Production and test of the LHCf microstrip silicon system

Florence, June 28th 2007 - RD07

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Outline

• Introduction
  – About the LHCf experiment (method and location)

• The LHCf apparatus
  – Some details about the detectors
  – The μ-strip silicon system: production and test

• Beam test
  – CERN, Sept. 2006 (few preliminary results)

• Summary and schedule
  – Toward the 2008 LHC operation
I) Introduction: the LHCf experiment

a) Method
b) Location
c) Detector
The direct measurement of the $\pi$ production cross section as function of $p_T$ is essential to correctly estimate the energy of the primary cosmic rays (LHC: $10^{17}$ eV)

Simulation of an atmospheric shower initiated by a $10^{19}$ eV proton.

LHCf experimental method is based on 2 independent detectors installed on both sides of IP1

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Detector I
- Tungsten
- Scintillator
- Scintillating fibers

ATLAS INTERACTION POINT (IP1)

Detector II
- Tungsten
- Scintillator
- Silicon $\mu$-strips

Beam line

140 m

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Location of detectors: **TAN absorbers at ±40m from IP**

- **TAN**: absorber for neutral particle from IP
- **LUMI** and **ATLAS ZDC**
- **LHCf**
- **IP1 underground**
- **Recombination Chamber** (1 $X_0$ shaped region)
- **Front**: marble
- **Body**: iron

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Detector #1

2 independent calorimeter “towers” 24 cm long vertically stacked (5 mm gap)

Lower tower: 2 cm x 2 cm area
Upper tower: 4 cm x 4 cm area

Each calorimeter tower allows reconstructing energy (scintillator) and impact point (SciFi) of incoming γ or n

22 absorber layers (Tungsten, 7mm thick)
Total: 44 $X_0$ (1.6 $\lambda_I$
(W: $X_0 = 3.5$mm, $R_M = 9$mm)

4 pairs of SciFi layers for tracking purpose (6, 10, 30, 42 $X_0$)

Beam line

16 scintillator layers (3 mm thick)
Trigger and energy profile measurements
Detector #2

2 independent calorimeter towers 24 cm long stacked on their edges and offset from one another

Lower: 2.5 cm x 2.5 cm area

Upper: 3.2 cm x 3.2 cm area

22 absorber layers
(Tungsten, 7mm thick)
Total: 44 $X_0$ (1.6 $\lambda_I$)
(W: $X_0 = 3.5$ mm, $R_M = 9$ mm)

16 scintillator layers (3 mm thick)
Trigger and energy profile measurements

4 pairs of silicon microstrip layers
(6, 12, 30, 42 $X_0$) for tracking purpose (X and Y) \(\rightarrow\) impact point
2) The LHCf detector

a) Some details about detector #2
b) Production of silicon modules
c) Test of front-end chip
Some details for detector #2

Florence, April 2007

Hamamatsu R7400U
Construction of silicon modules

- Al frame
- Scintillator
- W (absorber)
- Delrin frame
- Silicon
- Al layer 0.5 mm
- Fiber glass
- Kapton fanout
- Fiberglass fanout
- PACE3 chip
- Front-end PCBs
- \( \mu \)-bondings
- Samtec mini coaxial cable (to read-out PCB)
- X side
Assembling silicon module, X-side

Silicon sensor

63.96 mm

63.56 mm

bonding pads

fiberglass fan-out

front-end PCB (LEFT)

kapton fan-out (LEFT)

kapton fan-out (RIGHT)

Electrical insulation (50µm kapton tape) plus thin uniform epoxy glue layer (Araldite 2020)

thin uniform epoxy glue layer Araldite 2020

bias pad (conductive Ag-glue between pad and sensor backplane)
Silicon sensors details

- HAMAMATSU single side sensors developed for the barrel of the ATLAS SCT
- Size: (63.56 x 63.96) mm² x 285µm
- Implantation pitch: 80µm
- 768 strips + strip 0 and strip 769 as field shaping strips
- About 75V full depletion voltage
Y-side silicon layer with front-end

Dow Corning RTV 340 heat sink compound
Silicon modules final production (4 X and 4 Y)
PACE3 front-end chip

Developed for the CMS ECAL silicon preshower

- 32 analog-in channels
- high dynamic range
- 25 ns peaking time
- CMOS sub-micron (rad-hard)
- 600 mW consumption

DELTA chip: preamp. stage, internal calib. sys and some registers

PACE-AM chip: analog pipeline (matrix 192x32 capacitors), the control logic and the output lines

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PACE3 analog output for different input charge

![Graph showing ADC counts over time for different input charges (500 fC, 1000 fC, 1500 fC, 2000 fC). The graph indicates a 25 ns delay.]

