Detector open issues

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for the ISS-IDS detector working group

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Overview

- Introduction
- Far detectors
  - Tracking calorimeters
  - Emulsion detectors
  - Liquid Argon TPCs
  - Large Water Cherenkov detectors
- Hybrid detectors
- Near detectors
- Beam instrumentation
- Large magnetic volumes
- Priorities

Introduction

- A complete strategy is not yet designed
- Design a coherent hardware R&D program for the baseline detectors in order to understand the details. We should try to push their performance
- In parallel, R&D for other detectors (in general more challenging) is very important
- A lot of simulation studies are still missing. Each detector concept should understand:
  - Neutrino energy resolution
  - Lepton momentum and charge measurement
  - Quantitative study of detector efficiencies and backgrounds
- Hybrid detectors could be an interesting option
  - Useful thinking
  - Proof of principle with simulations

Tracking calorimeters

- Two options: MIND and TASD
- Conventional Nufact (20-50 GeV muons)
  - MIND: golden above ~2GeV
  - TASD: golden down to 0.5 GeV and may be platinum
- Low energy Nufact (~4.5 GeV muons):
  - TASD is the default option. Studies underway
- 1-5 GeV single flavoured beams:
  - A non magnetised TASD is an interesting option. No studies has been carried out yet
- Common points in detector technology
  - Scintillator, photodetectors and readout
  - Magnetic field: iron vs air-core

Common Technology

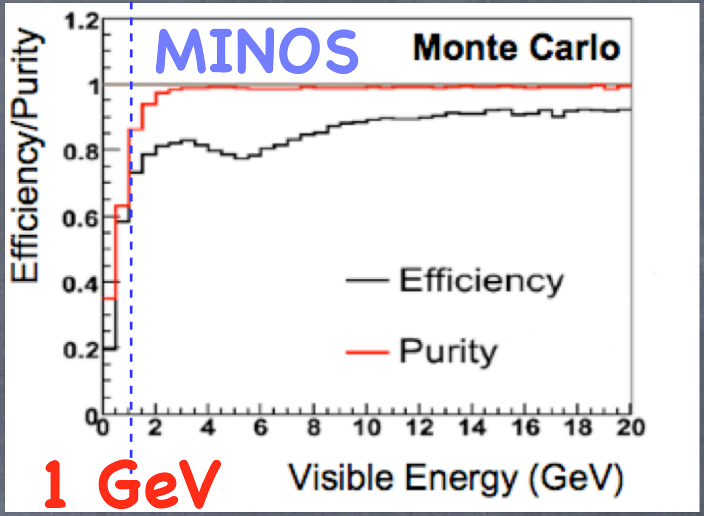
- R&D on extruded scintillator with optic fibre readout:
  - We need to measure attenuation of signal as a function of scintillator length
  - Optimisation of geometry of scintillator strips (square cross-section as in MINOS or triangular cross-section as in Minerva)

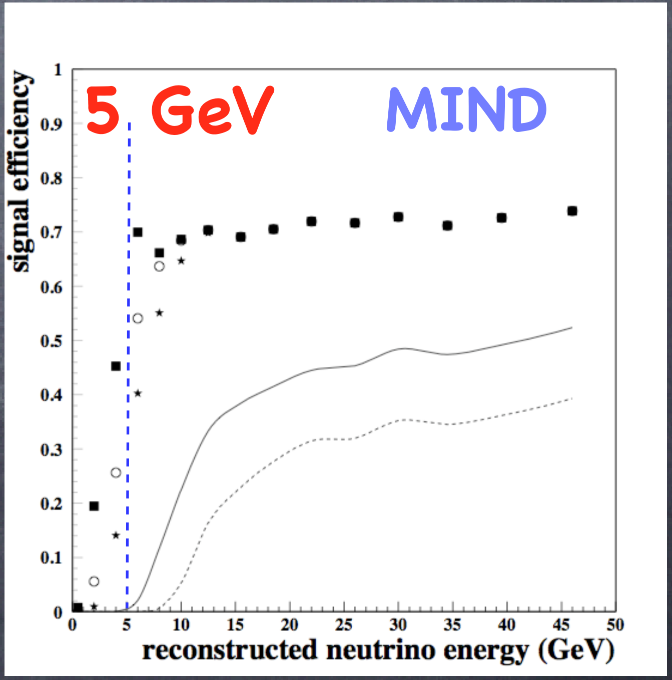
- R&D on photon detector technology (insensitive to magnetic fields),
  - Multi-Pixel Photon Counter (MPPC)
  - Silicon Photo-multiplier tubes (SiPM)
  - Avalanche Photo Diodes (APD)
  - or other technologies.

