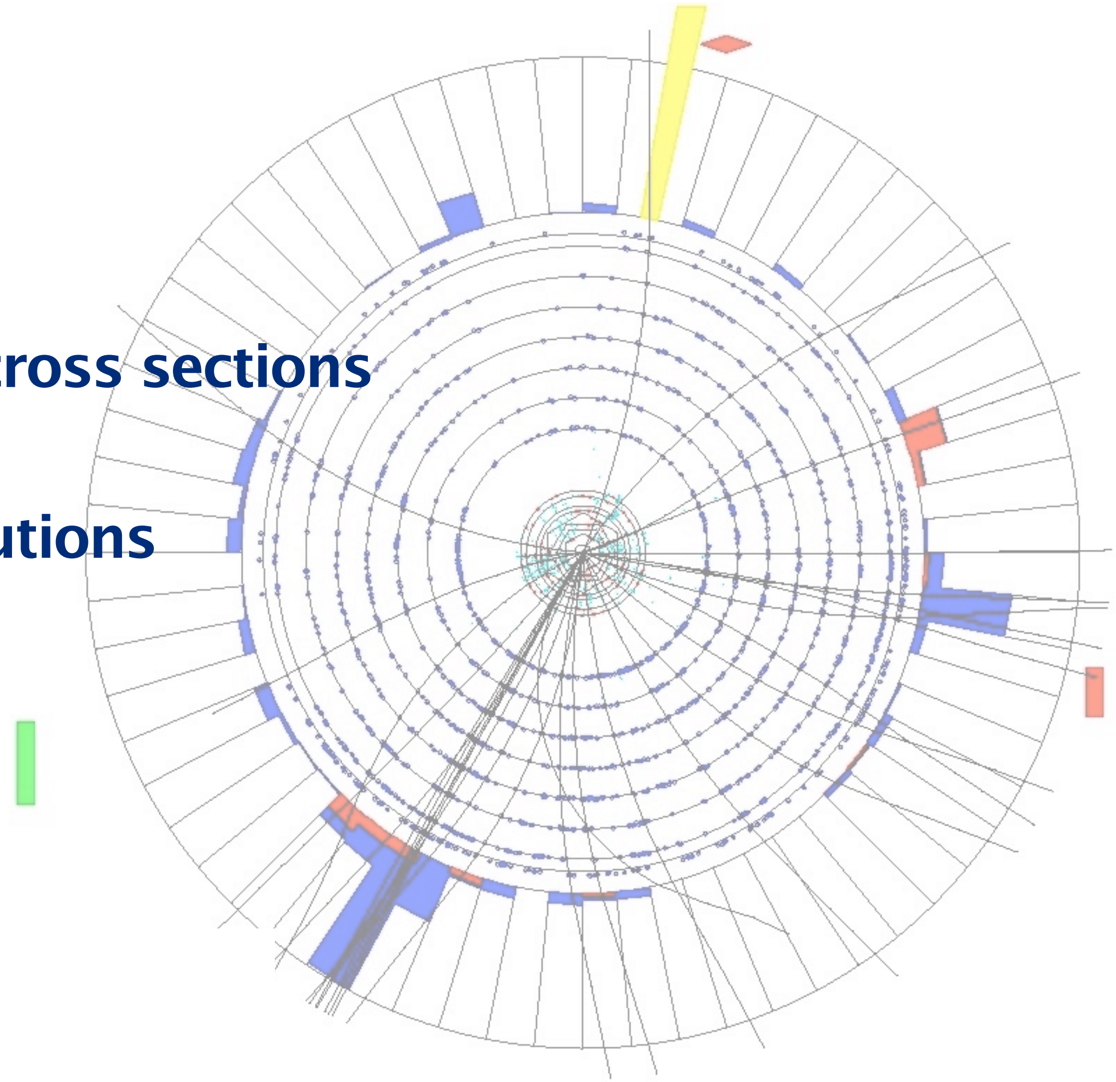
V + light quark jets at DØ

Harald Fox
for the DØ collaboration

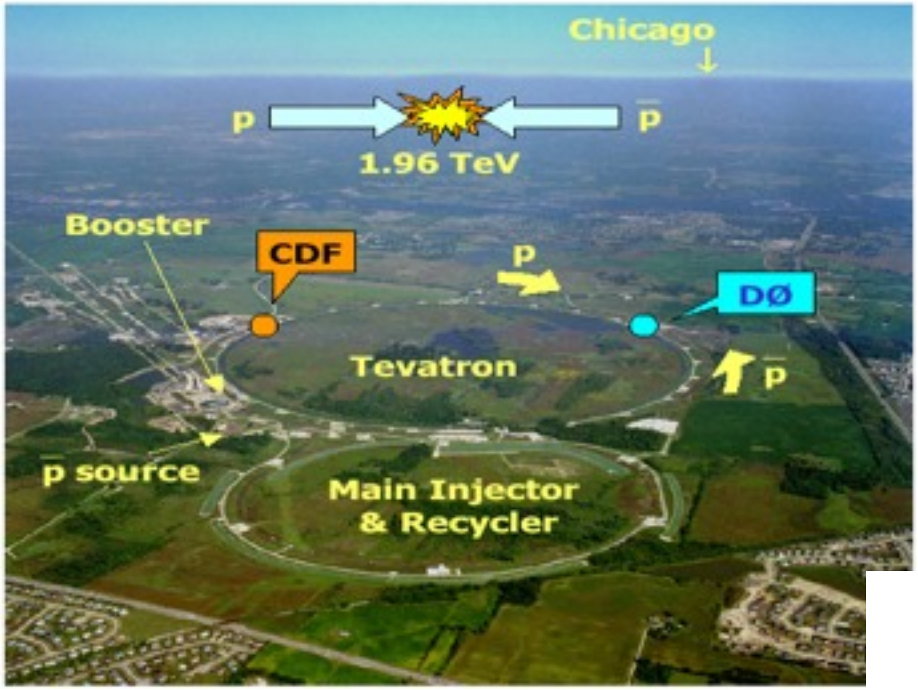
Special thanks to the Tevatron accelerator division and my DØ colleagues

Contents

- **Tevatron and DØ**
- **Differential Z+jet cross sections**
    - **inclusive**
    - **angular distributions**
    - **n-jet**

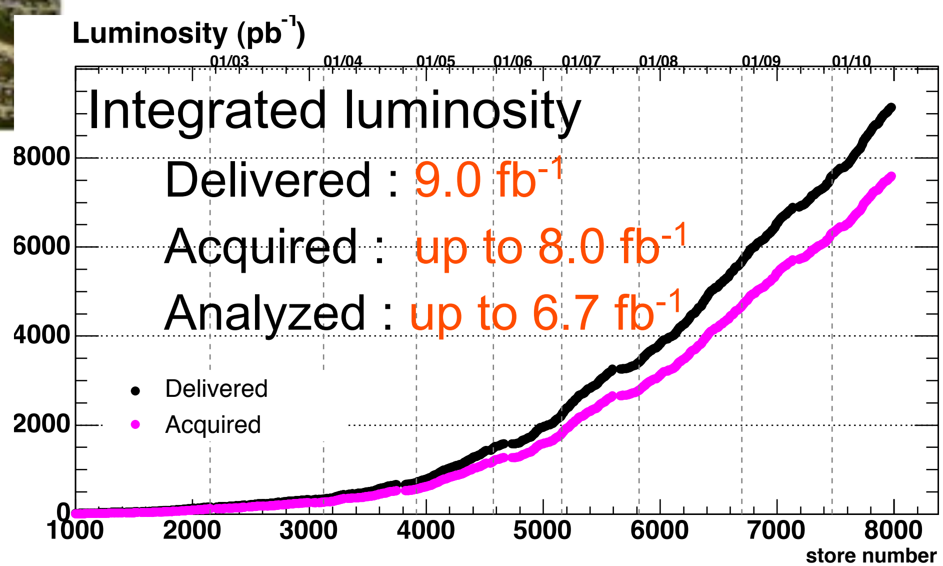


Tevatron



Tevatron:
- Proton–Antiproton Collider
- Centre-of-mass Energy 1.96 TeV

Luminosity
- Integrated luminosity 8.0 fb^{-1}
- Analysed so far: 6.7 fb^{-1}
- These analyses: up to 1.1 fb^{-1}



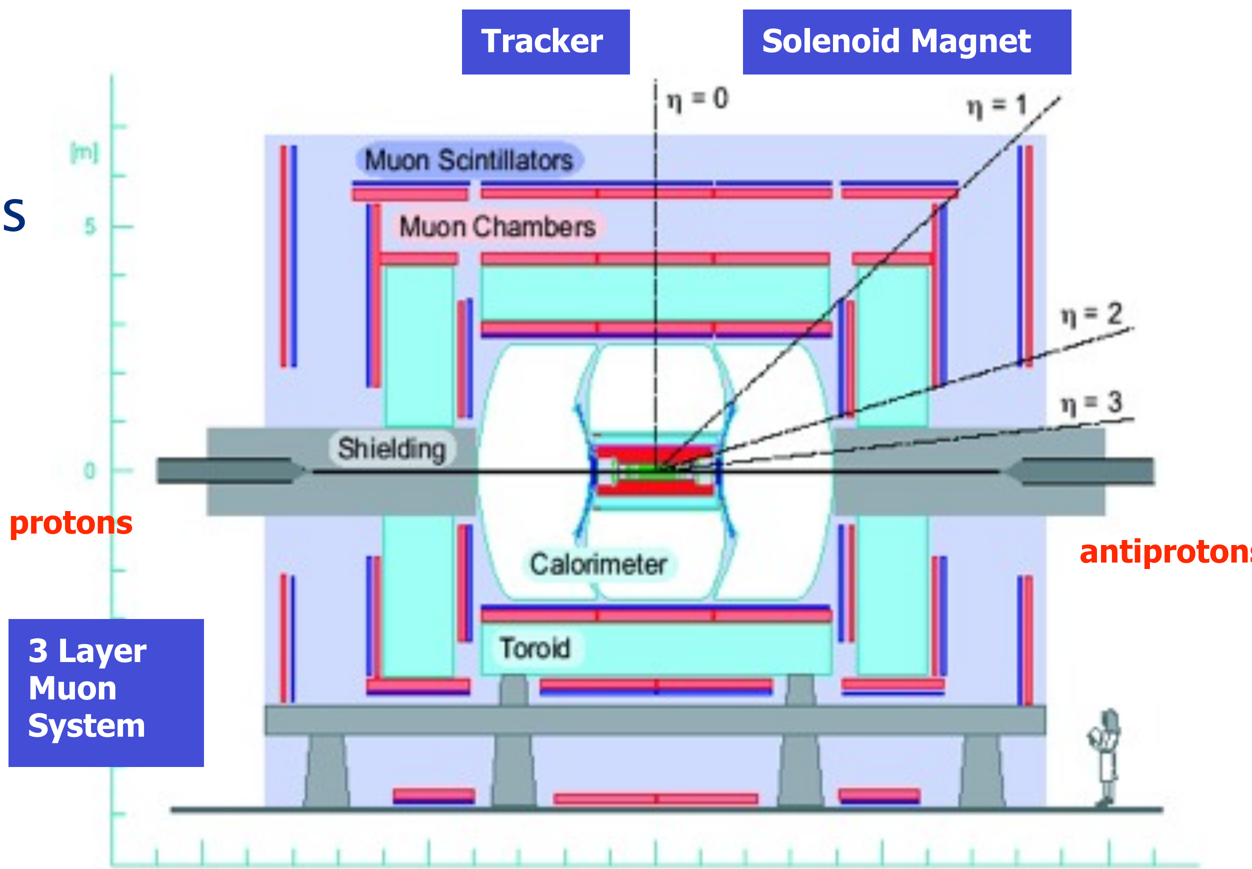
2002 2010

General Purpose Detector:

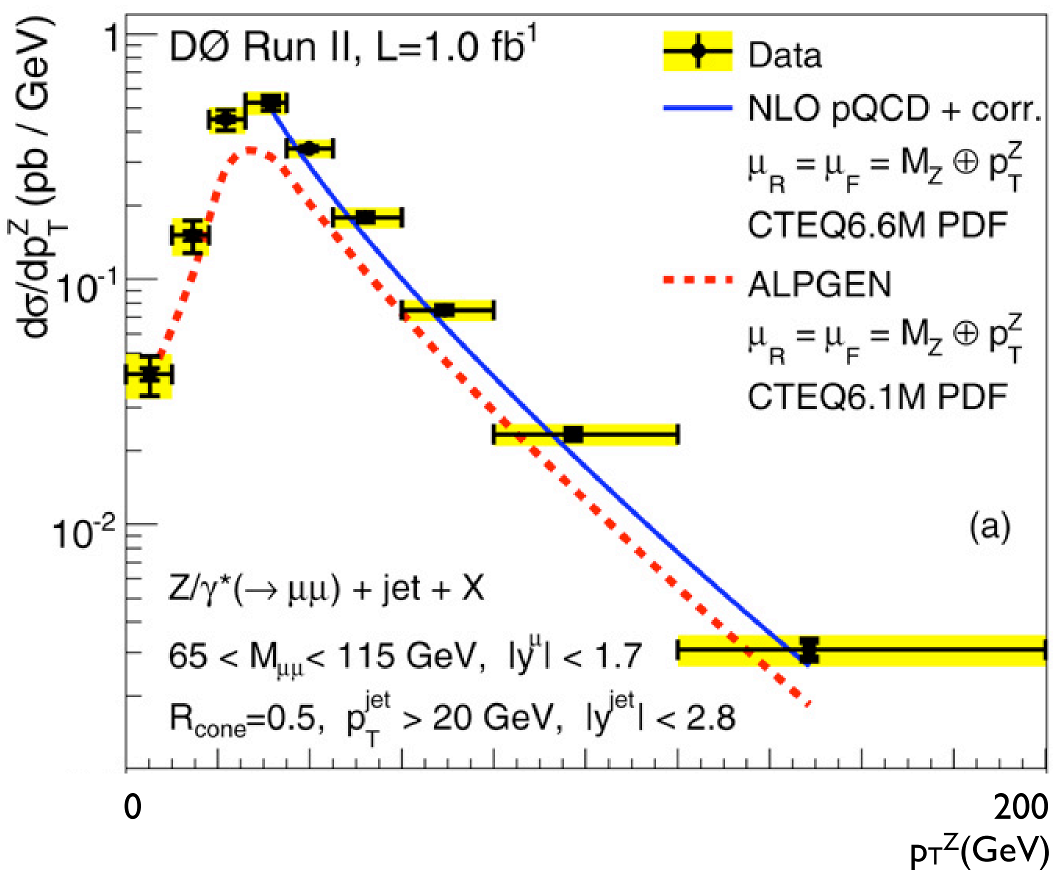
Electron acceptance	$\lvert\eta\rvert<3.0$
Muon acceptance	$\lvert\eta\rvert<2.0$
Silicon Precision tracking	$\lvert\eta\rvert<3.0$
Hermetic Calorimeter	$\lvert\eta\rvert<4.2$

