ETH
Eidgenössische Technische Hochschule Zürich
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R&D towards a Giant LAr Charge Imaging ExpeRiment (GLACIER)

André Rubbia (ETHZ)

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Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

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Some selected references (since 2000)

- A. Badertscher et al., “Towards a Long Baseline Neutrino and Nucleon Decay Experiment with a next-generation 100 kton Liquid Argon TPC detector at Okinoshima and an intensity upgraded J-PARC Neutrino beam”, **proposal P32 to the J-PARC PAC (2010)**
- A. Rubbia, “A CERN-based high-intensity high-energy proton source for long baseline neutrino oscillation experiments with next-generation large underground detectors for proton decay searches and neutrino physics and astrophysics”, **arXiv:1003.1921 (2010).**
- A. Badertscher et al., “Operation of a double-phase pure argon Large Electron Multiplier Time Projection Chamber: Comparison of single and double phase operation”, **Nucl.Instrum.Meth.A617:188-192,2010.**
- V. Boccone et al, “Development of wavelength shifter coated reflectors for the ArDM argon dark matter detector”, **JINST 4:P06001,2009**.
- A. Rubbia, “Underground Neutrino Detectors for Particle and Astroparticle Science: The Giant Liquid Argon Charge Imaging ExpeRiment (GLACIER)”, **J.Phys.Conf.Ser.171:012020,2009**.
- A. Badertscher et al., “A Possible Future Long Baseline Neutrino and Nucleon Decay Experiment with a 100 kton Liquid Argon TPC at Okinoshima using the J-PARC Neutrino Facility,” **NP08 workshop, arXiv:0804.2111 [hep-ph] (2008).**
- A.Bueno et al., “Nucleon decay searches with large liquid argon TPC detectors at shallow depths: Atmospheric neutrinos and cosmogenic backgrounds”, **JHEP 0704, 041 (2007)**.
- A. Meregaglia and A. Rubbia, “Neutrino oscillation physics at an upgraded CNGS with large next generation liquid argon TPC detectors”, **JHEP 0611, 032 (2006).**
- A. Ereditato and A. Rubbia, “Conceptual design of a scalable multi-kton superconducting magnetized liquid Argon TPC”, **Nucl.Phys.Proc.Suppl.155:233-236,2006**.
- A. Rubbia, “ArDM: A Ton-scale liquid Argon experiment for direct detection of dark matter in the universe”, **J.Phys.Conf.Ser.39:129-132,2006**.
- A. Badertscher et al., “First results from a liquid argon time projection chamber in a magnetic field”, **Nucl.Instrum.Meth.A555:294-309,2005.**
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- A. Cocco et al., “Supernova relic neutrinos in liquid argon detectors”, **JCAP 0412 (2004) 002**.
- I. Gil Botella and A.Rubbia, “Decoupling supernova and neutrino oscillation physics with LAr TPC detectors”, **JCAP 0408 (2004) 001.**
- A. Rubbia, “Experiments for CP-violation: A giant liquid argon scintillation, Cerenkov and charge imaging experiment?,” **Venice 2003, arXiv:hep-ph/0402110 (2004).**
- A. Bueno, M. Campanelli, A.Rubbia, “On the energy and baseline optimization to study effects related to the delta phase (CP / T violation) in neutrino oscillations at a neutrino factory”, **Nucl.Phys.B631:239-284,2002**.
- A. Rubbia, “Neutrino factories: Detector concepts for studies of CP and T violation effects in neutrino oscillations”, Venice 2001, **hep-ph/0106088**.
- A. Rubbia, “ICANOE and OPERA experiments at the LNGS / CNGS”, **Nucl.Phys.Proc.Suppl.91:223-229,2001.**
- A. Bueno et al., “Physics potential at a neutrino factory: Can we benefit from more than just detecting muons?”, **Nucl.Phys.B589:577-608, 2000**.

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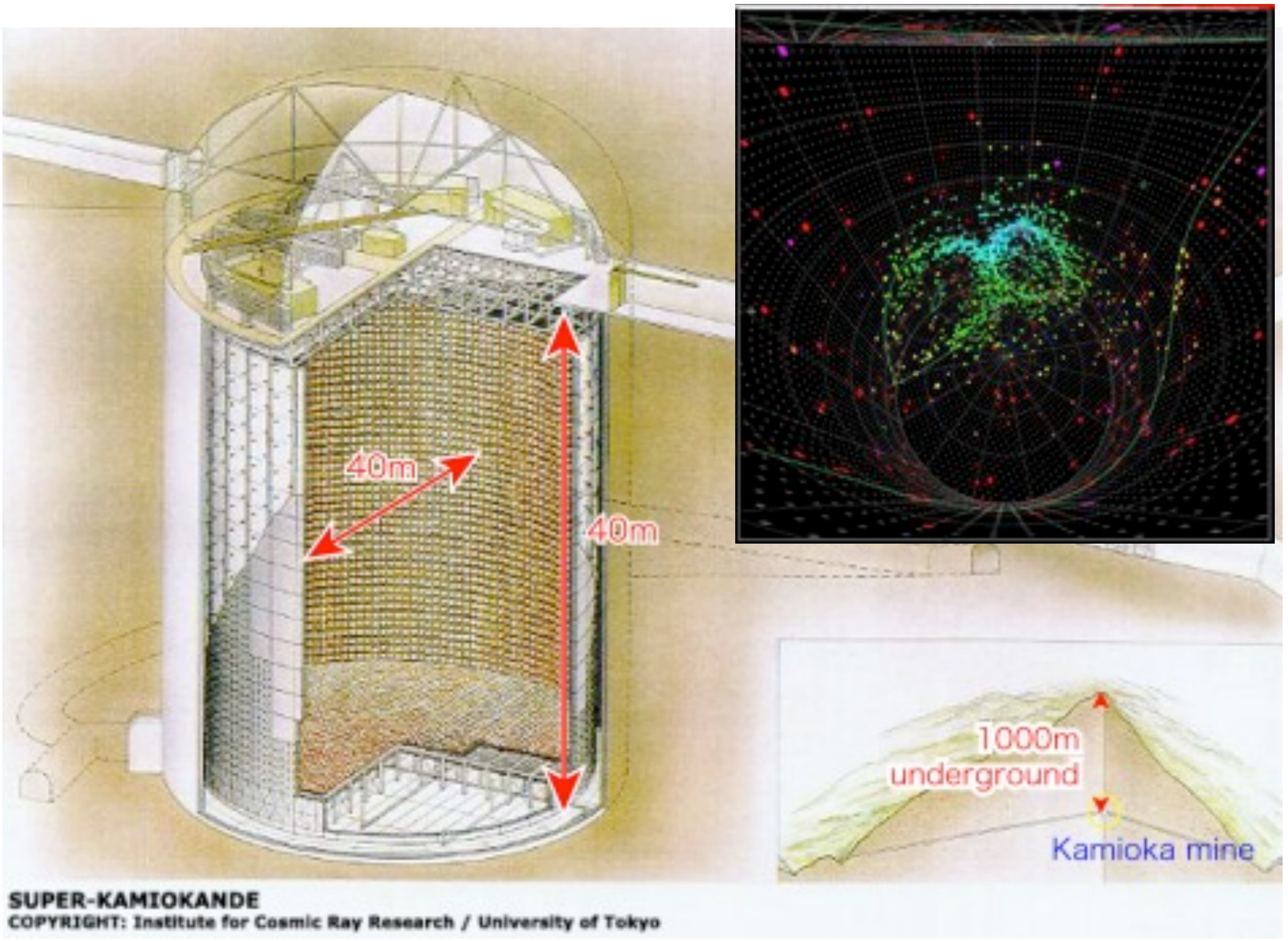
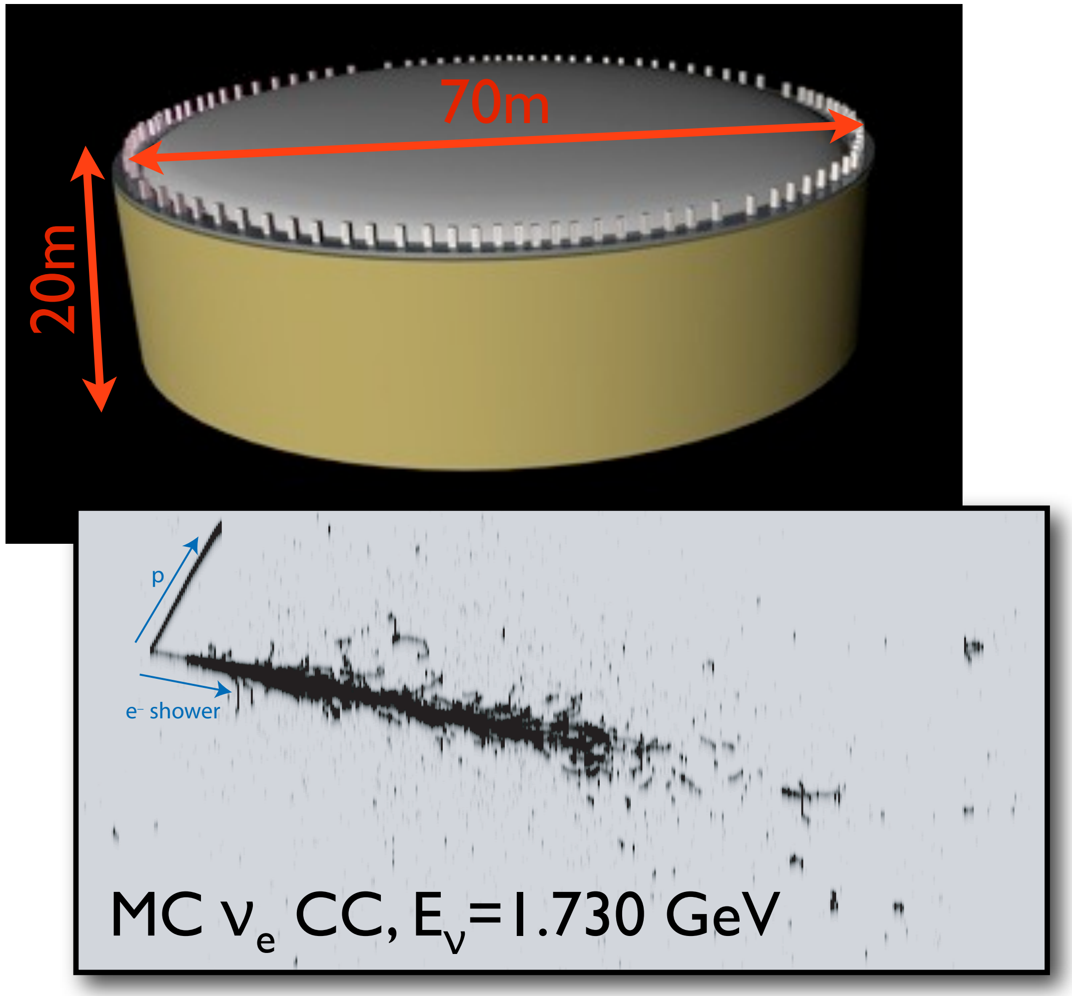
Not really bigger, but “different”...

1,000 m underground



>200 m underground



MC ν_e CC, E_ν=1.730 GeV

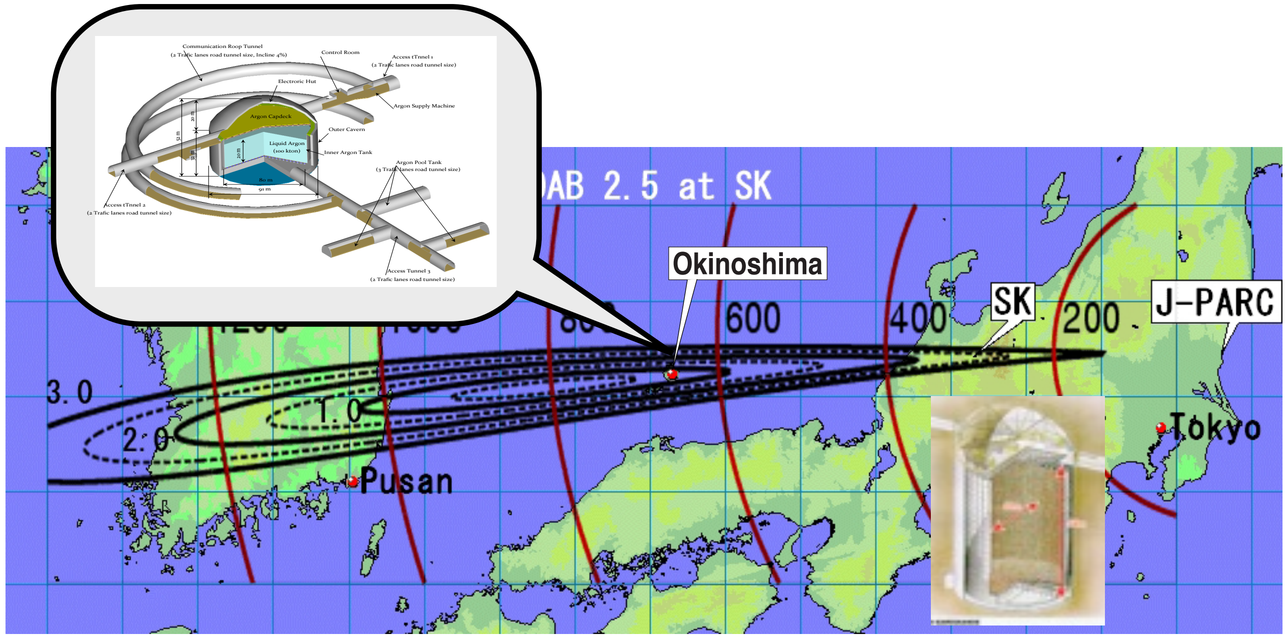
Superkamiokande
50’000 m^3 pure H_20
Cerenkov imaging
22.5 kton fiducial mass
(Data taking 1996-)

GLACIER
77’000 m^3 ultra pure LAr
Charge & Light imaging
100 kton fiducial mass
(202x ?)

*Complementary technologies, should **not** be located at same L & E from neutrino source !*

Conventional superbeams LBL exp.

<u>LAr TPC pros</u>: exclusive final states, low momentum threshold, excellent E-resolution, high efficiency, high background rejection, etc...



J-PARC to Okinoshima

arXiv:0804.2111 [hep-ph] (2008)

Distance = 658 km

Off-axis angle = 0.76° (2.5°@SK)

<u>cons</u>: beam fixed, 1.66MW

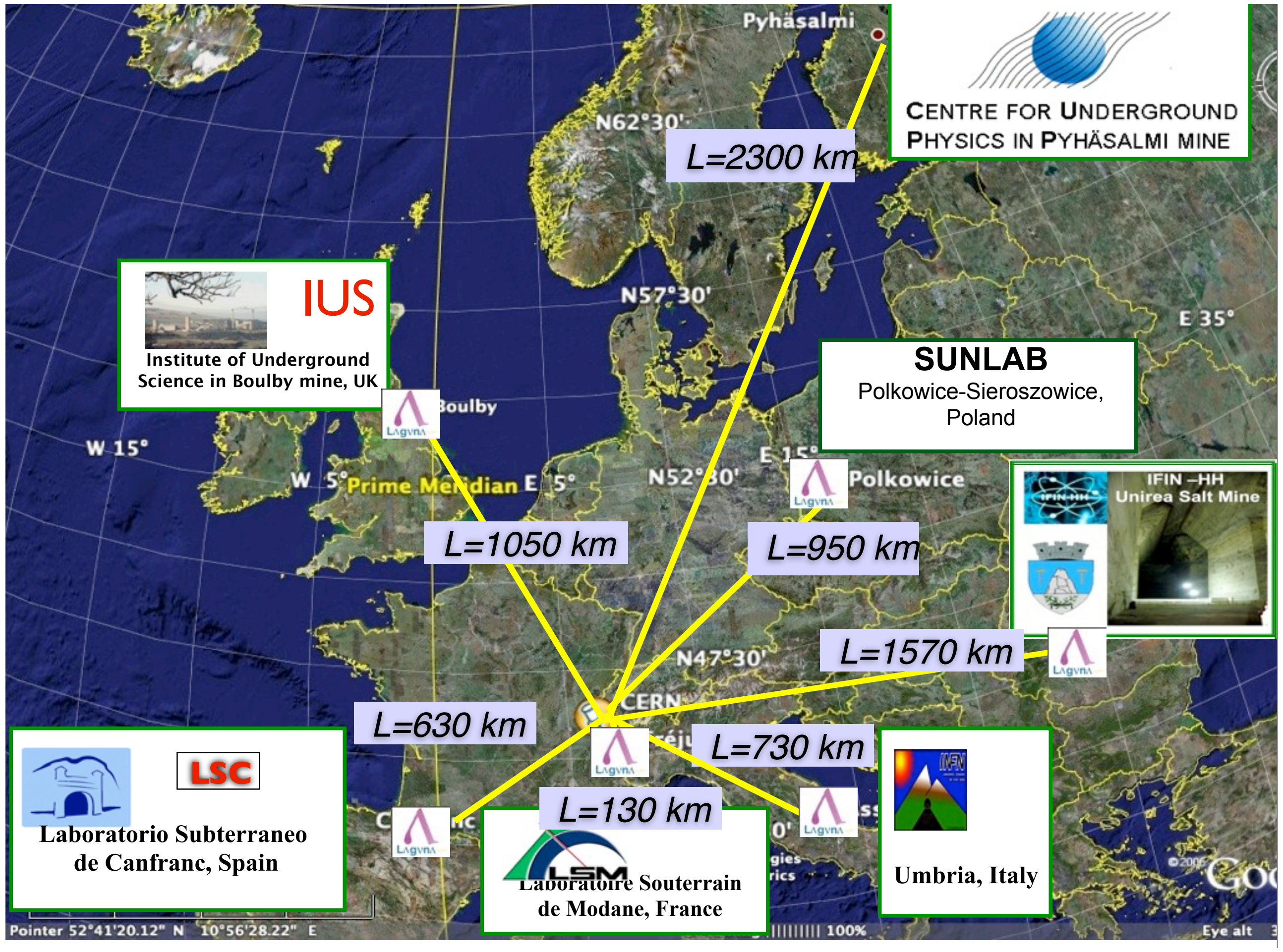
CERN to LAGUNA site

arXiv:1003.1921 (2010)

Distance = 130-2300 km

Off-axis angle = tbd

<u>cons</u>: requires multi-MW beamline from a CERN HP-SPL and/or a HP-PS(2) proton driver



2. Geology and geography for GLA cavern

➠ Yoshioka

ASAHI quarry

A single layer of the gneiss

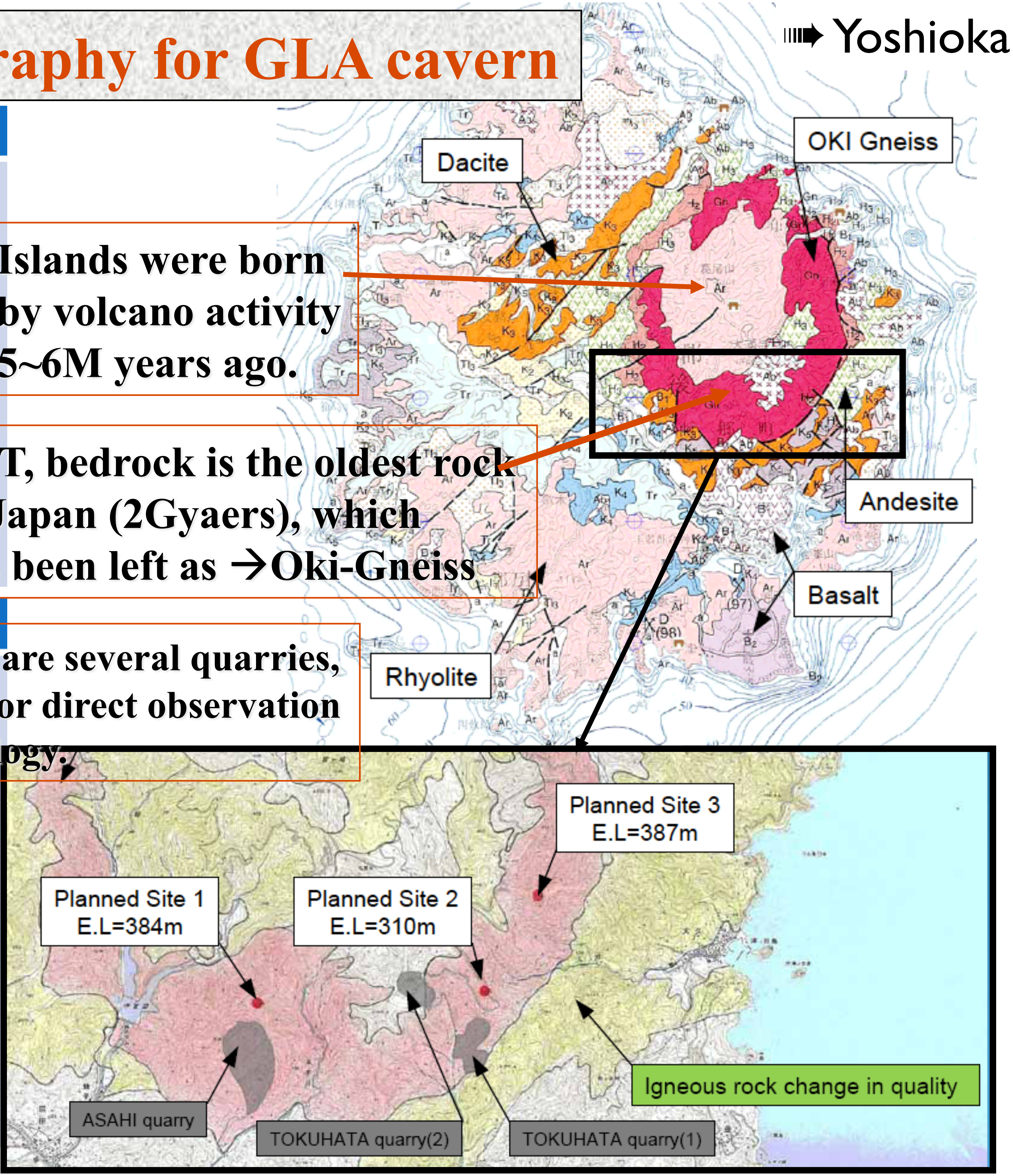
TOKUHATA No.2 quarry

The crackle of the Igneous rock to the gneiss

Islands were born by volcano activity 5~6M years ago.

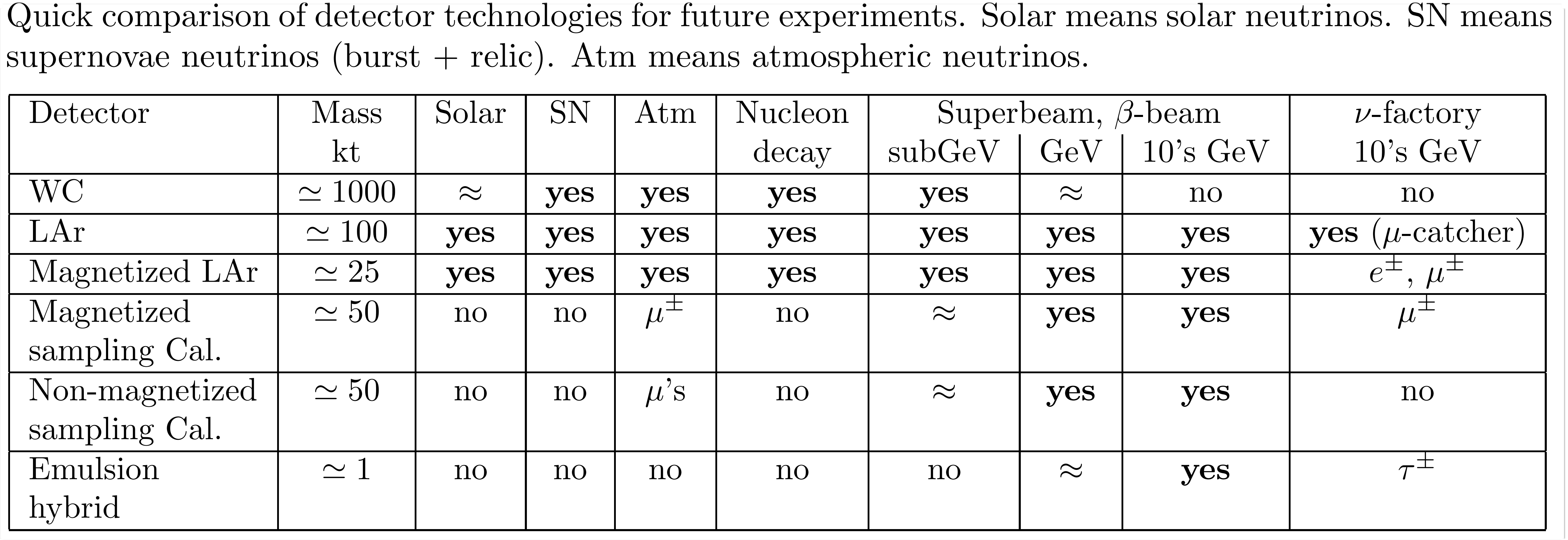
BUT, bedrock is the oldest rock in Japan (2Gyaers), which has been left as →Oki-Gneiss

There are several quarries, good for direct observation of geology.



