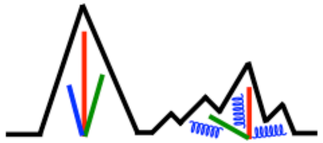
ISNET 8 —> Abridged for SANPC 2024

Information and Statistics in Nuclear Experiment and Theory

A Hitchhiker's Guide to Correlated Errors



A JETSCAPE—Inspired Story

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MSU, East Lansing
—> Jun 2024, Newport News

Physics goals for JETSCAPE publications to constrain energy-loss

- **Combine jet-quench models for early/late stage evolution**
- **Parameterize jet transport (q-hat) vs. jet energy and temperature**
- **Compare to data from different experiments, collision energies, geometries**

Methodology

- **Full Bayesian statistics package**
- **Treat errors as uncorrelated, fully correlated, and partially correlated**

$$\Sigma_k^E = \Sigma_k^{\text{uncorr}} + \Sigma_k^{\text{fcorr}} + \Sigma_k^{\text{lcorr}},$$

$$\Sigma_{k,ij}^{\text{uncorr}} = \sigma_{k,i}^{\text{uncorr}} \sigma_{k,j}^{\text{uncorr}} \delta_{ij},$$

$$\Sigma_{k,ij}^{\text{fcorr}} = \sigma_{k,i}^{\text{fcorr}} \sigma_{k,j}^{\text{fcorr}},$$

$$\Sigma_{k,ij}^{\text{lcorr}} = \sigma_{k,i}^{\text{lcorr}} \sigma_{k,j}^{\text{lcorr}} \exp\left[- \left| \frac{p_{k,i} - p_{k,j}}{\ell_k} \right|^{\alpha} \right].$$

JETSCAPE assumes correlation length, ℓ_k

A Tale of Two Error Conventions

Nuisance Parameters

data, model, sys-err, nuisance, stat-err

$$\chi^2 = \Sigma_i^N \frac{\left(d_i - t_i - \Sigma_j^K \alpha_j s_{ji}\right)}{\sigma_i^2} + \Sigma_j^K \alpha_j^2$$

$$C_{ij} = \sigma_i^2 \delta_{ij} + \Sigma_m^K s_{mi} s_{mj}$$

Covariant Error Matrix

error matrix

$$\chi^2 = \Sigma_{ij}^N (d_i - t_i)^T C^{-1} (d_j - t_j)$$

L. Demortier, CDF-MEMO-8661 (1991)
M. Heinz, LLNL-POST-735420 (2017)

Experimentalists currently provide σ_i and $\Sigma_j(s_{ij})$; We need s_{ij} or C_{ij}

A Tale of Two Experiments

- The Trackfields and McCals, distant descendents of legendary clans, who long ago abandoned their violent feud to settle their remaining differences in the open literature …
- Together, they set out to measure RAA, but constrained research budgets led them to different optimizations in constructing their detectors


"Devil Anse" Hatfield

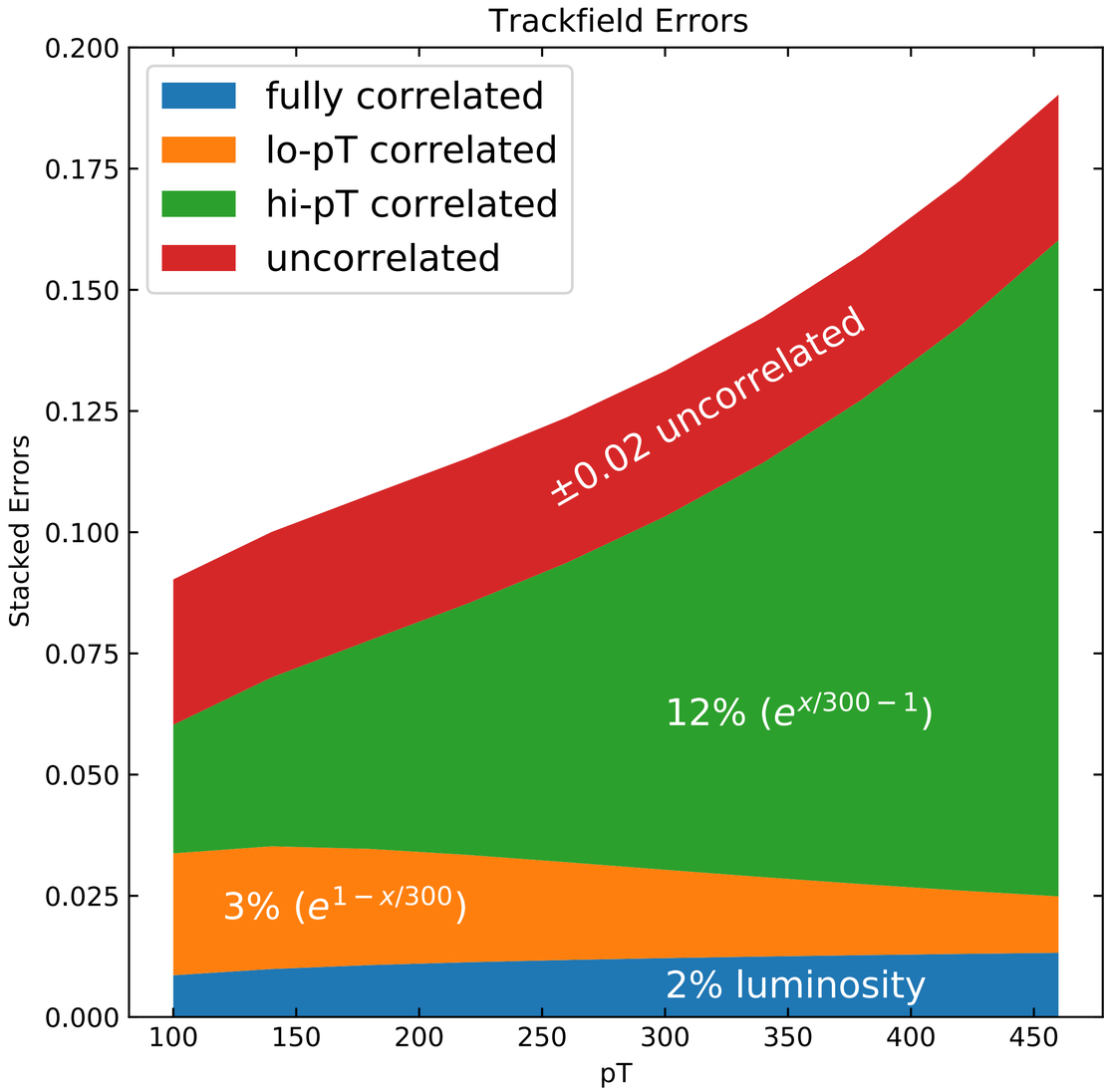
The Trackfields care more about low-pT and invested more of their budget in building high resolution, large accepance tracking detectors

