# Tau pair production in ultraperipheral collisions of lead ions with the ATLAS detector

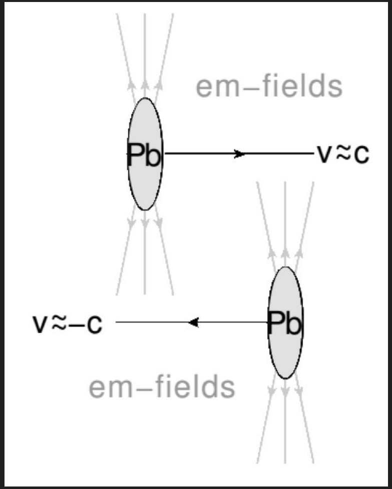
Anna Paliga, Stefan Horodeński
supervisor: Mateusz Dyndal

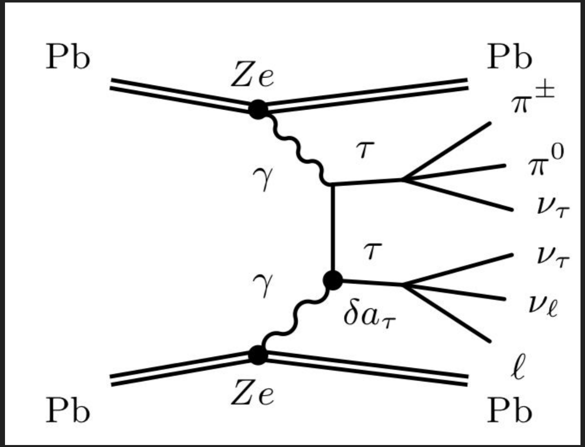
# Outline:

- Introduction:
  - Ultraperipheral collisions
  - Tau decay
- Signal and background process
- First validation plots
- System variables, application of the TLorentzVector + plots
- System cut of the transverse momentum
- Summary

# Introduction - ultraperipheral collisions

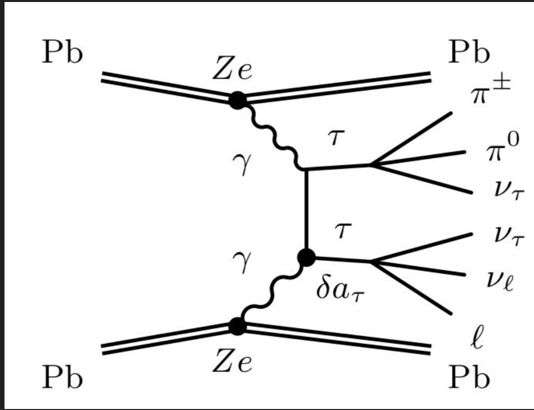
- Boosted charged-particles (Pb ions) can be intense source of photons
- This can give rise to photon-photon interactions at the LHC
- It is possible to produce tau pairs via photon-photon fusion



