

$K^{*\pm}(892)$ Production in DIS at HERA



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On behalf of the H1 Collaboration

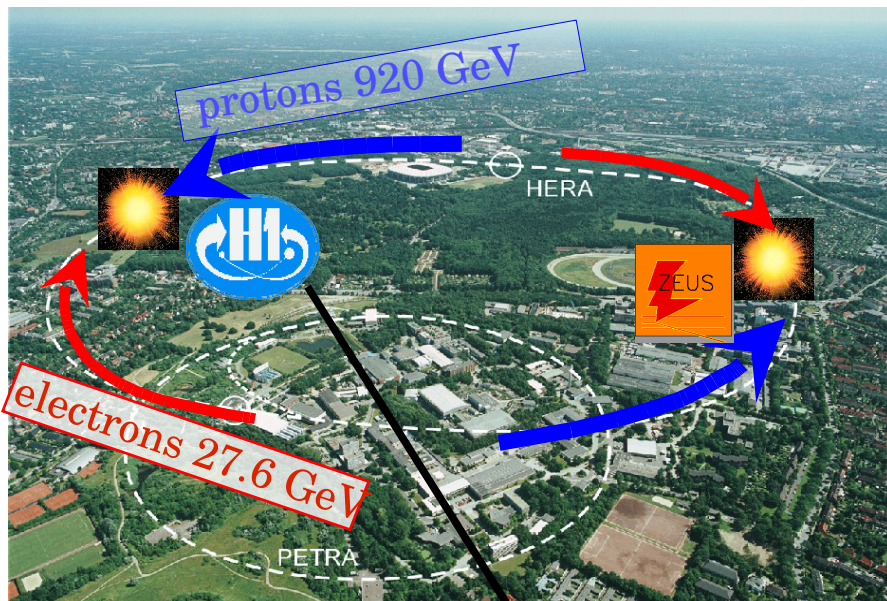


Outline

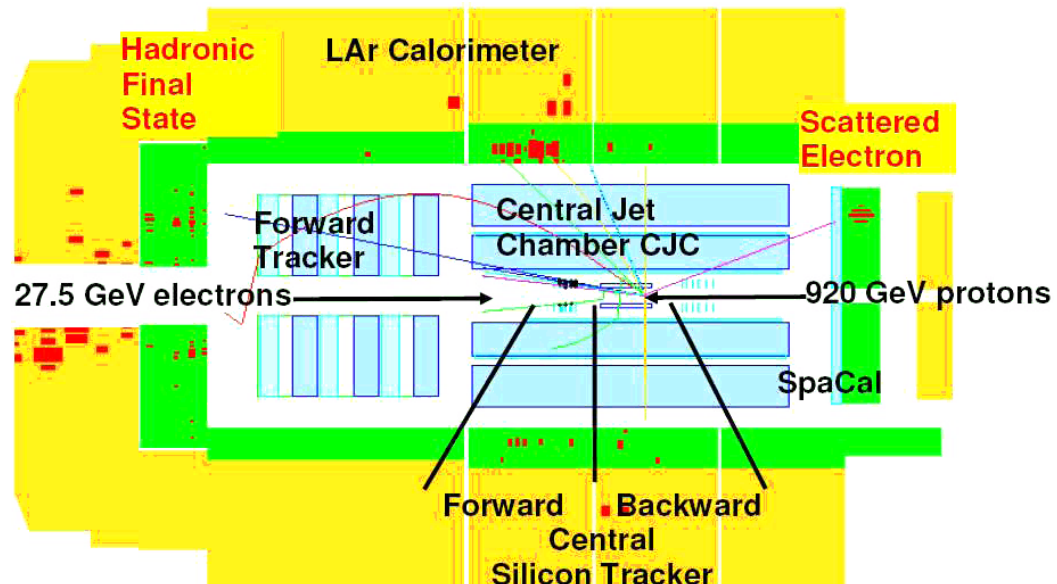
- HERA and H1
- Why measure K^* ?
- Analysis strategy
- $K^{*\pm}$ cross-sections
- Summary and Conclusion

XVII International Workshop on Deep-Inelastic Scattering and Related Subjects
DIS 2009, 26-30 April 2009
Madrid

HERA and H1



$\eta > 0$ forward $\eta < 0$ backward



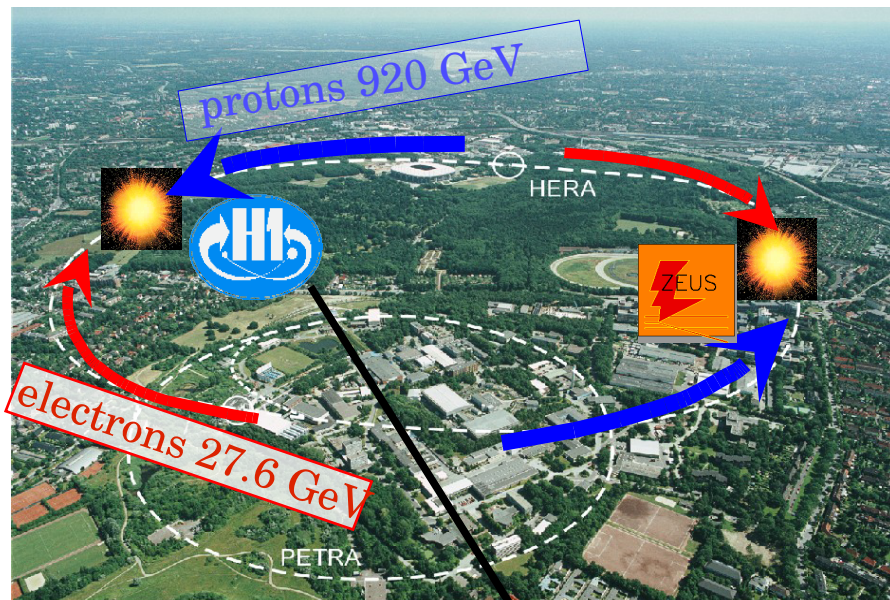
Stopped on 30.06.2007

HERA collider:

CM: 319 GeV

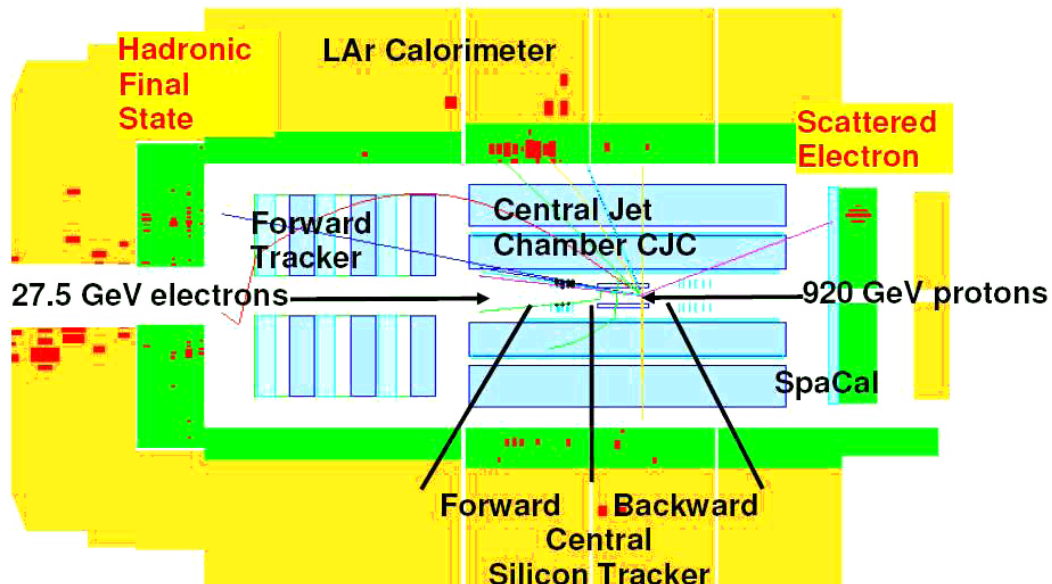


HERA and H1



$\eta > 0$ forward

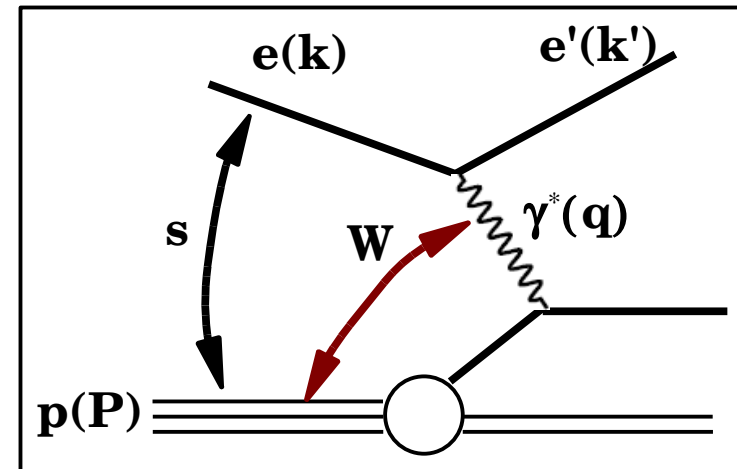
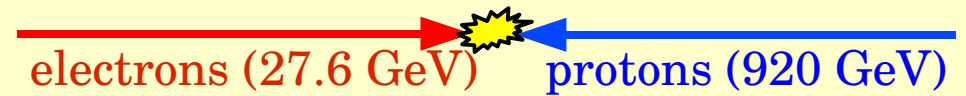
$\eta < 0$ backward



Stopped on 30.06.2007

HERA collider:

CM: 319 GeV

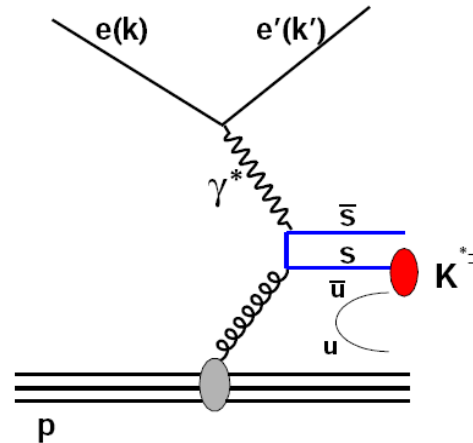
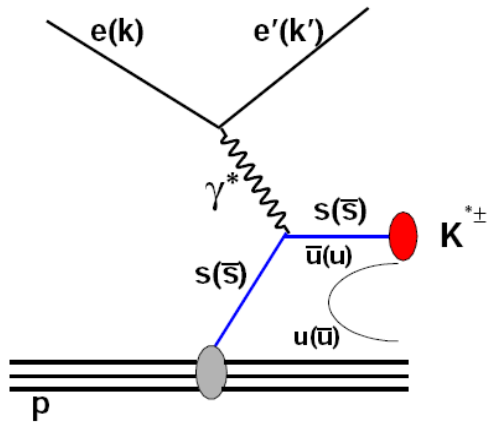


$$e(k) + p(P) \rightarrow e'(k') + X$$

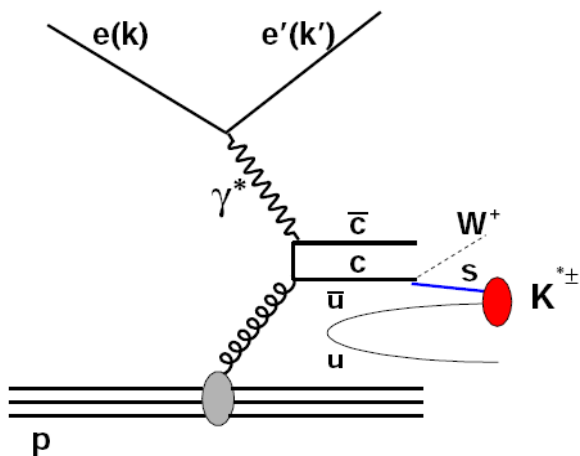
- Centre of mass energy $s = (P + k)^2$
- Energy of hadronic system $W^2 = (P + q)^2$
- Photon virtuality $Q^2 = -q^2 = -(k + k')^2$
- Inelasticity $y = qP / kP \approx (W^2 + Q^2) / s$
- Bjorken-x $x_{Bj} = Q^2 / 2qP \approx Q^2 / sy$

Why Measure K^* ?

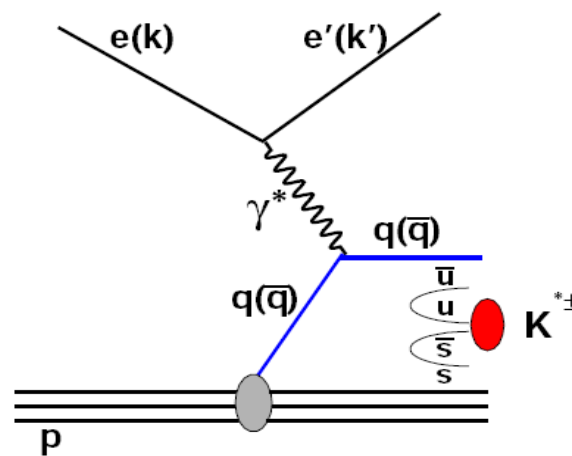
- Hard scattering of s sea quark
- Boson-gluon fusion



- Heavy quark decay
(non-perturbative)



- String fragmentation
(non-perturbative)