Powerful trigger systems ($2.5MHz \rightarrow 50Hz$)

Dilepton triggers with $p_T>4GeV$

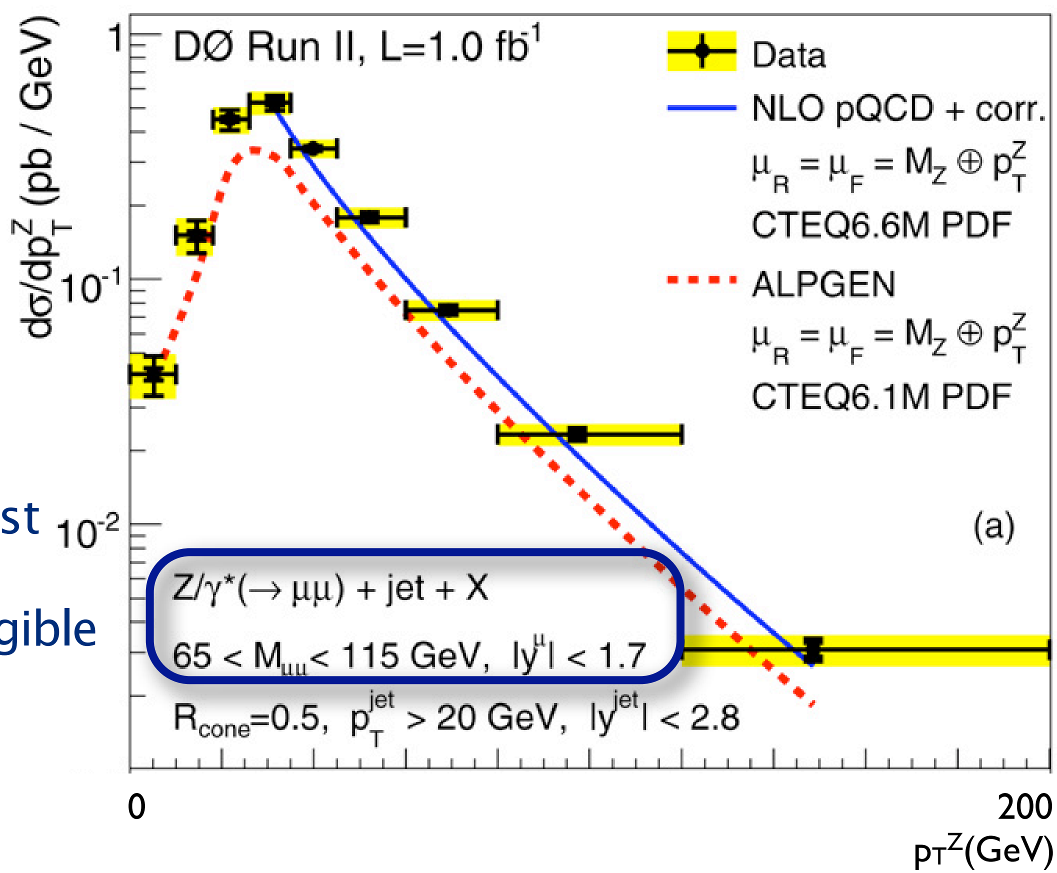


$p_T(Z)$ and $y(Z)$



PL B 669 (2008) 278-286

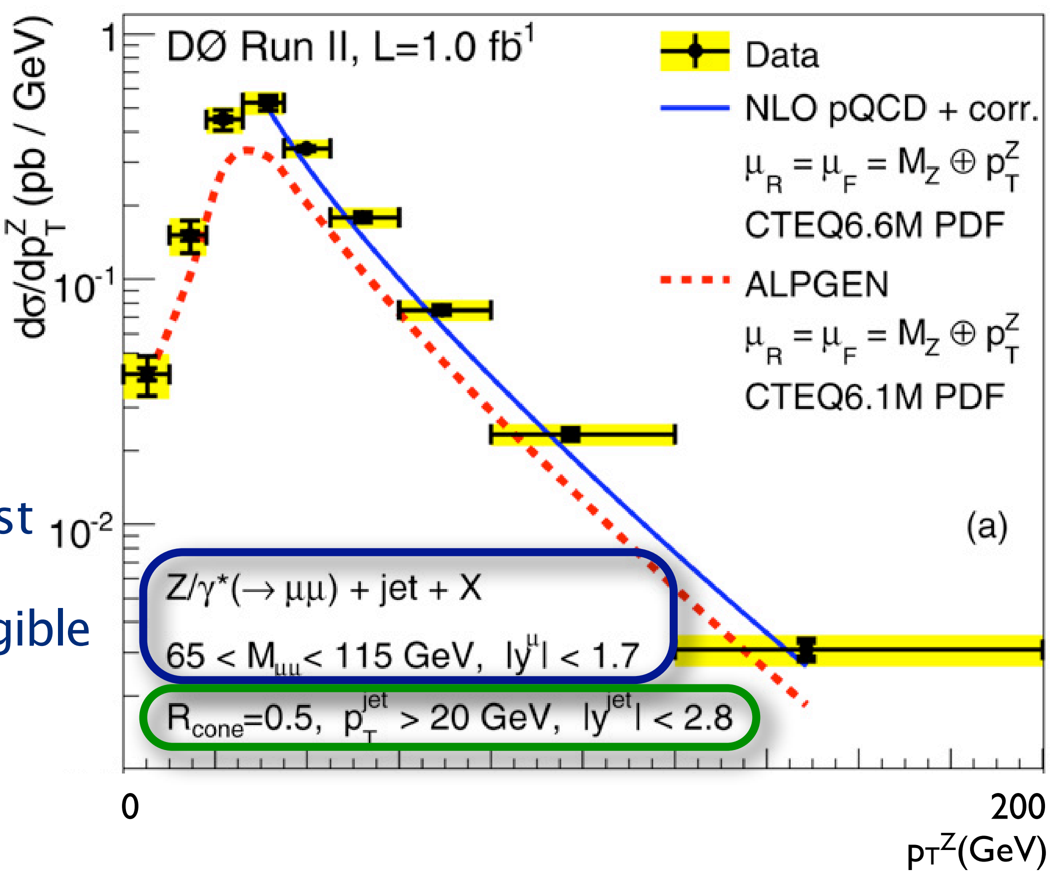
$p_T(Z)$ and $y(Z)$



μ & Z selection:
$p_T^\mu > 15$ GeV
μ isolation against W+jets
background negligible

PL B 669 (2008) 278-286

$p_T(Z)$ and $y(Z)$



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PL B 669 (2008) 278-286

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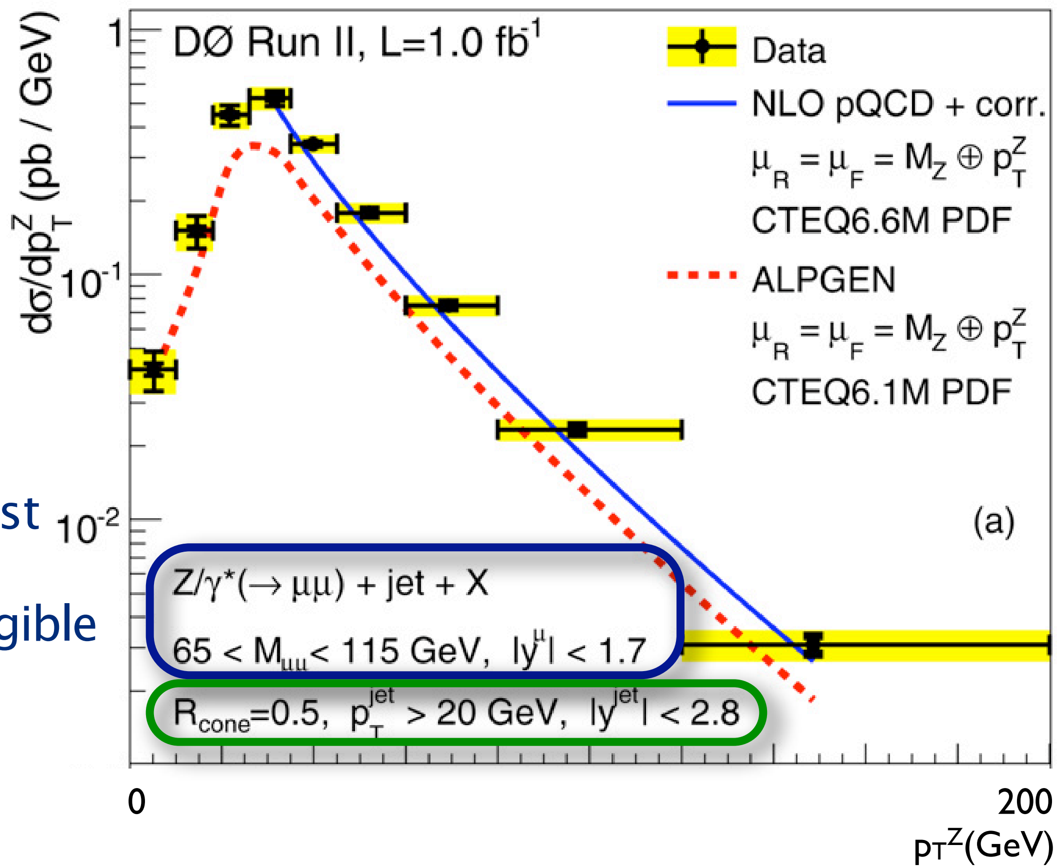

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9927 events

PL B 669 (2008) 278-286

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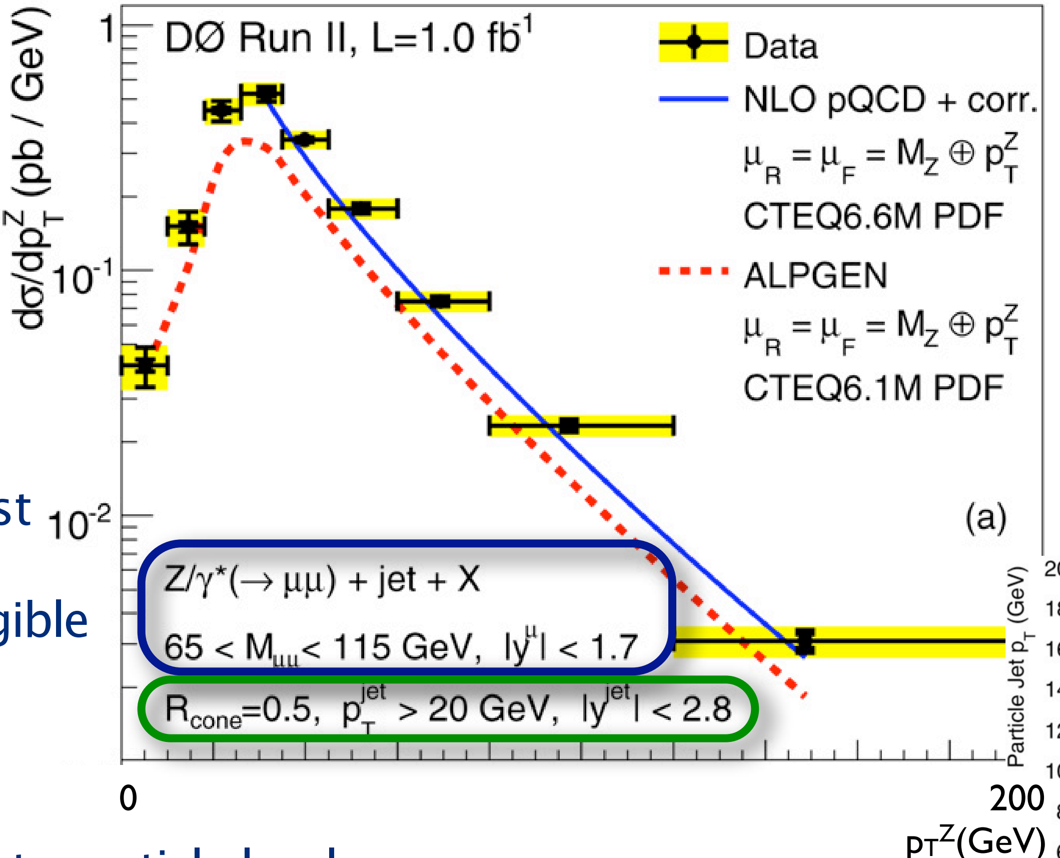
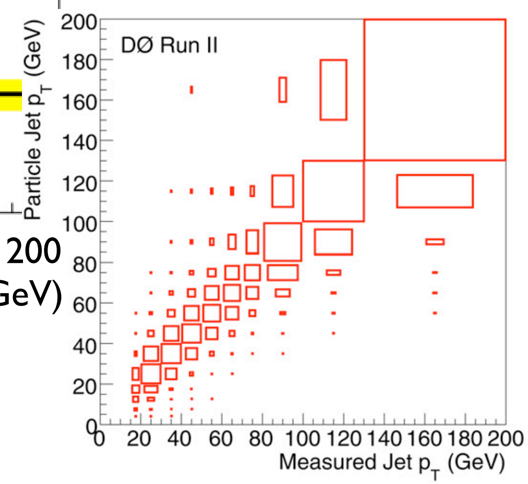


