HERA Event Generators for Low Mass Domain

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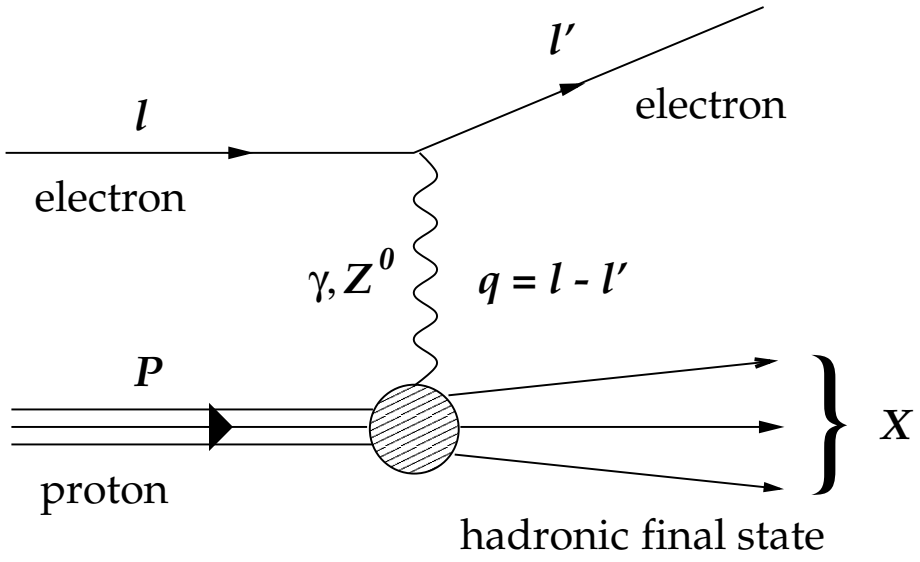
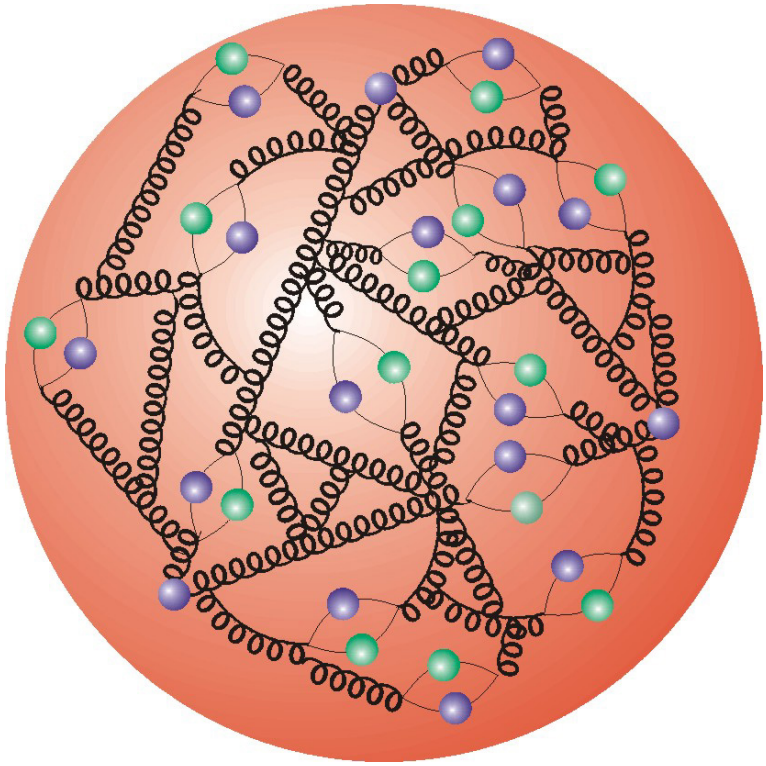
DESY

- Main kinematic region of HERA
- Processes involving low masses
- Hadronic final state at low masses
- Summary

HCP02 Karlsruhe, 4 Oct 2002

Energy Domain of HERA



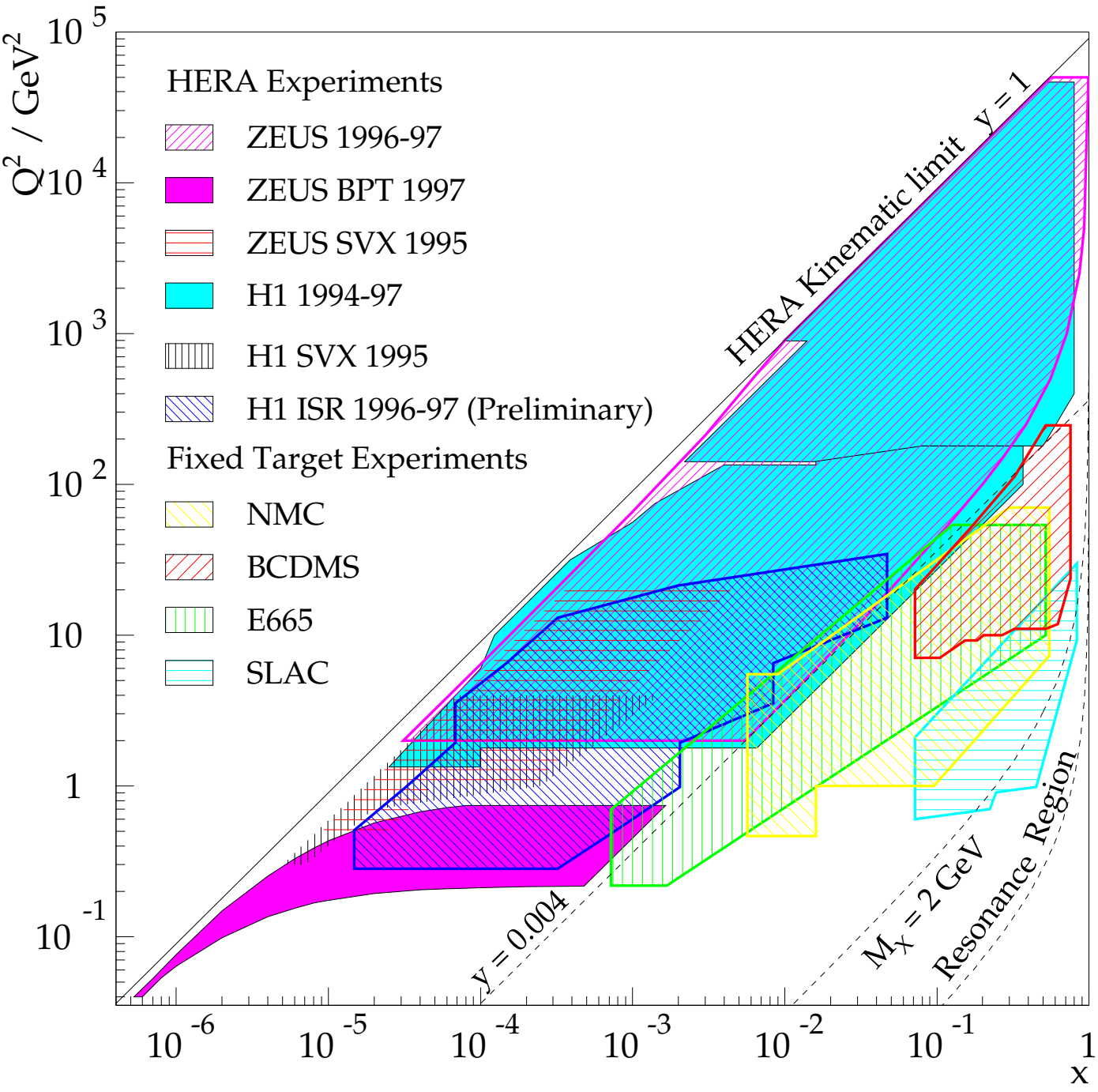


- Parton state (MEPS, CDM, ...)
- fragmentation
  - Lund string model (JETSET/PYTHIA)
  - cluster model (HERWIG)