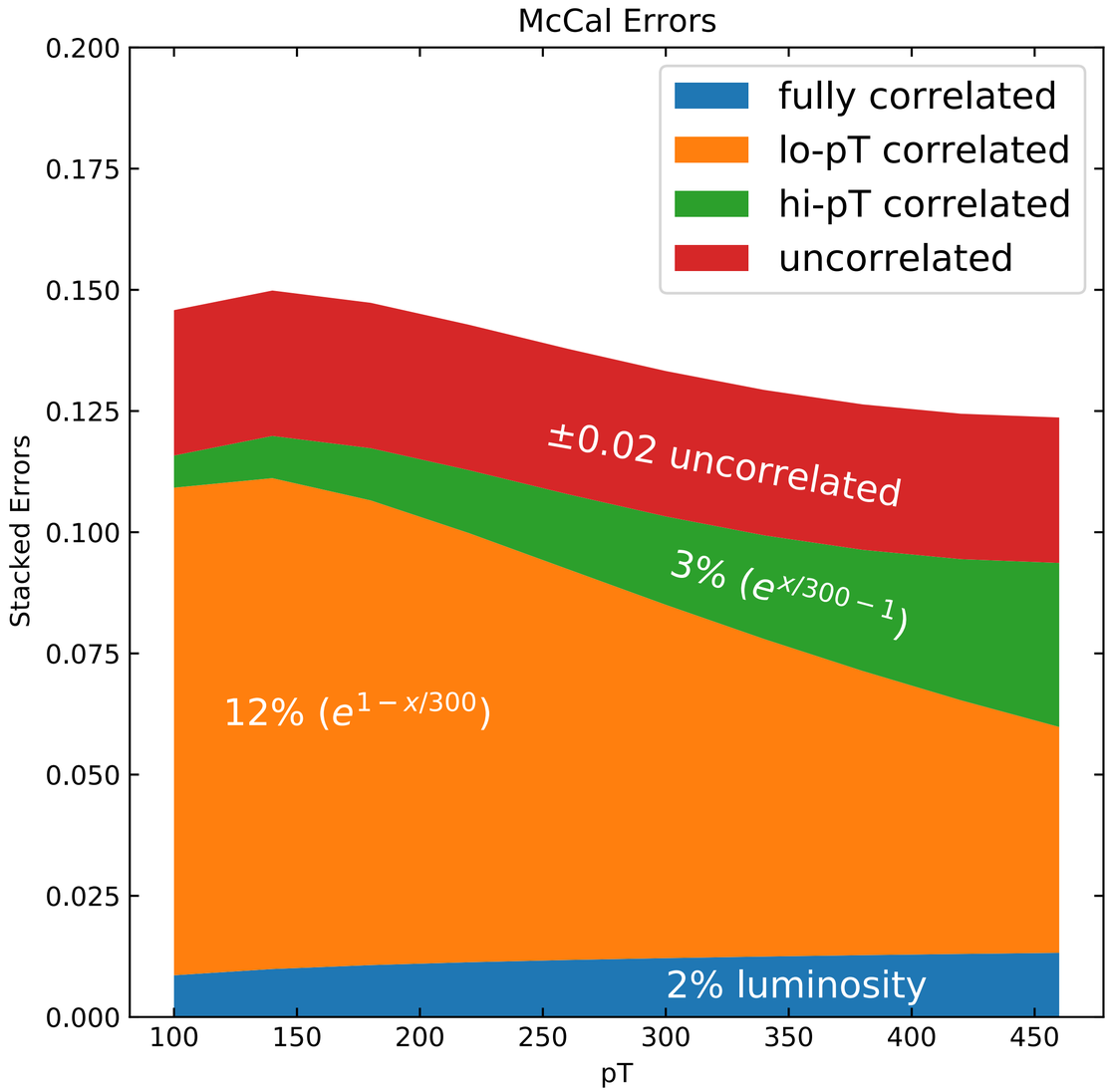
The McCals care more about high-pT and invested more of their budget in building hermetic, highly segmented calorimeters


