MEASURING PHOTON-INDUCED DILEPTON PAIRS IN PROTON COLLISIONS

Summer Student Project

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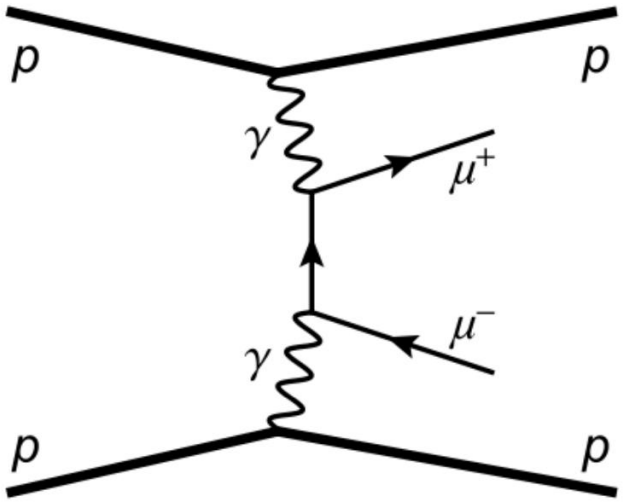
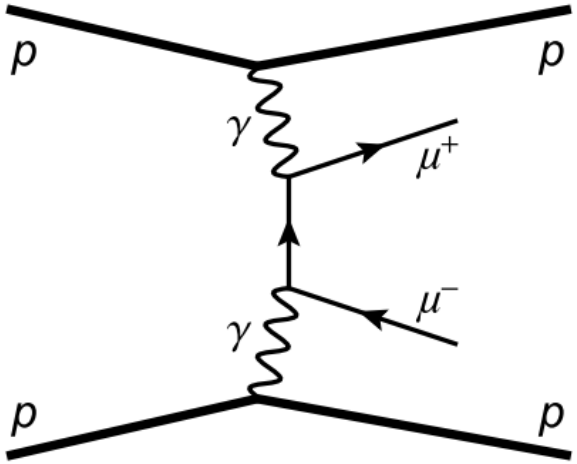
Motivation

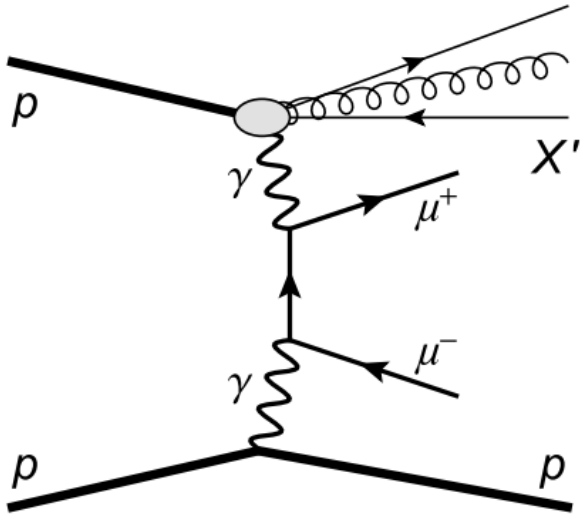
- LHC: proton–proton → usually strong interaction
- Protons also generate EM fields → quasi-real photons (EPA)
- Close pass → γγ collisions possible
- Clean final state: dilepton ($\mu^+\mu^-$)
- Test QED at TeV + search new physics
- Old data: 3.2 fb^{-1} → now 140 fb^{-1} (Run 2) + 250 fb^{-1} (Run 3)



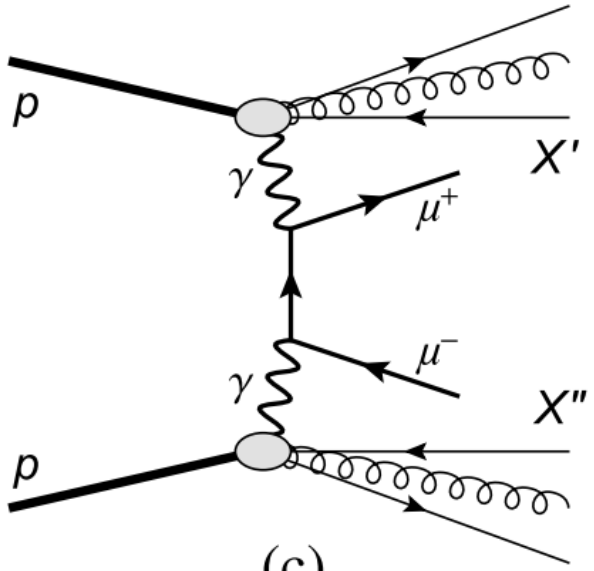
Theoretical background



(a)



(b)



(c)

