Experimental Summary

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Dilute systems

- Structure functions and parton distributions from HERA
- TEVATRON constraints on parton densities
- Heavy flavour @ HERA
- Jets @ HERA

Structure functions and parton distributions from HERA

K. Papageorgiou

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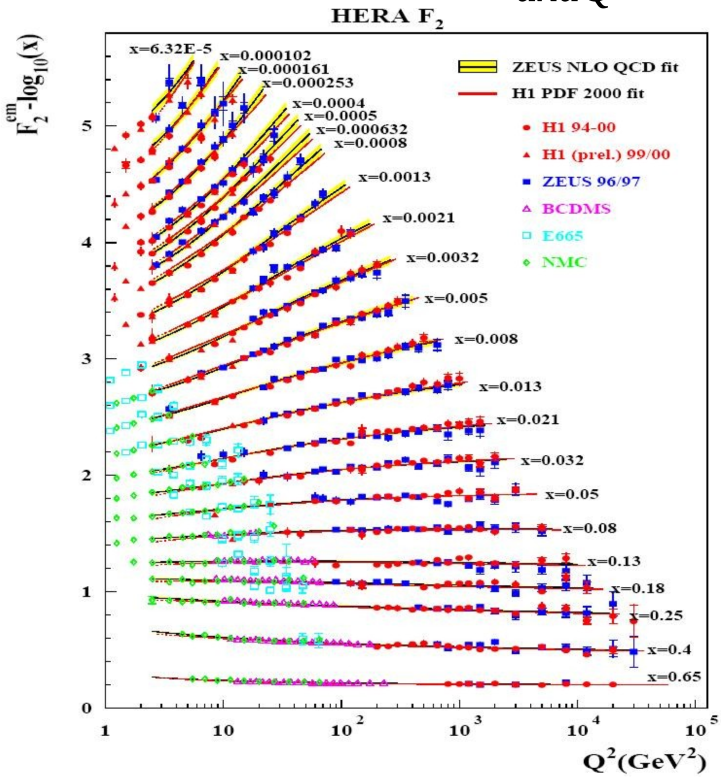
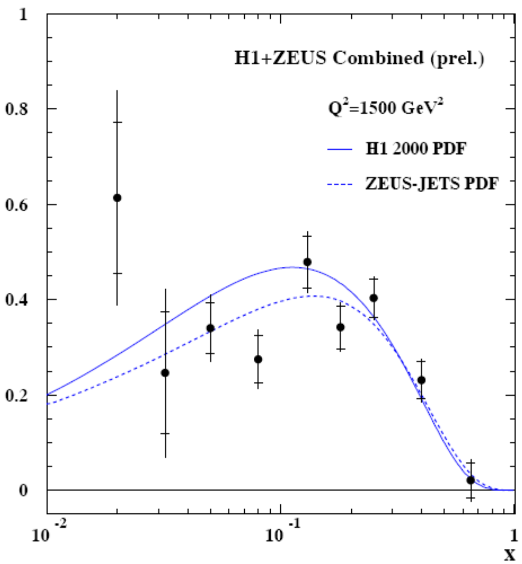
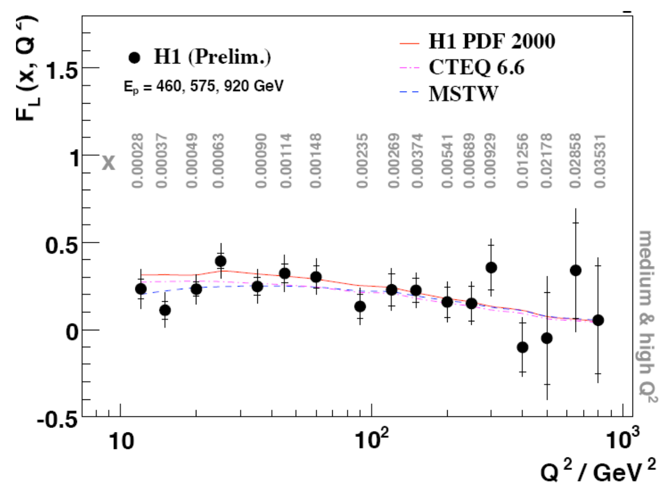
A tribute to HERA!

- The DIS cross section has been measured in great detail; structure functions F2, F3 and FL have been extracted

$$\frac{d^2\sigma(e^{\pm}p)}{dxdQ^2} = \frac{2\pi a^2}{xQ^4} Y_+ [F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2) \pm xF_3(x,Q^2)]$$



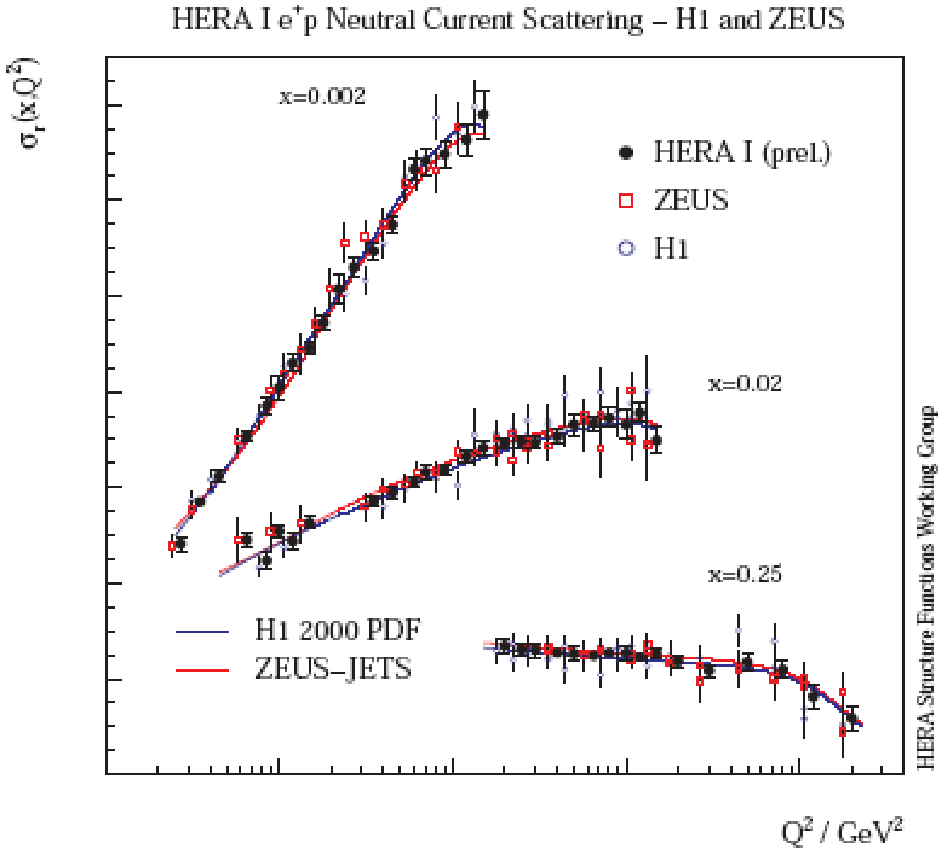




Structure functions and parton distributions from HERA

K. Papageorgiou, Li Gang

- H1+ZEUS combined HERA-I data has greatly improved precision: "systematic uncertainties are now smaller than statistical error across the x,Q^2 plane"



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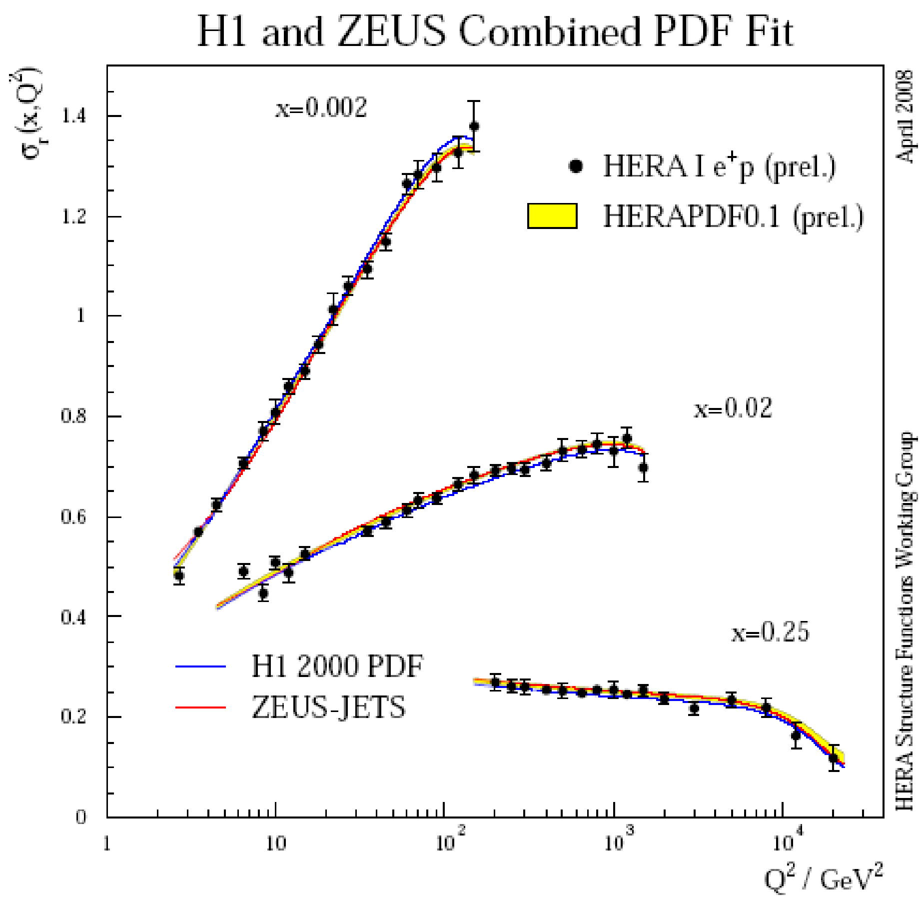
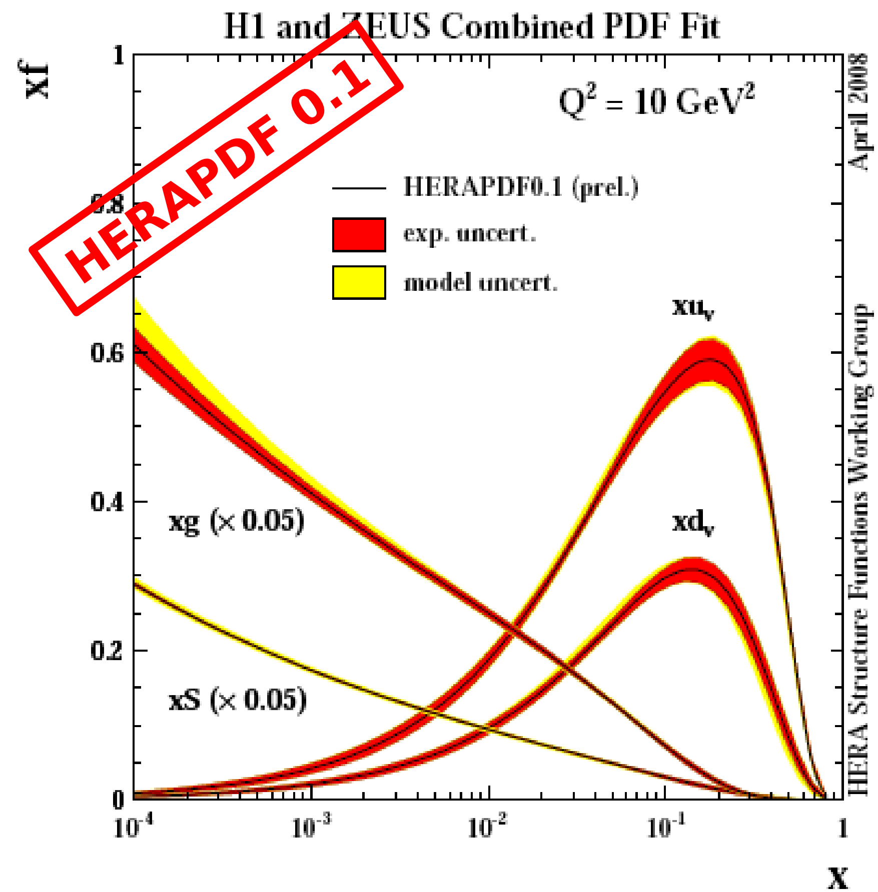
Structure functions and parton distributions from HERA

