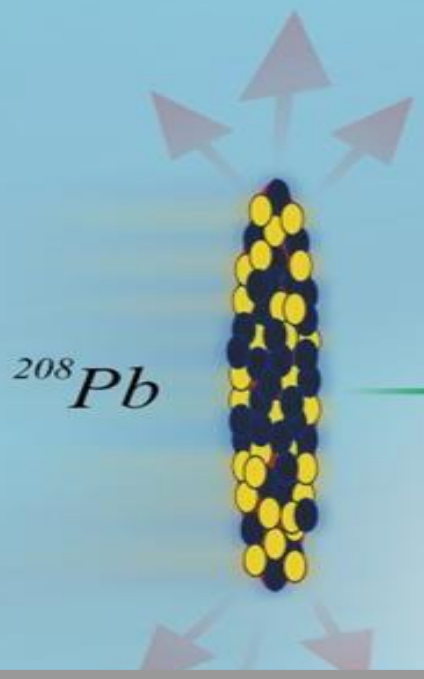
TITLE: Light-by-light scattering at low diphoton energies from ultraperipheral heavy-ion collisions at the LHC

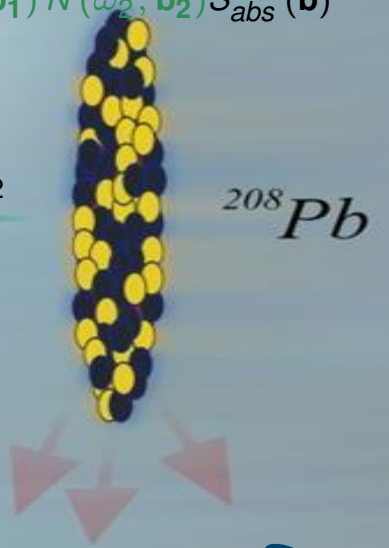


- ✓ M. K-G, P. Lebiedowicz and A. Szczurek, *Phys. Rev.* ***C93*** *(2016) 044907*, *Light-by-light scattering in ultraperipheral Pb-Pb collisions at energies available at the CERN Large Hadron Collider*;
- ✓ M. K-G, W. Schäfer and A. Szczurek, *Phys. Lett.* ***B761*** *(2016) 399*, *Two-gluon exchange contribution to elastic $\gamma\gamma \to \gamma\gamma$ scattering and production of two-photons in ultraperipheral ultrarelativistic heavy-ion and proton-proton collisions*;
- ✓ M. K-G, R. McNulty, R. Schicker and A. Szczurek, *Phys. Rev.* ***D99*** *(2019) 9, 093013*, *Light-by-light scattering in ultraperipheral heavy-ion collisions at low diphoton masses*
- ✓ Z. Citron, M. K-G et al., *CERN Yellow Rep. Monogr.* ***7*** *(2019) 1159-1410*, *Future physics opportunities for high-density QCD at the LHC with heavy-ion and proton beams*, Report from Working Group 5 on the Physics of the HL-LHC, and Perspectives at the HE-LHC.

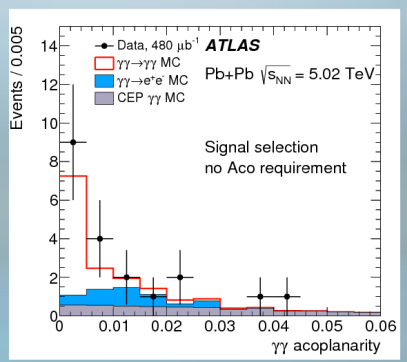
ULTRAPERIPHERAL COLLISIONS

$b > R_{min} = R_1 + R_2 \approx 14$ fm

$$\sigma_{A_1 A_2 \to A_1 A_2 X_1 X_2} = \int N(\omega_1, \mathbf{b_1})\, N(\omega_2, \mathbf{b_2})\, S^2_{abs}(\mathbf{b}) \times \sigma_{\gamma\gamma \to X_1 X_2}(W_{\gamma\gamma}) \times 2\pi b\,\mathrm{d}b\,\mathrm{d}\bar{b}_x\,\mathrm{d}\bar{b}_y \frac{W_{\gamma\gamma}}{2}\,\mathrm{d}W_{\gamma\gamma}\,\mathrm{d}Y_{X_1 X_2}$$

