nPDF/small-x/UPC: experimental

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on behalf of ALICE, ATLAS, CMS and LHCb

WORKSHOP ON THE PHYSICS OF HL-LHC, AND PERSPECTIVES AT HE-LHC

1 November 2017

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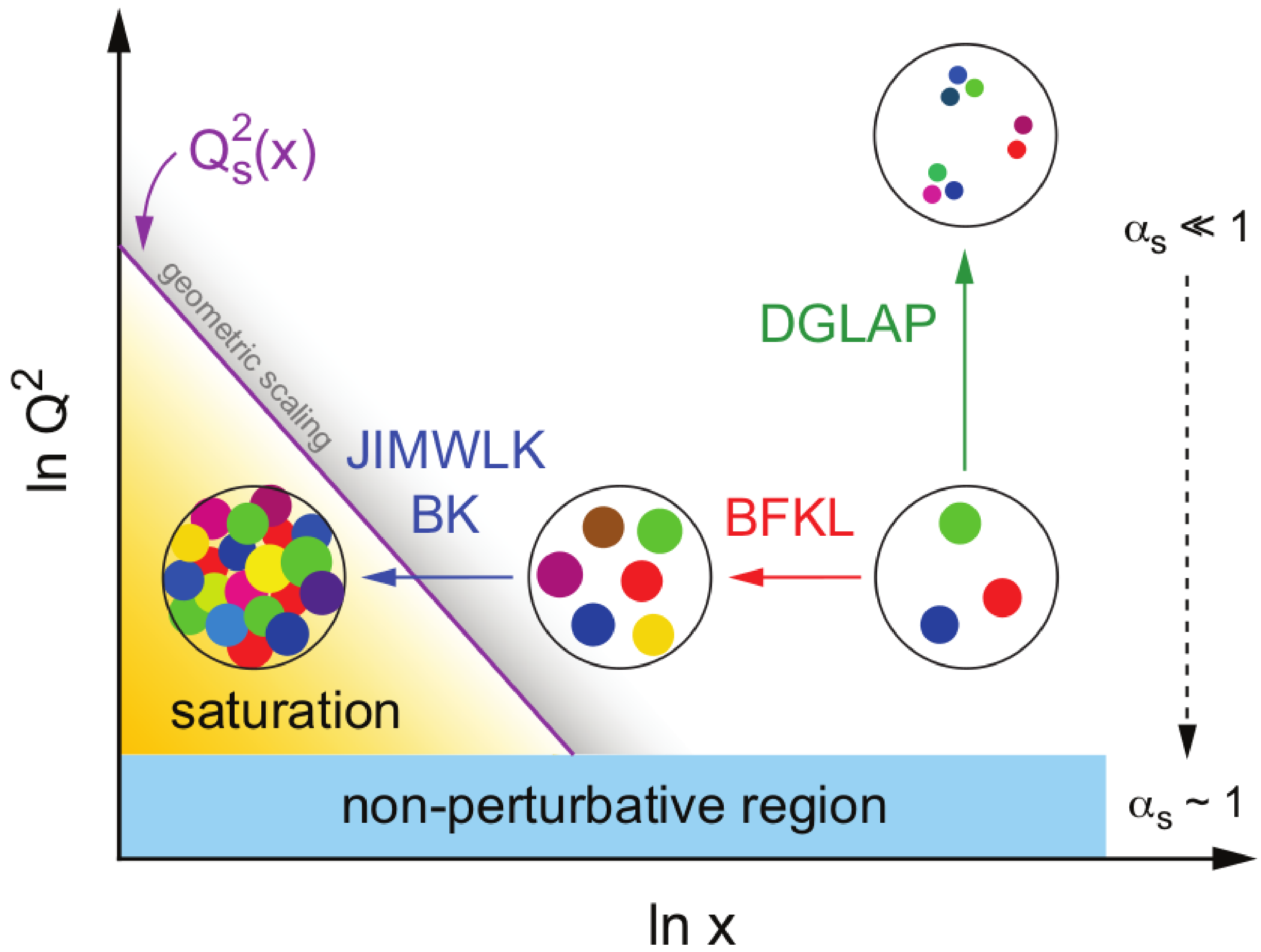
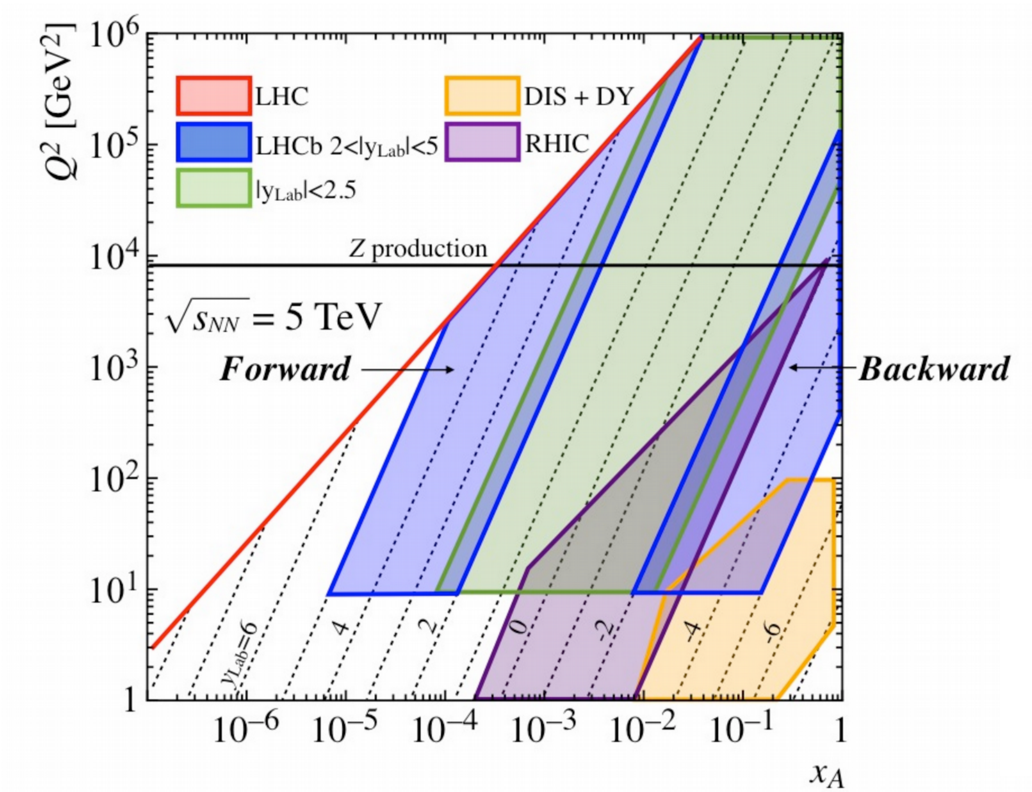
Motivations



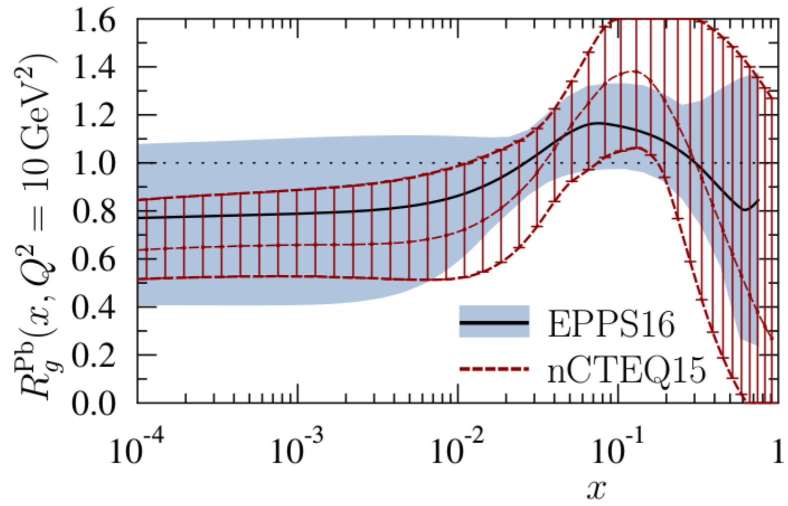
At LHC unique opportunity to precisely explore the parton dynamics over a large phase space

