W, Z AND QCD

Philippe Calfayan
Indiana University

On behalf of the ATLAS and CMS Collaborations

La Thuile
Les Rencontres de Physique de la Valle d'Aoste

March 8, 2023

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, under Award Number DE-SC0010120.

Introduction

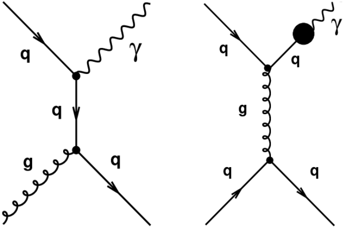
- Measurements of W and Z vector-boson, photon (γ), and jets production cross sections (σ) at the LHC are central in the LHC physics program in that they allow to:
  - Achieve precision tests of perturbative Quantum ChromoDynamics (pQCD)
  - Measure fundamental parameters of the Standard Model (SM)
  - Improve our understanding of Parton Density Functions (PDF)
  - Understand important background (bkg) to searches Beyond the Standard Model (BSM) and Higgs measurements
  - Provide important input to simulations

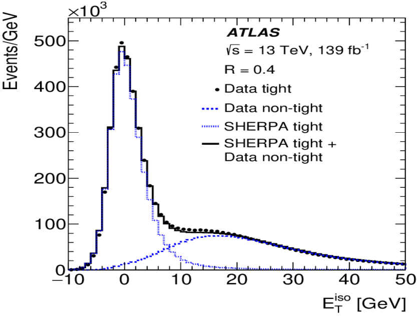
- Recent results from both CMS and ATLAS experiments are presented:
  - Inclusive γ and multijet (MJ) productions, that are dominated by QCD processes, and can be sensitive to the strong coupling constant (α_s) and the gluon (g) PDF
  - τ-leptons polarization in $\mathrm{Z} \to \tau\tau$ decays, which allow to infer the weak mixing angle ($\sin\theta_W^{eff}$)
  - Rarer processes, such as $\mathrm{W} + c$ production, that are sensitive to strange (s) PDF

[pQCD tests][ATLAS] Inclusive photon production

Submitted to JHEP, hep-ex/2302.00510, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

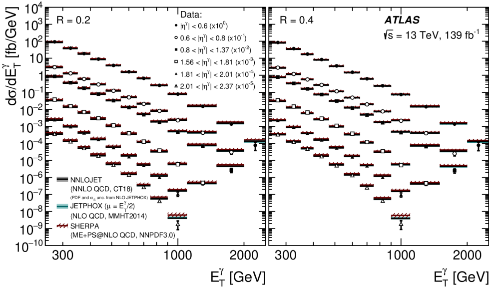
- Prompt photon production: direct and fragmentation processes primarily via $qg \to q\gamma$
- Probe pQCD in cleaner environnement than MJ, less hadronization effects
- Sensitive to constrain g PDF and able to reduce its uncertainty ($E_T^\gamma > 250\,\mathrm{GeV}$)
- γ isolation necessary to separate from neutral hadrons decays: E_T^{iso} around γ in fixed cone with $R = 0.4$ or 0.2 is constrained
- Main bkg: MJ with mis-id γ, estimated from data-driven method relying on data regions orthogonal in γ-quality and E_T^{iso}
- Total uncertainty on unfolded σ: 3 to 20% in (E_T^γ, $|\eta^\gamma|$) mostly from γ energy scale, MJ modelling ($R = 0.2$), and pile-up ($R = 0.4$)

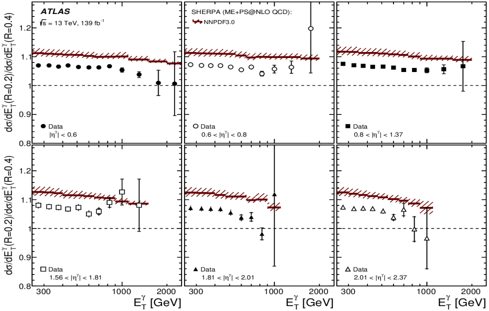




[pQCD tests][ATLAS] Inclusive photon production

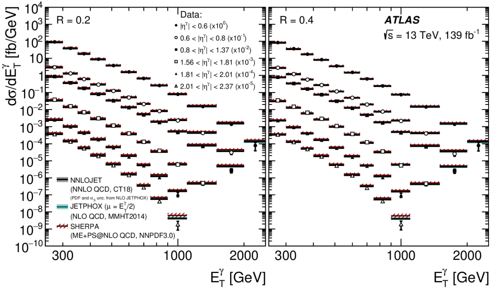
- Differential σ unfolded to particle-level, compared to SHERPA 2.2.2, and to JETPHOX and NNLOJET (with corrected parton level)
- Good predictions modelling overall
- σ larger for iso $R = 0.2$ than 0.4
- SHERPA (NLO) has higher σ (has parton shower, LO for 3-4 jets)
- $\sigma(R = 0.2)/\sigma(R = 0.4)$ modelling:
  - SHERPA (NLO) has higher ratio (no explicit fragmentation calculation)
  - JETPHOX (NLO) with different PDF shows good agreement overall
  - NNLOJET (NNLO) describes data very well

