Report of the Les Houches Quark/Gluon Subgroup

Jesse Thaler

= Jets are Les H.

on behalf of Andy Buckley, Jon Butterworth, Mario Campanelli, Marat Freytsis, Peter Loch, Philippe Gras, Deepak Kar, Simon Plätzer, Andrzej Siodmok, Peter Skands, Dave Soper, Gregory Soyez, Frank Tackmann

Les Houches Workshop — June 10, 2015

Hunting the White Whale: Quarks vs. Gluons

Cartoon:

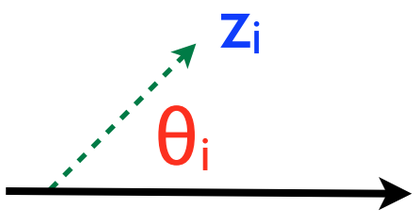
Quark: $C_F = 4/3$ **vs.** Gluon: $C_A = 3$

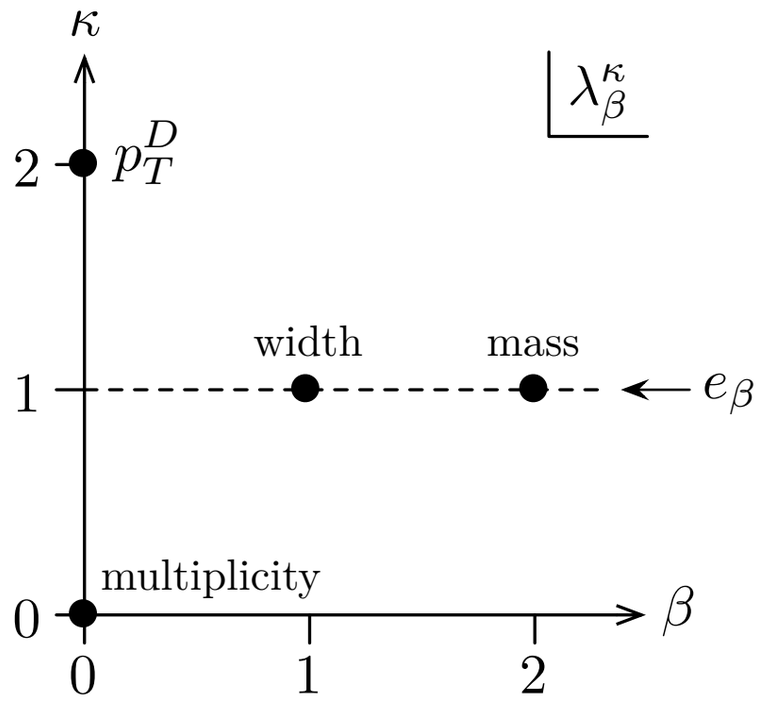
Probe radiation pattern with
e.g. Generalized Angularities

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

momentum fraction

angle to recoil-free axis





[Larkoski, JDT, Waalewijn, 1408.3122]
[based on Berger, Kucs, Sterman, hep-ph/0303051; Ellis, Vermilion, Walsh, Hornig, Lee, 1001.0014]
[see also Larkoski, Salam, JDT, 1305.0007; Larkoski, Neill, JDT, 1401.2158]
[For a more complete catalog, see Gallicchio, Schwartz, 1106.3076, 1211.7038]

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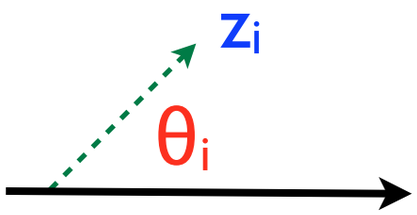

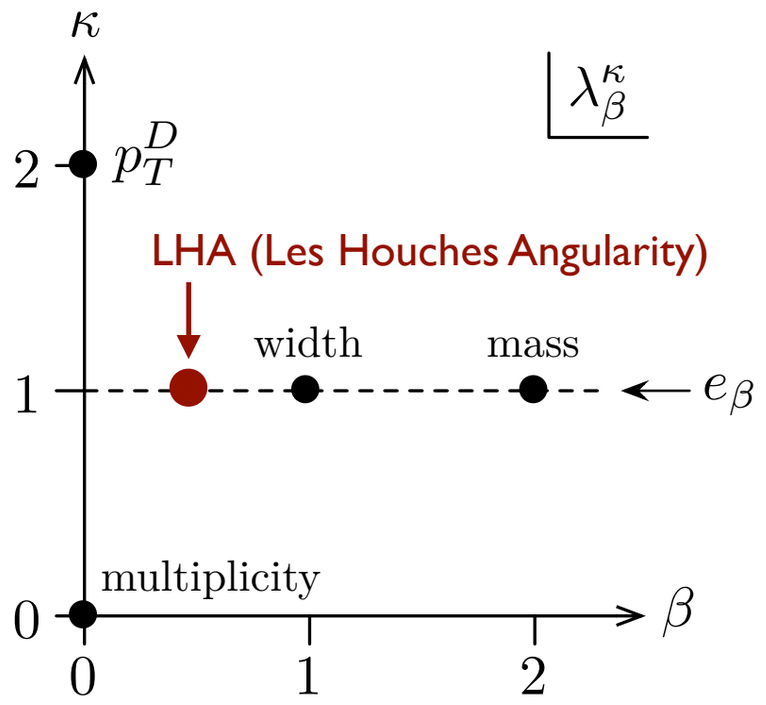

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What is a Quark Jet?

From lunch/dinner discussions

Ill-Defined

Well-Defined

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)

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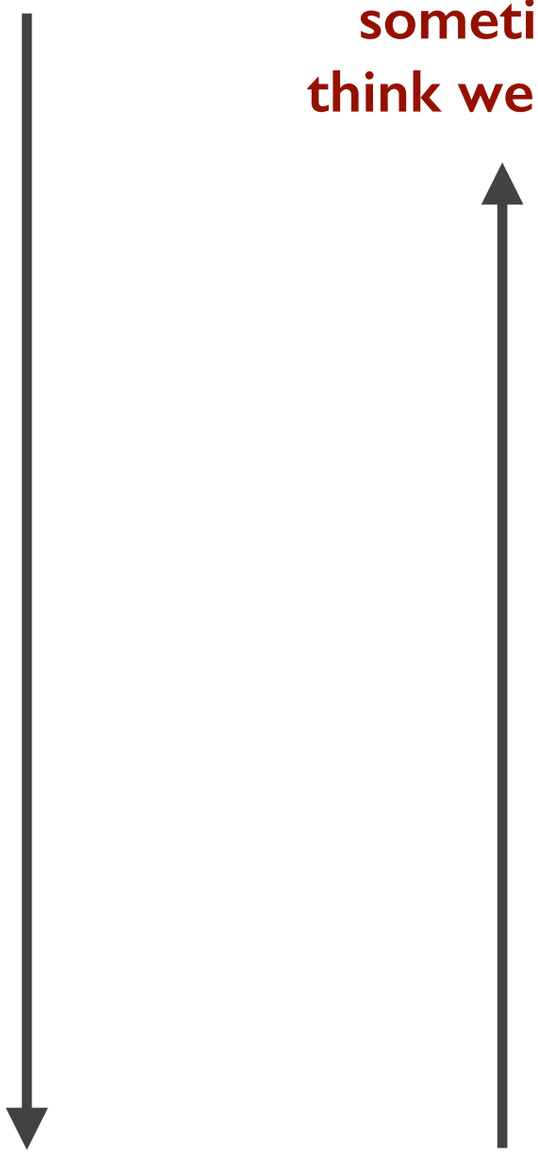
What people sometimes think we mean



Well-Defined

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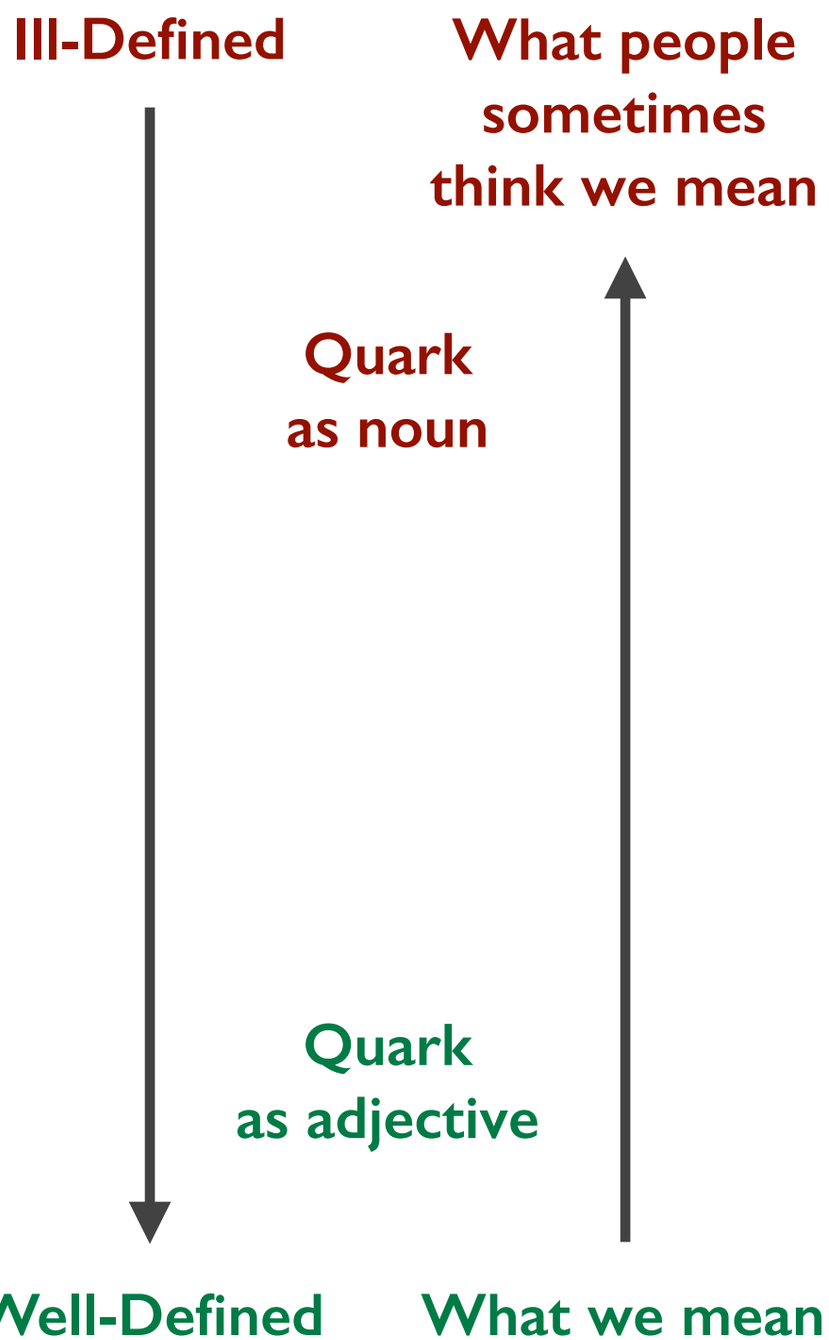