- Should we be considering RPCs for MIND, as in the INO proposal?
- Aim should be to be able to build a prototype to put in test beam.

MIND Simulations

- Crucial physics parameters:
  - Neutrino energy resolution
  - Threshold energy
  - Charge mis-id background
- MINOS studies suggest that the efficiency reaches a plateau at ~1 GeV
  - Probably due to efficient pattern recognition, QE and RES
- Charge misidentification is the main issue
  - Can we get higher fields (20% increase reduce bkg by one order of magnitude)
- TO DO: Full simulation and reconstruction
  - Effect of pattern recognition
  - Effect of QE and RES
  - Shower simulation and reconstruction





TASD simulations

- Main questions for conventional Nufact:
  - Is this detector suitable for Golden at high energies ?
    - Study background from hadron mis-id and decay
  - Is this detector suitable for platinum ?
    - Electron identification
    - Electron momentum resolution
    - Electron charge misidentification
- Simulation studies for few-GeV beams (including low-E Nufact)
- Simulation with neutrino event generator:
  - Angular resolution of the jet
  - Neutrino energy resolution
  - Signal efficiency and hadronic backgrounds

Prototypes

- Motivation:
  - Some aspects cannot be addressed with simulations:
    - Effect of non-Gaussian ms tails (crucial for MIND), showering profiles, pattern recognition, ...
  - Extremely important to keep motivation and get more people involved
- TASD prototyping
  - We need a magnet (HARP dipole ?)
  - Small prototype that fits into the magnet.
  - Electron showering profiles, electron charge identification, etc
- ~4x2x2 m prototype for MIND
  - 10-15 tons, less than 0.5 M€
  - charge misidentification for 1-5 GeV muons, energy resolution, showering profiles, etc
- Expose the detector to muons, pions, protons, kaons and electrons
- If possible, expose it also to neutrinos. Would be possible to use the CNGS beam ? After the hadron stop and before first muon station
- Results should be ready for ~2010