$\hookrightarrow M_X$ usually large

DIS Kinematic Regions

$$Q^2 = -q^2 = -(l - l')^2 \qquad x = \frac{Q^2}{2P \cdot q}$$

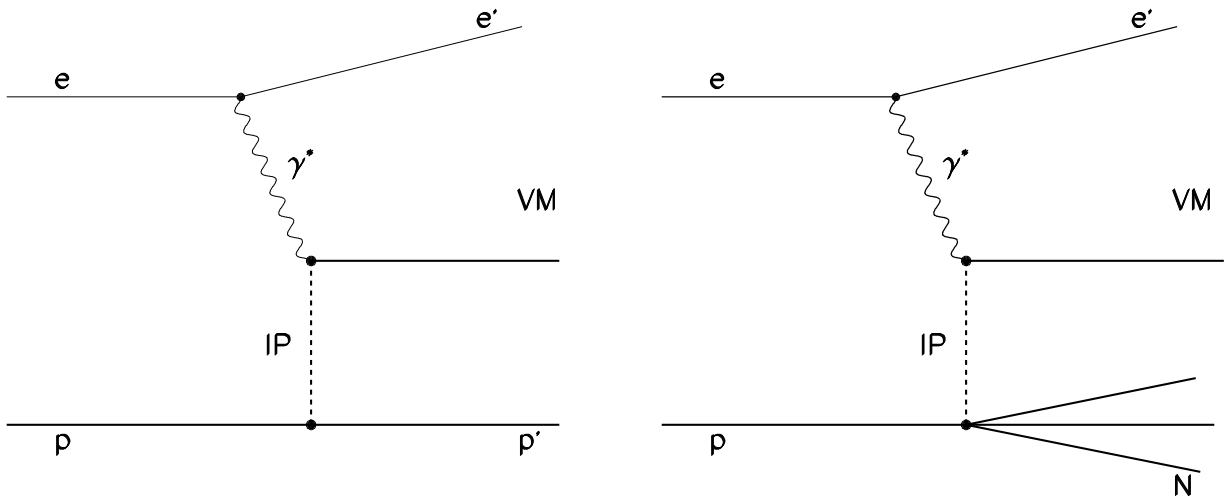


$$M_X^2 = Q^2 \frac{1 - x}{x} + m_p^2$$

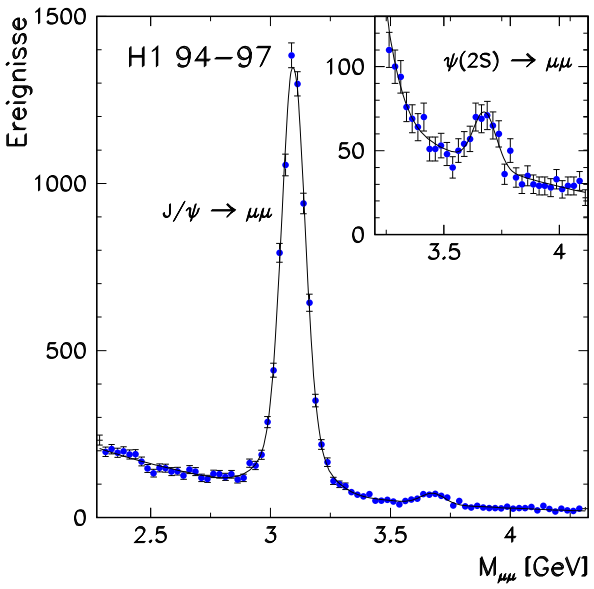
Diffractive Vector Meson

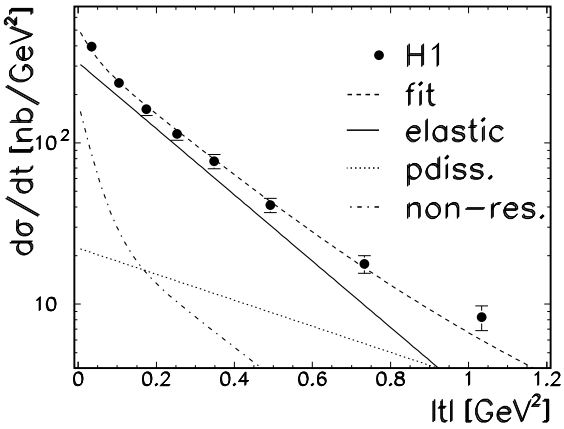
DIFFVM (B. List), EPSOFT (M. Kasprzak, L. Adamszyk, M. Inuzuka *et al*)