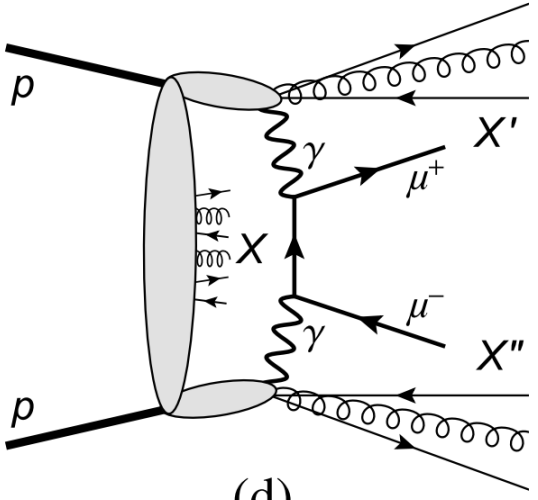
Photon-induced $\mu^+\mu^-$ topologies:

a) Exclusive (both protons intact)

b) Single dissociative (1 proton breaks)

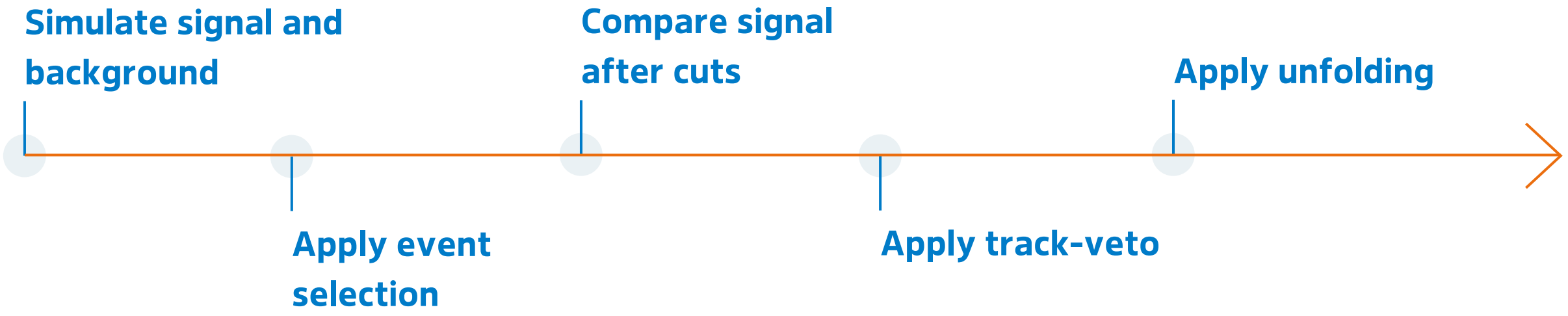
c) Double dissociative (both break)

