Measurement of tau $g-2$ in PbPb collisions

Arash Jofrehei* for the CMS Collaboration

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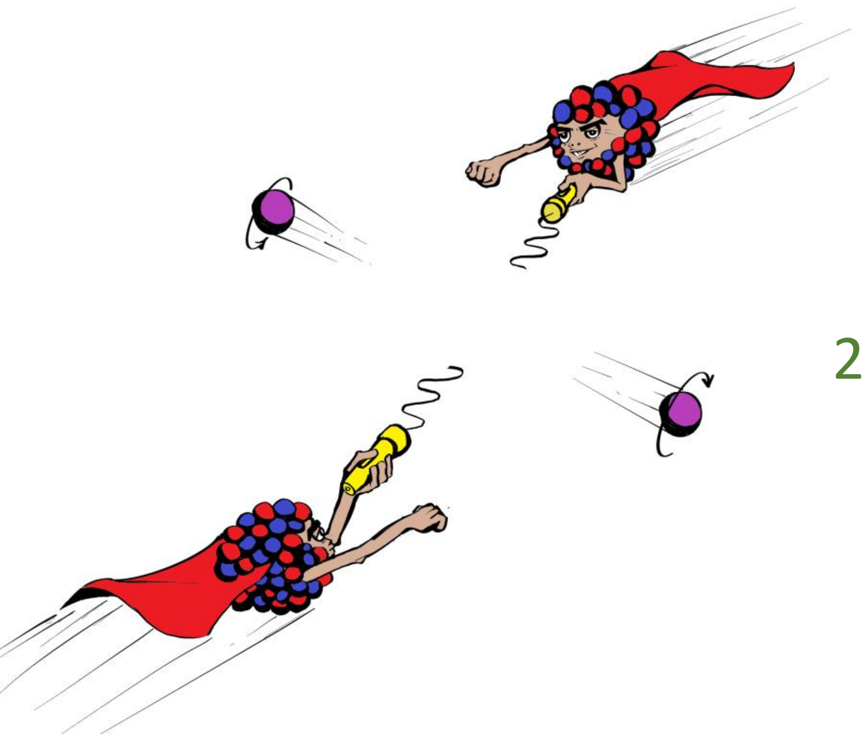
CMS NEW RESULT



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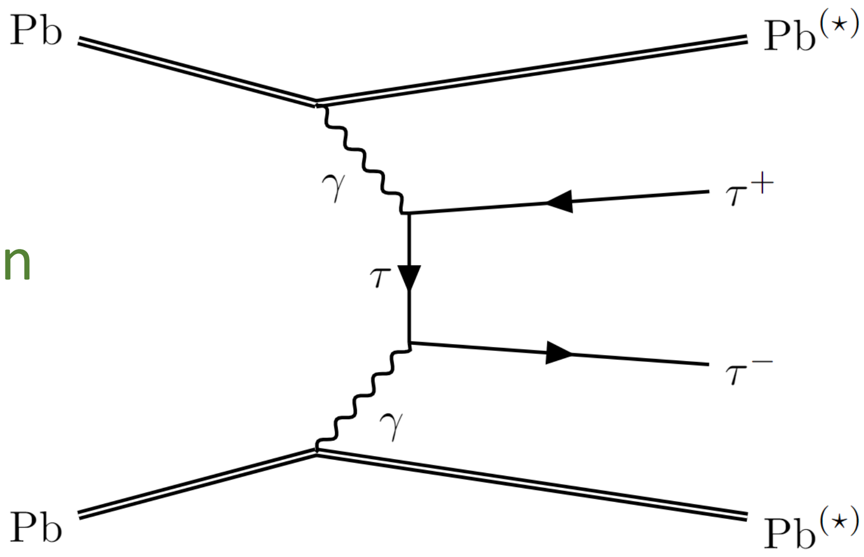
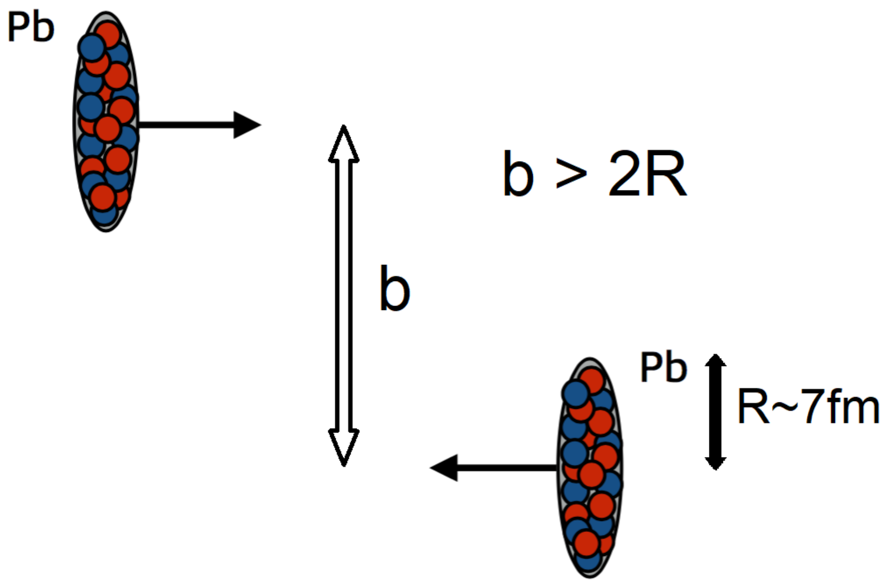


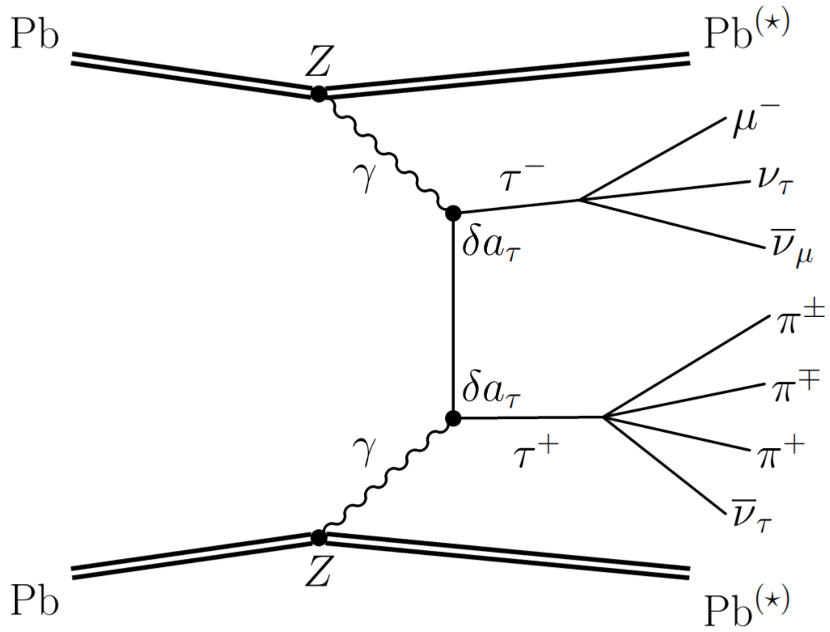
Hard Probes 2024

22-27th Sep. 2024, Nagasaki, Japan

UPC PbPb @ LHC

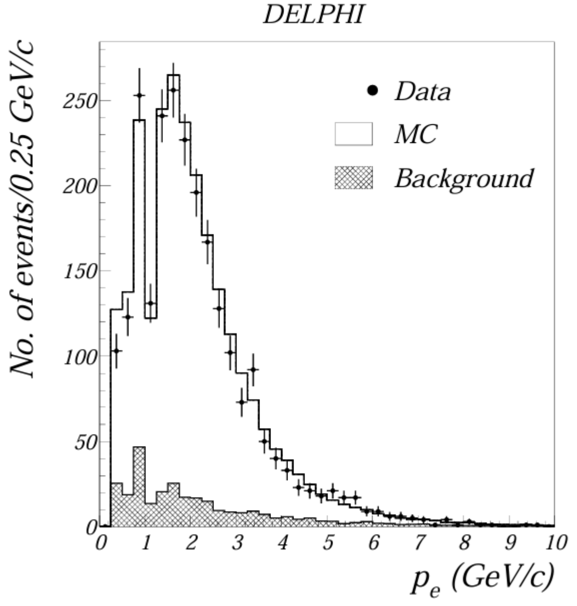
- Ultraperipheral Collisions (UPC) of PbPb at $\sqrt{s_{NN}} = 5.02$ TeV
  - High impact parameter, low forward activity
- Photon-photon processes in UPC → Cross section scales with Z^4
- Anomalous magnetic moment of tau: $a_\tau = \frac{(g-2)_\tau}{2}$
- Cross section & tau kinematics sensitive to a_τ



