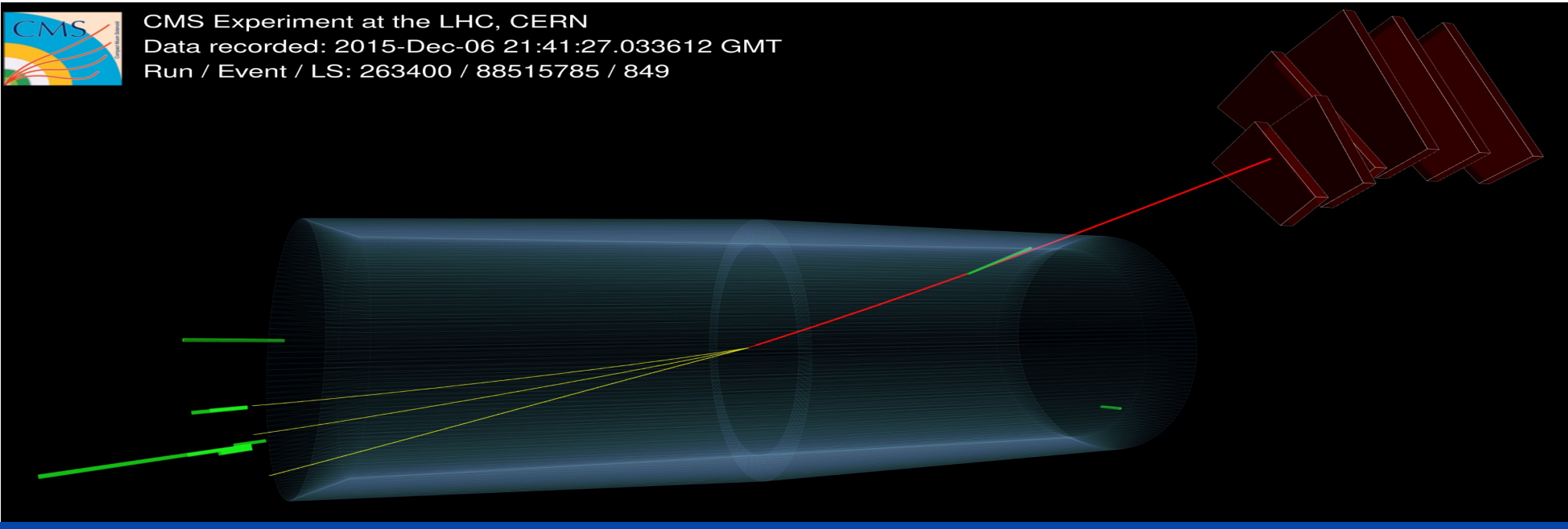
Ditau pair production in lead-lead ultra-peripheral collisions using UPCgen

E. Shokr*, A. Jofrehei, S. Leontsinis and B. Kilminster

CHIPP winter school, 2023



1- Introduction

2- Cross section for the elementary process ($\gamma\gamma \rightarrow \tau\tau$).

3- Dilepton production Cross Section in UPC ($AA \rightarrow AA + \tau\tau$).

4- muon + 3pion channel.

summary

1- Introduction

1- a_e

- The electron anomalous magnetic moment ($a_e = \frac{g-2}{2}$)
- Is among the most precisely measured quantities in nature agreement with QED.