d) Additional interactions

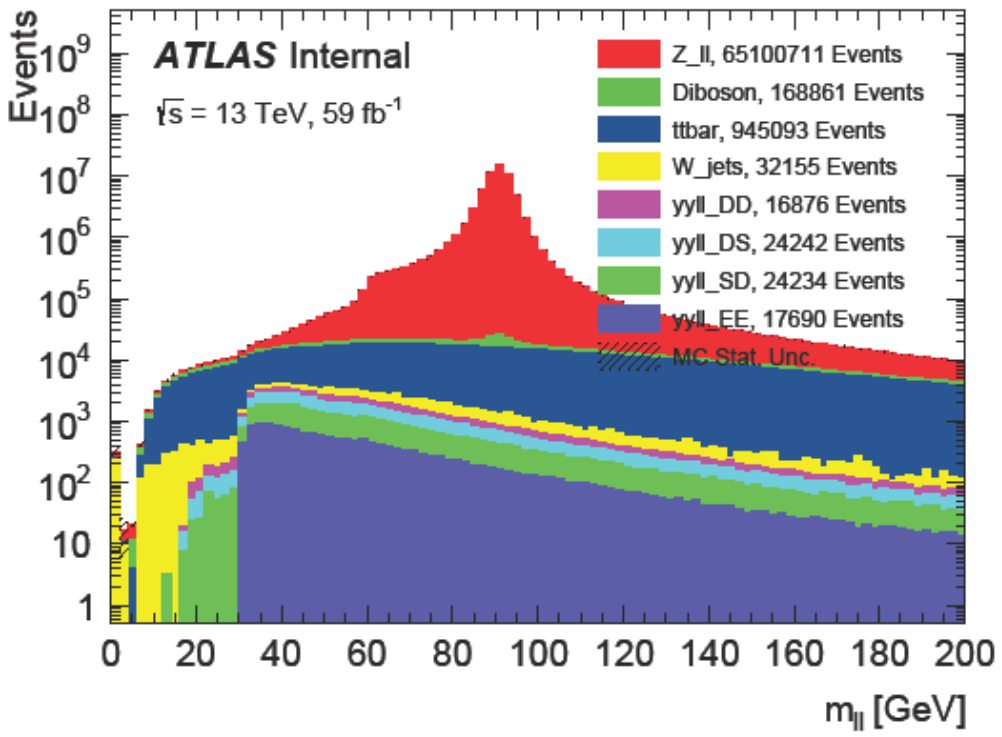


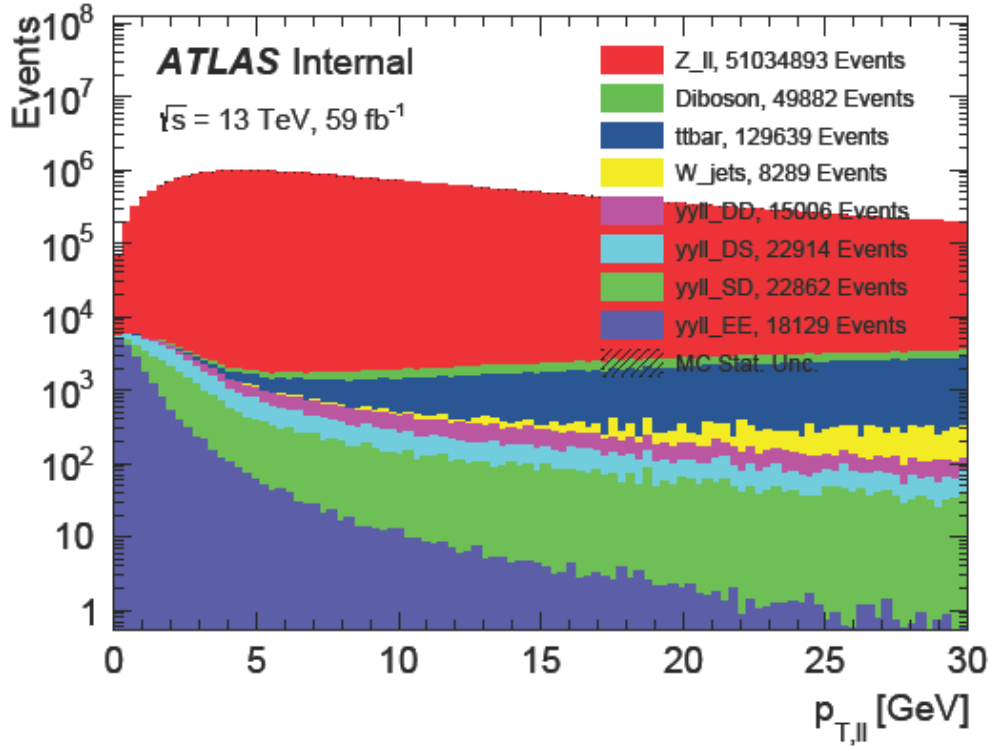
(d)

Project tasks



Results





- Dilepton pT: background wide, signal at very low pT
- Dilepton mass: big Z peak (background), signal outside
- Motivation for cuts

Event selection

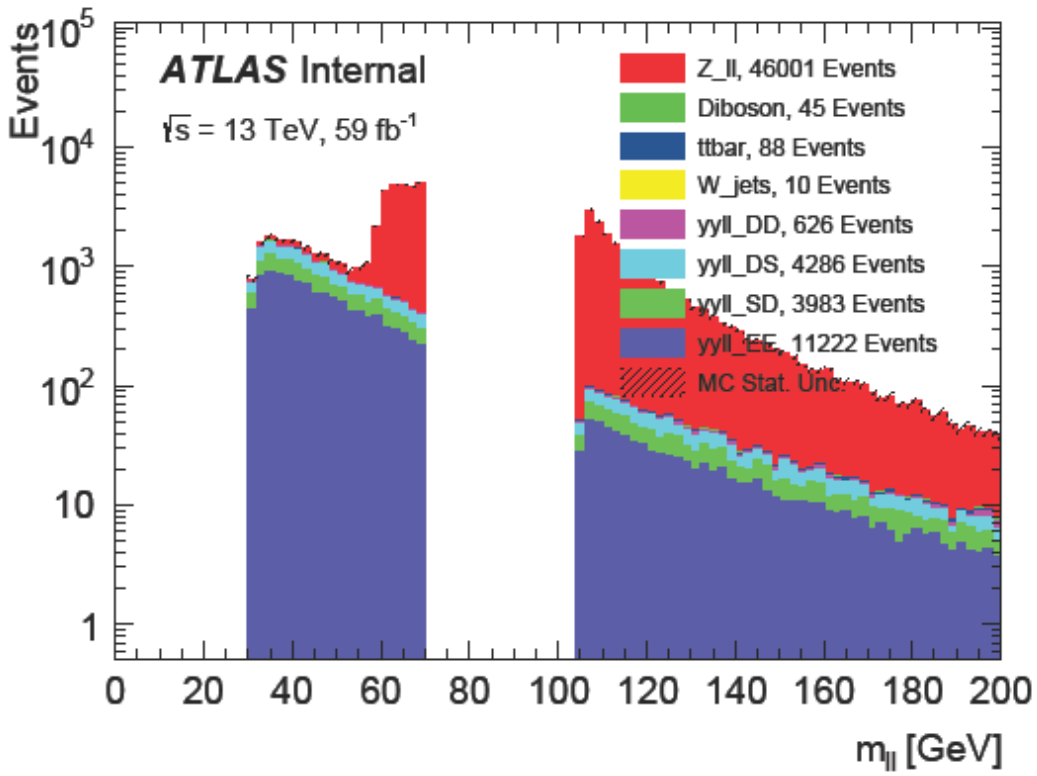
- ≥ 2 leptons
- Dilepton pT < 1.5 GeV
- Muon flavor requirement
- Invariant mass: exclude 70–105 GeV (Z region)

