gammaUPC4LHC

Improving Monte Carlo modeling of photon-induced processes in ultraperipheral collisions at the LHC

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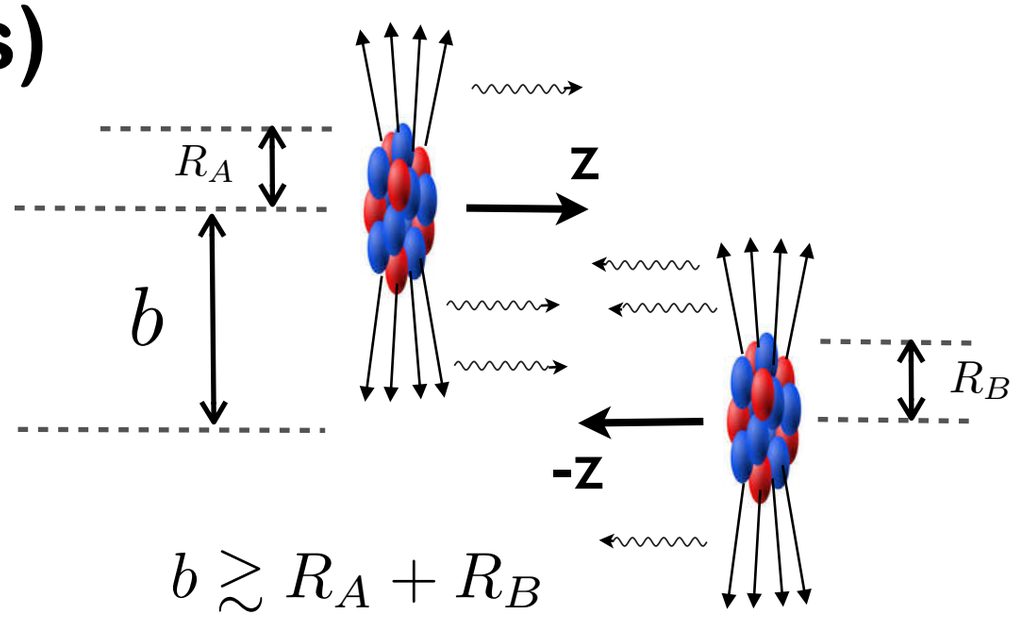
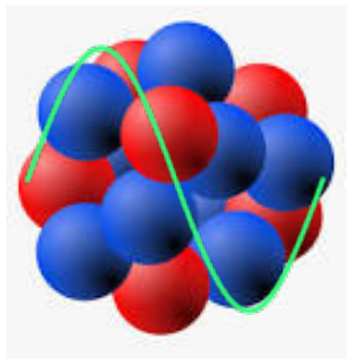
Ultraperipheral Collisions

- **Ultra-Peripheral Collisions (UPCs)**
- **Large photon flux** $\propto Z^2$
- **Cross section enhanced by** Z^4

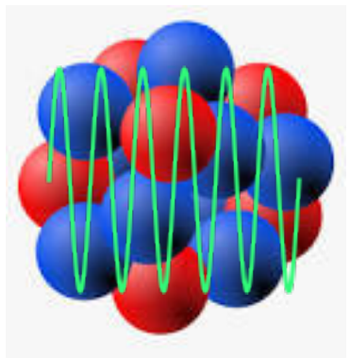
E.g., PbPb is Z^4 = 45M times larger than pp & e+e-



