Top-quark & Higgs production at FCC-ions

Ions at the FCC Meeting
CERN, Nov. 2015

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CERN

Introduction

- Physics with top-quarks at FCC-ions:

→ Full results available on x-sections, yields and impact on nPDF
[DdE, K.Krajczár, H.Paukkunen PLB746 (2015) 64-72]

→ Extra studies ongoing (or to be carried out): top-quark energy loss,...

→ I will show proposed plots & tables to be included in the report

- Physics with Higgs boson at FCC-ions

→ Work in progress to be submitted within a few months
[DdE, in preparation]

→ I will show preliminary plots & numbers to be included in the report

Motivations for top studies at FCC-ions

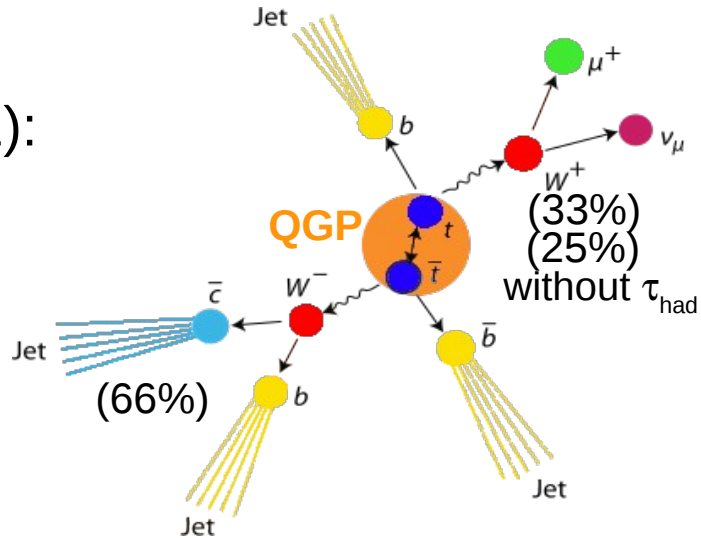
- Top-quark decays (τ~0.1 fm/c) before hadronization into W+b (BR~100%,V_{tb}~1):

  ttbar → bbar + 4jets (44%)

  ttbar → bbar + 2jets + 1ℓ + MET(ν) (44%)

  ttbar → bbar + 2ℓ + MET(2ν) (11%,6%)

  single t → b + 1ℓ + MET(ν) (33%,25%)



- Motivations for measurement:

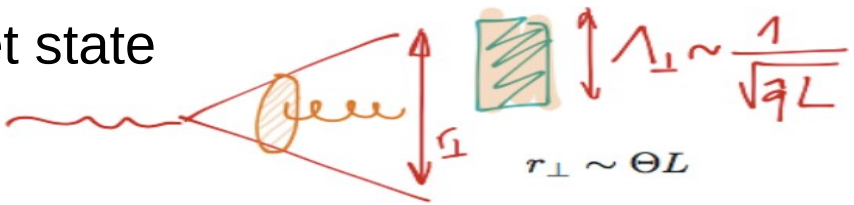
→ One of the few elementary particles (with τ,H) experimentally unobserved so far in A-A collisions.

