SEARCH FOR NEW PHYSICS WITH ULTRA-PERIPHERAL COLLISIONS IN ALICE

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SEARCH FOR NEW PHYSICS WITH ULTRA-PERIPHERAL COLLISIONS IN ALICE

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Contents

0.1 Abstract

The ALICE experiment at CERN LHC was designed to study heavy ion collisions as well as proton collisions. Electromagnetic interactions are present in such collisions; The electromagnetic field of a charged particle moving at ultrarelativistic velocities can be considered as a photon cloud that surrounds the particle. The photon cloud of a projectile nucleus can interact with the entire target nucleus, its constituents or its photon cloud, giving as result the production of new particles. To distinguish these processes from hadronic processes a condition in the impact parameter is required, it must be bigger than the raddi sum of colliding particles. Collisions that met this requirement are called ultraperipheral.
The study of τ-τ photoproduction at ALICE in ultraperiperipheral Pb-Pb collisions at $\sqrt{S}_{NN} = 5.02 TeV$ is presented.

0.2 Introduction

ALICE(A Large Ion Collider Experiment) is a major experiment at the Large Hadron Collider (LHC), Geneva, which is optimized for the study of QCD matter created in high-energy collisions between lead nuclei, though additional studies can be carried out due to the great capabilities of triggering and tracking of the detectors in ALICE. One of such studies are the ultraperipheral collisions in which particles do not interact hadronically, the interaction occurs through the electromagnetic field that surrounds them. The ALICE experiment is one of big experiments at the Large Hadron Collider (LHC) at CERN. It has been designed to study Quantum Chromodynamics (QCD) in dense environment, where thousands of particles are observed, and sparse environment with just few of them. ALICE has collected data coming from Pb-Pb collisions at the centre-of-mass energy per nucleon pair $\sqrt{s_{NN}} = 5.02\ TeV$ for different centrality classes. The central collisions are head-on collisions with the largest nuclei overlap. There is little overlap of two nuclei in ultra peripheral collisions (UPCs). UPCs provide a clear environment for studies photoproduction mechanisms. One of the processes of particular interest is the tau lepton pair photoproduction in Pb-Pb UPC. The cross section for 2 this process scales with Z^4, however, it is also suppressed by α_{EM} (α_{EM} is the fine structure constant). The difficulties related to tau leptons are coming from the fact that they decay quickly and cannot be observed directly. Moreover, they decay with at least one neutrino. What is particularly interesting in the tau lepton pair production, is the fact that this process is sensitive to the new physics hidden in the anomalous magnetic moment of tau lepton (a_τ). A measurement of tau lepton pair production can be used to constrain a_τ. The best experimental measurement of a_τ comes from DELPHI experiment and is $a_\tau = -0.018(17)$. However, Standard Model theoretical calculations are way more precise $a_\tau^{th} = 0.00117721(5)$. Recently, tau pair production was observed in CMS and ATLAS experiments with just few hundreds of events in data coming from Run 2. The similar statistics is expected in ALICE, which has an excellent low momentum particle tracking.

0.3 Ultra-Peripheral Collisions

An atom in its ground state can be taken to a excited state when it is irradiated with light of certain frequency; the atom energy raises due to the absorption of photons. Eventually the atom will return to its ground state through photons emission. On the other hand, a moving charged particle passing near a point p generates an electric field which changes over time at this point (and in the whole space), it can be shown that the electric field at this point is equivalent to light with certain frequency distribution passing through this point. And if an atom is placed at p a similar phenomena as the presented in the beginning will occur. Ultra-peripheral collisions (UPCs) are a type of collision between nuclei where the impact parameter[1], b, is large than the sum of their radius (see figure 1).

The strong interaction is not possible because the range on interation is significantly large. So they interact via the induced photons due to electromagnetic interaction. The photon flux scales with Z^2 for that we choose lead as nuclei for our collisions ($Z_{Pb} = 82$)

