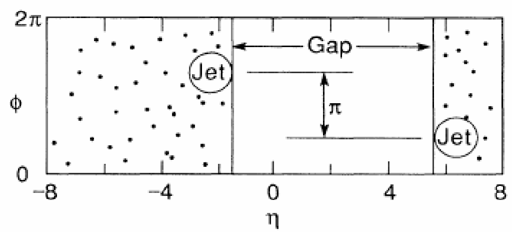
WG4: Experimental summary

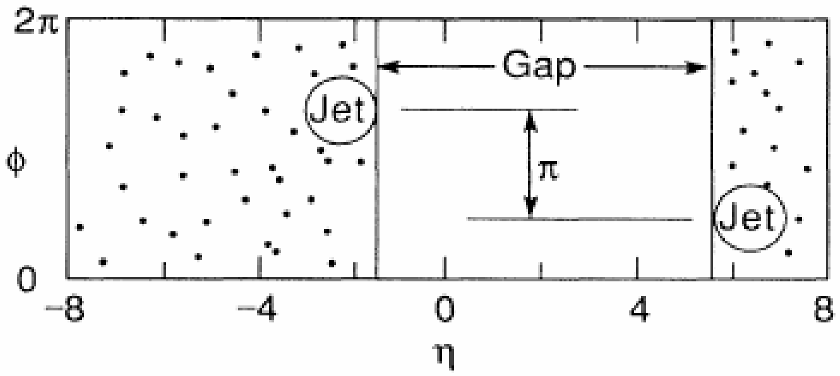
K. Piotrzkowski

UCLouvain

Physics with rapidity gaps



When it all has begun…



Rapidity gaps and jets as a new-physics signature in very-high-energy hadron-hadron collisions

Proposed by Dokshitzer,Khoze&Troyan (1986)

J. D. Bjorken

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309

Volume 256, number 3,4 PHYSICS LETTERS B 14 March 1991

Higgs production in pp collisions by double-pomeron exchange

A. Bialas
Institute of Physics, Jagellonian University, PL-30059 Cracow, Poland

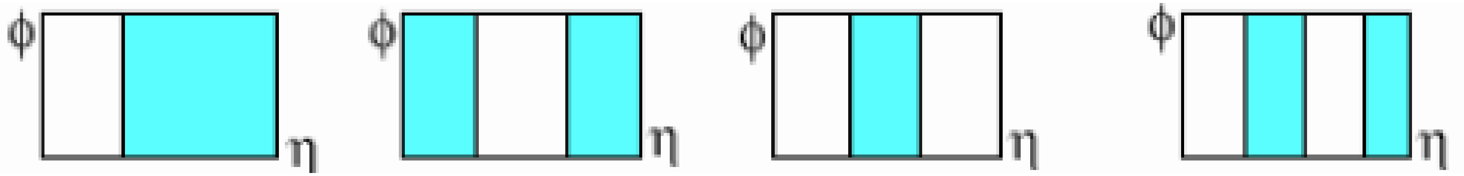
and

P.V. Landshoff
DAMTP, University of Cambridge, Cambridge CB3 9EW, UK

Physics Letters B 315 (1993) 481–493
North-Holland

Observation of events with a large rapidity gap in deep inelastic scattering at HERA

Why rapidity gaps?



- Large rapidity gaps are tell-tale signatures of color singlet exchanges (CSE) in hadronic interactions
  - CSE could be strongly or electro-weakly interacting objects as two-gluon exchange, or W and γ exchanges, respectively.

- Selecting these events leads usually to specific selection/filtering of the final states; kinematics of such events is better constrained/reconstructed.

- Physics of the strongly interacting CSE is interesting by its own.

Experimental contributions

H1: V. Andreev, A. Bunyatyan, X. Janssen, M. Kapishin, P. Laycock, P. van Mechelen, P. Newman, S. Schaetzel, F.-P. Schilling, K. Vervink

ZEUS: L. Adamczyk, M. Arneodo, A. Bruni, P. Groys, H. Kowalski, A. Mastroberardino, V. Monaco, A.Proskuryakov, R. Sacchi, K. Wichmann, G. Wolf, Y. Yamazaki

CMS: R. Bellan, A. De Roeck, M. Grothe, M. Murray, A. Panagiotou, K. Piotrzkowski, A. Sobol, M. Tasevsky

TOTEM: K. Eggert, F. Ferro, D. Macina, R. Orava, K. Osterberg, M. Ryynanen

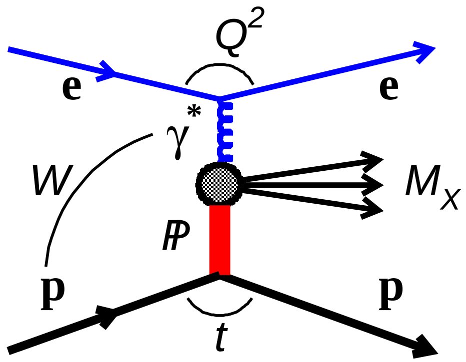
LHC: B. Cox, R. Croft, C. Hogg, J. Monk

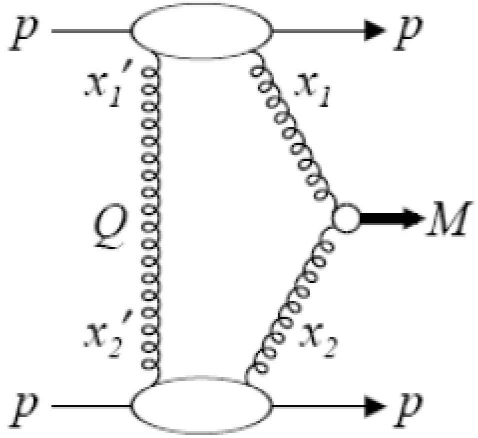
ATLAS: M. Boonekamp, I. Efthymiopoulos, P. Grafstrom

CDF: D. Goulianos, **D0**: C. Avila

Lot of activity – participation from the LHC side increasing in time – Looking forward to continuing very fruitful HERA-LHC exchange!

Part I: Strong case

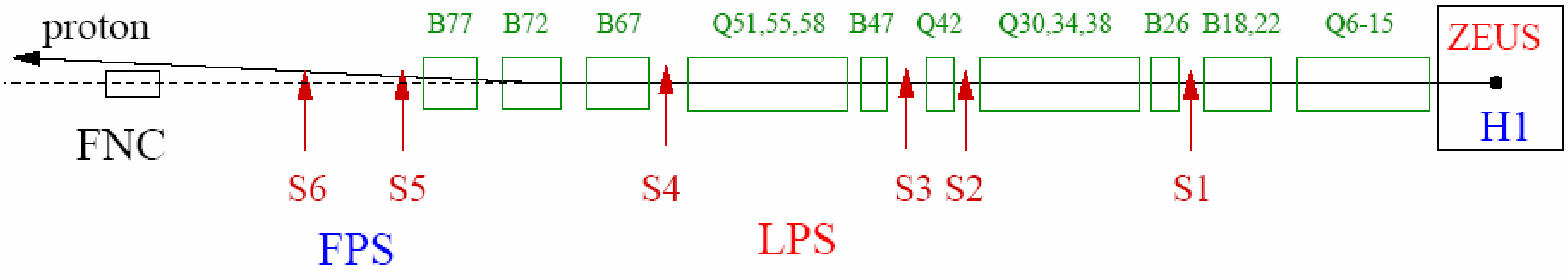




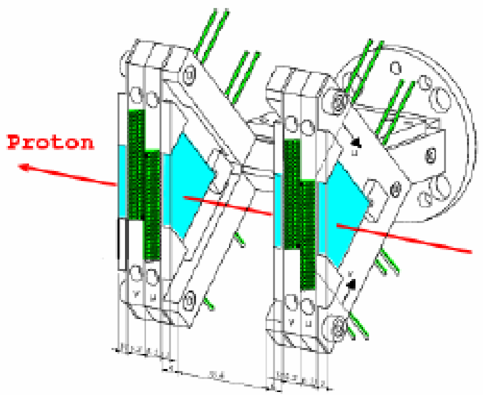
- Diffractive structure functions F_2^D
- QCD analysis to F_2^D; pdfs for CSE
- Rapidity gaps in CC events at HERA
- Exclusive Higgs production & detection at the LHC
- Experimental aspects: measuring forward protons with Roman Pot detectors and RapGap signatures

