ATLAS measurements of photon-photon fusion processes in Pb+Pb collisions

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On behalf of the ATLAS Collaboration
ICHEP 2022, Bologna, Italy
9 July 2022

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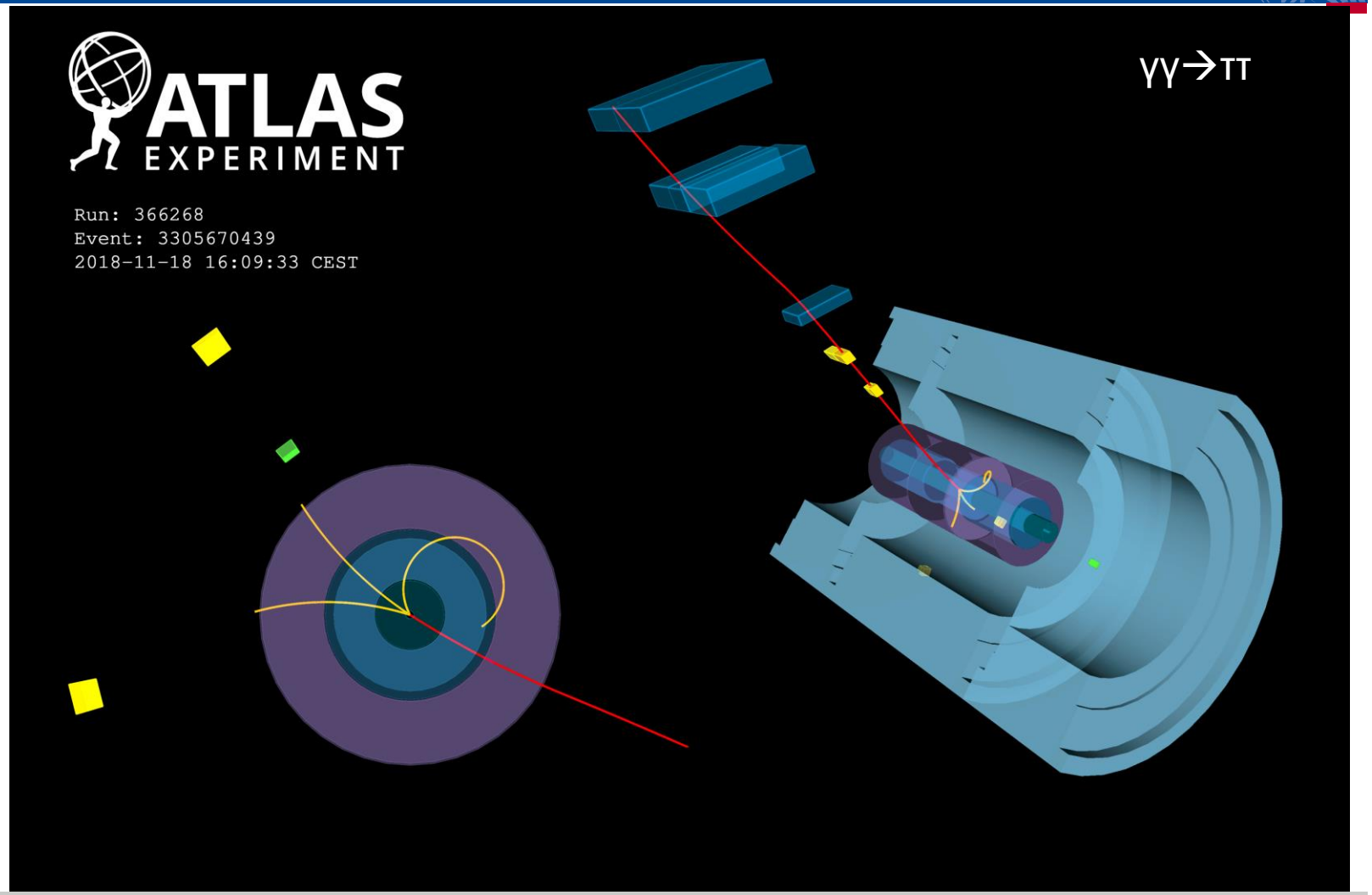
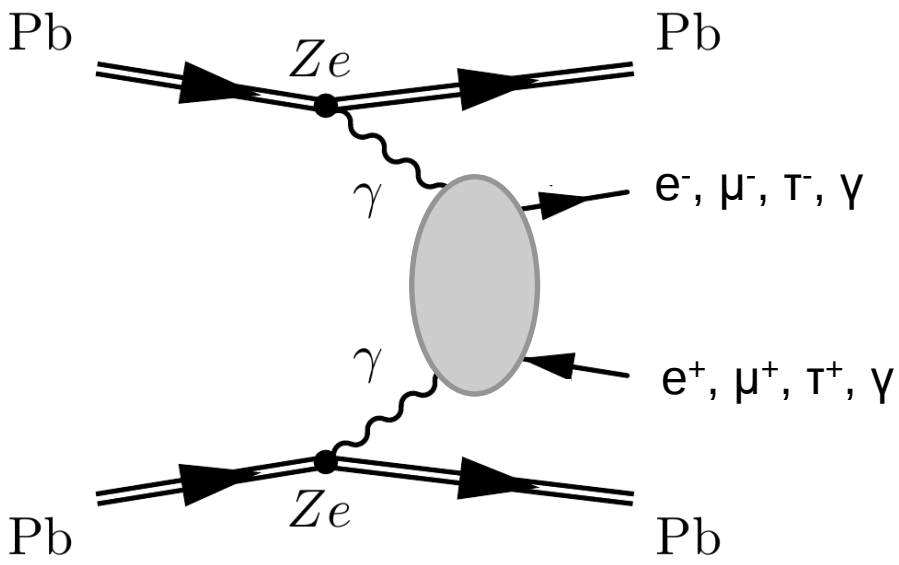
Particle physics with an (almost) empty detector

- At a hadron collider!
  - In PbPb collisions
  - With ATLAS
  - In Run-2 of the LHC (2015, 2018)
- … with many interesting results!



