# A Measurement of the Pomeron Trajectory from Elastic $\rho^0$ Photoproduction Data

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H1prelim-09-016

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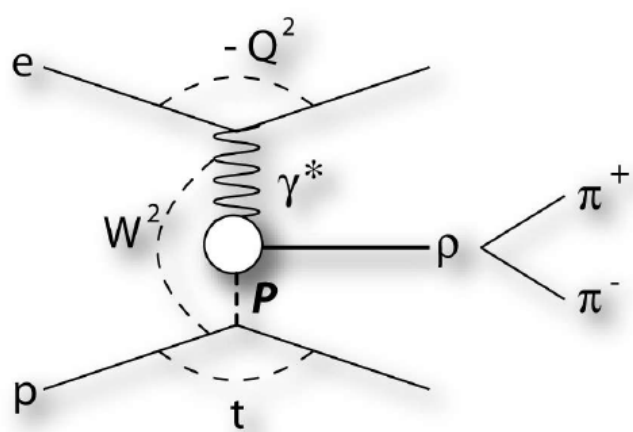
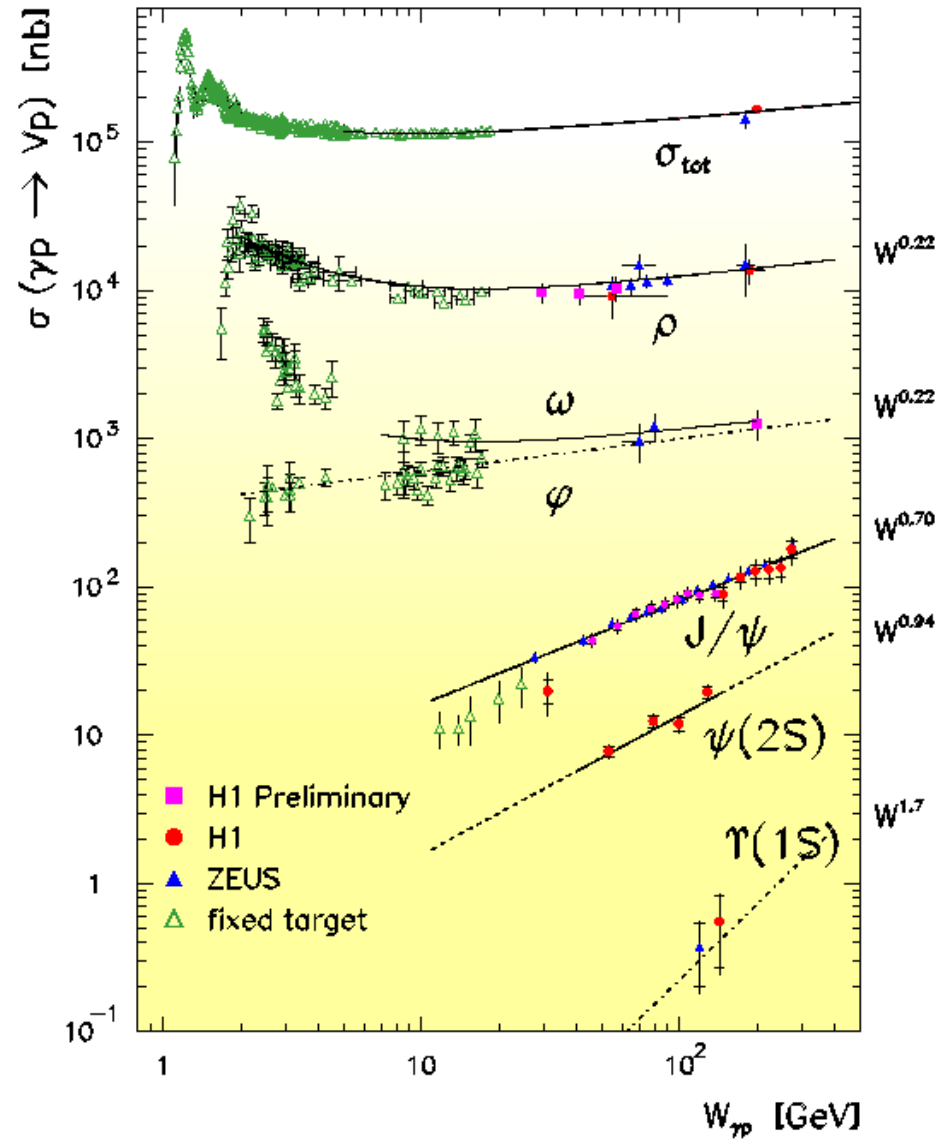
http://upload.wikimedia.org/wikipedia/commons/c/cc/M-30_(Madrid%2C_Spain)_04.jpg

# Introduction

- Photoproduction of $\rho^0$
  - No hard scales
  - Pure soft diffraction
- An ideal channel to investigate the soft pomeron
- Measurement in bins of t:
  Can extract Pomeron trajectory

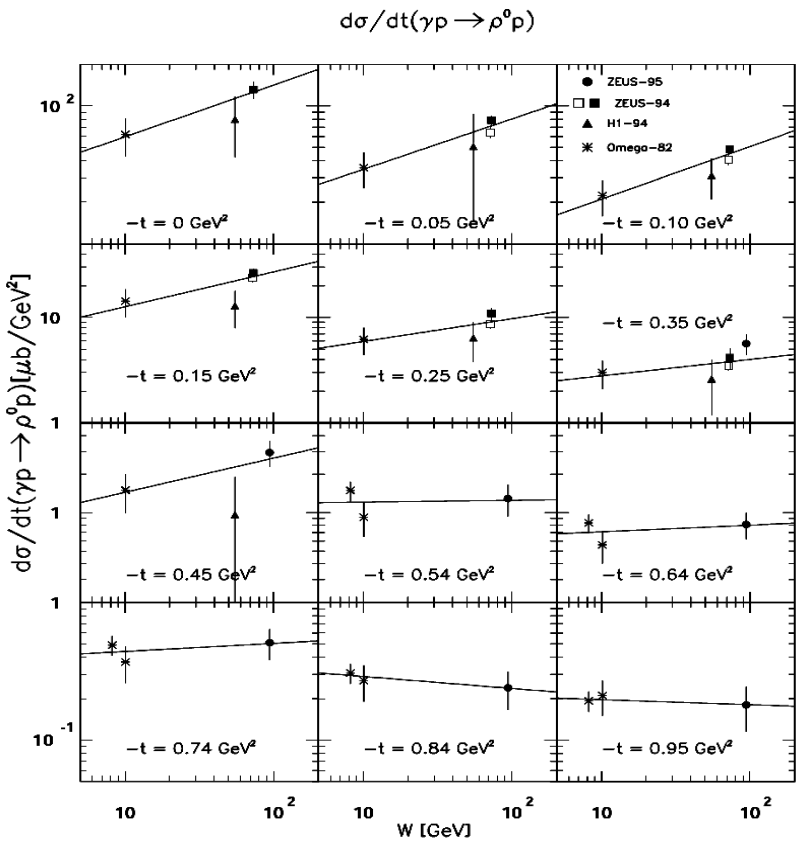
$$\frac{d\sigma^{elas}}{dt} \propto W^{4(\alpha(t)-1)}$$

