Summary of the HFS Working Group

(experimental part)

DIS2006, Tsukuba, 24 April 2006

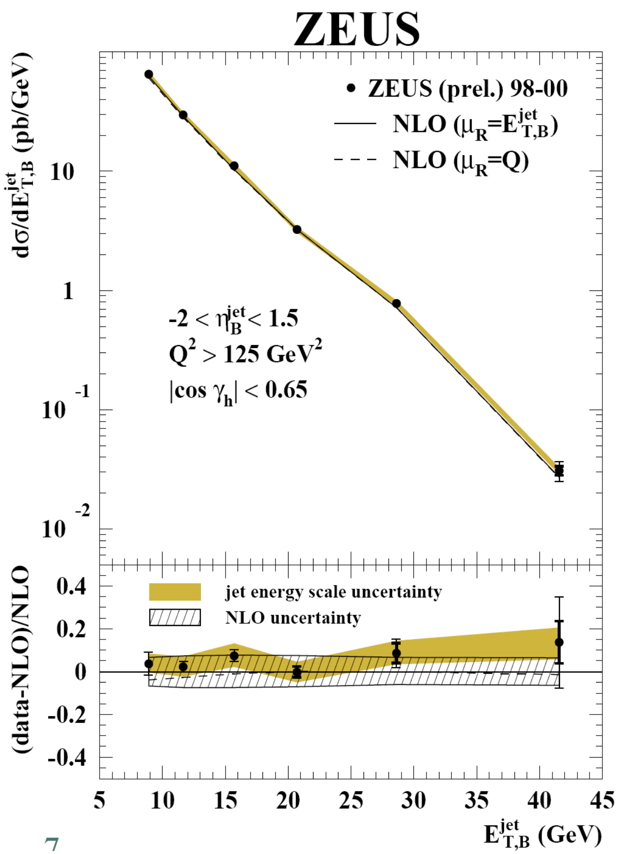
Zoltan Nagy
Juan Terron
Thomas Kluge

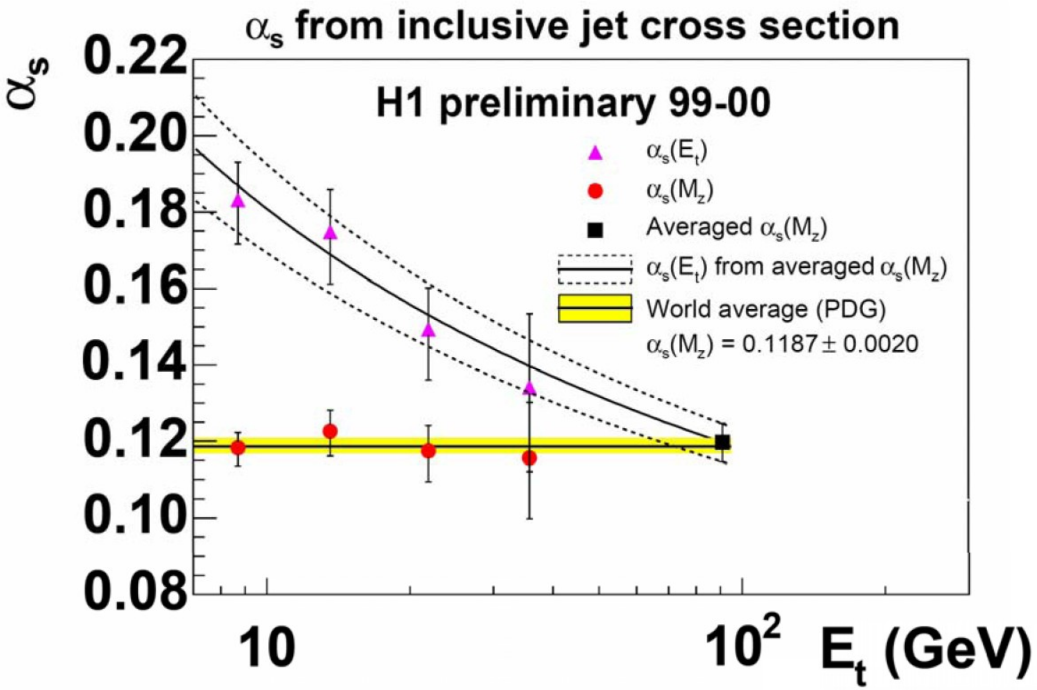
- 29 experimental talks in 9 sessions, 2 joined with heavy flavour
- many lively discussions, theory<->experiments: good!
- developments w.r.t.
  - improved precision
  - extended phase space
  - new “first” measurements
  - ....
- please refer to the full presentations for details, this talk only a glimpse

Inclusive Jet Cross Section in High Q^2 DIS

Steve Maxfield
Marcos Jimenez

textbook measurement
direct sensitivity to α_s and gluon
-> use in QCD fits!





- **Values of $\alpha_s(M_Z)$ have been extracted from $d\sigma/dE^{\rm jet}_{T,\rm B}$ and $d\sigma/dQ^2$**
  - $\longrightarrow$ they are in agreement with each other, with previous HERA determinations and with the world average
  - $\longrightarrow$ a value with very high precision has been obtained:

ZEUS: $\alpha_s(M_Z) = 0.1196 \pm 0.0011(stat.)^{+0.0019}_{-0.0025}(exp.)^{+0.0029}_{-0.0017}(\text{th.})$

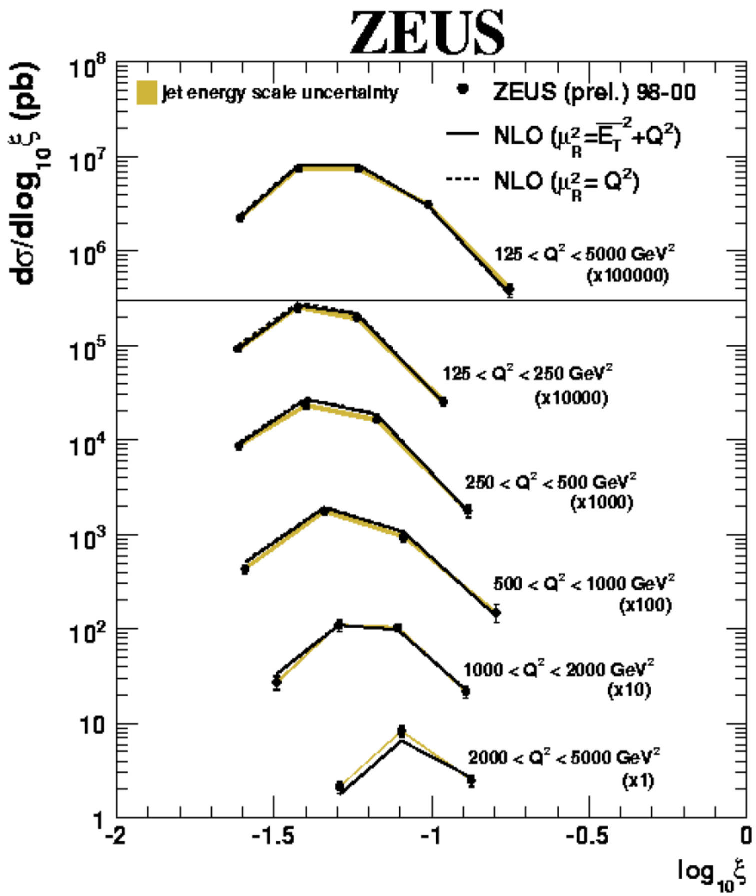
H1: $\alpha_s(M_Z) = 0.1197 \pm 0.0016(\text{exp.})^{+0.0046}_{-0.0048}(\text{th.})$

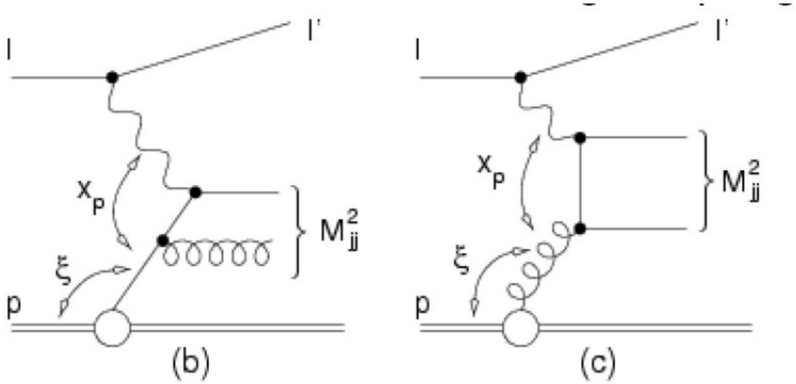
fit only higher Q^2, reduced scale dependence

Dijet Cross Section in High Q^2 DIS

Thomas Schörner-Sadenius

¶ The dijet data improve previous analyses:
- larger statistics (almost factor 3 with respect to 96-97 data)
- higher center-of-mass energy (920 versus 820 GeV)
- improved selection (Breit frame) and tighter cuts (smaller uncertainties).





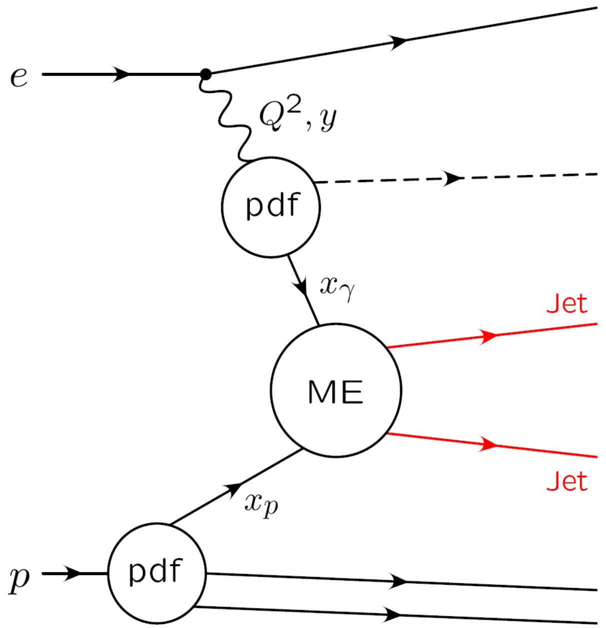
dijets are sensitive to $g(x,Q^2)$ at higher x

¶ The double-differential distributions are sensitive to the gluon density in the proton and should thus serve as input to global QCD fits of the PDFs.

Katja Krüger

New H1 publication: hep-ex/0603014

high E_t jets: small errors (exp. and theo.)



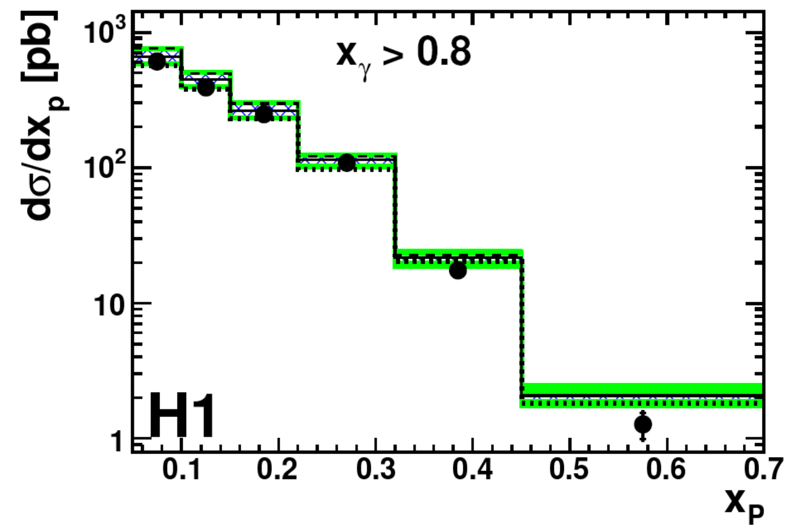
x_γ

$E_{t,\text{max}}$

$|\cos\theta^*|$

x_p

jet energy	$E_{t,\text{max}} > 25\text{GeV}$ $E_{t,\text{2nd}} > 15\text{GeV}$



large x_γ:
direct photon enhanced

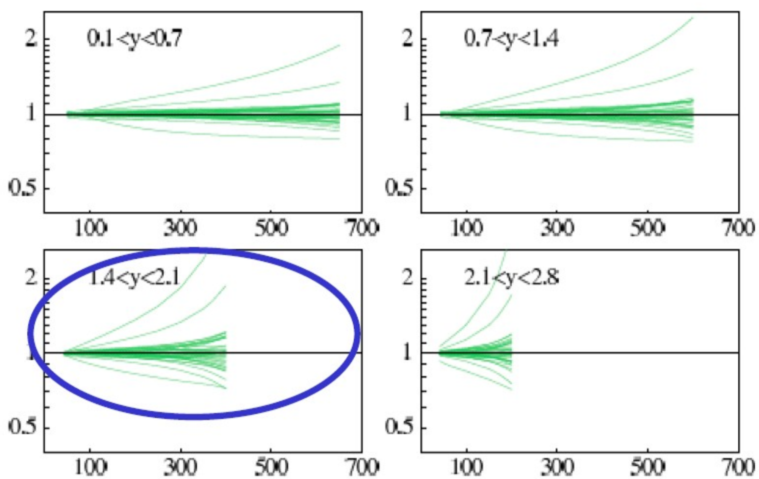
- new measurement of high E_t dijet photoproduction in extended x_p range
- sensitivity to proton parton density functions, especially at large x_p

