Study of Bose-Einstein Correlations in Deep Inelastic Scattering

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DIS02

- Introduction: Bose-Einstein (or HBT) effect
- Data selection
- Results for $Q^2 > 110$ GeV^2
- Comparisons with H1 and LEP1/LEP2
- Q^2 variation
- Conclusions/Plans

Bose-Einstein (BEC) interference (or HBT effect)

Consider two pions with momenta $\mathbf{p_1}$ and $\mathbf{p_2}$

QM probability of finding a pair of pions with $\mathbf{p_1}$ and $\mathbf{p_2}$:

$$\langle |A|^2 \rangle = 1 + \langle \cos[\mathbf{q}(\mathbf{r_1} - \mathbf{r_2})] \rangle, \qquad \mathbf{q} = \mathbf{p_1} - \mathbf{p_2}$$

For a Gaussian weight function (source distribution):

$$\rho(\mathbf{x_1}, \mathbf{x_2}) = (2\pi r^2)^{-3} \exp[-(x_1^2 + x_2^2)/(2r^2)]$$

one gets

$$\langle |A|^2 \rangle = 1 + \exp[-\mathbf{q}^2 r^2]$$

r is the radius of the sphere where the pions are produced

BEC effect can be measured as

$$C(\mathbf{p_1}, \mathbf{p_2}) = \frac{\rho(\mathbf{p_1}, \mathbf{p_2})}{\rho_{dis}(\mathbf{p_1}, \mathbf{p_2})} = \frac{N^{pairs}(\pm, \pm)}{N^{pairs}(+, -)}$$

$\rho_{dis}(\mathbf{p_1}, \mathbf{p_2})$ without the BEC effect (2 pions are distinguishable)

Method:

1) Define $Q_{12} = \sqrt{-(p_1 - p_2)^2} = \sqrt{M^2 - 4m_\pi^2}$

2) $\rho = (1/N) \times dn^{pair}/dQ_{12}$

3) $\xi(Q_{12}) = \rho(\pm\pm)/\rho(+-)$, $R = \xi^{data}(Q_{12})/\xi^{MC,noBE}(Q_{12})$

Importance of BEC

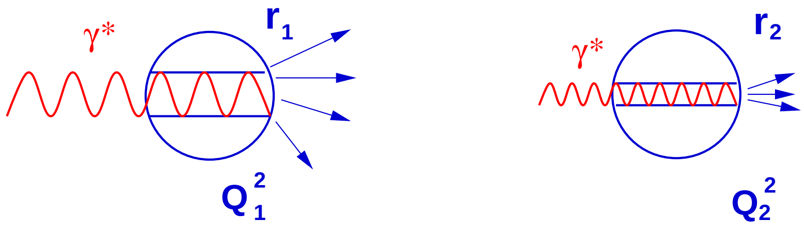
1) Standard technique in heavy ion physics used to measure the sizes of particle-production sources

2) Many aspects of hadronic final-state are affected by the effect

3) Can effect W mass study at LEP2

Two interpretations in DIS

1) BEC measures a "size of the production region", r



$$Q_2^2 > Q_1^2 \longrightarrow r_2 < r_1$$

Does **r** change with Q^2 ?

2) BEC contains no information on the hard subprocess:

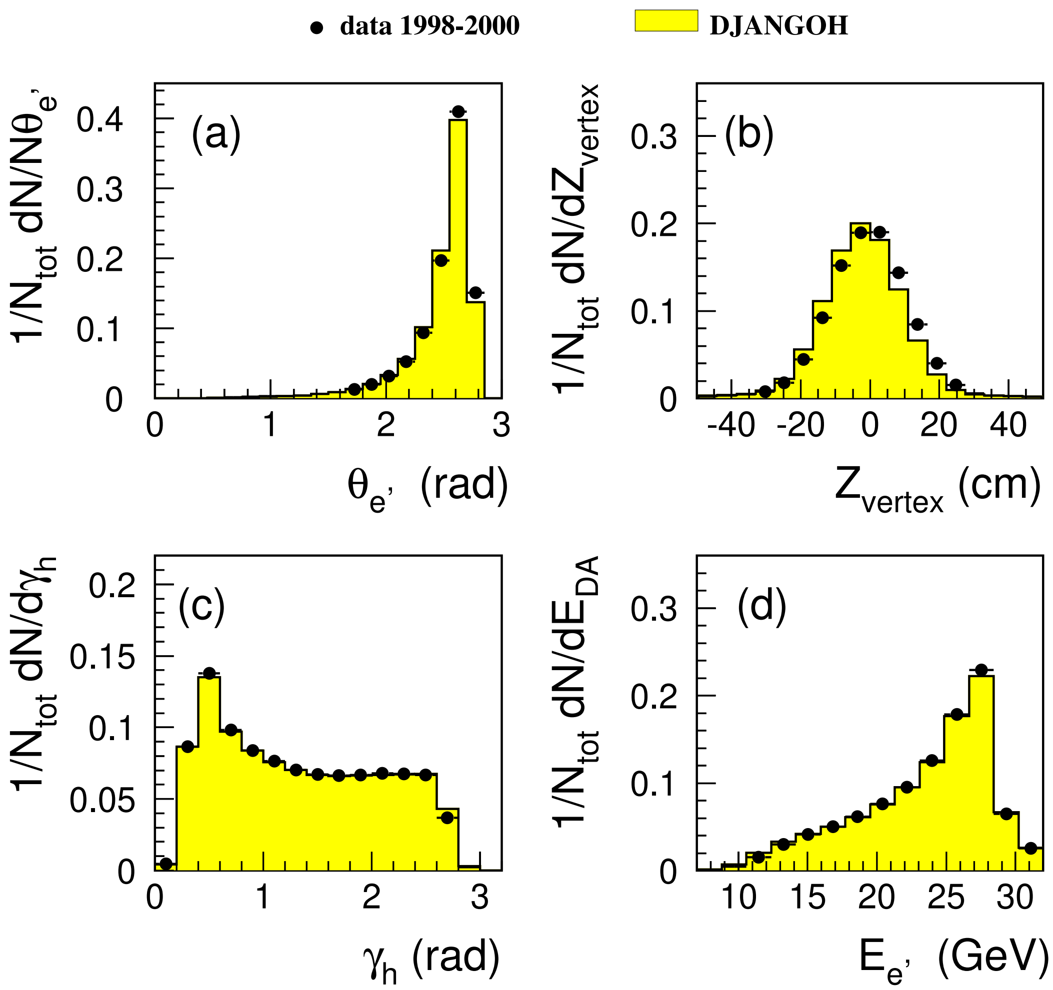
in this case **r** does not depend on Q^2

- Only modifies the final-state hadron spectra
- Can be understood from string fragmentation
- Usual probabilistic MCs do not contain the BEC effect
- But special fixes are available within MC technique