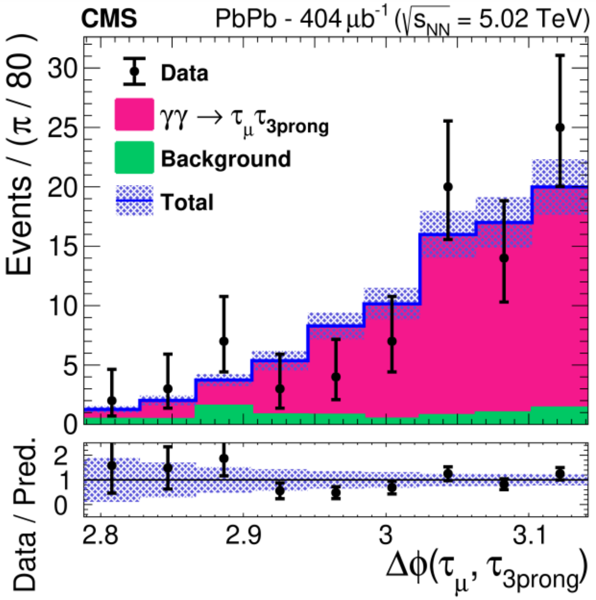


$\gamma\gamma \to \tau\tau$ to measure a_τ

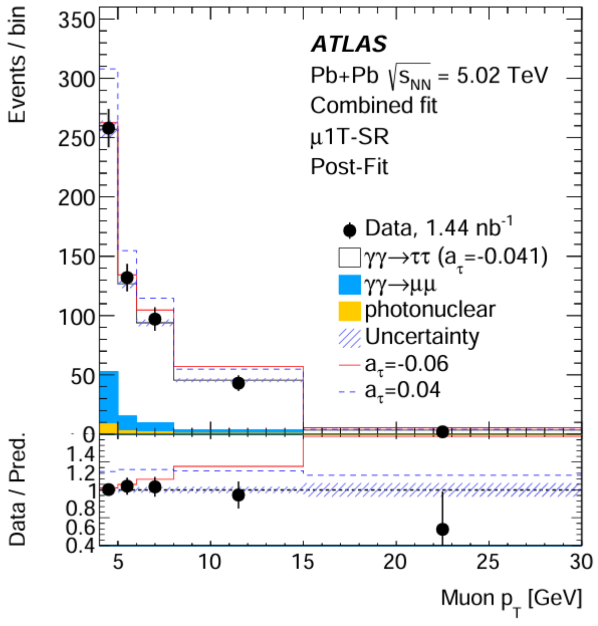
- DELPHI had the best measurement of a_τ since 2003.
- First LHC observations by CMS (2015 data) and ATLAS (2018 data) in PbPb
- CMS measurement in pp improved the previous best a_τ measurement by ATLAS & DELPHI by exploiting the high a_τ sensitivity in high $\tau\tau$ mass.



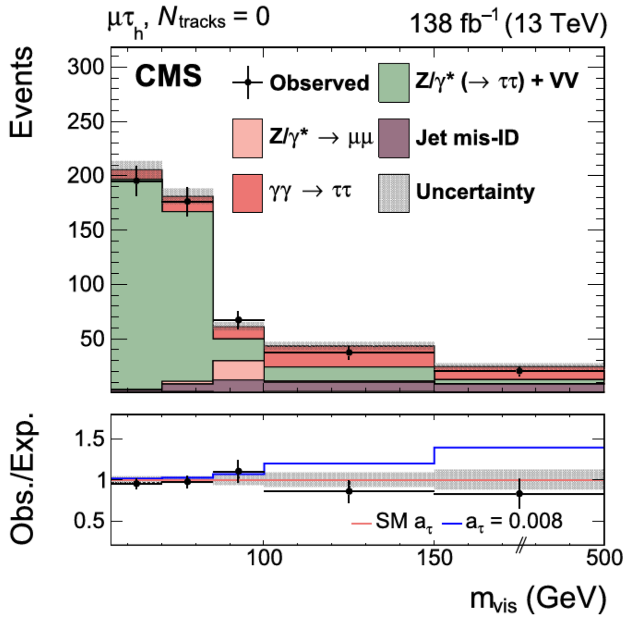
Eur.Phys.J.C 35 (2004) 159-170



Phys. Rev. Lett. **131**, 151803



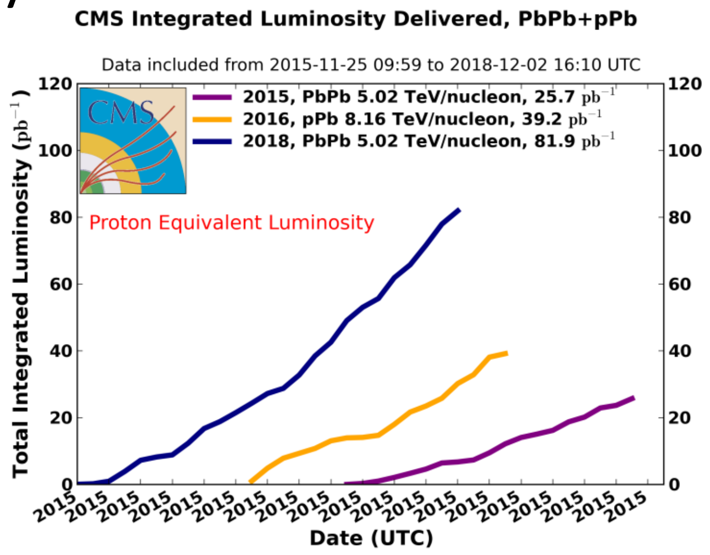
Phys. Rev. Lett. **131**, 151802



Rep. Prog. Phys. 87 107801

$\gamma\gamma \rightarrow \tau\tau$ to measure a_τ

- An improved PbPb measurement from CMS will be presented today.
  - Low $\tau\tau$ invariant mass: complementary to the pp analysis
  - 2018 dataset is ~4 times larger than 2015
  - 4 decay channels of μ+1prong, μ+3prong, μ+e, and e+3prong



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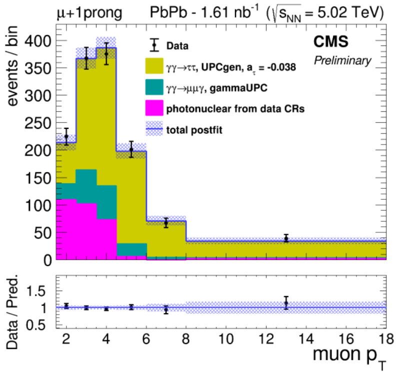
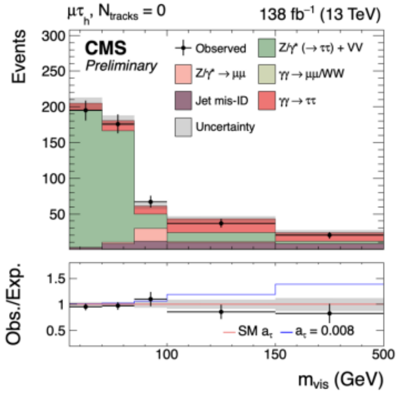
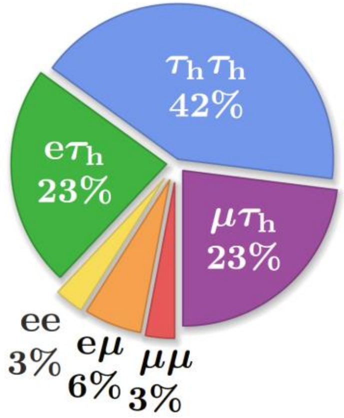


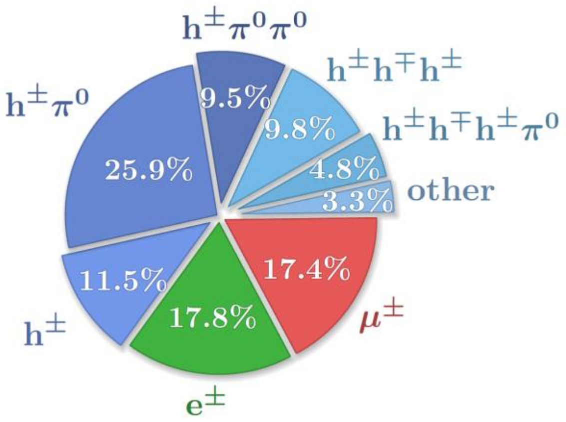


PPS approved for Run-4

[LHC seminar by Cecile Sarah Caillol](#)