$\Rightarrow$ data available for pdf fits

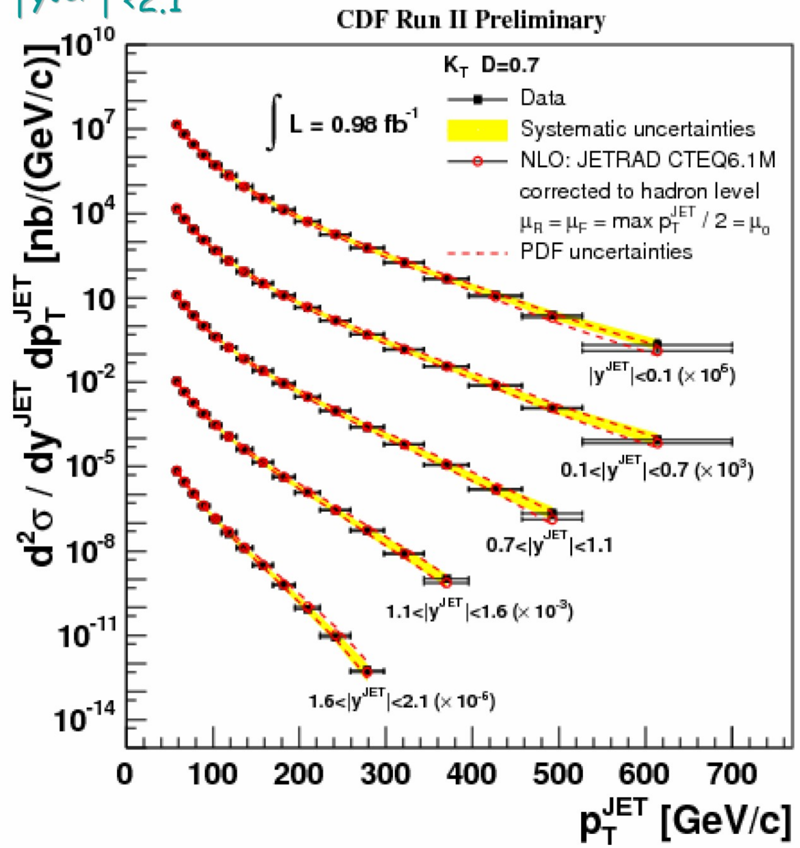
Olga Norniella

Jets cross sections using K_T (~ $1fb^{-1}$)

Results $|y^{Jet}| < 2.1$



Measurements in the forward region allow to constrain the gluon distribution



Good agreement with NLO

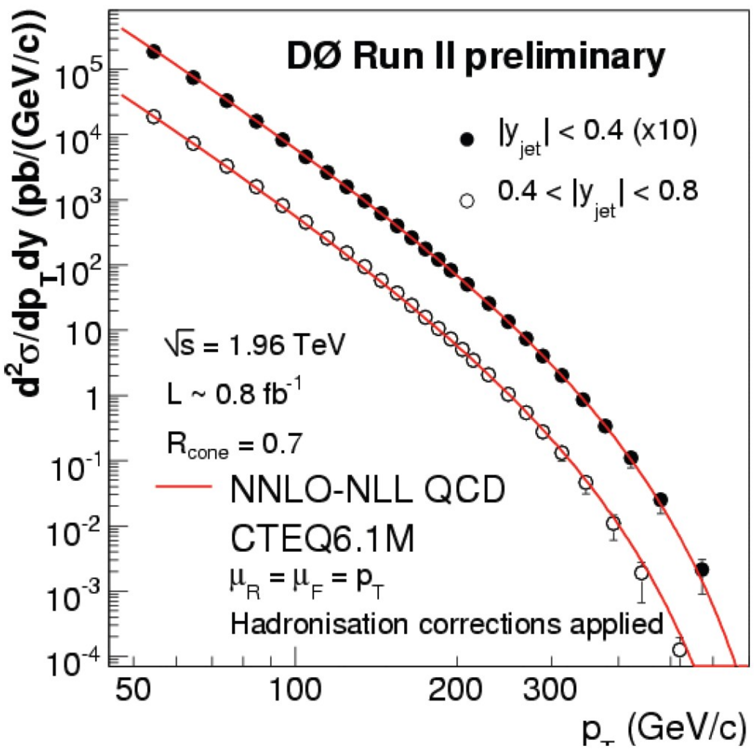
→ The K_T algorithm works fine in hadron colliders

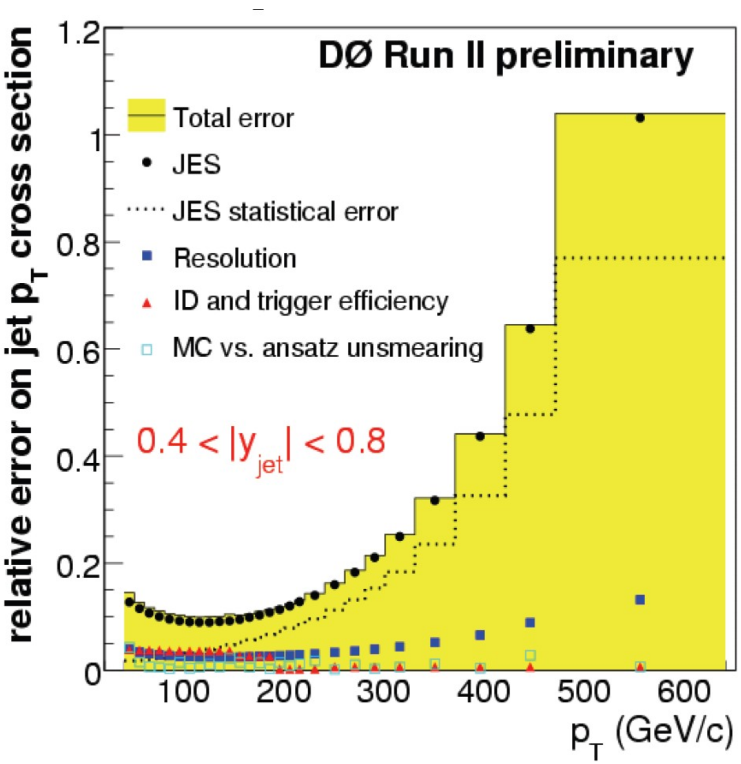
not obvious, might collect more "debris"

→We hope these measurements will be used to further constrain the PDFs (gluon at high x)

Inclusive Jet Cross Section in $p\bar{p}$

Mikko Voutilainen





- Current Jet Energy Scale was derived for a subsample (~10%) of the full dataset

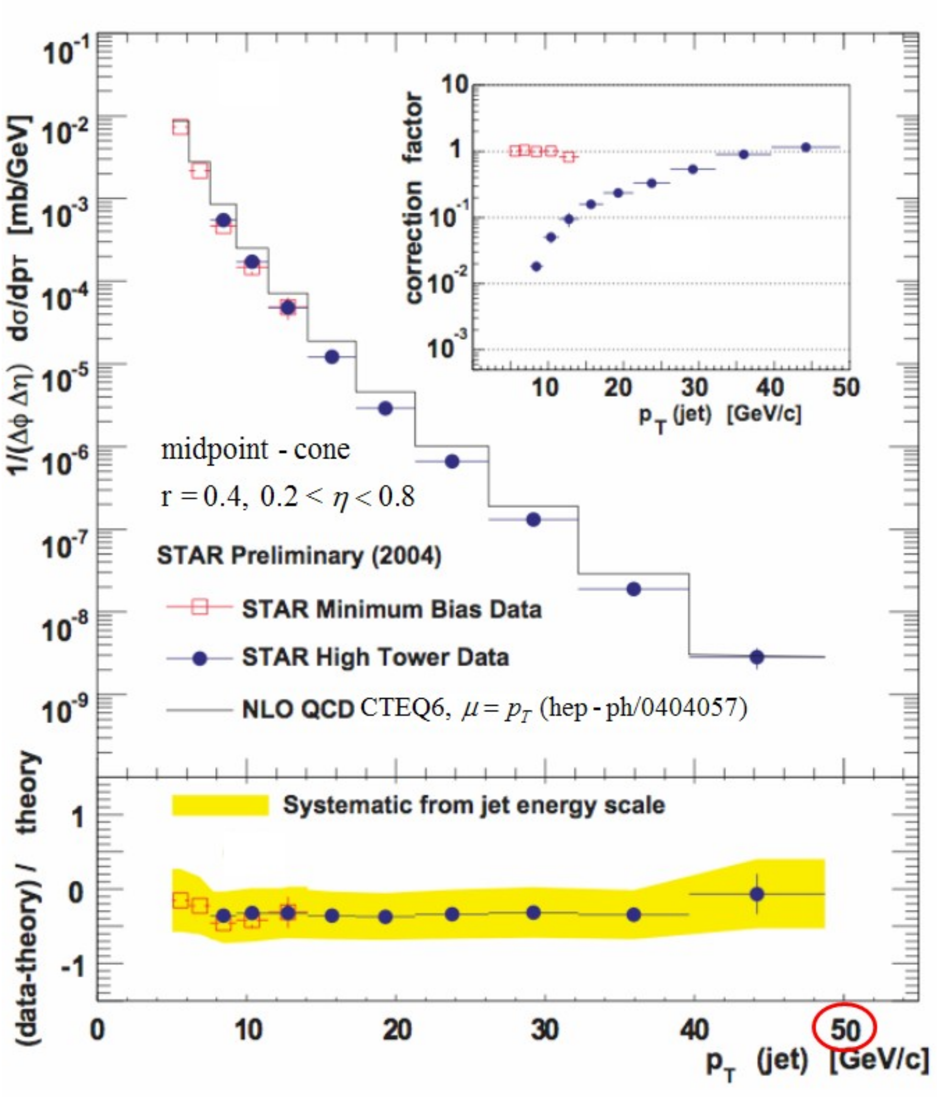
– Further improvements are expected with final JES by summer

– By summer we will also have the full cross section

Inclusive Jet Cross Section in pp

Michael Miller

RHIC offers polarised pp, energy range comparable to HERA



- First glimpse:
  - Significant p_T reach (~50 GeV/c)
  - Agreement within large systematics with NLO calculations
- A few primary issues under study:
  - Luminosity determination
  - Refined corrections
  - NLO clustering scheme
- Goal:
  - Bring 2004 (and 2003) analyses to efficient closure
- Bright Future
  - 2005: first real p+p run 3 pb^{-1} collected
  - 2006: first dedicated p+p run (goal 15 pb^{-1}) *with complete EMCal and commissioned jet and di-jet triggers*

k_t jet algorithm?

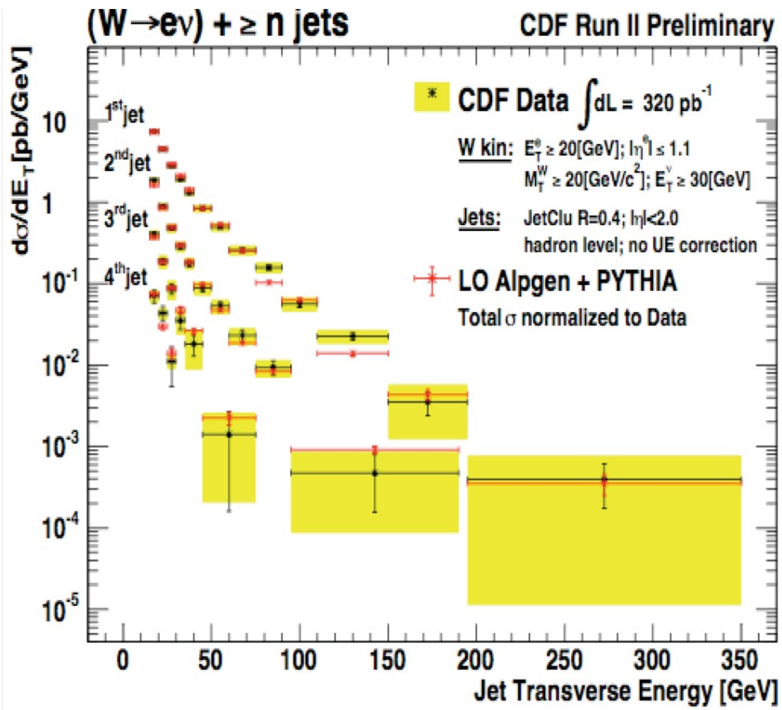
expect more from STAR the next years...

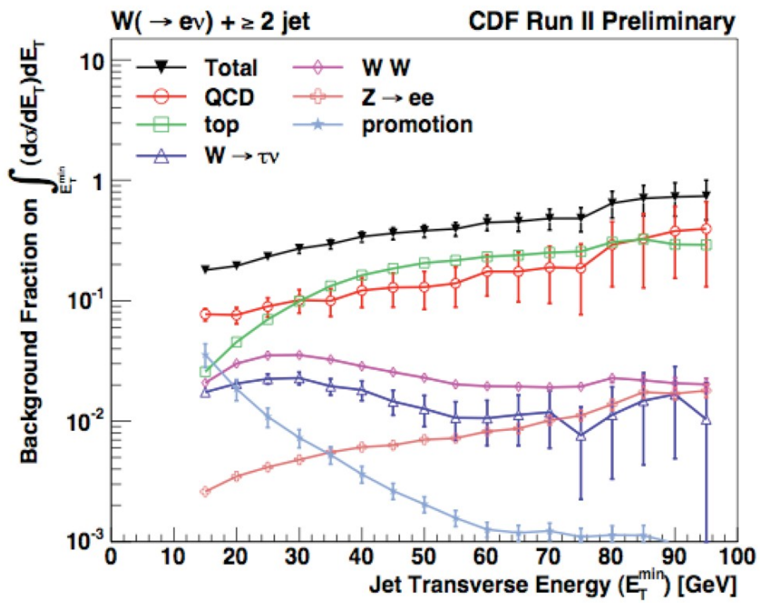
W+Jets Cross Section in $p\bar{p}$

Andrea Messina

Testing ground for pQCD in multijet environment

- ✓ The presence of a boson:
  - Ensures high Q^2 – pQCD
  - Large BR into leptons – easy to detect experimentally
- ✓ Study the underlying event in an alternative topology than inclusive jets
- ✓ This is not an EWK measurement: the W is a clean signal for high Q^2 events within which we can examine jet kinematics.





top quark serves as background here

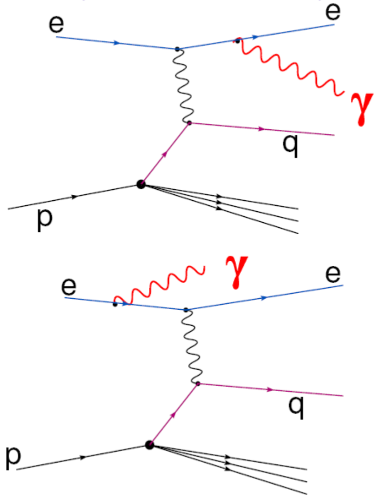
- ✓ Extend the measurement muons and to $1 fb^{-1}$:
  - Larger E_T range, more sensitive to the tail of the cross section
  - Better control on data driven background subtraction

MC have been normalized to inclusive data cross section in each jet sample!

