Measurement of the electromagnetic dissociation cross section at LHC with the ALICE Zero Degree Calorimeters

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1 Introduction

In ultra-peripheral collisions, where the two interacting nuclei collide at impact parameter larger than the sum of the nuclear radii, the interaction is purely electromagnetic. The impact of the Lorentz-boosted Coulomb field of a nucleus on the collision partner is usually treated as the absorption of virtual photons according to the Weizsacker-Williams method [1]. In particular two Coulomb induced processes, the bound-free pair production and the electromagnetic dissociation (EMD), have attracted special attention in the last years, since they limit strongly the beam lifetime in heavy-ion colliders [2]. A first measurement of cross section for electromagnetic dissociation of ^{208}Pb nuclei at $\sqrt{s_{NN}} = 2.76$ TeV was performed [3] by means of the Zero Degree Calorimeters (ZDC) of the ALICE experiment [4]. The ZDCs are ideally suited to tag EMD interactions since the most abundant particles produced in these processes are neutrons, which are expected to be emitted very close to beam rapidity. The data were collected using the neutron ZDCs (ZNs), located on both sides of the beam interaction point (IP), called A and C sides in ALICE, z=114 m away from the IP. Each ZN is placed at zero degree with respect to the LHC axis and detects neutral particles at pseudorapidities $\eta \geq 8.7$. For the present analysis two small forward electromagnetic calorimeters (ZEM), placed at z=7.35 m from the IP ($4.8 \leq \eta \leq 5.7$), on A side, are also used. The experimental results are presented and compared to theoretical predictions of the Relativistic ELectromagnetic DISsociation (RELDIS) model [5], which describes the electromagnetic interactions of ultra-relativistic heavy-ions.

2 Experimental results and theoretical predictions

During the $\sqrt{s_{NN}} = 2.76$ TeV Pb-Pb data taking, a dedicated EMD run was performed (3×10^6 events collected), requiring a minimum energy deposition in at least one of the two ZNs[1]. The trigger tagged mostly neutrons emitted in single EMD[2]

[1] Energy threshold: ~450 GeV for ZNA and ~500 GeV for ZNC.
[2] Single EMD: at least 1n emitted by one of the two Pb nuclei.

as well as hadronic interactions (see Figure 1, left panel), while mutual EMD[3] plus hadronic events are selected requiring a minimum signal in both ZNs (see Figure 1, right panel).

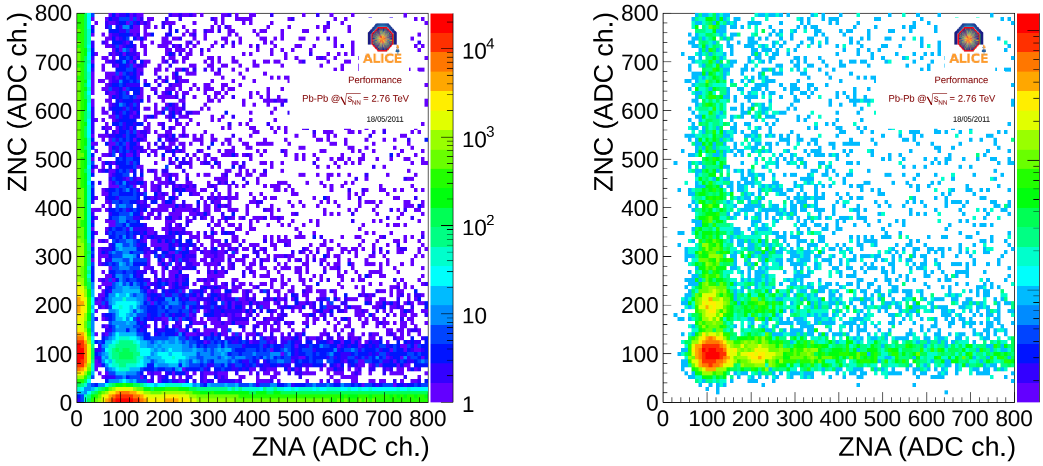

Figure 1: ZNC vs. ZNA ADC signal for single EMD plus hadronic events (left) and for mutual EMD plus hadronic events (right). The 1n signal is at channel ∼100.

In the 2010 Pb run ZNs were used as the ALICE luminometer, providing in particular three different logical combinations of signals during the van der Meer (vdM) scan [6] as reported in Table 1. The cross sections for the different processes measured during the vdM scan are still preliminary, including the systematic errors. These are of the order of (-6%+12%), with ±5% uncertainty coming from the ALICE vdM analysis and (-3% +11%) from LHC beam current evaluation.

The ADC spectrum for ZN side A is shown in Figure 2 (left panel), for events in which there is signal in at least one of the two ZNs. In both ZNA and ZNC ADC

[3]Mutual EMD: at least 1n emitted by both Pb nuclei.

ZDC Trigger	Physical Process	preliminary $\sigma^{vdM}(barn)$
ZNA OR ZNC	2×single EMD - mutual EMD + hadronic	362.61 ± 0.02 stat. $^{+43.88}_{-21.03}$ syst.
(ZNA AND ZNC) AND NOT (ZEM1 OR ZEM2)	mutual EMD	5.91 ± 0.18 stat. $^{+0.72}_{-0.34}$ syst.
(ZNA AND ZNC) AND (ZEM1 OR ZEM2)	hadronic	7.08 ± 0.15 stat. $^{+0.86}_{-0.41}$ syst.

