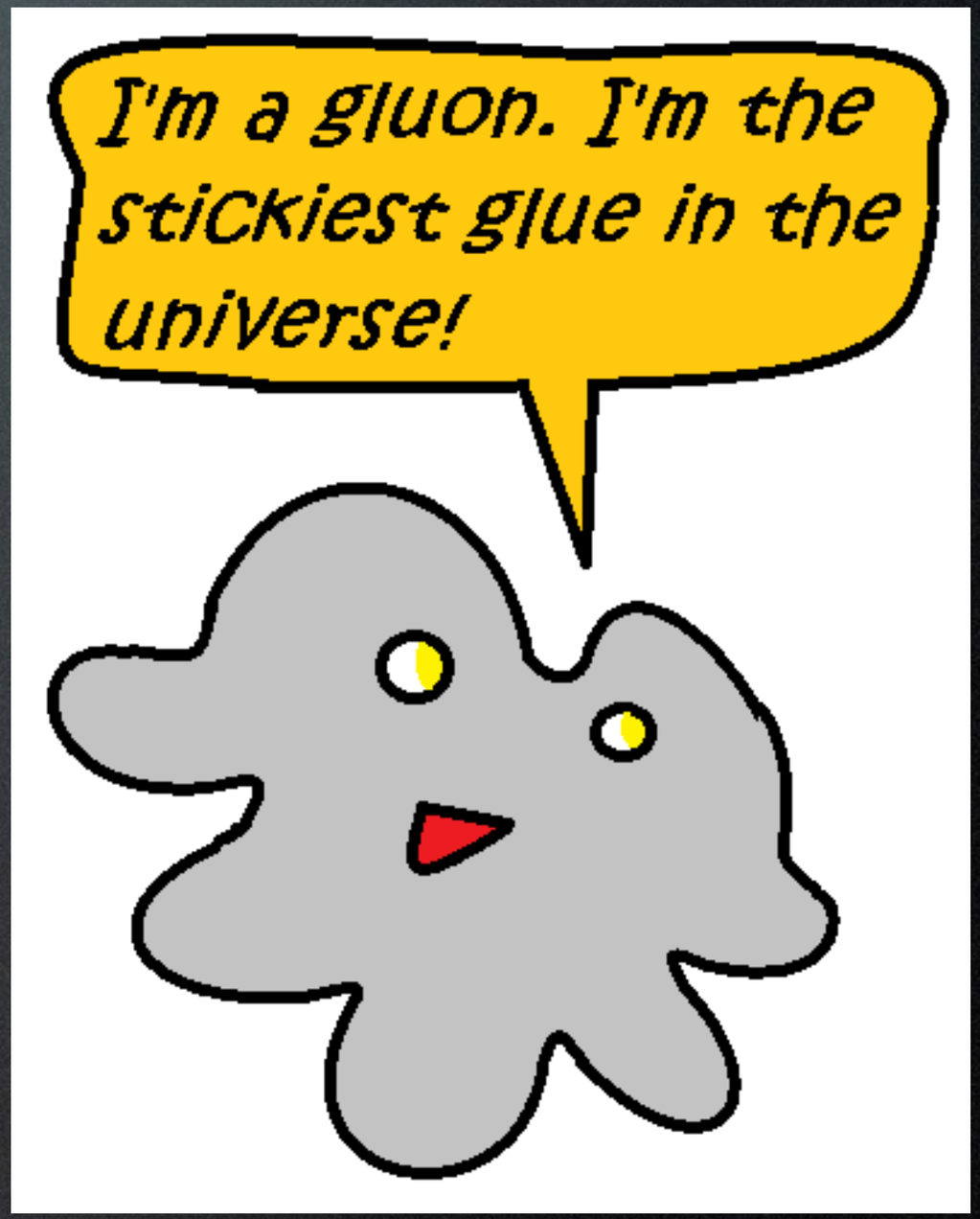
Systematics of quark/gluon tagging

Deepak Kar
(for the q/g team in Les Houches 2015)
Based on: arXiv:1605.04692 and work-in-progress

MPI@LHC, Chiapas, Mexico
27th November - 2nd December, 2016

Discriminate between...



From Quantum Diaries

Quark/gluon discrimination

- Ideally: identify quark-initiated or gluon initiated jets.
- Is that well defined?

What is a Quark Jet?

From lunch/dinner discussions

Ill-Defined

What people sometimes think we mean

A quark parton

A Born-level quark parton

The initiating quark parton in a final state shower

An eikonal line with baryon number 1/3 and carrying triplet color charge

A quark operator appearing in a hard matrix element in the context of a factorization theorem

A parton-level jet object that has been quark-tagged using a soft-safe flavored jet algorithm (automatically collinear safe if you sum constituent flavors)

A phase space region (as defined by an unambiguous hadronic fiducial cross section measurement) that yields an enriched sample of quarks (as interpreted by some suitable, though fundamentally ambiguous, criterion)

Well-Defined

What we mean

The study

- In leading order:

  quark radiation $\propto C_F$, gluon radiation $\propto C_A$

  - Affected strongly by subleading (perturbative and non-perturbative) effects
  - Modelled in MC generators, but needs constraining by data
  - Highlights modelling deficiencies

Variable

Generalised angularities:

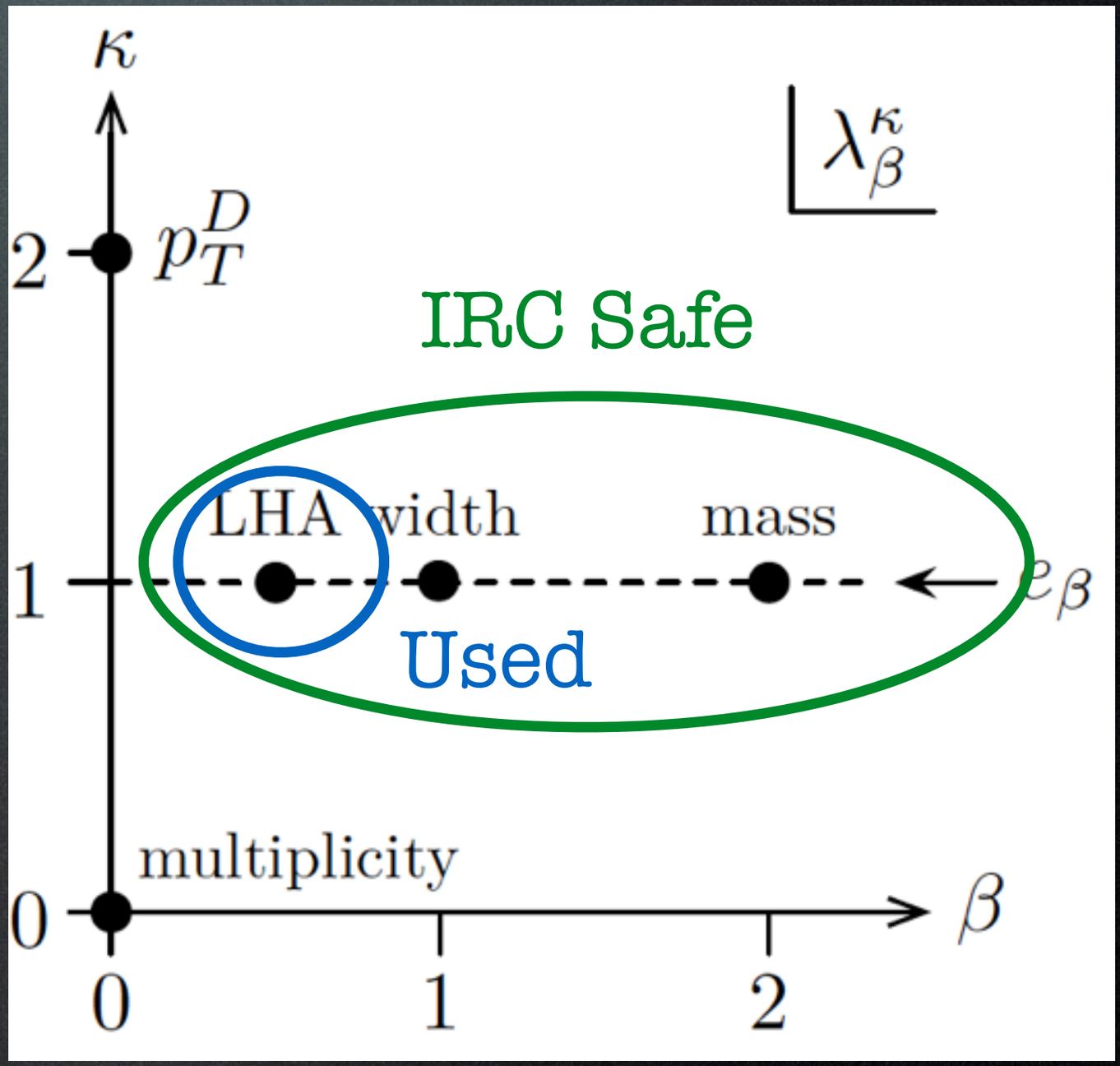
$$\lambda_\beta^\kappa = \sum_{i \in \text{jet}} z_i^\kappa \theta_i^\beta,$$

Define:

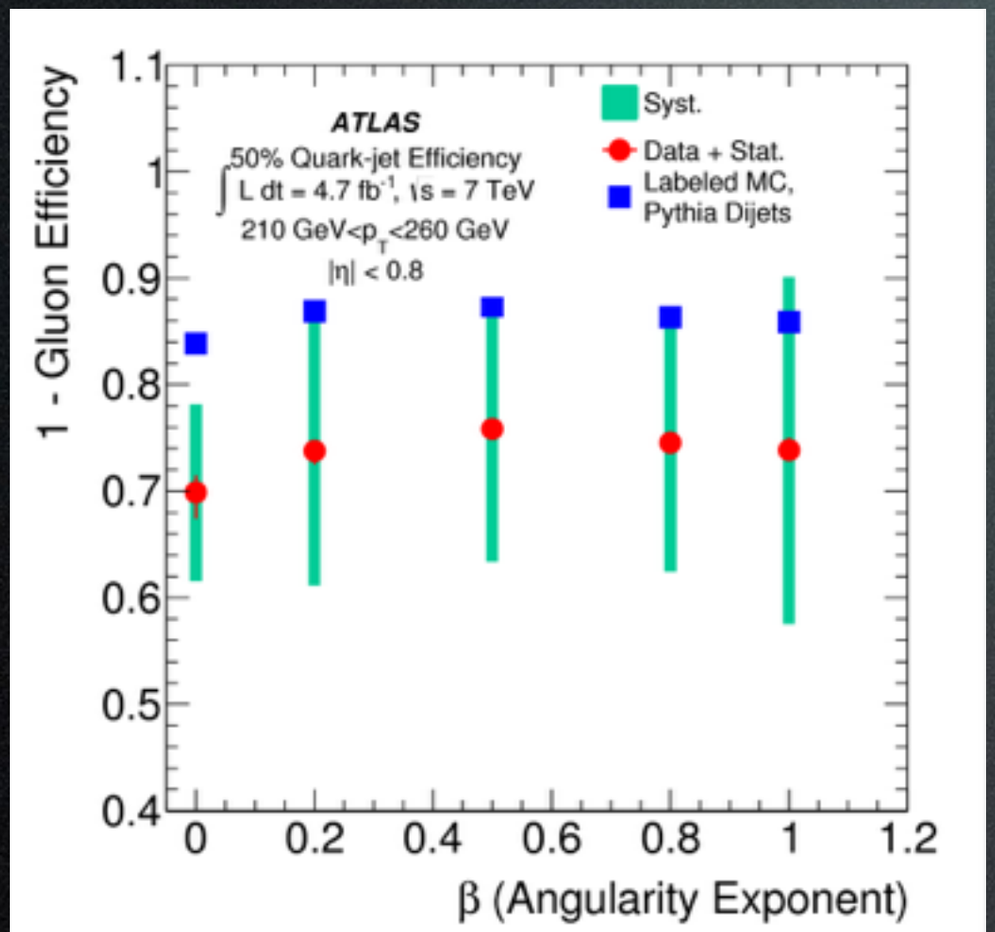
$$z_i \equiv \frac{E_i}{E_{\text{jet}}}, \qquad \theta_i \equiv \frac{\Omega_{i\hat{n}}}{R},$$

