

# Exclusive di-photon final states in pp collisions:

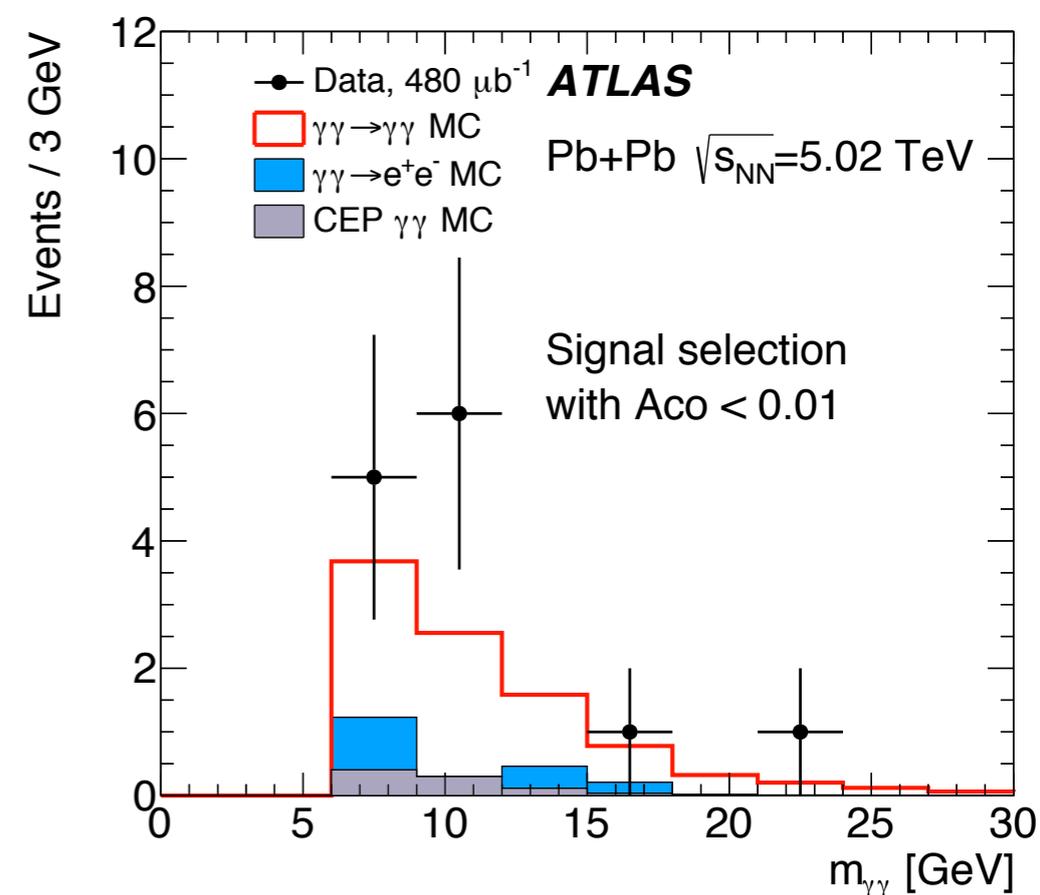
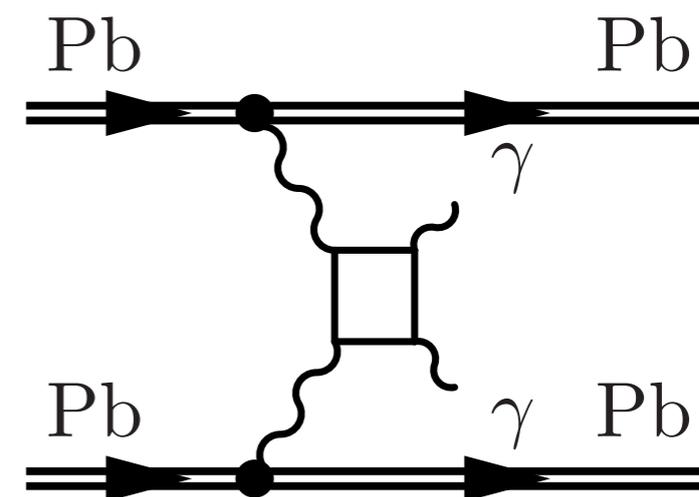
Search for axion like particles  
& light-by-light scattering

**HL/HE-LHC Working Group 1 meeting  
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# Light-by-Light scattering

- **In SM interaction does not exist at LO, mediated via box diagram**
  - Any charged particle can appear in the box
    - precision measurement of cross-section also probes new physics contributions
- **So far only observed in heavy ion collisions**
  - ATLAS result: [arxiv:1702.01625](https://arxiv.org/abs/1702.01625)
- **Fundamentally interesting to also observe it in pp!**
  - High statistics is of importance



