Future application of liquid Argon Time Projection Chambers on medium and large scale.

Introduction

- Within the ICARUS program, the concept of large cryogenic detectors based on noble liquids (Argon and Xenon) have been developed for many years. In such detectors, ionisation electrons are used to create an "image" of the tracks of the particles. Scintillation light may be used to trigger the event.

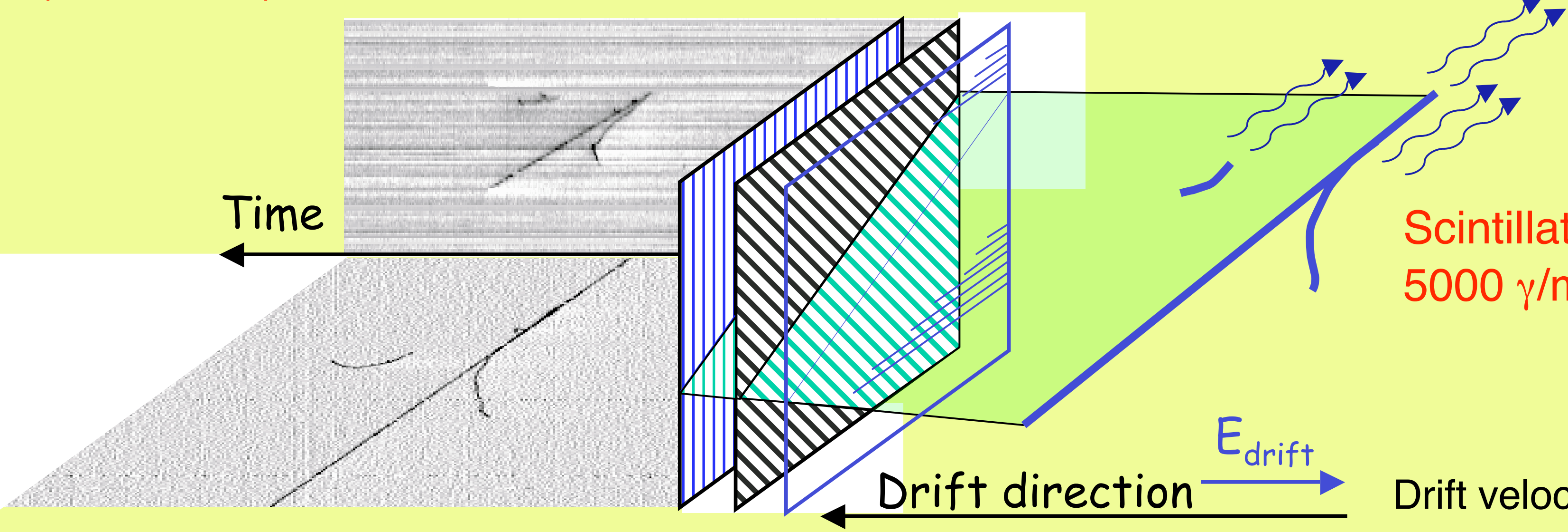
- A series of several modules of different sizes have been operated, in which all the basic features of ionisation, long electron drift and scintillation in liquid Argon (and to some extent also Xenon) have been systematically studied for a variety of incident particles. Applications to neutrino physics, proton decay searches and direct matter detection have been considered. The largest detector ever built has a mass of 600 tons to be used in the ICARUS experiment at Gran Sasso.

- In this talk, we report on our investigations regarding possible developments in the liquid Argon TPC technique in order to envisage its use in future neutrino experiments and nucleon decay searches:

- Experiments for CP violation: a giant liquid Argon scintillation, Cerenkov and charge imaging experiment, A.Rubbia, Proc. II Int. Workshop on Neutrinos in Venice, 2003, Italy, hep-ph/0402110
- Ideas for future liquid Argon detectors, A. Ereditato and A.Rubbia, Proc. Third International Workshop on Neutrino-Nucleus Interactions in the Few GeV Region, NUINT04, March 2004, Gran Sasso, Italy, **Nucl.Phys.Proc.Suppl.139:301-310,2005**, hep-ex/0409034
- Ideas for a next generation liquid Argon TPC detector for neutrino physics and nucleon decay searches, A. Ereditato and A.Rubbia, Proc. Workshop on Physics with a Multi-MW proton source, May 2004, CERN, Switzerland, submitted to SPSC Villars session
- Very massive underground detectors for proton decay searches, A.Rubbia, Proc. XI Int. Conf. on Calorimetry in H.E.P., CALOR04, Perugia, Italy, March 2004, hep-ph/0407297
- Liquid Argon TPC: mid & long term strategy and on-going R&D, A.Rubbia, Proc. Int. Conf. on NF and Superbeam, NUFACT04, Osaka, Japan, July 2004
- Liquid Argon TPC: a powerful detector for future neutrino experiments, A.Ereditato and A. Rubbia, HIF05, La Biodola, Italy, May 2005
- Neutrino detectors for future experiments, A.Rubbia, Nucl. Phys. B (Proc. Suppl.) 147 (2005) 103.

The Liquid Argon TPC principle

Charge yield ~ 6000 electrons/mm
(~ 1 fC/mm)



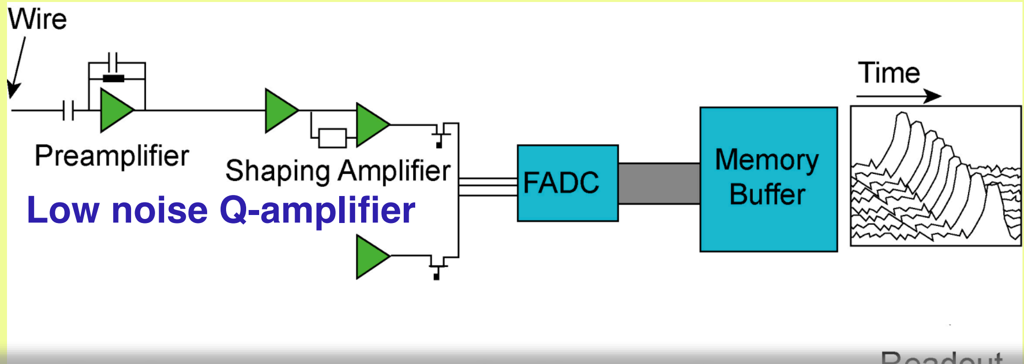
Scintillation light yield ~ 5000 γ/mm @ 128 nm

Drift velocity ≈ 2 mm/μs @ 1 kV/cm

Drift electron lifetime:

$$\tau \approx 300\mu s \times \frac{1\,ppb}{N(O_2)}$$

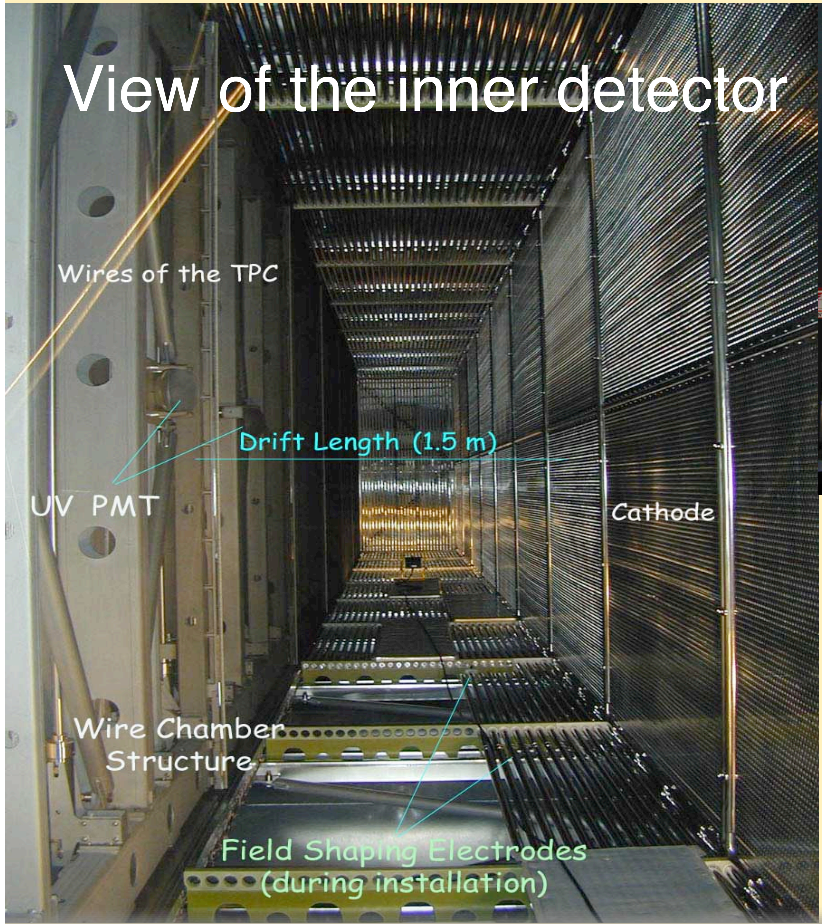
Purity < 0.1ppb O_2-equiv.

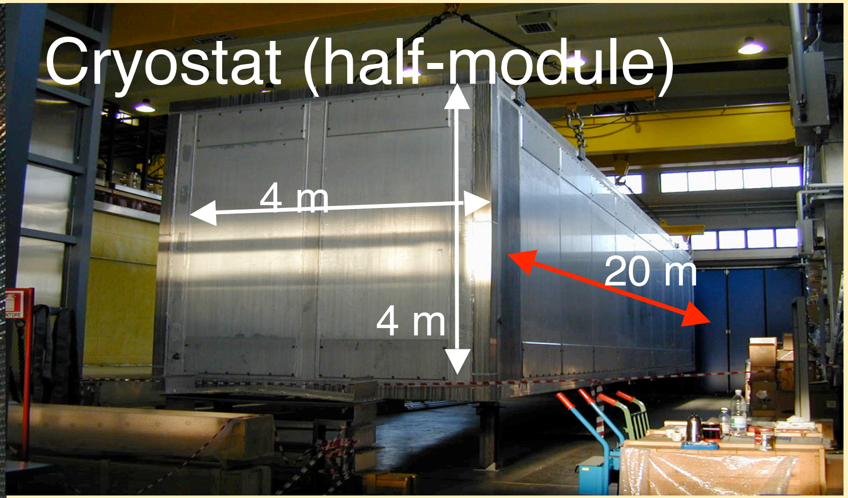


Continuous waveform recording → image

- The Liquid Argon Time Projection Chamber: a new concept for Neutrino Detector, C. Rubbia, CERN-EP/77-08 (1977).
- A study of ionization electrons drifting large distances in liquid and solid Argon, E. Aprile, K.L. Giboni and C. Rubbia, NIM A251 (1985) 62.
- A 3 ton liquid Argon Time Projection Chamber, ICARUS Collab., NIM A332 (1993) 395.
- Performance of a 3 ton liquid Argon Time Projection Chamber, ICARUS Collab., NIM A345 (1994) 230.
- The ICARUS 50 l LAr TPC in the CERN neutrino beam, ICARUS Collab, hep-ex/9812006 (1998).

Next milestone: ICARUS T600 Module, the living proof



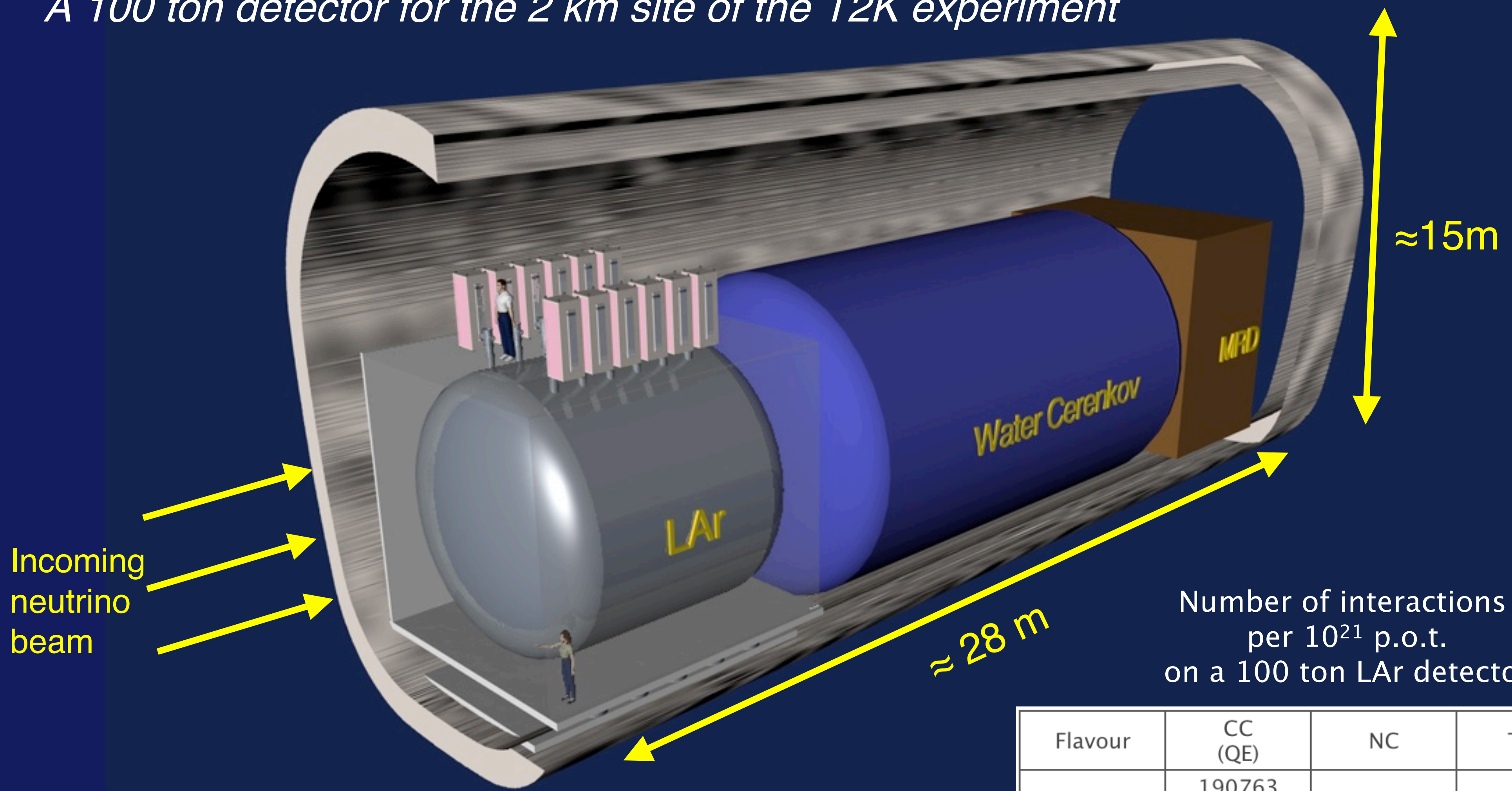


- Modular approach. Two separate containers, each of sensitive mass =238 ton
- 4 wire chambers with 3 readout planes at 0^0, ±60° per module
- Total ~54000 wires

- Design, construction and tests of the ICARUS T600 detector, ICARUS Collab, NIM A527 329 (2004).
- Study of electron recombination in liquid Argon with the ICARUS TPC, ICARUS Collab, NIMA523 275-286 (2004).
- Detection of Cerenkov light emission in liquid Argon, ICARUS Collab, NIM A516 348-363 (2004).
- Analysis of the liquid Argon purity in the ICARUS T600 TPC, ICARUS Collab, NIM A516 68-79 (2004).
- Observation of long ionizing tracks with the ICARUS T600 first half module, ICARUS Collab, NIM A508 287 (2003).
- Measurement of the muon decay spectrum with the ICARUS liquid Argon TPC, ICARUS Collab, EPJ C33 233-241 (2004).

Next-to-next milestone of the LAr TPC technique ?

A 100 ton detector for the 2 km site of the T2K experiment



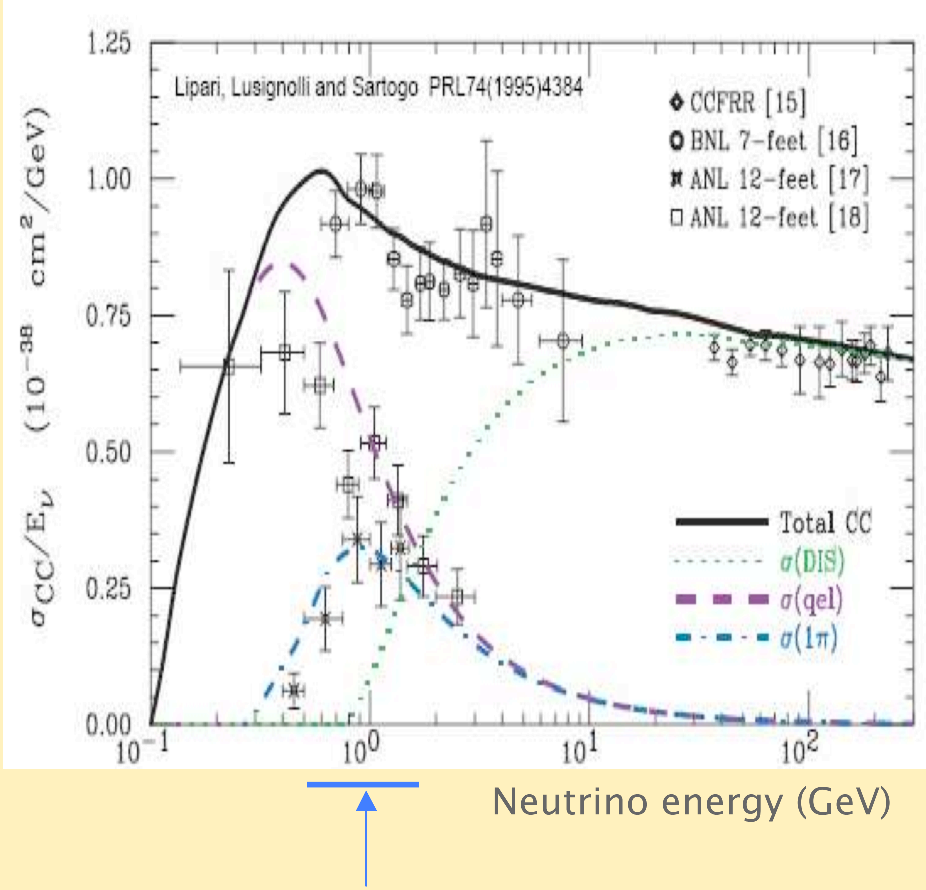
Number of interactions
per 10^{21} p.o.t.
on a 100 ton LAr detector

Flavour	CC (QE)	NC	TOT
ν_μ	190763 (121859)	26253	217016
$\overline{\nu_\mu}$	8023 (2764)	2063	10086
ν_e	3704 (1372)	725	4429
$\overline{\nu_e}$	372 (96)	100	472

EoI from 26 groups (EU, Japan, USA) for a detector complex at the intermediate site submitted to NuSAG panel.