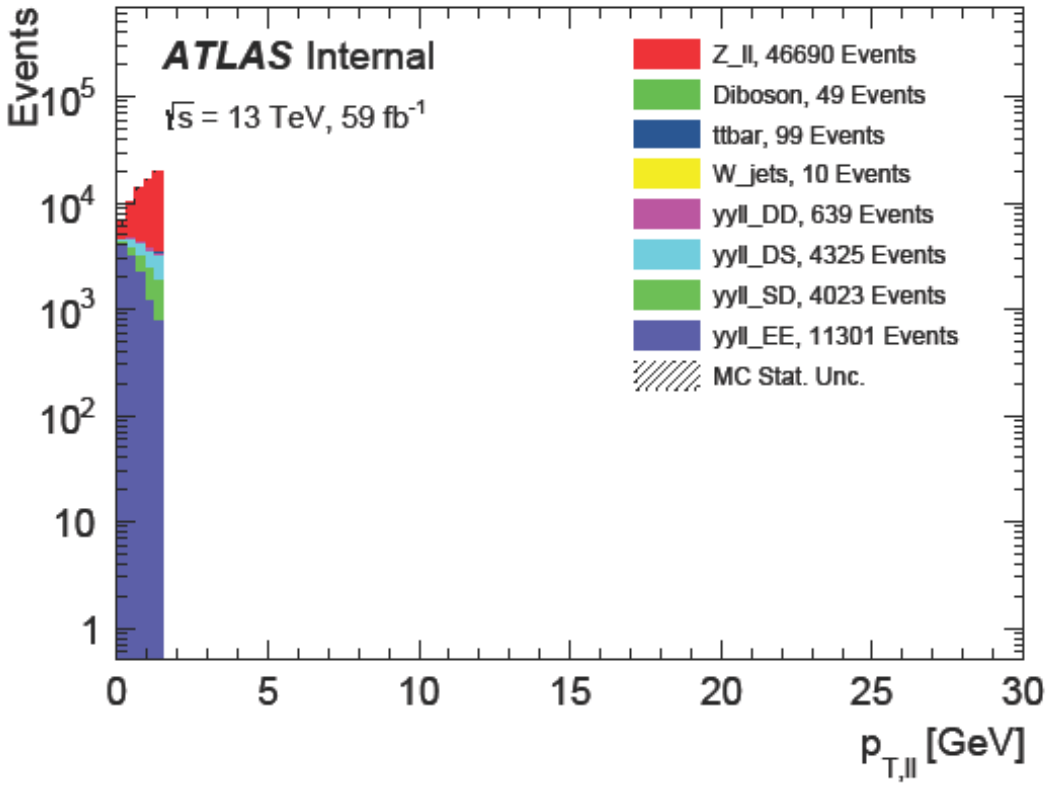
$p_T^{\mu^+\mu^-} < 1.5$ GeV

12 GeV < $m_{\mu^+\mu^-}$ < 70 GeV
or $m_{\mu^+\mu^-}$ > 105 GeV

Event selection used in previous analysis [1]