Li Gang

- H1+ZEUS combined NLO DGLAP fit yields impressive precision



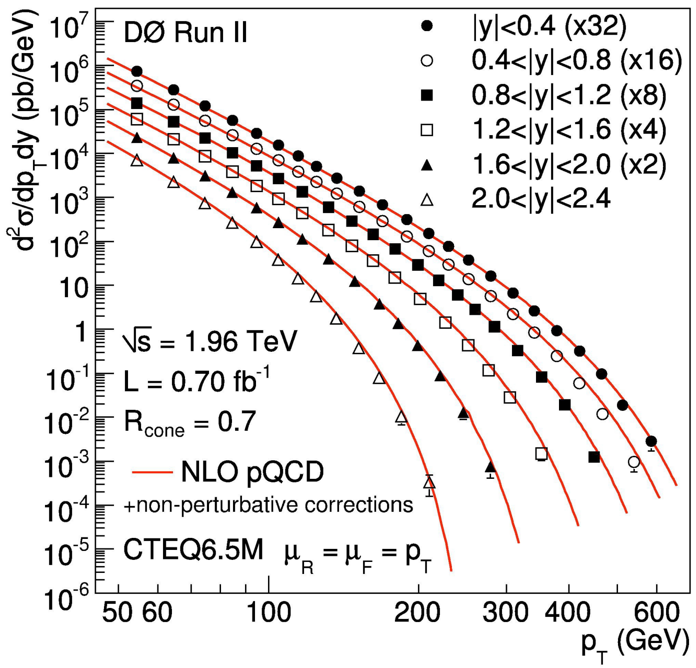


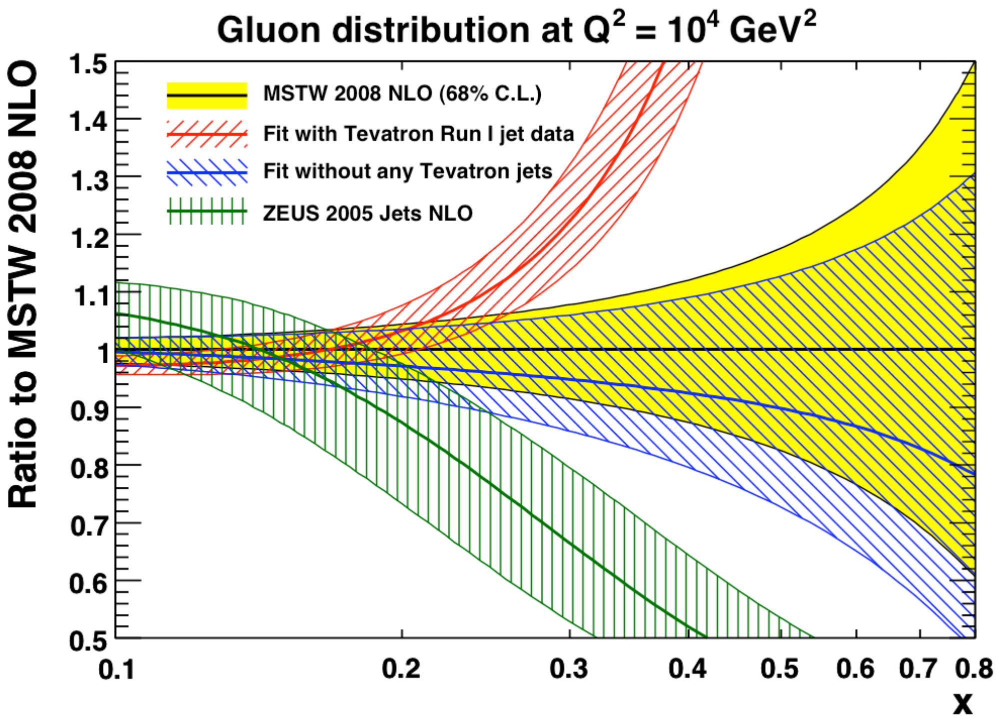
Just based on HERA-I NC&CC data sets
→ more to come!

TEVATRON constraints on parton densities

M. Lancaster

- **Inclusive jets**: impact on high-*x* gluon





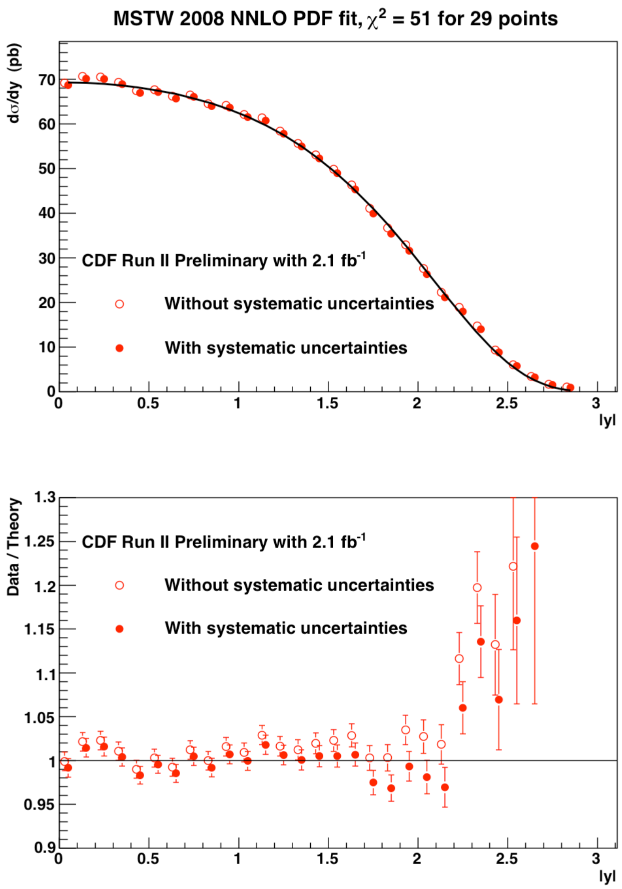
→ Data now prefer smaller high-*x* distribution than previous fits
→ Still large variance for gluons at high *x*

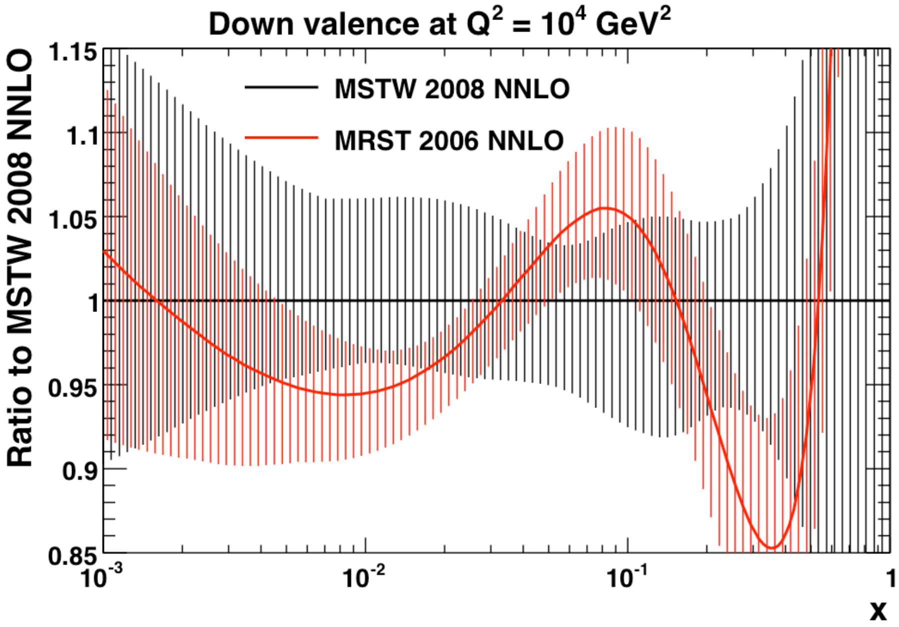
TEVATRON constraints on parton densities

