Discrimination of quark and gluon jets at 13TeV in the CMS experiment

Jyoti Babbar
Panjab University, India
On behalf of CMS Collaboration

DAE-BRNS 2022
12-16 December, 2022

Introduction

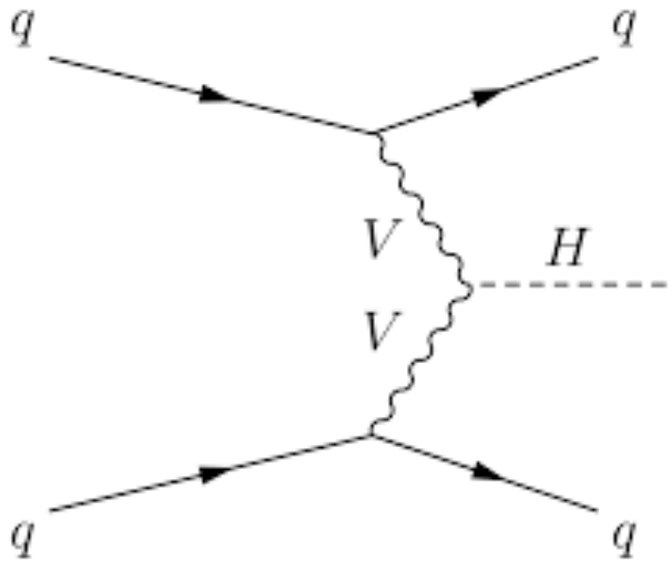
- Jets are formed from hadrons and other particles produced by the hadronization of a quark or gluon in a particle physics or heavy ion experiment.

  - Distinguishing quark jets from gluon jets is very important for many physics analysis

    - Numerous SM and BSM studies have quark final states, as VBF processes

    - But background is dominated by QCD enriched SM processes.

    - Signal efficiency can significantly improve if such backgrounds contribution from gluons could be reduced



We aim to build a technique to discriminate quark and gluon jets

Quark and Gluon Jets

- The jets originating from light flavor quarks and gluons differ, with the main differences :
  - Different particle multiplicities, gluon jets have higher multiplicities
  - Gluon jets are wider
  - Uniform energy fragmentation in gluon jets

- **The above can be utilized to build the discriminator for quark and gluon jets**

Quark/Gluon Discriminators

❖There are three discriminators under construction by CMS :

- Quark-Gluon Likelihood —> **constructed using 3 variables based on quark and gluon jet properties**
- DeepJet Discriminator
- ParticleNet Discriminator

NEW

Based on neural network with many input variables

❖Three variables for Quark-Gluon Likelihood (QGL)

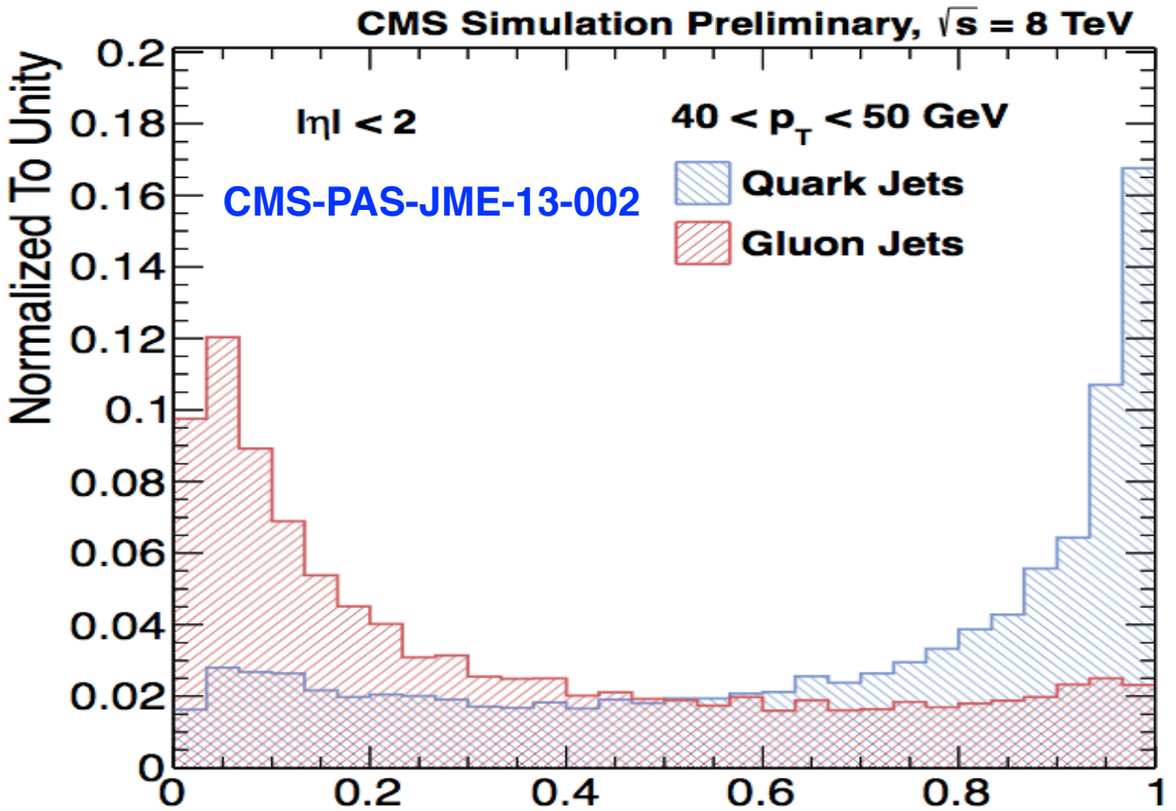
- Particle Multiplicity
- Jet energy sharing variable $p_T D = \sqrt{\frac{\sum p_T^2}{(\sum p_T)^2}}$
- The jet transverse minor ellipse axis σ_2

