W and Z P_T Distributions

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for the CDF and D-Zero **Collaborations**

QCD and Weak Boson Physics at Run2
Photon and Weak Bosons Working Group

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Outline

- Motivation
- Introduction to Theory
- Experimental method
- W&Z P_T (CDF and DØ)
- W Angular distribution (DØ)
- What could be done better?
- Conclusion

Motivation

- W/Z events have
  - Distinctive event signatures
  - Low backgrounds
  - Large Q^2
  - Well understood EW vertex

- Measurements of **$d\sigma/dP_T$ test**
  - pQCD at large P_T
  - Resummation techniques at small P_T
  - Extraction of non-perturbative parameters

$\Rightarrow$Needed for M_T (W) measurement

Knowledge of W/Z production lays foundation

for many searches for new physics

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W/Z P_T Introduction to Theory

- **Large P_T region** ($P_T \geq \sim 30$ GeV)
  Use pQCD, $O(\alpha_s^2)$ calculations exist

  Ellis, Martinelli, Petronzio (83); Arnold & Reno (89)
  Arnold, Ellis, Reno (89); Gonsalves, Pawlowski, Wai (89)

- **Small P_T region** ($\Lambda_{QCD} < P_T < 10$ GeV)
  Resum large logs: $\ln(Q^2/P_T^2)$

  Altarelli, Ellis, Greco, Martinelli (84);
  Collins, Soper, Sterman (85)

- **Very low P_T region** ($P_T \sim \Lambda_{QCD}$)
  Nonperturbative parameters extracted from data

  b-space:

  Parisi-Petronzio (79), Davies-Stirling (84),
  Collins-Soper-Sterman (85), Davies, Webber, Stirling (85),
  Arnold- Reno-Ellis (89), Arnold-Kaufann (91),
  Ladinsky-Yuan (94)

  qt-space:

  Dokshitser-Diaknov-Troian (80), Ellis-Stirling (81),
  Altarelli-Ellis-Greco-Martinelli (84),
  Gonsalves-Pawlowksl-Wai (89), Ellis-Ross-Veseli (97),
  Ellis-Veseli (98)

Cross Section Measurement

For ith bin in P_T:

$$\frac{d\sigma}{dp_T^i} = \frac{d_i - b_i}{a_i \times \varepsilon_i \times L \times \Delta p_T^i}$$

- d_i = # candidate events
- b_i = Background
- a_i = Acceptance
- e_i = Efficiency
- L = Luminosity
- ΔP_T^i = bin width

For current W analyses, P_T is measured.

Will compare to smeared theory.

Focus on shape comparisons.

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Current Measurements

- W P_T
  - D0 Run 1b electrons (82 pb^{-1}) NEW!
    (Compared to AK $O(\alpha_s^2)$ b-space)
  - CDF Run 1a+1b electrons (110 pb^{-1})
    (Compared to ERV $O(\alpha_s)$ b&qt space)

- Z P_T
  - D0 Run 1b electrons (82 pb^{-1})
    (Compared to AK $O(\alpha_s^2)$ & LY $O(\alpha_s)$ b-space)
  - CDF Run 1a+1b electrons (110 pb^{-1})
    (Compared to $O(\alpha_s)$ LY b-space & ERV $O(\alpha_s)$ qt-space)

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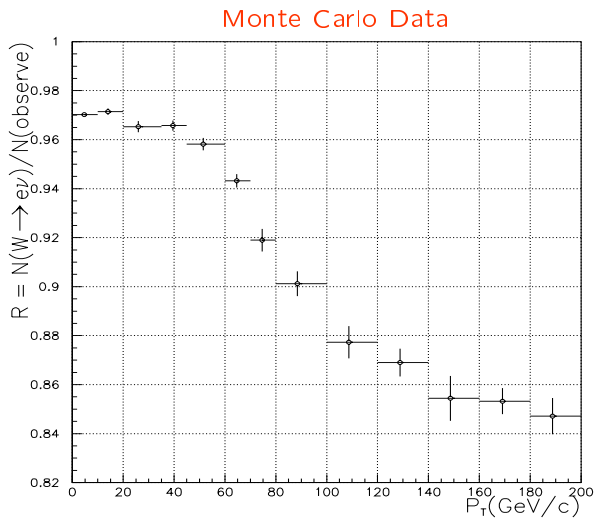
W Backgrounds

Low @ P_T<40 GeV, 15% @ P_T>40 GeV

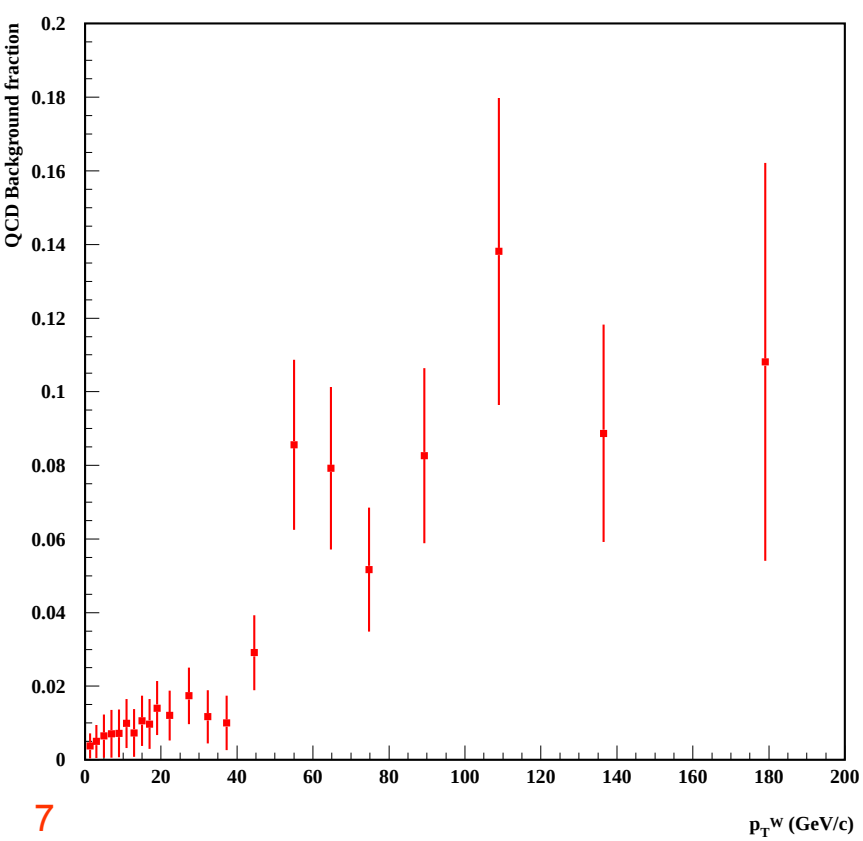
The Ratio of the Signal: $W \to e\nu$ to the observed events.

