Simulation Models for Low Hadronic Masses at HERA

Outline

- Introduction
- SOPHIA Model
- SOPHIA Applications at HERA
- Diffraction: DIFFVM and EPSOFT

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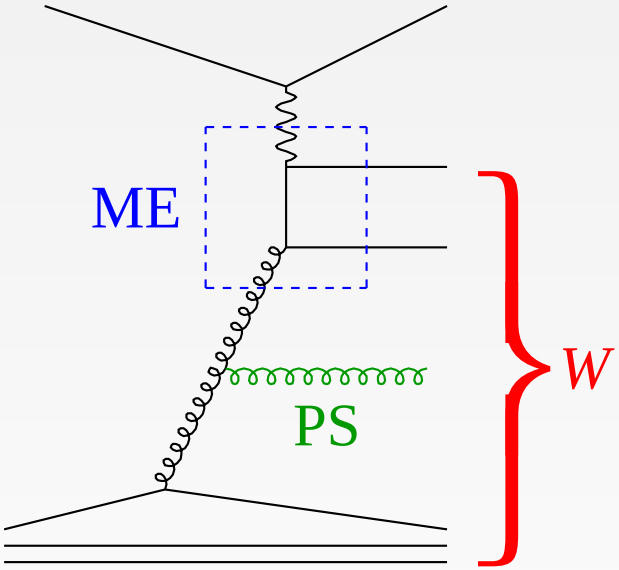
HERA–LHC Workshop
DESY, Hamburg, 31.10.2007

Simulation of Hadron Scattering



Standard way of simulation

- Matrix elements for hard scattering
- Parton showers (Pythia/Lepto, Herwig, CDM/Ariadne)
- Fragmentation (Pythia/Jetset, Herwig)

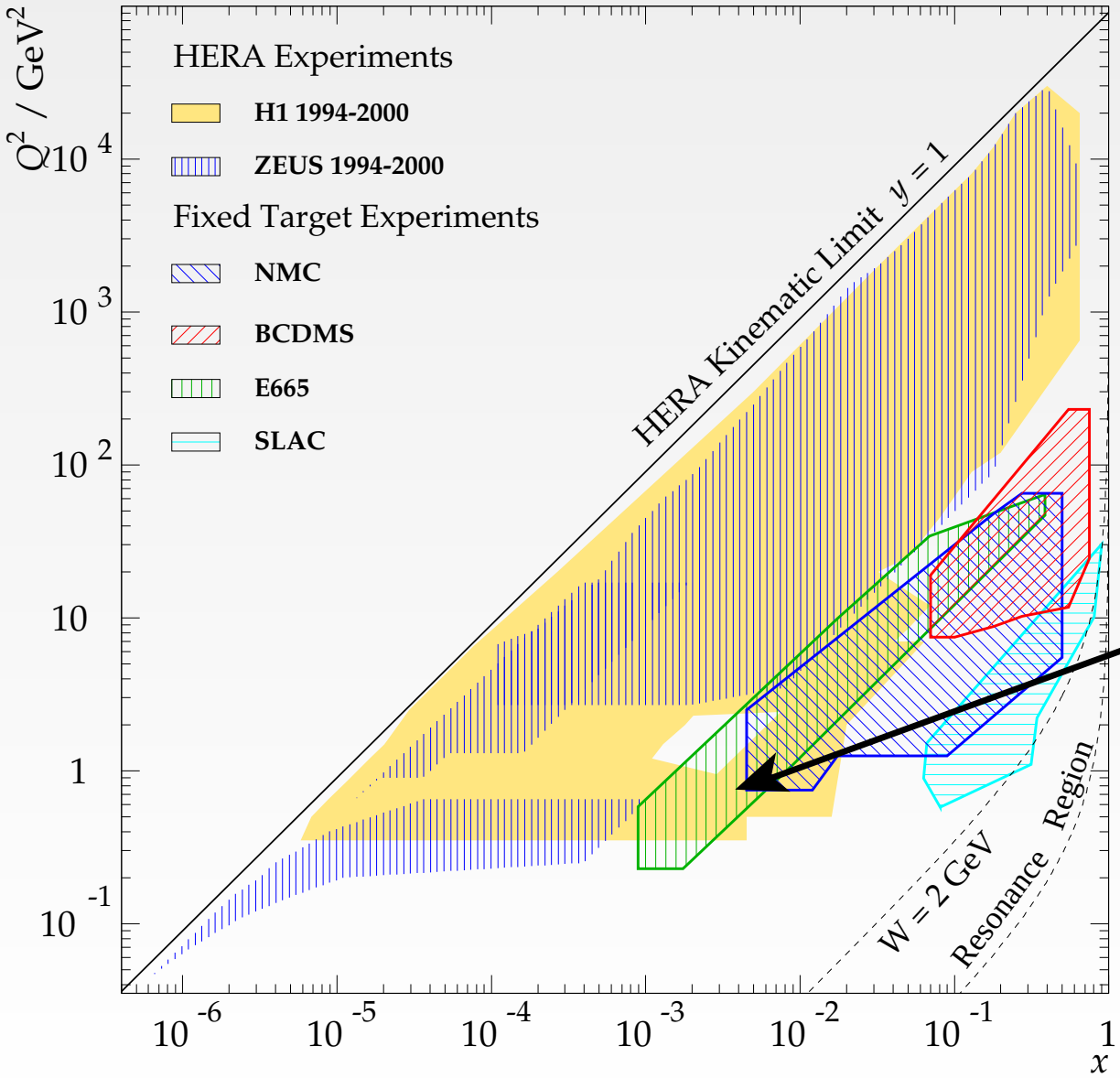
Problems at low W

- Does not work in resonance region $W \lesssim 2\,\mathrm{GeV}$
- Also problems at small $W > 2\,\mathrm{GeV}$