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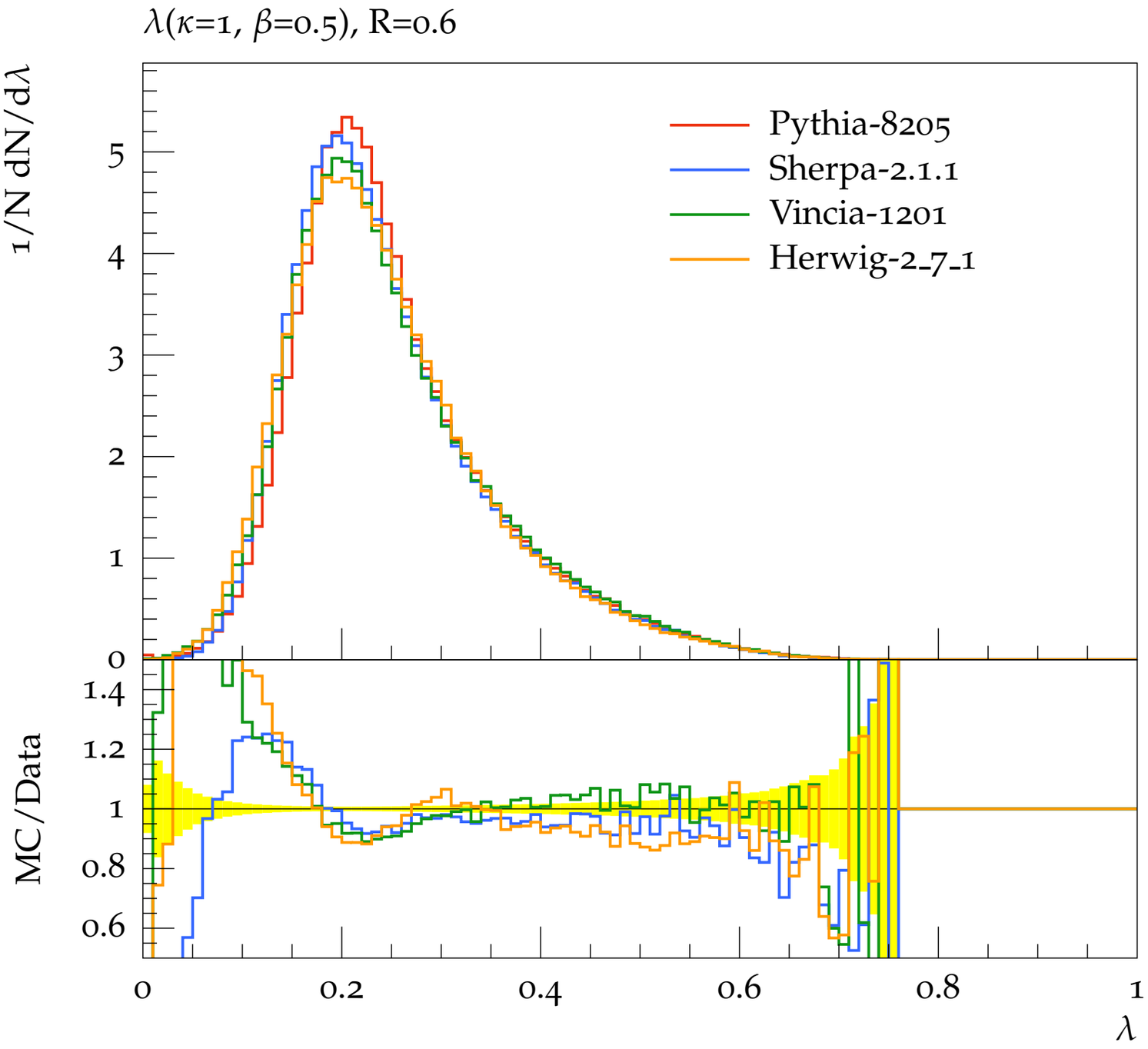
Les Houches Study of Monte Carlo Quark/Gluon Performance

$e^+e^- \to u\bar{u}$ **vs.** $e^+e^- \to gg$

Quark Tagged Gluon Tagged

Les Houches Angularity: Quarks

Hadron level, R=0.6, Q=200 GeV



Les Houches Angularity: Gluons

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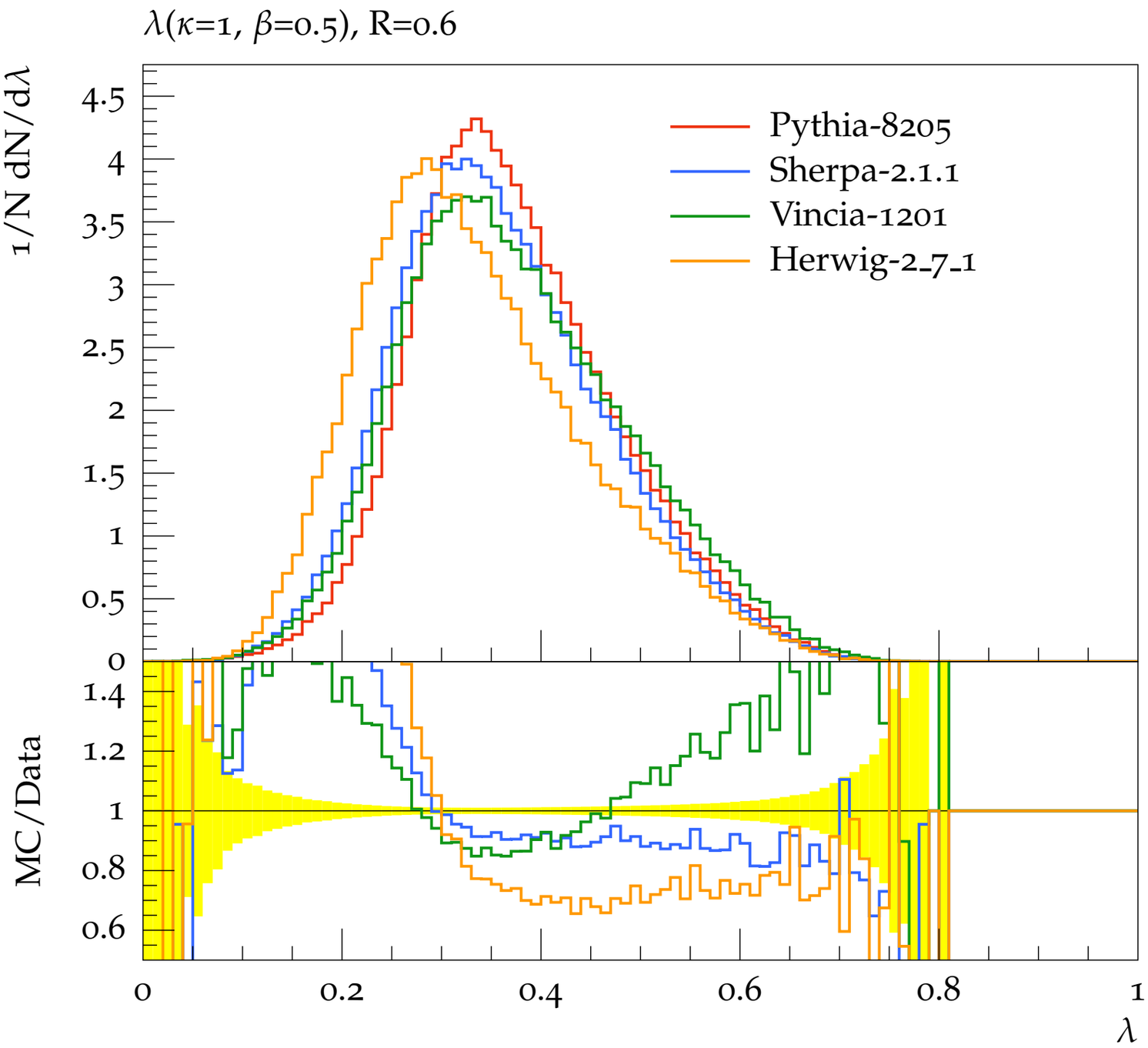
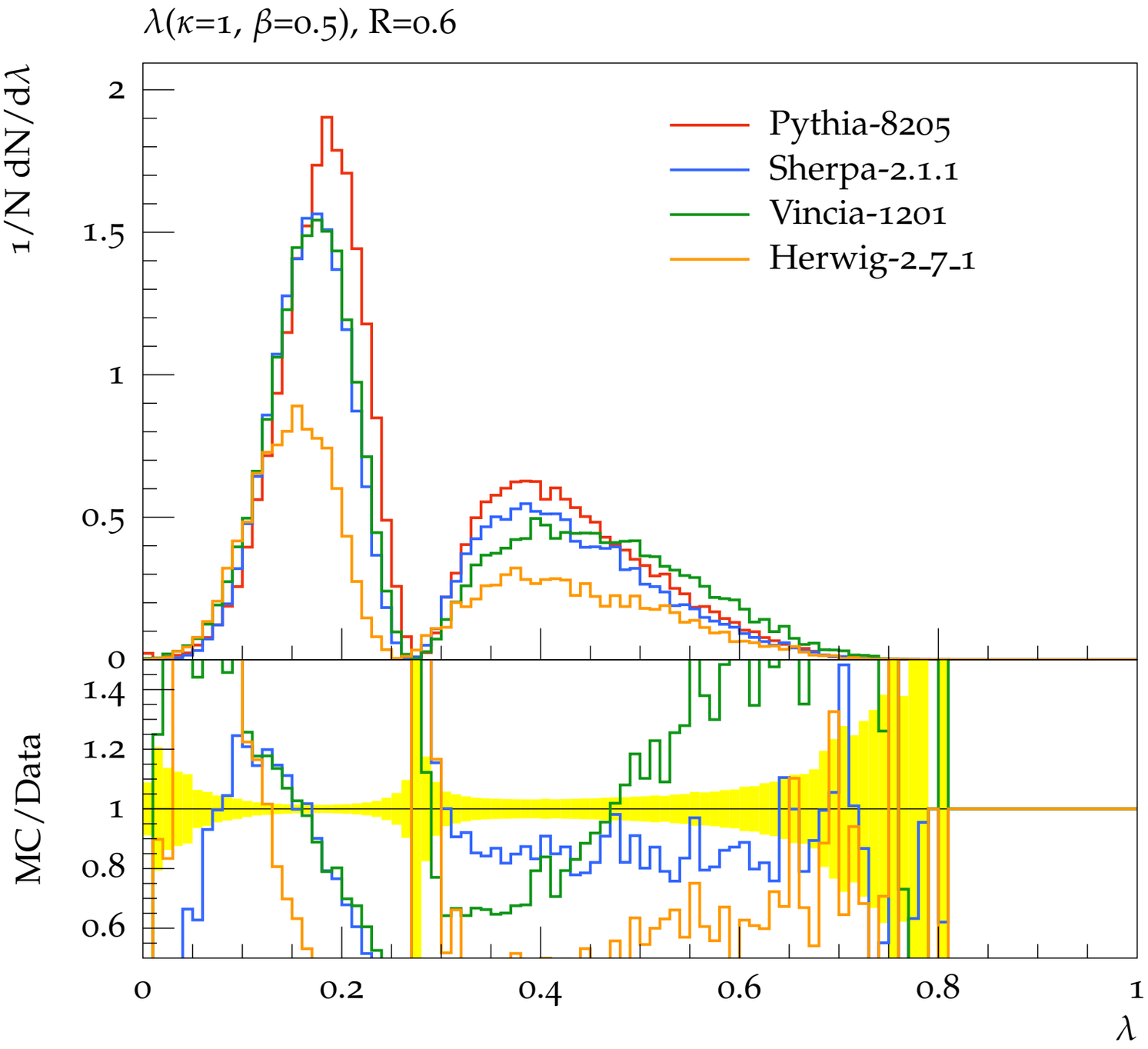