Results

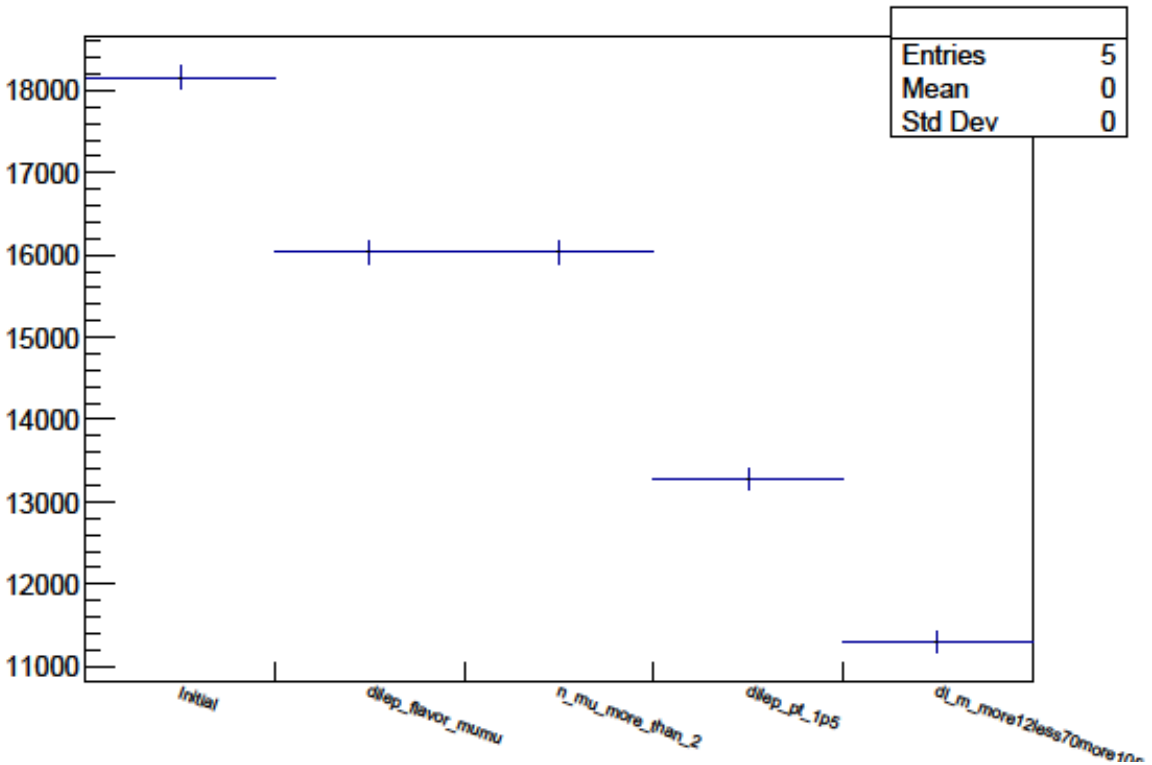




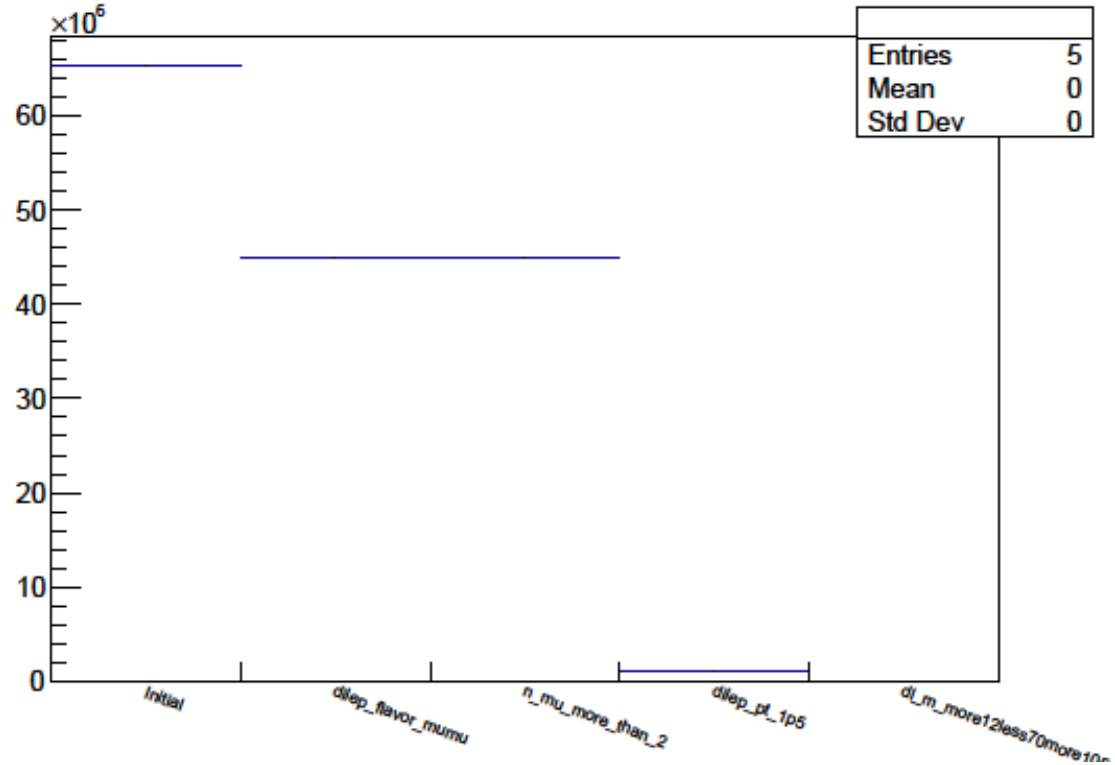
- Z peak suppressed in dilepton mass
- Low-pT signal becomes visible

Cutflow

- Track event counts after each cut
- See which cuts reduce background most
- Efficiency of selection strategy