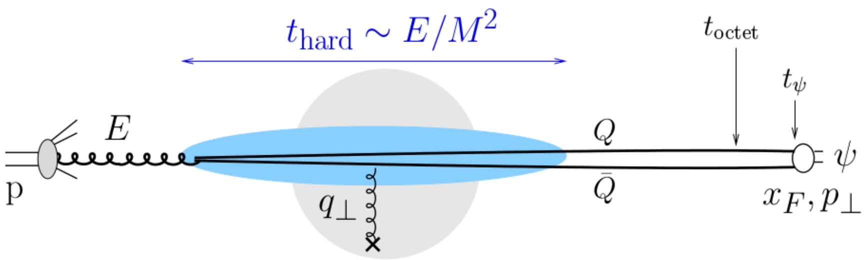
Crucial input to better understand PbPb results and to constrain models

Motivations



EPJC77 (2017) no.3, 163





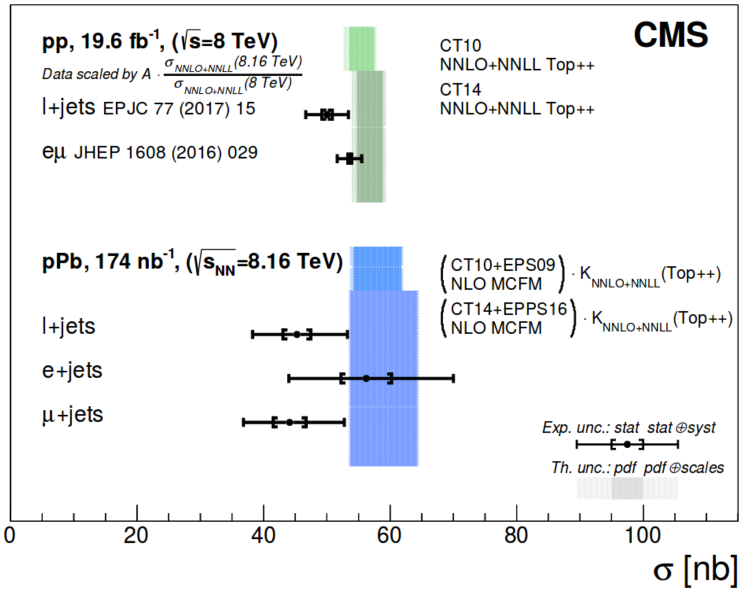
JHEP 1303 (2013) 122

- LHC experiments provide large acceptance up to very high Q^2 and down to very small x in the nucleus
- x values smaller than EIC, before EIC starts
- Common physics case with LHeC with complementary strengths (see link)
- Constrain parton distribution functions in nuclei
- Test saturation models

- We need clean probes: both theoretically and experimentally

Top production in p-Pb

- Run2 data allowed the observation of top production in pPb collisions
- Large Q^2, theoretical under control
- Sensitive to gluon PDF
- Need more statistics > x10

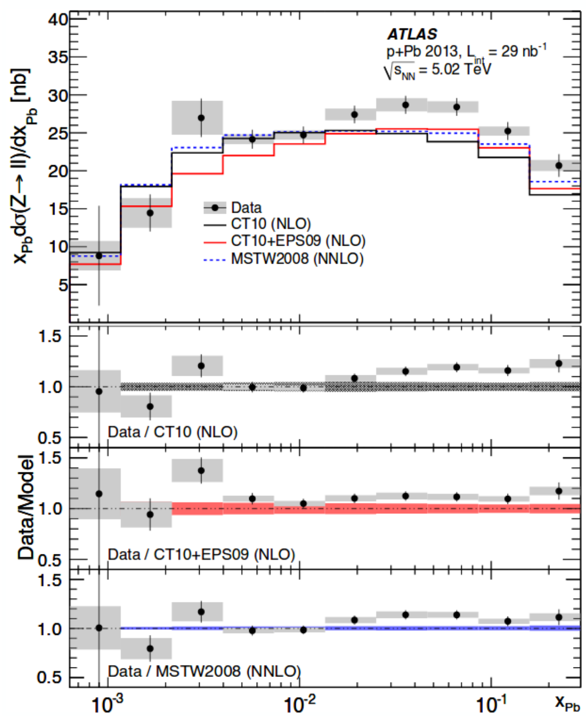


arXiv:1709.07411

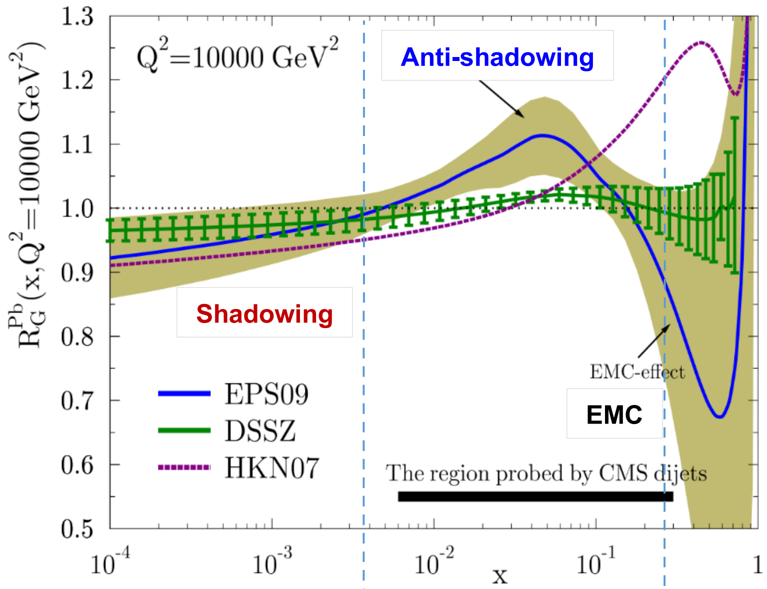
W/Z production in p-Pb

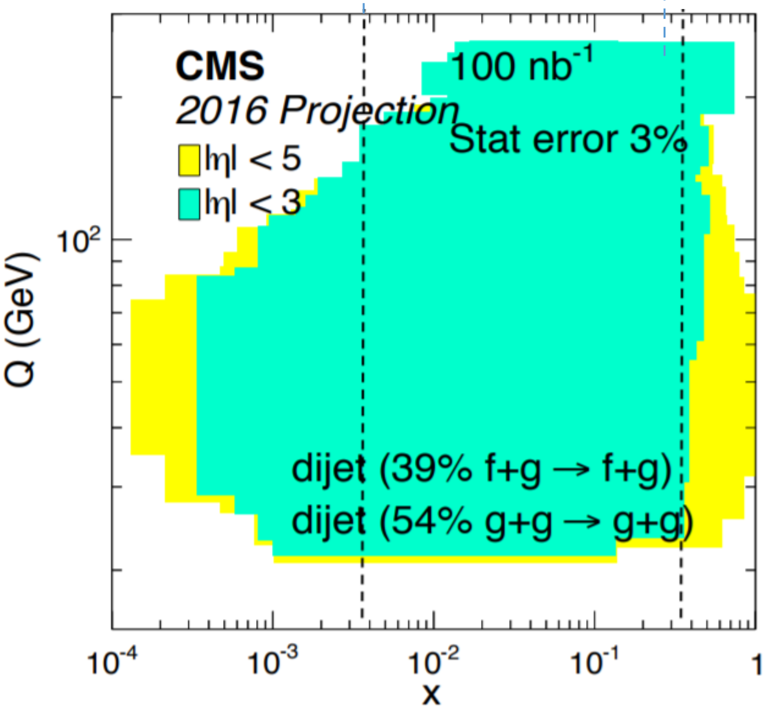
- Large Q^2, theoretical under control
- Sensitive to sea quarks
- Large statistics already available
- Run3/4, more differential studies