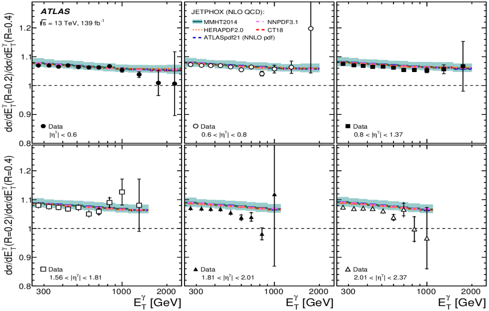




[pQCD tests][ATLAS] Inclusive photon production

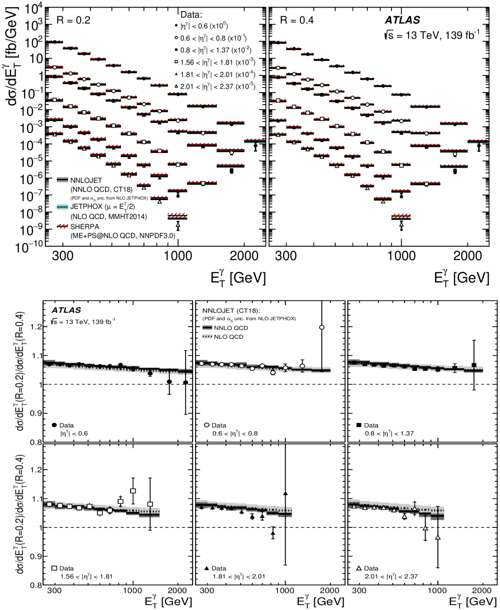
- Differential σ unfolded to particle-level, compared to SHERPA 2.2.2, and to JETPHOX and NNLOJET (with corrected parton level)
- Good predictions modelling overall
- σ larger for iso $R = 0.2$ than 0.4
- SHERPA (NLO) has higher σ (has parton shower, LO for 3-4 jets)
- $\sigma(R = 0.2)/\sigma(R = 0.4)$ modelling:
  - SHERPA (NLO) has higher ratio (no explicit fragmentation calculation)
  - JETPHOX (NLO) with different PDF shows good agreement overall
  - NNLOJET (NNLO) describes data very well





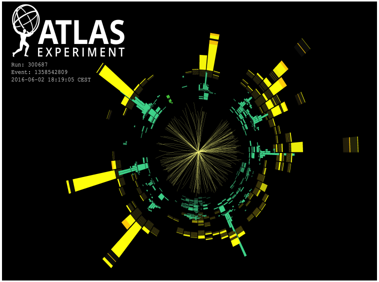
[pQCD tests][ATLAS] Inclusive photon production

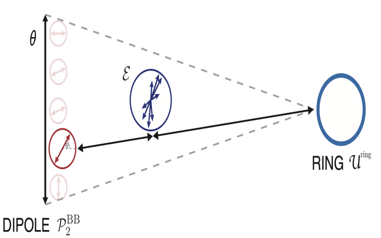
- Differential σ unfolded to particle-level, compared to SHERPA 2.2.2, and to JETPHOX and NNLOJET (with corrected parton level)
- Good predictions modelling overall
- σ larger for iso $R = 0.2$ than 0.4
- SHERPA (NLO) has higher σ (has parton shower, LO for 3-4 jets)
- $\sigma(R = 0.2)/\sigma(R = 0.4)$ modelling:
  - SHERPA (NLO) has higher ratio (no explicit fragmentation calculation)
  - JETPHOX (NLO) with different PDF shows good agreement overall
  - NNLOJET (NNLO) describes data very well



[pQCD tests][ATLAS] "Event shape" observables in multijet events

- Event shape defined as function of final state particles to characterize hadronic energy flow
- Transverse energy-energy correlation (TEEC): E_T-weighted azimuthal (ϕ) differences (in $\cos\phi$) between jet pairs
  $\rightarrow$ infrared-safe, NNLO corrections to 3-jets simulation, sensitive to g radiation
- Azimuthal TEEC (ATEEC): difference between forward and backward part of TEEC
  $\rightarrow$ cancels uncertainties symmetric in $\cos\phi$
- Event isotropy: measures distance I($\mathcal{E}$) between collider event and isotropic reference radiation pattern in terms of Energy-Mover's distance
  $\rightarrow$ infrared & colinear-safe, sensitive to isotropic events, probe specific QCD phase space
- Event shape measured vs $H_{T2} = p_T^{jet1} + p_T^{jet2}$



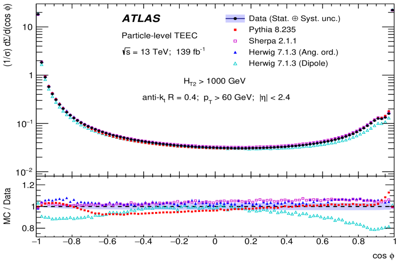


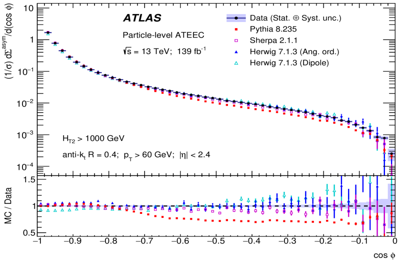
[pQCD tests][ATLAS] (A)TEEC in multijet events

