Hadronic Three Jet Production at Next–to–Leading Order

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- Motivation
- Methods
- Results and Applications
- Conclusions

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Motivation

- Why NLO?
  - Determine the Reliability of the Perturbative Calculation
  - Reduce Scale Dependence
  - Estimate Theoretical Uncertainty

Motivation

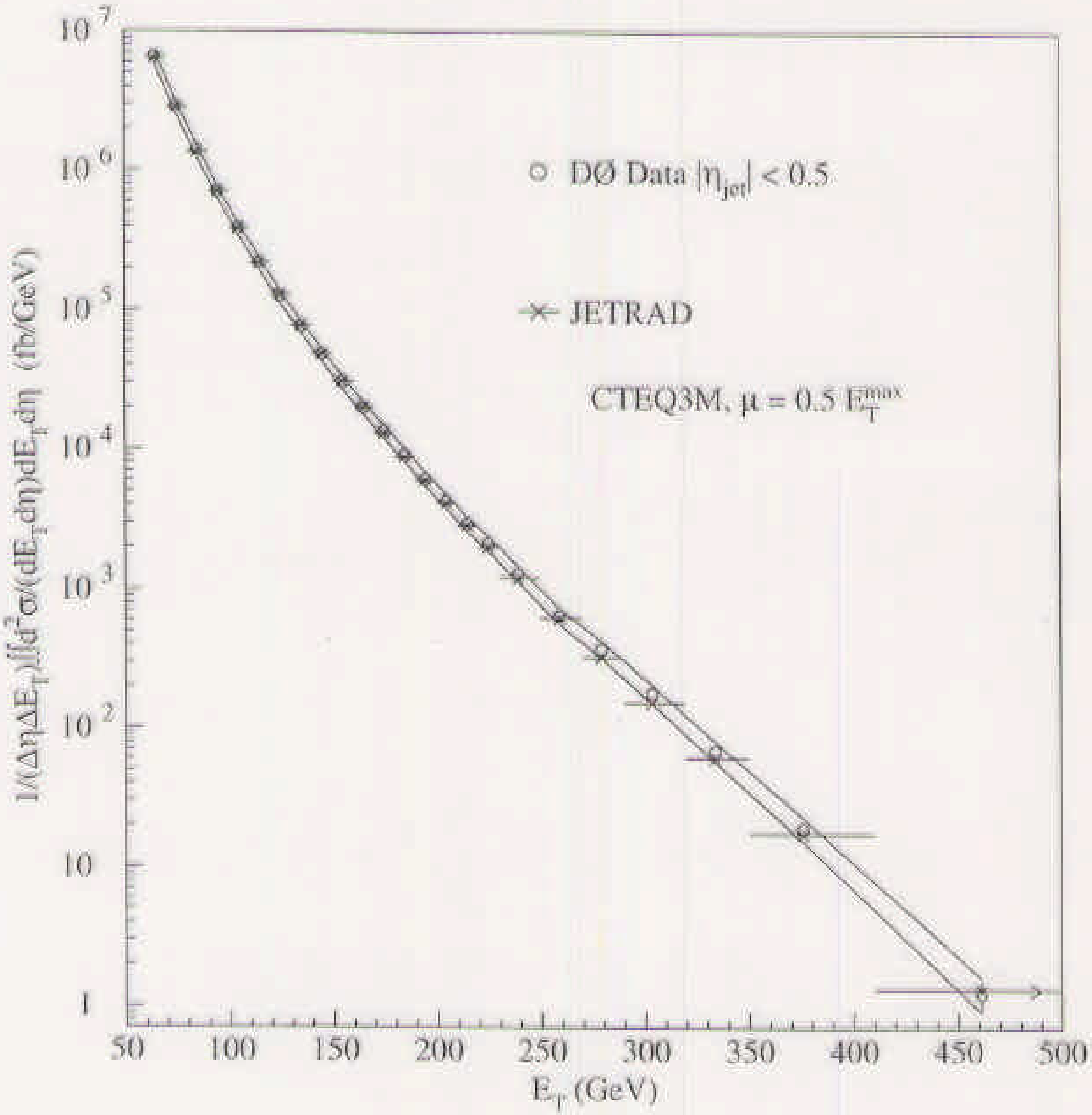
- Why NLO – * NOT to test QCD *

QCD is the theory of the strong interaction

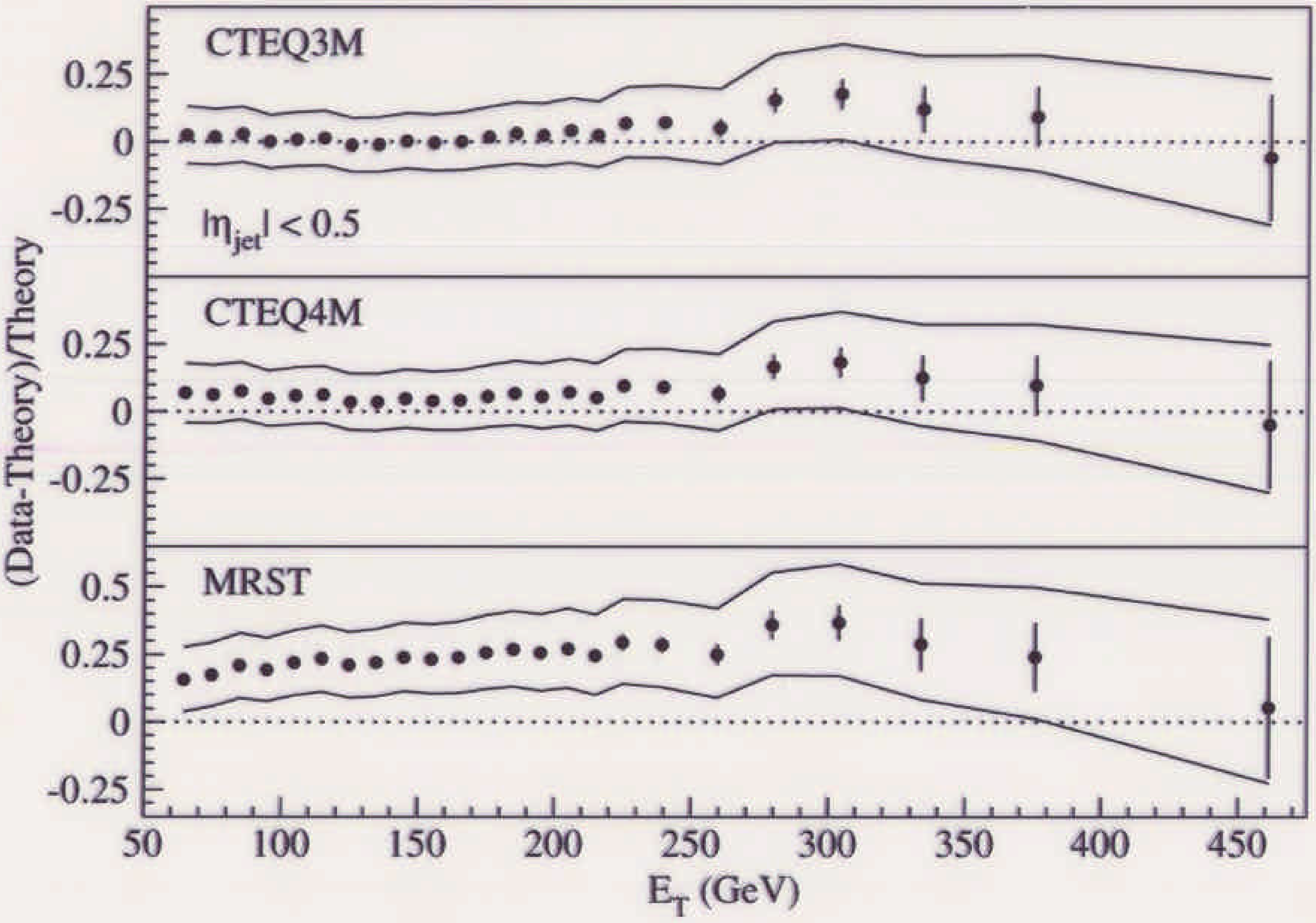
  - Asymptotic Freedom
  - Confinement
  - Sum Rules
  - One Jet Inclusive Spectrum

We can ...

  - Test limits of QCD
  - Look for new Physics in addition to QCD



10^7
10^6
10^5
10^4
10^3
10^2
10
1
50 100 150 200 250 300 350 400 450 500
E_T (GeV)
1/(ΔηΔE_T)∫(d²σ/(dE_T dη)dE_T dη (fb/GeV)
DØ Data |η_jet| < 0.5
JETRAD
CTEQ3M, μ = 0.5 E_T^max


CTEQ3M
CTEQ4M
MRST
$|\eta_{jet}| < 0.5$
(Data-Theory)/Theory
0.5
0.25
0
-0.25
50
100
150
200
250
300
350
400
450
E_T (GeV)

Why NLO Three Jets ?

A Wide Array of Phenomenological Applications

- Measure α_s
- Study Jet Algorithms
- Study Jet Structure and Shape
- Study Event Shape Variables
- Understand Backgrounds to New Physics
- Necessary Step Toward Calculating NNLO Two Jet Production

Methods - Matrix Elements

In QCD even tree-level multiparton amplitudes are complicated

1-loop matrix elements require a great deal of work and sophisticated techniques

$q\bar{q}Q\bar{Q}g$	Kunszt, Signer, Trocsanyi
$q\bar{q}ggg$, $ggggg$	Bern, Dixon, Kosower

Methods: IR Singularities

NLO 3 Jets combines:

2 –> 3 Parton Processes to One Loop

and

2 –> 4 Parton Processes at Tree Level

Both Contributions are IR Singular
Only the Sum is Finite and Meaningful!

