Experimental Summary of Working Group D

Heavy Flavors

Leonid Gladilin

(DESY, MSU, WIS)

DIS 2004, Strbske Pleso, Slovakia, 14-18 April 2004

26 experimental talks

CDF, D0, HERA-B, ZEUS, H1, BABAR, BELLE, DELPHI, ALEPH,

CHORUS, NuTeV, RHIC

New resonances

D/B decays

Top production

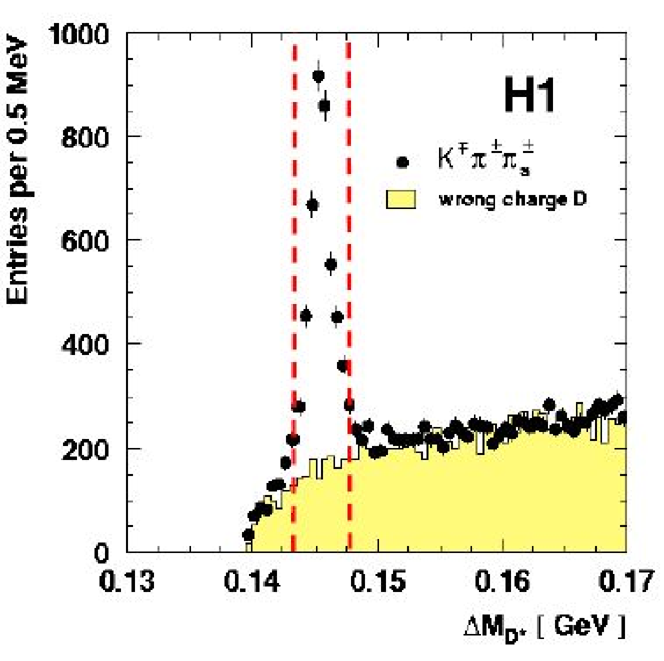
Beauty production

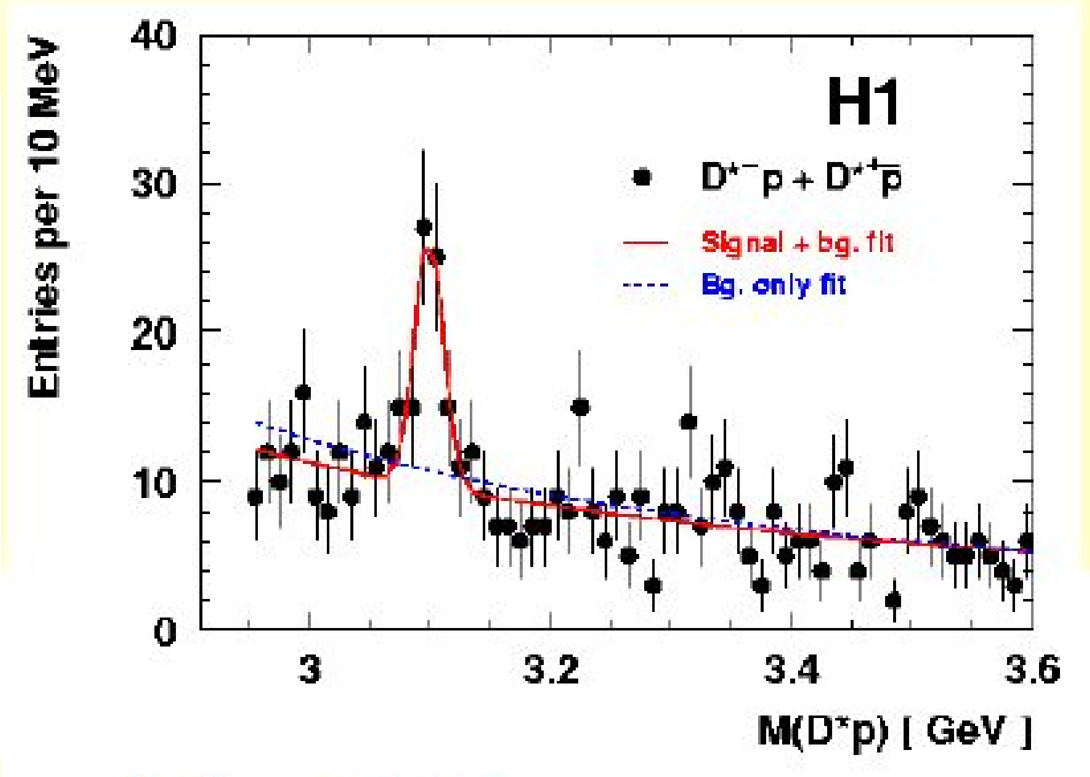
Charm production

Neutrino charm production

Evidence for a Narrow Exotic Anti-Charmed Baryon State

Sebastian Schmidt





3400 D* in DIS

$N(\Theta_c^0) = 50.6 \pm 11.2$

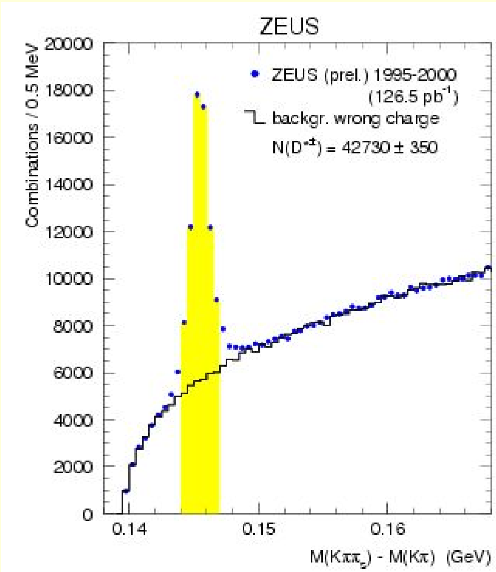
rate($D^{*\pm}$ from Θ_c^0) is "roughly 1%"

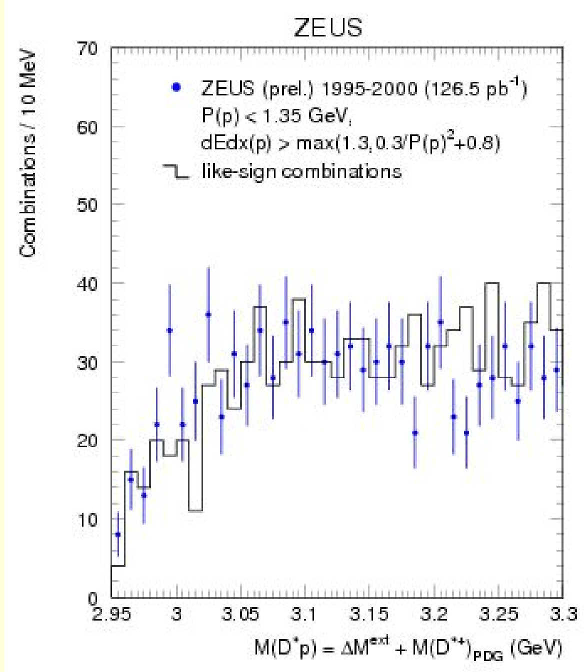
$M(\Theta_c^0) = 3099 \pm 3(stat.) \pm 5(syst.)$ **MeV**

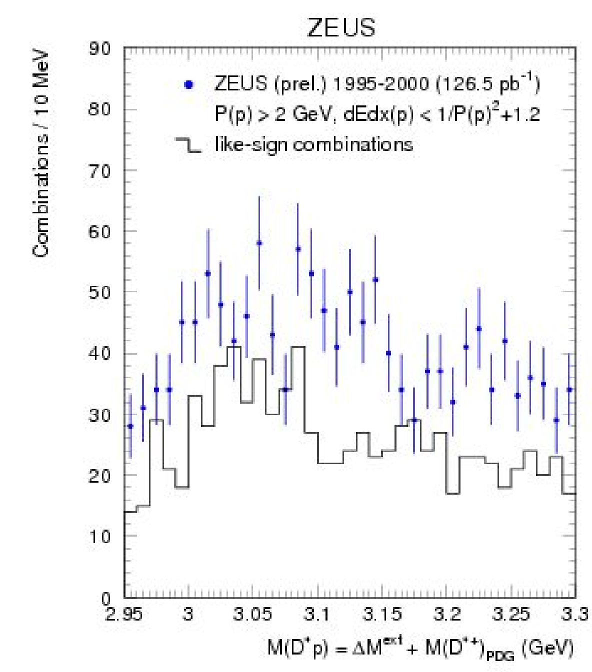
$\sigma(\Theta_c^0) = 12 \pm 3$ **MeV** (consist. with resolution)

Charm Hadron Spectroscopy with ZEUS

Uri Karshon







$N(D^{*\pm}) = 42730 \pm 350$

No signal observed

ALEPH : no signal (in WG C)

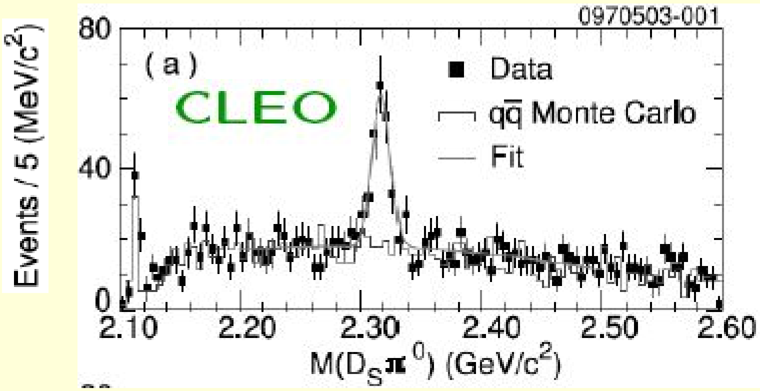
FOCUS, CDF, BABAR, BELLE ?

New resonances at Belle (and CLEO)

Hitoshi Yamamoto

BaBar observed a narrow $D_S(2317) \to D_S\pi^0$

Also a peak at 2.46 GeV in $D_S^*\pi^0$



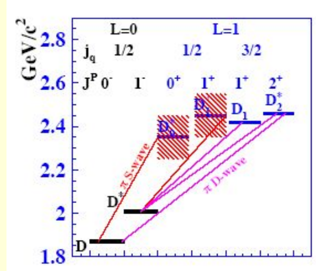
Belle (continuum) 87 fb^{-1}

$$\frac{Br(2457 \to D_S\gamma)}{Br(2457 \to D_S^*\pi^0)} = 0.55 \pm 0.13 \pm 0.08$$

$$\frac{Br(2457 \to D_S\pi^+\pi^-)}{Br(2457 \to D_S^*\pi^0)} = 0.14 \pm 0.04 \pm 0.02$$

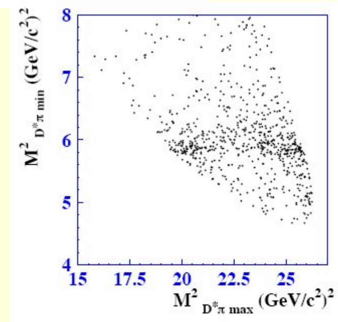
$(2457)1^+ \to D_S^*\pi$ ('main' mode) : isospin breaking

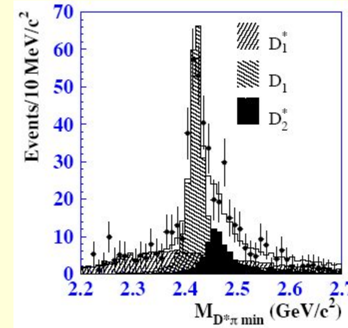
$(2317)0^+ \to D_S\pi$ ('main' mode) : isospin breaking



$B^- \to D^{**0}\pi^-$ (Belle 60 fb^{-1})

$$D^{**0} \to D^+\pi^-, \quad D^{*+}\pi^-$$





$$M_{D_1^0} = 2421.4 \pm 1.5 \pm 0.4 \pm 0.8\text{MeV}$$
$$\Gamma_{D_1^0} = 23.7 \pm 2.7 \pm 0.2 \pm 4.0\text{MeV}$$

(NEW)

$$M_{D_1'^0} = 2427 \pm 26 \pm 20 \pm 15\text{MeV}$$
$$\Gamma_{D_1'^0} = 384^{+107}_{-75} \pm 24 \pm 70\text{MeV}$$

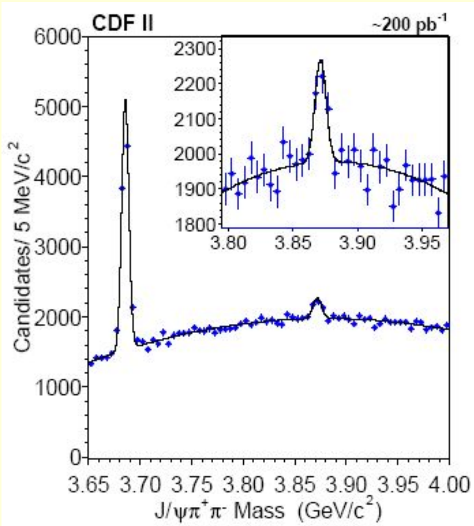
$D^+\pi^-\pi^-$ Dalitz plot fit results

(NEW)

$$M_{D_0^{*0}} = 2308 \pm 17 \pm 15 \pm 28\text{MeV}$$
$$\Gamma_{D_0^{*0}} = 276 \pm 21 \pm 18 \pm 60\text{MeV}$$

$$M_{D_2^{*0}} = 2461.6 \pm 2.1 \pm 0.5 \pm 3.3\text{MeV}$$
$$\Gamma_{D_2^{*0}} = 45.6 \pm 4.4 \pm 6.5 \pm 1.6\text{MeV}$$

