D^0 production in UPC Pb-Pb collisions at 5.36 TeV measured in 0nXn events with rapidity gap

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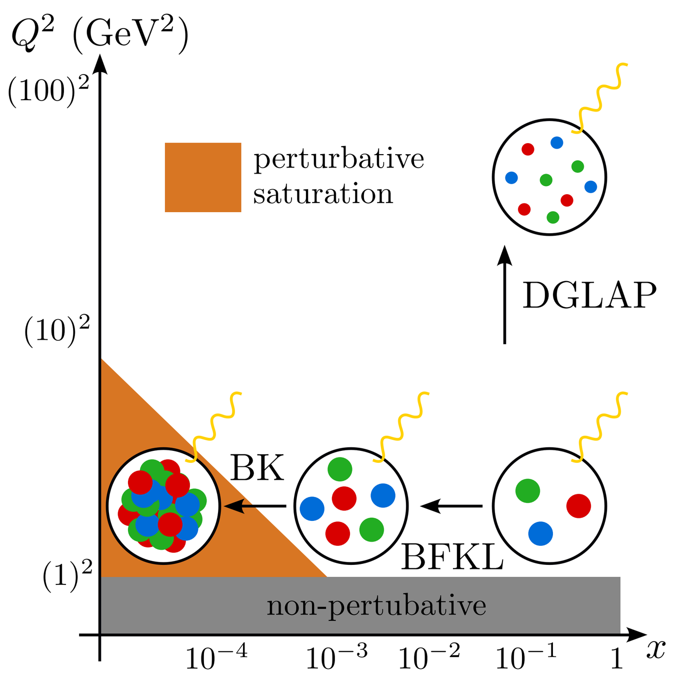
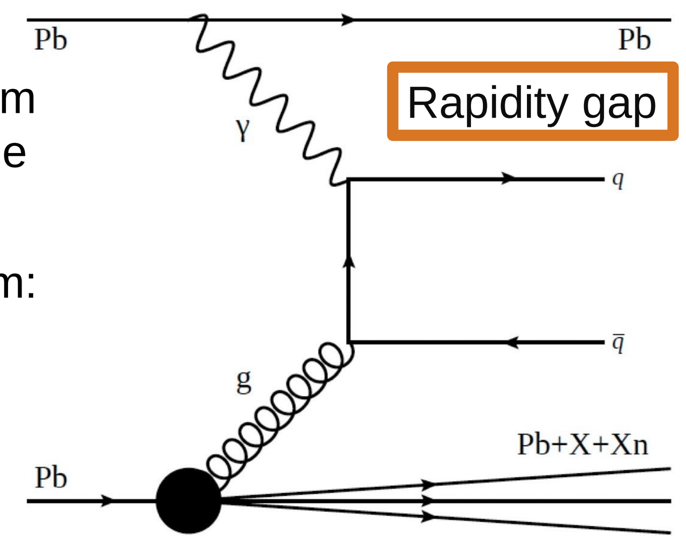
Why do we study charm photoproduction in UPCs?

- They provide constraints on the nuclear parton-distribution functions (nPDFs) of gluons in nuclei down to low x and on the emergence of the saturation regime.
- Ultra-peripheral heavy-ion collisions (UPCs) are characterized by a clean experimental environment, without significant contamination from final-state interactions.
- Open-heavy flavor measurements provide access to a wide region of (x,Q^2) space.
- Since $m_{c,b} > \Lambda_{QCD}$, heavy-flavor measurements can be described by perturbative QCD calculations down to p_T = 0 GeV/c.



How our signal events look like?

