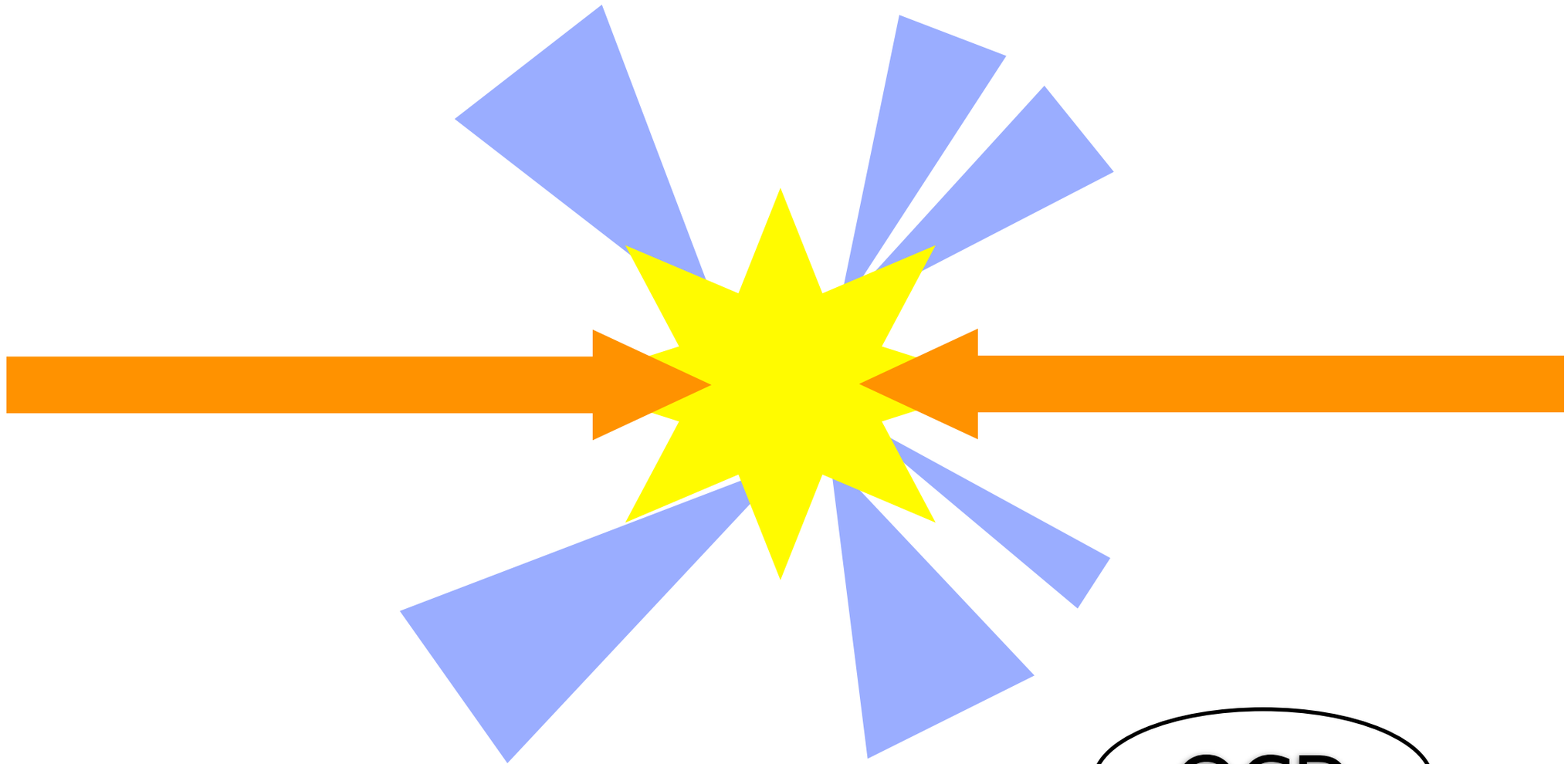
Evolution variable dependence on jet substructure

Yasuhito Sakaki

KEK, SOKENDAI

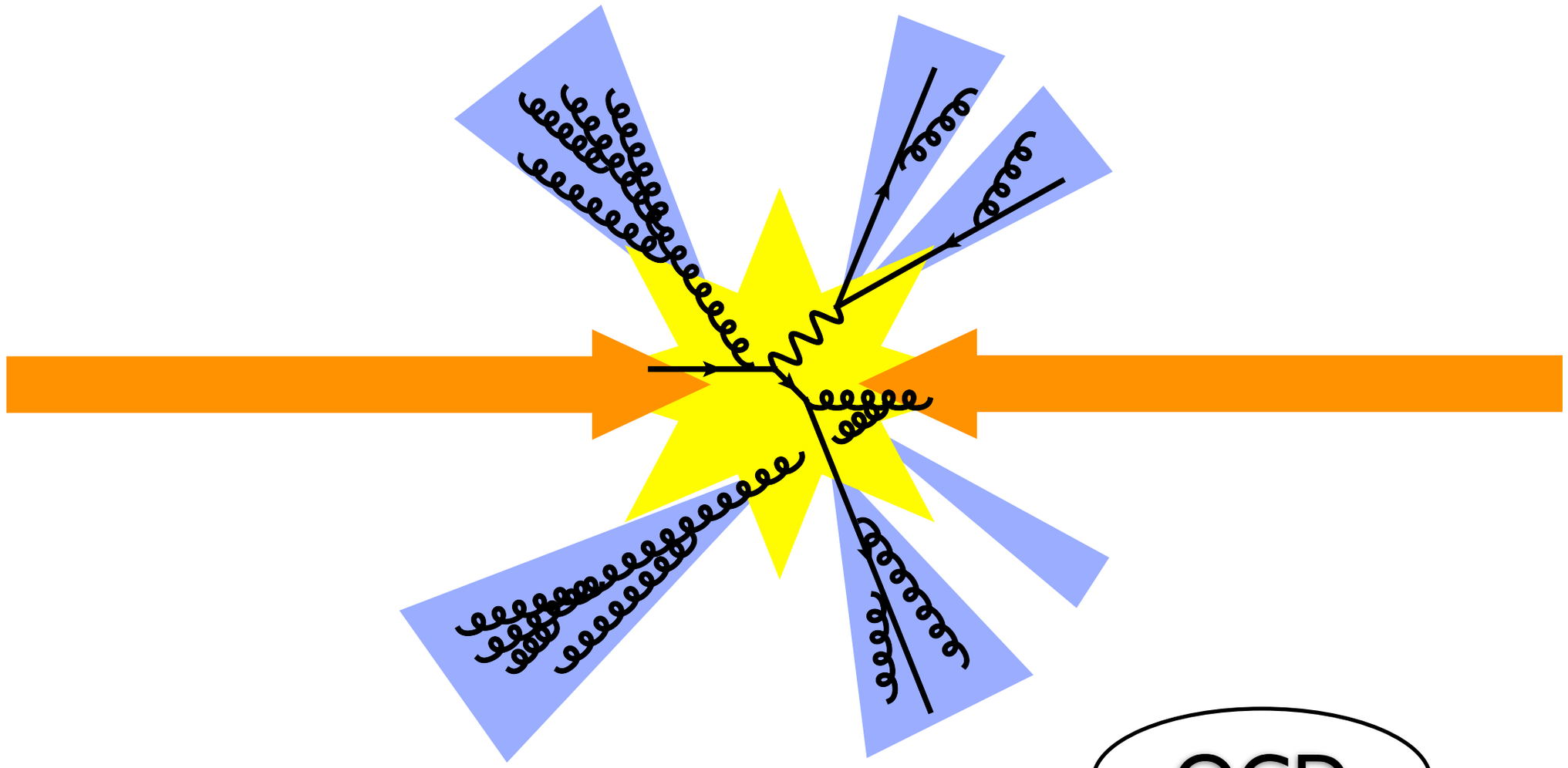
MC4BSM, May 20, 2015 @Fermilab

MC tools predict very well jet properties (jet number, momenta, shape...)



How about internal structure of the jets?

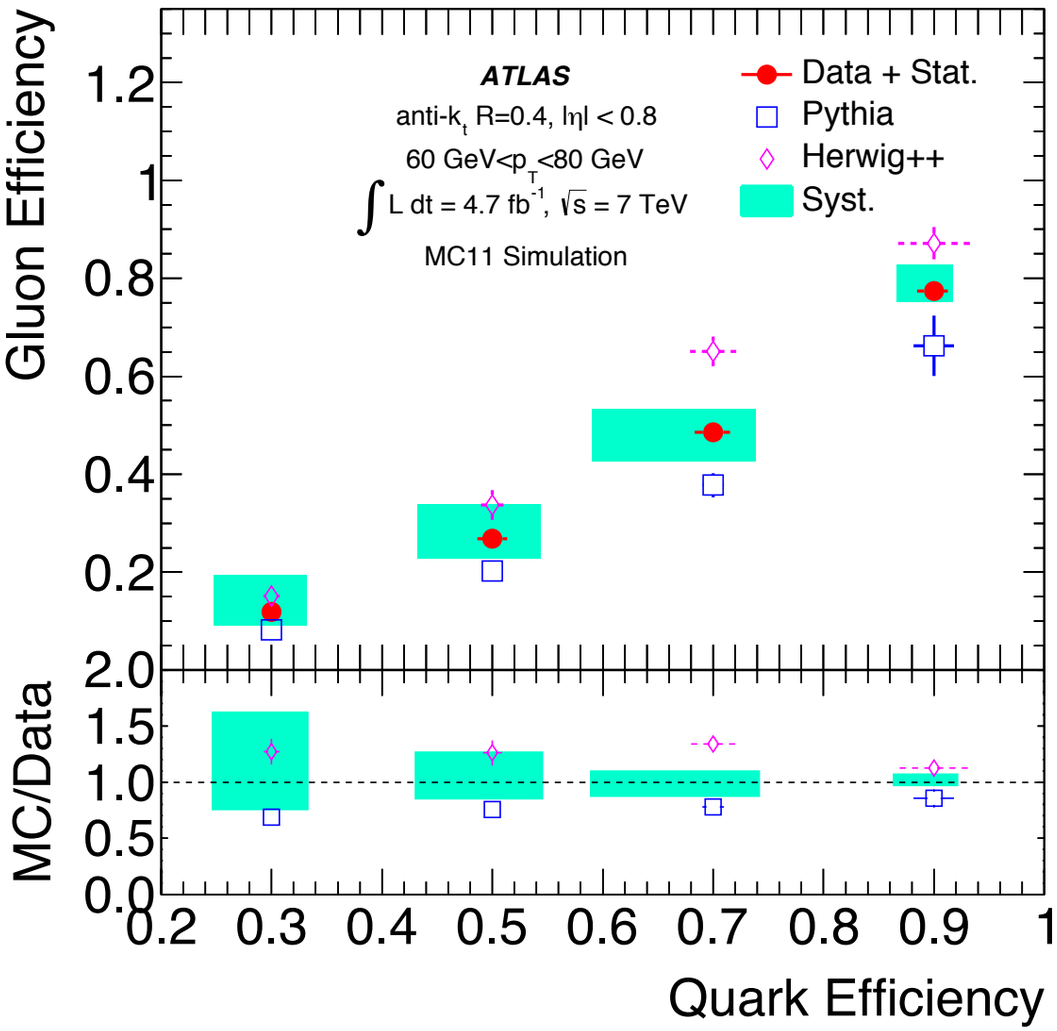
MC tools predict very well jet properties (jet number, momenta, shape...)

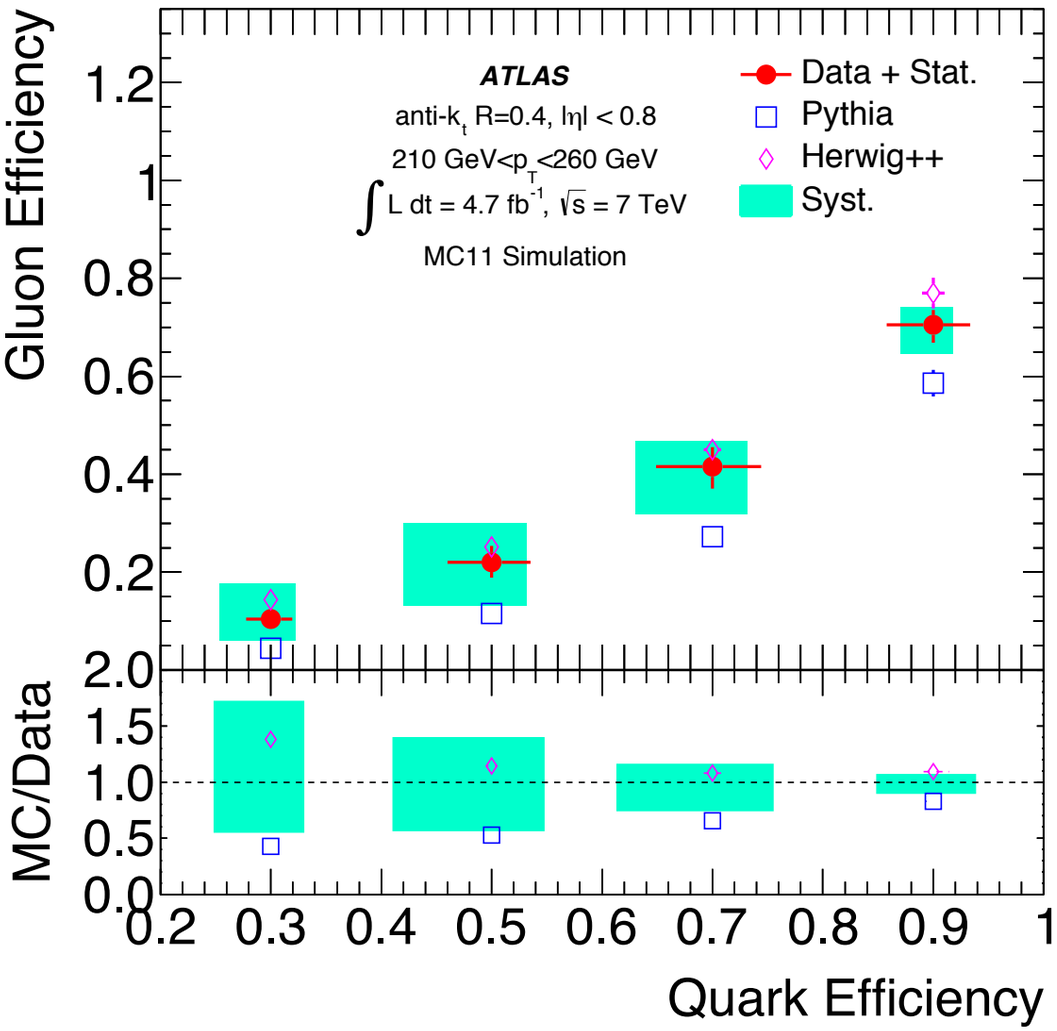


How about internal structure of the jets?

MC dependence on QCD jet substructure

ATLAS, 1405.6583





Data lies between Pythia and Herwig

Why different?

- It's difficult to answer easily due to many sources of difference among generators...

