Charged hadron multiplicities inside of jet:
Accessing Hadron Entropy?

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Entropy and Continuum Distribution

Neumann entropy:

$$S = -\sum_{i=1}^{N} (p_i \log p_i) \underset{N\to\infty}{\sim} \log N \underset{N\to\infty}{\longrightarrow} \infty$$

Generalisation to a continuum distribution:

$$S[F] := -\int F(x) \ln F(x) \mathrm{d}x$$

with $F(x)$ can be $xf(x)$ (PDF) or $zD(z)$ (FF).

Barone, Drago and Ma relation PhysRevC.62.062201:

$$D(z) \simeq zf\left(2 - \frac{1}{z}\right) \simeq zf(z)$$

when $z \to 1$ ($z = \frac{1}{1-(1-1/z)} \simeq 2 - \frac{1}{z}$).

Entropy and Quantum Entanglement

Based on PhysRevD.95.114008:

- **Von Neumann Entropy in DIS:** Interpreted as the entropy of entanglement between the spatial region probed by Deep Inelastic Scattering and the rest of the proton.
- **Entanglement Entropy and Parton Multiplicity:** Assuming the hadron multiplicity is proportional to the multiplicity of color-singlet dipoles: relation between the parton structure function and the entropy of produced hadrons.

$$S_{\text{partons}} = \ln\left(xg\left(x, Q^2\right)\right) \equiv S_{\text{hadrons}}$$

Can we apply the same idea with the FF?

$$S_{\text{hadrons}} \overset{?}{\equiv} \ln\left(zD\left(z, \mu^2\right)\right)$$

PYTHIA information

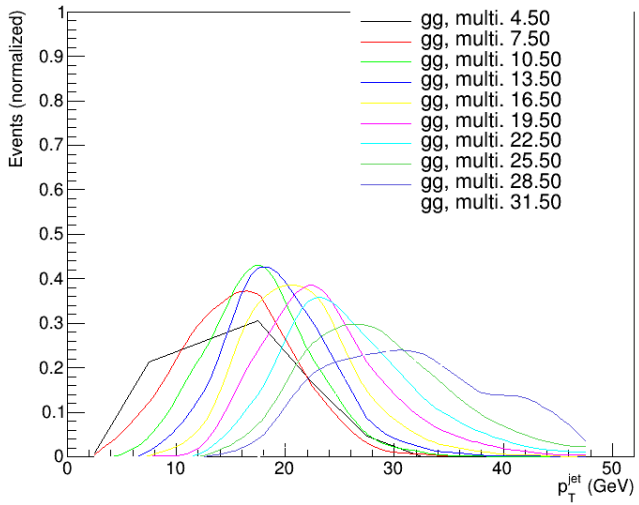
- pp collisions
- Hard QCD processes:
  1. gg to gg;
  2. gg to $q\bar{q}$.
- Anti-$k_{\perp}$ algorithm;
- Jet information:
  1. $R^{\text{Jets}} = 0.4$;
  2. $p_{\perp}^{\text{Jet}}$: not cut
- Initial-State Radiation (ISR): on/off
- Final-State Radiation (FSR): on/off

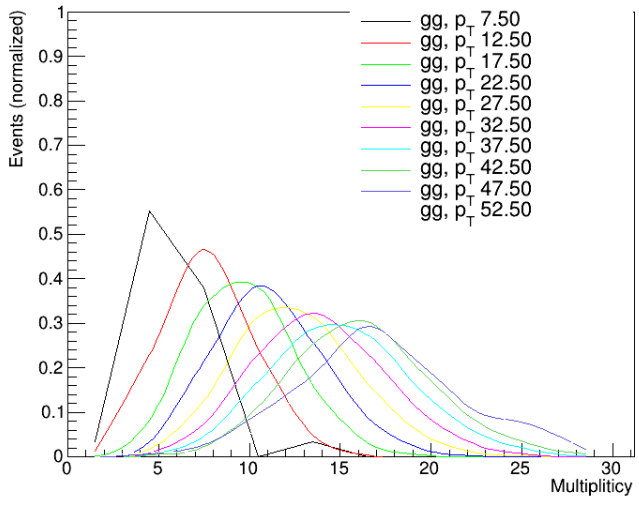
Observable:

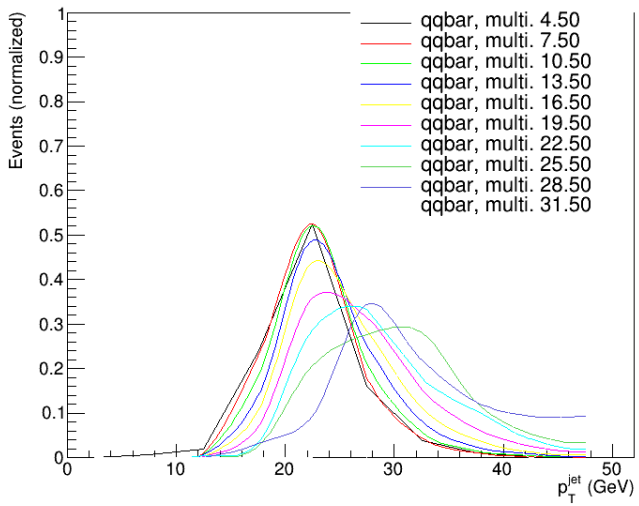
Multiplicity: Charged-hadron number inside of jet

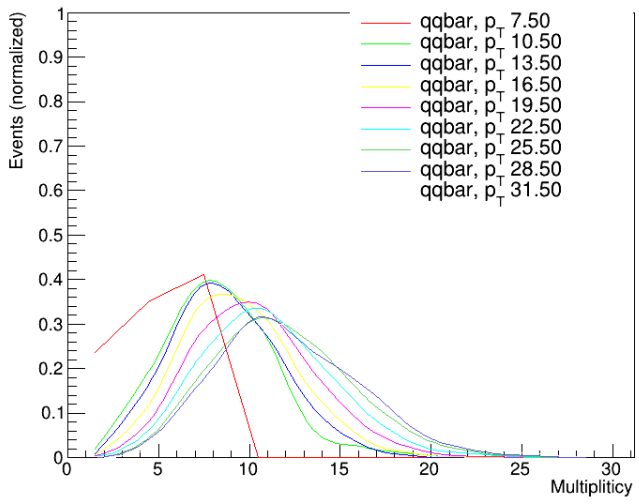
Multiplicity in jet - pp collisions at $\sqrt{s} = 500$ GeV