μ & Z selection:
$p_T^{\mu} > 15$ GeV
μ isolation against W+jets background negligible

jet selection:
9927 events

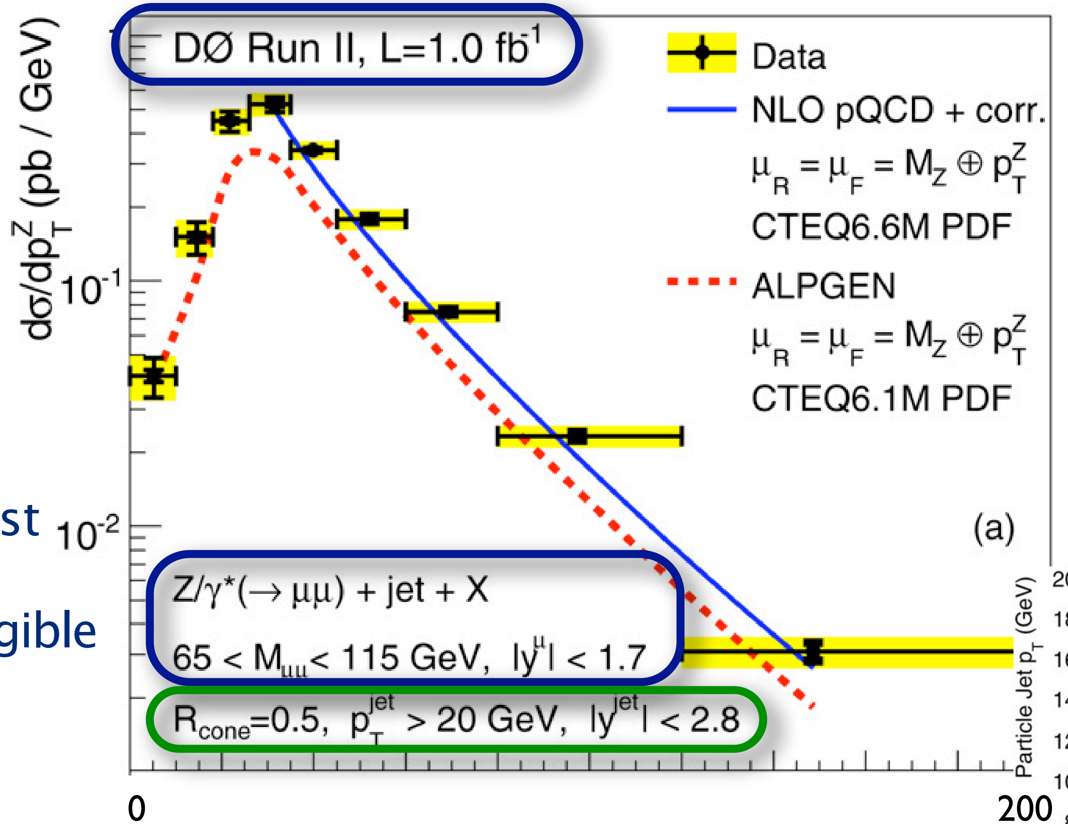
1. correction back to particle level $(11.8 \pm 0.2)\%$
2. correction for detector effects

PL B 669 (2008) 278-286



$p_T(Z)$ and $y(Z)$

normalized to bin width and integrated luminosity L=0.97 ± 6%



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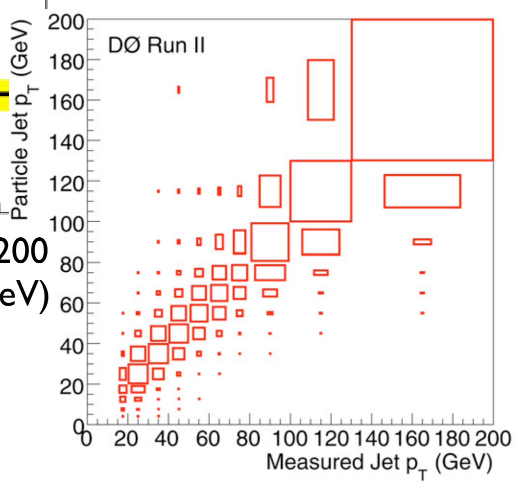


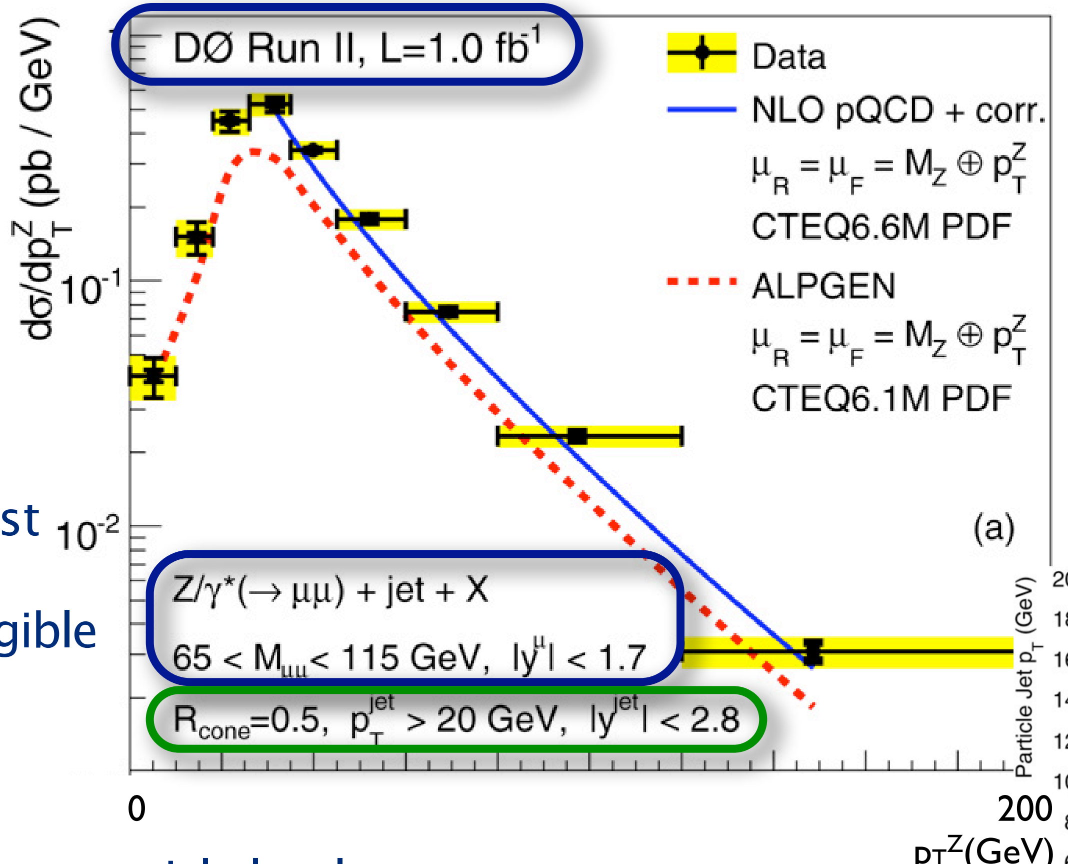
1. correction back to particle level (11.8 ± 0.2)%
2. correction for detector effects

PL B 669 (2008) 278-286

$p_T(Z)$ and $y(Z)$

Largest systematic:
JES: up to 10% at low p_T^Z due to pT(jet) cut

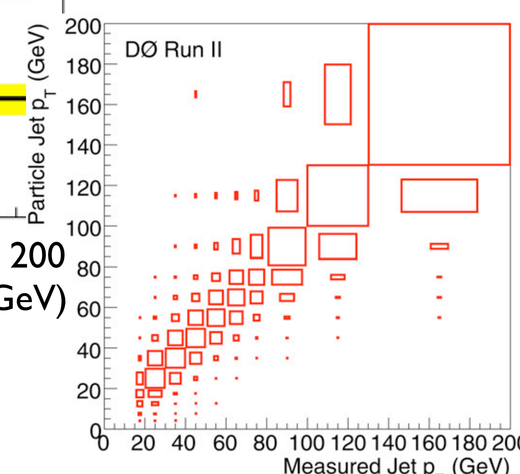
normalized to bin width and integrated luminosity L=0.97 ± 6%



μ & Z selection:
p_T^{μ} > 15 GeV
μ isolation against W+jets
background negligible

jet selection:

9927 events



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PL B 669 (2008) 278-286

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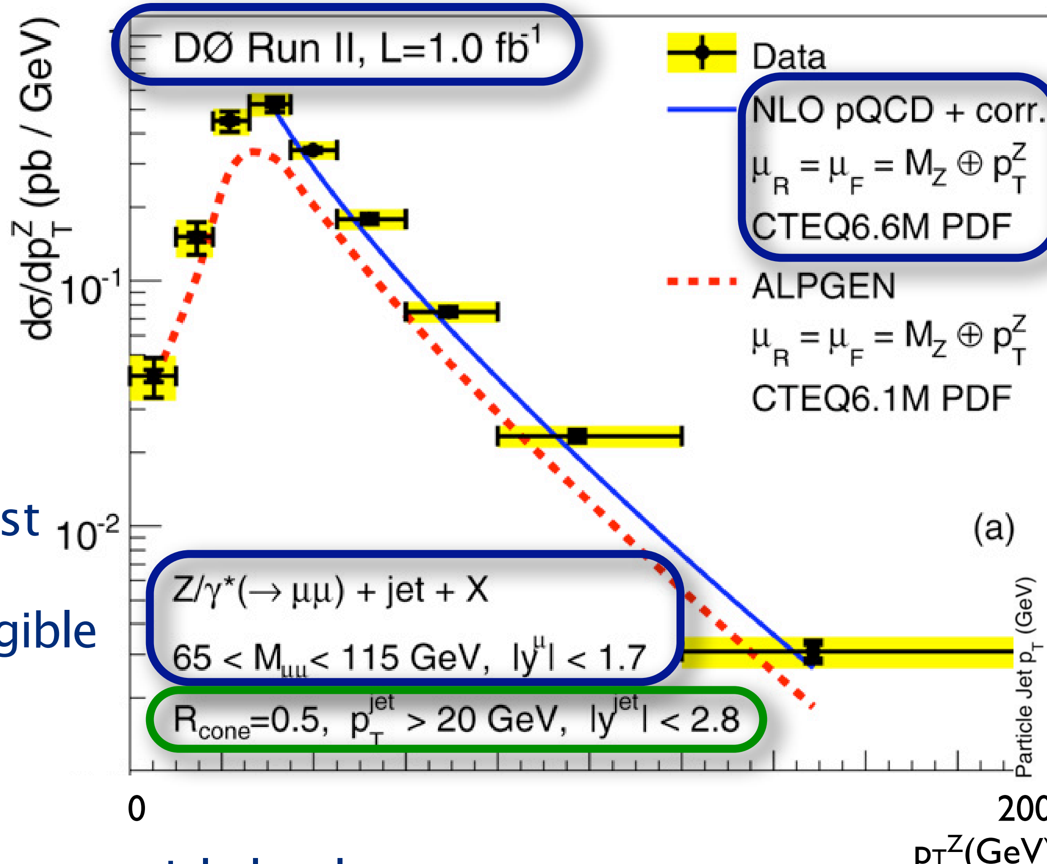

MCFM
hadr., ISR, FSR from Pythia
$2\times\mu_R(\mu_F)$: ±7%

μ & Z selection:
$p_T^\mu > 15$ GeV
μ isolation against W+jets background negligible

jet selection:

9927 events

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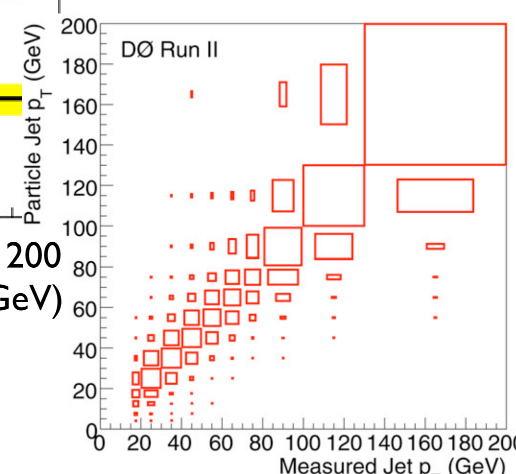
PL B 669 (2008) 278-286



