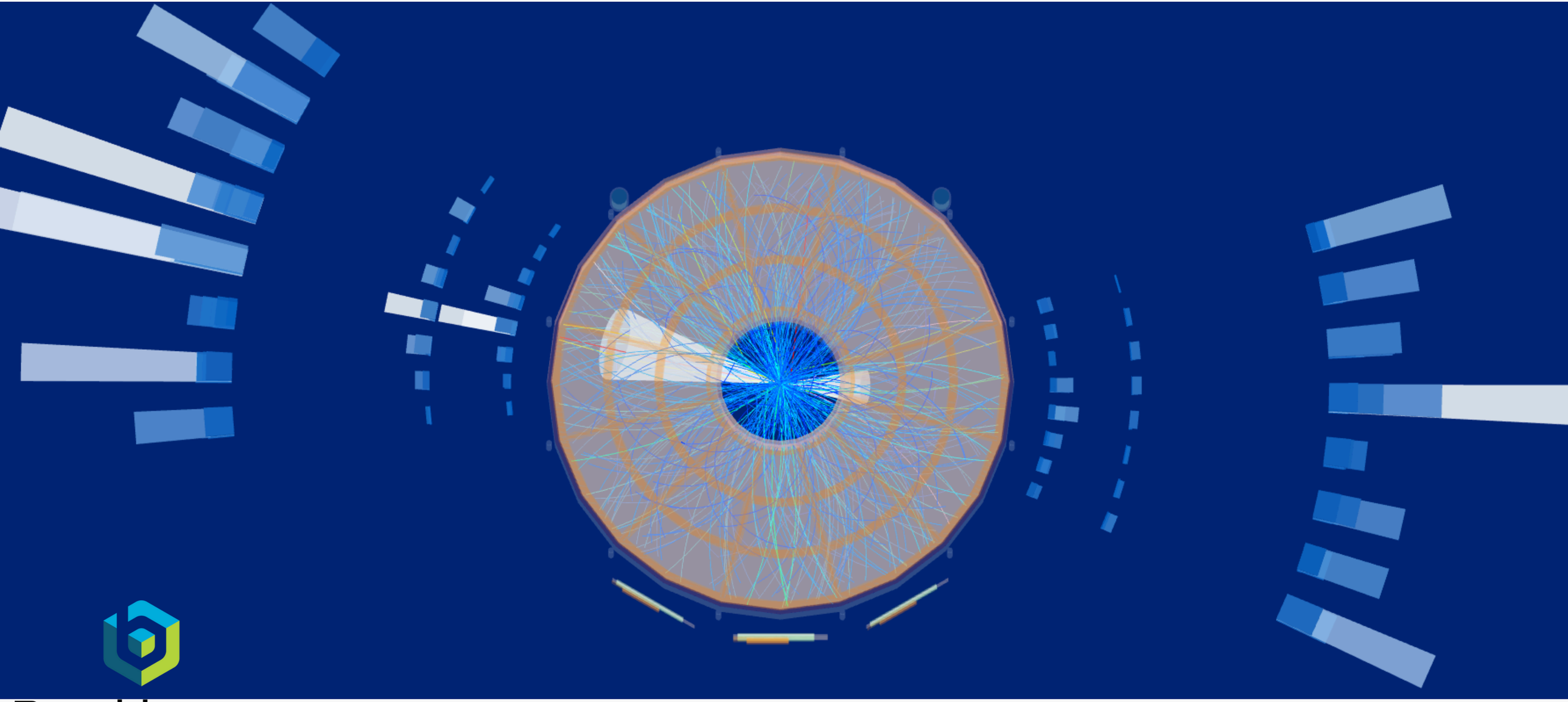
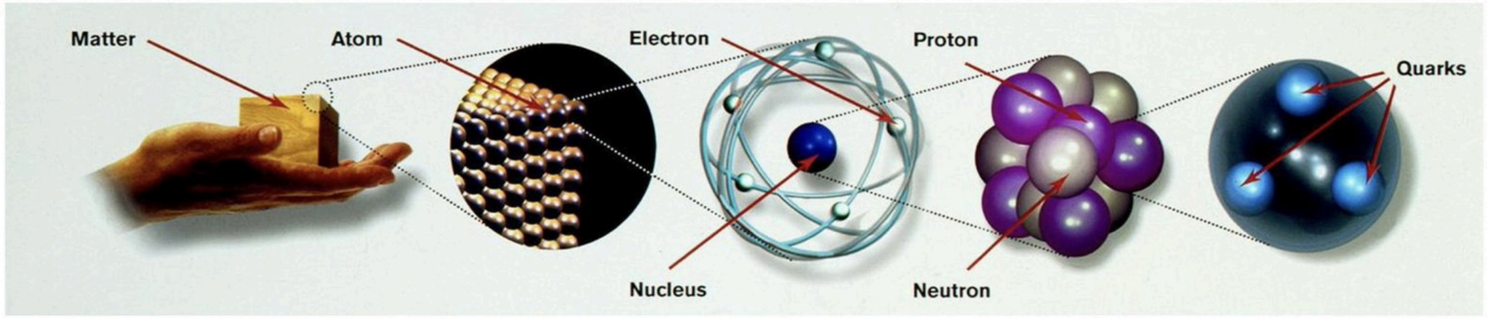
ENERGY FLOW CORRELATION WITHIN JETS