M. Lancaster

- **W/Z rapidity**: mostly constrains d-quark

Z/γ* rapidity distribution from CDF





→ in spite of better constraints, variance now larger than before due to more freedom in d_v parametrization

TEVATRON constraints on parton densities

M. Lancaster

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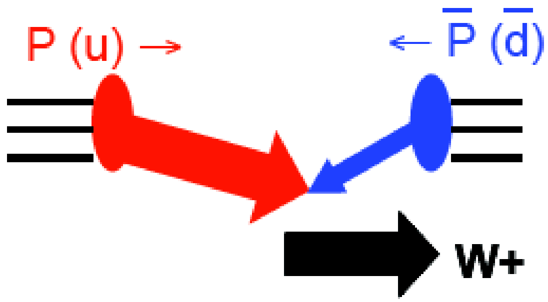
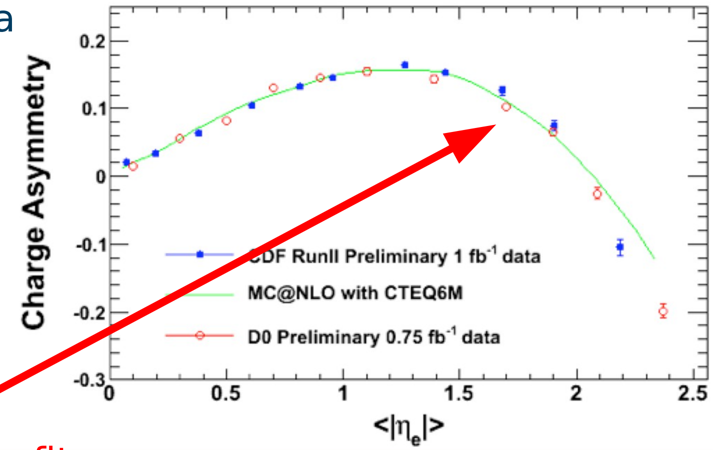
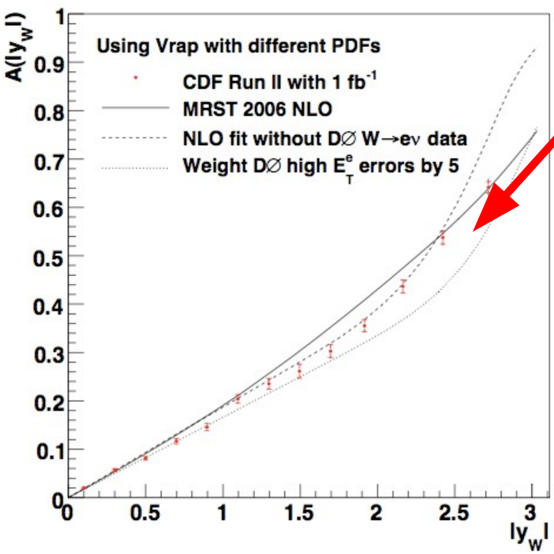
- **W charge asymmetry**: sensitive to (antiquark) sea

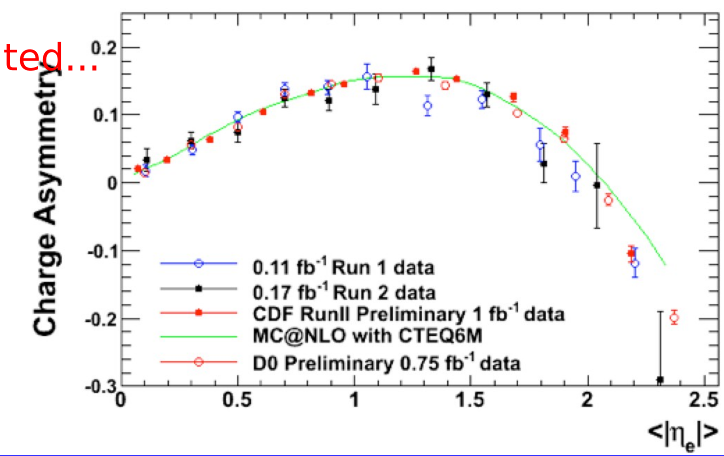




but: D0 below CDF
→ gives inconsistency in fits

to be investigated…





→ all this based on 0.2-2 fb-1 of data, much more to come!

Heavy flavour @ HERA

R. Shehzadi, P. Thompson

- Multi-scale problem: m_q, Q^2, p_T → different theory approaches

Massive scheme: → $m_{c,b}$

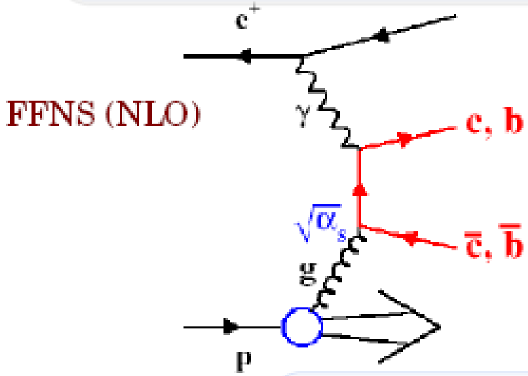
- c,b massive
- neglects $[\alpha_s \ln(Q^2, p_T^2/m_{c,b}^2)]^n$

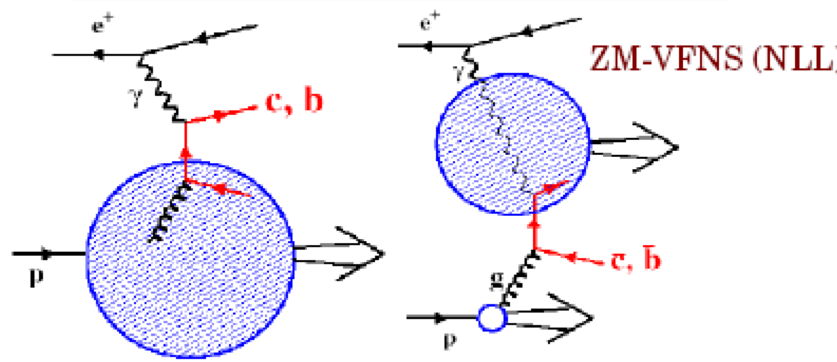
→ c,b produced perturbatively

Massless scheme: → Q^2, p_T^2

- c,b massless
- resums $[\alpha_s \ln(Q^2, p_T^2/m_{c,b}^2)]^n$

→ c,b also in Proton and Photon!





Variable Flavour Number Schemes (VFNS):

- massive at small Q^2, p_T^2
- massless at large Q^2, p_T^2

→ GM-VFNS (FONLL)

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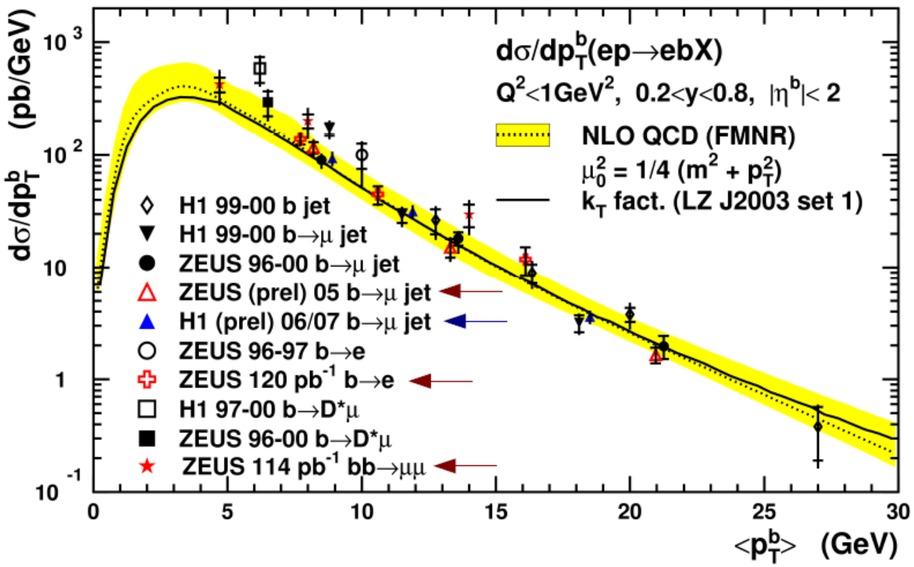
Heavy flavour @ HERA