$\tau\tau$ branching ratio



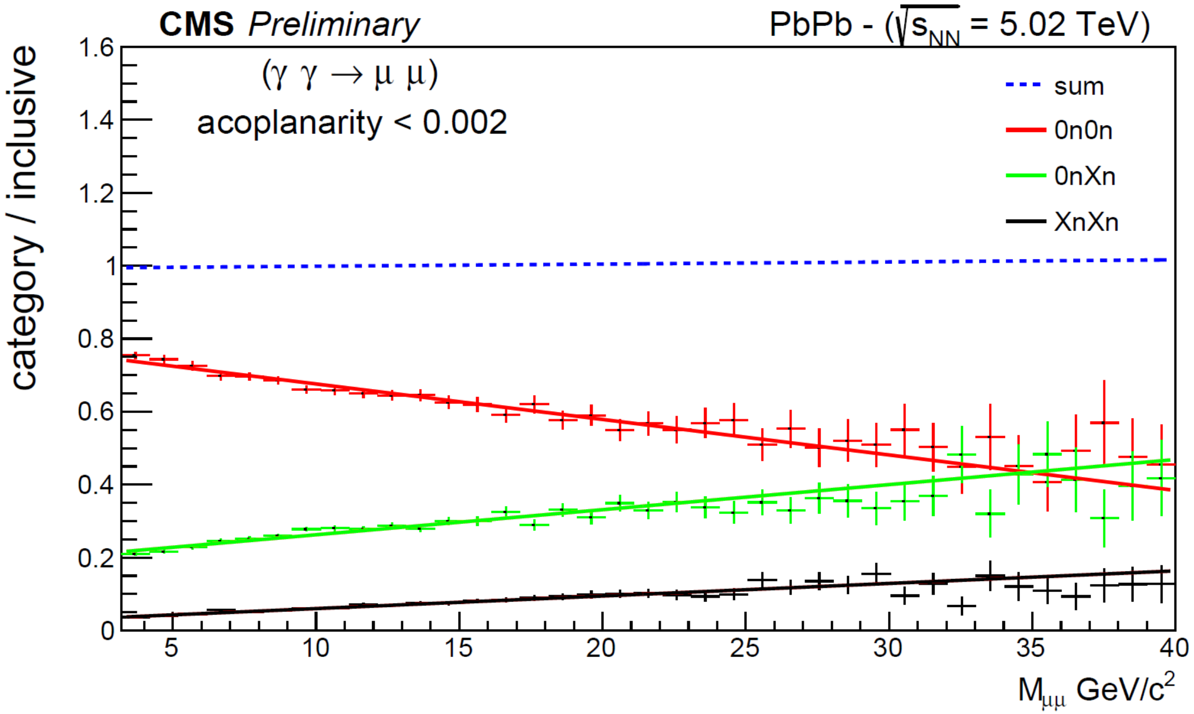
τ branching ratio

Analysis strategy

- 4 decay channels of μ+1prong, μ+3prong, μ+e, and e+3prong
- Exclusivity requirements to select exclusive UPC events
- Signal selection
- Modeling the remaining exclusive and non-exclusive background
- Ensure that excess of data over background is kinematically compatible with signal
- Measurement of cross section and a_τ

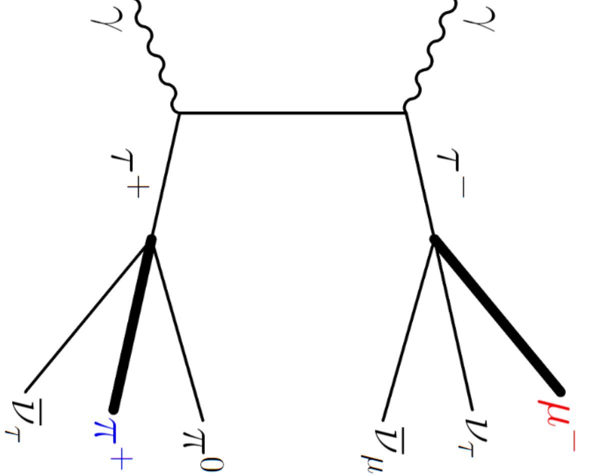
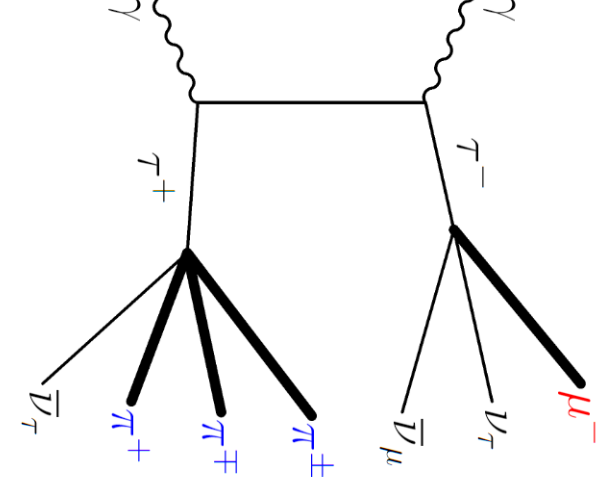
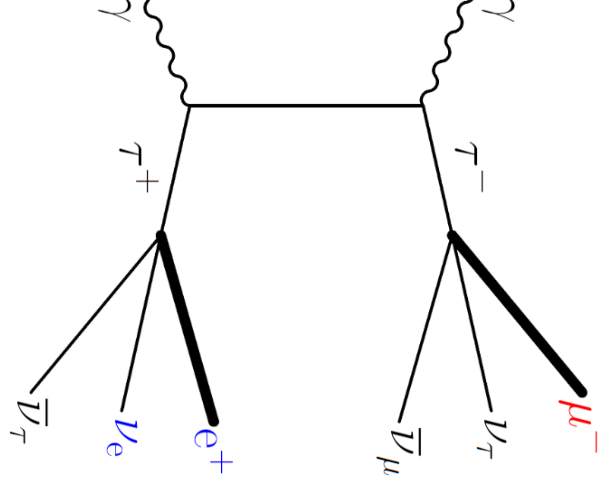
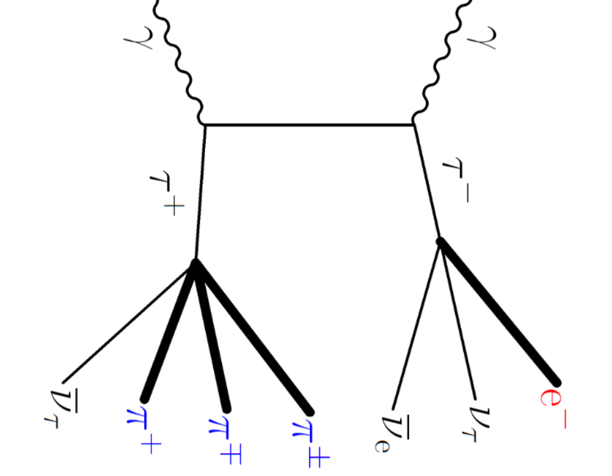
Ensuring exclusivity

- In all decay channels, leading Hadronic Forward (HF) tower < 6 GeV
- In μ+e, additional exclusivity cuts applied on calorimeter activities as below.
- In μ+1prong, no neutrons in the Zero Degree Calorimeters (ZDC) (0n0n)
    - MC samples normalized by 0n0n probability as a function of dilepton mass, extracted from $\gamma\gamma \rightarrow \mu\mu$



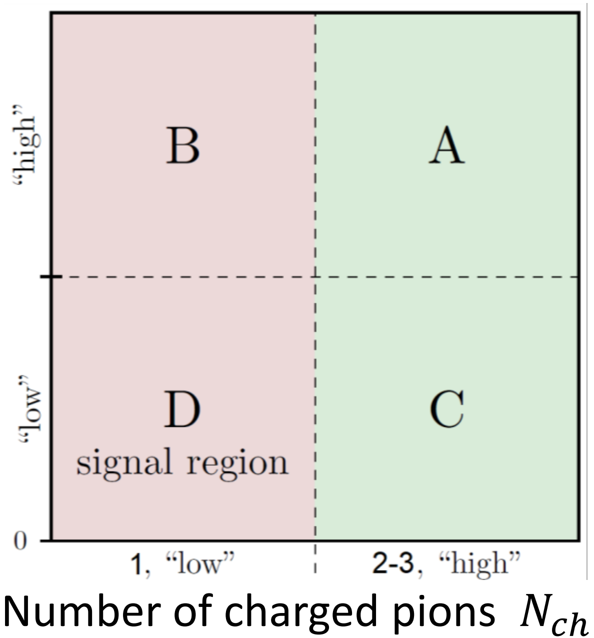
Sub-Calorimeters	η range	Threshold(GeV)
EB	$0 < \lvert\eta\rvert < 1.4442$	0.7
EE	$1.566 < \lvert\eta\rvert < 2.6$	3.0
HB	$0 < \lvert\eta\rvert < 1.305$	2.8
HE	$1.41 < \lvert\eta\rvert < 3$	1.0
HF$^+$	$3.15 < \eta < 5.2$	6.0
HF$^-$	$-5.2 < \eta < -3.15$	6.0