Submitted to JHEP, hep-ex/2301.09351, $\mathcal{L} = 139\,\text{fb}^{-1}$ at $13\,\text{TeV}$

- Particle-level unfolded TEEC depicts back-to-back, wide-angle radiated, and collinear jets in $\cos\phi$, compared to LO (PYTHI8 and SHERPA 2.2.1) and NLO (HERWIG7) MC with different showering
- Main uncertainties from jet calibration and MC modelling up to 2% (1%) and 2%(0.5%) for (A)TEEC
- Unfolded (A)TEEC also compared to NNLO parton-level (corrected) prediction using OPENLOOPS2, FIVEPOINTAMPLITUDES, and PENTAGONFUNCTIONS++ (first time)

→ Very good agreement overall, with MC slightly above data at high H_{T2} (may be limited PDF accuracy at high Bjorken x)



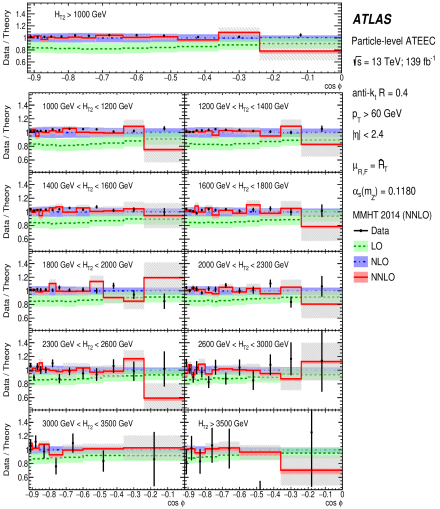


[pQCD tests][ATLAS] (A)TEEC in multijet events

Submitted to JHEP, hep-ex/2301.09351, $\mathcal{L} = 139\,\text{fb}^{-1}$ at $13\,\text{TeV}$

- Particle-level unfolded TEEC depicts back-to-back, wide-angle radiated, and collinear jets in $\cos\phi$, compared to LO (PYTHI8 and SHERPA 2.2.1) and NLO (HERWIG7) MC with different showering
- Main uncertainties from jet calibration and MC modelling up to 2% (1%) and 2%(0.5%) for (A)TEEC
- Unfolded (A)TEEC also compared to NNLO parton-level (corrected) prediction using OPENLOOPS2, FIVEPOINTAMPLITUDES, and PENTAGONFUNCTIONS++ (first time)

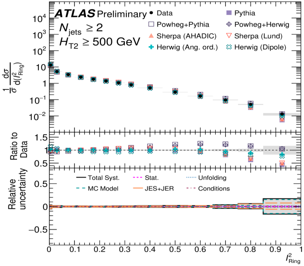
→ Very good agreement overall, with MC slightly above data at high H_{T2} (may be limited PDF accuracy at high Bjorken x)



[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\text{fb}^{-1}$ at $13\,\text{TeV}$

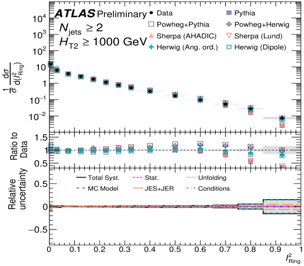
- Unfolded σ vs 3 event shapes I^N_{geom}, with N reference points in specific geometry
- Main uncertainy either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^2_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)



[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\text{fb}^{-1}$ at $13\,\text{TeV}$

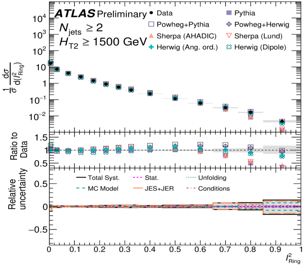
- Unfolded σ vs 3 event shapes I^{N}_{geom}, with N reference points in specific geometry
- Main uncertainty either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^2_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)



[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

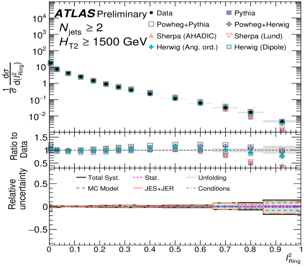
- Unfolded σ vs 3 event shapes I^N_{geom}, with N reference points in specific geometry
- Main uncertainy either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^2_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)

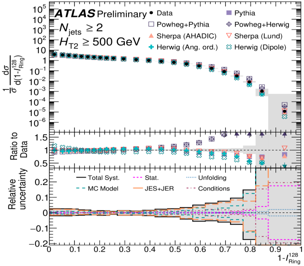


[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

- Unfolded σ vs 3 event shapes I^{N}_{geom}, with N reference points in specific geometry
- Main uncertainty either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^{2}_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)

