Inclusive Photoproduction of ρ°, K*° and φ Mesons at HERA

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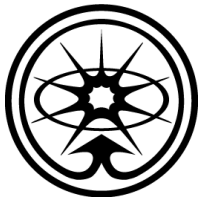
on behalf of
H1 Collaboration



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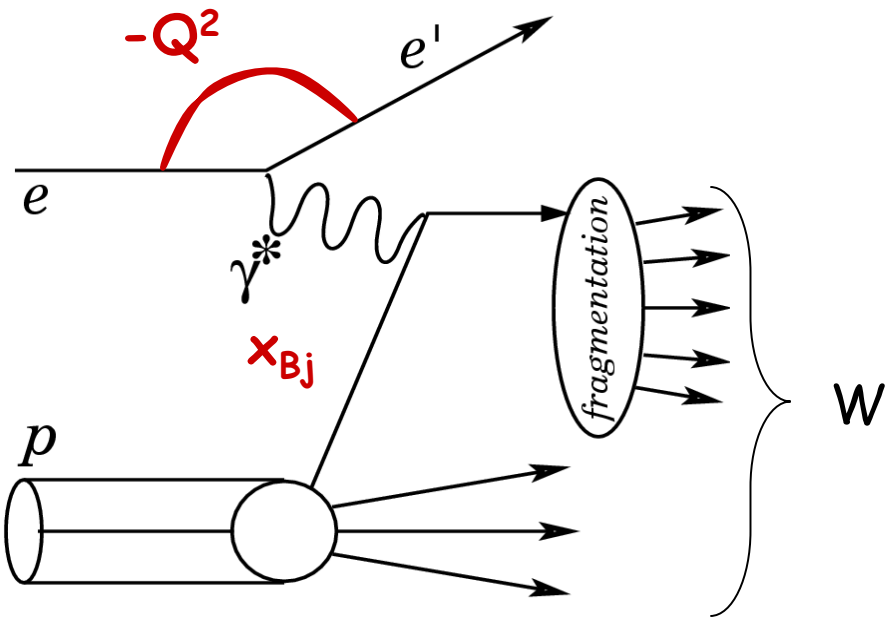
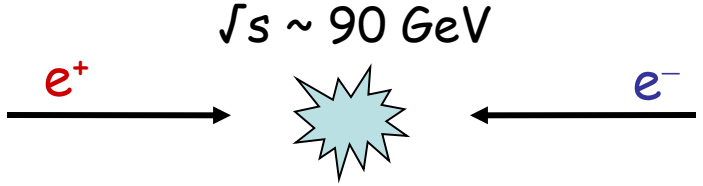
ep kinematics



energy c.m.: $\sqrt{s}$ = 300-320 GeV
hadronic energy: W = m(γ*p)
photon virtuality : Q^2
two regions: $Q^2 \approx 0$ GeV^2 — photoproduction
$Q^2 > 1$ GeV^2 — electroproduction (DIS)

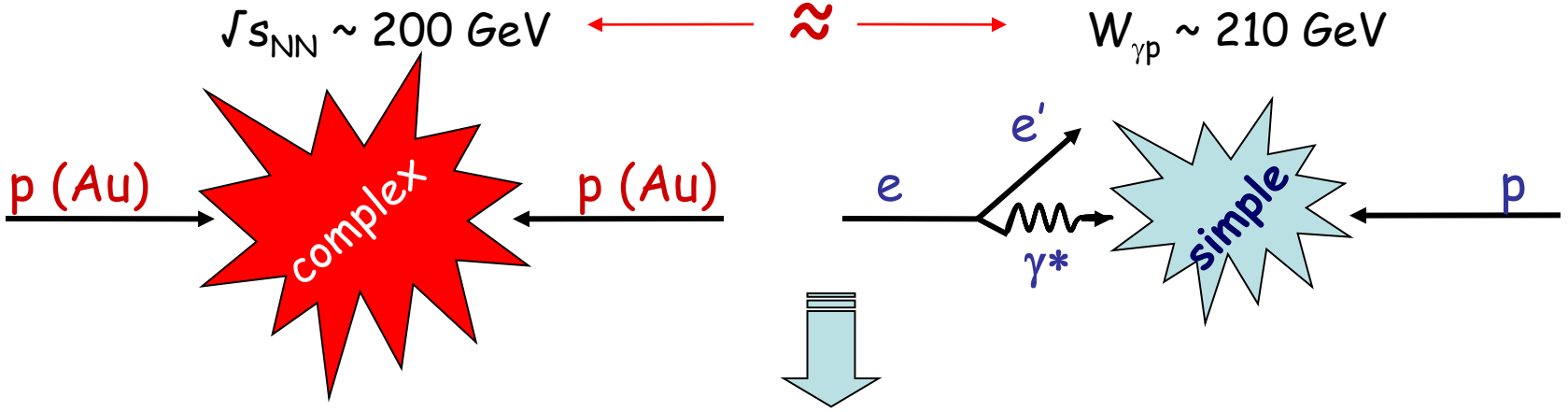
Motivation

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



- RHIC:
- H1:

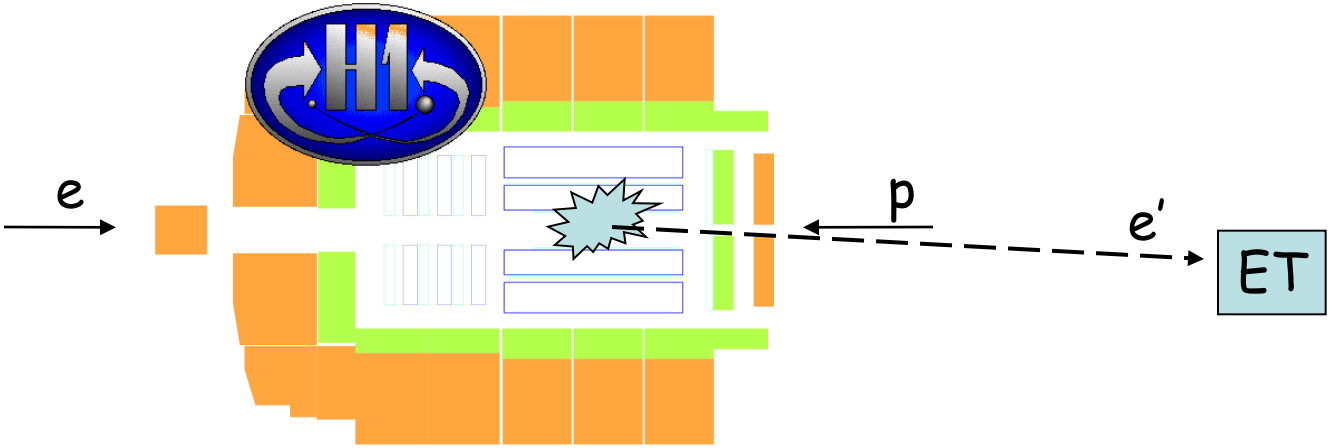
inclusive $\rho(770)^0$, $K^*(892)^0$ and $\varphi(1020)$



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

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

Selection

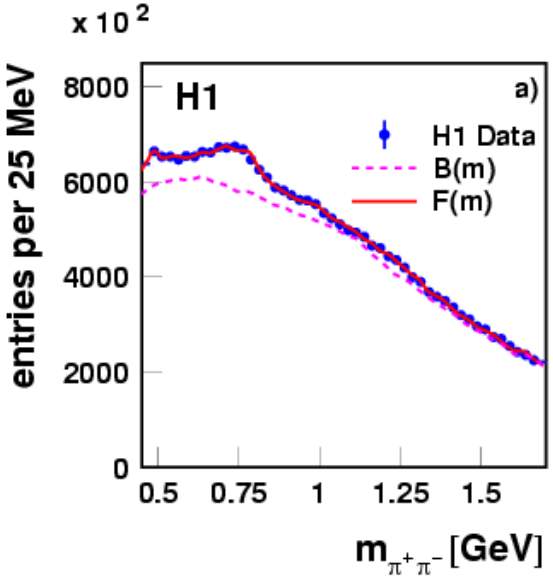


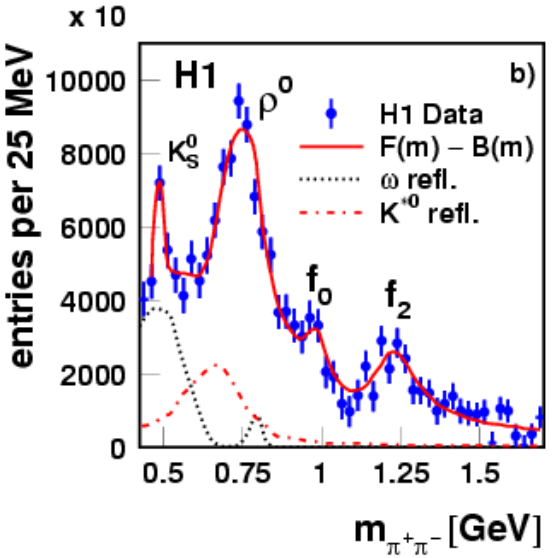
Main selection criteria for event:

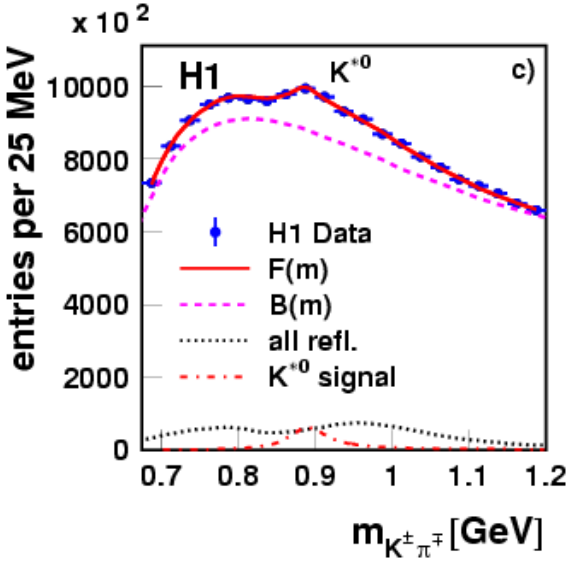
- H1 data 2000 with $\mathcal{L}$ = 36.5 pb^{-1}
- Photoproduction $Q^2 < 0.01$ GeV^2 with e' in ET (electron tagger)
- $174 < W < 256$ GeV $\Rightarrow \langle W \rangle = 210$ GeV
- Trigger requires at least 3 tracks in the Central Tracker with $p_T > 0.4$ GeV

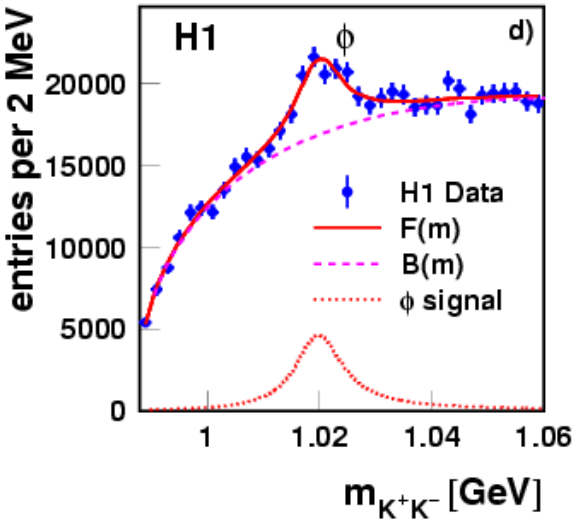
$\rho^0 \rightarrow \pi^+\pi^-$ $\quad$ $K^{*0} \rightarrow K\pi$ $\quad$ $\phi \rightarrow K^+K^-$

ρ^0, K* and ϕ signal









Fit function:

$F(m) = S(m) + R(m) + B(m)$

Signal

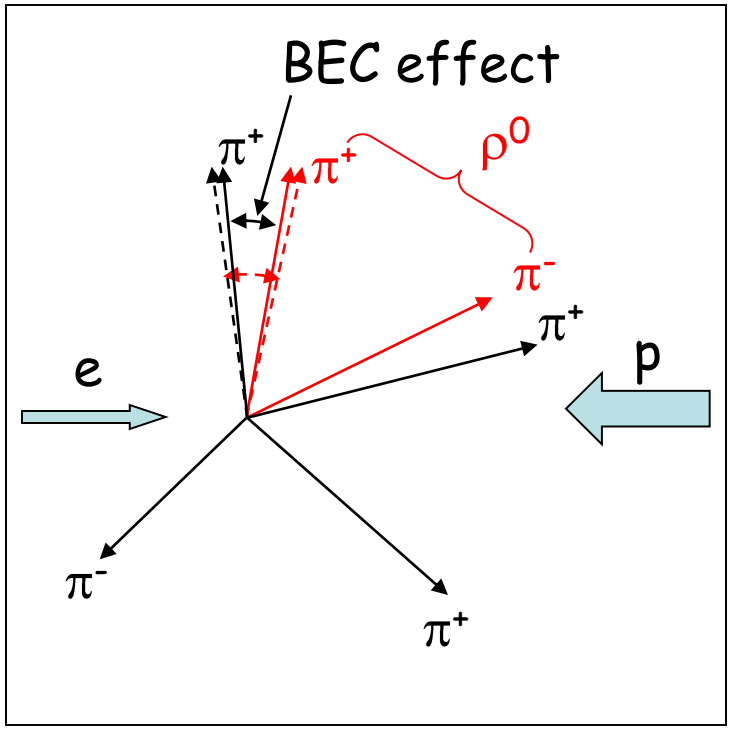
Reflection

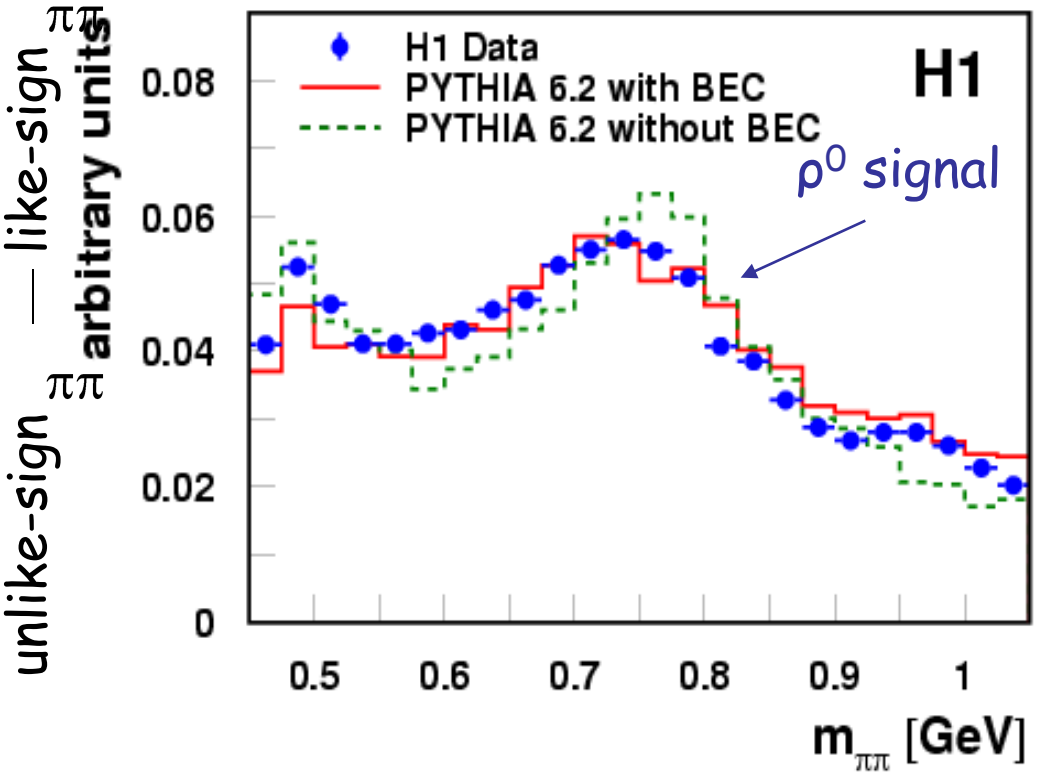
Comb. background

Clear signals of ρ^0, K* and ϕ mesons are observed

Bose-Einstein Correlations (BEC)

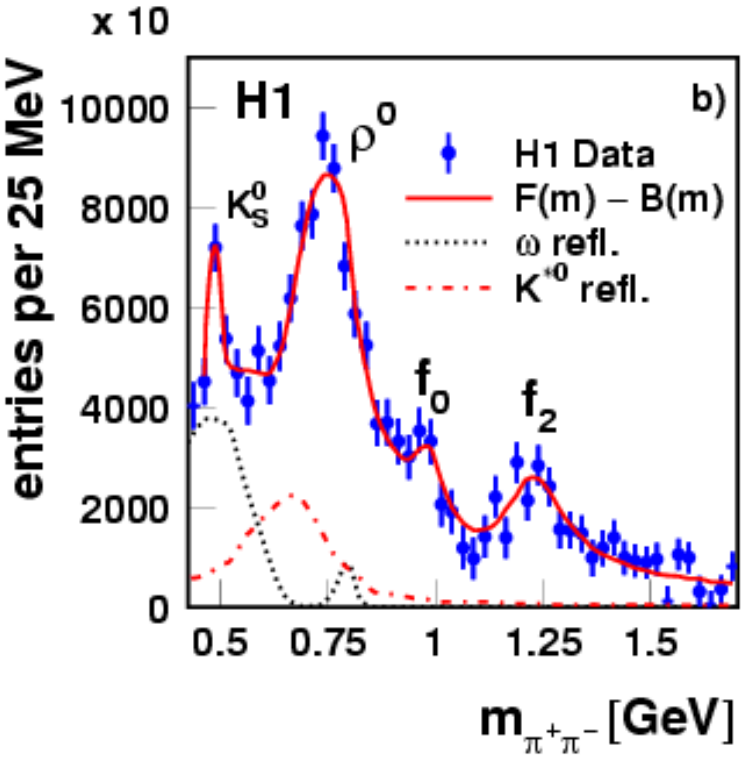
distortion of ρ^0 mass spectrum due to BEC





A modification of ρ^0 signal produced in γp collisions is described by taking into account Bose-Einstein correlations in Monte Carlo