CDF



DØ

- The horizontal axis is unsmeared P_T^W



Note that only CENTRAL W's are used.

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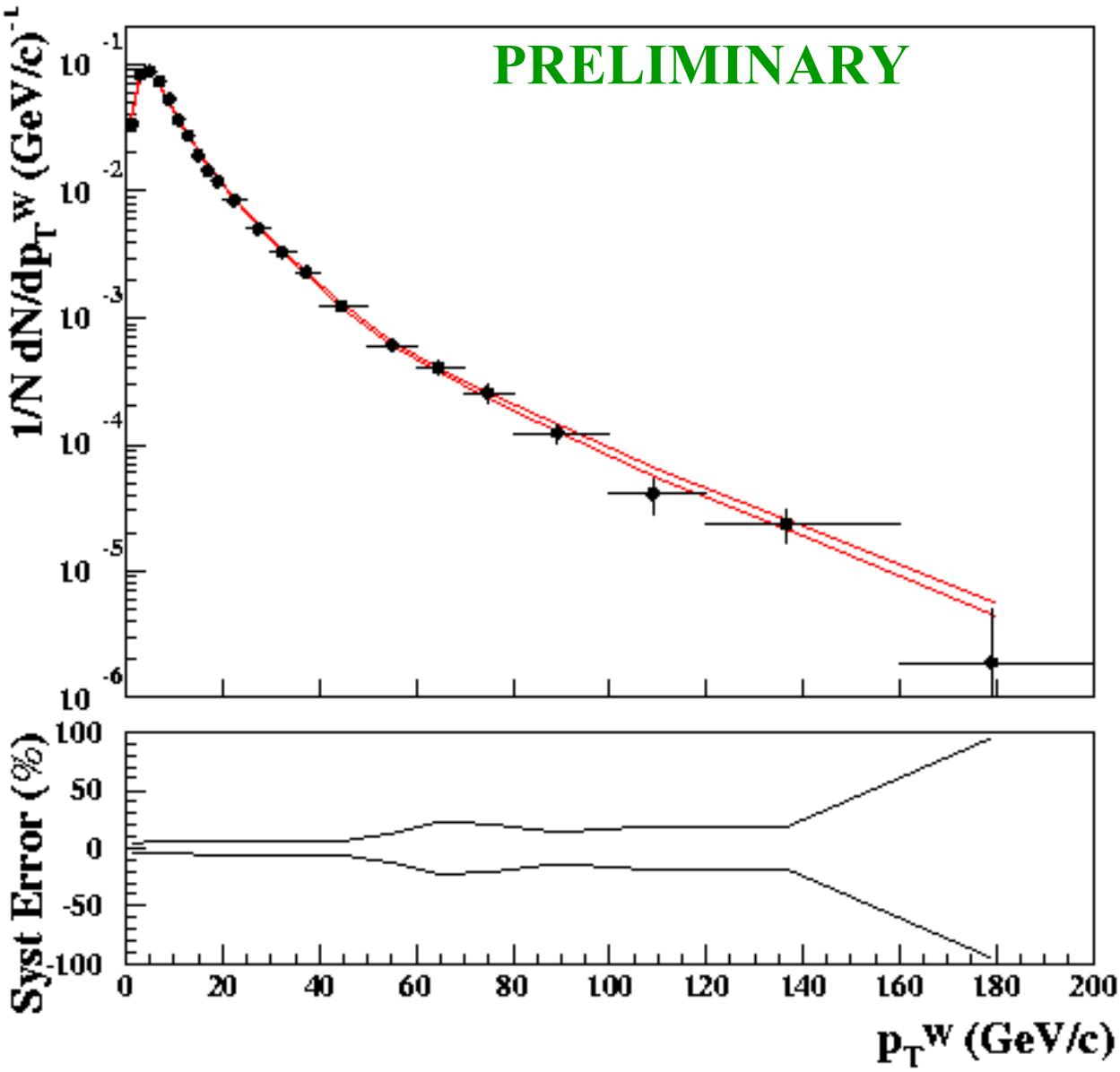
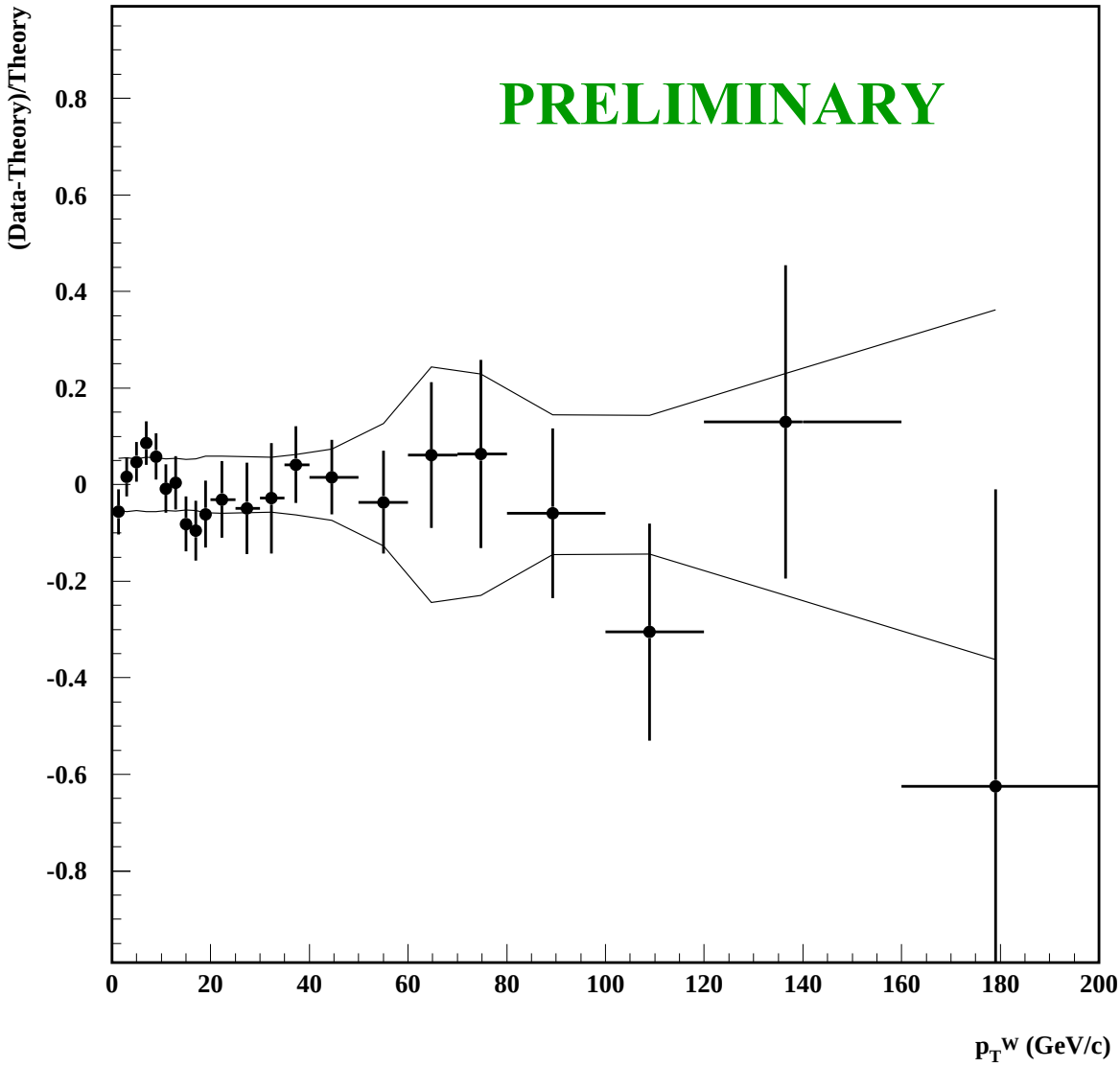
DØ 1b W P_T Spectrum