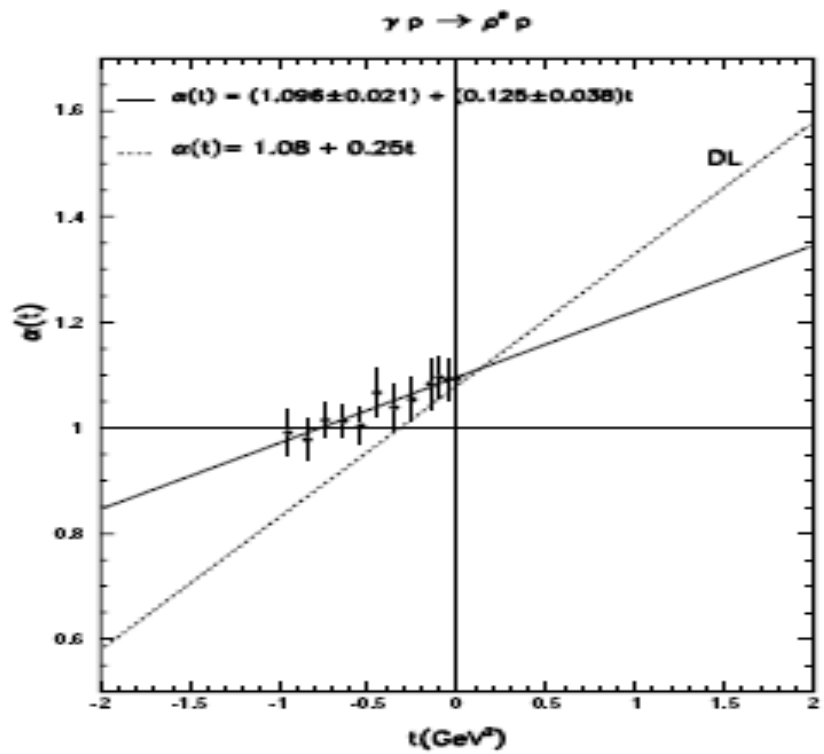


# The ZEUS Result from 2000

- ZEUS: EPJ **C14**(2000) 213-238.
- Combination of low-energy data (Omega) with ZEUS and H1('93) measurements at high W
- Result:
  - $\gamma p \to \rho^0 p: \quad \alpha_{I\!P}(t) = (1.096 \pm 0.021) + (0.125 \pm 0.038)t;$
  - $\gamma p \to \phi p: \quad \alpha_{I\!P}(t) = (1.081 \pm 0.010) + (0.158 \pm 0.028)t.$

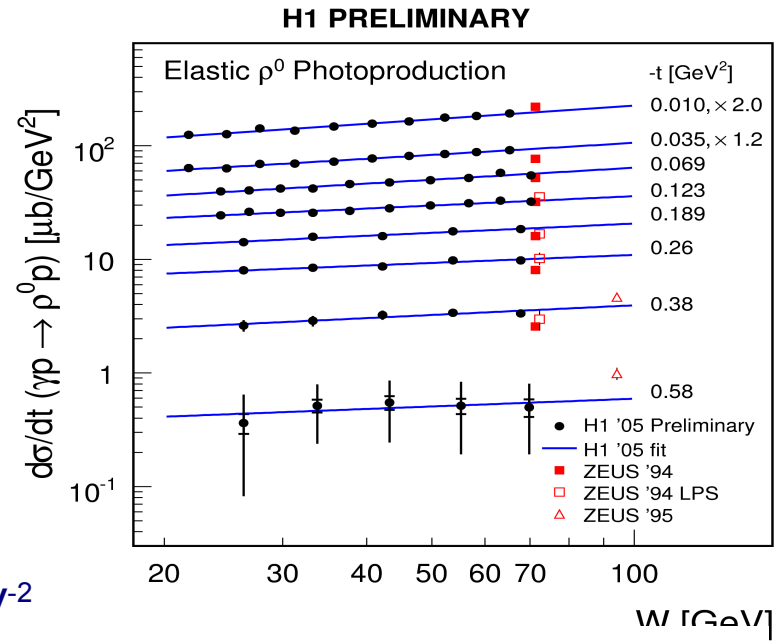


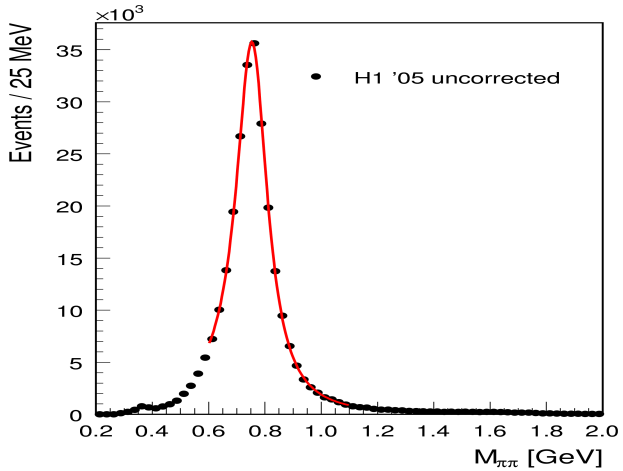




ZEUS, EPJ **C14**(2000)213.