Low hadronic masses appear in

- Some (semi-)inclusive measurements
- Diffractive measurements

HERA Kinematic Domain



Low W = low y = high x

Relevant for low Q^2 processes

SOPHIA Model

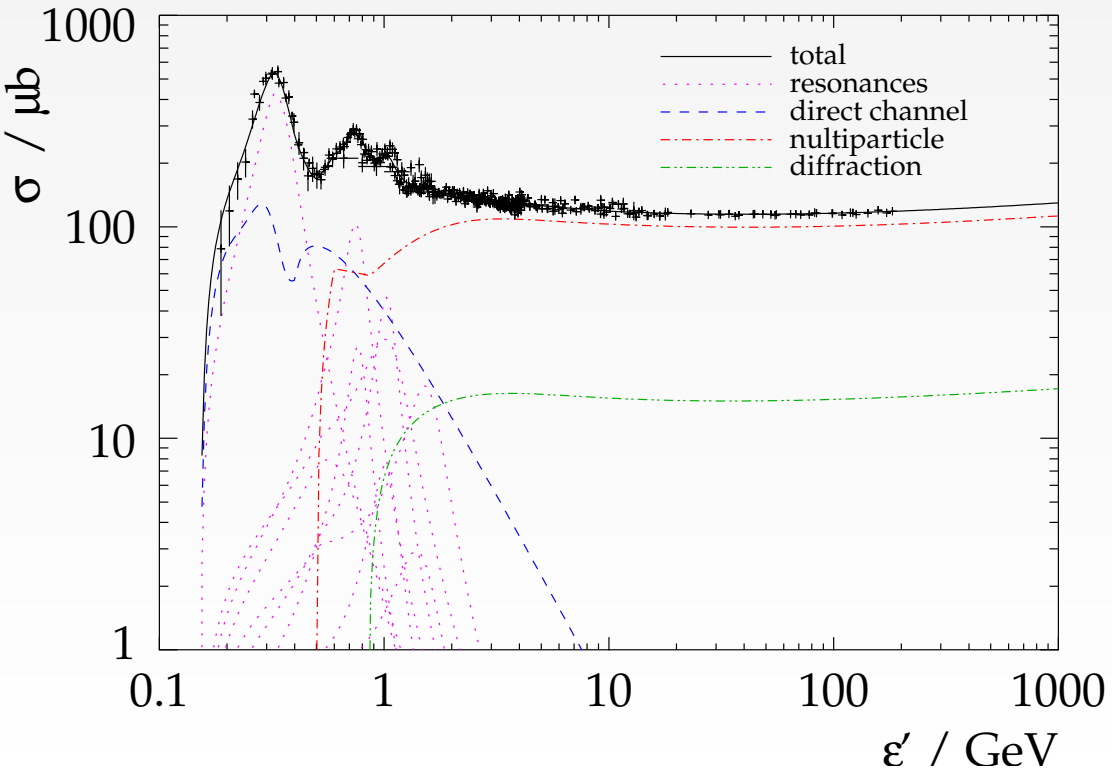
Simulations Of Poto Hadronic process In Astrophysics

A. Mücke, R. Engel, J. P. Rachen, R. J. Protheroe, T. Stanev: astro-ph/9903478, 9905153

"Photomeson production is the main energy loss for relativistic nucleons in dense radiation fields like the cosmic microwave background and the radiation fields in Gamma Ray Bursts (GRB) and jets of Active Galactic Nuclei (AGN). ..."

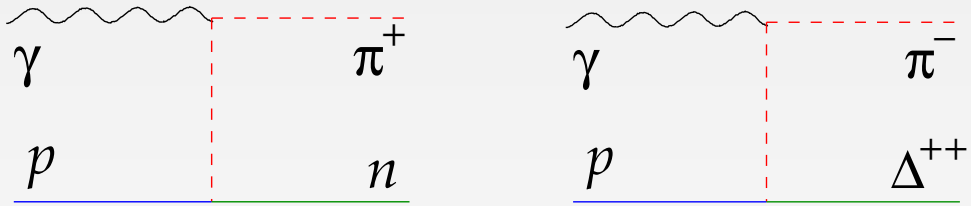
based on large set
of experimental x-section data:

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



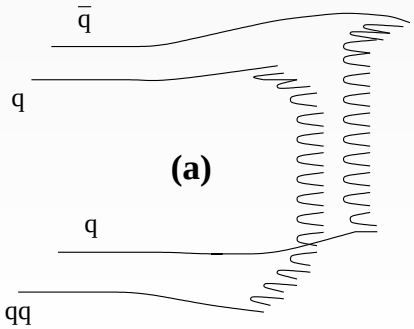
SOPHIA Model Details

- All significant Δ and N^* resonances
- Direct pion production

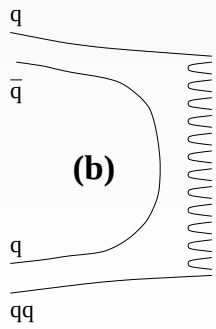


- Diffractive VM ρ, ω: $\sigma_{\text{diff}} = 0.15\sigma_{\text{non-diff}}$, $\sigma_\rho = 9\sigma_\omega$
- Multiparticle production – Dual Parton Model
  - Split $p \to q + qq, \gamma \to q + \bar{q}$
  - Exchange colors
  - Form color strings
  - Run Pythia/Jetset

