Searches for scalar resonances with di-photon in association with leptons and taus using the easyjet analysis framework in the ATLAS Detector at the LHC

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In collaboration with: Vuyolwethu Kakancu, Mukesh Kumar , Rachid Mazini, Njokweni Mbuyiswa, Bruce Mellado, Reda Mekouar, Baballo-Victor Ndhlovu, Kgothatso Ntumbe and Phuti Rapheeha

ATLAS EXPERIMENT

Institute for Collider Particle Physics

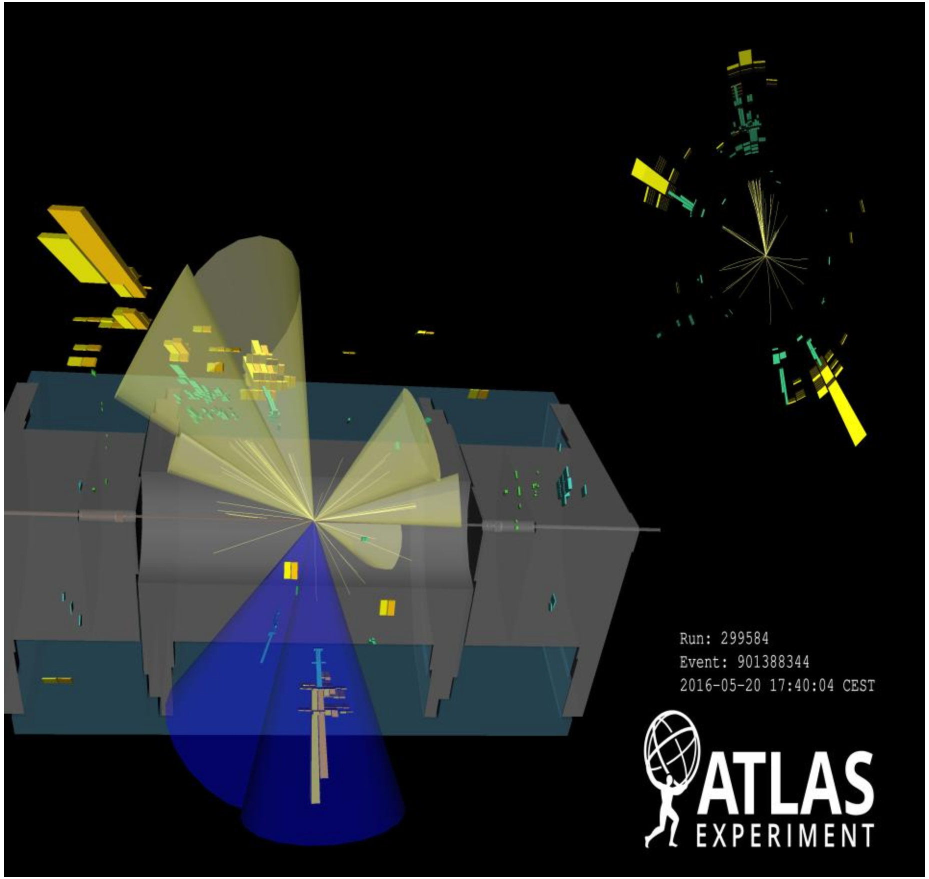
University of the Witwatersrand

NRF National Research Foundation

iThemba LABS Laboratory for Accelerator Based Sciences

Outline

- The Simplified Model
- Framework workflow
- Background samples
- Signal Filters
- Object Selections
- Kinematic Distributions
- Conclusions



The Simplified Model

- Mass Scans H [250 – 400] $\boldsymbol{GeV}$, S [150 – 275] $\boldsymbol{GeV}$, S' [95-125] $\boldsymbol{GeV}$ **(J. Phys. G 46 (2019) no.11, 115001 and Nature Review. Phys. 6, 294–309 (2024))**

- S decays to two photons ($\boldsymbol{\gamma\gamma}$) and S' decays to two taus/bjets ($\boldsymbol{\tau}$ **/b'**s)

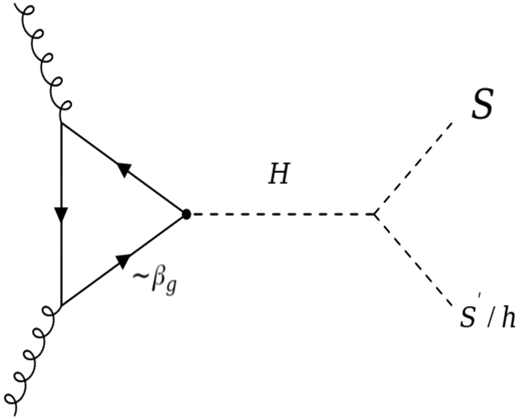
- Detailed information can be seen in Vuyolwethu's and Njokweni's talk

- Final states of interests : $\boldsymbol{\gamma\gamma +\ 0l1\tau, 0l2\tau\ , 1l1\tau, 2l0\tau, 1l0\tau, 1l1b}$

- My talk will be about the $\boldsymbol{\gamma\gamma +\ 0l1\tau, 1l1\tau}$ final states **[Background study using the signal final states]**

- Kgothatso will give a talk about the $\boldsymbol{\gamma\gamma + 2l0\tau, 1l0\tau, 1l1b}$ final states

- The tau candidate presented in this framework is the **hadronic tau**



$$gg \to H \to SS'$$

Easyjet Framework workflow

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Analysis Package
$\gamma\gamma$ +Multilepton analysis

→

Datasets used
$\gamma\gamma$jj
$tt\gamma\gamma$

→

Run
Locally/Grid to produce samples for analysis

↓

Analysis
Locally produce Ntuples for your own desired objects

→

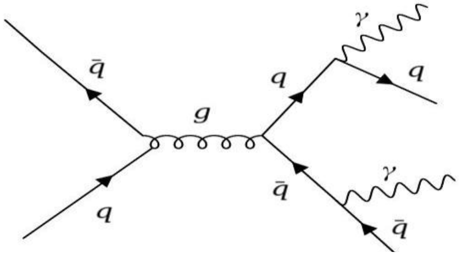
Current
Object Selections

→

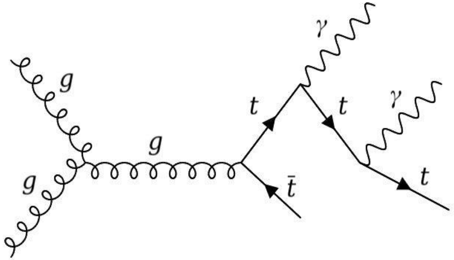
Next Step
Background Characterization

Background processes

$$pp \rightarrow \gamma\gamma jj$$



$$pp \rightarrow \gamma\gamma t\bar{t}$$



- Our two dominant background processes (above as shown)
- Since Top quarks decay via the weak interaction, their decays often result in W bosons and a b quark.
- W bosons have a chance to decay into any of the three charged leptons + missing energy.
- Hence we chose the diphoton + top quark pair production for this talk.

Signal processes and Filters

- As it stands we have submitted the sample request for the two signal processes mentioned on slide 3.

- We applied the following filters:

Selection Criteria	Tau Filter	MultiBjet Filter
Minimum Transverse Momentum (p_T)	$P_{T_{\ell=e,\mu}}$ = $12GeV$ $P_{T_{had}}$ = $25GeV$	$P_{T\text{b-quark}}$ = $5GeV$ $P_{T_{Jet}}$ = $20GeV$ $P_{T\text{lead}_{Jet}}$ = 5 GeV
Maximum Pseudorapidity (η)	2.5	2.5
Number of objects required	2	2

- $\eta = -In(tan\frac{\theta}{2})$

- $\Delta R < 0.4$

Object Selections ($\gamma\gamma + 0l1\tau$ Final State)

Photons

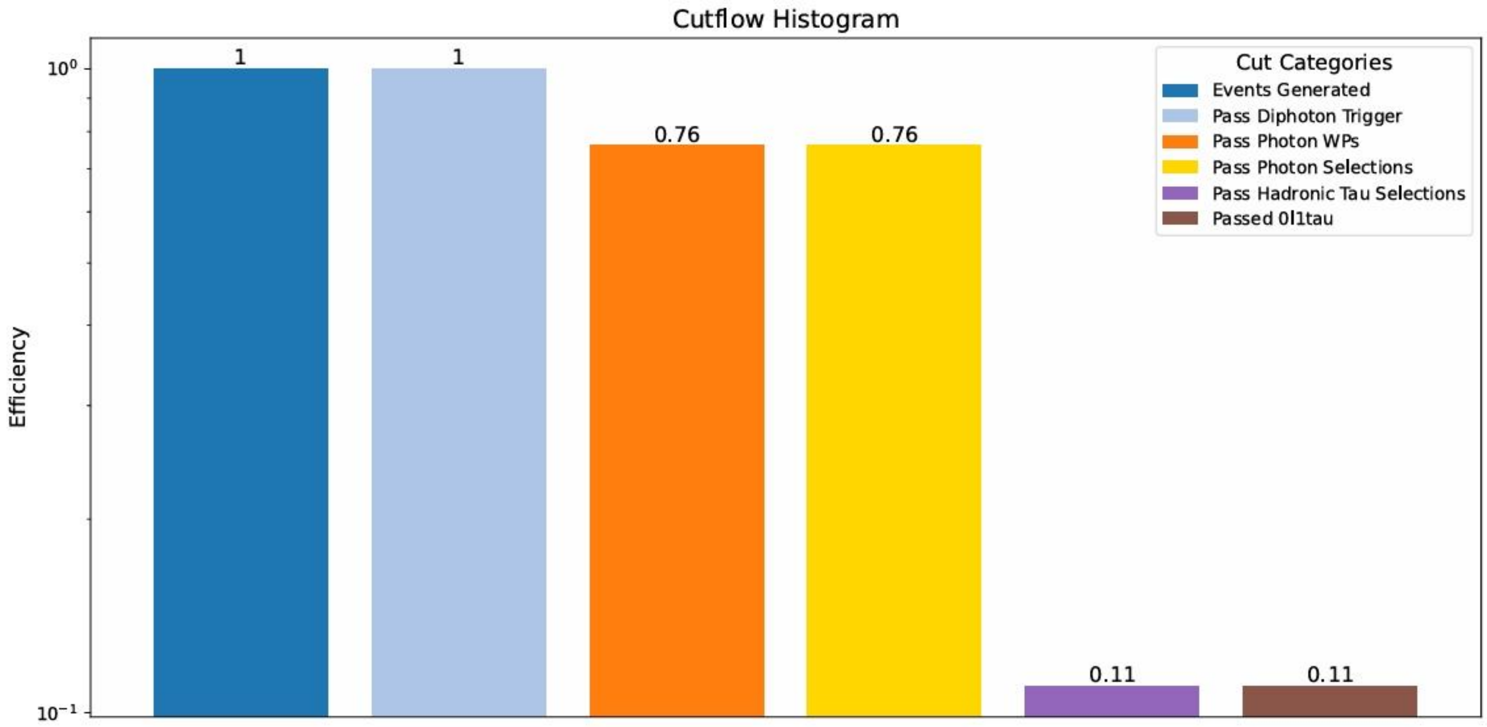
- Diphoton triggers
- 2 Loose and non Isolated photons
- lead (sub) $p_T \geq 35\ (25)\ GeV$
- $1.37 < |\eta| < 1.52$ rejected and $|\eta| \leq 2.37$

Hadronic Tau

- RNN Loose WP
- $p_T \geq 25$ GeV
- $1.37 < |\eta| < 1.52$ rejected and $|\eta| < 2.5$

- For photon Identification we used the **FixedCutLoose** Working Point (WP) because we are looking for higher signal efficiency.
- For photon Isolation we used the **NonIso** WP because we are looking to perform background estimation.
- For the hadronic tau we used the **Recurrent Neural Network Loose** WP because we want to include more tau candidates.
- After passing the above object selections we require the 0 lepton and 1 Tau final state for analysis
- More on the selections see paper ATLAS-CONF-2024-005

Cutflow Histogram ($\gamma\gamma + 0l1\tau$ Final State)



Object Selections ($\gamma\gamma + 1l1\tau$ Final State)

Photons

- Diphoton triggers
- 2 Loose and non Isolated photons
- lead (sub) $p_T \geq 35 \ (25) \ GeV$
- $1.37 < |\eta| < 1.52$ excluded and $|\eta| \leq 2.37$

Hadronic Tau

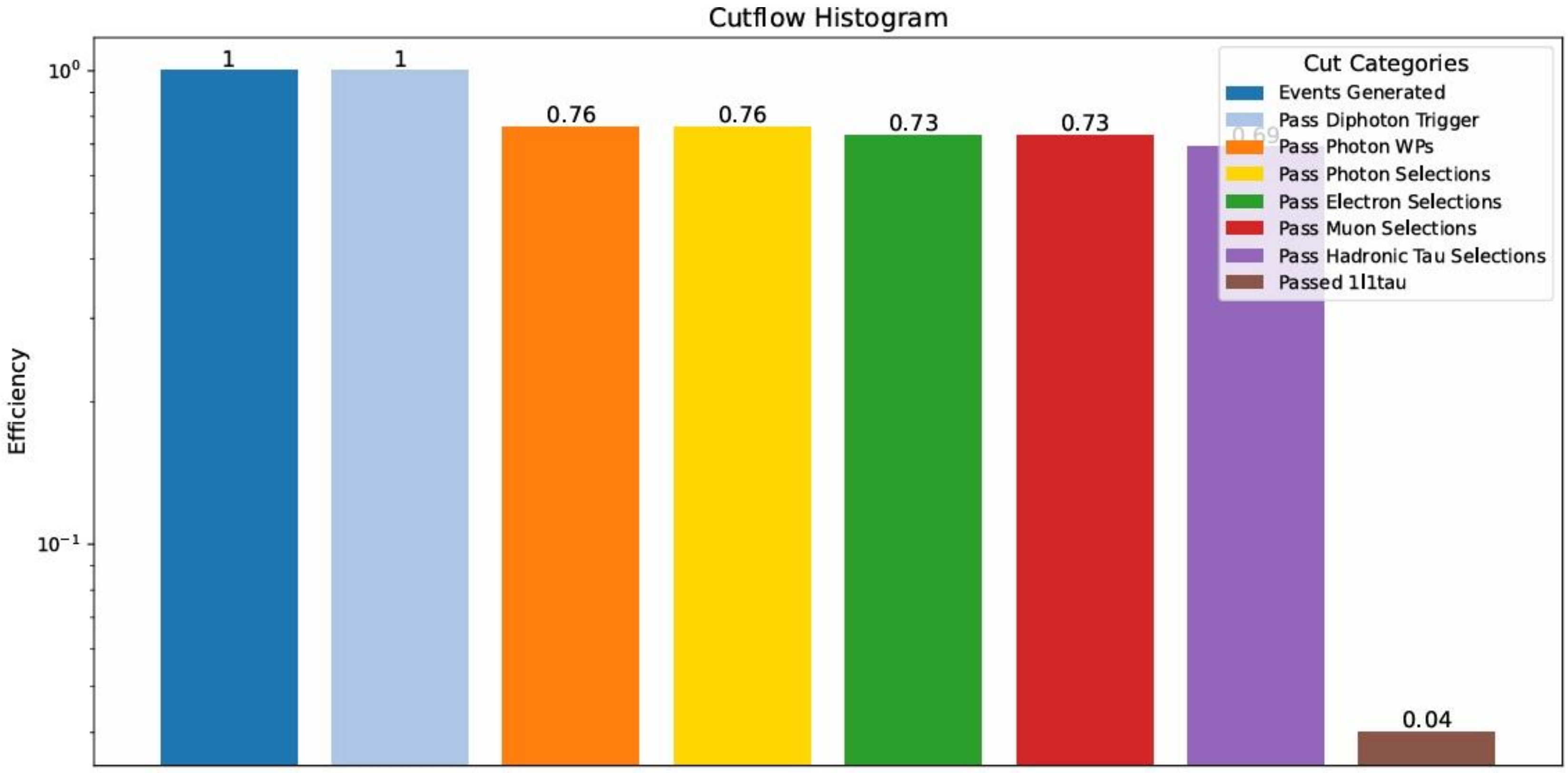
- RNN Loose WP
- $p_T \geq 25$ GeV
- $1.37 < |\eta| < 1.52$ excluded and $|\eta| < 2.5$

Leptons (Electron/Muon)

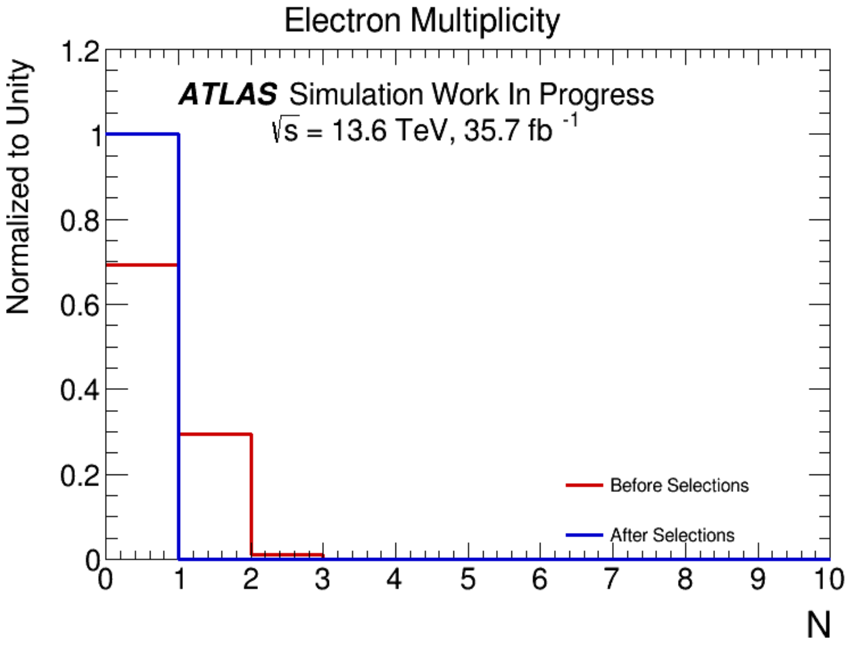
- The electon must have $p_T \geq 10$ GeV and $|1.37 < |\eta| < 1.52$ excluded and $|\eta| < 2.5$ at MediumDNNLoose Var Rad WP
- The muon must have $p_T \geq 10$ GeV and $|\eta| < 2.5$ at MediumPflow Loose Var Rad WP

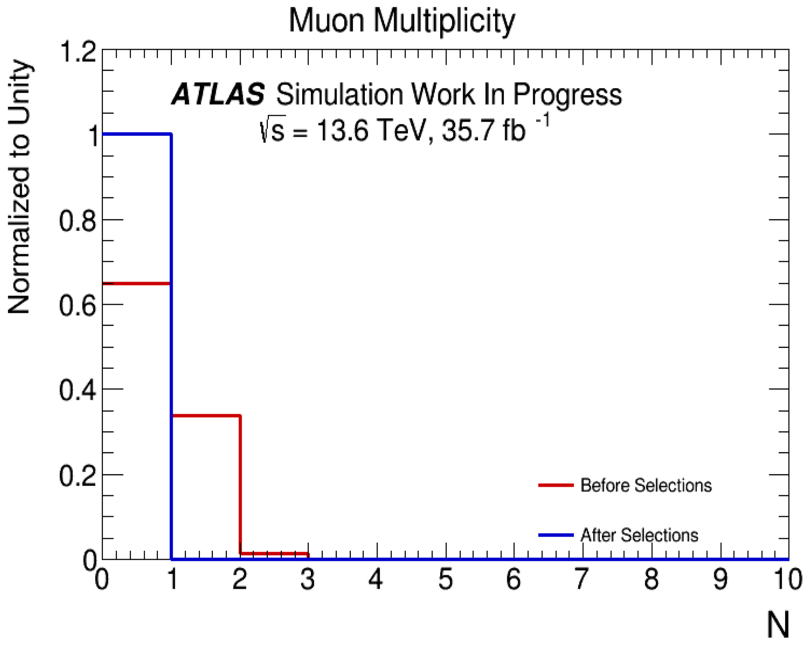
- For the electron we used the **MediumDNNLooseVarRad WP** to identify electrons that may have radiated photons and keep a high signal efficiency.
- For the muon we used **MediumPflowLooseVarRad WP** identify muons that have radiated energy and work with particle flow objects for better event construction.
- After passing the above object selections we require 1 lepton and 1 Tau final state for further study.
- More on the selections see paper **ATLAS-CONF-2024-005**

Cutflow Histogram ($\gamma\gamma + 1l1\tau$ Final State)

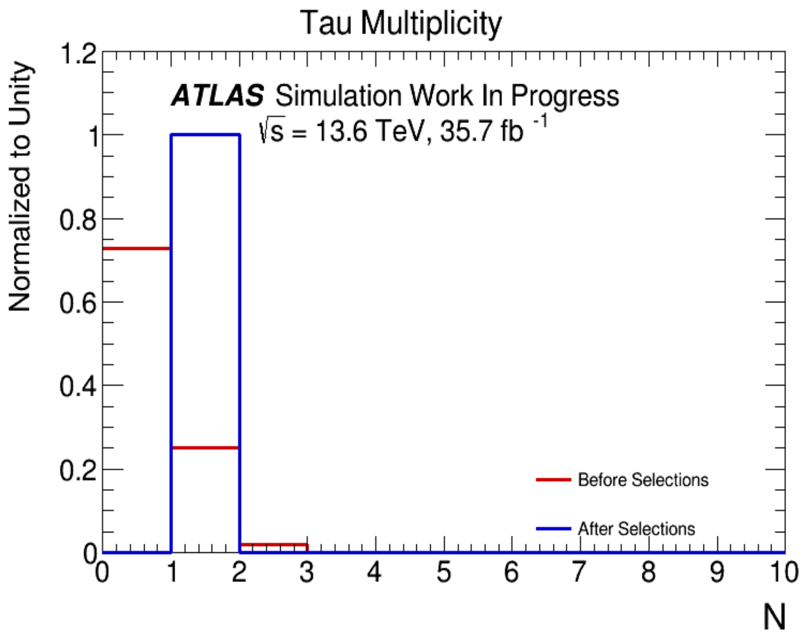


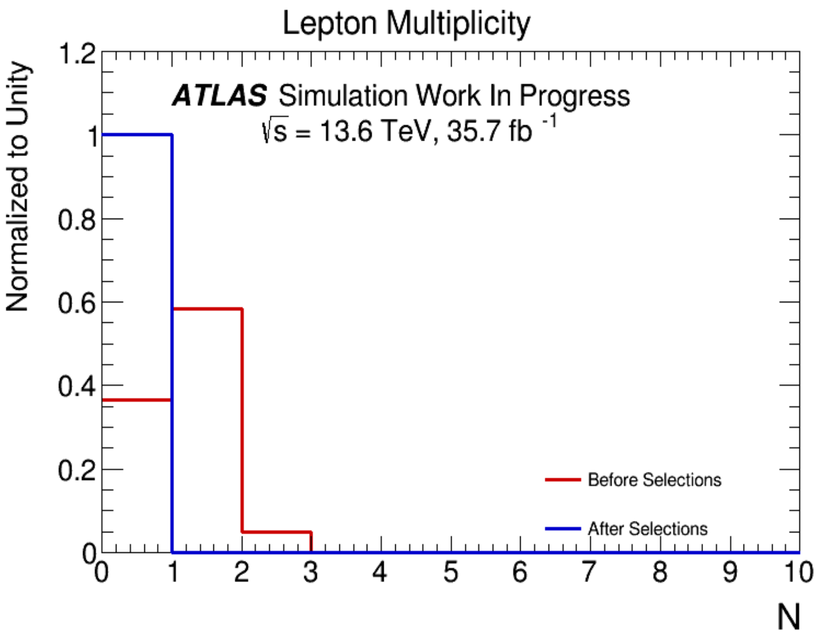
Kinematic Distributions ($\gamma\gamma + \ 0l1\tau$ Final State)