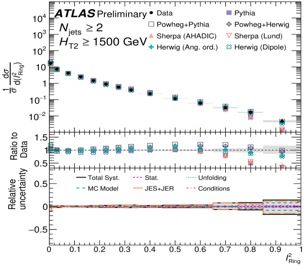


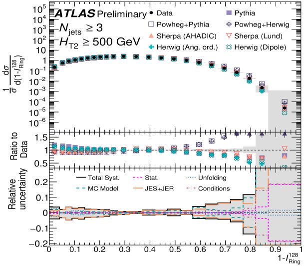


[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

- Unfolded σ vs 3 event shapes I^N_{geom}, with N reference points in specific geometry
- Main uncertainy either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^2_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)

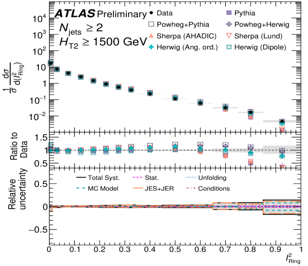


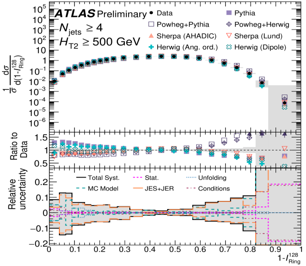


[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

- Unfolded σ vs 3 event shapes I^N_{geom}, with N reference points in specific geometry
- Main uncertainy either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^2_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)

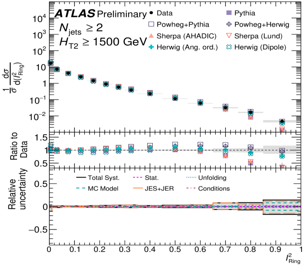


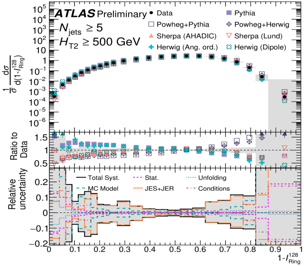


[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

- Unfolded σ vs 3 event shapes I^{N}_{geom}, with N reference points in specific geometry
- Main uncertainty either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^{2}_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)

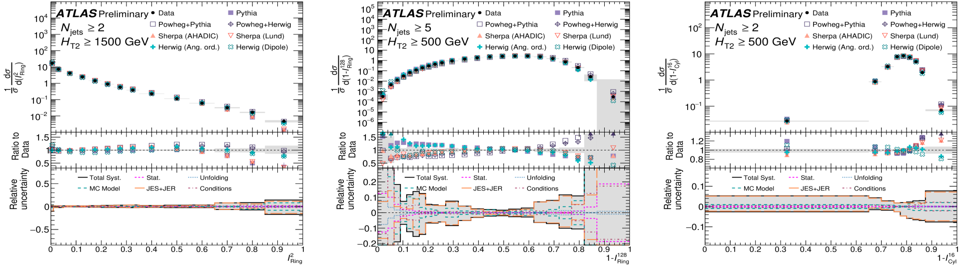




[pQCD tests][ATLAS] Event isotropies in multijet events

Preliminary: ATLAS-CONF-2022-056, $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

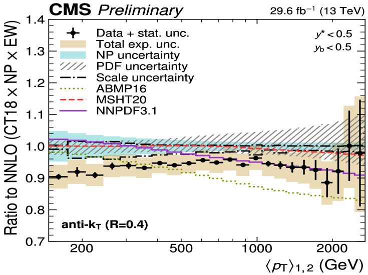
- Unfolded σ vs 3 event shapes I^N_{geom}, with N reference points in specific geometry
- Main uncertainy either from jet calibration of MC model used in unfolding
- Good description from MC in least isotropic region (where total uncertainty $< 5\%$)
- I^2_{ring}: compares to dijet (low values well modelled by NLO POWHEG), no trend vs H_{T2}
- $1 - I^{128}_{ring}$: compares to isotropic MJ (high values), degrades with inscreasing n_{jets}
- $1 - I^{16}_{cyl}$: compares to forward dijet and events evenly populated in η-ϕ plane (high values), not well modelled, differences in HERWIG7 showering (angle- vs dipole-ordered)

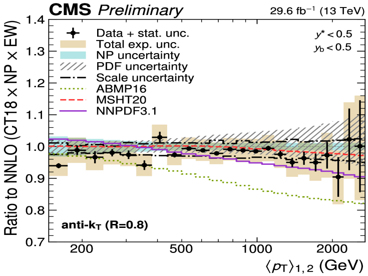


[pQCD tests][CMS] Multidimensional σ of dijet production

Preliminary: CMS-PAS-SMP-21-008, $\mathcal{L} = 36.3\,\text{fb}^{-1}$ at $13\,\text{TeV}$