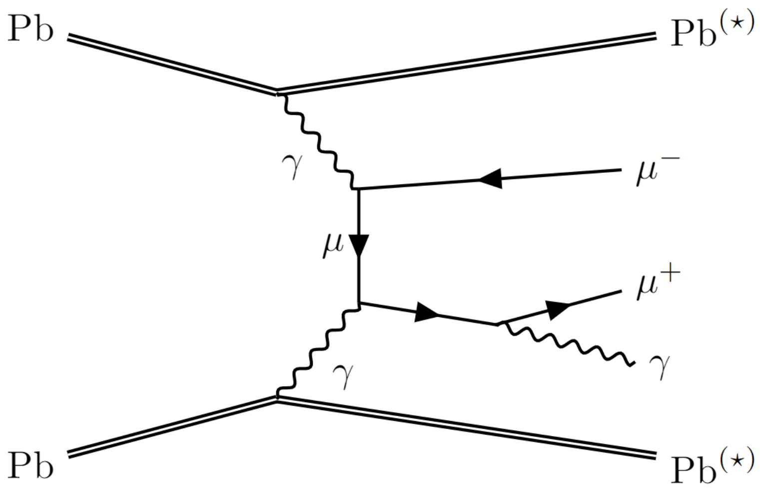
Event selection

μ+1prong	μ+3prong	μ+e	e+3prong
			
μ $p_T > 3.5$ GeV ($\|\eta\| < 1.2$), 1.5 ($1.2 < \|\eta\| < 2.4$) GeV			electron $p_T > 4$ GeV
$\pi^\pm$ $p_T > 0.3$ GeV	$\pi^\pm\pi^\mp\pi^\pm$ $p_T > 0.5$ GeV (leading) $p_T > 0.3$ GeV (2 subleadings) $\mathrm{M}(\pi^\pm\pi^\mp\pi^\pm) < 1.5$ GeV	electron $p_T > 2.5$ GeV	$\pi^\pm\pi^\mp\pi^\pm$ $p_T > 0.5$ GeV (leading) $p_T > 0.3$ GeV (2 subleadings) $\mathrm{M}(\pi^\pm\pi^\mp\pi^\pm) < 1.5$ GeV $p_T(\pi^\pm\pi^\mp\pi^\pm) > 1$ GeV
$\tau\tau$ $\alpha(\tau\tau) < 0.1$ $p_T(\tau\tau) > 1$ GeV	$\tau\tau$ $\alpha(\tau\tau) < 0.1$	$\tau\tau$ $\alpha(\tau\tau) > 0.01$	$\tau\tau$ $\alpha(\tau\tau) < 0.1$

Background modeling

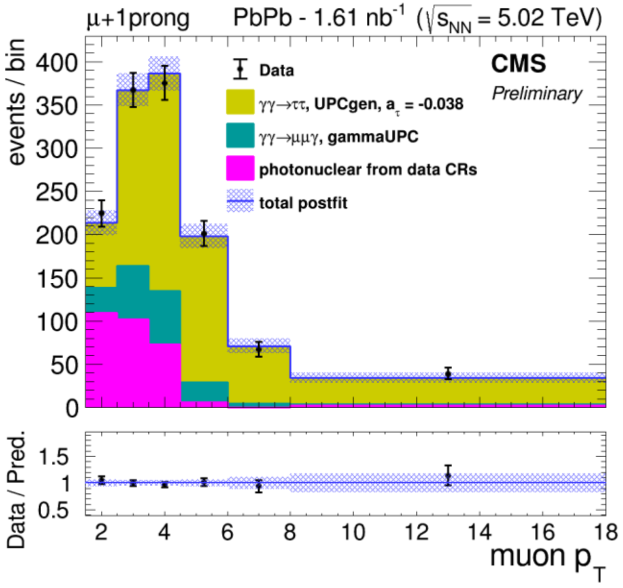
- Non-exclusive background in semi-leptonic channels is estimated with a data-driven ABCD method
  - 4 regions of phase space with high/low number of charged pions and HF activity
  - Background in signal region (D) estimated bin-by-bin with $B \times C/A$
- Exclusive $\gamma\gamma \to ee, \gamma\gamma \to \mu\mu,\ \& \, \gamma\gamma \to \mu\mu\gamma$ considered
  - Acoplanarity and di-track p_T cuts to remove or reduce these backgrounds
  - FSR photon reconstruction to further reduce $\gamma\gamma \to \mu\mu\gamma$ in μ+1prong





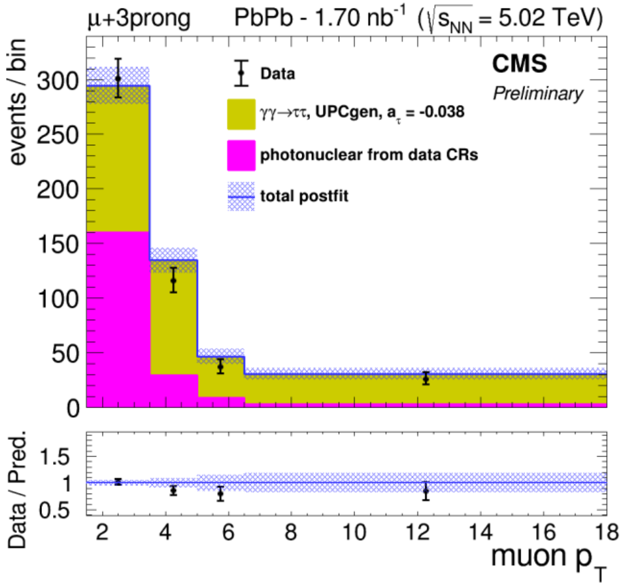
Kinematics consistent with signal

- Signal: $\gamma\gamma \rightarrow \tau\tau$ generated with UPCgen
- Signal stacked on top of background(s), compared to data
- Good agreement between data and the signal+background model

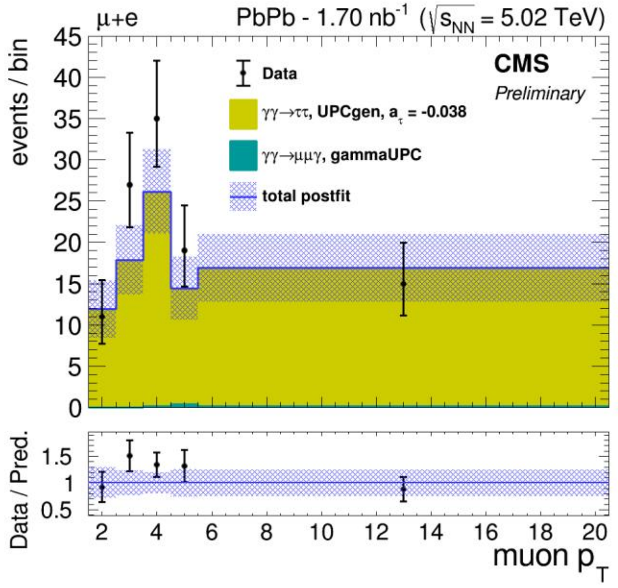


μ+1prong

(most a_τ sensitivity)

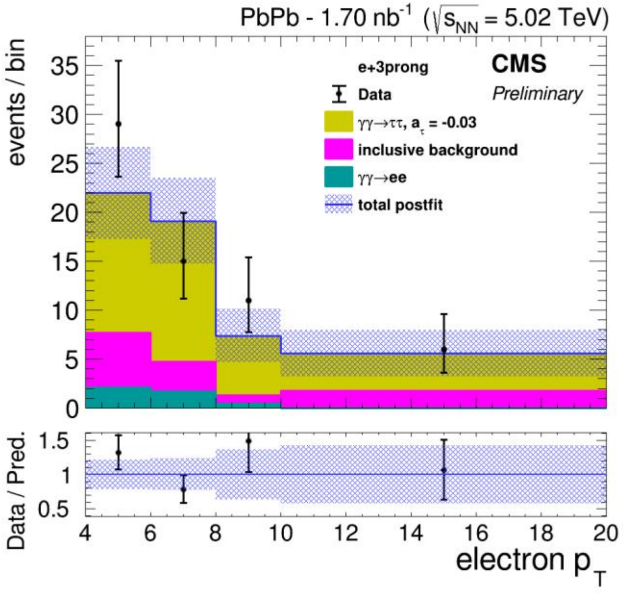


μ+3prong



μ+e

(cleanest)



e+3prong

Measuring a_τ and fiducial cross section

- $\gamma\gamma \rightarrow \tau\tau$ samples with $-0.1 < a_\tau < 0.1$ generated with UPCgen
  - Fiducial phase space: tau $p_T > 1$, tau $|\eta| < 3$
- Fit performed on lepton p_T with the most sensitivity to a_τ.
- Distributions of lepton p_T are smoothened and morphed as a function of a_τ.
- 2D and 1D limits on a_τ and fiducial cross section are extracted.