- Jet substructure is basically formed by QCD radiations (parton shower)
- Evolution variable is core in parton shower
- Equivalent choices are possible

$$\frac{dq^2}{q^2}dz = \frac{dQ^2_{\mathrm{Py}}}{Q^2_{\mathrm{Py}}}dz = \frac{dQ^2_{\mathrm{Hw}}}{Q^2_{\mathrm{Hw}}}dz = \ldots$$

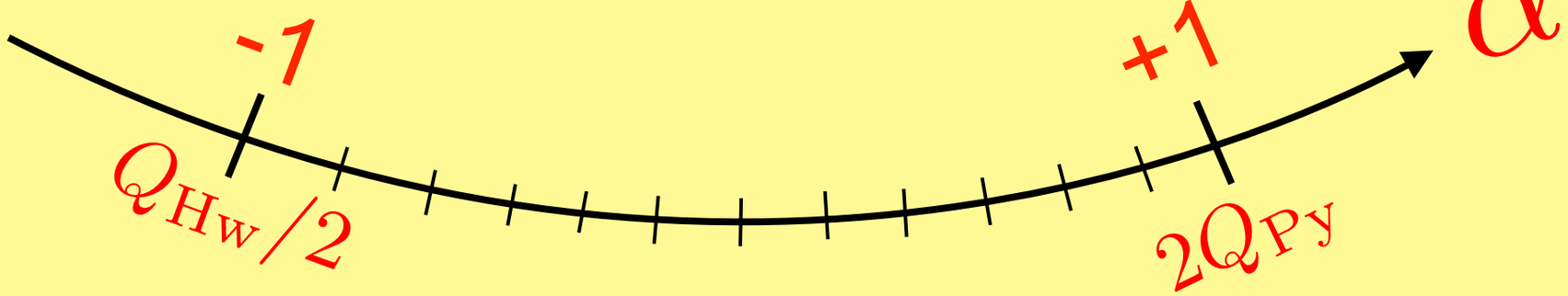
- Radiation pattern depends on the evolution variable

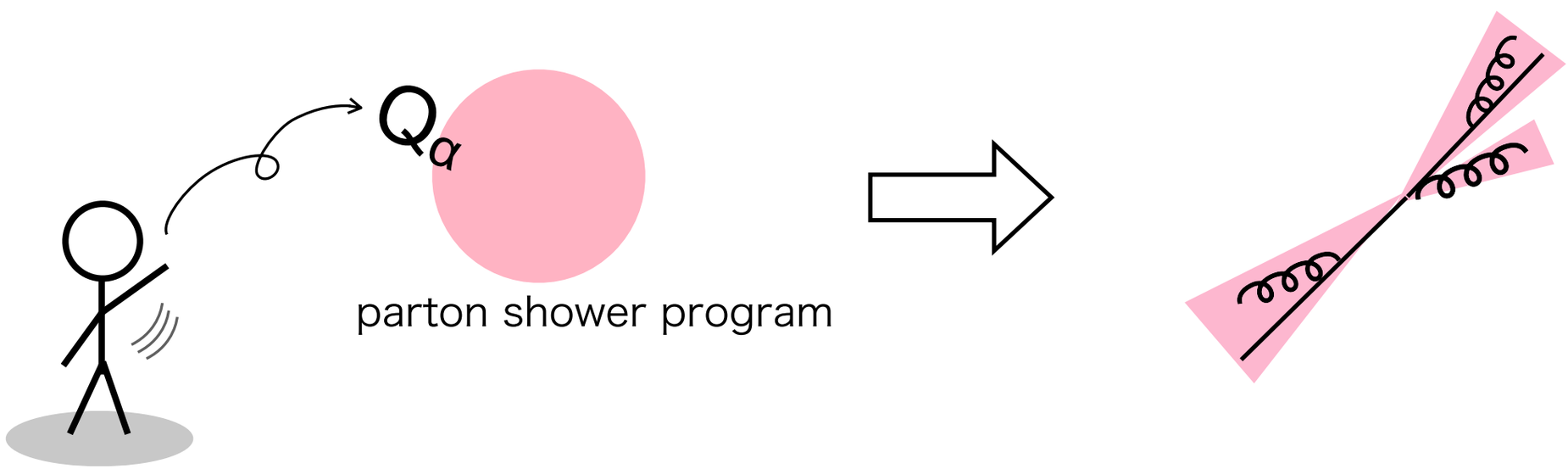
➡ Evolution variable dependence on jet substructure

Study of evolution variable dependence

in the same modeling of the parton shower

$$Q_\alpha^2 = [4z(1-z)]^\alpha q^2, \qquad \frac{dq^2}{q^2}dz = \frac{dQ_\alpha^2}{Q_\alpha^2}dz$$





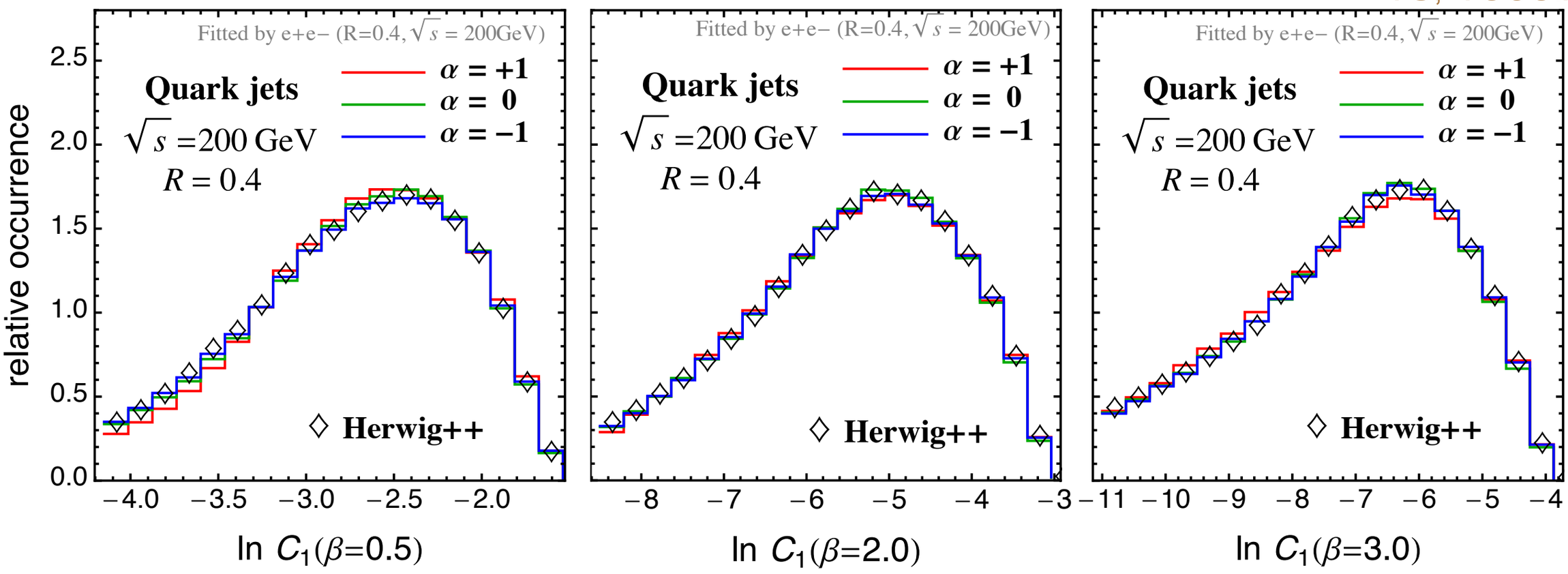
Tuning

	α	$\alpha_S(m_Z)$	$m_{\mathrm{qg}}[\mathrm{GeV}]$	r_{cut}
(PY)	$+1.0$	0.132	0.94	1.00
	$+0.5$	0.126	0.90	1.00
	± 0.0	0.121	0.84	1.05
	-0.5	0.119	0.83	1.16
(HW)	-1.0	0.119	0.85	1.25

- Three tunable parameters
- LEP data is often used to tune parametes
  ➡ need hadronization
- We use e+e- → qqbar events generated by Herwig++ with hadronization off as "*data*" alternatively.
- Three $C_1(\beta)$ distributions for fitting (R=0.4, $\sqrt{s}$=200GeV)
  ➡ $C_1(\beta=2)$ ⇔ jet mass, $C_1(\beta=1)$ ⇔ jet width/girth, ...

A. Larkoski, G. Salam, J. Thaler, 1305.0007

YS, 1505.xxxx



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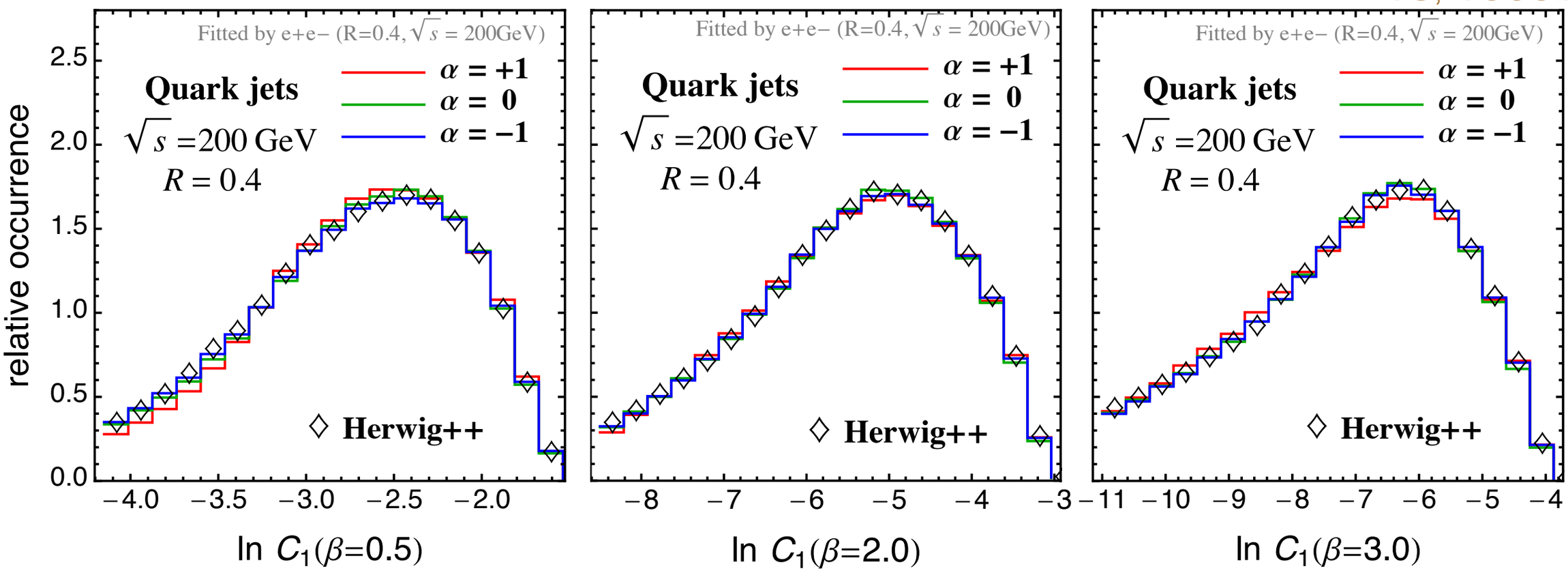
Pythia-like case (α=1)
choose larger value compare to
Herwig-like case (α=-1)