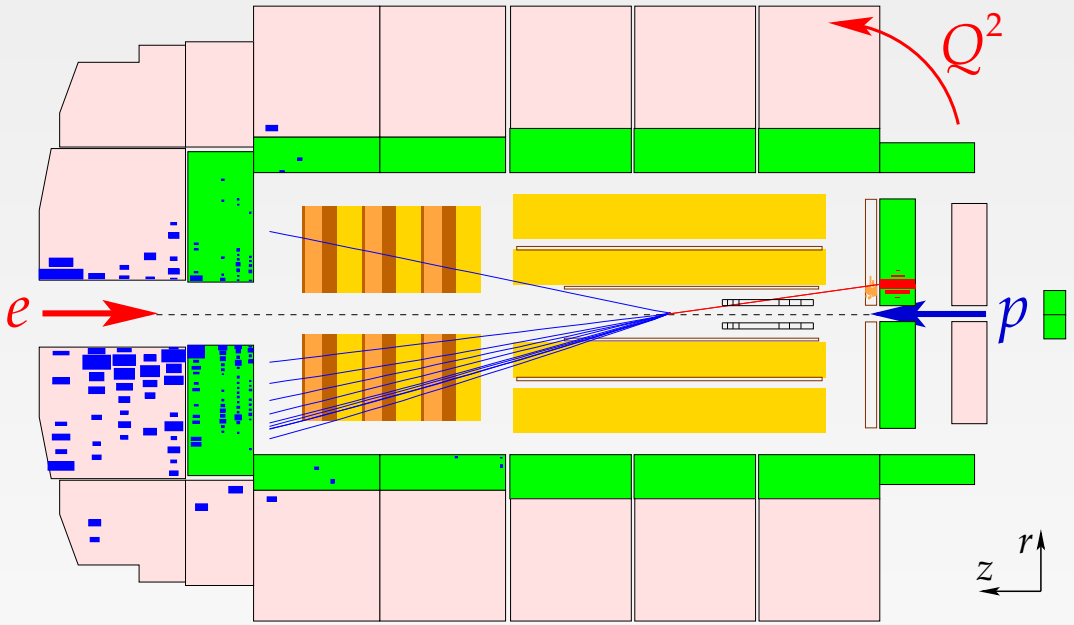
Pomeron



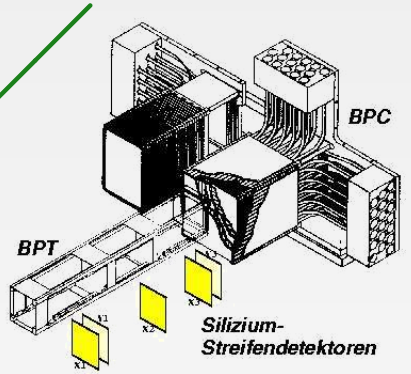
Reggeon

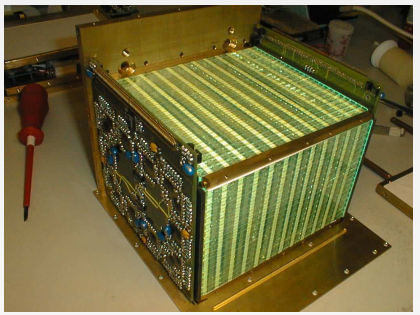


Experimental Techniques at Low Q^2

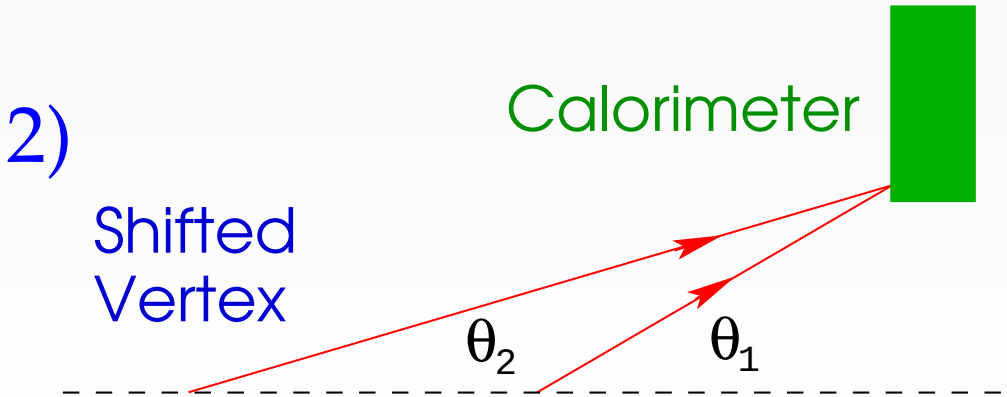


1) Very low Q^2 devices

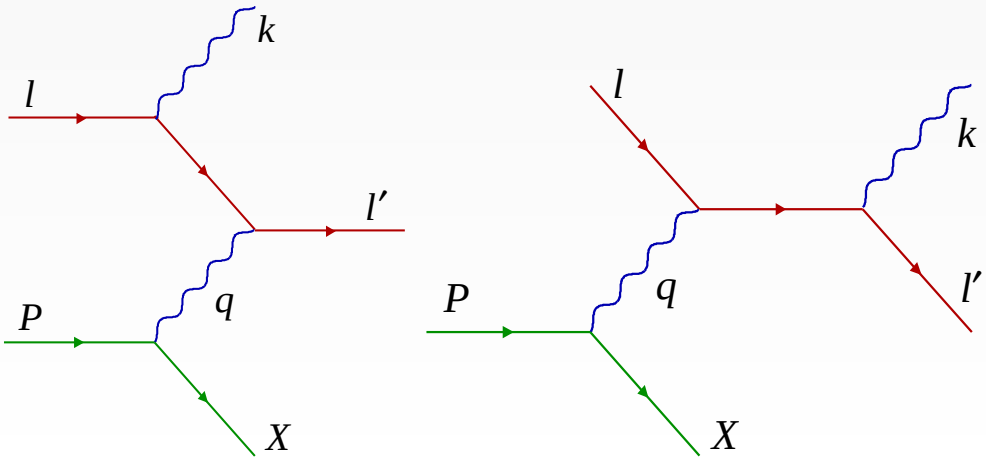




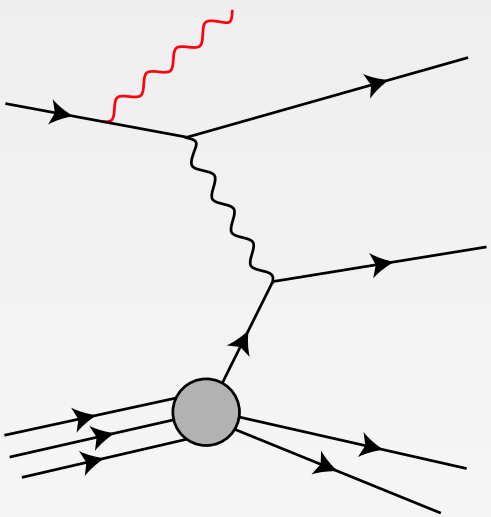
2)