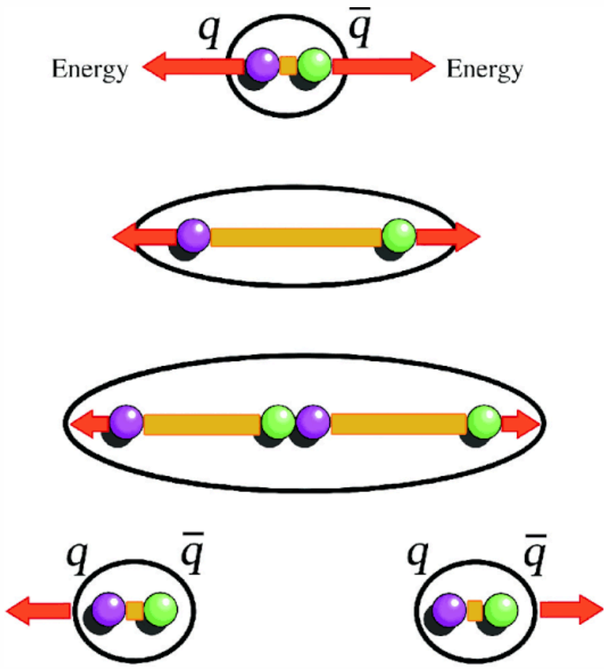
Brookhaven
National Laboratory

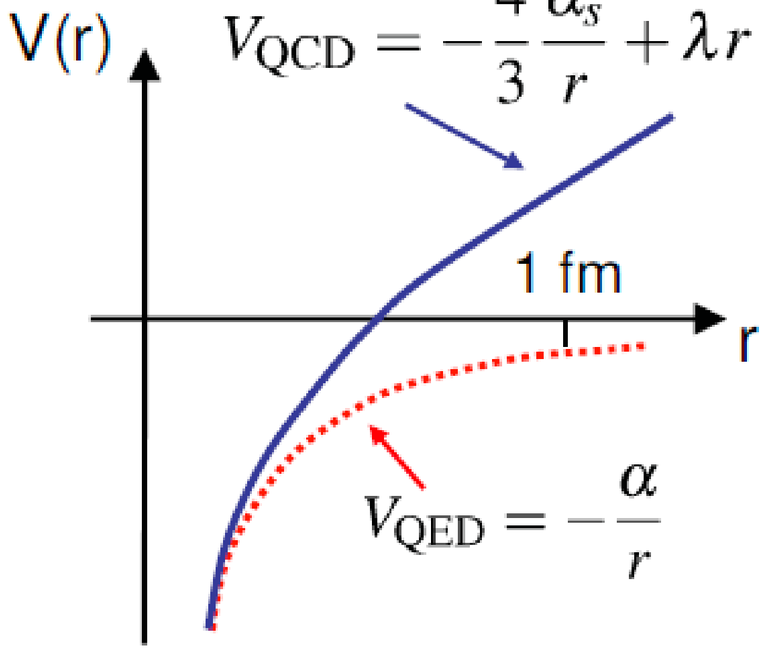
Ejiro Umaka, BNL | ECS/PD retreat, 09-18-24

QUANTUM CHROMODYNAMICS

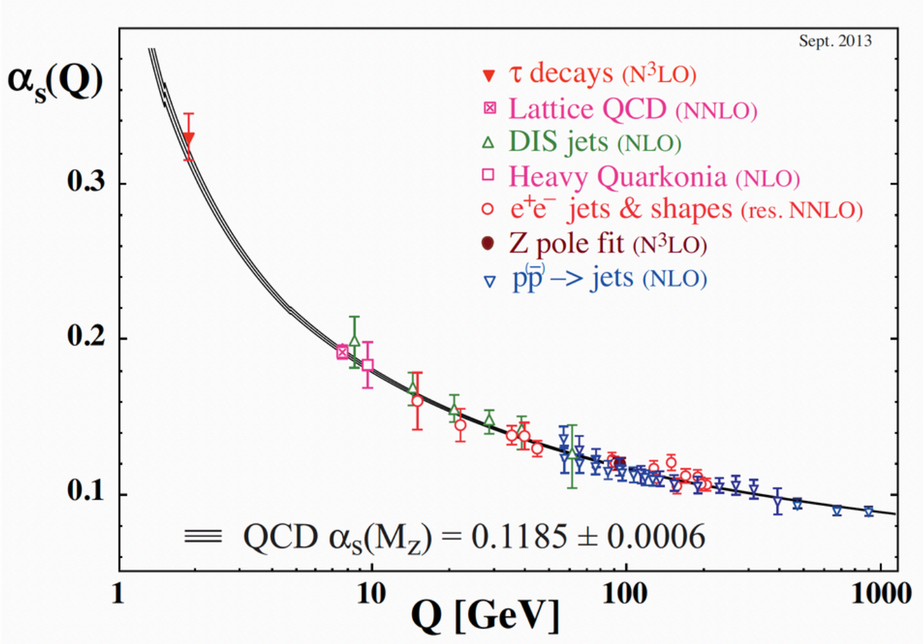


Quark and gluons (partons) are confined in hadrons
QCD is an established theory of strong interactions





Color confinement



[Particle Data Group (2013)]

Asymptotic freedom

JETS ARE SPRAYS OF PARTICLES EMERGING FROM HIGH ENERGY PARTICLE COLLISIONS

In a high energy collision quark and gluons initiate a parton shower. Generates a cascade of radiation which produces more quarks and gluons

Eventually the fragmentation ceases and the partons combine to form composite particles called hadrons