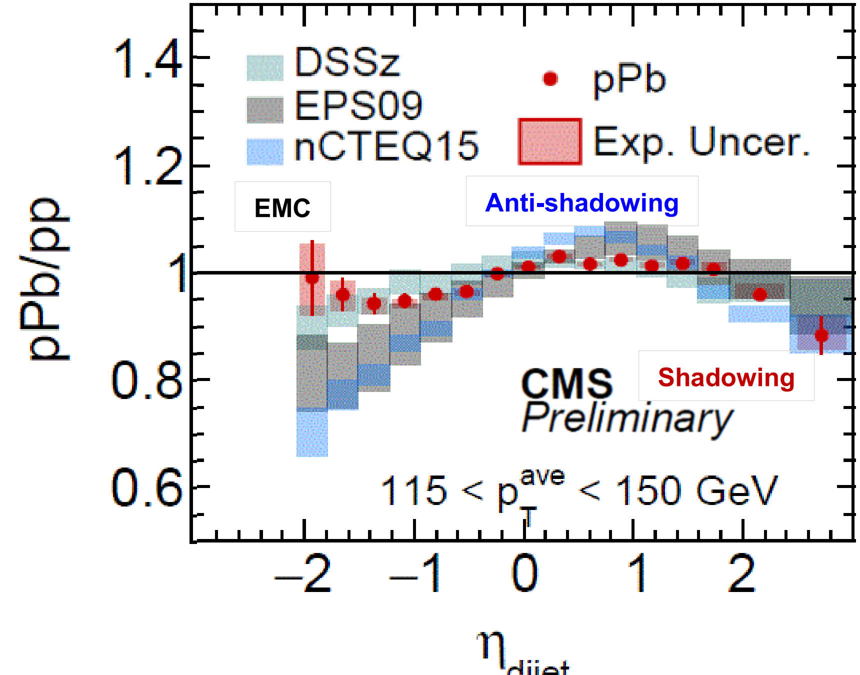
Phys. Rev. C 92, 044915 (2015)



Dijet Pseudorapidity







EPJC 74 (2014) 2951

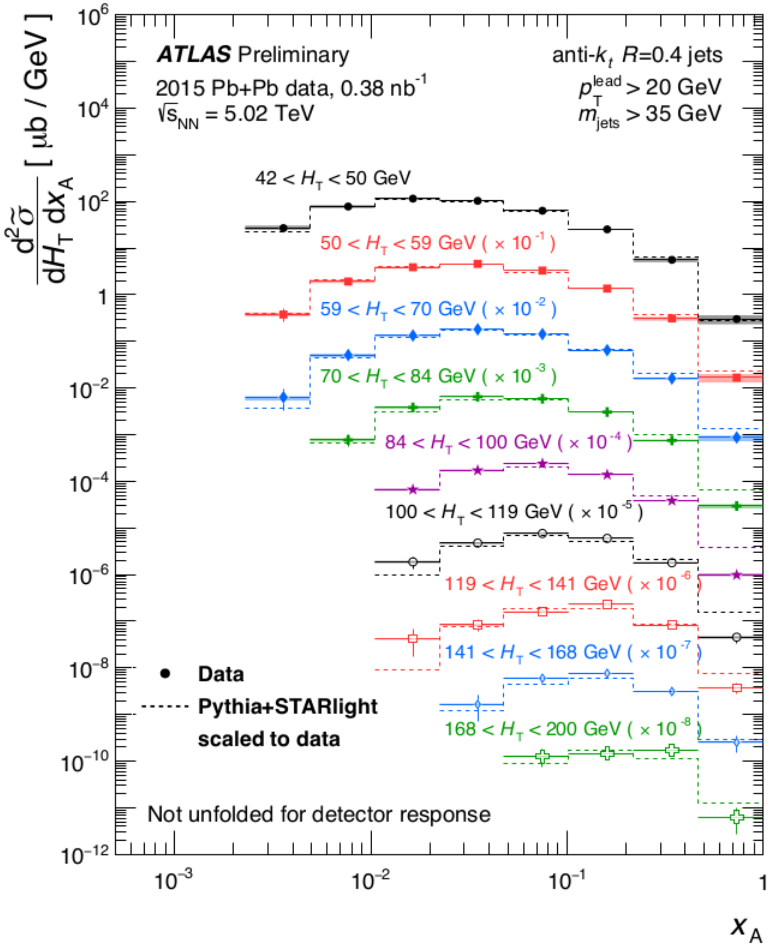
CMS-PAS-HIN-16-003

- nPDF could be constrained with high Q^2 dijet data, complementary to low Q data from hadrons. Important test for the factorization assumption
- The first dijet data has already been included in EPPS16 which improved gluon nPDF
- Significantly higher statistics pA data in HL-LHC could further reduce the statistical and systematical uncertainties and cover a wider x and Q phase space
- High precision heavy flavor jet (ex: b-dijet 96% from gg scattering) will become feasible with HL-LHC data

γA collisions: nPDF measurements

- Di-jet production as proof of principle →
- Diffractive jet production
  - Diffractive PDFs important input to shadowing models
- Heavy flavor (jets): Is there an EMC effect for gluons?
- **γ**-jet: Provides access to different flavor distributions

ATLAS-CONF-2017-011

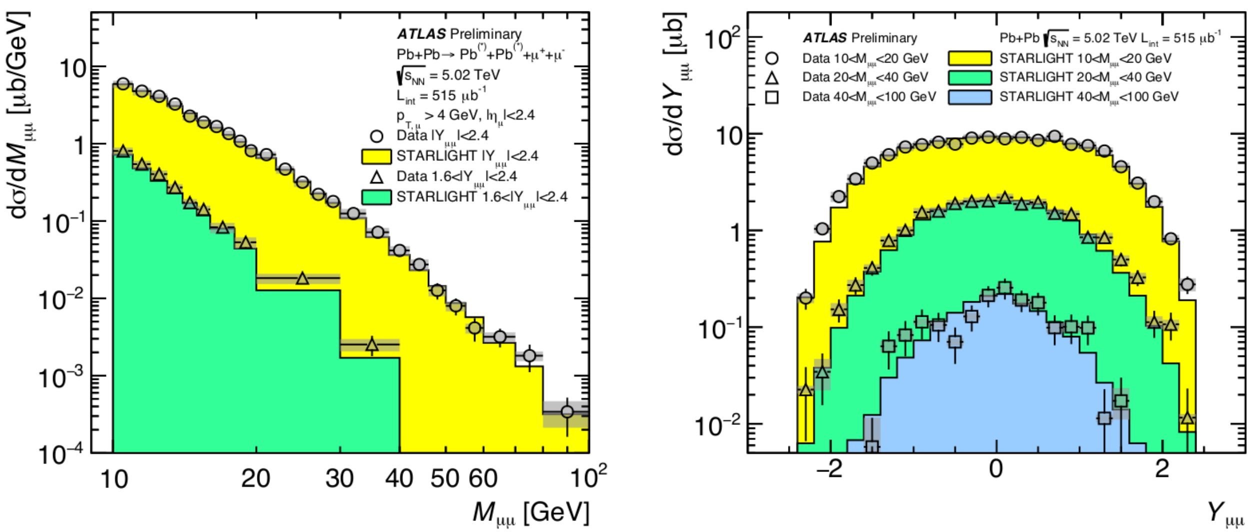


$\gamma\gamma$ collisions

QCD

- Process $\gamma\gamma\rightarrow q\bar{q}$ is an elementary QED process
- Rates can be calibrated with $\gamma\gamma\rightarrow\mu^{+}\mu^{-}$
- Clean QCD measurements a la $e^{+}e^{-}$

