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Particle production and fragmentation results from ZEUS

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on behalf of ZEUS Collaboration

- Introduction
- K_s^0, Λ and $\bar{\Lambda}$ particle production
- Bose-Einstein correlations between $K_s^0 K_s^0$ and $K^\pm K^\pm$
- Summary

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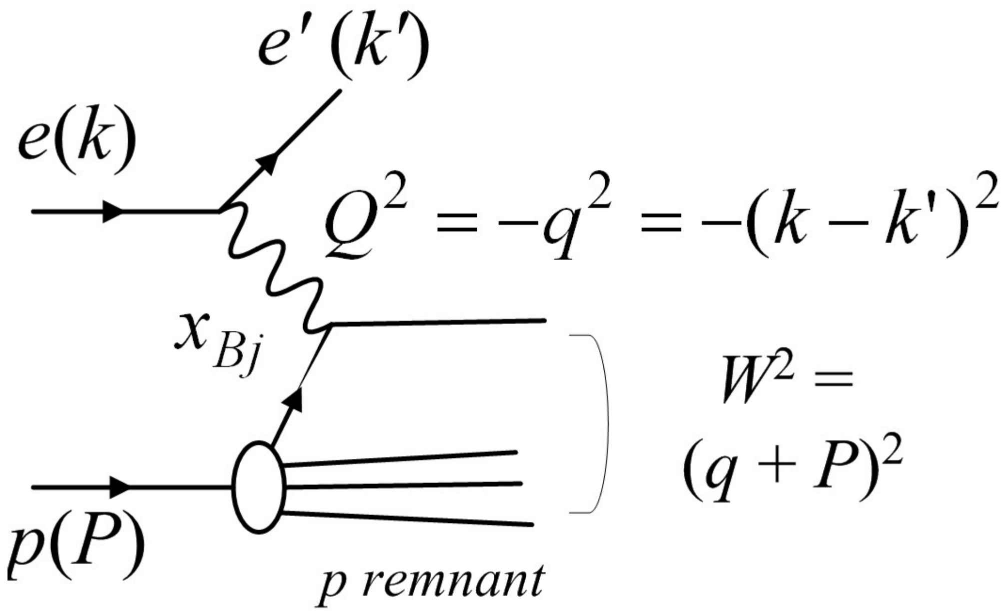
DIS kinematic variables



$ep \to eX$ collisions at HERA give informations about soft and hard processes.

@ HERA:

$e^{\pm}\ (27.6\ GeV) + p\ (820/920\ GeV)$

$\sqrt{s} = 300 - 318\ GeV$

$96 - 00\ e^{\pm}p$ ZEUS data $\Rightarrow L = 121\ pb^{-1}$

DIS kinematic variables for $ep \to eX$

P/k the initial-state four momenta of the proton and electron/positron

$s = (P+k)^2$ the cms energy squared of the ep system

$W = (P+q)^2$ the cms energy of the γ^* virtual-photon-proton system

The photon virtuality Q^2 and Bjorken variables are defined as:

$$Q^2 = -q^2 = -(k-k')^2$$

$$x_{B_J} = \frac{Q^2}{2P\cdot q}$$

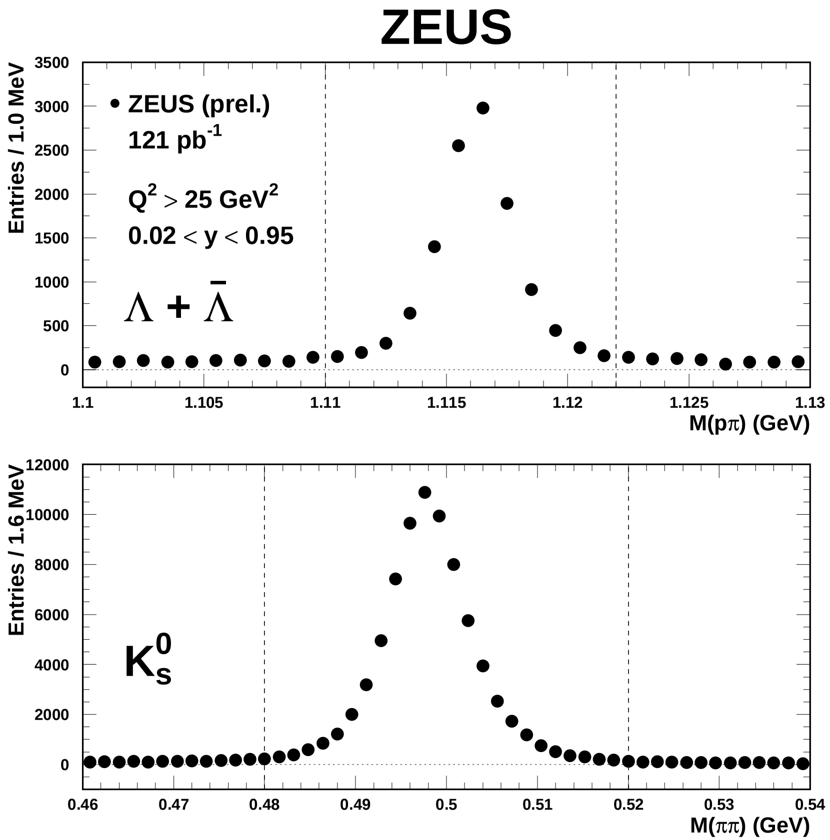
$$y_{B_J} = \frac{P\cdot q}{P\cdot k}$$

K^0_s, Λ and $\bar{\Lambda}$ cross-sections

- ★ $Q^2 > 25\ GeV^2$ and $0.02 < y_{B_J} < 0.95$
- ★ $5\ GeV^2 < Q^2 < 25\ GeV^2$ and $0.02 < y_{B_J} < 0.95$

