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Strangeness production in DIS at HERA

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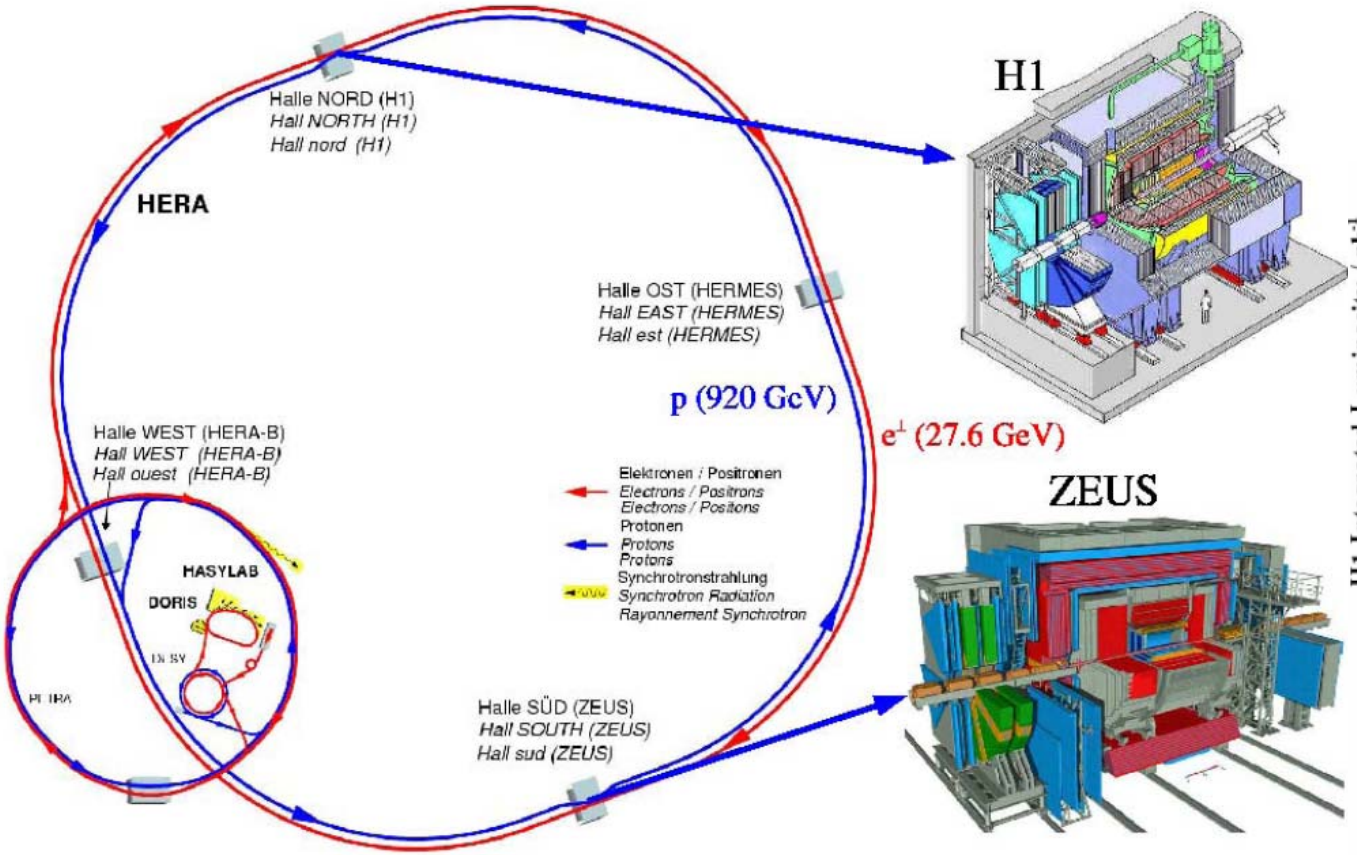
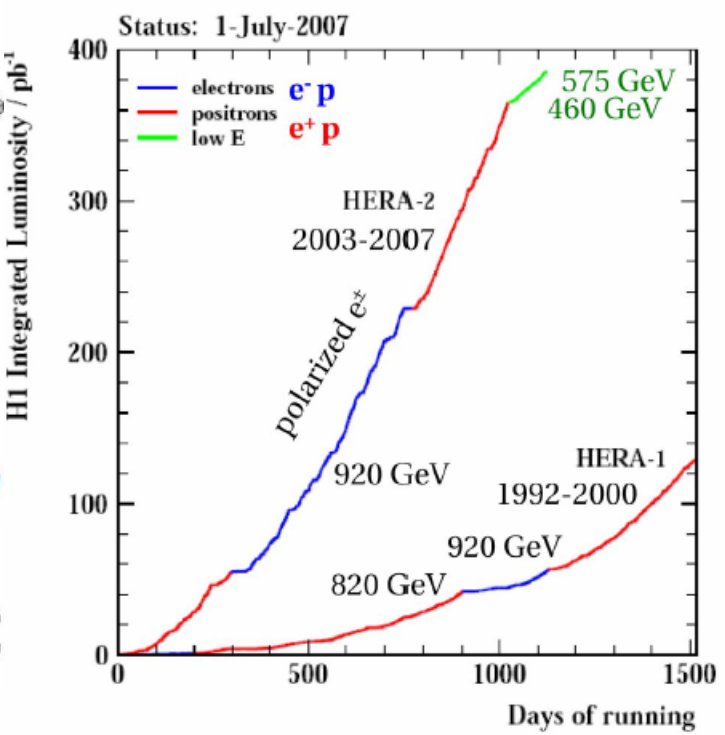
On behalf of the H1 and ZEUS Collaborations

- Introduction
- K^0_s and Λ production cross sections [H1 Coll., H1prelim-13-031, 13-033]
- Λ-$\bar{\Lambda}$ asymmetry
- Scaled momentum distributions of K^0_s and Λ [ZEUS Coll., JHEP 1203:020,2012]

HERA

The world's only electron/positron-proton collider at DESY, Hamburg
E_e = 27.6 GeV E_p = 920 GeV (also 820, 460 and 575 GeV)
(total centre-of-mass energy of collision up to $\sqrt{s} \approx 320$ GeV)