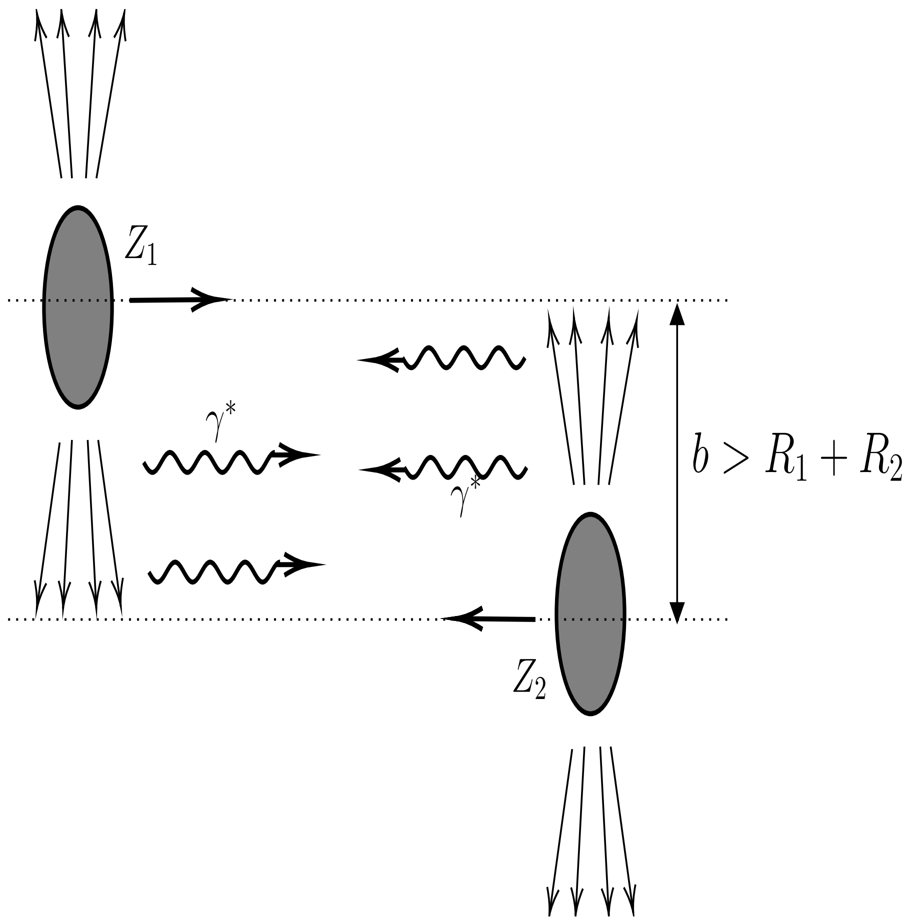

Figure 1: Illustration of UPCs collisions.

0.4 Motivations

In the lead-lead collisions the nuclei extchange photons and those photons materialized and create double taus, $\tau^{\pm}$, wich decay to new particles in the final state (see figure 2).

[1]impact parameter is the distance between the center of mass of the two nuclei.

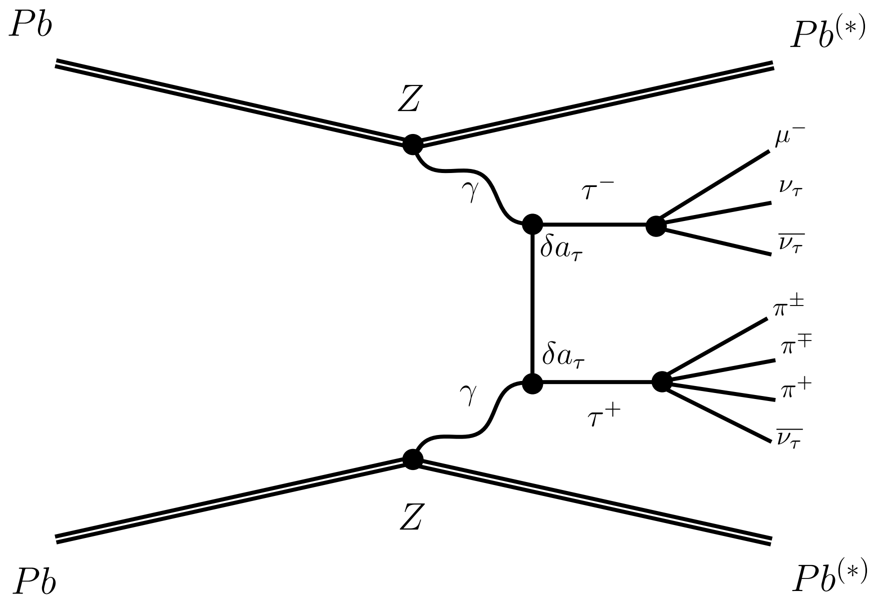

Figure 2: The Feynman diagram corresponding to lead-lead collision.

In this case τ leptons decays quickly and can not be observed directly due to at least 1 ν in each τ dacay and the cross section of τ pair production cross with Z^4.
One of the importante motivation is that τ pair production is sensitive to anomalous magnetic moment given by:

$$a_l = \frac{g_l - 2}{2}$$

Experimentaly we found that $a_\tau^{exp} = -0.018(17)$ [1], and acoording to the standard model $a_\tau^{th} = 0.00117721(5)$ [2]. This diference can be checken by styding lead-lead collision since the cross section and tau kinematics sensitive to a_τ [3, 5].

0.5 ALICE detector

ALICE (A Large Ion Collider Experiment) is a general-purpose, heavy-ion detector at the CERN LHC which focuses on QCD, the strong interaction sector of the Standard Model. It is designedto address the physics of strongly interacting matter and the quark-gluon plasma at extreme valuesof energy density and temperature in nucleus-nucleus collisions. It will allow a comprehensivestudy of hadrons, electrons, muons, and photons produced in the collision of heavy nuclei (Pb-Pb), up to the highest multiplicities anticipated at the LHC. The physics programme also includescollisions with lighter ions and at lower energy, in order to vary energy density and interactionvolume, as well as dedicated proton-nucleus runs. Data taking during proton-proton runs at thetop LHC energy will provide reference data for the heavy-ion programme and address a number ofspecific strong-interaction topics for which ALICE is complementary to the other LHC detectors.
The ALICE detector is built by a collaboration including currently over 1000 physicists andengineers from 105 Institutes in 30 countries. Its overall dimensions are 161626 m^3 with atotal weight of approximately 10 000 t. ALICE consists of a central barrel part, which measureshadrons, electrons, and photons, and a forward muon spectrometer. The central part covers polarangles from 45 deg to 135 deg and is embedded in a large solenoid magnet reused from the L3 experiment at LEP (Large Electron-Positron Collider). From the inside out, the barrel contains an Inner Tracking System (ITS) of sixplanes of high-resolution silicon pixel

