

Recent heavy ion results with the CMS experiment

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IHEP / CAS

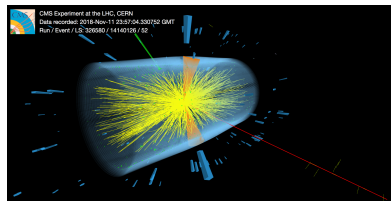
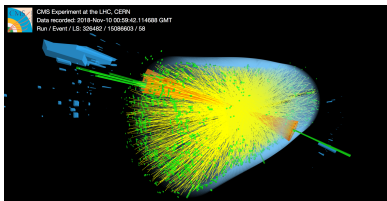
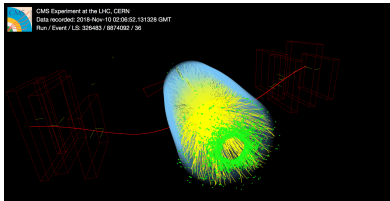
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Using the full experimental toolbox to probe heavy ion collisions:

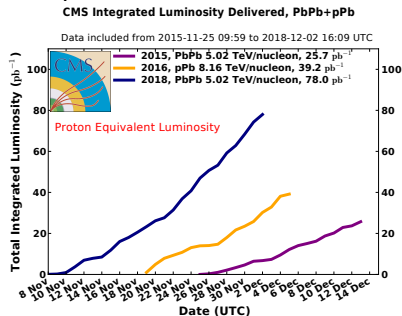
- Photon-induced processes (very large EM fields in PbPb)
- Electroweak bosons for initial state and nuclear PDFs
- Jet modifications for jet quenching and medium response
- Heavy quark dynamics from small to large systems
- New probes made accessible by high luminosity data samples



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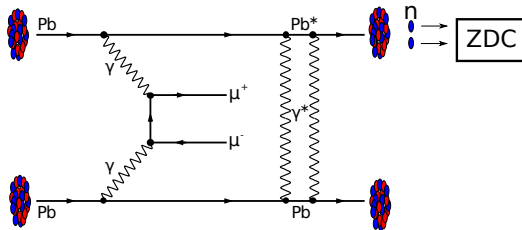
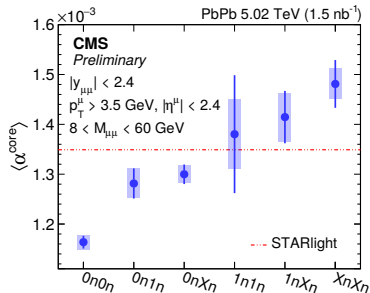
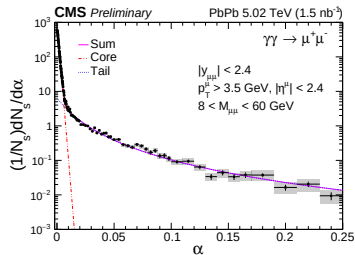
- Impressive LHC performance ($6\times$ design in 2018!)
- 2018 PbPb data:
 - 1.7 nb^{-1}
 - $\approx 4.5 \times 10^9$ minimum bias events





Forward neutron multiplicity in $\gamma\gamma \rightarrow \mu^+\mu^-$

CMS-PAS-HIN-19-014

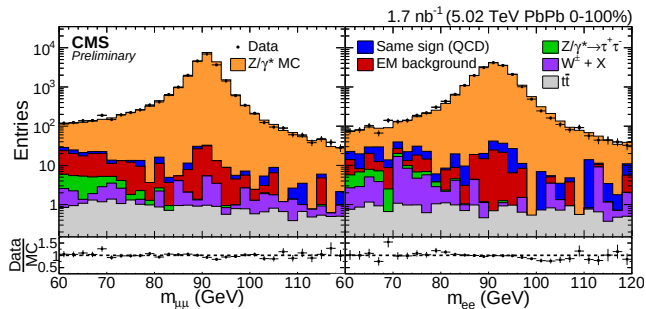
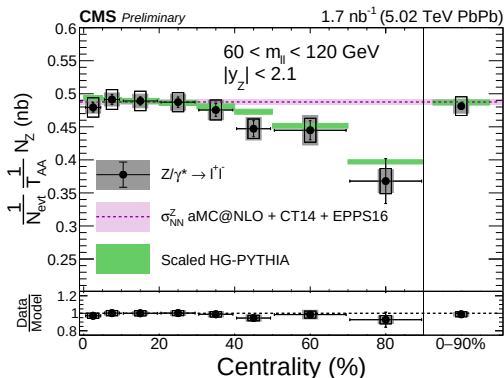


