

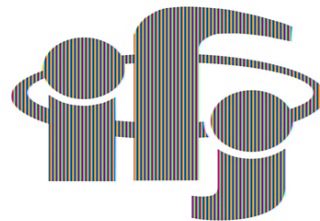
Separation of Quark and Gluon Jets using Angularities

Petr Baron

supervised by dr hab Andrzej Siodmok



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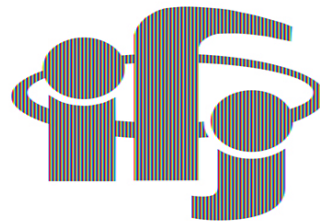
INSTYTUT FIZYKI JA
IM. HENRYKA NIEWODNICZ
POLSKIEJ AKADEMII

Separation of Quark and Gluon Jets using Angularities

- 1.) Motivation
- 2.) Theory
- 3.) Results

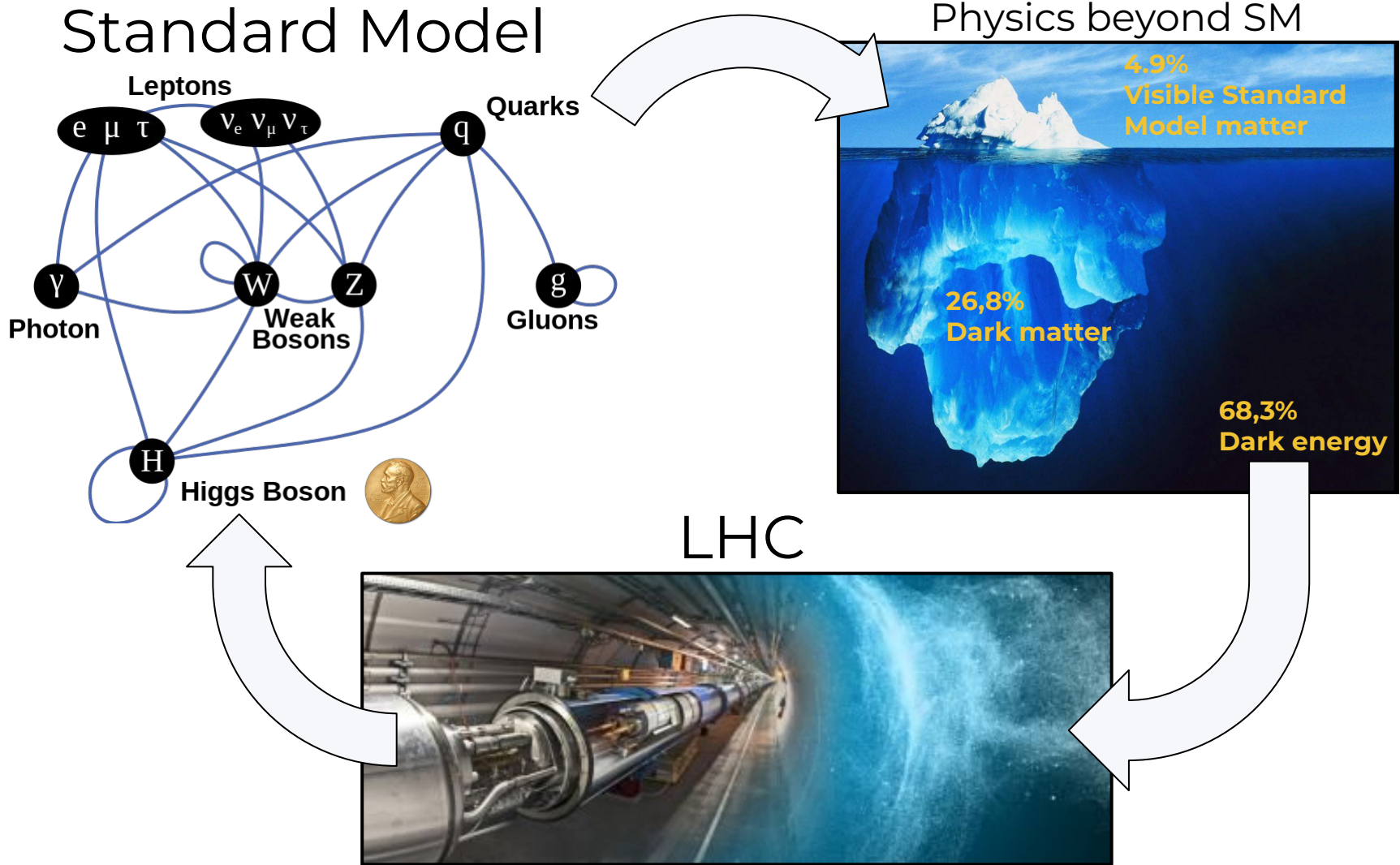


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Separation of Quark and Gluon Jets using Angularities



Motivation

Separation of Quark and Gluon Jets using Angularities

BSM searches: often signature for a BSM signals: many quark, backgrounds: QCD gluons

- 8-jet Gluino event: $pp \rightarrow \tilde{g}\tilde{g}$ and each \tilde{g} decays to 4 quarks:

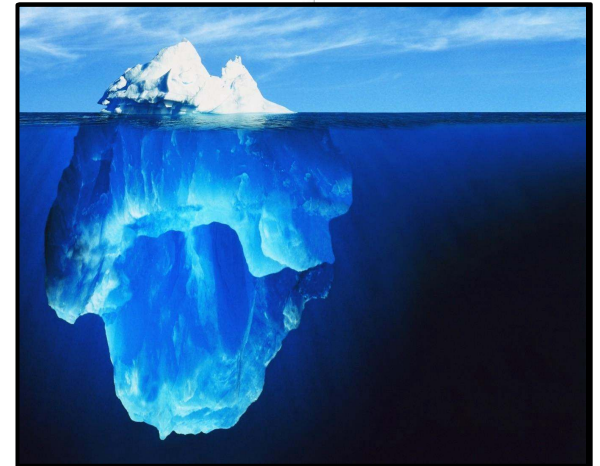
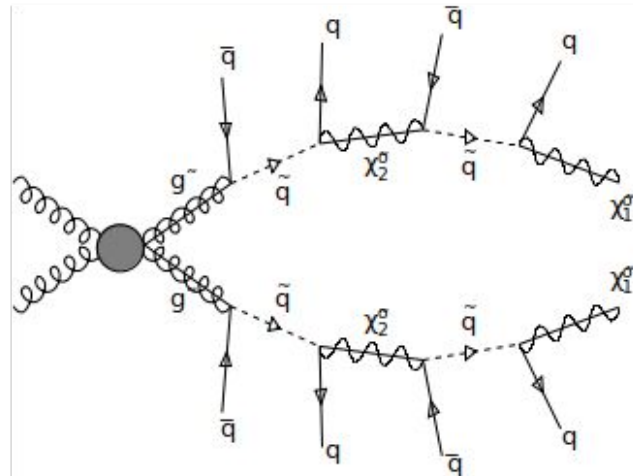


Fig. From J. Gallicchio and M. D. Schwartz, Phys. Rev. Lett.107 (2011)

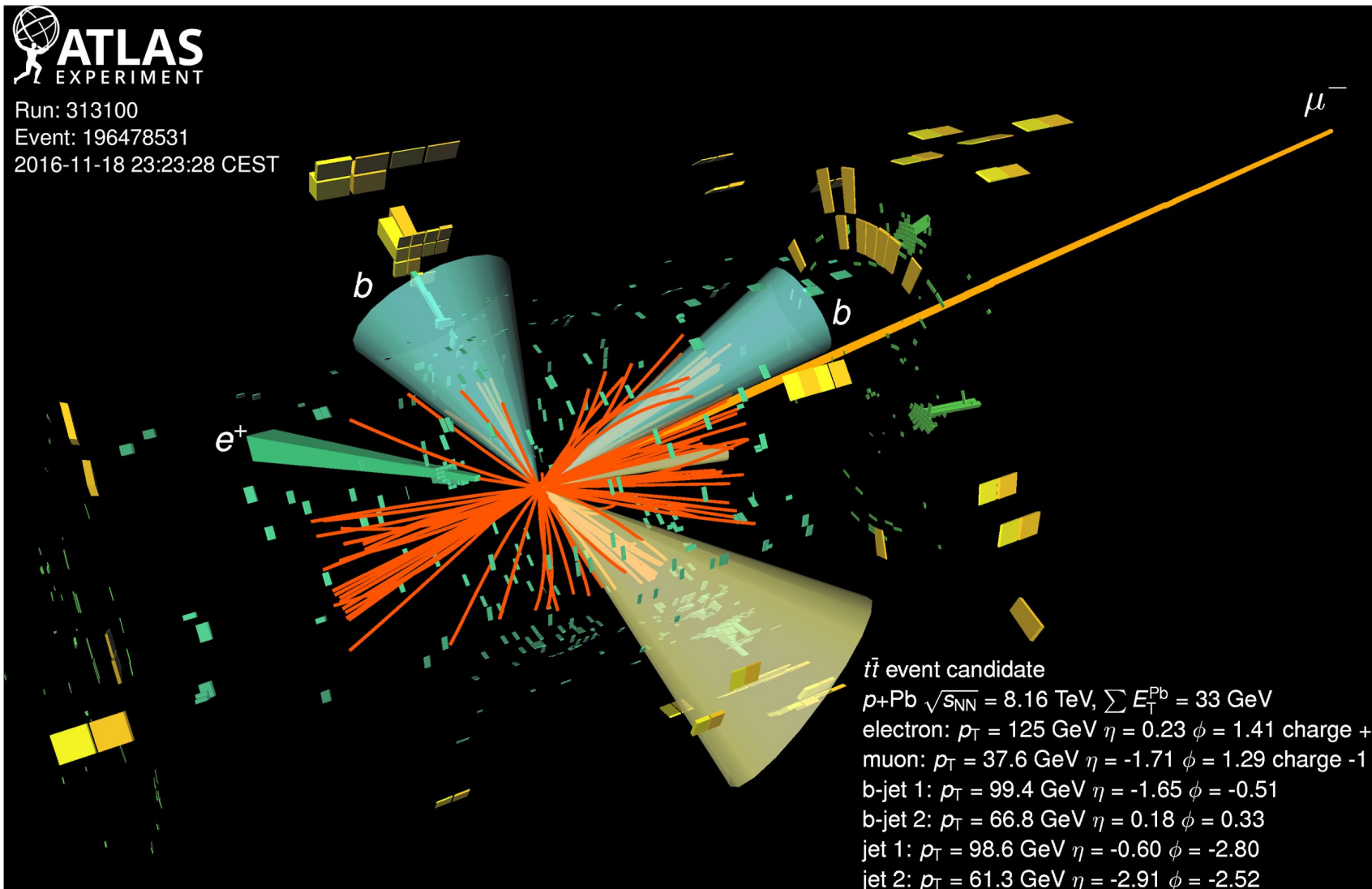
- Higgs $H^+ \rightarrow c\bar{s}$ (for charged Higgs mass between τ and t mass)
- Measure Z' coupling to hadrons (or find a leptophobic Z'/W')