(SPD), drift (SDD), and strip (SSD) detectors, a cylindrical Time-Projection Chamber (TPC), three particle identification arrays of Time-of-Flight (TOF), RingImaging Cherenkov (HMPID) and Transition Radiation (TRD) detectors, and two electromagnetic calorimeters (PHOS and EMCal). All detectors except HMPID, PHOS, and EMCal cover the fullazimuth. The forward muon arm (2○–9○) consists of a complex arrangement of absorbers, a largedipole magnet, and fourteen planes of tracking and triggering chambers. Several smaller detectors(ZDC, PMD, FMD, T0, V0) for global event characterization and triggering are located at smallangles. An array of scintillators (ACORDE) on top of the L3 magnet is used to trigger on cos-mic rays.
Most detector systems will be installed and ready for data taking by mid 2008 when the LHCis scheduled to start operation, with the exception of parts of PHOS (1 out of 5 modules installed),TRD (4 out of 18), PMD, and EMCal (construction started in 2008). These detectors will becompleted for the high-luminosity ion runs expected in 2010 and after.
The sub-detectors used in our analysis are:

- TOF : Time of Flight Detector, as it's name provides the time resolution. The time measured by the TOF, in conjunction with the moment and the length of the trajectory measured by the TPC and the ITS, is used to calculate the mass of the particles. Charged particle PID in the intermediate momentum range is provided by TOF. The TOF also provides a trigger for ultraperipheral collisions.

- V0 : Measure particles produced in collisions whose trace forms a small angle with respect to the beam axis, it consists of 2 counter arrays of scintillating plastic, called V0A and V0C, which are located asymmetrically on both sides of the interaction point. It has 2 parts V0A and V0C.

  Provide minimum bias trigger signals for center barrel detectors in p-p and Pb-Pb collisions.

  Each of the 64 channels can measure the charge of the incident particles and the moment at their arrival.

  Serve as an indicator of the centrality of the collision according to the multiplicity recorded in the event; there is a monotone dependence between the number of particles recorded in the V0 arrays and the number of primary particles emitted.

  Measurement of luminosity in pp collisions with a good precision of about 10%

  Identify Beam-Gas background; Due to the vacuum generated inside the beam tube is not ideal, there are gas particles inside it with which the beam particles can interact and generate background-fake signals in the detectors. The arrival time of the signal in the V0A and V0C modules is used in order to eliminate these noise signals. In the case of ultra–peripheral collisions the V0 detectors are used as veto detectors and are required to be empty in order to suppress avoid hadronic interactions.

- AD : The AD detector (ALICE Diffractive) is composed of 2 subdetectors called ADA and ADC, each one consists of 2 detector plates and each plate of four scintillation detector stations. This is a detector dedicated to the study of hard and soft diffractive events. In ALICE Experiment, it provides access the region of very low transverse moment of the particles produced.

- ZDC : Zero Degree Calorimeters (ZDCs), placed on the beam axis, providing a measurement of energy carried away by the non-interacting (spectator) nucleons directly related with the centrality of the collision.

- TPC : Time Projection Chamber and ITS : ITS (Inner Tracking System) are one of the three main tracking detectors.

- ZVertex: The purpose of a vertex detector is to measure position and angles of charged particle tracks to sufficient precision so as to be able to separate tracks originating from decay vertices from those produced at the interaction vertex. Such measurements are interesting because they permit the detection of weakly decaying particles with lifetimes down to 10-13s, among them the lepton and charm and beauty hadrons.

