Measurement of Mid-rapidity Inclusive Jet Cross Sections in pp Collisions at $\sqrt{s} = 200$ and 510 GeV

Dmitry Kalinkin
For the STAR Collaboration

[1]University of Kentucky – Lexington, KY

previously: [2]Indiana University – Bloomington, IN

previously: [3]Brookhaven National Laboratory – Upton, NY

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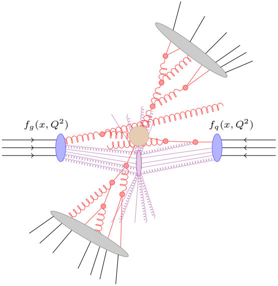
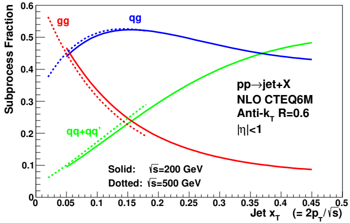
Proton Structure in Hard Interactions

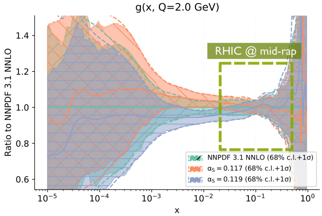


Jet production in high energy collisions of hadrons can be described in terms of following ingredients:

- Initial state of hadrons
- Hard collision of partons
- Parton Shower
- Underlying Event (UE)
- Hadronization

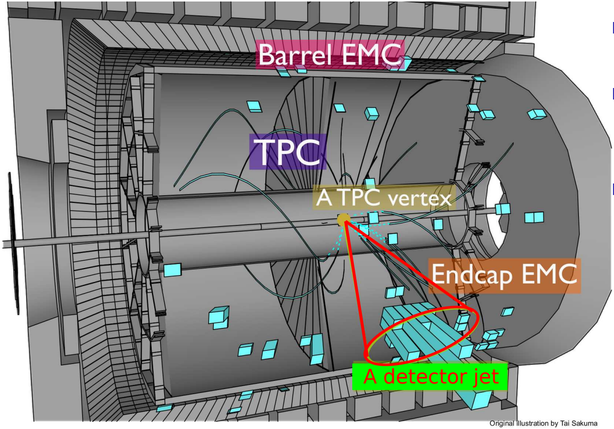
$$d\sigma_{pp\to jet+X}(Q^2) = \sum_{a,b} \int \underbrace{f_a(x_1, Q^2) f_b(x_2, Q^2)}_{\text{proton structure}} \underbrace{d\hat{\sigma}_{a+b\to jet+X}(x_1, x_2, Q^2)}_{\text{hard process+PS+Had.}} \, dx_1 \, dx_2$$



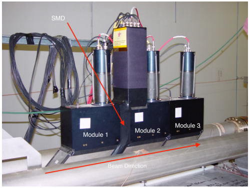


Original plot from NNPDF 3.1 Catalog of plots: α_S variations at NNLO

Jet Measurements using STAR Detector

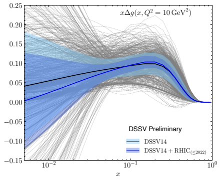


- **TPC**: Interaction vertex and charged particle tracks
- **BEMC** and **EEMC**: Photon energy measurement
- **Trigger condition** on deposited EM energy sum in 1×1 patches in $\eta - \phi$
- East and west **Zero Degree Calorimeter**: Absolute luminosity monitoring



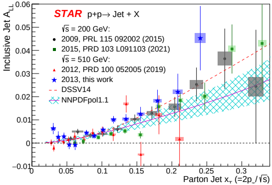
Gluon Polarization using Jets at STAR

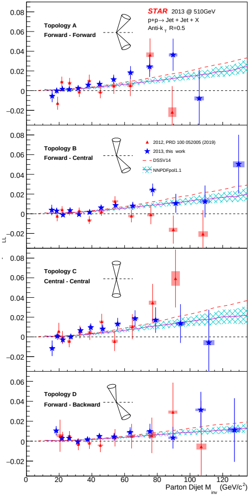
- Measurements using a similar collinear factorization framework $A_{LL} \sim \Delta f_a \otimes \Delta f_b \otimes \Delta\hat{\sigma}$ to determine Δg the helicity distribution of gluons inside the proton
- Detector effects are not unfolded but corrected by adjusting p_T (or M_{jj}) and A_{LL} of independent points
- Run 13 mid-rapidity inclusive jet and di-jet A_{LL} results recently published [PRD 105 (2022) 092011]
- Spin asymmetries for jet production analyzed for all RHIC runs