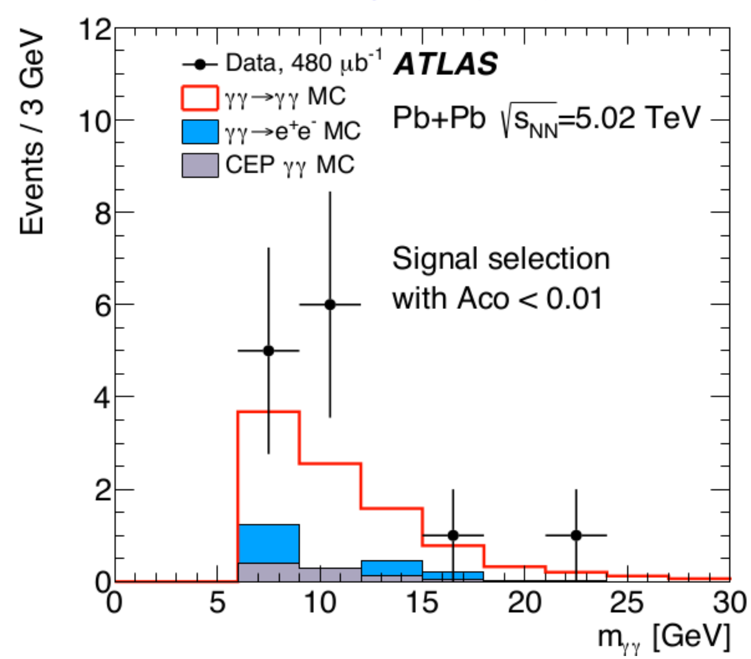
ATLAS-CONF-2016-025



Rare and BSM

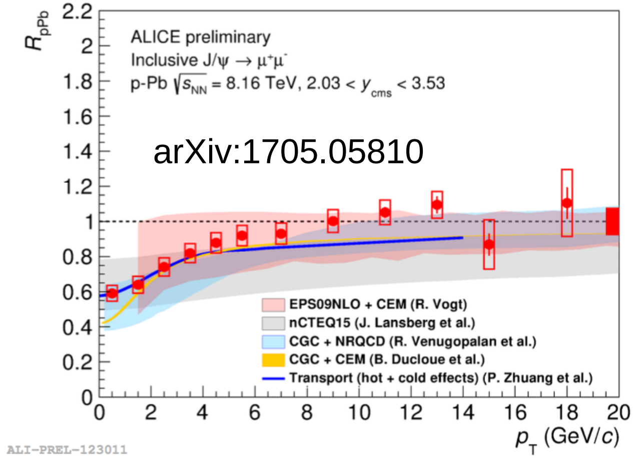
- Light by light scattering
- Currently 4.4 sigma evidence
- Leads to many exclusive SM processes
- Potential for searches: BSM, axion-like particles,...
- Will benefit from larger luminosities and increased detector acceptance

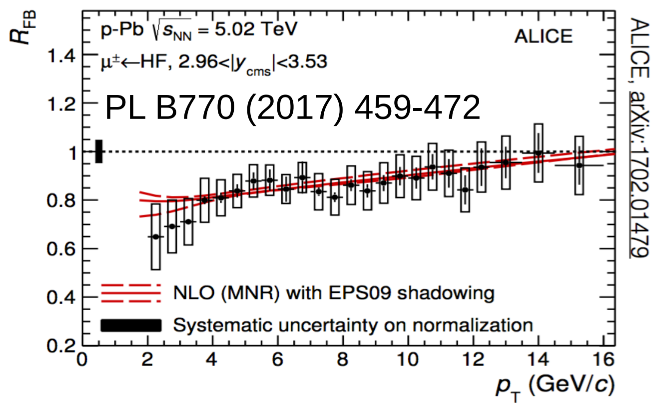
Nature Physics 13 (2017) 852

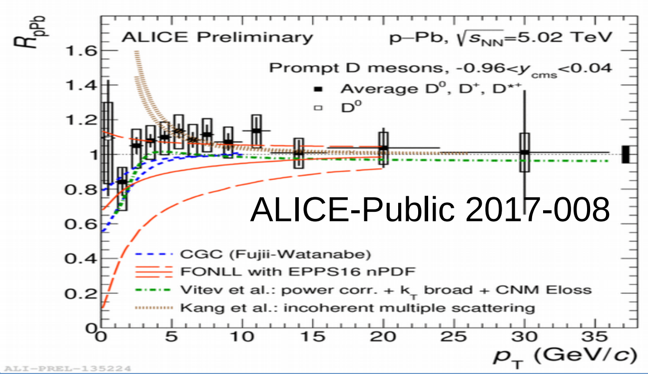


Accessing small-x with HF and quarkonia

PRESENT MEASUREMENTS

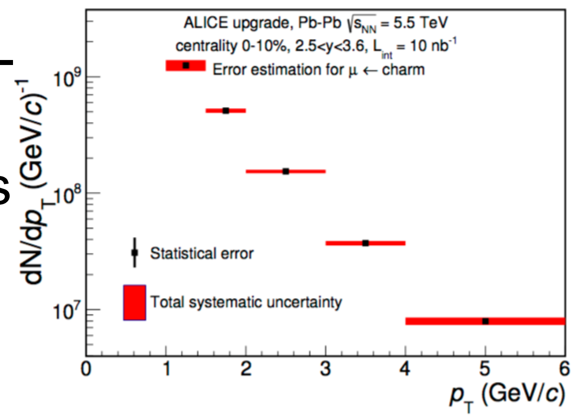






PROSPECTS AFTER LS2

- Separation of prompt and non-prompt J/ψ and central and forward rapidity
- Separation of D-decay and B-decay muons with MFT + reduction of systematic errors (now dominated by light-flv background)

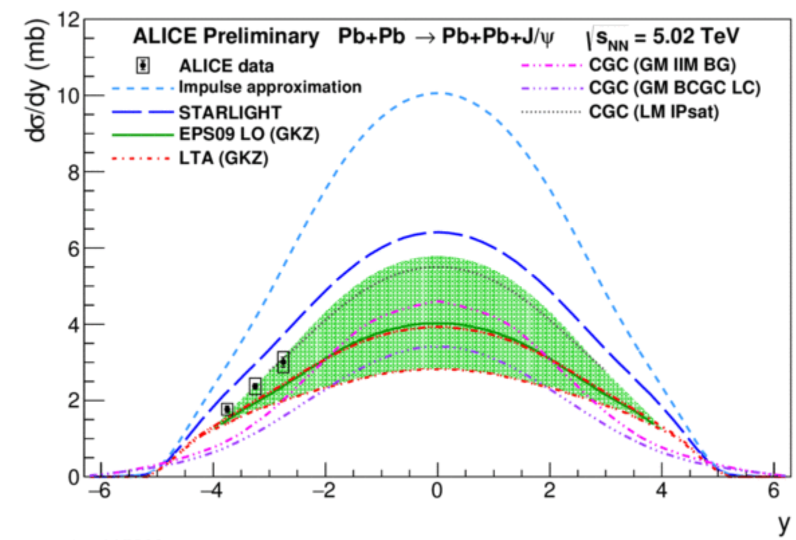


- Precise measurement of D mesons to p_T=0 at y=0 (complementarity rapidity coverage to LHCb)

