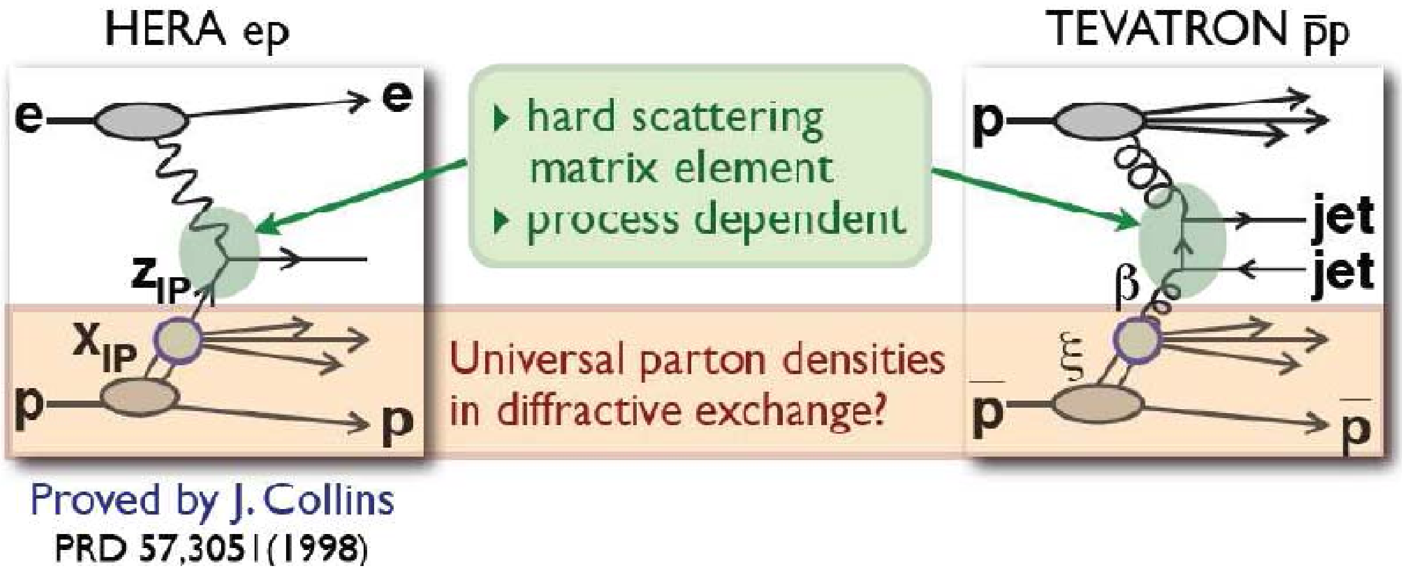
# Summary of the Experimental Talks Photon2007

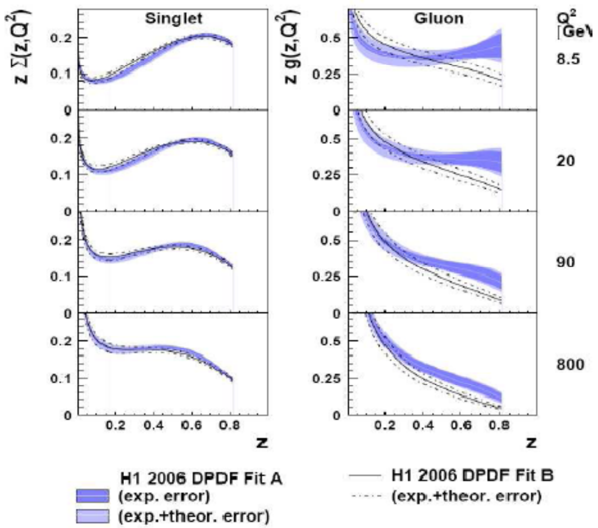
Stephen Maxfield (Liverpool)

- ~70 Talks many of which were themselves summaries of several analyses. So…
- Obviously impossible to cover everything
  – Apologies to speakers and contributors of the talks not mentioned…
  – Choices are idiosyncratic!
    - …and apologies for any misrepresentation of those included!

# Diffractive processes

# Experimental tests of factorisation in diffraction exchange

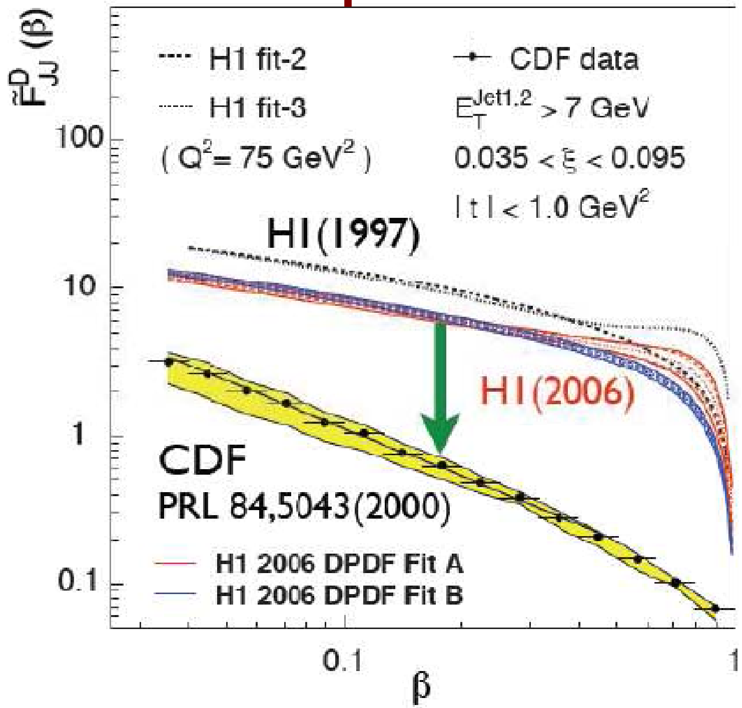


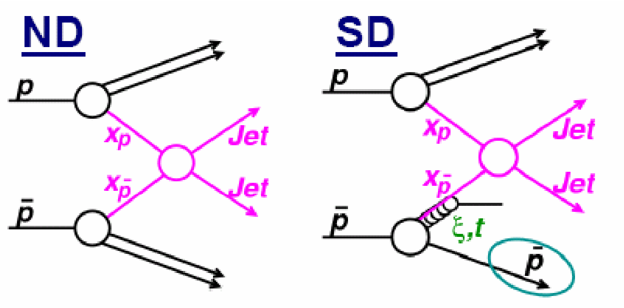




**Extract parton densities from inclusive diffraction**

**L. Schoeffel**

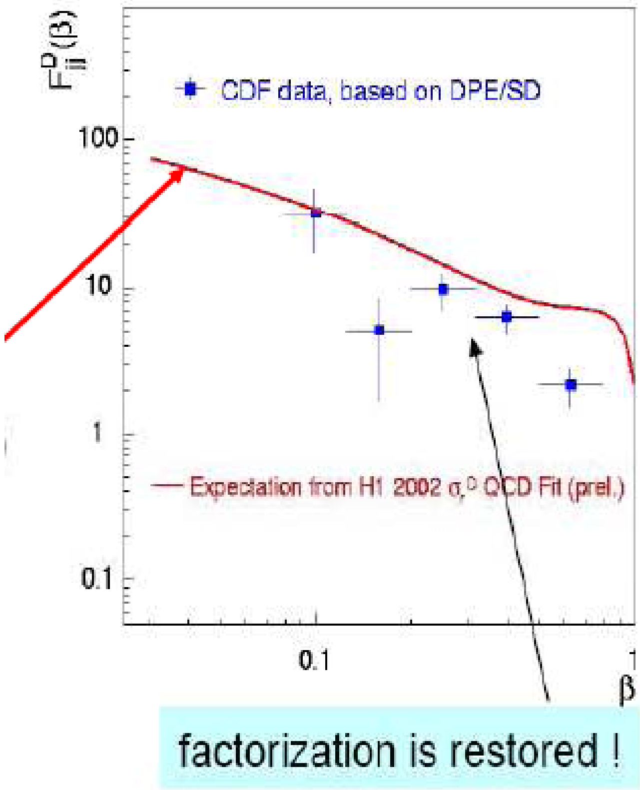
# But fails to predict tevatron data…



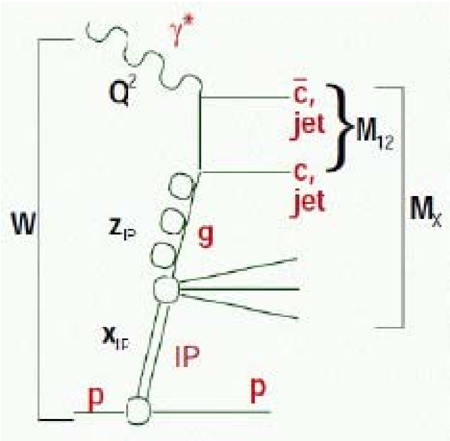



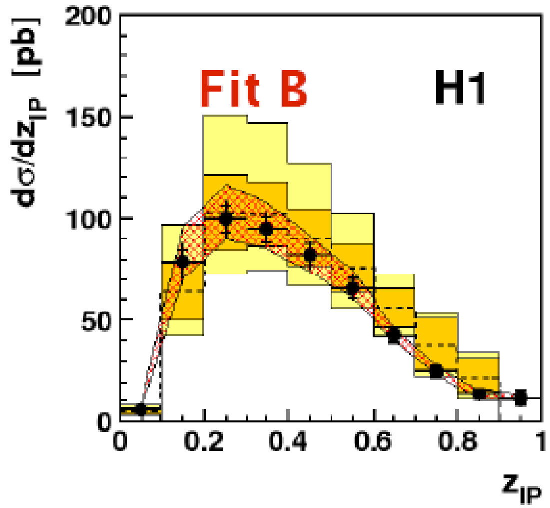

**Factorisaton breaking or gap suppression from spectator parton interactions?**

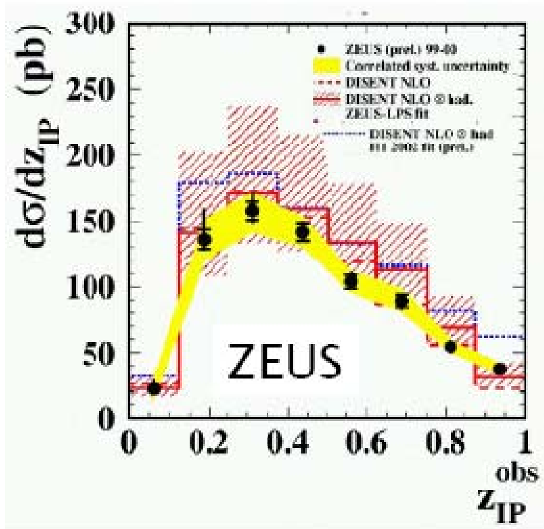
**Events with leading anti-proton – use ratio DPE/SD instead of SD/ND**
**Agreement with HERA prediction.**

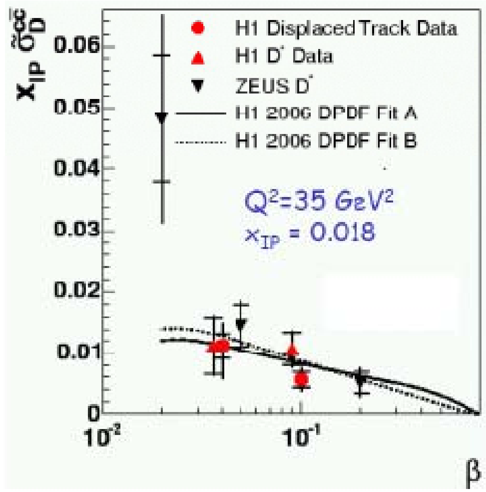


# Dijet production DIS vs. Photoproduction S.Schaetzel



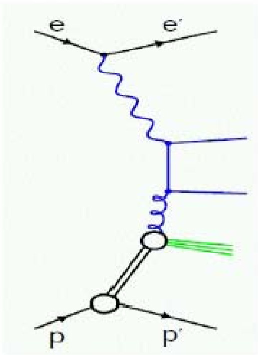
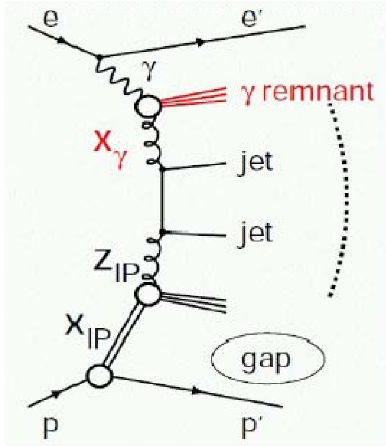
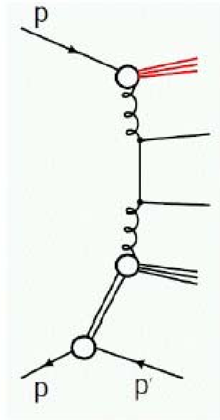




**In DIS dijets and Charm consistent with factorisation.**

# $\gamma p$: Transition from ep to pp

| ep | $\gamma p$ | $p\bar{p}$ |
|---|---|---|
|  |   |  |
| | $x_\gamma < 1$: photon remnant<br>$x_\gamma \approx 1$: no remnant | proton remnant |
| Factorisation works | Factorisation? | Factorisation broken |

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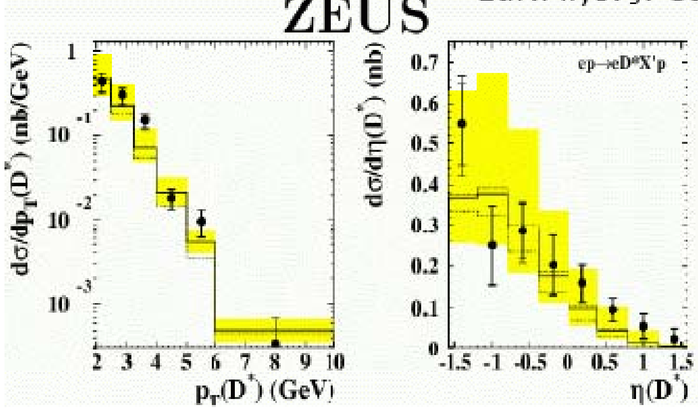
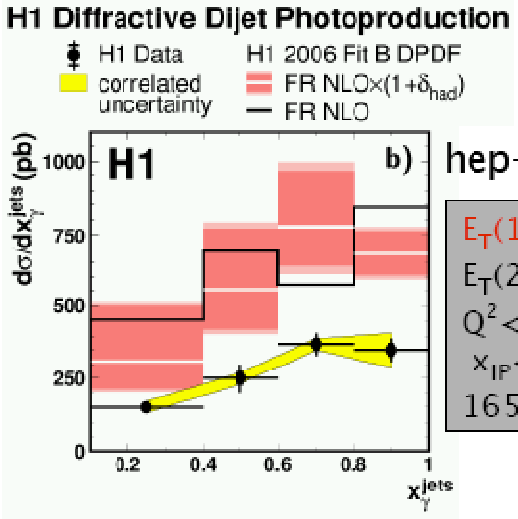
**Charm still OK**




**But...**

# Dijets in Photoproduction



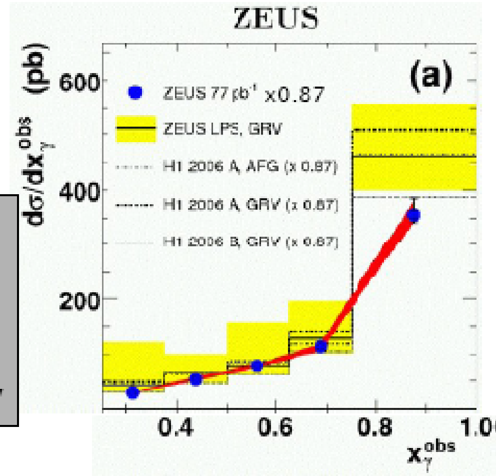

hep-ex/0703022

$E_T(1)>5$ GeV
$E_T(2)>4$ GeV
$Q^2<0.01$ GeV$^2$
$x_{IP}<0.03$
$165<W<242$ GeV

NLO prediction using Frixione/Ridolfi program

- Factorisation is broken
- suppression factor 0.5, independent of $x_\gamma$
- direct and resolved photon processes equally suppressed