Arnold-Kauffman Nucl. Phys. B349, 381
$O(\alpha_s^2)$ resummation (b -space) MRSA'
after detector simulation

DØ 1b W P_T Spectrum



- χ^2/dof=7/19 (p_T(W)<120 GeV/c) χ2 /dof=10/21 (p_T(W)<200GeV/c)

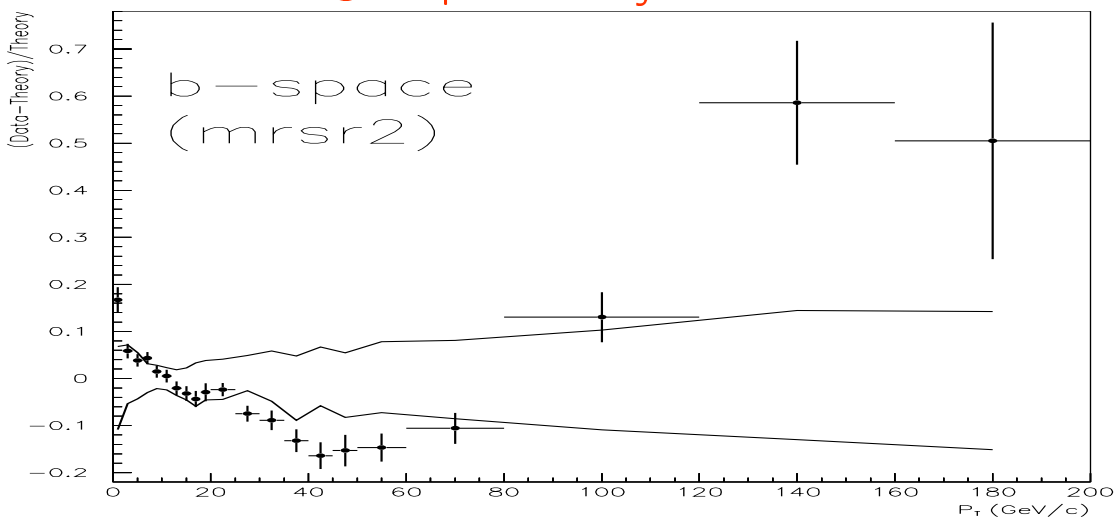
Resolution effects dominate at low P_T
High P_T dominated by statistics & backgrounds

