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# Bayesian quantification of the QGP with an IP-Glasma initial state



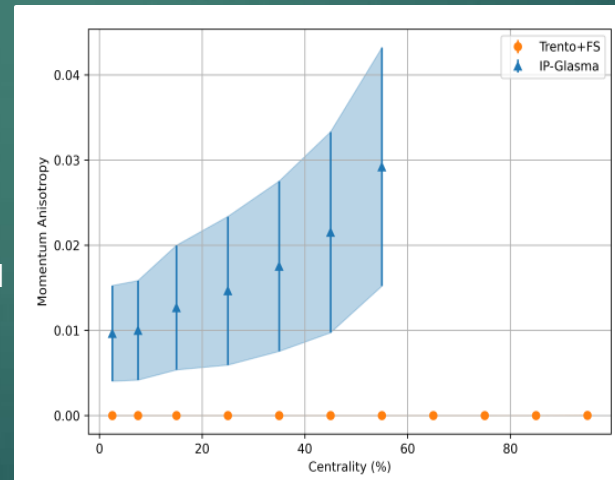
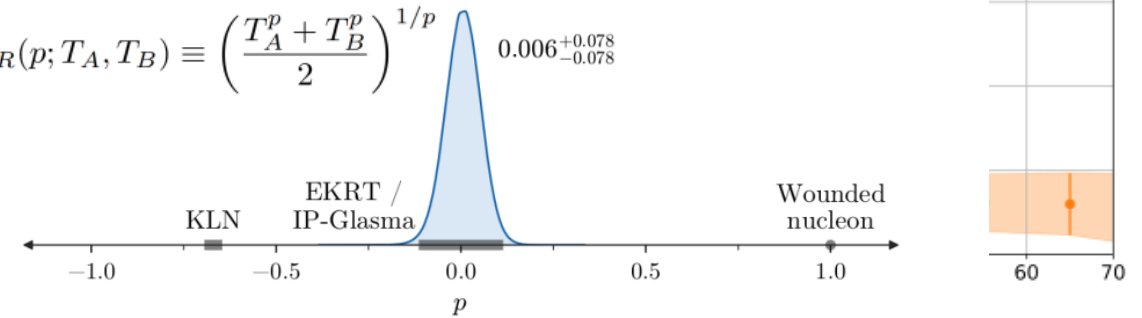
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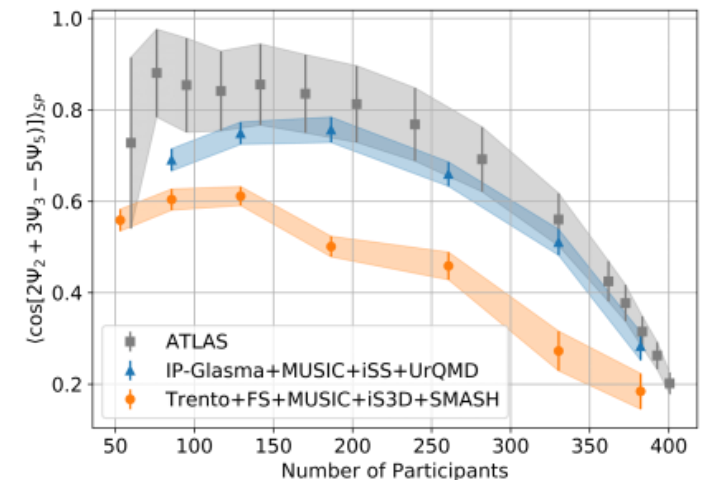
# Motivation: Accurately Infer Properties of QGP