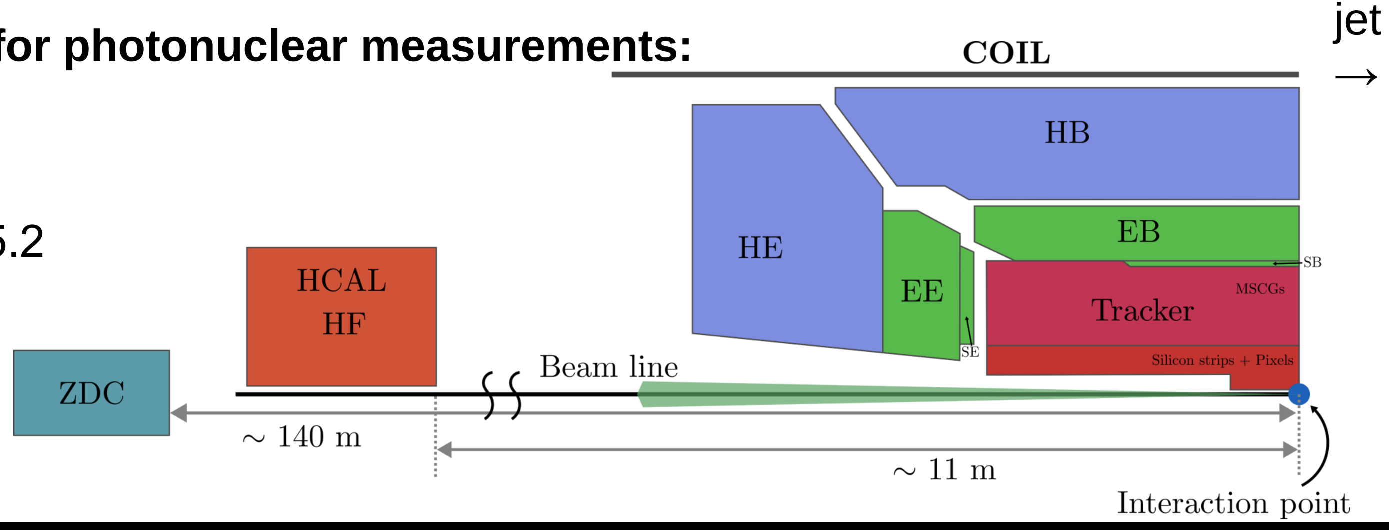
- D^0 mesons can be produced in ultra-peripheral Pb-Pb collisions in scatterings of **quasi-real photons** emitted by one nucleus with **partons** from the other colliding nucleus
- **Leading-order direct process**: a photon from one nucleus scatters directly on a gluon of the other nucleus and creates a $c-\bar{c}$ pair
- The measurement includes contributions from:
  - Direct and resolved-photon mechanisms
  - Prompt (c → D^0) and non-prompt (b → D^0) events
- Decay channel: $D^0 \rightarrow K^-\pi^+$ (and charge conj.)



New Level-1 trigger strategy for photoproduction with CMS:

- The CMS Level-1 (L1) trigger system uses custom hardware processes and fast information from the calorimeters to achieve the first significant data rate reduction
- **Challenge**: Very high rate compared to hadronic events → need for a strong rate reduction and quick decision to maximise the collected statistics

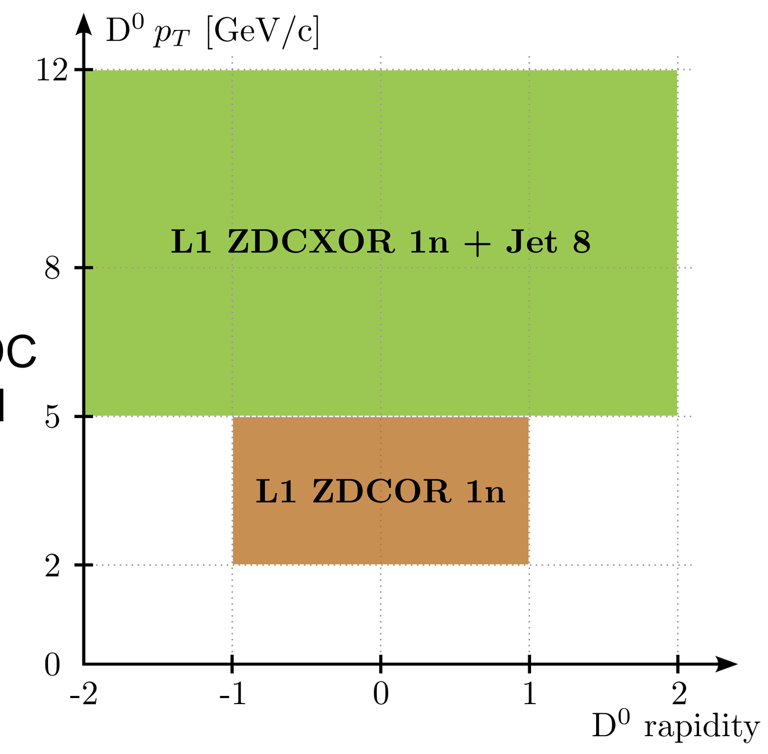
  → **Solution**: Level-1 trigger that uses both ZDC and HCAL/ECAL information
- **CMS has a unique coverage for photonuclear measurements:**
  - Tracker: |η| < 2.4
  - ECAL and HCAL: |η| < 3.0
  - HF calorimeter: 3.0 < |η| < 5.2
  - ZDC: |η| > 8.3



