Experimental Summary

Joerg Gayler, DESY

Results presented

from all 4 HERA experiments
D0
WA89 (hyperon beam)
SVD
PHENIX(RHIC)

Conclusion
many slides have name of the speakers, but they are not responsible at least not for the purple stuff

I tried to pick from all speakers the most important results

Very subjective and in a hurry
large phase space covered by HERA $e^+ p \ e^- p$ data at high $Q^2$ and $x$

Tevatron jet data contribute to pdf fitting
Deep Inelastic Scattering at HERA

\[ Q^2 = -q^2 = -(k - k')^2 \]

Virtuality of exchanged boson

Spatial resolution: \( \lambda \approx \frac{1}{\sqrt{Q^2}} \)

Momentum fraction of the struck quark

\[ x = \frac{Q^2}{2p \cdot q} \]

Inelasticity

\[ y = \frac{p \cdot q}{p \cdot k} \]

\[ s = (p + k)^2 = Q^2 = s \cdot x \cdot y \]

Only two independent

- Neutral Current: exchange of \( \gamma \) or \( Z^0 \)
- Charged Current: exchange of \( W^\pm \)
Measured NC and CC cross sections

Suppressed due to large mass of W boson compared to NC DIS

Electro-Weak unification at high $Q^2$

20-25 Sep 2005
Combined EW pQCD fit

Propagator mass analysis (H1)

In fit $G$-$M_{\text{prop}}$-PDFs,

- Sensitivity to $G$: normalisation of the CC cross section
- Sensitivity to $M_{\text{prop}}$: $Q^2$ dependence
- $G$ is consistent with $G_F$ obtained from the muon lifetime measurement
- Demonstrating the universality of the CC interaction over a large range of $Q^2$ values

In fit $M_{\text{prop}}$-PDFs, fixing $G$ to $G_F$,

$$M_{\text{prop}} = 82.87 \pm 1.82\,(\text{exp})^{+0.30}_{-0.16}\,(\text{mod})\text{GeV}$$

- Measurement of propagator mass in HERA space-like region is complementary and consistent with Tevatron/LEP time-like one

consistent result in space like region, this no effort to improve time like measurements
Combined EW pQCD fit

Determination of quark couplings to $Z^0$ (H1)

At high $Q^2$ and high $x$, NC cross sections are sensitive to the up- and down-type quark couplings dominated by the light $u$ and $d$ quarks.

Complementary measurement of heavy quark couplings measured very precisely by LEP.

$$a_q = I_q^3$$
For $u$, $a_q = +1/2$
For $d$, $a_q = -1/2$

$$v_q = I_q^3 - 2e_q \sin^2 \theta_w$$

$$xF_{3NC} \approx -a_e K_z \cdot 2x \sum_q e_q a_q(q - \bar{q})$$

$v_e$ is small, ignore $K_z^2$ term

More sensitivity to the $U$ couplings than to $D$ couplings due to PDFs and to the $a_q$ couplings than to $v_q$ couplings for $U$ due to $xF_{3NC}$

- Comparable precision to that from the Tevatron
- Remove LEP ambiguities
Data from HERA II with e polarisation

CC Total Cross-Section : H1 and ZEUS

Q^2 > 400 GeV^2, y < 0.9

Right Handed CC cross section is extrapolated by linear fit to H1+ZEUS e^+p data

\[ \sigma_{e^+p \rightarrow \nu X} (P_{e^+} = -100\%) = 0.2 \pm 1.8 (\text{stat.}) \pm 1.6 (\text{syst.}) \text{ pb} \]

Consistent with the SM prediction of: \( \sigma_{CC} (RH) = 0 \)

20-25 Sep 2005

HSQCD05@St.Petersburg
NC input to pQCD pdf analyses

HERA provides data over 4 orders of magnitude in $x$ and $Q^2$

cross sections at largest $x$

here large uncertainties
New technique at high $x$, jet in beam pipe
NC $e+p$, ratio to NLO expectation

$Q^2 = 576$

Data close to expectation, but tend to be above at highest $x$
To include in pdf fits
Jets in deep inelastic scattering

• Factorise jet cross-section into a convolution of PDF’s in the proton, $f_a$, with short distance subprocess, $\langle \sigma_q \rangle$:

$$d\sigma_{\text{jet}} = \sum_{a=q,g} \int \langle x \sigma_a \rangle_{\mu_F^2} \times \langle \sigma_a \rangle_{x,\alpha_s(\mu_R^2,\mu_F^2)} \times \langle 1 + \delta_{\text{had}} \rangle$$

• Longitudinally invariant $k_T$ algorithm (Catani et al).
  