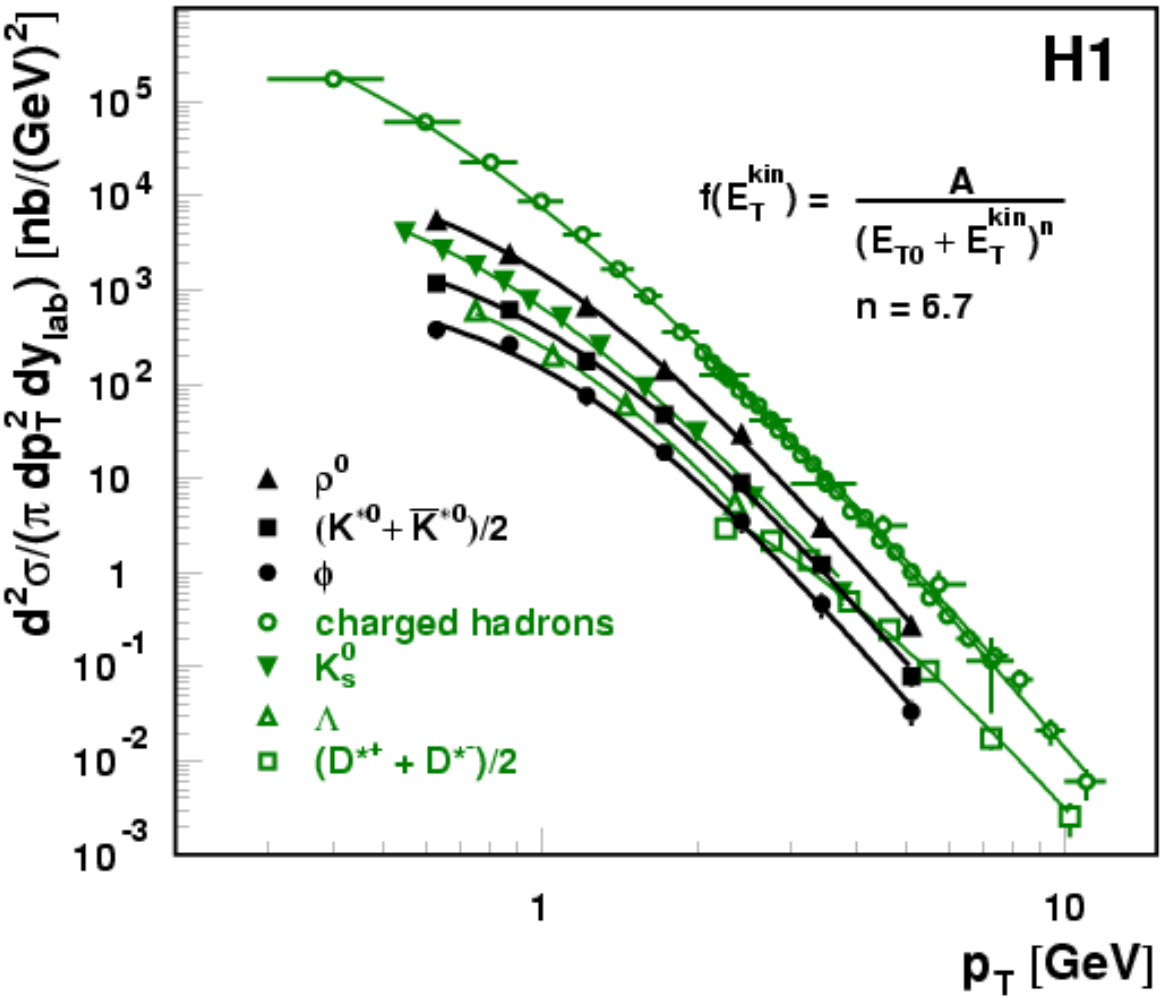
ρ^0, K* and ϕ: cross section measurement



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

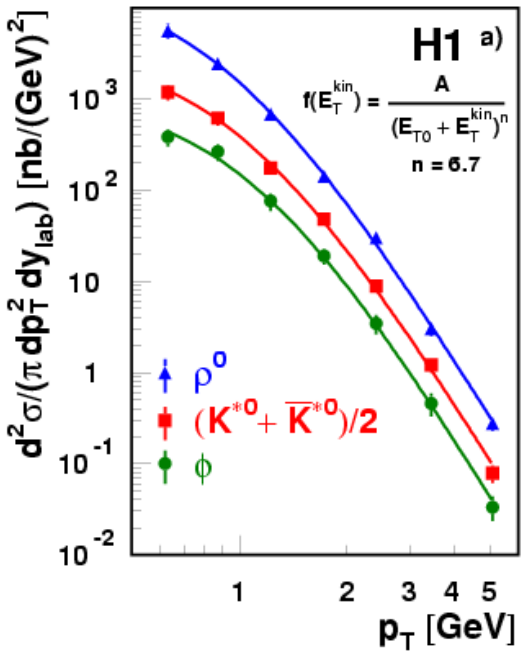
$$\sigma^{\gamma p}_{vis}(\gamma p \to \rho^0 X) = 25600 \pm 1800 \pm 2700\ nb$$
$$\sigma^{\gamma p}_{vis}(\gamma p \to K^{*0} X) = 6260 \pm 350 \pm 860\ nb$$
$$\sigma^{\gamma p}_{vis}(\gamma p \to \phi X) = 2400 \pm 180 \pm 340\ nb$$