- **Photon may interact either coherently or incoherently**



vs



$\lambda \gtrsim R_A$

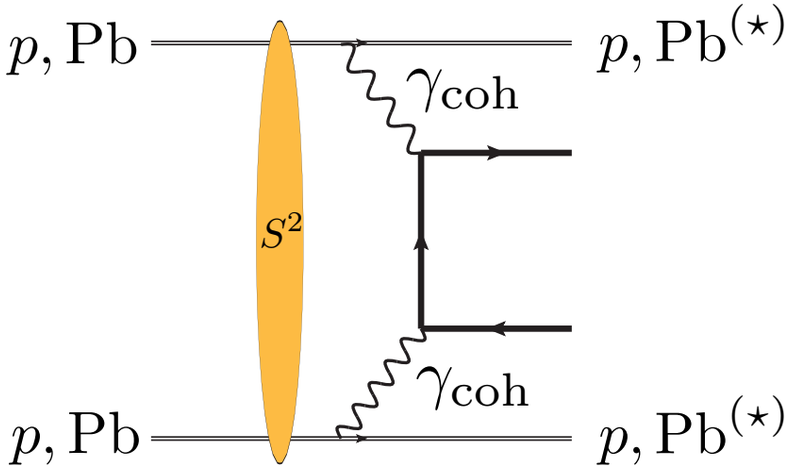
Coherent

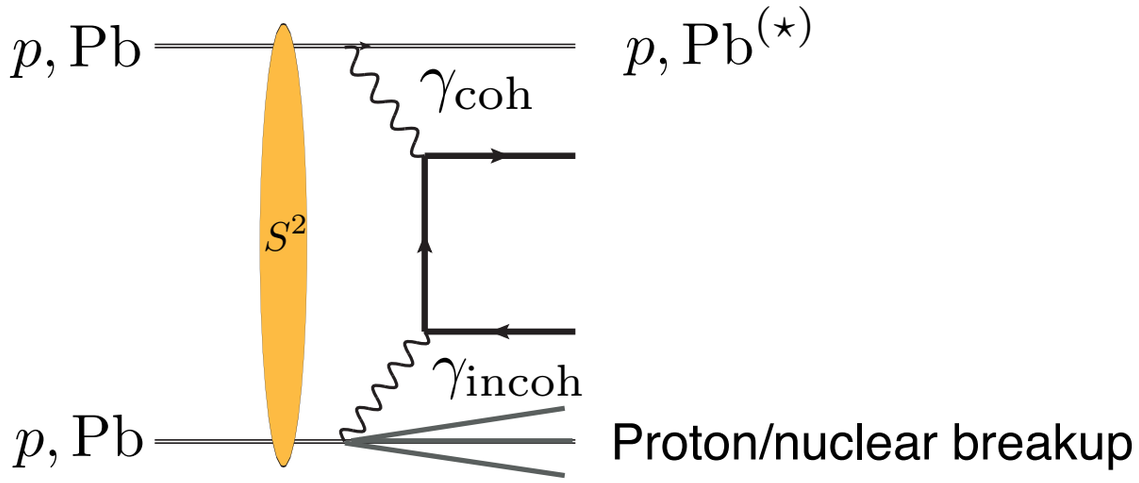
$\lambda < R_A$

Incoherent

Ultraperipheral Collisions

- **Photon-photon processes**

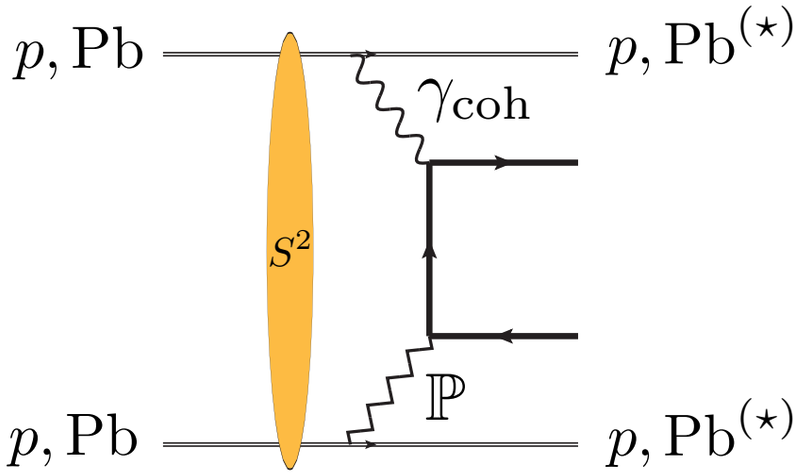


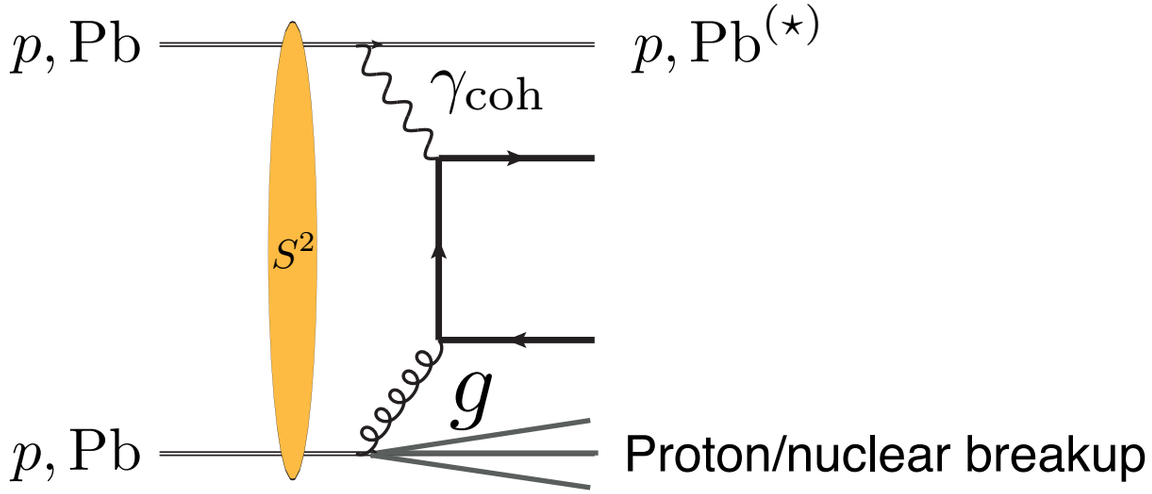


- Motivations: SM tests, BSM searches, photon fluxes …

  E.g., tau g-2, axion-like particles, anomalous quartic gauge couplings

- **Photon-hadron processes**





- Motivations: GPD, (proton/nuclear) PDF …

Research Objectives

- **Improving Monte Carlo Modeling of these processes**

- **gamma-UPC:** https://hshao.web.cern.ch/hshao/gammaupc.html

  - The first and currently the only public code for simulating arbitrary final states in coherent photon-photon collisions