3) Radiative events



F_2 in Shifted Vertex ISR

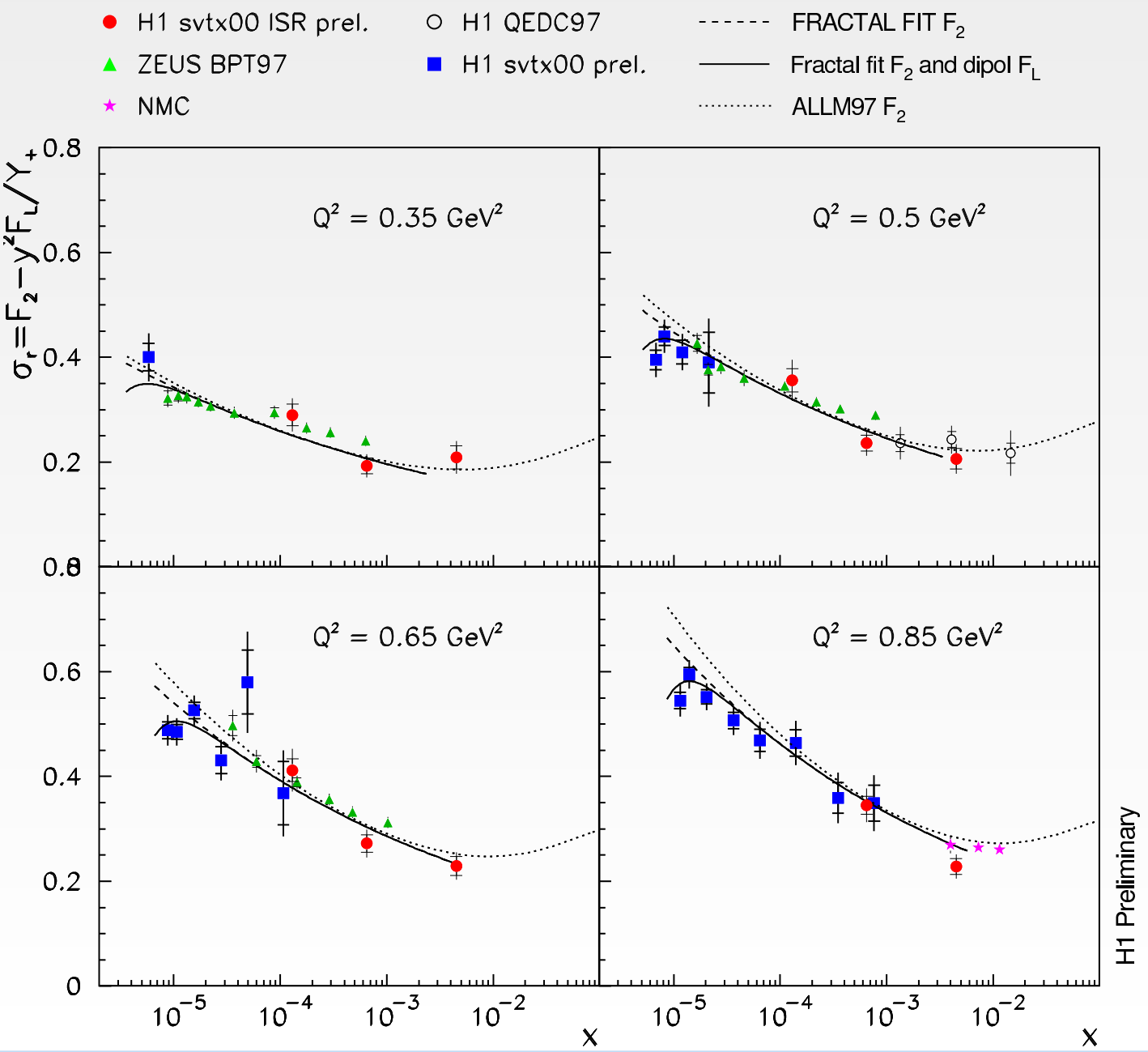


Equivalent to inclusive DIS at reduced s

$$Q^2 = xys$$

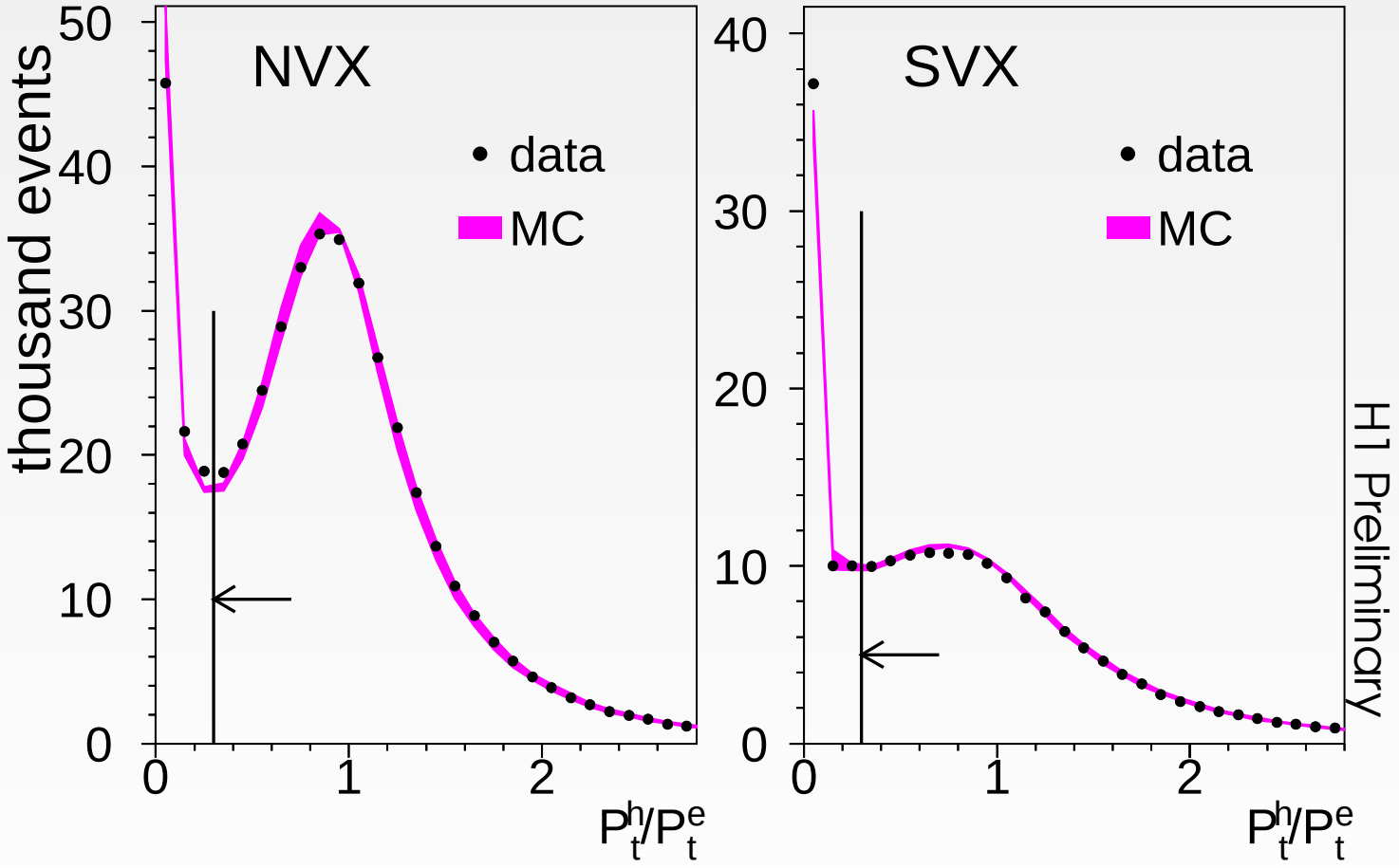
Access higher x = lower W

