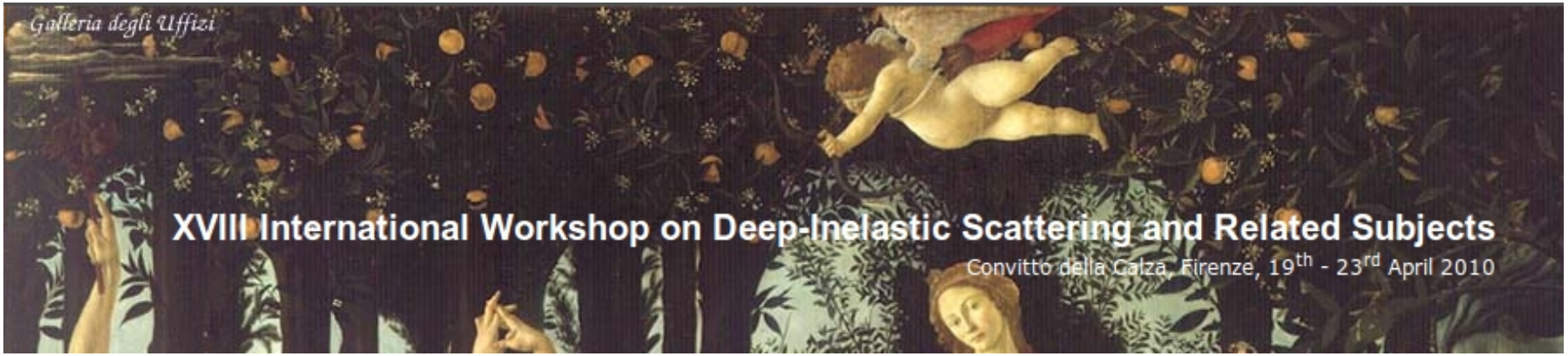
Summary of Small-x, Diffraction and VM Working Group (experimental part)

Robert Ciesielski



Overview (25 experimental talks)

- Diffractive electroproduction of rho and phi mesons at H1 (Xavier Janssen)
- Measurement of J/Psi photoproduction at high-t (Alessia Bruni)
- Direct extraction of helicity amplitude ratios on exclusive rho electroprod. at HERMES (Sergey Manaenkov)
- DVCS and its Beam Charge Assymmetry in e+-p Collissions at H1 (Laurent Favart)
- Deep exclusive reactions at Jefferson Lab Hall A (Carlos Munoz Camacho)
- Diffractive PDF fits at ZEUS (Matthew Wing, Aharon Levy)
- Measurement of Inclusive Diffractive DIS and of the Longitudinal diffractive structure function at H1 (Paul Laycock)
- H1 Measurement of Diffractive DIS with Leading Proton at HERA-II (Mikhail Kapishin)
- Operation, performance of the VFPS and Measurement of inclusive diffractive DIS (Tomas Hreus)
- Measurement of Leading Neutron Production in DIS at H1 (Armen Bunyatyan)
- Diffractive jets at H1 (Richard Polifka)

Overview (25 experimental talks)

- Evidence for high mass exclusive dijet production in the D0 experiment (Zdenek Hubacek)
- Measurement of the elastic ppbar differential cross section in the range 0.25<|t|<1.2 and sqrt(s)=1.96 TeV (Andrew Brandt)
- Diffraction results from CDF (Joey Huston)
- Exclusive production in CMS at LHC (Nicolas Schul)
- Measurement of the transverse energy flow in a large eta range and forward jets in CMS at LHC at sqrt(s) = 900 and 2360 GeV (Sercan Sen)
- Status of the ATLAS forward detectors (Andrew Brandt)
- An overview of the ATLAS forward physics program (Christophe Royon)
- Status of TOTEM (Hubert Niewiadomski)
- Luminosity measurement with LHCb (Dermot Anthony Moran)
- The status and preliminary results of the LHC forward experiment: LHCf (Hiroaki Menjo)
- Diffractive physics program with tagged forward protons at STAR/RHIC (J.H. Lee)
- Search for gluon Saturation with the PHENIX Experiment in d+Au Collisions at RHIC (Beau Meredith)
- Quarkonia in dAu and vector mesons at forward rapidity at Phenix (Kwangbok Lee)
- Property of QCD from the nuclear medium, results on color transparency at CLAS (William Brooks)

Diffractive electroproduction of ρ and ϕ mesons at HERA

Xavier Janssen

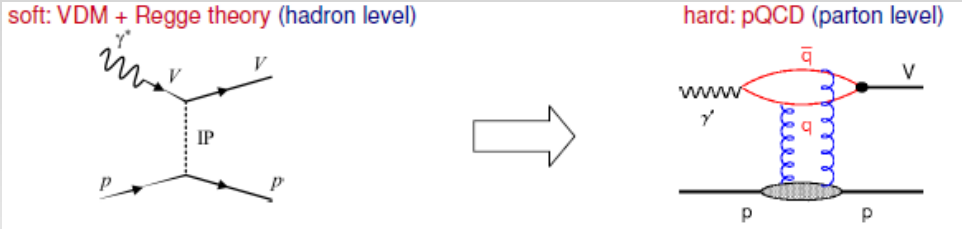
$2.5 < Q^2 < 60$ GeV^2

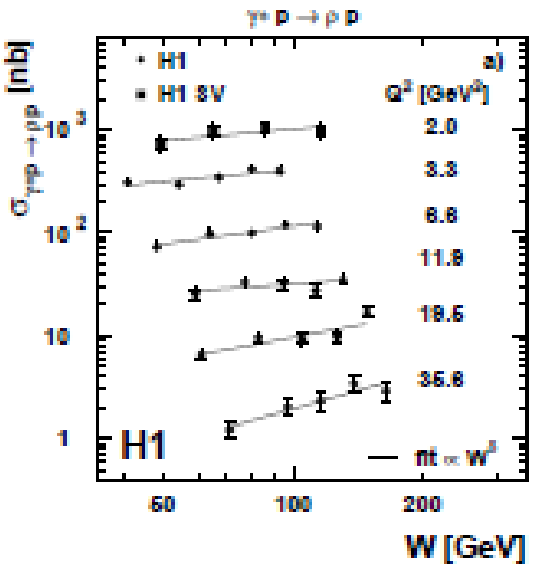
$35 < W < 180$ GeV

elastic: $|t| < 0.5$ GeV^2

p diss.: $|t| < 3$ GeV^2

$M_Y < 5$ GeV





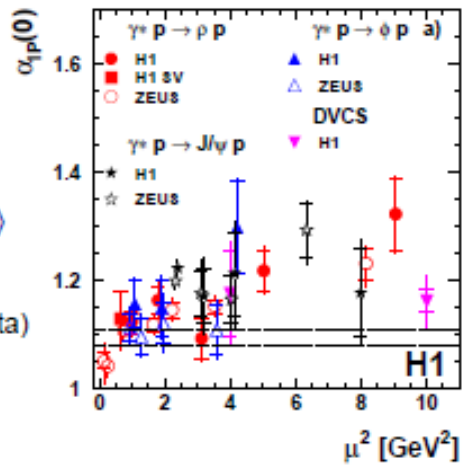
Soft to hard transition - $\sigma(W)$

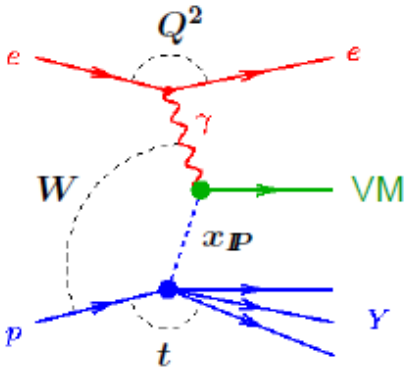
$\sigma(W) \propto W^{\delta}$

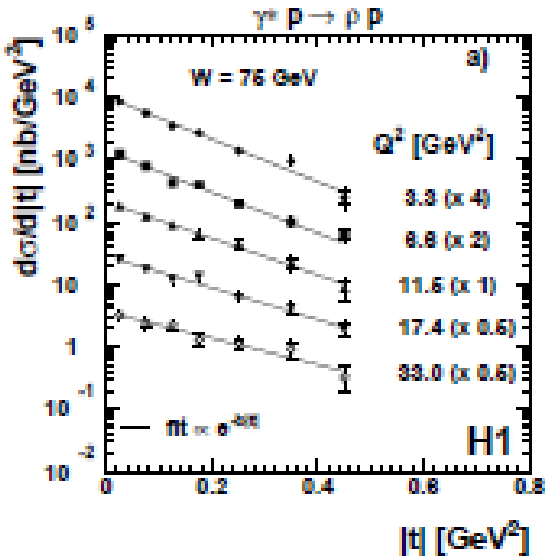
$\alpha_{\mathbb{P}}(0) = 1 + \delta/4 + \alpha'_{\mathbb{P}}/\langle|t|\rangle$

$\alpha'_{\mathbb{P}}$: 0-0.25 (→data)

$\langle|t|\rangle$: b-slopes (→data)





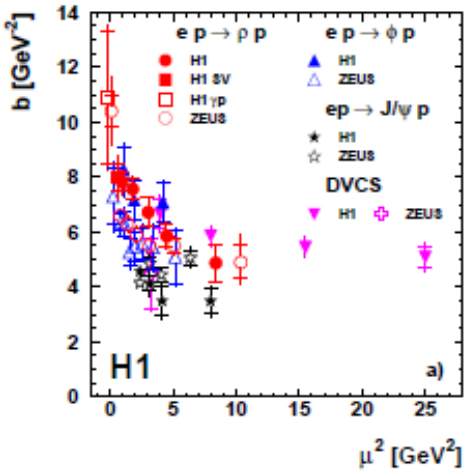


Soft to hard transition - t dependence

fit $e^{-b|t|}$

$b = b_p \otimes b_{q\bar{q}} \otimes b_{\mathbb{P}}$

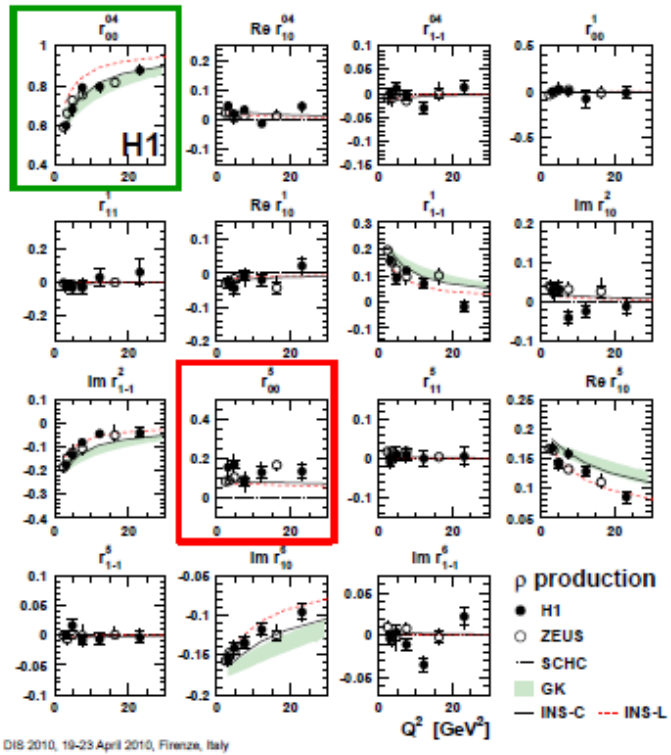
→ $b \propto q\bar{q}$ dipole size



Diffractive electroproduction of ρ and ϕ mesons at HERA

Xavier Janssen

ρ Polarisation - SDMEs vs. Q^2



- r^{04}_{00} increases with Q^2
  ↔ similar effects for r^1_{1-1}, Im r^2_{1-1}, Re r^5_{10} and Im r^6_{10} (in SCHC)
  ↔ Fair description by GK (GPD) model
- r^5_{00} violates SCHC
- Other SDME $\simeq 0$

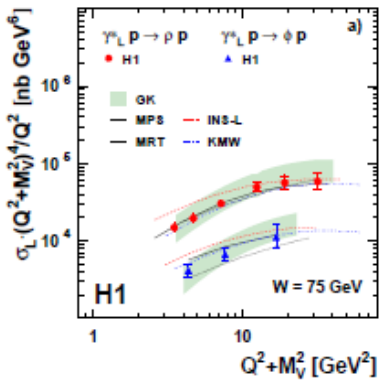
DIS 2010, 19-23 April 2010, Firenze, Italy

Xavier Janssen – p. 11

ρ and ϕ Polarisation - Cross-sections

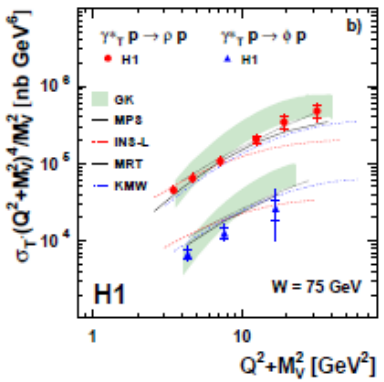
Longitudinal

$\sigma_L \propto \frac{Q^2/M_V^2}{(Q^2+M_V^2)^4}\,[\alpha_s(\mu^2)\,G(x,\mu^2)]^2$



Transverse

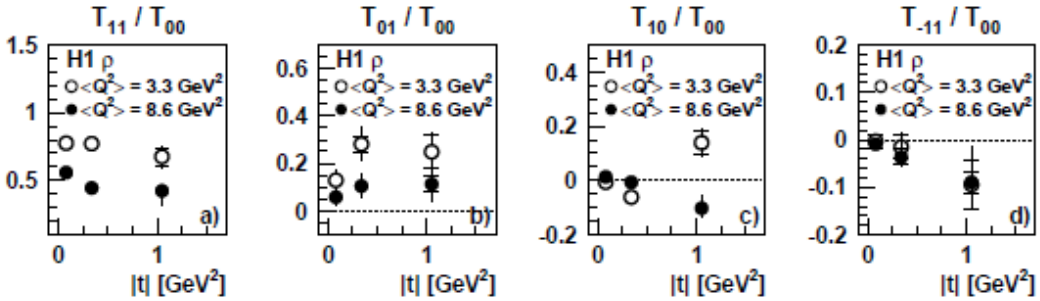
$\sigma_T \propto \frac{1}{(Q^2+M_V^2)^4}\,[\alpha_s(\mu^2)\,G(x,\mu^2)]^2$



Polarisation - Amplitude ratios vs. $|t|$

pQCD (IK): • $T_{11}/T_{00} \propto \frac{M}{Q}\,\frac{1+\gamma}{\gamma}$ • $T_{10}/T_{00} \propto -\frac{M\sqrt{|t|}}{Q^2}\,\frac{\sqrt{2}}{\gamma}$

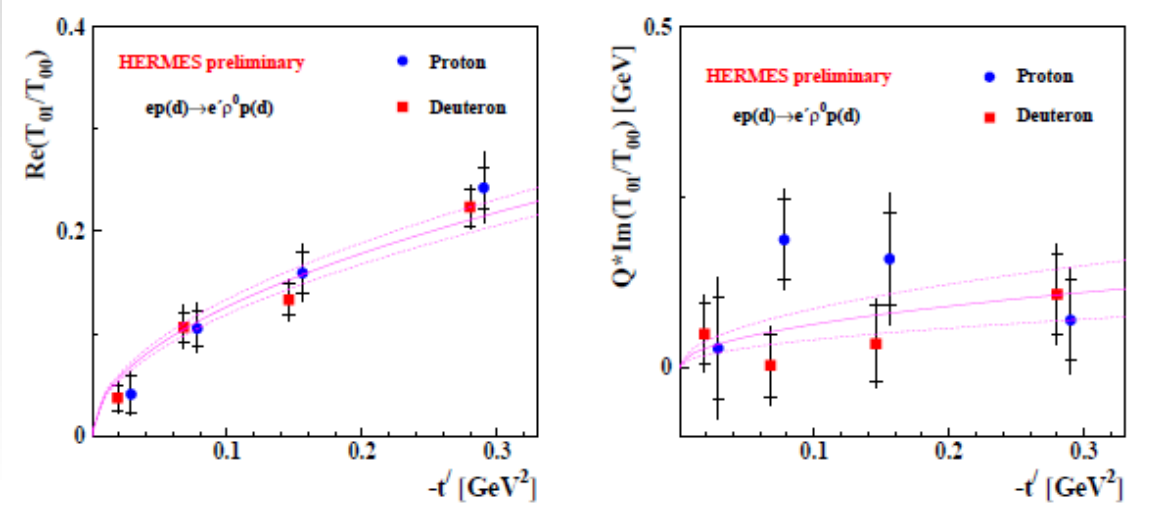
• $T_{01}/T_{00} \propto \frac{\sqrt{|t|}}{Q}\,\frac{1}{\sqrt{2}\gamma}$ γ : gluon anomalous dim.