$X(3872) \rightarrow J/\Psi\ \pi^+\ \pi^-$



PETER J BUSSEY

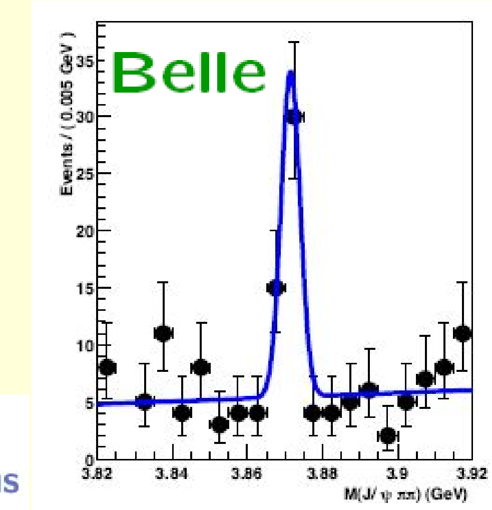
Significance is 11.6σ

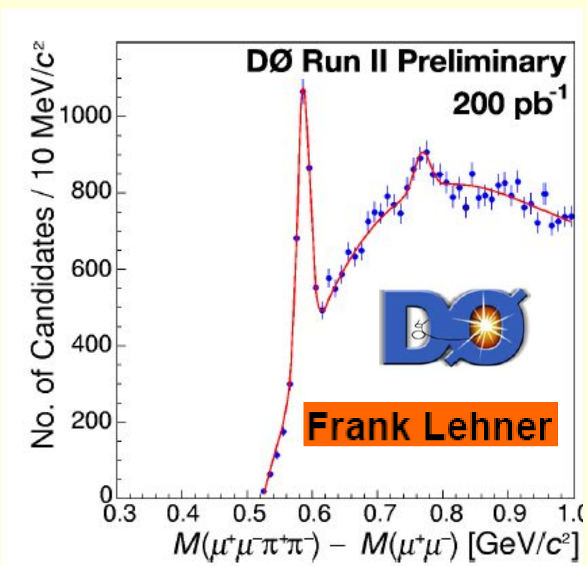
Resolution consistent with apparatus

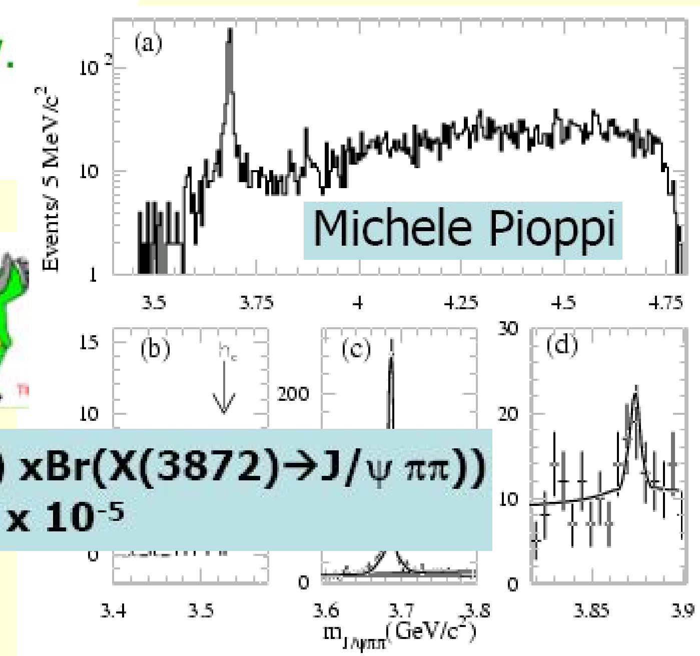
Fitted mass

$3871.3 \pm 0.7 \pm 0.4$ MeV.

BELLE: 3871.7 ± 0.6 MeV.







$Br(B^- \rightarrow X(3872)K^-) \times Br(X(3872) \rightarrow J/\psi\ \pi\pi))$
$= (1.28 \pm 0.41) \times 10^{-5}$

BELLE's observation is confirmed

Search for the Flavor-Changing Neutral Current Decay $D^0 \to \mu^+\mu^-$

Standard Model	10^{-13} – 10^{-19}
MSSM with R-parity violation	3.5×10^{-6}

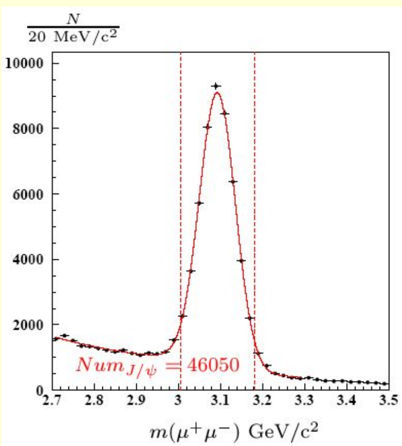
HERA B

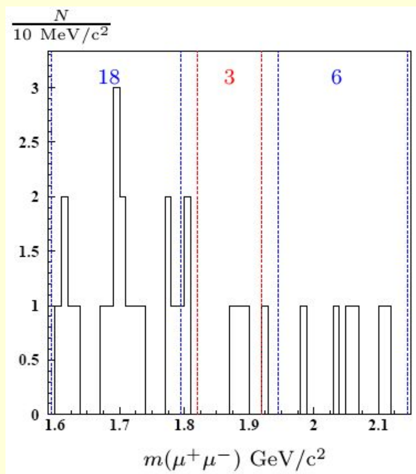
Viktor Egorytchev

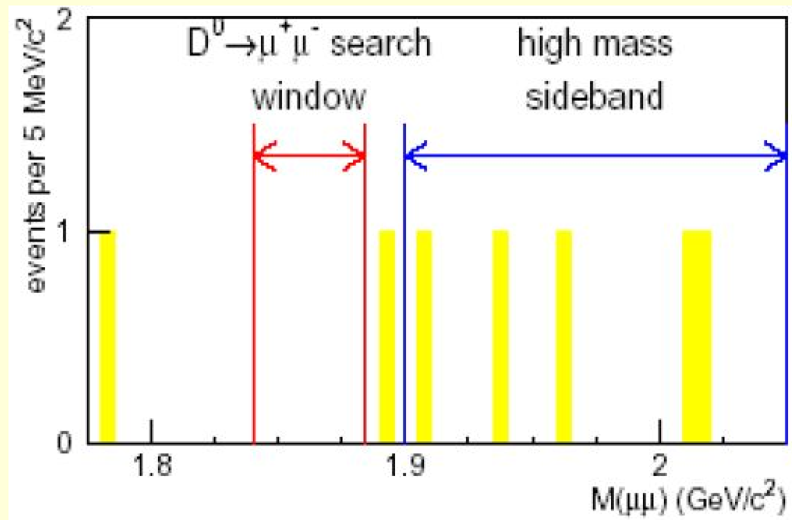
CDF

S. Donati

$$Br(D^0 \to \mu^+\mu^-) = \frac{N_{cl}}{N_{J/\psi}} \frac{\alpha_{J/\psi}}{\alpha_{D^0}\epsilon_{D^0}} \frac{\sigma^{pA}_{J/\psi}}{\sigma^{pA}_{D^0}} Br(J/\psi \to \mu^+\mu^-)$$





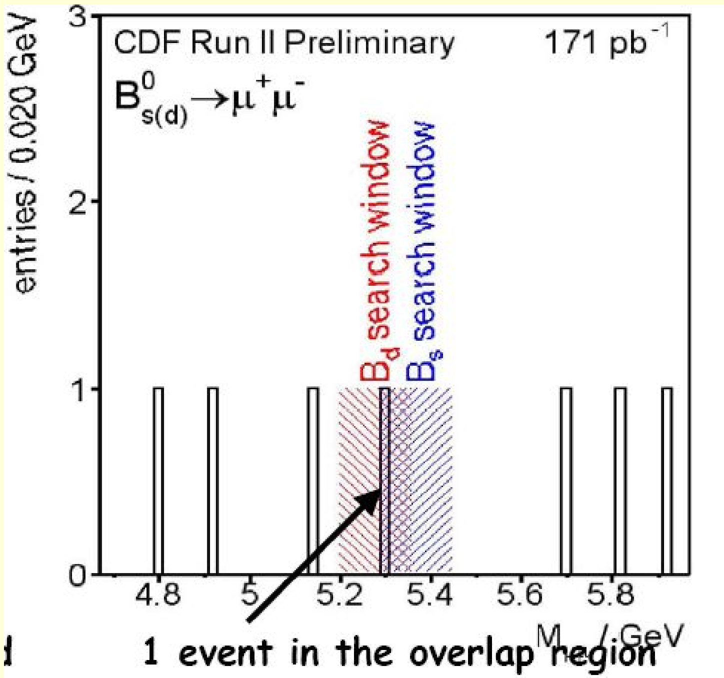


$$Br(D^0 \to \mu^+\mu^-) < 2.0 \times 10^{-6} \quad (90\ \%\ C.\ L.)$$

BR($D^0 \to \mu\mu$)< 2.5 (3.3) × 10^{-6} at 90% (95%) CL

The result constrains the product of R-parity violating couplings

Rare decays: $B_{d(s)} \to \mu^+\mu^-$ CDF S. Donati



	$B_s \to \mu^+\mu^-$	$B_d \to \mu^+\mu^-$
Background	1.05±0.30	1.07±0.31
Data	1	1
BR limit @95% C.L.	7.5×10^{-7}	1.9×10^{-7}
BR limit @90% C.L.	5.8×10^{-7}	1.5×10^{-7}

Best world result for B_s (improves CDF Run I)

Slightly better results than Belle and BaBar for Bd

1.6×10^{-7} 2.0×10^{-7}

Standard Model predicts

$$BR(B_s \to \mu^+\mu^-) = (3.8 \pm 1.0) \times 10^{-9}$$

no excess already constrains several SUSY models

D0 Frank Lehner

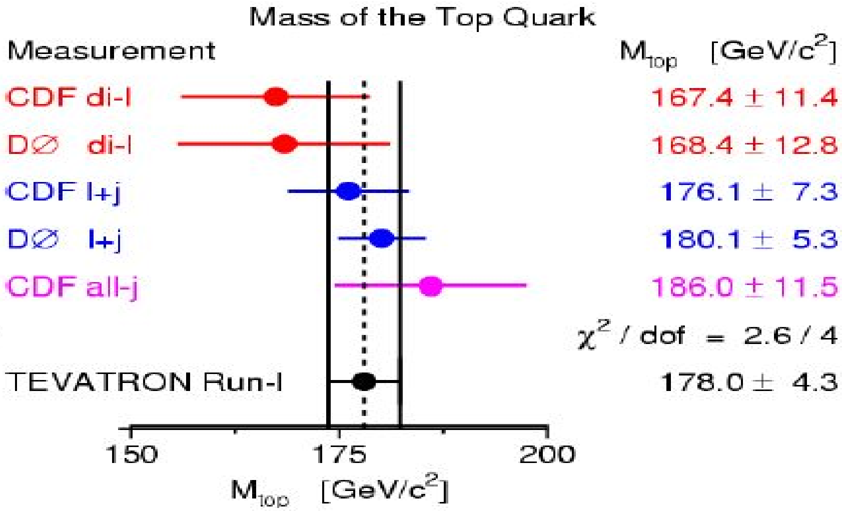
Work in progress

Top production and properties Roman Lysak

Summary of Run I top results

- Observed in first 70 pb^{-1} of Run I in 1995
- Final Run I analyses based on 110 pb^{-1}

- $t\bar{t}$ cross-section:
  $6.5^{+1.7}_{-1.4}$ pb (1.8 TeV)
- Single top production:
  < 13.5 pb @ 95% C.L.
- Overal agreement with SM, but small statistics (~100 events)

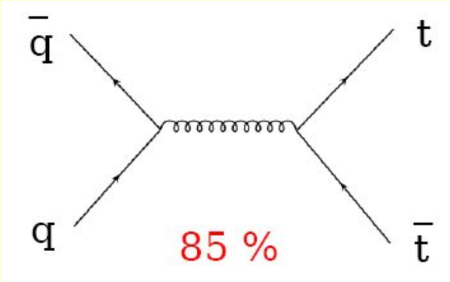


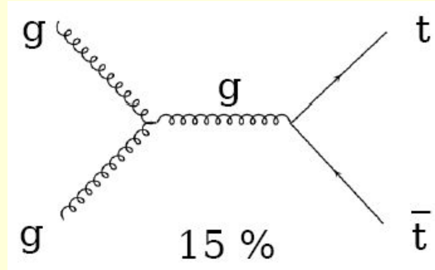
world average:

$M_{top} = 178.0 \pm 4.3$ GeV

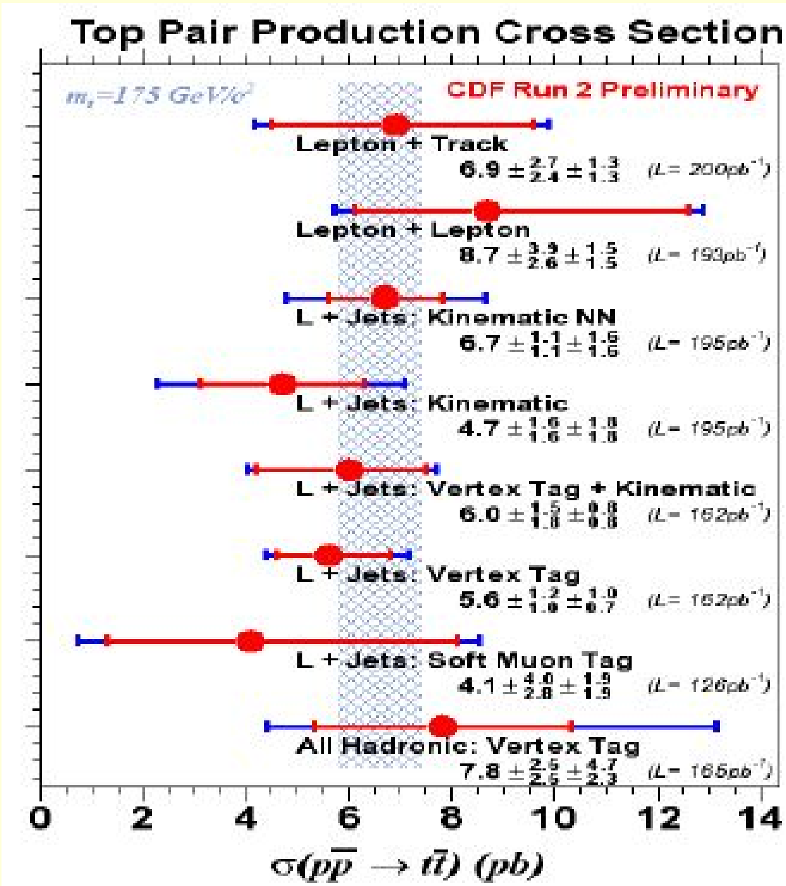
Accelerator: $\sqrt{s}$ 1.8 TeV ⟶ 1.96 TeV

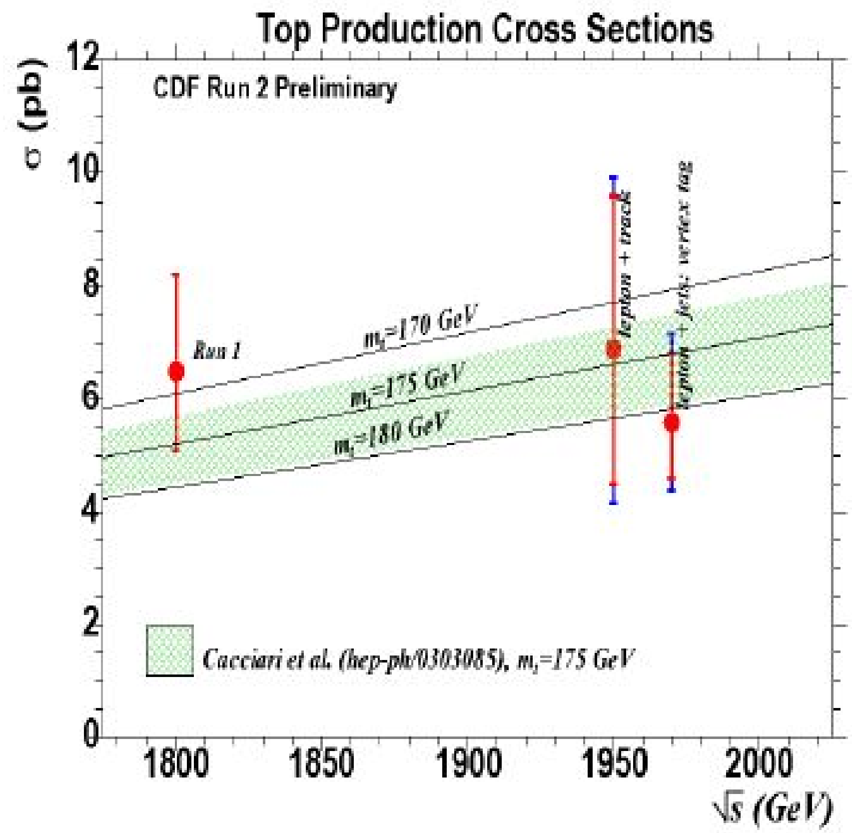
it gives 30%-40% increase in top cross-section


q̄
t
q
t̄
85 %


g
t
g
g
t̄
15 %

Roman Lysak


Top Pair Production Cross Section
m_t=175 GeV/c²
CDF Run 2 Preliminary
Lepton + Track
6.9 $\pm^{2.7}_{2.4} \pm^{1.3}_{1.3}$ (L= 200pb⁻¹)
Lepton + Lepton
8.7 $\pm^{3.9}_{2.6} \pm^{1.5}_{1.5}$ (L= 193pb⁻¹)
L + Jets: Kinematic NN
6.7 $\pm^{1.1}_{1.1} \pm^{1.6}_{1.6}$ (L= 195pb⁻¹)
L + Jets: Kinematic
4.7 $\pm^{1.6}_{1.6} \pm^{1.8}_{1.8}$ (L= 195pb⁻¹)
L + Jets: Vertex Tag + Kinematic
6.0 $\pm^{1.5}_{1.8} \pm^{0.8}_{0.8}$ (L= 162pb⁻¹)
L + Jets: Vertex Tag
5.6 $\pm^{1.2}_{1.0} \pm^{1.0}_{0.7}$ (L= 162pb⁻¹)
L + Jets: Soft Muon Tag
4.1 $\pm^{4.0}_{2.8} \pm^{1.9}_{1.9}$ (L= 126pb⁻¹)
All Hadronic: Vertex Tag
7.8 $\pm^{2.5}_{2.5} \pm^{4.7}_{2.3}$ (L= 165pb⁻¹)
0 2 4 6 8 10 12 14
σ(pp̄ → tt̄) (pb)


Top Production Cross Sections
CDF Run 2 Preliminary
σ (pb)
0 2 4 6 8 10 12
Run 1
m_t=170 GeV
m_t=175 GeV
m_t=180 GeV
lepton + track
lepton + jets: vertex tag
Cacciari et al. (hep-ph/0303085), m_t=175 GeV
1800 1850 1900 1950 2000
√s (GeV)

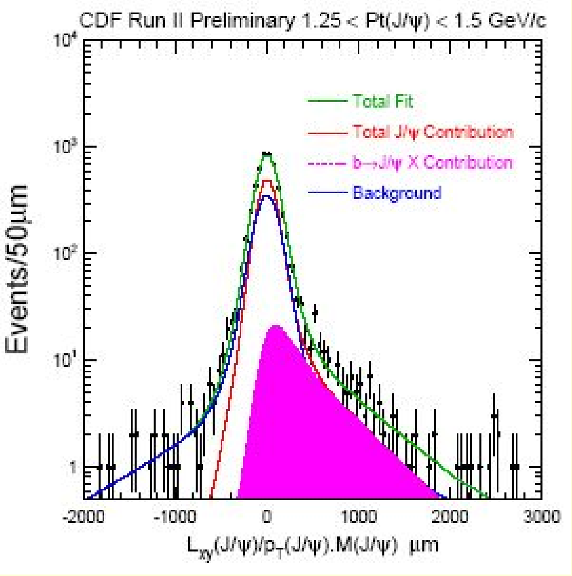
BEAUTY AT TEVATRON

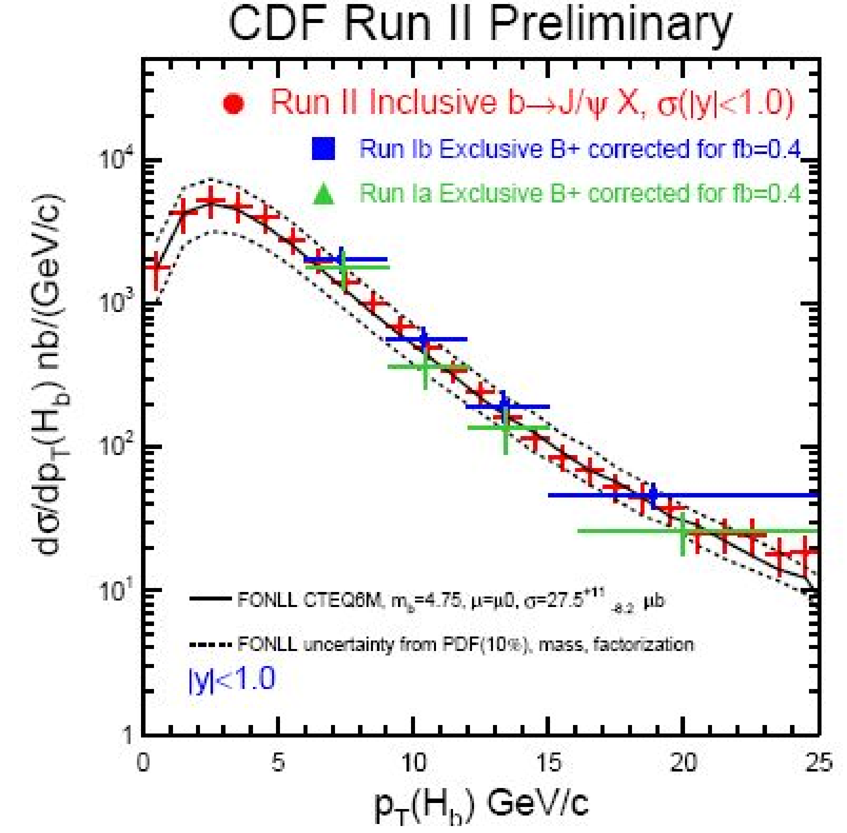
PETER J BUSSEY

New CDF inclusive b cross sections

Method:

- Start with $J/\psi \to \mu\mu$ signal
- Measure decay path L_{xy} in x, y
- Model known b-hadron $\to J/\psi$ processes
- Max likelihood fit to $L_{xy}/p_T(J/\psi)$ evaluates b-hadron fraction
- Include effects of acceptance etc.
- **Unfold to get b-hadron distribution.**





Beauty ditto – problems disappearing?

b quark→hadron treatment

PDFs now improved.

b fragmentation function

Christian Weiser

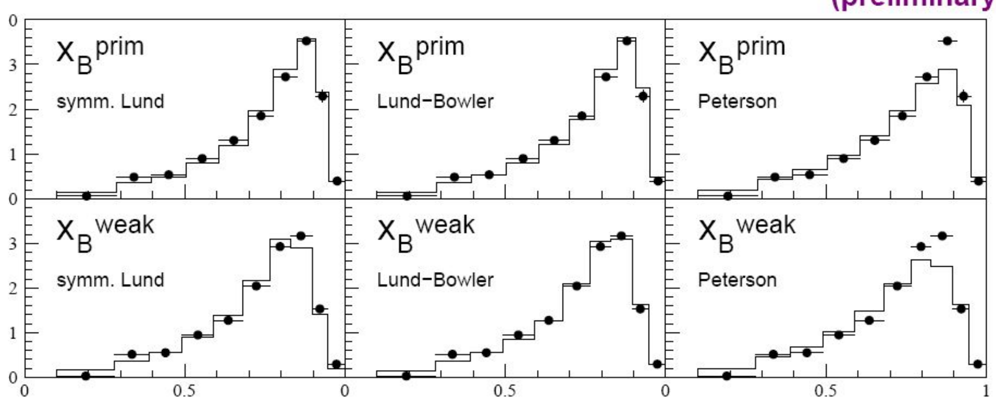
Several analysis methods:

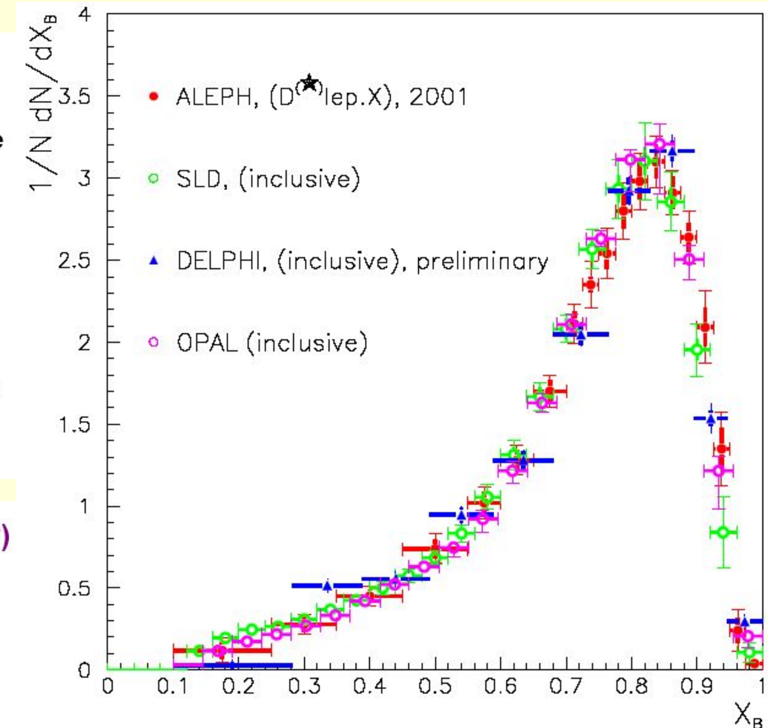
- **inclusive leptons from semileptonic decay:**
  large statistics, but limited by model uncertainties; poor sensitivity to shape
  ➔ obsolete; not used anymore!