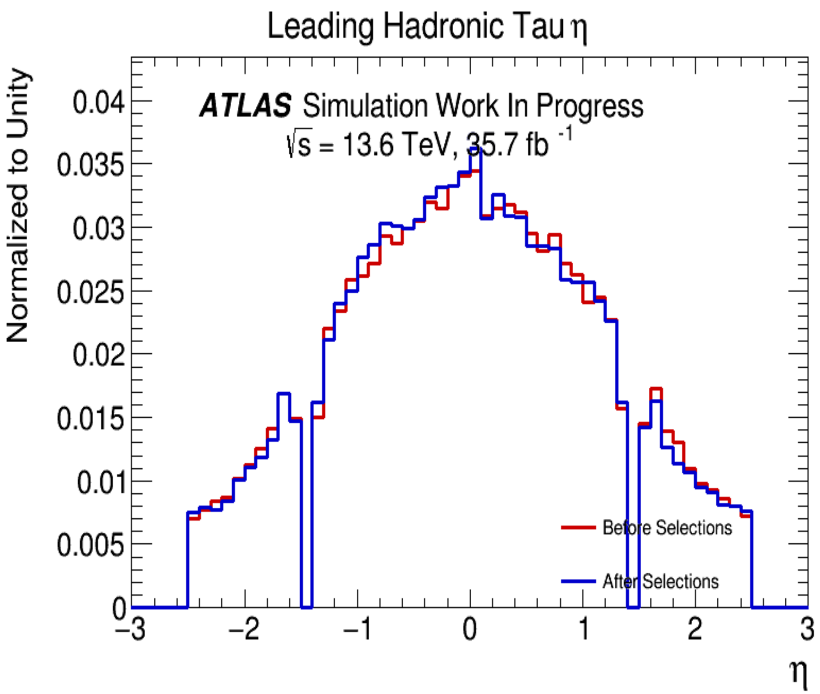


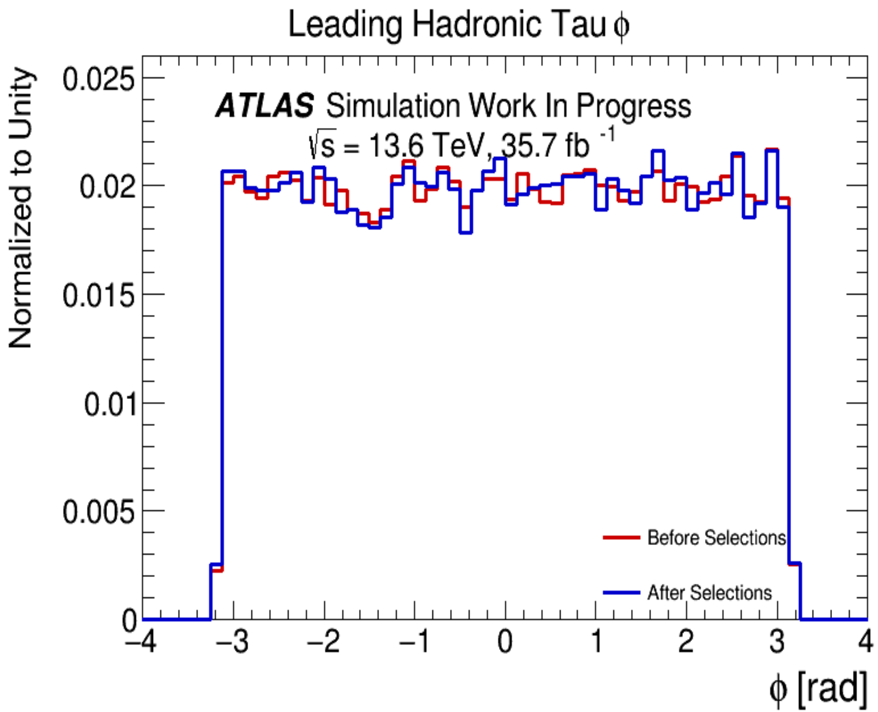
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



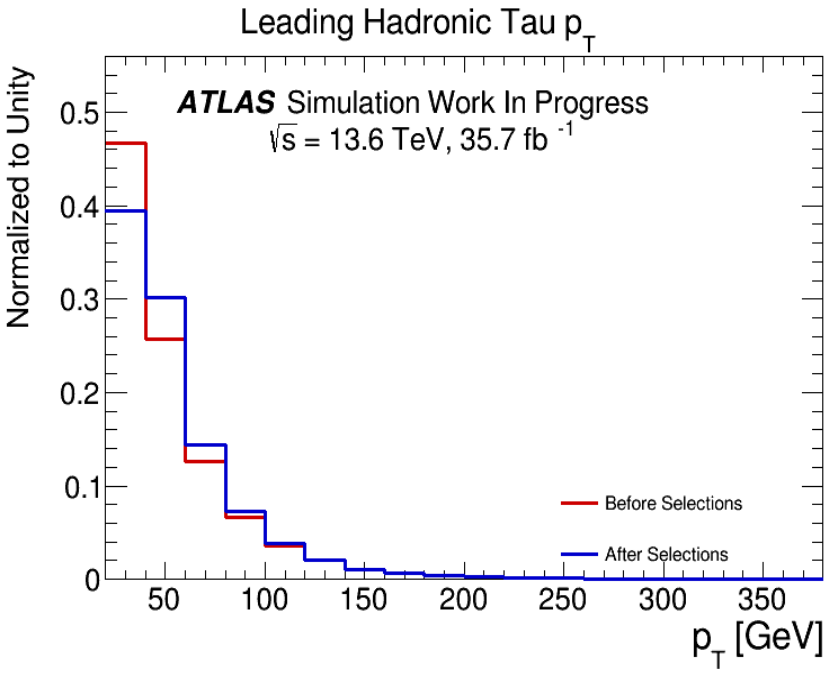


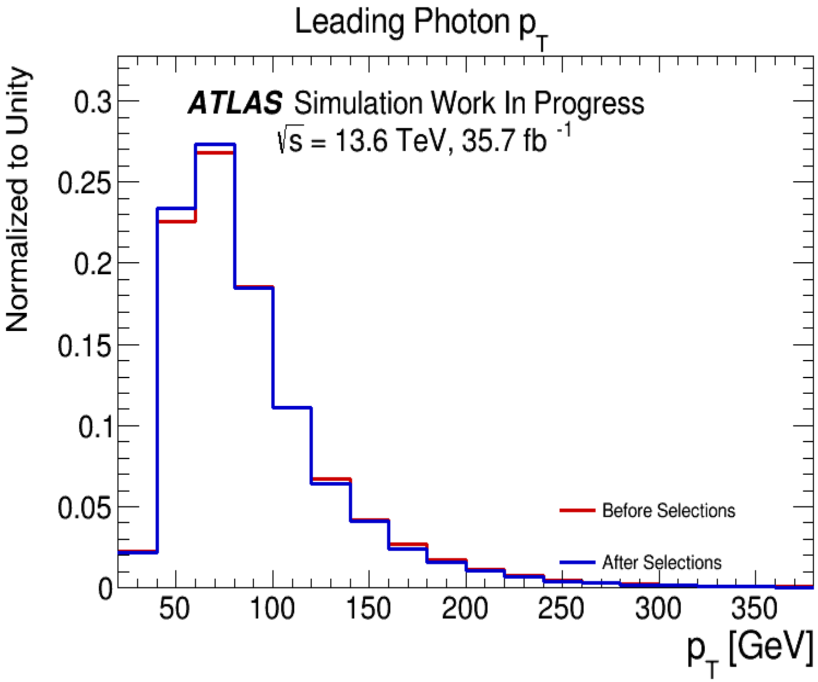
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



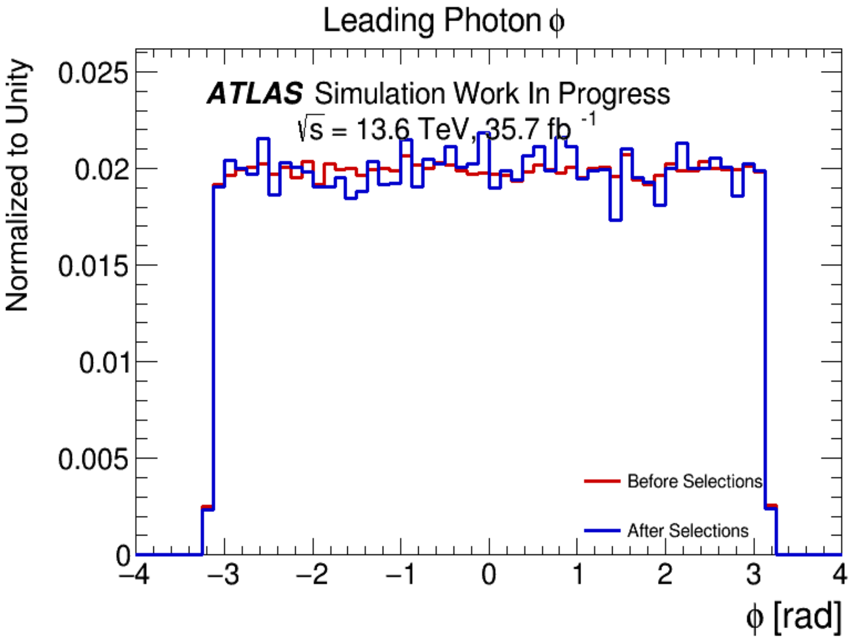


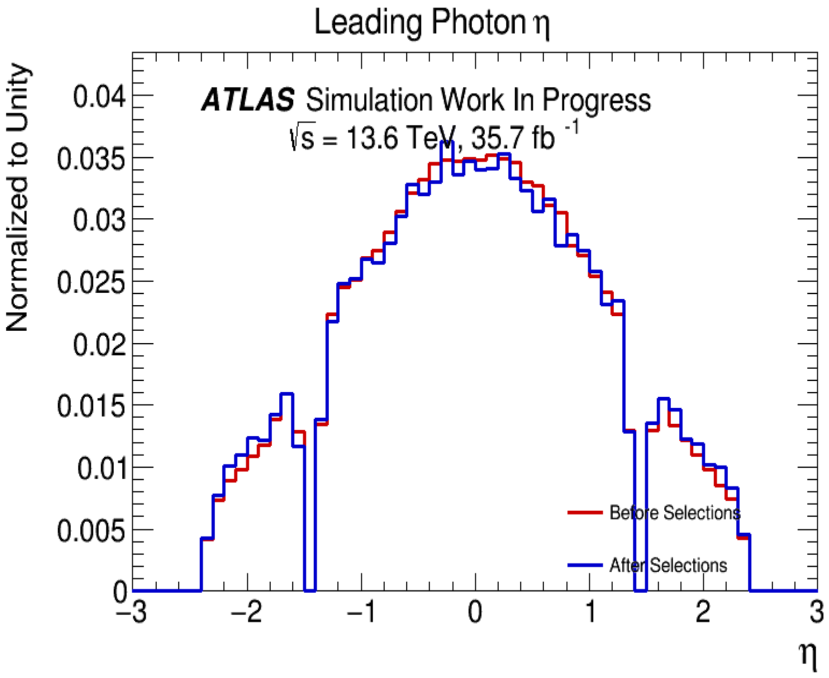
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



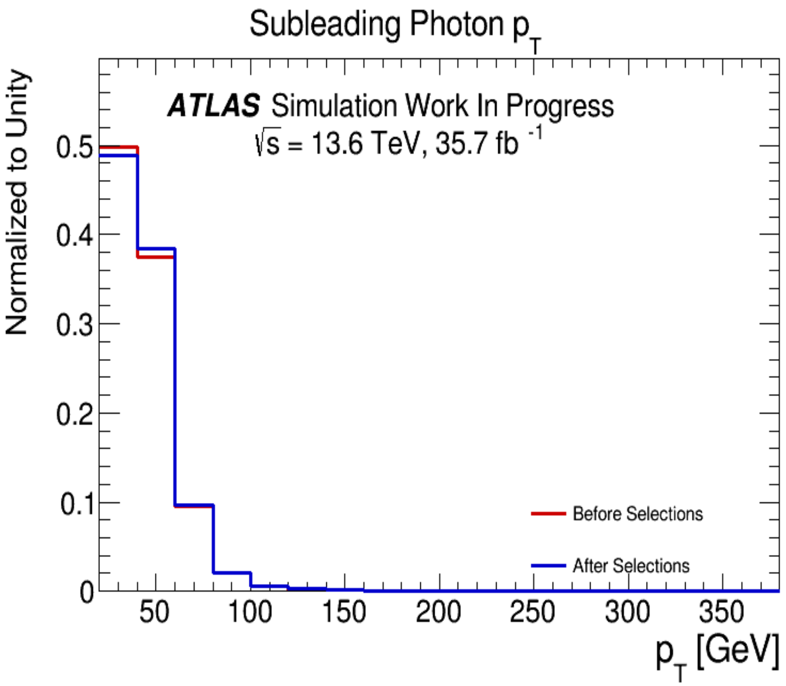


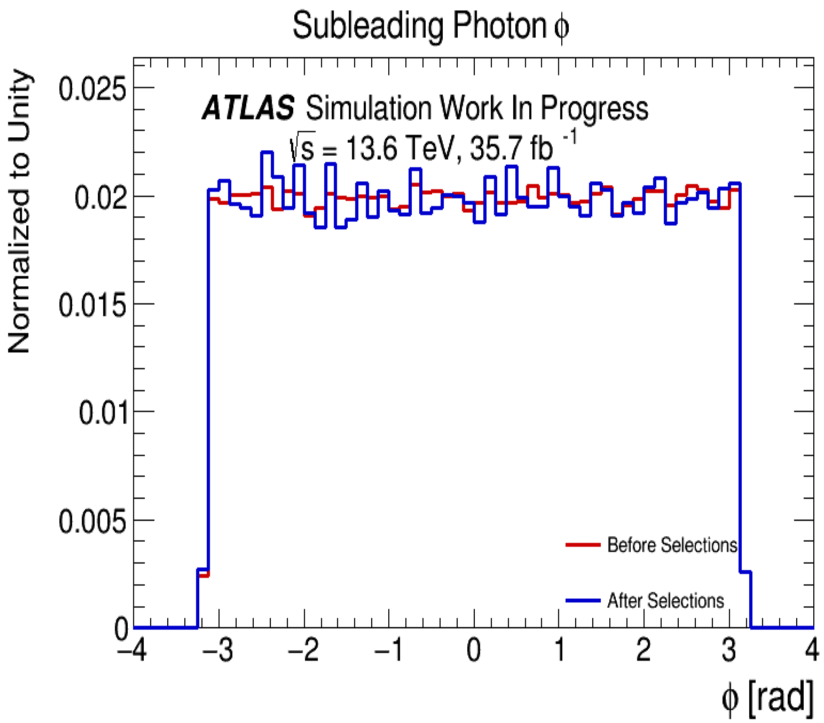
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



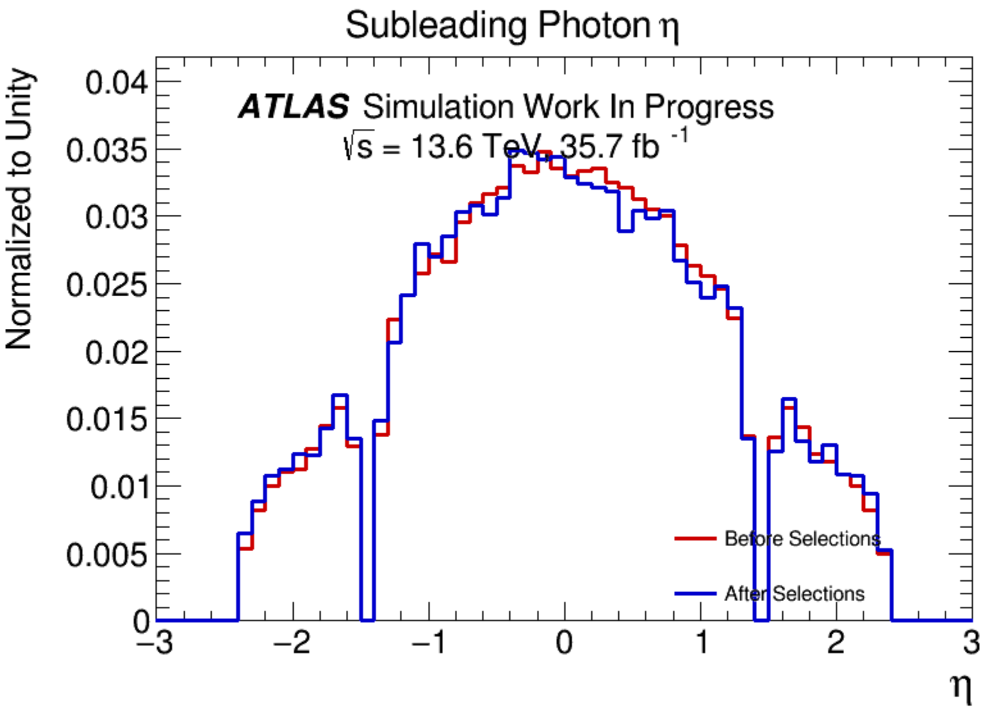


Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)

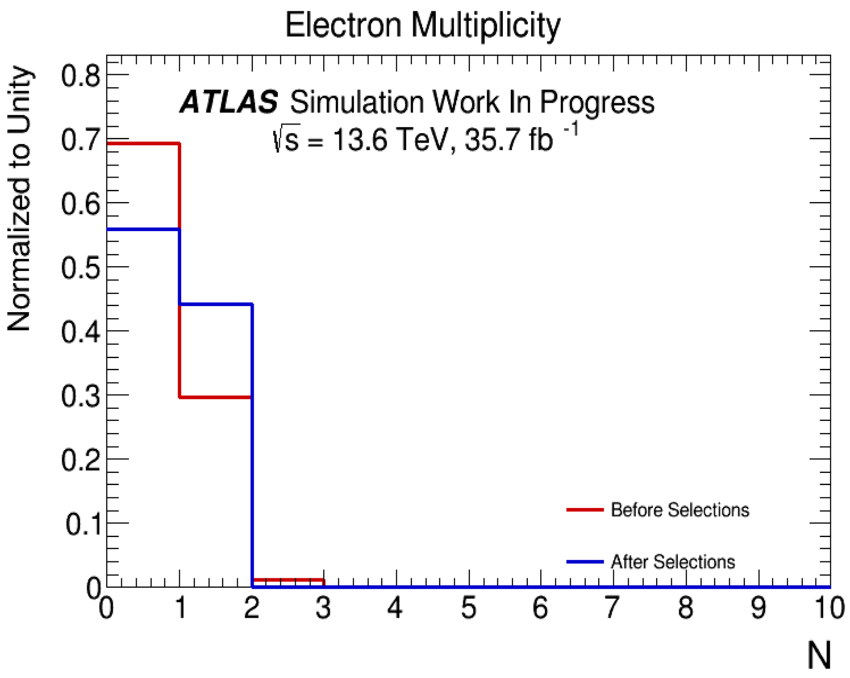


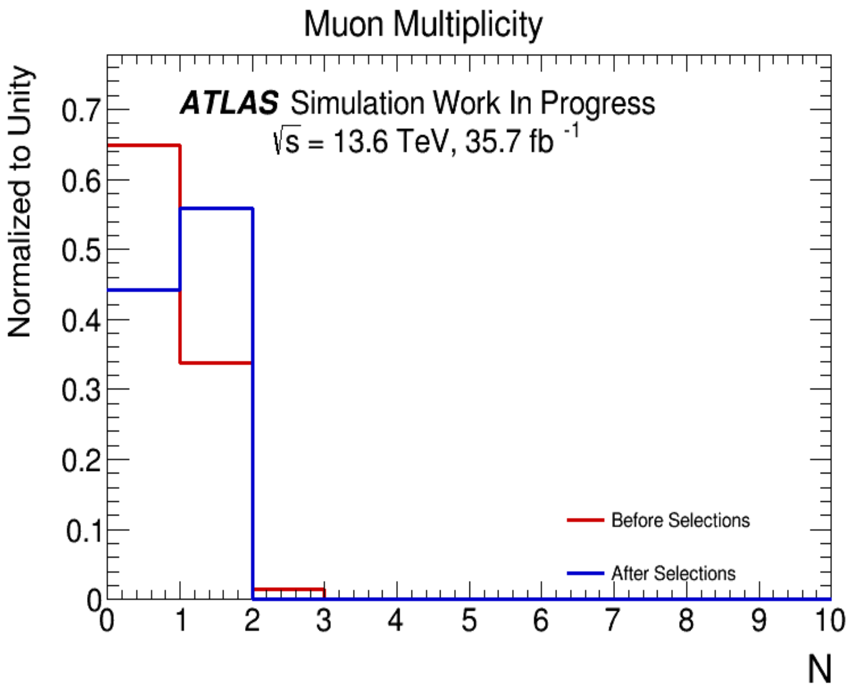


Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)

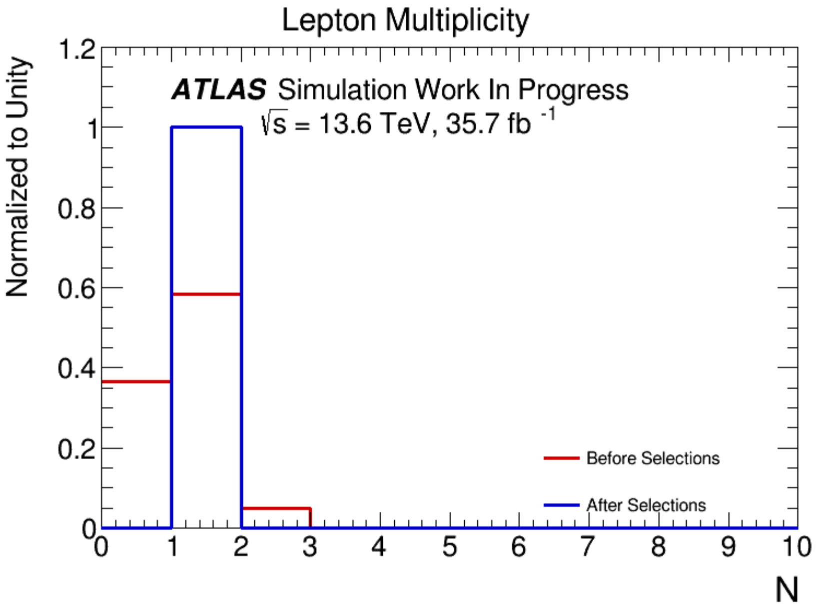


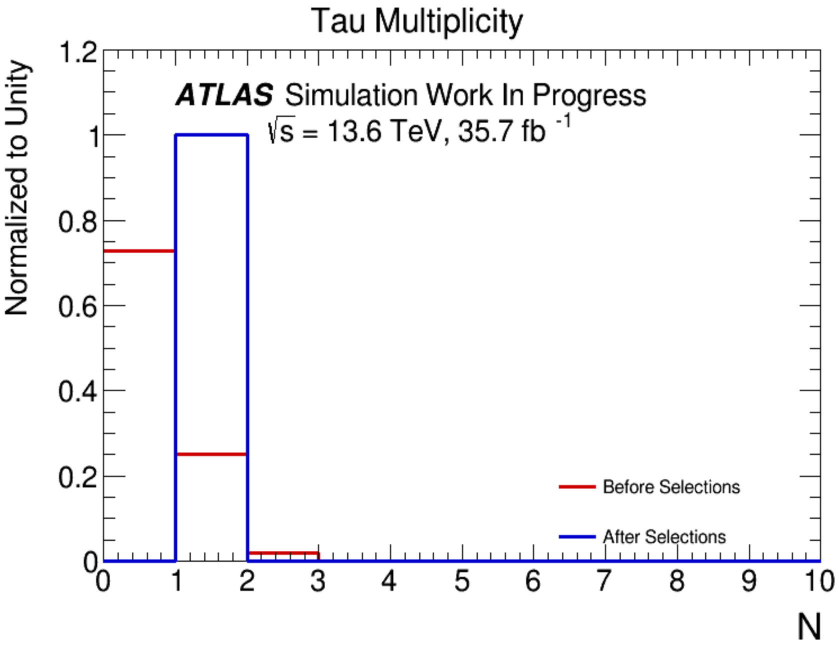
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