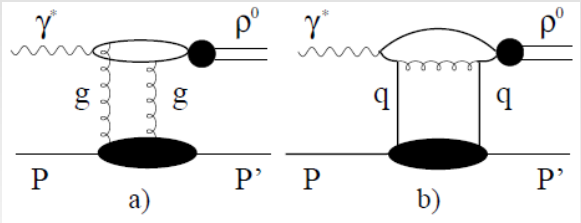


Direct Extraction of Helicity Amplitude Ratios on Exclusive ρ^0 Electroproduction

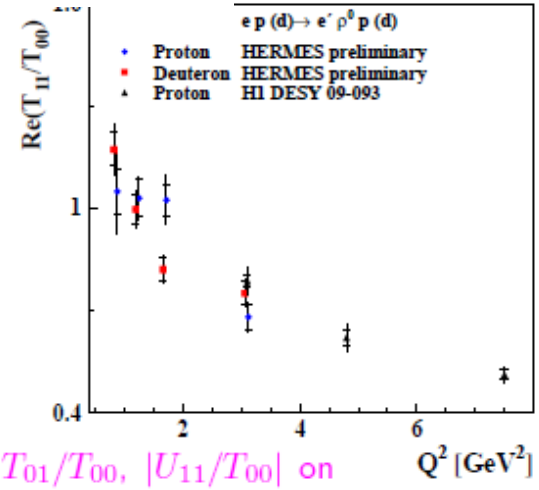
Sergey Manaenkov

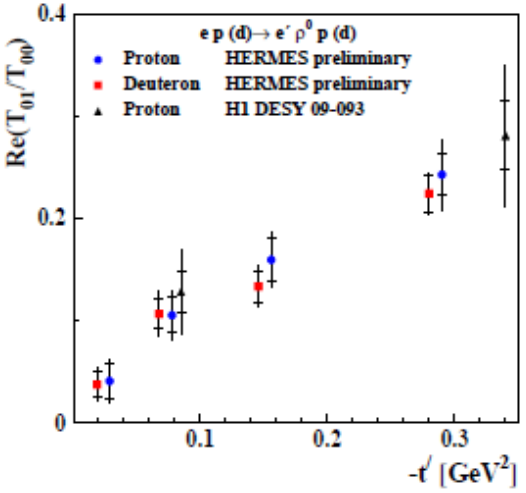
- H1: Unpolarized beam and unpolarized target (15 SDMEs), $< Q^2 >= 3.3$ GeV^2.
- HERMES: Longitudinally polarized beam and unpolarized target (23 SDMEs).





- $W = 3.0 \div 6.5$ GeV,
- $Q^2 = 0.5 \div 7.0$ GeV^2,
- $x_B = 0.01 \div 0.35$,
- $0 \leq -t' \leq 0.4$ GeV^2,



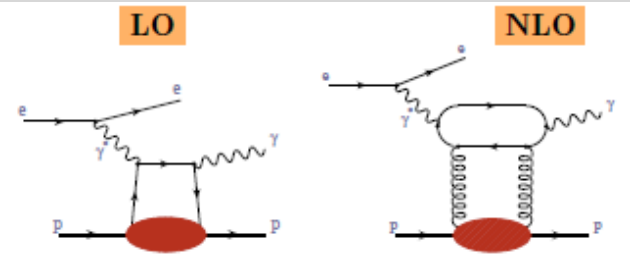


- Dependences of the most reliably obtained ratios T_{11}/T_{00}, T_{01}/T_{00}, $|U_{11}/T_{00}|$ on Q^2 and t' is studied. The observed dependences of $\mathrm{Im}(\mathrm{T}_{11}/\mathrm{T}_{00})$ and $|U_{11}/T_{00}|$ are in contradiction with high-Q asymptotic behaviour predicted in pQCD while dependences of $\mathrm{Re}(\mathrm{T}_{11}/\mathrm{T}_{00})$ and $\mathrm{Im}(\mathrm{T}_{01}/\mathrm{T}_{00})$ are in agreement with pQCD prediction.
- No statistically significant difference between proton and deuteron results for amplitude ratios T_{11}/T_{00}, T_{01}/T_{00}, $|U_{11}/T_{00}|$ is found.

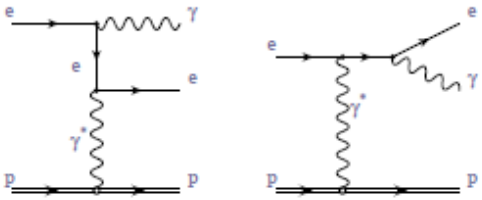
Deeply Virtual Compton Scattering and its Beam Charge Asymmetry in $e^{\pm}p$ collisions at HERA

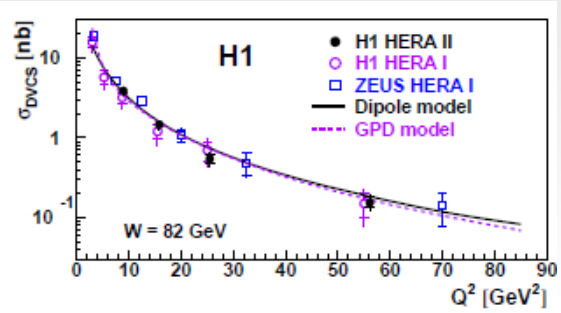
Laurent Favart

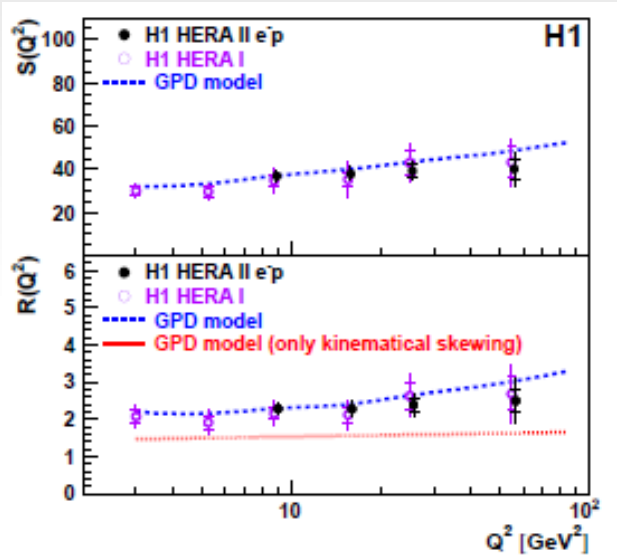
Data $e^{\pm}p$ HERA II - 2004-07

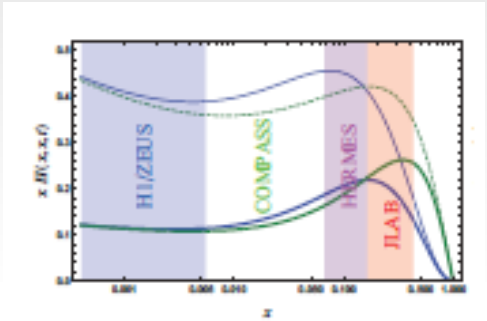


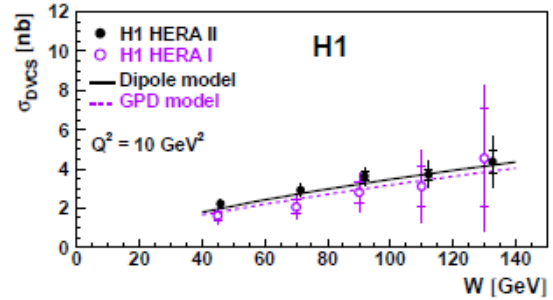
- Sensitivity to GPD (gluons, saturation?)
- Bethe-Heitler Process (Background + Interference)
- $\sigma_{DVCS} \simeq \sigma_{BH} \Rightarrow$ DVCS cross section measurement and high interference term sensitivity (asymmetry measurements)





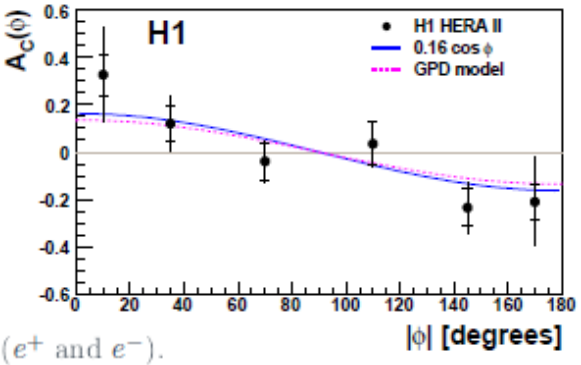






Beam Charge Asymmetry

First BCA measured at HERA: based on HERA II data (e^+ and e^-).



$$BCA \equiv \frac{\sigma(e^+p) - \sigma(e^-p)}{\sigma(e^+p) + \sigma(e^-p)}$$

$$\sim p_1 cos(\Phi)$$

$$p_1 = 0.16 \pm 0.04 \pm 0.06$$

$$p_1 = 2A_{BH}\frac{\mathrm{Re}A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2}$$

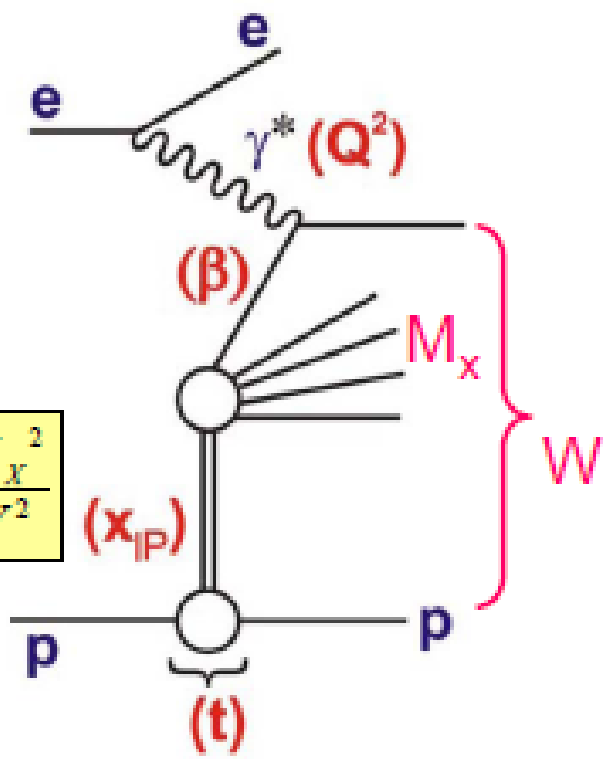
Diffractive DIS

Momentum fraction of color singlet carried by struck quark

$$\beta = \frac{x}{x_{IP}} \approx \frac{Q^2}{Q^2 + M_X^{\,2}}$$

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_X^{\,2}}{Q^2 + W^2}$$

Momentum fraction of proton carried by colour singlet exchange

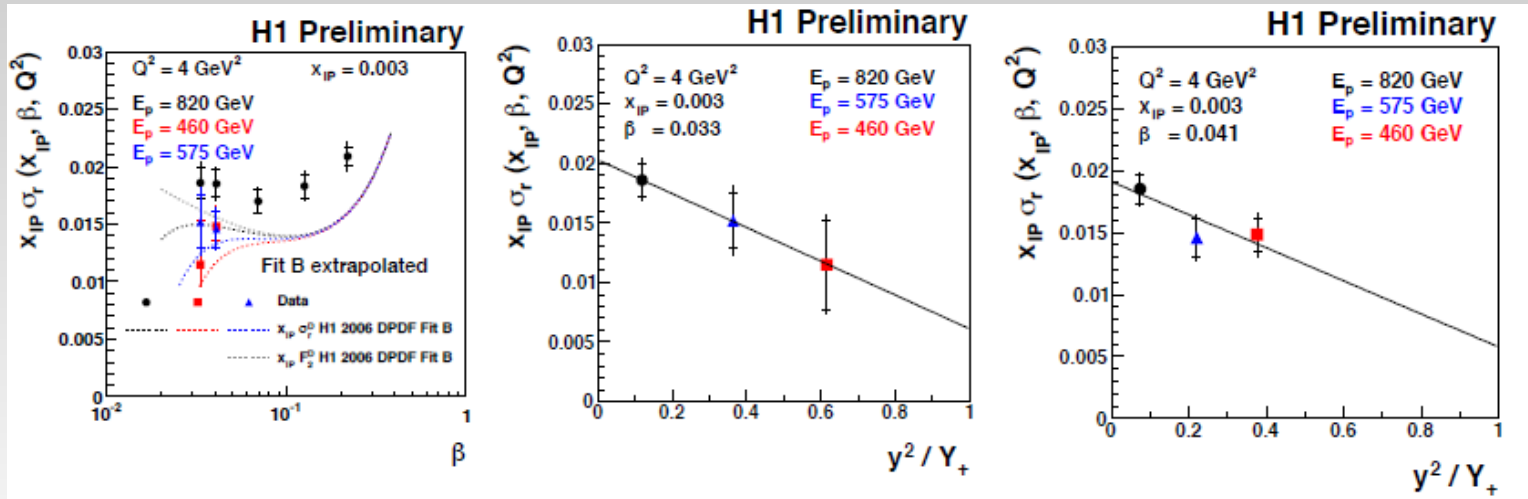


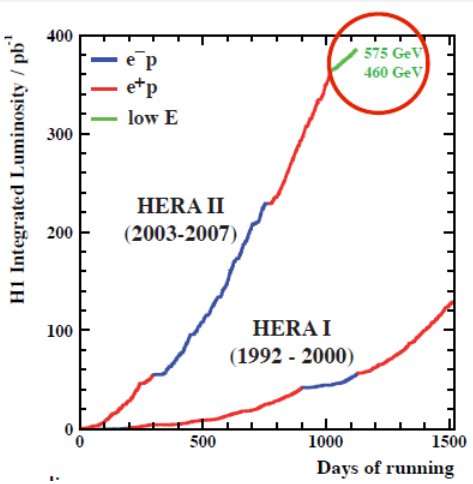
F_L^D

Paul Laycock

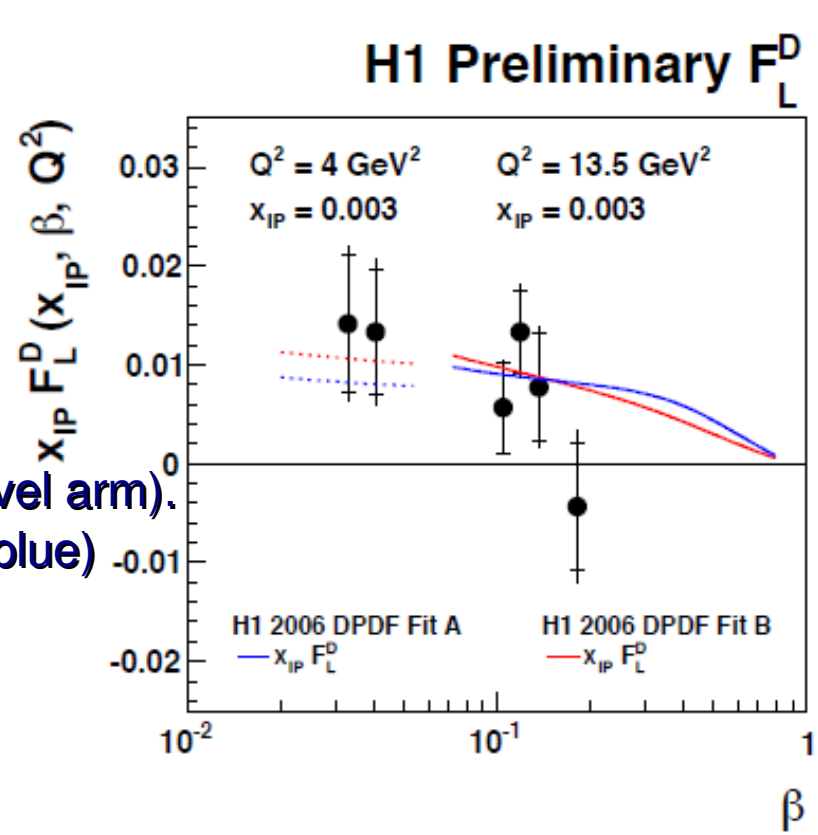
$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$

$$Y_+ = 1 + (1-y)^2$$





$$Q^2 = sxy$$

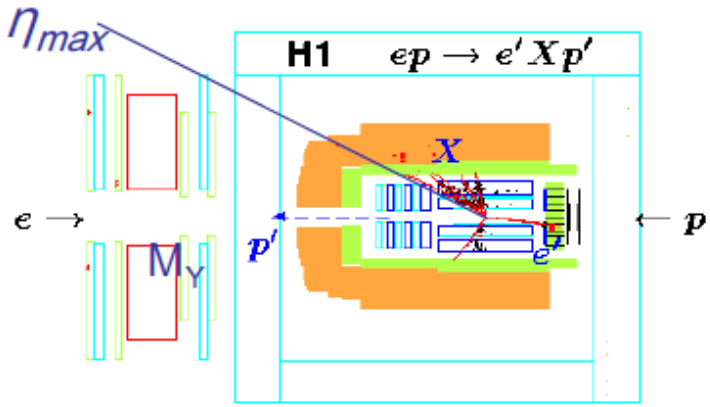


- Extend previous measurement down to Q^2=2.5 GeV^2.
- Measure cross sections at fixed x, Q^2 and different y (level arm).
- The low (E_p=460 GeV, red) and medium (E_p=575 GeV, blue) energy runs are used. The lowest y points (black) from published data with Ep=820 GeV.

