Light Mesons and Strange Particle Production at HERA

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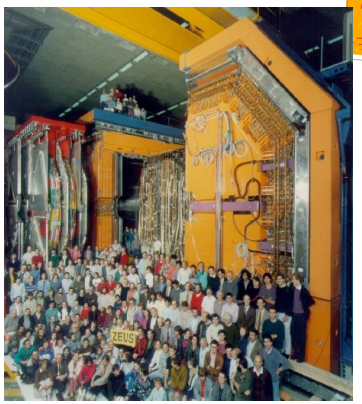
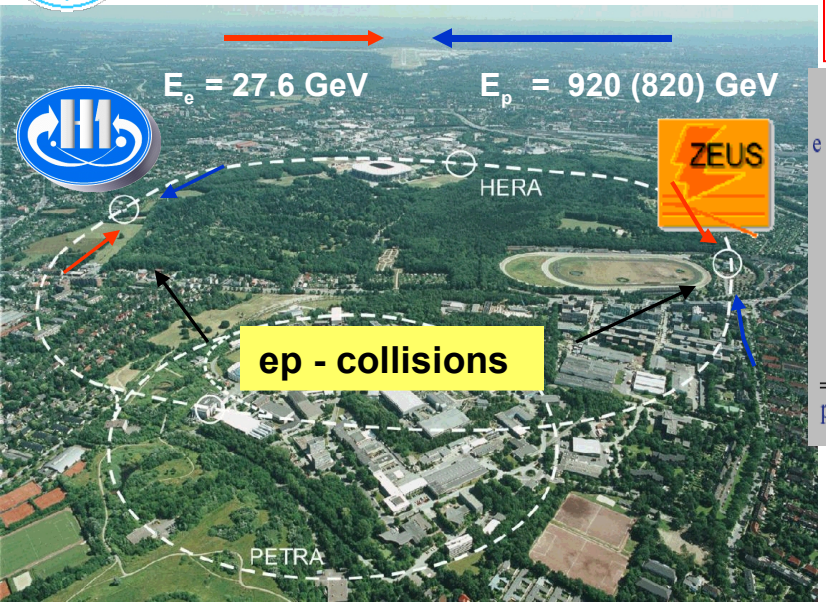
on behalf of the ZEUS and H1 Collaborations

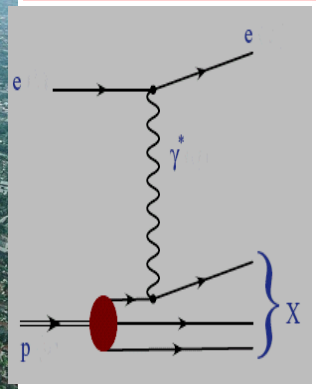
- Inclusive photoproduction of $\rho^0(770)$, $K^{*0}(892)$ and $\phi(1020)$
- Strangeness production in DIS at low and high Q^2
- Scaled momentum distribution for K^0 and Λ particles in DIS
- Summary



HERA - Hamburg



ep collisions: hard and soft processes
→ $\gamma^* p \rightarrow$ hadrons



s : e-p c.m. energy , $\sqrt{s} \approx$ **300 – 318 GeV**
Q^2 : = - q^2 , 4-momentum transfer squared
x : fraction of p momentum carried by quark
y : inelasticity parameter
W : γ-p c.m. energy

γ^* virtuality Q^2:
Q^2 (GeV^2) > 0 deep inelastic scattering (DIS)
Q^2 (GeV^2) ≈ 0 : (quasi) photoproduction

Hadronisation studies : non-perturbative process

Data:

- identified hadrons and resonances
- inclusive multihadron production

H1 and ZEUS experiments:
total integrated luminosity ~ 0.5 fb^{-1}
pro experiment

Theoretical description:

- NLO QCD
- Monte Carlo - (LO) QCD based models:

ARIADNE + JETSET
LEPTO + JETSET

Inclusive photoproduction of ρ^0 (770) , K^{*0} (892), ϕ(1020) mesons at HERA

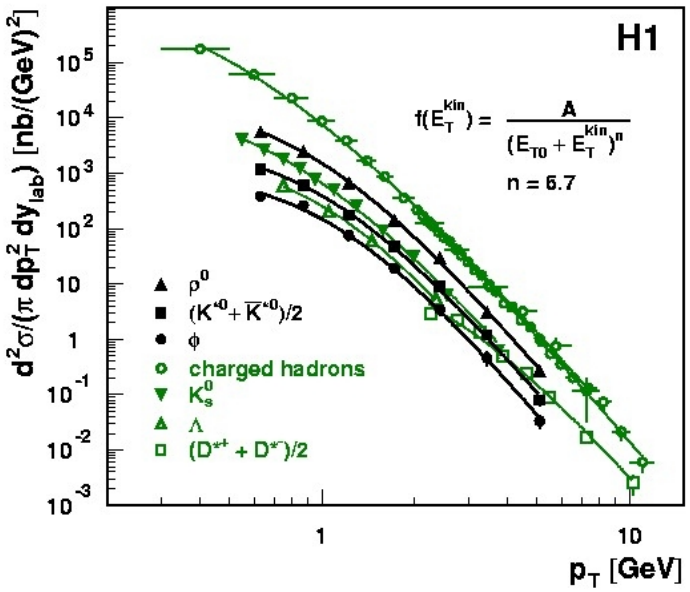
The inclusive differential cross sections as function of transverse momentum can be parametrized as power law distribution:

$$1/\pi\, d^2\sigma^{\gamma p} / dp^2_T dy_{lab} = A / (E_{T0} + E^{kin}_T)^n$$

H1: Phys.Lett. B 673 (2009) 119

More details:
see A. Rostovtsev talk (399)
at this conference
(Thursday 22 July)

Comparison ρ^0 , K^{*0}, ϕ mesons with other paricles:



The measured cross sections are well described by the power law distribution with the same n = 6.7.