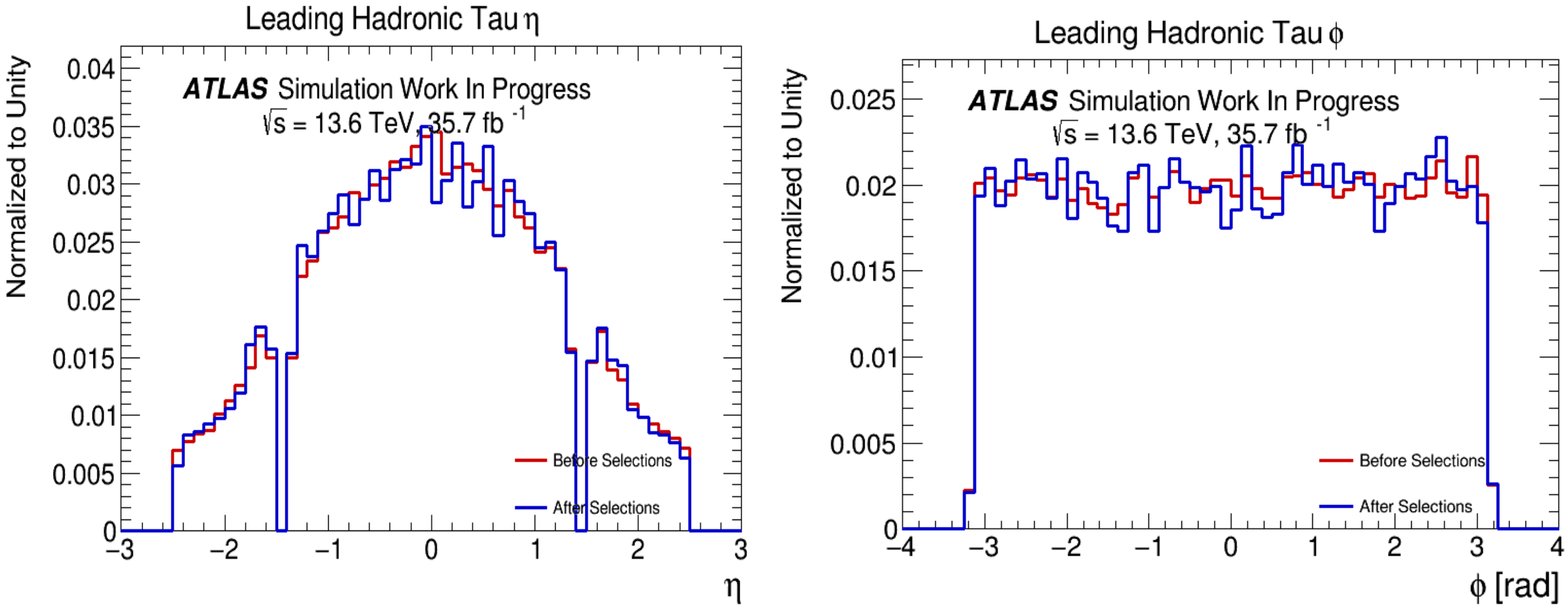


Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)

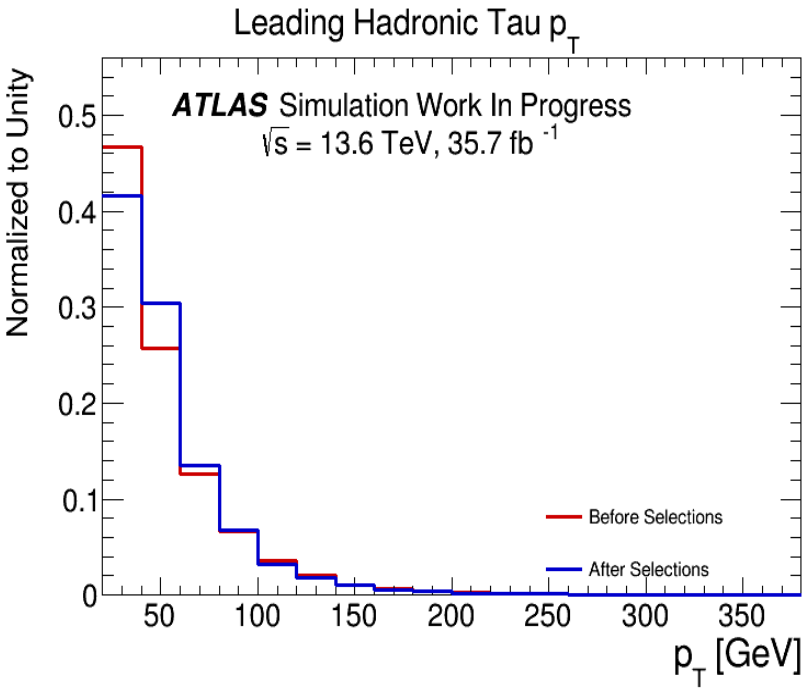


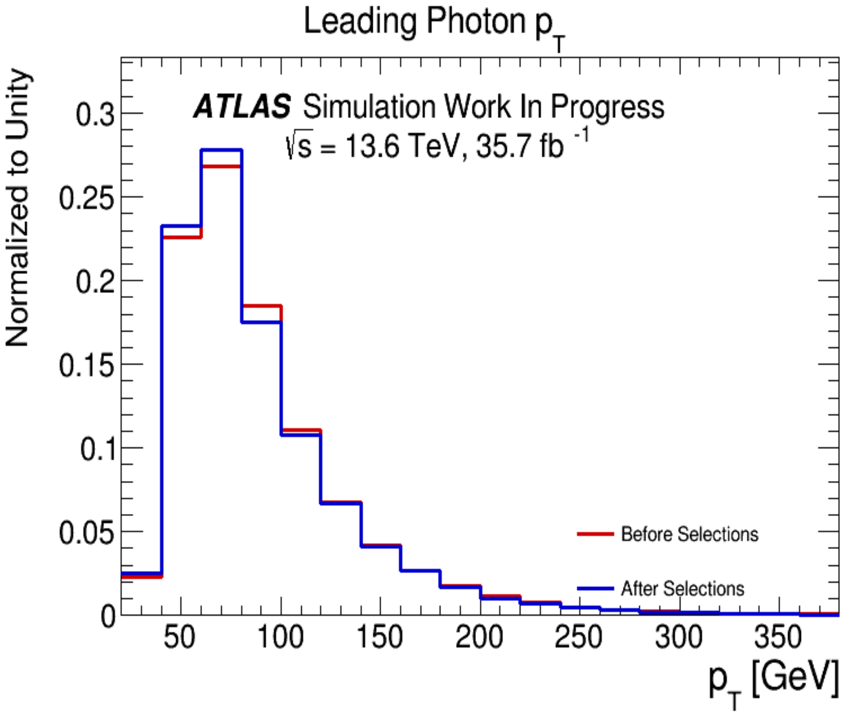


Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)

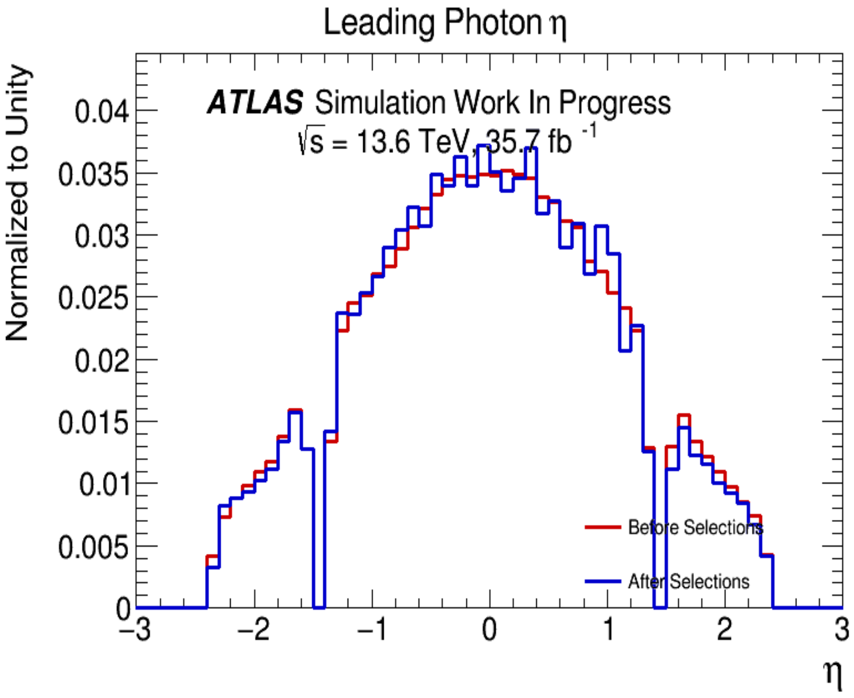


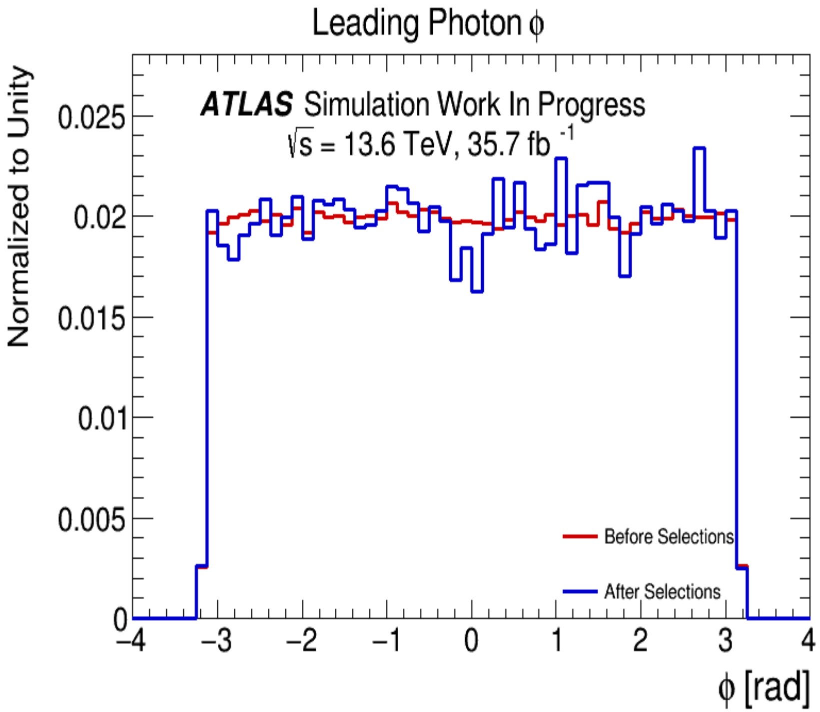
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



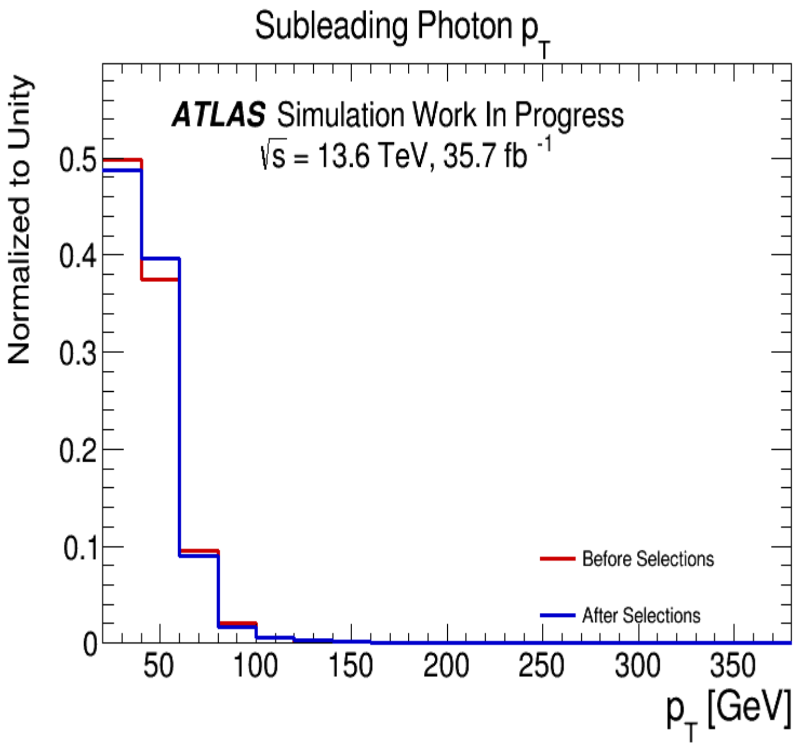


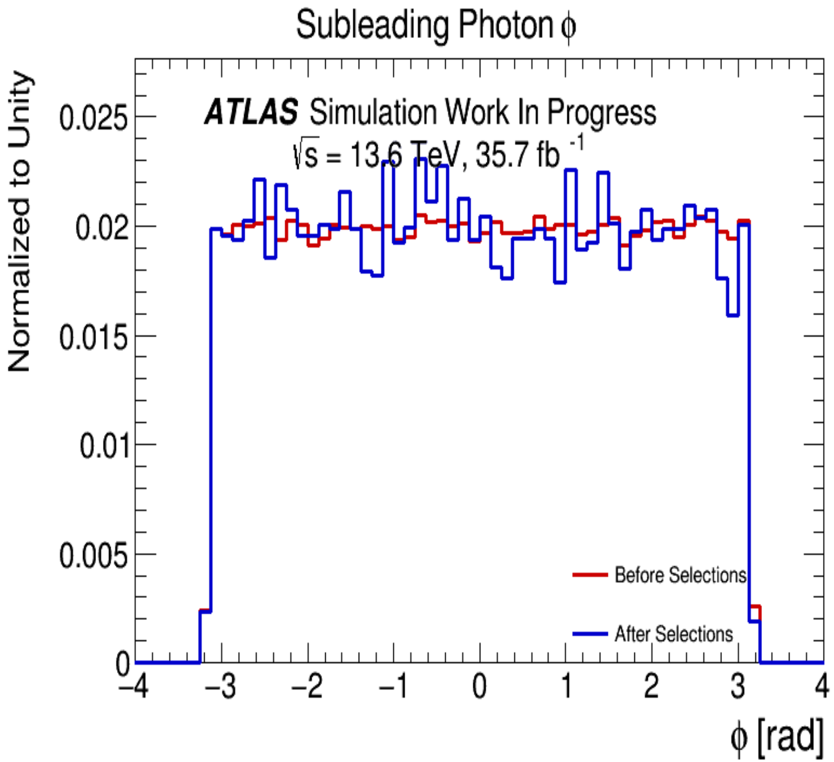
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



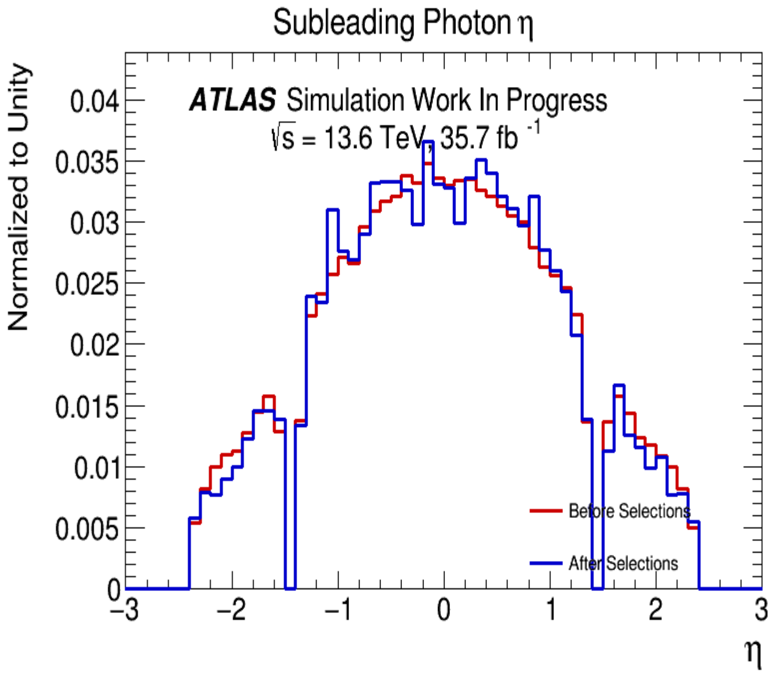


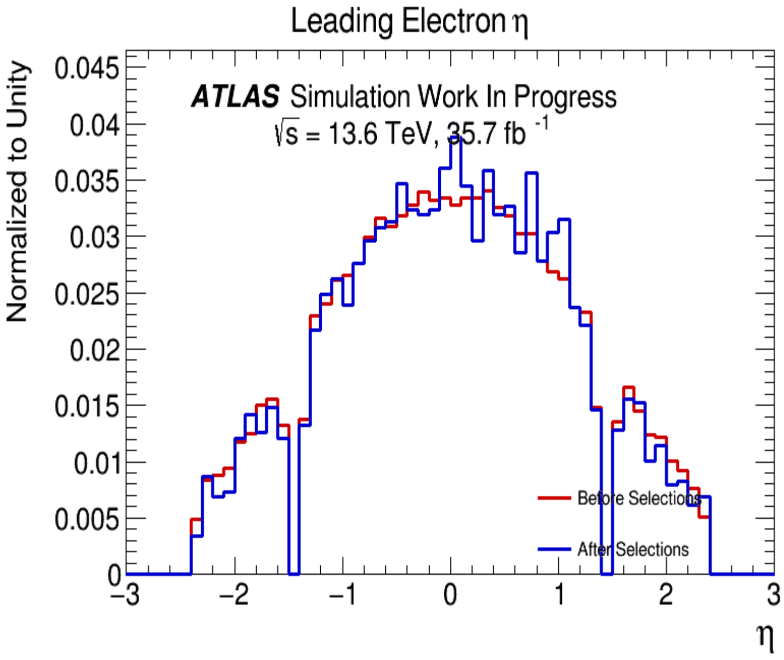
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



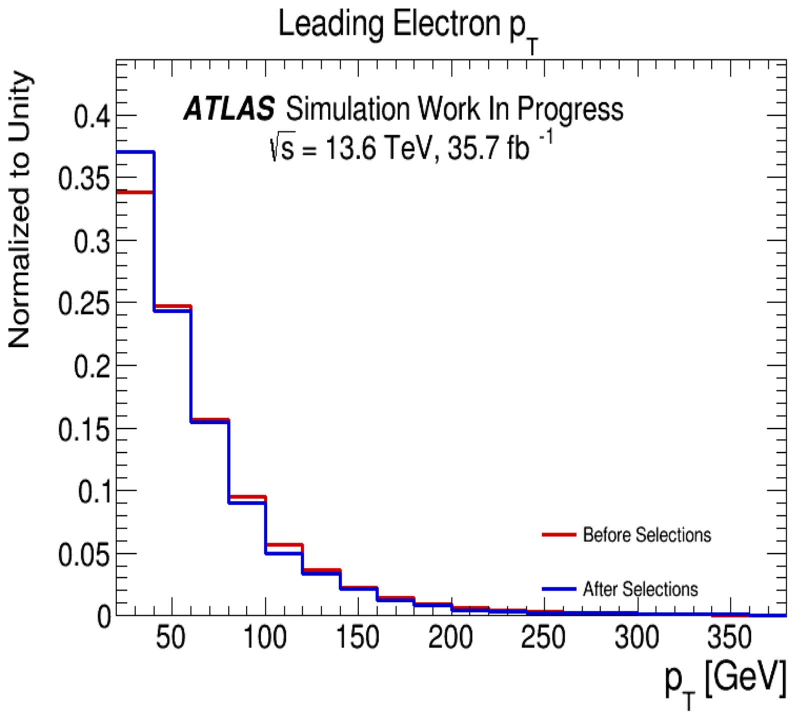


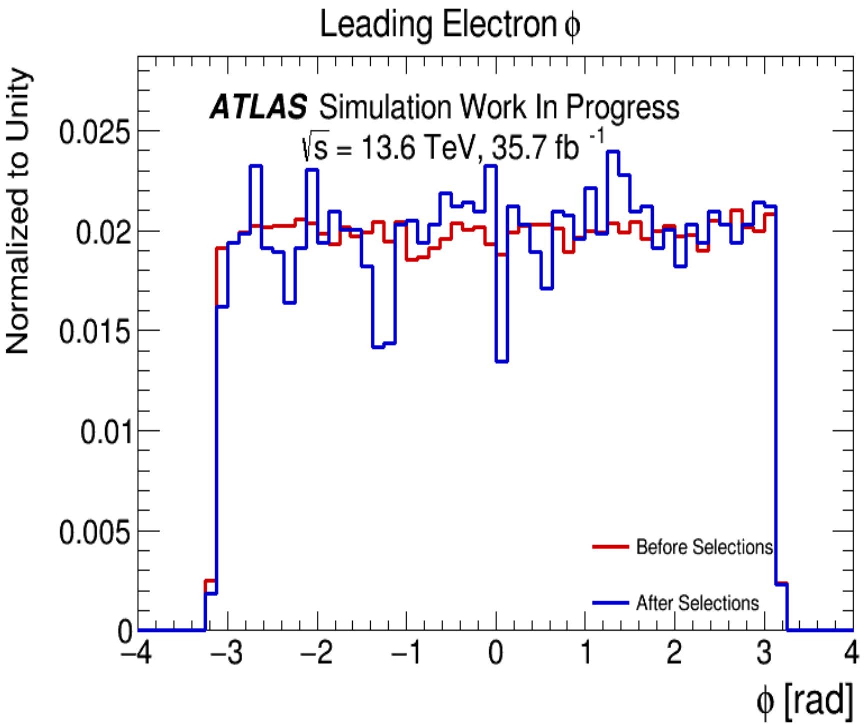
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