Measuring γγ-fusion processes

- Production of di-leptons/di-photons in ultra-peripheral (UPC) PbPb collisions
  - Initial photons from electromagnetic fields of Pb
  - Cross section enhanced by $Z^4 = 4.5*10^7$ w.r.t. pp
  - In $\sqrt{s_{NN}}$=5.02TeV, initial-E_γ up to 100GeV
  - Can include nuclear break-up



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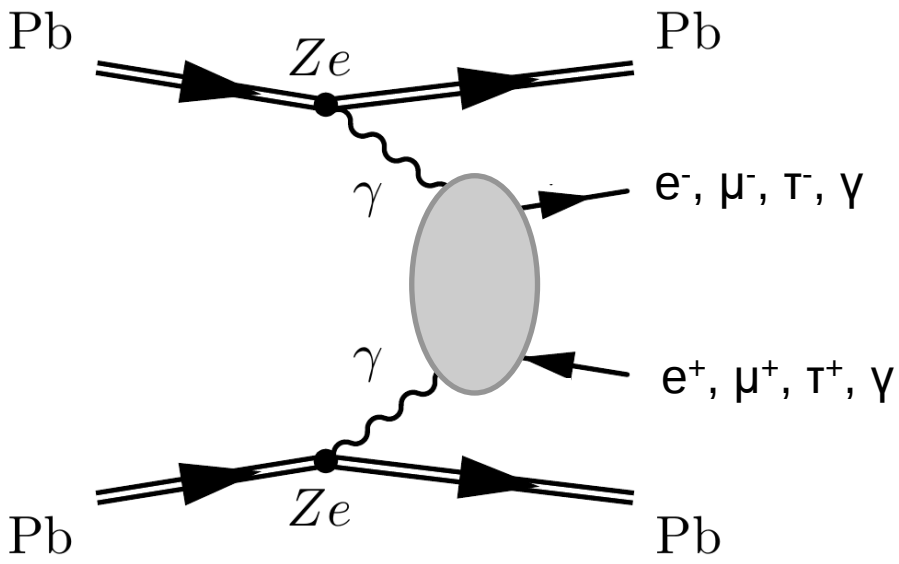
  - Can include nuclear break-up
- Covering the following signatures
  - γγ→ee - ***ATLAS-CONF-2022-025***
  - γγ→μμ - ***Phys. Rev. C 104 (2021) 024906***
  - γγ→ττ - ***arXiv:2204.13478***
  - γγ→γγ - ***JHEP 03 (2021) 243***
  - γγ→μμ (non-UPC) - ***arXiv:2206.12594***

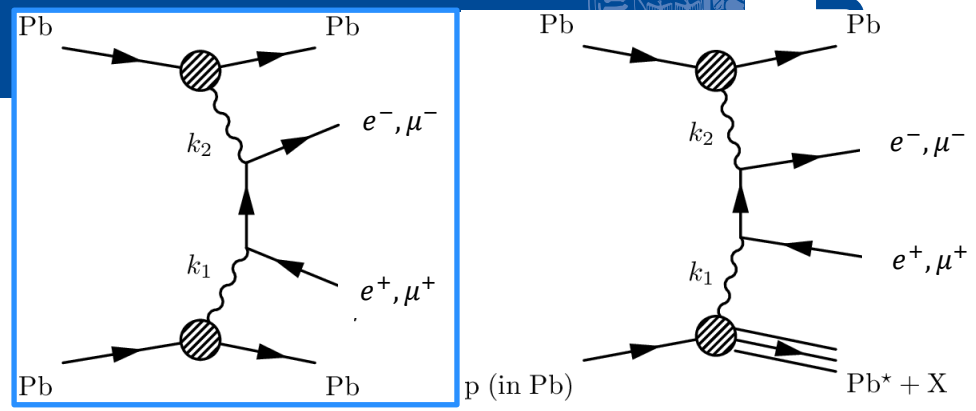


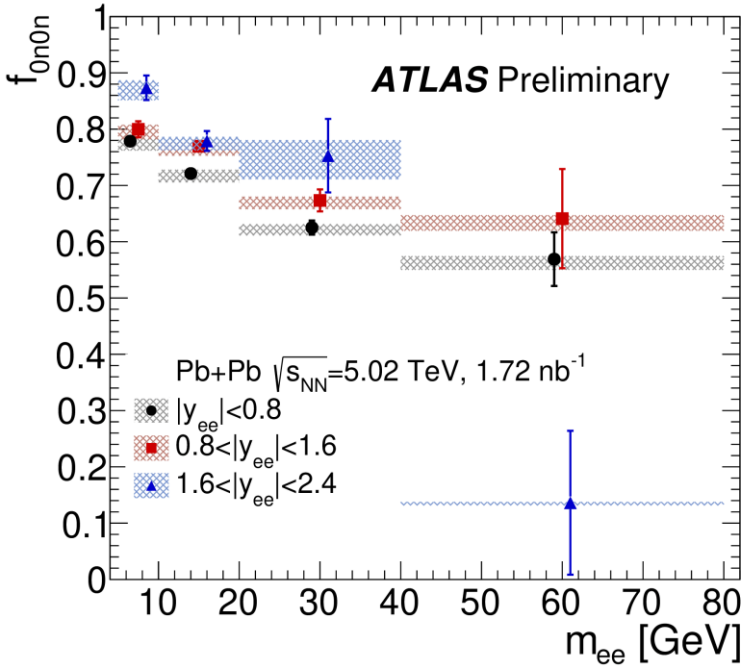
→ Just a teaser for the publications – feel free to read further ☺

Di-electron and di-muon production

ATLAS-CONF-2022-025
Phys. Rev. C 104 (2021) 024906

- Measurements of integrated and differential fiducial cross sections in UPC
  - Suppress dissociative production (with nucleus break-up) → Measure 0n0n fraction





→ Implicit test of the origin of the photons!
→ In dissociative production, photon from the substructure of the nucleon