$$W^2 = ys - Q^2 + m_p^2$$



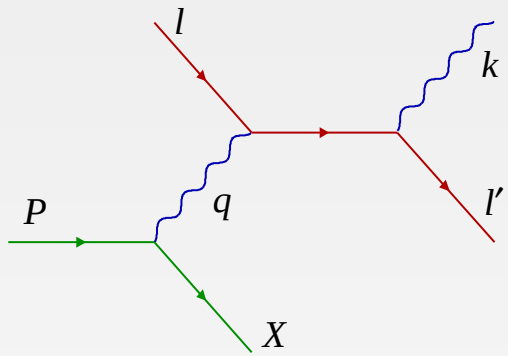
Hadronic Final State at Low Q^2

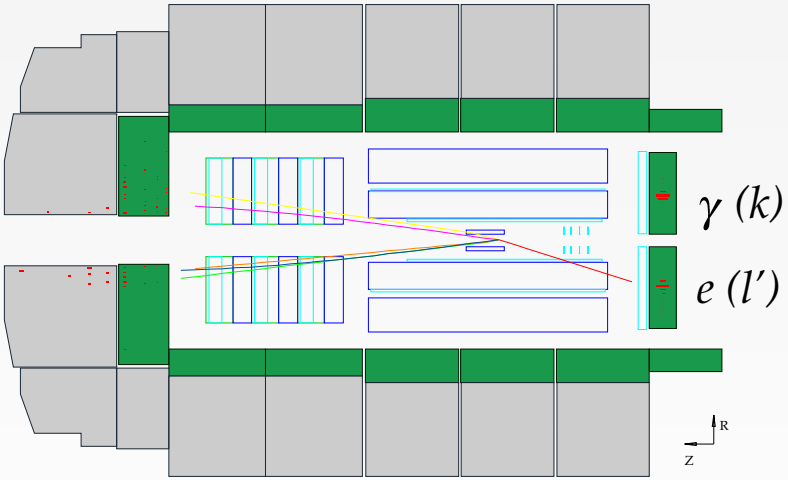
Using DJANGOH 1.4 with ARIADNE for $W > 5\,\text{GeV}$ and with SOPHIA for $W < 5\,\text{GeV}$