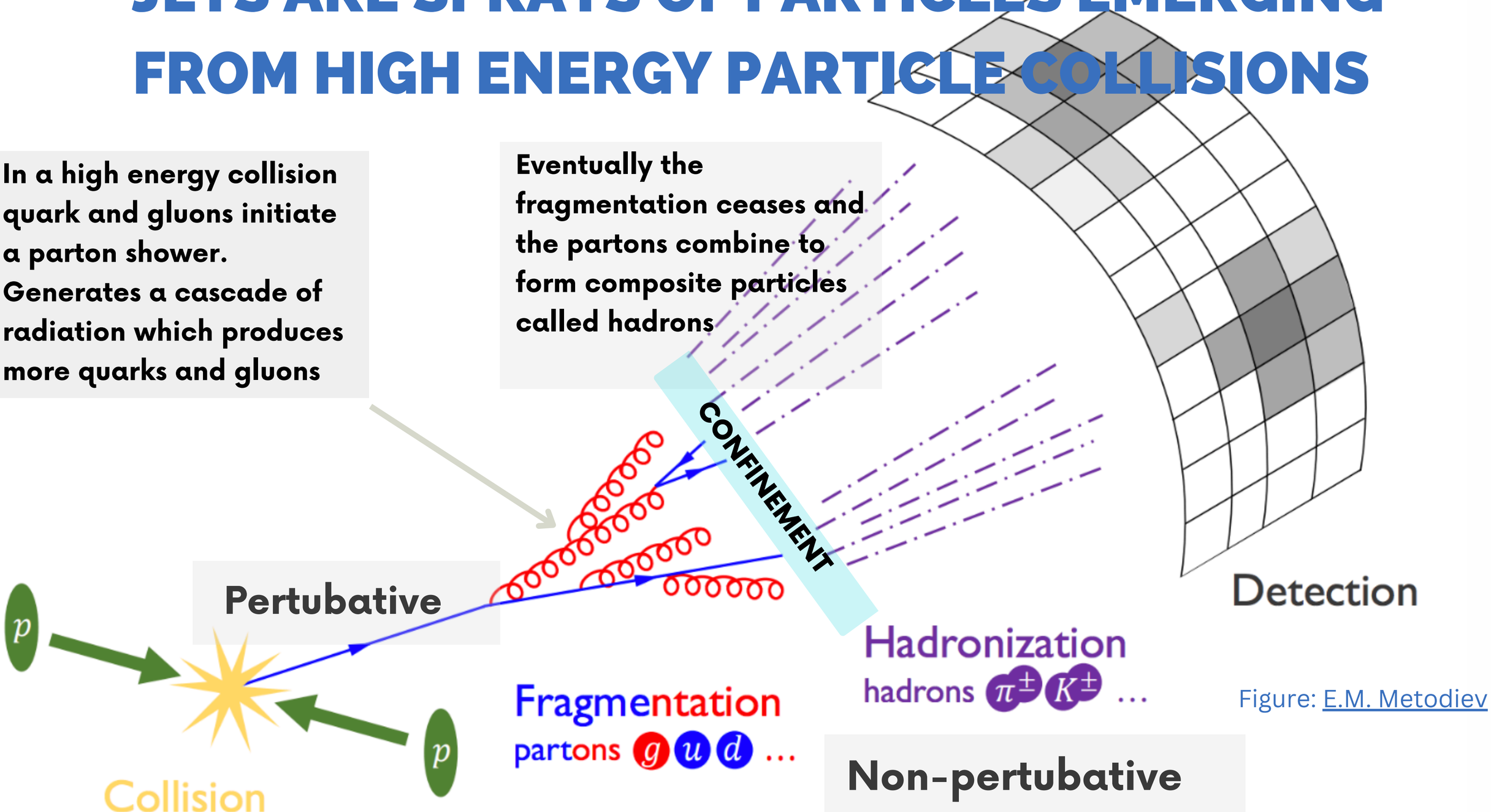
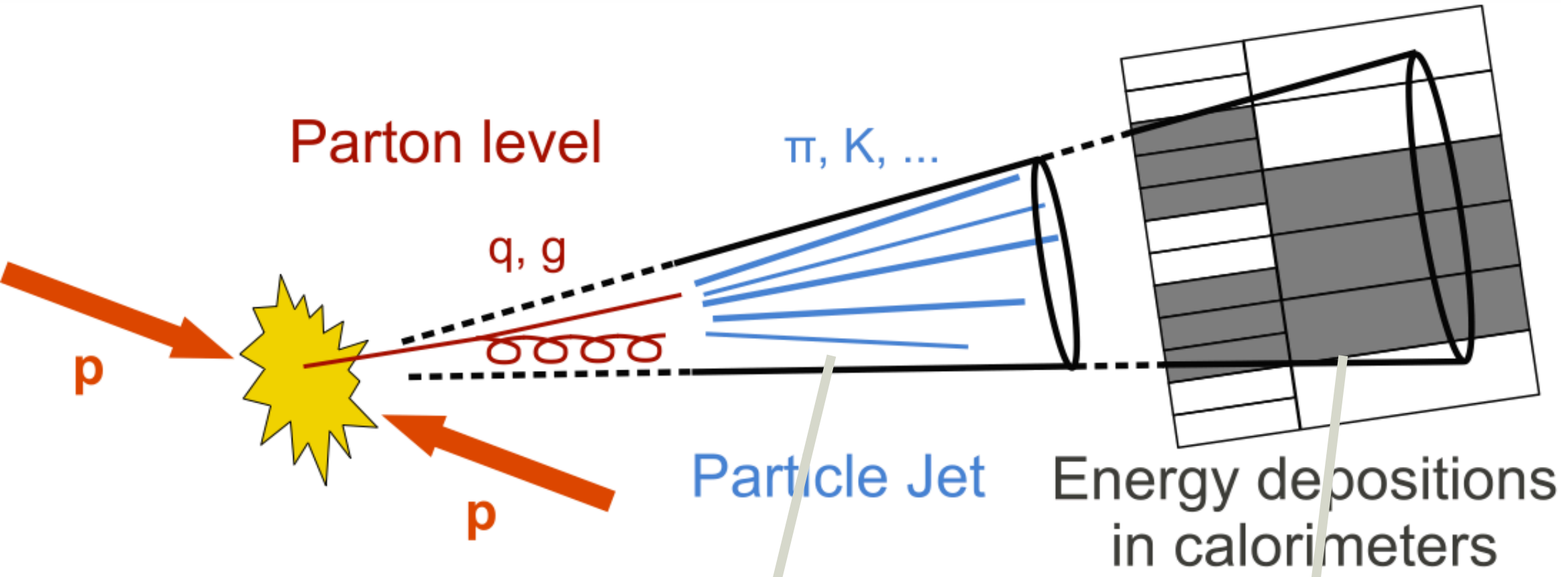