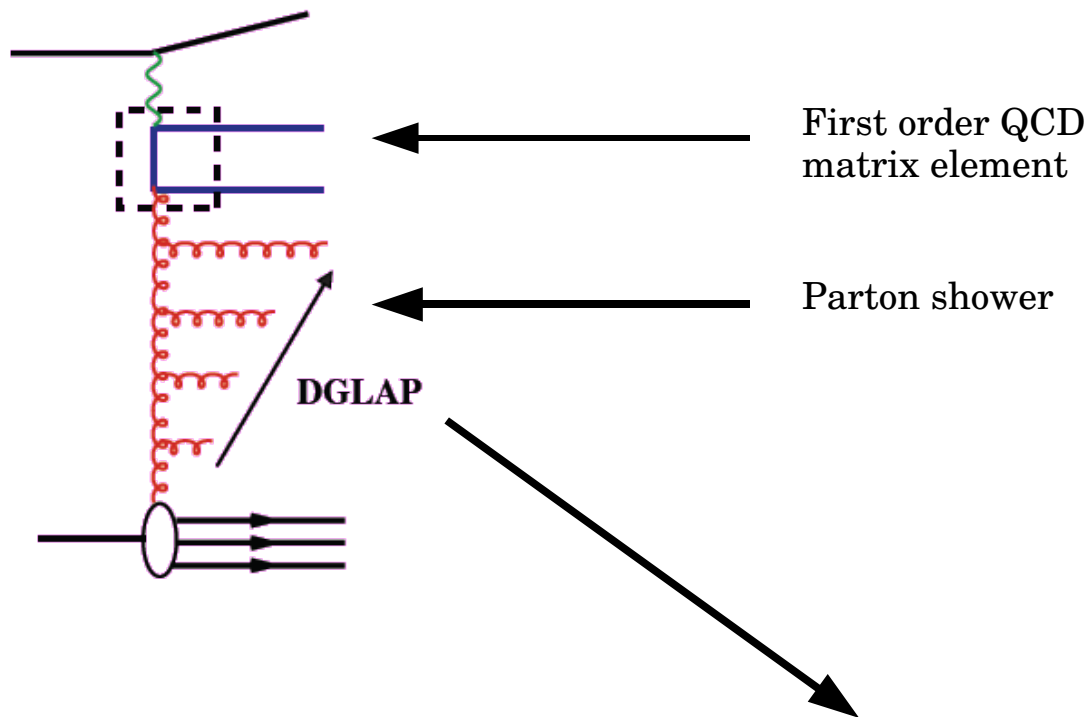


- First measurement of $K^{*\pm}$ meson at HERA
- Strange production dominated by string fragmentation (non-perturbative process)
- Vector mesons $K^{*\pm}$
 - Direct information about the strangeness suppression factor $\lambda_s = P(s)/P(u)$
 - To test parton fragmentation models
 - Improve understanding of hadronisation process
- Difference in the K^{*+} and K^{*-} cross-sections \Rightarrow asymmetric quark sea in the proton
- Primary quark flavour being the flavour entering the hard interaction from the proton side

Monte Carlo Models

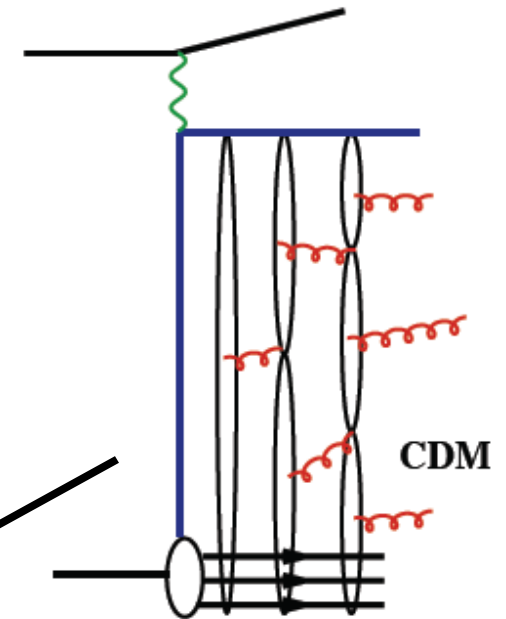
RAPGAP

- LO Matrix Element + Parton Shower (MEPS)-DGLAP
- Strong ordering in k_T



DJANGO (ARIADNE)

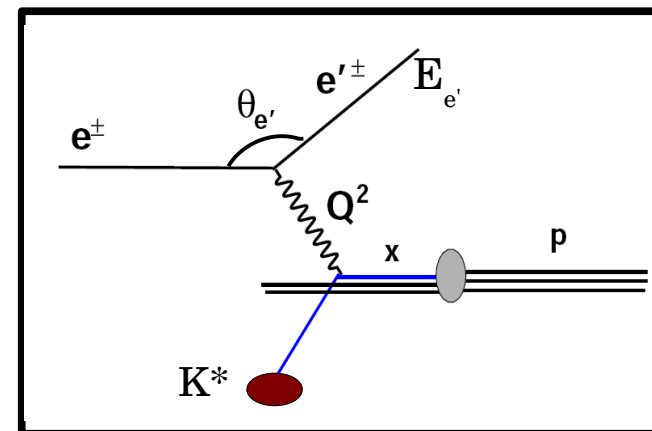
- LO Matrix Element + Color Dipole Model (CDM) implemented
- No strong ordering in k_T



Both MC interfaced to Lund string model for fragmentation

DIS Event Selection

- DATA 2005-2007 (Lumi = 301 pb⁻¹)
- Electron- Σ method used for reconstruction



Kinematic Cuts

- $5 < Q_e^2 < 100 \text{ GeV}^2$
- $0.1 < y_{e\Sigma} < 0.6$
- Scattered electron selection
 - $E_{e'} > 11 \text{ GeV}$
 - $156^\circ < \theta_{e'} < 173^\circ$

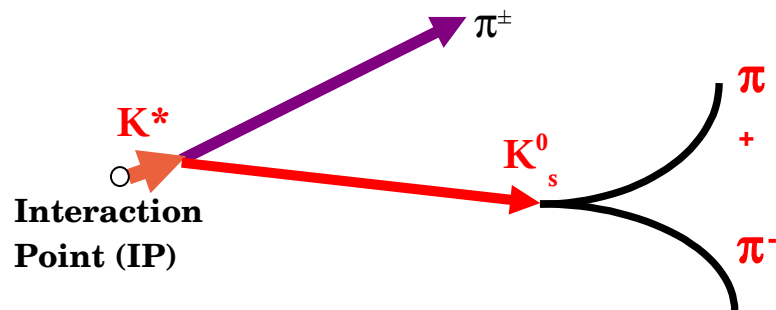
Technical Cuts

- Trigger
 - scattered electron in backward Calorimeter
 - at least 1 high momentum track candidate
- $35 < E - P_z < 70 \text{ GeV}$
- $-35 < z_{\text{vtx}} < 35 \text{ cm}$

K* Reconstruction

K^{*} measurement via decay channel: $\text{K}^{*\pm} \rightarrow \text{K}_s^0 \pi^\pm$

$\quad\quad\quad | \rightarrow \pi^+ \pi^-$



Resonance	K*(892)
BR [%]	~23.06
Width [MeV]	50.7

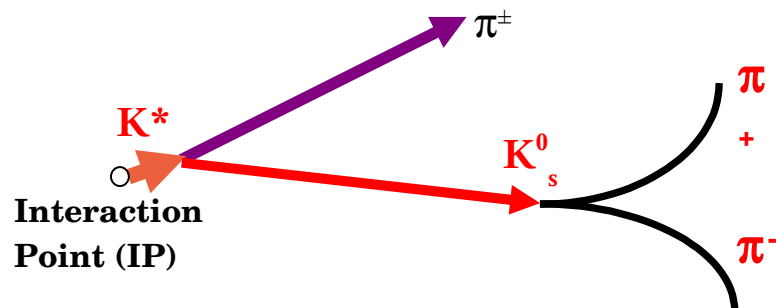
K_s⁰ Selection

- Pairs of oppositely charged tracks originating from a common secondary vertex
- $p_T > 0.12 \text{ GeV}$
- $|\eta| < 1.5$
- $0.470 < M_{K^0_s} < 0.520 \text{ GeV}$

K* Reconstruction

K^{*} measurement via decay channel: K^{*±} → K_s⁰ π[±]

|→ π⁺ π⁻



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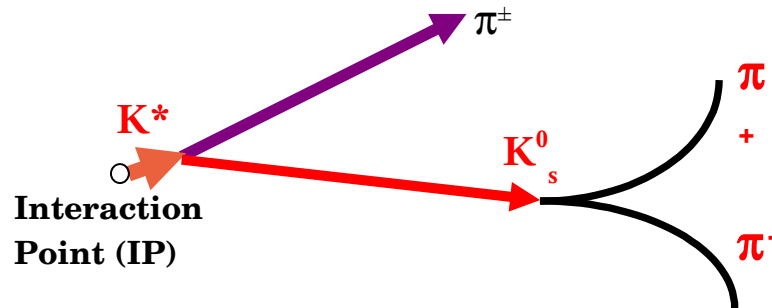
Primary π Selection