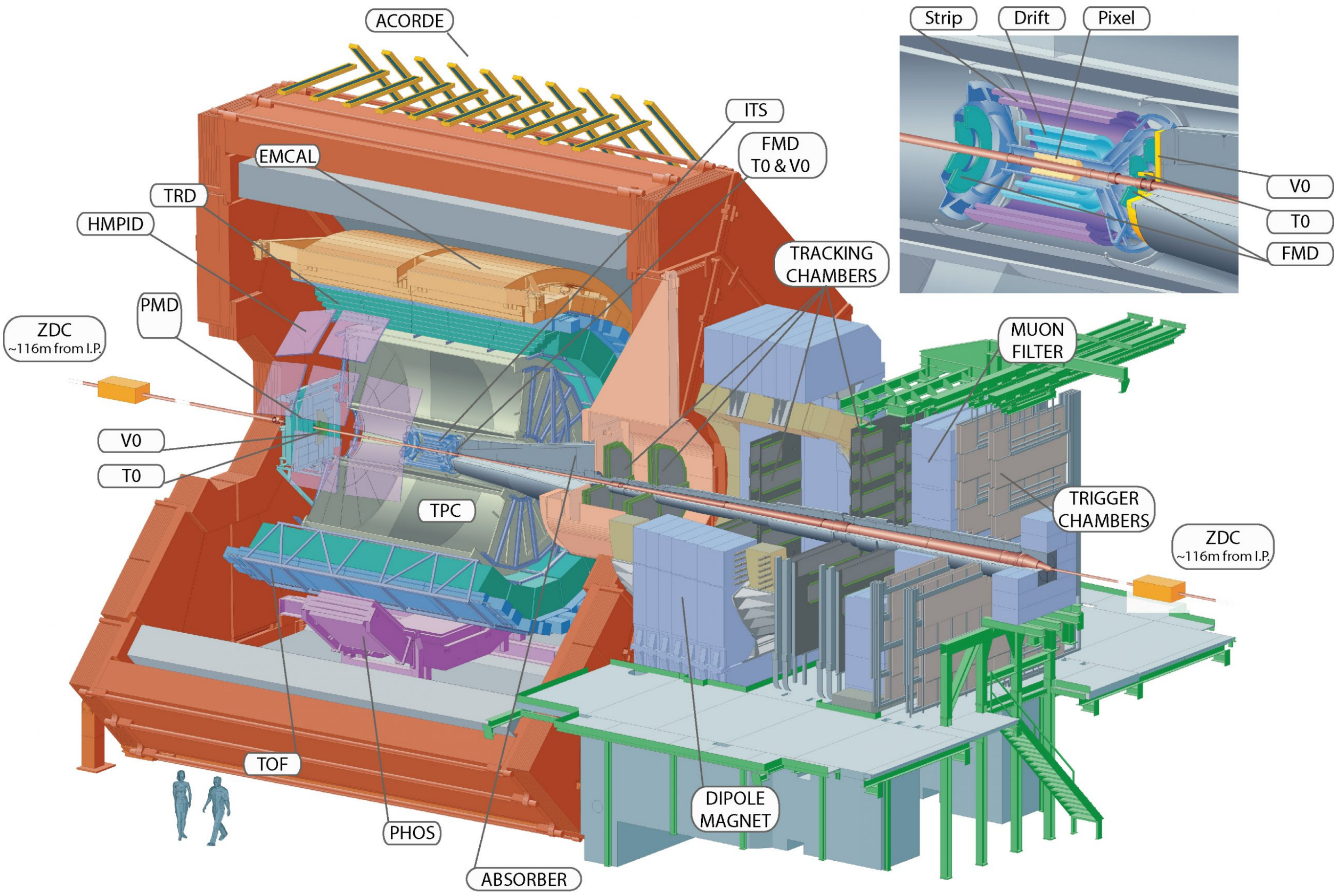

Figure 3: ALICE detector.

0.6 Selections

These are the certain selections we applied in the kinematic range we decided to study:

- UPC Triggers require certain angle between tracks found in ITS, some information from TOF and rapidity gap.

- Vertex: $|Vz| < 10cm\ +\ N_{vertex\ contributors} > 1$; A primary vertex in $\pm$ 10cm in the beam direction.

- AD offline veto (ADA / C = 0) and V0 offline veto (V0A / C =0): we use this selection to reduce the number of events and remove the fake events.

- $\sqrt{E^2_{ZNA} + E^2_{ZNC}} < 1000$ crosscheck with ZPA/C: we use this selection to obtain region of No hadronic dissociacion.

- 2 opposite finding TPC tracks and ITS.
- Veto in $M(\rho)$ region $[0.6GeV; 0.9GeV]$ and $M(J/\psi)$ region $[2.9GeV; 3.2GeV]$: we use this veto to reject ρ and ψ particles because they decay to the same particles to wich taus decay (ρ decays to $\pi^+\pi^-$ and ψ decays to $e^+e^-/\mu^+\mu^-$).

0.7 Results

To study $\tau\tau$ pair production, we have to select the regions without hadron dissociations in ZNA/C. The following figure shows those regions (figur 4). The intense regin (surrounded by a red circle) is the main region where we do not have hadronic desociations. We can also check the other regions like the region characterized by (ZNAenergy = 2500 and ZNCenergy=0) and the region characterized by (ZNAenergy=0 and ZNCenergy=2500).

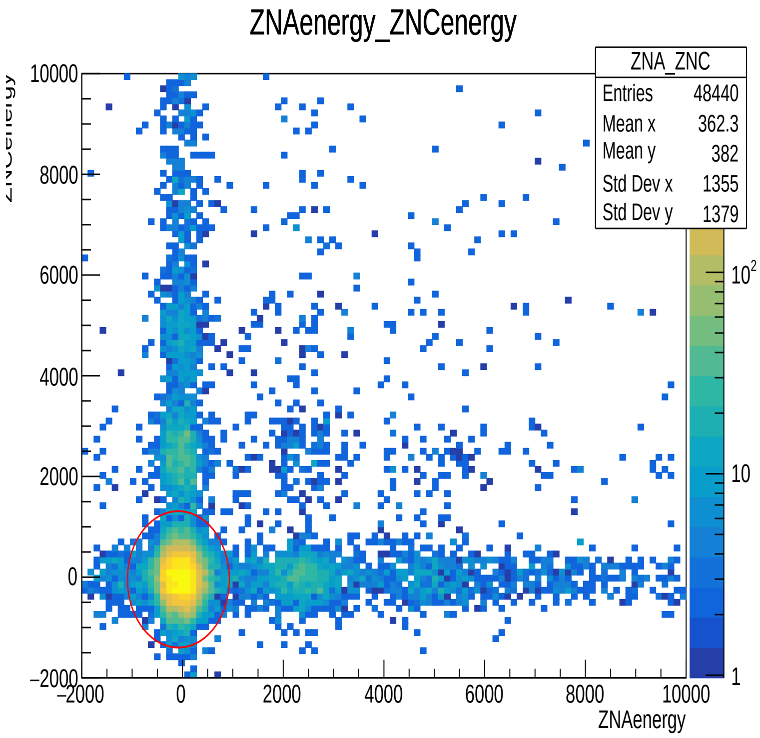

Figure 4: Regions without hadronic dissociations

The next figure (figure 5) shows the region where we do not have any adronic dissociarion in the final state. This region is characterized by the ϕ between 0 and 6.4. We added a selection on η to eliminate the fake events.