YS, 1505.xxxx

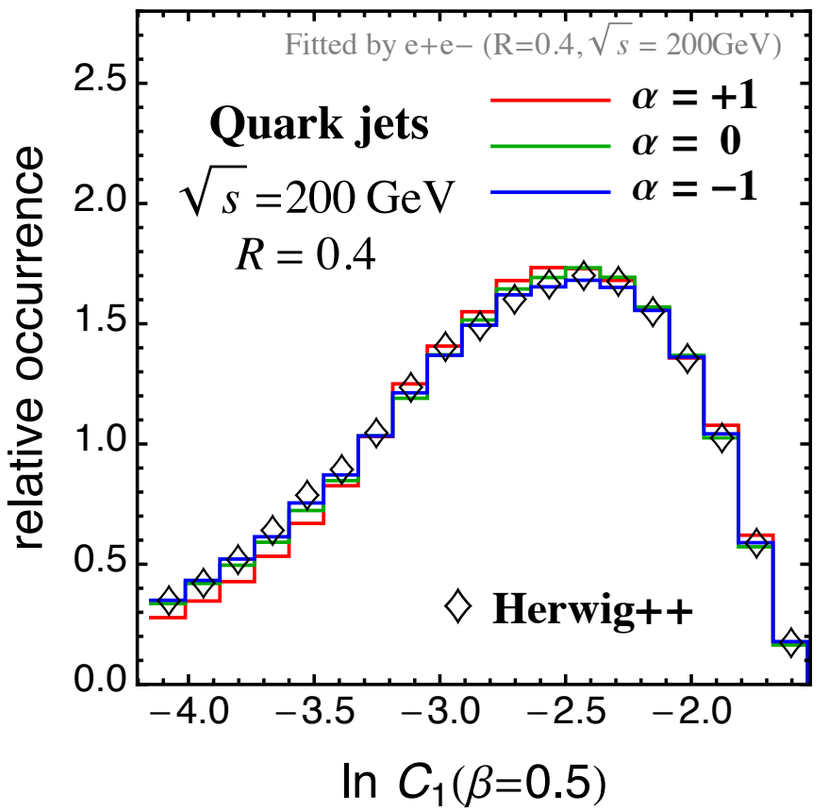


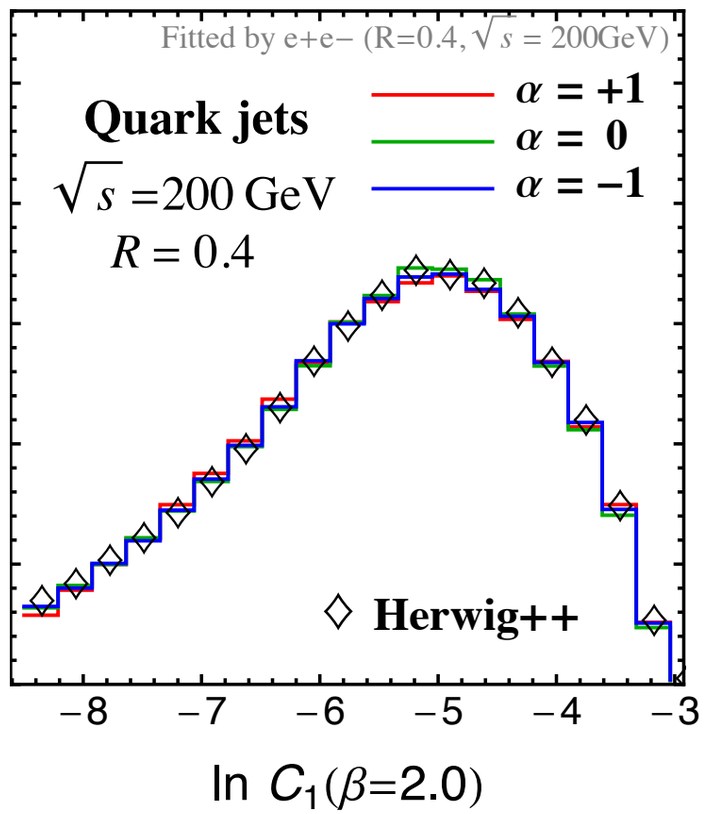
Fitted results

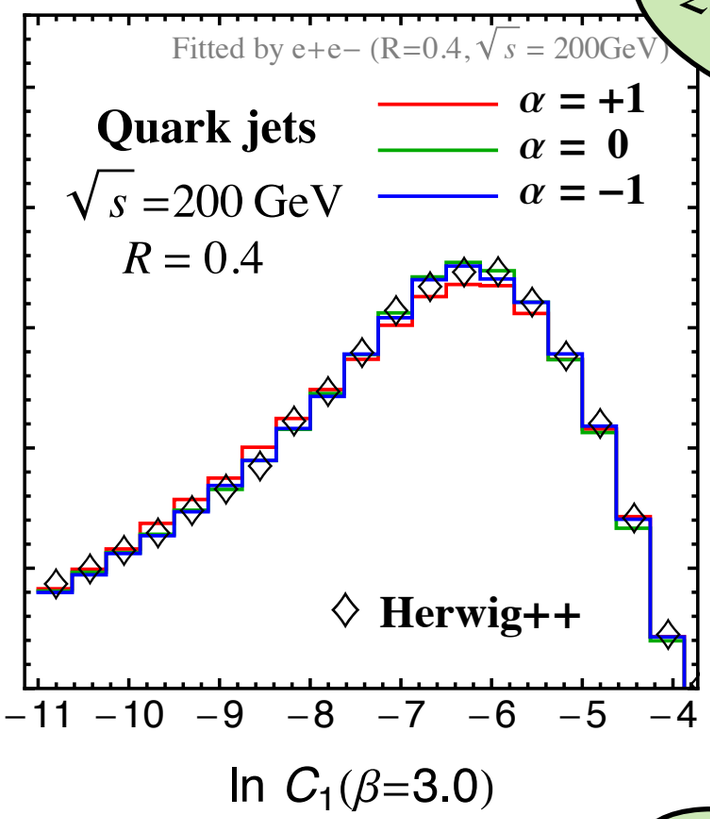
YS, 1505.xxxx

Quark jets

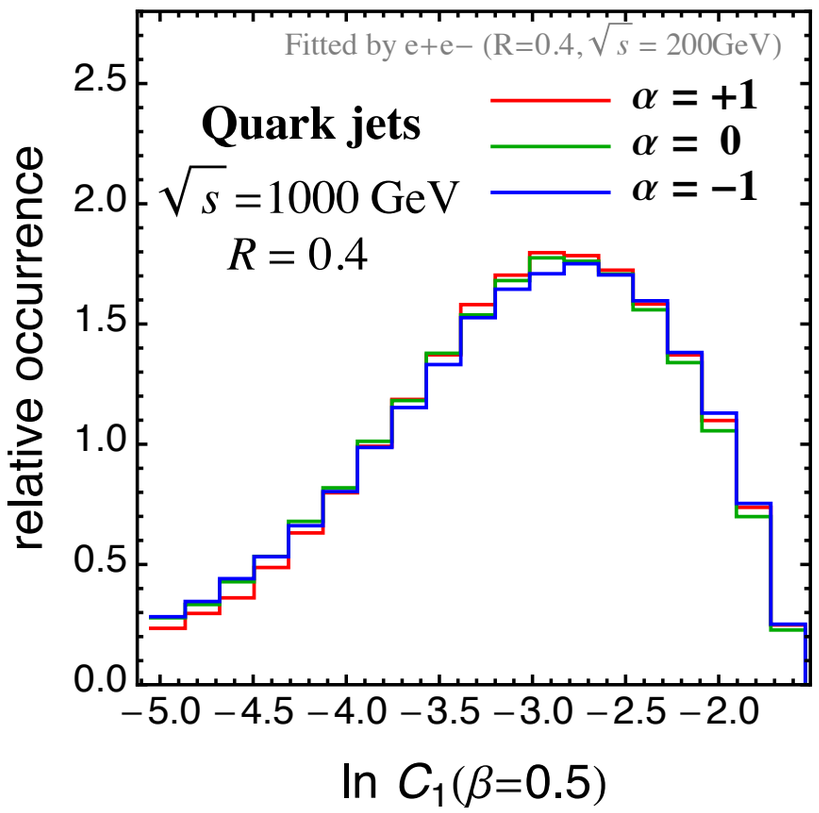
200GeV

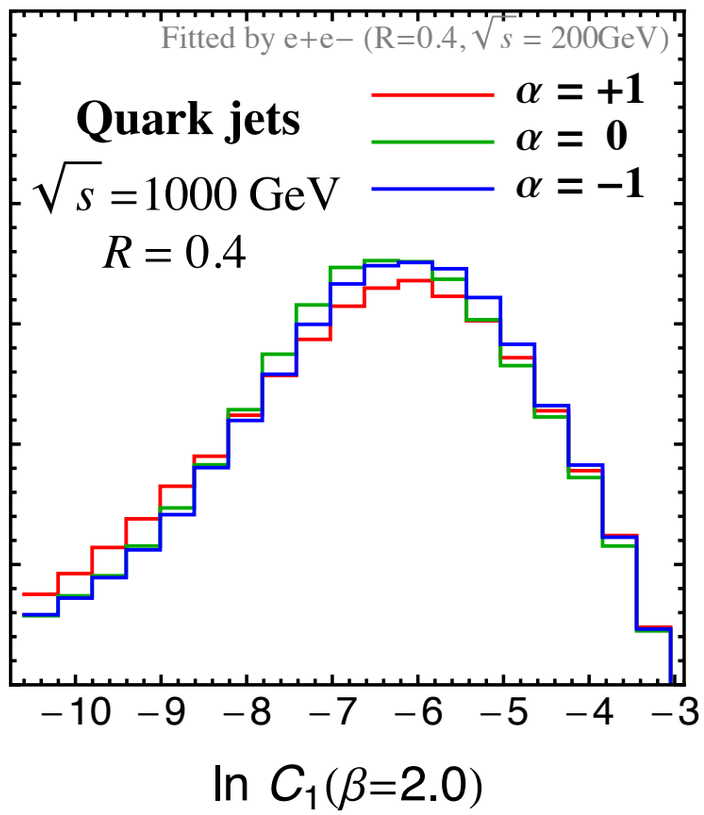


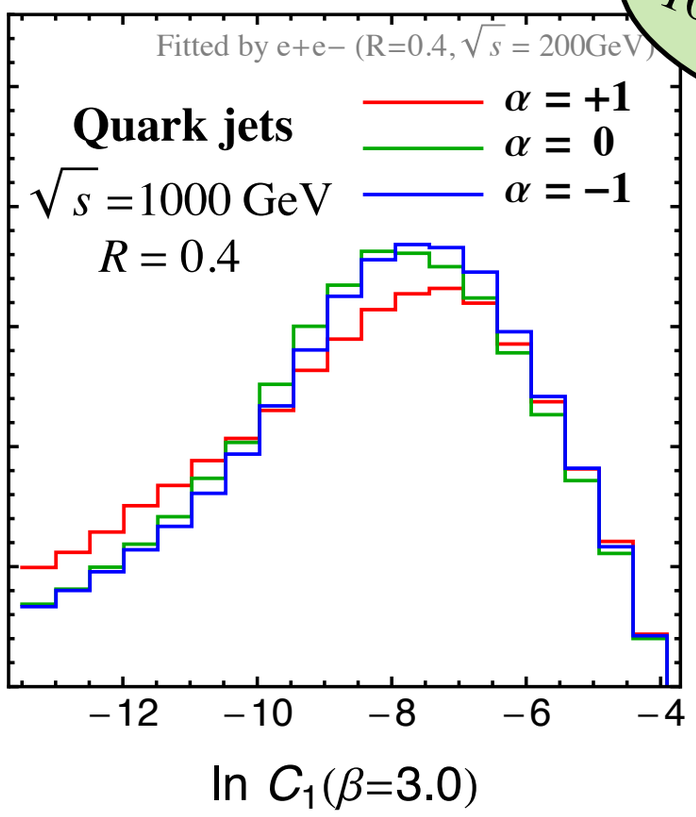




1000GeV





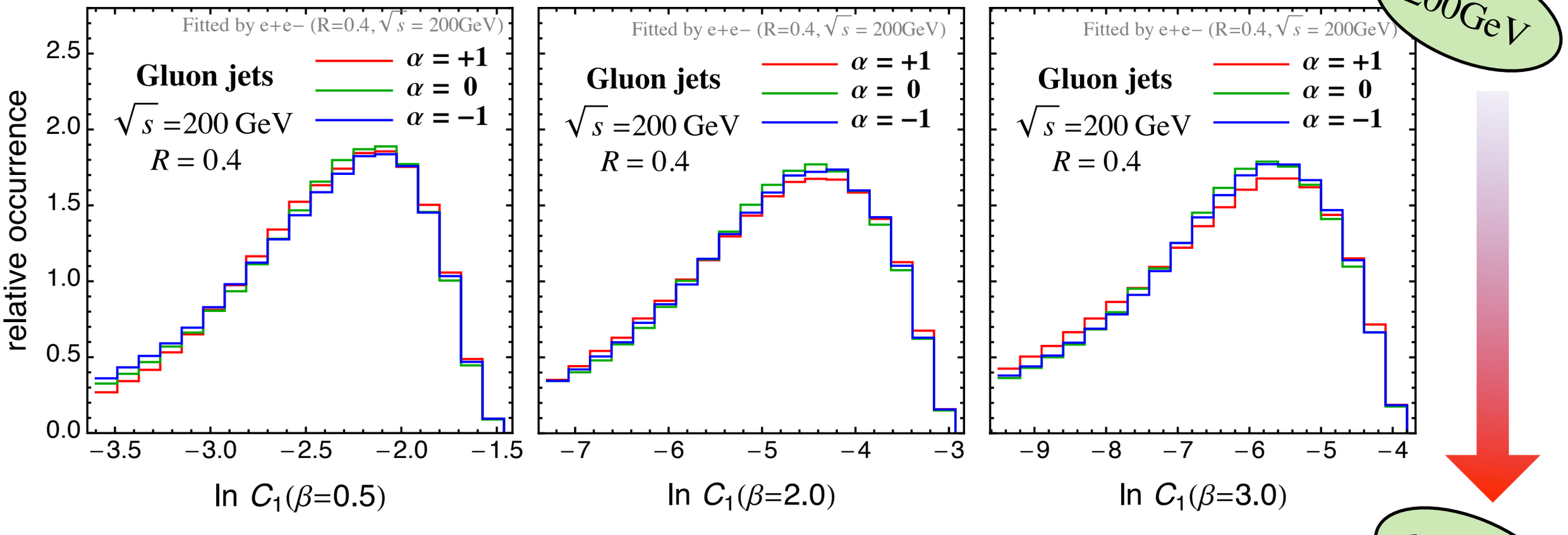


Fitted results

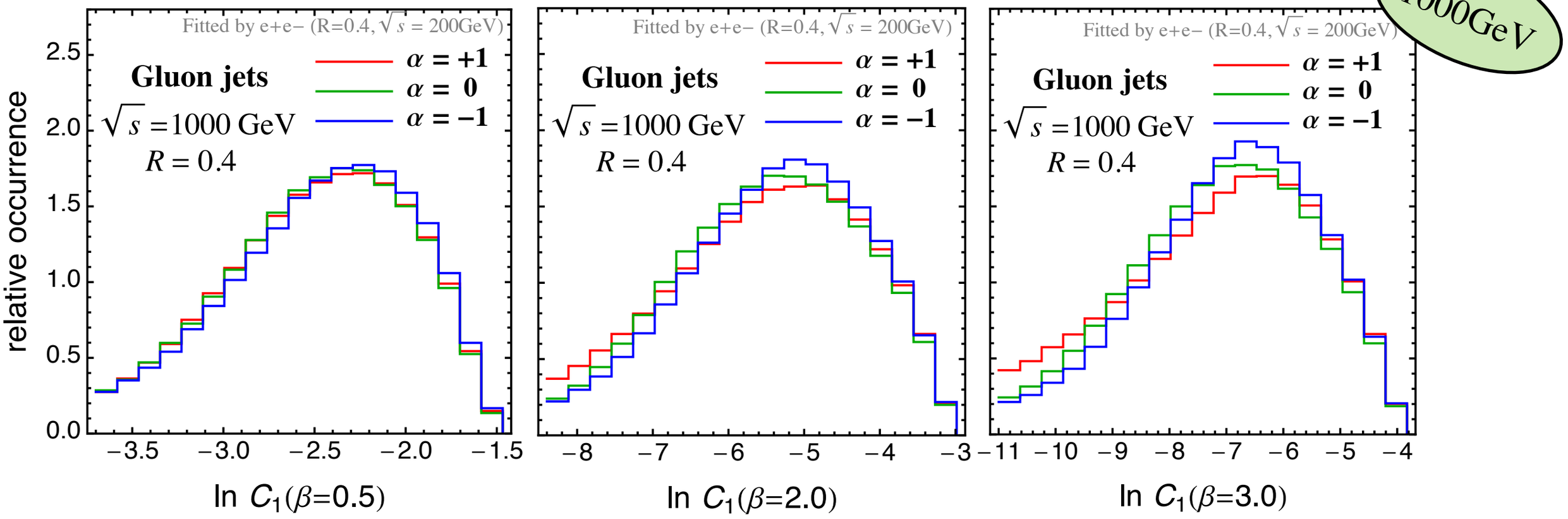
YS, 1505.xxxx

Gluon jets

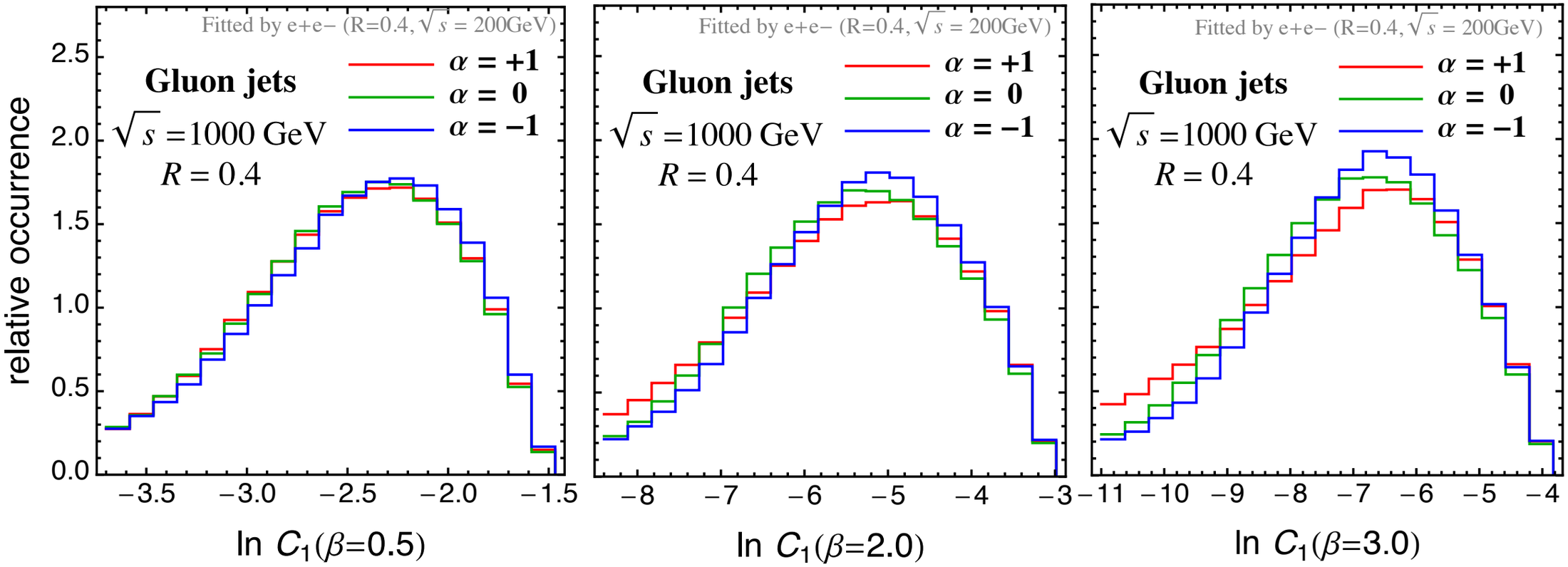
200GeV



1000GeV



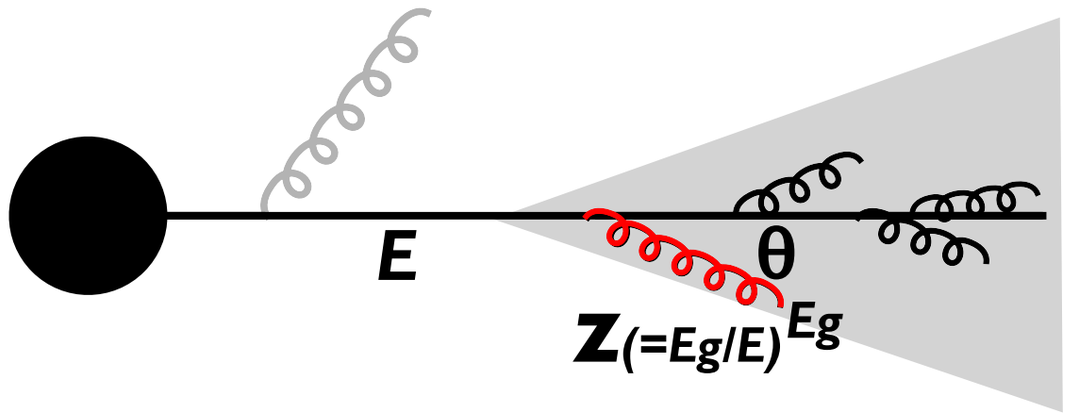
Wideness of emissions in jet



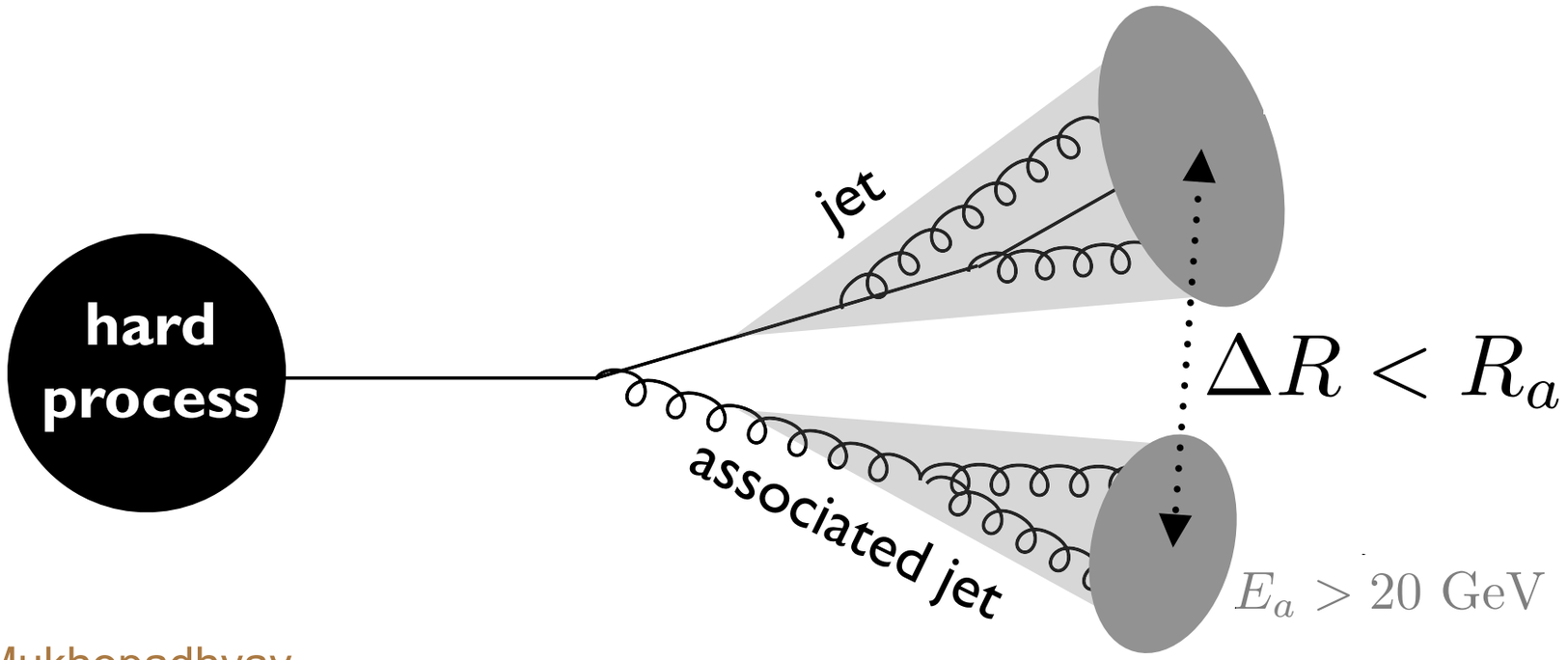
The larger β is, the larger the α-dependence on C_1 become