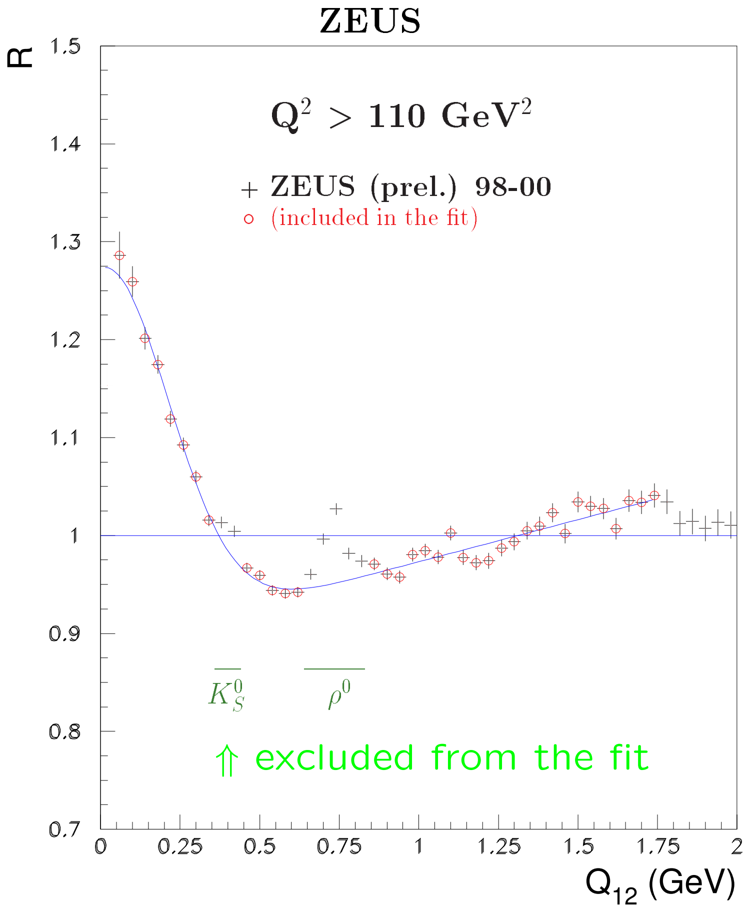
DIS Selection

- 1998-2000 data (84 pb^{-1})
- $Q^2_{DA} > 110$ GeV^2 $E_{e'} > 10$ GeV
  $Prob > 0.9$ $y_e \leq 0.95$ $y_{jb} \geq 0.04$
  $|Z_{vertex}| < 50\,\mathrm{cm}$ $40 \leq \delta \leq 60$
- An additional sample: $25 < Q^2_{DA} < 40$ GeV^2
- Track selection:
  CTD tracks:
  $p_t > 0.15$ GeV, $-1.75 < \eta < 1.75$
- $\sim$ 400000 selected DIS events

Control plots for $Q^2 > 110$ GeV^2



BEC for $Q^2 > 110$ GeV^2



$$R = \alpha(1 + \beta Q_{12})\,(1 + \lambda e^{-r^2 Q_{12}^2})$$

r - source radius $\qquad$ λ - coherence parameter

β - reflects long-range correlations ($\sim 0.04 - 0.06$)

