Jet Quenching and the Role Of Fluctuation

Umair Ahmad

June 11, 2026

Supervisor : Matthew Sievert

New Mexico State University

Las Cruces, New Mexico.

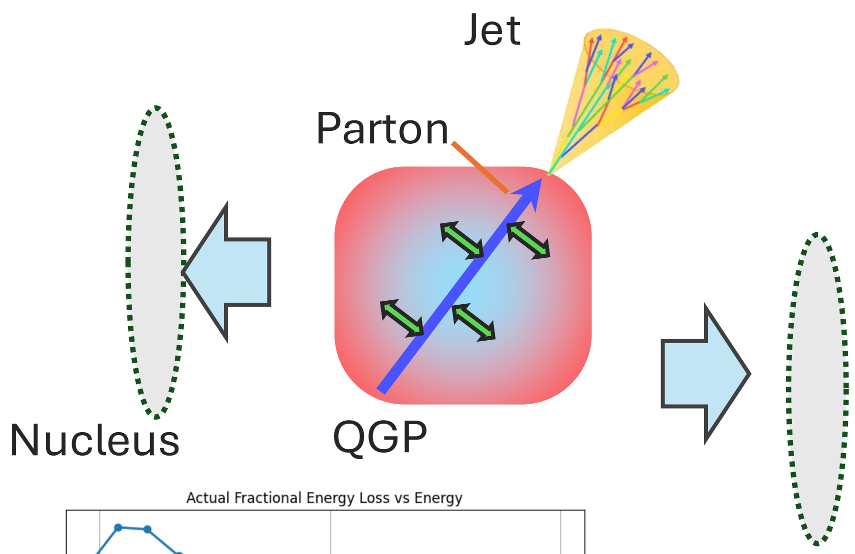
CNFS Summer School 2026

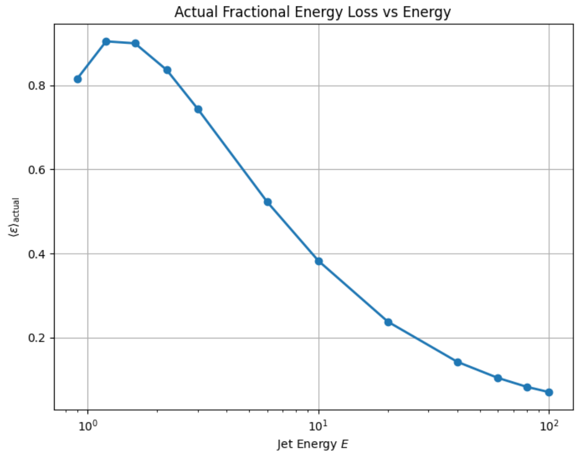
Introduction/Background

1. Jet is the collimated spray of particles produced by a high energy quark or gluons.
2. As the Jet passes through the QGP, it loses energy through interaction with the medium, a phenomenon known as Jet Quenching.
3. The amount of energy loss by jet tells us about the properties of QGP, it is also called "Jet Tomography".
4. Most studies in the past have focused on non fluctuating energy loss and the fraction of loss is computed in the following way using non fluctuating model.

$\epsilon = \int_{xo}^{1-x0} x\rho(x,E)dx$ where $\rho = C_R.\alpha.E.L\gamma(\pi + 2\gamma log\gamma)/(\pi.\lambda.x.E(1+\gamma^2))$ and $\gamma = \frac{\mu^2 L}{4xE}$