  At high $E_T$ hadronisation effects are small more reliable QCD predictions.

• Large scale variation possible in both $Q^2$ and $E_T$. 

M.Sutton – The Hadronic Final State and Parton Dynamics at HERA
DIS high Q2 jet data are consistent with pQCD calculations allowing extraction of $\alpha_s$.

Extraction of the strong coupling constant

**ZEUS**

- H1 value $\alpha_s(M_Z) = 0.1197 \pm 0.0016^{+0.0046}_{-0.0048}($exp$)$
- ZEUS value $\alpha_s(M_Z) = 0.1196 \pm 0.0011^{+0.0019}_{-0.0025}($stat$)$ + $0.0029^{+0.0029}_{-0.0017}($th.$)

**H1 preliminary 99-00**

- $\alpha_s(E_T)$
- $\alpha_s(M_Z)$
- Averaged $\alpha_s(M_Z)$
- $\alpha_s(E_T)$ from averaged $\alpha_s(M_Z)$
- World average (PDG) $\alpha_s(M_Z) = 0.1187 \pm 0.0020$
increased sensitivity to gluons using inclusive ep and jets in QCD analysis

BGF
Boson Gluon Fusion

jets sensitive to gluon distribution in LO

in BGF full correlation with $\alpha_s$, different in QCD-Compton graphs

QCDC

**di-jets in photoproduction**

**ZEUS**

$$d\sigma/dE_T^{jet} \text{ (pb/GeV)}$$

$\alpha_s$ jets

$\gamma p$ 96-97

Jet energy scale uncert.

$E_T^{jet}$ (GeV)

$F_{jet}$ (GeV)

$z_T^{obs} > 0.75$

-510 -410 -310 -210 -110 1 10 210 310 410 510 610 710

Tot. uncert.

-5 -4 -3 -2 -1 1 10 20 30 40 50 60 70
Impact of jet data on gluon determination in ZEUS-JETS fit

fractional error of g(x)

NC, CC only
jets included

jet data constrain g(x) at medium and high x (0.01 to 0.4)
HERA results

- Inclusive jet cross sections in NC DIS
  - ZEUS prel. (contributed paper to EPS05)
- Inclusive jet cross sections in NC DIS
  - H1 prel. (contributed paper to EPS05)
- Multi-jets in NC DIS
  - ZEUS (DESY 05-050 - hep-ex/0503274)
- NLO QCD fit
- Jet shapes in NC DIS
- Subject multiplicity in CC DIS
  - ZEUS (Eur Phys Jour C 31 (2003) 149)
- Subject multiplicity in NC DIS
- NLO QCD fit
- NLO QCD fit
  - ZEUS (DESY 05-050 - hep-ex/0503274)
- NLO QCD fit
- Inclusive jet cross sections in NC DIS
- Inclusive jet cross sections in NC DIS
- Dijet cross sections in NC DIS
  - ZEUS (Phys Lett B 507 (2001) 70)
- World average
  - (S. Bethke, hep-ex/0407021)

\[ \alpha_s(M_Z) \]

\( \alpha_s \) results of inclusive DIS pdf fits (with \( \alpha_s(M_Z) \) as free parameter)
consistent with final state analyses and world average

- exp. precision calls for NNLO analysis
- calculations exist for inclusive DIS
  (Moch, Vermaseren, Vogt)
• In dijet production, at very low $Q^2$, we have $Q^2 < E_T^2$ and large logarithms of $E_T/Q^2$, formally resum into “resolved” photon structure.

Photon can interact directly or via a parton with some momentum fraction $x\gamma < 1$.

