CURRENT STATUS OF THE LHC FORWARD (LHCF) EXPERIMENT

Takashi SAKO for the LHCf Collaboration
Solar-Terrestrial Environment Laboratory / Kobayashi-Maskawa Institute,
Nagoya University, Japan

32nd ICRC, Beijing, China, 11-18 Aug 2011
Hadron interaction model
- major source of uncertainty -

LHC data is expected to reduce the uncertainty
What should be measured at colliders?

Multiplicity and energy flux at LHC 14TeV collisions

Pseudo-rapidity: $\eta = -\ln(\tan(\theta/2))$

<table>
<thead>
<tr>
<th>Multiplicity</th>
<th>Energy Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>All particles</td>
<td>Neutral particles</td>
</tr>
</tbody>
</table>

Most of the energy flows into very forward
The LHCf Collaboration

Solar-Terrestrial Environment Laboratory, Nagoya University, Japan

H. Menjo  
Kobayashi-Maskawa Institute, Nagoya University, Japan

K. Yoshida  
Shibaura Institute of Technology, Japan

Waseda University, Japan

T. Tamura  
Kanagawa University, Japan

M. Haguenauer  
Ecole Polytechnique, France

W. C. Turner  
LBNL, Berkeley, USA

O. Adriani, L. Bonechi, M. Bongi, R. D’Alessandro, M. Grandi, P. Papini, S. Ricciarini, G. Castellini  
INFN, Univ. di Firenze, Italy

K. Noda, A. Tricomi  
INFN, Univ. di Catania, Italy

J. Velasco, A. Faus  
IFIC, Centro Mixto CSIC-UVEG, Spain

A.-L. Perrot  
CERN, Switzerland
Detector Location

LHCf Detector (Arm#1)

Two independent detectors at either side of IP1 (Arm#1, Arm#2)

LHCf Detector (Arm#2)

96mm

TAN - Neutral Particle Absorber - transition from one common beam pipe to two pipes
Slot: 100mm(w) x 607mm(H) x 1000mm(T)
LHCF Detectors

- Imaging sampling shower calorimeters
- Two independent calorimeters in each detector (Tungsten 44r.l., 1.6λ, sample with plastic scintillators)
  (Detector performance; Mase et al., poster 378)

Arm#1 Detector
20mmx20mm+40mmx40mm
4 XY SciFi+MAPMT

Arm#2 Detector
25mmx25mm+32mmx32mm
4 XY Silicon strip detectors
Event category of LHCf

- Leading baryon (neutron)
- Multi meson production
- Single photon event
- Pi-zero event (photon pair)
- LHCf calos
- Single hadron event
Expected Results at $\sqrt{s}=14$ TeV Collisions
(MC assuming 0.1nb$^{-1}$ statistics)

Single photon

Detector response not considered

Single neutron
Summary of Operations in 2009 and 2010

With Stable Beam at 900 GeV

Total of 42 hours for physics
About 100 k showers events in Arm1+Arm2

With Stable Beam at 7 TeV

- Total of 150 hours for physics with different setups
- Different vertical position to increase the accessible kinematical range
- Runs with or without beam crossing angle
- ∼400 M shower events in Arm1+Arm2
- ∼1 M π^0 events in Arm1+Arm2

Status

- Completed program for 900 GeV and 7 TeV
- Removed detectors from tunnel in July 2010
- Post-calibration beam test in October 2010
- Upgrade to more rad-hard detectors to operate at 14 TeV in 2014
Operation

LHCf control room = barrack
**EM shower and π⁰ identification**

- A Pi0 candidate event
- 599GeV & 419GeV photons in 25mm and 32mm tower, respectively
- \( M = \theta \sqrt{E_1 \times E_2} \)  
  (Detail; Menjo et al., poster 1335)

![Graphs and diagrams showing longitudinal and lateral development of EM showers, and invariant mass of photon pairs.](image)

Comparison with models, coming soon
Particle ID

- EM and hadronic shower separation based on the longitudinal shower development
- $N_{\text{photon}}/N_{\text{hadron}}$ ratio will give a good information for model
- Response of detectors to hadrons in study

Detail in the next talk by G. Mitsuka
Photon spectra at $\sqrt{s}=7\text{TeV}$ collisions

- Spectra of Arm1, Arm2 at common rapidity
- $N_{\text{ine}} = \sigma_{\text{ine}} \int \text{L} \text{d}t$
  
  ($\sigma_{\text{ine}} = 71.5\text{mb}$ assumed; consistent with recent ATLAS result)
  
  (Luminosity determination ; Taki et al., poster 374)

Detail in the next talk by G. Mitsuka
Summary ~status of LHCf~

**Analysis**
- Photon spectra at $\sqrt{s} = 7$TeV published PLB in press, talk by Mitsuka
- Photon spectra at $\sqrt{s} = 0.9$ TeV in analysis
- $\pi^0$ spectra in analysis (poster by Menjo)
- Impact on EAS
- Energy determination improve (poster by Noda, 421)
- $P_T$ spectra
- Hadron spectra (photon/hadron ratio)
- Test for LPM effect
- Correlation with central production (joint analysis with ATLAS)

**Measurements**
- LHC $\sqrt{s} = 7$ TeV pp already completed
- LHC $\sqrt{s} = 14$ TeV pp scheduled after 2014; rad-hard upgrade on going (posters by Kawade, 959 and Suzuki, 264)
- LHC p-Pb in study
- Possibility in the other colliders
- Dream : N-p, N-N, N-Fe (N; Nitrogen) in future
Conclusion

Still many dishes to enjoy and cooking next dishes !!
Backup
① Inelastic cross section

If large $\sigma$
- rapid development
If small $\sigma$
- deep penetrating

② Forward energy spectrum

If softer
- shallow development
If harder
- deep penetrating

③ Inelasticity $k$

$(1 - E_{\text{leading}})/E_0$

If large $k$
- rapid development
If small $k$
- deep penetrating

④ Secondary interactions
2010 operation at $\sqrt{s}=7$TeV

Low luminosity (L=2~10e28cm$^2$s$^{-1}$)
(1~2.5e10ppb, $\beta^*=2m,N_b=1$~4)
No crossing angle

High luminosity (L=3~20e29cm$^2$s$^{-1}$)
(1e11ppb, $b^*=3.5m,N_b=1$~8)
100$\mu$rad crossing

- Detector removed
- 900GeV
- # of $\pi^0$
- 100K
- 500K
- 1000K
- 4/1 15/04 29/04 13/05 10/06 24/06 08/07 7/22
- 4/4 04/18 05/02 05/16 06/13 06/27 07/11 07/25
Game with modified meson spectrum

LHCf $\sqrt{s}=7$TeV
Gamma-ray like
$8.81 < \eta < 8.99, \Delta\phi = 20^\circ$

Data 2010, $\int Ldt=0.5 nb^{-1}$
- DPMJET 3
- DPMJET 3 (Modified)

Proton-Air simulations
$E_{\text{proton}} = 2.5\times10^{16}$ eV

Play within the model uncertainty
Play within the LHCf error
Acceptance ($\pi^0$)
Photon acceptance at √s = 14 TeV pp collision
Test for LPM effect

- Study by MC assures clear difference
- Careful treatment in ch-to-ch calibration is important
- Reanalysis of SPS data (<200GeV electron) on going