For hadron colliders:

$$z_i \equiv \frac{p_{Ti}}{\sum_{j \in \text{jet}} p_{Tj}}, \qquad \theta_i \equiv \frac{R_{i\hat{n}}}{R},$$



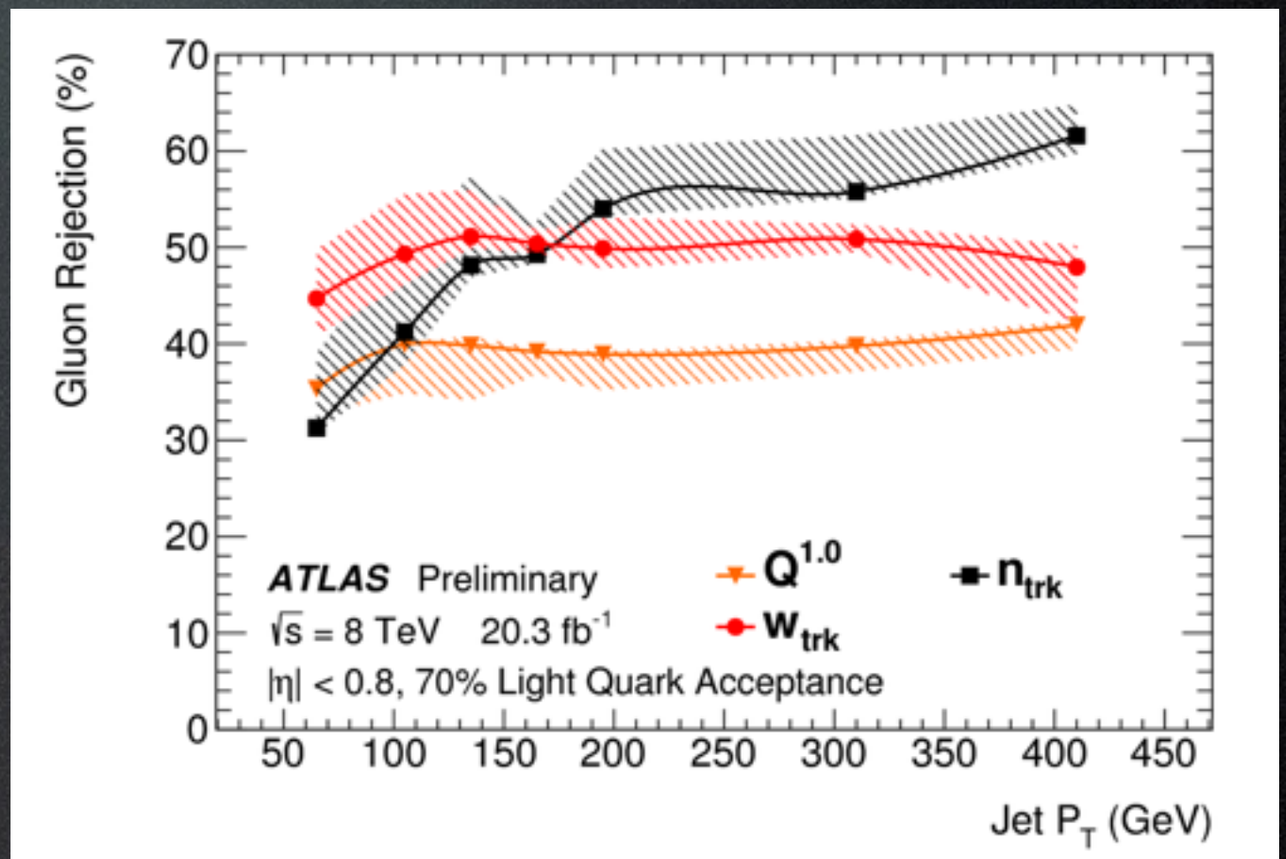
ATLAS Result(s)



Eur. Phys. J. C (2014) 74: 3023

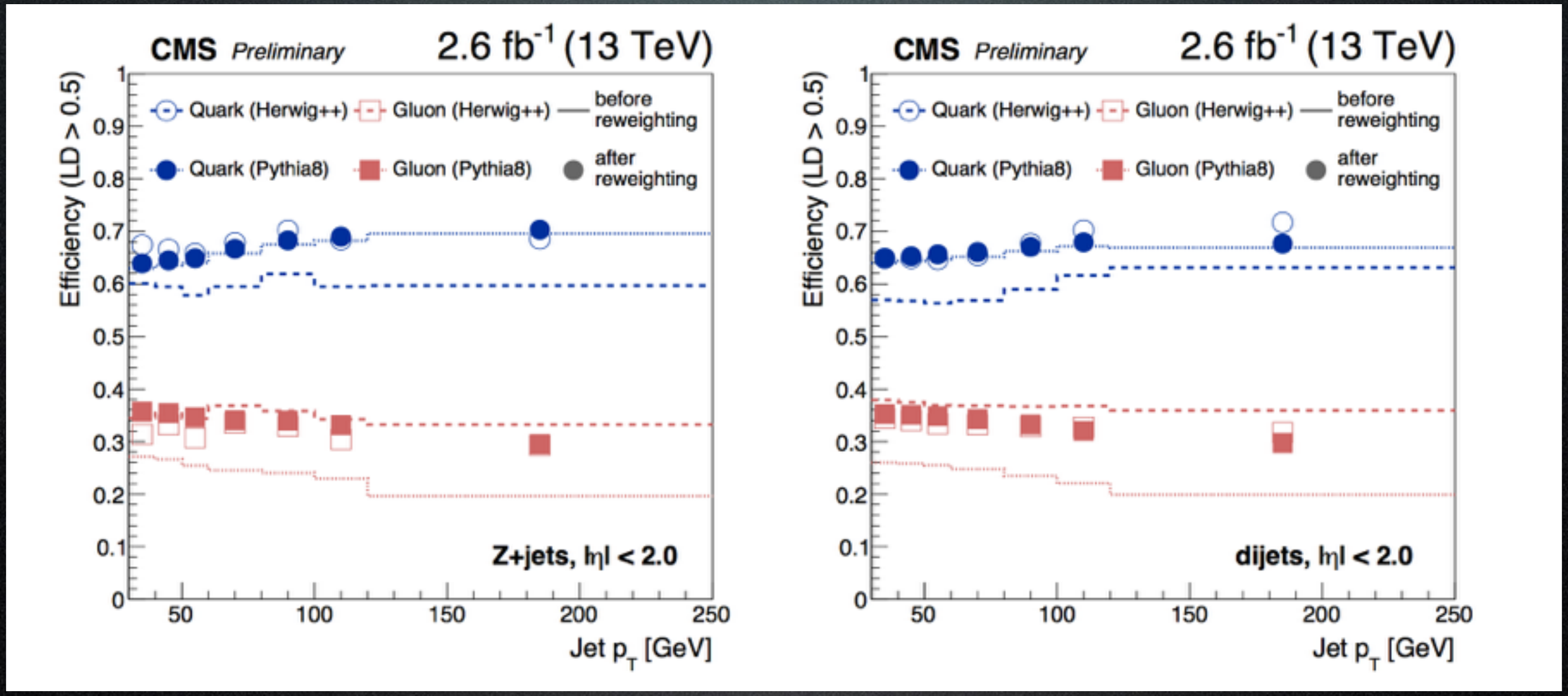
Data-MC difference
(but very optimistic!)

Discriminant composed
of different observables



ATLAS-CONF-2016-034

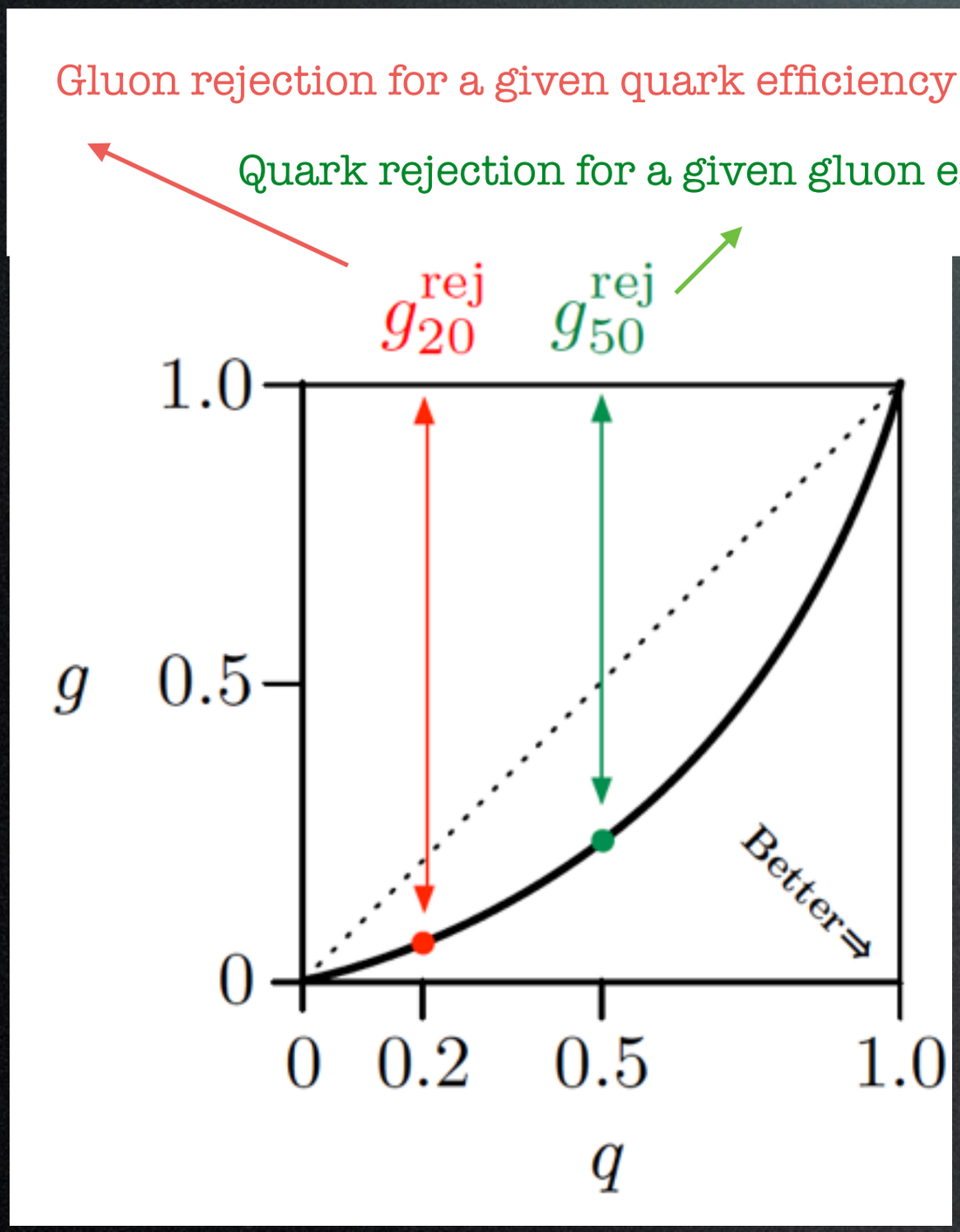
CMS Result



CERN-CMS-DP-2016-070

Need MC reweighting to match (data) efficiencies

Discriminant



Discriminator:

$$\Delta = \frac{1}{2}\int d\lambda \frac{\left(p_q(\lambda) - p_g(\lambda)\right)^2}{p_q(\lambda) + p_g(\lambda)},$$

p_q (p_g) is the probability distribution for the quark jet (gluon jet) sample as a function of the classifier λ