$E_T(1)>7.5$ GeV
$E_T(2)>6.5$ GeV
$Q^2<1$ GeV$^2$
$x_{IP}<0.025$
$143<W<295$ GeV

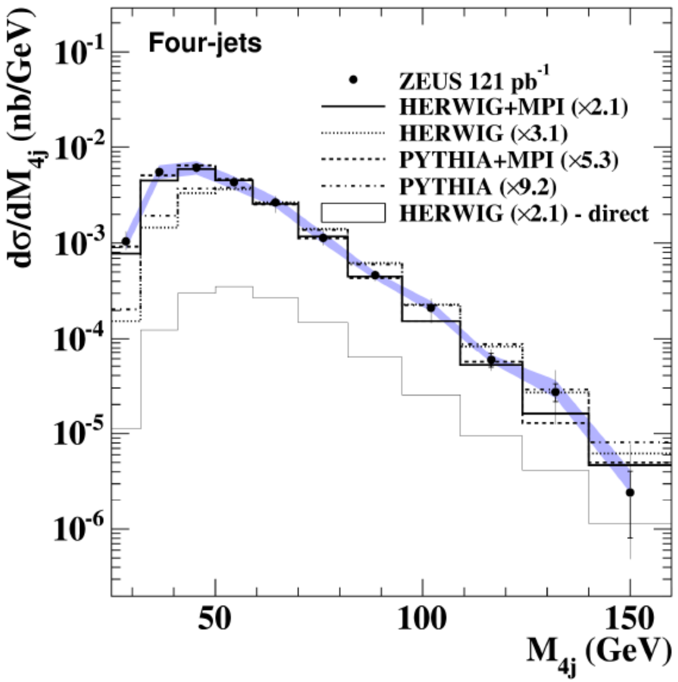


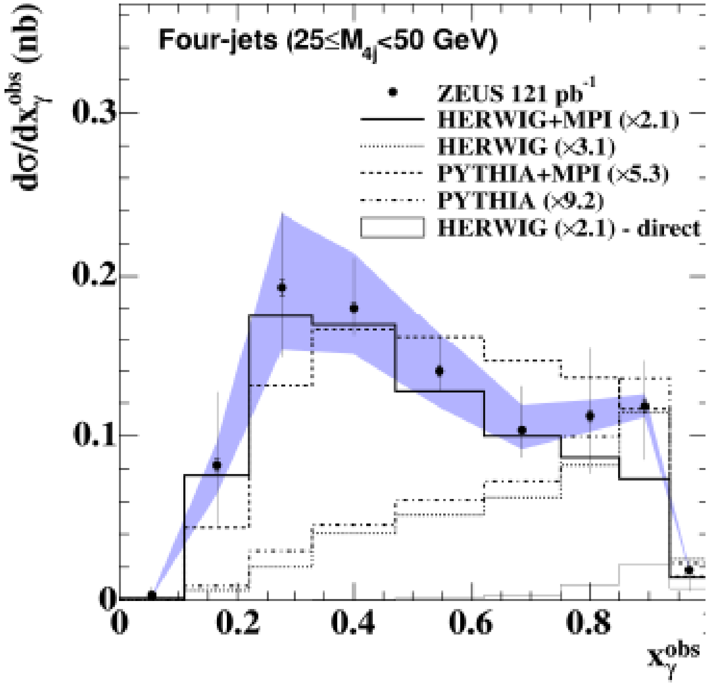

using NLO program from Klasen/Kramer

- suppression factor ≈0.8 for both direct and resolved
- not significant
- compared to H1:
  - harder jets
  - bigger $Q^2$

**Factorisation broken but in odd way!**

**Role of multi-parton interactions…**




MC w/o MPI is normalized to high mass region (M_nj > 50 GeV)

- Low mass data not described without MPI's

→ Most significant for 4-jet scenario

# Mini jets in DIS (H1)

*(S. Osman)*

***Kinematic Range***

- $5 < Q^2 < 100.0\ \mathrm{GeV}^2$
- $0.1 < y < 0.7$
- $W > 200\ \mathrm{GeV}$

***Jet Selection***

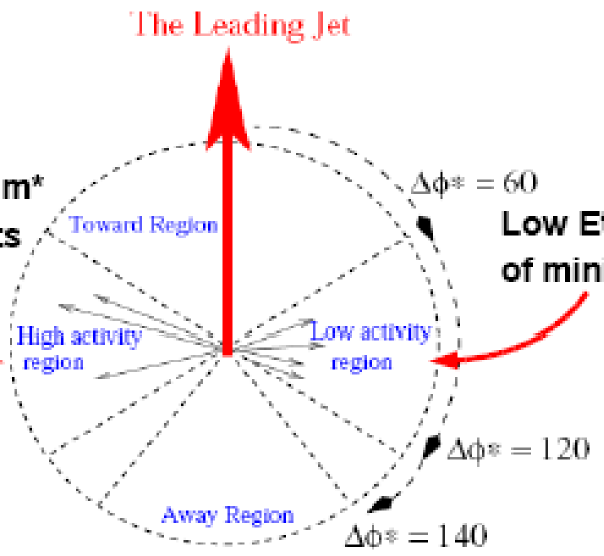
**2 samples: Inclusive 1-jet sample and di-jet sample:**

- $P_{T,1(2)}^{jet} > 5\ \mathrm{GeV}$
- $-1.79 < \eta_{1(2)}^{jet} < 2.79$
- $|\phi_1^* - \phi_2^*| > 140$

***Mini Jet Selection***

- $-1.79 < \eta^{minijet} < 2.79$
- $P_T^{minijet} > 3\ \mathrm{GeV}$

**High Etsum* of mini jets**




**Low Etsum* of mini jets**

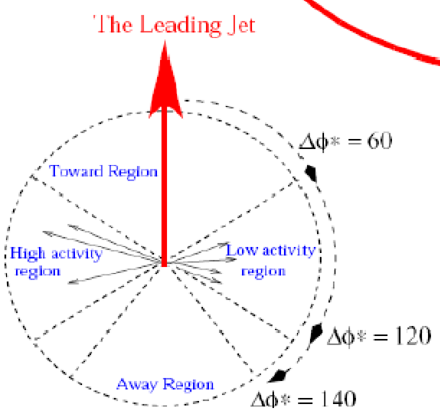
**Measure** $< N_{Minijets} >= \frac{\sum^{N_{events}} N_{Minijet}}{N_{events}}$ **in bins of** $Q^2$ **and** $\eta_1^{jet}$ **as a function of** $P_{T,1}^{jet*}$

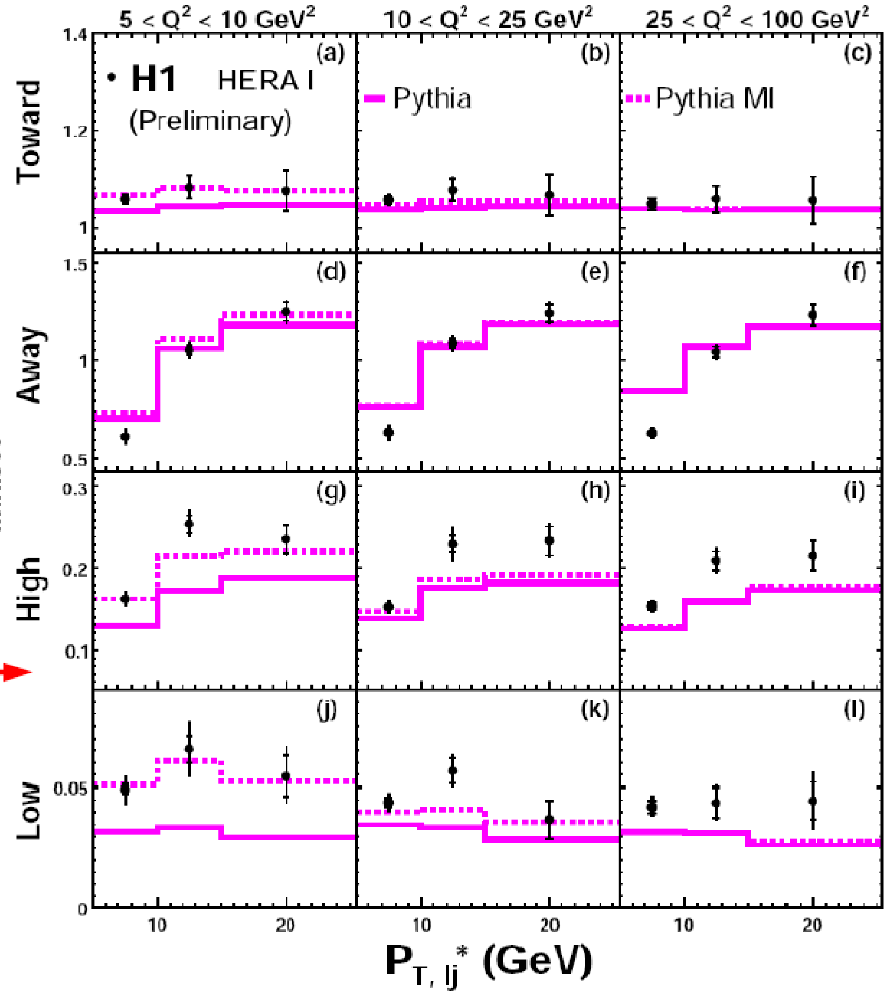
**Inclusive 1 jet sample**

**and**

$0.5 < \eta^{jet} < 2.79$

**•Again, activity from MPI improves description of data at low Q2 in transverse regions**

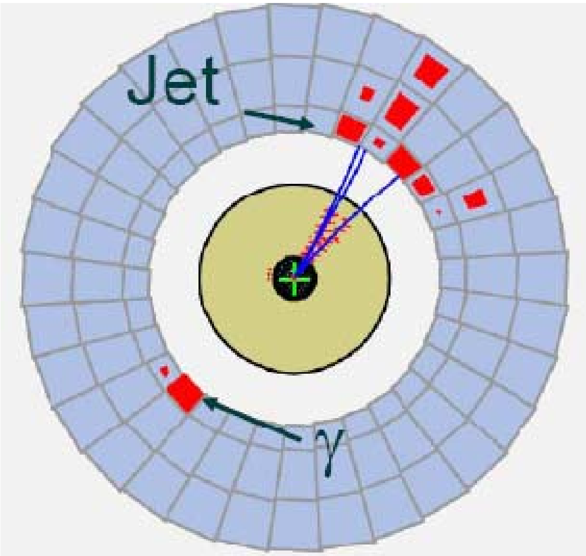



**…but still not described. Pythia tuning?**

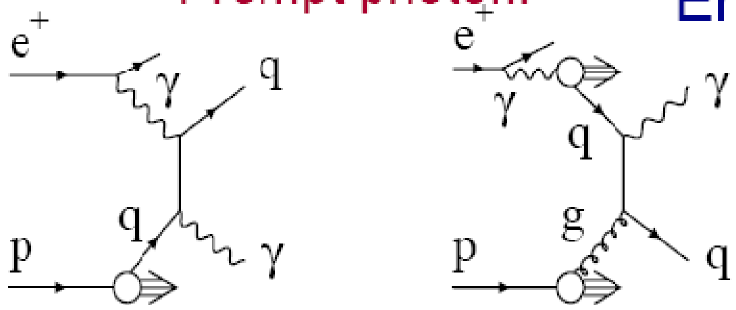
# Photons in the final state

# Prompt photons from HERA. In Photoproduction and DIS




Prompt photon:

Eric Brownson




(a) Direct (b) Resolved

Constrains gluon

NLO calculations:

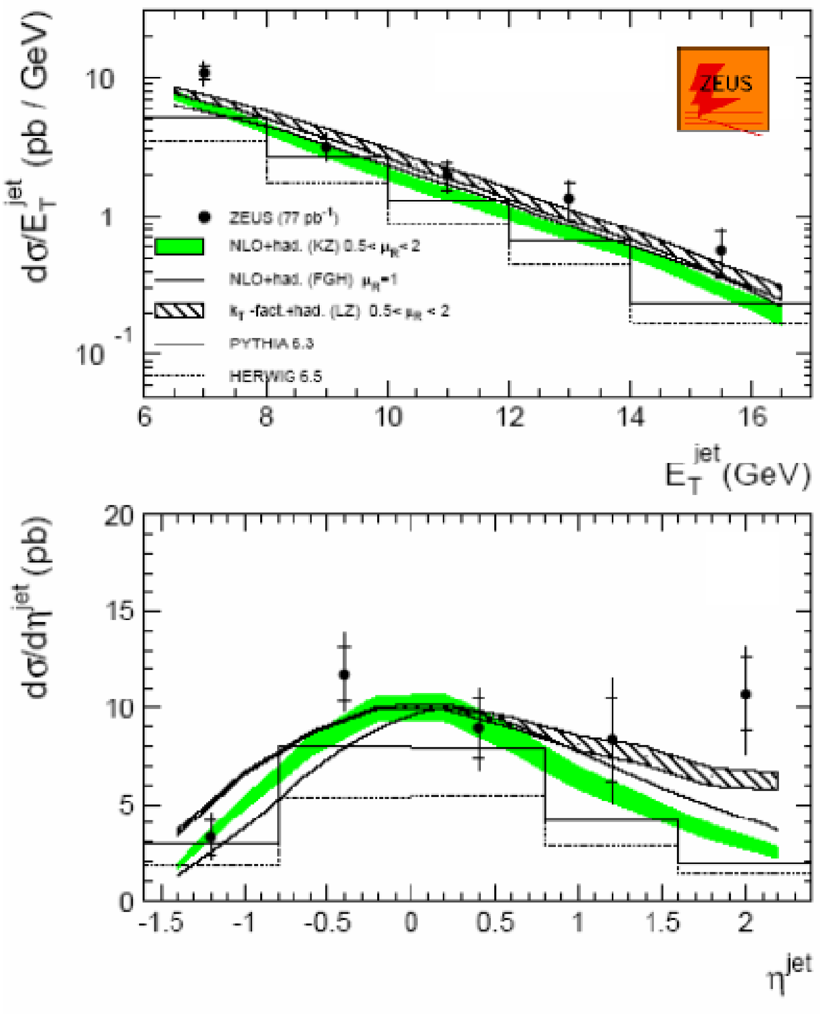
**K.Krawczyk & A.Zembrzuski (KZ):**
- **GRV parametrisation:**
  - photon structure function
  - proton structure function
  - fragmentation function

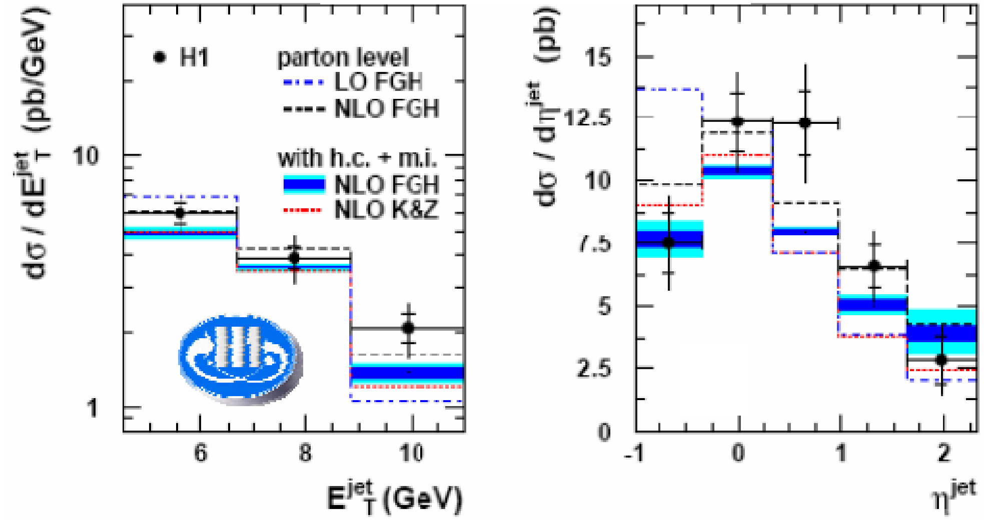
**Fontanaz, Guillet & Heinrich (FGH):**
- **MRST** proton structure function
- **AFG** photon structure function