# Axion-like particles

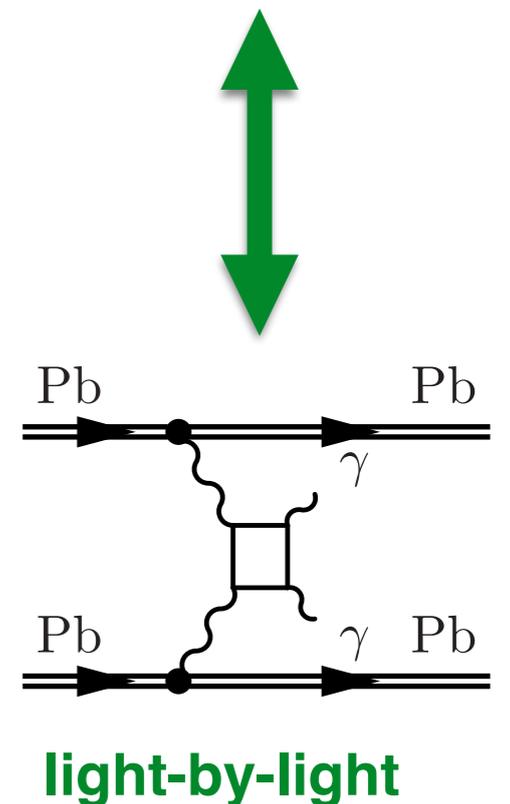
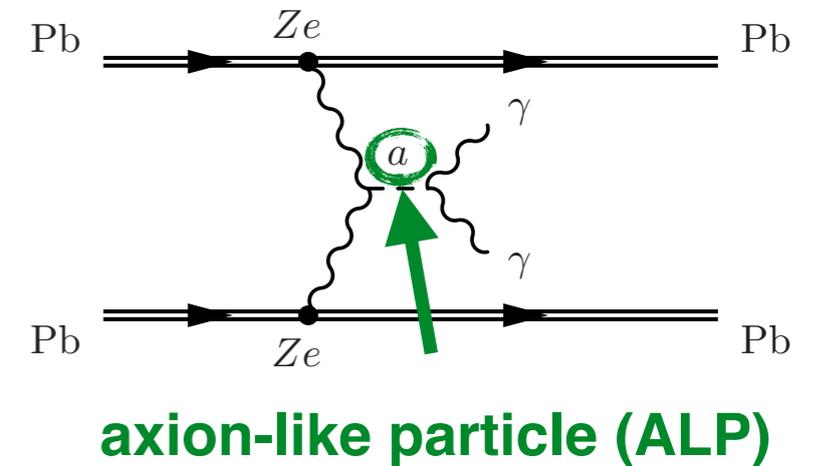
- **“Original” Peccei-Quinn axion must be very light (sub-GeV) → more general: axion-like particle (ALP)**

- (Pseudo-)scalar, not necessarily light, does not have to solve strong CP problem
- Many possible origins for ALPs
  - Pseudo-Nambu-Goldstone bosons of spontaneously broken symmetries
  - Mixing with Higgs sector
  - Messenger to dark matter - could even be dark matter!

