Understanding Uncertainties in Jet Quenching in High-Energy Nucleus-Nucleus Collisions

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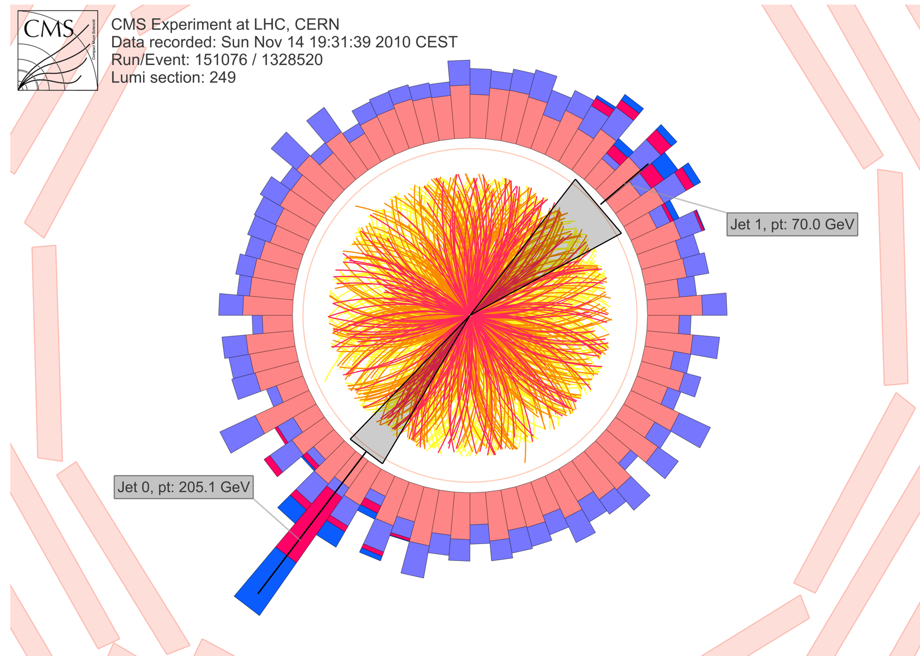
Introduction to Jet Physics

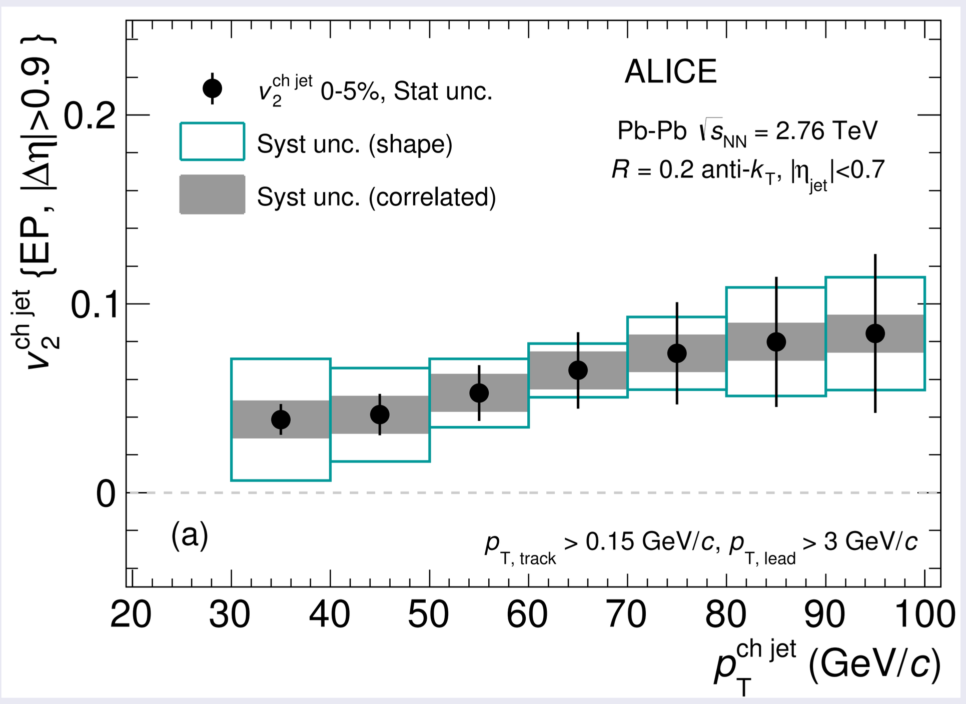
- Two dominant processes in high-energy nuclear collisions
  - Energy deposited as nuclei interact heats vacuum to form a quark gluon plasma (QGP)
  - Hard scattering of partons in nucleons creating jets
- Jets must pass through the QGP and interact with it
- As a result, jets can function as a probe into the structure of QGP