“Does it all” technology ?

__LAr TPC pros__: wide energy range, exclusive final states, low momentum threshold, excellent E-resolution, high efficiency, high background rejection, possibility to magnetize, etc...



Quick comparison of detector technologies for future experiments. Solar means solar neutrinos. SN means supernovae neutrinos (burst + relic). Atm means atmospheric neutrinos.

Detector	Mass kt	Solar	SN	Atm	Nucleon decay	Superbeam, β-beam subGeV	GeV	10’s GeV	ν-factory 10’s GeV
WC	$\simeq 1000$	$\approx$	**yes**	**yes**	**yes**	**yes**	$\approx$	no	no
LAr	$\simeq 100$	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes** (μ-catcher)
Magnetized LAr	$\simeq 25$	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	$e^\pm$, $\mu^\pm$
Magnetized sampling Cal.	$\simeq 50$	no	no	$\mu^\pm$	no	$\approx$	**yes**	**yes**	$\mu^\pm$
Non-magnetized sampling Cal.	$\simeq 50$	no	no	μ’s	no	$\approx$	**yes**	**yes**	no
Emulsion hybrid	$\simeq 1$	no	no	no	no	no	$\approx$	**yes**	$\tau^\pm$

AR, Nucl.Phys.Proc.Suppl.147:103-115 (2005)

__But LAr TPC cons__: challenging, complicated, unsafe, “costly”, and large extrapolation needed to reach the relevant scale...

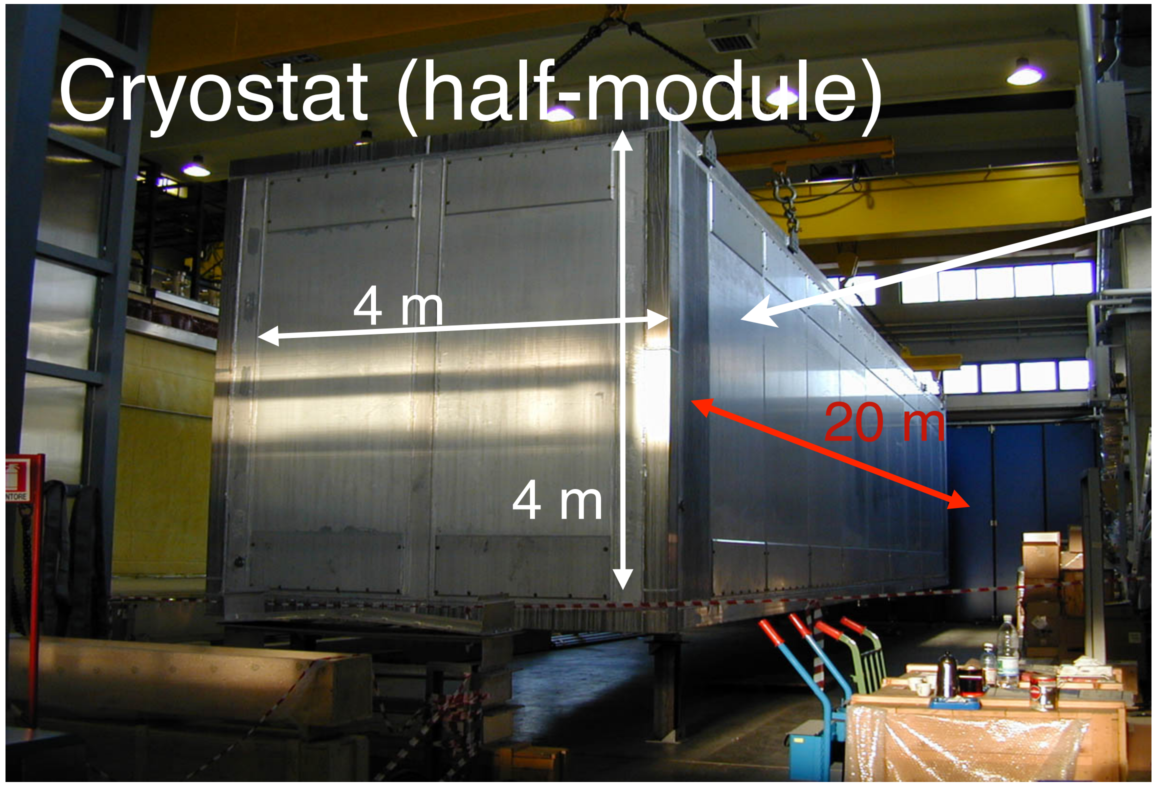
ICARUS (CNGS2): the first large scale LAr experiment

- ICARUS represents a major milestone in the practical realization of a large scale LAr detector. Successfully operated on surface in Pavia in 2002, will soon be operational in the underground HallB of LNGS.
- The T600 at LNGS will collect simultaneously "bubble chamber like" neutrino events events of different nature
- Cosmic ray events
  - ≈ 100 ev/year of unbiased atmospheric CC neutrinos.
  - Solar neutrino electron rates >5 MeV. ~1-2 ev/day
  - Supernovae neutrinos.
  - A zero background proton decay with 3 x 10^{32} nucleons for "exotic" channels.
- CERN beam associated events: 1200 n_m CC ev/y and 7-8 n_e CC ev/year
  - Observation of neu-tau events in the electron channel (with sensitivity comparable to OPERA
  - A search fo sterile neutrinos
- Other unexpected phenomena

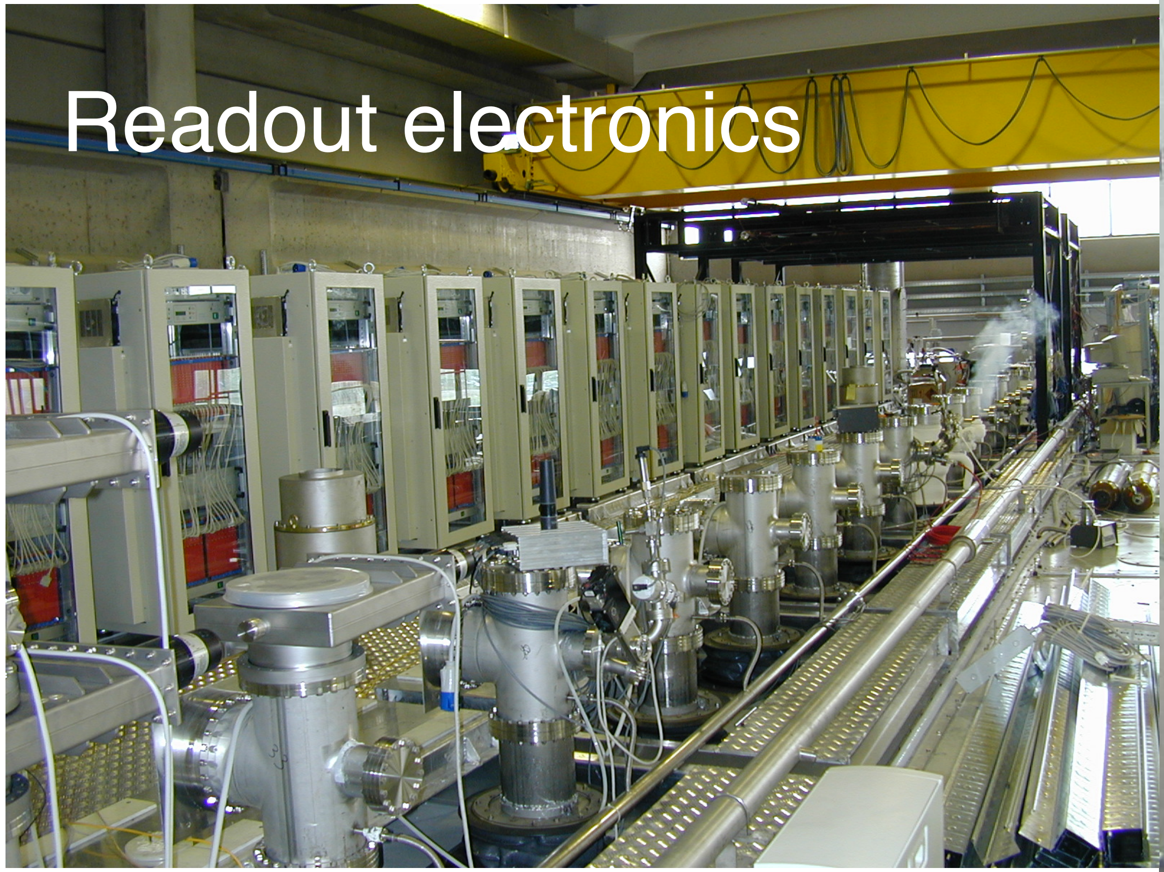
Looking forward to see start of physics programme !

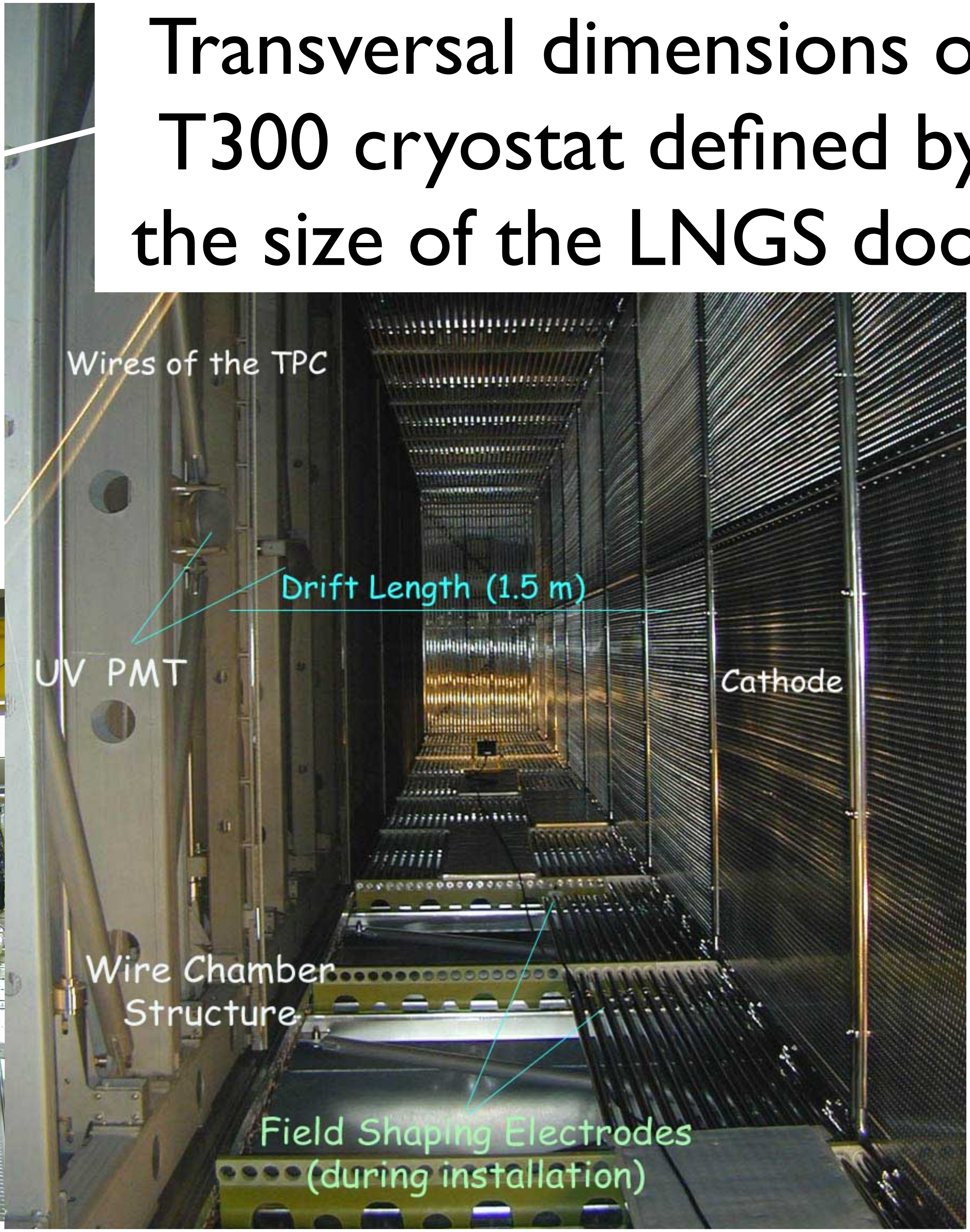
C.Rubbia, GLA2010 workshop, March 2010

ICARUS T300 prototype



Transversal dimensions of T300 cryostat defined by the size of the LNGS door





Almost 10 years from surface to underground operation @ LNGS !

Almost 10 years from surface to underground operation @ LNGS !

First CNGS events successfully recorded in T600 at LNGS in May 2010 !

Almost 10 years from surface to underground operation @ LNGS !

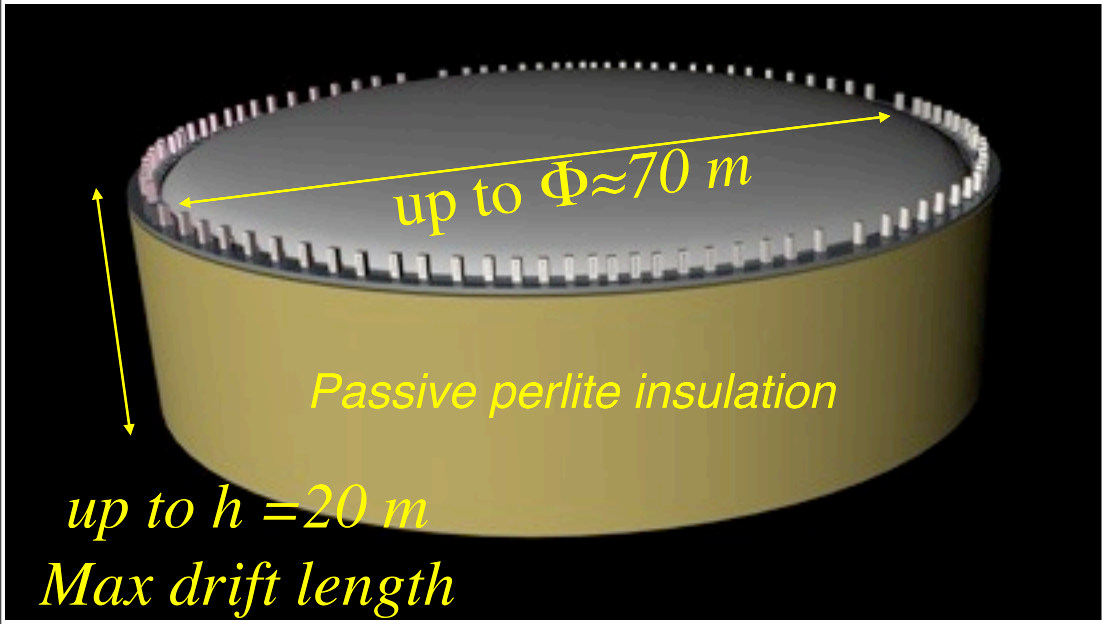
First CNGS events successfully recorded in T600 at LNGS in May 2010 !

Next generation detectors will be constructed in dedicated caverns and underground

➠ no need for “modules” approach

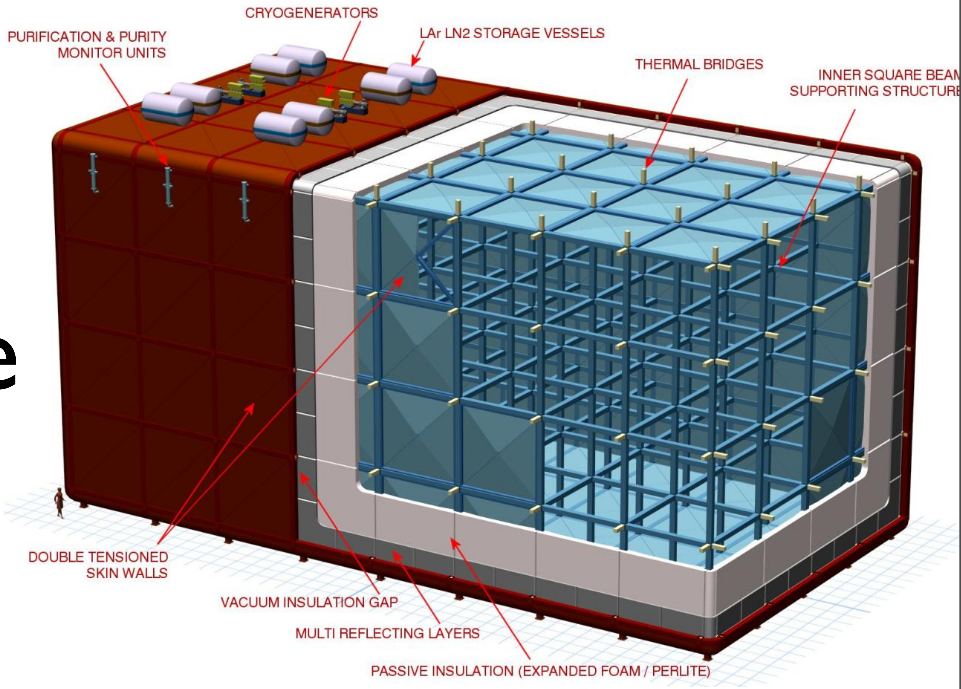
Concepts for Giant LAr detectors

Consider dedicated caverns and underground construction

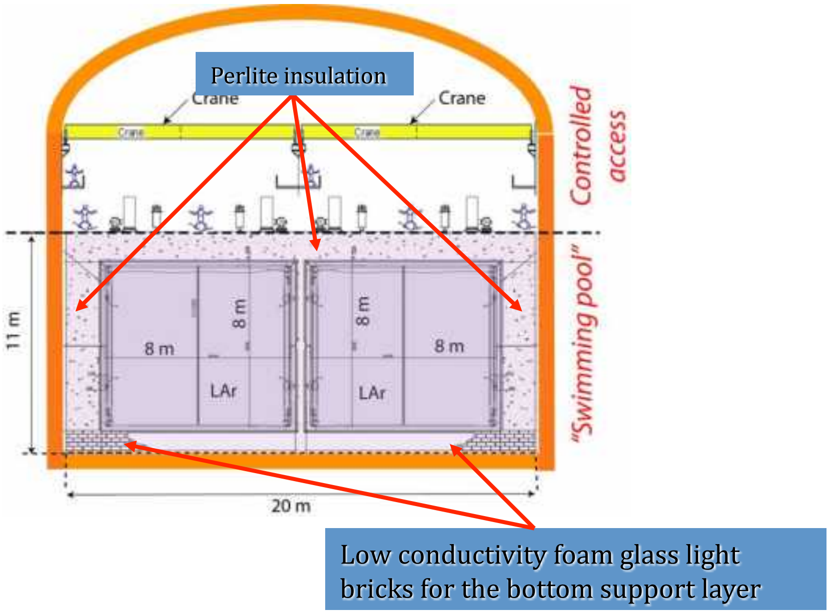


GLACIER (2003)
LNG-tank up to
100 kton

evacuable
LANND
(2006)



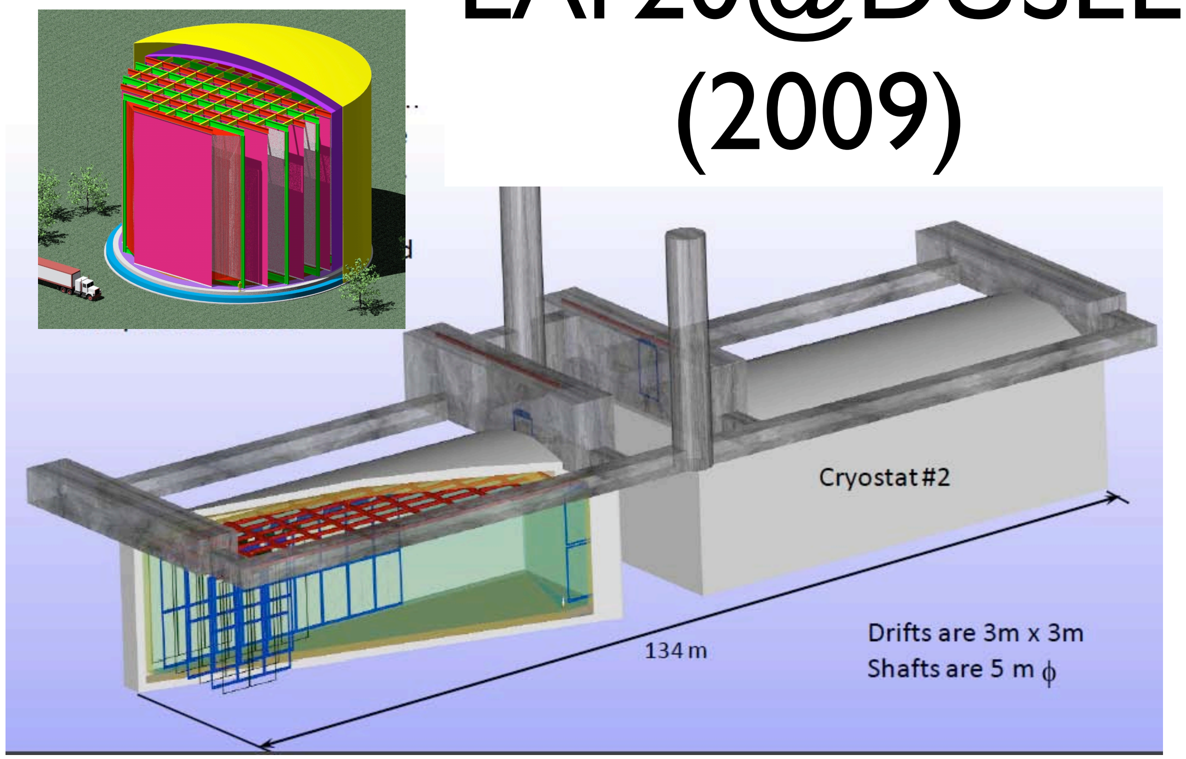
MODULAr
(2008)
10 kton



Low conductivity foam glass light bricks for the bottom support layer

LAr20@DUSEL
(2009)

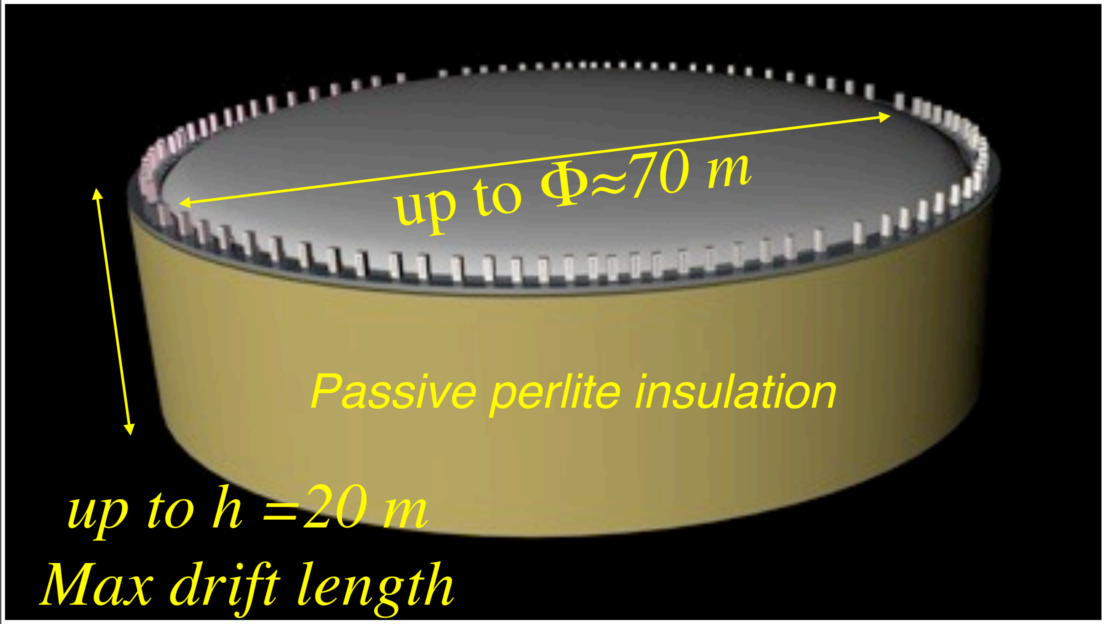
FLARE detector (2005)