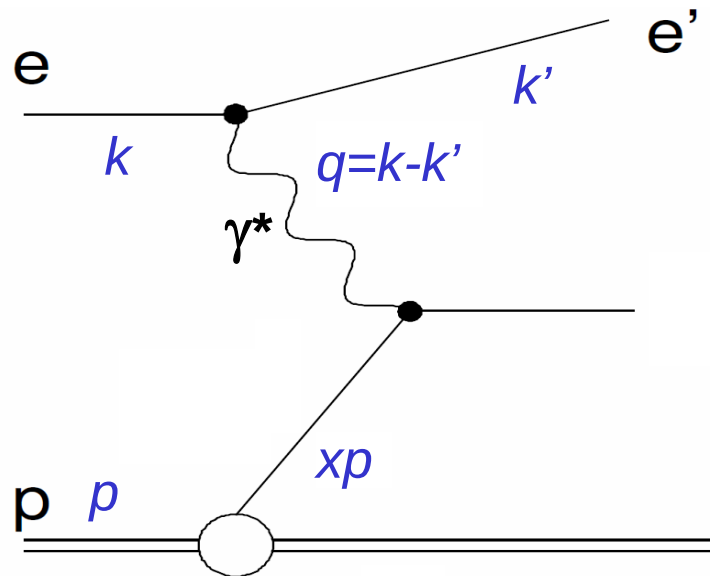




Two collider experiments: H1 and ZEUS

HERA-1: 1992 - 2000
HERA-2: 2003 - 2007
total lumi: 0.5 fb^{-1} per experiment

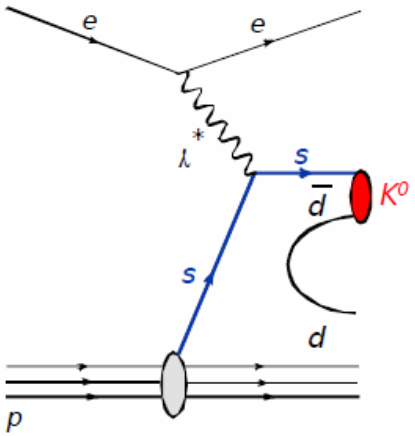
Kinematics of Deep Inelastic Scattering



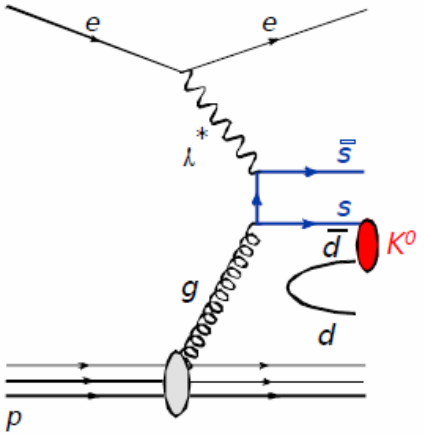
$Q^2=-(k-k')^2$	virtuality of exchanged boson - 'resolving power' of probe
$x = Q^2/2p\cdot q$	Bjorken scaling variable – fraction of proton momentum carried by struck quark
$y = p\cdot q/p\cdot k$	inelasticity variable: $y= Q^2/(s\cdot x)$

Strange hadron production in DIS

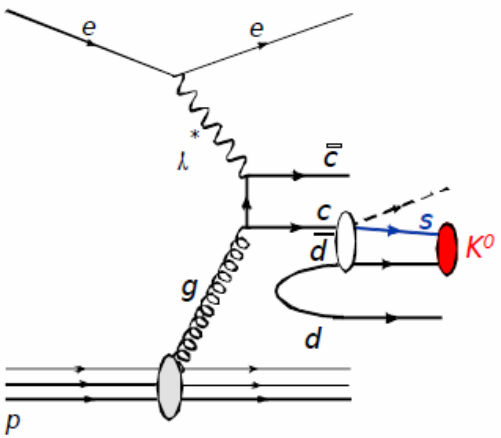
Different mechanisms contribute



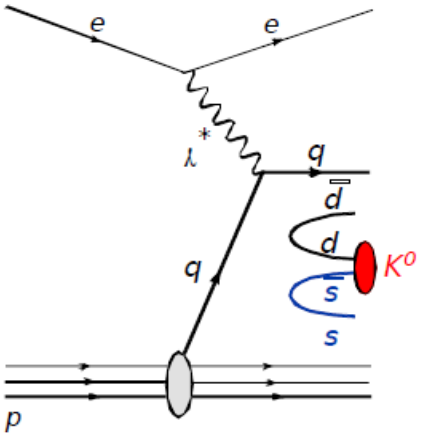
direct production from QPM



boson gluon fusion



heavy quark decays



hadronisation

$$\sigma(ep \to ehX) = \sum_{j,j'=q,\bar{q},g} f_j(x,Q^2) \otimes \hat{\sigma}_{j,j'}(x,Q^2) \otimes F_{j' \to h}(z,Q^2)$$

Proton PDF — Partonic cross-section — Hadronisation, Fragmentation Function

Measurements of strange particles at HERA (K^0_S, Λ) allow us to:

- test the QCD predictions
- investigate suppression of strangeness relative to light flavours
- test of λ_s universality
- test of fragmentation/hadronisation models
- optimise the Monte Carlo parameters
- constrain fragmentation functions

Monte Carlo models and NLO programs

MC: hard partonic processes at the Born level at leading order in α_s

higher order QCD effects: MEPS **(Rapgap, Lepto)**

CDM **(Djangoh)**

JETSET - hadronisation process in the Lund string fragmentation model:

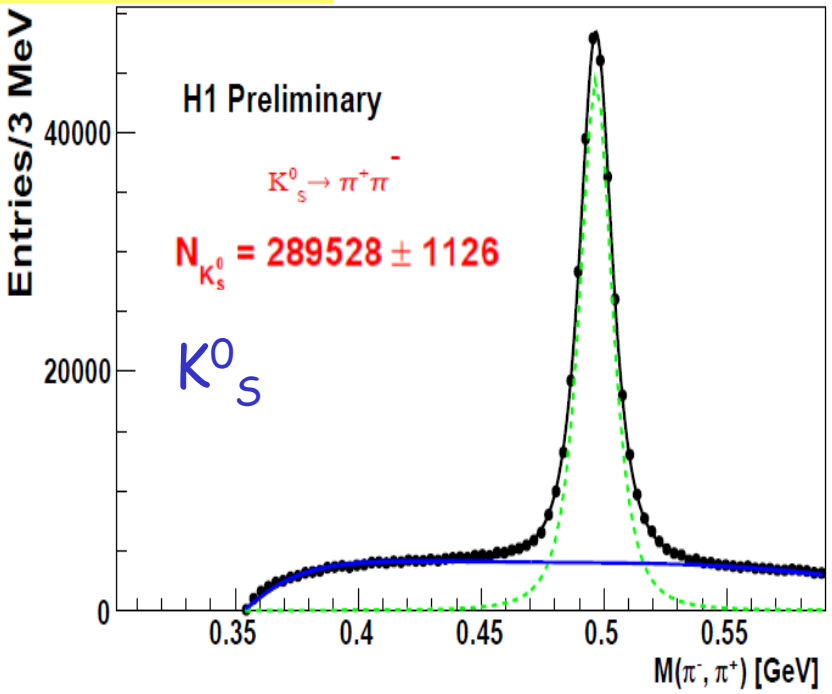
$\lambda_s = 0.286$, $\lambda_{qq} = 0.108$, $\lambda_{sq} = 0.690$ tuned to e^+e^- data (ALEPH)

NLO QCD & FF: **AKK+CYCLOPS**: e+e- (Albino, Kniehl, Kramer)

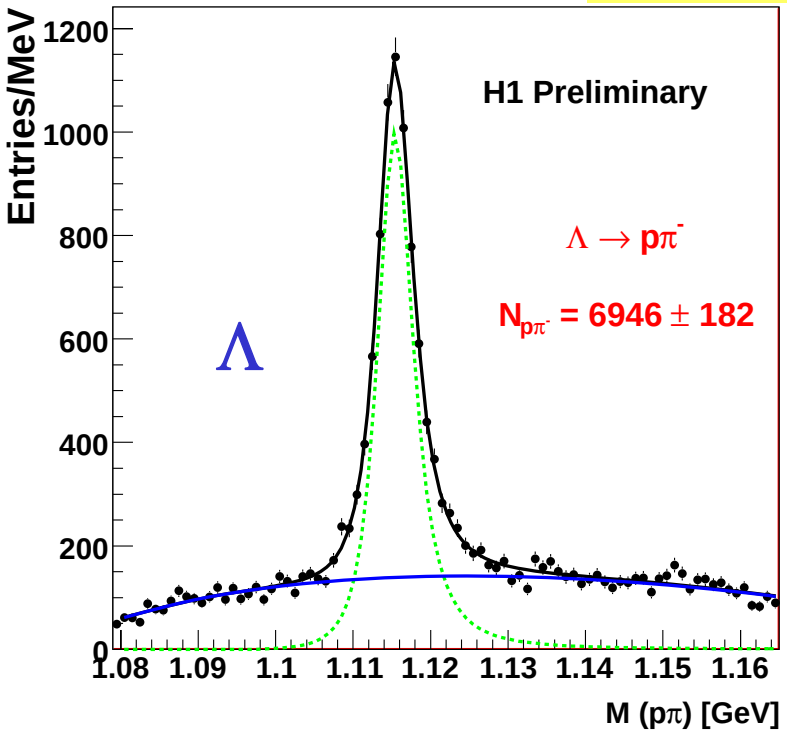
DSS: e+e-, pp, ep (DeFlorian, Sassot, Stratmann)

