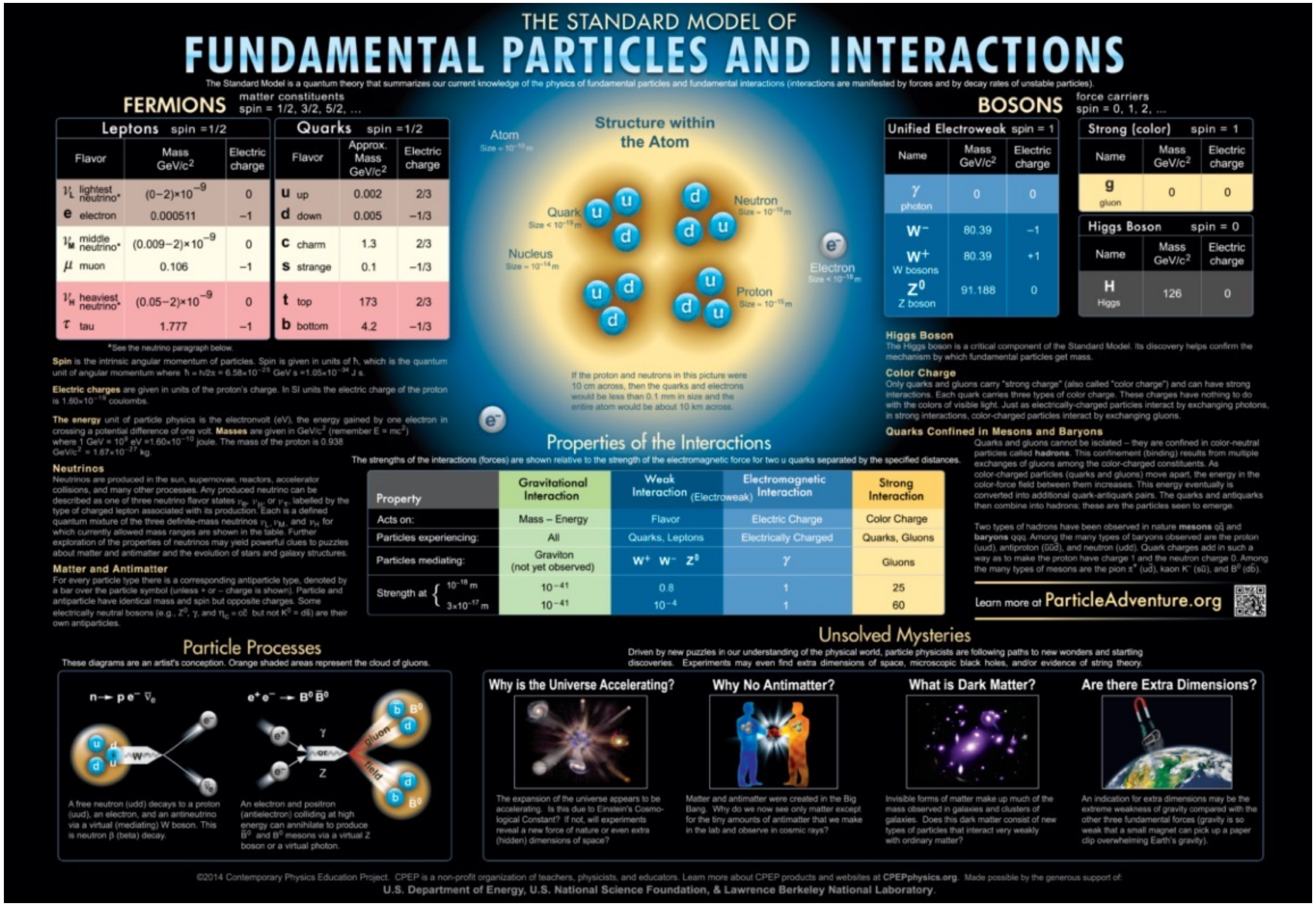
Testing QCD universality

Peter Jacobs, NSD

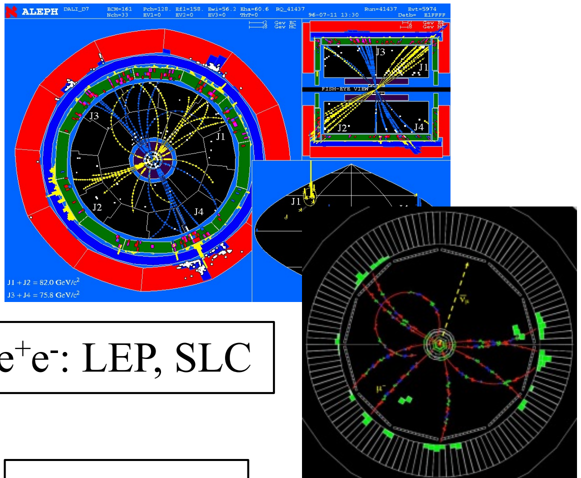
What am I doing here?



Jim Siegrist, talk to NSD prior to turn-on of RHIC (late 1990s):
“Once supersymmetry is discovered, all this is Nuclear Physics.”

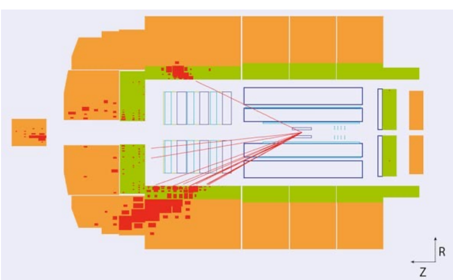
QCD at Colliders

Past



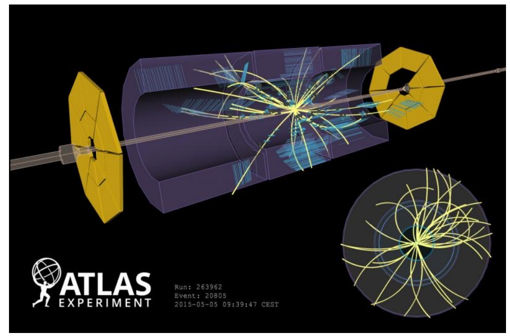
e$^+$e$^-$: LEP, SLC

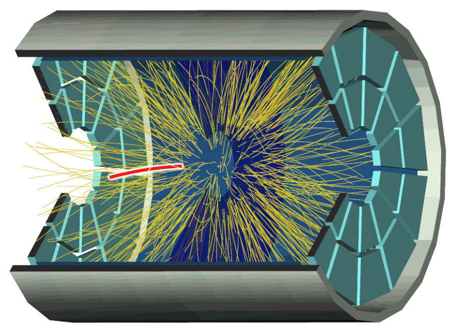
e+p: HERA



Present

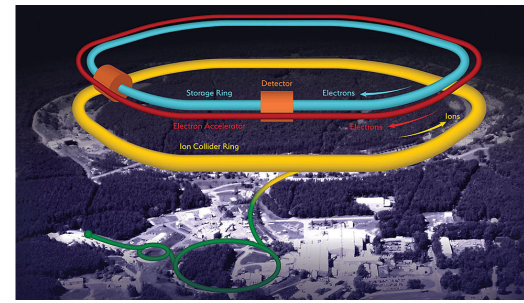
p+p, A+A: LHC, RHIC





Future

e+p, e+A: EIC



e$^+$e$^-$: LBNL?

Final states strongly dominated by QCD
Past colliders: archived data now being analyzed by modern tools
Last decade: major advances in QCD theory+exp (SCET, grooming,…)

Opportunity: comprehensive QCD analysis using data from multiple colliders

→ can we learn something new and interesting about QCD universality?

Example: testing the universality of hadronization across collision systems

work in progress

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consider in our study. The goal is to study universality of nonperturbative corrections to perturbative QCD predictions that can then be measured in experiments. There are two types of "universality" that we mean here: (i) universality of nonperturbative effects in different *observables* in the *same* collider environment, and (ii) universality of nonperturbative effects in different (but related) observables in *different* collider environments. We will consider both types, though the type (ii) is certainly stronger.

