ALICE diffractive physics in p-p and Pb-Pb collisions at the LHC

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Abstract. The ALICE experiment at the Large Hadron Collider LHC is presently being commissioned. ALICE consists of a central barrel, a muon spectrometer and neutron calorimeters at 0°. Additional detectors for event classification and trigger purposes are located on both sides of the central barrel. The geometry of the ALICE detector allows the implementation of a diffractive double gap trigger by requiring two or more tracks in the central barrel but no activity in the event classification detectors. Some selected diffractive physics channels are discussed which become accessible by a double gap trigger. The interest of such diffractive measurements in proton-proton as well as in lead-lead collisions is outlined.

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THE ALICE EXPERIMENT

The ALICE experiment is designed for taking data in the high multiplicity environment of lead-lead collisions at the Large Hadron Collider (LHC) [1, 2]. The ALICE experiment consists of a central barrel covering the pseudorapidity range \(-0.9 < \eta < 0.9\) and a muon spectrometer in the range \(-4.0 < \eta < -2.4\). Additional detectors for trigger purposes and for event classification exist in the range \(-4.0 < \eta < 5.0\).

The ALICE Central Barrel

The detectors in the ALICE central barrel track and identify hadrons, electrons and photons in the pseudorapidity range \(-0.9 < \eta < 0.9\). The magnetic field strength of 0.5 T allows the measurement of tracks from very low transverse momenta of about 100 MeV/c to fairly high values of about 100 GeV/c. The tracking detectors are designed to reconstruct secondary vertices resulting from decays of hyperons, D and B mesons. The main detector systems for these tasks are the Inner Tracking System, the Time Projection Chamber, the Transition Radiation Detector and the Time of Flight array. These systems cover the full azimuthal angle within the pseudorapidity range \(-0.9 < \eta < 0.9\). Additional detectors with partial coverage of the central barrel are a PHOton Spectrometer (PHOS), an electromagnetic calorimeter (EMCAL) and a High-Momentum Particle Identification Detector (HMPID).
The ALICE Zero Degree Neutron Calorimeter

The Zero Degree Neutron Calorimeters (ZDC) are placed on both sides of the interaction point at a distance of 116 m. The ZDC information can be used to select different diffractive topologies. Events of the types $pp \rightarrow ppX, pN^*X, N^*N^*X$ will have no signal, signal in one or in both of the ZDC calorimeters, respectively. Here, X denotes a centrally produced diffractive state from which the diffractive L0 trigger is derived.

THE ALICE DIFFRACTIVE GAP TRIGGER

Additional detectors for event classification and trigger purposes are located on both sides of the ALICE central barrel. First, an array of scintillator detectors (V0) is placed on both sides of the central barrel. These arrays are labeled V0A and V0C on the two sides, respectively. Each of these arrays covers a pseudorapidity interval of about two units with a fourfold segmentation of half a unit. The azimuthal coverage is divided into eight segments of $45^0$ degrees hence each array is composed of 32 individual counters. Second, a Forward Multiplicity Detector (FMD) is located on both sides of the central barrel. The pseudorapidity coverage of this detector is $-3.4 < \eta < -1.7$ and $1.7 < \eta < 5.1$, respectively.

![Figure 1](image.png)

FIGURE 1. Pseudorapidity coverage of trigger detectors and of detectors in central barrel

Fig. 1 shows the pseudorapidity coverage of the detector systems described above. The geometry of the central barrel in conjunction with the additional detectors V0 and FMD is well suited for the definition of a rapidity gap trigger. Such a gap trigger can be defined by the requirement of signals coming from the central barrel detectors while V0 and FMD not showing any activity. This scheme requires a trigger signal from within the central barrel for L0 decision. The pixel detector of the Inner Tracking System or the Time Of Flight array can deliver such a signal.

The high level trigger HLT has access to the information of all the detectors shown in Fig. 1 and will hence be able to select events with rapidity gaps in the range $-4 < \eta < -1$ and $1 < \eta < 5$. These gaps extend over seven units of pseudorapidity and are hence expected to suppress minimum bias inelastic events by many orders of magnitude.
In addition to the scheme described above, the ALICE diffractive L0 trigger signal can be generated from the Neutron ZDC if no central state is present in the reaction. A L0 signal from ZDC does not arrive at the central trigger processor within the standard L0 time window. A L0 trigger from ZDC is, however, possible during special data taking runs for which the standard L0 time limit is extended.

**ALICE DIFFRACTIVE PHYSICS**

The tracking capabilities at very low transverse momenta in conjunction with the excellent particle identification make ALICE an unique facility at LHC to pursue a long term physics program of diffractive physics. The low luminosity of ALICE as compared to the other LHC experiments restricts the ALICE physics program to reactions with cross section at a level of a few nb per unit of rapidity.

![FIGURE 2. Rapidity and transverse momentum acceptance of the LHC experiments](image)

Fig.2 shows the transverse momentum acceptance of the four main LHC experiments. Not shown in this figure is the TOTEM experiment. The acceptance of the TOTEM telescopes is in the range of $3.1 < |\eta| < 4.7$ and $5.3 < |\eta| < 6.5$. The CMS transverse momentum acceptance of about 1 GeV/c shown in Fig.2 represents a nominal value. The CMS analysis framework foresees the reconstruction of a few selected data samples to values as low as 0.2 GeV/c[5].

