Liquid Argon R&D in the UK for Future Detectors

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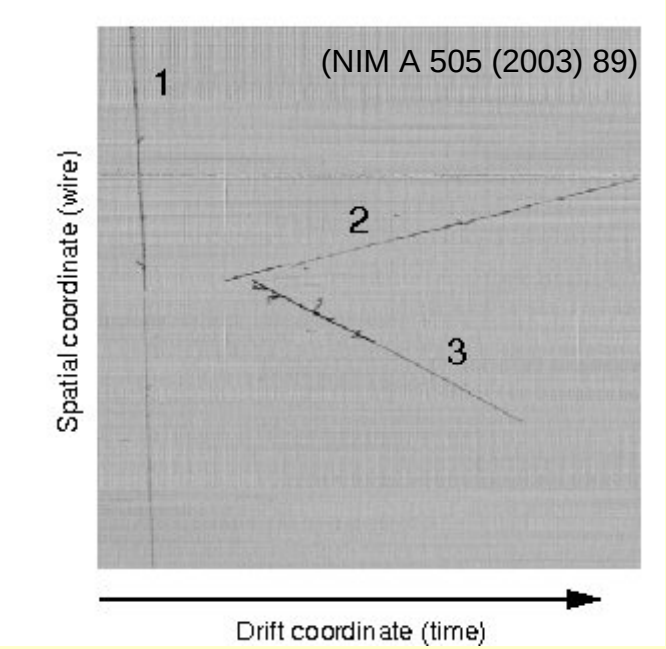
Introduction

- The use of liquid argon for calorimetry and more recently for 3-D imaging with bubble-chamber precision is now a mature technology
- Recent years has seen progress in solving problems associated with making large-scale, practical detectors applicable to next generation neutrino detectors – vigorous programme underway in Europe and USA
- The Sheffield and Warwick groups believe the time is right to build on what is known and kick-start a UK R&D initiative in LAr

Liquid Argon

Charged particle traversing LAr:

- **Ionisation**: W_e=23.6 eV, 6000 electrons/mm for a m.i.p.
- **Scintillation**: W_γ=19.5 eV, UV line at λ=128nm or 9.7 eV ->largely transparent 5000 photons/mm per m.i.p.
- Some **Cherenkov** light

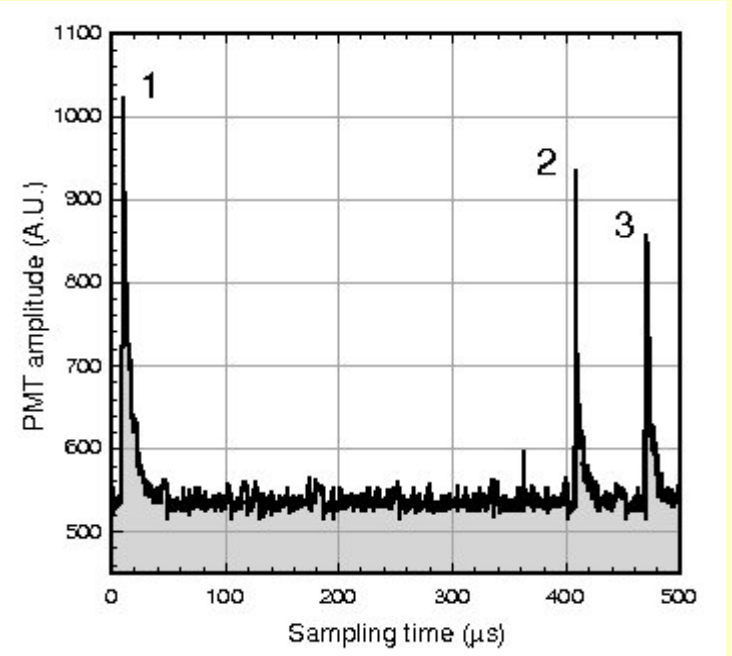


➢High granularity sampling 0.02 X_0

➢Tracking capability combined with timing provides true 3D imaging

➢Possibility of precision dE/dx

➢Also a total absorption calorimeter capable of measuring neutrino energy to σ_E/E =10% or better.



ISS Conclusions

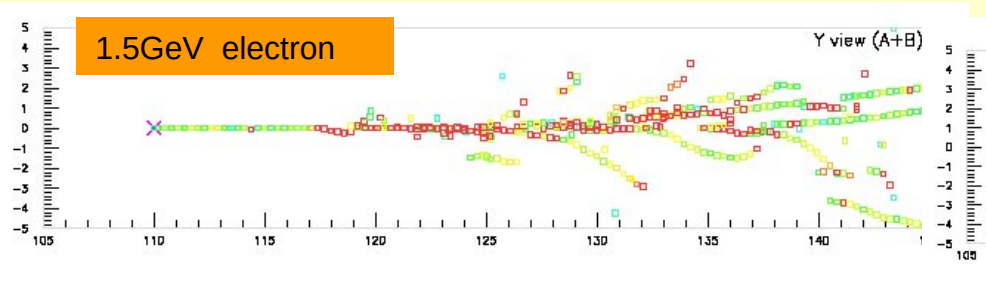
BEAM	FAR DETECTOR	R&D NEEDED
Sub GeV Beta-Beam and Super-Beam	**Liquid Argon TPC** **(100kton)**	Clarify advantage over WC?
1-5 GeV Beta-Beam and Super-Beam	**Liquid Argon TPC**	Long drifts and wires, LEMS etc
Neutrino Factory (20-50 GeV, 2500-7000km)	**Magnetised Liquid Argon TPC**	Large volume magnet Long drifts and wires, LEMS etc

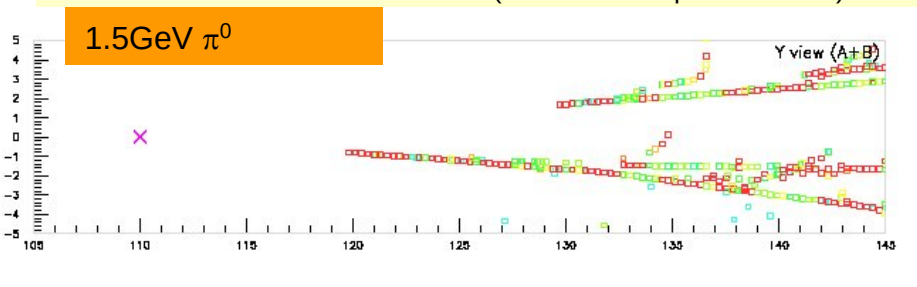
 Baseline Beyond baseline

Physics Capability

- ν_e appearance at **Superbeams**: π^0 NC background reduced to per-mil retaining 90% of signal