New H1 measurements with HERA-II data using: (1) LRG, (2) FPS, (3) VFPS

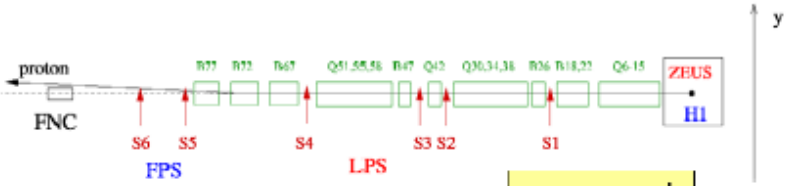
Selection of diffraction at HERA

Large rapidity gap (LRG) between leading proton p' and X



- high statistics, data integrated over $|t|<1\,\mathrm{GeV}^2$
- p-dissociation contribution
- limited by systematic uncertainties related to missing proton

Forward Proton Spectrometer H1 FPS



+ ZEUS LPS
+ H1 VFPS

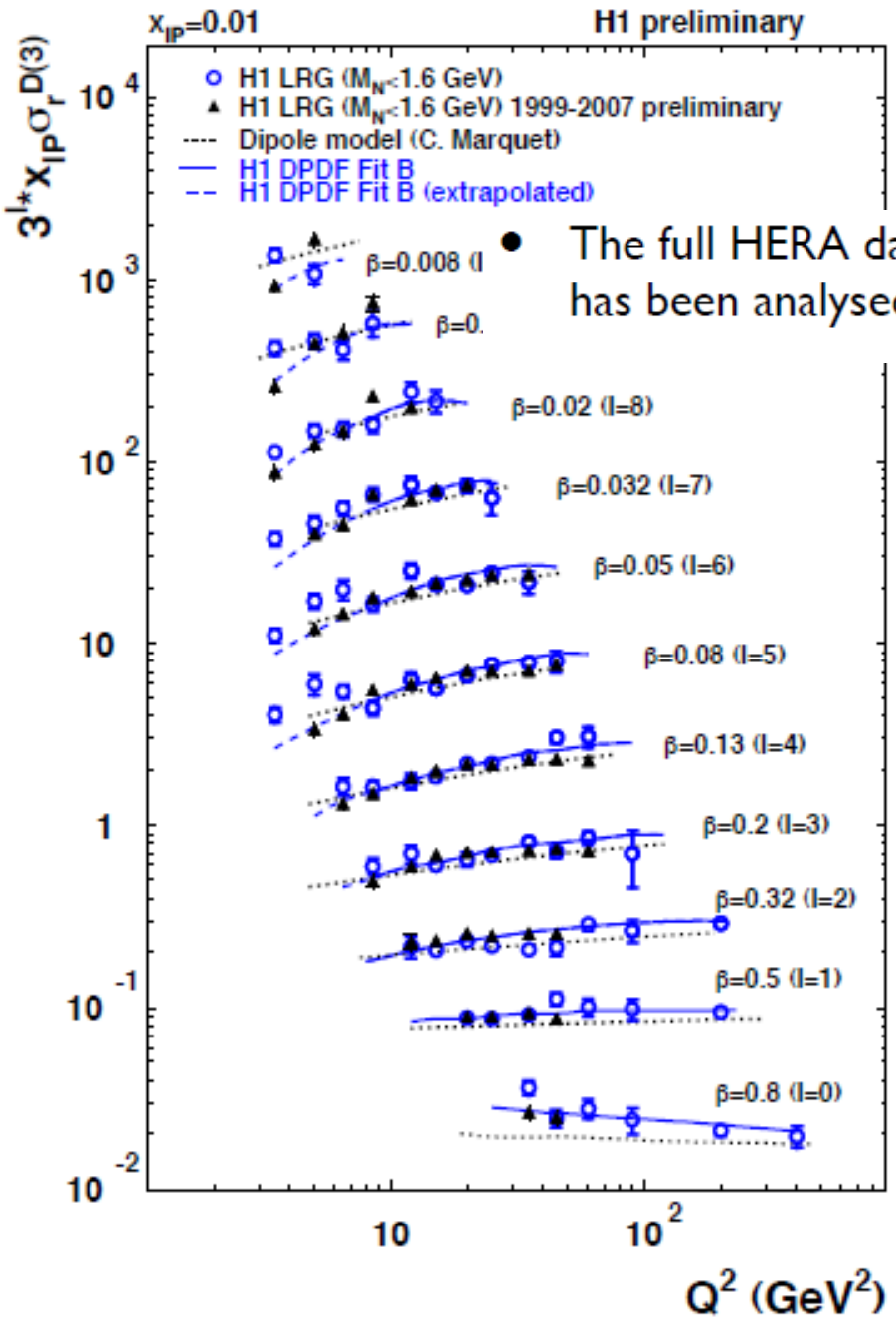
$$x_{IP} = 1 - \frac{E'_p}{E_p}$$

- free of p-dissociation background
- x_{IP} and t-measurements
- access to high x_{IP} range (IP+IR)
- low geometrical acceptance
  - H1 VFPS has high acceptance (see talk of Tomas Hreus)

➔ LRG and FPS methods have different systematic uncertainties

(1) LRG method σ_r^D at fixed x_{IP}

Paul Laycock



- The full HERA data sample, including both HERA I and HERA II datasets, has been analysed in order to measure σ_r^D to the best precision possible

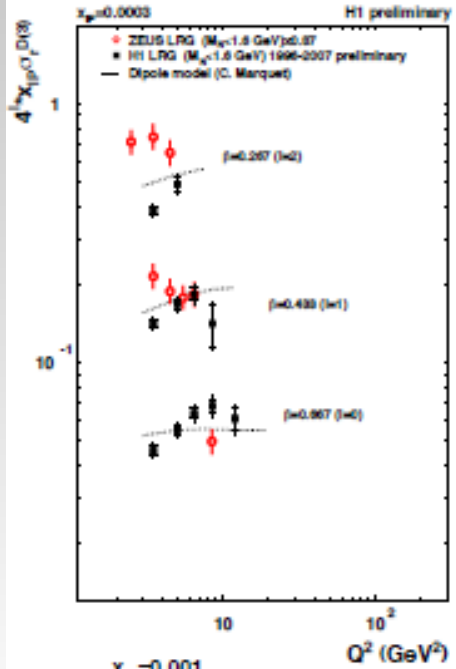
- The larger dataset allow a more precise extraction of the reduced cross section compared to the published data

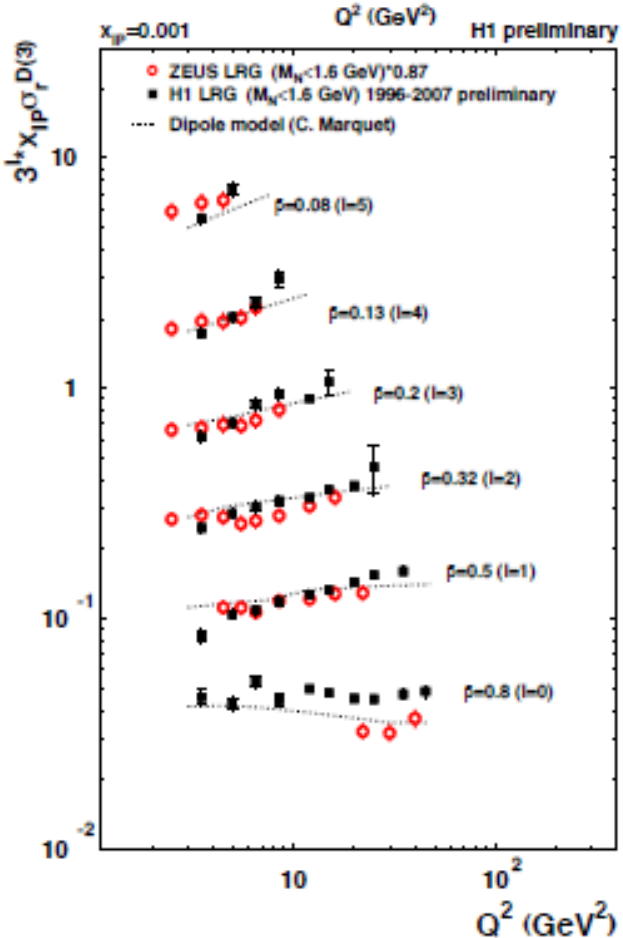
- The new H1 LRG data has been combined with the published data to create

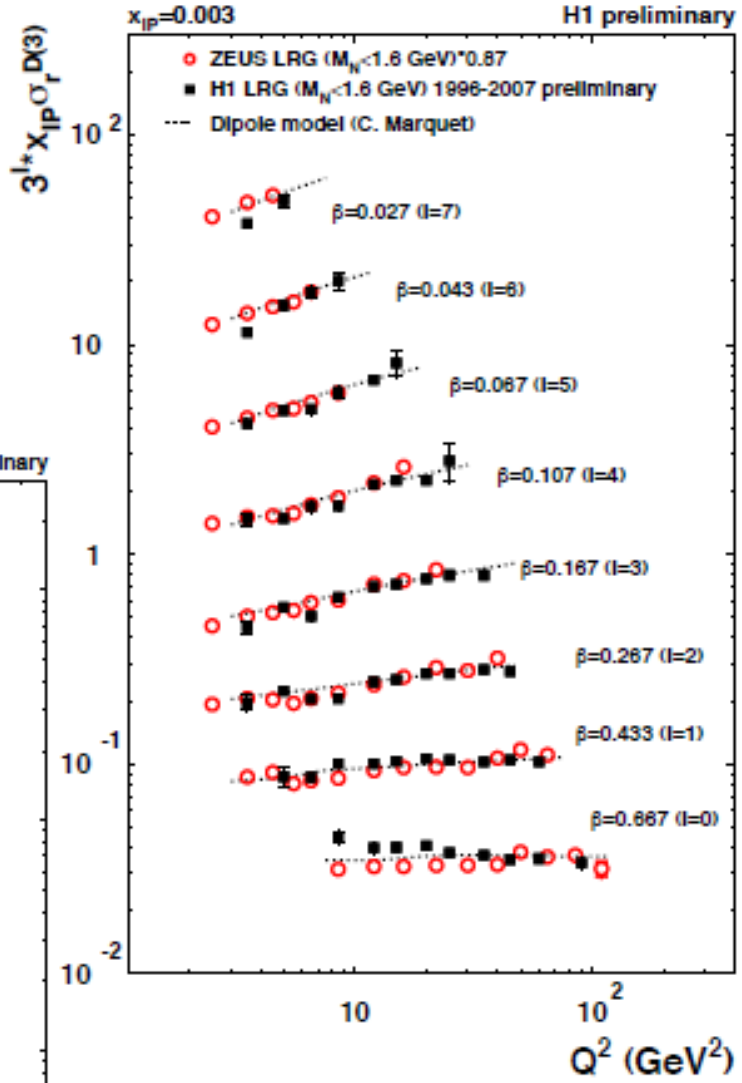
  one combined H1 LRG dataset

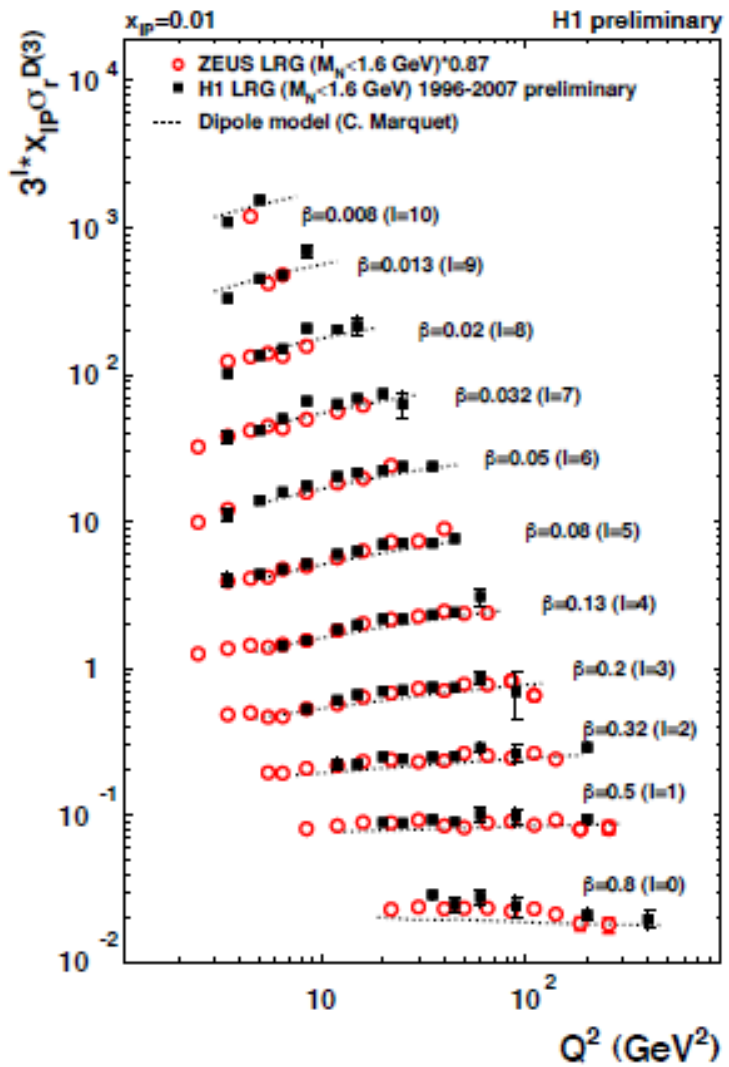
σ_r^D at fixed x_{IP} H1 and Zeus

Paul Laycock









Good agreement between two high precision measurements

Next step: Combination of H1+ZEUS results?

