

CAN WE CONTRAIN
ANOMALOUS MAGNETIC AND/OR ELECTRIC DIPOLE MOMENTS
OF τ LEPTON FROM $PbPb \rightarrow PbPb\tau^+\tau^-$ REACTION
AT THE LHC?

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- ✓ M. Dyndal, M. Klusek-Gawenda, A. Szczurek and M. Schott,
Anomalous electromagnetic moments of τ lepton in $\gamma\gamma \rightarrow \tau^+\tau^-$ reaction in Pb+Pb collisions at the LHC, arXiv: 2002.05503.
- ✓ $AA \rightarrow AA\tau^+\tau^-$ framework
- ✓ $\gamma\gamma \rightarrow \tau^+\tau^-$ process
- ✓ Fiducial selection of τ decays.
- ✓ Results and discussion

INTRODUCTION

- UPC of heavy ions provide a very **clean environment** to study **two-photon** induced processes
- Study $Pb + Pb \rightarrow Pb + Pb + \tau^+ \tau^-$ at the LHC
- The presence of $\gamma\tau\tau$ vertex (twice) gives sensitivity to **anomalous magnetic moment** (beyond Standard Model).
- The strongest experimental constraints on a_τ comes from DELPHI(LEP2) measurement on $e^+ e^- \rightarrow e^+ e^- \tau^+ \tau^-$

$$-0.052 < a_\tau < 0.013$$

- The theoretical Standard Model value is significantly smaller than the currently available

$$a_\tau^{th} = 0.00117721 \pm 0.00000005$$

- BSM:
 - ✱ lepton compositness,
 - ✱ TeV-scale leptoquarks,
 - ✱ left-right symmetric models,
 - ✱ unparticle physics
- Also electric dipole moment d_τ can be studied

THEORETICAL FRAMEWORK

The nuclear cross section for the production of l^+l^- pair in ultraperipheral ultrarelativistic heavy ion collision is calculated in the impact parameter space (Klusek-Gawenda and Szczurek):

$$\sigma(AA \rightarrow AA l^+ l^-; \sqrt{s_{AA}}) = \int \sigma(\gamma\gamma \rightarrow l^+ l^-; W_{\gamma\gamma}) N(\omega_1, b_1) N(\omega_2, b_2) S_{abs}^2(\mathbf{b}) \times \frac{W_{\gamma\gamma}}{2} dW_{\gamma\gamma} dY_{l^+ l^-} d\bar{b}_x d\bar{b}_y d^2 b. \quad (1)$$

The amplitude for the $\gamma\gamma \rightarrow l^+ l^-$ reaction for the t - and u -channel is:

$$\begin{aligned} \mathcal{M} = & (-i) \epsilon_{1\mu} \epsilon_{2\nu} \bar{u}(p_3) \left(i\Gamma^{(\gamma l^+ l^-)\mu}(p_3, p_t) \frac{i(\not{p}_t + m_l)}{t - m_l^2 + i\epsilon} i\Gamma^{(\gamma l^+ l^-)\nu}(p_{t'} - p_4) \right. \\ & \left. + i\Gamma^{(\gamma l^+ l^-)\nu}(p_3, p_u) \frac{i(\not{p}_u + m_l)}{u - m_l^2 + i\epsilon} i\Gamma^{(\gamma l^+ l^-)\mu}(p_{u'} - p_4) \right) v(p_4). \end{aligned} \quad (2)$$

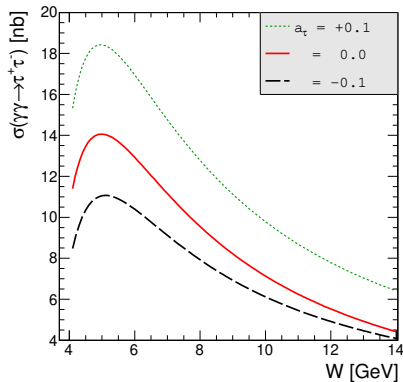
Here we introduce photon-lepton vertex function that is a function of momentum transfer.

$$i\Gamma_{\mu}^{(\gamma l^+ l^-)}(p', p) = -ie \left[\gamma_{\mu} F_1(q^2) + \frac{i}{2m_l} \sigma_{\mu\nu} q^{\nu} F_2(q^2) + \frac{i}{2m_l} \gamma^5 \sigma_{\mu\nu} q^{\nu} F_3(q^2) \right], \quad (3)$$

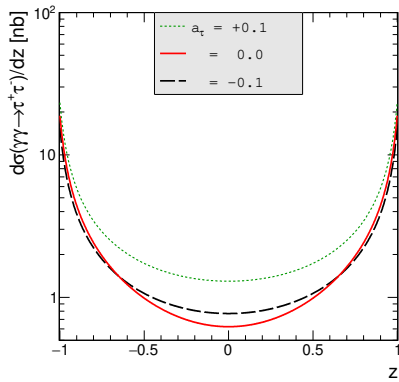
$\sigma_{\mu\nu} = \frac{i}{2}[\gamma_{\mu}, \gamma_{\nu}]$, $F_1(q^2)$ and $F_2(q^2)$ are the Dirac and Pauli form factors, $F_3(q^2)$ is the electric dipole form factor. The differential cross section for the dilepton production in the $\gamma\gamma$ -fusion:

$$\frac{d\sigma(\gamma\gamma \rightarrow l^+ l^-)}{dz} = \frac{2\pi}{64\pi^2 s} \frac{p_{out}}{p_{in}} \frac{1}{4} \sum_{\text{spin}} |\mathcal{M}|^2.$$