Randel McCoy

- It also matters to JETSCAPE, but we'll return to this during discussion …

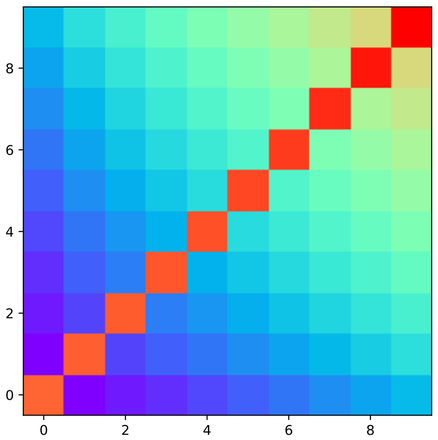
Stacked 1σ Error Bands for Trackfields and McCals

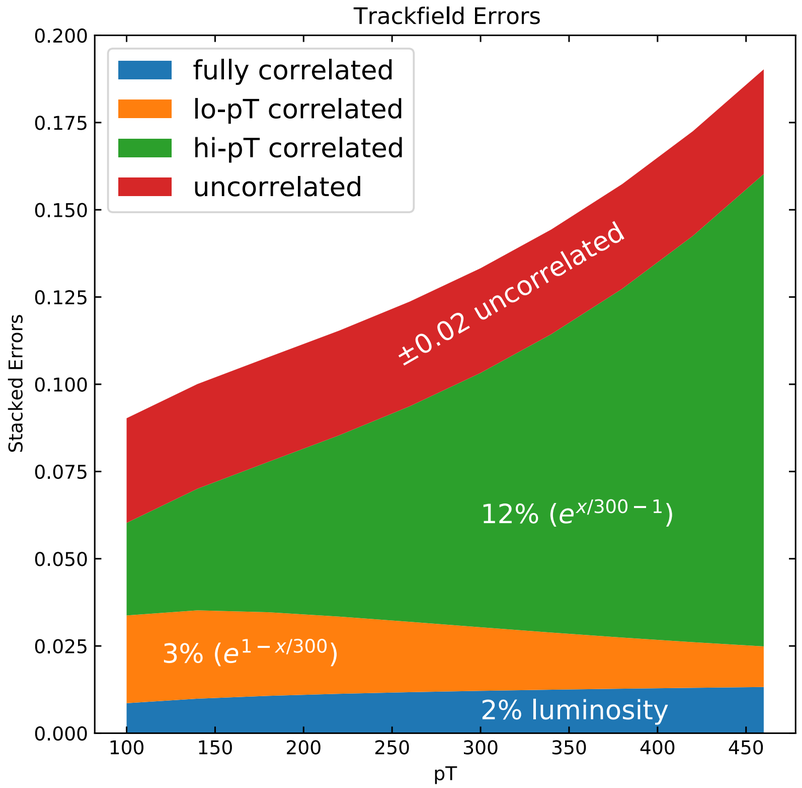


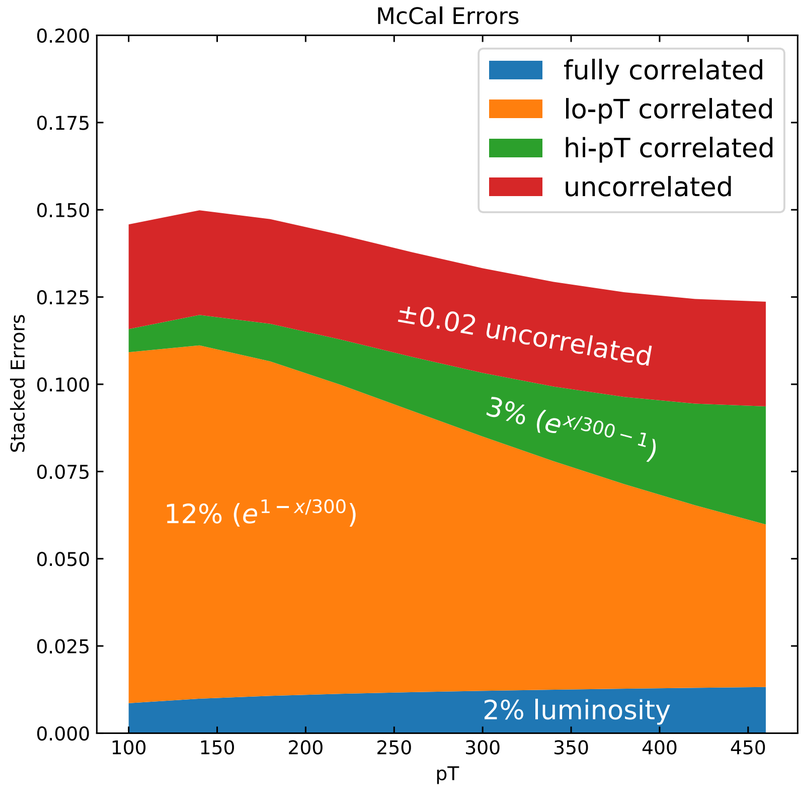


Stacked Error Bands and Cov. Error Matrices

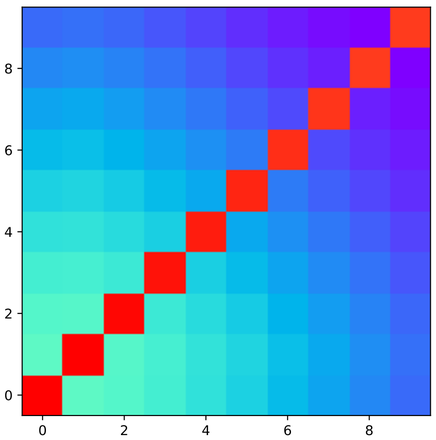
Trackfield log(C_{ij})