Resonances with different masses, lifetimes and strangeness content are produced with about similar average transverse kinetic energy

→ support to thermodynamic picture of hadronic productions.

K^0_S and Λ production at low and high Q^2

Strange hadrons production, particularly baryons, is not well understood. Recent results from H1 and ZEUS extend knowledge on the fragmentation/ hadronisation process for strange particles production.

- H1: K^0_S, Λ, $2 < Q^2 < 100$ GeV^2, HERA I ; Phys. J. C (2009) 61, 185 : Strangeness production at low Q^2 in deep-inelastic ep scattering at HERA
- H1 : K^0_S, $145 < Q^2 < 20000$ GeV^2, HERA II ; Preliminary results, H1-prelim-10-031
- ZEUS : K^0_S, Λ, $10 < Q^2 < 40000$ GeV^2, HERA II; Preliminary results , ZEUS-prel-10-013

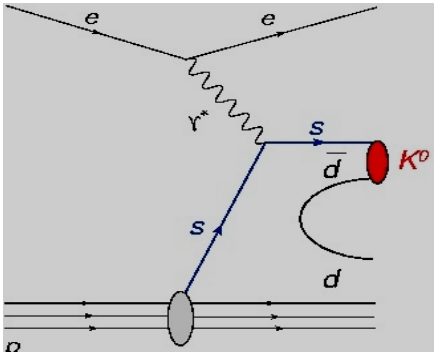
Goals:

LAB and the Breit frame measurements

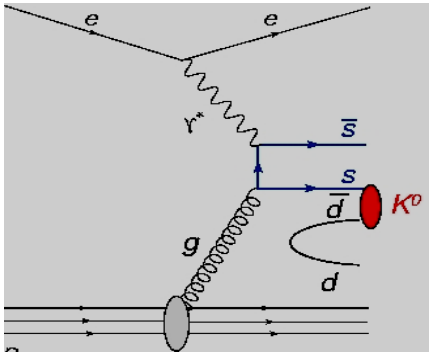
- Test of models of fragmentation/hadronisation
- Test of λ_s universality (strangeness suppression factor)
- Fragmentation properties of K^0_S and Λ from scaled momentum distributions
- Test NLO QCD calculations and universality of factorization theorem

Main mechanisms of strange quark production

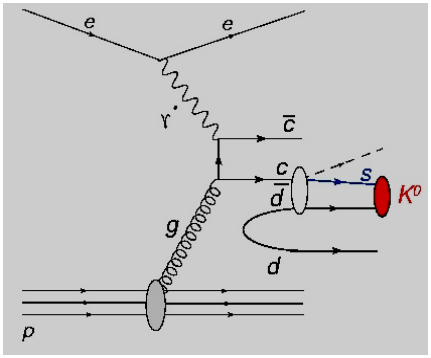
QPM, hard scattering of sea quark



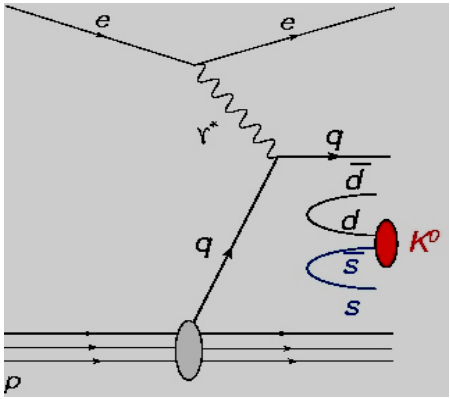
Boson-gluon fusion



Heavy quark decay

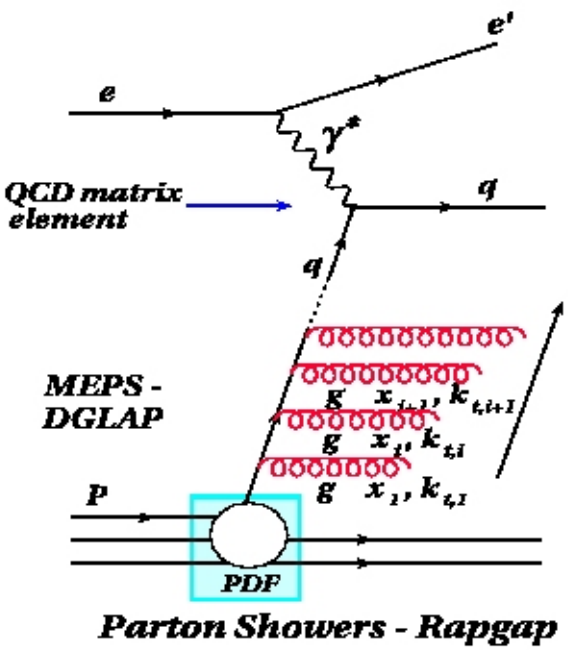


Hadronisation

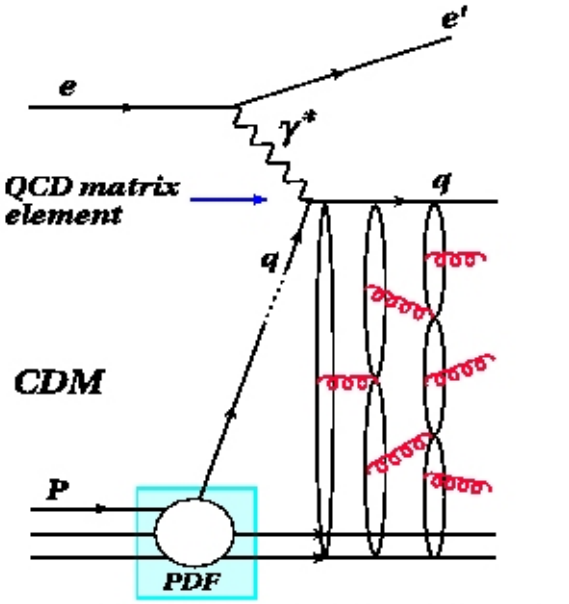


Next step : fragmentation to hadrons – non perturbative process is described by Lund string fragmentation model incorporated in Jetset Monte Calo