Wideness of emissions in jet is different

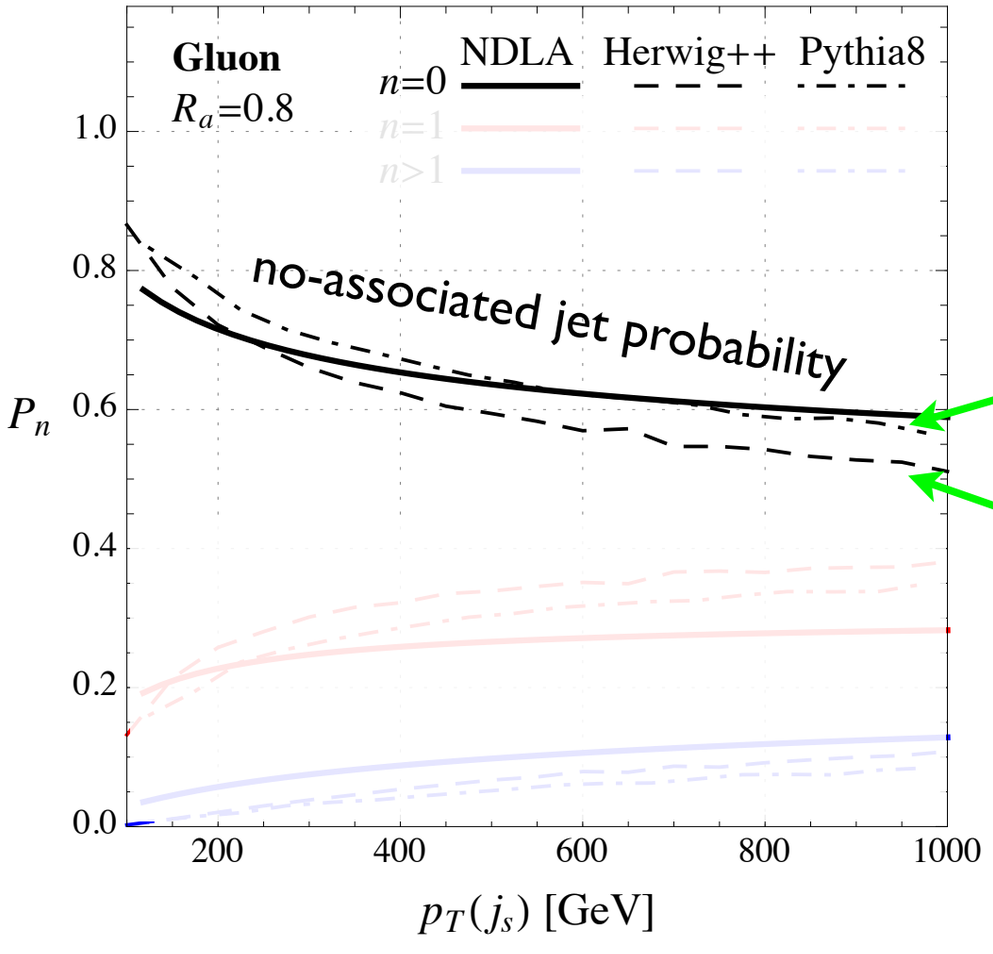
$$\ln C_1^{(\beta)} \sim \ln z + \underline{\beta \ln \theta}$$



Associated jet



B. Bhattacherjee, S. Mukhopadhyay,
M. M. Nojiri, YS, B. R. Webber, 1501.04794



Low no-associated jet probability

= Wide emissions

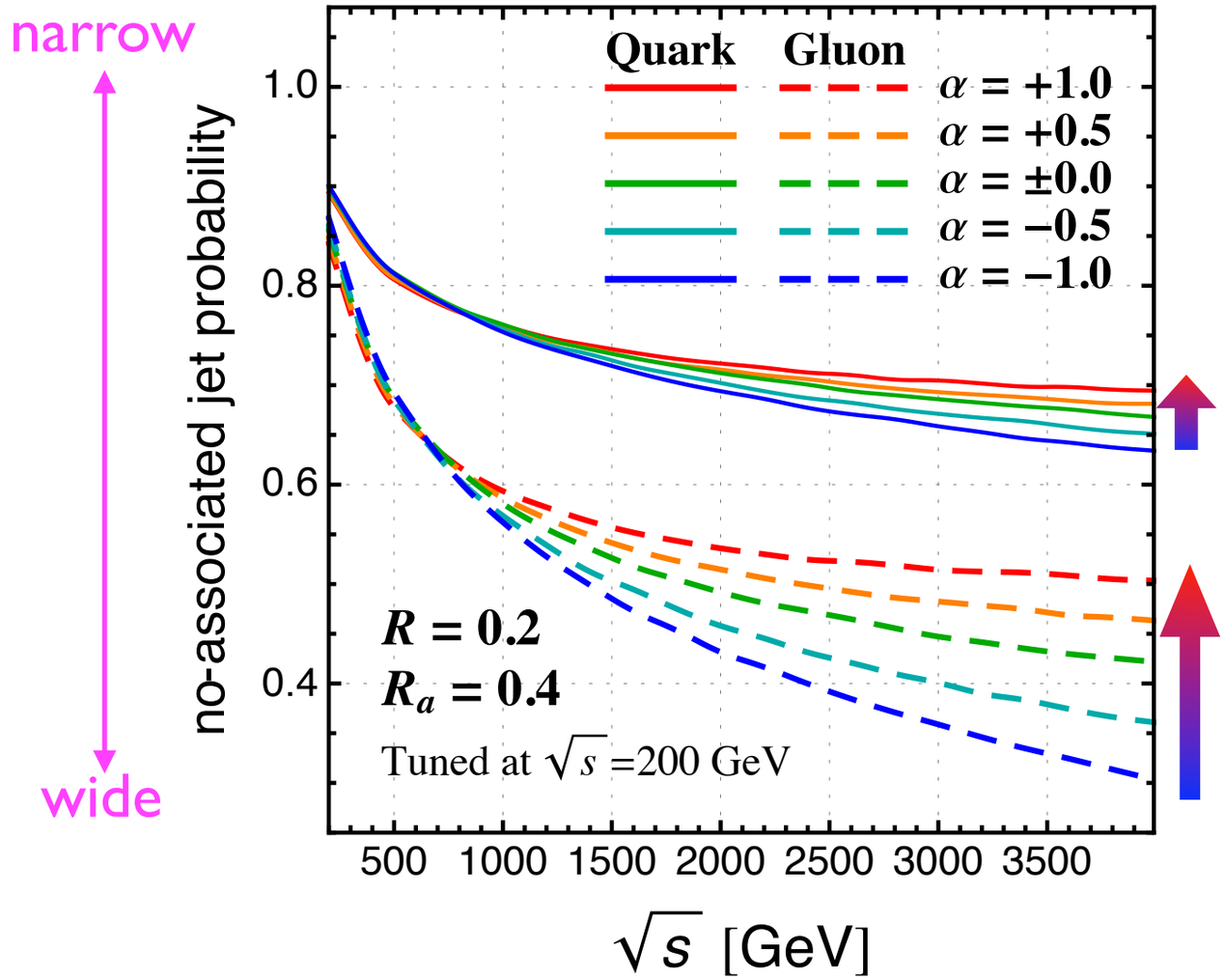
Pythia

Herwig

- Herwig predicts wide jets, while Pythia predicts narrower jets.

Associated jet

YS, 1505.xxxx



- The larger α is, the larger the no-associated jet probabilities become
- Angular ordered shower (α = −1) predicts most wide jets, while $p_\perp$ ordered shower (α = +1) predicts narrower jets
- This is other qualitative coincidens between Pythia and Herwig
- Wideness is tunable by α

Summary

- MC dependence on QCD jet substructure exist
- Study of evolutoin variable dependence on the jet substructure in the same modeling of parton shower
  - ➡ $Q_\alpha = [4z(1-z)]^\alpha q^2$
- The α-dependence on jet shape variables (class of C_1) and no-associated jet probability exist
- Two qualitative coincidences of the difference between Pythia and Herwig just by changing α
  - ➡ Value of tuned $\alpha_s(m_Z)$
  - ➡ Wideness of emissions in/around leading jets
    - The wideness is tunable by α

Back up

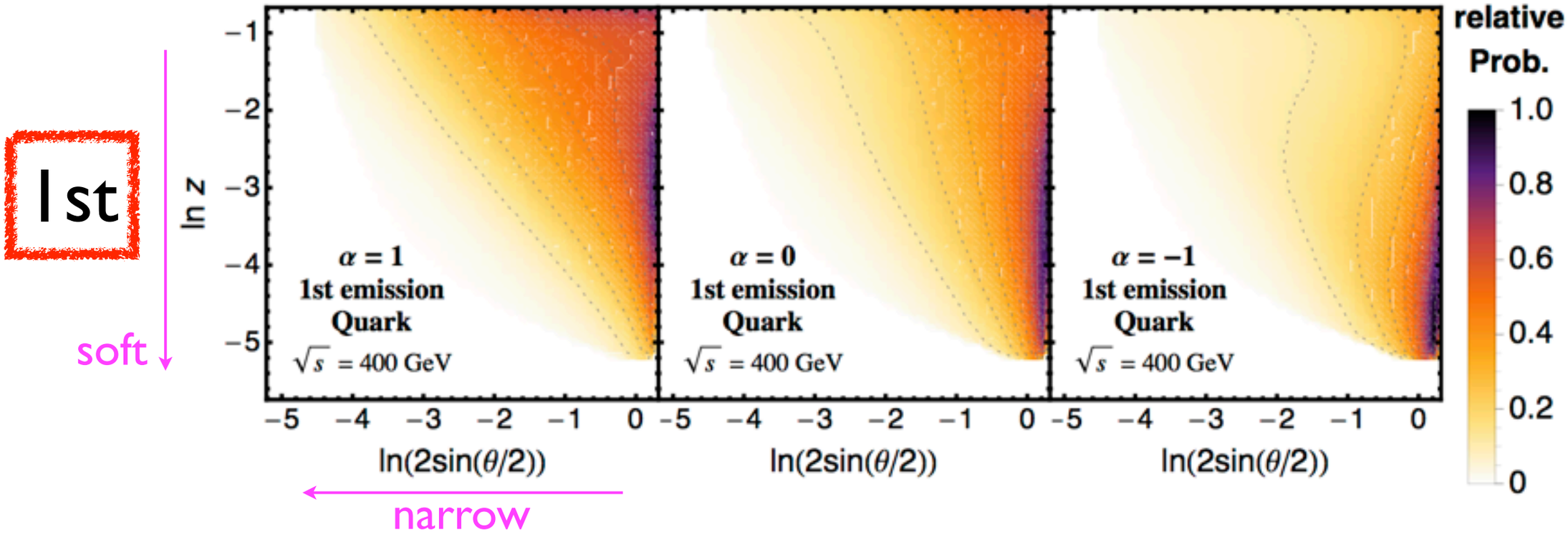
Belle II

Quick explanation to formalizm

- Using kinematics on Herwig++
- Traditional $1 \rightarrow 2$ branching
- 1-loop running constant
- Imposing anglular ordering by vetoing (excepting $\alpha = -1$)
- No hadronization
- Three tunable parameters
  - $\alpha_S(m_Z)$
  - m_{qg} : effective mass for massless partons (to avoid soft collinear singularity). k_T cut off.
  - r_{cut} : $(Q_{cut} / Q_{min}) = (Q_{cut} / 2m_{qg})$

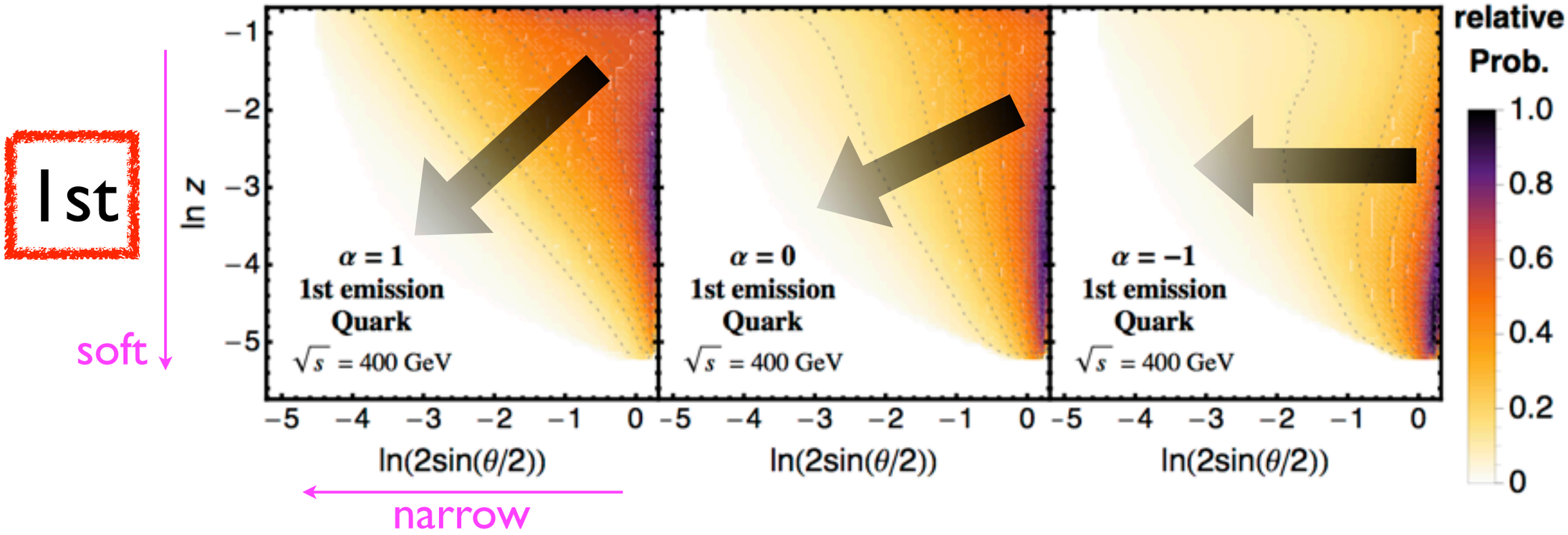
Radiation pattern (Quark)