ELEMENTARY CROSS SECTION, a_τ DEPENDENCE



(a)



(b)

FIG.: (a) Elementary cross section as a function of energy
(b) Differential cross as a function of $z = \cos \theta$ for fixed value of energy

NUCLEAR CROSS SECTION, a_T DEPENDENCE

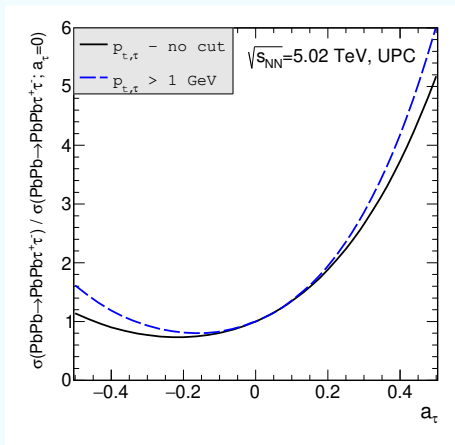


FIG.: Ratio of the total nuclear cross sections for $Pb+Pb \rightarrow Pb+Pb_{\tau\tau}$ production at the LHC energies as a function of a_T , relative to SM ($a_T = 0$).

The ratio of the cross sections for extra $p_{T,\tau} > 1$ GeV is also shown.

FIDUCIAL SELECTION AND τ DECAYS

Tau is the heaviest lepton with a lifetime of 3×10^{-13} that can decay into lighter leptons (electron or muon) or hadrons (mainly pions and kaons). The primary τ decay channels produce one charged particle (denoted as 1ch, or one-prong):

$$\tau \rightarrow \nu_\tau + \ell + \nu_\ell \quad (\ell = e, \mu)$$

$$\tau \rightarrow \nu_\tau + \pi^\pm + n\pi^0$$

or three charged particles (denoted as 3ch, or three-prong):

$$\tau \rightarrow \nu_\tau + \pi^\pm + \pi^\mp + \pi^\pm + n\pi^0$$

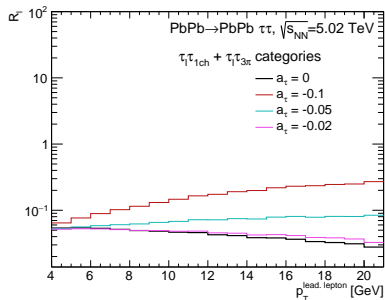
Approximately 80% of all τ decays are the one-prong decays and 20% of them are the three-prong decays.

In order to model τ decays we use [Pythia 8.243](#) program.

We propose that the $\gamma\gamma \rightarrow \tau^+\tau^-$ candidates events are selected by requiring **at least one τ lepton to decay leptonically**, as this allows that existing triggering algorithms of the ATLAS or CMS detector can be used.

The leading electron or muon is required to have $p_T > 4 \text{ GeV}$ and $|\eta| < 2.5$.

RESULTS



(b)

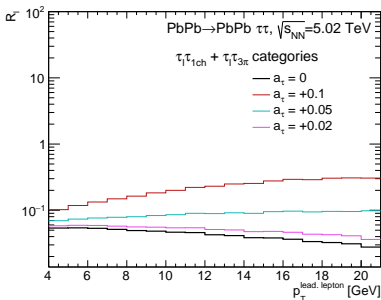
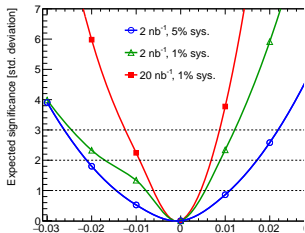


FIG.: Ratio of the fiducial cross sections between $\gamma\gamma \rightarrow \tau^+\tau^-$ and $\gamma\gamma \rightarrow \ell^+\ell^-$ ($\ell = e$ or μ) processes as a function of p_T of the leading lepton for all event categories summed together.

RESULTS



(a)

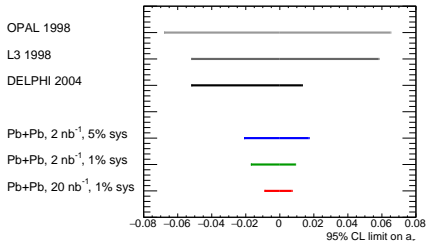


FIG.: (a) Expected signal significance for various assumptions on Pb+Pb integrated luminosity and total systematic uncertainty.

(b) Expected 95% CL limits on a_τ measurement for various assumptions on Pb+Pb integrated luminosity and total systematic uncertainty.

CONCLUSION

- We have used UPC calculation for $Pb + Pb \rightarrow Pb + Pb + \tau^+ \tau^-$
- We have studied the dependence of the $\gamma\gamma \rightarrow \tau^+ \tau^-$ on a_τ
- All channels with at least one leading lepton have been accepted
- We suggest to measure the ratio of:
 $\gamma\gamma \rightarrow \tau^+ \tau^- \rightarrow (\dots\dots\dots)$ to $\gamma\gamma \rightarrow e^+ e^- (\mu^+ \mu^-)$
- The limitations with present data **seems better** than those from DELPHI
- **Spin-spin correlations** probably small