(FLARE LOI hep-ex/0408121)

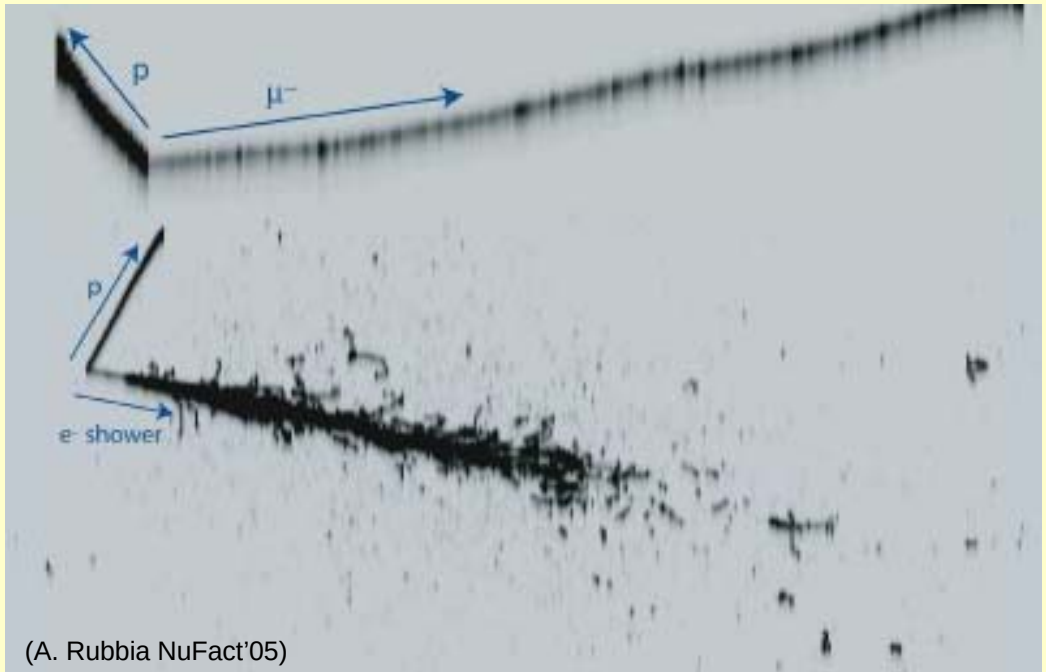




Neutrino Factories:

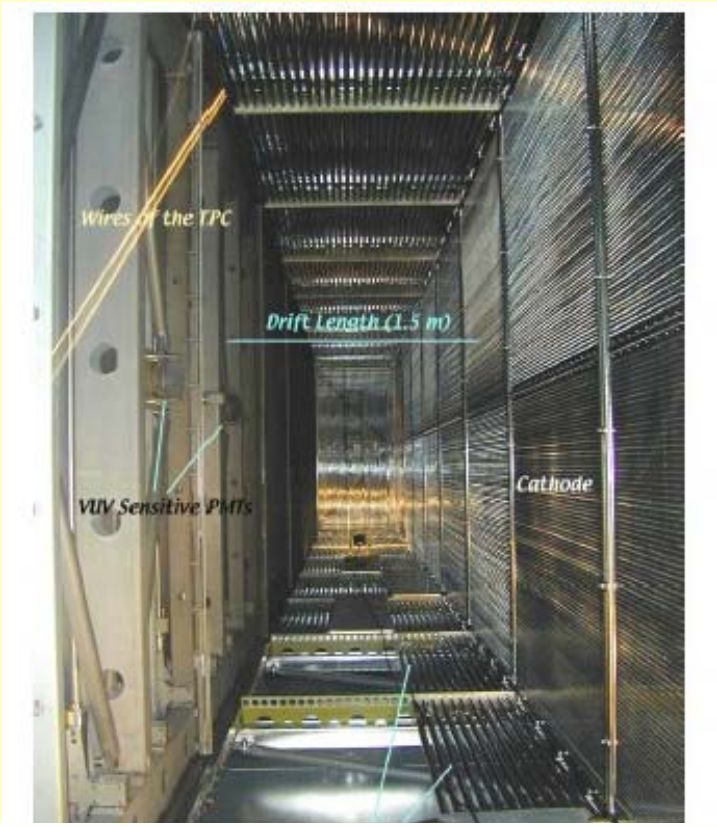
•electron+ muon ID and charge recon.(B-field!) -> well suited to detection of wrong-sign (Golden) muons from (ν_e-ν_μ) oscillations and `platinum' (ν_μ–ν_e) channels

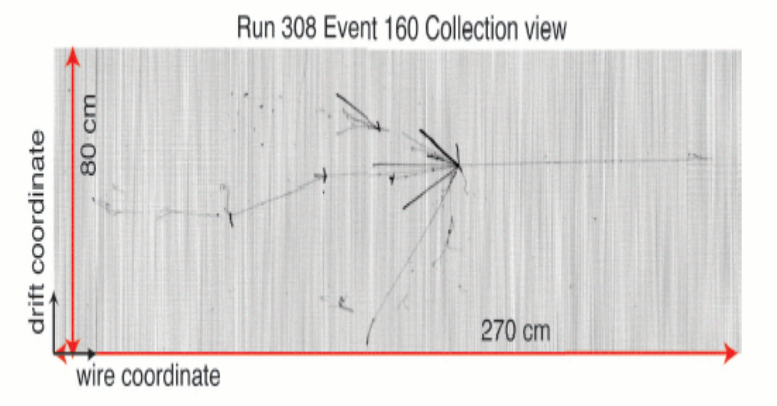
•tau recon. (ICARUS) gives sensitivity to `silver' (ν_e -ν_τ) oscil. channels



(A. Rubbia NuFact'05)