  - Leading order and next-to-leading order QCD and electroweak accuracy of elementary final-state particles using gamma-UPC together with MadGraph5_aMC@NLO in collinear factorization

  - Leading order accuracy of elementary particles+quarkonia using gamma-UPC together with HELAC-Onia in collinear factorization

- **We aim to go beyond the state of the art**

Research Objectives

- **Five main research axes:**

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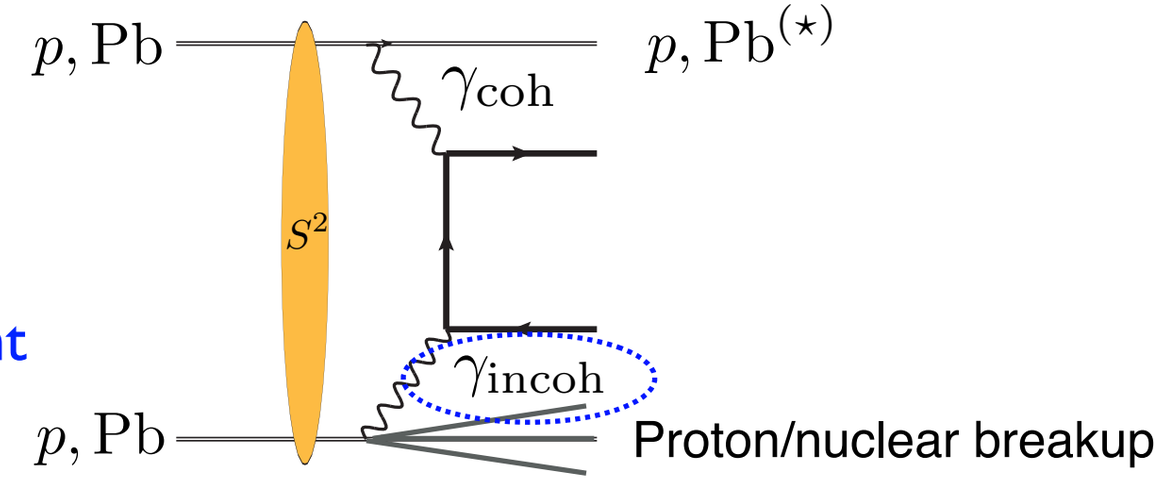
  - 1) Incoherent photon-induced UPC processes
    - Important backgrounds