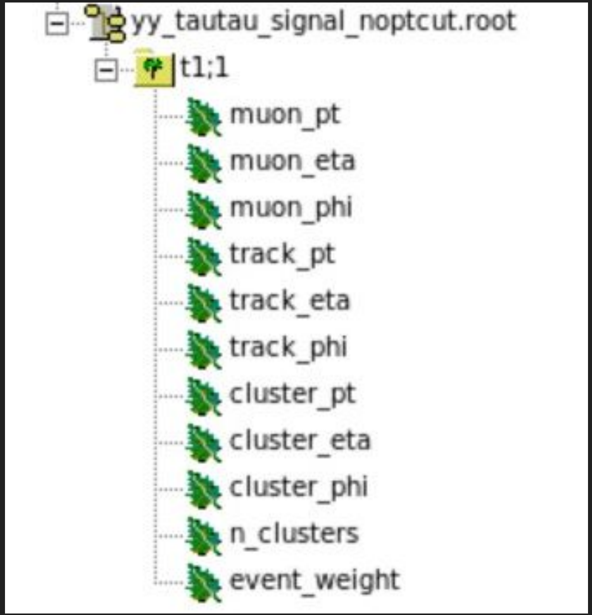
# Introduction - tau decays

- The branching fractions of the dominant tau decays are:
  - 17.8% for decay into a tau neutrino, electron and electron antineutrino;
  - 17.4% for decay into a tau neutrino, muon, and muon antineutrino.
  - 25.4% for decay into a charged pion, a neutral pion, and a tau neutrino;
  - 10.8% for decay into a charged pion and a tau neutrino;
  - 9.3% for decay into a charged pion, two neutral pions, and a tau neutrino;
  - 9.0% for decay into three charged pions and a tau neutrino;
- In this exercise we focus on tau decays into **muon**+neutrinos (first tau) and into a final state with **one charged particle**+neutrino(s)+neutral pion(s) (second tau)
  - Charged particle = pion or electron or muon
  - Neutrinos escape detection thus we only measure 1 muon and 1 extra charged-particle in the detector



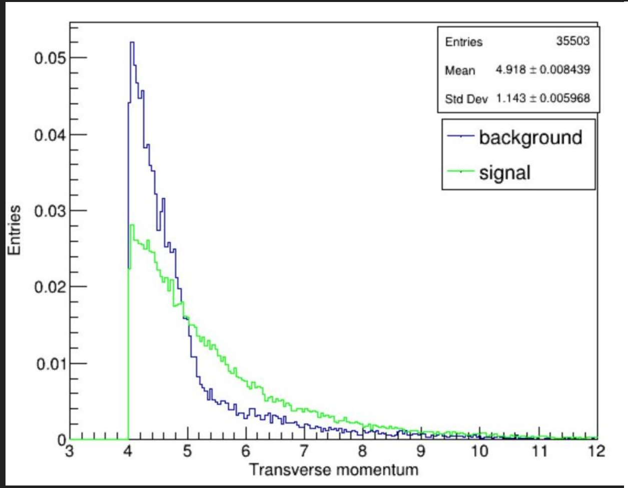
# Signal and background processes

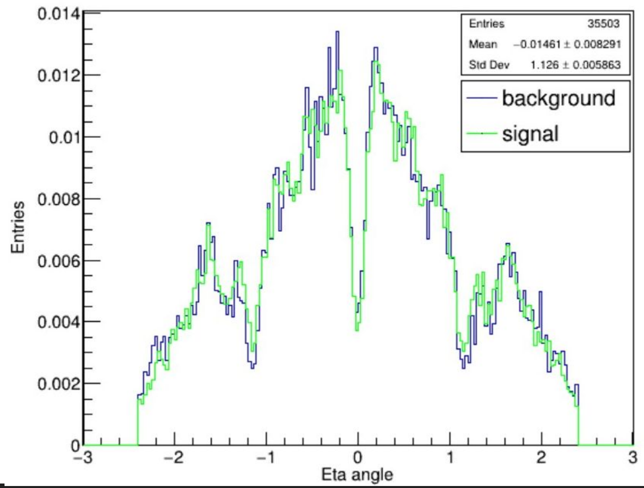
- We analyzed simulated MC samples with full simulation of ATLAS detector response
  - Signal sample: **yy->tau+tau- (->muon+1track)** process
  - Background sample **yy->muon+muon-** process (similar final state)
- Samples are normalised using per-event weights (event_weight variable)
  - N = sigma * L

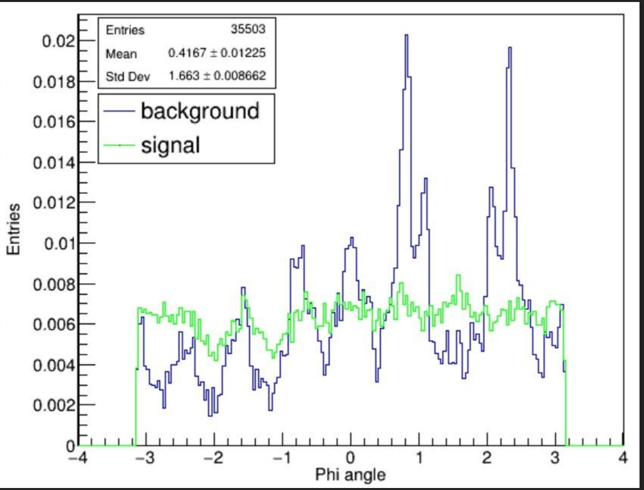


# First validation plots

- Comparison of kinematic variables for signal and background (**muon variables**)
  - All distributions are normalized to unity