- Acoplanarity α of muon pairs from $\gamma\gamma \rightarrow \mu^+\mu^-$
- Strong neutron multiplicity dependence of the width of the peak around $\alpha = 0$
 - Neutrons detected using Zero Degree Calorimeters
- b dependence of photon p_T and energy



Z bosons in PbPb

CMS-PAS-HIN-19-003

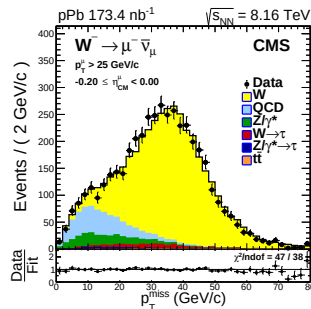
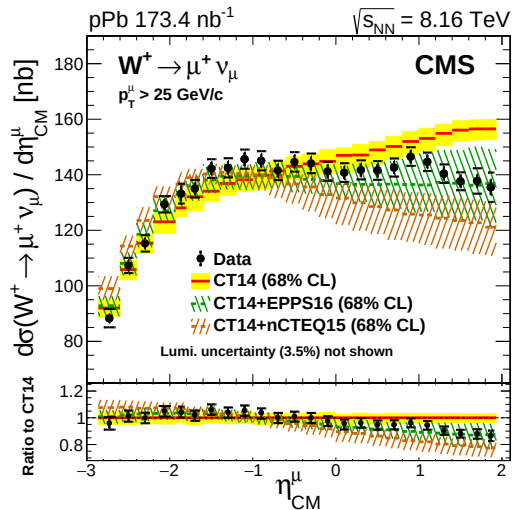


- Centrality dependence: deviation from canonical scaling
- Centrality selection biases?
- Not shown: v_2 , y - and p_T -dependent cross sections



W bosons in pPb

PLB 800 (2020) 135048

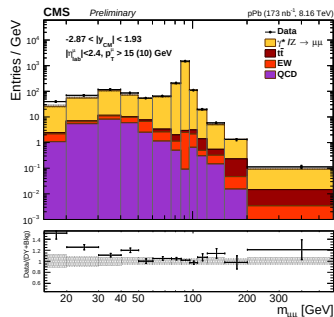
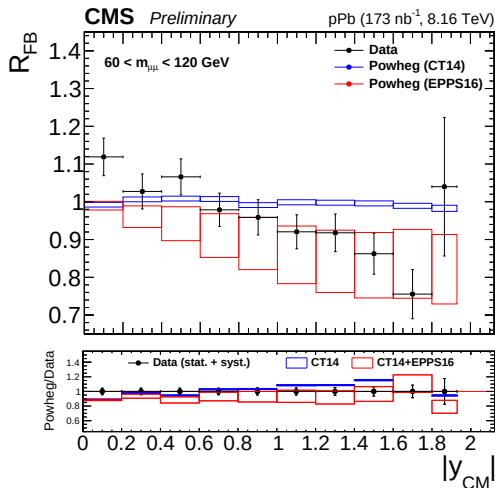


- Very precise data!
- Inconsistent with proton PDF, favour EPPS16
- Valuable input to improve nPDF models



Drell-Yan (Z/γ^*) in pPb

CMS-PAS-HIN-18-003

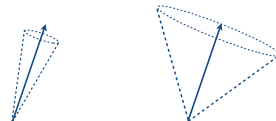
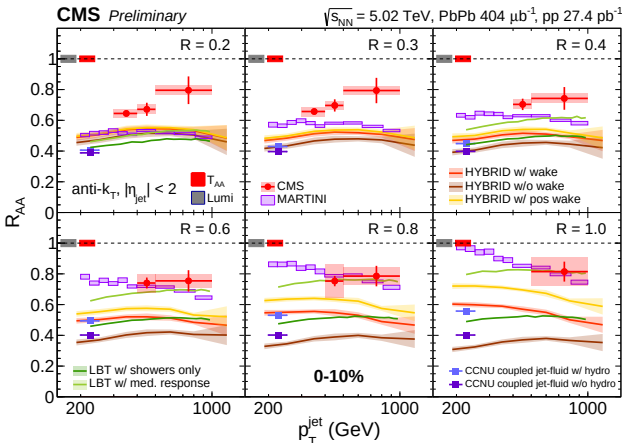


- First time measurement of the continuum in this mass range
- Rapidity dependence favours EPPS16
- Not shown: cross sections (y , p_T , ϕ^*) for $15 < M < 60$ and $60 < M < 120 \text{ GeV}$