Visible cross sections for K^0_s and Λ

H1prelim-13-033



H1prelim-13-031



$7 < Q^2 < 100$ GeV^2 , $0.1 < y < 0.6$

$145 < Q^2 < 20000$ GeV^2 , $0.2 < y < 0.6$

$$\sigma_{vis}(ep \to eK^0_S X) = 10.66 \pm 0.04(stat.)^{+0.50}_{-0.53}(sys.)\,nb$$

$$\sigma_{vis}(ep \to e\Lambda X) = 144.7 \pm 4.7(stat.)^{+9.4}_{-8.5}(sys.)\,pb$$

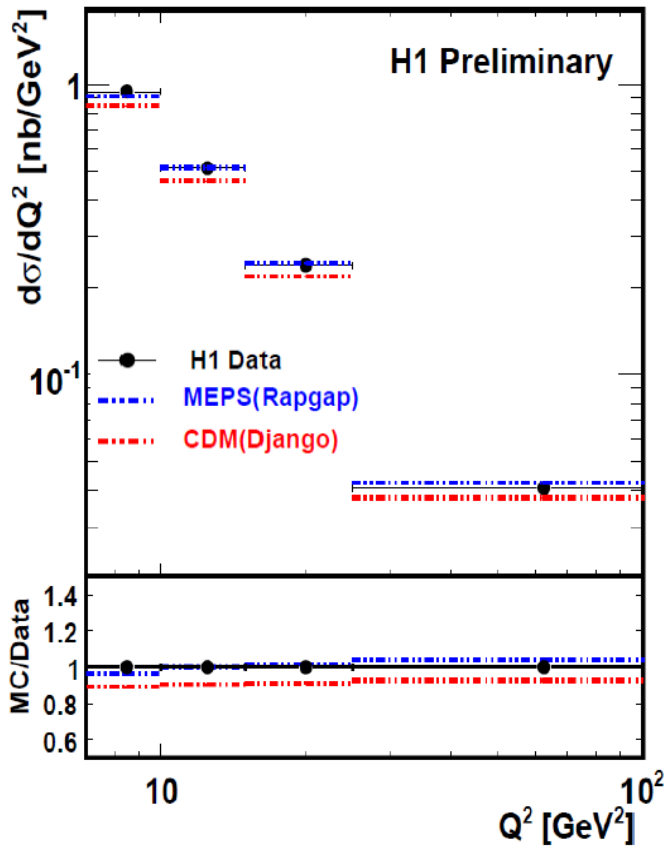
λ_s	0.286
$\sigma_{vis}(ep \to eK^0_s X)$ CDM	9.88 nb
$\sigma_{vis}(ep \to eK^0_s X)$ MEPS	10.93 nb

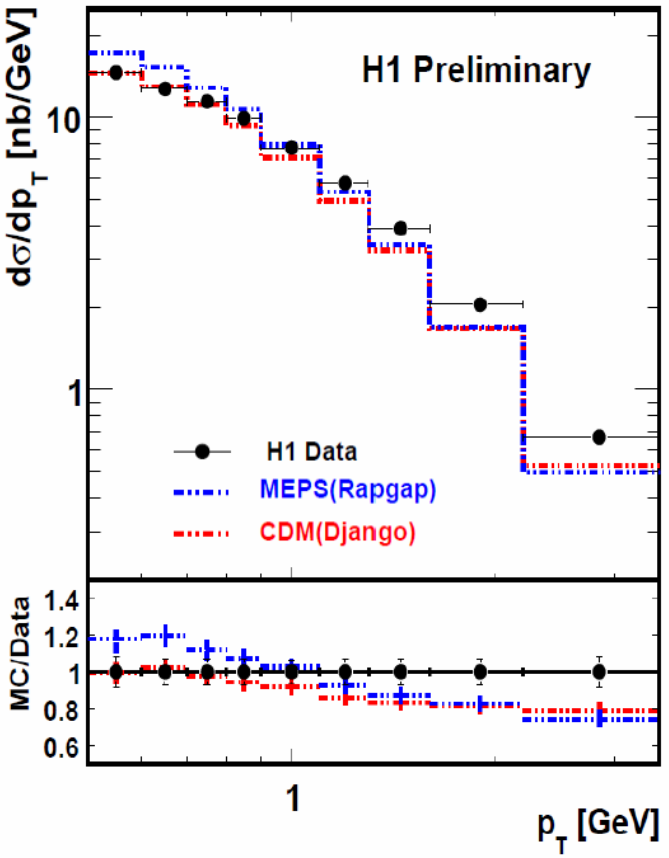
λ_s	0.220	0.286
$\sigma_{vis}(ep \to e\Lambda X)$ CDM	136 pb	161 pb
$\sigma_{vis}(ep \to e\Lambda X)$ MEPS	120 pb	144 pb

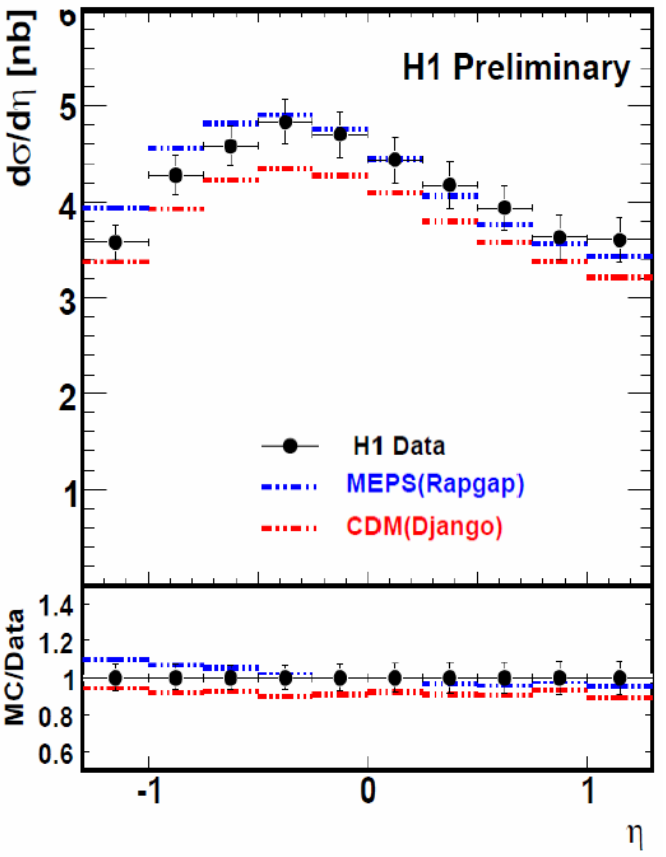
K^0_S differential cross sections

$7 < Q^2 < 100\ GeV^2$, $0.1 < y < 0.6$ (low Q^2 region)