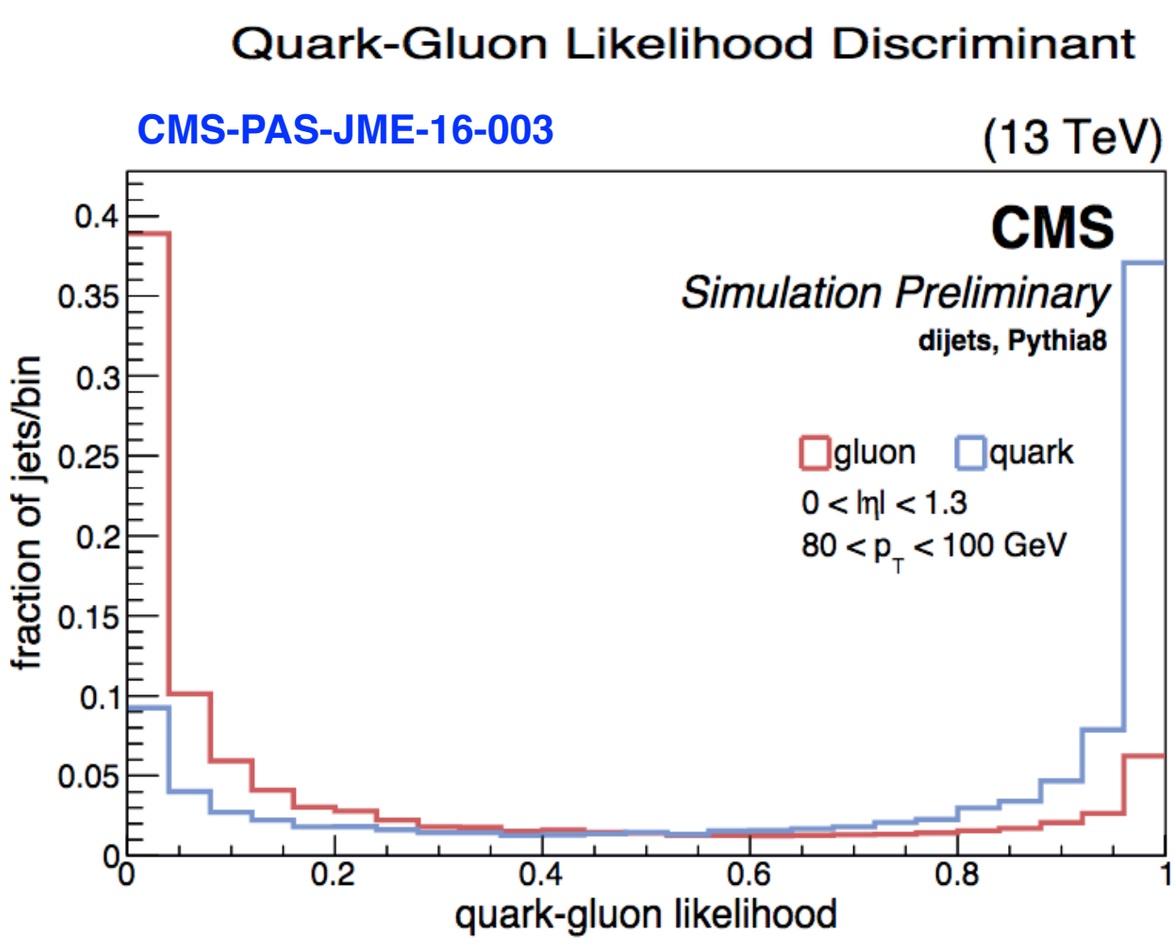
Previously defined
CMS-PAS-JME-16-003
(Link)

Quark/Gluon Discriminators

- The variable constructed for quark/ gluon discriminator varies in the range 0 to 1.
  - Peak at 0 for gluons
  - Peak at 1 for quarks.