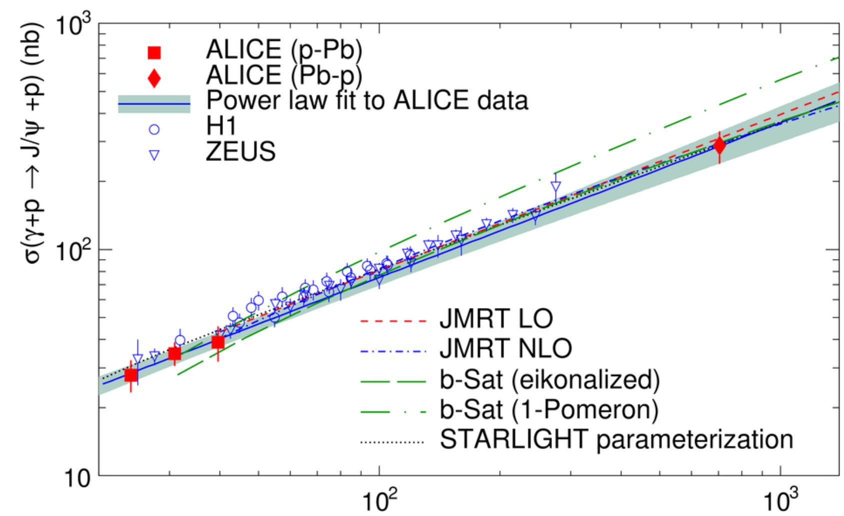
UPCs in ALICE

- Data taking and UPC-tagging scenarios already defined: continuous readout for all detectors needed for UPC analysis + offline tagging with FIT veto and ITS+TPC or MUON track pair
- Multi-differential studies J/ψ, $\psi(2S)$
  - Few 10^6 J/ψ and ~10^5 $\psi(2S)$ with 10/nb
  - b-slope dependence → transverse gluon distributions (1611.05471)
  - ZDC signal → disentangle low-x and high-x contributions
- High-mass vector mesons:
  - $\psi(3S)$ → DDbar (not measured at HERA, ~10^3 evts with 10/nb) and Υ
- $\gamma\gamma$ collisions: under study
- Coherent UPC Φ production

arXiv:1710.03417



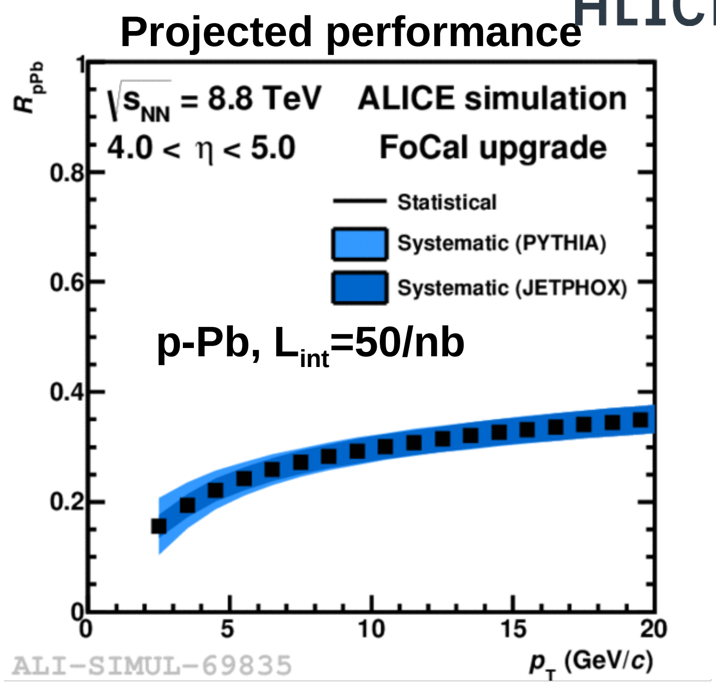
ALI-PREL-117502

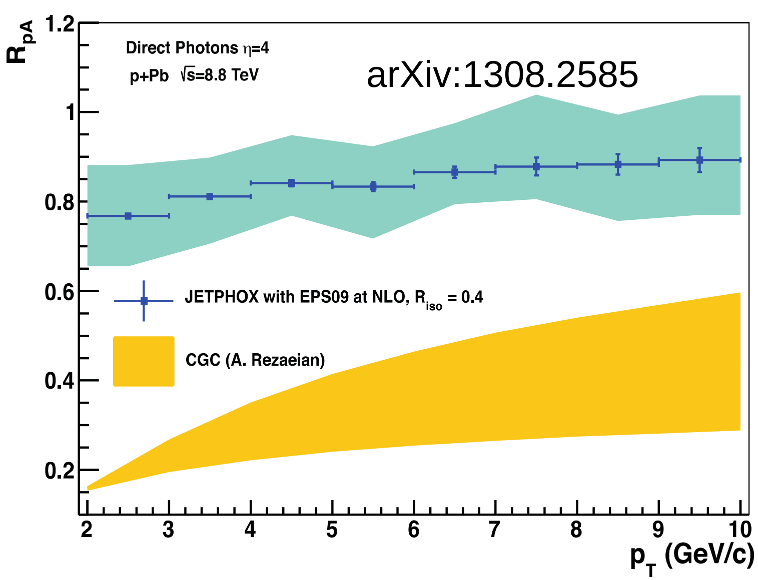


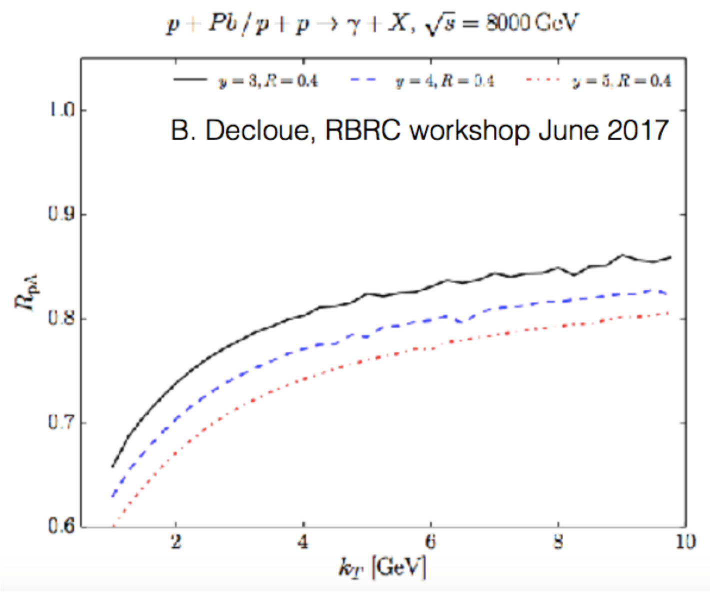
Phys. Rev. Lett. 113 (2014) 232504

Under discussion in ALICE: FoCal

- FoCal: R&D for a high-granularity calorimeter at η~3-5 with focus on saturation physics studies
  - Possible installation during/after LS3
- Benchmark measurement: direct photons η~4-5 in p-Pb (x~10^{-5})
  - Sensitive to Shadowing vs. CGC ?
  - However, recent CGC calculation gives R_{pA} similar to nPDF