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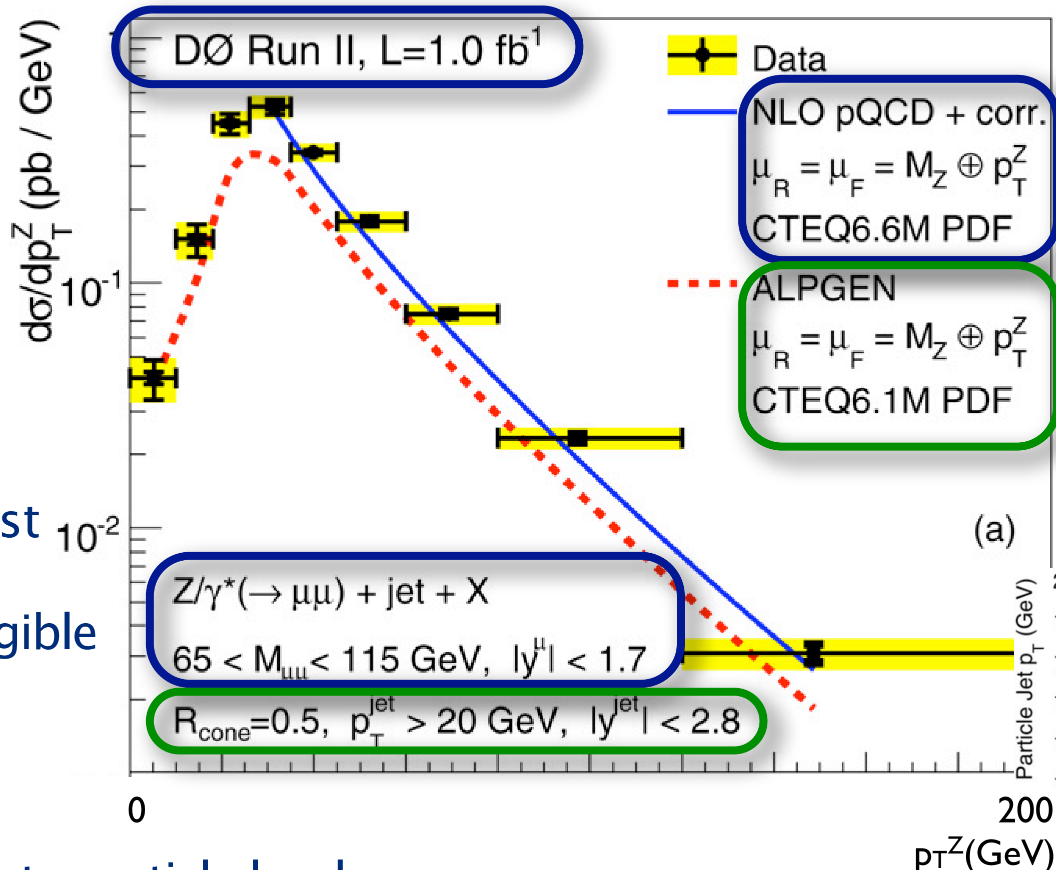

MCFM
hadr., ISR, FSR from Pythia
$2\times\mu_R(\mu_F)$: ±7%

ALPGEN 2.13
≤3 partons
+ Pythia tune QW

μ & Z selection:
$p_T^{\mu} > 15$ GeV
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background negligible

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9927 events

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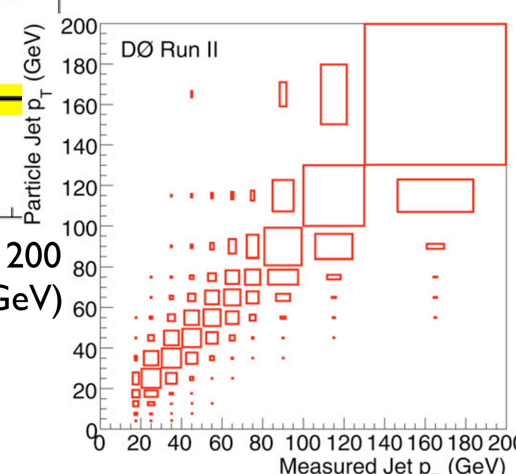
PL B 669 (2008) 278-286



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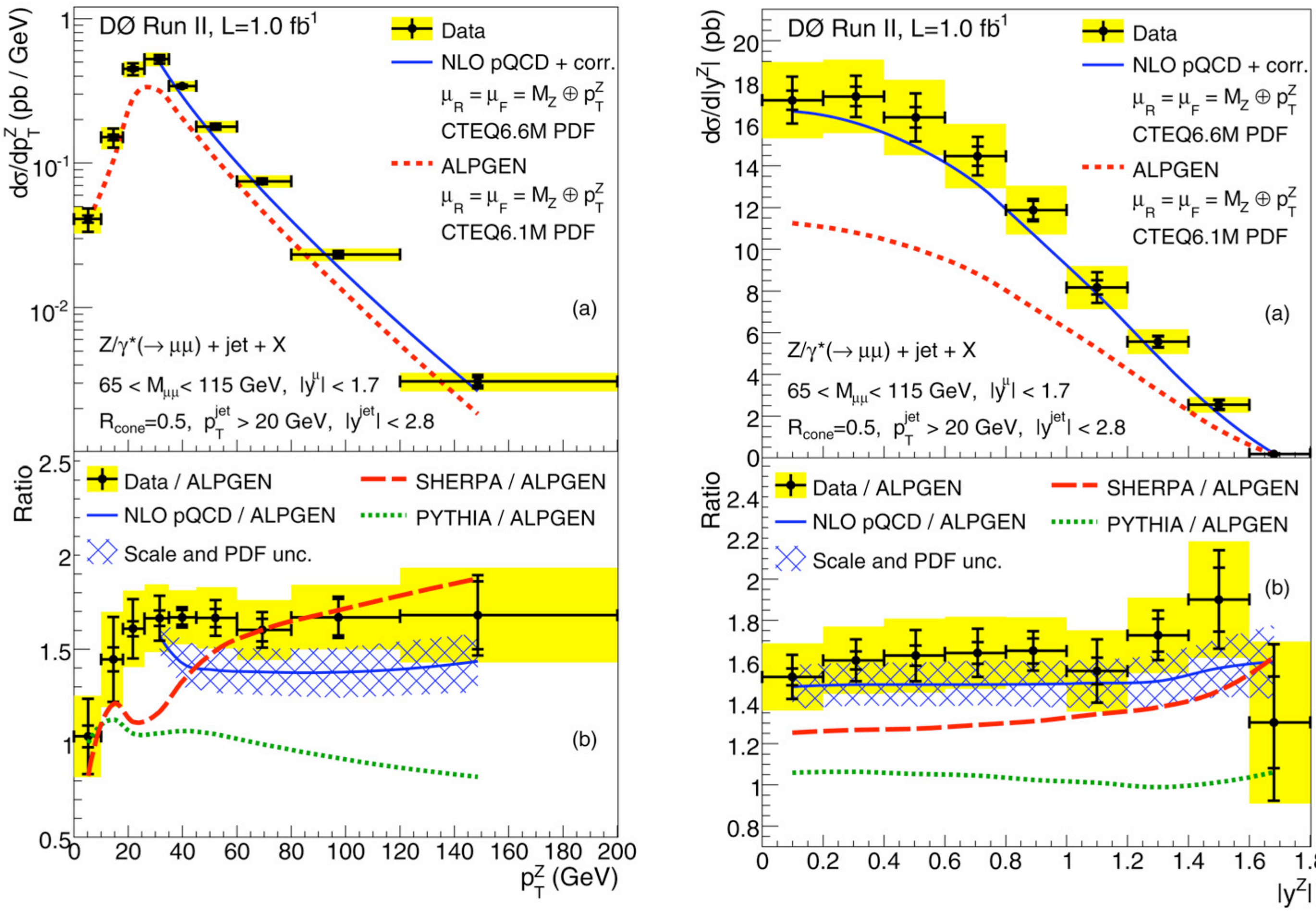


DØ Run II, L=1.0 fb^{-1}
Data
NLO pQCD + corr.
$\mu_R = \mu_F = M_Z \oplus p_T^Z$
CTEQ6.6M PDF
ALPGEN
$\mu_R = \mu_F = M_Z \oplus p_T^Z$
CTEQ6.1M PDF
(a)
$Z/\gamma^*(\rightarrow \mu\mu)$ + jet + X
65 < $M_{\mu\mu}$ < 115 GeV, $|y^\mu|$ < 1.7
R_{cone}=0.5, p_T^{jet} > 20 GeV, $|y^{jet}|$ < 2.8
$d\sigma/dp_T^Z$ (pb / GeV)
Data / ALPGEN
NLO pQCD / ALPGEN
Scale and PDF unc.
SHERPA / ALPGEN
PYTHIA / ALPGEN
(b)
Ratio
p_T^Z (GeV)
$d\sigma/d|y^Z|$ (pb)
$|y^Z|$

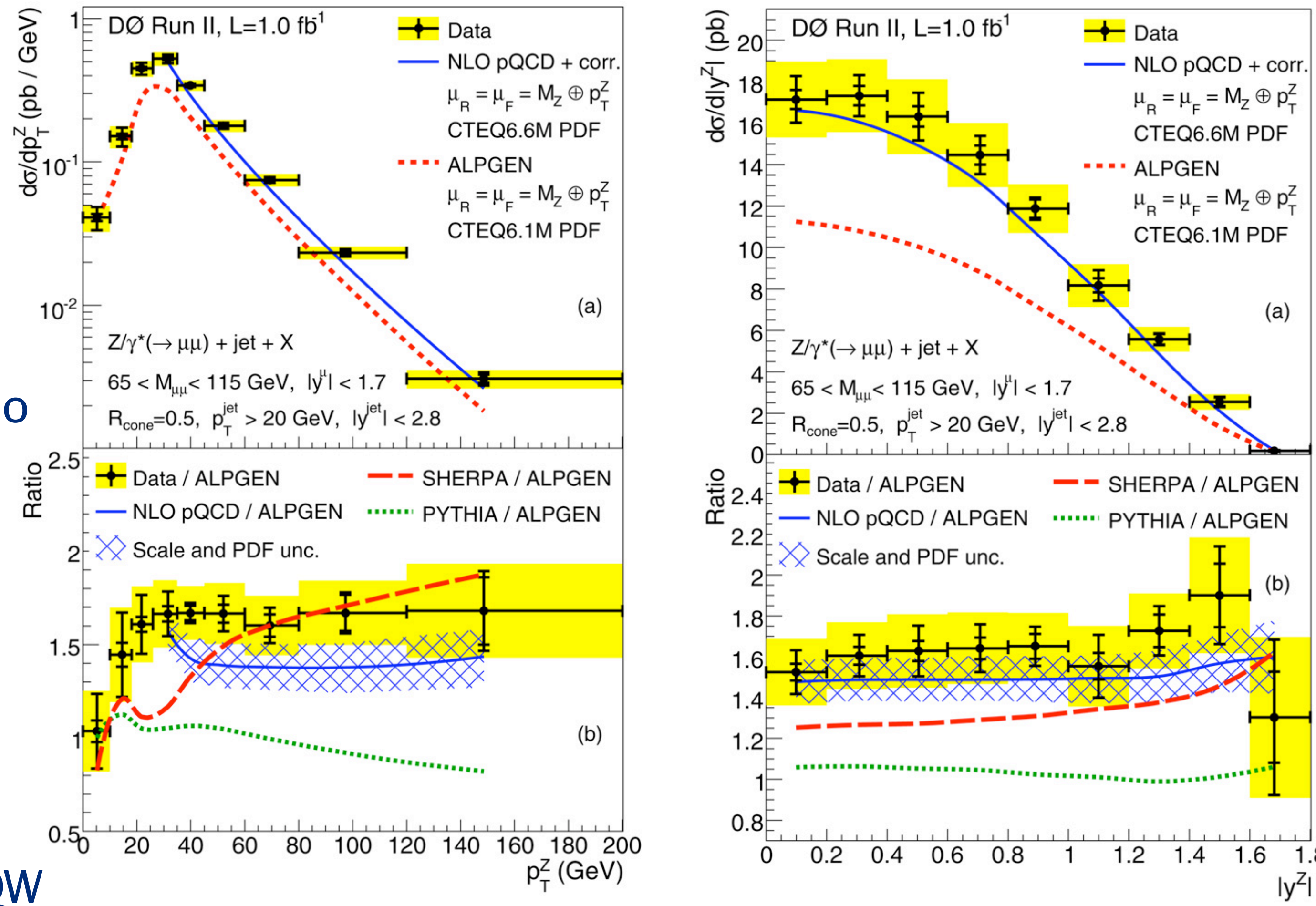
$p_T(Z)$ and $y(Z)$

for comparison: ratio to ALPGEN

Sherpa 1.1.1 with ≤3 partons

matching scale 15GeV

Pythia 6.418 tune QW CTEQ6.1M



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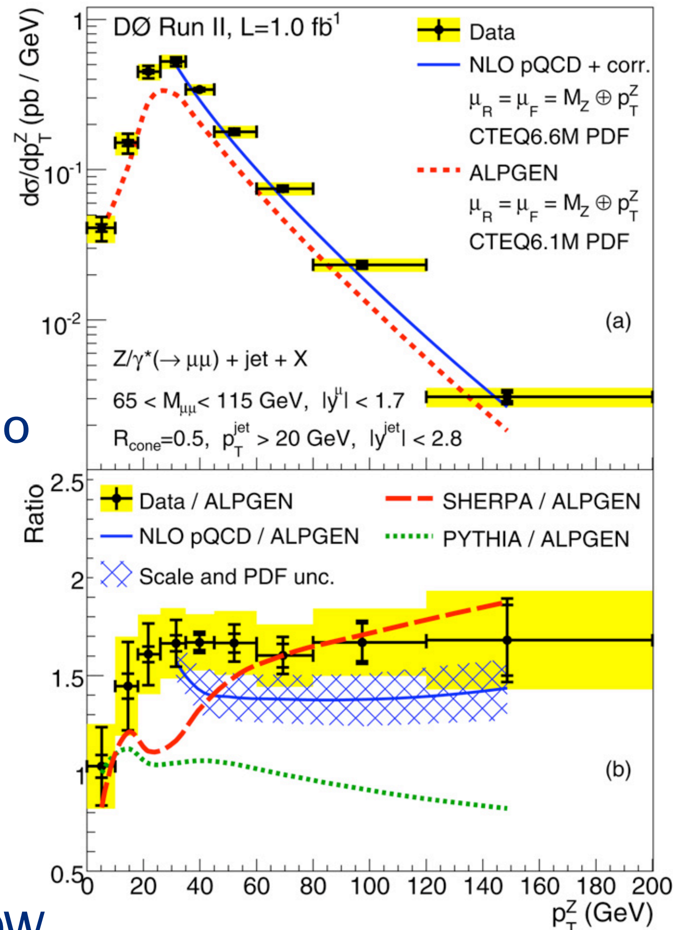

