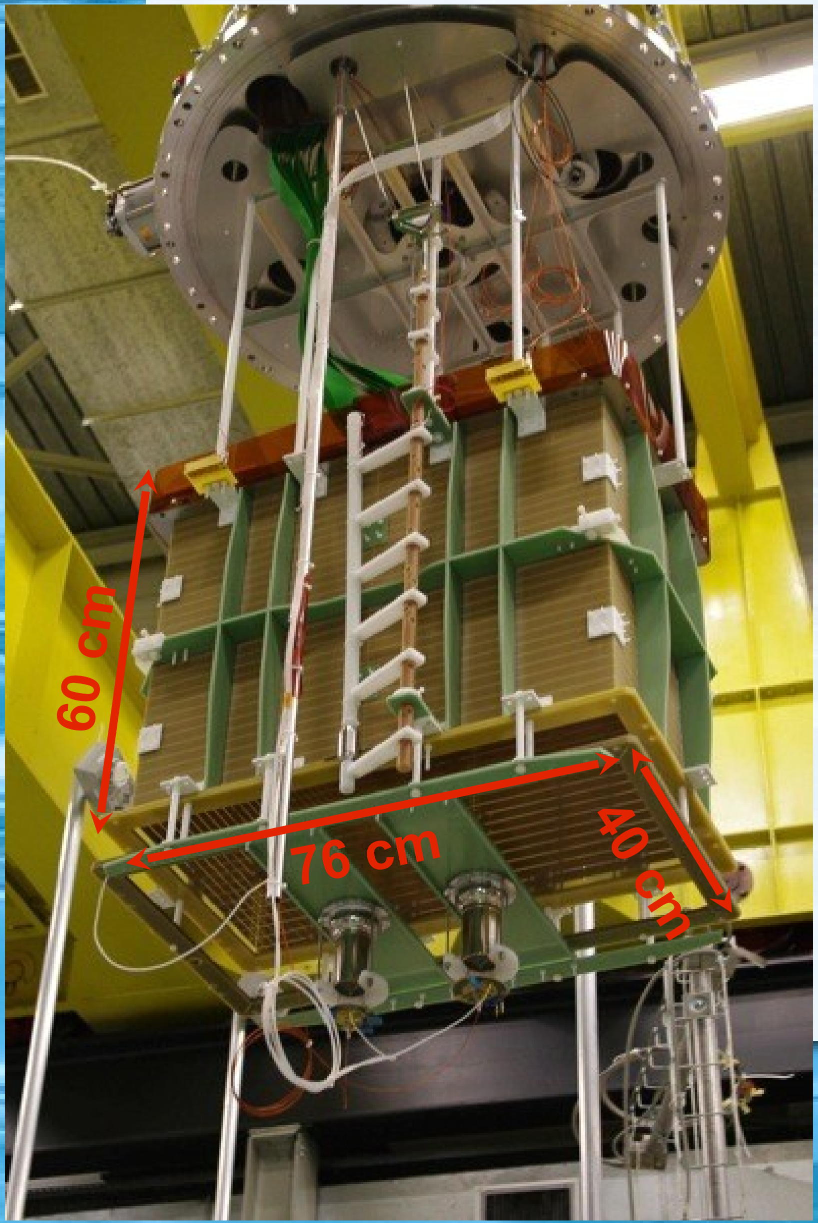


WA105

20-50kt

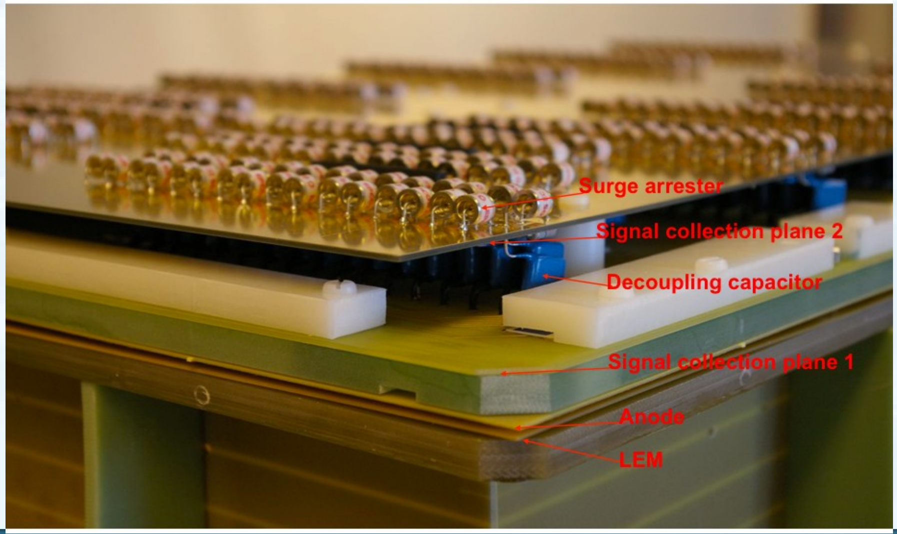


Validation of the concept

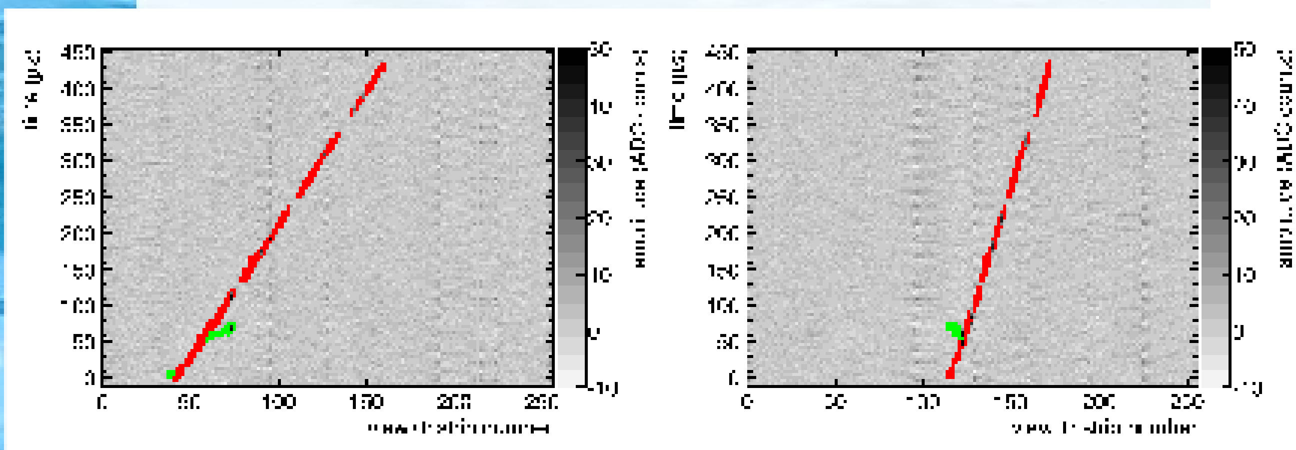