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Study of PACE3 output linearity

- exp values
- linear fit

Nominal working range

Difference \( = 6\% \)
3) Beam test (sept. 2006)

A few VERY preliminary results
Beam test at CERN-SPS (Sept. 2006)

- LHCf detector #2
- Additional silicon tracker
- e, p, µ beams
- energies between 100 and 350 GeV
- LHCf silicon system read-out PCBs

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Beam profile

Beam profile is measured by means of an additional silicon tracking system made of 5 double-sided layers with intrinsic resolutions about 3 $\mu$m and 11 $\mu$m along X and Y direction.

200 GeV electron
Shower transverse profiles for a single electron event

200 GeV electron

Preliminary results

Single event – LOW gain – e (200 GeV)

Position – x side (strip #)

Position – y side (strip #)

Signal (ADC counts)

Entries 192
Mean x 95.01
Mean y 30.04
RMS x 55.7
RMS y 76.3

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Charge distribution and correlation

200 GeV electron

Preliminary results

Energy release - x side (ADC counts)

Energy release - y side (ADC counts)
Expected spatial resolution for shower center

Simulation with the FLUKA software of silicon layers installed at different depth inside the LHCf towers.

Shower transversal shape is approximated using a generalized Lorentz function:

\[
L = \frac{p_1}{\left[ p_2 + (x - p_3)^2 \right]^{p_4}}
\]
A few conclusions and schedule

1. LHCf apparatus
   - Both LHCf detectors have been completed
   - Read-out electronics is under development for detector #2 silicon system

2. Installation
   - Successful pre-installation done in 2007 for both detectors
   - New pre-installation and test foreseen in autumn for detector #2 to test some modifications with respect to first pre-installation
   - Final installation between end 2007 and first months of 2008

3. Beam test at CERN SPS (August 24th - September 11th)

4. Running
   - Data taking foreseen at the beginning of LHC running at low luminosity (less than $10^{31}\text{cm}^{-2}\text{s}^{-1}$), in 2008
Backup slides
LHCf performances: Monte Carlo $\gamma$-ray energy spectrum
(5% energy resolution is taken into account)

10^6 generated LHC interactions $\rightarrow$ 1 Minute exposure@10^{29} cm^{-2}s^{-1} luminosity

Discrimination between various models is feasible

Quantitative discrimination with the help of a properly defined $c^2$ discriminating variable based on the spectrum shape (see TDR for details)
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LHCf performances:
model dependence of neutron energy distribution

Original n energy

30% energy resolution

Neutron Energy Distributions

Counts [100GeV/10°/nna]

QGSJET
QGSJET II
DPMJET3
SIBYLL

Neutron Energy Spectrum of 20mm Calorimeter at beam center

30% Energy Resolution
Performances of the LHCf Detector

Measured at the SPS
Beam Test in 2004

SciFi Position Resolution

<table>
<thead>
<tr>
<th>Energy Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Experiment (20mm)</td>
</tr>
<tr>
<td>- Experiment (40mm)</td>
</tr>
<tr>
<td>- Solid Line: Monte Carlo (20mm)</td>
</tr>
<tr>
<td>- Dashed Line: Monte Carlo (40mm)</td>
</tr>
</tbody>
</table>

LHCf can measure (and provide to LHC) the center of neutral flux from the collisions

If the center of the neutral flux hits LHCf \( \Rightarrow \ll 1 \text{ mm resolution} \)

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Geometrical limits for LHCf measurements

I. Free space between the two beam pipes in the recombination chamber is 96 mm wide

II. Critical part of beam pipe is in D1 magnet region, where it is of elliptical shape

Combination of these two limits for detector #1 and #2 is sketched in the two following slides, superimposed to the detector geometry
Transverse position of detector #1 in TAN slot
Transverse position of detector #2 in TAN slot
Calibration of PACE3 channels
Readout and control scheme for Arm2 Silicon

USA15
- VME Crate
- TSC+FEC
- Control PC
- Power Supply
- High Voltage

TAN
- Arm2
- Distribution Board
- Power
- Thermistors

~ 240 m

Multimode Optical Fibers
- Monomode Optical Fibers

High Current Cables
- Sense wires

DOH
- MB + ADC

Splitter Box

Signal + Control

Thermistors

Control PC

MB + ADC

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