# The 2005 H1 Analysis

- Measurement of elastic $\rho^0$ photoproduction from ~240000 events
- Kinematic range $20 < W < 90$ GeV
  $0 < |t| < 0.7$ GeV$^2$ (elastic data)
  → could measure W-dependence of $d\sigma/dt$ in a single experiment
- Result:
  $\alpha_{P,0} = 1.093 \pm 0.003(\text{stat}) + 0.008/-0.007\ (\text{syst})$
  $\alpha_P' = 0.116 \pm 0.027(\text{stat}) + 0.036/-0.046\ (\text{syst})\ \text{GeV}^{-2}$
  → almost identical with ZEUS result

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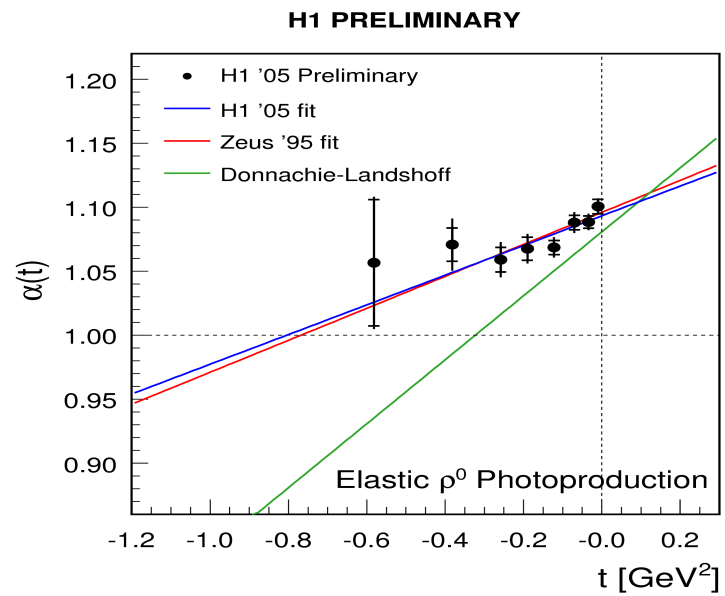


# Inputs to the Global Fit

Goal of the present analysis:
**Make a global fit of all data on elastic $\rho^0$ photoproduction data in bins of t.**

We confine this analysis to W>8GeV, to minimize the influence of subleading exchanges

- Input Data:
  - Omega: D. Aston et al., Nucl. Phys. **B209** (1982) 56.
  - H1 1995: Nucl. Phys. **B463** (1996) 3.
  - H1 2005: H1prelim-06-011
  - ZEUS 1994 LPS: Z. Phys. **C73** (1997) 253.
  - ZEUS 1994 low-t: EPJ **C2** (1998) 247.
  - ZEUS 2000 high-t: EPJ **C14** (2000) 213.
- Fit data in bins of t
  - needs partially swimming of data to common t bins
  - For each t bin: 2 parameters: $d\sigma/dt$ ($W_0$), $\alpha(t)$
  - Do a global fit, keeping correlations

# Global Fit: Chi2

- Use similar method as used in $F_2$ averaging (H1, arXiv:0904.0929)

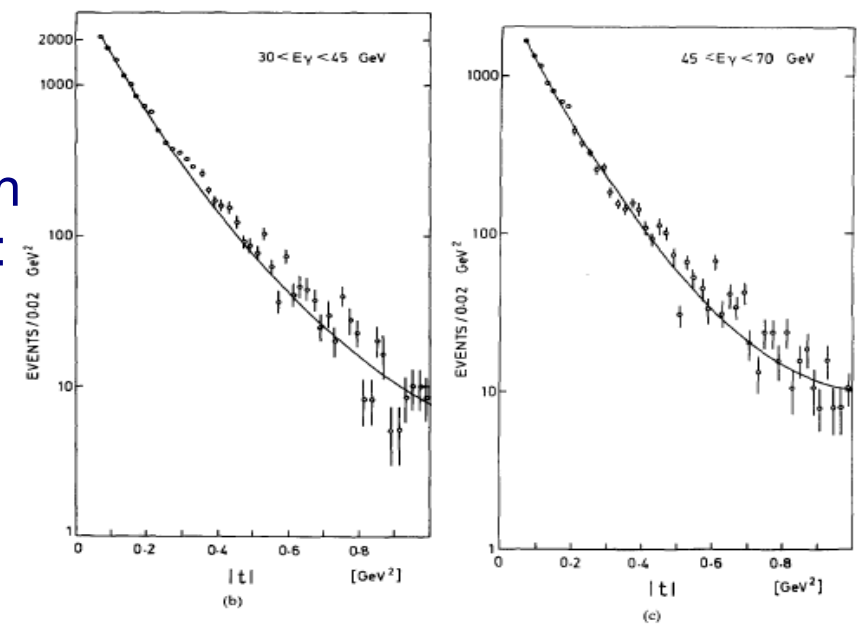
$$\chi^2 = \sum_i \frac{(m_i + \sum_k \sigma_{ik} b_k - f_i)^2}{\sigma_i^2} + \sum_k b_k^2$$

| | |
|---|---|
| $m_i$ | Measured values $(i = 1 \ldots M)$ |
| $\sigma_i$ | Errors (systematic and uncorrelated systematic) |
| $f_i(a_j)$ | Function values |
| $a_j$ | Parameters $(j = 1 \ldots N)$ |
| $b_k$ | Systematic error shifts $(k = 1 \ldots K)$ |
| $\sigma_{ik}$ | Coefficients for systematic errors |

- Function parameters are defined separately for each t bin
- Result of the fit:
  - Function parameters $a_j$ , i.e. $d\sigma/dt$ $(W_0)$ and $\alpha(t_i)$ in each t bin
  - Shifts and errors for all sources of correlated errors