Methods: IR Singularities

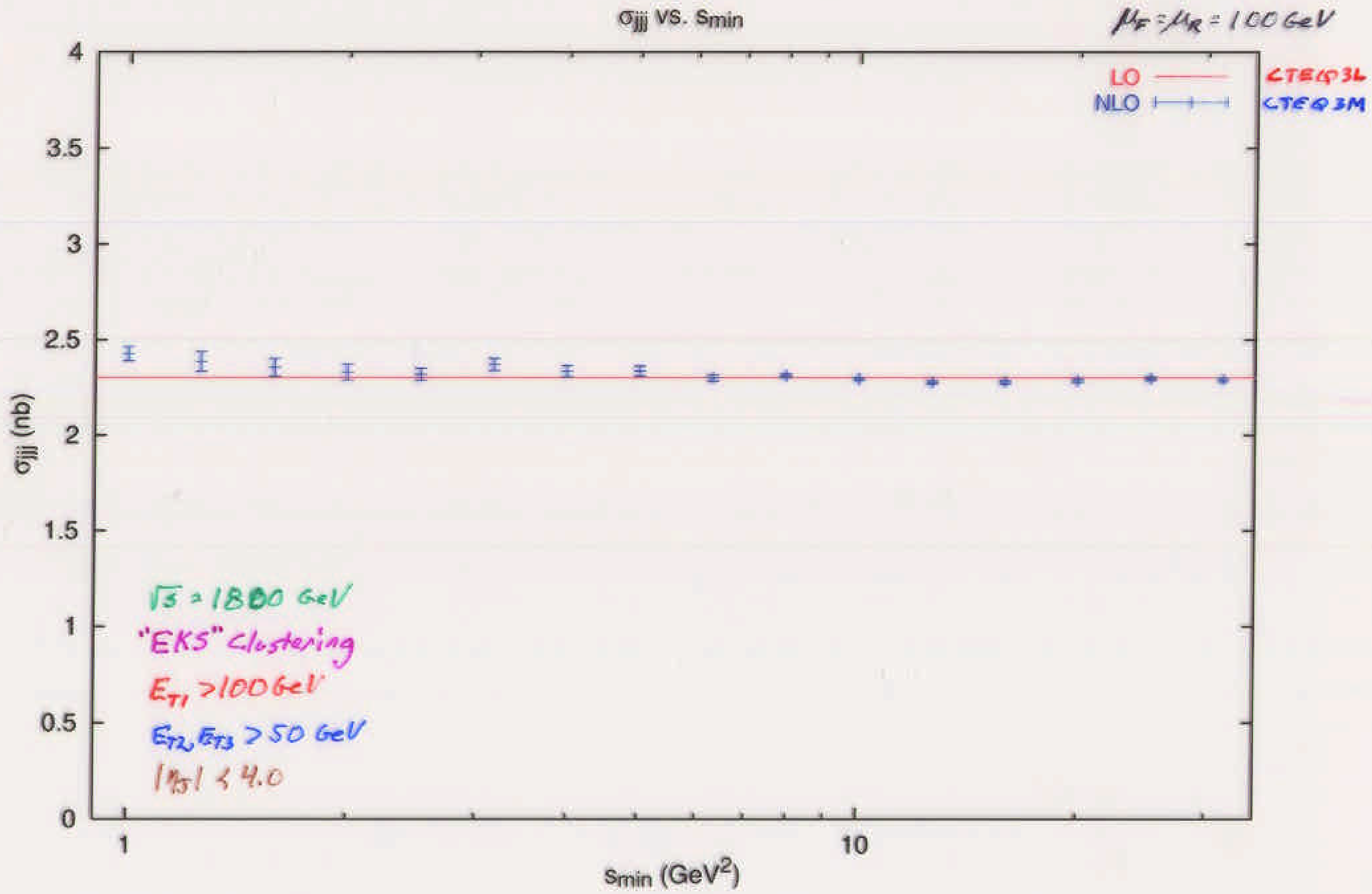
We impose an unphysical resolution criterion to reorganize the calculation and permit numerical integration

We use the subtraction–improved phase space slicing algorithm with resolution criterion