Motivation

Separation of Quark and Gluon Jets using Angularities

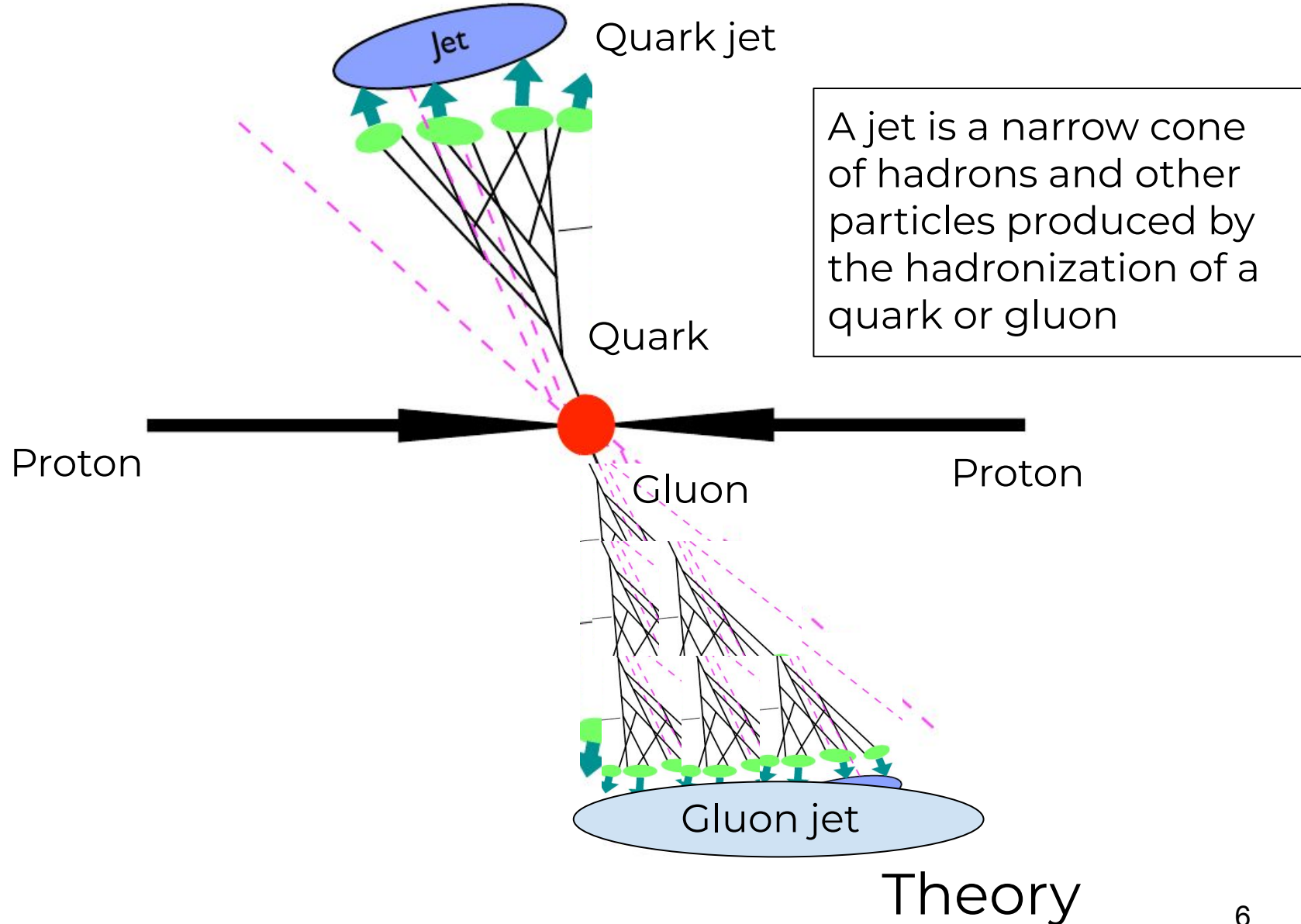


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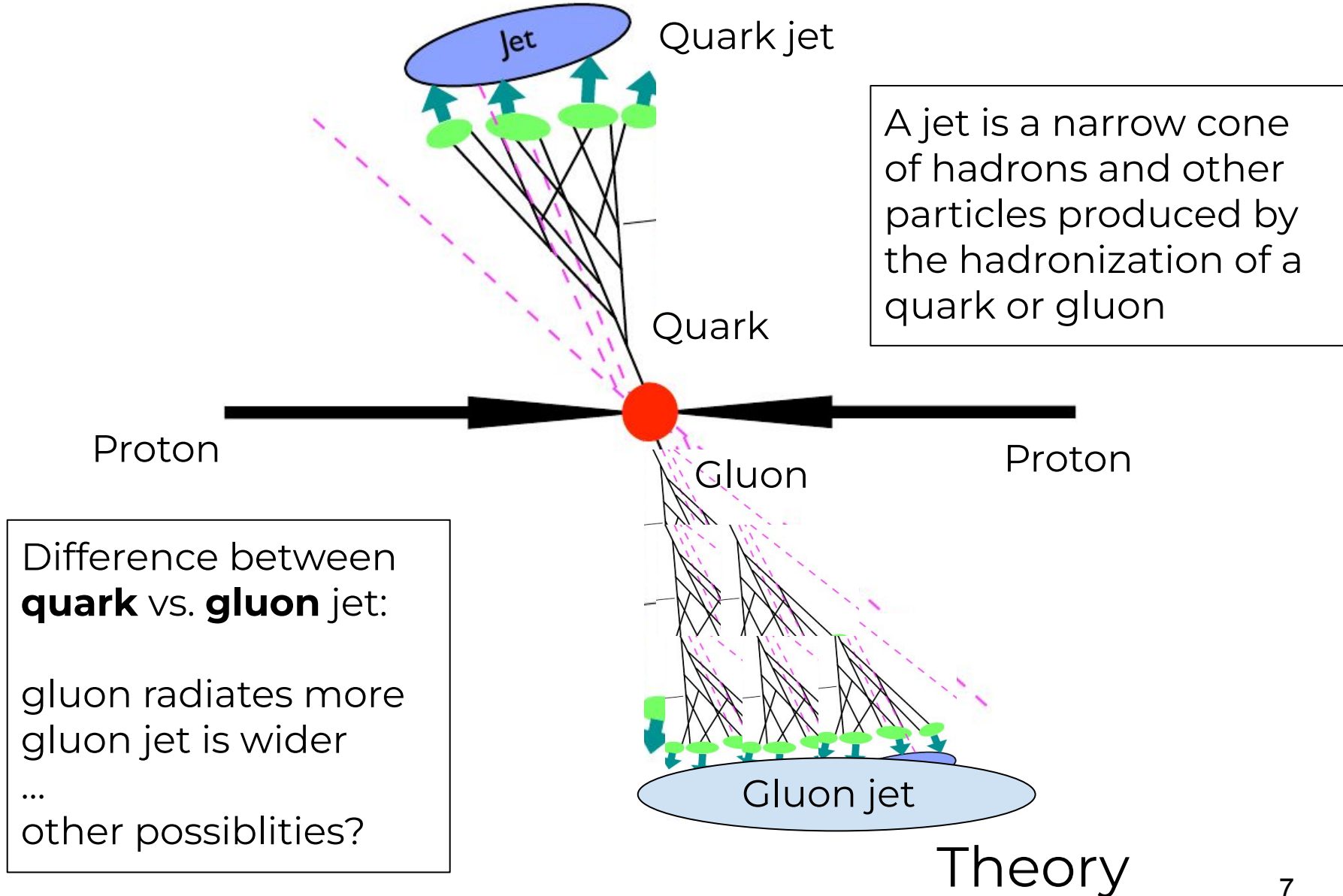


Theory

Separation of Quark and Gluon Jets using Angularities



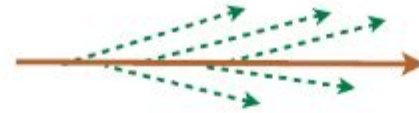
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Separation of Quark and Gluon Jets using Angularities

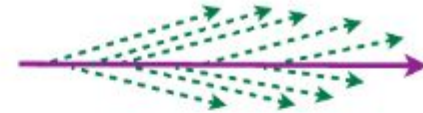
[Gras, Hoeche, Kar, Larkoski, Lönnblad, Plätzer, AS, Skands, Soyez, Thaler, JHEP 1707 (2017) 091]

Cartoon:



Quark

vs.



Gluon

Probe radiation pattern with e.g. Generalized Angularities

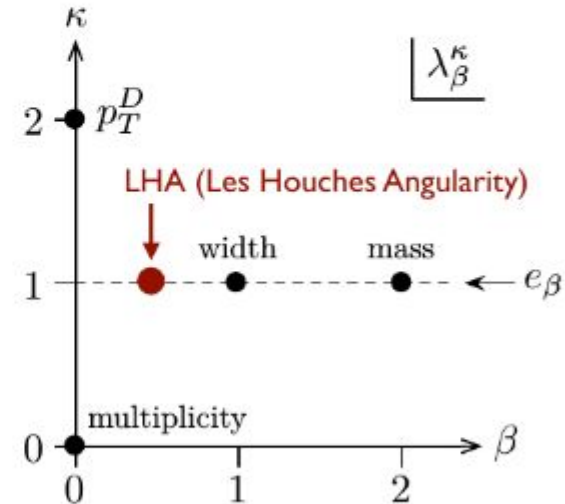
$$\lambda_{\beta}^{\kappa} = \sum_{i \in \text{jet}} z_i^{\kappa} \theta_i^{\beta}$$

momentum fraction

angle to recoil-free axis



$$(\lambda_{\beta}^{\kappa})_{\text{quark}} < (\lambda_{\beta}^{\kappa})_{\text{gluon}}$$



[Larkoski, Salam, Thaler, 13]
[Larkoski, Thaler, Waalewijn, 14]

Theory

Separation of Quark and Gluon Jets using Angularities

Each angularity Λ is composed of gluon Λ_g and quark Λ_q angularities

Theory

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Separation of Quark and Gluon Jets using Angularities

Each angularity λ is composed of gluon λ_g and quark λ_q angularities

$$\lambda = f \lambda_g + (1-f) \lambda_q$$

Separation of Quark and Gluon Jets using Angularities

Each angularity λ is composed of gluon λ_g and quark λ_q angularities

$$\lambda = f \lambda_g + (1-f) \lambda_q$$

f ... gluon fraction

$(1-f)$... quark fraction

Separation of Quark and Gluon Jets using Angularities

Lets write equations for measurement at energy 900 GeV and 13 000 GeV

Theory

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Separation of Quark and Gluon Jets using Angularities

Lets write equations for measurement at energy 900 GeV and 13 000 GeV

$$\lambda^{900} = f^{900} \lambda_g + (1-f^{900}) \lambda_q$$

$$\lambda^{13000} = f^{13000} \lambda_g + (1-f^{13000}) \lambda_q$$

Theory

Separation of Quark and Gluon Jets using Angularities

Lets write equations for measurement at energy 900 GeV and 13 000 GeV

$$\lambda^{900} = f^{900} \lambda_g + (1-f^{900})\lambda_q$$

$$\lambda^{13000} = f^{13000} \lambda_g + (1-f^{13000})\lambda_q$$

One can reverse:

$$\lambda_g = \frac{(1 - f^{13000})\lambda^{900} - (1 - f^{900})\lambda^{13000}}{f^{900} - f^{13000}}$$

$$\lambda_q = \frac{f^{900}\lambda^{13000} - f^{13000}\lambda^{900}}{f^{900} - f^{13000}} ;$$

Theory

Separation of Quark and Gluon Jets using Angularities

$$\lambda_g = \frac{(1 - f^{13000})\lambda^{900} - (1 - f^{900})\lambda^{13000}}{f^{900} - f^{13000}}$$

$$\lambda_q = \frac{f^{900}\lambda^{13000} - f^{13000}\lambda^{900}}{f^{900} - f^{13000}} :$$

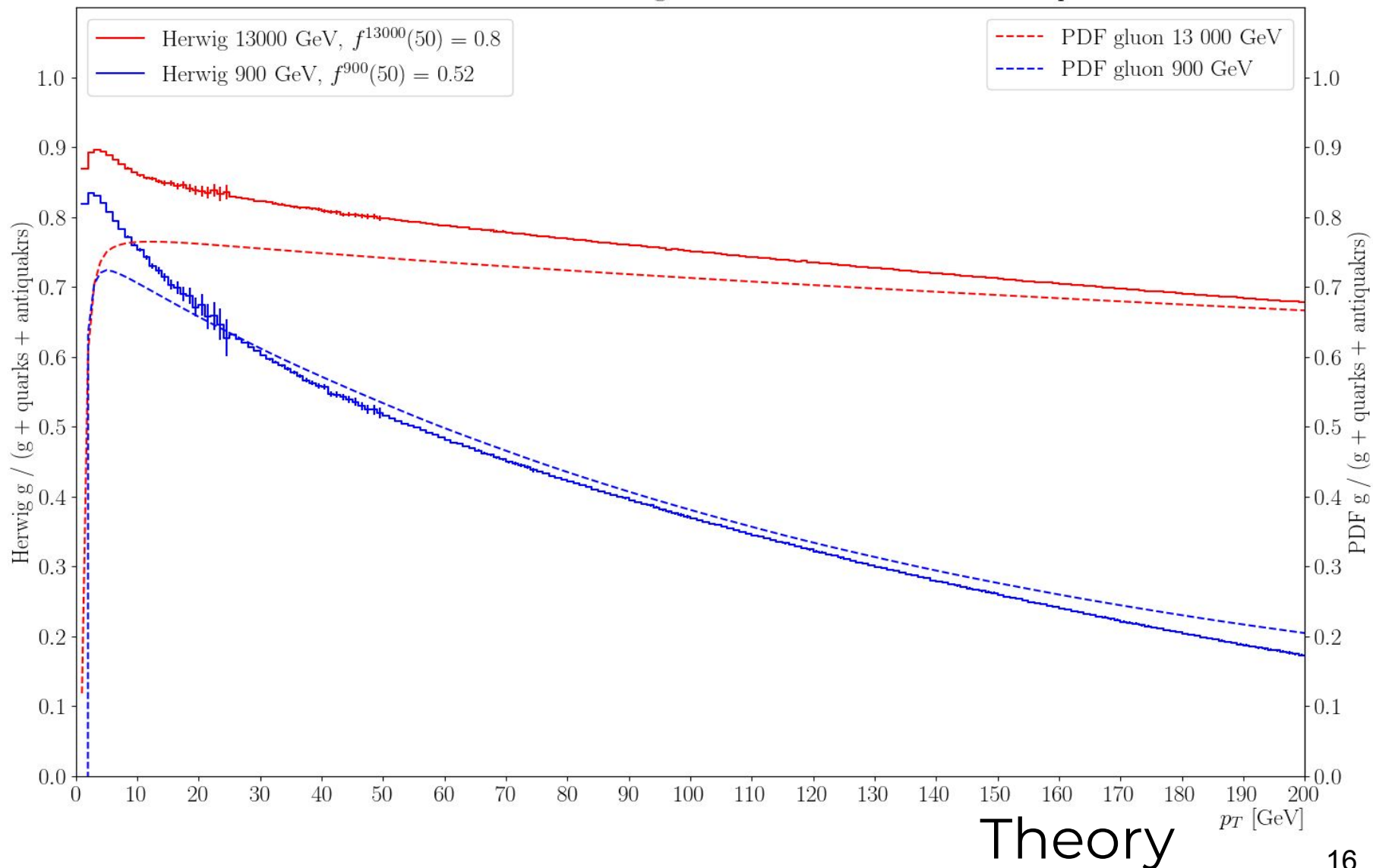
$\lambda^{900}, \lambda^{13000}$... measurement (same cuts, average $p_T > 50$ GeV)