LHA: Quark/Gluon Separation

Hadron level, R=0.6, Q=200 GeV

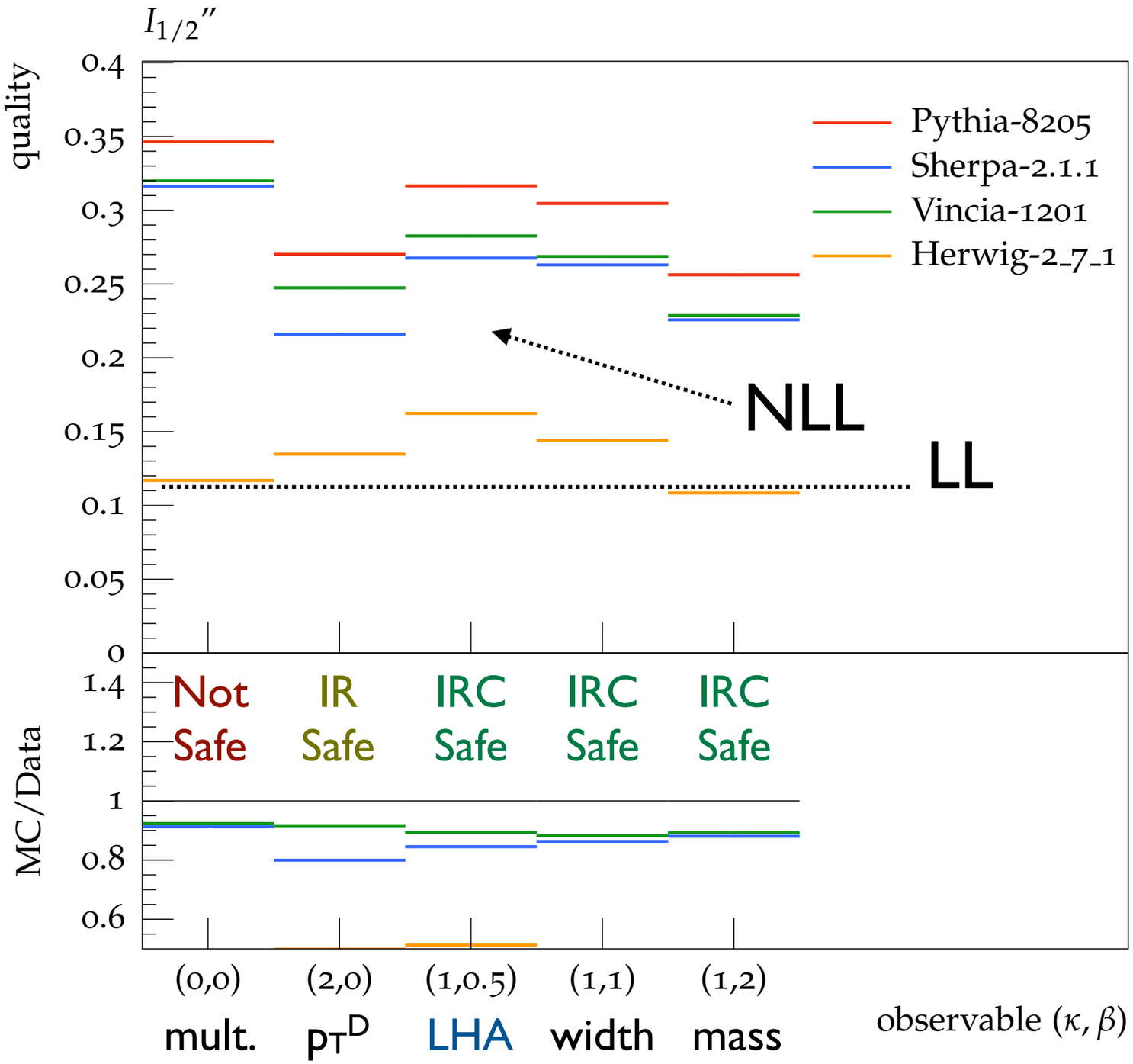
$$\frac{\left(S(\lambda)-B(\lambda)\right)^2}{2\left(S(\lambda)+B(\lambda)\right)}$$



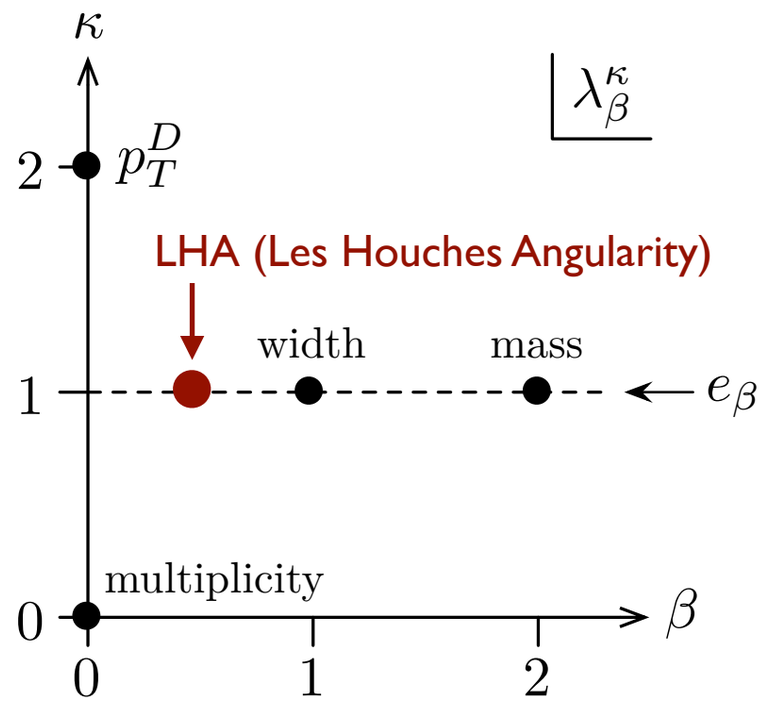
Total Separation Power

Hadron level, R=0.6, Q=200 GeV

$$\int \mathrm{d}\lambda \, \frac{\big(S(\lambda) - B(\lambda)\big)^2}{2\big(S(\lambda) + B(\lambda)\big)}$$