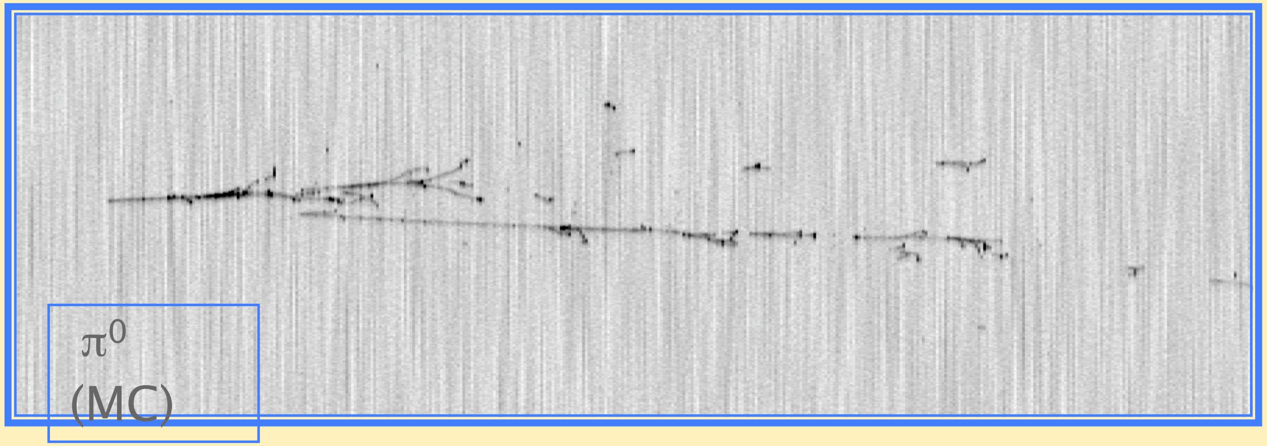
Why 2km LAr TPC?

- Fully active, homogeneous, high-resolution device ⇒ high statistics neutrino interaction studies with bubble chamber accuracy .
- Reconstruction of low momentum hadrons (below Cherenkov threshold), especially recoiling protons.
- Independent measurement of off-axis flux and QE/nonQE event ratio.
- Exclusive measurement of νNC events with clean π^0 identification for an independent determination of systematic errors on the NC/CC ratio.
- Measurement of the intrinsic ν_eCC background.
- Collection of a large statistical sample of neutrino interactions in the GeV region for the study of the quasi-elastic, deep-inelastic and resonance modelling and of nuclear effects.

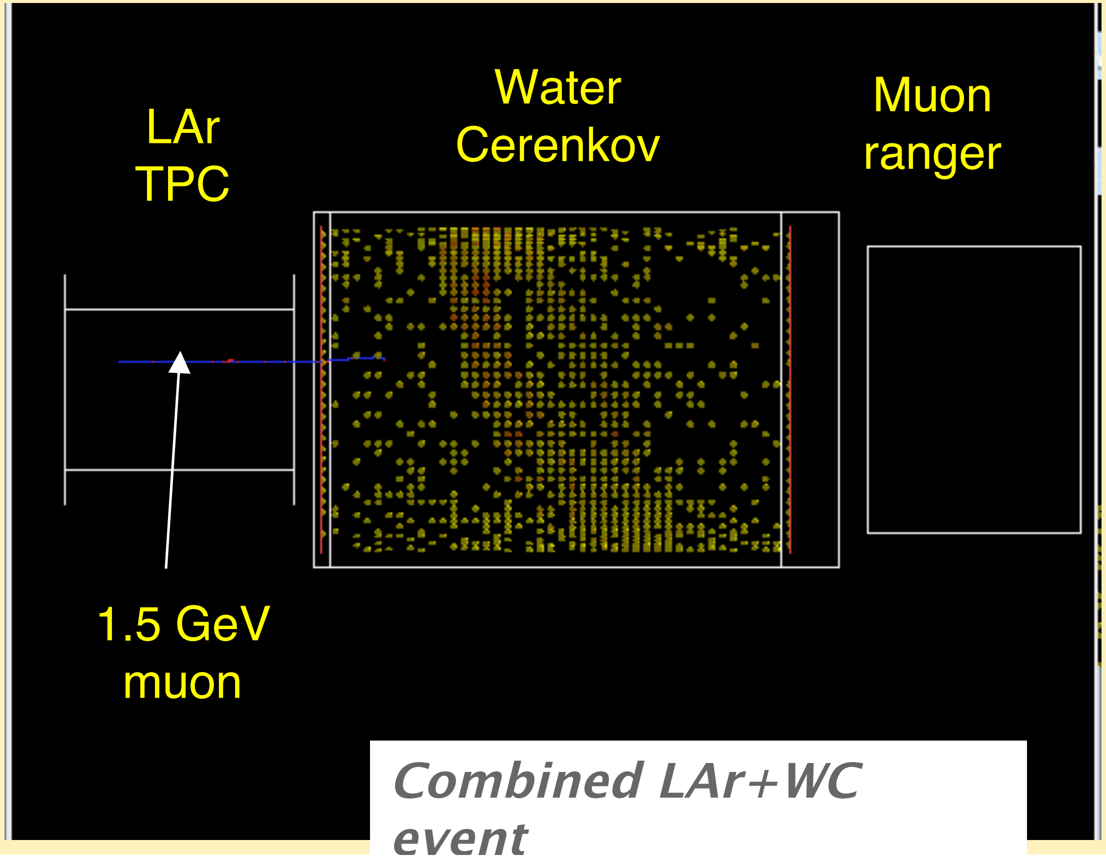


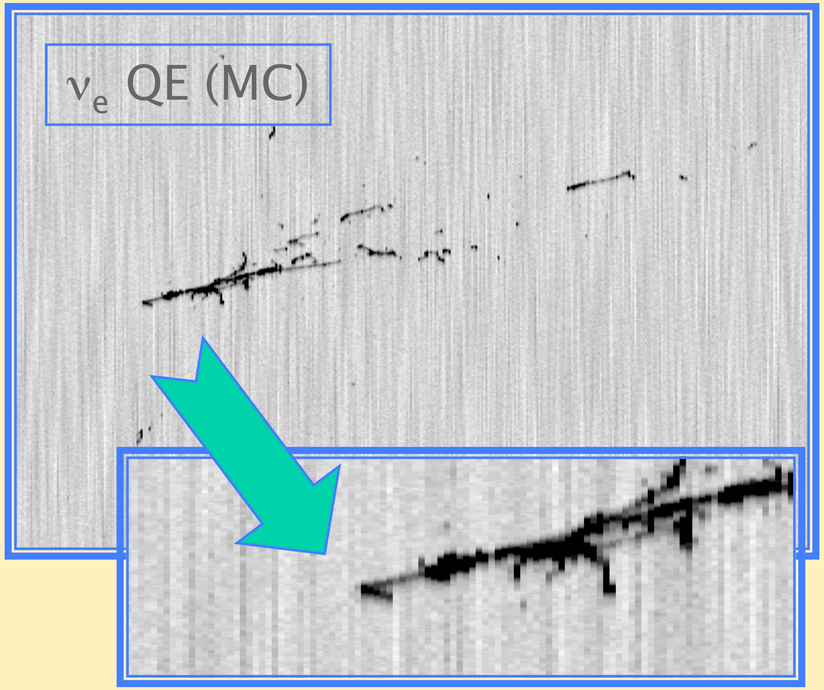
A fundamental milestone for the LAr TPC technique !

Examples of LAr TPC high resolution imaging



High granularity: Sampling = 0.02 X_0





Nucl. Phys. B 631 239;
Nucl. Phys. B 589 577;
hep-ph/0402110;
hep-ph/0106088

A possible improvement of the LAr TPC technique ?

Operation of the LAr TPC embedded in a magnetic field

The possibility to complement the features of the LAr TPC with those provided by a magnetic field has been considered and would open new possibilities (a) charge discrimination, (b) momentum measurement of particles escaping the detector (e.g. high energy muons), (c) very precise kinematics, since the measurement precision is limited by multiple scattering. These features are mandatory at a NF.

Momentum measurement:

$$\frac{\Delta p}{p} \approx \frac{0.14}{B(Tesla)\sqrt{(x(m))}\ \cos\lambda}$$

x=track length

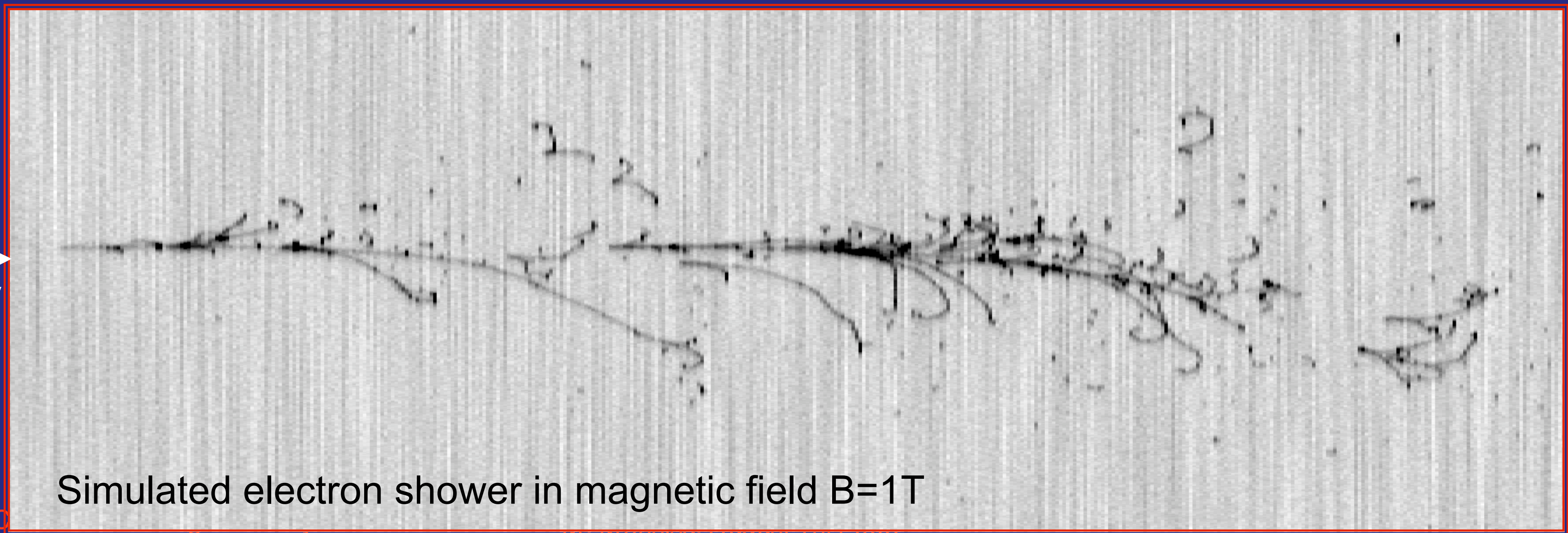
λ=pitch angle

Required field for 3σ charge discrimination:

$$B \geq \frac{0.2\,(Tesla)}{\sqrt{x(m)\ \cos^3\lambda}}$$

e^-

2.5 GeV



Simulated electron shower in magnetic field B=1T

First operation of a 10 lt LAr TPC embedded in a B-field

First real events in B-field (B=0.55T):