→ Probes gluon nPDF in unexplored range: x~$m_t/\sqrt{s}$~10^{-2},Q~m_t~173 GeV

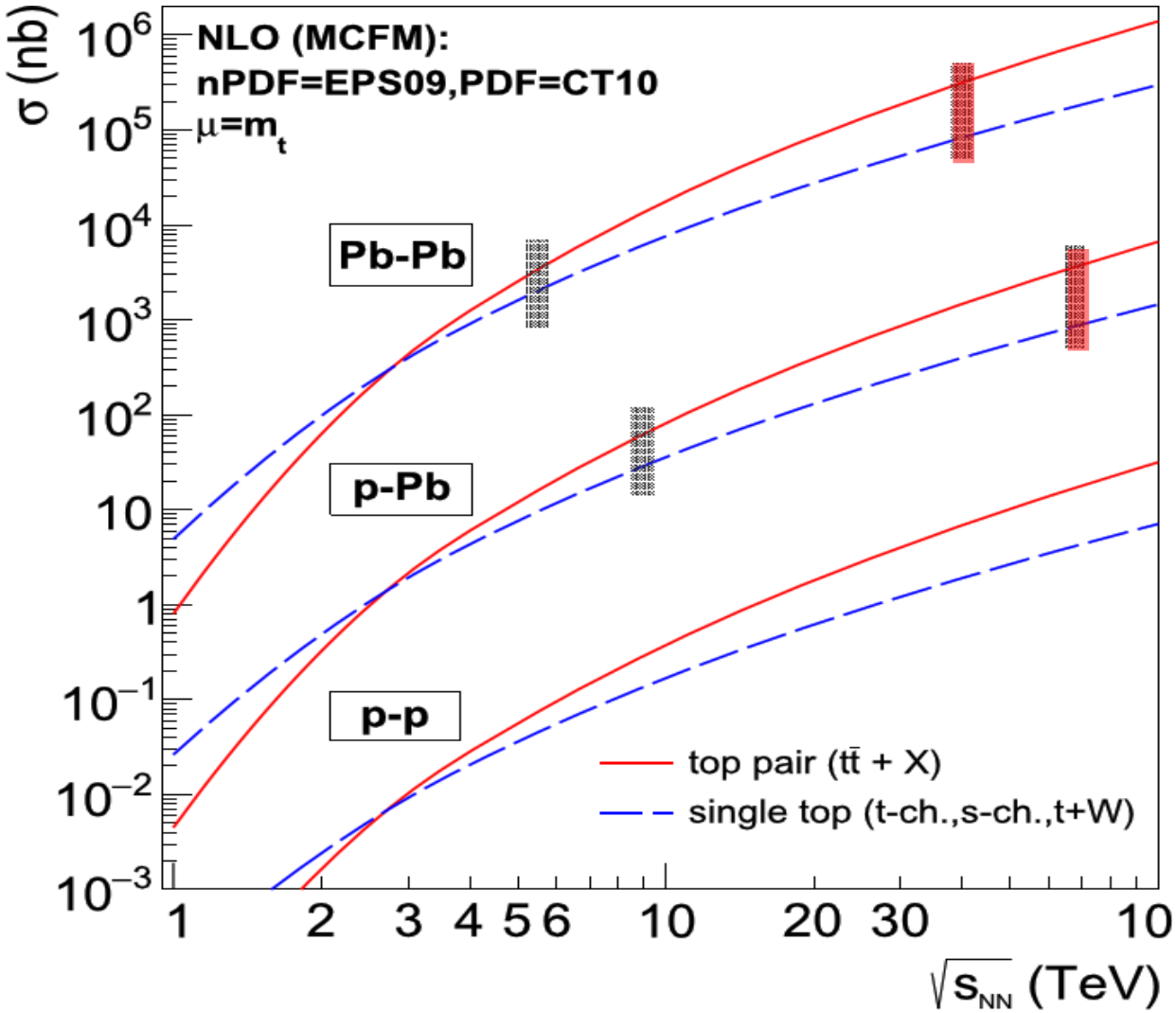
→ Decay within-QGP: Colour reconnection of decay b,q's ?

→ Boosted single-top (e.g. 1 TeV): τ~1 fm/c (g radiation in QGP)

→ Boosted t-tbar pair = color-singlet state probes medium opacity at different time-scales



Single & pair top x-sections in p-Pb, Pb-Pb



- Pb-Pb at FCC(39 TeV):
  - σ(ttbar) ~ 300 μb
  - σ(single-t) ~ 70 μb
- p-Pb at FCC(63 TeV):
  - σ(ttbar) ~ 3.2 μb
  - σ(single-t) ~ 780 nb

nPDF (anti)shadowing:

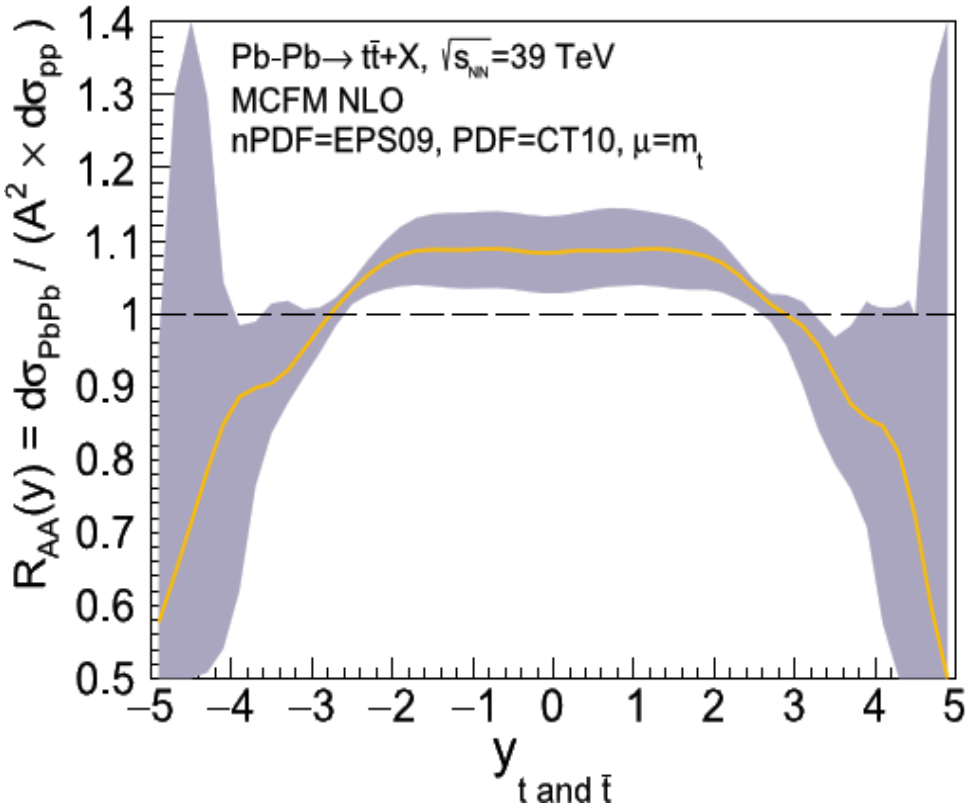
- increases σ_{tt} by +(3-8)%
- changes $\sigma_{single\text{-}t}$ by ±2%