Kinematic coverage and trigger choice:

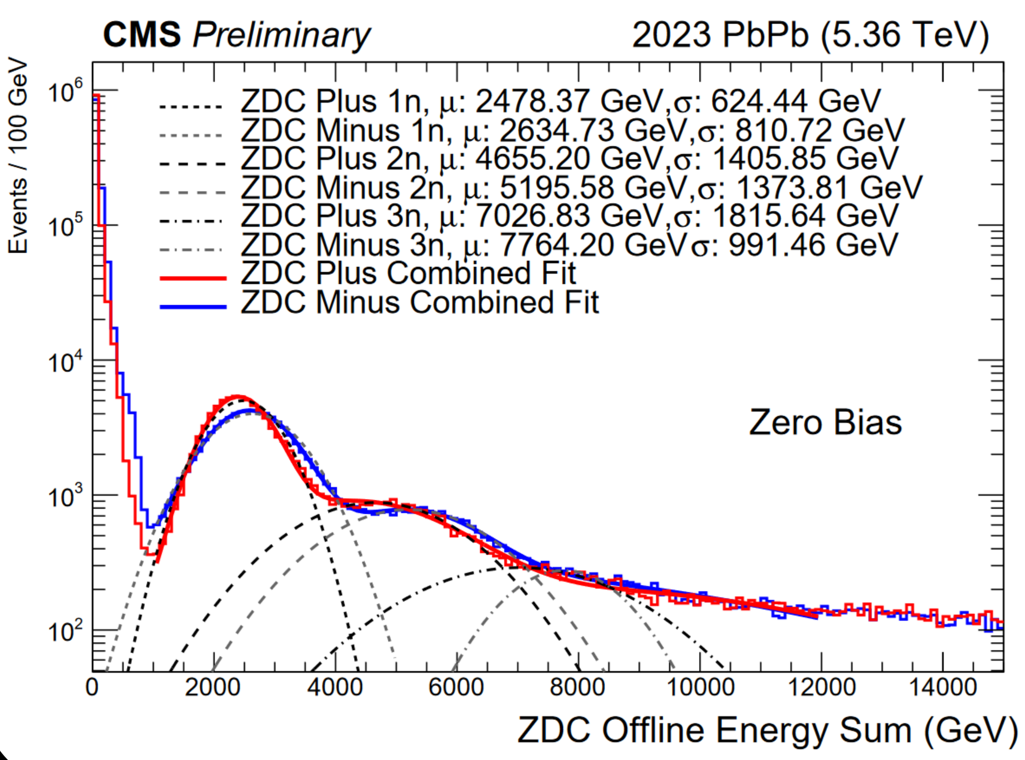
- **For high p_T D^0 (p_T > 5 GeV/c),** L1 jet (8 GeV) trigger combined with ZDC exclusive OR condition (Xn0n or 0nXn)
- **For low p_T D^0 (2 < p_T < 5 GeV/c),** jet triggers become very inefficient