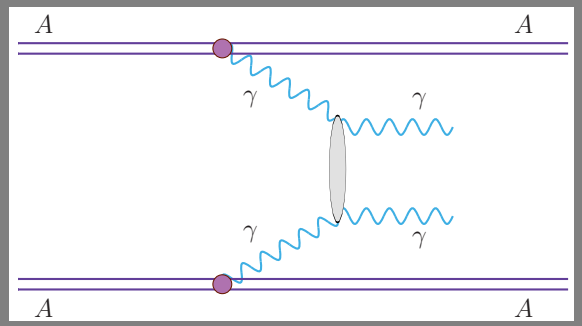


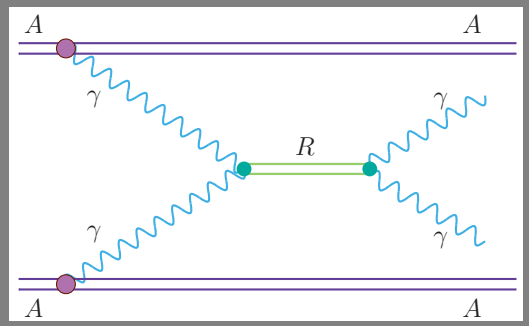
1. **Equivalent Photon Approximation**
2. **Light-by-light scattering**
   - **Elementary cross section**
     - **Fermionic boxes**
     - **Resonances**
     - **Pionic background**
   - **Nuclear cross section**

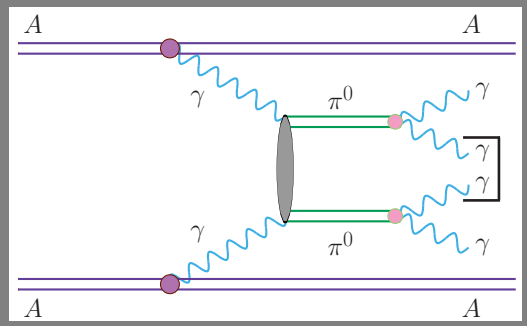


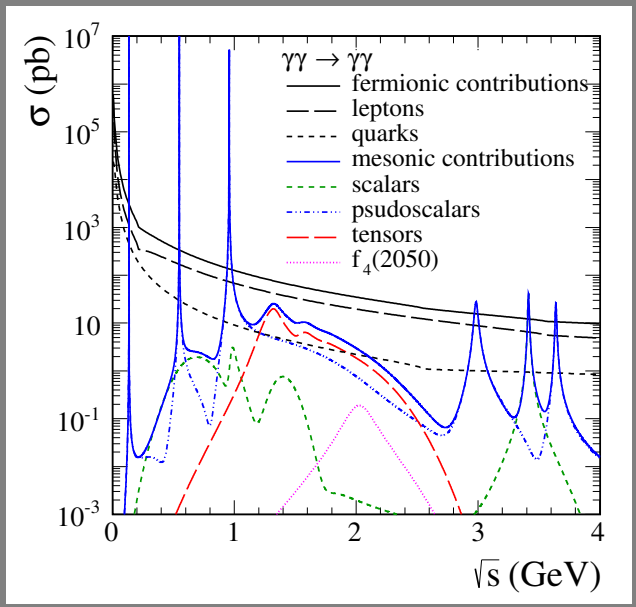
AA→AAγγ FOR $M_{\gamma\gamma} < 5$ GEV ?