- ▶ All recent Bayesian studies use a Trento + simple dynamics initial state
- ▶ Simple dynamics are insufficient for accurate inference of QGP properties and known impacts exist
- ▶ Can't just **add parameters** forever
- ▶ More on differences between Trento-based simulations and IP-Glasma:
  - ▶ Heffernan, Gale, Jeon, Paquet, APS April Meeting 2021
  - ▶ Heffernan, Gale, Jeon, Paquet, Initial Stages 2021

$$T_R(p; T_A, T_B) \equiv \left( \frac{T_A^p + T_B^p}{2} \right)^{1/p}$$



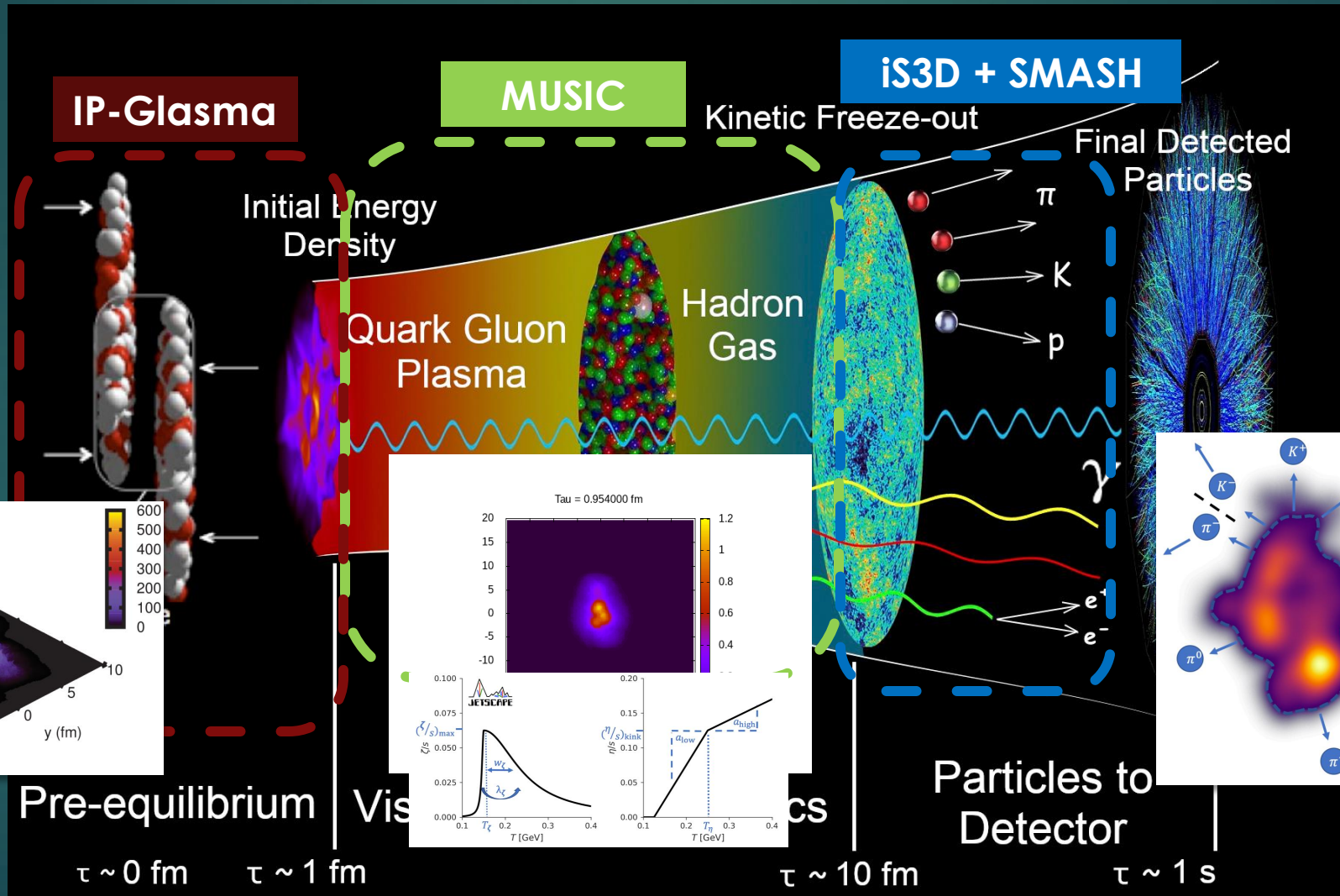
$$\mu \approx 0.102 \quad \sigma \approx 0.09$$