Experimental Techniques

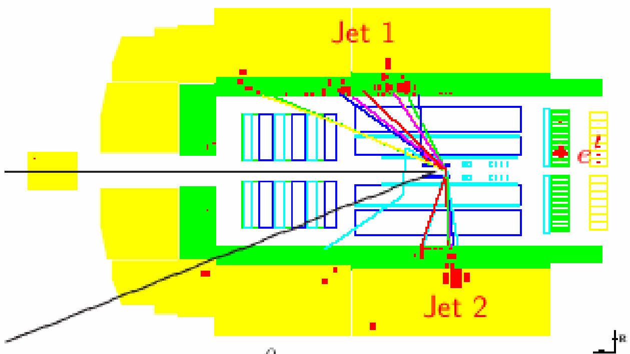
From F.P. Schilling



Forward Proton Spectrometers at $z = 24 \ldots 90$ m



Rapidity Gap Selection in central detector



$\eta_{max} = -\ln \tan \frac{\theta}{2}$

Measure leading proton

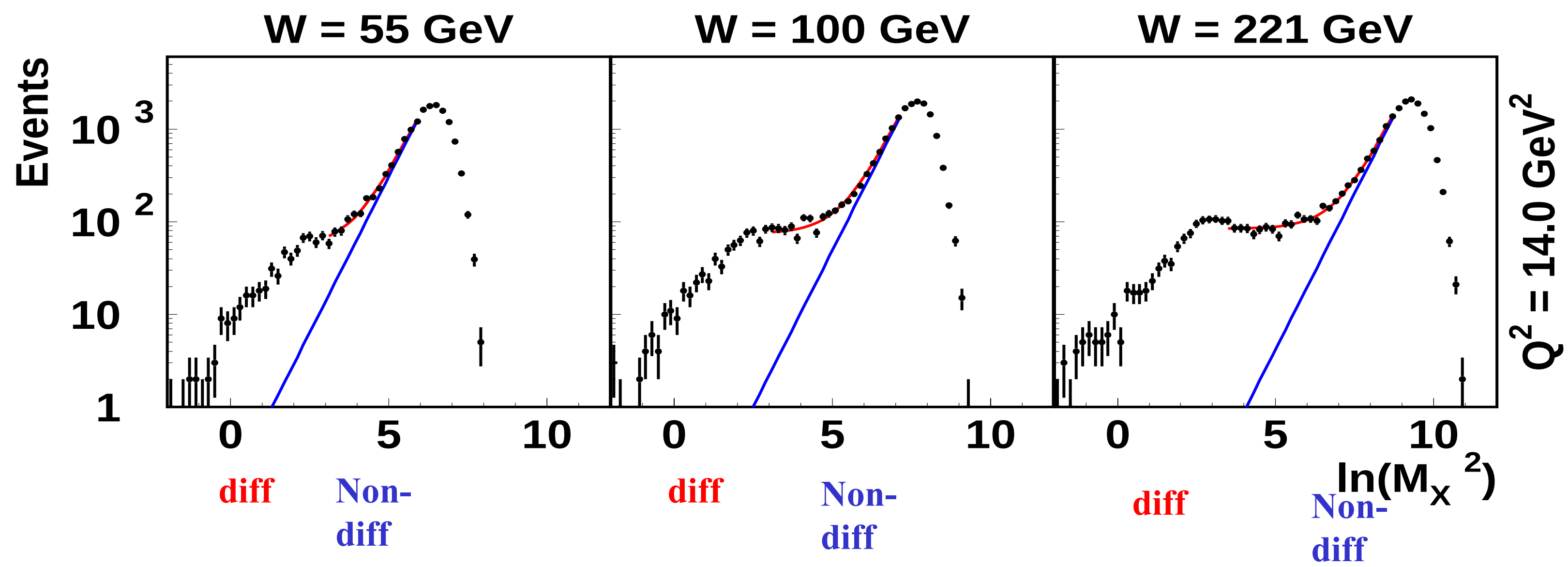
- Free of dissociation bkgd.
- Measure p 4-momentum
- low statistics (acceptance)

Require large rapidity gap

- $\Delta\eta$ large when $M_{\text{central}} \ll W_{\gamma p}$
- integrate over outgoing p system
- high statistics (similar: M_X method)

M_X Method

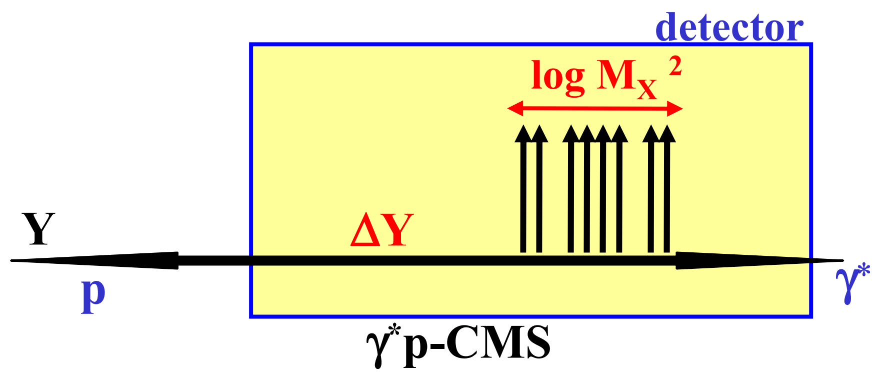
*



Non-Diffraction

$dN/dM^2_X \sim \exp(\lambda \log(M^2_X))$

Gap suppression coefficient λ independent of Q^2 and W^2 for $Q^2 > 4$ GeV^2



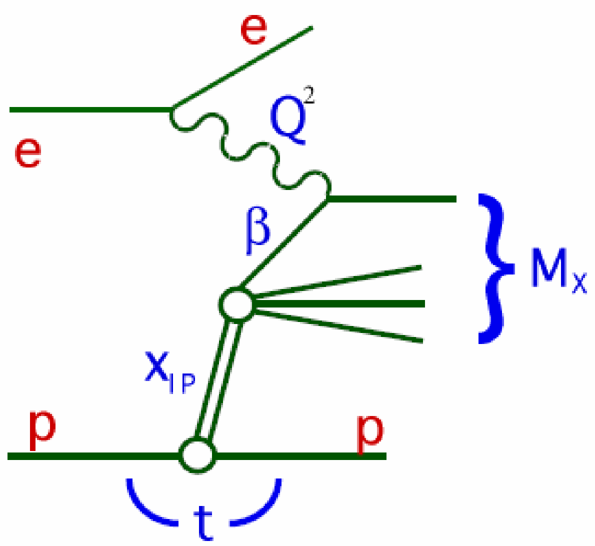
Diffraction

$dN/d\log M^2_X \sim \text{const}$

From H. Kowalski

F_2^D at HERA

From F.P. Schilling



$x_{I\!P} = \xi = \frac{Q^2+M_X^2}{Q^2+W^2} = x_{I\!P/p}$
(momentum fraction of colour singlet exchange)

$\beta = \frac{Q^2}{Q^2+M_X^2} = x_{q/I\!P}$
(fraction of exchange momentum of q coupling to γ^*, $x = x_{I\!P}\beta$)

$t = (p - p')^2$
(4-momentum transfer squared)

Diffractive reduced cross section σ_r^D:

$$\frac{d^4\sigma}{dx_{I\!P}\; dt\; d\beta\; dQ^2} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_r^{D(4)}(x_{I\!P}, t, \beta, Q^2)$$

Structure functions F_2^D and F_L^D:

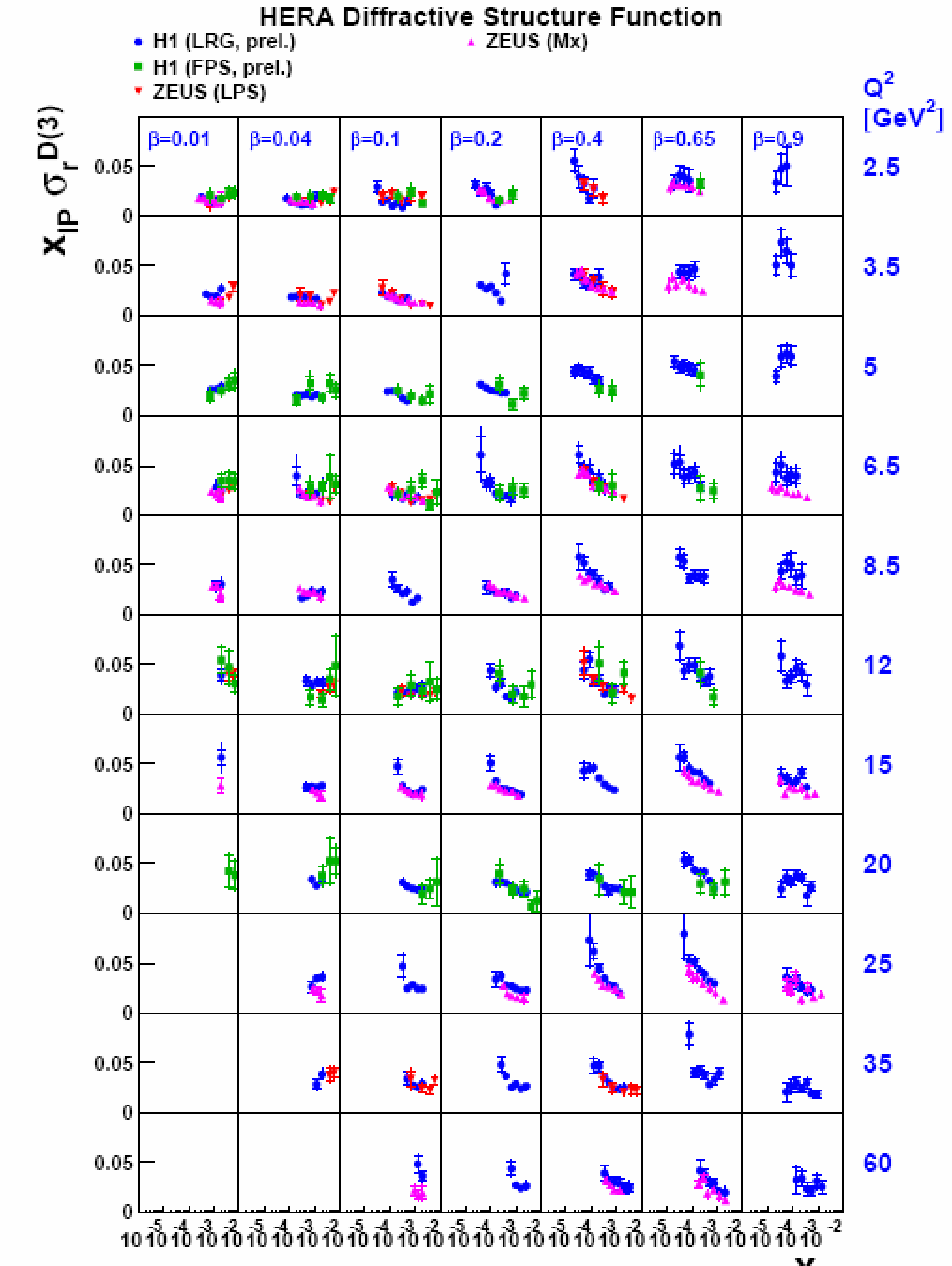
$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{2(1-y+y^2/2)} F_L^{D(4)}$$

Integrated over t: $F_2^{D(3)} = \int dt\; F_2^{D(4)}$

– Longitudinal F_L^D: affects σ_r^D at high y
– If $F_L^D = 0$: $\sigma_r^D = F_2^D$

[γ inelasticity $y = Q^2/sx$]

Grand F_2^D summary



From P. Newman

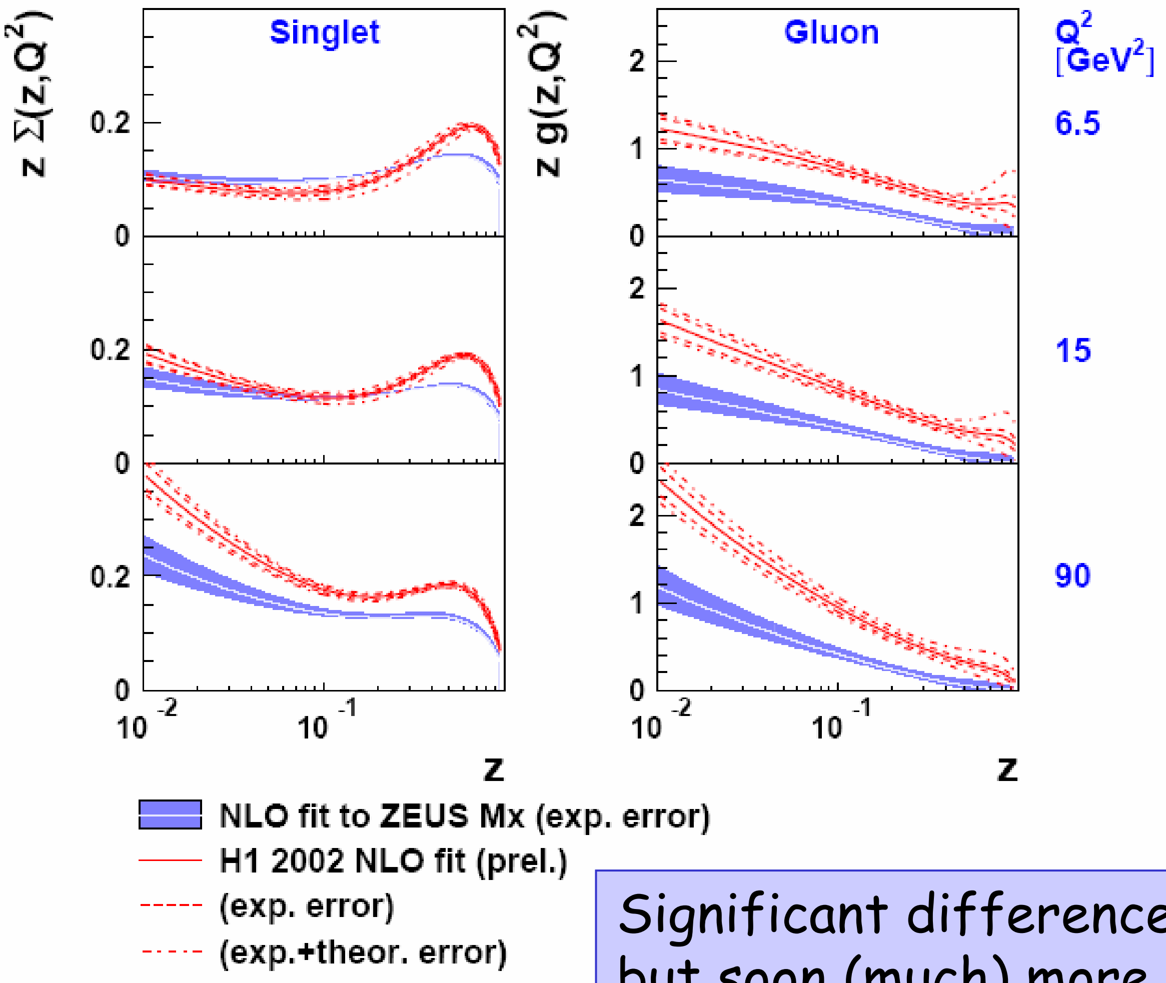
F_2^D is crucial for understanding CSE in hadronic interactions:

At this workshop 1st step was made towards final, combined F_2^D from HERA!

Present status: In unified analysis of measured cross-sections reasonable global agreement between H1 & ZEUS is found, and regions of significant discrepancies identified.

QCD analysis

NLO QCD fits to H1 and ZEUS data



QCD Fit Technique:

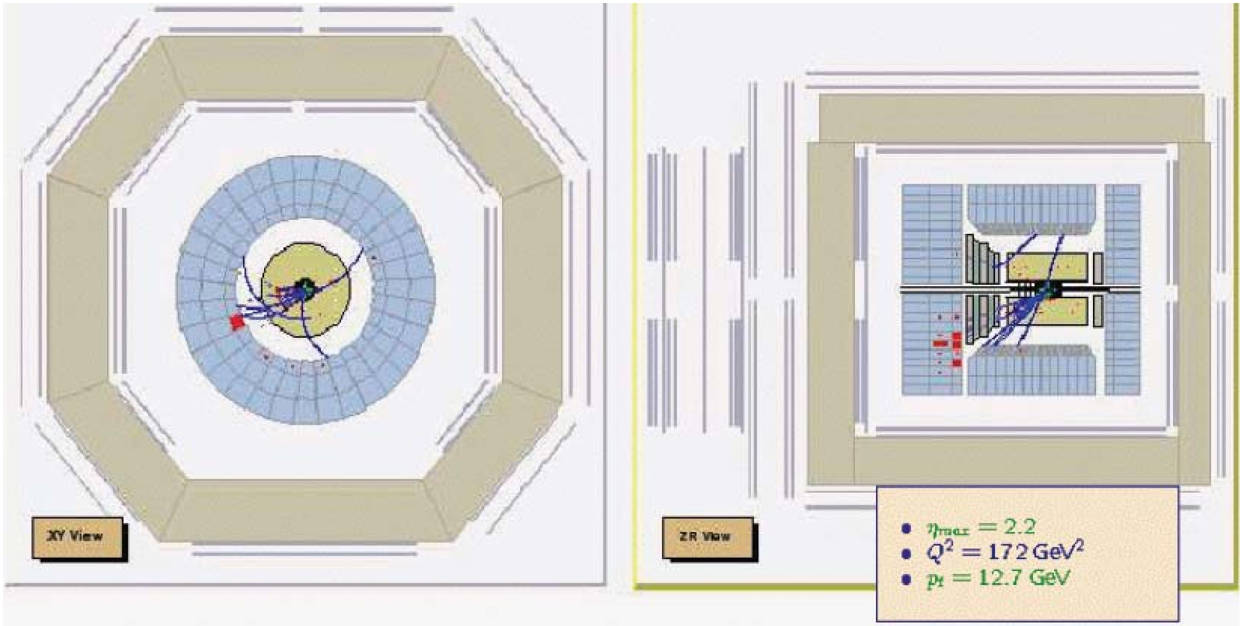
- factorize $f(x_{I\!P})f(z,Q^2)$
- Singlet Σ and gluon g parameterized at $Q_0^2 = 3\ \text{GeV}^2$
- NLO DGLAP evolution
- Fit data for $Q^2 > 6.5\ \text{GeV}^2$, $M_X > 2\ \text{GeV}$