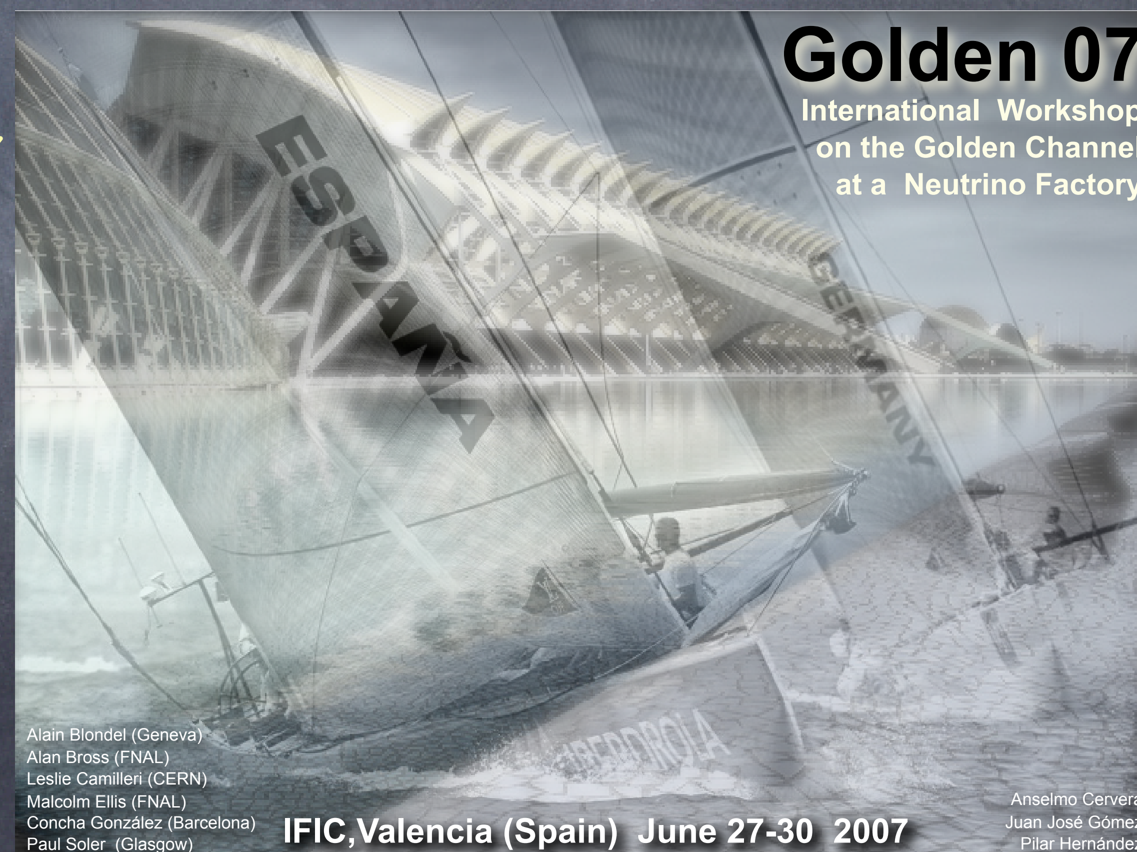
Golden07 workshop

- This year workshop will be mainly focused on the detector optimisation and R&D program:
  - Theory: input to experiments, new ideas
  - Golden detectors: MIND and TASD, current understanding and open issues
  - Proposal of detector prototypes and test beam areas

temporary URL
http://www.cern.ch/acervera/golden07

America's Cup final is taking place those dates (23 June - 7 July)

Early accommodation and flight booking is essential



Golden07 topics

- Physics of the Golden channel and optimisation of parameters: energy, baseline, channels
- New ideas: low energy neutrino factory, etc
- Detectors for the Golden channel: iron detectors versus totally active
- Experience from MINOS, NOvA, MINERvA, INO, etc.
- Atmospheric neutrinos at golden detectors
- Synergies with platinum and silver channels. Hybrid detectors
- Scintillator and photo-detector technologies
- Large magnetic volumes
- Detector prototypes
- Test beam areas

Water Cherenkov

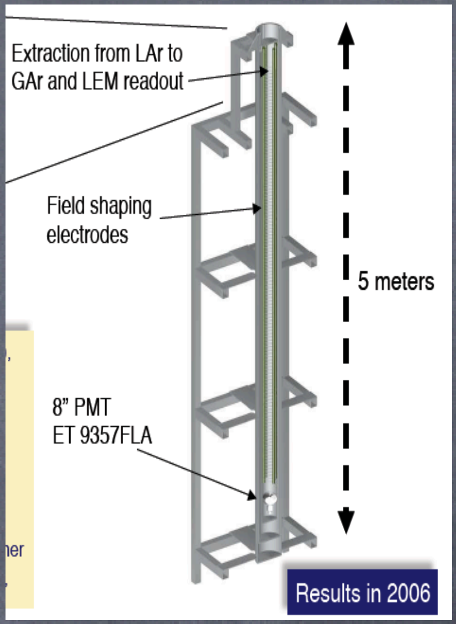
- This is a mature technology, however new issues related to the size of the projects have appeared:
  - Engineering and cost of excavation at different sites
  - Engineering studies of mechanics
  - R&D on water container (vessels versus multi-liners).
    - Important for radioactivity background suppression
    - Detector mechanical design and impact on detector cost.
  - R&D on photon detectors: large area HPDs or standard PMTs
    - Reduction of photon detection and readout cost
    - Reduction of energy threshold through material selection of PMTs
- Studies of energy resolution at low energy (ie ~250 MeV) .