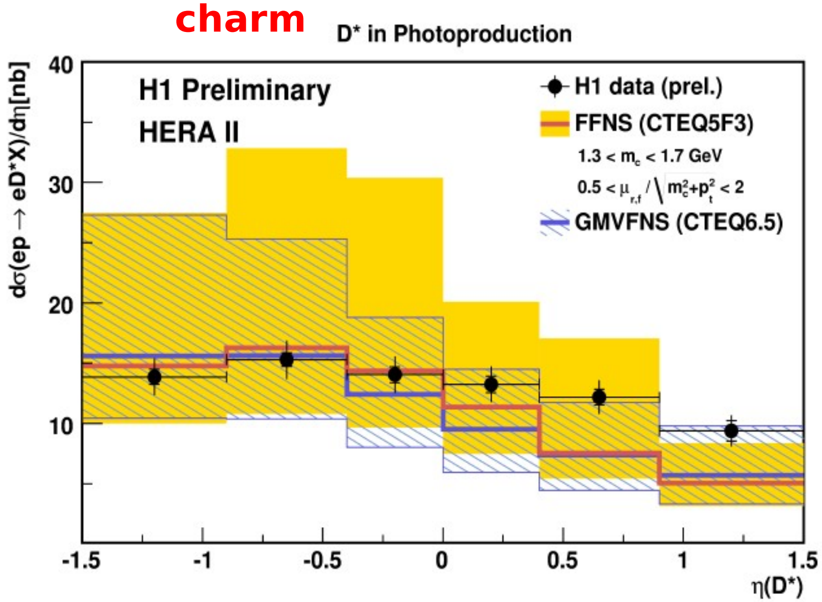
R. Shehzadi, P. Thompson

- **Charm and beauty in photoproduction**

beauty



charm

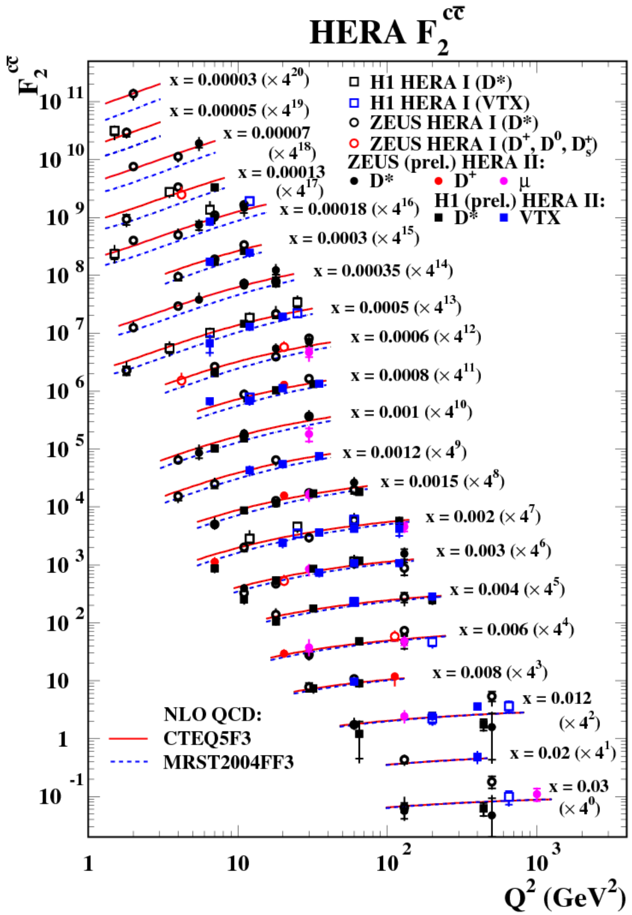


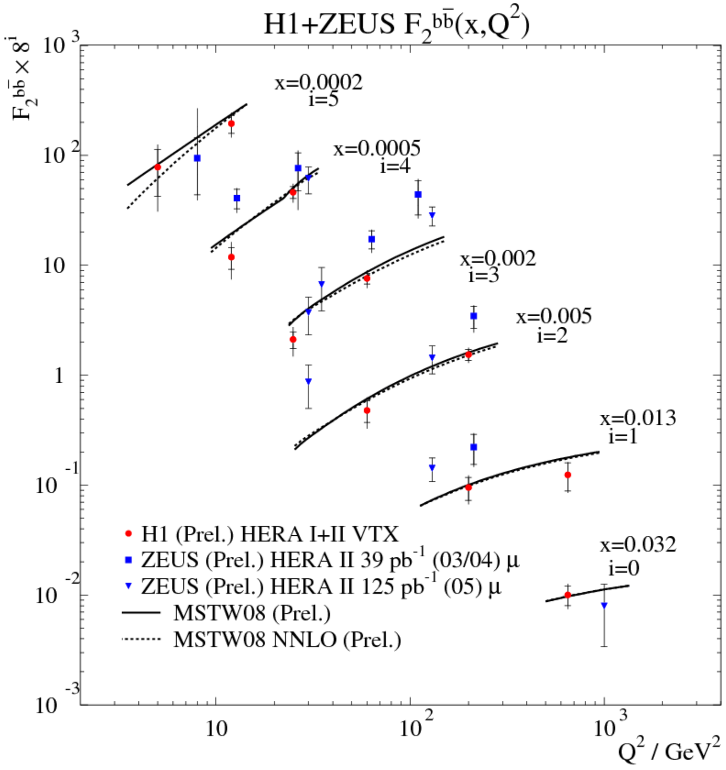
→ overall good description by NLO QCD
→ mass and scale uncertainties often larger than experimental errors
→ NNLO predictions needed, especially at forward rapidity

Heavy flavour @ HERA

R. Shehzadi, P. Thompson

- **Charm and beauty in DIS** → charm and beauty structure functions





→ models differ at low $Q^2 < m_q^2$

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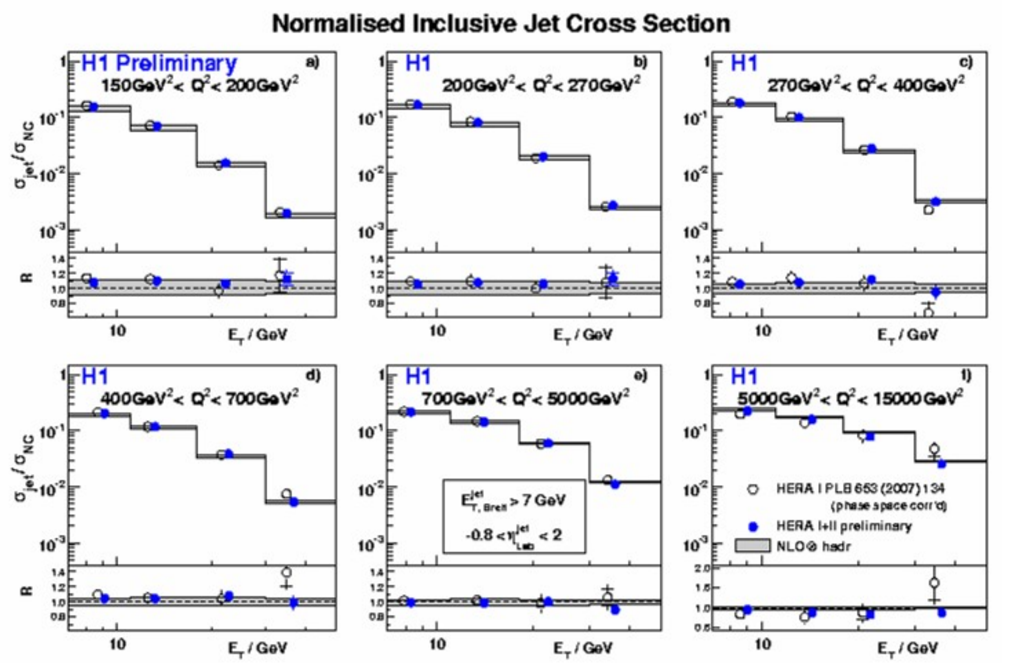
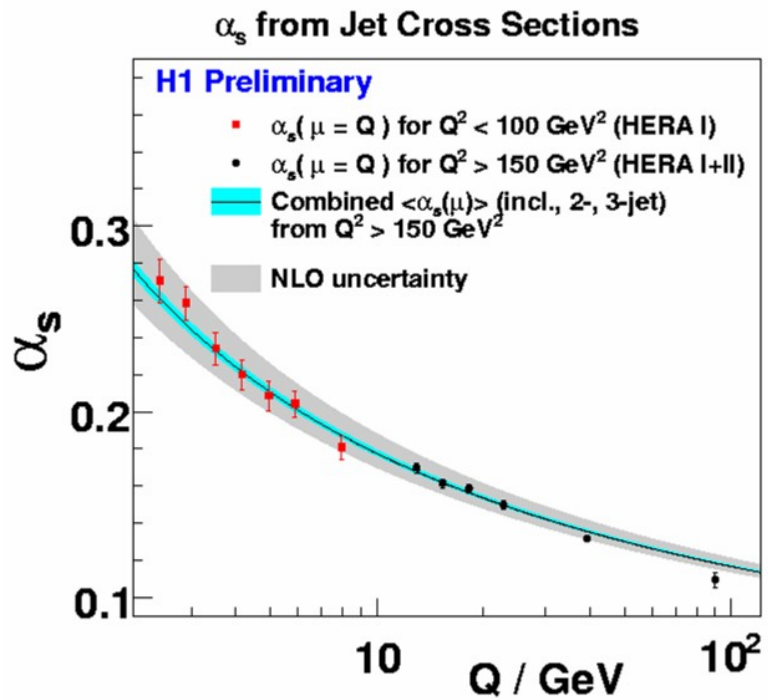
Jets @ HERA