- Primary central tracks with $p_T > 0.12$ GeV
- $|\eta| < 1.5$

K* Reconstruction

K^{*} measurement via decay channel: K^{*±} → K_s⁰ π[±]

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Primary π Selection

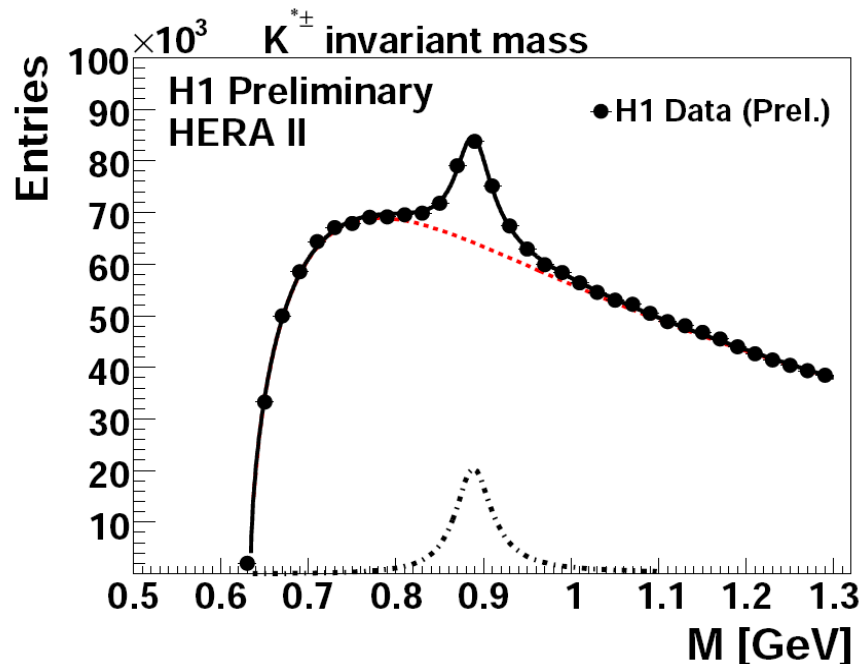
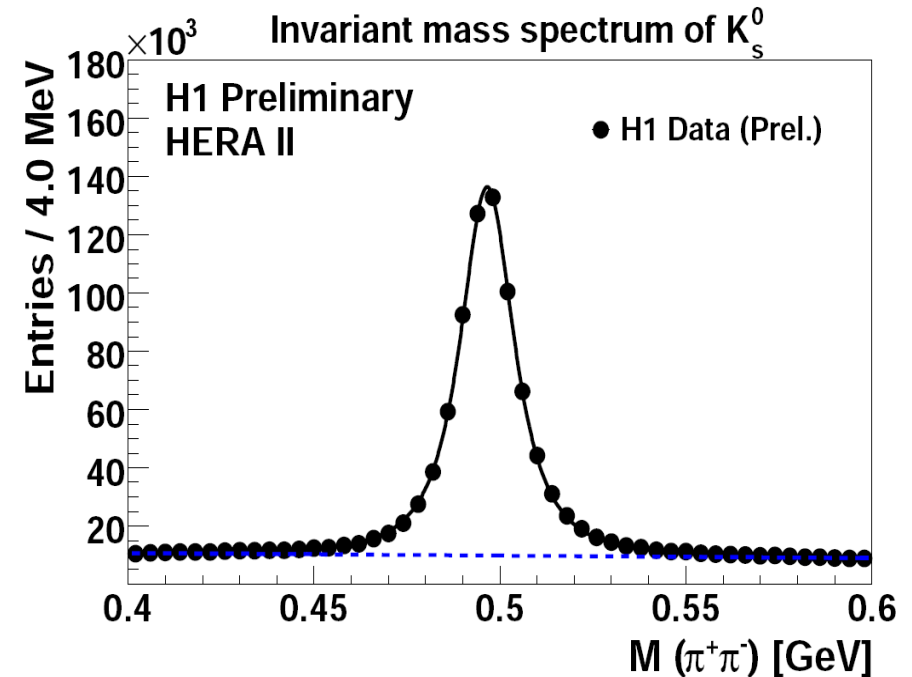
- Primary central tracks with $p_T > 0.12$ GeV
- $|\eta| < 1.5$

K* Selection

- Combine K_s^0 candidates with primary π
- $p_{T(K_s^*)} > 1 \text{ GeV}$, $|\eta_{(K_s^*)}| < 1.5$

Signal Extractions

- K_s^0 extraction:
 - t-student function (signal)
 - linear polynomial (background)
- Total number of reconstructed yield K_s^0 from the fit $N_{K_s^0} \sim 1.32 \times 10^6$
- Obtained invariant mass ($M_{K_s^0}$) and decay length ($c \cdot \tau$) consistent with PDG values



- K^* extraction:
 - Breit–Wigner function (signal)
 - Polynomial (3rd order) exponential (background)
- Clear signal above the large background
- $N_{\text{TOTAL}} (K^{*\pm}) \sim 80000$ obtained from the fit
- For the following differential cross section measurements fit is repeated binned in kinematic variables

$K^{*\pm}$ Cross Sections in Lab Frame

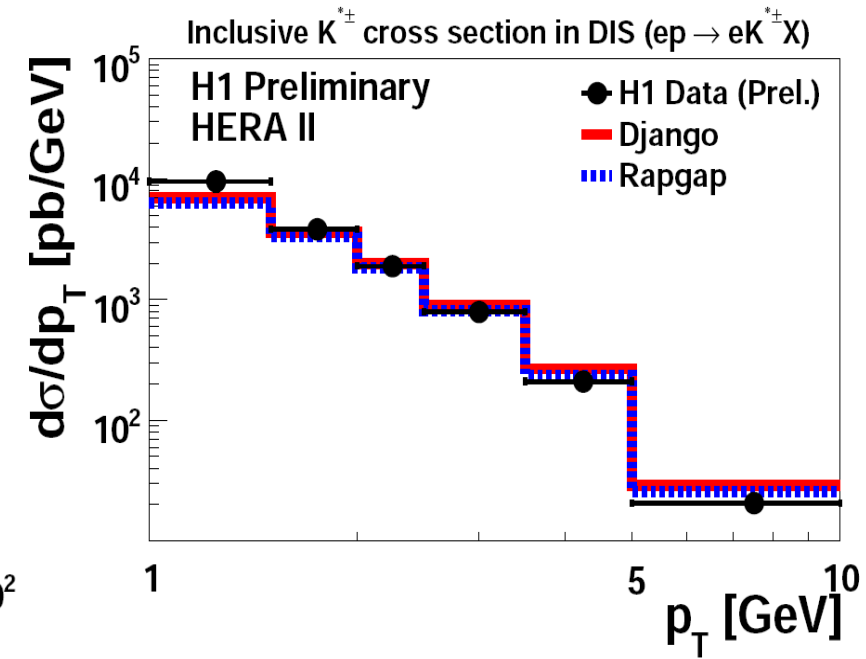
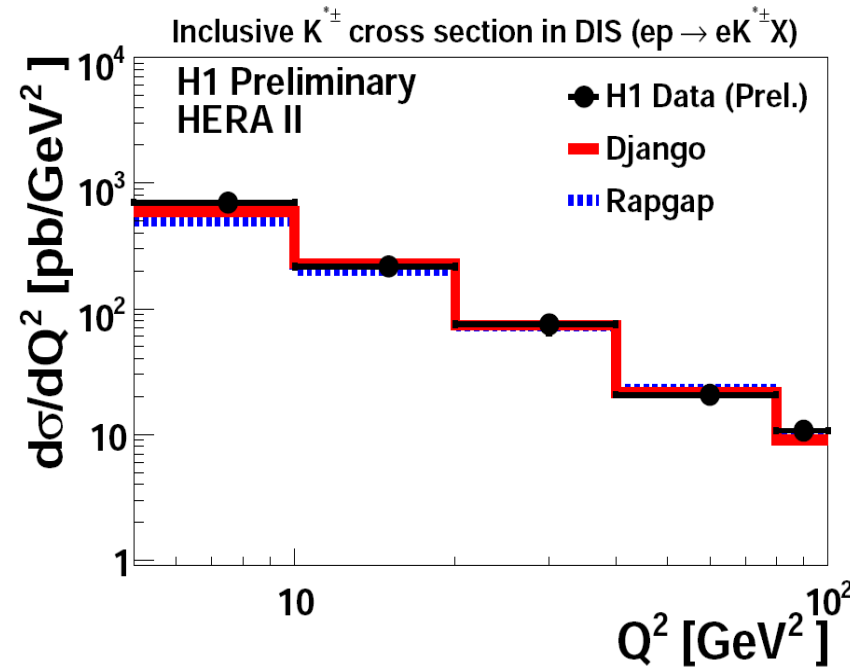
Visible Range