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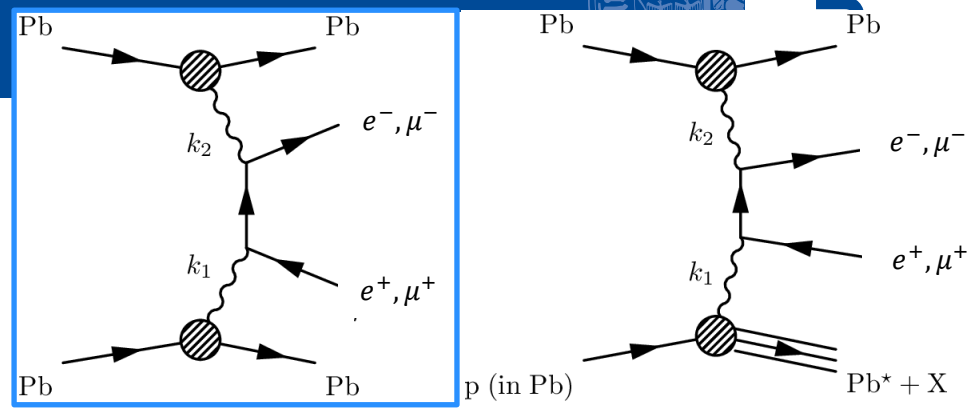

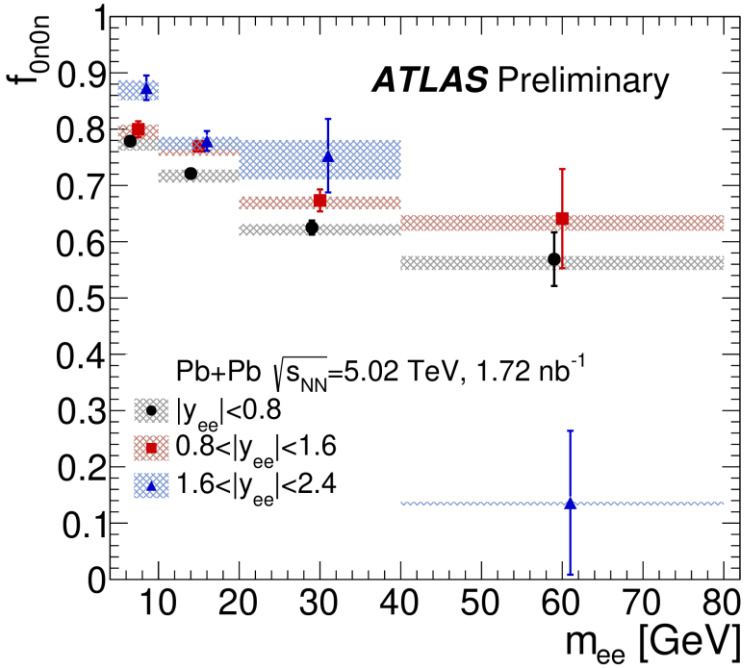

→ Implicit test of the origin of the photons!
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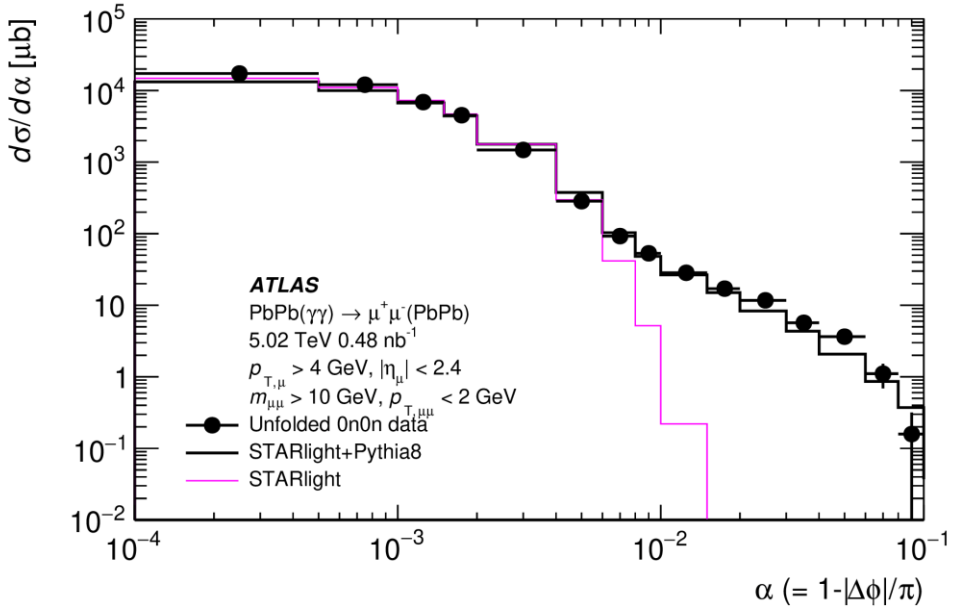
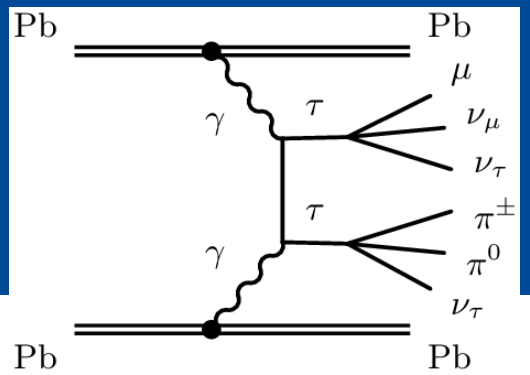
→ Measurement of differential cross section