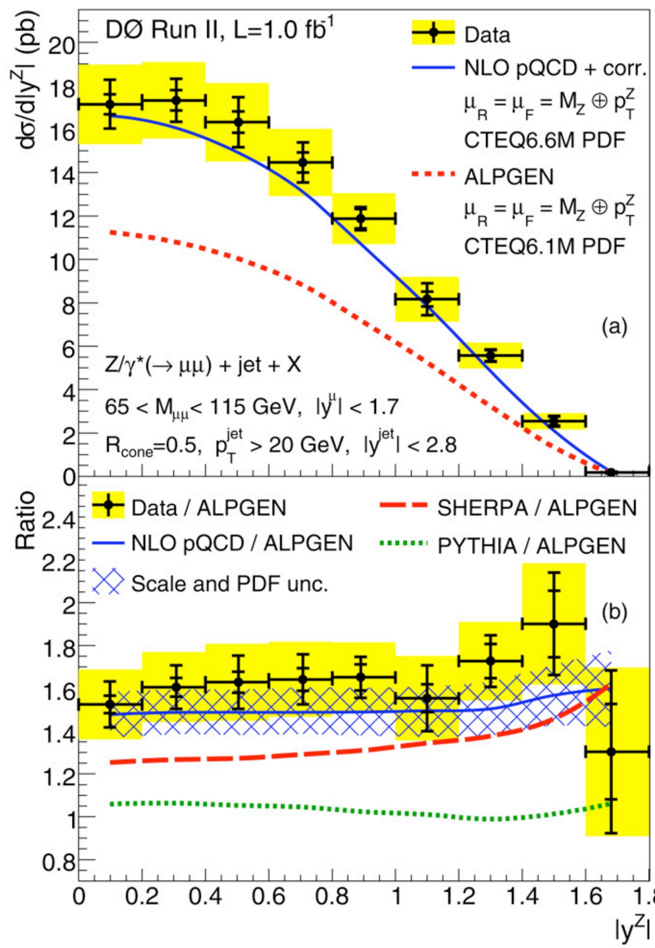

shaded region:

stat + syst + corr syst

$p_T(Z)$ and $y(Z)$

for comparison: ratio to ALPGEN

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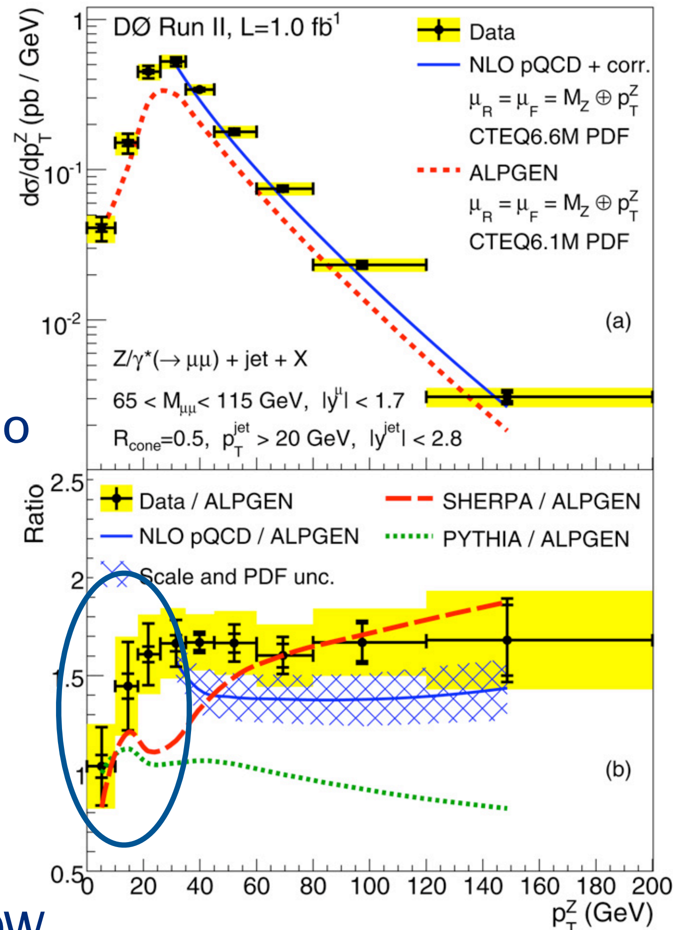
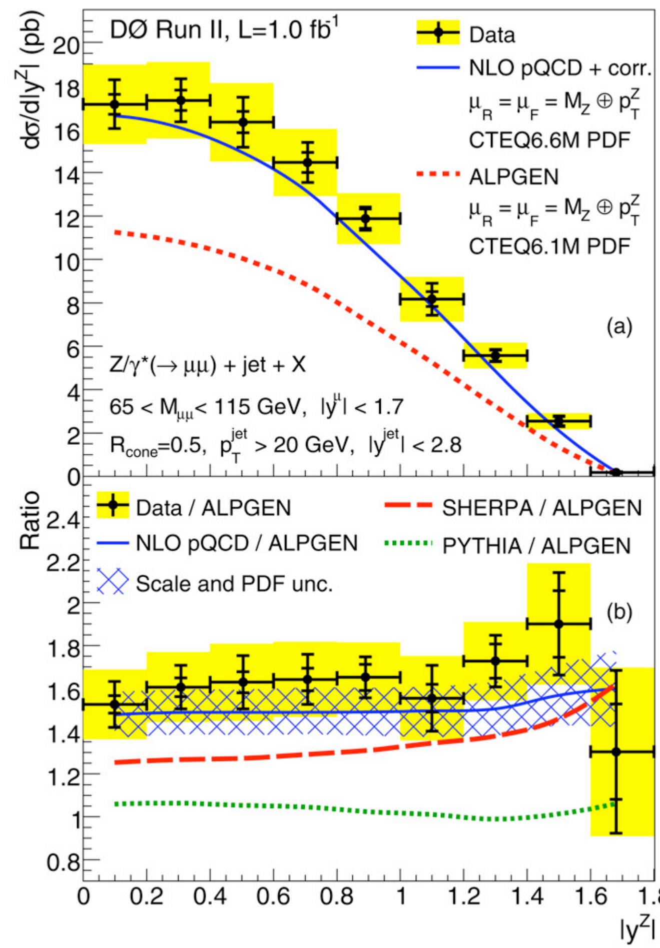


low pT region: no pQCD prediction

cuts: $p_T^Z > 25$GeV / 45 GeV



shaded region:

stat + syst + corr syst

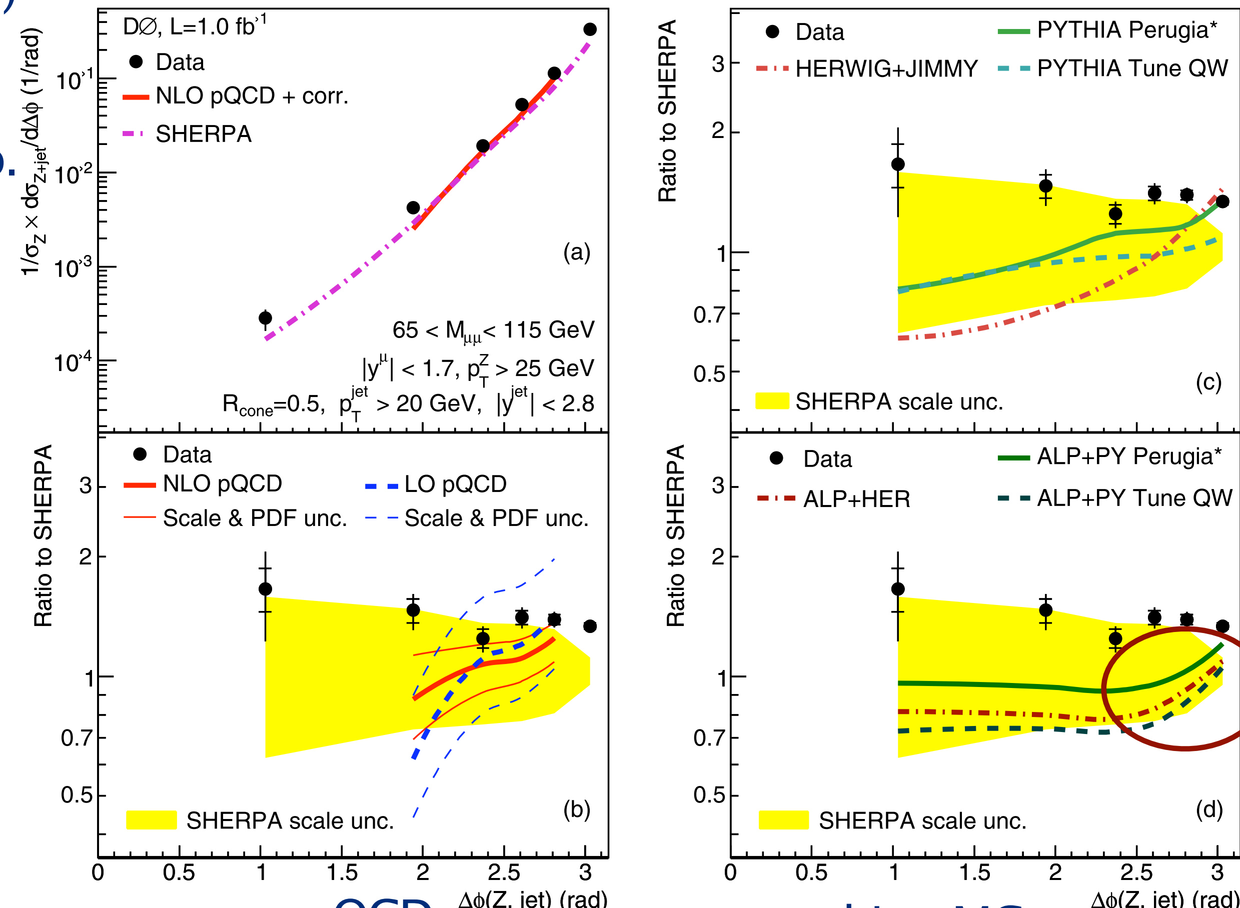
Z–jet Angles: $\Delta\phi$, p_T^Z>25GeV

Sherpa 1.1.3 (matching scale: 13 GeV) provides a good match. Used for ratio.

CTEQ6.1M
μ_R: CKKW

parton shower MC

p_T ordered, MRST 2007 LO*
Q^2 ordered



pQCD

matching MC

matching scale 13GeV

problem for Alpgen?

shaded region:

Sherpa scale uncertainty

PL B 682 (2010) 370-380

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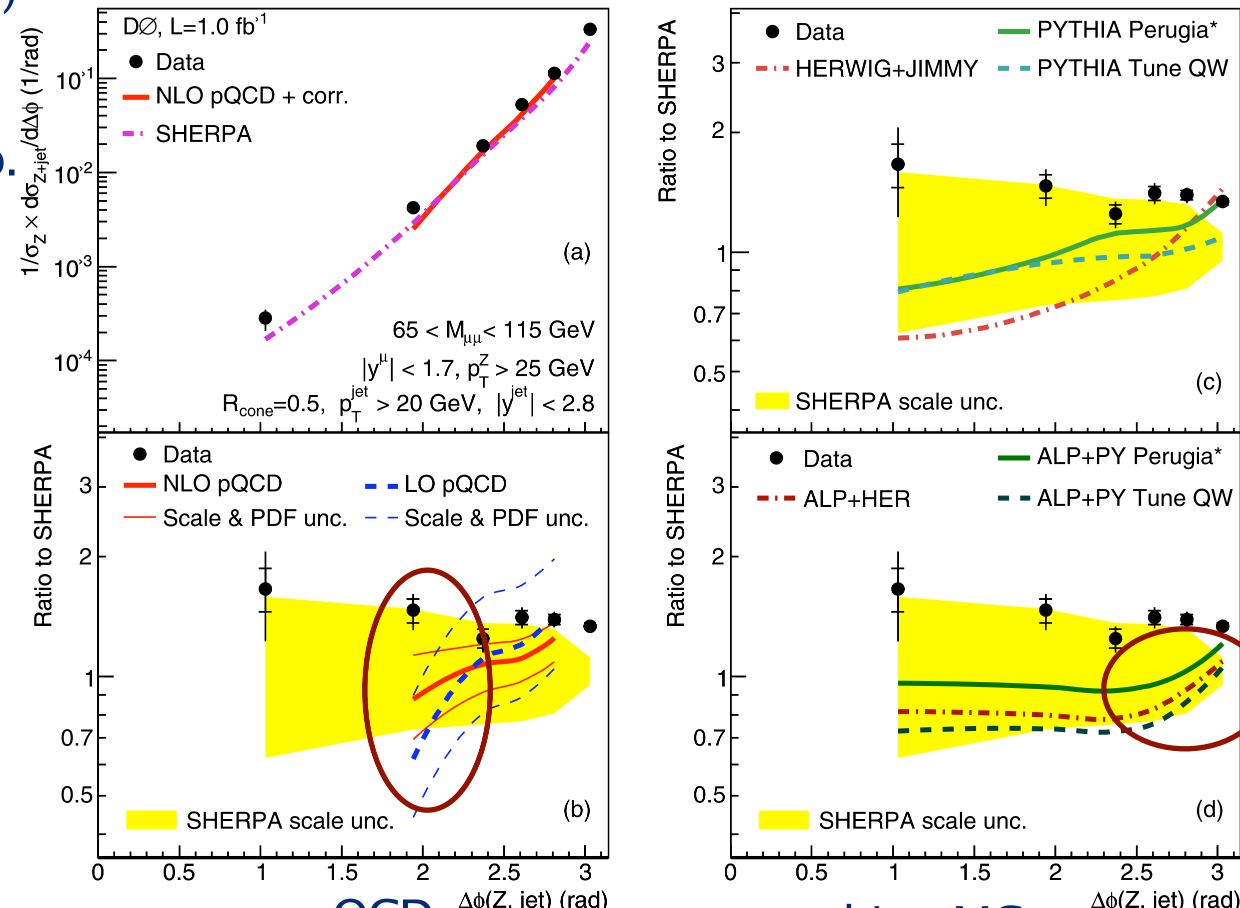

pQCD

matching MC

matching scale 13GeV

problem for Alpgen?