- Singlet similar at low Q^2, evolving differenly to higher Q^2 due to coupling to gluon
- Gluon factor $\sim$ 2 smaller than H1 gluon

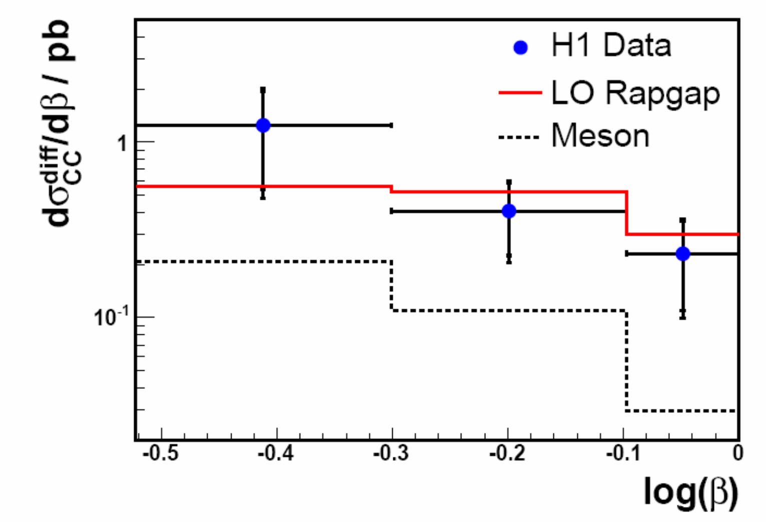
Significant differences observed for gluon pdfs, but soon (much) more data with RPs (little backgr.) and with charm (photon-gluon fusion) will help to sort it out

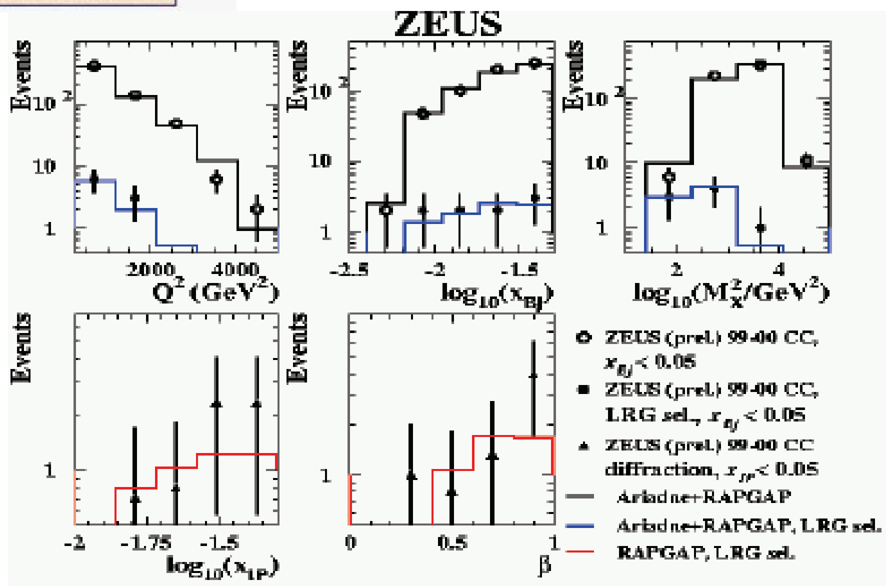
From P. Newman

Rap gaps in CC events



Important test of universality of F_2^D, for now statistically limited, but with full HERA II sample stringent tests will be possible.