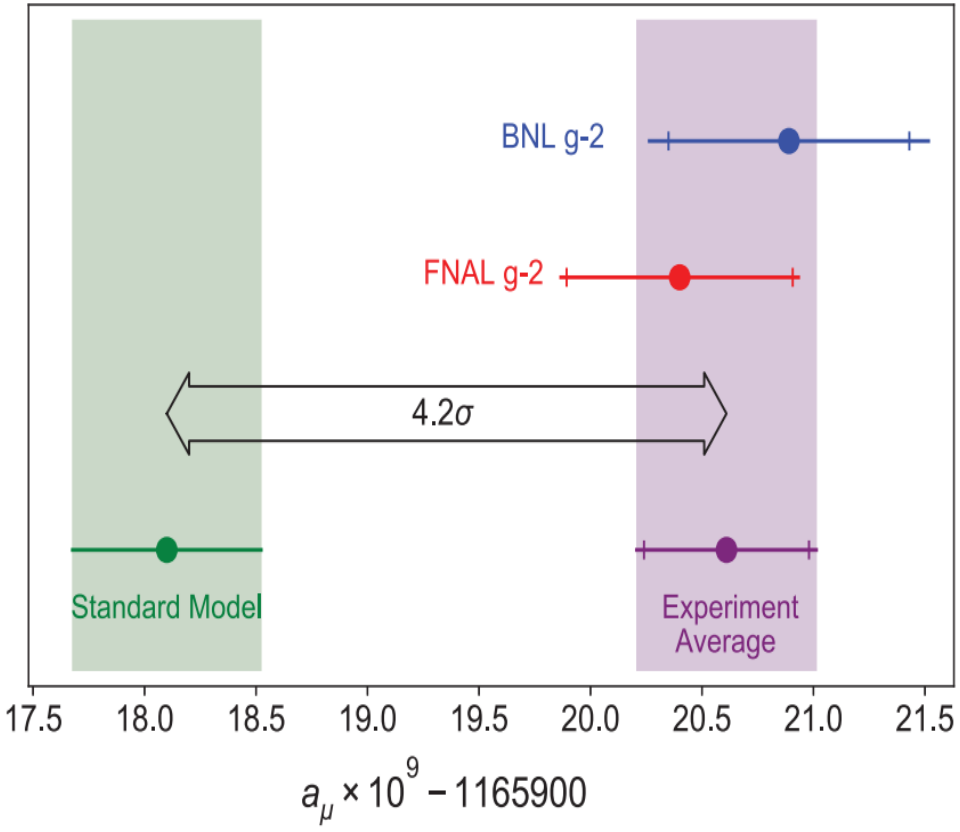
The. a_e = 0.001 159 652 181 643(764)
Exp. a_e = 0.001 159 652 180 73(28)

3- a_τ

- The current best measurement has been done at DELPHI (LEP) in 2004.

2- a_μ

- Has been measured recently by FermiLab with more than $4\,\sigma$ discrepancy with SM.



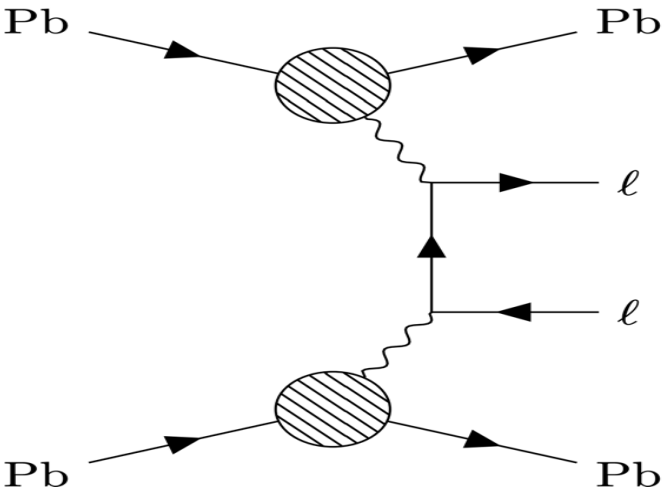
https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.126.141801

1- Introduction

Why tau?:

* Particles contribute with the square of their mass in the new physics models so tau will be about, $\frac{m_\tau^2}{m_\mu^2} \approx 280$ times more sensitive than muon.

As tau is much heavier than the muon, in principle, it should be more sensitive to new physics. But it has a very big problem which is it has very small life time about $2.9*10^{-13}$ sec which prevent us from using the previous method and led us to use ultra peripheral collision (UPC) of heavy ions for this purpose.



Why ion ion UPC not proton proton?

- $\sigma(Pb + pb \text{ -> } Pb\ (\gamma\gamma \rightarrow \tau\tau)\ pb) \propto Z^4$

-> Z=82 for pb

- Low track multiplicity
- No pileup.