YS, 1505.xxxx



Radiation pattern (Quark)

YS, 1505.xxxx

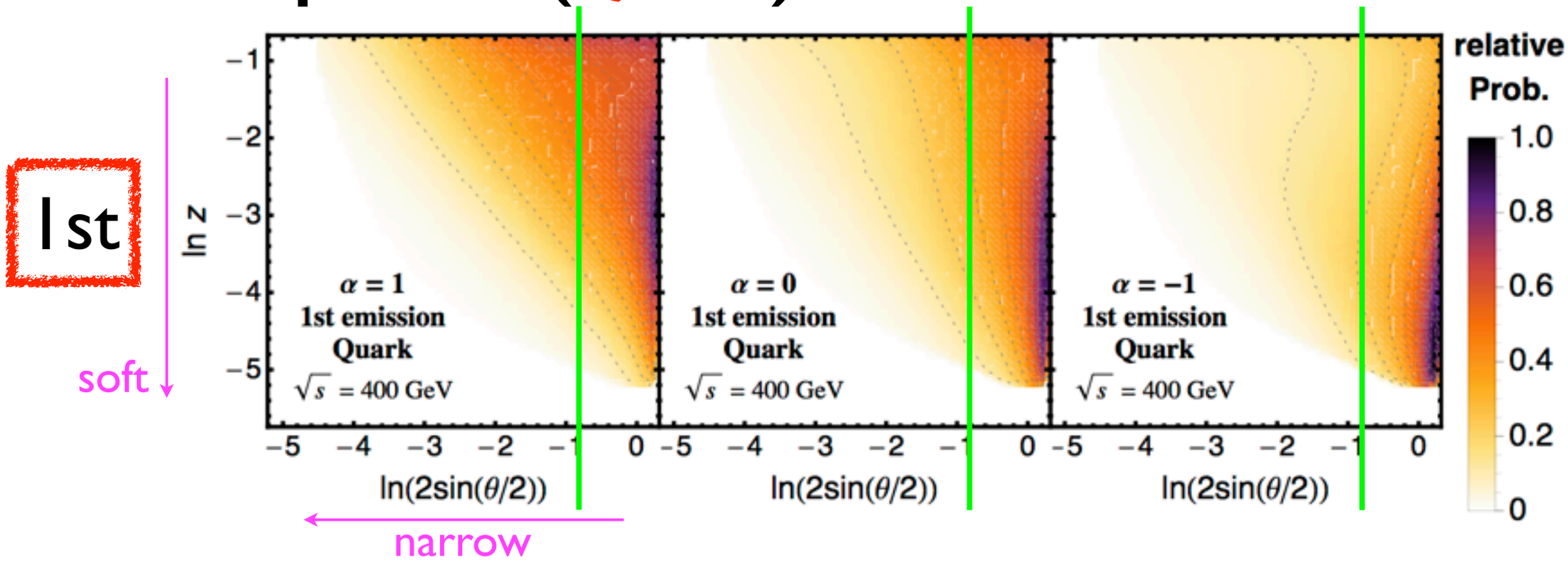


$p_\perp$-ordering

angular-ordering

Radiation pattern (Quark)

θ=0.4 YS, 1505.xxxx



- The 1st emissions are wide and soft for small α.
- The emissoins are negrected (or often vetoed in matching)

Radiation pattern (Quark)

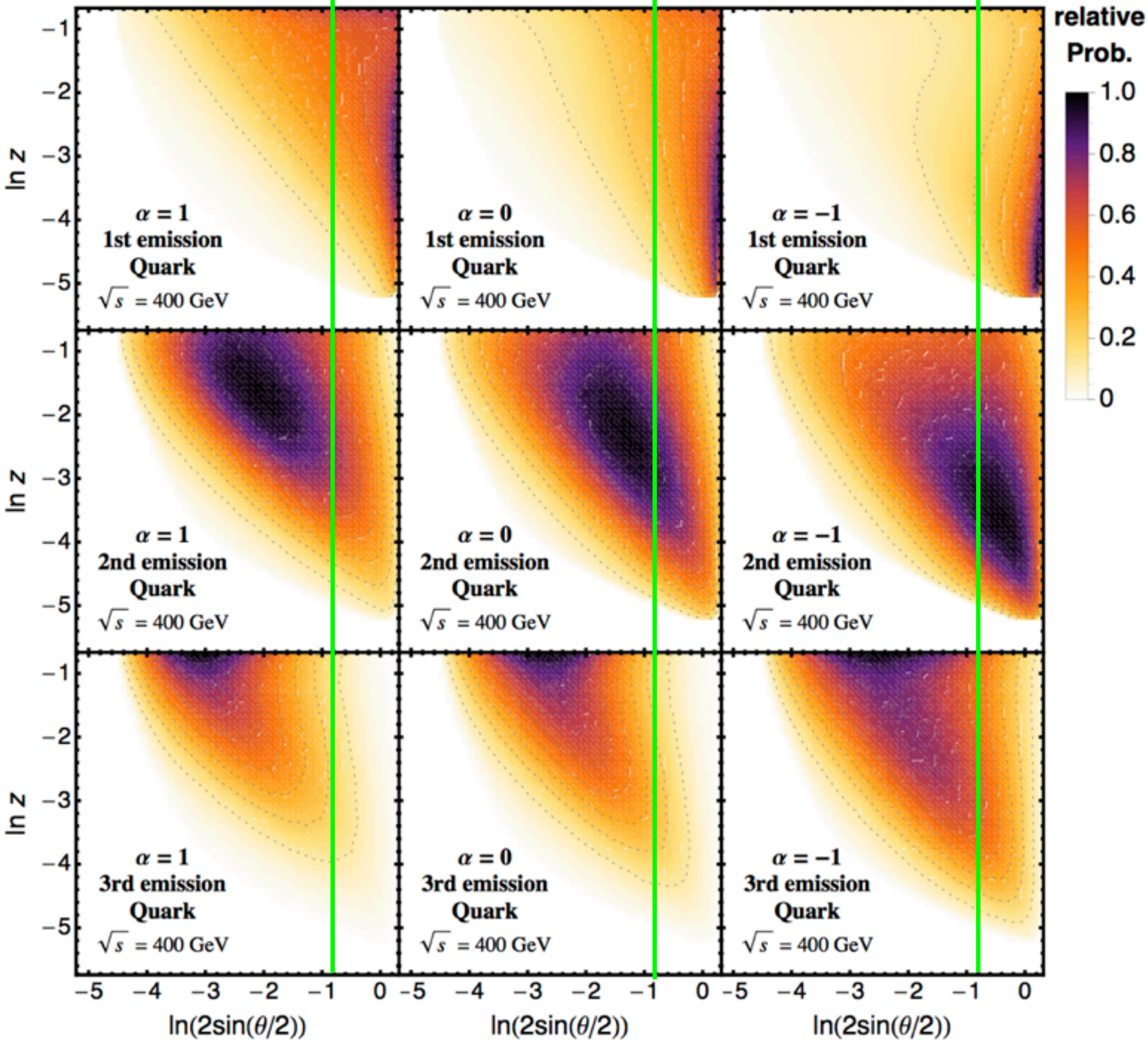
θ=0.4

YS, 1505.xxxx

1st

2nd

3rd



Radiation pattern (Gluon)

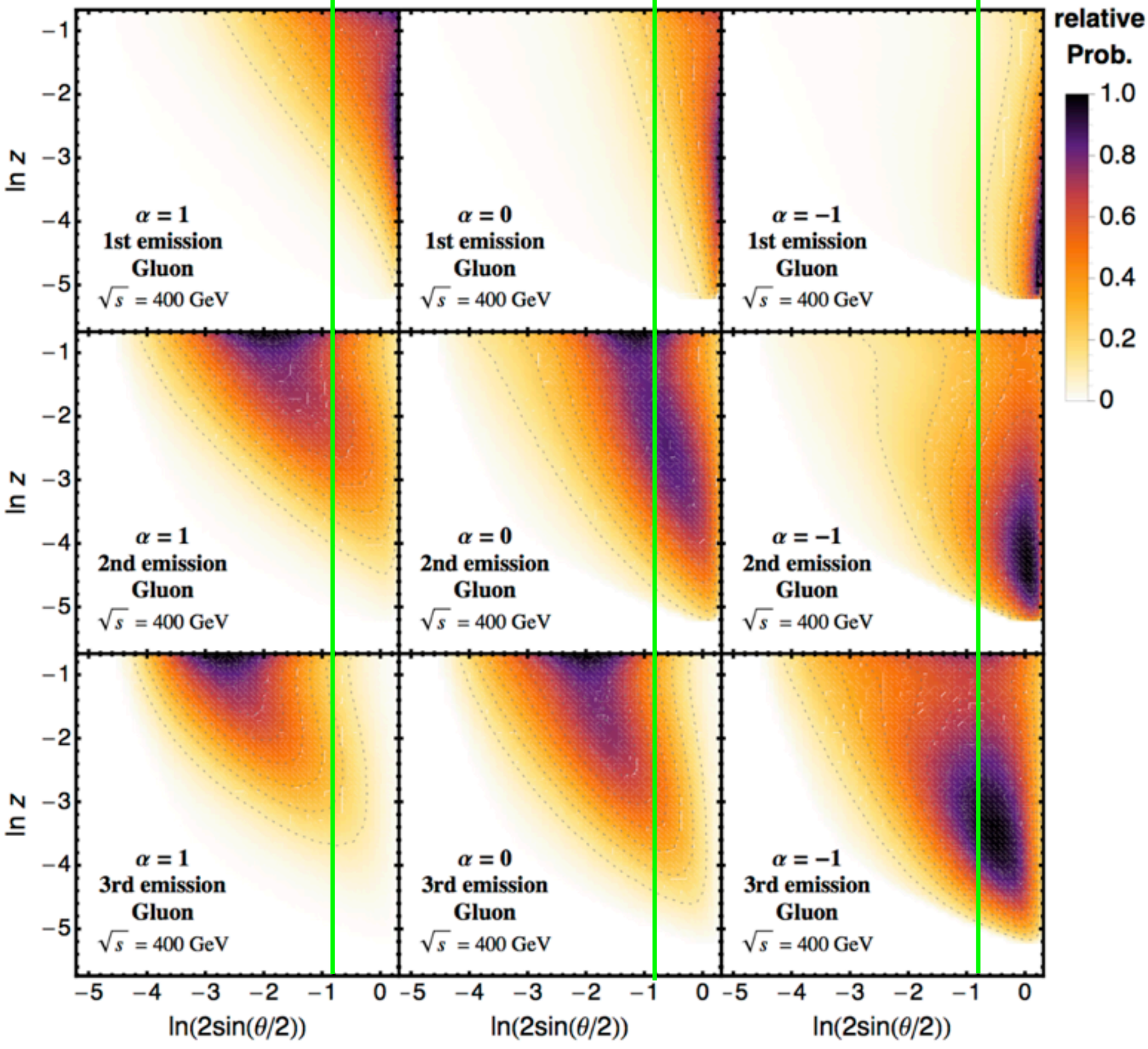
θ=0.4

YS, 1505.xxxx

1st

2nd

3rd



Observable

A. Larkoski, G. Salam, J. Thaler, JHEP06(2013)108
A. Larkoski, D. Neill, J. Thaler, JHEP04(2014)017

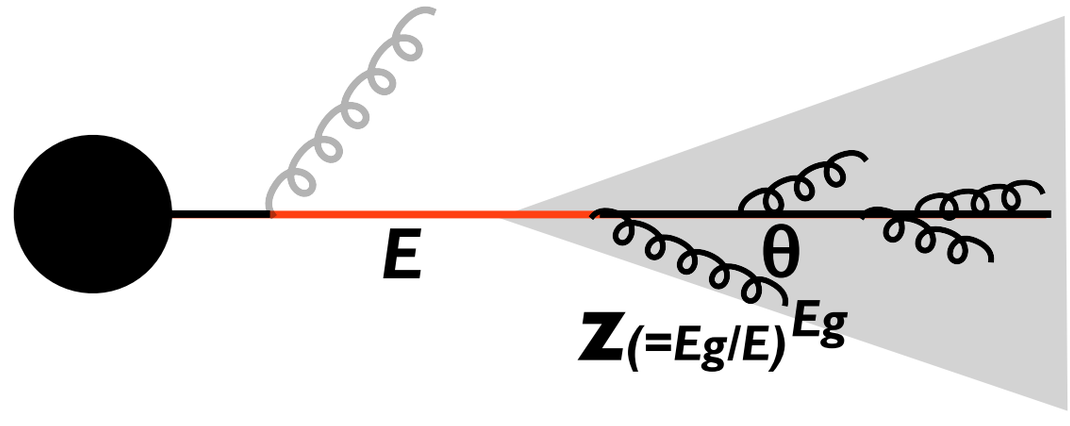
- One of well-studied jet shape variables

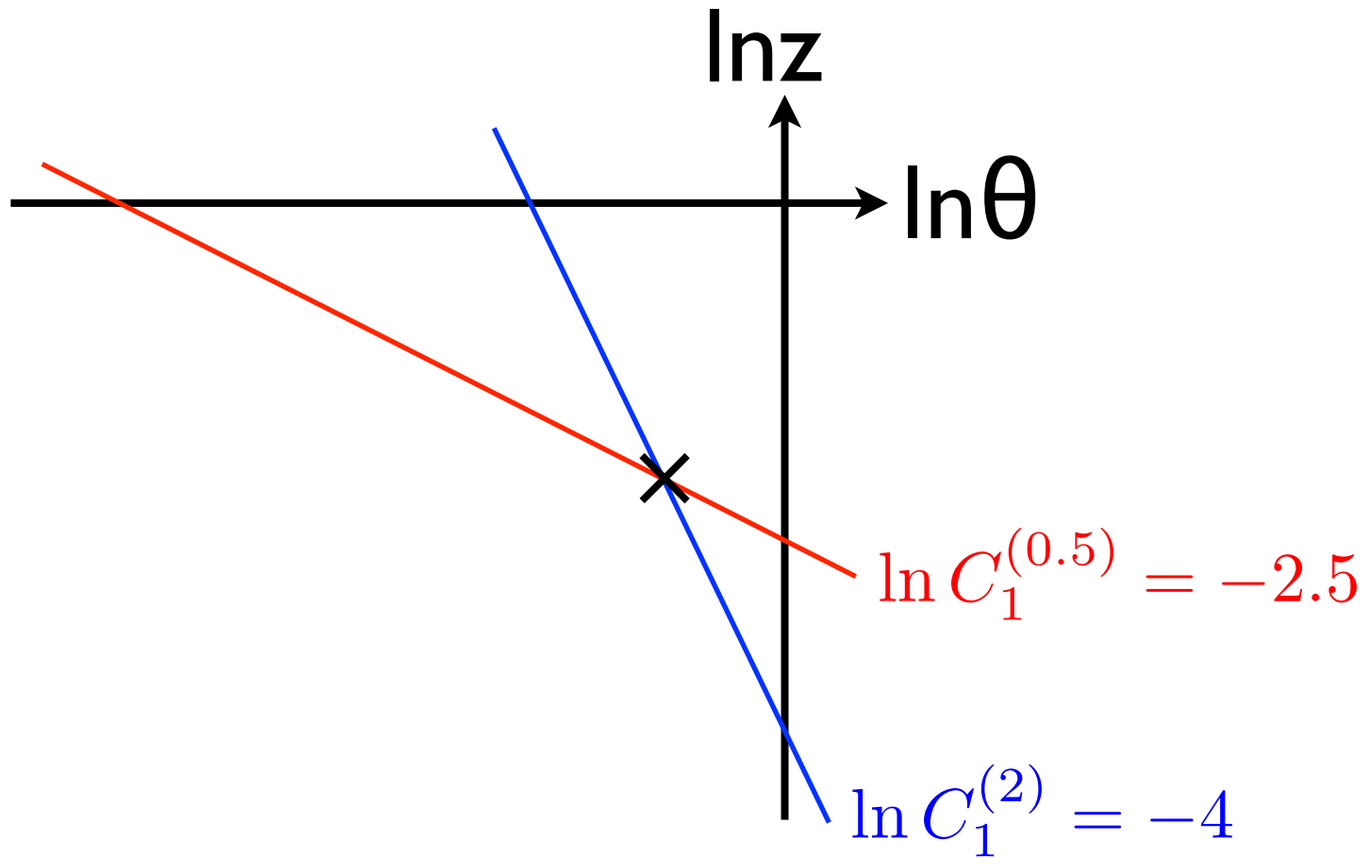
$$C_1^{(\beta)} = \sum_{i<j\in\text{jet}} \frac{E_i}{E_{\text{jet}}} \frac{E_j}{E_{\text{jet}}} \left(2\sin\frac{\theta_{ij}}{2}\right)^{\beta}$$