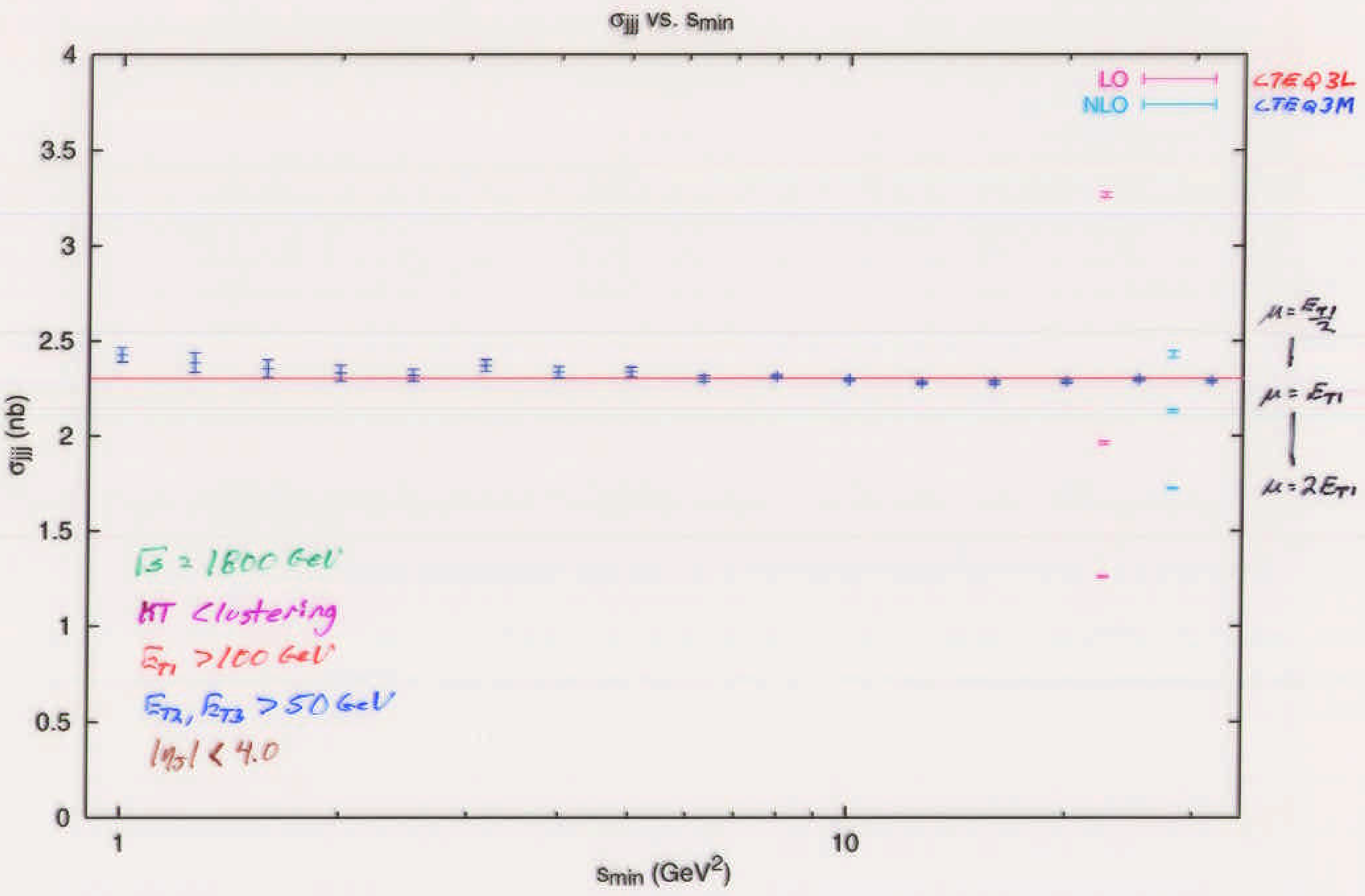
$$s_{ij} = 2E_iE_j(1-\cos\theta_{ij}) > s_{min}$$

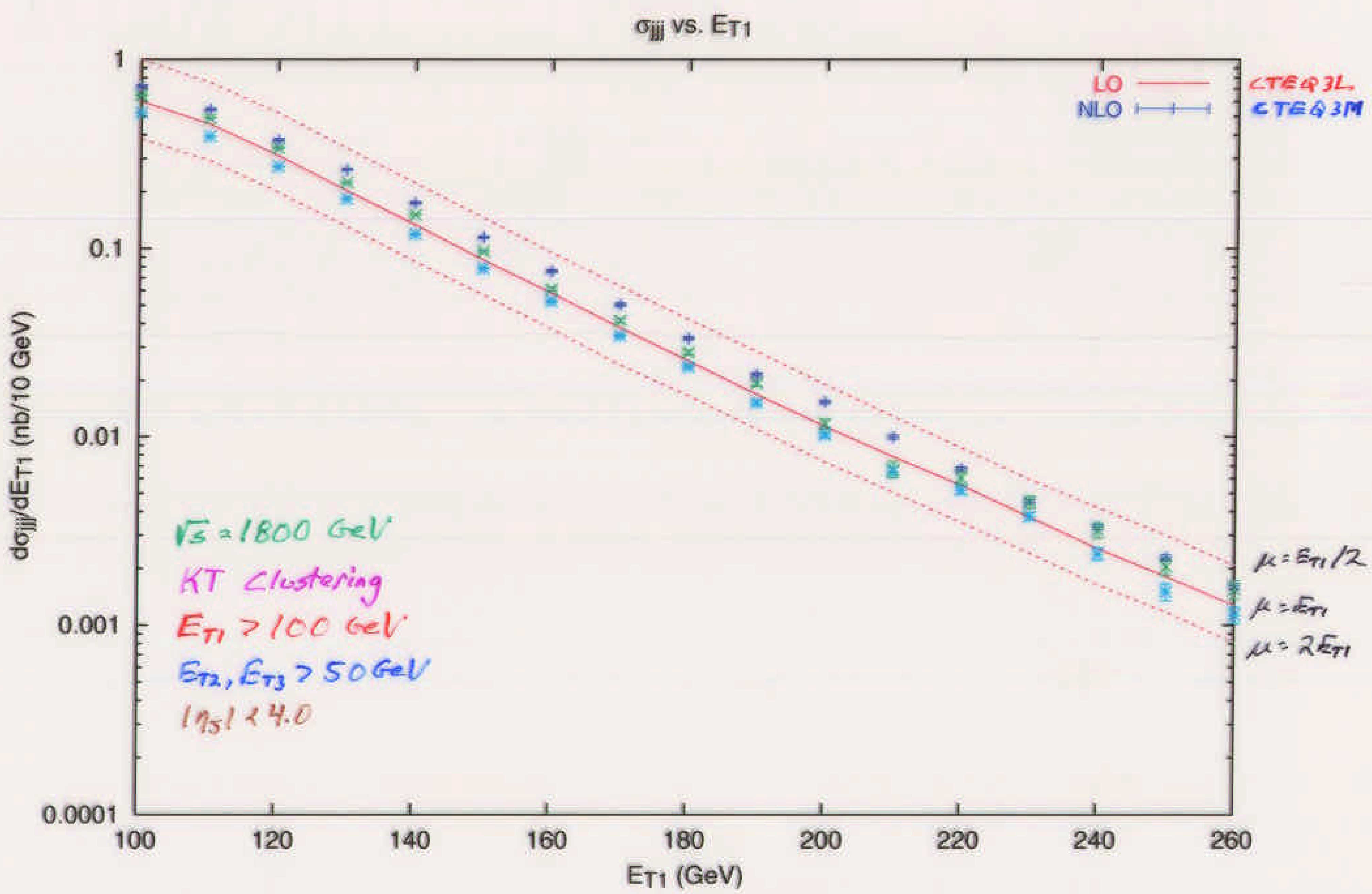
Since s_{min} is arbitrary, the cross section must be s_{min} independent.