5. Our focus is to discus the role of fluctuation in the energy loss.





New Mexico State University

Poisson Method

1. Fraction of loss from this compound Poisson distribution is computed by the following.

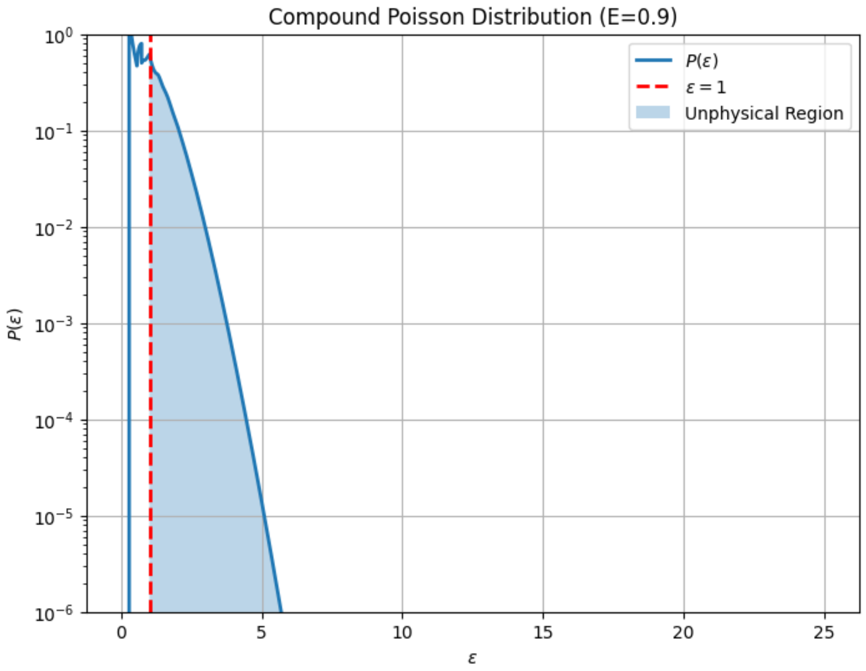
$$\epsilon = \int_0^\infty \epsilon \, P(\epsilon, E) d\epsilon$$

where,

$$P(\epsilon, E) = \sum_{n=0}^{n=25} w_n P_n(\epsilon, E) = w_0 \delta(\epsilon) + \sum_{n=1}^{n=25} w_n \, P_n(\epsilon, E)$$

Where,

$P_n(\epsilon, E) = \int P_1 P_{n-1}(\epsilon - x, E) d\epsilon$, $w_n = \sum_{n=1}^{n=25} (N_g^n / n!) e\hat{}(-N_g)$ and $P1 = \rho / Ng$



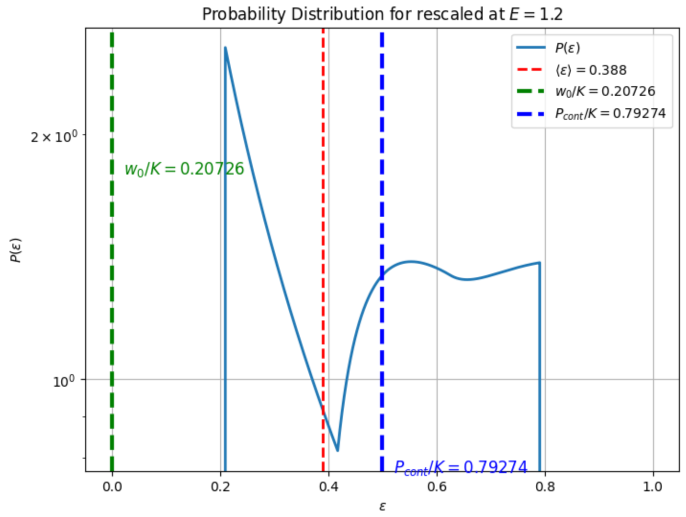
2. Here , total probability distribution goes beyond 1 which does not make sense.
3. From this probability distribution we can also compute R_{AA} by using the following formula

$$R_{AA} = w_0 + \int_{x0}^{1-x0} P(\epsilon, E)(1-\epsilon)^{n_{fixed}-1} d\epsilon$$

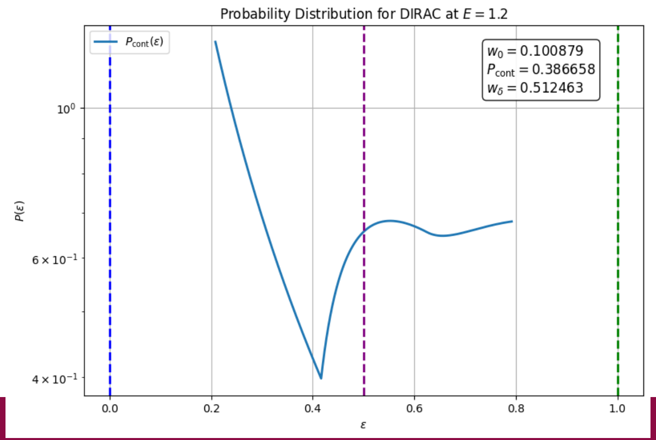
Fixes To The Naive Poisson Method

1. **Rescaled Method**: Cutoff all the probabilities greater than 1 and rescaled the the probabilities from cutoff limit to 1-cutoff limit by dividing with a factor k such that total probability is 1.

$$k = w_0 + \int_{xo}^{1-x0} w_n P_n d\epsilon$$



2. **Dirac Method**:Cutoff all the probability greater than 1 and put it at $\epsilon = 1$, such that again the total probability is equal to 1.