H1prelim-13-033





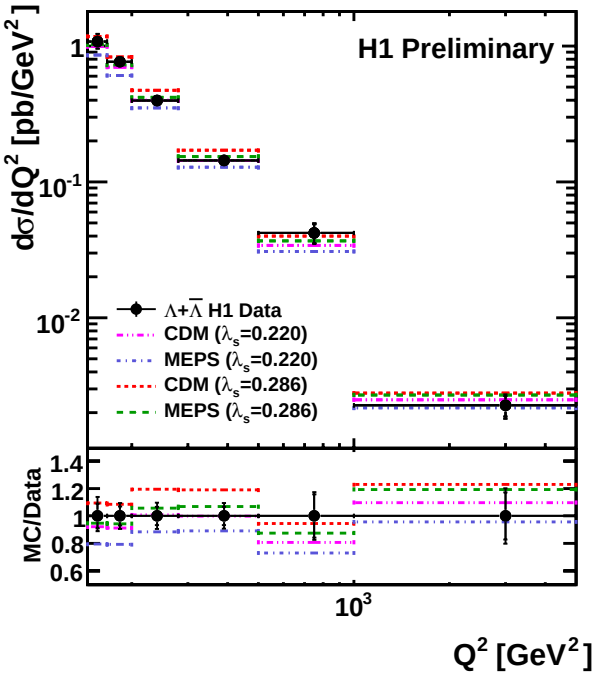


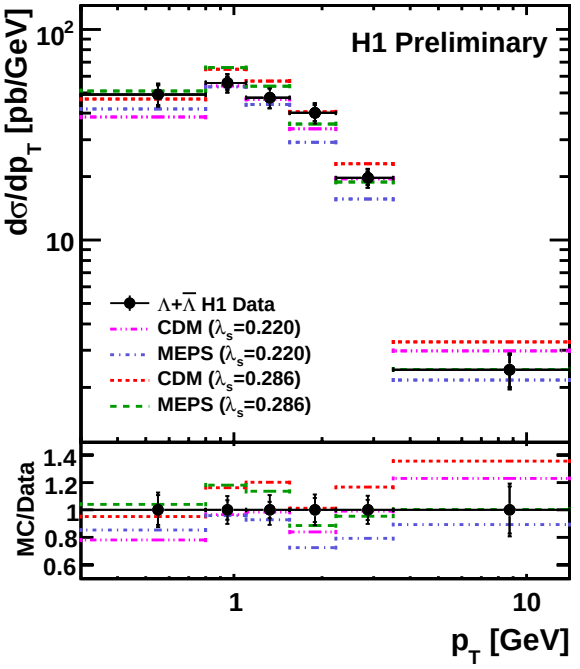
- The cross sections fall rapidly with Q^2 and p_T
- MEPS (Rapgap) describes Q^2 and η
- CDM (Djangoh) is slightly below the data
- Both models fail to describe the p_T dependence

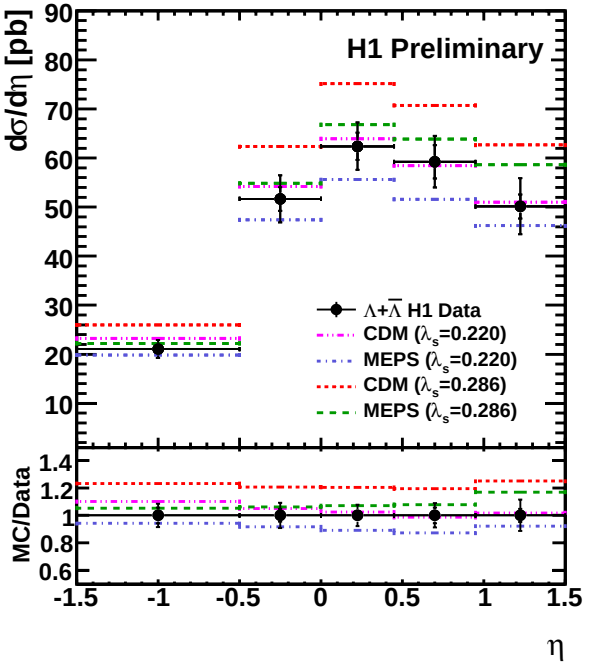
Λ differential measurements

145< Q^2< 20000 GeV^2 , 0.2 < y < 0.6 (high Q^2 region)

H1prelim-13-031





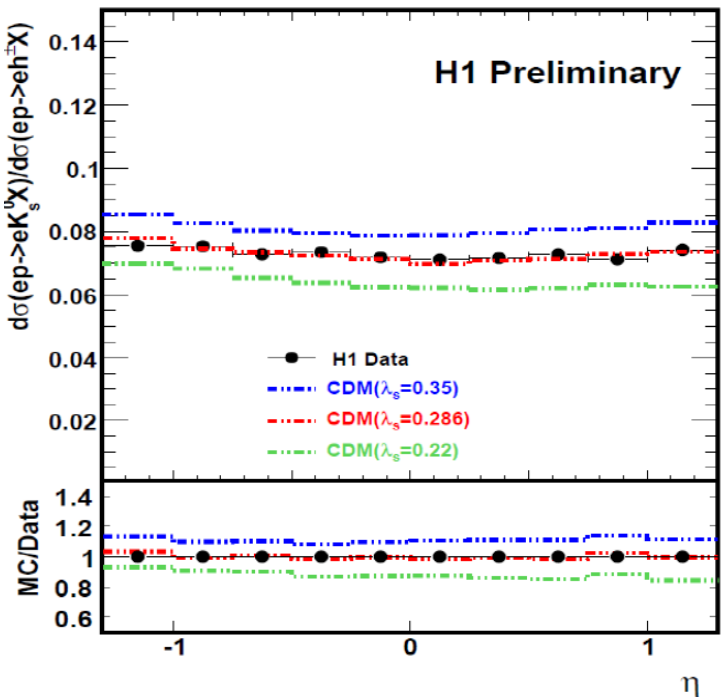


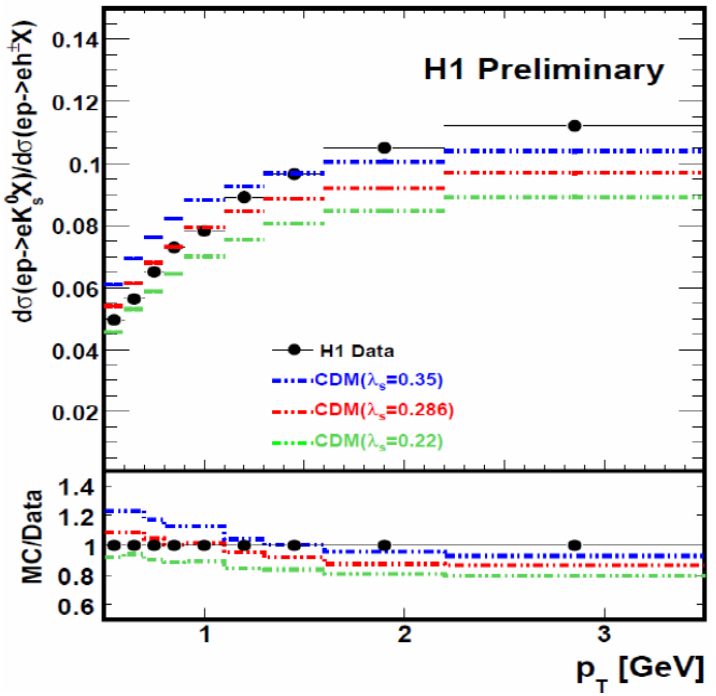
- The cross sections fall rapidly with Q^2 and p_T
- MC models follow the general behavior of data
- Best description is obtained for MEPS with λ_s= 0.220

Ratio of visible cross sections for K^0_s to charged partcles

H1prelim-13-033

$$R = \frac{\sigma_{vis}(ep \to eK^0_s X)}{\sigma_{vis}(ep \to eh^{\pm} X)} = 0.0721 \pm 0.0003\,(stat.)^{+0.0019}_{-0.0024}\,(sys.)$$





$7<Q^2<100$ GeV2
$0.1<y<0.6$

- best description for CDM is obtained for $\lambda_s = 0.286$
- p_T shape of the ratio is not described
- large sensitivity on λ_s