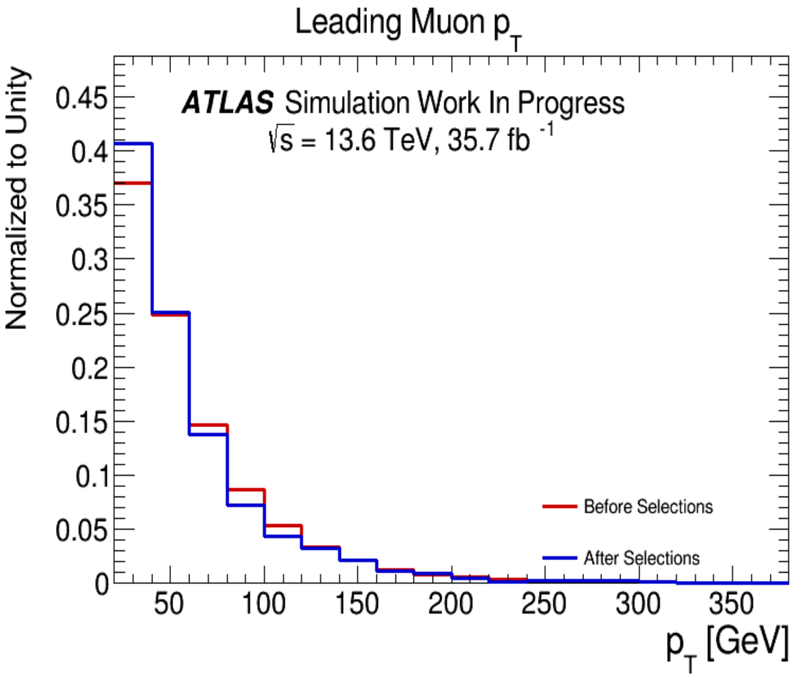


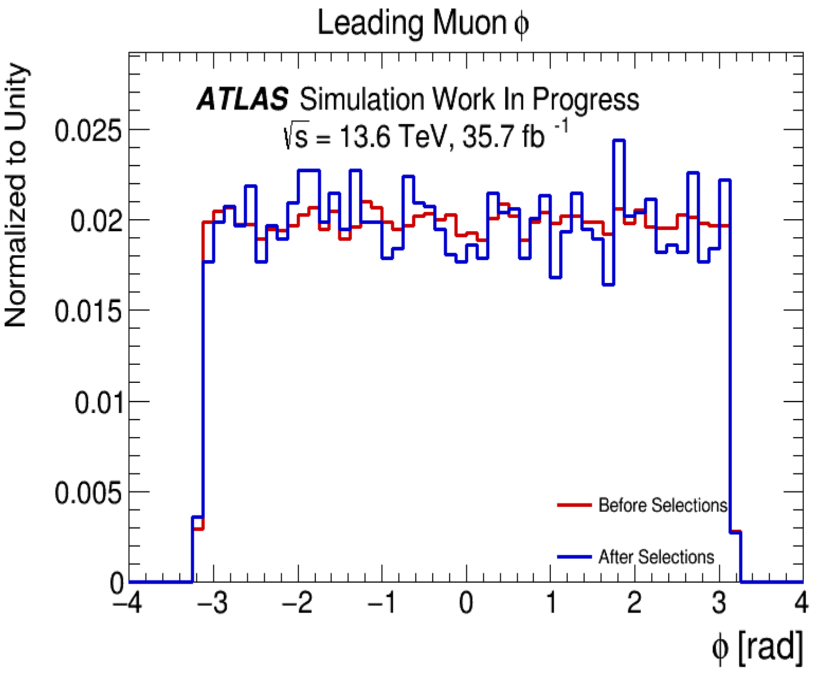
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



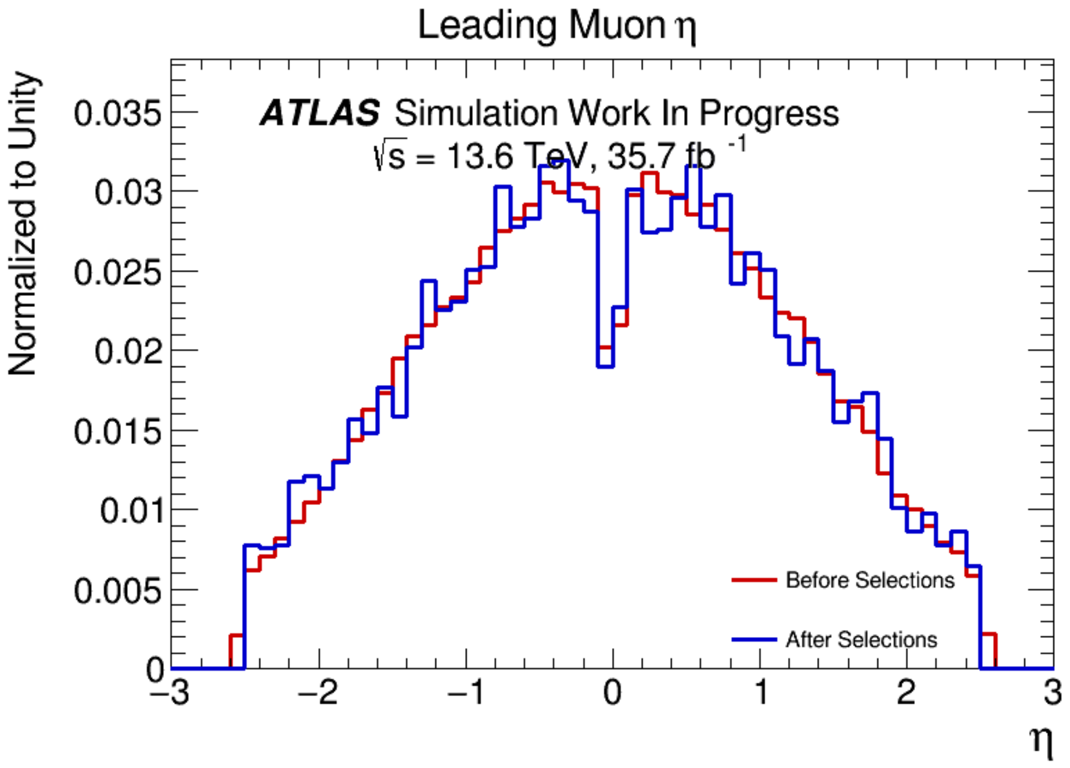


Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)





Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



Conclusions

- We submitted requests for the production of the dilepton and one lepton final state (see Njokweni's Talk).
- About to receive the signal samples ($\gamma\gamma + 2\tau$ /**b**'s final states) and the next step is to include them in our analysis.
- Successfully managed to make the desired object selections for our background.
- Background characterisation is the next step to follow.

THANK YOU FOR LISTENING

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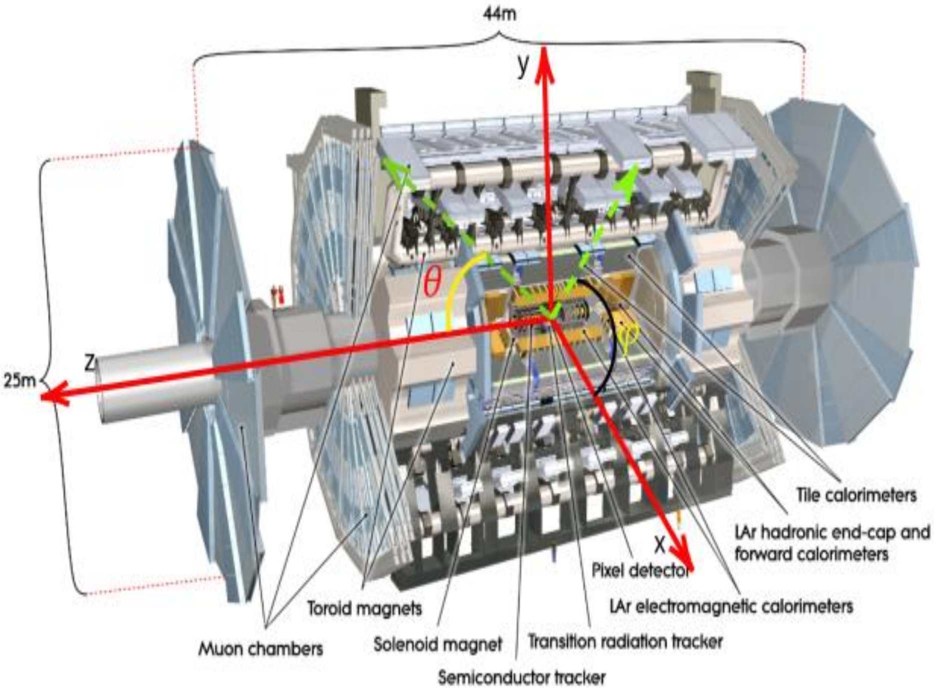
BACK UP SLIDES

The layout of the ATLAS Experiment

- The z –axis aligns with the beam direction, the x-axis point toward the center of the LHC ring and the y-axis points upward.

- While the polar angle θ is sometimes used, pseudorapidity η is preferred for its Lorentz invariance under boosts along the beam direction and in relativistic terms η closely approximates rapidity y.

- y = $\frac{1}{2}\ In\ (\frac{E+Pz}{E-Pz})$ where E is the particle's energy and Pz is the longitudinal momentum.



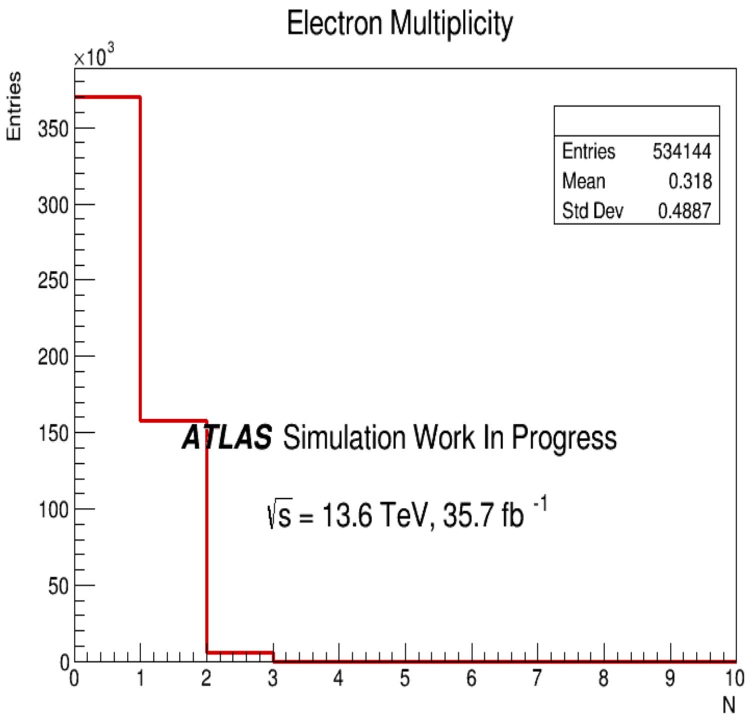
Cutflow Table ($\gamma\gamma + \ 0l1\tau$ Final State)

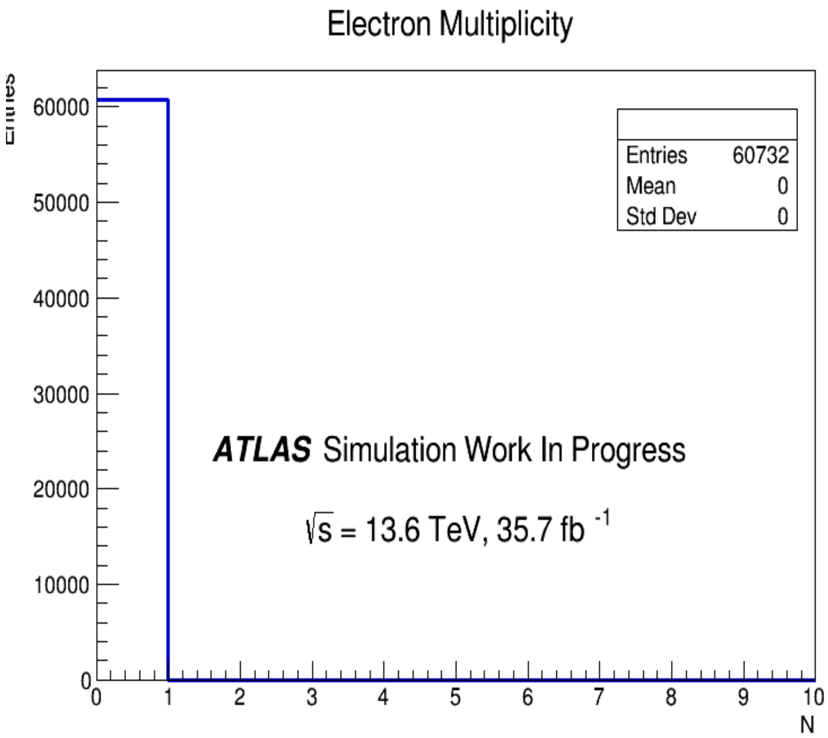
Description	Events Passed
Events Generated	534144
Events Passing the Trigger	534144
Pass Photon WPs	405764
Pass Photon Selections	405558
Pass Hadronic Tau Selections	60732
Pass 0 lepton 1 tau	60732

Cutflow Table ($\gamma\gamma + 1l1\tau$ Final State)

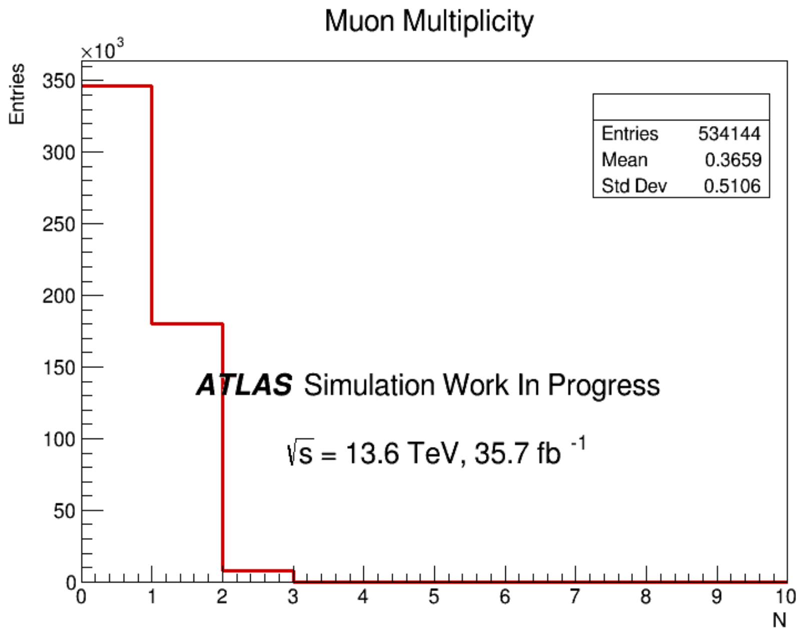
Description	Events Passed
Events Generated	534144
Events Passing the Trigger	534144
Pass Photon WPs	405764
Pass Photon Selections	405558
Pass Electron Selections	391766
Pass Muon Selections	382576
Pass Hadronic Tau Selections	367598
Pass 1 lepton 1 tau	19246

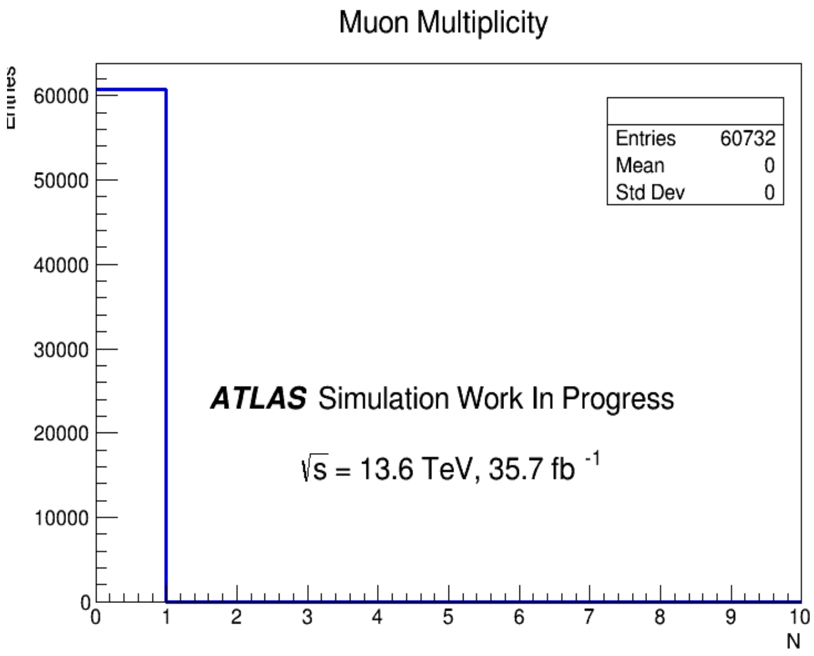
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



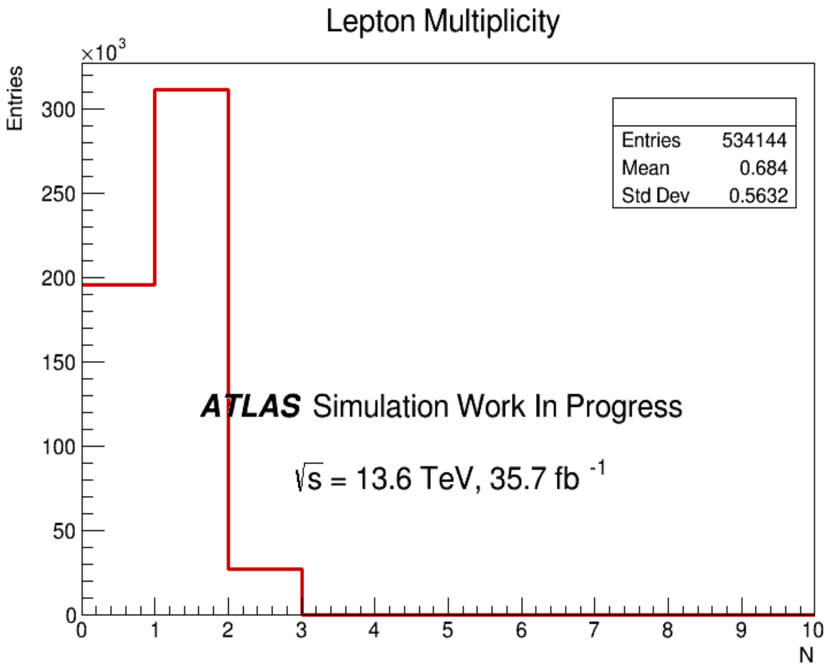


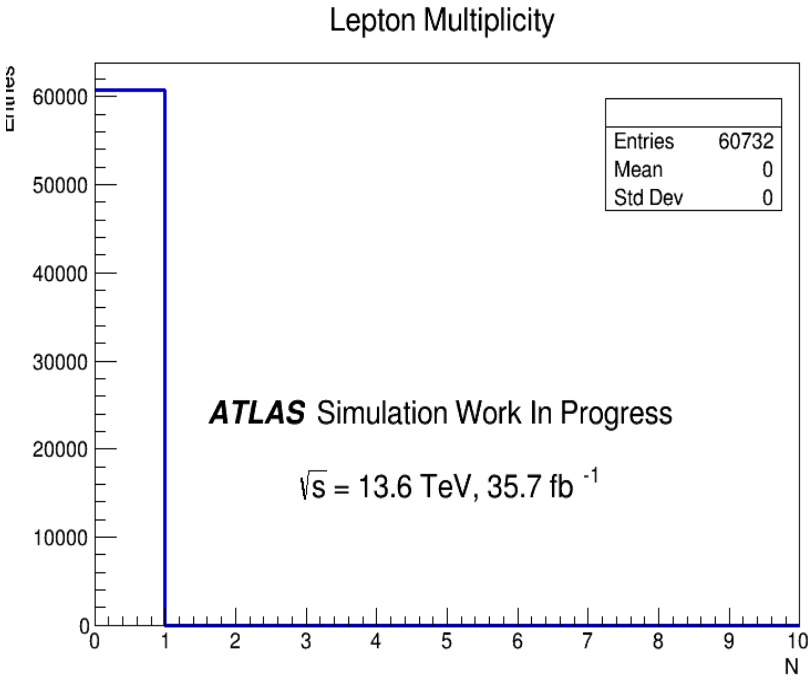
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



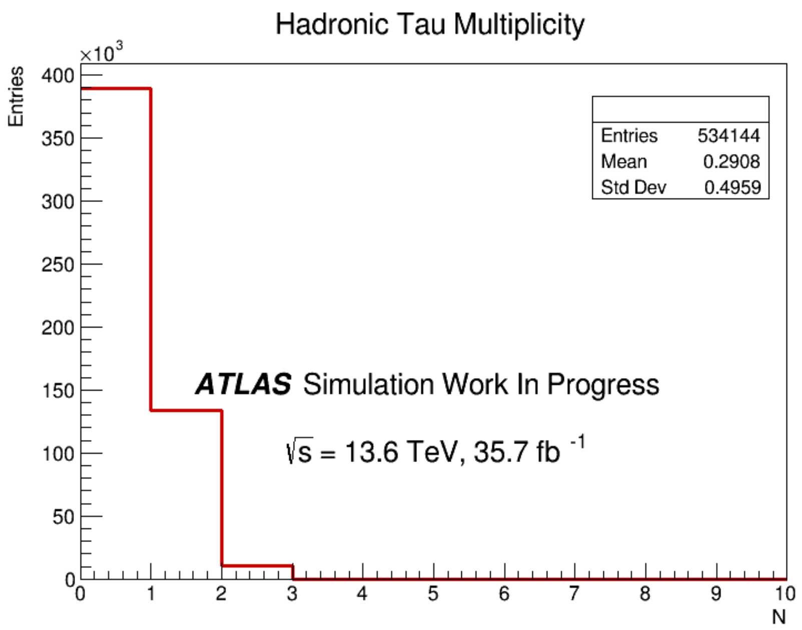


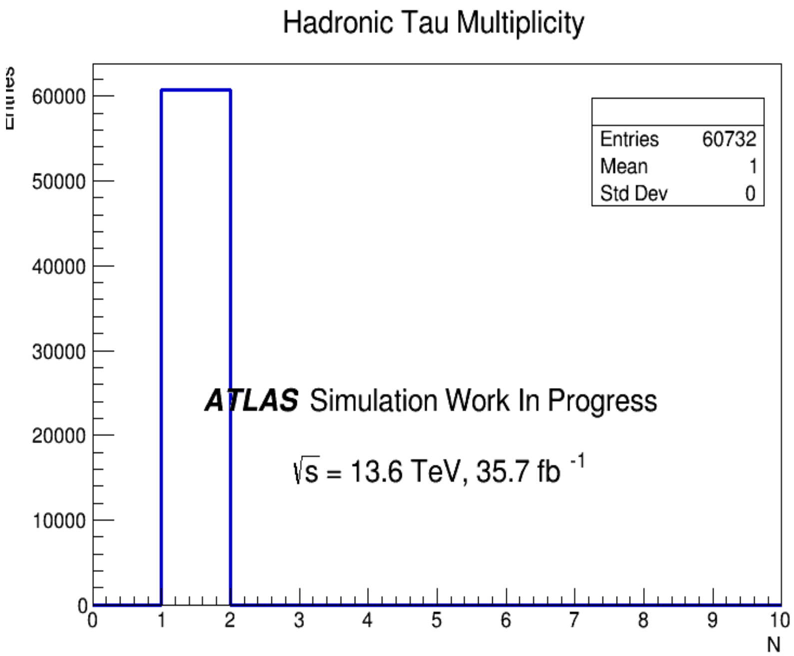
Kinematic Distributions ($\gamma\gamma + \ 0l1\tau$ Final State)



