R&D for Detectors

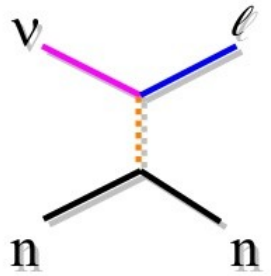
Gary Barker

University of Warwick

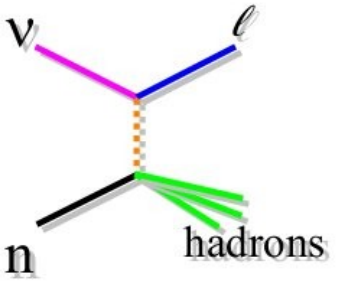
Thanks to: M. Ellis, P. Kyberd, P. Lightfoot, P.Soler, N. Spooner

What's Needed (Physics)?

Regardless of facility (Superbeam, beta-beam or Neutrino Factory) the ideal detector would reconstruct all oscillation channels:



- $\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_\mu$; $\overset{(-)}{\nu}_e \to \overset{(-)}{\nu}_e$ disappearance
- $\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_e$; $\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_\tau$ appearance
- $\overset{(-)}{\nu}_e \to \overset{(-)}{\nu}_\mu$ appearance (Golden channel)
- $\overset{(-)}{\nu}_e \to \overset{(-)}{\nu}_\tau$ appearance (Silver channel)

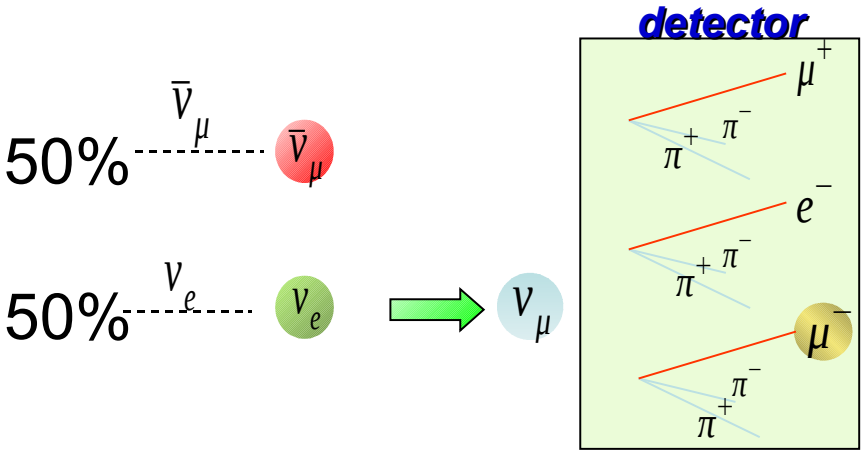


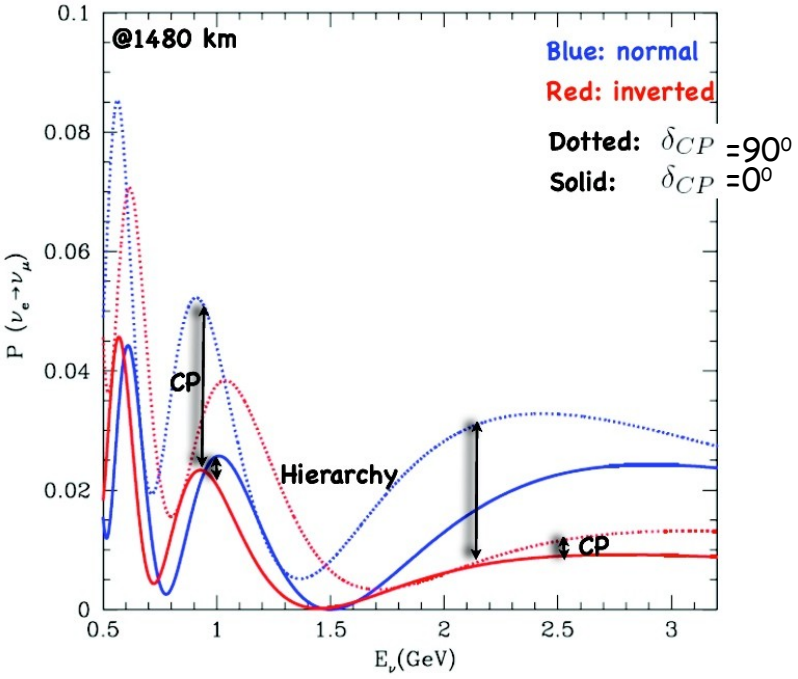
Will probably also need to be multipurpose e.g.