CMS NEW RESULT

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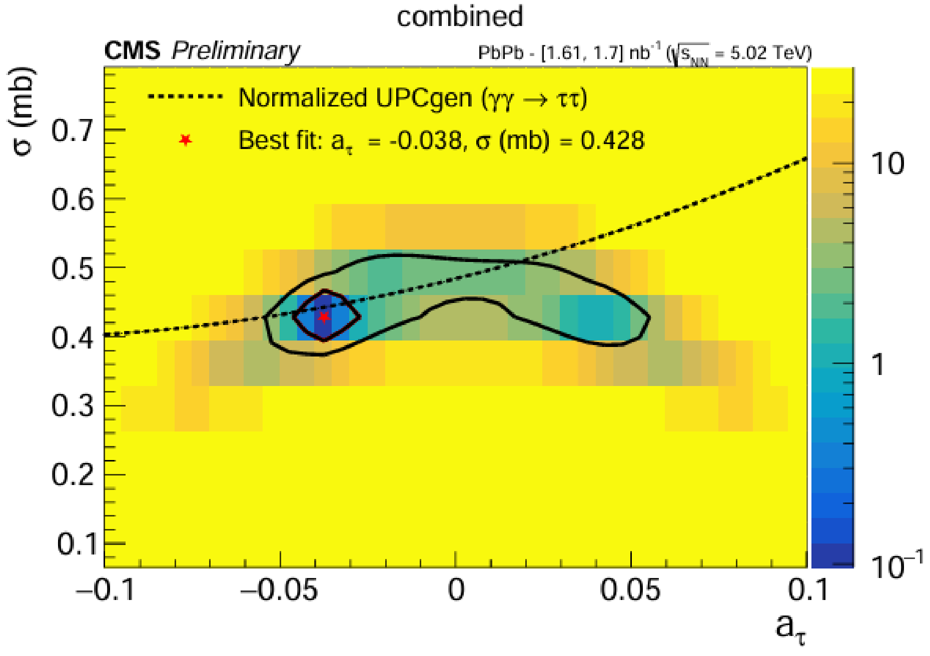
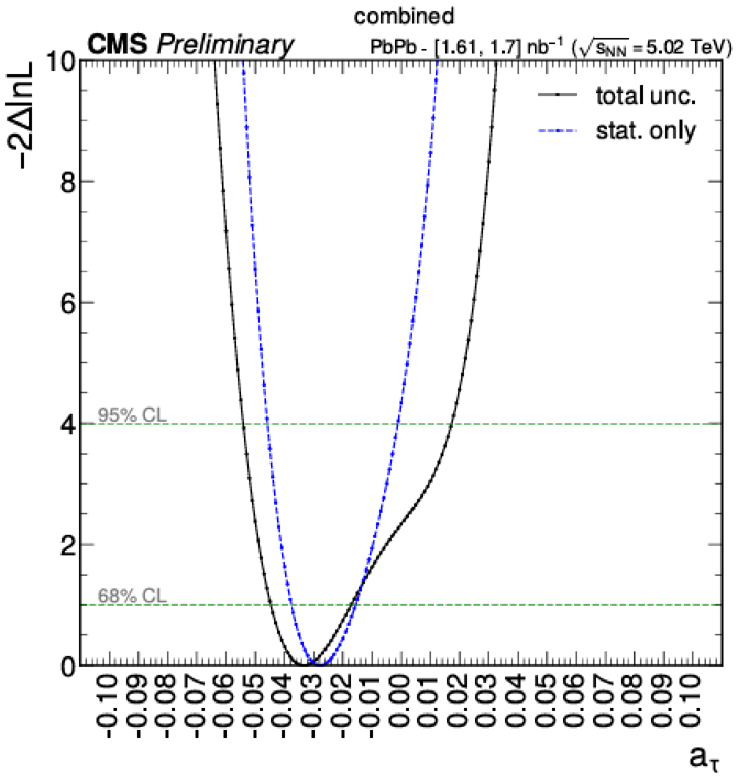
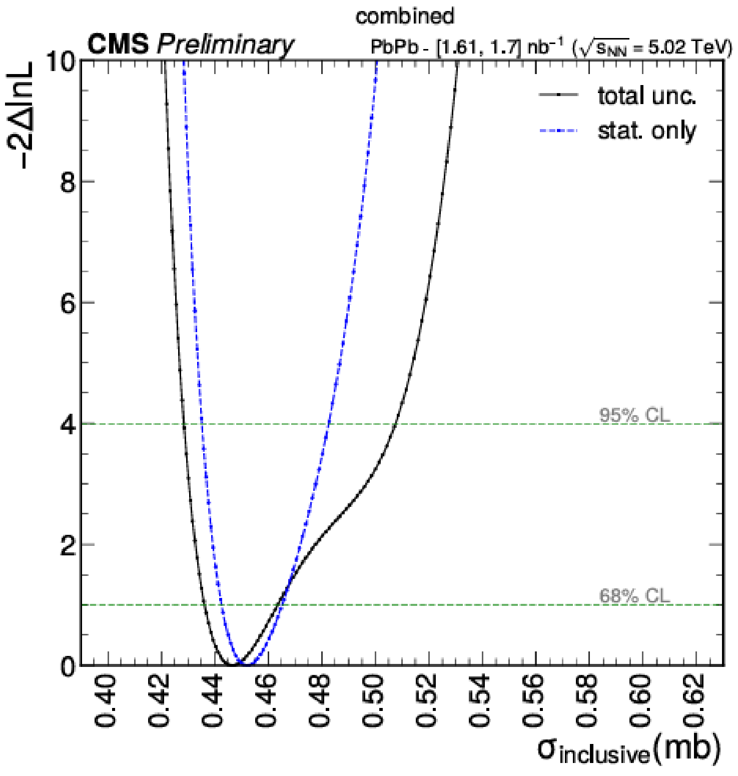






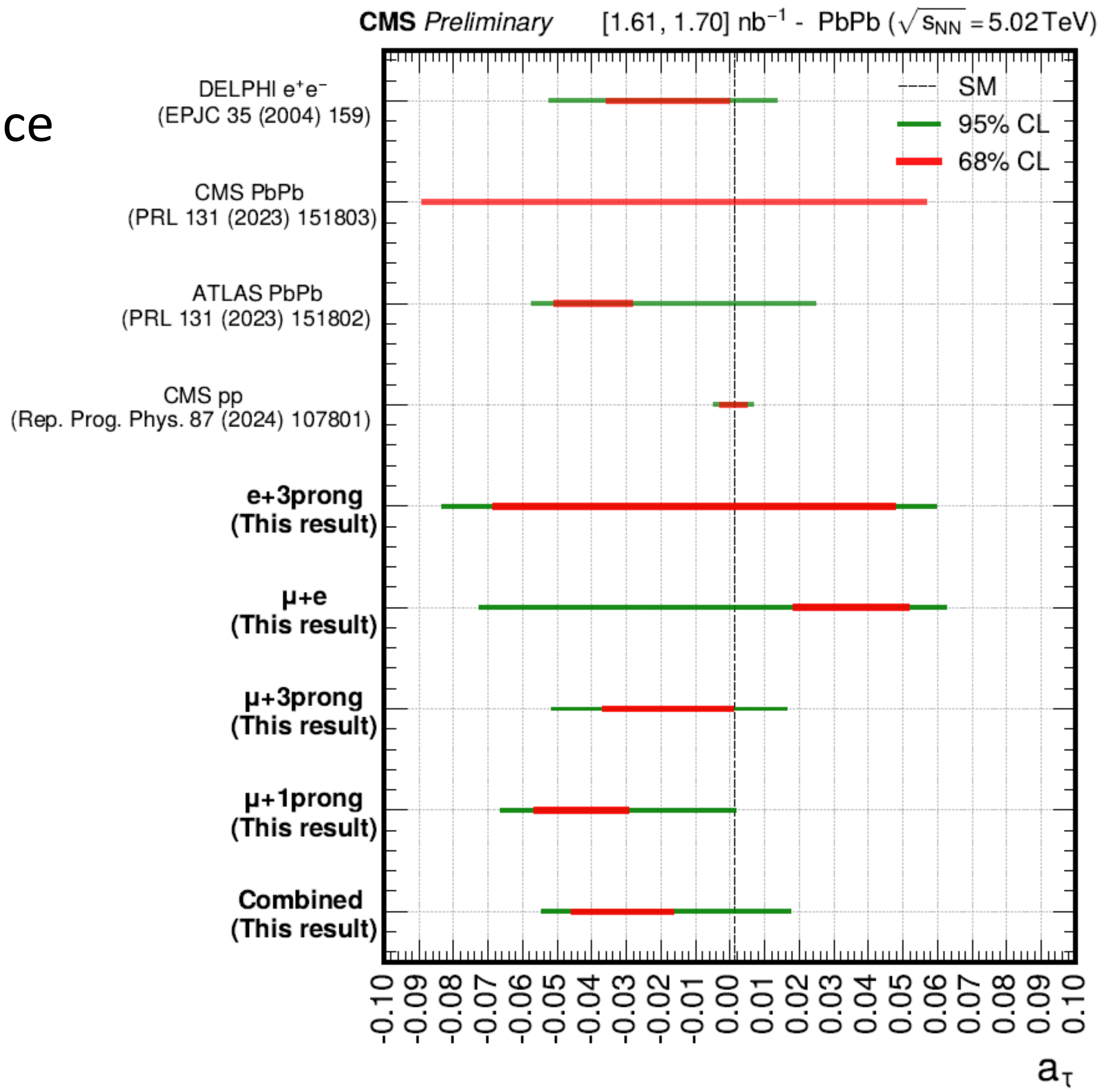
Systematics

- Main sources of systematic uncertainty on signal yield at $a_\tau = 0$:
  - Muon efficiency (trigger, identification) → 2.7%
  - Pion tracking efficiency → 2.0%
  - Luminosity → 1.5%
  - Choice of specific ABCD regions → 1.4%
  - Limited MC size, tau BR, electron efficiency, exclusivity cuts, ZDC categorization …
  - **Total ≈ 5%**