- σ unfolded to particle-level vs 2 or 3 dijet system kinematic variables ($m_{1,2}$, $\langle p_T \rangle_{1,2}$, $|y_{max}|$, y separation y^*, and boost y_b)
- Main uncertainties: jet energy scale 2-30% (2D) and 3-60% (3D), stat at high-E (up to 40%)
- Results compared to (corrected) parton-level NNLO NNLOJET+FASTNLO via APPLFAST
  Lead-color and flavor-number approximation
  EWK corrections up to 20% at high $m_{1,2}$.
- Jets with distance parameter $R = 0.8$ have better modelling than with $R = 0.4$
- Prediction using different PDF sets: good agreement with data except for ABMP16
- Prediction shows good modelling overall except in ends of energy spectra and outer y regions

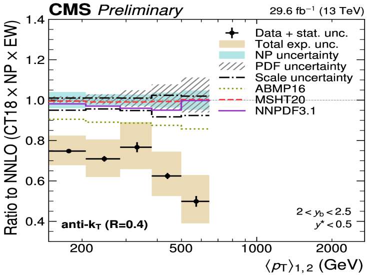


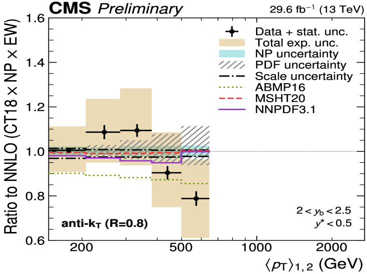


[pQCD tests][CMS] Multidimensional σ of dijet production

Preliminary: CMS-PAS-SMP-21-008, $\mathcal{L} = 36.3\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

- σ unfolded to particle-level vs 2 or 3 dijet system kinematic variables ($m_{1,2}$, $\langle p_T \rangle_{1,2}$, $|y_{max}|$, y separation y^*, and boost y_b)
- Main uncertainties: jet energy scale 2-30% (2D) and 3-60% (3D), stat at high-E (up to 40%)
- Results compared to (corrected) parton-level NNLO NNLOJET+FASTNLO via APPLFAST Lead-color and flavor-number approximation EWK corrections up to 20% at high $m_{1,2}$.
- Jets with distance parameter $R = 0.8$ have better modelling than with $R = 0.4$
- Prediction using different PDF sets: good agreement with data except for ABMP16
- Prediction shows good modelling overall except in ends of energy spectra and outer y regions





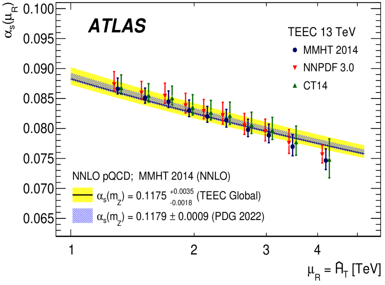
[SM parameters][ATLAS][CMS] α_s measurement in multijet events

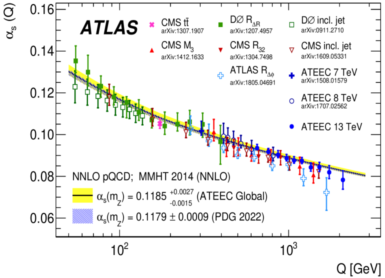
- World average: $\alpha_s(m_Z) = 0.1179 \pm 0.0009$
- Extraction via CMS dijet analysis:
  - At Z pole mass, derived from simultaneously fit together with PDF parametrization to account for correlation with g PDF
  - Assuming MMHT2014:

$$\alpha_s(m_Z) = 0.1201 \pm 0.0021 \text{ (2D)}$$
$$= 0.1201 \pm 0.0020 \text{ (3D)}$$

- Extraction via ATLAS (A)TEEC analysis:
  - In each H_{T2} interval with different PDF sets
  - Uncertainties dominated by theory
  - Assuming MMHT2014:

$$\alpha_s(m_Z) = 0.1175^{+0.0035}_{-0.0018} \text{ (TEEC)}$$
$$= 0.1185^{+0.0027}_{-0.0015} \text{ (ATEEC)}$$

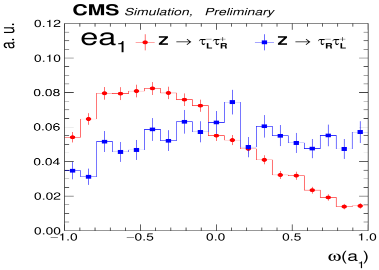


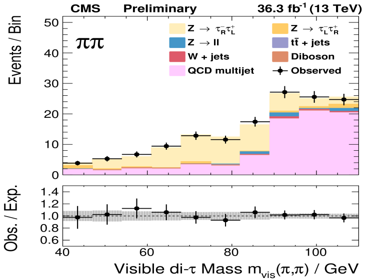


[SM parameters][CMS] Measurement of τ polarization in $\mathrm{Z} \to \tau\tau$ events

Preliminary: CMS-PAS-SMP-18-010, $\mathcal{L} = 36.3\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