Drifts are 3m x 3m
Shafts are 5 m ϕ

GLACIER: Giant Liquid Ar Charge Imaging ExpeRiment

AR, hep-ph/0402110, Venice 2003

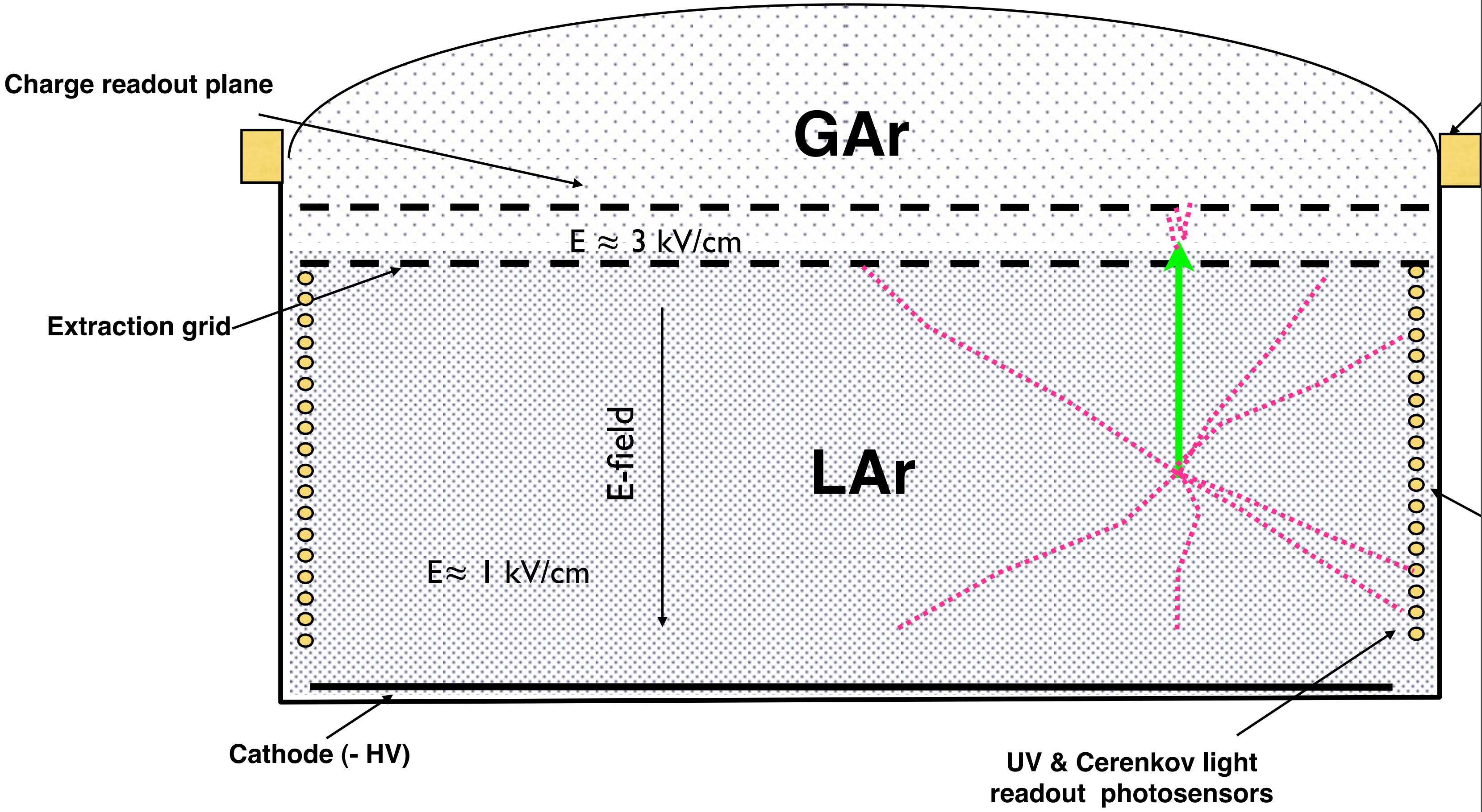


- Single module non-evacuable cryo-tank based on industrial LNG technology
- Cylindrical shape with excellent surface / volume ratio
- Simple, scalable detector design, possibly up to 100 kton
- Single very long vertical drift with full active mass
- A very large area LAr LEM-TPC for long drift paths
- Possibly immersed visible light readout for Cerenkov imaging
- Possibly immersed (high Tc) superconducting solenoid to obtain magnetized detector
- Reasonable excavation requirements (<250‘000 m^3)

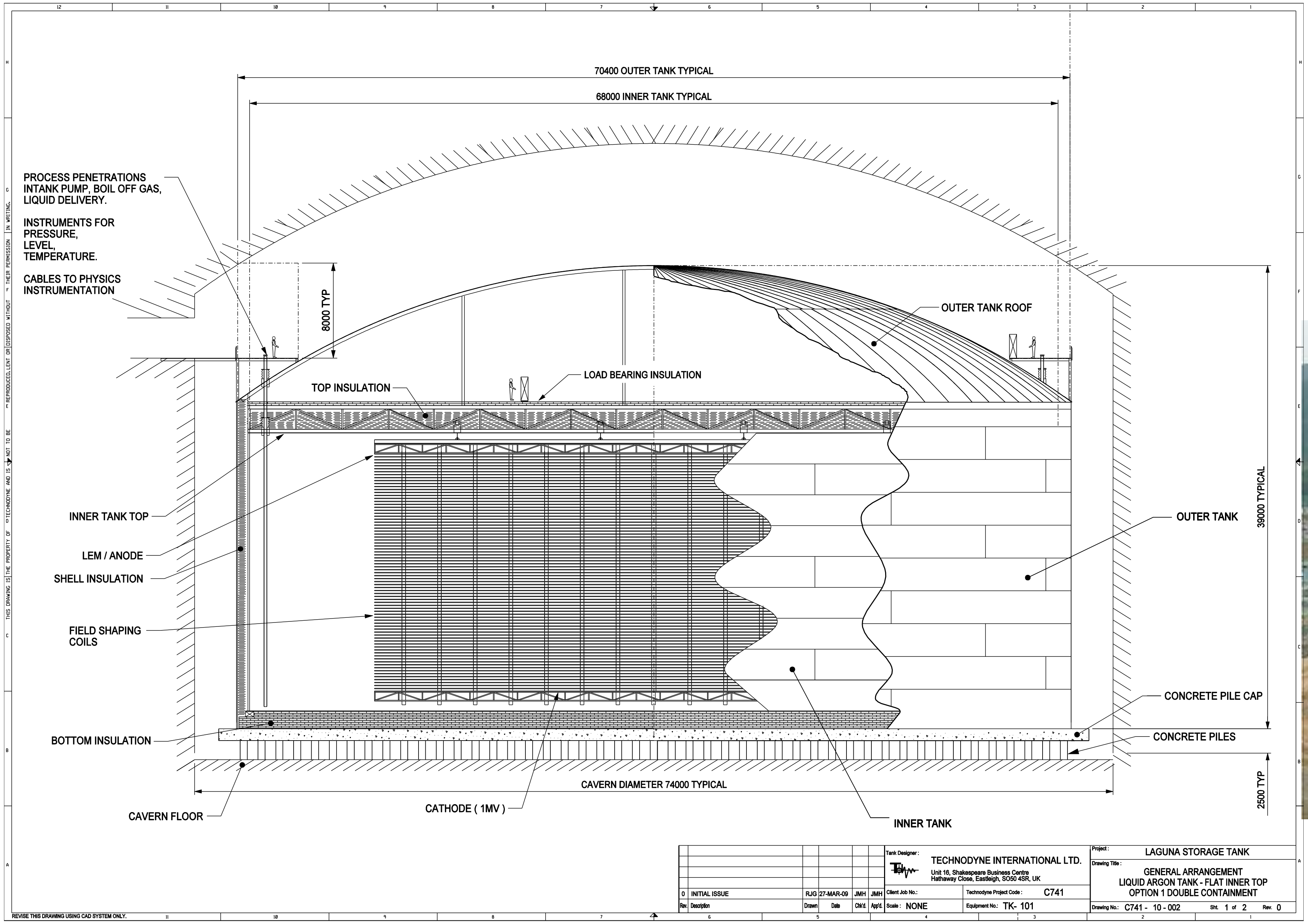
Design technical issues:

- Tank with passive insulation heat loss ≈ 80kW@LAr
- LEM+anode readout with 3mm readout pitch, modular readout, strip length modulable, 2.5x10^6 channels
- Purification to < 0.01 ppb (O_2 equiv.) in large non-evacuable vessel
- Immersed HV Cockcroft-Walton for drift field (1 kV/cm) up to 2 MV
- Readout electronics (digital F/E with CAEN; cold preamp R&D ongoing; network data flow & time stamp distrib.)
- WLS-coated 1000x 8” PMT and reflectors for DUV light detection

(Green: less challenging, Red: more challenging)



Engineering of tank & detector

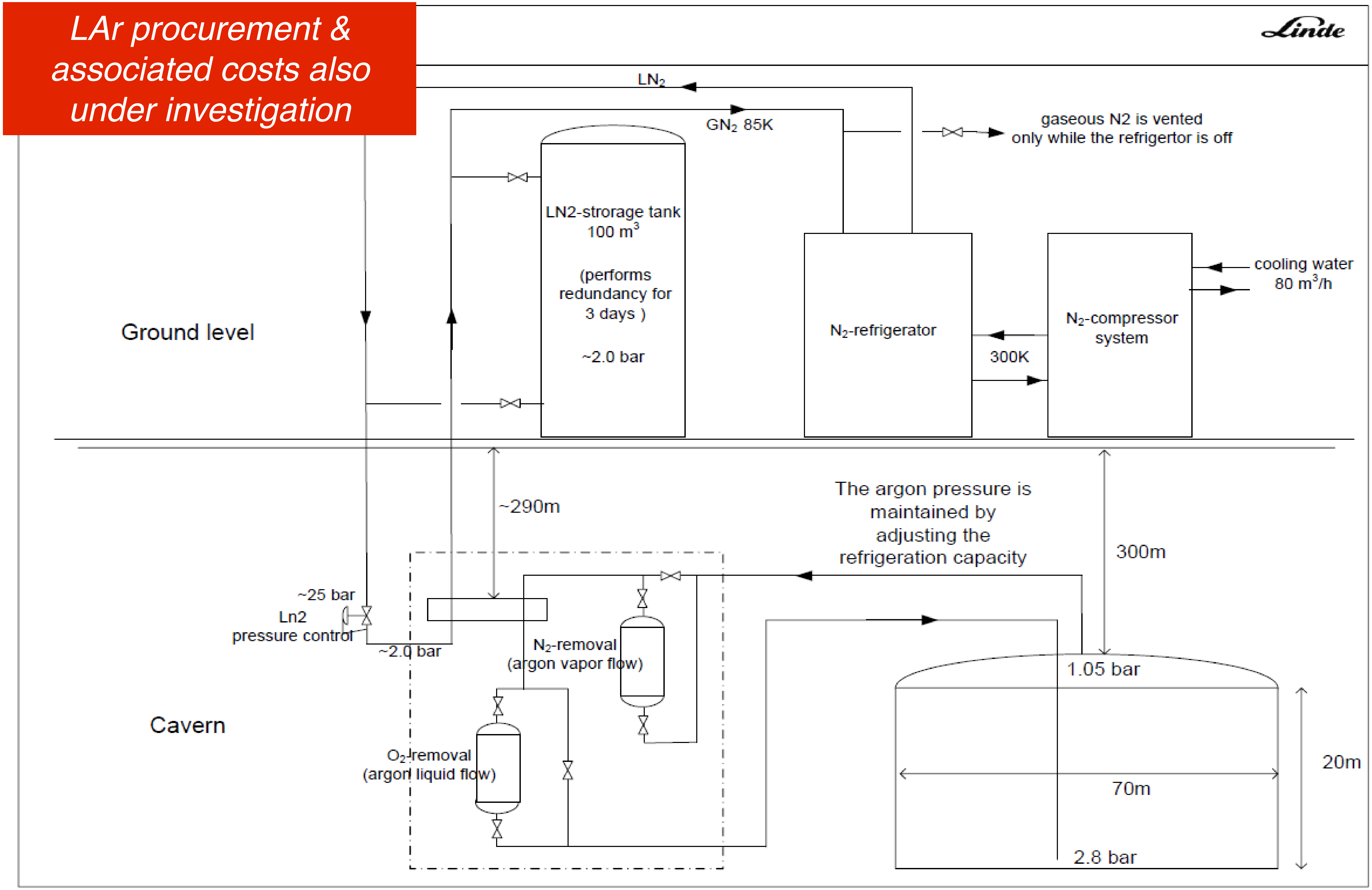


LNG technology feasibility & safety already proven at the required scale

- Study started in 2004 with Technodyne International Ltd
- Recent progress within the EU FP7 LAGUNA DS
- study covers conceptual design including detector support, tank construction sequence, and tank costing (for high&low seismic region)
- considers incremental cost (multiplicative) for underground construction

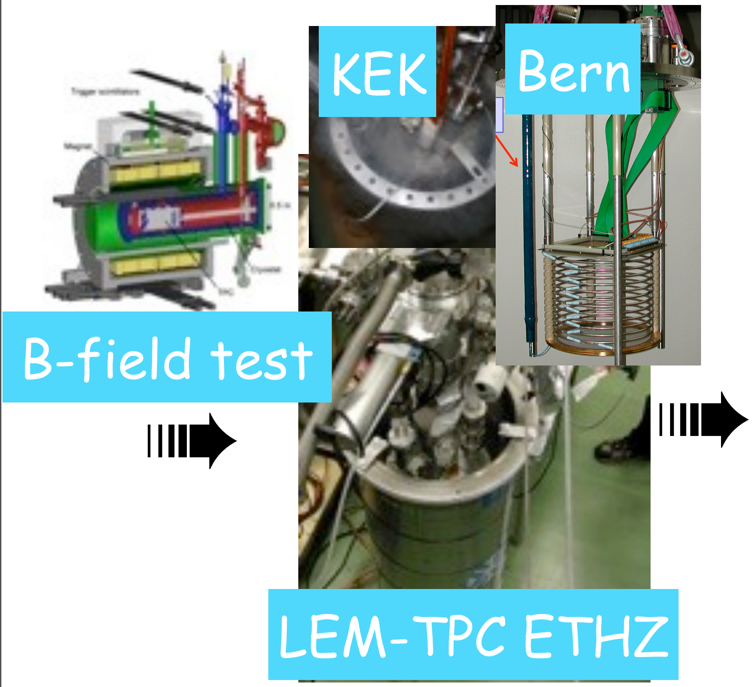
Concept for the cryogenic process

LAr procurement & associated costs also under investigation



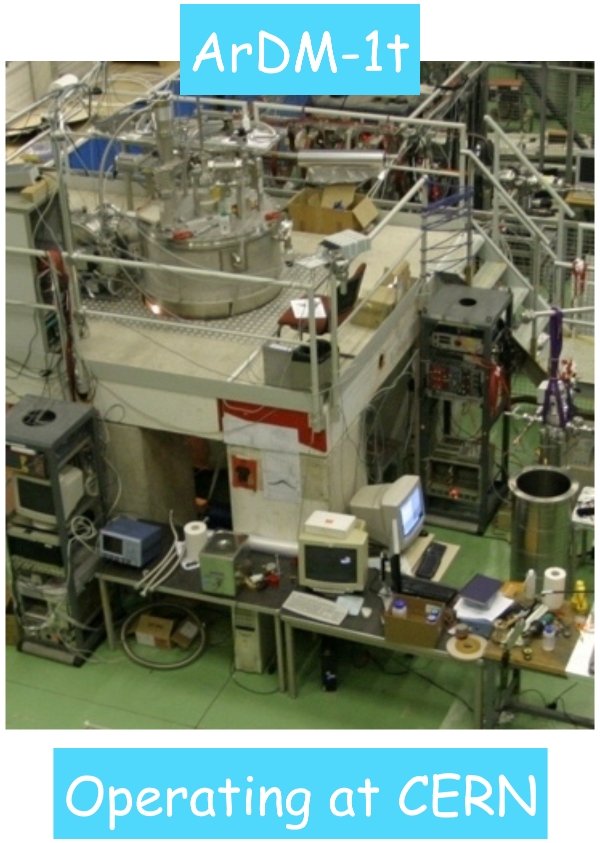
GLACIER roadmap

see J.Phys.Conf.Ser.171:012020,2009

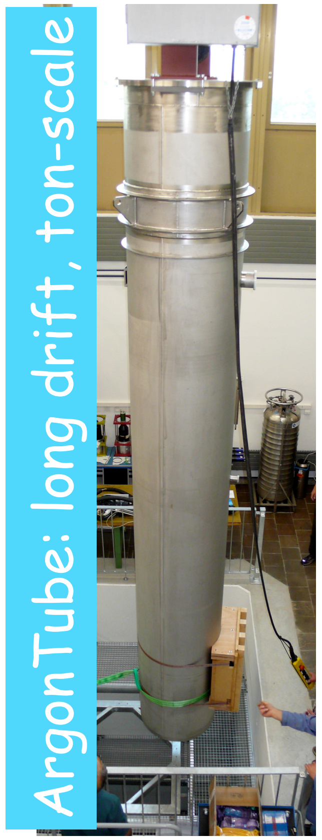


proof of principle double-phase LAr LEM-TPC on 0.1x0.1 m² scale

LEM readout on 1x1 m² scale UHV, cryogenic system at ton scale, cryogenic pump for recirculation, PMT operation in cold, light reflector and collection, very high-voltage systems, feed-throughs, industrial readout electronics, safety (in Collab. with CERN)



direct proof of long drift path up to 5 m

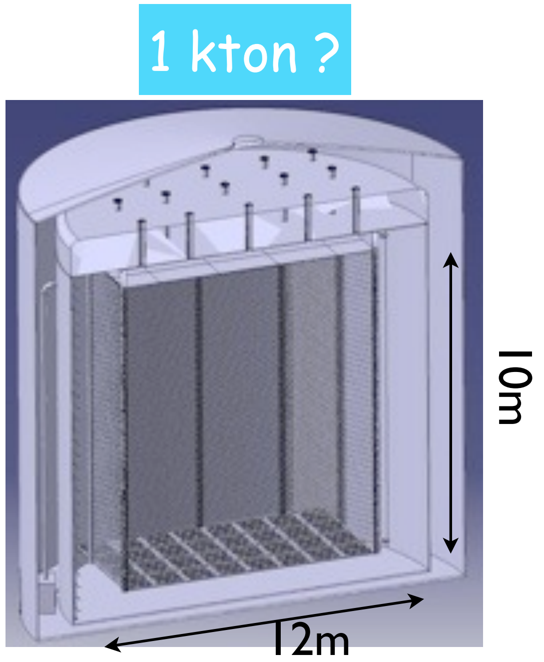


Application of LAr LEM TPC to neutrino physics: particle reconstruction & identification (e.g. 1 GeV e/μ/π/K), optimization of readout and electronics, possibility of neutrino beam exposure

6m3 → CERN NA ?

full engineering demonstrator for larger detectors, acting as near detector for neutrino fluxes and cross-sections measurements, or with a stand-alone short baseline physics programme

A precursor step



New methods of charge readout

“to save the features of the LAr TPC” (Radeka)

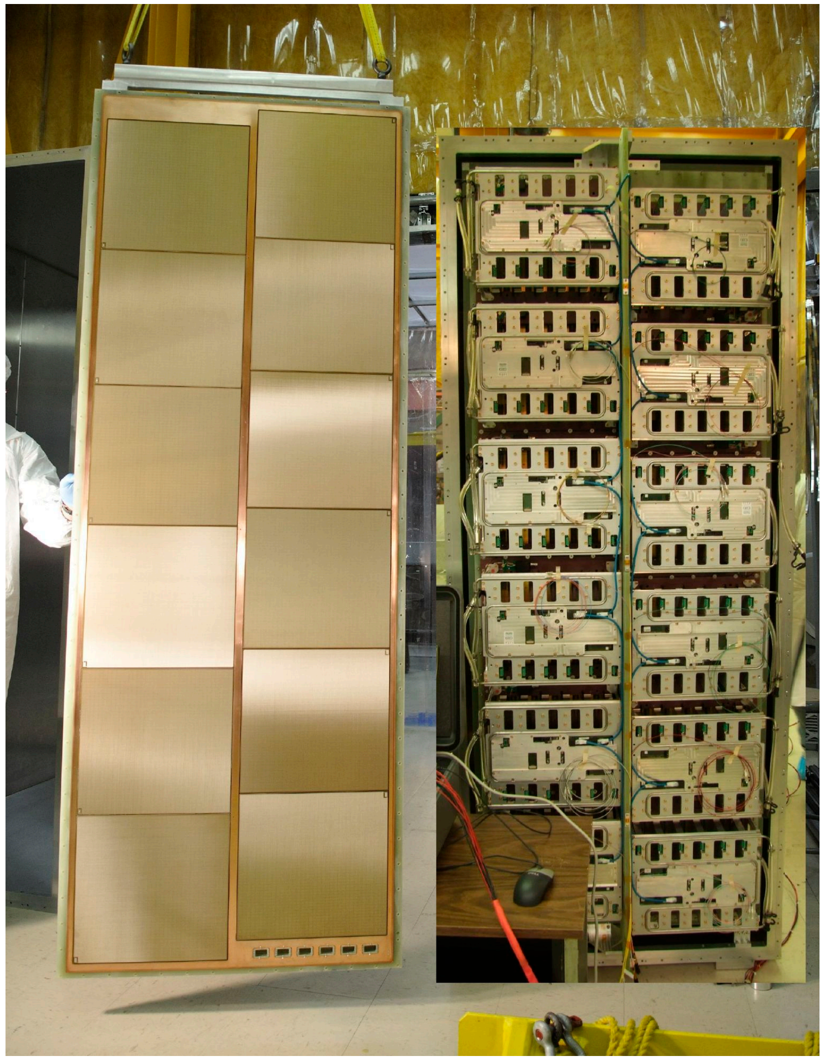
against loss of signal from diffusion, attachment to electronegative impurities, ...