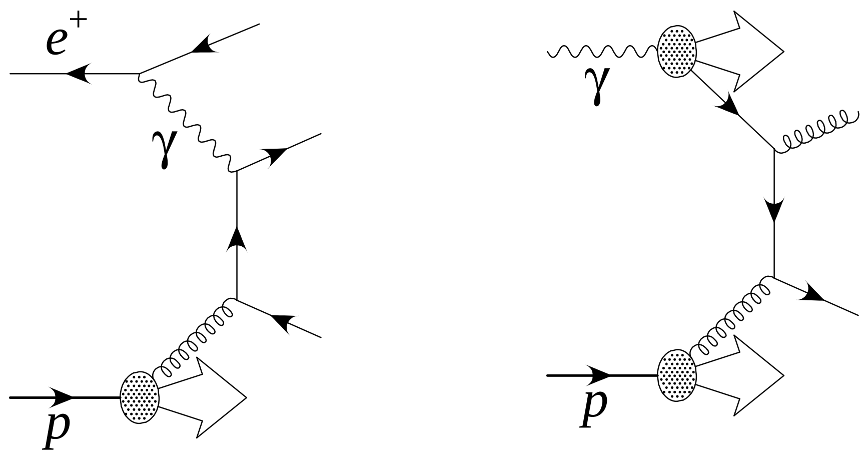
  } + $|\eta^{K^0_s,\Lambda,\bar{\Lambda}}| < 1.2$, $0.6 < p_T^{K^0_s,\Lambda,\bar{\Lambda}} < 2.5\ GeV$

- ★ $1\ GeV^2 < Q^2$ and $0.02 < y_{B_J} < 0.85$ (PHP) } + $|\eta^{jet}| < 2.4$, $E_T^{jet} > 5\ GeV$ $+\ 2\ jets$



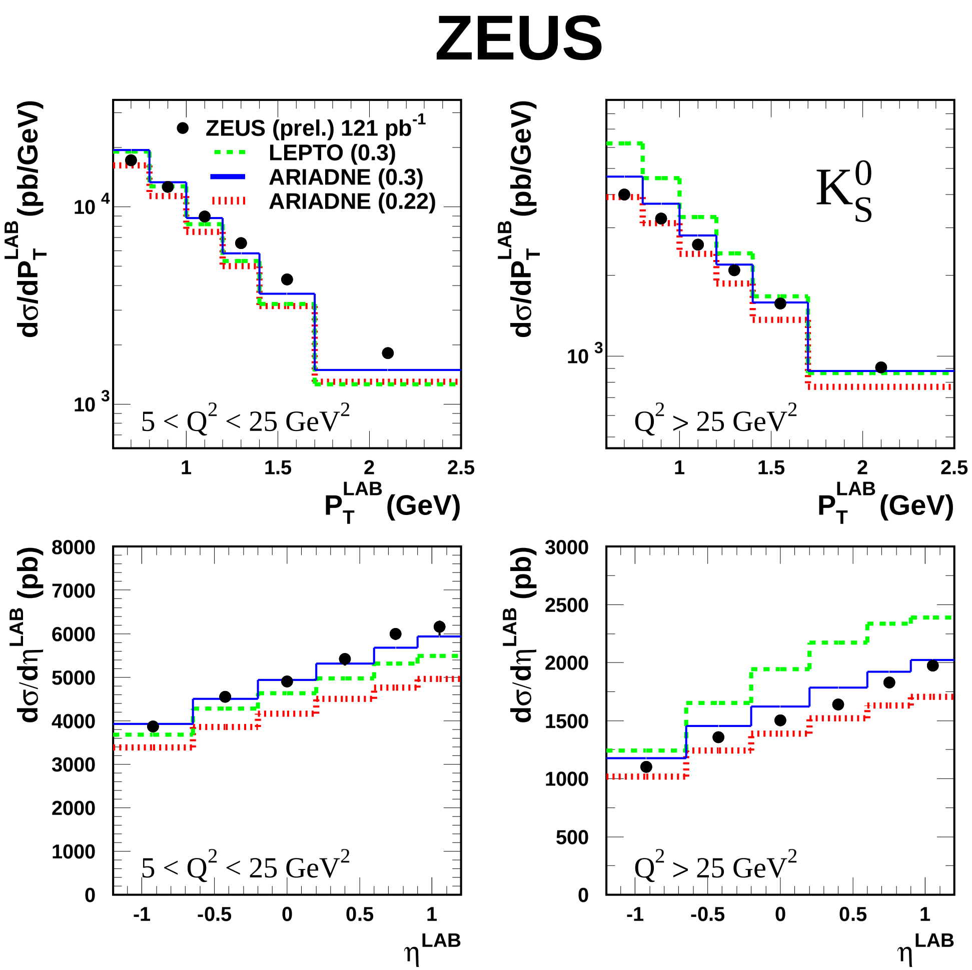
The differential cross-sections were measured as functions of:

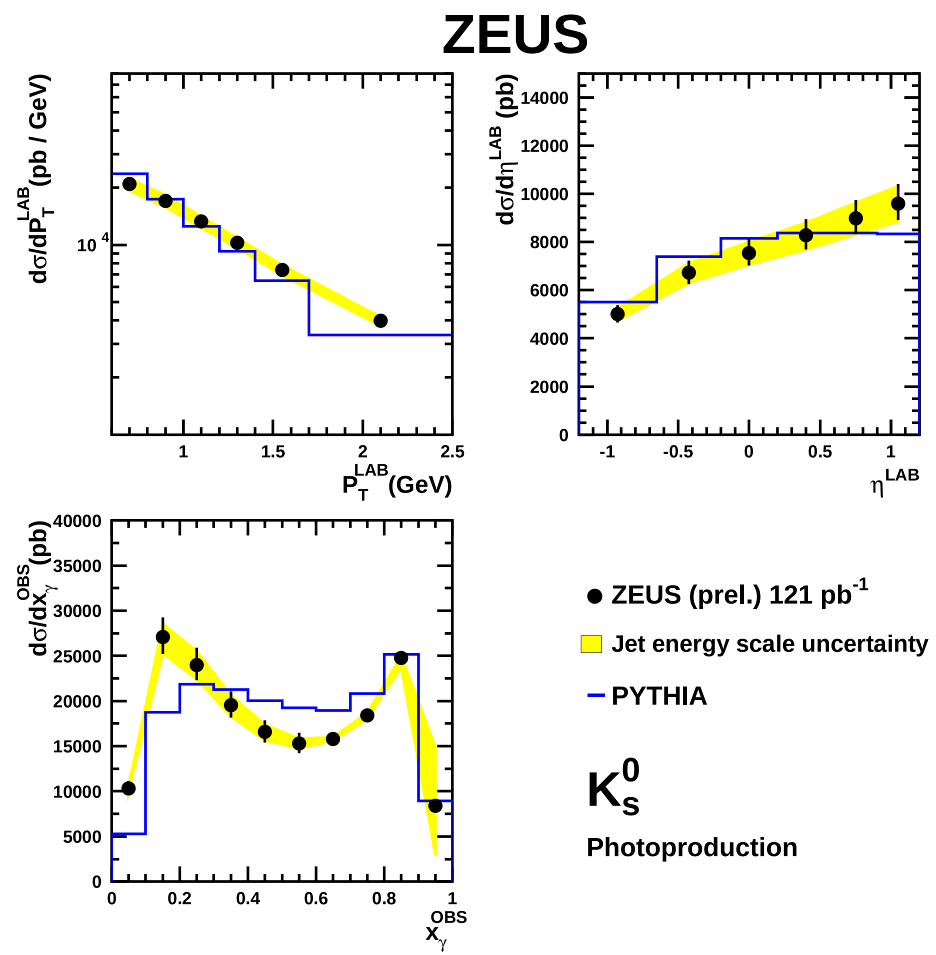
- ★ $p_T^{K^0_s,\Lambda,\bar{\Lambda}}$, $\eta^{K^0_s,\Lambda,\bar{\Lambda}}$, x_{B_J}, Q^2 (DIS)
- ★ $p_T^{K^0_s,\Lambda,\bar{\Lambda}}$, $\eta^{K^0_s,\Lambda,\bar{\Lambda}}$, x_γ^{OBS} (PHP)