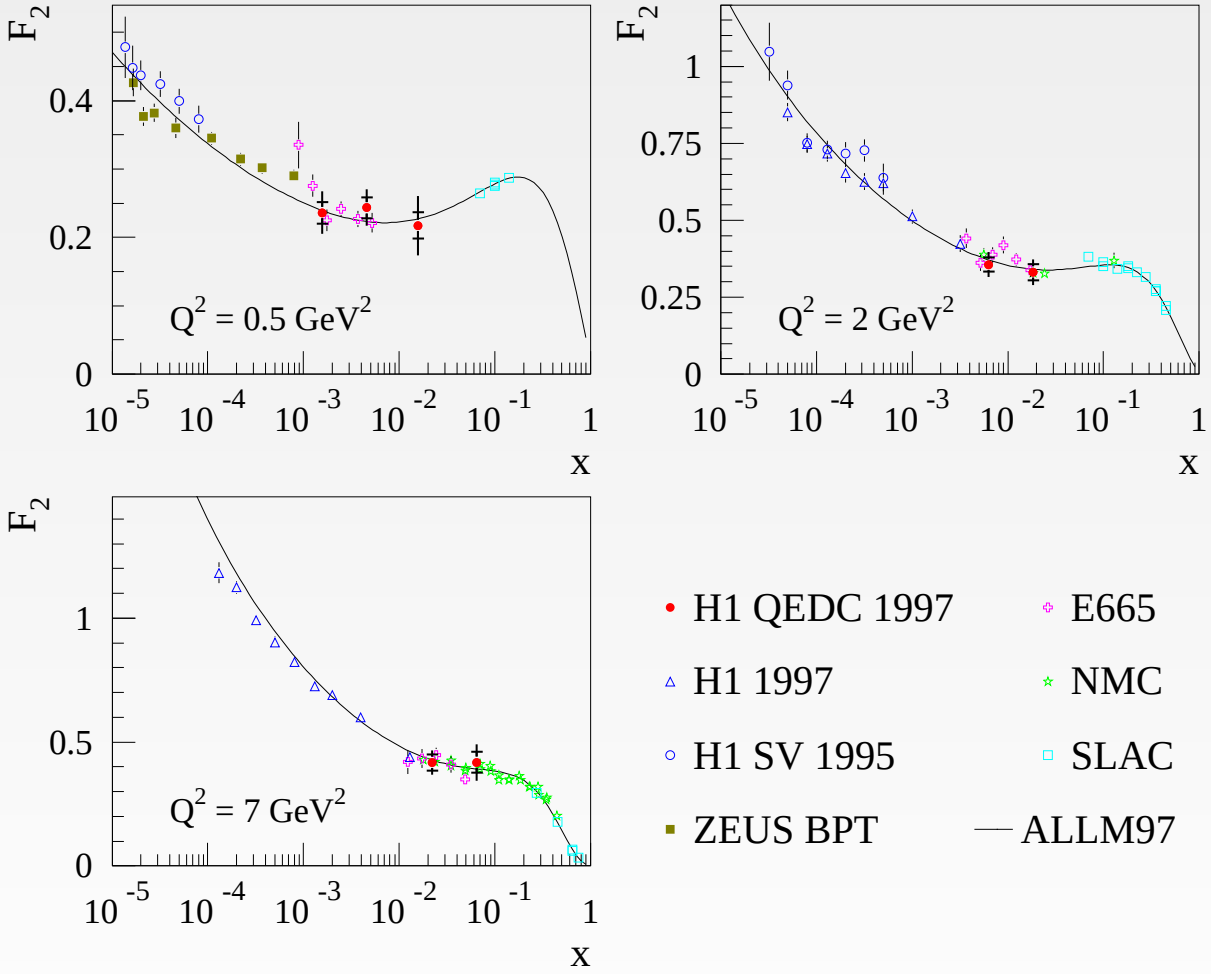


Good description of p_t balance down to 0 for both samples

F_2 in QED Compton Events



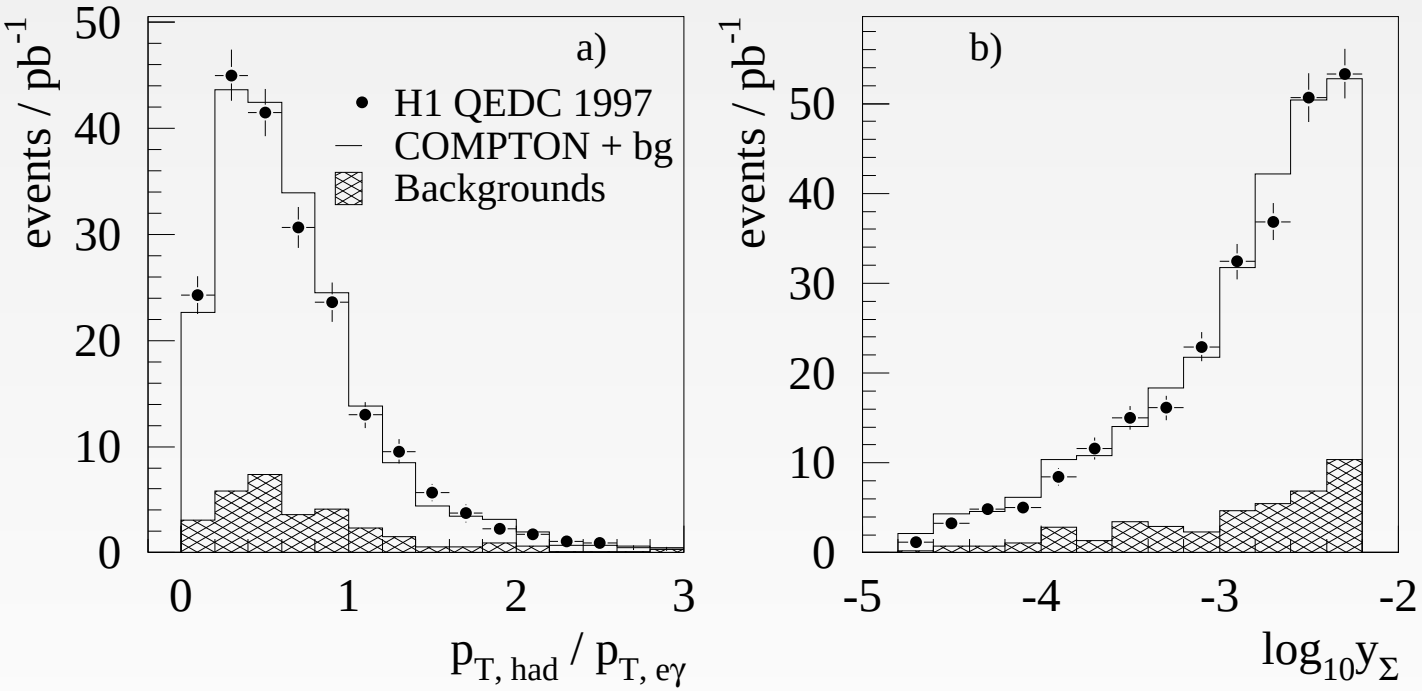




Restricted to relatively low y due to DIS background (π^0 fakes γ)

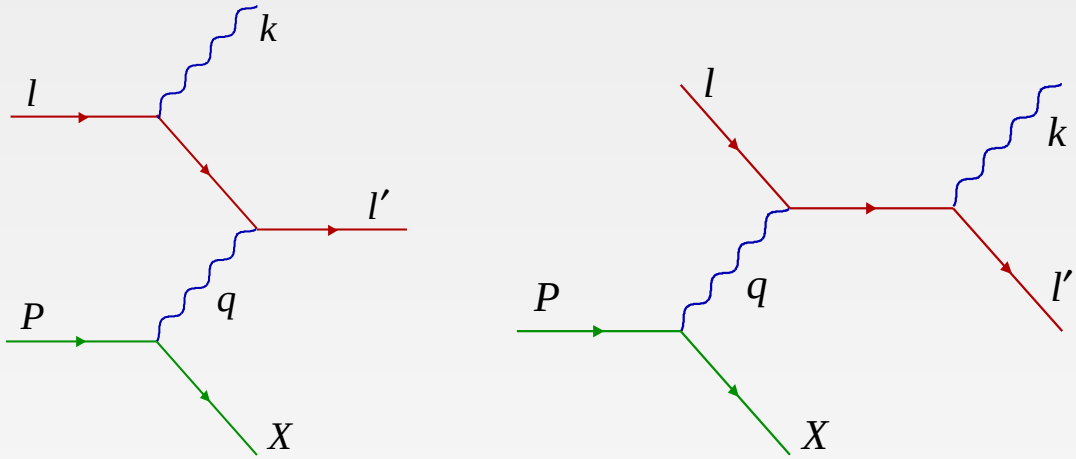
Hadronic Final State in QEDC