→ Modelling of final state radiation essential

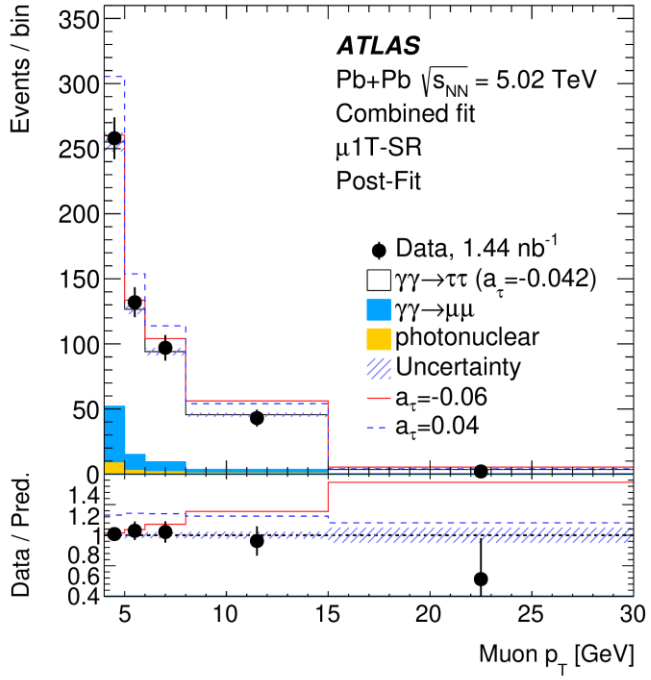
τ-lepton pairs in UPC

arXiv:2204.13478



- Reconstruct τ-leptons from decay products
  - Trigger on presence of muon in one τ-decay
  - Hadronic decays reconstructed via tracks with p_T > 100MeV

→ In signal region with 1 muon and 1 track



→ γγ→ττ production clearly visible by eye ☺

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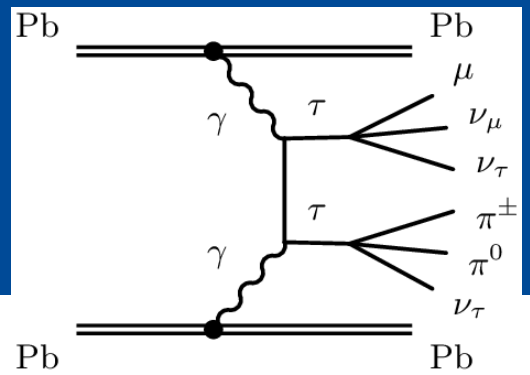

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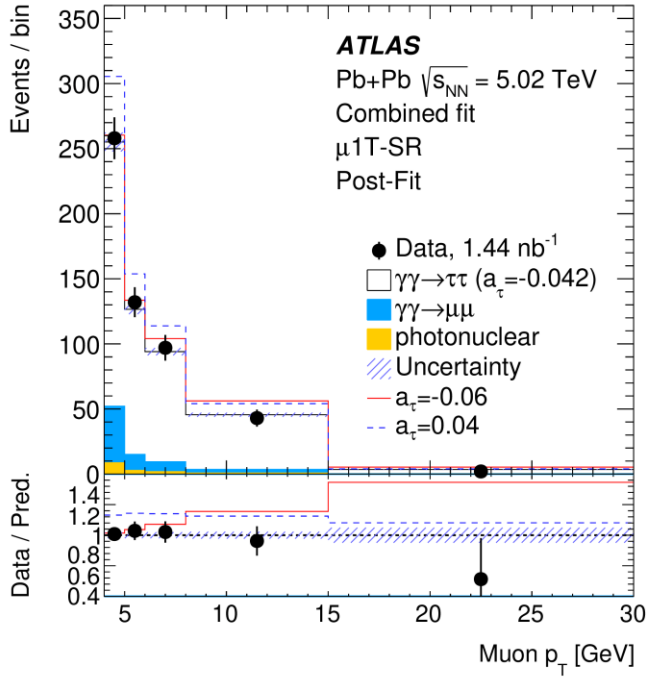

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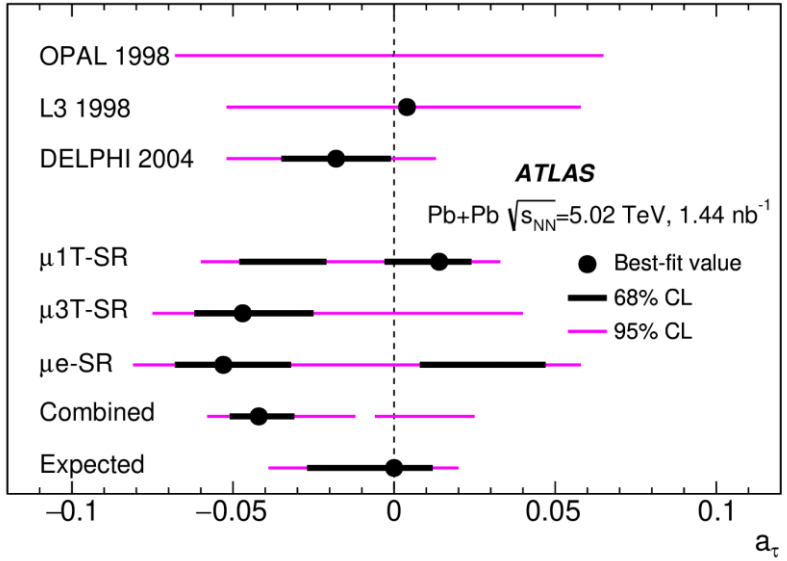
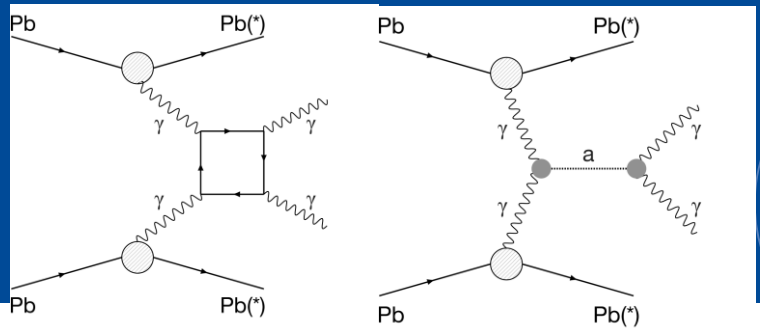
→ Extract anomalous magnetic moment of the τ-lepton: a_τ