ICARUS

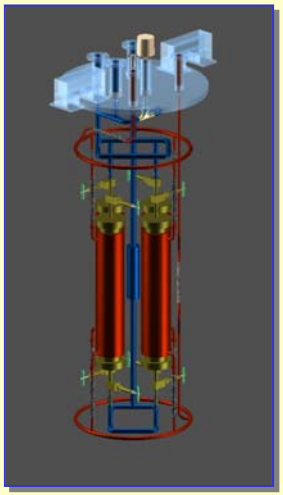




- **Long term R&D project / LAr TPC with wire plane readout (few mm pitch)**
- **T600 (600 ton) module taking data in CNGS beam this year**
- **Developed solutions to many issues: purity,low-noise pre-amplification etc**
- **Proven principle of large volume LAr TPC**

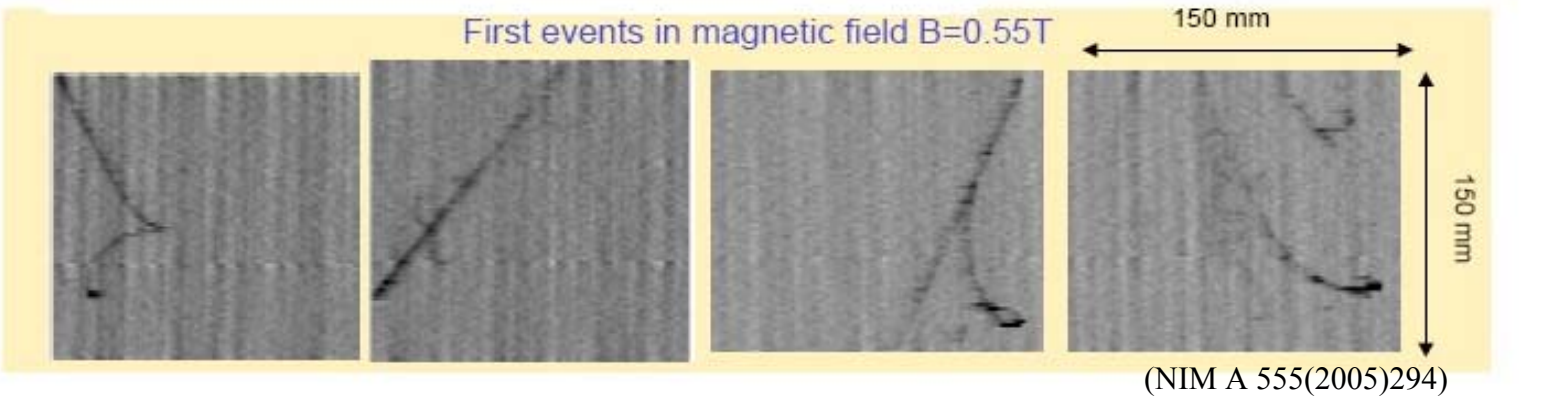
Promising Developments

T600 Purification Unit



- Chemical filters (Oxysorb™) routinely achieve contamination levels <0.1ppb (O_2-equiv.)
- Developments to purification system (e.g. new Sheffield/Technodyne cyrogenic pump, operation all in liquid phase)

- (A. Rubbia group) first events taken in B-field (0.55T) parallel to 15cm drift
- Working towards large-scale magnetisation –> solenoid in liquid volume (perhaps superconducting)



(NIM A 555(2005)294)

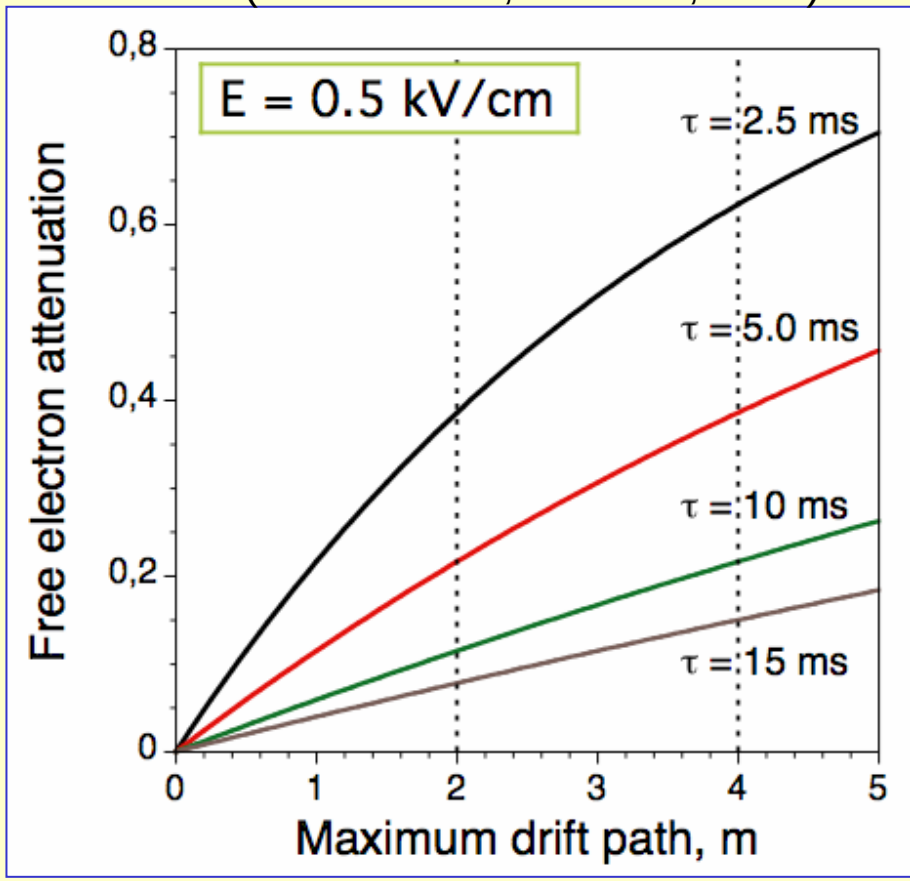
How do we scale up this technology to 10-100kt ?