CDF W P_T Spectrum

$\frac{(Data-Theory)}{Theory}$

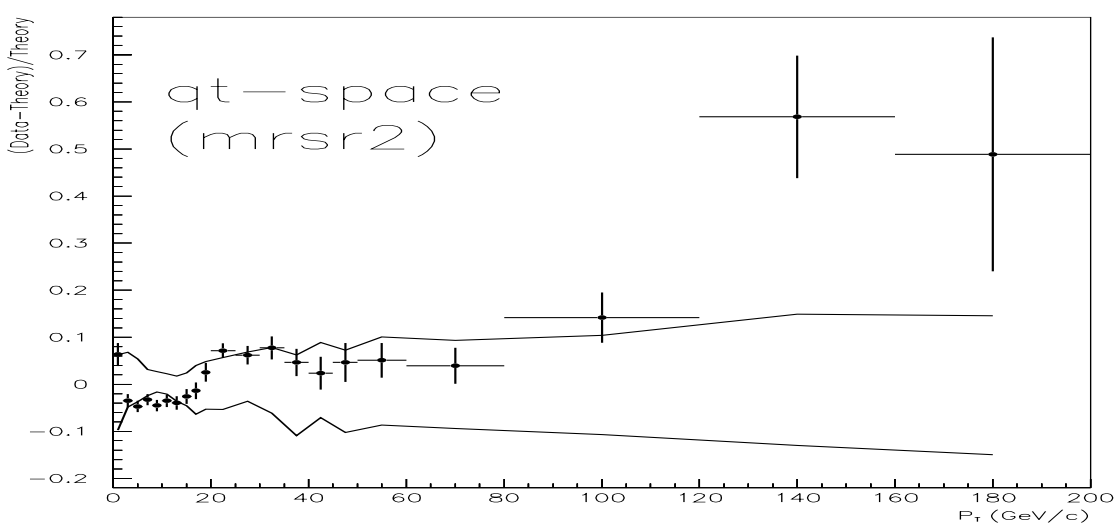
PRELIMINARY

CDF preliminary Run 1 Data



$\chi^2/d.o.f. = 1.85$ ($P_T^W < 120$ GeV/c), 2.49 (< 200 GeV/c)

- χ^2/dof=1.85 (p_T(W)<120 GeV/c) χ^2/dof=2.49 (p_T(W)<200GeV/c)



- χ^2/dof=1.05 (p_T(W)<120 GeV/c) χ^2/dof=1.71 (p_T(W)<200GeV/c)

$\chi^2/d.o.f. = 1.05$ ($P_T^W < 120$ GeV/c), 1.71 (< 200 GeV/c)

