# Light Mesons in Photoproduction

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on behalf of
H1 Collaboration

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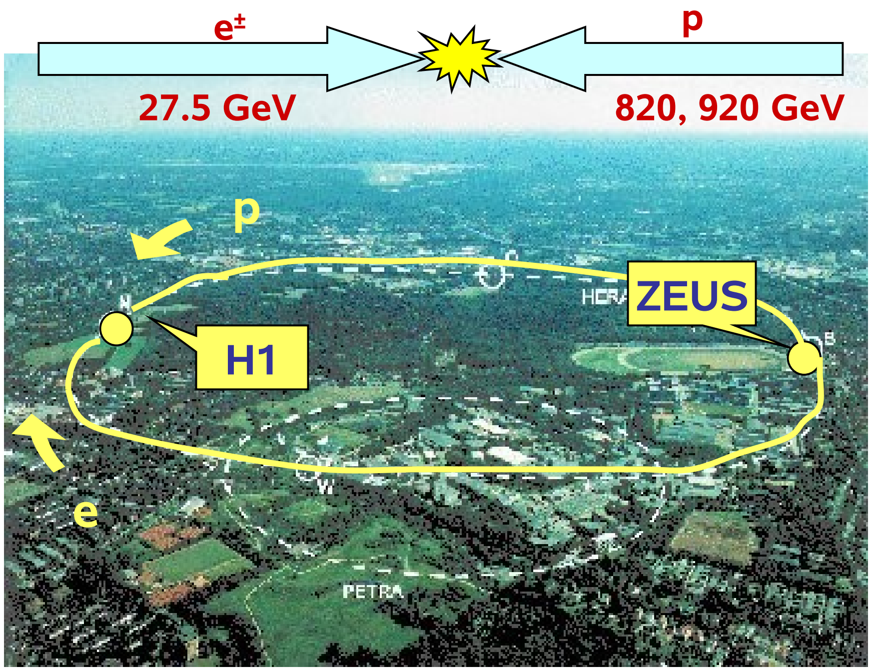
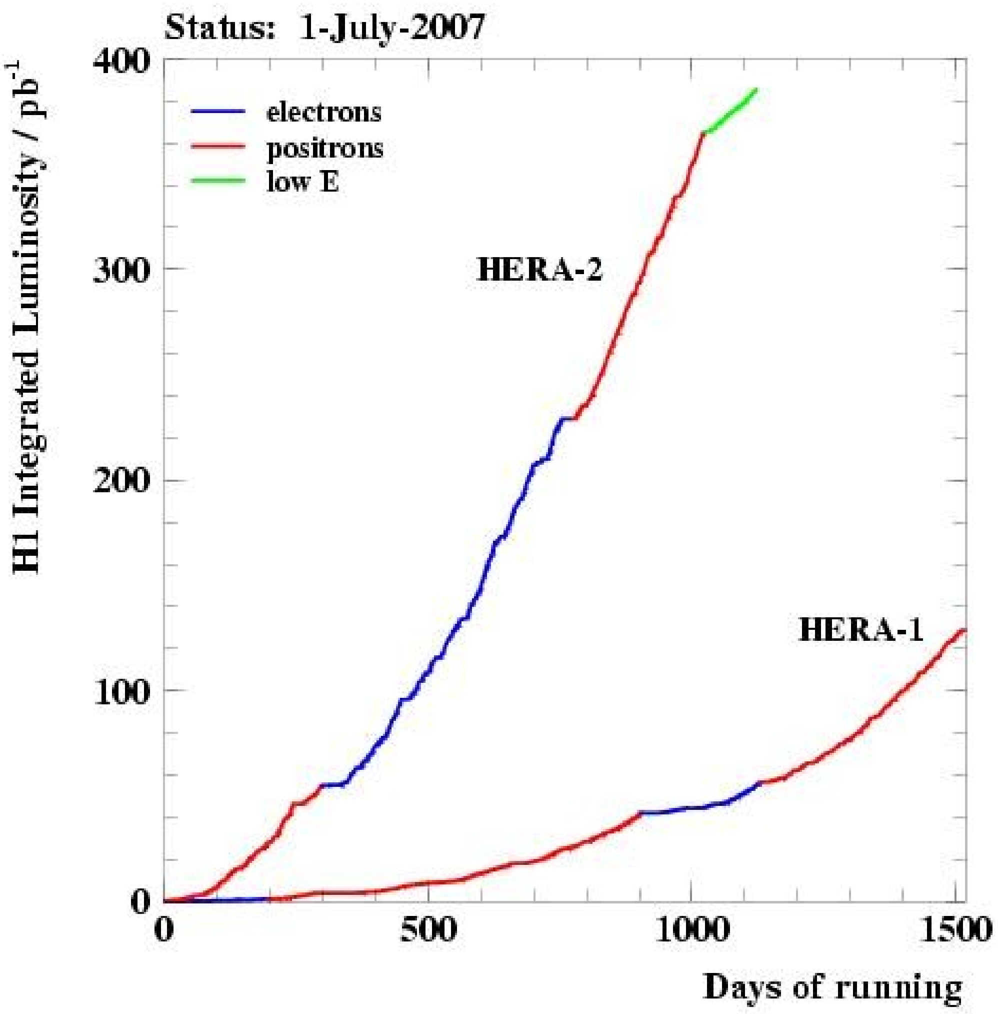
- Introduction
- Cross section measurements: $\rho^0$, $K^{*0}(892)$, $\phi(1020)$ ***meson***
- Comparison with models
- Comparison with RHIC results