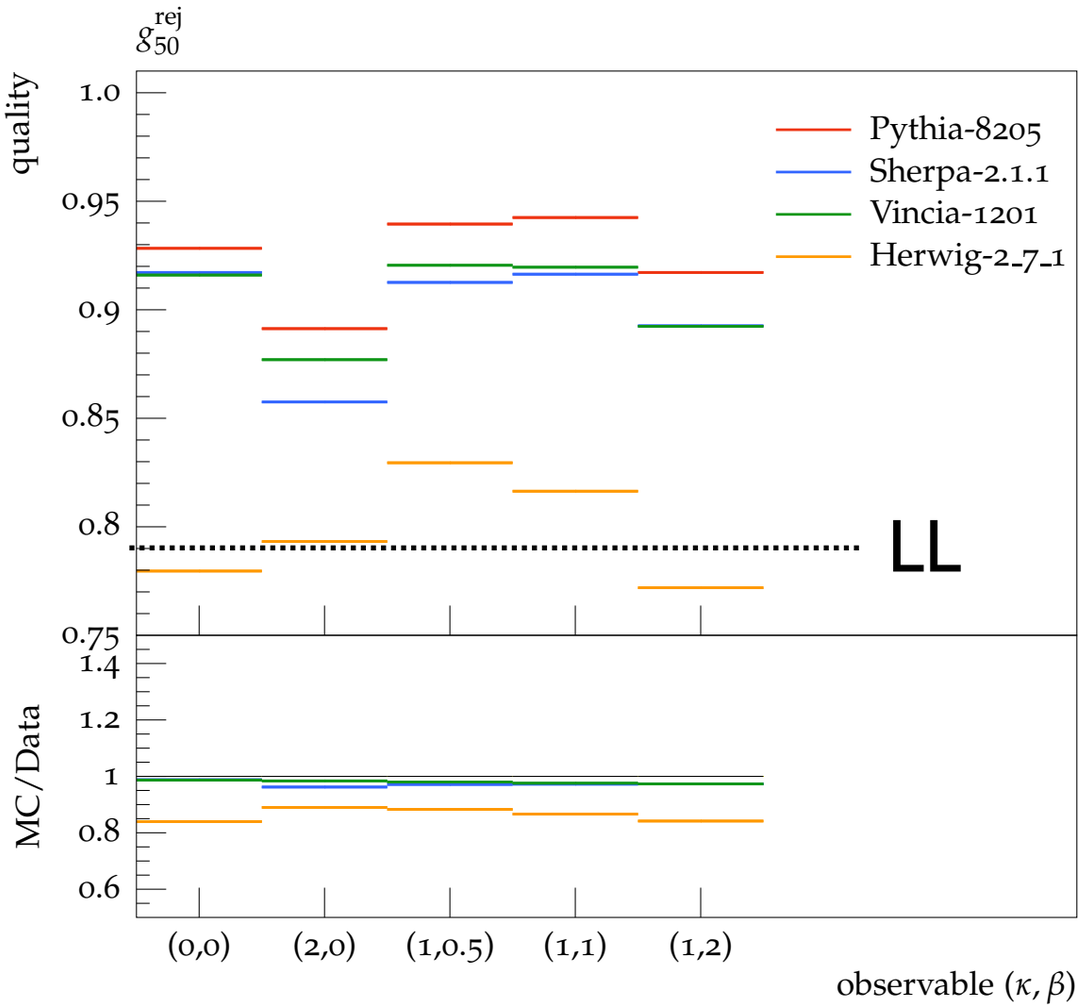
$$\lambda_\beta^\kappa = \sum_{i \in \mathrm{jet}} z_i^\kappa \theta_i^\beta$$



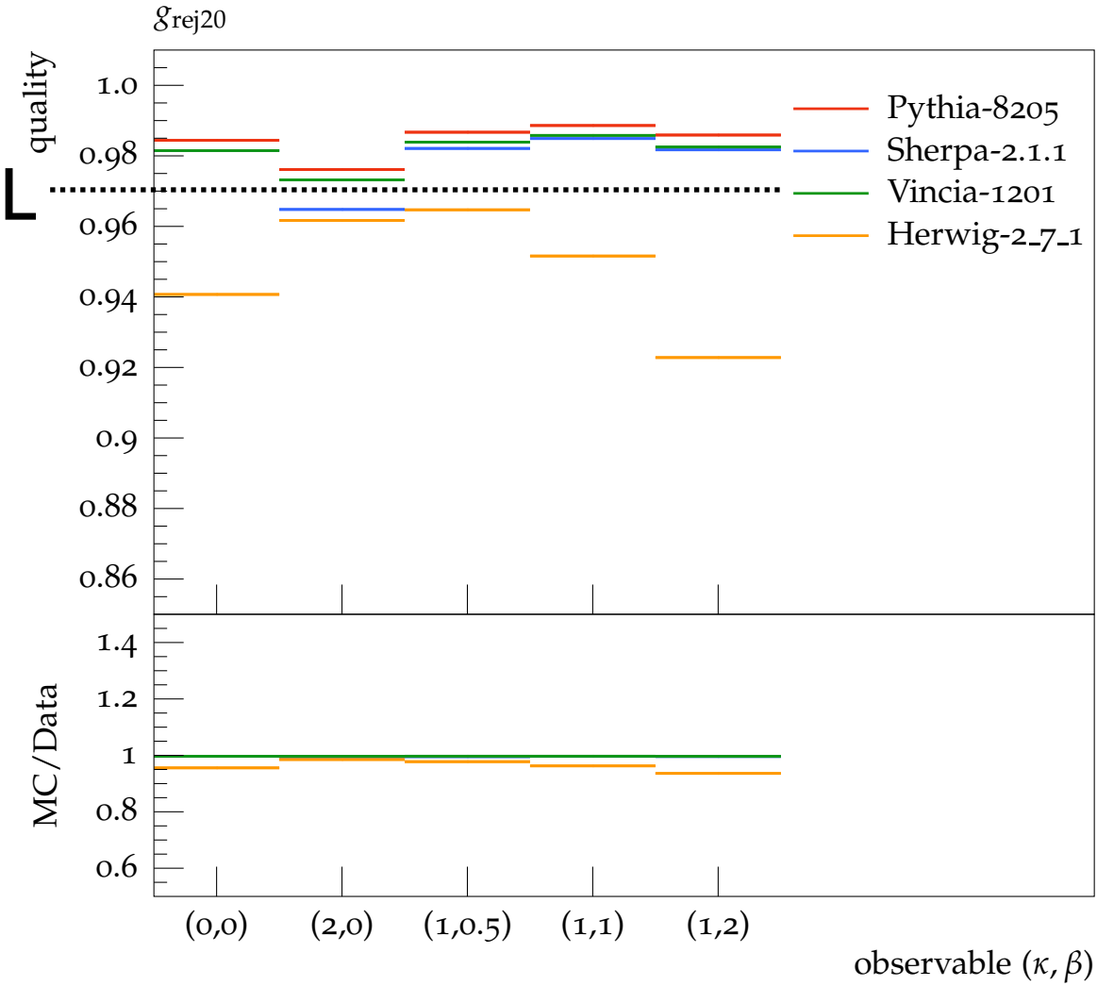
Gluon Rejection Factors @ …

Hadron level, R=0.6, Q=200 GeV

50% Quark Eff.



20% Quark Eff.