**Virtual photon structure – comparison with NLO theory**

- $x_{\gamma obs} < 0.75$ resolved enhanced
- Not described
  - $E_T^{\gamma \gamma} > 7.5, 6.5$ GeV.
  - $-3 < \eta_{\gamma \gamma}^{lep} < 0$
  - NLO DIS calculation no resolved photon.
  - Ratio of direct enhanced to resolved enhanced too low at lower $Q^2$.
  - Expect larger resolved fraction when including resolved virtual photon.
  - Need additional NLO calculations at lower $Q^2$.

**difficulties at low $Q^2$**

Mark Sutton
HSQCD 2005 – September 19th, St Petersburg
QCD Dynamics at low $x$

Perturbative expansion of parton evolution equations

\[ \sum_{mn} A_{mn} \ln(Q^2)^m \ln(1/x)^n \]

- **DGLAP:** \[ \sum (\alpha_s \ln Q^2)^n \]
  \[ k_{T,1}^2 < k_{T,2}^2 < ... < k_{T,n-1}^2 < k_{T,n}^2 \approx Q^2 \]
  \[ x_1 > x_2 > ... > x_{n-1} > x_n = x_{Bj} \]

- **BFKL:** \[ \sum (\alpha_s \ln (1/x))^n \]
  \[ x_1 >> x_2 >> ... >> x_{n-1} >> x_n = x_{Bj} \]

- **CCFM:** \[ \ln(Q^2) \text{ and } \ln (1/x) \]
  \[ \theta_n >> \theta_{n-1} >> ... >> \theta_2 >> \theta_1 \]

- **DGLAP** successful at high scale ($Q^2$) but expected to fail at low scales and low $x$
- **BFKL** should be applicable at very low-$x$
- **CCFM** expected to be valid in whole $x$, $Q^2$ range

Goal: Identify the phase space regions where these different parton evolution models are applicable by studying forward jets at HERA
Forward Jet Measurement with H1 data

CCFM does not describe the shape of x dependence

DGLAP is similar to NLO

DGLAP with res-$\gamma$ improves significantly the description, low-$x_{Bj}$ $\rightarrow$ possible BFKL signal

CDM (non-ordered $E_T$ emotions) gives a reasonable description for higher x

$\mu_r^2 = E_{T-dijet}^2$

$\mu_f^2 = E_{T-jet}^2$

CDM and RG-DIR+RES are very similar and reasonable
not shown yet here

two central jets (PT > 6 GeV) in addition to forward jet to enhance unordered emission

now besides CASCADE also RG-DIR+RES fails

CDM with unordered emissions quite good description

most BFKL like?
Inclusive DØ Single Jet Cross Section vs. $y$

- First corrected Run II cross section for forward jets
- Important PDF information in cross section vs. rapidity
- Jet Energy Scale uncertainties dominate – need to beat these down!

Beautiful agreement with pQCD but huge systematics due to calorimetric energy uncertainty
How to improve?
$\Delta \phi$ between jets – Comparison with pQCD

NLO pQCD describes angular correlation well at high pt
no call for higher orders
Inclusive Diffraction

Diffraction kinematics

Kinematic variables definition

Colorless exchange, vacuum quantum numbers

- proton survives the collision intact or
  dissociates to low mass state
- large region in pseudorapidity is left empty
- small momentum transfer $t$

\[
Q^2 = -q^2 \quad \text{photon virtuality}
\]
\[
x = \frac{Q^2}{2q \cdot p} \quad \text{Bjorken scaling variable}
\]
\[
W^2 = (p + q)^2 \quad \gamma^* p \ \text{CM energy squared}
\]
\[
t = (p - p_Y)^2 \quad 4\text{-momentum transfer squared}
\]
\[
x_P = \frac{q \cdot (p - Y)}{q \cdot p} \quad \text{fraction of } p \text{ momentum transferred to } IP \ (x_P \simeq 1 - E_Y/E_p)
\]
\[
\beta = \frac{Q^2}{2q \cdot (p - Y)} \quad \text{fraction of } IP \text{ momentum carried by struck quark } (x_P \beta = x)
\]

\[
M_X \quad \text{Inv. mass of system } X
\]

~10% of DIS events at HERA are diffractive
Apply same NLO QCD DGLAP technique to $Q^2$ and $\beta$ dependencies as for inclusive DIS