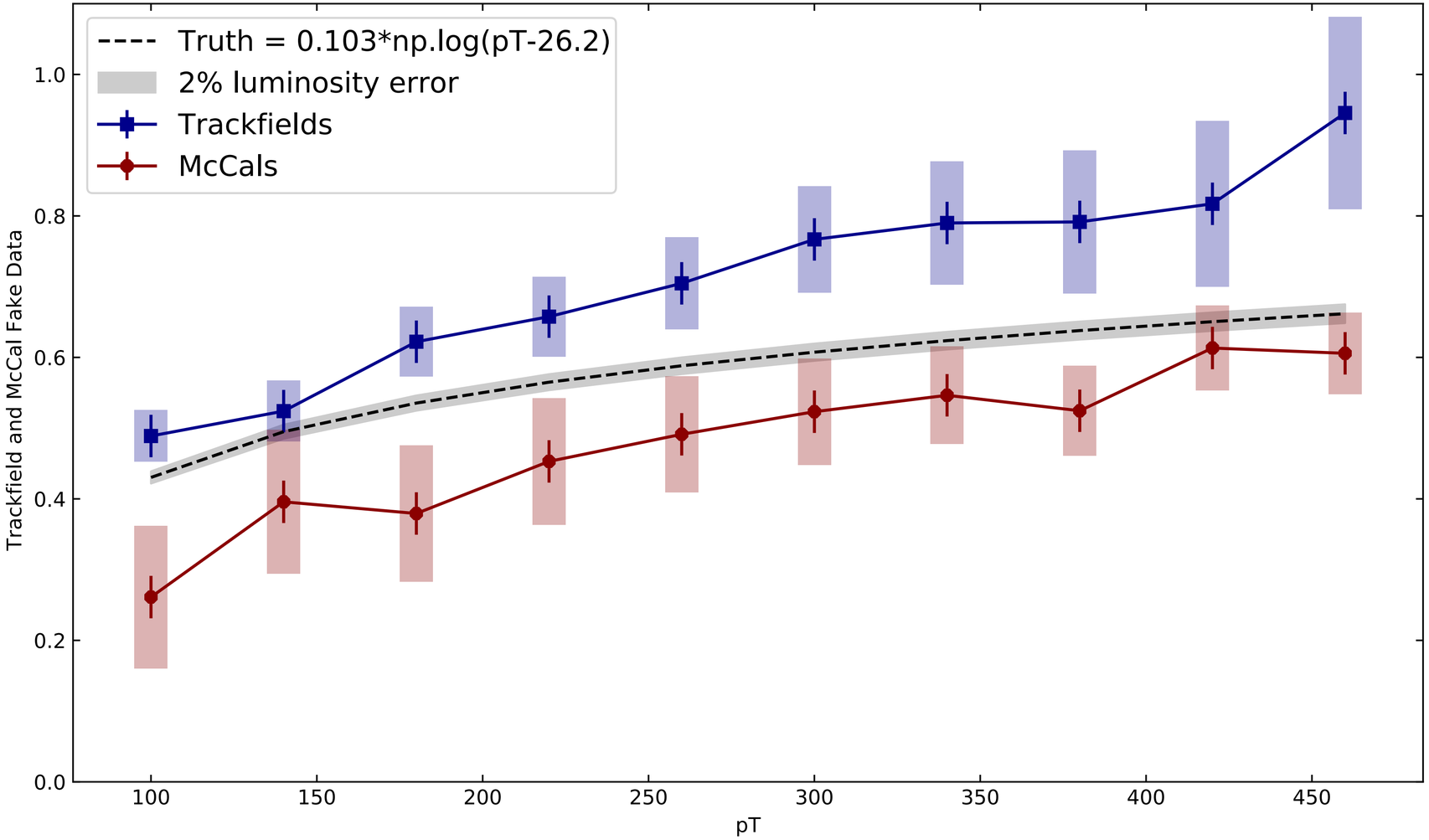


McCal log(C_{ij})