**A.Lipatov & N.Zotov (LZ):**
- $K_t$-factorization approach
  - Unintegrated quark/gluon densities using Kimber-Martin-Ryskin prescription

## Eric Brownson

$$ep \rightarrow \gamma(prompt) + jet + X$$




HERWIG & PYTHIA:

- Underestimate the measured cross section, particularly at high $\eta^{jet}$

KZ & FGH:

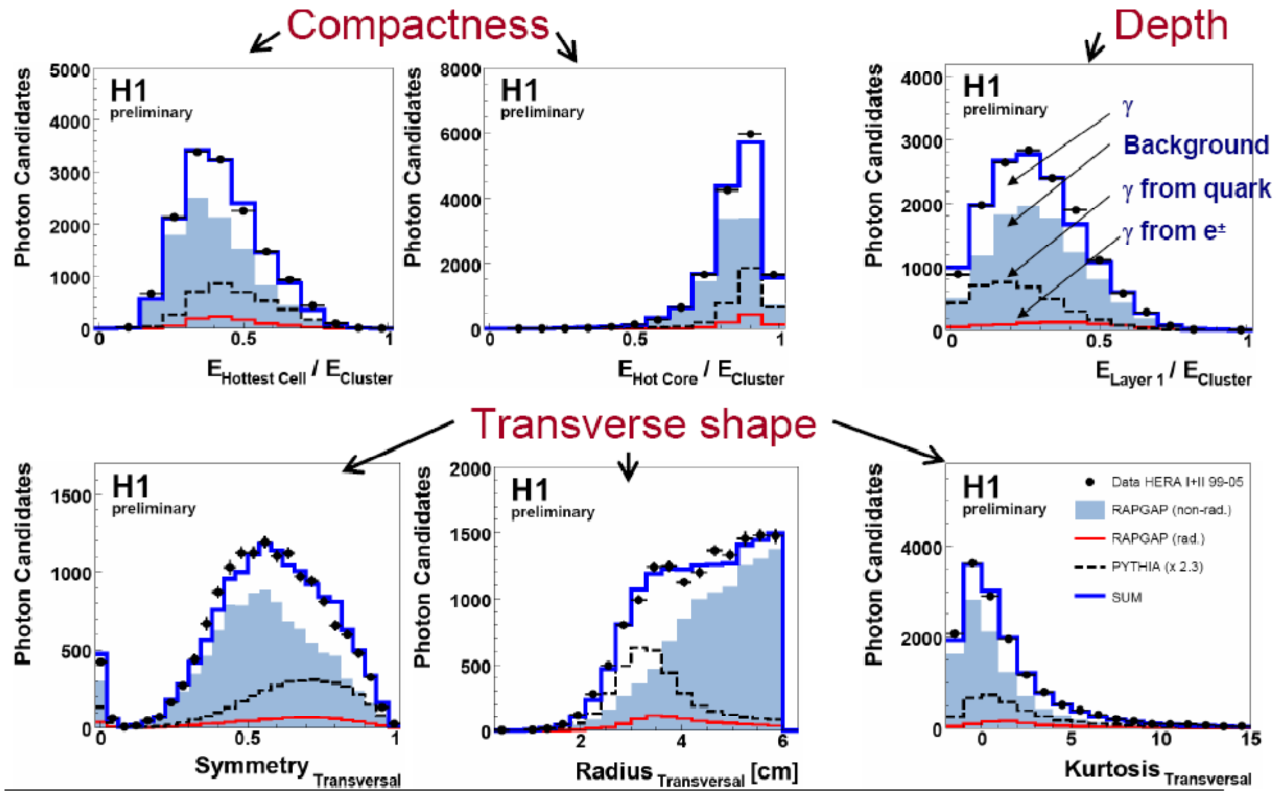
- Improved agreement with the measured cross section
- Hadronic corrections are necessary

LZ:

- Improves description of high $\eta^{jet}$

**Experimentally challenging final state.**

**Needs very good understanding of the detector**




**c.f. Tevatron:**

Nikolay Skachkov

**Photon candidate selection cuts:**

1. γ - candidate is an isolated cluster of energy in calorimeter layers EM1 – EM4 ( cells 0.1 x 0.1 of 2, 2, 7 and 10 rad. length)

$$R^{\gamma}_{clust} = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.2$$

2. $Iso\,(\Delta R = 02) = \dfrac{E(R \le 0.4) - E(R \le 0.2)}{E(R \le 0.2)} \le 0.07$

3. γ - candidate originates from the best primary vertex: fit of:
   1. center of gravity of EM cluster energy in EM1 – EM4 layers &
   2. Central Preshower cluster position
4. EM fiducial cuts (internal calorimeter structure + cracks)
   ⇨ total geometrical acceptance A=0.80 – 0.83
5. EM fraction in calorimeter: *EMFr > 0.96* (deposited E)
6. Probability of charged track matching ≤ *0.001*
7. Limit on the width of energy cluster in the finely-segmented EM3 layer (cells with 0.05 x 0.05 size)

⇨ Three additional variables (used for the inclusive photon analysis )

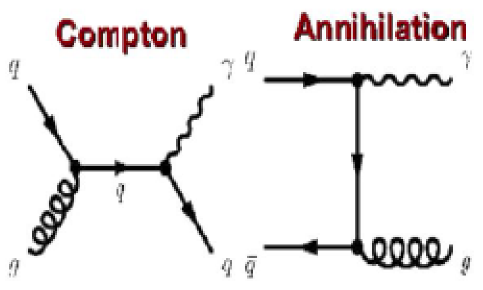
1) number of cells in EM1 (with $E_T^{cell} > 0.4$ )

2) fraction of E deposited in EM1 (with $E_T^{cell} > 0.4$ )

3) $\sum P_T^{track}$ in the ring (*0.05 ≤ R ≤ 0.4*) (with $p_T^{track} > 0.4$ )

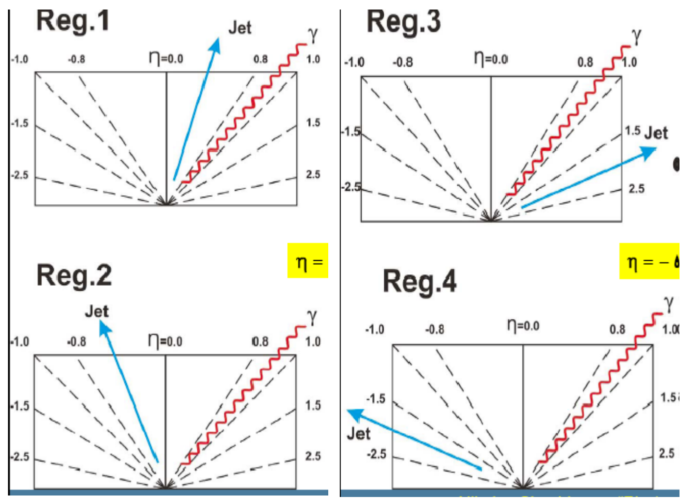
used as input for ANN (JETNET) ⇨

8. Additional cut on the ANN output: $O_{NN} > 0.7$ , is applied.



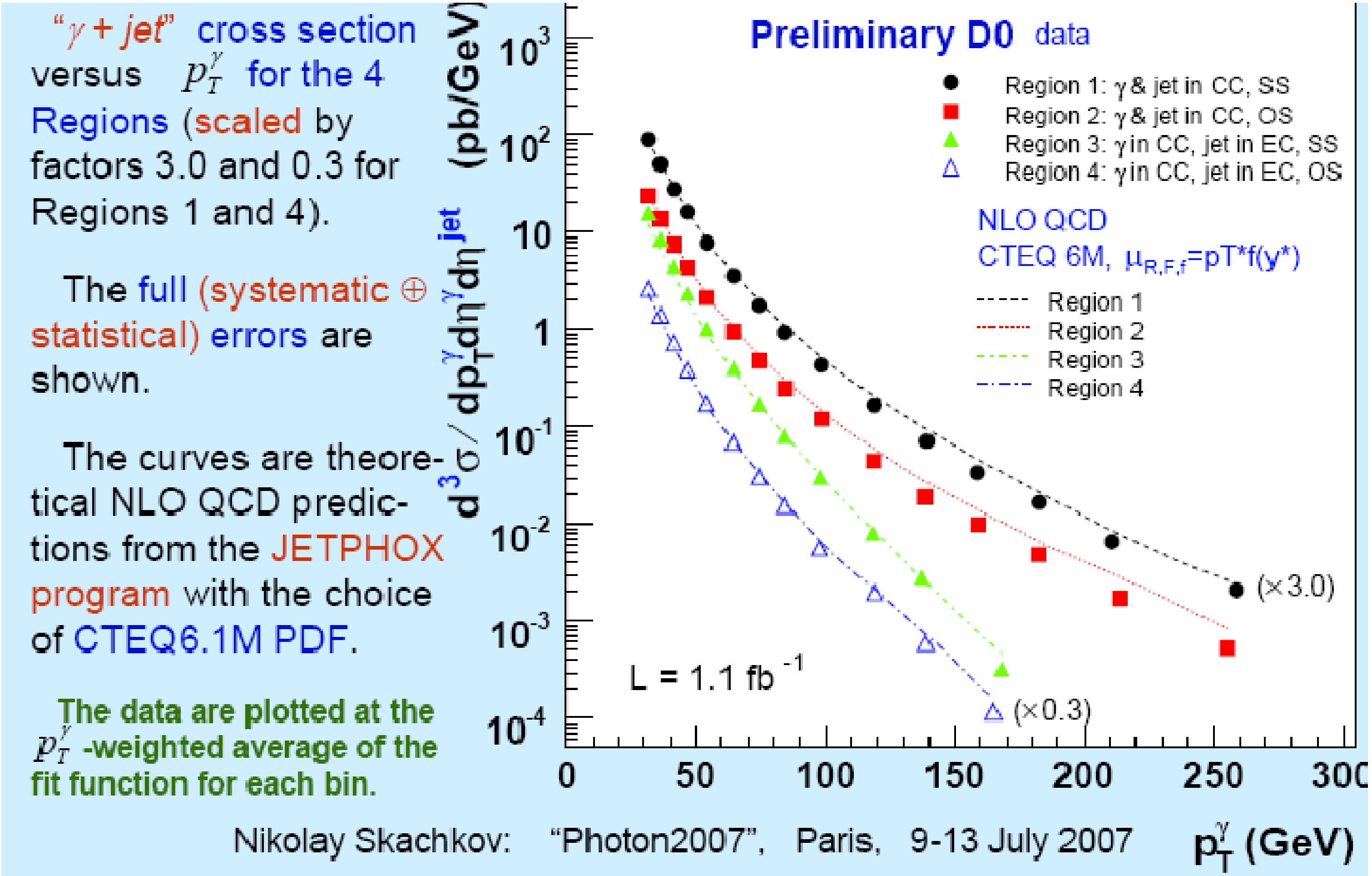

# D0

## Isolated γ+jets triple differential Cross section



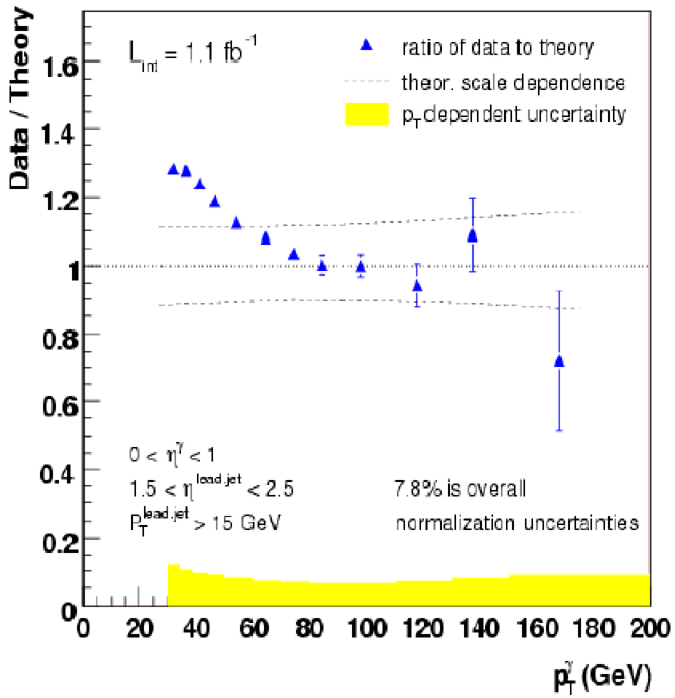

**Great care taken with Photon ID**

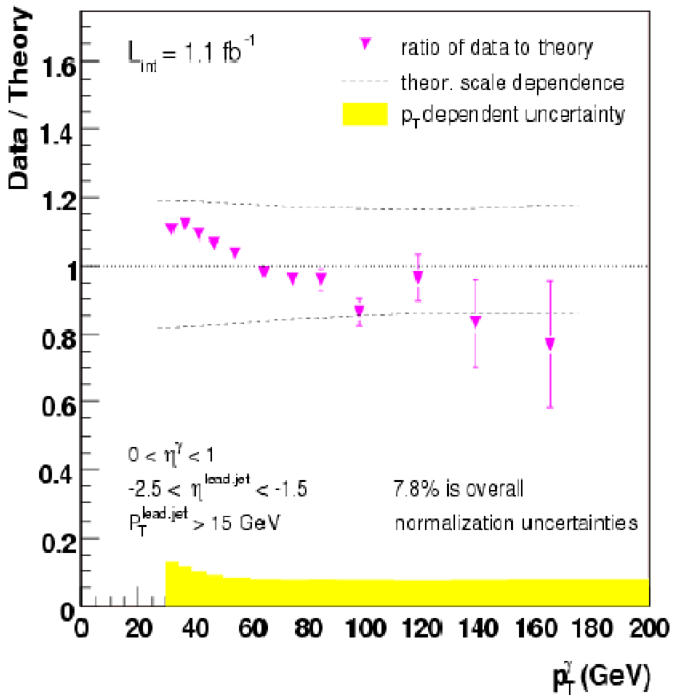
**High statistics measurement, 5 orders of magnitude, good qualitative description by NLO…**



## …but deviations from NLO predictions seen.

Theory to Data (preliminary) ratio for Reg.3 and Reg. 4 (i.e.with forward jet)