➜ Top-pair x-sections increase by ×55–85 from LHC to FCC

➜ Single-top x-sections increase by ×25–30 from LHC to FCC

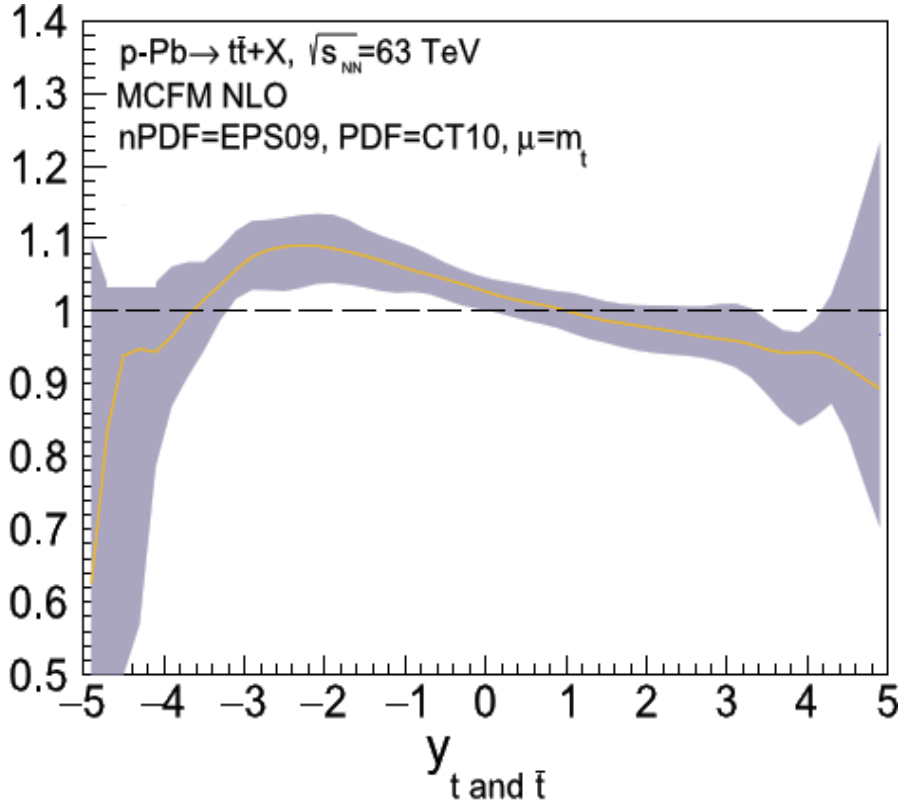
$R_{AA}(y)$ for top-pair in p-Pb, Pb-Pb

- Pb-Pb at FCC(39 TeV):



- nPDF effects: –25% (fwd/bckwd)
  +10% (central)

- p-Pb at FCC(63 TeV):



- nPDF effects: –(10-20)% (fwd/bckwd)
  ±10% (central)

Expected t-tbar & single-top yields

- Leptonic final states:
  ttbar → bbar + 2ℓ (e,μ) + MET(2ν)
  single t → b + 1ℓ (e,μ) + MET(ν)

Analysis cuts
b-jets (anti-k_T algorithm with $R = 0.5$): $p_T > 30$ GeV; $\|\eta\| < 2.5$ (LHC), 5 (FCC)
charged leptons $\ell(R_{isol} = 0.3)$: $p_T > 20$ GeV; $\|\eta\| < 2.5$ (LHC), 5 (FCC)
neutrinos: $\not{E}_T > 40$ GeV

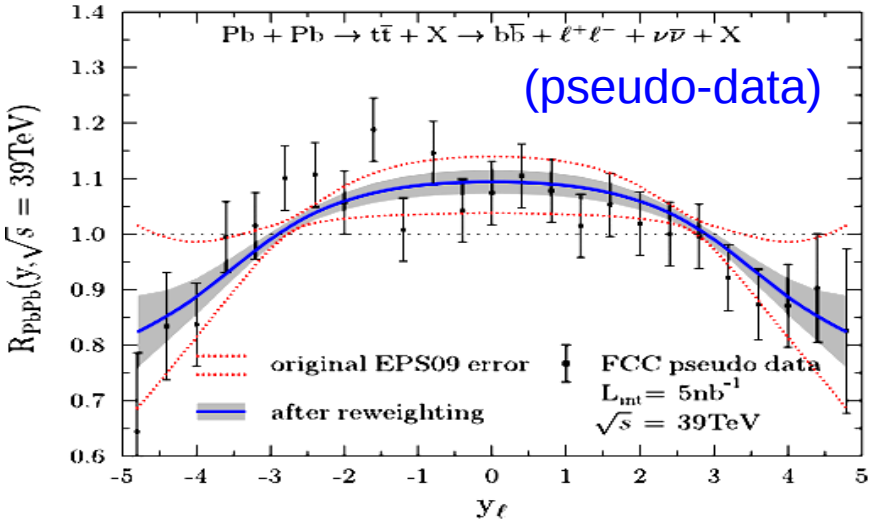
- Expected t-tbar pairs & single-top in Pb-Pb, p-Pb

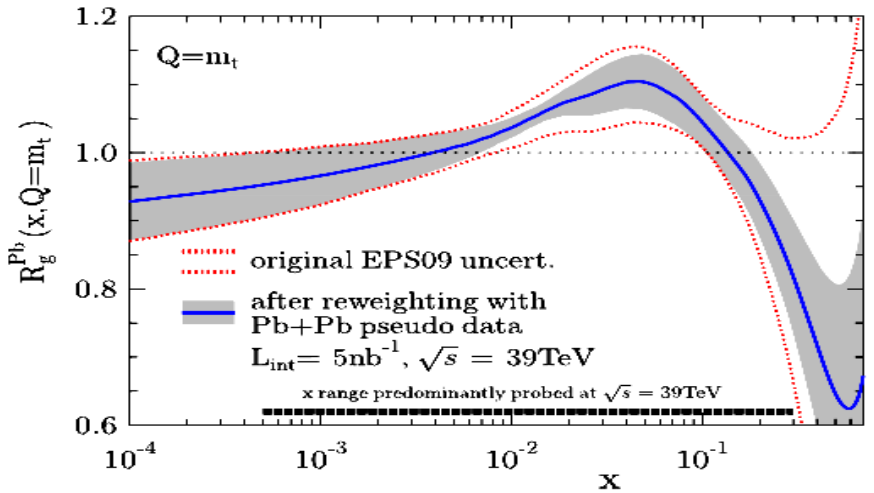
System	$\sqrt{s}$	$\mathcal{L}_{int}$	Number of top + antitop quarks $t\bar{t} \to b\bar{b}\,\ell\ell\,\nu\nu$	Number of top + antitop quarks $tW \to b\,\ell\ell\,\nu\nu$
Pb–Pb	39. TeV	5 nb^{-1}	47 000	1300
p–Pb	63. TeV	1 pb^{-1}	100 000	2600

Large statistics: 50.000–100.000 top-quarks/year in Pb-Pb, p-Pb

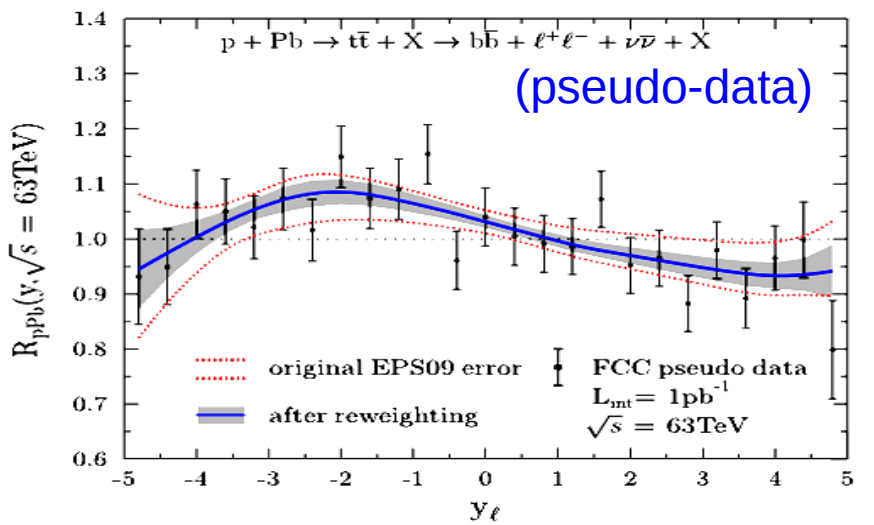
$R_{AA}(y)$ for $\ell^{\pm}$ & R_g^{Pb} from t-tbar in p-Pb, Pb-Pb

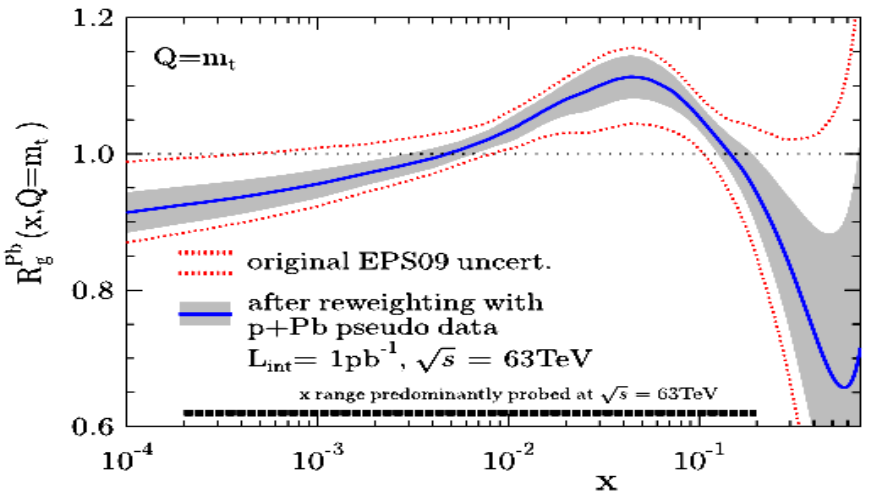
- Pb-Pb at FCC(39 TeV):





- p-Pb at FCC(63 TeV):

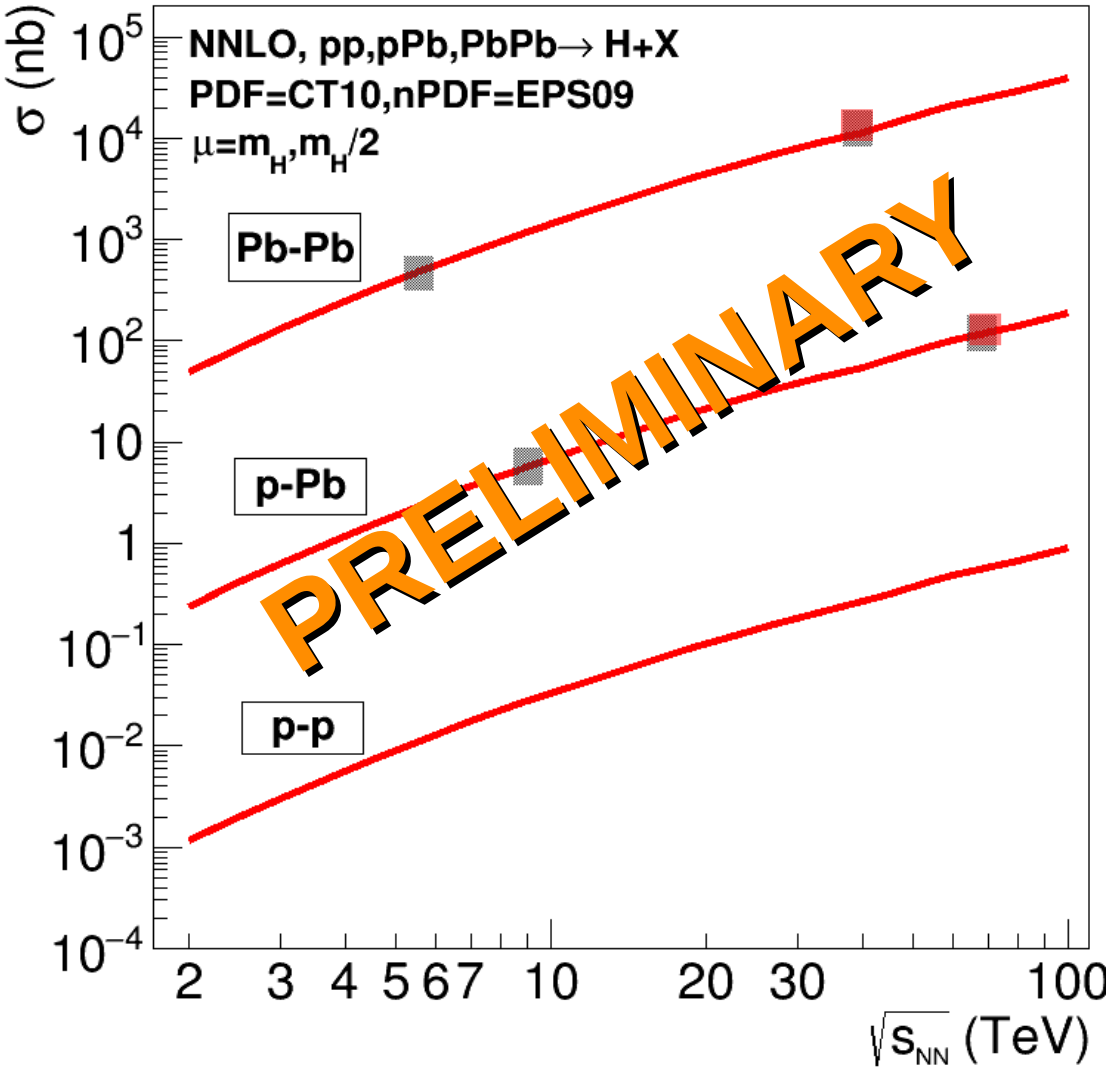




- nPDF effects (iso-lepton): ±(10-20)%
- nPDF effects (iso-lepton): ±10%

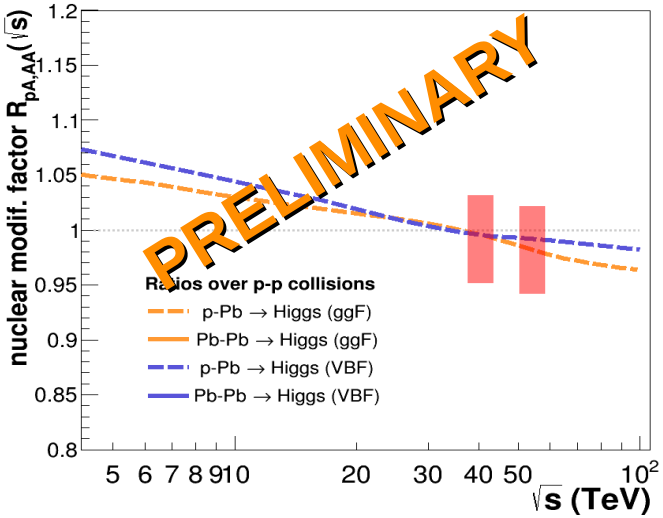
Nuclear (EPS09 NLO) gluon uncertainties reduced by ~70%.

Higgs x-sections in p-Pb, Pb-Pb



- Pb-Pb at FCC(39 TeV): σ(H) ~ 12 μb
- p-Pb at FCC(63 TeV): σ(H) ~ 120 nb

Negligible nPDF effects at FCC PbPb, pPb:



➜ Higgs x-sections increase by ×20–30 from LHC to FCC

Expected Higgs yields

- Final-states (high-precision channels):
  $H \rightarrow \gamma\gamma$
  $H \rightarrow Z\,Z^* \rightarrow 4\ell$ (e,μ)

  Ongoing (simplified) replication of CMS/ATLAS Run-1 analyses with FCC-scaled backgrounds.

- PRELIMINARY ~200 H(γγ) counts expected in Pb-Pb, p-Pb for L_{int} nominal.

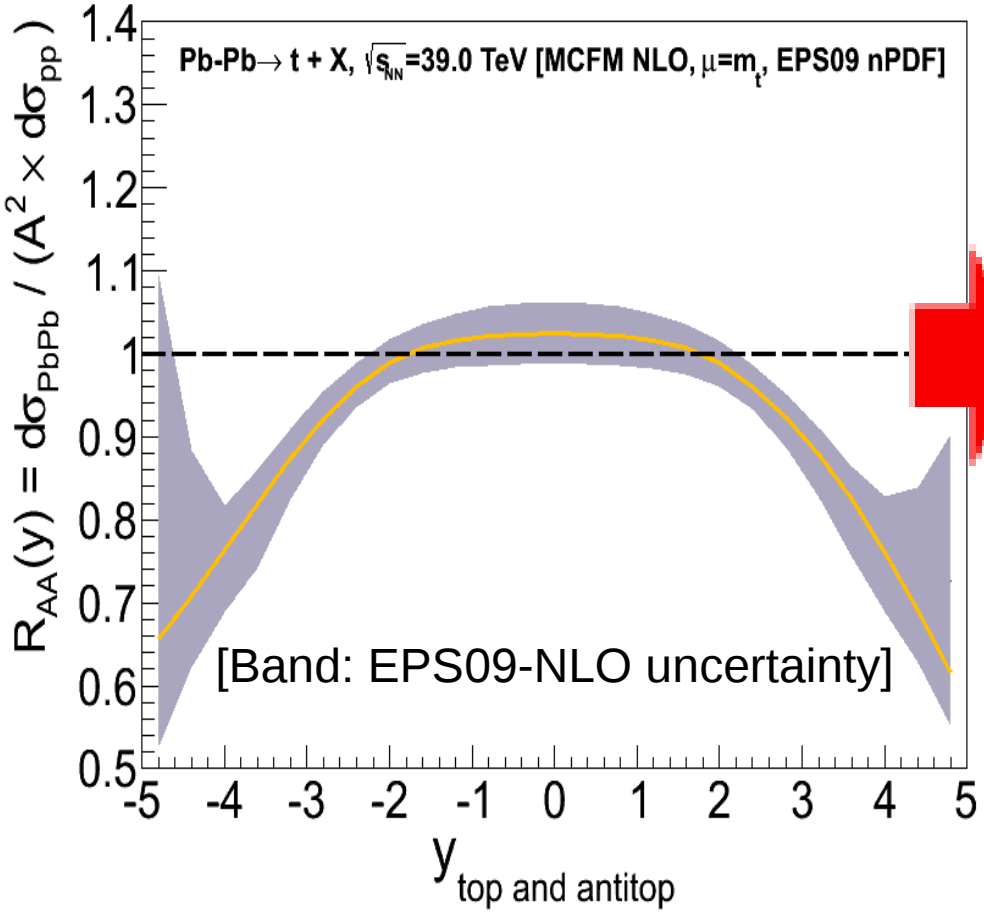
  Note: ~500 H(γγ) counts at 8 TeV for Run-1 5σ-discovery

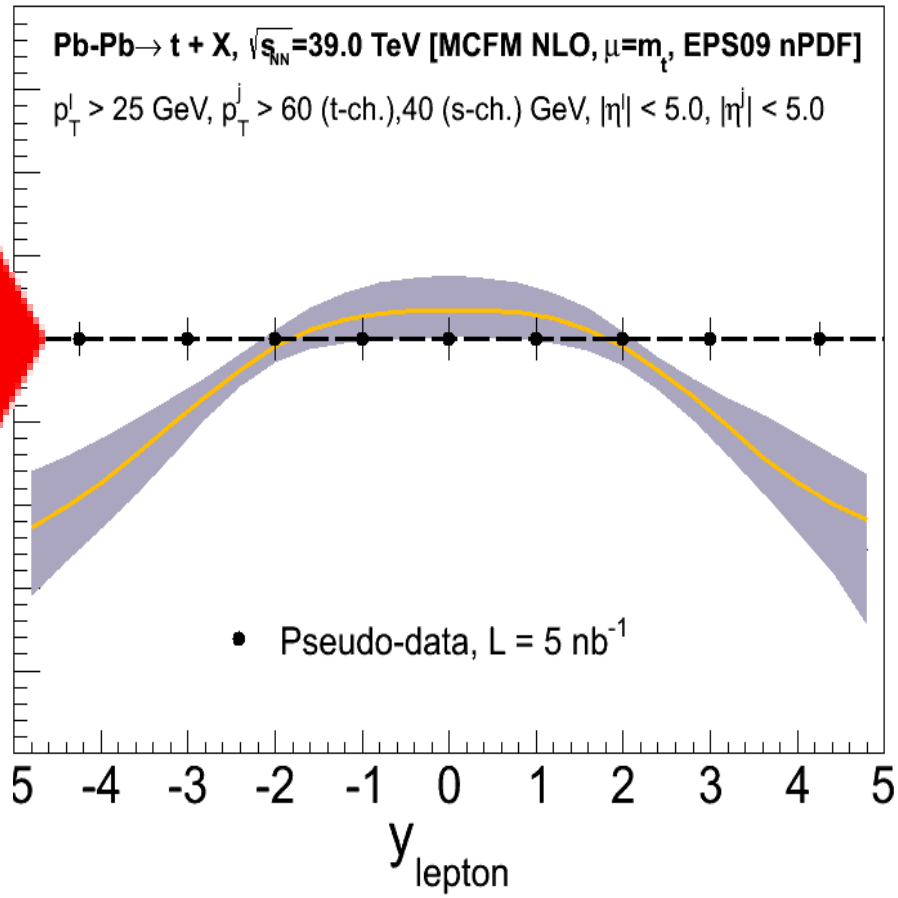
  i.e. combination of H(γγ)+H(ZZ*) should yield 5σ.

Back-up slides

$R_{AA}(y)$ for PbPb → single-t+X (39 TeV)

- Top quark y-distrib. (no cuts):
- Isolated lepton y-distrib. after cuts:

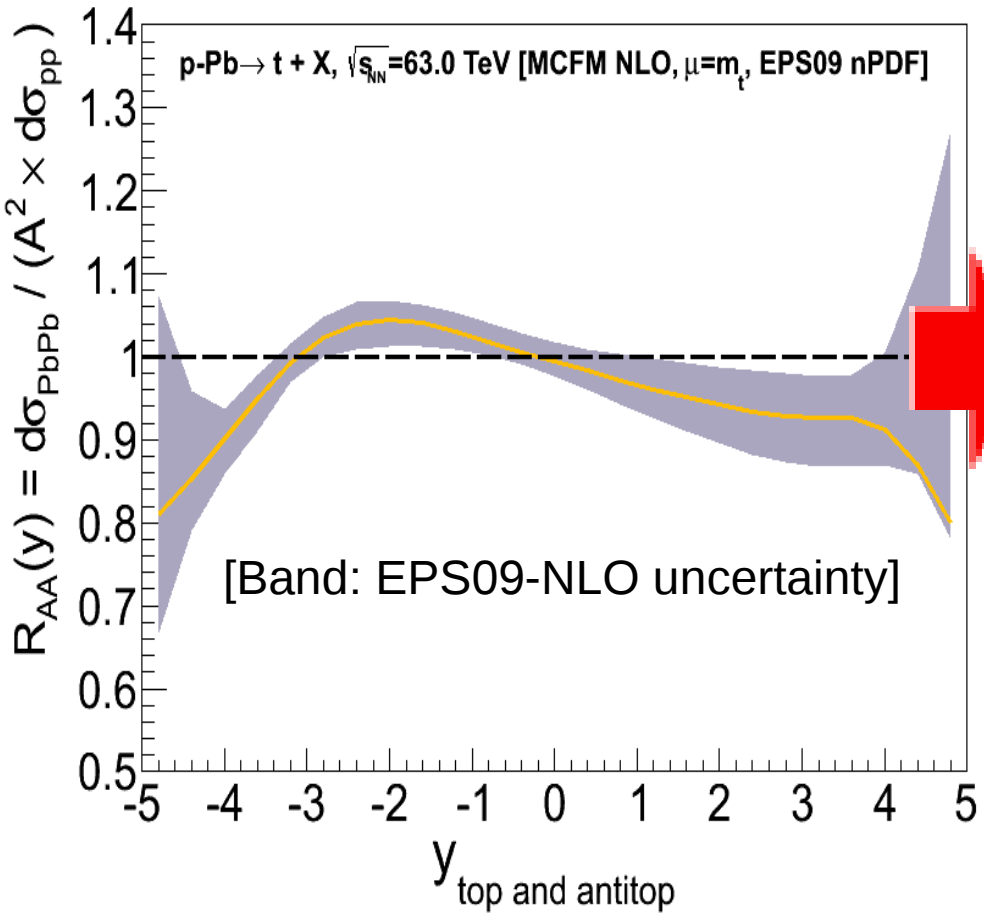


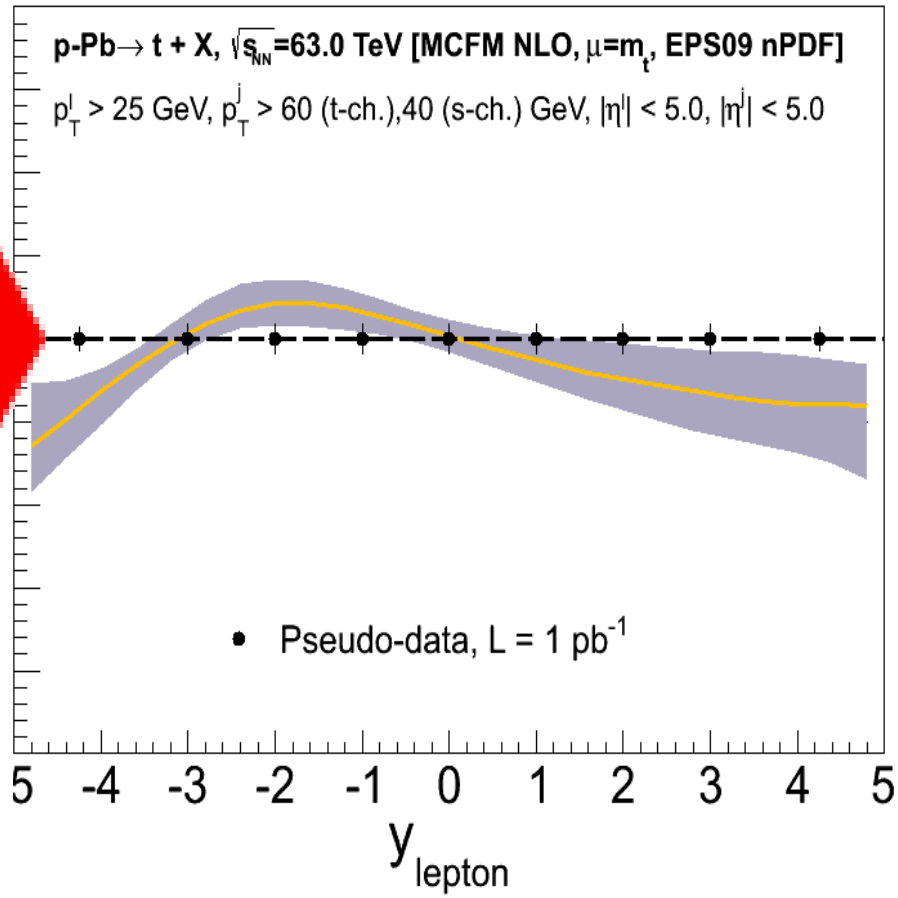


- nPDF effects (top):-30% (fwd/bckwd)
  Smaller nPDF uncertainties than t-tbar
- nPDF effects (lepton):-20% (fwd/bckwd)
  Strong constraining power
  (iff large background controlled)

$R_{AA}(y)$ for pPb → single-t+X (63 TeV)

- Top quark y-distrib. (no cuts):
- Isolated lepton y-distrib. after cuts:





- nPDF effects: -20% (bckwd)
  -10% (forward)
  Smaller nPDF uncertainties than t-tbar
- nPDF effects (lepton): ±10% (fwd/bckwd)
  Strong constraining power
  (iff large background controlled)