Event selection strategy for charged-particle R_{AA} measurement in light ion collisions

Based on CMS-PAS-HIN-25-008 and CMS-PAS-HIN-25-014

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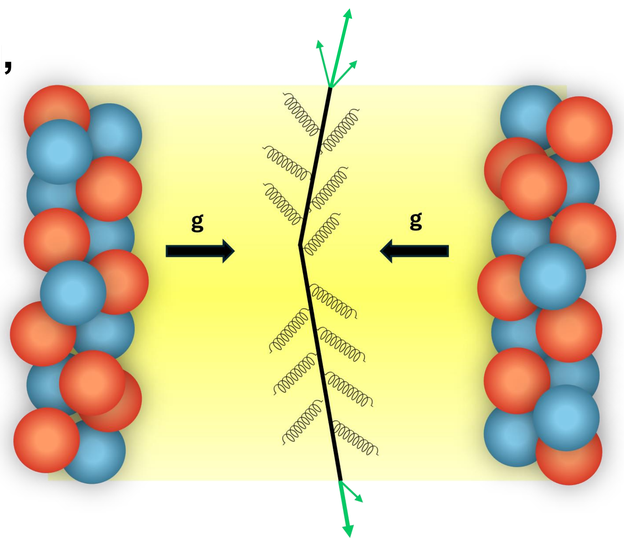
The driver of jet-quenching, quark-gluon plasma

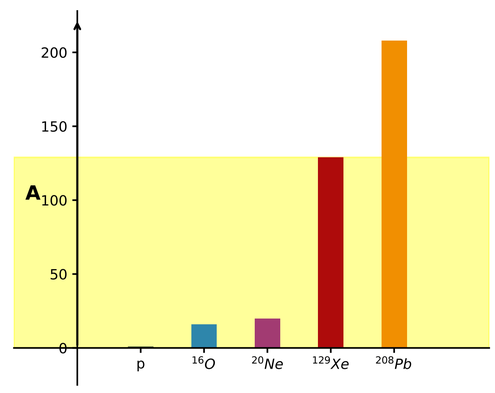
- **QGP:** hot and dense medium of deconfined partons
- QGP is created by colliding heavy ions at ultrarelativistic speed
- Partons lose energy in QGP ⟹ **suppression of particle yield** in the intermediate p_T region
- Microscopic structure of QGP can be studied



Partons lose energy when propagating through QGP

What makes light ion collisions interesting?

- **Jet-quenching:** observed in **large systems**, such as **Pb+Pb** and **Xe+Xe** collisions
- **Small systems:**
  - **QGP-like phenomena** (strangeness-enhancement, flow) observed in pPb and pp, **no jet-quenching**
  - At what system-size does jet-quenching emerge?
- **Medium-sized ^{16}O** and **^{20}Ne** bridge the gap between small and large systems



Nuclear mass number of heavy ions studied by CMS in R_{AA} analyses

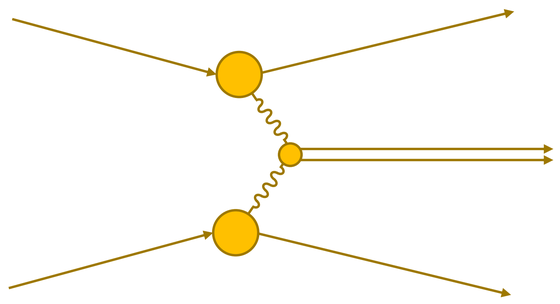
Nuclear modification factor R_{AA}

- Quantifies the suppression in the particle yields
- **Ratio** of the particle production **cross-section in nucleus–nucleus collisions** to the corresponding **cross-section in proton–proton collisions**, scaled by the **square of the nuclear mass number**
- Holds for **minimum-bias collisions** (inclusive in centrality)
- Definition is **independent** of the Glauber model

$$R_{AA} = \frac{1}{A^2}\left[\left(\frac{d\sigma^{AA}}{dp_T}\right)\Big/\left(\frac{d\sigma^{pp}}{dp_T}\right)\right]$$

Comparing events in proton-proton and light ion collisions

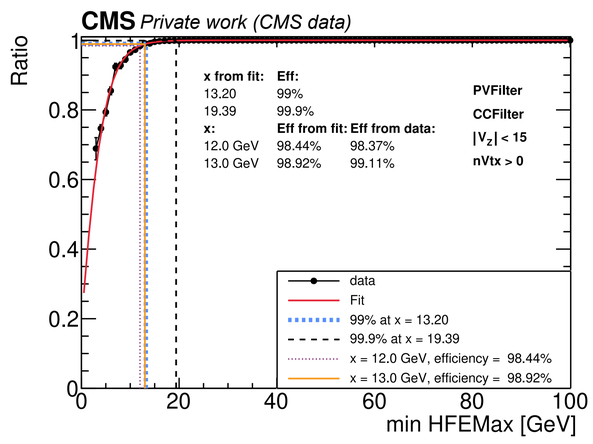
- **Hadronic events:** ions interact via the strong force (short range)
- **Non-hadronic events to be removed:**
  - **Photonuclear event:** interaction of photon and nuclei, one or both nuclei stay intact
  - **Two-photon event:** interaction of two photons, both nuclei stay intact
  - More frequent in nucleus-nucleus collisions ⇒ filtered out via event selection