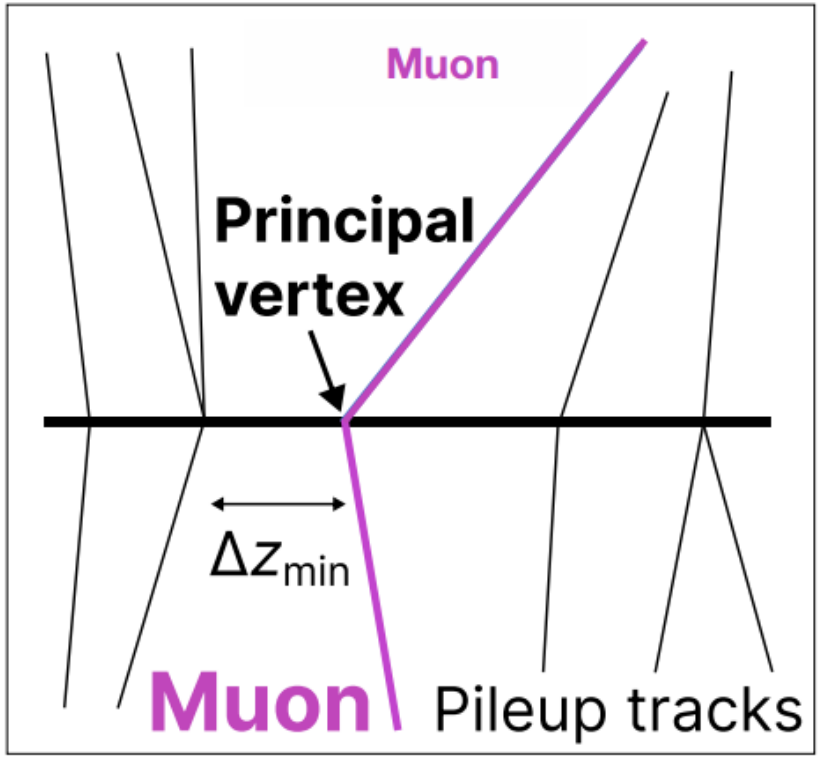
yyll_EE cutflow



Z_ll cutflow

1 mm vertex isolation (track-veto)

- Even after cuts → still background left
- Photon-induced: exclusive, protons intact, no extra particles
- Drell–Yan: many extra tracks from remnants
- Use 1 mm isolation window around vertex
- Extra tracks in window → event rejected
- This is the basis of the track veto



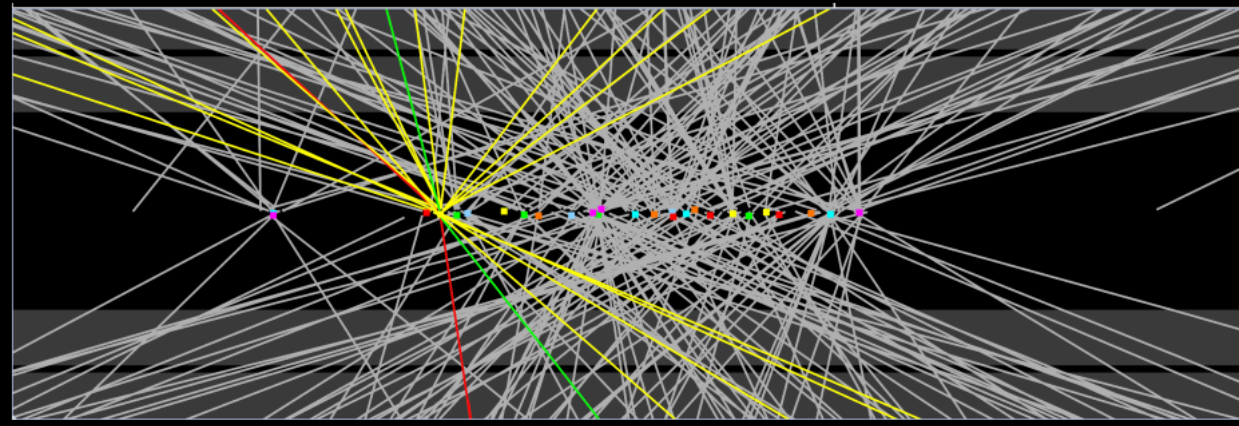
Track-veto

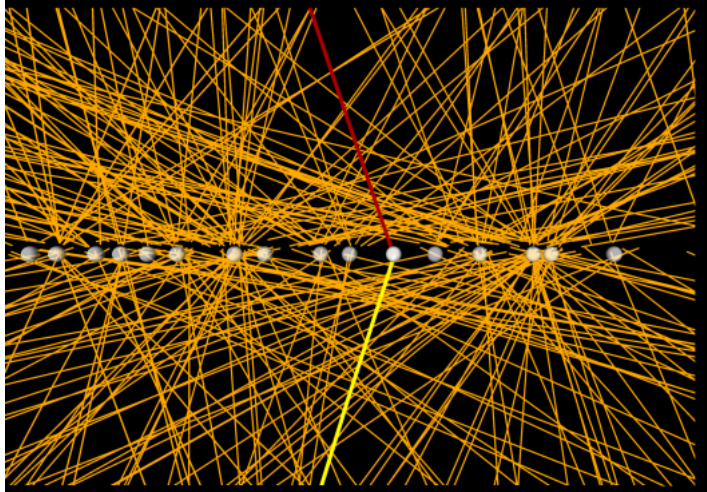
- Photon-induced: exactly 2 muons, nothing else
- Drell–Yan/QCD: many extra tracks from interactions
- Track veto strongly suppresses background
- Some signal lost, but background reduction much larger
- Makes selection very powerful

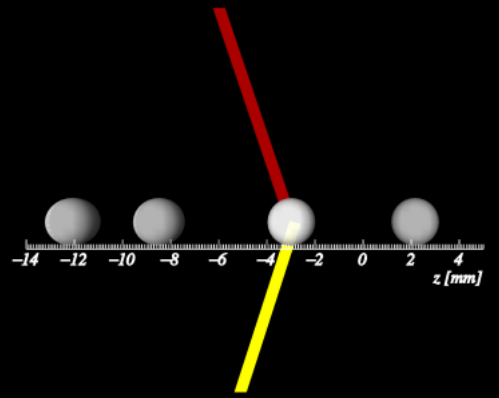
Photon collisions in pp data

ATLAS EXPERIMENT
Run Number: 304431, Event Number: 2206548301
Date: 2016-07-25 05:01:07 UTC