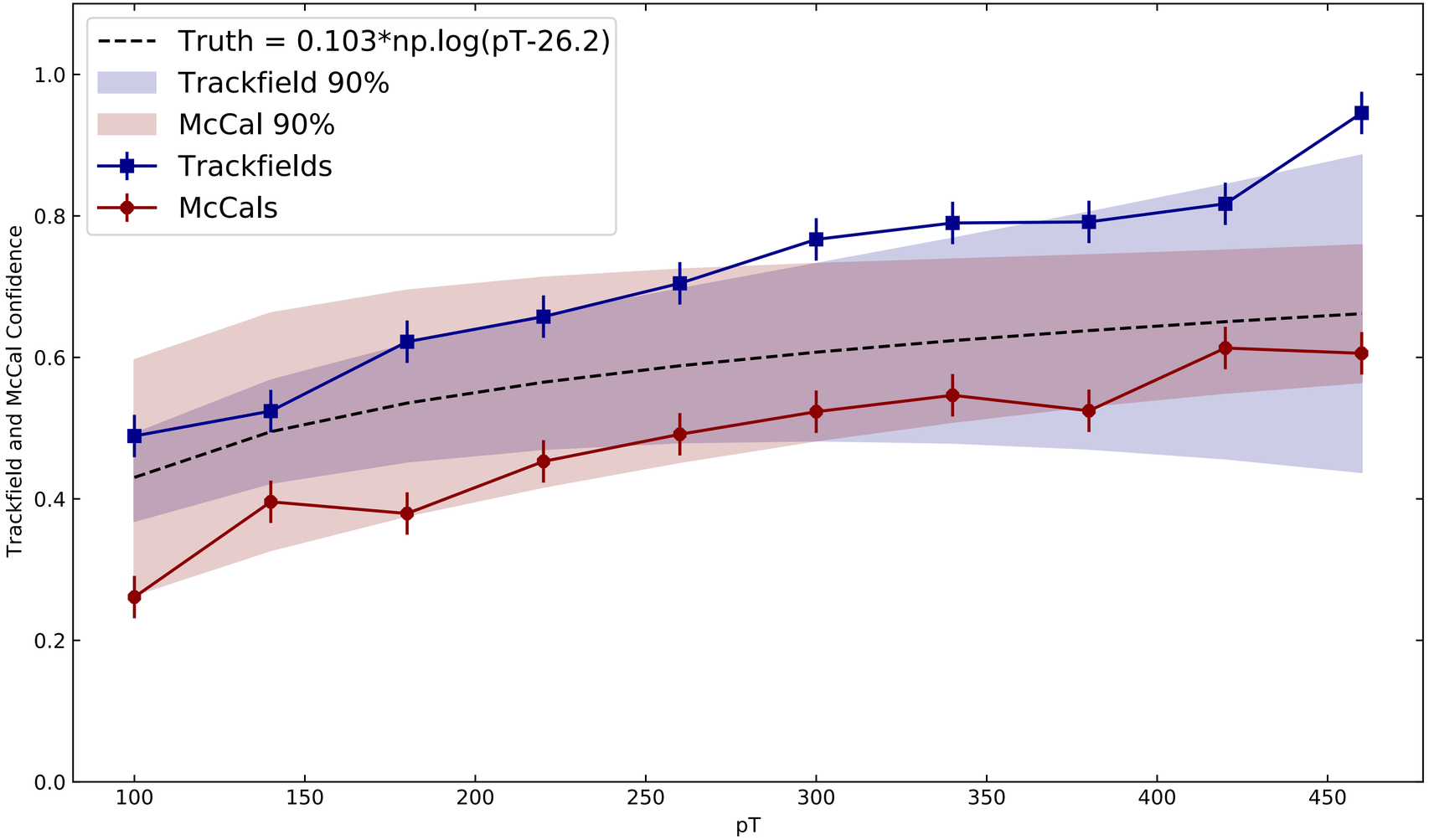
<u>This is what experimentalists need to provide</u>