Simulation programs



Parton Showers - Rapgap



Color Dipole Model - Django

MEPS

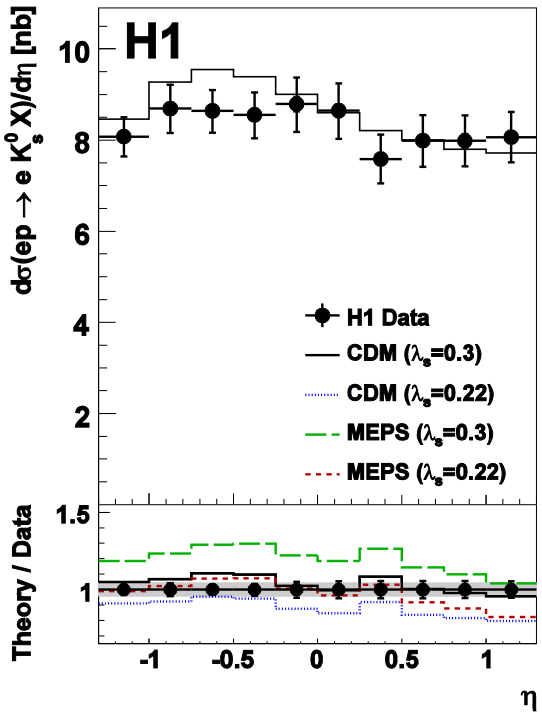
CDM

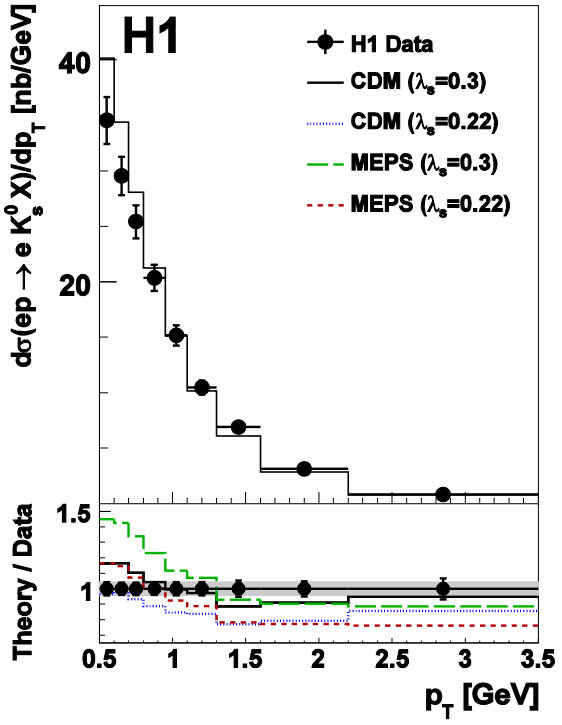
plus Lund colour string model for hadronisation (JETSET)

In comparison of the measuremets with MC predictions:
the values of strangeness suppression factor λ_s (λ_s = P(s)/P(q) ; q = u,d):
0.22, 0.286 and 0.3 were used in MC.
Other JETSET parameters used by ALEPH at LEP were taken as default:
(λ_{qq} = 0.108 : λ_{qq} =P(qq)/P(q), λ_{sq} = 0.690 : λ_{sq} = (P(sq)/P(qq))/λ_s)

K^0_s production at low Q^2

Laboratory frame (LAB): Differential cross sections -η and p_T distributions



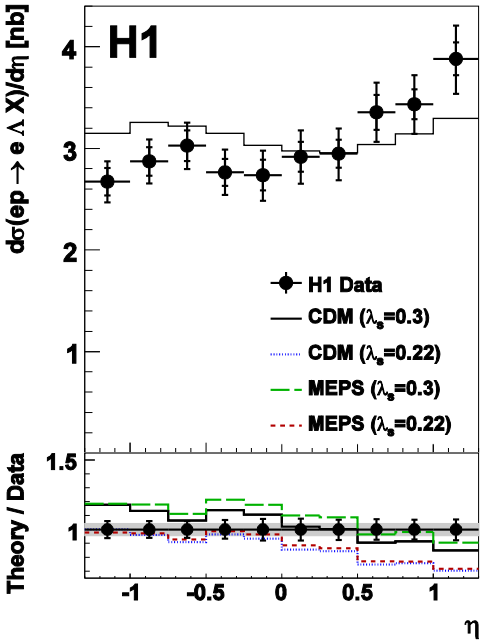


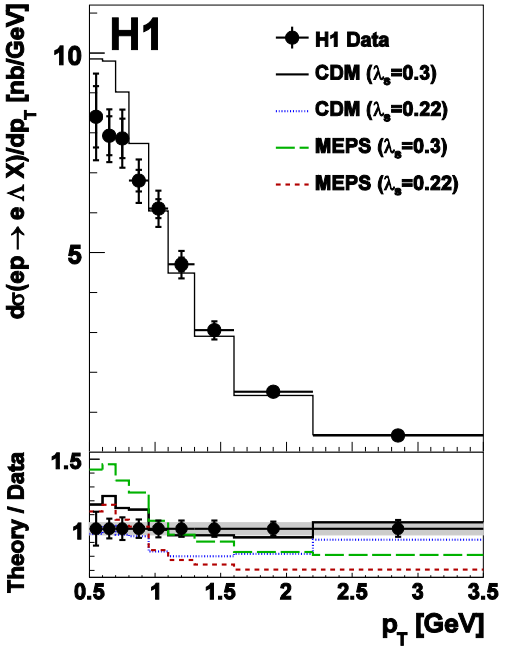
Flat K^0_s production along η

MC predictions cannot describe the p_T distribution in the whole region. CDM with λ_s = 0.3 gives better description of the data but it overestimates the data in small p_T region.