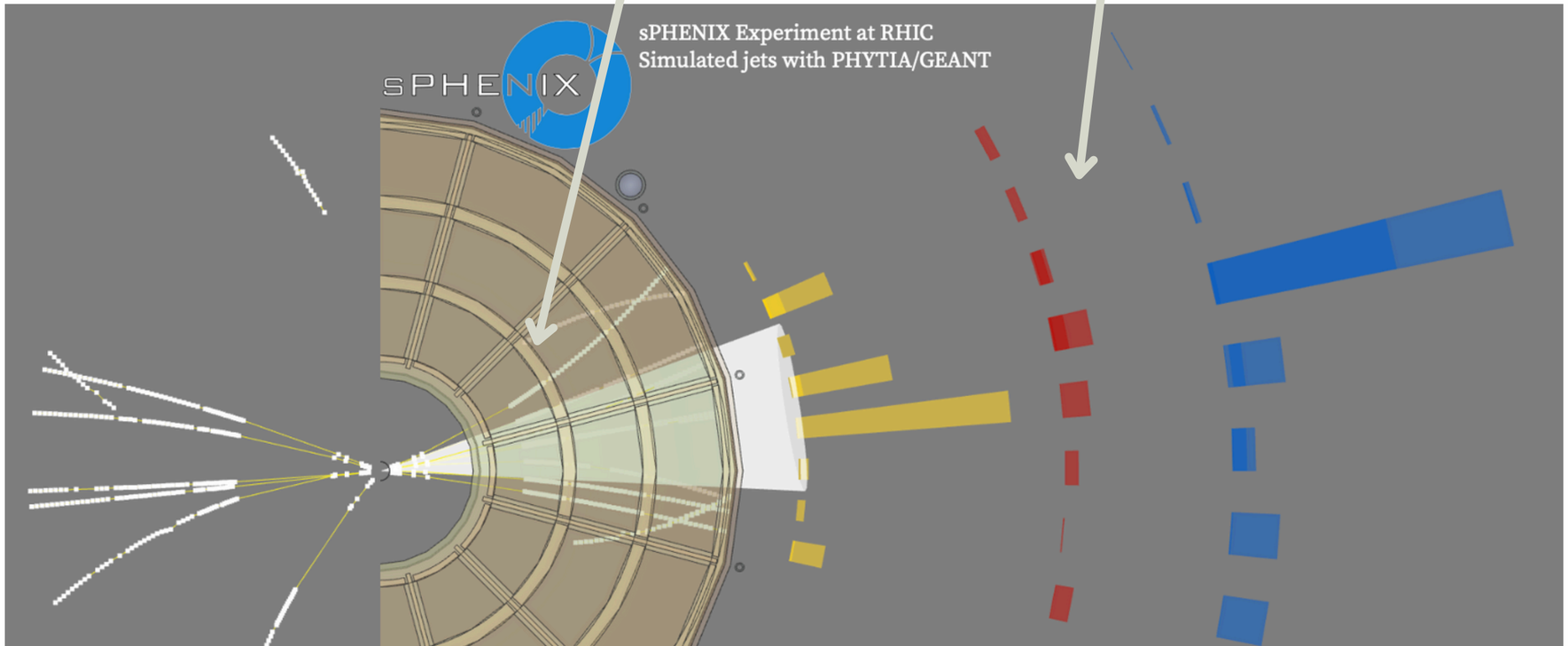