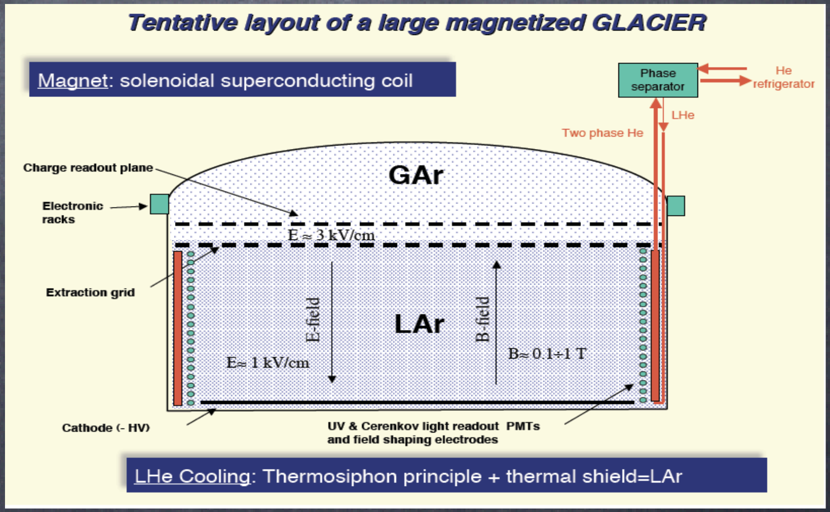
Liquid Argon TPC

- A beautiful detector. The most challenging one !!!
- An interesting option for platinum
- R&D programme well advanced in USA and Europe
- Simulations show that e/π^0 separation should be very efficient. This needs however to be demonstrated experimentally
  - A 100-130 ton detector is in the proposal stage in the US to operate either at NuMI or Booster neutrino beams
  - GLACIER is foreseen a similar strategy with ePILAr, which is in the design stage.

Detector R&D

- Underground lab
  - Logistics, infrastructure and safety
  - How shallow can operate a TPC ? (>200 m)
- Large container, production, purification safety
  - Safety to be carefully investigated. However it doesn't seem to be a problem (LNG tankers)
  - Engineering of large containers
  - Technical feasibility of large scale purification system
- Charge collection:
  - Wire tensioning
  - Two phase Ar with LEM readout: underway
  - High pressure: prototype at 4 bar (2006)
- Long drift distances
  - Diffusion, attenuation
  - 5 m long prototype underway (argontube)
- Magnet for Nufact
  - 0.1 T for muons and 1 T for electrons
  - Solenoid immerse in the LAr
    - Conventional sol. successfully operated
    - HTS prototype underway



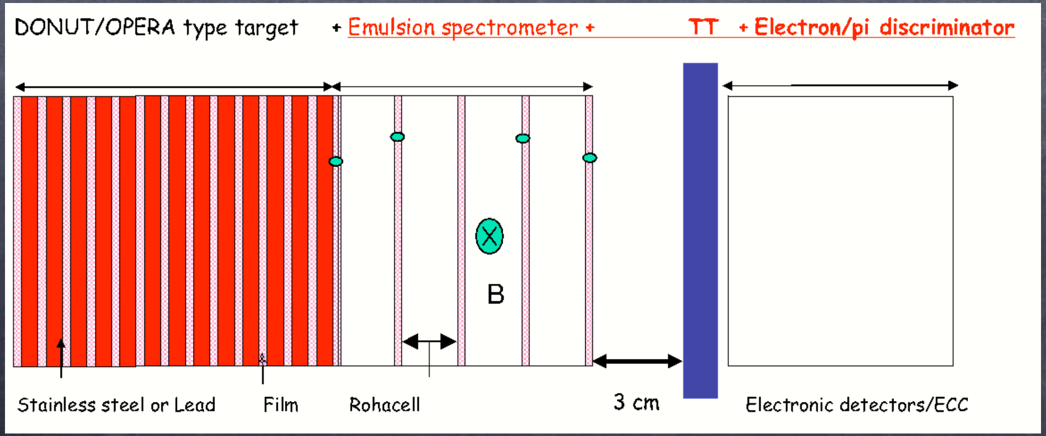


LAr TPC simulations

- There are simulations of a LAr TPC for a super-beam facility
- Simulations for a Neutrino Factory and a beta-beam does not exist. No clear plan yet
- There are studies of electron charge measurement, giving promising results
    - This studies are old and should be revised
    - Upper electron energy for measurement of its charge (5 GeV)