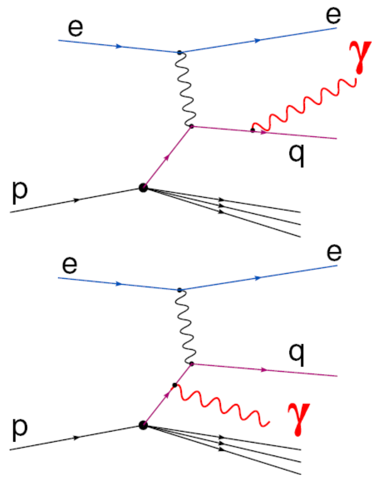
Prompt Photon Cross Section in DIS

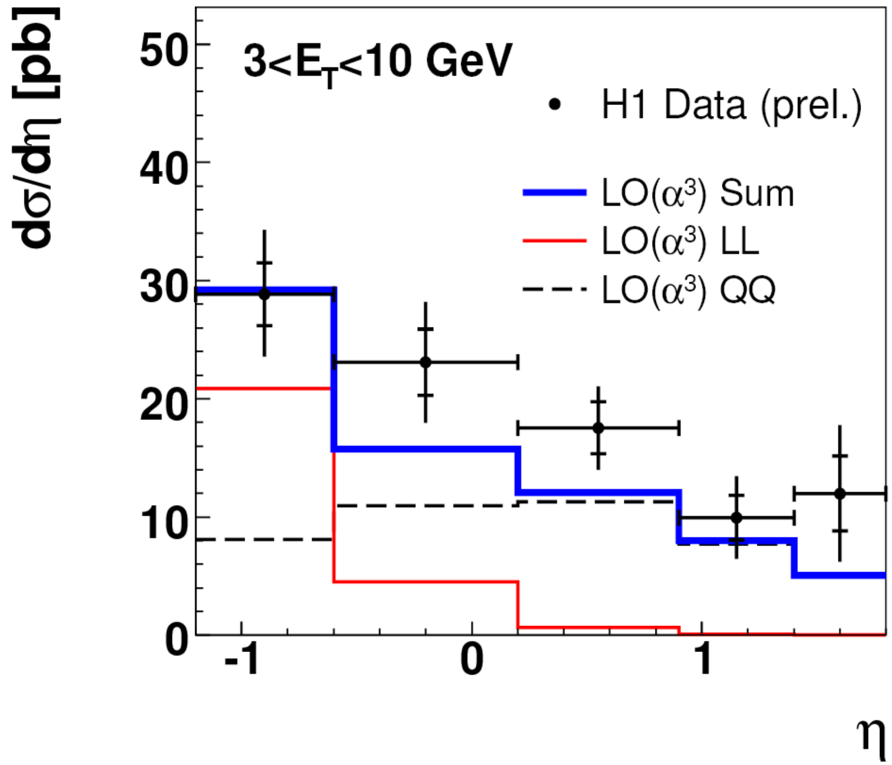
Carsten Schmitz

Electron (FSR and ISR)



Quark (FSR and ISR)





- The measured cross sections are well described by a new LO(α^3) QED calculation (Gehrmann et al., hep-ph/0601073 and hep-ph/0604030) – It is the first calculation for the **inclusive** prompt photon production in DIS!

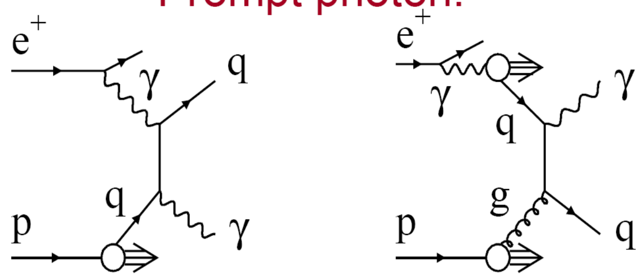
- Compared to the previous measurement (ZEUS '04, hep-ex/0402019) the phasespace is significantly extended (about 10x higher total cross section expectation).

outlook: constrain quark-photon fragmentation function

Prompt Photon Cross Section in gammaP

Eric Brownson

Prompt photon:



(a) Direct (b) Resolved

Previous analyses used shower-shape variables (e.g. D0, H1, ZEUS)

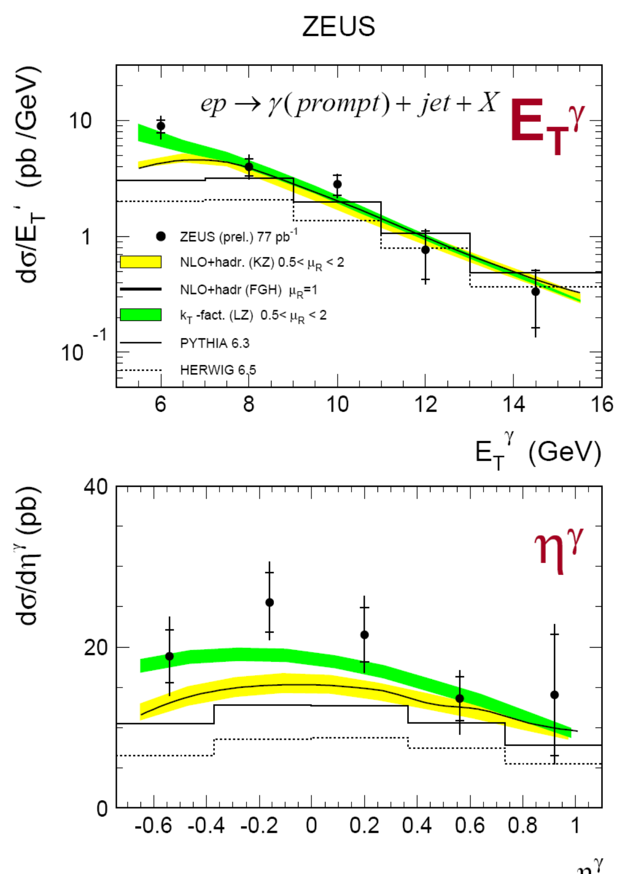
Now we use preshower detector (e.g. CDF)

- Particle decay before the preshower detector

Use the K_t jet finder on both the photon and hadron jet

- Keeps the hadron and the 'photon' jet on equal footing
- Require isolation for NLO & MC (E_t^{γ} / $E_t^{\gamma\text{-total}}$) > 0.9

reach high E_t



Data:

- Corrected for acceptance to the hadron level

HERWIG & PYTHIA:

- Do not rise as steeply as data at low E_t^{γ}
- Underestimate the measured cross section

KZ & FGH:

- Improved agreement with the measured cross section, but deviates at low E_t^{γ}

LZ:

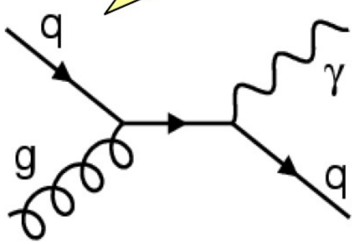
- Improves description for E_t^{γ} and low η^{γ}

data prefer prediction using unintegrated pdfs (Lipatov, Zotov)

Prompt Photon Cross Section in $p\bar{p}$

Ashish Kumar

Dominant



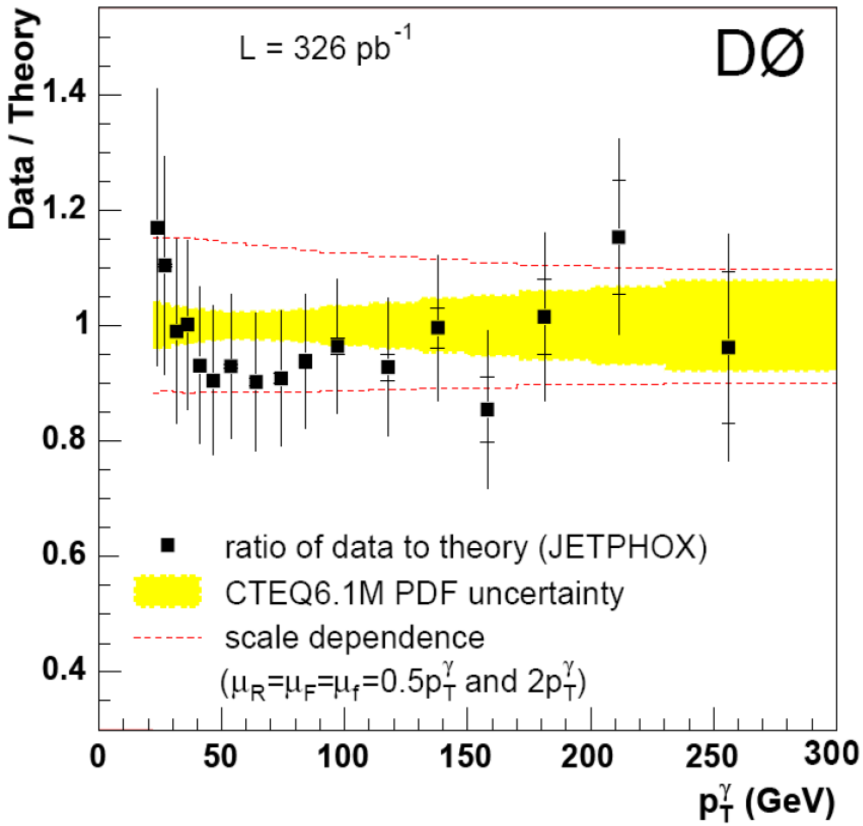
Compton

- **Precision test of pQCD**
- **Direct information on gluon density** in the proton : gluon involved at LO in contrast to DIS & DY processes
- Test of soft gluon resummation, models of gluon radiation,..
- Understanding the QCD production mechanisms of photons is prerequisite to searches for new physics.

DØ has measured inclusive cross section of isolated photons in central region ($|\eta|<0.9$) and in the widest p_T^γ domain ever covered ($23 < p_T^\gamma < 300$ GeV). Results from the NLO pQCD agree with the measurement within uncertainties.

hep-ex/0511045

Accepted by Phys.Lett. B



use high E_t data in future global pdf fits!

Event Shape Variables in e^+e^-

Marek Tasevsky

event shapes similar to jets but no minimum E_t required
-> soft gluons important
(lower scales also hadronisation)

LEP experiments measured lots of them

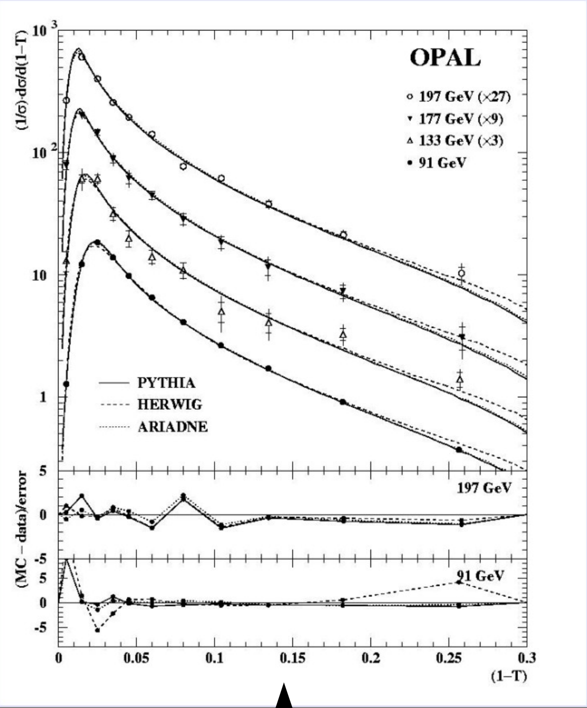
Thrust

$$T = \max_{\vec{n}_T} \left(\frac{\sum_i |\vec{p}_i \cdot \vec{n}_T|}{\sum_i |\vec{p}_i|} \right)$$