# Next-generation analysis: Inference with IP-Glasma

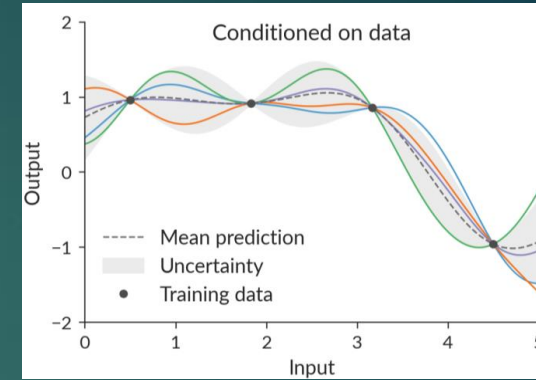
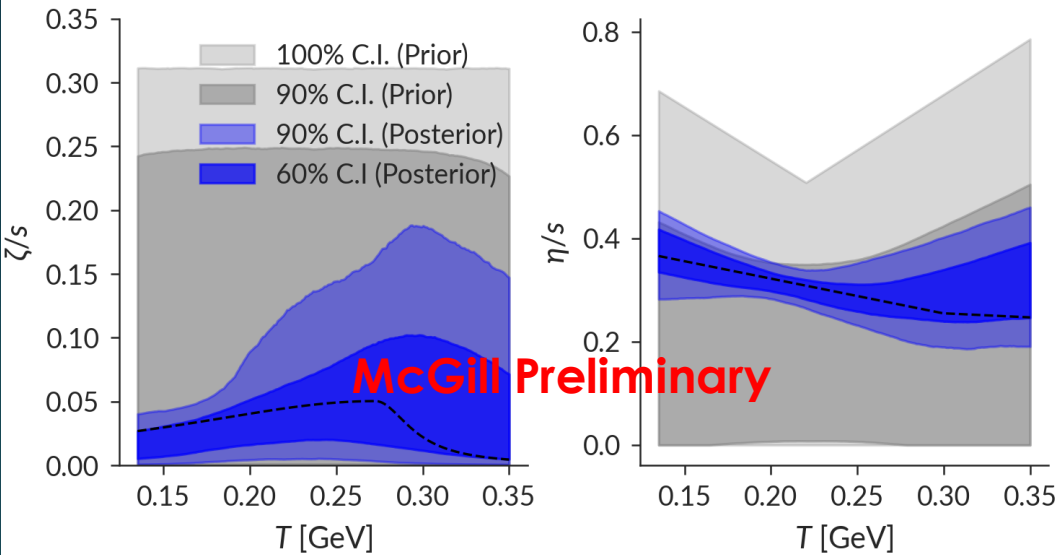
- ▶ **Improve models, gain insight**
  - ▶ Early stage is a significant source of uncertainty
  - ▶ Isolate physics from parametric flexibility
- ▶ **Connect to first-principles QCD-based theory**
  - ▶ Addresses theoretical uncertainty
  - ▶ Enable feedback between theoretical effort and measurements
- ▶ **Intelligently expand observables**
  - ▶ Choose quantities known to simultaneously constrain viscosity and initial state geometry
- ▶ Keep rest of analysis **consistent with JETSCAPE** to allow for iterative improvement
  - ▶ [JETSCAPE Collaboration, PRL 126, 242301, JETSCAPE Collaboration, PRC 103, 054904]
- ▶ Note: **Current results are preliminary** and include only 190/350 design points, ordered to maximize coverage of the intermediary set

