Status of Unpolarized Fragmentation Functions

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Global Analyses of Unpolarized FFs

- Light charged hadrons (l.c.h.) $\pi^\pm$, $K^\pm$, $p/\bar{p}$
- Σ Hadron (quark) spins and charge

Most recent are

Kniehl-Kramer-Pötter (2000)

$$\begin{aligned} D_u^{\pi^\pm}(x,M_0) &= D_d^{\pi^\pm}(x,M_0) \\ D_u^{K^\pm}(x,M_0) &= D_s^{K^\pm}(x,M_0) \\ D_u^{p/\overline{p}}(x,M_0) &= 2D_d^{p/\overline{p}}(x,M_0) \end{aligned}$$

Albino-Kniehl-Kramer (2005)

- Update of KKP
- $D^h_{u,d,s}$ from OPAL tagging probabilities
- Also for K_0^S, Λ

Since 2000, l.c.h. studies also from

- Bourhis, Fontannaz, Guillet, Werlen (charged)
- Kretzer ($\pi^\pm$, $K^\pm$, charged)

Data

Rely mostly on e$^+$+e$^-$ $\to Z, \gamma \to X + h (= h^+ + h^-)$

- h identified
- ALEPH, DELPHI, SLD ($\sqrt{s} = 91$ GeV), TPC (29 GeV) (uds, c, b)
- OPAL tagging probabilities ($\sqrt{s} = 91$ GeV) (u, d, s, c, b)

OPAL data rather model independent

Primary quark info by tagging high energy hadrons

Excluded in AKK:

- h unidentified (contaminated with other charged particles) - use for checking
- $x_p < 0.1$ (soft gluon logarithms)

Calculation

Factorization theorem I

($e^+e^- \to$ parton $i \to h$)

$$\frac{d\sigma^h}{dx_p}(x_p,s)=\sum_i\int_{x_p}^1\frac{dy}{y}\frac{d\sigma^i}{d(x_p/y)}\left(\frac{x_p}{y},M_f,s\right)D_i^h(y,M_f)$$

Neglect $O(1/\sqrt{s})$ higher twist

Factorization theorem II

(DGLAP evolution)

$$\frac{d}{d\ln M_f}D_i^h(x,M_f)=\sum_j\int_x^1\frac{dy}{y}P_{ij}\left(\frac{x}{y},a_s(M_f)\right)D_j^h(y,M_f)$$

$D_i^h(x,M_f)$ are universal

Work to NLO, freedoms:

- Scale: $\mu=M_f=\sqrt{s}$
- Scheme: $\overline{\mathrm{MS}}$
- $D_q^h(x,M_f<2m_q)=0$

$$D^h_{q=\bar{q},g}(x,M_0=\sqrt{2}\,\mathrm{GeV})=Nx^\alpha(1-x)^\beta$$

$\alpha_s(M_Z)$ Determination

Experimental errors

Vary $\alpha_s(M_Z)$ until $\Delta\chi^2_{\mathrm{DF}} = 1$

Theoretical errors

Fits with $\frac{M_f}{\sqrt{s}} = \frac{1}{2}, 2$

AKK

$$\alpha_s(M_Z) = 0.1176^{+0.0053(E)+0.0007(T)}_{-0.0067(E)-0.0009(T)}$$
$$= 0.1176^{+0.0053}_{-0.0068}$$

KKP

$$\alpha_s(M_Z) = 0.1170^{+0.0058}_{-0.0073}$$

PDG: $\alpha_s(M_Z) = 0.1187 \pm 0.002$

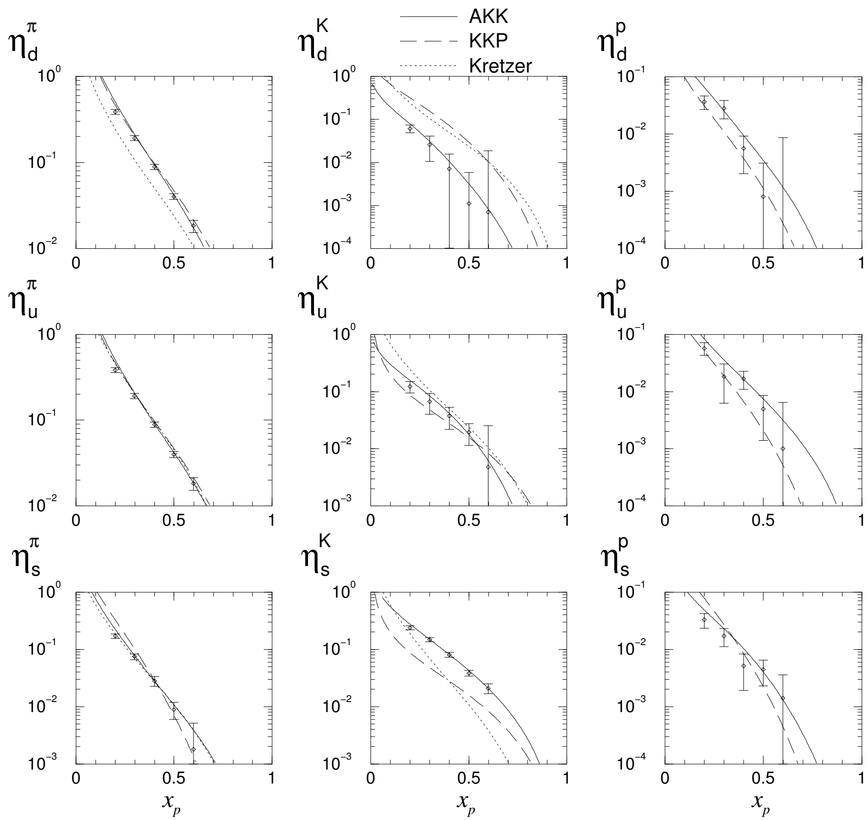
Inclusive hadroproduction data sensitive to $\alpha_s(M_Z)$

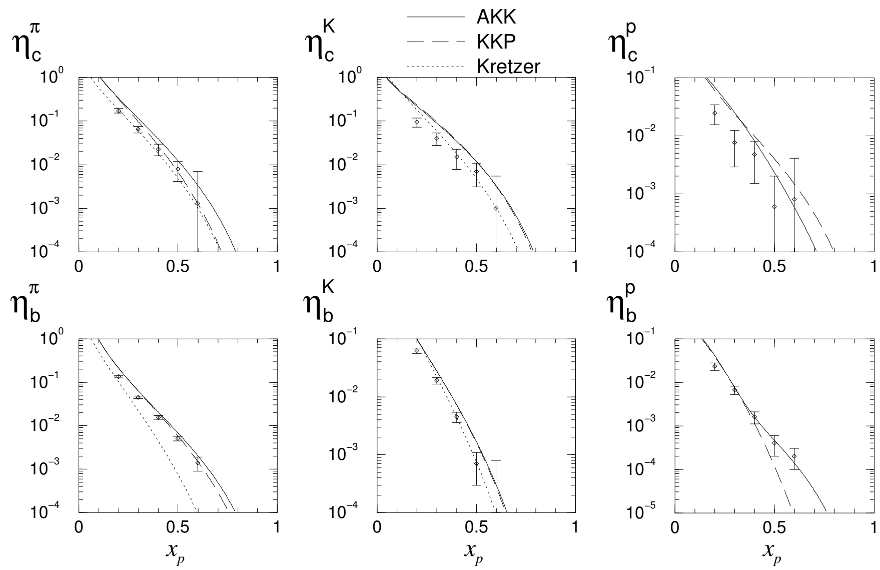
OPAL tagging probabilities

G. Abbiendi et al., Eur. Phys. J. C 16 (2000) 407

$$\eta^h_{q=\bar{q}}(x_p, s) = \int_{x_p}^1 dx \frac{\frac{d\sigma_q^h}{dx}(x,s)}{\sigma_q(s)}$$

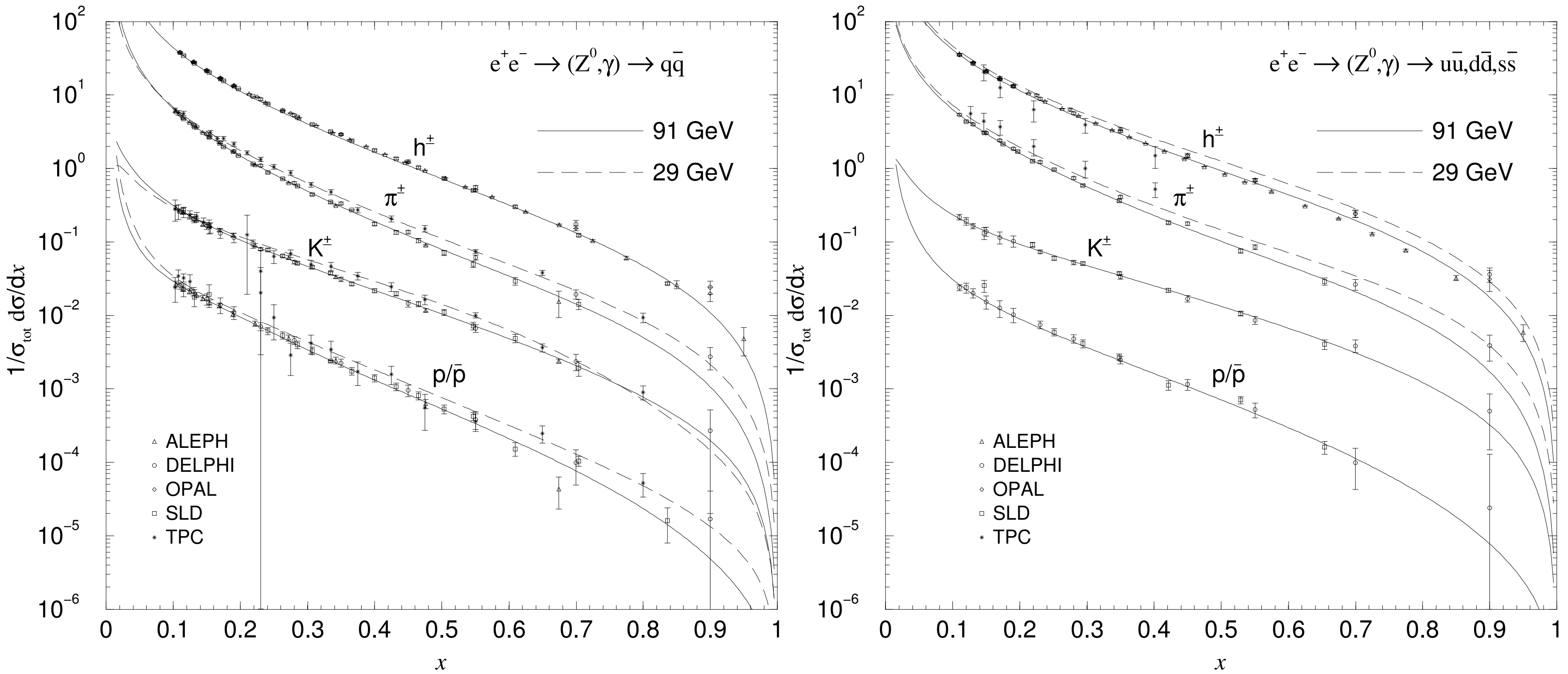
$q = u, d, s \qquad x_p \neq 0.2$: $\chi^2_{DF} \simeq 1$ $\qquad\qquad q = c, b \qquad \chi^2_{DF} \gg 1$



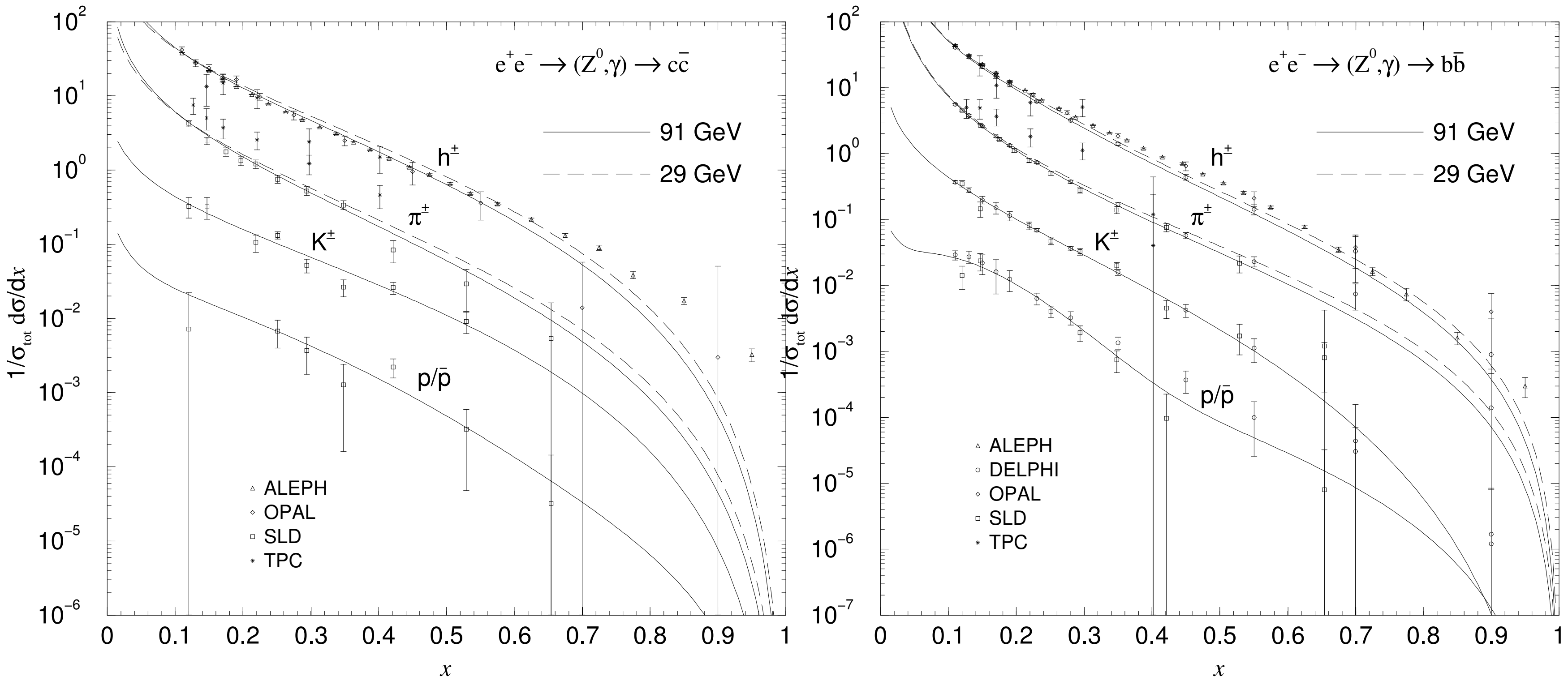


This framework: OPAL low x + heavy quark $\not\leftrightarrow$ other data

Light charged hadron data



Light charged hadron data



ALEPH, OPAL summed l.c.h. data overshoot (see KKP work)

$\rightarrow$ These data may contain other charged particles

Gluon sensitivity

Not included in fit

3-jet data $\simeq D_g(x, M_f = 2E_{\rm jet})$

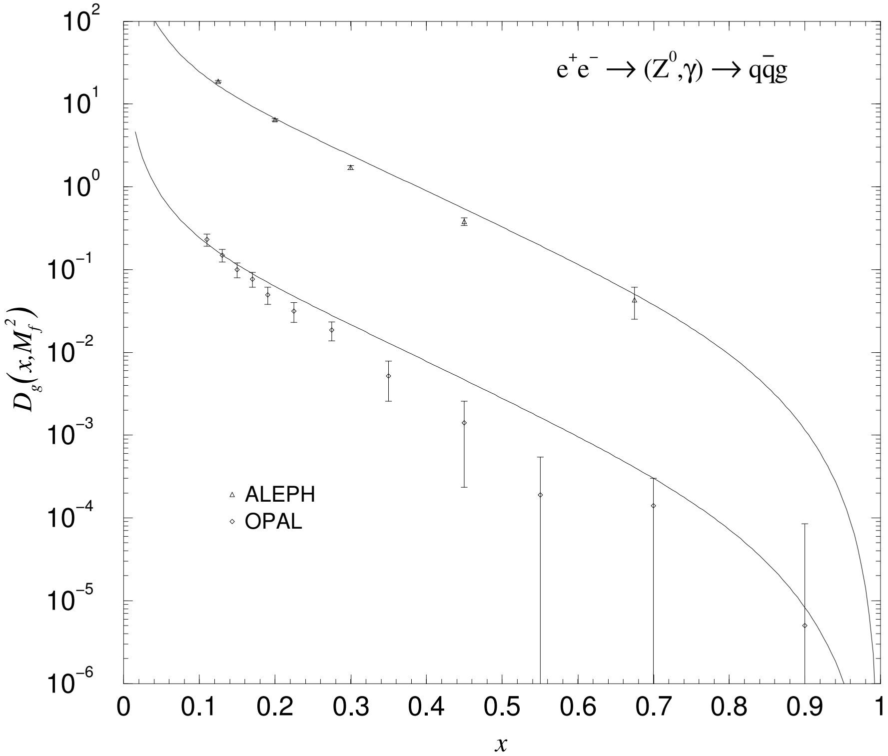
$E_{\rm jet}$(ALEPH)=26.2 GeV

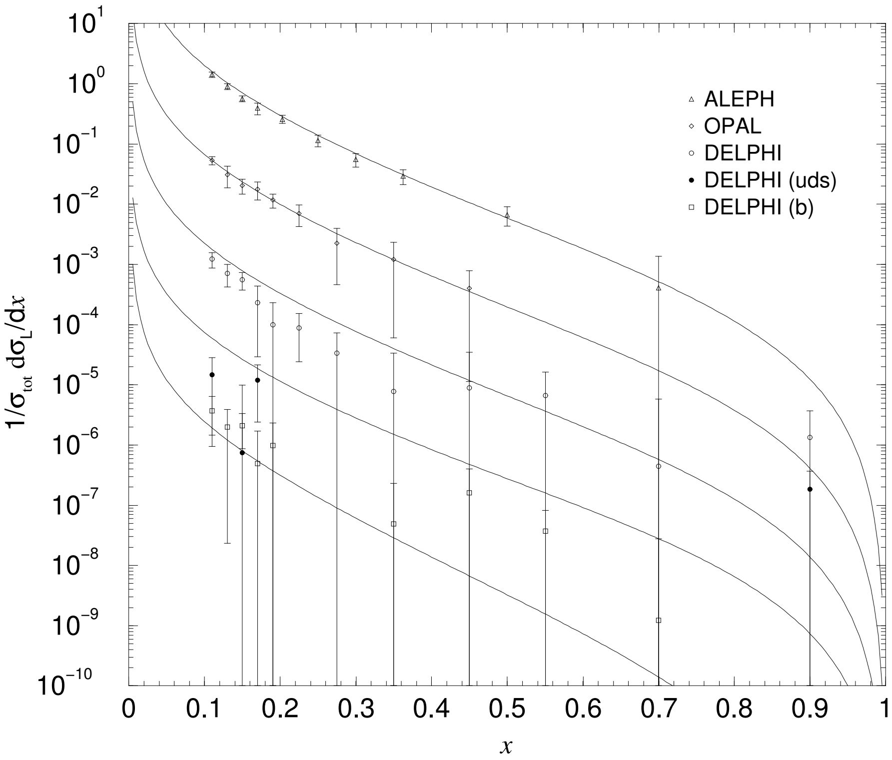
$E_{\rm jet}$(OPAL)=40.1 GeV

$d\sigma_L$ well defined

D_g at LO

$\rightarrow D_g$ OK





$p + p(\overline{p}) \rightarrow h + X$

Not included in fit

$$M_f/p_T = 1/2, 1, 2$$

PHENIX 200 GeV

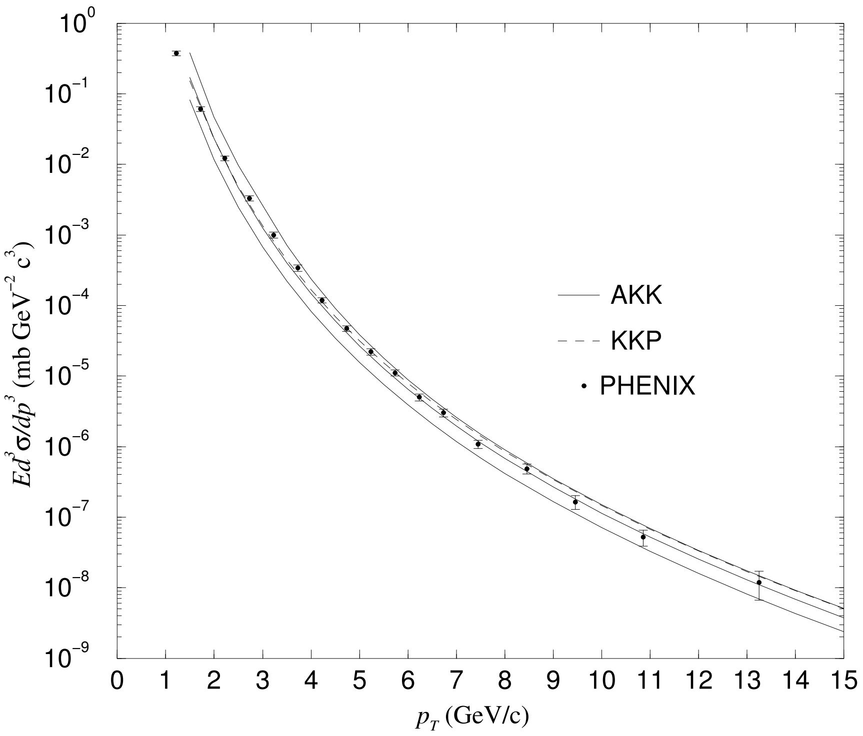
$$p + p \rightarrow \pi^0 + X$$

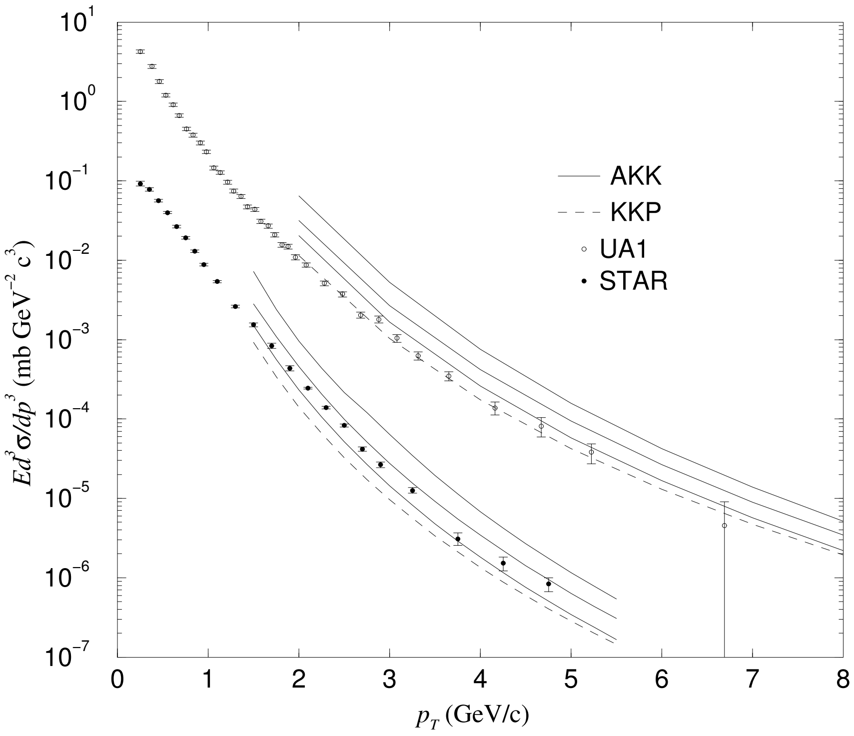
$$D_a^{\pi^0}(x, M_f) = \frac{1}{2} D_a^{\pi^\pm}(x, M_f)$$

STAR / UA1 200 / 630 GeV

$$p + p/\overline{p} \rightarrow K_S^0 + X$$

$$D_a^{K_S^0}(x, M_f) = \frac{1}{2} D_{a(u\leftrightarrow d)}^{K^\pm}(x, M_f)$$



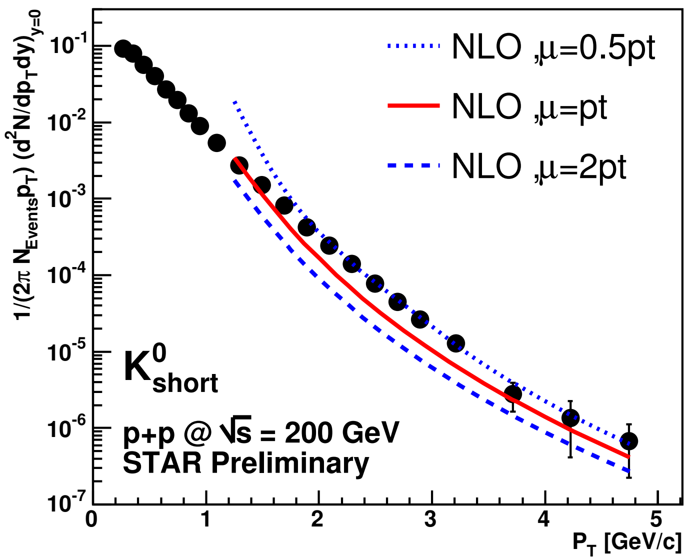


Neutral weakly decaying K_S^0 and Λ

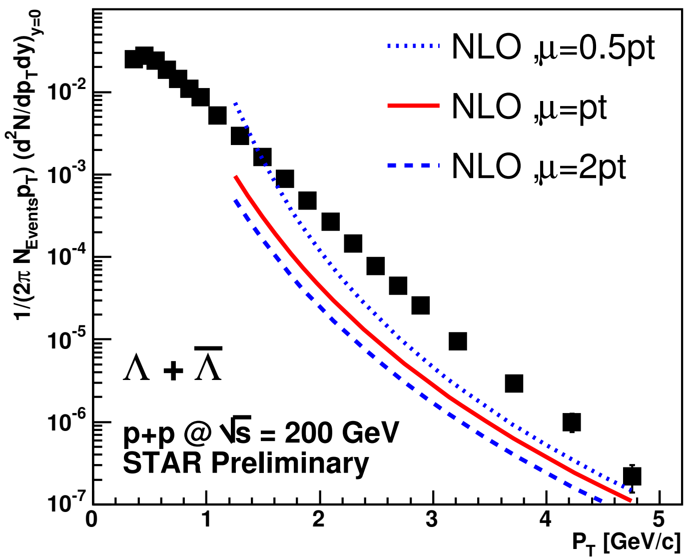
Decaying to charged particles $\rightarrow$ production observable

Previous determinations by

- K_S^0: Greco, Rolli - HERWIG (1995)
- Λ: de Florian, Stratmann, Vogelsang (1998); Bourrely, Soffer (2003)



KKP ($K^{\pm}$)



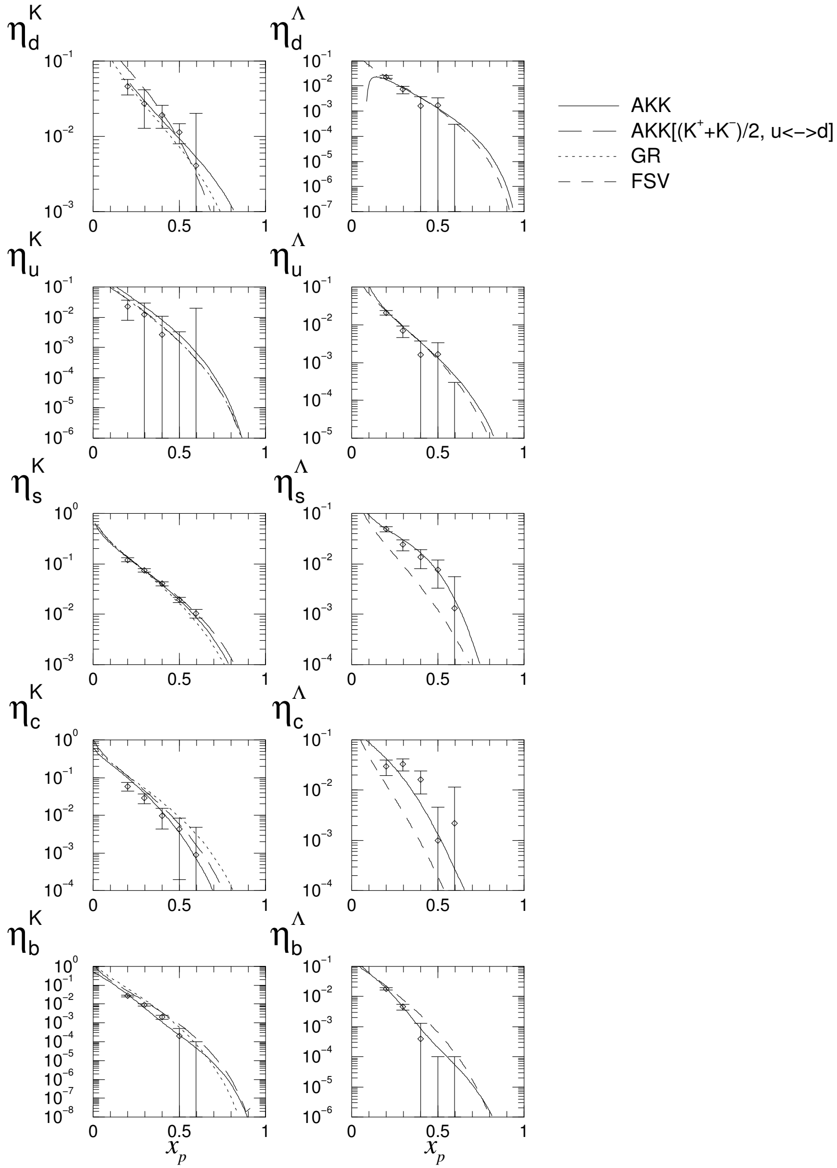
FSV

New n.w.h. data from STAR@RHIC merits improved FFs

K^0_S, Λ - OPAL tagging probabilities

Data quality: n.w.h. < l.c.h.

- Fix $\alpha_s(M_Z) = 0.1176$ (AKK central value)
- Fix gluon FF (see later slide)



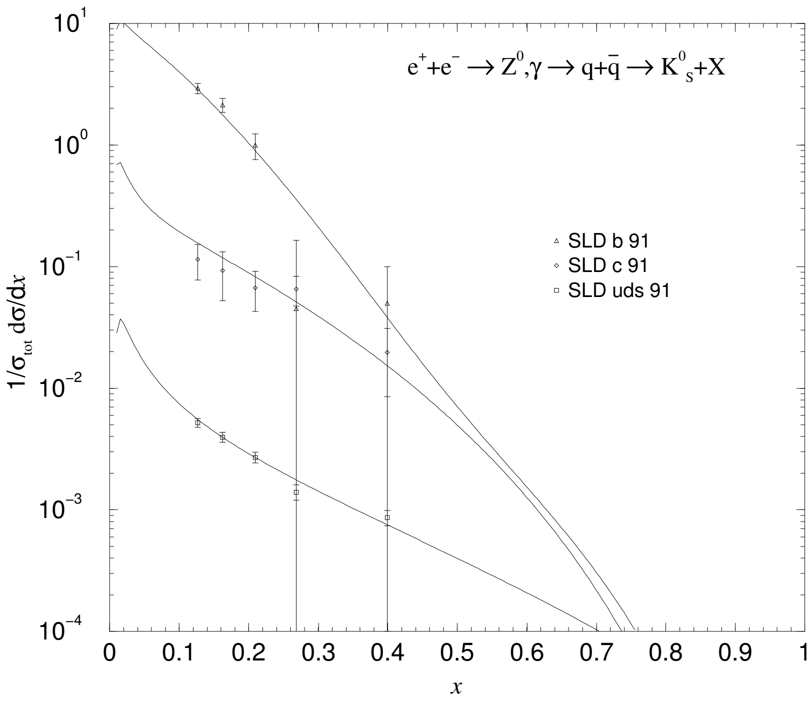
Again, separate u, d, s with OPAL tagging probabilities

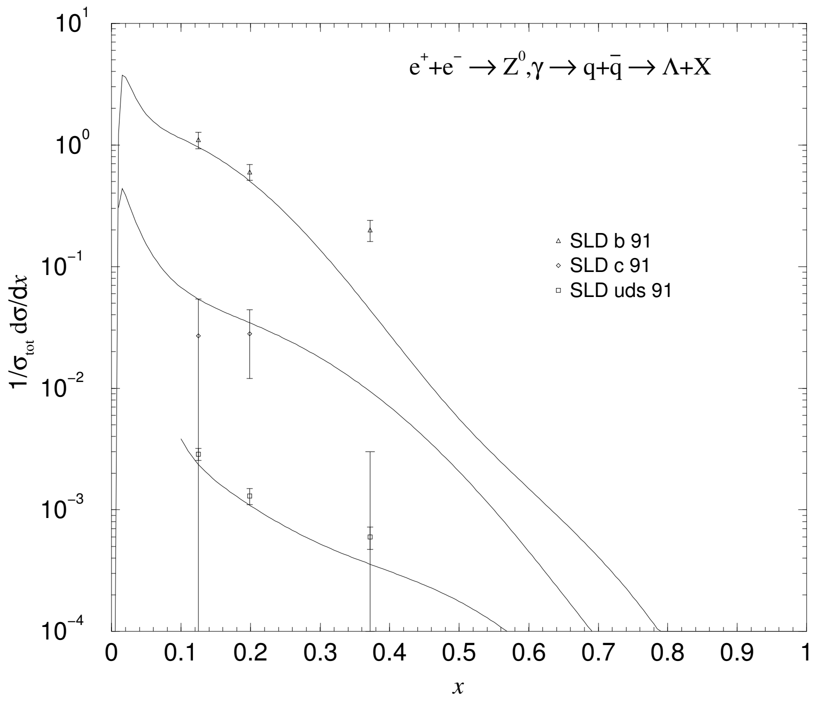
Low x + heavy quark data: good fit (in contrast to l.c.h. data)

Λ, large x: s, $c \gg u$, d, b

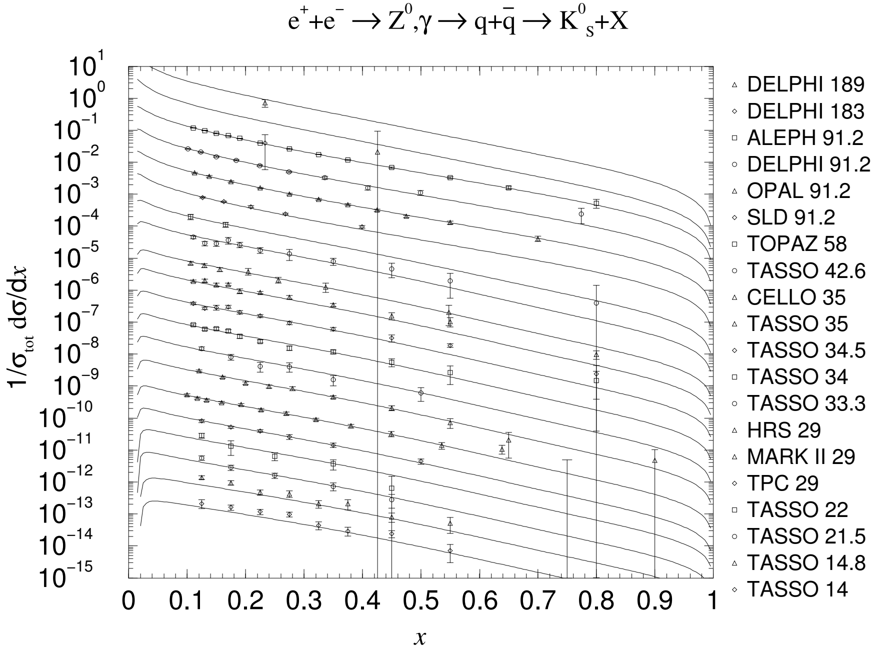
Λ implicitly contains parton$\rightarrow \Sigma^0 \rightarrow \Lambda$

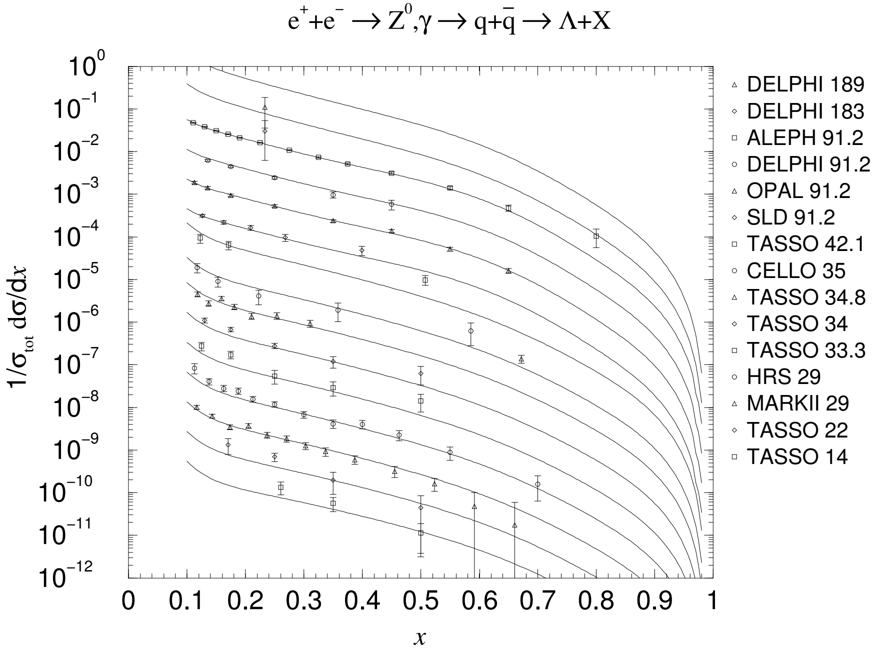
K_S^0, Λ - quark tagging





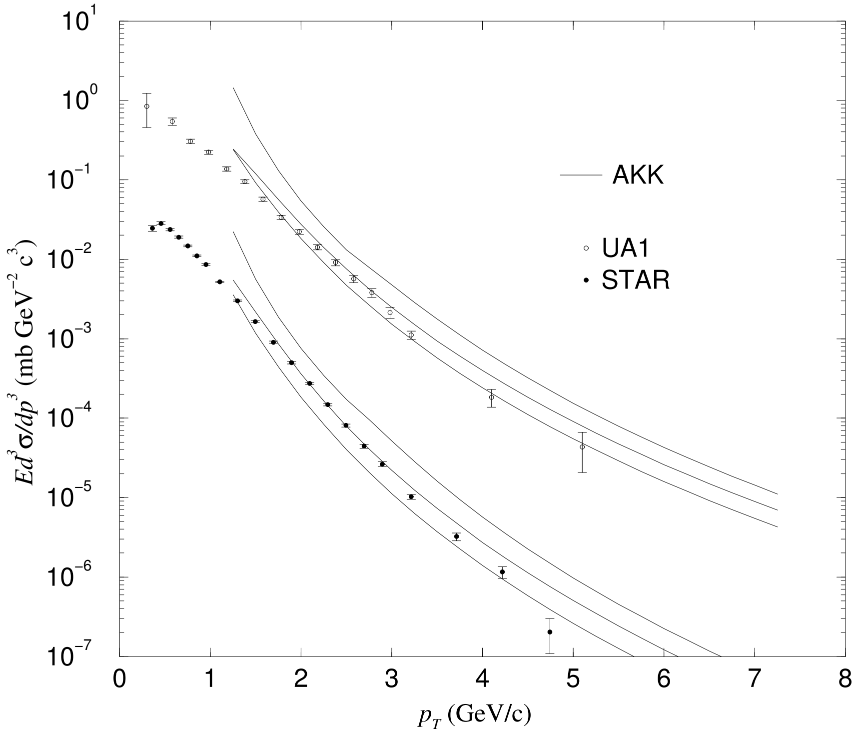
K_S^0, Λ - untagged



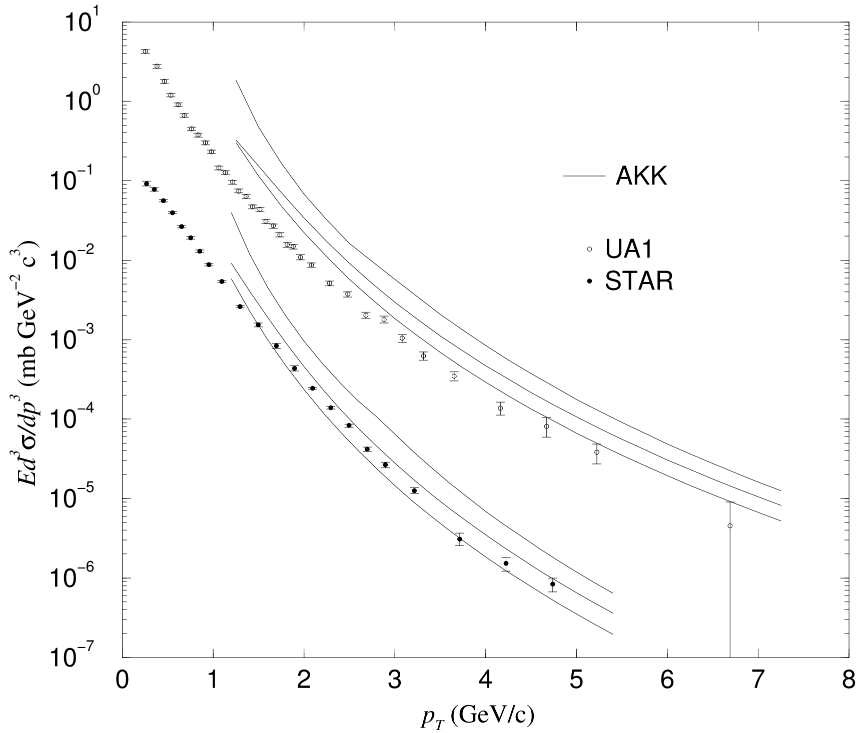


$p + p(\overline{p}) \rightarrow K_S^0/\Lambda + X$

$D_g^\Lambda = \frac{D_g^p}{3}$ (3: STAR motivated)



$D_g^{K_S^0} = \frac{1}{2} D_g^{K^\pm}$



Strong dependence on D_g^Λ

Summary

AKK: Includes OPAL tagging probabilities

$\rightarrow g, u, d, s, c, b$ for $\pi^\pm$, $K^\pm$, $p/\overline{p}$, K^0_S, Λ for first time

Sensible result for $\alpha_s(M_Z)$

AKK l.c.h., compared to KKP:

- Smaller $d \rightarrow K^\pm$, larger $s \rightarrow K^\pm$
- Better agreement with K^0_S@STAR, worse with K^0_S@UA1

AKK n.w.h.:

- $K^0_S \simeq$ GR's — K^0_S@STAR good, K^0_S@UA1 not
- $s, c \rightarrow \Lambda \gg$ FSV's — Λ@STAR+UA1 good

http://www.desy.de/ simon/AKK2005FF.html

Simple to make KKP $\rightarrow$ AKK update to software