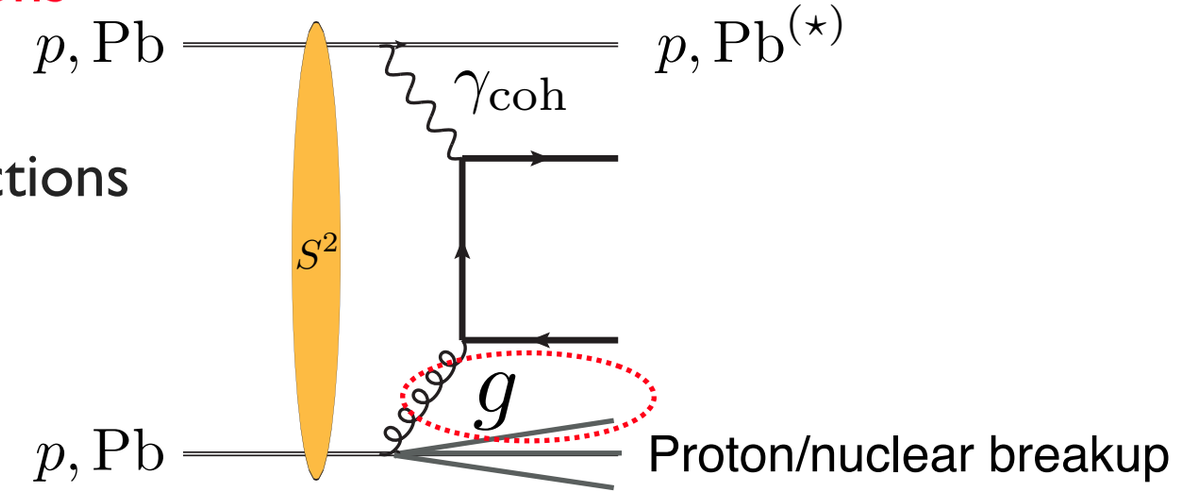
      E.g., tau g-2 in pp UPC

    - Knowledge of impact-parameter-dependent incoherent photon fluxes



Research Objectives

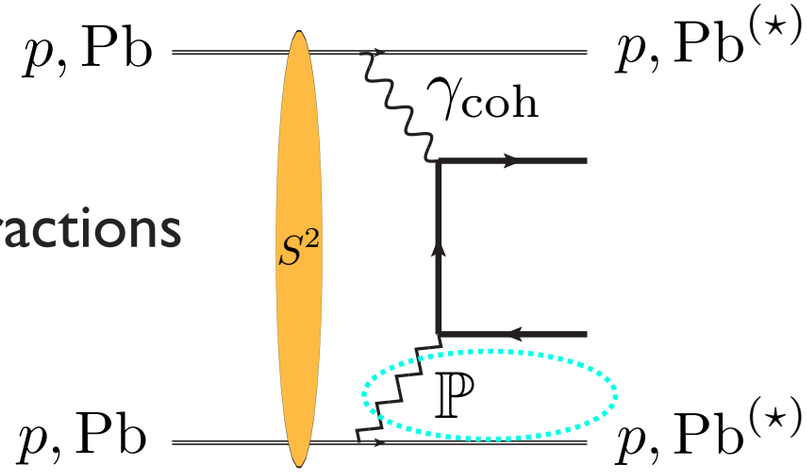
- **Five main research axes:**
  - 1) Incoherent photon-induced UPC processes
  - 2) Inclusive UPC photoproduction processes
    - New probes of parton-distribution functions
    - Complementary (x,Q^2) w.r.t inclusive reactions
      E.g., dijet and open charm in PbPb UPC



Research Objectives

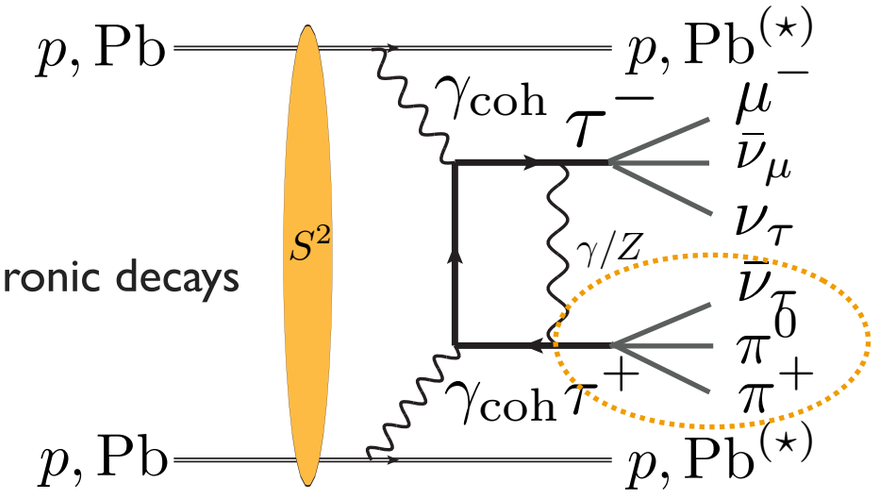
- **Five main research axes:**
  - 1) Incoherent photon-induced UPC processes
  - 2) Inclusive UPC photoproduction processes
  - 3) Automated coherent photoproduction processes with GPDs

- Probing generalized parton distributions
- Main challenge: threshold-singularity subtractions



Research Objectives

- **Five main research axes:**
  - 1) Incoherent photon-induced UPC processes
  - 2) Inclusive UPC photoproduction processes
  - 3) Automated coherent photoproduction processes with GPDs
  - 4) Spin-entangled tau hadronic decay with NLO EW corrections
    - Tau g-2 in the SM is part of NLO EW corrections
    - To enable tau spin-entangled hadronic decay at NLO EW
    - To add consistently spin correlations including NLO EW and tau hadronic decays



Research Objectives

- **Five main research axes:**
  - 1) Incoherent photon-induced UPC processes
  - 2) Inclusive UPC photoproduction processes
  - 3) Automated coherent photoproduction processes with GPDs
  - 4) Spin-entangled tau hadronic decay with NLO EW corrections
  - 5) Extension beyond collinear factorization
    - Coherent photons in UPCs are linearly polarized
    - TMD factorization allows to study TMD-sensitive observables, such as azimuthal angle modulations
    - Also probing (coherent) photon GTMD

Research Objectives

- **Five main research axes:**
  - 1) Incoherent photon-induced UPC processes
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  - 5) Extension beyond collinear factorization

This proposal develops tools to support experimental measurements at CERN LHC and has potential connections to the VAs NLOAccess, GPDPortal, TMDPortal

Research Team & Funding Request

Team members :

- Hua-Sheng Shao (leader, LPTHE Paris, CNRS)
- David d'Enterria (CERN)
- A 2-year postdoc hired by CNRS based at LPTHE in Paris