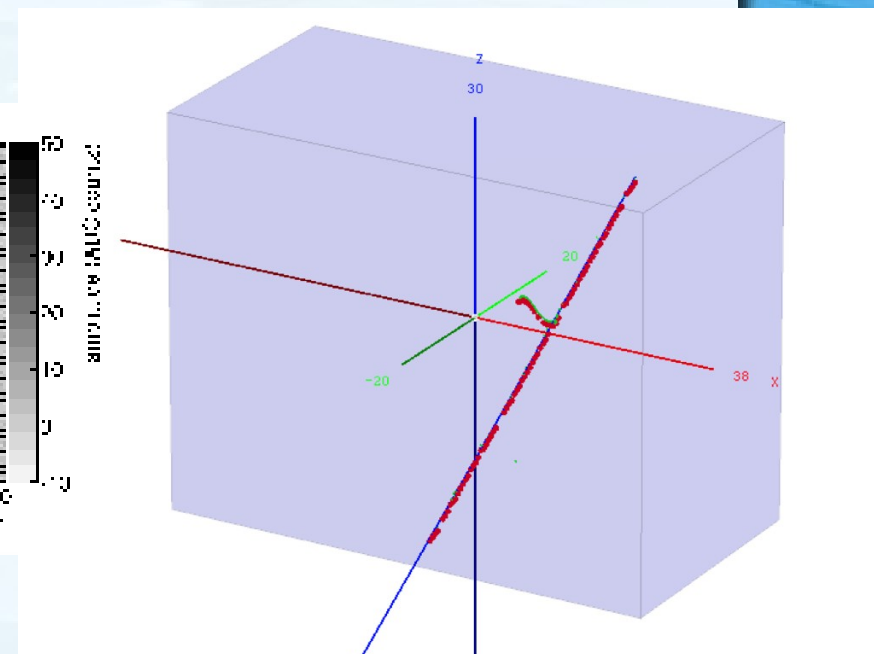
The 40x76 cm^2 prototype at CERN after several years of experience with smaller devices