Event shape in DIS: N-Jettiness

Kang et. al., Phys.Rev.D88:054004 (2013)

Global event shape measuring collimation of event along jet and beam directions

- Do jet reco; select N hardest jets in event
- N+1 axes *q*: beam + N jets
- For each hadron *i*: 4-vec projection onto each axis; select minimum q.p

$$\tau_N = \frac{2}{Q^2} \sum_{i \in X} \min\{q_B \cdot p_i, q_1 \cdot p_i, \ldots, q_N \cdot p_i\}\,,$$

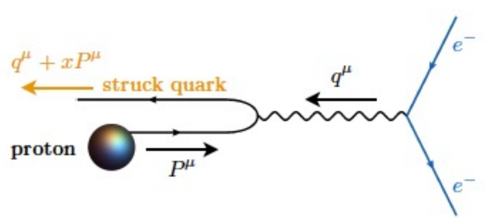
$\tau_N \to 0$ = perfectly collimated jets

$\tau_N \to 1$ = spherically distributed event

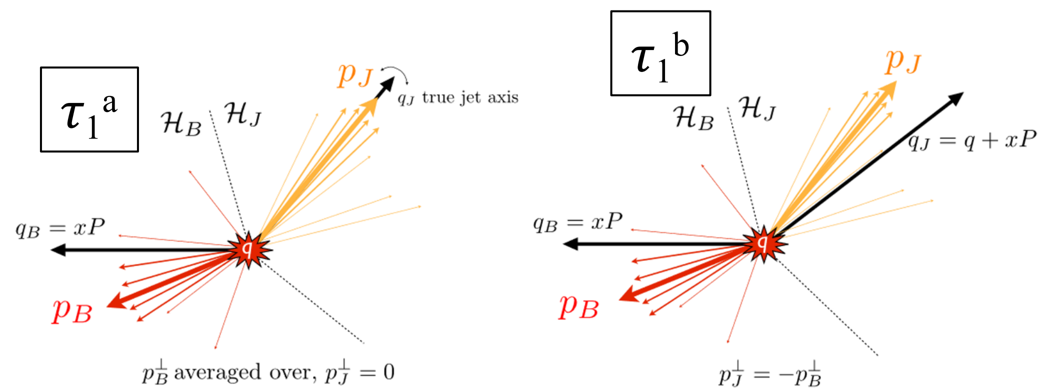
1-jettiness

$$\boxed{\tau_1 = \frac{2}{Q^2} \sum_{i \in X} \min\{q_B \cdot p_i, q_J \cdot p_i\}}$$

Breit frame



Choices of jet direction



(a) τ_1^a (b) τ_1^b

q: jet reco ***q***: kinematic balance

Non-perturbative corrections to τ

SCET factorization:

$$\frac{1}{\sigma}\frac{d\sigma}{d\tau} = \frac{1}{\sigma}\int dk \frac{d\sigma_{\rm PT}}{d\tau}\left(\tau - \frac{k}{Q}\right) F\left(k - c_\tau \Omega_1\right), \qquad \text{or} \qquad \langle\tau\rangle = \langle\tau\rangle_{\rm PT} + \frac{c_\tau \Omega_1}{Q}$$

Hard component
Perturbatively calculable

Soft component
NP

c_τ: pure number
$\Omega \sim \Lambda_{QCD}$

Ω is process-dependent but SCET predicts simple and deep scaling rules between:

- e+p DIS (HERA, EIC): event shapes (τ_1)
- p+p (LHC, RHIC): recoil jet mass for γ/Z + 1 jet (isolated)

Probes the same QCD matrix element → new (and, we hope, incisive) test of QCD universality

Experimental issues being worked out

- data: HERA (H1 archived); LHC (ATLAS, ALICE, CMS, LHCb)

Similar connection to event shapes in e^+e^-?

- Color flow is different than with hadron in initial state
- Work in progress
- Candidate for LBNL e^+e^- Collider science program