- **semi-exclusive decays $B \rightarrow D^{(*)} l \nu$ (ALEPH):**
  low statistics but better energy estimate; but: uncertainties from final state!
  only sensitive to B-mesons for these final states!

- **inclusive analyses (DELPHI, OPAL, SLD):**
  OPAL, DELPHI: huge statistics, worse resolution ➔ systematics dominates
  SLD: lower statistics but excellent vertexing possible
  ➔ better resolution, stat. ≈ syst.

DELPHI: fit model parameters to unfolded distributions (preliminary)



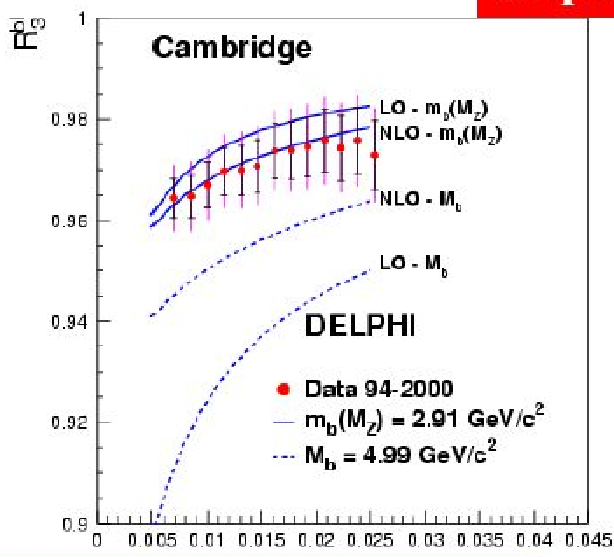


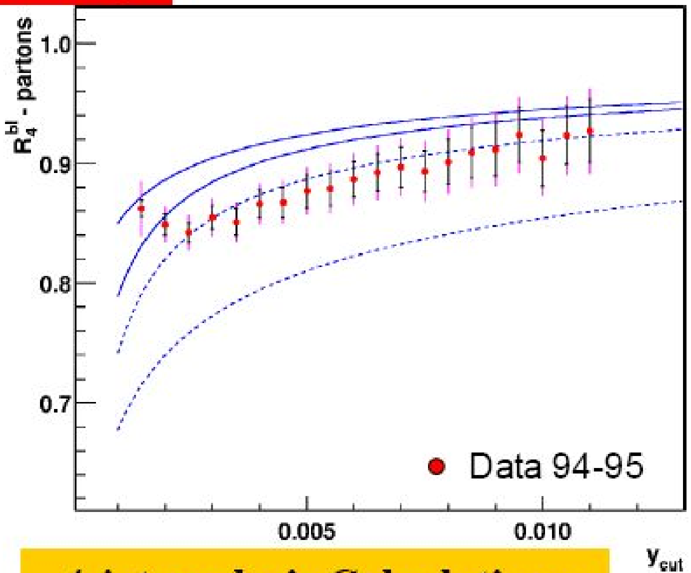
LUND and Bowler give best description of the data,
better than e.g. the Peterson model, which has been invented for heavy quarks

Determinations of the b quark mass from $R_{3,4}^{b\ell}$

Maria Jose Costa

Delphi (preliminary)





3-jet analysis Calculation
Massive NLO

4-jet analysis Calculations
Massive LO + *Massless NLO*

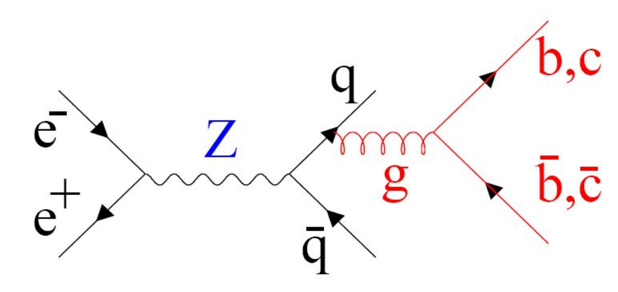
Running Mass: (Cambridge)

$$m_b(M_Z) = 2.85 \pm 0.33\ \mathrm{GeV}/c^2$$

4 jets $\longrightarrow$ $(3.54 \pm 0.62\ \mathrm{GeV}/c^2)$

Gluon splitting to $b\bar{b}$ and $c\bar{c}$

Andrea Giammanco (ALEPH)

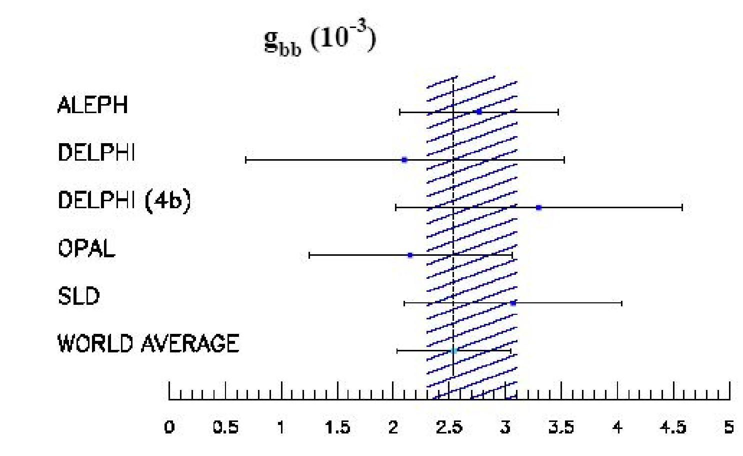


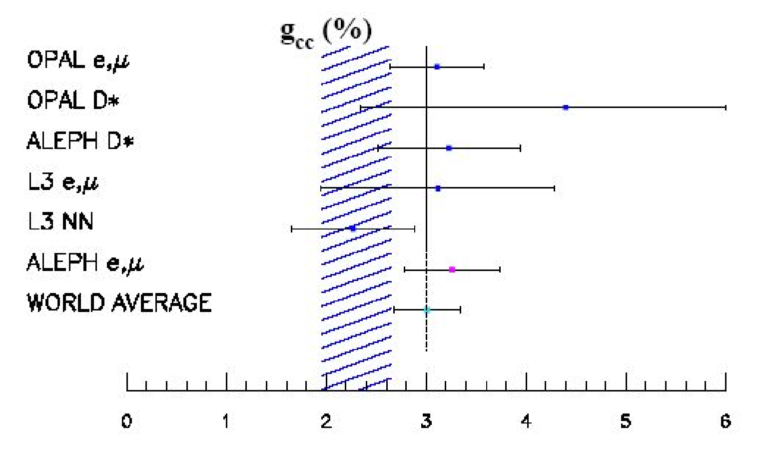
$$g_{Q\bar{Q}} = \frac{\text{N. of events with } g \to Q\bar{Q}}{\text{Total number of } Z \to q\bar{q}}$$

Theoretical predictions

$g_{c\bar{c}} = 2.3 \times 10^{-2}$	$m_c = 1.2$ GeV
$g_{c\bar{c}} = 1.7 \times 10^{-2}$	$m_c = 1.5$ GeV
$g_{b\bar{b}} = 2.7 \times 10^{-3}$	$m_b = 4.5$ GeV
$g_{b\bar{b}} = 2.4 \times 10^{-3}$	$m_b = 4.75$ GeV

15 – 30% uncertainty due to the truncation of the perturbative series.





World Average:

$g_{c\bar{c}} = (3.01 \pm 0.33)\%$

$g_{b\bar{b}} = (2.54 \pm 0.51) \times 10^{-3}$

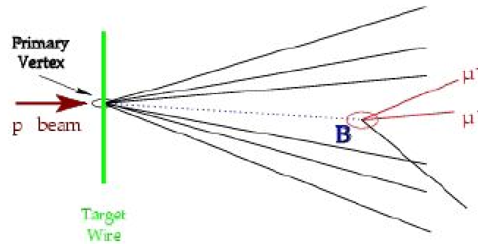
Open Beauty Production

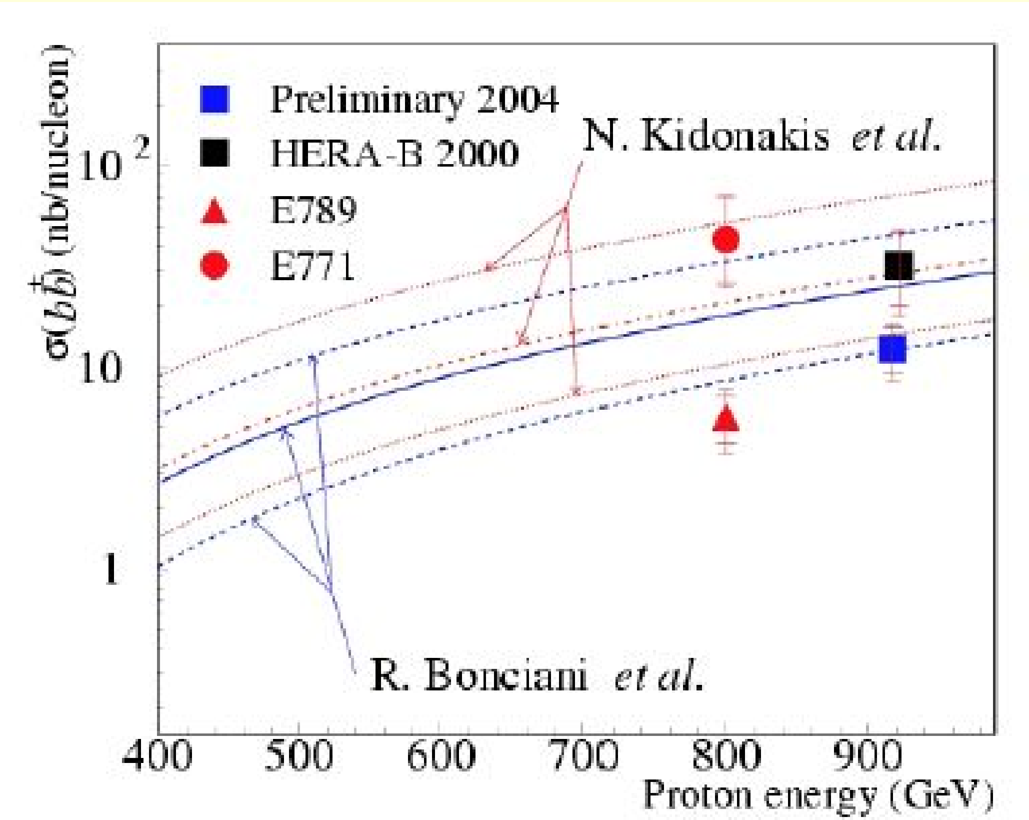
Silvia Masciocchi

$pA \rightarrow b\bar{b} + X$

$b(\bar{b}) \rightarrow B \rightarrow J/\psi + Y$

$\hookrightarrow \mu^+\mu^-, e^+e^-$





$\sigma(b\bar{b})$ = $12.3^{+3.5}_{-3.2}{}^{stat}$

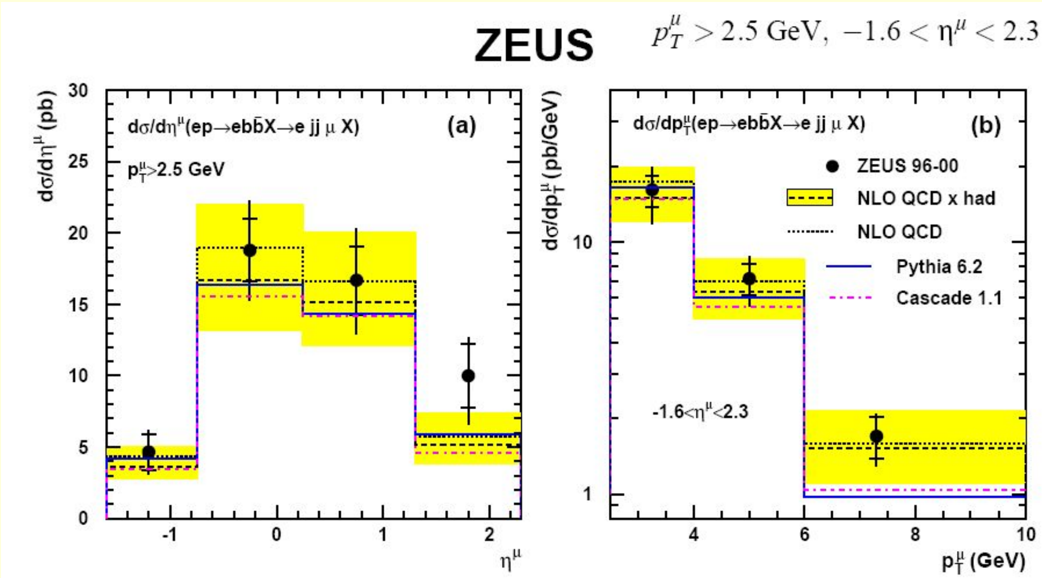
Previous Hera-B result

$\sigma(b\bar{b})$ = $32^{+15}_{-12} \pm 8_{sys}$ nb/nucleon

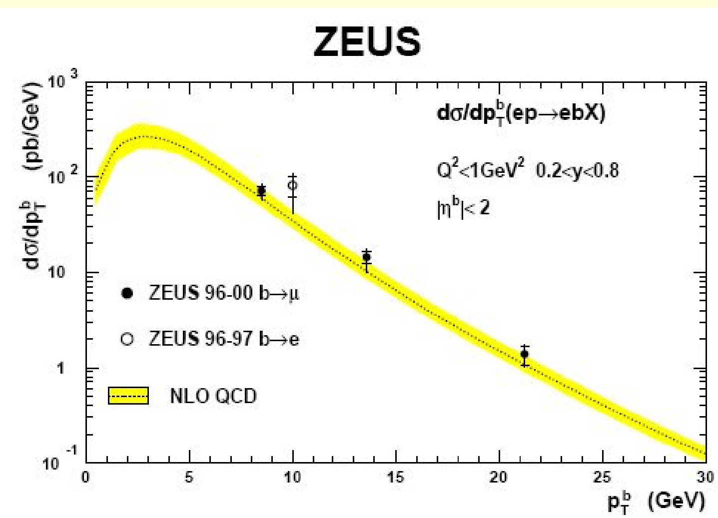
The full 2002-3 statistics is a factor 3 larger

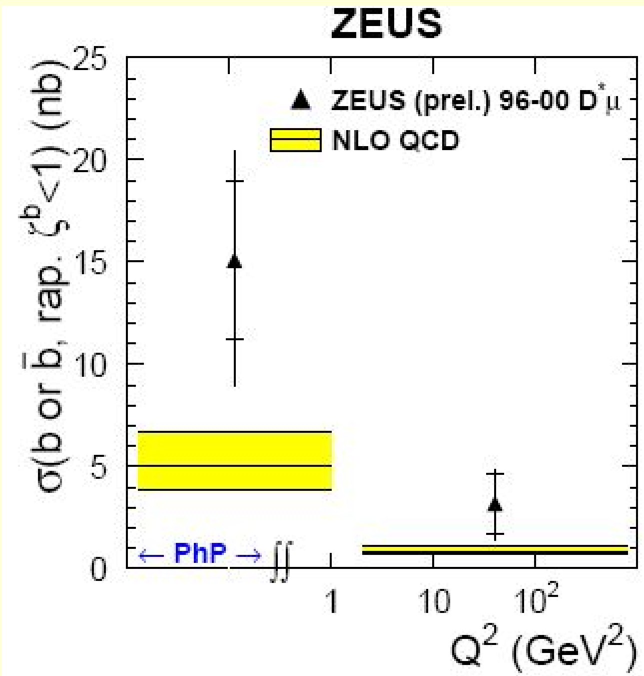
Beauty Photoproduction at ZEUS

Monica Turcato



$D^* + \mu$ analysis





Analysis sensitive to very low b quark transverse momenta.

agreement between data and NLO QCD

Beauty Production in DIS

Katarzyna Wichmann

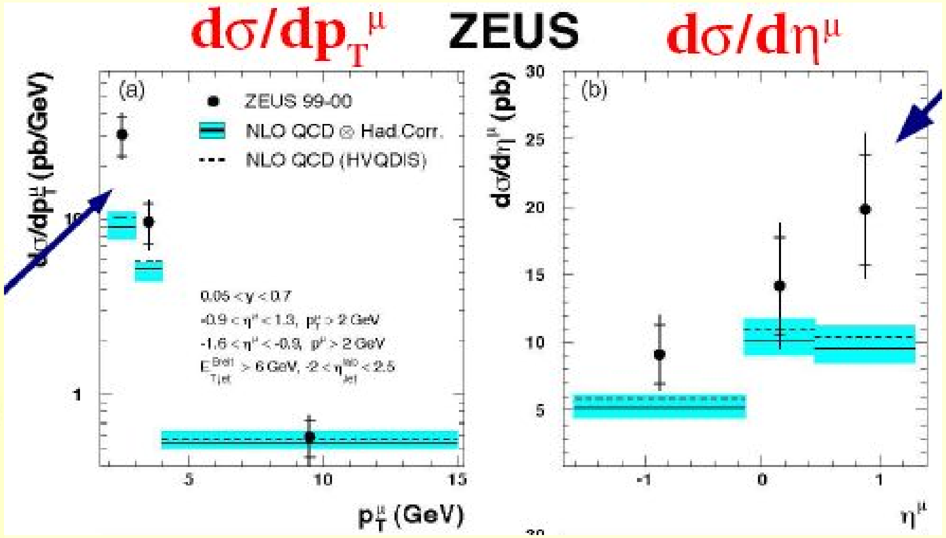
ZEUS results: 99/00, ~ 72.4 pb-1

corrected for radiative effects (HERACLES)

$\sigma\ (ep \rightarrow e\, bb\, X \rightarrow eJet\ \mu\ X)$

kinematic region:

$Q^2 > 2\ GeV^2,\ 0.05 < y < 0.7$

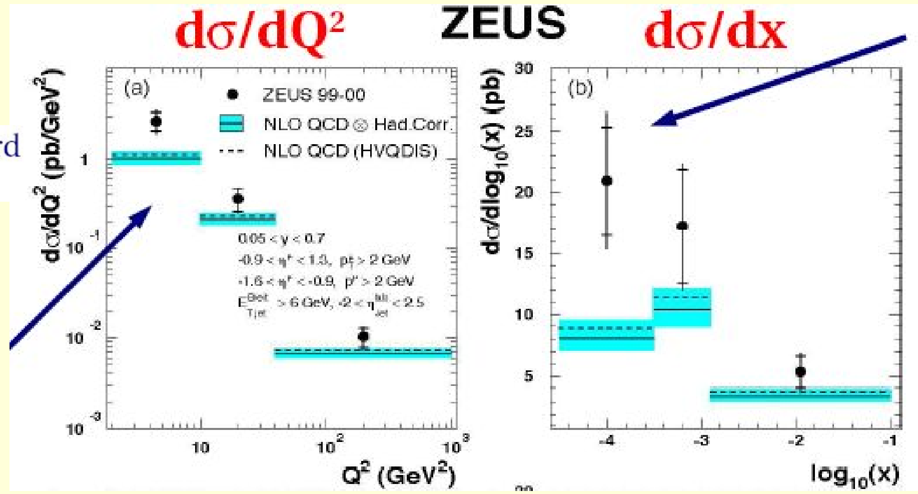


Measured Cross Section:

$\sigma = 40.9 \pm 5.7$ **(stat.) +6.0 -4.4 (syst.) pb**

NLO QCD (HVQDIS)

$\sigma = 20.6\ +3.1\ -3.1$ **pb**



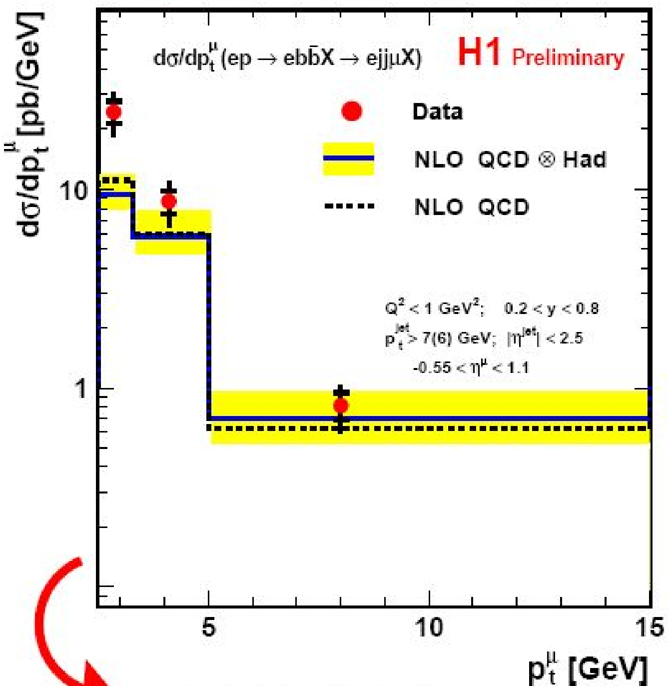
NLO prediction consistent with the data but lies 2.5 standard deviations below

Beauty Production at H1

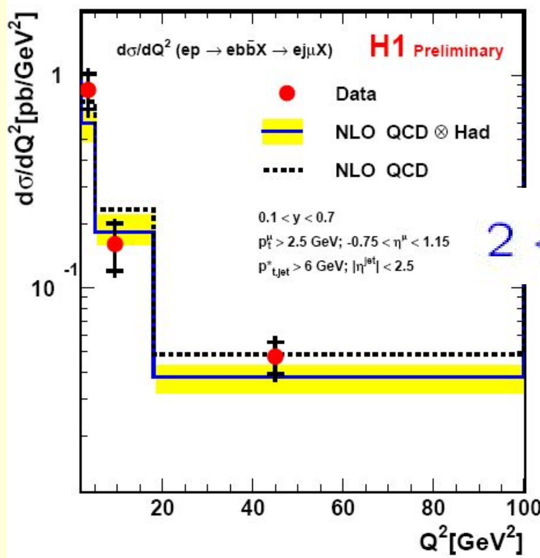
Andreas B. Meyer

$Q^2 \sim 0$

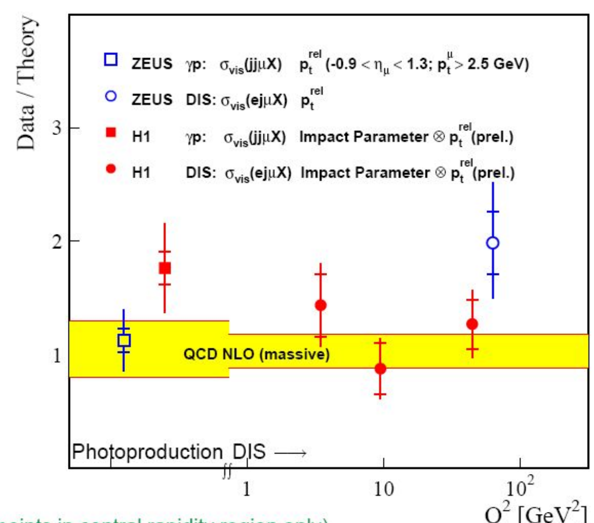
$p_t^{jet} > 7(6)$ GeV, $|\eta^{jet}| < 2.5$, $0.2 < y < 0.8$
$p_t^{\mu} > 2.5$ GeV, $-0.55 < \eta^{\mu} < 1.1$



NLO QCD (FMNR):
Too low at low p_T^{μ}



$2 < Q^2 < 100$ GeV^2

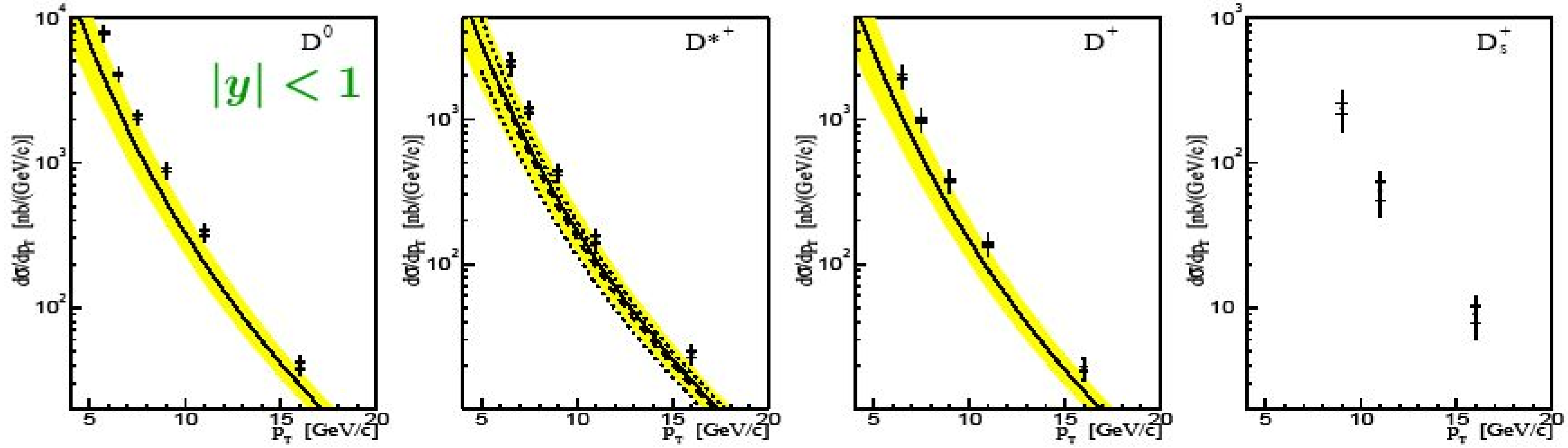


(Data points in central rapidity region only)