- Using leptonic and hadronic τ decays: $\tau_h\tau_h$, $\tau_e\tau_h$, $\tau_\mu\tau_h$, $\tau_e\tau_\mu$, with $\tau_h \to h\nu$ $(h = \pi, \rho, a_1)$
- Channels split into 11 categories depending on τ decay mode, each associated to an optimized observable sensitive to τ helicity (e.g., ω, m_{vis})
- ω: angle between polarimetric vector $\vec{h}$ and τ In τ rest frame: $d\Gamma_\tau \propto (1 + \vec{h}.\vec{\tau}_{spin})$
- Average τ polarization: $\langle \mathcal{P}_\tau \rangle$ $(\frac{m_{\tau\tau}}{\mathrm{GeV}} \in [75, 120])$ extracted from global fit to data of signal and bkg templates for 11 observables, distinguishing 2 helicity states $\mathrm{Z} \to \tau^-_{L(R)}\tau^+_{R(L)}$
- Main bkg from mis-id τ_h in MJ (up to 84% in $\tau_h\tau_h$), and W+jets (~30% in $\tau_\ell\tau_h$), estimated from fake enriched data regions
- Main (shape) systematics include mis-id τ_h decay (up to 3.7%)





[SM parameters][CMS] Measurement of τ polarization in Z events

- $\langle \mathcal{P}_\tau \rangle = -0.140 \pm 0.006\,(\text{stat}) \pm 0.014\,(\text{syst})$
  - Best sensitivity from $\mu{+}\rho$ channel
  - Full hadronic limited by trigger thresholds
- $\langle \mathcal{P}_\tau \rangle$ corrected to its value at Z pole via MADGRAPH5_aMC@NLO simulation:

$\Rightarrow$ $\boxed{\mathcal{P}_\tau(Z^0) = -0.144 \pm 0.015}$

- If vector coupling (v) $\ll$ axial-vector coupling (a) for initial-state fermions:

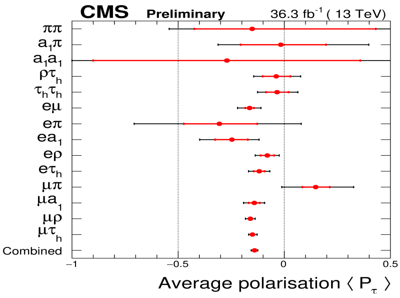
$$\mathcal{P}_\tau = -A_\tau \approx -2v_\tau/a_\tau = -2(1 - 4\sin^2\theta_W^{eff})$$

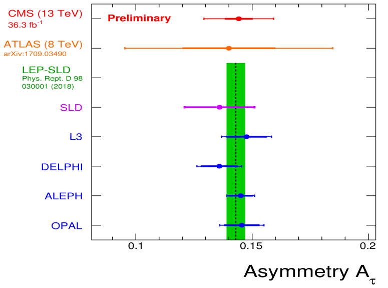
with $\sin\theta_W^{eff}$: effective weak mixing angle

$\Rightarrow$ $\boxed{\sin^2\theta_W^{eff} = 0.2319 \pm 0.008\,(\text{stat}) \pm 0.018\,(\text{syst})}$

Best at LHC. LEP-SLD: 0.2315 ± 0.0002

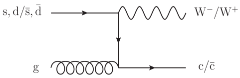
- Test of lepton universality: agreement with SM predicted value $A_\ell = 0.1468 \pm 0.0003$





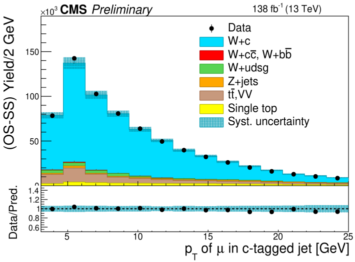
[PDF constraints][CMS] Measurement of W + c-jet

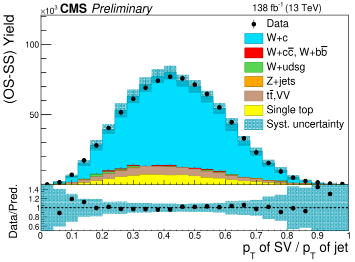
Preliminary: CMS-PAS-SMP-21-005, $\mathcal{L} = 138\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$



- Sensitive to s PDF as dominated by $gs \to Wc$
- Motivation: constrain s-$\bar{s}$ PDF asymmetry and $R_s = \frac{s+\bar{s}}{\bar{u}+\bar{d}}$, major bkg (e.g., $\mathrm{W}(\mathrm{H} \to c\bar{c})$), tune MC simulation
- Strategy: identify c via c-jet reconstruction
- Four independant channels:
  - e or μ W decays (isolated high-p_T lepton)
  - semileptonic (SL) c decay (μ inside jet) or reconstructed secondary vertex (SV) in jet
- c and ℓ from W have opposite-signs (OS), bkg $\mathrm{W} + c\bar{c}$ and $t\bar{t}$ suppressed by same-sign (SS) subtraction, surviving $t\bar{t}$ constrained from data

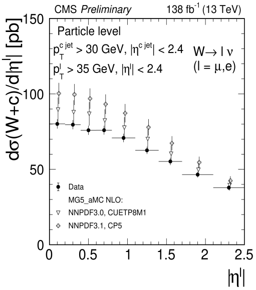
  Z+jets suppressed (SL channel) with large μ impact parameter, constrained from data