The postdoc will develop a fraction of the 5 research axes mentioned before

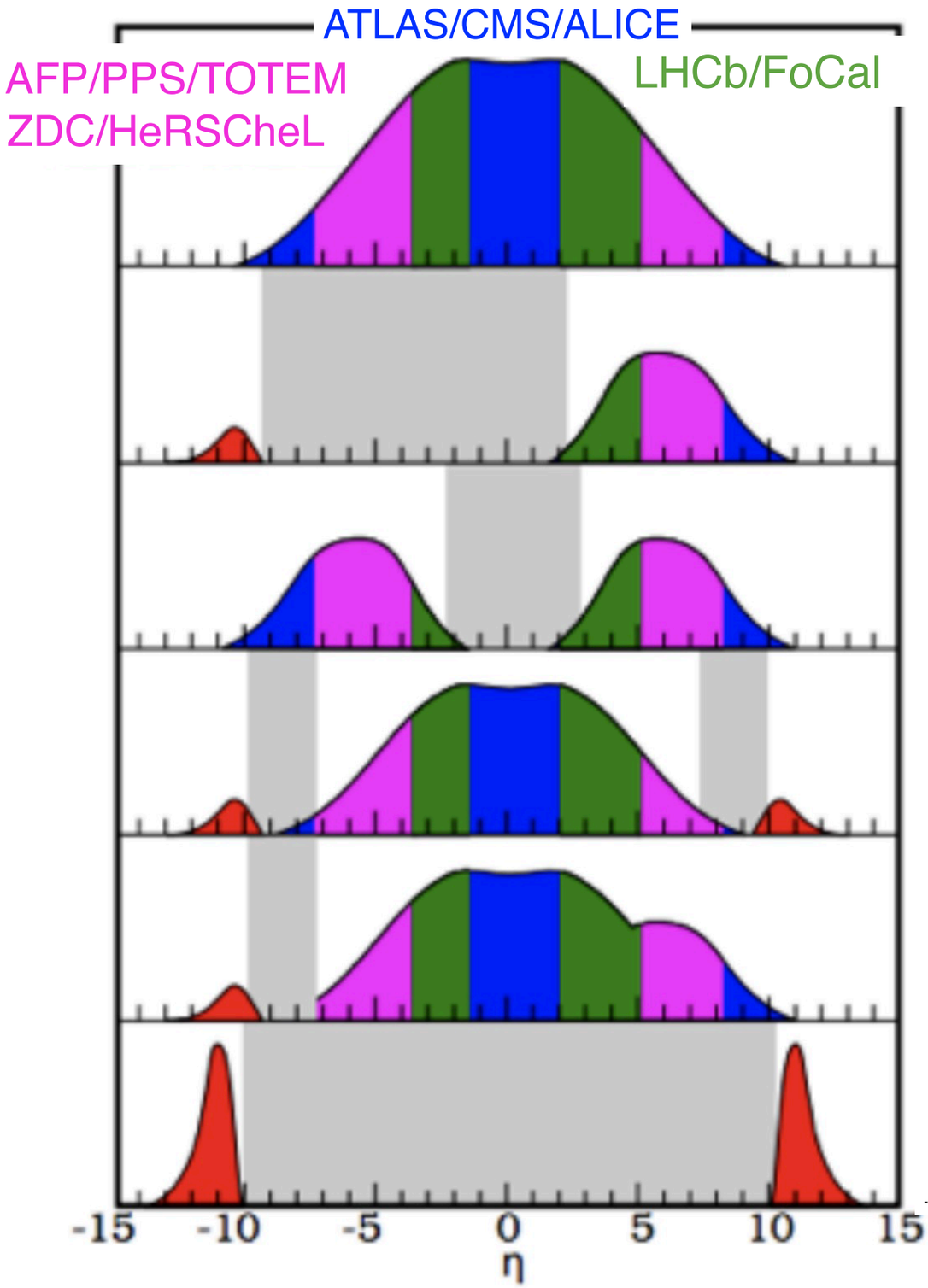
Funding request :

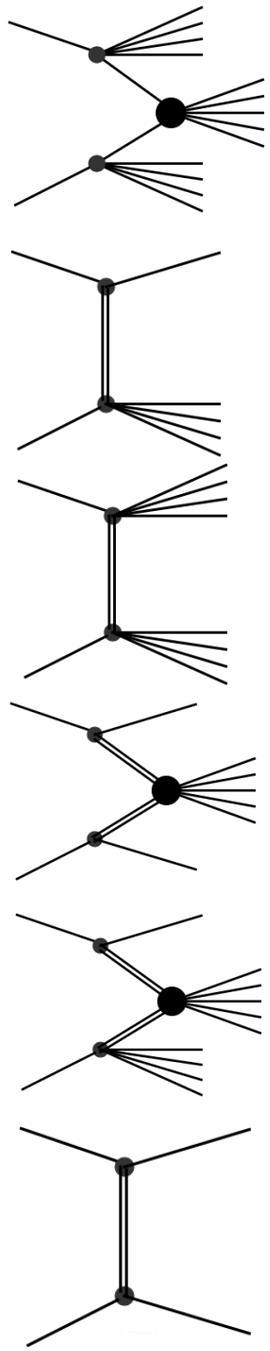
- 2-year CNRS postdoc contract (165k Euros, w/ 25% overhead)
- Travel budget (30k Euros, including visits to CERN)
- Total budget: 195k Euros