OPEN CHARM PRODUCTION

PETER J BUSSEY

CDF inclusive cross sections for D^0, D^{*+}, D^+, D_s^+ vs. p_T

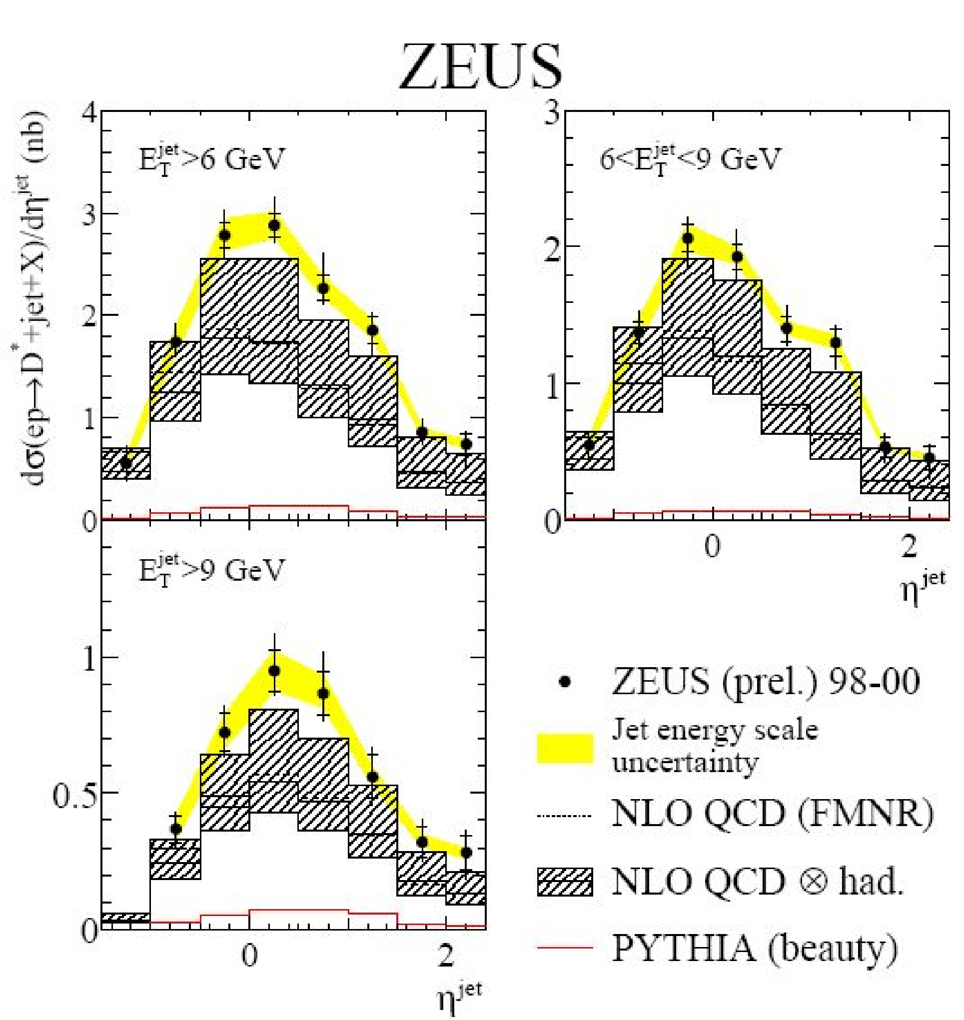


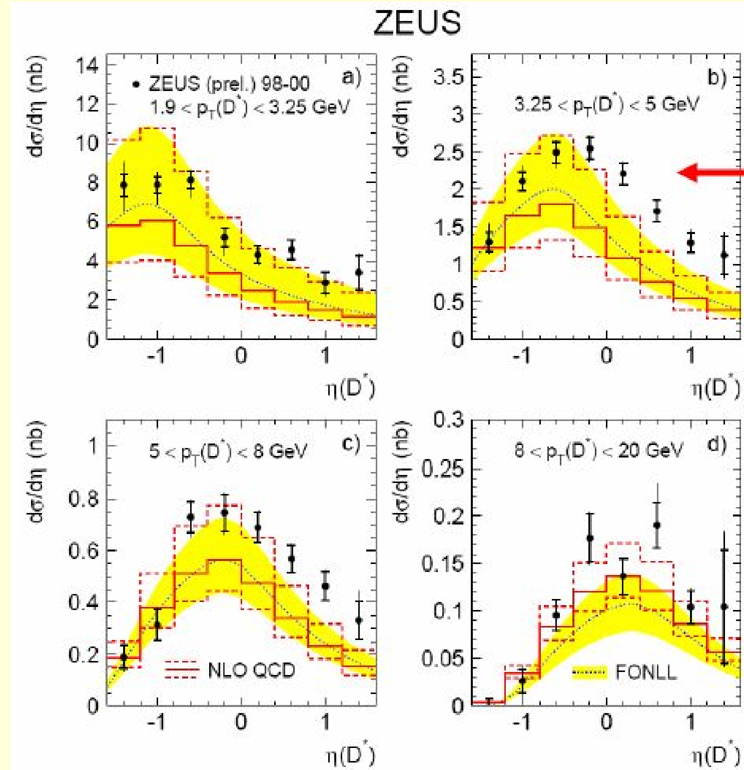
Band: Cacciari and Nason, hep-ph/0306212. FONLL method

Dashed: Kniehl et al. calculation (priv. comm.) for D^{*+}

Jet cross sections in D^* photoproduction

Takanori Kohno



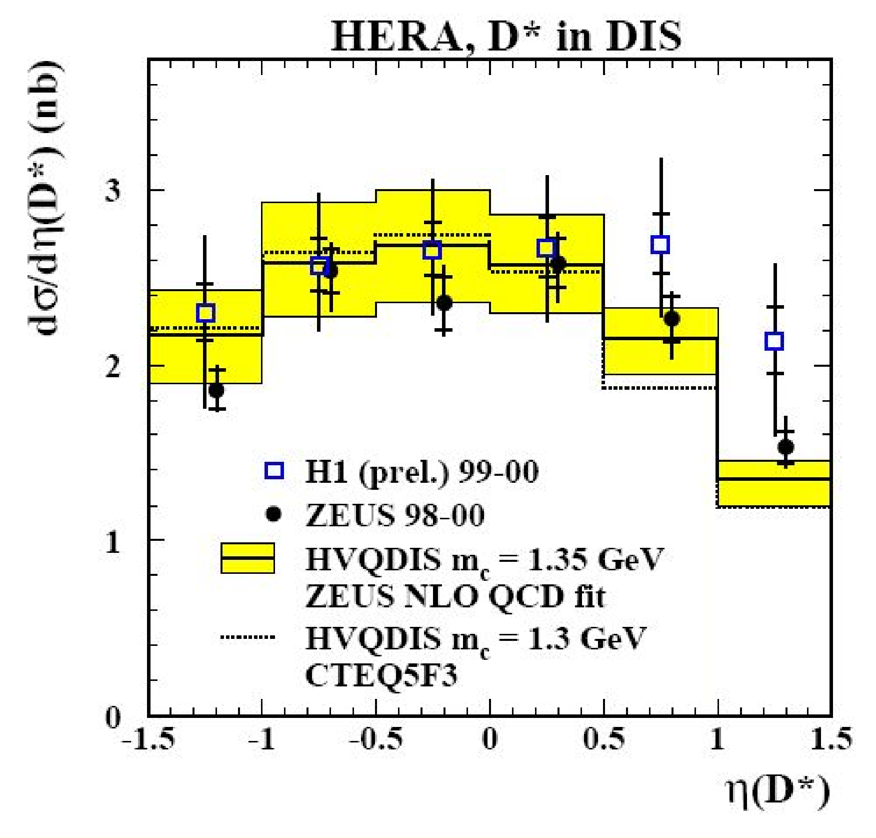


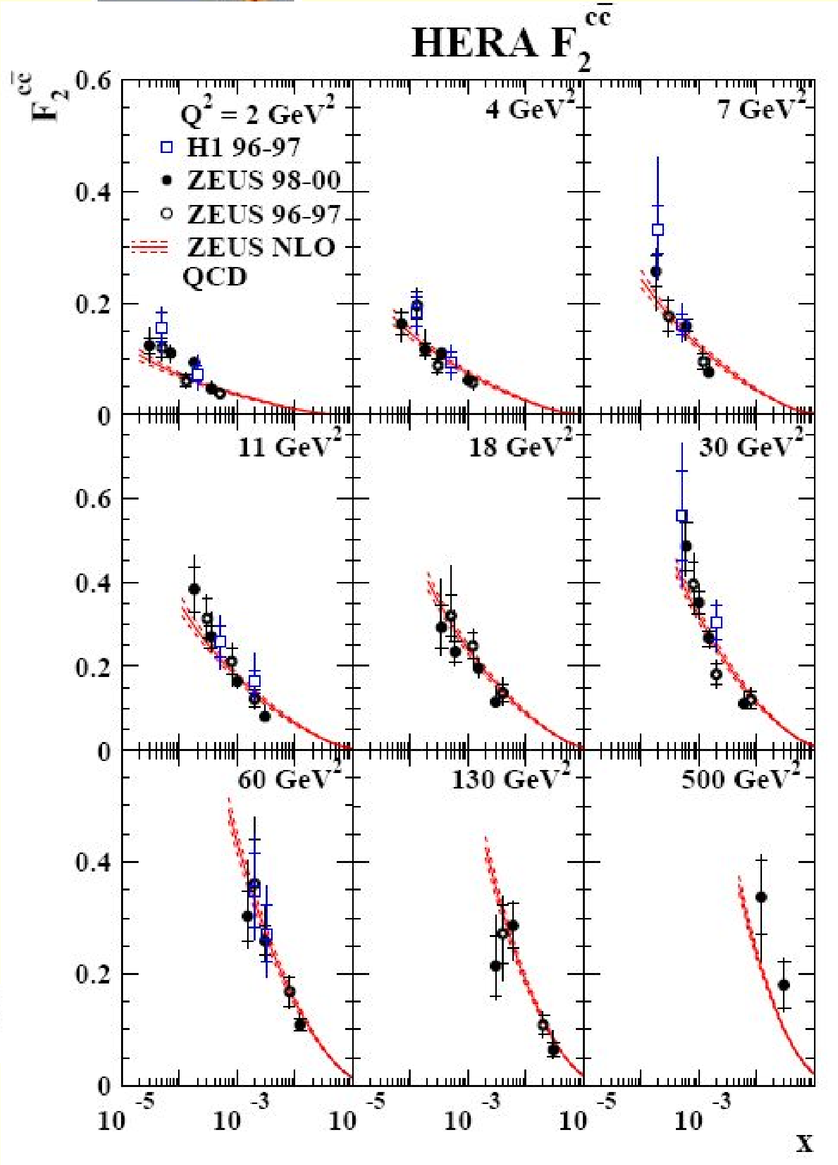
Data > NLO QCD at medium p_T and forward region ($\eta > 0$).

Larger than central value of NLO QCD prediction but compatible within theoretical uncertainty.