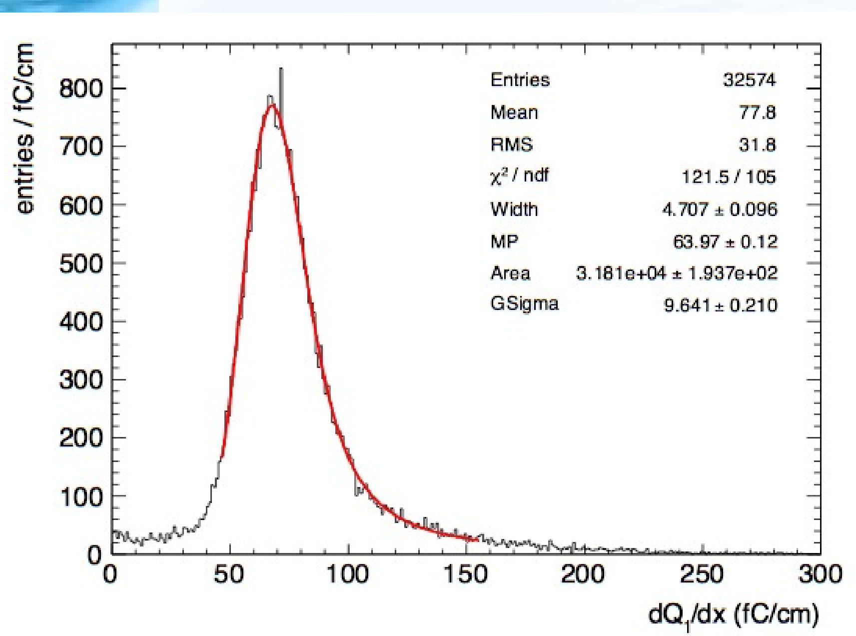
A. Badertscher et al. JINST 8 (2013)P04012,