$\Delta \to 0$: no discrimination
$\Delta \to 1$: perfect discrimination

Idealised ep collider

Quark: $e^+e^- \to (\gamma/Z)^* \to u\bar{u}$

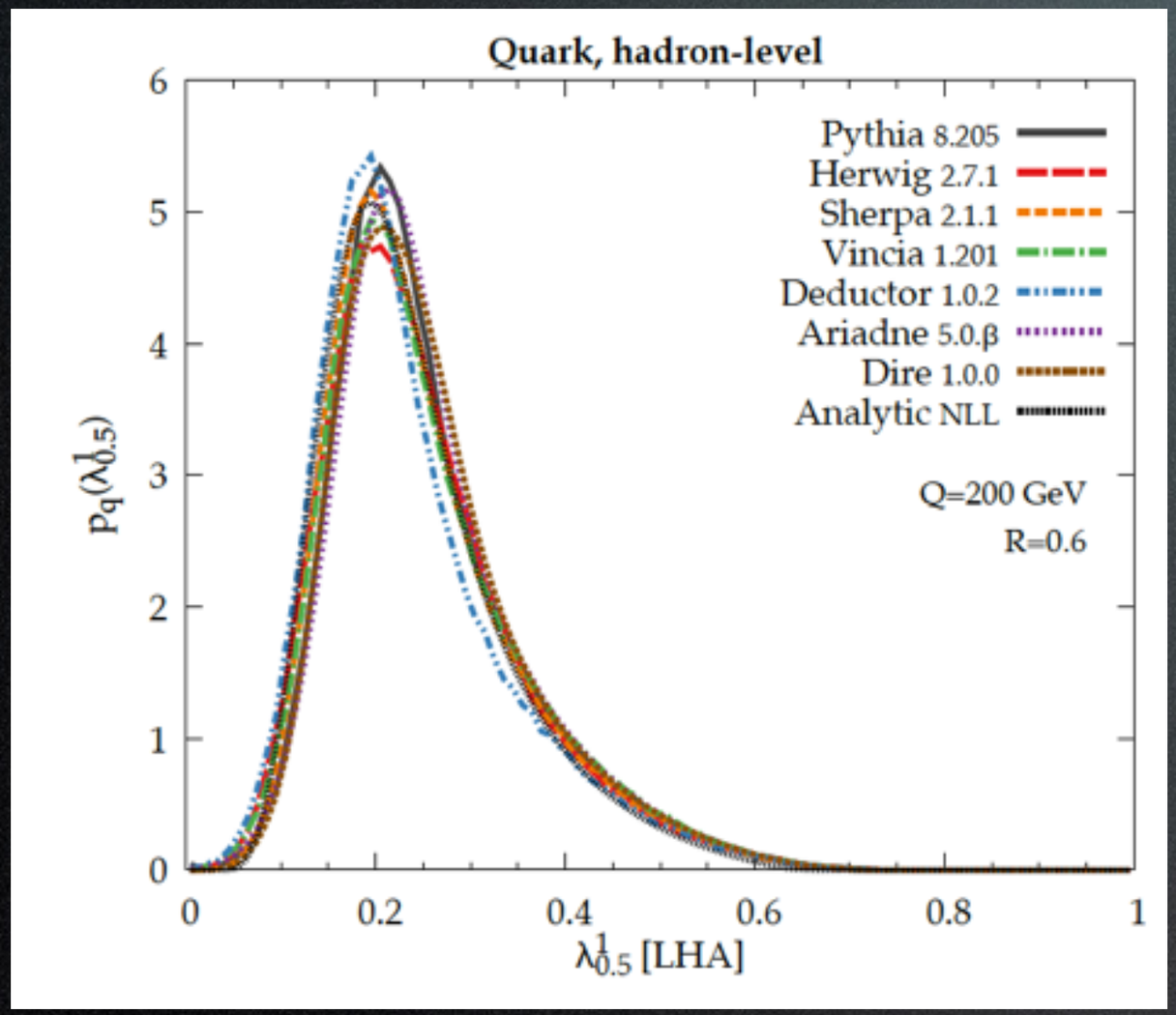
Gluon: $e^+e^- \to H^* \to gg$

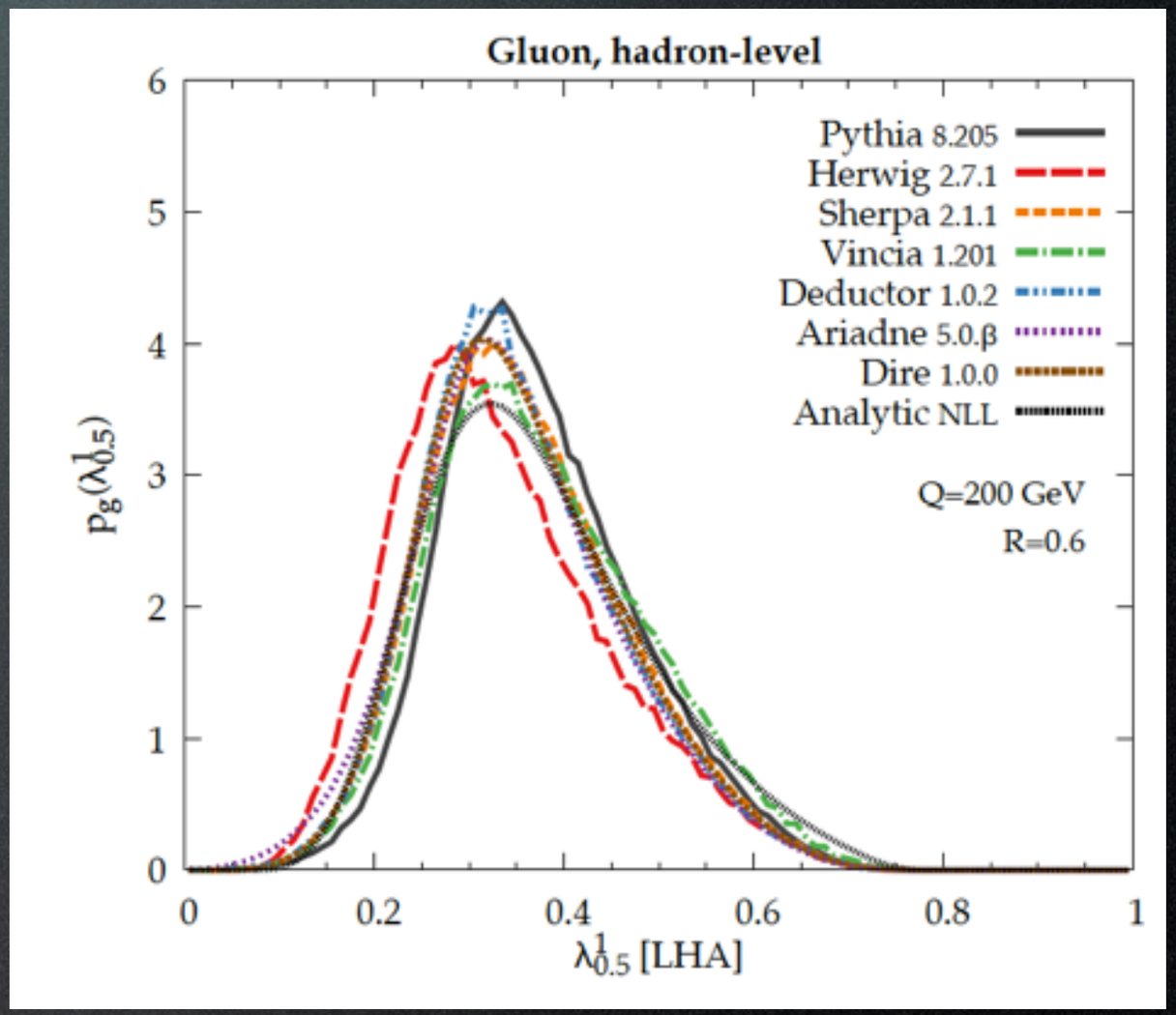
$$\frac{E_{\text{jet}}}{Q/2} > 0.8,$$

Suppress wide angle radiation

- Useful to understand final state evolution (ignoring initial state complications)
- Vary collisions energy (Q), jet radius (R)
- Look at both hadron and parton level