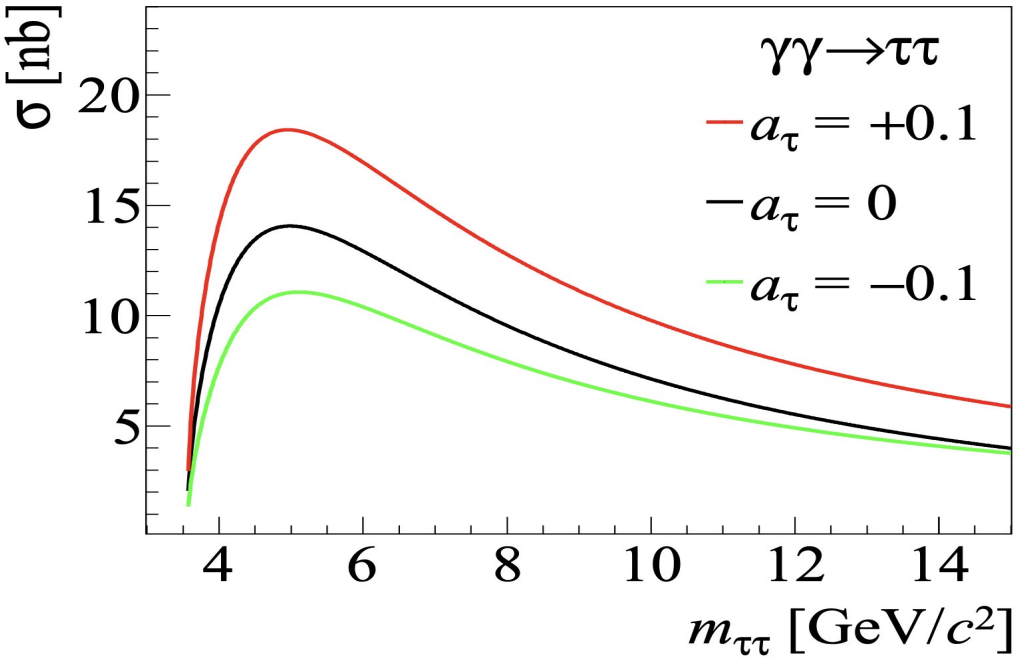
https://arxiv.org/pdf/1908.05180.pdf

2- Cross section for the elementary process ($\gamma\gamma \rightarrow \tau\tau$).

UPCgen: a recent (March 2022) Monte Carlo simulation program for dilepton pair production in ultra-peripheral collisions of heavy ions. https://arxiv.org/pdf/2111.11383.pdf

* It has very important features, the most prominent is the ability to **tune the anomalous magnetic moment of the generated leptons**.

Cross Section is sensitive to a_τ



$$\frac{d\sigma(\gamma\gamma\rightarrow\ell\ell)}{dz} = \frac{2\pi}{64\pi^2 s}\frac{|\vec{p}_\ell|}{|\vec{p}_\gamma|}\frac{1}{4}\sum_{spin}|\mathcal{M}|^2$$

- $z = \cos\vartheta$, ϑ is the angle of the outgoing lepton in the final state relative to the beam direction in the photon-photon center-of-mass frame.
- s is the squared invariant mass of two photons.
- p_l and p_γ are the momenta of the lepton and photon respectively.
- M is amplitude for the $\gamma\gamma \rightarrow \tau\tau$ reaction in the t- and u-channels.

3- Dilepton production Cross Section in UPC ($AA \rightarrow AA + \tau\tau$).

$$\frac{\mathrm{d}^2\sigma(AA\rightarrow AA+\ell\ell)}{\mathrm{d}Y\,\mathrm{d}M} = \frac{\mathrm{d}^2N_{\gamma\gamma}}{\mathrm{d}Y\,\mathrm{d}M}\sigma(\gamma\gamma\rightarrow\ell\ell)$$

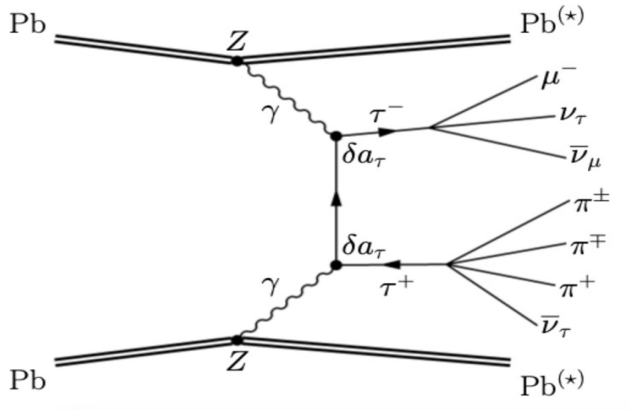
* $\frac{\mathrm{d}^2N_{\gamma\gamma}}{\mathrm{d}Y\,\mathrm{d}M}$ is the two-photons luminosity.