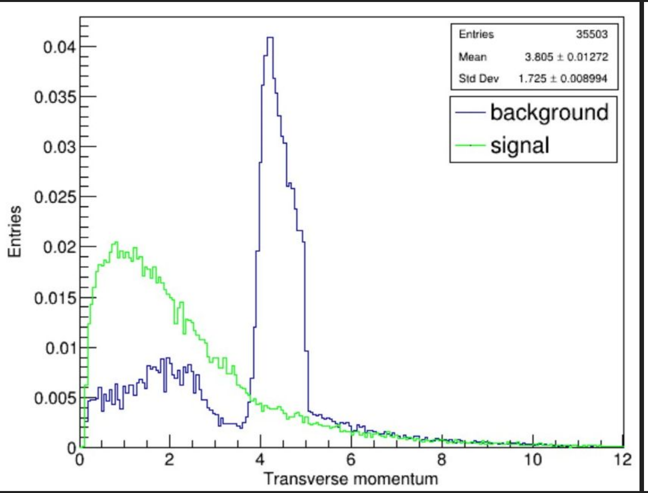


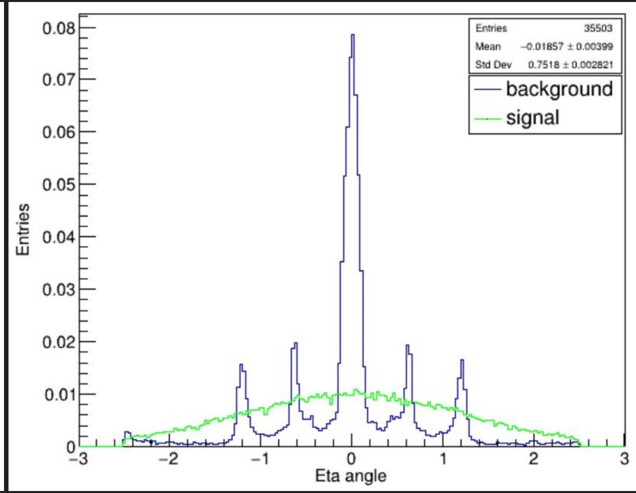



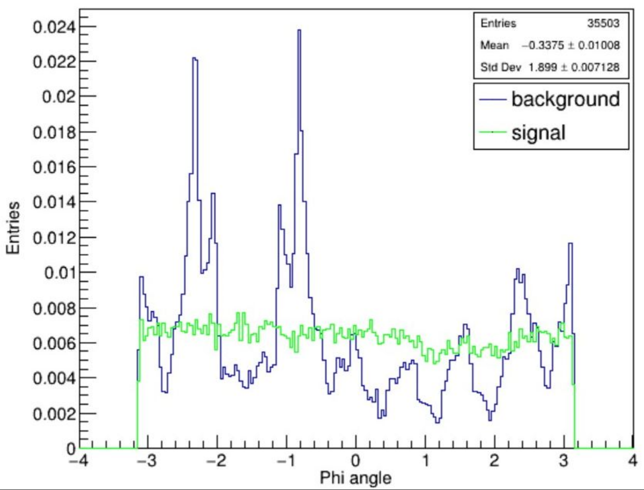



# First validation plots

- Comparison of kinematic variables for signal and background (**track variables**)
  - All distributions are normalized to unity



# muon+track system variables

- We use TLorentzVector objects to calculate:
  - muon+track system transverse momentum (system pT)
  - muon+track system invariant mass (system M)