Results with the 40x76 cm^2 prototype





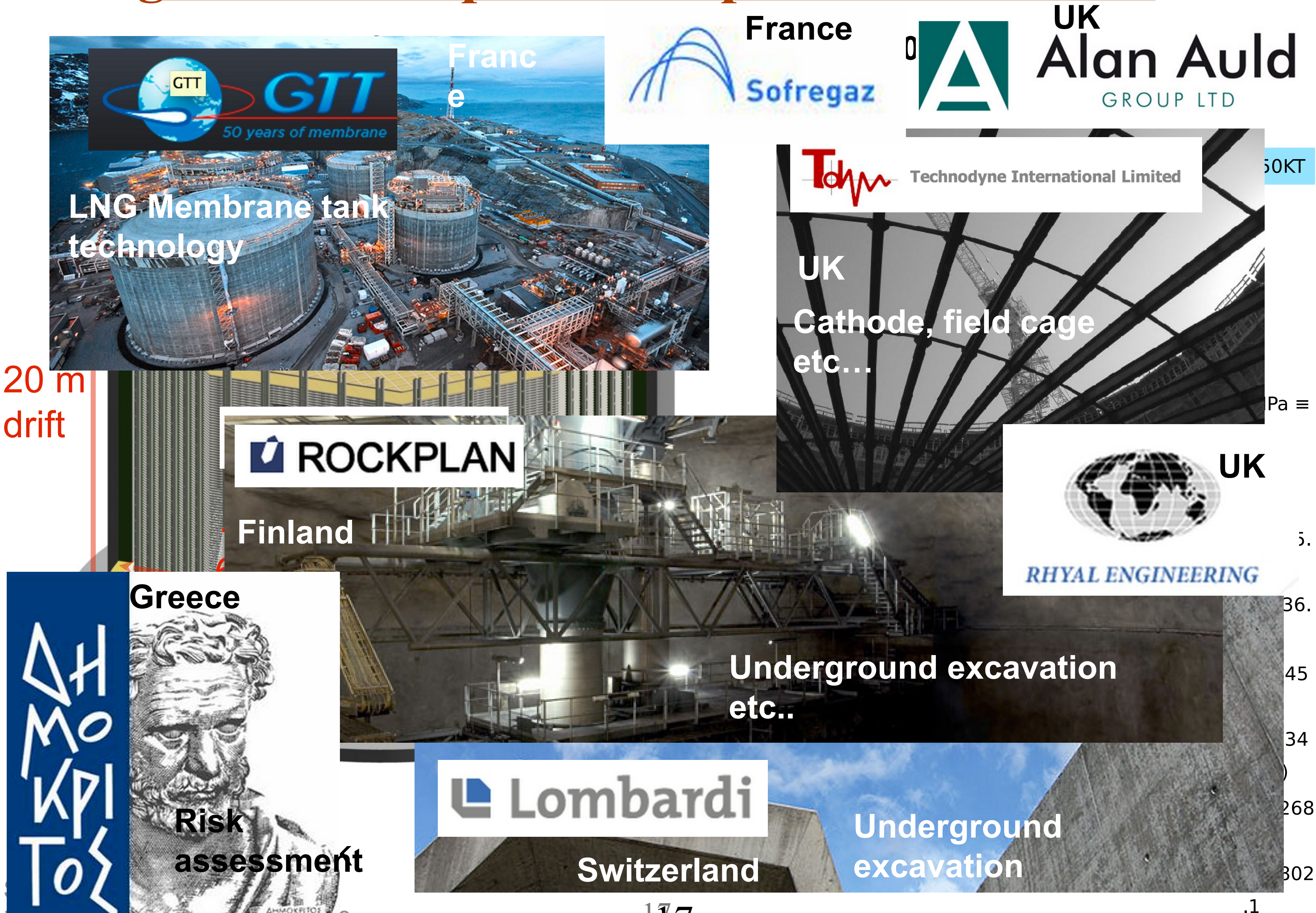


Effective gain≈14.6, (S/N≈30)
charge sharing between the two views:
$(Q_1-Q_0)/(Q_1+Q_0)\approx 8\%$

Engineering studies of the GLACIER detector

- LAGUNA (2008-2011) : feasibility of large underground caverns in several European sites
- LAGUNA-LBNO (2011-2014): engineering solutions for the underground infrastructure, the tank and the detector including the Argon handling. Construction plans and detailed costing as main deliverable to EU