NLO better than LO

off by 1σ

data: $122 \pm 2 \pm 4 \times 10^{-3}$

pQCD: $111 \pm 6 \pm 2 \times 10^{-3}$
(scale) (pdf)

shaded region:

Sherpa scale uncertainty

PL B 682 (2010) 370-380

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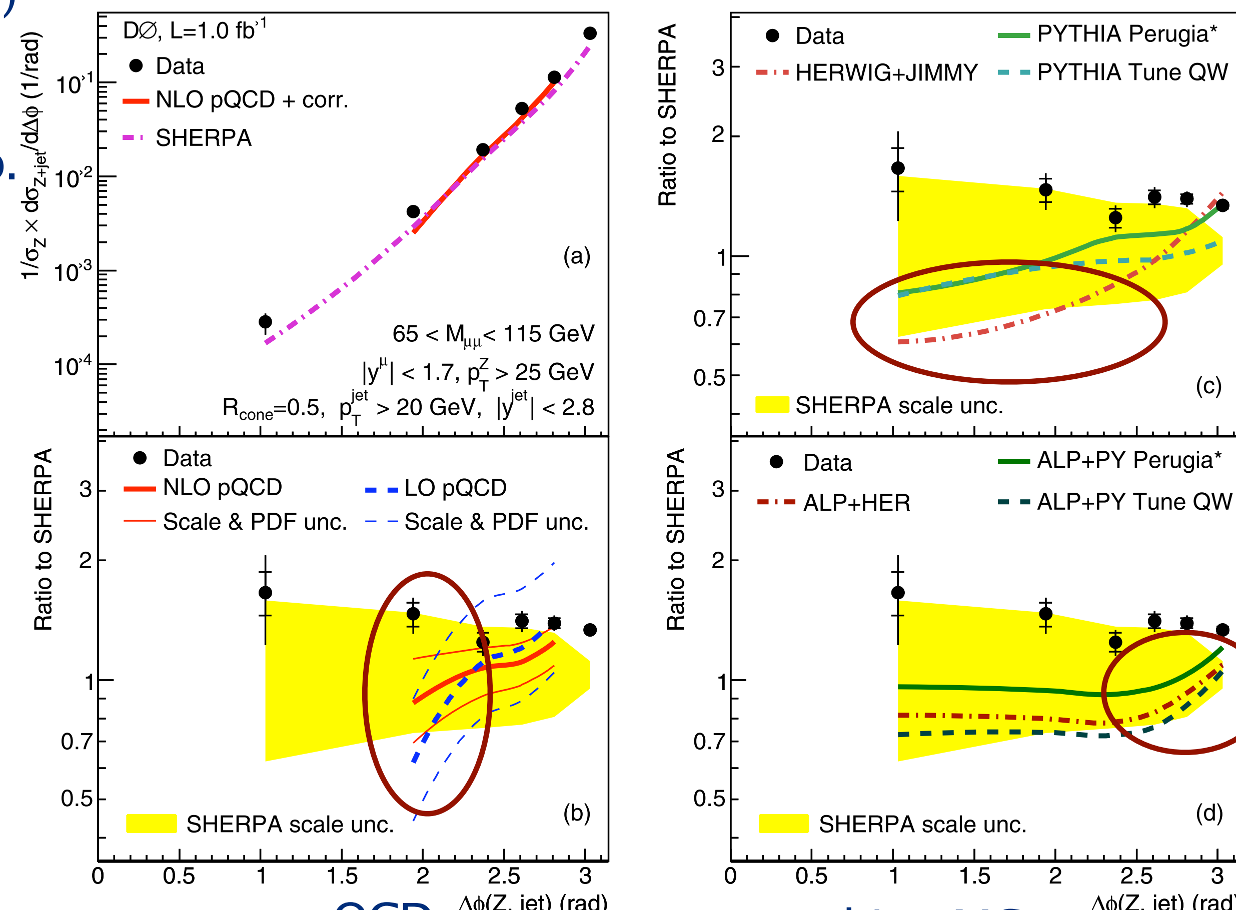


problem for Herwig and Pythia (Perugia)?

matching scale 13GeV

NLO better than LO

problem for Alpgen?

pQCD

matching MC

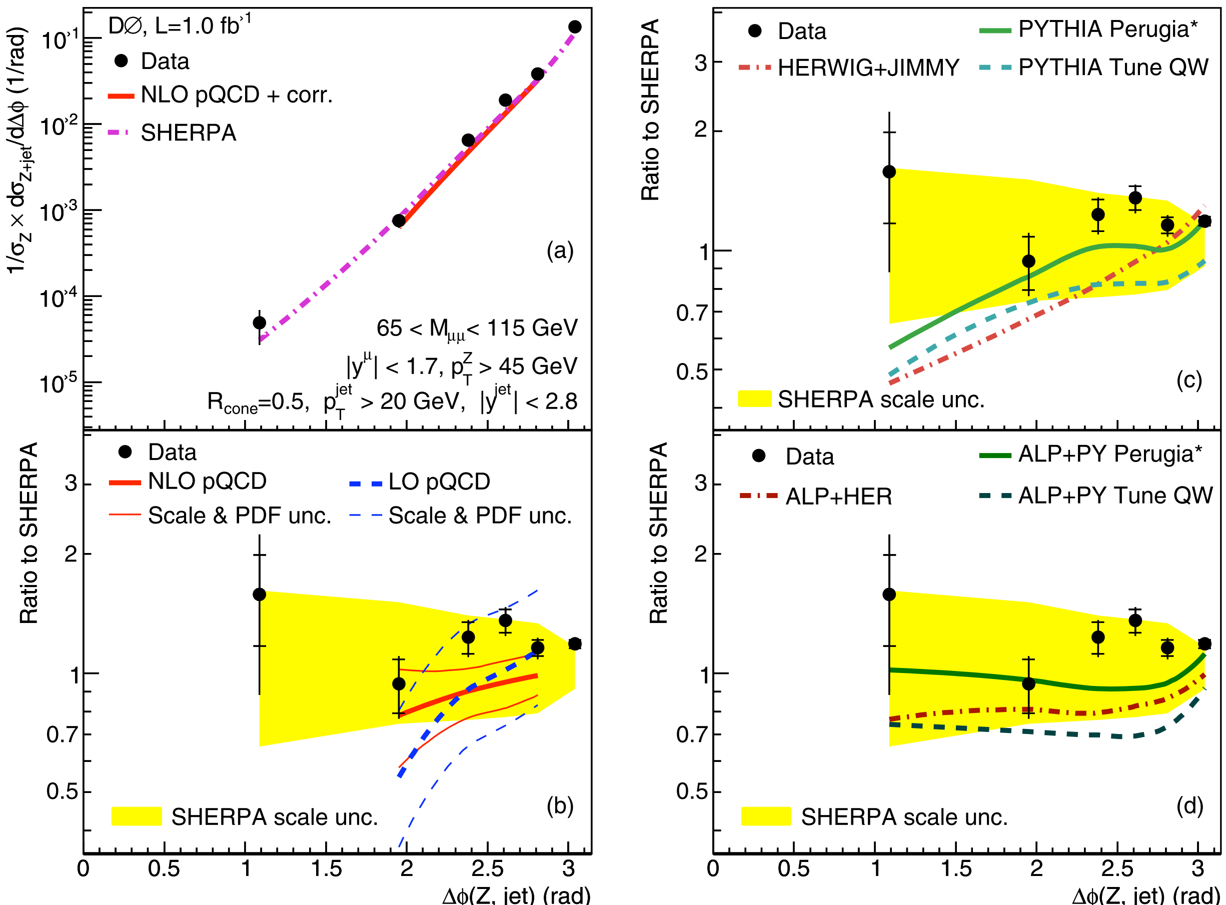
off by 1σ
data: 122±2±4 × 10^{-3}
pQCD: 111±6±2 × 10^{-3}
(scale) (pdf)

shaded region:
Sherpa scale uncertainty

PL B 682 (2010) 370-380

Z–jet Angles: $\Delta\phi$, p_T^Z>45GeV

parton shower MC



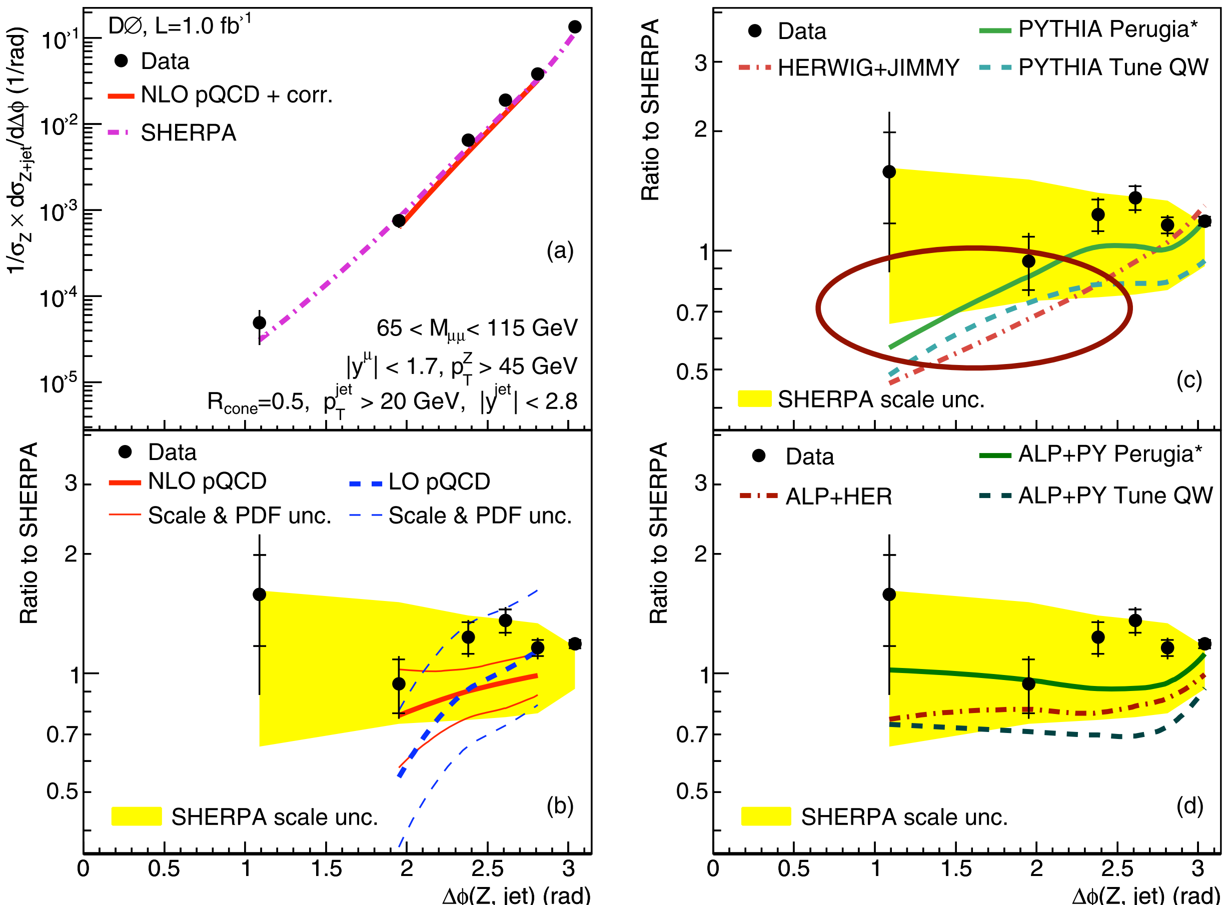
pQCD

matching MC

PL B 682 (2010) 370-380

Z–jet Angles: Δϕ, p_T^Z>45GeV

parton shower MC



problem for Pythia, too?