f^{900}, f^{13000} ... simulation hadr. off

Theory

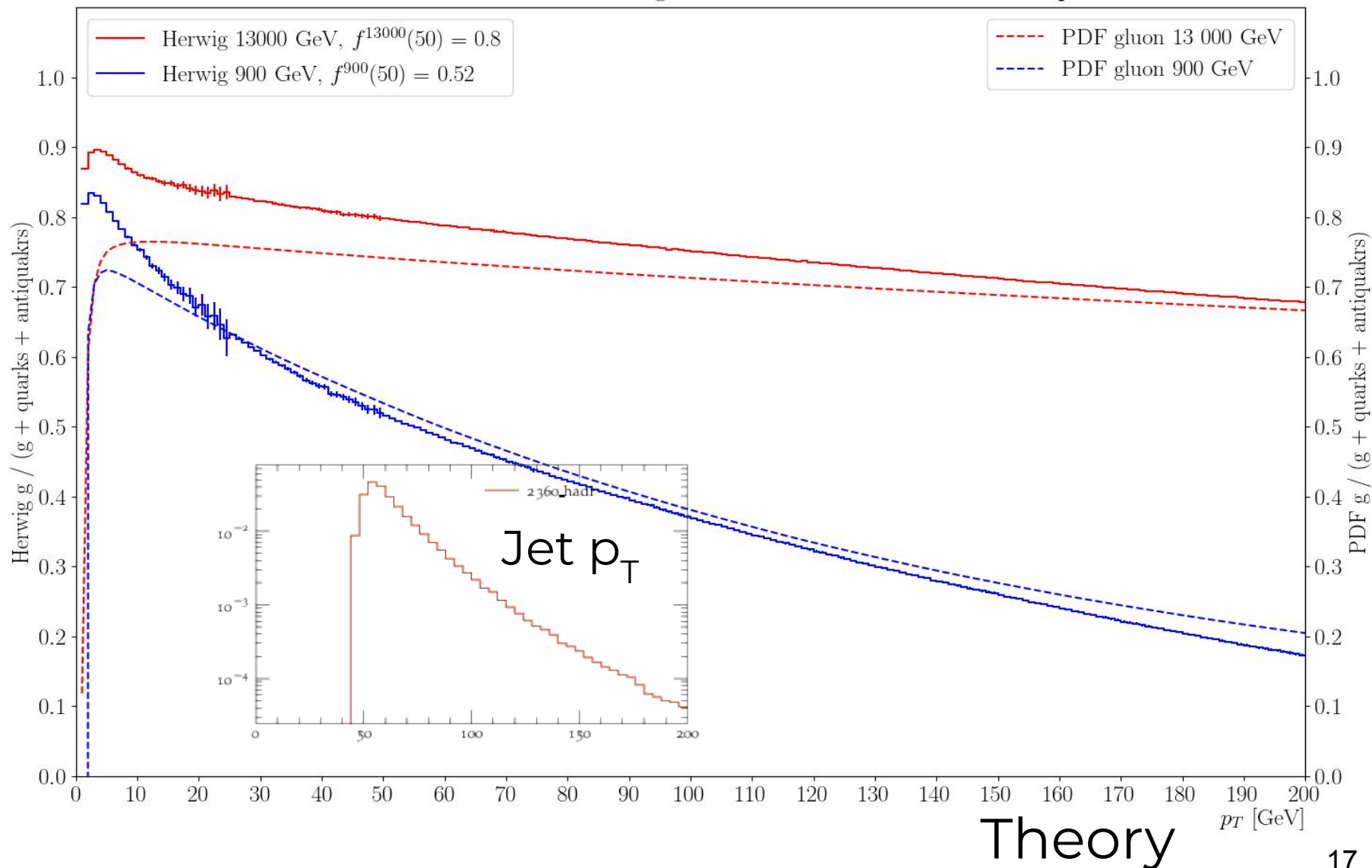
Separation of Quark and Gluon Jets using Angularities