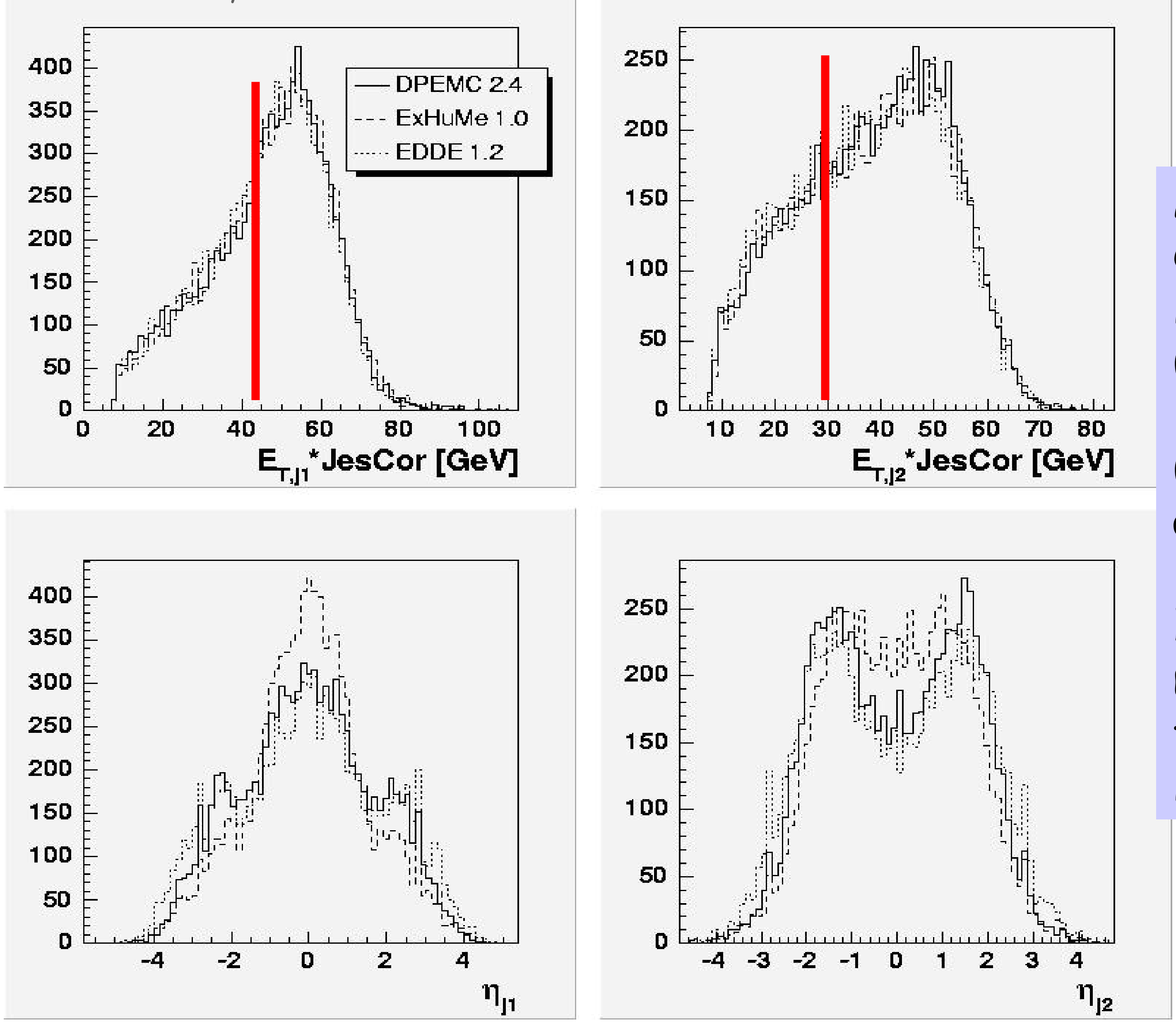




From P.Laycock&K.Wichmann

H->bb, M_H=120 GeV: Detector level b-jets

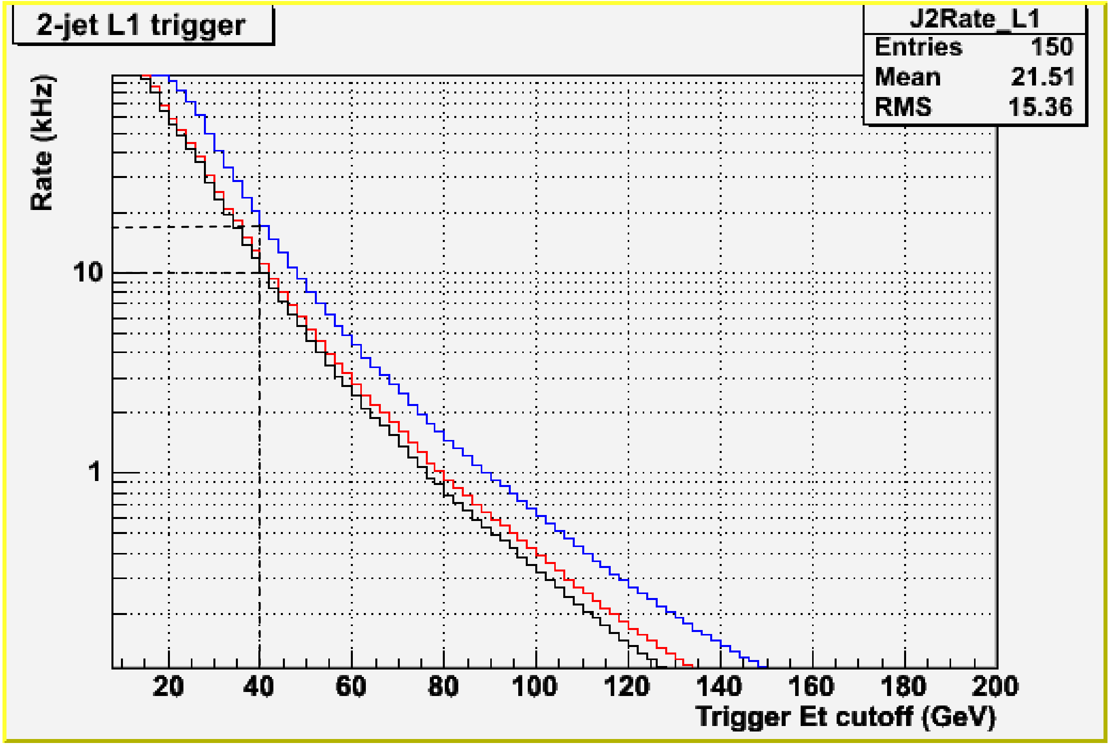
From M. Tasevsky



Modeling in Monte Carlo exclusive Higgs production (+backgrounds) and its detection (trigger!) is very active field, but it is just beginning … here examples of model comparisons for exclusive H -> $b\bar{b}$

L1 trigger challenge for exclusive Higgs

In absence of a RP trigger



L1 rate (integrated) in kHz as function of 2-jet E_T cutoff

$L = 10^{33}$ with full pile-up (including diff and elastics)

L1 jet calibration applied

Blue: no H_T cut
Sum(2-jet E_T)/H_T > 0.9 red
> 0.95 black

Plot Creighton Hogg

Possible L1 condition that comes closest to a rap gap trigger (rap gap > 2):
2 jets in central Cal ($|\eta|<3$)with Σ(E_T 2 jets) / H_T > threshold
H_T = sum of the scalar E_T of all jets in the event with E_T(jet)>threshold

Clearly need additional L1 condition for 2-jet E_T cutoff around 40GeV
Note: L1 jet E_T resolution ~30%, b pair from Higgs decay has E_T < 60GeV

From M. Grothe

HERA know-how transfer

The LPS Alignment

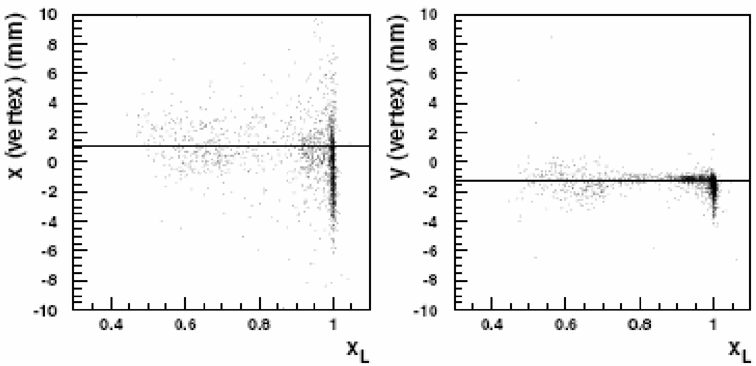
Difficult ! Key values for the reconstruction are:

- **magnetic field of 23 beam elements** (known with good accu
- **position of quadrupole axes**
- **position of detector strips** (parametrized as *strip equations*)
- **vertex position and beam tilt at the I.P.**
- **position of beam apertures**

Method: use tracks (x_L is a-priori unknown !!)

- align the detectors planes within each station
- align stations S5,S6 relative to S4 (use $x_L = 1$ kinematic peak)
  $\Rightarrow$ calculate proton momentum from 3-station tracks
- fit the LPS spectrometer position relative to ZEUS with

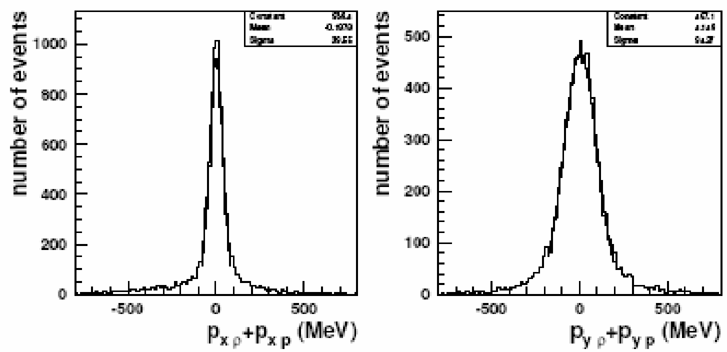
$$\chi^2 = \sum_{i=1}^{n} \left(\frac{(xv_{LPS} - xv_{CTD})}{\sigma_x} \right)^2 + \left(\frac{(yv_{LPS} - yv_{CTD})}{\sigma_y} \right)^2$$



CTD

The p_T Calibration

choose a set of elastic ρ° photoproduced ($\gamma p \rightarrow \rho^0 p$)
(line $x_L = 1$ spectrum; $\Delta(x_L) \simeq 10^{-4}$)
$\Rightarrow \theta_x = p_{x\rho^0} + p_{xp}$; $\theta_y = p_{y\rho^0} + p_{yp}$