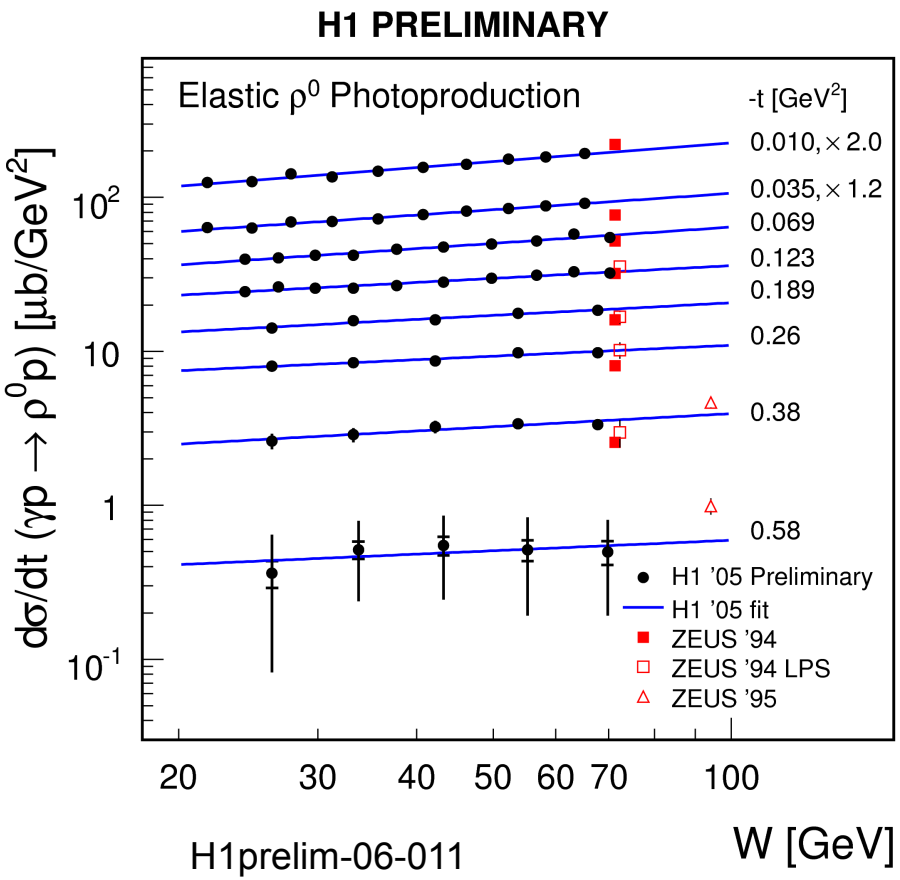
# The Omega Data Set

- Reference: D. Aston et al., *Photoproduction of $\rho^0$ and $\omega$ on hydrogen at photon energies of 20 to 70GeV,* Nucl. Phys. B 209 (1982) 56.
- 3 Bins of Eγ: 20-30, 30-45, 45-70GeV → <W> = 6.8, 8.3, 10.3GeV
  use data at 8.3 and 10.3 GeV (subleading trajectory largest at 6.8 GeV)
- $0.06 < |t| < 1\text{GeV}^2$
- Original data recovered from plots in paper, moved to bin centres of fit and averaged
- Statistical errors scaled by $\sqrt{(\chi^2/df)}$ of t-fit
- Correct for mass range of x-section definition
  $0.56<m_{\pi\pi}<0.92\text{GeV} \rightarrow 0.27<m_{\pi\pi}<1.52\text{GeV}$:
  factor 1.187±0.053
- Overall normalization taken from t-integrated cross section, normalization error 10-13%



# The H1 2005 Data Set

- Very precise data set, covering a large W range
- 10 sources of correlated systematic errors are considered
- Correlations are fully kept in the fit
- Dominant uncertainty: subtraction of p-dissociative bg. at large |t|
- Normalization uncertainty 5.3%
- Sufficient for α(t) determination at |t| < 0.6 GeV

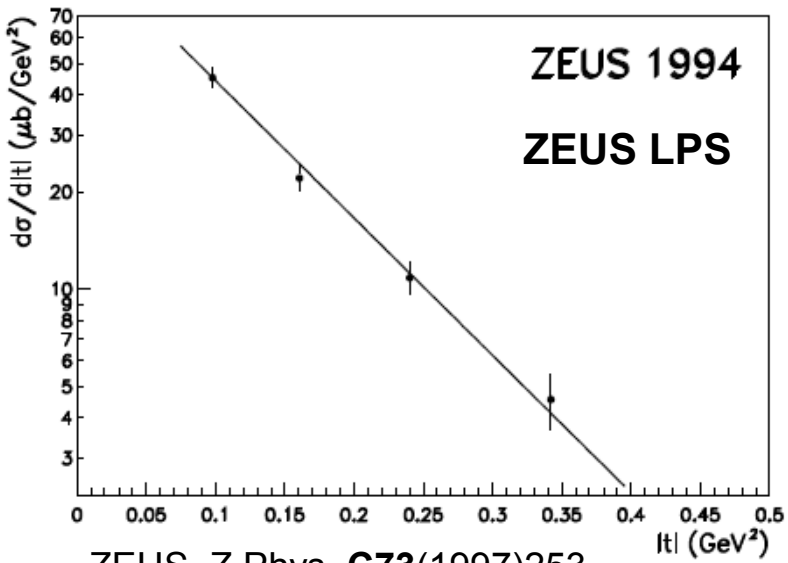


# The ZEUS 1994 Data Sets

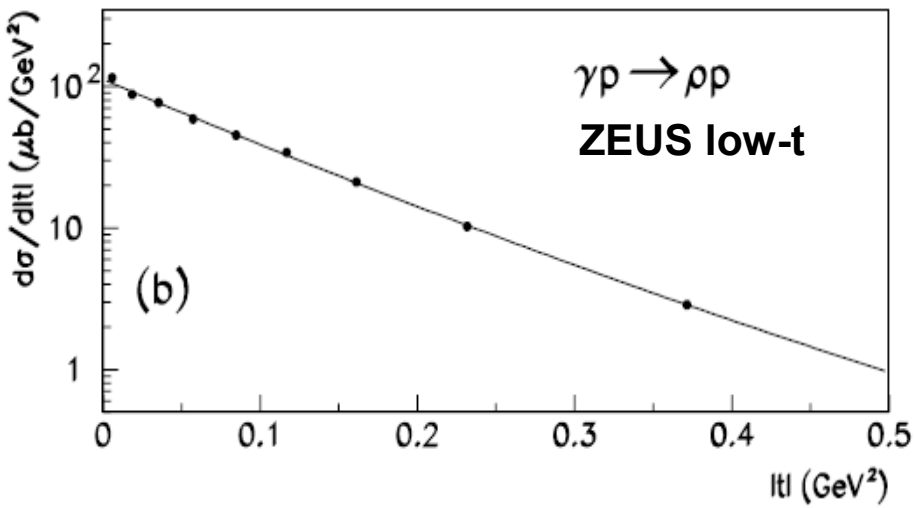
- References:
  M. Derrick *et al.* (ZEUS Collab.): Z.Phys. **C73**(1997)253. (ZEUS LPS)
  J. Breitweg *et al.* (ZEUS Collab.): EPJ **C2**(1998)247. (ZEUS low-t)

- ZEUS LPS: <W>=73GeV, 4 t bins, $0.073 < |t| < 0.4\text{GeV}^2$,
  mass range correction 1.09,
  syst. errors: 11% uncorrelated, 6% normalization