Fixes To The Naive Poisson Method

3. **Sievert Method:** In this method we preserve the fraction of loss because cutting the probabilities greater than 1 reduces the fraction
of loss at smaller energy, and also preserve the total probability by the use of following equations.

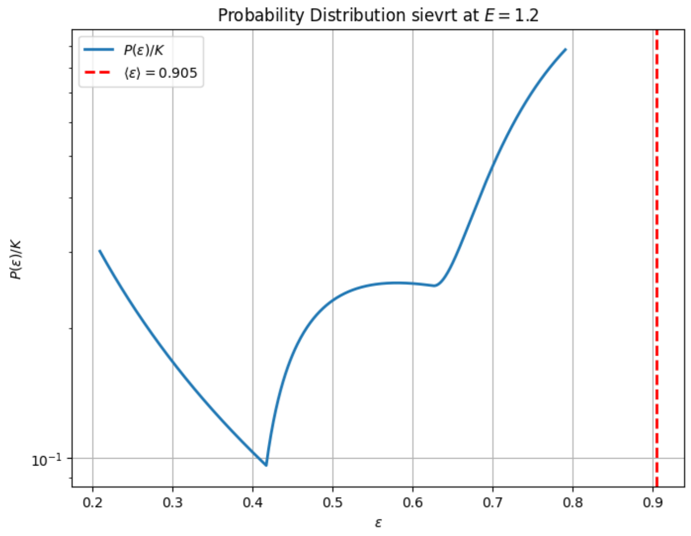
$$\epsilon = ((1/K)\sum_{n=1}^{n=25} w_n \int_{x0}^{1-x0} P_n d\epsilon) + W_\delta$$

$$1 = \left(\frac{1}{K}\right)\left(w_0 + \int_{xo}^{1-x0} P(x,E)dx\right) + w\_\delta$$

where,

$$\mathrm{K} = (w_0 + \int_{x0}^{1-x0} w_n P_n d\epsilon - \int_{x0}^{1-x0} w_n x P_n d\epsilon)/(1 - \int_{x0}^{1-x0} w_n x P_n d\epsilon) \text{ and}$$

$$W_\delta = (\epsilon\left(w_0 + \int_{x0}^{1-x0} w_n P_n d\epsilon\right) - \int_{x0}^{1-x0} w_n x P_n d\epsilon\,))/(1 - \int_{x0}^{1-x0} w_n x P_n d\epsilon)$$

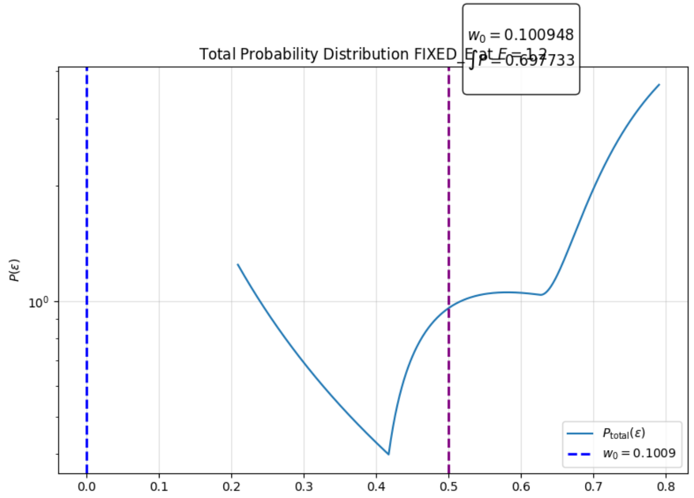


Fixes Beyond The Naive Poisson Method

4. **Fixed E Method**: Cutoff the probability greater than 1 and normalized the physical part between cutoff to 1-cutoff limit such that total probability is conserved. Probability distribution Is given by.

$$P(\epsilon, E) = w_0 \delta(\epsilon) + \sum_{n=1}^{n=25} w_n \int_{x0}^{1-x0} P_n(\epsilon, E) d\epsilon \text{ with}$$