Comparison with previous measurements

- ~6x better limits than the previous CMS PbPb
- Similar data size to ATLAS, but larger phase space
- Among best limits in the low $\tau\tau$ mass region

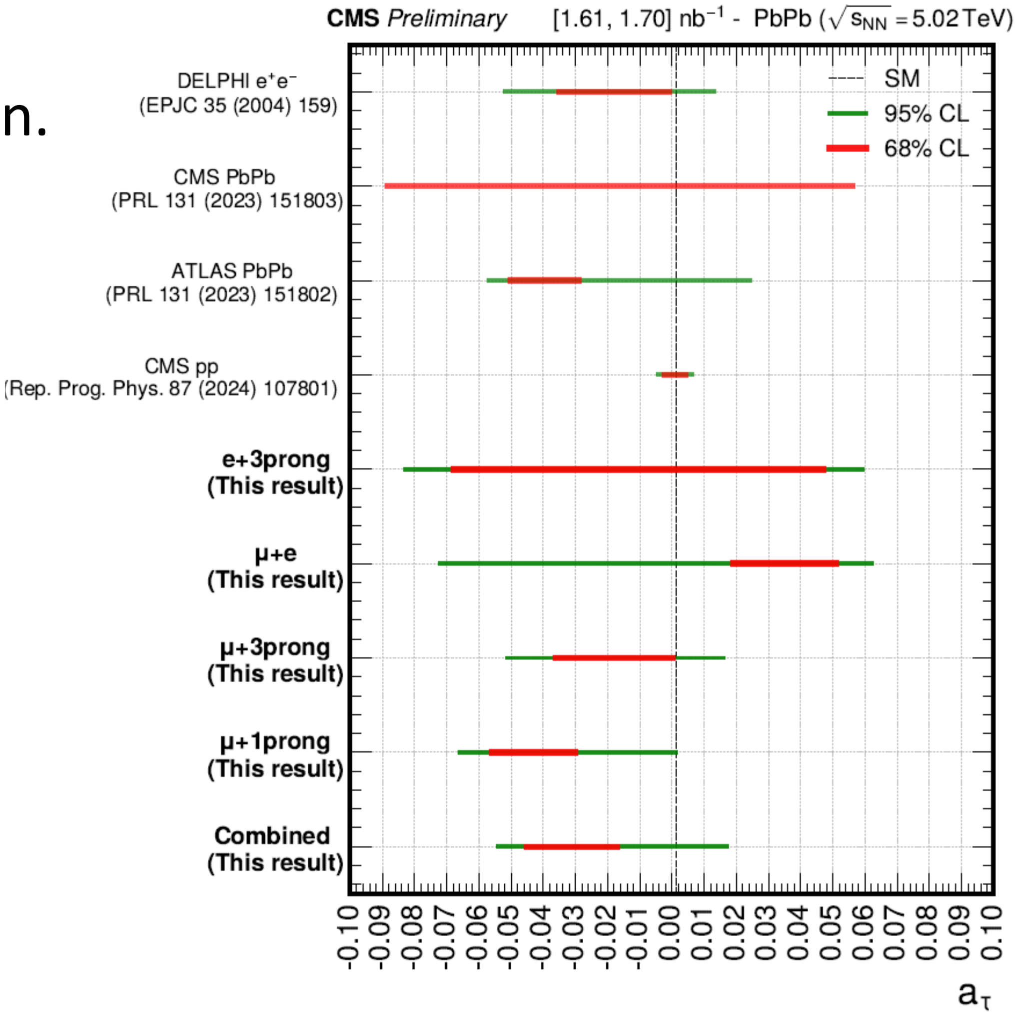
CMS-PAS-HIN-24-011



Summary

- Precision measurement of a_τ at CMS in three complementary phase spaces
- $a_\tau = -35^{+11(stat)+18(stat+sys)}_{-3(stat)-10(stat+sys)} \times 10^{-3}$
  - SM calculation: $a_\tau = 0.001\,177\,21(5)$
- The most precise measurement of $\gamma\gamma \to \tau\tau$ cross section.
  - $\sigma_{fiducual}(ub) = 447^{+18(stat)+16(stat+sys)}_{-5(stat)-11(stat+sys)}$

[CMS-PAS-HIN-24-011](CMS-PAS-HIN-24-011)



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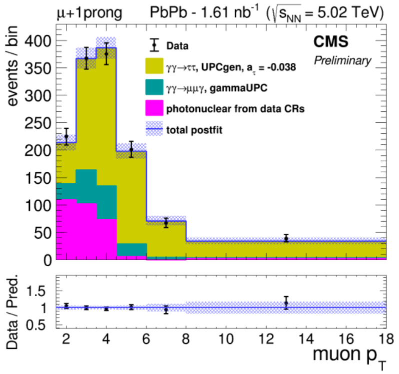

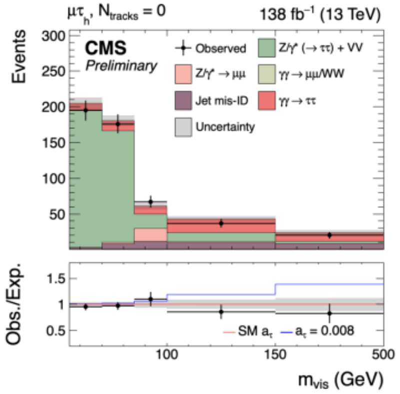

PPS approved for Run-4

LHC seminar by Cecile Sarah Caillol

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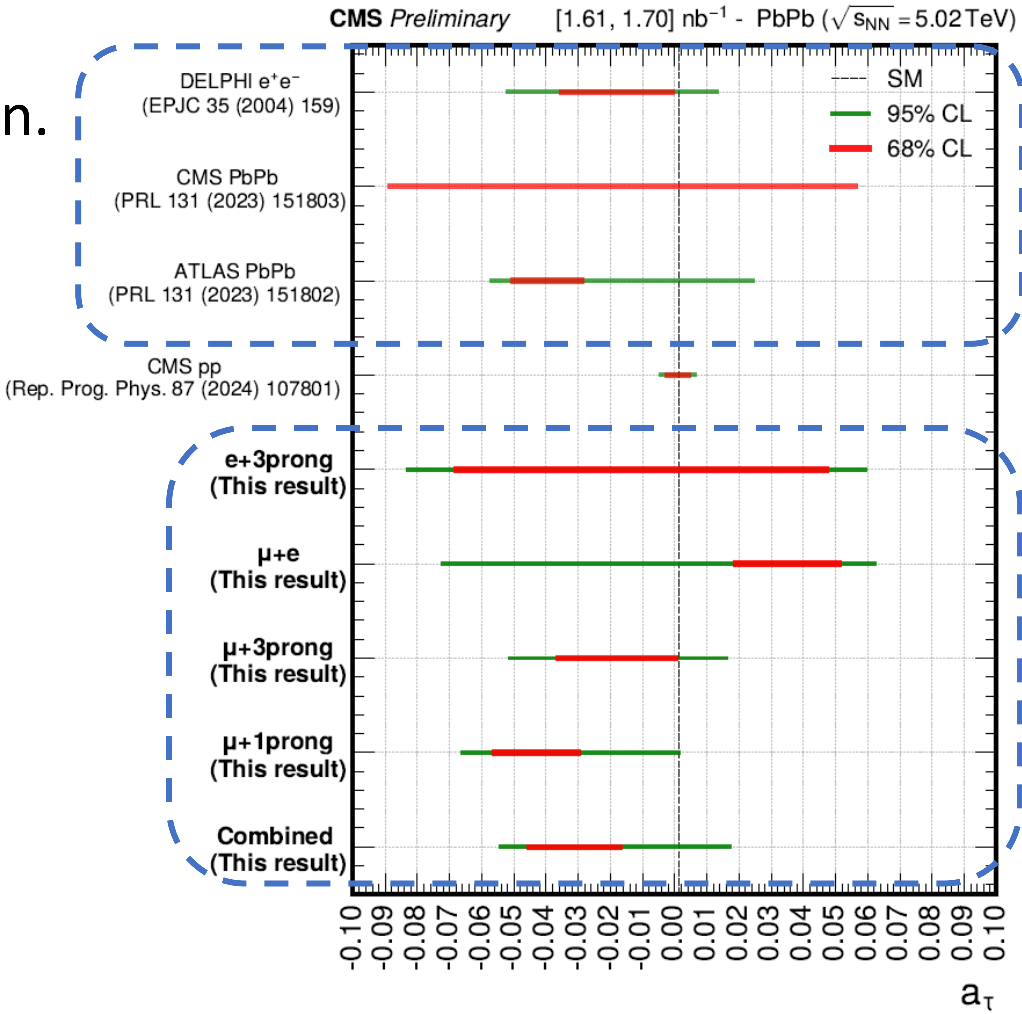

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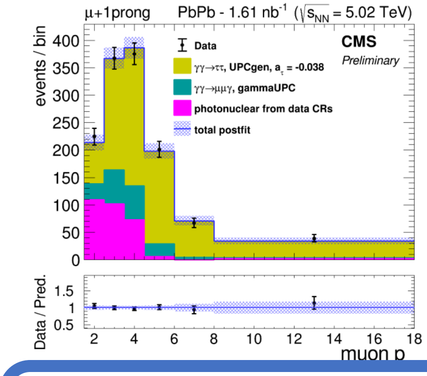