A. Savin

- **Inclusive jets in photoproduction and DIS**



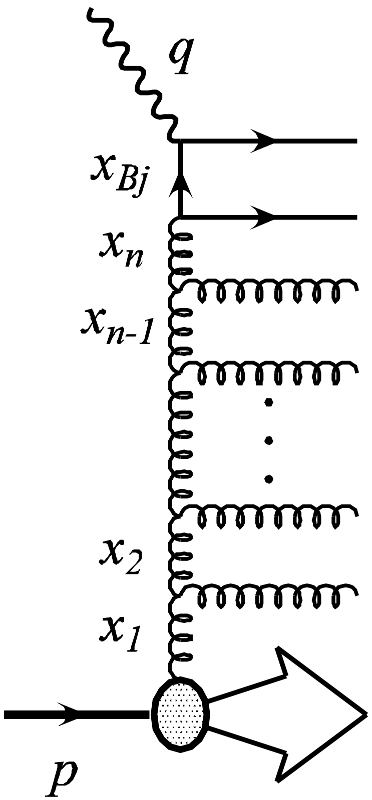


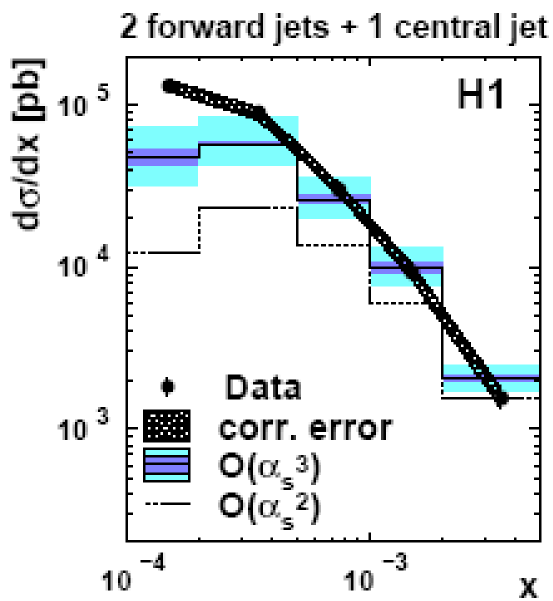
→ NLO pQCD generally works well

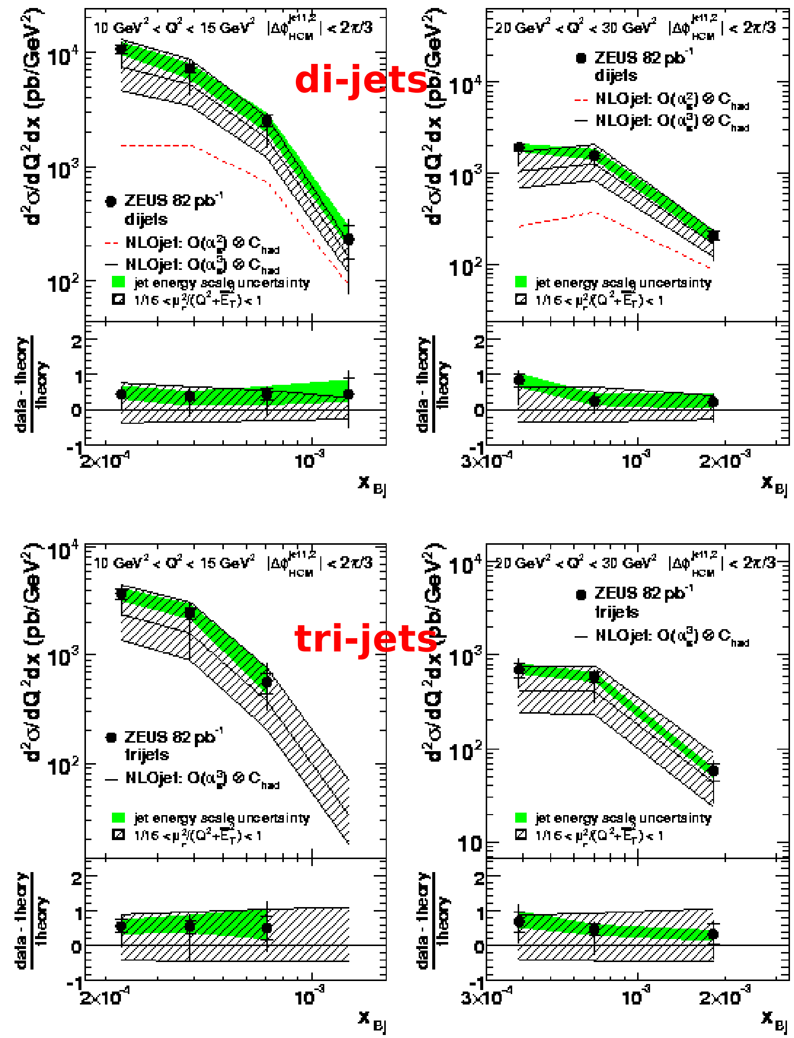
Jets @ HERA

A. Savin

- **Forward and multi-jets at low *x***







Discrepancies at low x can be covered by:

- non kT-ordered parton showers
- NNLO corrections

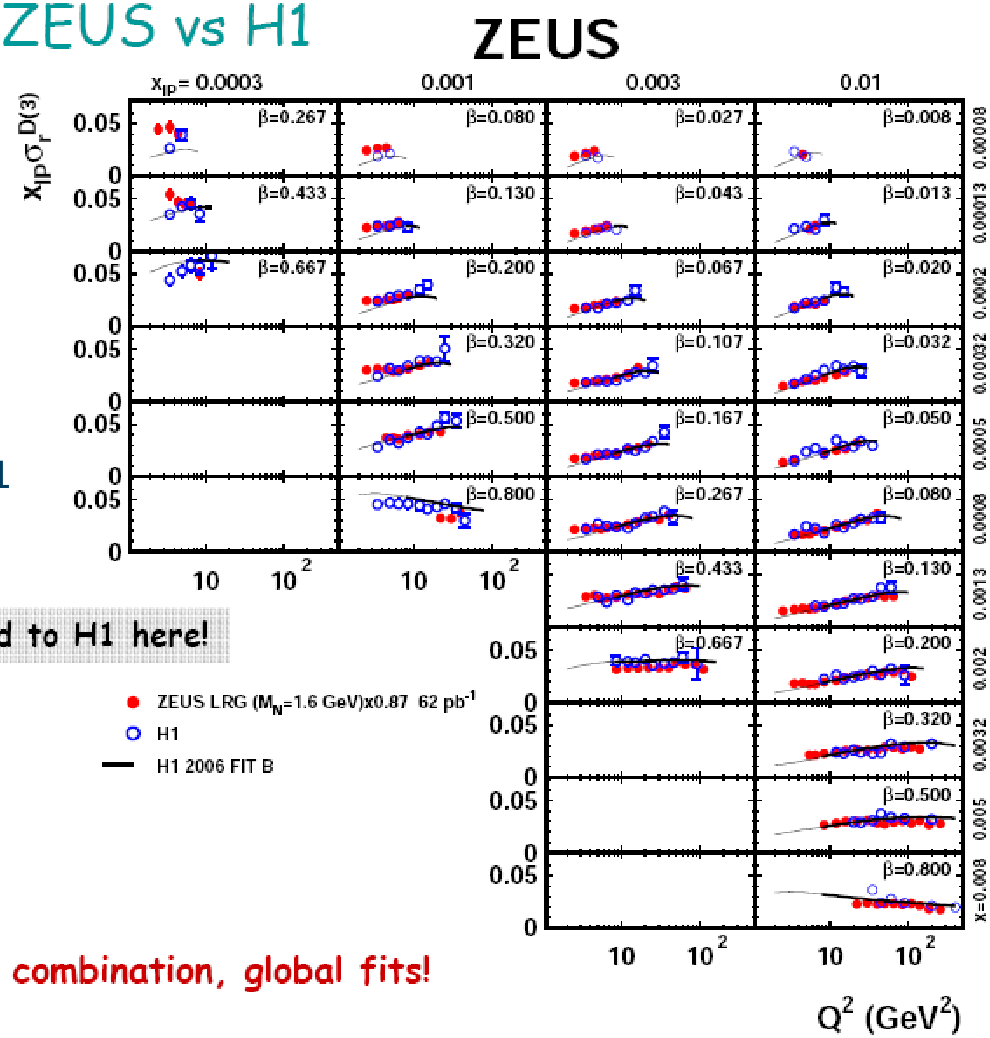
Interpolation region

- Diffractive interactions at HERA
- Diffraction and Central Exclusive Production at the TEVATRON
- Diffraction at the LHC

Inclusive diffraction and jets

M. Wing

$\sigma_r^{D(3)}$ LRG ZEUS vs H1



- LRG, M_X and LPS measurements from H1 and ZEUS all consistent within uncertainties

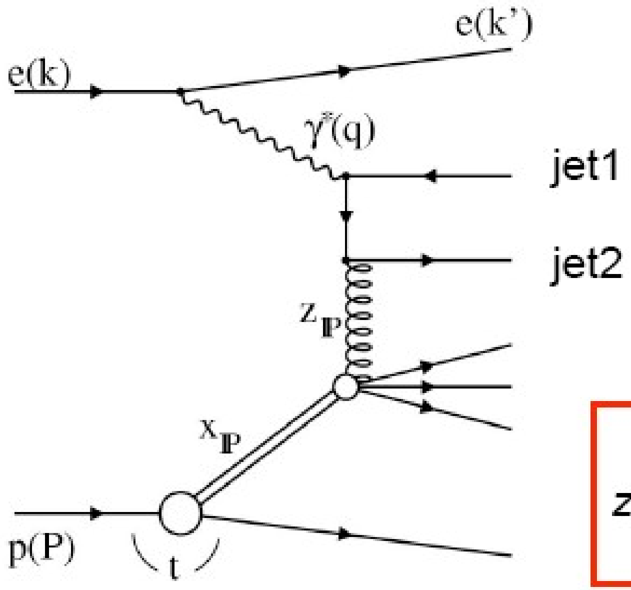
ZEUS normalised to H1 here!

- Remaining normalisation difference of 13% is covered by the uncertainty on the proton dissociation correction (8%) and the relative normalisation uncertainty (7%)

Time for data combination, global fits!