Vector Dominance Model + Regge phenomenology



VM: $\rho, \omega, \phi, J/\psi, \psi(2S)$, Υ

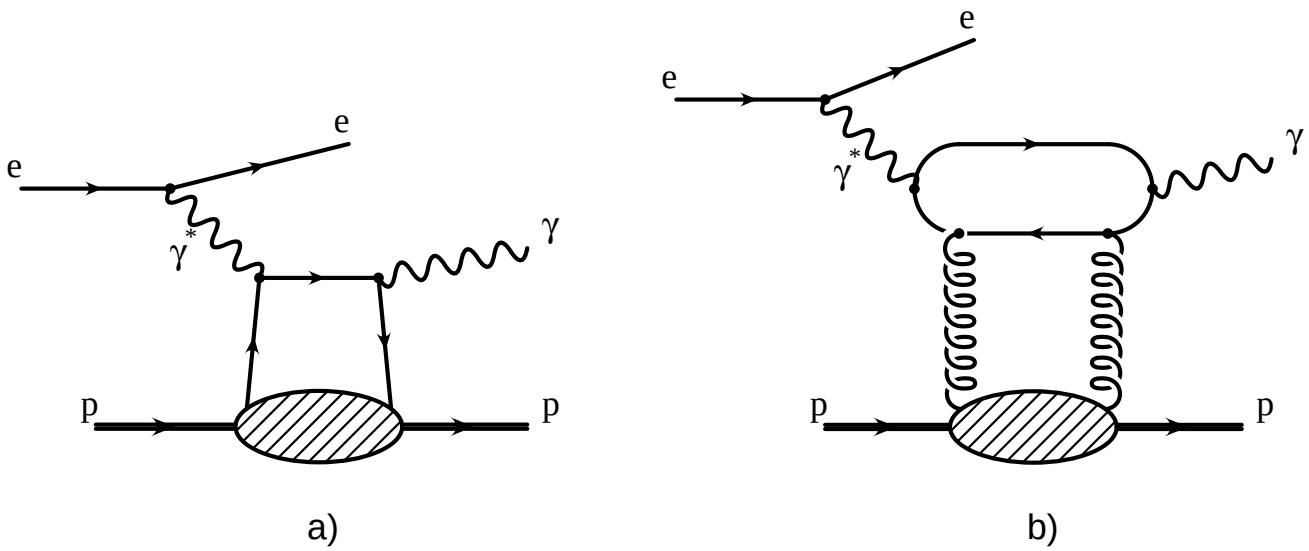




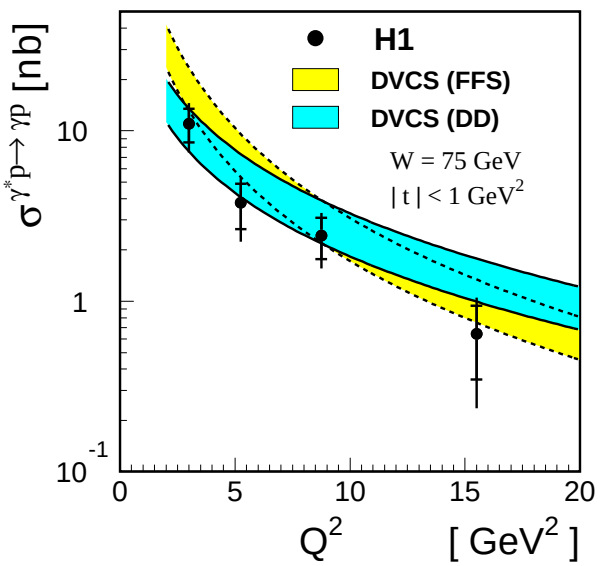
Low mass hadronisation at $p\mathcal{P}$ vertex

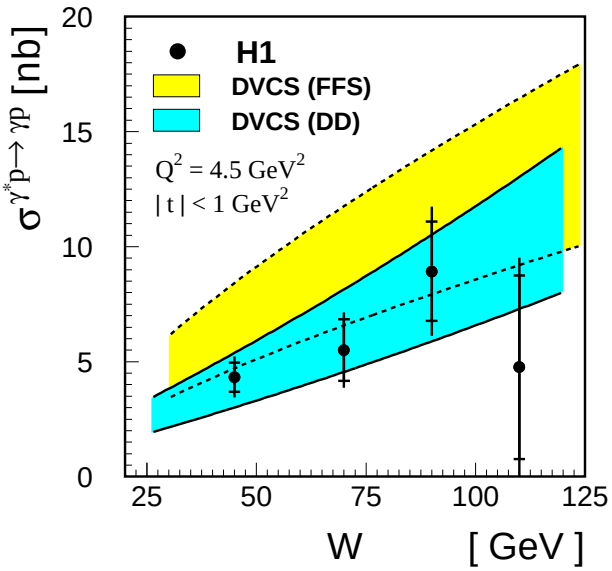
DVCS

Deeply Virtual Compton Scattering



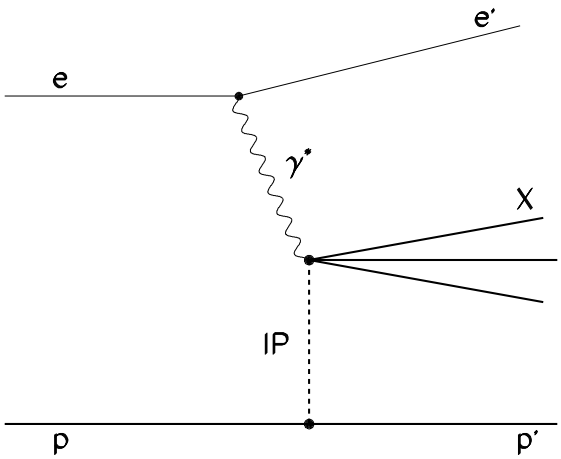
skewed parton distributions

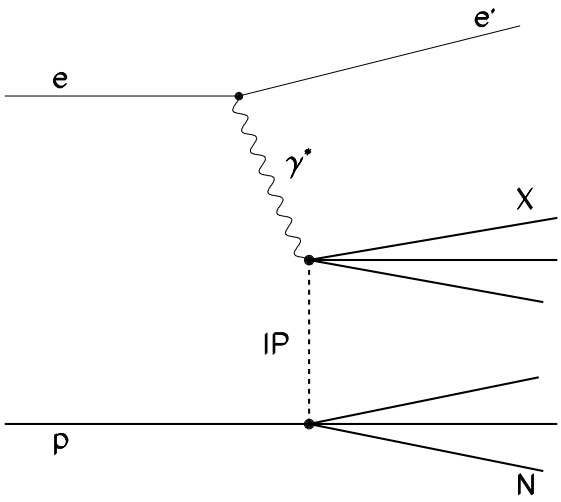




↪ Distinguish elastic $\Longleftrightarrow$ inelastic

Inclusive Diffraction





Measurement of

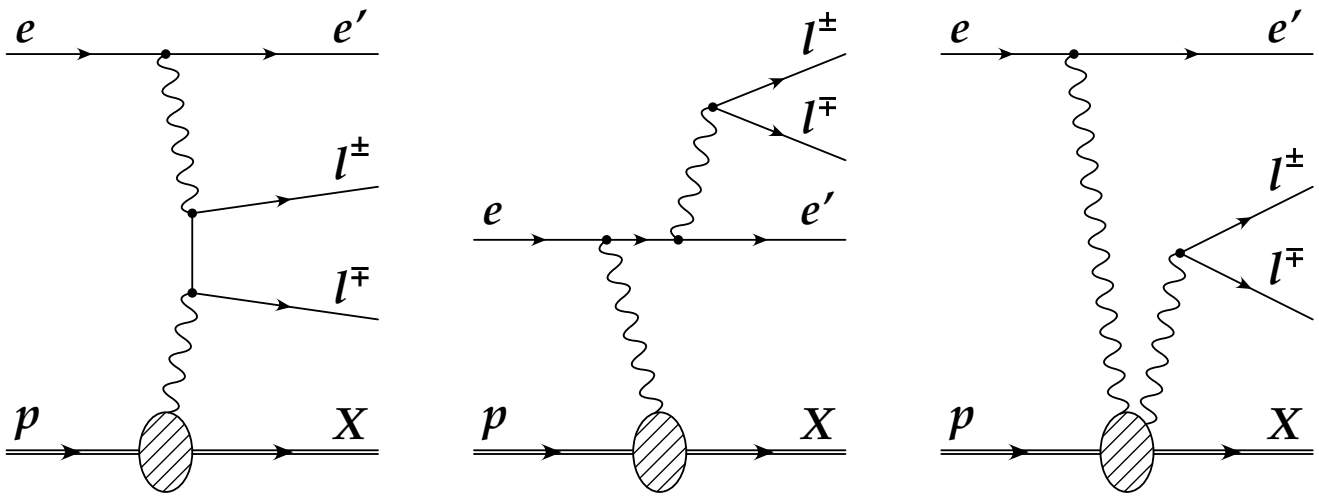
- Diffractive DIS cross section
- $F_2^{D(3)}$
- Diffractive jet production
- ...