Figure: E.M. Metodiev

MEASURING JETS AT COLLIDER EXPERIMENTS



Jets measured at collider experiments provide key information to probe the time evolution from partons to hadrons



Measuring the energy and angular correlations of particles within a jet probes the time evolution from partons to hadrons

ENERGY CORRELATORS

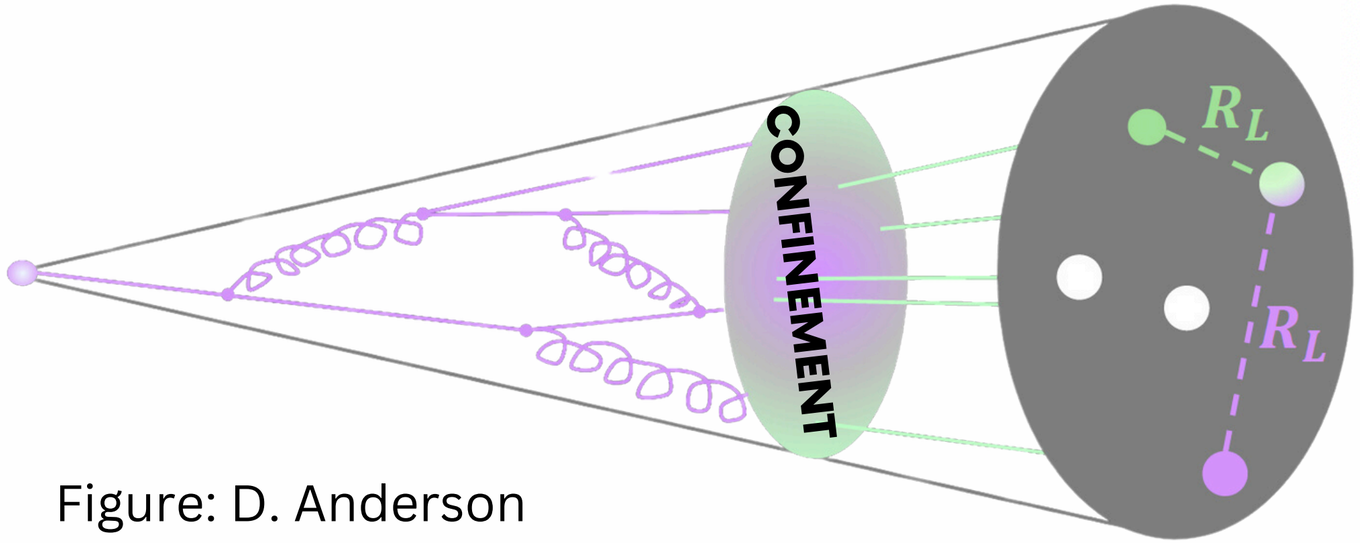
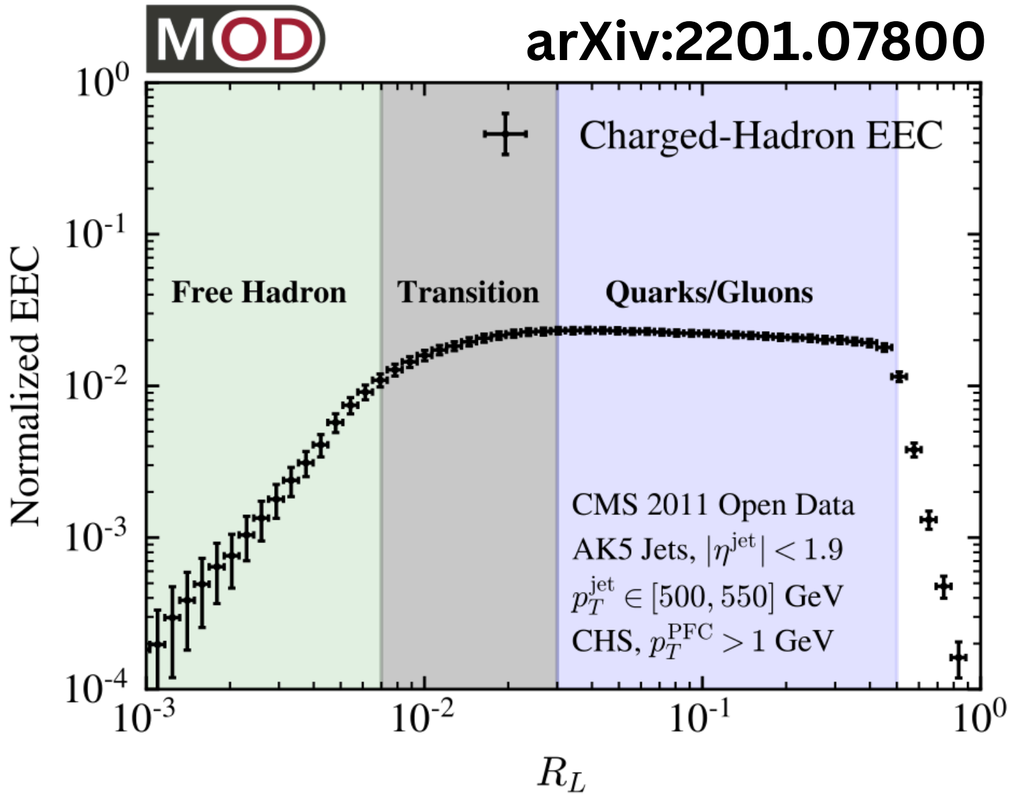


Figure: D. Anderson

$$\frac{\mathrm{d}\sigma_{\mathrm{EEC}}}{\mathrm{d}R_{\mathrm{L}}} = \sum_{i,j} \int d\sigma(R'_{\mathrm{L}}) \, \frac{p_{\mathrm{T},i}\, p_{\mathrm{T},j}}{p^2_{\mathrm{T,jet}}} \, \delta(R'_{\mathrm{L}} - R_{\mathrm{L},ij})$$

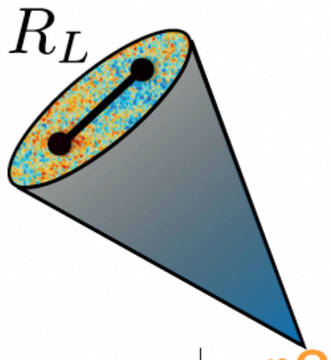
$$R_{\mathrm{L}} = \sqrt{\Delta\varphi_{ij}^2 + \Delta\eta_{ij}^2} \qquad \tau \simeq 1/(p_{\mathrm{T}} R_{\mathrm{L}}^2)$$



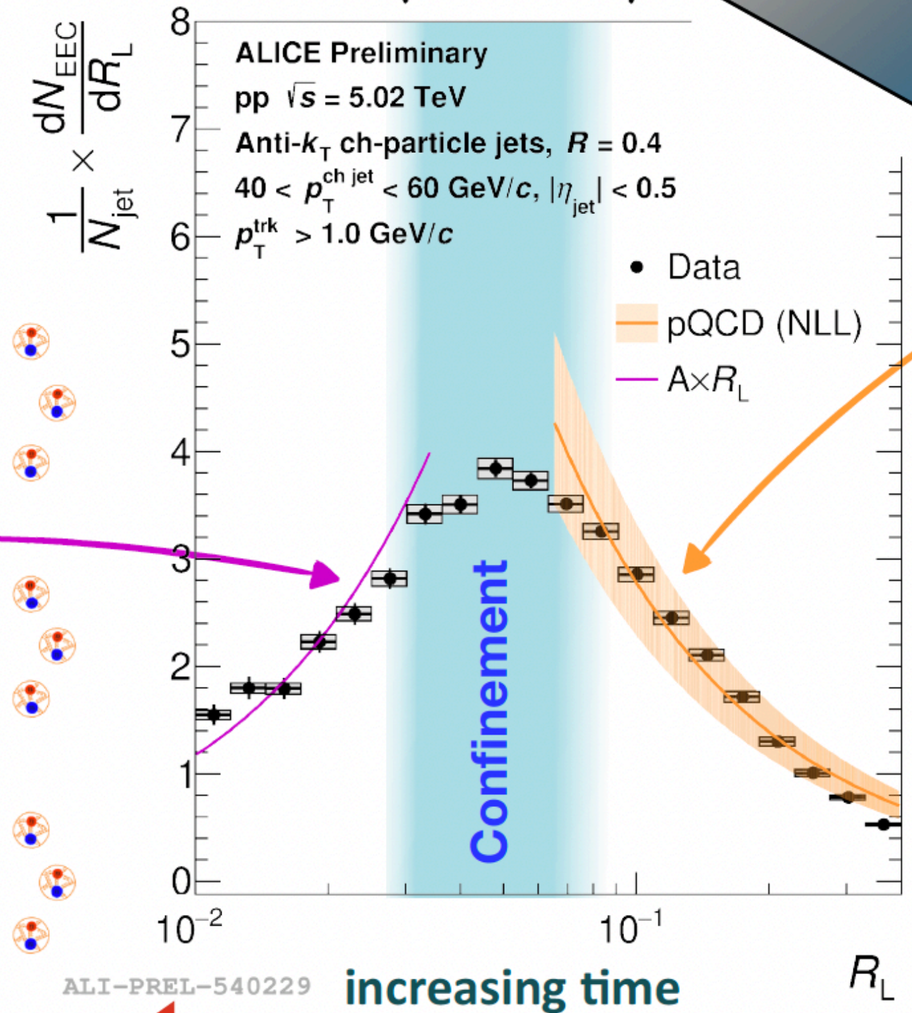
Simplest of such energy correlators is the E2C where the angular distance between any two particles inside a jet is plotted with weigths proportional to their energy fraction within the jets.