Comparing Model and Experiment

- Goal is to compare models of jet quenching via medium with experimental results
- Must be careful with how statistical and systematic uncertainties are handled
- Understanding in detail the nature of uncertainties is essential to verifying consistency between theory and experiment

Sample Measurement from ALICE



Traditional vs Covariant Treatment of Errors

- Current errors given bin by bin
- Statistical errors assumed to be uncorrelated
- Other uncorrelated systematics lumped in with statistical errors
- Any correlated systematics are fully correlated across all bins
- Covariance matrix defined as:

$$C_{ij} = \rho_{ij}\sigma_i\sigma_j$$

- ρ_{ij} is the covariance coefficient between the i^{th} and j^{th} bins
- For uncorrelated errors, $\rho_{ij} = \delta_{ij}$
- For fully correlated errors, $\rho_{ij} = 1$
- Covariance matrix formulation of errors allows for non-uniform covariance
- In particular, it supports errors with a correlation length

Apply Covariance Formalism to Previous Result

- ALICE measurement of v_2 provides good test for covariance formalism equivalence
- Has uncorrelated, correlated, and shape uncertainties
- p-values published in paper are obtained by minimizing χ^2
- Equivalent calculation of minimized χ^2 via covariance matrices looks like:

$$\chi^2_{min} = \Delta^T C^{-1} \Delta$$

- Resulting p-values are exactly equal:

p_T range	χ^2 minimization	Covariance matrix
30-100 GeV	0.1247858497	0.1247858497
30-60 GeV	0.0685915881	0.0685915881
60-100 GeV	0.0211009165	0.0211009165

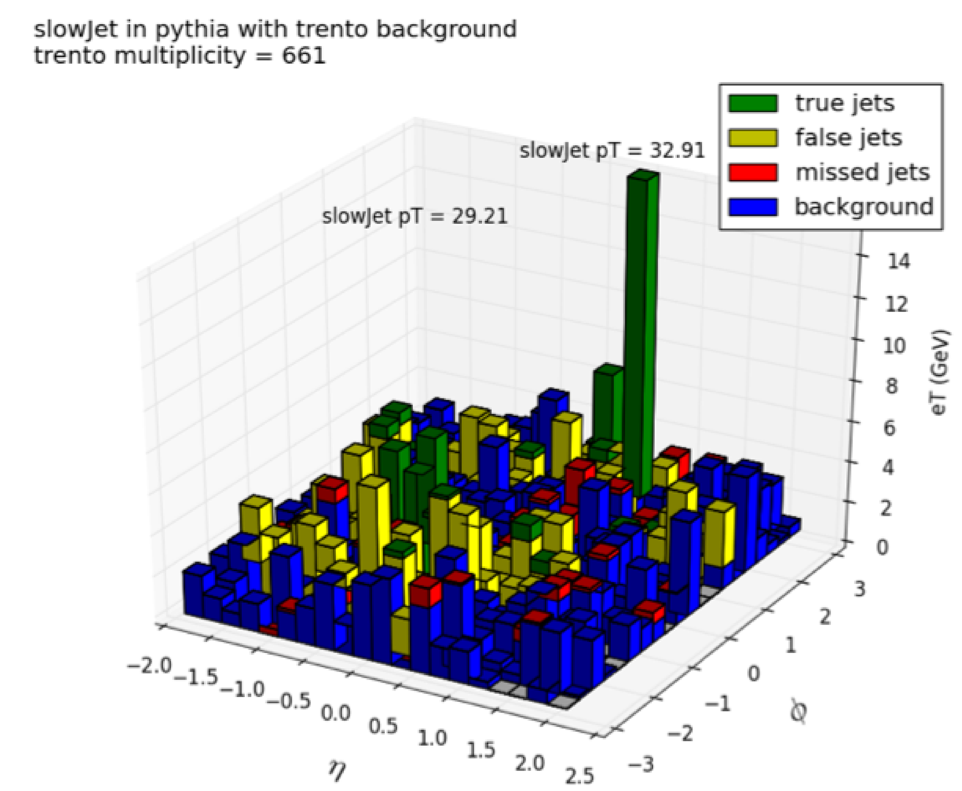
Table: p-values reported to machine level significance calculated using traditional χ^2 minimization and covariance method.

Incorperating Covariance into HEPData

- Current HEPData schema lacks support for full covariance matrices
- Adapted schema to support:
  - (A)symmetric uncorrelated errors
  - (A)symmetric fully correlated errors
  - Full covariance matrices
- Distinct treatment of uncorrelated and fully correlated errors to save space
- Would like to see adoption of this modified schema by the HEPData community for future experimental results

Future Work

- Continue work to develop jet quench simulation tool to study errors
- Constrain jet quench parameter with Bayesian methods
- Estimate subtraction bias
- Consider software-level checks for HEPData validity
- Advocate for a move to covariance matrix expression of uncertainties



References

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.