Charge Drift Region

(C. Montanari, Criodet2, 2007)

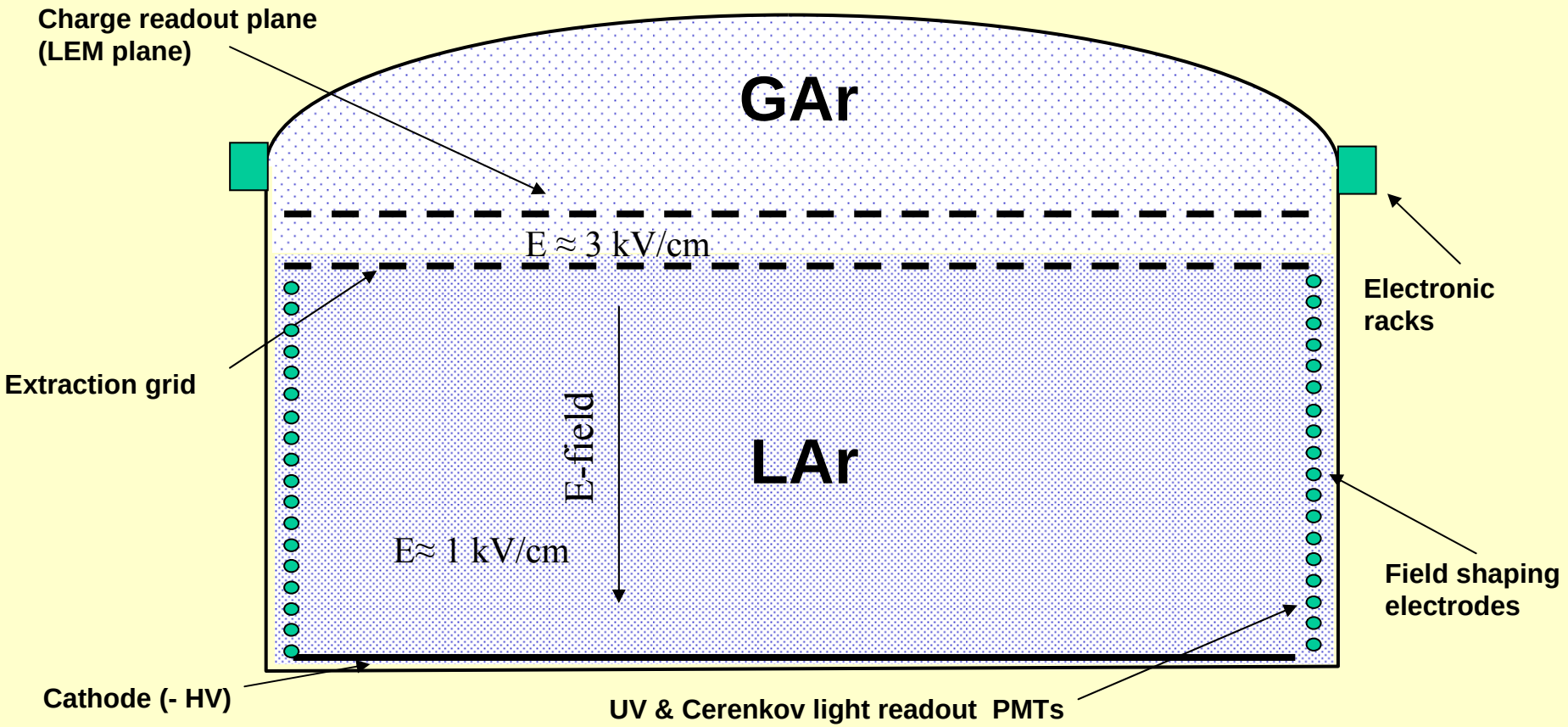
- Current best results (ICARUS and others) suggests that free electron lifetimes in access of 10ms are achievable

- This limits max. drift paths to e.g. 4m(about 28 X_0) if charge losses of >20% are not to occur



The GLACIER Approach

100kt detector, 70m diameter LNG tank, 20m max. drift



The GLACIER Approach

- Drift distances up to 20m means electron attenuation up to a factor 150 (hep-ph/1422)

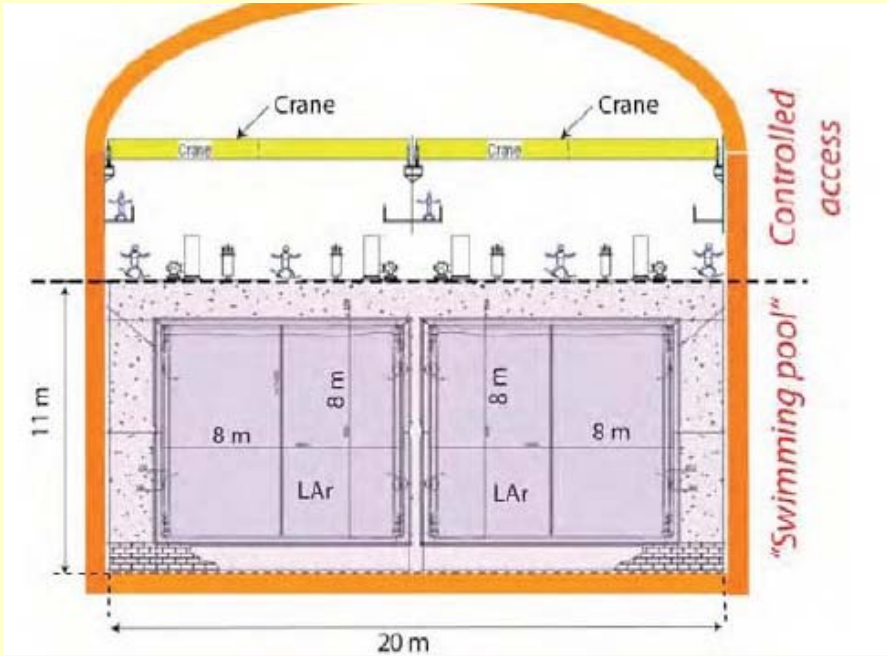
-> 2-phase operation (liquid+gas) with readout in gas at gain of 10^3