Sample Generation

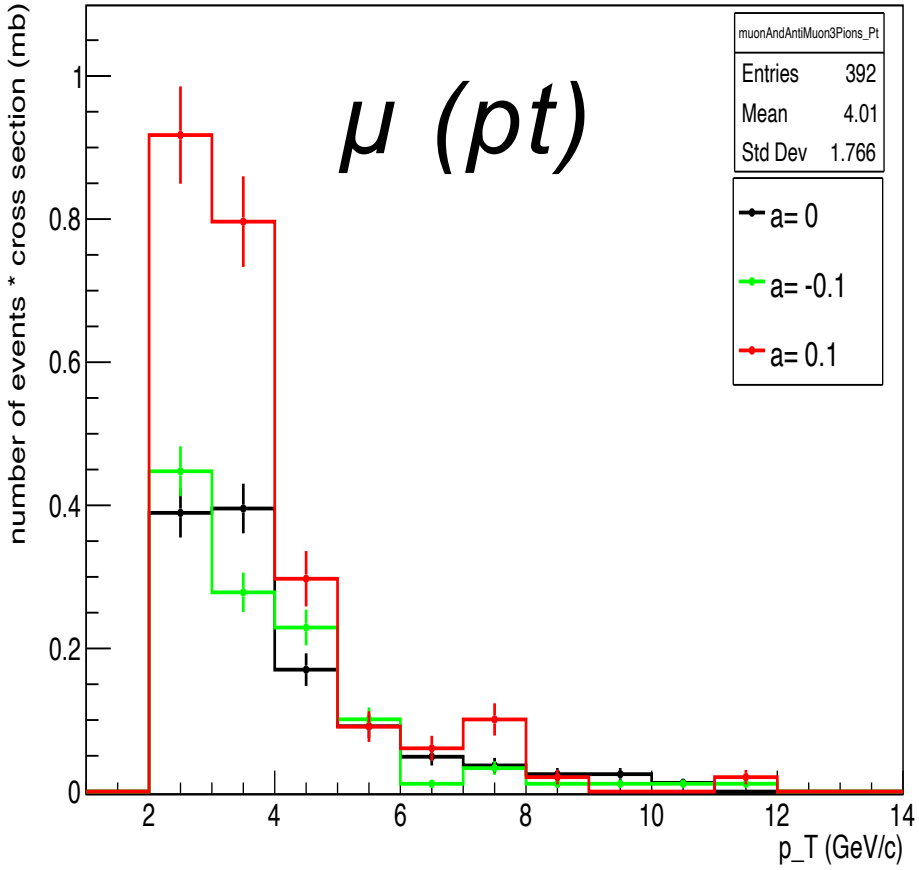
- 50 k UPC ; $pb + pb$ -> $pb\ (\gamma\gamma \rightarrow \tau\tau)\ pb$
- $\sqrt{s}$ = 5.02 TeV & $a_\tau = -0.1, 0, 0.1$
- taus allowed to decay using PYTHIA 8
- -2.5 <eta < 2.5 & tau pt> 1 GeV/c