(1) double phase Ar LEM/THGEM TPC

ETHZ group

Badertscher et al., IEEE Proc. arXiv0811.3384 and NIMA617:188-192,2010

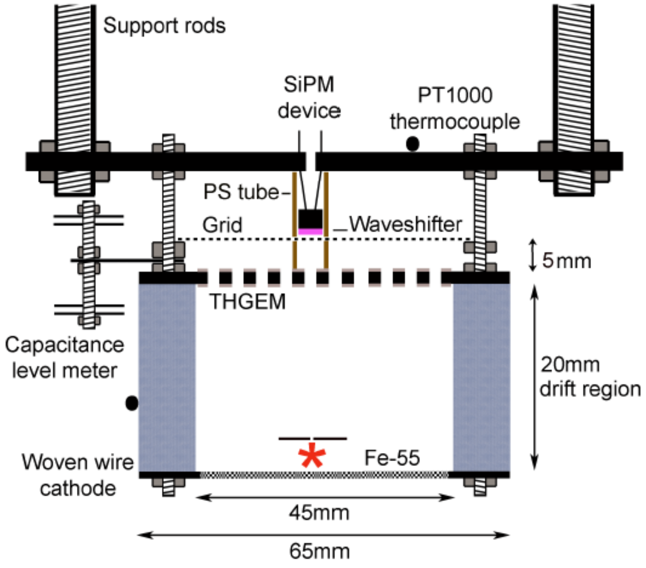
(2) Double phase+ MicroMegas



Saclay group

A. Delbart et al., GLA2010 workshop

(3) secondary scintillation from THGEM (optical readout)



Sheffield group

P K Lightfoot et al., JINST 4:P04002,2009

see also A. Bondar et al., arXiv: 1005.5216 (May 28th 2010)

The new LAr LEM-TPC

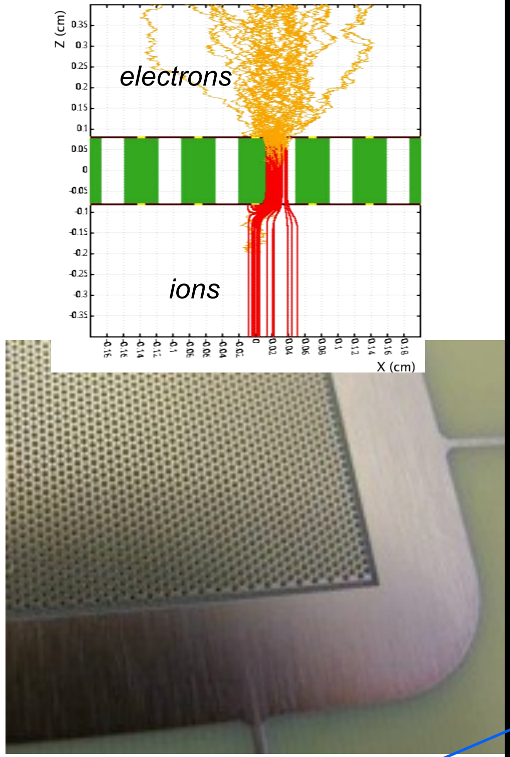
LAr LEM TPC = Double phase TPC with gain in GAr vapor

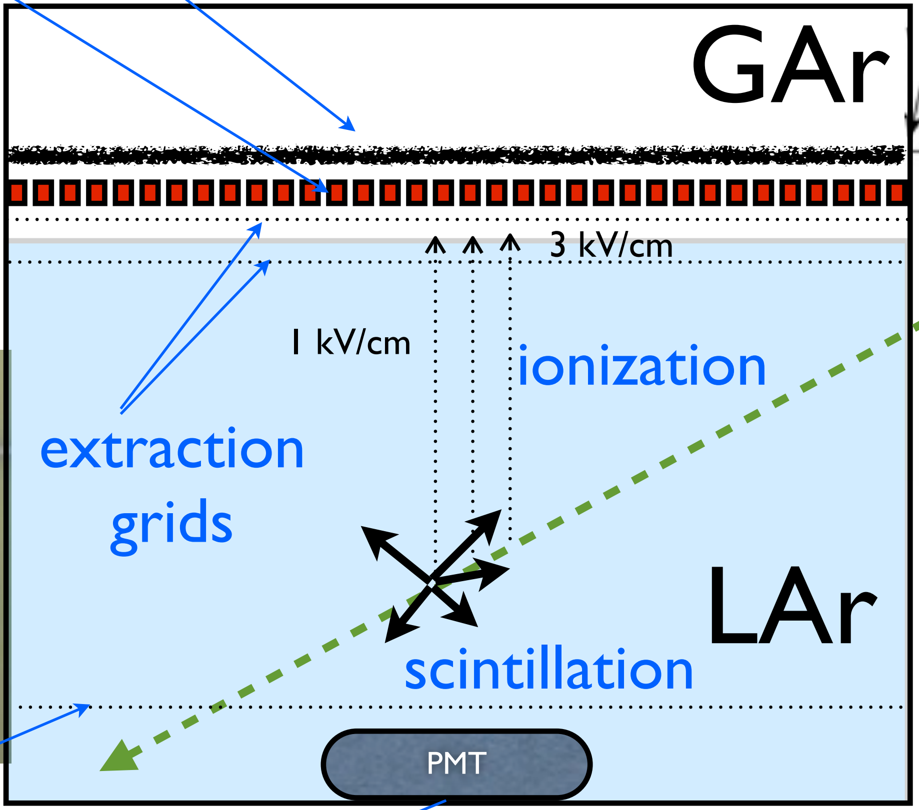
Motivated by the very long drift path needed in giant detectors and DM applications (keV detection)

hep-ph/0402110, arXiv:0811.3384, arXiv:0907.2944, J.Phys.Conf.Ser.171:012020,2009, arXiv:1001.0076

segmented anode

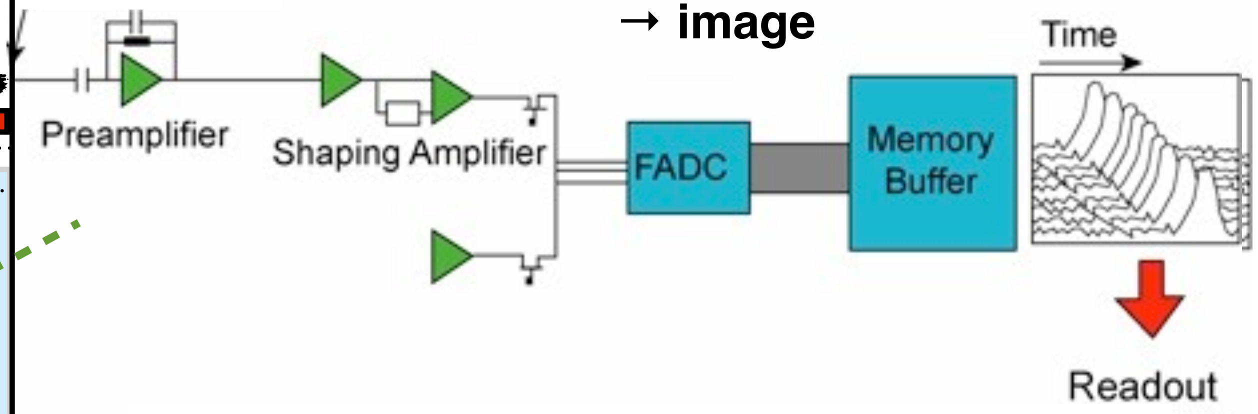
amplification stage



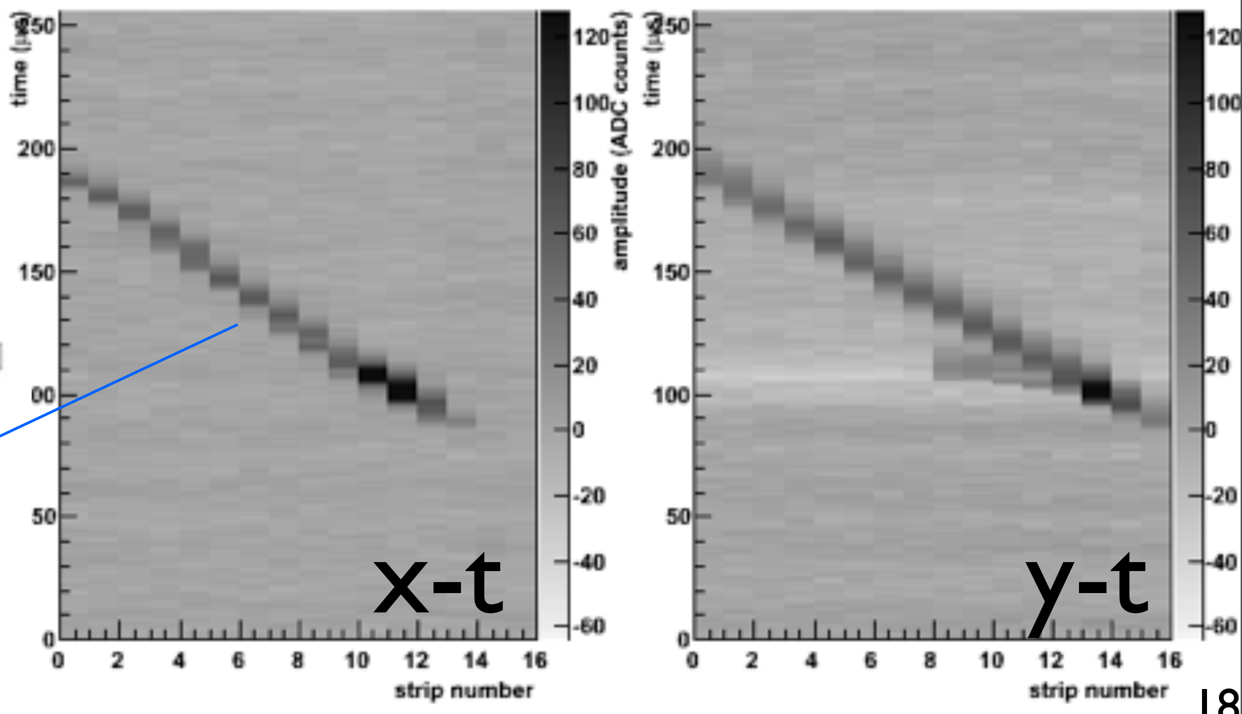


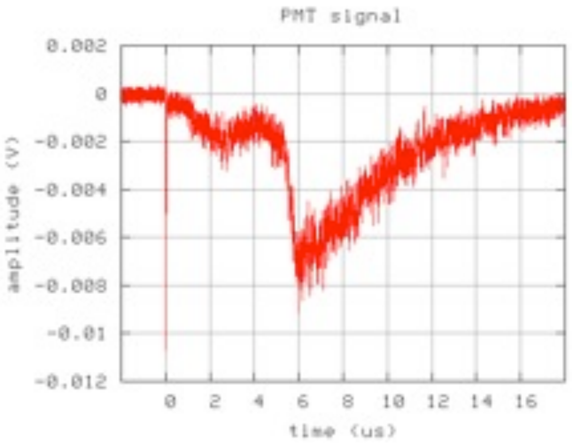
cathode

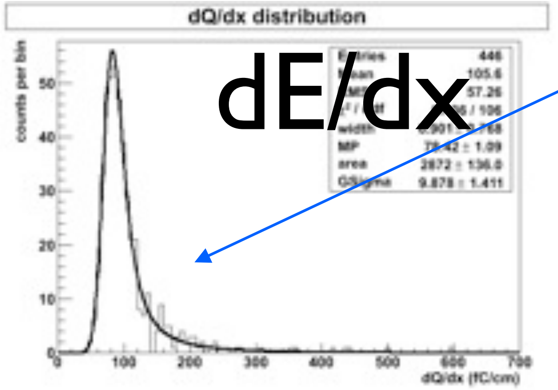
Continuous waveform recording → image



Cosmic tracks in 3 lt prototype (G≈6):

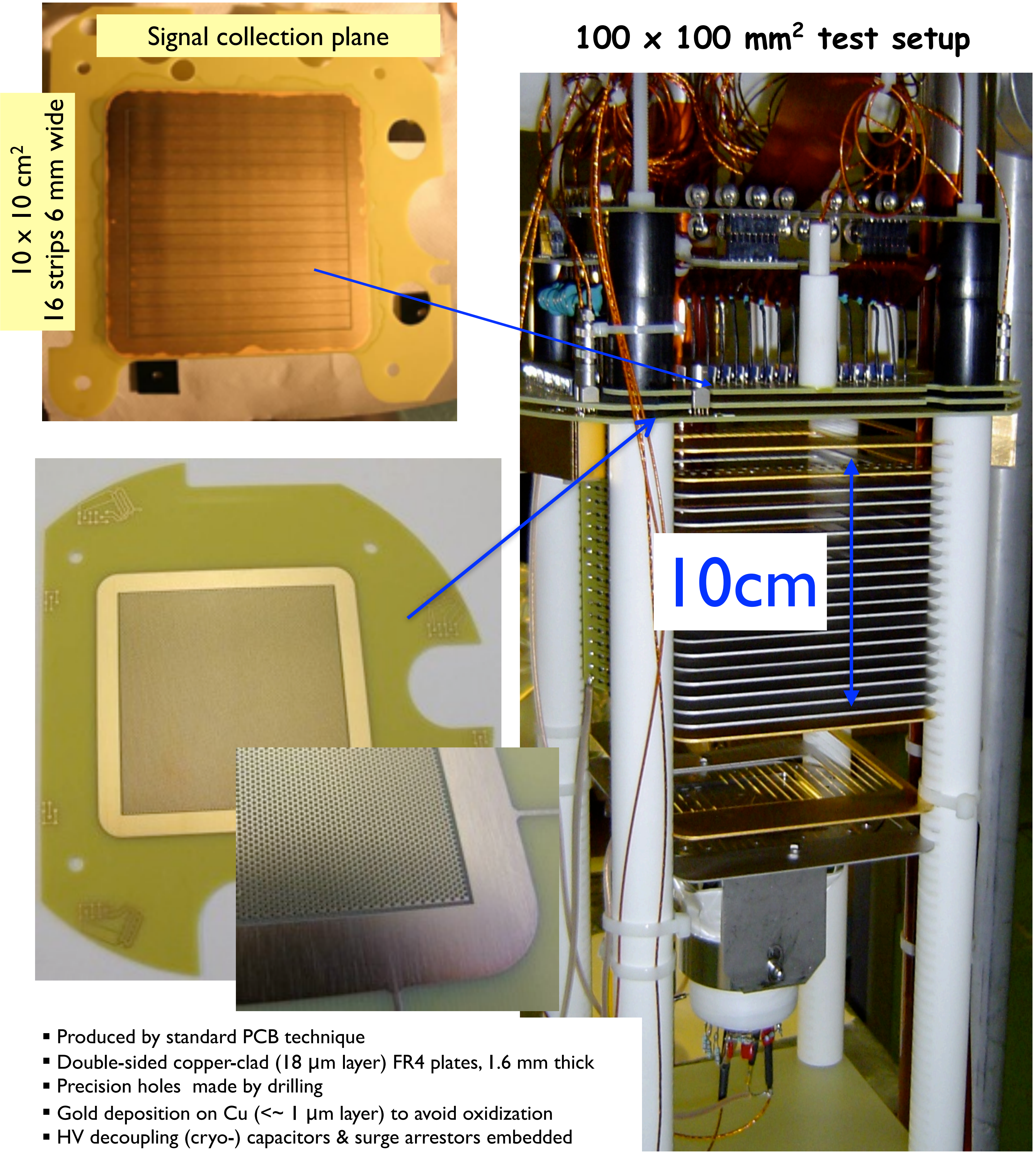






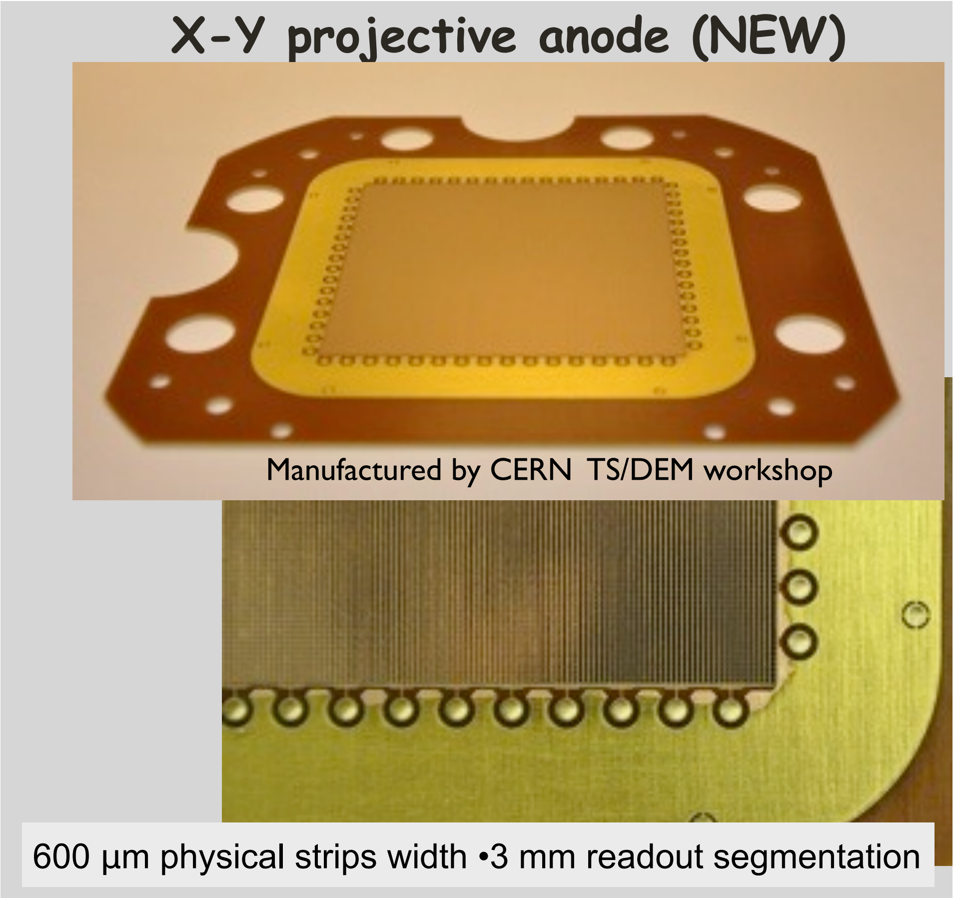
LAr LEM-TPC 3lt setup @ CERN

100 x 100 mm^2 test setup



- Produced by standard PCB technique
- Double-sided copper-clad (18 μm layer) FR4 plates, 1.6 mm thick
- Precision holes made by drilling
- Gold deposition on Cu (<~ 1 μm layer) to avoid oxidization
- HV decoupling (cryo-) capacitors & surge arrestors embedded

X-Y projective anode (NEW)


Manufactured by CERN TS/DEM workshop

600 μm physical strips width •3 mm readout segmentation


600 x 600 mm2 THGEM protoypes

ELTOS S.p.A. (eltos.it)

CERN RD51

~600,000 holes/piece
(very large gerber file)
Ø: 0.4, p.: 0.8, th.: 0.6 mm
rim: 5 μm (micro-etching)
Ni-Au coating

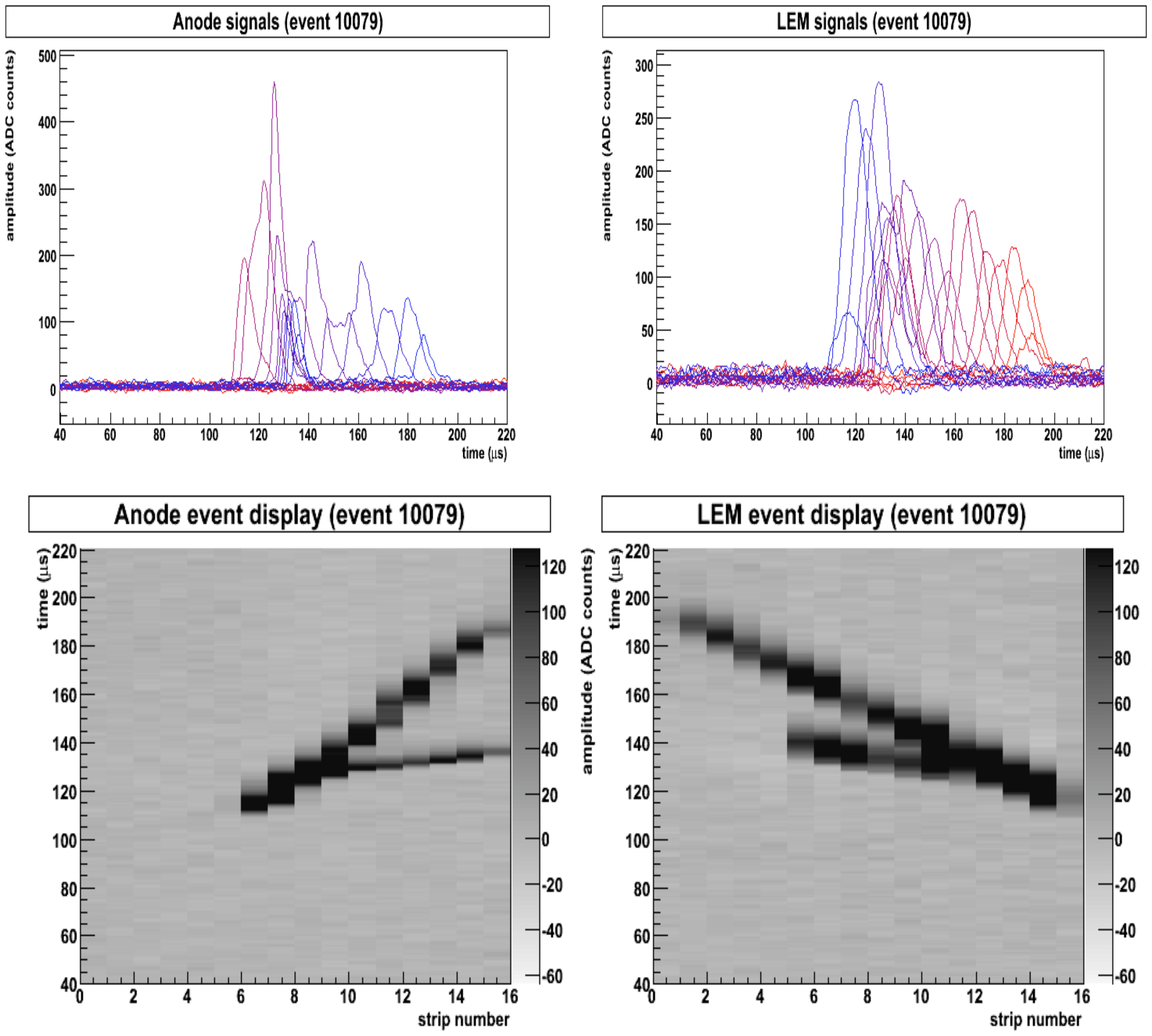
THGEM discussion, 02/11/2009 THGEM production at ELTOS **Fulvio TESSAROTTO**

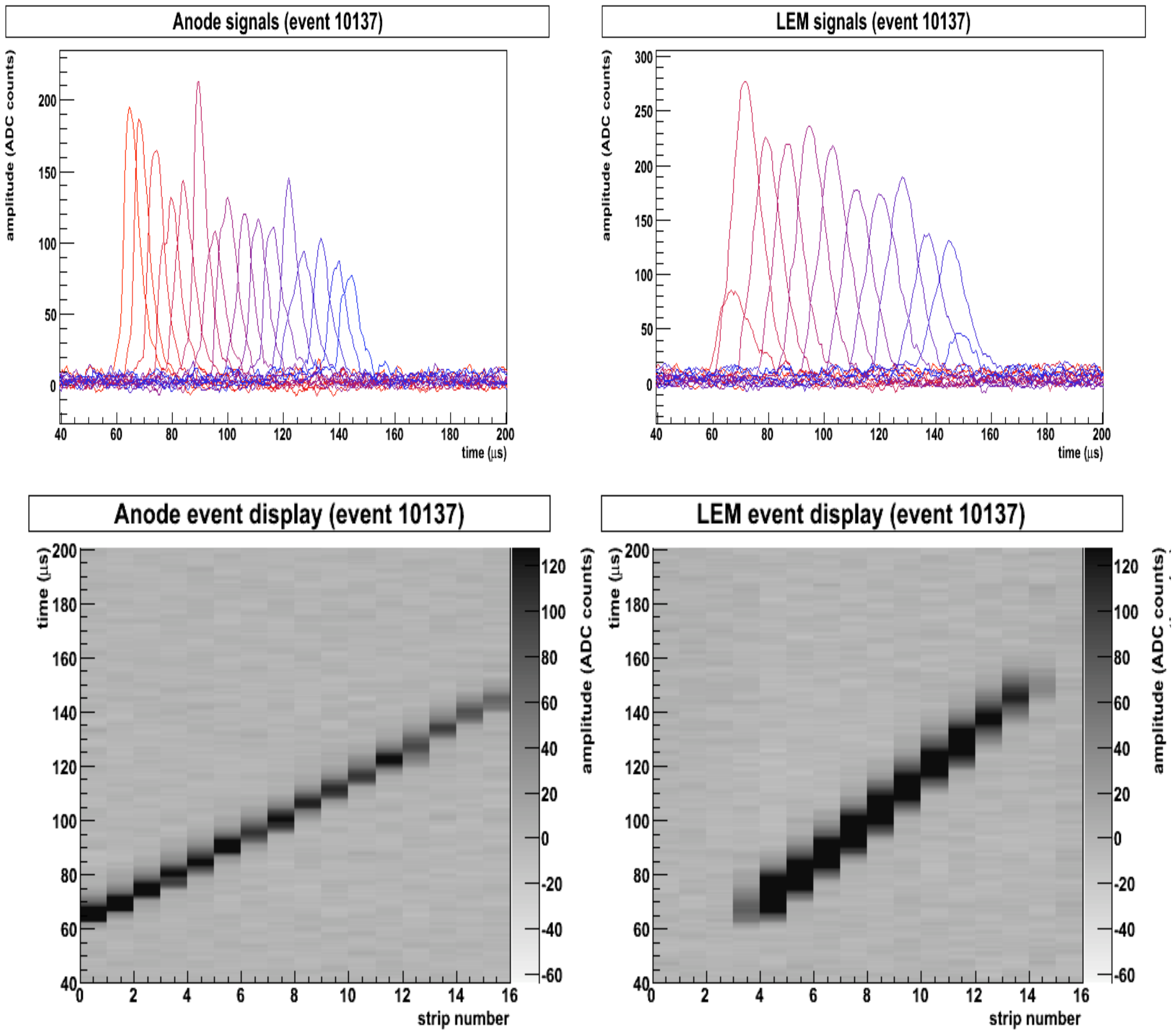
Cosmic tracks in 3lt setup @ CERN

- Double phase (1.0bar, 87K).
- Amplification:
  - single stage (1x1.0mm LEM).

- Charge readout:
  - anode and top LEM electrodes.
- Gain: ~6.5.
- O_2 contamination: ~2ppb.