- Proton decay ($p \to e^+ + \pi^0$; $p \to K^+ + \nu$)
- Supernova neutrinos

What's Needed (Detector)?

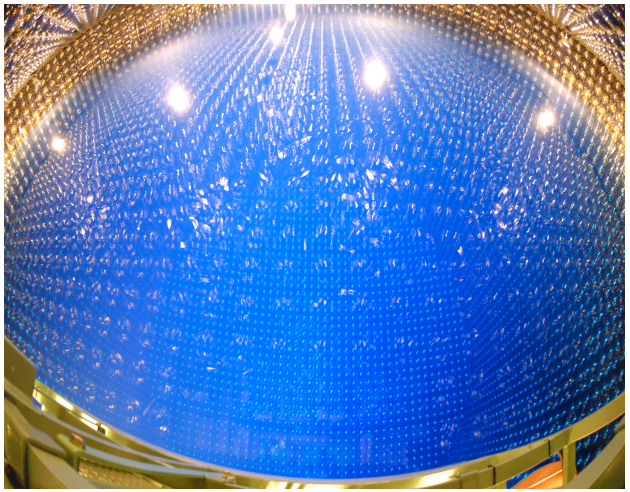
- Massive for rates (>10kt)
- Able to reconstruct muons and electrons
- Reconstruct lepton charge (e.g. `wrong-sign' muons in Golden channel)
- Identify tau decay topologies
- Excellent E-resolution, low thresholds
- Possibly magnetised (at least for a neutrino factory)
- Affordable i.e. simple and scalable
- Probably underground (engineering issues)



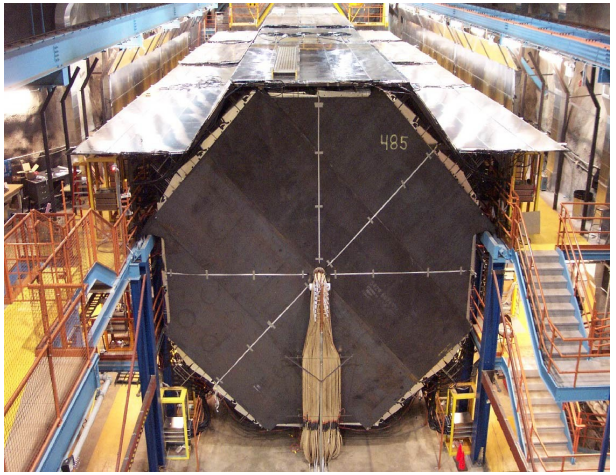


Realistic Options

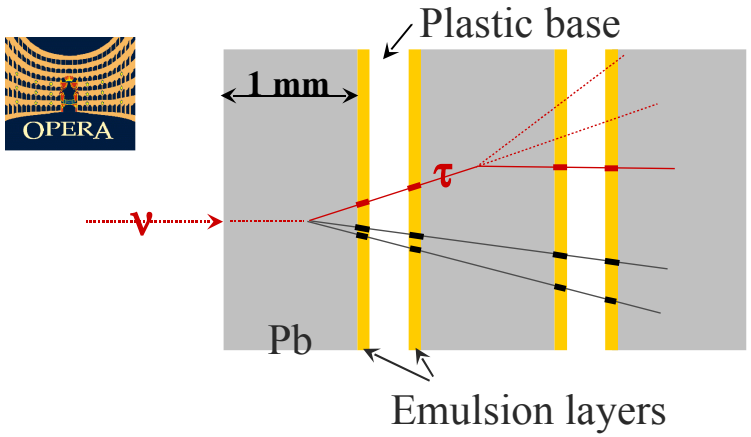
- **Water Cherenkov**



- **Tracking Calorimeter**



- **Emulsion?**



- **Liquid argon TPC**

EU projects

- **EUROnu(FP7 design study for neutrino oscillation facility in Europe):**
  - Simulation studies: MIND (Neutrino Factory), Water Cherenkov detector (for Super-Beam and Beta Beam) and Near Detector (all facilities).
  - Glasgow(MIND studies and Near Detector studies)
  - No detector R&D funded
- **LAGUNA(FP7 design study for large proton decay + neutrino astrophysics):**
  - Studies: large underground chambers for Liquid Argon or Water Cherenkov detectors
  - Sheffield(Site evaluation) and Durham(Physics)+Technodyne Ltd(UK)
  - No detector R&D funded
- **DevDet(Euro Integrating Activity Project):**
  - **New** bid to be submitted end of 2009 targeted at test beam infrastructure at CERN for detector prototyping