Jet R_{AA} : jet radius scan

CMS-PAS-HIN-18-014



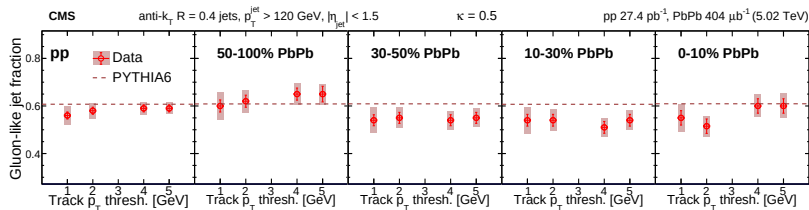
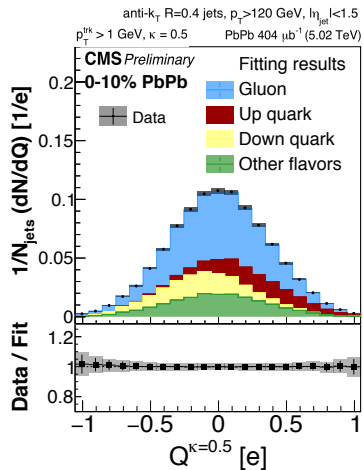
Jet R_{AA} as a function of jet p_T and radius

- First measurement up to $R = 1.0$
- Competing effects for wide jets (suppression vs recovery of quenched energy)
- New constraints on jet quenching models



Jet charge in pp and PbPb

arXiv:2004.00602



Quark / gluon fraction extracted from jet charge

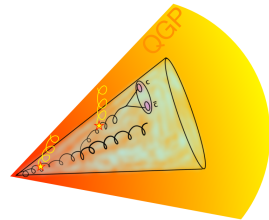
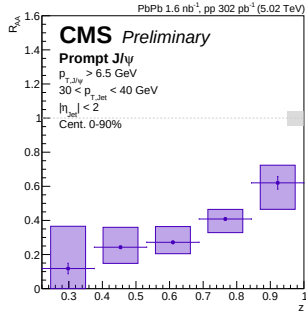
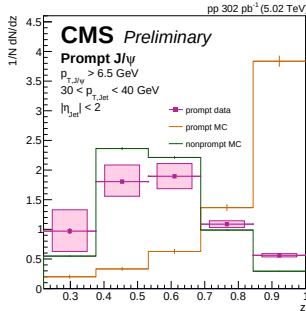
- No modification of jet charge distribution in PbPb
 - Extraction of quark / gluon fraction using PYTHIA templates
- Consistent fractions in pp and PbPb



Fragmentation of jets containing a J/ψ meson

CMS-PAS-HIN-19-007

sketch: B. Diab



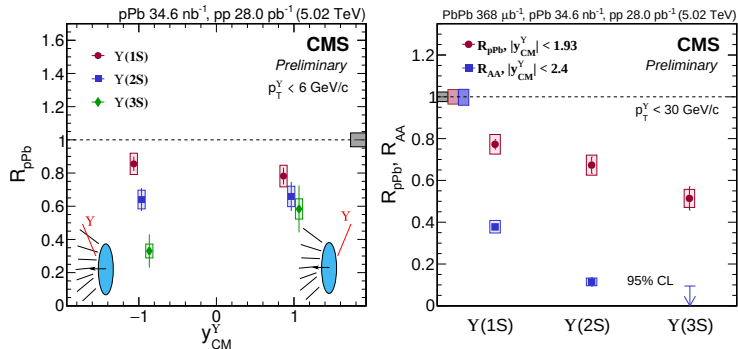
$$z = \frac{p_T(J/\psi)}{p_T(jet)}$$

- z distribution very badly reproduced in PYTHIA 8
- J/ψ in jets (low z) are more suppressed than isolated J/ψ (high z)



$\Upsilon(1S,2S,3S)$ in pPb

CMS-PAS-HIN-18-005

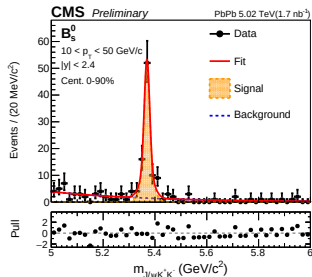
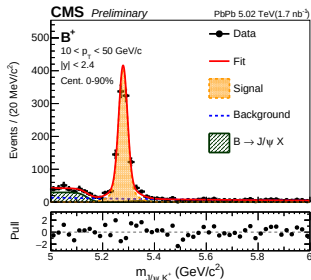
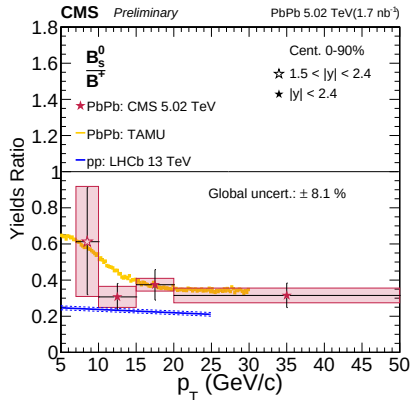