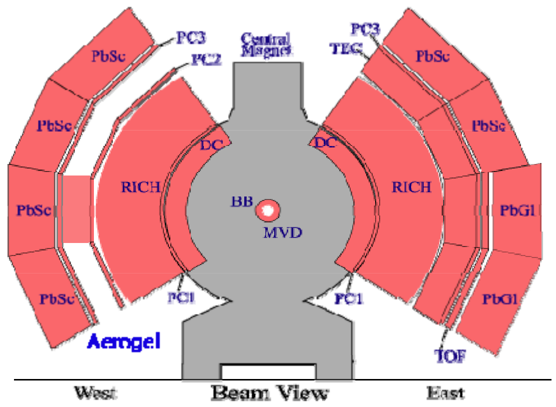


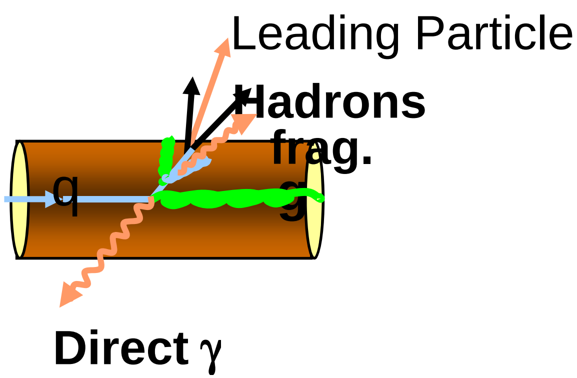



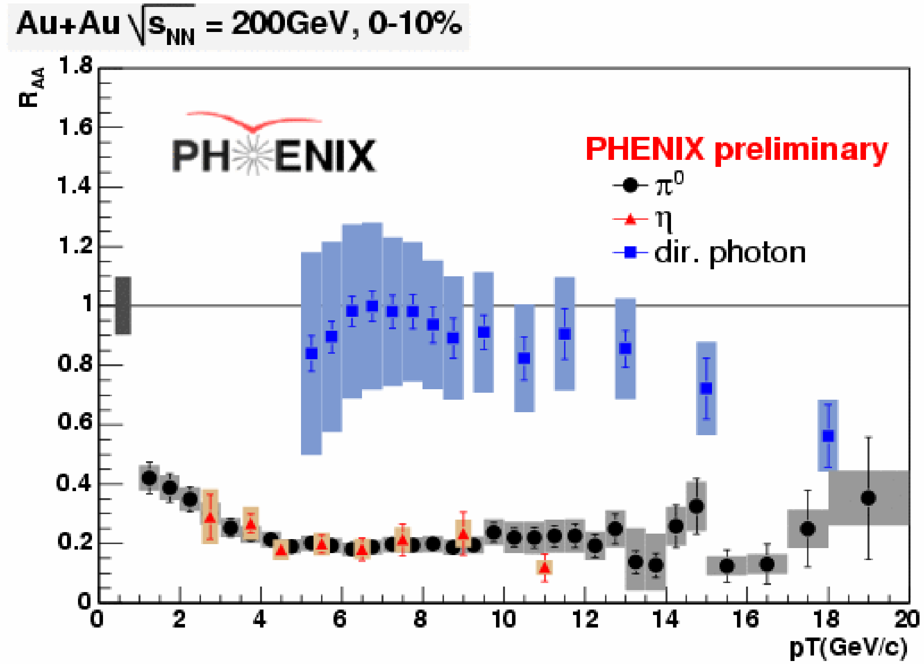
# …and RHIC

# Henner Buesching

- photons in A+A
  - direct photons
    - hard
      - direct
      - fragmentation
    - pre-equilibrium
    - thermal
      - QGP
      - hadron gas
    - jet-plasma-interact.
      - jet-γ-conv.
      - medium-induc. γ bremsstr.
  - decay photons



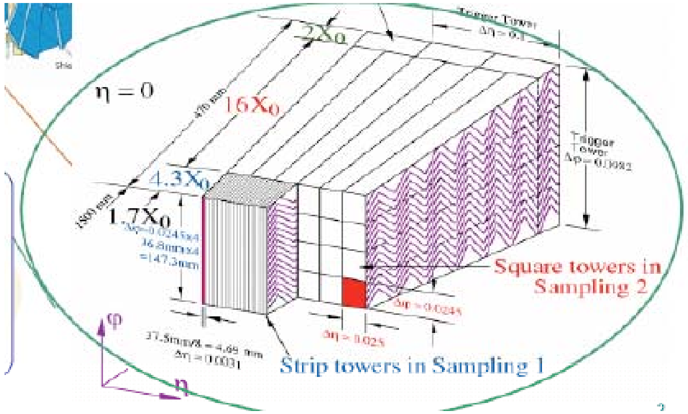




## Nuclear modification factor

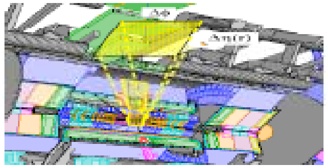
## …and at LHC Valeria Perez Reale

## Main interest H → $\gamma\gamma$

…but also *very* high $p_t$ $\gamma\gamma$ final states G → $\gamma\gamma$




### (III) Basis of $\gamma$/jet and $\gamma/\pi 0$ separation



L1 Trigger: **EM candidate**
EM and HAD isolation
coarse granularity

↓

High Level Trigger $\gamma$:
confirms L1 decision with
more refined granularity

↓

Offline Analysis $\gamma$: more
up to date calibration.
Conversion recovery and
track veto (use of ID info)

**$\gamma$-ID**

Leakage in Hadronic calorimeter

↓

*EM sampling 2* : different transverse development of electromagnetic and hadronic showers.
- shower shapes in η and φ
- shower width in η direction

↓

*EM sampling 1* : only jets with a little hadronic activity survive. Fine segmentation of the strips :
- look for substructures in strips
- shower width in η

η dependent photon identification selection

**Excellent understanding of calorimetry/tracking will be needed to understand fake rates**

# Where's the $\gamma\gamma$ physics?

**…still in the traditional places:**

## $f_0(980)$ in $\gamma\gamma \to \pi^+\pi^-$

**Note huge statistics!**

$f_0(980)$ 85.9fb$^{-1}$

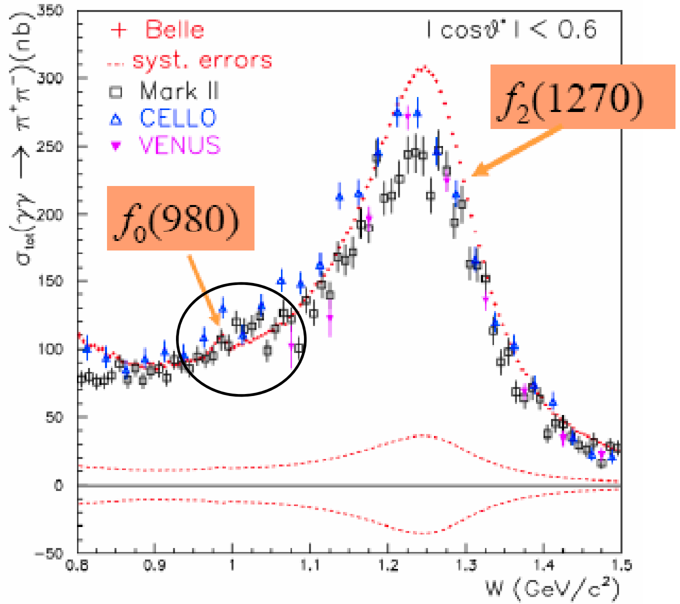
– is an ordinary $q\bar{q}$ meson?
- an exotic state?
- some special theory needed?

Its two-photon coupling is a crucial key.

Prediction of $\Gamma_{\gamma\gamma}$ :

| | |
|---|---|
| $u\bar{u}$, $d\bar{d}$ | --- 1.3 – 1.8 keV |
| $s\bar{s}$ | --- 0.3 – 0.5 keV |
| $K\bar{K}$ molecule | --- 0.2 – 0.6 keV |

$\pi/\mu$ separation:
by comparing energy deposit in the CsI calorimeter between data and MC




$f_0(980)$ appears as a small but statistically significant peak.

*Photon2007, 9 July, 2007*, S.Uehara, Belle 6

**Fit to lineshape:**

$f_0(980) \to \pi^+\pi^-$

$M = 985.6^{+1.2+1.1}_{-1.5-1.6}$ MeV/c$^2$

$\Gamma_{\pi^+\pi^-} = 34.2^{+13.9+8.8}_{-11.8-2.5}$ MeV

$\Gamma_{\gamma\gamma} = 205^{+95+147}_{-83-117}$ eV

**…so not conclusive**

**Also look** near 958MeV/c$^2$ → New upper limit for $Br(\eta' \to \pi^+\pi^-) < 2.8 \times 10^{-3}$

# ..and LEP

A. Finch



## Measurement of the Cross Section for open b-Quark Production in Two-Photon Interactions at LEP

•B-tagging by signed impact parameter. Use to calculate probabilities that tracks come from main vertex.

•Iterative Discriminant Analysis

- $P_{\text{event}}$, $P_{\text{jet1}}$, $P_{\text{jet2}}$
- mass and $p_t$ of Jet 1
- 5 largest $S$
- the thrust of the event

$$\sigma(e^+e^- \to e^+e^- b\bar{b}X) = (5.4 \pm 0.8_{\,\text{stat}} \pm 0.8_{\,\text{syst}})\,\text{pb}$$

which is consistent with the prediction of NLO QCD of between 2.1 and 4.5 pb

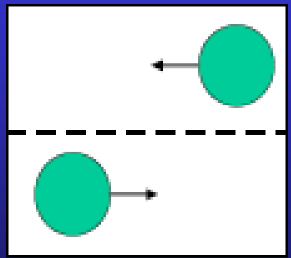
but barely consistent with the result quoted by the L3 Collaboration, $(12.8 \pm 1.7_{\text{stat}} \pm 2.3_{\text{syst}})$ pb.

…but also more exotic places…

# Ultra-peripheral Collisions:

## Ultra-Peripheral Collisions

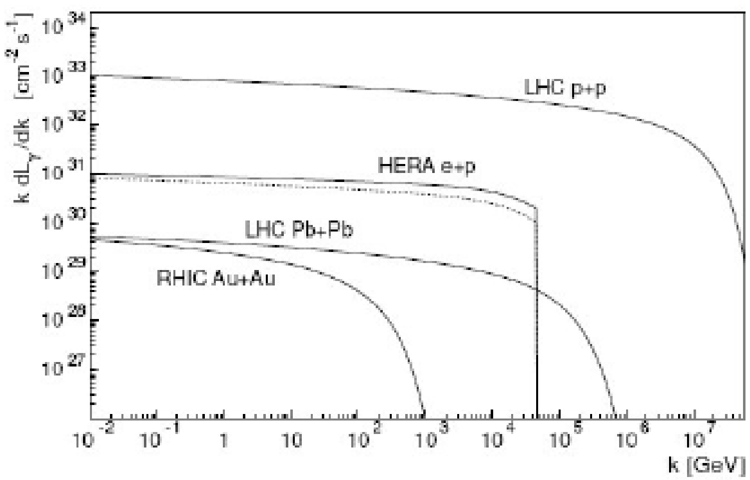
Joakim Nystrand



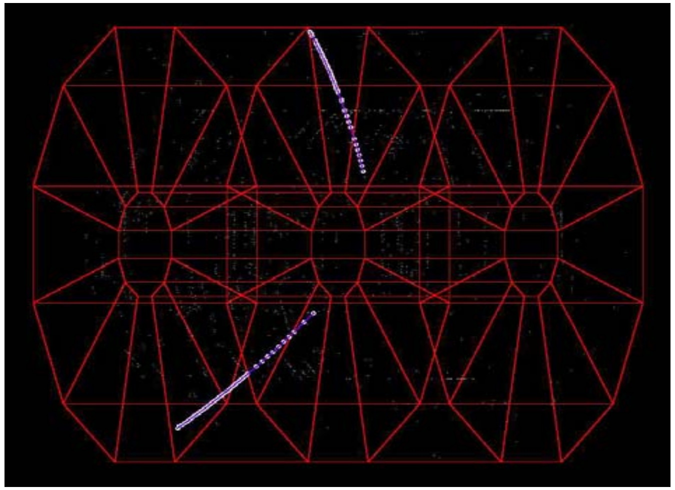
Collisions between two "hadrons" (protons, nuclei) in which no strong interactions occur. Implies impact parameters b > or >> 2R, typically in the range ~ 10 – 100 fm.

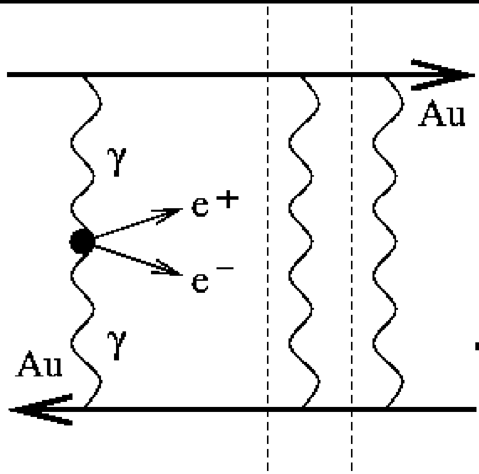
**Very strong Electric field:** $E_{max} \sim \frac{Ze}{b^2}\gamma$

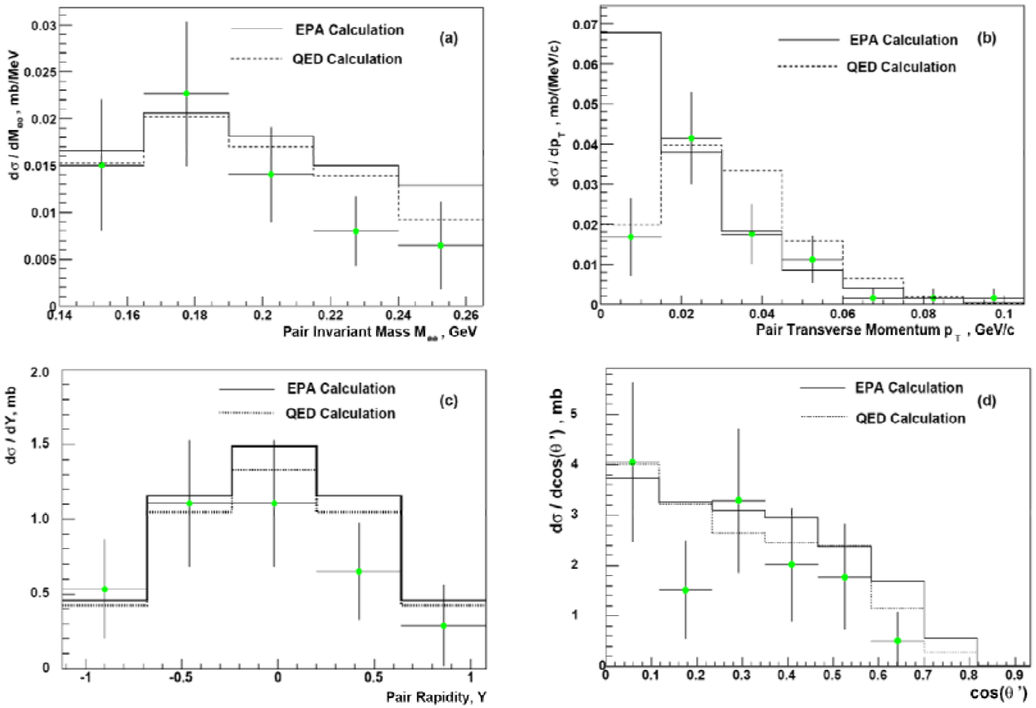
**Short pulse:** $\tau_{\text{collision}} \sim \frac{b}{\gamma v}$