Gluon Fraction PDF and Herwig MHT2014nlo68cl as a function of p_T



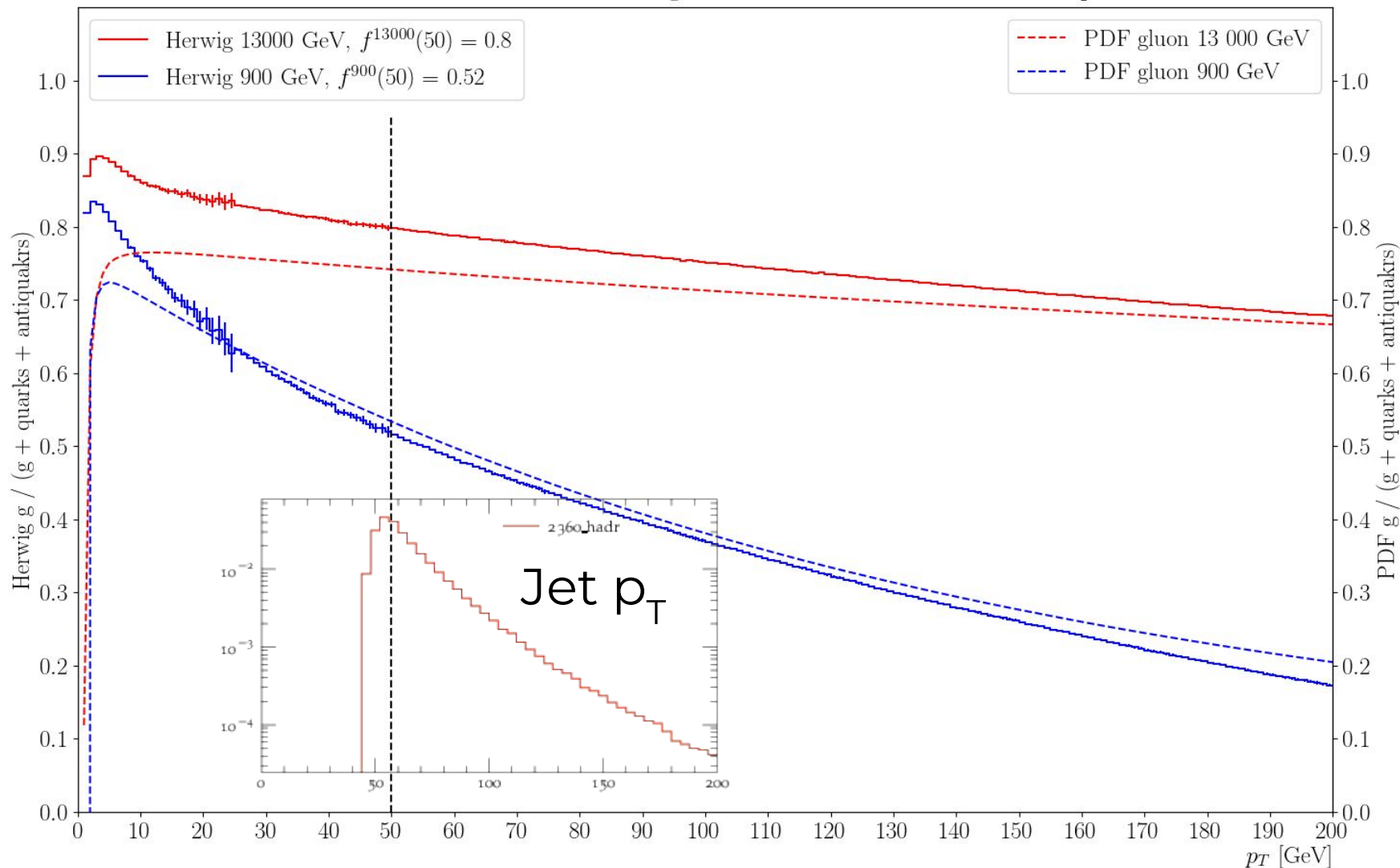
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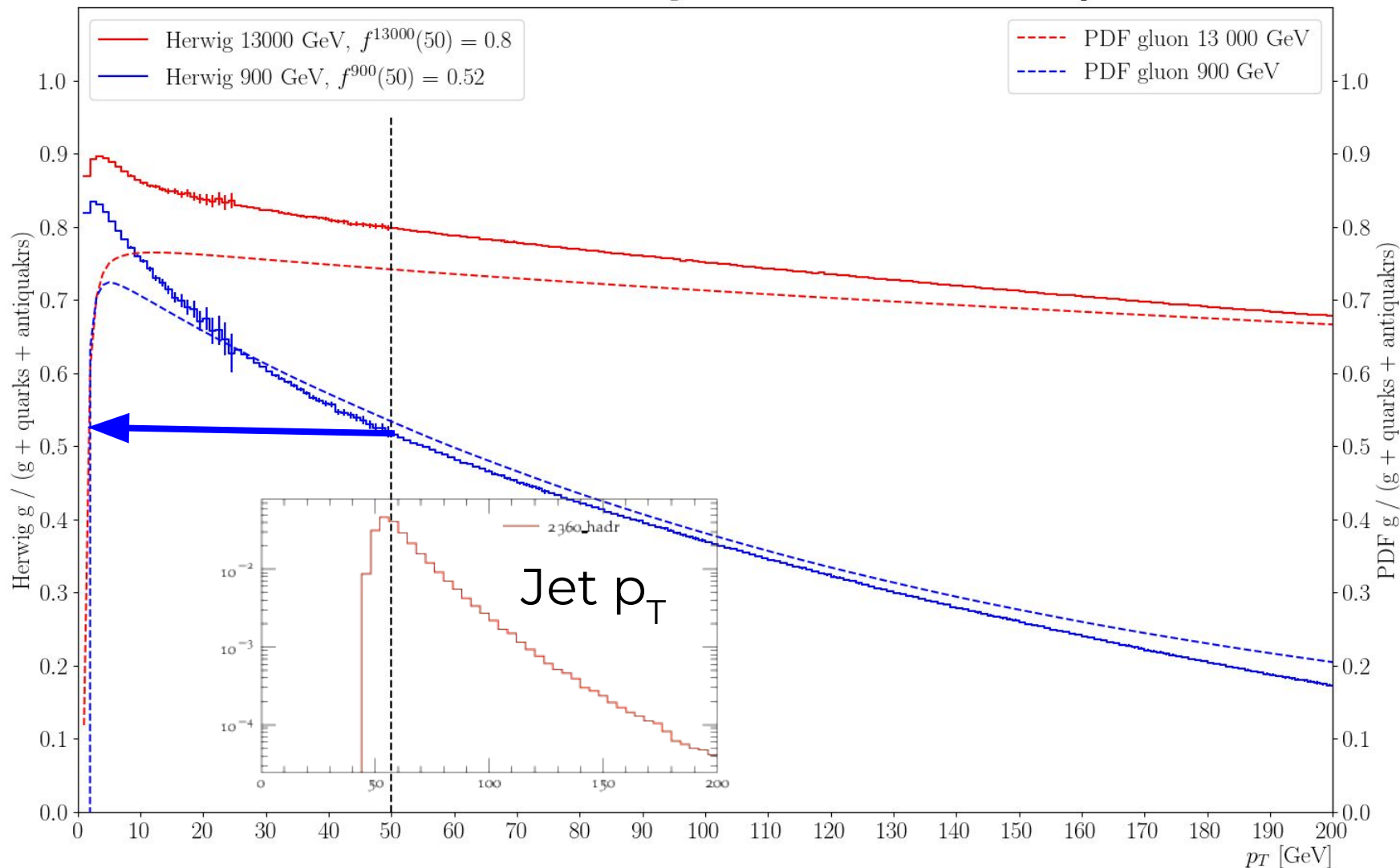
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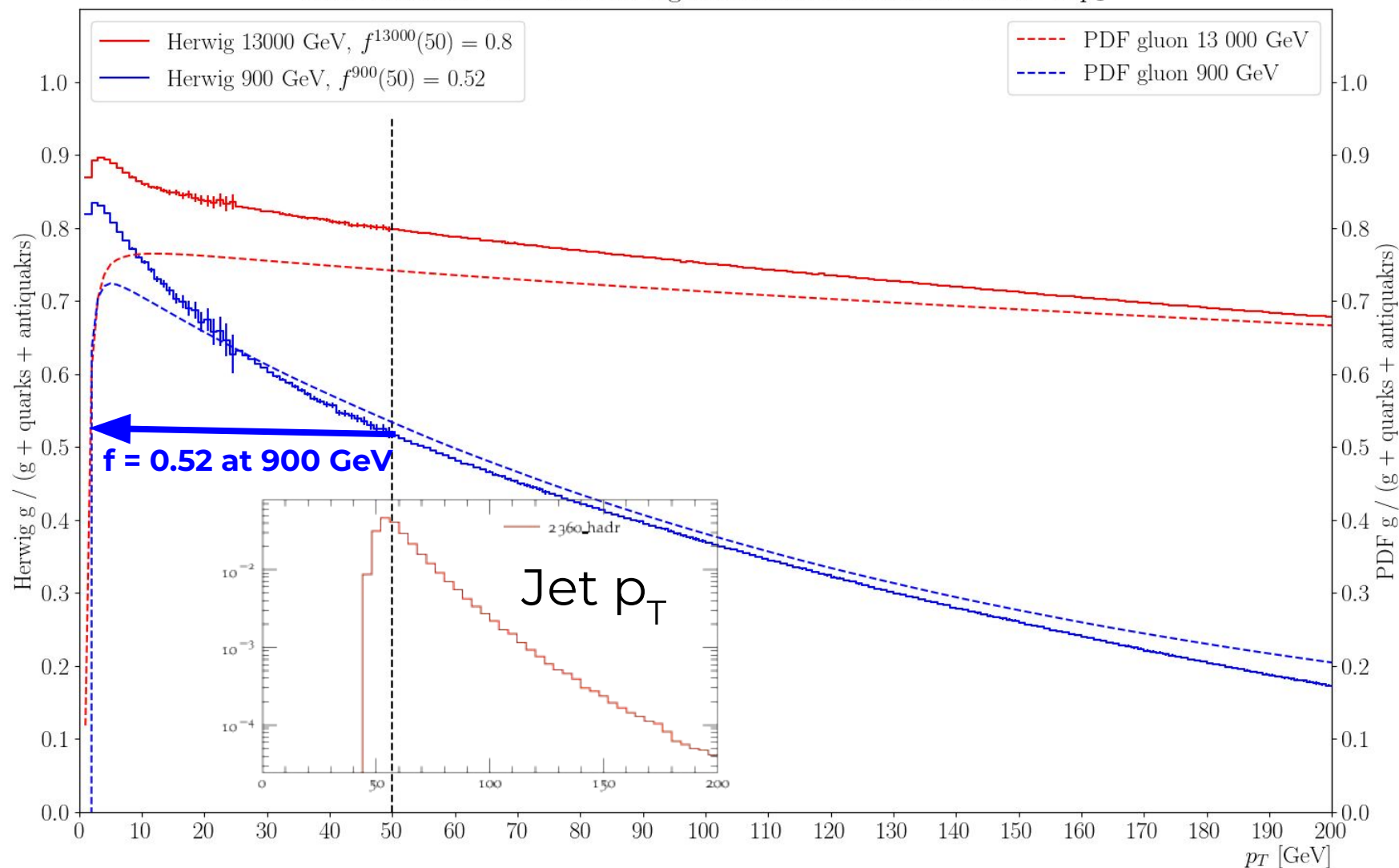
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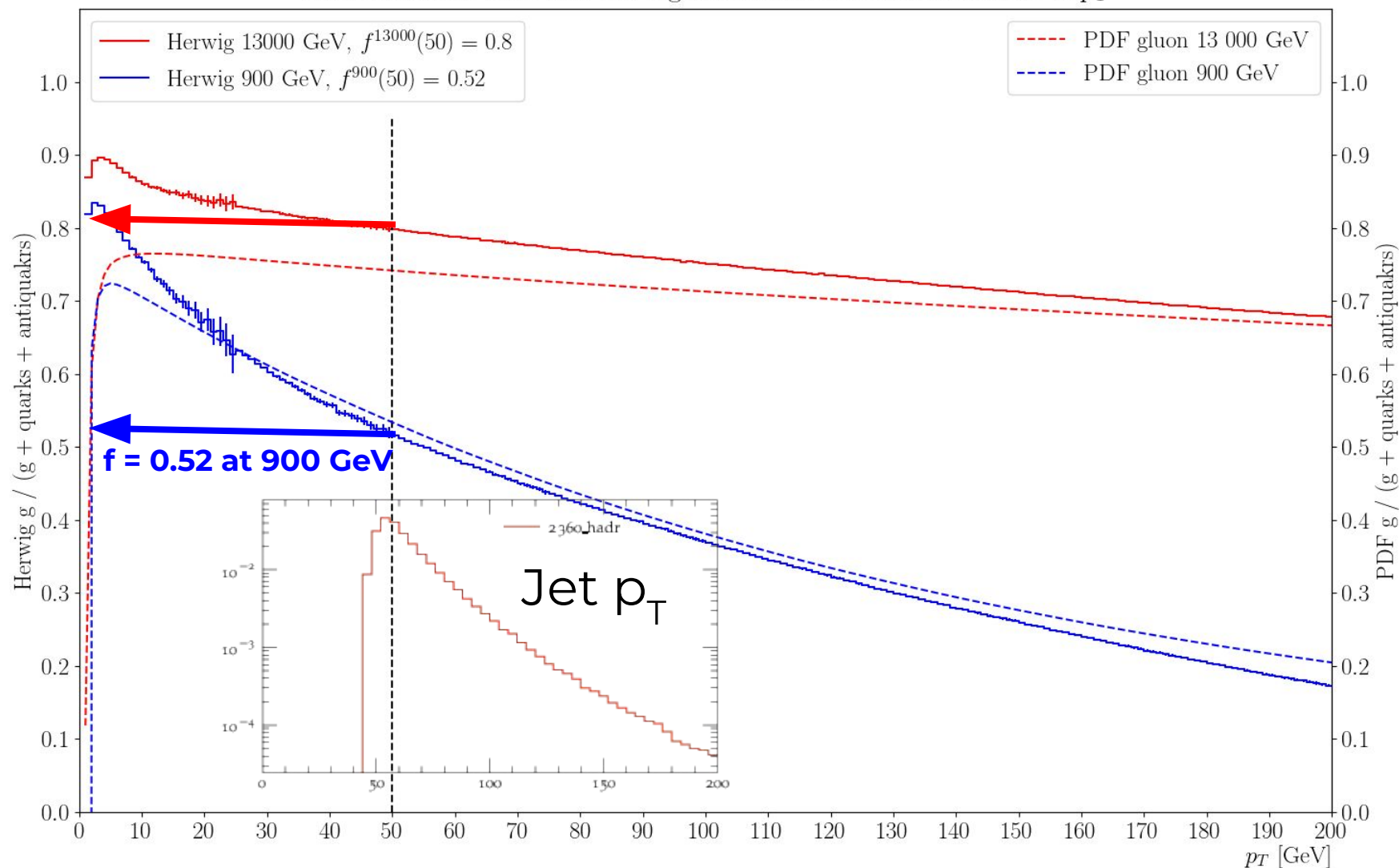
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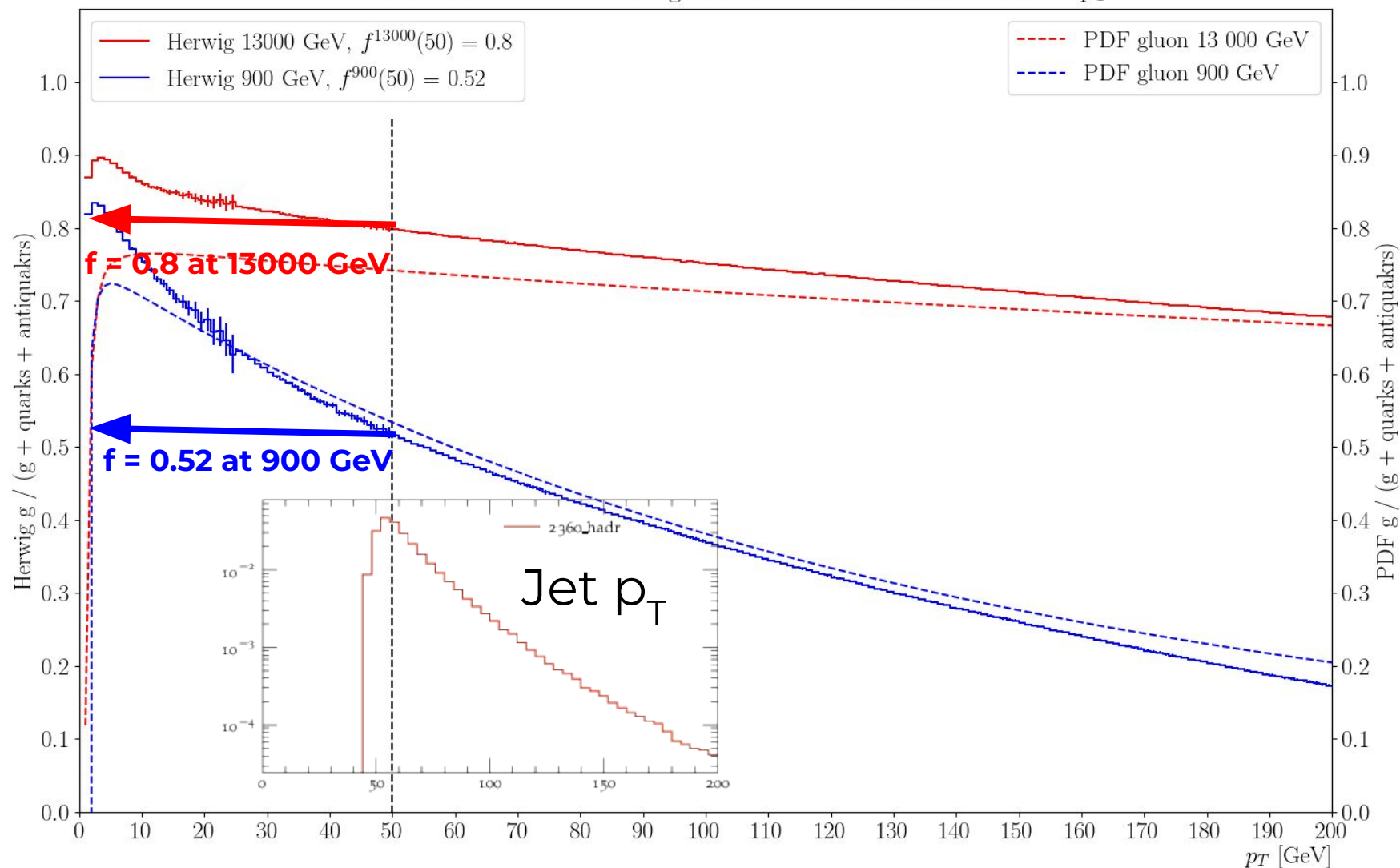