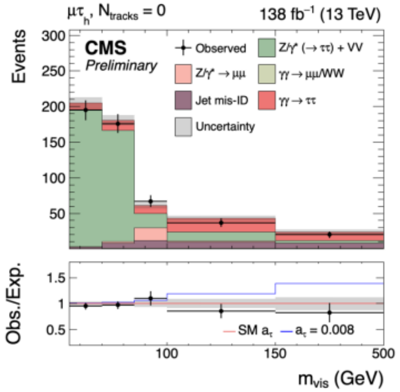

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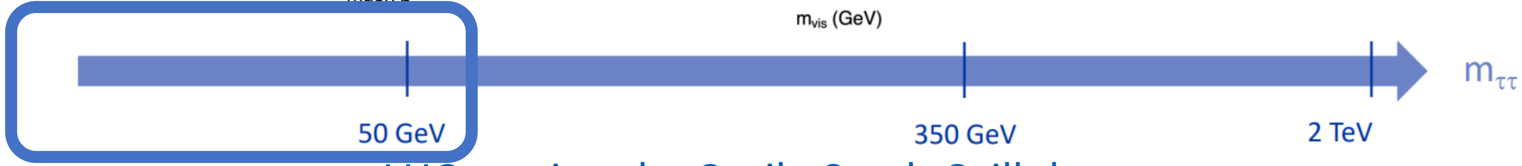

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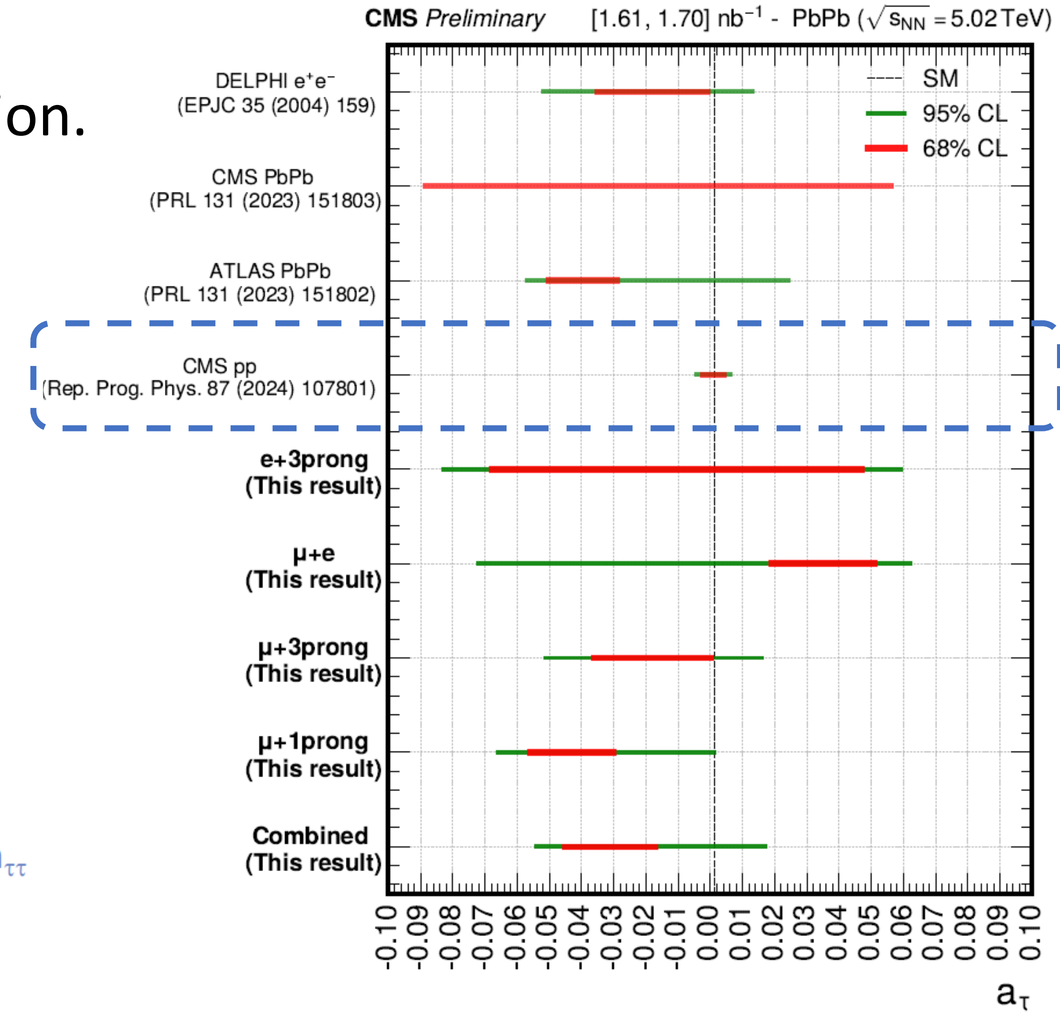

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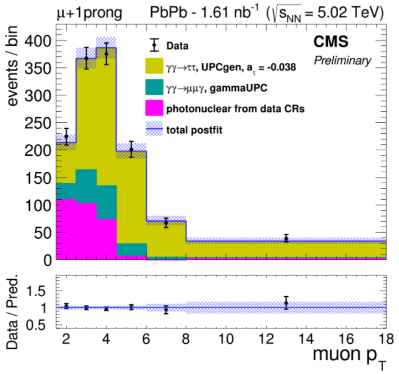

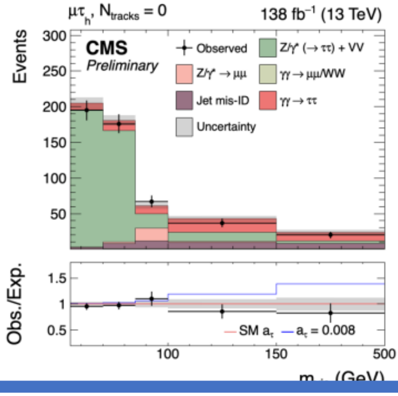

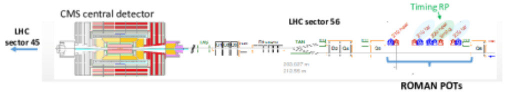

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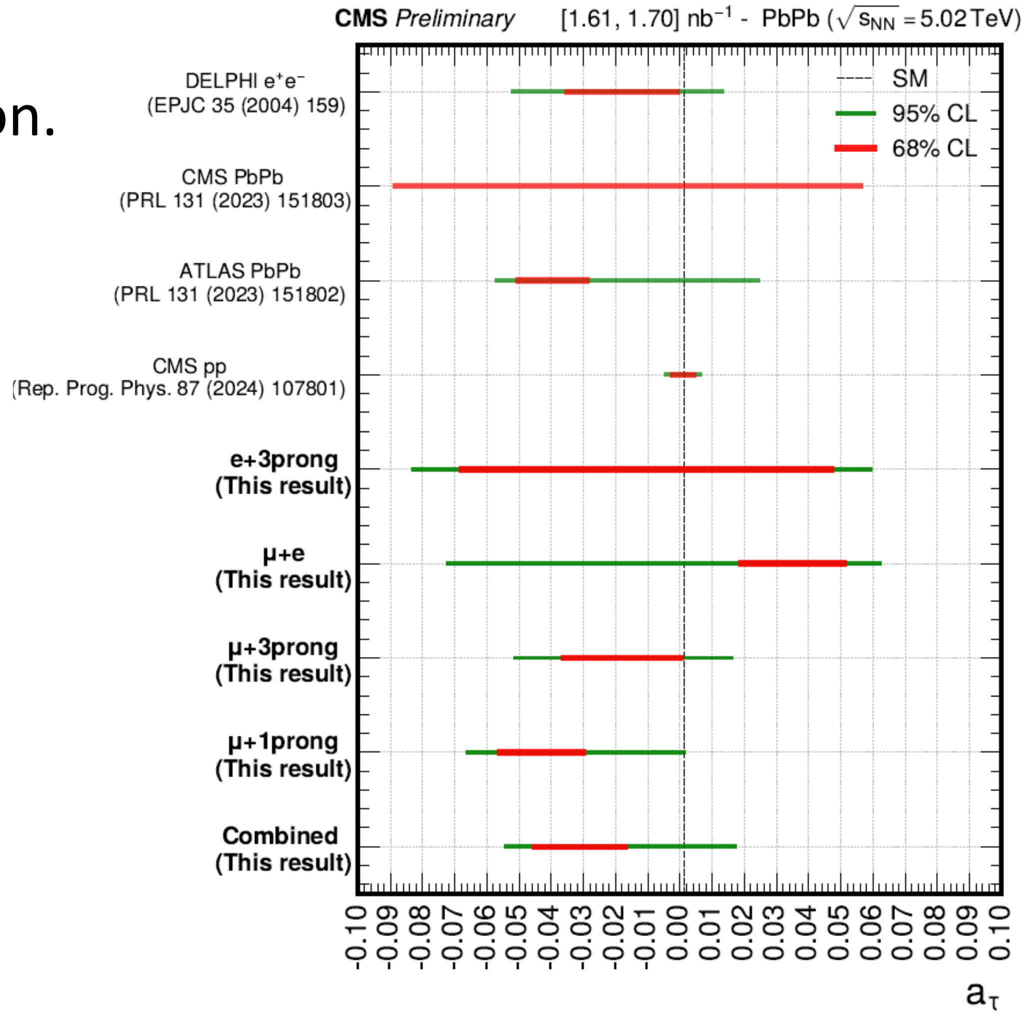