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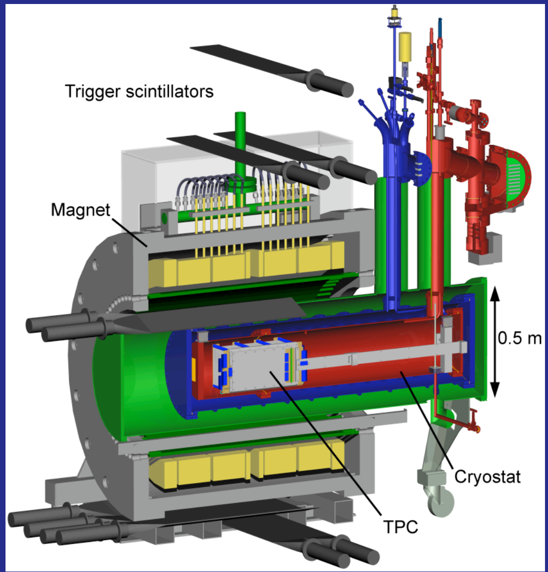
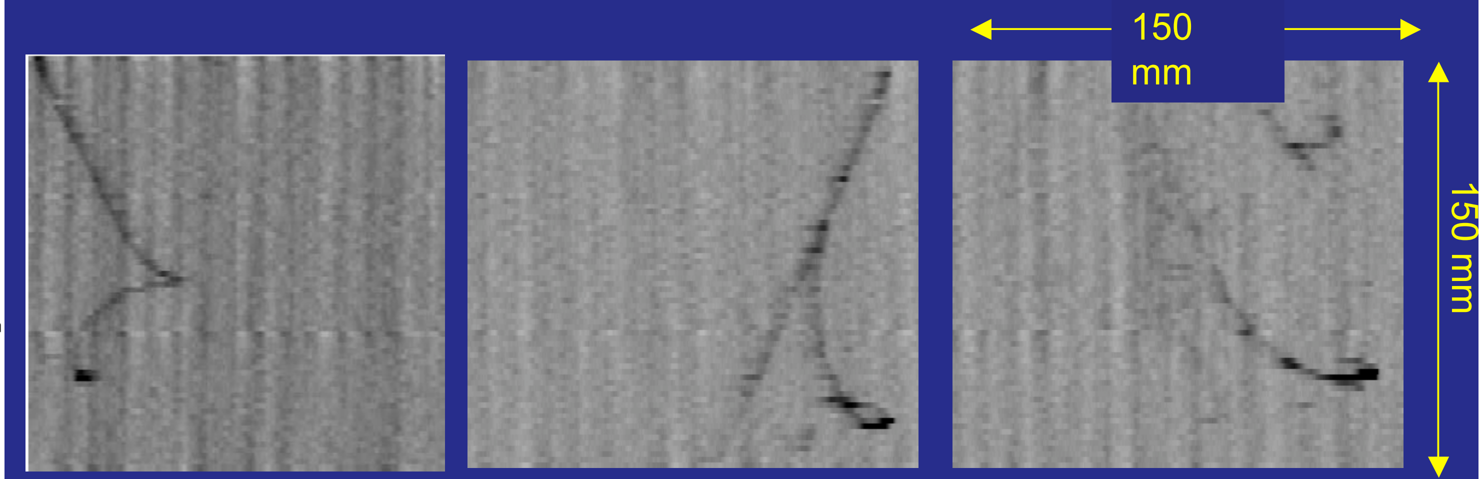
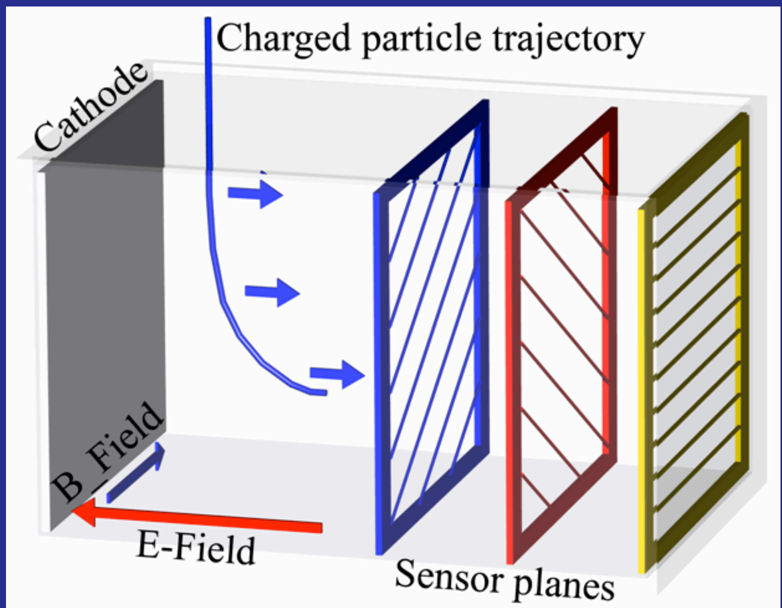
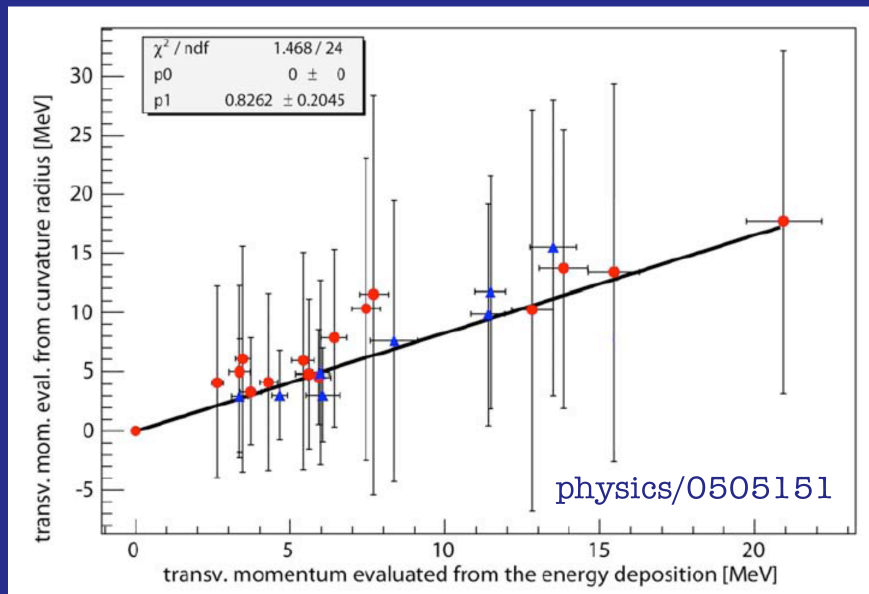
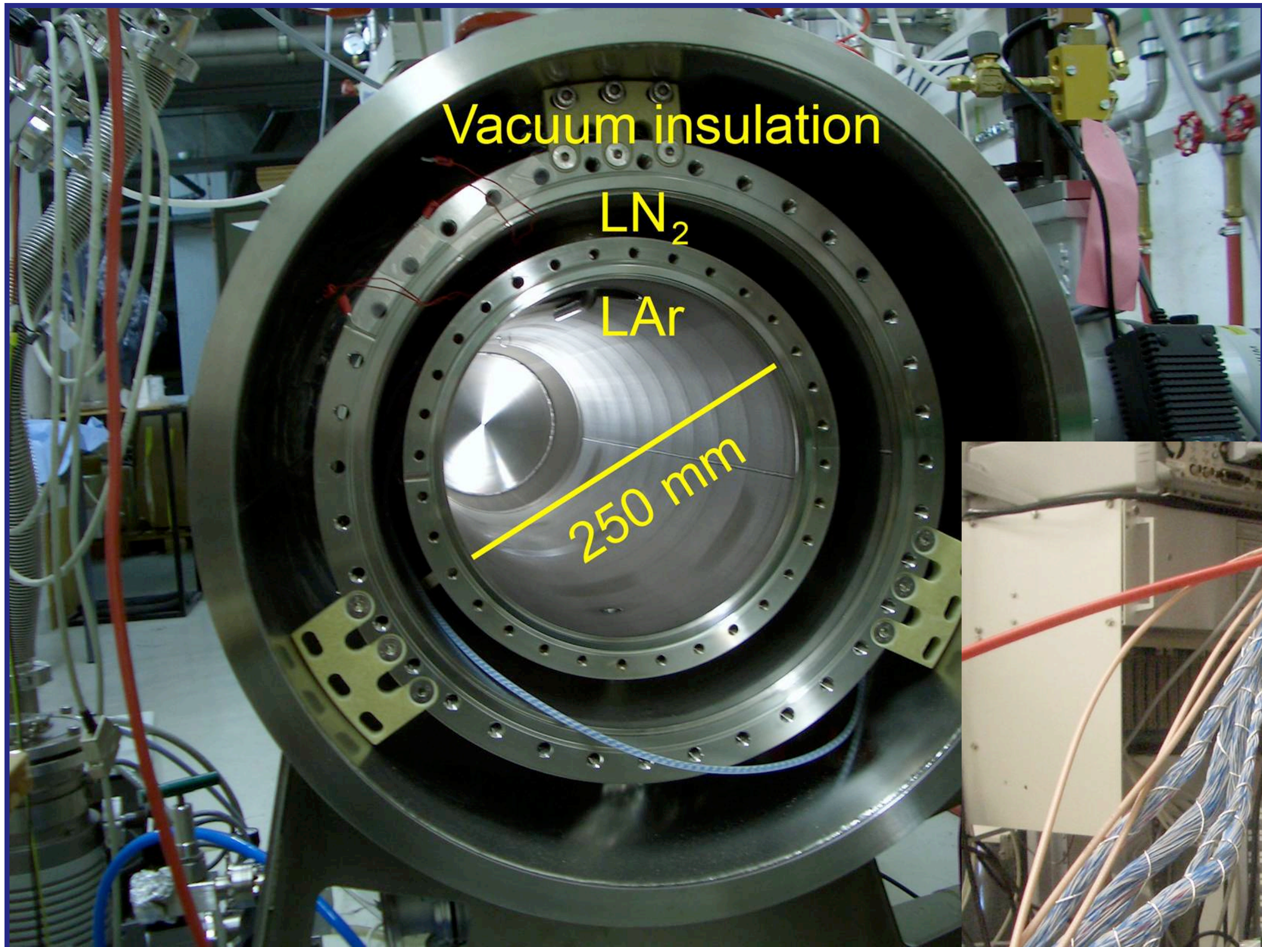




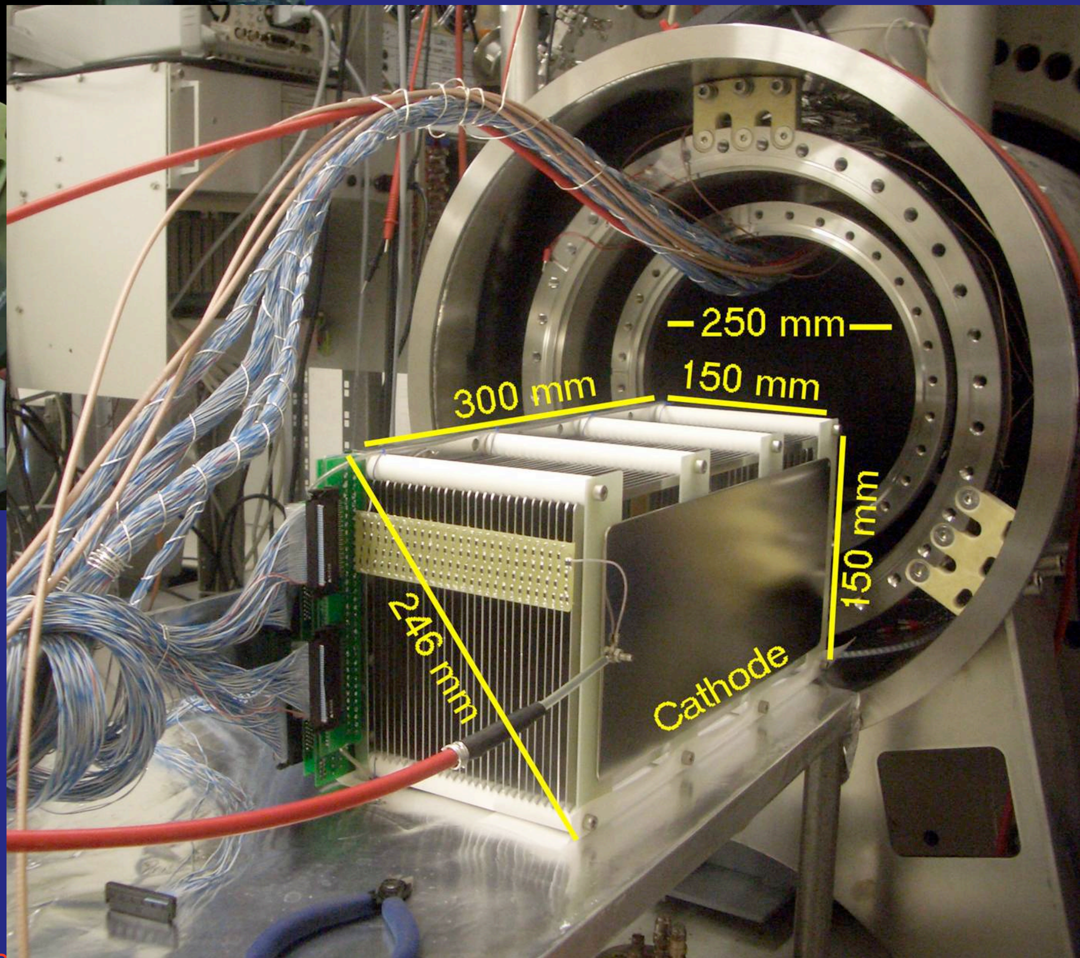


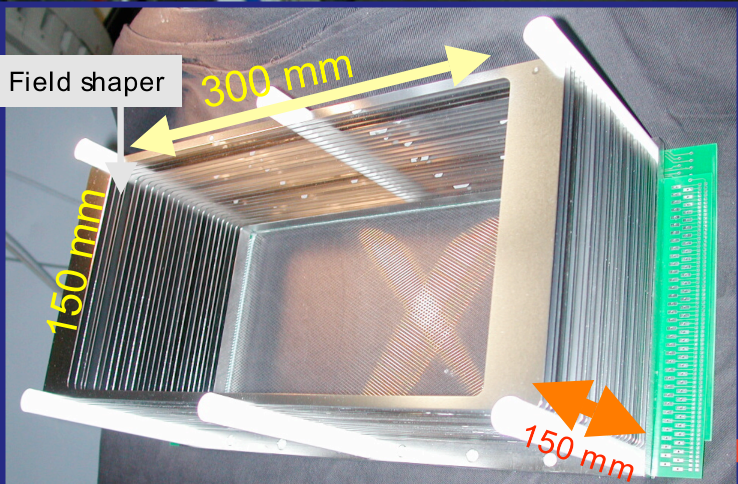
Correlation between calorimetry and magnetic measurement for contained tracks:





See
physics/0505151





Goals at future neutrino beams

Physics	Value of $\sin^2 2\theta_{13}$ $> 4 \times 10^{-2}$	$> 1 \times 10^{-2}$	$> 10^{-3}$	$> 10^{-4}$
Seeing $\theta_{13} \neq 0$	MINOS CNGS	Conventional Superbeams Phase I	Conventional Superbeams Phase II	ν Factory $L \geq 3500\ km$
Mass Hierarchy	Combinations of Phase I Superbeams	Combinations of Phase II Super/β-beams	Combinations of ν Factory and Super/β-beams	ν Factory $L \sim 7700\ km$
Evidence for CP-violation	Combinations of Phase I Superbeams	Combinations of Phase II Super/β-beams	Combinations of ν Factory and Super/β-beams	Combinations of ν Factory 2 baselines

How to achieve these outstanding physics goals will depend on the value of θ_{13}, for which there is no theoretical input.

The liquid Argon TPC has the capability to act as a general purpose technique which will be modulated to the various physics programs depending on their relevance

Neutrino detectors for future experiments: the choice of technologies

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**	$e^{\pm}$, $\mu^{\pm}$, $\tau^{\pm}$
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**	$\tau^{\pm}$

The liquid Argon TPC has the capability to provide multi-purpose detectors to reach a broad and comprehensive physics program.

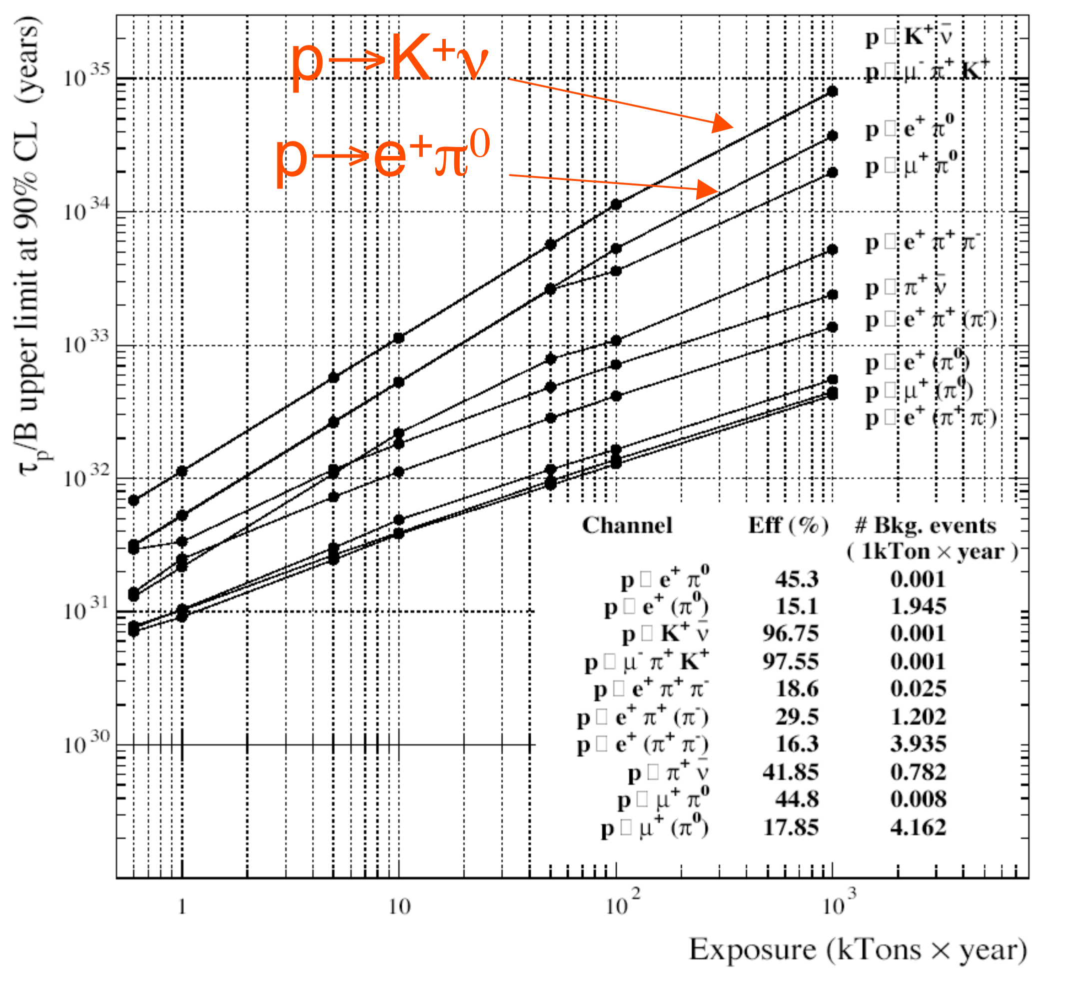
With a magnetized LAr TPC it is possible to directly consider both CP (“golden”) and T-violation (“platinum?”) searches at a NF.