Both clans publish their results after 2-years of data-taking



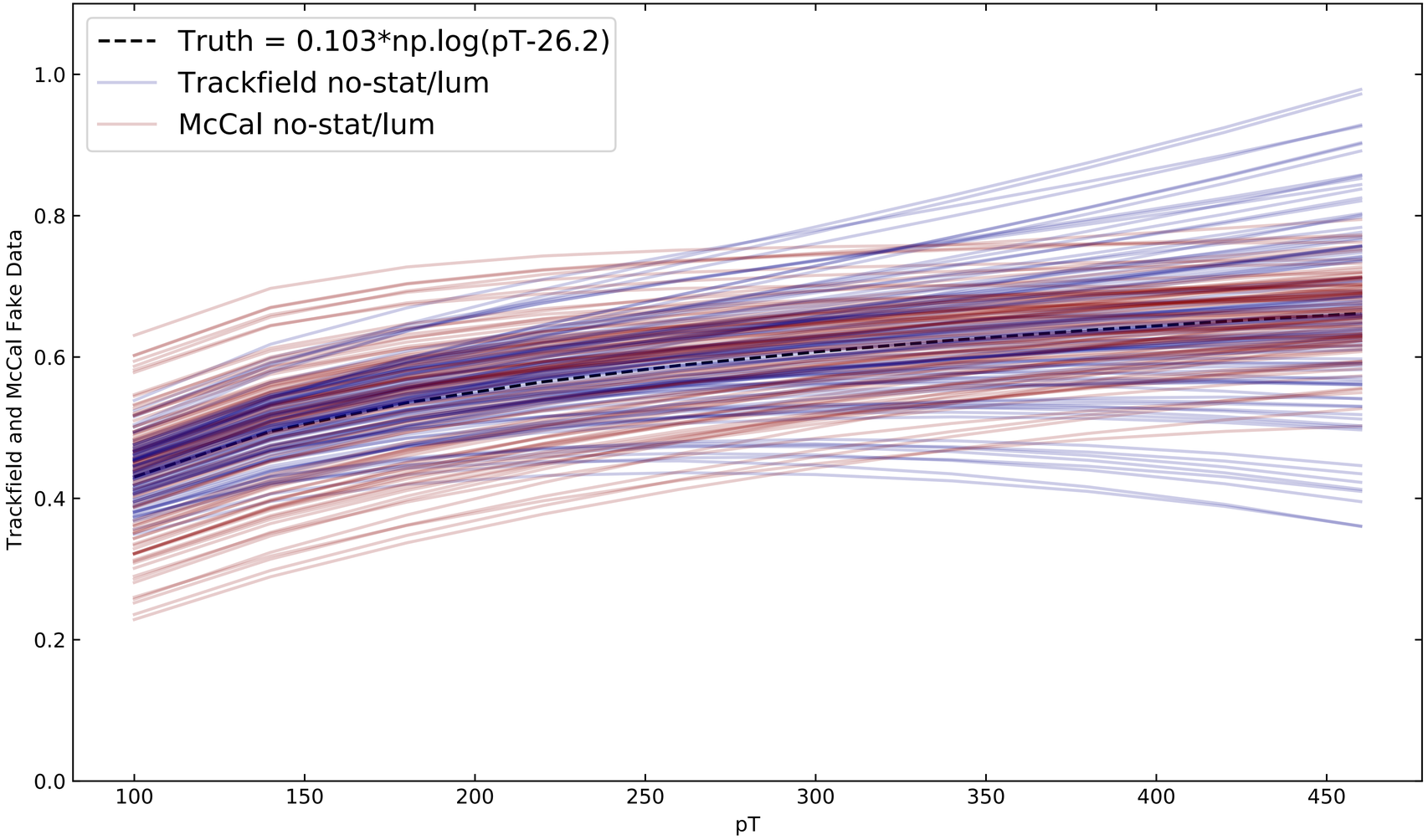
What they actually measured

Confidence limits based on expected errors



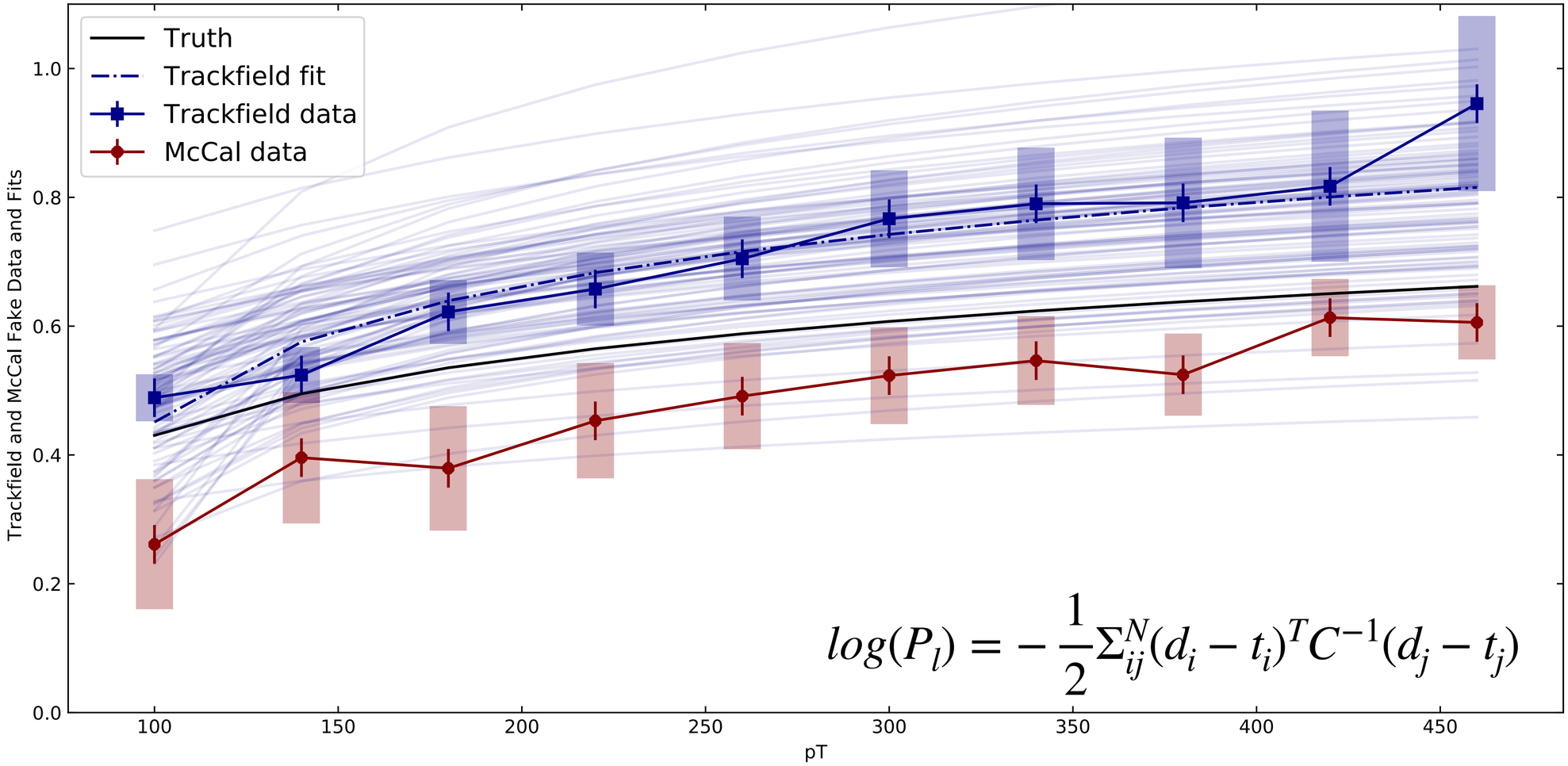