- **Must couple to photons**

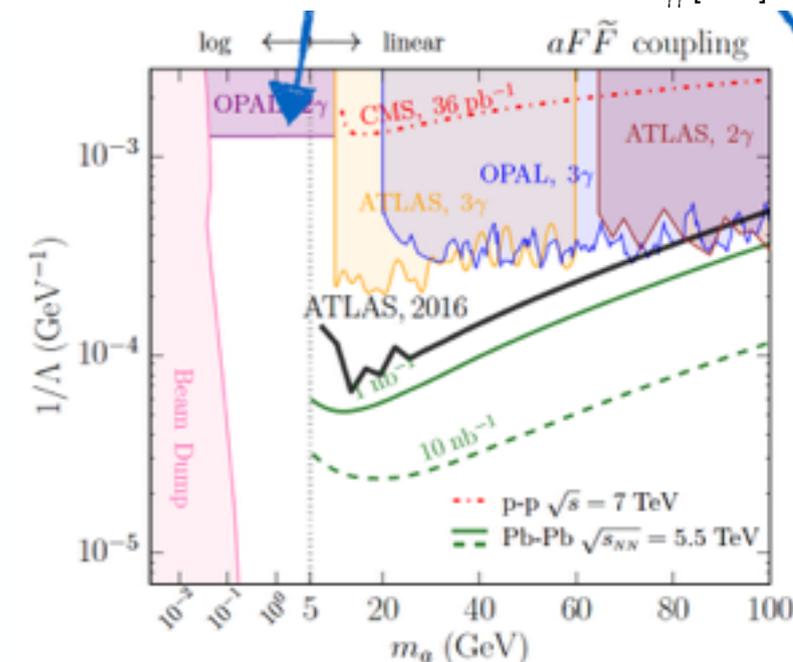
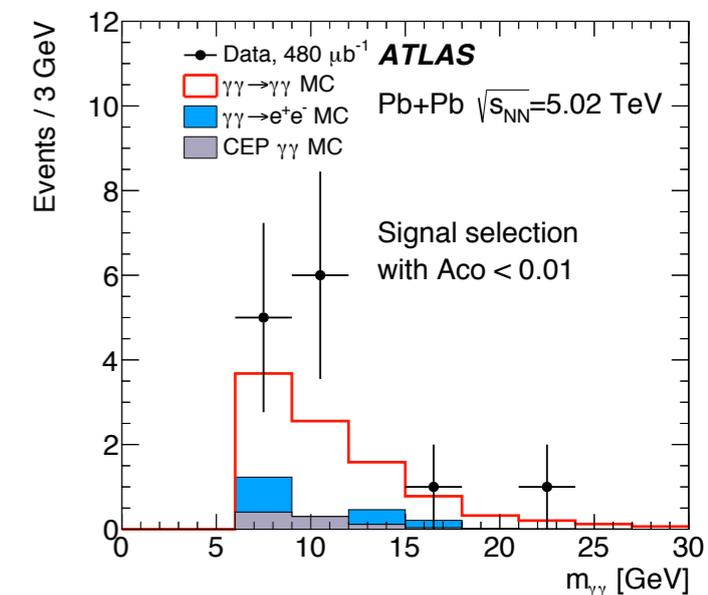
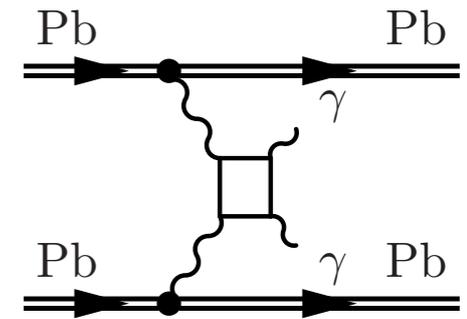
→ **Focus on di-photon initial and final state**

- May couple to fermions / EWK bosons as well, depending on model details
- **Lots of interest in theory and phenomenology, no dedicated analysis at LHC so far**
  - E.g. arxiv:1607.06083, arxiv:1509.00476, ...



# Exclusive di-photon final state

- Initial-state photons from high electromagnetic field around colliding particles
  - Initial state protons / ions stay intact (HI: “ultra-peripheral collisions”)
- Exclusively 2 photons in final state, no other activity**
- Need to tag forward protons/ions and/or veto all other event activity
  - **Analysis requires no/very low pile-up!**
- Benefit from all available tracking and timing detectors to tag intact protons/ions and to discriminate from pileup
- Go as low as possible in di-photon mass / photon  $E_T$** 
  - Challenging for reconstruction, ID, ...
- Backgrounds**
  - CEP ( $gg \rightarrow \text{gamma gamma}$ )
  - Mis-identified electrons



# Using pp or Pb-Pb collisions?

- **Photon flux scales with  $Z^4$**   
→ **huge gain for PbPb ( $45e^6$  compared to pp)**
- But: photons from pp more energetic
  - change in production xsec, advantage for heavier ALP resonances
- →  **$500 \mu\text{b}^{-1}$  PbPb (taken in 2015) equivalent to  $\sim 1 \text{fb}^{-1}$  pp**
- **Low- $\mu$  pp:**
  - 2017: collected in total  $300 \text{pb}^{-1}$  @  $\langle\mu\rangle=2$  (5 TeV & 13 TeV)  
+ 25h @  $\langle\mu\rangle = 0.5$
  - 2018:  $\sim 200 \text{pb}^{-1}$  low  $\mu$  run scheduled
- → **Worth looking also at pp data as well as pPb!**

# HE/HL-LHC

- **Both HE-LHC and HL-LHC might be interesting**
  - Main question: is such an analysis at all feasible with significant pileup?
- **Exploiting detector upgrade for pile-up suppression**
  - Pileup suppression using HGTD (high granularity timing detector)
  - Use converted photons for vertexing → profit from ITK
- **If approach works: significant improvement of light-by-light cross section precision, improvement of ALP limits**
- Small, challenging analysis project
  - Using ATLAS for low  $E_T$  photon physics, not exactly what it was made for...
- ALPs are active field in Theory / Phenomenology!
  - Could have a significant impact! Complementary to results from  $Z+\gamma$  like analyses (larger ALP masses) and other experiments like NA62 (lower ALP masses)
- Study in initial stage, person power 2x30% FTE → more contributors welcome!
  - Next: need MC with moderate and high pile up to check sensitivity to light-by-light