- **QCD simulation is used for training for the variables.**

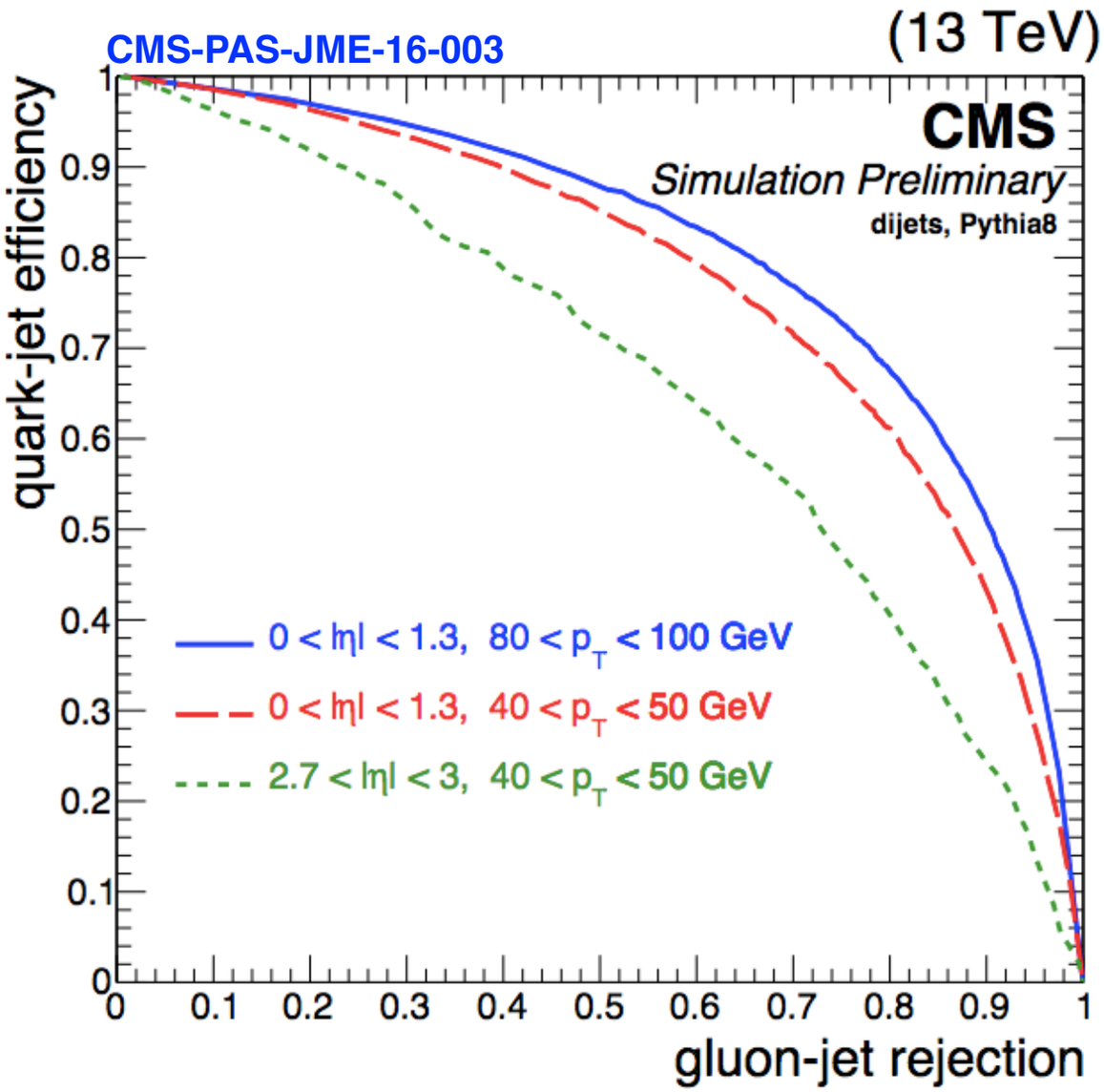




Tagger Performances

- The performances of the tagger is based on ROC curves

- The discriminating power of the taggers are studied separately in low and high pT regions.
  - The tagger efficiency improves for higher pT.