Now also looking into performance for π^0-π^0 correlation measurements

Open heavy flavour hadrons in p-Pb

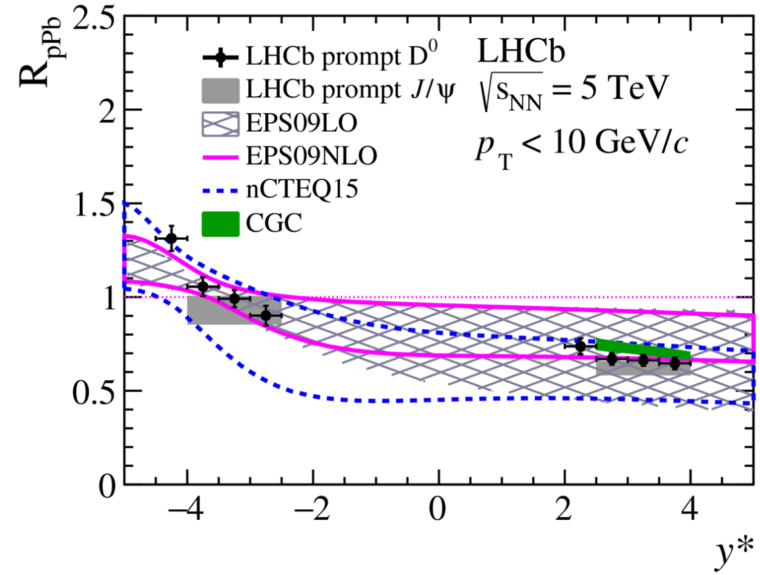
Charm and beauty sensitive to gluon PDF

Open charm

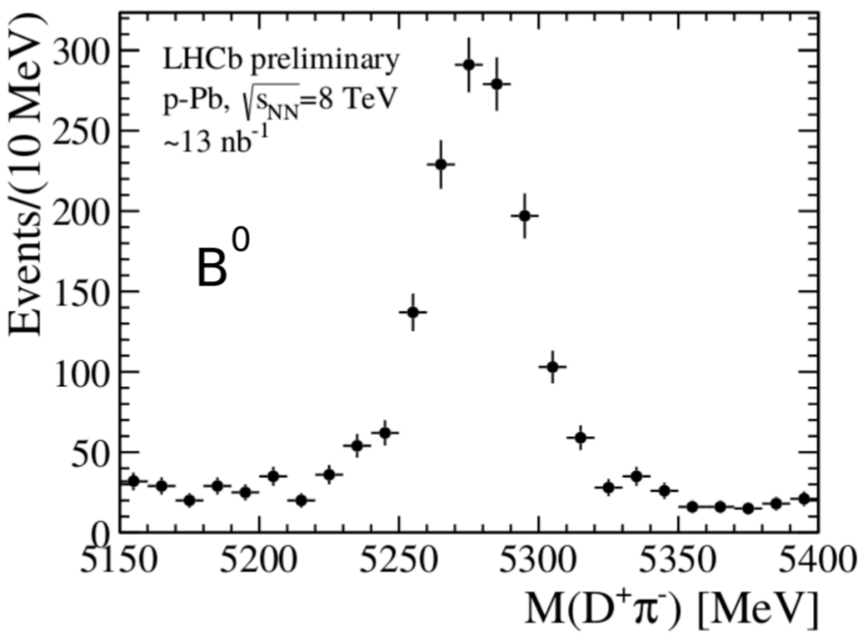
- Run 1 and Run 2: already large statistics.
- Results can already be used to constrain PDF
- Charm at forward rapidity allows one to explore $x \sim 10^{-5}$ for $Q^2 \sim 100 GeV^2$.

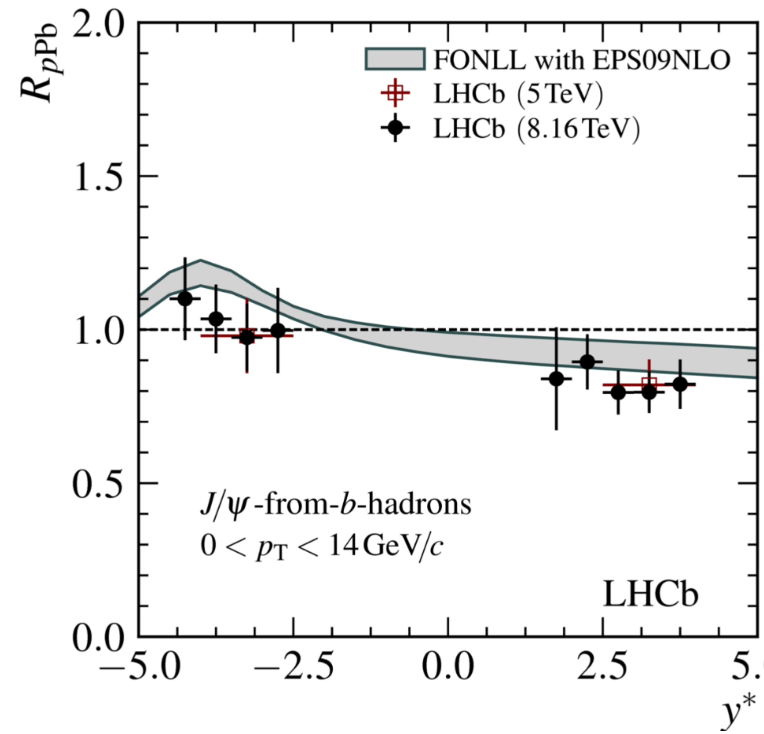
Open beauty

- Measurement via detached J/ψ
- Fully reconstructed b-hadrons
- Run3/4 will allow one precise differential measurements



arXiv:1707.02750
accepted by JHEP





arXiv:1706.07122
accepted by PLB

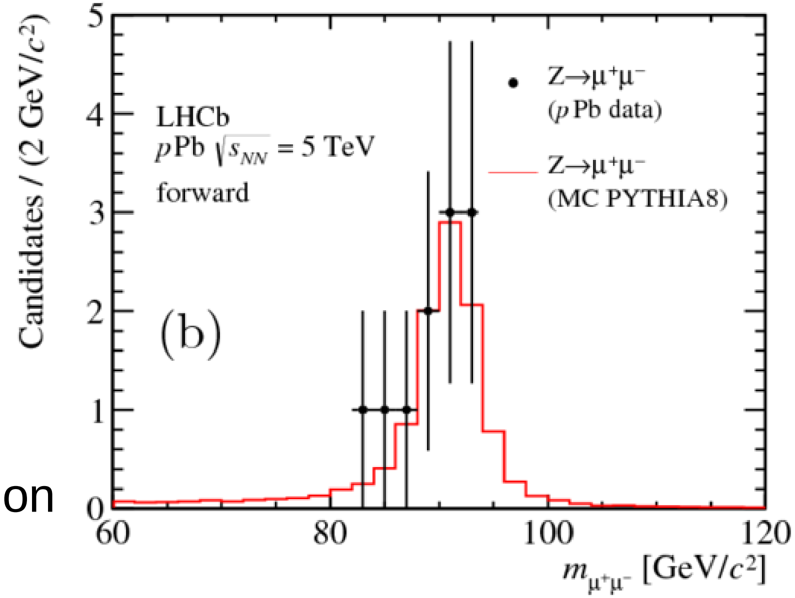
Drell-Yan and EW bosons

EW bosons
- Forward region more sensible to isospin dependence of PDFs
- Complementary to CMS/ATLAS
- Current Run1/2 statistics too limited