# The HERA Collider

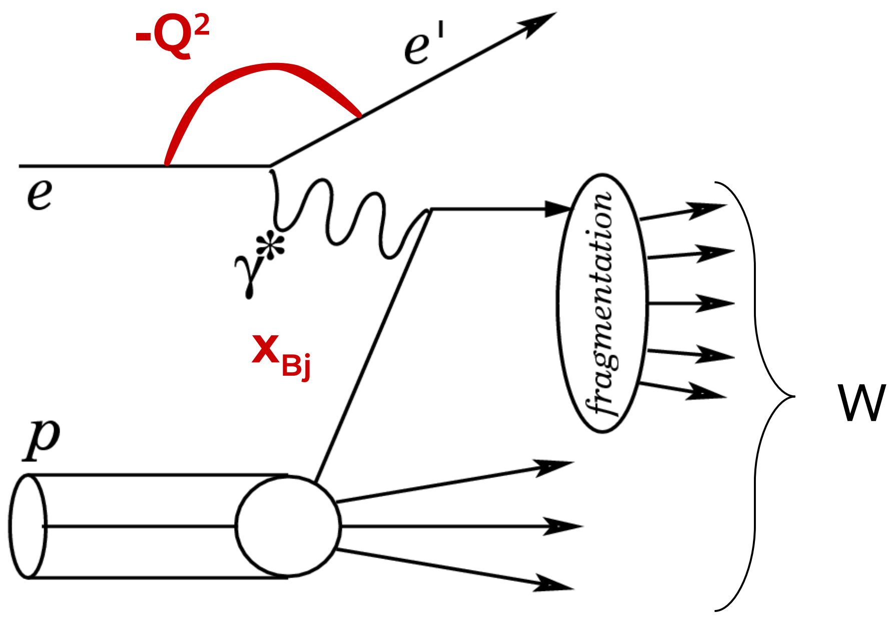



H1 and ZEUS:

- 92 - 07 years
- Lumi ~ 0.5 $fb^{-1}$ (each exper.)

# ep kinematics




energy c.m.: $\sqrt{s}$ = 300-320 GeV

hadronic energy: W = m(γ*p)

photon virtuality : $Q^2$

two regions: $Q^2 \approx 0$ GeV² — photoproduction

$Q^2 > 1$ GeV² — electroproduction (DIS)

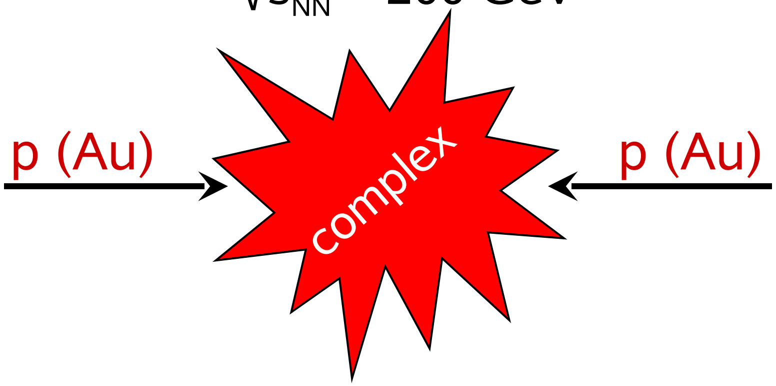
# Motivation

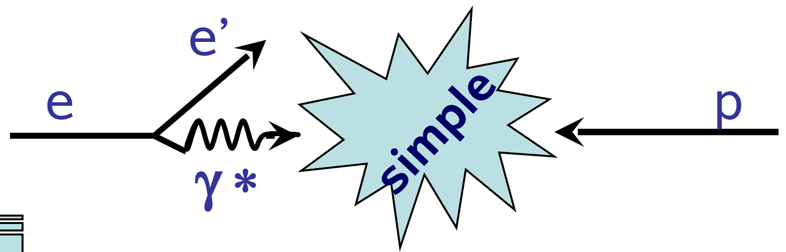
- $e^+e^-$ collisions at LEP:
  distortion of $\rho^0$ line shape and shift towards lower masses was observed


- RHIC:
- H1:

inclusive $\rho(770)^0$, $K^*(892)^0$ and $\phi(1020)$

$\sqrt{s_{NN}} \sim 200$ GeV ← ≈ → $W_{\gamma p} \sim 210$ GeV

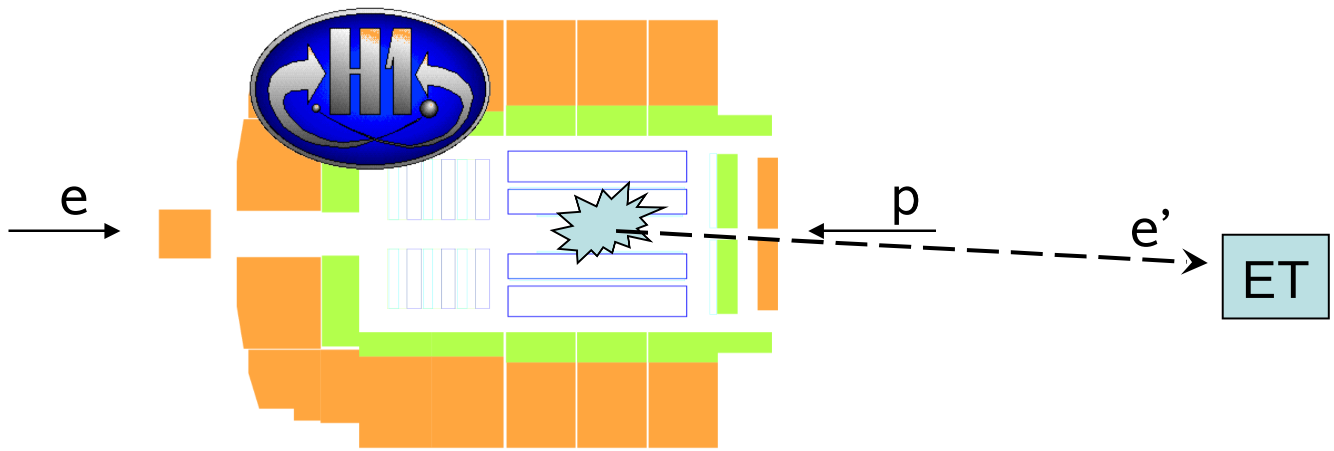



give a unique opportunity to make comparison of RHIC results with simpler interaction system (HERA)

*$\rho^0$, $K^{*0}(892)$, $\phi(1020)$* measurements at HERA help to study hadronisation

# Selection

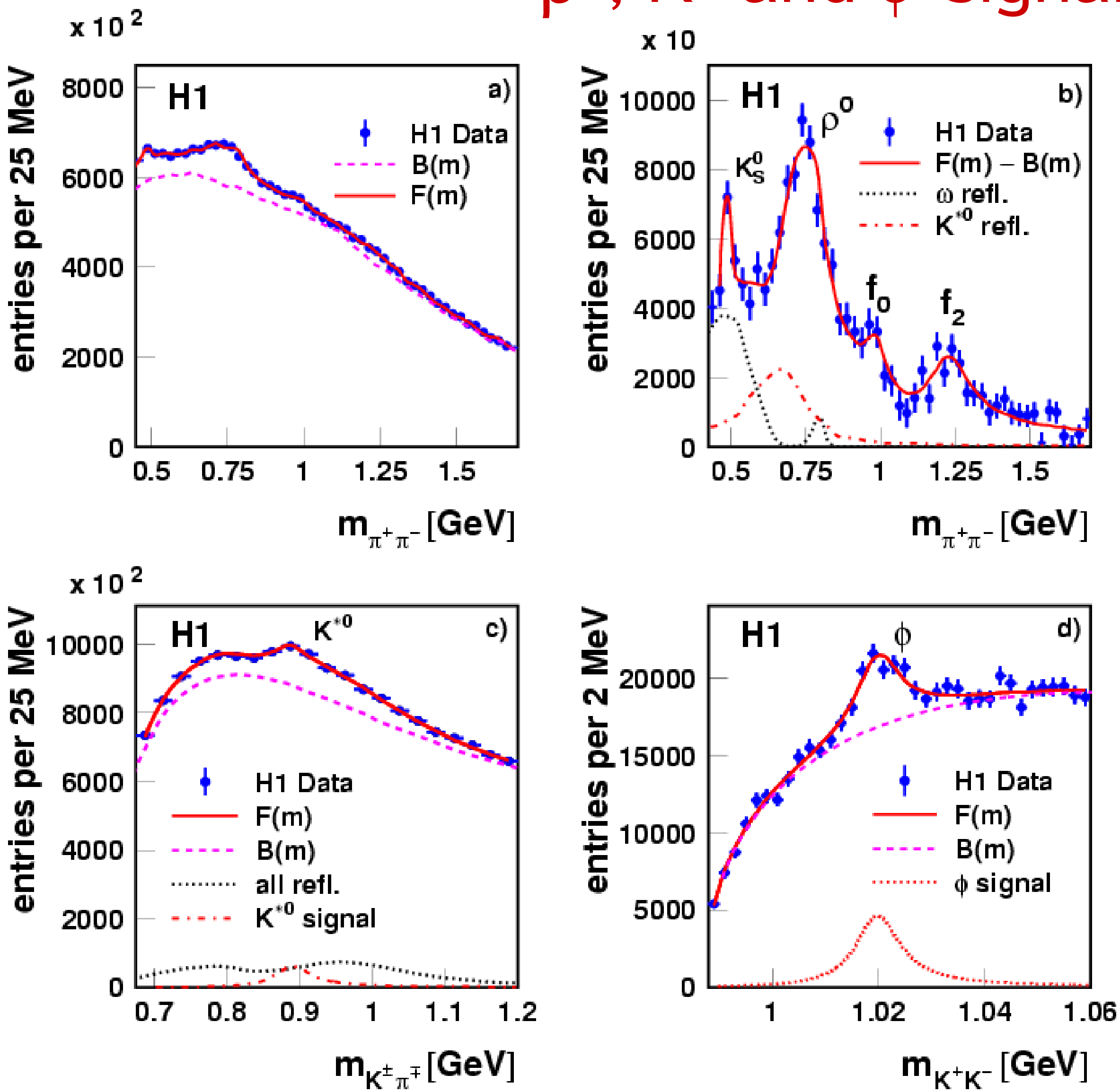



Main selection criteria for event:

- H1 data 2000 with $L = 36.5\ pb^{-1}$
- Photoproduction $Q^2 < 0.01\ GeV^2$ with e' in ET (electron tagger)
- $174 < W < 256$ GeV $\Rightarrow \langle W \rangle = 210$ GeV
- Trigger requires at least 3 tracks in the Central Tracker with $p_T > 0.4$ GeV