Ellis - Ross -Veseli $O(\alpha_s)$ Nucl. Phys. B503, 309 (97) smeared

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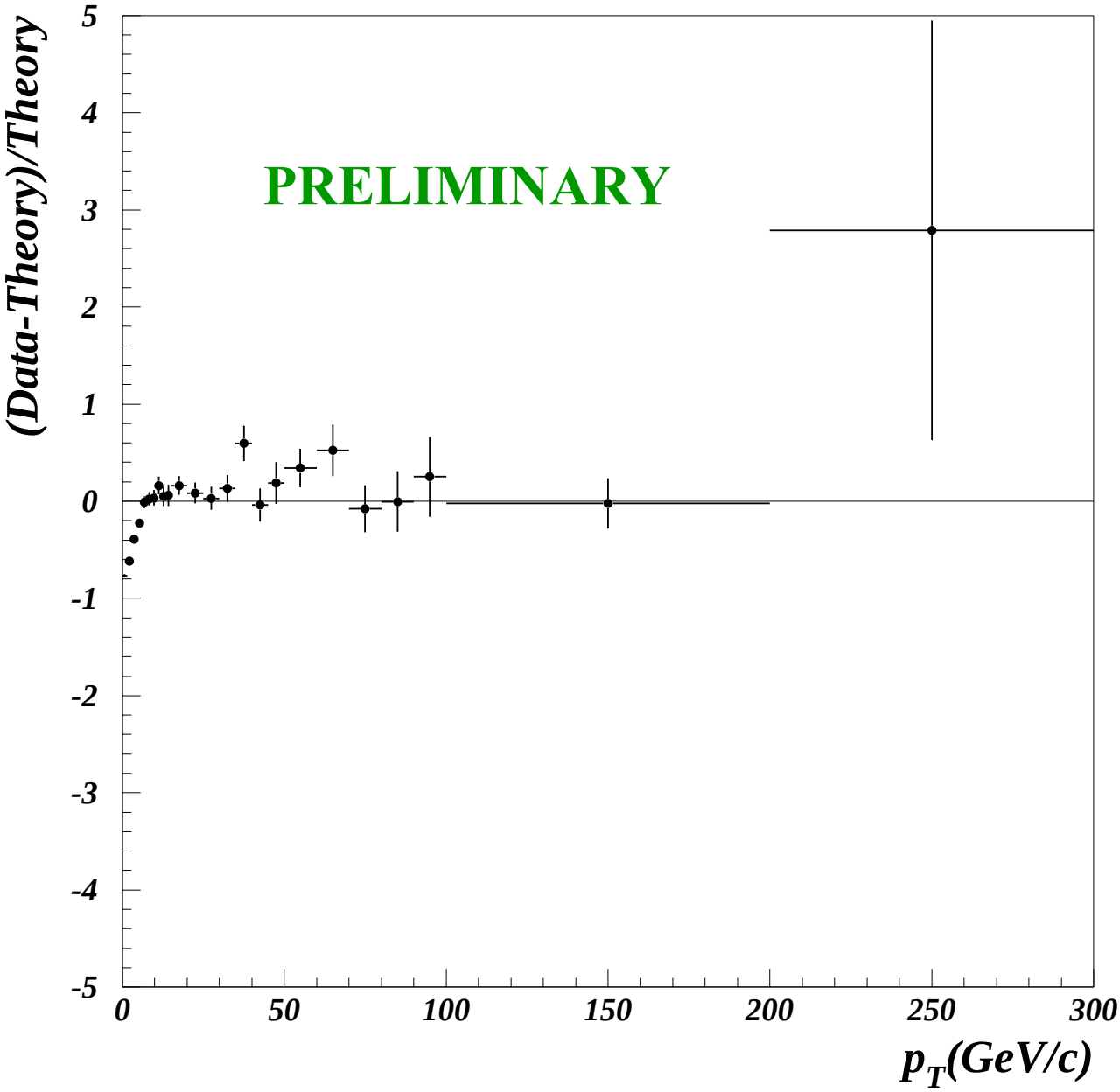
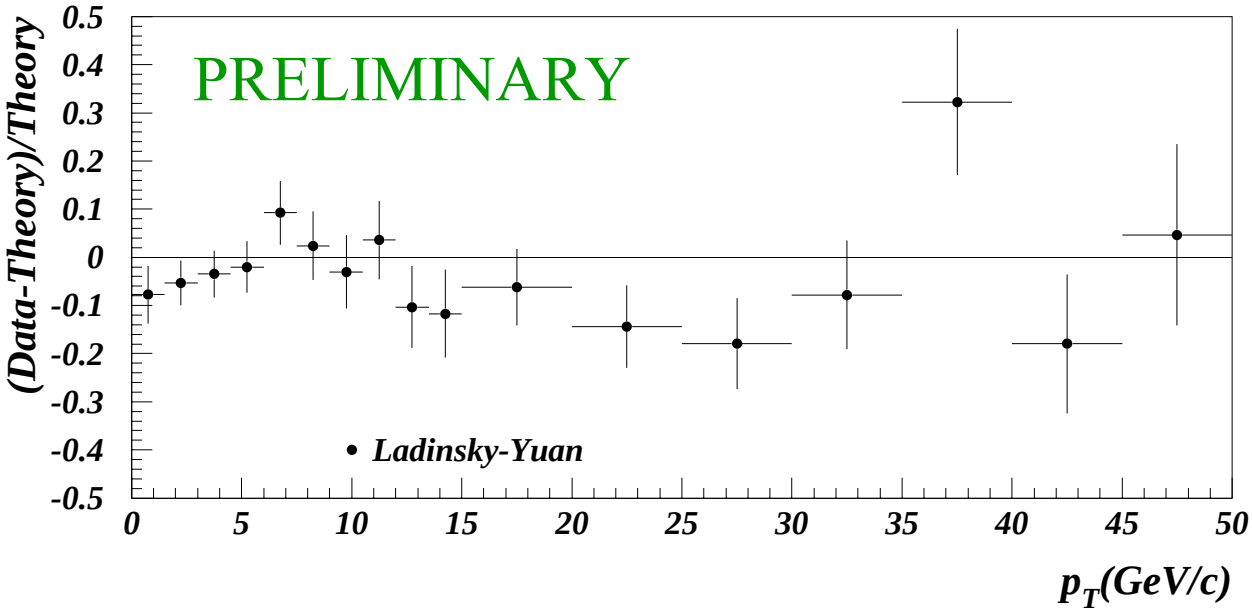
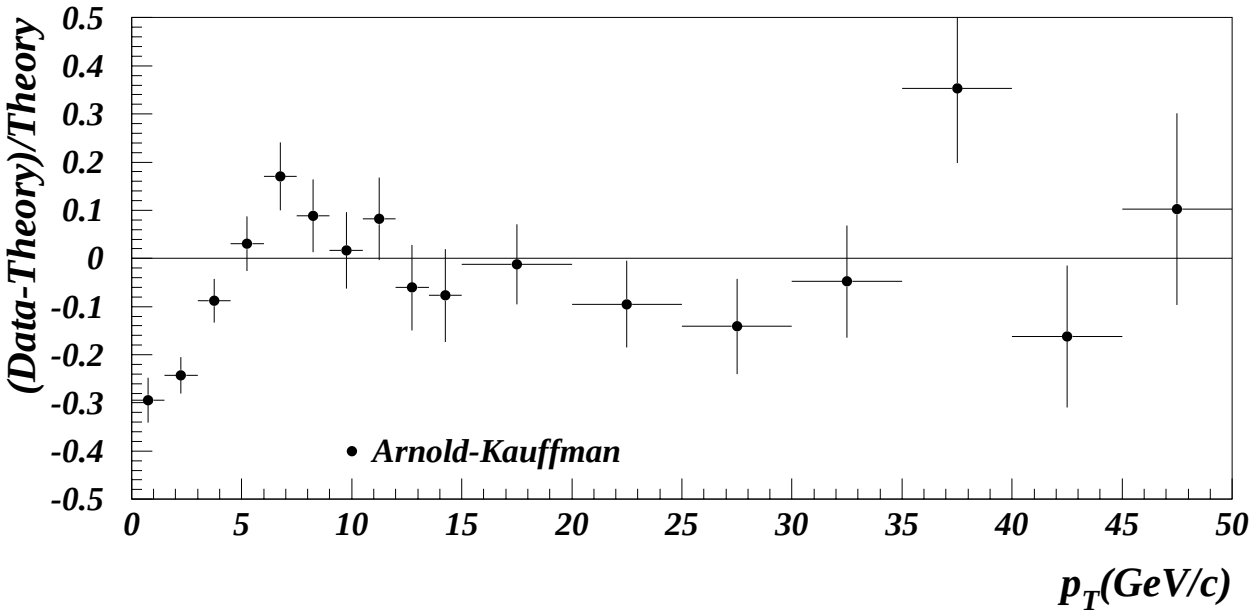
DØ 1b Z P_T Spectrum



Arnold - Reno pQCD Nucl. Phys. B319, 37
$O(\alpha_s^2)$ after detector simulation MRSA'