(2) Forward Proton Spectrometer

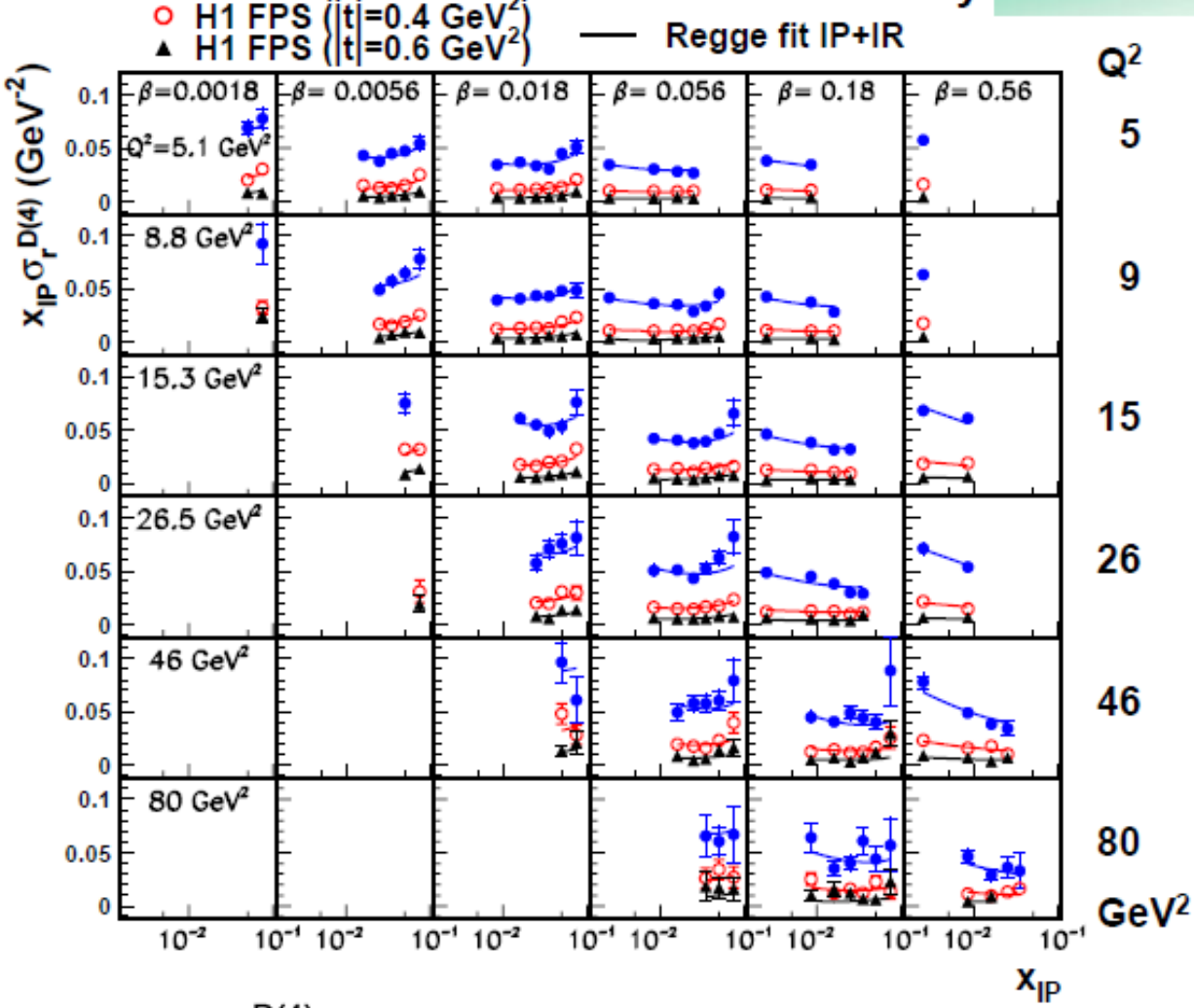
Mikhail Kapishin

HERA-2: FPS detector upgrade

➔ 20 times higher statistics than collected at HERA-1

Horizontal detectors at 61m and 80m: $x_{IP}<0.1$

$x_{IP}\sigma_r^{D(4)}(\beta,Q^2,x_{IP},t)$



- FPS |t|=0.2 GeV²
- FPS |t|=0.4 GeV²
- FPS |t|=0.6 GeV²
- Regge fit IP+IR

x_{IP}-dependence in (Q^2,β,t) bins

→ IP and IR contributions

• FPS $\sigma_r^{D(4)}$ data: syst. uncertainty ~8%, norm. uncertainty ~4.3%

Result of Regge fit

$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha_{IP}'t$$

$$B = B_{IP} + 2\alpha'_{IP}\ln(1/x_{IP})$$

$\alpha_{IP}(0) = 1.10 \pm 0.02\ (exp.) \pm {}^{0.03}_{0.02}\ (model)$

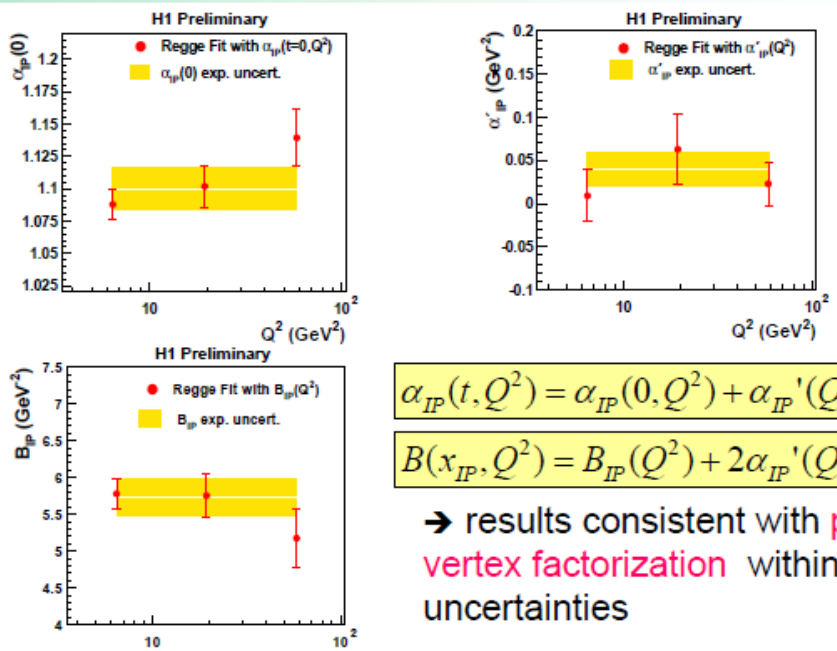
$\alpha'_{IP} = 0.04 \pm 0.02\ (exp.) \pm 0.03\ (model)\ GeV^{-2}$

$B_{IP} = 5.73 \pm 0.25\ (exp.) \pm 0.60\ (model)\ GeV^{-2}$

➔ $\alpha'_{IP} \simeq 0 \rightarrow$ no "shrinkage" (α'_{IP}(soft)~0.25 GeV^{-2})

➔ $B_{IP} \simeq B_{IP}$(hard process), $\alpha_{IP}(0) \simeq \alpha_{IP}$(soft)~1.08

Modified Regge Fit in Q^2 bins



$$\alpha_{IP}(t,Q^2) = \alpha_{IP}(0,Q^2) + \alpha_{IP}'(Q^2)t$$

$$B(x_{IP},Q^2) = B_{IP}(Q^2) + 2\alpha_{IP}'(Q^2)\ln(1/x_{IP})$$

➔ results consistent with proton vertex factorization within uncertainties

M.Kapishin Diffractive DIS with a Leading Proton at HERA-2 12

(3) A Very Forward Proton Spectrometer in H1

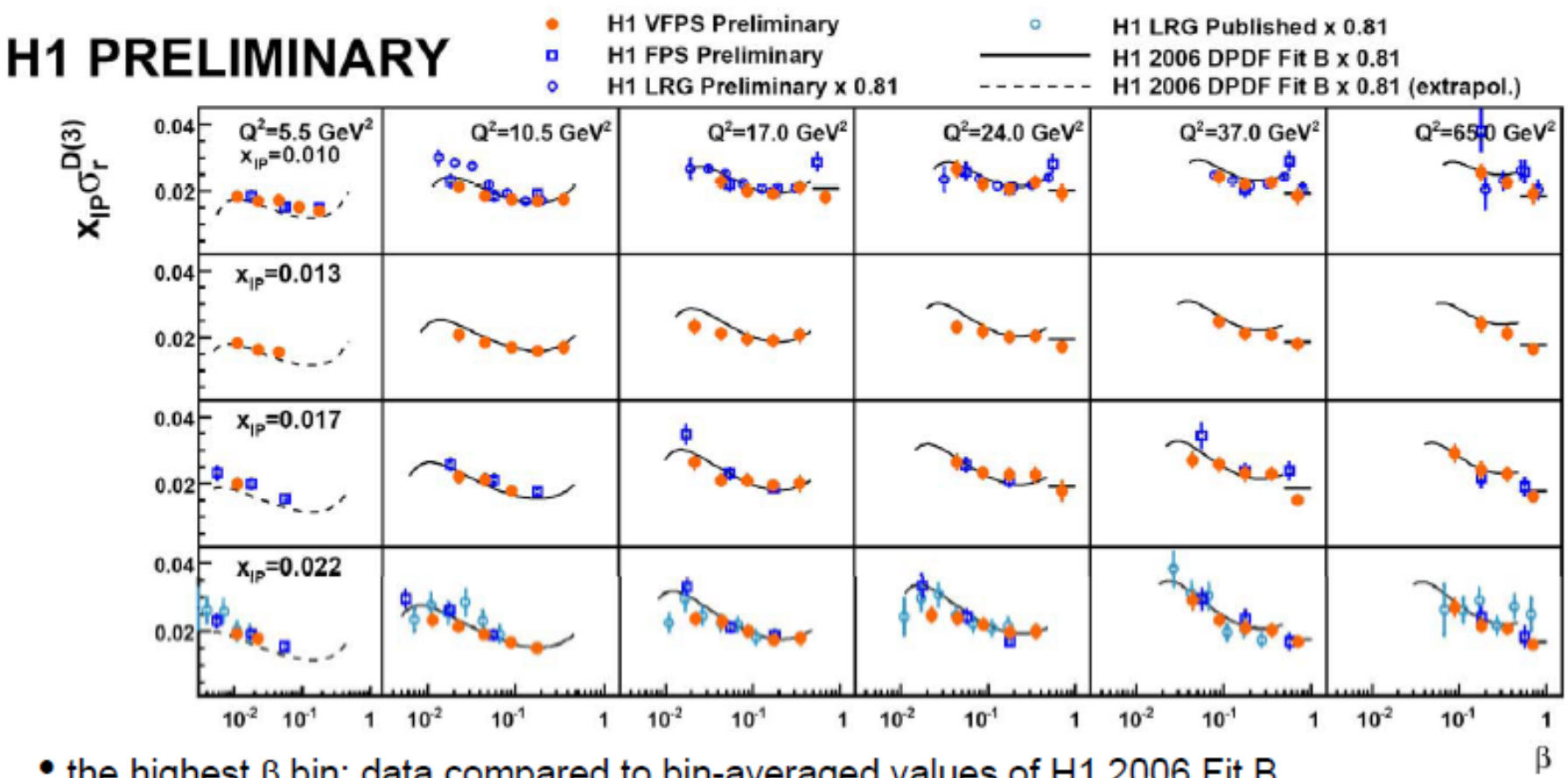
Tomas Hreus

- free of proton dissociation (VFPS is at 220m)
- high acceptance in $0.006 < x_{IP} < 0.025$ and $|t| < 0.25$ GeV^2
  - low normalisation uncertainty (5%)
- improved resolution in x_{IP} and β (both reconstructed from VFPS)

total systematic error: 8% - 14 %

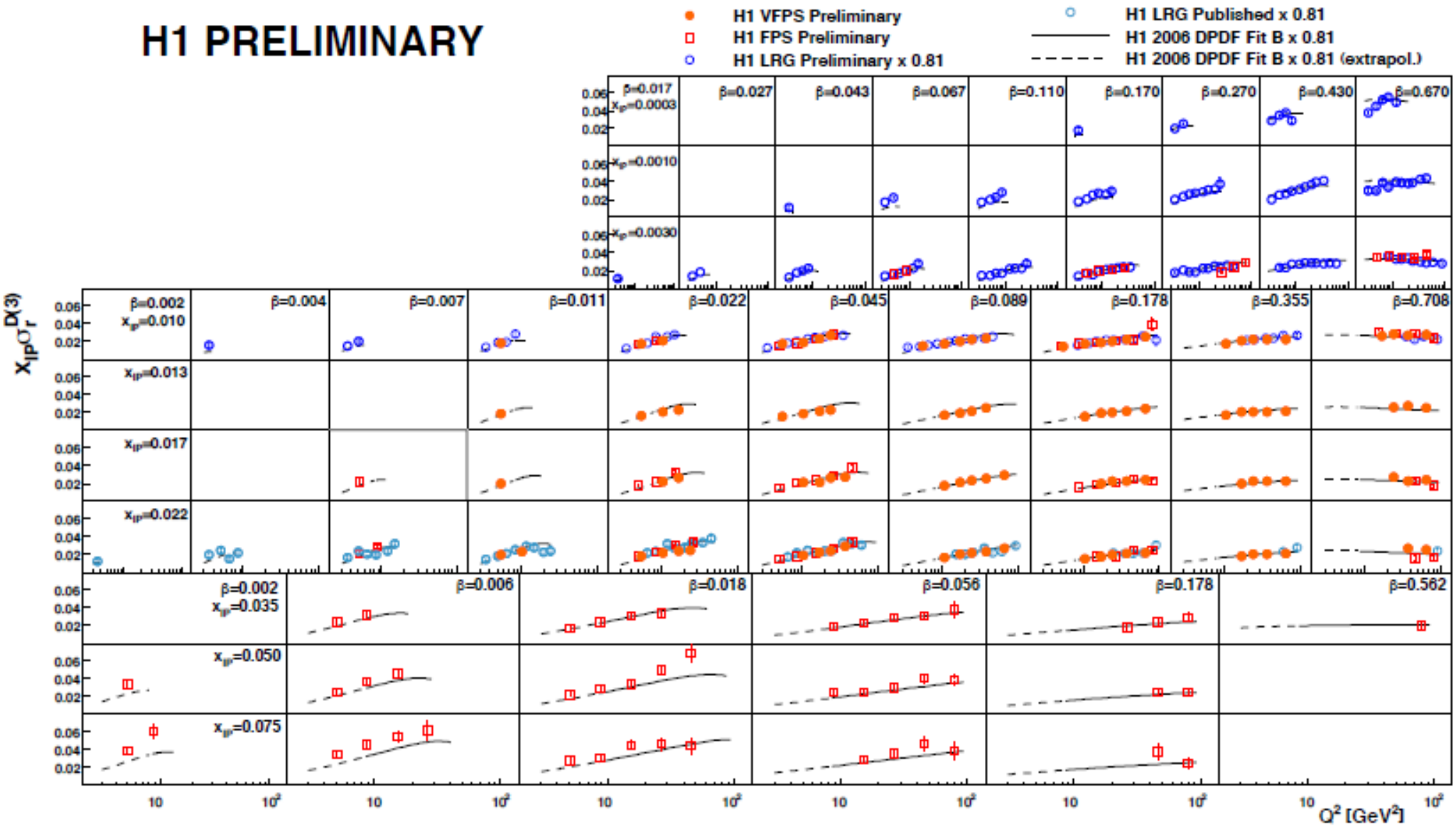
Using H1 data collected in 2006 and 2007 (e^+p reactions, $s^{1/2}$ = 319 GeV), integrated luminosity when VFPS was in operation (close to beam): **87.4 pb^{-1}**

Reduced Cross Section



- the highest β bin: data compared to bin-averaged values of H1 2006 Fit B

Towards a complete H1 diffractive dataset

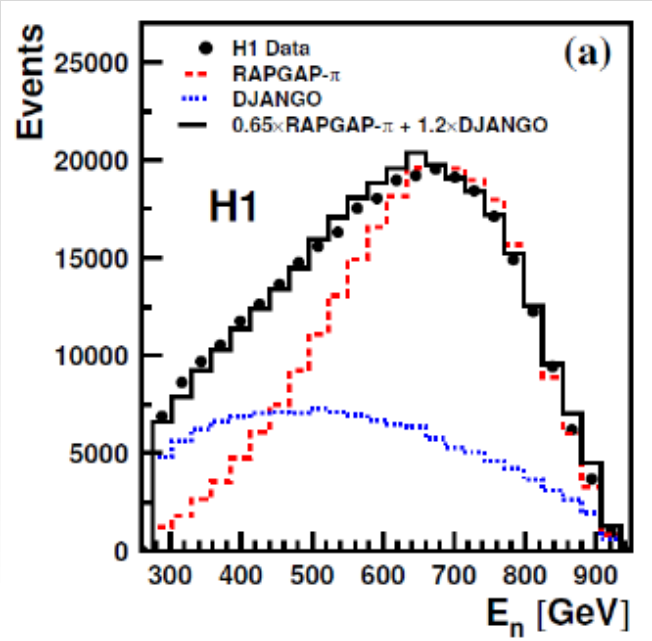


VERY PRECISE MEASRUEMENTS OF SCALING VIOLATIONS FOR DIFFRACTION

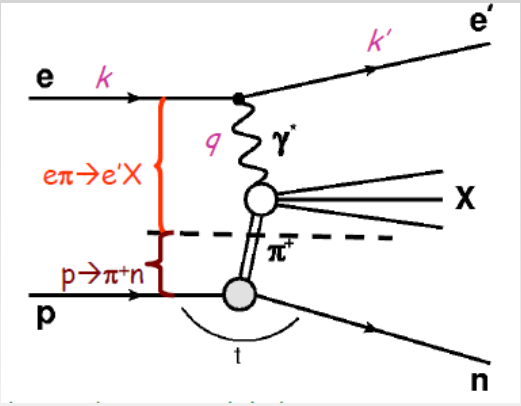
- Still fantastic prospects to come from using all LRG, FPS and VFPS data!

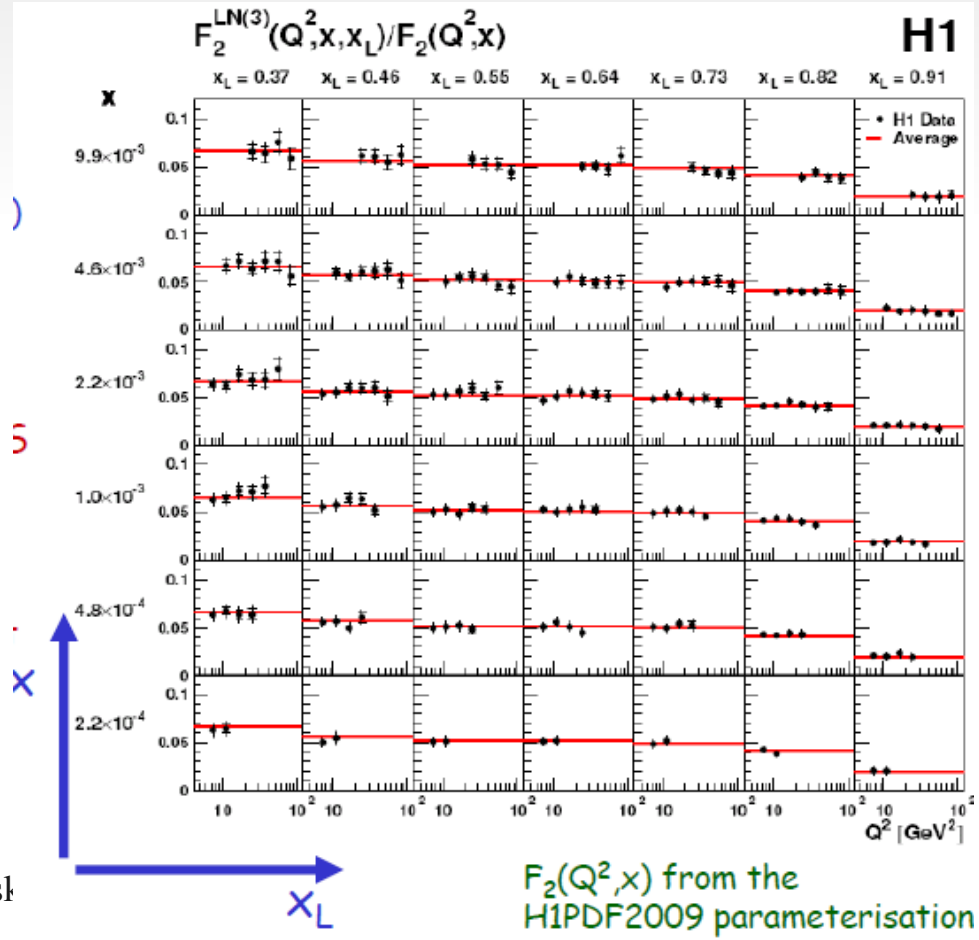
Leading Neutron Production in DIS at HERA

Armen Bunyatyan



$6<Q^2<100$ GeV^2; $0.02<y<0.6$; $1.5\cdot10^{-4}<x<3\cdot10^{-2}$; $0.32<x_L<0.95$, $p_{T,n}<0.2$ GeV





$F_2(Q^2,x)$ from the H1PDF2009 parameterisation

- HERA-II data
- Described by pion exchange model (x_L>0.7) and standard fragmentation models
- F^{LN}_2 similar Q^2, x behaviour as F_2 (limiting fragmentation)
- Proton vertex factorisation (from beta dep.)
- Scaling violation similar to pion and proton SF
- Pion SF estimated as well.