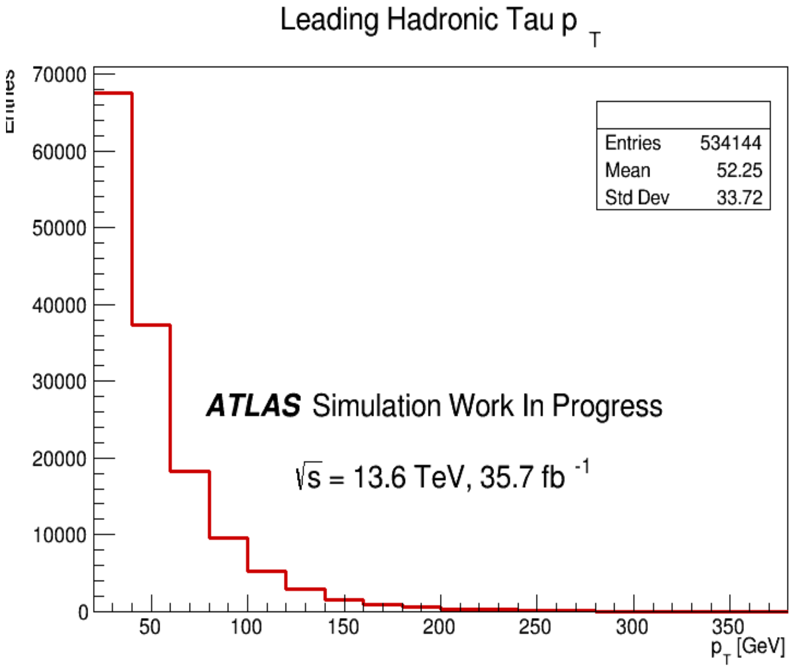


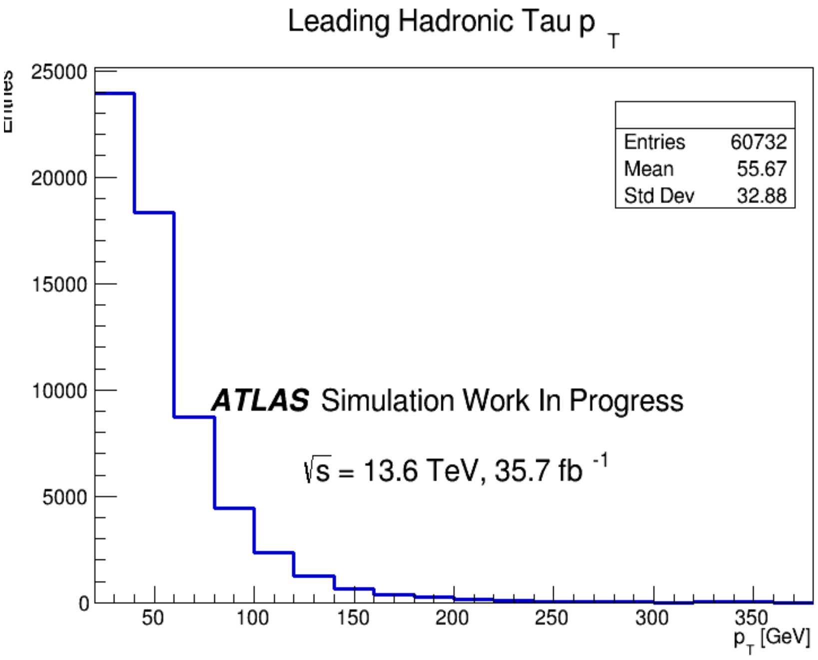
Kinematic Distributions ($\gamma\gamma + \; 0l1\tau$ Final State)



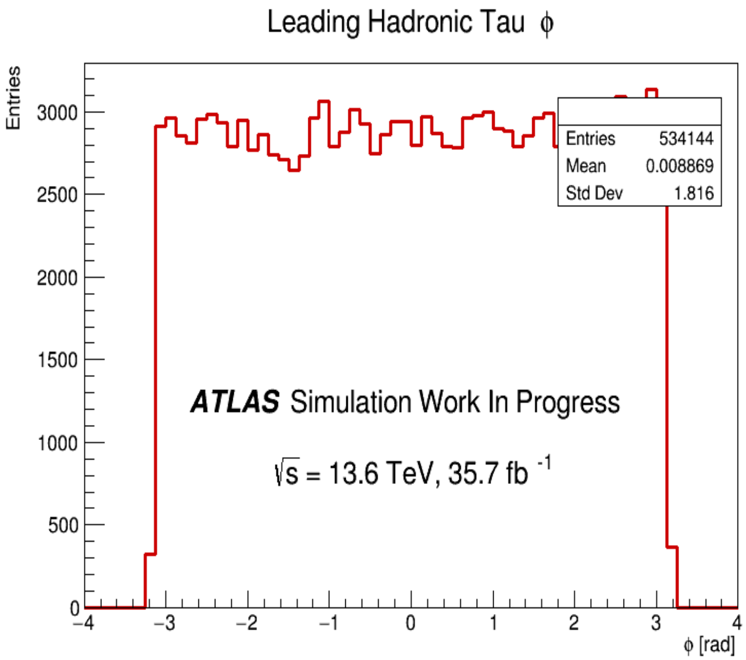


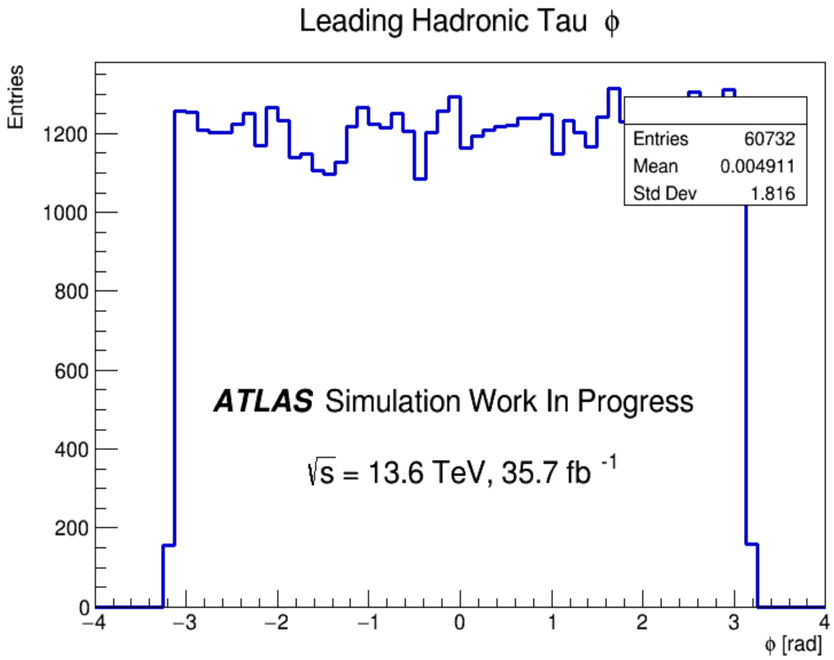
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



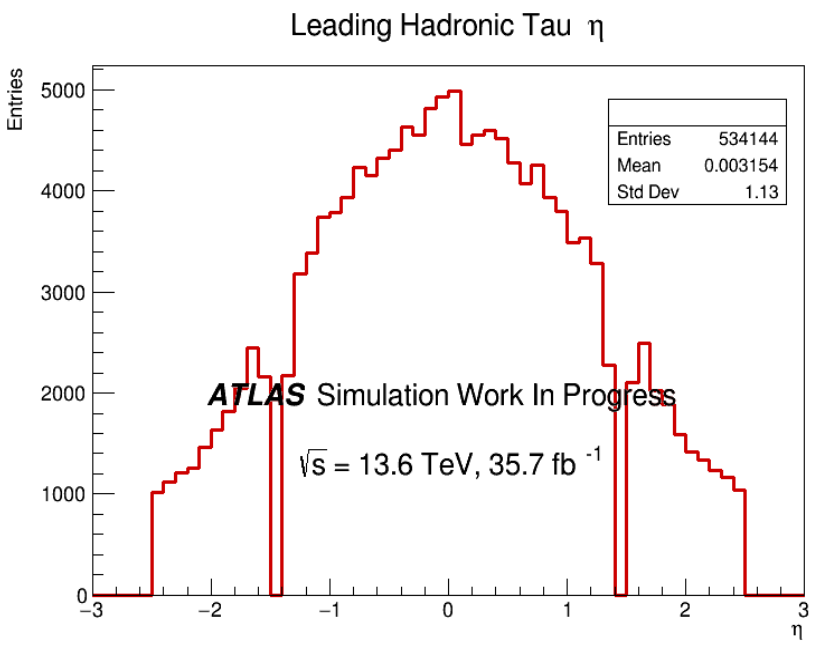


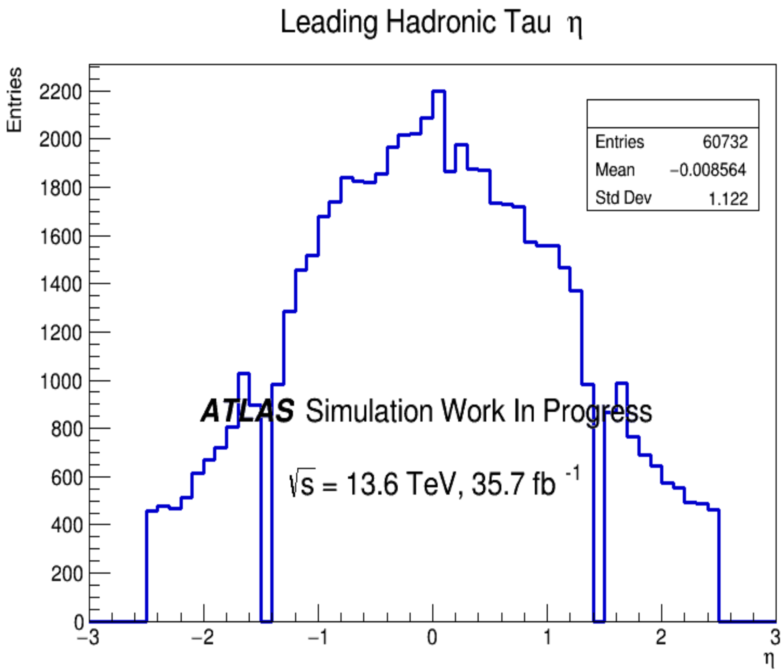
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



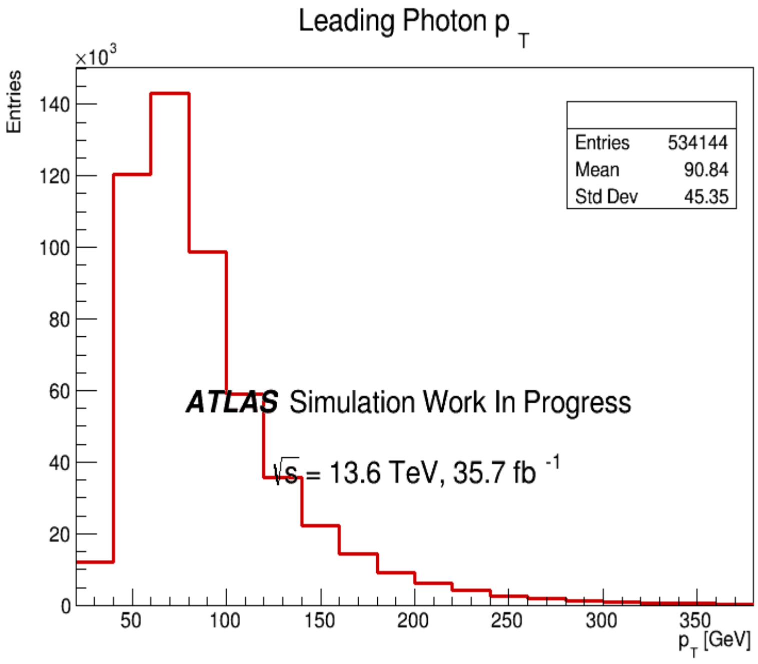


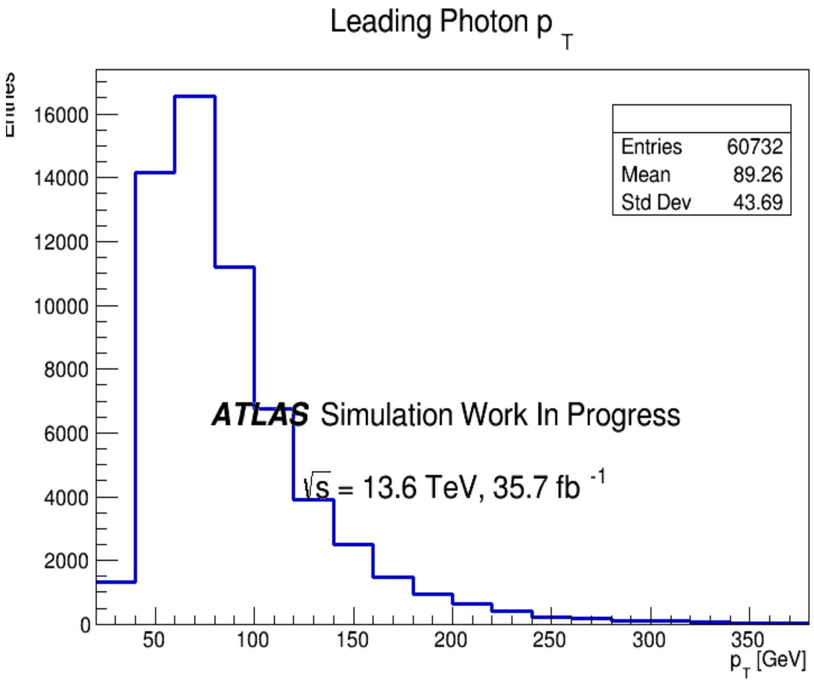
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



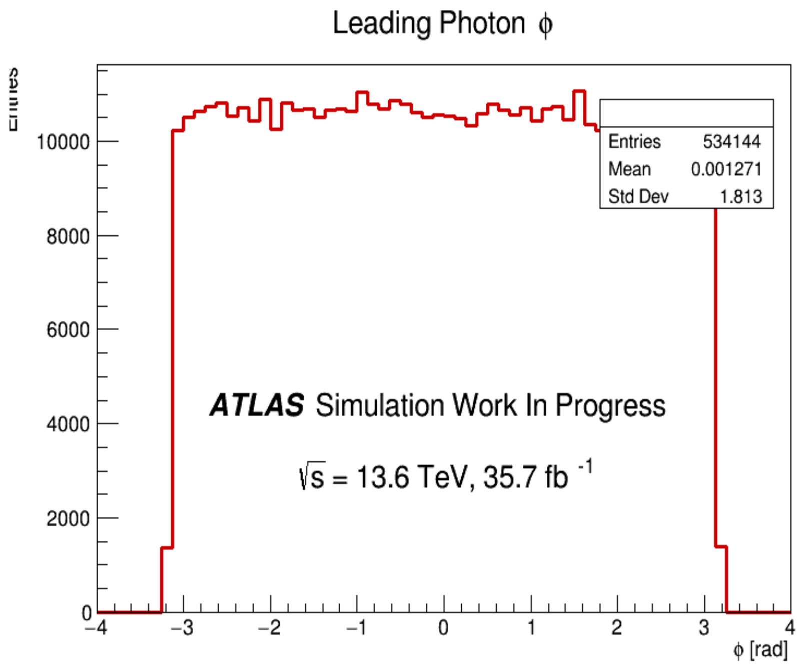


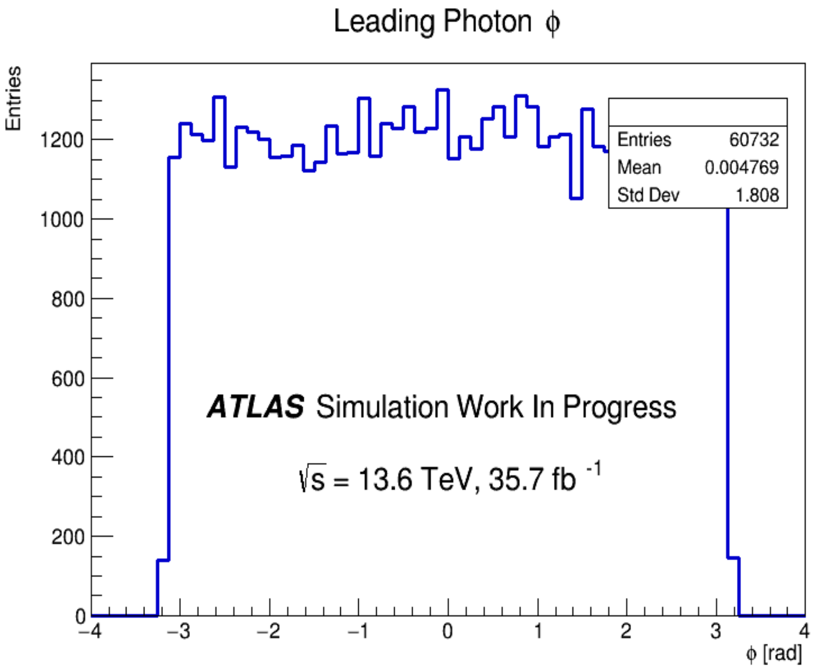
Kinematic Distributions ($\gamma\gamma + \ 0l1\tau$ Final State)



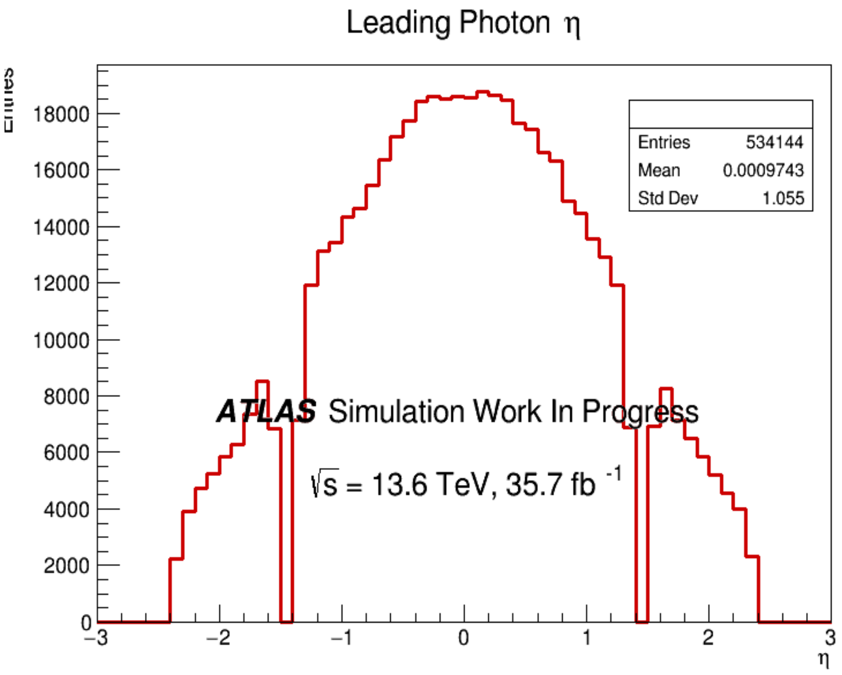


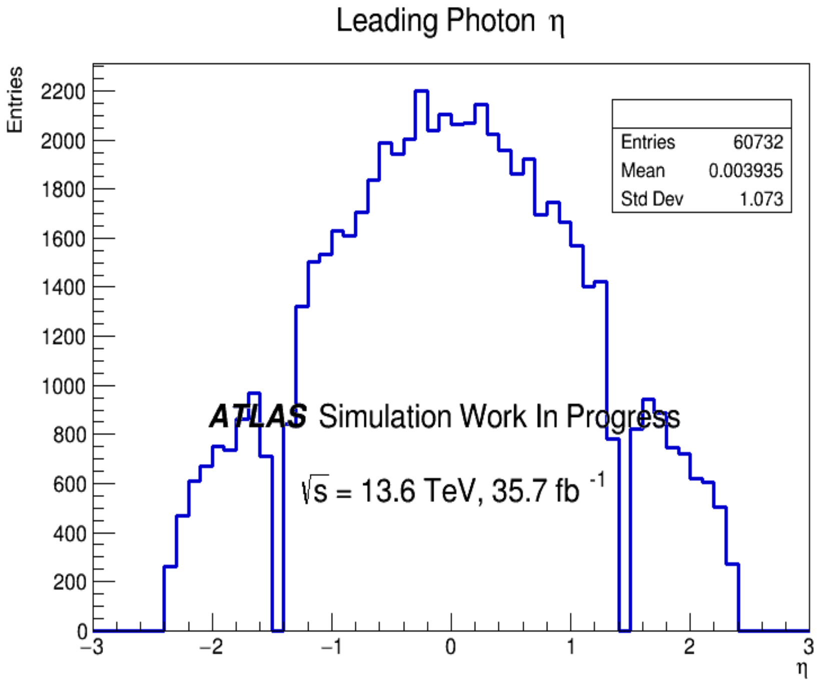
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



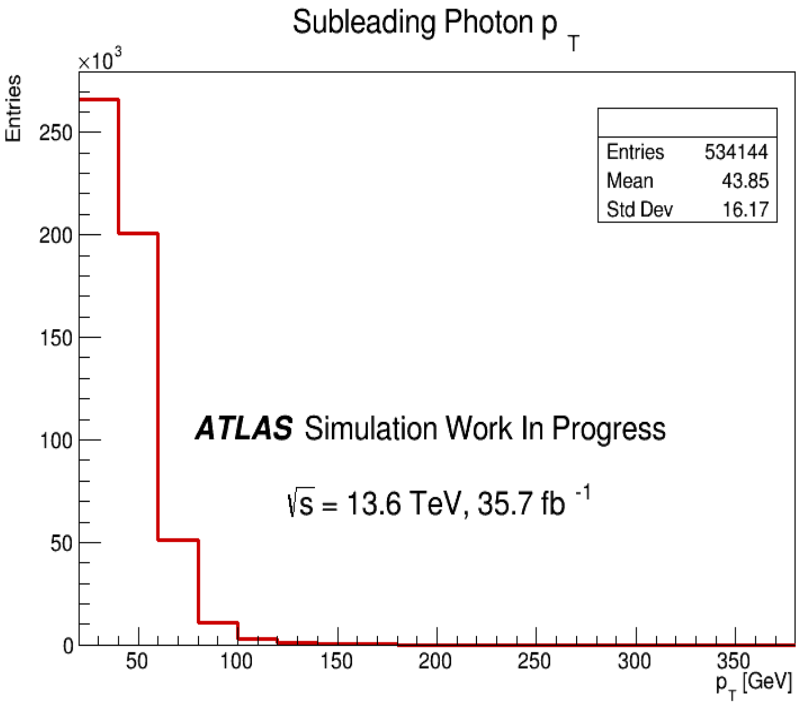


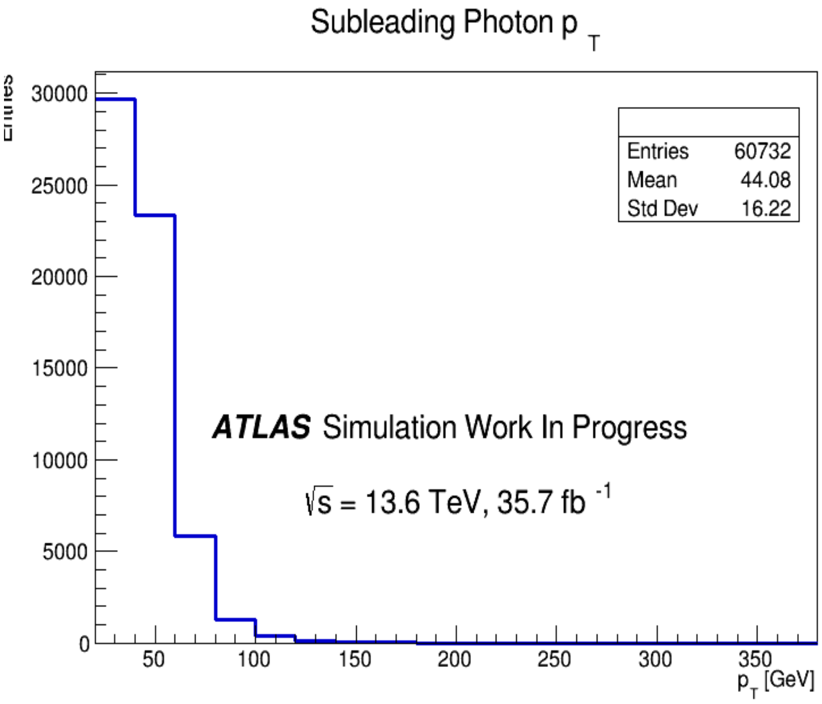
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