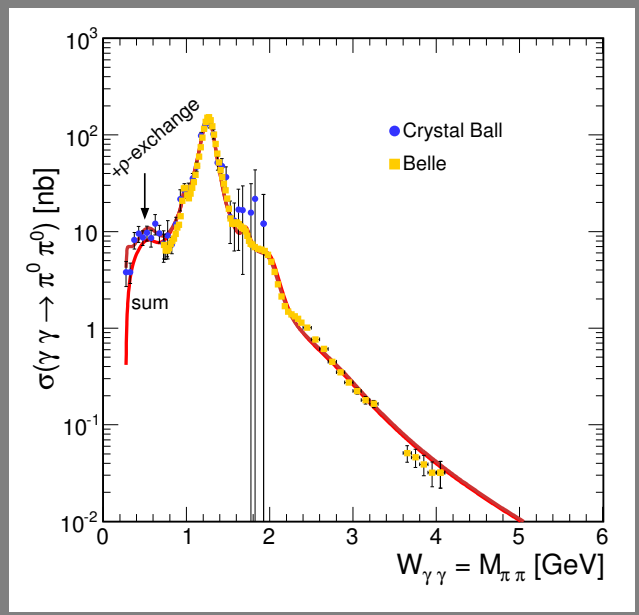
CONTINUUM **RESONANCES** **BACKGROUND**











- P. Lebiedowicz, A. Szczurek, *Phys. Lett.* ***B772*** *(2017) 330*, The role of meson exchanges in light-by-light scattering
- M. K-G, A. Szczurek, *Phys. Rev.* ***C87*** *(2013) 054908*; $\pi^+\pi^-$ and $\pi^0\pi^0$ pair production in photon-photon and in ultraperipheral ultrarelativistic heavy-ion collisions

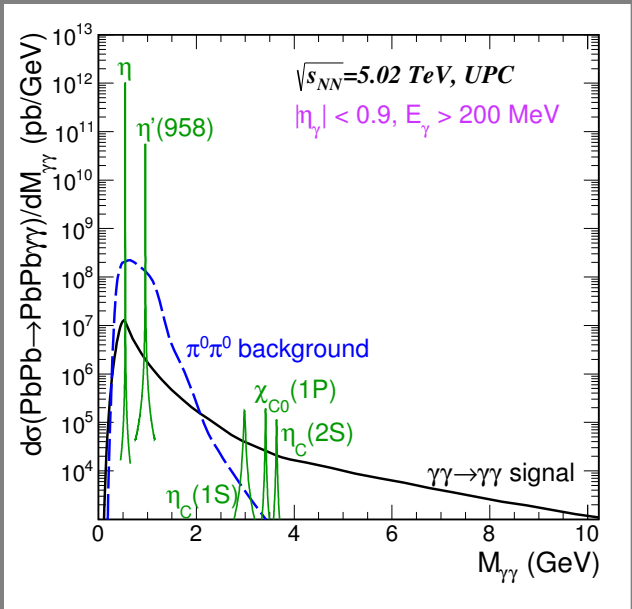
THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

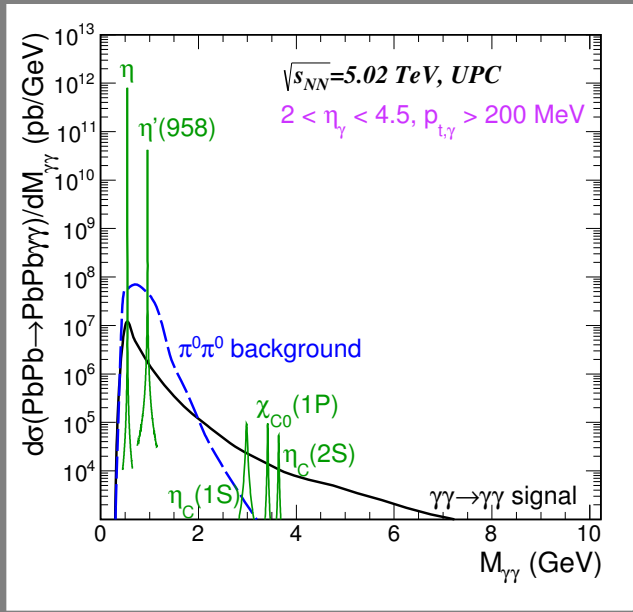
UPC OF AA...

