ATLAS TUNGSTEN FCAL MODULES

ATLAS FCAL Collaborators

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Outline

Overview of the detector
Technical requirements
Design
Prototyping
Testbeam Simulation
Thermal Studies
FCAL is integrated into the ENDCAP cryostat of ATLAS

- a large rapidity region is covered by a relatively small calorimeter
  \[ 3.0 < |\eta| < 4.9 \]

- the calorimeter must be dense to accommodate \(~10\lambda\) of material in a small space

\[
\begin{align*}
FCAL1 & : \text{Cu matrix + rods} \\
       & : 2.6\lambda \\
FCAL2/3 & : \text{W matrix, W rods} \\
       & : \text{Cu skeleton} \\
       & : 3.5\lambda/3.4\lambda
\end{align*}
\]
**Radiation Hardness**

**Neutron Fluence**

Up to $10^{16} \text{n/cm}^2/\text{yr}$ at peak luminosity

**Ionizing Dose**

$\sim 230 \text{ MRad/yr at the lower edge of FCAL}$

All FCAL components must be mechanically radiation hard to allow the device to perform properly for may years of data taking.

For safety, trace amounts of such elements as Co must be kept low. Activation of these trace elements can become a problem when servicing the device.
**Liquid Argon Purity**

Liquid argon as an ionization medium is very sensitive to impurities which limit the yield of signal charge.

Under neutron irradiation, construction components must be stable against poisoning the liquid argon. This is especially important for the FCAL since we share the same LAr volume as the EEC and HEC.

**To satisfy the technical requirements:**

The calorimeters are being built with as few components as possible, all of which have been demonstrated to be radiation robust

**FCAL2/3 - sintered W, pure W, copper, PEEK**

The modules are constructed in a clean room environment

The construction methodology and tooling has been chosen to eliminate contaminants

Outgassing studies have been performed on the W
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Cu endplates

Cu tubes for mechanical support and electrodes

Sintered W slugs locked in place by tubes

Continuous, formed Cu pieces for inner and outer periphery

Ionization gap formed between ID of Cu tube and OD of W rod

Matrix - W slugs
97% W, 2.1% Ni,
0.9% Fe
ρ = 18.5 g/cm³

Electrodes - Pure W
ρ = 19.2 g/cm³
Endplate Hole Groove

-300µm deep
Cu tubes swaged into place during assembly
forms a clean, weldless joint

Electrode Spacers

Radhard polyimide material (PEEK)
Centre the rod inside the Cu tube
Resulting gap is the ionization readout gap
375 µm for FCAL2
500 µm for FCAL3
Engineering prototype - "Maquette" (Summer/Fall 1996)

Full-featured, 104 electrode device

Constructed as a “proof-of-principle” device to verify the design concept of the FCAL W modules

Used for mechanical and electrical tests

We have made modifications to the design of the modules based on our experience with this module

Module - 0 (Fall/Winter 1997/98)

1/4 segment of one complete FCAL2 module - this is large enough to fully contain hadronic showers up to 200 GeV

Purpose - test the physics performance of the calorimeter in testbeam studies

Will be tested at CERN in summer 1998 both as a standalone device and in conjunction with an FCAL1 module-0

**FCAL Testbeam Programme**
- 1993 - FCAL1 prototype at BNL/CERN (e)
- 1995 - FCAL1 prototype at CERN (full depth) (e)
- 1998 - FCAL1/FCAL2 at CERN (e, π)
CAUSE FOR CONCERN

The FCAL modules are subjected to high fluxes of particles which deposit a non-negligible amount of energy (heat) in the devices. Given that the ΔT for LAr is ~ 3.5 K, does this heat induce boiling of the LAr in the thin gaps of the FCAL modules?

Heating Estimates (at nominal luminosity):

- FCAL1: 30.8 W
- FCAL2: 10.3 W
- FCAL3: 3.2 W

Heating studies are progressing on two fronts:

(1) Estimations based on geometrical arguments and assumptions about heat transport

Preliminary calculations for FCAL2 indicate that the majority of the heat is transported through the absorber matrix and gives rise to a temperature difference of no more than 0.4 K

Some of the assumptions going into the calculation (heat capacities, thermal conductivities, etc.) are being measured on the FCAL2 maquette. This should shed some light on the validity and accuracy of the calculations

(2) FEA studies

Work is in progress to model the heat transport in ANSYS
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\[ K(\text{Cu}) = 0.514 \text{ W/mm-K} \]
\[ K(\text{LAr}) = 0.00012 \text{ W/mm-K} \]
\[ K(\text{W}) = 0.244 \text{ W/mm-K} \]

**FEA** \[ \Rightarrow \]
\[ K_{xx} = 0.00501 \text{ W/mm-K} \]
\[ K_{yy} = 0.00501 \text{ W/mm-K} \]
\[ K_{zz} \rightarrow \text{still to come!} \]
The design of the FCAL hadronic modules is now mature and satisfies the technical requirements for a calorimeter in the high $\eta$ region of the ATLAS detector.

The process of prototyping is well underway, with production of the final modules expected to begin in early 1999.