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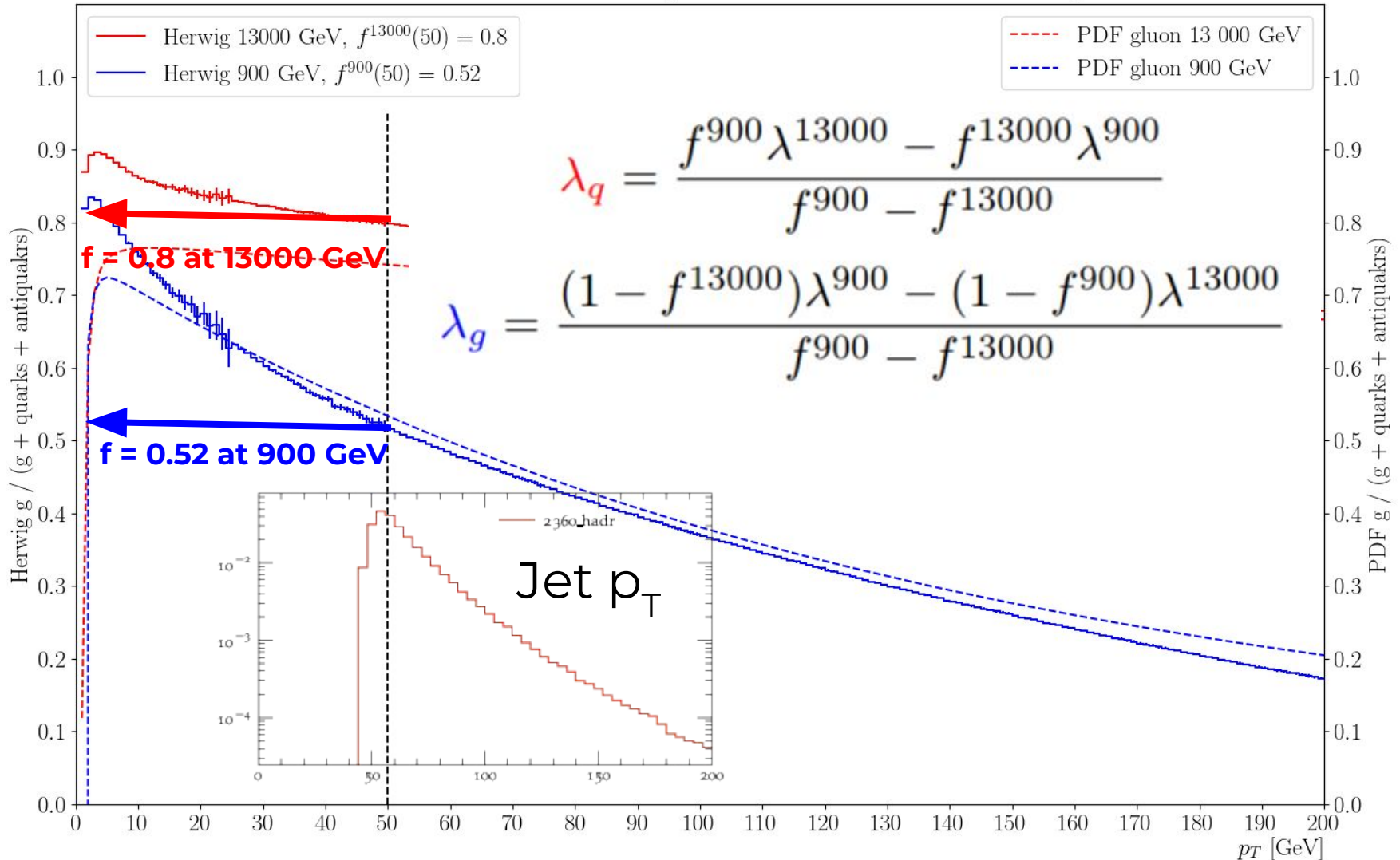
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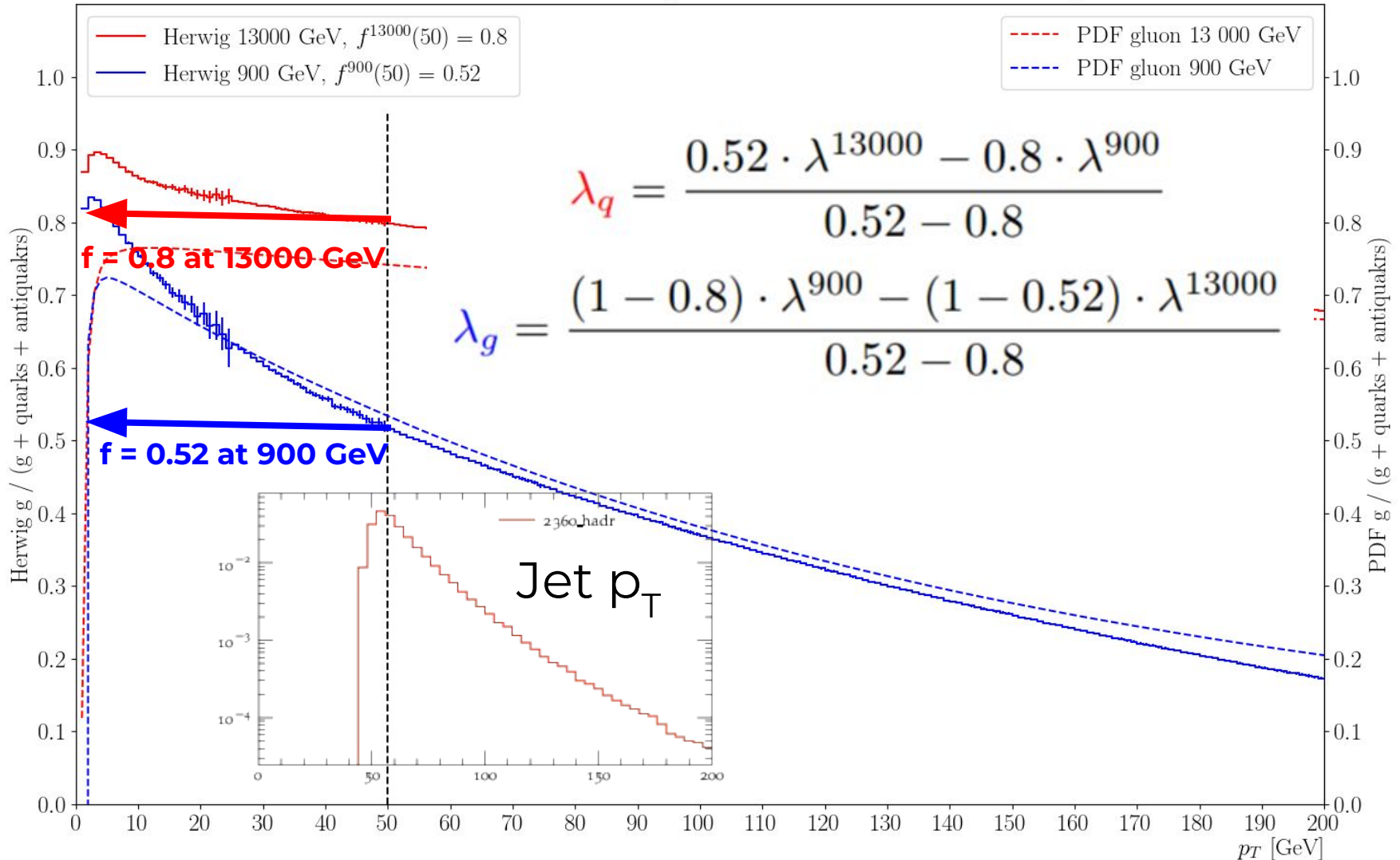
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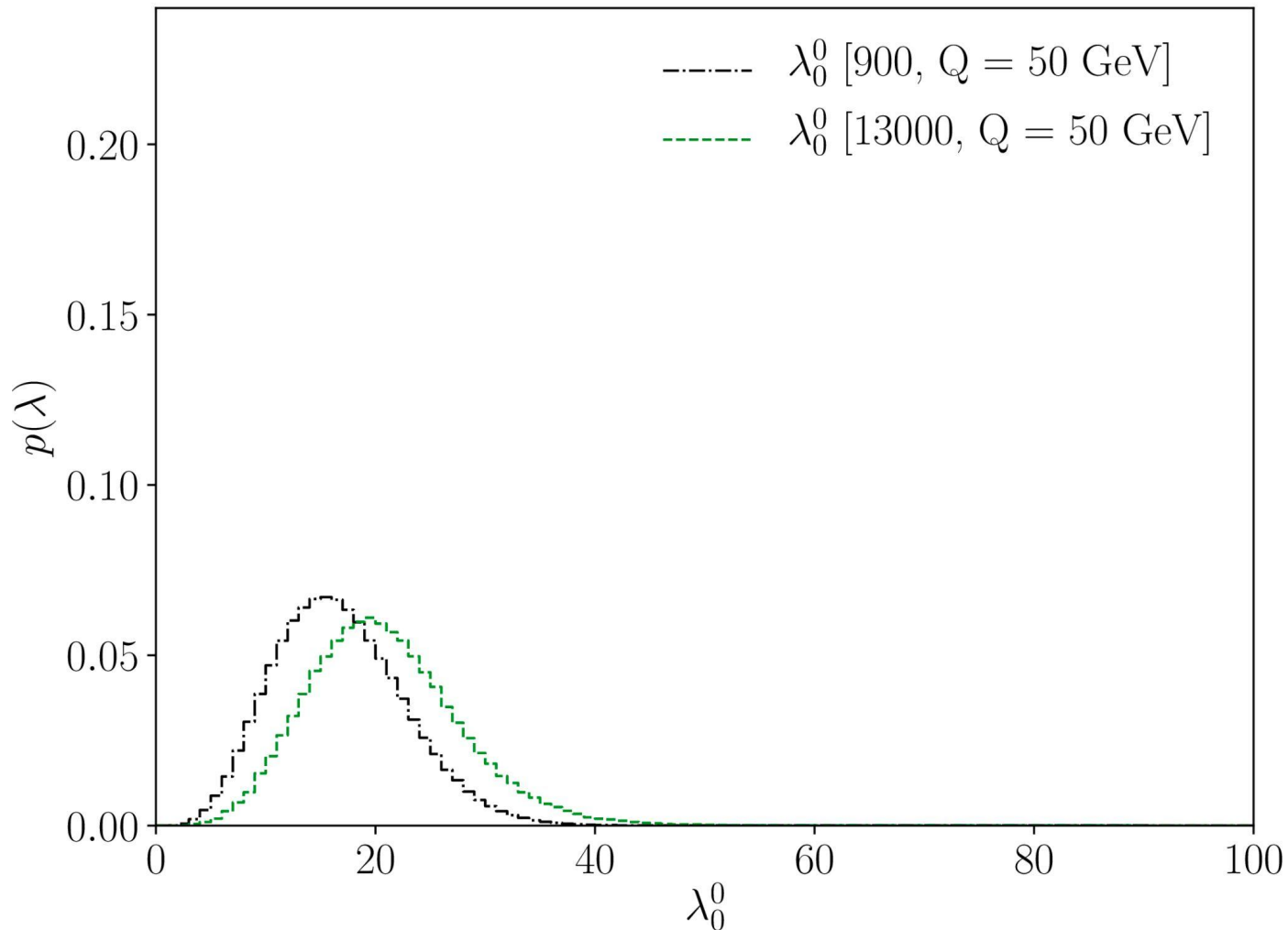
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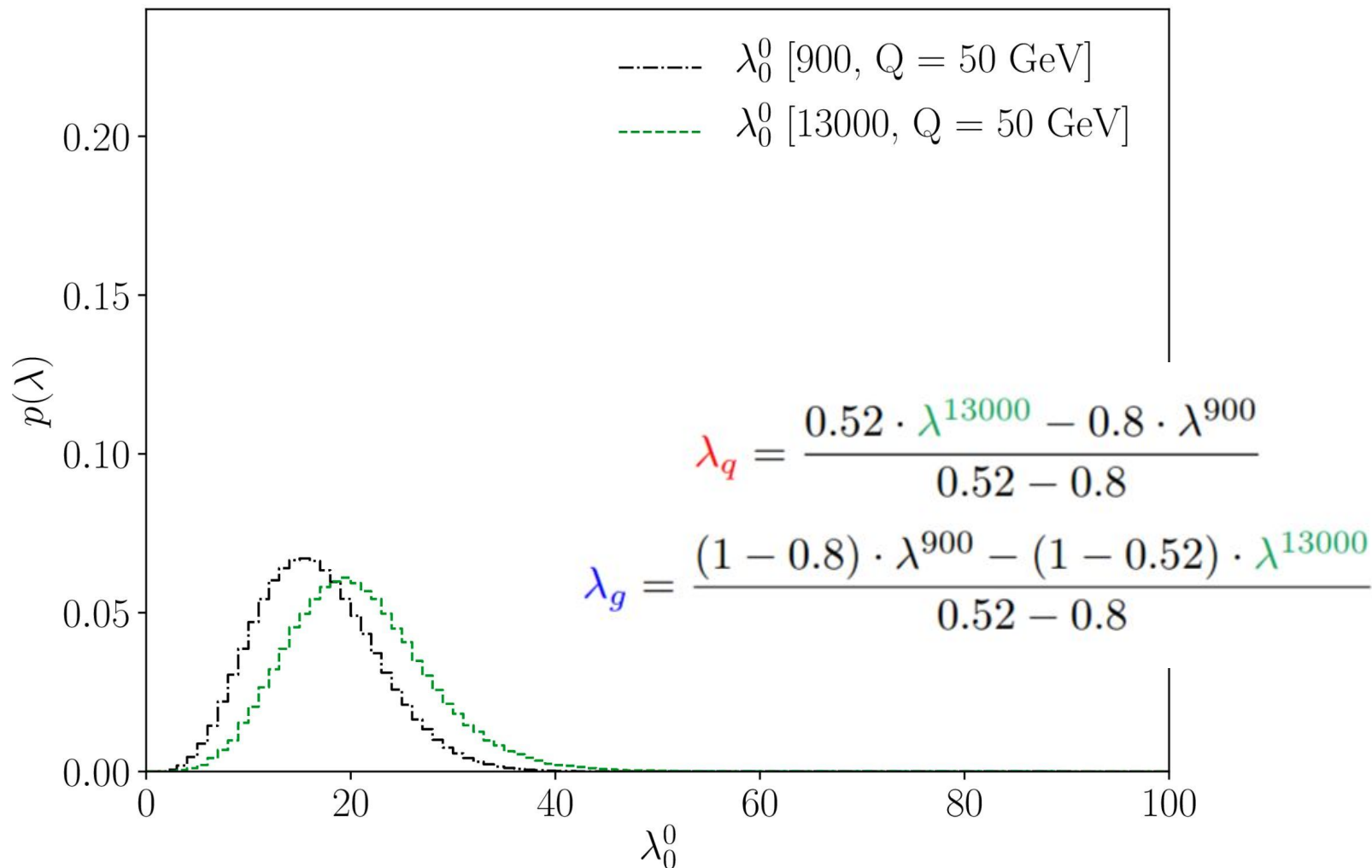
Multiplicity, $pp \rightarrow 2j$, $R = 0.4$