$$5 < Q_{e\Sigma}^2 < 100 \text{ GeV}^2$$

$$0.1 < y_{e\Sigma} < 0.6$$

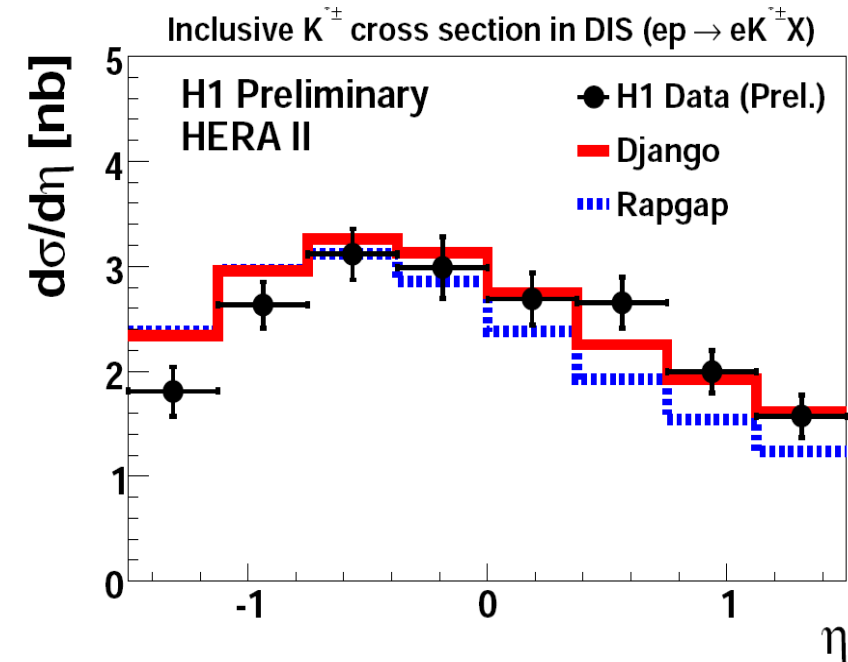
$$p_{T(K^*)} > 1 \text{ GeV}$$

$$|\eta_{(K^*)}| < 1.5$$



$$\sigma_{\text{TOTAL}} = 7.36 \pm 0.087 \text{ (stat.)} \pm 0.88 \text{ (sys.) nb}$$

- Comparison with **DJANGO (CDM)** and **RAPGAP (MEPS)**
- Kinematic variable : Q^2 , K^* quantity : η and p_T
- Overall features described by both MC but fail to describe the details in η shape



$K^{*\pm}$ Cross Sections in Lab Frame

Visible Range

$$5 < Q_{e\Sigma}^2 < 100 \text{ GeV}^2$$

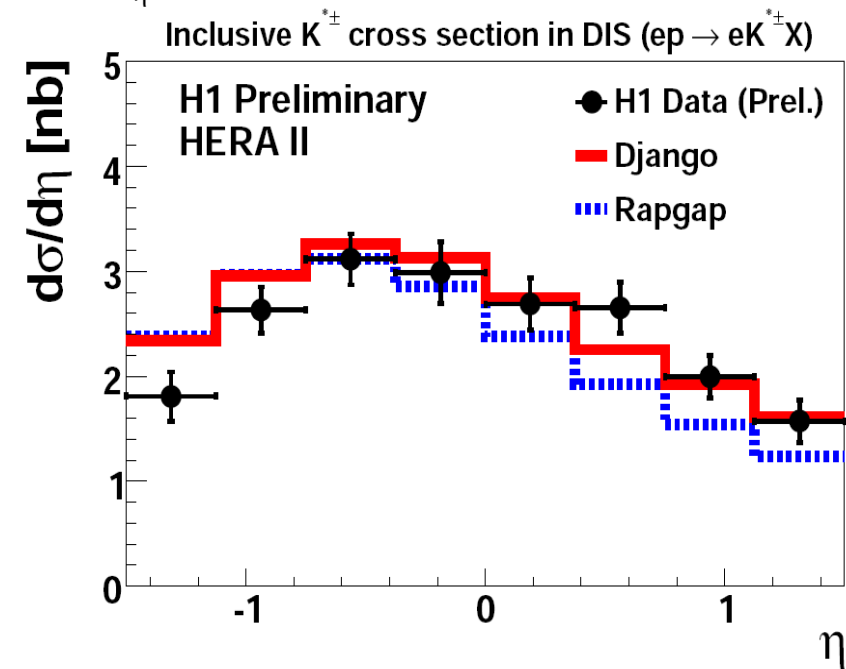
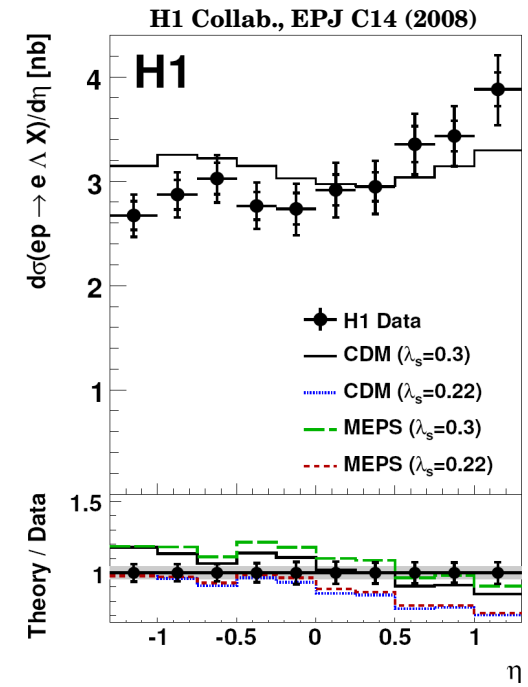
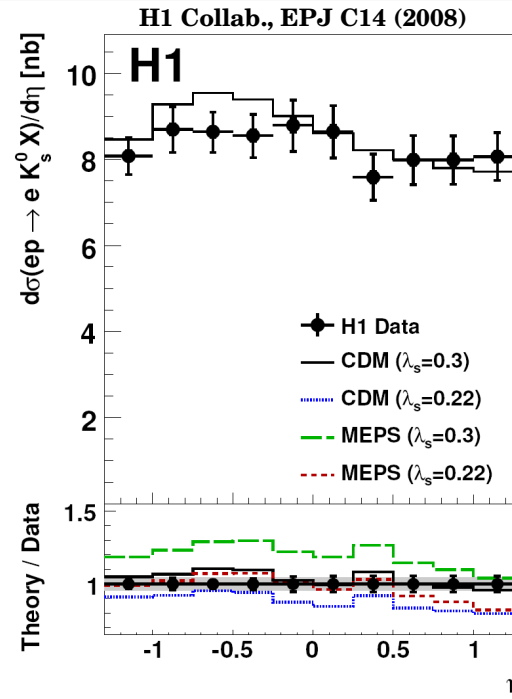
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- Comparison with **DJANGO (CDM)** and **RAPGAP (MEPS)**
- Kinematic variable : Q^2 , K^* quantity : η and p_T
- Overall features described by both MC but fail to describe the details in η shape
- Similar observation for H1 K_s^0 and Λ measurements