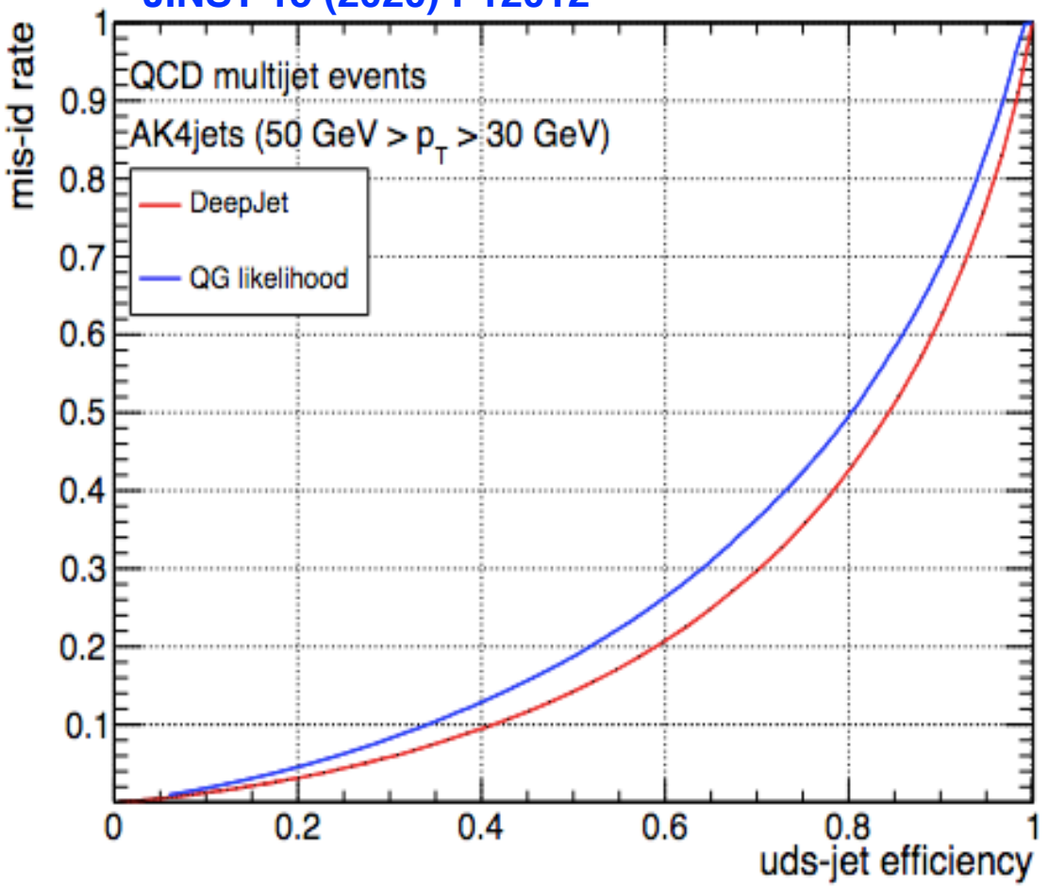


QG Likelihood

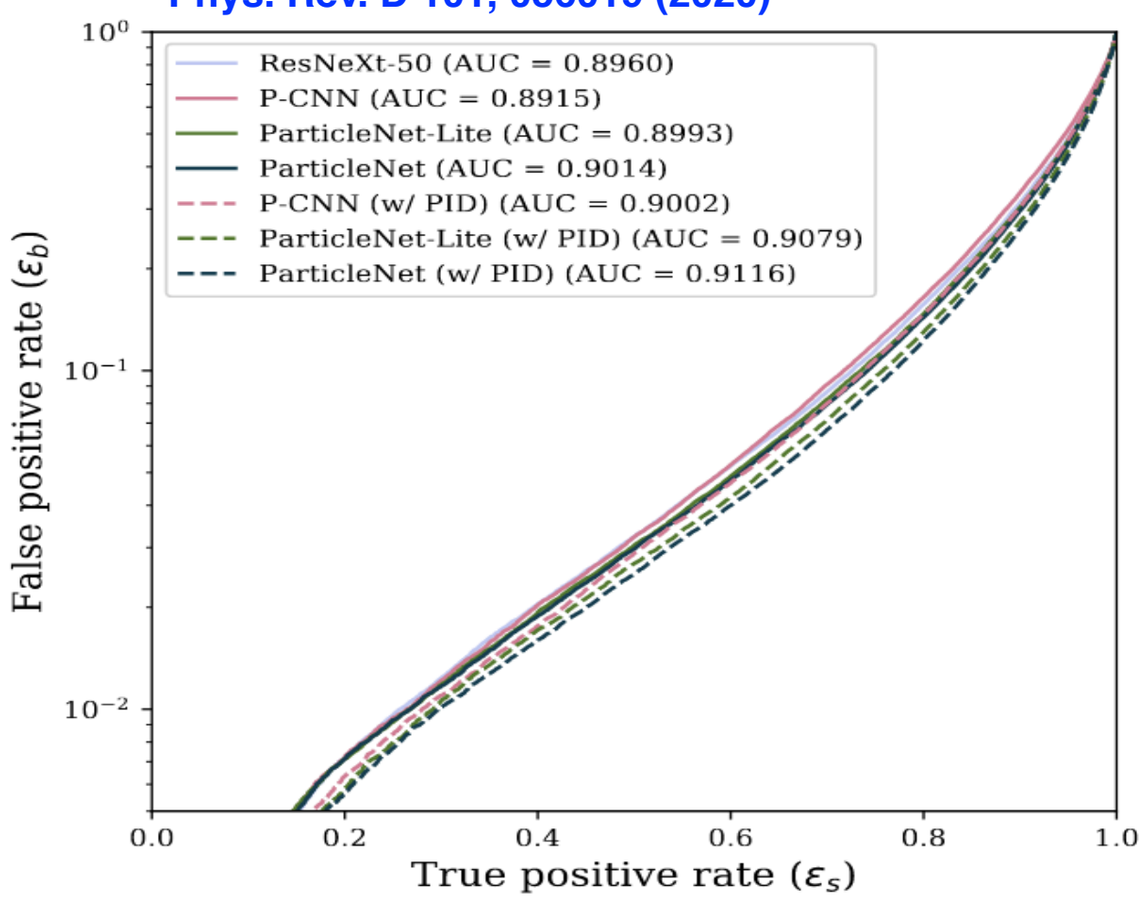
Neural Network Based Taggers

- DeepJet Tagger is a multi-class approach of tagging different flavors of jets and it outperforms other NN discriminators
- ParticleNet tagger is also Neural network based tagger but uses particle-level information in an unordered way to train a model
- The neural network based DeepJet tagger shows better performances than QG Likelihood
- ParticleNet tagger for quark-gluon tagging shows better performance with other alternative models