- ZEUS low-t: <W>=71.7GeV, 12 t bins for $0<|t|<0.5\text{GeV}^2$
  syst. Errors: 10% uncorrelated, 5% normalization
  measurements are corrected for different t-binning and averaged



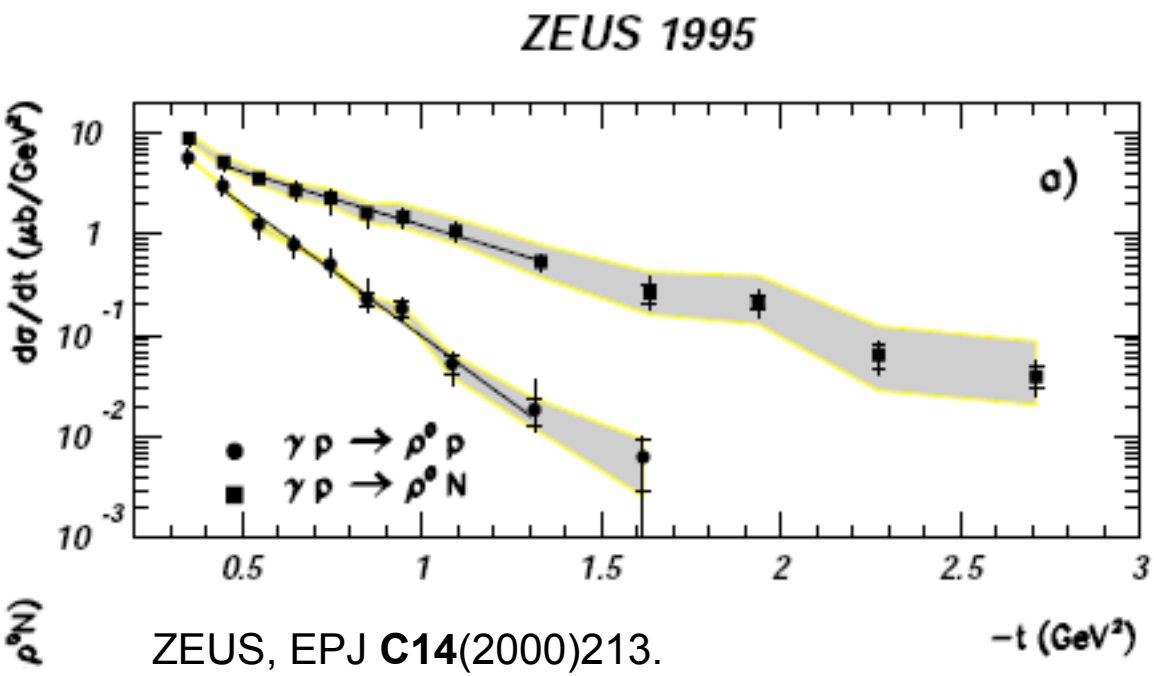

ZEUS, Z.Phys. **C73**(1997)253.




ZEUS, EPJ **C2**(1998)247.

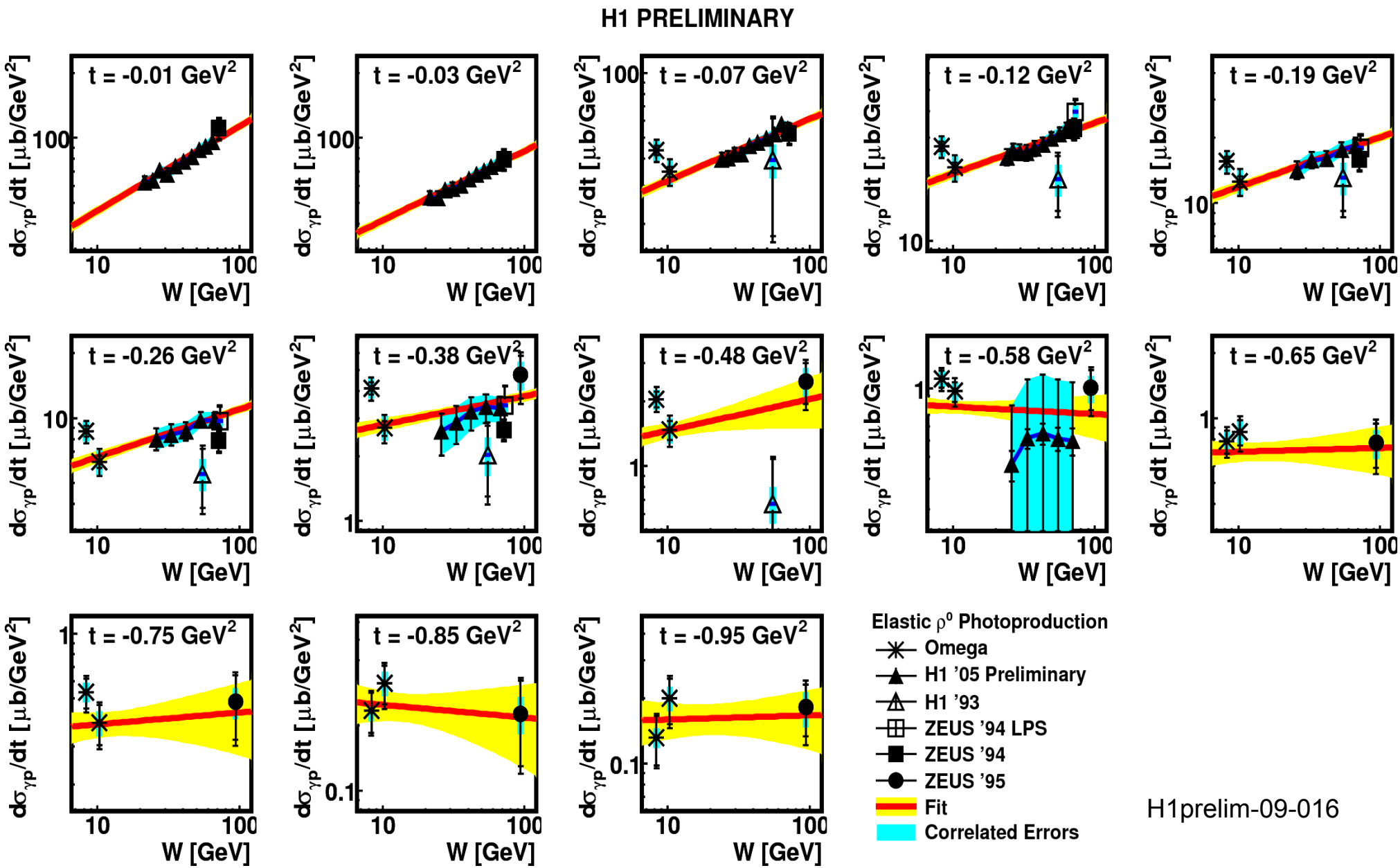
# The ZEUS High-t Data Set

- ZEUS, EPJ **C14**(2000)213.
- Measurement of elastic rho production from 1995 data at <W>=94GeV for 0.3 < |t| < 1.6GeV$^2$
- Correlated errors from proton dissociation subtraction are available and taken into account, plus 15% normalization uncertainty




ZEUS, EPJ **C14**(2000)213.