Demonstration of s_{min} independence indicates that the IR cancellation has been properly carried out.

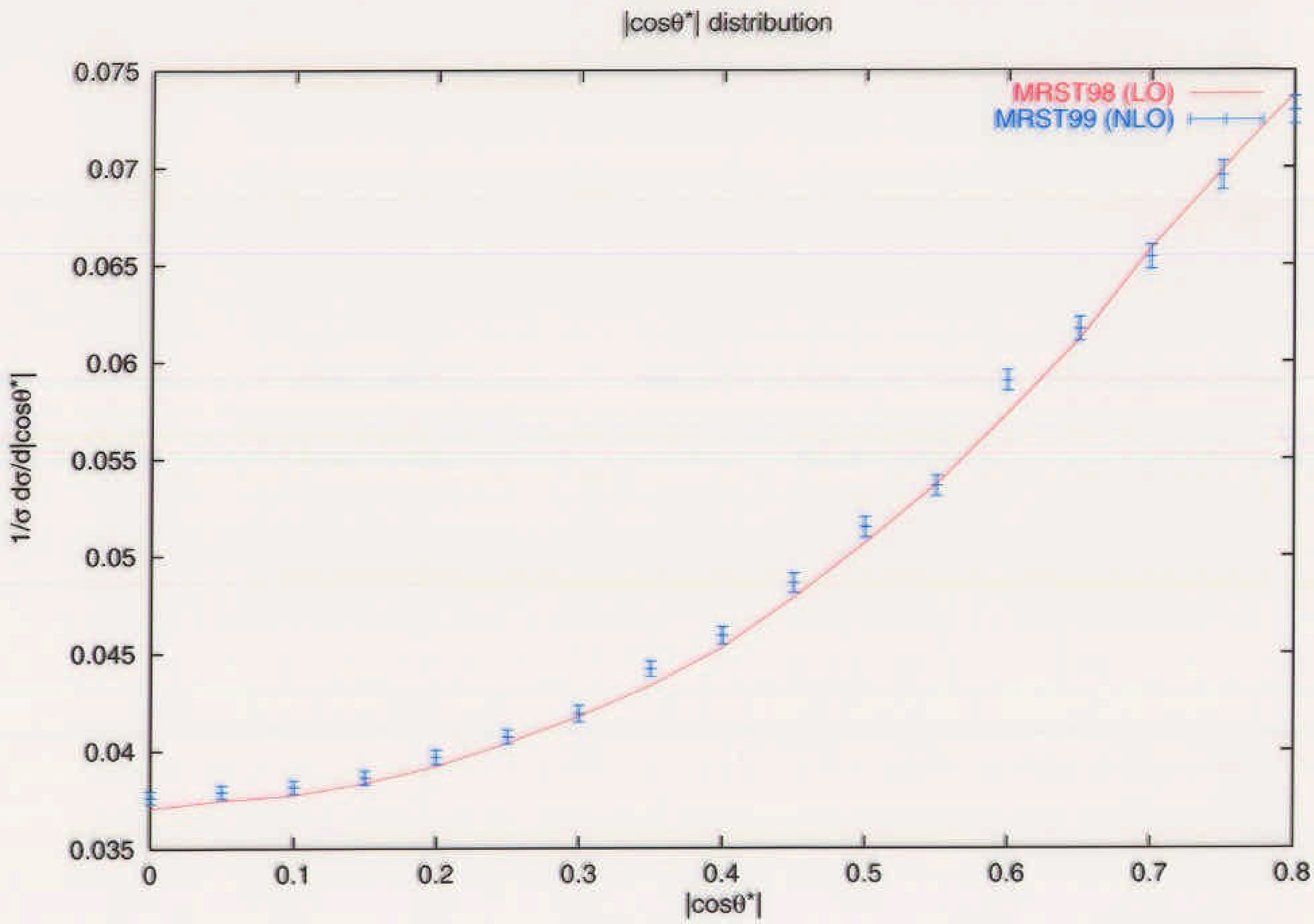


σjjj vs. Smin
$\mu_F = \mu_R = 100$ GeV
LO CTEQ3L
NLO CTEQ3M
σjjj (nb)
0
0.5
1
1.5
2
2.5
3
3.5
4
1
10
Smin (GeV^2)
$\sqrt{s} = 1800$ GeV
"EKS" Clustering