impact on global fit by DSSV,

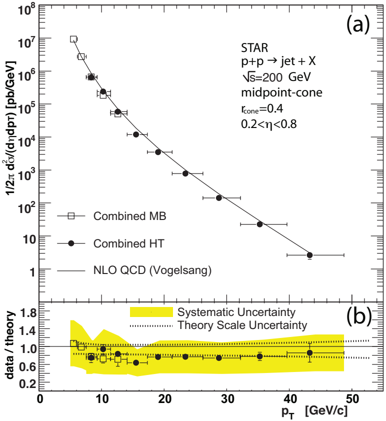
RHIC Cold QCD White Paper arXiv:2302.00605





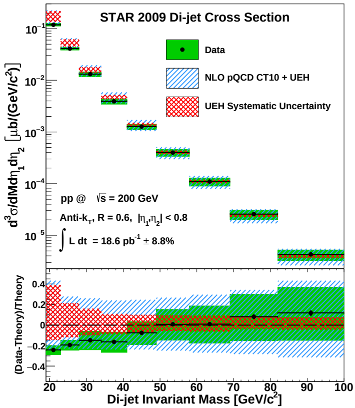
STAR Collaboration, PRD 105 (2022) 092011

Published Jet Cross Sections from STAR



Phys. Rev. Lett. 97 (2006) 252001

- An inclusive jet cross section
- Mid-point cone algorithm
- Not corrected for UE or hadronization
- Bin-by-bin detector effects correction
- Limited acceptance

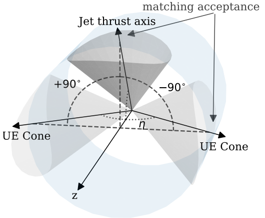


Phys Rev D 95 (2017) 071103

- A di-jet cross section
- anti-k_T algorithm
- Detector effects unfolded
- No data-driven UE correction

Underlying Event Correction

- Two off-axis cone regions defined as $(\varphi - \varphi_{\text{jet}} \pm \pi/2)^2 + (\eta - \eta_{\text{jet}})^2 \leq R_{\text{UE}}{}^2$ with $R_{\text{UE}} = 0.5$

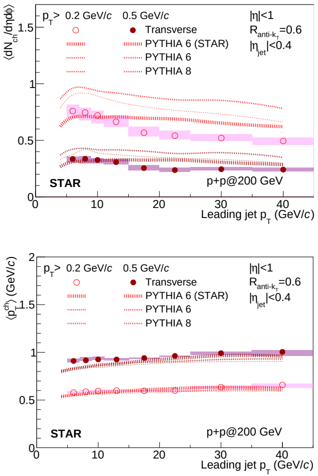


- For each jet calculate a jet area A and a p_T-density of constituents ρ_{UE}
- Correction implemented via a jet p_T shift:

$$(\text{jet } p_T) \rightarrow (\text{jet } p_T) - A \cdot \rho_{\text{UE}}$$

- This was previously done at ALICE: PRD 91 (2015) 112012
- Applied to data before unfolding and to simulation in the definition of the detector response

Charged UE measured at STAR:

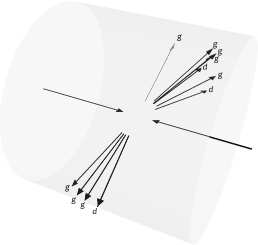


Phys Rev D 101 (2020) 052004

A different set of regions defined as $|\varphi - \varphi_{\text{jet}} \pm \pi/2| < \pi/6$

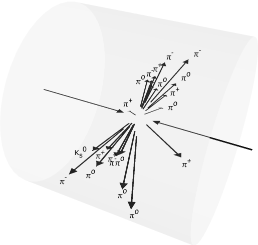
Jets at Three Levels

Parton jets



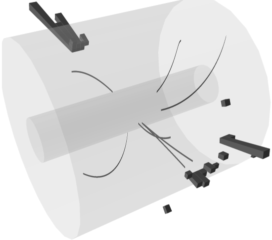
- Made of partons outgoing from the hard interaction
- Definition flexible depending on theoretical needs (e.g. fit using pQCD)

Particle jets



- Made of stable particles (at STAR the π^0 treated as stable)
- Universal – Free from all detector effects
- Includes effects of
  - QCD radiation
  - Hadronization
  - UE (unless subtracted)