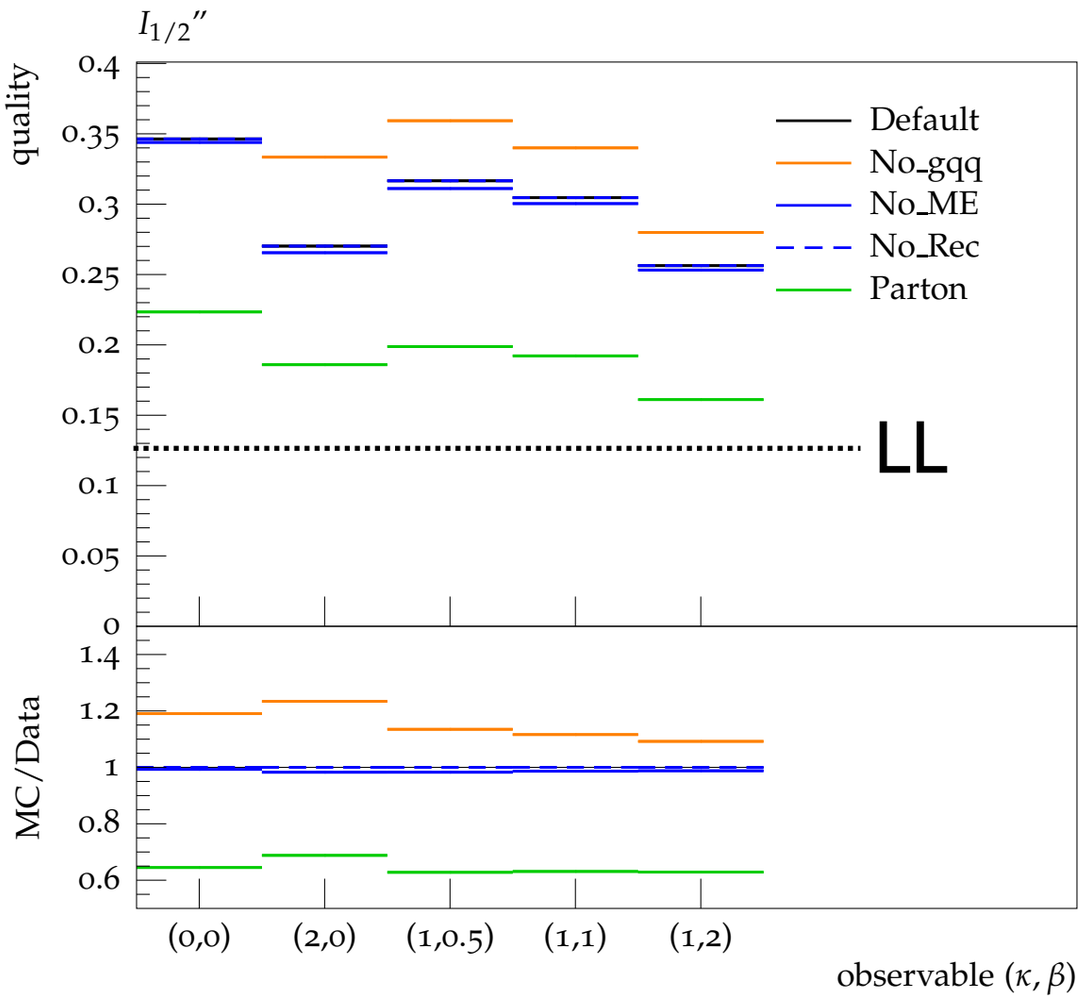


Sweeping Shower Options

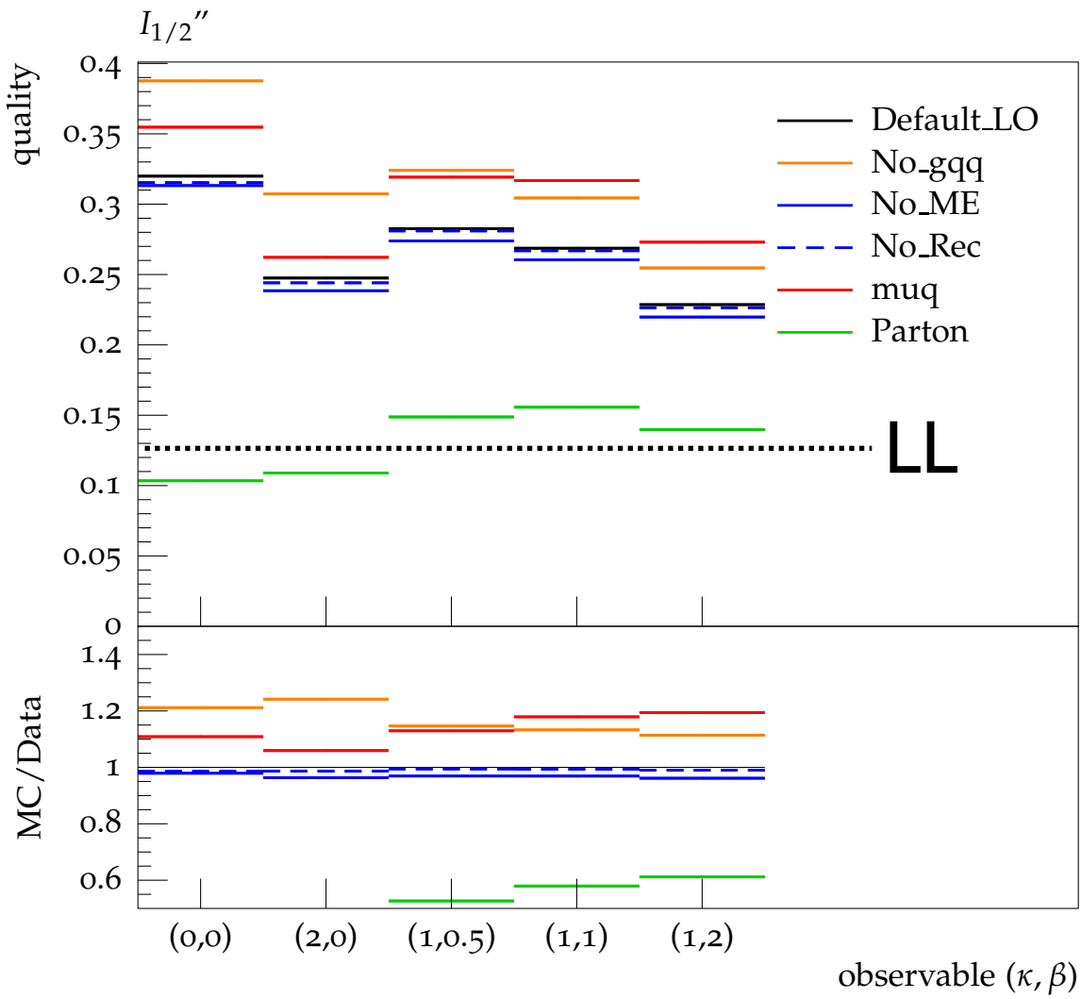
Hadron level, R=0.6, Q=200 GeV

$$\int \mathrm{d}\lambda \, \frac{\left(S(\lambda) - B(\lambda)\right)^2}{2\left(S(\lambda) + B(\lambda)\right)}$$

Pythia 8.205



Vincia 1.201

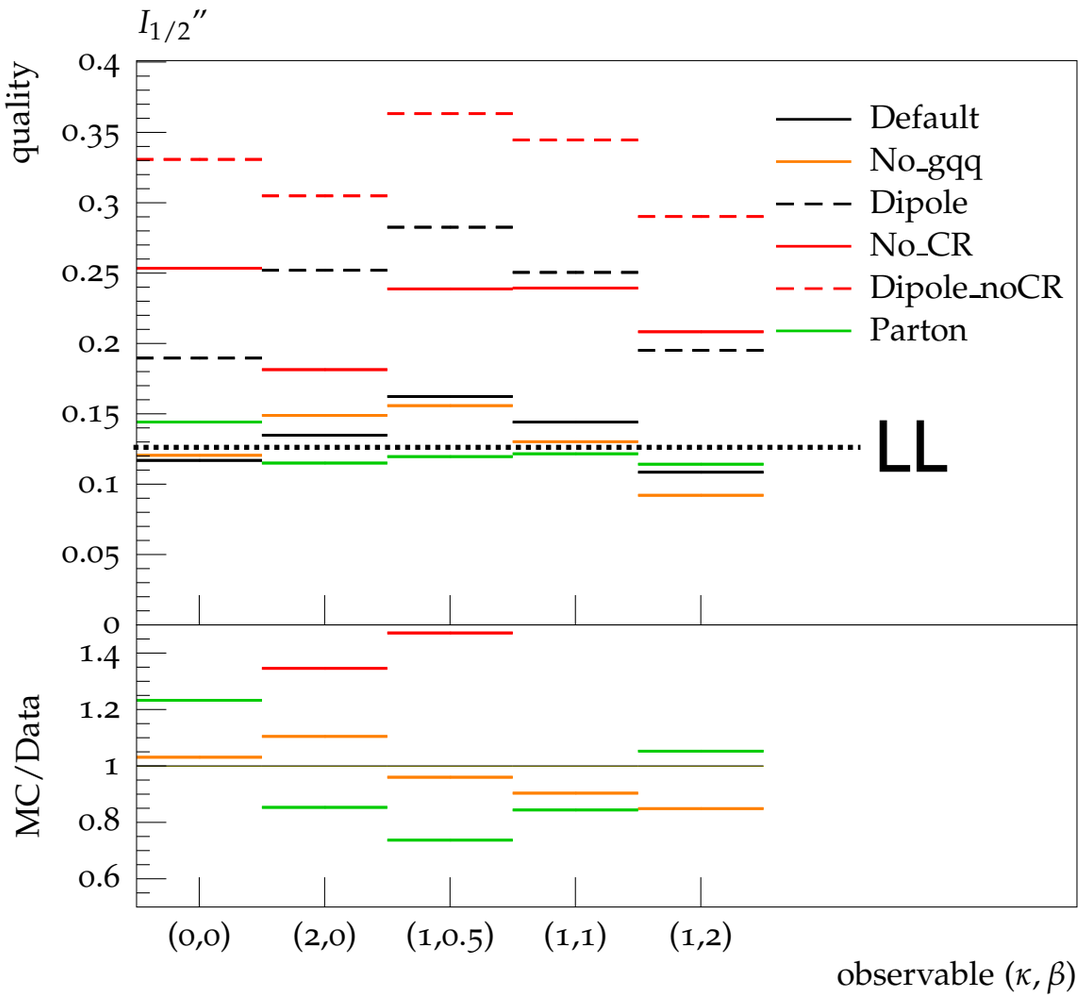


Sweeping Shower Options

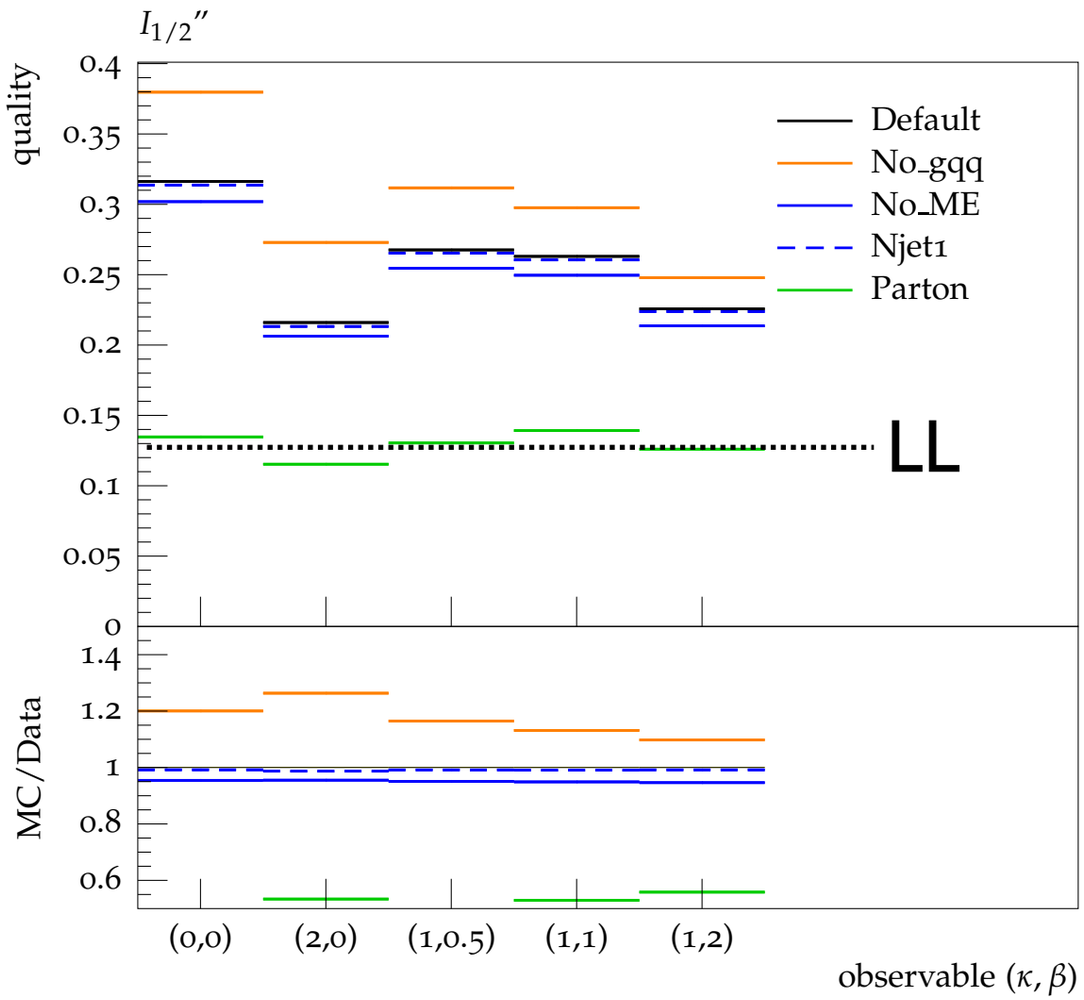
Hadron level, R=0.6, Q=200 GeV

$$\int \mathrm{d}\lambda \, \frac{\left(S(\lambda) - B(\lambda)\right)^2}{2(S(\lambda) + B(\lambda))}$$