JINST 15 (2020) P12012



Phys. Rev. D 101, 056019 (2020)



Validation with Data

- The validation studies with Data are performed will be performed all three taggers.

- DiJet sample (which is Gluon enriched) and Z+Jets (that is quark enriched sample) are used to perform the validation studies

Data/MC

- To improve the agreement between Data and MC , data-driven reweighting is done.

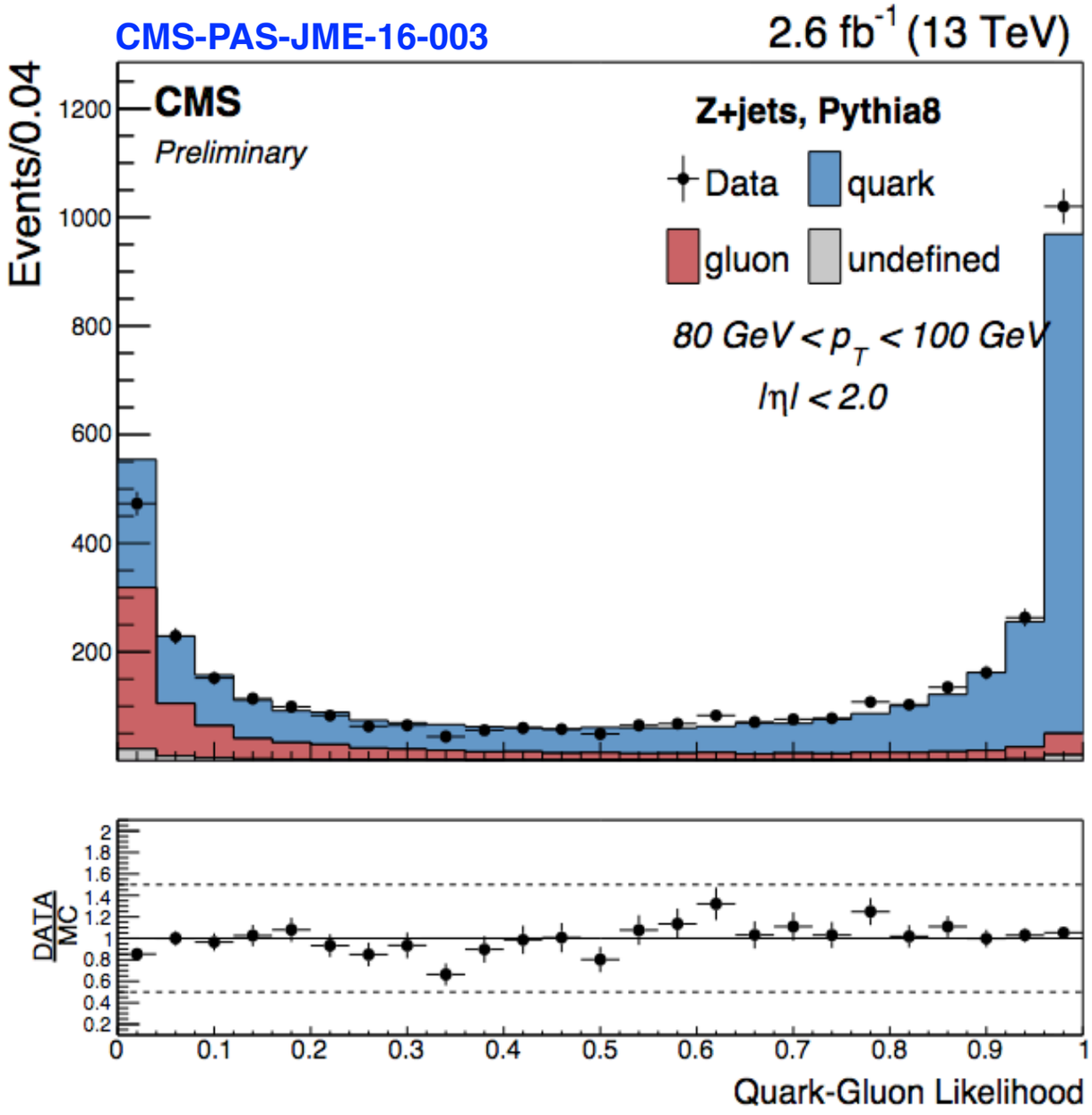
- To derive the first order of corrections to the Q/G taggers, quark and gluon weights are obtained by solving a system of equations for each Q/G tagger output bin