ZEUS $(Q^2 > 110)$ **GeV^2:**

$\lambda = 0.431 \pm 0.012^{+0.042}_{-0.130}$

radius $= 0.671 \pm 0.016^{+0.030}_{-0.032}$ fm

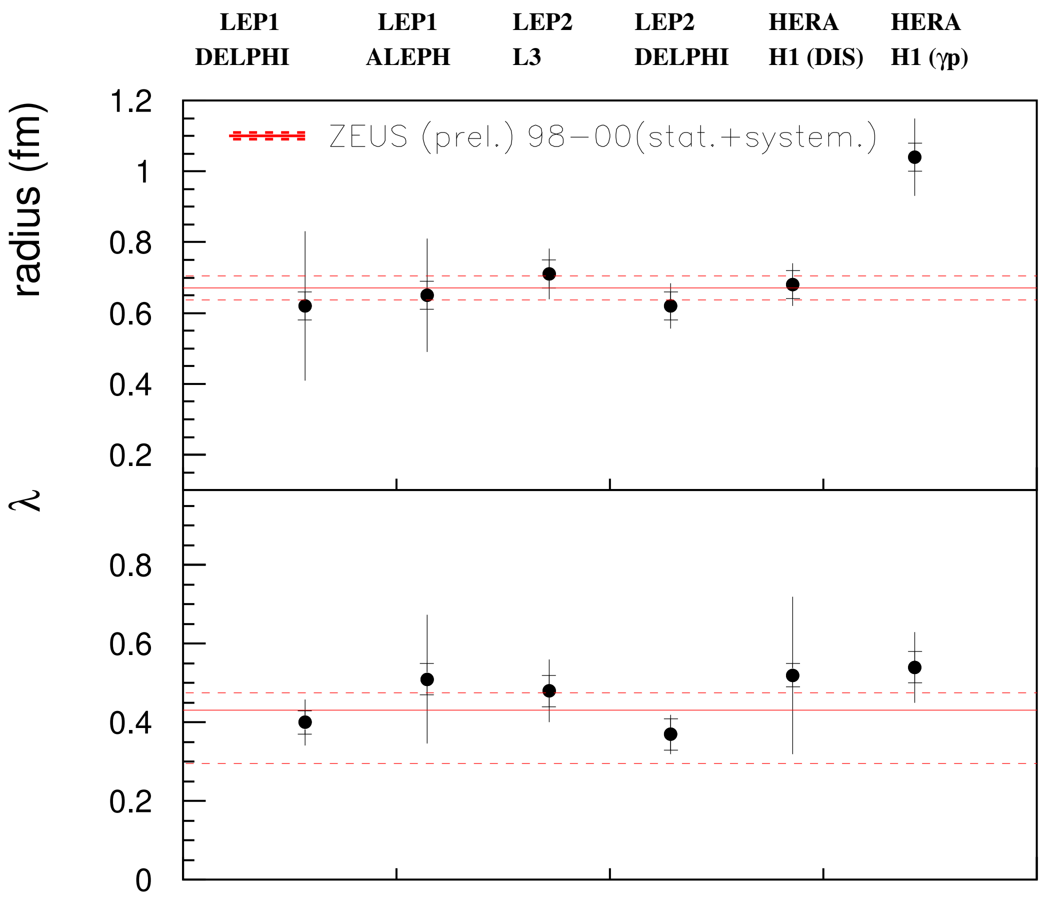
H1 $(6 < Q^2 < 100)$ **GeV^2:**

$\lambda = 0.52 \pm 0.03^{+0.19}_{-0.21}$

radius $= 0.68 \pm 0.04^{+0.02}_{-0.05}$ fm

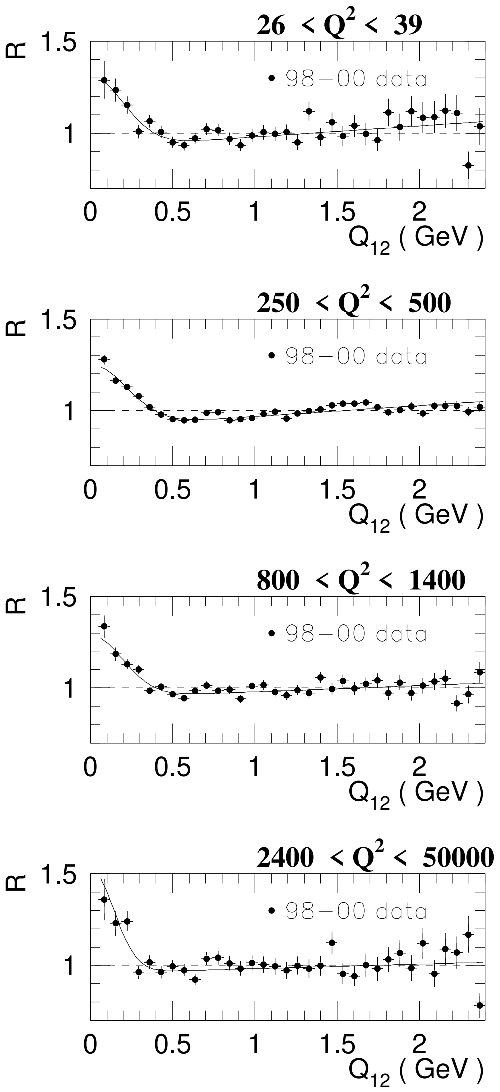
ZEUS and H1 are consistent
even though Q^2 regions do not overlap