RAPGAP (H. Jung)

- inclusive and diffractive DIS and γp (different models for pomeron structure, resolved photon model, ...)
- No low M_Y hadronisation yet

Selection: no Y in detector $\longrightarrow$ $M_Y < 1.6\,\text{GeV}$
– correction estimated by DIFFVM or EPSOFT for low mass hadronisation at $p\mathcal{P}$ vertex
$\hookrightarrow$ typically 5 – 10%

Dilepton Production



Background for

- J/ψ, Υ production
- Searches for new physics

LPAIR or GRAPE

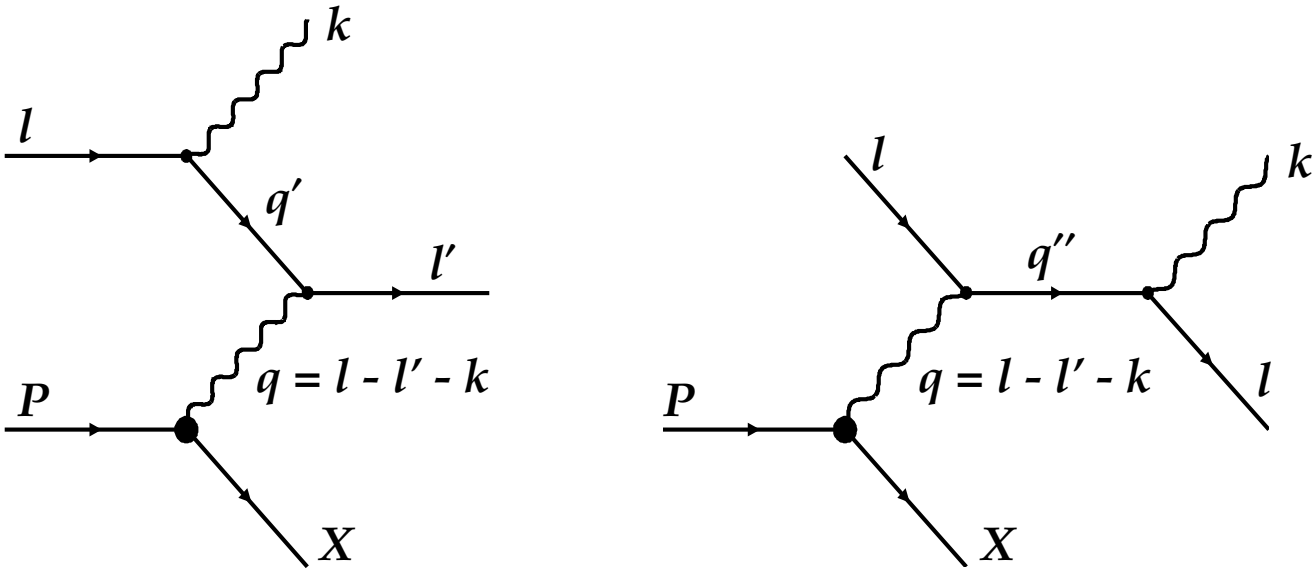
GRACE-based MC for Proton Electron collisions

(T. Abe, J. Fujimoto, T. Ishikawa, K. Kato, Y. Kurihara, T. Watanabe)

1. All EW diagrams by GRACE – automatic calculation of amplitudes
2. Integration/Generation by BASES/SPRING
3. Interface to hadronisation package (EPSOFT, SOPHIA)

Radiative ep Scattering

$$e + p \longrightarrow e + \gamma + X$$



- Radiative Corrections to DIS :
  $\vec{k} \parallel \vec{l}$ — Initial State Radiation (ISR)
  $\vec{k} \parallel \vec{l'}$ — Final State Radiation (FSR)

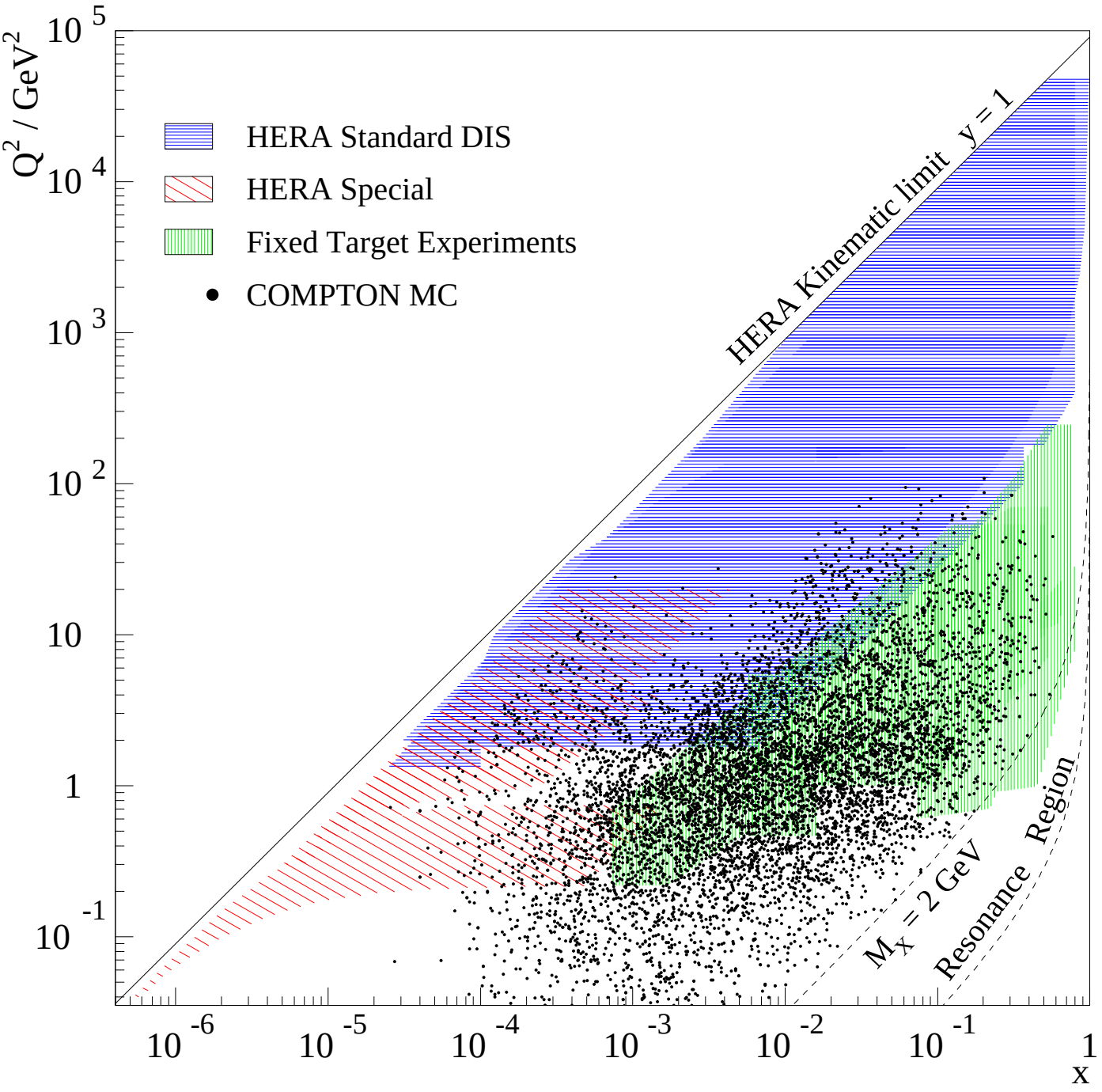
- QED Compton : $q^2 \sim 0 \iff \vec{q} \parallel \vec{P}$
  Compton scattering of a quasi-real photon off an electron

$$Q^2 = \frac{p_{t,e\gamma}^2}{1-y} \qquad x = \frac{Q^2}{2P \cdot q} \qquad M_X^2 = Q^2 \frac{1-x}{x} + m_p^2$$