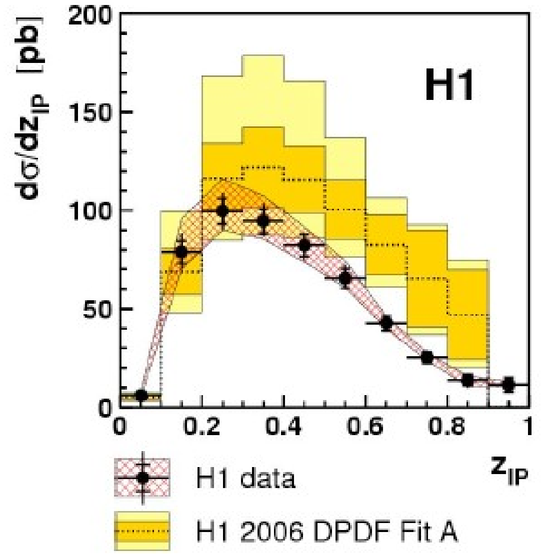
Inclusive diffraction and jets

M. Wing

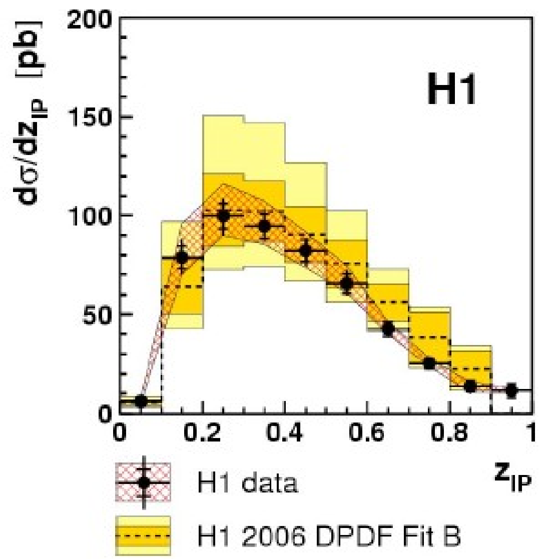


Fit A in good agreement with data at low z, overshooting at high z

$$z_{IP} = \frac{M_{12}^2 + Q^2}{M_X^2 + Q^2}$$



Fit B in good agreement with data at all z



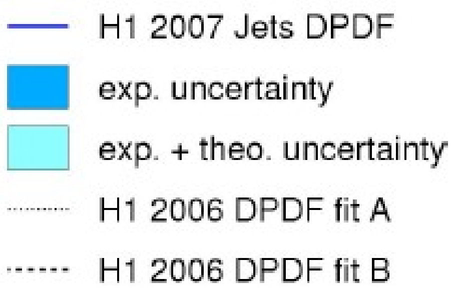
→ QCD factorisation holds in DDIS

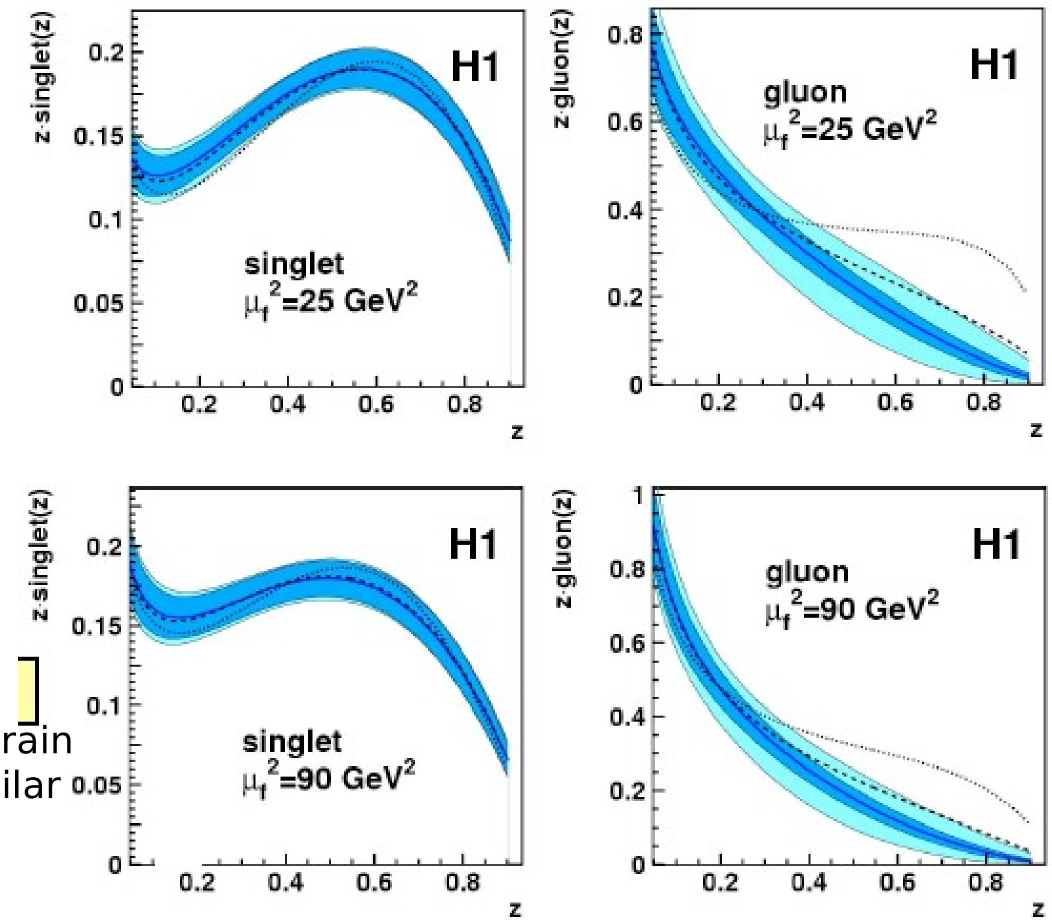
→ Fit B preferred by DDIS dijets

Inclusive diffraction and jets

M. Wing

- **H1 Jets 2007 DPDF fit**
  use DDIS dijet data as additional constraint in a NLO QCD fit





$\chi^2 = 196 / 218$ d.o.f.

→ Combined inclusive + dijet fit constrain both quark and gluon DPDFs to similar good precision

→ H1 Jets 2007 fit yields most precise DPDFs to date

$$z\Sigma(z, Q_0^2) = A_q z^{B_q}(1-z)^{C_q}$$

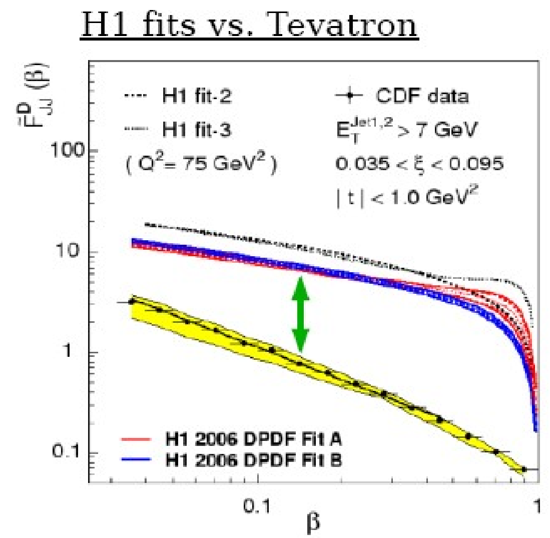
$$z_g(z, Q_0^2) = A_g z^{B_g}(1-z)^{C_g}$$

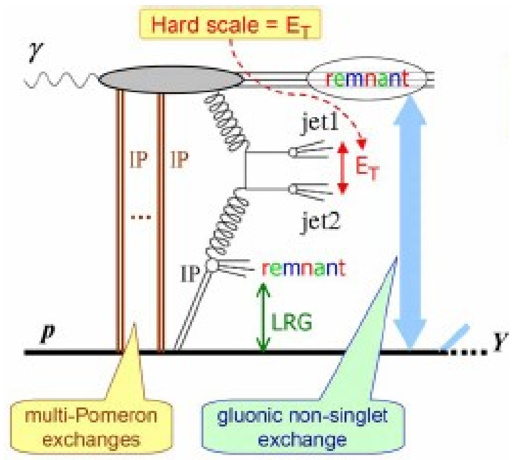
QCD factorisation breaking

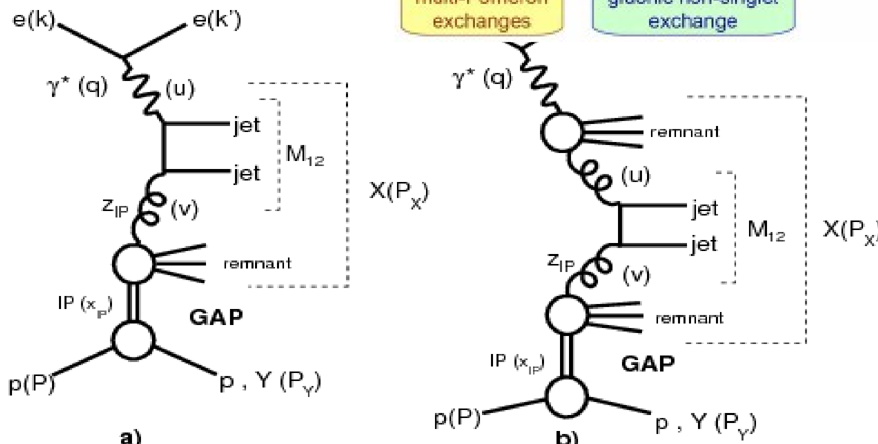
- DPDF fits fail to predict TEVATRON data
  QCD factorisation not expected to hold in pp diffraction!
  - multi-pomeron exchanges
  - remnant interactions
  - Screening

  → gap survival probability

- Look at DPHP dijets







Note: separation between direct and resolved only possible at fixed order!