$E_{T1} > 100$ GeV
$E_{T2}, E_{T3} > 50$ GeV
$|\eta_J| < 4.0$

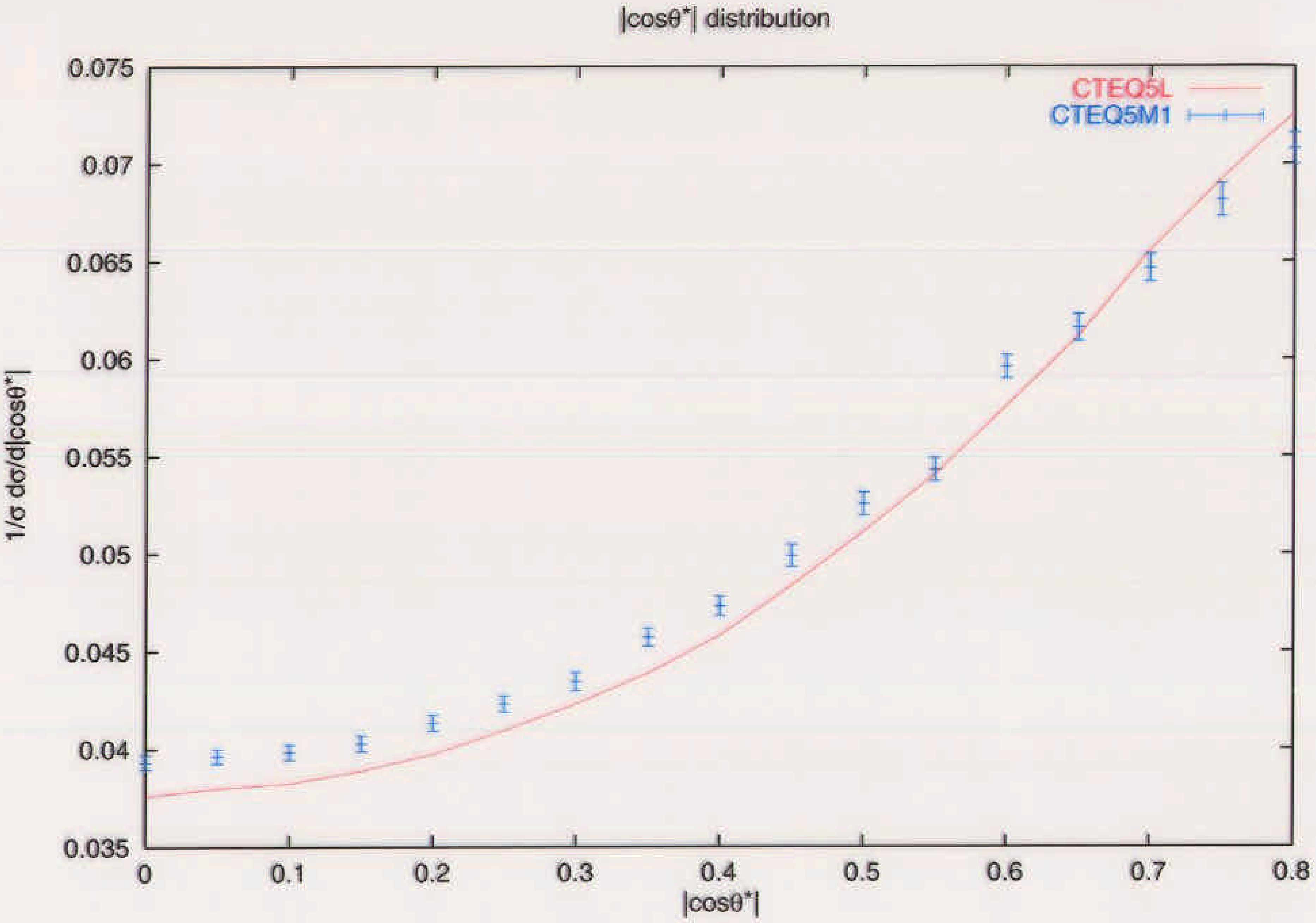

σjjj vs. smin
LO
NLO
CTEQ3L
CTEQ3M
μ = ET1/2
μ = ET1
μ = 2ET1
√s = 1800 GeV
KT Clustering
ET1 > 100 GeV
ET2, ET3 > 50 GeV
|ηJ| < 4.0
σjjj (nb)
smin (GeV2)
4
3.5
3
2.5
2
1.5
1
0.5
0
1
10