- quark density directly from $F_2^D$
- gluon density from scaling violation

Assume Regge factorization:  

$$F_2^{D(4)}(x_{IP}, t, Q^2, \beta) = f_{IP/p}(x_{IP}, t) F_2^{IP}(Q^2, \beta)$$

pdfs from inclusive diffractive work also for jets in and diffractive charm in DIS

$$F_2^{D(4)}(x_{IP}, t, Q^2, \beta) = f_{IP/p}(x_{IP}, t) F_2^{IP}(Q^2, \beta)$$

this supports factorisation, but Tevatron $p\bar{p}$ diffractive is overestimated

photoproduction may be closer to $p\bar{p}$ ?
Jets in photoproduction

Direct and resolved $\gamma$ interaction:
- $\gamma$ involved point-like into $\gamma p$: $x_\gamma \sim 1$
- $\gamma$ fluctuate into hadronic system: $x_\gamma < 1$

$$x_\gamma = \sum_{\text{jets}} \frac{(E - p_z)}{2yE_e}$$
Momentum fraction of $\gamma$ carried by $\gamma$-parton

$$y = \frac{Q^2}{sx}$$
inelasticity

NLO overestimates dijet in photoproduction data by factor 2 for both direct and resolved photon

Ratio data/NLO for dijets in photoproduction

Factorization fails
**Vector Mesons at HERA**

**J/ψ - testing gluon densities!**

- Even more prominent in $W$ dependence
- Normalise predictions at $W = 90$ GeV, compare shapes
- Access to gluon densities in regions poorly constrained by inclusive DIS data (very low $x$)
- Uncertainties on Gluon distributions not taken into account

**Theoretical alternative:** Dipole model by Frankfurt, McDermott and Strikman (FMS)  
(JHEP 0103 (2001) 045)

**H1:** To be published in Eur.Phys.J. C  
new data discussed: $J/\psi \gamma p$, DIS high $t$, $\phi$ DIS, $\rho^0 \gamma p$ high $t$

Vector Mesons: Summary

- As soon as a hard scale is involved, measurements disagree with soft pomeron
- $J/\Psi$ Measurements and theory together come close to constraining gluon densities
- Light vector mesons at high $t$ or in electroproduction can shed light on soft-hard transition and test QCD models

rich field for QCD models
Comparisons of DGLAP and BFKL calculations
The HERMES Experiment @ DESY

HERA pol e beam on pol and unpol gas targets

- 27.6 GeV HERA e-beam
- Internal, pure gas target: \( \tilde{\text{He}}, \tilde{\text{H}}, \tilde{\text{D}}, \text{H} \uparrow \);
  unpol: \( \text{H}_2, \text{D}_2, \text{He}, \text{N}, \text{Ne}, \text{Kr}, \text{Xe} \)
- Resolution: \( \Delta p/p = 1.4 - 2.5 \% \), \( \Delta \theta < 0.6 \) mrad
- Lepton/hadron separation: TRD, Preshower, Calorimeter, Cherenkov (1995-97)
- Target polarization: longitudinal (1996-2000) \( \langle P_t \rangle \sim 85 \% \)
  & transverse (2002-2005) \( \langle P_t \rangle \sim 75 \% \); flipping every 90s
- HERA beam polarization \( \langle P_b \rangle = 53 \% \) longitudinal
measure quark helicity in polarised nucleon

Distribution Functions

In leading twist, integrating over quark transverse momenta, 3 DFs:

\[ f_1 = \quad \text{unpolarized quarks in unpolarized nucleons} \]

\[ g_1 = \quad \text{longitudinally polarized quarks in longitudinal nucleons} \]

\[ h_1 = \quad \text{transversely polarized quarks in transverse nucleons} \]

\[ \Rightarrow \quad \text{Unpolarized DF } q(x) : \text{spin averaged, very well known} \]

\[ \Rightarrow \quad \text{Helicity DF } \Delta q(x) \equiv q^{\uparrow \uparrow}(x) - q^{\downarrow \downarrow}(x) : \text{helicity difference, well known (HERMES-I)} \]

\[ \Rightarrow \quad \text{Transversity } \delta q = q^{\uparrow \uparrow} - q^{\downarrow \downarrow} : \text{helicity flip, unknown (HERMES-II)} \]
in Transversity studies, consider quark pt in nucleon and fragmentation measure:
single-spin azimuthal asymmetries in $e + p \rightarrow e + h + X$ on a polarized target

**Collins effect:** $A \sim h_1(x) H^\perp_1(z)$

effect of quarks polarisation on pt in fragmentation

**Sivers effect:** $A \sim f^\perp_{1T}(x) D_1(z)$

Sivers function $f^\perp_{1T}$

effect of quarks pt in polarised nucleon on fragmentation.

