Observation of $t\bar{t}$ production in p+Pb collisions

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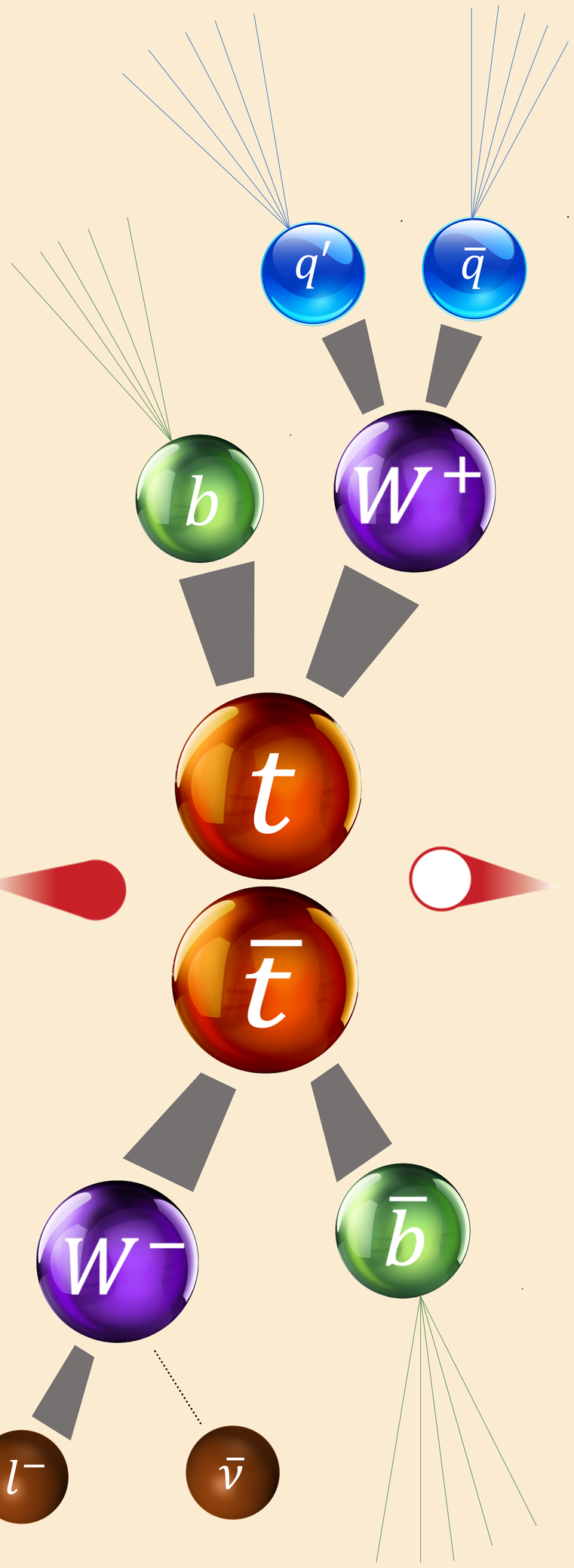
Motivation

The top quark, the heaviest elementary particle, is short-lived and decays through $t \to Wb$ with a branching ratio of almost 100%.

In p-Pb collisions, top-quark production is expected to be sensitive to nuclear modifications of parton distribution functions at high Bjoerken-x values, which are difficult to access experimentally with other available probes.

The result paves a new way for physicists to study Parton Distribution Functions (PDFs) – which describe how a proton's momentum is distributed among its constituent quarks and gluons – in a new kinematic domain.



Data & Monte Carlo samples

- p+Pb data at $\sqrt{s_{NN}}$ = 8.16 TeV collected in 2016 (**165 nb^{-1}**)
- Single-top, $t\bar{t}$ (+alternative for systematics), W+jets (W+b, W+c, W+light), Z+jets (Z+b, Z+c, Z+light), Diboson.

Analysis strategy

$H_T^{\ell,j}$ - the scalar sum of all lepton and jet p_T is used a discriminating observables based on separation power study and simultaneously fitted in six signal regions

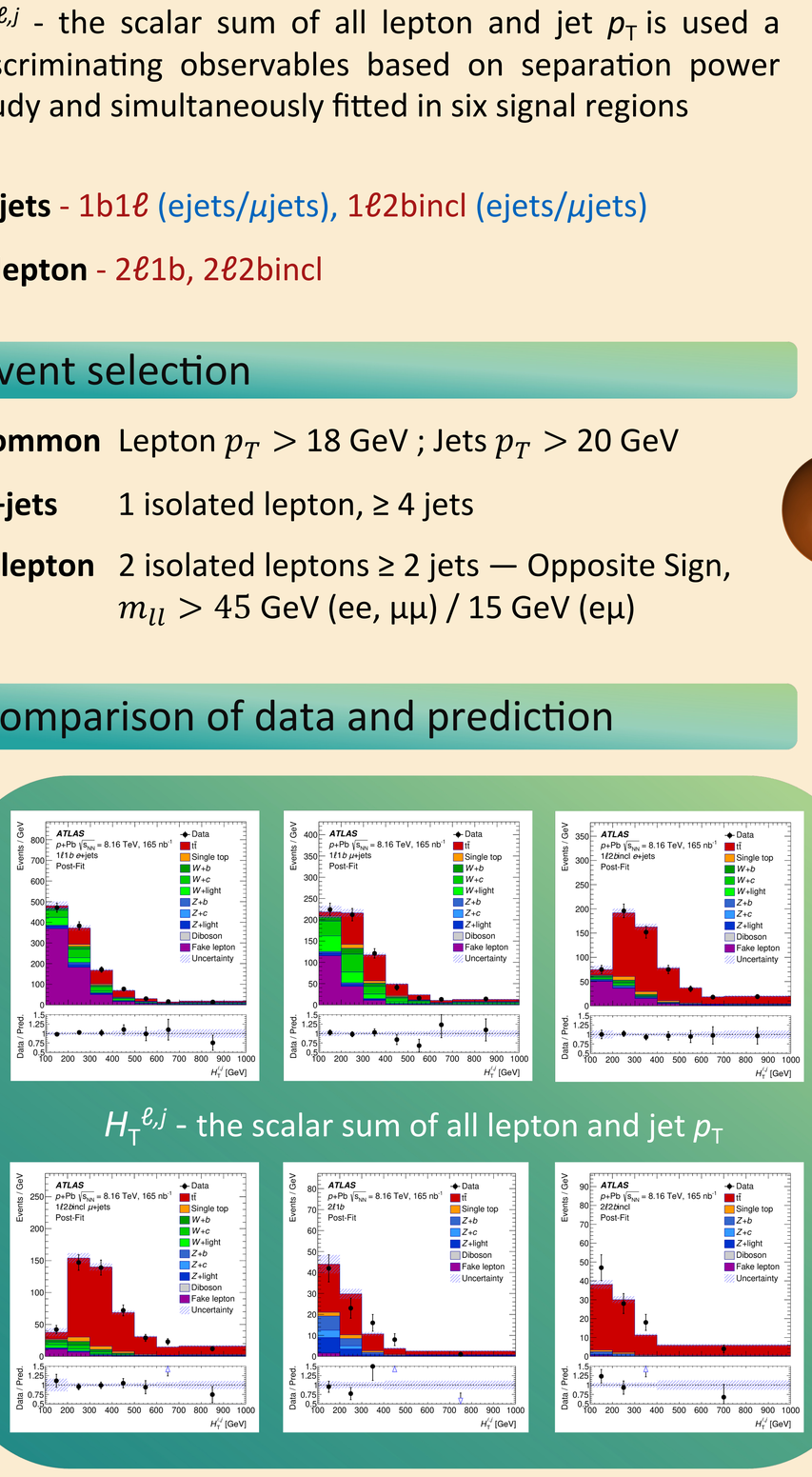
ℓ+jets - 1b1ℓ (ejets/μjets), 1ℓ2bincl (ejets/μjets)

Dilepton - 2ℓ1b, 2ℓ2bincl

Event selection

Common	Lepton $p_T > 18$ GeV ; Jets $p_T > 20$ GeV
ℓ+jets	1 isolated lepton, ≥ 4 jets
Dilepton	2 isolated leptons ≥ 2 jets — Opposite Sign, $m_{ll} > 45$ GeV (ee, μμ) / 15 GeV (eμ)

Comparison of data and prediction



$H_T^{\ell,j}$ - the scalar sum of all lepton and jet p_T

Background overview

The main background contributions:

- W+jets (ℓ+jets)
- Z+jets (dilepton)
- non-prompt and fake lepton background

Data driven Matrix Method has been used to estimate the fakes.

Systematic uncertainties

Luminosity, signal-background modelling, flavour, lepton-jet reconstructions and fake systematics.

Source	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ unc. up [%]	unc. down [%]
Jet energy scale	+4.6	-4.1
$t\bar{t}$ generator	+4.5	-4.0
Fake-lepton background	+3.1	-2.8
Background	+3.1	-2.6
Luminosity	+2.8	-2.5
Muon uncertainties	+2.3	-2.0
W+jets	+2.2	-2.0
b-tagging	+2.1	-1.9
Other Syst.	+2.0	-1.8

Results

The inclusive cross-section is extracted using a profile likelihood fit. The measured $\mu_{t\bar{t}}$ value is translated to the inclusive cross-section ($\sigma_{t\bar{t}}$).

$$\sigma_{t\bar{t}} = 58.1 + 2.0\,(stat.) \,^{+4.8}_{-4.4}\,((syst.)$$

The significance is well above 5 in both individual and combined channel fits. This establishes the observation of $t\bar{t}$ production in the individual ℓ+jets and dilepton channels.

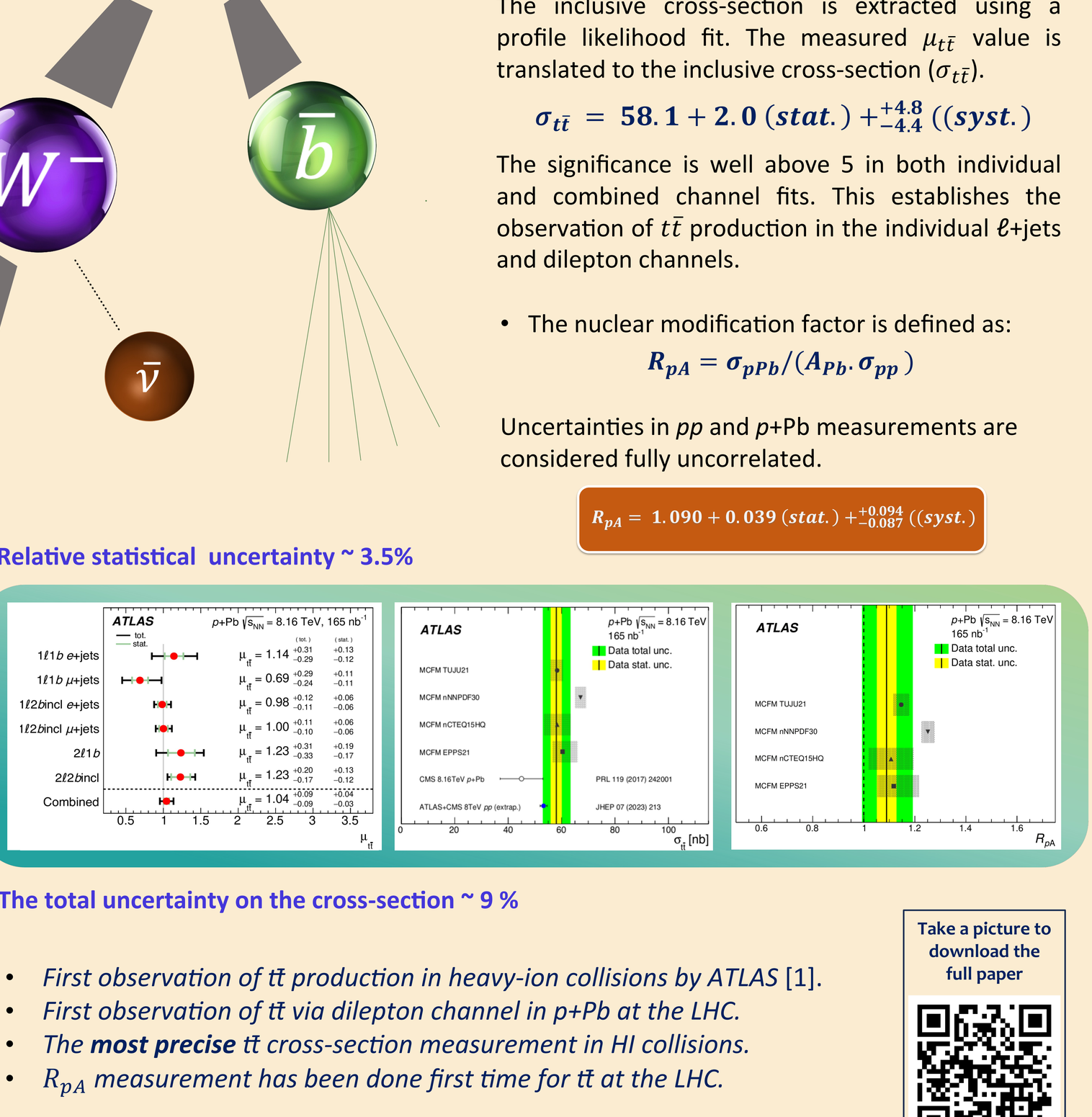
- The nuclear modification factor is defined as:

$$R_{pA} = \sigma_{pPb}/(A_{Pb}.\sigma_{pp})$$

Uncertainties in pp and p+Pb measurements are considered fully uncorrelated.

$$R_{pA} = 1.090 + 0.039\,(stat.) \,^{+0.094}_{-0.087}\,((syst.)$$

Relative statistical uncertainty ~ 3.5%



The total uncertainty on the cross-section ~ 9 %

- *First observation of $t\bar{t}$ production in heavy-ion collisions by ATLAS* [1].
- *First observation of $t\bar{t}$ via dilepton channel in p+Pb at the LHC.*
- *The **most precise** $t\bar{t}$ cross-section measurement in HI collisions.*
- *R_{pA} measurement has been done first time for $t\bar{t}$ at the LHC.*

Take a picture to download the full paper

[1] https://arxiv.org/pdf/2405.05078