Herwig 2.7.1



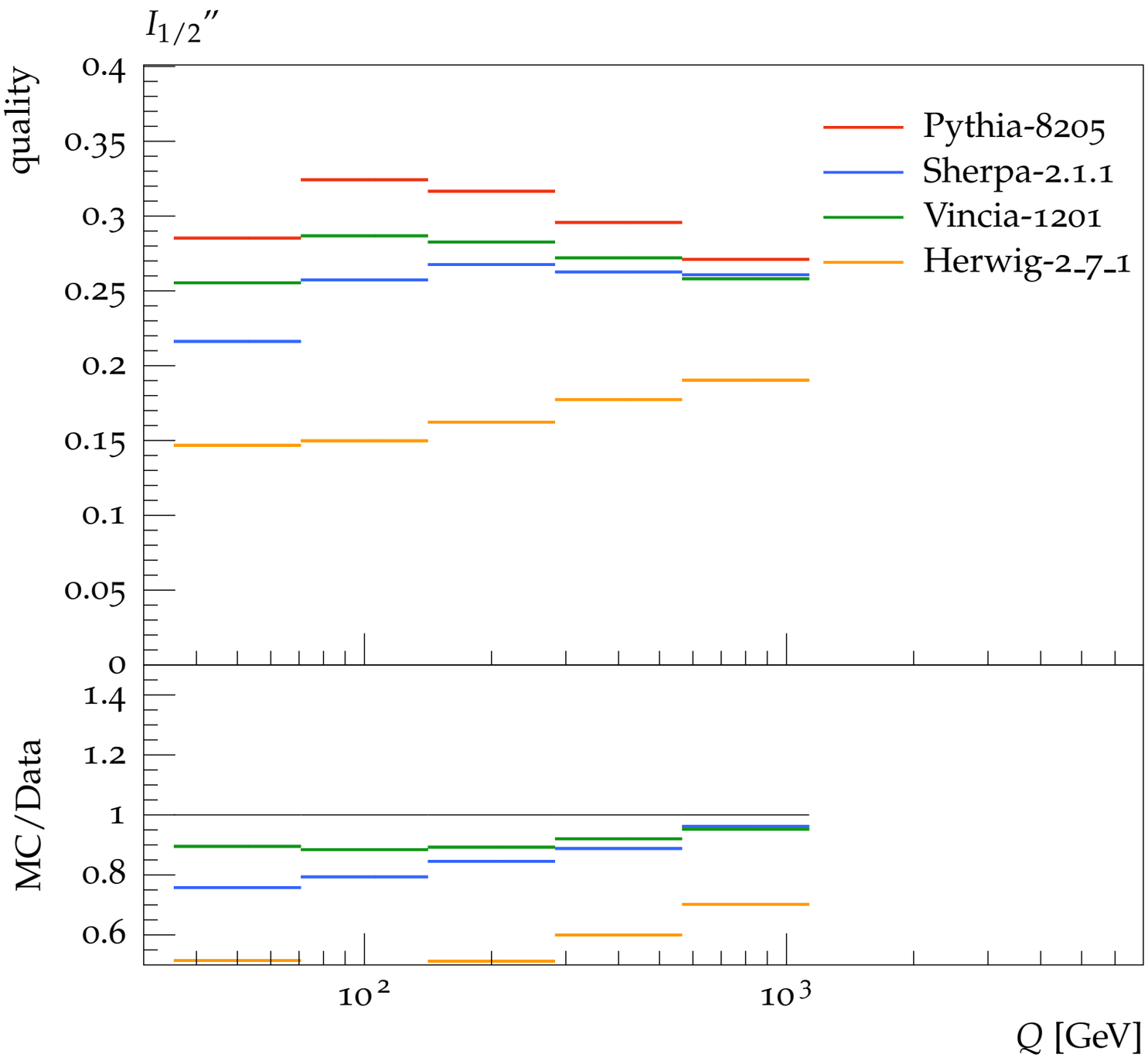
Sherpa 2.1.1



Sweeping Hard Scale Q

Hadron level, R=0.6, LH Angularity

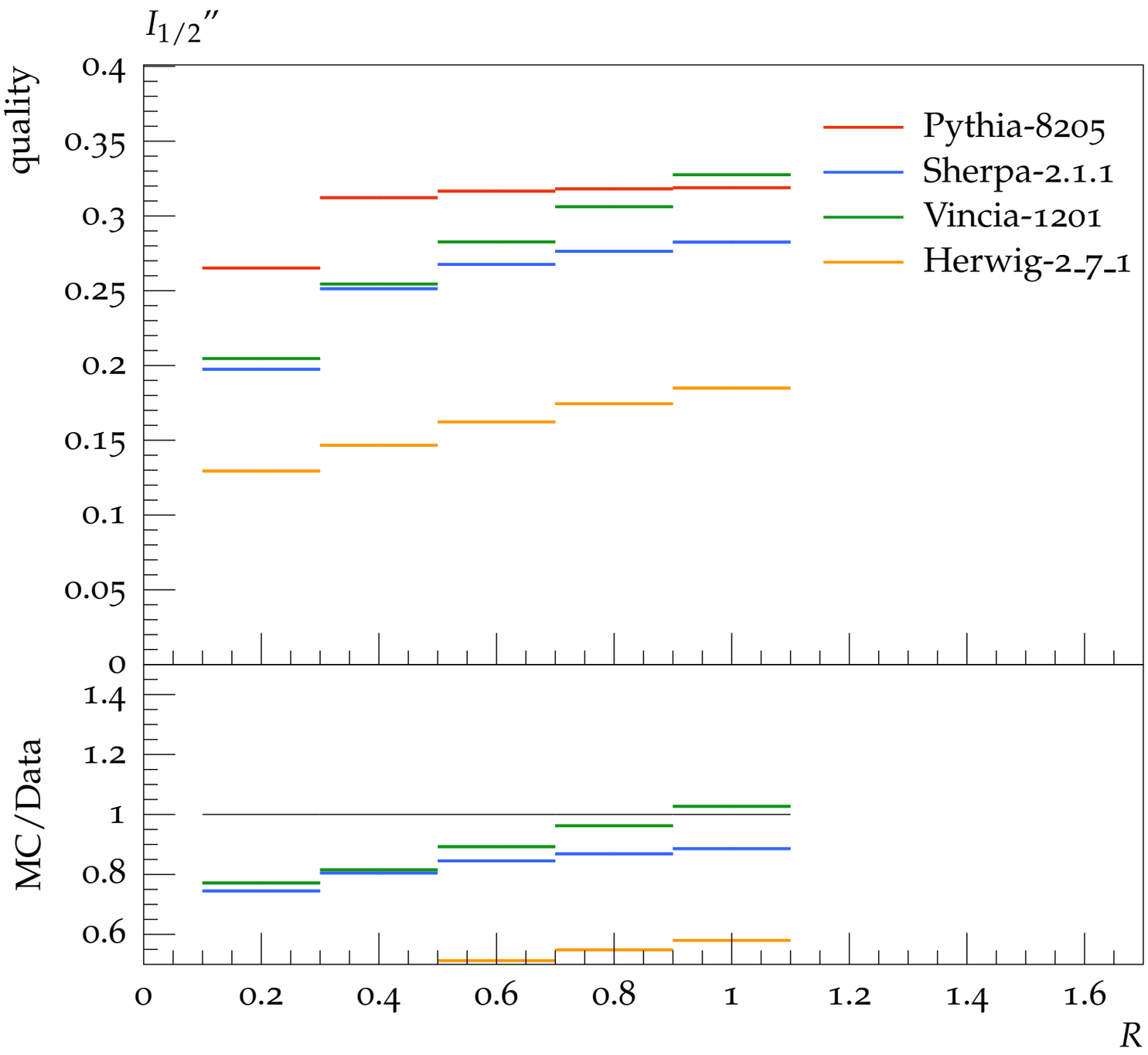
$$\int \mathrm{d}\lambda \, \frac{\left(S(\lambda) - B(\lambda)\right)^2}{2(S(\lambda) + B(\lambda))}$$



Sweeping Jet Radius R

Hadron level, Q=200 GeV, LH Angularity

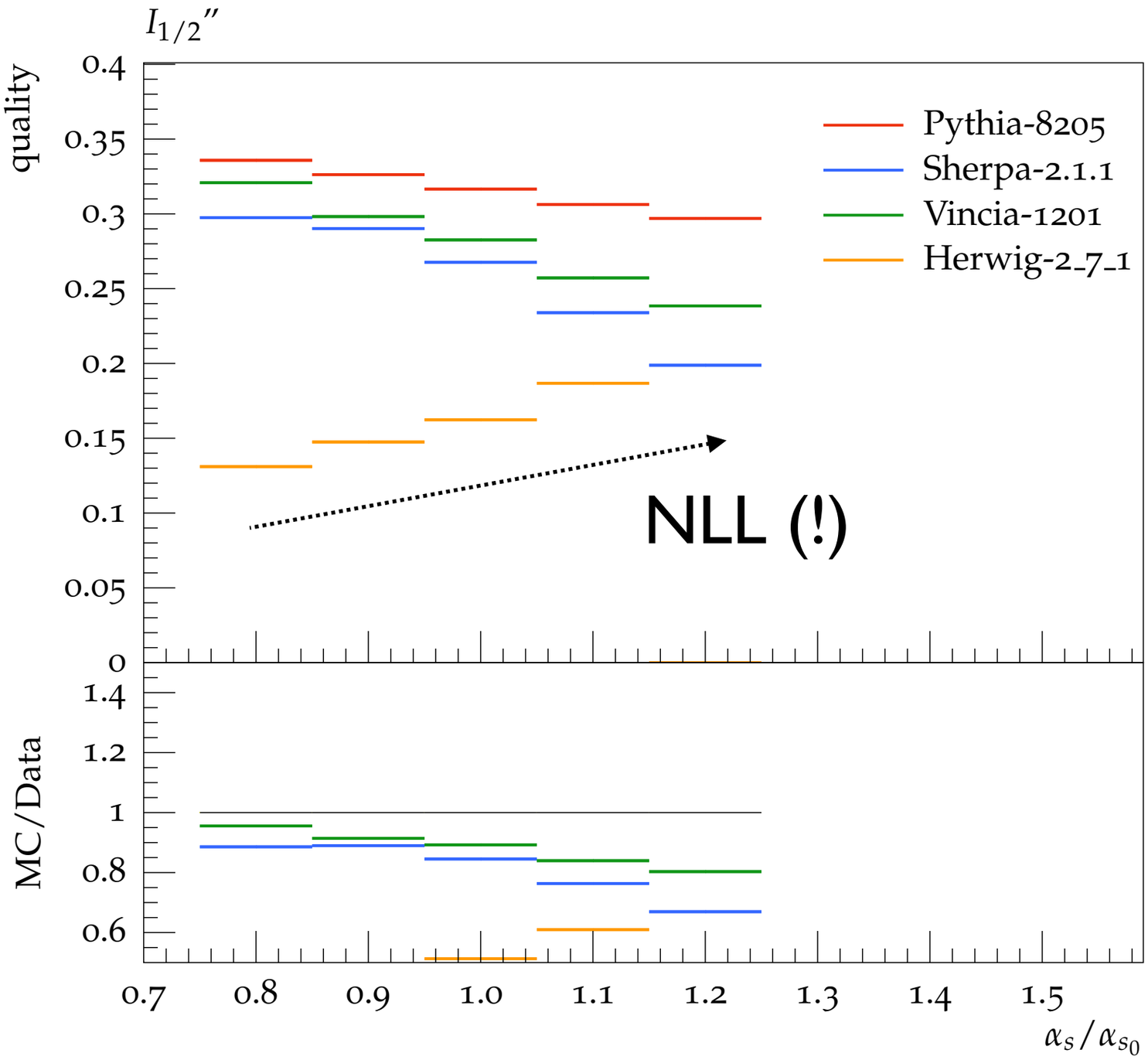
$$\int \mathrm{d}\lambda \, \frac{\left(S(\lambda) - B(\lambda)\right)^2}{2(S(\lambda) + B(\lambda))}$$