$\rho^0 \to \pi^+\pi^-$ $K^{*0} \to K\pi$ $\phi \to K^+K^-$

# $\rho^0$, K* and $\phi$ signal



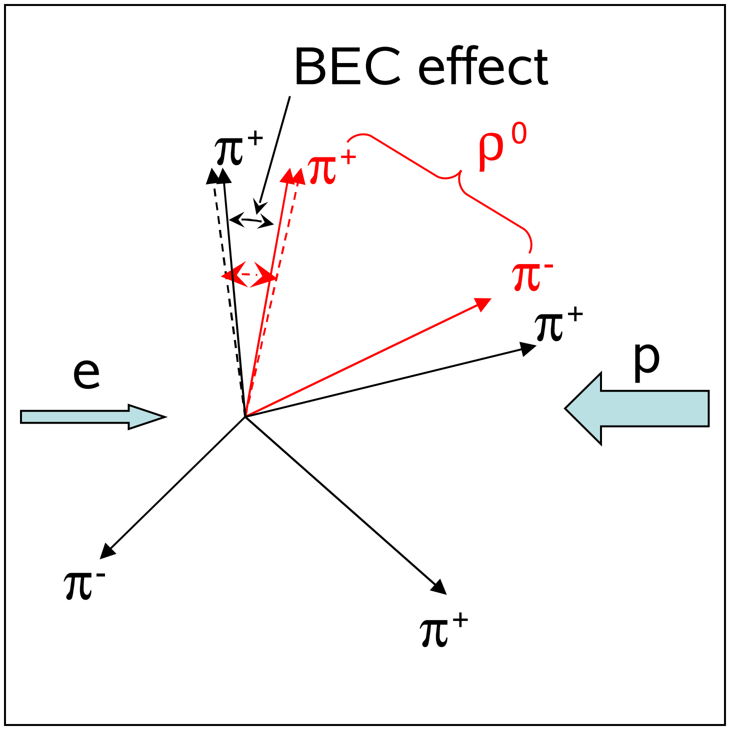

Fit function:
$F(m) = S(m) + R(m) + B(m)$

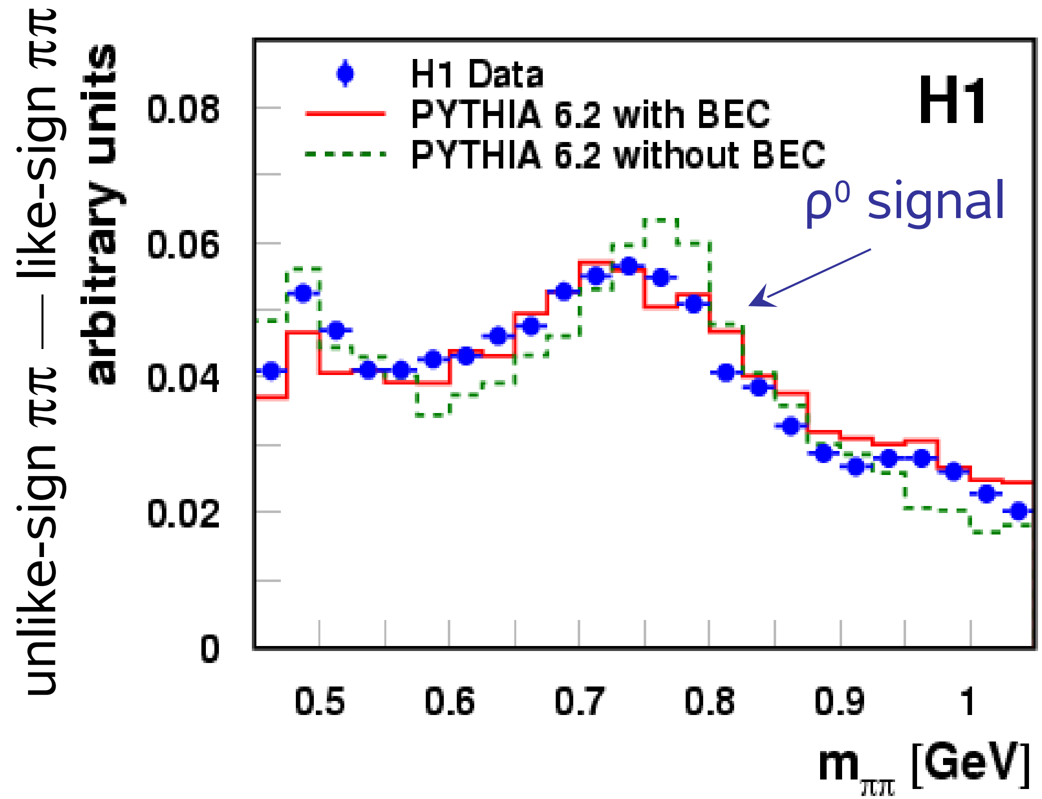
Signal
Reflection
Comb. background

Clear signals of $\rho^0$, K* and $\phi$ mesons are observed

# Bose-Einstein Correlations (BEC)

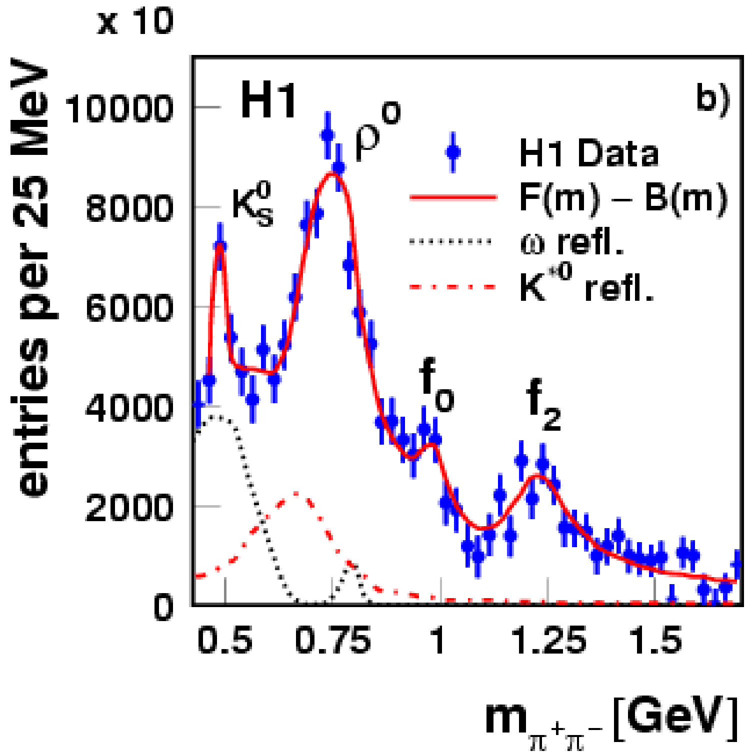
distortion of $\rho^0$ mass spectrum due to BEC




A modification of $\rho^0$ produced in $\gamma p$ collisions is described by taking into account Bose-Einstein correlations in Monte Carlo