Outstanding non-accelerator physics goals

	Water Cerenkov	Liquid Argon TPC
Total mass	650 kton	100 kton
$p \rightarrow e\,\pi^0$ in 10 years	$1.6\text{x}10^{35}$ years ε = 17%, ≈ 1 BG event	$0.5\text{x}10^{35}$ years ε = 45%, <1 BG event
$p \rightarrow \nu\,K$ in 10 years	$0.2\text{x}10^{35}$ years ε = 8.6%, ≈ 37 BG events	$1.1\text{x}10^{35}$ years ε = 97%, <1 BG event
$p \rightarrow \mu\,\pi\,K$ in 10 years	No	$1.1\text{x}10^{35}$ years ε = 98%, <1 BG event
SN cool off @ 10 kpc	194000 (mostly $\bar{\nu}_e p \rightarrow e^+ n$)	38500 (all flavors) (64000 if NH-L mixing)
SN in Andromeda	40 events	7 (12 if NH-L mixing)
SN burst @ 10 kpc	≈330 ν-e elastic scattering	380 ν_e CC (flavor sensitive)
SN relic	Yes	Yes
Atmospheric neutrinos	60000 events/year	10000 events/year
Solar neutrinos	$E_e > 7$ MeV (40% coverage)	324000 events/year $E_e > 5$ MeV

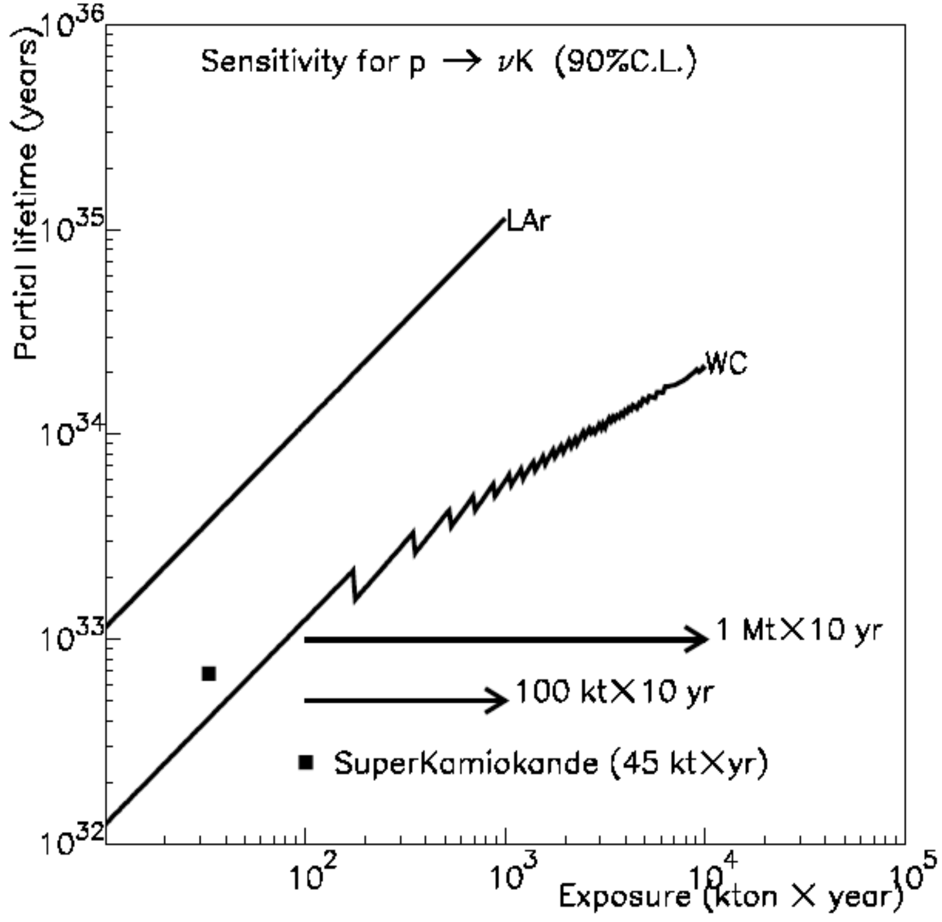
Proton decay sensitivity

Many channels accessible



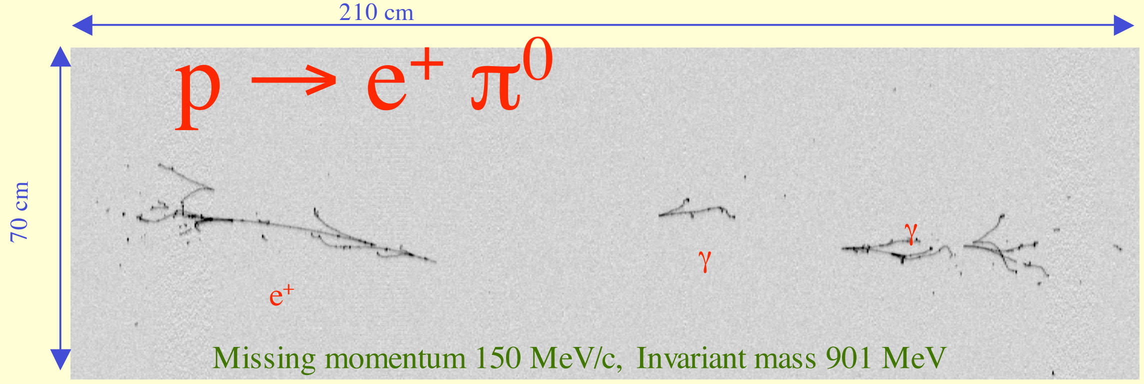
Channel	Eff (%)	# Bkg. events (1kTon × year)
p □ $e^+ \pi^0$	45.3	0.001
p □ $e^+ (\pi^0)$	15.1	1.945
p □ $K^+ \bar{\nu}$	96.75	0.001
p □ $\mu^- \pi^+ K^+$	97.55	0.001
p □ $e^+ \pi^+ \pi^-$	18.6	0.025
p □ $e^+ \pi^+ (\pi^-)$	29.5	1.202
p □ $e^+ (\pi^+ \pi^-)$	16.3	3.935
p □ $\pi^+ \bar{\nu}$	41.85	0.782
p □ $\mu^+ \pi^0$	44.8	0.008
p □ $\mu^+ (\pi^0)$	17.85	4.162

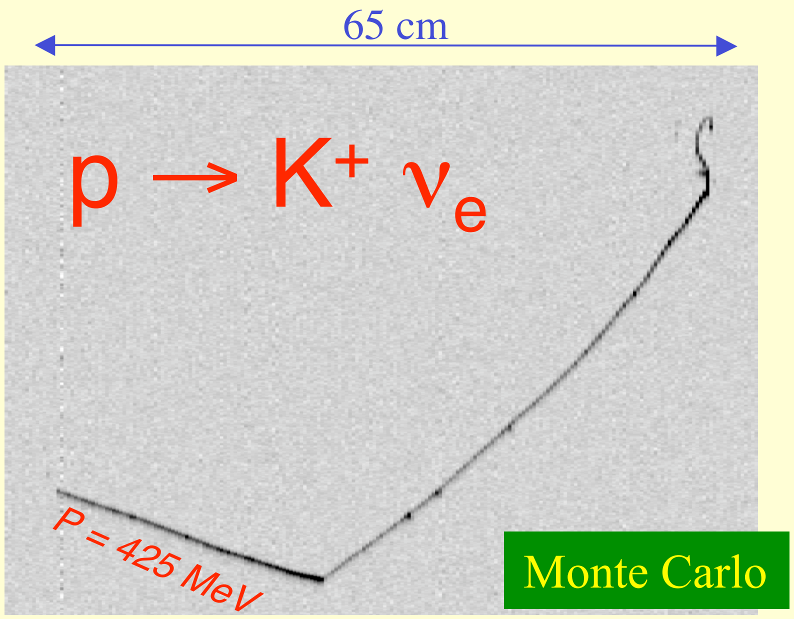
Complementarity

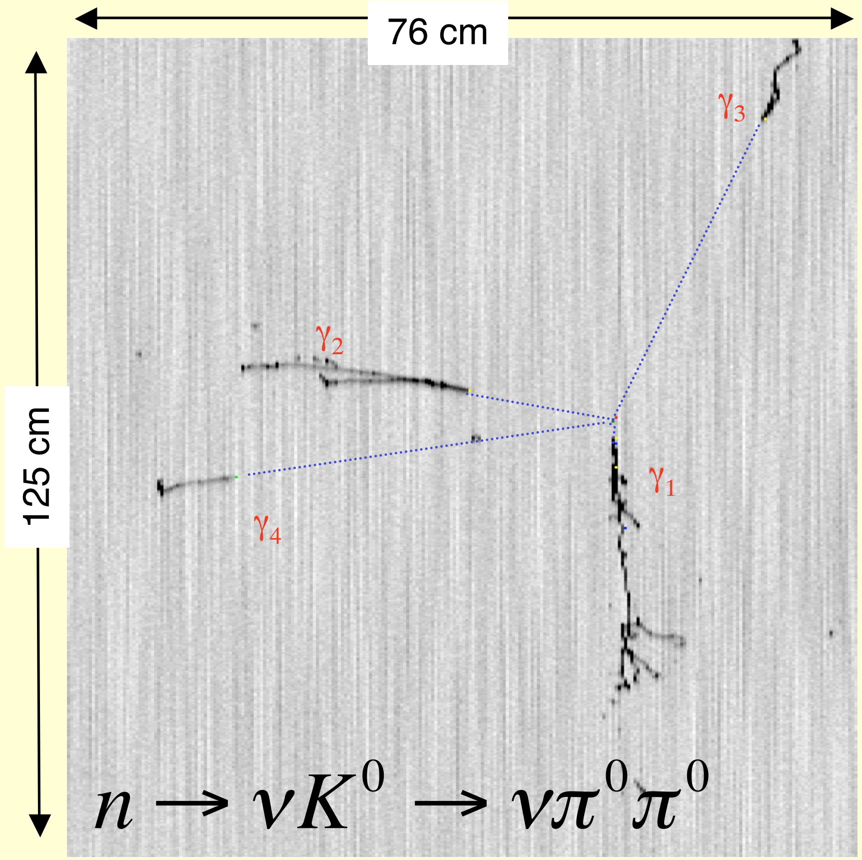


LAr TPC provides ultimate fine-grain tracking and calorimetry as necessary for proton decay searches

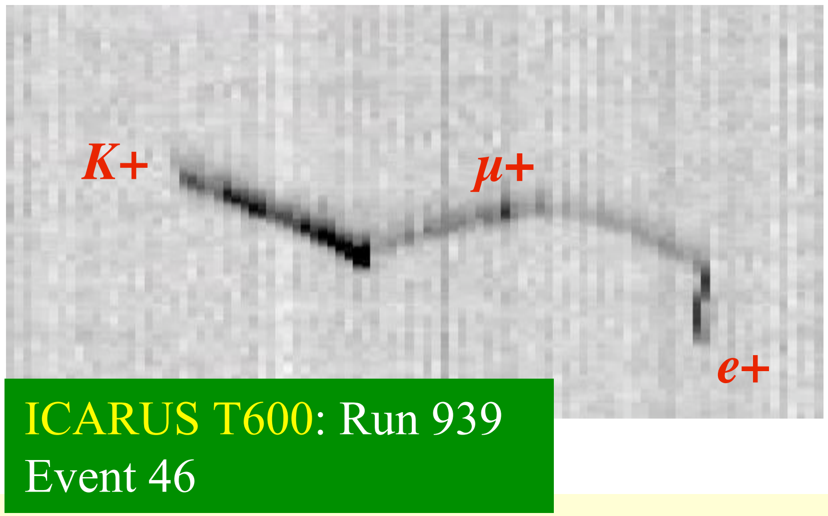
Nucleon decay



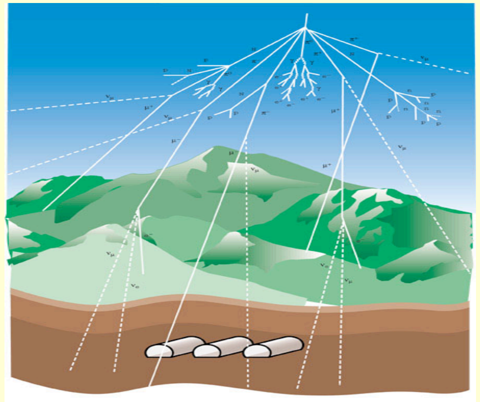




"Single" event detection capability

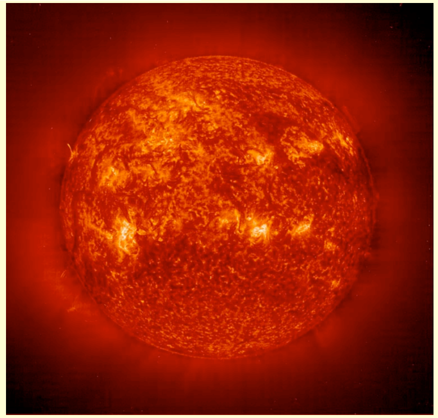


Astrophysical neutrinos



Atmospheric neutrinos:

- High statistics, precision measurements
- L/E dependence
- Tau appearance, electron appearance
- Earth matter effects
- …



Solar neutrinos:

- High statistics, precision measurement of flux
- Time variation of flux
- Solar flares
- …

Supernova type-II neutrinos:

- Access supernova and neutrino physics simultaneously
- Decouple supernova & neutrino properties via different detection channels
- Relic supernova
- Supernova in our galaxy or in Andromeda (1/15 years)
- Initial burst

JCAP 0408 (2004) 001
JCAP 0310 (2003) 009
hep-ph/0307222
JCAP 0412 (2004) 002

A strategy for long-term application of the liquid Argon TPC

In order to reach the adequate fiducial mass for long-term future physics programs, a new concept is required to extrapolate further the technology.

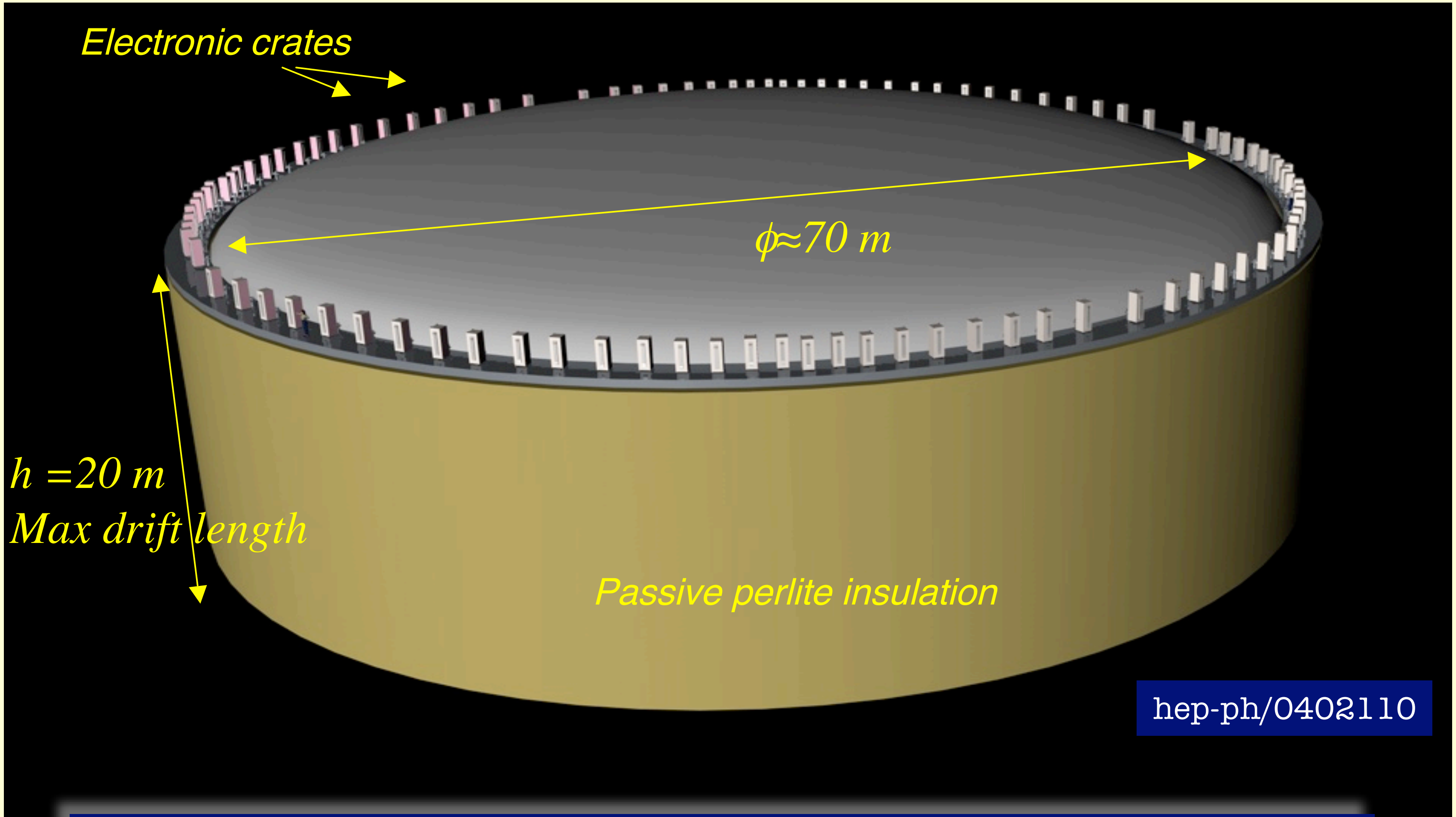
We consider two mass scales:

- A O(100 kton) liquid Argon TPC will deliver extraordinary physics output. It will be an ideal match for a future Superbeam, Betabeam or Neutrino Factory. This program is very challenging.

- A O(10 kton) prototype (10% full-scale) could be readily envisaged as an engineering design test with a physics program of its own. This step could be detached from a neutrino facility.

- An open issue is the necessity of a magnetic field encompassing the liquid Argon volume (only necessary for the neutrino factory). We have demonstrated the possibility to use magnetic field in a small prototype. We discuss here possible 10-100 kton in magnetic fields (see later).