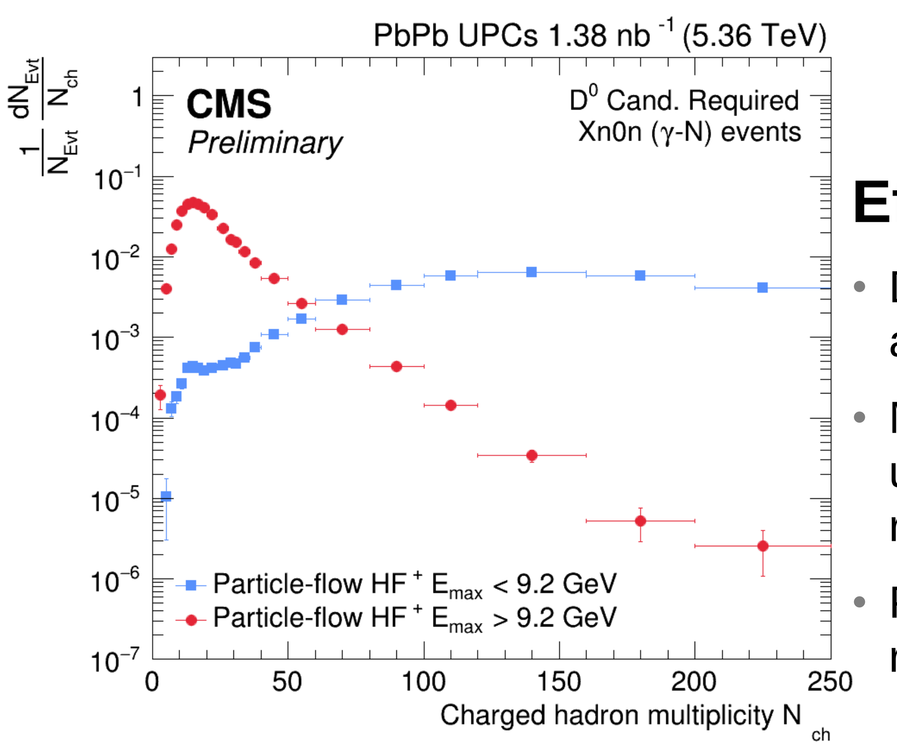
  → L1 ZDCOR 1n: at least one of the ZDC signals under the 1 neutron threshold



Offline event selections

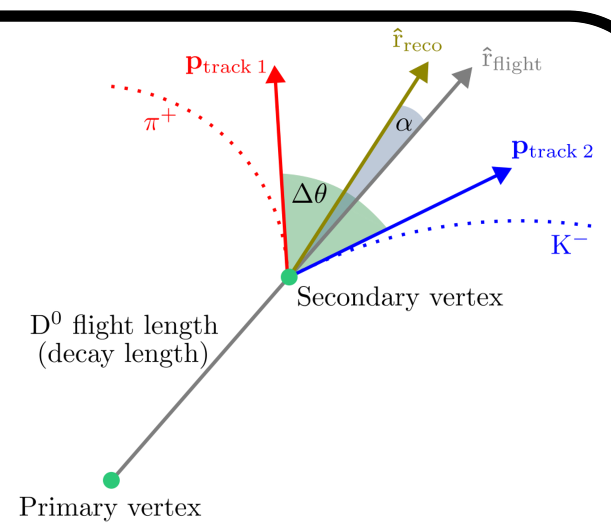
- **ZDC selection**: exactly one ZDC signal is above the 1n threshold (Xn0n or 0nXn)
- **Rapidity gap** on the side of „empty" ZDC: No particle-flow candidate is found above a given energy in the HF calorimeter
- Primary vertex selection and beam-gas/machine induced background rejection





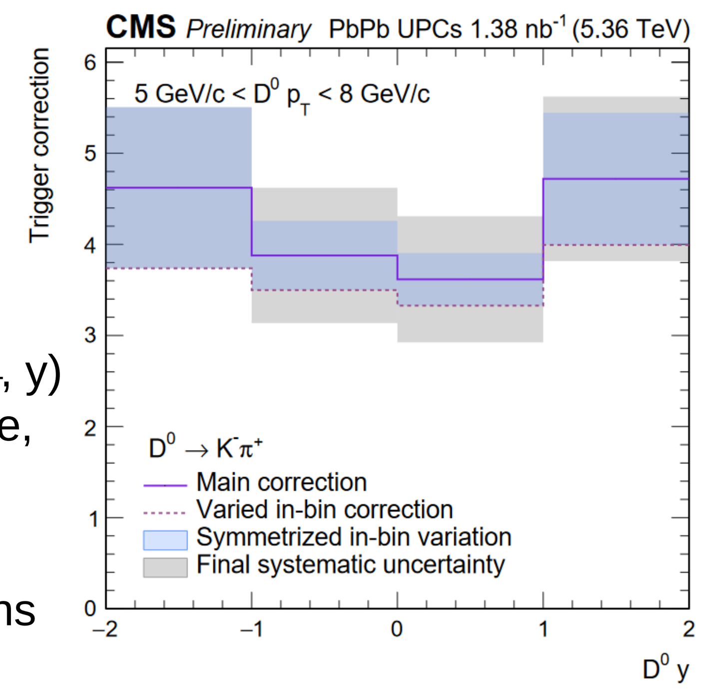
Offline D^0 selections

- D^0 candidates reconstructed from oppositely charged pairs of high-purity tracks
- Rectangular cuts (validated with a BDT-based optimization), which exploit the following topological variables:
  - 3D decay length, normalized by its uncertainty
  - Pointing (α) and opening angles ($\Delta\theta$)
  - Secondary vertex reconstruction probability