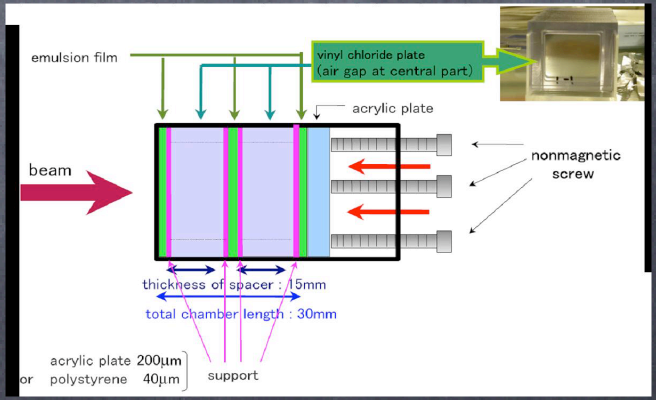
Emulsion detectors

- Define, on the basis of the experience with OPERA, the maximum MECC mass that can be affordable in terms of scanning power and cost, as well the minimum mass to have good sensitivity to the silver channel
- Carry out a realistic and cost effective design of the magnet
- Study the synergy with other detectors that could act as the electron/pion discriminator. This will open the possibility to search for the golden, the silver and the platinum channels with the same detector



Simulations and prototypes

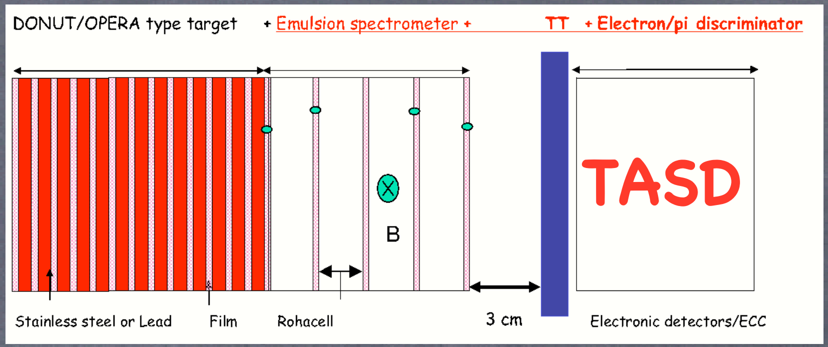
- Once the previous points have been studied, a full simulation with neutrino events has to be performed in order to evaluate the detector sensitivity for the golden and the silver channels, and for the oscillations that produce an electron in the final state. No clear plan jet.
- There is no clear plan yet
- Given the high modularity of the detector, prototyping is easy
- A small prototype with 3 emulsion films and 2 spacers (3cm total) was exposed to a pion beam at KEK:
  - 14% momentum resolution
  - Alignment precision between elements of few microns (should be worst in proposed MECC



- A bigger prototype is foreseen:
  - Study the effect of alignment precision, etc
  - Small dipole (70x70 cm) available at CERN. Used for TOSCA tests

Hybrid detectors

- No real work work with simulations has been done yet. There are few ideas
- MECC + TASD
  - TASD for e/pi discriminator
  - golden + silver + platinum



- MECC + MIND
  - golden + silver
- MIND+TASD: in mass 85% MIND, 15% TASD
  - MIND measures golden for E>2-3 GeV
  - TASD measures platinum
  - MIND helps TASD in shower containment
  - TASD helps MIND in measuring muon charge at low momentum

- MECC+MIND+TASD could do everything
- No hybrids with LAr have been yet considered

Near detectors

For Nufact

- Silicon vertex detector: study comparison of performance and cost of pixel versus strip detectors. Possible solutions could include Monolithic Active Pixels or DEPFET pixel detectors, currently being studied in the context of the linear collider. Study whether a passive target is necessary (boron carbide or other low mass target).
- Tracking device: determine feasibility and cost of a scintillating fibre tracker that serves as target and tracking medium. Are there any other options for the tracker (eg. gas TPC, drift chambers, ...)?
- Other detectors needed: What is the required resolution in a calorimeter? Is particle identification necessary (for example a DIRC Cherenkov counter as in Babar could provide such PID)? What detector should be used for the muon chambers? ...