A 100 kton liquid Argon TPC detector



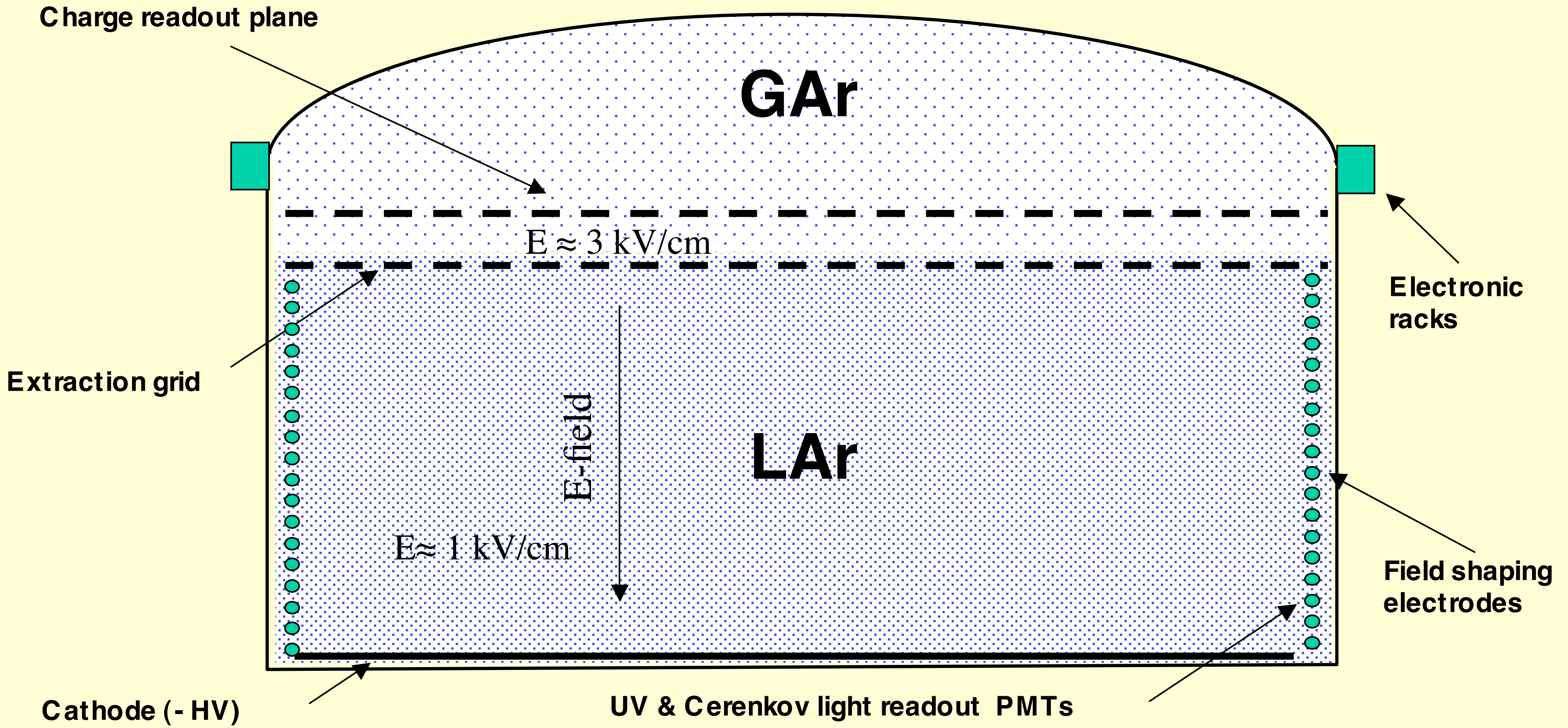
Single module cryo-tanker based on industrial LNG technology

A "general-purpose" detector for superbeams, beta-beams and neutrino factories with broad non-accelerator physics program (SN ν, p-decay, atm ν, …)

A tentative detector layout

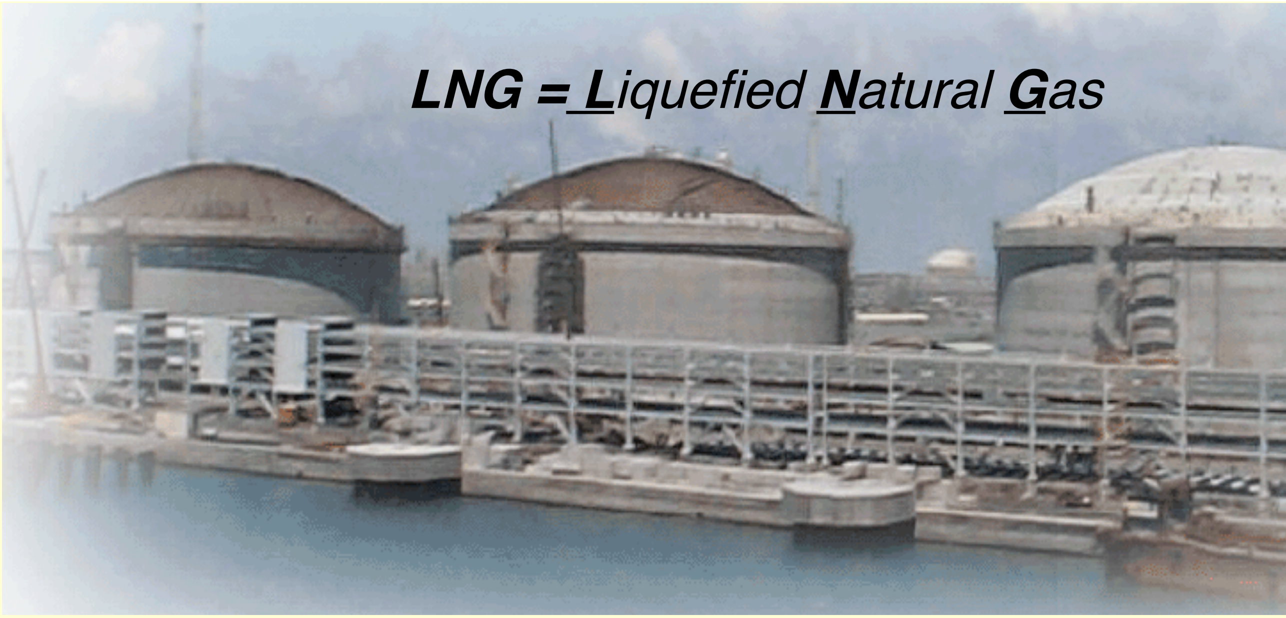
<u>Single detector</u>: charge imaging, scintillation, Cerenkov light

Dewar	$\phi \approx 70$ m, height ≈ 20 m, perlite insulated, heat input ≈ 5 W/m^2
Argon storage	Boiling Argon, low pressure (<100 mbar overpressure)
Argon total volume	73000 m^3, ratio area/volume $\approx$ 15%
Argon total mass	102000 tons
Hydrostatic pressure at bottom	3 atmospheres
Inner detector dimensions	Disc $\phi \approx 70$ m located in gas phase above liquid phase
Charge readout electronics	100000 channels, 100 racks on top of the dewar
Scintillation light readout	Yes (also for triggering), 1000 immersed 8" PMTs with WLS
Visible light readout	Yes (Cerenkov light), 27000 immersed 8" PMTs of 20% coverage, single γ counting capability



Cryogenic storage tankers for LNG

LNG = <u>L</u>iquefied <u>N</u>atural <u>G</u>as



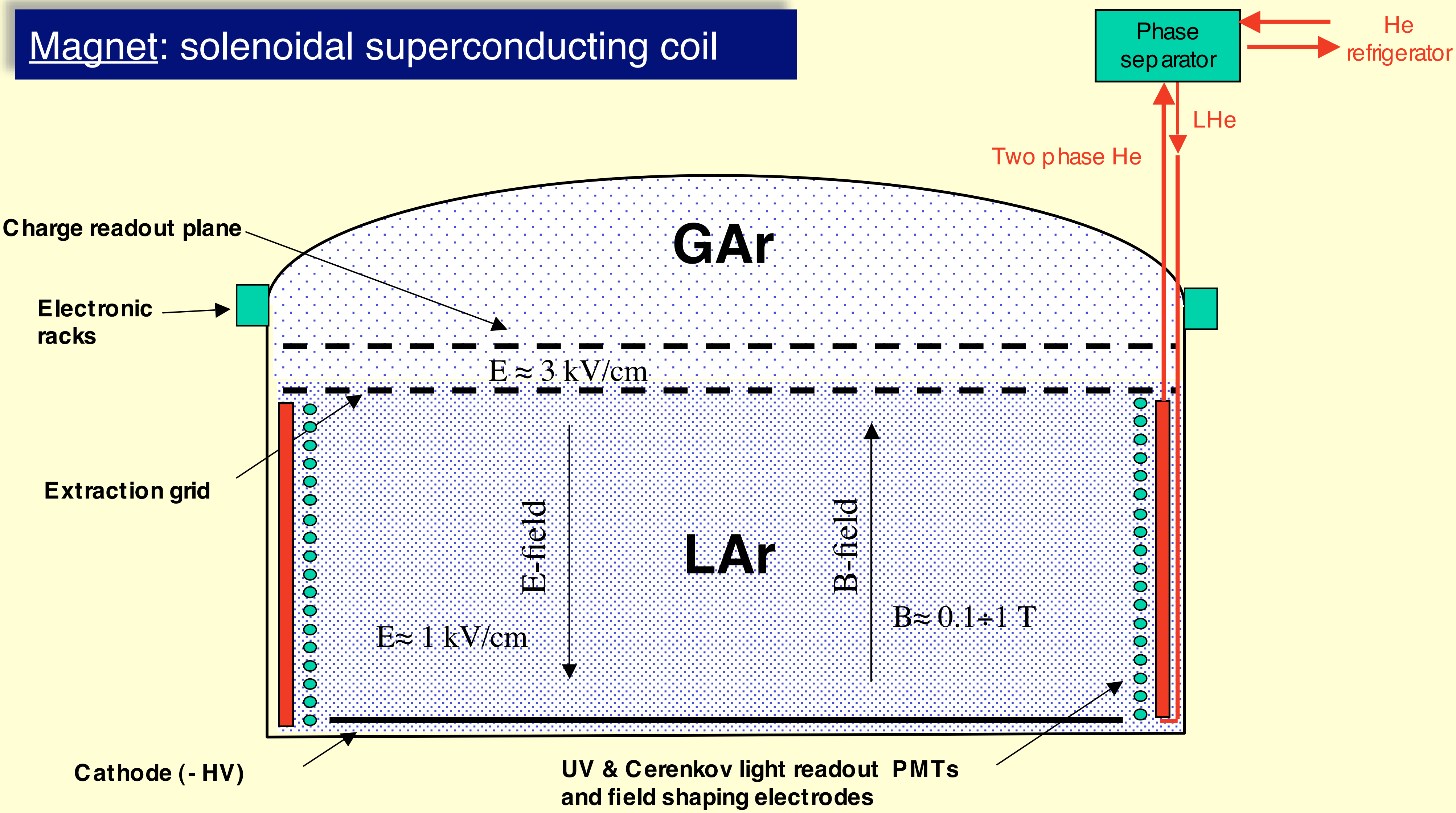
About 2000 cryogenic tankers exist in the world, with volume up to ≈ 200000 m^3

Process, design and safety issues already solved by petrochemical industry

Cooling by "auto-refrigeration"

Tentative layout of a large magnetized GLACIER

Magnet: solenoidal superconducting coil



LHe Cooling: Thermosiphon principle + thermal shield=LAr

Tentative coil parameters

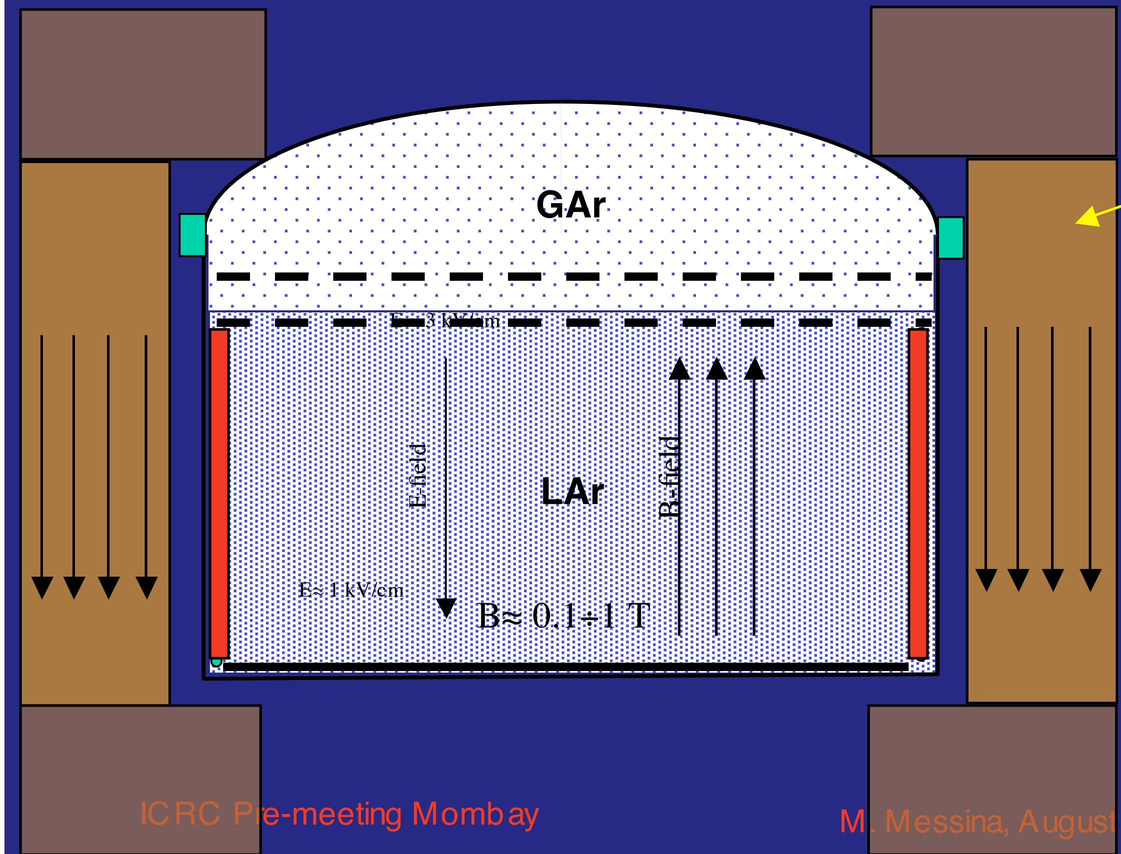
Other examples: ALEPH, CDF, ATLAS Toroids, AMS-II

	10 kton LAr			100 kton LAr			ATLAS solenoid	CMS
Magnetic induction (T)	0.1	0.4	1.0	0.1	0.4	1.0	2.0	4.0
Solenoid diameter (m)	30			70			2.4	6
Solenoid length (m)	10			20			5.3	12.5
Magnetic volume (m^3)	7700			77000			21	400
Stored magnetic energy (GJ)	0.03	0.5	3	0.3	5	30	0.04	2.7
Magnetomotive force (MAt)	0.8	3.2	8	1.6	6.4	16	9.3	42
Radial magnetic pressure (kPa)	4	64	400	4	64	400	1600	6500
Coil current (kA)	30 (I/I_c=50%)						8	20
Total length conductor (km)	2.5	10	25	12	57	117	5.6	45
Conductor type	NbTi/Cu normal superconductor, T=4.4K							

(Detailed magnetic, mechanical, thermal and quench analysis yet to be performed…)

Tentative Yoke parameters

Cylindrical Fe yoke	10 kton LAr			100 kton LAr		
Magnetic induction (T)	0.1	0.4	1.0	0.1	0.4	1.0
Magnetic flux (Weber)	70	280	710	385	1540	3850
Assumed saturation field in Fe (T)	1.8			1.8		
Thickness (m)	0.4	1.6	3.7	1	3.7	8.7
Height (m)	10			20		
Mass (kton)	6.3	25	63	34	137	342



Cylindrical Fe yoke. (Instrumented?)

NB: Superconducting Magnetic Energy Storage (SMES) systems were considered for underground storage of MJ energy without return yoke buried in tunnels in bedrock (see e.g. Eyssa and Hilal, J. Phys. D: Appl. Phys 13 (1980) 69). Avoid using a yoke?

R&D strategy

In order to assess our conceptual design, we are performing dedicated tests in the laboratory and studying specific items in more details:

- **Optimization of methods for charge extraction and amplification**
- **Study of suitable drift high voltage system to eventually reach MV**
- **Realization and test of a 5 m long detector column-like prototype**

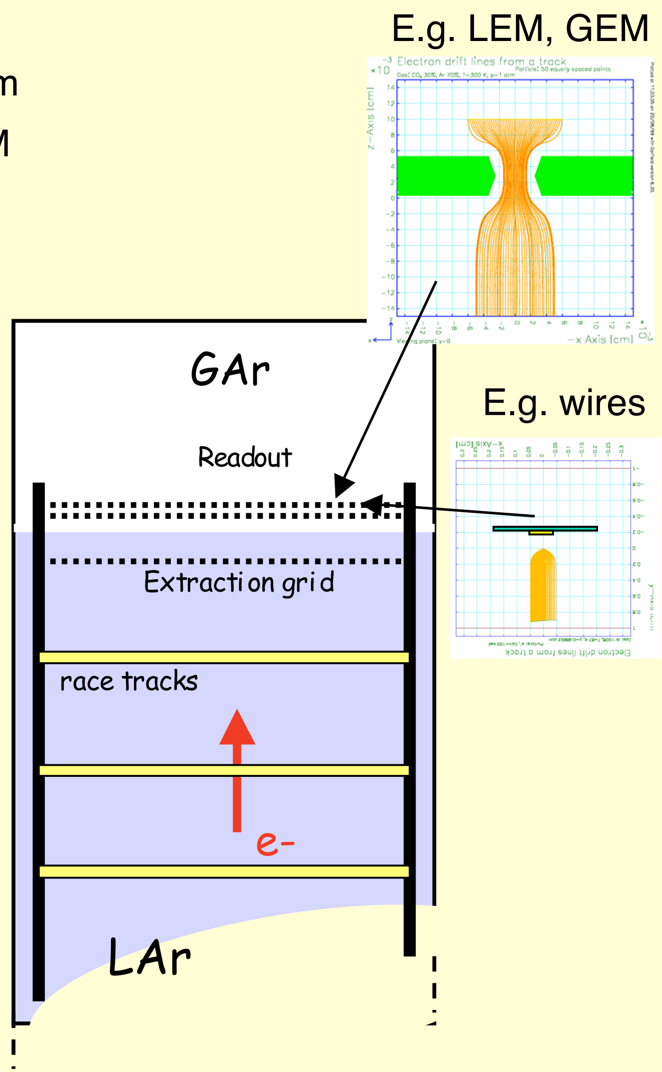
- **Study of a 50 ton magnetized prototype for calorimetry and charge discrimination studies**
- **Study of large liquid underground storage tank, costing**
- **Study of logistics, infrastructure and safety issues for underground sites**
- **Study of large scale argon purification**