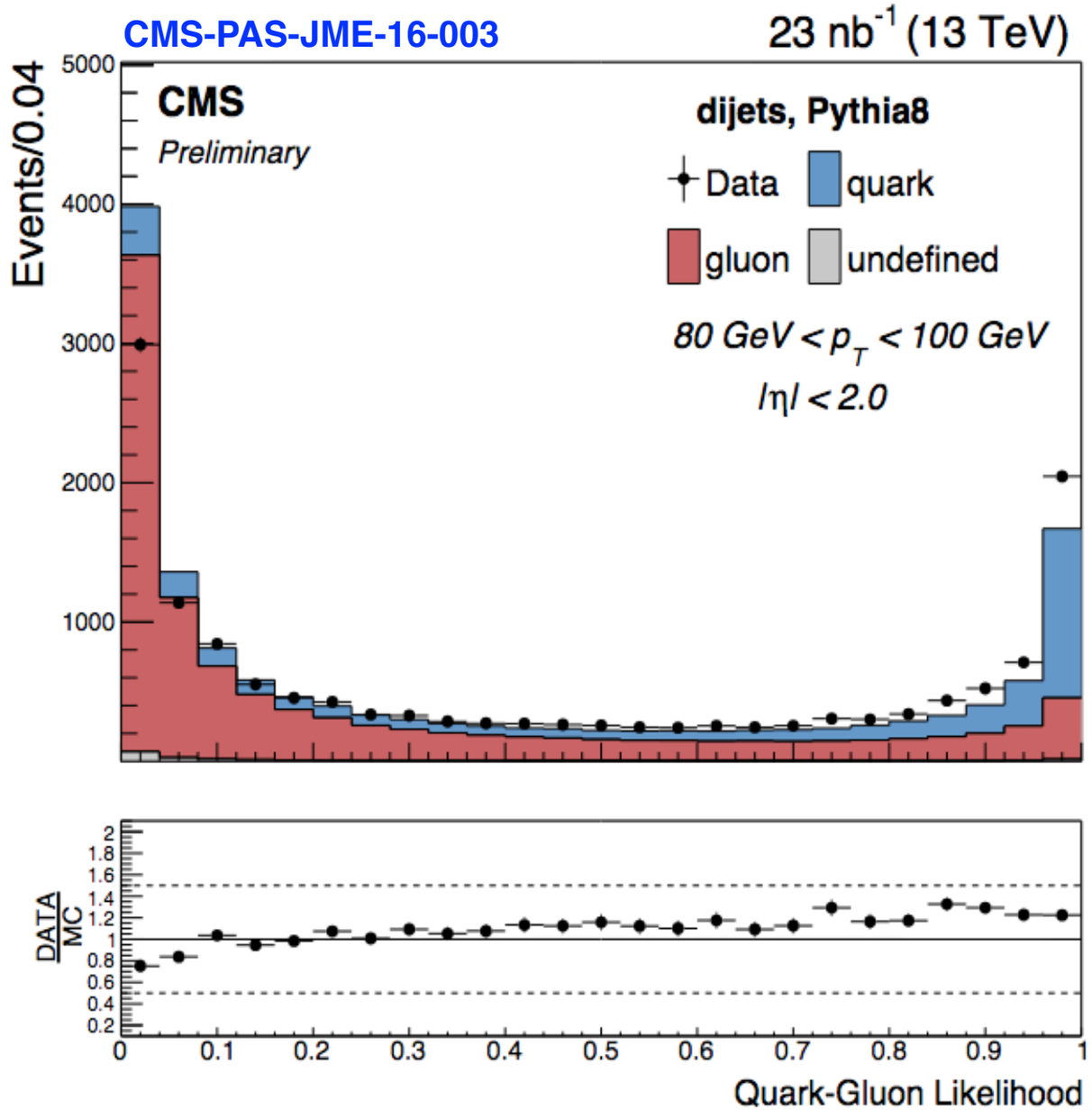
$$N^{DY}_{data} = \alpha_g N^{DY}_{MC,gluons} + \alpha_q N^{DY}_{MC,quarks} + N^{DY}_{MC,undef}$$
$$N^{QCD}_{data} = \alpha_g N^{QCD}_{MC,gluons} + \alpha_q N^{QCD}_{MC,quarks} + N^{QCD}_{MC,undef}$$