Thrust axis n_T chosen to maximise the expression

1-T=0: 2-jet event

1-T=1/2: spherical event



3-jet observ.: well described by event generators

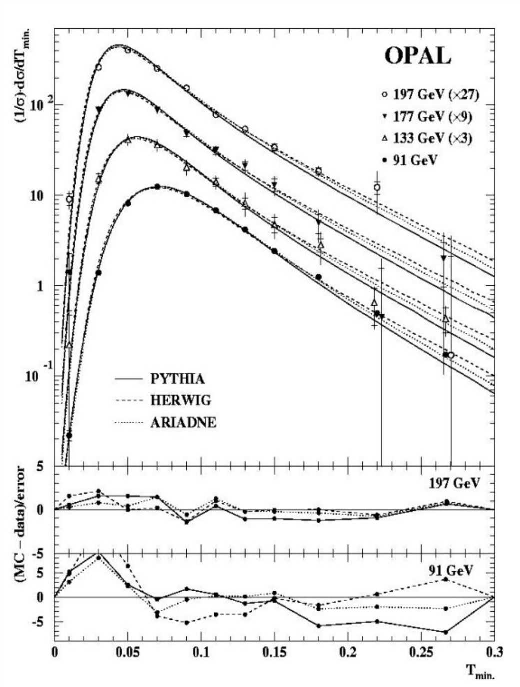
Thrust minor

$$T_{\mathrm{min}} = \frac{\sum_i |\vec{p}_i \cdot \vec{n}_{T_{\mathrm{min}}}|}{\sum_i |\vec{p}_i|}$$

$$\vec{n}_{T_{\mathrm{min}}} = \vec{n}_T \times \vec{n}_{T_{\mathrm{maj}}}$$

T_{min} =0: 2-jet event
T_{min} =0: 3-jet event
T_{min} =1/2: spherical event

- 4-jet observable



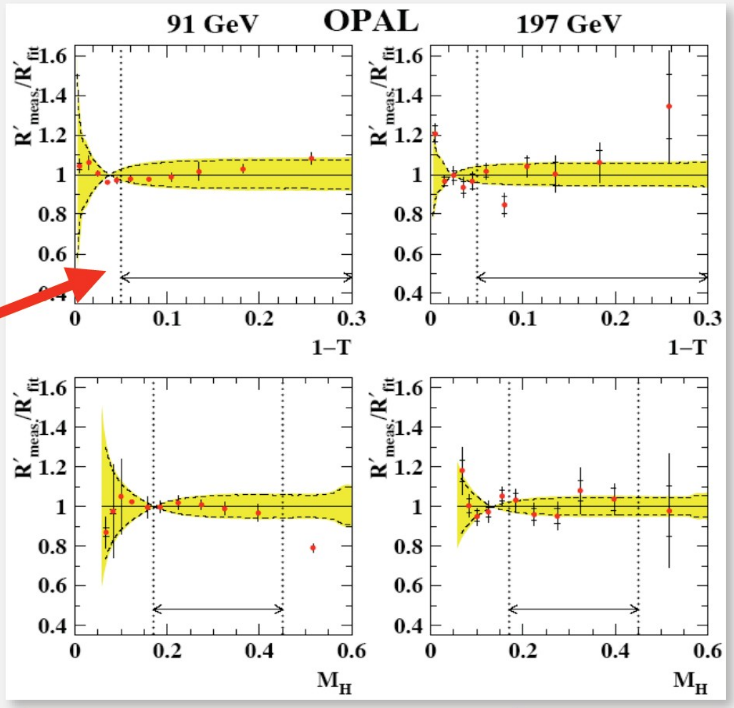
4-jet observ.: problems at lower scale

Event Shape Variables in e^+e^-

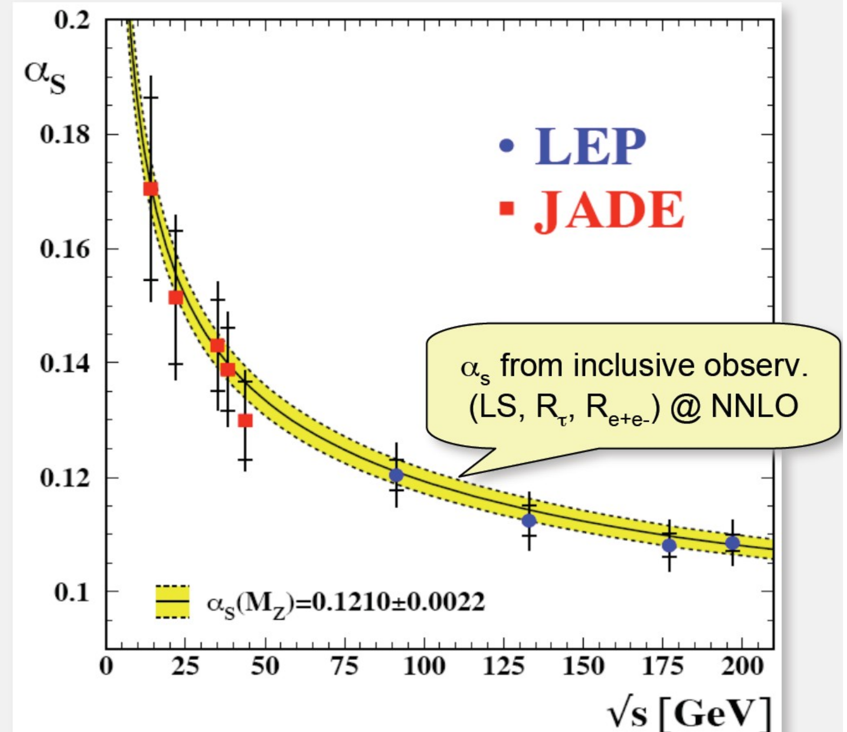
Thorsten Wengler

fit α_s to event shapes where theory is reliable

Fit Range



Thrust and heavy jet mass



results compatible to fit to incl. observables

LEP combined $\alpha_s(m_Z)$: 0.1201±0.0053 (uncertainty dominated by theory)

Event Shape Variables in DIS

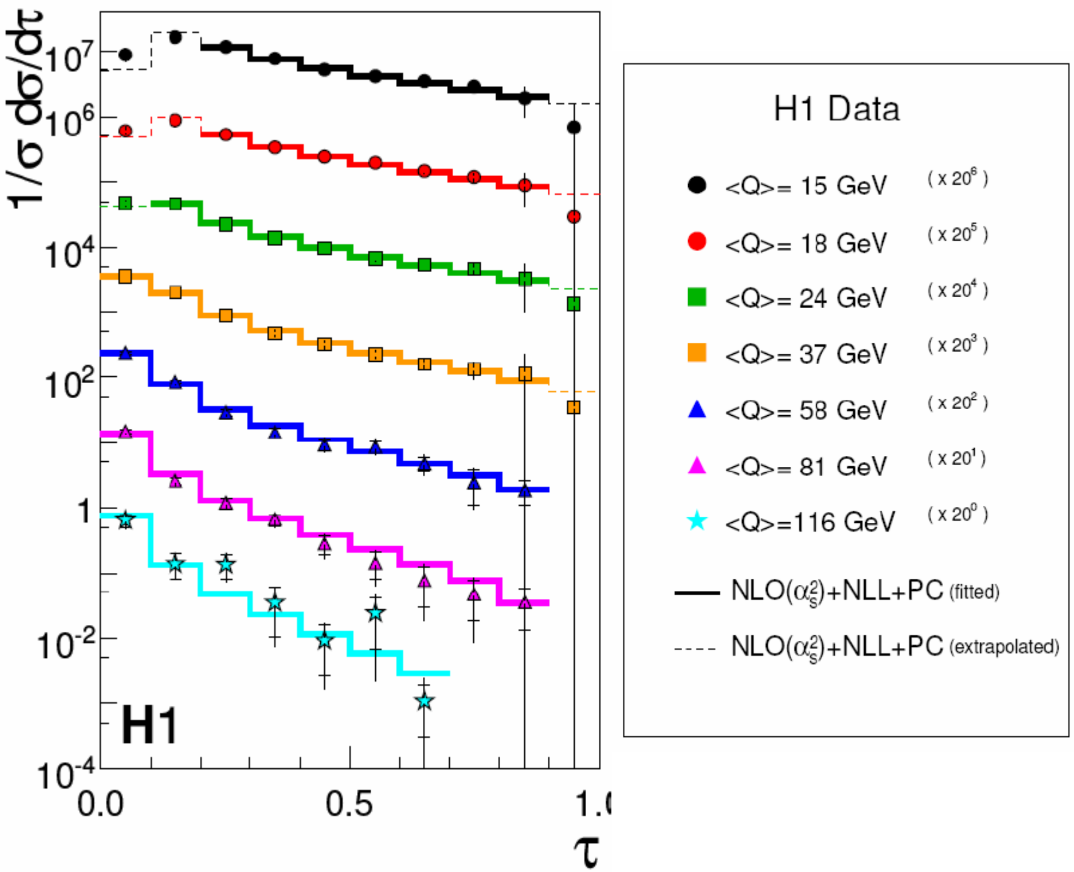
Jacek Turnau

again event shapes, but now emphasis on PT-NP interplay

Power corrections: part of ambitious program to describe hadronic final states in terms of Feynmann diagrams parametrizing confinement with one universal constant

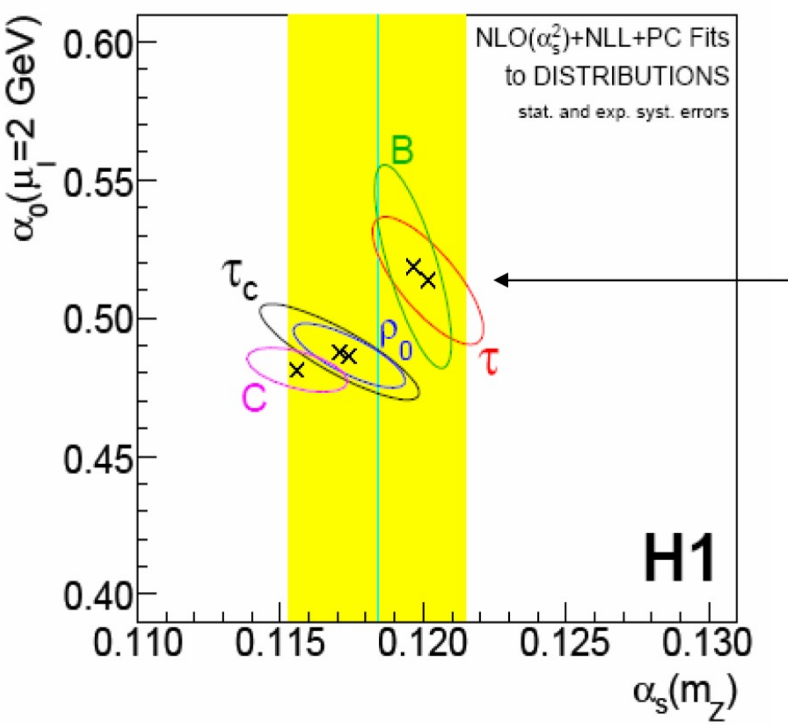
$$\alpha_0 = \frac{1}{\mu_I}\int_0^{\mu_I} dk\,\alpha_s(k^2) \quad \mu_I = 2\,\mathrm{GeV}$$

Power corrections provide much cleaner connection between parton and hadron levels



large range of scale in single experiment

hep-ex/0512014, accepted by Eur. Phys. J.



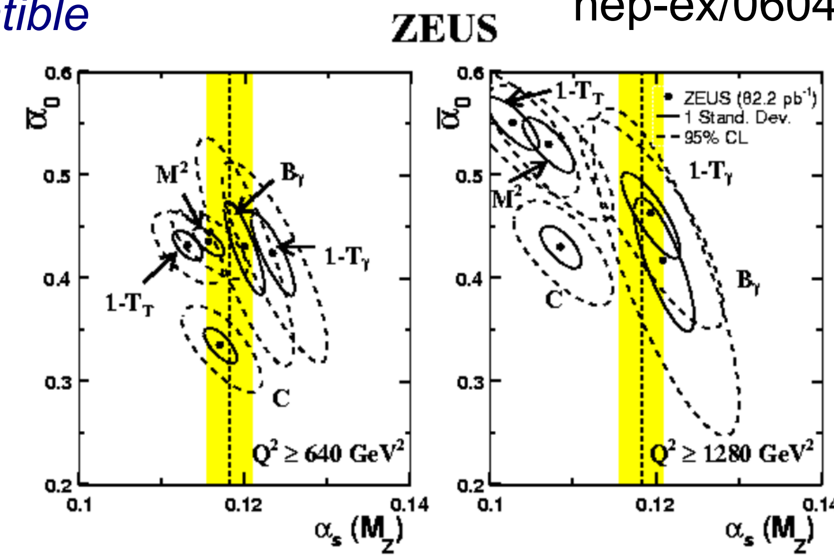
consistent fits for five event shapes (exp. errors only)
support for power corrections