MEASURED ENERGY CORRELATORS COMPARISON TO THEORY

Figure: W. Fan

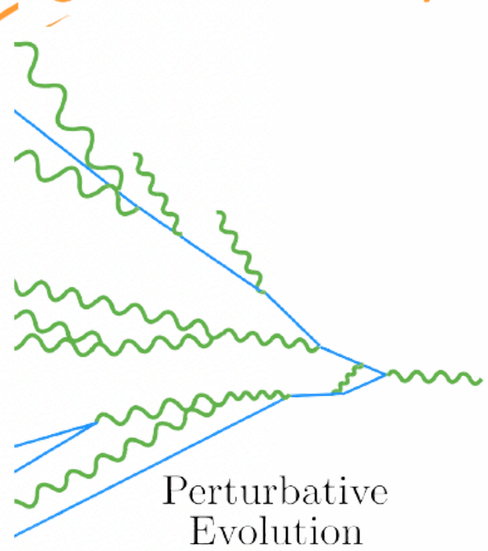


$$\langle \mathcal{E}_1 \mathcal{E}_2 \rangle$$



Free hadron scaling (hadronic degree of freedom)

pQCD scaling (partonic degree of freedom)



increasing time

Small angle

Large angle

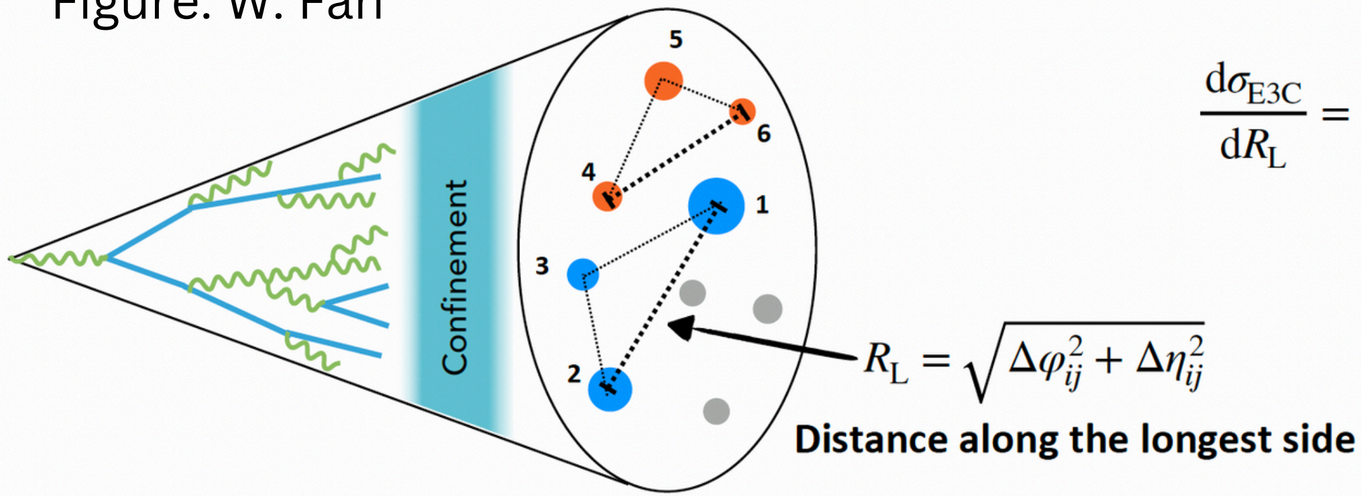
decreasing energy scale

Rising behavior expected at small angles (soft hadrons) and a falling behavior expected at large angles (partonic interactions)