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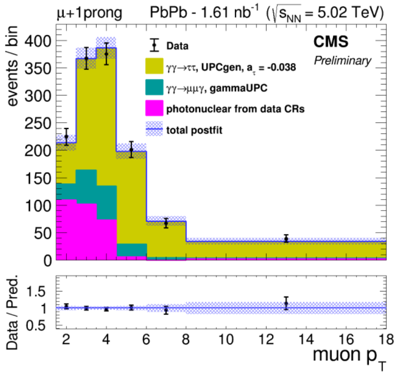

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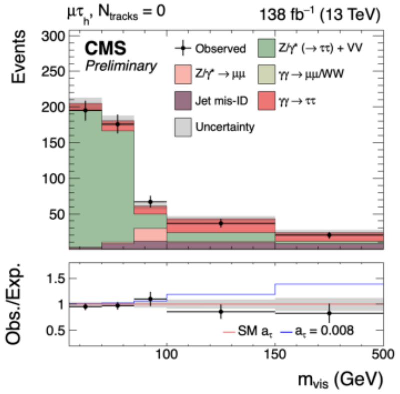

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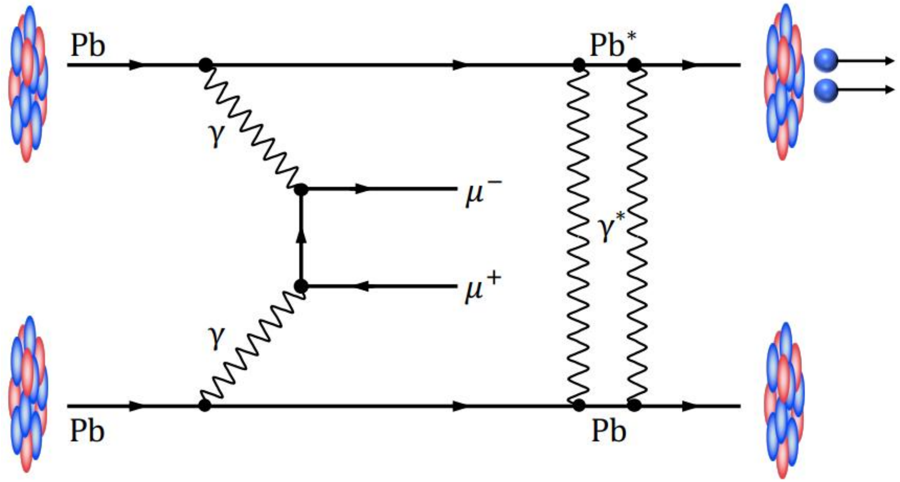
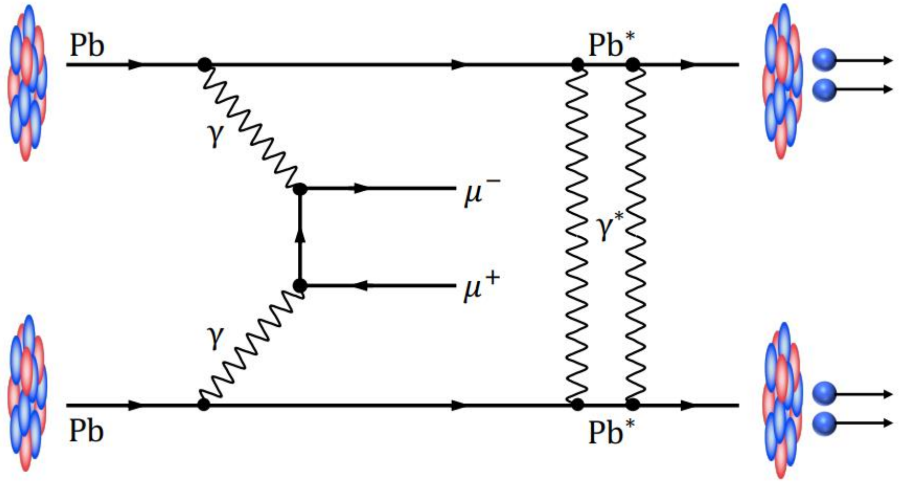
Backup

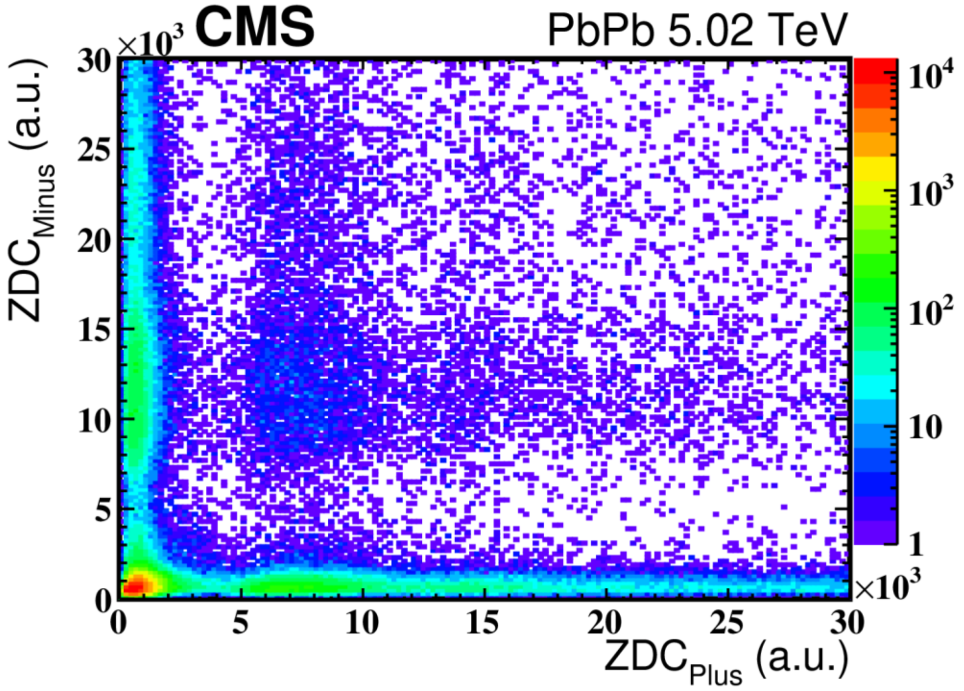
Neutron multiplicity with ZDC

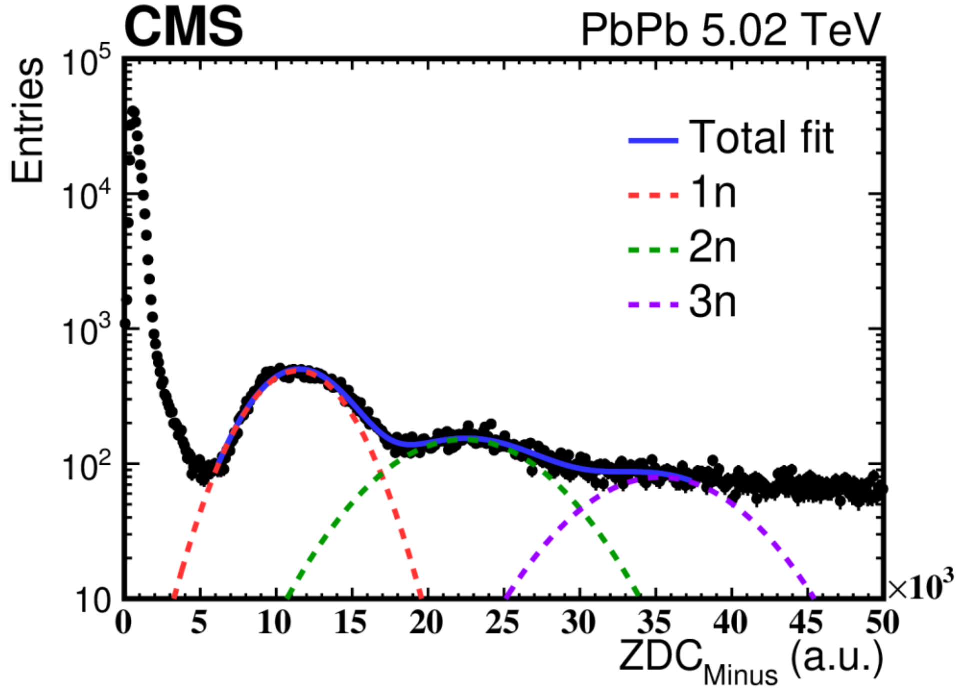


Xn (>1 neutron)

0n







CMS-HIN-19-014