Hadron Level λ_{LHA}

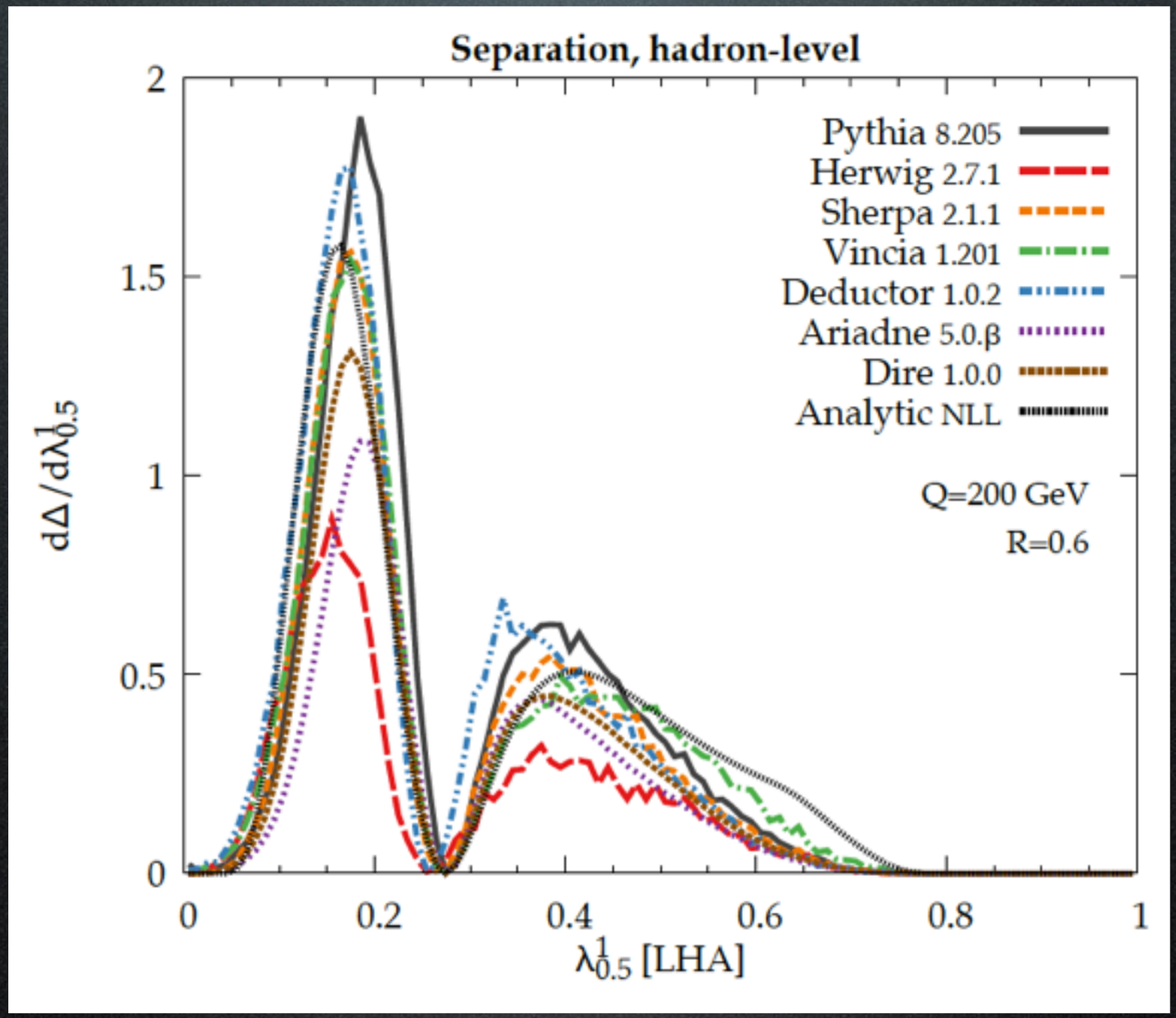




Good agreement
LEP data available

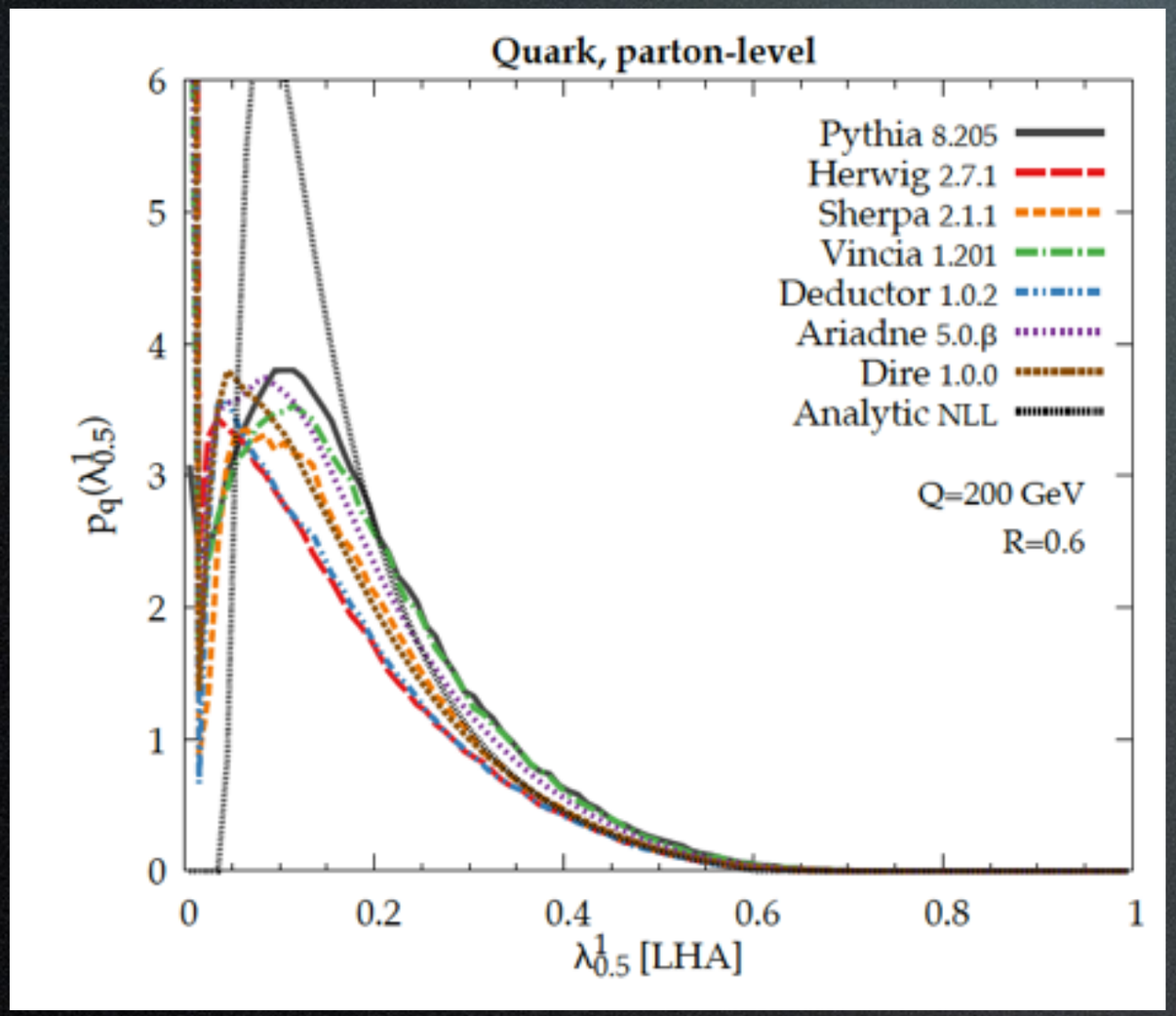
Larger spread
No data available

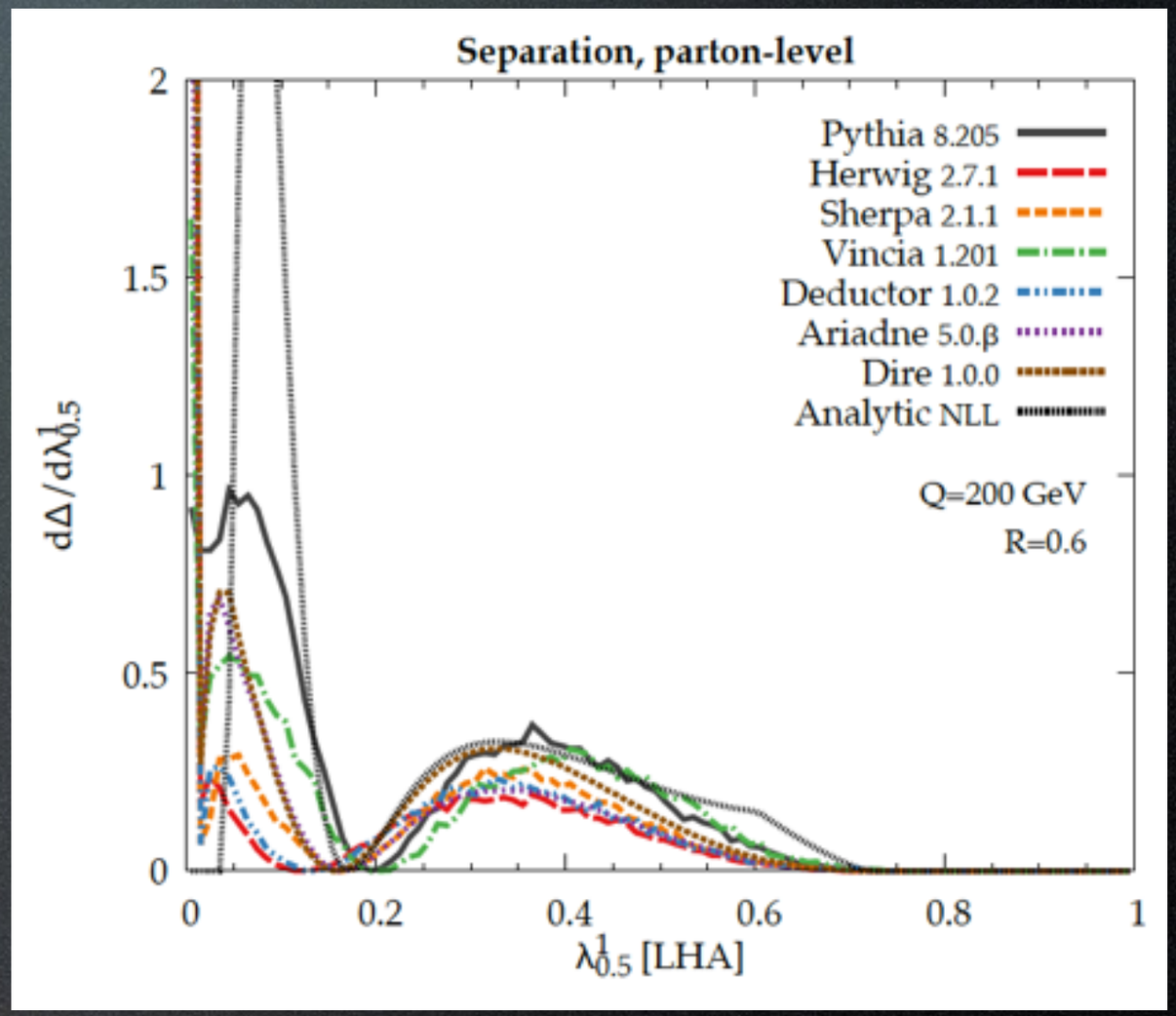
Seperation



Pythia8 more optimistic, Herwig++ more pessimistic

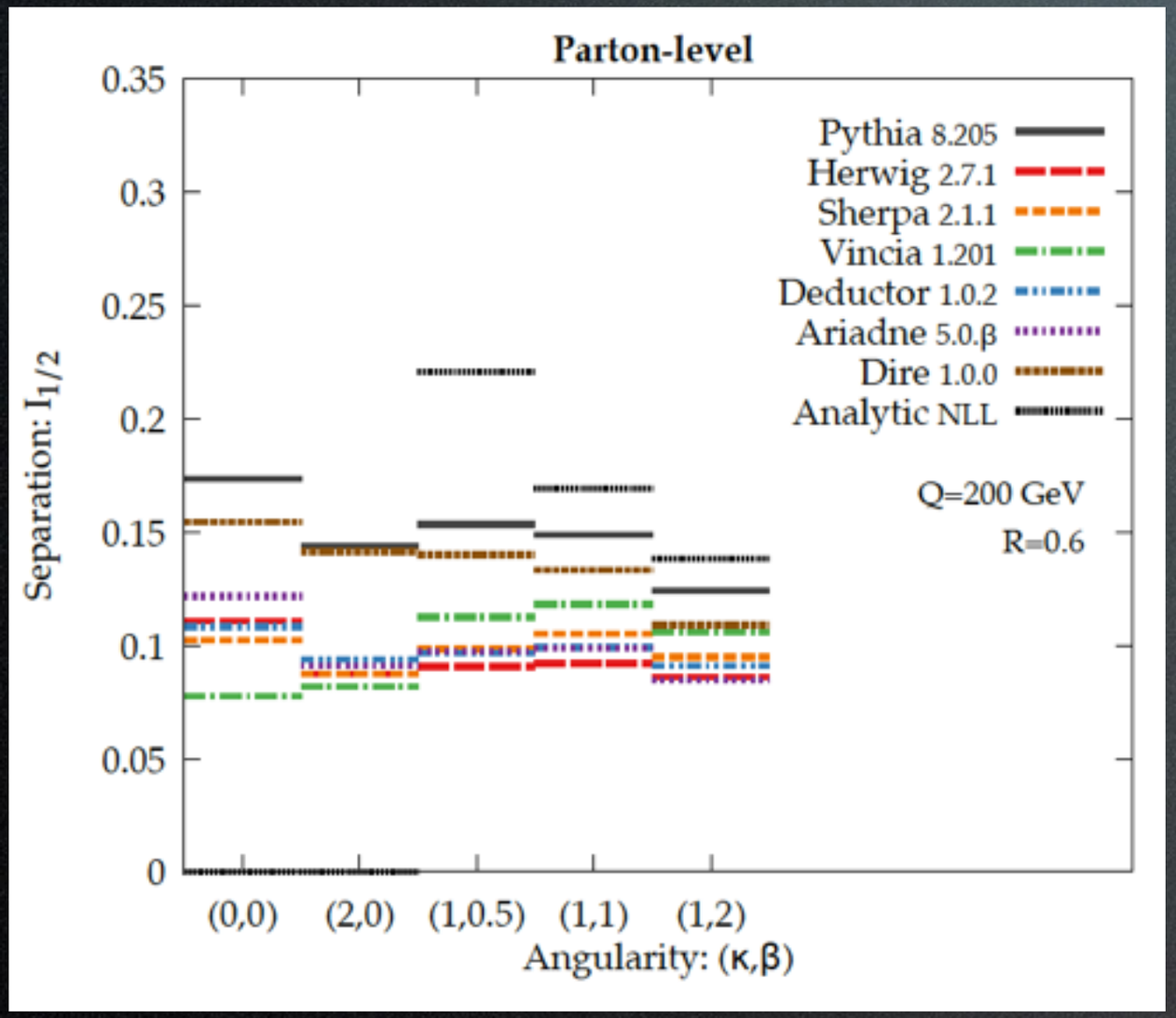