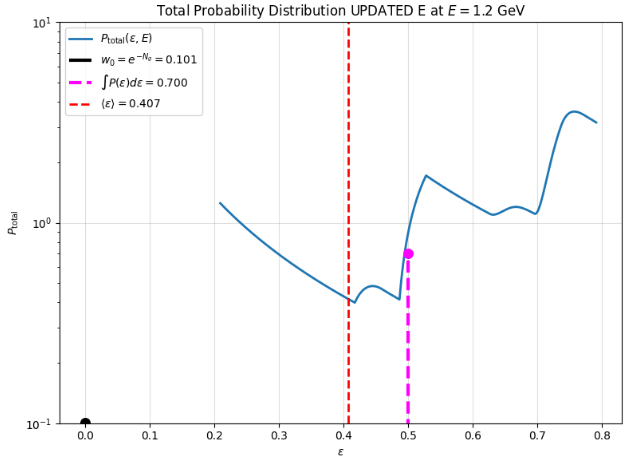
$$Pn(\epsilon\,, E) = \sum_{n=2}^{n=25} \int_{x0}^{1-x0} P_1 P_{n-1}(\epsilon, E) d\epsilon$$



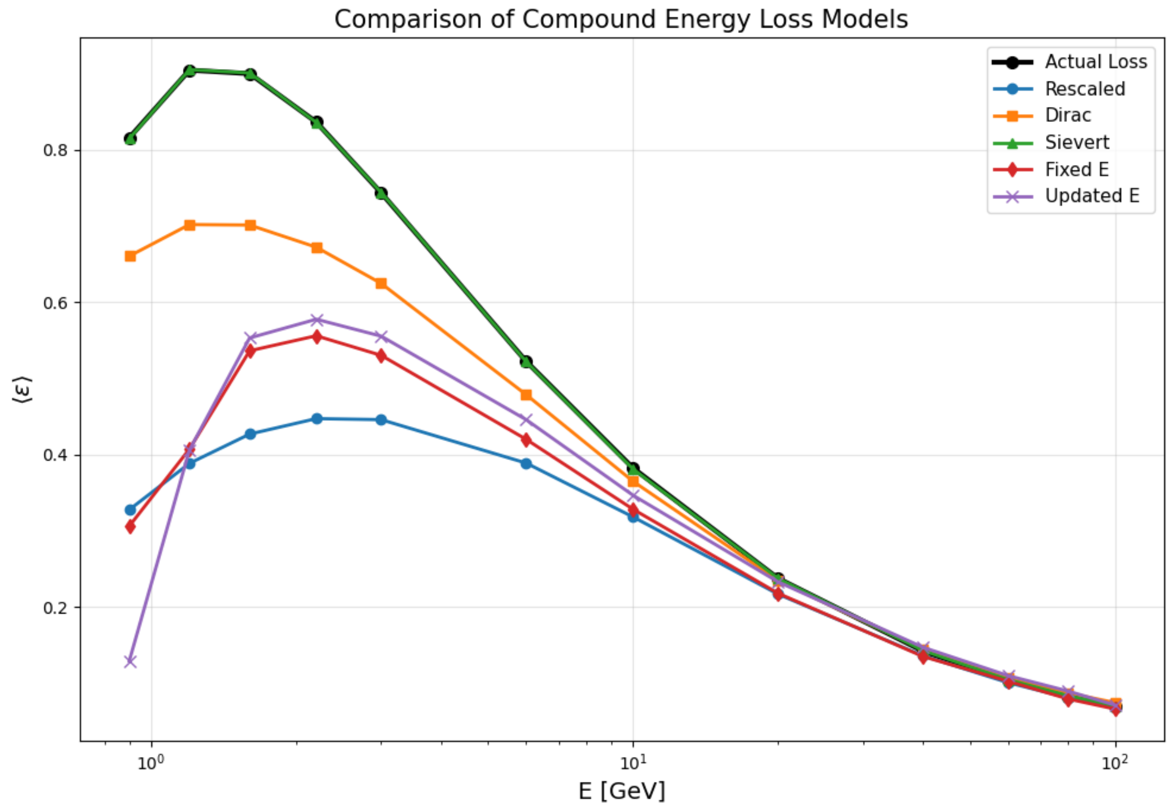
5. **Updated E Method**:Here, we cutoff the probabilities greater than 1 but changed the energy for next emission i.e the energy for next emission is smaller than the previous.