ISR and FSR activated





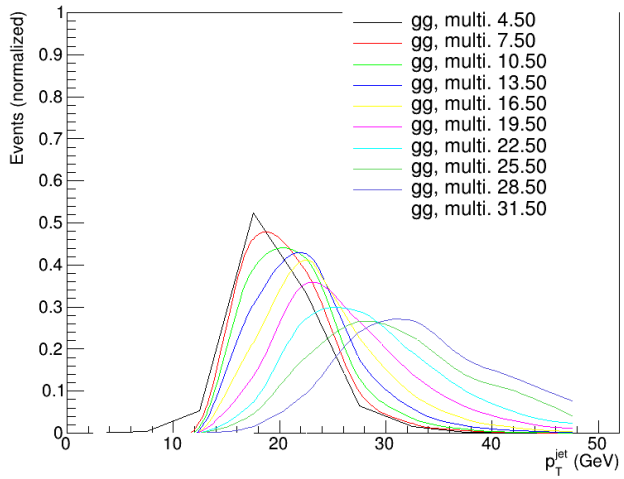


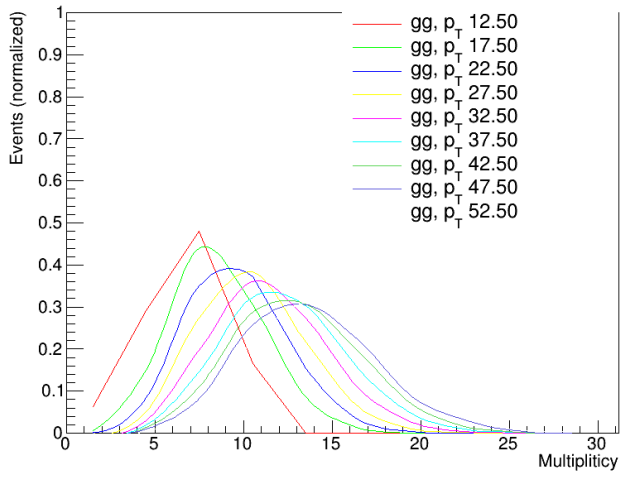


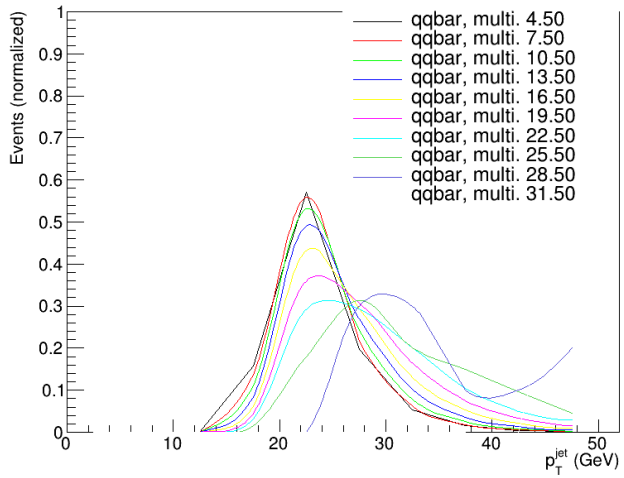
- p_T^{jets} and multiplicity: large p_T^{jets} dependence.

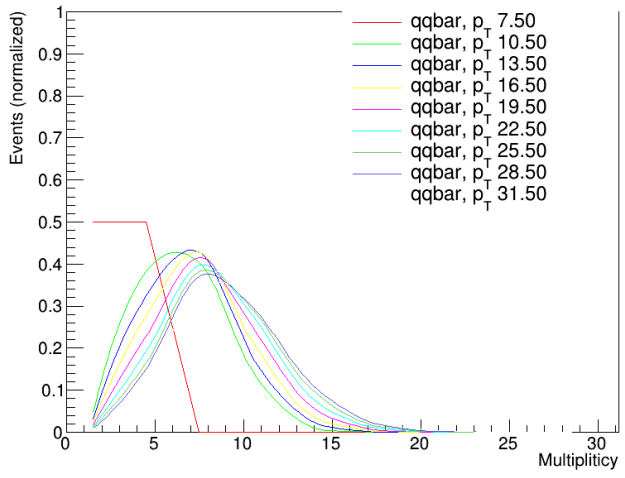
Multiplicity in jet - pp collisions at $\sqrt{s} = 500$ GeV