λ_s	0.220	0.286	0.350
CDM	0.064	0.073	0.081

Raito of Λ production to DIS cross section

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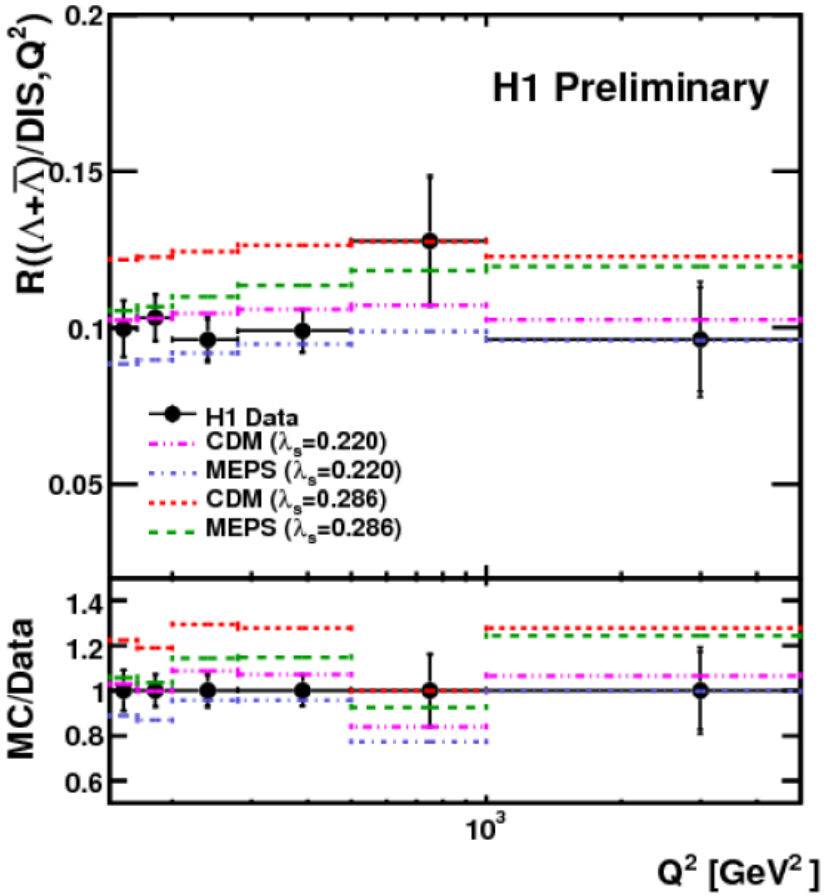
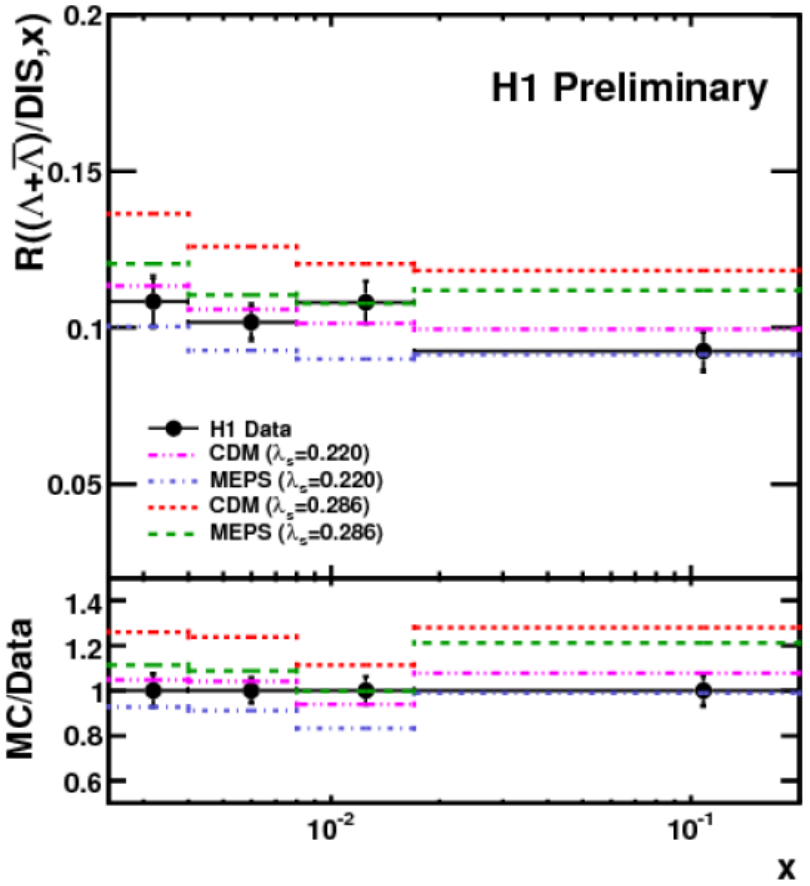




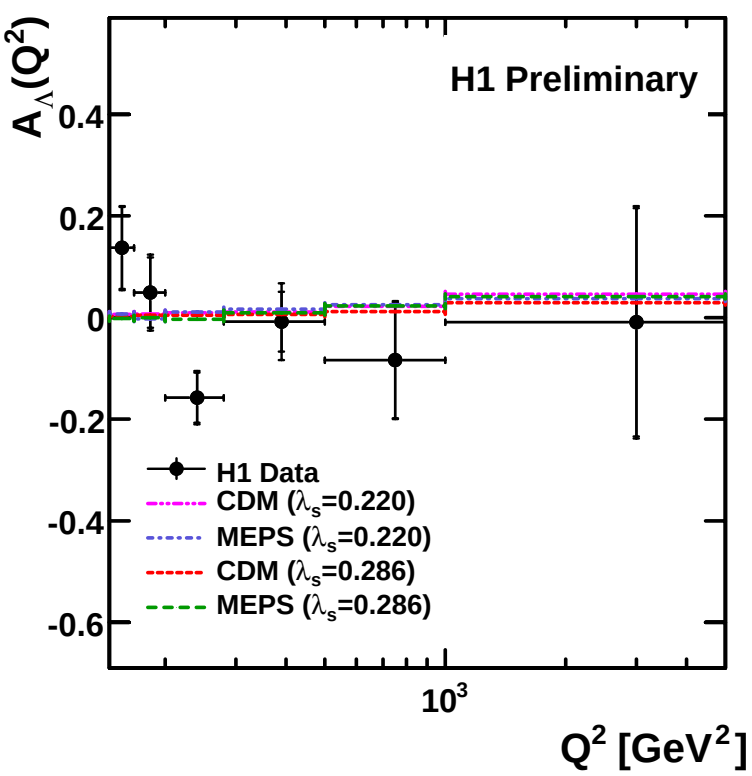
Best description is obtained by CDM (Djangoh) for λ_s= 0.220

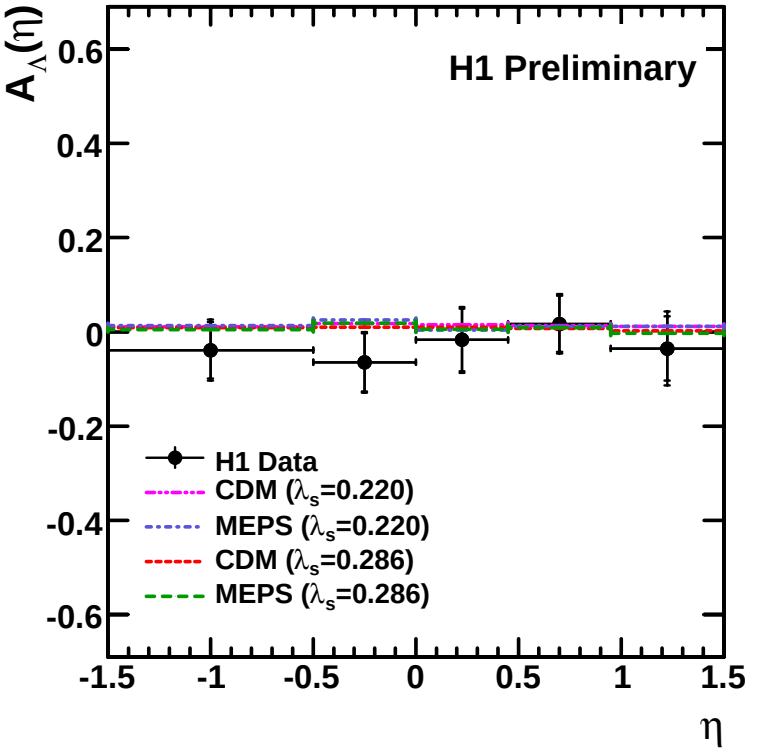
$\Lambda-\bar{\Lambda}$ asymmetry

$145 < Q^2 < 20000\ GeV^2$, $0.2 < y < 0.6$

H1prelim-13-031

$$A_\Lambda = \frac{\sigma_{vis}(ep \to e\Lambda X) - \sigma_{vis}(ep \to e\bar{\Lambda} X)}{\sigma_{vis}(ep \to e\Lambda X) + \sigma_{vis}(ep \to e\bar{\Lambda} X)} = 0.002 \pm 0.022(stat.) \pm 0.018(sys.)$$