**POMERON SIGNATURES IN PROTON-PROTON COLLISIONS**

The ALICE experiment will take data in proton-proton mode at a luminosity of $\mathcal{L} = 5 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$. Double pomeron events in proton-proton collisions as shown in Fig.3 are expected to possess a few interesting properties.

- The production cross section of glueball states is expected to be enhanced in Pomeron fusion events as compared to minimum bias inelastic events. It will therefore be interesting to study the resonances produced in the central region when two rapidity gaps are required[6].
The slope $\alpha'$ of the Pomeron trajectory is rather small: $\alpha' \sim 0.25 \text{ GeV}^{-2}$ in DL fit and $\alpha' \sim 0.1 \text{ GeV}^{-2}$ in vector meson production at HERA[7]. These values of $\alpha'$ in conjunction with the small $t$-slope ($< 1 \text{ GeV}^{-2}$) of the triple Pomeron vertex indicate that the mean transverse momentum $k_t$ in the Pomeron wave function is relatively large $\alpha' \sim 1/k_t^2$, most probably $k_t > 1 \text{ GeV}$. The transverse momenta of secondaries produced in Pomeron-Pomeron interactions are of the order of this $k_t$. Thus the mean transverse momenta of secondaries produced in Pomeron-Pomeron fusion is expected to be larger as compared to inelastic minimum bias events.

- The large $k_t$ described above corresponds to a large effective temperature. A suppression of strange quark production is not expected. Hence the $K/\pi$ ratio is expected to be enhanced in Pomeron-Pomeron fusion as compared to inelastic minimum bias events[8]. Similarly, the $\eta/\pi$ and $\eta'/\pi$ ratios are expected to be enhanced due to the hidden strangeness content and due to the gluon components in the Fock states of $\eta, \eta'$.

**POMERON SIGNATURES IN LEAD-LEAD COLLISIONS**

ALICE will take data in lead-lead mode at a luminosity of $\mathcal{L} = 5 \times 10^{27} \text{ cm}^{-2} \text{s}^{-1}$.

The cross section of double pomeron induced reaction channels will be modified as compared to the proton-proton case due to absorption and screening as illustrated in Fig.4. The A-dependence of the cross section for specific pomeron induced channels hence reflects the contribution of these multi-pomeron diagrams. The study of multi-pomeron couplings is an important ingredient in the analysis of soft diffraction data and in the evaluation of the total pp cross section at LHC energies[9].
ODDERON SIGNATURES

Odderon signatures can be looked for in exclusive reactions where the Odderon (besides the Photon) is the only possible exchange. Diffractively produced C-odd states such as vector mesons $\phi, J/\psi, \Upsilon$ can result from Photon-Pomeron or Odderon-Pomeron exchange. Any excess beyond the Photon contribution is indication of Odderon exchange.

Cross section estimates for diffractively produced $J/\psi$ in pp collisions at LHC energies were first given by Schäfer [10]. More refined calculations result in a $t$-integrated photon and Odderon contribution of $\frac{d\sigma}{dy}\big|_{y=0} \sim 15 \text{ nb}$ and 1 nb, respectively [11].

If the diffractively produced final state is not an eigenstate of C-parity, then interference effects between photon-Pomeron and photon-Odderon amplitudes can be analyzed.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure5.png}
\caption{photon-Pomeron and photon-Odderon amplitudes}
\end{figure}

Fig. 5 shows the photon-Pomeron and the photon-Odderon amplitudes for $q\bar{q}$ production. A study of open charm diffractive photoproduction estimates the asymmetry in fractional energy to be on the order of 15% [12]. The forward-backward charge asymmetry in diffractive production of pion pairs is calculated to be on the order of 10% for pair masses in the range $1 \text{ GeV}/c^2 < m_{\pi^+\pi^-} < 1.3 \text{ GeV}/c^2$ [13, 14].

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REFERENCES

1. F. Carminati et al, ALICE Collaboration, J. Phys. G 30 (2004) 1517
2. B. Alessandro et al, ALICE Collaboration, J. Phys. G 32 (2006) 1295
3. R. Arnaldi et al, Nucl. Instr. and Meth. A 564 (2006) 235
4. The ALICE coll., K. Aamodt et al, The ALICE experiment at the CERN LHC, (2008) JINST_3_S08002
5. D. d’Enterria et al, Addendum CMS technical design report, J. Phys. G 34 (2007) 2307
6. F. Close et al, Phys. Lett. B 477 (2000) 13
7. A. Donnachie et al, Phys. Lett. B 595 (2004) 393
8. T. Åkesson et al, Nucl. Phys. B 264 (1986) 154
9. A. Martin, these proceedings
10. A. Schäfer et al, Phys. Lett. B 272 (1991) 419
11. A. Bzdak et al, Phys. Rev. D 75 (2007) 094023
12. S.J. Brodsky et al, Phys. Lett. B 461 (1999) 114
13. P. Hägler et al, Phys. Lett. B 535 (2002) 117
14. I.F. Ginzburg et al, Eur. Phys. J. C5 (2003) 02