Sweeping Strong Coupling α_S

Hadron level, R=0.6, Q=200 GeV, LHA

$$\int \mathrm{d}\lambda \, \frac{\left(S(\lambda) - B(\lambda)\right)^2}{2\left(S(\lambda) + B(\lambda)\right)}$$



Lessons Learned

LEP measured quark (not gluon) event shapes

Hadronization is important, even for IRC safe angularities

Improving quark/gluon robustness seems synonymous with controlling final state shower uncertainties

Herwig++ results highlight interplay of pre-confinement and color reconnections (in e^+e^-!)

Qualitative trends predictable from first principles (e.g. NLL), so what is happening with α_s? (A: Non-perturbative physics)

Future Plans

Write a quark/gluon manifesto

Solidify e^+e^- study with careful MC comparison, inclusion of other tools (e.g. Deductor), inclusion of analytic resummed predictions

Extend e^+e^- study to pp (dijets, γ/W/Z/H + jet)

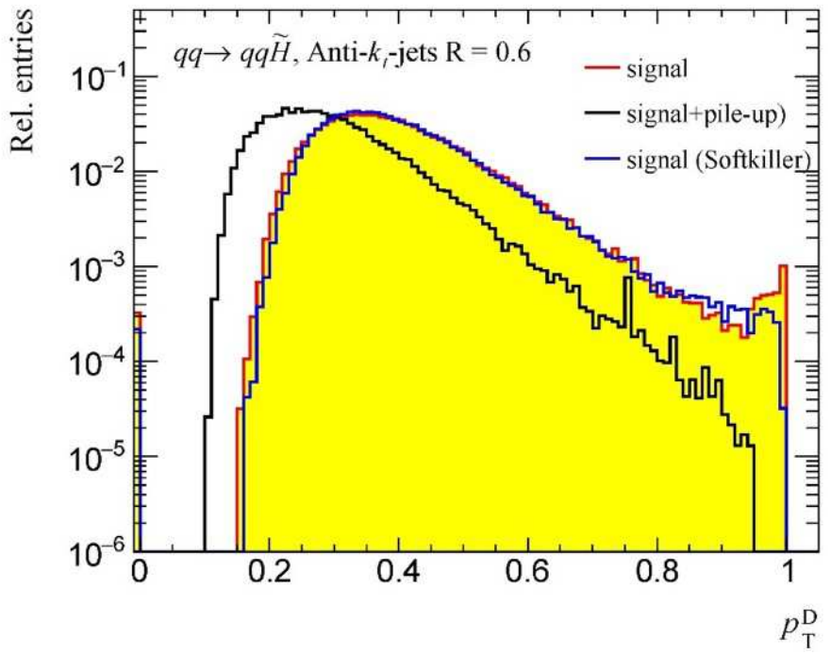
Identify future/past LHC measures that constrain Monte Carlo uncertainties

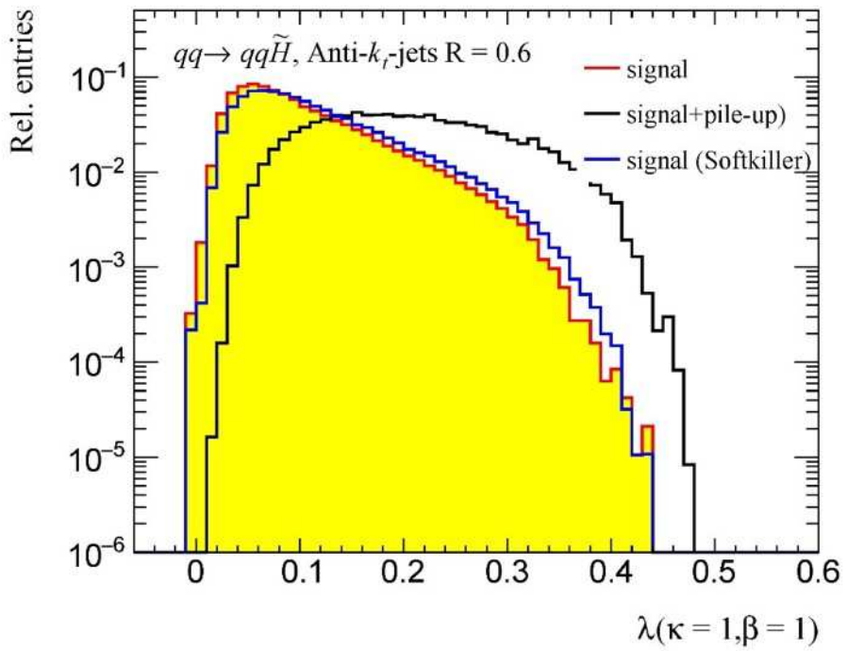
Related Les Houches Discussions

Quark/Gluon Jet Tagging in VBF/VBS

From Peter Loch

- Motivation
  - Backgrounds to VBF/VBS tag jets
    - QCD and pile-up jets often gluon generated
    - Tag jets induced by scattered quarks
- First look at useful jet observables
  - Experimentally accessible
    - Jet mass
    - Jet width $\lambda(\kappa = 1, \beta = 1)$
    - Jet $p_{\mathrm{D}}^{\mathrm{T}}$
    - Jet core energy fraction
  - Sensitive to pile-up
    - Mitigation at particle level possible using e.g. SoftKiller
    - Mitigation seems to perform better for mass and $p_{\mathrm{D}}^{\mathrm{T}}$ than for width
- Experimental feasibility to be confirmed
  - Pseudo-detectors
    - Tower grids
    - DELPHES





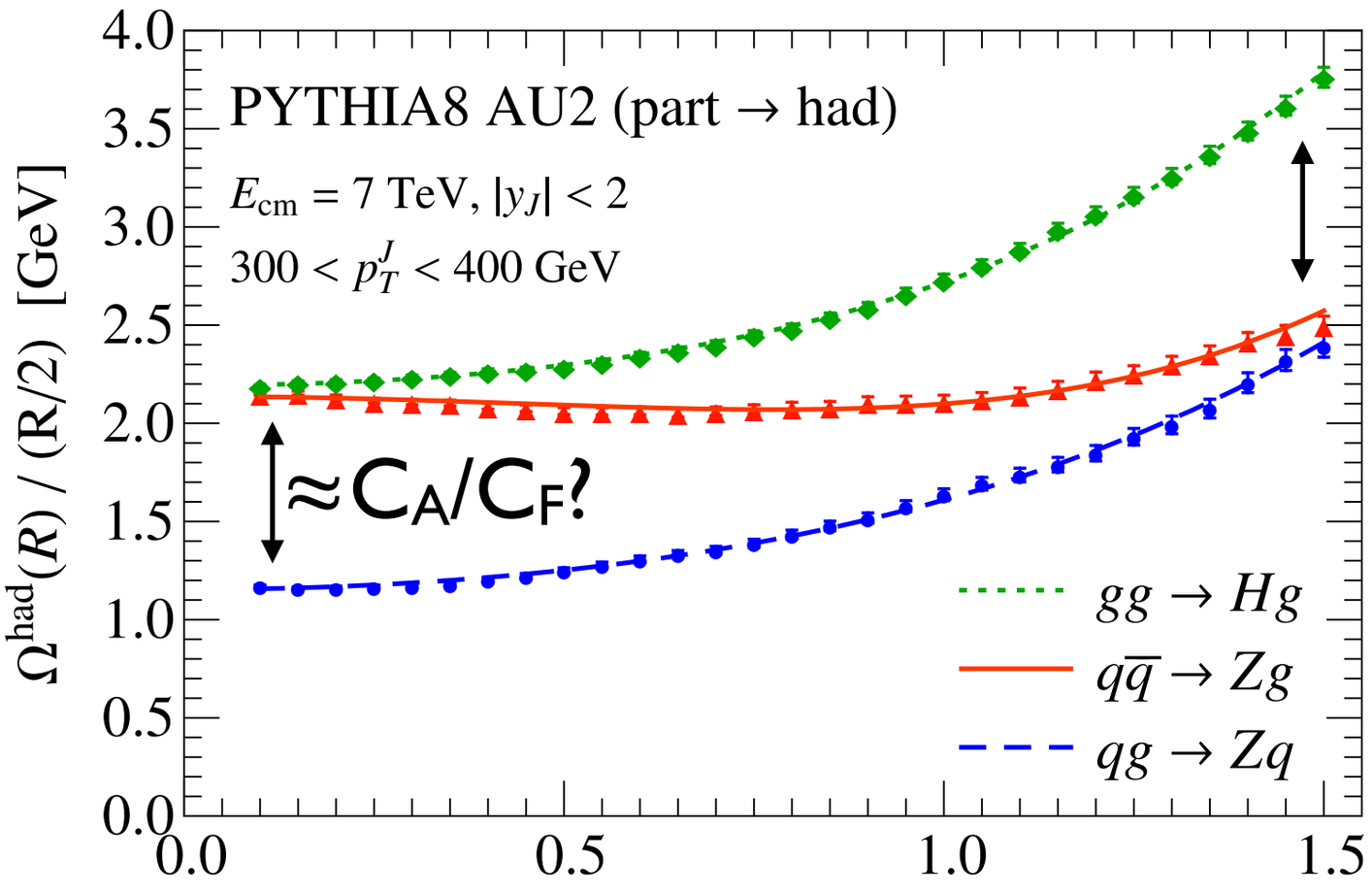
Scaling of Hadronization Corrections

From Frank Tackmann

$$M_1 = \frac{1}{\sigma}\int \mathrm{d}m_J^2\, m_J^2\, \frac{\mathrm{d}\sigma}{\mathrm{d}m_J^2}$$ = Jet mass first moment