- $R_{pA}(\Upsilon(1S)) > R_{pA}(\Upsilon(2S)) > R_{pA}(\Upsilon(3S))$
- Larger $\Upsilon(3S)$ suppression at low p_T and in the Pb fragmentation region
- $R_{pA} > R_{AA}$



B_s^0 and B^+ mesons in PbPb

CMS-PAS-HIN-19-011

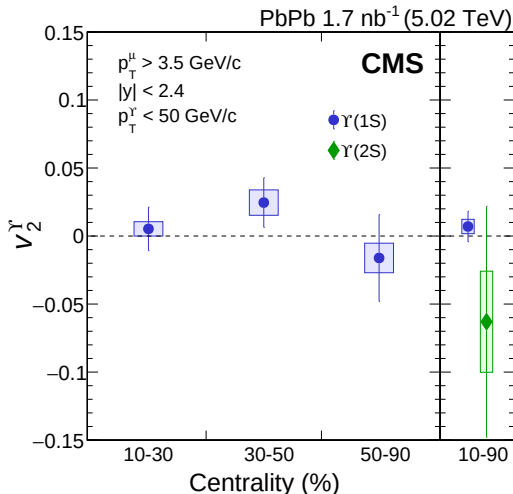


- First observation of B_s^0 in PbPb
- Yields ratio consistent with expectation from pp
- **Similar modification of B_s^0 and B^+ in PbPb in the measured kinematic range**



$\Upsilon(1S)$ and $\Upsilon(2S)$ v_2 in PbPb

arXiv:2006.07707



Elliptic flow of bottomonia in PbPb

- Precise $\Upsilon(1S)$ v_2 measurement:

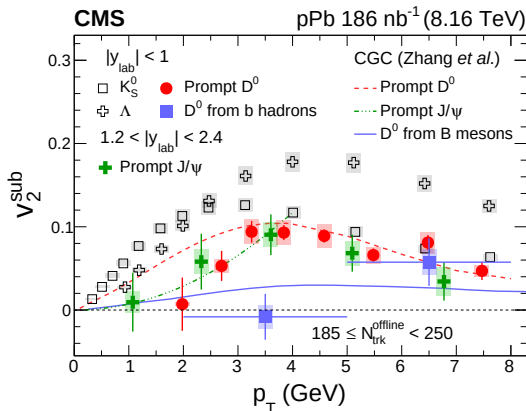
$$v_2(\Upsilon(1S)) = 0.007 \pm 0.011(\text{stat.}) \pm 0.005(\text{syst.})$$

- First $\Upsilon(2S)$ v_2 measurement!
- Contrast with larger J/ψ v_2



Prompt and nonprompt D^0 v_2 in pPb

arXiv:2009.07065



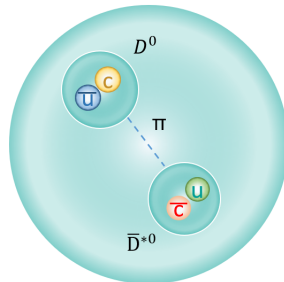
- Charm v_2 in pPb
 - Open charm: (prompt D^0)
 - Similar to hidden charm: prompt J/ψ
- **Beauty (nonprompt D^0) v_2 in pPb**
 - First measurement: consistent with 0
 - Smaller than prompt D^0 at low p_T
- Heavy quark collectivity puzzle in small systems
 - Charm flows even in pp (not shown here)!



New probe: $X(3872) \rightarrow J/\psi \pi^+ \pi^-$

Sketch: Y.-J. Lee

Tetraquark (4q)