In between the two behaviors is the parton to hadron confinement transition

ENERGY FLUX WITH THREE PARTICLES WITHIN A JET

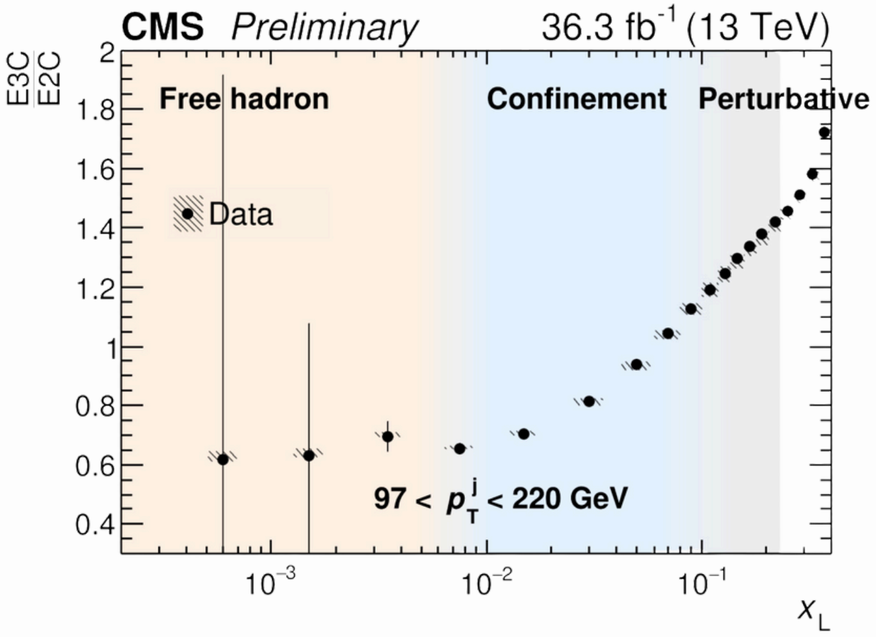
Figure: W. Fan

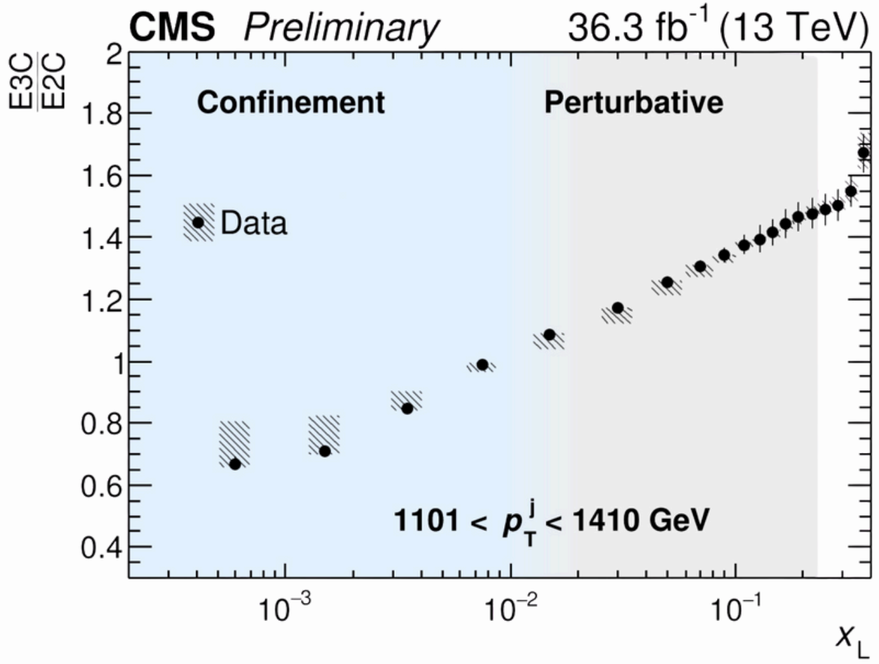


$$\frac{d\sigma_{E3C}}{dR_L} = \sum_{i,j,k} \int d\sigma(R'_L) \frac{p_{T,i}\, p_{T,j}\, p_{T,k}}{p_{T,jet}^3} \delta(R'_L - R_{L,ijk})$$