Backup Slides

Introduction

- **Scattering processes at the LHC: rapidity coverage**





Inelastic $\sigma^{pp}_{\rm inel} \sim 70$ mb

Single diffraction $\sigma^{pp}_{\rm sd} \sim 10$ mb

Double diffraction

CEP+UPC elastic $\sigma^{pp}_{\rm CEP} \sim 100$ μb

CEP+UPC inelastic

Elastic $\sigma^{pp}_{\rm el} \sim 30$ mb

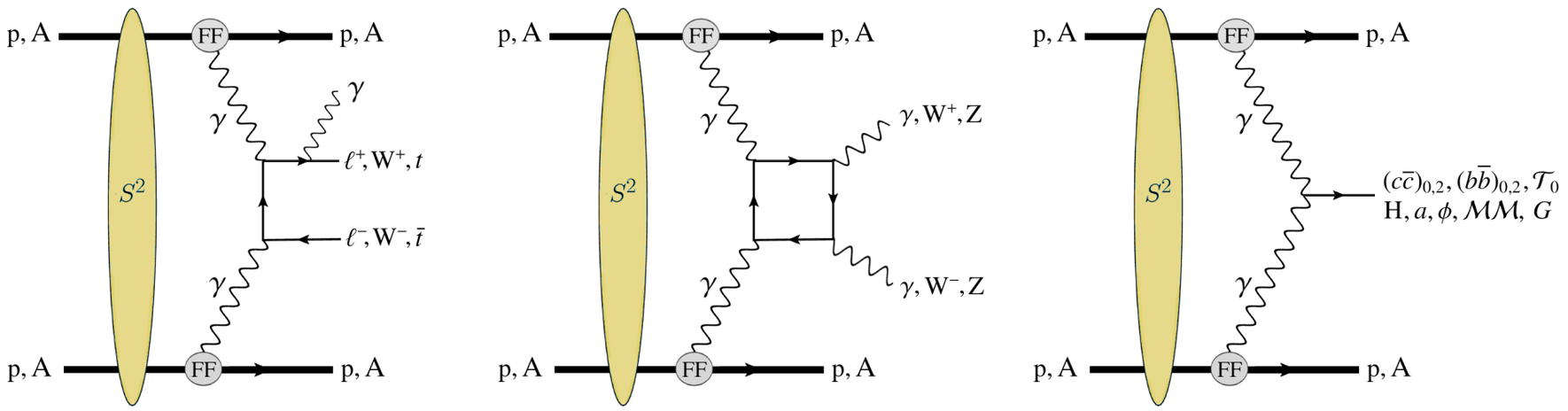
Two-Photon Processes

- **Gold-plated SM and BSM processes**

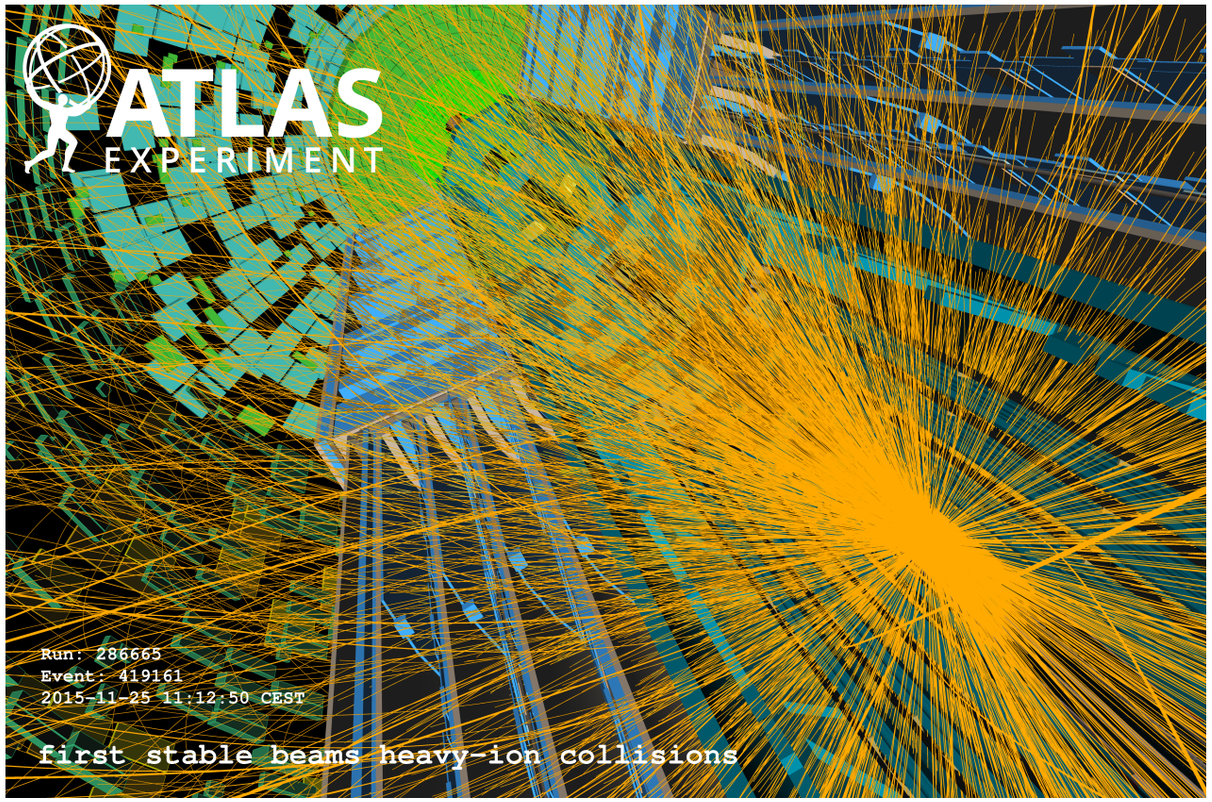
Loop-induced in the SM !