Water Cherenkov

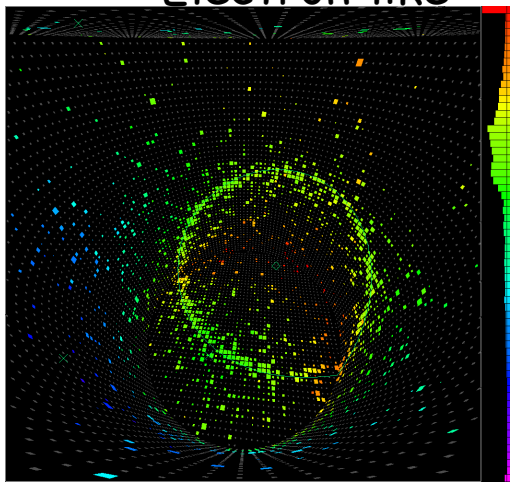
For:

- Proven technology
- Excellent e-muon separation

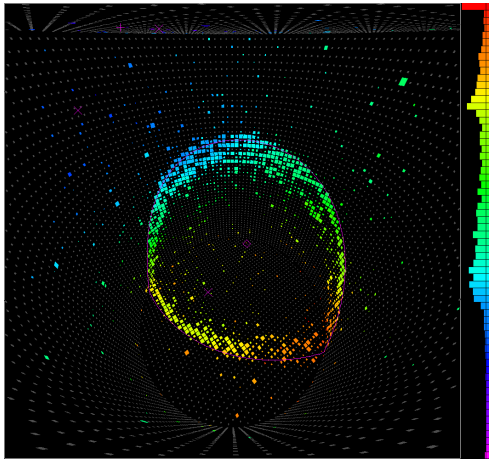
Against:

- Only a low E_ν option(0.2-1GeV)
- How to magnetise?
- Relatively poor E_ν resolution
- Rates too high for use as Near Det.
- 1mT is costly(0.5-1GEuro?)
- **Kaons below Cherenkov threshold in p->K^+ + ν**

Electron-like



Muon-like

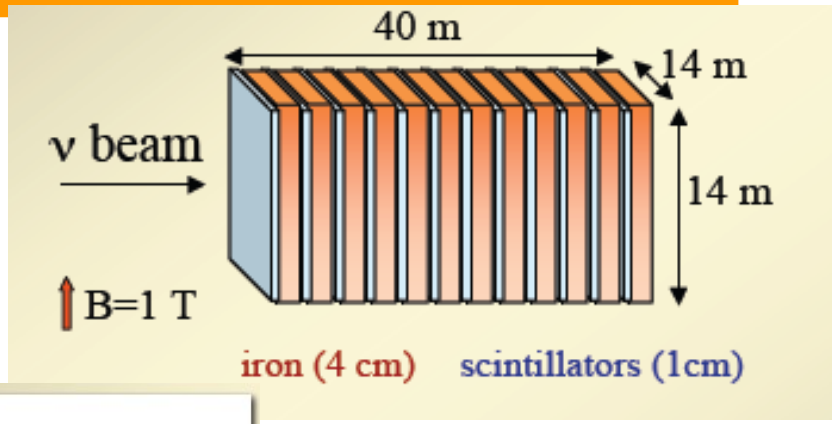


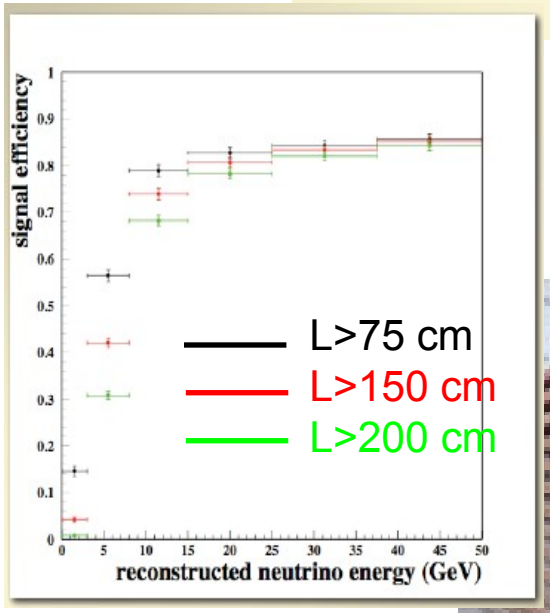
Magnetised Iron Neutrino Detector: MIND

- Iron-scintillator sandwich (like 9x MINOS)
- Simulation/reconstruction effort – Glasgow(Soler et al.) in collab. with Valencia group
- Links with Indian Neutrino Oservatory(INO),American and European colleagues