Asymmetry implies effect of quark angular momentum
Extracted Sivers Moments

striking difference of $\pi^+$ and $\pi^-$
should have a clear explanation

- Sivers moment significantly positive for $\pi^+$; requires a non-vanishing quark orbital angular momentum
- Sivers moment consistent with zero for $\pi^-$
- Extraction of Sivers function in principle possible (known unpolarized fragmentation function)

is it a consequence of different polarisation u and d valence?
Deeply Virtual Compton Scattering

\[ d\sigma(eN \rightarrow eN\gamma) \propto |T_{BH}|^2 + |T_{DVCS}|^2 + T_{BH}T_{DVCS}^* + T_{BH}^*T_{DVCS} \]

Interference term gives rise to azimuthal asymmetries

\[ A(\phi) = \frac{N^+(\phi) - N^-(-\phi)}{N^+(\phi) + N^-(-\phi)} \]

BH \gg DVCS for HERMES kinematics

Present H1 and ZEUS data (no interference yet)
Accessing Generalized Parton Distributions

Final state quantum numbers select different GPDs:

- **Deeply Virtual Compton Scattering:** $H, E, \tilde{H}, \tilde{E}$
  - Beam charge asymmetry ($e^+ \leftrightarrow e^-$): $H$
  - Beam-spin Azimuthal Asymmetry: $H$
  - Longitudinal Target Spin Asymmetry: $\tilde{H}$
  - Transverse Target Spin Asymmetry: $E, J_q$

**for example**

**Longitudinal Target Spin Asymmetry**

$$A_{UL} : d\sigma(\vec{p}, \phi) - d\sigma(\vec{p}, \phi) \propto A_{UL}^{\sin \phi} \sin \phi + A_{UL}^{\sin 2\phi} \sin 2\phi$$

**HERMES PRELIMINARY**

$e^+ p/\bar{d} \rightarrow e^+ X$ ($M_s < 1.7$ GeV)

(in HERMES acceptance)

- proton
- deuteron

proton ($WW$ tw-3, $b_s=1$):
  - fac, $b_s=1$
  - fac, $b_s=\infty$
  - Regge, $b_s=\infty$
  - Regge, $b_s=1$

**HERMES PRELIMINARY**

$e^+ p/\bar{d} \rightarrow e^+ X$ ($M_s < 1.7$ GeV)

(in HERMES acceptance)

- proton ($b_s=1, b_t=1$):
  - Regge, $WW$ tw-3
  - Regge, no tw-3
  - fac, $WW$ tw-3
  - fac, no tw-3

**theoretically not yet understood**

**expect better selection of elasticDVCS with HERMES recoil detector**

(end of 2005)
DVCS: Comparison with QCD Predictions

Comparison to NLO QCD:

- Band width reduced by $t$ slope measurement
- Good description of the data
- Sensitive to GPD parametrisations?

beam and charge and pol asymmetries now accessible at HERA
will measure amplitudes by interference with BH at high energies
DVCS: Comparison with Colour Dipoles

In proton rest frame:

Photon fluctuates to $q\bar{q}$

G. Shaw showed other dipole model, describing data well

- Good description of shape and normalisation
A measurement of $\Lambda$ and $\Xi^-$ polarization in inclusive production by $\Sigma^-$ of 340 GeV/c in C and Cu targets

polarisation normal to production plane (parity conservation)

polarisation observed in many experiments

hyperon polarizations in inclusive production by protons:
$\Lambda$: negative, reaches $\sim$-40% at large $x_f$ and $p_t$.
$\Sigma^{\pm}$: positive
$\Xi^-, \Xi^0$: negative
$\Omega$: zero

$\Lambda$ polarization in production by neutrons: $\approx$ same as by protons
$\pi^-$: small, negative
$K^-$: twice as large as by protons, positive