Diffractive ZEUS NLO QCD fits

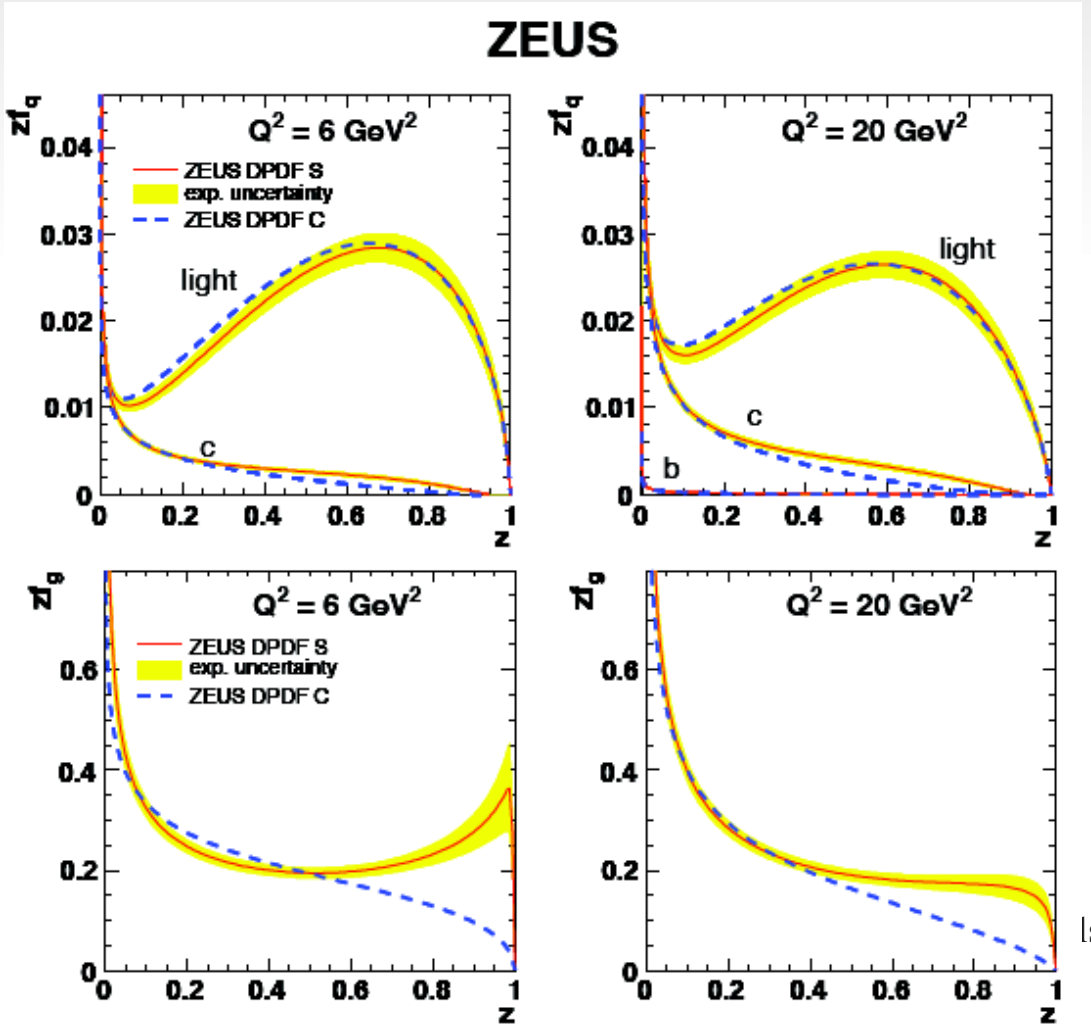
Matthew Wing

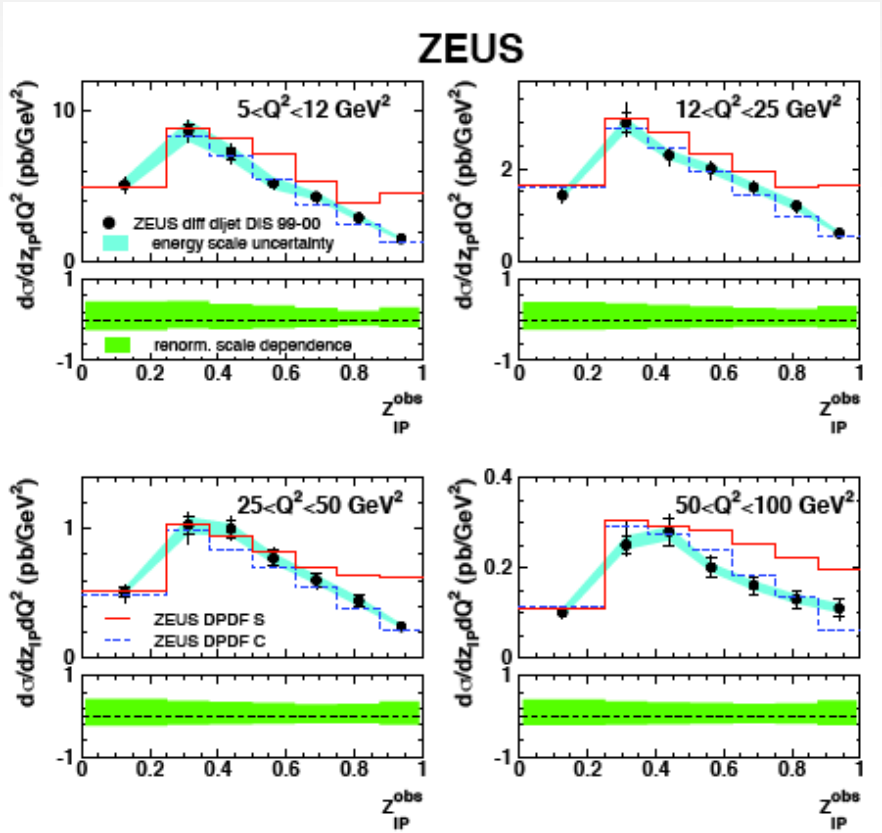
$$\sigma^{(D)}_{ep\to eX(p)} \sim f^{(D)}_{i/p} \otimes \sigma_{i\gamma\to jk}$$

Parton densities in "Pomeron" (*i.e.* when there is a fast proton in the final state)

Data samples

- LRG : $40 < W < 240$ GeV, $2 < Q^2 < 305$ GeV^2, $2 < M_X < 25$ GeV, $0.0002 < x_{IP} < 0.02$
- LPS : $40 < W < 240$ GeV, $2 < Q^2 < 120$ GeV^2, $2 < M_X < 40$ GeV, $0.002 < x_{IP} < 0.1$
- Jet : $100 < W < 250$ GeV, $5 < Q^2 < 100$ GeV^2, $E_T^{jet1,2} > 5{,}4$ GeV, $x_{IP} < 0.03$



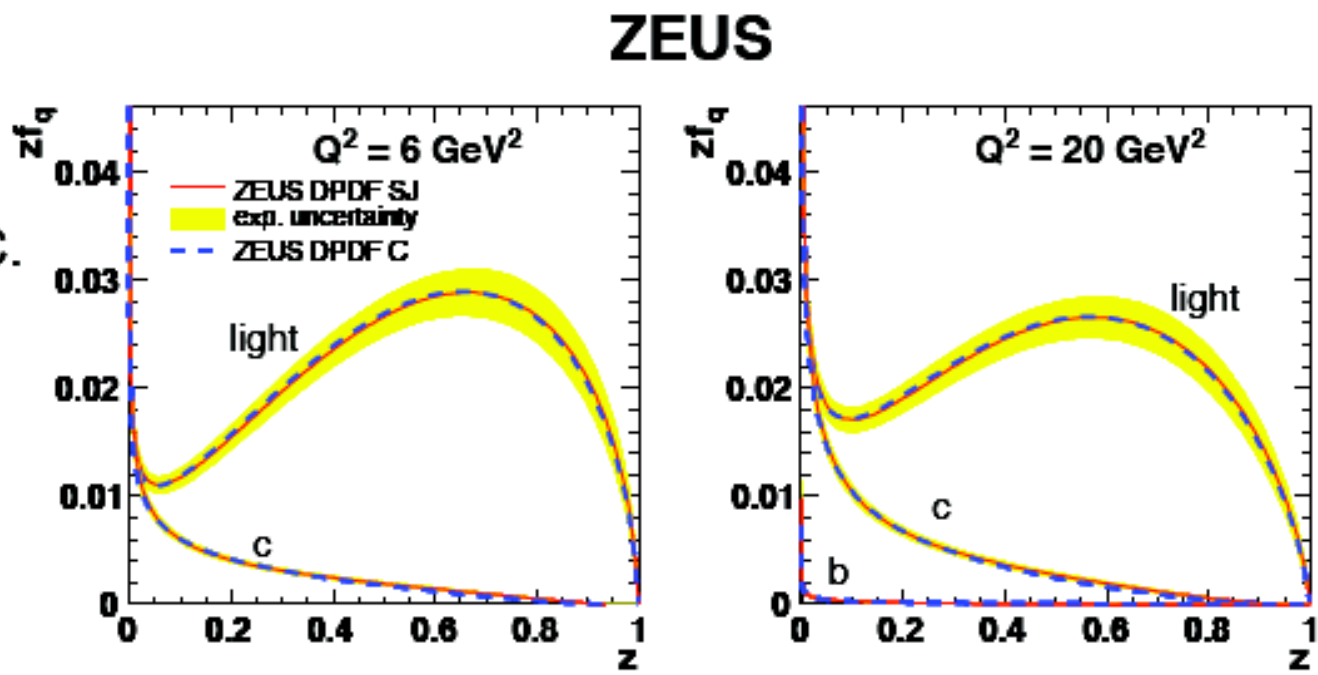


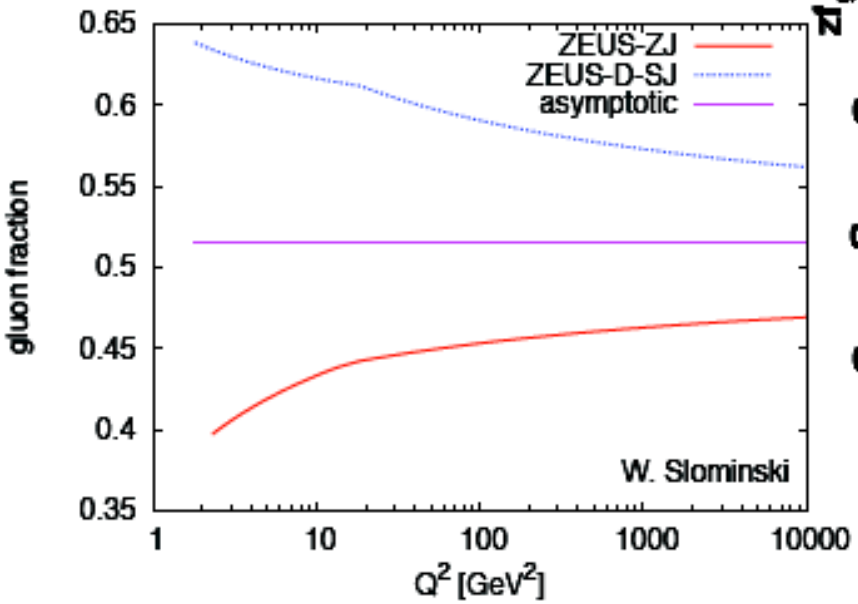
- Need jet data to constrain gluon density.

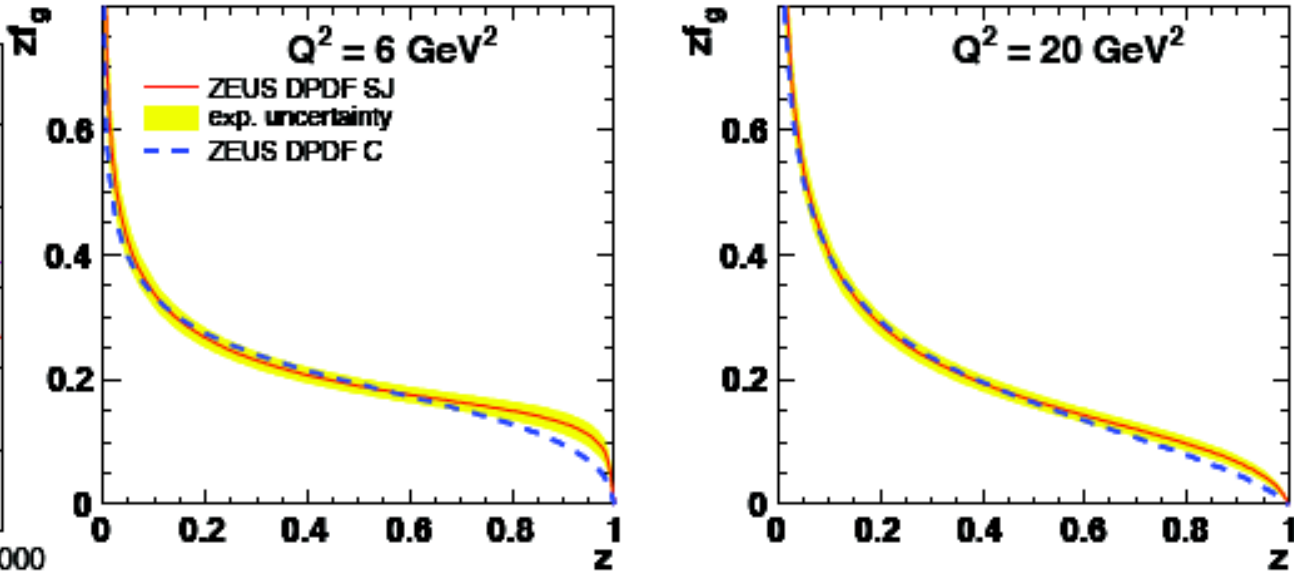
$z_{IP} = (Q^2+M_{jj}^2) / (Q^2+M_X^2)$

Resultant DPDFs including jets

- Fit C shown as reference.
- Quark distributions similar.
- Gluon distribution similar to fit C.
- Similarly good description of inclusive data.
- Much better determination of gluon density.
- Which is about 60% of the momentum of the exchange.





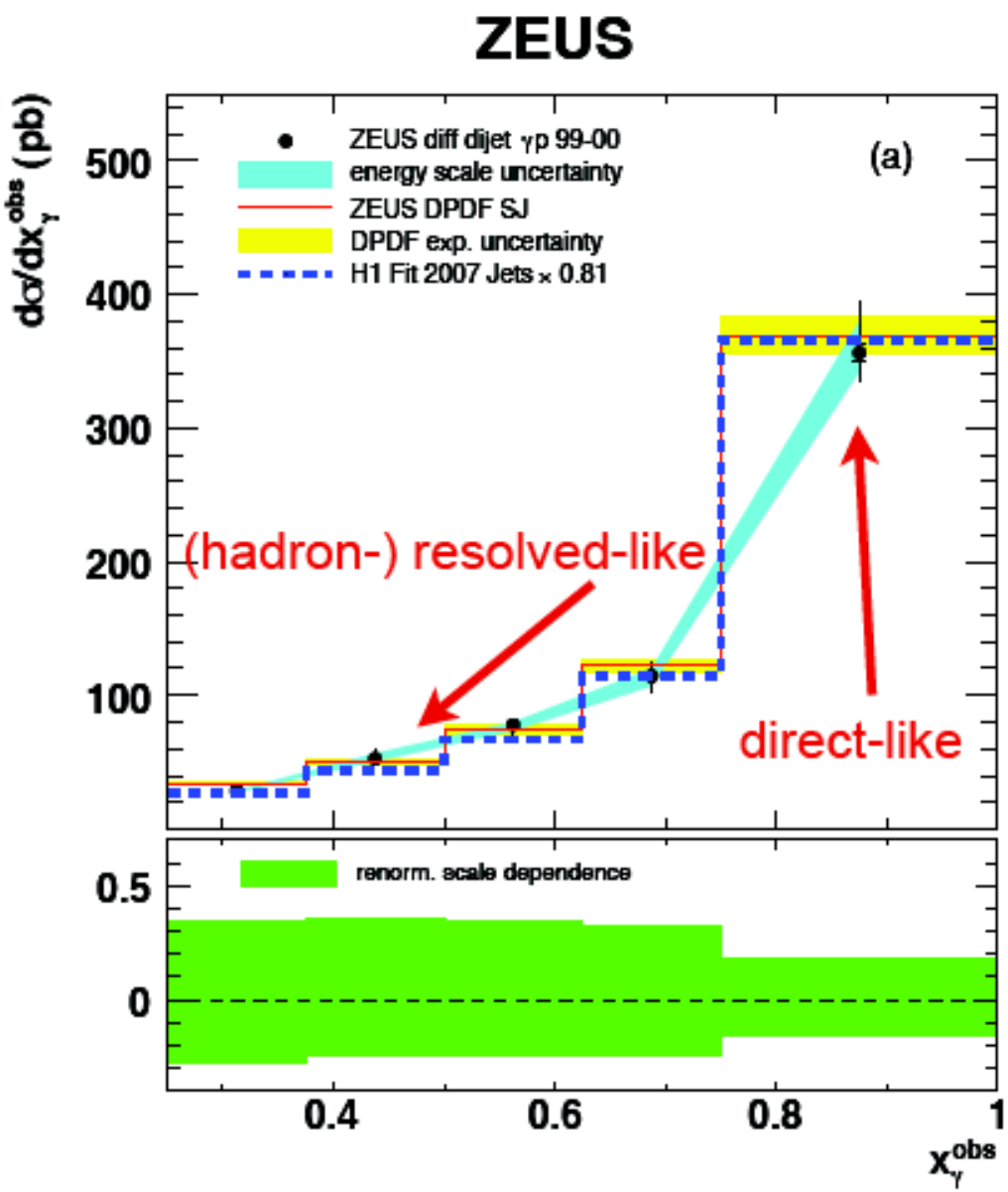


Comparison of fits with other data

To compare with independent data set and different process.

