A MICE muon identifier based on the KLOE calorimeter design

- The task
- Detector concept
- Technical drawings
- Simulation and PID
The task

» Provide “final” muon tag with highest possible Efficiency and Purity > 99.9%

Spectra and energy distributions:
• Softer particles than previously estimated
• Electrons are more spread out than muons
Fine-grained calorimeter technique

1mm diameter scintillating fibres embedded in grooved lead layers

Same construction technique as KLOE e.m. calorimeter
Lead-fibre composite

≈ 0.9 mm pitch \( \perp \) to the beam
1.35 mm pitch of lead foil grooving
0.3 mm Lead + 1 mm Fiber
\( X_0 \approx 20 \text{ mm (estimated)} \)

≈ 1.2 mm pitch \( \perp \) to the beam
1.35 mm pitch of lead foil grooving
0.5 mm Lead + 1 mm Fiber
\( X_0 \approx 12 \text{ mm (experimental)} \)
Lead foils

Spools of lead foils of various thickness for tests (LNF & Roma III)
Lead-shaping machine

The grooving rollers consist of 13 “disks” (*), 50 mm thick and 400 mm in diameter, made of hardened steel and ground to shape by a sintered diamond tool; the rollers are fixed by means of ball bearings (*) on a very rigid frame and are aligned and checked with a set of micrometers.

- Achievable thickness uniformity is around few tens of µm and
- The grooves can deviate from a straight line by less than 0.1 mm per foil length.

Designed and used for construction of KLOE EmCal (barrel modules)

(*) require some maintenance and/or replacement

MICE CM, Frascati 27 June 2005
MICE calorimeter
Machine dismantled for refurbishing

Balls bearing to be replaced

The grooving roller

Spare disks at Roma III (thanks to S.B.)
Lead-shaping

Lead spool

Big lead shaping machine

Rely on LNF for manufacturing
Tests at LNF Metrology lab

Lead grooved foil

To be done at LNF

Microscope

Enlarged view

Measurement
Scintillating fibres

- Pol.Hi.Tech is out of the game

- Offer by Kuraray only for SCSF 81 type (single and double cladding)

- Foreseen cost for 25 km ≈ 20 keuro (tax free, transport included)
Calorimeter assembling

Example of Single plane with double side read out

Example of four planes superimposed alternating the fibers direction
Readout: Light guides

Final design to be defined accordingly with optimal cell size
(simulation studies in progress)
Readout: PMTs

Photomultipliers and H.V. system previously used in CHORUS and HARP, then installed in T2K, now taken to MINOS (will be back in time!)

- Photomultipliers Hamamatsu 1355
- Voltage dividers 2624 type
- Housing boxes with 2 mu-metal shielding each
- Impedance adapters
- HV system available (to be recovered from Roma I and/or CERN)
Components assembling

Multiple housing for PMs

Light guides for a Sector

End plug (int. and ext.)
Sector active area 40x120 cm$^2$:

- Max transverse size set by grooving rollers width
- No limitation on longitudinal size

Plane active area 120x120 cm$^2$
Calorimeter assembling
Calorimeter mounting

Calorimeter mechanical support structure

Insertion in the downstream PID support structure (design under way by S.Yang)
## Cost estimates

<table>
<thead>
<tr>
<th>Raw Materials and Cables</th>
<th>Provider</th>
<th>Unit Cost</th>
<th>Amount</th>
<th>Total Cost</th>
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<td>2400</td>
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<td>Cables and Connectors for HV and Signal</td>
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Miscellaneous (Tools, Mijar, Consumables...)

**Total**

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**Total**

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### Construction (workshop operation and installation)

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### Modules Workings, Sharpening, Polishing

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**Total**

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(a) = Estimate for 2007 budget year

**Gen Total**

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Electron vs muon identification

Pattern of visible energy

It’s possible to distinguish electrons from muons by means of:

- path reconstruction based on the energy released inside the calorimeter’s elements
- combination of cluster length, total energy, energy per plane ...

Example: KLOE
Barycenter depth

\[ Z_b = \frac{\sum Z_i E_i}{\sum E_i} \]
Calorimeter simulation and PID

- Calorimeter simulation in G4MICE (by R. Sandstrom)
  - Full geometry (fiber-by-fiber)
  - Detailed digitization
  - Validation from comparison with KLOE data (in progress)

- Particle identification: separation of positrons from muons with a Neural Network
  - 11 input variables: total charge, shower barycenter depth, products and ratios of amplitudes at two sides in each layer
  - Excellent efficiency and purity achieved
PID with a Neural Network

Two of the input variables

The result, with
- Muon momentum \(~200\) MeV/c
- full simulation of cooling channels and downstream detectors
- electrons from “true” muon decays (initial purity 99.542%)
PID with a Neural Network

Work in progress to achieve best possible $\mu$ tag downstream:

- Best use of full calorimeter information (incl. timing)
- Combination with other detectors (tracker, TOF, Ckov)
EmCal Summary

• Fine grained calorimeter: scintillating fibers embedded in grooved lead foils
  – Lead layer thickness 0.3 mm
  – Read-out: 4 Layers, each read out by PMTs at both ends
  – Read-out cell size: 4x4 cm² or 3x5 cm²
  – Total calorimeter size: 120 x 120 x (16 or 12) cm³

• Muon/electron separation based on energy deposition and shower development
  – Identification algorithms studied with G4MICE
  – using a Neutral Network, purity and efficiency >99.9% can be achieved

• PID capabilities are adequate for MICE requirements

• In progress: design optimisation