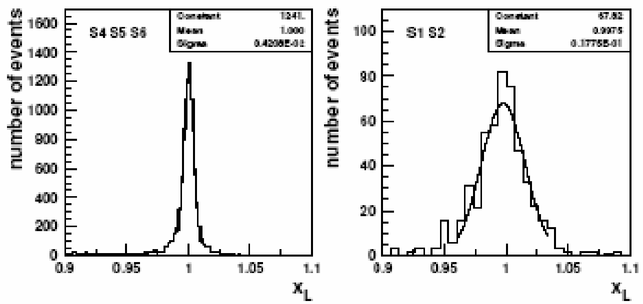


proton beam spread $\sigma_{p_x} \approx 40MeV$, $\sigma_{p_y} \approx 90MeV$

x_L resolution

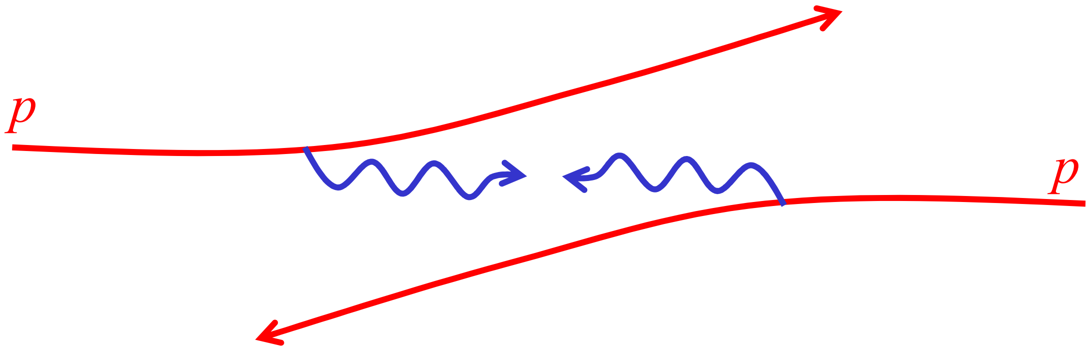
$\frac{\sigma_{x_L}}{x_L}$(s4→s6)~0.4%

$\frac{\sigma_{x_L}}{x_L}$(s1,s2)~2%

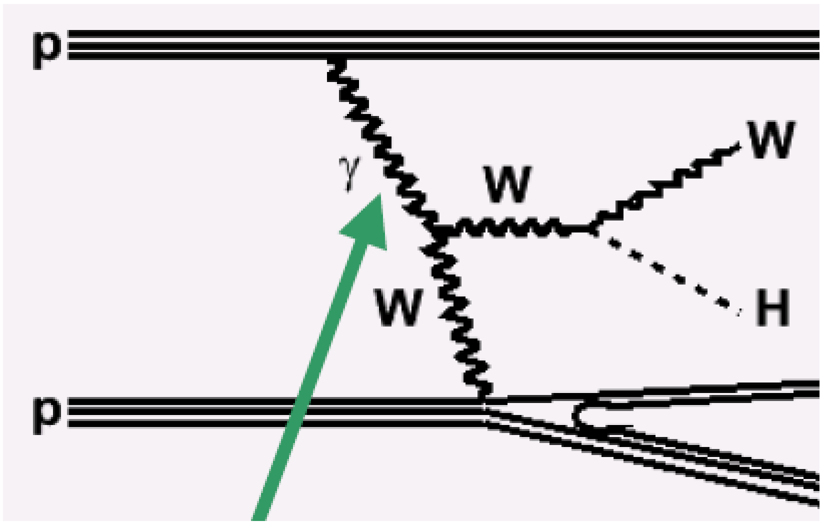


From R. Sacchi

Part II: Photon (& W) case



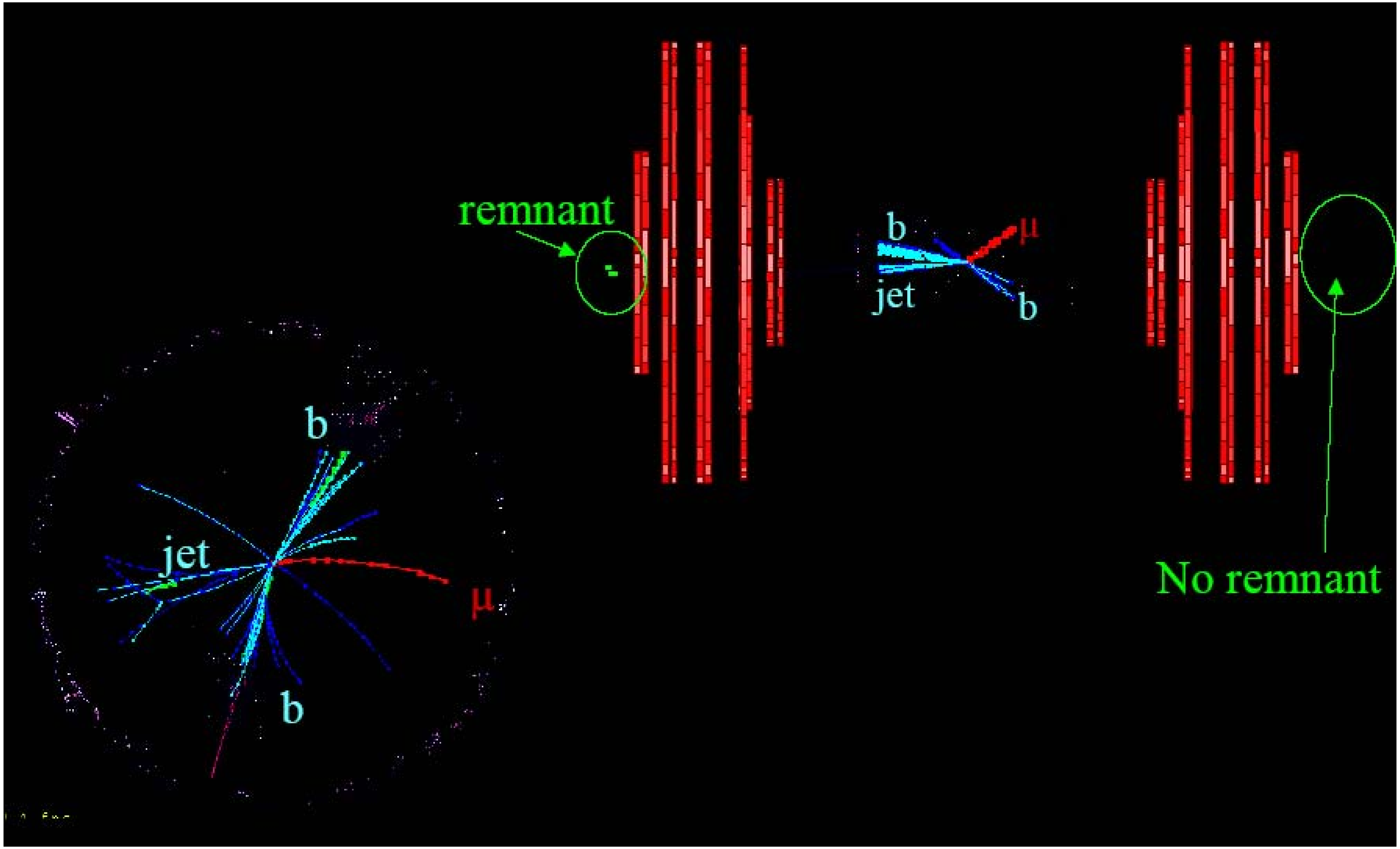
- Using LHC as a photon-photon collider
- Photon-proton collisions – super-HERA at CERN



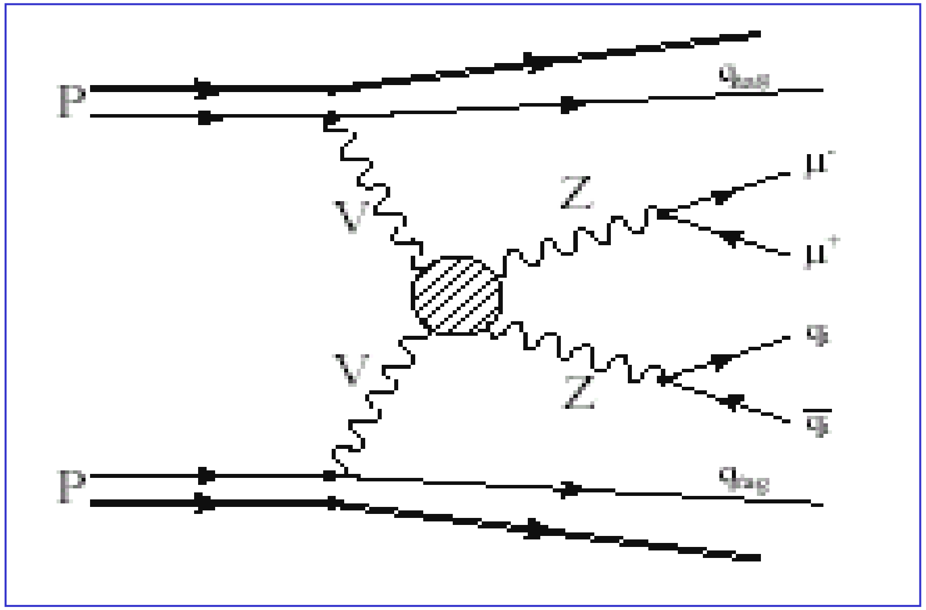
Higgs in photoproduction @ LHC!