σjjj vs. ET1
dσjjj/dET1 (nb/10 GeV)
ET1 (GeV)
LO
NLO
CTEQ3L
CTEQ3M
√s = 1800 GeV
KT Clustering
ET1 > 100 GeV
ET2, ET3 > 50 GeV
|ηs| < 4.0
μ = ET1/2
μ = ET1
μ = 2ET1
1
0.1
0.01
0.001
0.0001
100
120
140
160
180
200
220
240
260

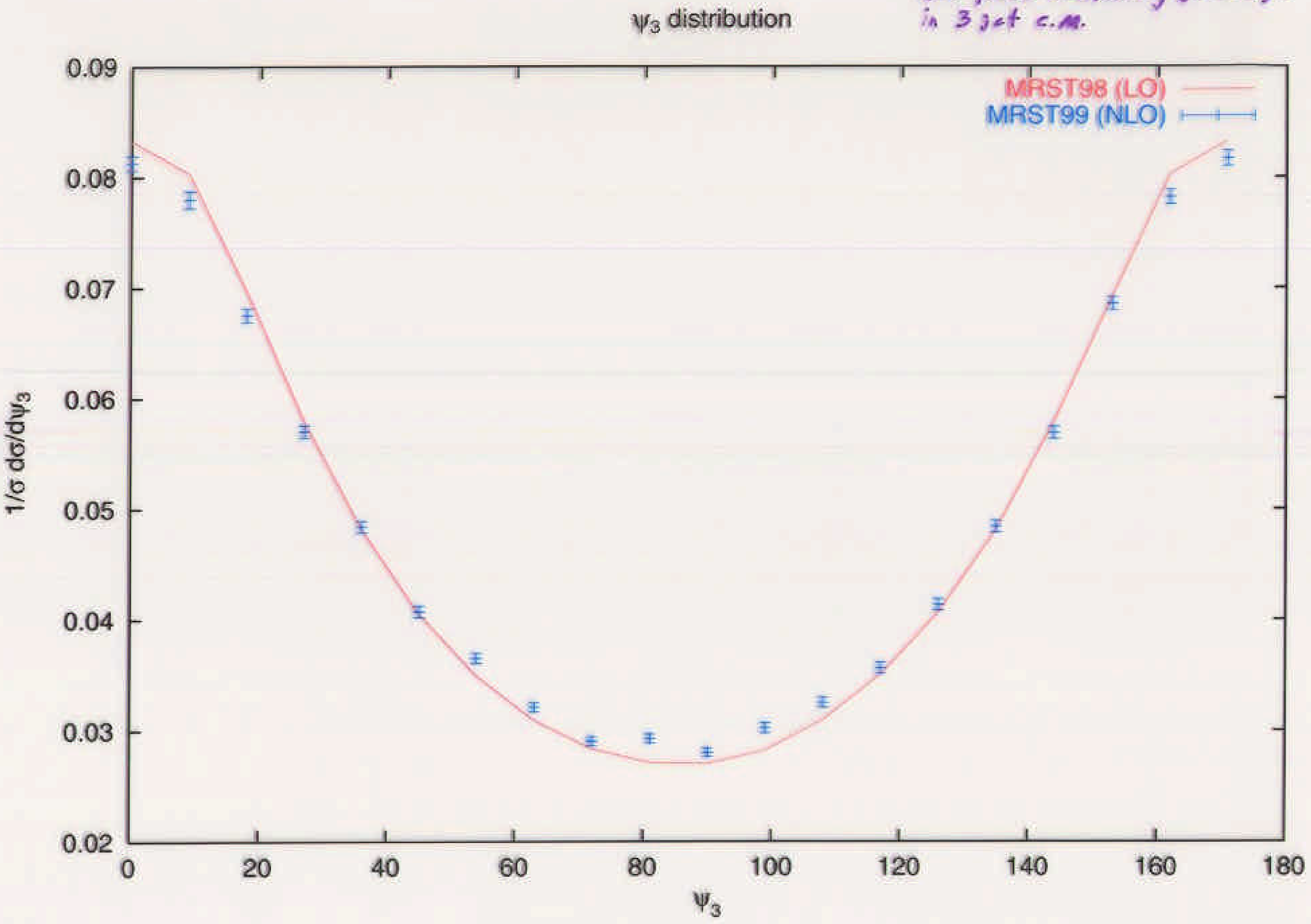
θ* = polar angle of leading jet in 3 jet c.m.



$\theta^* \approx$ polar angle of leading jet in 3 jet c.m.



ψ_3 = angle between plane containing jet 1 and beam and plane containing jets 2,3 in 3 jet c.m.