# The Global Fit

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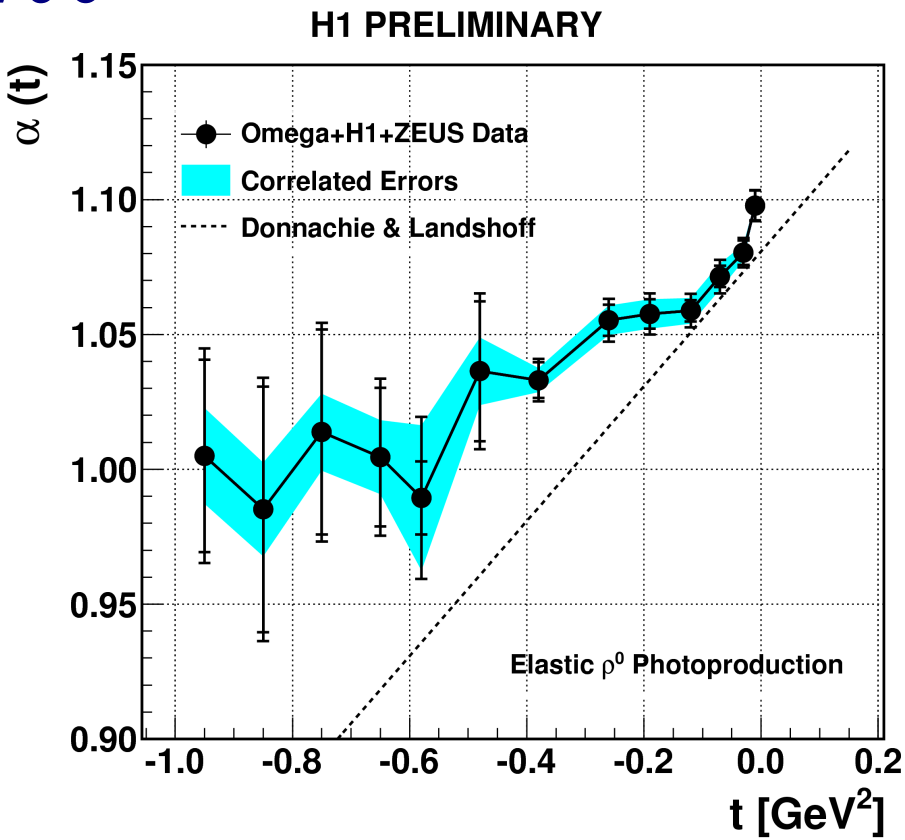
# The Fit Result

- Overall $\chi^2$/df = 111.7 / 80
  (106 data points - 2x13 parameters)
  → satisfactory fit quality
- Omega data at W=8.3GeV lie systematically high
  → some tension in normalization, below 3 σ
- Error correlations (especially from normalization) are fully propagated
- High |t| bins profit from precise data at low |t|, which constrains the relative normalization of data sets

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# New Pomeron Trajectory Result: Linear Fit

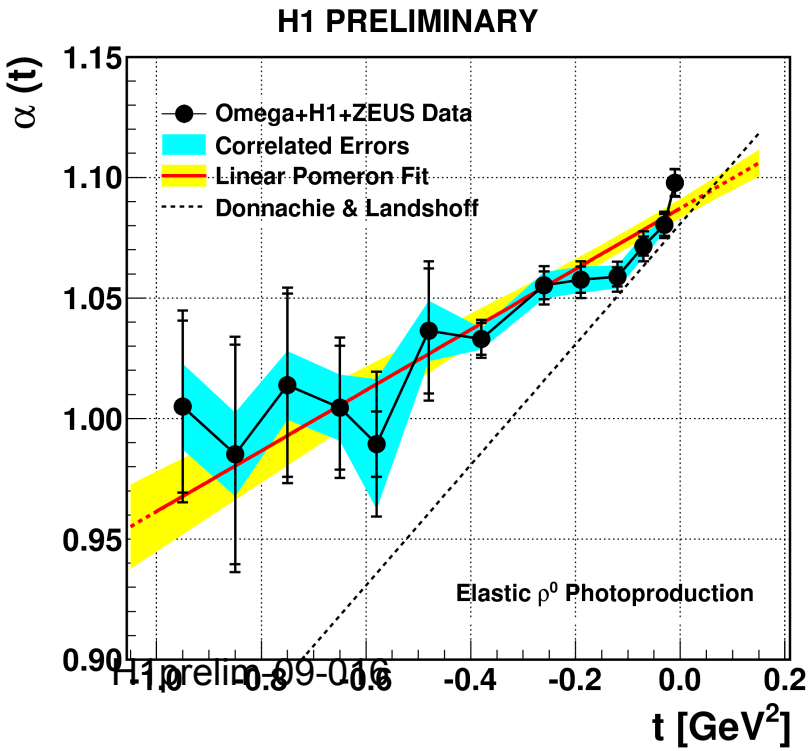
- The new result from the global fit:

  $\alpha_0 = 1.0871 \pm 0.0026(\text{stat}) \pm 0.0030\ (\text{syst})$
  $\alpha' = 0.126 \pm 0.013(\text{stat}) \pm 0.012\ (\text{syst})\ \text{GeV}^{-2}$

  $\chi^2/\text{df} = 14.7 / (13-2)$
  (correlations taken into account)

- H1Prelim-06-011 (H1 data alone):
  $\alpha_0 = 1.093 \pm 0.003(\text{stat})\ ^{+0.008}_{-0.007}\ (\text{syst})$
  $\alpha' = 0.116 \pm 0.027(\text{stat})\ ^{+0.036}_{-0.046}\ (\text{syst})\ \text{GeV}^{-2}$

- ZEUS EPJ C14(2000)213:
  $\alpha_0 = 1.096 \pm 0.021$
  $\alpha' = 0.125 \pm 0.038\ \text{GeV}^{-2}$