Non-Perturbative Effects

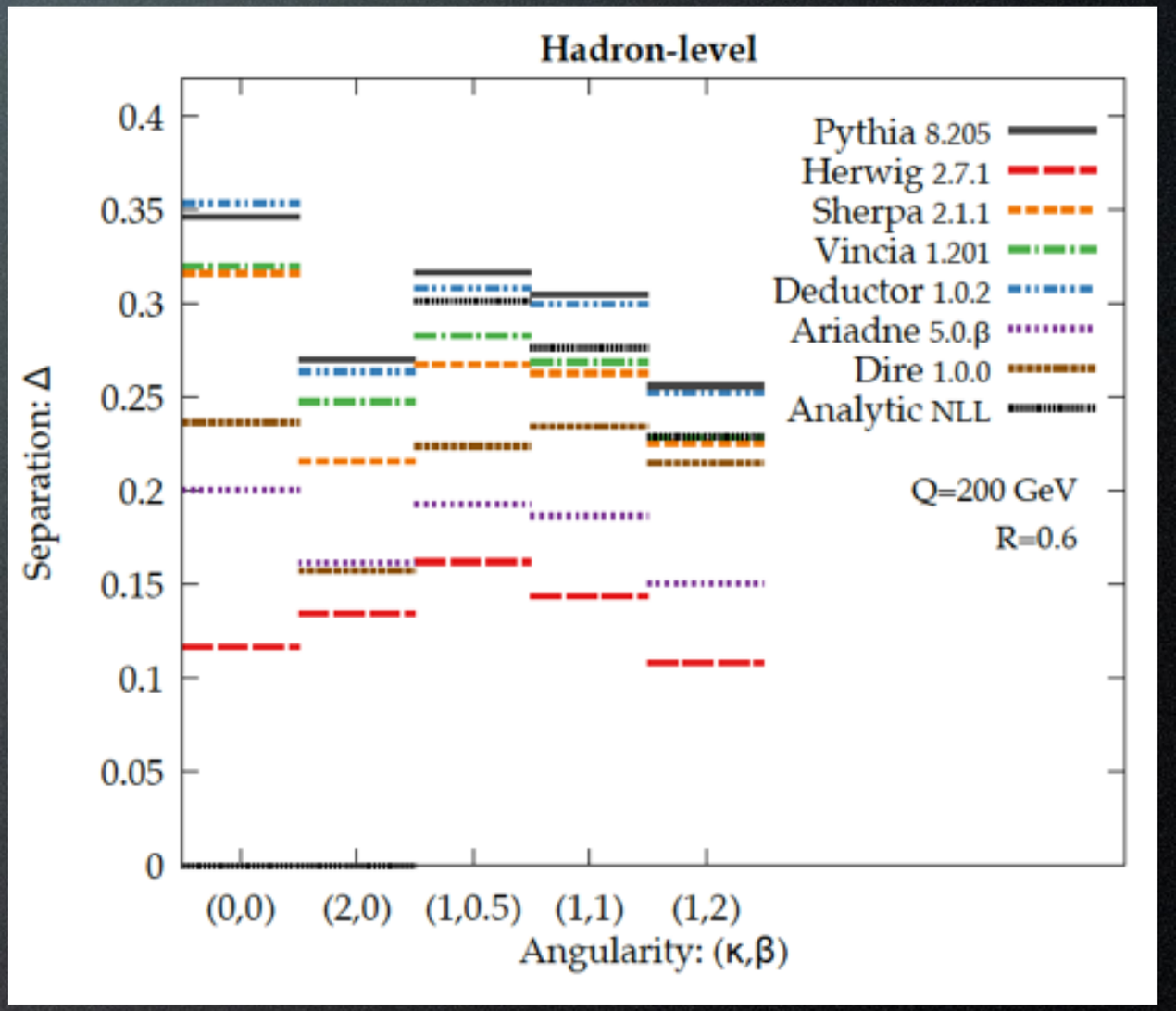




Large effect of hadronisation
More difference among MC models as well

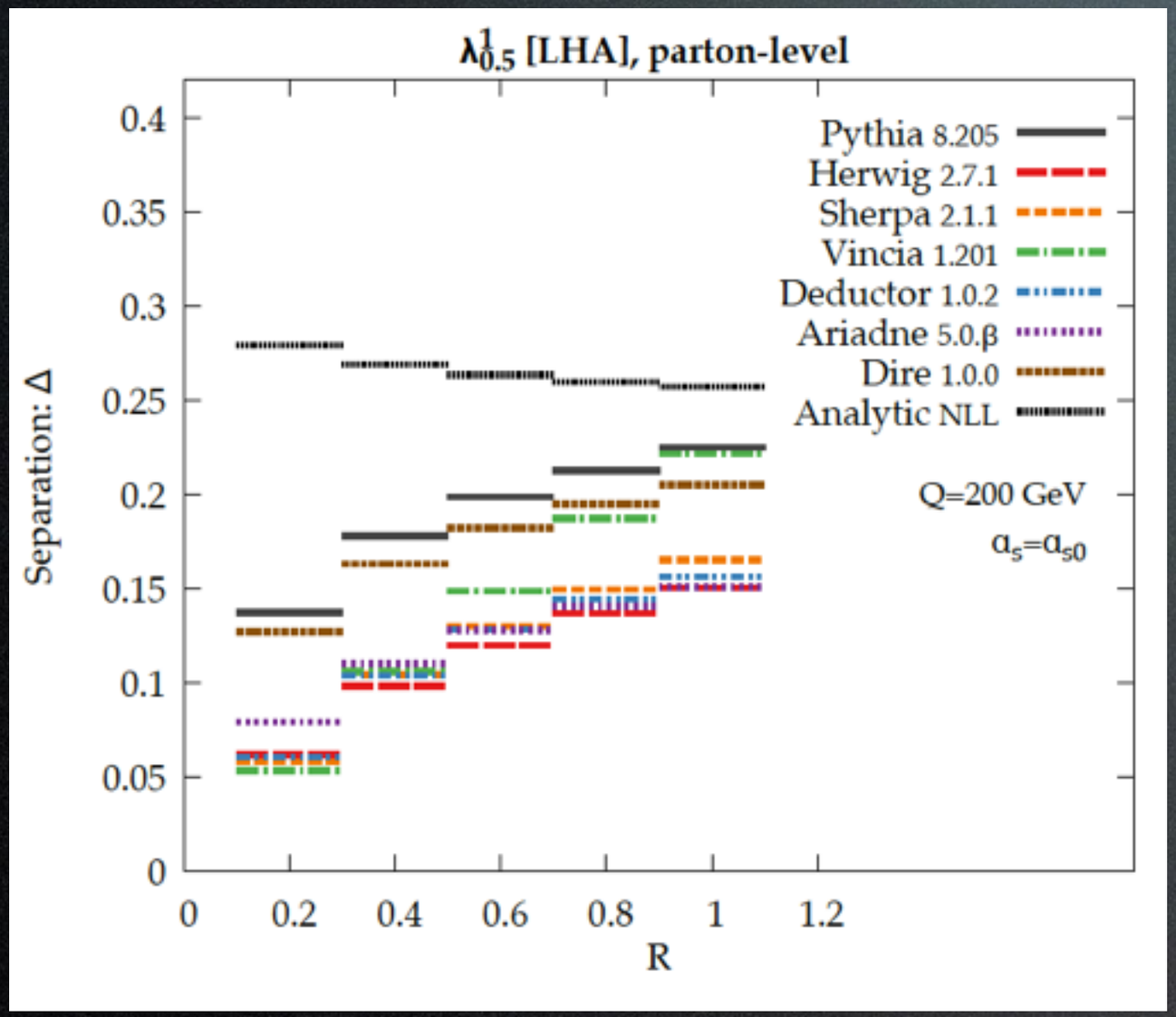
Overall Separation

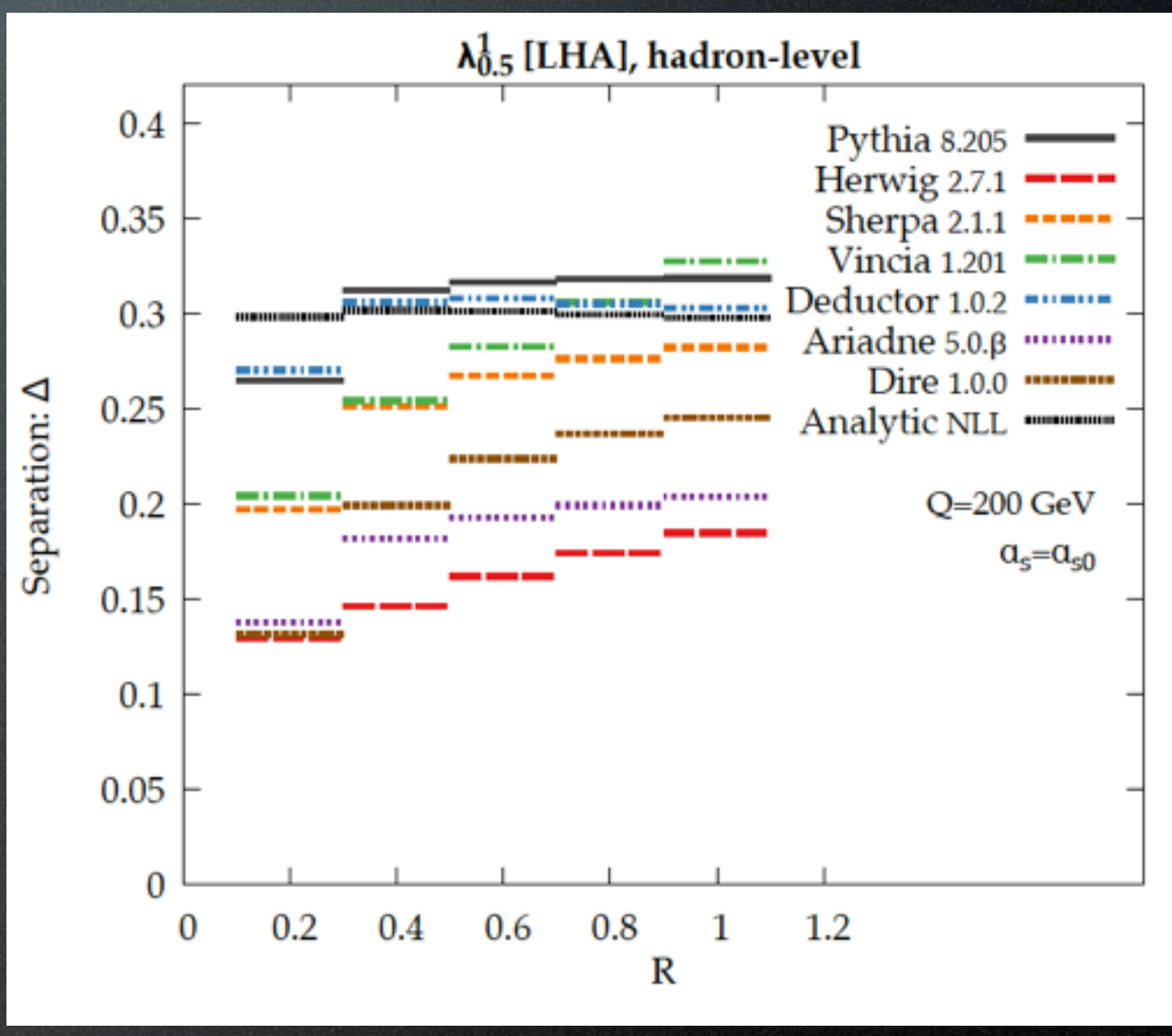




Large spread in discrimination power (even more at hadron level)