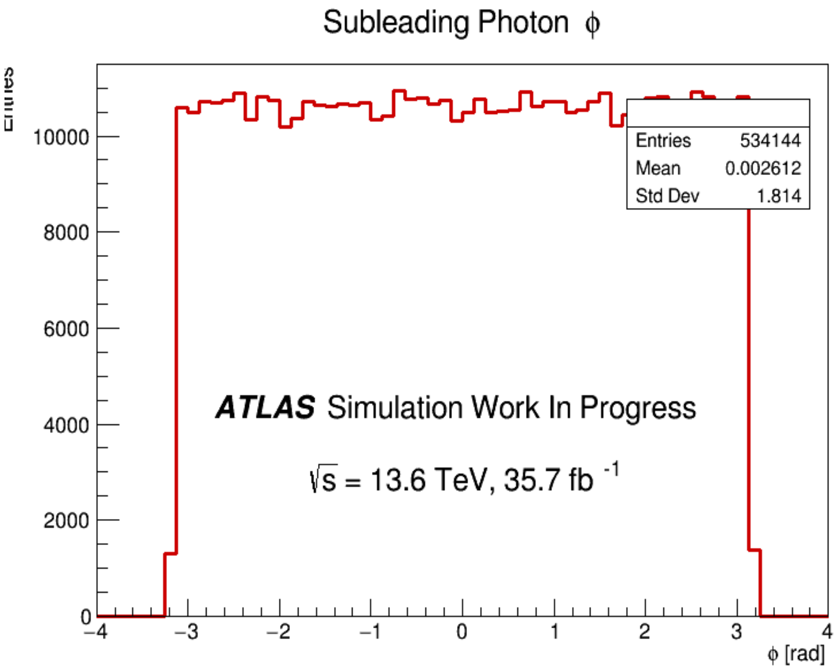


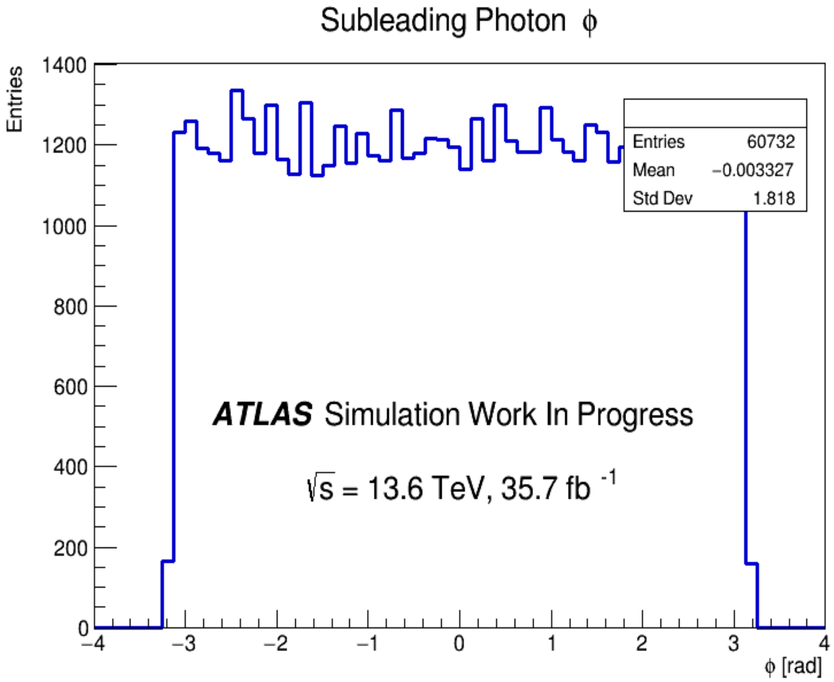
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



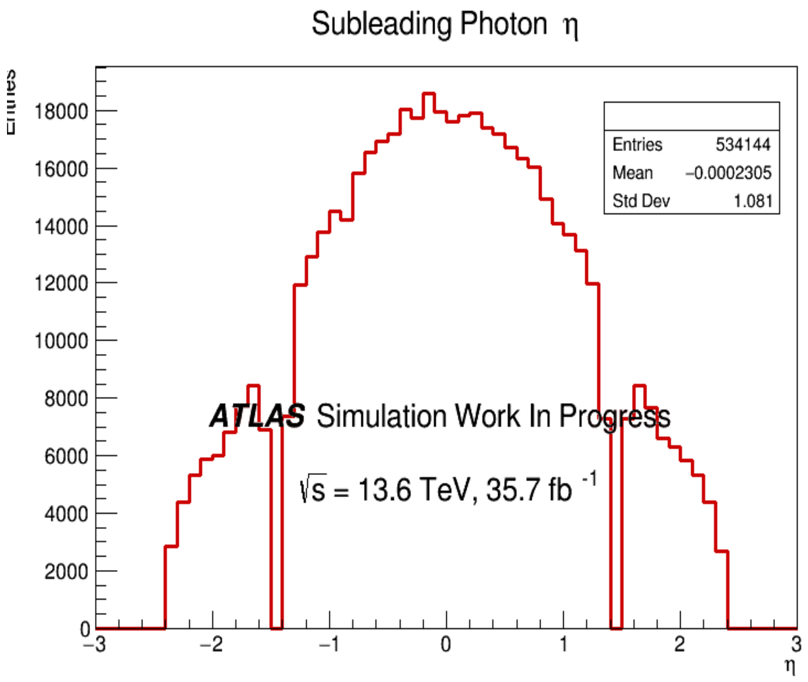


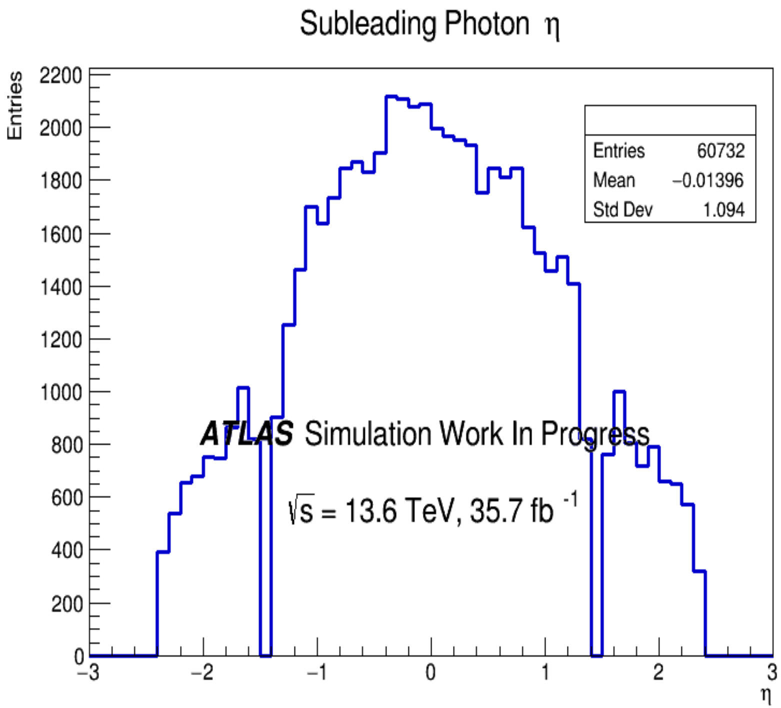
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



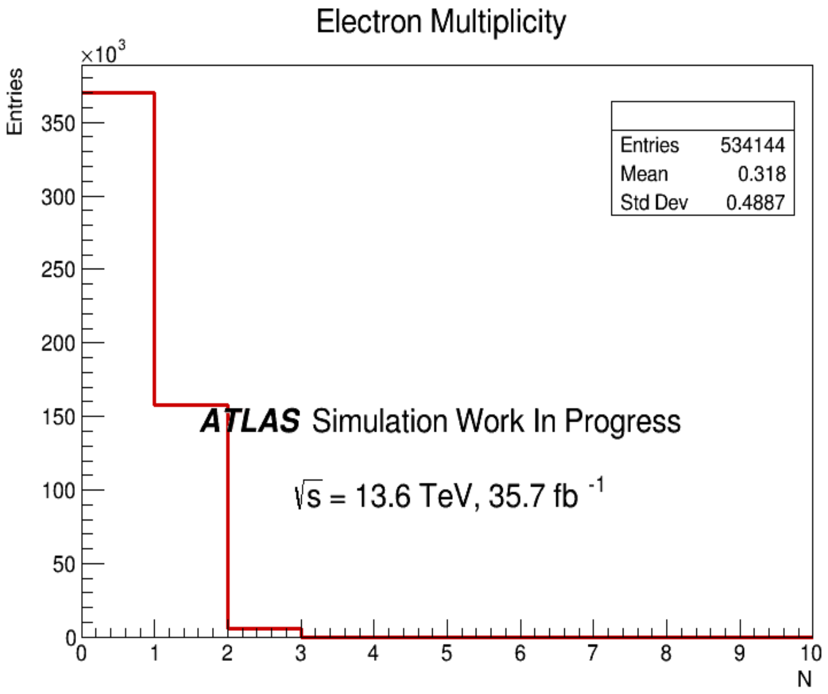


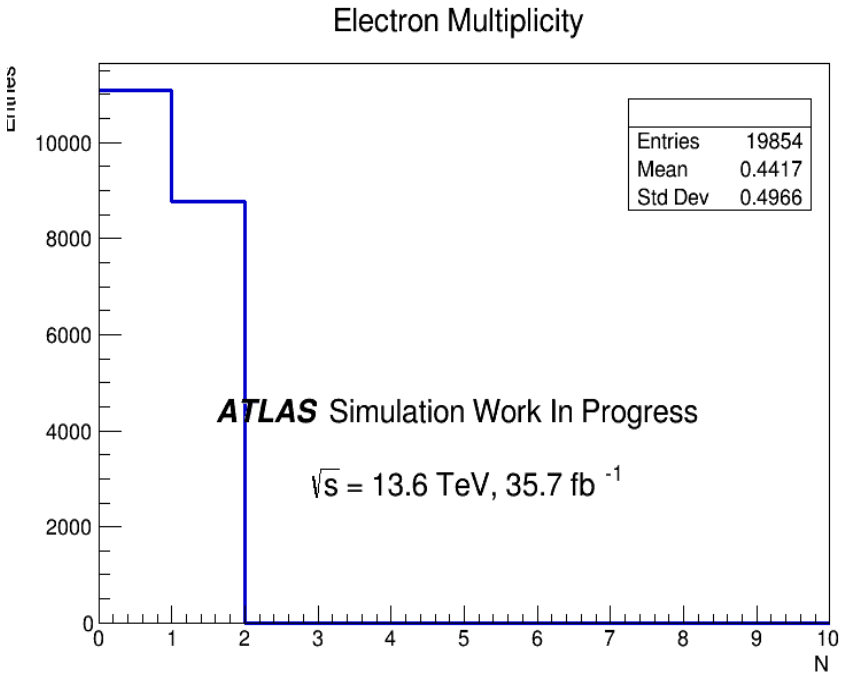
Kinematic Distributions ($\gamma\gamma + 0l1\tau$ Final State)



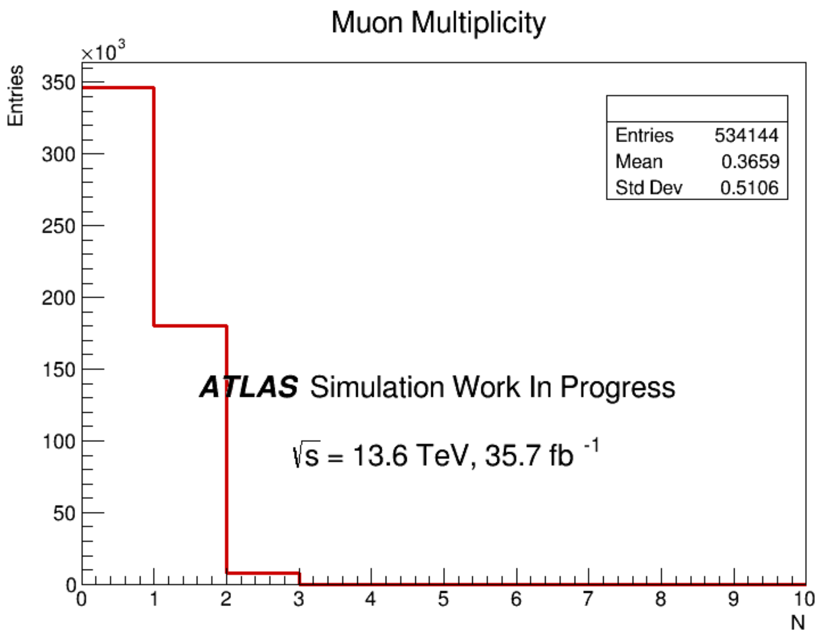


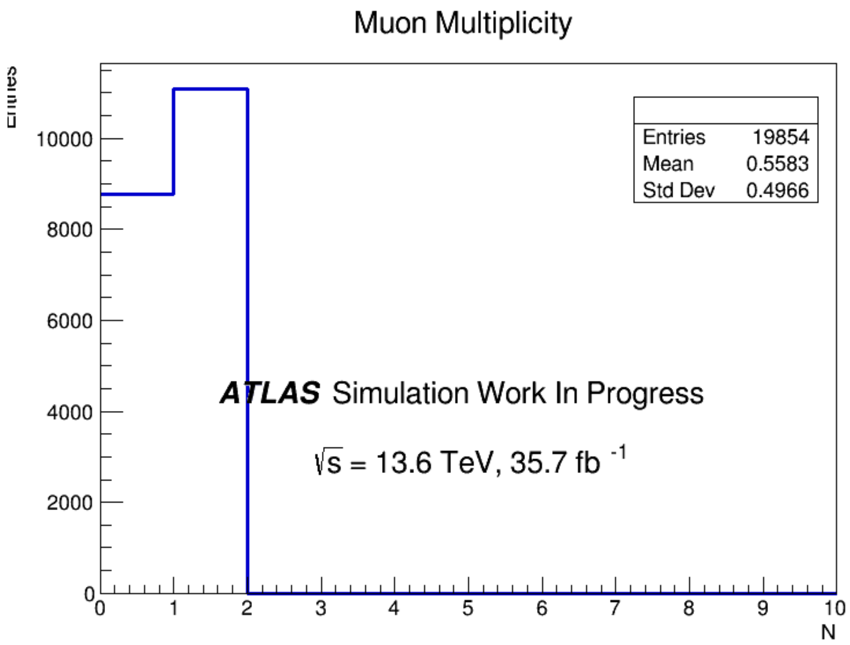
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



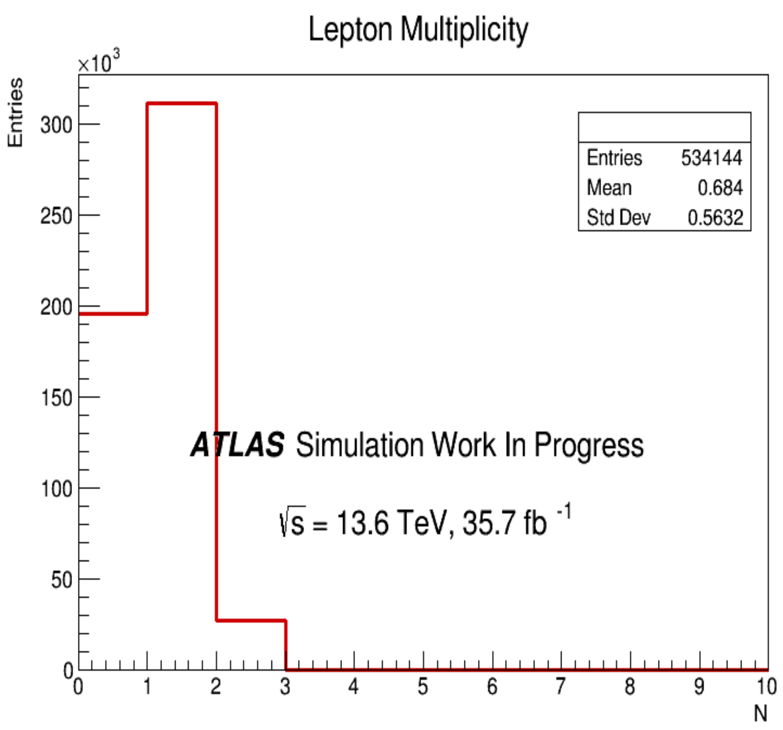


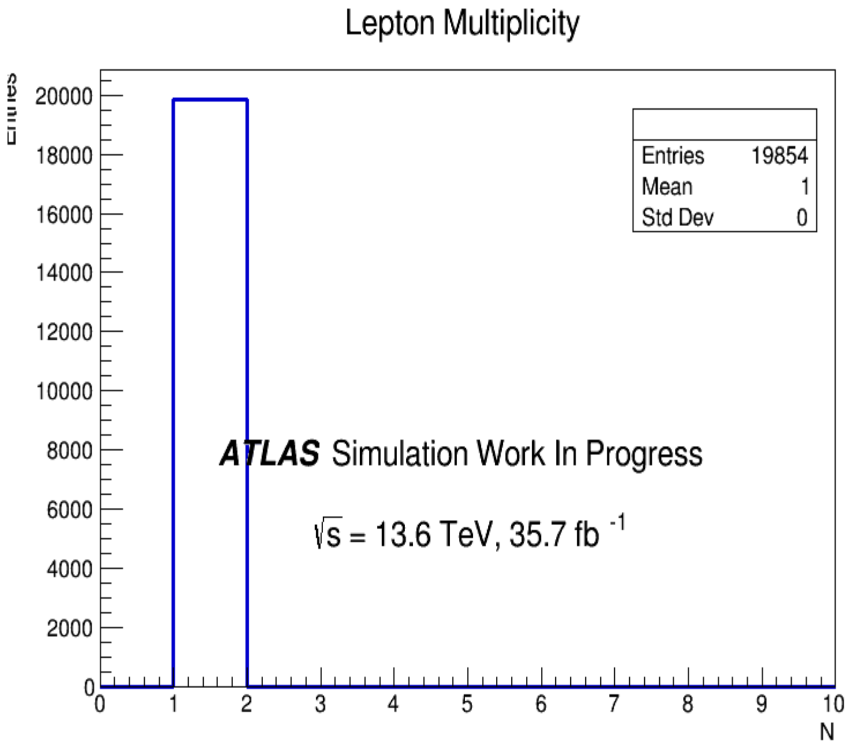
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



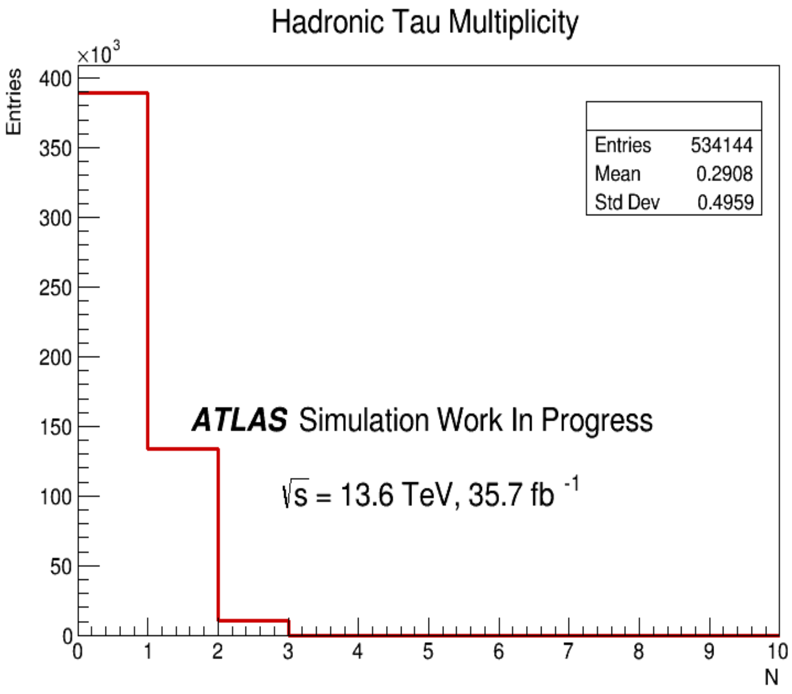


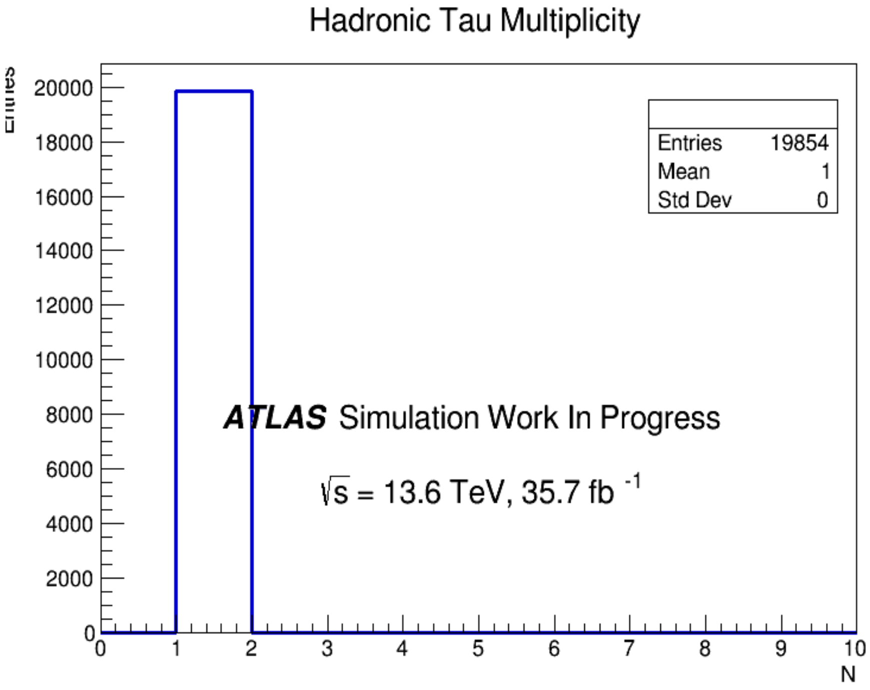
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