Efficiency and trigger corrections:

- Data-driven jet trigger correction in bins of D^0 p_T and rapidity
- MC-based (Pythia 8) corrections in bins of D^0 (p_T, y) used for event selection efficiency, D^0 acceptance, reconstruction and selection efficiency
- Pythia 8 distributions of generated-level D^0 reweighted according to FONLL-based predictions

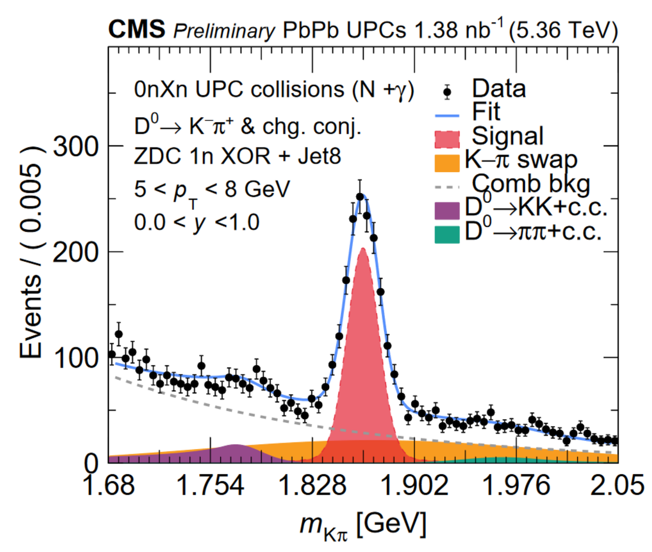


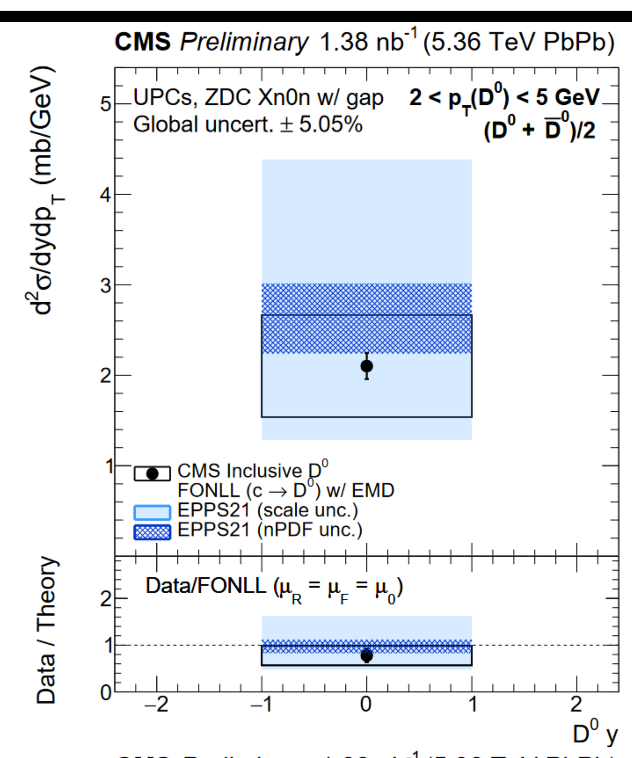
Signal extraction and cross section calculations