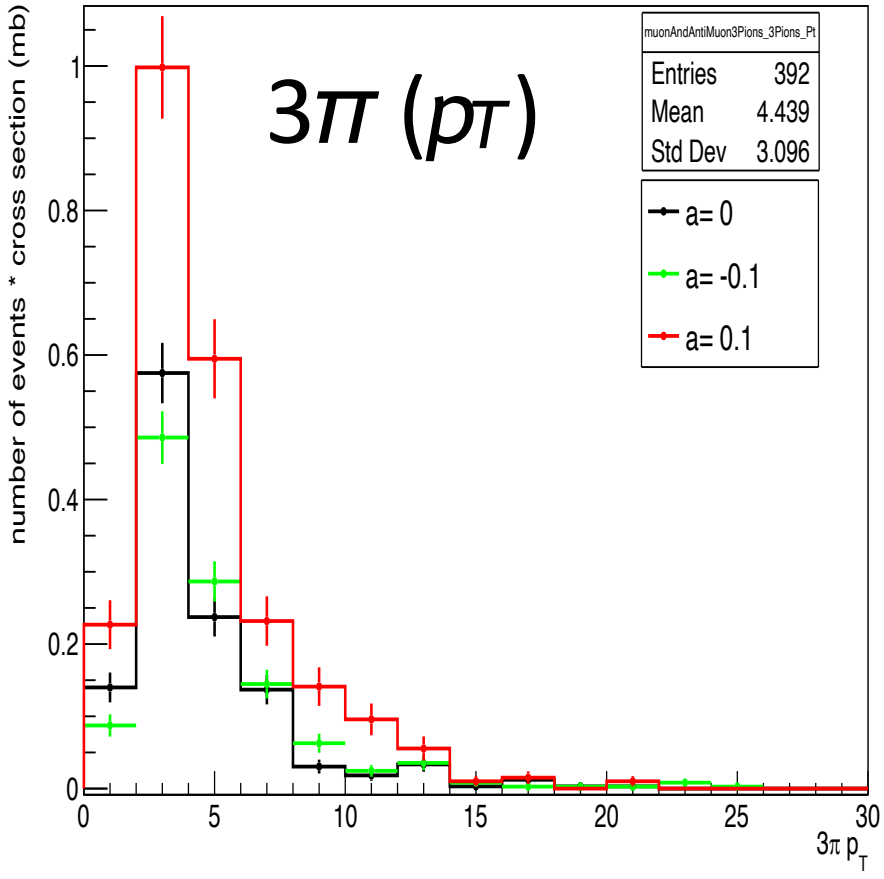
a_τ	CS with cuts (*mb*)	CS without cuts (*mb*)
0.1	0.532834	1.139995
0	0.388107	0.847772
-0.1	0.322611	0.680211

4- muon + 3pion: μ (pt) & 3π (p_T)



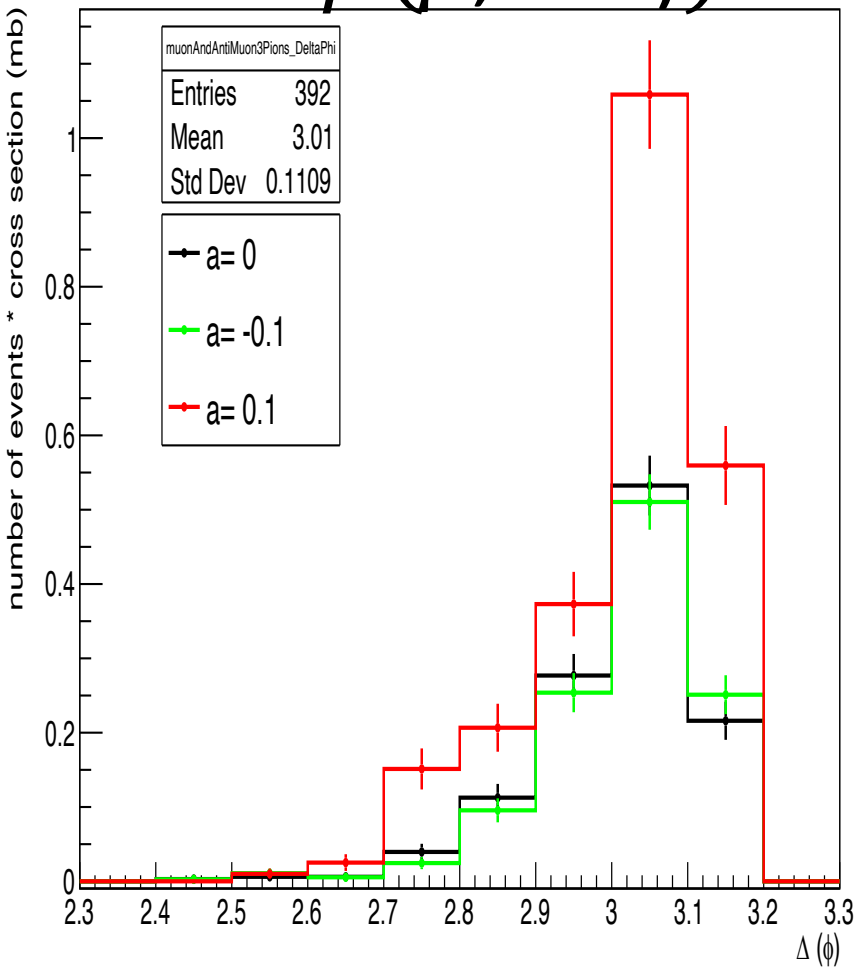
Selection: muon $p_T > 2.5\ GeV/c$
& each pion $p_T > 0.3\ GeV/c$.