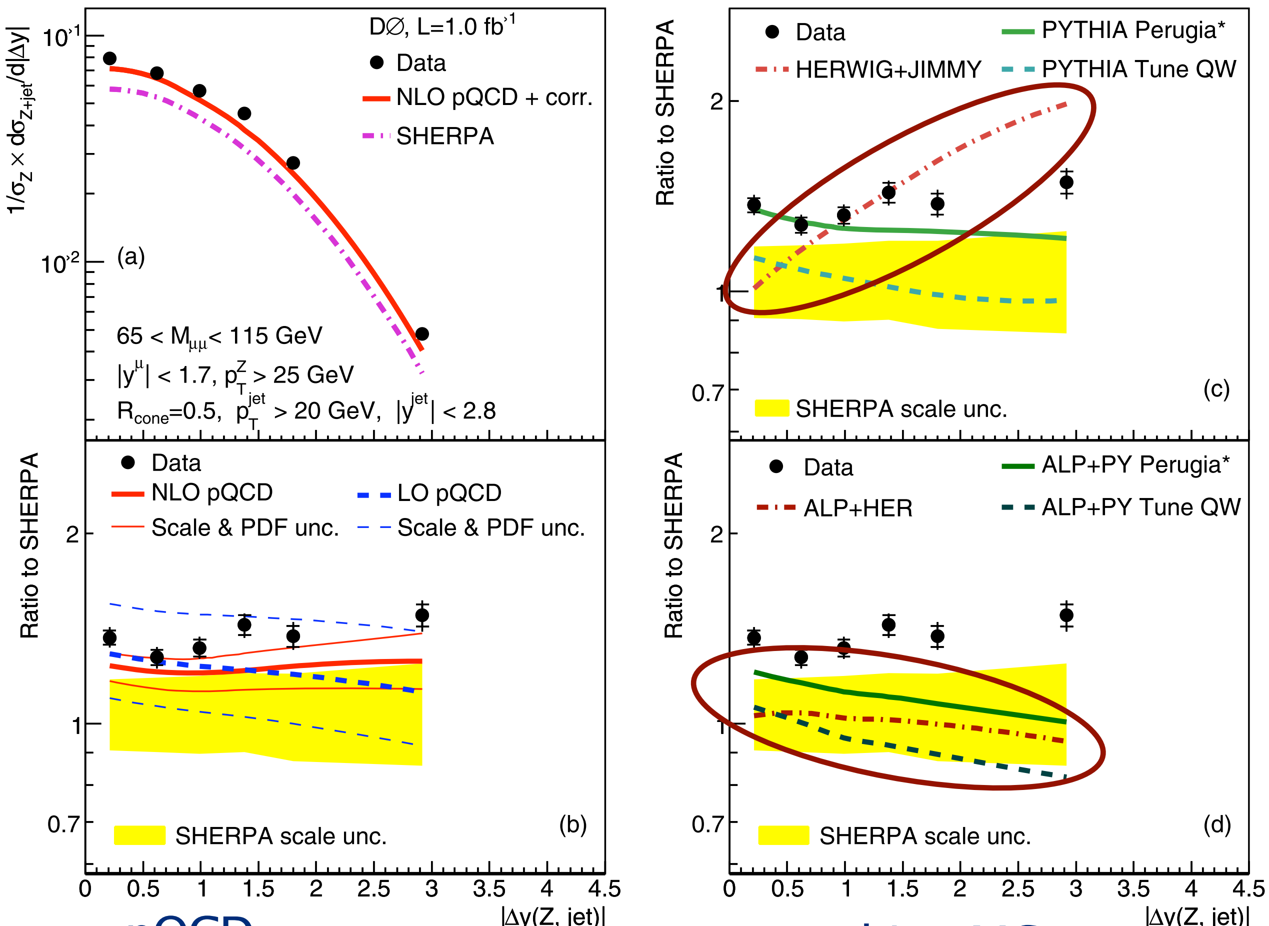
pQCD

matching MC

PL B 682 (2010) 370-380

Z–jet Angles: Δy, p_T^Z>25GeV

parton shower MC



problem for Herwig?

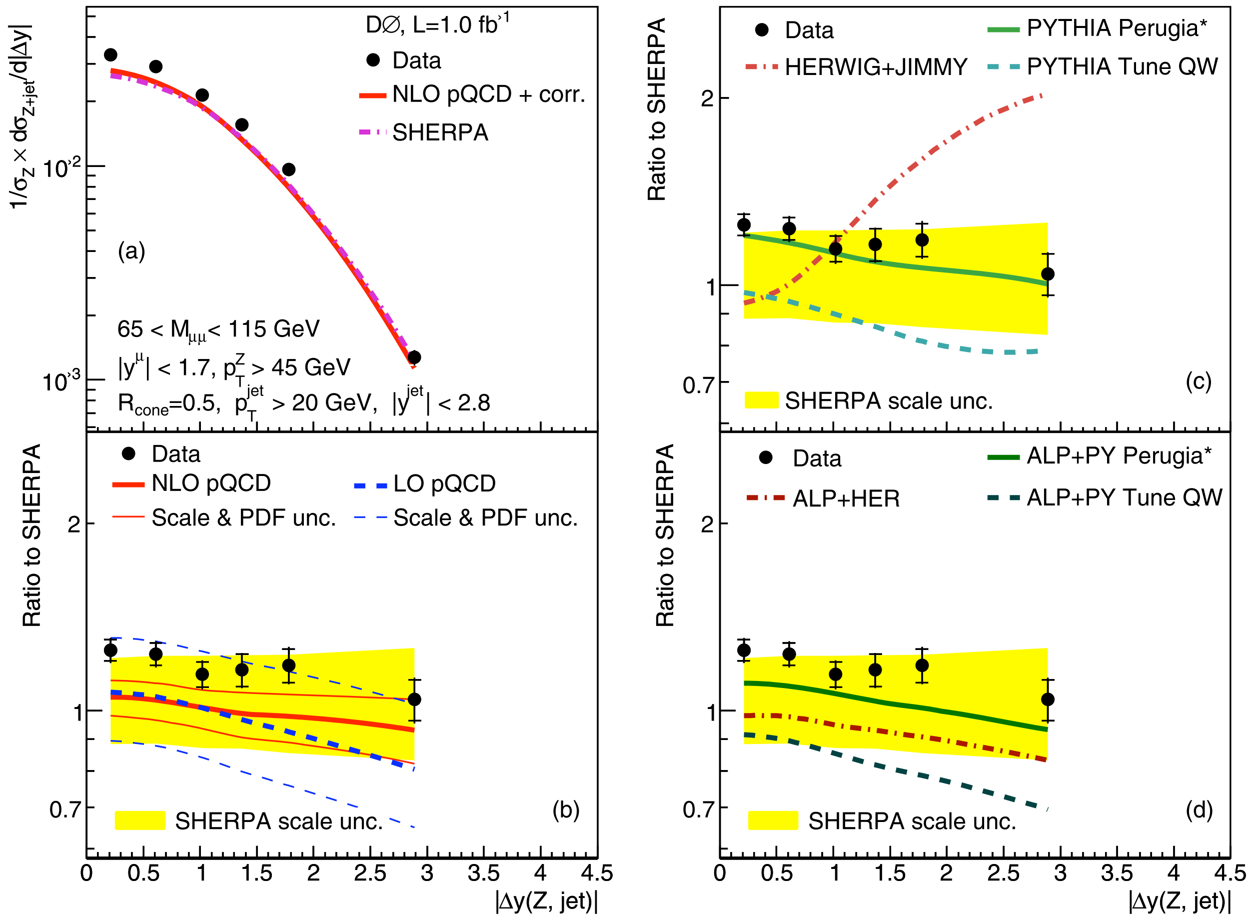
problem for Alpgen?

pQCD

matching MC

Z–jet Angles: Δy, p_T^Z>45GeV

parton shower MC

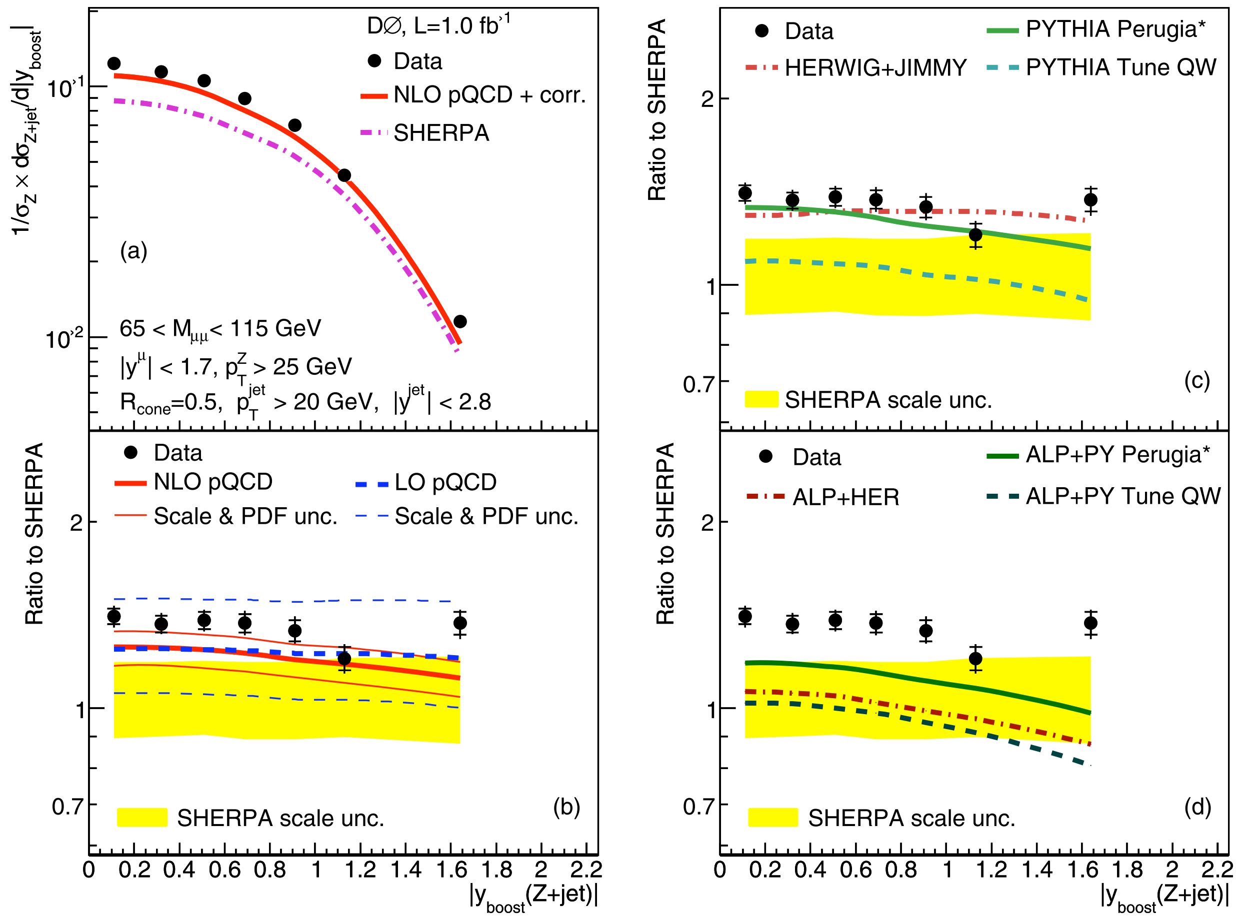


pQCD

matching MC

Z–jet Angles: y_{boost}, p_T^Z>25GeV

parton shower MC

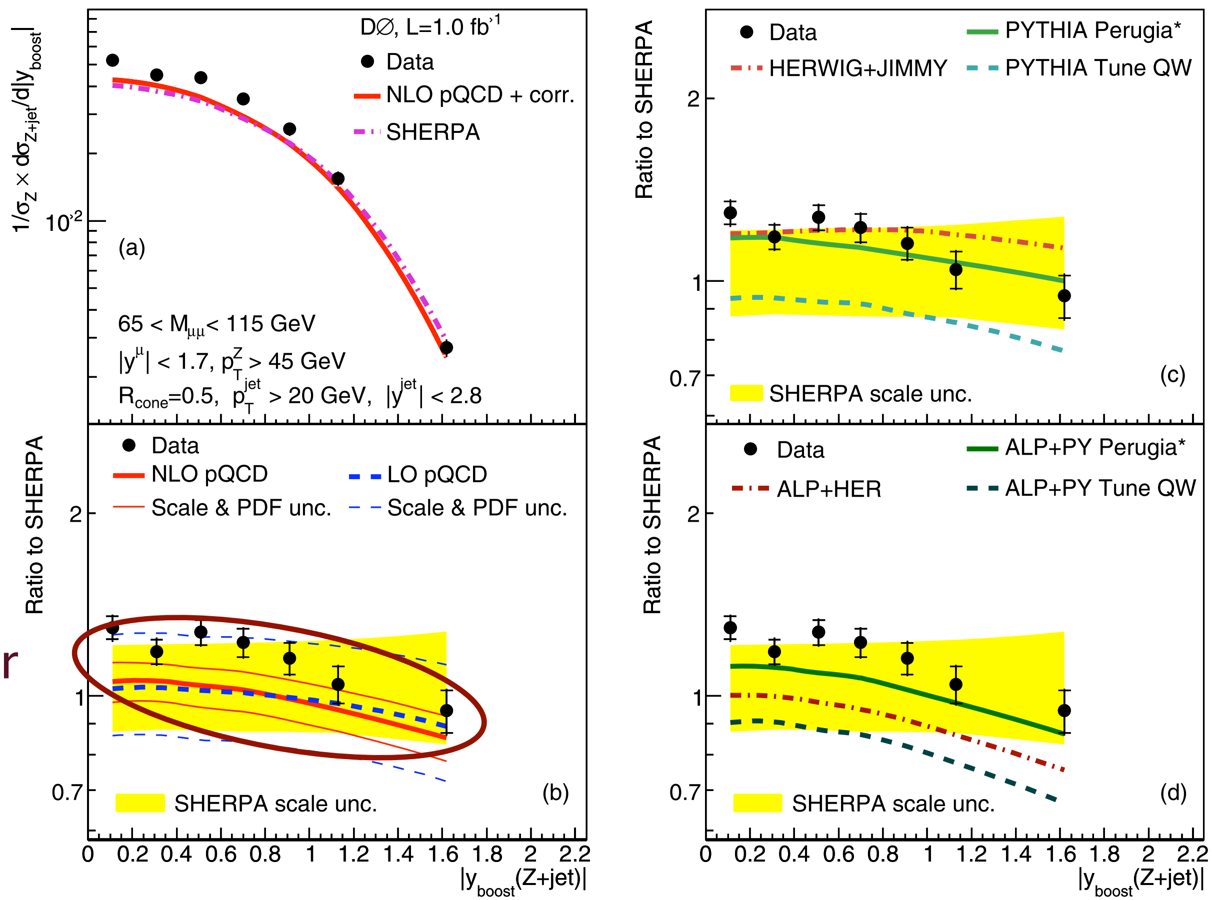


pQCD

matching MC

Z–jet Angles: y_{boost}, p_T^Z>45GeV

parton shower MC



problem for Sherpa?