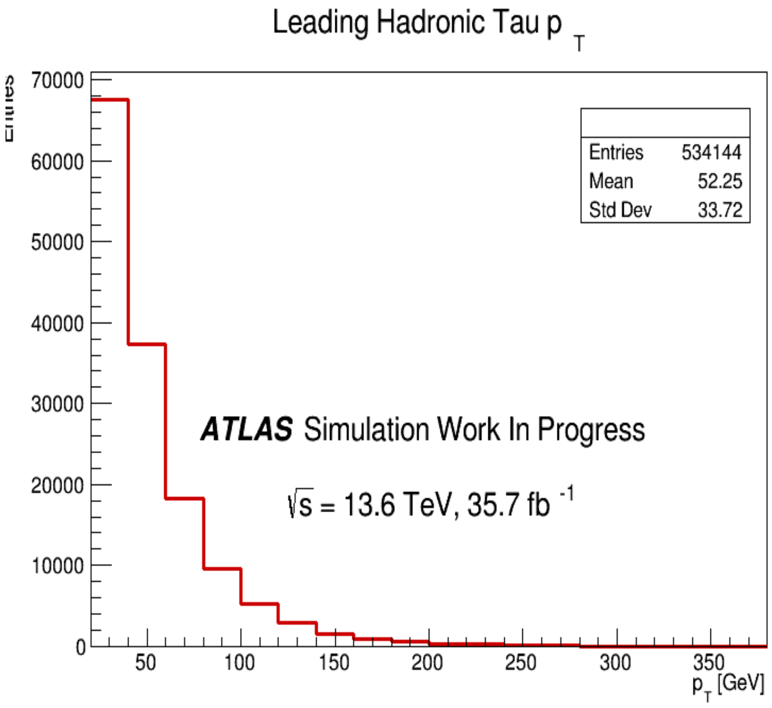


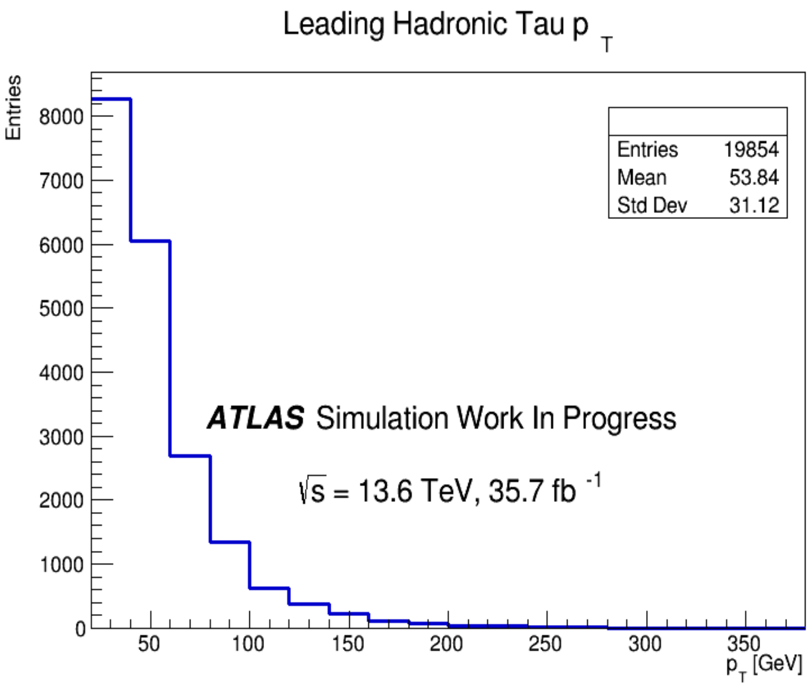
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



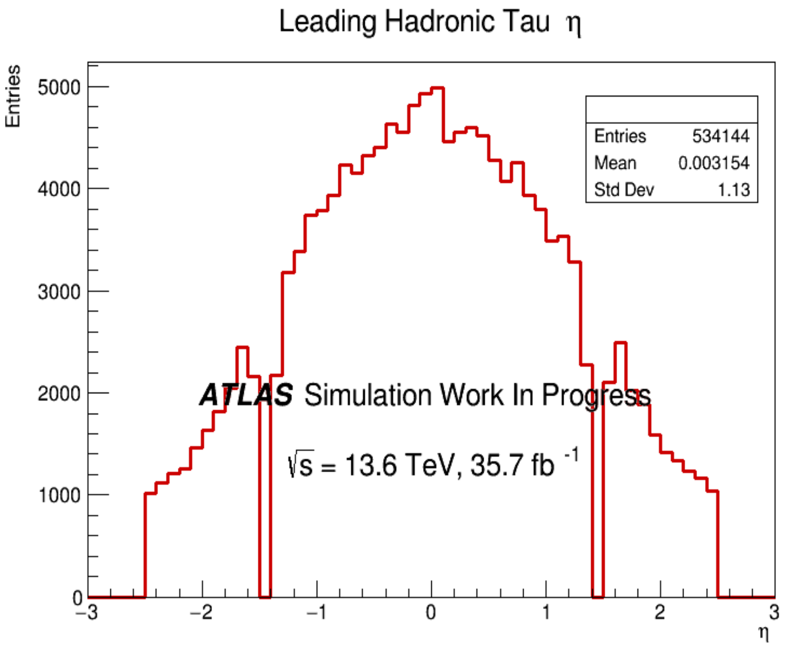


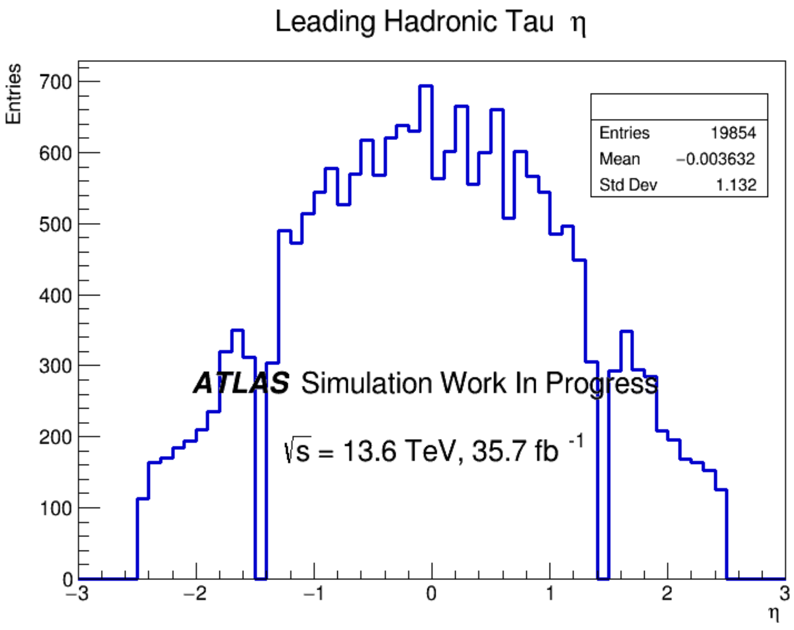
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



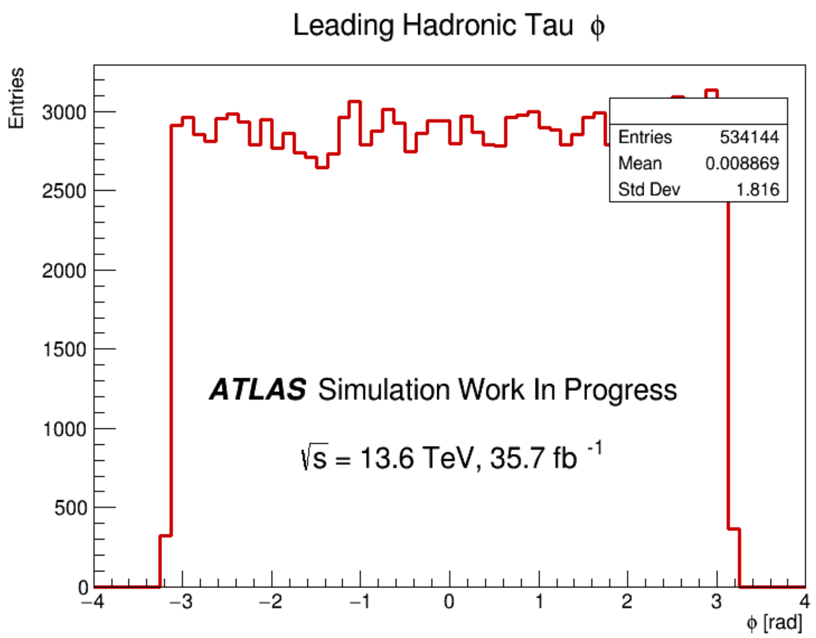


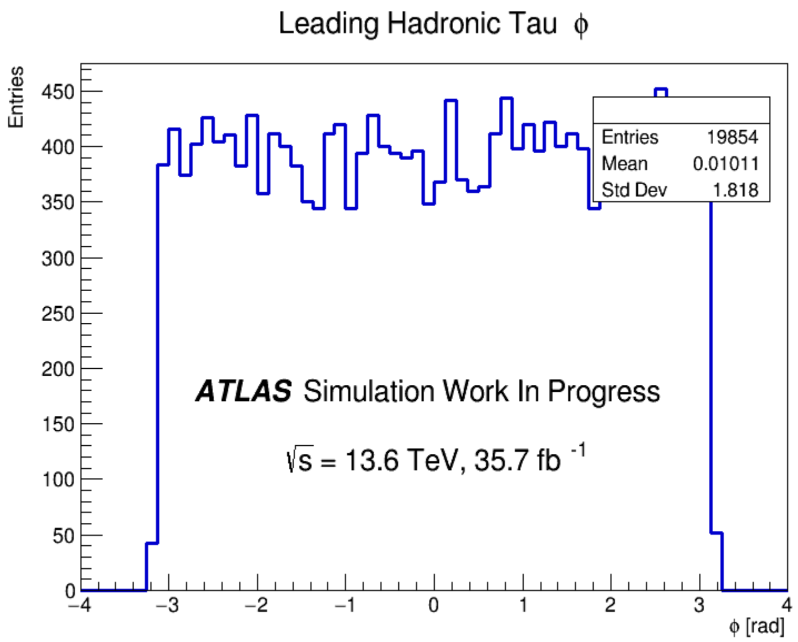
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



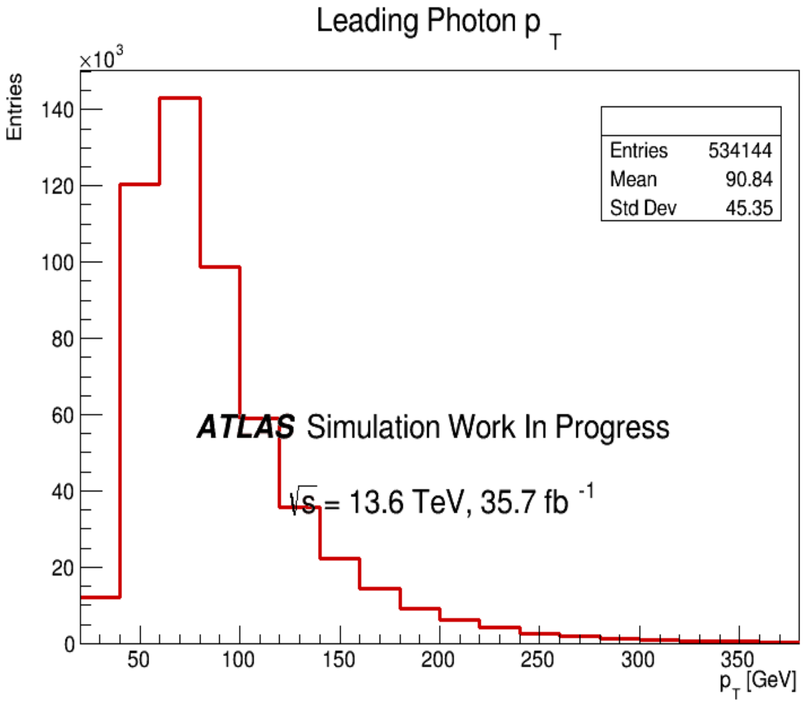


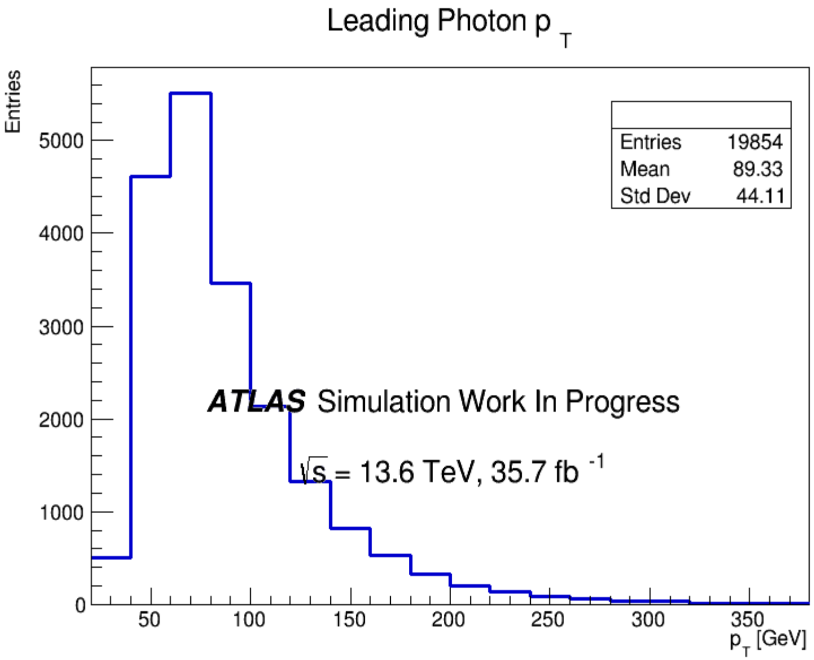
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



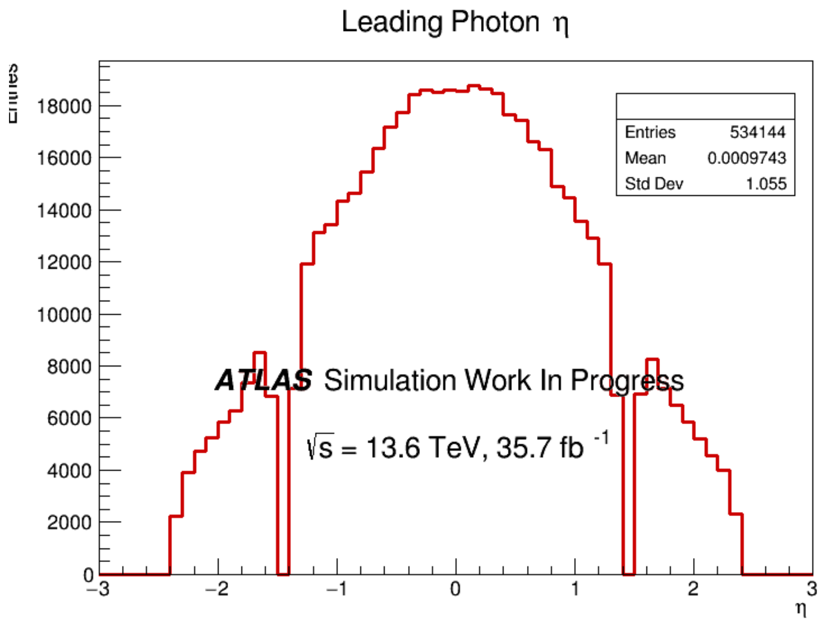


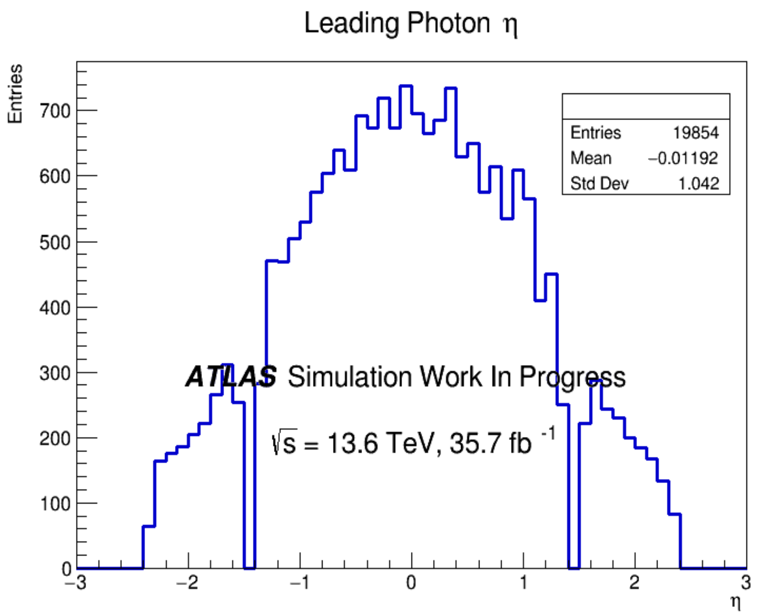
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



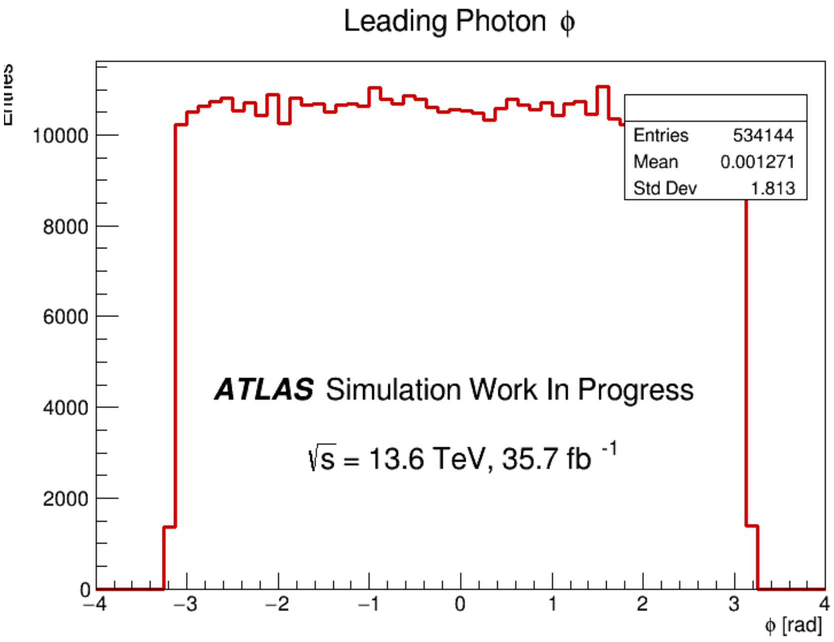


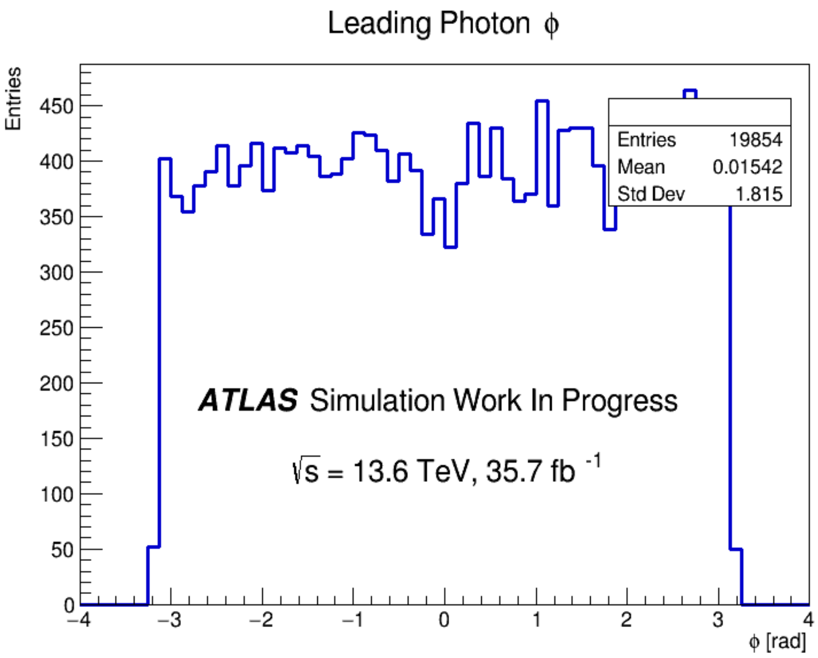
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



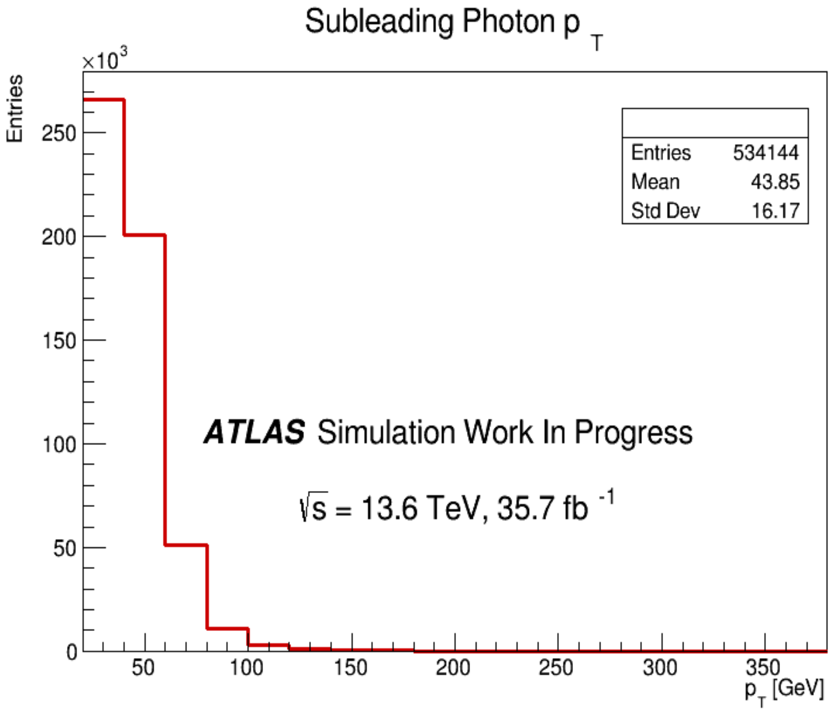


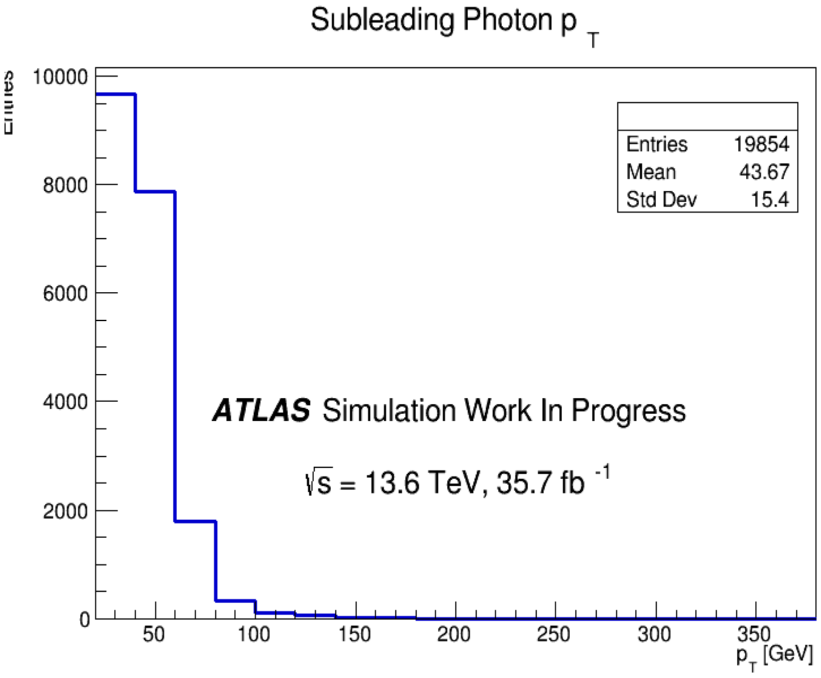
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