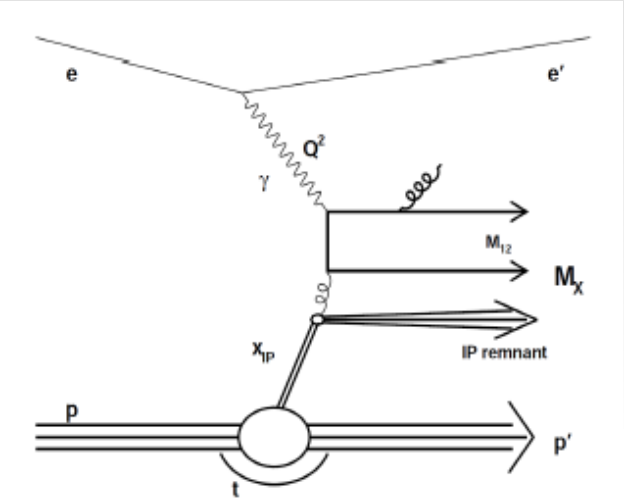
- Dijet photoproduction ($Q^2 \sim 0$) fits the bill.
- Consider the fraction of the photon's energy invested in producing the dijets.
- Reasonable description of data by DPDFs used in NLO QCD calculation.
- Difference wrt H1 Fit up to 20%.
- These data do not suggest any suppression or factorisation breaking versus x_γ^{obs} (or E_T).

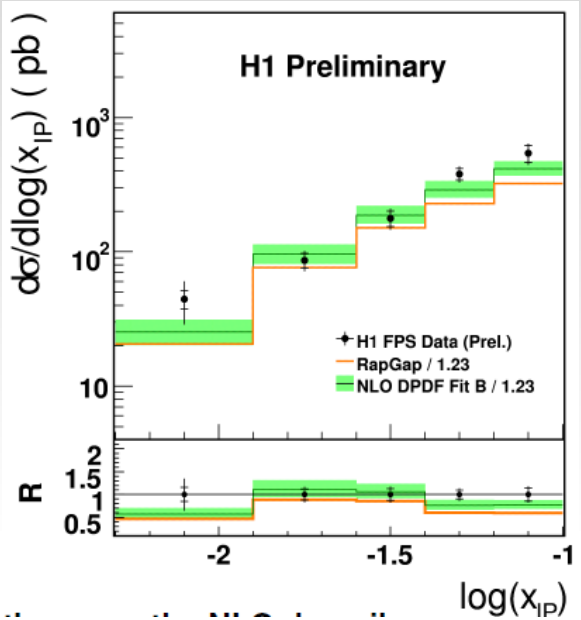
- (Also compared to charm in DIS.)

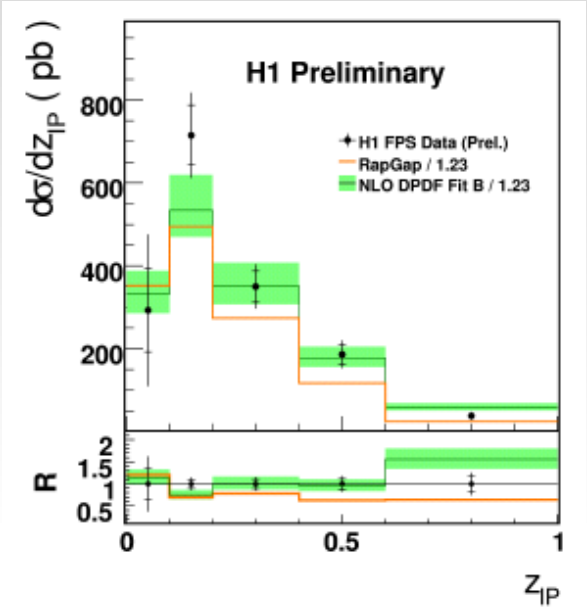


H1 Diffractive Dijets

Richard Polifka







$z_{IP} = (Q^2+M_{jj}^2) / (Q^2+M_X^2)$

$4 < Q^2 < 110$ GeV^2

$0.05 < y < 0.7$

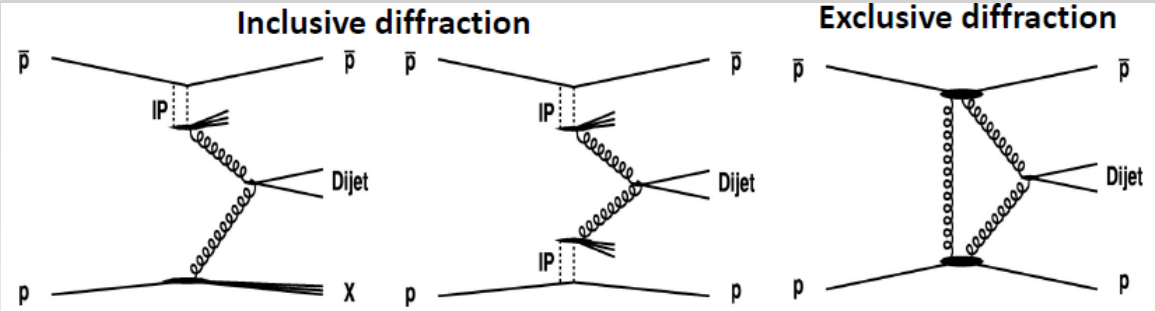
$X_{IP} < 0.1$

$p_{T1}^* > 5$ GeV

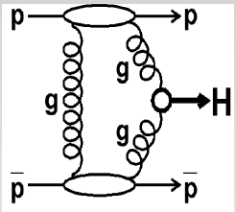
$p_{T2}^* > 4$ GeV

- Central jets with FPS measured
- HERA II period 20x higher statistics → first tagged proton dijet measurement in ep ever
- DPDFs tested in new kinematical region up to $x_{IP} < 0.1$
- Within errors NLO describes the data, RapGap is off in normalisation

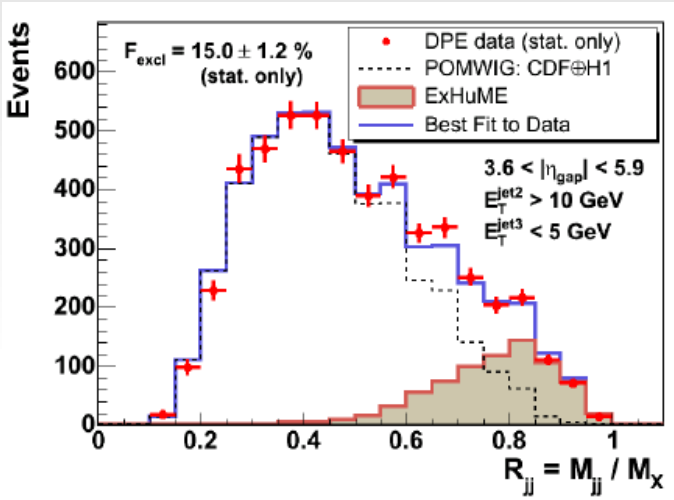
Exclusive Dijet Production at Tevatron



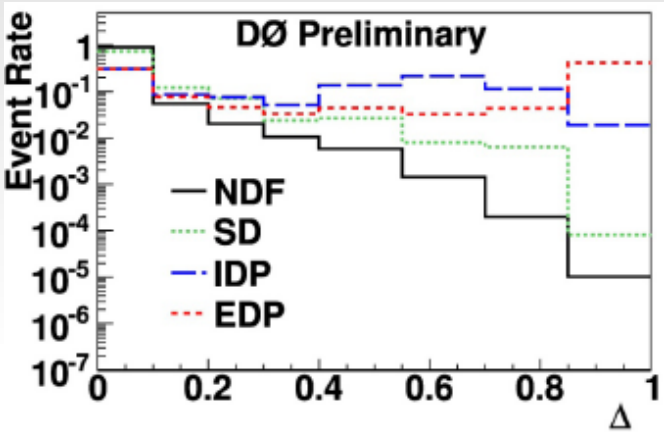
@LHC:



Christina Mestropian



Zdenek Hubacek



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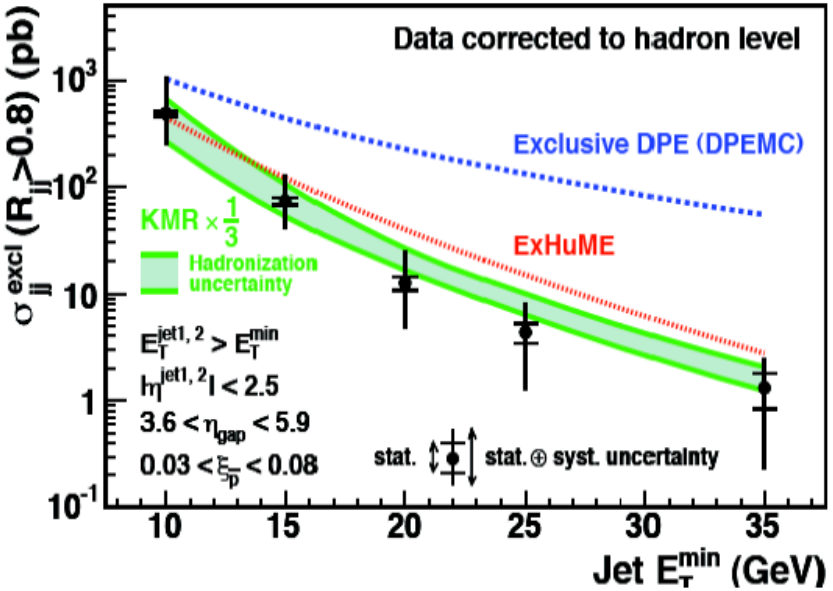
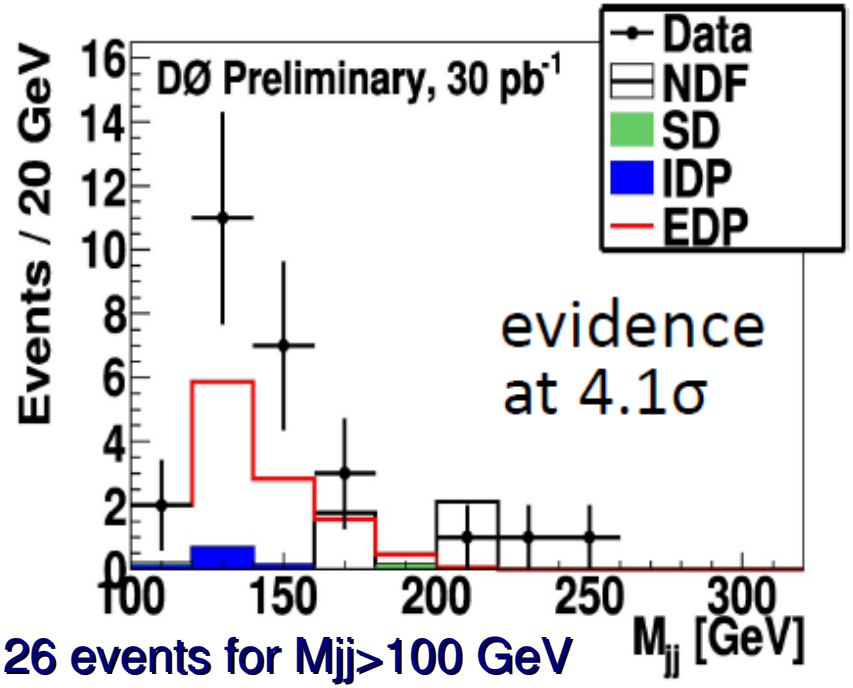


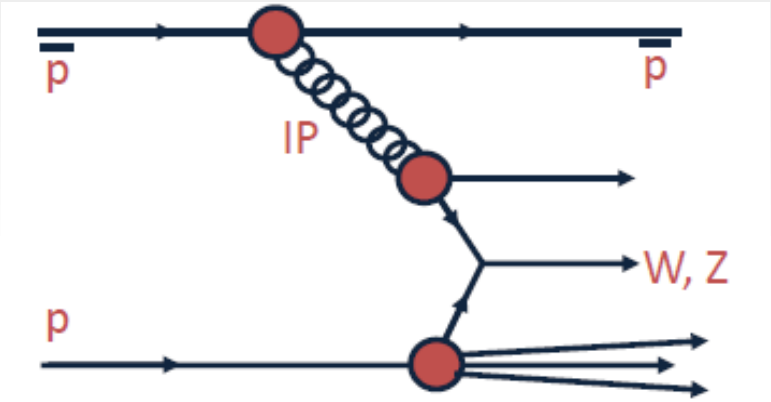


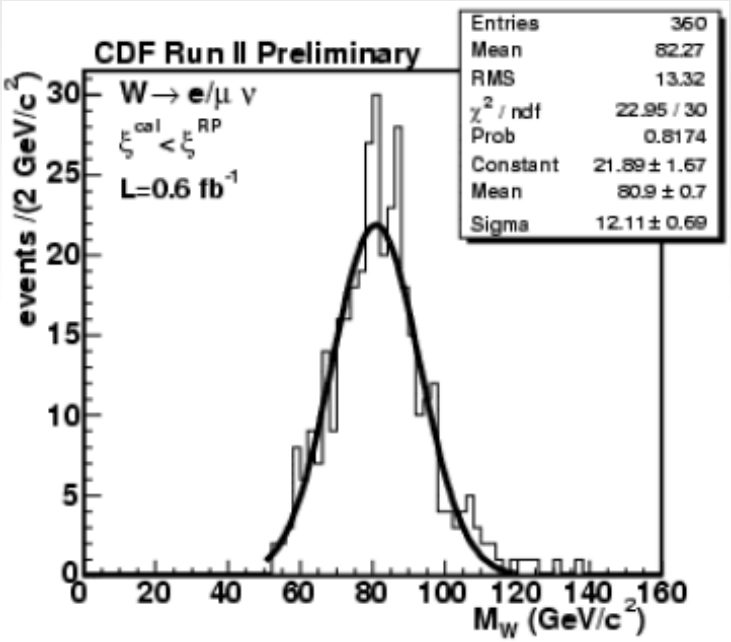
26 events for Mjj>100 GeV

Diffractive W Production – Run II

Christina Mestropian

Diffractive W/Z production probes the quark content of the Pomeron





Fraction of diffractive W

R_W (0.03<ξ<0.10, |t|<1)= [0.97 ±0.05(stat) ±0.10(syst)]%

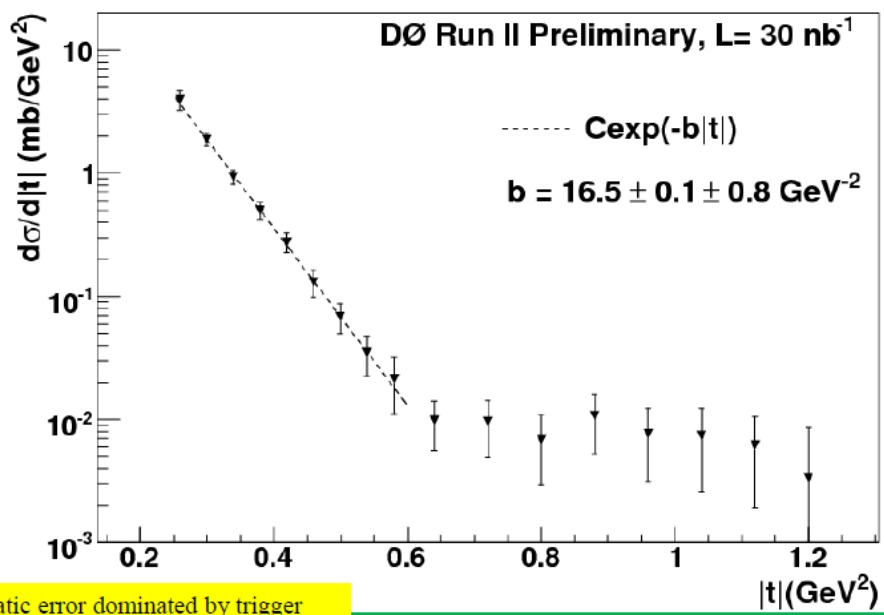
consistent with Run I result, extrapolated to all ξ