Theory

Separation of Quark and Gluon Jets using Angularities

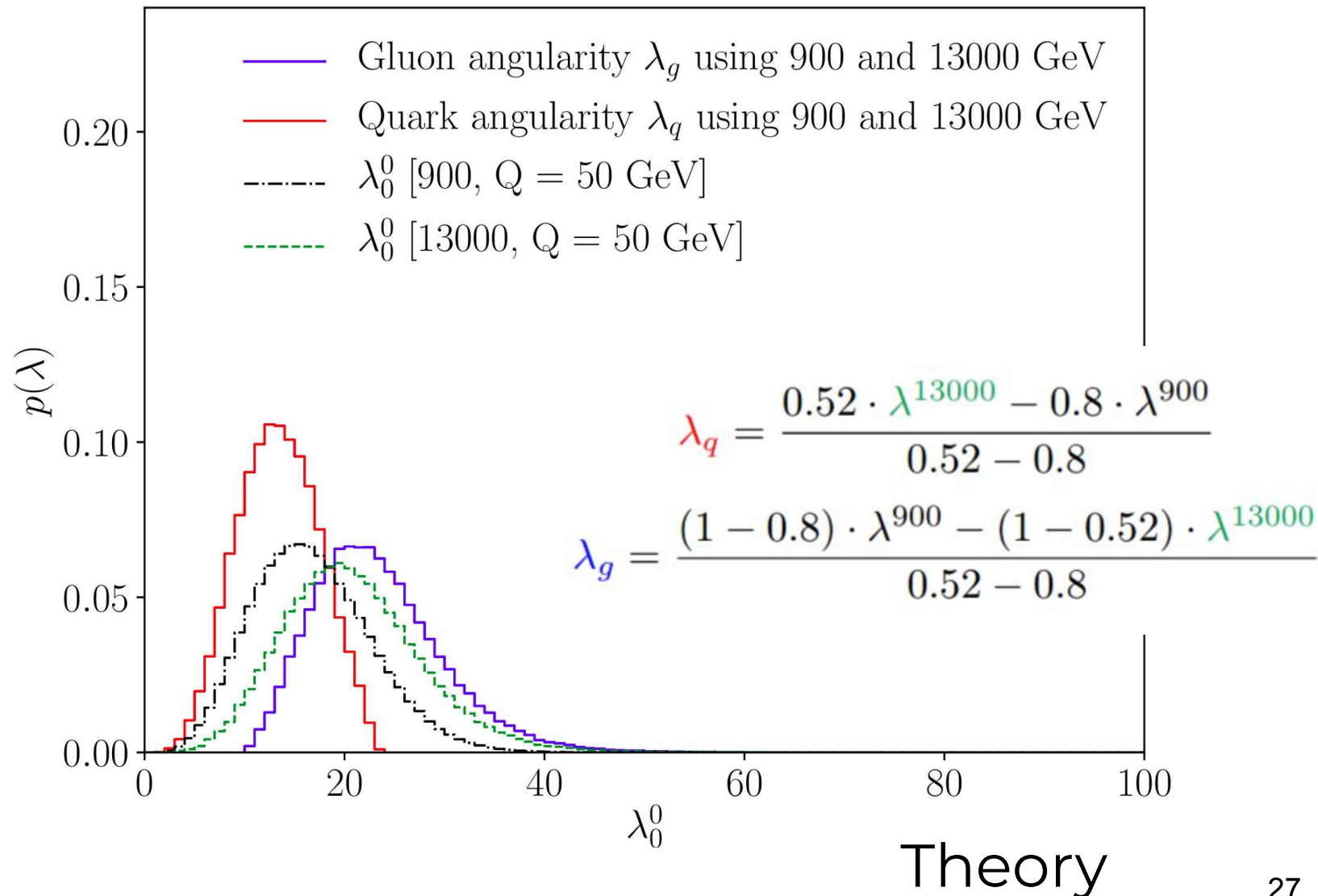
Multiplicity, $pp \rightarrow 2j$, $R = 0.4$



Theory

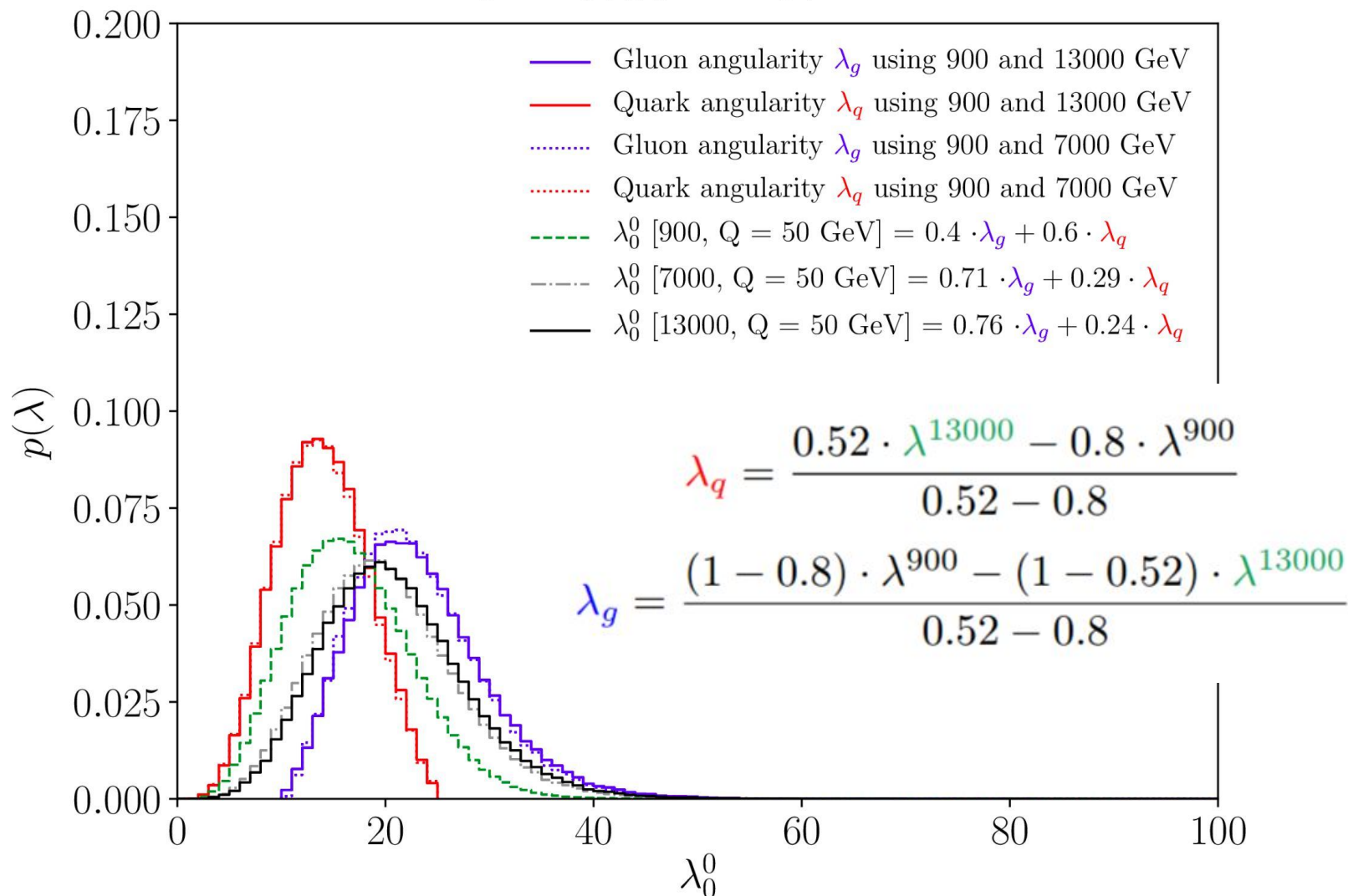
Separation of Quark and Gluon Jets using Angularities

Multiplicity, $pp \rightarrow 2j$, $R = 0.4$



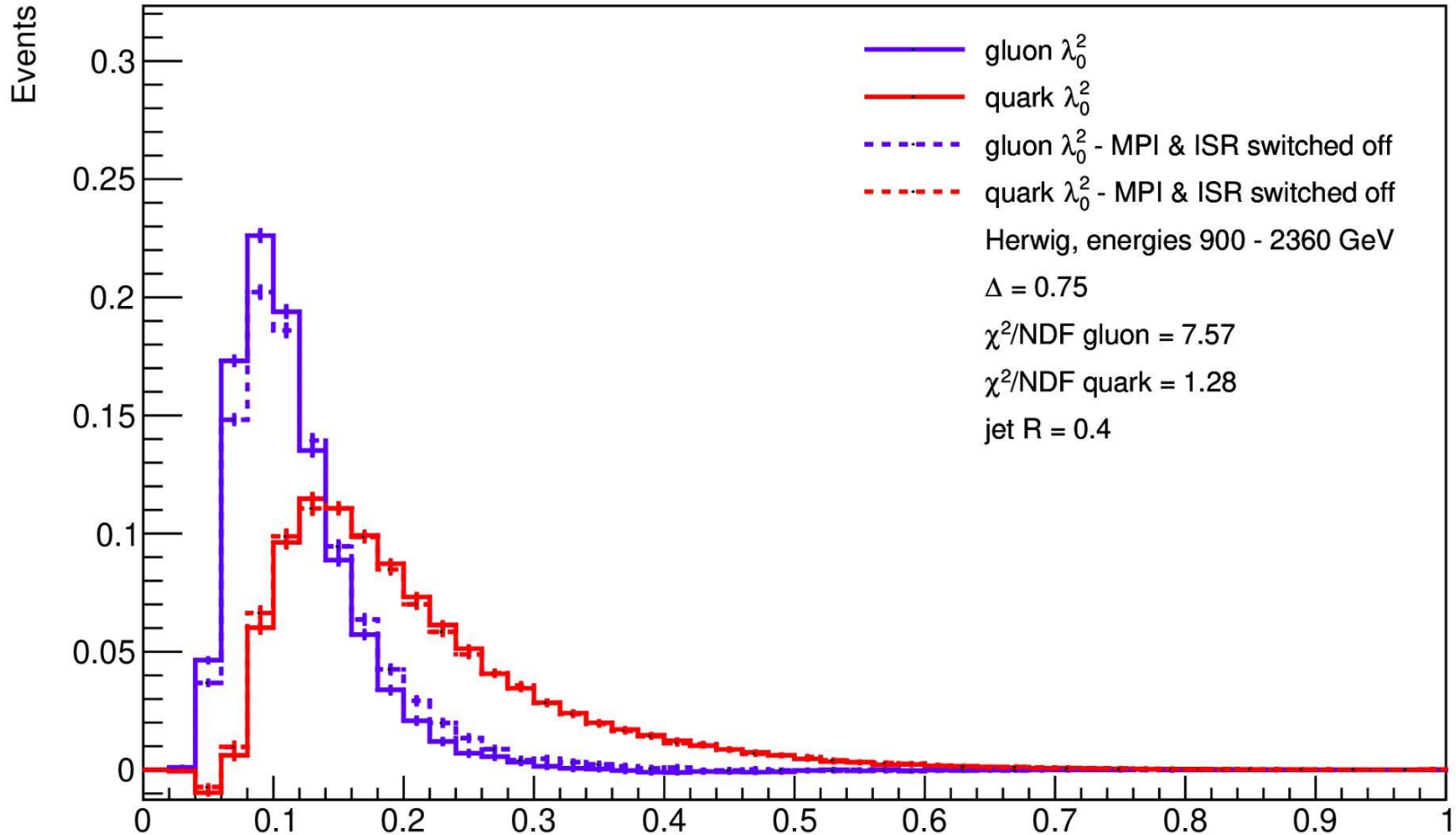
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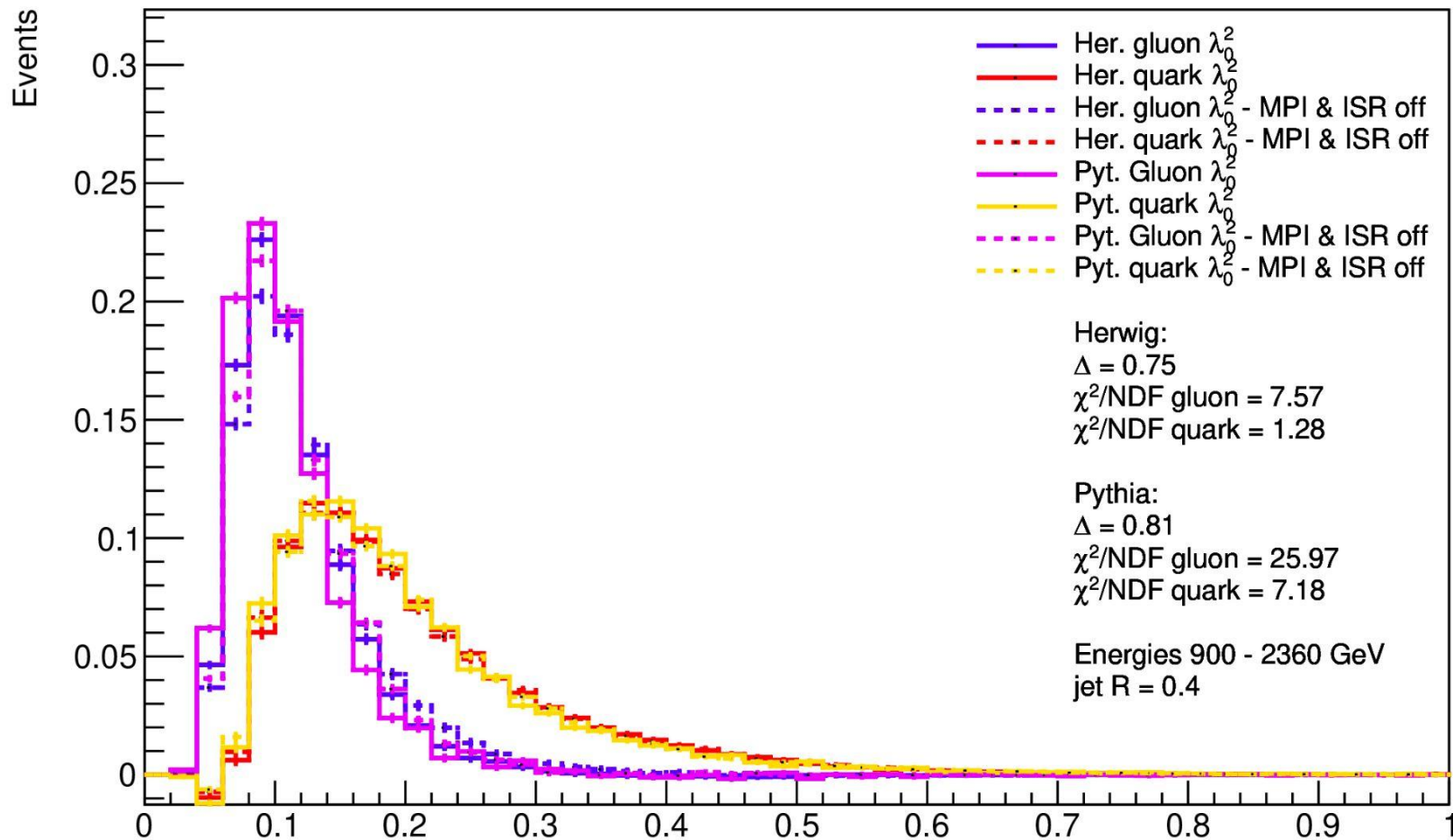
Theory