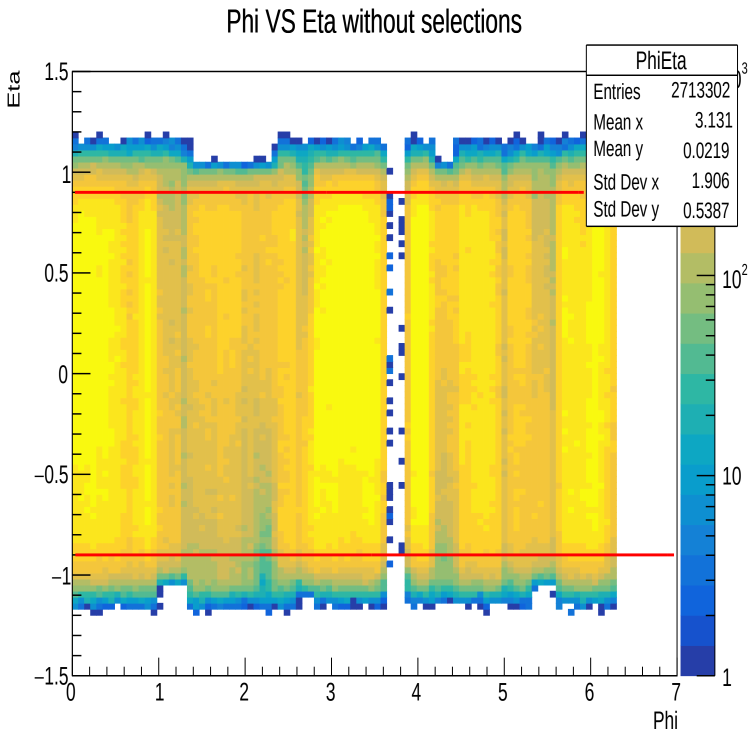

Figure 5: Regions without hadronic dissociations

The following graph (figure 6) depicts the masses of particles and corresponding transverse momenta. We understand the highest number of particles present have mass range from 0.5 to 1.5 GeV. With peak transverse momenta near 0.5GeV.

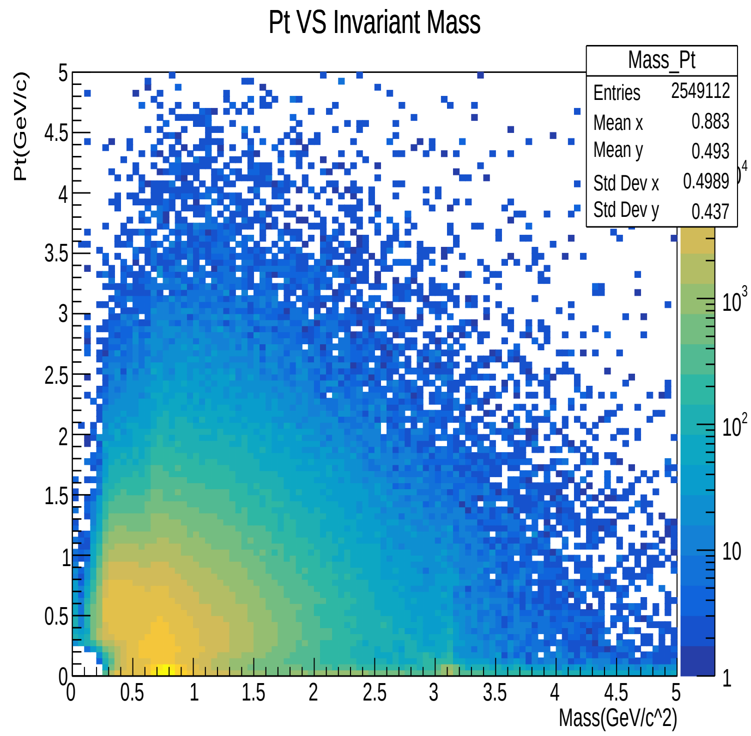

Figure 6: Totale momentum vs total mass of the two tracks in the final state

The next plots (figure 7, 8, 9, 10) shows the correlation between electron and different particles. We can conclude that we can distinguish between electron and kaon, electron and muon, electron and proton, and lectron and pion in the final state.