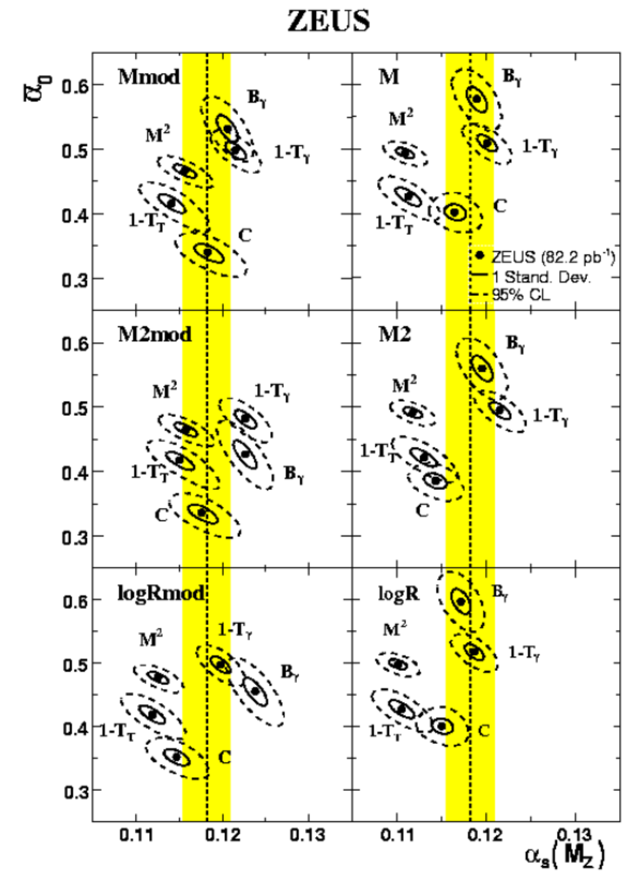
Event Shape Variables in DIS

Alexandre Savin

ZEUS did similar analysis to H1
slightly different binning and
data correction techniques
-> data points compatible

hep-ex/0604032





Consistent with being independent of the Q range

Extracted parameters

- **Extracted α_s values are consistent with each other and H1**

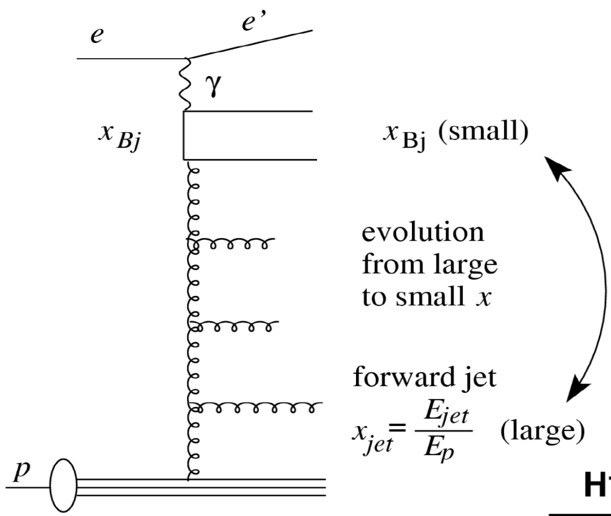
Major theoretical uncertainties

- **Fit range ;**
- **Theoretical parameters: renormalization scale, logarithmic rescale factor, power factor in modification term etc**

- **Power-correction method provides a reasonable description of the data for all event-shape variables with α_0 0.4-0.5 for most of the variables.**
- **The lack of consistency in the (α_s,α_0) extraction suggests the importance of high-order processes that are not yet included in the model**

Forward Jet Cross Section in low x DIS

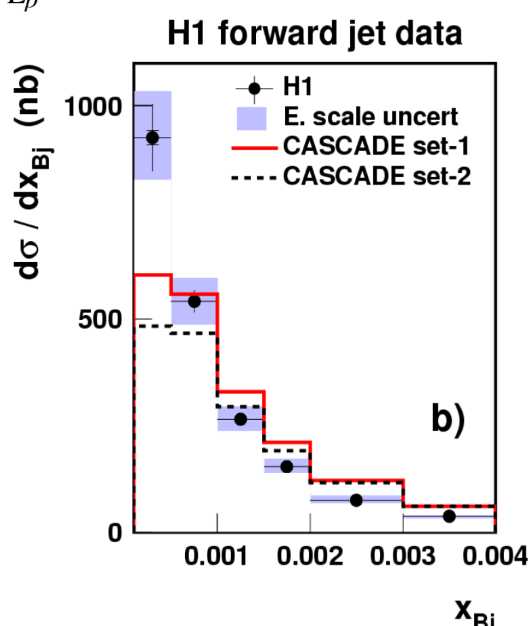
Christiane Risler



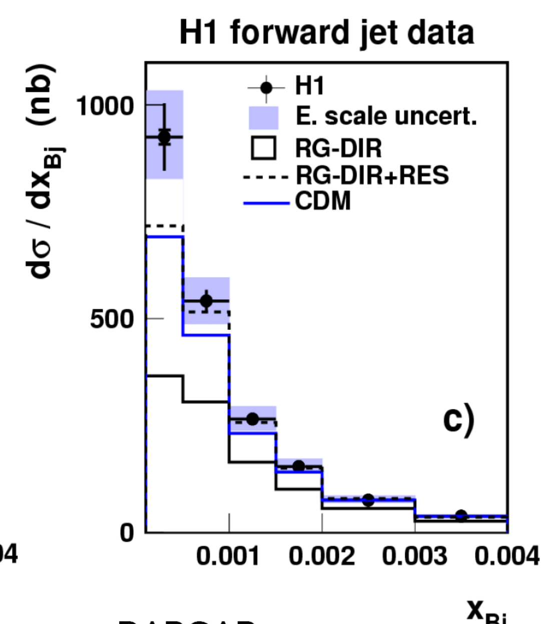
test QCD at small x
parton dynamics beyond DGLAP?

Select phase space for evolution in x
BFKL
xbj << xjet

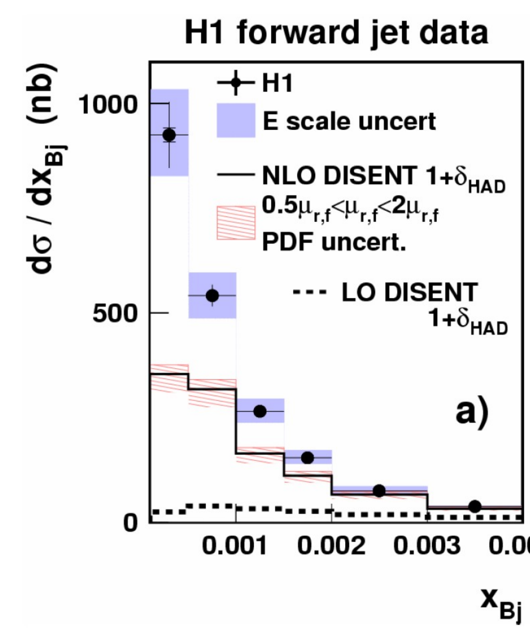
suppress phase space for
evolution in Q2 DGLAP
$p_{t,\mathrm{fwd\ jet}}^2 \sim Q^2$



CASCADE



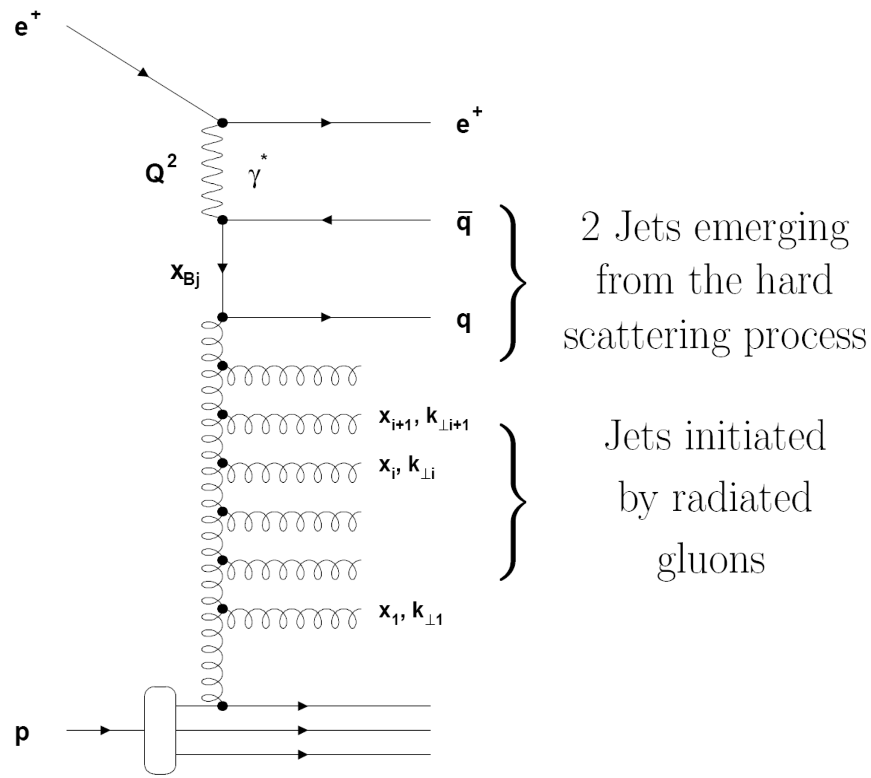
RAPGAP

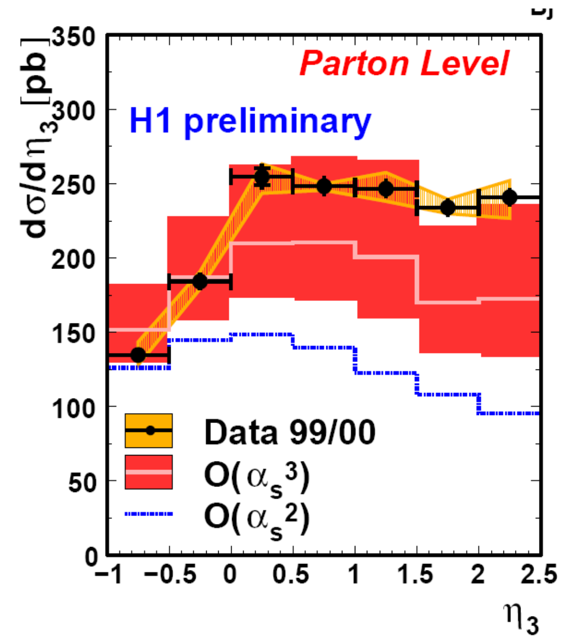


best desription of data by RAPGAP-DIR+RES and CDM
while CASCADE, RG-DIR fail
NLO(α_s^2) dijet only good description at large x_{bj} or large Q_2, large p_t^2

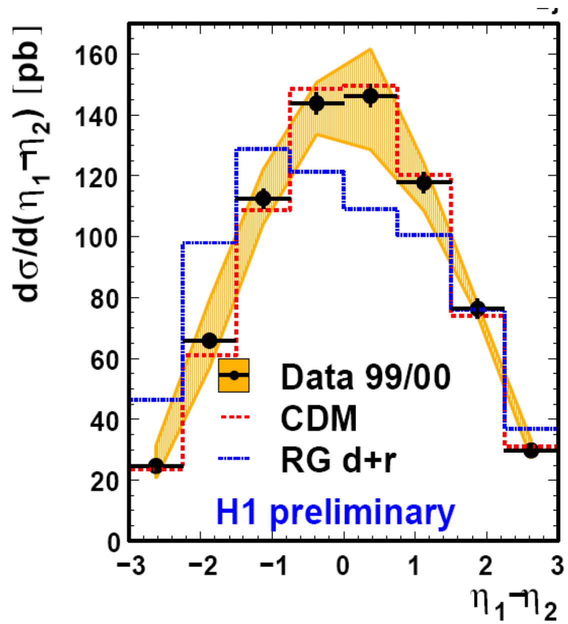
3-Jet Cross Section in low x DIS

Christoph Werner





3-jets at low x: expect 1 (fwd) jet from the gluon ladder

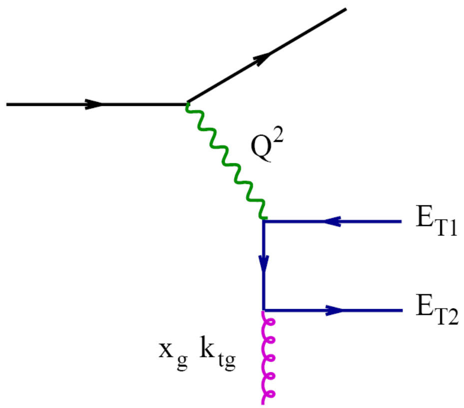


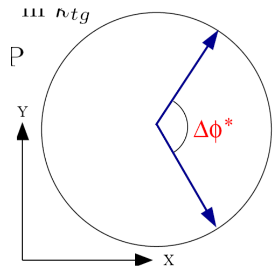
- only MC Generator with unordered radiation of gluons describes data satisfactory
- strong hints for radiation of gluons unordered in $p_\perp$

how well would DGLAP NNLO perform?