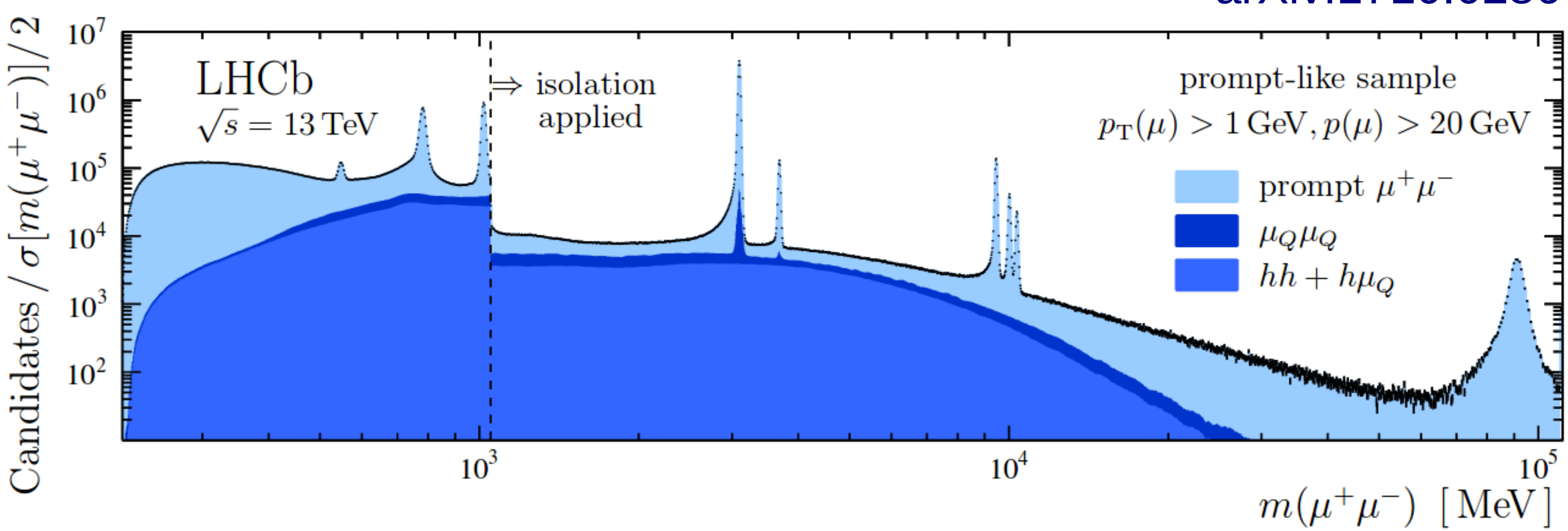
Drell-Yan
- Theoretically clean, experimentally cleanest
- From Z down to J/ψ (and maybe lower)
- HF background can be removed with vertexing and isolation

Needs
- Data driven DY analysis needs 10k reconstructed Z bosons
- In pPb, it corresponds roughly at L=450/nb for Run3/4

JHEP 09 (2014) 030

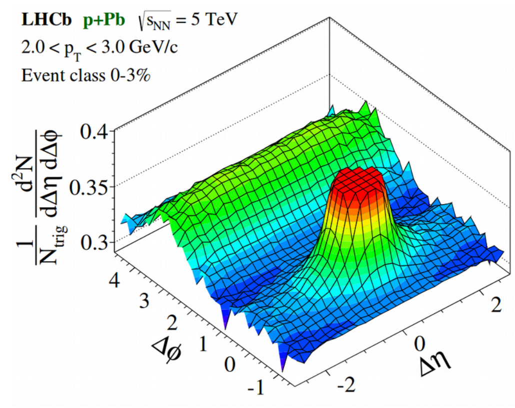


arXiv:1710.02867

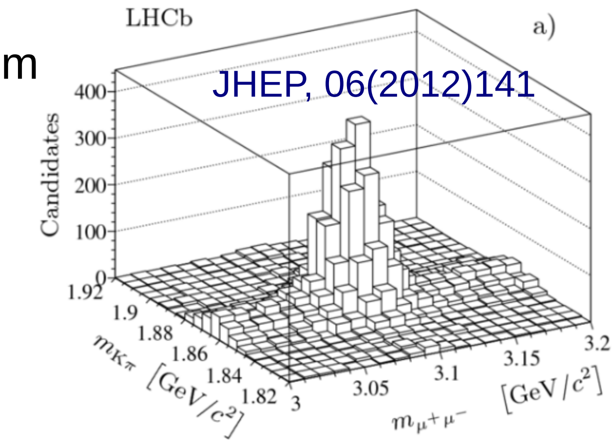


Correlations in pPb

- Two particle correlations can be sensitive to initial state correlations, it will be extended to identified particles
- gamma+jet sensitive at leading oder to the gluon content
- Double charm/beauty correlations. Access to DPS in nuclei and gluon saturation studies
- Upgrade proposals during LS3: CERN-LHCC-2011-001
  - TORCH: Cherenokov time-of-flight to extend PID to lower momentum
  - Tracking stations on magnet sides to extend tracking to lower momentum

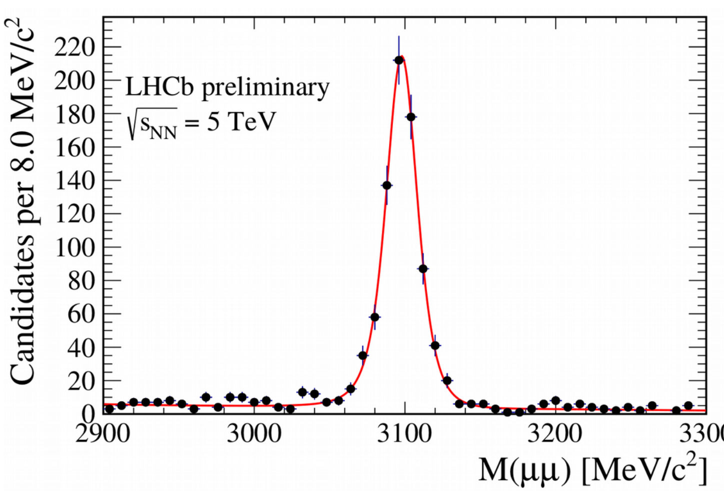


PLB762 (2016) 473-483



UPC

- Well established physics interest for Central Exclusive Production in pp
- Extended to pPb and PbPb, analysis ongoing
- Larger (> x10) PbPb luminosity would allow to study higher mass states and gamma-gamma scattering