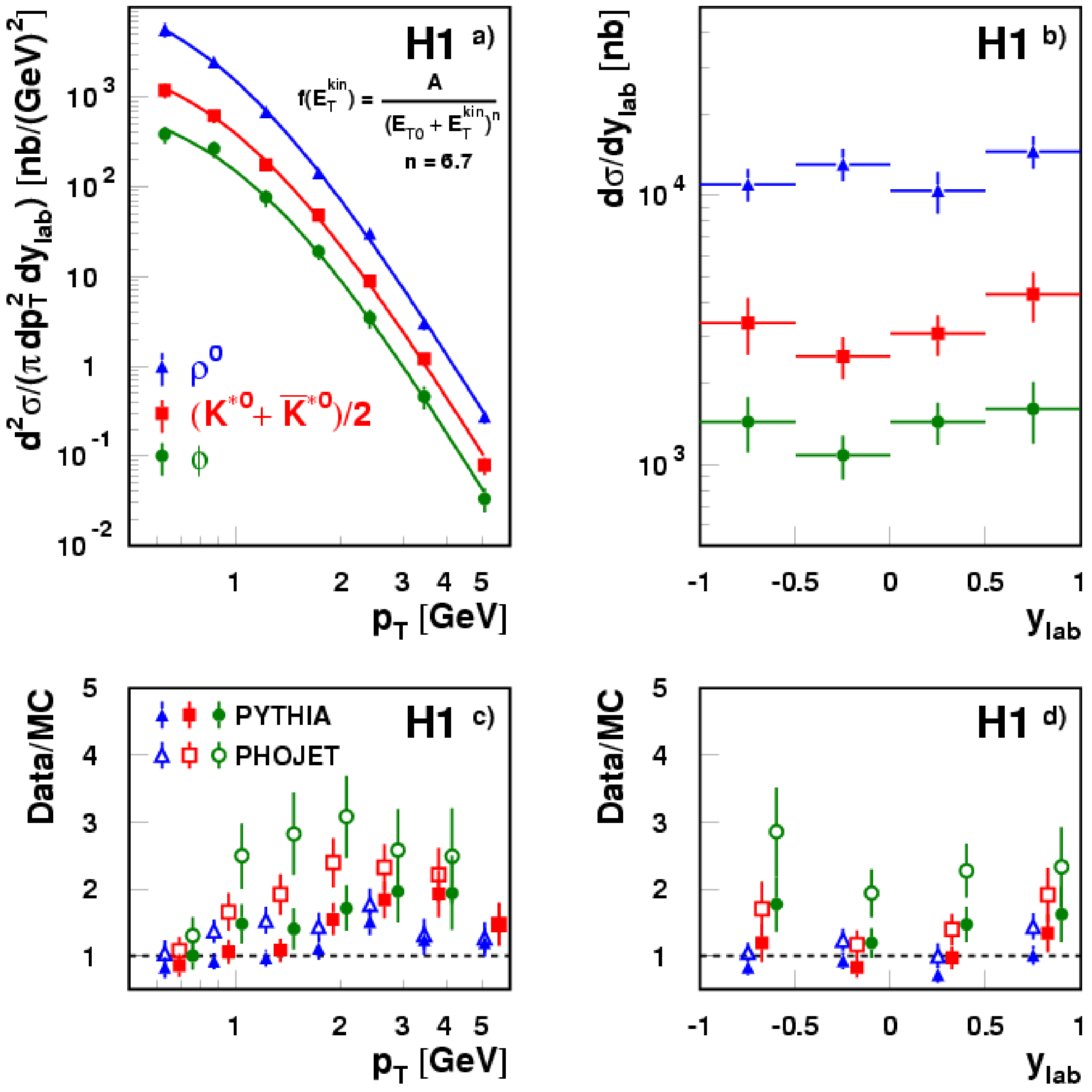
# $\rho^0$, K* and $\phi$: cross section measurement




$Q^2 < 0.01$ GeV$^2$ && $174 < W < 256$ GeV, $p_T > 0.5$ GeV && $|y_{lab}| < 1$:

$$\sigma^{\gamma p}_{vis}(\gamma p \rightarrow \rho^0 X) = 25600 \pm 1800 \pm 2700 \text{ nb}$$
$$\sigma^{\gamma p}_{vis}(\gamma p \rightarrow K^{*0} X) = 6260 \pm 350 \pm 860 \text{ nb}$$
$$\sigma^{\gamma p}_{vis}(\gamma p \rightarrow \phi X) = 2400 \pm 180 \pm 340 \text{ nb}$$