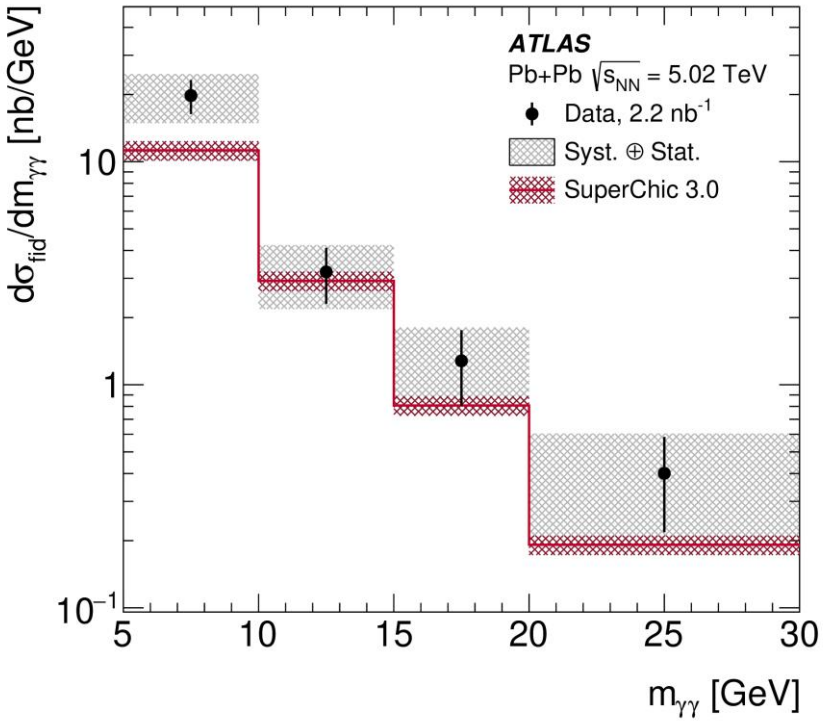
→ Expected 95% confidence level interval competitive with the world-best measurement from DELPHI (2004)

Light-by-light scattering

JHEP 03 (2021) 243



- Could also have axion-like particles (ALPs) as intermediate particle
  - Measure differential cross sections



→ Agreement within 2σ

→ Uncertainty = Statistics dominated

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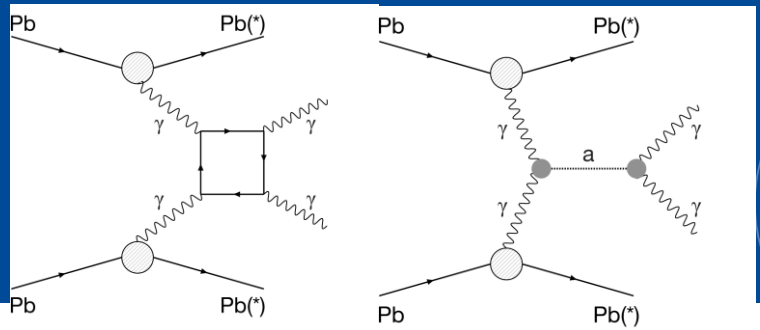
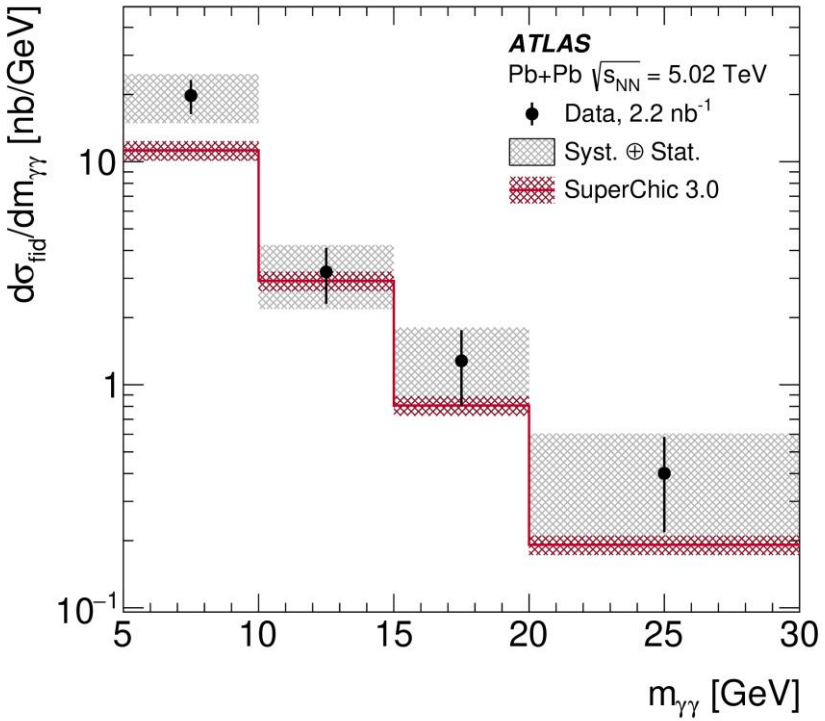
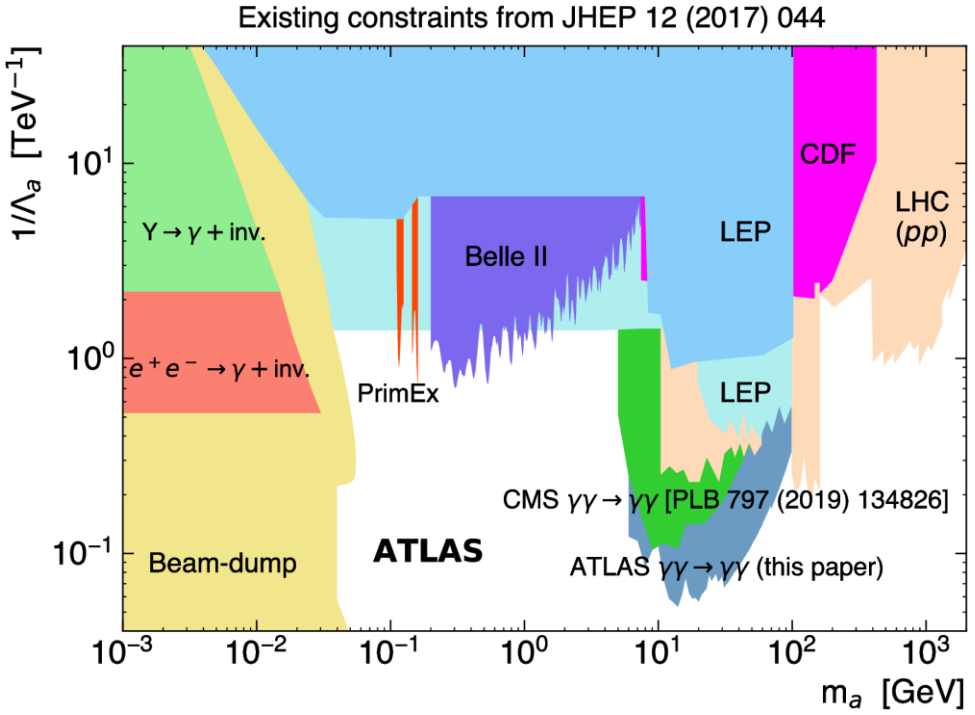