$$P(\epsilon, E) = w_0 \delta(\epsilon) + \sum_{n=1}^{n=25} w_n \int_{x0}^{1-x0} P_n(\epsilon, E) d\epsilon \text{ with}$$

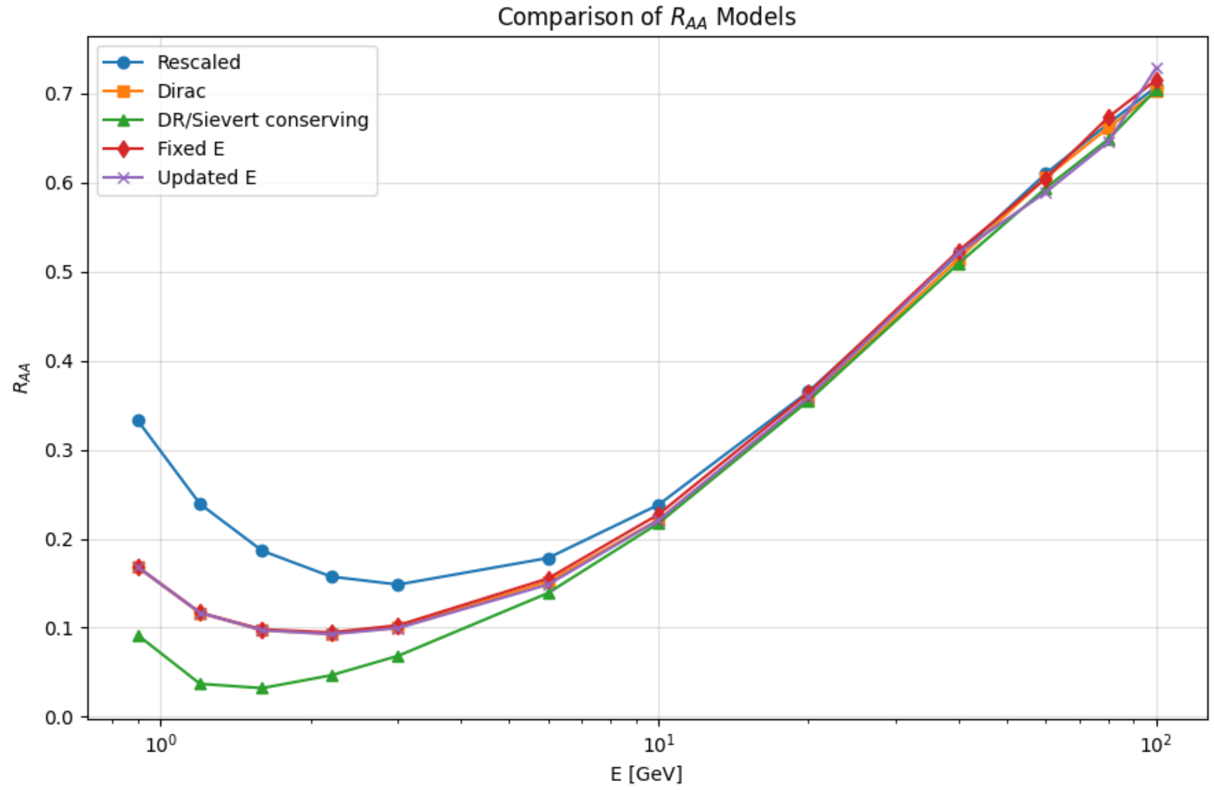
$$Pn(\epsilon\,, E) = \sum_{n=2}^{n=25} \int_{x0}^{1-x0} P_1 P_{n-1}(\epsilon, (1-x)E) dx$$



Results



Comparison of Compound Energy Loss Models
Actual Loss
Rescaled
Dirac
Sievert
Fixed E
Updated E
⟨ε⟩
E [GeV]



Comparison of R_{AA} Models
Rescaled
Dirac
DR/Sievert conserving
Fixed E
Updated E
R_{AA}
E [GeV]

Conclusion

1. Compound fraction of loss is sensitive to models, all models give the different fraction of loss.
2. R_{AA} is not much sensitive to the models, dirac, fixed E, updated E models give us but Sievert and rescaled model give us different R_{AA} because of this rescaled k factor which is different in both model and is the reason to change the R_{AA}.
3. Next we will look to jet drift and prediction is this observable is sensitive to fluctuation and for different fraction of loss we will get different jet drift value.