Charm in deep inelastic scattering

Matthew Wing



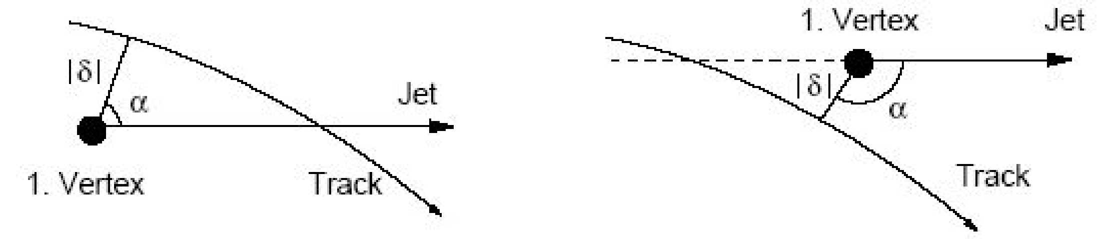


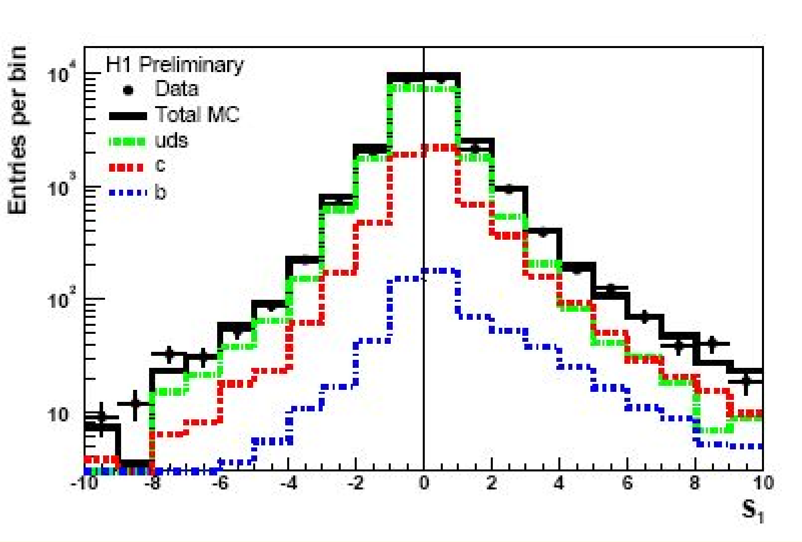
Good description of the data

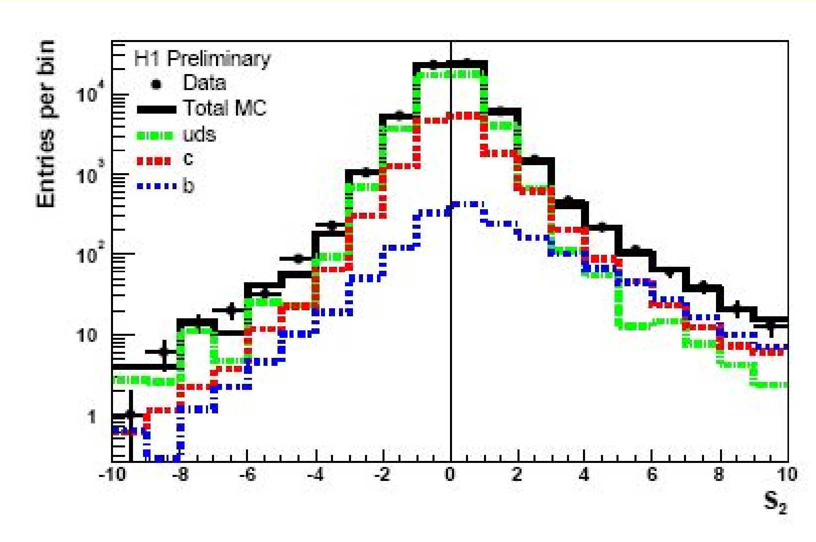
by NLO QCD using a modern PDF

Charm and Beauty Measurements at High Q^2 using the H1 Vertex Detector

P.Thompson



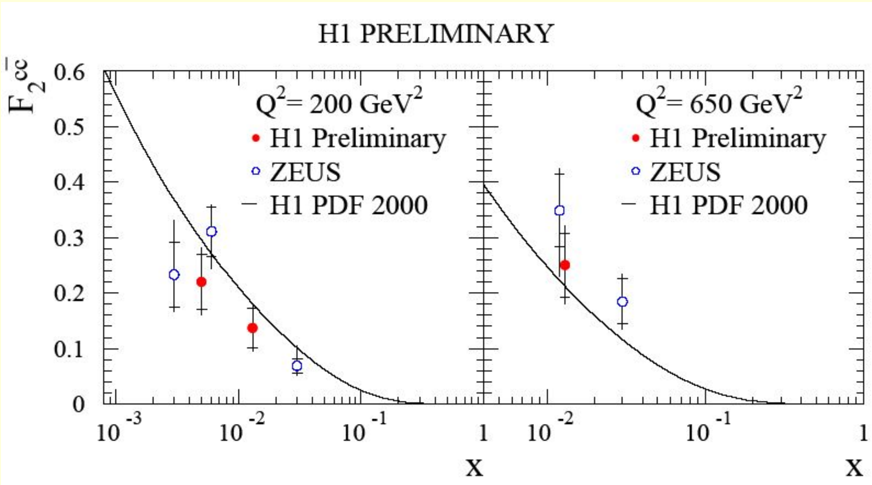


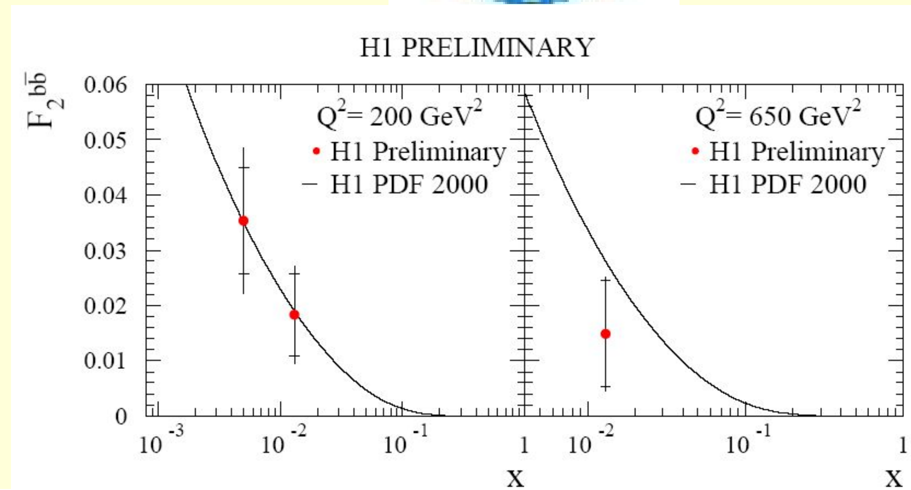


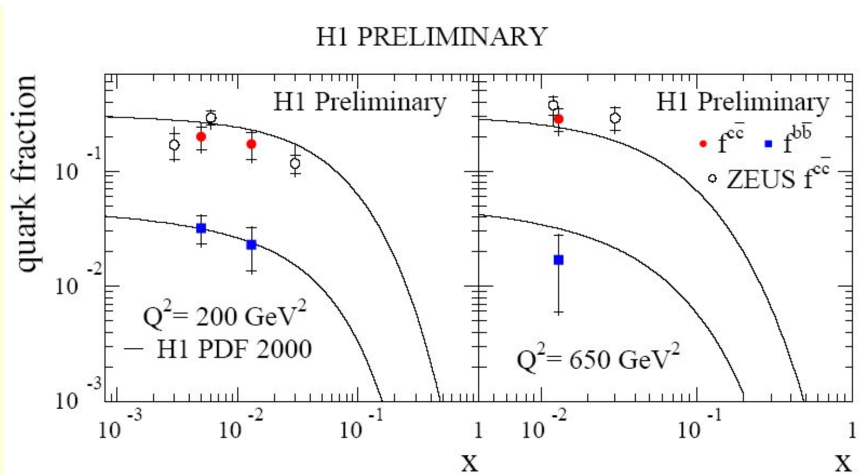
S_1 Highest significance track

S_2 2^{nd} highest significance track for > 1 track events

Conversion to $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$



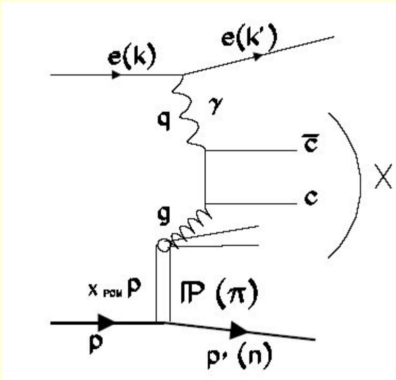




Exciting extensions using low Q^2 samples

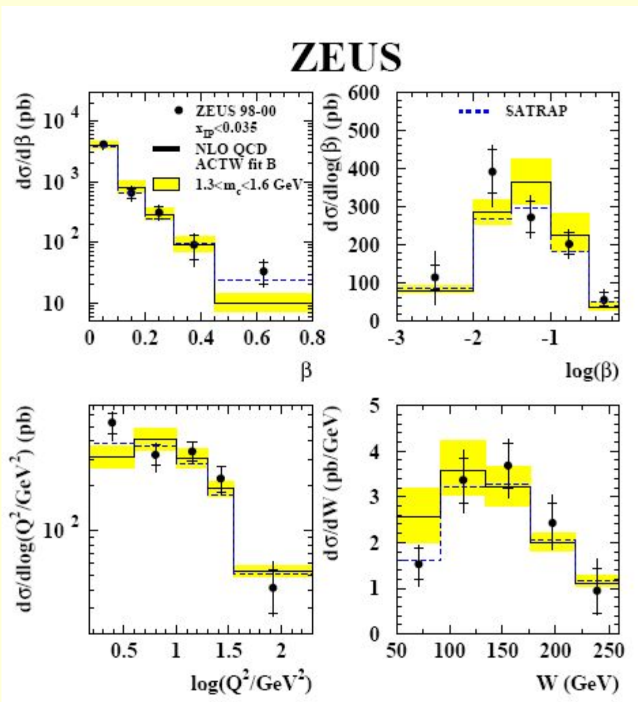
D^* in Diffraction

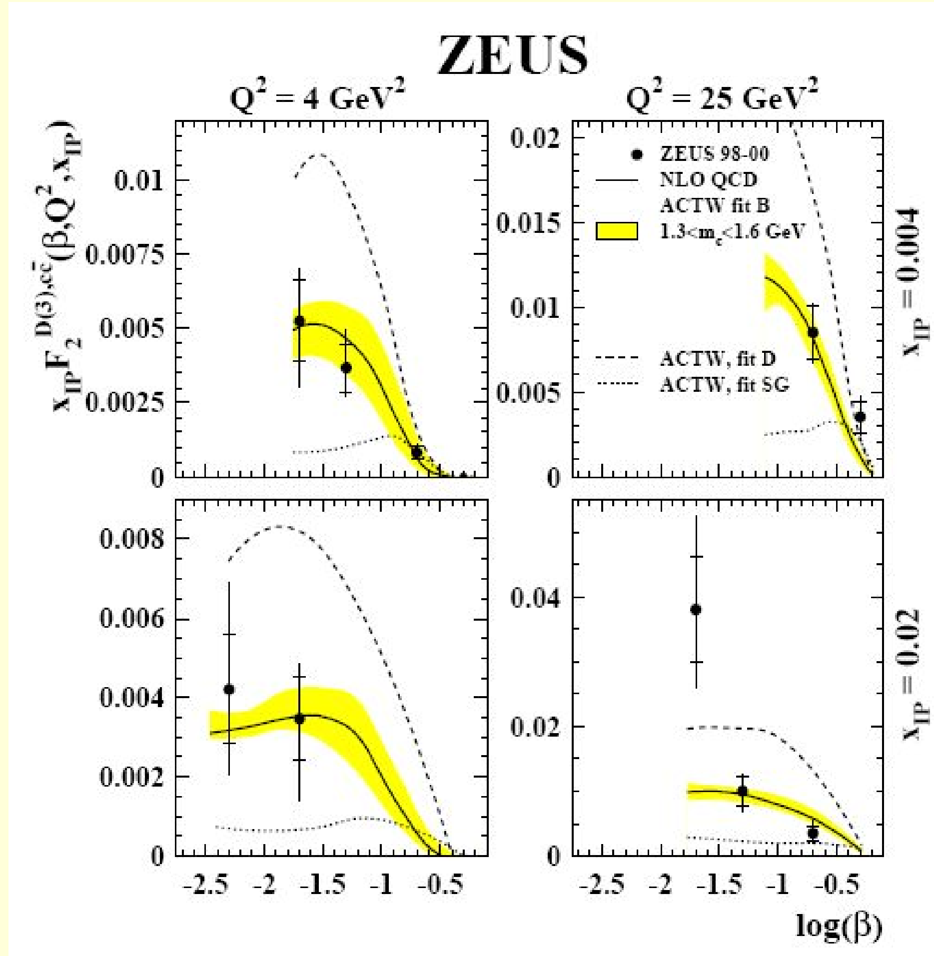
Nikolai N. Vlasov



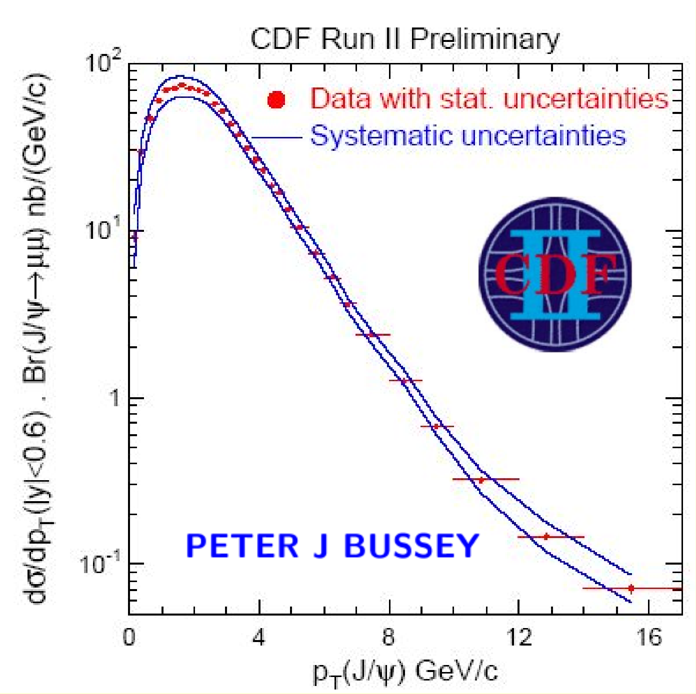
$$x_{IP} = \frac{M_X^2+Q^2}{W^2+Q^2}$$

$$\beta = \frac{Q^2}{Q^2+M_X^2}$$





CHARMONIUM PRODUCTION



Run II: $\sigma(p\bar{p} \to J/\psi X) =$

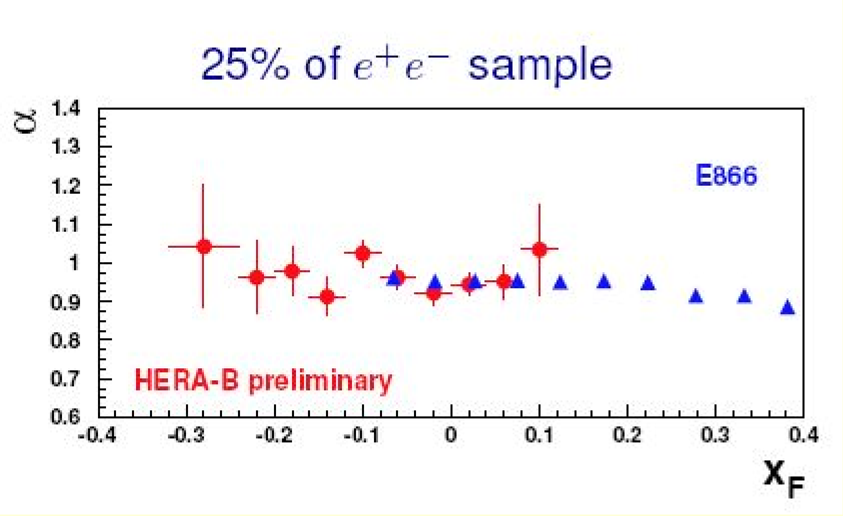
$4.08 \pm 0.02(stat)^{+0.60}_{-0.48}(sys)\ \mu b$

New resummed colour octet matrix elements awaited

Marko Starič

A-dependence of J/ψ

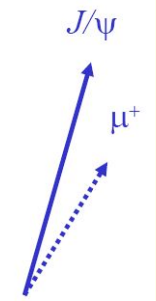
$$\sigma_{pA} = \sigma_{pN} \cdot A^{\alpha}$$



NRQCD: α is decreasing with decreasing x_F

J/ψ helicity measurements in PHP

A. Bertolin

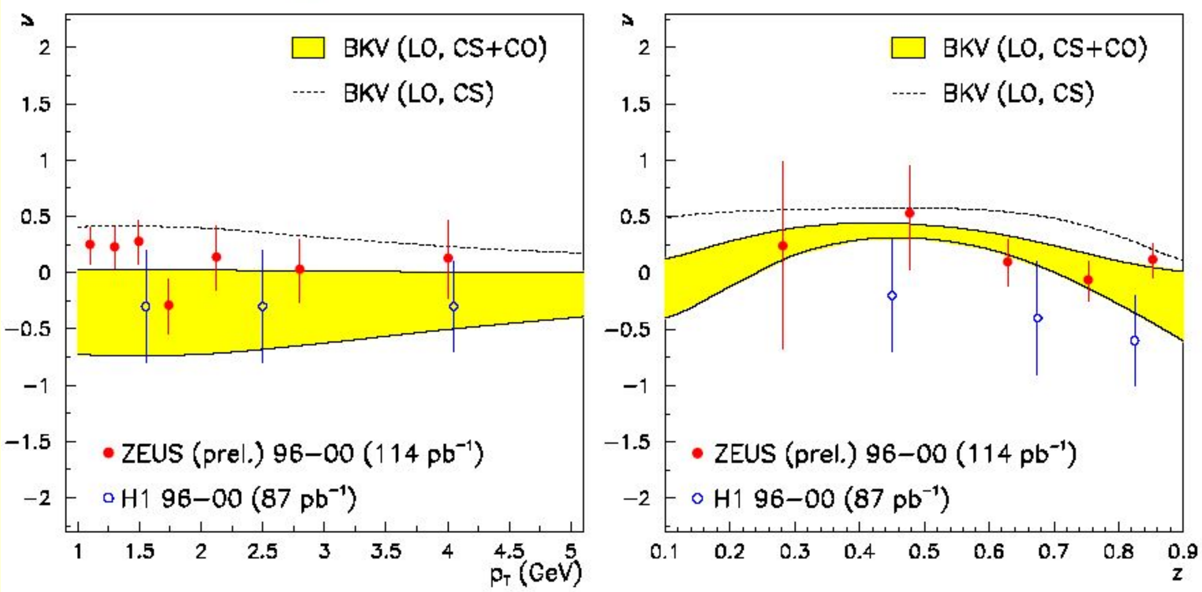


θ*: polar analysis
ϕ*: azimuthal analysis

$1/\sigma\, d^2\sigma/(d\cos\theta^*\, dy) \propto 1 + \lambda(y)\cos^2\theta^*$

$1/\sigma\, d^2\sigma/(d\phi^*\, dy) \propto 1 + \lambda(y)/3 + \nu(y)/3\cos 2\phi^*$

azimuthal analysis:

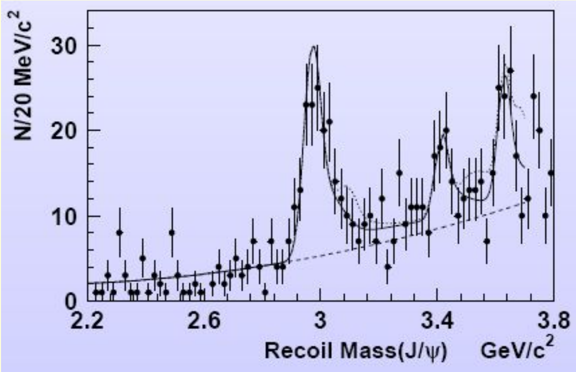


some hints of deviations from the naïve CS expectations