$$x_\gamma^{OBS} = \frac{\sum_{jets} E_T^{jet} e^{-\eta^{jets}}}{2yE_e}$$

Differential K_s^0 cross-sections



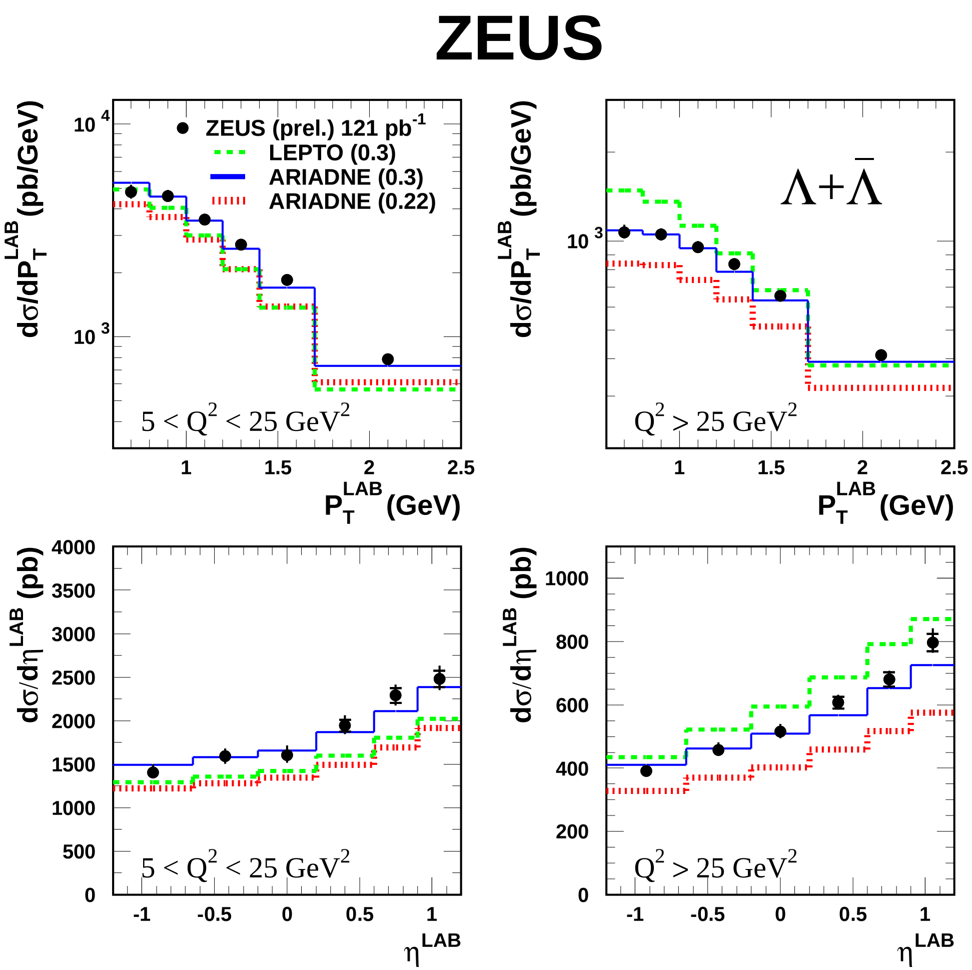


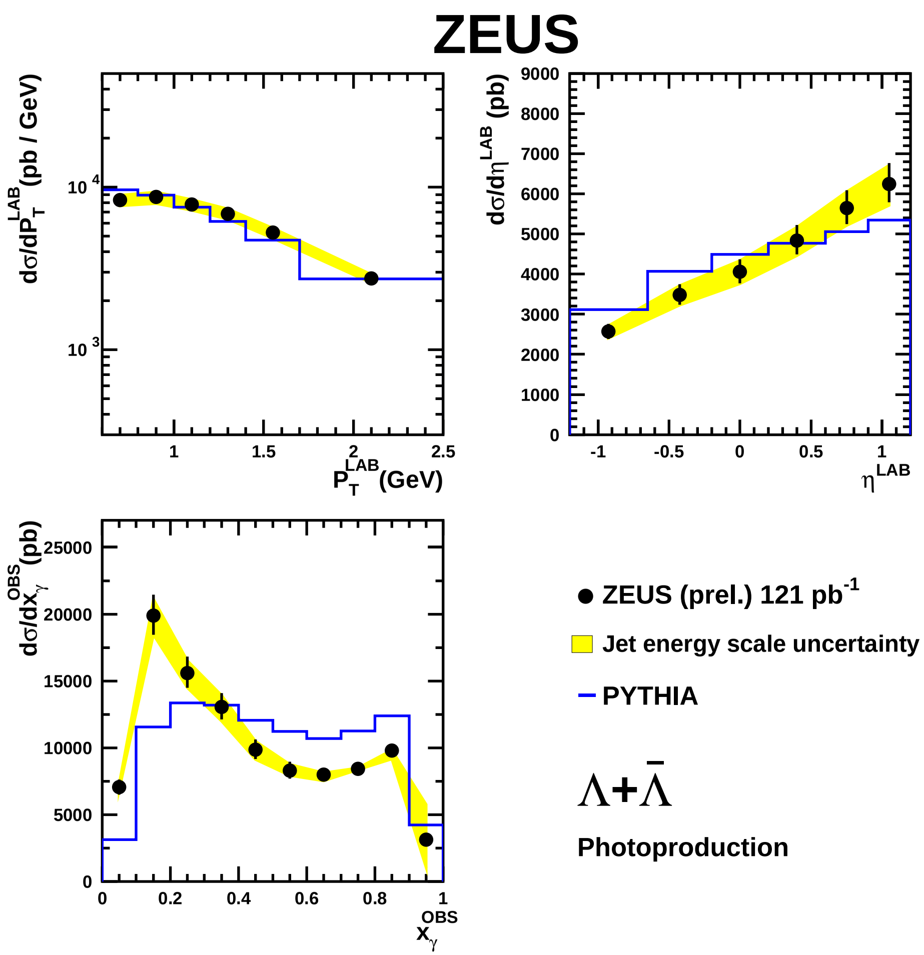
★ ARIADNE $(\lambda_s = 0.3)$ describes data reasonably well