$\Rightarrow$ an interesting and complex set of data!!
no pQCD predictions exist

Qualitative explanation in **Lund model**
B. Andersson et al., Physics Reports **97** (1983) 31

if \( \bar{s}s \) pair has spin 1,
local conservation of angular momentum will
cause \( s \) polarization \( \uparrow \uparrow \) prod. normal

Signs explained, no predictions of magnitude or dependence on \( x_f \) or \( p_t \).

another approach: the **recombination model**

recombination of a maximum number of valence \( q \) from the beam particle with a minimum number
of sea \( q/\bar{q} \)

the force between the beam fragment and the \( q \) or diquark created from the sea will not be parallel
to the velocities \( \rightarrow \) **Thomas precession**
Experiment WA89 at CERN ran from 1990 to 1994 in the CERN West Hall.

$\Sigma^-$ beam, mean momentum 340 GeV/c

$\Xi^-$ polarizations

$\Xi^-$ polarizations as a function of $x_F$ for fixed bins in $p_t$, in units of %.

Negative sign is no surprise but: positive sign at high $x_F$, low $p_t$ ??

$\Lambda$ pol positive!
Conclusion:

$\Xi^-$ polarization agrees with qualitative expectations

the positive sign of the $\Lambda$ polarization and the breakdown above $\approx 1.2$ GeV/c were unexpected at the time of the experiment, now an explanation is offered in an extension of the recombination model

No comprehensive explanation of all polarization data exists, not even a coherent phenomenological description !!

Food for theorists ....

LHC: polarization studies may (will) need an estimate of polarizations in hadronic interaction backgrounds
Beauty and Charm production is expected to be described by pQCD:

LO with “resolved photon”

heavy quarks provide a hard scale

NNLO and partially NNLO calculations available
fraction of

\( F_2^{\text{inclusive}} \)

\( f_{c\bar{c}} \sim 20\% \) to \( 30\% \)

\( f_{b\bar{b}} \sim 0.3\% \) to \( 3\% \)

- QCD calculations fit the data reasonably well; NNLO calculations now available.
- Scaling violations apparent at low \( x \).
Summary of Beauty Results

- Good coverage of measurements.
- Tendency of data to lie above NLO prediction.
- Measurements with smaller errors closer to theory.
- Improved theoretical understanding needed to include higher orders.
Charm fragmentation function in $ep$ and $e^+e^-$ collisions

**ZEUS**

- **ZEUS (preliminary)** 1996-2000: $E_{T}^{jet} > 9$ GeV, $z = (E + p_T)/E_T^{jet}$
- OPAL: $\sqrt{s} = 91.2$ GeV, $z = 2E_T^{jet}/\sqrt{s}$
- ARGUS: $\sqrt{s} = 10.6$ GeV, $z = p_T/\sqrt{E_T^{beam} - m_H^2}$

Z = 0.8

**H1 and ZEUS:**
many fragmentation results
u/d, $V/(P+S)$, $\gamma_s$
consistent with $e^+e^-$
(“universality”)
Study of excited $D$ mesons at HERA

Orbitally excited:

1) $D_1^0, D_2^{*0} \to D^{*+} \pi^- (+ \text{ c.c.})$

2) $D_{s1}^+ \to D^{*+} K^0 (+ \text{ c.c.}) \quad \implies \text{disc}

Search for radially excited:

3) $D^{*'+} \to D^{*+} \pi^+ \pi^- (+ \text{ c.c.})$
Fragmentation fractions for excited $D$ mesons

Using world average for $f(c \to D^{*+})$:

<table>
<thead>
<tr>
<th></th>
<th>$f(c \to D_{1}^{0})$ [%]</th>
<th>$f(c \to D_{2}^{0})$ [%]</th>
<th>$f(c \to D_{s1}^{+})$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZEUS (prel.)</td>
<td>$1.46 \pm 0.18^{+0.33}_{-0.27} \pm 0.06$</td>
<td>$2.00 \pm 0.58^{+1.40}_{-0.48} \pm 0.41$</td>
<td>$1.24 \pm 0.18^{+0.08}_{-0.06} \pm 0.14$</td>
</tr>
<tr>
<td>CLEO</td>
<td>$1.8 \pm 0.3$</td>
<td>$1.9 \pm 0.3$</td>
<td></td>
</tr>
<tr>
<td>OPAL</td>
<td>$2.1 \pm 0.8$</td>
<td>$5.2 \pm 2.6$</td>
<td>$1.6 \pm 0.4 \pm 0.3$</td>
</tr>
<tr>
<td>ALEPH</td>
<td>$1.6 \pm 0.5$</td>
<td>$4.7 \pm 1.0$</td>
<td>$0.94 \pm 0.22 \pm 0.07$</td>
</tr>
<tr>
<td>DELPHI</td>
<td>$1.9 \pm 0.4$</td>
<td>$4.7 \pm 1.3$</td>
<td></td>
</tr>
</tbody>
</table>

1) the same amounts of excited $D$ mesons in $e^+e^-$ and $ep$ data

2) situation with $f(c \to D_{2}^{0})$ is not clear

3) $f(c \to D_{s1}^{+})$ is twice as large as the expectation:

$$\gamma_s \times f(c \to D_{1}^{0}) \approx 0.3 \times 2\% = 0.6\%$$

Why $f(c \to D_{s1}^{+})$ is so large?

Is it connected with its strange helicity?
920 GeV p, fixed target stopped data taking, analysis ongoing

Physics topics

Di-lepton trigger
- J/ψ: A-dependence, Pt distribution, Xf distribution
- Ψ(2S)/J/ψ production ratio
- χc / J/ψ production ratio
- FCNC D0 -> μμ Br limit
- b b cross section
- γ production

MB data
- J/ψ production cross section
- Strangeness and hyperon production
- Pentaquark search
- Λ polarization
- Deuteron/anti-deuteron production
- Open charm production

Disclaimer: all results presented in this talk are preliminary !!!
**J/ψ differential distribution: \( X_F \)**

- e⁺ e⁻ sample, C wire

![Graph showing J/ψ differential distribution](image)

- Large acceptance for negative \( X_F \) region
- Acceptable agreement in the overlap ranges with existing experimental data

**Remarks:**
- Different targets provide a consistent picture for forward/backward symmetric scenarios.
- See also talk of Mikhail Ryzhinsky.
Open beauty production

- Previous measurements (E789, E771) do not agree with each other
- The present value is within 1.5 $\sigma$ of the E789 experiment (after rescaling to the same $\sqrt{s}$)
- $1.8 \sigma$ below the rescaled E771 measurement
- Theoretical uncertainty:
  - renormalization and factorization scales
  - $b$-quark mass

\[ \sigma (b \bar{b}) = 14.6 \pm 2.3 \text{ (stat)} \pm 2.4 \text{ (sys)} \text{ nb/nucleon} \]

Cross section obtained by using the value of $\sigma (J/\psi) = 493 \pm 20 \pm 43 \text{ nb/nucleon}$

HERA-B has still provide much information on heavy quark physics with nuclei
Searches for new physics at HERA

Outline

- Introduction to HERA
- Rare SM Processes
  - Isolated Leptons and Missing Transverse Momentum
  - Multi Lepton Events
  - General Search for New Phenomena
- Searches for BSM Physics
  - Leptoquark Production and Lepton Flavour Violation
  - SUSY and R-parity Violating Squark production
  - Bosonic Stop Decays in R-parity Violating SUSY
  - Search for Gaugino Production
  - Light Gravitinos in Events with Photons and Missing Transverse Momentum
- Summary of Results