Dijet Azimuthal Decorrelation in low x DIS

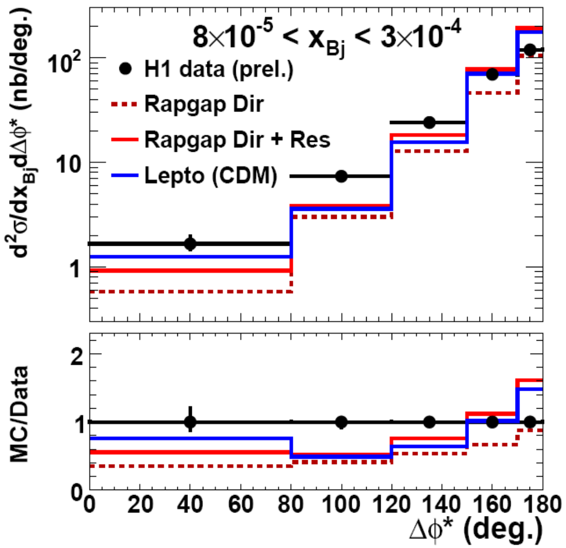
Magnus Hansson

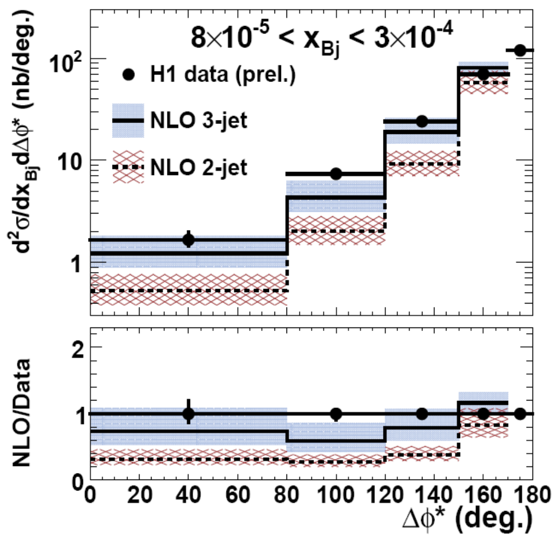


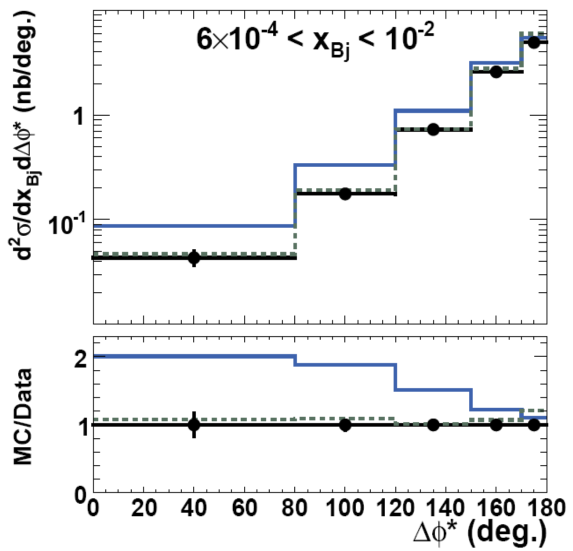


the dijets get a kick from a third jet/intrinsic gluon k_t

- Azimuthal decorrelations in dijet events measured in bins of Q^2 and in bins of x_{Bj}







- Rapgap Dir, Rapgap Dir+Res and Lepto(CDM) fail to describe the data
- Data show sensitivity to the unintegrated gluon density, they prefer J2003 compared to A0

Fragmentation Functions in DIS

Daniel Traynor

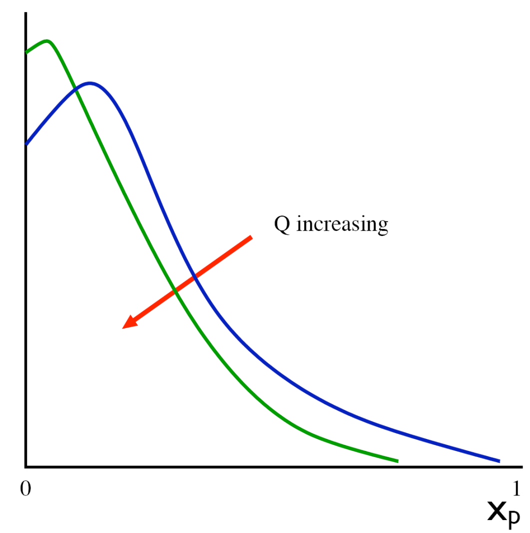
$$x_p = \frac{(2P_h)}{Q}$$

$$D(x_p) = \frac{1}{N_{event}} dn/dx_p$$

x_p = scaled momentum variable

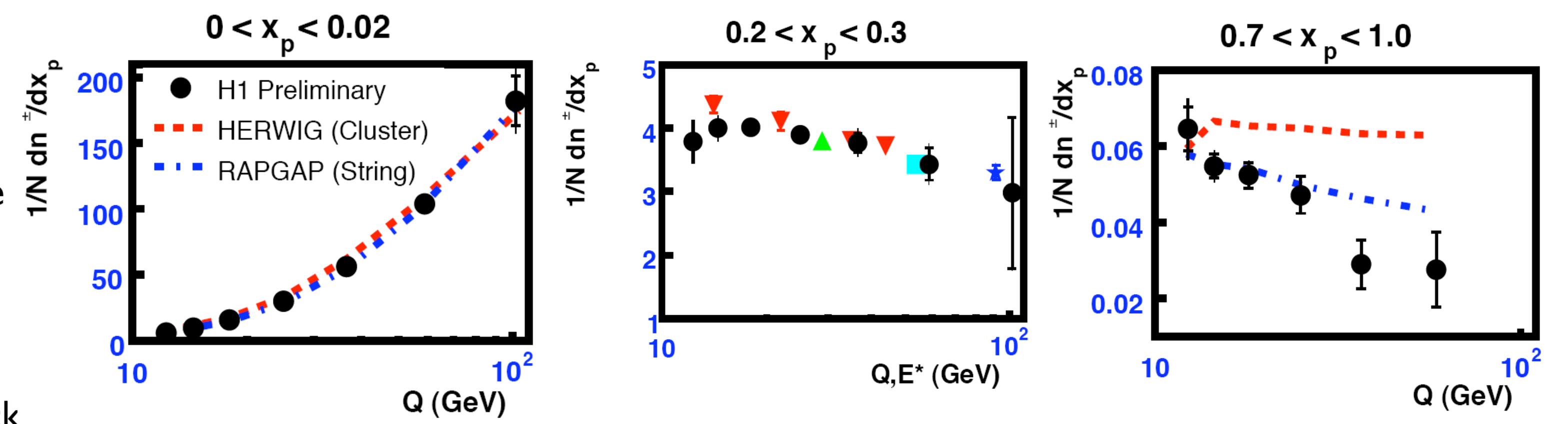
Q = Scale in current region of Breit Frame

p_h = momentum of charged track in current region of Breit Frame



hardness of charged particle in Breit frame: scaling violations

H1



- Presented new results on the D(xp) distribution in current region of Breit frame in DIS ep interactions.
- DIS and e^+e^- results in agreement at high Q (this analysis).
- String hadronisation better than cluster
- Monte Carlo tuned from LEP data can successfully describes ep data over large region of Q.
- Comparison with full NLO predictions (CYCLOPS program).

constrain fragmentation functions: difficult...

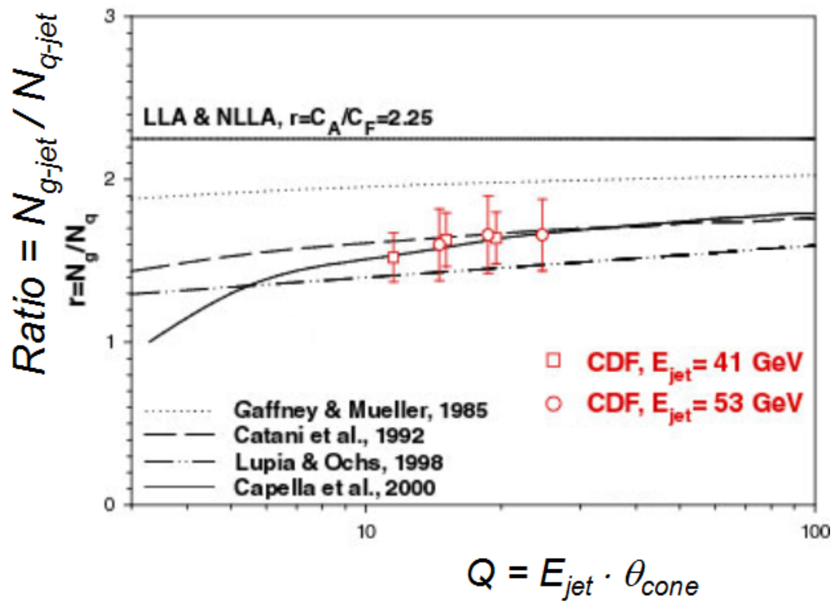
Andrey Korytov

Charged particle multiplicities in gluon and quark jets:

- measured multiplicities in di-jet and γ-jet events can be resolved for multiplicities in quark and gluon jets

- Results agree with NNLLA
  - ratio r = 1.64 ± 0.17 at Q~20 GeV

- Most recent LEP result (OPAL)
  - ratio r = 1.51 ± 0.04 at Q~90 GeV

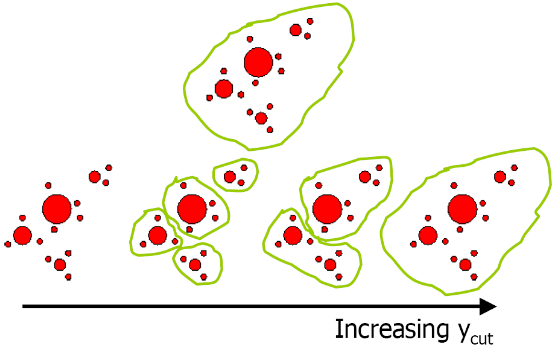


Multiplicity of charged particles in jets:

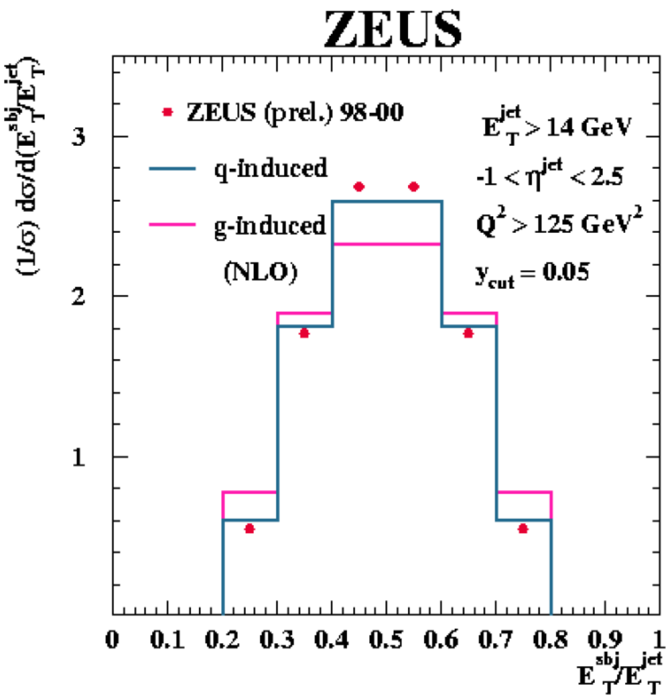
- Particle multiplicity is proportional to that of partons: $N_{hadrons} = K_{LPHD} N_{partons}$
- K_{LPHD}=0.56±0.10 for the entire range M_{jj}=80-600 GeV/c^2
- Ratio of multiplicities in gluon and quark jets r_{LPHD}=1.6±0.2 is consistent with pQCD

Subjet Distributions in DIS

Thomas Schörner-Sadenius



¶ Exactly two subjets resolved in a jet at y_{cut} = 0.05 (small hadronisation corrections).



¶ Slightly different shapes of quark- and gluon-induced contributions to the NLO cross section.

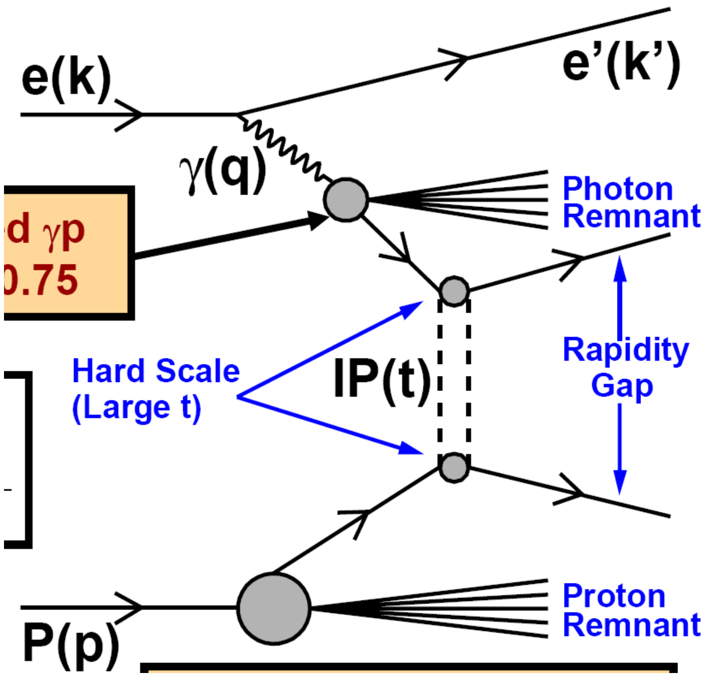
¶ Data better described by quark-induced contribution which in the phase-space considered amounts to 82%.

¶ ZEUS subjet distributions
- allow study of QCD radiation pattern within jets in perturbative regime
- are nicely described by NLO QCD calculations with up to three partons in one jet
- are dominated by quark-induced contributions for the phase-space region in question (and provide discrimination power between gluon- und quark-induced contributions).