## Very low $p_T$ $e^+e^-$ in STAR at RHIC Janet Seger





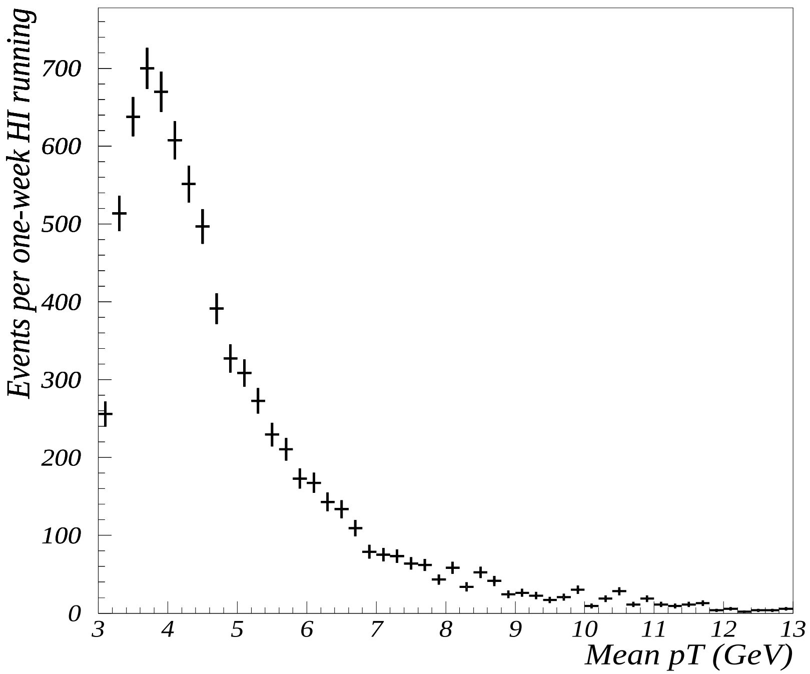




**…and much much more. See also talks from e.g:**

| | |
|---|---|
| Joakim Nystrand: | RHIC and ALICE |
| David D'Enterria: | RHIC and CMS |

V. Podznyakov

# high $p_T$ jets




Events with two jets within pseudorapidity 2.7 and transverse energy more than 3 GeV selected by $K_T$-clustering algorithm

Background coming from peripheral HI collisions is estimated to be few percents

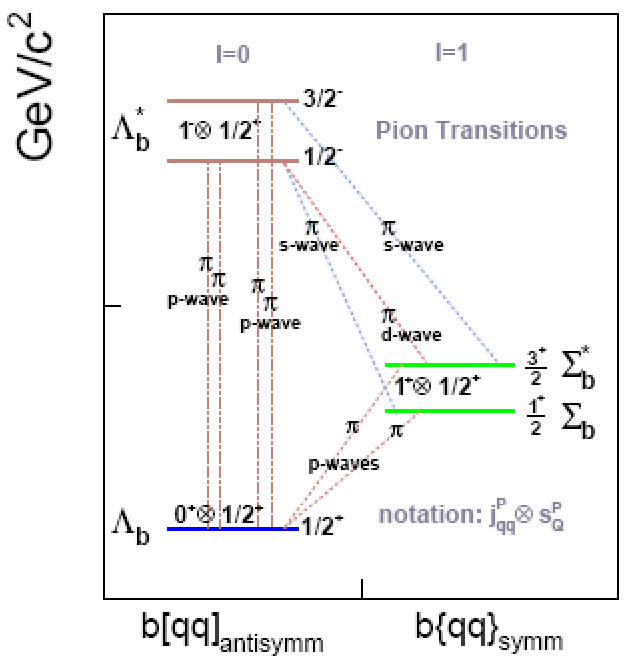
Expected statistics of one-week running (around ten thousands events) is enough to make a comparison with QCD-based calculations

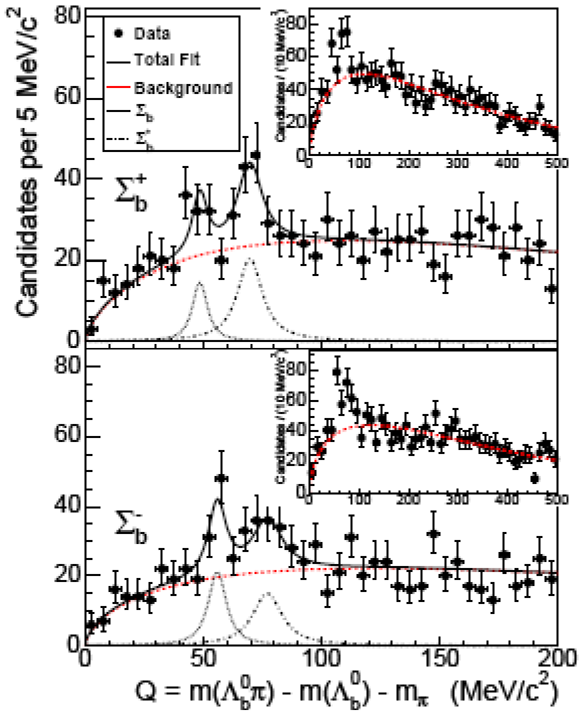
# More Charm and Beauty

Igor V. Gorelov
(On behalf of the CDF Collaboration)



# First Observation of Heavy Baryons $\Sigma_b$ and $\Sigma_b^*$ in CDF

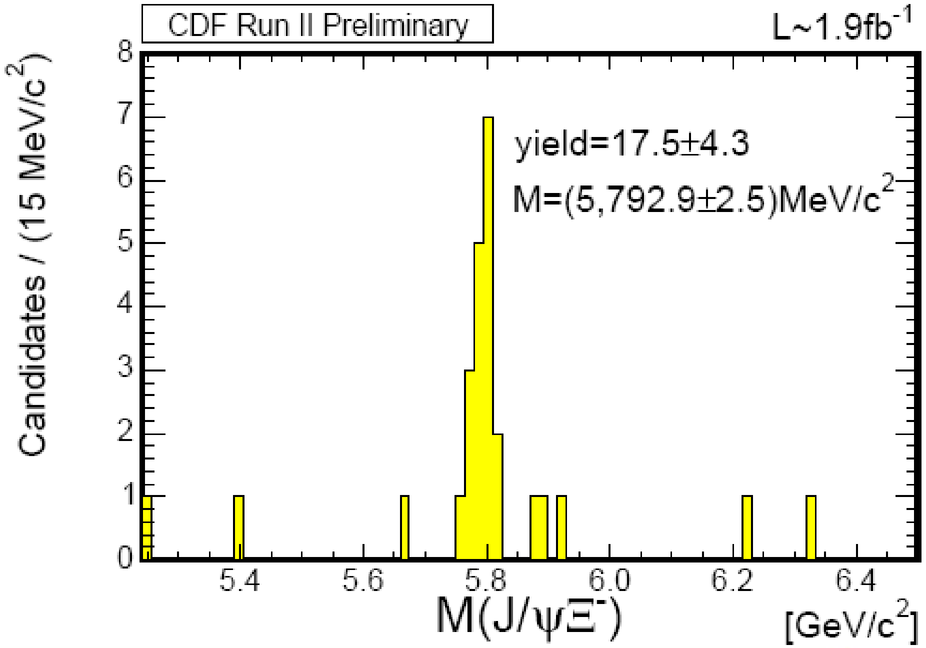



- Modes: $\Sigma_b^{(*)\pm} \to \Lambda_b^0 \pi^\pm_{soft}$, $\Lambda_b^0 \to \Lambda_c^+ \pi^-$, $\Lambda_c^+ \to pK^-\pi^+$
- submitted to PRL recently: arXiv:0706.3868v1 [hep-ex]

**Total luminosity: $\mathcal{L} = 1.1$ fb$^{-1}$**

# Cascade Bottom Baryon $\Xi_b$: Signal in CDF Detector




- **Yield** $= \mathbf{17.5} \pm \mathbf{4.3}$(stat) with significance of $\mathbf{7.7}\sigma$
- **Mass** $= \mathbf{5792.9} \pm \mathbf{2.5}$(stat) $\pm$ $\mathbf{1.7}$(syst) MeV/$\mathbf{c^2}$



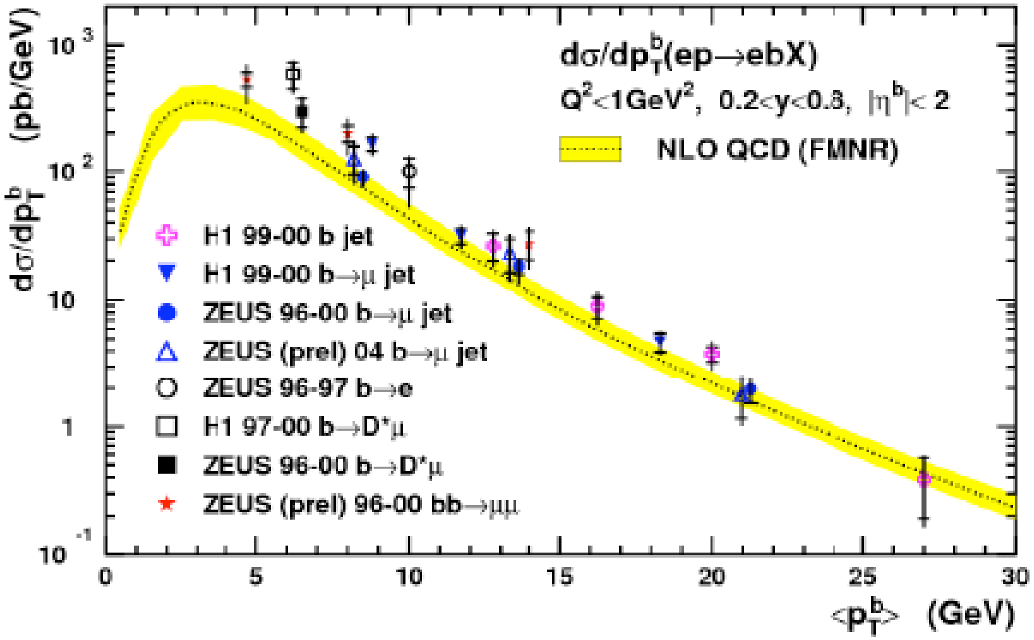
- **CDF result is consistent with DØ and both are consistent with theory predictions**

**Results on:**

- Inclusive cross sections.
- D* and Jet production.
- Charm fragmentation.
- Beauty production

**e.g.**

# Beauty Production




**NLO QCD underestimates data?**

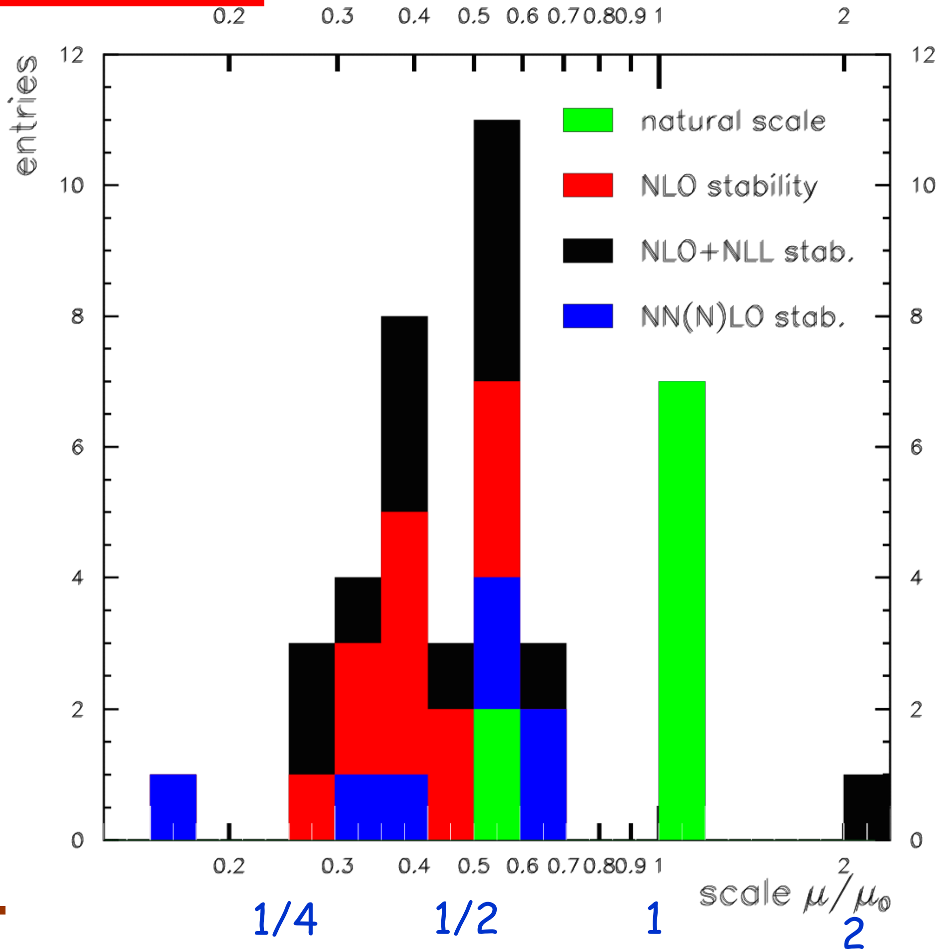
**not necessarily…best choice of scale?**

**According to Achim Geiser: Time to resurrect some old ideas!**

- **Scale choice best done on case by case basis but…**
- **Usual recipe – central value 'natural' scale; vary by factor 2, ½. Better might be:**
- **NLO = LO => hope: NNLO = NLO**
- **or $d\sigma/d\mu = 0$** => hope: minimize NLO corrections
- *NNLO now exists in some cases so can test*

$\mu_0/2 < \mu < 2\mu_0$ "standard" scale range

$\mu_0/4 < \mu < \mu_0$ **proposed new default**




NLO (NNLO) QCD survey of:

- beauty at Sp$\bar{p}$S, Tevatron, HERA-B
- top at Tevatron
- Z, H at LHC

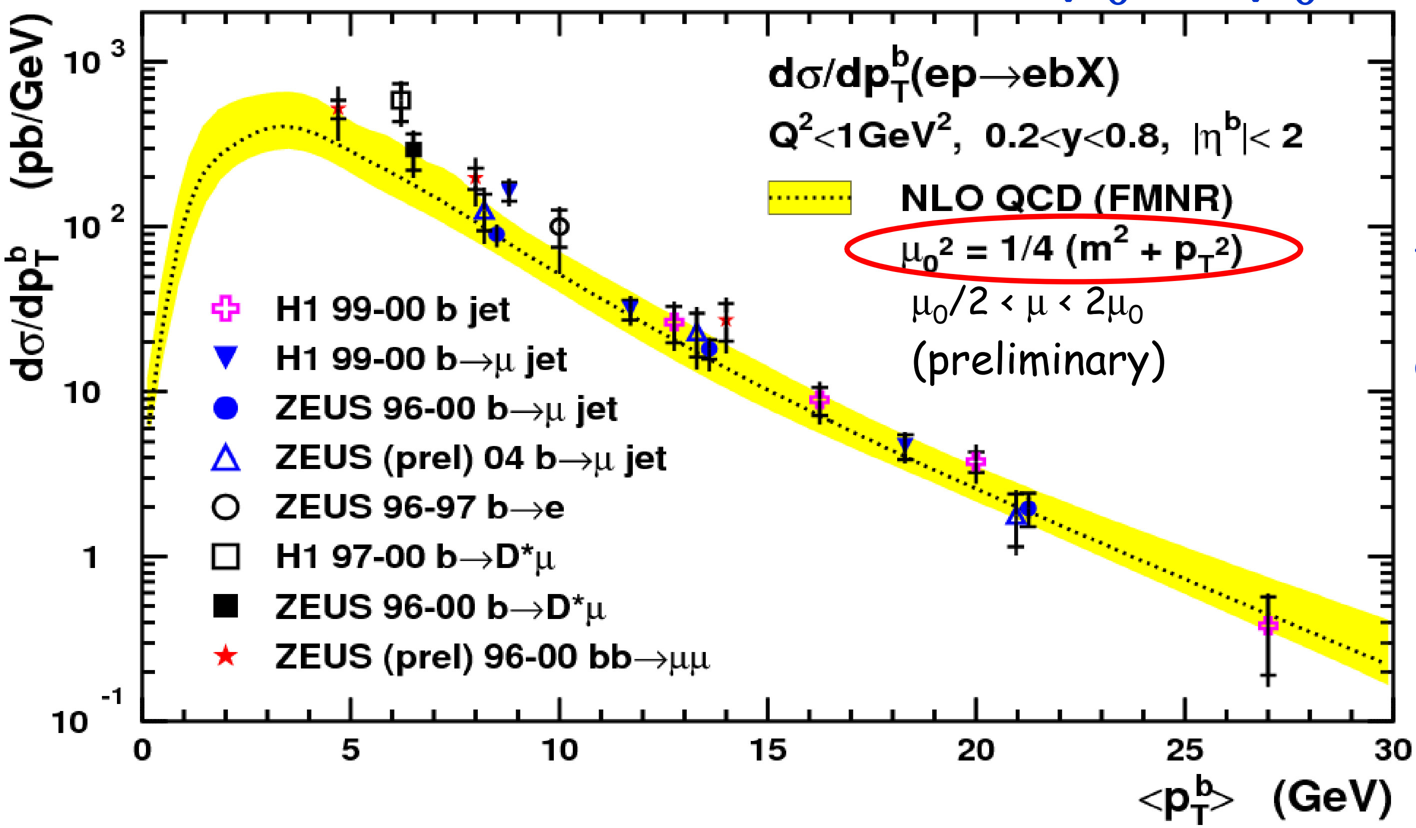
$\mu_0^2 = m^2 (+ p_T^2)$

- jets in γp and at Tevatron

$\mu_0^2 = E_T^2$

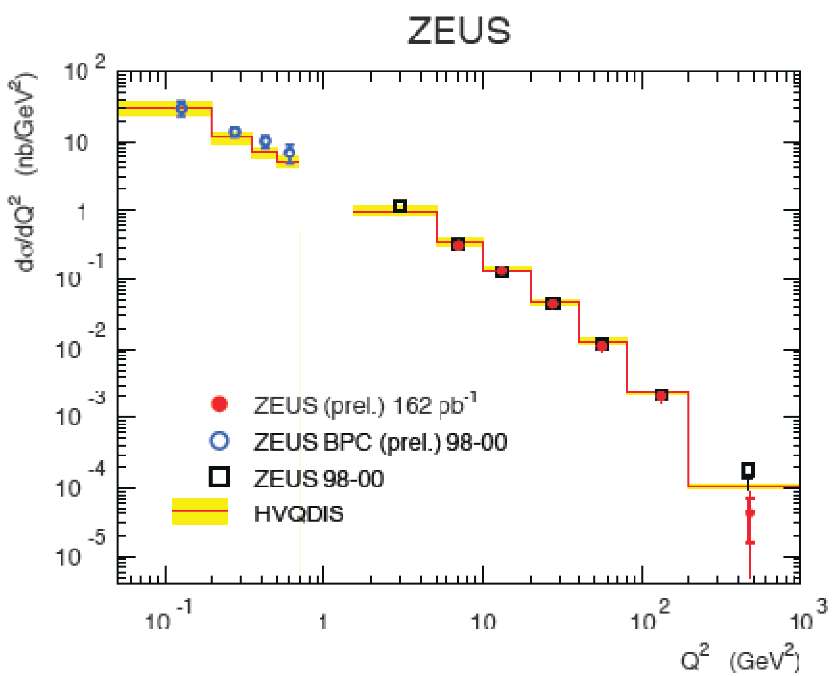
# HERA

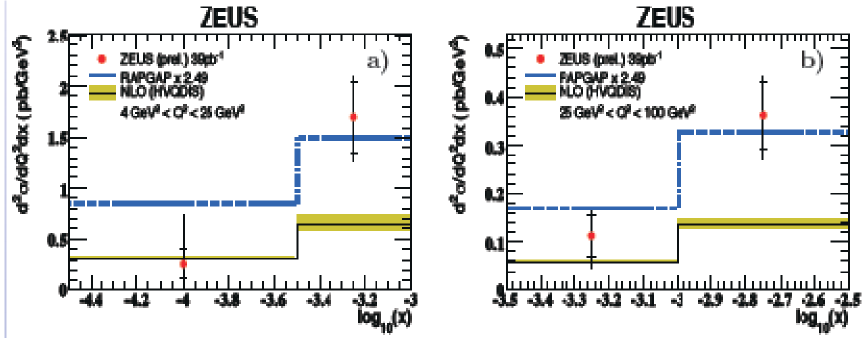
**new scale**
$\mu_0 \to \mu_0/2$

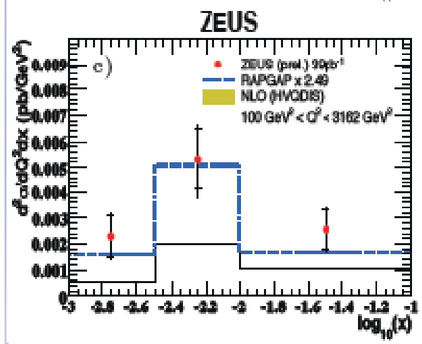



thanks to E. Nuncio-Quiroz

***…and new recipe may also apply in numerous other places***




visible range:

- $Q^2 > 4\ GeV^2$
- $0.05 < y < 0.7$
- $p^{\mu} > 1.5\ GeV$
- $\eta^{\mu} > -1.6$
- $E_t^{jet} > 5\ GeV$
- $-2 < \eta^{jet} < 2.5$

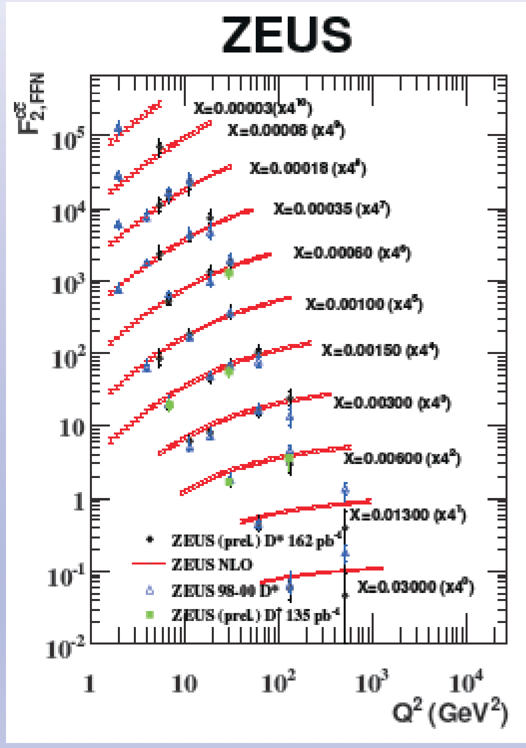
**Charm:**

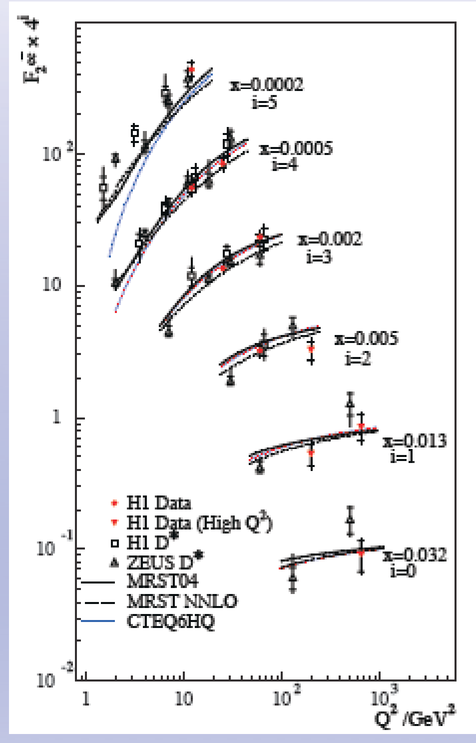
- good description achieved
- some deviations are seen (Forward low $p_t$)

**Beauty:**

- reasonable agreement between data and theory
- data tends to be higher than theory

# $F_2^{cc}$ from H1 & ZEUS



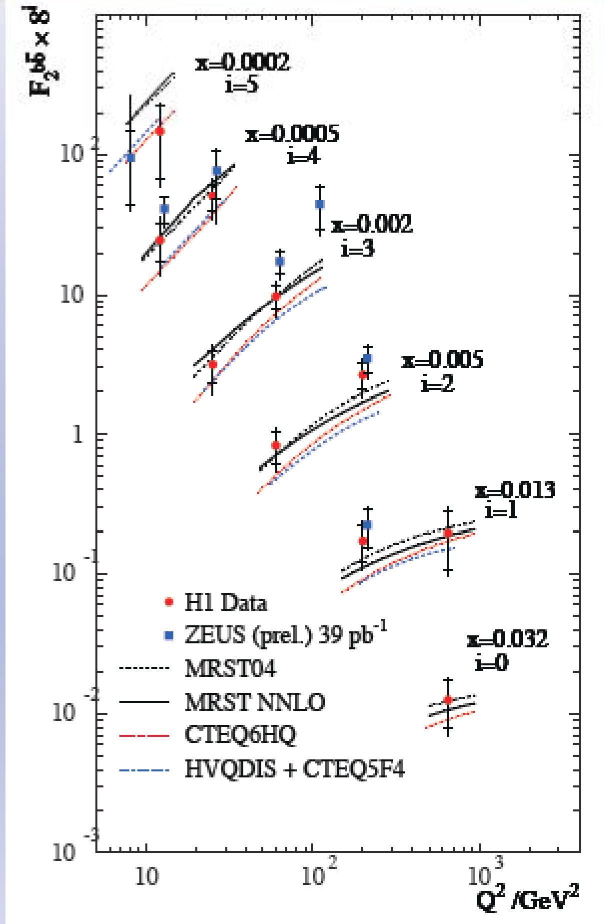




- good agreement between the different measurements
- scaling violations clearly visible

- Differences caused by matching procedure of **massive** and **massless** calculations
- high precision data → able to distinguish between predictions

# $F_2^{bb}$ Results

- first measurements of $F_2^{bb}$
- statistical error dominates,
- but more data is coming (factor of 5-10 more)
- data not yet decisive
- predictions differ up to a factor 2