# Modeling the Soft Sector

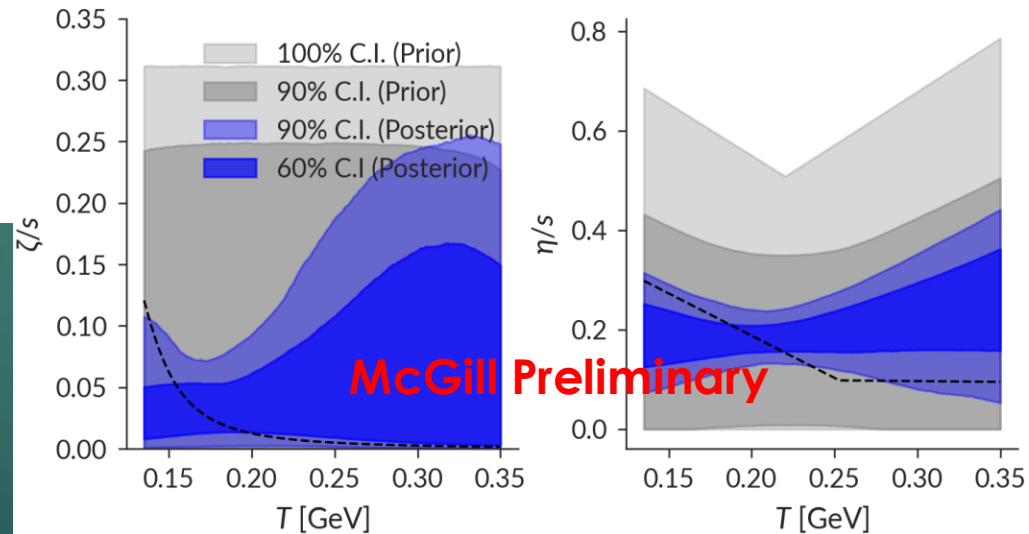


# Surrogate Model Validation

Viscosity Posterior : Grad



Viscosity Posterior : Grad



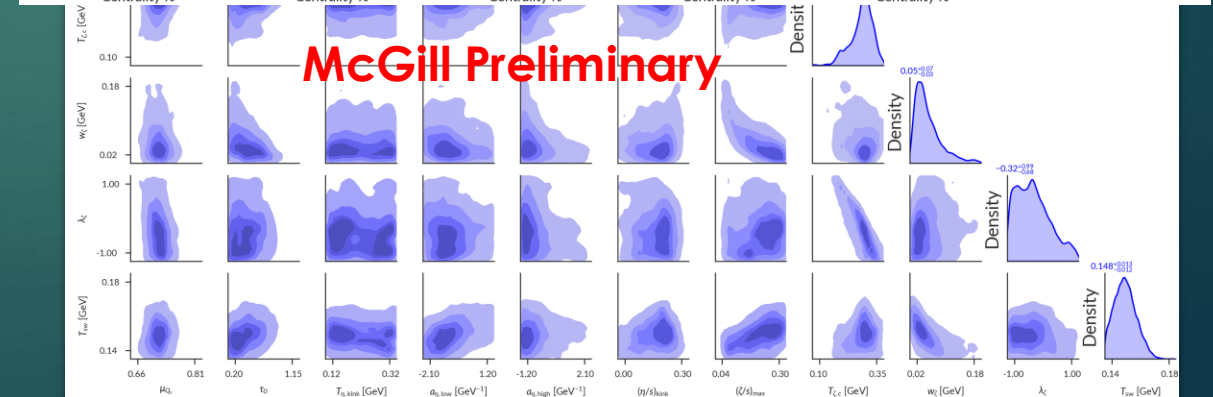
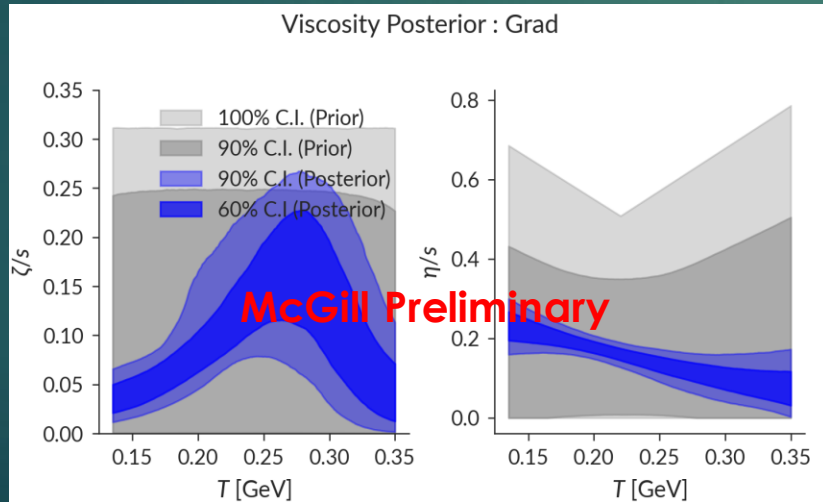
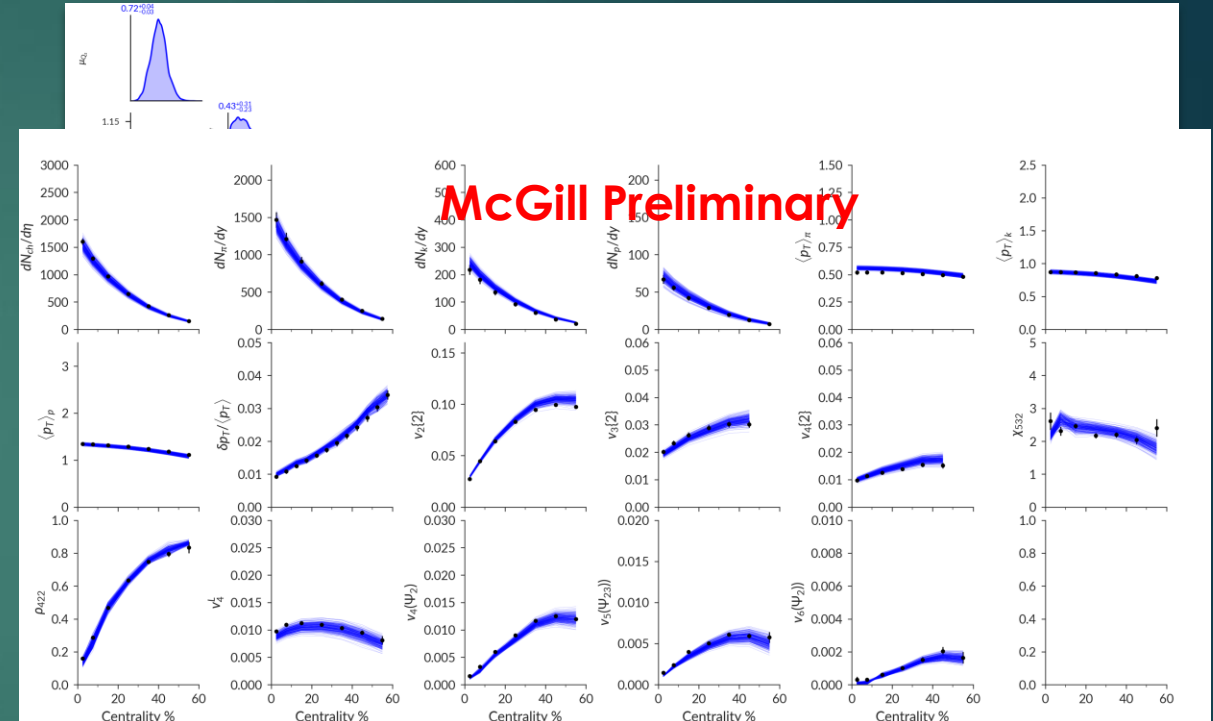
- ▶ Train a "surrogate": hybrid model evaluations are prohibitively expensive
- ▶ Broad ability to capture parameter dependence even with partial design

# Posterior distribution

$$p(H|d, I) = \frac{p(d|H, I)p(H, I)}{p(d, I)}$$

Likelihood      Prior  
Posterior

- ▶ Clearly able to learn from data
- ▶ Bulk inconsistent with 0: impact of realistic initial dynamics?
- ▶ Shear is temperature-dependent
- ▶ Bayes Factor comparisons on the way
- ▶ Model has 11 parameters – fewer than many others - and fits experiment well



# Conclusions

- ▶ **Preliminary results already highly promising**
  - ▶ **Improvements to design improve emulator performance and reduce artificial uncertainty**
- ▶ Early results suggest demonstrable constraints on knowledge of the viscosities we're interested in
- ▶ Extracted viscosities are highly sensitive to initial state dynamics
  - ▶ By using a more physically-motivated initial state with dynamics, we have a greater degree-of-belief that extracted parameters describe the QGP
- ▶ **Full results coming soon**
  - ▶ **Multiple viscous corrections**
  - ▶ **Detailed sensitivity analysis**