What could have been measured

Sample draws for both measurements

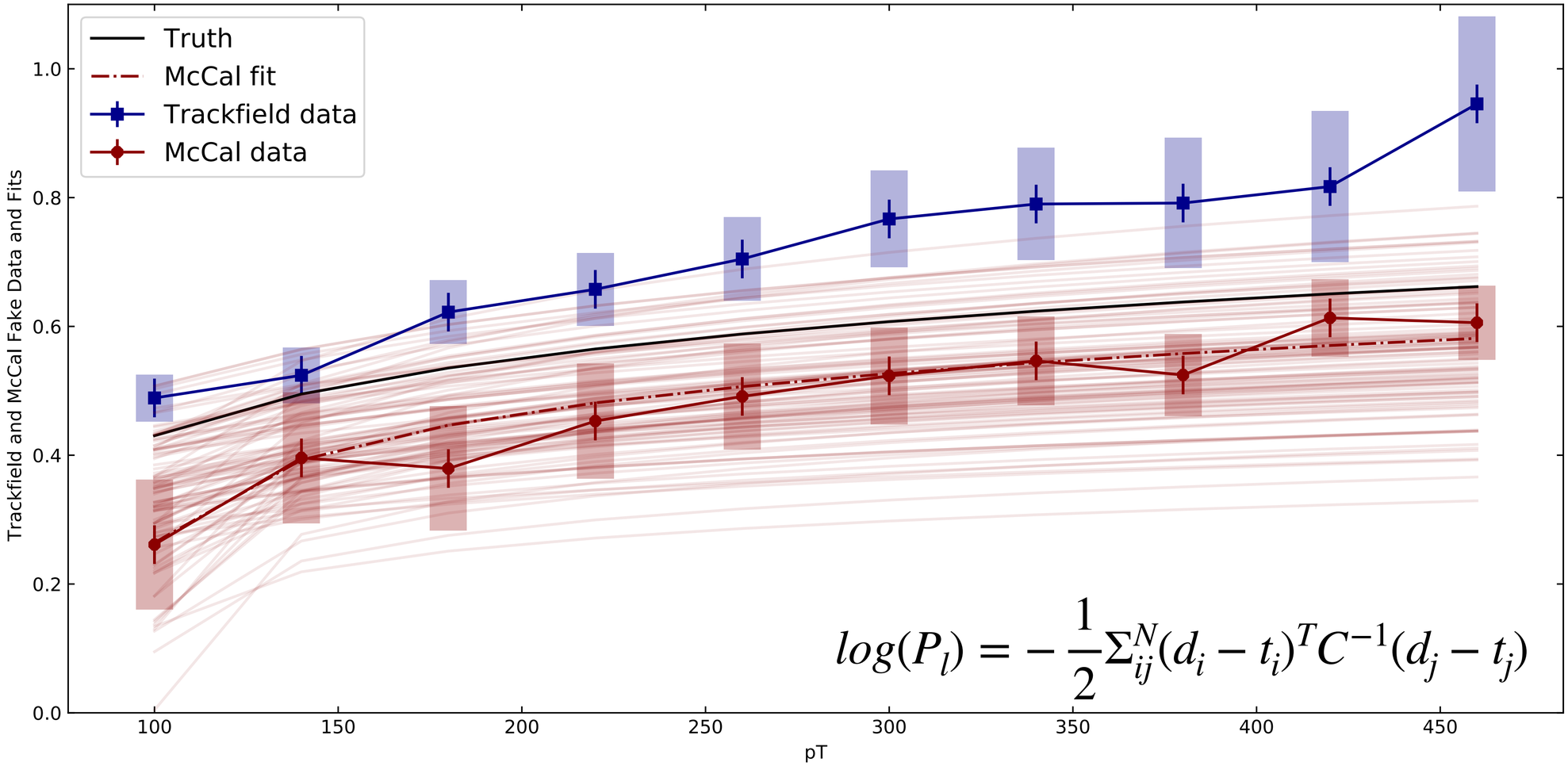


What might have been measured

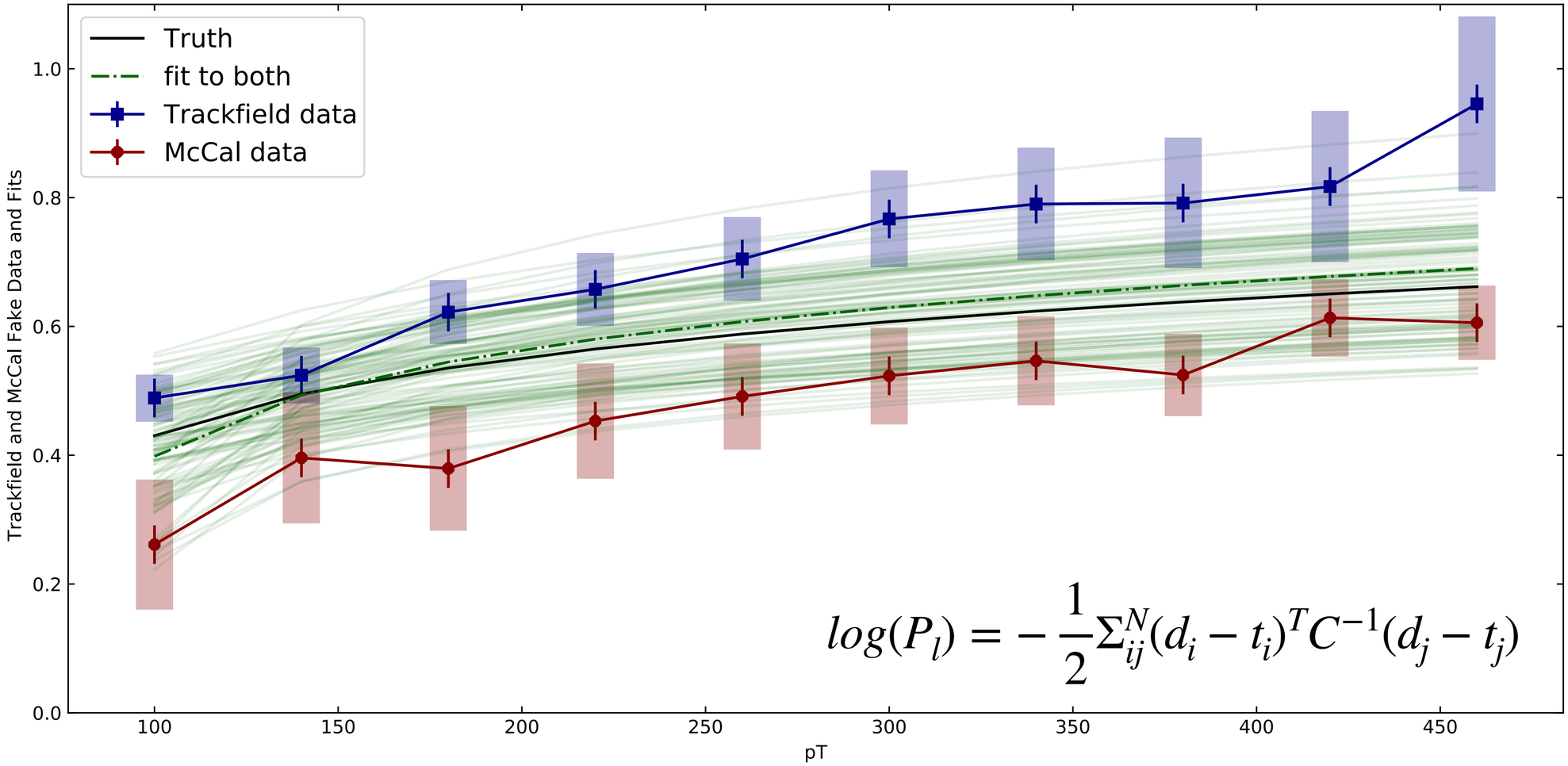
2-parameter Bayesian estimation by the Trackfields