For: relatively little R&D

Against: Detector optimised for golden channel at high-E neutrino factory only (relatively high thresholds, no electron ID)





Totally Active Scintillator Detector:TASD

- Like a larger Nova/Minerva
- Brunel in UK (Ellis, Kyberd et al.):

-simulation/reconstruction studies

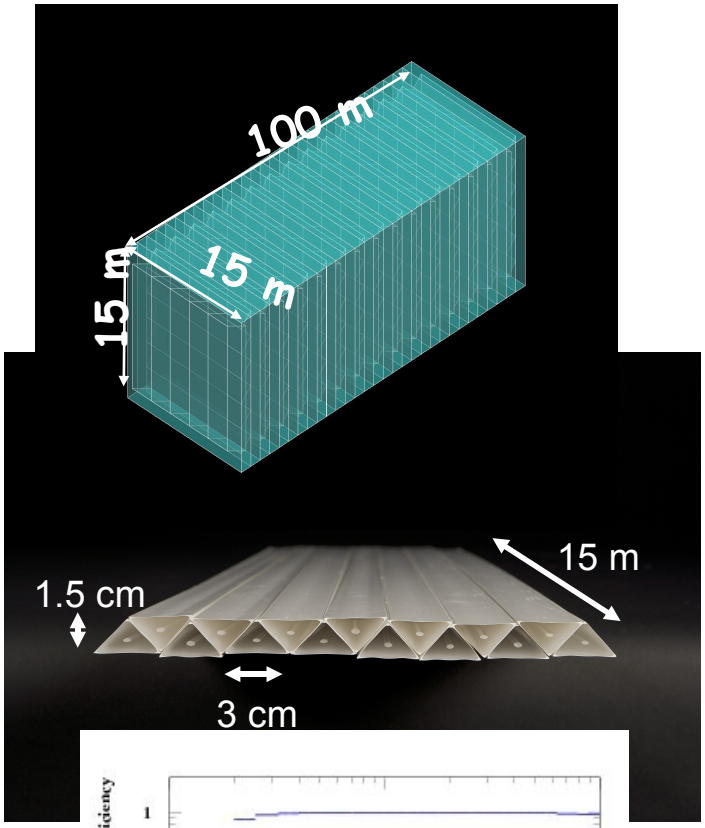
-supply scintillator coextruded with fibre via Wolfson Centre for Materials Processing

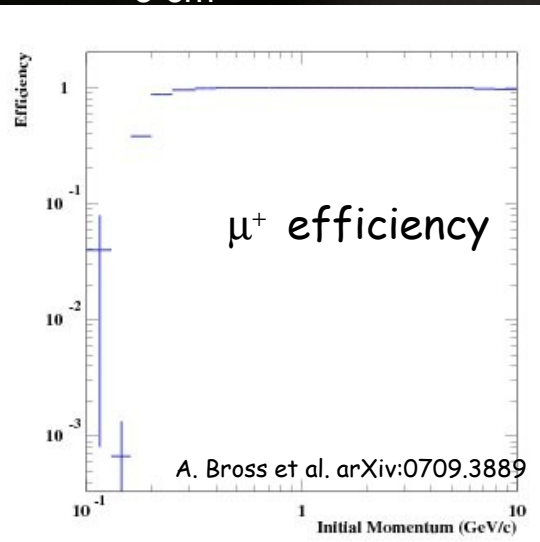
For:

- Tried and trusted
- Few mm transverse spatial resolution
- Relatively low thresholds (100MeV)

Against:

- Large number of channels -> cost
- Magnetise?
- R&D needed to prove coextrusion/light levels
- Event reconstruction can get complicated – must match 2D measurement planes