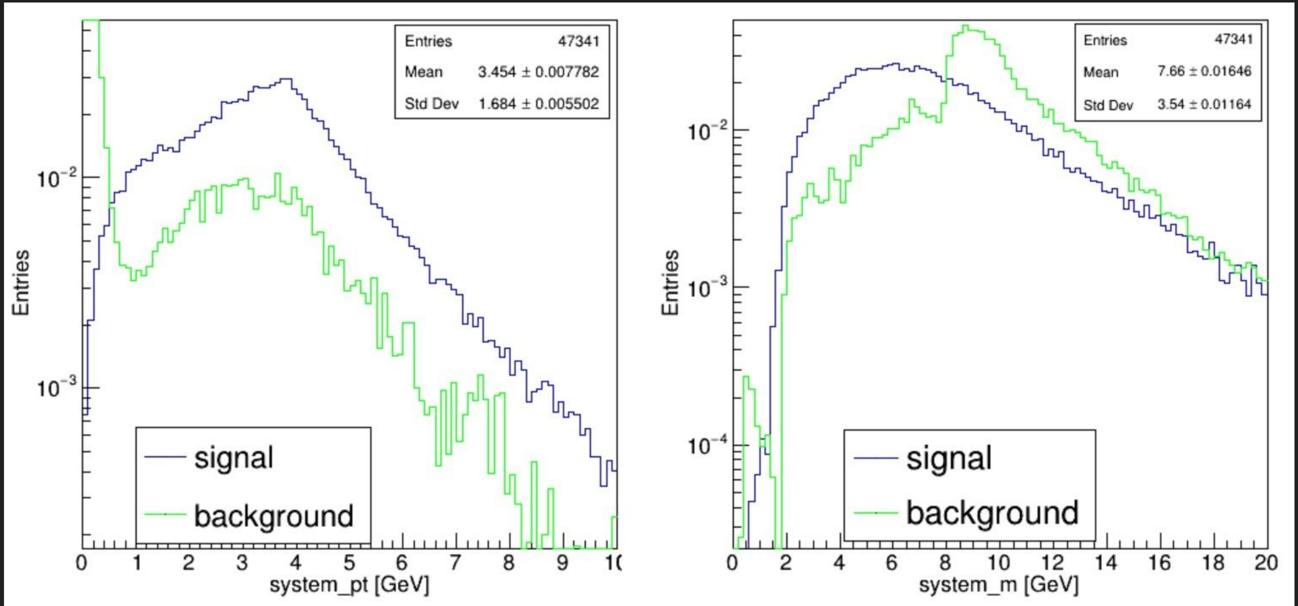
```
Long64_t nentries = t1->GetEntries();
Float_t m_muon = 0.105658, m_track = 0.139570;      // GeV

for (Long64_t i=0; i<nentries; i++) {
        t1->GetEntry(i);
        vector4_muon.SetPtEtaPhiM(muon_pt, muon_eta, muon_phi, m_muon);
        vector4_track.SetPtEtaPhiM(track_pt, track_eta, track_phi, m_track);

        vector4_sum = vector4_muon + vector4_track;
        hvector_pt   -> Fill(vector4_sum.Pt(), event_weight);
        hvector_m    -> Fill(vector4_sum.M(), event_weight);
 }
```

# muon+track system variables

- We observe significant difference in the shape of system pT distribution between the signal and background



# Adding system pT > 1 GeV cut

- To increase S/B we decided to apply a system pT > 1 GeV requirement
  - This cut reduces signal by 7.44% but reduces the background by 68.34%.

| Data set | Before cut | After cut | Percentage reduction |
|---|---|---|---|
| Signal | 501.321930 | 464.002936 | 7.44% |
| Background | 742.292585 | 235.034797 | 68.34% |

# Summary

- In a certain conditions particles can be created due to interaction of the strong EM field of Pb ions, instead of direct (head-on) collision
- Studied are simulated events with exclusive tau pair production
- Adding a cut on the system transverse momentum (> 1 GeV) enables to increase signal to background ratio
  - TLorentzVector class is very useful in calculating two-particle system kinematic variables