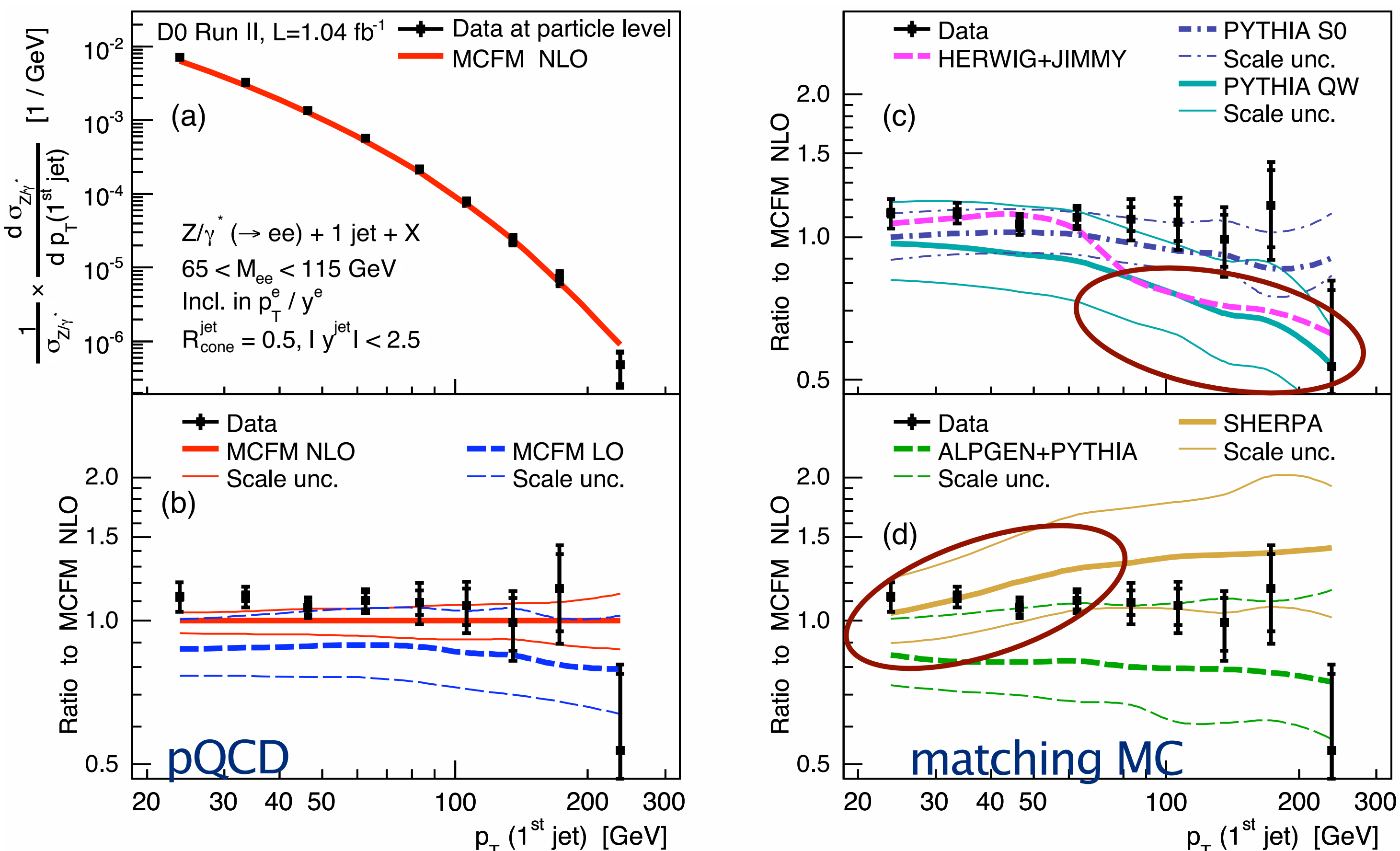
pQCD

matching MC

σ vs 1st jet p_T

Z→ee in this case
8452 / 1233 / 167
events with 1 / 2 / 3 jets

parton shower MC



$\mu_F = M_Z$
$\mu_R = a\, p_T^{rel}$

p_T ordering works for first jet

problem for Pythia QW and Herwig?

slope problem for Sherpa?

large scale dependence problematic

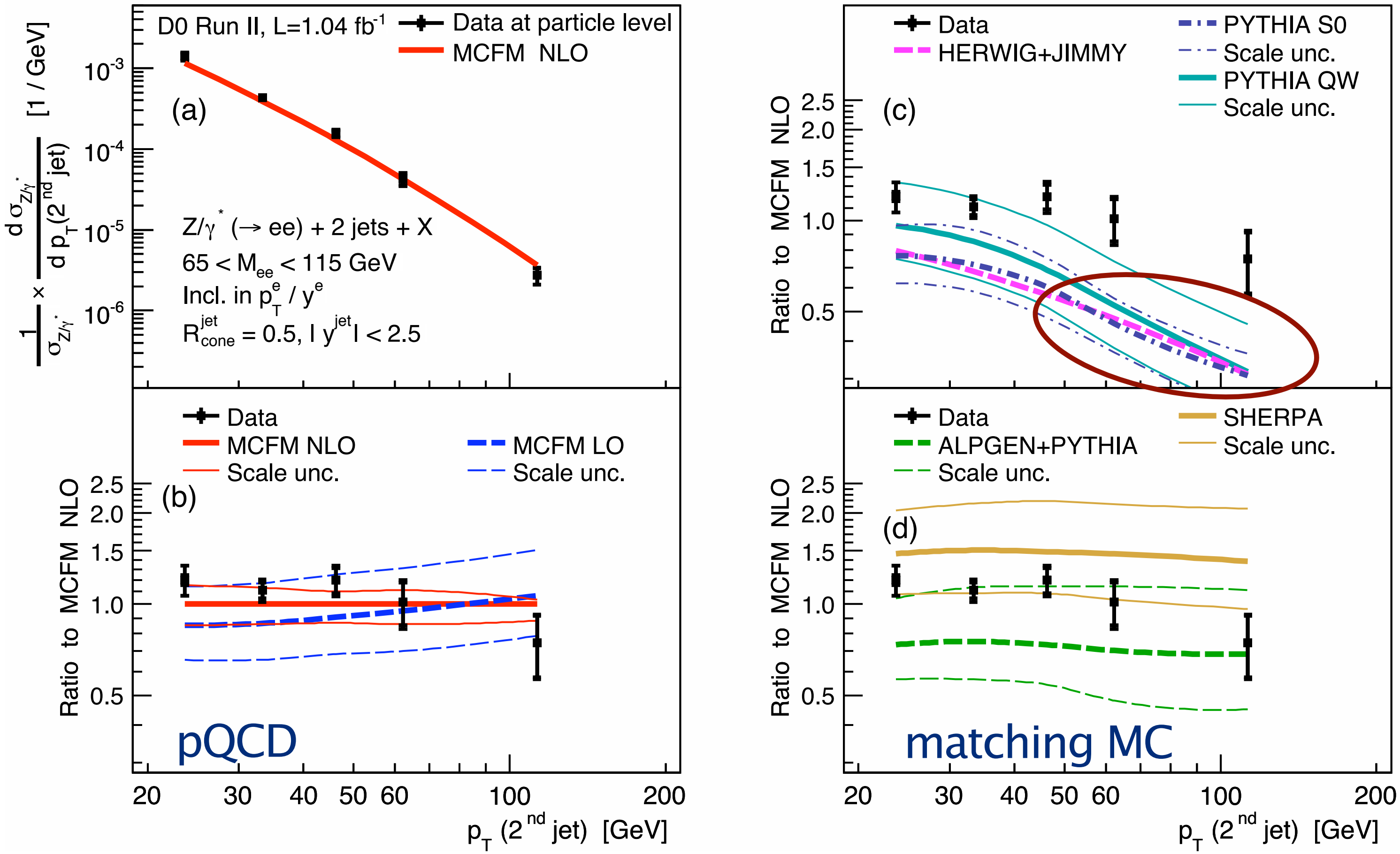
scale uncertainties smaller for NLO

PL B 678 (2009) 45-54

σ vs 2nd jet p_T

Z + 2 jet + X

parton shower MC

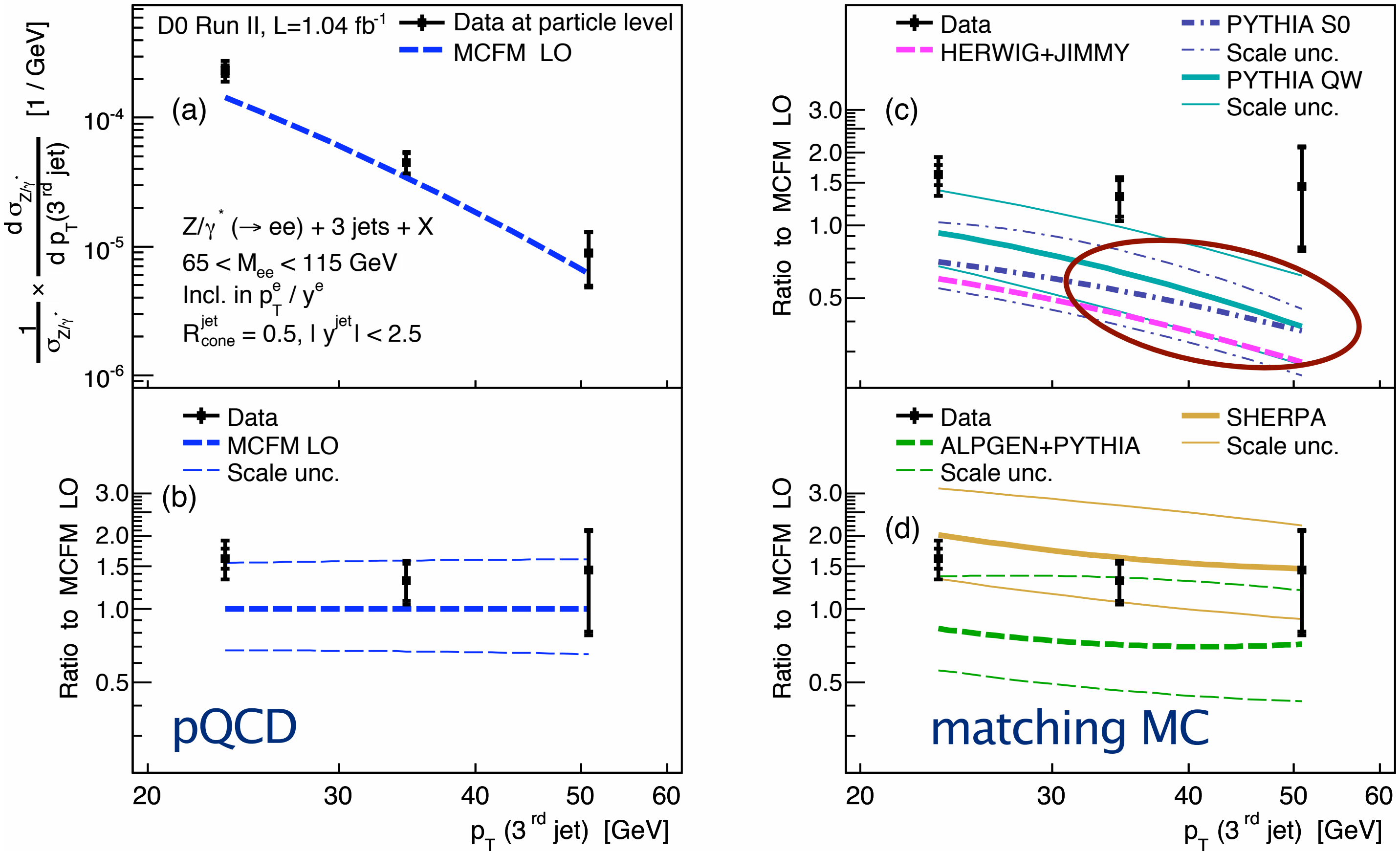


Pythia and Herwig are too soft

σ vs 3rd jet pT

Z + 2 jet + X

parton shower MC



Pythia and Herwig are too soft

Conclusion

MC with matching algorithms are a huge improvement over PS only generators.

Still, none of the existing MC provides a “perfect” description of all variables. As experimentalists we still have to re-weight our MC distributions. This is important as we train our NN with MC!

The scale uncertainties are in general too large!

THANKS to all
theorists working on
the MCs for us!