ISR and FSR not activated





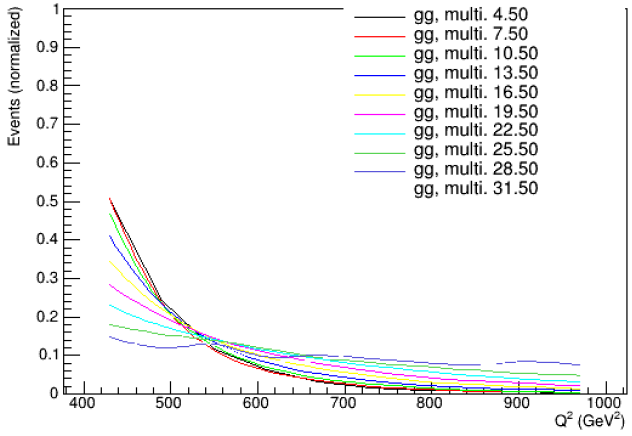


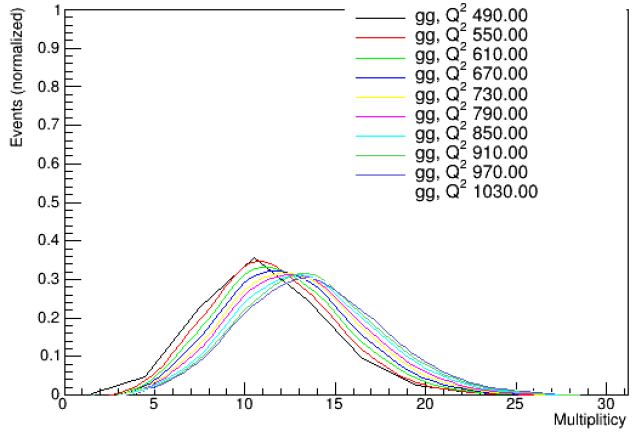


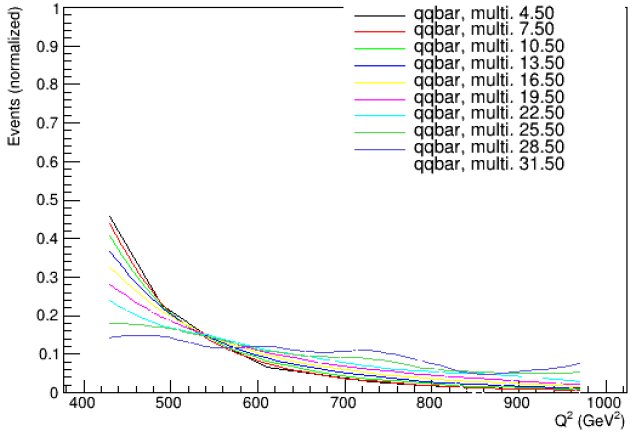
- p_T^{jets} and multiplicity: less multiplicity compare to gg channel.

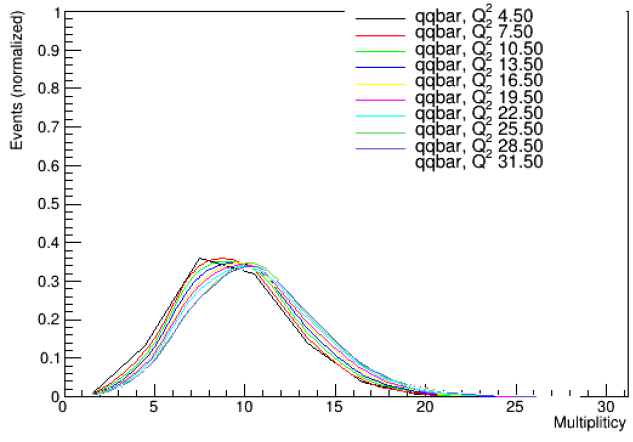
Multiplicity in jet - pp collisions at $\sqrt{s} = 500$ GeV