Pat Ryan

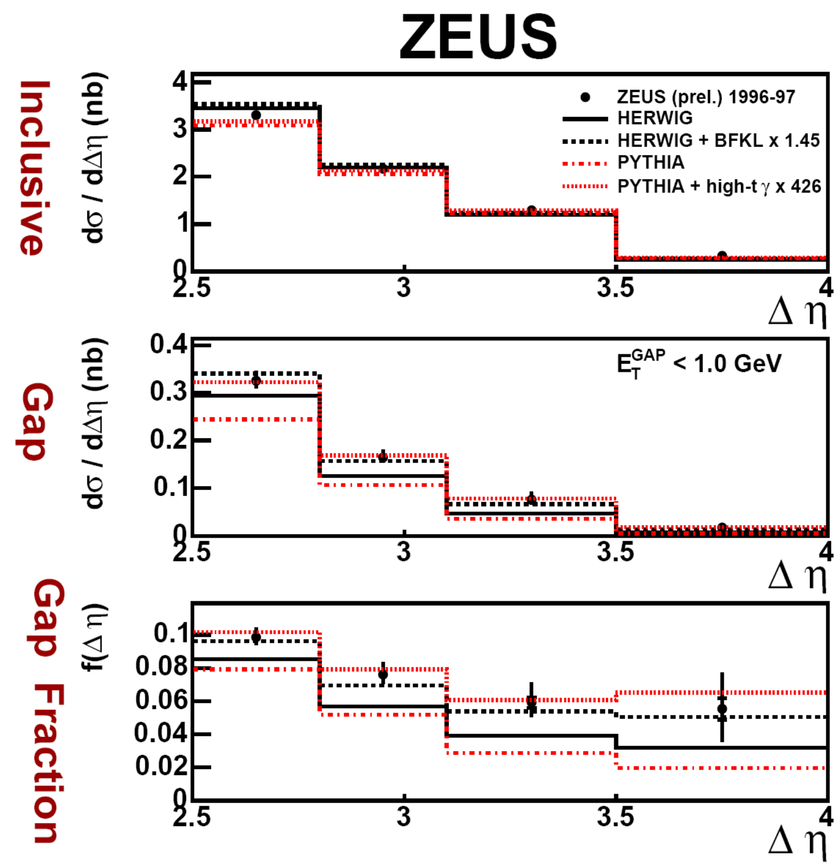
- **Study the nature of the Pomeron**
  - **Observe Color-Singlet exchange**
- **Hard Scale allows application of pQCD to diffractive process**

Rapidity Gap Between Jets



- **2 Sources of Rapidity Gaps between Jets**
  - **Color-singlet Exchange**
    - Lack of color radiation produces gap
    - Example: Pomeron
  - **Color-Non-Singet Exchange**
    - Fluctuations in particle multiplicity produces gap
    - Non-diffractive

multiple interactions



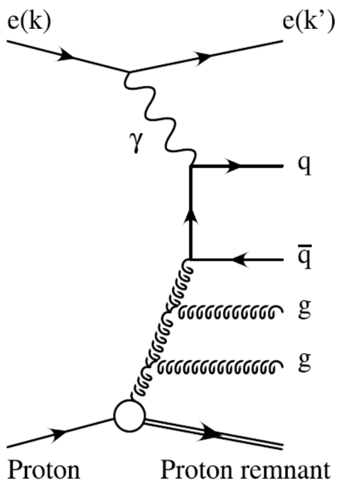
- **Conclusions**
  - **Data demonstrate evidence of ~3% Color-Singlet contribution estimated at the cross section level for entire phase space**
    - Corresponds to ~1-2% Color-Singlet in resolved region
  - **Data consistent with published ZEUS and H1 results**
  - **PYTHIA and HERWIG describe data well after the Color-Singlet contribution is added**

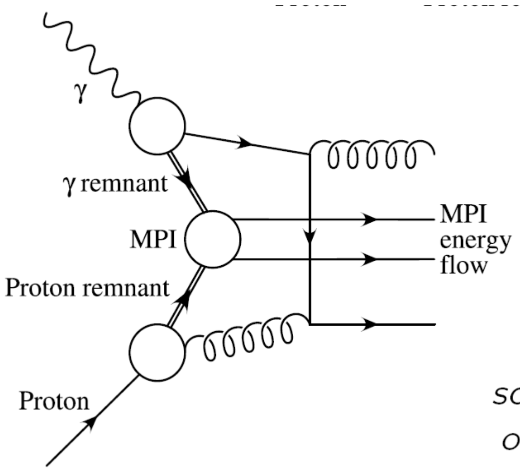
compare to Tevatron data...

Tim Nasoo

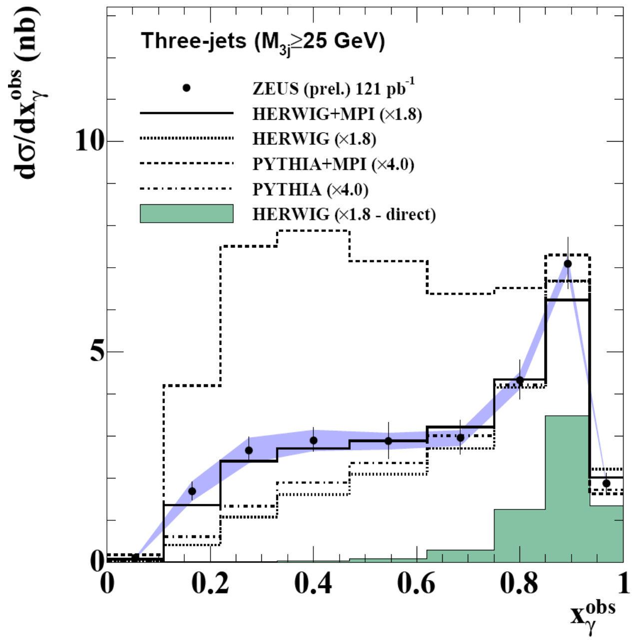
7.5x more data for 3-jets, 4-jets first measurement

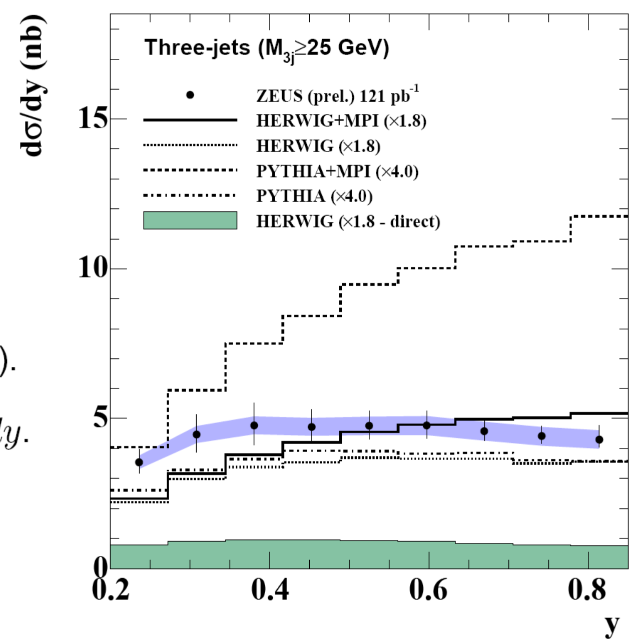
- Three- & four-jet states in PHP measured differentially with 121 pb^{-1}





schematic of a MPI





- LO ME+PS MCs do not describe the data well - require an additional component.
- MPIs can account for this correctly (HERWIG)... BUT...
- ...MPIs tuned to general (albeit less sensitive) collider data fail dramatically (PYTHIA).
- the introduction of MPIs in both HERWIG & PYTHIA disrupts the description of $d\sigma/dy$.

use this data to tune multiple parton interactions!

Pentaquarks in gammaLD$_2$

Norihito Muramatsu

Overview of Θ^+ status

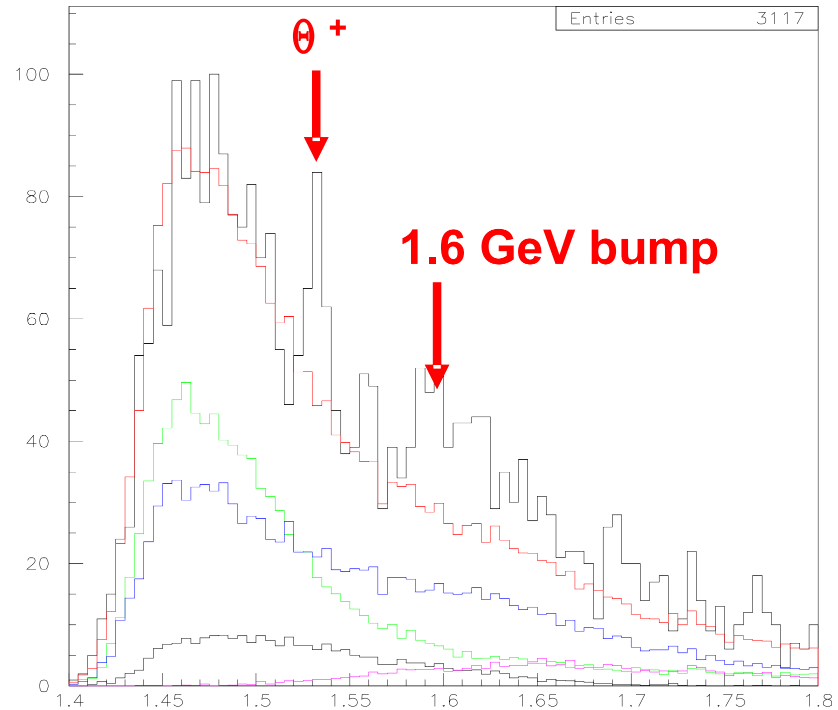
	searched mode	mass [MeV/c^2]	width [MeV/c^2]	statistical significance	
LEPS(C)	$\gamma C \to K^+K^-X$	1540±10	< 25	4.6σ	
DIANA	$K^+Xe \to K_S^0pX$	1539±2	< 9	4.4σ	Belle ?
~~CLAS(d)~~	~~$\gamma d \to K^+K^-p(n)$~~	~~1542±5~~	~~< 21~~	~~5.2σ~~	CLAS(d)
~~SAPHIR~~	~~$\gamma p \to K^+K^0(n)$~~	~~1540±6~~	~~< 25~~	~~4.8σ~~	CLAS(p)
ITEP	$\nu A \to K_S^0pX$	1533±5	< 20	6.7σ	
CLAS(p)	$\gamma p \to \pi^+K^-K^+(n)$	1555±10	< 26	7.8σ	
HERMES	$e^+d \to K_S^0pX$	1528±3	13±9	~5σ	
ZEUS	$e^+p \to e'K_S^0pX$	1522±3	8±4	~5σ	
COSY	$pp \to K_S^0p\Sigma^+$	1530±5	< 18	4-6σ	
SVD(2004)	$pA \to K_S^0pX$	1526±4	< 24	5.6σ	
SVD(2005)	$pA \to K_S^0pX$	1523±4	< 14	8.0σ	independent sample
KEK E522	$\pi^-p \to K^-X$	1531±3	< 10	~2.5σ	P_π=1.92 GeV/c only

New results will appear from LEPS(d), DIANA, COSY, …

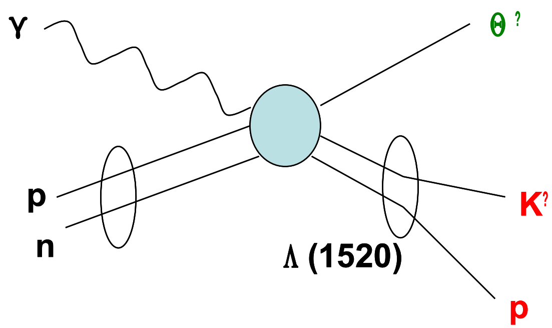
Negative results in high energy experiments. (BES, BaBar, Belle, LEP, HERA-B, SPHINX, HyperCP, CDF, FOCUS, PHENIX)

$\gamma d \to \Theta^+ K^- p$ σ<450 pb, but acceptance coverage is different from LEPS (forward region). . Θ^+ is not killed.

LEPS **LD$_2$ data (preliminary)**
1.50< M(pK?)<1.54 GeV/c^2



MMd(γ,pK?) GeV/c^2



missing mass

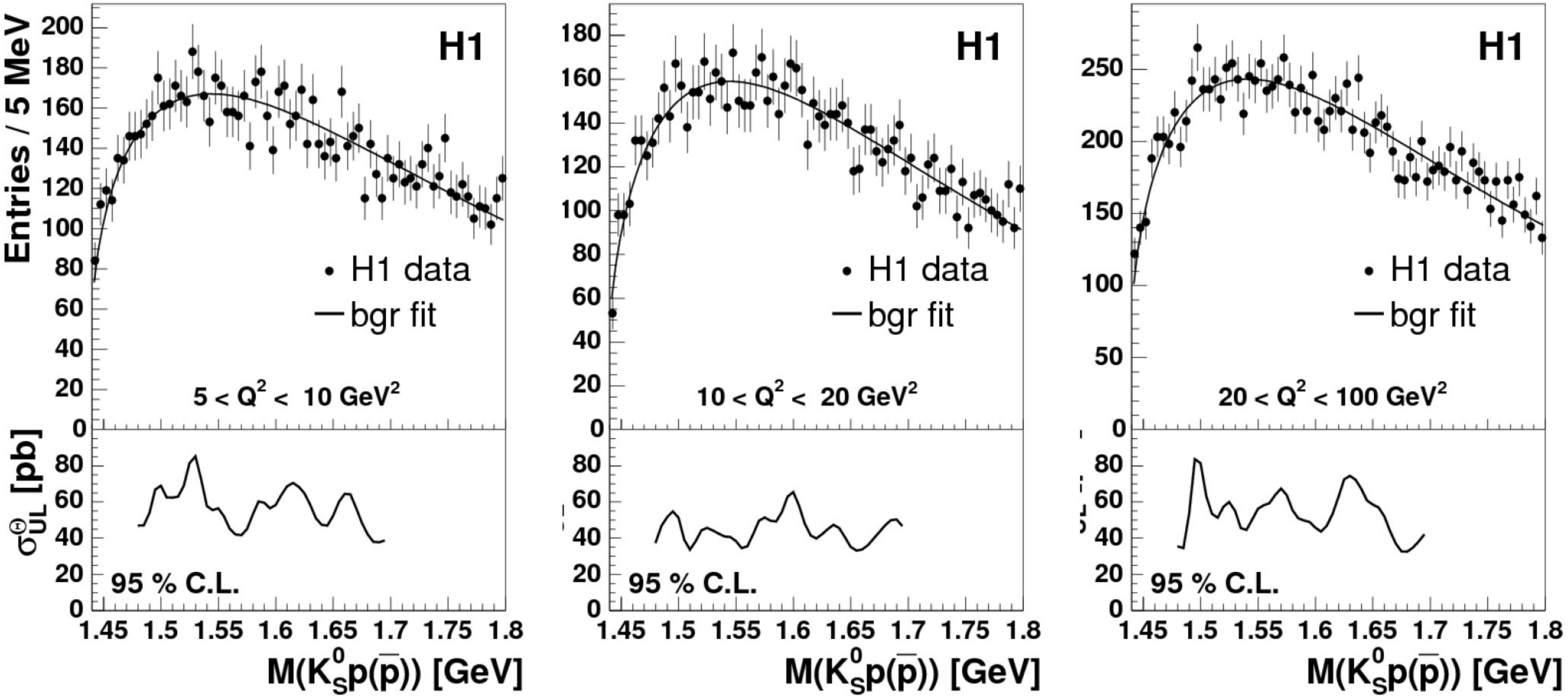
mass ~1.53 GeV/c^2
s/sqrt[s+b] ~ 4σ

plans to extend LEPS detector acceptance (overlap with CLAS)