Factorization predicts

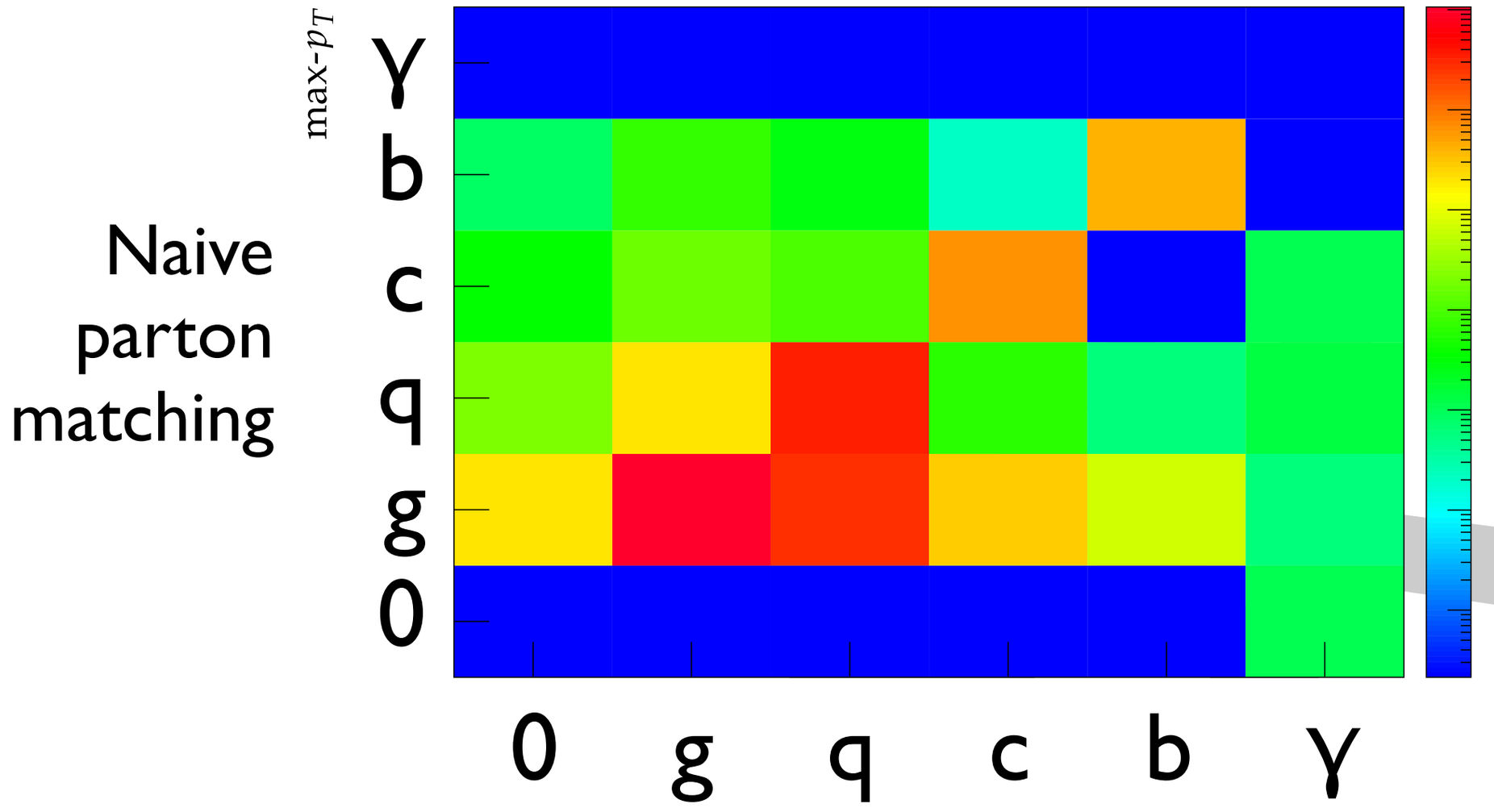
$$M_1 = M_{1\,\kappa}^{\mathrm{pert}}(p_T^J, y_J, R) + 2p_T^J \boxed{\Omega_\kappa(R)}$$ Non-pert. power correction



Soft color factors?

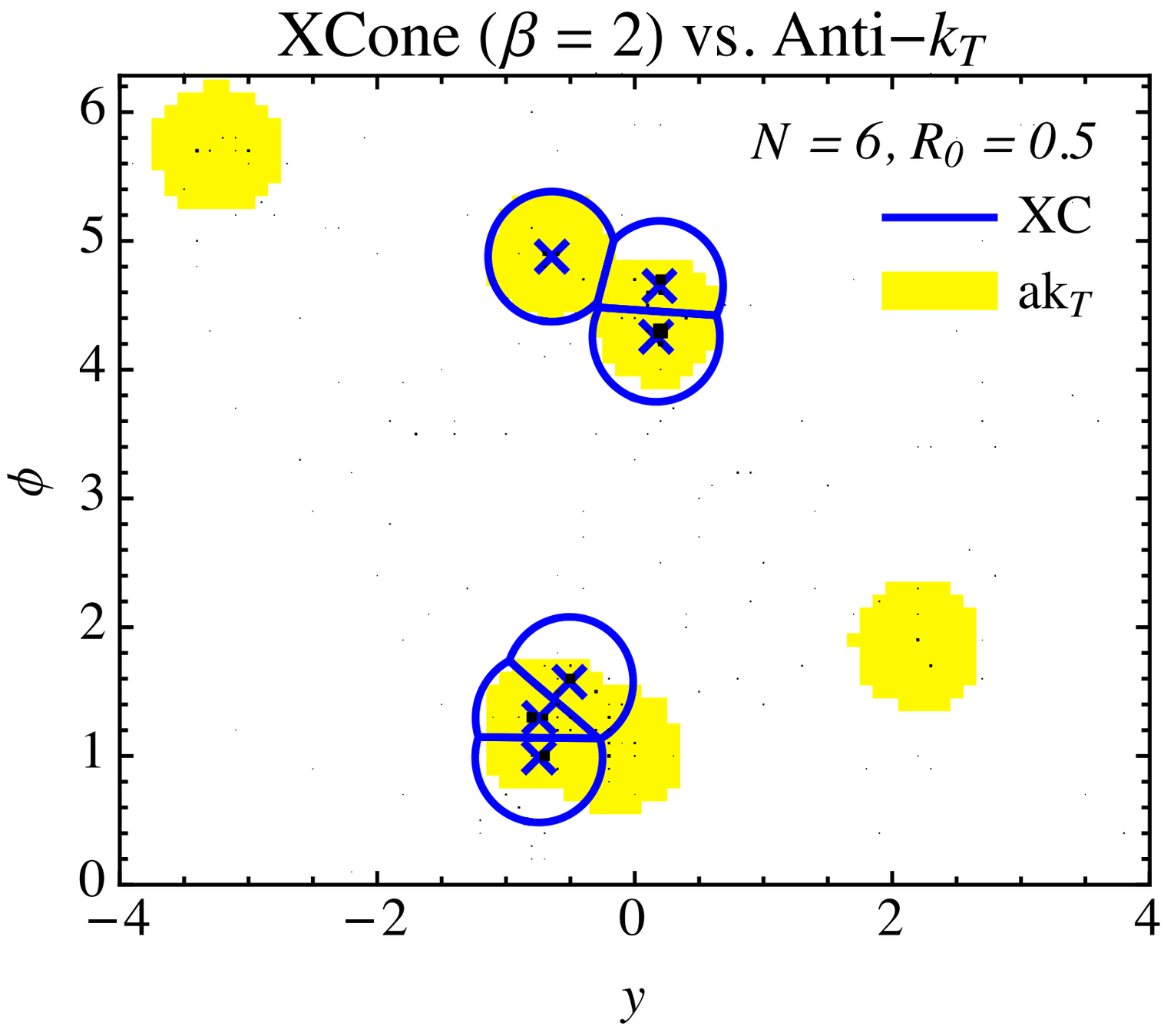
QCD Aware Jet Clustering

From Andy Buckley



Reinvigorating Safe Cone Algorithms

with Frank Tackmann



[Stewart, Tackmann, JDT, Vermilion, Wilkason, 1506.xxxxx]

Bottom Line (From Opening)

Wide array of jet physics tools, both new and old

Steadily gaining improved analytic understanding

Something amiss in quark/gluon radiation patterns

Looking forward to a fun workshop!

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Wide array of jet physics tools, both new and old

Steadily gaining improved analytic understanding

Gaining understanding of

~~Something amiss~~ in quark/gluon radiation patterns

full Les Houches study!

Looking forward to a ~~fun workshop~~!

Hope to see some of you across the Atlantic!

Possible Points for Discussion (From Opening)

Pulled from the wiki…

Jets as a Tool for (B)SM Physics

Importance/relevance of jet radius variation, multiple jet algorithms
Making jet substructure part of everyday analyses (e.g. pileup mitigation, jet shapes)
Improved VBF tagging, jet vetoes for Higgs physics
…

Jets as a Precision Probe of QCD

Wishlist of jet shape measurements (e.g. angularities)
Interplay between fixed order and resummation for jet observables (esp. PS/ME matching)
IRC Unsafe but Sudakov Safe observables where resummation is essential
Analytic handles on soft QCD (e.g. underlying event, hadronization)
…

Many points of contact with other working groups