Typical cosmic muon tracks

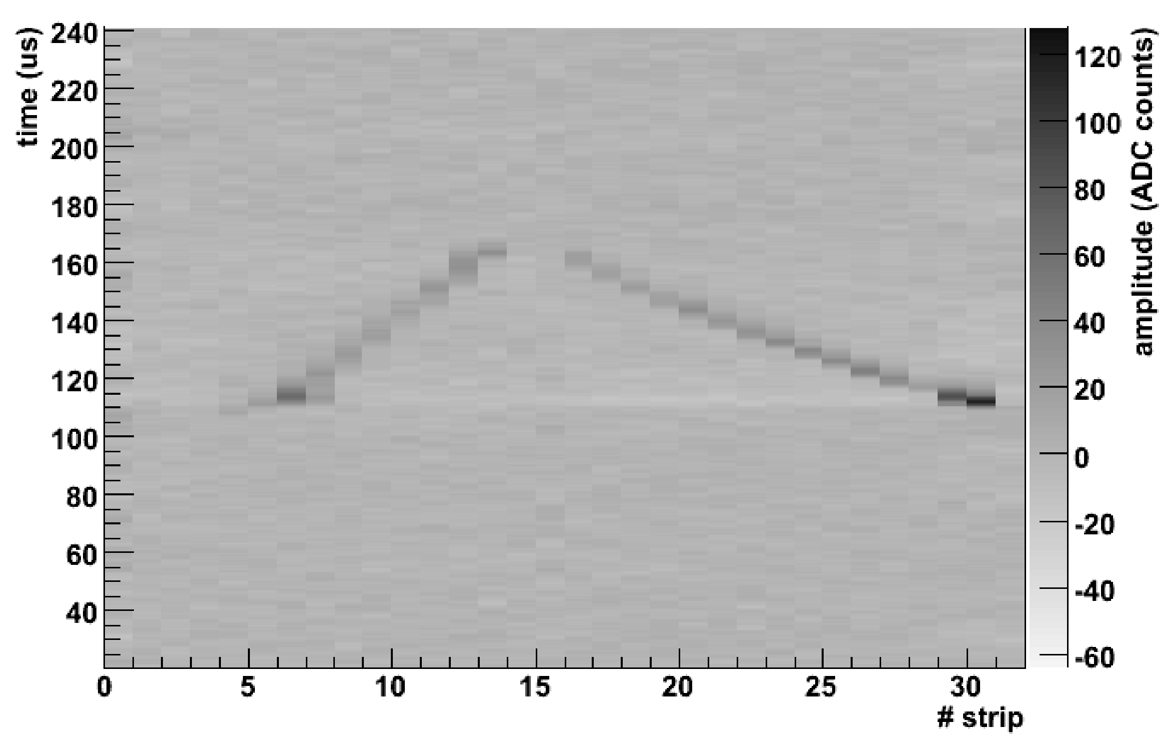


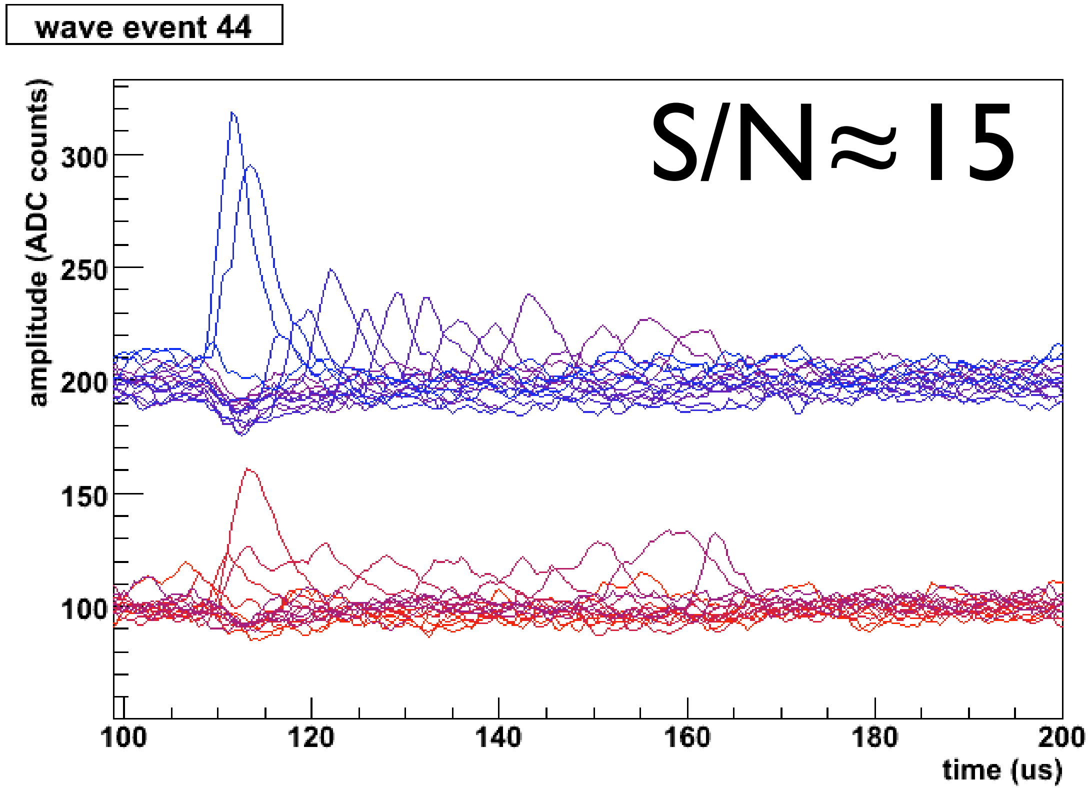


Single(LEM immersed) vs Double phase

A. Badertscher et al., NIMA617:188-192,2010

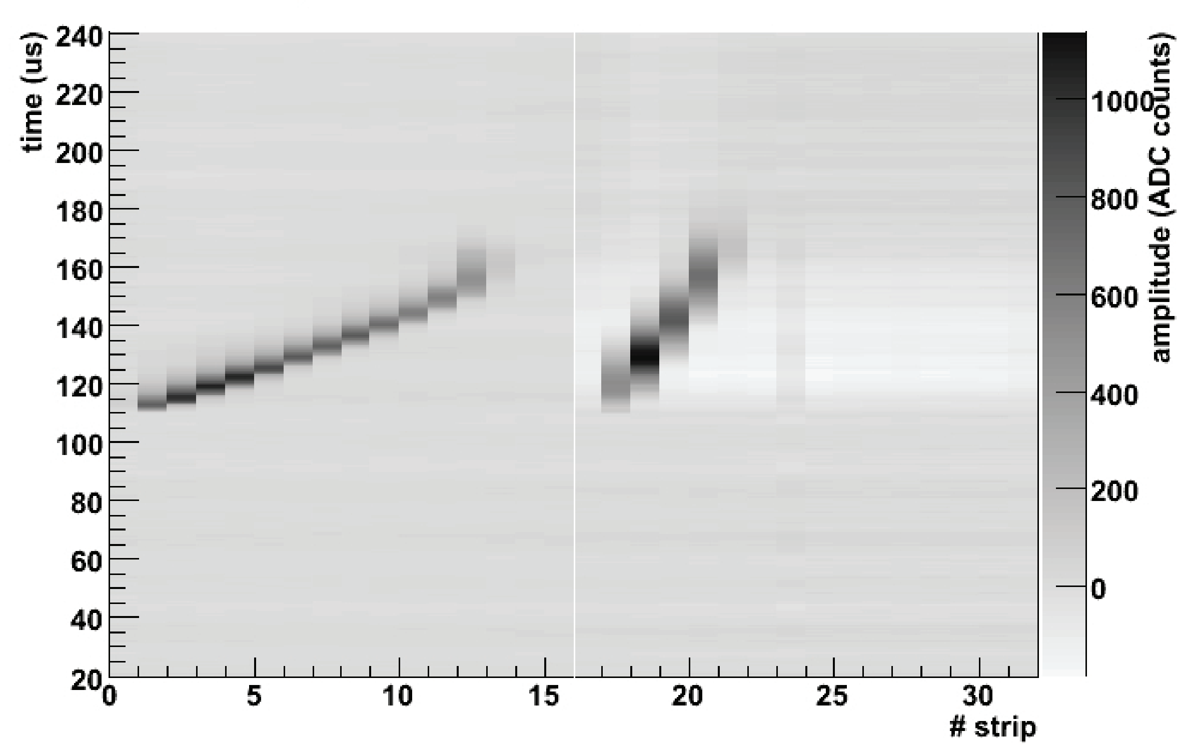
Without gain (G=1) (after offline noise filtering)

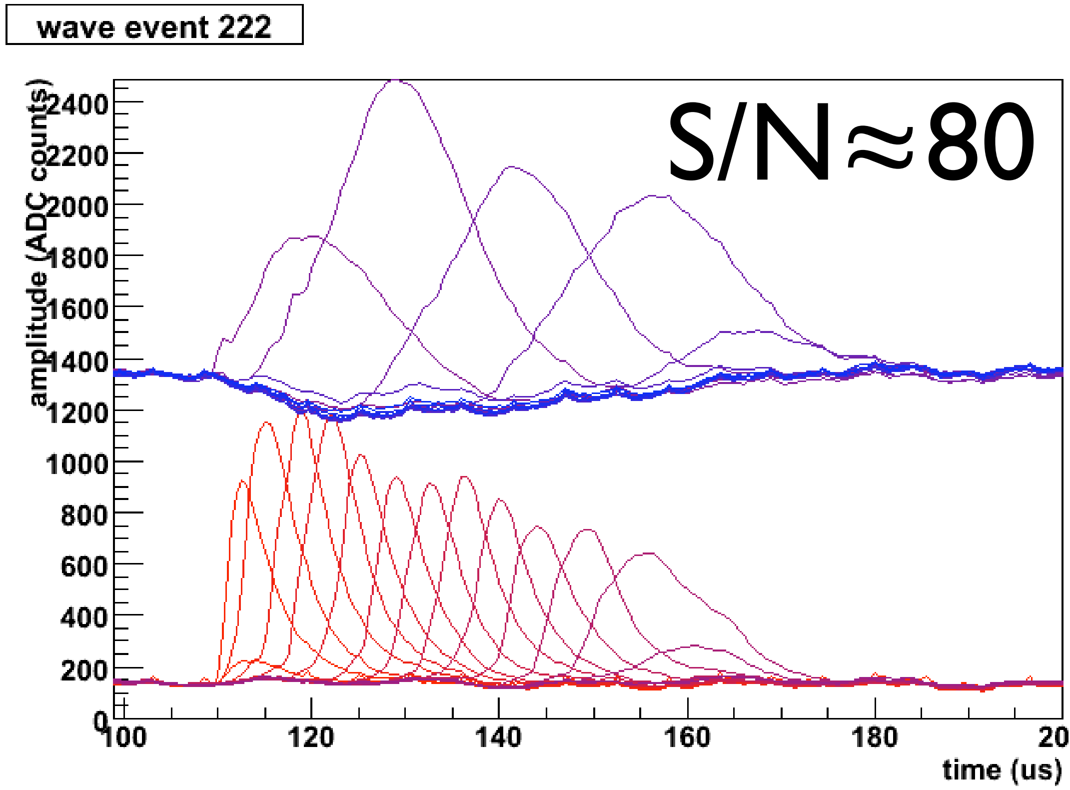




S/N≈15

With gain (G≈10) (no offline filtering)



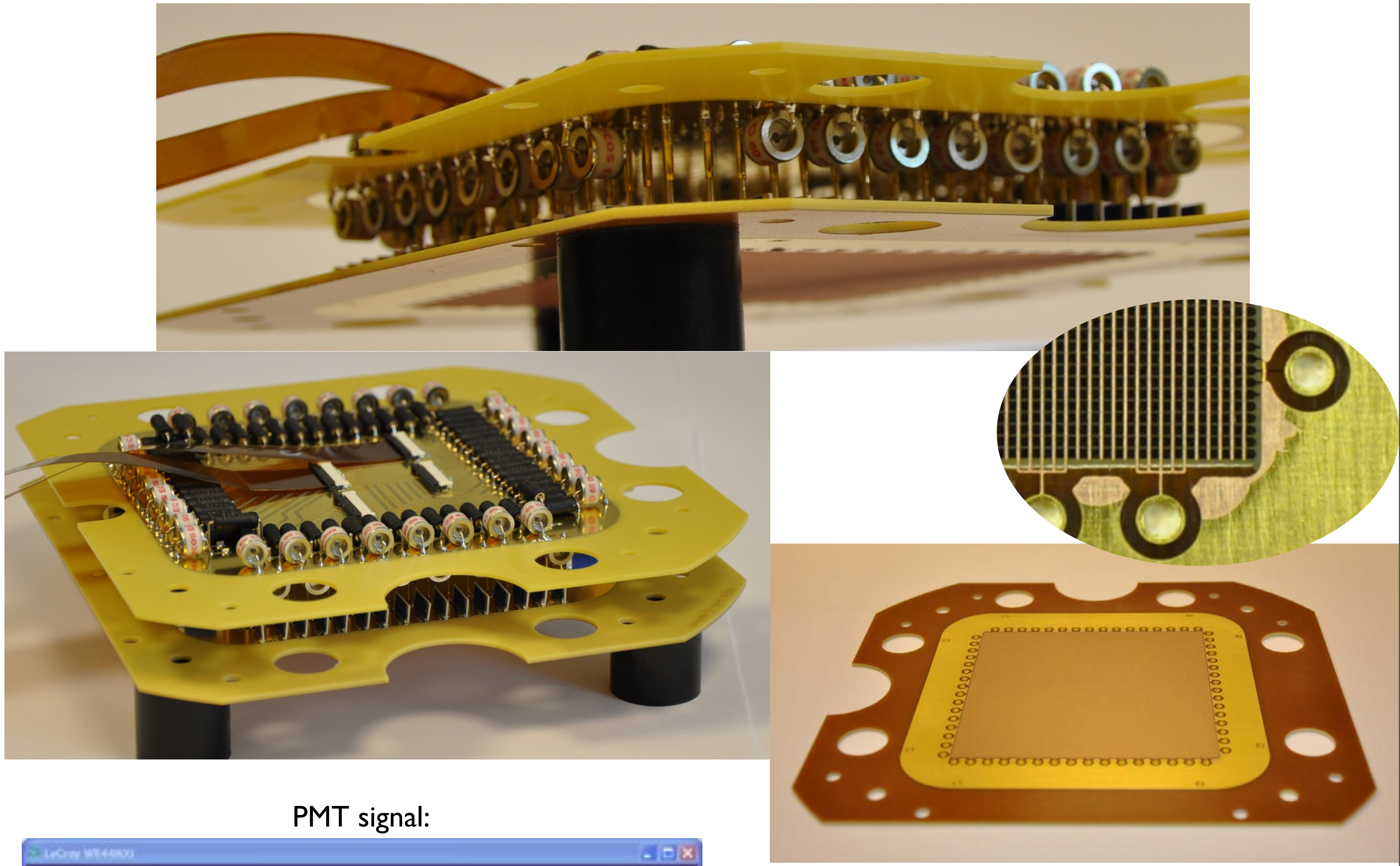


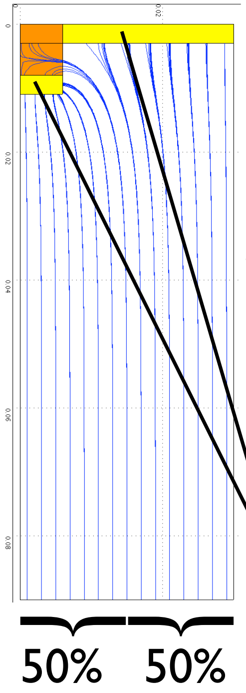
S/N≈80

Next step: LEM-TPC with two view anode

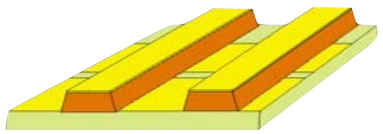
D. Lussi & F. Resnati, ETHZ PhD theses

- Decouple the amplification and the readout stages.
  - Design almost independent of LEM development.
- The charge is equally shared between X and Y strips.
- No segmentation and capacitors on the LEMs.
  - Decrease the discharge probability and the charge involved in a spark.
- Same signal shape of both coordinates.
  - Same analysis treatment of both signal types.





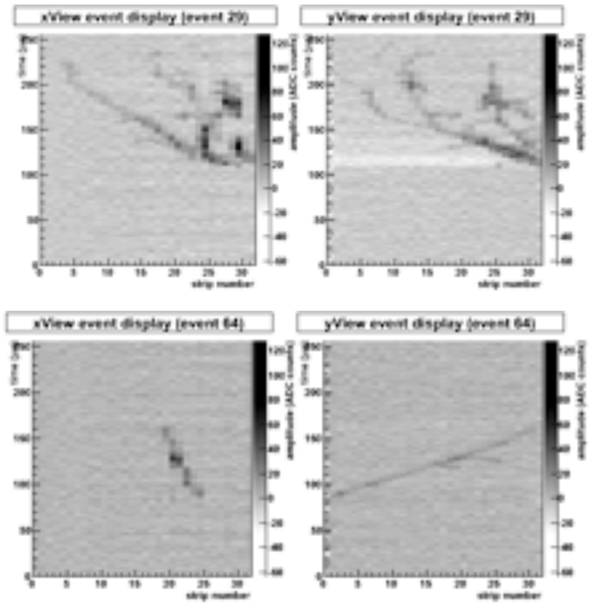
Compass Experiment



Readout pitch	3mm
Strip pitch	600μm
Covered strip width	500μm
Exposed strip width	120μm
Kapton thickness	50μm
Segmentation	2x32ch

PMT signal:

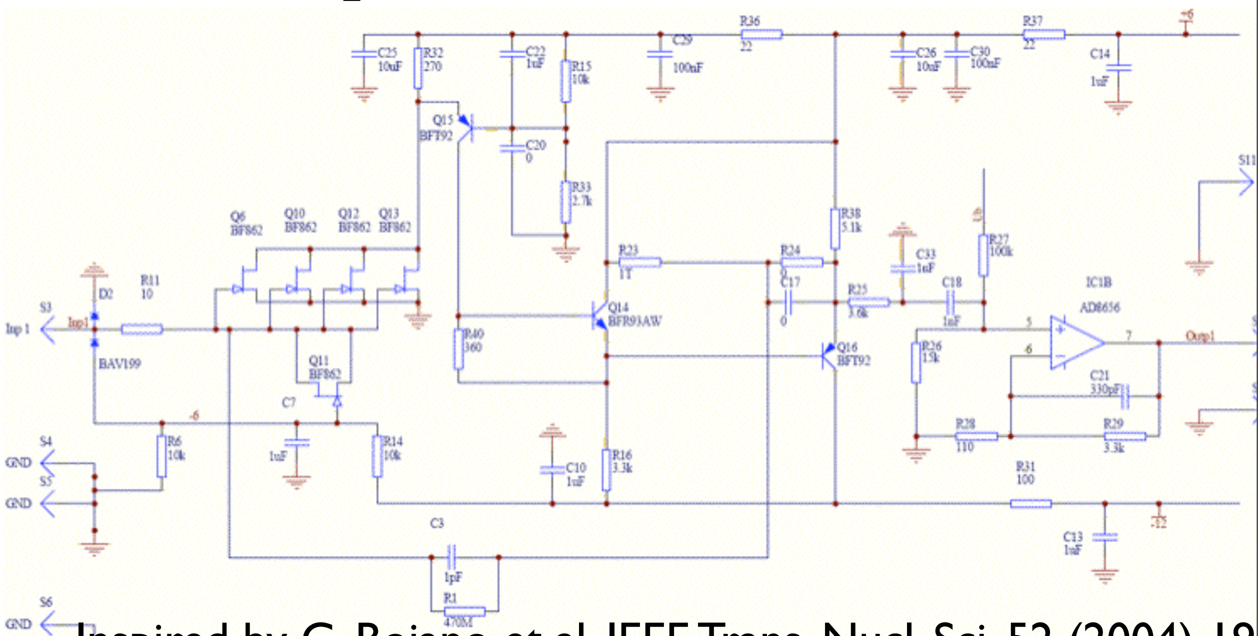
Cosmic tracks



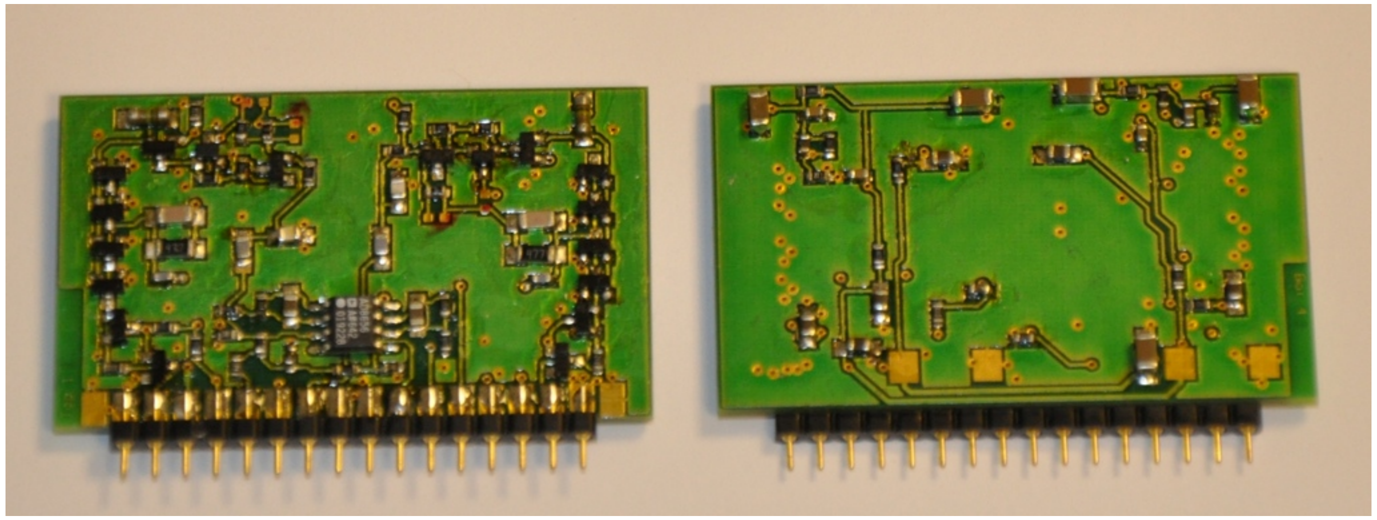
LAr TPC readout system

Custom made front-end charge preamp and shaper:

- 2 channel per chip.
- rise time 0.6μs, fall time 2μs.
- gain ~11mV/fC.
- S/N ~10 @ 1fC and 200pF.



Inspired by C. Boiano et al. IEEE Trans. Nucl. Sci. 52 (2004) 19



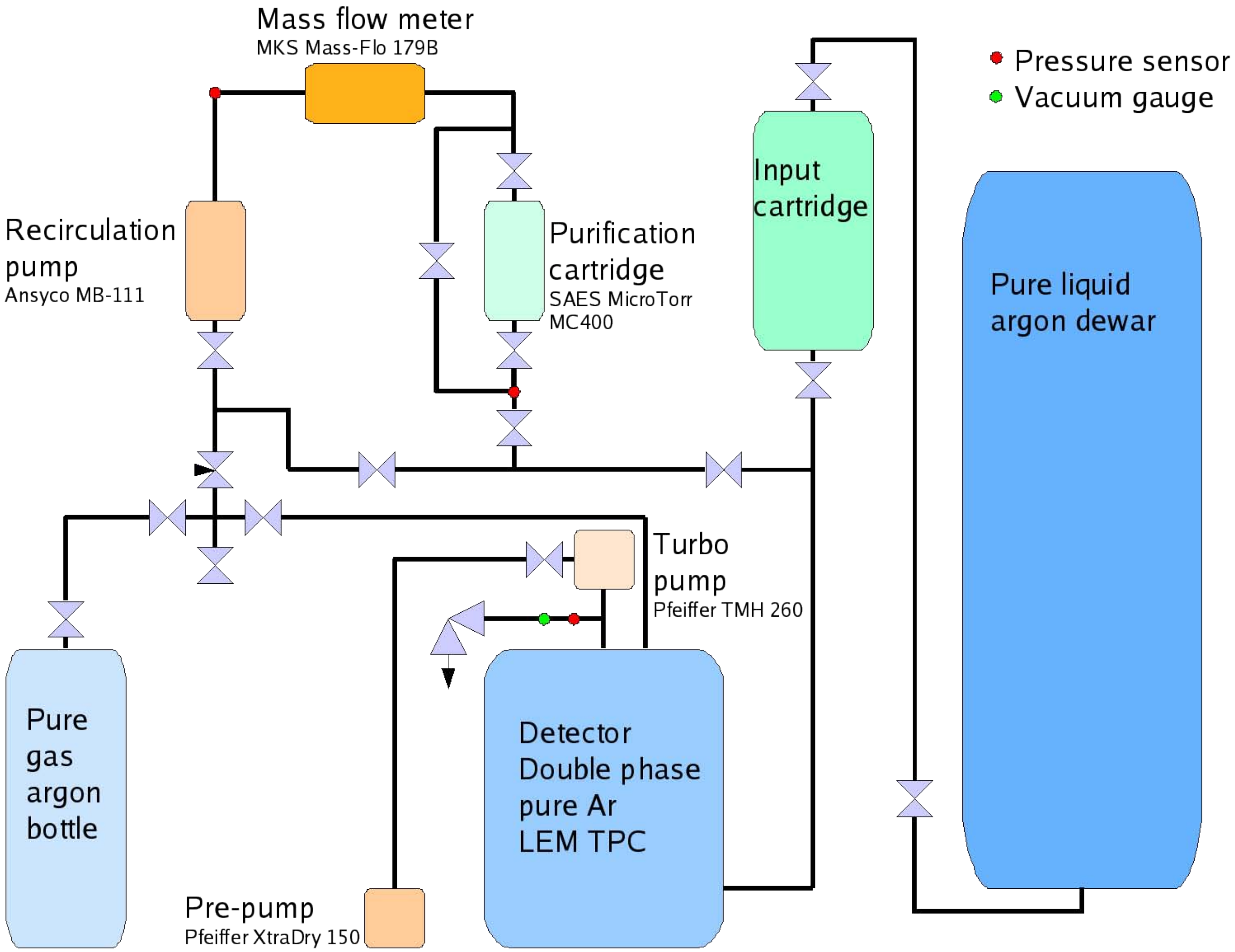
CAEN in collaboration with ETHZ developed a full ADC and DAQ system:

- 12 bit 2.5 MS/s flash ADC.
- Programmable FPGA.
- Implementation of Zero suppression.
- Channel-by-channel trigger and global "trigger alert".
- 256 channel crate.
- Chainable optical link.