Kinematic Region of Continuum QEDC

↪ COMPTON 2.00 (A. Courau, P. Kessler, S. Kermiche, T. Carli)

Version 2.14 (V. Lendermann)



Hadronic Final State at Low Masses

Goals

- Distinguish elastic $\longleftrightarrow$ inelastic
- Separate X from Y
- Measure F_2 in extended region

Challenges

- Low Q^2 – partonic structure?
  region of non-perturbative QCD
- Low M – problems with Lund string model

$\hookrightarrow$ Special models for hadronisation

DIFFVM Model

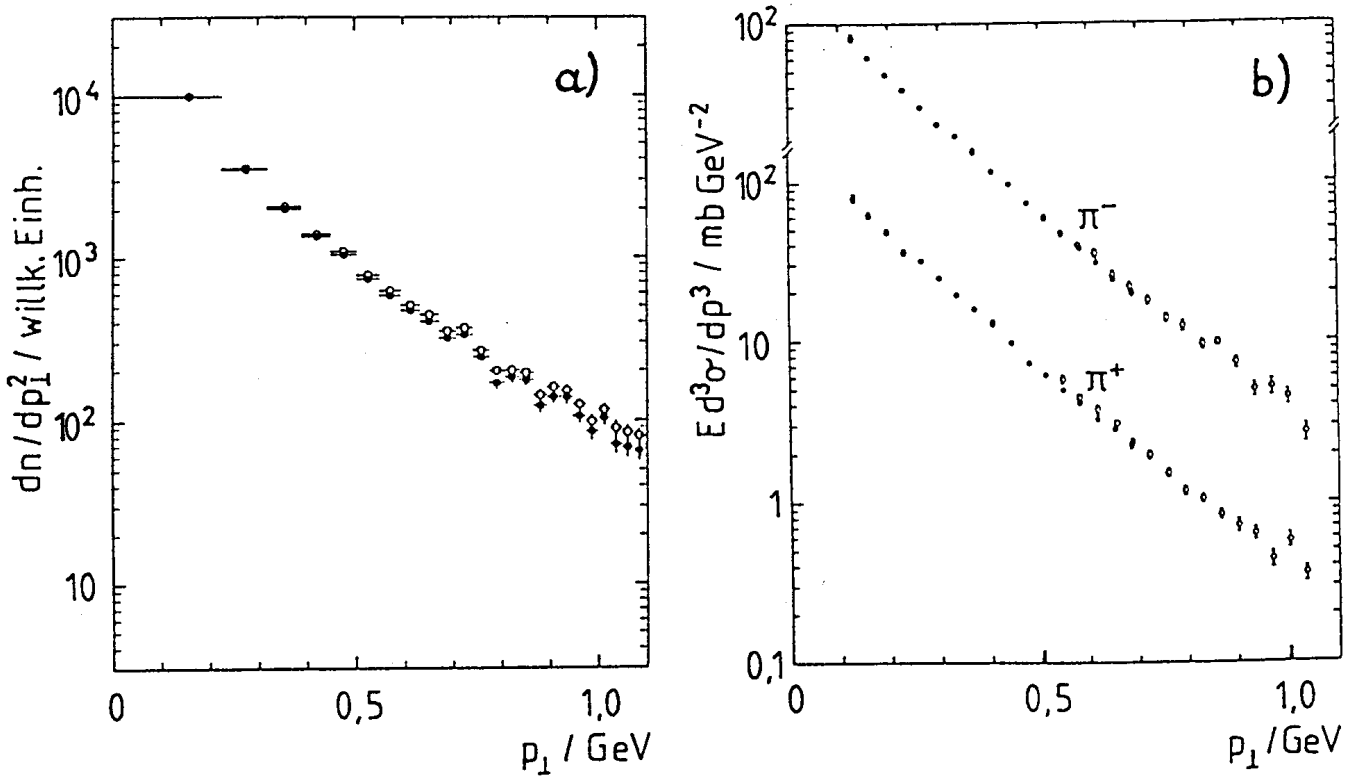
- Multiplicity $N(M_r)$ $[M_r = M_X - m_p]$ – KNO scaling (Z. Koba, H. B. Nielsen and P. Olesen):

$$N_c = \begin{cases} \sqrt{M_r} & \text{for } M_r \leq 1 \\ a + b \ln M_r + c \ln^2 M_r & \text{for } M_r > 1 \end{cases}$$

  Low M_r – ISR pp, high M_r – SPS pp
  Gaussian smearing around N_c

- Flavours: only pions
- Multi-body phase space decay by RAMBO – Random Momentum Booster

  (R. Kleiss, W. J. Stirling, S. D. Ellis)