Pentaquarks in DIS

Dmitri Ozerov

- H1 performed a search in DIS for a narrow resonance decaying to $K_s^0 p / K_s^0 \bar{p}$
- No significant signal observed in the Q^2 region between 5 and 100 GeV^2



(interpolated to ZEUS y-region):

$\sigma(M = 1.52) < 100\, pb\, (95\, C.L.)$

ZEUS : preliminary result (DIS 2005)
$Q^2 > 20.0$ GeV^2, $0.04 < y < 0.95$

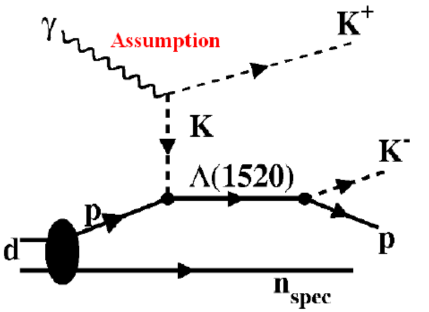
$\sigma(e\,p \rightarrow e\,\theta\,X \rightarrow e\,K^0\,p\,X) = 125 \pm 27(stat)^{+38}_{-28}(syst)\, pb$

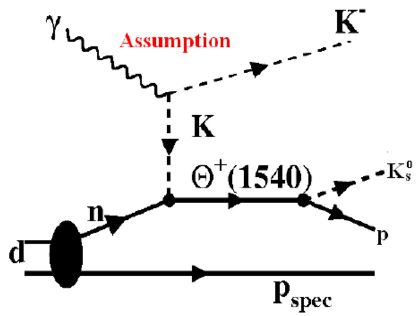
- With similar selection and phase space as in the ZEUS analysis:
  no significant signal observed
  H1 does not support the ZEUS evidence,
  as expressed in their preliminary cross section

H1 limit does not contradict ZEUS evidence

Strange Baryon Cross Sections in DIS

Siguang Wang

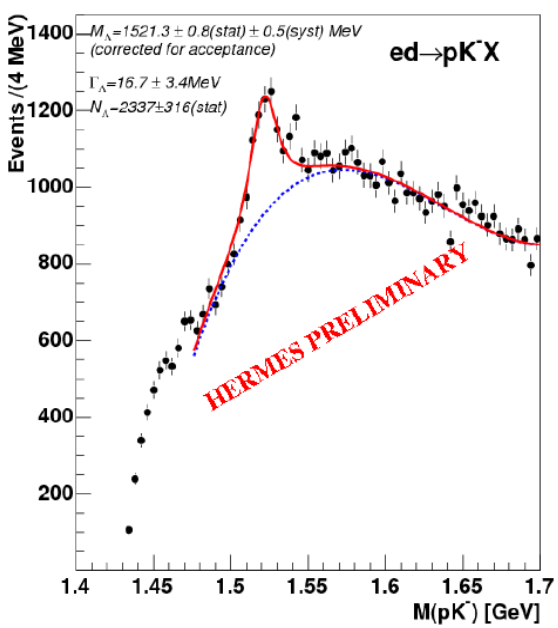


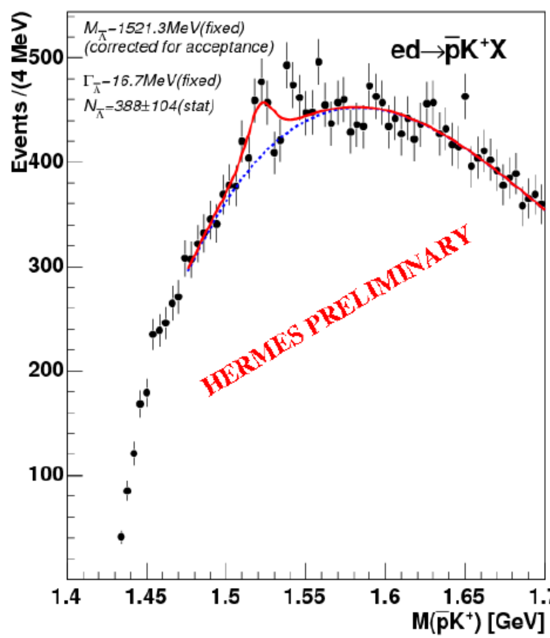


Assumption: Same production mechanism for $\Lambda(1520)$ and Θ^+

- HERMES: evidence Θ^+ seen, $\bar{\Theta}^+$ not (Numbers: $59 \pm 16/3 \pm 6$)
- Also saw $\Lambda(1520)$, how about the $\bar{\Lambda}(1520)$? $\sigma_{\bar{\Lambda}(1520)} =?$ $\sigma_{\Lambda(1520)} =?$

$\Lambda(1520)$ and $\bar{\Lambda}(1520)$ Spectra





Base on the assumption of same production mechanism for $\Lambda(1520)$ and Θ^+, and also assumption of $\frac{N_{\bar{\Theta}^+}}{N_{\Theta^+}} = \frac{N_{\bar{\Lambda}}}{N_{\Lambda}}$, $N_{\bar{\Theta}^+}$ estimated as

1. $N_{\bar{\Theta}^+} = \frac{N_{\bar{\Lambda}}}{N_{\Lambda}} N_{\Theta^+} \approx 10 \pm 4$ should be seen
2. $N_{\bar{\Theta}^+} = 3 \pm 6$ has been seen

(Anti)Proton-Deuteron Cross Sections in DIS

Takahiro Matsumoto

- Light nuclei production is interesting topics in heavy ion collisions

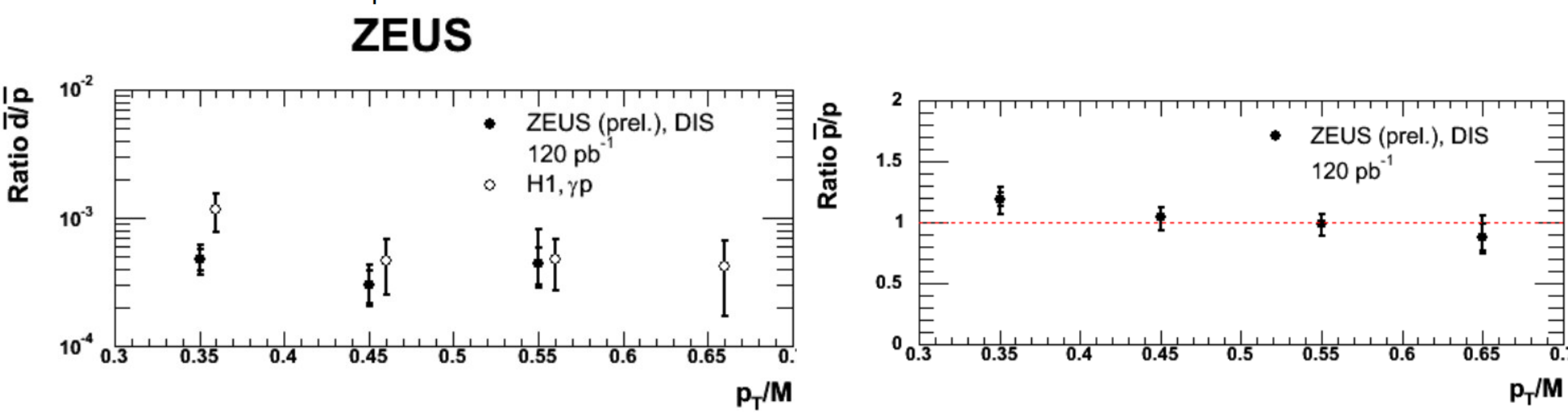
- However, still few measurements in elementary collision

  <u>Some results on antideuteron</u>
  - ARGUS ($e^+e^- \rightarrow \gamma^* \rightarrow q\bar{q}$); < 1.7 x 10^{-5} anti-d/evt
  - OPAL ($e^+e^- \rightarrow Z^0$); < 0.8 x 10^{-5} anti-d/evt
  - ALEPH ($e^+e^- \rightarrow Z^0$); 0.6 x 10^{-5} anti-d/evt; *hep-ex/0604023* *New!*
  - ARGUS ($e^+e^- \rightarrow \Upsilon(1S,2S)$); 6×10^{-5} anti-d/evt, $\bar{d}/\bar{p} \sim 3\times10^{-4}$ (19 anti-d's)
  - H1 (Photoproduction); $\bar{d}/\bar{p} \sim 5\times10^{-4}$ (45 anti-d's)

  Different production mechanism among processes?

  → *We searched for heavy stable-particles in NC DIS (first results)*

- Possible relations between antideuteron and pentaquarks are recently discussed
  - Both are multi-quark states, formed with coalescence model, hard to observe in e^+e^- process

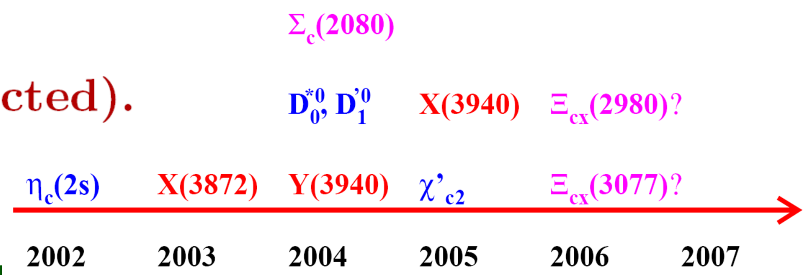


first time measurement of anti deuterons in DIS; no proton-antiproton asymmetry

Two Photon Production in e^+e^-

Alex Kuzmin

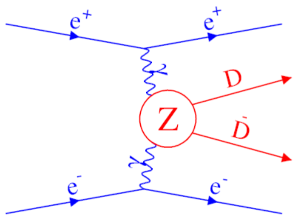
- B-factories are a unique source of new particles.
- Many new states were discovered (many unexpected).



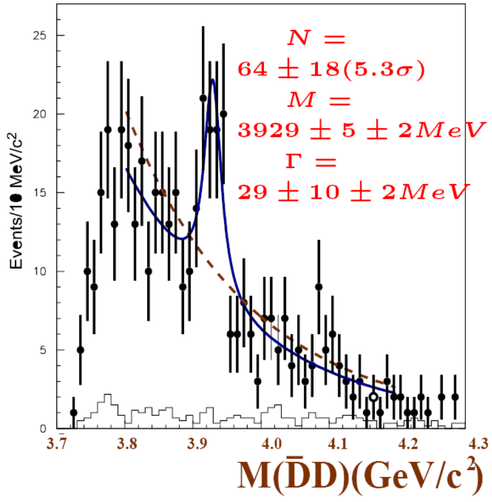
BELLE

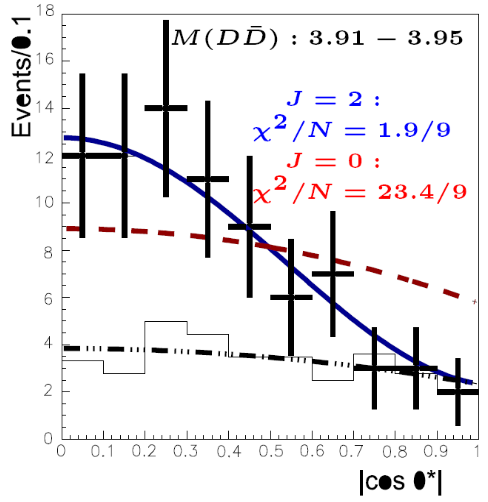
$Z(3930)$ two photon production

$L \approx 395\ fb^{-1}$, PRL 96, 082003 (2006)



- un-tagged $\gamma\gamma \to D\bar{D}$ events
- $D^0 \to K^-\pi^+,\ K^-\pi^+\pi^0,\ K3\pi,\quad D^+ \to K^-\pi^+\pi^+$
- $P_t(D\bar{D}) < 0.05 GeV/c$





$$\Gamma_{\gamma\gamma}(Z)Br(Z \to D\bar{D}) = 0.18 \pm 0.05 \pm 0.03\ keV$$

The observed state is χ'_{c2}

Summary

- new data rolling in:
  - (*allows for*) larger phase space, higher E_t
  - (*and often also*) reduced systematics
  - (*study rarer processes e.g.*) prompt photons, high jet multiplicities
  - (*all this leads to*) improved **precision** for pdfs, α_s
  - (*and even better:*) HERA II, Tevatron Run II still to be fully exploited
- towards improved **understanding** of QCD
  - parton dynamics beyond DGLAP
  - confinement: hadronisation/fragmentation
  - process universality e^+e^-,ep,gammap,pp
- strong contribution of **Hadronic Final States** to many aspects of standard model
- plea to theorists: NNLO and/or robust estimate on higher order uncertainty needed in many analyses!

Thanks to all the speakers of the HFS session and to the organisers!