gluon weight *quark weight*

Validation with Data

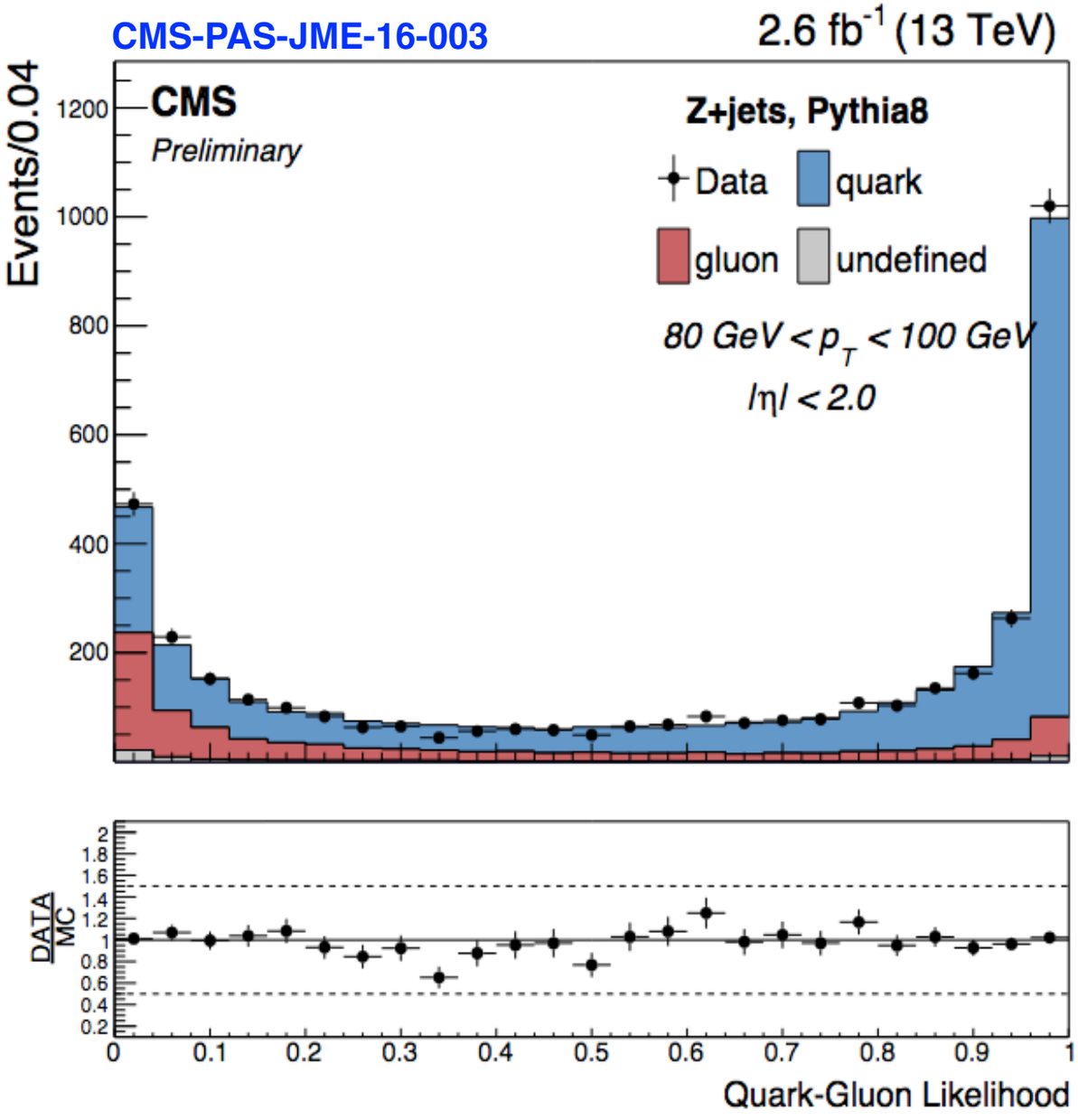
- Data-MC comparison for the quark-gluon discriminant in quark enriched and gluon enriched validation for the central region of the detector
- The discrepancies are corrected with reweighting by scale factors