Andrew Brandt

Elastic Scattering at √s=1.96 TeV Using the DØ Forward Proton Detector

- In 2005 DØ proposed a store with special optics to maximize the |t| acceptance of the FPD
- In February 2006, the accelerator was run with the injection tune, $\beta^* = 1.6$m (about 5x larger than normal)
- Only 1 proton and 1 anti-proton bunch were injected
- Integrated Luminosity (**30 ± 4 nb^{-1}**) was determined by comparing the number of jets from Run IIA measurements with the number in the Large β^* store
- A total of 20 million events were recorded with a special FPD trigger list

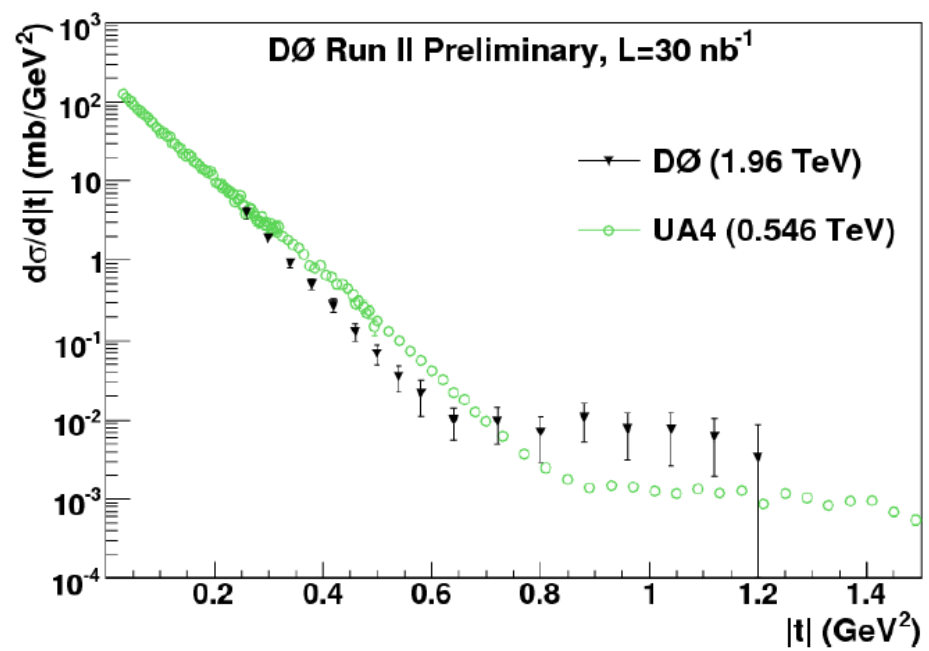
Measurement of Elastic Slope (b)



•Systematic error dominated by trigger efficiency correction
•Second biggest uncertainty (alignment) = ± 0.3 GeV^2

First measurement of b at √s=1.96 TeV

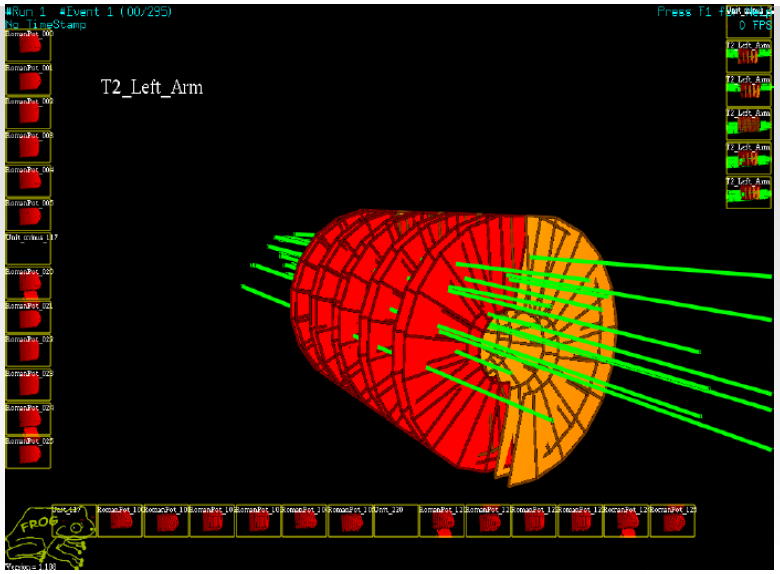
dσ/d|t| Compared to UA4

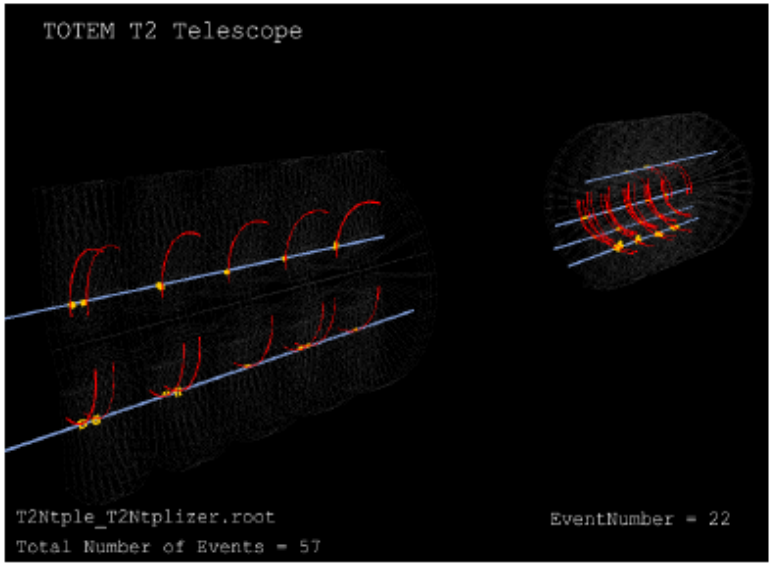


Slope steeper and slope change earlier for higher √s (shrinkage)

Status of the TOTEM experiment and early runs results

Hubert Niewiadomski





Event Display of a Minimum Bias event
$\sqrt{s}$ = 7 TeV

Conclusions

- The Roman Pots (220 m) and the T2 detector are now fully installed and are in the commissioning phase.
- We gained useful experience with data taking in December 2009 and in early 2010.
- DCS, DAQ, online and offline software are ready for the runs.
- For both detectors the trigger has to be commissioned before physics data taking. Background rates need to be measured.
- Proton reconstruction in Roman Pots requires precise knowledge of beam optics. Study of beam optics errors is mandatory for unbiased physics reconstruction.
- β^*=90m optics would be of great help to commission the Roman Pots and to get ready for σ_{TOT} measurement before longer, dedicated runs.
- Half of the T1 detector is ready to be installed in a technical stop, the second will be ready soon. Full T1 and 12 Roman Pots at 147 m will be installed by the end of 2010.

Physics & running 2010

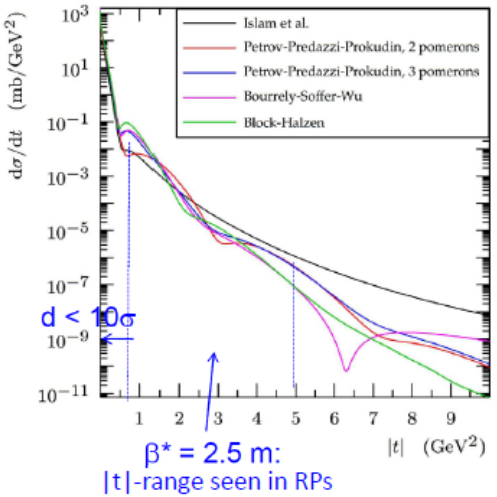
Physics at $\sqrt{s} \approx 7$ TeV with early low β^* optics:

– **forward charge particle event topology**
high σ → short T2 runs to get sufficient statistics (repeatable after analysis)

– **large |t| elastic scattering**
relatively low σ → requires relatively large $\int L$ especially for the high |t| end → longer RP vertical runs

– **high mass single & central diffraction**
relatively high σ & requires common RP & T2 runs → short combined RP horizontal & T2 runs (repeatable after analysis)

Elastic scattering, $\sqrt{s}$ = 2.36 TeV



The status and preliminary results of the LHC forward experiment: LHCf

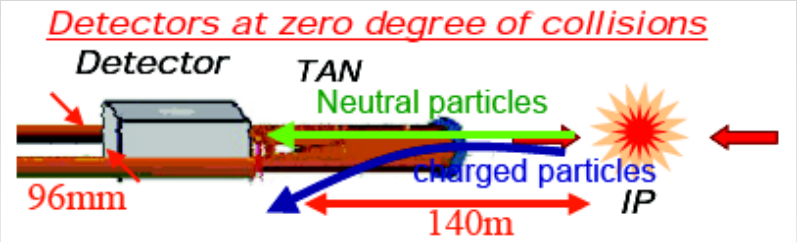
LHCf = "LHC forward"

Hiroaki Menjo

- Detector : calorimeters covering $\eta > 8.4$ in IP1.
- Measurement : energy spectra and P_T distributions of energetic neutral particles.

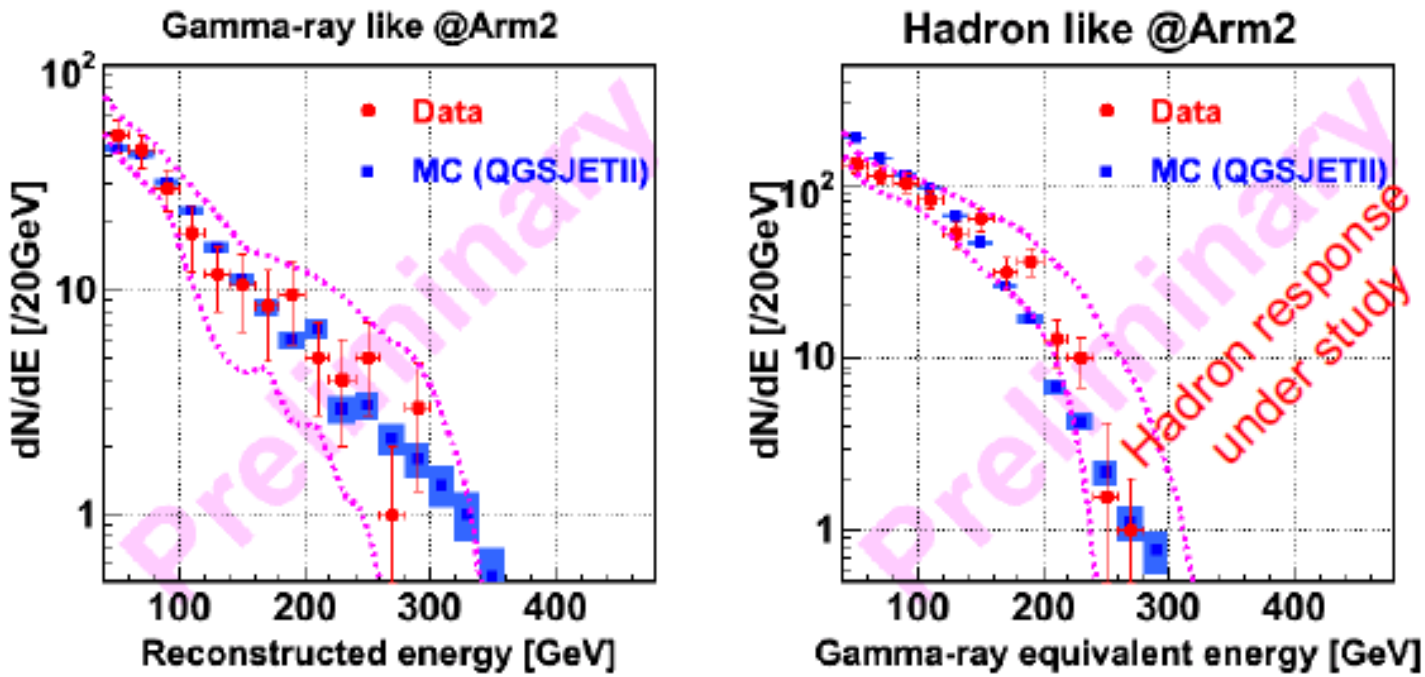
Preliminary results in 900GeV collisions

Very preliminary results at 7TeV collisions



The Aim is to calibrate hadron interaction models for ultra high energy cosmic ray physics.

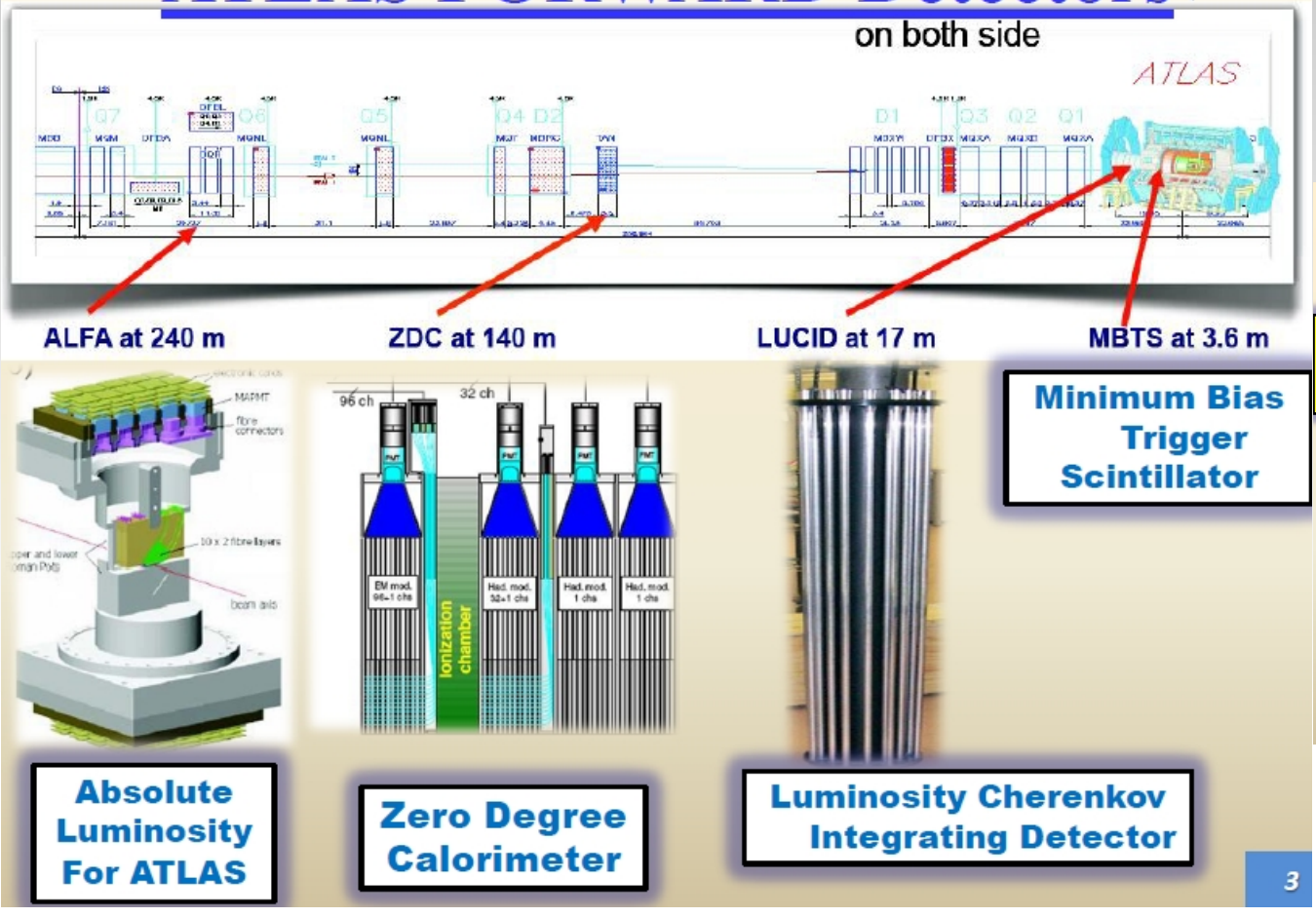
Comparison with MC @ Arm2



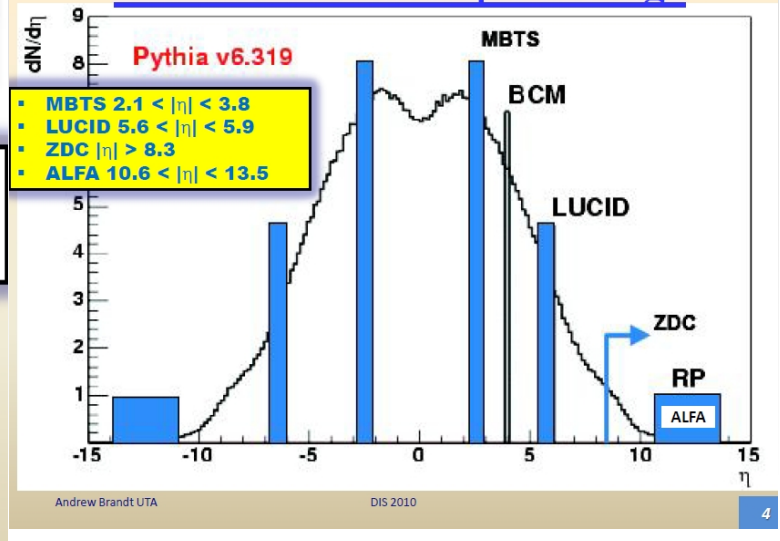
More statistics by data taking at 900GeV soon