Λ production at low Q^2

LAB: Differential cross sections – η and p_T distributions



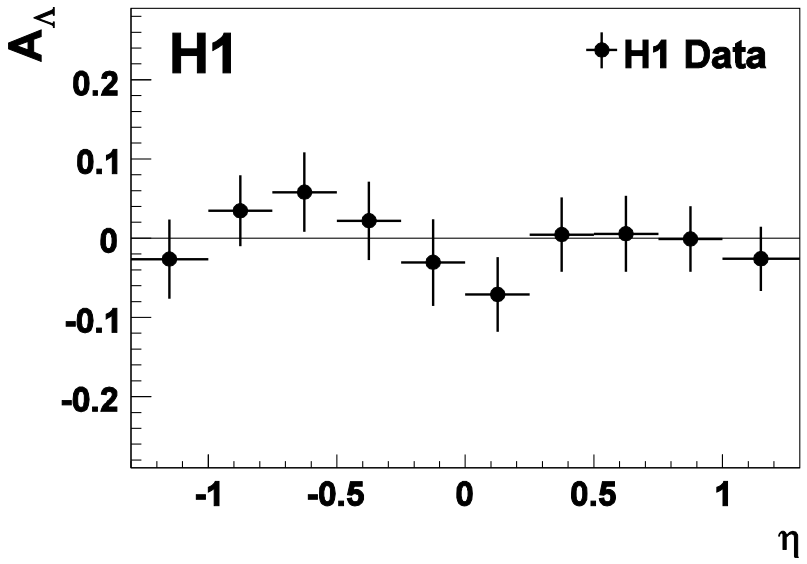


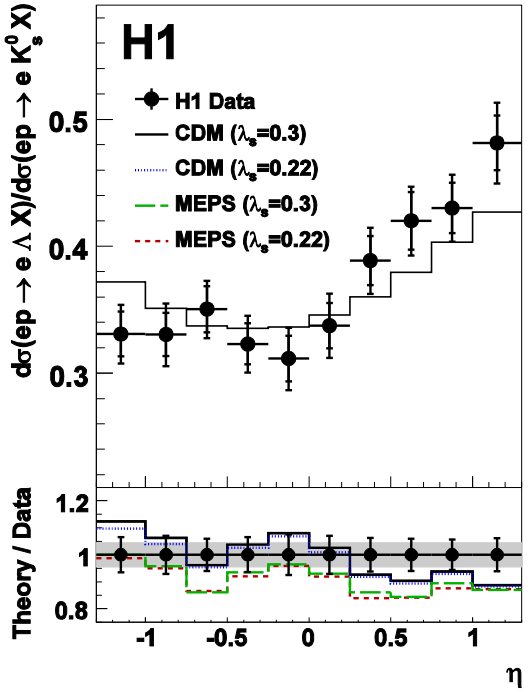
- Both MC predictions with different values of λ_s parameter used: λ_s = 0.22 or 0.3 cannot describe the data
- A rise in a forward direction is observed in the data

Λ p_T distribution is not described by CDM with λ_s = 0.3:
CDM overestimates the data in low p_T region

Low Q^2 : Λ - $\bar{\Lambda}$ asymmetry and ratio Λ / K^0_s

LAB:





Within the experimental uncertainties no baryon antibaryon asymmetry was found
→ No evidence for a transfer of the baryon number from the proton beam to the final state strange particles

- The ratio is almost not sensitive to changes in λ_s
- The CDM and MEPS predictions underestimate the ratio.
- At large, positive η, a rise is observed in the data

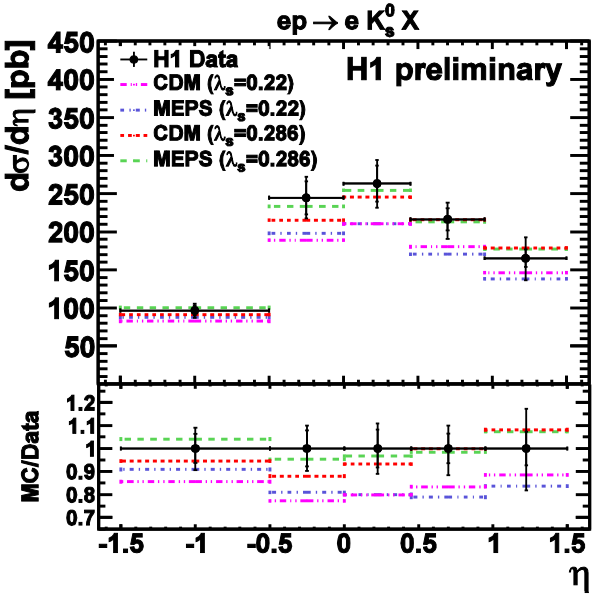
K^0_S production at high Q^2

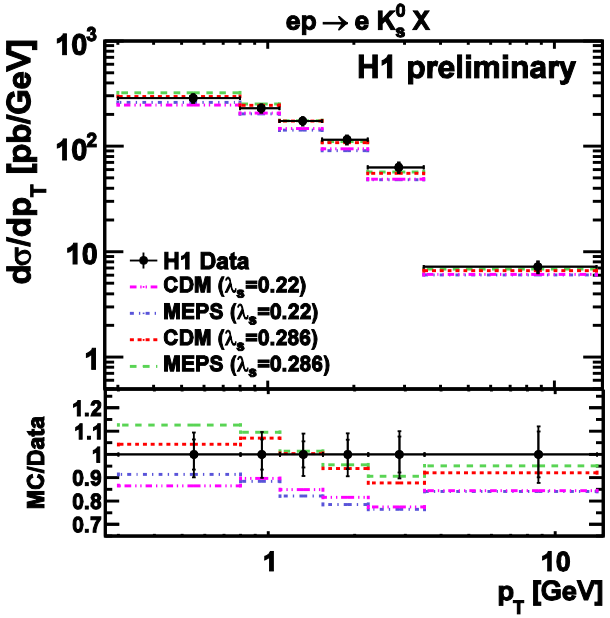
LAB: Differential cross sections - η and p_T distributions