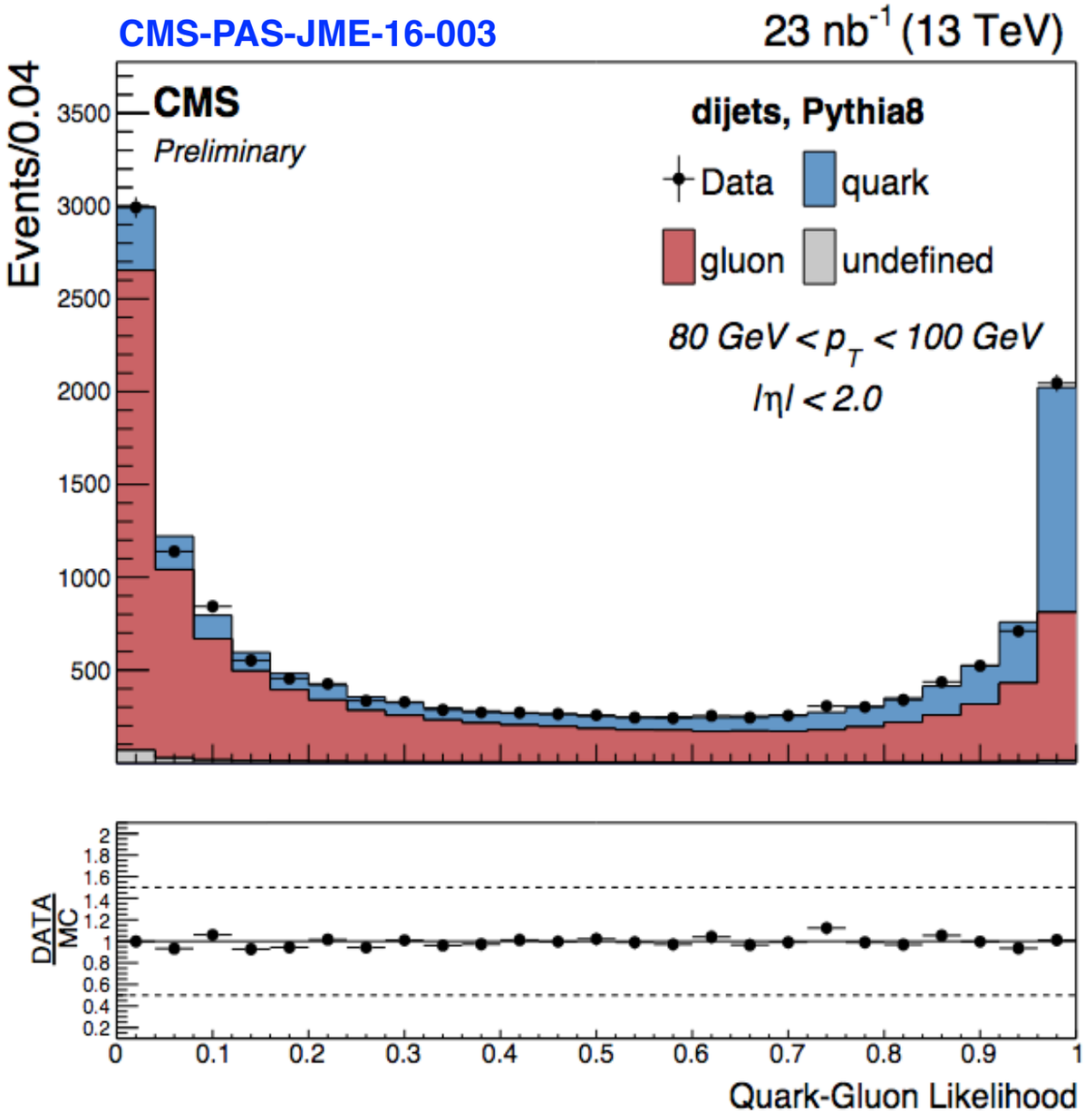




Extracted Weights and Re-weighting

- The weights are derived for both quark and gluon samples.
- The corresponding weights are applied to the discriminator variable for shape correction.
- The agreement between data and simulations is improved with this reweighting applied.





Summary and Conclusion

- Three variables for discriminating the quark and gluons jets are constructed by CMS experiment.
- It will help many analysis to better identify their signal and reduce background contributions
- Neural Network based tagger shows better discriminating power.
- The comparison of three taggers based on ROC curves is under study.

Thank You!

References

- References :

1. CMS Collaboration, Performance of quark/gluon discrimination in 13 TeV data, 2016, CMS-DP-2016-070
2. CMS Collaboration, Performance of quark/gluon discrimination in 8 TeV pp data, 2013, CMS-PAS-JME-13-002
3. ParticleNet tagger : Q. Huilin and L. Gouskos, “ParticleNet: Jet Tagging via Particle Clouds", Phys. Rev. D 101,056019 (2020)
4. DeepJet tagger : CMS collaboration, “Identification of heavy-flavour jets with the CMS detector in pp collisions at 13 TeV", JINST 13 (2018) P05011.