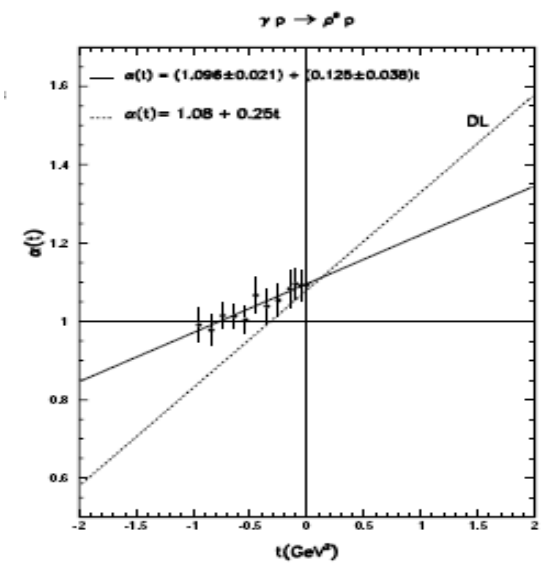


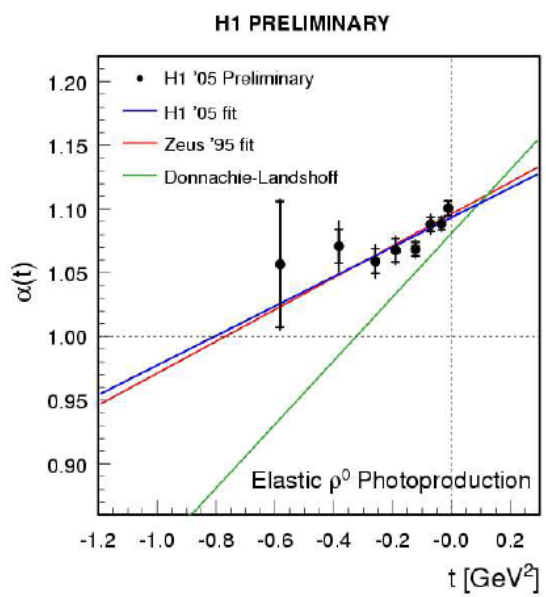

- All 3 results are in perfect agreement
  (expected, as ZEUS and H1prelim-06-011 are consistent)

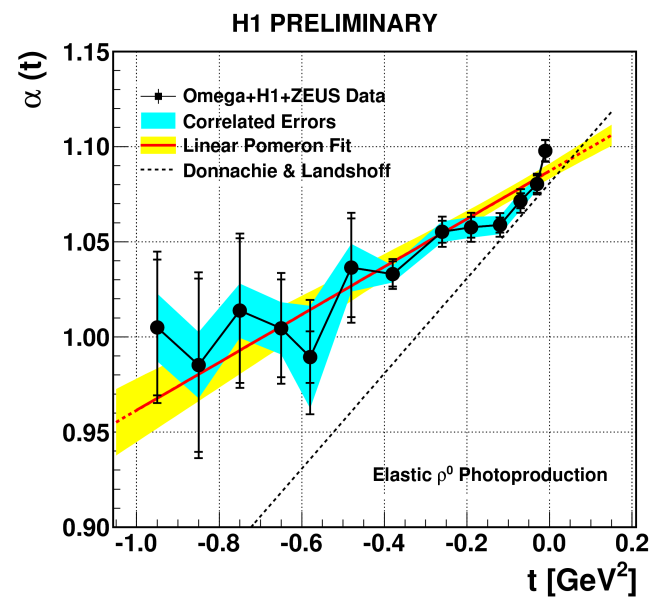
- Compare to Donnachie & Landshoff:
  $\alpha_0 = 1.0808$ Donnachie, Landshoff PL **B296**(1992)227
  $\alpha' = 0.25\ \text{GeV}^{-2}$ Jaroszkiewicz, Landshoff, PR **D10**(1997)170; Landshoff, NP Proc.Suppl.**12**(1990)397

# The Three Results

- ZEUS (+Omega+H1 '94): suggests completely linear trajectory
- H1 '05: agrees with D&L slope at low t, is from a single experiment
- New result: gives same slope again, as expected
  BUT: is much more precise than ZEUS '00 result at low |t|,
  may hint at flattening of trajectory,
  compatible with D&L slope at low |t|!