(1) Charge extraction, amplification, readout

Detector is running in bi-phase mode TO ALLOW FOR A VERY LONG DRIFT PATH

- Long drift (≈ 20 m) ⇒ charge attenuation to be compensated by charge amplification near anodes located in gas phase (18000 e^- / 3 mm for a MIP in LAr)
- Amplification operates in proportional mode
- After maximum drift of 20 m @ 1 kV/cm ⇒ diffusion ≈ readout pitch ≈ 3 mm
- Amplification can be implemented in different ways: wires+pad, GEM, LEM

Electron drift in liquid	**20 m maximum drift, HV = 2 MV for E = 1 kV/cm, $v_d \approx$ 2 mm/μs, max drift time ≈ 10 ms**
Charge readout view	**2 perpendicular views, 3 mm pitch, 100000 readout channels**
Maximum charge diffusion	**$\sigma \approx$ 2.8 mm ($\sqrt{2Dt_{max}}$ for D = 4 cm²/s)**
Maximum charge attenuation	**$e^{-(t_{max}/\tau)} \approx$ 1/150 for τ = 2 ms electron lifetime**
Needed charge amplification	**From 100 to 1000**
Methods for amplification	**Extraction to and amplification in gas phase**
Possible solutions	**Thin wires ($\phi \approx$ 30 μm) + pad readout, GEM, LEM**

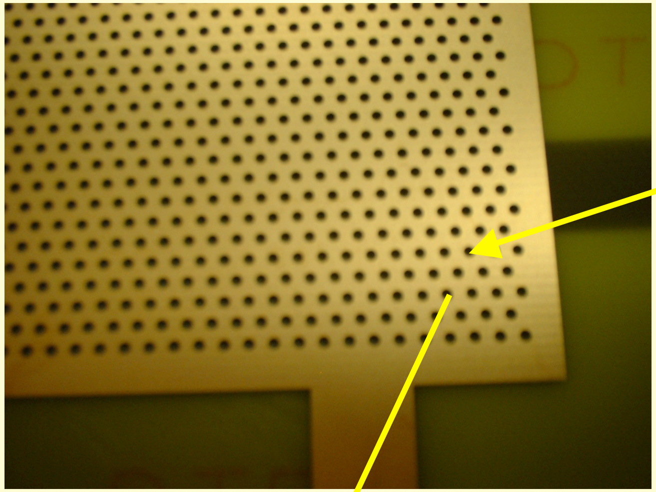


Thick Large Electron Multiplier (LEM)

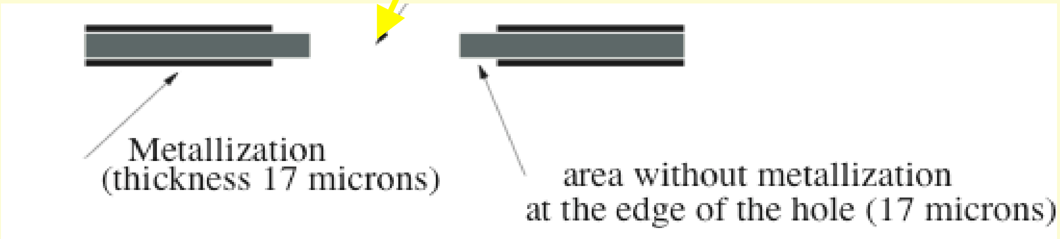
Thick-LEM (vetronite Cu coated + holes)

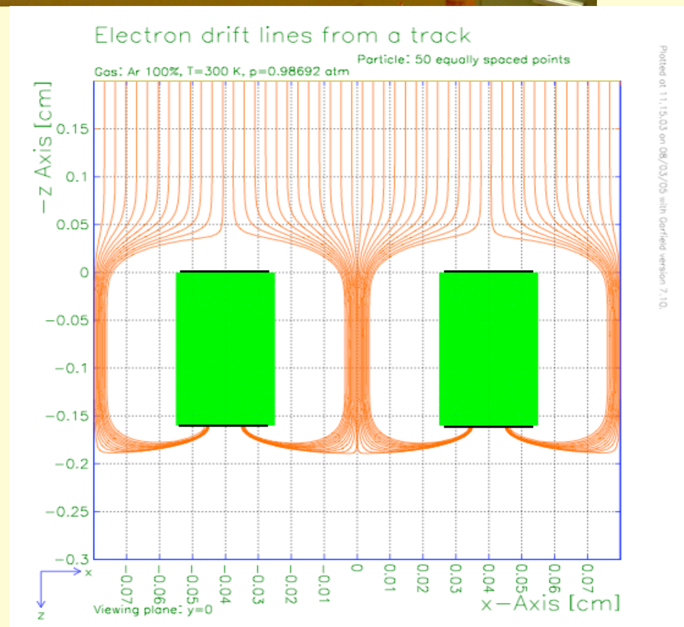
Sort of macroscopic GEM

A priori more easy to operate at cryogenic temperature



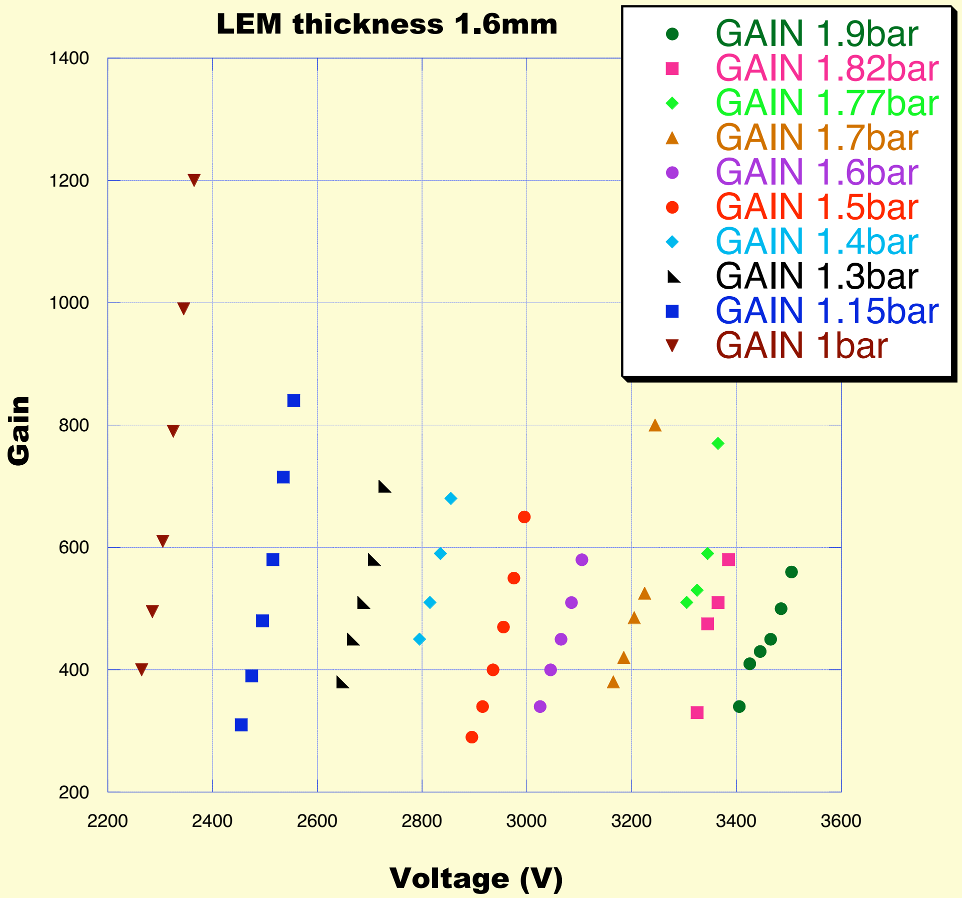
- Three thicknesses: 1, 1.6 and 2.4 mm
- Amplification hole diameter = 500 μm

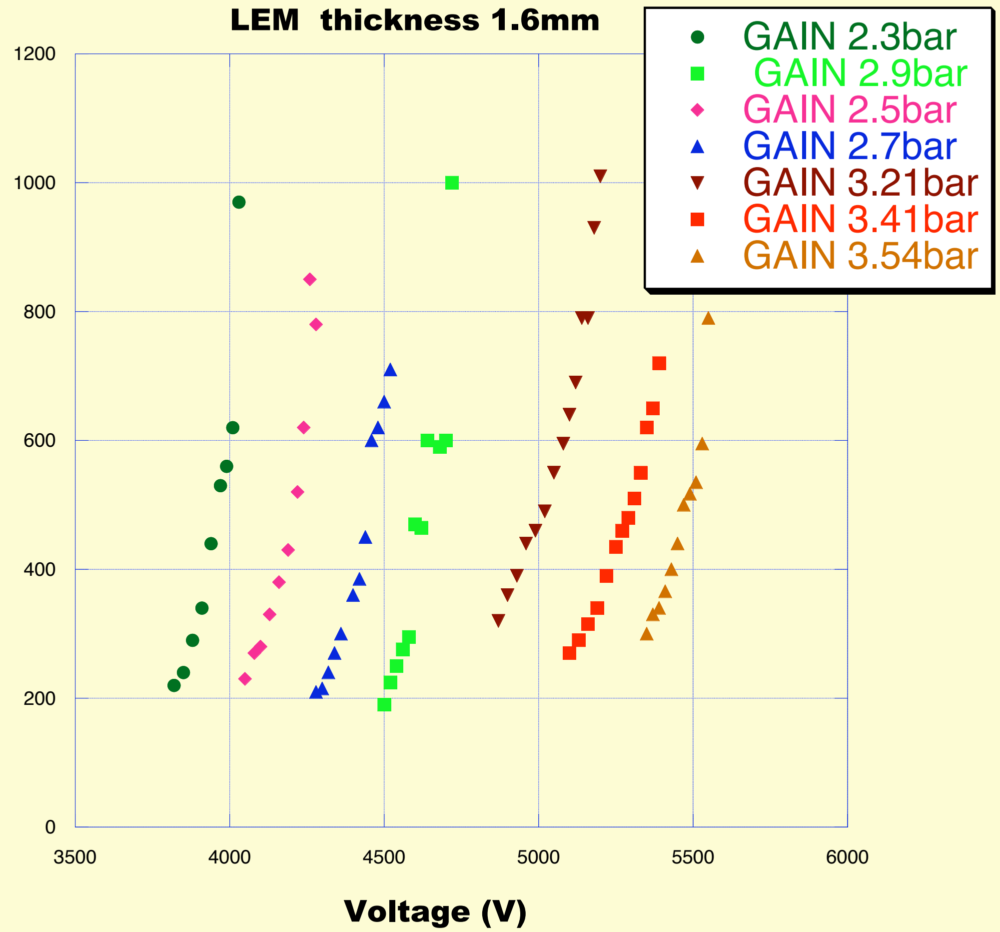




High gain operation of LEM in pure Ar at high pressure

- Fe-55 & Cd-109 sources, Argon 100%, Room temperature





Gain up to ≈800 possible even at high pressure (good prospects for operation in cold)

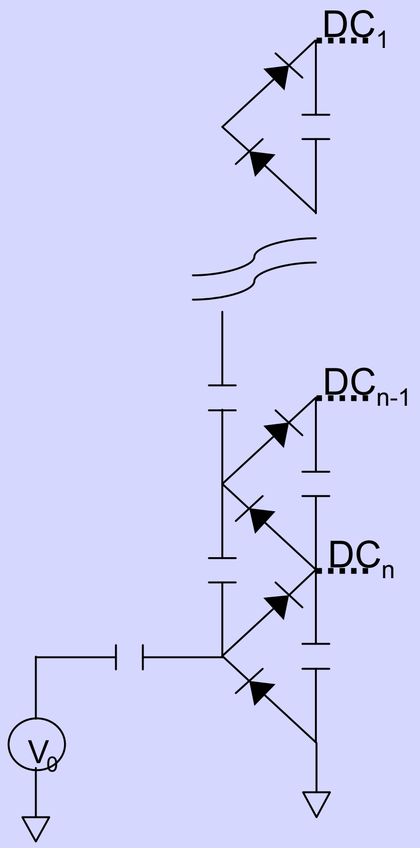
Resolution ≈ 28% FWHM for Fe-55 source

Results in agreement with GARFIELD simulations

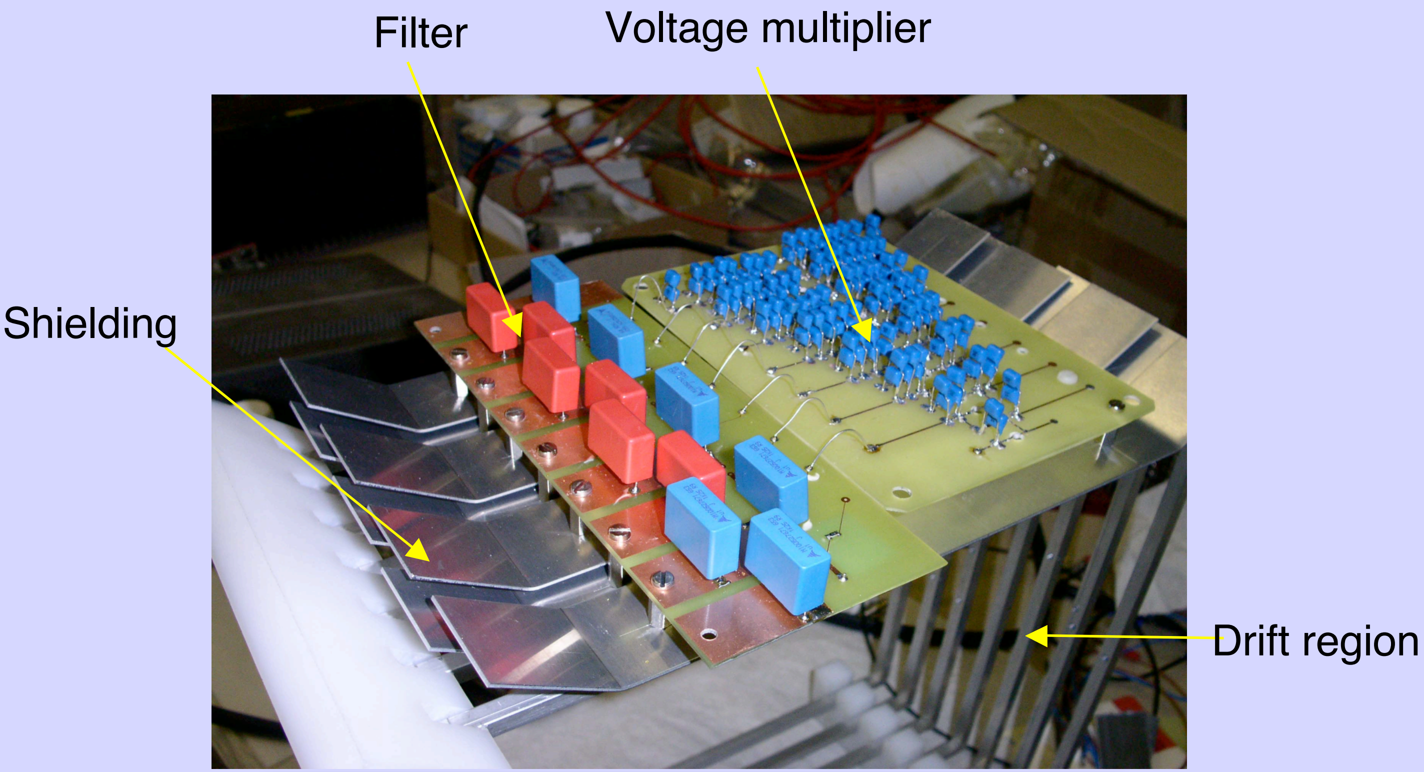
e-print in preparation

(2) Drift very high voltage: Greinacher circuit

- No load to avoid resistive ripple
- Low frequency (50-500 Hz) to induce noise with a spectrum far from the bandwidth of the preamplifiers used to read out the wires or strips
- Possibility to stop feeding circuit during an event trigger

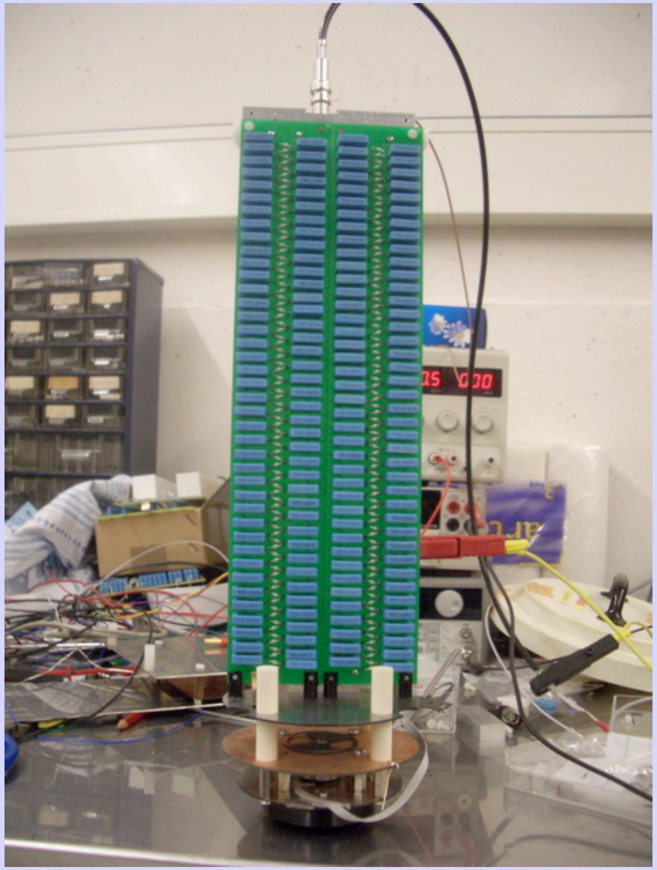


Greinacher or Cockroft/Walton voltage multiplier



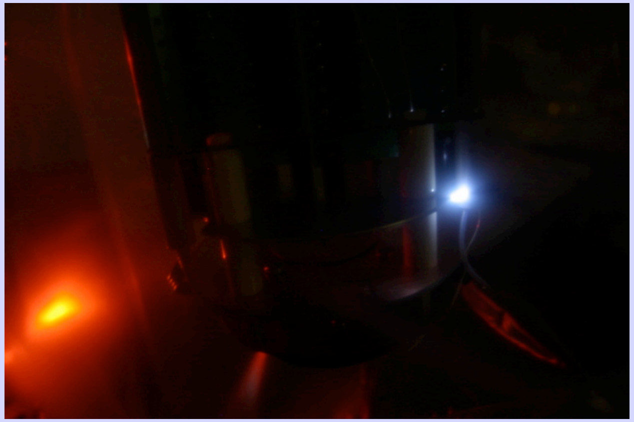
Prototype connected to actual electrodes of 50 liter TPC (ripple noise test)
Successfully tested up to ≈20kV