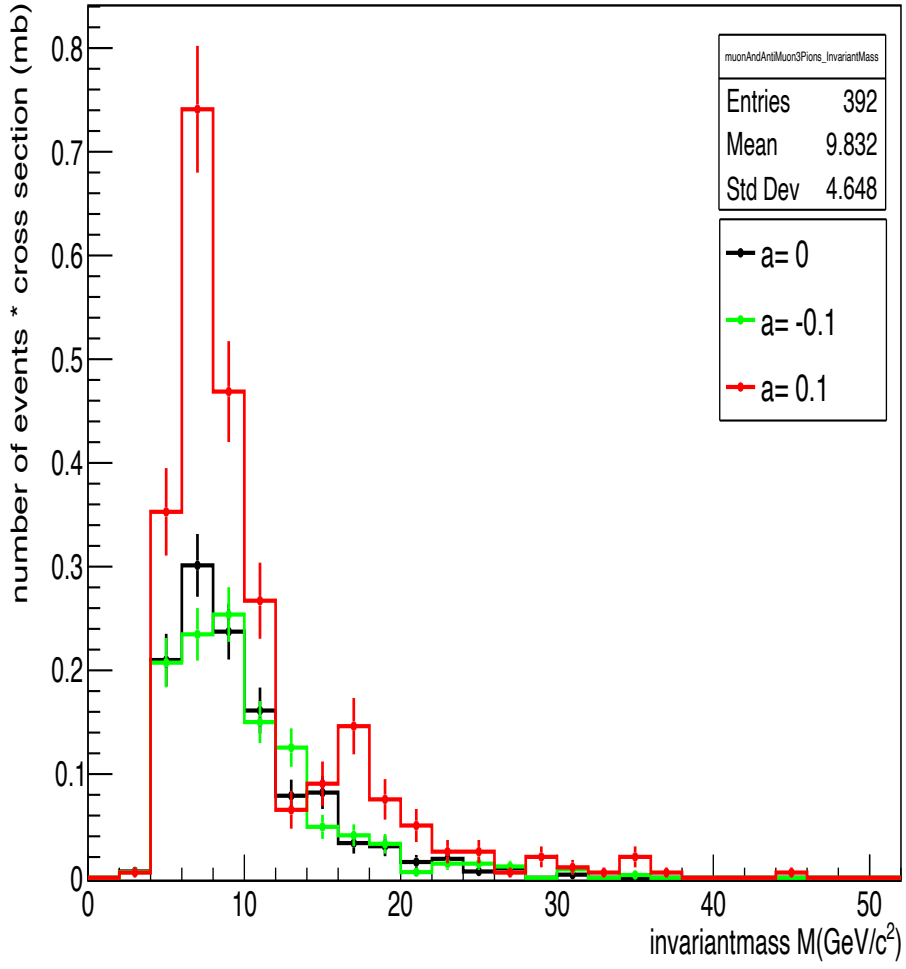


4.2- muon + 3pion: ($\Delta\varphi$ and Invariant Mass)

$\Delta\varphi$ (μ, π ±))



Invariant Mass



Summary

1. UPCgen can be used to generate different distributions at different values of a_τ ; this allows us to use the combine tool to find the best a_τ value that fits our data.
2. We are now working on making the reconstruction of the gen-level particles.
3. muon + 3pion already done by my group and we are now working on different channels.

Thank You