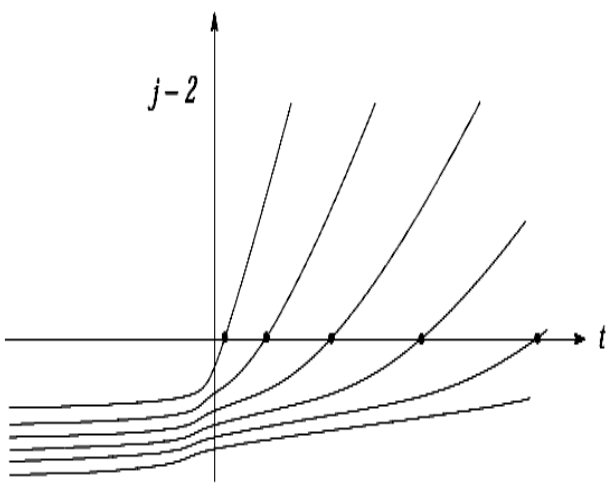


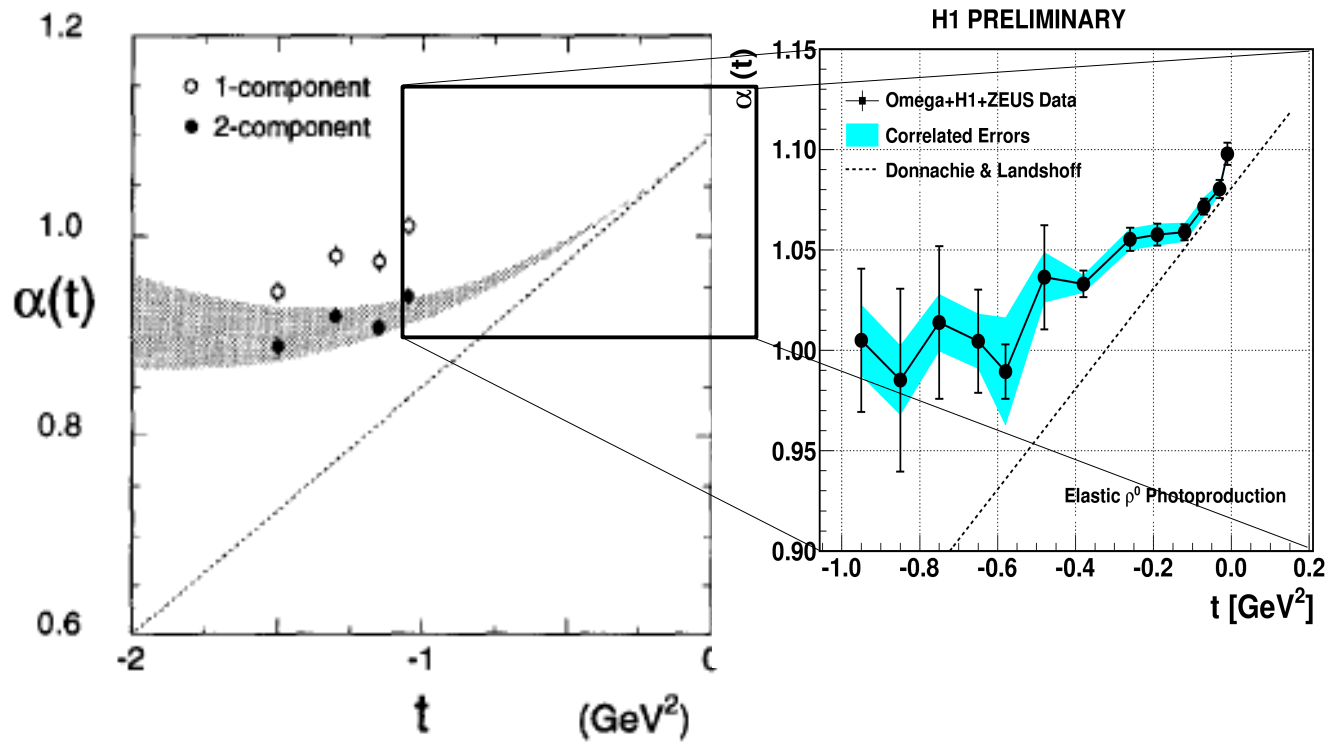



# Flattening of the Pomeron Trajectory?

- Do we see a flattening of the Pomeron trajectory?
  Has been predicted from Gauge/String duality and observed by UA8
- It seems that even at large |t|, the rho cross section does never fall with W, it seems to stay constant => α(t) >= 1




Brower et al., *The pomeron and Gauge/ String duality*, JHEP 0712(2007)005 [arXiv:hep-th/0603115]




A. Brandt [UA8], NP **B5141**(1998)3.

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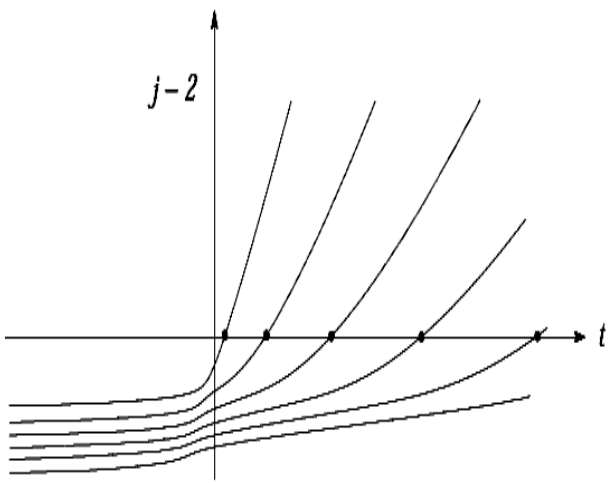


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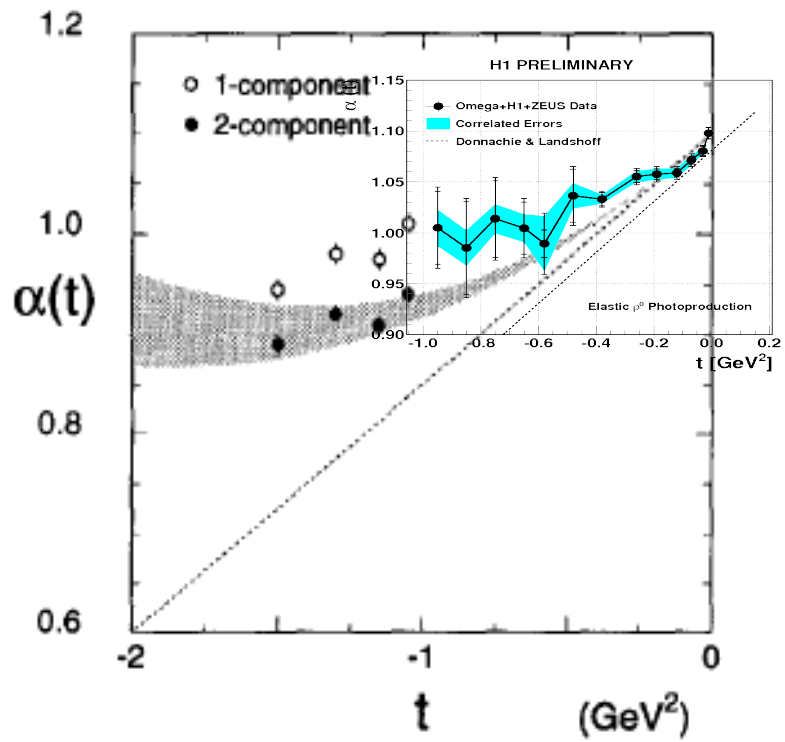


A. Brandt [UA8], NP **B5141**(1998)3.

# Summary and Conclusions

- A new global fit of elastic $\rho^0$ photoproduction data for $8 < W < 100$ GeV has been performed in 13 bins of t, at $0.01 < |t| < 0.95\text{GeV}^2$, taking into account error correlations
- From the W-dependence of $d\sigma/dt \sim W^{4(\alpha(t)-1)}$, the Pomeron trajectory has been extracted
- The resulting values for $\alpha_P(t)$ are in agreement with
  - A fit to Omega+H1'93+ZEUS data
  - A fit to the H1 2005 data alone
- The new global fit shows significant deviation from D&L pomeron at $|t| > 0.5\text{GeV}^2$
- A linear Pomeron trajectory with slope $\alpha' = 0.125\text{GeV}^{-2}$ is not excluded
- But: data is also compatible with (and suggestive of)
  - the D&L pomeron at low |t|
  - and a <u>constant</u> trajectory at larger |t|