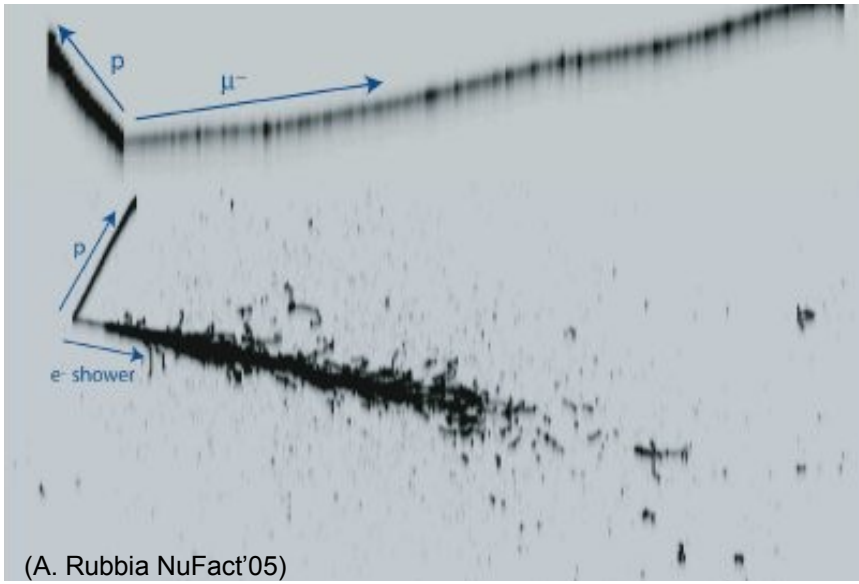
Liquid Argon TPC's

For:

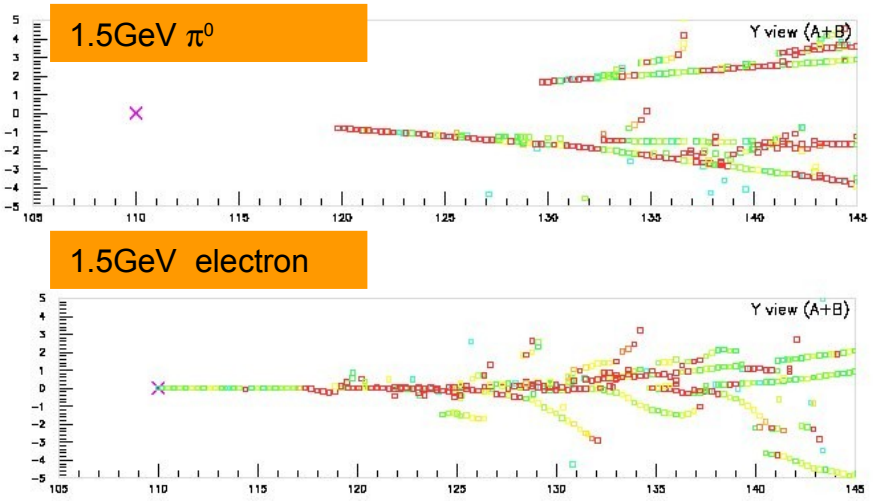
- Multipurpose + will deliver oscilln. program at Superbeam and NF
- True 3D imaging with pixel size~(x,y,z)=(3mmx3mmx0.3mm)
- High granularity dE/dx sampling - e/γ separation >90% (π^0 background to electrons negligible)
- Total absorption cal σ_E/E <10%
- Low energy threshold (few 10'sMeV)
- Continuously live
- Q and scintillation light readout

Against:

- R&D needed:scalability,engineering,purity,
- B-field?



(A. Rubbia NuFact'05)

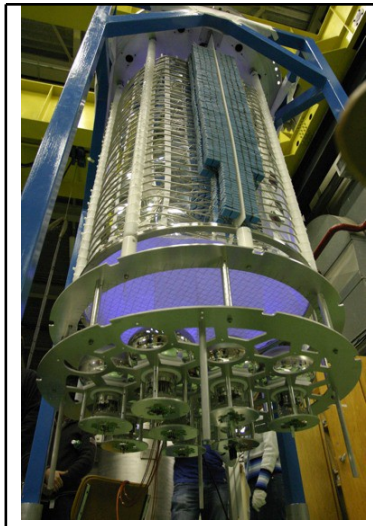


(FLARE LOI hep-ex/0408121)

LAr: Current Activity

M.Dracos Taup09

- LAr TPC @Gran Sasso looking at CERN CNGS beam
- ~480T fiducial mass
- Vacuum leak testing
- T600 fill-up in Sept.'09