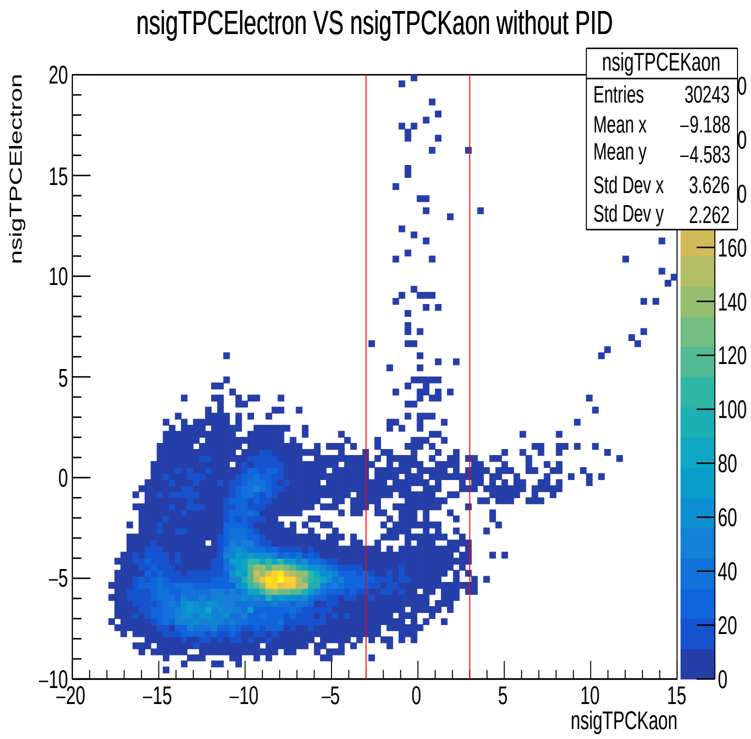

Figure 7: Correlation between electron and Kaon in the final state.

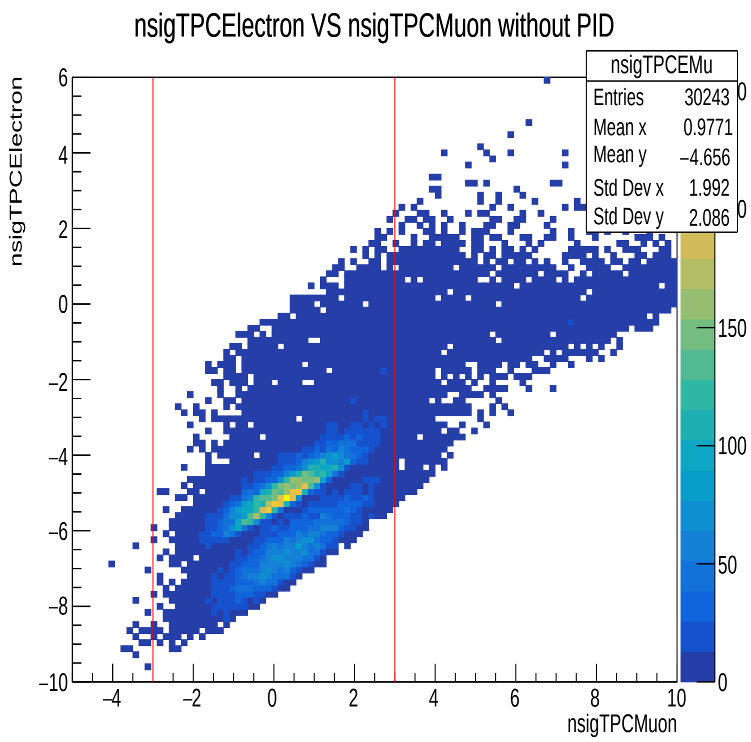

Figure 8: Correlation between electron and muon in the final state.

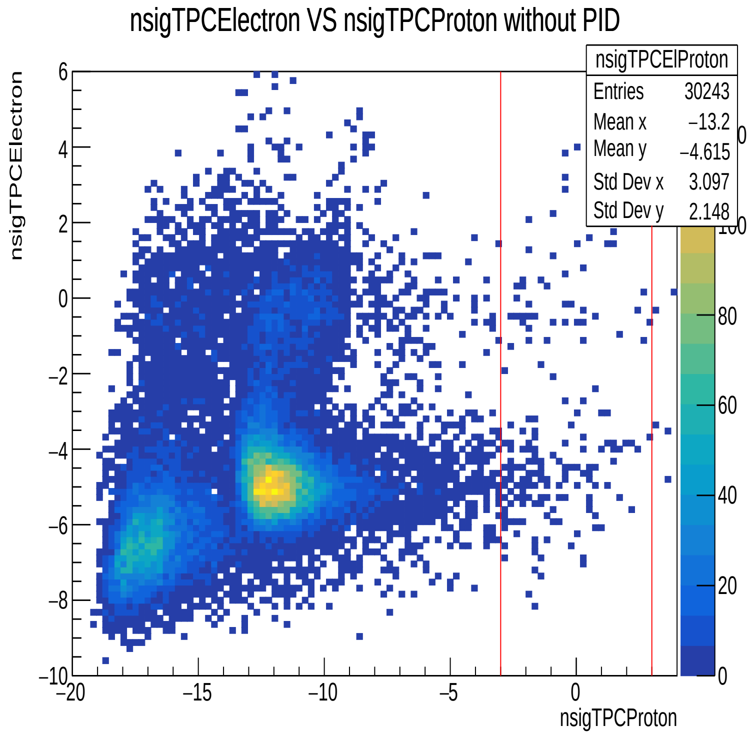

Figure 9: Correlation between electron and Kaon in the final state.

