standby
The LHCf experiment:

Observes forward energetic neutral particles at LHC to calibrate hadronic interaction models for cosmic-ray physics

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for the LHCf collaboration.

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LHCf: a tiny new experiment joins the LHC

While most of the LHC experiments are on a grand scale, LHC forward (LHCf) is quite different. Unlike the massive detectors that are used by ATLAS or CMS, LHCf's largest detector is a mere 30 cm.

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Cosmic-Ray Energy Spectrum

- $< 10^{14} \text{eV}: \text{accel. SNR}$
- nearby e- source?
- dark mater?
- B/C ratio ...

$\ast > 10^{15} \text{eV}; \text{knee}$
$\ast \text{composition, origin, accel?}$

High Energy End
Super GZK?
ExtraGalactic origin
Where, How?

Fluxes of Cosmic Rays
(1 particle per m$^2$-second)
Knee (1 particle per m$^2$-year)

Air shower

$1/y \cdot m^2$
$1/y \cdot (10 \text{km})^2$

LHCf
TA Auger

$10^{15} \text{eV}$
$10^{20} \text{eV}$

Wednesday, September 1, 2010
If Super GZK: various interesting scenarios:

New results: GZK cutoff

Hillas plot

Composition

Auger

TA

HiRes
• SD: Surface array Detectors
• FD: Fluorescence Detectors
• Cherenkov
• Radio
M.C: Indispensable tool

- Energy scale
- Composition
- Trigger efficiency, $S\Omega$

Problems:
- Hadronic interaction model
- Computation time at $>10^{16}\text{eV}$
• Hadronic Interaction model

• Several interaction models in cosmic ray field
  • qgsjet1
  • qgsjet2
  • dpmjet3
  • sibyll
  • EPOS
For Ne and Nγ

- large x is important

For Nμ

- small x (or η_{cm} ≈ 0) is also important
electron/ gamma in AS

\(~60\%\) are from pi, K with \(x>0.1\)
or
\(~40\%\) from \(\gamma\) with \(x>0.05\)
Meson pseudo rapidity

\[ \frac{dN}{d\eta} \text{ / event} \]

\[ 10^{17} \text{ eV} \]

\[ \sim 100 \text{ GeV} \]

Cumulative fractional energy

(\( \eta \)) of mesons(%)
neutral particles

TAN area

96mm

front counter

2 tower calorimeters
Photon vs Neutron

400 GeV photon

1 TeV Neutron
Arm #1

- 8 MAPMT's
- 4cm x 4cm tower
- 2cm x 2cm tower
- 9cm
- optical fibers

Arm #2

- 32 PMT's
- 4 Silicon strip tracking layers
- 44X0
- 1.7λc

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\[ \eta > 8.4 \quad 450 \mu \text{rad} \]
\[ \eta > 8.7 \quad 310 \mu \text{rad} \]
Detector performance: SPS test and M.C

Gamma-rays ($E>100\text{GeV}, \Delta E/E<5\%$)
Neutral Hadrons ($E>\text{a few 100 GeV}, \Delta E/E\sim30\%$)
Neutral Pion ($E>700\text{GeV}, \Delta E/E<3\%$)
at pseudo-rapidity range >8.4

at $7\text{TeV} + 7\text{TeV}$ pp

We can see the difference!
2009-2010 run summary

\( \sqrt{s} = 900 \ \text{GeV run (no crossing angle)} \)

06 Dec.- 15 Dec. 2009 (27.7 hrs, 500k collisions)
2.8k/3.7k single showers at Arm1/Arm2

02 May-27 May 2010 (15 hrs, 5.5M collisions)
44k/63k single showers at Arm1/Arm2

\( \sqrt{s} = 7 \text{TeV run (0 and 100 } \mu \text{ rad crossing angle)} \)

30 Mar.- 19 July, 2010 (~150 hrs.)
172M/161M single showes at Arm1/Arm2
345k/676k Pi0’s at Arm1/Arm2

Detectors were removed at 20 Jul. 2010
Def. of L90%

L20 & L90%: Data vs MC

Partilce ID

gamma like  shower transition curve  hadron like

Wednesday, September 1, 2010
900 GeV collisions

**Arm 1**

Normalization: by total number stat. error only

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**Gamma**

- Data
- DPMJET3
- QGSJET1
- QGSJET2
- SIBYLL
- EPOS

**Hadron**

- Data
- DPMJET3
- QGSJET1
- QGSJET2
- SIBYLL
- EPOS

**Small tower (w/o PID)**

- Data
- DPMJET3
- QGSJET1
- QGSJET2
- SIBYLL
- EPOS

**Large tower (w/o PID)**

- Data
- DPMJET3
- QGSJET1
- QGSJET2
- SIBYLL
- EPOS

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Wednesday, September 1, 2010
Arm1 and Arm2 are quite consistent
Preliminary conclusion at 900 GeV:
qgsjet2 is most consistent with the data
7TeV (3.5TeV x 3.5TeV) run

We expect our observation can tell a better model.
π\text{0} calibration

2 towers in each Arm enables this

π\text{0} mass

Arm 1

π\text{0} energy

Arm 2

Preliminary

highest energy π\text{0}
ever observed!
$\eta$ candidates

![Graph showing $\pi_0$ candidates and $\eta$ candidates with invariant mass in MeV on the x-axis and events per 10 MeV on the y-axis. The graph is labeled as preliminary.]
Wait a bit for the spectrum!
Summary

- LHCf has completed 0.9 and 7TeV runs
- Performance is as expected
- 7 TeV run result will appear soon and we will be able to tell the best model
- We will be back to the tunnel when 14 TeV beam will be ready
- Last but not least:
  We thank CERN and all the related staff at CERN for the successful LHCf operation
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Thank you for your attention
backup
$E_0 = 10^{19}$ eV
Vertical

- DPMJET 2.5
- QGSJET 01
- SIBYLL 2.1

number of charged particles

10^9

atmospheric depth (g/cm^2)

By Heck et al
7 TeV run

Arm 1

very preliminary

Arm 2
Muons are complex

Eta dist. of last interaction which produced muons:

$p \ 10^{17} \text{eV}$: Eta dist. at the last int. for obsvd mu
Number of muons produced from descendent of first interaction: $p \ 10^{17}$ eV

$dN_\mu/d\eta$

$10^{17}$ eV

$p10^{17}$ eV: eta dist. at first col. which finally gave mu at 875 g/cm^2