From M. Vander Donckt

$\gamma q \rightarrow q'hW \rightarrow q'bbl\nu$ (iguana)

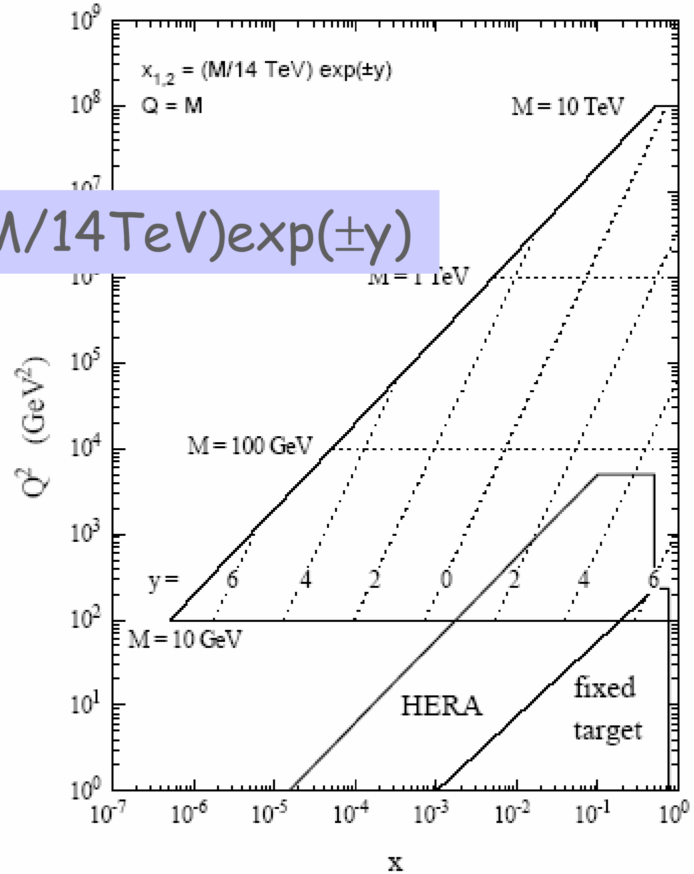


More of W exchange & very low-x @ LHC



- Low mass objects are produced at LHC in very wide x range
- First attempts towards detection of DY pairs (inclusive & diffractive) – could saturation effects be seen that way?

$x_{1,2}$=(M/14TeV)exp($\pm$y)



- WW fusion is hot topic at the LHC…
- Can HERA contribute here – in forward jet tagging aspects?

Coming soon from HERA II (selection)

HERA I: ZEUS Leading Proton Spectrometer and H1 FPS

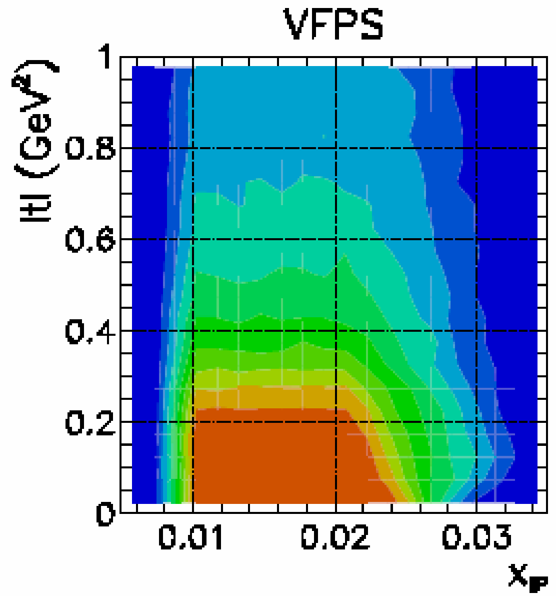
HERA II: H1 Forward and Very Forward Proton Spectrometer

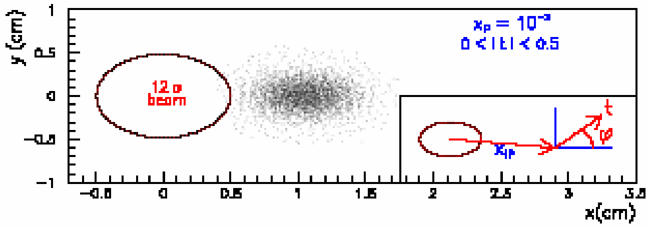
$\longrightarrow$ direct measurement of t

elastic protons without background of proton dissociation

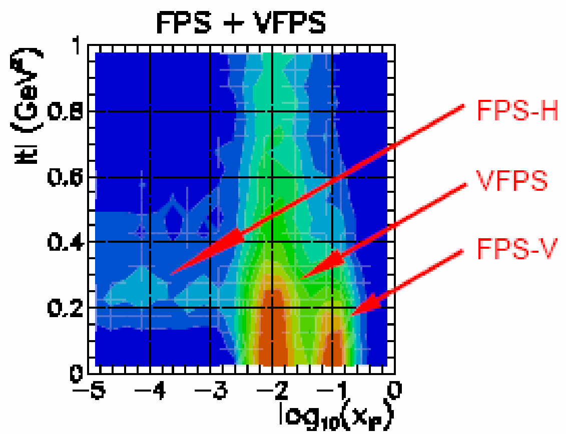
VFPS Acceptance

Acceptance defined by beam optics and envelope (12 σ detector approach limit)





Complementary to FPS (High $x_{I\!P}$)

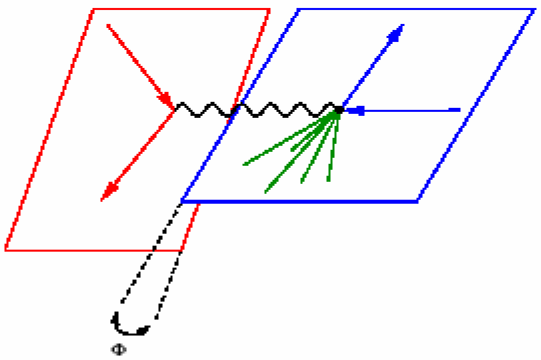


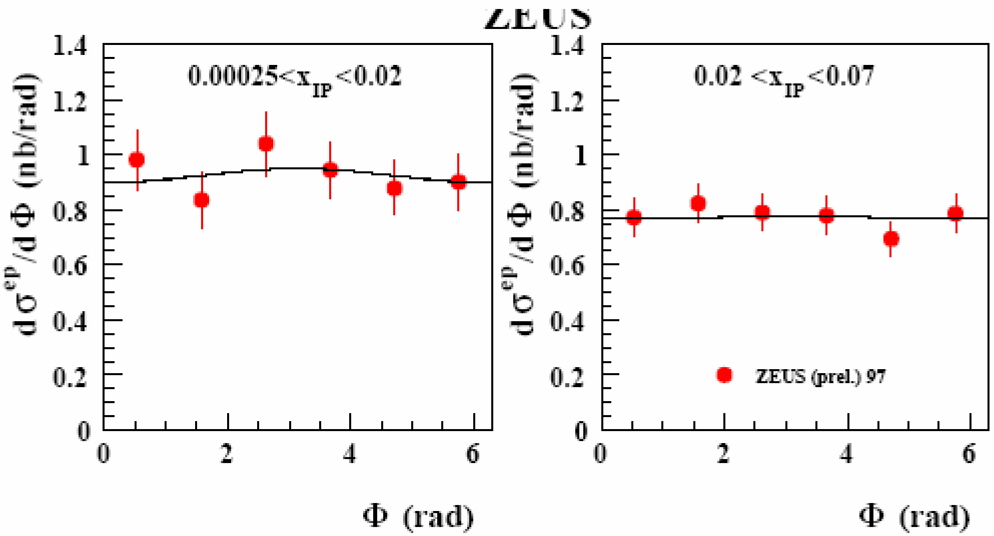
X Janssen (this meeting)

$\Longrightarrow \sim 100\%$ acceptance for $|t| \lesssim 0.2\ \mathrm{GeV}^2$ and $0.01 \lesssim x_{I\!P} \lesssim 0.02$

Expected Results: F_L^D *Measurments*

$$\frac{d\sigma^D}{d\phi} \propto \sigma_T + \sigma_L - 2\sqrt{\epsilon(1+\epsilon)}\sigma_{LT}\cos\phi - \sigma_{TT}\cos 2\phi$$





ZEUS results: Assymetries are small at low β

BUT:

pQCD calculable higher twist F_L^D expected dominant at high β

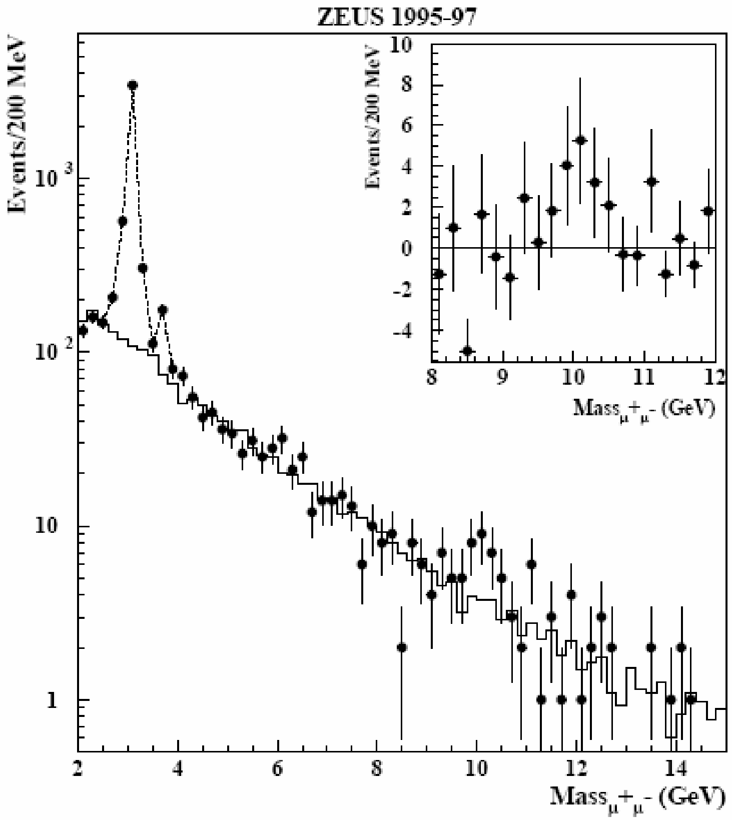
$\longrightarrow$ Measure ϕ asymmetries as function of β (and Q^2)