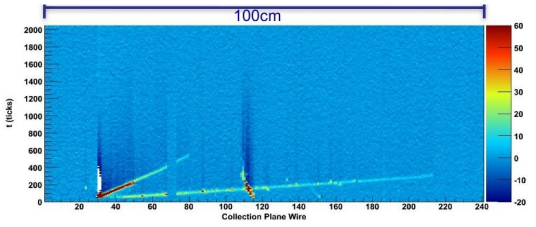


ArgonDM

- 1T LAr @CERN
- Readout: charge(TGEM in gas phase) and light (PMT's in base)
- Filled and seeing light (Sheffield PMTcoatings)
- Charge readout to start in Sept.'09

ArgoNeuT

- First LAr TPC in low E ν–beam
- 179L
- Running since May'09

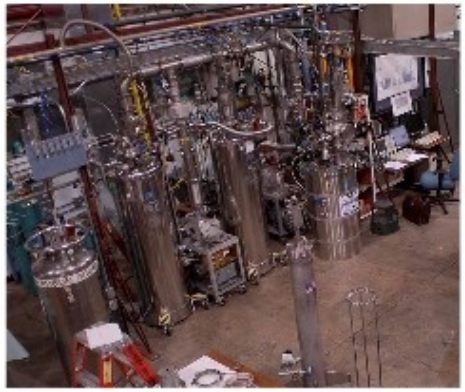


Spitz, Taup'09

- 5m long charge drift tests @CERN
- ArgonTube@BERN

LAr in the U.S.

Materials Test Stand



Bo

Rapid progress in LArTPC development

UCLA/Pisa Long-Drift Test at CERN

2007 100% R&D

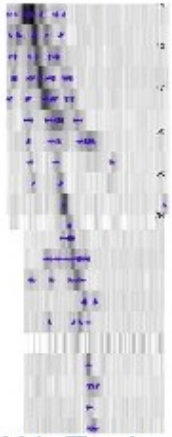
2007-

2008-

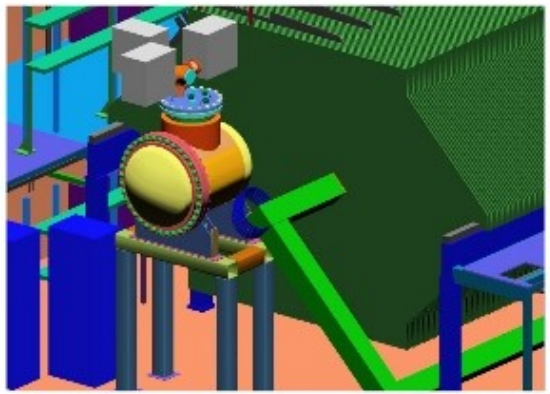
2011

100% Physics 201?

