Recent Results from LHCf

Gaku Mitsuka (Nagoya University, Japan) for the LHCf collaboration
Outline

- Introduction and Physics motivation
- The LHCf detectors
- Status of the LHCf experiment
- First results at $\sqrt{s}=900\text{GeV}$ and $7\text{TeV}$
  - All data at $\sqrt{s}=900\text{GeV}$
  - Focusing on March-May at $\sqrt{s}=7\text{TeV}$
- Conclusions and Future prospects
Totally ~40 collaborators

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Introduction

The LHCf experiment...

- aims to reduce the uncertainty of hadron interaction models around the TeV energy region using LHC, which are mainly used in cosmic ray experiments.
- observes neutral particles produced by the p-p collisions emitted in the very forward (including zero degree, $\eta > 8.4$), equivalent to air-shower of cosmic ray.
- can discriminate the existing interaction models (e.g. DPMJET3, QGSJET, etc...) by comparison and provide crucial data for building future models.
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Forward measurements

- Zero degree instrumentation slot at 140m away from IP1 (ATLAS).
- p-p collision at $\sqrt{s}=14$ TeV corresponds to $E_{\text{lab}}=10^{17}$ eV.
Forward measurements

Fluxes of Cosmic Rays

Interests of UHE-CR obs.

CMS / TOT

ALICE

ATLAS / LHCf

26.7km

p-p collision at \( \sqrt{s} = 14 \text{TeV} \) corresponds to \( E_{\text{lab}} = 10^{17} \text{eV} \).
The LHCf detector

- Sampling & imaging calorimeters either side of IP1.
- Two compact towers in both detectors.
  - Tungsten absorbers: 44 r.l., 1.7\(\lambda\)
  - 16 plastic scintillator sampling layers
  - 4 position sensitive layers

Arm 1 detector

20mmx20mm + 40mmx40mm
Consists of scintillation fibers
Located at 6, 10, 30, 42 r.l.

Arm 2 detector

25mmx25mm + 32mmx32mm
Consists of silicon strip detector
Located at 6, 12, 30, 42 r.l.
Expected phenomena

All figures assume $10^7$ collisions@14TeV

- Spectrum in the forward region at 140m away from IP (=LHCf site).
- Energy resolution is taken into account by smearing the true energy instead of detector simulation.
- Neutron/Gamma ratio is also applicable to the discrimination.

<table>
<thead>
<tr>
<th>Particles/collision</th>
<th>Neutron Energy [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPMJET3</td>
<td>QGSJET1</td>
</tr>
<tr>
<td>QGSJET2</td>
<td>SIBYLL</td>
</tr>
<tr>
<td>30% Energy Resolution</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Particles/(200GeV)</th>
<th>Gamma Energy [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPMJET3</td>
<td>QGSJET1</td>
</tr>
<tr>
<td>QGSJET2</td>
<td>SIBYLL</td>
</tr>
</tbody>
</table>

Vertical bar indicates stat.err

$\gamma^0$
**Operation in 2009-10**

### Run in 2009
- From End of October 2009 LHC restarted operation
  - 450 GeV + 450 GeV → 1.2 TeV + 1.2 TeV
- Few weeks of ‘smooth’ running allowed LHCf to collect some statistics at 450+450 GeV in the stable beam conditions.
- Extremely useful period to debug all the system
  - No particular problem came out from the run
  - Detectors are working very well and in a stable way

### Run in 2010
- Successful data taking at 7TeV ongoing
  - Integrated luminosity ~ 14nb⁻¹ until the technical stop on May.
  - 35M showers and 330K π⁰s obtained ( arm1+arm2 ).
  - Energy scale calibration with a π⁰ peak.
- Statistics improved at 900 GeV >10times larger than 2009.
- Detector shows good performance with stable quality.
  - Good stability < ±2% level. No radiation problem until May.
Analysis@900GeV
(Run2009+2010)
Gamma and hadron showers can be discriminated by the difference of the longitudinal shower development. Longitudinal development is parametrized with L20% and L90%. PID performance is checked with SPS calibration data taken in 2007. - 50-200GeV for electrons - 150, 350 GeV for protons ~90% purity both for gamma and hadron. PID study is still ongoing.
Spectra of 900GeV data

- QGSJET2 seems to agree with data, *but conclusion is too early*.
- Note that the detector response for hadron showers is under study with SPS 350,150GeV proton data and very conservative systematic error for energy scale +10%-4% must be taken into account.

More precise analysis is ongoing.
Analysis@7TeV
Data taking has been carried out quite stably.

### Total Statistics in March 30 - May 30

<table>
<thead>
<tr>
<th></th>
<th>Gamma-like</th>
<th>Hadron-like</th>
<th>( \pi^0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm1</td>
<td>1.7E7</td>
<td>3.3E7</td>
<td>1.0E5</td>
</tr>
<tr>
<td>Arm2</td>
<td>1.8E7</td>
<td>3.5E7</td>
<td>2.3E5</td>
</tr>
</tbody>
</table>
**π₀ measurement**

\[ \theta = \frac{R}{140\text{m}} \]

**Event display of π₀(2-gamma)**

- **Lateral view**
- **Longitudinal view**

**π₀ mass**

- **Arm I**
  - \( \sigma = 6.3\text{MeV} \)

**π₀ energy**

- Extremely high energy \( \pi^0 \)
High statistics
- Only 1% of total data are used

Very clean sample
- Beam-gas BG is ~ 1%

Ongoing studies:
- Model discrimination
- $\eta$, strange meson
- LPM effects
η search

π⁰

η~50 events
LHCf will go out from the TAN(LHCf site) day after tomorrow.
- Plastic scintillator degrades a few % by >5Gy on July 15th (~200nb⁻¹).
- “Post”-calibration by a SPS test beam are planned on October.
- Revisit LHC at the next energy upgrade. R&D and fabrication of radiation-hard GSO scintillator are on-going for the “phase-2” of the LHCf detector.

GSO bar

GSO scintillator
Conclusions

- LHCf has started physics program quite successfully.
  - 100K showers at 900GeV (Run2009 + 2010)
  - 35M showers and 330K $\pi^0$ at 7TeV (Run2010 until May technical stop)

- Detectors work fine and stably.
  - Almost negligible beam-gas background ~1%
  - The $\pi^0$ peak demonstrates good performance as expected.

- Detectors will leave LHC tunnel on Tuesday.

- Rapid progress in analysis.
  - 900GeV results and 7TeV results, need more precise studies
  - Finalizing SPS beam test data (energy scale, PID and hadron shower)
Q&A

1. How to trigger signal far away from IP?
   - I explained the trigger scheme (BPTX, L1T, L2T).

2. Can you show the BG spectra?
   - I showed supplement plots and said “beam-gas MC is under study”.

3. Does LHCf has a luminosity monitor (because I omitted to mention FC in the talk) and plan to normalize by yourself?
   - I explained FC and said "uncertainty is about 25% and at first normalization must be free even if possible".

4. Can LHCf contribute to tune PYHITA at large eta area?
   - "Yes, but rapidity doesn't overlap with other experiments. Thus I'm not sure this can be useful to tune PYTHIA for MB events".

5. Can TOTEM do similar analysis and contribute to CR experiment? (from CMS guy)
   - "Yes, but contribution is rather indirect than LHCf".

6. Is LHCf the Cloud experiment? (asked at a lunch)
   - "No!!"
Supplements
Flux at $\sqrt{s}=7\text{TeV}$