Process	Physics motivation
$\gamma\gamma \to e^+e^-, \mu^+\mu^-$	"Standard candles" for proton/nucleus γ fluxes, EPA calculations, and higher-order QED corrections
$\gamma\gamma \to \tau^+\tau^-$	Anomalous τ lepton e.m. moments [29–32]
$\gamma\gamma \to \gamma\gamma$	aQGC [25], ALPs [27], BI QED [28], noncommut. interactions [36], extra dims. [37],...
$\gamma\gamma \to \mathcal{T}_0$	Ditauonium properties (heaviest QED bound state) [38, 39]
$\gamma\gamma \to (c\bar{c})_{0,2}, (b\bar{b})_{0,2}$	Properties of scalar and tensor charmonia and bottomonia [40, 41]
$\gamma\gamma \to$ XYZ	Properties of spin-even XYZ heavy-quark exotic states [42]
$\gamma\gamma \to$ VM VM	(with VM = ρ, ω, ϕ, J/ψ, Υ): BFKL-Pomeron dynamics [43–46]
$\gamma\gamma \to$ W$^+$W$^-$, ZZ, Zγ, $\cdots$	anomalous quartic gauge couplings [11, 26, 47, 48]
$\gamma\gamma \to$ H	Higgs-γ coupling, total H width [49, 50]
$\gamma\gamma \to$ HH	Higgs potential [51], quartic $\gamma\gamma$HH coupling
$\gamma\gamma \to t\bar{t}$	anomalous top-quark e.m. couplings [11, 49]
$\gamma\gamma \to \tilde{\ell}\tilde{\ell}, \tilde{\chi}^+\tilde{\chi}^-$, H^{++}H^{--}	SUSY pairs: slepton [11, 52, 53], chargino [11, 54], doubly-charged Higgs bosons [11, 55].
$\gamma\gamma \to a, \phi, \mathcal{MM}, G$	ALPs [27, 56], radions [57], monopoles [58–61], gravitons [62–64],...

HSS d'Enterria (JHEP'22)



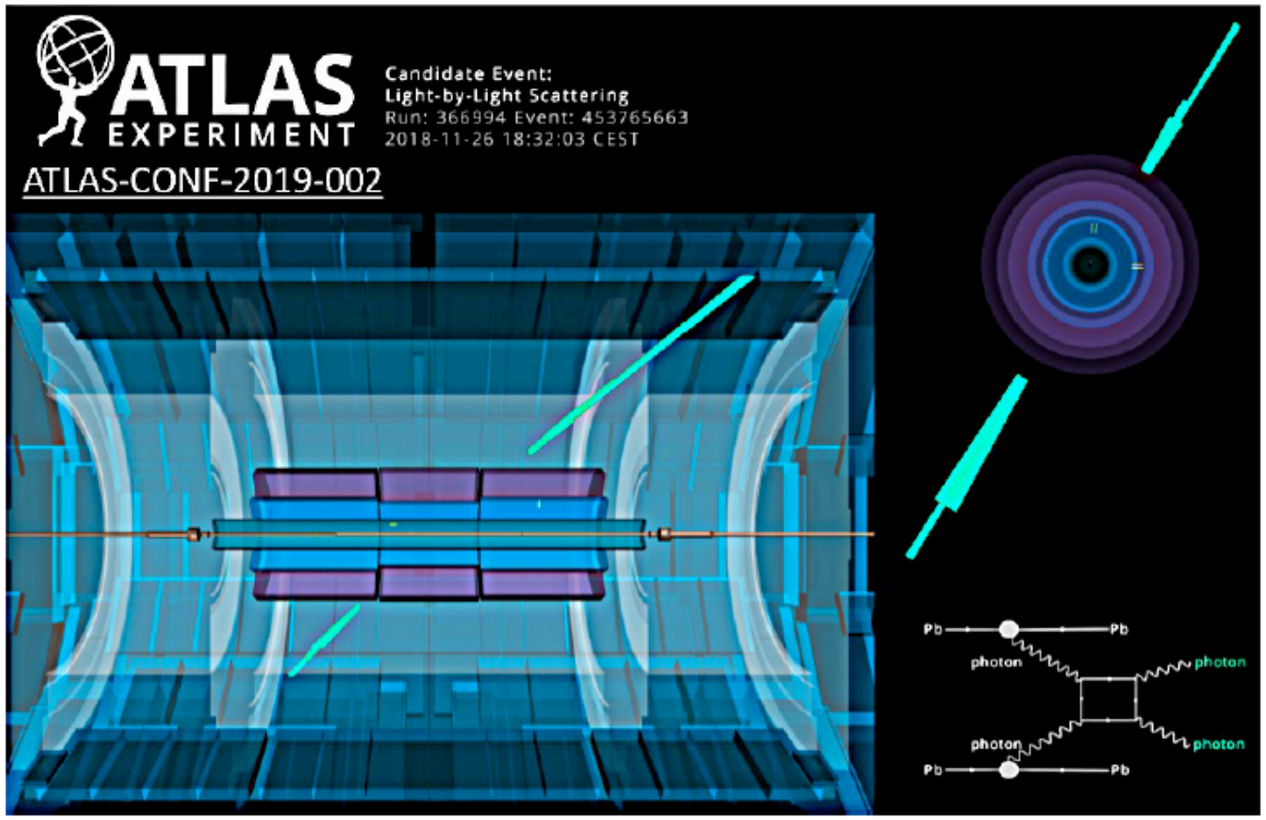
How do events look like ?