Andrew Brandt

ATLAS FORWARD Detectors



ATLAS Forward η Coverage



Conclusions

- Just getting started
- Looking FORWARD to completed detectors, new capabilities
- See Christophe Royon's talk about plans to use these detectors

The ATLAS Forward Physics Program @14 TeV

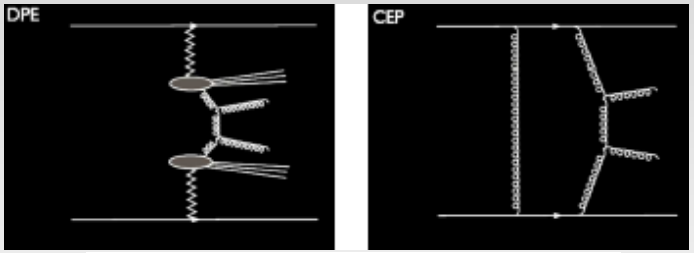
Christophe Royon

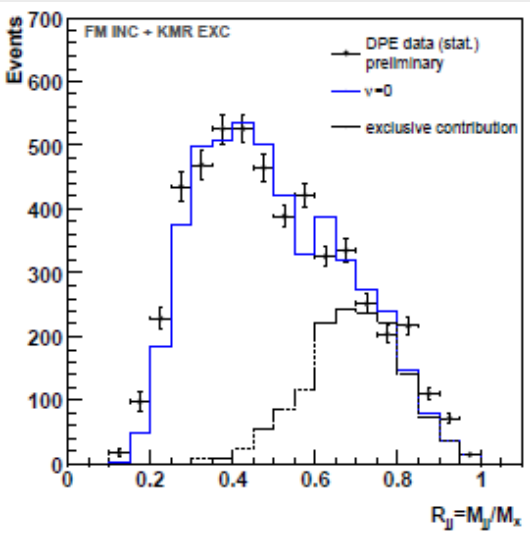
Conclusion: Diffractive program in ATLAS

Luminosity	Possible measurements
10 pb^{-1}	Jet gap jet (Mueller Navelet) Soft single diffraction total cross section (ALFA) Hard Single diffraction (jets, b jets...)
10-100 pb^{-1}	Central exclusive production (jets) Single diffractive W/Z
100-200 pb^{-1}	WW via photon exchange dilepton production CEP $\tau\tau$
30 fb^{-1}	Higgs (with AFP) Anomalous $W\gamma$ couplings (with AFP) Test of Higgsless / extradim models (with AFP)

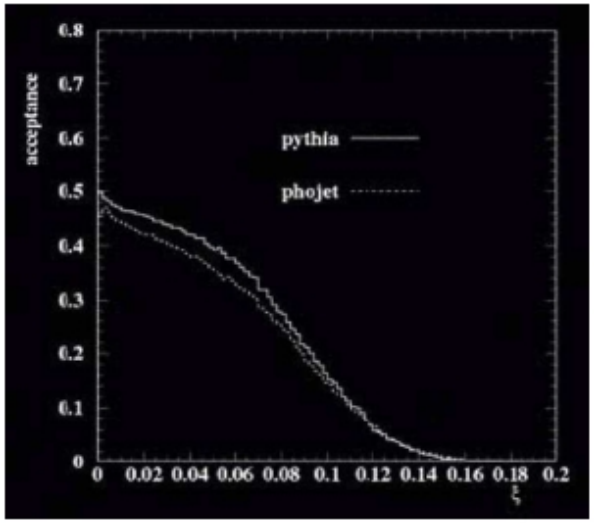
Many different possible measurements using rapidity gap method (low luminosity), ALFA, and AFP project

DPE and Central Exclusive Processes

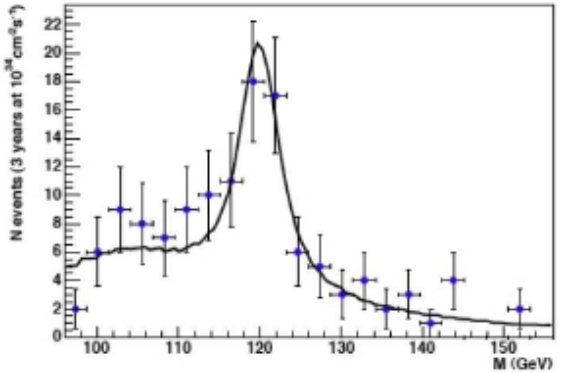




Soft single diffraction with ALFA



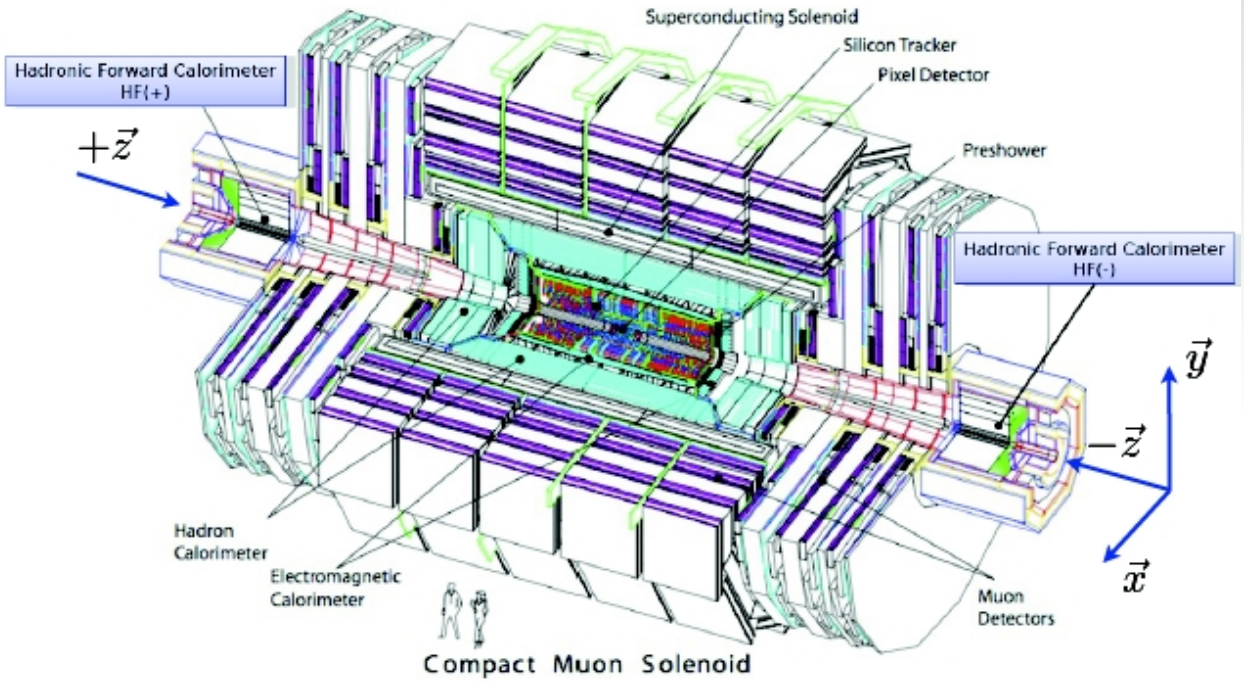
SUSY Higgs Signal significance using AFP

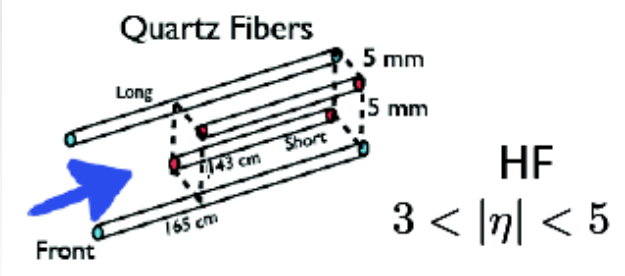


First Step to Measure Energy Flow in Forward Rapidity and Observation of Forward Jets in First Collisions at LHC

Sercan Sen

CMS Detector



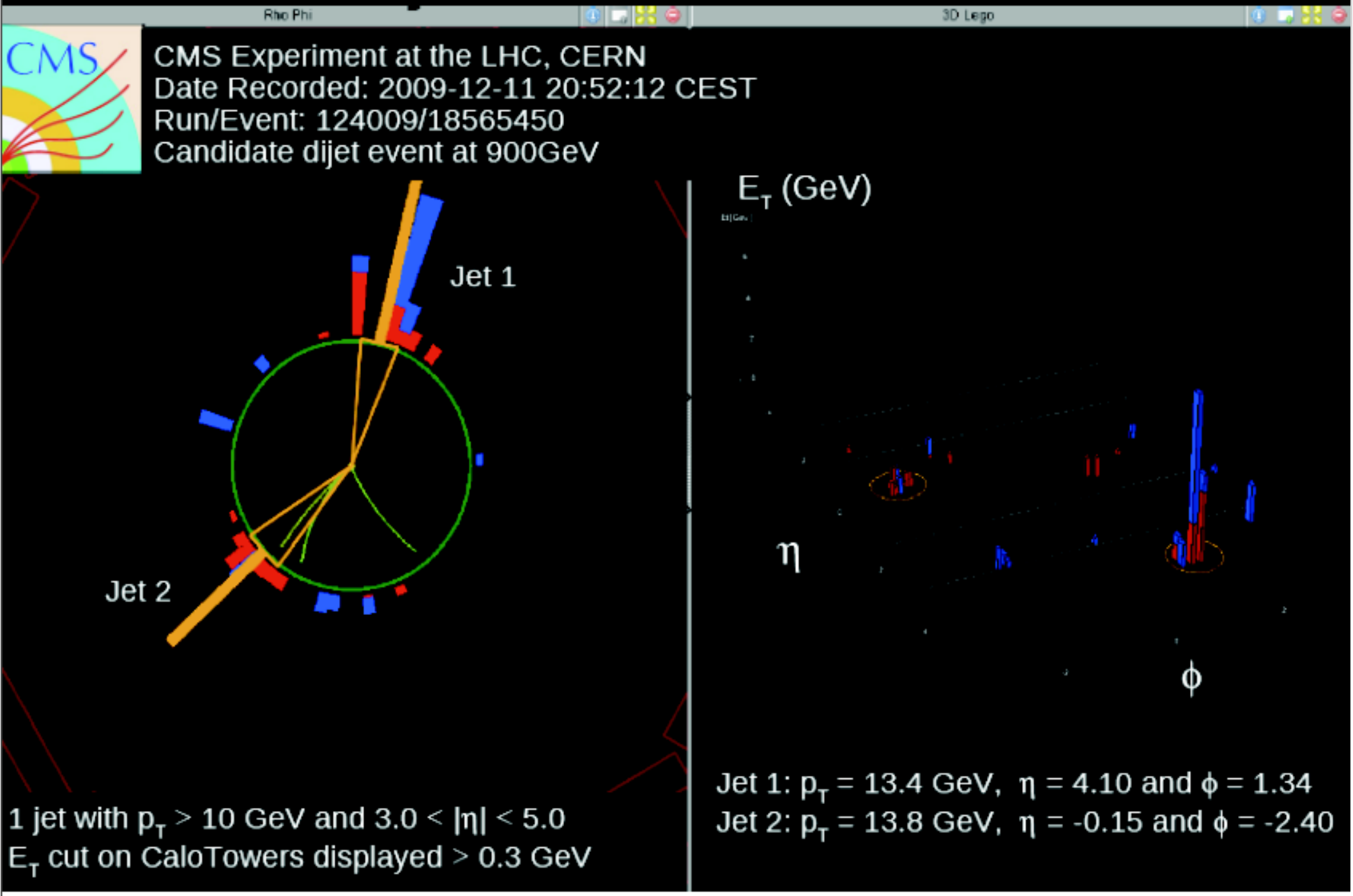


Collision Events Selection

- BPTX and BSCs triggers to select minimum bias events. Also used other triggers based on BSCs to reject beam halo events.
- At least 10 tracks with 25% of the tracks to be high purity. This requirement rejects non-IP collision events.
- At least one primary vertex which has z distance to CMS interaction point with $|z| \leq 15\,cm$ and impact parameter $d_0 \leq 2\,cm$ has been reconstructed with number of tracks > 3.

Observation of Forward Jets

Sercan Sen



Sercan Sen

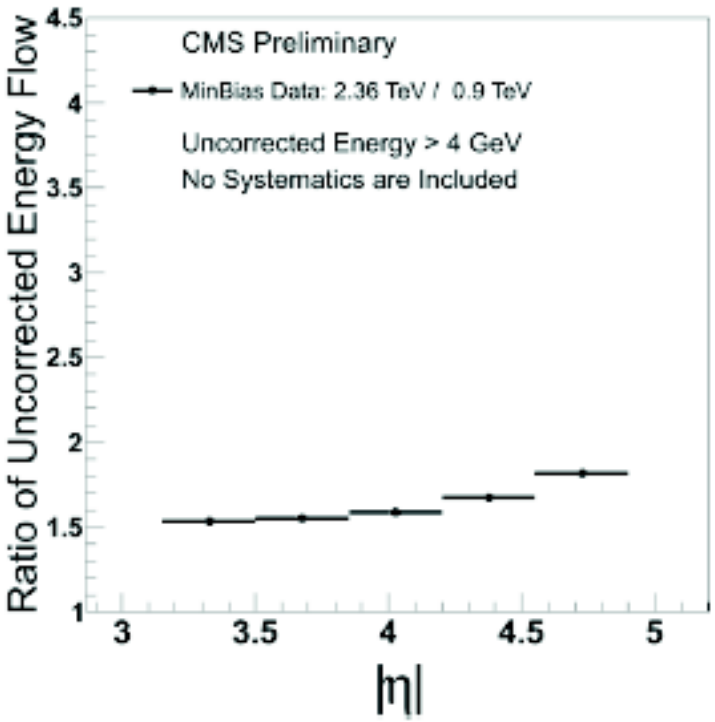
$$R_{Eflow}^{\sqrt{s_1},\sqrt{s_2}} = \frac{\frac{1}{N_{\sqrt{s_1}}}\frac{\Delta E_{\sqrt{s_1}}}{\Delta\eta}}{\frac{1}{N_{\sqrt{s_2}}}\frac{\Delta E_{\sqrt{s_2}}}{\Delta\eta}}$$

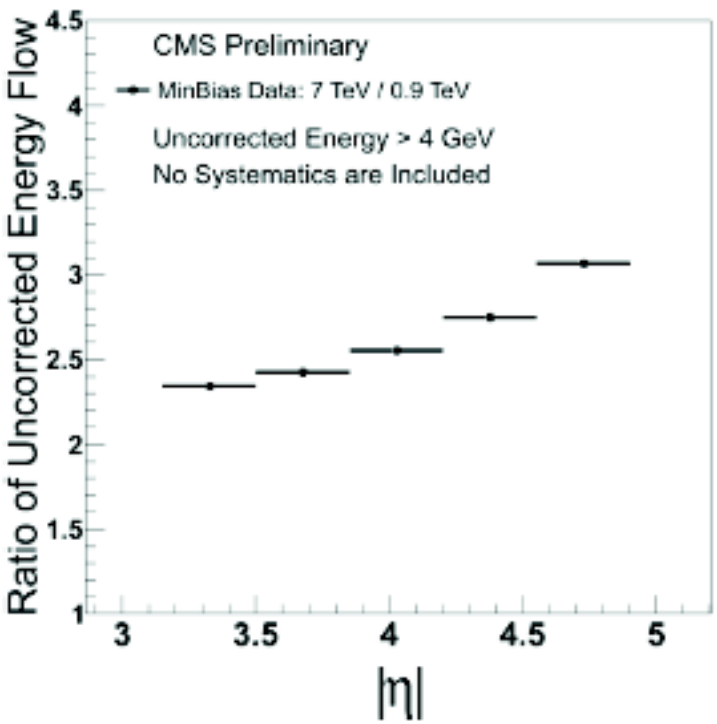
$\sqrt{s_1} = 2.36\,TeV$ or $7\,TeV$

$\sqrt{s_2} = 0.9\,TeV$

Ratio of Energy Flow for Different Energies

Collision Data





Data are on detector level only, no systematic uncertainties included.
More energy deposition with the increasing energy.
Energy deposition also increases with eta.

- We are in the new era with LHC to understand multiple parton interaction by using energy flow measurements.

Summary

- Many exciting results have been presented
  (and many more not included in this talk!)

- Experiments (including seniors) measure rear processes and diffractive data become more and more precise.

- New experiments are preparing or ready to start.

- Or started (we just saw collision events with forward jets from LHC:-)

Thank you for your attention.