Argon purification

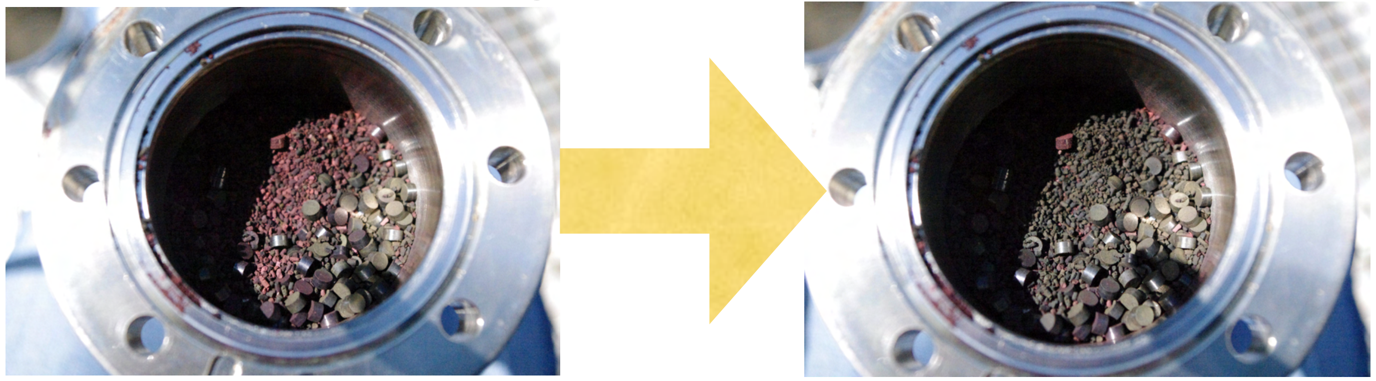
A. Badertscher et al., NIMA617:188-192,2010

- Input purification:
  - A custom made cartridge purifies LAr at the detector input.
- Recirculation:
  - Heating resistors evaporate LAr.
  - A metal bellows pump pushes GAr through a commercial getter (1vol/48h).
  - The pure GAr condensates in the detector volume.
  - During the cool down phase GAr is purified: molecules from outgas or cold leaks are trapped into the getter and the detector is uniformly cooled.



Best purity got after filling is better than 0.6ppb (O_2)

activated Cu
(redish)



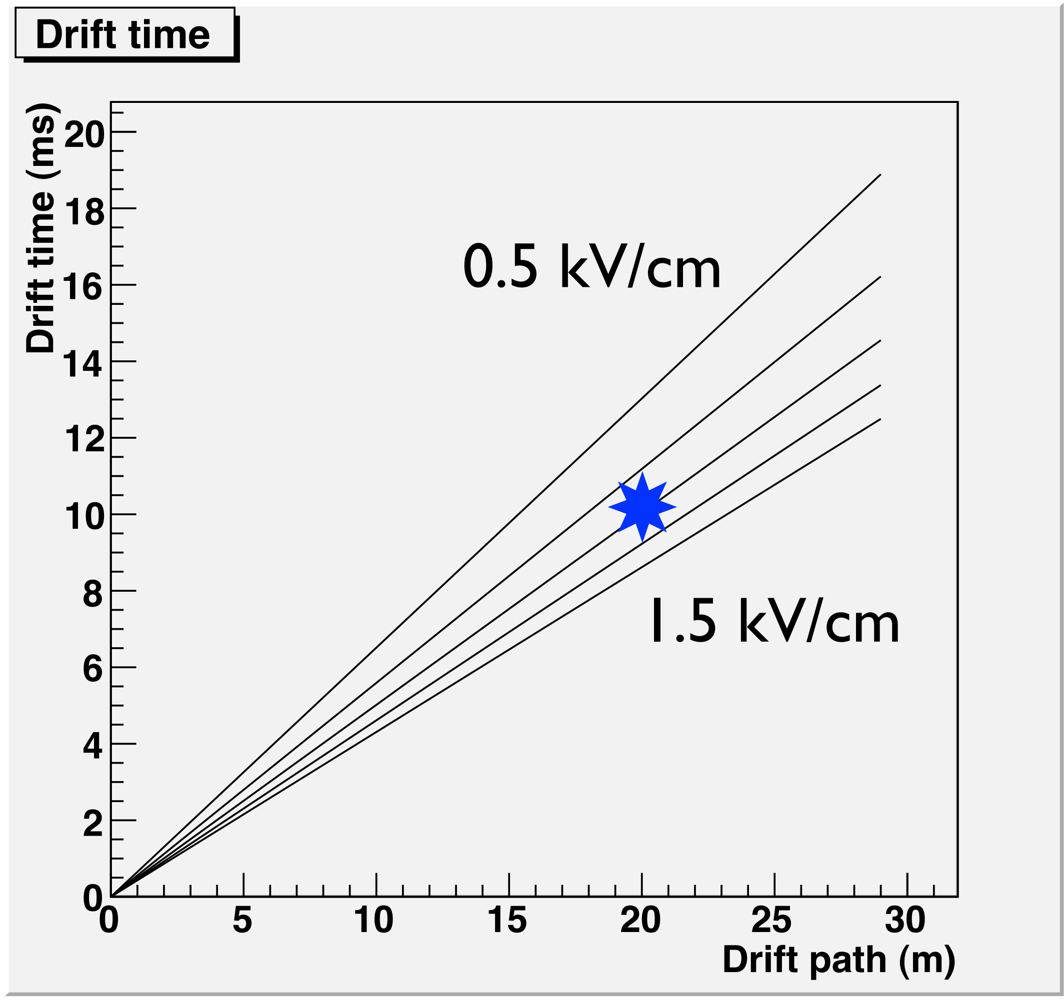
after few
seconds in air

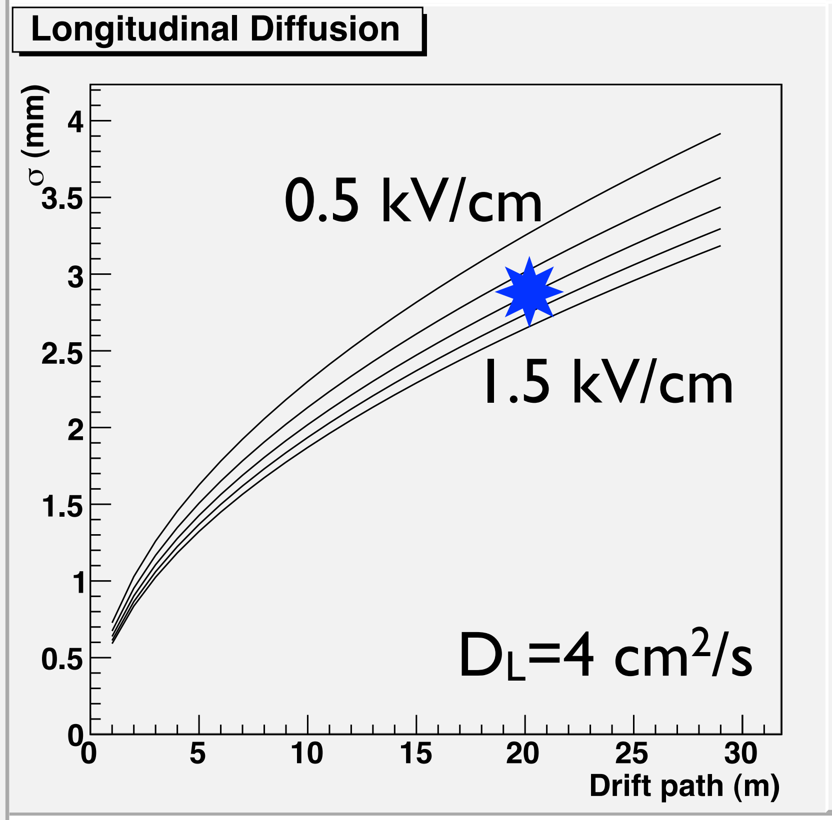
Long drift paths...

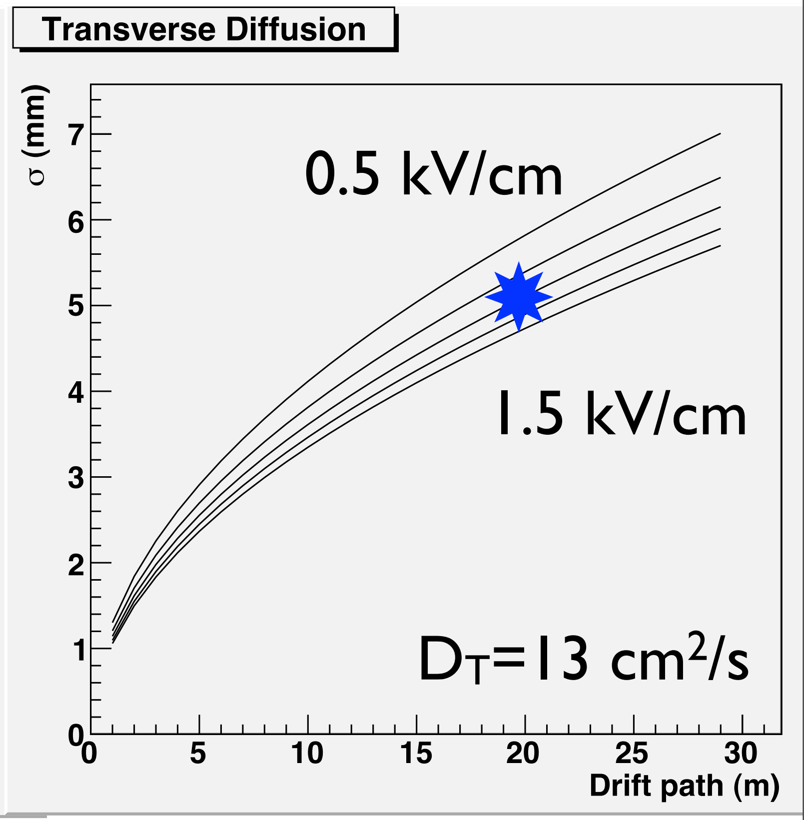
Papers on diffusion see e.g.
K. McDonald, LArTPC Document 532-v1

Challenge: very long drift paths ➠ 5m ➠ 10m... ➠ 20m...

Drift fields E=0.5,0.75,1,1.25,1.5 kV/cm



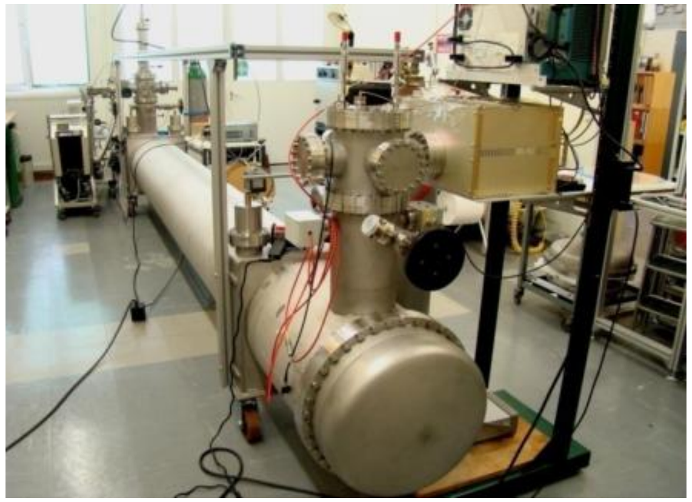




Experimental verification needed:

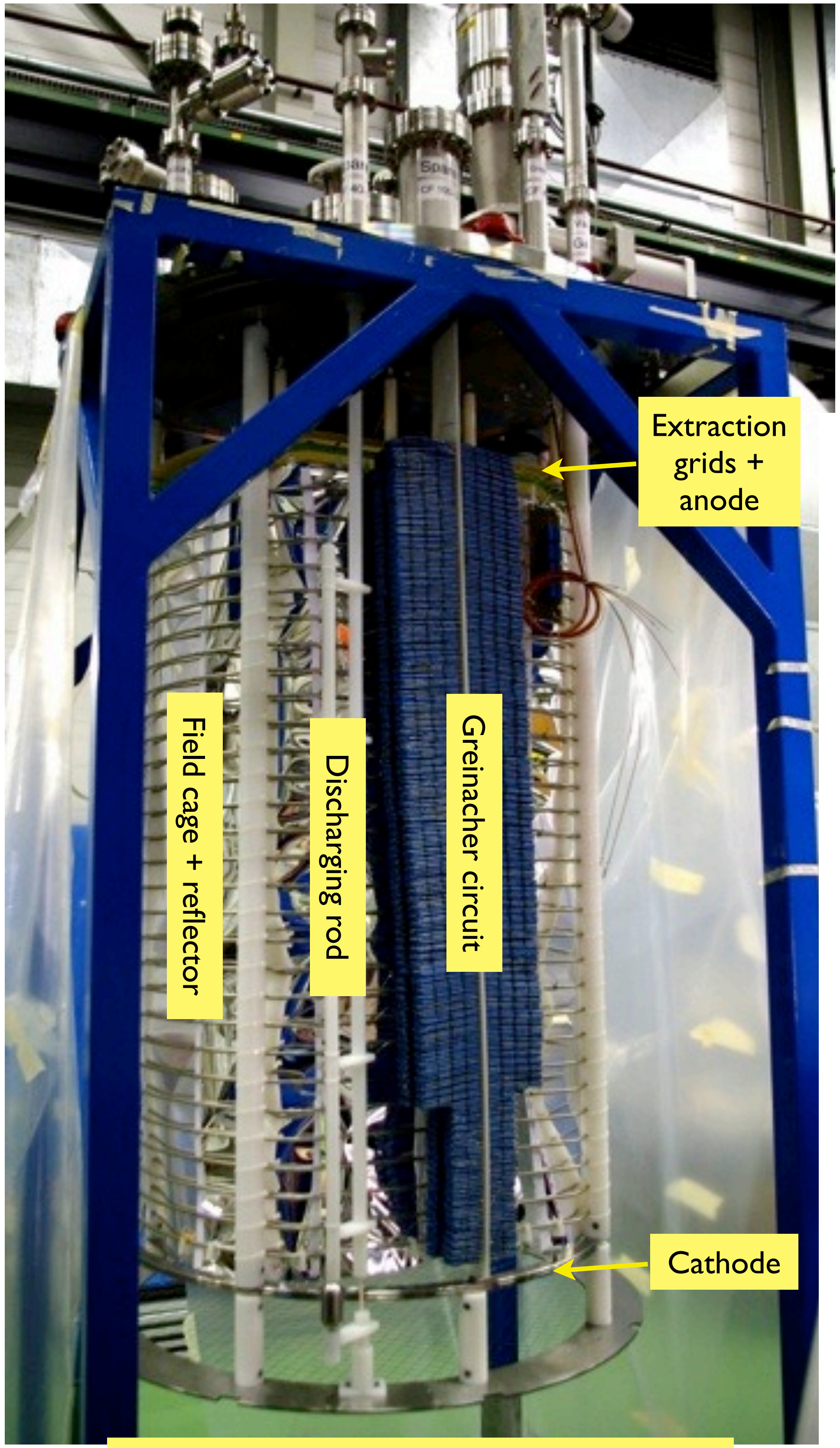
➠5m drift, ArgonTube

B. Rossi et al., GLA2010 workshop

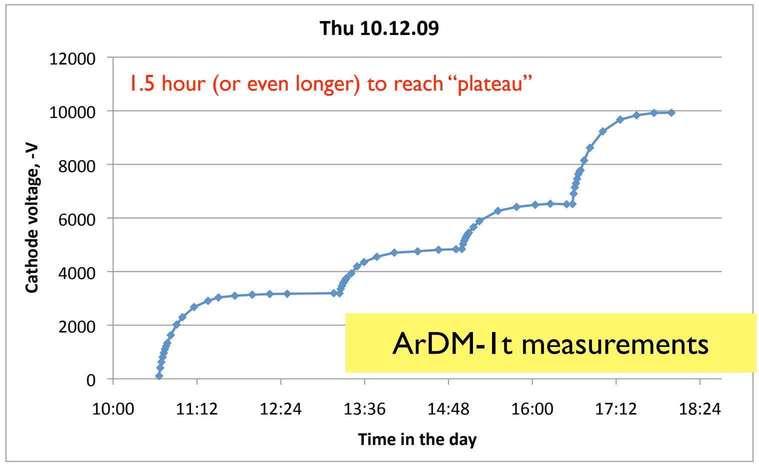


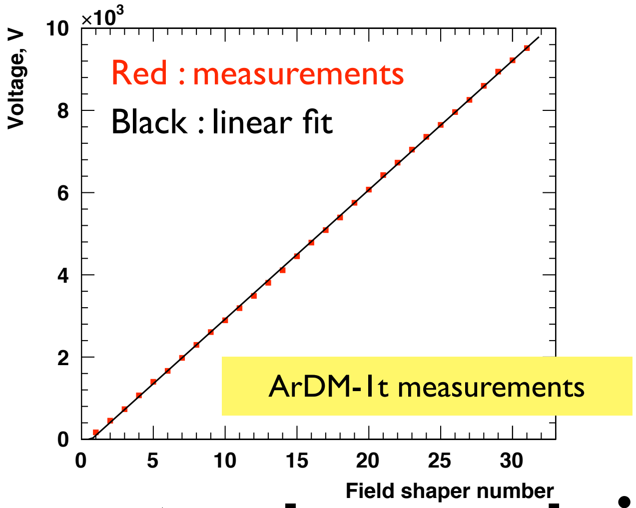
Very high drift “high” voltage...

S. Horikawa et al.,
GLA2010 workshop



ArDM-1t detector





Extrapolation to long drift

Extrapolation of the ArDM design

Changing Cs for fixed Cp = 2.35 pF and Vpp-in = 2E = 2.5 kV

		ArDM				
Drift length	m	1.24	5	10		20
Total output voltage for 1 kV/cm	V	124k	500k	1M		2M
Input voltage Vpp-in = 2E	V	820	2.5k	2.5k	$\times\sqrt{2}$	3.5k
Shunt capacitance, Cp	F	2.35p	2.35p	2.35p	$\times 1/2$	1.18p
Capacitor	F	328/164n	475n	1.90μ		1.90μ
Number of stages, N	–	210	319	638		903
N per 10 cm	–	16.9	6.38	6.38		4.51
Total capacitance	F	125μ	303μ	2.43m		3.43m
Capacitance per 10 cm	F	10.4μ	5.99μ	24.3μ		17.2μ
Total stored energy	J	21.7	948	7.58k		21.5k

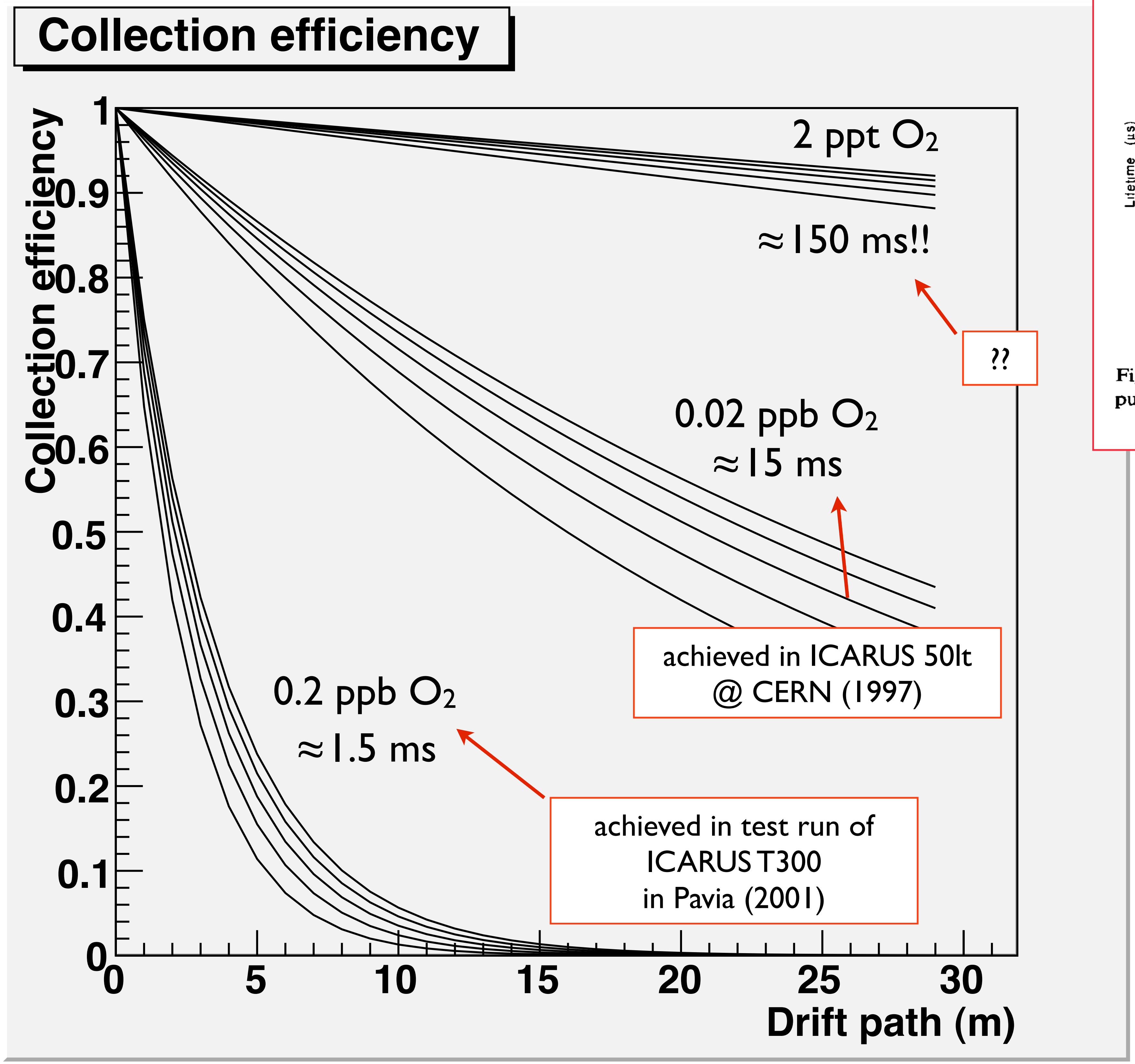
Actual ArDM parameters are given just for comparison.

For extrapolation, 2γN = 1.42 is always assumed.

LAr vaporization heat 160 kJ/kg

$$V_{\mathrm{max}} = \frac{E}{\gamma}, \quad \gamma \approx \sqrt{\frac{C_{\mathrm{p}}}{C_{\mathrm{s}}}}$$

And the purity issue...



2 ppt O_2

≈150 ms!!

??