Summary

- Controlling nPDF and small-x physics is crucial for precise interpretation of PbPb results
- p-Pb and UPC studies not only reference for PbPb
- Detector upgrades will improve and extend current capabilities
- Larger samples in Run3/4 will allow us to precisely explore the parton phase space
- We will be able to constrain gluon and sea quarks nPDF and look for signs of saturation
- $\gamma\gamma$ collisions: not core heavy-ion physics, but great potential for SM and BSM physics

backups

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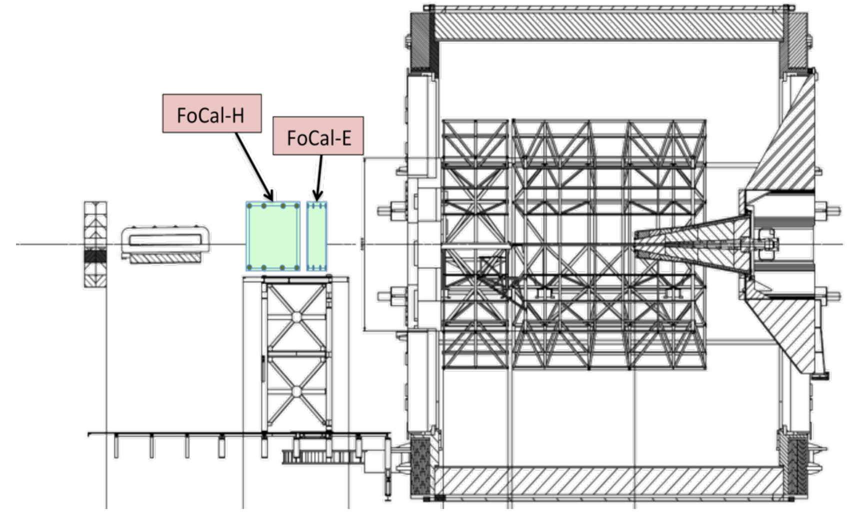
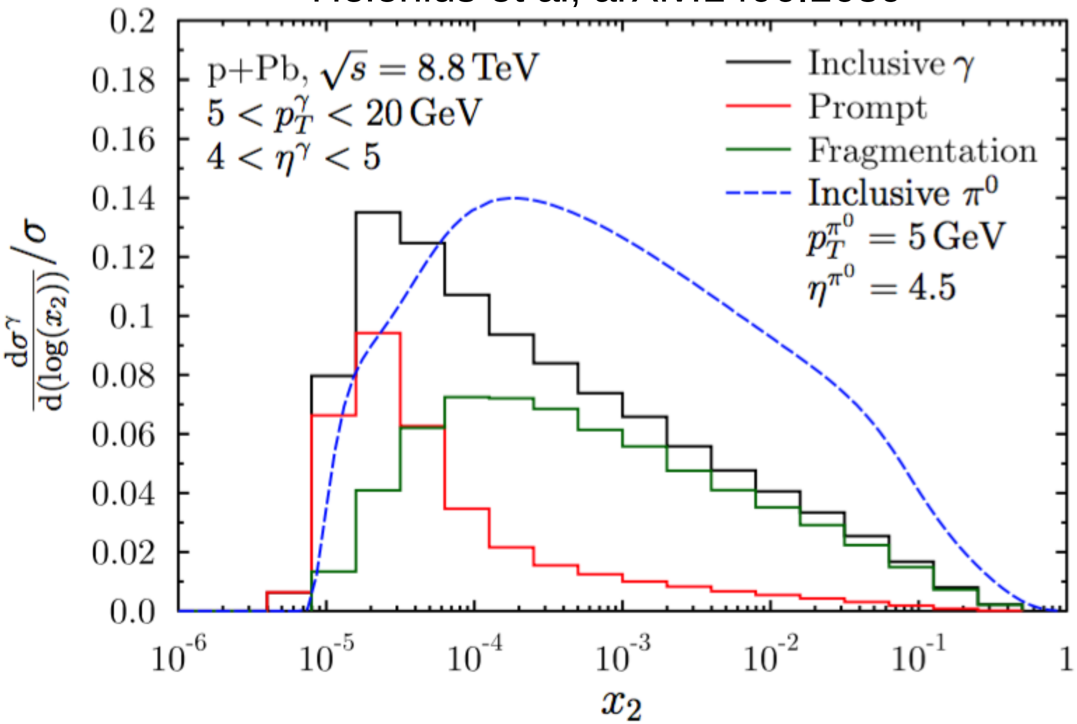
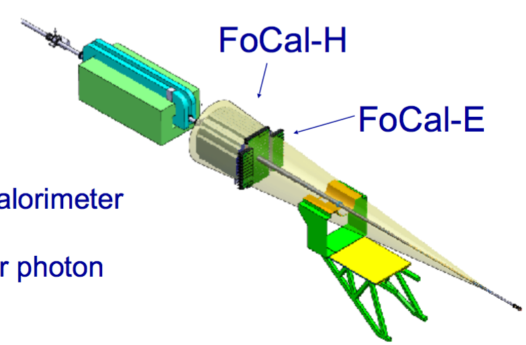


Helenius et al, arXiv:1406.1689



3.2 < η < 5.3



FoCal-E: high-granularity Si-W calorimeter for photons and π^0
FoCal-H: hadronic calorimeter for photon isolation and jets

Observables:
- π^0
- Direct (isolated) photons
- Jets

Advantage in ALICE:
forward region not instrumented;
'unobstructed' view of interaction point

LHCb TORCH

LHCb-PROC-2015-001

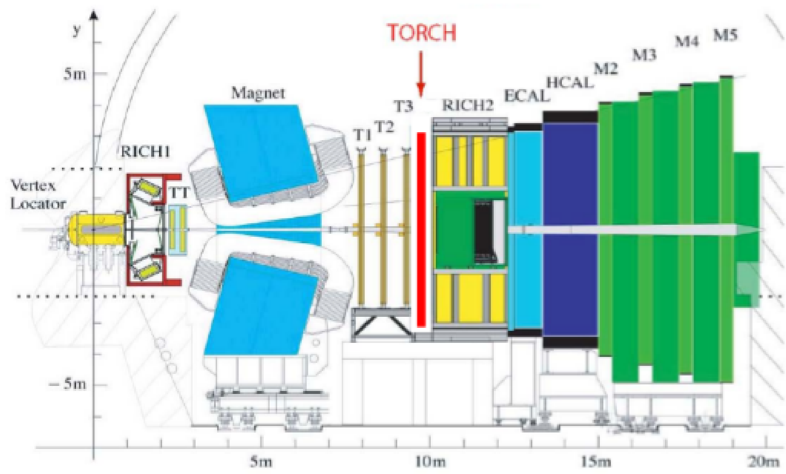


Fig. 1. Side view of LHCb with the proposed position of TORCH between the tracking stations T1-T3 to the left and RICH2 to the right.

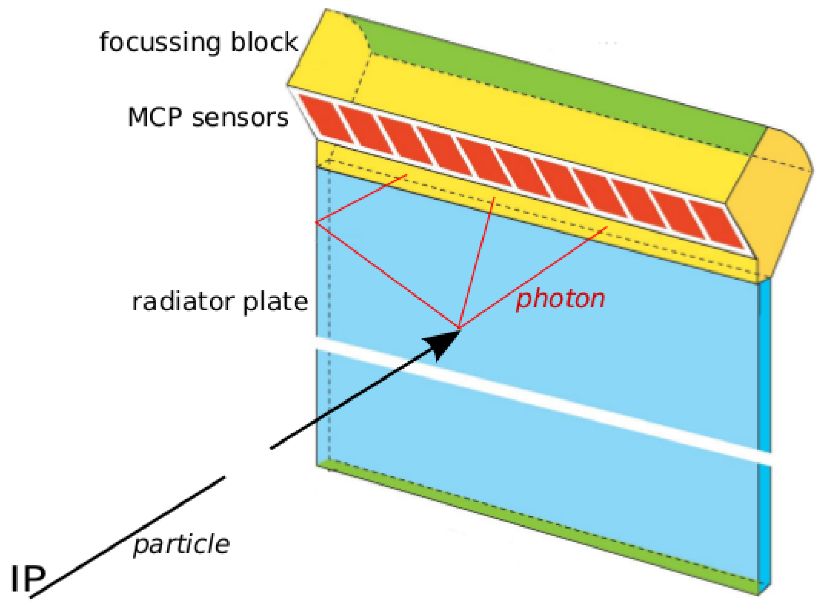


Fig. 2. TORCH principle with the particle path from the IP to the radiator shown in black and three sample photon propagation paths shown in red.