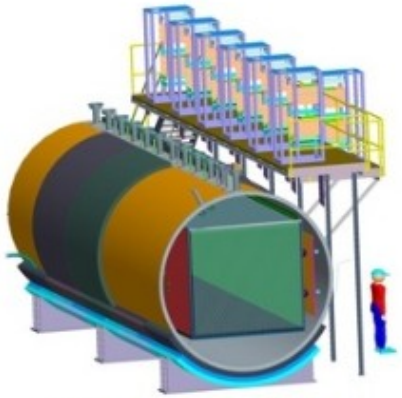
100 Kilotons



Yale Tracks



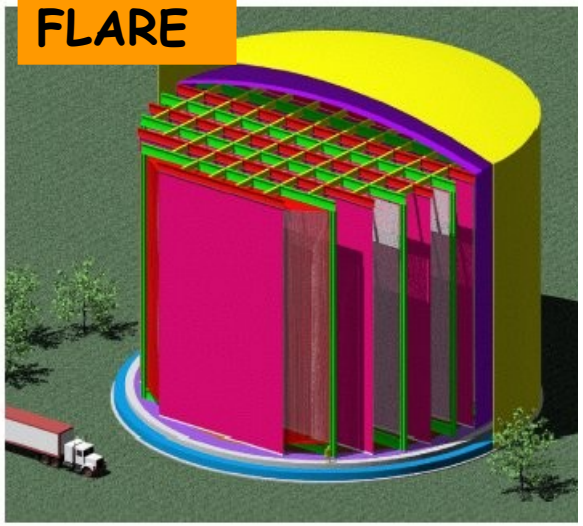
ArgoNeuT



MicroBooNE

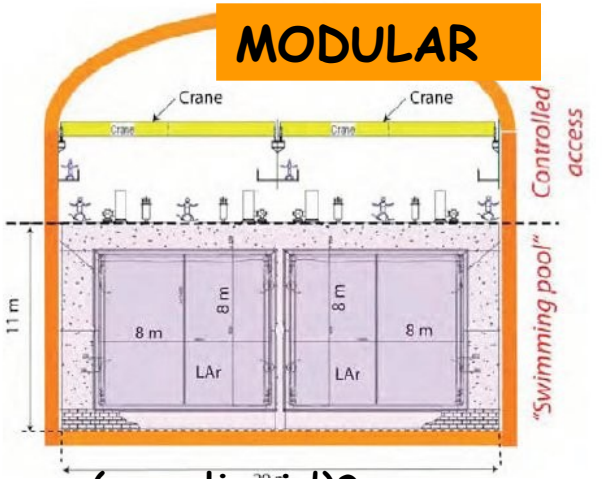
LAr Scalability: 100kT Concepts

FLARE



- **FNAL to DUSEL?**
- **CERN SPL to Frejus?**
- **JPARC to Somewhere**

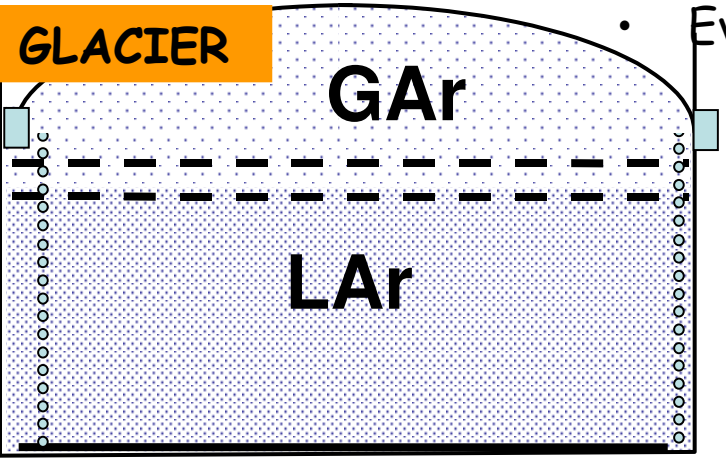
MODULAR



ISSUES:

- Single-phase (liquid) or 2-phase(gas+liquid)?
- Detect ionisation charge with/without amplification?
- Modular or single large volume
- Evacuable or non-evacuable dewar ….etc

GLACIER



LANNDD

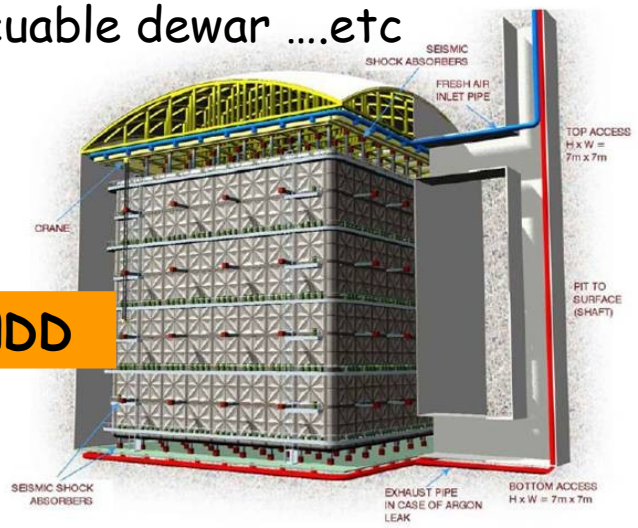


Figure 1. LANNDD in an underground cavern.