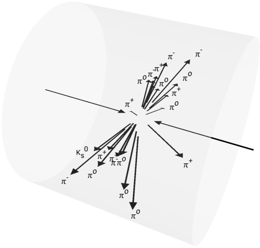
Detector jets



- Made of tracks and discrete calorimeter towers
- Experiment specific

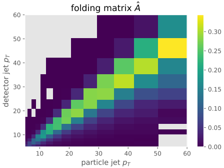
Detector Effects Unfolding

Particle jets

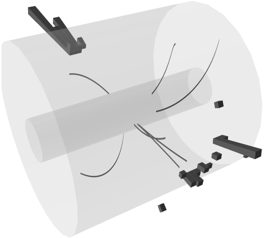


Simulation with Pythia 6 and GEANT3

Unfolding of p_T spectrum by inverting the detector response matrix:

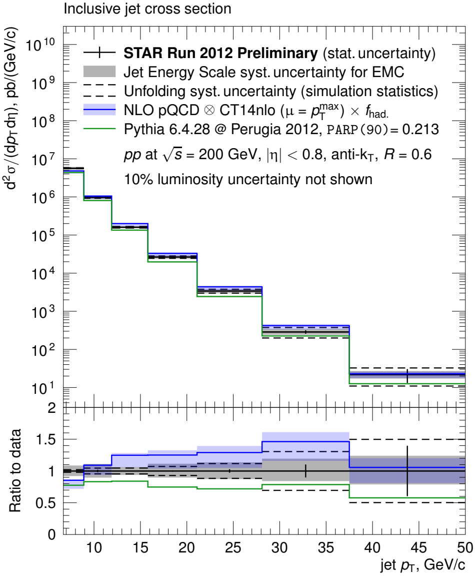


Detector jets

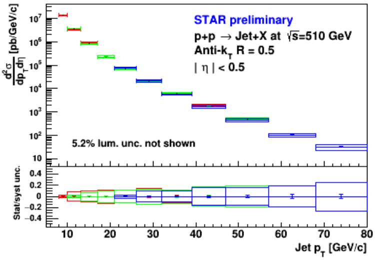


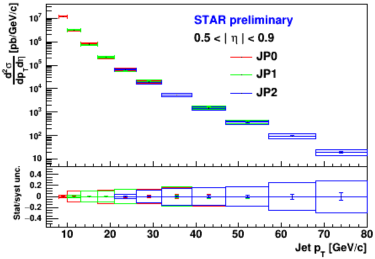
- Matrix inversion gives the exact result for the maximum likelihood estimator
- Statistical fluctuations are regularized by choosing sufficiently large bin sizes
- Need to estimate uncertainty due to the choice of prior (in this case, Pythia)

Inclusive Jet Cross Section at $\sqrt{s} = 200$ GeV, Particle Level



- With UE subtraction
- $0.067 < x_T = \frac{2p_T}{\sqrt{s}} < 0.5$
- Jet Energy Scale uncertainty from the EM calorimeter response – **leading systematic uncertainty**
- **Final result** will use a larger simulation sample to do unfolding in **finer binning in jet p_T and also in η**





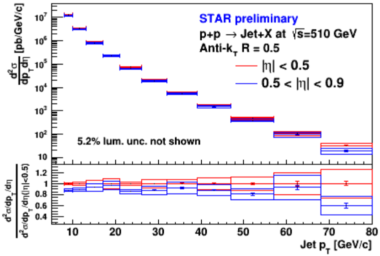
- With UE subtraction
- $0.021 < x_T = \frac{2p_T}{\sqrt{s}} < 0.32$

Different triggers:

- JP0: $E \geq 5.4$ GeV
- JP1: $E \geq 7.3$ GeV
- JP2: $E \geq 14.4$ GeV

Measured in two η-ranges:

- $0 < |\eta| < 0.5$
- $0.5 < |\eta| < 0.9$



Summary

- Jet measurements at STAR are extended to the unpolarized case, with **absolute cross section normalization**
- First measurement with jet p_T defined with **the off-axis UE density subtracted**
- Inclusive jet measurements at RHIC will allow to better constrain **high-x behaviour of the gluon PDF**
- …and serve as a normalization for **hadron fragmentation inside jets**
- …or as a reference for future R_{AA} measurements at RHIC
- Measurements at two values of $\sqrt{s}$, at 200 GeV and 510 GeV, provide insights into energy dependence for **MC tuning**