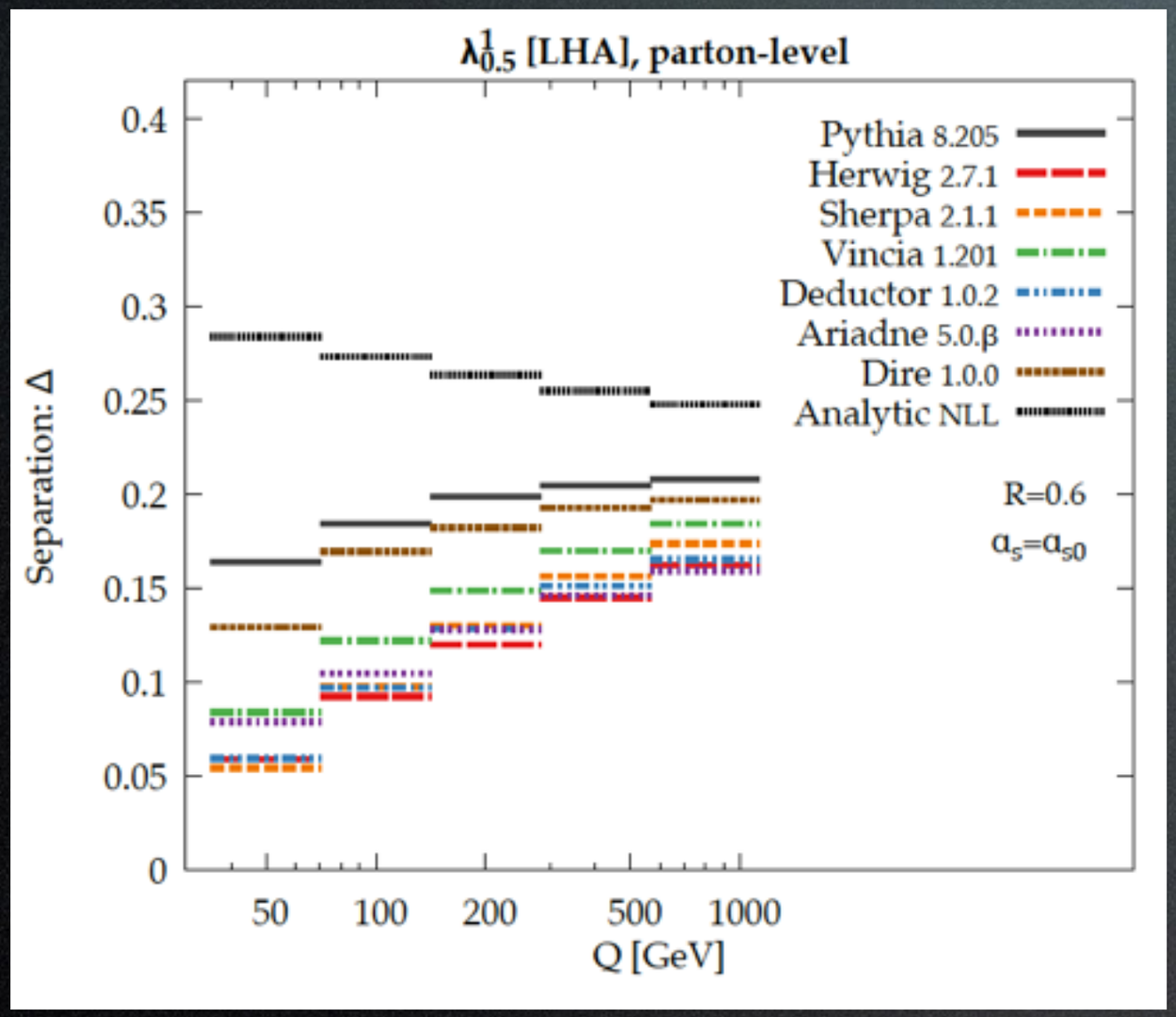
Dependance on R

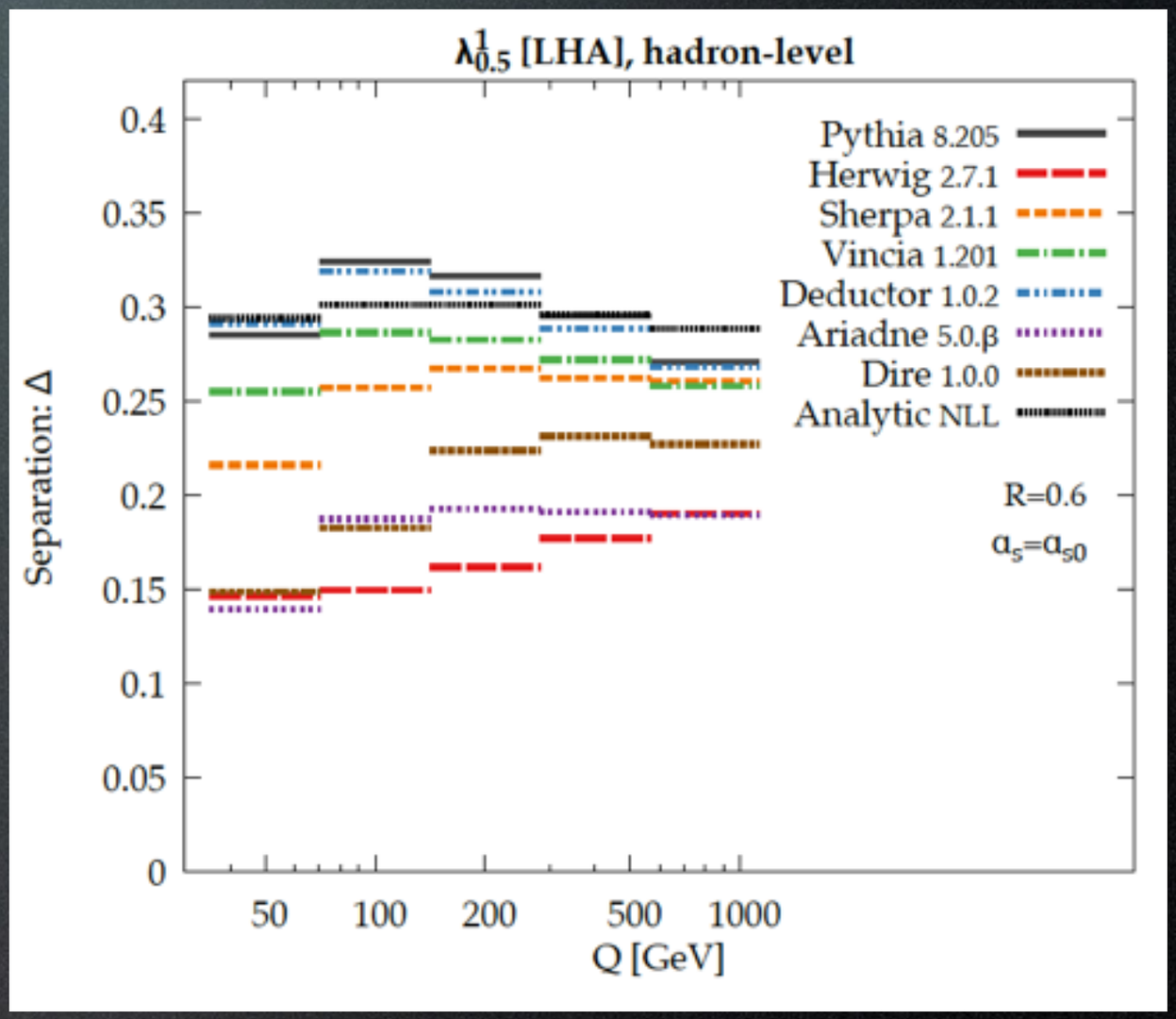




Separation increases with R (more phase space?)

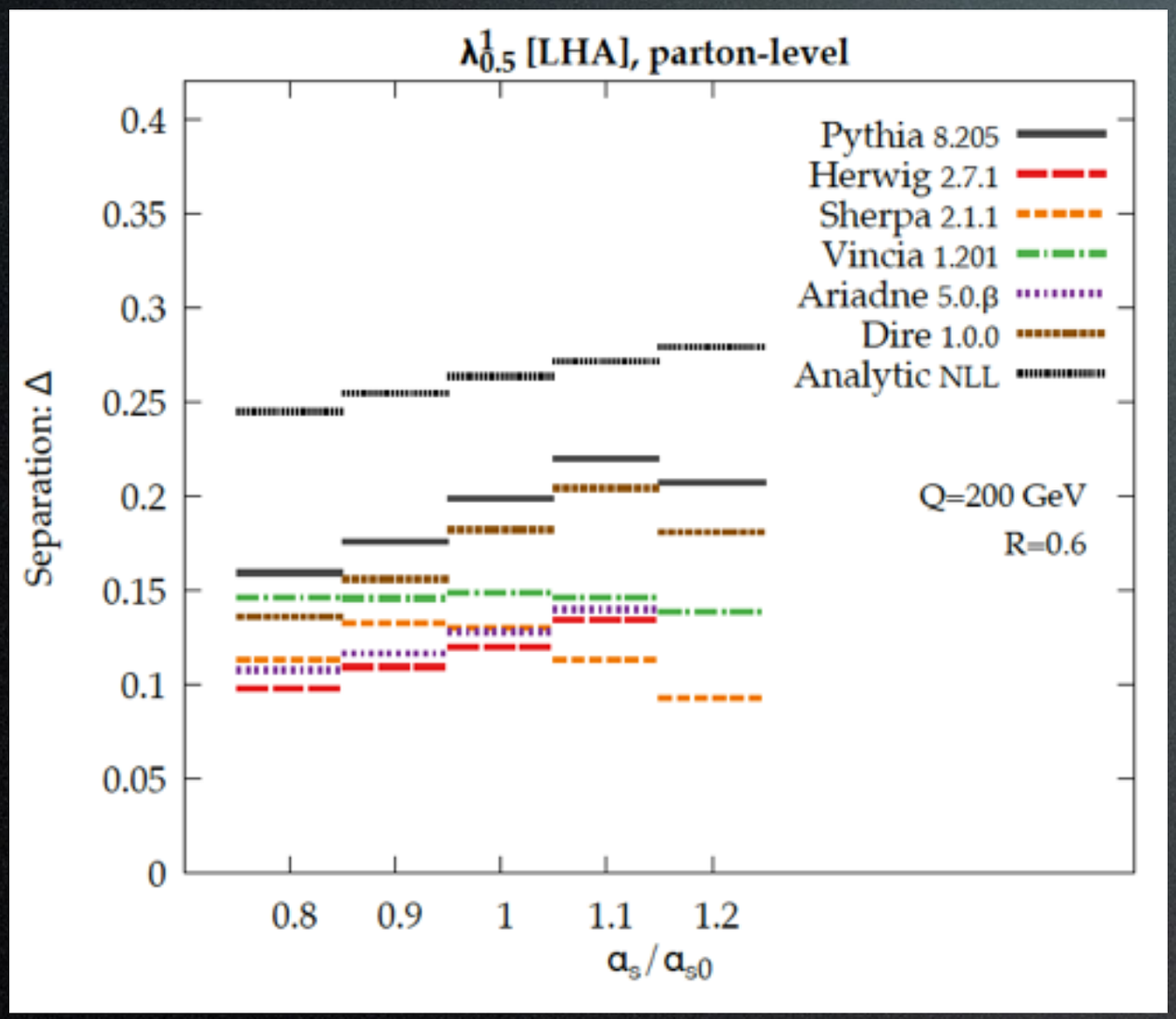
Dependance on Q

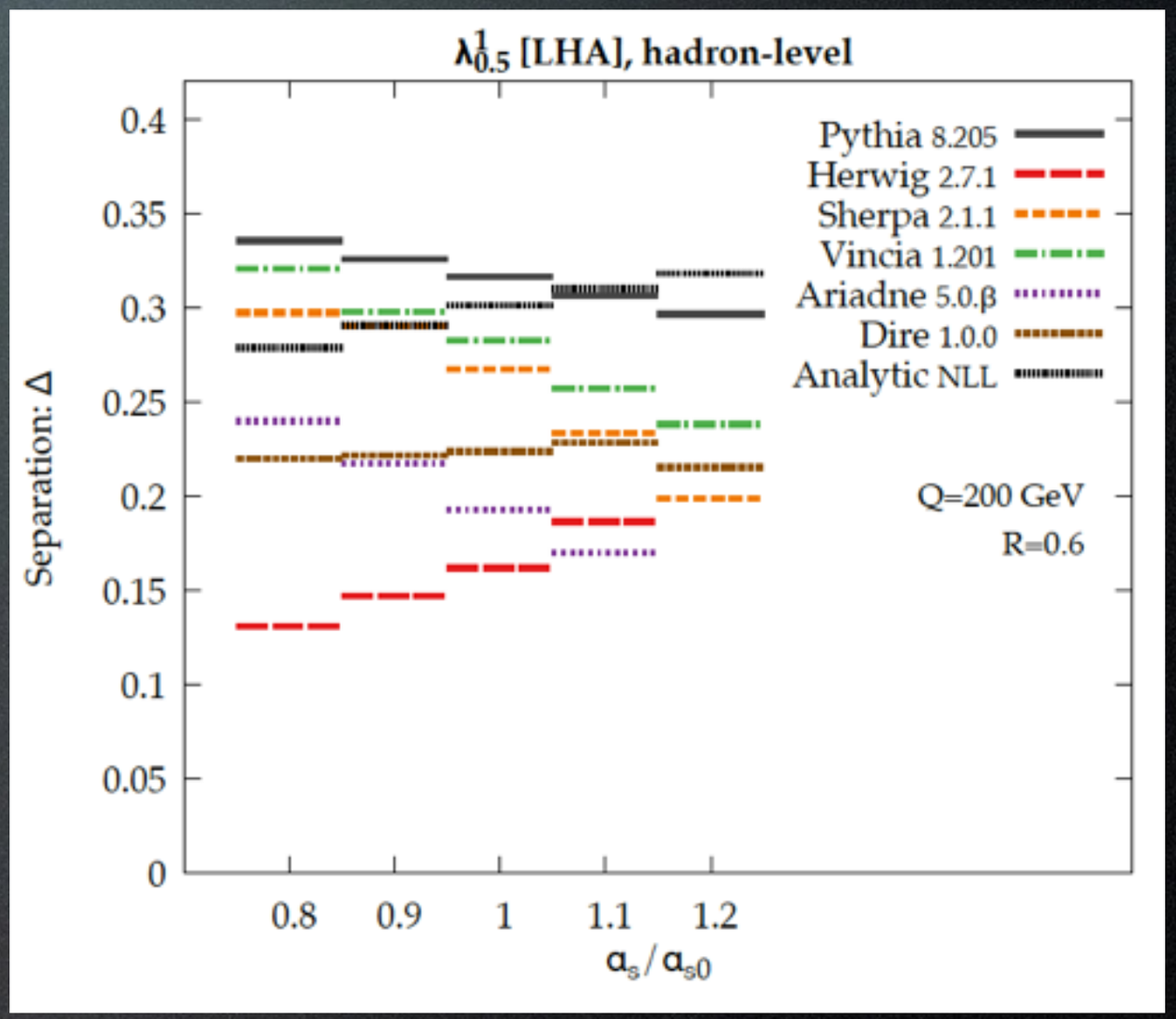




Separation increases with Q at parton level
(more phase space?)