ISR and FSR not activated



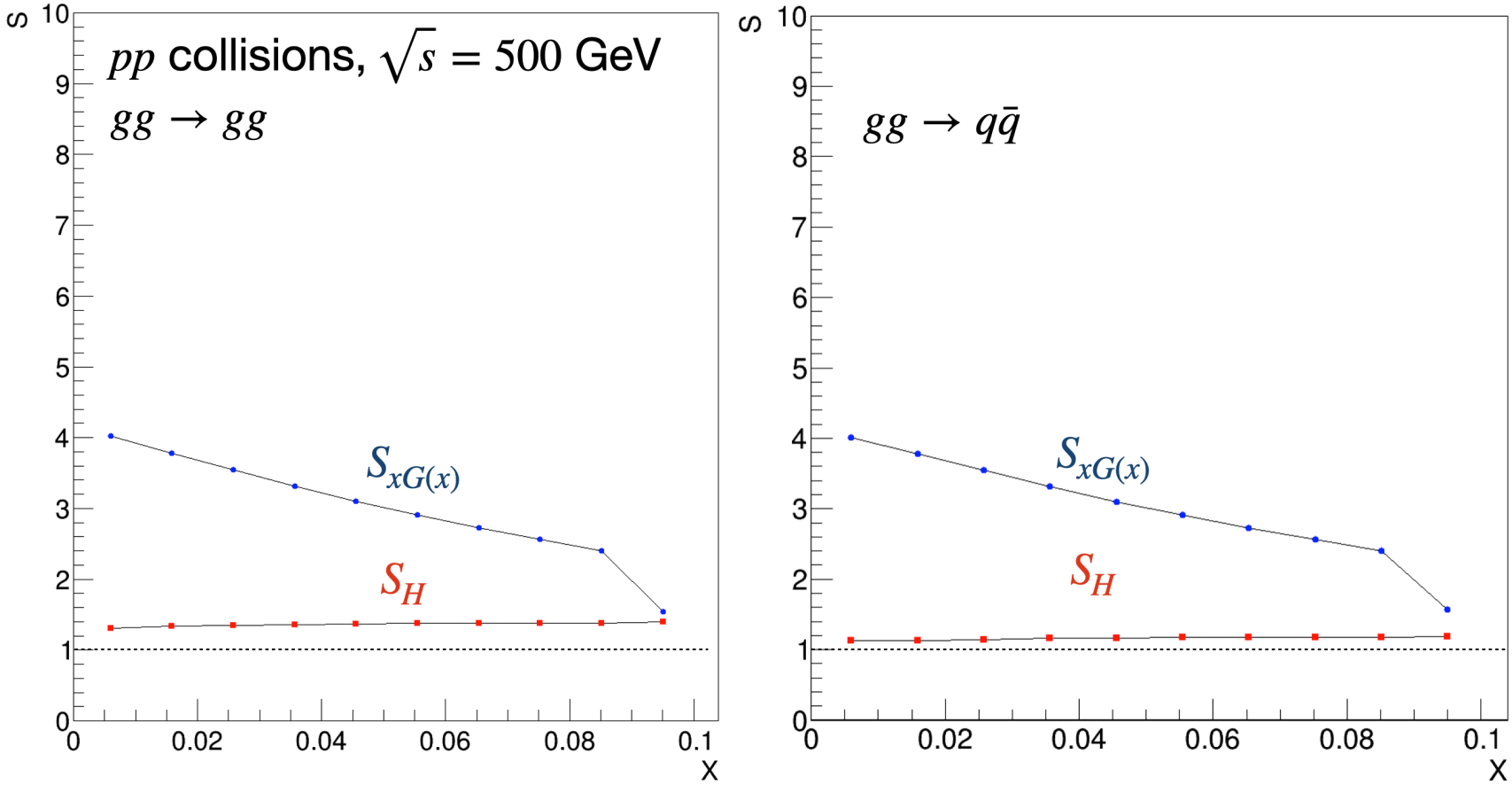






- Q^2 and multiplicity: not a large dependence.

xG(x), Multiplitiy, and Entropy



- **Left**: $gg \to gg$ and **Right**: $gg \to q\bar{q}$.

Fragmentation Function and Entropy

Fragmentation function: $f(z) = \frac{1}{z} \cdot (1-z)^a \cdot e^{-\frac{bm_T^2}{z}}$
with a, b parameters of the Lund symmetric fragmentation function from data fit.

- Calculate the entropy from the FF and compare with the charge-hadron multiplicity.

Conclusion

- We observe a higher hadron multiplicity in $gg \to gg$ compared to $gg \to q\bar{q}$.
- The maximum entropy is reached more quickly in $gg \to q\bar{q}$.
- Small dependence of multiplicity on Q^2.
- Disagreement between S_{xGx} and S_H.
- S_{xDz}, work in progress.