σ_{E3C}

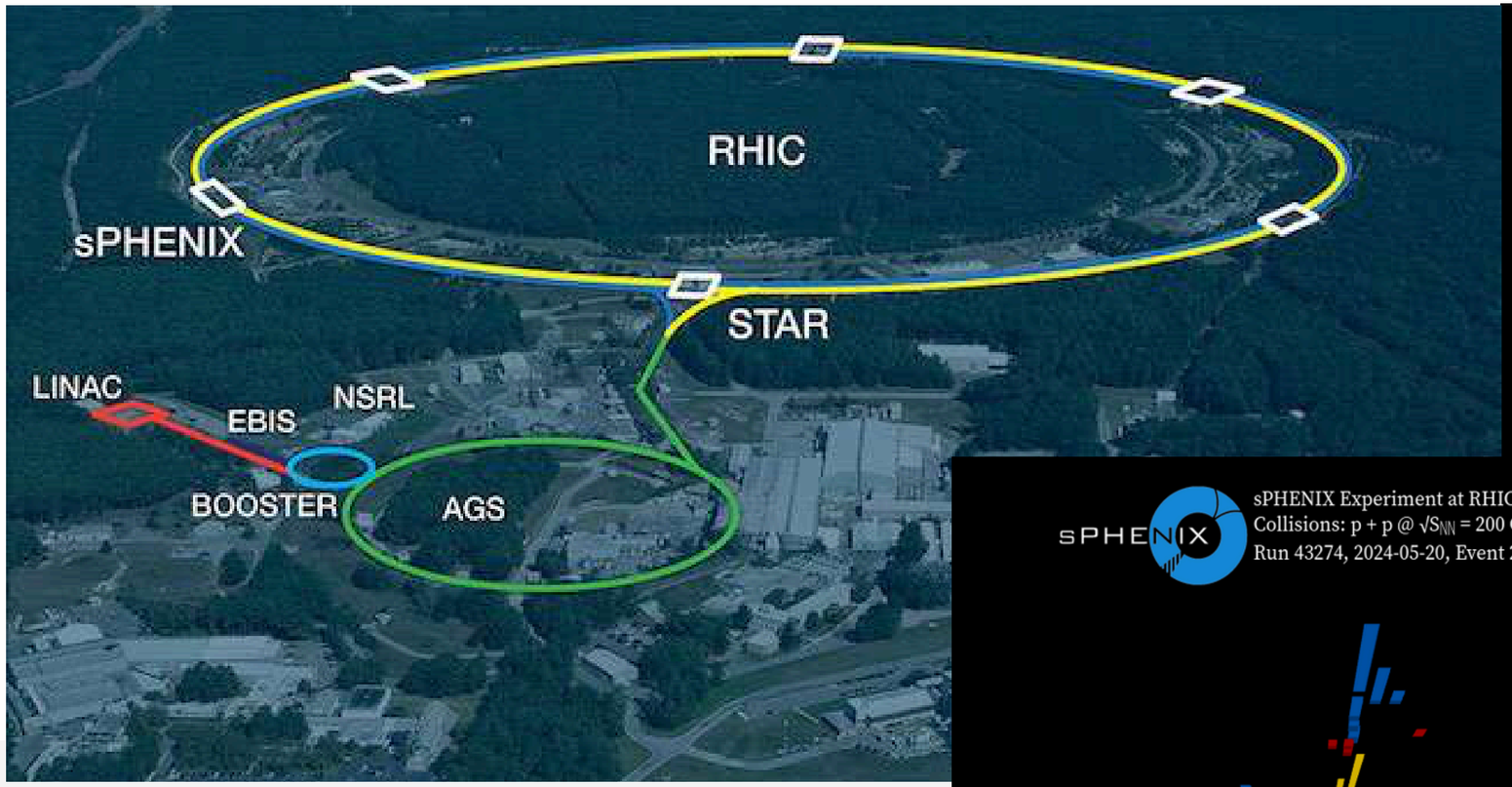
Ref: CMS Collaboration

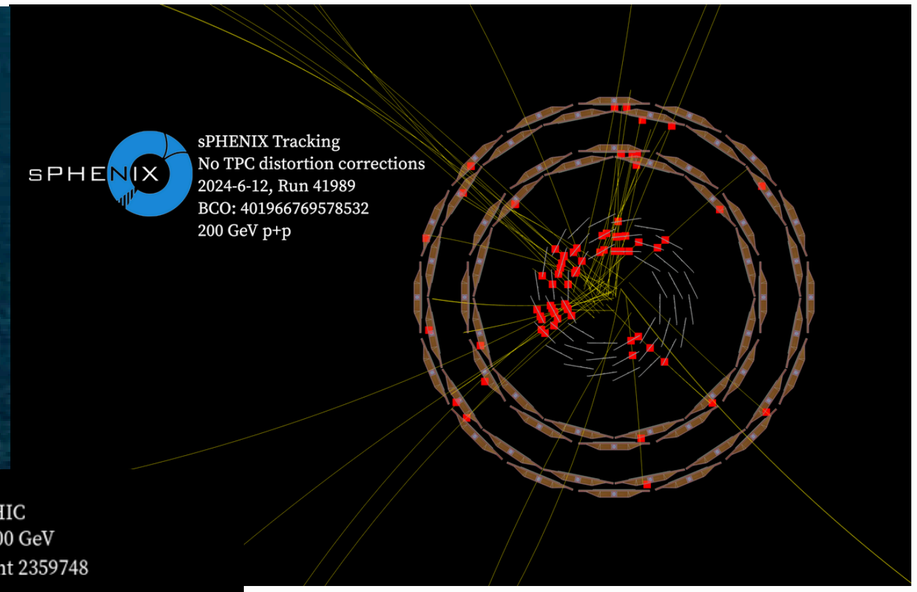


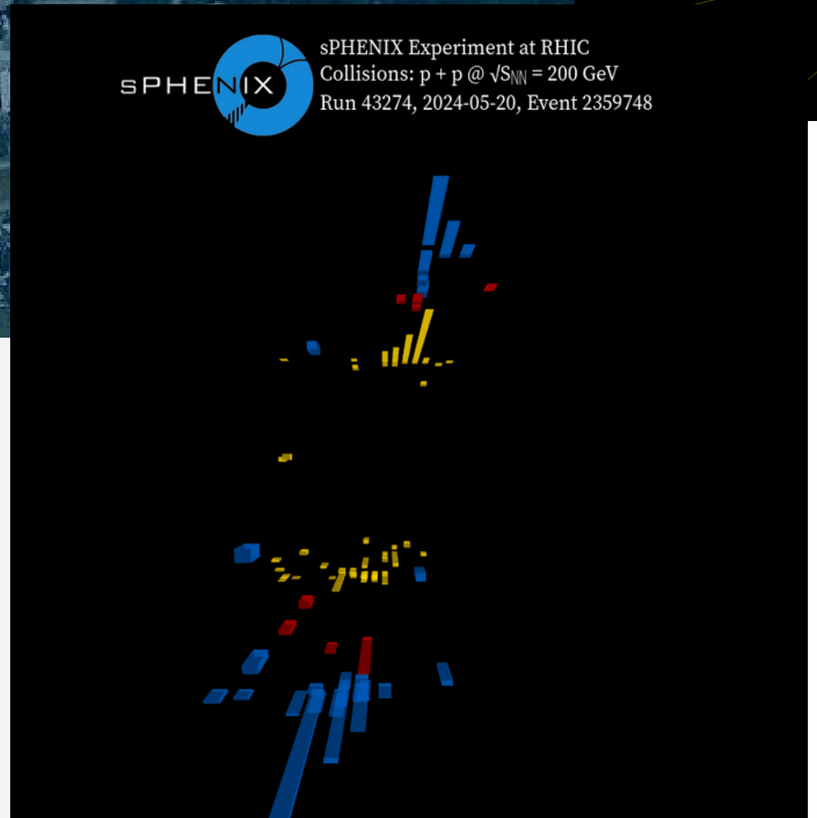


Ratio of E3C to E2C is proportional to the strong coupling constant. The slope of the ratio in the pertubative region varies with momentum indicating that the coupling constant decreases with energy scale, i.e. asymptotic freedom

ENERGY CORRELATORS WITH SPHENIX AND BEYOND







sPHENIX is a jet detector at RHIC.

- **Excellent tracking (our TPC works (now)!)**
- **Full calorimeter system (EM and Hadronic) to measure the full jet energy**
- **High statistics data!**

ENC study directions:

- **How does the distribution/QCD dynamics change when a quark gluon plasma is involved?**
- **What role does quark mass play?**
- **What about in e+p/e+A collisions (CNM)?**

THANK YOU