- Could also have axion-like particles (ALPs) as intermediate particle
  - Measure differential cross sections → Exclude couplings to ALPs





→ Agreement within 2σ
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→ Most stringent limits on ALPs couplings for ALPs masses of 6-100GeV

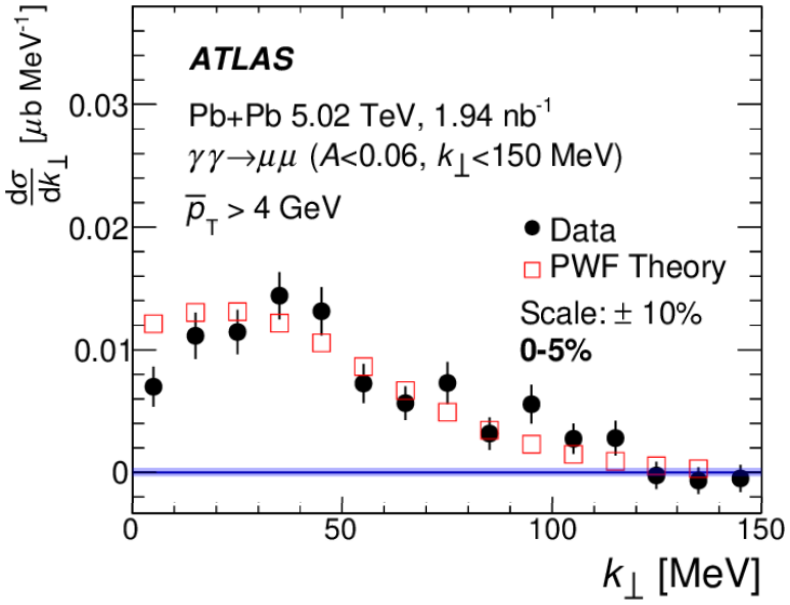
γγ→μμ with non-UPC configuration

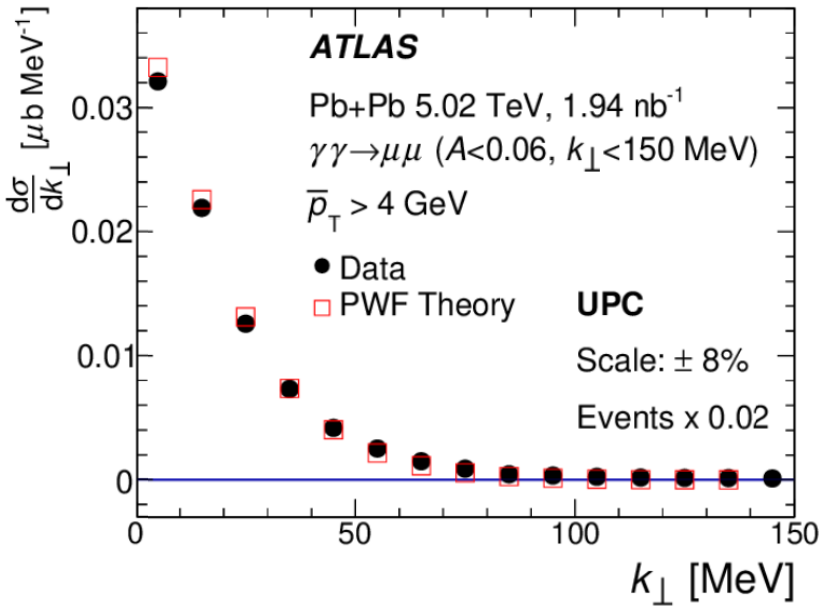
arXiv:2206.12594

NEW

- Muon pairs as electromagnetic probes of the quark-gluon plasma
  - Consider transverse momentum scale: $k_\perp = 1/2(p_{T1}+p_{T2})(\pi - |\phi_1 - \phi_2|)$
    - $k_\perp \approx 0$, if leptons are back-to-back in ϕ
    - $k_\perp \approx$ factor*average p_T, where factor is larger if leptons are more aligned in ϕ

