STRANGE AND CHARMED PARTICLE PRODUCTION AT MID-RAPIDITY WITH THE HERA-*B* EXPERIMENT

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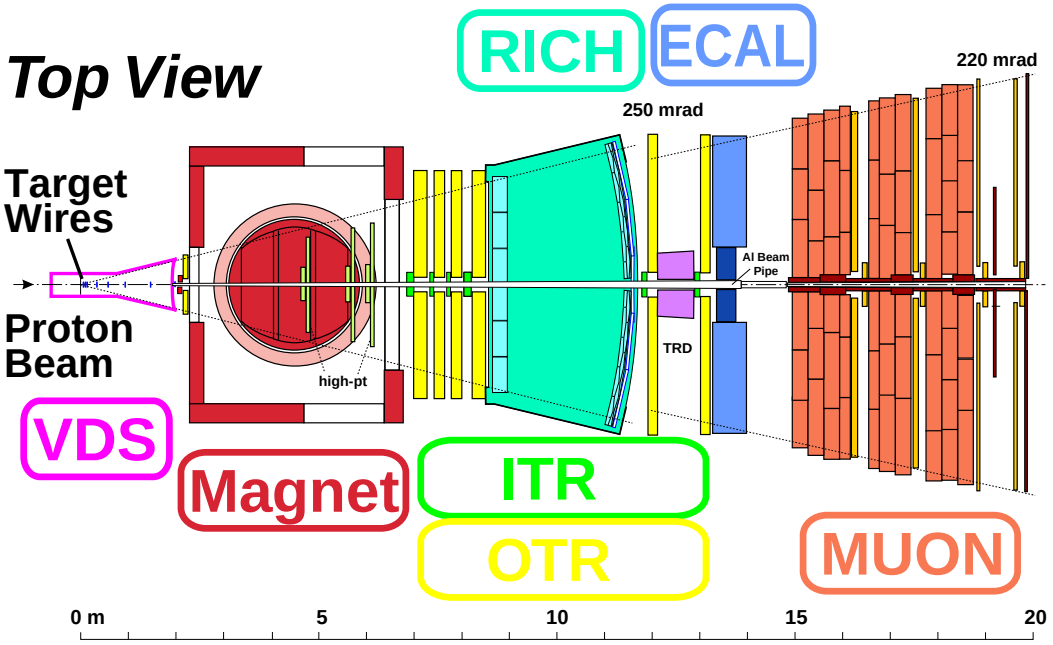
Quark Matter 2004, Oakland, 15 January 2004

- HERA-*B* spectrometer/experiment
- Data sets
- Physics program with MB data
- Results - production of:
  Strange: K^0_S, Λ, ϕ, K^{*0}, hyperons, pentaquarks
  Charmed: D^0, D^+, D^{*+}

The HERA-*B* Spectrometer

- HERA-*B* experiment on HERA storage ring at DESY, Hamburg, Germany
- Fixed target experiment (using beam halo)
- 920 GeV p energy ($\sqrt{s} = 41.6$ GeV)
- Angular acceptance: 15-220 mrad (bending plane), 15-160 mrad (vertical)

- Target: 5 different materials (C, Al, Ti, Pd, W)
  - 8 target wires
  - steered individually
- Tracking:
  - VDS (Si strips, pitch ≈50 μm)
  - main tracker (OTR+ITR)
- Magnet: $\int B\, dz = 2.13$ Tm
- Excellent particle ID:
  - RICH: identification of π, K and p
  - ECAL: identification of e
  - MUON: identification of μ



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Data sets

Two data taking periods:

- 2000 - first data with fully operational spectrometer
- 2002/2003 - main data statistics obtained

Data were taken in two modes:

- J/ψ triggered data:

  $J/\psi \rightarrow \mu\mu$ and ee (see talk by J. Spengler and posters by M. Villa and W. Gradl)

  $\approx$ 150M events

- Minimum bias data: **presented in this talk**

  Interaction 'trigger': selecting only non-empty events (with hits in RICH or ECAL energy above threshold)

  data taken with 3 different target materials (C, Ti and W)

  approximately 210M events

  DAQ logging rate: 1000 Hz (1.7 TB/day)

Physics program with MB data

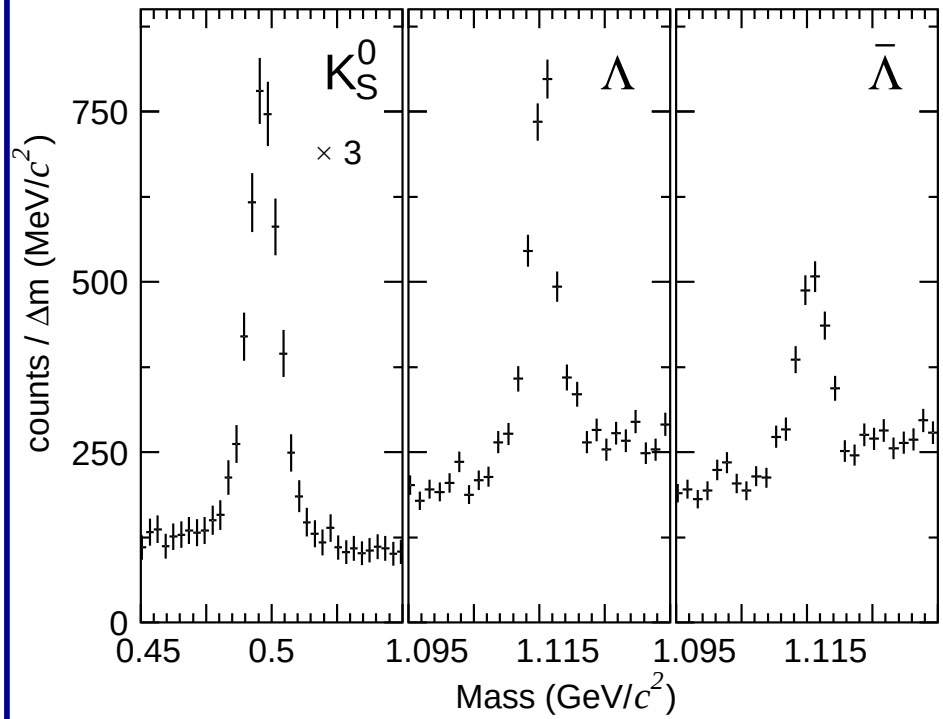
- wide range of signals reconstructed
- strange particle production:
  K_s^0 and Λ
  ϕ, K^{*0} $\rightarrow$(poster by M. Symala & C. van Eldik)
  hyperons $\rightarrow$(poster by T. Živko)
  pentaquark search $\rightarrow$(poster by K. T. Knöpfle)
- charmed particle production:
  open charm signals: D^0, D^+, D^{*+},...
- many other topics: double particle production, Λ polarization, Bose-Einstein correlations, glueball, exotics...

In many topics mentioned above first **preliminary** results (based on 2002/2003 data) are already available and will be presented in this talk.

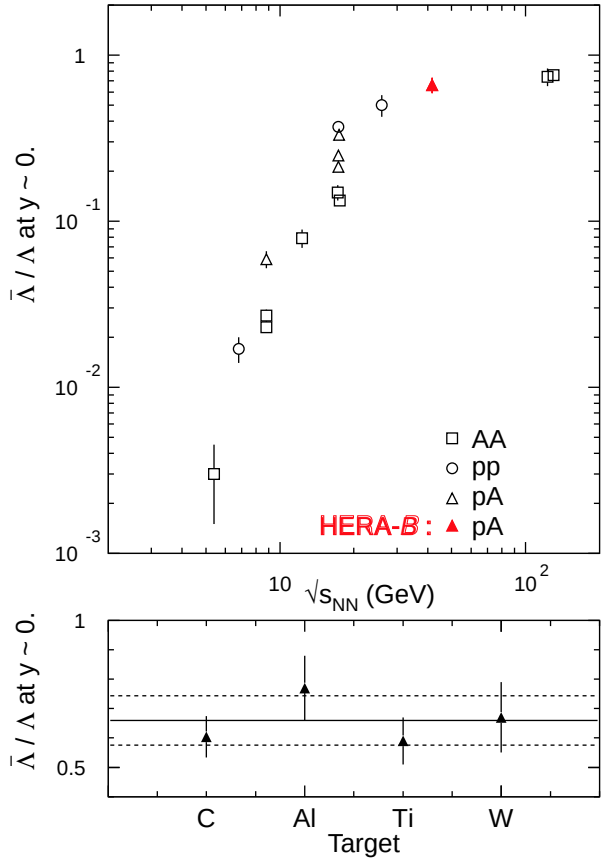
K^0_s and Λ

Results based on 2000 data (published in ***Eur.Phys.J.C 29, 181-190 (2003)***)

Reconstructed $\pi^+\pi^-$, $p\pi^-$ and $\bar{p}\pi^+$ invariant masses:



Ratio of $\bar{\Lambda}$ over Λ @ mid-rapidity determined:

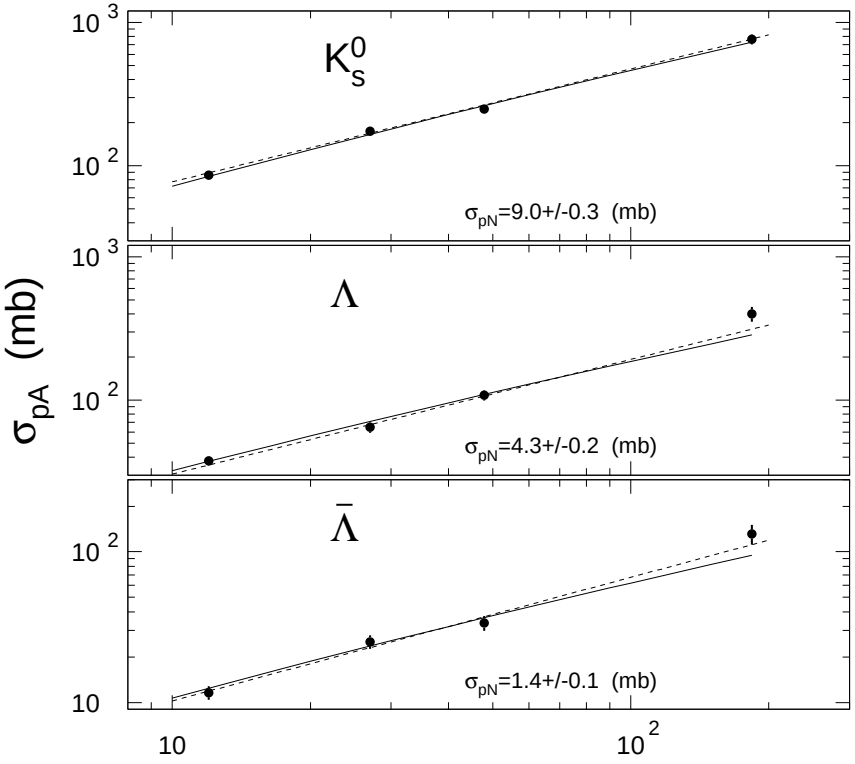


≈2.4M randomly triggered events

$$\mathrm{d}\sigma(\bar{\Lambda})/\mathrm{d}\sigma(\Lambda) = 0.66 \pm 0.07$$

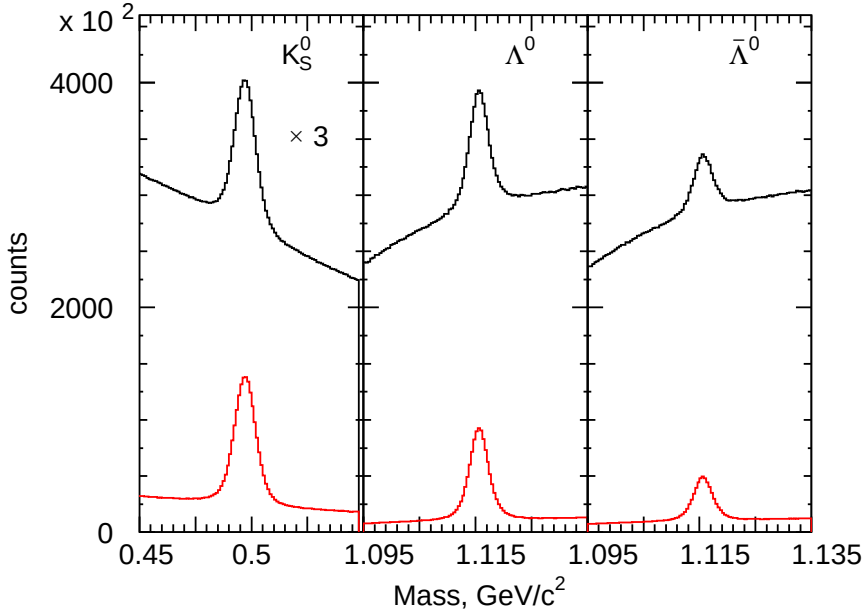
K^0_s and Λ cont.

Signal was reconstructed using different target materials (C, Al, Ti, W):



$$\sigma = \sigma_0 A^{\alpha}$$

Data of 2002-2003 with more than **100** times larger statistics are being analyzed.



	K^0_s	Λ	$\bar{\Lambda}$
N_{peak}	≈3M	≈1M	≈0.4M

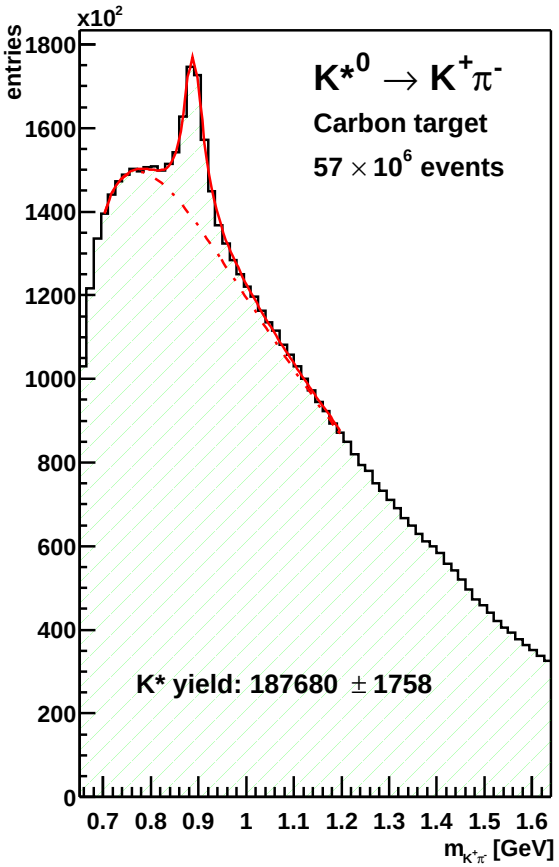
ϕ and K^{*0}

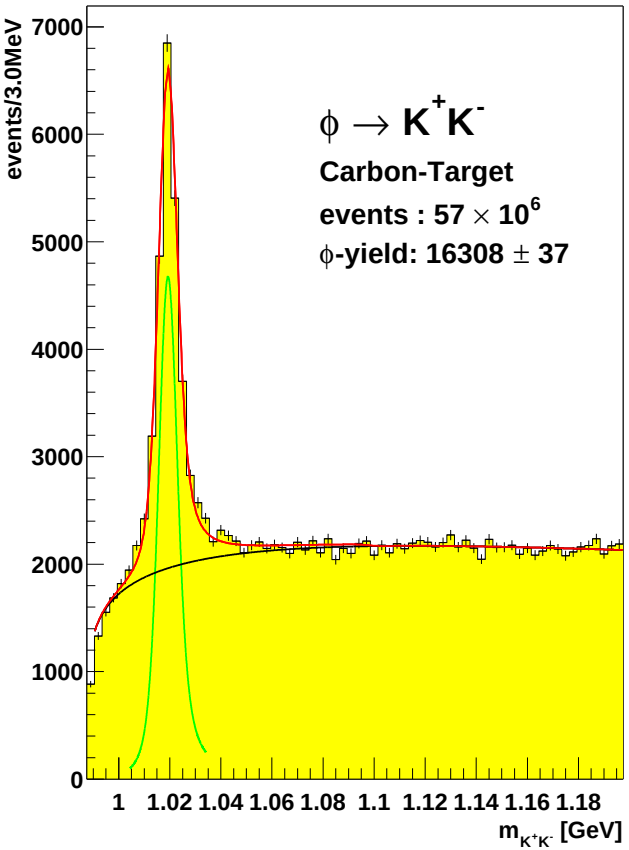
Data of 2002/2003:

- $\approx$ 50k $\phi \to K^+K^-$ reconstructed (both K identified in RICH)
- $\approx$ 530k $K^{*0} \to K^+\pi^- + \text{c.c.}$ (K identified in RICH)
- signals reconstructed on 3 different targets (C, Ti and W)

We expect to measure:

- total production cross section
- A-dependence (α parameter)
- differential distributions ($\mathrm{d}\sigma/\mathrm{d}p_T^2$, $\mathrm{d}\sigma/\mathrm{d}y$)
- $\alpha = \alpha(p_T^2)$





→ See poster by C. van Eldik & M. Symalla

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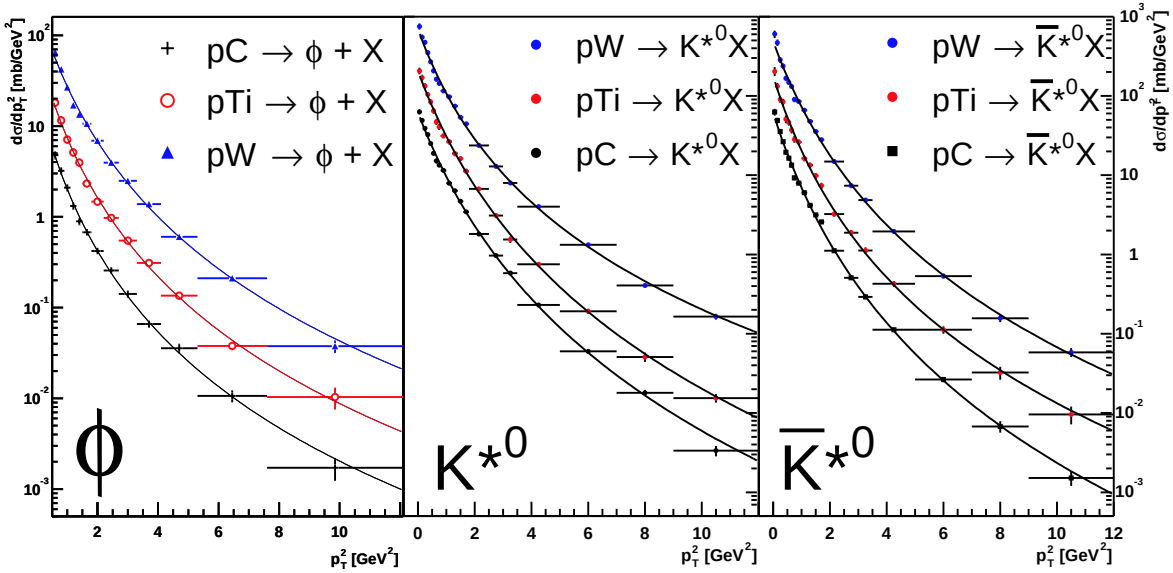
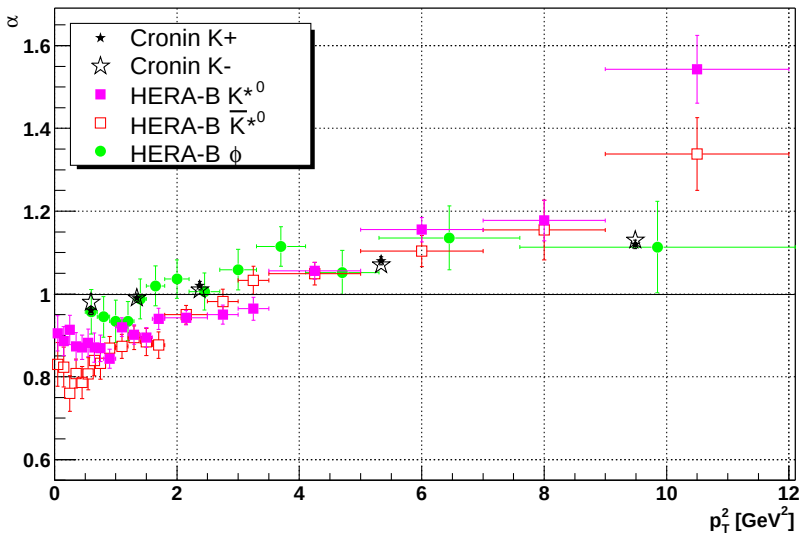
ϕ and K^{*0} cont.

Preliminary result on differential cross section

Parameterization: $\frac{\mathrm{d}\sigma}{\mathrm{d}p_T^2} \propto \left(1 + \frac{p_T^2}{p_0^2}\right)^{-\beta}$



- Cronin effect observed ($\alpha > 1$ for large p_T^2)



material	β_ϕ	β_{K^*}	$\beta_{\bar{K}^*}$
C	$4.32 \pm 0.31_{\mathrm{stat}}$	$6.02 \pm 0.18_{\mathrm{stat}}$	$6.10 \pm 0.22_{\mathrm{stat}}$
Ti	$4.29 \pm 0.34_{\mathrm{stat}}$	$5.83 \pm 0.23_{\mathrm{stat}}$	$5.23 \pm 0.25_{\mathrm{stat}}$
W	$4.34 \pm 0.23_{\mathrm{stat}}$	$4.42 \pm 0.11_{\mathrm{stat}}$	$5.31 \pm 0.19_{\mathrm{stat}}$

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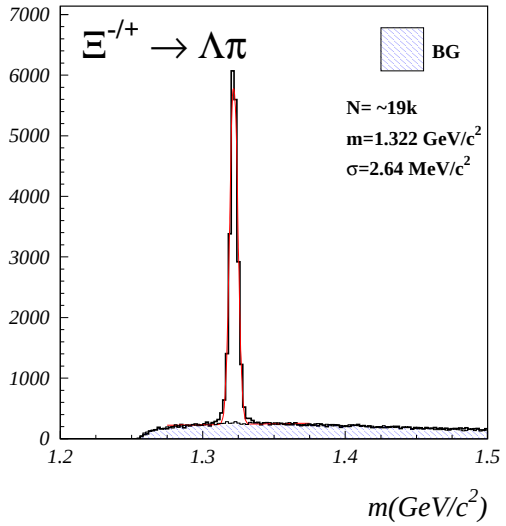
Hyperons

Hyperons decaying through Λ were seen:

hyperon	reaction	num of rec.
$\Xi^{+/-}$	$\Xi^- \to \Lambda\pi^- + \text{c.c.}$	≈19000
$\Omega^{+/-}$	$\Omega^- \to \Lambda K^- + \text{c.c.}$	≈1250
$\Xi^0(1530)$	$\Xi^0(1530) \to \Xi^-\pi^+ + \text{c.c.}$	≈2800

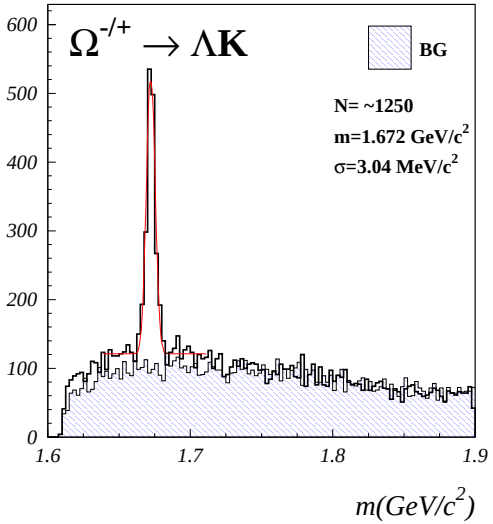


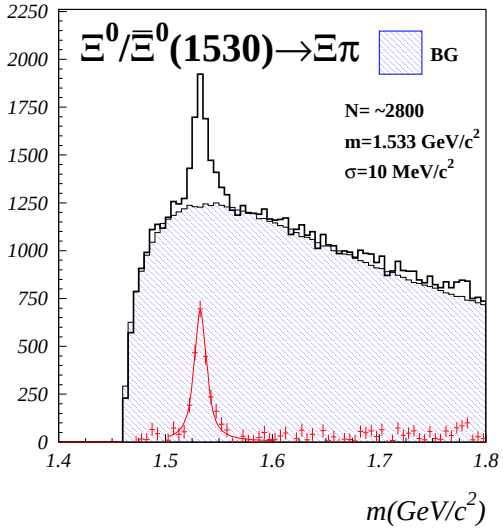
Program:

- measure the production cross section
  + A-dependance
- differential cross section $\mathrm{d}\sigma/\mathrm{d}x_F$
- asymetry in producing the hyperons and anti-hyperons $\frac{\sigma-\bar{\sigma}}{\sigma+\bar{\sigma}}$
  x_F dependance

Analysis still ongoing.

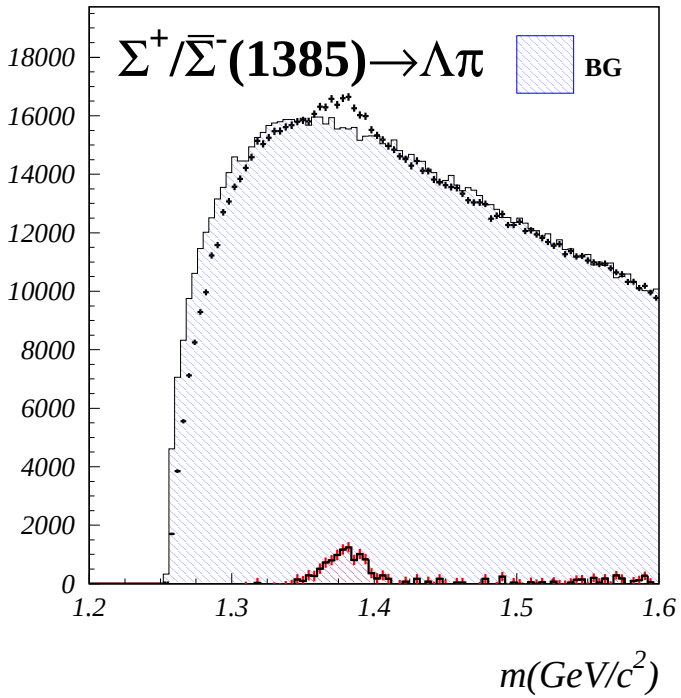
See poster by T. Živko.

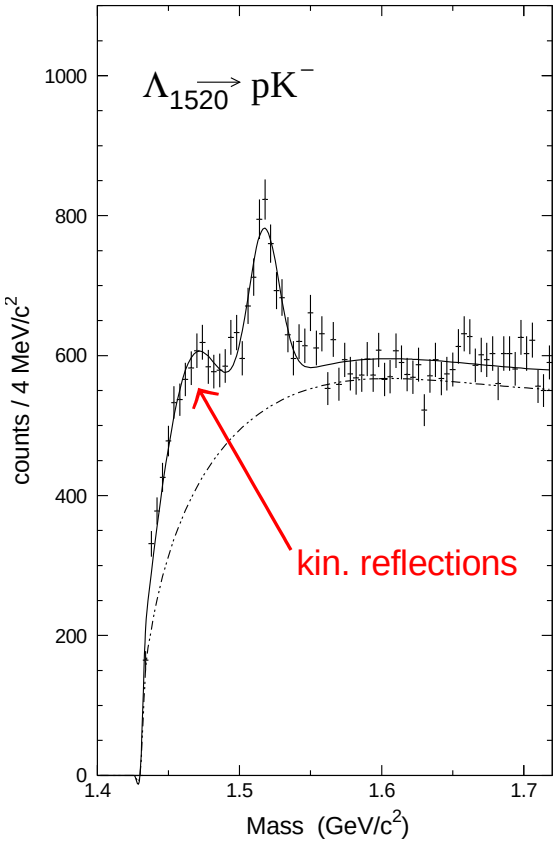


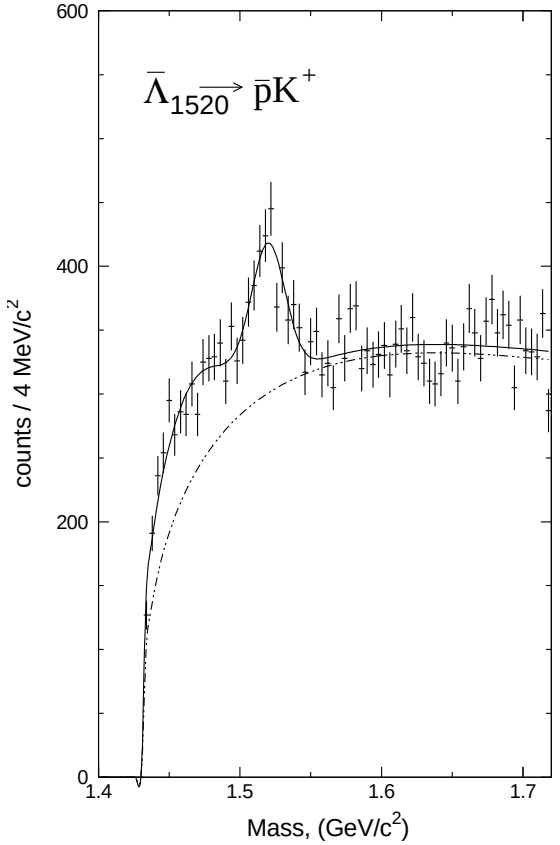


Hyperons - cont.

Other hyperons signals reconstructed ($\Sigma^+(1385)$, $\bar{\Sigma}^-(1385)$, $\Lambda(1520)$ and $\bar{\Lambda}(1520)$):

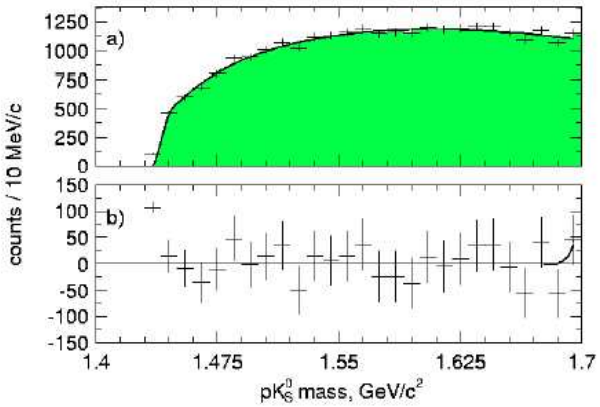




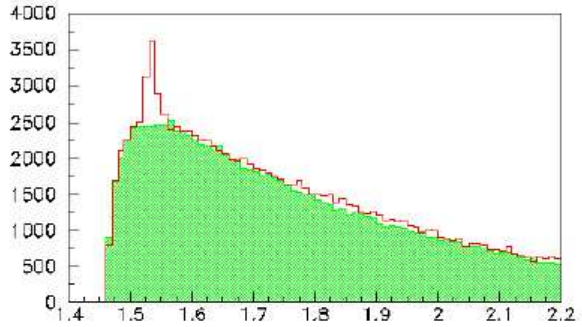


Pentaquark search at mid-rapidity

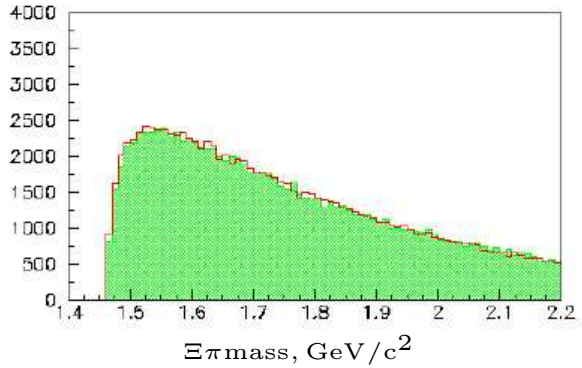
pK^0_s invariant mass
no indication of $\Theta^+(1530)$ →



$\Xi^0(1530) \to \Xi^-\pi^+$ signal →



$\Xi^-\pi^-$+c.c. invariant mass
no evidence for
$\Xi^{--/++}(1862)$ →



→ poster by K. T. Knöpfle

- strong signals of:
  $\Lambda(1520) \to pK^-$
  $\Xi^0(1530) \to \Xi^-\pi^+$
- no evidence for
  $\Theta^+(1530)$ or $\Xi^{--/++}(1862)$
- sensitivity in $br \cdot \mathrm{d}\sigma/\mathrm{d}x_F$ at mid-y better than:
  $5\mu\mathrm{b/nucl.}$ ($\Theta^+(1530)$)
  $10\mu\mathrm{b/nucl.}$ ($\Xi^{--/++}(1862)$)
- ratio:
  $\Theta^+(1530)/\Lambda(1520) < 0.002$
  $\Xi^{++}(1862)/\Xi^0(1530) < 0.04$
  (95% C.L.)

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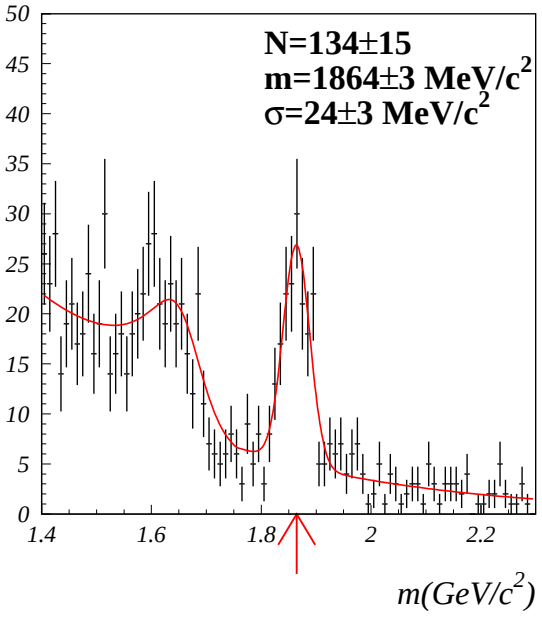
Open-charm - Introduction

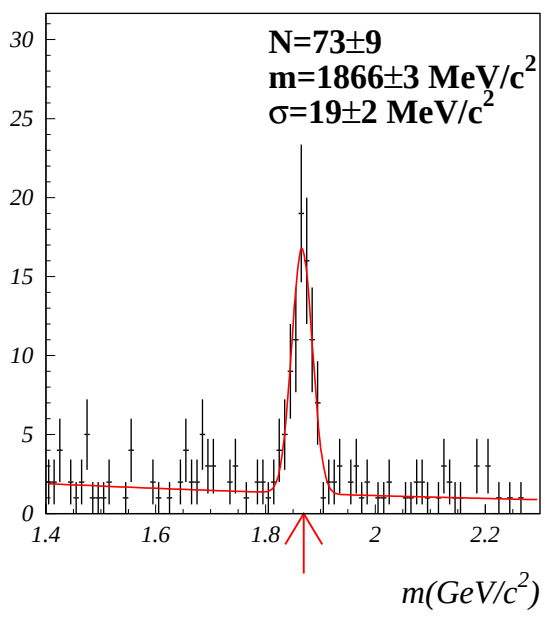
- Open-charm signals observed in:

$$D^0 \to K^-\pi^+ + \text{c.c.}$$
$$D^+ \to K^-\pi^+\pi^+ + \text{c.c.}$$
$$D^{*+} \to D^0\pi^+ \to K^-\pi^+\pi^+ + \text{c.c.}$$

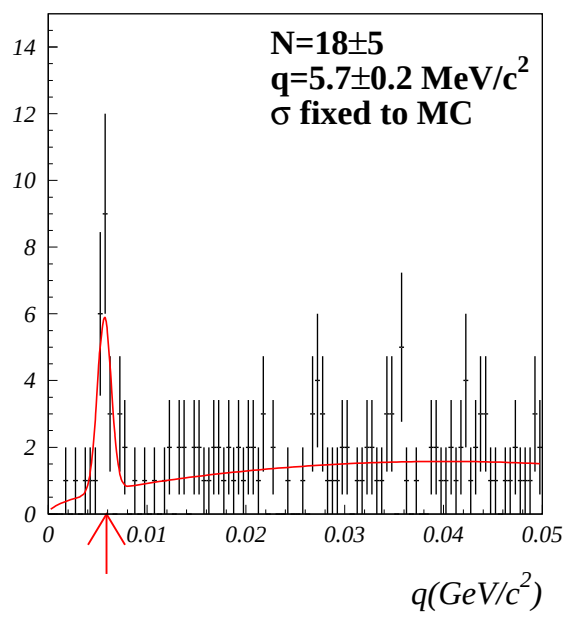
$D^0 \to K^-\pi^+ + \text{c.c.}$



$D^+ \to K^-\pi^+\pi^+ + \text{c.c.}$



$D^{*+} \to D^0\pi^+ \to K^-\pi^+\pi^+ + \text{c.c.}$



- Preliminary results on total production cross section for D^0 and D^+
- Preliminary results for production ratio D^+/D^0

$$q = m_{K\pi\pi} - m_{K\pi} - m_\pi$$

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Open-charm - data analysis

To select events the following selection criteria were used:

- *Event selection:* $\geq$1 prim. vertex reconstructed
- *Particle ID:* identification of K and π in RICH
- *Kinematical & geometric cuts:*

	D^0	D^+
x_f range	$-0.1 < x_f < 0.05$	$-0.1 < x_f < 0.05$
vertex prob(χ^2,ndf)	> 0.01	> 0.01
distance significance	$>$ **6**	$>$ **10**
D impact par. significance	< 3	< 3
K impact par. significance *	> 4	
π impact par. significance *	> 4	> 4

* if several primaries, the minimal value of significances was taken

Open-charm - efficiency

- Cross-section:

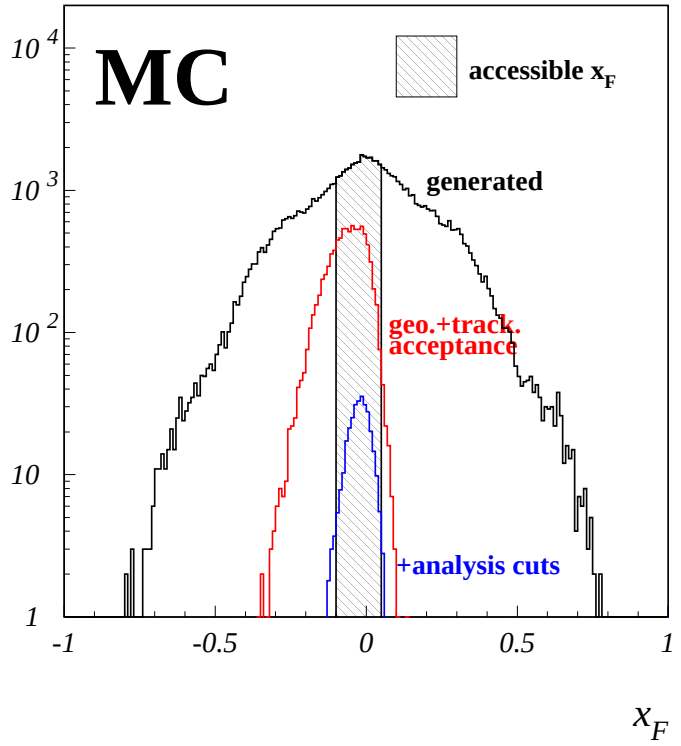
$$\sigma_D = \frac{N_D}{\epsilon \cdot br \cdot \sum A_i L_i}, \qquad \sum A_i L_i = 10794 \mu b^{-1}$$

($\alpha = 1$ assumed)

- MC used for efficiency determination
  PHYTIA 5.7 - $pN \to Q\bar{Q}X$
  FRITIOF 7.02 - the remaining part

- Efficiency for $D^0 \to K^-\pi^+$:
  overall: **0.58%**
  main losses:
  $\to$ detector acceptance ($\approx$13%)
  $\to$ detached vertex ($\approx$10%)

- Accessible kinematic range: $x_F \in [-0.1, 0.05]$



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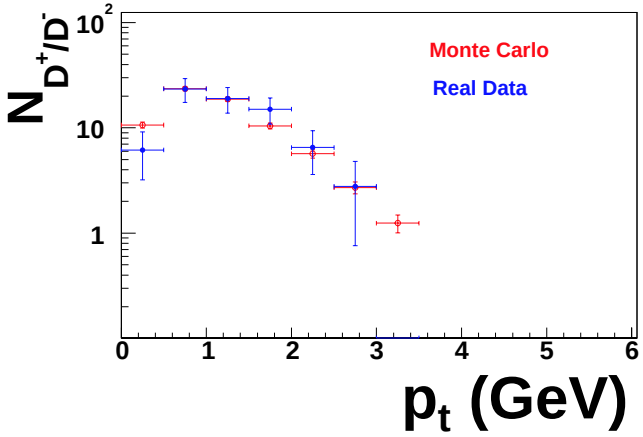
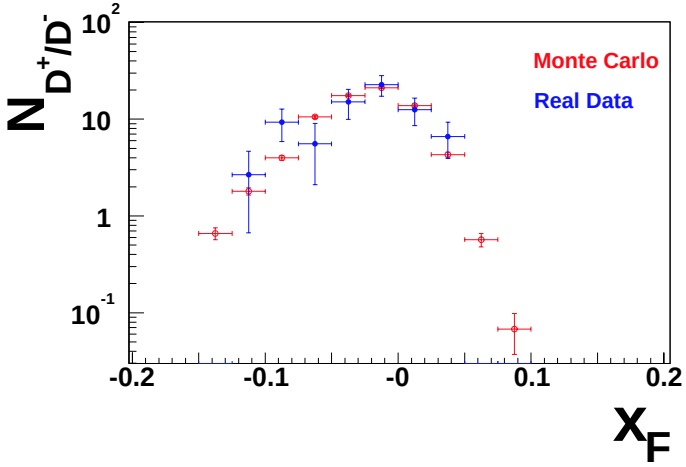
Open-charm - distributions

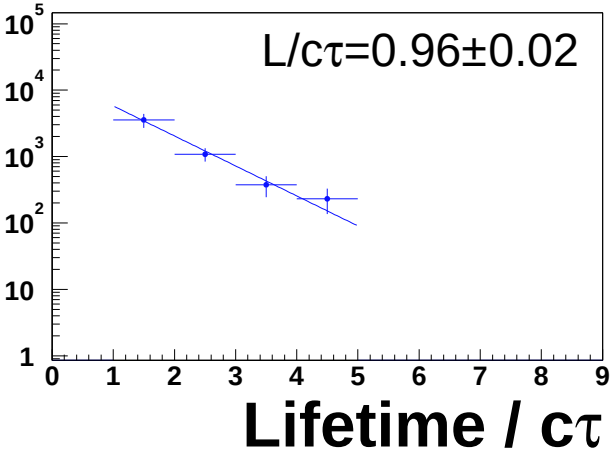
p_t

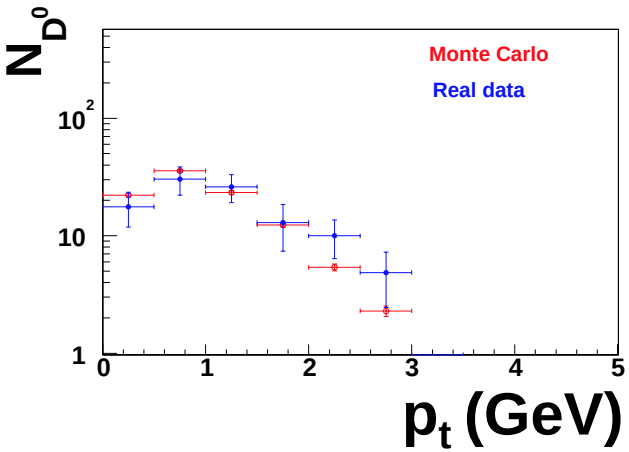


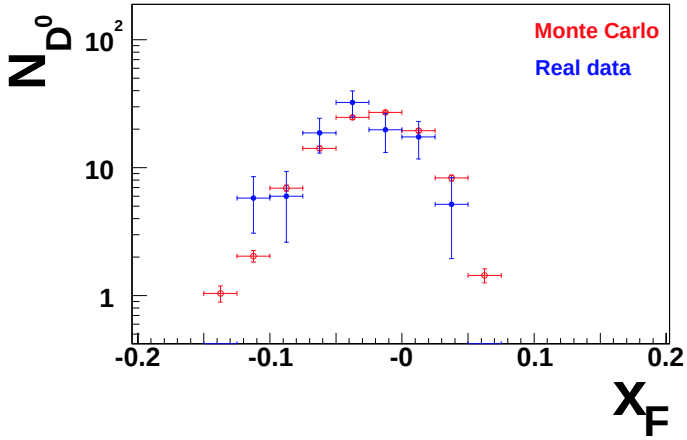
x_F

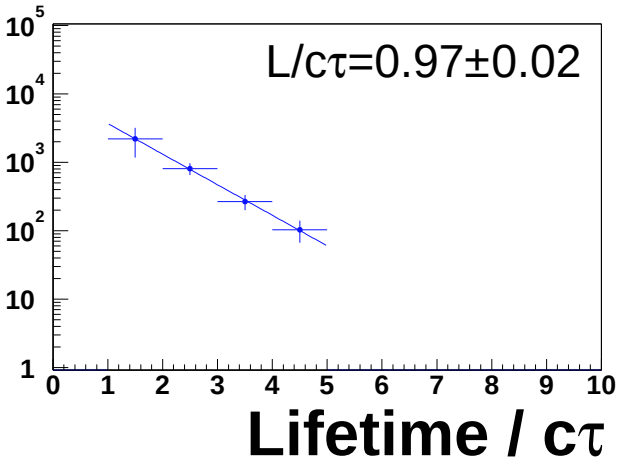


$c\tau$





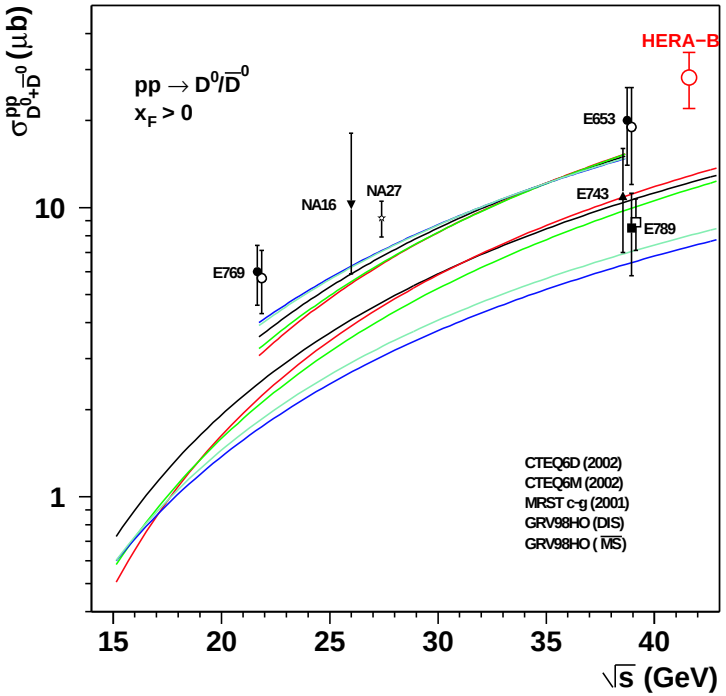


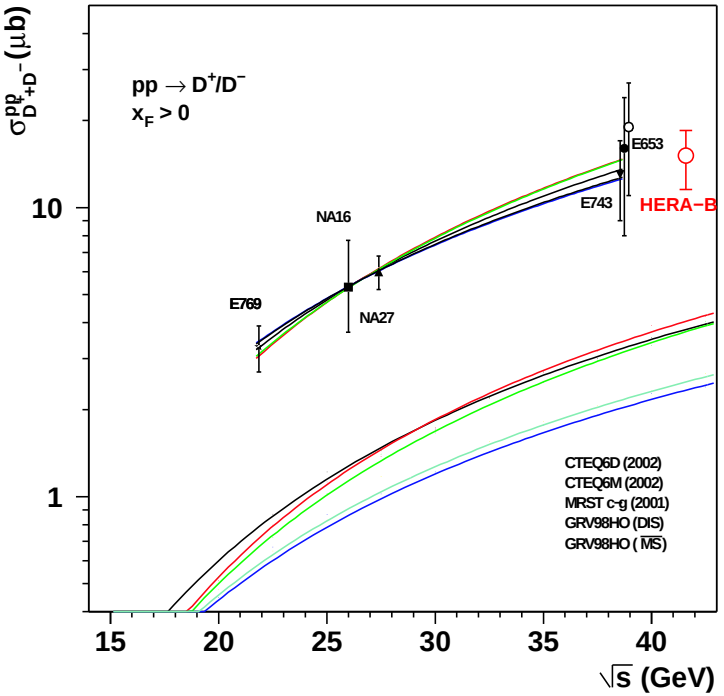


Open-charm - cross section & ratio

Preliminary results for D^0 and D^+ production cross section and their ratio @ HERA-B obtained

	total (full x_F)	$-0.1 < x_F < 0.05$
$\sigma(D^0)$ μb/nucl	**56.3**$\pm$**8.5**$_{\rm stat}\pm$**9.5**$_{\rm syst}$	21.4 $\pm$ 3.2 $_{\rm stat}\pm$3.6$_{\rm syst}$
$\sigma(D^+)$ μb/nucl	**30.2** $\pm$ **4.5** $_{\rm stat}\pm$**5.8**$_{\rm syst}$	11.5 $\pm$ 1.7 $_{\rm stat}\pm$2.2$_{\rm syst}$
$R(D^+/D^0)$	**0.54** $\pm$ **0.11** $_{\rm stat}\pm$ **0.14**$_{\rm syst}$	





Reference: *C. Lourenco and H. Wöhri, private communication*

Summary

- Presented published results on K^0_s and Λ production based on 2000 data.
- Presented preliminary results based on data form 2002-2003
  - ***s***: ϕ and K^{*0} differential cross section
  - ***s***: $\alpha(p_T^2)$ for ϕ and K^{*0}
  - ***s***: limits on pentaquark production
  - ***c***: D^0 and D^+ production cross section
  - ***c***: production ratio $R = D^0/D^+$
- Presented signals:
  - ***s***: hyperons ($\Xi^{+/-}$, $\Omega^{+/-}$, $\Xi^0(1530)$, $\Sigma^+/\bar{\Sigma}^-(1385)$, $\Lambda/\bar{\Lambda}(1520)$)
  - ***c***: D^{*+}
- On all topics the analysis is still ongoing

Outlook:

- finalize analyses
- K^0_s and Λ 2002-3
- production cross sections (ϕ, K^{*0}, hyperons, D^{*+}, J/ψ,...)
- A-dependence
- asymmetry (hyperons, open-charm,...)