LHCf: A new experiment to study very forward particle emission at LHC

~smallest experiment in the HE session~

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Introduction
Puzzles of the highest energy cosmic ray physics
GZK cut off, chemical composition

Idea of LHCf
Measurement of neutral particles emitted into very forward of the LHC interaction point

Technical hurdles and Prototype test
Validity of small calorimeters

Summary and Roadmap
Toward the 2007 LHC operation
Existence of the GZK cut off is one of the most important theme in the cosmic ray physics.

Large attempts are paid to overcome the crucial point, namely, \textit{Statistics}, by TA, Auger, EUSO.

These new projects also study \textit{Systematic} effects of the detector and atmosphere very hard.

\textbf{HOWEVER}

Different interaction models give different answers for the primary cosmic ray energy estimate.
Composition Problem

Not only GZK...

Different interaction models lead different conclusions about the composition of the primary cosmic rays.

Knapp et al., 2003
Calibration of the models is indispensable.

Let’s use LHC, the highest energy accelerator!!

At LHC, 7 TeV protons collide, corresponding to $10^{17}$ eV in the laboratory system, just below the GZK energy range.

Major LHC detectors (ATLAS, CMS, ...) measure the particles emitted in the central region. But for the development of air showers, forward emission is important.

*LHCf is an original experiment placed at this niche of LHC.*
The beam pipes of LHC are separated by 96mm at 140m from the interaction point.

Charged particles are swept out by magnets.

LHCf measures the distribution of the Feynman x parameter (practically energy) of neutral particles emitted in the very forward region using position sensitive calorimeters placed in this 96mm gap.
LHCf Detector

SciFi to measure the shower position (@ 6,10,34 r.l.)

Sampling with 17 plastic scintillators

Shower calorimeters of 50 r.l. Tungsten
Acceptance of LHCf

Expected E-Pt of gamma-ray

LHCf acceptance
Model dependent energy distributions

\[ X = \frac{E_\gamma}{E_0} \]

DPMJET (3.03)
QGSJET
Ad-hoc
Technical hurdles

Science of LHCf is approved by LHC Committee in 2004.

Technical questions were,
1: Can we really construct such a compact calorimeter?
2: Can we really measure the shower energy with such a small calorimeter?

Prototype test in 2004 at CERN SPS with
- 250 GeV/c (max) electron beam
- 350 GeV/c (max) proton beam
- 150 GeV/c muon beam
LHCf Prototype

MAPMT and FEC for SciFi readout

Clear fiber light guide

10mm φ PMT HAMAMATSU H3164-10

4cm calorimeter

2cm calorimeter

90mm width
LHCf Prototype test

Main detector

Silicon tracker for position calibration

Beam
Event Sample (transition curves)

- 200GeV/c electron fully contained
- 200GeV/c electron partially contained
- 50GeV/c electron fully contained
- 350GeV/c proton

Shower leakage is apparent!!
Leak Correction

MC predicts that the leakage is energy independent!

Prototype Experiment

Monte Carlo

Distance from Edge

MC Leak Normalised

MC Leak Normalised to 200GeV/c
Energy Resolution

- Red Line: Monte Carlo (2cm)
- Blue Line: Monte Carlo (4cm)

Energy Resolution (%) vs Electron Energy (GeV/c)
Summary

New accelerator experiment, LHCf, has started.

LHCf examines particle emission in the very forward region of $10^{17}$ eV interaction, which is important to understand air shower development.

Major technical questions are solved in the beam test in 2004.

Matching to the LHC circumstance is in progress.
<table>
<thead>
<tr>
<th>Year</th>
<th>Activities</th>
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| 2005 | Matching study with the LHC circumstance  
|      | Detector optimization  
|      | Prototype data analysis for hadrons  
|      | Establishment of the PMT calibration method |
| 2006 | Detector construction  
|      | Beam test at CERN SPS |
| 2007 | Installation in LHC  
|      | Run in the early stage of LHC  
|      | LHC’s first science experiment!! |
End
SciFi Data@10r.l. (200GeV/c electron)

Simple shower

Multi Hits?
Setup at the Prototype Test

LHCf 2004
Detectors Set-up

Silicon tracker

40mm calorimeter

20mm calorimeter

Moving Table

(calculator not correct)
Front End Circuit for SciFi and MAPMT

VA chip

MAPMT (64 ch)

Readout Unit (8 PMT)
Prototype Elements
Invariant mass of $\pi^0$ can be calculated from the observed two gamma ray energies.
Air shower development with different models

Transition Curve

$10^{17}$ eV proton primary

DPMJET (3.03)
ad-hoc
QGSJET II

Number of Particles

Atmospheric Depth ($g/cm^2$)