Using COMPTON generator interfaced to SOPHIA



Hadronic final state is well described by SOPHIA

Luminosity Cross Checks Using Elastic QEDC

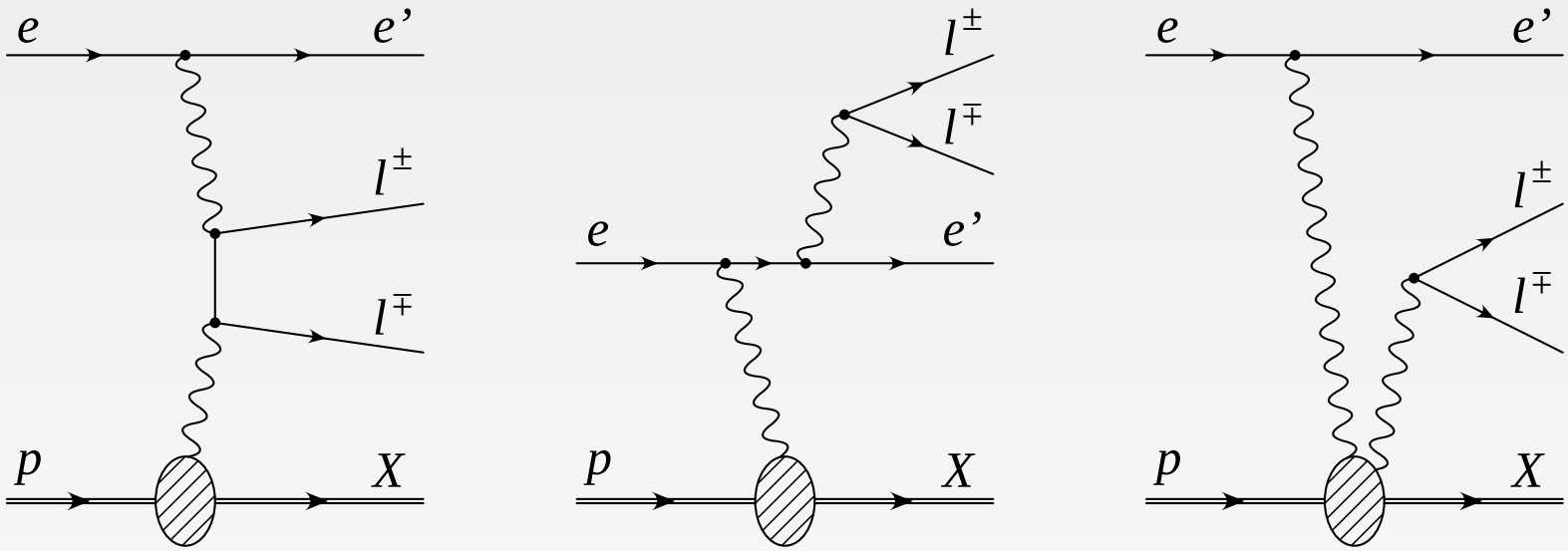


- Elastic QED Compton ≡ Bethe–Heitler process (same as for lumi system)
- Precision of a few % can be reached