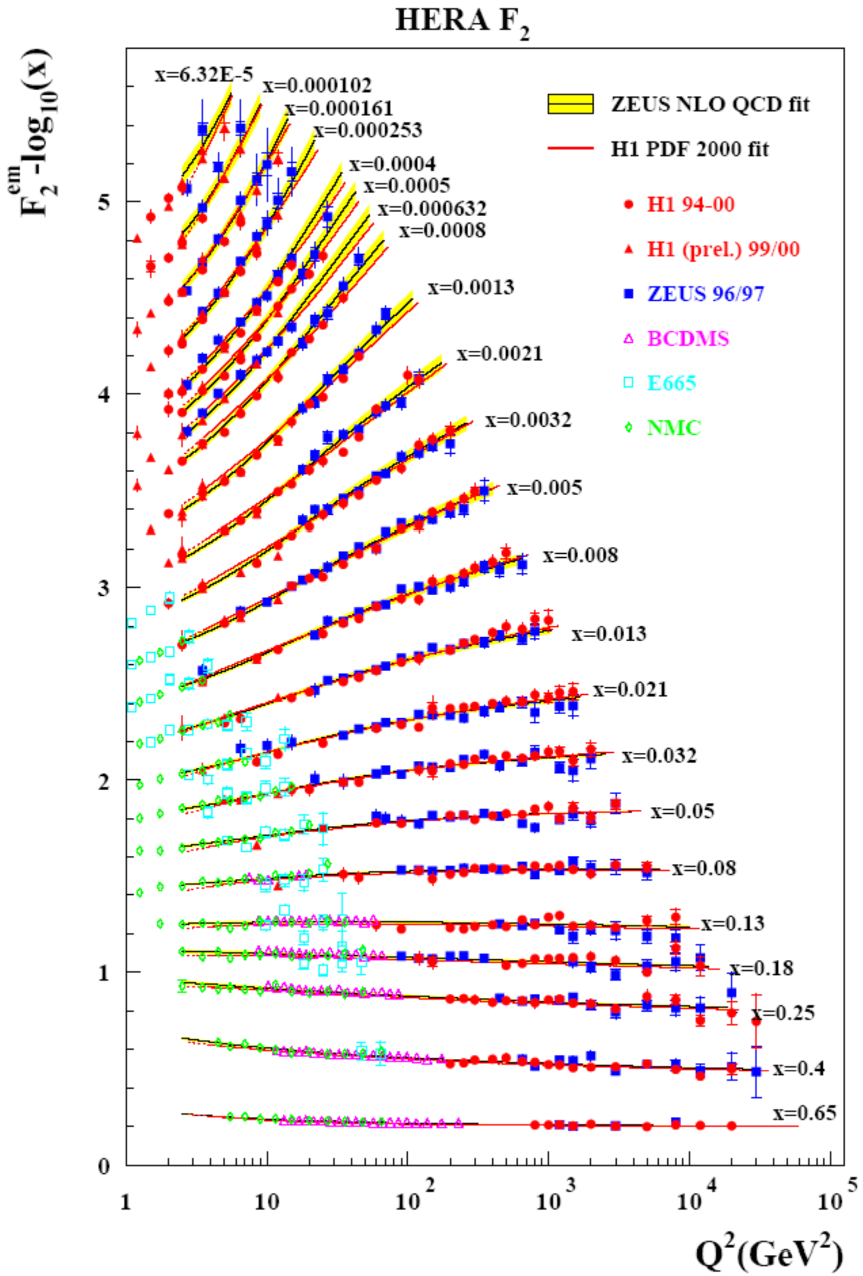


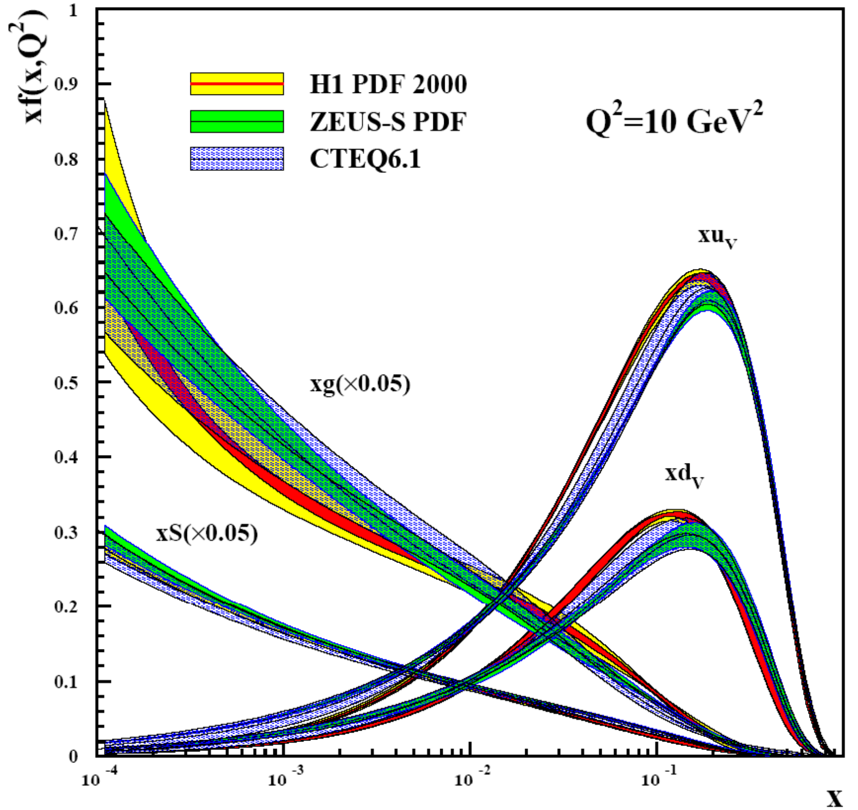

Marc-Oliver Bönig, Universität Dortmund 21 Photon 07, 11.07.2007

## Proton Structure:

## …not at all the end of a (H)era

E. Perez

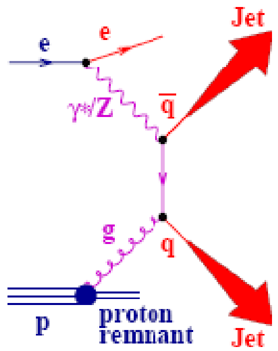


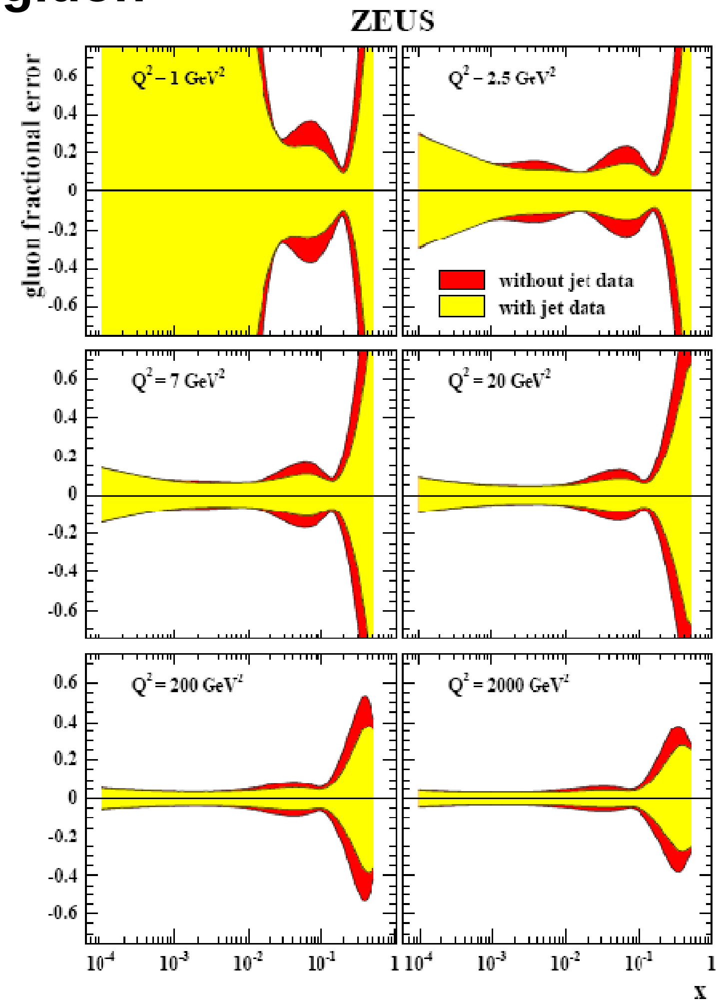




**Many measurements now incorporated into fits. See talk for details. A couple that were talked about here…**

Jimenez

# HERA jet data has reduced the gluon uncertainty …

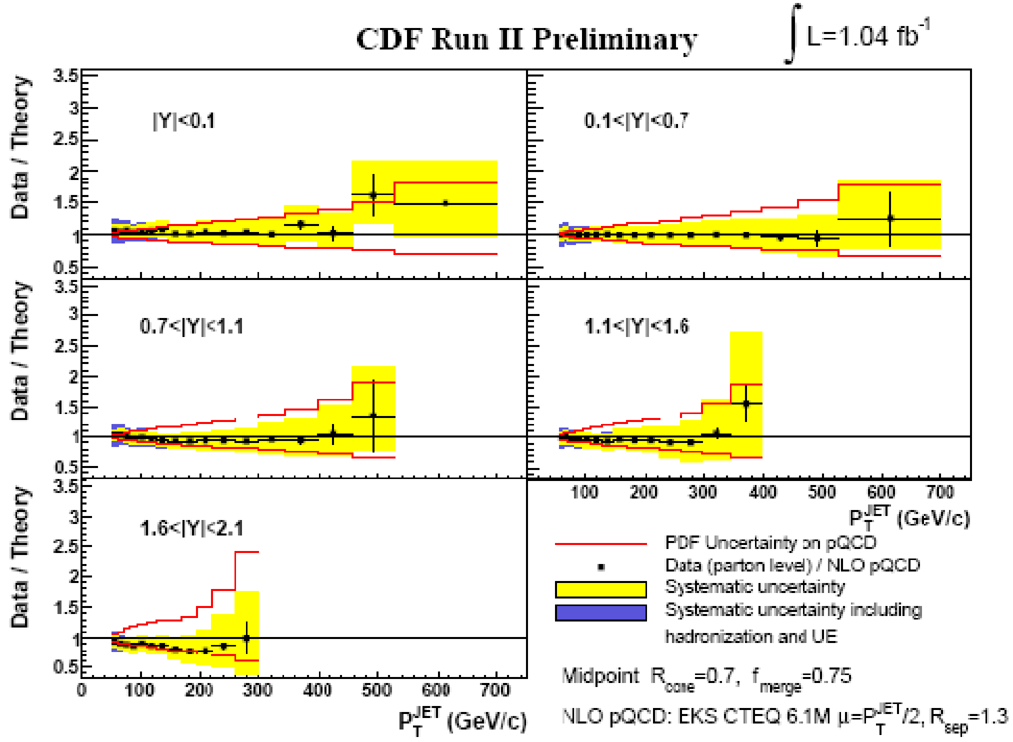


# Constraints from Tevatron Data

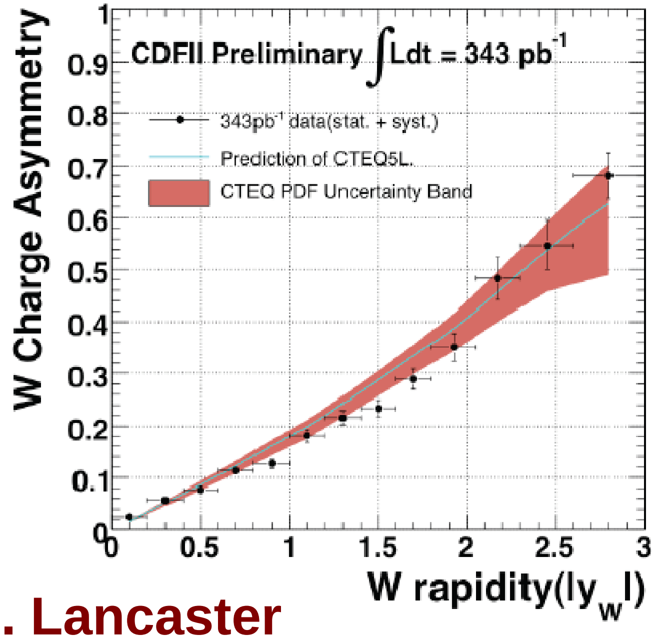
A. Kupco

## e.g. from inclusive High $p_t$ jets




- errors are comparable with PDF uncertainty

## …and W,Z

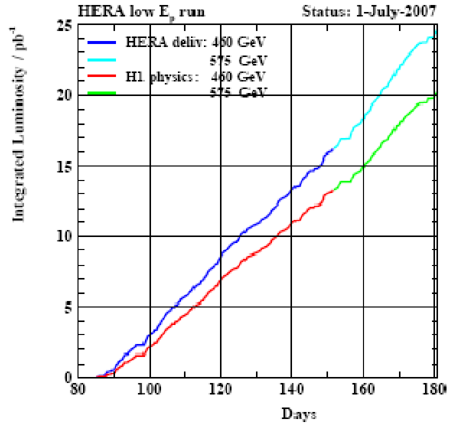



## N.B. x10 statistics to come

M. Lancaster

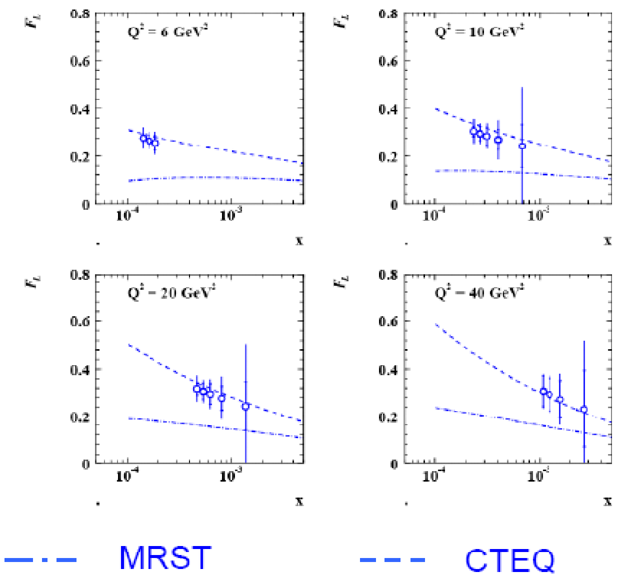
## $F_L$ to come shortly

## Alexey Petrukhin

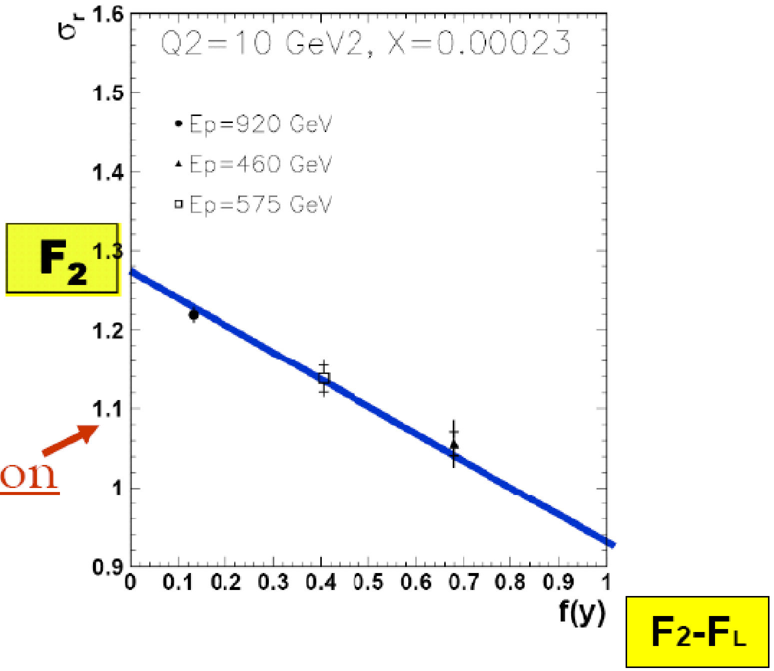



- HERA structure function measurement program will be completed by measuring of $F_L$
- Direct measurement of $F_L$ can be performed only by measuring cross section for the same $Q^2$-x but with different proton beam energies (different y):

$$\sigma_r = F_2 - f(y)F_L$$

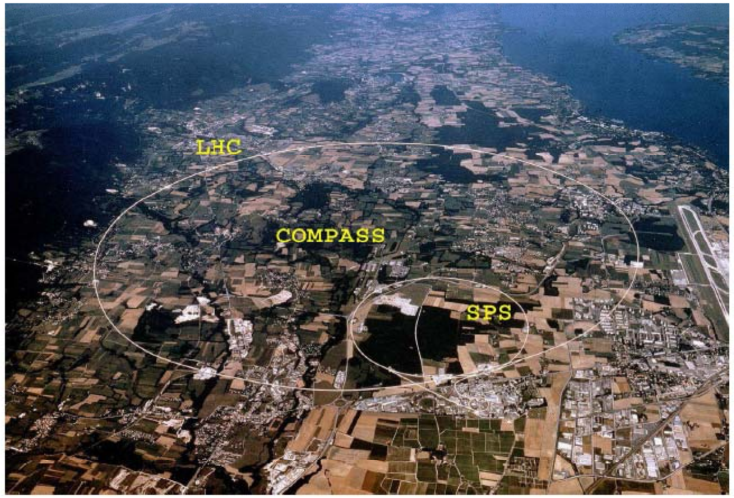



simulation



## And there's beautiful data on the spin dependent structure functions…

COMPASS @ CERN




**Talks from M.Stolarski, D. Reggiani, C; Schill**

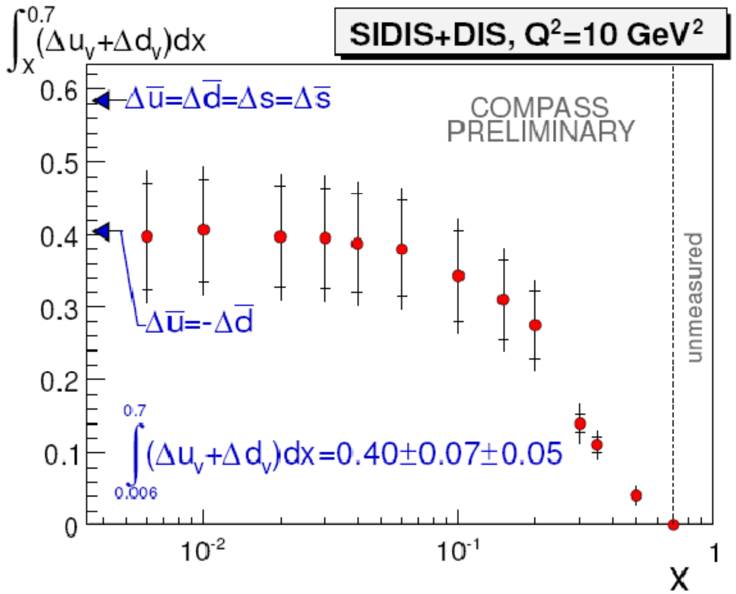
- gluon polarization
- spin dependent structure function
- polarized quark distributions
- transversity

**e.g.**

Handle on polarised sea

Non-symmetric favoured

### Calculation of $\Gamma_v$



# Finally…

## Where's the virtual photon structure?

**Paris 21 years ago!**

- 158 -

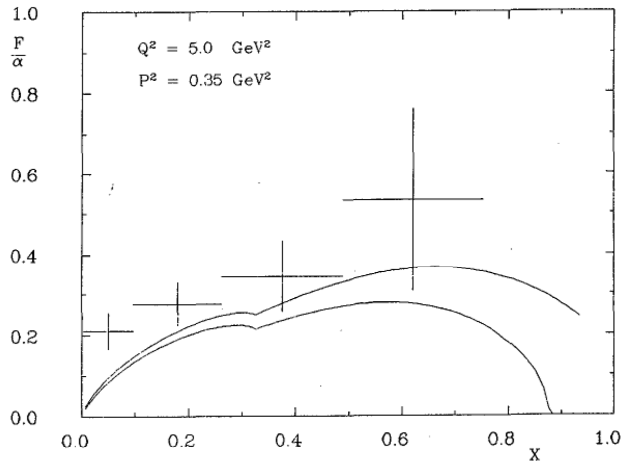
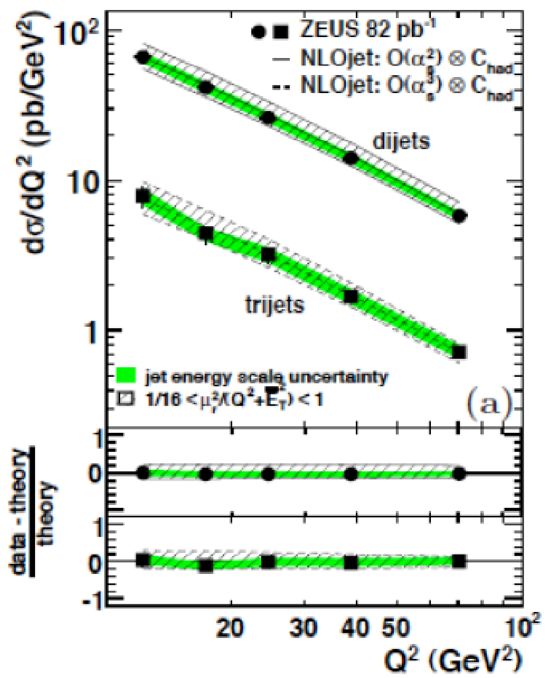



Figure 7.2: $F/\alpha$ for $Q^2$=5 GeV$^2$ and $P^2$=0.35 GeV$^2$ plotted vs. x. The curves are the QPM predictions for $F(x)/\alpha$. The upper curve is for massless u,d and s quarks and the c quark with constituent mass. In the lower curve all four quarks have constituent masses. (See text.) The points with error bars are the unfolded data.