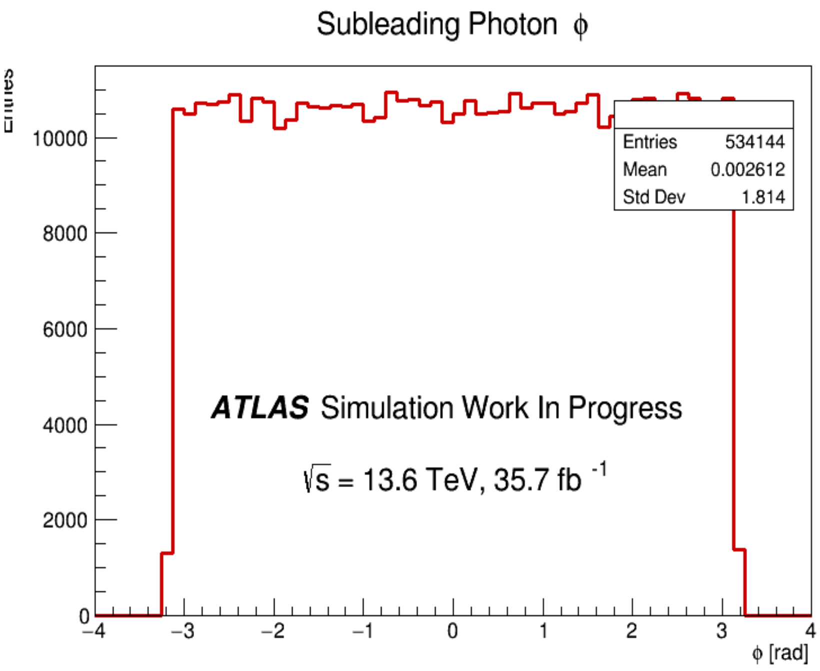


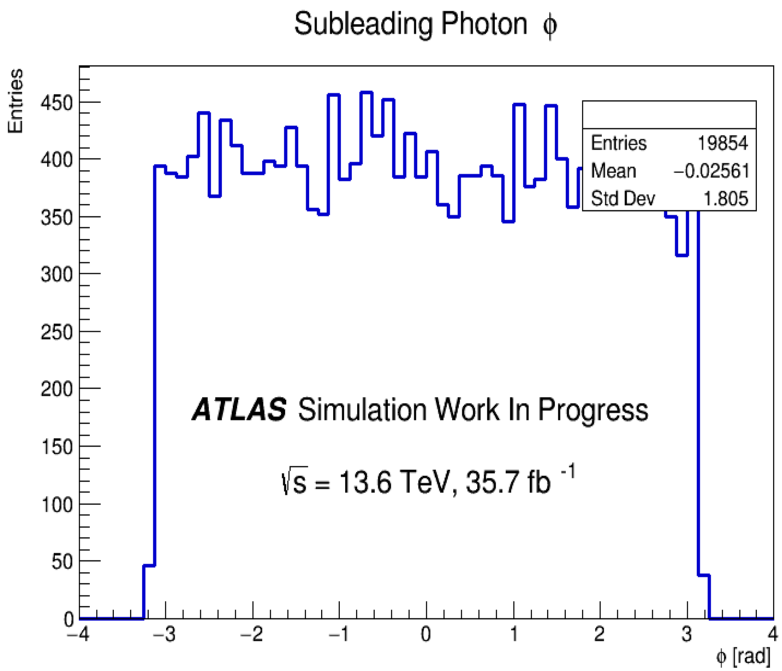
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



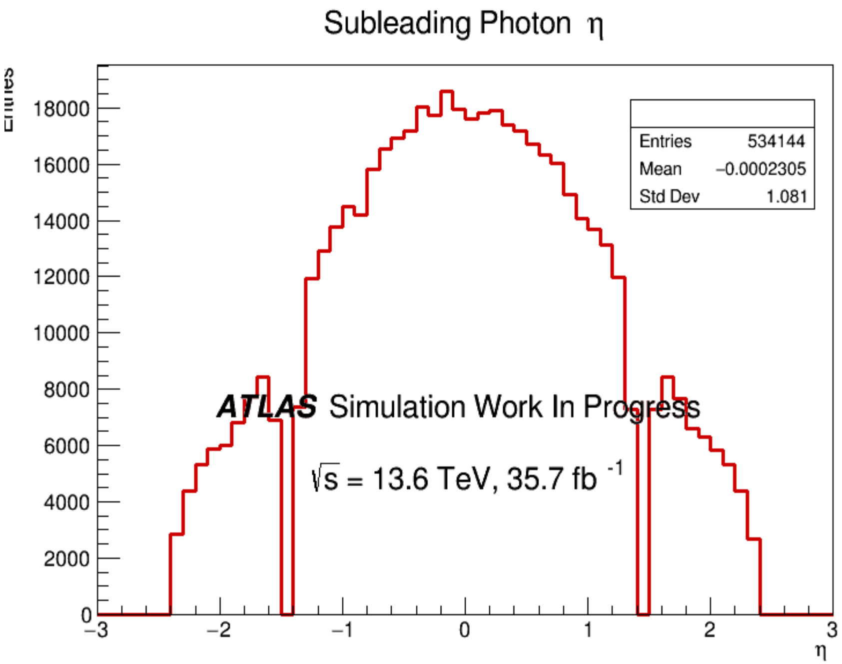


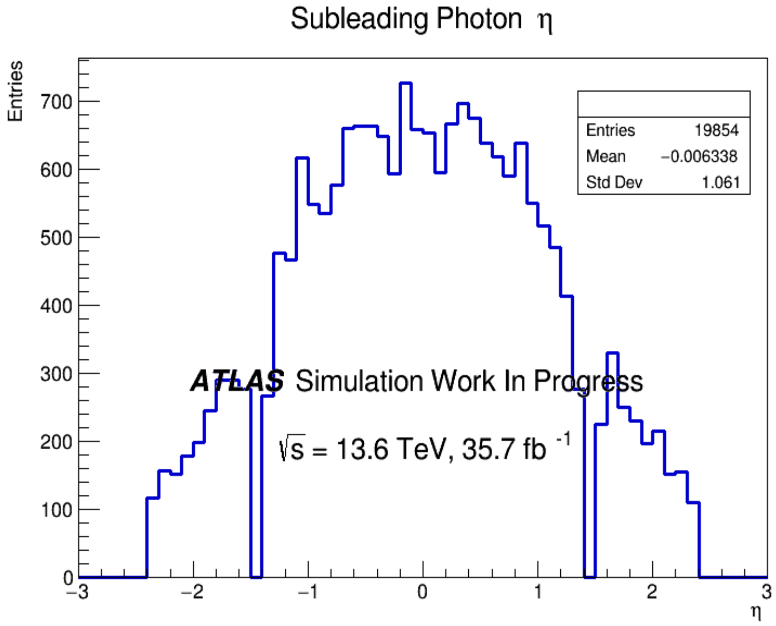
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



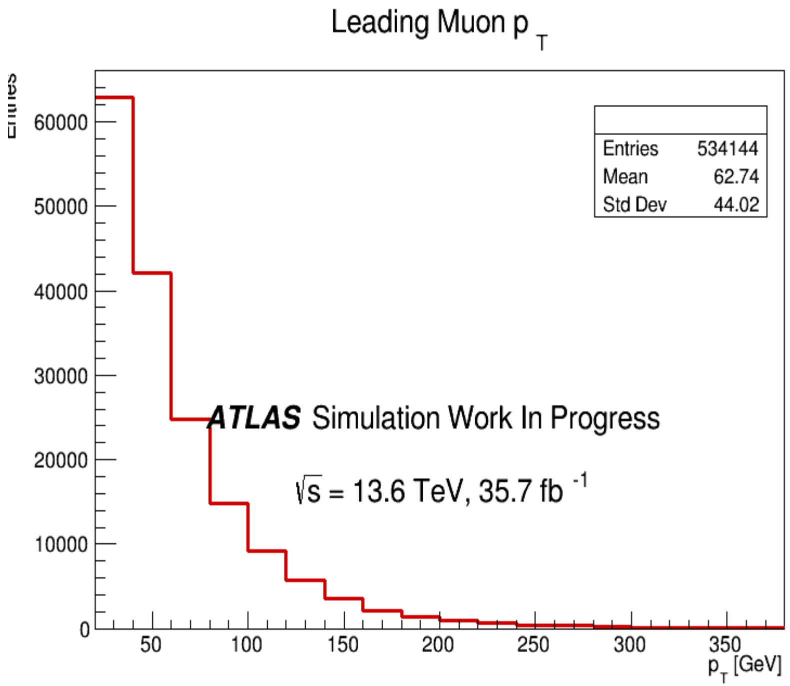


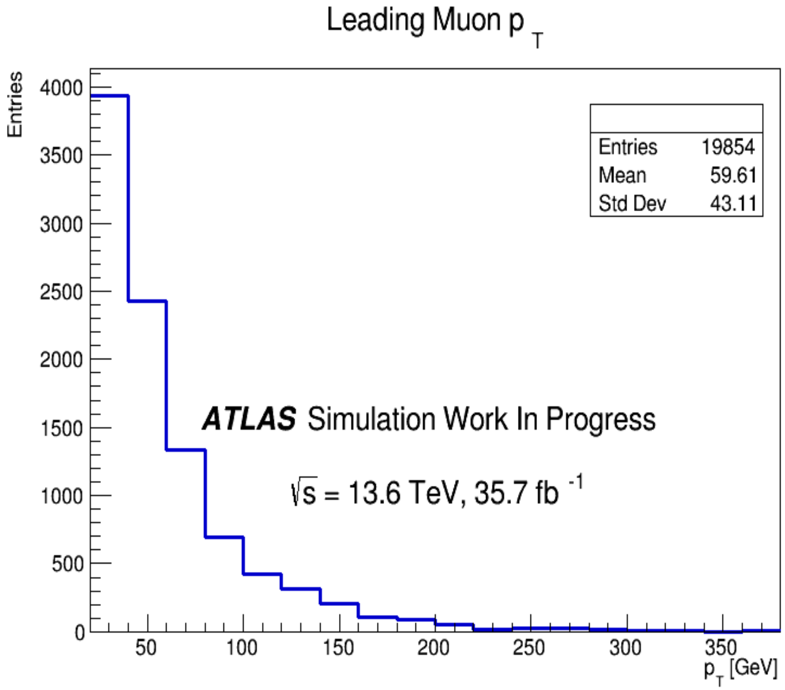
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



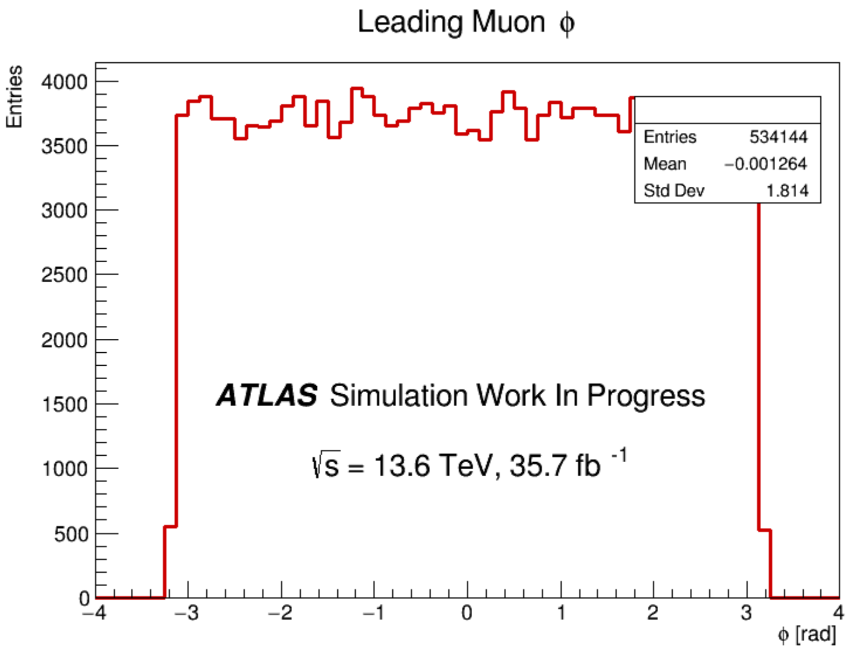


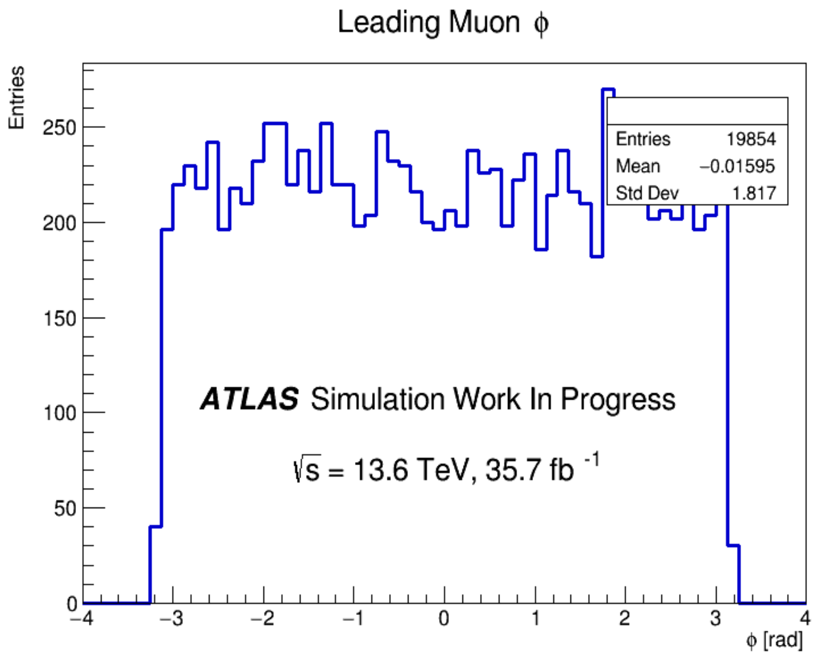
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)



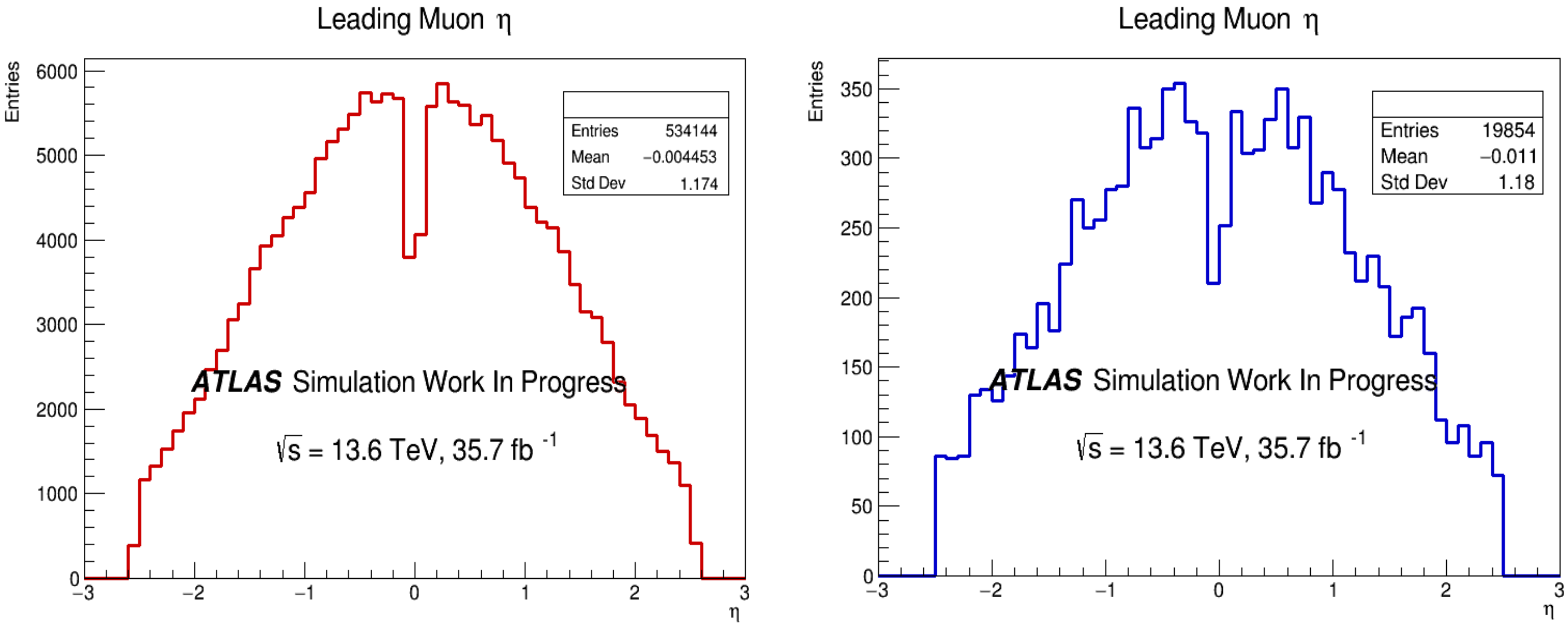


Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)

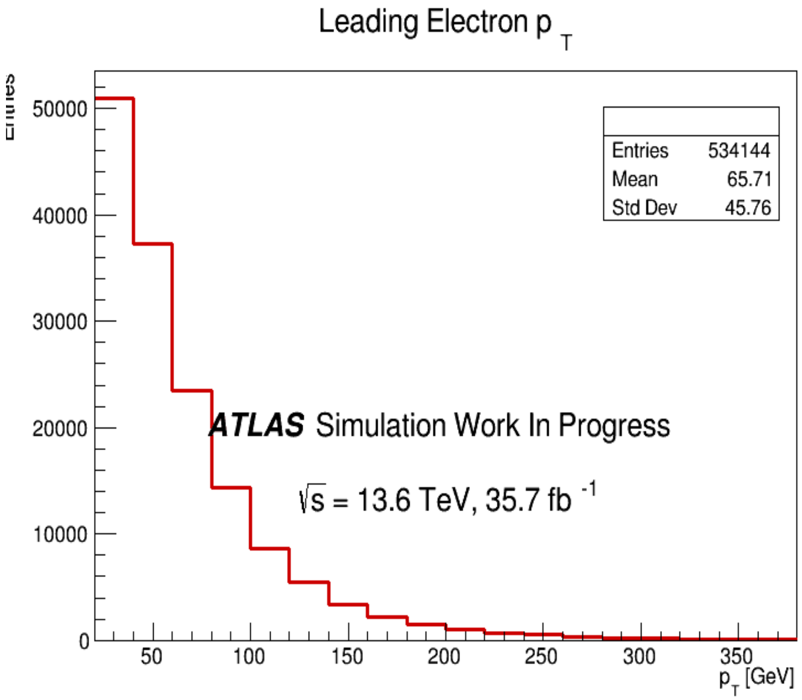


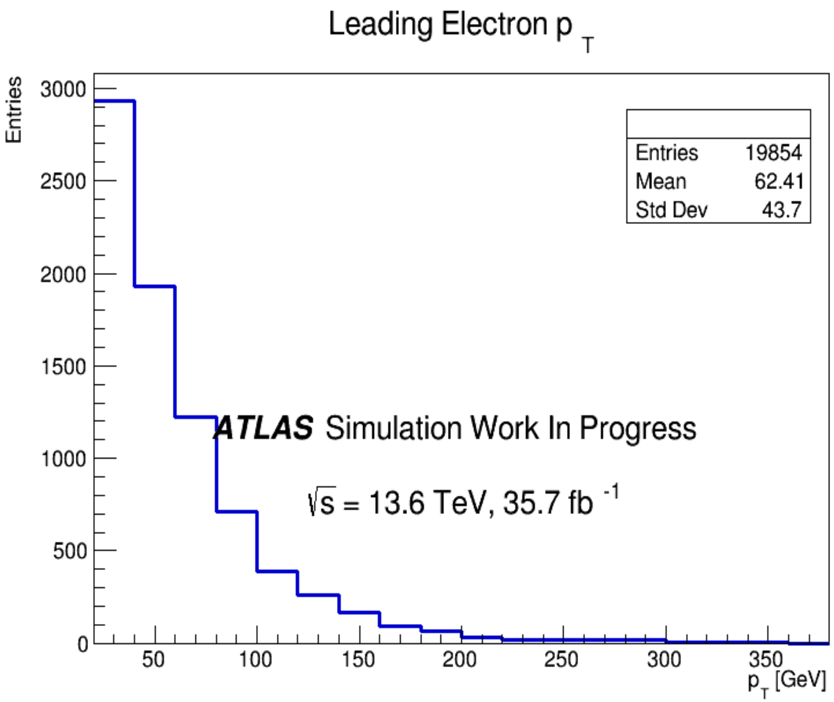


Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)

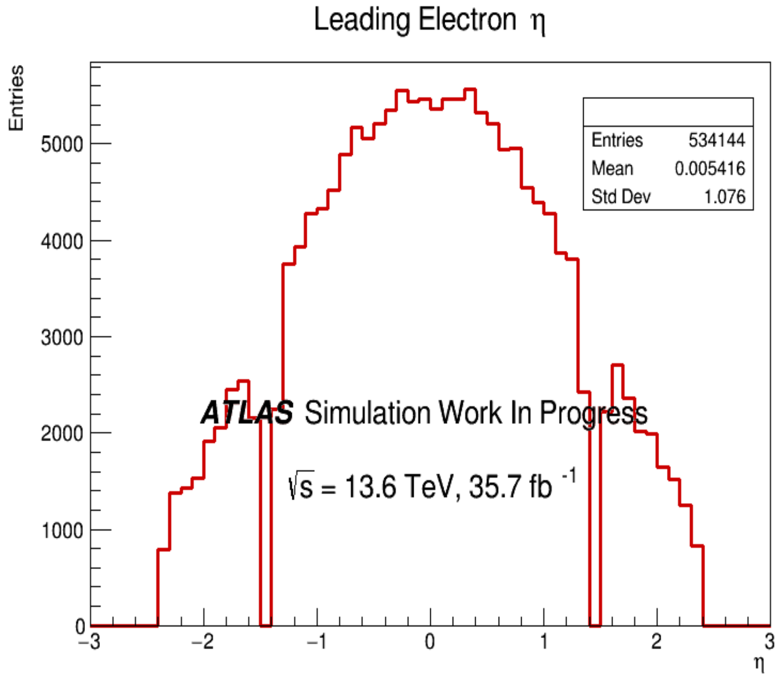


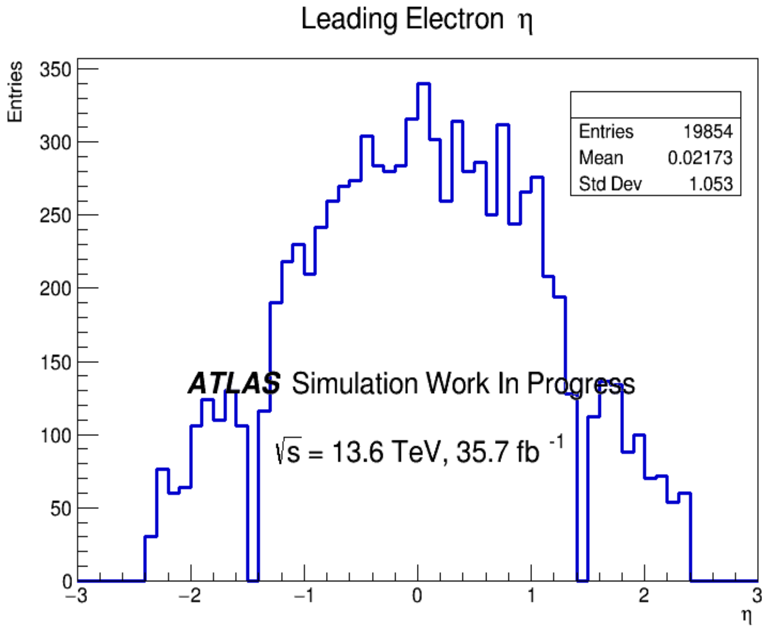
Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)





Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)





Kinematic Distributions ($\gamma\gamma + 1l1\tau$ Final State)