ALICE cuts

- ✔ boxes
- ✔ bkg
- ✔ mesons

LHCb cuts



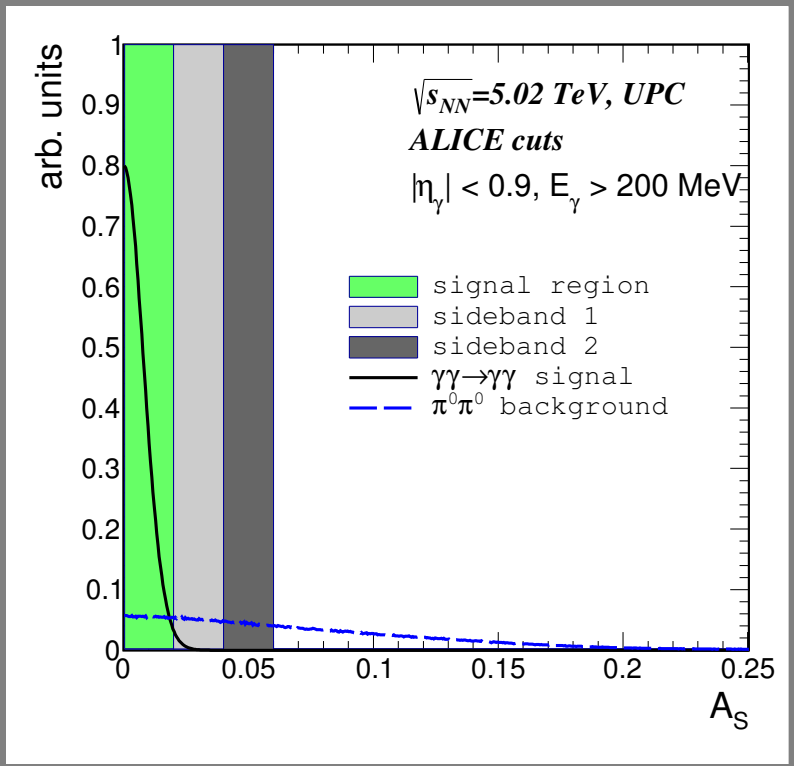


Total nuclear cross section [nb]				
Energy	$W_{\gamma\gamma} = (0-2)$ GeV		$W_{\gamma\gamma} > 2$ GeV	
Fiducial region	ALICE	LHCb	ALICE	LHCb
Boxes	4 890	3 818	146	79
$\pi^0\pi^0$ bkg	135 300	40 866	46	24
η	722 573	568 499		
$\eta'(958)$	54 241	40 482		
$\eta_c(1S)$			9	5
$\chi_{c0}(1P)$			4	2
$\eta_c(2S)$			2	1