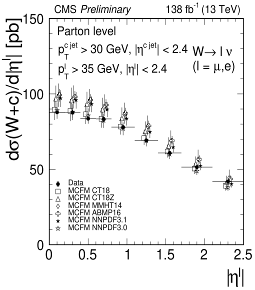


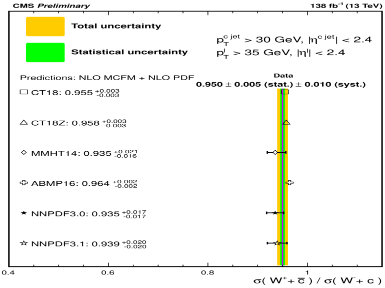


[PDF constraints][CMS] Measurement of W + c-jet

- Total uncertainty of 5% in both channels, dominated by muon-in-jet and SV reconstructions (3% each)
- Unfolded parton-level $\sigma(W+c)$ 10% smaller than at particle-level due to p_T^c smeared below analysis threshold ($30\,\mathrm{GeV}$) during hadronization and jet clustering
- $R_c^{\pm} = \frac{\sigma(W^+ + c)}{\sigma(W^- + c)} = 0.950 \pm 0.005\,(\mathrm{stat}) \pm 0.010\,(\mathrm{syst})$, in agreement with NLO prediction, with total uncertainty reaching $\sim 1\%$
- CT18 and ABMP16 assume $s = \bar{s}$ and lead to smaller uncertaintes in predictions



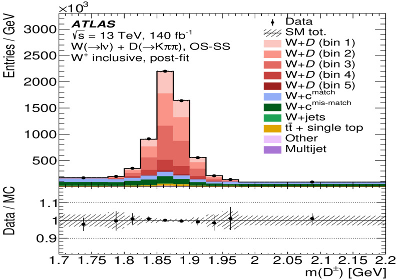


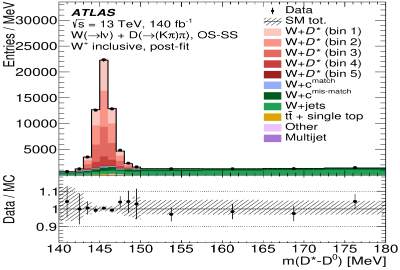


[PDF constraints][ATLAS] Measurement of W + charmed hadron

Submitted to PRD, hep-ex/2302.00336, $\mathcal{L} = 140\,\mathrm{fb}^{-1}$ at $13\,\mathrm{TeV}$

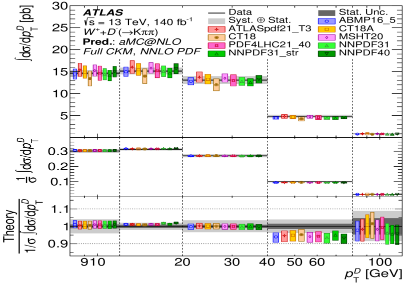
- Strategy: identify c via charmed-hadron reconstruction (using SV mass observable)
  - $D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$ via $m(D^{\pm})$
  - $D^{*\pm} \to D^{0}\pi^{\pm} \to (K^{\mp}\pi^{\pm})\pi^{\pm}$ via $m(D^{*\pm}\text{-}D^{0})$
- Both e and μ W decays
- Main bkg (suppressed exploiting OS-SS subtraction):
  - $W + c^{match}$: tracks in SV belong to different c-hadron or decay mode
  - $W + c^{mis-match}$: not all tracks belong to $D^{\pm(*)}$ candidate
  - W+jets: no track belong to $D^{\pm(*)}$ candidate
  - Top constrained in data region with ≥ 1 b-jet
  - Multijet from fake-enriched events in data

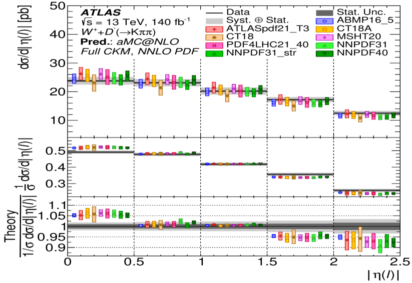




[PDF constraints][ATLAS] Measurement of W + charmed hadron

- Bkg normalization and systematics constraints via likelihood fit of 5 $p_T(D^{\pm(*)})$ or $|\eta(\ell)|$ bins, and control regions
- Differential unfolded σ measurements: smaller systematics in $|\eta(\ell)|$ than $p_T(D^{\pm(*)})$ (SV reconstruction independent of $\eta(\ell)$)
- Ratio of σ in 2 decay channels in agreement with world average: 1.021 ± 0.034
- Systematics in "+" and "-" channels mostly cancel out in $R_C^{\pm}$. MC and Data statistics dominate with 1.1-1.3% and 0.7-1.0%, resp.
- $R_c^{\pm}$ with higher precision using CT18 and AMBP16 (assumes $s = \bar{s}$): suggests s-$\bar{s}$ asymmetry is small
- Global PDF fit ATLASpdf21 agrees well