Dependance on α_s

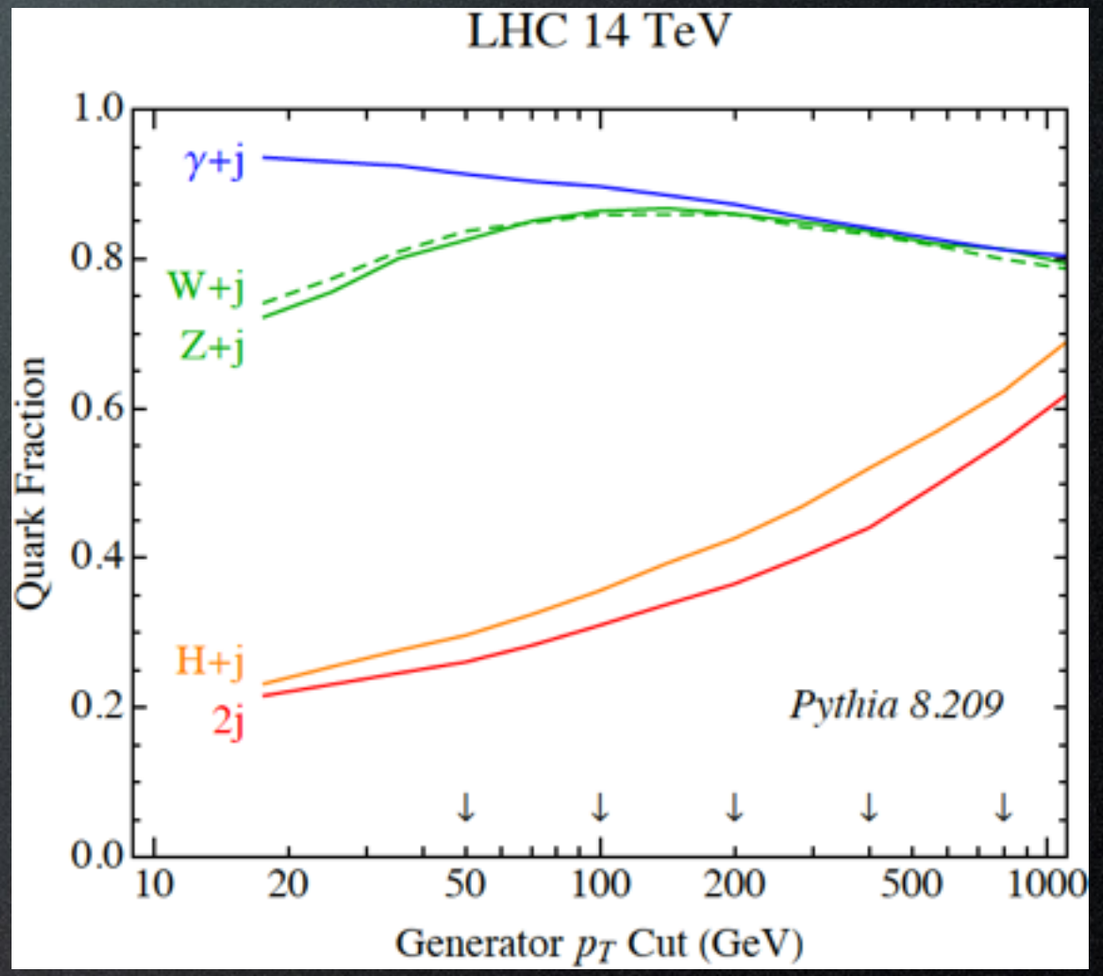




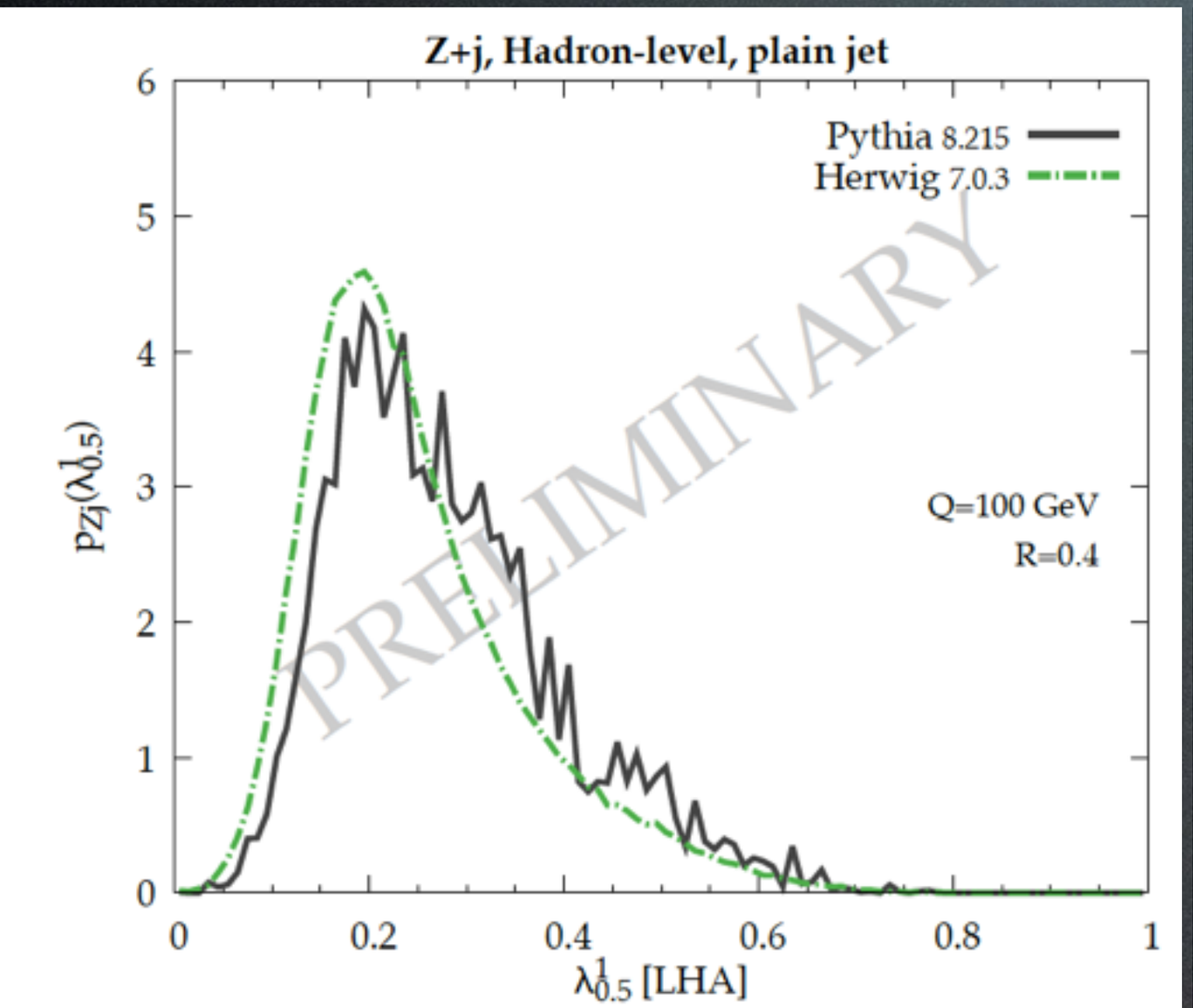
No clear trend at parton level, except Herwig++,
rest decreases at hadron level

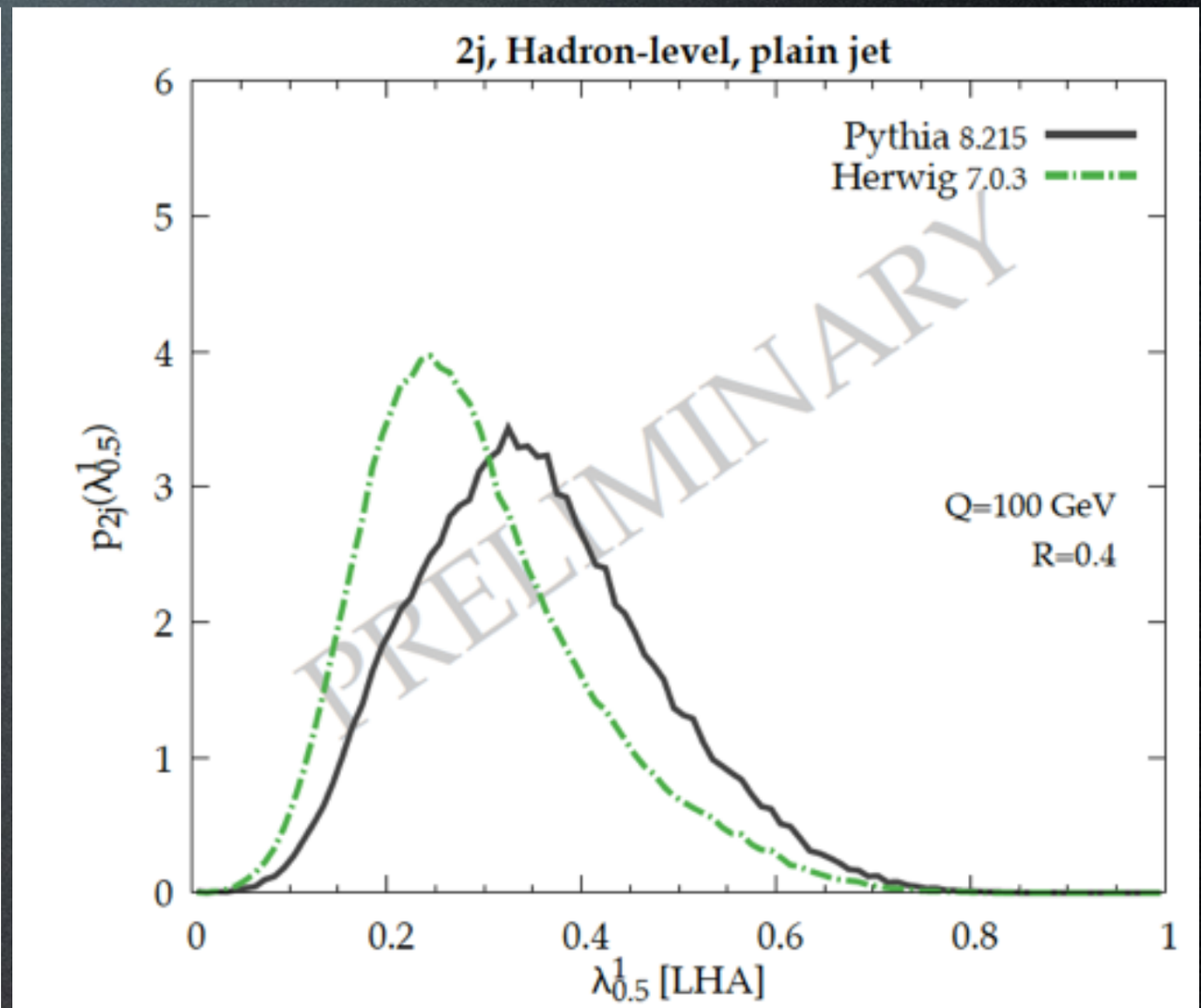
Proton-proton Results

- Very preliminary
- Z+jets (quark enriched), dijets (gluon enriched)
- Shown standard jets, but mMDT /Soft drop effects also looked at