  → Dependence on collision centrality





$\gamma\gamma \rightarrow \mu\mu$ with non-UPC configuration

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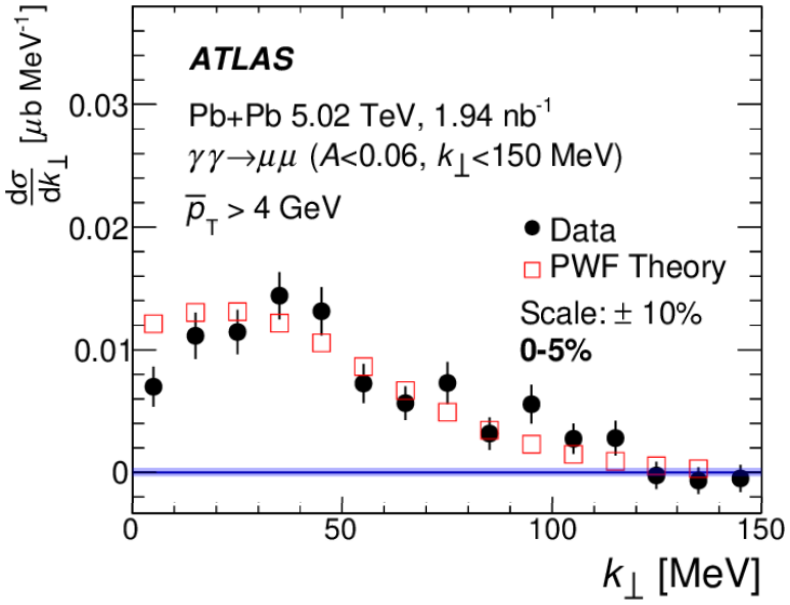
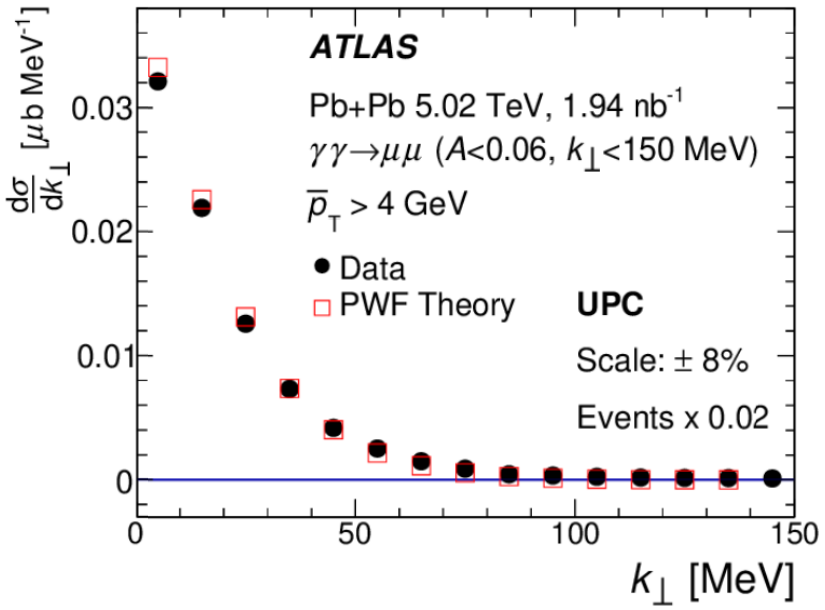
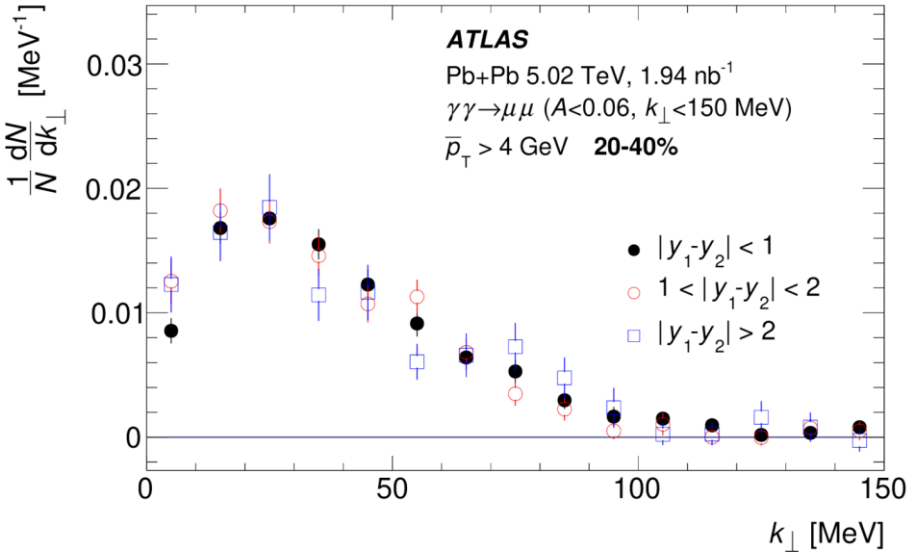
→ Dependence on collision centrality

→ Influence of magnetic field effects?