CDM and MEPS predictions with:

$\lambda_S = 0.22$ used in low Q^2 measurements and

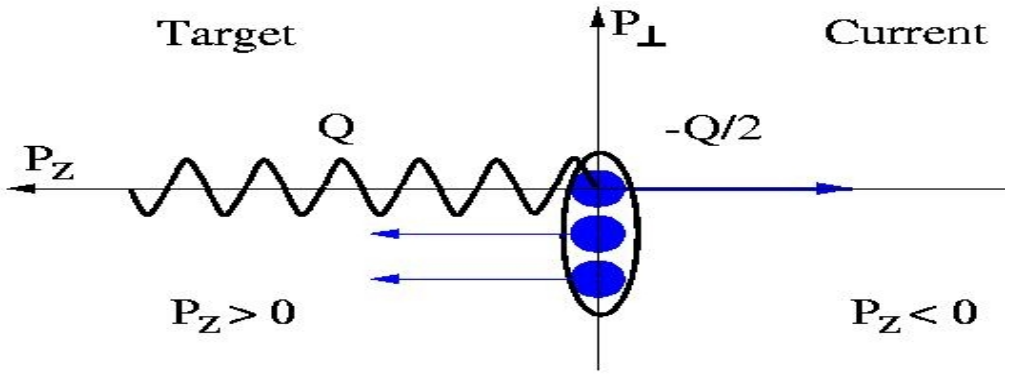
$\lambda_S = 0.286$ - used by ALEPH for e^+e^- LEP data



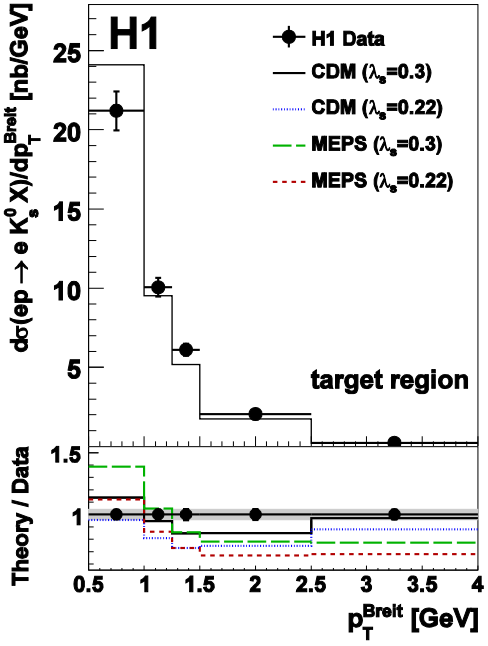


Agreement between data and Monte Carlo (MEPS and CDM) predictions for $\lambda_S = 0.286$

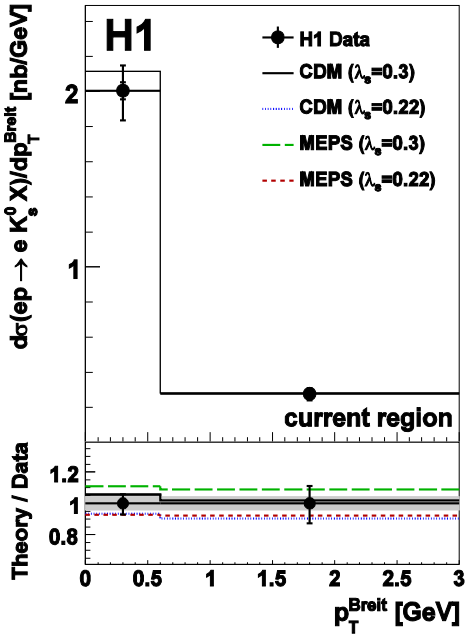
Low Q^2: K^0_s in the Breit frame



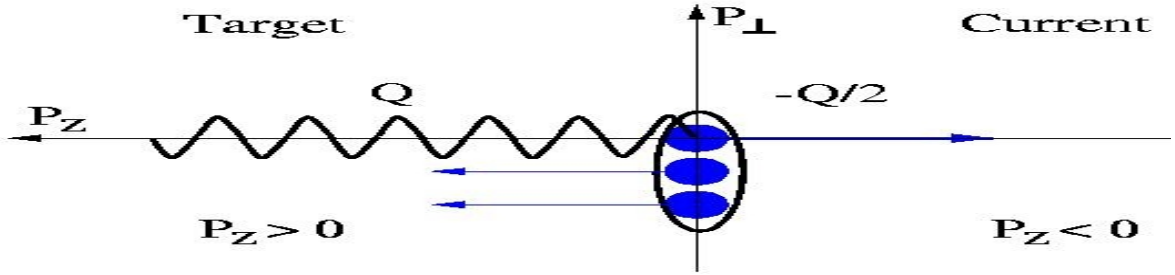
- Separates struck quark (current hemisphere) and proton remnant (target hemisphere)
- Fragmentation studies based on scaled momentum distribution $x_p = 2\, p^{Breit} / Q$
- Current region is analogous to single hemisphere of e^+e^- annihilation