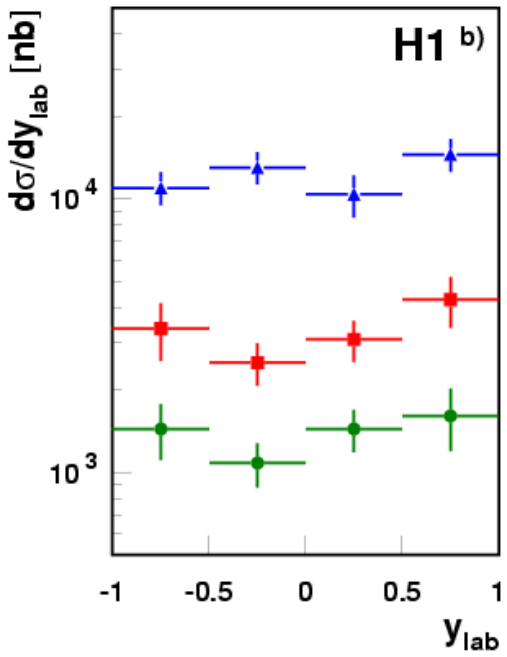
Hadron photoproduction at H1

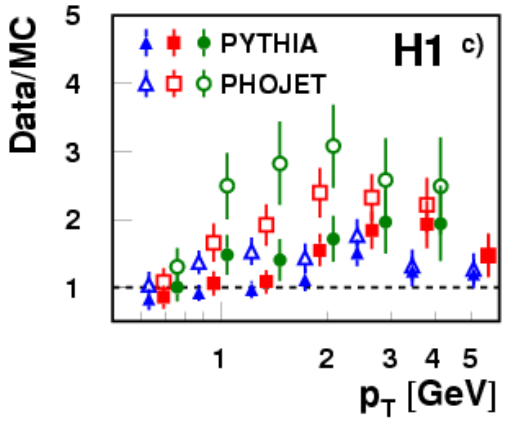


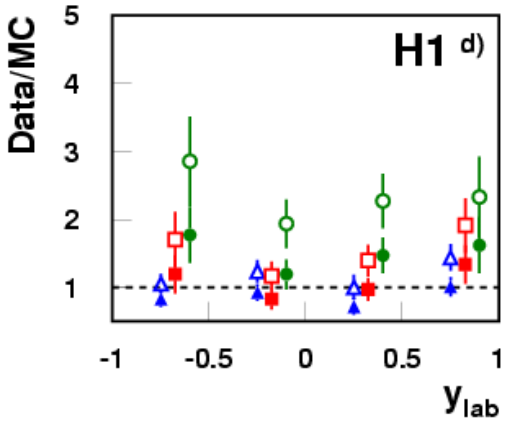
All inclusive photoproduction cross sections measured at H1 are described by power law distribution with the same n = 6.7 calculated from charged hadrons

ρ^0, K* and ϕ: cross section









PHOJET10: Dual Parton Model

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

ρ^0, K* and ϕ: power law distribution

$$f(E_T^{kin}) = \frac{A}{(E_0 + E_T^{kin})^n} = \begin{cases} \frac{A}{(E_T^{kin})^n}, & E_T^{kin} > E_0 \\ \exp(-E_T^{kin}/T), & E_T^{kin} < E_0 \end{cases}$$

