The ALICE Electromagnetic Calorimeter (EMCAL)

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1. ALICE @ LHC - CERN

- 4 large experiments
- ALICE
  - mainly dedicated to heavy-ion physics
  - p-p run for physics and reference
- Hard & Soft physics
- Excellent PID
- Tracking down to very low momenta
QCD expectations

Protons and neutrons are colorless objects made by confined colored quarks and gluons: QCD

QCD asymptotic freedom (Nobel 2004 to Gross-Wilczek-Politzer): at very high momentum transfer, the hadronic matter will melt in a plasma of deconfined and colored quarks and gluons.

The critical temperature of 170 MeV has been reached by SPS and RHIC but evidence of residual interaction has been shown.

The matter created at RHIC behaves like a liquid and not like a gas!

LHC will go well above the critical temperature.

A Quark Gluon Plasma can be created, as it was in the early Universe just after the Big Bang.
Dynamics and signals
(that will be studied by ALICE)
The 2009 longer shutdown (+ new cosmic run) was used to complete installation and to improve detector performances.
2. EMCAL: Location into ALICE and Characteristics

To do jet (quenching) physics:
- large coverage
- good granularity

**EMCAL**
- located inside the L3 solenoidal magnet
- **sampling** calorimeter: 20.1 $X_0$
- sandwich, 1.44 mm Pb/1.76 mm Scint
- final geometry when installation completed:
  - $-0.7 \lt \eta \lt 0.7$
  - $\Delta \Phi = 100^\circ$
  - small $\Phi$ gaps ($\sim 3$ cm)
    - aligned w/ TPC gaps
- sampling fraction 1/10.5
- density 5.86 g/cm$^3$
- $R_M = 3.20$ cm; $X_0 = 12.3$ mm
- Scintillator = Polystyrene (BASF143E + 1.5% pTP + 0.04% POPOP)
- 10 super-modules in total
- granularity: **11520 towers**
  - tower size: $\Delta \eta \times \Delta \phi \sim 0.0143 \times 0.0143$
  - $\sigma_E/E \sim 10\%$
- installed back to back with PHOS
**Containment: 88 parts**
1) Back (holes: 144 thru for fibers + springs + mech. support), 1
2) Compression (holes: 144 thru for fibers + springs), 1
3) Front Plate (holes: 144 thru for fibers + springs + mech. support), 1
4) 5) Plungers (10)
6) Belleville washers (75)

**Tensioning and Isolation: 40 parts**
7) Stainless steel straps (4)
8) Screws (24)
9) Flanges (8)
10) Light tight stickers (4)

**Sandwich: 538 parts**
11) Lead tiles (76)
12) Scintillator tiles (308)
13) Bond paper sheets (154)

**Readout: 165 parts**
14) WLS fibers (144)
15) APD (4)
16) CSP (4)
17) Light guides (4)
18) Mount (4)
19) Collars (4)
20) Diffuser (1)

**TOTAL components: 20**
**TOTAL parts: 831**
Plus cabling, GMS and mech. supports
Module Production

Assembly station

Scintillator tile

Final module

350 Kg pressure

Lead tile

WLS insertion
The EMCAL Readout

**Y-11 (200) WLS double clad fibers**

\[ \lambda_A = 430 \text{ nm}, \quad \lambda_E = 476 \text{ nm}, \quad \tau = 7 \text{ ns} \]

**S8664-55 APD+CSP package**

\[ \lambda_A = 480 \text{ nm}, \quad \varepsilon_\lambda = 80\%, \quad T = 25^\circ \text{C} \]

**fibers + light guide on package**

The image shows a graph labeled "Fibers test" with data points for polished fiber ends with and without a mirror. The graph plots distance (cm) against light output (arbitrary units).
The EMCAL Modular Structure

One Module

12 modules (4 for Prototypes)

- 1 Module = 26.7 kg
- 1 Strip Module = 324 kg
- 1 Super-Module = 288 modules ~ 7.7 tons

Full detector:
10 Super Modules,
total weight ~ 80 tons

One FULL Strip Module

One Super Module
3. Final results from test beams

EMCAL prototypes (4 modules x 4 strips) under test beams:
FNAL, November 2005 & SPS + PS, September - October 2007

Energy resolution for electrons as a function of the incident beam momentum:

\[ \frac{\sigma(E)}{E} = 1.7 + \frac{11}{\sqrt{E}} + \frac{5.1}{E} \]

Linearity better than 1% above 20 GeV (3x3 tower cluster)
EMCAL response to $h$ and $e^-$

Hadron Rejection Factor $10^2$-$10^3$

Position Resolution (mm):
$$\Delta x = \Delta y = 1.5 + 5.3 / \sqrt{E}$$

Response of 384 towers before/after gain calibration
4. EMCAL Status

• 4 SMs installed in ALICE (2 in March 09, 2 in July 09), operational and taking data (see next slides for first results)
  installed coverage:
  \( \Delta \eta \times \Delta \phi = 1.4 \times 1.05 \)

• 4 SM ready and under testing/calibration (for calibration details see J. Faivre’s talk)
• 2 SM in preparation
• Assembly of EMCAL expected to be completed before summer 2010
• Cosmic calibration will be completed in fall 2010

As soon as a long shutdown in LHC will be available, the full EMCal can be installed in ALICE (2011)
5. First results from data taking

First collision on Nov. 23, 2009

284 events in 43 mins

Data taking: 6-16/12/2009 p-p @ 900 GeV from 31/03/2010 p-p @ 7 TeV
EMCal $\pi^0$'s

EMCAL: $N_{\text{dig}} = 1$, $E_{\text{clus}} > 0.3$ GeV, 600<T<700 ns

28.04.2010

pi0 in calorimeters

from Yuri Karlov
EMCal $\pi^0$'s - Non linearity

EMCAL: $\pi^0$ mass and width

Need to get non-linearity correction and geometry correct before rescaling energy scale

Cluster selection does not affect the $\pi^0$ mass and width

from Yuri Karlov
EMCal Dead Channels

Noisy Channels (9)
Dead Channels (3)
Warm Channels (1)

Work in progress

from Francesco Blanco
EMCal $\gamma$ events in HLT reconstructed online

from Federico Ronchetti
Despite EMCal was the last ALICE detector proposed, approved assembled, and (still partially) installed, the first upgrade approved (by November 2009) by the ALICE collaboration is an extension of EMCal \( \rightarrow \) DCal back to back with EMCal for jet-jet and \( \gamma \)-jet physics.

Assembly of 6 DCal SMs will start in summer, after the completion of EMCAL SMs. DCAL IS NOT A (NEW) PROJECT: work on DCAL already started!!!!

**DCAL modules:**
- Same technology of EMCal
- Shorter SM (2/3 of EMCal SM)
  - Shortened DCal SM
    - 16 strip modules
    - Installed \( \eta = 0 \) to ~0.7 (including PHOS)
    - \( \Delta \phi \) ~20 degrees
- Standard EMCal SM
  - 24 strip modules
  - (3 shown)
7. Summary

- Final results from test beams: performances satisfy all design criteria

- First 4 EMCAL SMs already installed for $\pi^0$, $\gamma$ and first jet physics

- First results from data taking obtained: EMCAL works fine, first results promising, investigation and optimization going on

- EMCAL assembly going on, completion by Summer 2010

- Long shutdown needed for installation (2011)

- EMCAL upgrade: DCAL completion for $\gamma$-jet and jet-jet physics, work already started, long shutdown needed (2011)