Large industrial partnerships within LAGUNA

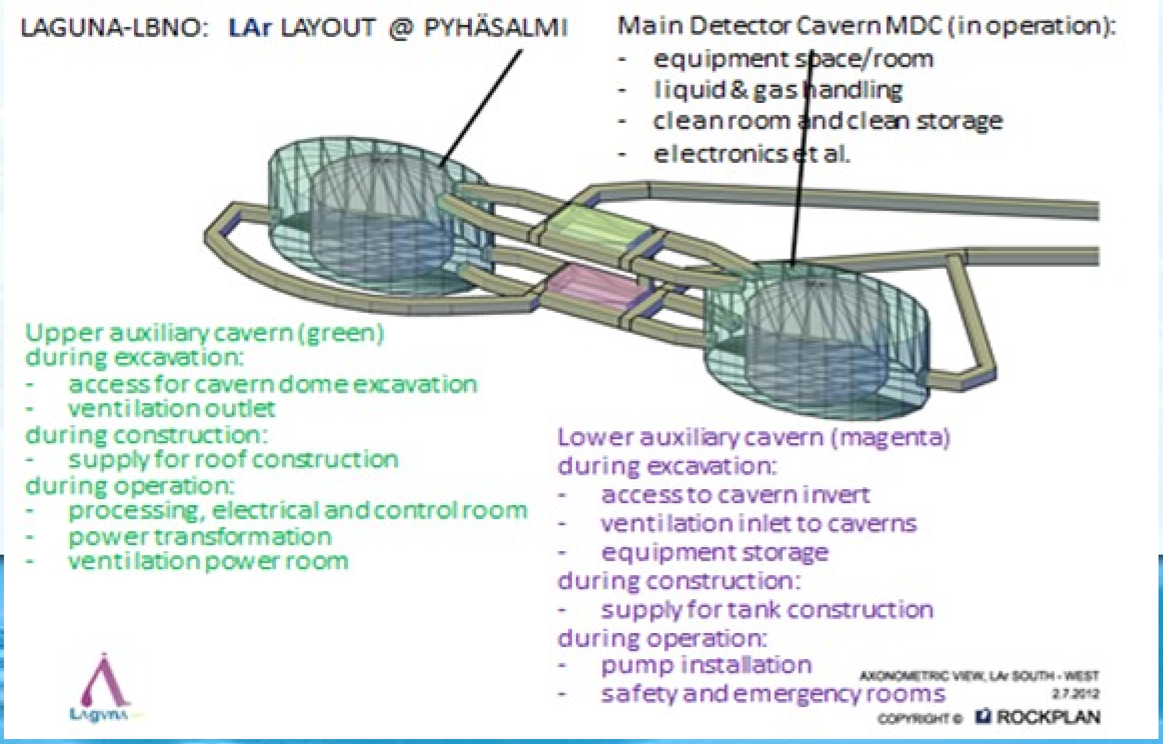


Designing an underground detector

- We recognized early on the absolute need to design the detector as an underground infrastructure from day 1
- Strong coupling of the detector with the cavern, its access and the whole laboratory design
- Need to take into account a variety of aspects including: logistics, underground construction, safety hazards, Argon handling ...