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

pQCD

$T = E_{T_0} / n$

Thermodynamic model

$$A = \frac{d\sigma}{dy\,2\pi p_T dp_T} \frac{(n-1)(n-2)}{2\pi(nT + m_0)(nT)}$$

is extrapolated
cross section in all p_T range

ρ^0, K* and ϕ: cross section fit parameters

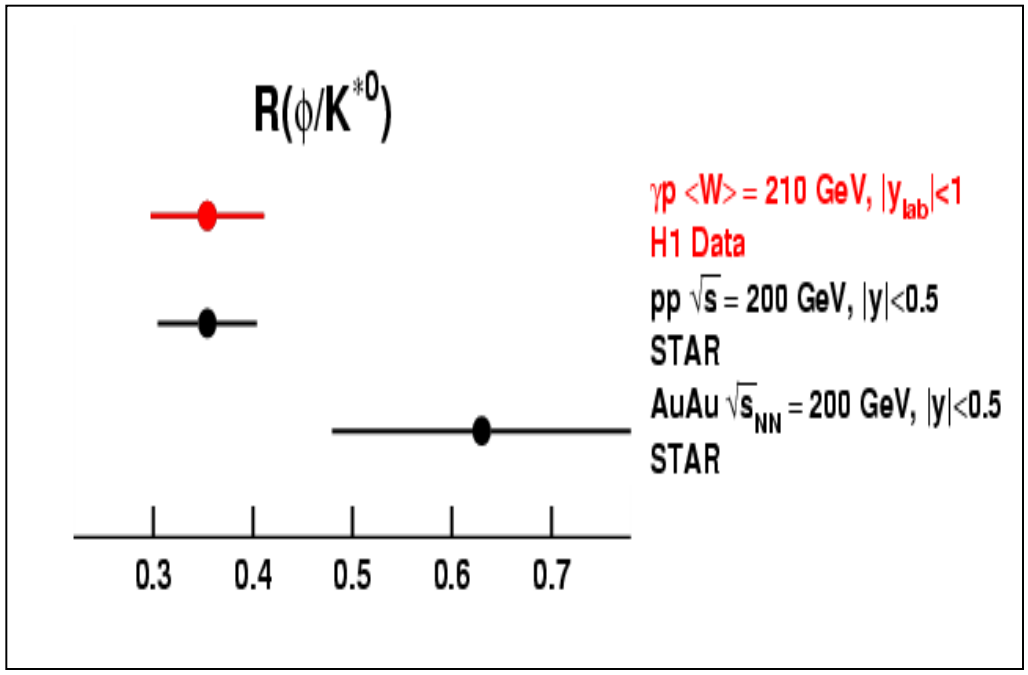
$$f(E_T^{kin}) = \frac{A}{(E_0 + E_T^{kin})^n} \Rightarrow \langle E_T^{kin} \rangle$$

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

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

- ρ^0, K* and ϕ 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

ρ^0, K* and ϕ: comparison with RHIC



	dN/dy * 1000	
	γp (H1)	pp(STAR)
ρ^0	236±30	259±40
K*	52±7	51±7
ϕ	18±3	18±1

Remarkable agreement between production rates in pp and photoproduction

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

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 ρ^0 shape of the meson is improved by taking Bose-Einstein correlations into account
- p_T-spectra are described by power law distribution
- ρ^0, K^* and ϕ 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 γp is in agreement with pp results at about the same collision energy at RHIC
  - Some tendency for ϕ 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

ρ^0, K* and ϕ: 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.

ϕ: 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 φ 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.

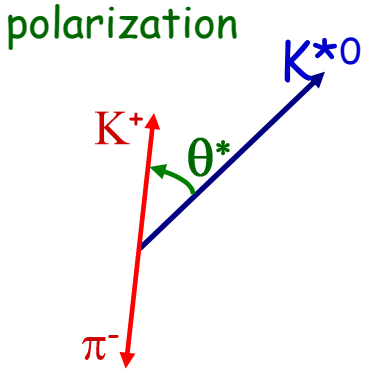
Extra cuts for mesons:

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

ϕ: 1-4 bin: Kaon dE/dx identification

y – rapidity of mesons

p_T – transverse momentum of mesons



Fit Procedure

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

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

reflection $R(m)$:

for ρ^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 ϕ: —

combinatorial background $B(m)$:

for ρ^0 and K^{*0}:

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

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

ρ^0, K* and ϕ: 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

Δp_T^2 and Δy_{lab} – bin widths

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

Φ_γ = 0.0127 – photon flux

BR = 1. for ρ^0, 0.67 for K^{*0} and 0.49 for ϕ

$\varepsilon = \varepsilon_{rec} \cdot \mathcal{A}_{etag} \cdot \mathcal{A}_3 \cdot \varepsilon_{trig}$ – efficiency