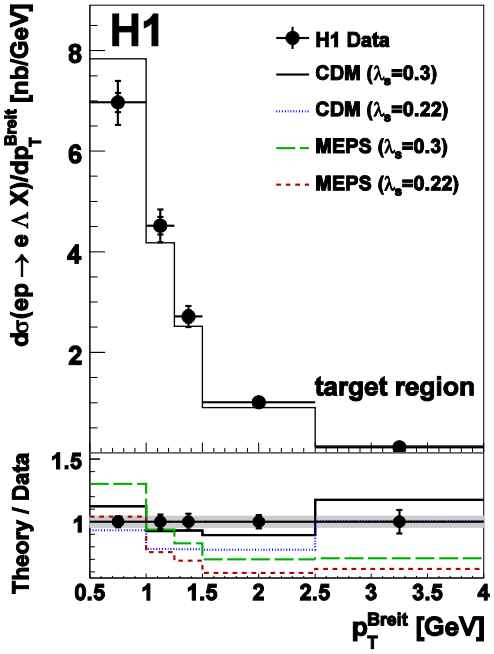


- The measured x- section in target region is ~ one order of magnitude larger than in the current region.
- The p_T distributions are not described by MEPS or CDM
- The current region is less sensitive to λ_s than target region
  → small statistics available – large errors
  → a fraction of strangeness production in perturbative processes achieve ~ 50 % in comparison to ~25 % for target region



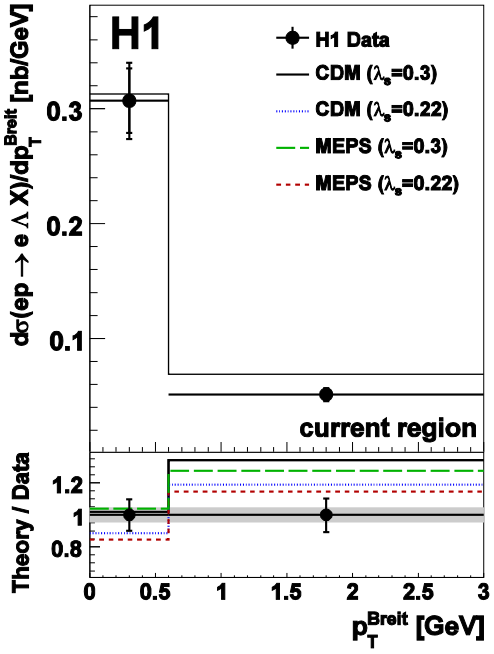
Low Q^2: Λ in the Breit frame





The similar behavior as for K^0_s is observed:

- Cross section in target region is significantly larger than in current region.
- The p_T distributions are not described by MC. They tend to be softer than in data.
- The ~50 % contribution to strangeness production in the current region comes from perturbative processes



Scaled momentum distribution for K^0_S and Λ in DIS

Motivation:

Comparison of K^0_S and Λ production in the current fragmentation region of DIS with NL0 QCD calculations plus fragmentation functions (FF).
FF: fits to ll, lp and pp data; scaling violations in Q^2 are expected.

NLO QCD:

$$d\sigma/dx_p = f(x,Q^2) \otimes \sigma(Q^2) \otimes D(z,Q^2)$$ - universality of factorization theorem

$f(x,Q^2)$ – parton density in proton
$\sigma(Q^2)$ – hard-scattering process – NLO (full matrix elements)
$D(z,Q^2)$ – fragmentation function: probablity for a parton to fragment into a hadron carrying fraction of its momentum

Two different predictions were compared to the data:

AKK + CYCLOPS (**S. Albino, B. A.Kniehl, G. Kramer)** -

→ FFs were obtained from fits to e^+e^- data,
→ hadrons mass effect was included

DSS (D. de Florian, R. Sassot, M. Stratmann)

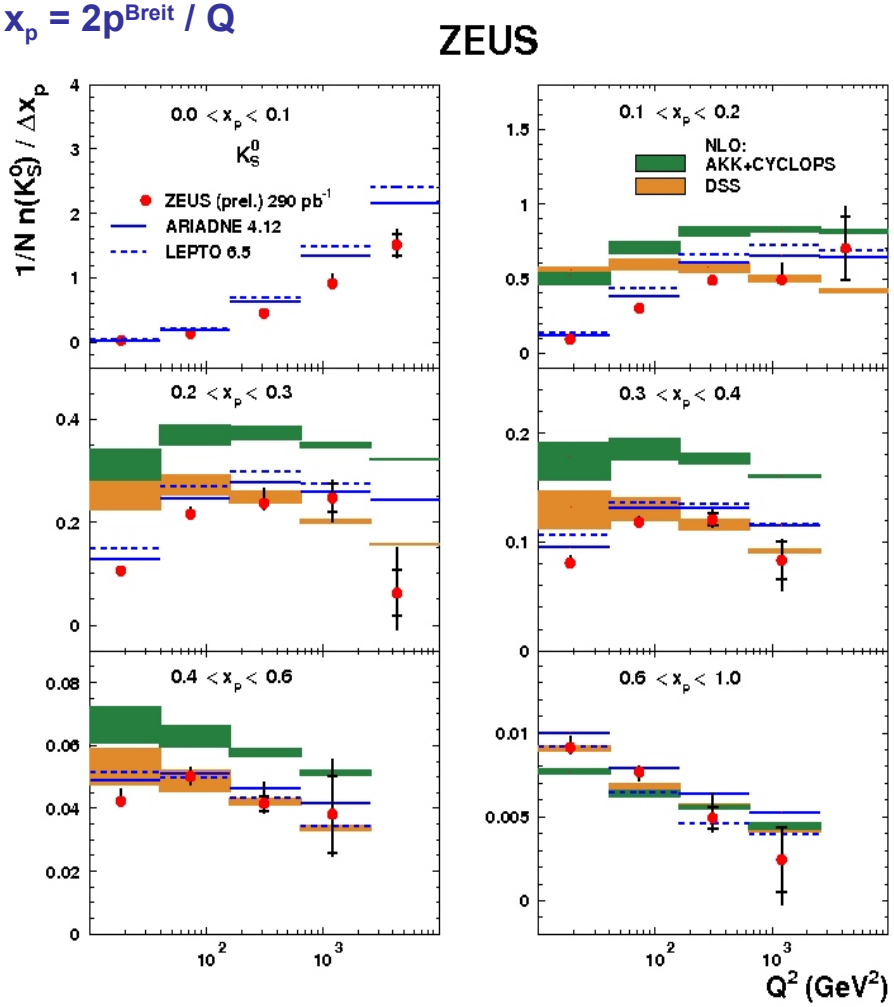
→ FFs were obtained from fits to lp and pp data,
→ hadron mass effect was not included