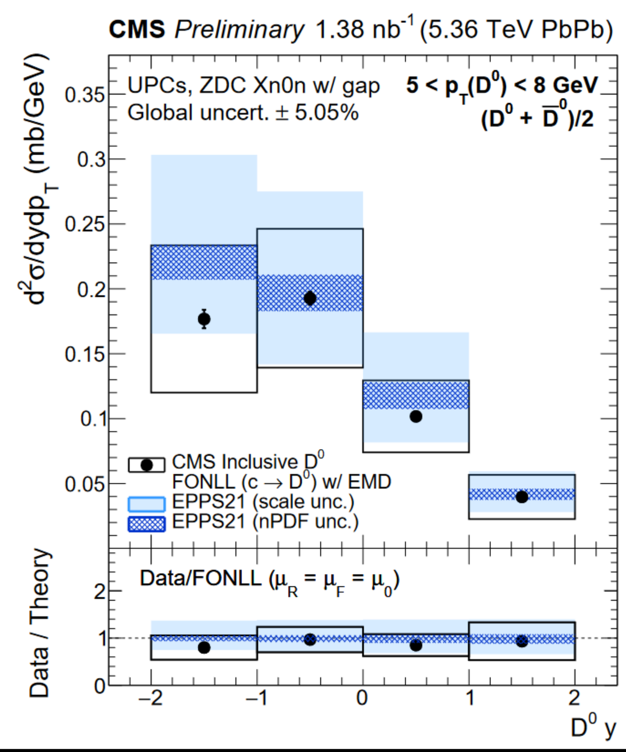
- Signal yield extracted in intervals of D^0 p_T and y with unbinned fits to the D^0 invariant mass distributions:
  - Double-Gaussian signal shape to model the distribution of signal D^0
  - Single Gaussian for D^0 candidates with wrong mass hypothesis
  - Exponential shape for the combinatorial background
  - Crystal Ball function templates for $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$ decay channels
- Corrected cross section:

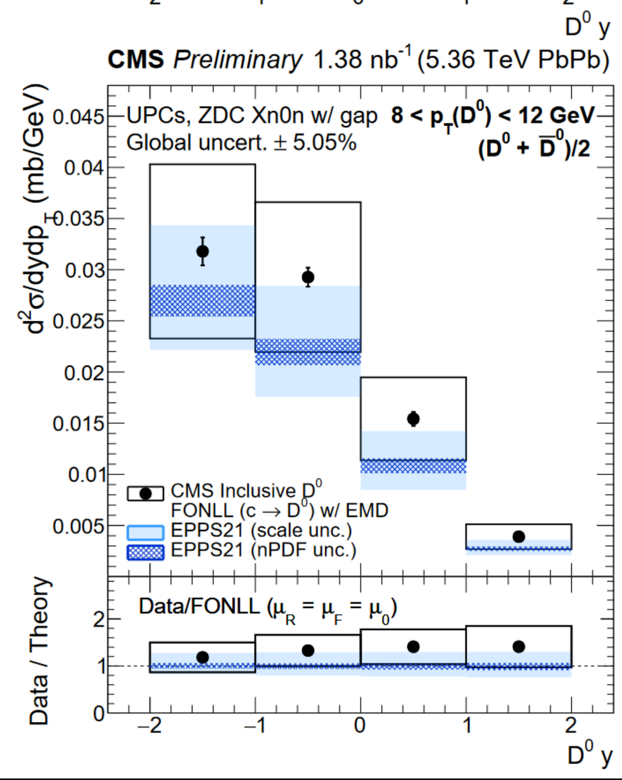
$$\frac{d^2\sigma}{dp_T dy}(D^0 p_T, D^0 y) = \frac{1}{2}\frac{1}{\mathcal{L}\mathcal{B}}\frac{N^{\mathrm{raw}}_{D^0}}{\Delta p_T \Delta y}\,\frac{1}{\epsilon_{\mathrm{evt}}\ \epsilon_{\mathrm{trigger}}\ P_{\mathrm{prescale}}\ (\alpha\ \epsilon_{D^0})\ \epsilon_{\mathrm{EM,pileup}}}$$

- Systematic uncertainties included for luminosity estimation, electromagnetic pileup correction, track reconstruction, event selection efficiencies, D^0 acceptance, selection and reconstruction efficiencies, yield extraction, trigger correction, MC reweighting
- Measurements compared with prompt FONLL inclusive photoproduction calculations









Conclusions:

- New experimental constraints obtained on nuclear matter with heavy-quark observables in a large region of x and Q^2
- This measurement opens the way for a new experimental program exploiting fully reconstructed heavy-flavour hadrons and heavy-flavour jets in ultra-peripheral heavy-ion collisions at the LHC.

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