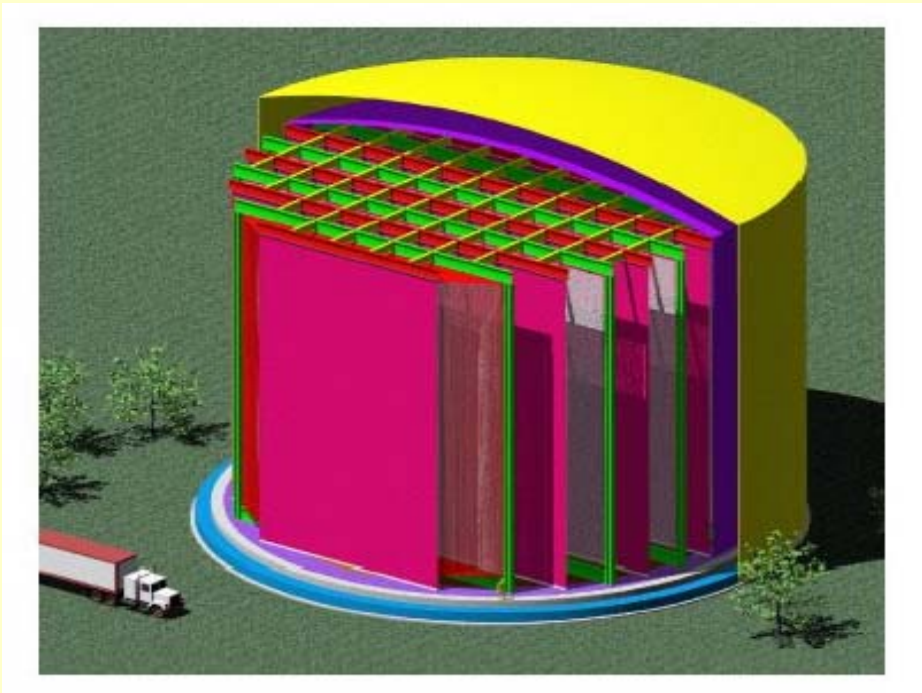
- WARP/XENON shown that free electrons cross gas-liquid interface (for E=few kV/cm) but hint that ion build up distort/trap charge at interface

-> likely to be problem on GLACIER scales (await results of ARGONTUBE)

MODULAr/FLARE Approach

- Proposal for CNGS beam
- Based on T300 module
- 10kt and 4m max. drift distance





- Proposal for NUMI beam
- Segmented LNG tank volume restricts drift to <3m

Sheffield/Warwick Approach

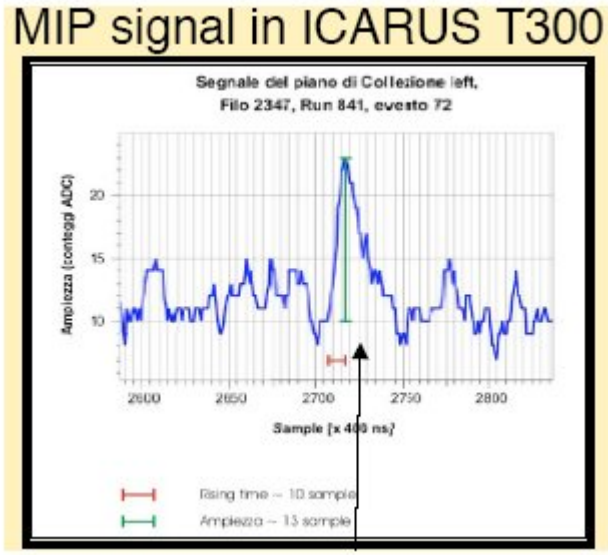
Take best aspects of existing R+D as start point for large scale, practical, detector design

- Single phase (liquid) operation (extensive experience in Sheffield)
- Modular approach – relatively short drift distances, low electron diffusion, fast readout, high purity and uniformity, low applied drift voltages, convenient/practical for production, safety against large leaks etc…
- Charge collection by TGEMS not wires (some experience in Warwick)
- Charge vs light readout - develop further schemes to image UV emission (SPM experience from T2K)
- Costs loaded towards per channel readout costs – develop in-house solutions at Warwick

GEM's Not Wires

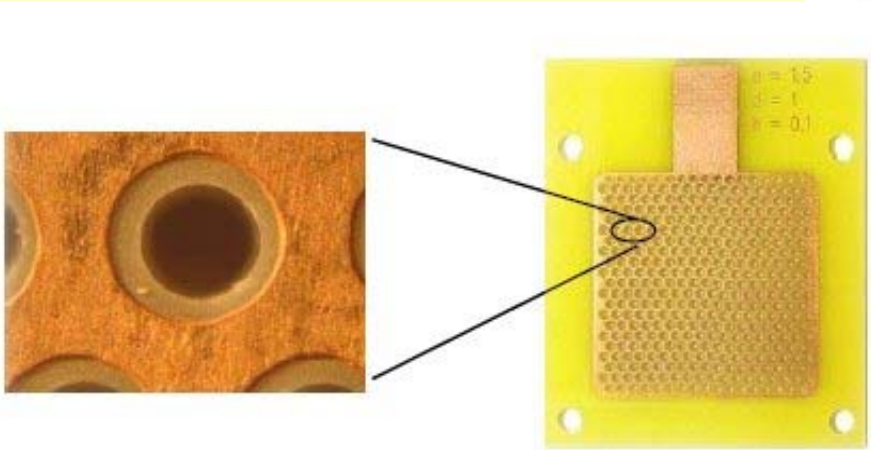
ICARUS-style wire readout:

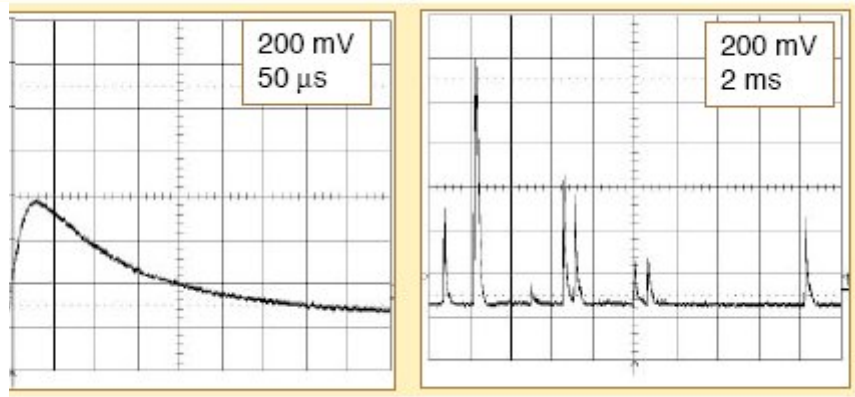
- Noisy – m.i.p. in T300 already poor
- Noise will scale with length as capacitive noise increases
- Wire breaks could wipe out large portions of detector



TGEM's provide proven alternative:

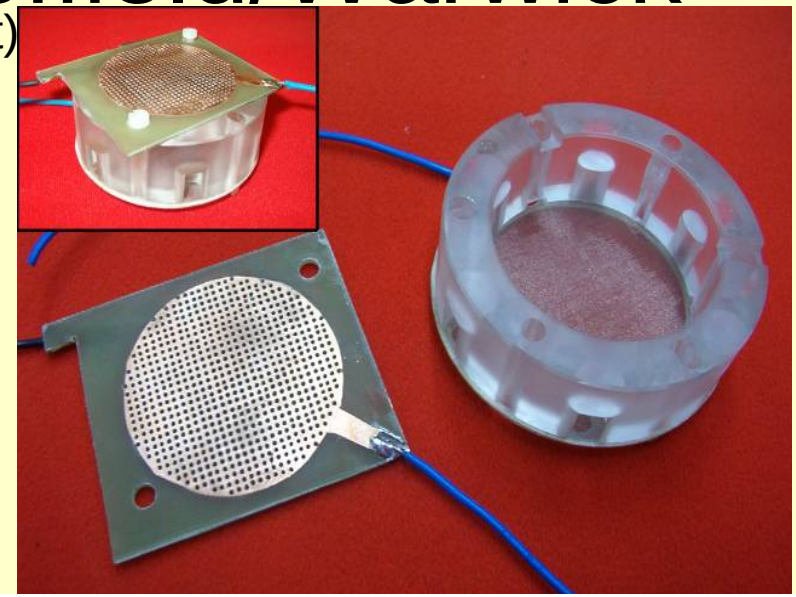
(Rubbia, CHIPP Workshop'06)



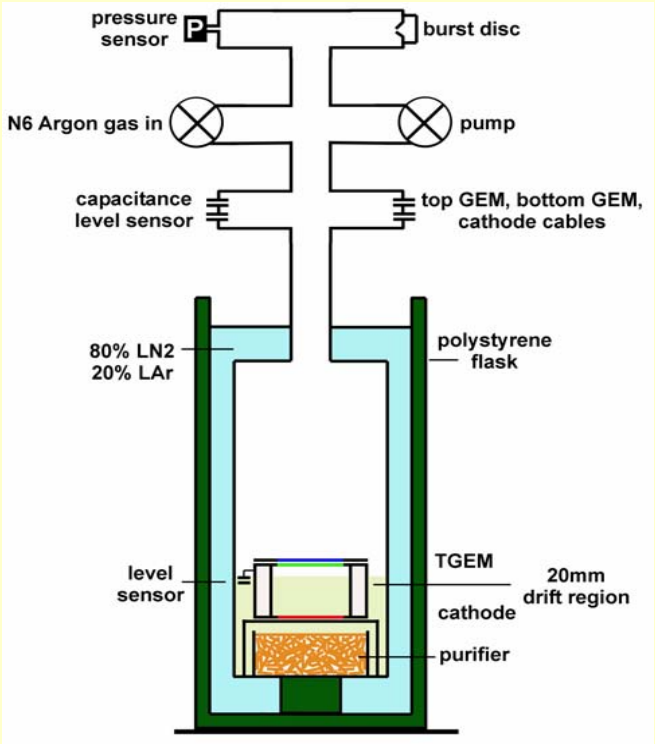


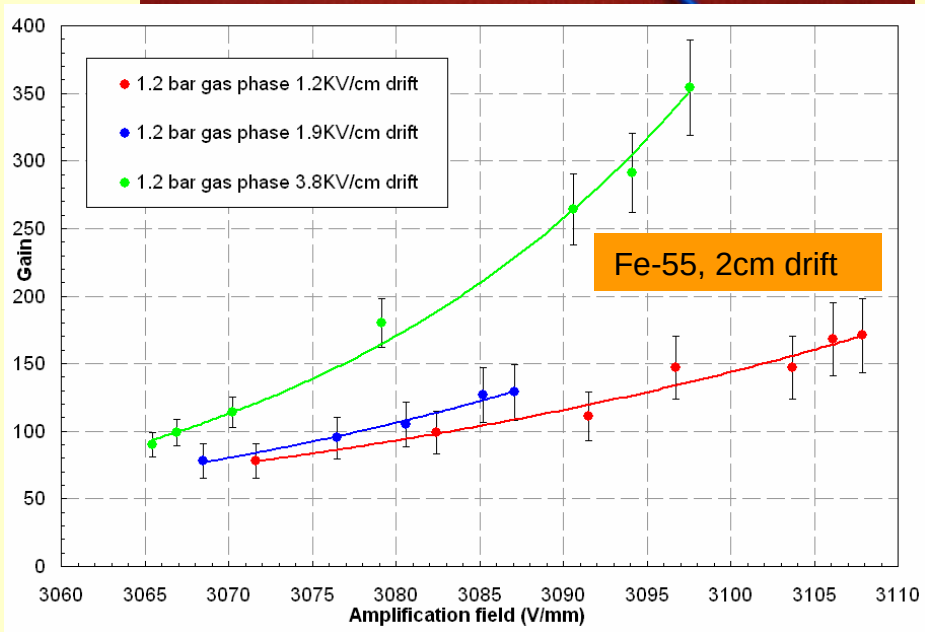
TGEM Studies Sheffield/Warwick

(Results from P. Lightfoot)