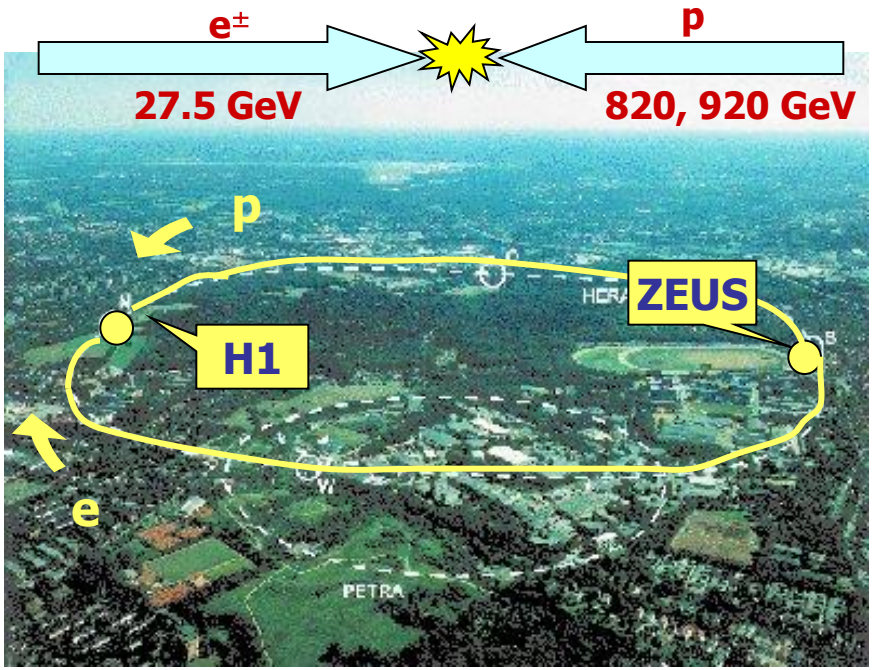
reconstruction efficiency for the meson ε_{rec} varies from 45% to 90% (using Monte Carlo)

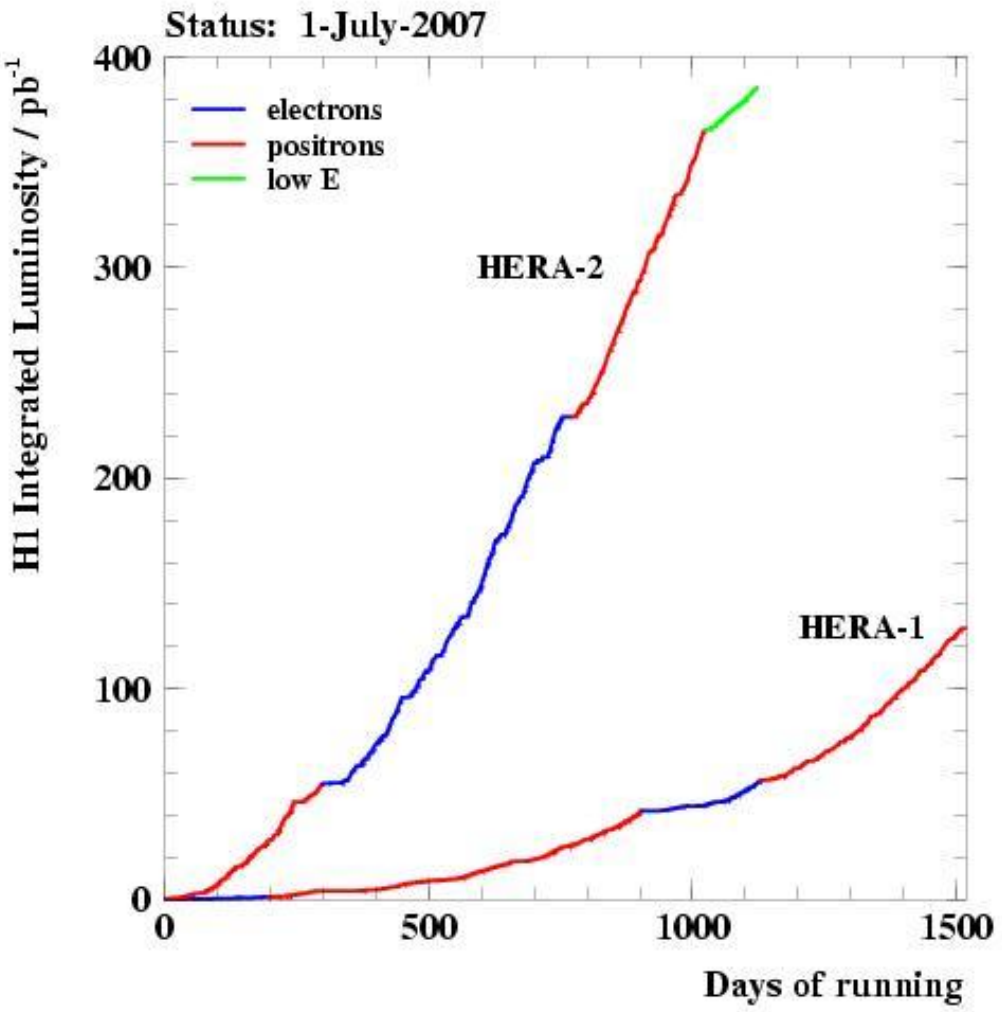
positron tagger acceptance $\mathcal{A}_{etag}$ = 48.5%

trigger acceptance $\mathcal{A}_3$ varies from 50% to 95% (using Monte Carlo)

trigger efficiency ε_{trig} ~ 90% (using Monitor Triggers)

The HERA Collider





H1 and ZEUS:

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