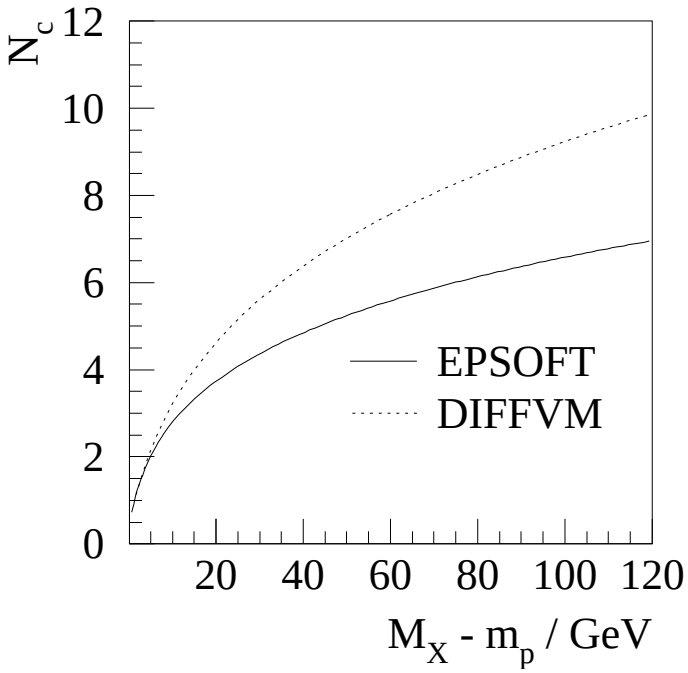
EPSOFT Model

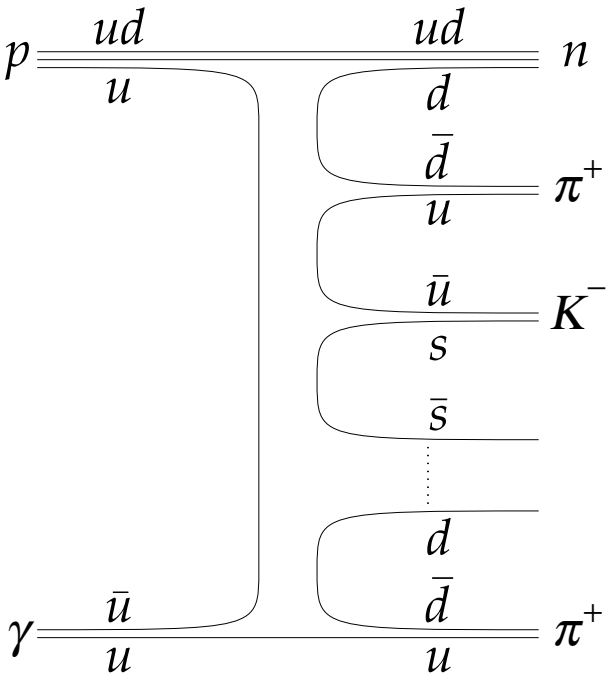
UA5 minimum bias event generator $\longrightarrow$
HERWIG soft underlying event generator $\longrightarrow$
ZEUS EPSOFT – different versions

- Multiplicity $N(M_r)$ $\quad [M_r = M_X - m_p]$:

$$N_c = a \ln^2 M_r + b \ln M_r + c$$

Low M_r – ISR pp, high M_r – ZEUS γp
Very low M_r – Gaussian, higher M_r – NBD





- Flavours: u, d, s
- Transverse momenta: $\frac{dP}{dp_t^2} \propto \exp\left(-\kappa\sqrt{p_t^2 + m^2}\right)$
- Longidutinal momenta: flat in rapidity with Gaussian shoulders

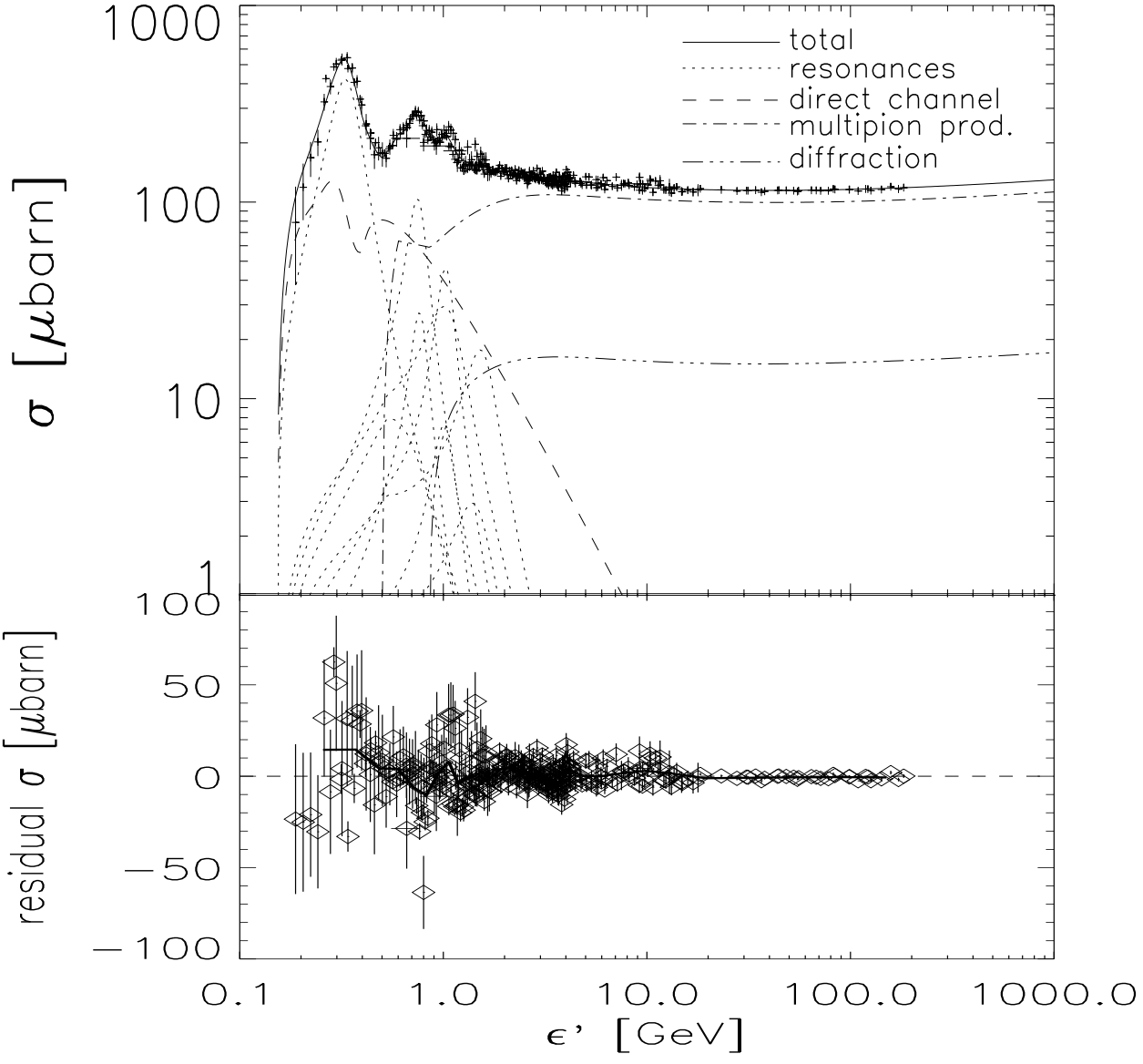
SOPHIA Model

Simulations Of PhotoHadronic process In Astrophysics

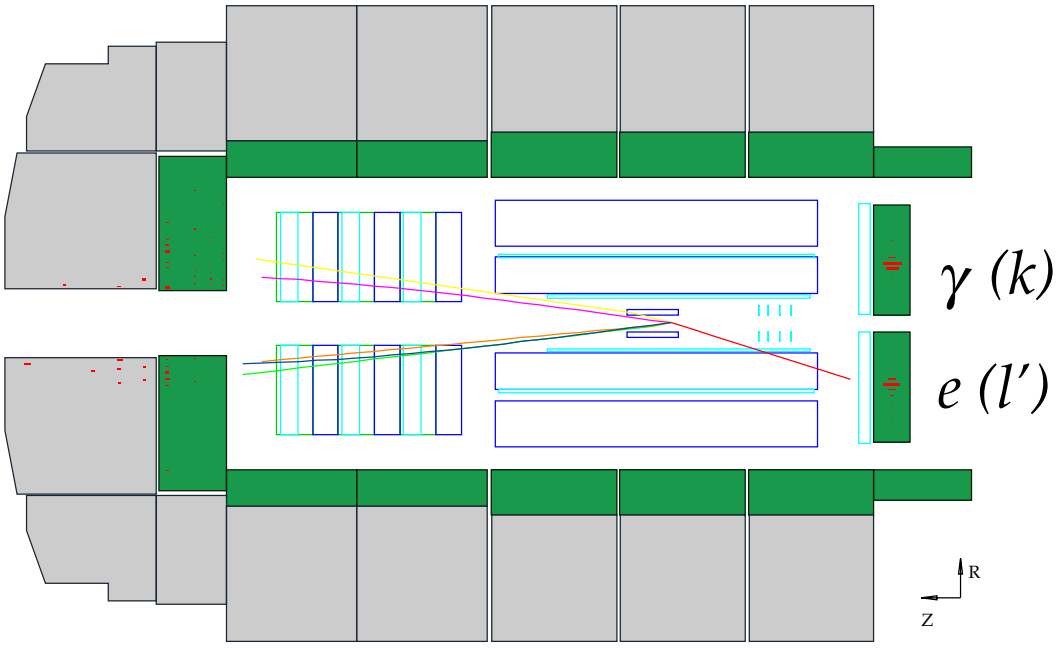
(A. Mücke, R. Engel, J. P. Rachen, R. J. Protheroe, T. Stanev)

includes large set of experimental σ data:

- resonance production
- direct pion production
- diffractive vector meson production
- multiparticle production based on Dual Parton Model + tuned JETSET/PYTHIA

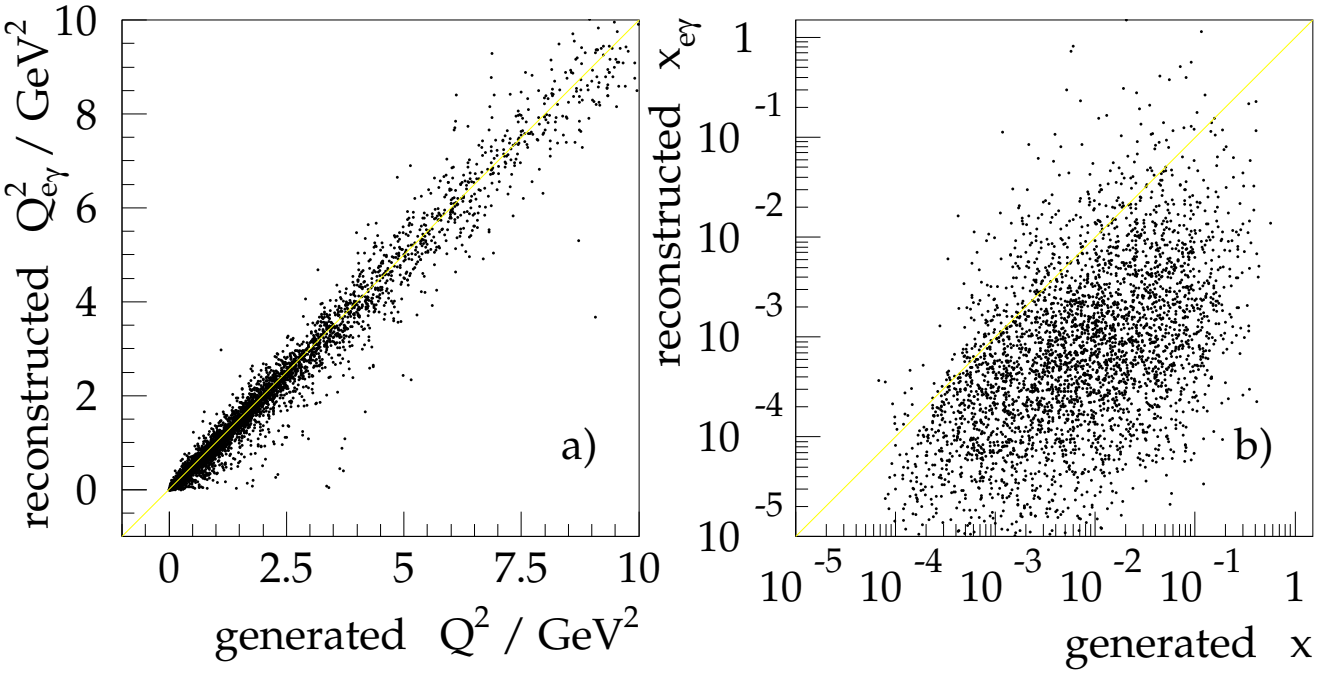


x and Q^2 Reconstruction



- From the lepton side: $Q^2_{e\gamma} = -(l - l' - k)^2$

$$y_{e\gamma} = 1 - \frac{\sum_{e,\gamma}(E - p_z)}{2E_{e-\text{beam}}} \qquad x_{e\gamma} = \frac{Q^2_{e\gamma}}{s y_{e\gamma}}$$