DØ 1b Z P_T Spectrum

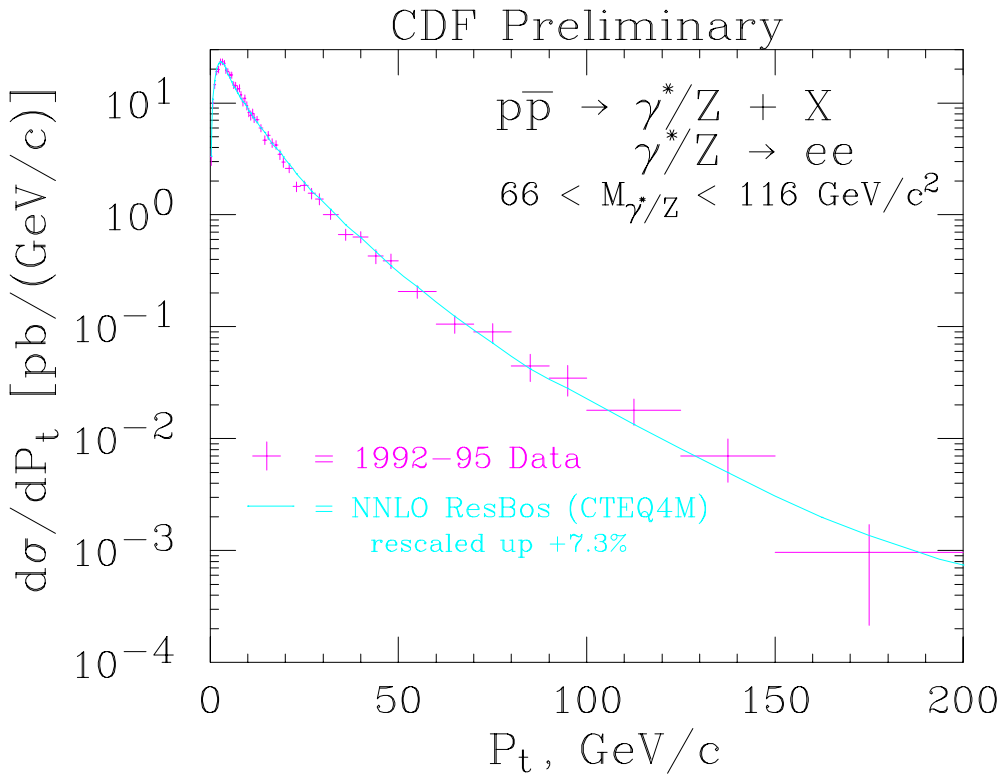


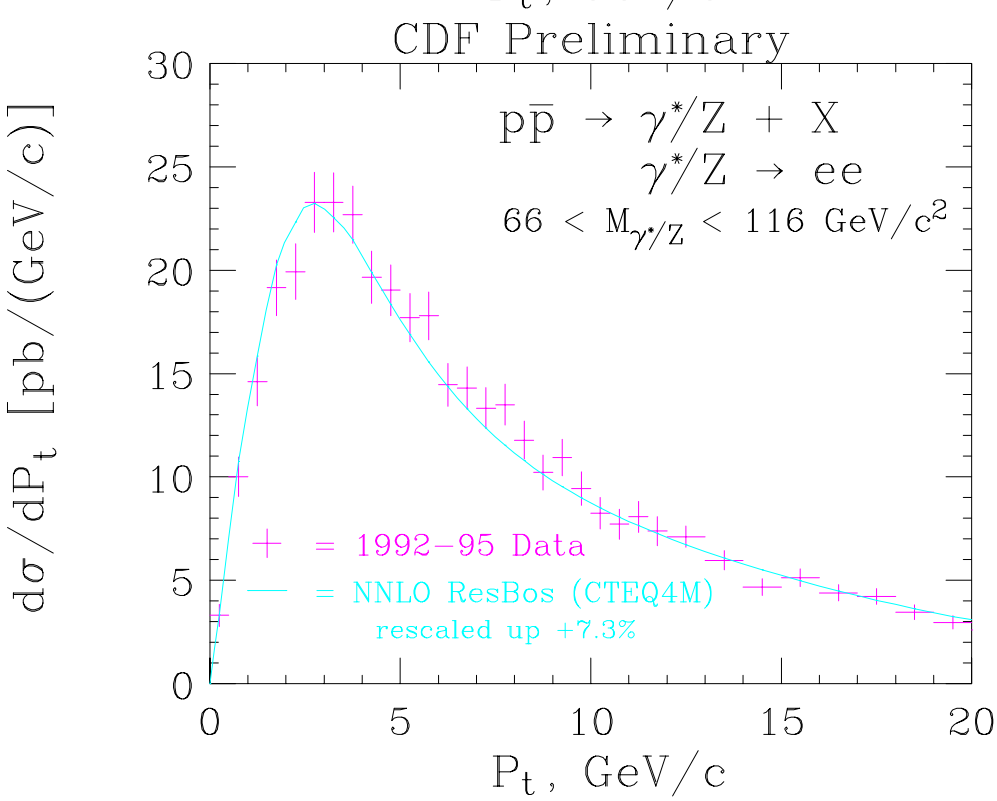


□χ^2/dof=17/16 (LY) χ^2/dof=83/16 (AK)

Data resolution allows to discriminate between different models for VB production.

CDF Z P_T Spectrum





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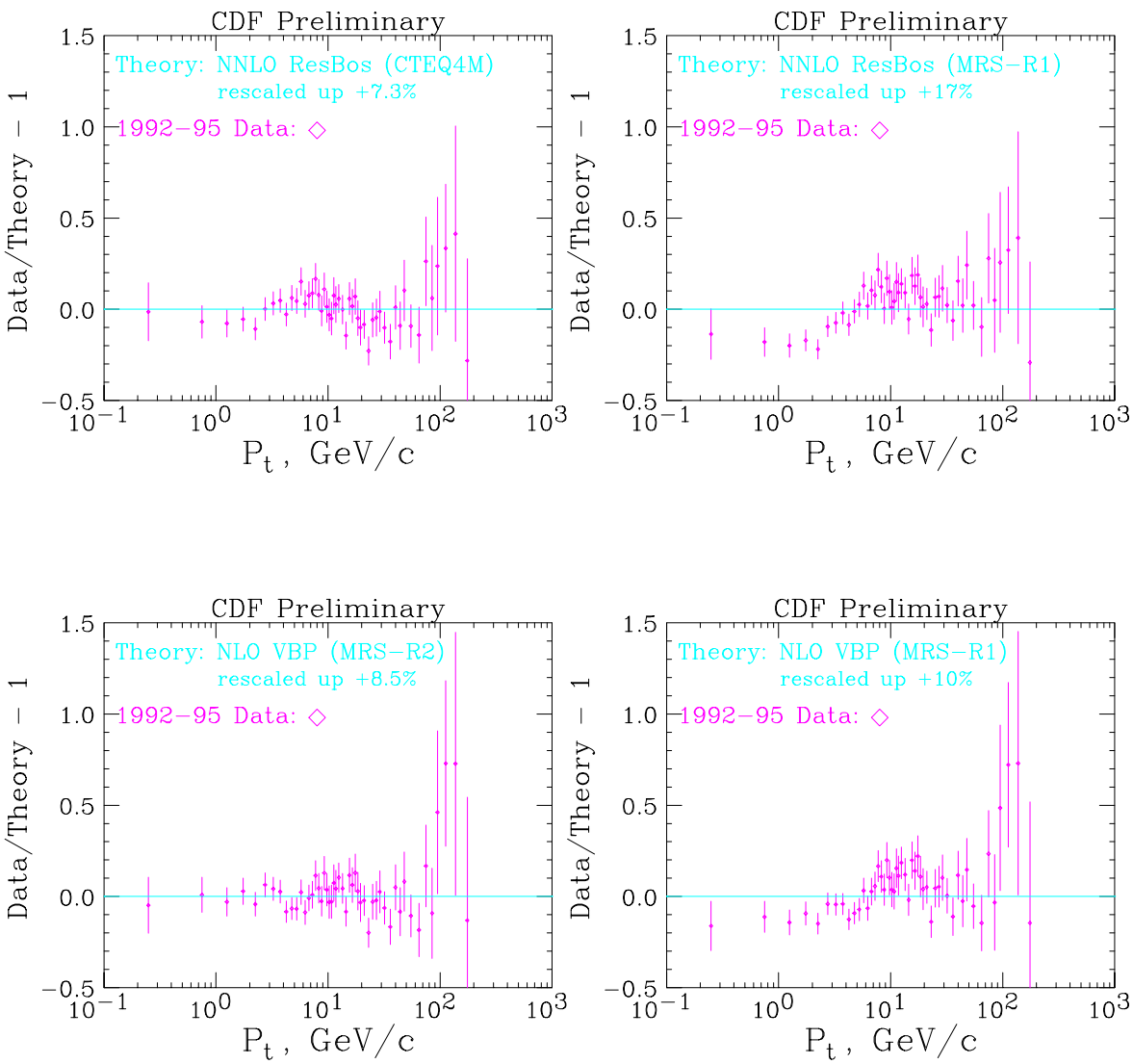
CDF Z P_T Spectrum