signals above expectation

many limits
see his talk

David South (DESY)
Isolated Leptons and Missing $P_T$

H1 HERA II isolated lepton event at large $P_T^X$

<table>
<thead>
<tr>
<th>$P_T^X$ (GeV)</th>
<th>Full Sample</th>
<th>$P_T^X &gt; 25$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^\pm_p$</td>
<td>$25 / 20.38 \pm 2.92$ (68%)</td>
<td>$11 / 3.22 \pm 0.59$ (77%)</td>
</tr>
<tr>
<td>$\mu^\pm_p$</td>
<td>$9 / 5.35 \pm 1.10$ (82%)</td>
<td>$6 / 3.20 \pm 0.54$ (81%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Isolated e candidates</th>
<th>$12 &lt; P_T^X &lt; 25$ GeV</th>
<th>$P_T^X &gt; 25$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZEUS (prel.) HERA I 99-00 (66 pb$^{-1}$)</td>
<td>$1 / 1.04 \pm 0.11$ (57%)</td>
<td>$1 / 0.92 \pm 0.09$ (79%)</td>
</tr>
<tr>
<td>ZEUS (prel.) HERA II 03-04 (40 pb$^{-1}$)</td>
<td>$0 / 0.46 \pm 0.10$ (64%)</td>
<td>$0 / 0.58 \pm 0.09$ (76%)</td>
</tr>
</tbody>
</table>

Excess not confirmed by ZEUS, need more data

H1 Prel  electron  muon  combined

1994-2005 $e^\pm_p$ 211 pb$^{-1}$

Isolated Leptons and Missing $P_T$

Isolated Lepton, $P_T^l$

Jet, $P_T^X$

Neutrino, $P_T^{\text{miss}}$

main SM contribution

Excess not confirmed by ZEUS, need more data
Multi Lepton Events at H1

- At low mass combinations, good agreement with the SM
- Interesting events seen a large mass combinations (M > 100 GeV)
- 3 ee events (SM: $0.44 \pm 0.10$) and 3 eee events (SM: $0.29 \pm 0.06$) observed in HERA I data
- 2 $e\mu\mu$ events observed in HERA II data at high mass

again, more data needed
Pentaquarks

V. Popov: signal of SVD-2

important to give kinematic details!

negative and positive evidences discussed in

V. Popov: Review on PQs

Leonid Gladilin: only H1 sees $\Theta_c(3100)$ in direct contradiction to ZEUS

ZEUS sees $\Theta^+(1522)$, H1 not (statistically still compatible)

ZEUS sees no signal $\Xi^{--}_{3/2}$(WA89)

H. -W. Siebert: negative evidence for $\Xi^{--}_{3/2}$ (known from phase shifts)

bump in $\Sigma(1760)^+ \rightarrow pK_S$

Tensor glue balls: M. Mateev: discussion of 3 states, around 2000 MeV, width ~500 MeV
Elliptic energy flow in Au Au collisions (PHENIX, RHIC)

Elliptic flow comes from the azimuthal dependence of pressure gradients and generated mainly during the highest density phase of the collision before the spatial asymmetry of the plasma disappears.

Calculations (hydro and parton transport) – $v_2$ is generated before 3 fm/c. -> It is very difficult to convert the spatial anisotropy of the matter into a momentum space anisotropy once the system cools into the mixed phase.

concludes, that seen for all hadrons (on question also for photons) seems to develop early (quark/gluon phase)
Facility for Antiproton and Ion Research at Darmstadt, Germany

FAIR Will Probe the Intensity Frontier With Secondary Beams

- $10^{12}$/s; 1.5 GeV/u; $^{238}$U$^{28+}$
- $10^{10}$/s $^{238}$U$^{73+}$ up to 35 GeV/u
- $3 \times 10^{13}$/s 30 GeV protons

- Broad range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 in intensity over present
- Antiprotons 3 (0) - 30 GeV

Technical Challenges include: Storage rings and high energy electron cooling

Storage and Cooler Rings

- Radioactive beams
- $10^{11}$ stored and cooled 1 - 15 GeV/c antiprotons

Jim Ritman

approved facility \(\sim\) 2013
Hadron Spectroscopy with PANDA – Pbar Annihilations at Darmstadt

Spectroscopy of Charmed Hadrons:
- Charmonium
- New D states

Search for Exotic Hadrons
- Glueballs
- Hybrids

Charm Production in pbar A
- Properties of Charmonium and open charm
Why Antiprotons?

• e+e- annihilation via virtual photon: only states with J^{pc} = 1--

• In pp annihilation all mesons can be formed

• Resolution of the mass and width is only limited by the beam momentum resolution
Conclusion

• still intensive experimental activity addressing QCD
• HERA, TEVATRON, RHIC will provide important information before LHC will have results
• We experimenters have not yet provided the data which need BFKL beyond any doubt
• Looking forward to next HSQCD