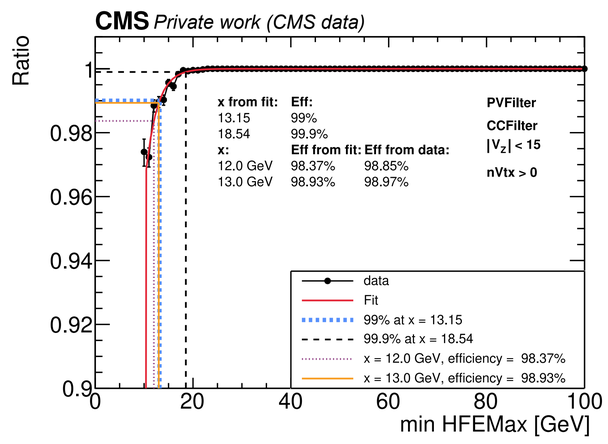


Two-photon interaction with hadronic final states, to be rejected by the event selection

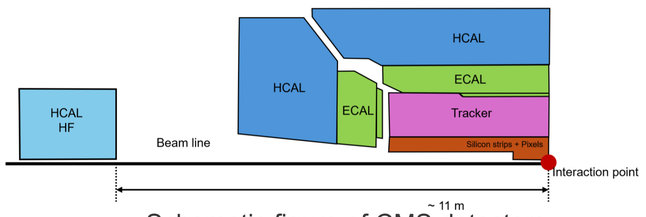
Event selection strategy

- Selecting on signals in **hadron forward calorimeter (HF)** to limit non-hadronic background
- **Minimum-bias trigger** based on HF in an **"OR" logic**
- Larger than **13 GeV** HF activity required in both hemispheres
  - **Photonuclear and two-photon residuals largely reduced**
  - **Hadronic events retained**
- Additional offline event selection **to remove non-collisional background**
  - Reconstructed **primary vertex** required **to lie in the center of the detector** (± 15 cm on the z axis and ± 2 cm in the transverse plane), with at least **2 reconstructed tracks**
  - **Cluster compatibility**: width of hit cluster must agree with expected width calculated from η and the z coordinate of the collision vertex





Efficiency of minimum bias trigger as function of the smaller of the maximum recorded energy on each side, corresponding to an "AND" logic selection for O+O (left) and Ne+Ne (right) collisions

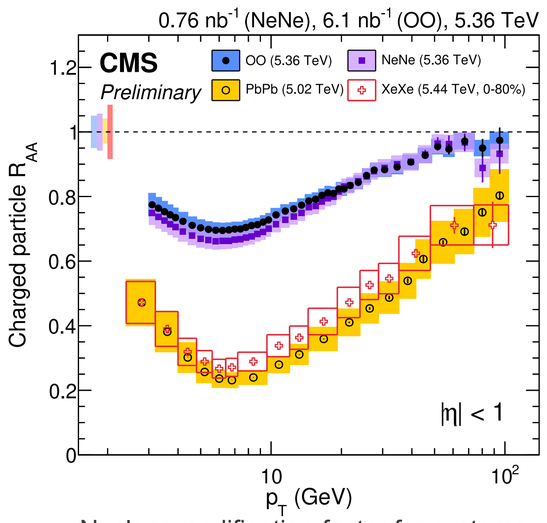


Schematic figure of CMS detectors

Charged-particle R_{AA} in systems measured by CMS

- A **significant suppression** is observed in light ion collisions
- **Steeper** slope and **stronger** suppression for larger ions
- R_{AA} rises towards **1 at high p_T** for all systems presented
- **Centrality-inclusive** measurement for light ions (O+O, Ne+Ne) and Pb+Pb, 0-80% centrality for Xe+Xe

[1]: CMS Collaboration, *JHEP* 04 (2017) 039
[2]: CMS Collaboration, *JHEP* 10 (2018) 138



Nuclear modification factor for systems measured by CMS [1, 2]

Conclusions

- Minimum-bias HF trigger is used to reject non-hadronic events
- Trigger efficiency is maximalized by offline selection on HF signal
- Particle yield is **significantly suppressed** in light ion collisions
- **Inclusive R_{AA} is reported for light ions** for the first time, providing a useful perspective on the properties of quark-gluon plasma

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