- Results in gas confirm gain reported elsewhere

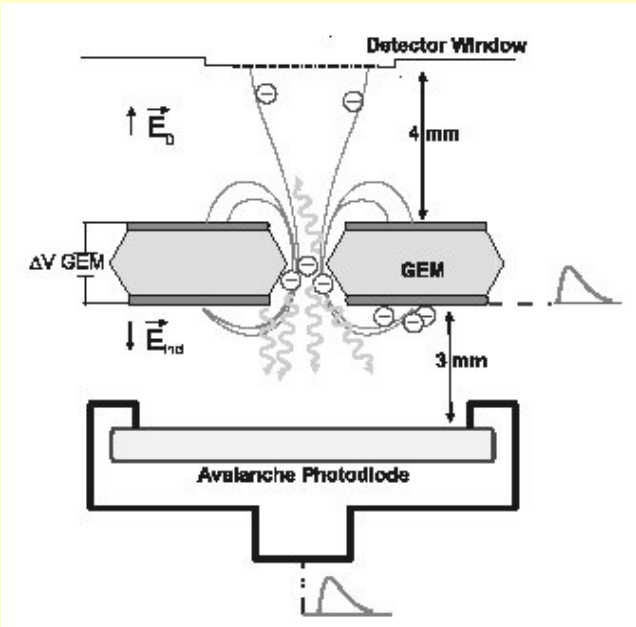




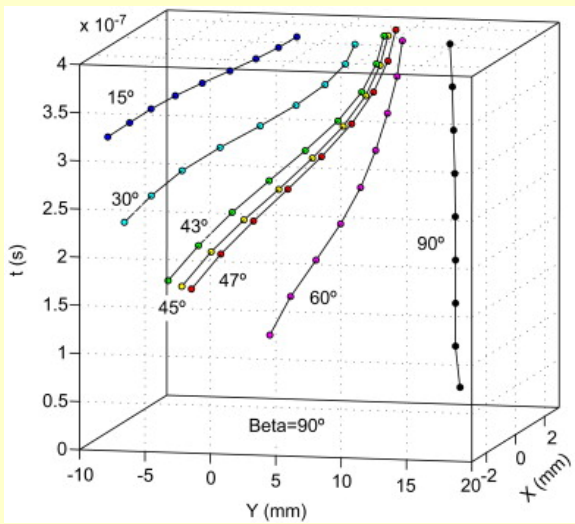
- Gain seen in gas phase above liquid and studies underway to see gain in LAr
- Large gains not needed with m.i.p. depositing 10^5 charges per cm

GEM Electroluminescence Light

- ELum. light originating from within the GEM holes has huge potential: of order 10^2 photons/primary e, fast signal, de-coupled from electronic noise/pick-up/HV



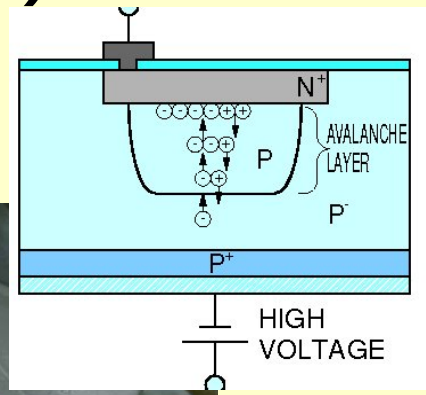
- No one really looking at ELum. light in LAr: Coimbra Group recently reported alpha track reconstruction in Ar gas with PMT's mounted below GEM plane (NIM A 581(2007)) and large gains(10^4) from APD's below GEM foils (2007 JINST 2 P09010)

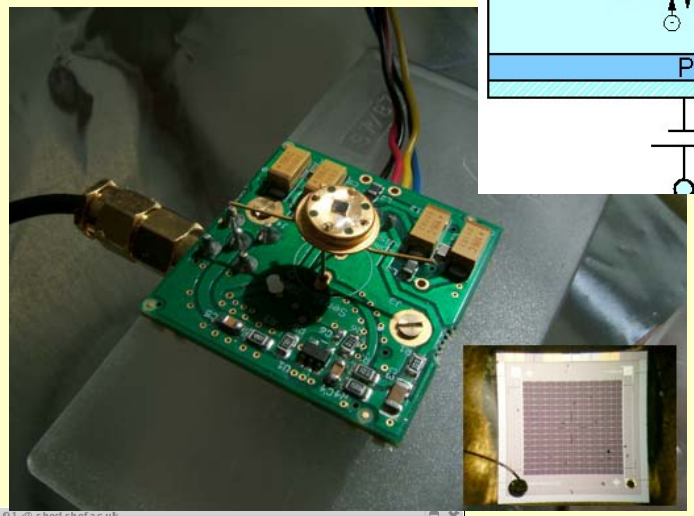


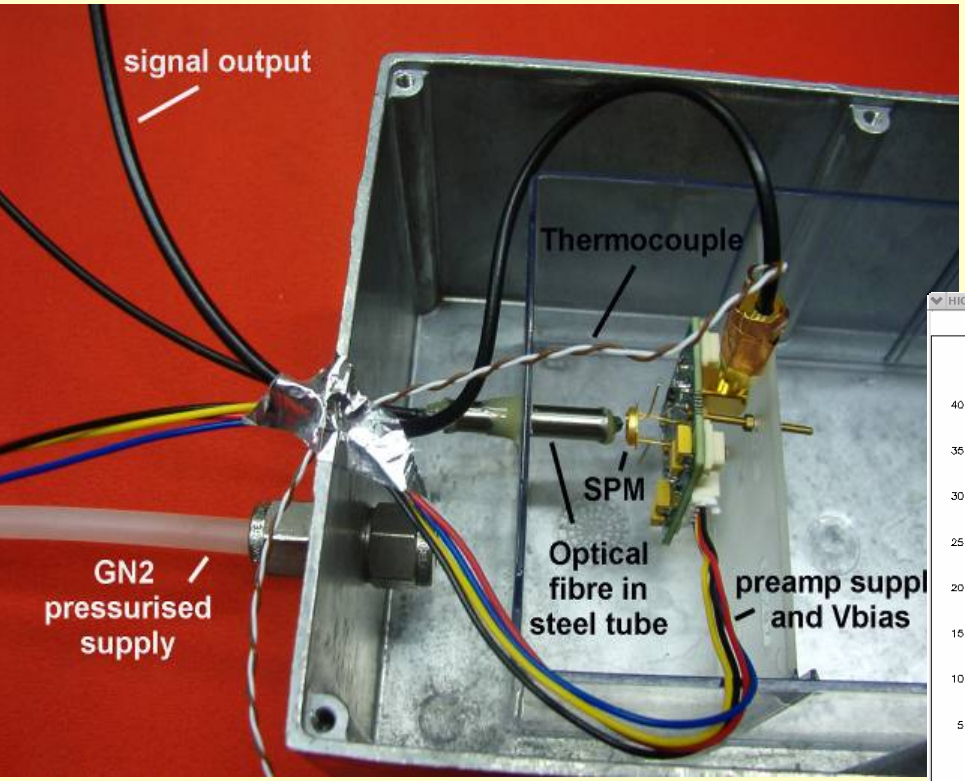
- Opens possibility of applying our experience in LAr+TGEM+SPM's to image TGEM plane using a gridwork of SPM's- first studies already underway in Sheffield