Direct photon ($x_\gamma = 1$)
→ factorisation should hold

Resolved photon ($x_\gamma < 1$)
→ suppression is expected

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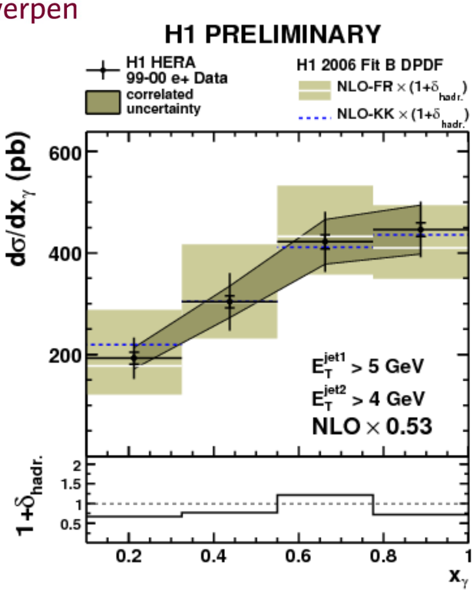
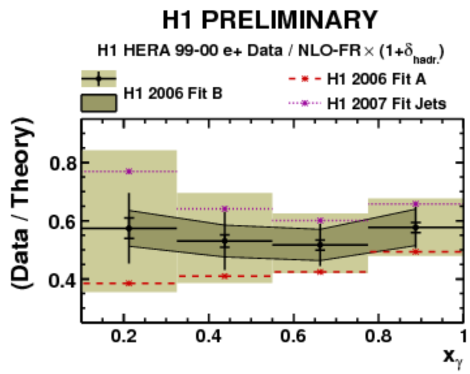
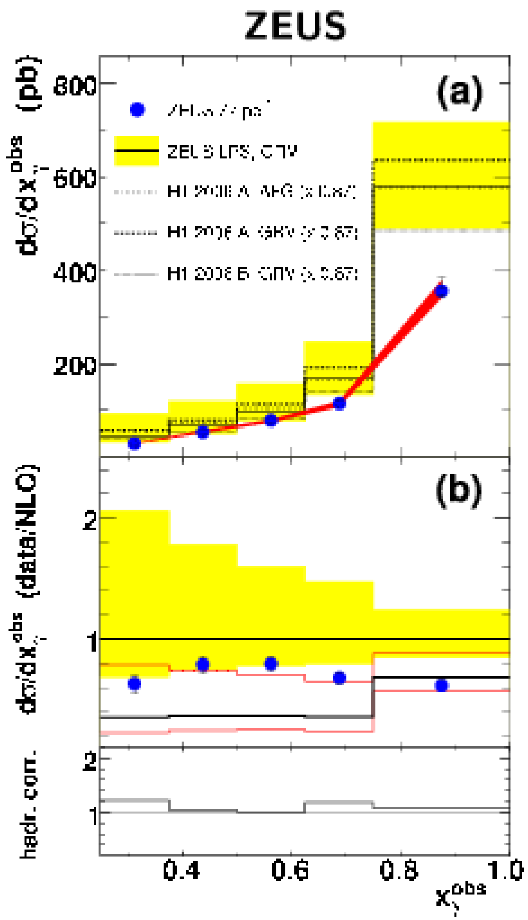
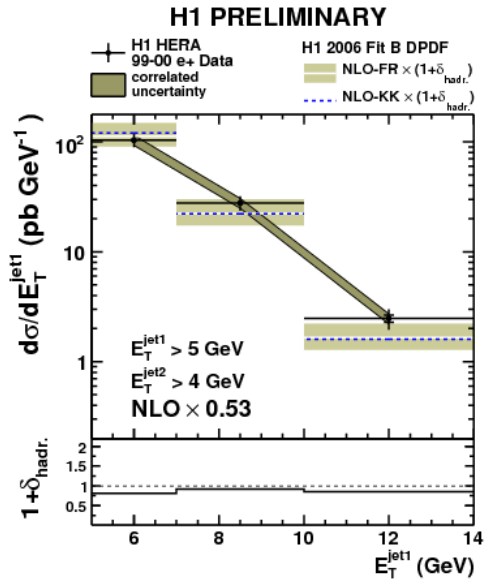
Survival probability from H1 and ZEUS

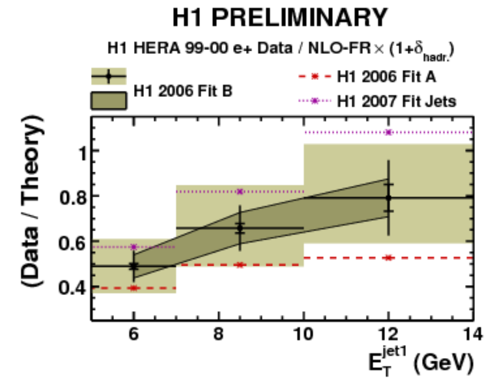
M. Wing









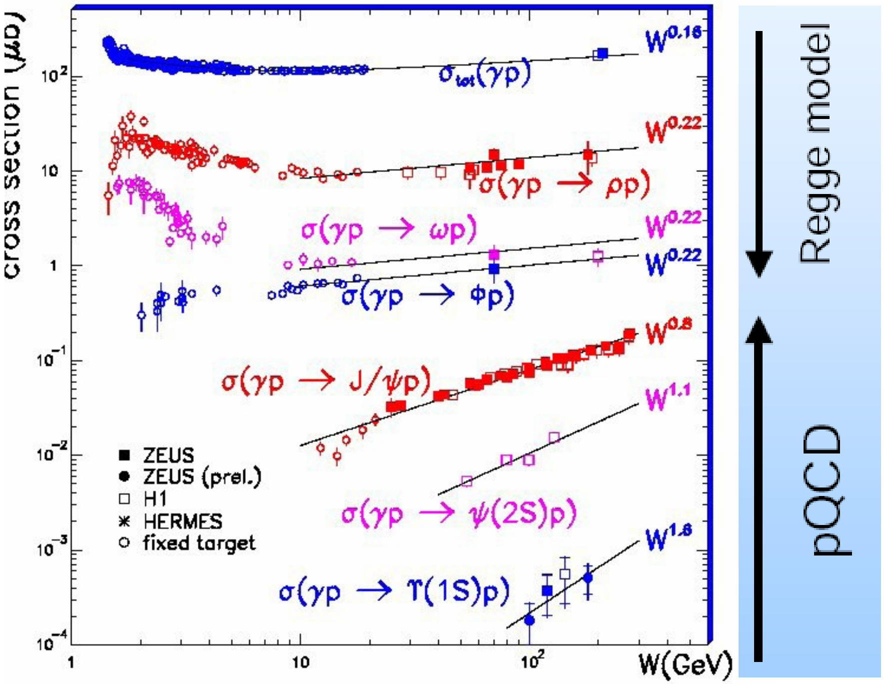


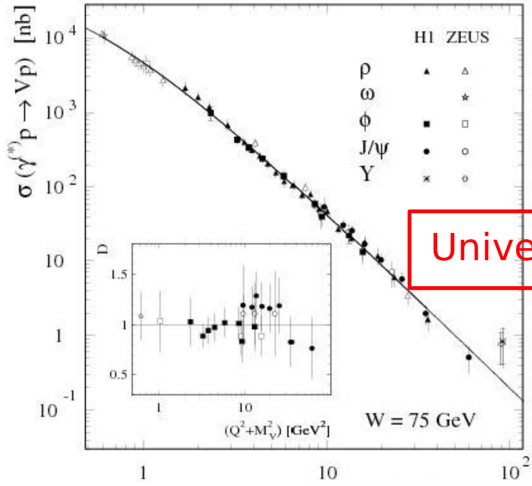
- → Neither experiment observes a x_γ dependence
- → H1 observes a larger suppression than ZEUS
- → Harder E_T slope in data than in NLO theory
- → H1 and ZEUS suppression factors are consistent