$$\sim z(1-z)\theta^{\beta}$$

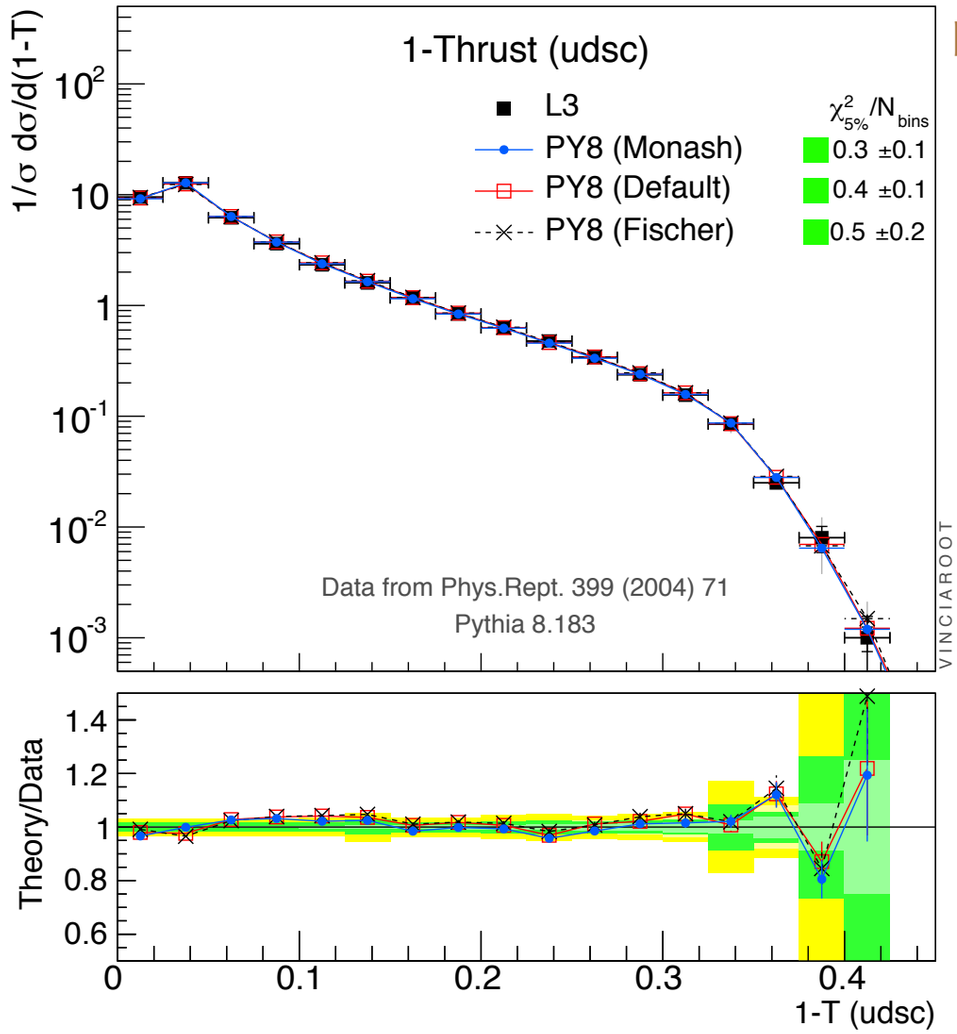
$$\sim z\theta^{\beta}$$

$$\ln C_1^{(\beta)} \sim \ln z + \beta \ln\theta$$





Tuning



P.Skands, S.Carrazza2, J.Rojo, 1404.5630

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- We use e+e- → qqbar events generated by Herwig++ with hadronization off as "*data*" alternatively.
- Three C_1 distributions for tuning (R=0.4, √s=200GeV)

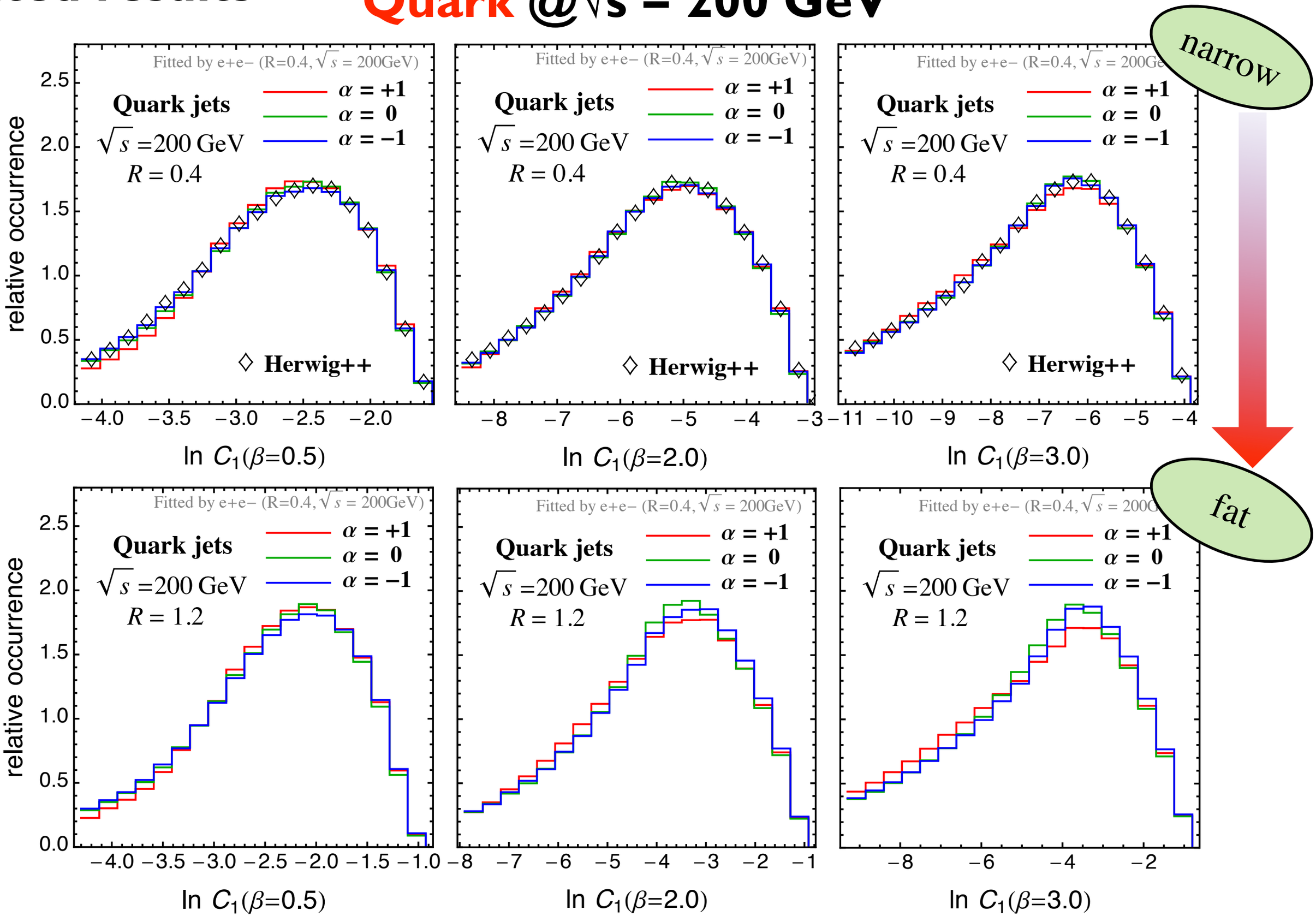
$$C_1^{(\beta)} = \sum_{i<j\in \mathrm{jet}(R)} \frac{E_i}{E_{\mathrm{jet}}} \frac{E_j}{E_{\mathrm{jet}}} \left(2\sin\frac{\theta_{ij}}{2}\right)^{\beta}$$