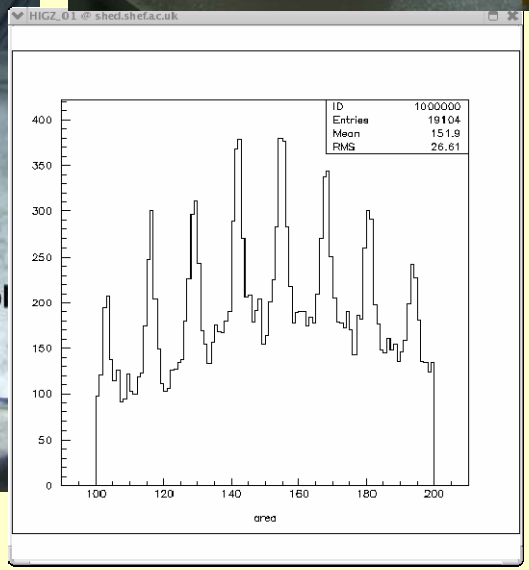
Silicon Photomultipliers(SPM) in LAr

- Avalanche photodiodes running in `Geiger mode'
- SPM's +amplifier test modules from SensL



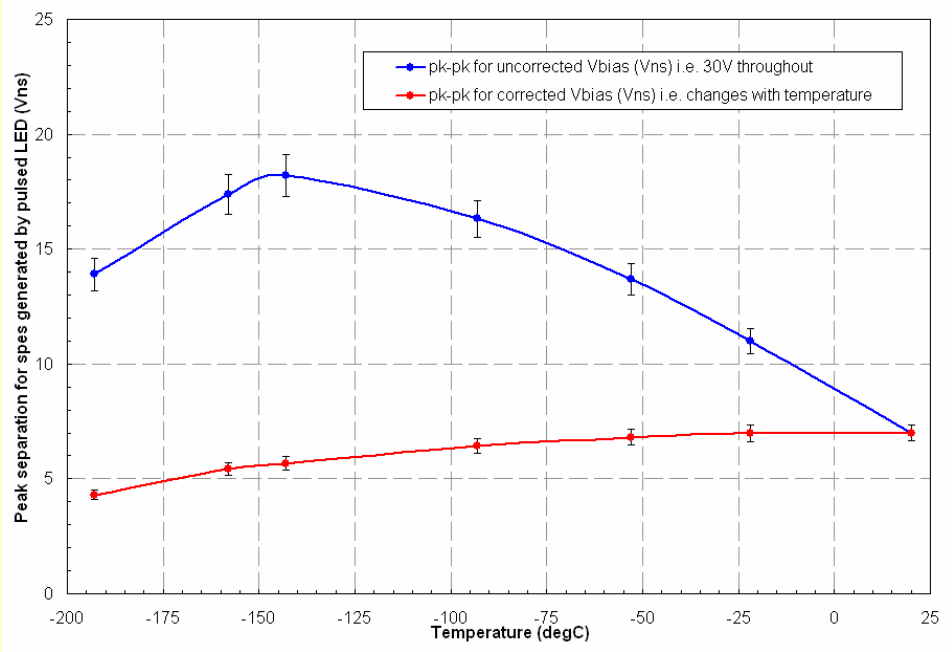




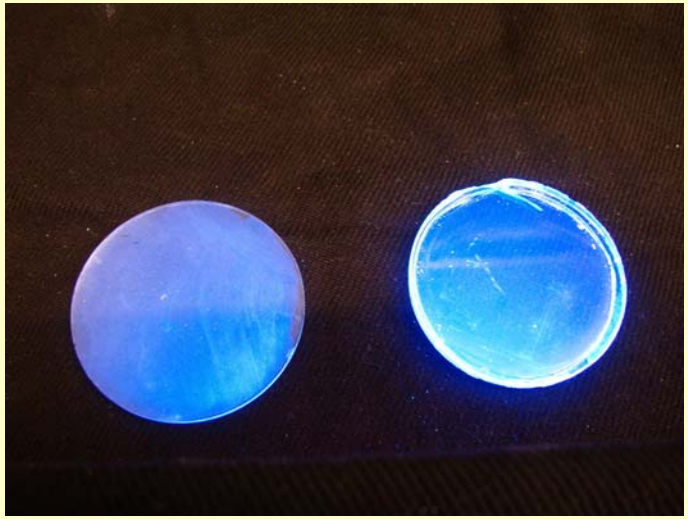


- Shown to function in liquid nitrogen at T= -197C ! (P.Lightfoot)

SPM's in LAr



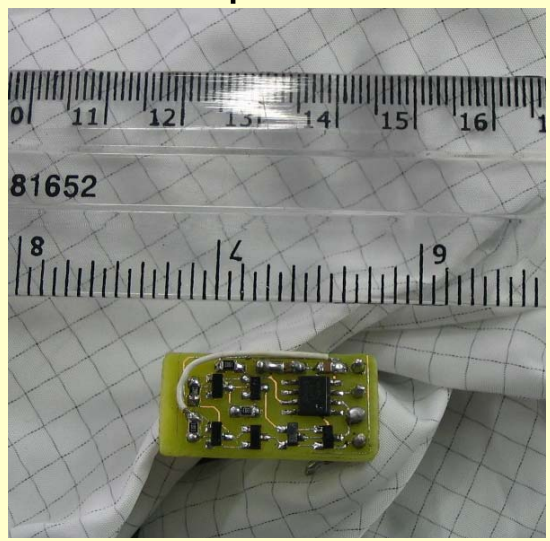
- Gain measured to be 2×10^6 at T=20C
- Drops to 61% of max. at T= -193C
- Working with SensL to understand cyrogenic functionality
- Currently setting up to detect ELum. light at 128nm
- Prelim. detection of ELum. light in Ar gas (Sheffield) using wavelength shifting coating TPB (128 – 440nm)



Readout

- Recent estimates: Euro 60 `wire to computer' MODULAr (arXiv:0704.1422) ; Euro 50/channel ArDM (A. Rubbia,CHIPP'06)
- Expected to dominate total cost of large-scale LAr expt.

- Warwick investigating new multi-channel readout vendors as well as developing in-house (preamp+digitiser) modules for operation in liquid: aim for per channel costs < pounds 20/channel.



- Sparse readout of large areas by SPM's under study ($10-20 now, in 10 years ?) or direct light-to-digital devices (e.g. SensL) may well be cheaper still

Next Steps

- Sheffield and Warwick groups are planning a R&D programme for next 2-3 years aimed at constructing a 1m x 1m prototype module (25cm drift) that will test many of our ideas on LAr volumes, TGEM's, charge/light detection and readout
- We are inviting closer collaboration with other interested parties in the UK - already a nucleus of interest from within the UK T2K community where there is an obvious synergy with the proposed T2K 2km detector
- Next meeting will be in Sheffield next week