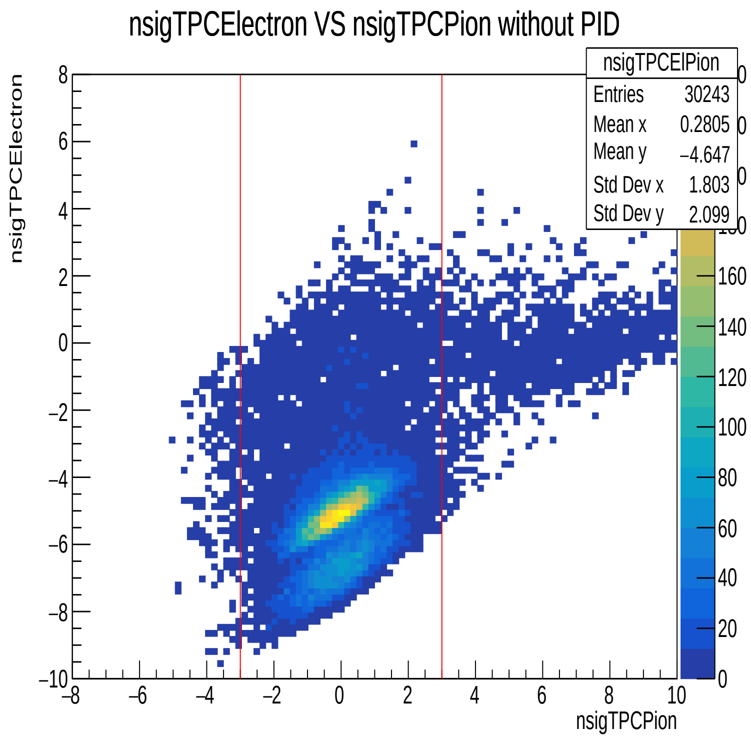

Figure 10: Correlation between electron and muon in the final state.

The figure 11 represents the energy loss by the particles in the region of no hadronic dissociation. It's commonly known as "stopping power". We can distinguish four particles which are pion, electron, proton, and kaon.

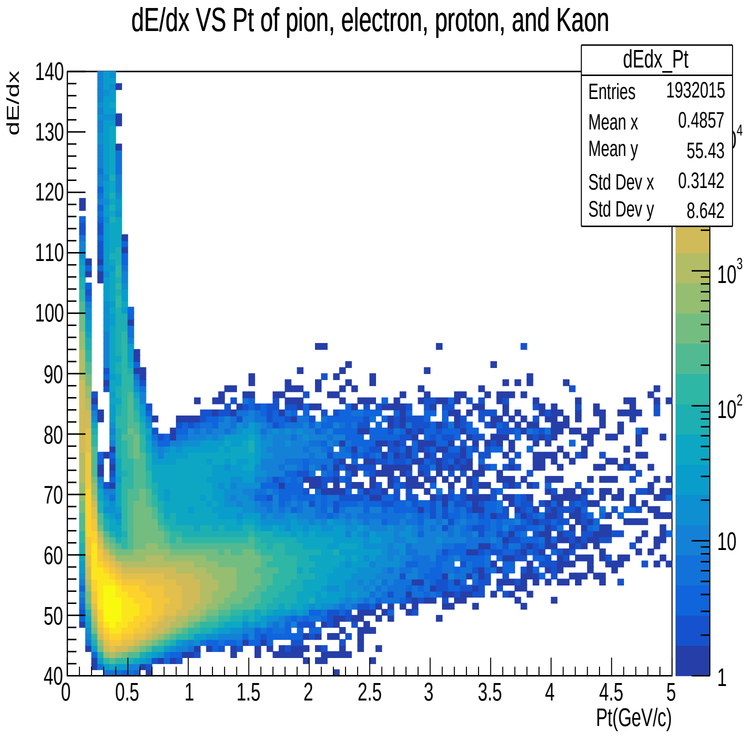

Figure 11: Identification of particles (stopping power).

Here are electrons, whose particle track gets recorded in the Time Projection Chamber without any selections (figure 12) and electrons with selections (figure 14). The electrons with selections are the same electrons we have in the stopping power plot.