Data do not show any evidence for a non-vanishing $\Lambda-\bar{\Lambda}$ asymmetry in the phase space region investigated

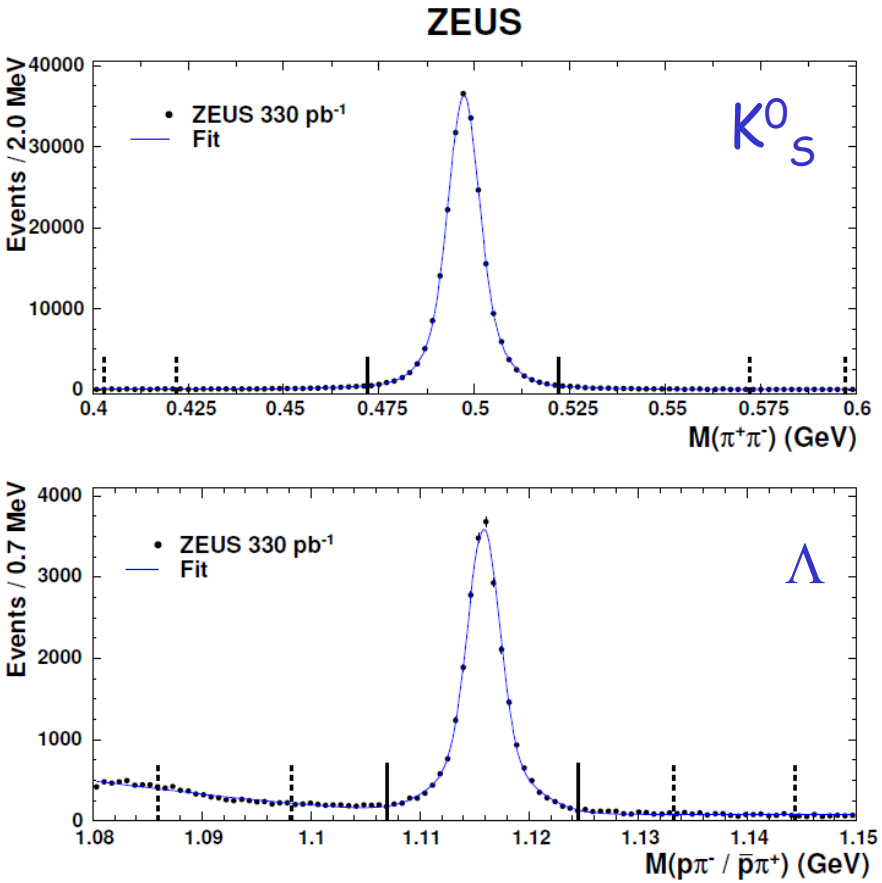
K^0_S and Λ scaled momentum spectra in DIS

Fragmenation Functions for strange hadrons are poorly constrained

Strange hadron production in ep provides constrains of quark, antiquark and gluon contributions to the FFs

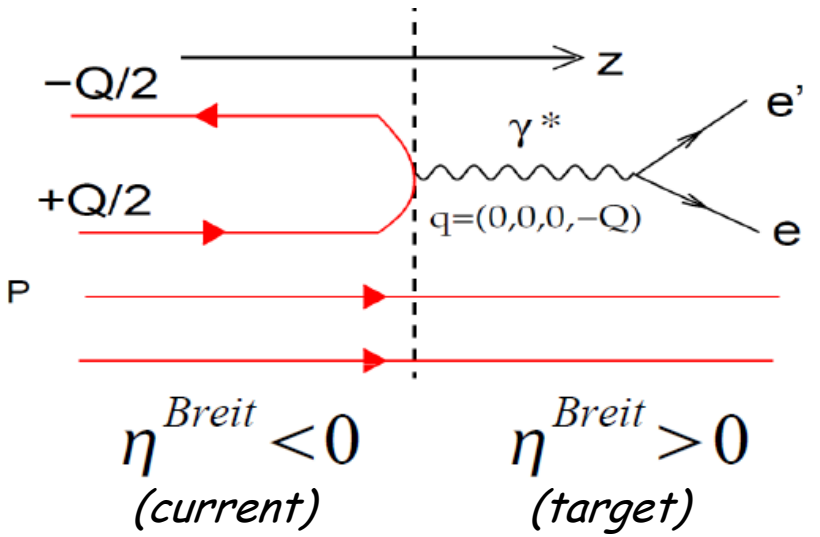
➔ new HERA data may provide additional constrains