x Reconstruction

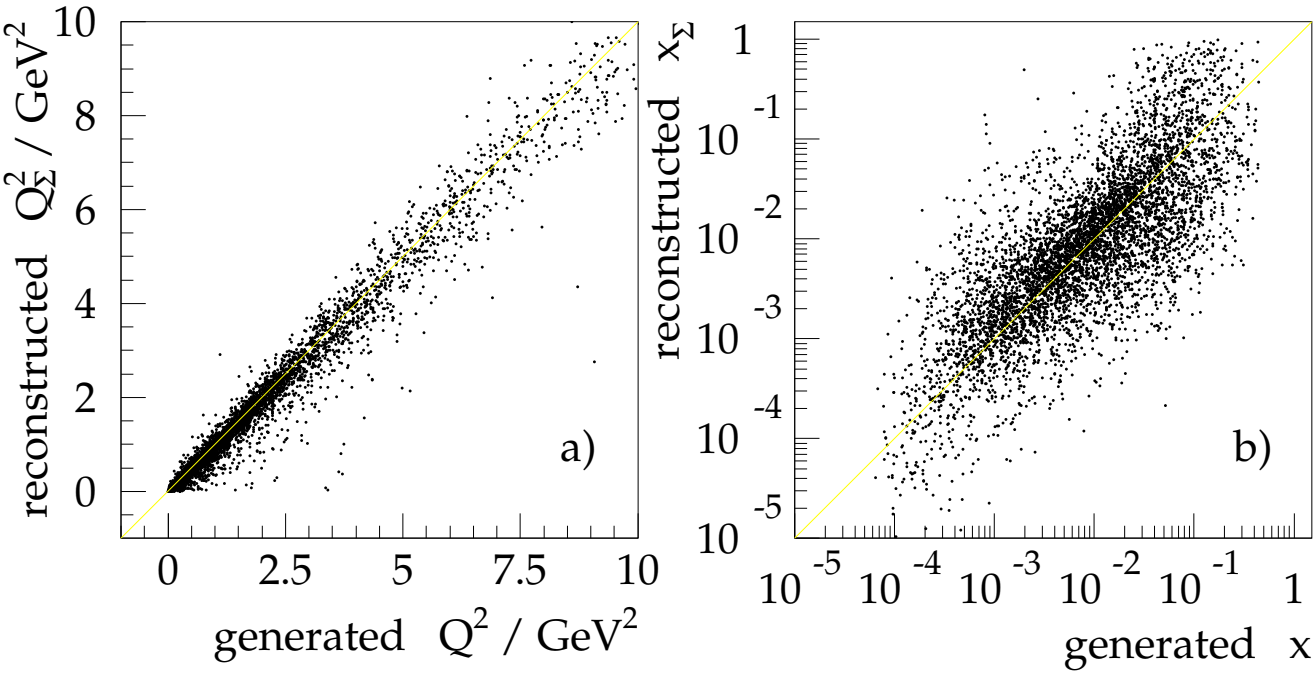
- Sigma method

  x and y from the hadronic final state

$$\Sigma = \sum_{i=1}^{N_h} (E_i - p_{z,i})$$

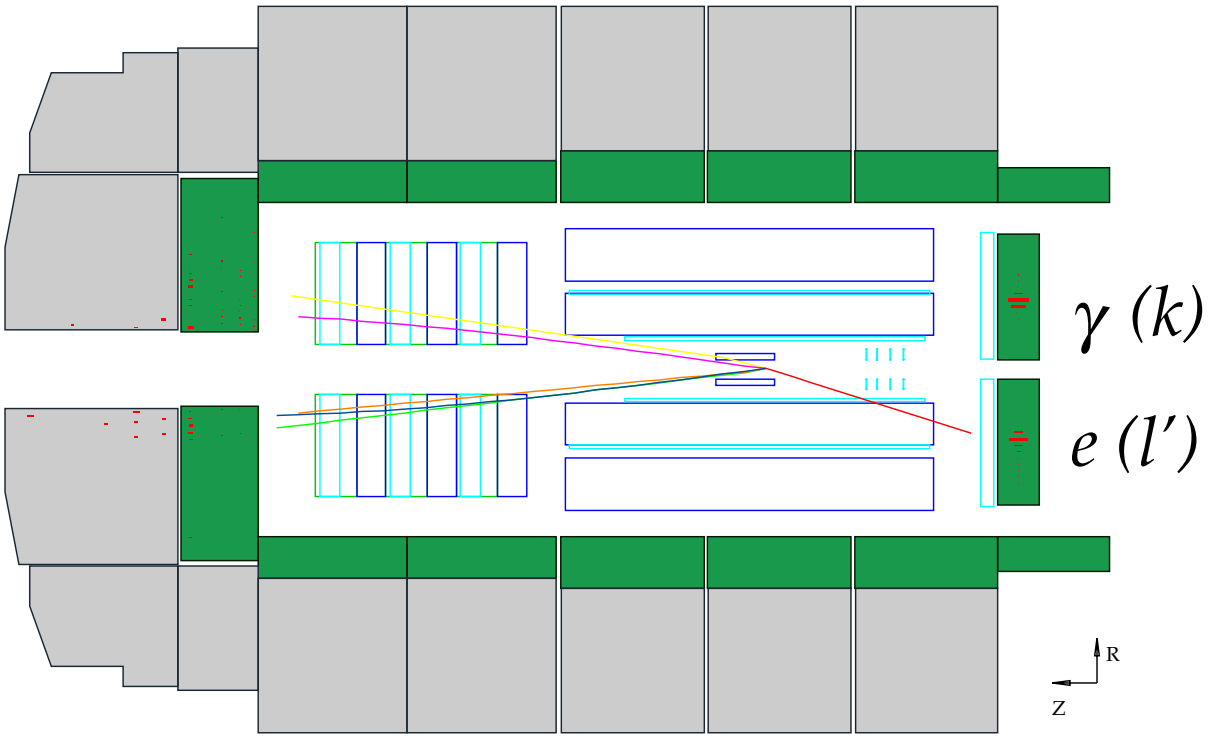
$$y_\Sigma = \frac{\Sigma}{\Sigma + (E_e - p_{z,e}) + (E_\gamma - p_{z,\gamma})}$$

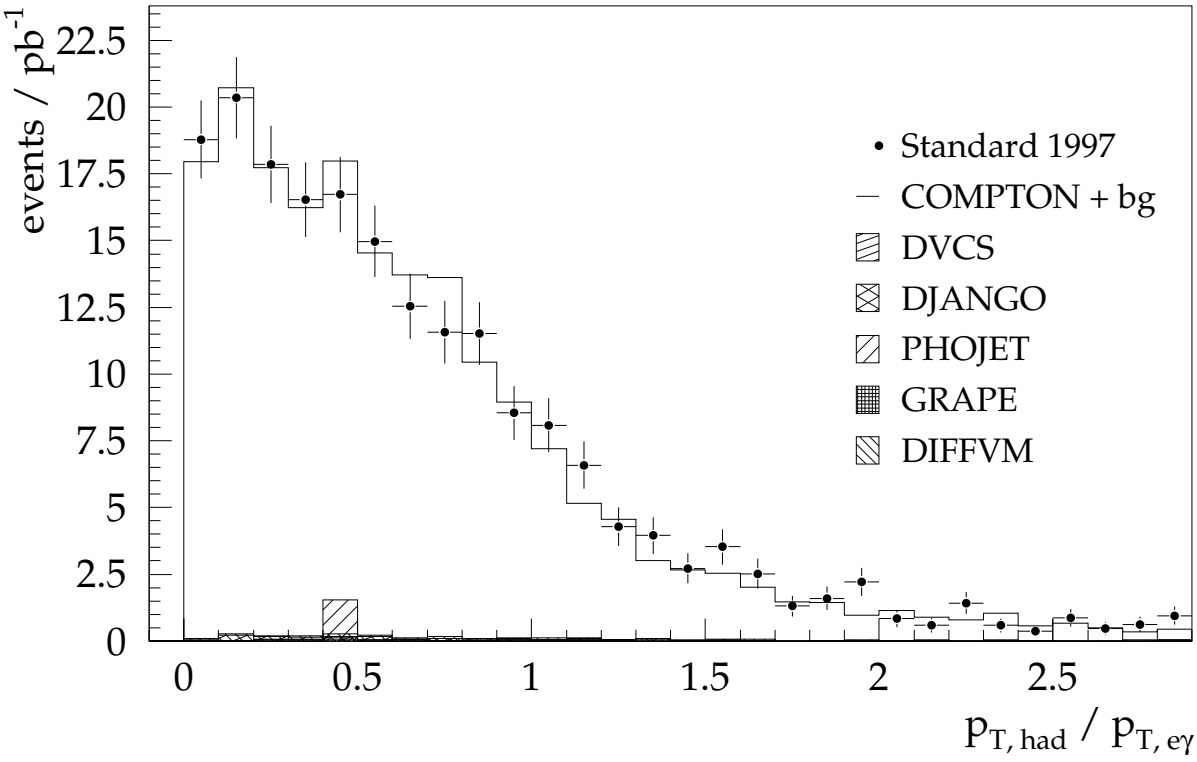
$$Q^2_\Sigma = \frac{p^2_{t,e\gamma}}{1 - y_\Sigma} \qquad x_\Sigma = \frac{Q^2_\Sigma}{s y_\Sigma}$$



- Hadronic final state in COMPTON 2.14:
  DIFFVM, EPSOFT, SOPHIA

Measurement Challenges





- Losses in beam pipe
- Noise – due to small $E - P_z$

Summary

- Domain of low hadronic masses at HERA mostly in exclusive processes
- Special models of hadronisation
  - DIFFVM
  - EPSOFT
  - SOPHIA
- Outlook: measure F_2 at low M_X / low Q^2 in transition region from DIS to γp