Head-on pp collision



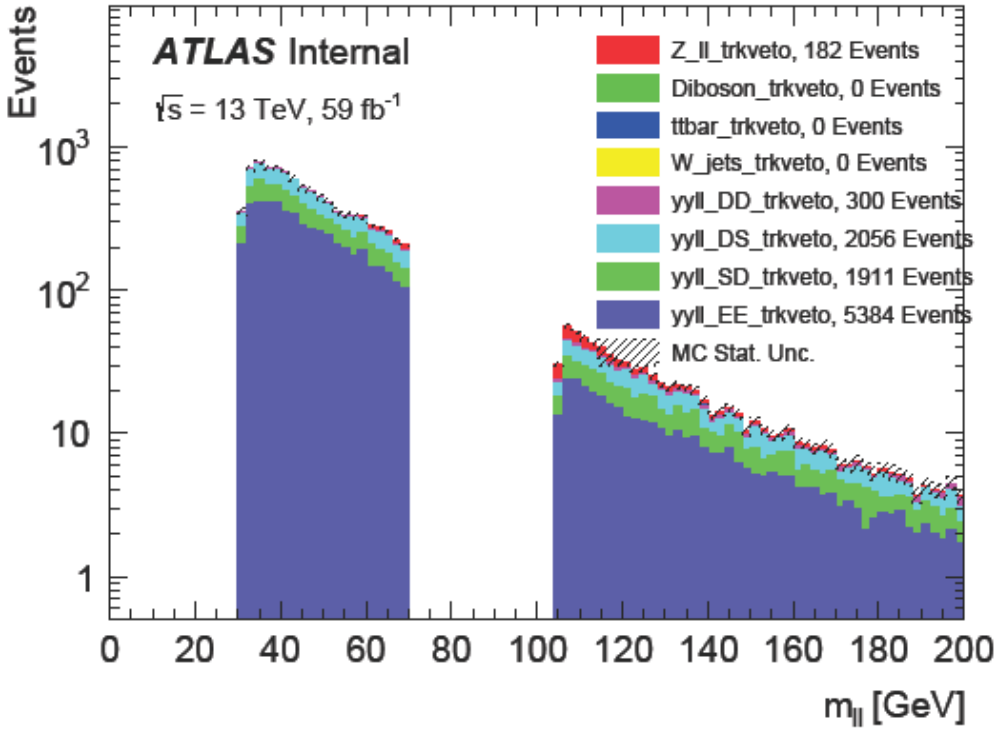


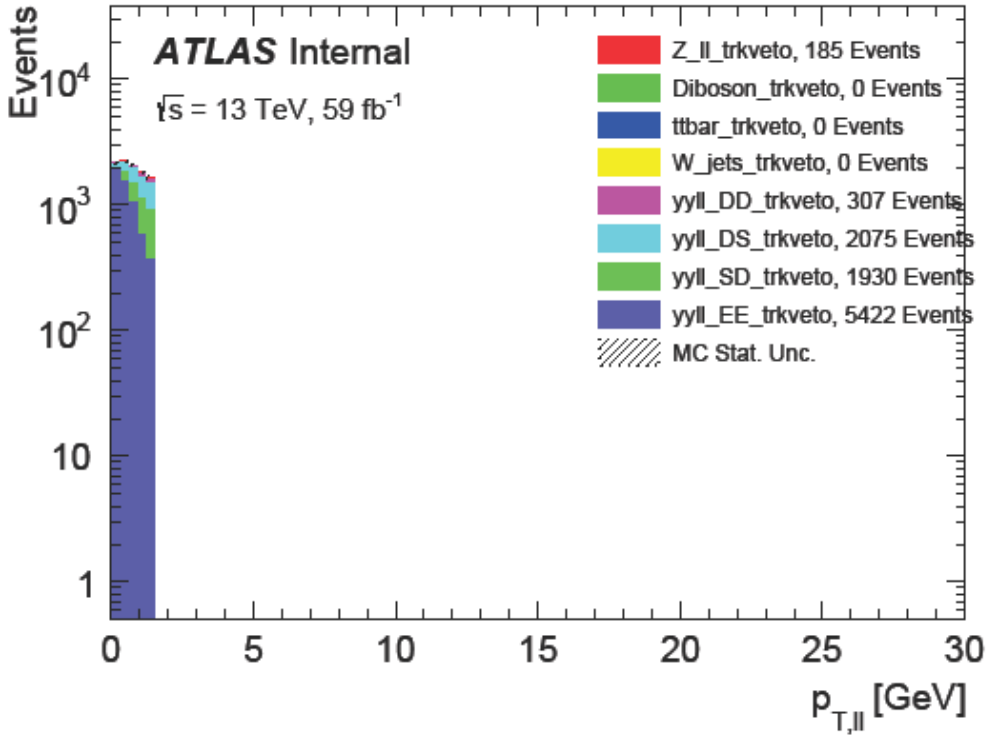


Photon-fusion pp collision

ATLAS EXPERIMENT
Run: 357620
Event: 653219636
2018-08-06 01:08:33 CEST

Results



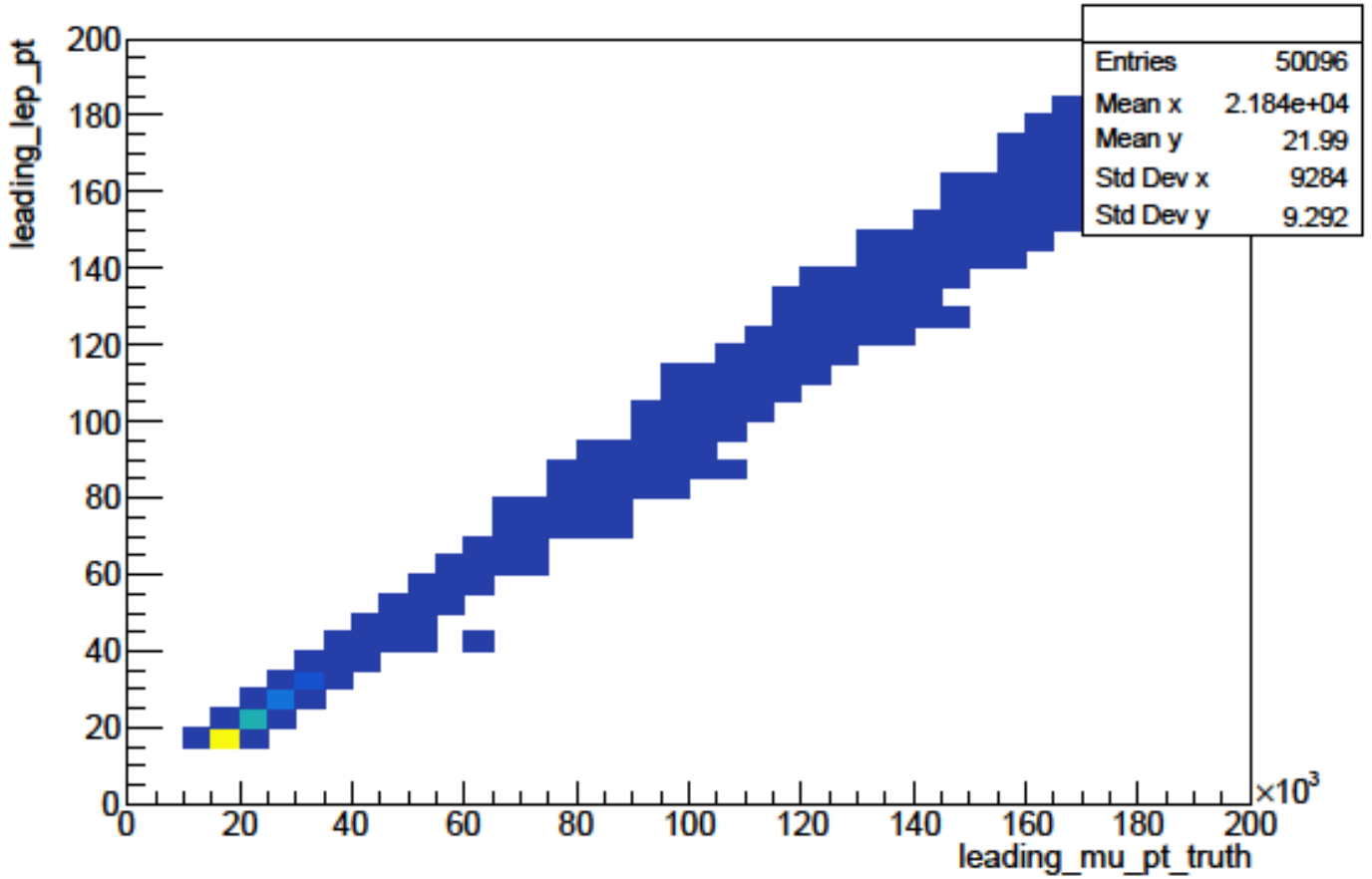


- Selections suppress Z peak in dilepton mass
- Background reduced by 99.6%
- Signal reduced by only ~50% (due to pile-up interactions)
- Signal-to-background ratio strongly improved

Unfolding

- Next challenge: correct detector effects
- Detector causes smearing, resolution limits, efficiency loss
- Need particle-level distributions for theory comparison
- Build response matrix from simulation
- Apply unfolding algorithms

Results (response matrix after selection)



- Nearly diagonal → good detector resolution
- Basis for profile likelihood unfolding
- Unfolding procedure still in progress

Conclusions

- Photon-induced dileptons = clean QED probe at TeV scale
- Selections + track veto → isolate signal from background
- Unfolding → physical cross-sections, compare with theory
- Run 2 & 3 datasets → most precise measurement possible

Thank you for your attention!

References:
[1] "Measurement of the exclusive $\gamma\gamma \rightarrow \mu^+\mu^-$ process in proton-proton collisions at $\sqrt{s}$=$13\ TeV$ with the ATLAS detector" ATLAS Collaboration
Phys. Lett. B, 777 (2018), p. 303, 10.1016/j.physletb.2017.12.043
arXiv:1708.04053