★ ARIADNE $(\lambda_s = 0.22)$ and LEPTO describe the data less satisfactory

★ PYTHIA describes the data well

Differential $\Lambda + \bar{\Lambda}$ cross-section



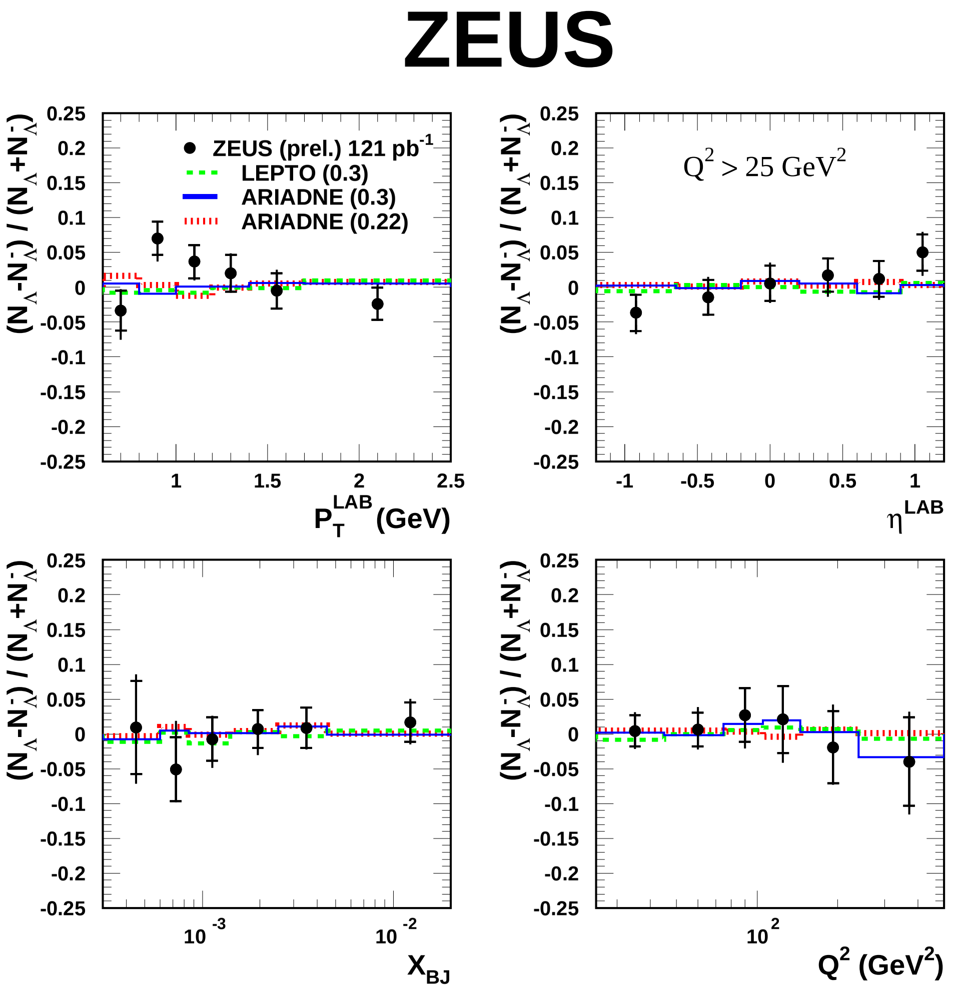


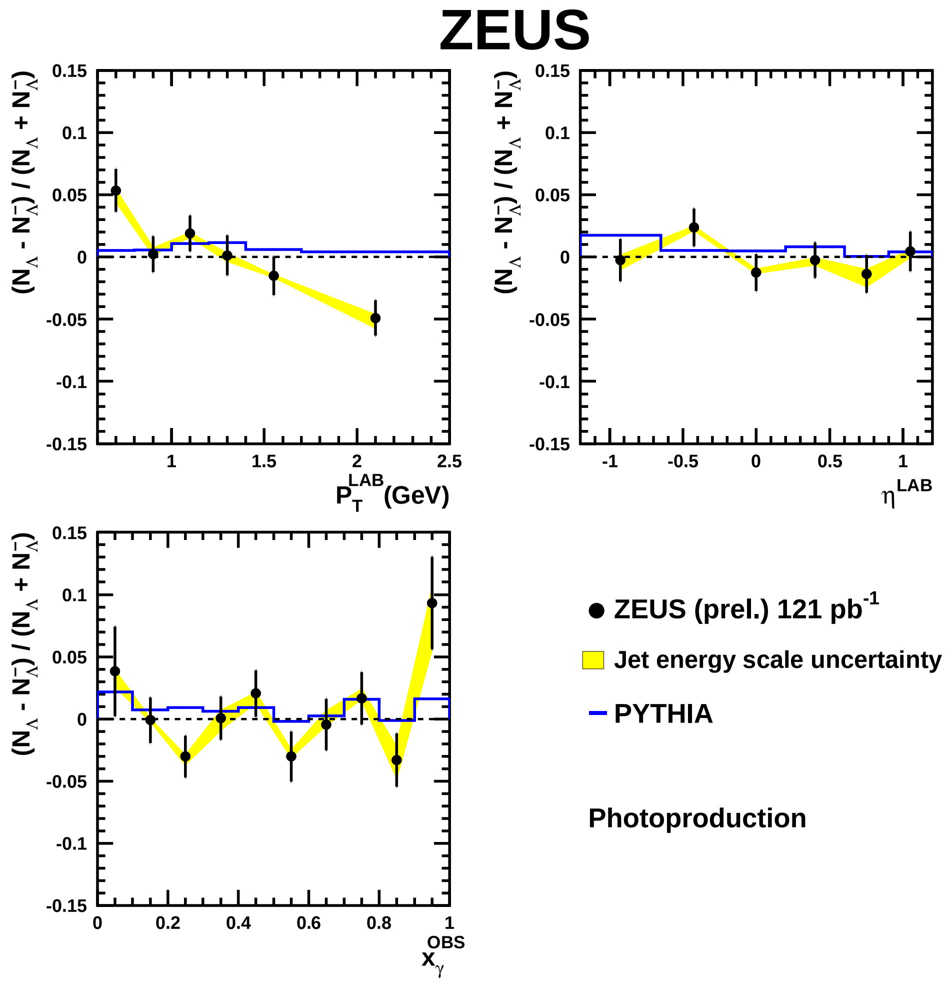
★ ARIADNE $(\lambda_s = 0.3)$ describes the data reasonably well