Comparisons with other experiments

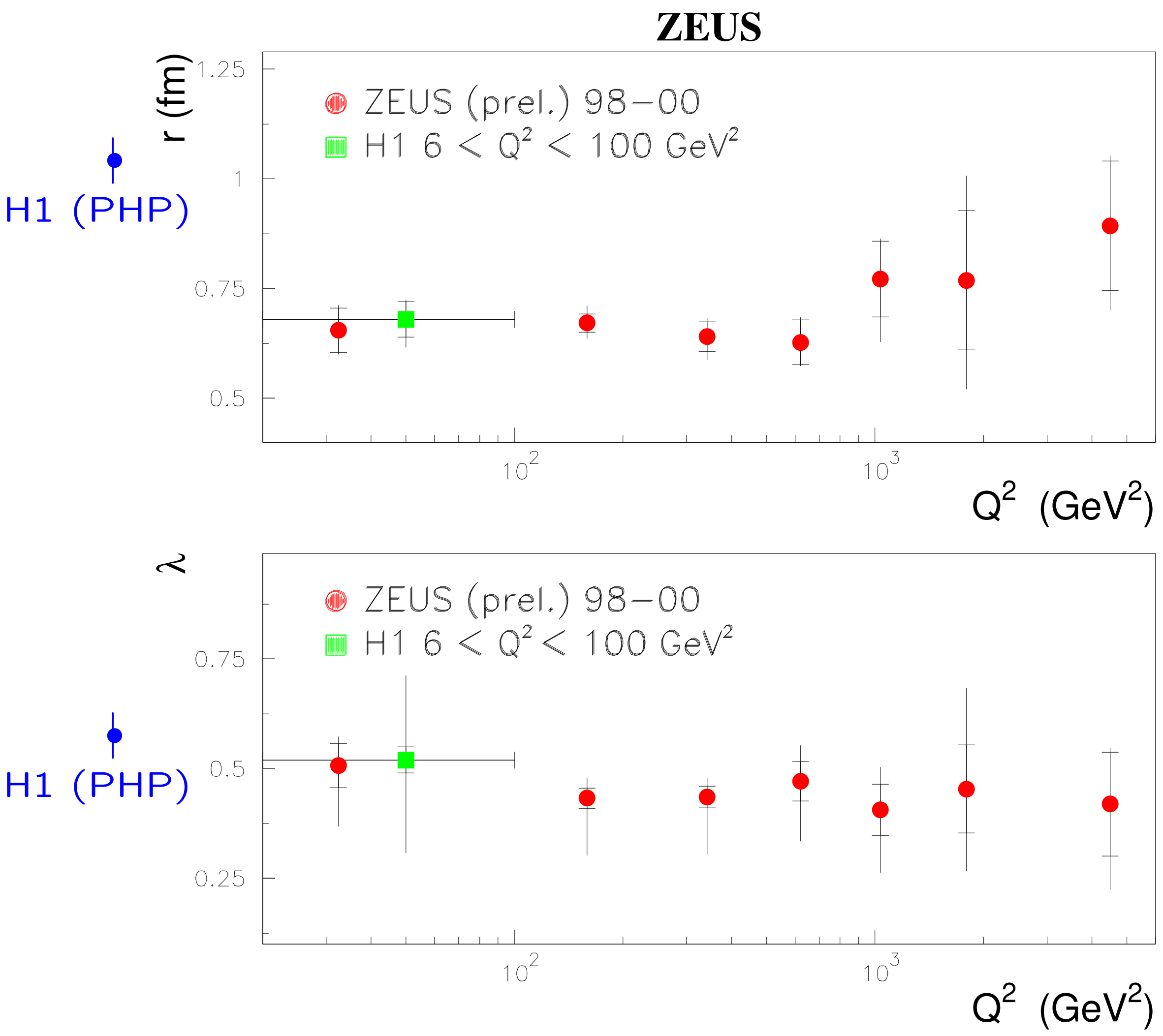


- o ZEUS is generally consistent with LEP (for $\pi^{\pm}$)
- o Discrepancies with recent L3 results
- o H1 (γp) shows larger radius

BEC effect seen for all Q^2 intervals



BEC effect for Q^2 intervals



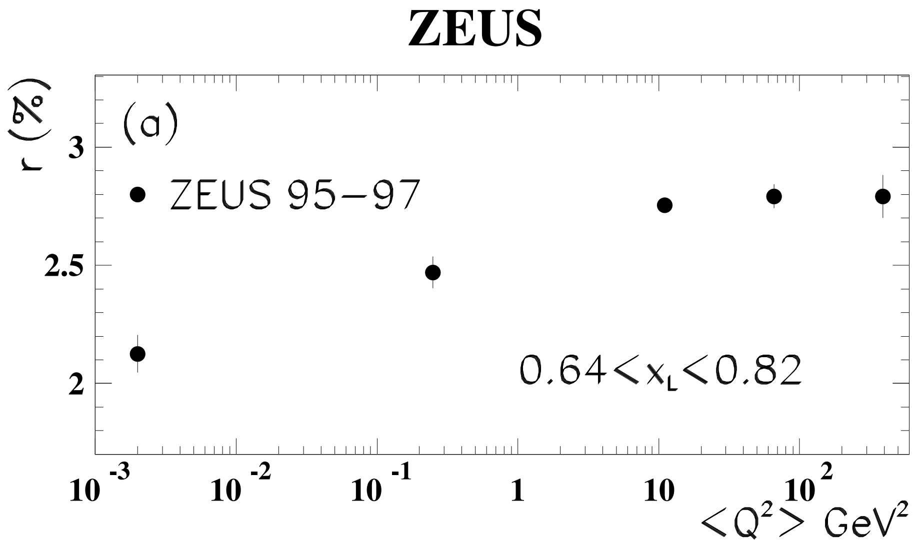
No Q^2 dependence within DIS region

Conclusions

- First measurement of the BEC in DIS at $Q^2 > 100$ GeV^2.
- No Q^2 dependence within DIS region
- BEC signal is consistent with LEP measurements
- Future:
  - $\rightarrow$ Two-dimensional study of BEC
  - $\rightarrow$ Q^2 (~ 0.1 GeV^2) would be interesting to study

Other indications of hadron size?

ZEUS leading neutron result from FNC:



r - fractional yield of leading high-energy neutrons

Q^2 dependence is seen for very low Q^2

ascribed to absorption