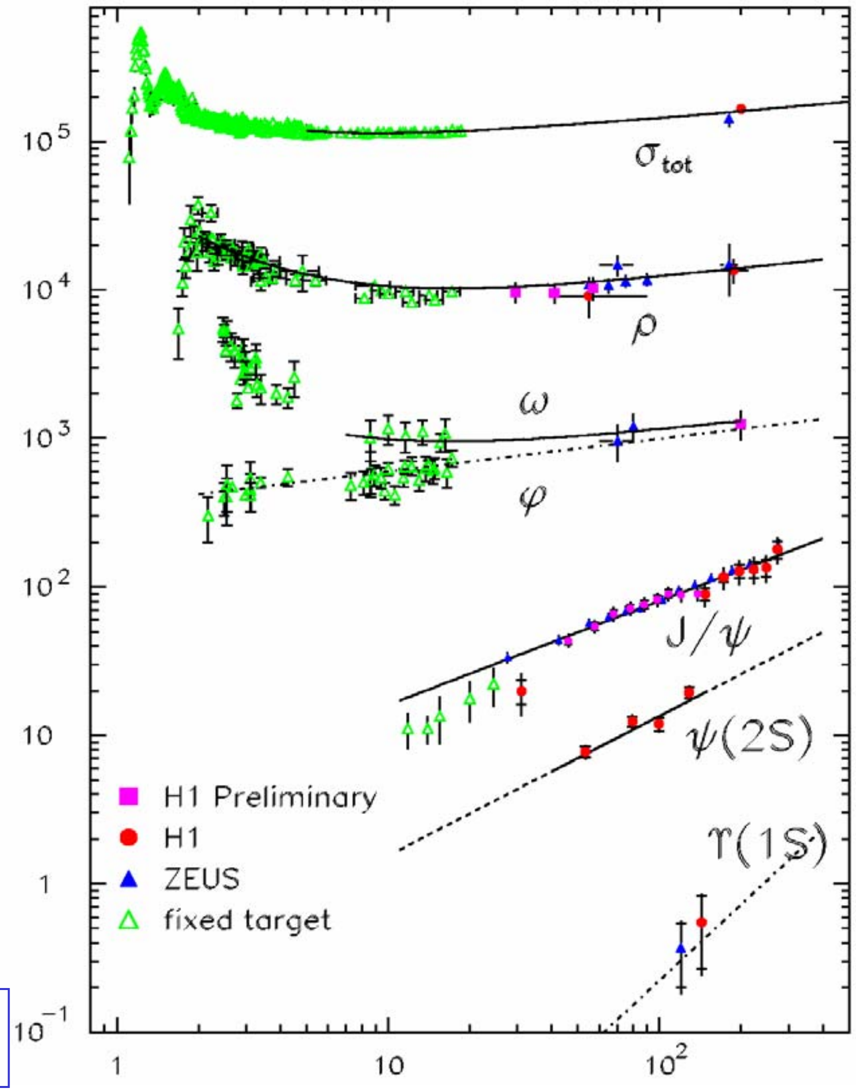
VFPS : 15 bins in ϕ with 10000 events each for $|t| > 0.2\ \mathrm{GeV}^2$

From X. Janssen

Vector mesons Upsilon

Data 1995-1997 (43.2 pb⁻1), DESY-98-089



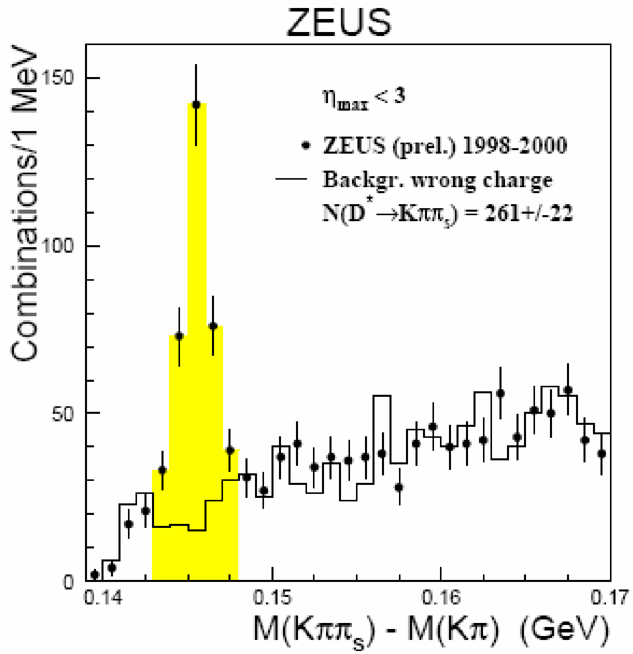


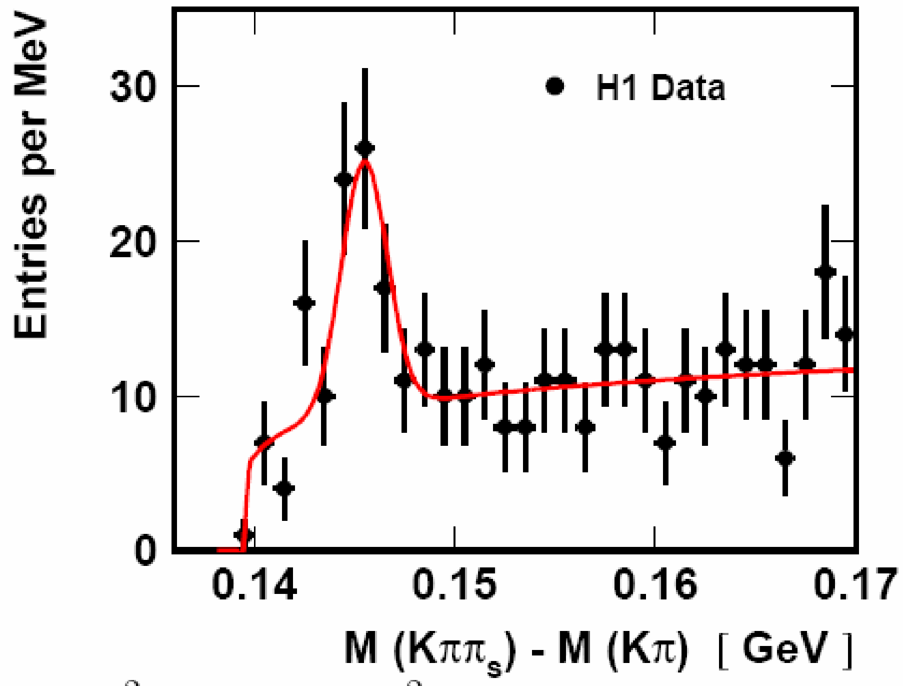
@ HERA II expect > 10x more

From A. Bruni

Diffractive Open Charm in DIS

Use $D^* \to D_0\pi_s \to K\pi\pi_s$





$1.5 < Q^2 < 200\ \mathrm{GeV}^2$
$x_{I\!P} < 0.035$
$p_{T,D^*} > 1.5\ \mathrm{GeV}, |\eta_{D^*}| < 1.5$

$2 < Q^2 < 100\ \mathrm{GeV}^2$
$x_{I\!P} < 0.04$
$p^*_{T,D^*} > 2\ \mathrm{GeV}, |\eta_{D^*}| < 1.5$

So far measurements statistics limited

Soon also with protons measured with VFPS

From A. Bruni

Outlook

- WG4 was very active, however many subjects are only opened and would profit from further collaboration HERA-LHC, eg. in experimental know-how of rapidity gap signature

- We arrived to firm conclusions on priority measurements for our field to be completed at HERA: final combined F_2^D from HERA, precise determination of low-x gluon generalized p.d.f., and further studies of gap survival probability

- We look forward to next meetings and to many more exchanges between two communities

- Let me thank all the WG4 members for a very interesting and enjoyable workshop (and sorry for not being able to do justice today to many contributions…)