★ ARIADNE $(\lambda_s = 0.22)$ and LEPTO do not describe the data well

★ PYTHIA describes the data well

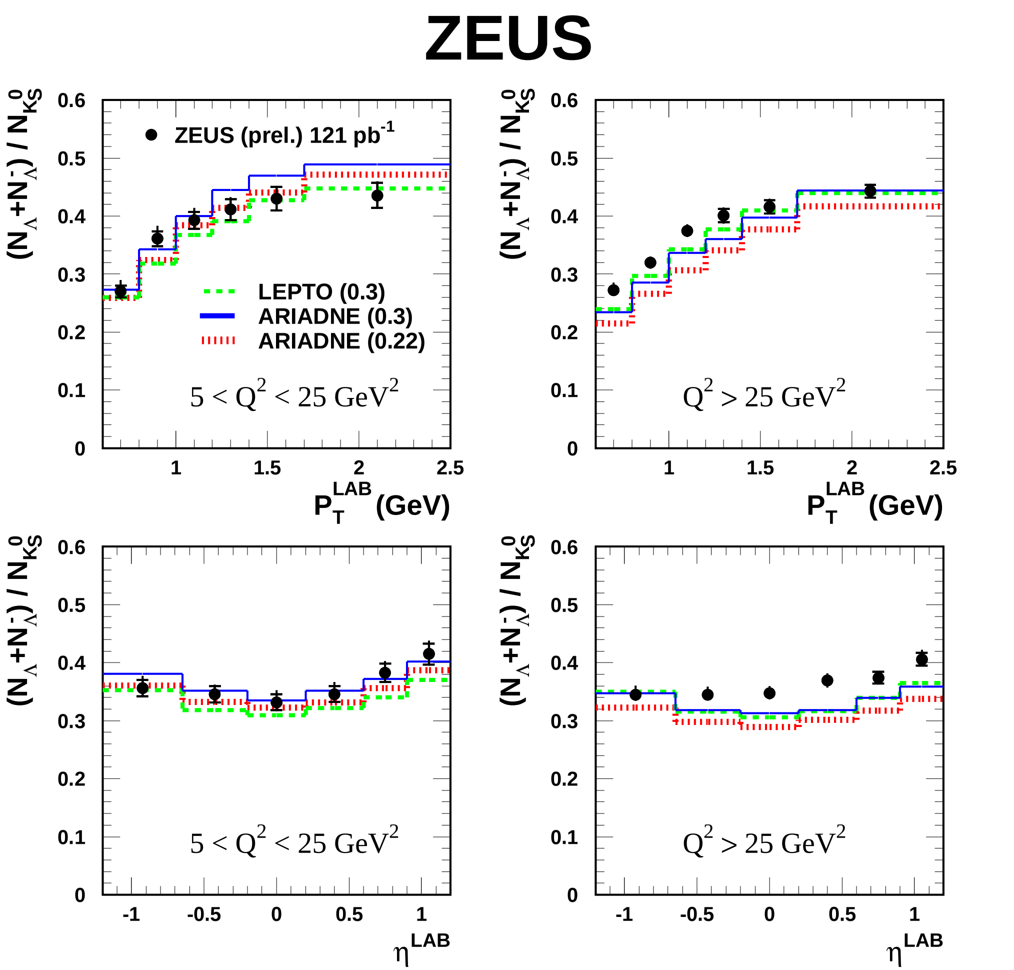
Baryon-antibaryon asymmetry

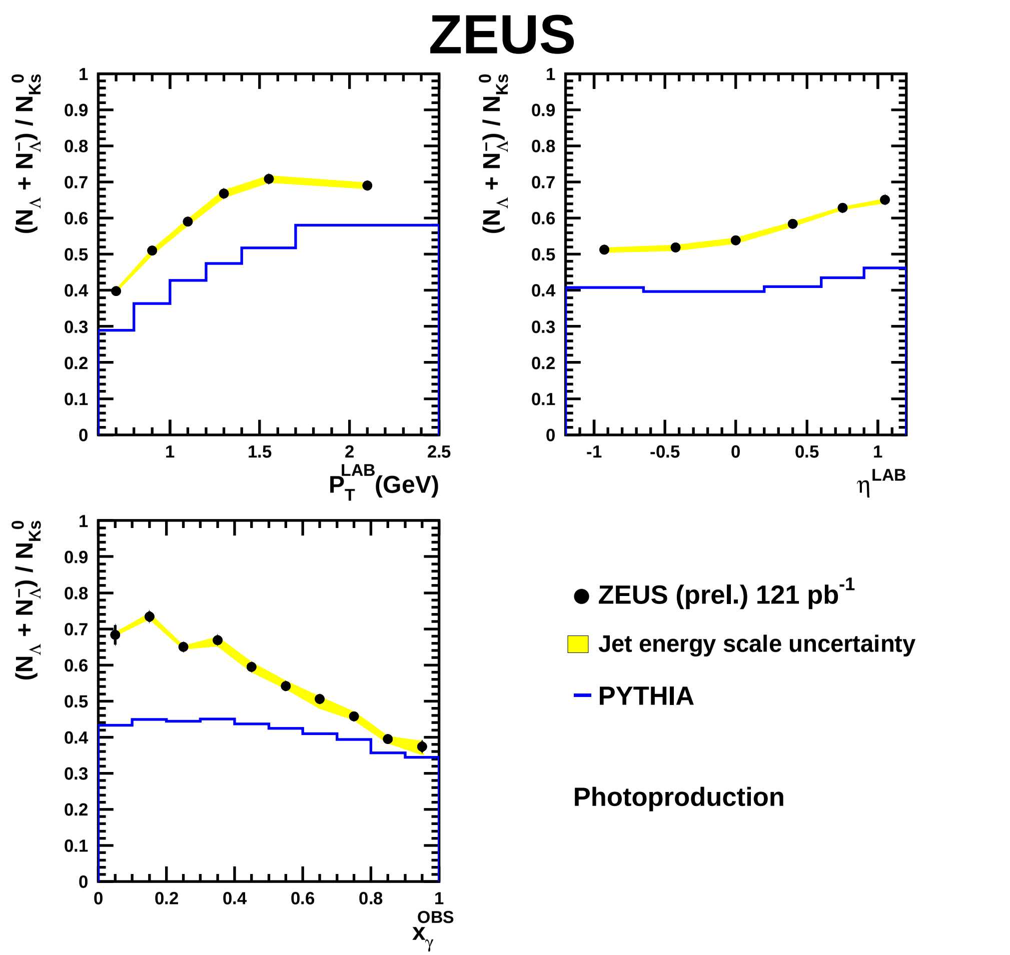




- ★ No baryon-antibaryon asymmetry was observed in all cases
- ★ The same number of Λ and $\bar{\Lambda}$ produced