Separation of Quark and Gluon Jets using Angularities



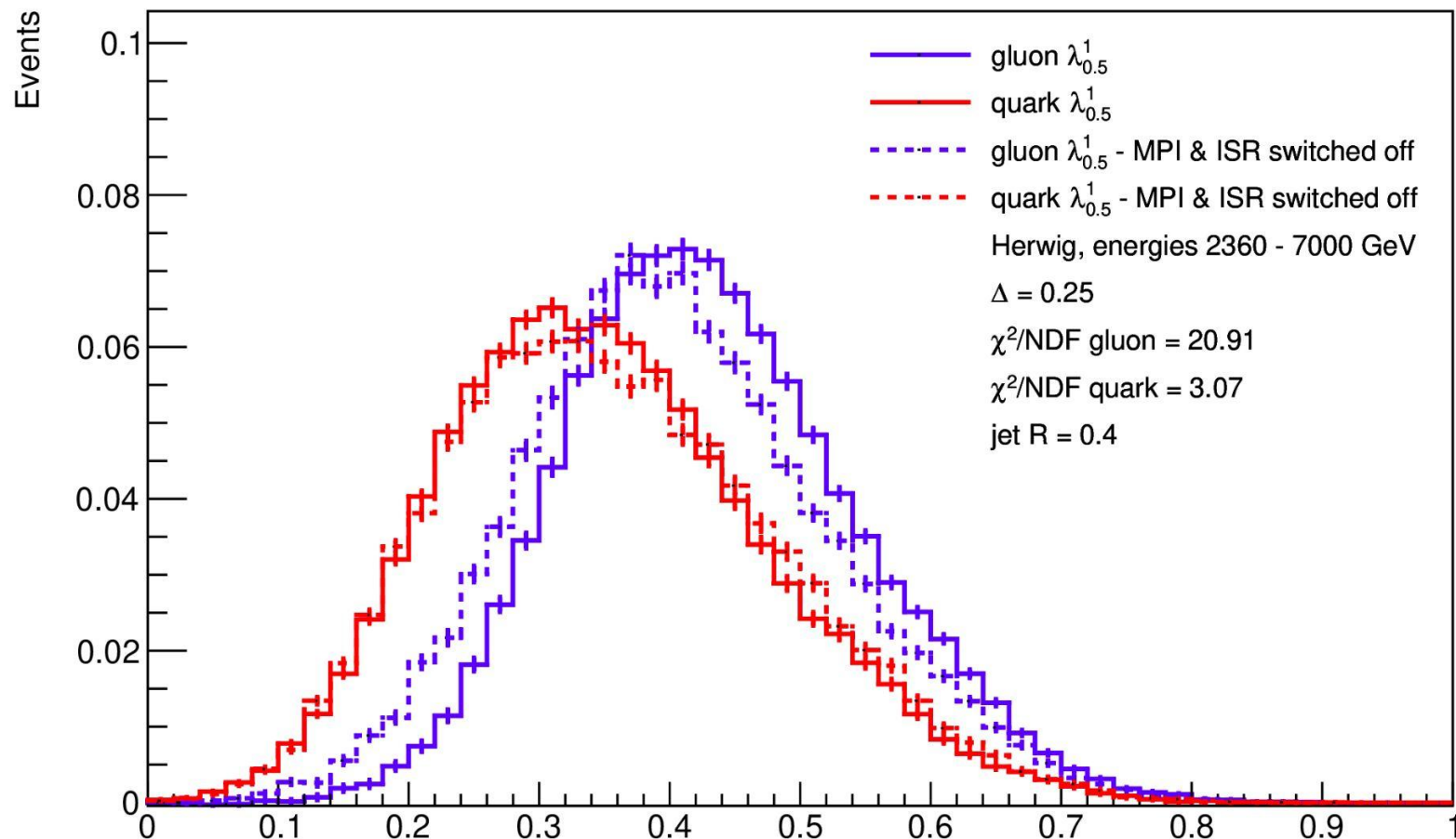
Results

Separation of Quark and Gluon Jets using Angularities



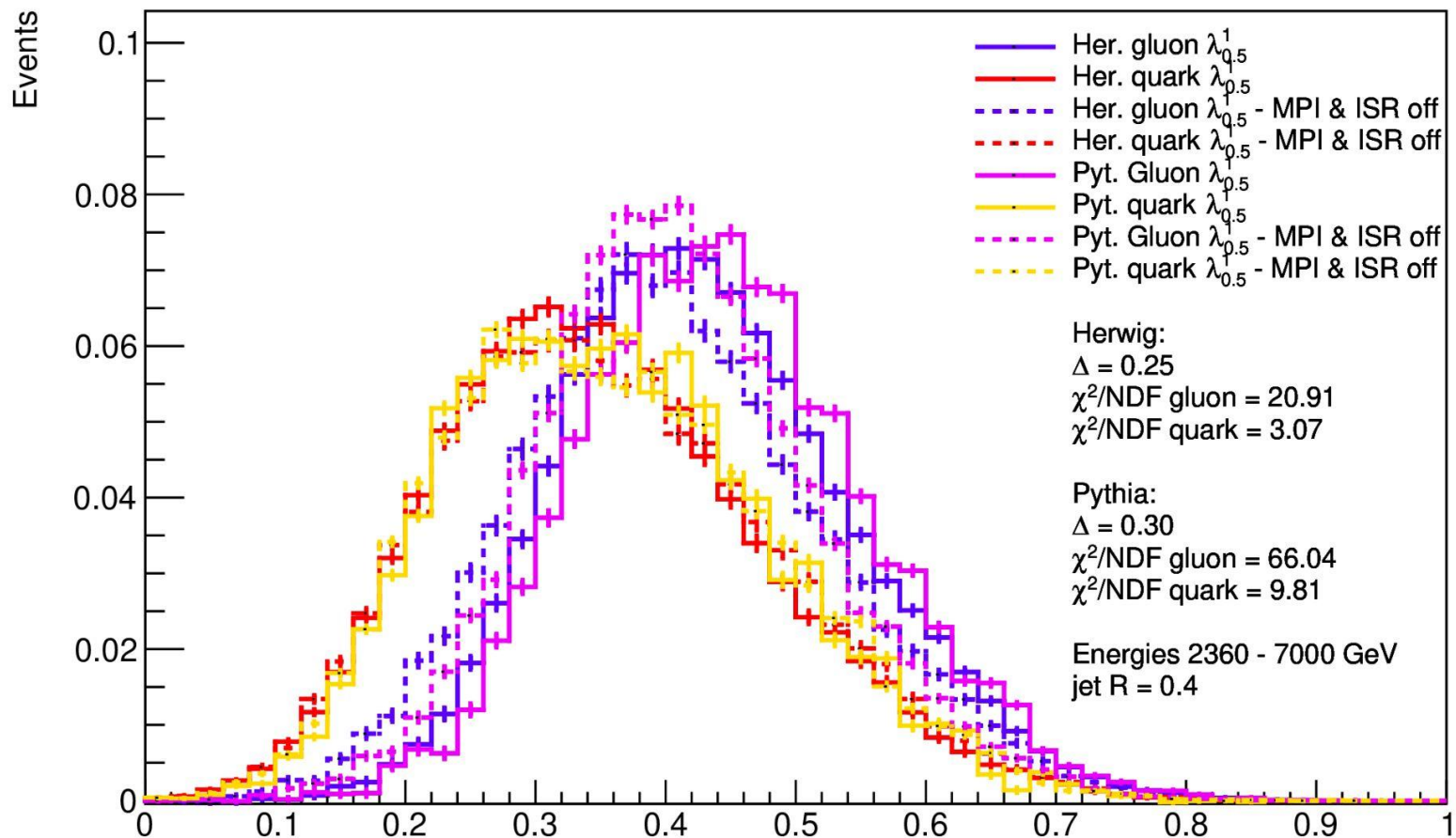
Results

Separation of Quark and Gluon Jets using Angularities



Results

Separation of Quark and Gluon Jets using Angularities



Results

Separation of Quark and Gluon Jets using Angularities

Conclusion

- The study of 5 jet angularities λ 's with various jet radii (0.2-1.0), energy combinations 900, 2300, 7000, and 13000 GeV, trimmed / no trimmed jets, Herwig / Pythia, etc. (in total 2400 variations) was performed.
- Presented results are robust to Initial State Radiation (ISR) and Mutli Parton Interactions (MPI).
- The aim is to perform the measument at LHC

References

- [1] M. W. Krasny, F. Fayette, W. Placzek and A. Siodmok, *Z-boson as 'the standard candle' for high precision W-boson physics at LHC*, *Eur. Phys. J.* **C51** (2007) 607–617, [[hep-ph/0702251](https://arxiv.org/abs/hep-ph/0702251)].
- [2] P. Gras, S. Höche, D. Kar, A. Larkoski, L. Lönnblad, S. Plätzer et al., *Systematics of quark/gluon tagging*, *JHEP* **07** (2017) 091, [[1704.03878](https://arxiv.org/abs/1704.03878)].
- [3] A. J. Larkoski, J. Thaler and W. J. Waalewijn, *Gaining (Mutual) Information about Quark/Gluon Discrimination*, *JHEP* **11** (2014) 129, [[1408.3122](https://arxiv.org/abs/1408.3122)].

links:

[1] <https://arxiv.org/abs/hep-ph/0702251>

[2] <https://arxiv.org/abs/1704.03878>

[3] <https://arxiv.org/abs/1408.3122>

Back-up

Lets write equations for measurement at energy 900 GeV and 13 000 GeV

$$\lambda^{900} = f^{900} \lambda_g + (1-f^{900}) \lambda_q$$

$$\lambda^{2360} = f^{2360} \lambda_g + (1-f^{2360}) \lambda_q$$

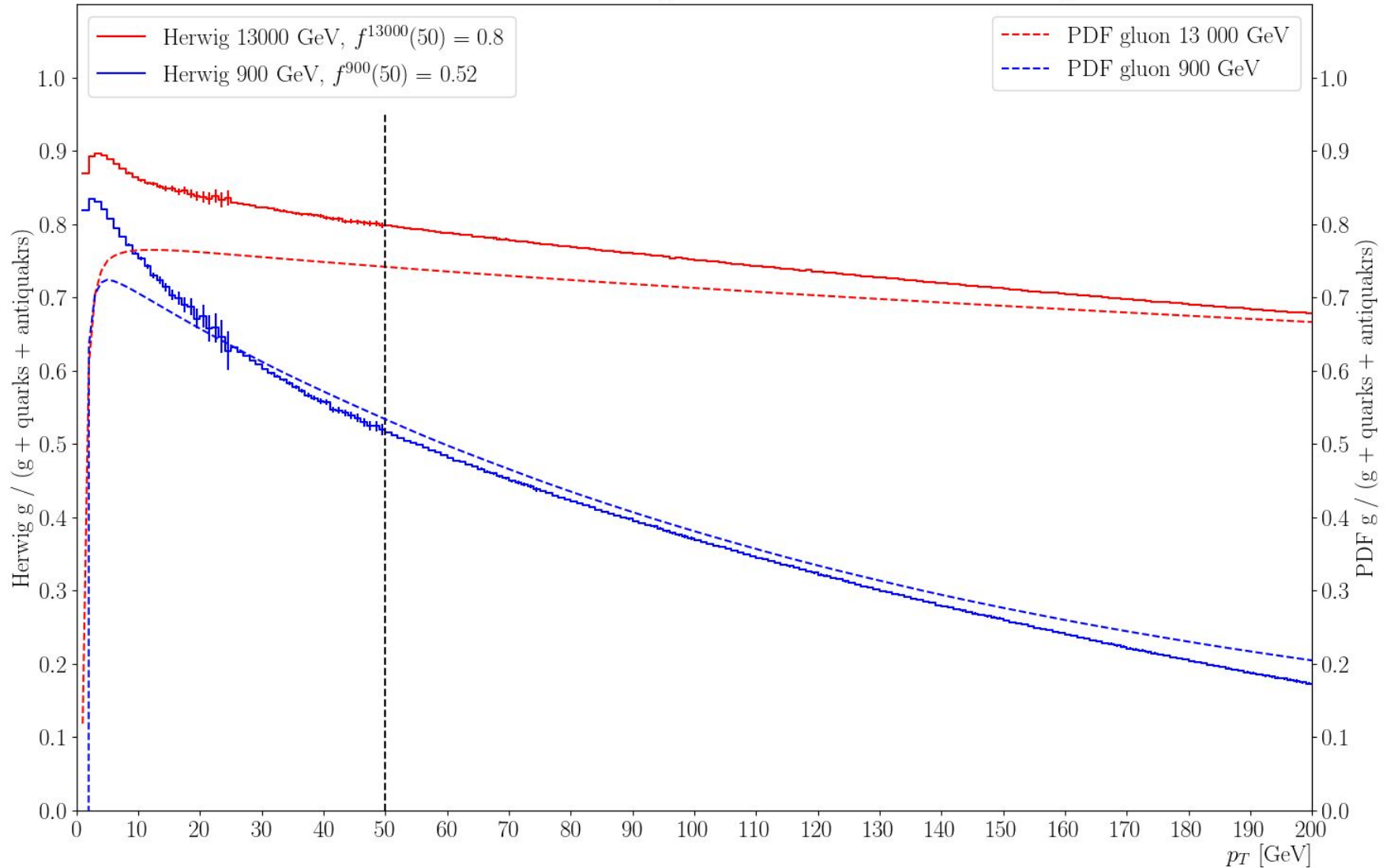
$$\lambda^{13000} = f^{13000} \lambda_g + (1-f^{13000}) \lambda_q$$

$$\lambda_g = \frac{(1 - f^{13000}) \lambda^{900} - (1 - f^{900}) \lambda^{13000}}{f^{900} - f^{13000}} \quad \lambda_q = \frac{f^{900} \lambda^{2360} - f^{2360} \lambda^{900}}{f^{900} - f^{2360}}$$

$$\lambda_q = \frac{f^{900} \lambda^{13000} - f^{13000} \lambda^{900}}{f^{900} - f^{13000}} ; \quad \lambda_g = \frac{(1 - f^{2360}) \lambda^{900} - (1 - f^{900}) \lambda^{2360}}{f^{900} - f^{2360}}$$