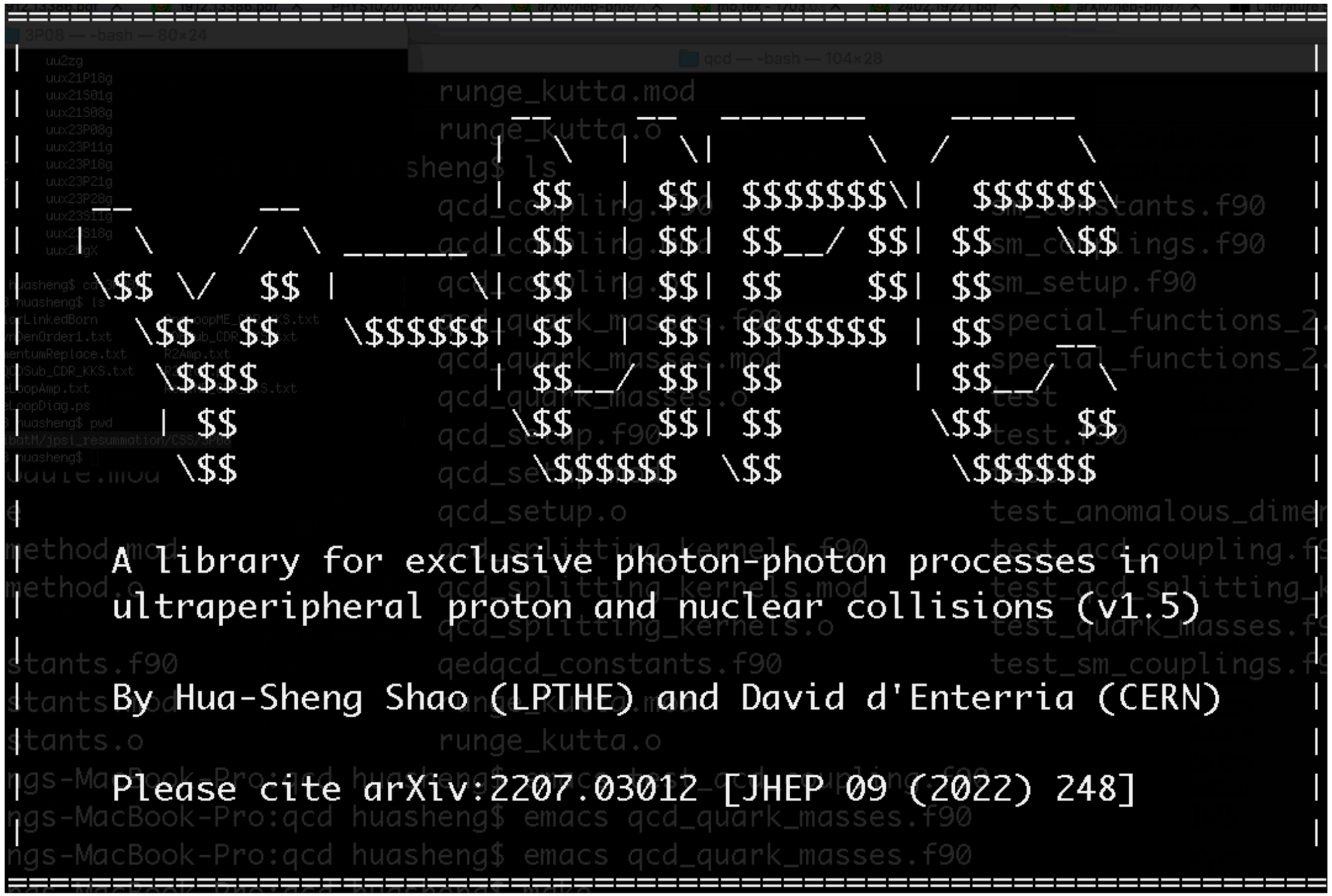


Most collisions have enormous multiplicities.

VS

UPC: low multiplicities





https://hshao.web.cern.ch/hshao/gammaupc.html