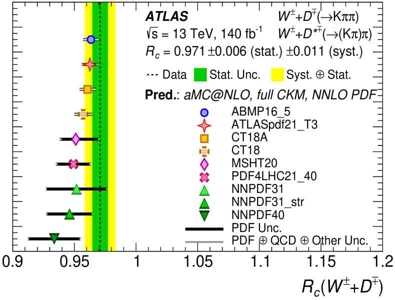




[PDF constraints][ATLAS] Measurement of W + charmed hadron

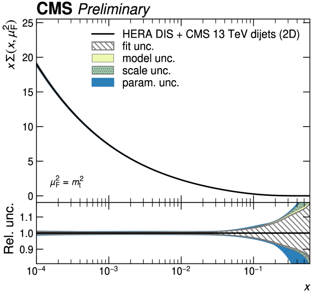
- Bkg normalization and systematics constraints via likelihood fit of 5 $p_T(D^{\pm(*)})$ or $|\eta(\ell)|$ bins, and control regions
- Differential unfolded σ measurements: smaller systematics in $|\eta(\ell)|$ than $p_T(D^{\pm(*)})$ (SV reconstruction independent of $\eta(\ell)$)
- Ratio of σ in 2 decay channels in agreement with world average: 1.021 ± 0.034
- Systematics in "+" and "-" channels mostly cancel out in $R_C^{\pm}$. MC and Data statistics dominate with 1.1-1.3% and 0.7-1.0%, resp.
- $R_c^{\pm}$ with higher precision using CT18 and AMBP16 (assumes $s = \bar{s}$): suggests s-$\bar{s}$ asymmetry is small
- Global PDF fit ATLASpdf21 agrees well

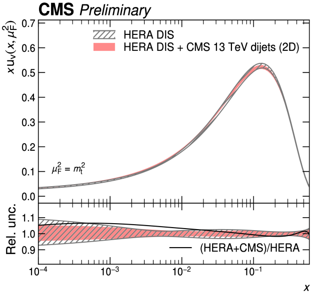
Channel	$\sigma_{\text{fid}}^{\text{OS-SS}}(W{+}D^{(*)}) \times B(W \to \ell\nu)$ [pb]
$W^-{+}D^+$	50.2 ± 0.2 (stat.) $^{+2.4}_{-2.3}$ (syst.)
$W^+{+}D^-$	48.5 ± 0.2 (stat.) $^{+2.3}_{-2.2}$ (syst.)
$W^-{+}D^{*+}$	51.1 ± 0.4 (stat.) $^{+1.9}_{-1.8}$ (syst.)
$W^+{+}D^{*-}$	50.0 ± 0.4 (stat.) $^{+1.9}_{-1.8}$ (syst.)
	$R_c^{\pm} = \sigma_{\text{fid}}^{\text{OS-SS}}(W^+{+}D^{(*)})/\sigma_{\text{fid}}^{\text{OS-SS}}(W^-{+}D^{(*)})$
$R_c^{\pm}(D^+)$	0.965 ± 0.007 (stat.) ± 0.012 (syst.)
$R_c^{\pm}(D^{*+})$	0.980 ± 0.010 (stat.) ± 0.013 (syst.)
$R_c^{\pm}(D^{(*)})$	0.971 ± 0.006 (stat.) ± 0.011 (syst.)

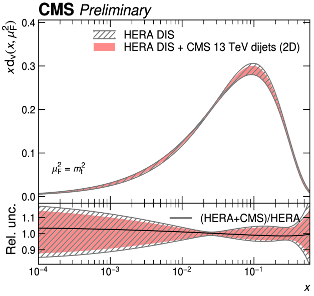


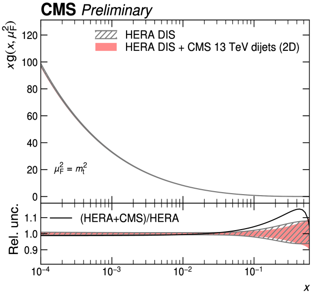
[PDF constraints][CMS] up, down, and g PDF constraints in dijet events

- PDF fit of CMS dijet multidimensional σ measurement (R=0.8) together with HERA DIS results
- Uncertainties (smaller with 2D input): errors in measurements (fit unc), non-PDF parameters (model unc), alternative parametrization, scale variation
- Overall PDF precision improved, and especially for g PDF at $x > 0.1$









Summary

- Fiducial and unfolded differential production cross sections have been determined for multiple processes of the SM, considering observables sensitive to perturbative QCD effects, fundamental SM parameters (α_s, $\sin^2\theta_W^{eff}$), and PDF
- Accurate measurements were carried out with different luminosities up to the complete statistics of LHC Run 2
- Different final states were analyzed, involving data-driven techniques to constrain background processes when simulation is not sufficient

⋆ For more information (Standard Model public results):

→ ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults

→ CMS: http://cms-results.web.cern.ch/cms-results/public-results/publications/SMP

⋆ ATLAS & CMS electroweak results covered in presentation on “Dibosons and other EWK physics measurements” (L. Horyn)