LAr: UK Activity

- Collaboration between Sheffield(Lightfoot,Spooner et al.) and Warwick(Barker,Ramachers et al.)- R&D focussed on LAr detectors scaling to large sizes:

-LAr test stands in both labs

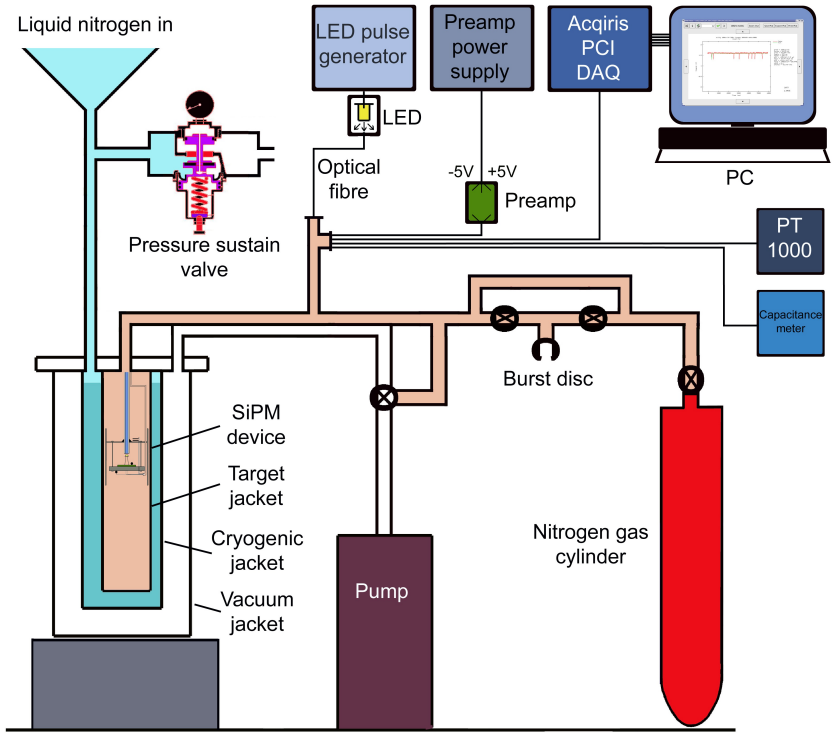
-Light readout over charge(JINST 3 P10001(2008); JINST 4 P04002(2009))

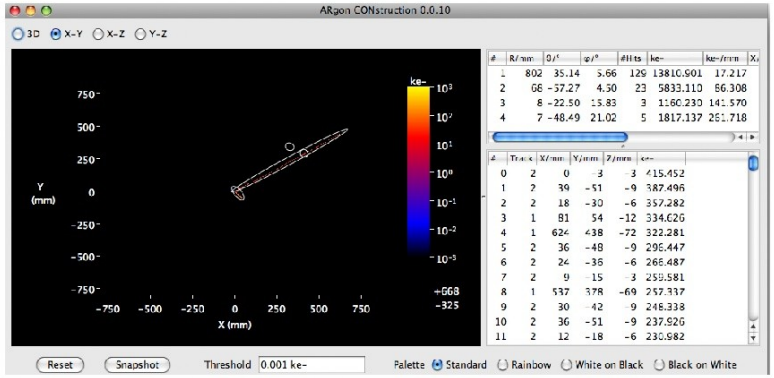
-Pipe-lined readout electronics

- Event simulation/reconstruction in LAr volumes(ETH,Sheffield,Warwick):

- Never before automated!

-GEANT4 simulation + recon. algorithm studies





Next Steps…….

MIND

- DevDet funding could bring MIND prototype kickstart hardware R&D (readout, photosensors etc)

TASD

- SOI to DUSEL imminent- Brunel group proposing coextruded scintillator+fibre

Liquid Argon TPC

- SOI recently reviewed by PPAN (JPARC upgrade: beam elements, LAr detector R&D with European collaborators) – proposal later this year
- Other R&D funding: LAGUNA? DevDet?
- Closer links with US effort?

University of Glasgow

Brunel UNIVERSITY WEST LONDON

THE UNIVERSITY OF WARWICK

Queen Mary University of London

The University Of Sheffield.

LANCASTER UNIVERSITY

UNIVERSITY OF LIVERPOOL

UNIVERSITY OF OXFORD

Imperial College London

Science & Technology Facilities Council

And Finally…..

- Quite some activity in UK on detectors even though funded by (as yet) modest EU funding or people's spare-time activities
- Areas of Interest in UK community reflected by targeted R&D activity that is already taking place (MIND, TASD and LAr)
- IDS/NF, JPARC upgrade, DUSEL timescale for technology choice is all around 2012/13 - now is time for R&D if any of the non-baseline options are going to be serious contenders (build period for a large detector is of order 5 years from 2013)
- Typical Resources:
  - Next 3 years for R&D and prototyping: few £M.
  - Full construction (excluding site or machine): few x £100M

  (of which perhaps the UK contribution might reasonably be 10%)