statistically not yet significant

Belle extends and updates $e^+e^- \to J/\psi +$ *charmonium*

Timofey Uglov



RECOIL CHARMONIUM	RECONSTRUCTED CHARMONIUM			
	J/ψ	χ_{c1}	χ_{c2}	$\psi(2S)$
η_c	$46 \pm 6^{+7}_{-9}\,(2.3)$	$< 21\ (1.3 \cdot 10^{-3})$	$< 38\,(0.5 \cdot 10^{-3})$	$18 \pm 8 \pm 7\,(0.9)$
J/ψ	$< 8\ (8.7)$	< 21	< 38	$< 64\ (7.2)$
χ_{c0}	$16 \pm 5 \pm 4$	< 21	< 38	$17 \pm 8 \pm 7$
χ_{c1}	< 8	< 21	< 38	< 24
χ_{c2}	< 8	< 21	< 38	< 24
$\eta_c(2S)$	$25 \pm 6 \pm 6\ (0.9)$	$< 21(0.5 \pm \cdot 10^{-3})$	$< 38(0.2 \cdot 10^{-3})$	$31 \pm 9 \pm 10\ (0.4)$
$\psi(2S)$	$< 16(7.2)$	< 21	< 38	$< 18(1.5)$

HQET prediction are in brackets

Double $(c\bar{c})$ continuum production is not yet understood

$e^+e^- \to D^+D^{*-}$ and $e^+e^- \to D^{*+}D^{*-}$ processes are observed

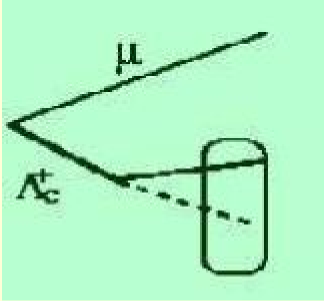
Charm production with neutrinos

Aysel Kayis Topaksu,

CHORUS

$\sigma(\Lambda c)/\sigma(CC) = (1.54 \pm 0.35(stat) \pm 0.18\ (syst)) \times 10^{-2}$

$$\frac{\sigma_{QEcharm}}{\sigma_{CC}} = 0.23^{+0.12}_{-0.06}(\mathrm{stat})^{+0.02}_{-0.03}(\mathrm{syst})\ \mathrm{x}10^{-2}$$

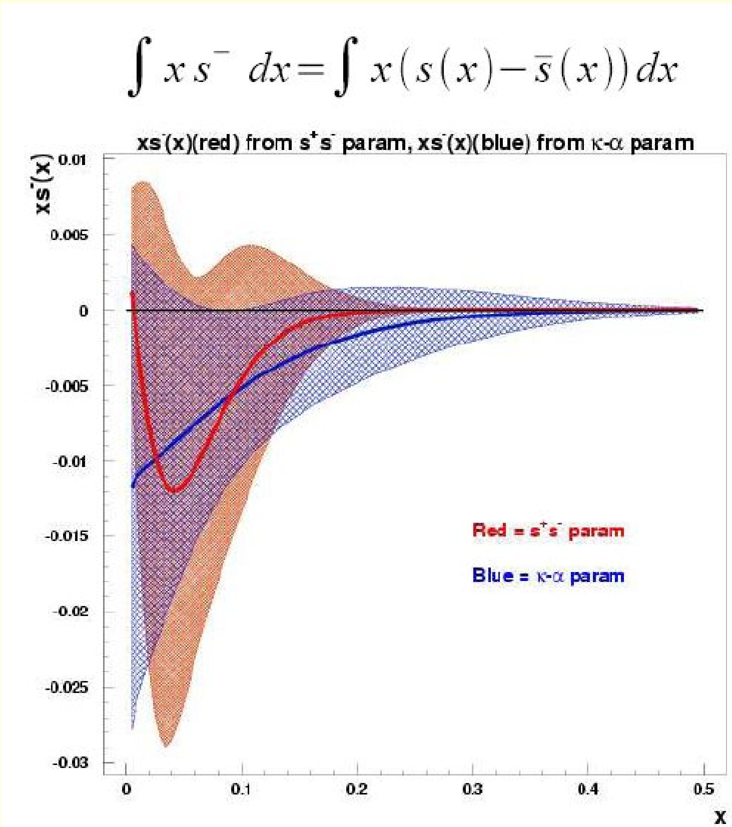


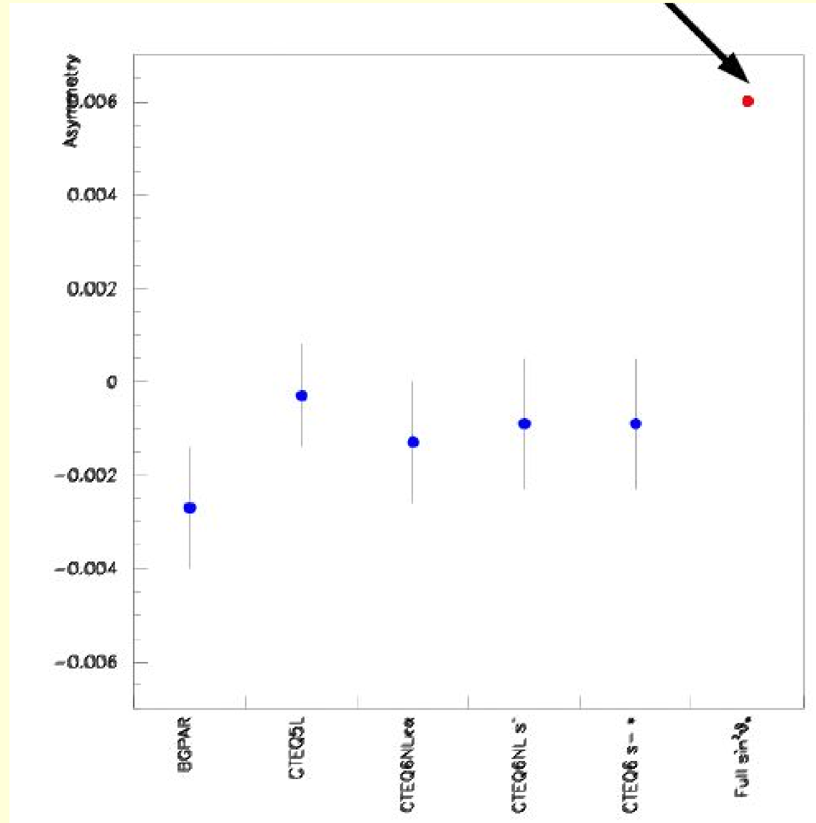
$\sigma(D^0)/\sigma(CC) = 2.71 \pm 0.22 \times 10^{-2}$

$\sigma(\bar{\nu} N \rightarrow \mu^+ cX)/\sigma(\bar{\nu} N \rightarrow \mu^+ X) = 4.8^{+1.2}_{-0.9}\ \%$

NuTeV strange sea asymmetry

Panagiotis Spentzouris





- NuTeV measured strange asymmetry is at most consistent with zero
  - » both LO and NLO
  - » with different parameterizations

NuTeV will assist with implementation of dimuon x-section NLO fitting to global analysis

Many thanks to all speakers

and to organizers !

We enjoined the session.

Karin Daum

Stefan Kretzer

Leonid Gladilin