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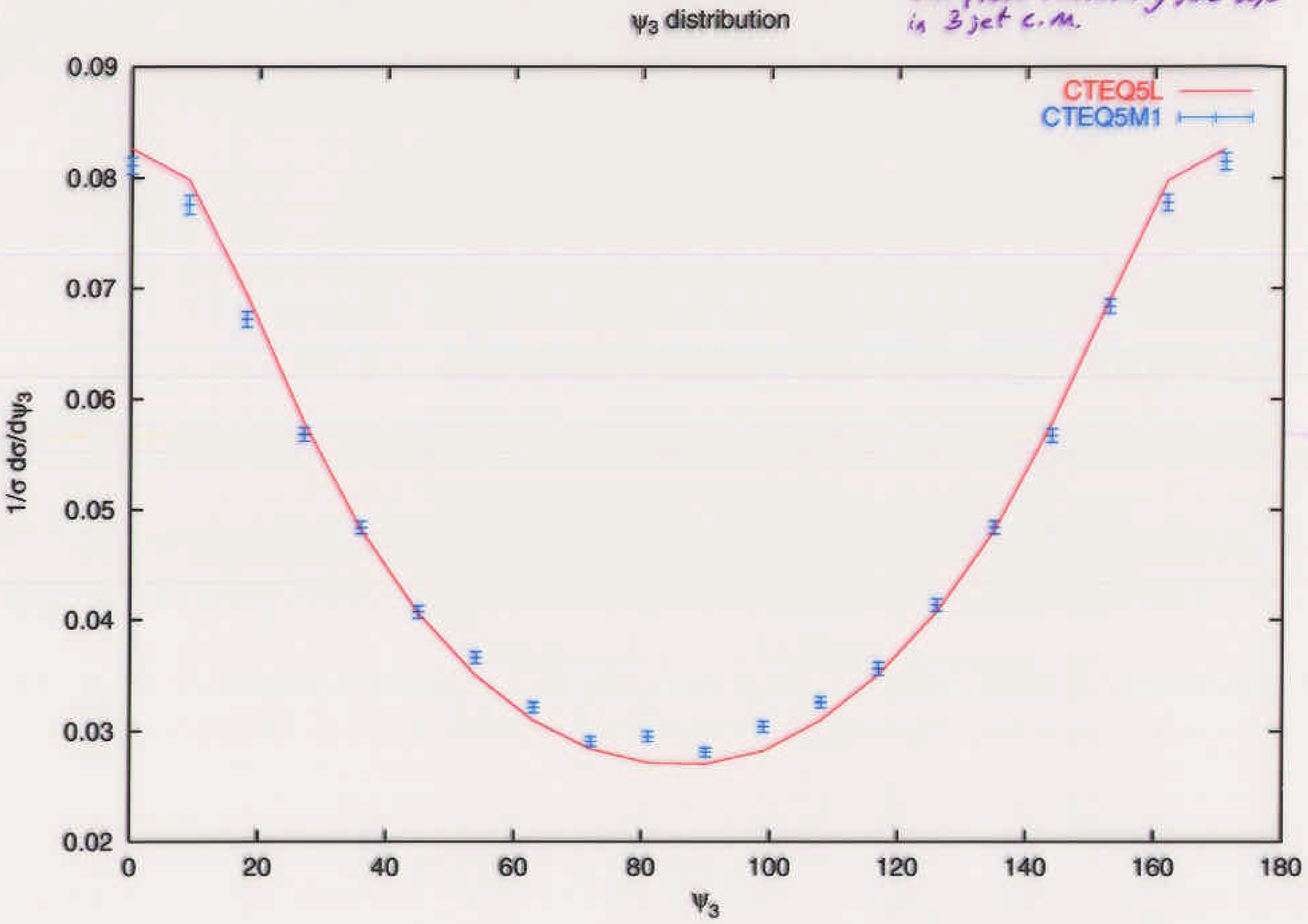

Applications

Measure α_s

α_s is the only fundamental parameter of QCD. The precise determination of α_s is essential to

- Precision Electroweak Fits
- RGE running (SUSY model building)

Ideas for measuring α_s include

- Three Jet to Two Jet Production Ration
- Event Shape Variables

Applications

Jet Algorithms

2 Parton Final States

LO 2 Jets:
Insensitive to Jet Algorithm

3 Parton Final States

LO 3 and NLO 2 Jets:
Separated by Jet Algorithm
but insensitive to details

4 Parton Final States

LO 4, NLO 3, NNLO 2 Jets:
Separation of NLO 3 Jets
and NNLO 2 Jets depends
on details of Jet Algorithms

Applications

Studies of Jet Structure and Shape

This calculation permits the first NLO determination of jet shape observables at hadron colliders.

Interesting observables include:

- jet profile $\Psi(r;R) = \frac{\sum_i E_{T_i}\,\Theta(r - R_{i,jet})}{\sum_i E_{T_i}\,\Theta(R - R_{i,jet})}$
- differential jet profile $\psi(r;R) = \frac{d\Psi(r;R)}{dr}$
- radial moment $\langle r \rangle$

Applications:

Improved Quantitative Understanding of Backgrounds to New Physics

Find your favorite SUSY Signal

Dispose of the latest experimental anomaly

Conclusions

The Next–to–Leading Order Monte Carlo Calculation is working and producing results.

Phenomenological are proceeding as data are slowly accumulated