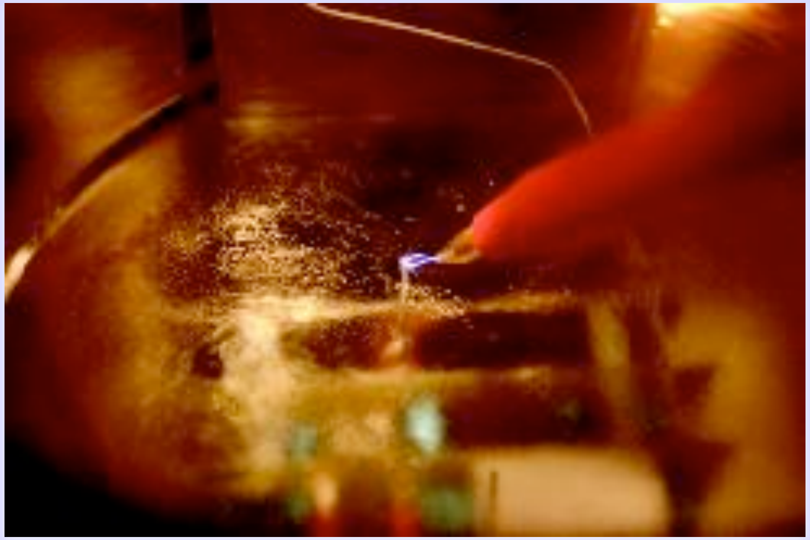
Very high voltage: 80 kV multiplier in LAr



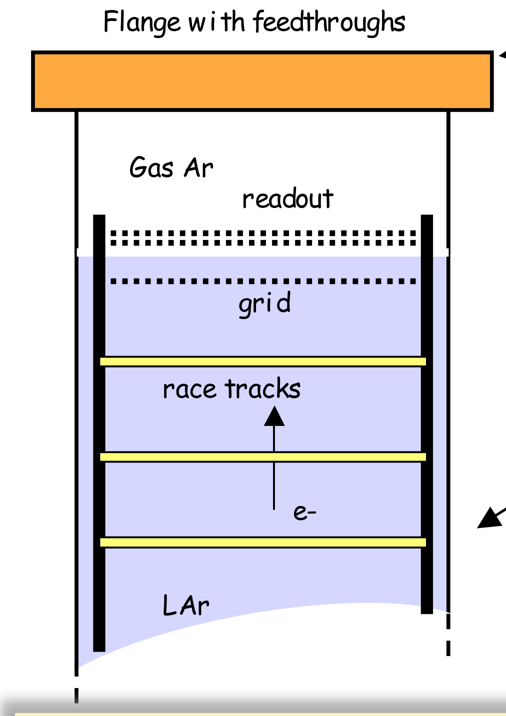
•NOVACAP(USA) NP0 dielectric capacitors, stable in temperature and against discharge. Tested successfully in our lab.
•New capacitors with piezoelectric dielectric have been tested successfully. They are able to double the capacitance in the cold by a factor 2.

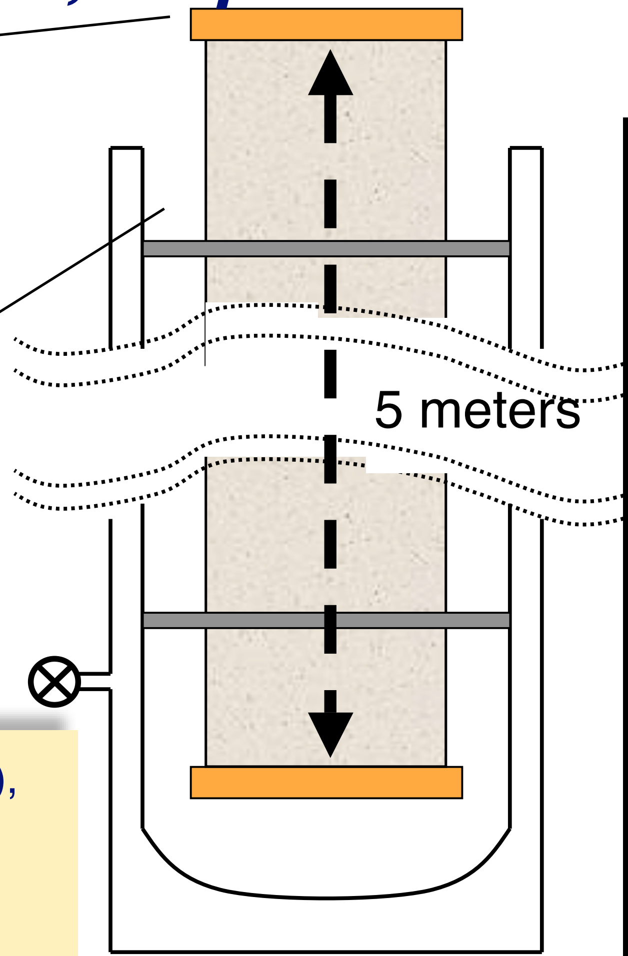
•HV diodes from Vishay/Phillips

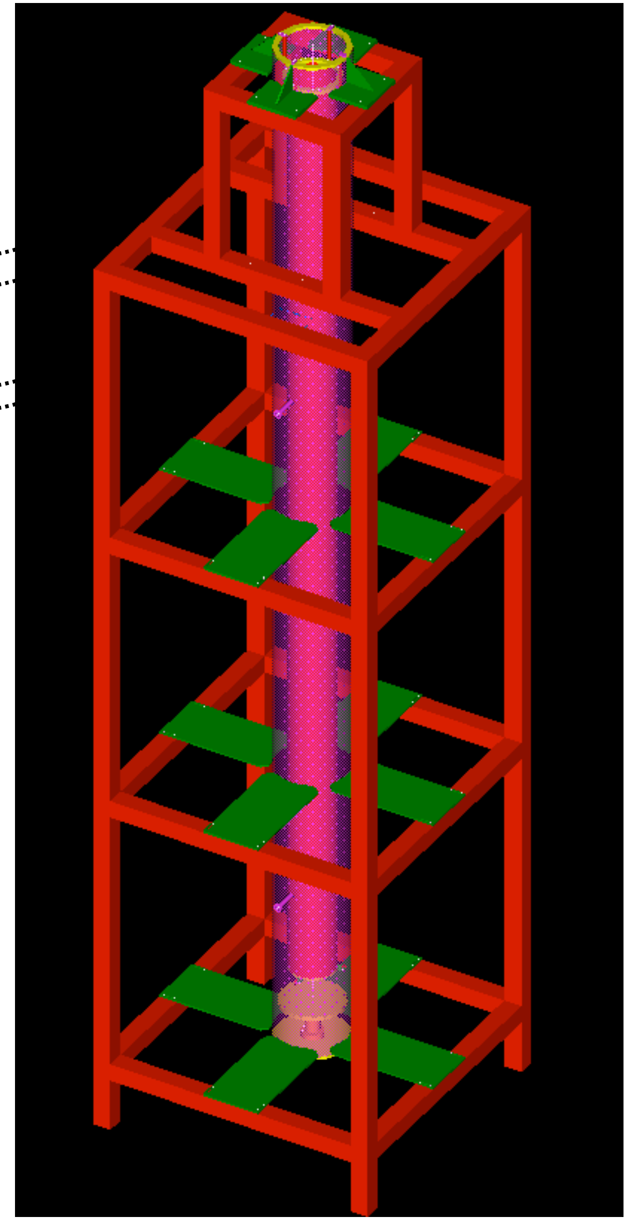




(4) Long drift, extraction, amplification: “ARGONTUBE”







- Full scale measurement of long drift (5 m), signal attenuation and multiplication
- Simulate ‘very long’ drift (10-20 m) by reduced E field & LAr purity
- High voltage test (up to 500 kV)
- Design & assembly:

completed: external dewar, detector container
in progress: inner detector, readout system, …

Results in 2006

Inner diameter 250 mm, drift length 5000 mm
drift HV up to 500 kV

(6) Study of large underground storage tank

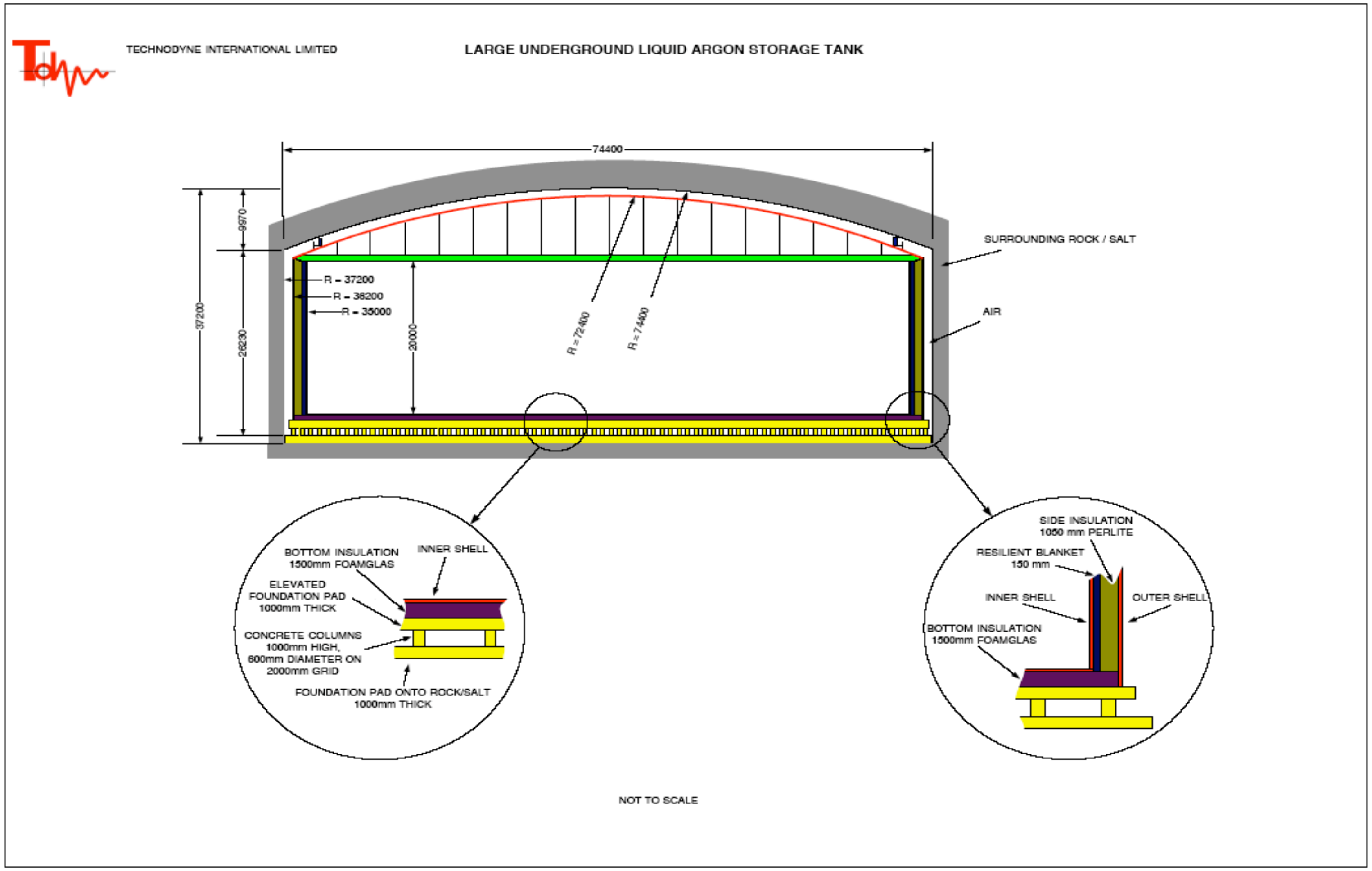
A feasibility study mandated to Technodyne LtD (UK)

Study duration: February - December 2004 Funded by ETHZ

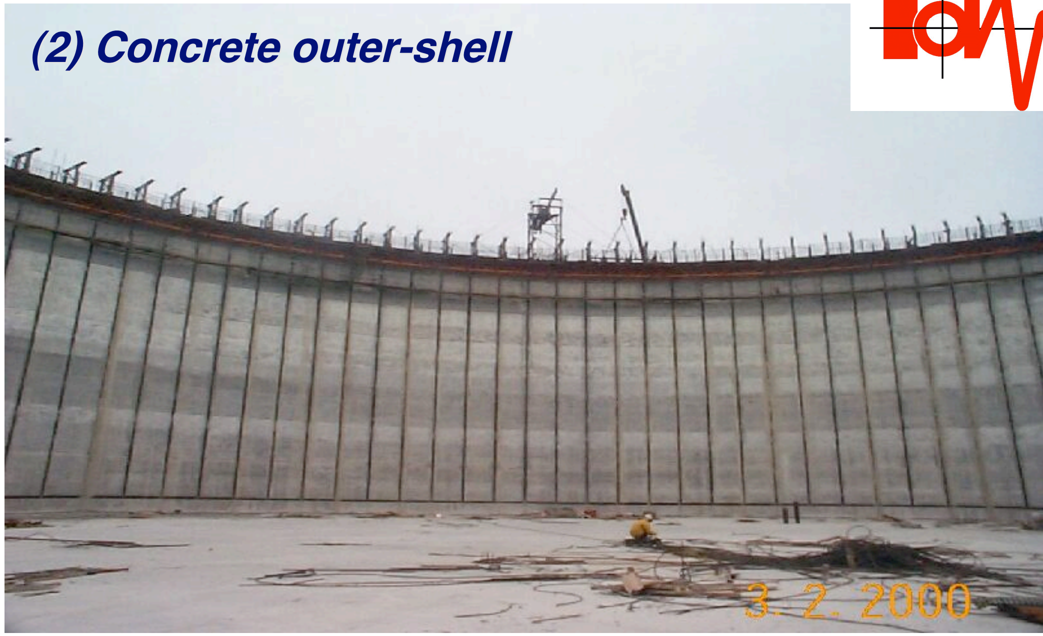
Project: Large Underground Argon Storage Tank

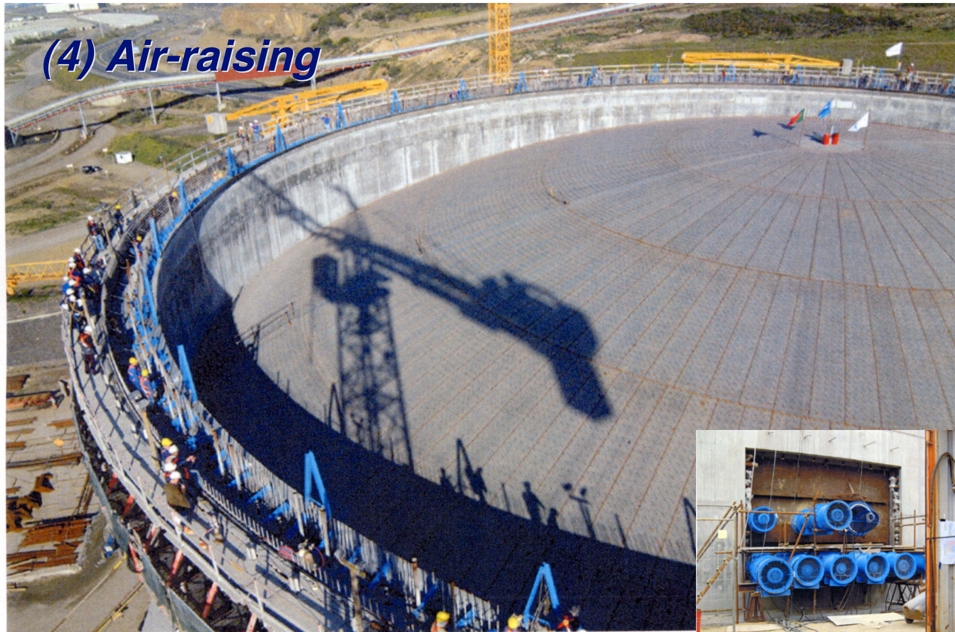
Issued By: JMH

Date:

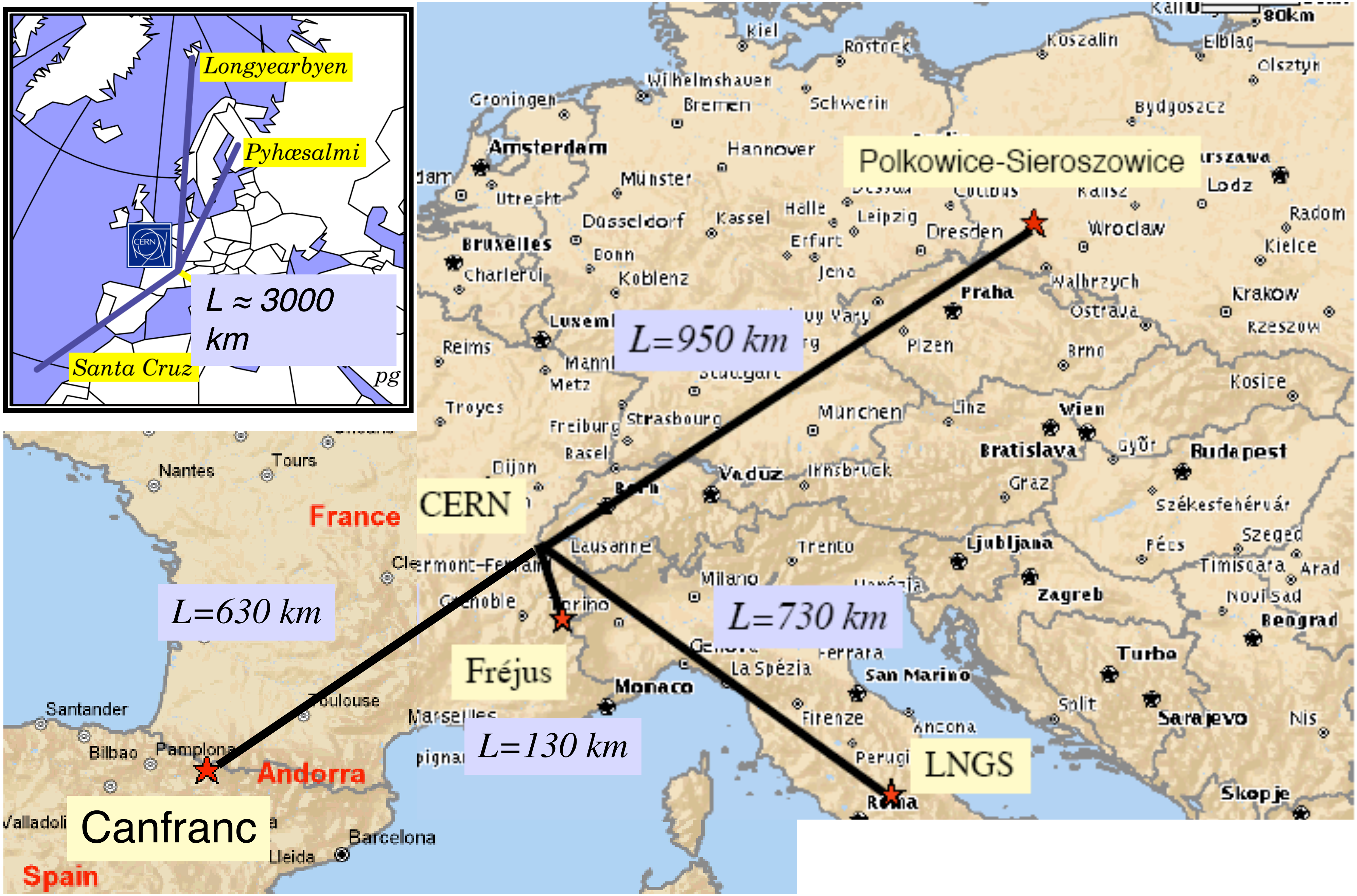


A dream come true?

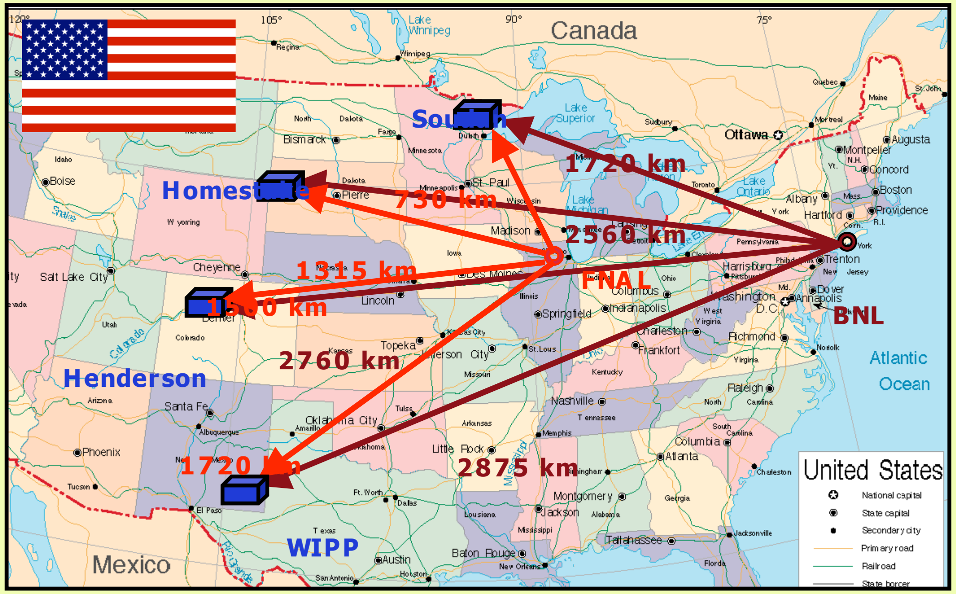


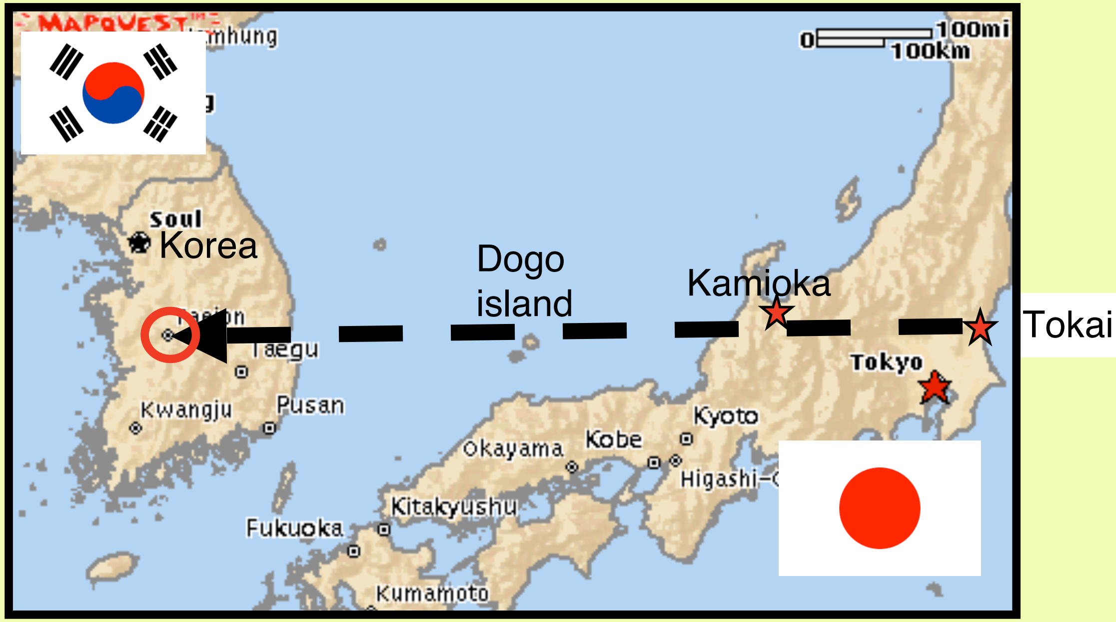


Possible underground sites in Europe ?



Non-European sites for very large liquid argon TPC



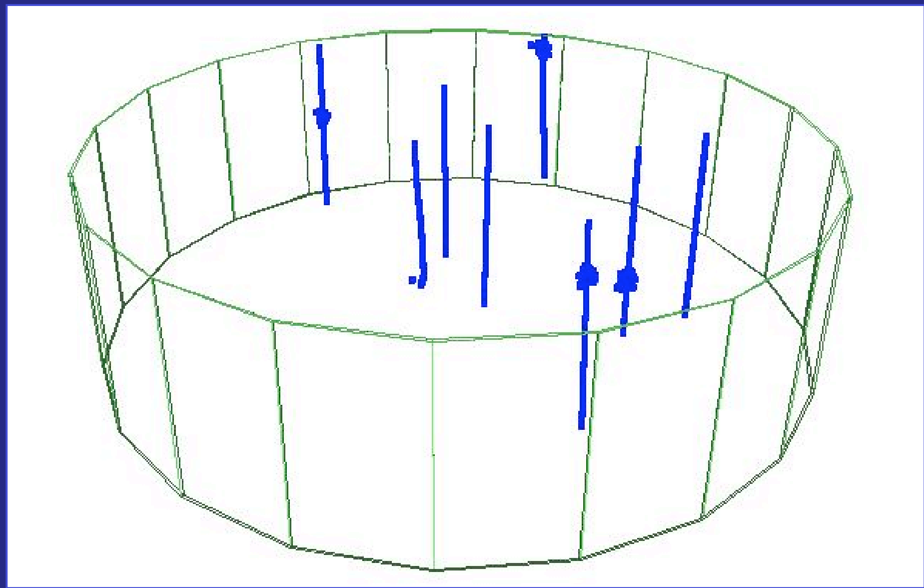


Liquid Argon TPC provides high efficiency for broad energy range: Flexibility in L & E choice

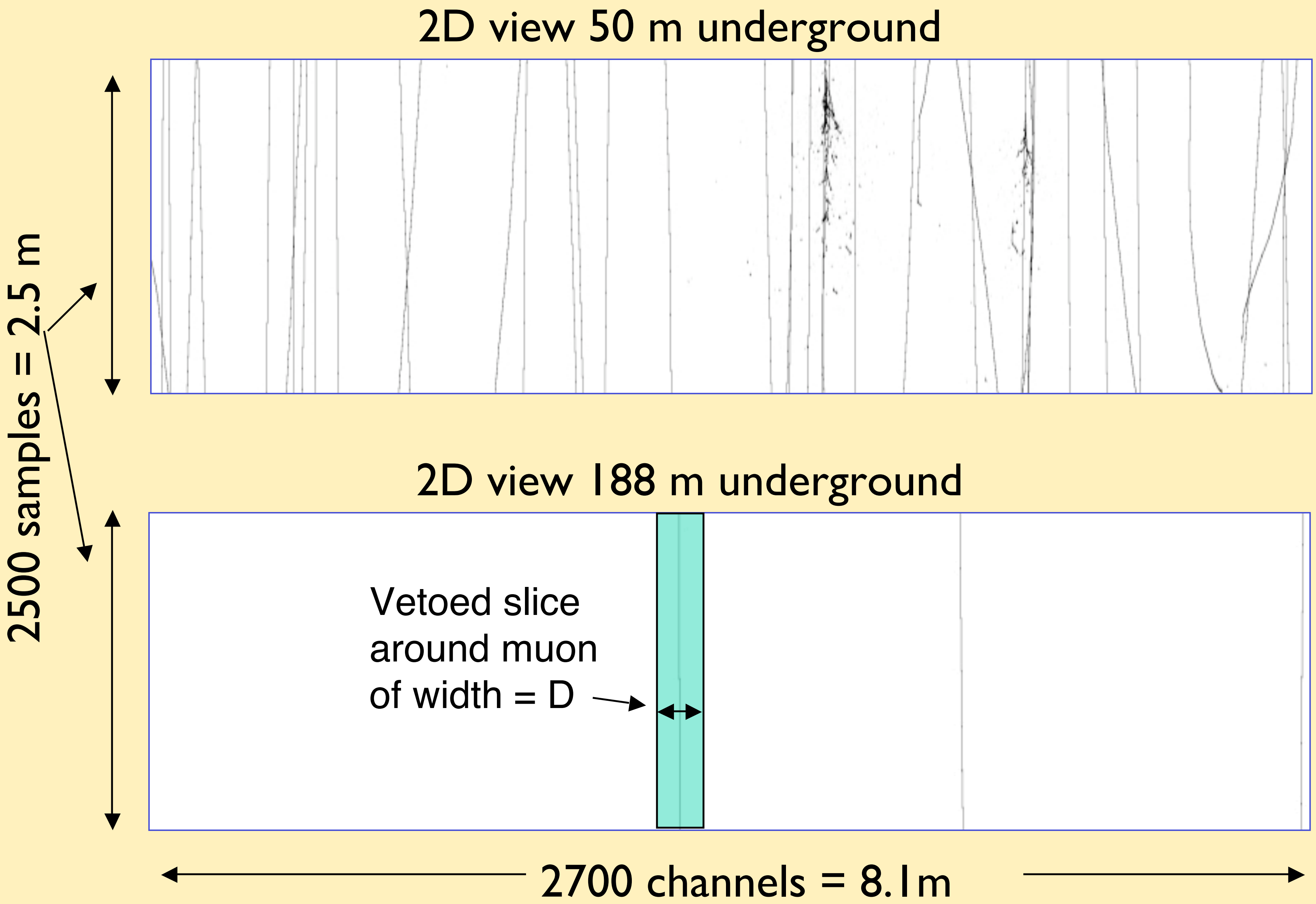
Preliminary assessments on detector depth

- It is generally assumed that the detector will be located deep underground in order to shield it from cosmic rays.
  - ➥ **Is a shallow depth operation possible?**
- This is not a trivial question. We have started to perform detailed simulations to understand operation at a shallow depth (At a minimum of 50 meter underground and below)
- Preliminary results on (a) crossing muons rates which are important to design detector readout system and fiducial volume definition (b) background to proton decay searches associated to cosmogenic backgrounds

Underground muons are essentially vertical and in our drift configuration point along the drift direction to minimize impact on number of touched channels.
When a muon cross the detector, we “veto” a slice around it of width = D



Example for 50m vs 188m rock overburden



Crossing muon rates at different detector depths

Muon flux on surface = 70 m^{-2} s^{-1} sr^{-1} with E_μ > 1GeV

Depth rock	**Total crossing muons (E> 1GeV) per 10ms**	**Fiducial mass after slice of size D around each muon is vetoed**		
		D=10 cm	D=20 cm	D=30 cm
Surface	**13000**	…	…	…
50 m	**100**	50 kton	25 kton	10 kton
188 m	**3.2**	98 kton	96 kton	94 kton
377 m (1 km w.e)	**0.65**	100 kton	100 kton	100 kton
755 m (2 km w.e)	**0.062**	100 kton	100 kton	100 kton
1.13 km (3 km w.e)	**0.010**	100 kton	100 kton	100 kton

GLACIER mailing list

- Physics institutes:

ETHZ:	A. Badertscher, L. Knecht, M. Laffranchi, A. Meregaglia, M. Messina, G. Natterer, P.Otiougova, A. Rubbia, J. Ulbricht
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- Cryogenic departments:

Southampton University:	C. Beduz, Y. Yang

- Industry:

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CUPRUM (KGHM group), Wroclaw, Poland

CAEN, Viareggio, Italy

Summary

- **R&D program needed to extrapolate liquid Argon TPC concept to O(100 kton) detectors under progress**
  - ➥ Internal issues: Purification, long drift paths, magnetic field,…
  - ➥ External issues: safety, modularity (installation, access, operation, …)

- **The state of the art of our conceptual design has been presented.**

- **It relies on**
  - ➥ (a) industrial tankers developed by the petrochemical industry (no R&D required, readily available, safe) and their extrapolation to underground LAr storage. At this stage we do not see an extended physics program in a potential surface operation.
  - ➥ (b) improved detector performance for very long drift paths w e.g. LEM readout
  - ➥ (c) new solutions for drift very HV
  - ➥ (d) a modularity at the level of 100 kton (limited by cavern size)
  - ➥ (e) the possibility to embed the LAr in B-field (conceptually proven). Magnetic field strength to be determined by physics requirements.

Outlook - a possible roadmap

- Our roadmap considers a “graded strategy” to eventually reach the 100 kton scale.
- In the short term, ICARUS at LNGS will act as the “demonstrator” for a deep underground operation of the LAr technology.
- On the mid-term, a coordinated T2K-LAr effort will be fundamental for the understanding of neutrino interactions on Argon (and possibly water) target and will represent an important and very high statistics milestone for the liquid Argon technology.
- In parallel, we have developed the conceptual design for a 50 ton magnetized LAr TPC for calorimetry and charge discrimination studies. Measurement campaign at CERN, FNAL or KEK ?
- On the longer term, we think that there might be a window of opportunity to consider a ≈10kton full-scale, cost effective prototype of the 100 kton design, as an engineering design test with a physics program of its own, directly comparable to that of Superkamiokande. This detector could be magnetized.
- Eventually, the strategy of the neutrino mixing matrix studies and ultimate proton decay searches should envisage a possibily magnetized 100 kton liquid Argon TPC. The tentative design outlined above seems technically sound and would deliver extraordinary physics output. It would be an ideal match for a Superbeam, Betabeam or a Neutrino Factory. The definition of this phase would benefit from the results of T2K & NoVa.