A. Larkoski, G. Salam, J. Thaler, JHEP06(2013)108
A. Larkoski, D. Neill, J. Thaler, JHEP04(2014)017

Fitted results

Quark @√s = 200 GeV

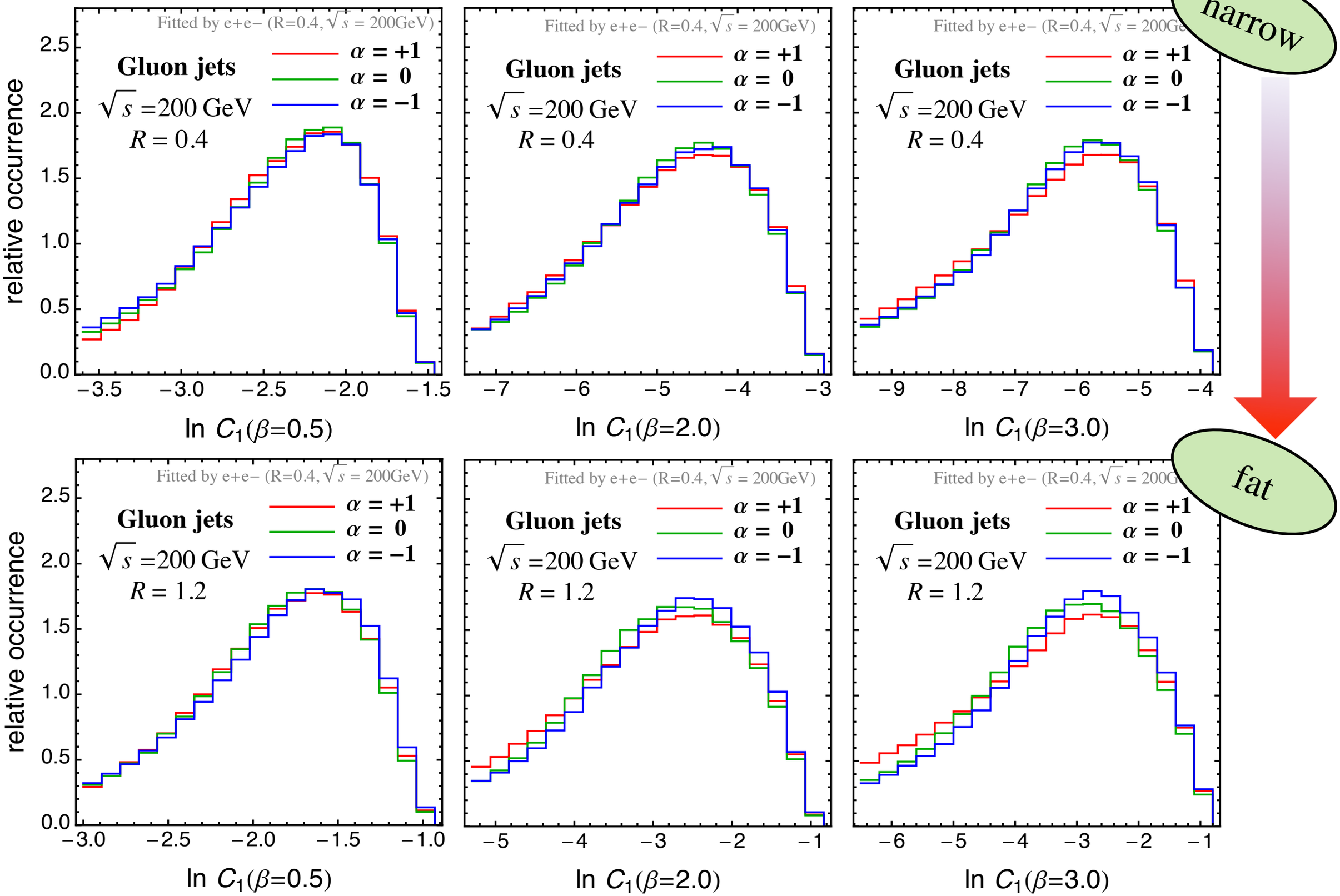
YS, 1505.xxxx



Fitted results

Gluon @√s = 200 GeV

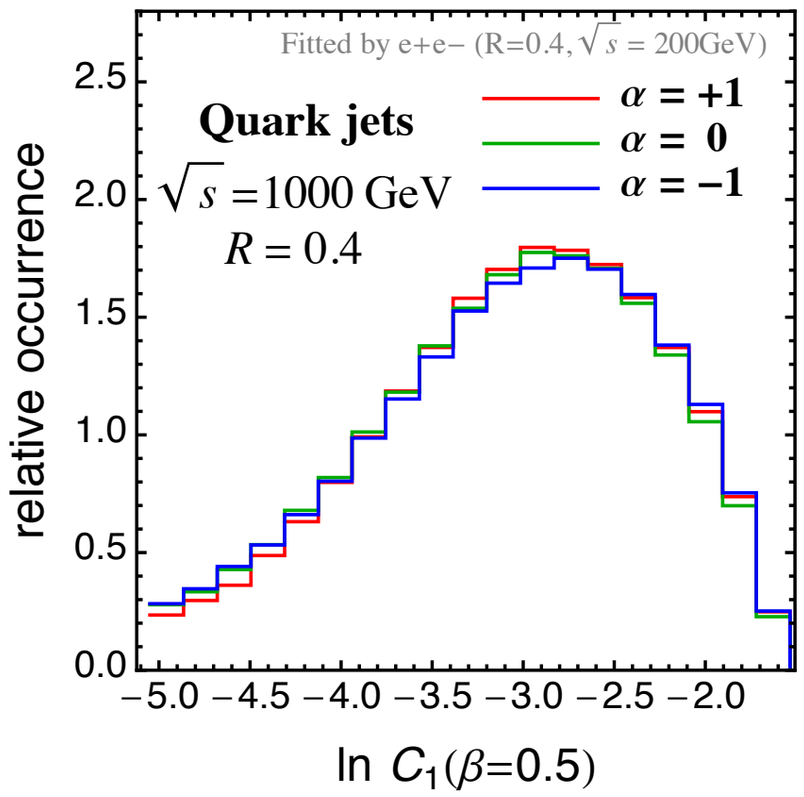
YS, 1505.xxxx

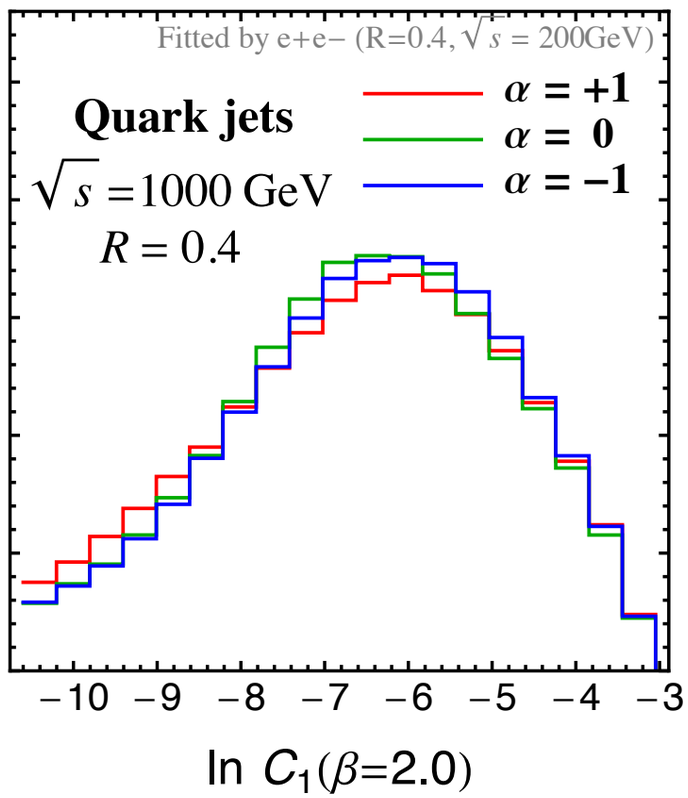


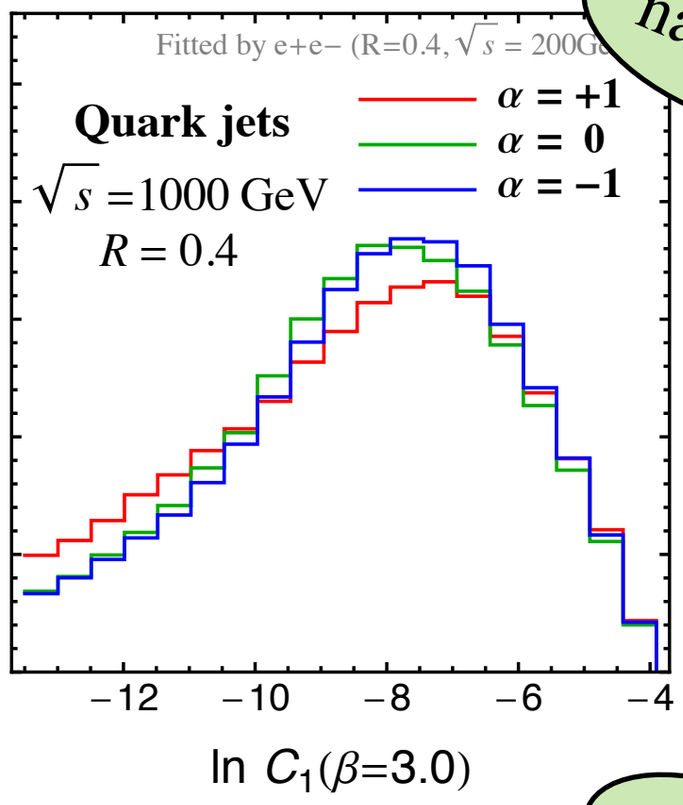
Fitted results

Quark @√s = 1000 GeV

YS, 1505.xxxx

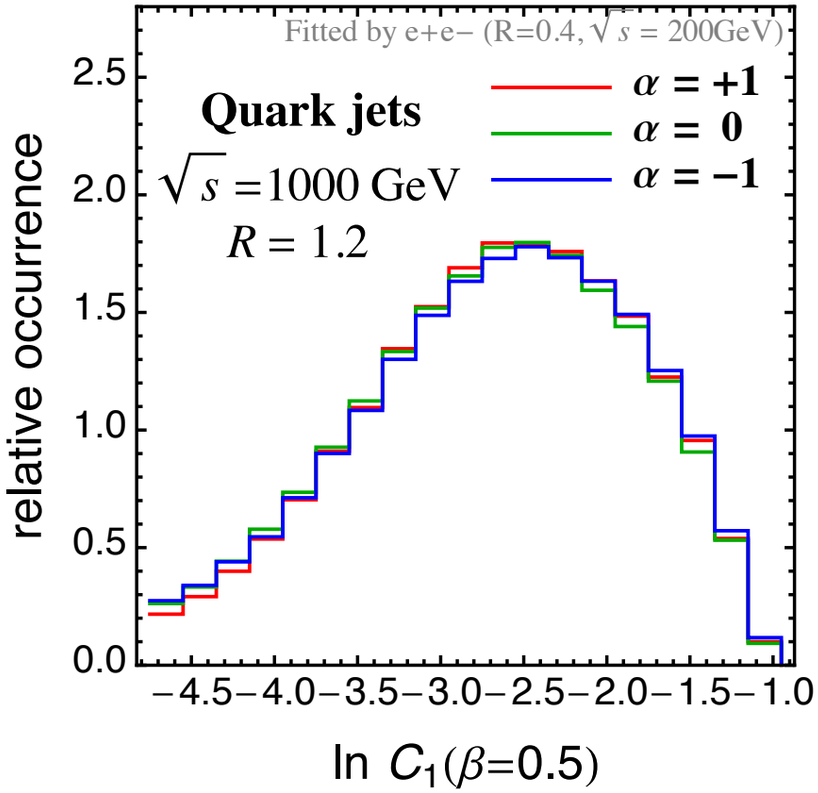


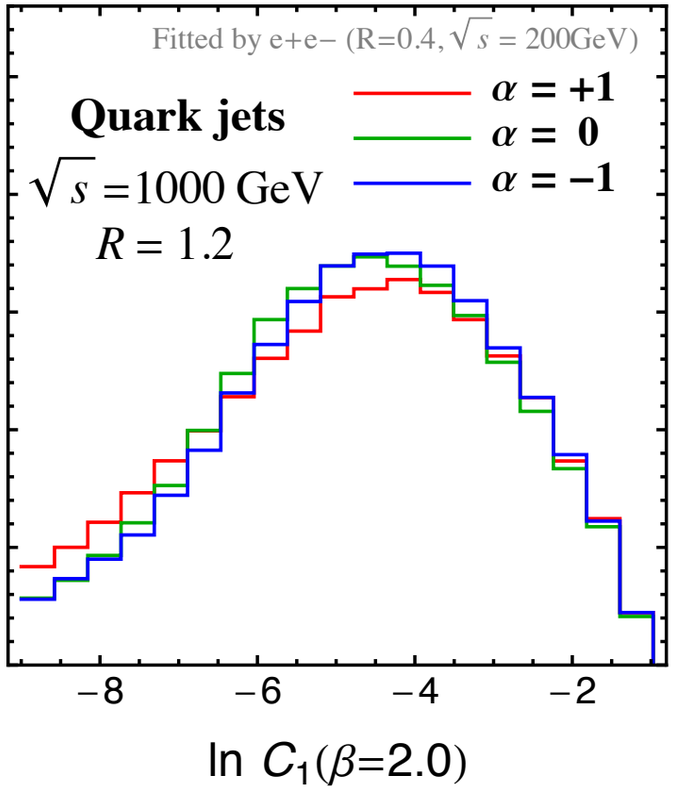


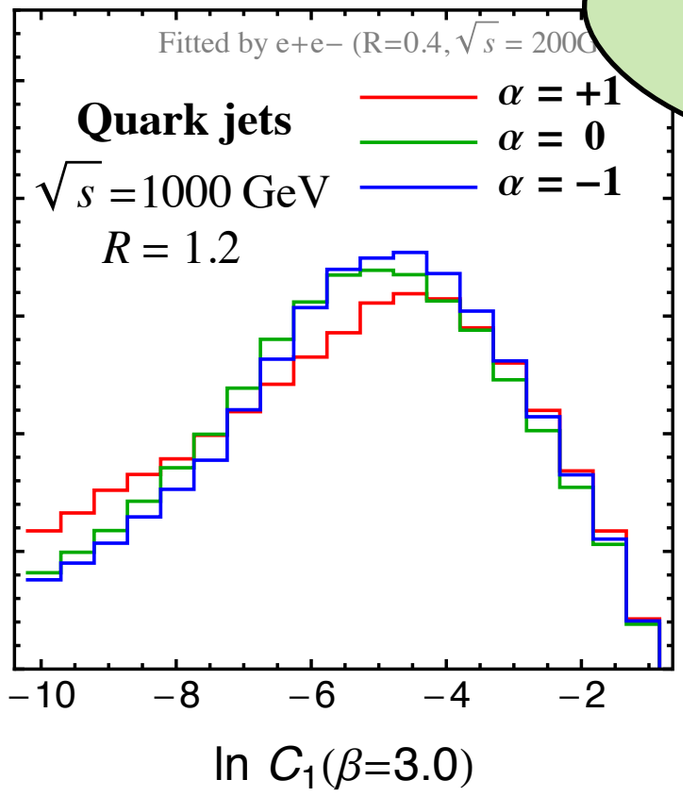


narrow

fat



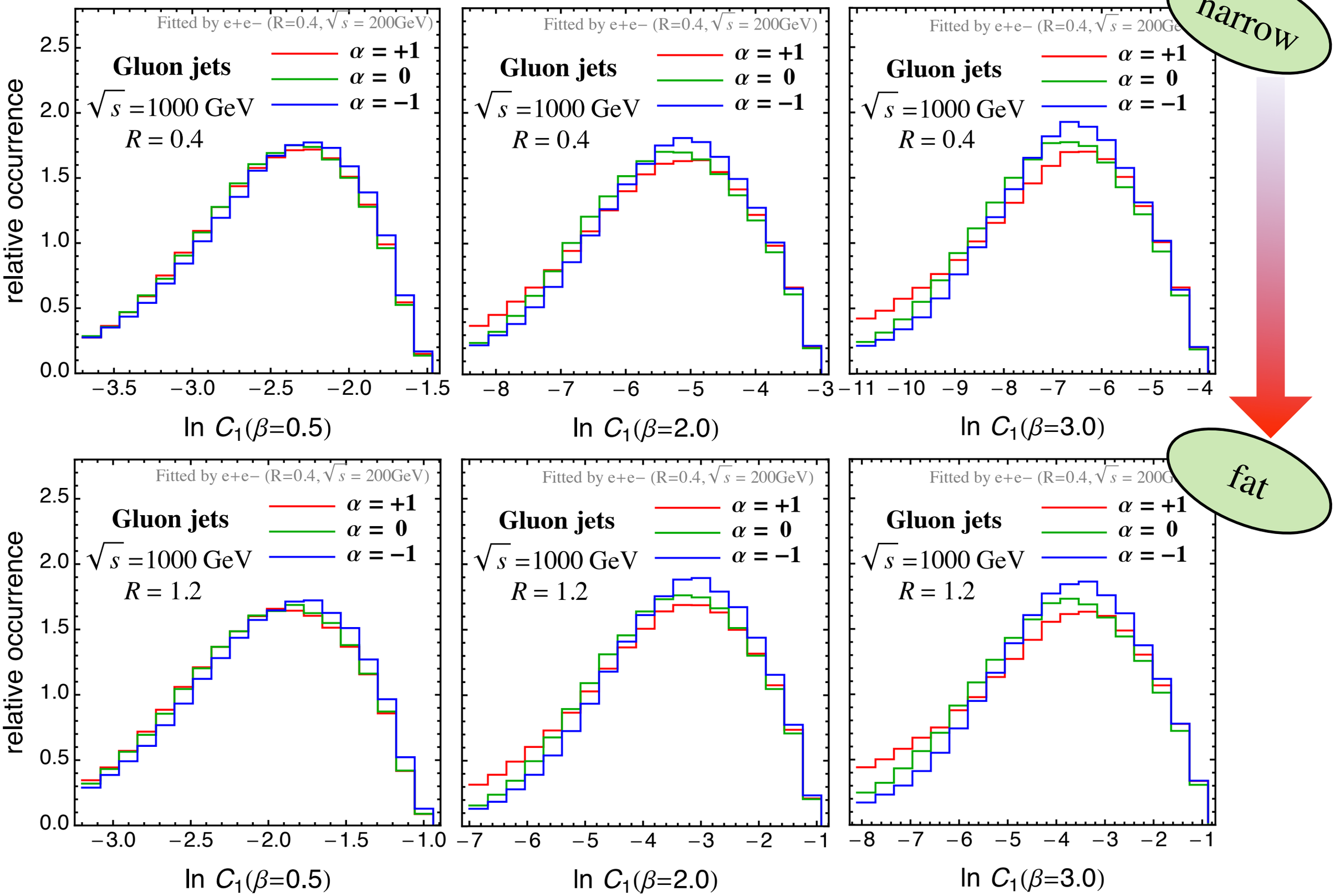




Fitted results

Gluon @√s = 1000 GeV

YS, 1505.xxxx

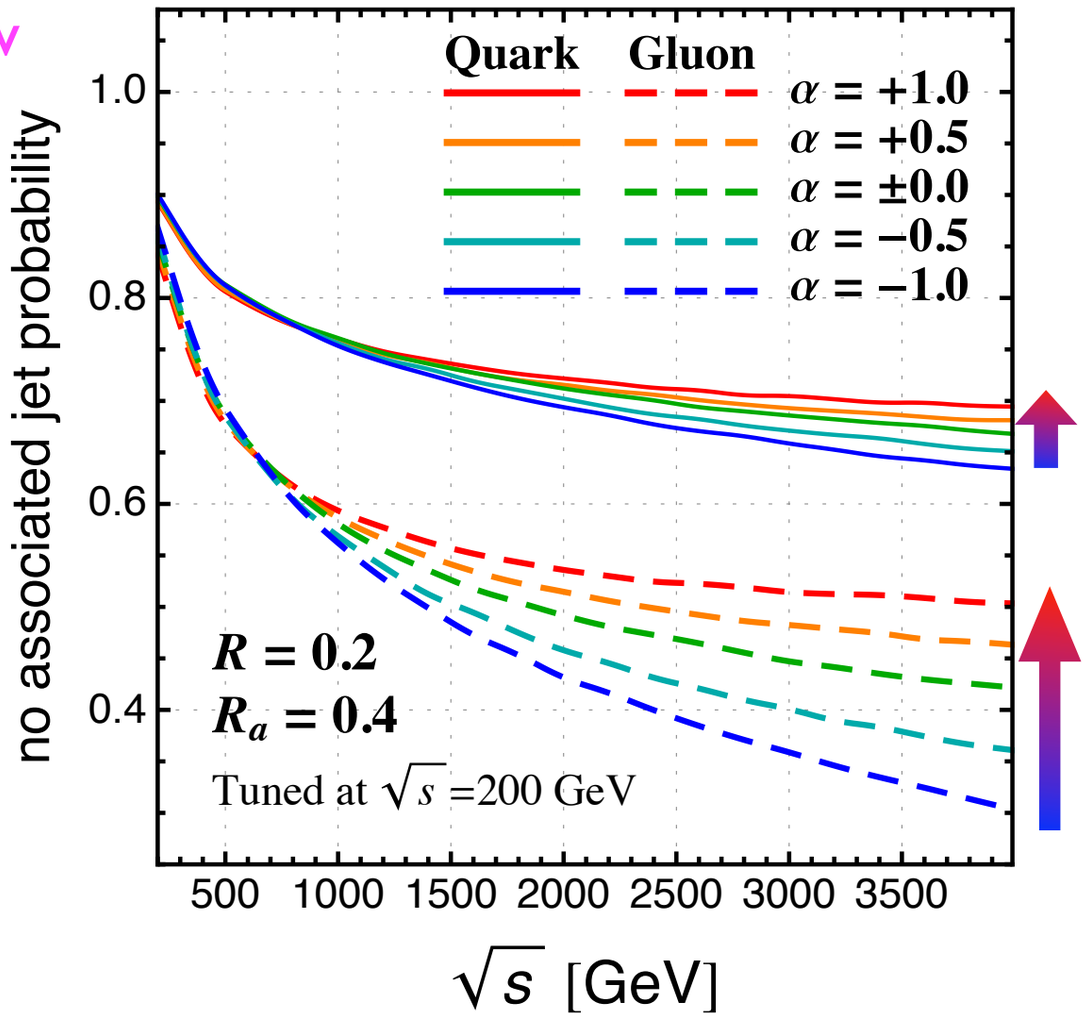


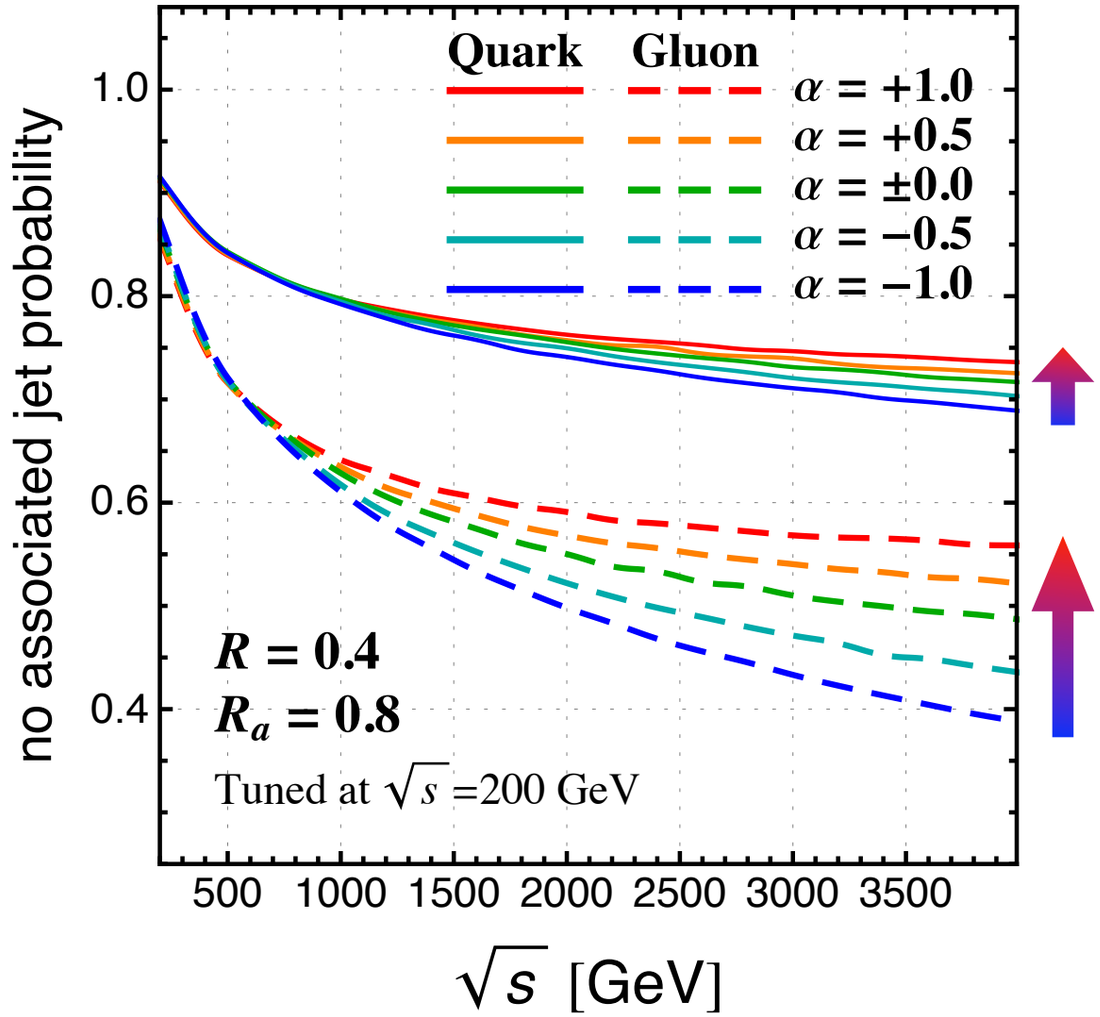
Associated jet

YS, 1505.xxxx

narrow

wide





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- Angular ordered shower (α = −1) predicts most wide jets, while $p_\perp$ ordered shower (α = +1) predicts narrower jets
- This is other qualitative coincidens between Pythia and Herwig
- Wideness is tunable by α