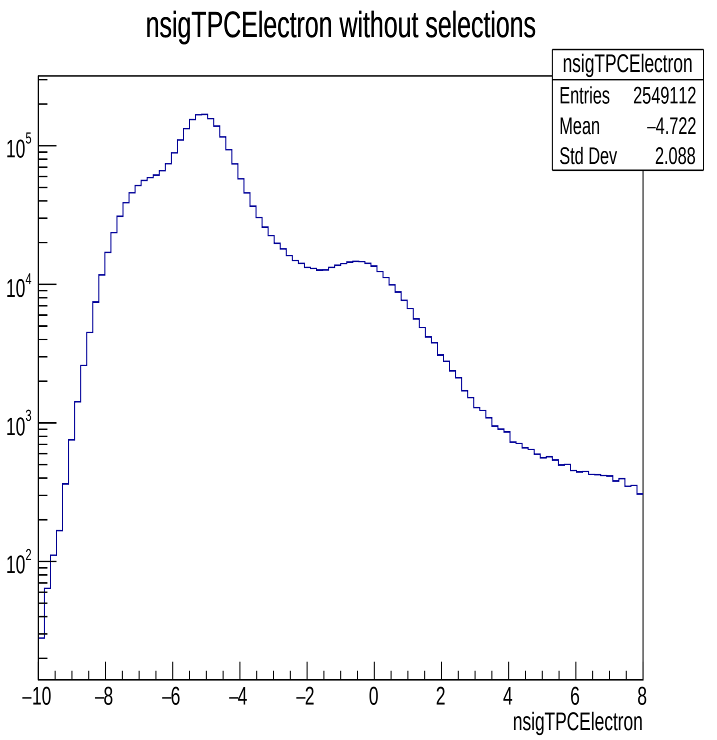

Figure 12: Particle track gets recorded in the TPC without selections.

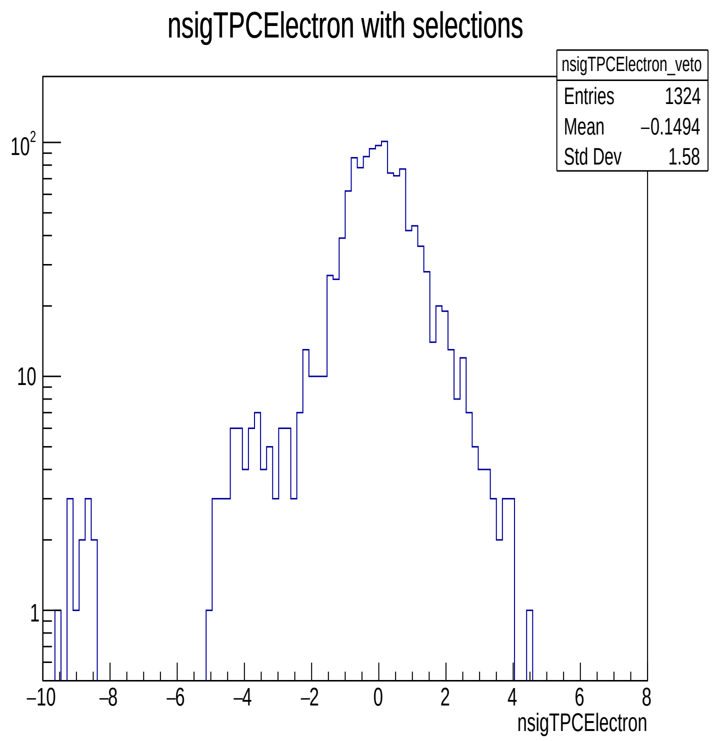

Figure 13: Particle track gets recorded in the TPC with selections.

The next figure shows the transverse momenta of these selected electrons. We can observe that maximum pT of electrons is at 0.5 which is also the most luminous in the stopping power potential plot.

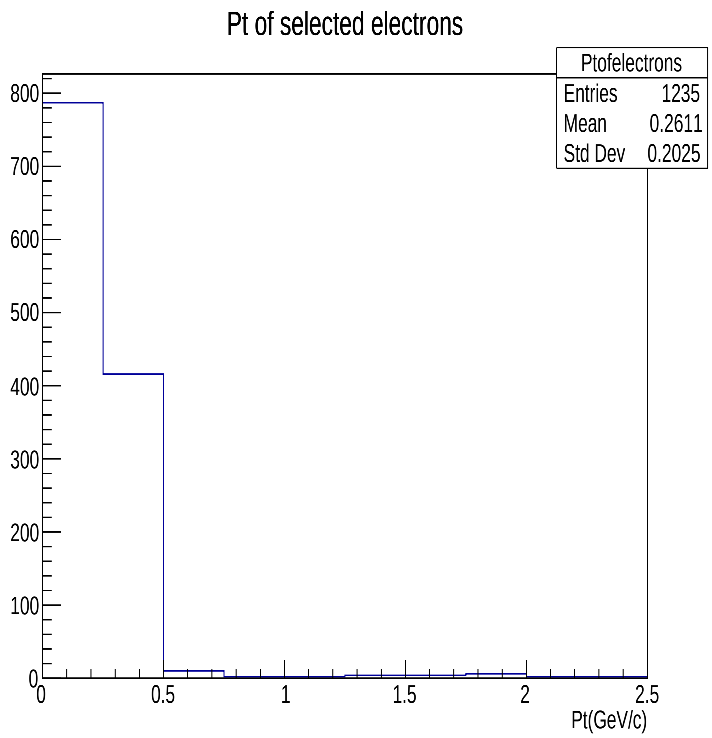

Figure 14: The transverse momenta of these selected electrons.

0.8 Conclusion and perspectives

During our project we analysed of Pb-Pb data to look for $\tau\tau$ pair production. We used the trigger selections to isolate UPC events and study decay remnants of $\tau\tau$ pair. We Identied the paricles proton, Kaon, muon, electron, and pion and we studied the correlation between the particles in the final state.
There is plenty of background present and different regions we haven't looked into to study this tau photoproduction. But the possibility is always there. For example, the kinematic region, which we choose to study, we couldn't actually differentiate particles candidates for μ and π in that region. Vetoing one type of particle would remove the other one as well. So we need better selection criteria for this.

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