- Typically require no hadronic activity in the detector
- Need exact determination of inelastic QEDC admixture

  $\Longrightarrow$ Simulation at low W is important

Dilepton Production



Background for

- J/ψ production
- Searches for new physics

Using GRAPE

- Automatic calculation of amplitudes by GRACE
- Integration/Generation by BASES/SPRING
- Interface to SOPHIA

DIFFVM Model

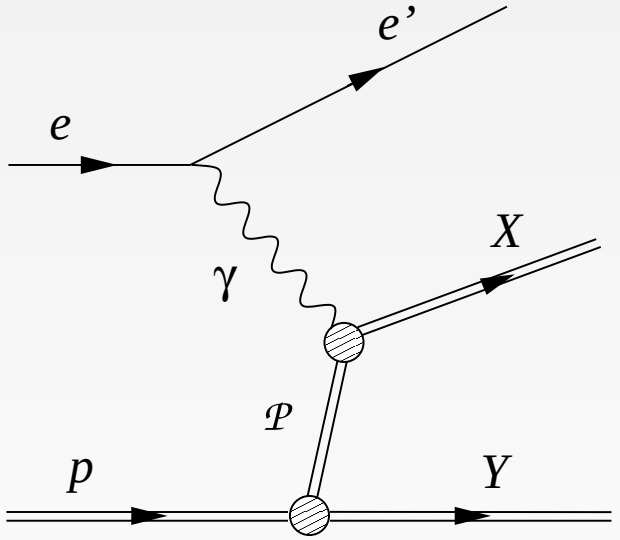
B. List, A. Mastroberardino, Proc. Workshop "MC for HERA", DESY-PROC-1999-02

Low hadronic masses appear in diffraction

- photon dissociation – low M_X
- proton dissociation – low M_Y

DIFFVM model

- N^* Resonances for $M_Y - m_p \lesssim 1\,\mathrm{GeV}$
- Continuum region
  - Split $X \to q + \bar{q}$, $Y \to q + qq$
  - Define string
  - Run Jetset/Pythia



Used in H1 and in some ZEUS analyses

EPSOFT Model

UA5 minimum bias MC $\Longrightarrow$ HERWIG soft underlying event generator $\Longrightarrow$ ZEUS EPSOFT

M. Kasprzak, M. Inuzuka, L. Adamszyk

- Average charged pair multiplicity $N_c(M_r)$ $\quad [M_r = M_Y - m_p]$

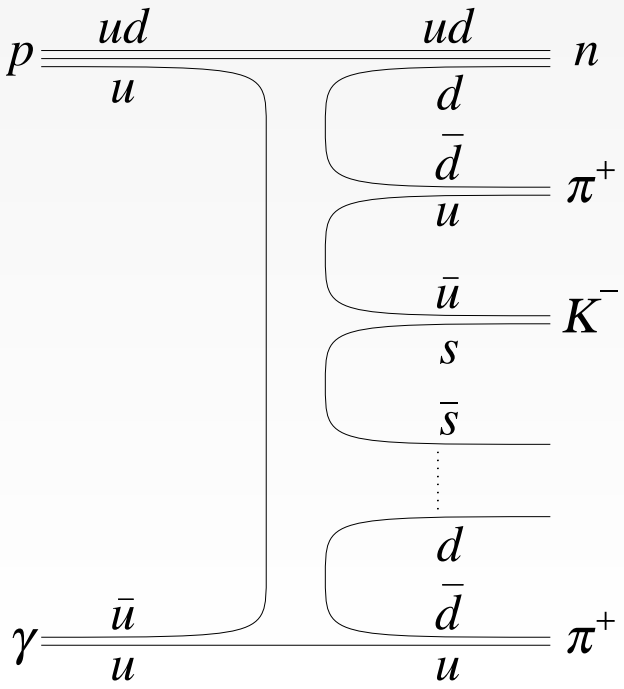
$$N_c = a \ln^2 M_r + b \ln M_r + c$$

  Using ISR and SPS data

- Spread using Gaussian for low M_r, NBD for higher M_r
- Valence quark flow using flavours u, d, s
- Transverse momenta

$$\frac{dP}{dp_T^2} \propto \exp\left(-\kappa\sqrt{p_T^2 + m^2}\right)$$

- Longitudinal momenta
  flat rapidity distribution with Gaussian shoulders



Summary

- Dedicated hadronisation models are used for low hadronic masses at HERA.
- Low W appear in some (semi-)inclusive low Q^2 processes:
  ISR, QED Compton, Dilepton production.
- SOPHIA works well at low W.
  Implemented in DJANGOH, RAPGAP, COMPTON, GRAPE.
- Low M_X, M_Y appear in diffractive processes (VM, F_2^{D3}, DVCS).
- For diffractive dissociation DIFFVM and EPSOFT models are used.
  DIFFVM model is also implemented in RAPGAP and MILOU (DVCS).