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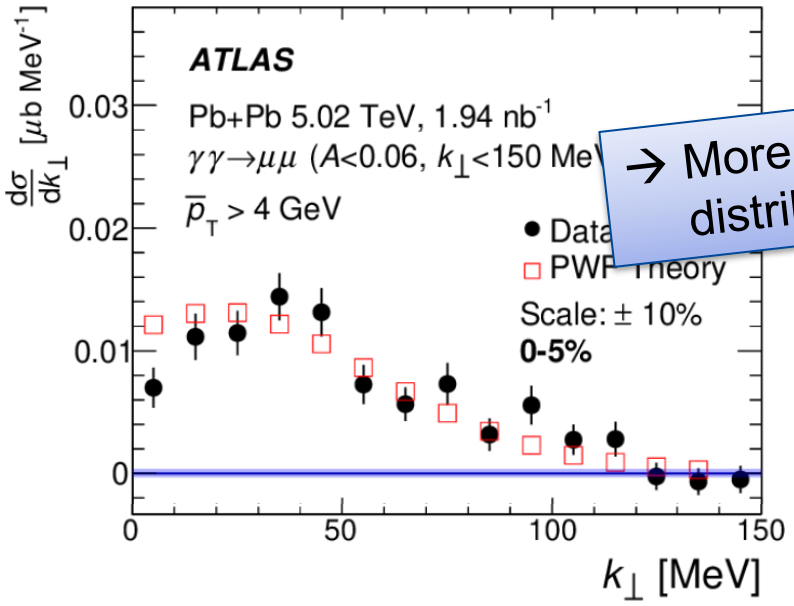
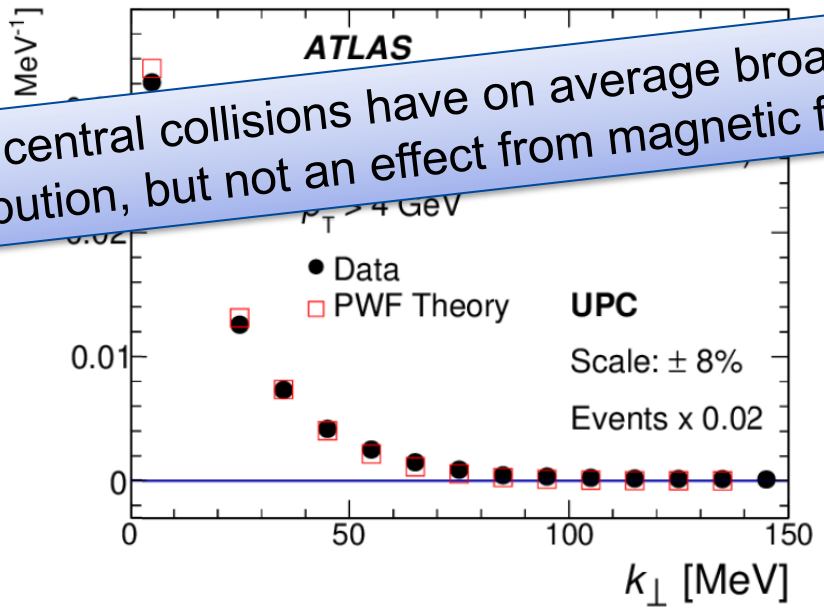
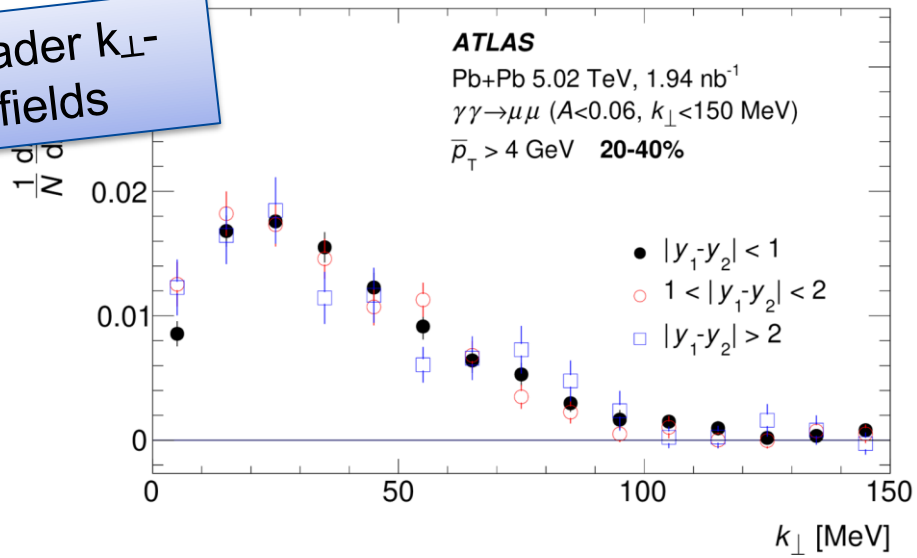




→ More central collisions have on average broader $k_\perp$-distribution, but not an effect from magnetic fields



Summary

- Interesting physics with nearly empty detectors possible
  - Photo-production of lepton pairs, and light-by-light scattering measured in Run-2
  - Measurement of (fiducial) cross sections, but also beyond standard model constraints
    - Testing Monte-Carlo simulations with γγ→ee and γγ→μμ production
    - First observation of γγ→ττ production and competitive confidence interval for anomalous magnetic moment of τ-lepton
    - Best limits on axion-like particle searches with 6-100GeV particle mass from γγ→γγ
    - Magnetic effects not the main source for γγ→μμ azimuthal effects in non-UPC

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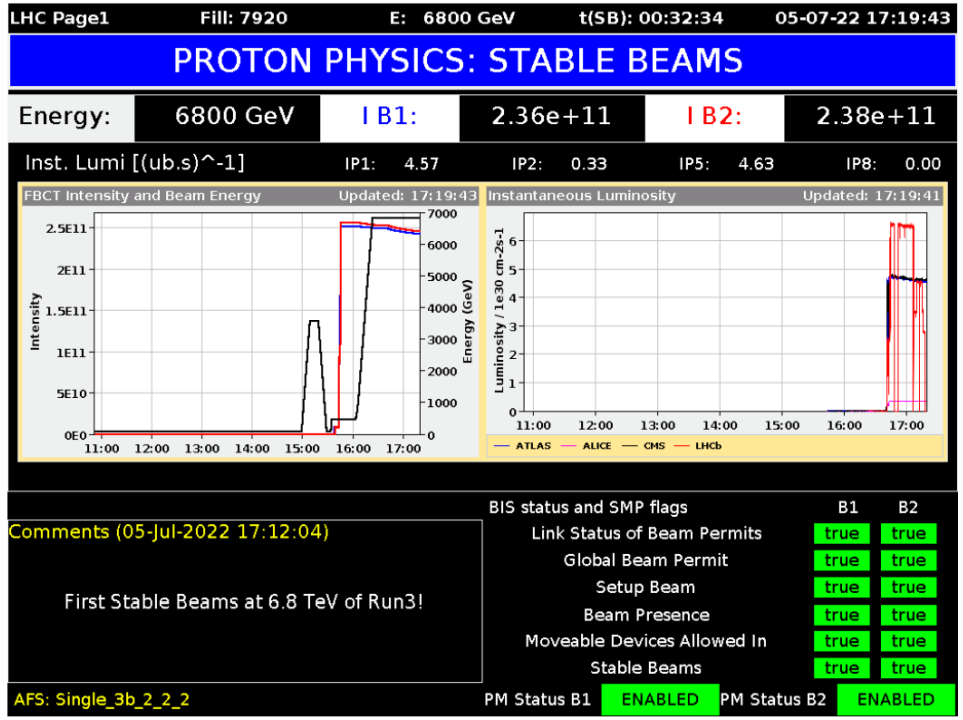
→ Fun to push the ATLAS detector into regions it was not designed for ☺
→ Only getting started and more data to come



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Thank you for your attention

Backup

Measuring particles from collision

- ATLAS detector - Multi-purpose detector with near 4π coverage
  - Near-beam rapidity neutrons detected in Zero degree calorimeter (ZDC)
    - Covers $|\eta| > 8.3$ → 140m away from interaction point (IP)
    - Measure centrality of PbPb collisions by amount of activity in ZDC arms