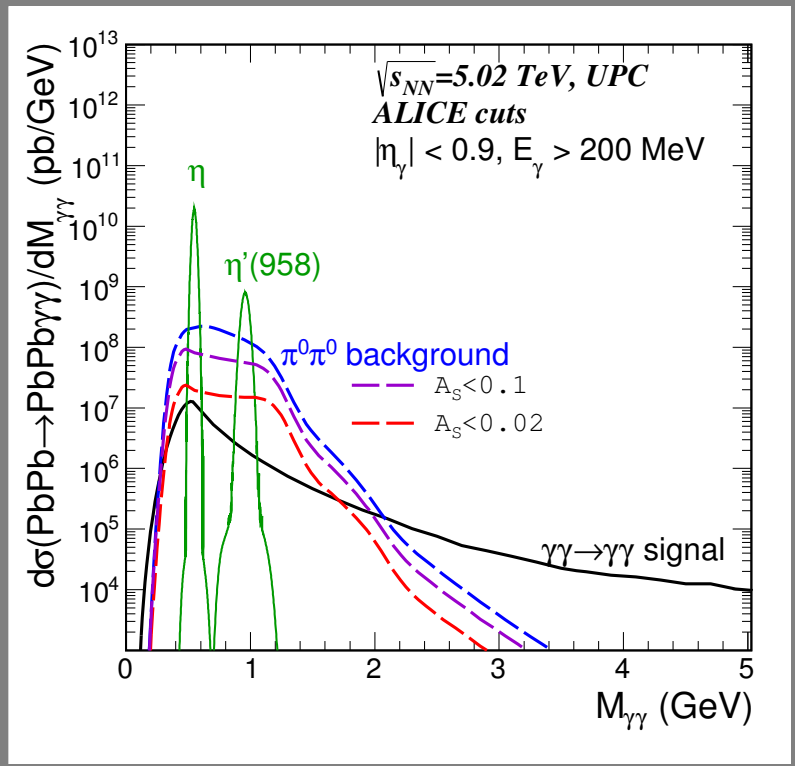
EXPERIMENTAL RESOLUTION & SCALAR ASYMMETRY & "UNWANTED" BKG

$$A_S = \left| \frac{|\vec{p}_T(1)| - |\vec{p}_T(2)|}{|\vec{p}_T(1)| + |\vec{p}_T(2)|} \right|$$

A_S



$M_{\gamma\gamma}$

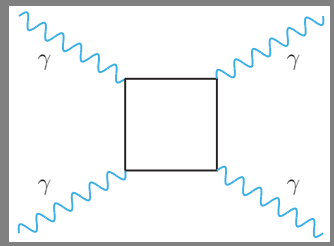


80% of the signal events at $A_S < 0.02$

THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

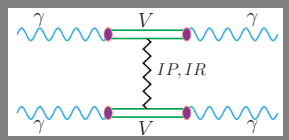
CONCLUSION

- Maxwell classical theory
  - ✓ light doesn't interact with each other
- Quantum theory
  - ✓ interaction of photons through quantum fluctuations

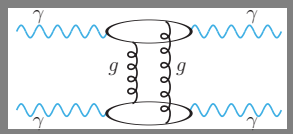


- $\sigma(\gamma\gamma \to \gamma\gamma) \propto \alpha_{em}^4$ → very small
- Photon beams
  - ✗ High-power lasers
    - ➢ K. Homma, K. Matsuura, K. Nakajima, PTEP 2016 (2016) 013C01 *Testing helicity-dependent $\gamma\gamma \to \gamma\gamma$ scattering in the region of MeV*
  - ✔ Ultrarelativistic heavy-ion collision
    - Cross section $\propto Z^4$
    - Quasi-real photons

- UPC of heavy-ion opens a possibility to measure or to test the $\gamma\gamma \to \gamma\gamma$ scattering:
  1. mesons decay ($W_{\gamma\gamma} < 4$ GeV),
  2. pionic background ($W_{\gamma\gamma} < 2$ GeV),
  3. fermionic boxes ($W_{\gamma\gamma} > 2$ GeV),
  4. VDM-Regge ($W_{\gamma\gamma} > 30$ GeV),



  5. 2-gluon exchange ($W_{\gamma\gamma} > 30$ GeV).



- Measurable cross section;
- ATLAS/CMS have observed 13→59→70/14 events confirming LbL scattering in UPC;
- ALICE and LHCb could measure LbyL scattering for $W_{\gamma\gamma} > 2$ GeV in Pb-Pb and Ar-Ar collisions with very good statistic. Run 5: $L_{\text{int}}^{\text{Ar-Ar}} = (3 - 8.8)$ pb → 1460–4280 signal events ;
- Importance of η & η' for $W_{\gamma\gamma} < 2$ GeV.

THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES