Pentaquark Searches with H1 at HERA

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DESY
on behalf of the H1 collaboration

Outline:

- HERA and H1
- Search for Strange Pentaquark
- Search for Charm Pentaquark

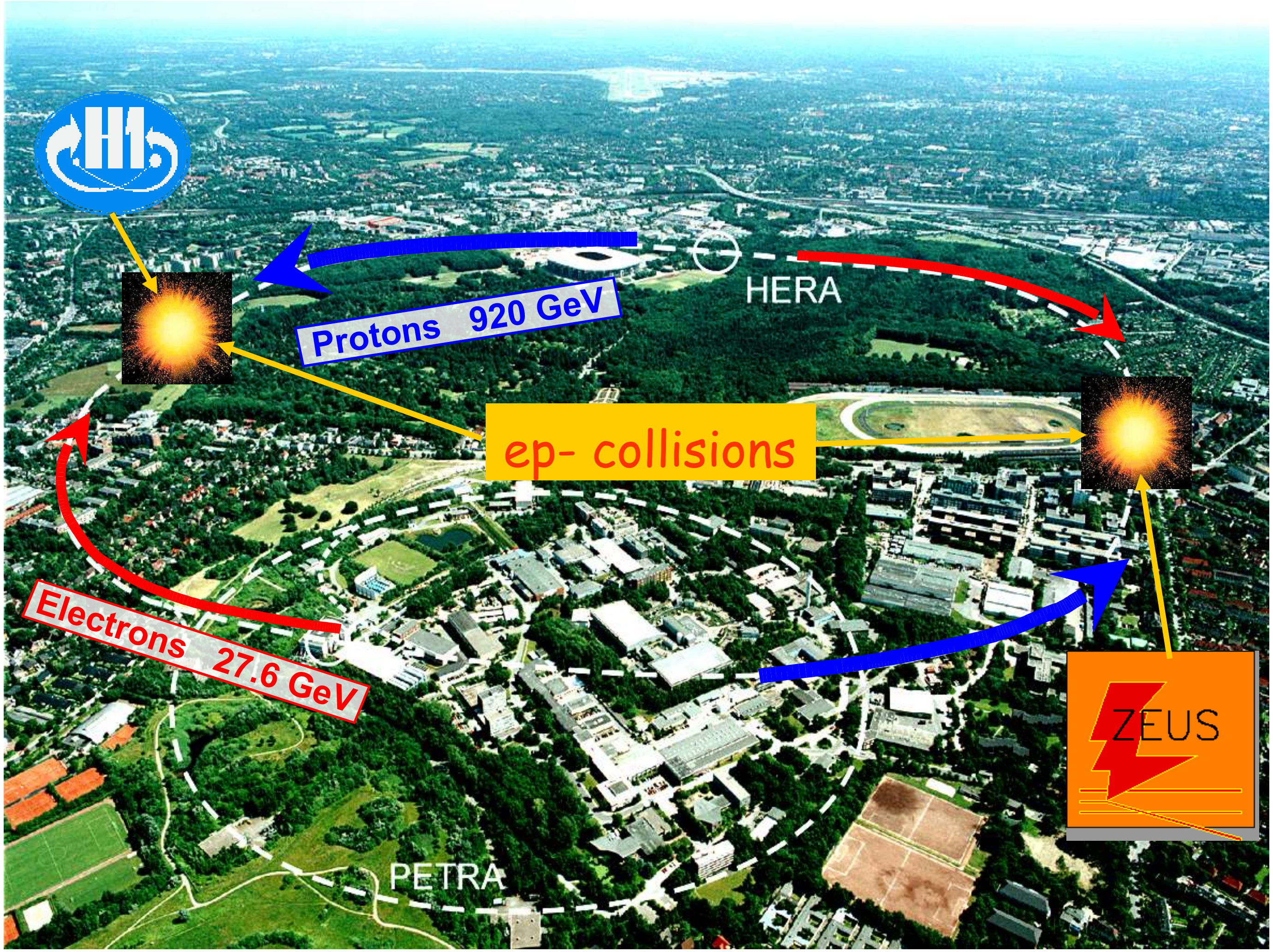
The HERA accelerator

E_e = 27.6 GeV

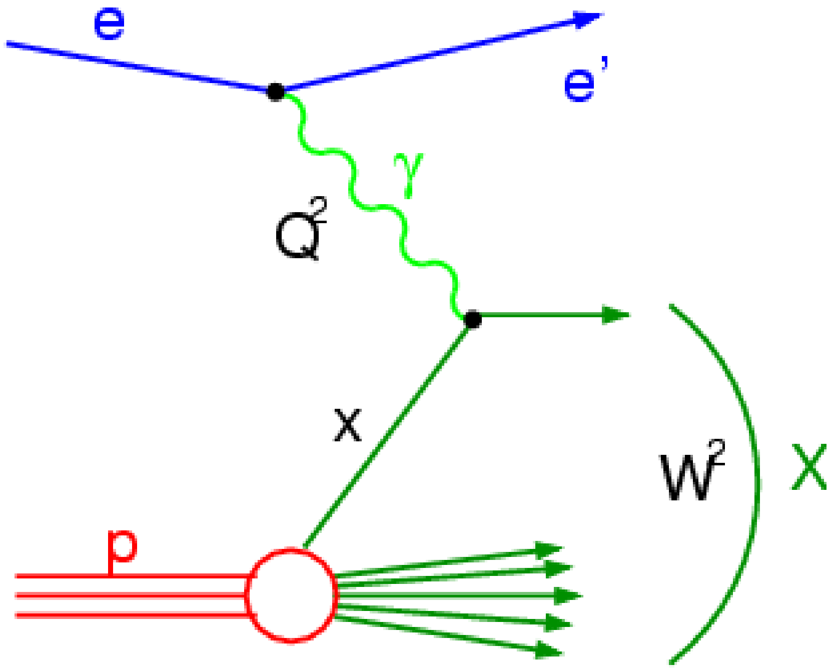
E_p= 920 (820) GeV

ep collisions at $\sqrt{s}$ ≈300-320 GeV

DESY
Hamburg
Germany



Deep-inelastic scattering (DIS) kinematics



E_e=27.6 GeV

E_p=920 (820) GeV

$\sqrt{s}$ ≈300-320 GeV

DIS kinematics:

pairs of Lorentz invariants:

- 4-momentum transfer squared
  $Q^2 = -q^2$
- Bjorken scaling variable: fraction of proton momentum carried by quark
  $x = Q^2/(2\, q\, P)$
- inelasticity $y = qP/kP$
- mass squared of the hadronic system
  $W^2 = (P + q)^2$

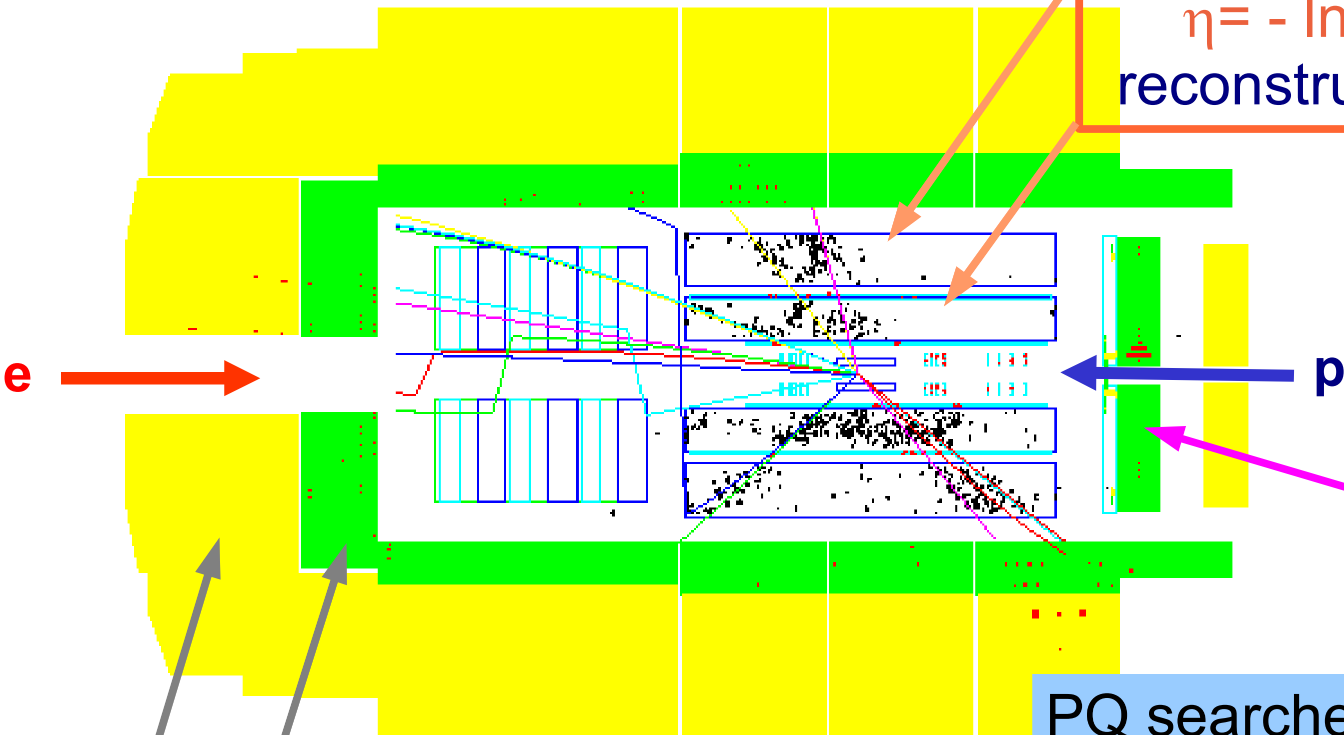
Kinematic regimes:

- **Q^2 >≈ 1 GeV^2 : DIS** — **scattered e in detector**
- **Q^2 <≈ 1 GeV^2 : Photoproduction, γp** — **scattered e in beampipe**

H1 detector at HERA

E_e=27.6 GeV
E_p=920 (820) GeV
$\sqrt{s}$ ≈300-320 GeV

Central jet chamber CJC
tracking, particle ID via dE/dx
acceptance $-1.75 < \eta < 1.75$
$\eta = -\ln \tan \theta/2$
reconstruction of K^0_s, D*, protons



backward
electromagnetic
calorimeter SpaCal
rec. of scattered e

Lar Calorimeter

PQ searches in $K^0_s\, p(\bar{p})$ and $D^* p(\bar{p})$
H1 data, 96-00, 75 pb^{-1}
DIS events, 5(1) $<Q^2<$100 GeV^2,
$0.1 < y < 0.6$ ($0.05 < y < 0.7$)

Strange Pentaquark Search

K^0_s reconstruction

K^0_s selection

$K^0_s \to \pi^+\pi^-$

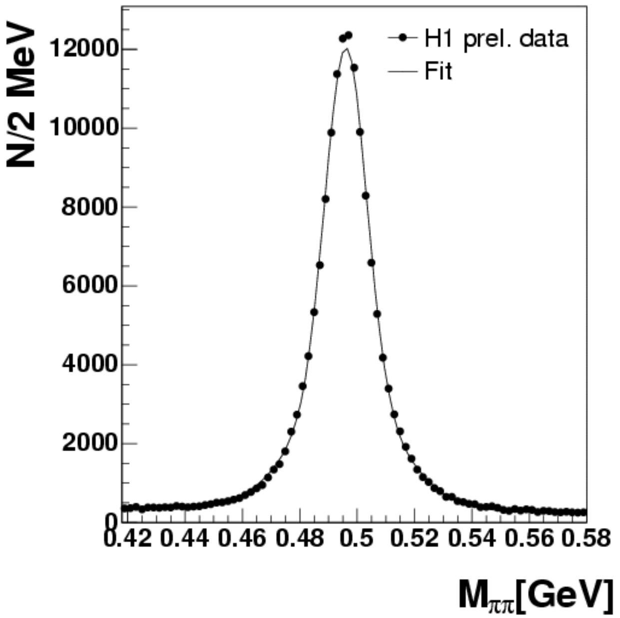
secondary vertices : combinations of oppositely charged tracks

$p_T(K^0s)>0.3$ GeV, $|\eta| < 1.5$

remove combinatorial background and contaminations from Λ decays, photon conversions

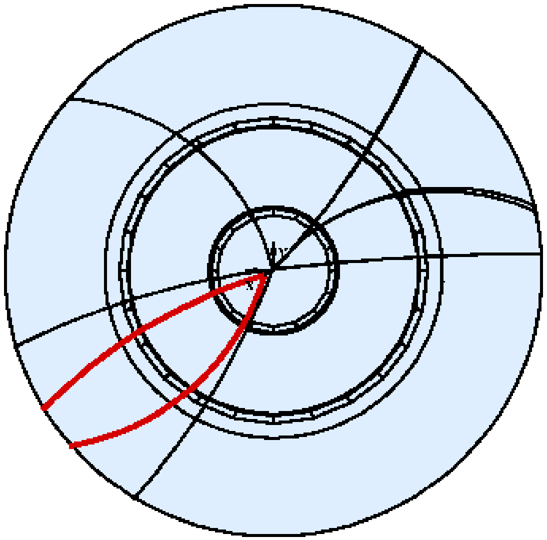
Inclusive K^0_s signal

$Q^2>5GeV^2$



$N(K^0_s) \approx 140\ 000$

K0s in the central jet chamber



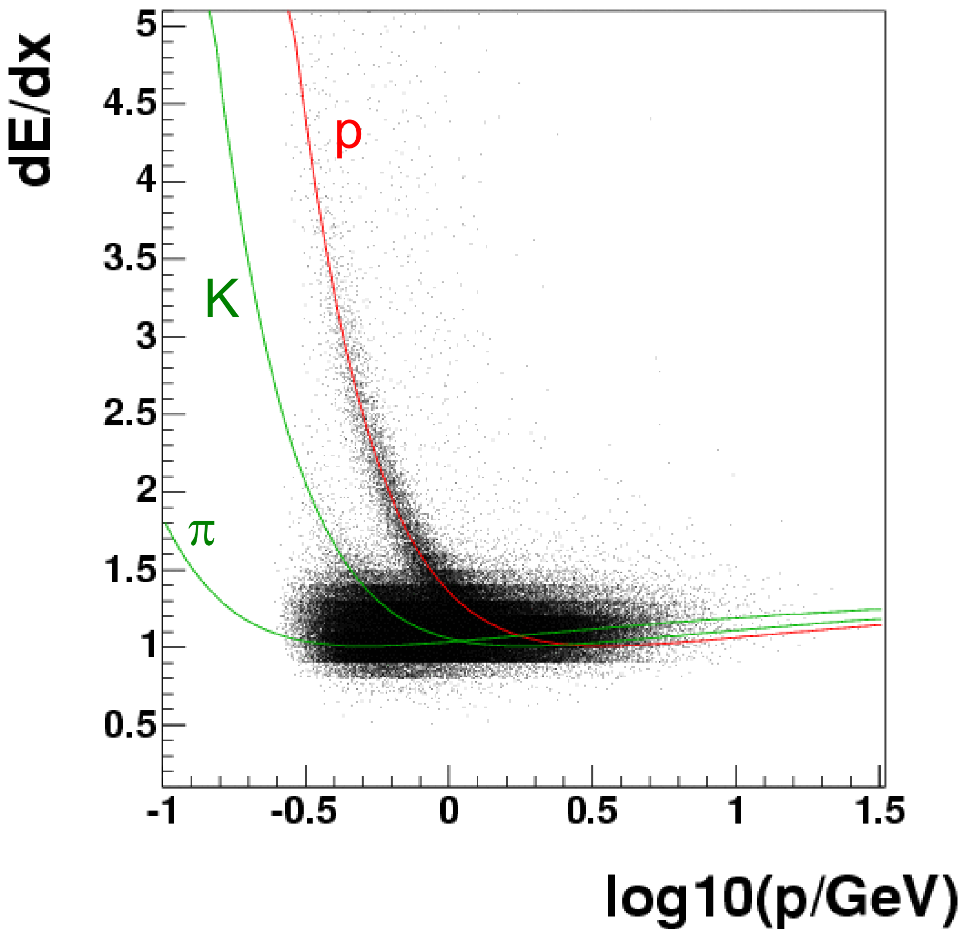
Proton selection via energy loss dE/dx

- resolution for mininal ionizing particles ~8%

- most probable dE/dx: phenomen. parameterisation (Bethe Bloch)

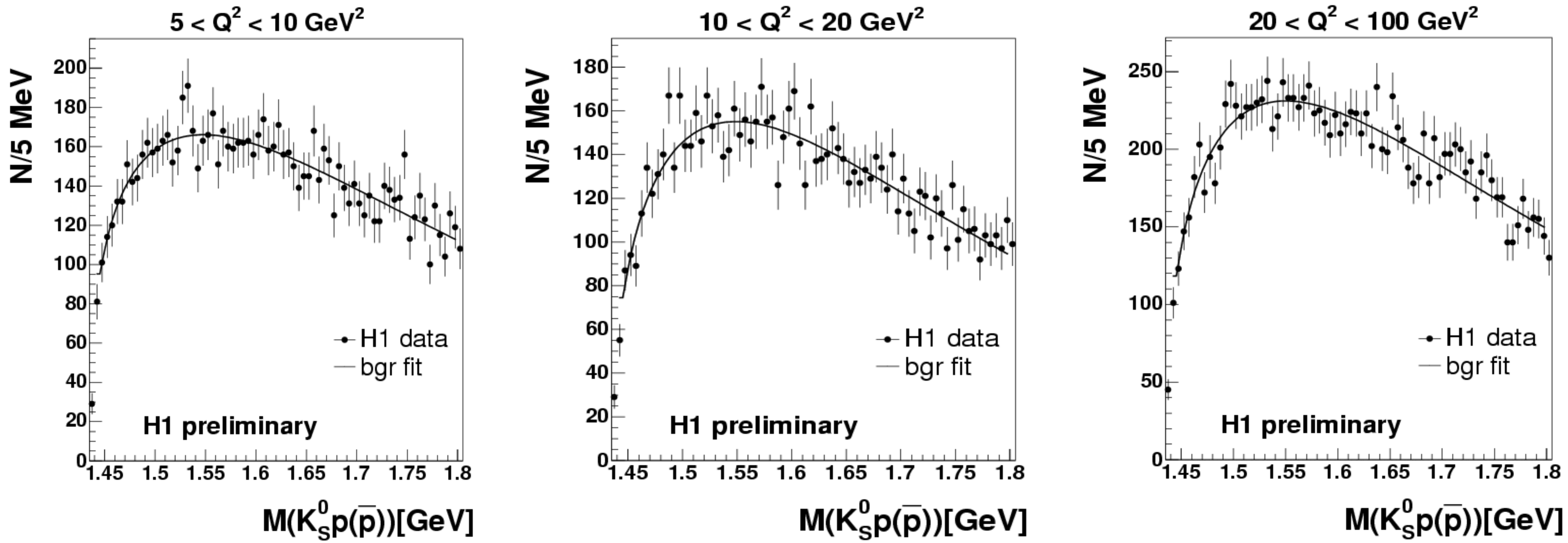
- use likelihoods for separation of protons and π large momentum range

- average proton efficiency ~90%
- π-suppression probability
  86%
  96 % at low momenta (p<1.5 GeV)



Invariant $K^0_s\, p(\bar{p})$ mass

visible range : $p_T(K^0{}_s p) > 0.5$, $|\eta(K^0{}_s p)|<1.5$



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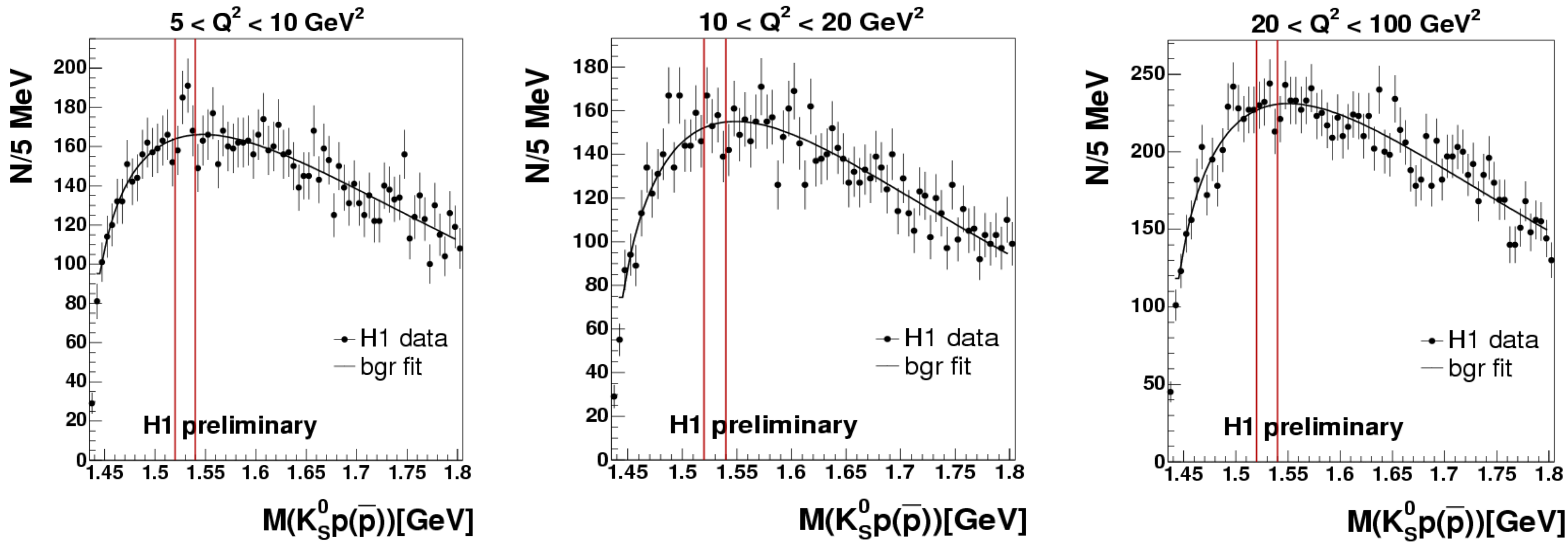
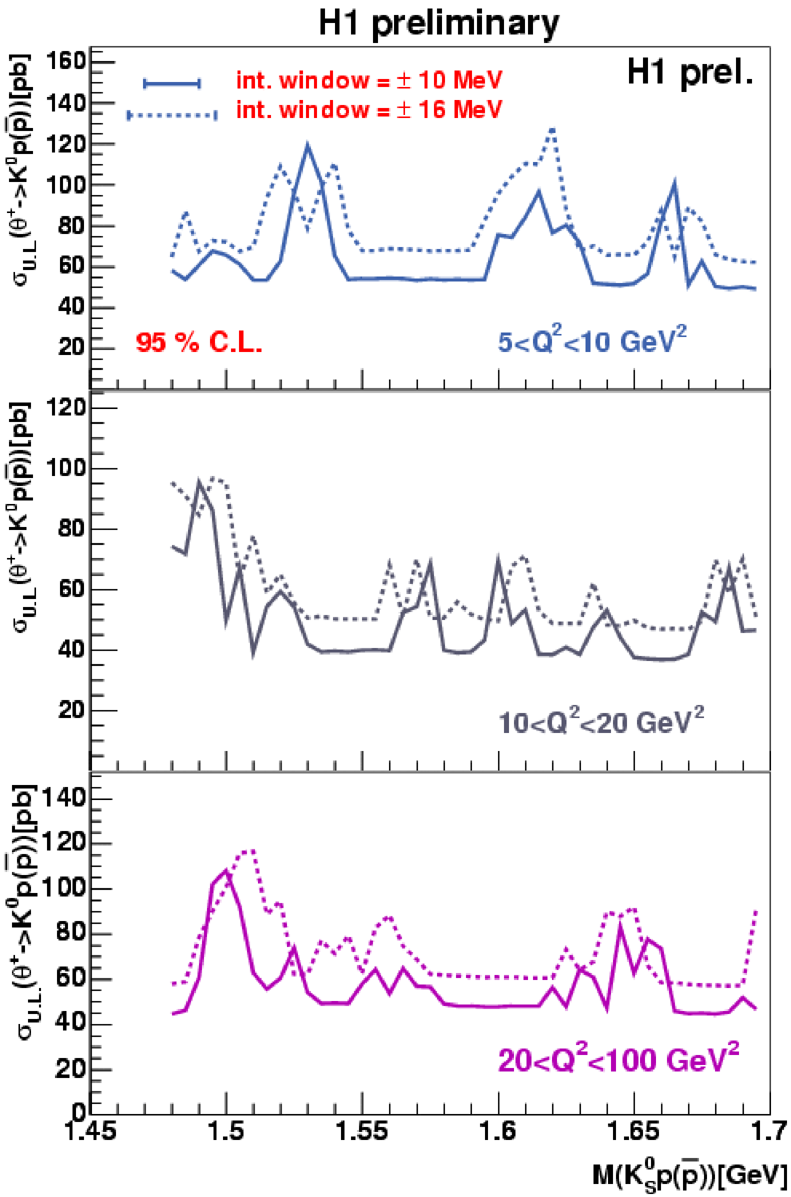


no significant signal in the interesing mass range 1.52 to 1.54 GeV

Upper Limit (95%C.L.) on $\sigma(ep\text{-}> e\theta\ X\text{-}> eK^0p(\bar{p})X)$



- 95 % upper limits extracted
- background subtraction in integration window

  M ± 10 MeV, ±16 MeV

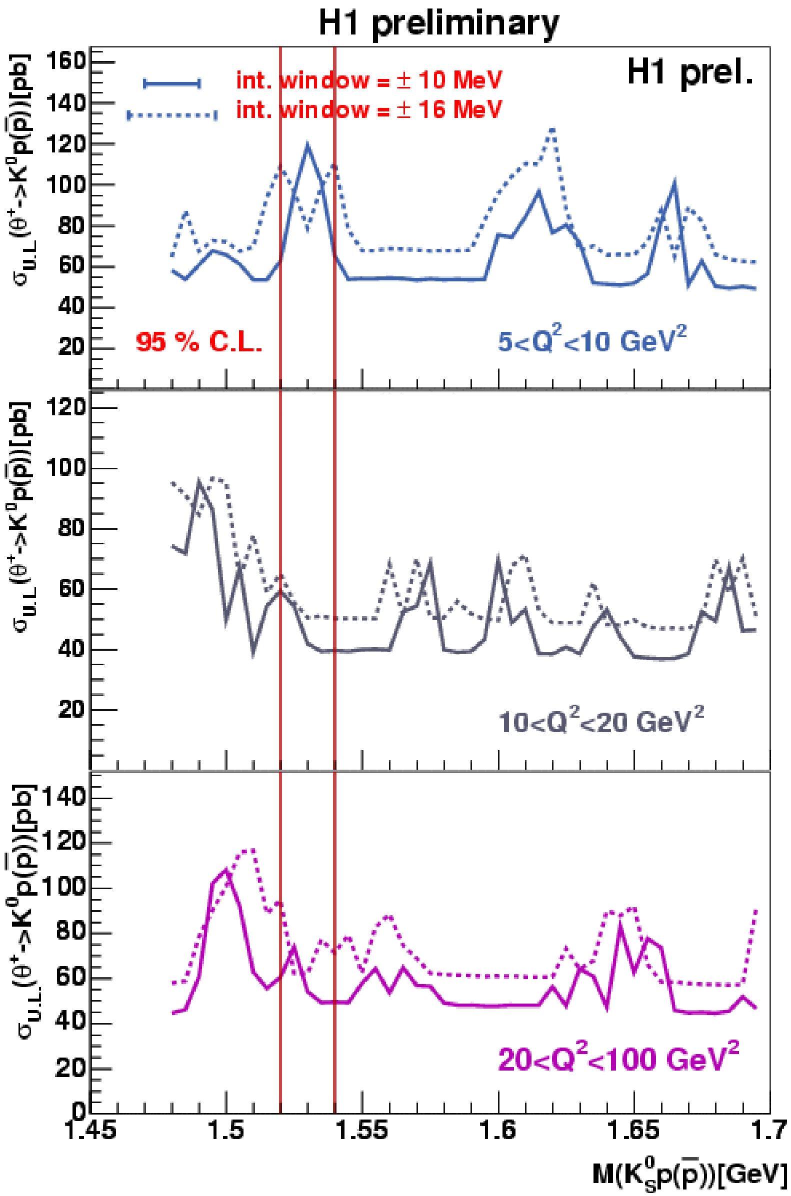
  corr. to 2σ assuming a resolution of 5(8) MeV
- scan M in the range 1.48 to 1.7 GeV

- **Signal Monte Carlo**
- RAPGAP 3.1

  change decay properties of Σ^*

  to M=1.52(1.54), σ=0
- detector resolution ~ 5MeV
- acceptance $\varepsilon \approx 5$ %

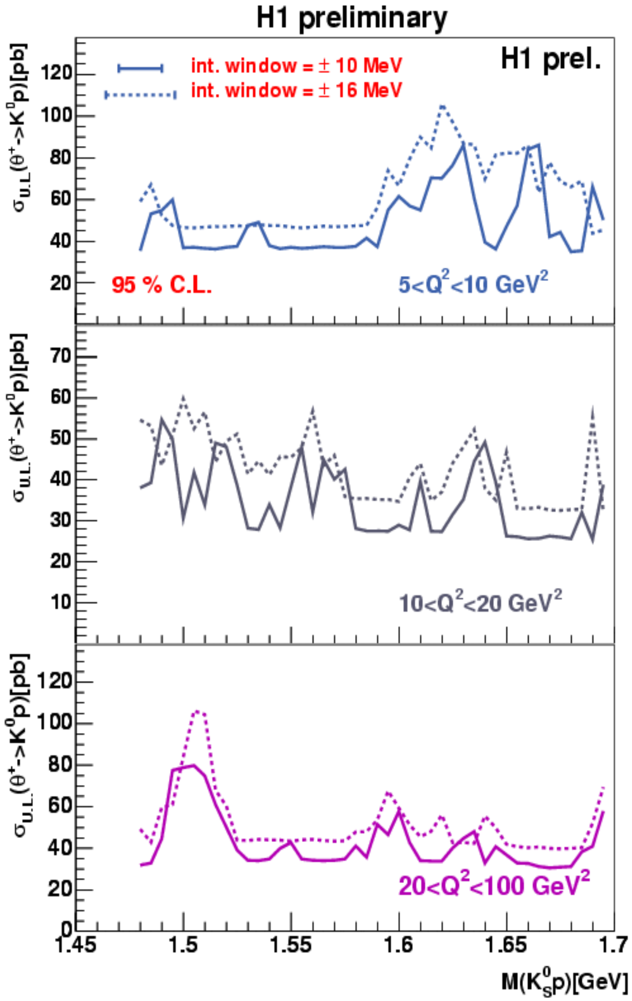
Upper Limit (95%C.L.) on $\sigma(ep \to e\theta X \to eK^0p(\bar{p})X)$



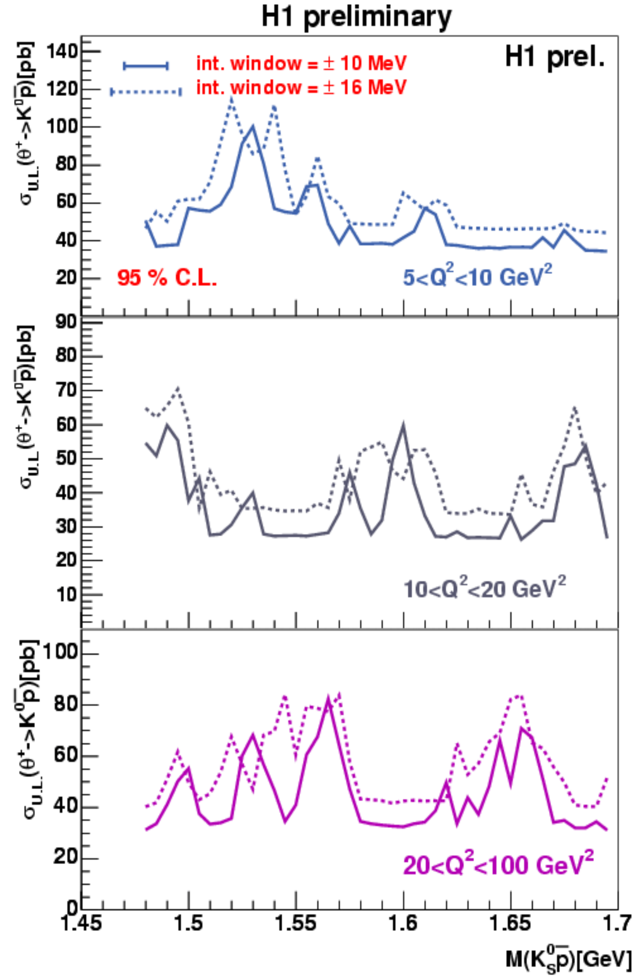
- $5<Q^2<100$ GeV^2, $0.1 < y < 0.6$
- visible range :
  $p_T(K^0{}_s p) > 0.5$, $|\eta(K^0{}_s p)|<1.5$
- different fluctuations in Q^2 bins
- 95% C.L. upper limit on cross section
  $\sigma_{U.L.}(ep \to e\,\theta\, X \to e\, K^0p(\bar{p})\, X) \sim 40\text{-}120$ pb

Upper Limit (95%C.L.) on σ(ep-> eθ X-> eK^{0}p($\bar{p}$)X): charges

protons



antiprotons



- limits for $K^0{}_s p$ and $K^0{}_s\bar{p}$ compatible
- fluctuations at different masses for p and $\bar{p}$

Upper Limit (95%C.L.) on $\sigma(ep \to e\theta X \to eK^0p(\bar{p})X)$: charges

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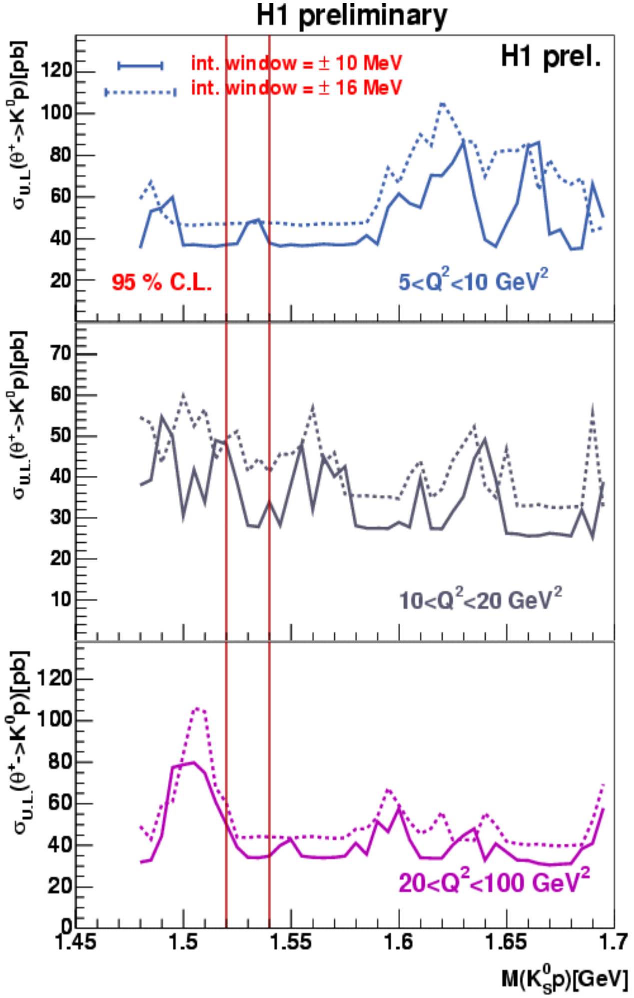

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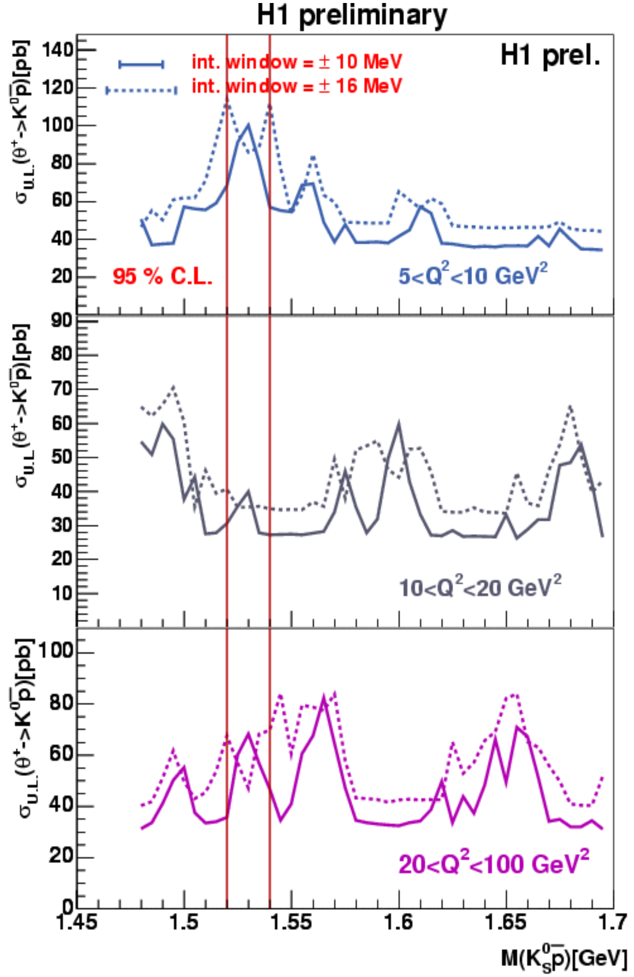


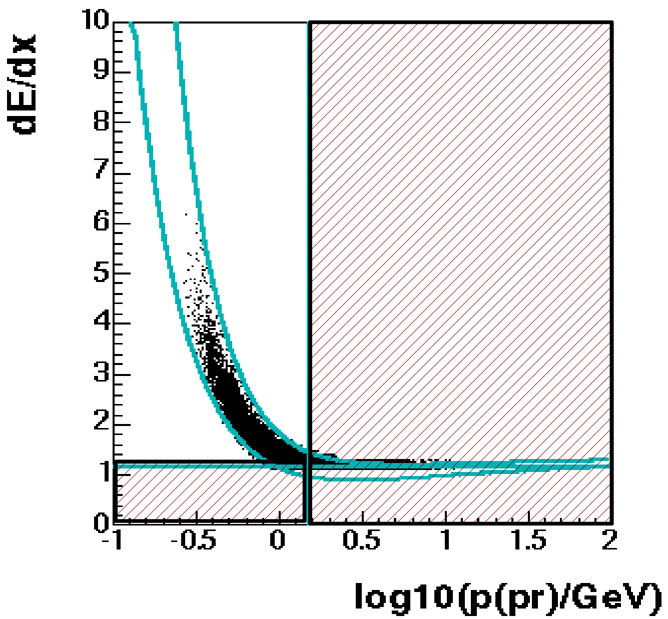
- limits for $K^0{}_sp$ and $K^0{}_s\bar{p}$ compatible
- fluctuations at different masses for p and $\bar{p}$

Comparison with ZEUS

ZEUS: signal at 1.522 GeV observed
Q^2>20 GeV^2, 0.04 < y <0.95, p_T>0.5, $|\eta|$<1.5
σ(ep->e θ X->eK^{0}pX)=125 ± 27(stat) +36 -28 (syst.) pb (prel.)
dE/dx selection, p(pr) < 1.5 GeV

low-momentum dE/dx selection:

- use selection of bands in dE/dx and momentum
- dE/dx > 1.15
- proton momentum < 1.5 GeV



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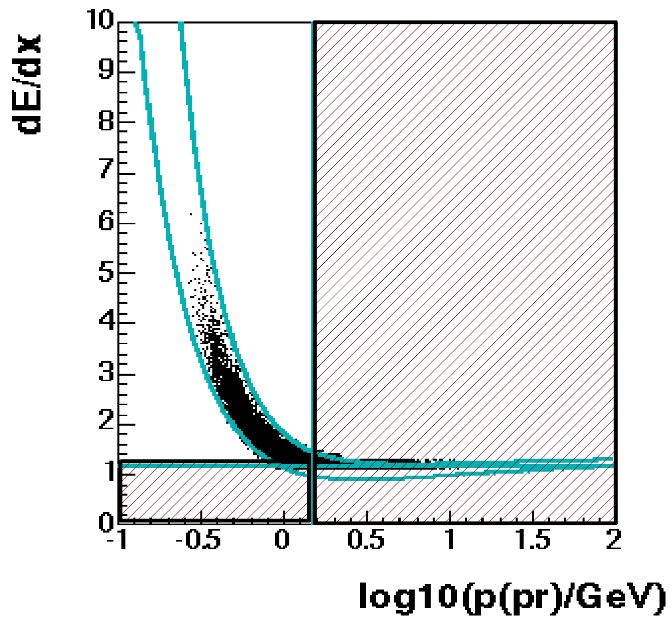
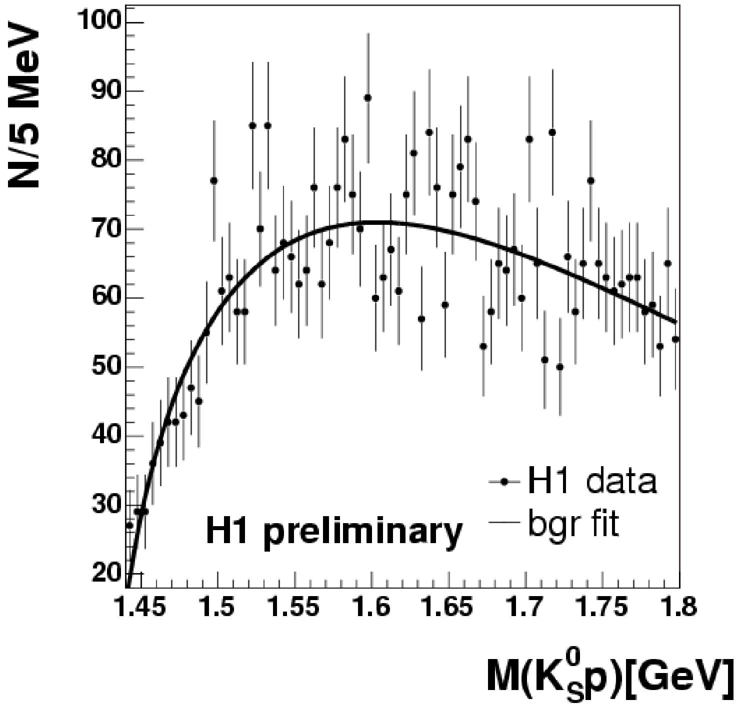


$20 < Q^2 < 100$ GeV^2
$0.1 < y < 0.6$



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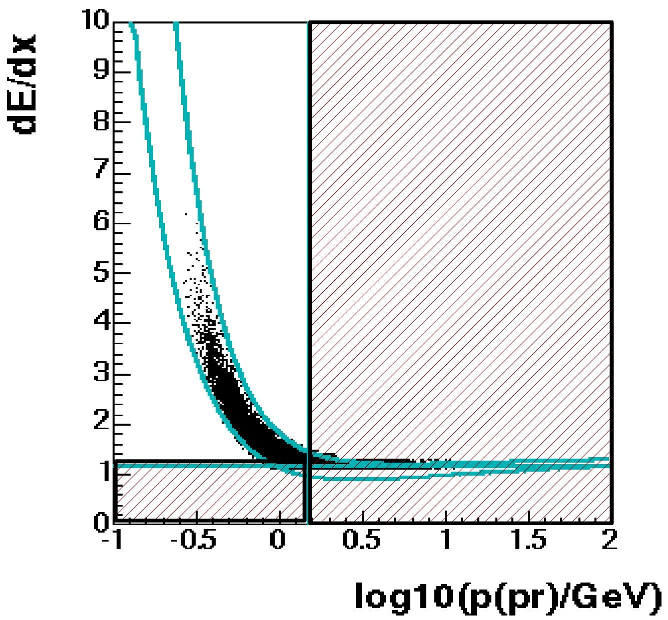

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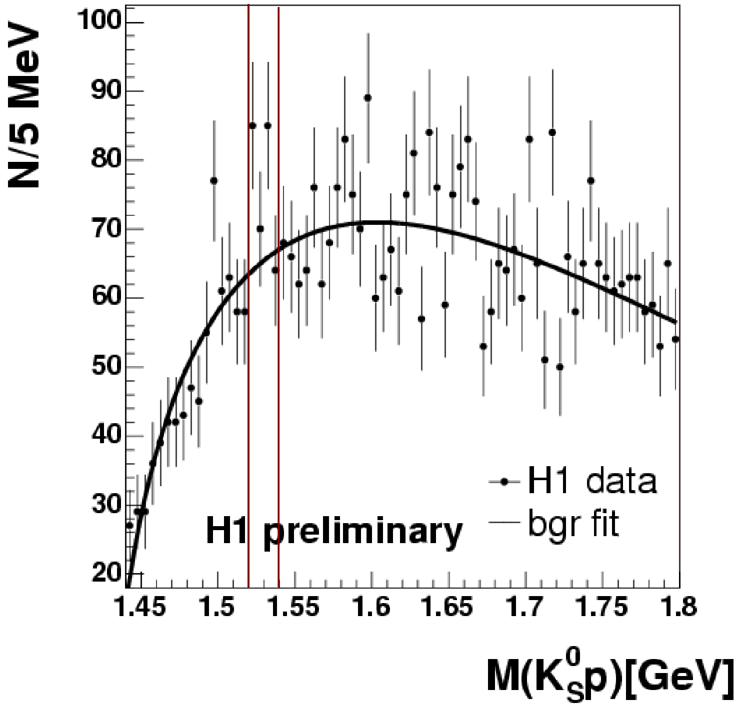

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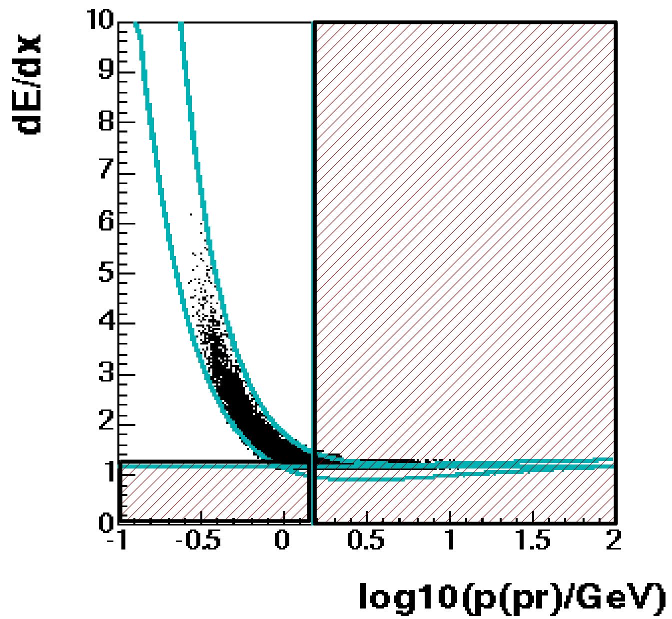
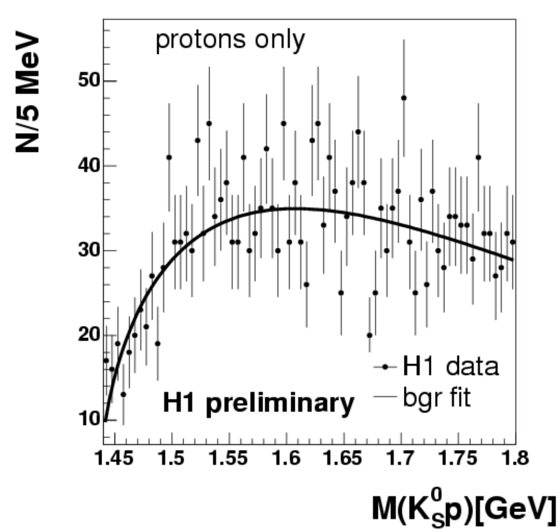


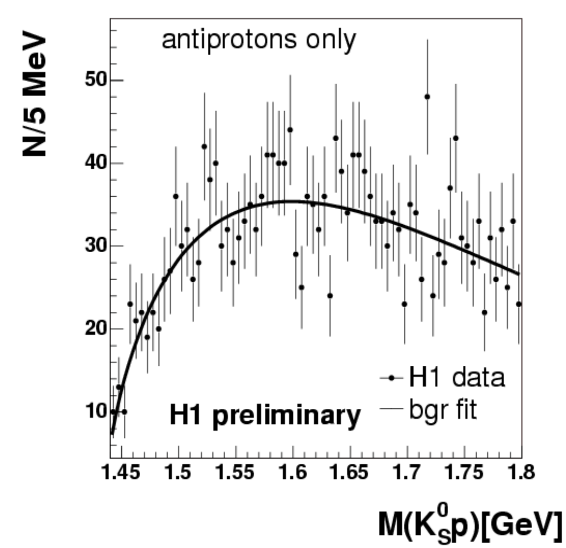
$20<Q^2<100$ GeV^2
$0.1 < y < 0.6$

separate charges:

invariant K^0s p mass



invariant K^0s $\bar{p}$



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dE/dx selection, p(pr) < 1.5 GeV

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- use selection of bands in dE/dx and momentum
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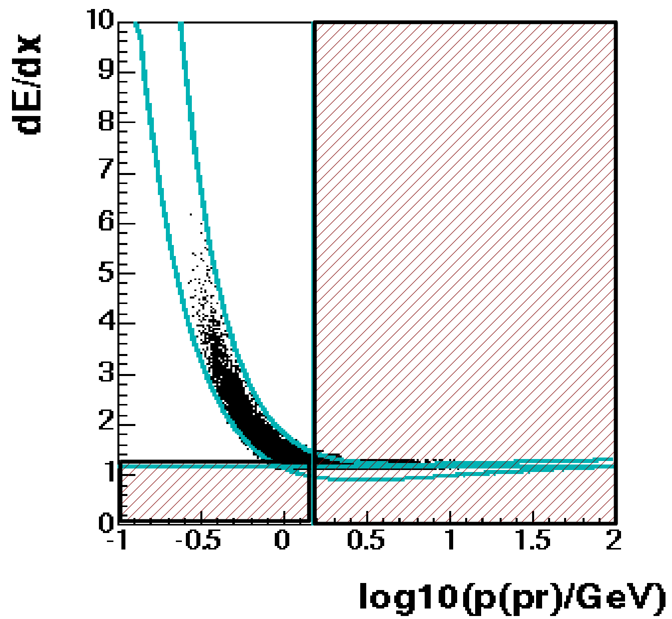
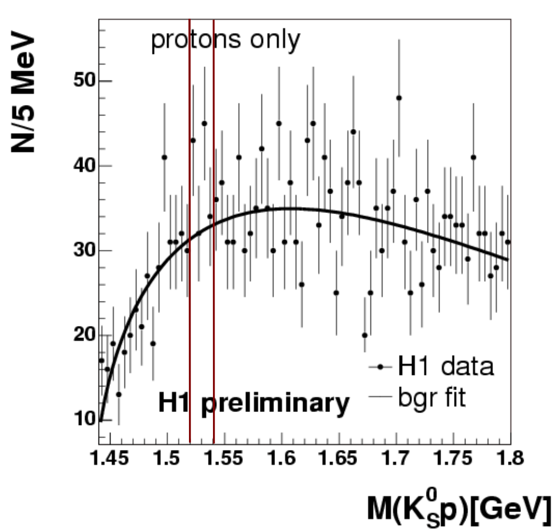
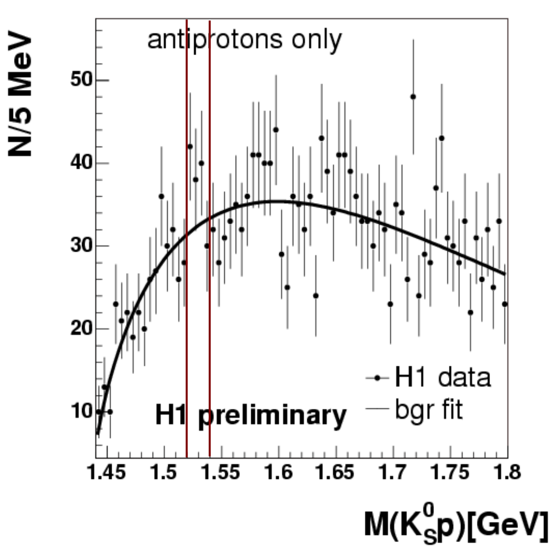
separate charges:

invariant K^0s p mass

invariant $K^0s\ \bar{p}$

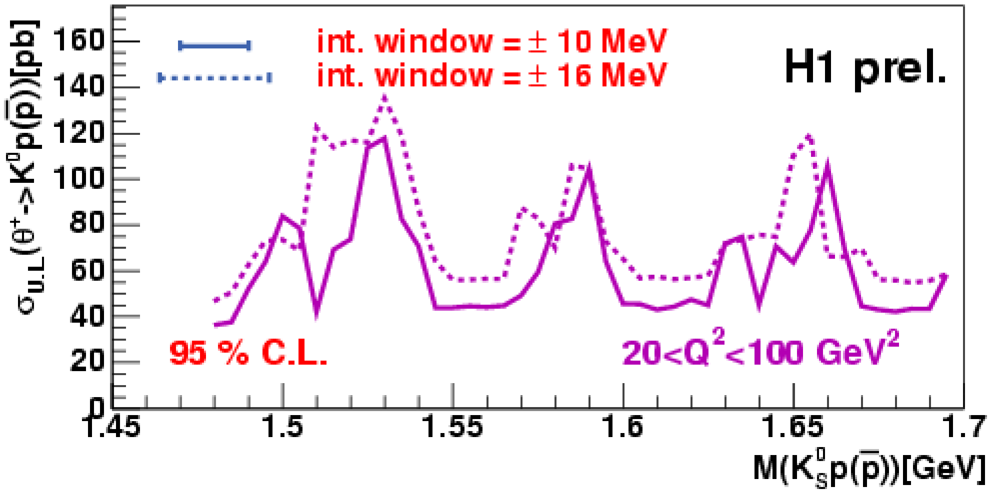




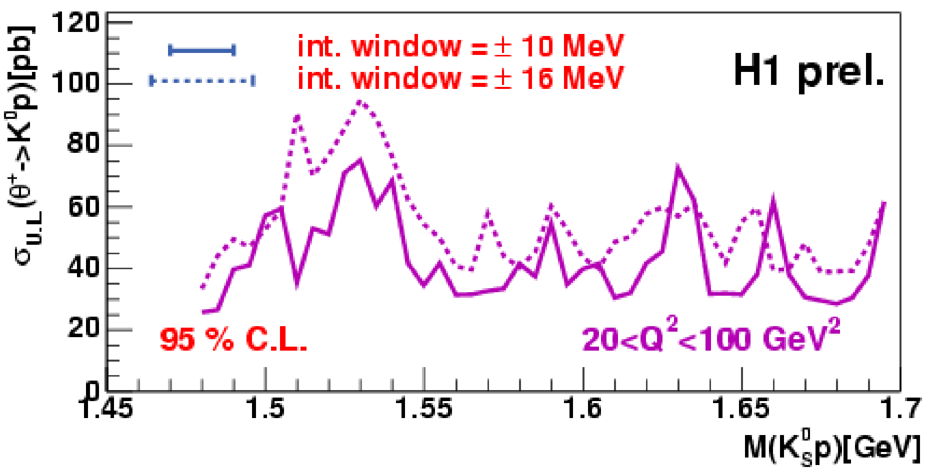


Upper Limit (95%C.L.) on $\sigma(ep\to e\Theta X \to e K^0 p(\bar{p})X)$: low p selection

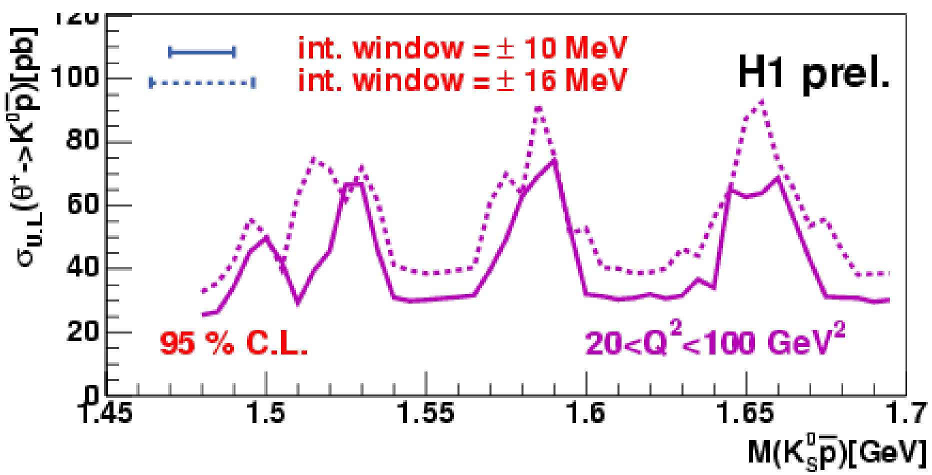
low-momentum dE/dx selection
$20<Q^2<100$ GeV^2
$0.1 < y < 0.6$



protons



antiprotons



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$20<Q^2<100$ GeV^2
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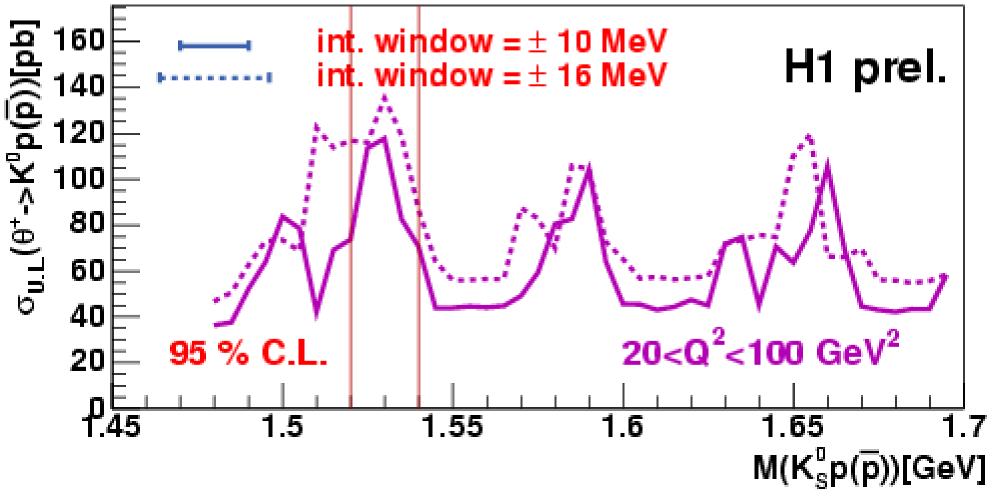
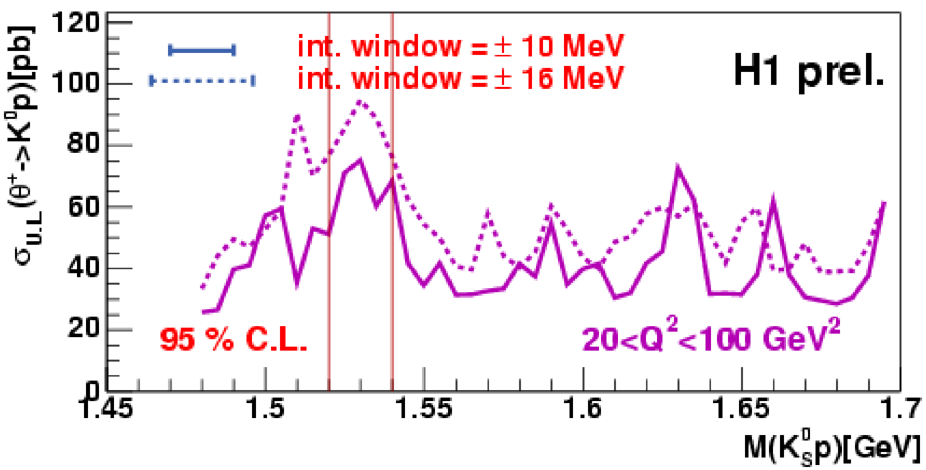
M=1.52 GeV $\sigma_{U.L.}$~ 100 pb



protons



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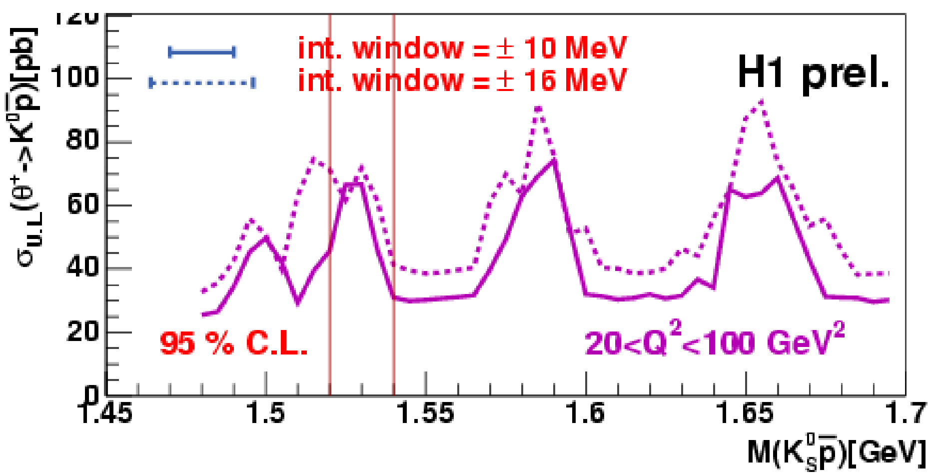

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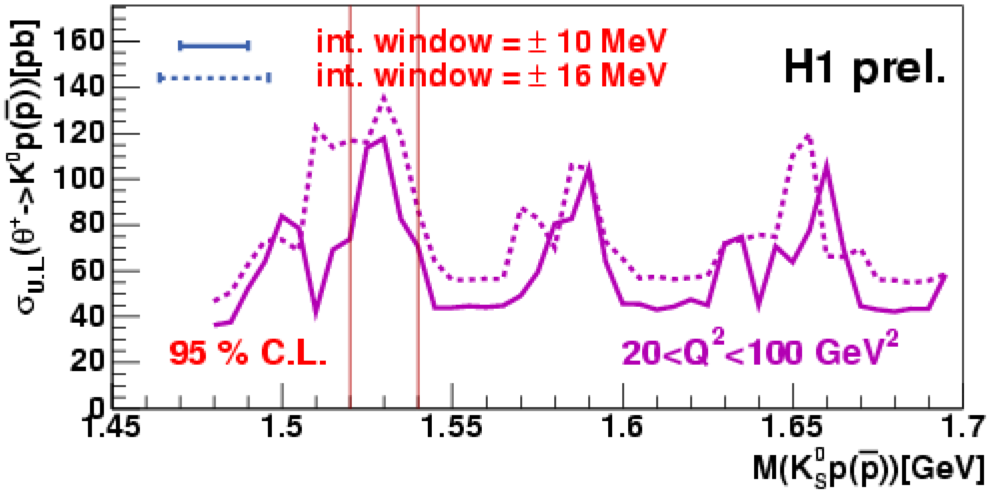
M=1.52 GeV $\sigma_{U.L.}$~ 100 pb *



ZEUS observation:
Q2>20 GeV2, $0.04 < y < 0.95$, $p_T > 0.5$, $|\eta|<1.5$
σ(ep->e +X->eK^{0}pX)=125 ± 27(stat) +36 -28 (syst.) pb (prel.)

$\sigma_{U.L.}$ ~ 100 pb not in contradiction with ZEUS measured cross section

* at M=1.522 GeV assuming a resolution of 5 (8) MeV
$\sigma_{U.L.}$ = 89.6 (116.3) pb

Summary on strange PQ Search

Strange PQ Search:

- no significant signal for a baryonic resonance decaying to $K^0_s p(\bar{p})$ observed
- 95% C.L. upper limit $\sigma_{U.L.}(ep \rightarrow \theta X \rightarrow K^0 p(\bar{p}) X)$ in different Q^2 ranges
  visible range: $p_T(K^0_s p) > 0.5$, $|\eta(K^0_s p)| < 1.5$ varies 40 -120 pb
  for M= 1.48 – 1.7 GeV
- similar selection and phase space as for the ZEUS analysis
  - no significant signal observed
  - upper limit does not exclude preliminary ZEUS cross section

Charm Pentaquark Search

- inspired by observation of the strange pentaquark with quark content uudd$\bar{s}$
- possible existence of strange pentaquark implies that a heavy pentaquark(uudd$\bar{c}$) could also exist
- mass of charm pentaquark > $M(D^{*\pm}) + M(p) = 2.948$ GeV decay to $D^{*\pm}$ p possible

D* signal

Golden decay channel:

$D^{*+} \rightarrow D^0 \pi_s^+ \rightarrow K^- \pi^+ \pi_s^+$ (+ c.c.)

low branching ratio, but clean signal

- apply "mass difference method":

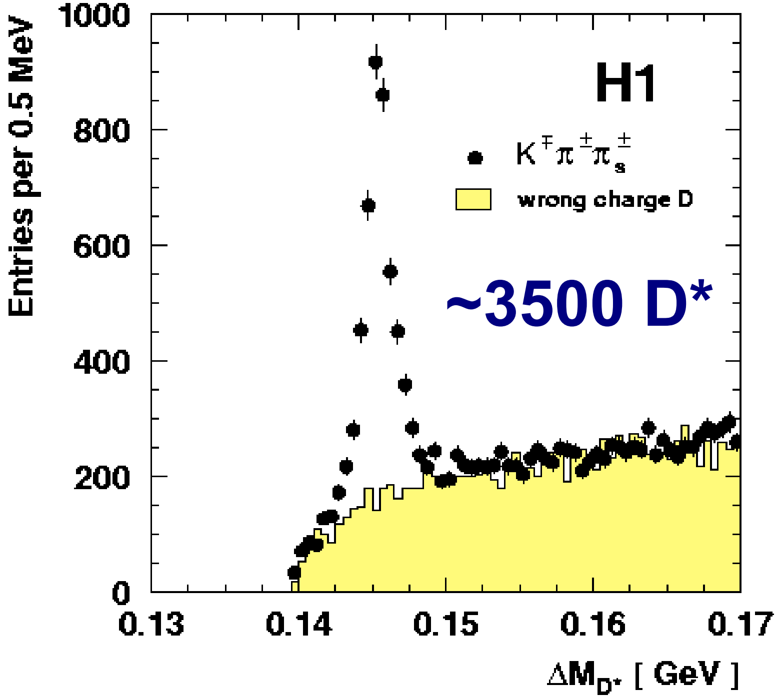
$\Delta M(D^*) = M(K\,\pi\,\pi_S) - M(K\pi)$

- Estimate combinatorial bgr (non charm): replace $D^0 \rightarrow K^- \pi^+$ by 2 same charge tracks

"wrong charge D" :
fake D^0 ($K^+ \pi^+$/ $K^- \pi^-$) + π_S

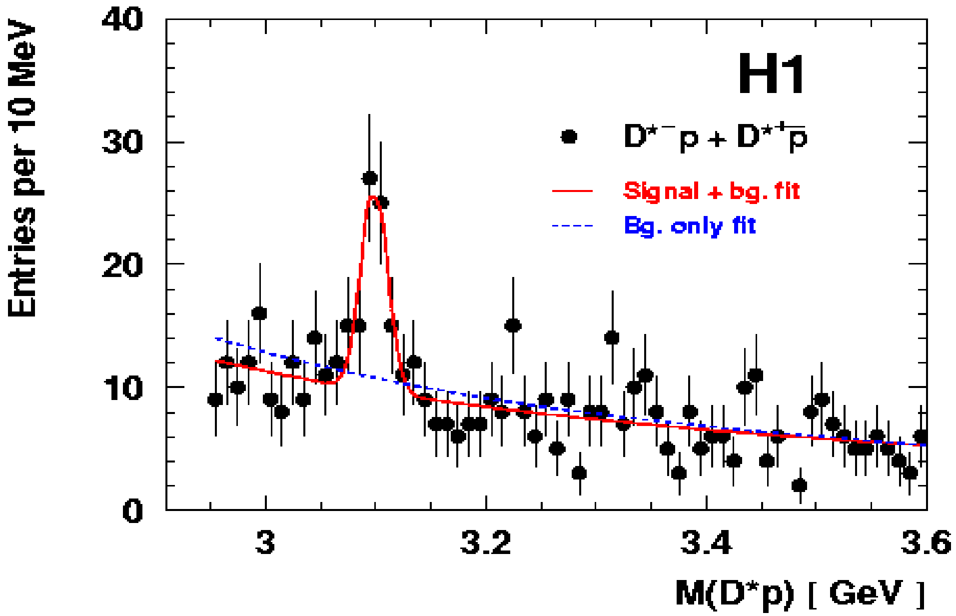
DIS events:

- 96-00 data, Lumi 75 pb^{-1}
- scattered electron in calorimeter
- $1 < Q^2 < 100\ GeV^2$, $0.05 < y < 0.7$



combine resonstructed D* mesons and protons (from dE/dx)

D*p invariant mass distribution



mass difference
$M(D^*p)=m(K\pi\pi\ \pi)-m(K\pi\pi) + M_{PDG}(D^*)$

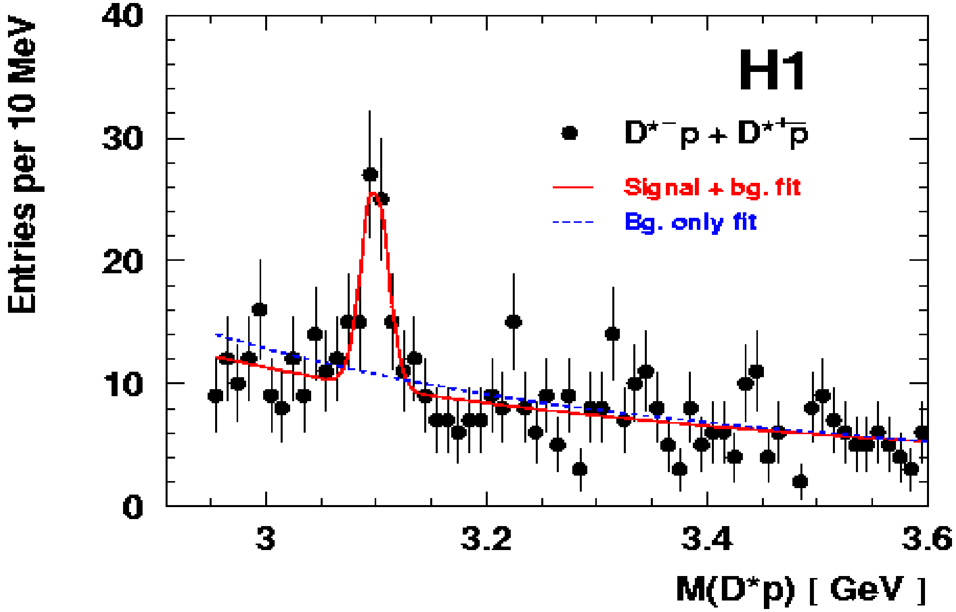
narrow resonance at M=3099±3(stat.) ±5 (syst.) MeV

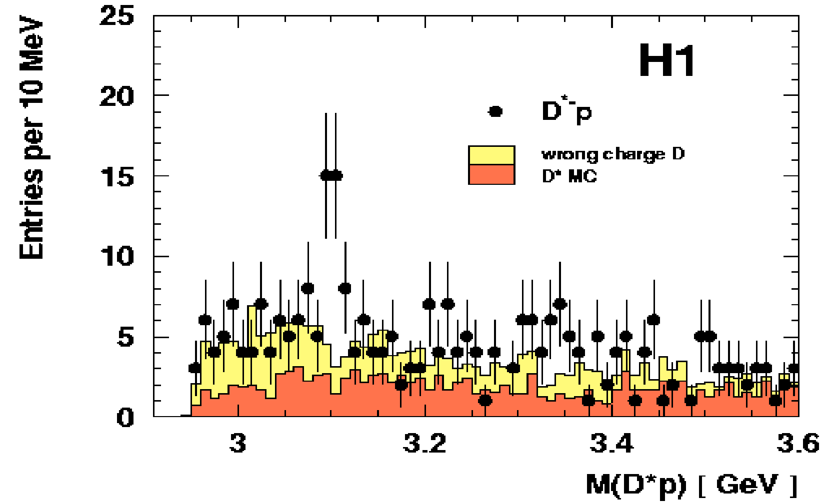
50.6±11.2 events

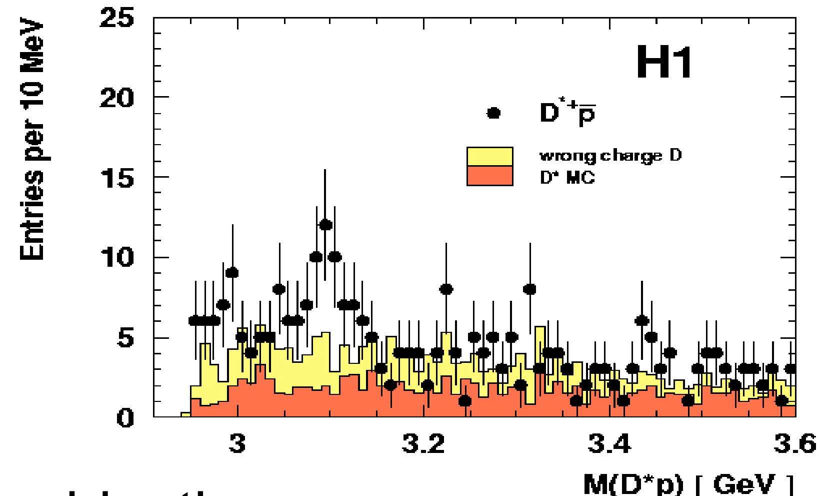
width: 12±3 MeV (consistent with exp. resolution)

background fluctuation probability: $4 * 10^{-8}$ (Poisson) (5.4 σ Gauss)

D*p invariant mass distribution



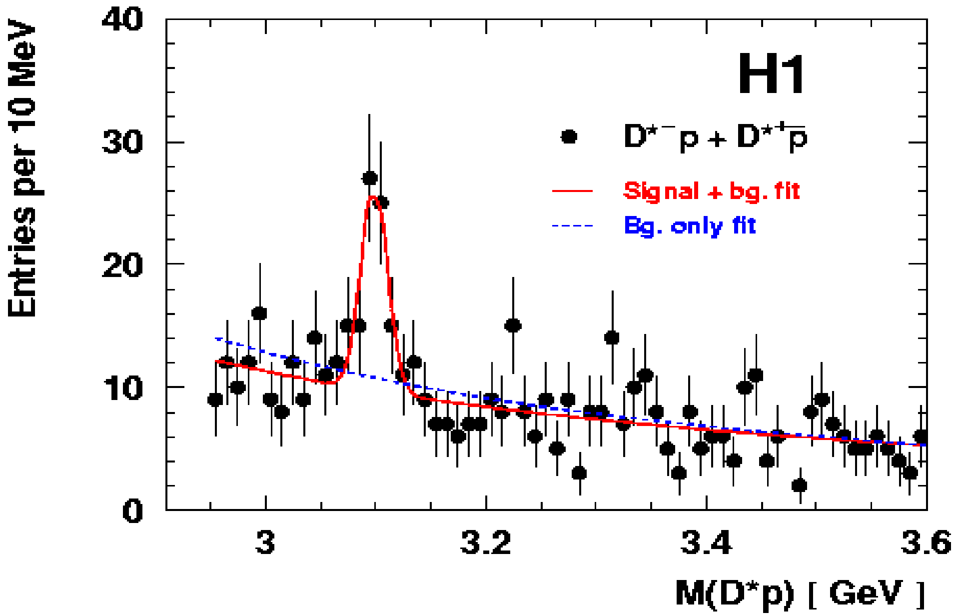


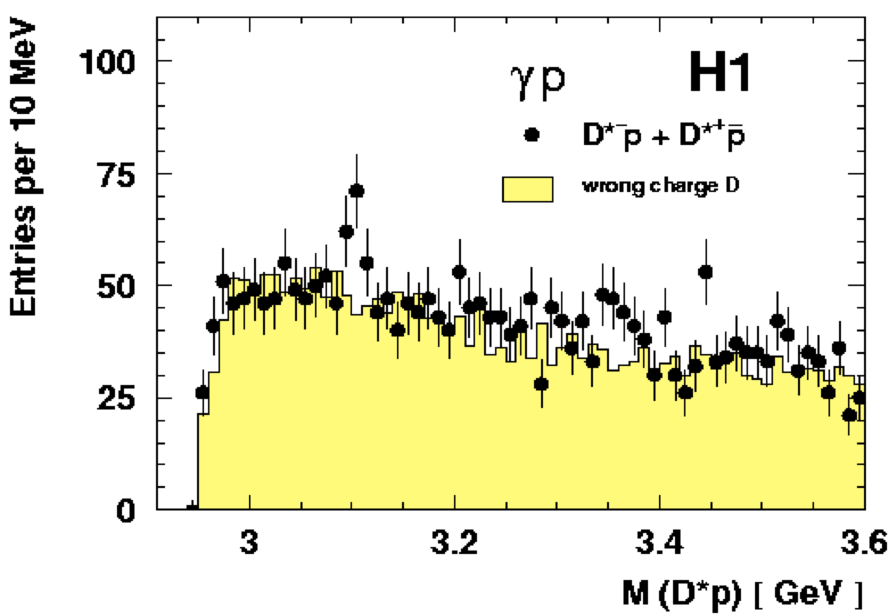


Signal visible in both charges $D^{*-}p$ and in $D^{*+}\bar{p}$ with similar strength and compatible mass

No signal seen in like sign $D^{*-}\bar{p}$ or $D^{*+}p$ combinations

D*p invariant mass distribution



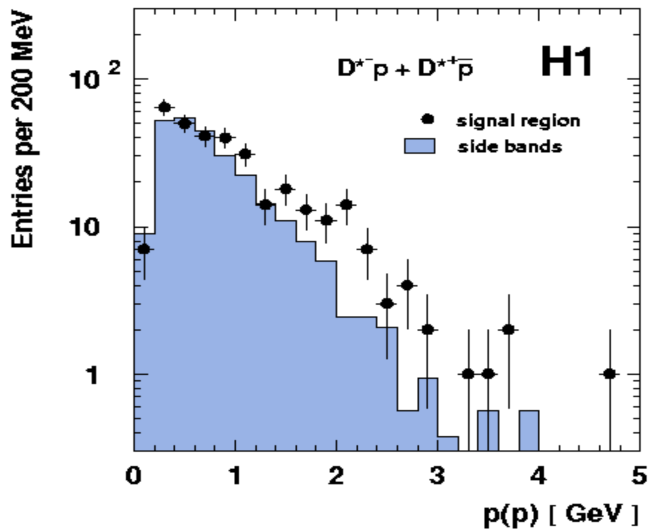


- all events visually scanned – no anomalies observed
- several kinematic and reflection tests performed: D*p(3100) passed all tests

Signal at 3.1 GeV is present also in independent photoproduction (Q^2 <1 GeV^2) sample (~ 4900 D*)

D*p invariant mass at high proton momenta

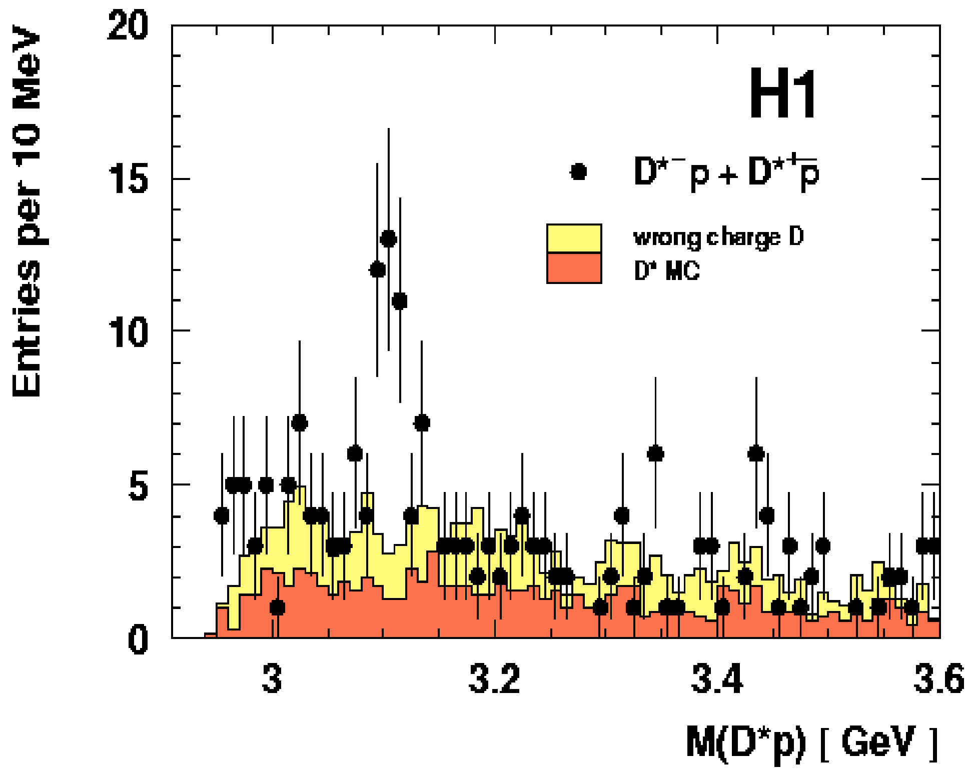
momentum distribution of
proton candidates :
(no proton identification via dE/dx)



proton momentum spectrum harder for signal region than for sidebands

at high momenta: better S/B

D*p combinations for p(p)>2GeV
(no proton identification via dE/dx) :



prominent signal is visible
without dE/dx selection

Acceptance corrected Ratio R_{cor} (D*p(3100)/D*)

Kinematic region: $1<Q^2<100$ GeV^2, $0.05 < y < 0.7$

1.) in the visible D*p range: pt(D*p) > 1.5 GeV, $-1.5 < \eta$(D*p)< 1.0

and visible D* range: pt(D*)> 1.5, $-1.5 < \eta$(D*)< 1.0, z(D*)>0.2

(applied to inclusive D* and D* from D*p(3100) decay)

R_{cor}(D*p(3100)/D*) = $(1.59 \pm 0.33\,^{+0.33}_{-0.45})$ % (preliminary)

95% upper limit from ZEUS for DIS : < 0.59 %

(0.51 % both D^0 decay channels)

in different phase space: $Q^2>1$ GeV^2 , $y_e < 0.95$

pt(D*)>1.35 GeV, $|\eta$(D*p)$|<1.6$,

pt(D*)/$\Sigma E_t^{\theta>10}$ > 0.12

* Systematic errors include uncertainties due to:
D*, D*p selection, veto for D_1D_2, background shape, dE/dx-measurement,
Variation of D*p(3100) fragmentation and pseudo-rapidity η

Acceptance corrected Ratio R_{cor} (D*p(3100)/D*)

Kinematic region: $1<Q^2<100$ GeV^2, $0.05 < y < 0.7$

1.) in the visible D*p range: pt(D*p) > 1.5 GeV, $-1.5 < \eta$(D*p)< 1.0

and visible D* range: pt(D*)> 1.5, $-1.5 < \eta$(D*)< 1.0, z(D*)>0.2

(applied to inclusive D* and D* from D*p(3100) decay)

R_{cor}(D*p(3100)/D*) = $(1.59 \pm 0.33\ ^{+0.33}_{-0.45})$ % (preliminary)

2.) extrapolated to the full D* phase space in the D*p(3100) decay

visible D*p/D* range: pt > 1.5 GeV, $-1.5 < \eta < 1.0$

(applied to D* for incl. D* and to D*p for D*p(3100)

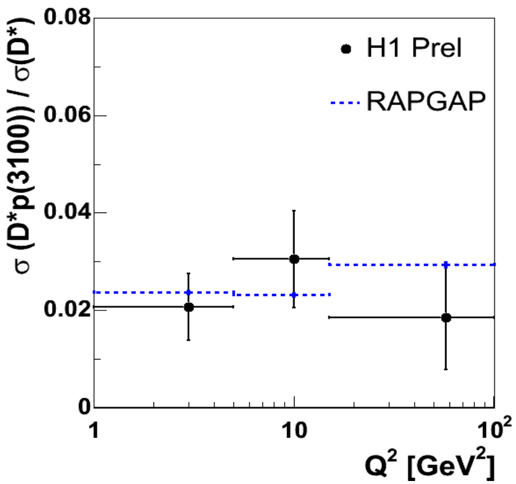
no visbility cuts on any decay products)

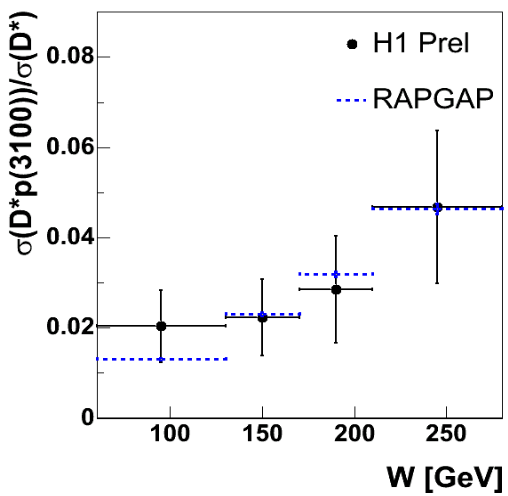
σ(D*p(3100)/D*) = $(2.48 \pm 0.52\ ^{+0.85}_{-0.64})$ % (preliminary)

* Systematic errors include uncertainties due to:
D*, D*p selection, veto for D_1D_2, background shape, dE/dx-measurement,
Variation of D*p(3100) fragmentation and pseudo-rapidity η

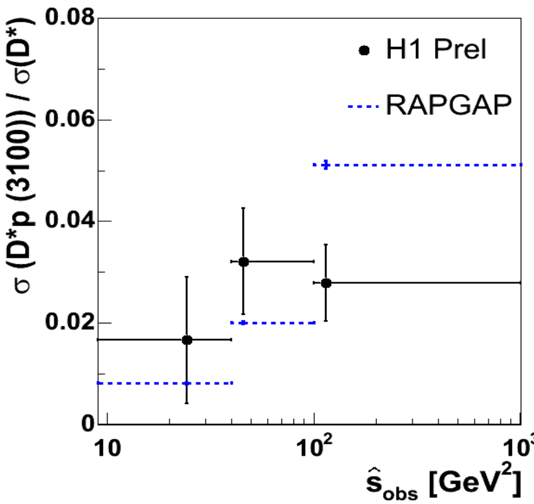
$\sigma(D^*p(3100))/\sigma(D^*)$ as function of event kinematics

MC (for correction and comparison)
RAPGAP 3.1 with naïve PQ
production by modification of mass
and decay of D1(2420) and D2(2460)





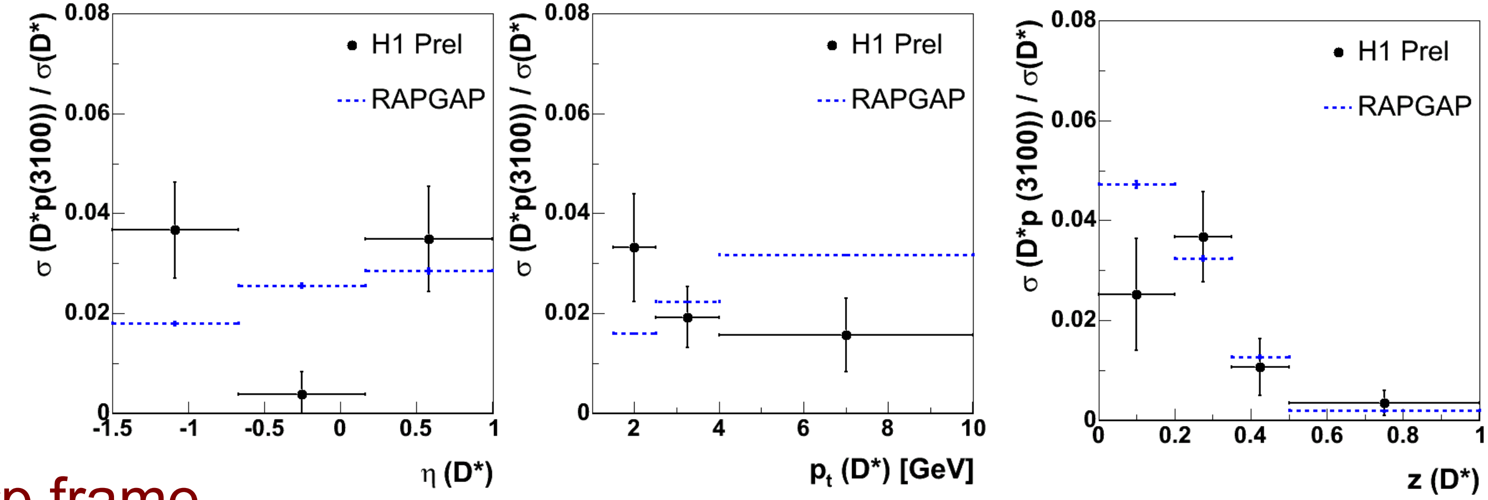
- W and Q^2 distributions well described by MC
- different behaviour of $\hat{s}_{obs}$ for data and MC



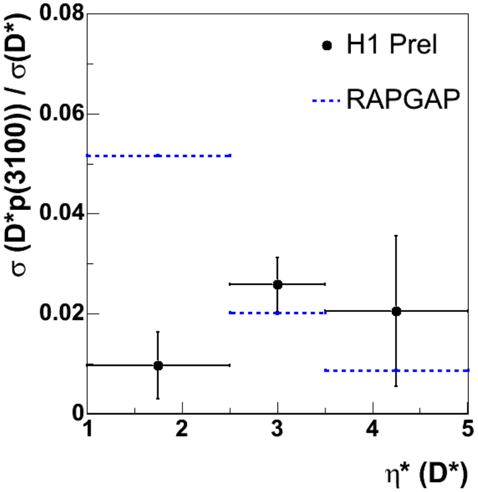
$\hat{s}$: invariant mass of $c\bar{c}$ system

σ(D*p(3100))/σ(D*) as function of D* variables

Lab frame



γp frame



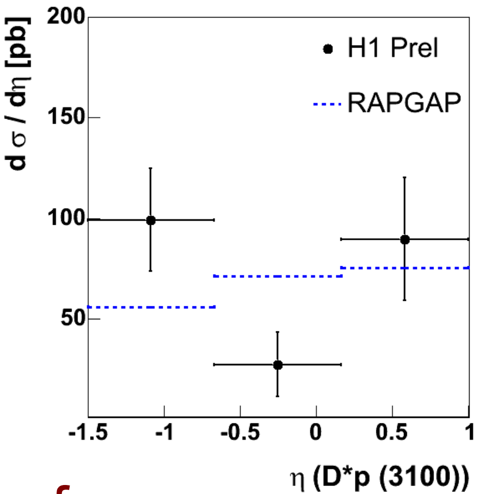
Compared to inclusive D*production
D* from D*p(3100) decays are ...

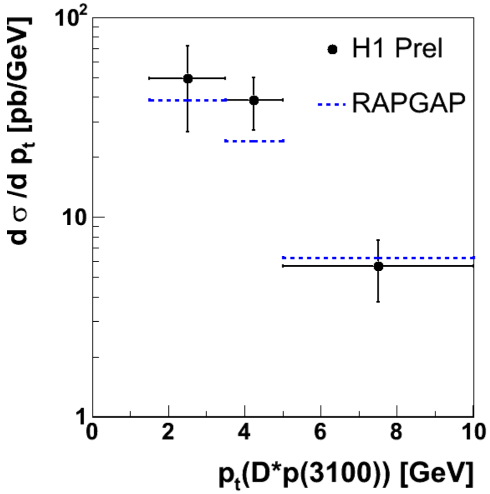
- suppressed in the central η region in the lab frame
- softer in p_T(D*) and z(D*)
- suppressed at low η* in the γp frame

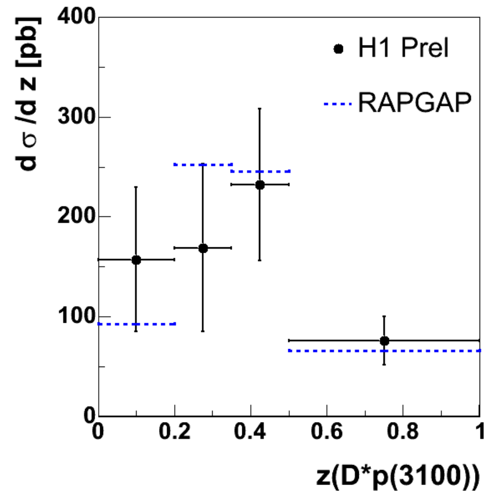
simple MC does not describe data

σ(D*p(3100)) as function of D*p variables

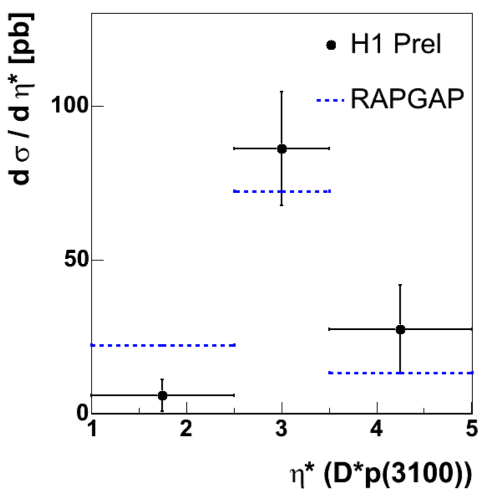
Lab frame







γp frame

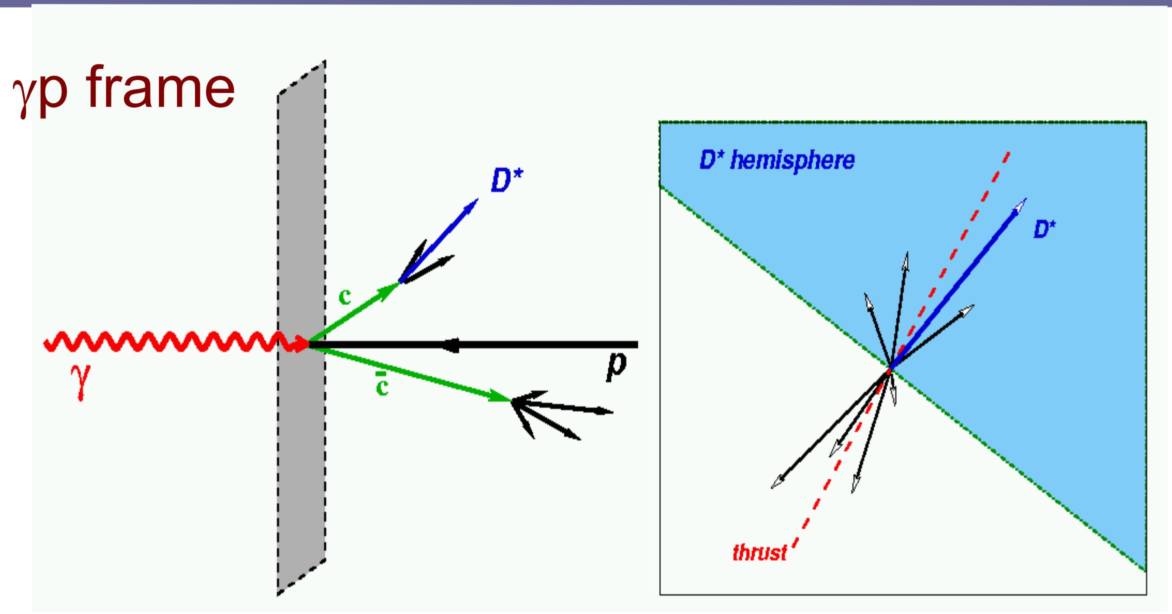


D*p production is ...

- suppressed in the central η region in the lab frame
- close to photon direction in η^* in the gp frame

these features are not described by simple MC while p_T and z distribution are reasonably well described

Fragmentation functions of D*p(3100) and D*

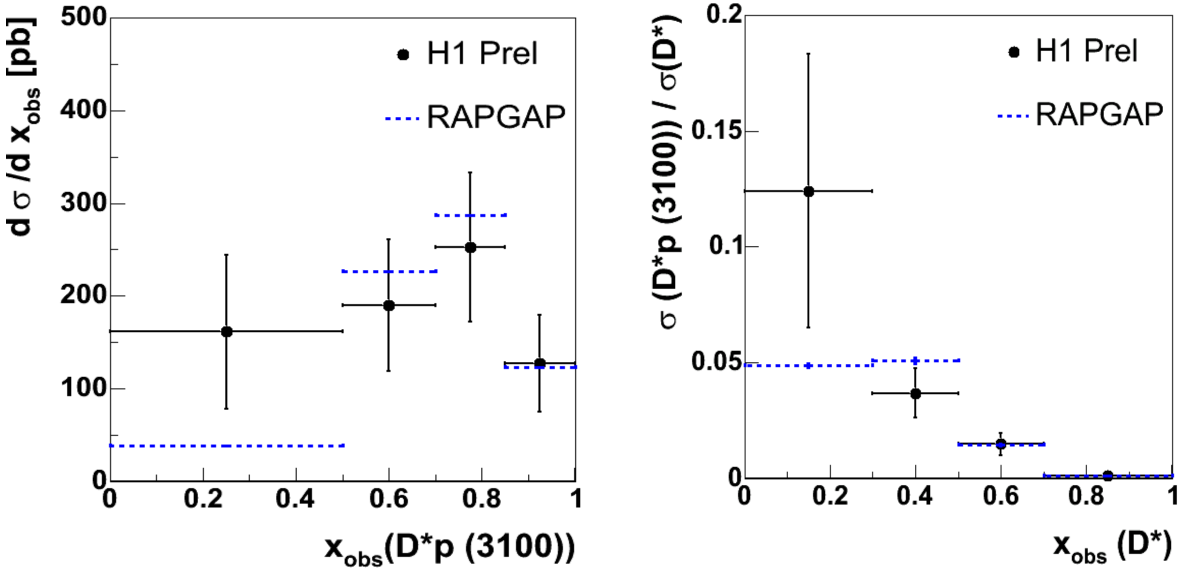


$$x_{obs}(D^*p,D^*) = \frac{(E-p_z)_{lab}(D^*p,D^*)}{\Sigma hemi\ (E-p_z)_{lab}}$$

- projection of all particles into plane perpendicular to γ direction
- 2 hemispheres defined by D* direction

D* hemisphere ◄► c-quark (including QCD effects)

Fragmentation functions of D*p(3100) and D*



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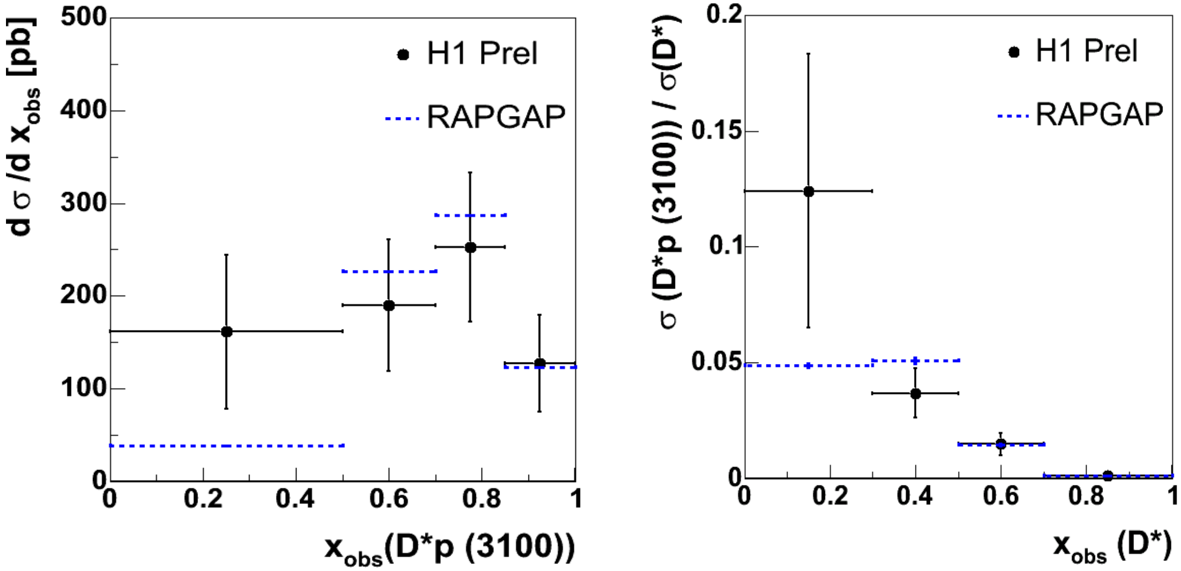
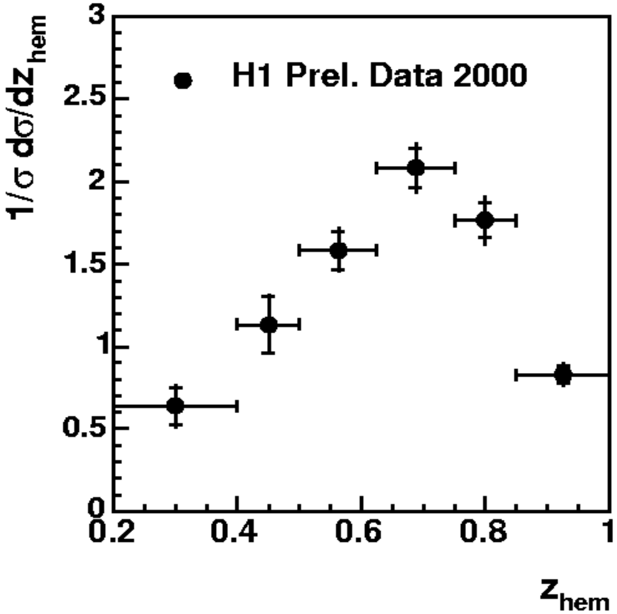
- D*p fragmentation is hard (as expected from its mass)
- D* from D*p(3100) gets very little energy from c-quark

Fragmentation functions of D*p(3100) and D*



$$x_{obs}(D^*p,D^*) = \frac{(E-p_z)_{lab}(D^*p,D^*)}{\Sigma hemi\ (E-p_z)_{lab}}$$

for comparison:
fragmentation function
of inclusive D*:



- D*p fragmentation is hard
  (as expected from its mass)
- D* from D*p(3100) gets very little
  energy from c-quark

Summary

Strange PQ Search:

- no significant signal for a baryonic resonance decaying to $K^0{}_s p(\bar{p})$ observed
- 95% C.L. upper limit $\sigma_{U.L.}(ep \rightarrow \theta X \rightarrow K^0 p(\bar{p})X)$ in different Q^2 ranges
  visible range: $p_T(K^0{}_s p) > 0.5$, $|\eta(K^0{}_s p)|<1.5$ varies 40 -120 pb
  for M= 1.48 – 1.7 GeV
- similar selection and phase space as for the ZEUS analysis
  - no significant signal observed
  - upper limit does not exclude preliminary ZEUS cross section

Charm PQ Search:

- narrow resonance in D*p sprectrum observed at 3099 MeV

$$R_{cor}(D^*p(3100)/D^*) = (1.59 \pm 0.33 {}^{+0.33}_{-0.45})\ \%\ \text{(preliminary)}$$

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Charm PQ Search:

- narrow resonance in D*p sprectrum observed at 3099 MeV

phase space studies of this signal show

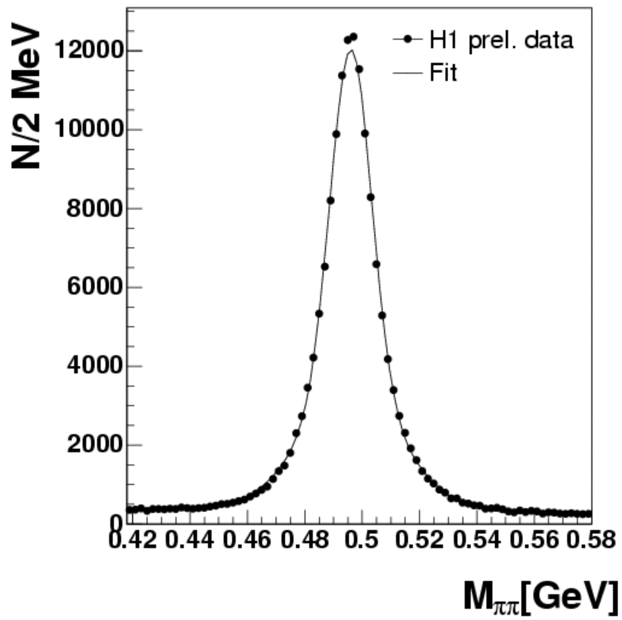
- suppression of D*p(3100) at central rapidity in lab and γp frame
  D*p(3100) fragmentation is hard and similar to charmed hadrons
  D* from D*p(3100) have softer fragmentation functions than inclusive D*

- higher statistics at HERA II data will help to resolve current discrepancy between H1 and ZEUS results

Backup Slides

Strange PQ Search

K^0_s Signal



Q2>5GeV2

Result from fit: (bgr function + 2 gaussians)

N= 142505 ± 430

M= 496.08 ± 0.03 MeV

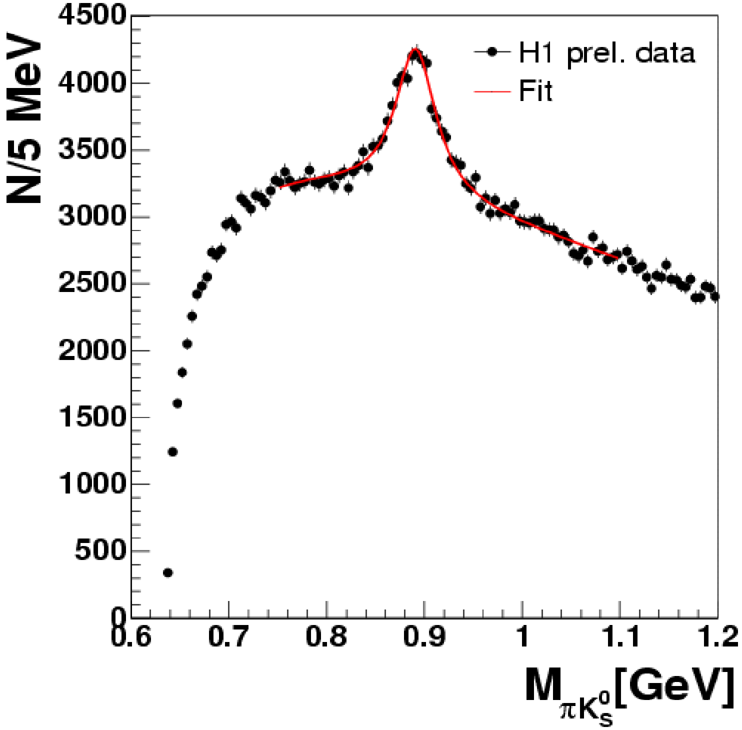
σ1=7.06 ± 0.07 MeV

σ2=17.47 ± 0.02 MeV

Invariant $K^0_S\,\pi$ mass

- combine K^0_S with primary tracks
- no dE/dx requirement

K^* signal



result from fit: (conv. B.W. and gaussian)

M= 891 ± 1 MeV

(PDG M = 891.66 ± 0.26 MeV)

N= 18939 ± 844 (stat.)

Γ= 50.8 MeV (fixed)

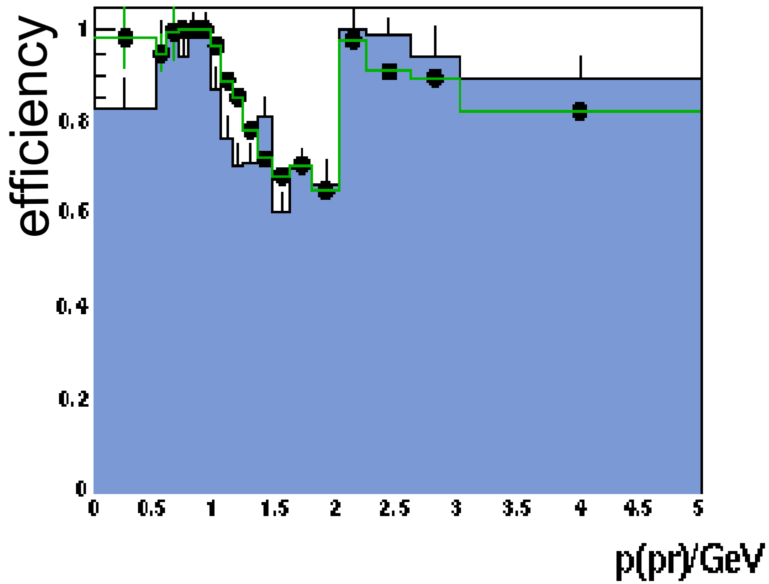
(PDG Γ=50.8 ± 0.9 MeV)

σ = 7.79 ± 2.34 MeV

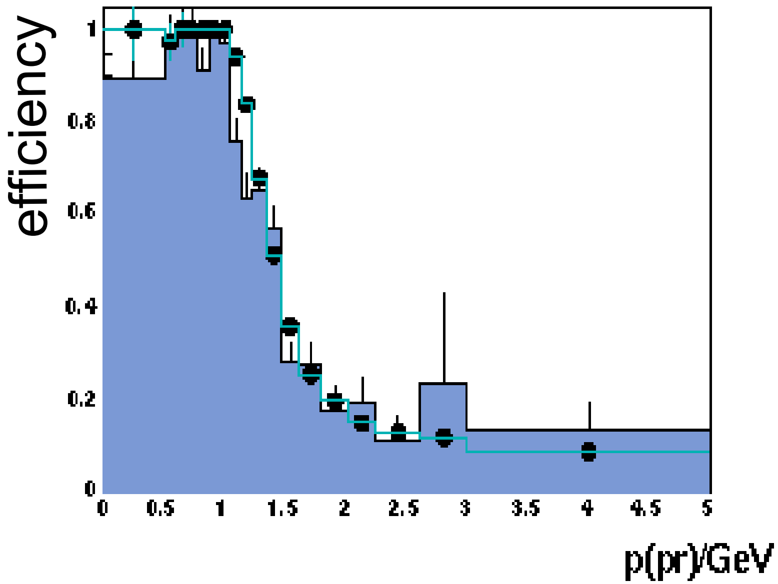
mass and width
agree with expectations

Proton selection efficiency

- momentum dependent cut on Likelihoods
- p <= 2GeV : >25hits, LH>30%
- p > 2GeV : >15 hits, LH>10%



- like ZEUS - bands
- without cut p(pr)<1.5



dE/dx efficiency described by MC within ~5%
possible differences in pt and η distribution of protons from Λ or θ+
contribution to systematic uncercainty: +- 10%

Proton selection efficiency

- N(K*) before and after dE/dx selection:

  20975 +- 841 K* and 3064 +- 207 K*

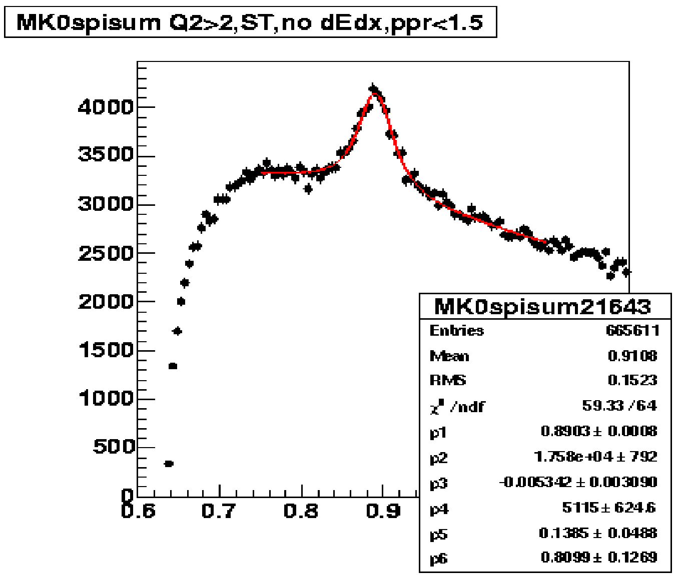
  14 % of pions survive dE/dx cut

- N(K*) before and after low momentum dE/dx selection, p(pr) <1.5 GeV:

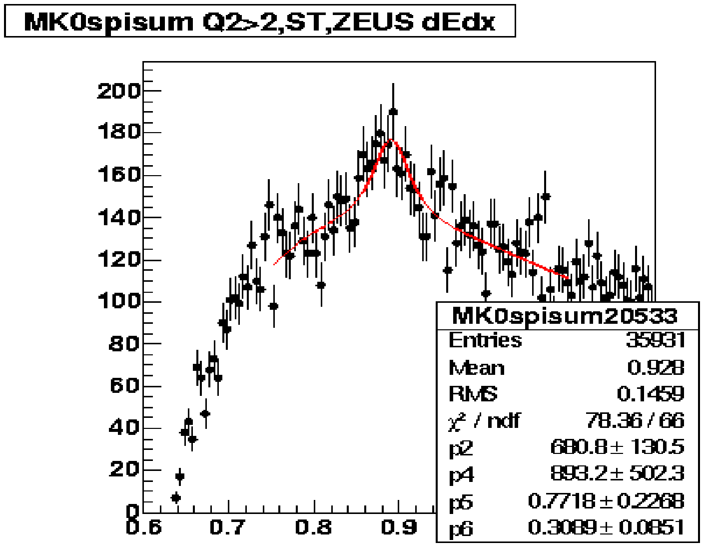
  17581 +- 792 K*   681 +- 131 K*

  3.8% of pions survive dE/dx cut

Invariant M(K0sπ) , p(pr)<1.5 GeV before and after dE/dx selection:



M($K^0{}_S\pi$)/GeV



M($K^0{}_S\pi$)/GeV

Limit Extraction

- Fitting procedure: 3 different hypothesis

1) bgr only:

$$f(M)= a*(M- (m_K+m_p))^b * \exp(- (M - (m_K+m_p)*c)$$

2) exclude signal region from fit
3) bgr + gaussian signal

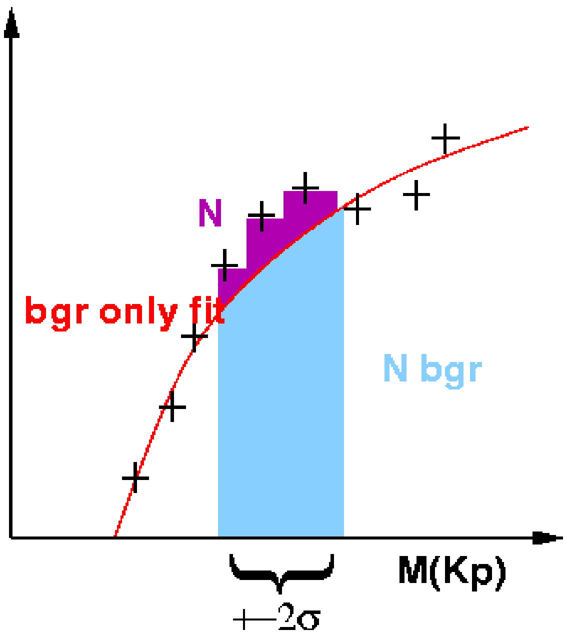
- upper limit on N (95 % C.L)

  N + 1.64*sqrt(N)

- upper limit on N(θ+) (95% C.L.) :

$$(\mathit{max}(N -Nbgr,0)+\underbrace{1.64}_{\text{95\%C.L.}}*\mathrm{sqrt}(N)) / \underbrace{0.95}_{\text{extrapol from } 2\sigma}$$

Extracting Upper Limits on θ+ production



- fit background
- 3 different hypothesis
  1) bgr only:
     $f(M)= a^*(M- (m_K+m_p))^b * \exp(- (M - (m_K+m_p)^*c)$
  2) exclude signal region from fit
  3) bgr + gaussian signal
- background subtraction in integration window
  M ± 10 MeV, ±16 MeV
  corr. to 2σ assuming a resolution of 5(8) MeV
- scan M in the range 1.48 to 1.7 GeV

upper limit on N(θ+) (95% C.L.) :

(*max*(N -Nbgr,0)+1.64*sqrt(N)) / 0.95

95%C.L.

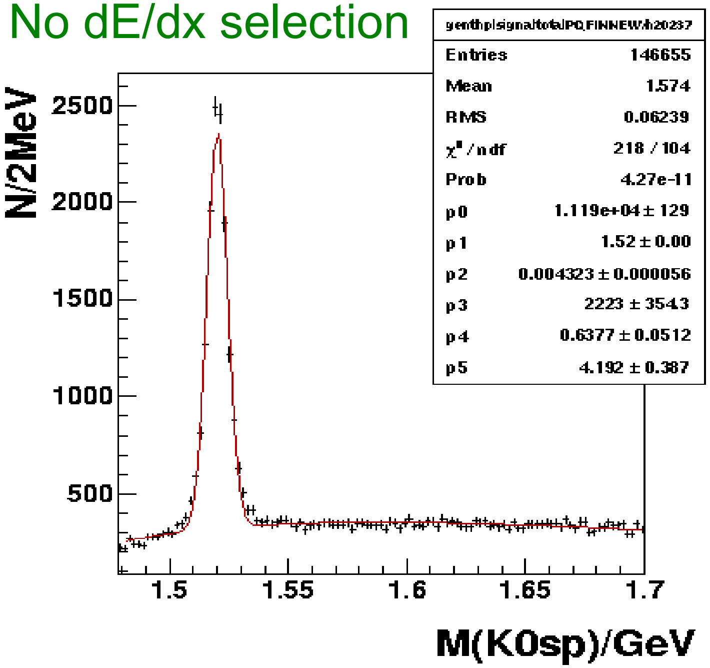
extrapol from 2σ

$$\sigma_{U.L.}(\theta^+ \to K^0\ p) = \frac{N_{u.l.}(\theta^+ \to K^0_s\ p)}{BR * \varepsilon * L}$$

- $BR(K^0_s \to \pi^+ \pi^-) * BR(K^0 \to K^0_s) = 0.343$
- $L=75\ pb^{-1}$

Detector resolution estimated from Signal MC

No dE/dx selection



RAPGAP3.1

changed decay properties of Σ^*

$\theta^+ \to K^0_s\, p$ at M=1540 MeV and M=1520 MeV

Fit Result: M=1520MeV	Fit Result: M=1540 MeV
M=1519.5 +- 0.1 MeV	M=1539.7 +- 0.1 MeV
σ=4.323 +- 0.056 MeV	σ=4.839 +- 0.084 MeV

- detector resolution ~ 5 MeV

Acceptances (before proton ID) :

	$5<Q^2<10$	$10<Q^2<20$	$20<Q^2<100$ GeV^2
M=1520	6.52 %	7.82 %	7.3%
M=1540	6.77 %	7.9 %	7.64%

(contribution to systematic error 3%)

Systematic uncertainties

Different fit methods

- bgr function only, full mass range
- bgr function, exclude signal region M+-2σ
- fit bgr + signal (fixed width)

Differences small ~2% always use most conservative

averaging weights

- average weight in Q2 bins (from fit) +- 4%

dE/dx

- efficiency described within 5% +- 10 %

Triggerefficienies S2/S61 (corrected by using MC)

- discrepancy of up to 8% +- 8%

Tracking

- single tracks: 1.8% uncertainty, 3 tracks ~6% +- 6%

e reconstruction

- +- 10%

Model dependece

- difference between signal MC M=1520 and M=1540 +- 3%

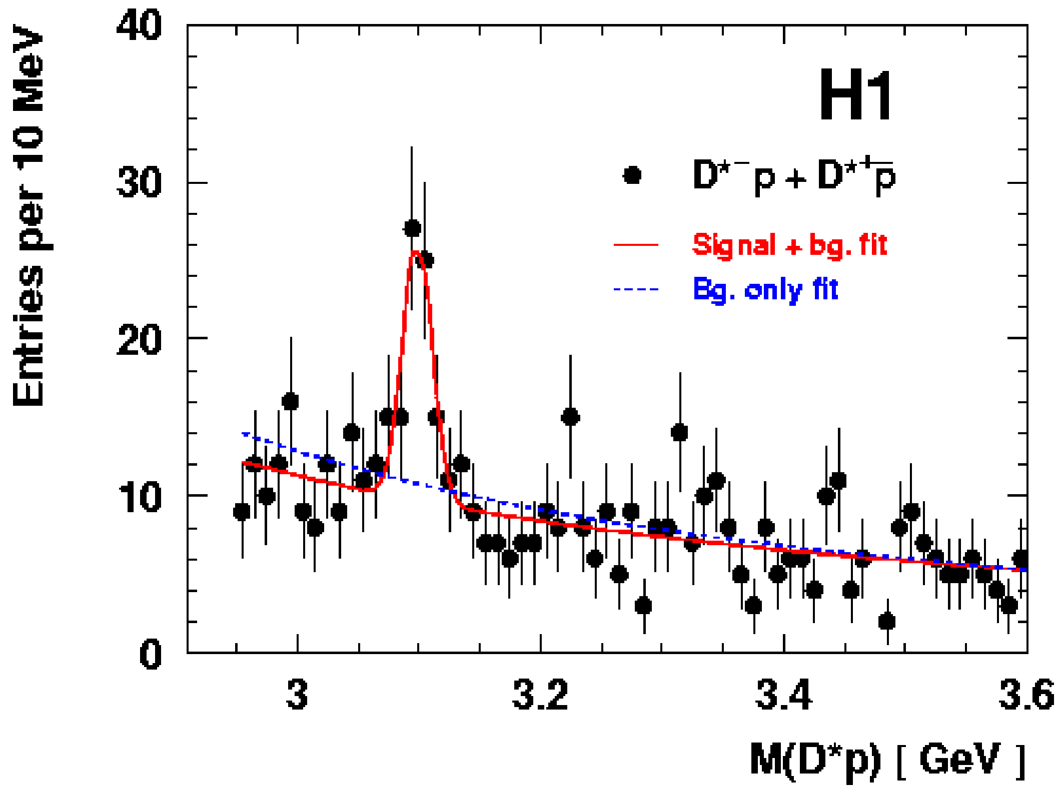
Lumi

+- 1.5 %

Total increase upper limit by 18.1 %

Charm PQ Search

Details of fit



Charges	M[MeV]	[MeV]	N_S
$D^{*-}p + D^{*+}\bar{p}$	3099 ± 3	12 ± 3	50.6 ± 11.2
$D^{*-}p$	3102 ± 3	9 ± 3	25.8 ± 7.1
$D^{*+}\bar{p}$	3096 ± 6	13 ± 6	23.4 ± 8.6

All Checks (I)

check events

•signal events scanned visually: no anomalies

• double entries ?

1.) Within +- 24 MeV around peak: 1 double entry

2.) All M(D*p) < 3.6 GeV: 1.12 entries / event

signal from D*,p?

• backward D* analysis: signal region D* rich

• well identified protons (p<1.2, hard dE/dx): signal there

average norm. likelihood in signal region $\langle L_p \rangle = 0.92$

physics in signal and bgr region?

• physics on/off resonance: proton spectrum harder on resonance

peak stable?

• signal present in subsamples (in Q^2, x, y, η, p_t, data taking period)

• variations of binning and selection: mass, width stable

• signal present in photoproduction

All Checks (II)

signal from bgr or from D*, protons?

- wrong charge D bgr instead of real D*: no peak
- D* sidebands instead of $\Delta M(D^*)$ signal window: no peak
- K, π selected (via dE/dx) instead of protons (p-mass assigned): no peak
- Kπ combinations with masses above region where charm contributes: no peak

check refelections

- reflections from possible signal in D*K (D*p) mass distribution?
  protons assigned K, π mass: no peak
- reflections from D_1^0, D_2^{0*}: expected contribution (MC): 4 evts (±24MeV)
- signal due to $D^{*0} \rightarrow D^0 \gamma \rightarrow D^0 e^+ e^-$? no (e+e- misidentified as π and proton)
- possible peak structure in all possible mass combinations with all possible mass hypotheses of the particles making the D* and the D*p system to search for real or fake resonences, e.g. $\Lambda,^0\Delta,^{++}\Delta_s^0$, K^2,ϕ,f no enhancements found
- possible peak strucutures in all possible mass correlations among the proton candidate and the remaining charged particles of the event with all possible mass assignments to search for real or fake peaks no enhancements found

All Checks (III)

studies of D*p and associated K^0s or Λ

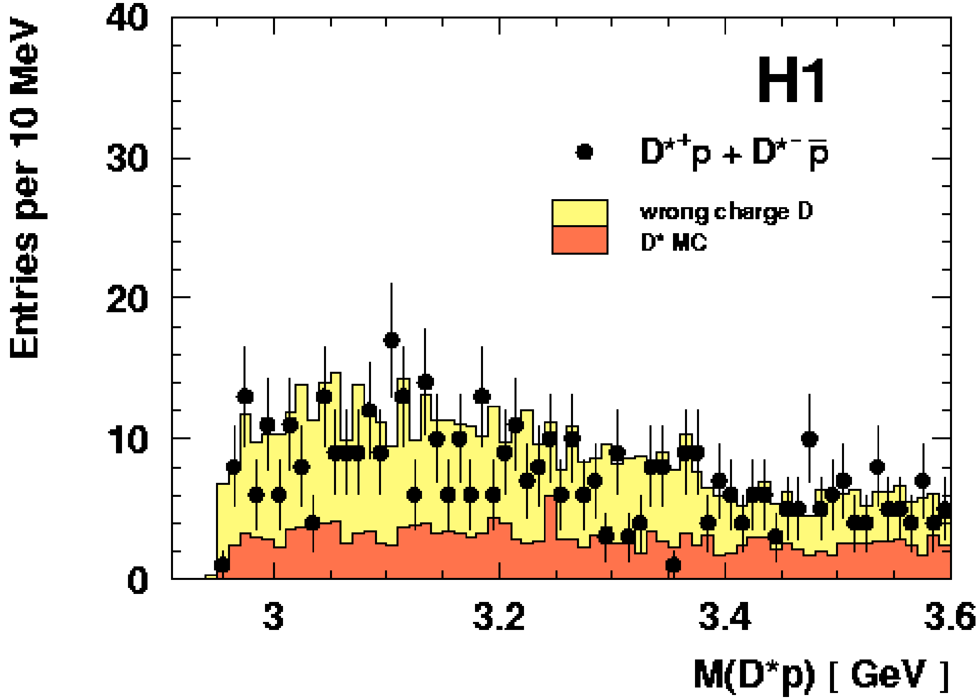
- D*p and K^0s selected. If at least 1 common track required (in D*p mass region): no indication of K^0s signal
- select $D^0 \to K^-\pi^-$ (and c.c.) and search for Λ (or antiΛ) with appropriate quark content: no Λ signal left in dm(D*) window
- Select Λ signal region and study M(KpΛ) or M(D*p): D*p signal not faked by Λ

Signal visible also in like sign D*p ?

data consistent with
background estimation

No significant peak in
like sign D* p

No!



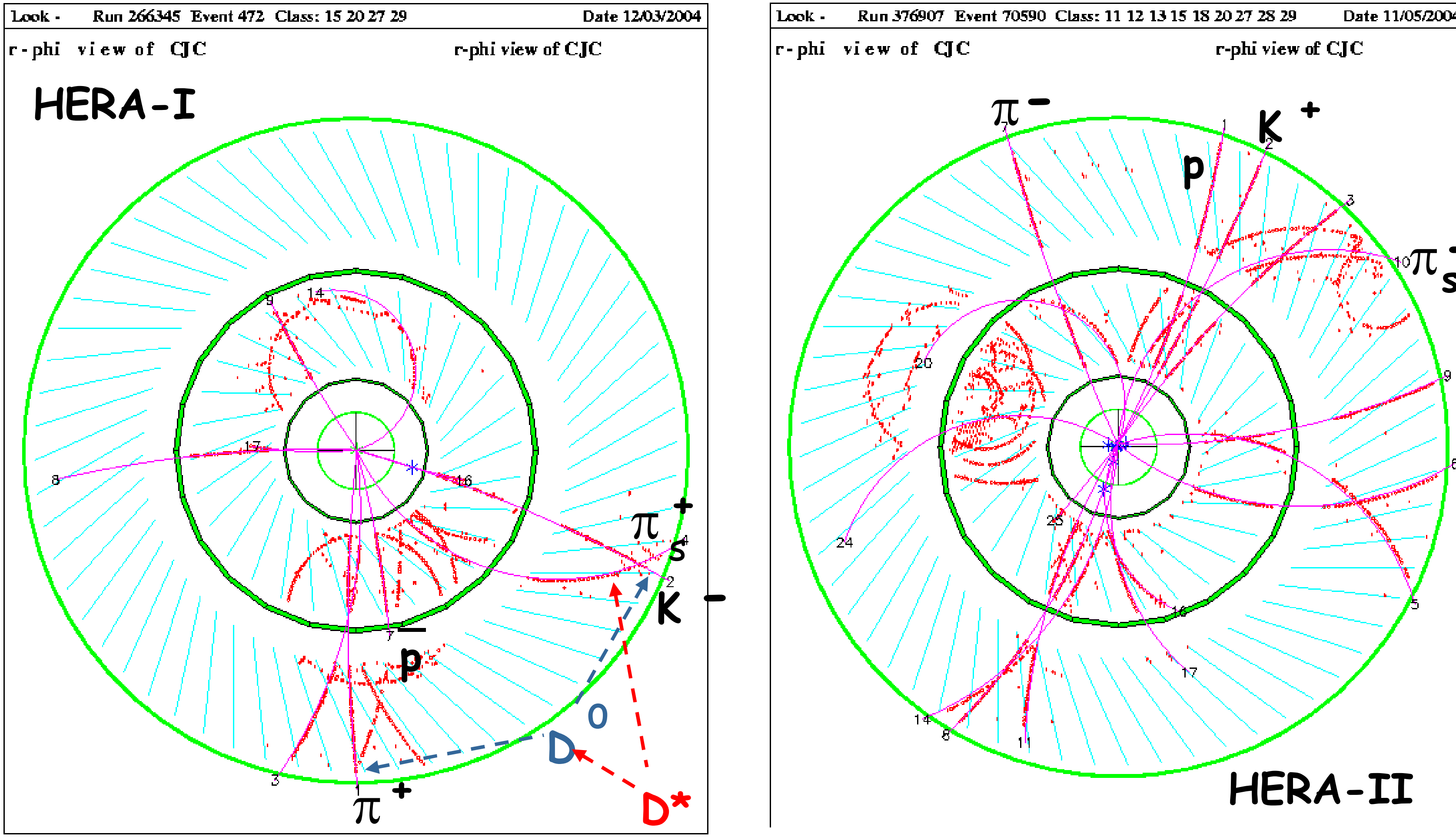
charm and non-charm bgr:

- no enhancement in D* Monte Carlo
- no enhancement in wrong charge D

Background well described by D* MC and "wrong charge D" from data

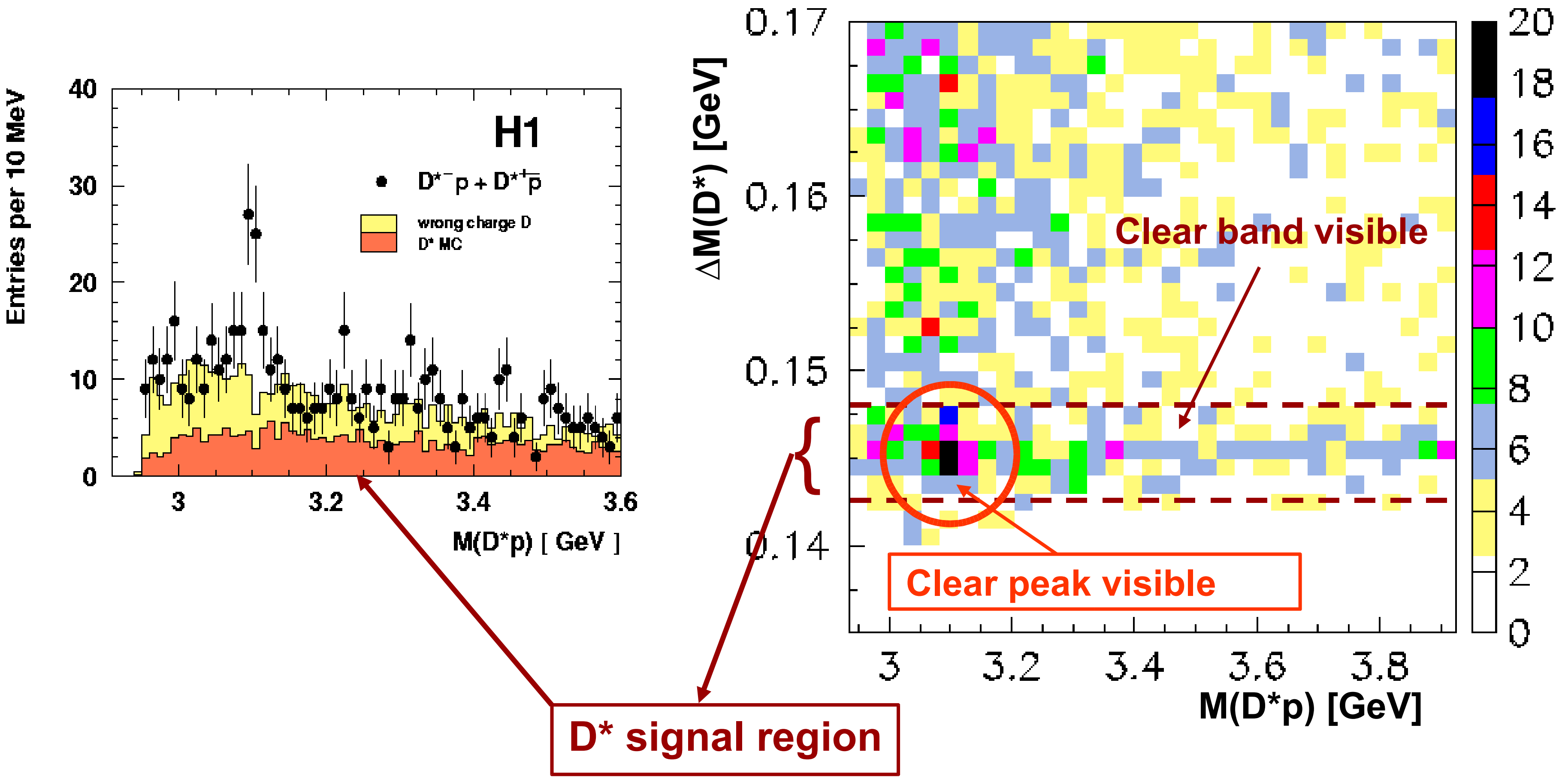
Signal faked by reconstruction problem?

Typical D*p candidates:



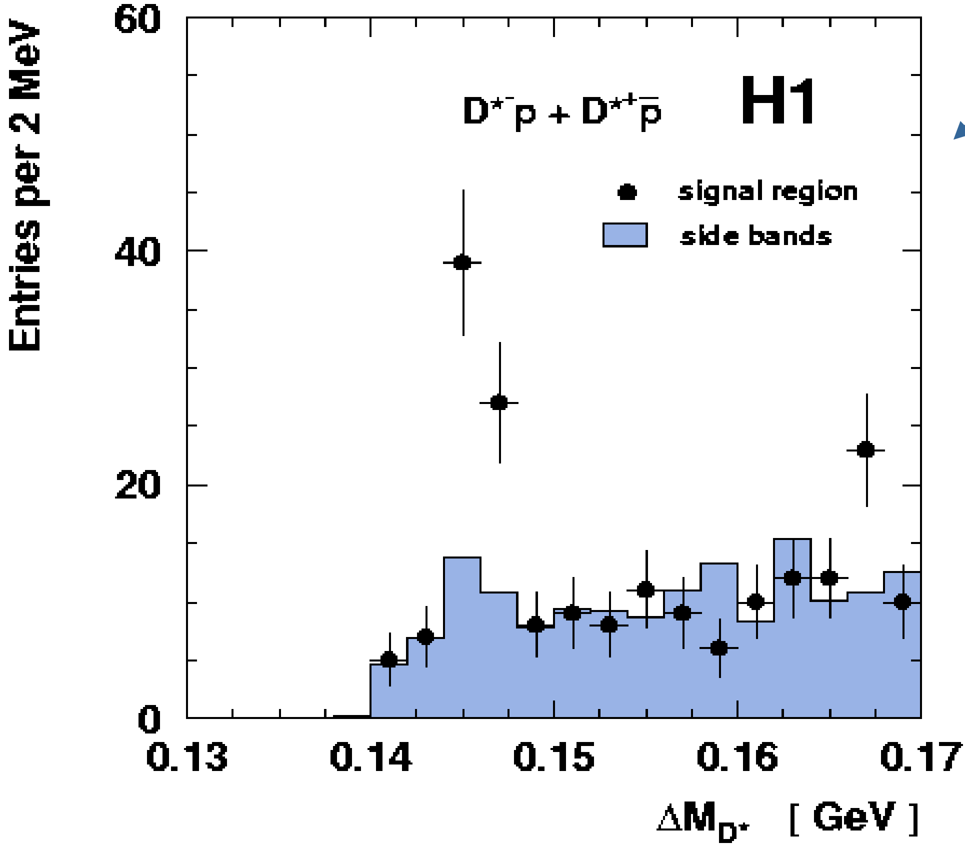
All signal events visually scanned – no anomalies **No!**

Does Resonance come from D*?

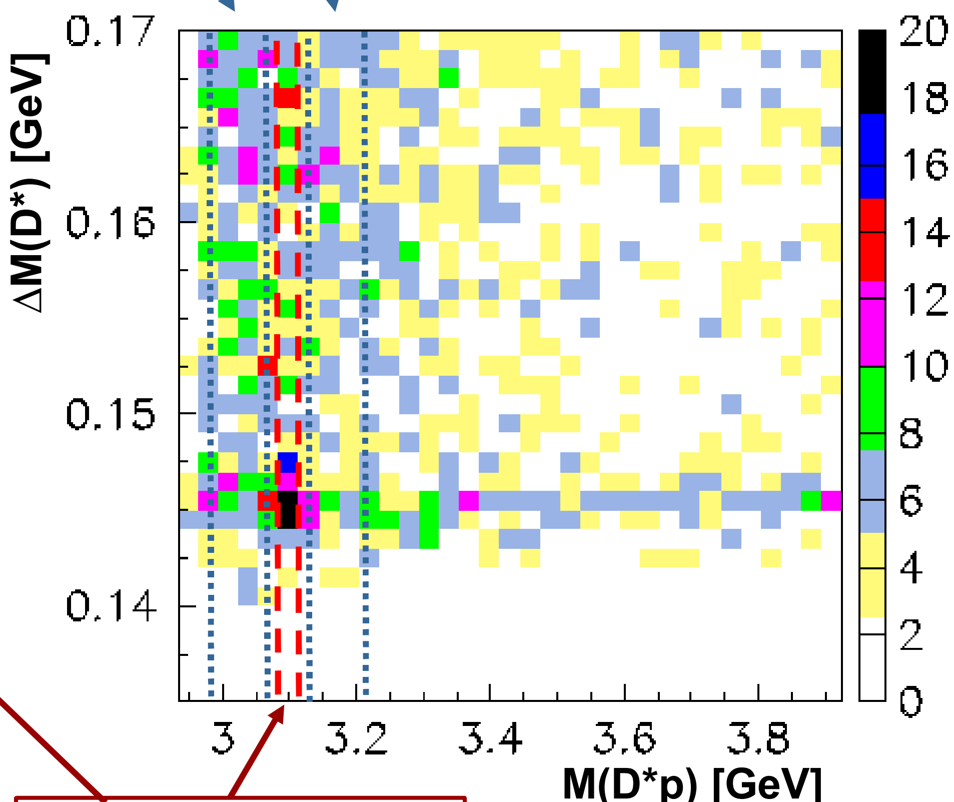


Does Resonance come from D*?

ΔM(D*) in D*p – signal region and sidebands:



D*p Side bands



D*p signal region

Side band scaled to the width
of the signal window in M(D*p)
no further normalization!

Yes!

D*p signal region is richer in D* than sidebands

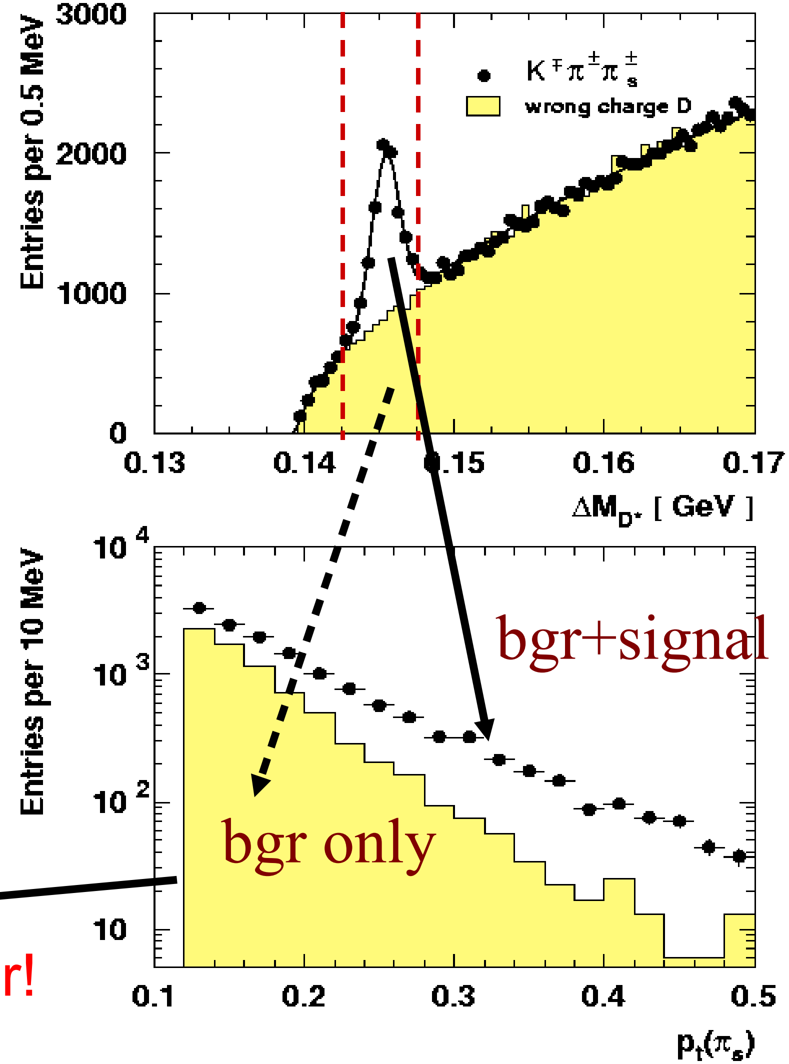
on and off resonance kinematics of D*

- single charged particles:
  momentum spectrum steeply falling!
  preserved in combinatorial bgr

- Particles from decay:
  - → Lorentzboost
  - → particles may be emitted in direction of flight

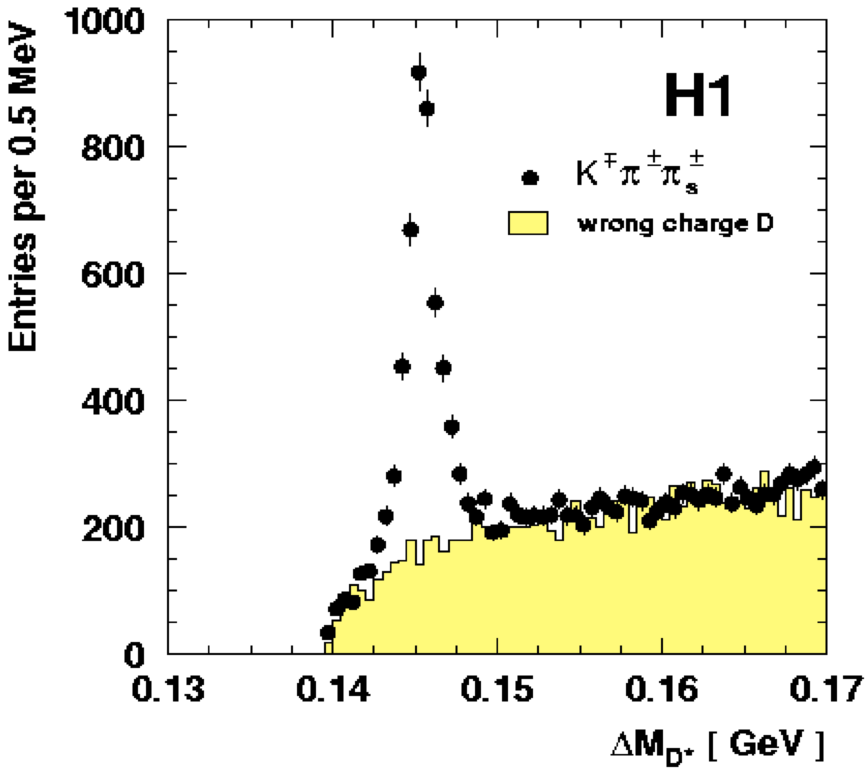
Harder momentum spectrum expected for particles from decay

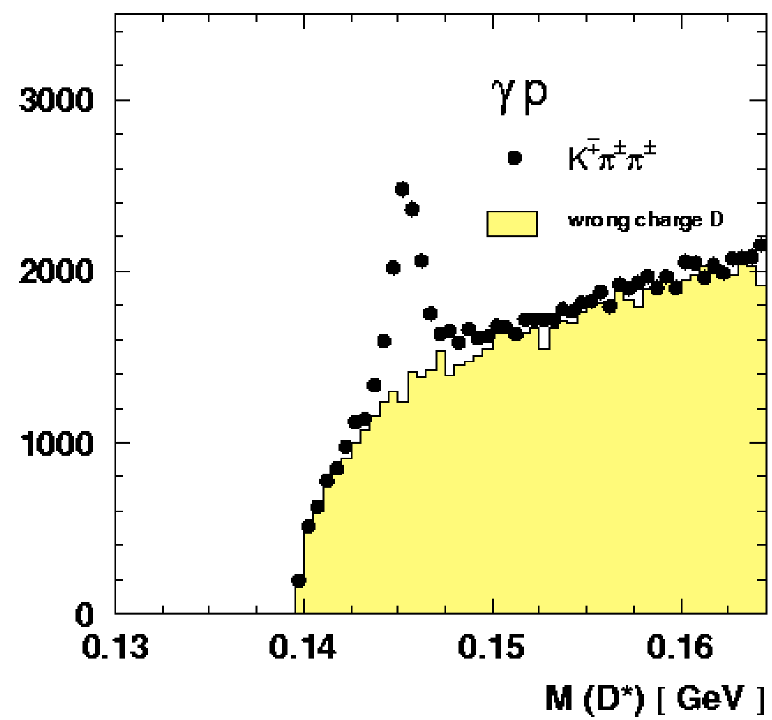
example: π_S from D* (looser selection)



Check assumption using D*:
π_S momentum spectrum
harder for D* than for wrong charge D bgr!

D* signal in DIS and photoproduction

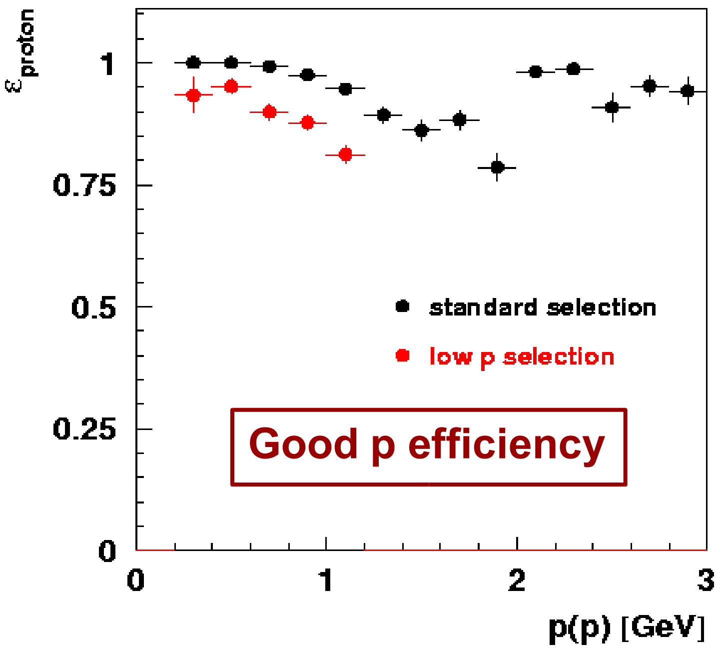




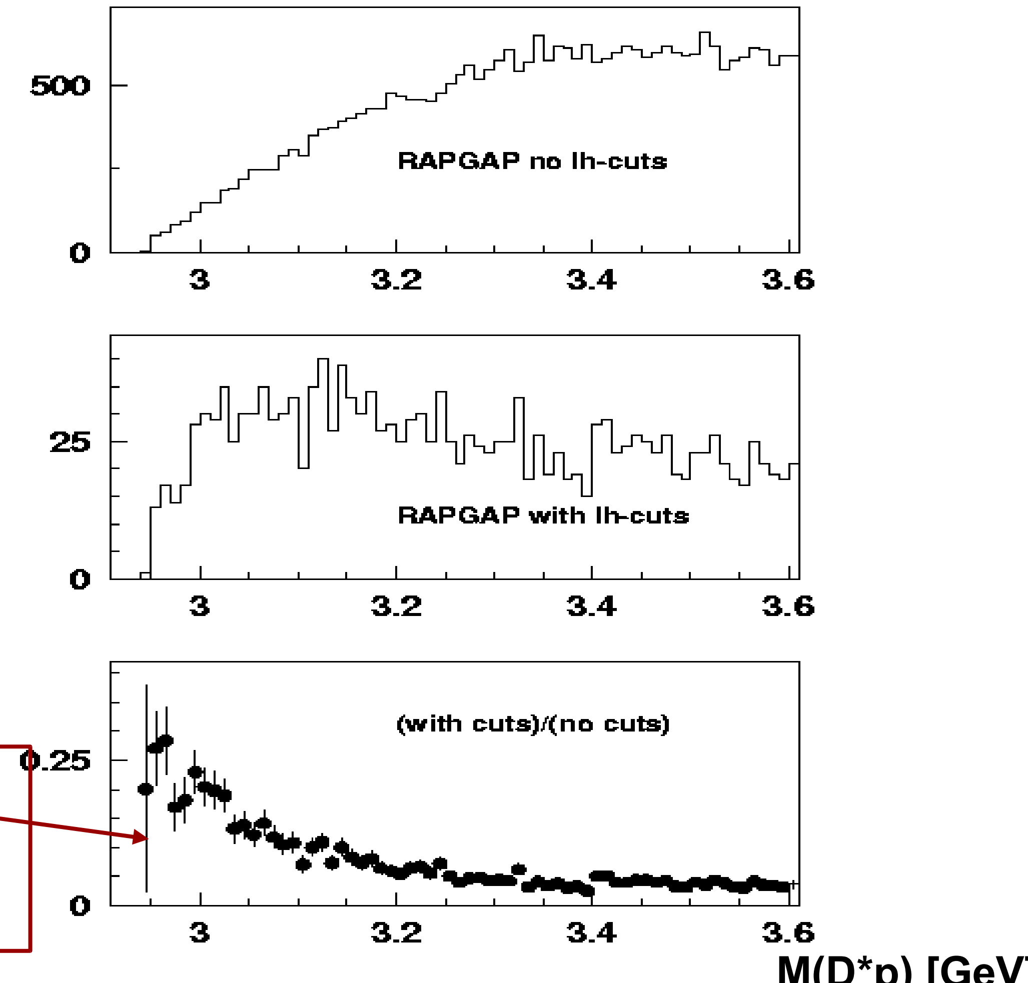
- DIS cleaner signal
- photoproduction: supporting evidence

Acceptance effects?

Proton efficiency



"Pion survival probability"



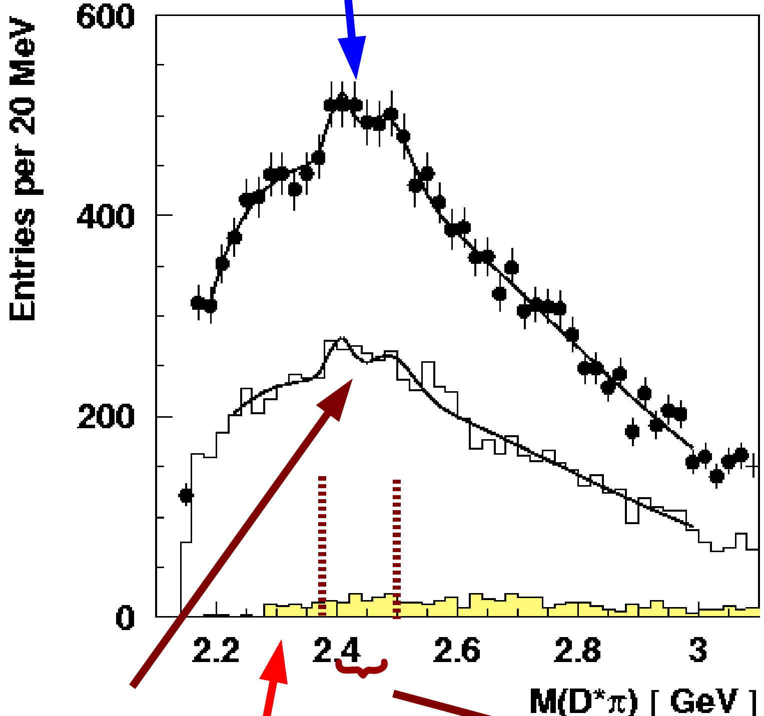
Smooth variation with M(D*p)
Shape reflects opening of phase space

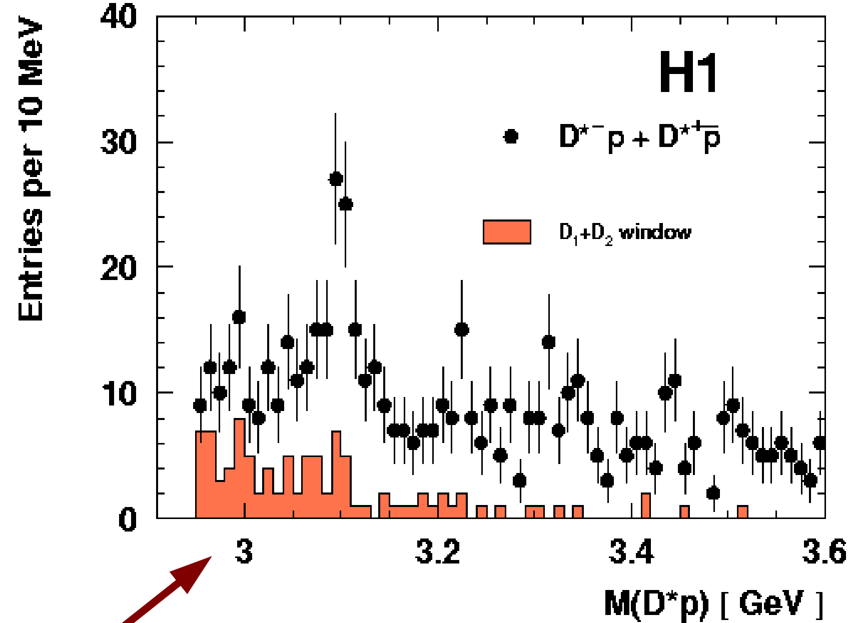
$$M(D^*p) = m(K\pi\pi p) - m(K\pi\pi) + M_{PDG}(D^*)$$

Reflections from decays to D*π ?

loose D* cuts
π selection

D_1^0, $D_2^{0*} \rightarrow D^*\pi$





D* cuts of D*p
π selection

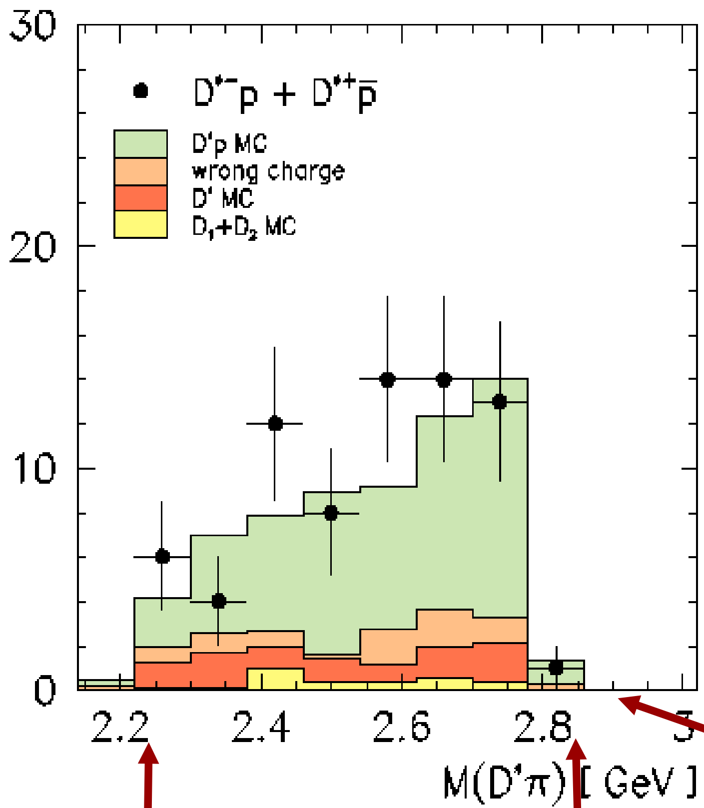
D_1 , D_2 window

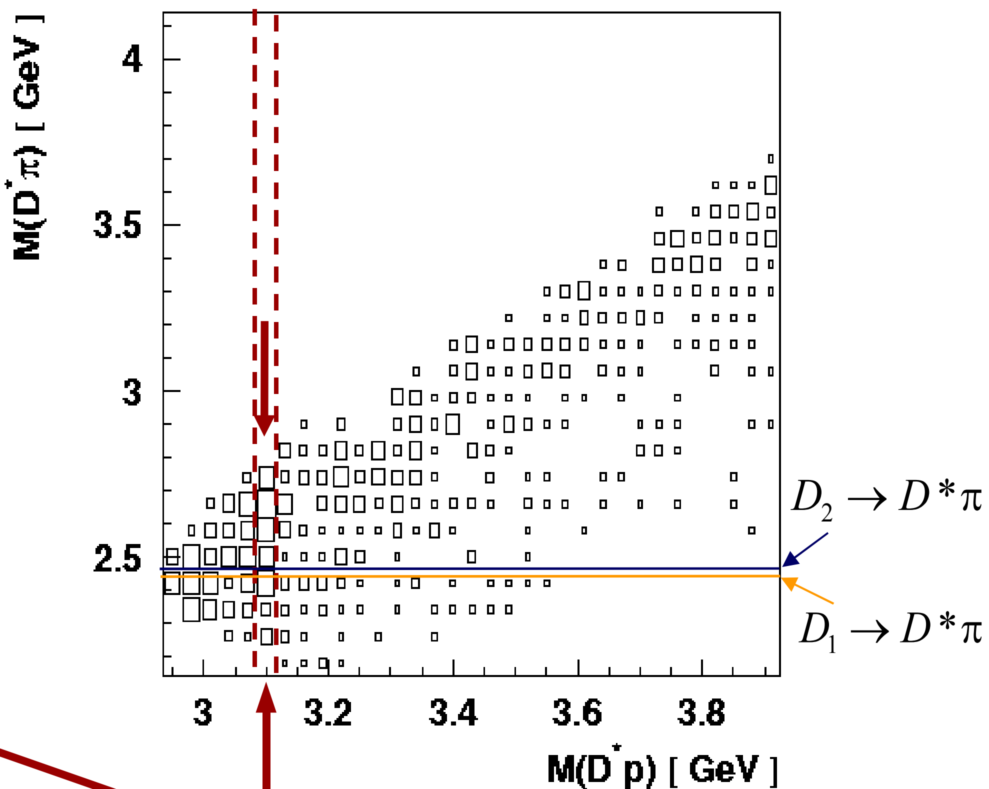
D* cuts of D*p
proton selection

Expect 3.5 decays (D_1^0, $D_2^{0*} \rightarrow D^*\pi$) in D*p signal

Reflections from decays to D*π ?

D_1^0, $D_2^{0*} \rightarrow D^*\pi$





go to the D*p signal region

Signal for X→D*p: available phase space in D*π completely used

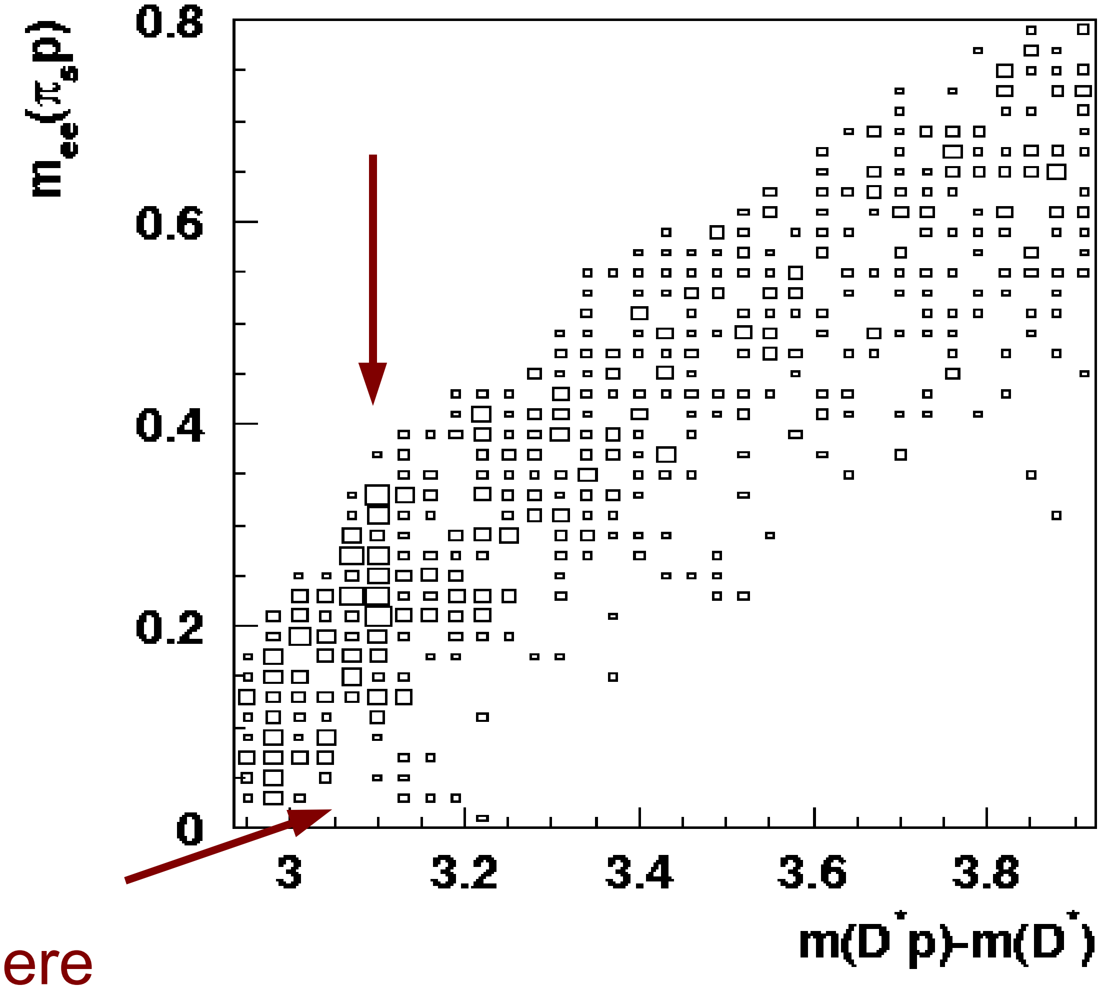
Within ±24 MeV around D*p signal:
4 events from D_1^0, D_2^{0*} expected

Could signal be due to decay $D^{0*} \to D^0 \gamma$?

$D^{0*} \to D^0 \gamma \to D^0 e^+e^-$

electrons

- asymmetric in energy
- misidentified as proton and π_s ?



No accumulation at small m_{ee} in D*p signal region or elsewhere

Systematic error for R_{cor} (D*p(3100)/D*)in visible D* region

Relative systematic errors:

Δdm(D*) window 1.5 MeV instead of 2.5 MeV - 9 %
Fit with our background model instead of $(M(D^*p)-M(D^*))^{\alpha}$ - 12 %
z(D*)>0.1 instead of z(D*)>0.2 - 21 %
Exclude D_1,D_2 signal region by $|m(D^*\pi)-2.45|>50$ MeV + 18 %
Uncertainty in dE/dx ± 10 %
Re-weighting of D*p fragmentation function - 5 %
Re-weighting of η(D*p) distribution - 3 %

Total - 28 + 21 %

Total systematic error : -0.45+0.33%

Systematic error for $\sigma(D^*p)/\sigma(D^*)$ for full D* region

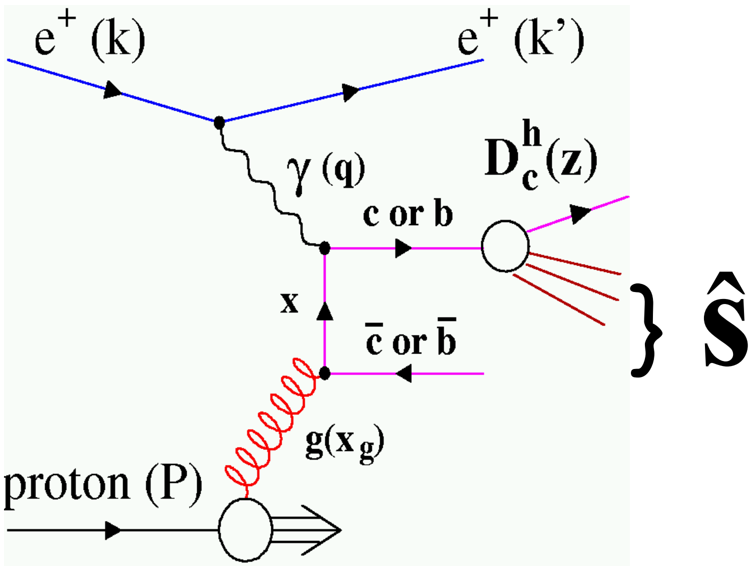
Relative systematic errors:

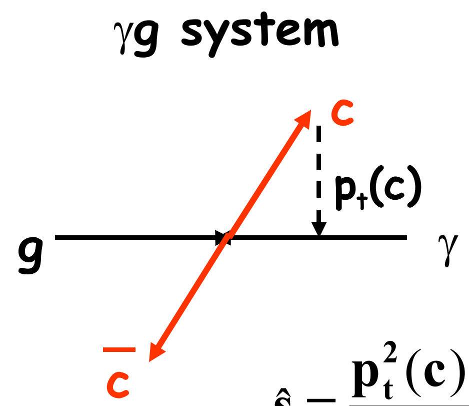
$\Delta dm(D^*)$ window 1.5 MeV instead of 2.5 MeV	- 10 %
Fit with our background model instead of $(M(D^*p)-M(D^*))^\alpha$	- 14 %
$z(D^*)>0.1$ instead of $z(D^*)>0.2$	- 8 %
Exclude D_1,D_2 signal region by $\lvert m(D^*\pi)-2.45\rvert>50$ MeV	+ 17 %
Selection with $x_{obs}(D^*p)$ instead of $z(D^*)$	- 15 %
Uncertainty in dE/dx	± 10 %
Re-weighting of D*p fragmentation function (*)	+ 28 %
Re-weighting of $\eta(D^*p)$ distribution	- 4 %
Total	- 26 + 34 %

Total systematic error : -0.64+0.85%

(*) if the $x_{obs}(D^*p)$ cut is used instead of the $z(D^*)$ cut the systematic uncertainty due to fragmentation reduces to 11%

Acceptance corrected D*p/D* yield ratio: definition of shat





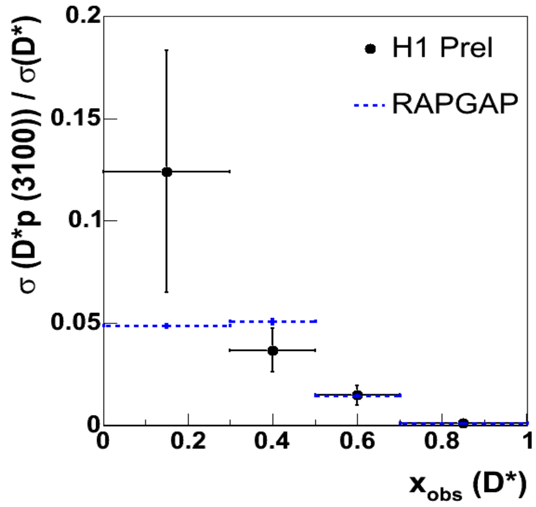
$$\hat{s} = \frac{p_t^2(c) + m_c^2}{z(z-1)}$$

But: we observe charmed hadrons instead of quarks
Normal procedure: Replace quantities of c-quark by those of D*
We measure also fragmentation variable x_{obs} --> we can do better :

$$\hat{s} = \frac{p_t^2(D^*)/x_{obs}(D^*) + m_c^2\, x_{obs}(D^*)}{z(D^*)(z(D^*)/x_{obs}(D^*) - 1)}$$

Reconstruction of shat: purity: 74-81% (65-92%) with D* (and Θ_C) MC
stability: 74-82 % (65-93%)

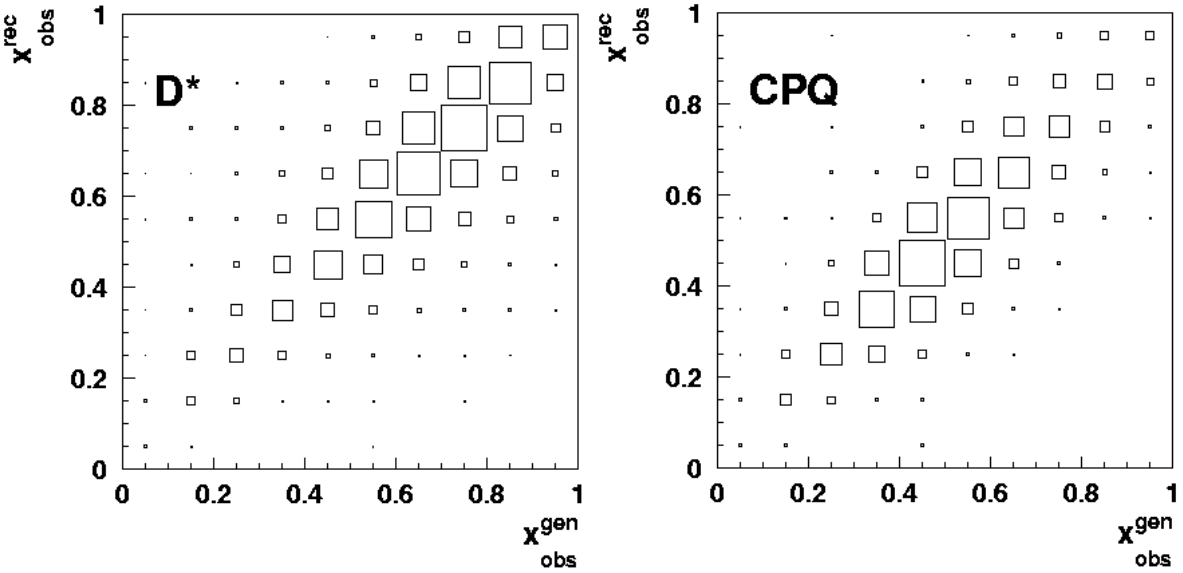
Remarks on $\sigma(D^*p)/\ \sigma(D^*)(x_{obs})$



$x_{obs}(D^*)$ very soft !

for $x_{obs}(D^*)>0.5$:
$\sigma(D^*p)/\sigma(D^*)=1.08\pm0.31\%$

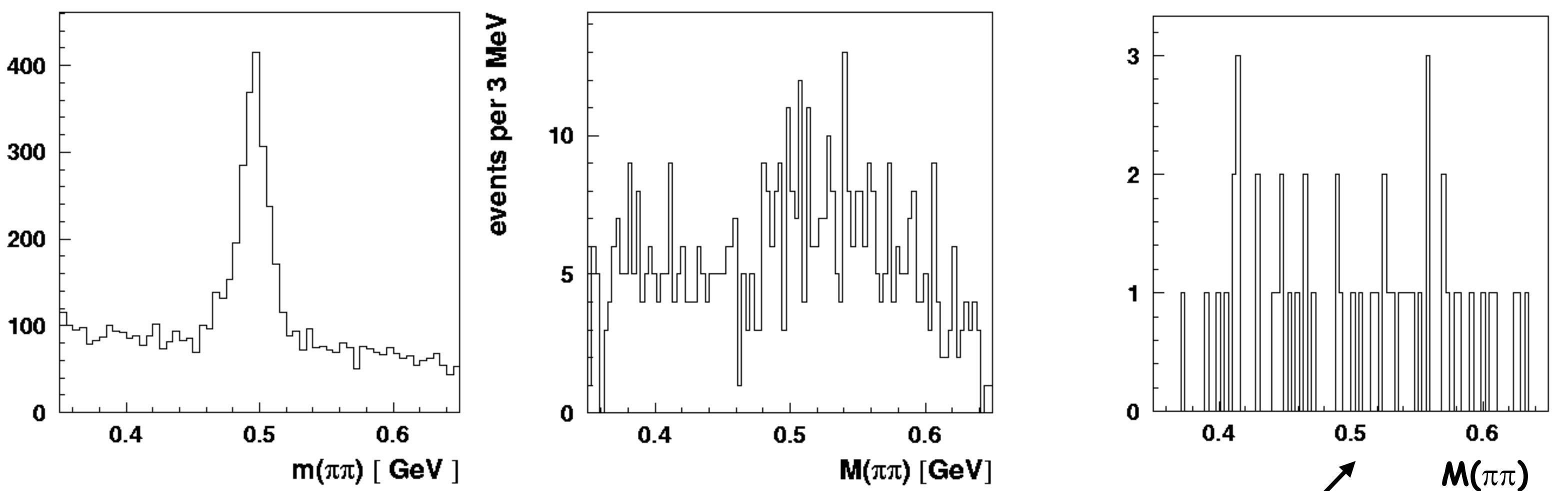
for $x_{obs}(D^*)>0.7$:
$\sigma(D^*p)/\ (D^*)=0.17\pm0.13\%$



Investigation of D*p and associated K^0's

selection of D* DIS-events (dm<170MeV,right and wrong charge combi.) with V^0 candidates

At least on track in common



No obvious K^0 signal

D*p signal region

No indication for a K^0 signal