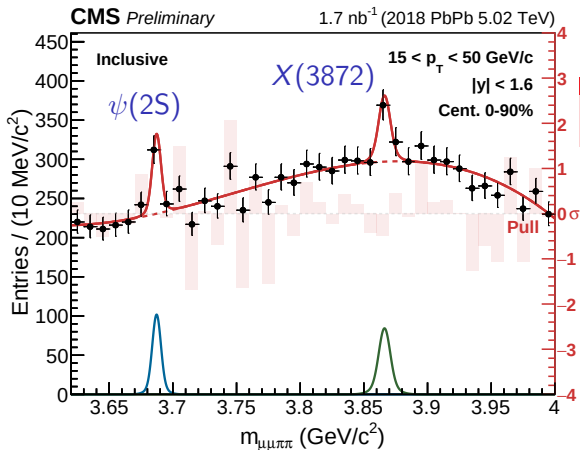
 $D^0 - \bar{D}^{*0}$ molecule

- **What is the nature of $X(3872)$?**
 - Tetraquark? $D^0 - \bar{D}^{*0}$ molecule? Hybrid?
- Coalescence for a 4-quark / molecular state?
- **Probing the $X(3872)$ structure using the QGP!**



New probe: $X(3872) \rightarrow J/\psi \pi^+ \pi^-$

CMS-PAS-HIN-19-005



4.2 σ : strong evidence!

$$\left. \frac{X(3872)}{\psi(2S)} \right|_{AA} = 1.10 \pm 0.51(\text{stat.}) \pm 0.53(\text{syst.})$$

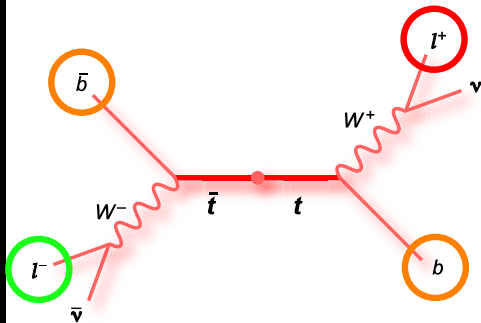
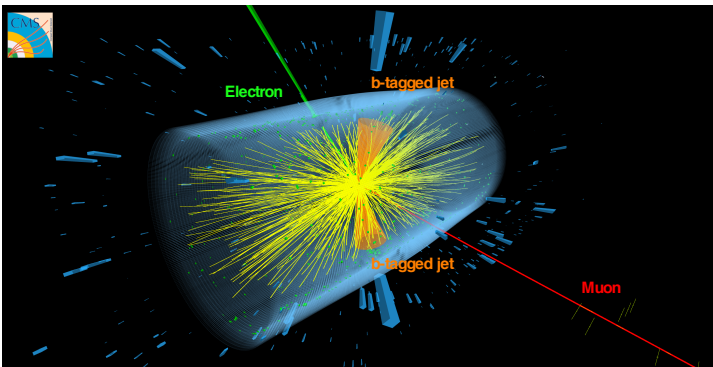
$$> \left. \frac{X(3872)}{\psi(2S)} \right|_{pp}$$

Is $X(3872)$ less suppressed than $\psi(2S)$ in AA?



New probe: top quarks

arXiv:2006.11110



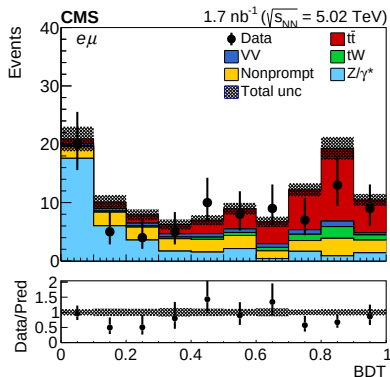
The top quark:

- Top quarks decay well before QGP is formed
- nPDF: **probing high-x gluons**
- With more data: **probing the formation time of the QGP**

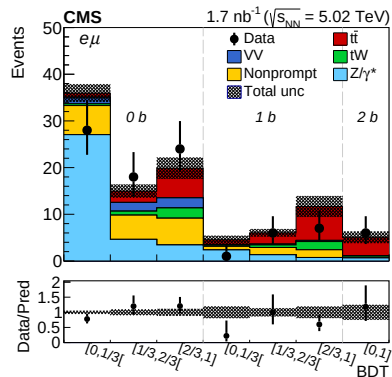
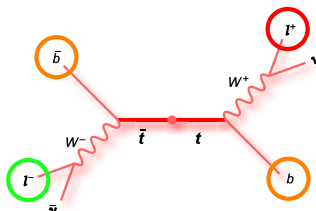


New probe: top quarks

arXiv:2006.11110



Di-lepton multivariate analysis



Also b-jet counting

4.0σ : strong evidence!



Summary

Many new results exploring the rich physics of heavy ion collisions:

- Exclusive and photon-induced processes
- Initial state and nuclear PDFs
- Jets and medium response
- Heavy flavour
- New rare probes

Links to all CMS heavy ion results

- Preliminary: <http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIN/index.html>
- Publications: <http://cms-results.web.cern.ch/cms-results/public-results/publications/HIN/index.html>