$10<Q^2<40.000\ GeV^2$, $10^{-3}<x<0.75$



Measurements done in the current region of Breit frame

Scaled momentum: $x_p = \frac{2\,p^{Breit}}{\sqrt{Q^2}}$



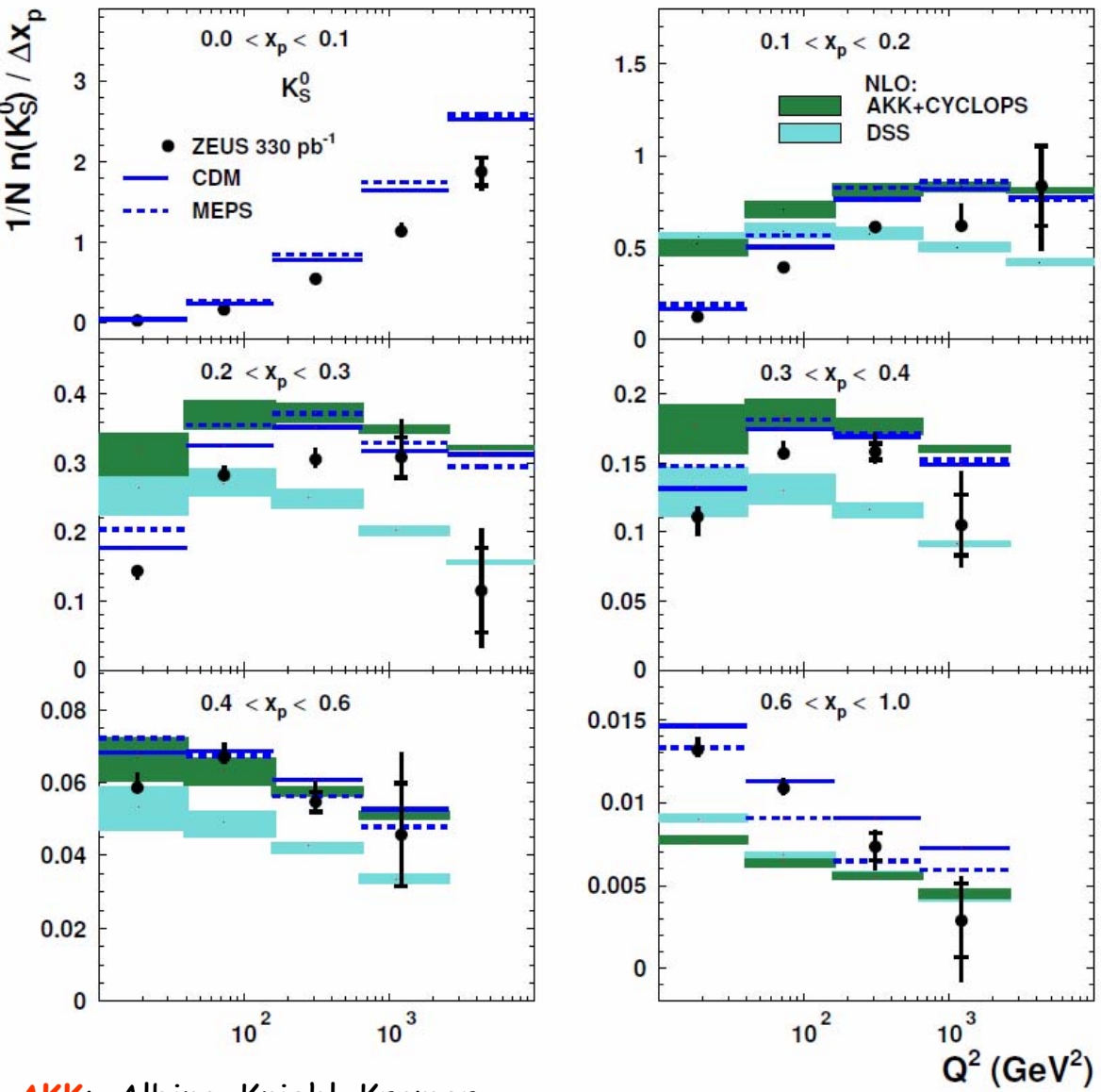
JHEP 1203:020,2012

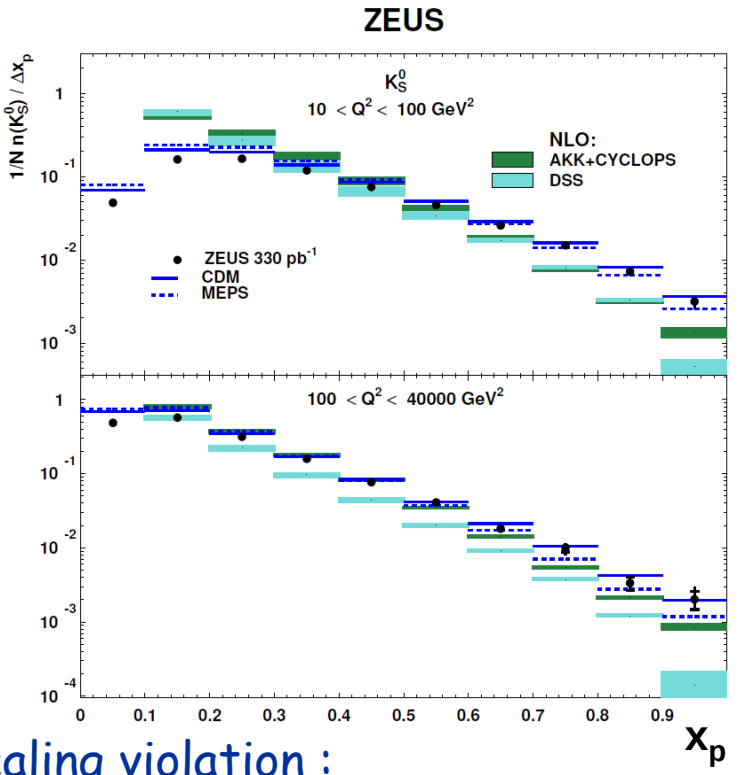
Q^2 and x_p distribution: K^0_s

JHEP 1203:020,2012

ZEUS

$10 < Q^2 < 40000\ GeV^2$
$0.001 < x < 0.75$





- Scaling violation :
larger Q^2 → more soft gluons emitted
- MC - reasonable shape description
- NLO QCD+FF predictions fail to describe the data.
DSS is better at medium x_p and low Q^2, while AKK at high Q^2
- similar conclusions for Λ

AKK: Albino, Kniehl, Kramer
DSS: DeFlorian, Sassot, Stratmann

x_p distribution: comparison K^0_S and Λ to inclusive data

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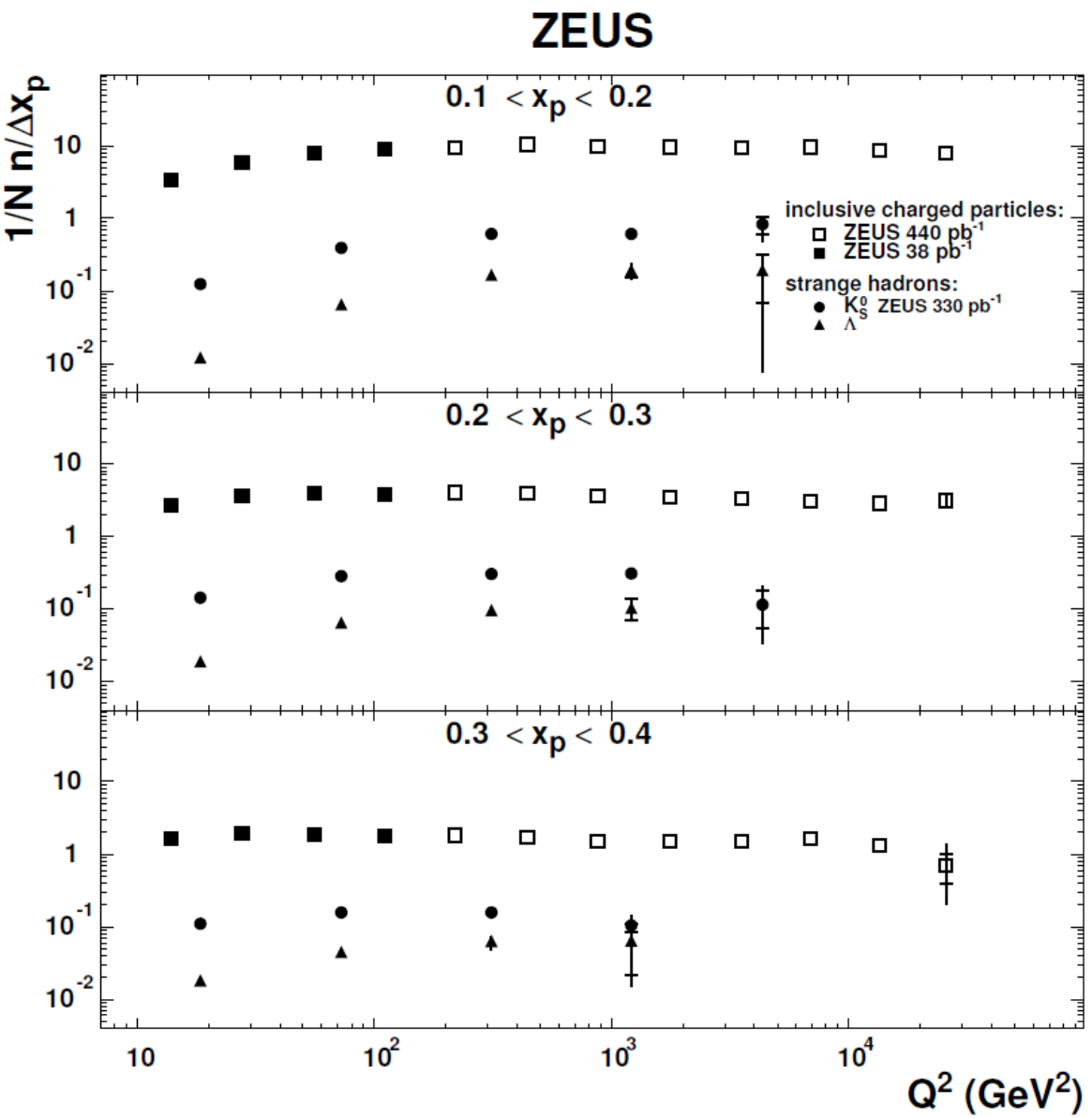