ResBos: b-space (*Balasz-Yuan PRD 56, 5558(1997)*)
VBP: qt-space (*Ellis-Veseli Nucl.Phys. B511,649(1998)*)

Data is unsmeared . Theory is re-scaled to match the measured CDF cross-section of 245pb.

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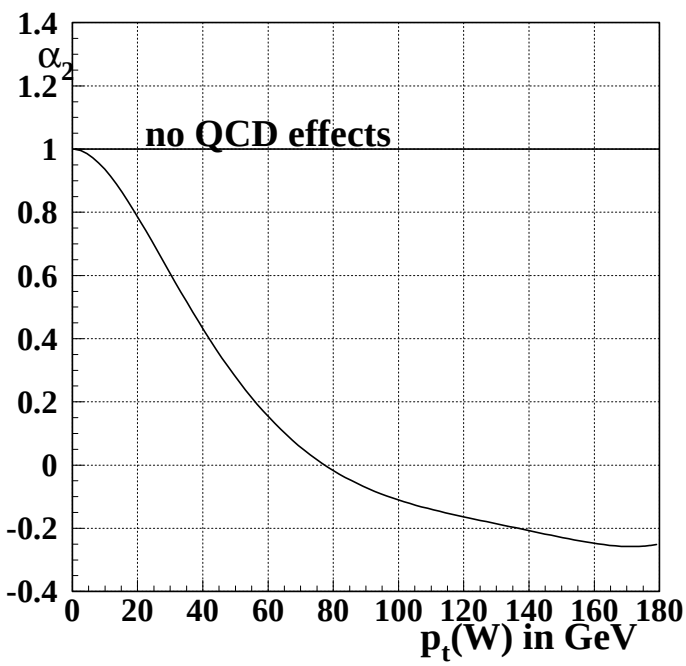
W Angular Distributions

(Measurement of the lepton angle in the W rest frame)

- NLO pQCD (*Mirkes, Nucl. Phys. B387, 3,1992*)

$$\frac{d\sigma}{dP_T dy d\cos\theta^*} \propto 1 + P(W)\alpha_1 \cos\theta^* + \alpha_2 (\cos\theta^*)^2 ;\ \alpha_i = \alpha_i(P_T)$$

- Pure V-A : $\alpha_1 = \pm 2 \quad \alpha_2 = 1$



- Measurement of α_2 vs $P_T(W)$
  - Test QCD
  - Non-negligible contribution to W mass

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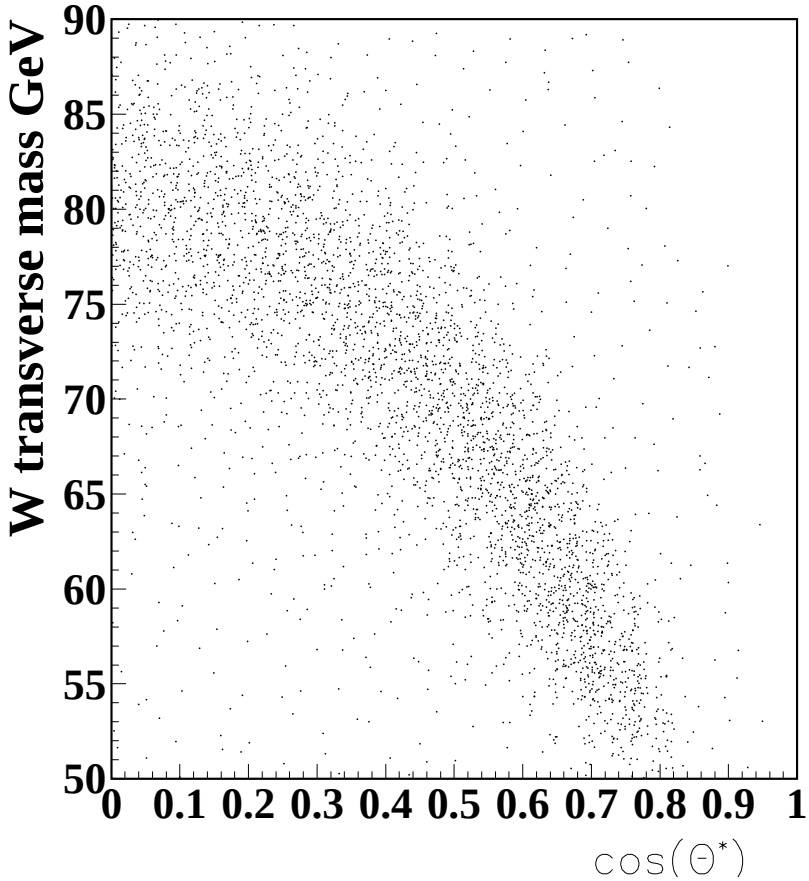
α_2 Method

- $P_Z(\nu)$ unknown => W rest frame cannot be reconstructed.
- Use correlation between $\cos\theta*$ & m_T to infer $\cos\theta*$ on a statistical basis.