# $\rho^0$, K* and $\phi$: cross section




PHOJET10: DPM

PYTHIA6.2: LO QCD ME
with a very low $p_T$ cut-off
and PS

- invariant differential cross section can be described by power law distribution
- within rapidity range, the meson production rates are constant as a function of rapidity, within errors
- PYTHIA and PHOJET models do not describe the shape of the measured $p_T$ spectrum

# $\rho^0$, K* and $\phi$: power law distribution

$$f(E_T^{kin}) = \frac{A}{(E_{T_0} + E_T^{kin})^n} = \begin{cases} \dfrac{A}{(E_T^{kin})^n}, & E_T^{kin} >> E_{T_0} \\ \exp(-E_T^{kin}/T), & E_T^{kin} < E_{T_0}, \quad T = E_{T_0}/n \end{cases}$$

$$E_T^{kin} = \sqrt{m_0^2 + p_T^2} - m_0$$

$\dfrac{A}{(E_T^{kin})^n}$ ← pQCD

$\exp(-E_T^{kin}/T)$ ← Thermodynamic model

$$A = \left\langle \frac{d\sigma}{dy_{lab}} \right\rangle_{|y_{lab}|<1} \frac{(n-1)(n-2)(E_{T_0})^{n-1}}{2\pi(E_{T_0} + (n-2)m_0)}$$

$\left\langle \frac{d\sigma}{dy_{lab}} \right\rangle_{|y_{lab}|<1}$ is extrapolated cross section in all $p_T$ range

# $\rho^0$, K* and $\phi$: cross section fit parameters

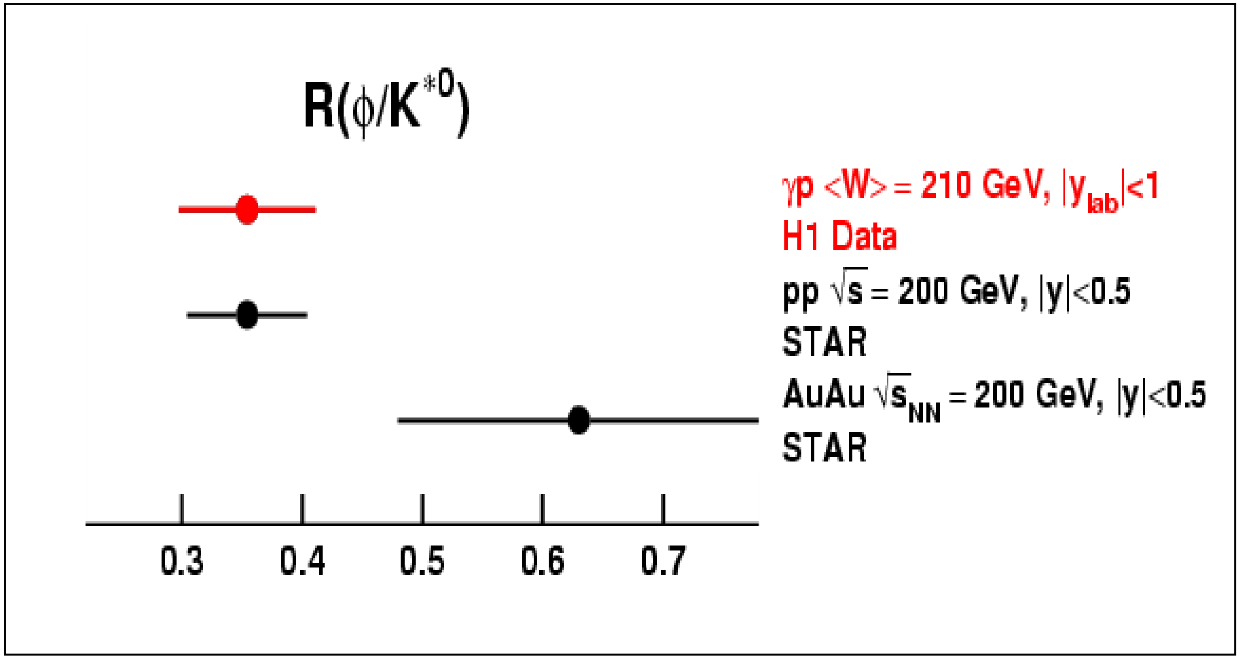
$$f(E_T^{kin}) = \frac{A}{(E_{T_0} + E_T^{kin})^n} \Rightarrow \langle E_T^{kin} \rangle$$

$$\langle E_T \rangle = \langle E_T^{kin} \rangle + m_0 \qquad \langle p_T \rangle = \sqrt{\langle E_T \rangle^2 - m_0^2}$$

| | | $\rho^0$ | $(K^{*0} + \overline{K}^{*0})/2$ | $\phi$ |
|---|---|---|---|---|
| $\gamma p$ | $\langle d\sigma/dy_{lab}\rangle\vert_{\vert y_{lab}\vert<1}$ [nb] | $23600 \pm 2700$ | $5220 \pm 600$ | $1850 \pm 230$ |
| | $E_{T_0}/n$ = $T$ [GeV] | $0.151 \pm 0.011$ | $0.166 \pm 0.012$ | $0.170 \pm 0.012$ |
| | $\langle E_T \rangle$ [GeV] | $1.062 \pm 0.018$ | $1.205 \pm 0.020$ | $1.333 \pm 0.022$ |
| | $\langle E_T^{kin} \rangle$ [GeV] | $0.287 \pm 0.018$ | $0.313 \pm 0.020$ | $0.314 \pm 0.022$ |
| | $\langle p_T \rangle$ [GeV] | $0.726 \pm 0.027$ | $0.810 \pm 0.030$ | $0.860 \pm 0.035$ |
| $pp$ | $\langle p_T \rangle_{pp}$ [GeV] | $0.616 \pm 0.062$ | $0.81 \pm 0.14$ | $0.82 \pm 0.03$ |
| Au-Au | $\langle p_T \rangle_{AuAu}$ [GeV] | $0.83 \pm 0.10$ | $1.08 \pm 0.14$ | $0.97 \pm 0.02$ |