- Inclusive charged-particle and neutral-strange-hadron data show a plateau for $Q^2 > 100$ GeV^2
- At low Q^2 (and low x_p) mass effects visible

Conclusions

K^0_S production:

- MEPS(Rapgap) - reasonable description of the data in Q^2, η but softer p_T spectrum
- CDM(Django) - reasonable in shape, but below the data

- $K^0_s/h^{\pm}$ ratio shows large sensitivity to value of λ_s

MEPS(Rapgap) - larger $K^0_s/h^{\pm}$ yields for $\lambda_s = 0.286$ then measured
- good description for large p_T

CDM(Django) - good description in $K^0_s/h^{\pm}$ yield for $\lambda_s = 0.286$
- good description at small p_T

Λ production:

- The measured visible cross section at high Q^2 is described best by CDM using $\lambda_s = 0.220$ and MEPS using $\lambda_s = 0.286$
- $(\Lambda - \bar{\Lambda})$ asymmetry is found to be consistent with zero

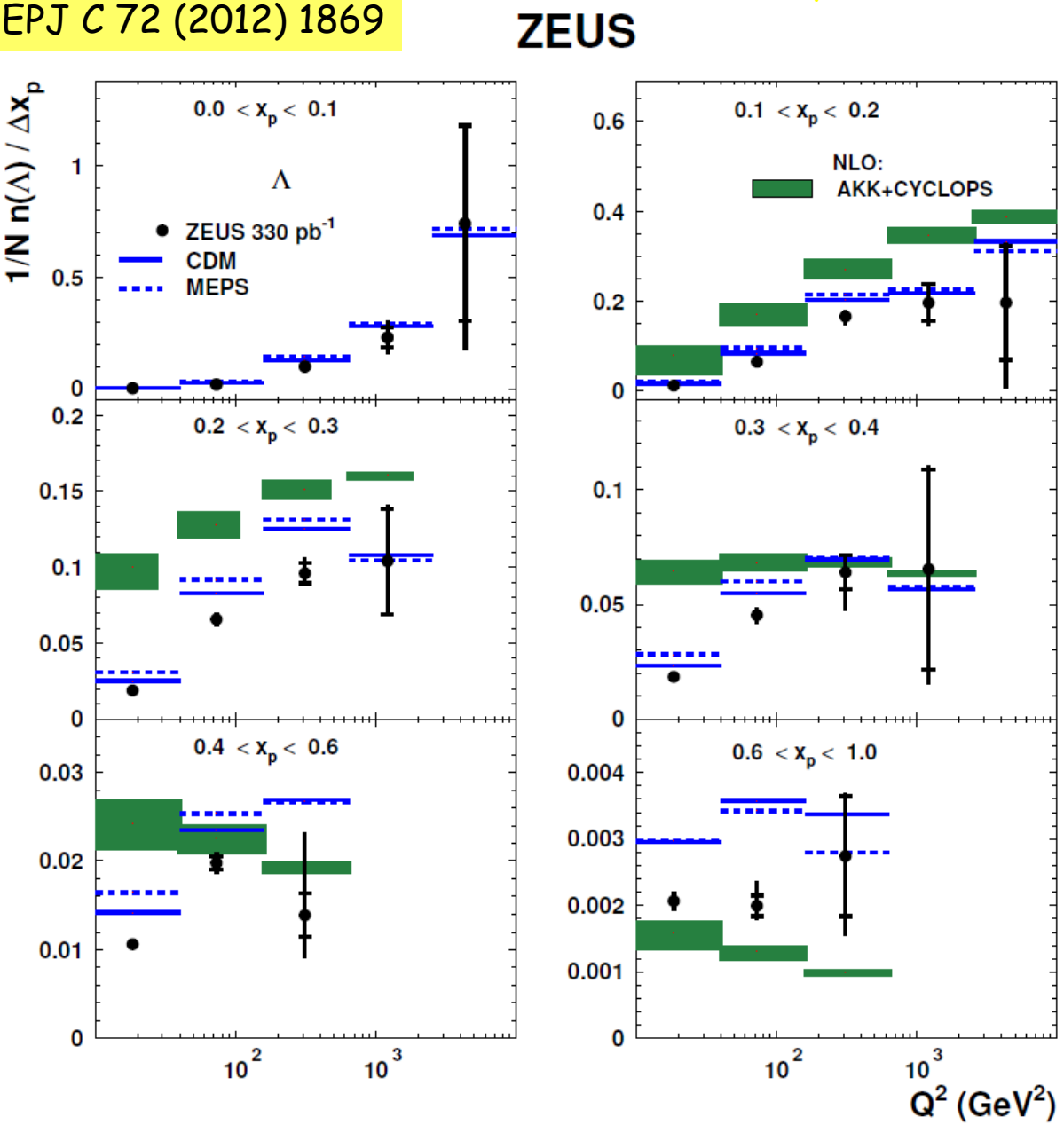
Scaled momentum distribution of K^0_S and Λ:

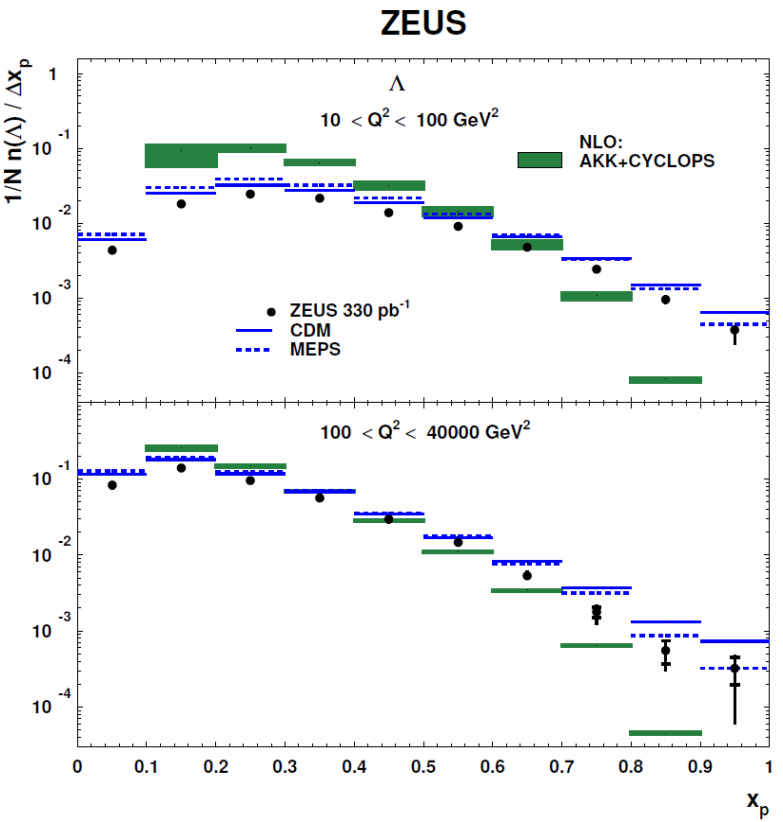
- Scaling violation observed
- NLO QCD calculations with recent fits of FFs do not describe the data

→ the HERA data have potential to further constrain fragmentation functions for the strange hadrons

Q^2 and x_p distribution: Λ

EPJ C 72 (2012) 1869





- Scaling violation : larger Q^2→ more soft gluons emitted
- NLO QCD+FF predictions fail to describe the data. DSS calculations are better at medium x_p and low Q^2, while AKK at high Q^2
- MC provide reasonable description