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α_2 Method (cont)

- Define probability function

$$f(m_T, \cos\theta^*) = \frac{1}{N} g(m_T / \cos\theta^*) h(\cos\theta^*)$$

- For each $P_T(W)$ bin, plot background subtracted $m_T(W)$ and get

$$n_i = \sum_{m_{T_j}} N_{m_{T_j}} f(m_{T_j}, \cos\theta_i^*)$$

- Compare to n_i templates from MC
- Use log-likelihood to determine best value of $\alpha_2(P_T(W))$
- Method Tested with MC sample

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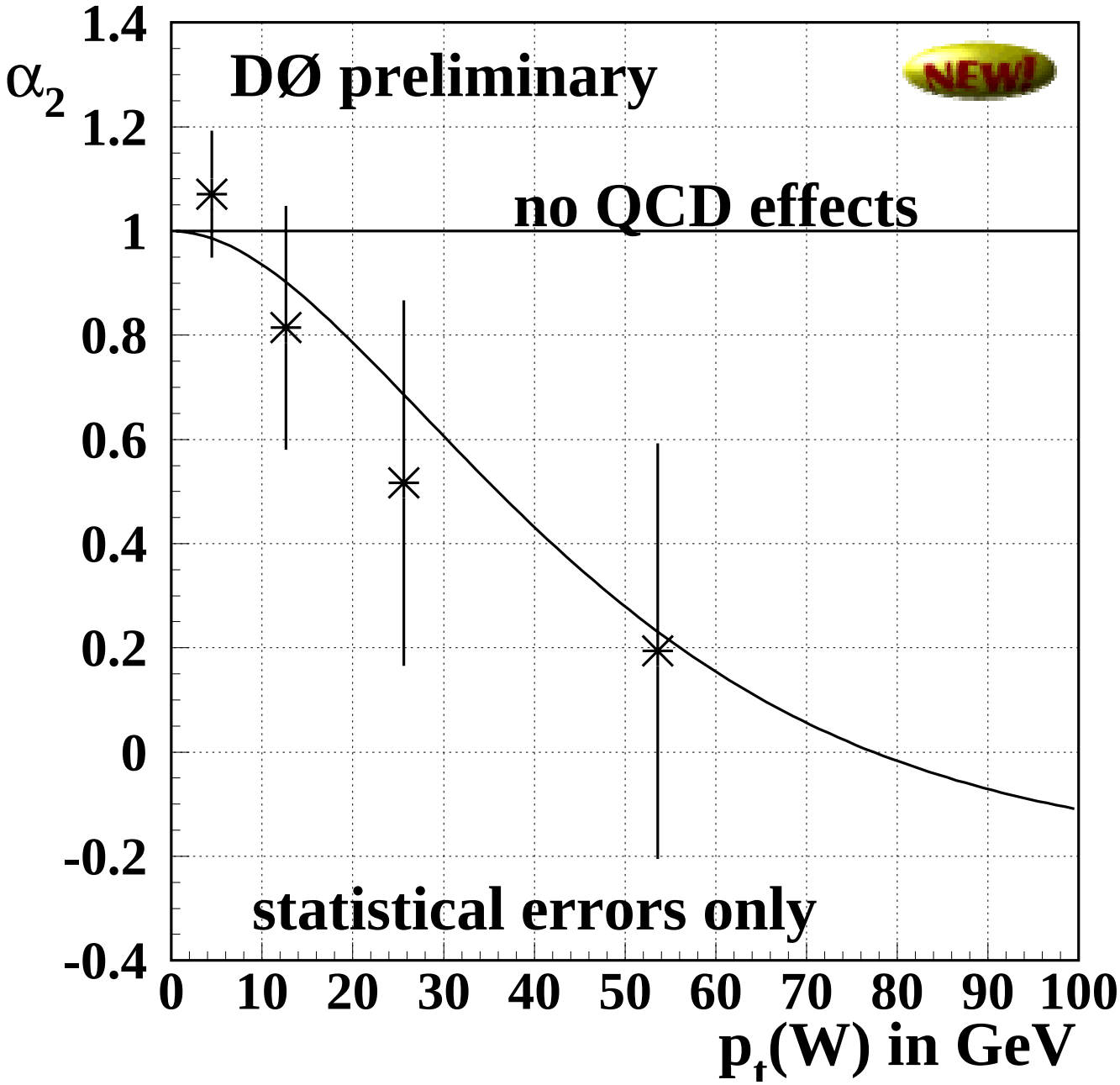
DØ α_2 versus P_T



Prob(pQCD) = 87% Prob(V-A)=7%

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What could be done better ?

(Willis, Minato, Steinbrueck,Casey,…)

- More statistics in both W&Z helps
  - P_T (Z) & α_2 statistically limited
  - efficiencies and detector model from Z

  BUT: will need to understand detector effects down to the few% level

- Data based background estimates
  - Need enough statistics in background trigger ...
  - correlation between Met and fake electron efficiency??

- Unfolding of P_T(W)
  - is tuning of recoil model using Z's really OK ??

Wish list for Run 2

- Simulations need full event generation with good agreement with data P_T distribution

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Conclusions

- CDF & DØ measured W&Z P_T
  - good agreement with VBP models
  - working on unfolding W distribution
- DØ measured α_2 (P_T (W))
  - pQCD preferred over pure V-A
  - working on quantifying preference
- Starting to build up Wish List for Run2
  - need work from experiments and theory to improve measurements

Looking forward to working group conclusions by the end of 1999!

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