Hadron Level λ_{LHA}

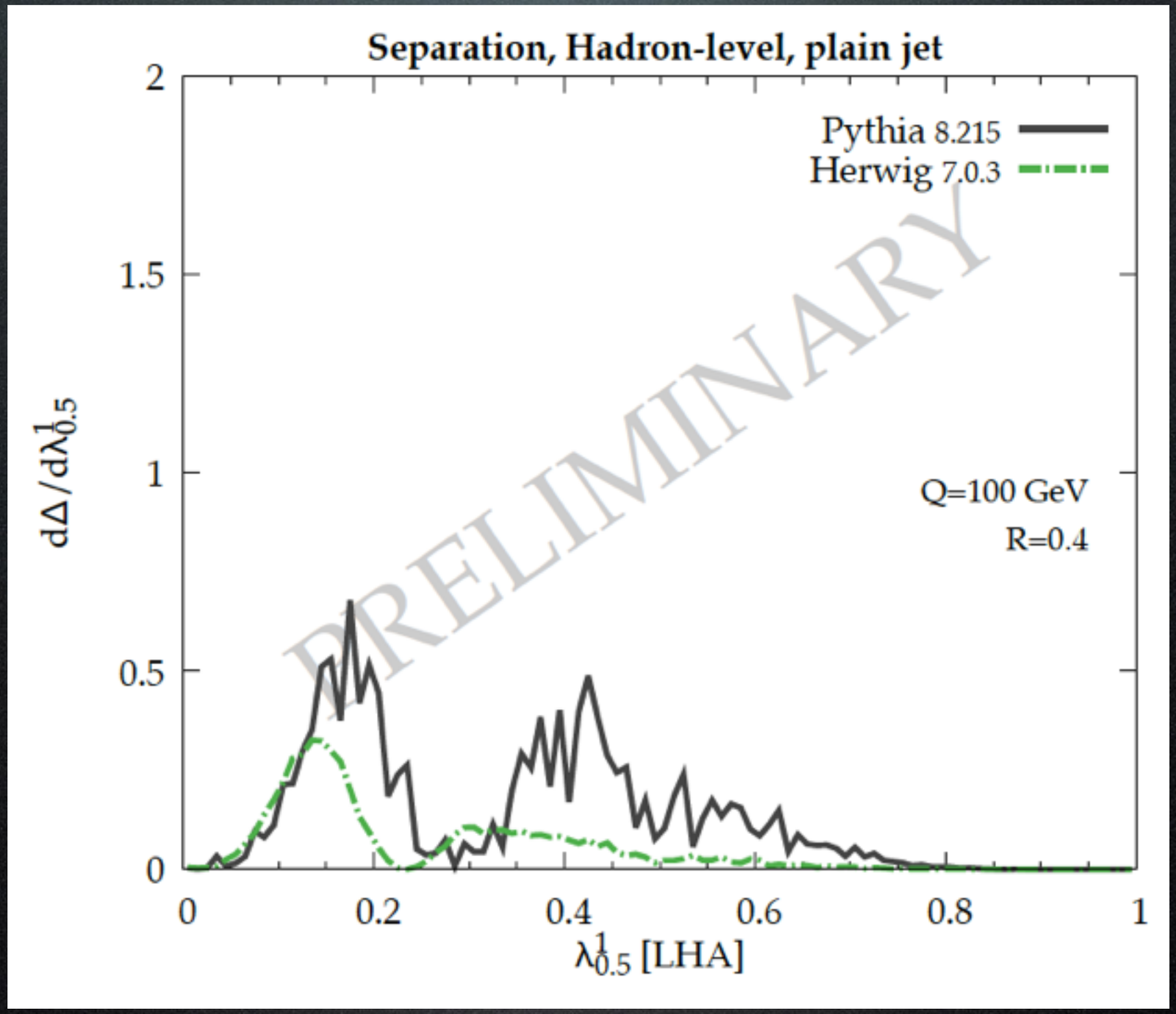




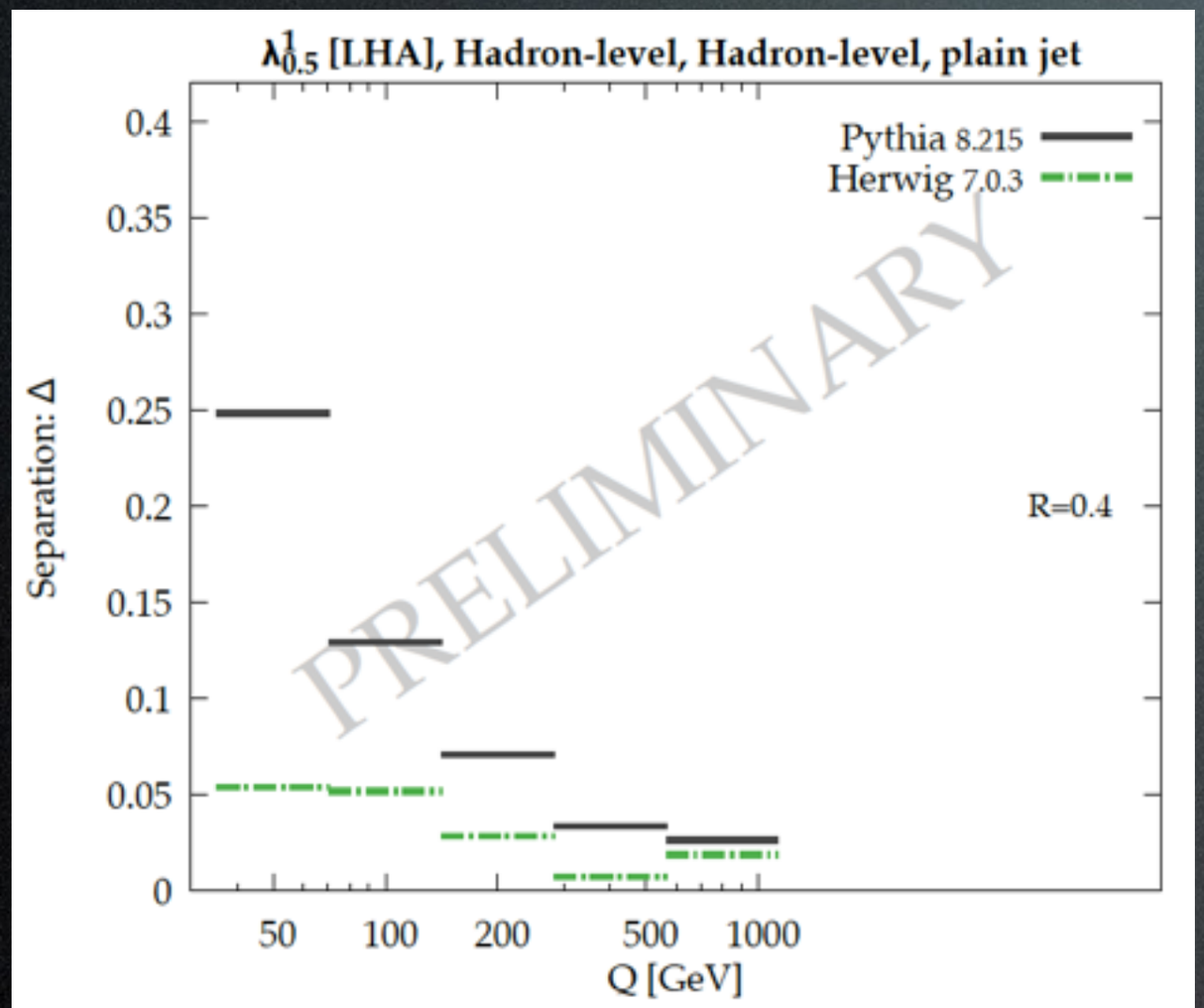
Decent agreement

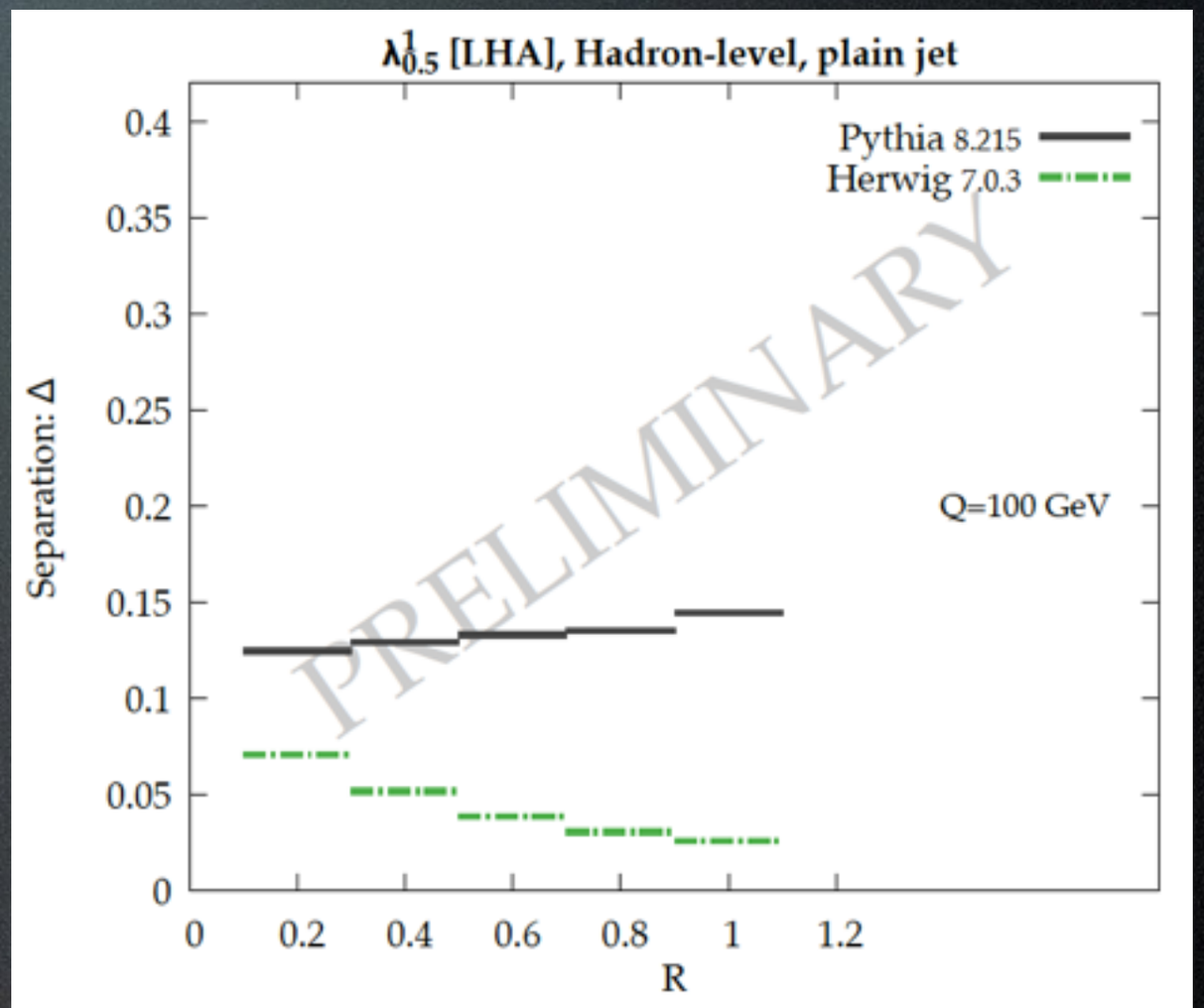
Larger Difference

Separation


Separation, Hadron-level, plain jet
Pythia 8.215
Herwig 7.0.3
Q=100 GeV
R=0.4
PRELIMINARY
$d\Delta/d\lambda^1_{0.5}$
$\lambda^1_{0.5}$ [LHA]
0
0.5
1
1.5
2
0.2
0.4
0.6
0.8

Separation





Pythia more optimistic

Opposite trend

Summary

- Important physics applications
- Large effect for generator setting, non-perturbative/shower effects
- Need (unfolded) measurements, specially for gluon processes