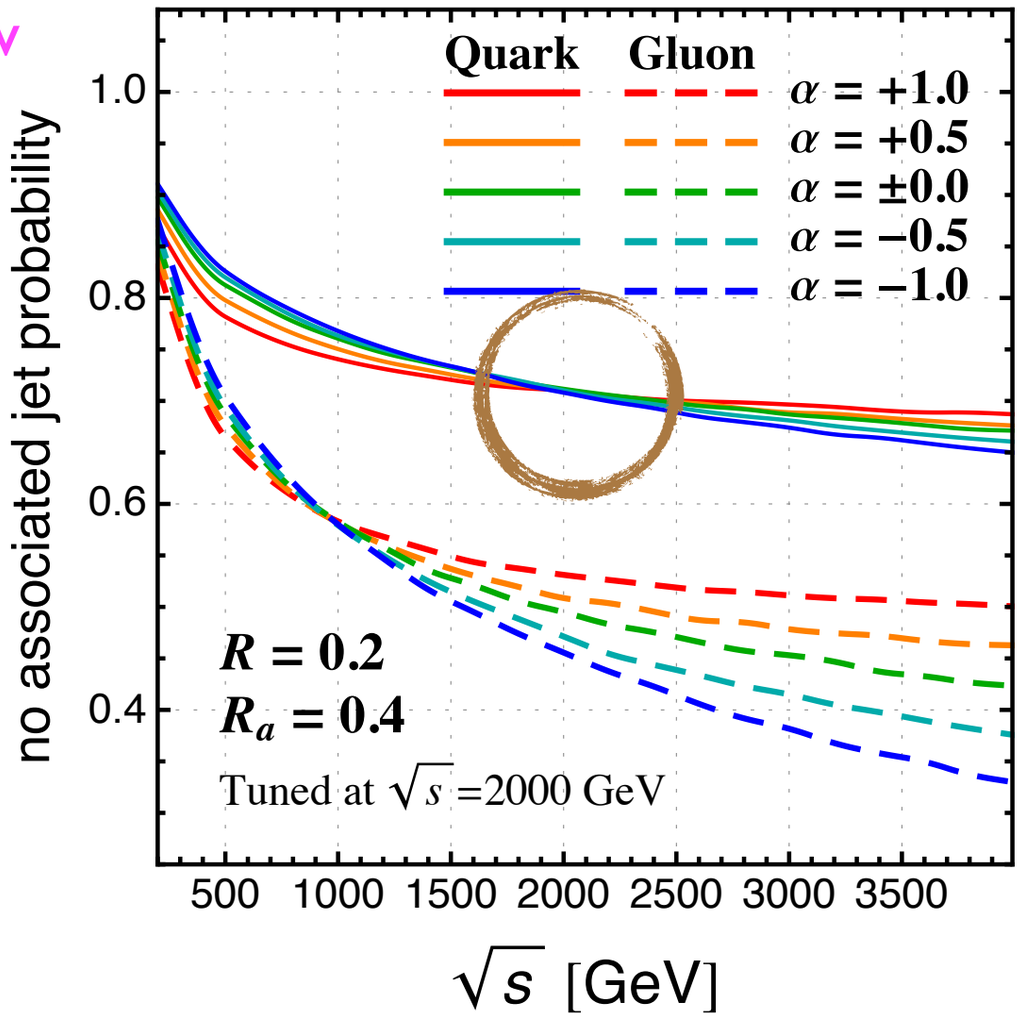
Associated jet

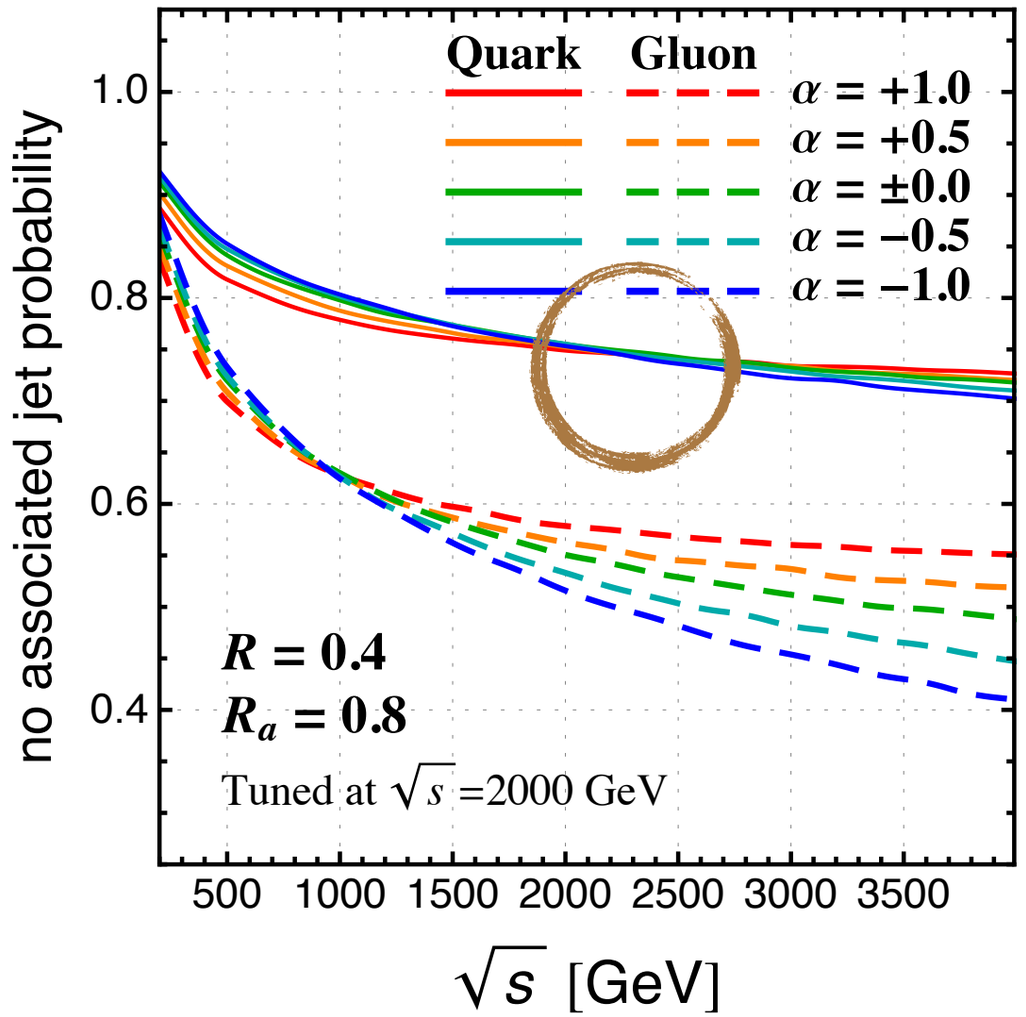
YS, 1505.xxxx

Tuned @$\sqrt{s}$ = 2000 GeV

narrow

wide





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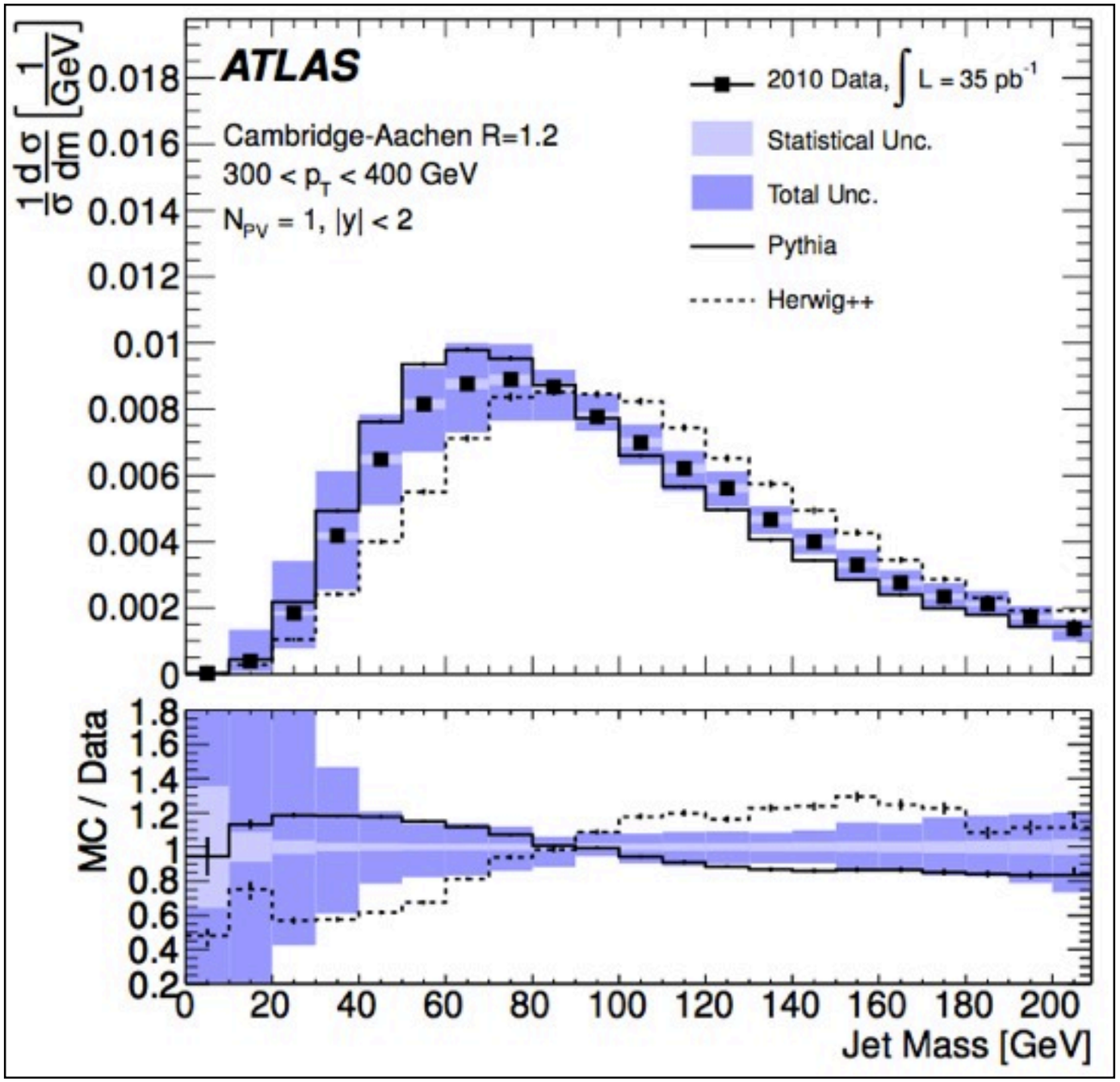
triggers

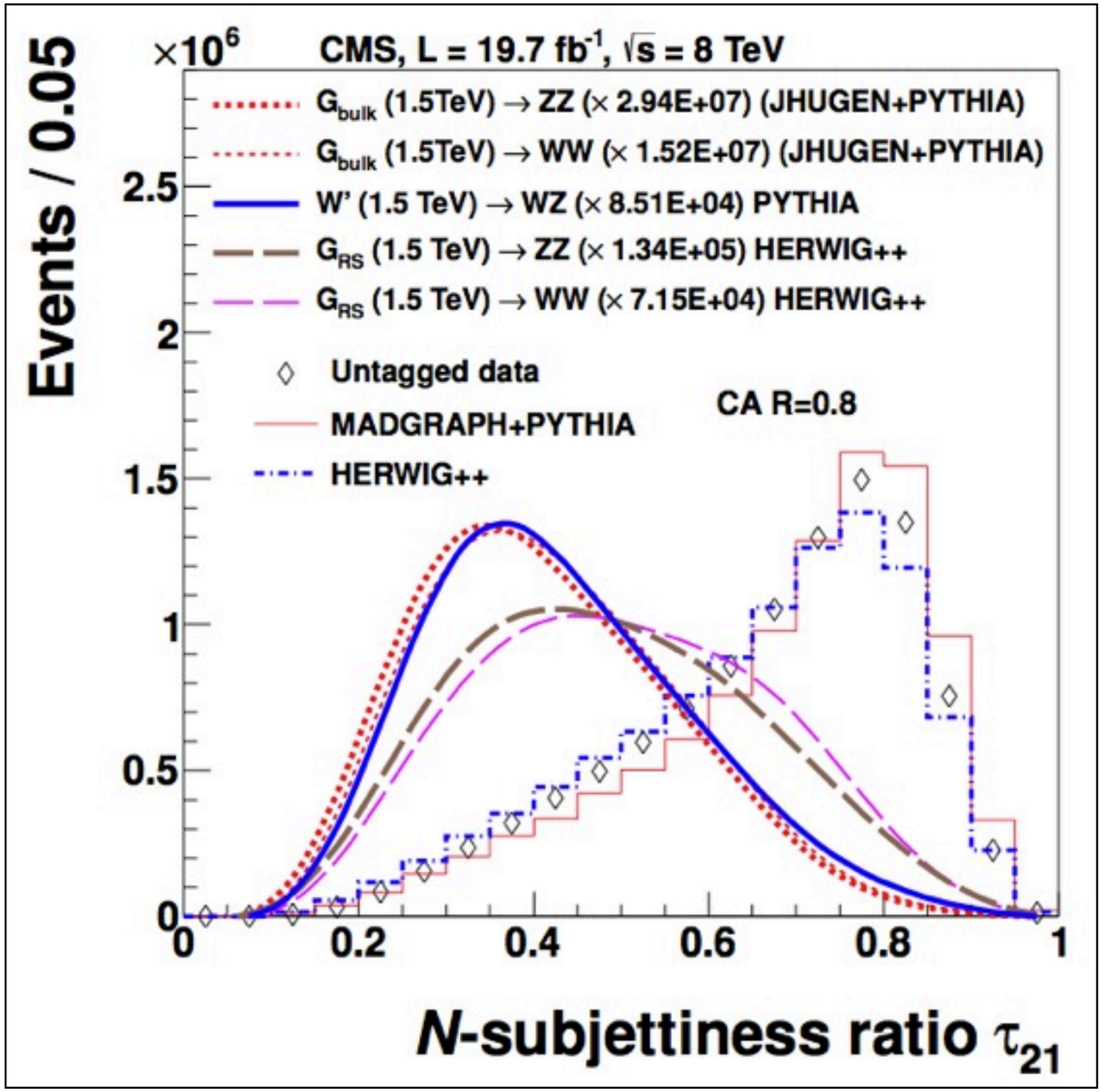
ATLAS, 1203.4606



- Nature live between Pythia and Herwig

triggers

CMS, 1405.1994



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