Table 1: Preliminary results from the $\sqrt{s_{NN}} = 2.76$ TeV PbPb van der Meer scan.

spectra a strong 1n peak at channel ∼100 is present, but also smaller 2n, 3n, 4n, 5n... peaks are clearly identified. The pedestal peak, at channel ∼0, corresponds to neutron emission on the other side. The resolution on the 1n peak (1.38 TeV) is of the order of 20%(RMS). The number of events for single EMD plus hadronic processes is calculated subtracting the pedestal contribution, for both ZNs separately.

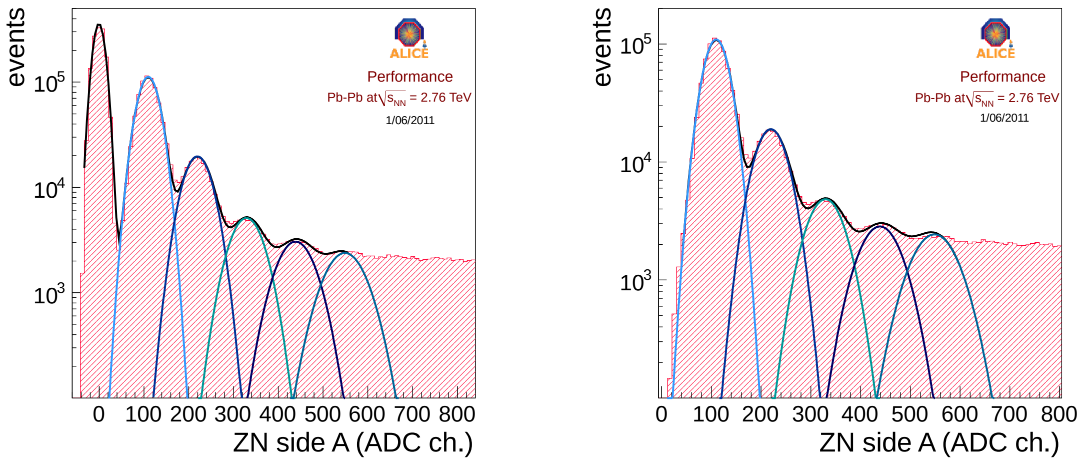

Figure 2: ZNA ADC spectra requiring signal in ZNA or ZNC (left) or in ZNA but not in ZNC (right).

In order to reject the hadronic events, a second event selection is performed requiring a signal in one ZNs but not in the other one (see Figure 2, right panel). In this case the selected process is the single EMD minus mutual EMD. The cross sections for both selected processes, shown in Table 2, are calculated using the (ZNA OR ZNC) cross section measured during the vdM scan.[4] The calculated values are

[4] $\sigma_{proc} = \sigma^{vdM}_{ZNA\,OR\,ZNC} \times N_{proc}/N_{ZNA\,OR\,ZNC}$, where N_{proc} is the number of events in our sample for the selected process and $N_{ZNA\,OR\,ZNC}$ is the number of events collected with the same trigger used to determine $\sigma^{vdM}_{ZNA\,OR\,ZNC}$.

Physical Process	$\sigma(barn)$-Preliminary Data	$\sigma(barn)$-RELDIS
single EMD + hadronic	195.6±0.1 stat. $^{+24.2}_{-11.7}$ syst.	192.9±9.2
single EMD - mutual EMD	176.9±0.1 stat. $^{+21.6}_{-10.6}$ syst.	179.7±9.2
mutual EMD	5.7±0.2 stat. $^{+0.7}_{-0.3}$ syst.	5.5±0.6
single EMD	185.7±0.2 stat. $^{+22.6}_{-11.1}$ syst.	185.2±9.2

Table 2: EMD cross sections for $\sqrt{s_{NN}} = 2.76$ TeV PbPb interactions.The systematic errors are dominated by the uncertainty on the vdM analysis.

corrected for the ZN detection probability (∼99%), estimated through a Monte Carlo using RELDIS as event generator.

The predictions of the RELDIS model for $\sqrt{s_{NN}} = 2.76$ TeV Pb-Pb EMD interactions are shown in Table 2. The error on $\sigma_{SingleEMD}$ includes the difference between RELDIS and other theoretical predictions [7].

Finally, in order to select mutual EMD and hadronic events, a minimum energy deposition in both ZNs is required. In order to disentangle the two processes the signal coming from the two ZEMs is taken into account respectively selecting events with no signal in any ZEMs or signal in at least one of the two ZEMs[5]. The ZEM trigger efficiencies for mutual EMD and hadronic event selection, calculated from simulation using respectively RELDIS and HIJING[8] plus a simple fragmentation model as event generator, are respectively of $97.0 \pm 0.6\%$ and $92.2 \pm 1.1\%$. Applying these correction factors, we estimated the contamination of hadronic events in the mutual EMD sample and then we calculated the related cross section value. The results are summarized and compared to the RELDIS prediction in Table 2.

3 Conclusions

A first measurement of Coulomb dissociation in $\sqrt{s_{NN}} = 2.76$ TeV Pb-Pb collisions was performed at LHC, detecting the emitted neutrons with the ALICE ZDCs. The predictions from the RELDIS model are in very good agreement with experimental results within systematic errors. The ALICE ZDCs can therefore provide an independent check of the beam luminosity measuring the rate of neutron emission by EMD processes. This luminosity estimate relies mainly on the accuracy on the theoretical calculation.

References

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[5]Energy threshold for each ZEM: ∼15 GeV.