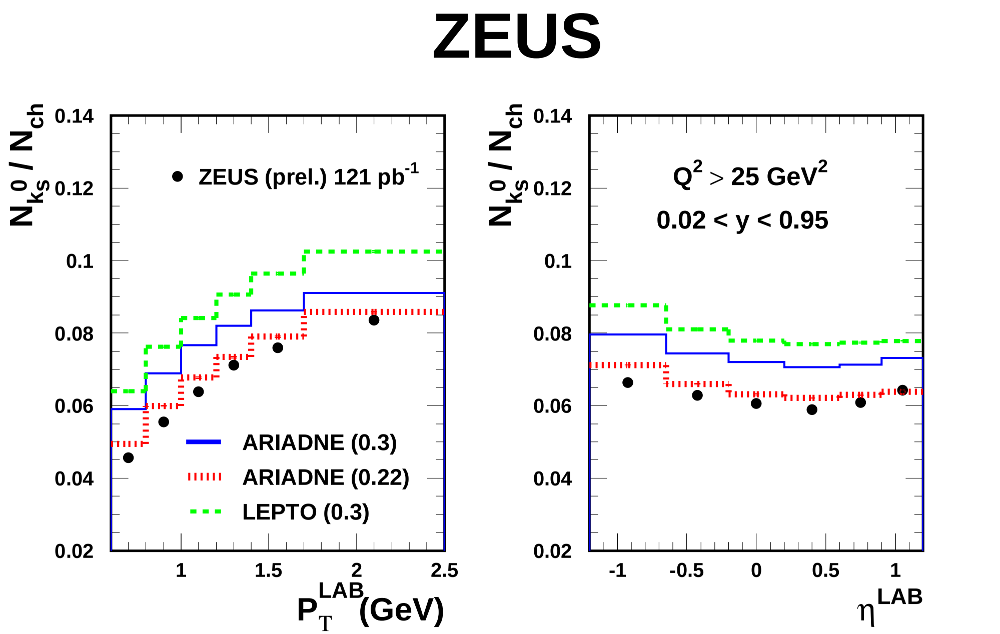
Baryon to meson ratio



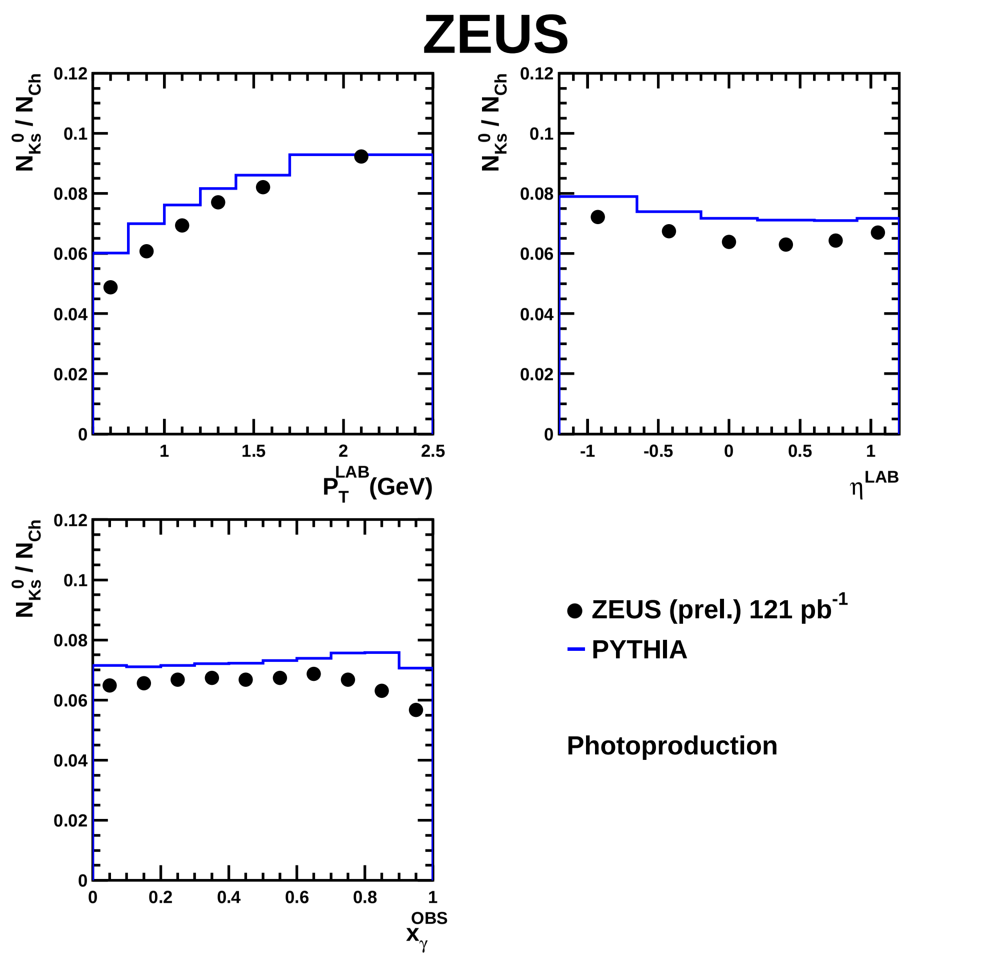


- ★ ARIADNE $(\lambda_s = 0.3)$ follows the shape of the data
- ★ Baryon to meson ratio increases at low x_γ up to 0.7, not predicted by PYTHIA
- ★ For $x_\gamma = 1$, same baryon to meson ratio as in DIS and e^+e^-

Strange to light hadrons ratio



N_{ch} - number of $\pi^{\pm}, K^{\pm}, p, \bar{p}$ together



★ $\lambda_s = 0.22$ is favoured

★ PYTHIA describes data well

★ Strangeness production is flat in x_γ^{OBS}

BE correlations between $K_s^0 K_s^0$ and $K^\pm K^\pm$

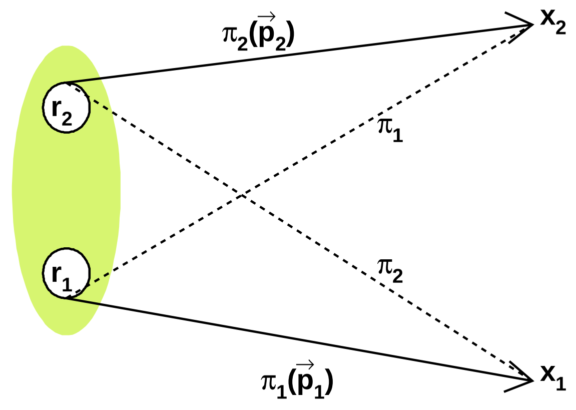
Bose-Einstein effect is an enhancement in the production of identical bosons with similar momenta.

BE effect is related to the time-space characteristic of the particle emission source.

In experiment: $$R(Q_{12}) = \frac{P(Q_{12})}{P_{ref}(Q_{12})}$$

$$Q_{12} = \sqrt{-(p_1 - p_2)^2} = \sqrt{M^2 - 4m_{boson}^2}$$

Two bosons with momenta $\vec{p_1}$, $\vec{p_1}$ produced at points r_1 and r_2



π_1, π_2 - bosons

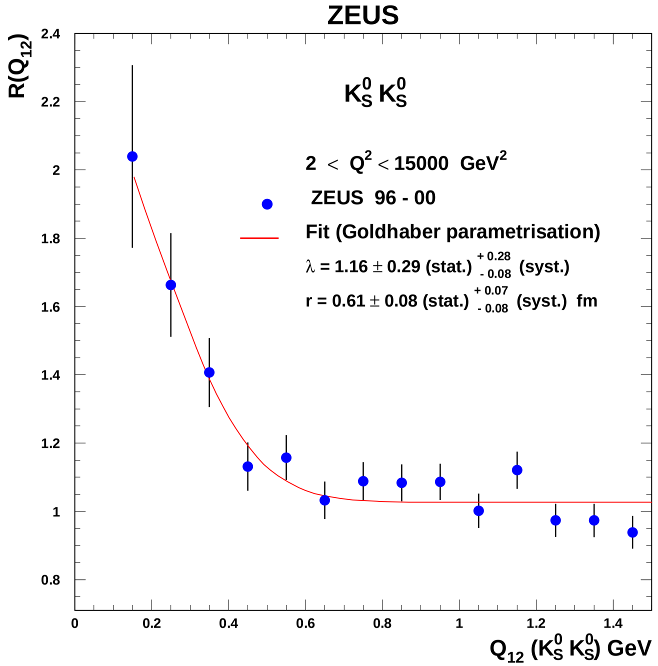
Standard parametrisation of $R(Q_{12})$ is Goldhaber-like parametrisation:

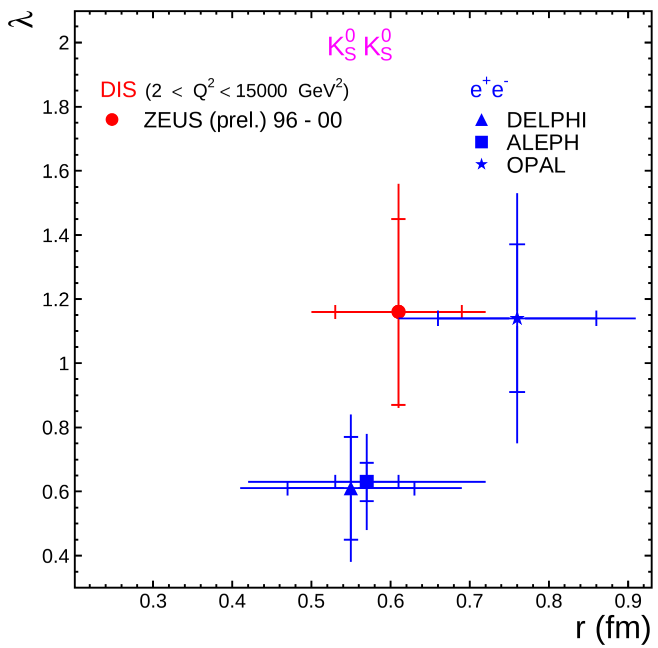
$$R(Q_{12}) = \alpha(1 + \lambda e^{-Q_{12}^2 \mathbf{r}^2})(1 + \delta Q_{12})$$

The correlation function $R(Q_{12})$ is measured using double ratio method:

$$R(Q_{12}) = \frac{P(Q_{12})_{data}}{P_{mix}(Q_{12})_{data}} \Big/ \frac{P(Q_{12})_{MCnoBEC}}{P_{mix}(Q_{12})_{MCnoBEC}}$$