For beta-beam and Super-beams

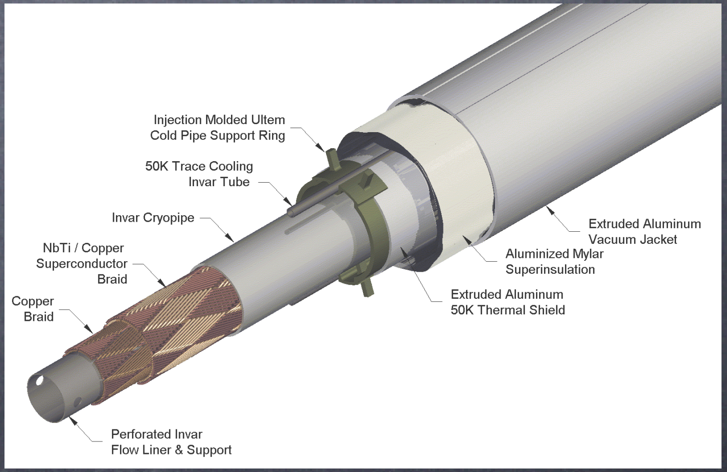
- No real work done on this so far. However, there is experience from MINOS, K2K, T2K on near detector design. The most relevant example is T2K, since it will measure cross-sections between 500 MeV and a few GeV for a number of targets.

Beam instrumentation

- The monitoring of the muon beam angular divergence in the storage ring is for the moment a very challenging concept that needs to be turned into a demonstrably feasible object.
  - A low-pressure He Cherenkov with extremely thin windows
  - It is not clear that a permanent device can be devised or if a different system needs to be invented
- Absolute flux monitoring should not be a problem for a ring geometry (large BCT).
  - Is the size a problem?
  - Beam backgrounds can induce opposite current, are they a problem ? Not in principle.
  - Can we reach the 0.1% ?
  - In principle, no prototype needed, some simulations could be enough
- Muon polarimeter should not be a problem
- No real work done so far for beta-beams and super-beams

Large magnetic volumes

- Conventional room-temperature and super-conducting coils are not an option
- HTS superconducting magnets are a promising option. Current HTS cable is too expensive to be operated at 77K, but HTS operating at 30K could provide enough current-carrying capability to produce the required field. A foam-insulated cryostat is still an option for 30K operation, but would be relatively thick (1m). HTS cable is a rapidly developing field and the technological situation could change significantly in the near future
- The super-conducting transfer line (STL) is probably the most promising option for large magnetic volumes at reasonable cost. A more detailed engineering study is need to get a better estimate of the system cost
  - how the STL would be wound ?
  - what is needed for the support cylinder ?
  - how the detector would be supported ?, etc



- The cost of the STL itself is well understood, but an analysis of its use for this application needs to be done with regard to forces on the conductor and optimisation of the STL design for this application.

Priorities

- Full understanding of baseline detectors:
  - Low energy: WC is a mature technology. Main R&D:
    - Large underground cavities and photodetectors
  - Medium energy: a lot of R&D required
    - Magnetisation of TASD for low energy Nufact
    - LAr: complete the long R&D program
  - High energy: iron calorimeter well understood. Main R&D:
    - How to increase magnetic field in iron
    - MIND prototyping is crucial for charge measurement and efficiency threshold
  - Full simulations for all
  - Realistic cost estimates for all
- Simulation of hybrid detectors

Necessary

- R&D for challenging second option detectors. We should be ambitious !!!
  - TASD for conventional nufact:
    - large magnetic volumes
  - GLACIER: 100 kton magnetised LAr TPC:
    - Magnetisation of large LAr volumes
    - Very long drift distances
  - MECC for Golden at conventional nufact:
    - Maximum affordable mass (cost, scanning time, ...)
    - Minimum mass for silver channel
  - Full performance study with simulations for all
  - Realistic cost estimates

Conclusions

- We have a preliminary R&D plan, but it still needs to be designed carefully
- The detector R&D plan should foresee synergies between the same detector at different facilities
  - For example, the same TASD prototype should be useful for all facilities
- Some work still needs to be done for Super-beams and beta-beams, mainly on the beam instrumentation and near detectors side
- Prototyping is essential and should happen now !!!
- We should get more people involved