0.02 ppb O_2
≈15 ms

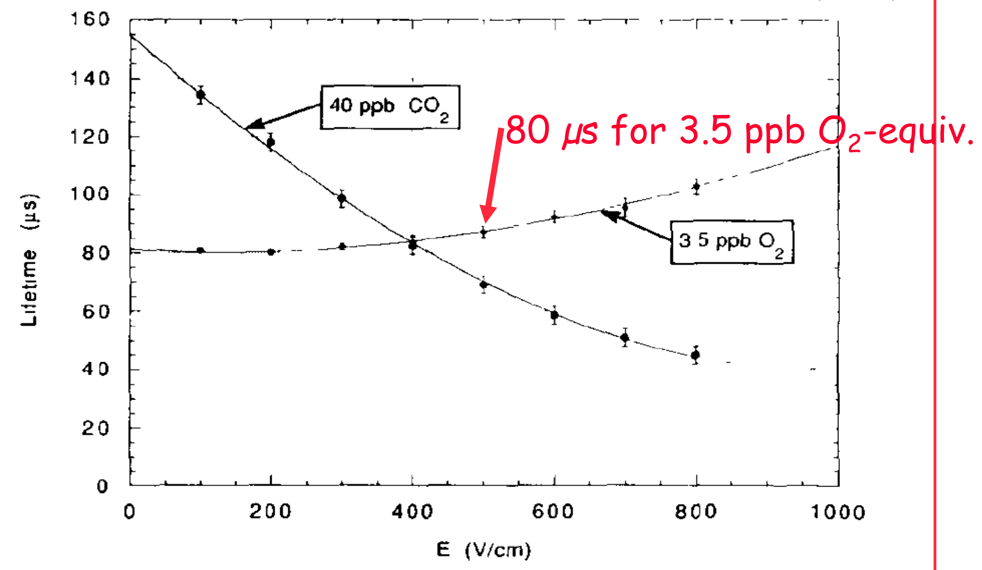
achieved in ICARUS 50lt
@ CERN (1997)

0.2 ppb O_2
≈1.5 ms

achieved in test run of
ICARUS T300
in Pavia (2001)

Drift fields E=0.5,0.75,1,1.25,1.5 kV/cm

A. Bettini et al., NIM A305 (1991) 177



80 µs for 3.5 ppb O_2-equiv.

Fig. 12. Electric field dependence of the electron lifetime τ in purified LAr doped with 40 ppb CO_2 and 3.5 ppb O_2. Lines are drawn to guide the eye.

$$\tau \approx \frac{300\,\mu s}{O_2(ppb)}$$

More efforts needed to understand "ultimate" purity on large non-evacuated volumes

Methods to attack the purity problem

- In future, we will need three very large scale independent systems:
  (1) **Warm GAr flushing**
  (2) **Closed GAr recirculation & purification through cartridges (= activated Cu + molecular sieves)** and
  (3) **LAr recirculation through cartridges**

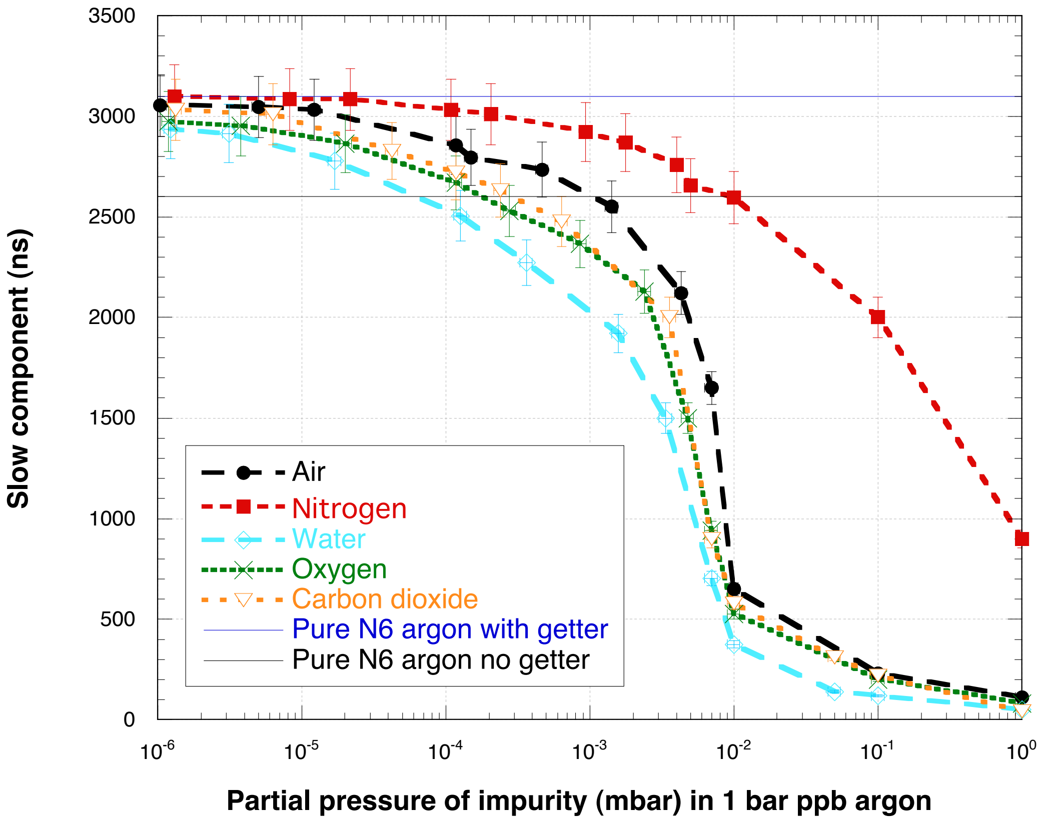
- **GAr flushing** (no evacuation) ➠ 6m3 @ CERN

- **GAr purification**
  - ICARUS 50lt (in 1997) ➠ best result <30 ppt after several weeks
  - 3 lt setup @ CERN (2010) ➠ best result 0.6 ppb at filling
  - 12 m3 GAr/hr (from 6m3@CERN), GAr recirculation pump + SAES getters to be tested soon ➠ 6m3 @ CERN

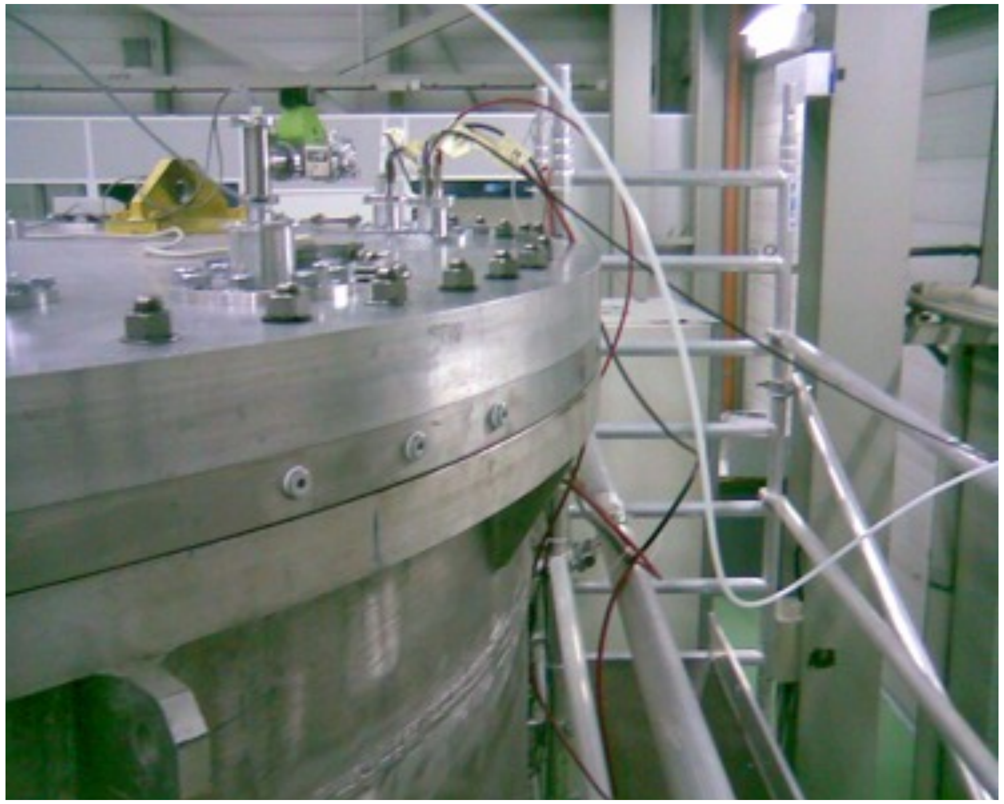
- **Liquid recirculation**
  - Industrial purification system developed by Airliquide for ICARUS (composed of Barber&Nichols pumps + Messers-Griesheim Hydrosorb+Oxysorb)
    ➠ Unit capacity: 2500 lt LAr/hr per T300
    ➠ best result 0.2 ppb after 50 days
  - Study within LAGUNA
    ➠ Flow rate required is around 300 m3/hr (full 100kton in 10 days) !
    ➠ Enquiry by Nikkiso Co Ltd, Ebara International Corporation, J C Carter Cryogenics have confirmed that their products will be suitable for application with liquid argon.

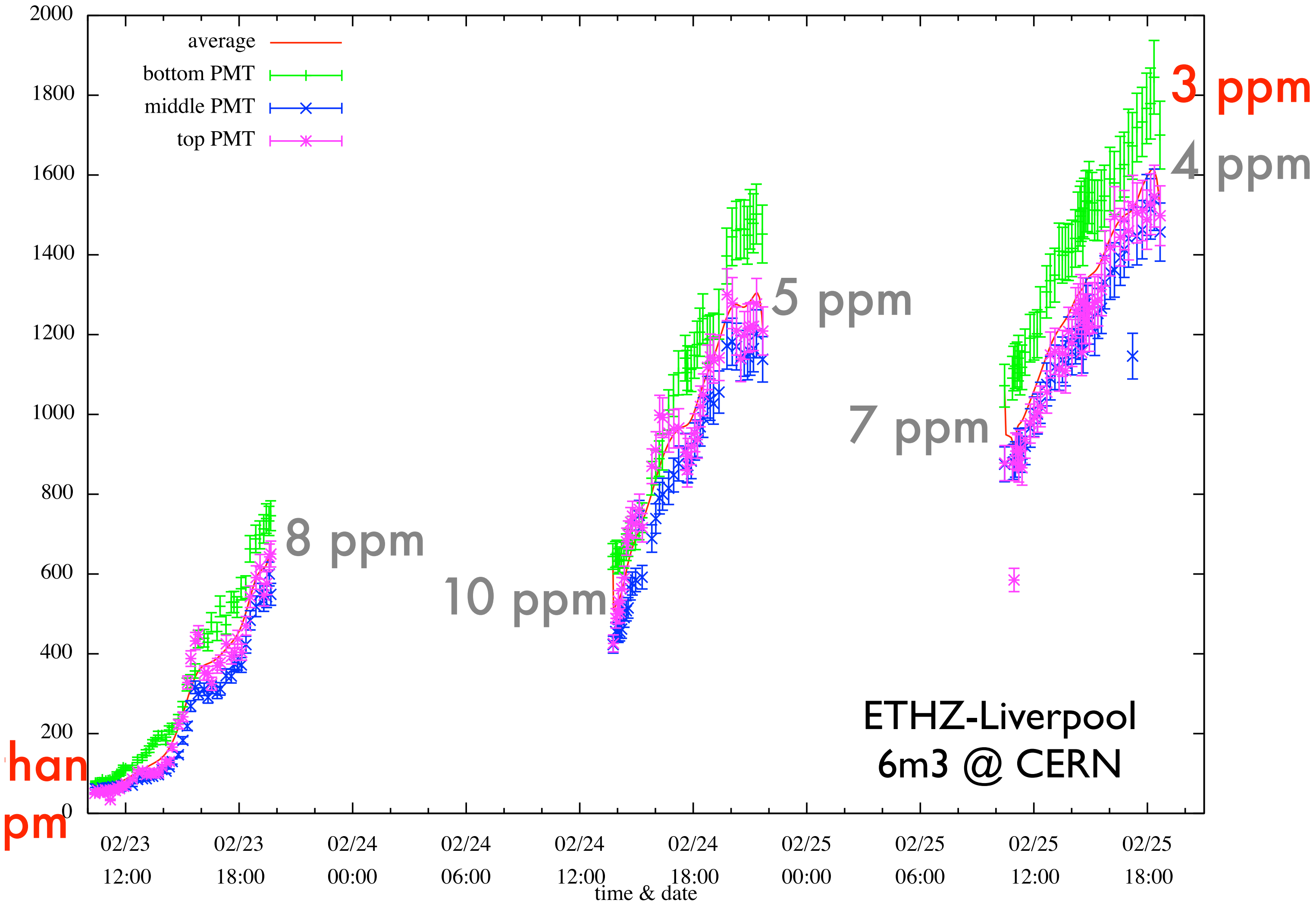
6m3 @ CERN

A. Curioni et al.,
GLA2010 workshop



- R&D towards non evacuated vessels on large vessel
- Purity measured with direct scintillation light measurement !
- First test purging - satisfactory!
- Piston effect seen
- Reached **3ppm** O_2 contamination via flushing
- Gas recirculation under construction





Liquid Argon Purity Demonstrator

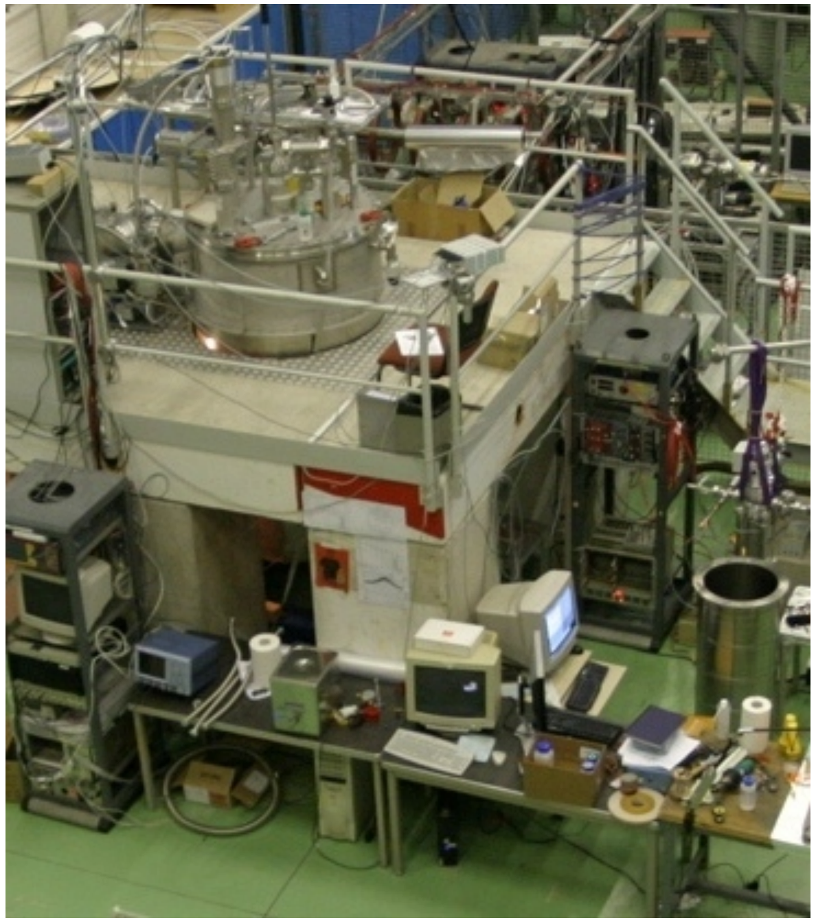
- Currently operating systems such as test stands at FNAL and ArgoNeuT use evacuation as the first cleaning step
- Building large vessels that can be evacuated is very expensive - scales the cost by at least a factor of 2 for small vessels, worse for large vessels
- Need to find an alternative to evacuation for large vessels - LAPD is test stand at FNAL to study alternatives
- Vessel holds ~30 t of LAr and is 3/16 inch thick stainless steel
- Makes use of MTS experience in design of system

On-going tests at ton-scale

250 lt @ KEK

0.4 ton LAr, vacuum, cryogenic system, gas purging, argon liquefaction, optimized for test beam pion / kaon response

ArDM (RE18) @ CERN



1 ton LAr, large area readout, 1m drift with Cockroft-Walton, LAr recirculation and purification, electronics, safety, optimized for dark matter searches, underground location foreseen for 2011

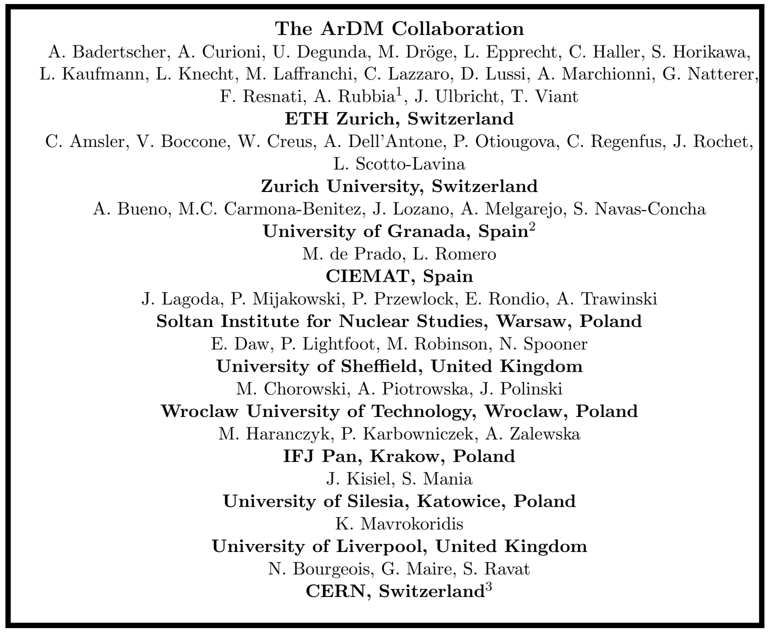
6m3 @ CERN

R&D towards non evacuated vessels, warm Ar purging starting from air, high capacity closed gas recirculation

ArDM-1t (CERN RE18)

A. Marchionni et al.,
GLA2010 workshop

AR, J.Phys.Conf.Ser 39:129-132,2006



The ArDM Collaboration
A. Badertscher, A. Curioni, U. Degunda, M. Dröge, L. Epprecht, C. Haller, S. Horikawa, L. Kaufmann, L. Knecht, M. Laffranchi, C. Lazzaro, D. Lussi, A. Marchionni, G. Natterer, F. Resnati, A. Rubbia[1], J. Ulbricht, T. Viant
ETH Zurich, Switzerland
C. Amsler, V. Boccone, W. Creus, A. Dell'Antone, P. Otiougova, C. Regenfus, J. Rochet, L. Scotto-Lavina
Zurich University, Switzerland
A. Bueno, M.C. Carmona-Benitez, J. Lozano, A. Melgarejo, S. Navas-Concha
University of Granada, Spain[2]
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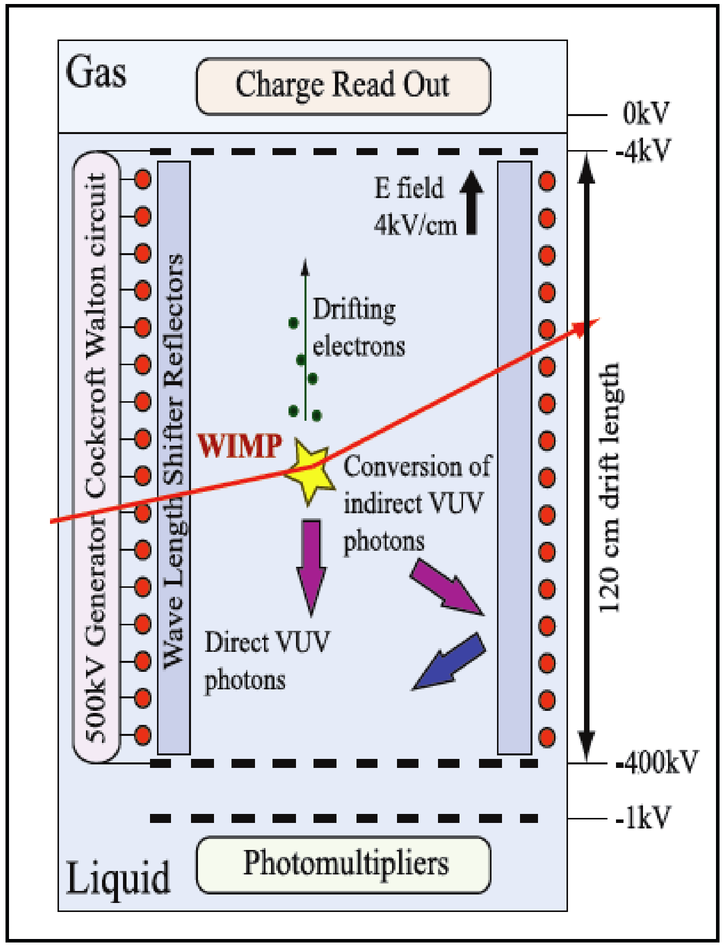
J. Lagoda, P. Mijakowski, P. Przewlock, E. Rondio, A. Trawinski
Soltan Institute for Nuclear Studies, Warsaw, Poland
E. Daw, P. Lightfoot, M. Robinson, N. Spooner
University of Sheffield, United Kingdom
M. Chorowski, A. Piotrowska, J. Polinski
Wroclaw University of Technology, Wroclaw, Poland
M. Haranczyk, P. Karbowniczek, A. Zalewska
IFJ Pan, Krakow, Poland
J. Kisiel, S. Mania
University of Silesia, Katowice, Poland
K. Mavrokoridis
University of Liverpool, United Kingdom
N. Bourgeois, G. Maire, S. Ravat
CERN, Switzerland[3]

- a 1 ton LAr detector presently installed on surface at CERN to fully tests all functionalities
- to be moved to an underground location within 2011



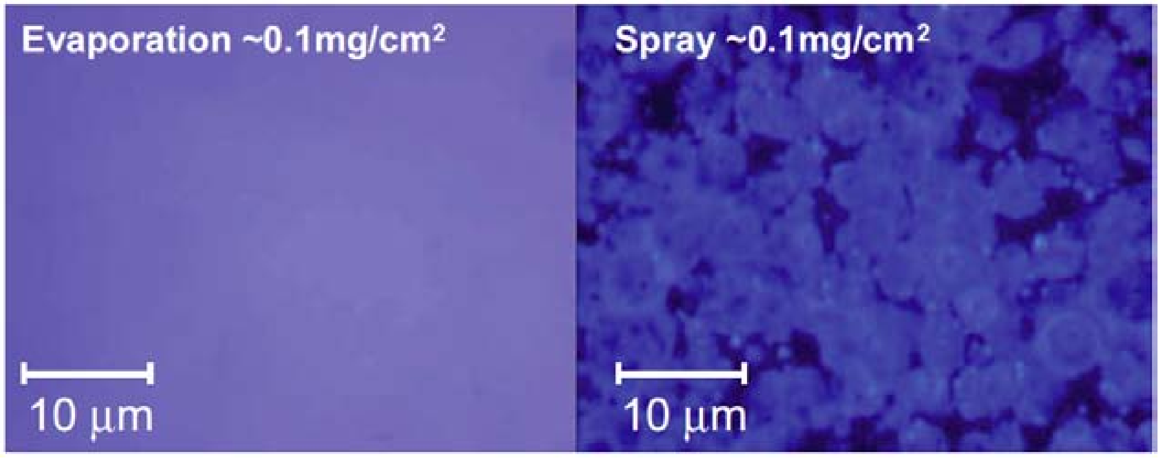
Light readout composed of 14 low radioactivity 8" PMT Hamamatsu R5912-02MOD coated with TPB WLS
Option to upgrade to 3" R11065 under investigation

WLS coated reflector foils

V. Boccone et al. JINST 4 P06001 2009

- **LAr emission spectrum peaked at 128 nm**
- **use reflector foils coated with TPB in order to use standard bialkali PMTs**
  - TPB shifts to a mean wavelength of 430 nm
- **15 cylindrically arranged overlapping foils of TTX (120x25 cm^2) coated with 1.0 mg/cm^2 TPB by vacuum evaporation**
  - TTX is an aligned polytetrafluoroethylene (PTFE) fibrous cloth
- **measured a reflection coefficient close to 97% at 430 nm**

coating achieved by evaporation of TPB is very uniform



ArDM 1st cooldown and filling test

- May 2009 - 4 weeks long run
- Goals:

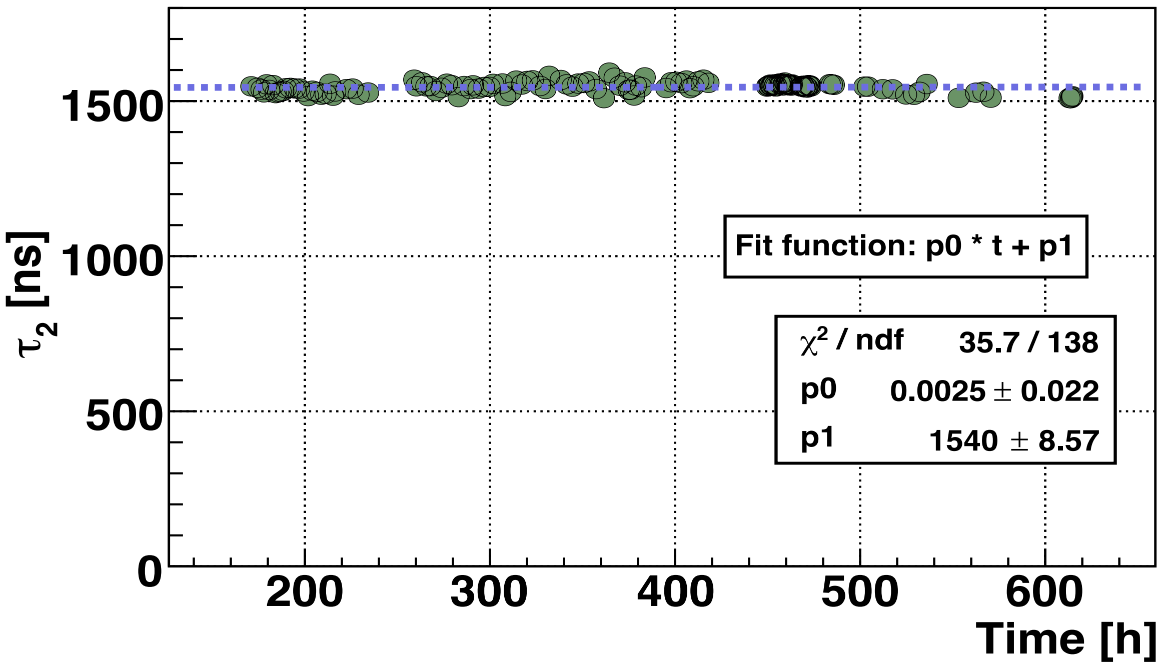
a. Test cryogenic system [cool down and stable operation]

b. Achieve good LAr purity and stability

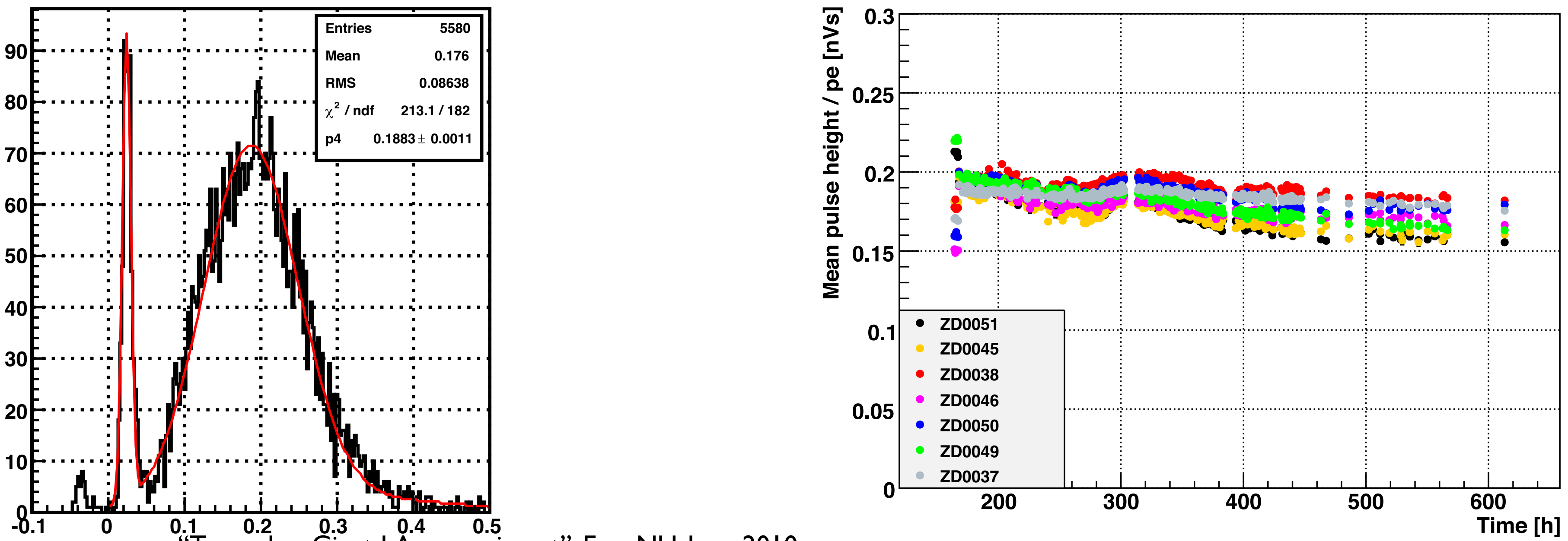
c. Commissioning and stable operation of light readout [7 PMTs] system in LAr

d. Preliminary measurement of light yield

e. Data reconstruction and benchmark of MC simulation



Lifetime of slow component of Ar scintillation light, sensitivity to impurities in Ar. The plot shows stable, excellent purity

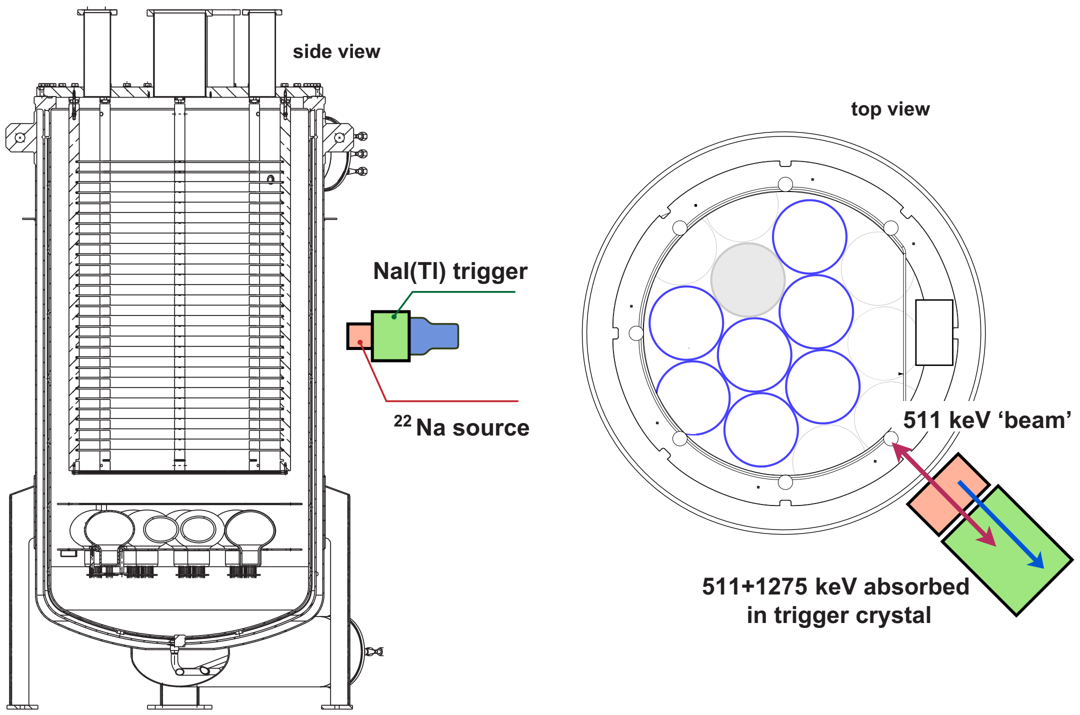


Single photon spectrum and time evolution of calibration for 7 PMTs

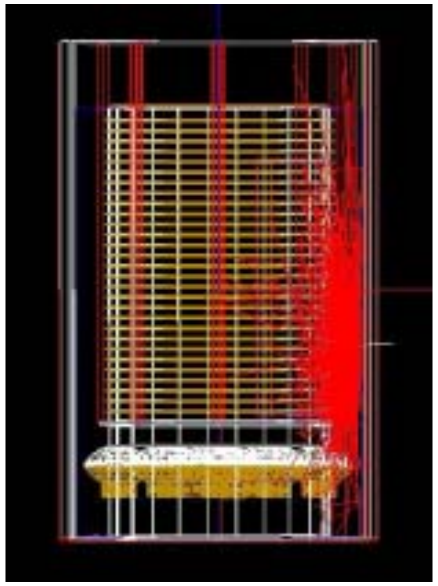
ArDM low energy meas'ments

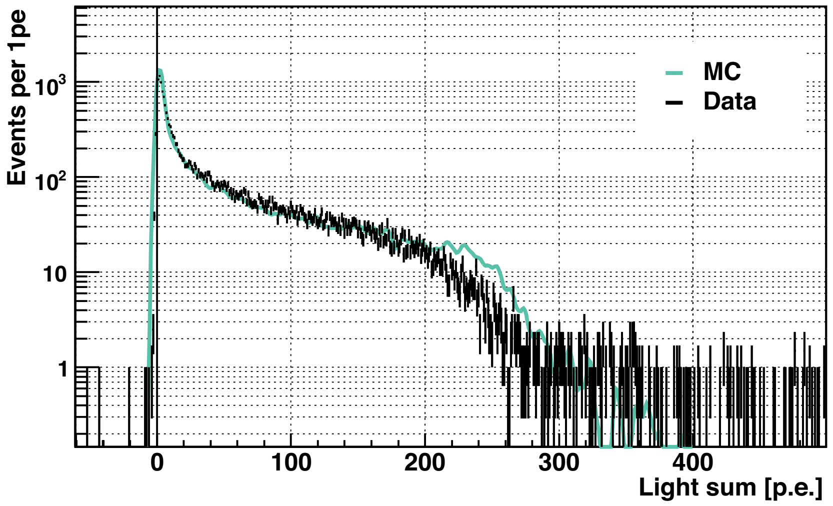
- calibration data taken with 511, 662, 1275 keV gamma rays and neutrons from AmBe - various trigger configurations [including external trigger]

ArDM, in preparation



- Data analysis and MC:





Noise ≈ 2 p.e.
Good agreement between data and MC (full light propagation)

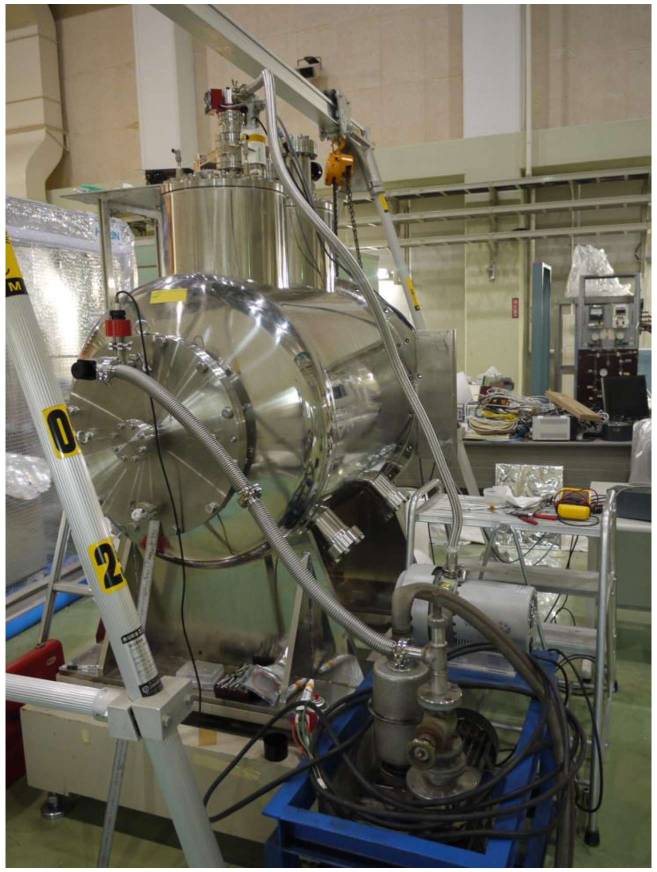
Light yield with 7 PMTs: ≈0.5 p.e. / keVee

J-PARC P32

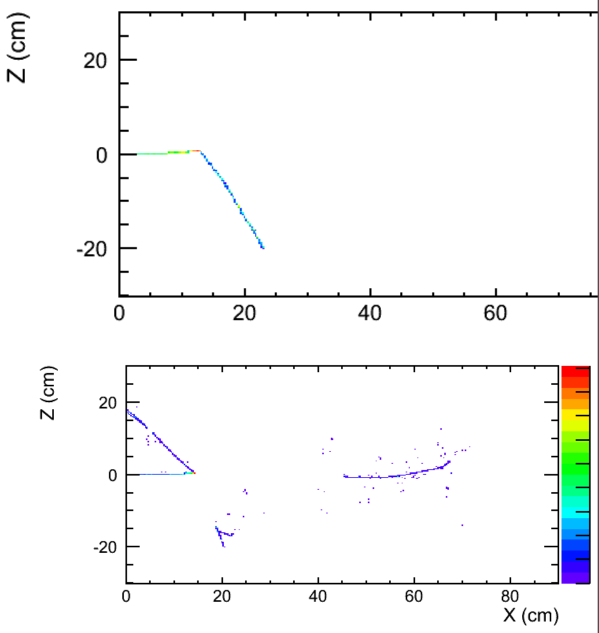
T. Maruyama et al.,
GLA2010 workshop

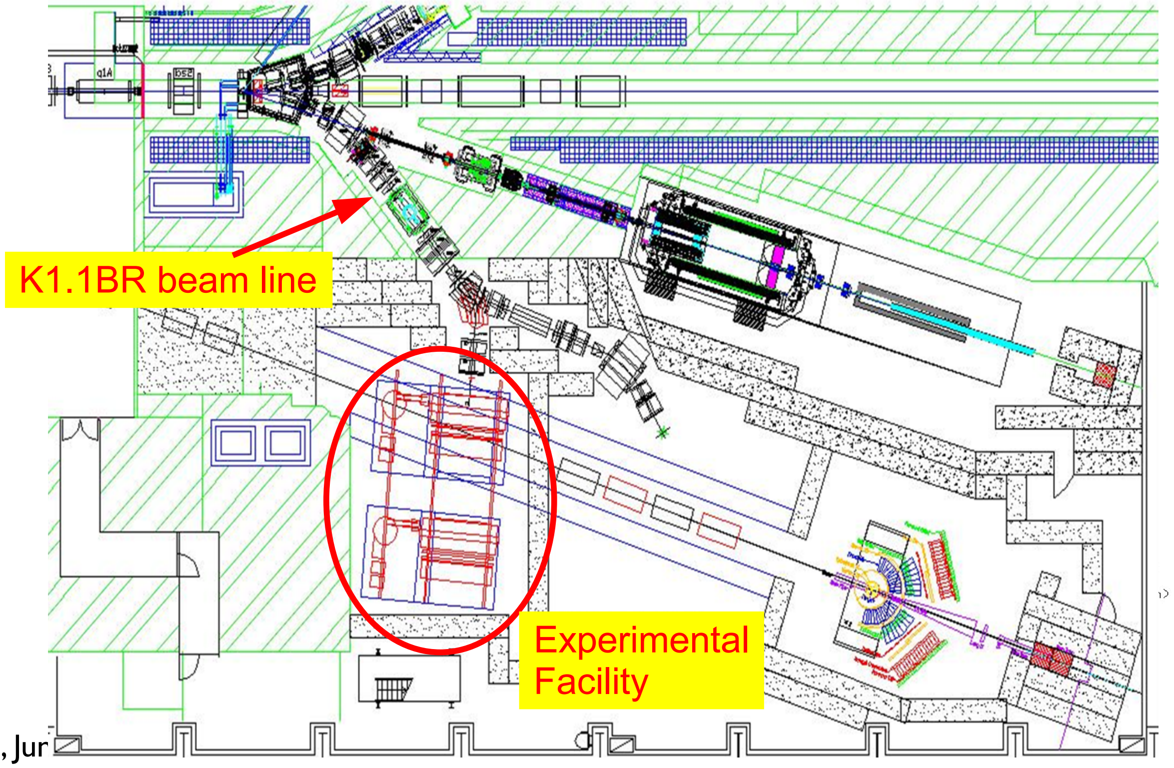
Project to operate a small-scale LAr TPC at J-PARC

- Cryogenic vessel originally built for MEG liquid xenon calorimeter
- Vessel currently at KEK LAr lab
- Ultra-Vacuum established
- Cryocooler and liquid argon filling under investigation
- Liquid argon purification system under procurement
- Chamber being designed and built
- Exposure to low-momentum separated kaon beam @ K1.1Br
- <u>Timescale</u>: October 2010 in beam



340 MeV/c K+

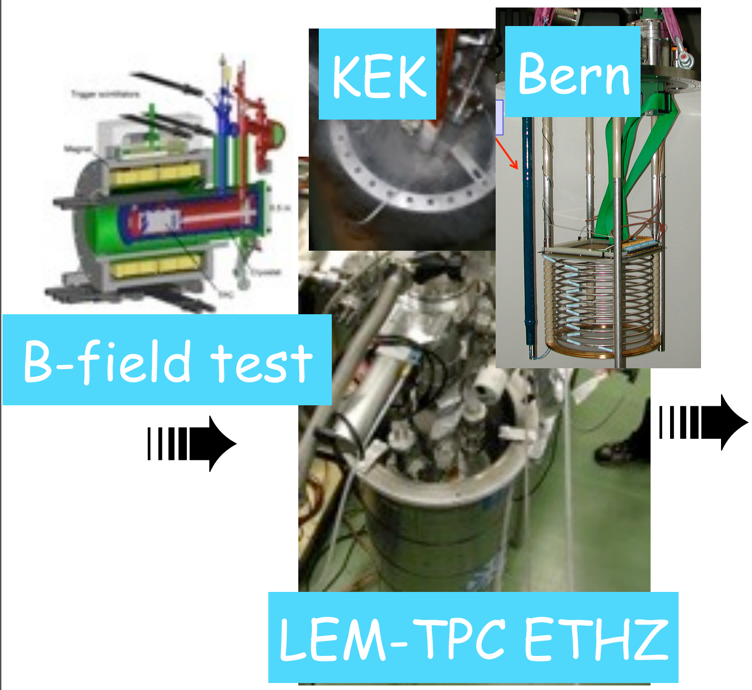




“Towards a Giant LAr experiment”, EuroNU, Jur

GLACIER roadmap

see J.Phys.Conf.Ser.171:012020,2009


KEK

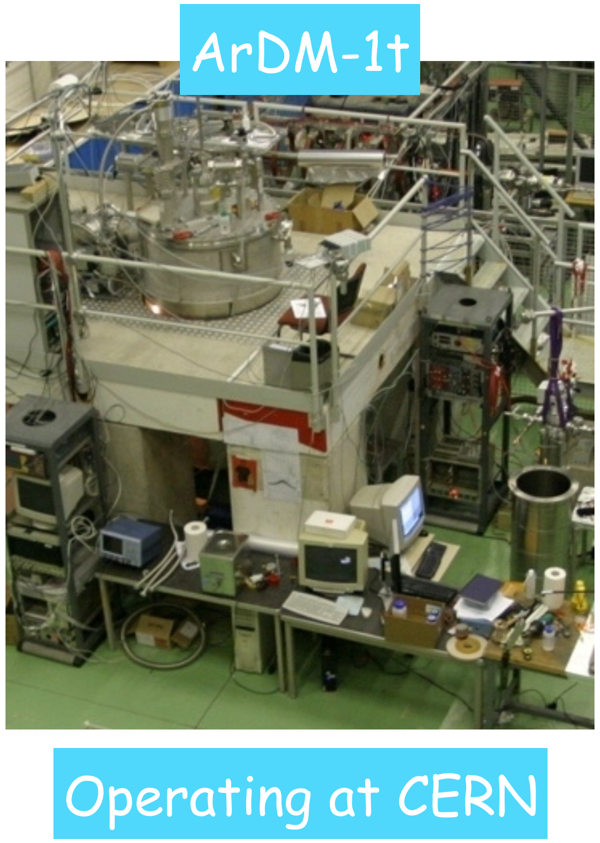
Bern

B-field test

LEM-TPC ETHZ

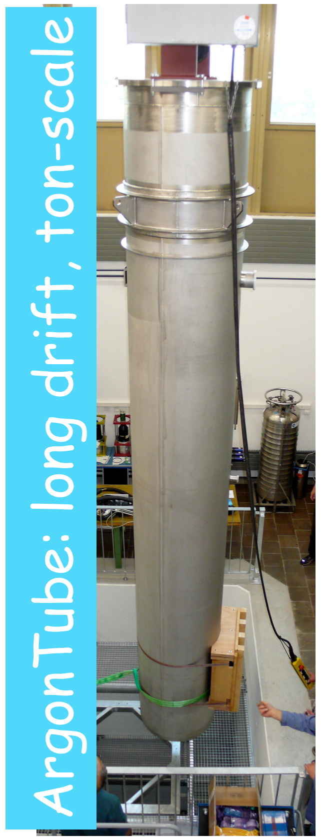
proof of principle double-phase LAr LEM-TPC on 0.1x0.1 m² scale

LEM readout on 1x1 m² scale UHV, cryogenic system at ton scale, cryogenic pump for recirculation, PMT operation in cold, light reflector and collection, very high-voltage systems, feed-throughs, industrial readout electronics, safety (in Collab. with CERN)


ArDM-1t

Operating at CERN

direct proof of long drift path up to 5 m


ArgonTube: long drift, ton-scale

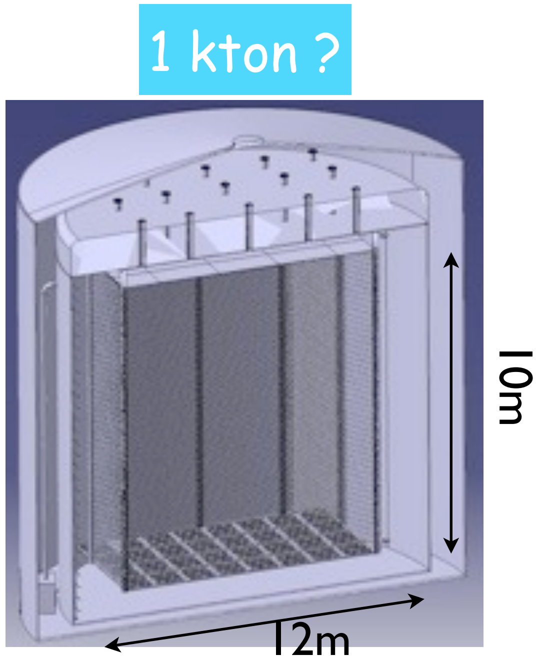
Application of LAr LEM TPC to neutrino physics: particle reconstruction & identification (e.g. 1 GeV e/μ/π/K), optimization of readout and electronics, possibility of neutrino beam exposure

6m3 → CERN NA ?


250L

full engineering demonstrator for larger detectors, acting as near detector for neutrino fluxes and cross-sections measurements, or with a stand-alone short baseline physics programme

A precursor step


1 kton ?

CERN Liquid ARgon Experiment - **CLARE** (*)

(*) preliminary name

Background:

- CERN has a very long tradition in neutrino beams (since 1963 @ PS and 1977 @ SPS)
- Two classes of successful experiments were performed: (1) massive coarse counter experiments (CDHS, CHARM) and (2) small high granularity bubble chambers (Gargamelle, BEBC), and more recently the light NOMAD&CHORUS fine grain electronic or emulsion detectors. Today focused at LBL to LNGS (CNGS).

➡ **We contemplate a new neutrino short-baseline experiment with a “bubble-chamber-like granularity” and “total mass of a counter experiment”, taking in addition advantage of the enhanced proton intensities available today (e.g. SPS (3-4)e19pots/yr)**

Physics goals:

- Measure exclusive (anti)neutrino-nucleon cross-sections (non-perturbative region, NC/CC, ...)
- Measure (anti)neutrino-electron scattering process (Weinberg angle)
- Search for active-active or active-sterile transitions in the eV^2-range
- Search for NHL states (predicted if ν is a Majorana particle)
- etc.

Design: a 1000 ton detector is necessary

- Built as precursor of future 100 kton experiment ➟ LNG-based tank (not evacuable), very long drift path as play-ground for new readout designs, purity demonstrator, new HV and electronics, etc.
- With an eventual deployment deep underground (somewhere...)

In preparation: Expression of Interest for CERN West Area

- Beams simulation & optimization: started (WBB@PS, NBB@SPS, etc...)
- Physics program & performance : started
- Detector design (main detector, μ-catchers, near station (?), ...): started
- Financing: not yet

Work in progress

Conclusion

- ICARUS T600 (1.5m drift, 50k wires) started commissioning @ LNGS recording events including CNGS
- Active R&D programme focused at extrapolation 100 kton scale
- A technical "precursor step" detector in the range of the 1 kton mass, which could perform a sensible neutrino physics program in addition to being the playground for future technical solutions, has been considered since a while.
- Its feasibility @ CERN could provide an ideal setting → needs more detailed studies, assessment and eventually financing → an expression of interest
- A significant part of this detector (e.g. cryogenic components, purification systems, detectors, electronics, etc..) could be eventually deployed underground as an "pilot underground experiment".