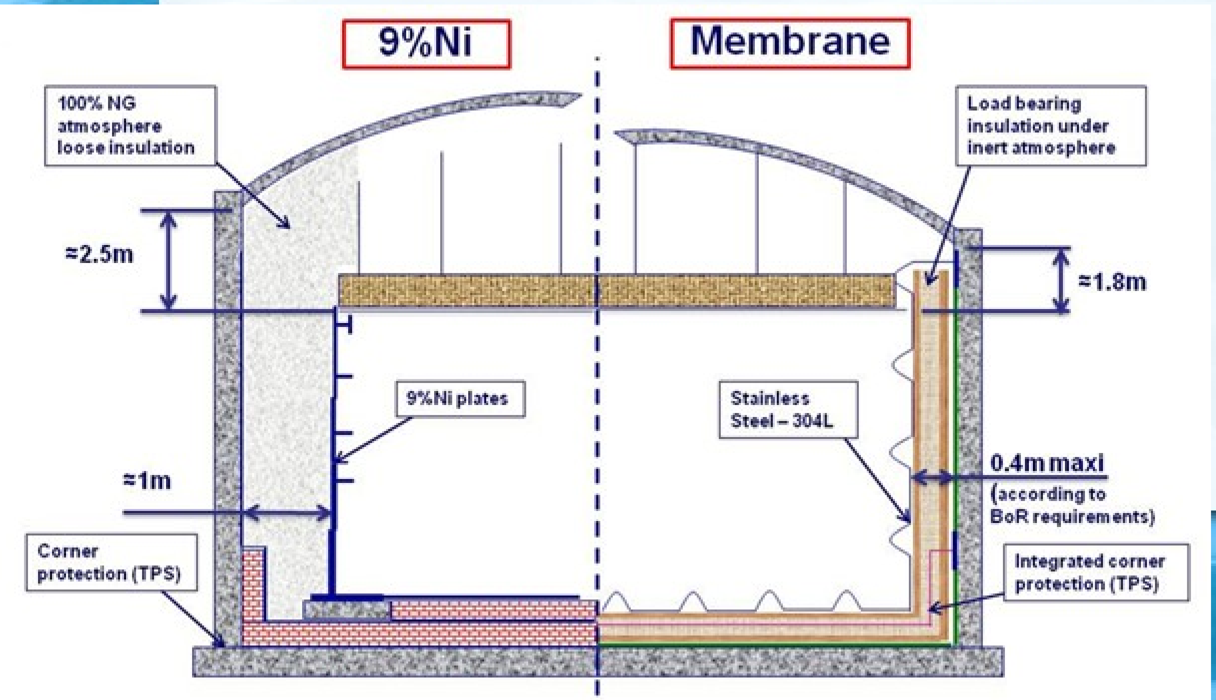
The underground infrastructure

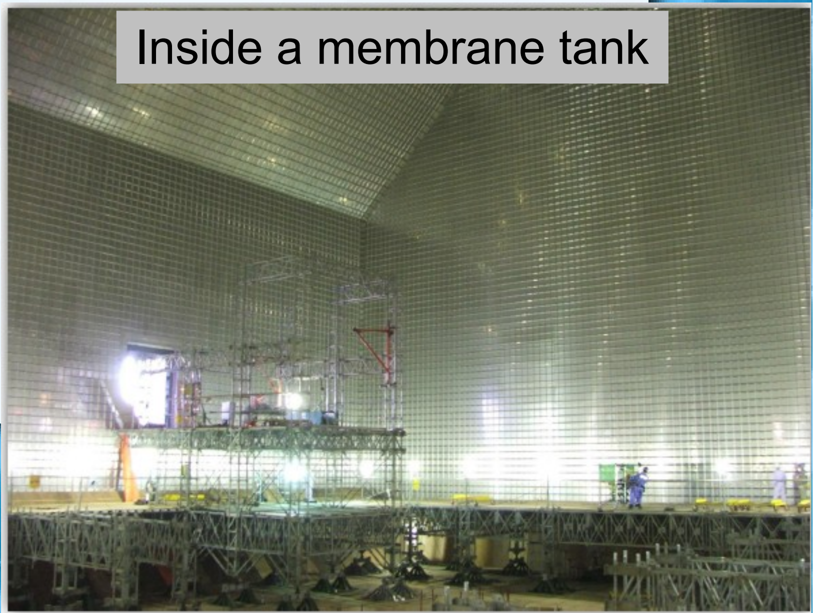
- The design has been conducted including: rock mechanical aspects (the large cavern will have a large 65m span), ancillary spaces, accesses, shafts. Additional site investigation ongoing in Pyhasalmi.



Industrial technologies for the tank

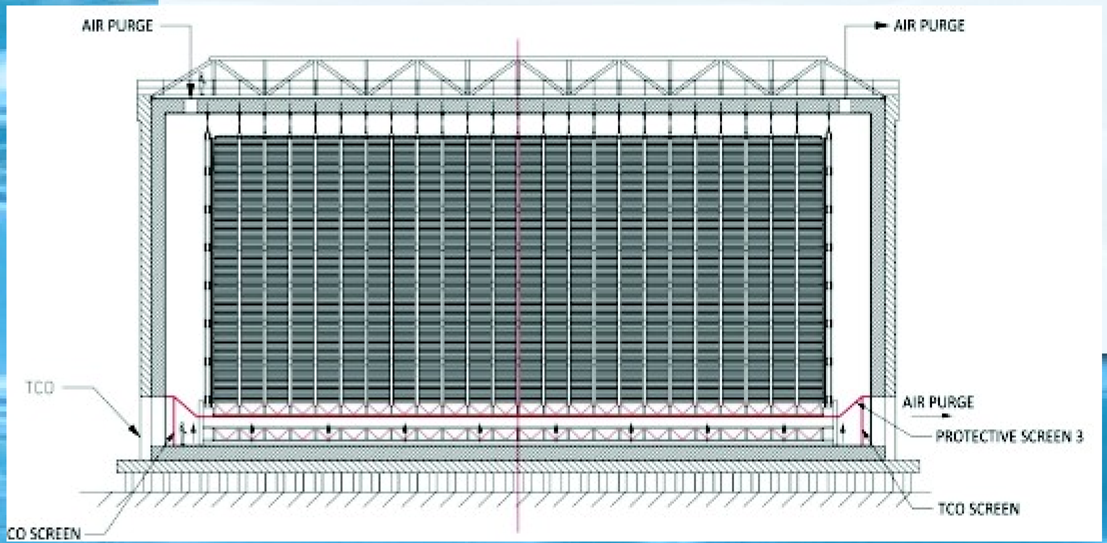
- Study of the tank completed, including costing and construction plans.
- Both a steel tank and a membrane tank are feasible. The membrane tank is the favored option.