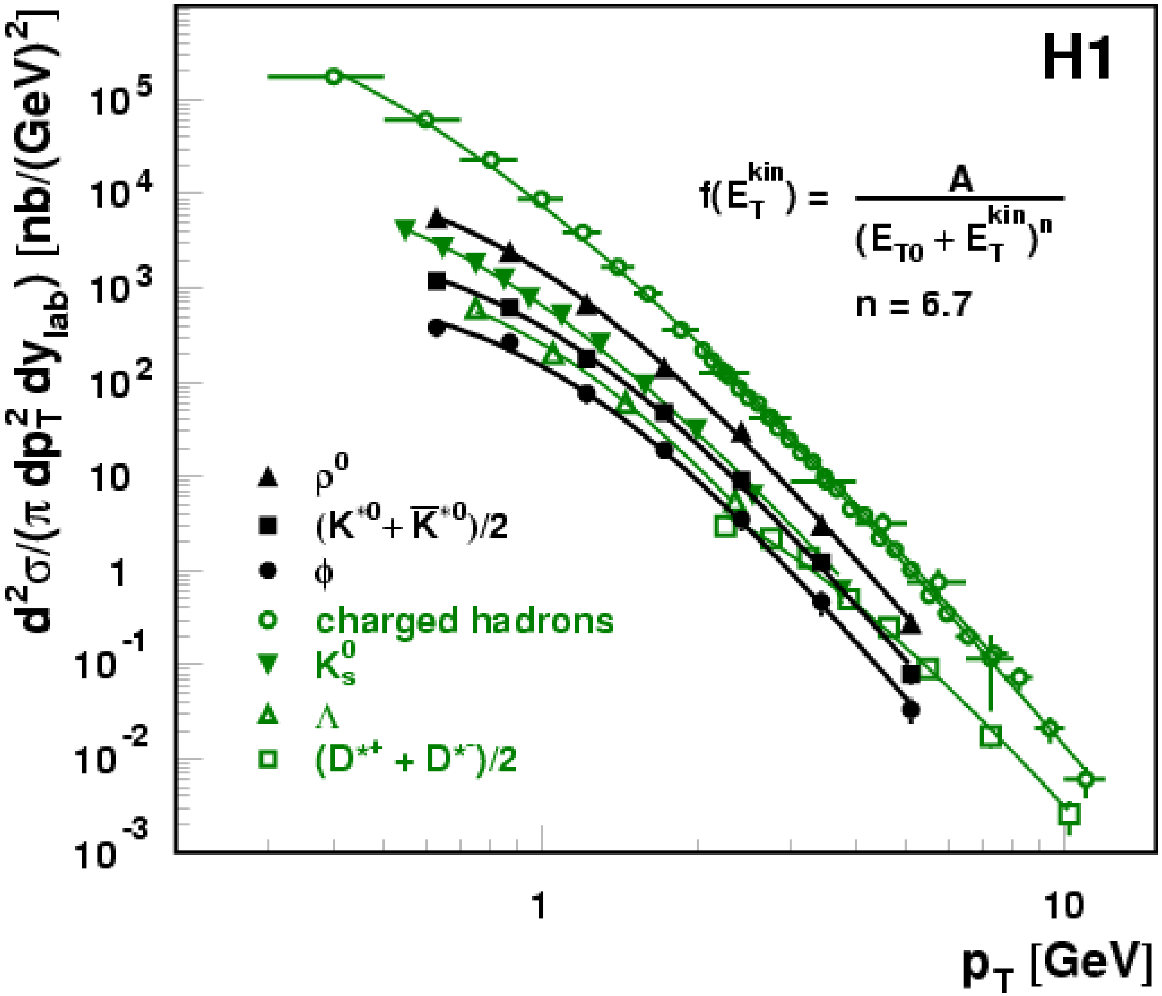
- $\rho^0$, K* and $\phi$ are produced with about the same value of the average $\langle E_T^{kin} \rangle$
  $\Rightarrow$ supports a thermodynamic picture of hadronic interactions
- n is described by Monte Carlo while T is not (non pQCD)
- $\langle p_T \rangle$ in H1 is in agreement with RHIC pp and is lower than RHIC AuAu

# $\rho^0$, K* and $\phi$: comparison with RHIC




The ratio of the production cross-sections R($\phi$/K*) measured in $\gamma$p is in agreement with pp results and below that for AuAu measured at about the same collision energy at RHIC

# Hadron photoproduction at H1




All inclusive photoproduction cross sections measured at H1 are described by power law distribution with the same n = 6.7 calculated from charged hadrons

# Summary

Light $\rho(770)^0$, $K^*(892)^0$ and $\phi(1020)$ mesons photoproduction at HERA:

- first measurement in photoproduction at HERA
- the description of the $\rho^0$ shape of the meson is improved by taking Bose-Einstein correlations into account
- $p_T$-spectra are described by power law distribution
- $\rho^0$, $K^*$ and $\phi$ are produced with about the same value of $\langle E_T^{kin} \rangle$
  $\Rightarrow$ support a thermodynamic picture of hadronic interactions
- comparison with RHIC results
  - The ratio of the production cross-sections $R(\phi/K^*)$ measured in $\gamma p$ is in agreement with pp results at about the same collision energy at RHIC
  - Some tendency for $\phi$ meson production to be more abundant in Au-Au collisions is observed
- universality in $p_T$-spectra of hadrons at H1 is observed

# Back up

# $\rho^0$, K* and $\phi$: visible kinematical range

All mesons are analyzed in following:

- $|y| < 1$ in 7 $p_T$ bins:

| 1 bin | 2 bin | 3 bin | 4 bin | 5 bin | 6 bin | 7 bin |
|---|---|---|---|---|---|---|
| 0.5-0.75 | 0.75-1. | 1.-1.5 | 1.5-2. | 2.-3. | 3.-4. | 4.-7. GeV |

Extra cuts for mesons:

$K^{*0}$: 1 bin: Kaon dE/dx ident. && $\cos\theta^* < 0$; 2-3 bin: Kaon dE/dx ident.

$\phi$: 1-3 bin: Kaon dE/dx identification

bin $p_T$: 0.-0.25 GeV is excluded due to non description DATA and MC

bin $p_T$: 0.25-0.5 GeV is excluded due to big Background for $K^{*0}$ and small $\varphi$ meson reconstructed efficiency

- $p_T > 0.5$ GeV in 4 $y$ bins:

| 1 bin | 2 bin | 3 bin | 4 bin |
|---|---|---|---|
| -1.:-0.5 | -0.5-0. | 0.-0.5 | 0.5-1. |

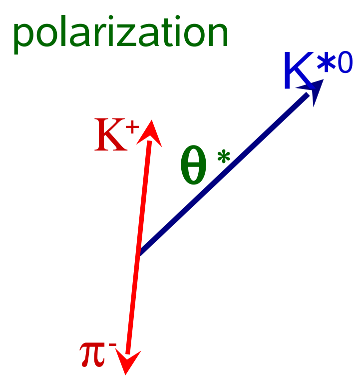
Extra cuts for mesons:

$K^{*0}$: 1-4 bin: Kaon dE/dx ident. && $\cos\theta^* < 0$

$\phi$: 1-4 bin: Kaon dE/dx identification

$y$ – rapidity of mesons

$p_T$ – transverse momentum of mesons



# Fit Procedure

$\rho^0 \to \pi^+\pi^-$ $K^{*0} \to K\pi$ $\phi \to K^+K^-$

Fit function: $F(m) = S(m) + R(m) + B(m)$

Signal $S(m)$ = convolution of $BW(m)$ and $res(m, m')$

rel. Breit-Wigner $BW(m) = Amm_0\Gamma(m)/[(m^2-m_0^2)^2 + m_0^2\Gamma^2(m)]$

$$\Gamma(m) = \Gamma_0(q/q_0)^{2l+1} m_0/m$$

resolution function $res(m, m') = 1/[2p] \bullet \Gamma_{res}/[(m-m')^2 + (\Gamma_{res}/2)^2]$

reflection $R(m)$:

- for $\rho^0$: $K^{*0} \to K\pi$ and $\omega \to \pi^+\pi^-(\pi^0)$
- for $K^{*0}$: $\rho^0 \to \pi^+\pi^-$, $\omega \to \pi^+\pi^-(\pi^0)$, $\phi \to K^+K^-$ and self-reflection $K^{*0} \to K\pi$
- for $\phi$: —

combinatorial background $B(m)$:

for $\rho^0$ and $K^{*0}$:

$B(m) = \{M(\pi^\pm\pi^\pm)$ or $M(K^\pm\pi^\pm)\} \bullet \{Pol(2\text{-}3)$ or $(a_1+a_2\bullet x)\bullet \exp(-a_3\bullet x-a_4\bullet x^2)\}$

for $\phi$: $B(m) = b_1\bullet(m^2 - 4m_K^2)^{b_2}\bullet \exp(-b_3\bullet m)$

# $\rho^0$, K* and $\phi$: cross section calculation

Invariant differential cross section:

$$\frac{1}{\pi}\frac{d^2\sigma^{\gamma p}}{dp_T^2\,dy_{lab}} = \frac{N}{\pi\cdot\mathcal{L}\cdot BR\cdot\Phi_\gamma\cdot\epsilon\cdot\Delta p_T^2\cdot\Delta y_{lab}}$$

Differential cross section:

$$\frac{d\sigma^{\gamma p}}{dy_{lab}} = \frac{N}{\mathcal{L}\cdot BR\cdot\Phi_\gamma\cdot\epsilon\cdot\Delta y_{lab}}$$

N – number of mesons from fit

$\Delta p_T^2$ and $\Delta y_{lab}$ – bin widths

$L$ = 36.5 $pb^{-1}$

$\Phi_\gamma$ = 0.0127 – photon flux

BR = 1. for $\rho^0$, 0.67 for $K^{*0}$ and 0.49 for $\phi$

$\varepsilon = \varepsilon_{rec} \bullet A_{etag} \bullet A_3 \bullet \varepsilon_{trig}$ – efficiency

reconstruction efficiency for the meson $\varepsilon_{rec}$ varies from 45% to 90% (using Monte Carlo)

positron tagger acceptance $A_{etag}$ = 48.5%

trigger acceptance $A_3$ varies from 50% to 95% (using Monte Carlo)

trigger efficiency $\varepsilon_{trig}$ ~ 90% (using Monitor Triggers)