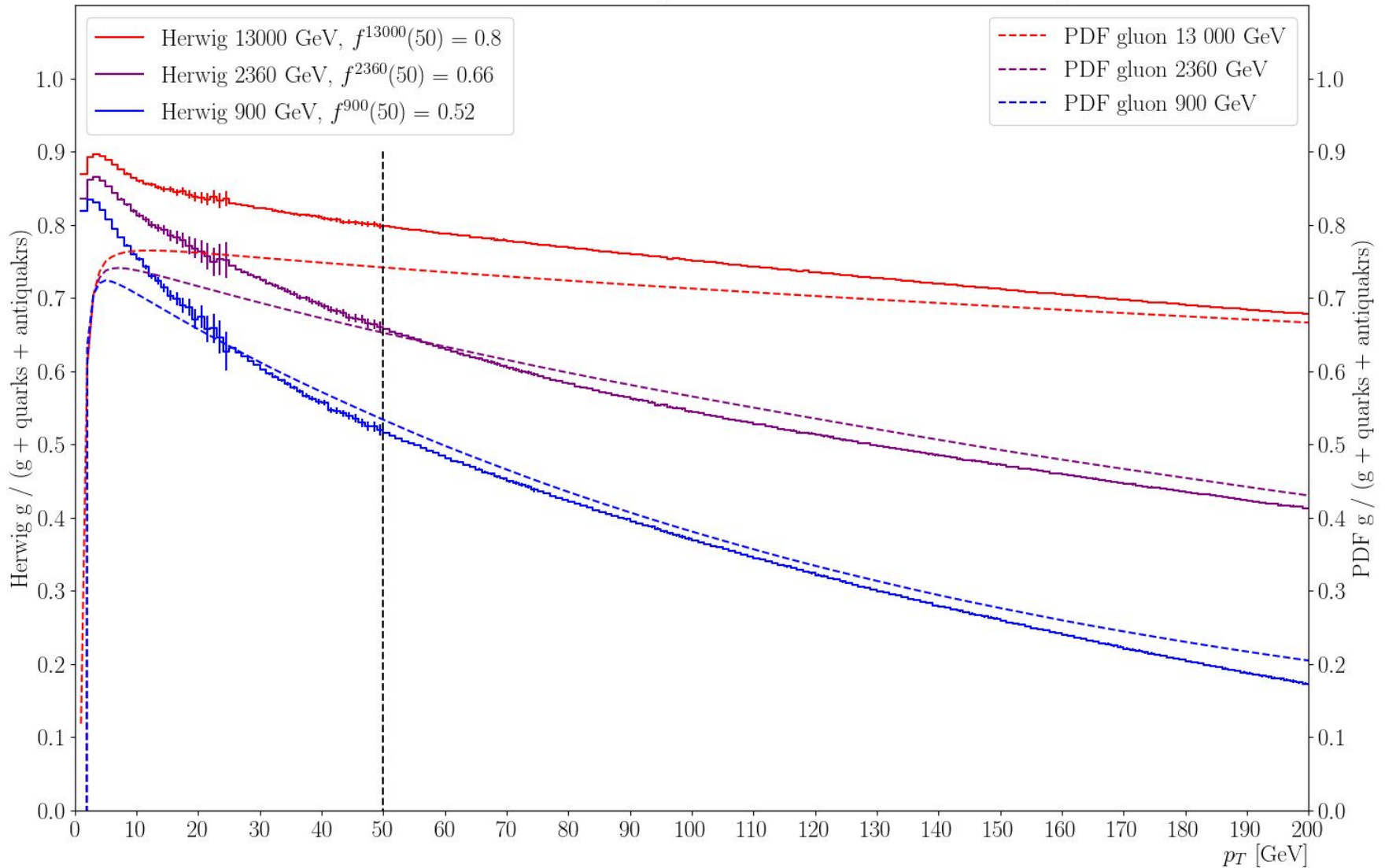
Back-up

Gluon Fraction PDF and Herwig MHT2014nl068cl as a function of p_T



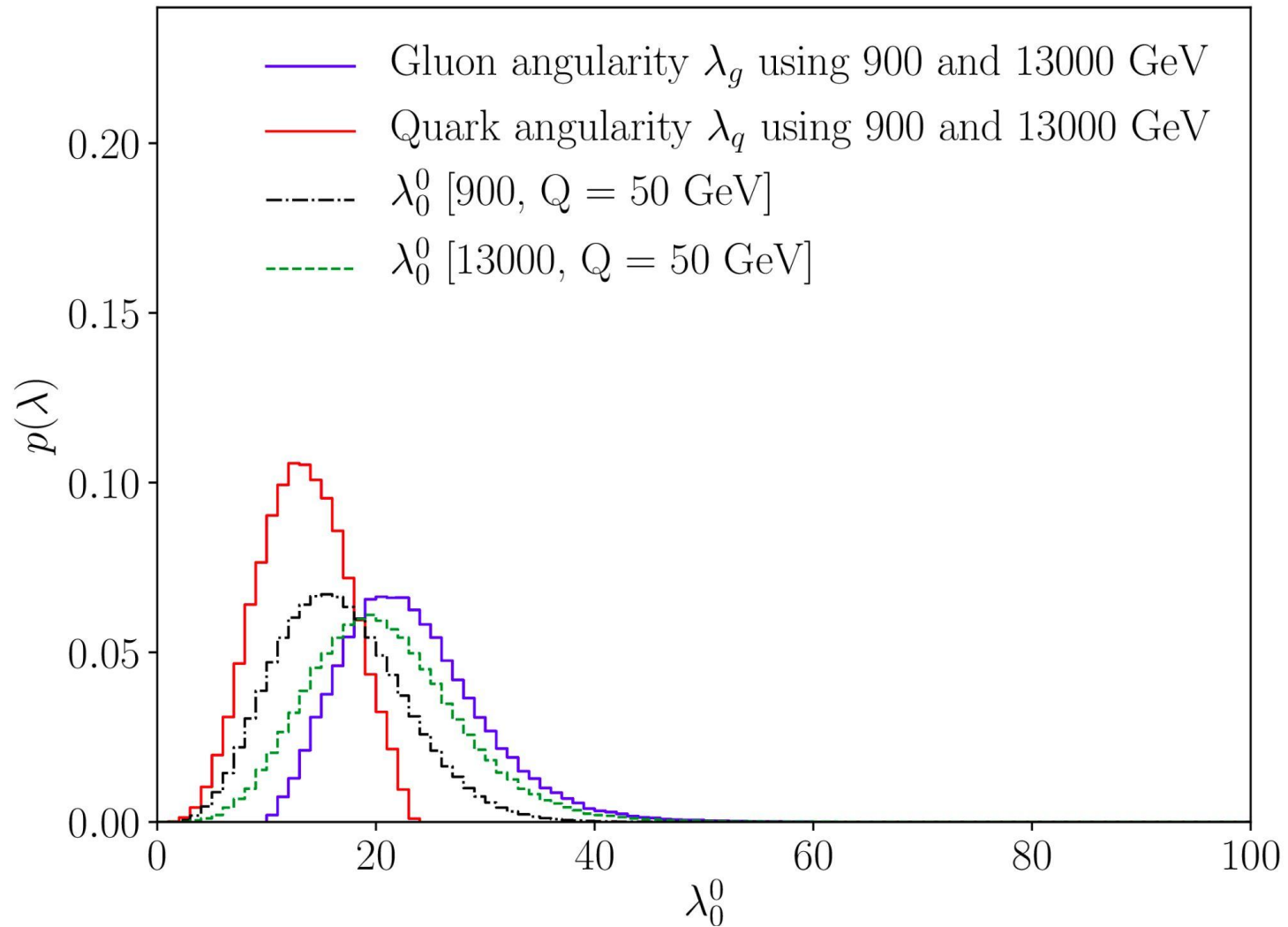
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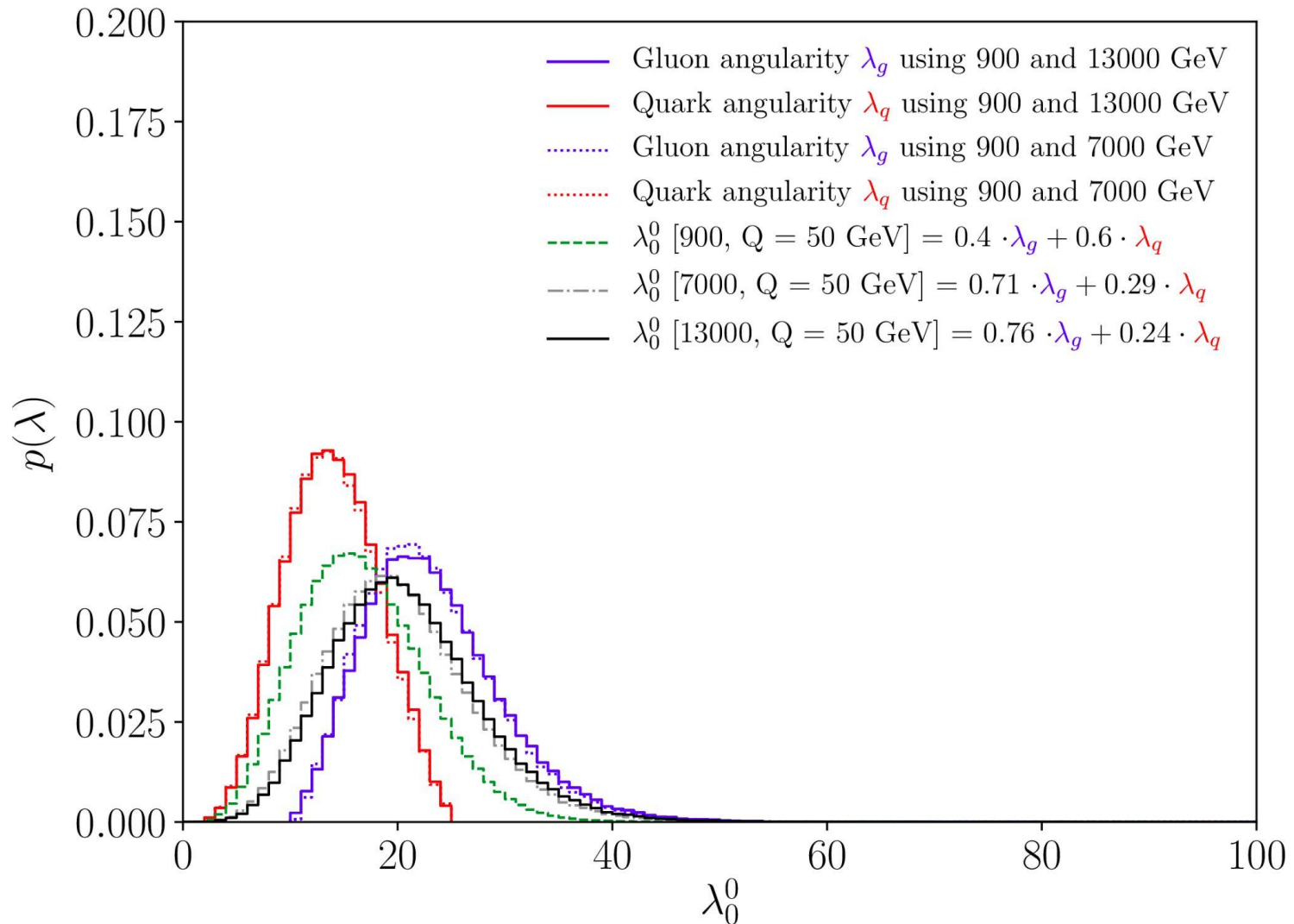
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Multiplicity, $pp \rightarrow 2j$, $R = 0.4$



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Multiplicity, $pp \rightarrow 2j$, $R = 0.4$



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