UK Liquid Argon Status Report

Phil Lightfoot, Kostas Mavrokoridis, Neil Spooner
(University of Sheffield)
Gary Barker, Yorck Ramachers
(University of Warwick)
Introduction

– The use of liquid argon for calorimetry and more recently for 3-D imaging with bubble-chamber precision is now a mature technology
– Next generation LAr neutrino detectors – vigorous programmes 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 Detector

Charged particle traversing LAr:

- Ionisation: $W_e = 23.6$ eV, 6000 electrons/mm for a m.i.p.
- Scintillation: $W_\gamma = 19.5$ eV, UV line at $\lambda = 128$nm or 9.7 eV $\rightarrow$ 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 $\sigma_E/E = 10\%$ or better.

(A. Rubbia NuFact'05)
Sheffield/Warwick Strategy

Pick the best from existing concepts for each detector element

(1) Condensed detection medium
(2) Modular detection volumes
(3) Robust = Amplified signal operation
(4) Affordable read-out electronics

Concept for a homogeneous tracking calorimeter based on Liquid (or Solid) Argon using planar, optical tracking read-out
Concept and Status

Module Concept

(1) LAr drift volume

(2) Amplifier TGEM

(3) Tracking signal optical readout: SiPM-array
Concept and Status 2

(1) Argon volume:
   (a) Operation in condensed Argon = Homogeneity
   (b) Trigger and calorimetry from plain Argon volume scintillation
   (c) Purity requirements down = cost down → shorter drift distance
   (d) Shorter drift = more readout-planes = higher cost
   (e) Compromise on the order of one to a few meter – Find out!

Need to build a prototype – funding required!
(2) and (3): Optical read-out with Amplification in Liquid: New Technique using known elements!

(3) SiPM operation at 77K in liquid demonstrated extensively: P.K. Lightfoot et al., accepted for publ. in JINST 2008

(2) TGEM amplification with SiPM read-out in liquid demonstrated in detail (from gas to liquid): P.K. Lightfoot et al., to be submitted soon
Gallery

LAr setup at Sheffield
LAr test cell at Sheffield
SenSL SiPM example

Dark count rate with temperature

Gain as function of SiPM bias
Gallery

TGEM: drilled holes in standard PCB – simple, reproducible, cheap

Sheffield TGEM

Warwick TGEM

Many variations possible and available in hole diam./pitch/thickness
Charge gain from the cold gas phase of a double phase argon system

Charge gain spectrum from Fe-55

Charge gain versus drift field

Charge gain generated from a TGEM at a constant 2.5KV/cm drift field
Electroluminescence from the cold gas phase of a double phase argon system

Secondary scintillation spectrum from Fe-55

Secondary scintillation versus drift field

Secondary scintillation generated within a TGEM at a constant 2.5KV/cm drift field
Electroluminescence from liquid argon

Secondary scintillation spectrum from Fe-55

Secondary scintillation generated within a TGEM at a constant 2.5KV/cm drift field
Read-out Challenges

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

Baseline concept:
- SiPM array 20x20 as imaging 'camera' per m²
- Strip-readout = 20+20 channels
- Target Cost: less than 20 pounds/channel readout
- SiPM low-cost elements now, in 10 years even less

Baseline Concept is work in progress:
- Tested successfully circuit design for cold FE-electronics
- Current cost £4/channel + cost for central fast digital readout
- System-tests pending (4x4 array in LAr next)
Conclusion

➔ New technology for large volume LAr detector development demonstrated

➔ Particle tracker concept in Liquid Argon with optical readout shown in 2 recent publications

➔ High S/N ratio and O(mm) spatial resolution expected with optimised prototype (TGEM, SiPM array, readout, etc)

➔ Scalable, robust and affordable technology

➔ Work in progress: Monte-Carlo, FE-readout

➔ Of interest for NF/T2K detector efforts but need funding for a prototype – Work in progress!
Signal Challenge

Long signal tracks mixed with detailed short track structures

'Typical' $\nu_\mu$ event (15 GeV) in LAr

B. Morgan (Warwick), M. Robinson (Sheffield): Full Geant4 sim for LAr detector working
Signal Challenge 2

How to make the most of it?

Requirements:
• spatial resolution order mm for high PID efficiency (Rare events)
• Large detection volume for track containment, calorimetry, event rate
• Affordability???