$K^{*\pm}$ Cross Sections in γp Frame

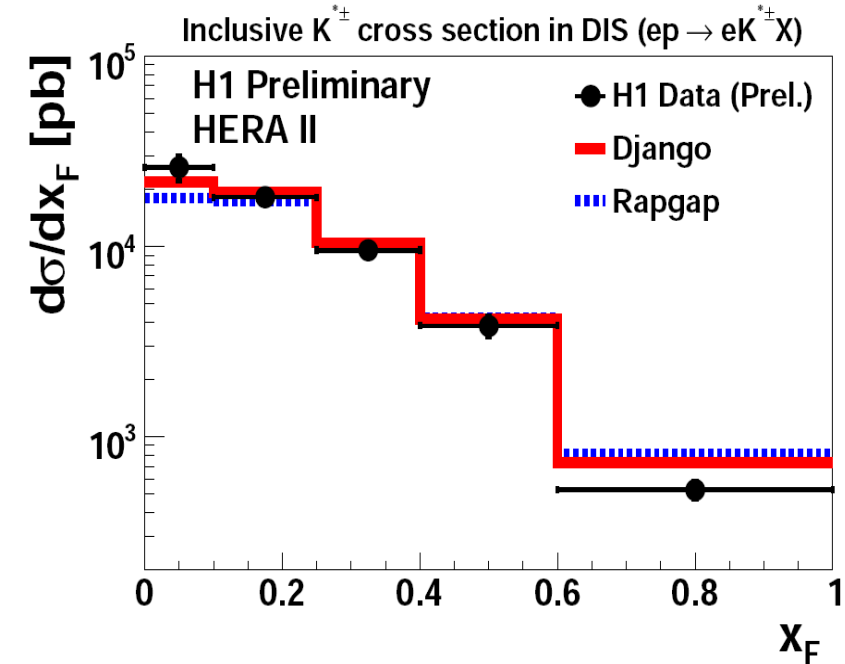
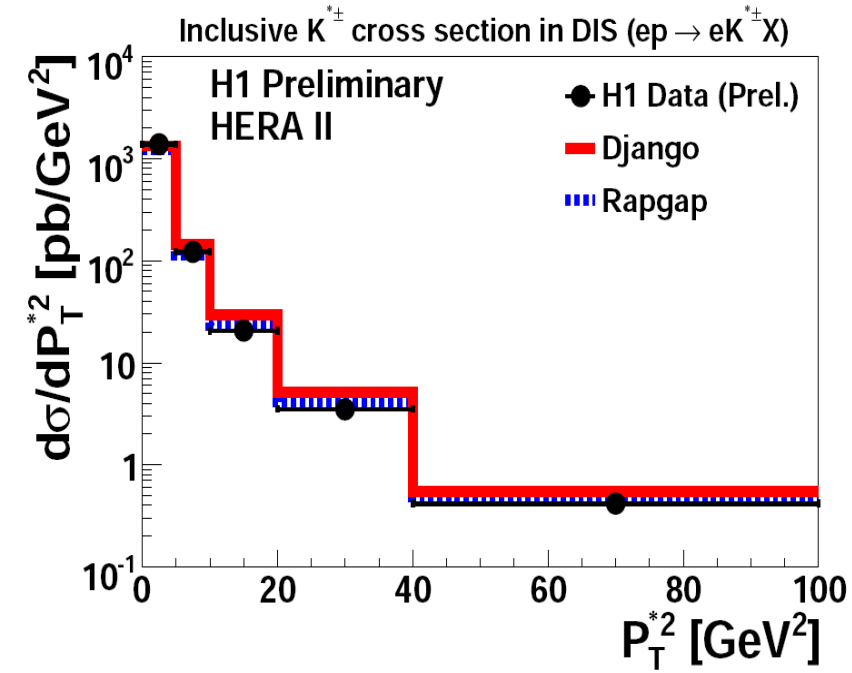
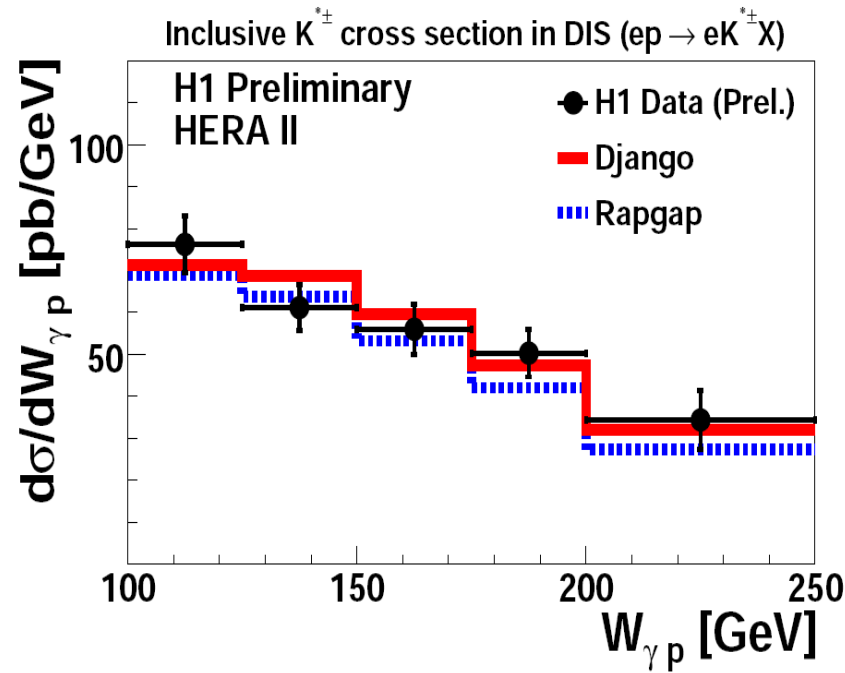
Visible Range

