Coulomb Dissociation Measurements in Isobaric Collisions at $\sqrt{s_{NN}}$ = 200 GeV with The STAR Experiment

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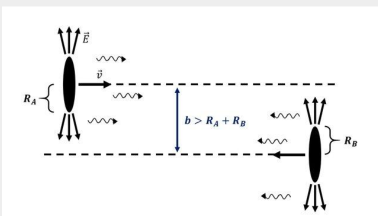
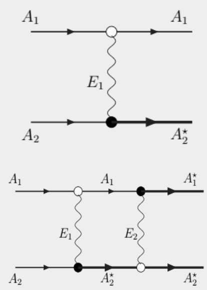
Abstract

The STAR experiment has collected a large dataset from isobaric (same mass but different proton number) collisions, providing a unique opportunity to study differences in electromagnetic effects. These effects can be analyzed by measuring neutron emission during ultra-peripheral collisions. We present new measurements of neutron emission from Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}} = 200$ GeV, including cross-section calculation for various neutron emission channels associated with both Single- and Mutual-Coulomb dissociation. The measurements, performed using the STAR Zero-Degree Calorimeter (ZDC), demonstrate how electromagnetic effects—driven by proton number differences in isobars—shape neutron emission behavior.

Introduction





Ultra-peripheral collisions

- Two ions ($v \sim$ c) pass each other ($b > 2R$).
- Cloud of virtual photon as EM sources [1,2].
- Neutron emission due to photoabsorption.

Coulomb dissociation

- One ion absorbing other emitted photon affects neutron emission (one side).
- Both ions emitting and absorbing photon follow neutron emission (both sides).

Dataset & Detector Part

- Run 18 of STAR Isobar (Ru+Ru & Zr+Zr, $\sqrt{s_{NN}} = 200$ GeV).

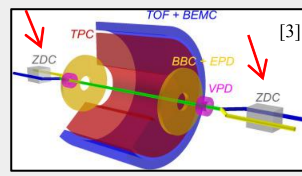
Ru	Zr
A = 96	A = 96
Z = 44	Z = 40
N / Z ≈ *1.18*	N / Z ≈ *1.40*

Trigger

- ZDC-Monitor (ZDC-Mon) with luminosity ≈ *1.10* μbarns^{-1}.
  Triggering at least 1n- threshold of both east and west side.
- Zerobias with luminosity ≈ *2.89* mbarns^{-1}.
  Unbiased trigger & built on RHIC-clock.

STAR Detector

- **Z**ero-**d**egree **C**alorimeter (ZDC).
  Neutral particle detector.
- **B**eam-**b**eam **C**ounter (BBC).
  Detector for vetoing hadronic particle.



Extracting Coulomb dissociation Signal

- Avoiding hadronic particle by applying BBC veto.
- Using ZDC to select the associated neutron emission channels :
  > Single-Coulomb dissociation : (0n1n), (0nXn), and (0nXn+Xn0n).
  > Mutual-Coulomb dissociation : (1n1n), (1nXn), and (XnXn).
- Extract neutron emission through fitting procedures.
- Calculate **cross-section** for each neutron channel.

$$TotalFit = g_1(x,\mu_1,\sigma_1) + g_2(x,\mu_2,\sigma_2) + g_3(x,\mu_3,\sigma_3) + eg(x,\mu_4,\sigma_4)$$

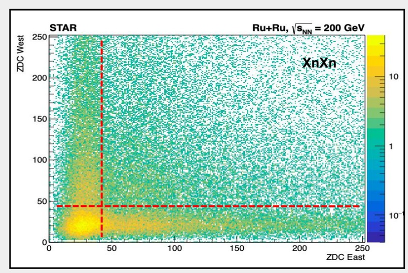
$$g(x,\mu,\sigma) = \frac{A}{2\sigma\sqrt{\pi}} \exp -\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2 \qquad eg(x,\mu,\sigma) = A\left(\frac{\lambda}{2}\exp\left(\frac{\lambda}{2}(2\mu+\lambda\sigma^2-2x)\right)\left(1+erf\left(\frac{x-\mu-\lambda\sigma^2}{\sigma\sqrt{2}}\right)\right)\right)$$

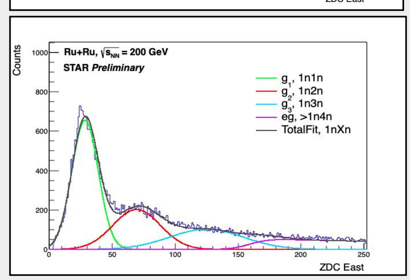
with $\mu_2 = 2\mu_1$; $\mu_3 = 3\mu_1$; $\sigma_2 = \sqrt{2}\sigma_1$; $\sigma_3 = \sqrt{3}\sigma_1$;

Cross-section

$$\sigma_{cd} = \frac{\sum N_{cd}}{L}$$

- σ_{cd} = Cross-section of Coulomb dissociation.
- $\sum N_{cd}$ = Number of event.
- L = Luminosity.





Coulomb dissociation Measurement

➢ **Single-Coulomb dissociation (SCD)**

Neutron	Ru (b)	Zr (b)	Ratio (Ru/Zr)
0n1n	$2.006 \pm 0.017 \pm 0.204$	$1.255 \pm 0.014 \pm 0.127$	$1.598 \pm 0.022 \pm 0.040$
0nXn	$4.478 \pm 0.022 \pm 0.452$	$4.360 \pm 0.022 \pm 0.444$	$1.027 \pm 0.007 \pm 0.024$
0nXn+Xn0n	$8.956 \pm 0.044 \pm 0.904$	$8.720 \pm 0.043 \pm 0.887$	$1.027 \pm 0.007 \pm 0.024$

➢ **Mutual-Coulomb dissociation (MCD)**

Neutron	Ru (mb)	Zr (mb)	Ratio (Ru/Zr)
1n1n	$14.210 \pm 0.085 \pm 1.698$	$6.511 \pm 0.055 \pm 0.792$	$2.182 \pm 0.023 \pm 0.208$
1nXn	$47.608 \pm 0.143 \pm 5.531$	$33.225 \pm 0.112 \pm 3.802$	$1.433 \pm 0.006 \pm 0.116$
XnXn	$167.993 \pm 0.390 \pm 20.947$	$190.190 \pm 0.420 \pm 23.506$	$0.883 \pm 0.003 \pm 0.092$

Table 1. Preliminary result of the Coulomb dissociation measurement

Summary & Outlook

✓ Cross sections of the Coulomb dissociations in isobar collisions have been measured by STAR.
✓ Cross sections are significantly higher in Ru+Ru than Zr+Zr for single-neutron channels (MCD 1n1n &1nXn; SCD 0n1n) but show no significant difference for total-neutron emission channels (SCD 0nXn, MCD XnXn).
✓ Cross-section comparisons in Ru+Ru vs. Zr+Zr collisions suggest differences in their E&M response, pointing to possible nuclear structure effects.

❖These preliminary result will be used to further study the nuclear structure.

References:

[1] C.F. von Weizsacker, Z. Phys. 88 (1934) 612.
[2] E.J. Williams, Phys. Rev. 45 (1934) 729.
[3] J. Adam, et. al. Nucl. Inst, Meth. A 1013 (2021) 165644

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