2-parameter Bayesian estimation by the McCals



Combined Bayesian estimation by the Trackfields & McCals



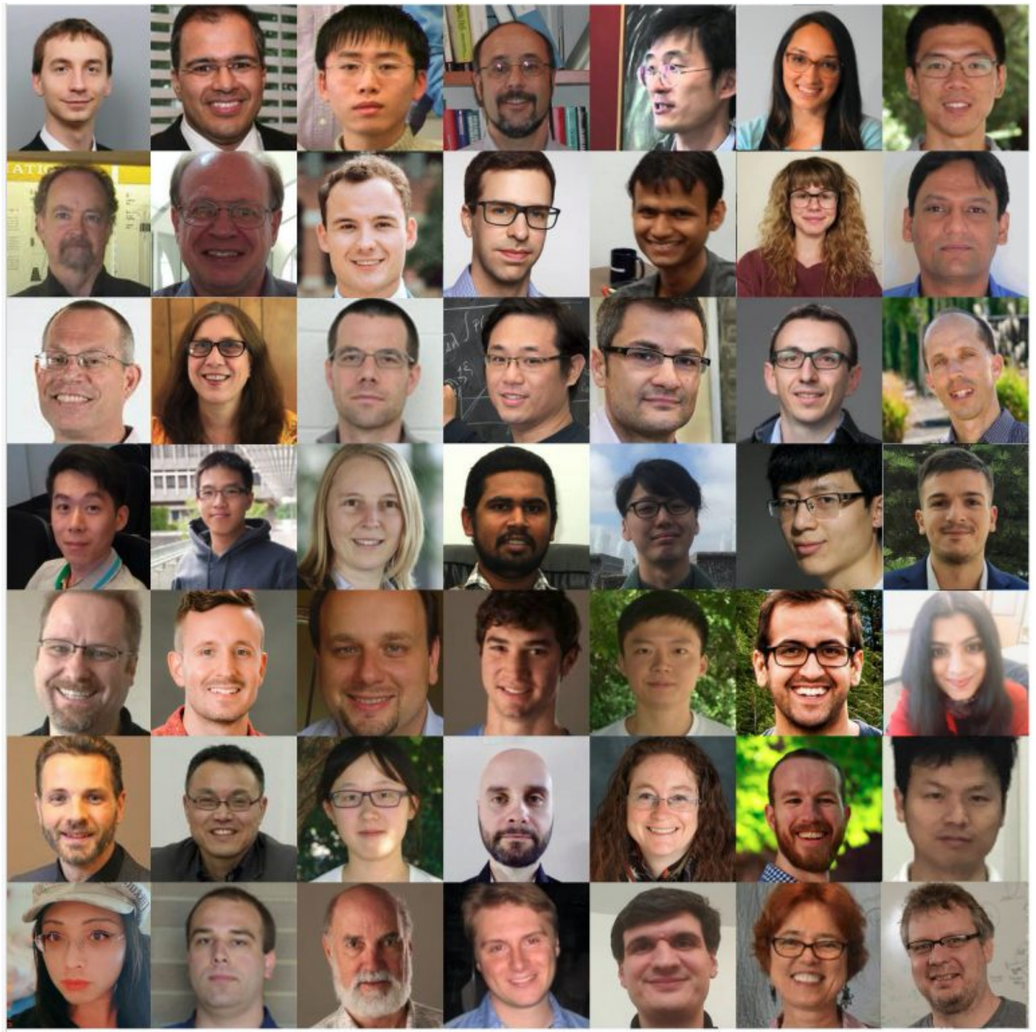
$$log(P_l) = -\frac{1}{2}\Sigma_{ij}^{N}(d_i - t_i)^T C^{-1}(d_j - t_j)$$

Conclusions and Questions

- **We should all follow the example of the Trackfields and McCals**
- **Provide all nuisance parameter bands or full covariance error matrices to enable comparisons across measurements.**
- **Having several measurements/experiments with different systematics is a good thing.**
- **How to communicate uncertainty when performing comparisons across experiments/measurements with different systematics ?**
  - All-inclusive error bands don't show correlations
  - Multi-layered bands and draws can be confusing

Thanks to…

JETSCAPE Collaboration



circa 2019