$$5 < Q_{e\Sigma}^2 < 100 \text{ GeV}^2$$

$$0.1 < y_{e\Sigma} < 0.6$$

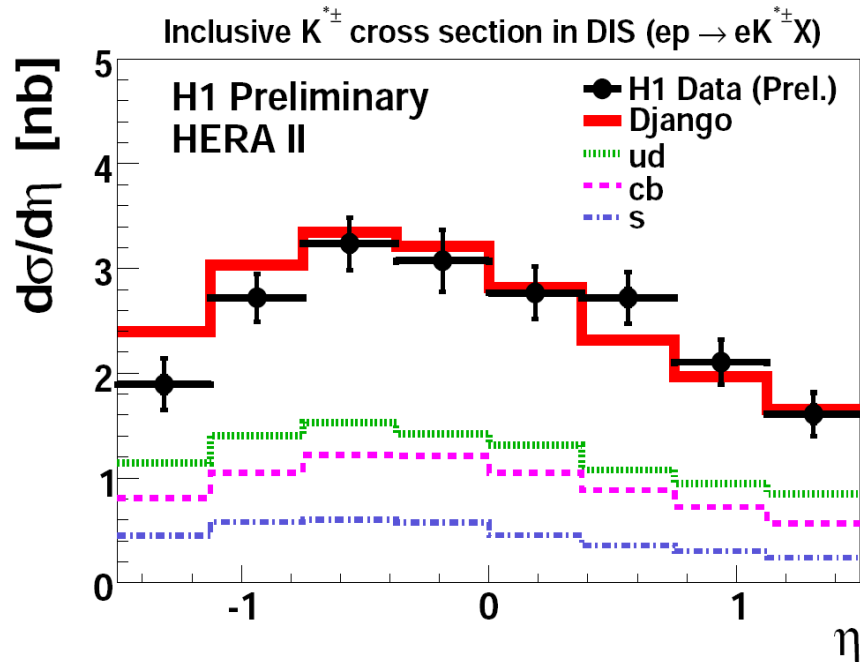
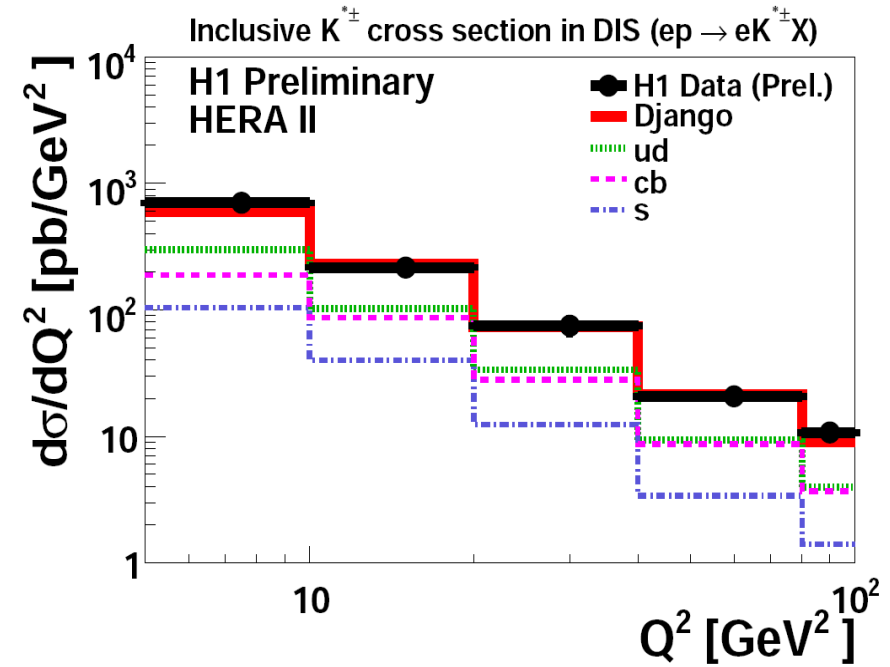
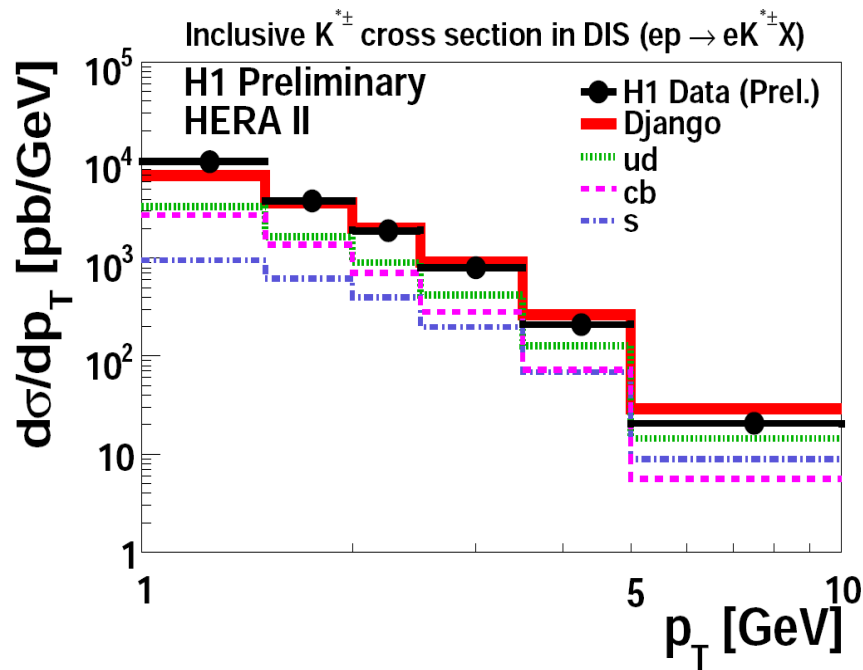
$$p_{T(K^*)} > 1 \text{ GeV}$$