K^0_S: scaled momentum distributions x_p and QCD predictions

ZEUS : Preliminary results

Current hemisphere of the Breit frame (CBF)

$x_p = 2p^{Breit} / Q$

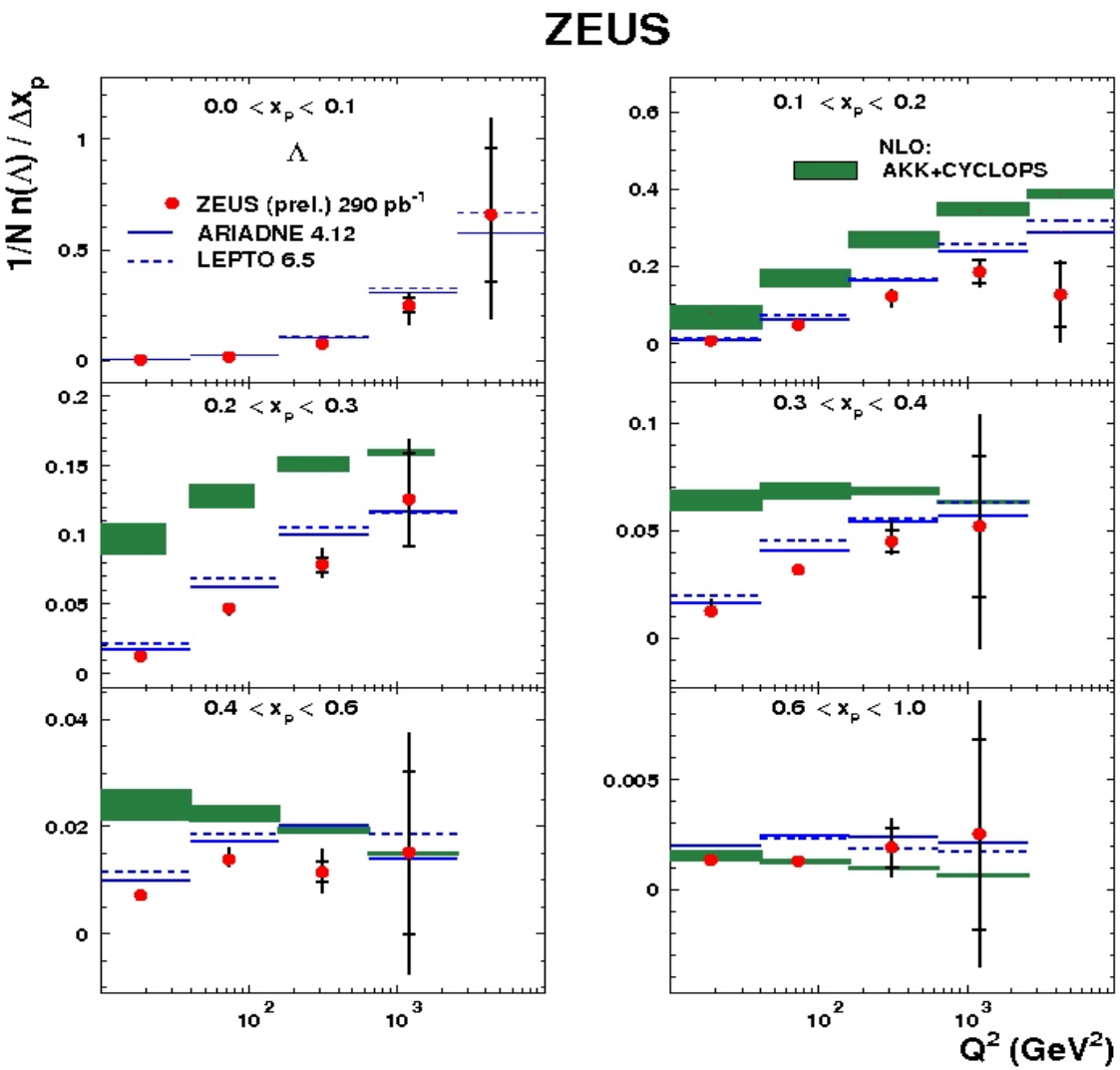


- Scaling violations are observed
- QCD NLO predictions describe the data only in certain regions of the phase space
- LO predictions :
  ARIADNE (CDM) and LEPTO (MEPS)
  describe the data in full phase space
- Hadron mass effect included in AKK+CYCLOP prediction improve agreement with the data for small x_p and Q

Λ measurement and QCD predictions

CBF:

ZEUS : Preliminary results

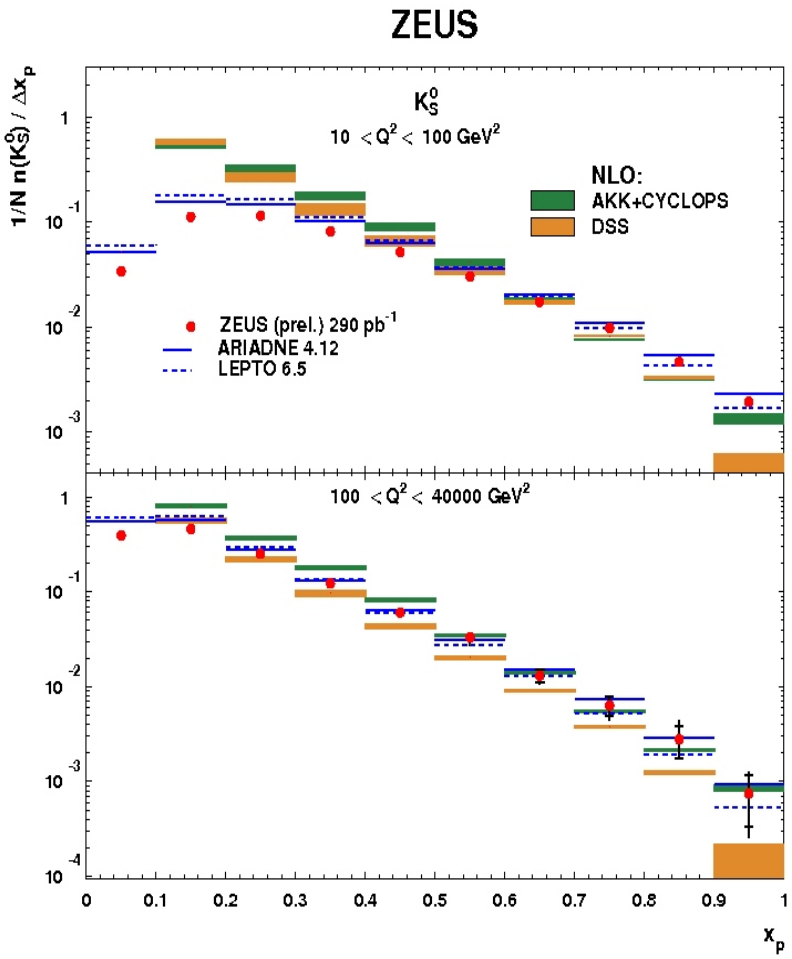


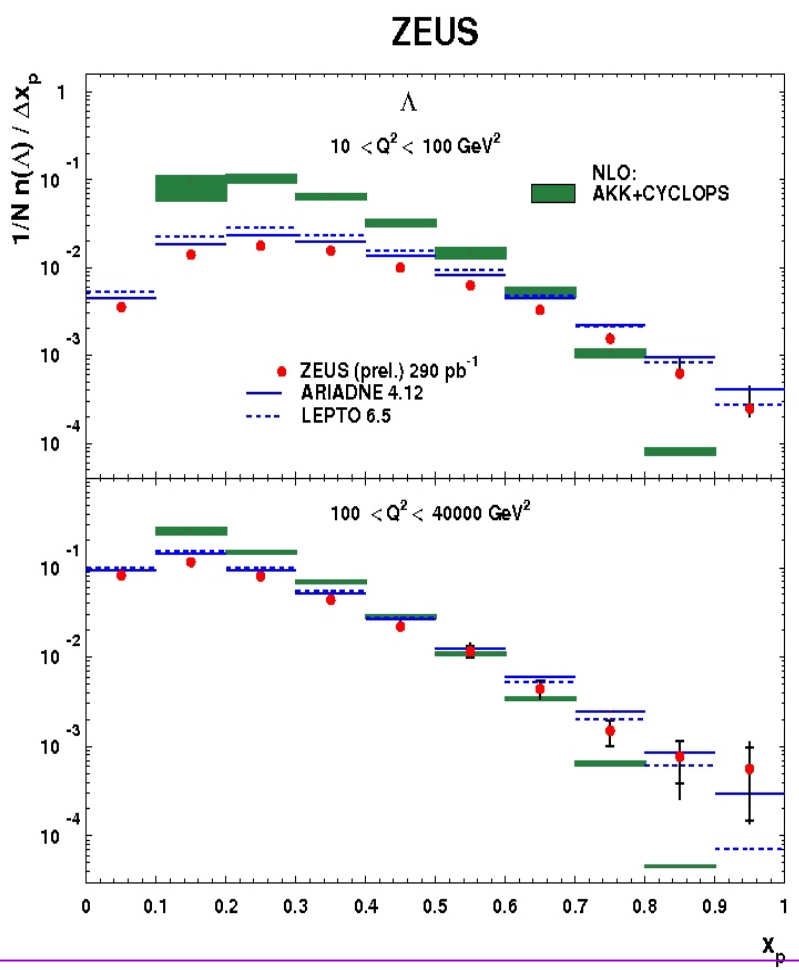
- Scaling violations are observed
- NLO QCD prediction does not descibe the data
- LO predictions : ARIADNE and LEPTO supply much better description of the data in most parts of phase space

Scaled momentum distribution for K^0_S and Λ at low and high Q^2

CBF:

ZEUS : Preliminary results





- NLO QCD predictions describe the data in the high Q^2 region and high x_p
- LO MC (ARIADNE, LEPTO) gives a reasonable description of the data in full phase space

Summary

Inclusive, light mesons and strange particles production give good tests of the hadronisation models:

- A power law distribution describes the differential cross sections for production light mesons as function of transverse momentum.
- The mesons are produced with similar value of the average transverse kinetic energy → this supports a thermodynamic picture of hadronic interactions

- K^0_S and Λ cross sections, as measured in LAB and the Breit frame, cannot be descibed at low Q^2 by CDM or MEPS MC using a single value of strangeness suppression factor λ_s.
  For high Q^2, MC with $\lambda_s = 0.286$, gives good description of the data

- Scaled momentum distributions show scaling violations
- NLO QCD predictions for different fragmentation functions, describe the data only in certain regions of the phase space.
- LO Monte Carlo (ARIADNE, LEPTO) predictions supply better agreement with data in full phase space
- We hope that the results will be useful to constrain the theoretical uncertainties in a description of the Λ hadrons .