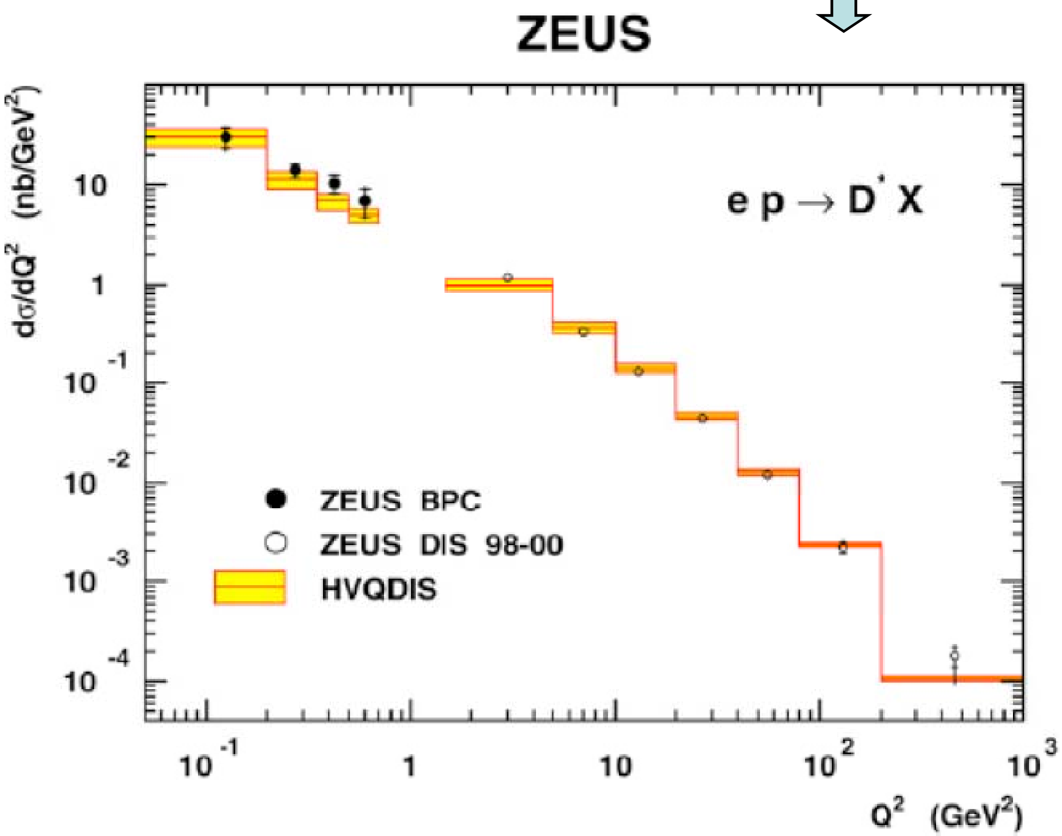
## Resolved $\gamma^*$ and NLO QCD

G. Grindhammer

**NLO predictions generally do well in DIS:**

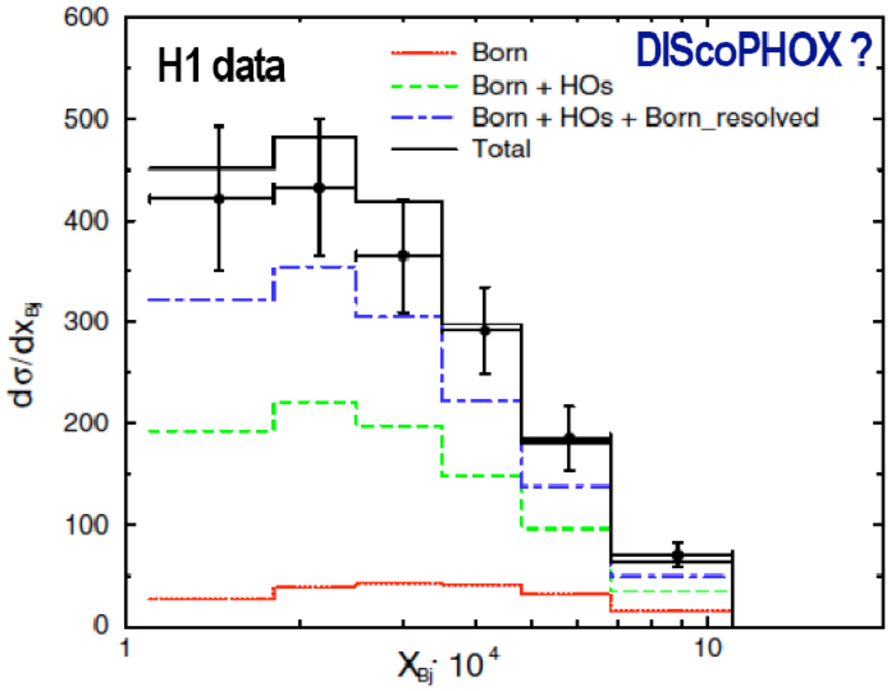



**Or where another hard scale**



# Forward $\pi_0$ production

- H1: EPJ C 36, 441 (2004); 21pb-1
  - $4.5 (2) < Q^2 < 15 (70)$ GeV$^2$
  - $0.1 < y < 0.6$
  - $5° < \theta_\pi < 25°$
  - $x_\pi > 0.1$
  - $E^*_{T,\pi} > 2.5$ GeV
- NLO calc. by Fontannaz
  - includes virtual photon struct. in NLO
  - CTEQ6M, $\gamma^*$ PDF also by Fontannaz
  - all scales = $\mu^2 = E^{*2}_{T,\pi} + Q^2$
  - Kniehl, Kramer, Pötter frag. function



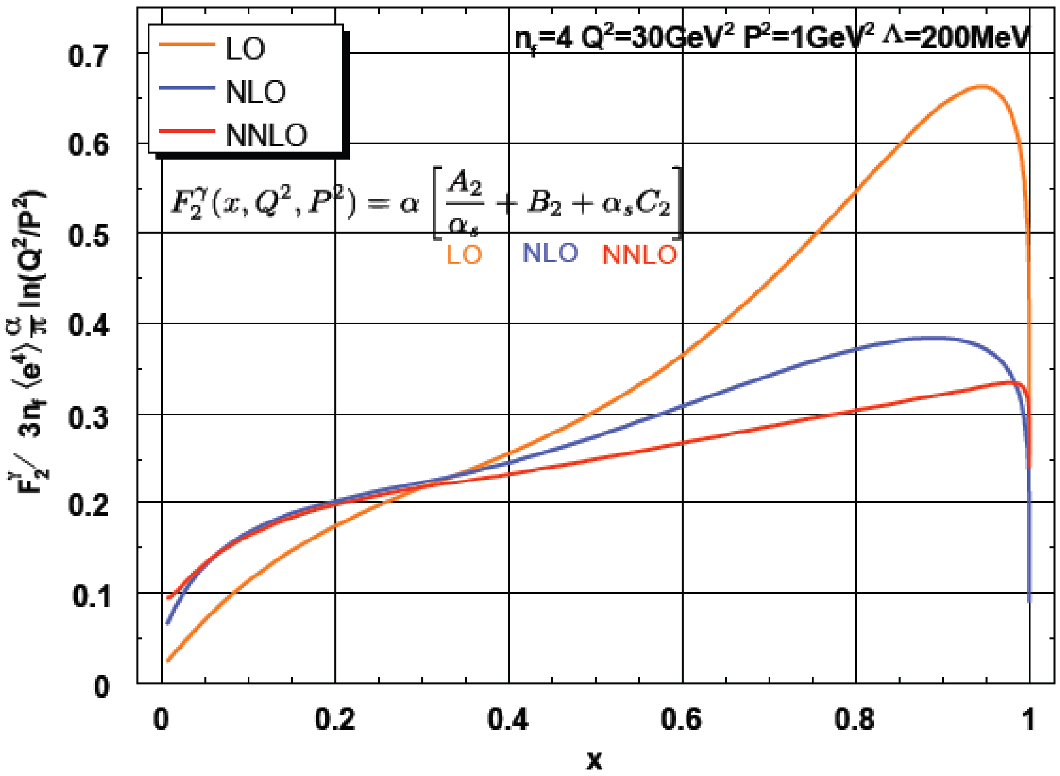

NLO from Aurenche et al., EPJ C 42, 43 (2005)

☞ good description of the data
☞ all corrections LO dir to NLO dir, LO resolved to NLO resolved are large (at least for the chosen scale)

**…but generally situation complicated:**

**HO, $k_T$ factorisation etc. Scale choice etc.**

## …and meanwhile Ken Sasaki and colaborators have been busy!



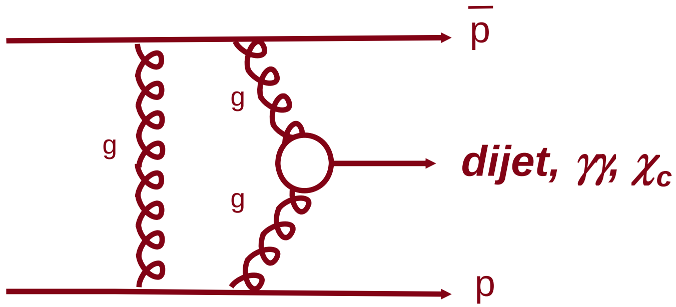

**Maybe have to wait for ILC**

# Conclusions

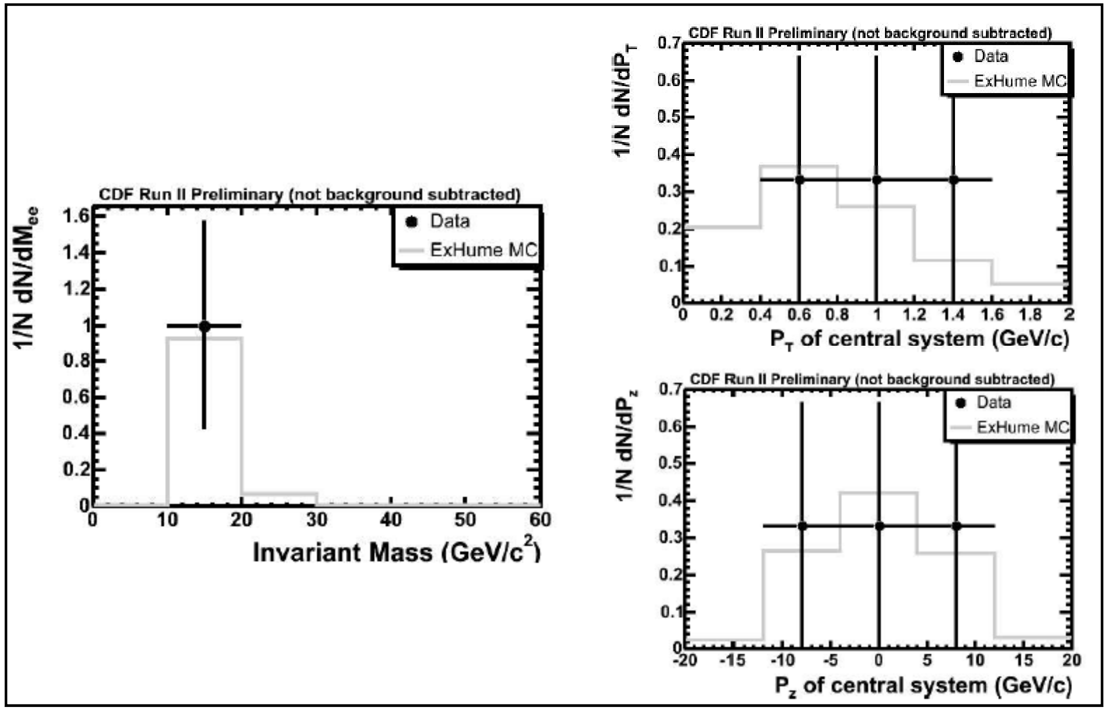
## …don't always need a lot of or in events for a significant result…

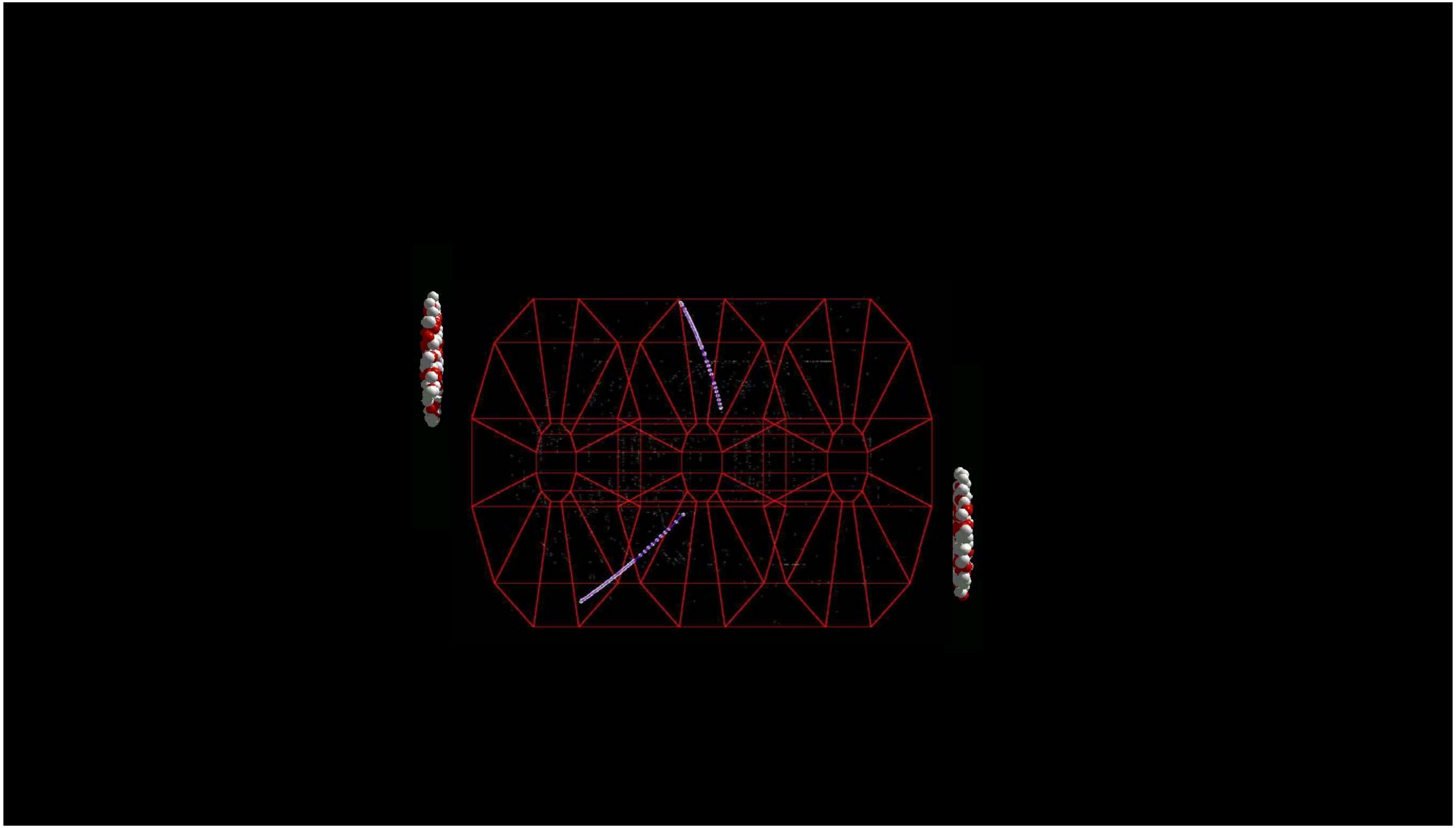
**CDF** **J. Pinfold**

# Exclusive γγ Study




"standard candle"
For exclusive Higgs production





Nicked from Guenter