$$|\eta_{(K^*)}| < 1.5$$



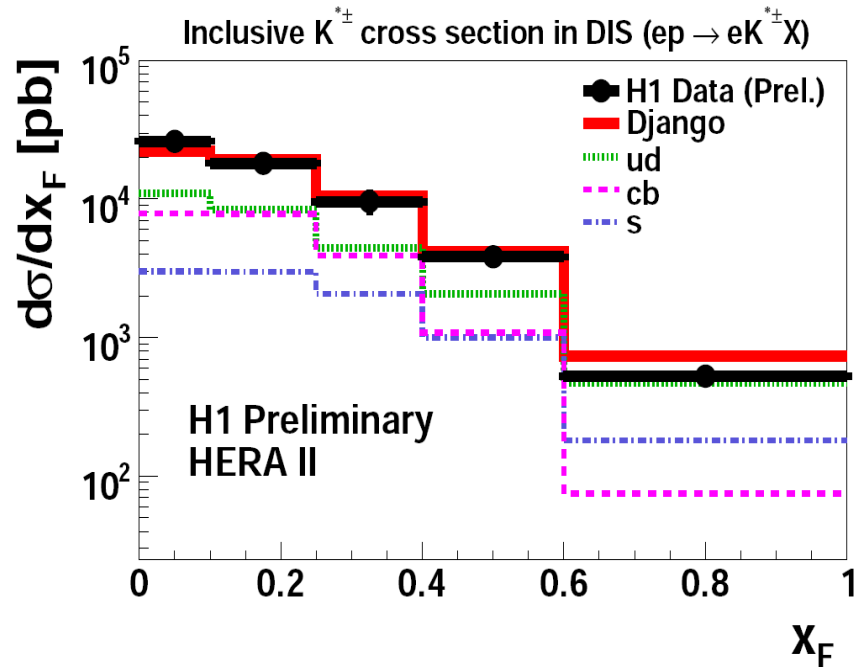
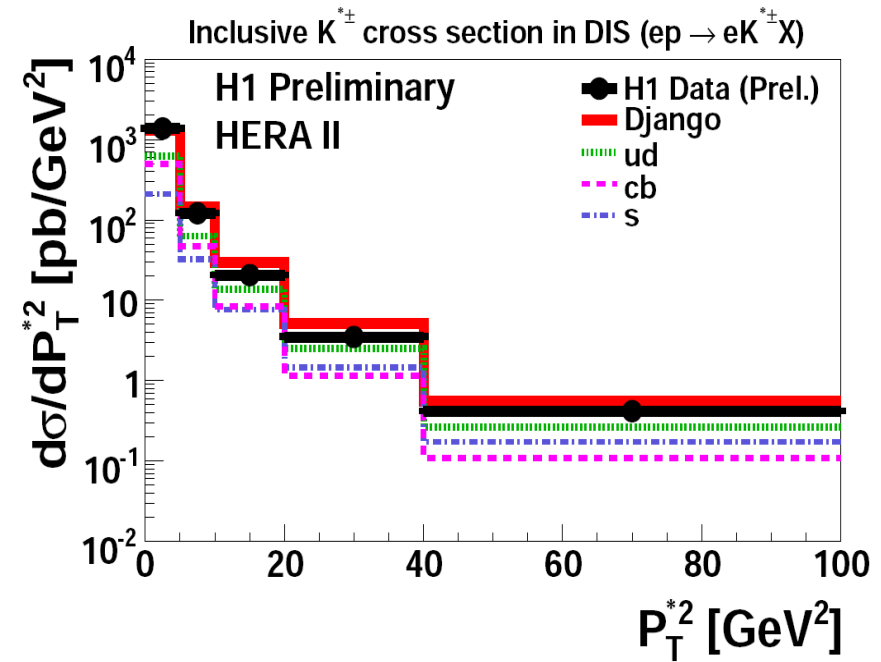
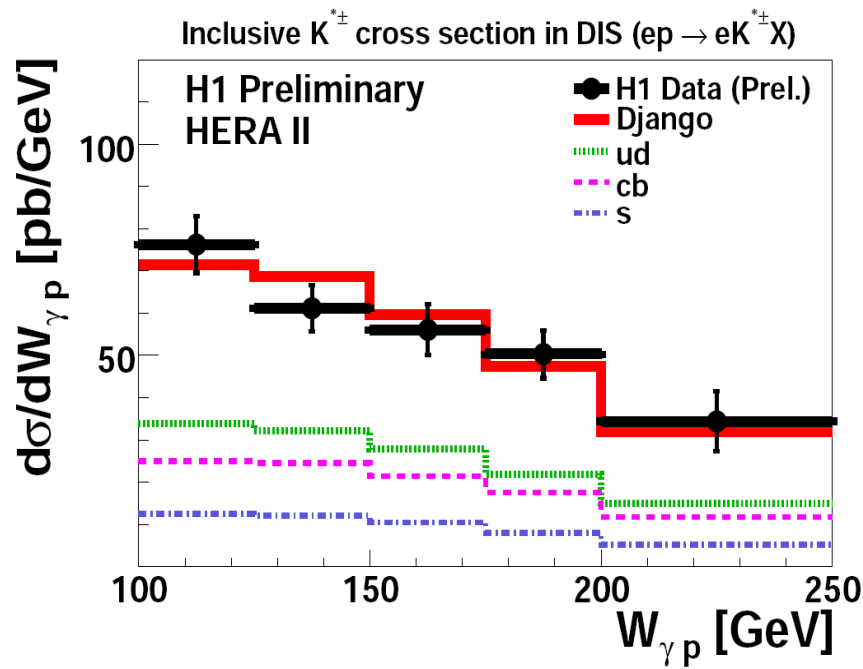
- Kinematic variable : $W_{\gamma p}$
- K^* quantity : P_T^{*2} and $x_F = \frac{2P_L}{W}$
- Both MC give good description
- DJANGO (CDM) slightly better in shape

Primary Flavor Contributions



- Largest contribution from **u** and **d** quarks in overall variables
- Next largest contribution from **c** and **b** quarks
- ~20% of K^* originate from **s** quarks

Primary Flavor Contributions (II)



K^* from

- **ud** are from fragmentation \Rightarrow small dependence on x_F
- **cb** are mainly from decays of heavy hadrons
heavy quarks exclusively via BGF \Rightarrow predominantly at small x_F
- **s** also directly from hard subprocess \Rightarrow fraction rises with x_F

Conclusions

- ✓ First measurement of $K^{*\pm}$ meson production studied in DIS (data taken 2005 -2007) at HERA
- ✓ Differential charged K^* cross sections (Q^2 , η , p_T , $W_{\gamma p}$, P_T^{*2} and x_F)
- ✓ CDM and MEPS describe overall features well; differences seen in details (consistent with K_s^0 and Λ measurements at HERA)
- ✓ 3 different contributions to strange mesons:
fragmentation, charm and strange quark production
- ✓ Only 20% of $K^{*\pm}$ originate from “strange” quarks
- ✓ Contribution of strange quarks become prominent at high P_T^{*2} and x_F

Backup Slides

Systematic Uncertainty

Possible sources	Variation	$\Delta\sigma$
Fit function	Polynomial-Chebyshev bkg function usage	3% (2.6% - 7.8%)
K0s description		3%
Signal extraction		2%
Primary Vertex		2.5%
Trigger efficiency	data-MC difference	2 %
Luminosity		3.62%
Photo-production Bkg.		0.3%
MC statistics		2.2%
θ_e	± 1 mrad	2%
E'_e	$\pm 1\%$	3.4%
Track reconstruction		2% (per track)
Model	$0.5 \cdot (\text{CDM-MEPS}) / \text{CDM}$	3% (9% at low x, high W, high η)

Overall systematic error ~ 9%
(varies between bins 7% - 15%)

Fit Function

DELPHI Coll., P. Abreu et al., Phys.Lett.B275:231-242,1992.

Relativistic Breit-Wigner distribution (used for DATA)

ALEPH Coll., D. Buskulic et al., Z.Phys.C69:379-392,1996.

$$BW_{K'} = \frac{m}{q} \cdot \frac{\Gamma_K'}{(m^2 - m_K^2)^2 + (m_K \cdot \Gamma_K')^2}$$

$$q = \frac{[(M^2 - (m_1 + m_2)^2) \cdot (M^2 - (m_1 - m_2)^2)]^{1/2}}{2M}$$

Non-relativistic Breit-Wigner distribution (used for MC)

$$BW_{K'} = \frac{\Gamma_K}{(m - m_K)^2 + \frac{\Gamma_K^2}{4}}$$

$$\Delta M = (M - m_{K_s^0} - m_\pi)$$

Background Function

$$BG(M) = a * (\Delta M)^b \exp(c * M + d * M^2 + e * M^3)$$

Background Function (Chebyshev Polynomials) – For systematic error determination

$$BG(M) = a * (\Delta M)^b \exp(\sum_{i=0}^3 a_i T_i(\Delta M))$$

m_K : central mass value of the K^*

Γ_K : width

M : K^* mass

m : mass of the $K\pi$ system

q : π momentum in $K\pi$ rest frame

m_1 : K_s^0 mass

m_2 : π mass