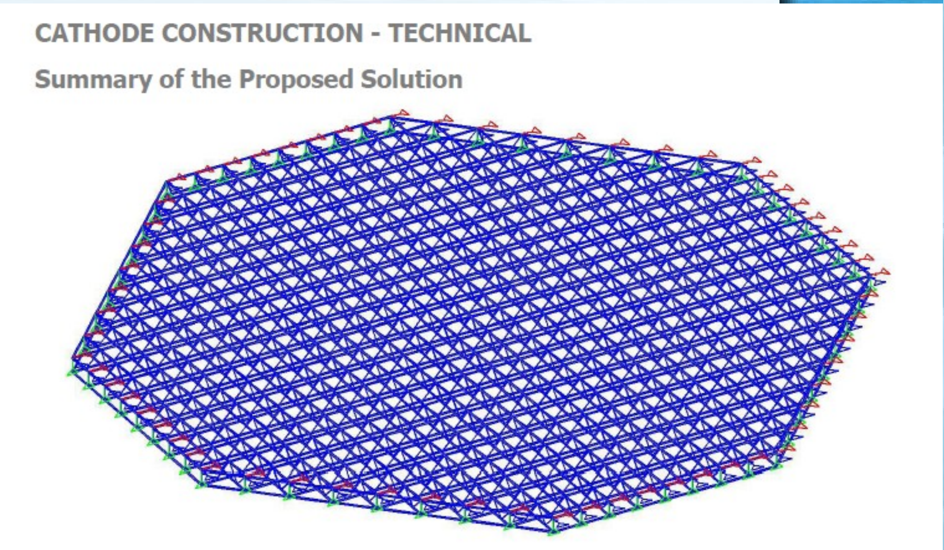




The TPC structure

- Includes and the anode-LEM-grid structure, the field cage and the cathode
- Design almost completed
- Includes the interplay of the tank construction, modularity, cleanliness requirements





LBNO: design and costing

The LBNO collaboration is nearing completion of an EU-funded design study, and the detailed engineering and full costing of LBNO Pilot, Phase 1 (20kton LAr) and Phase 2 (20+50kton) at Pyhäsalmi will be delivered in June 2014.

Technical Deliverables

Guido Nujten
LAGUNA-LBNO
Technical Coordinator

Conclusions

- The GLACIER double phase liquid argon TPC has been proposed to serve as the far detector in a comprehensive study of the PMNS paradigm
- Proof of principle and invaluable experience with several prototypes
- Extensive engineering studies towards the construction plans
- Looking forward to the WA105 large demonstrator and beam test data

GLACIER: references

2003: the GLACIER concept. A. Rubbia hep-ph/0402110.

2008-2011: Proof of principle with 10x10 cm^2 double phase LAr LEM-TPC prototype: arXiv:0811.3384 NIM A641 (2011) p.48-57

2011: First successful operation of a 40x80 cm^2 device

JINST 7 (2012) P08026 JINST 8 (2013) P04012

2012-2013: further R&D towards final, simplified charge readout for GLACIER