BEC between $K_s^0 K_s^0$



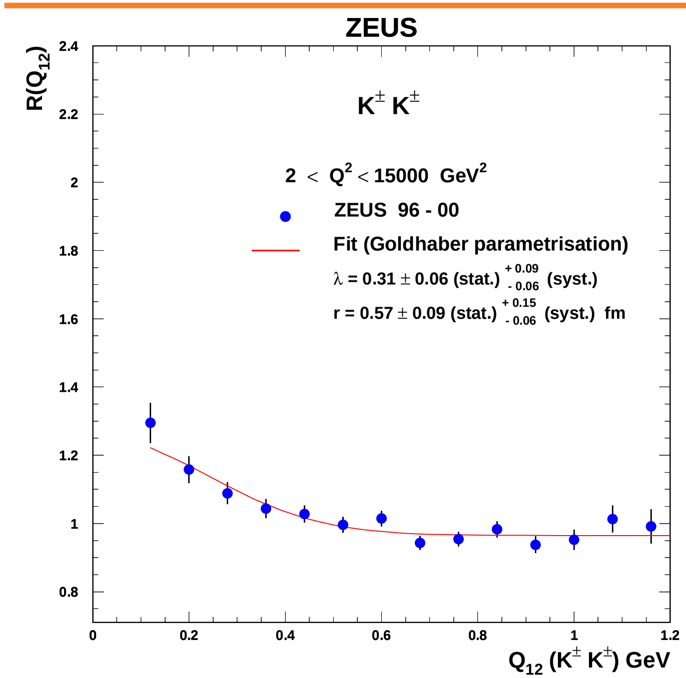


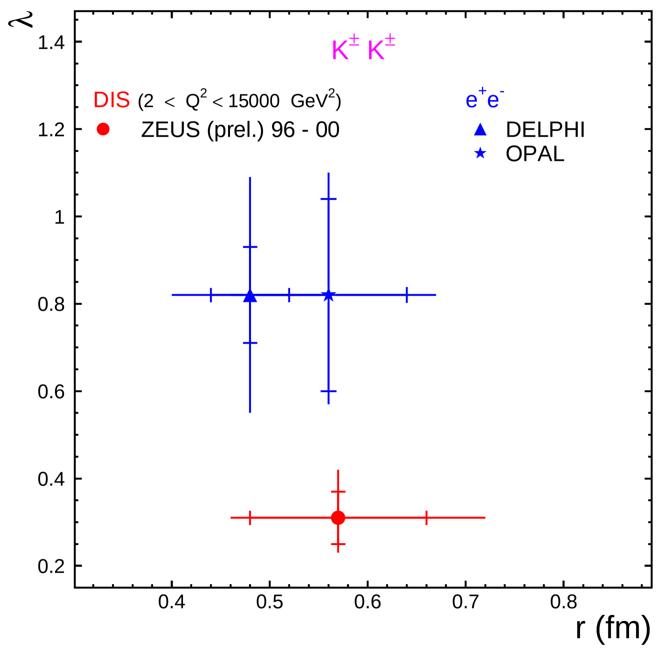
- ★ $96-00\ e^{\pm}p$ ZEUS data $\Rightarrow L = 121\ pb^{-1}$
- ★ DIS events sample: $2 < Q^2 < 15000\ GeV^2$
- ★ BE clearly effect visible
- ★ r value for $K_s^0 K_s^0$ is similar to $\pi^{\pm}\pi^{\pm}$

$$\left.\begin{array}{l} \lambda = 0.475 \pm 0.007(stat)^{+0.011}_{-0.003}(sys) \\ r = 0.666 \pm 0.009(stat)^{+0.022}_{-0.036}(sys)\,fm \end{array}\right\}$$ $\pi^{\pm}\pi^{\pm}$ (ZEUS) Phys. Lett. **B583** (2004) 231

- ★ good agreement with LEP for radius
- ★ higher λ value than for ALEPH, DELPHI
- ★ the $f_0(980)$ resonance is expected in the same low Q_{12} region where BEC are measured
- ★ small contribution of $f_0(980)$ in data can significantly change λ value
- ★ the estimation of $f_0(980)$ in data is $\sim 10\%$
- ★ the ALEPH, DELPHI removed f_0 resonance

BEC between $K^{\pm}K^{\pm}$





- ★ $96-00\ e^{\pm}p$ ZEUS data $\Rightarrow L = 121\ pb^{-1}$
- ★ DIS events sample: $2 < Q^2 < 15000\ GeV^2$
- ★ BE effect visible
- ★ r value for $K^{\pm}K^{\pm}$ is similar to $\pi^{\pm}\pi^{\pm}$ and $K_s^0K_s^0$

$$\lambda = 0.475 \pm 0.007(stat)^{+0.011}_{-0.003}(sys)$$
$$r = 0.666 \pm 0.009(stat)^{+0.022}_{-0.036}(sys)\,fm$$

$\pi^{\pm}\pi^{\pm}$ (ZEUS) Phys. Lett. **B583** (2004) 231

$$\lambda = 1.16 \pm 0.29(stat)^{+0.28}_{-0.08}(sys)$$
$$r = 0.61 \pm 0.08(stat)^{+0.07}_{-0.08}(sys)$$

$K_s^0K_s^0$ (ZEUS)

- ★ good agreement with LEP for radius
- ★ smaller λ value than for e^+e-
- ★ different fragmentation processes in $e^{\pm}p$ and e^+e^-
- ★ proton influence is expected - ZEUS data populate mostly proton fragmentation region
- ★ K^+K^- production from $\phi_0(1020)$ resonance decay - strong signal of $\phi_0(1020)$ in ZEUS data

Summary

- ★ The measurements of K_s^0, Λ, $\bar{\Lambda}$ production have been made at ZEUS
- ★ In high and low Q^2 DIS, ARIADNE generally describes the cross-sections
- ★ PYTHIA describes cross-sections in PHP well, except the x_γ^{OBS} dependence
- ★ ARIADNE follows the shape of the ratio of baryons to mesons
- ★ The baryon to meson ratio increases up to 0.7 at low x_γ^{OBS}, not predicted by PYTHIA
- ★ With good approximation, there is the same number of Λ and $\bar{\Lambda}$ produced
- ★ For strange to light meson ratio, ARIADNE requires $\lambda_s = 0.22$ rather than $\lambda_s = 0.3$
- ★ The BEC of $K_s^0 K_s^0$ and $K^\pm K^\pm$ were measured and compared to LEP results
- ★ The radius value for $K_s^0 K_s^0$ is consistent with $K^\pm K^\pm$ and with $\pi^\pm \pi^\pm$
- ★ The radius value is compatible with LEP results
- ★ λ value for $K_s^0 K_s^0$ is high due to the $f_0(980)$ influence in low Q_{12} region
- ★ Smaller λ for $K^\pm K^\pm$ in comparison with LEP due to proton influence