Exclusive diffraction at HERA

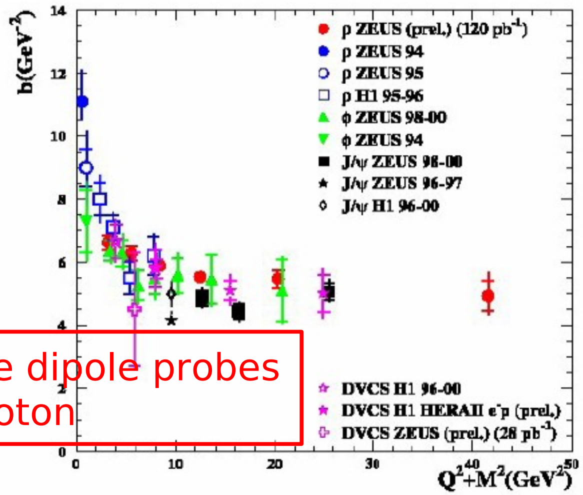
D. Wegener

- **Exclusive vector meson production:**
  Continuous soft ↔ hard transition





Universal scale $Q^2 + M_V^2$



Q^2>10 GeV^2: pointlike dipole probes gluon cloud of the proton

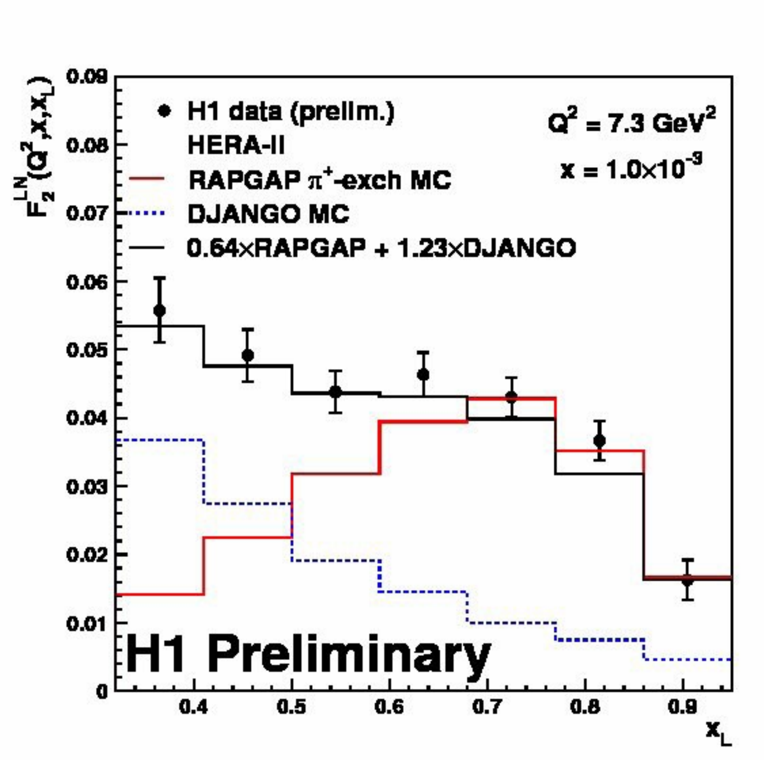
→ dipole (saturation) model works well

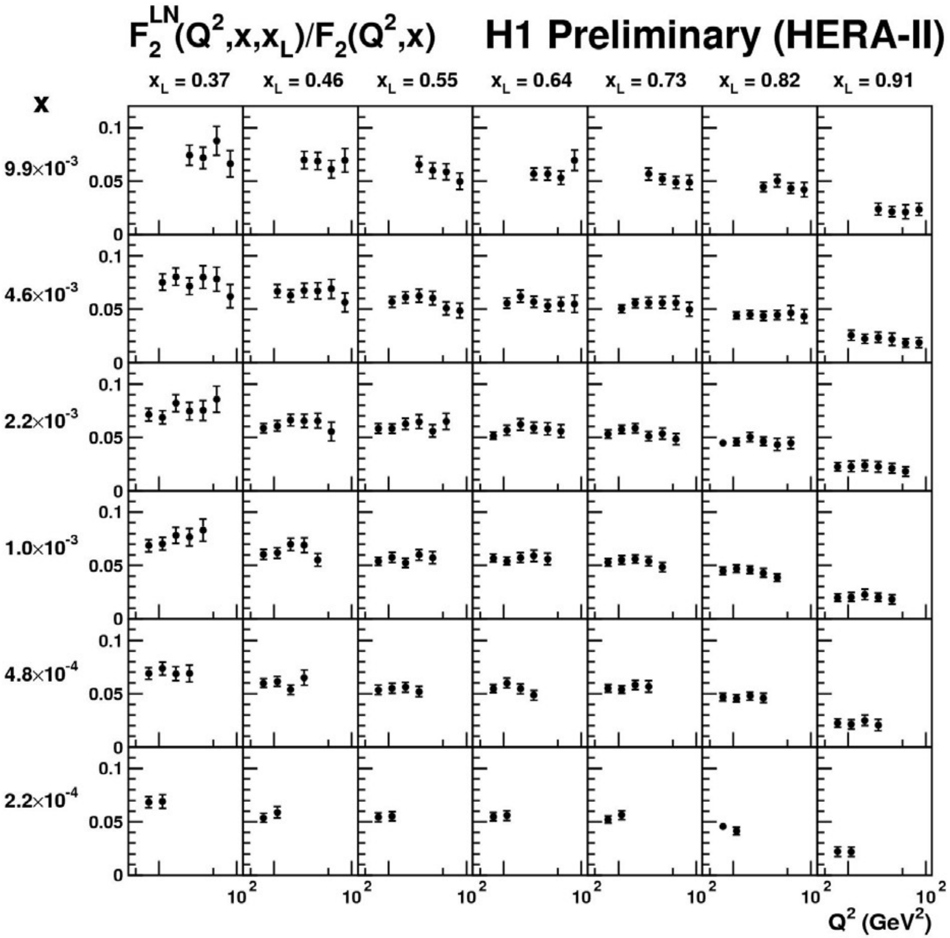
→ 2-gluon exchange works for hard interactions → constrain gluon at small x

Leading baryons at HERA

D. Wegener

- **Leading neutrons**
  fragmentation+π exchange?





→ fragmentation models fail
→ best mixture of DJANGO + RAPGAP π exchange

→ F_2^{LN}/F_2 ratio x,Q^2 independent

Diffractive production of jets and vector bosons at the TEVATRON

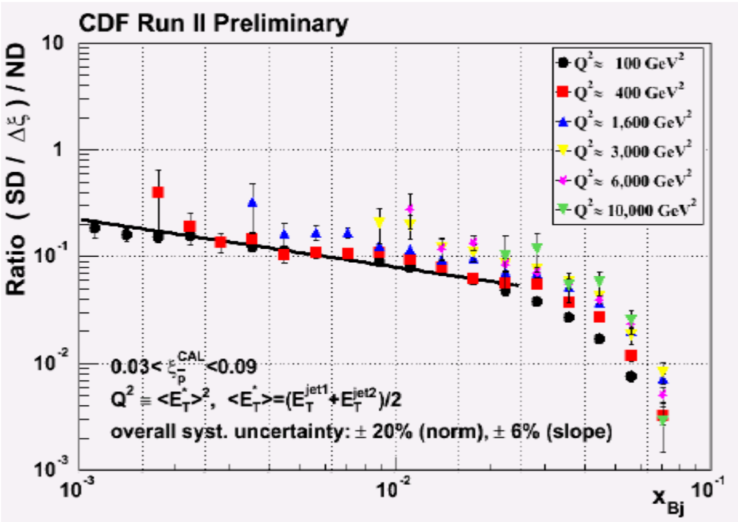
K. Hatakeyama

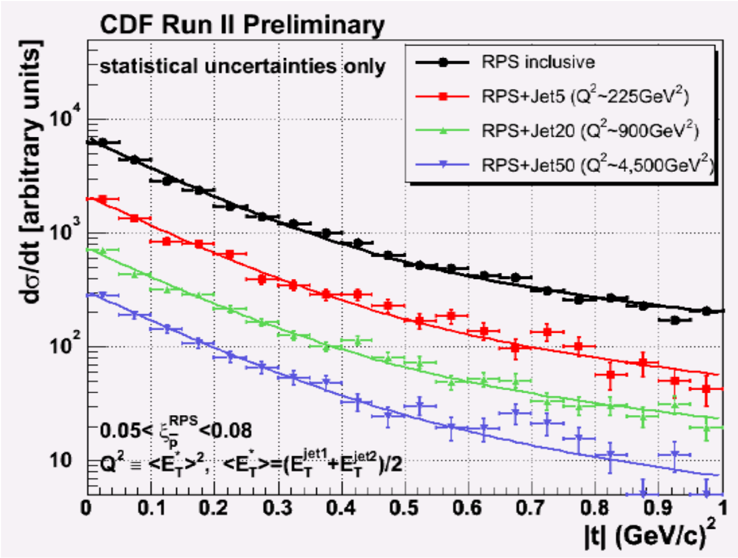
- ratio of SD to ND dijet production extended to higher Q^2:
  no Q^2 dependence
  → IP evolves similarly as p

- t-distribution in dijet production:
  slope parameter b is Q^2 independent

- W/Z production with Roman Pots:
  $R_W(0.03<\xi<0.10, |t|<1)=$
  $[0.97 \pm 0.05(\text{stat}) \pm 0.11(\text{syst})]\%$
  $R_Z(0.03<\xi<0.10, |t|<1)=$
  $[0.85 \pm 0.20(\text{stat}) \pm 0.11(\text{syst})]\%$

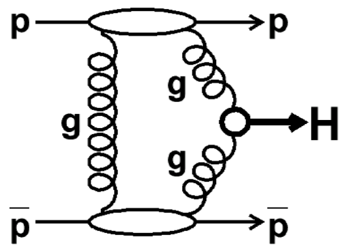
- Study of rapidity gaps between jets with $\Delta\eta$ up to 7
  → aim to observe azimuthal decorrelation





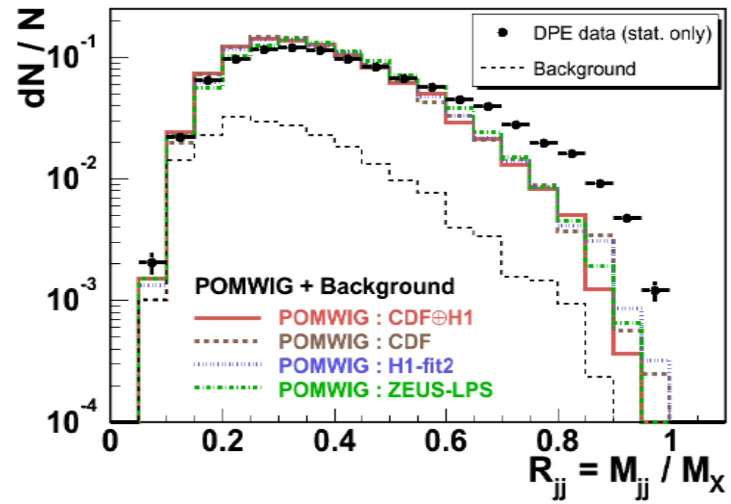
Central exclusive production at the TEVATRON

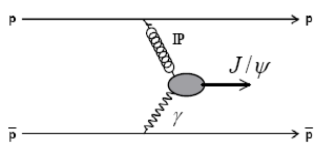
K. Hatakeyama, M. Albrow



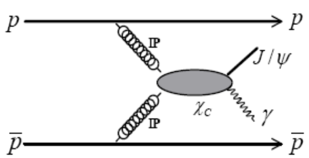
CEP has been observed!

- Dijets validate KMR calculation (within factor 3 uncertainty)
- e^+e^-, $\mu^+\mu^-$, J/ψ, ψ(2S), χ_c, Υ provide evidence for γ-γ, γ-IP and IP-IP exchange at the TEVATRON
- These processes can be used as "standard candles" for CEP and for calibration of forward proton spectrometers

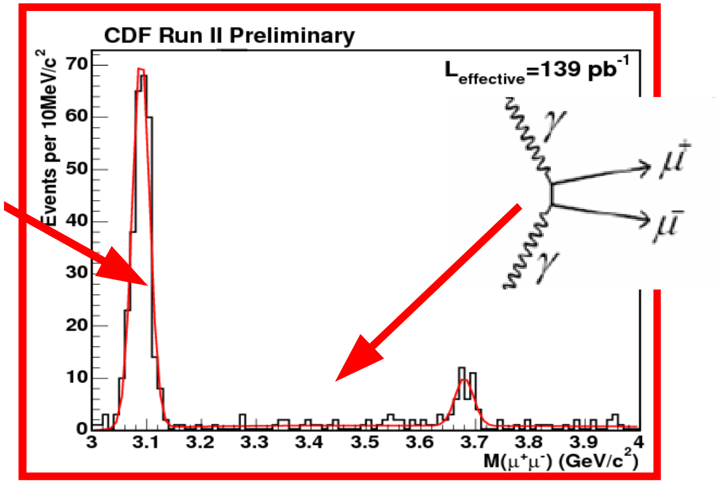


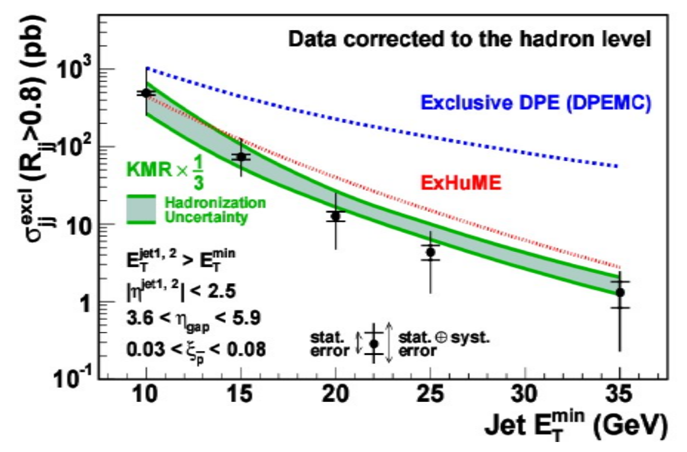


$$\gamma + IP \rightarrow J/\psi \rightarrow \mu^+\mu^-$$

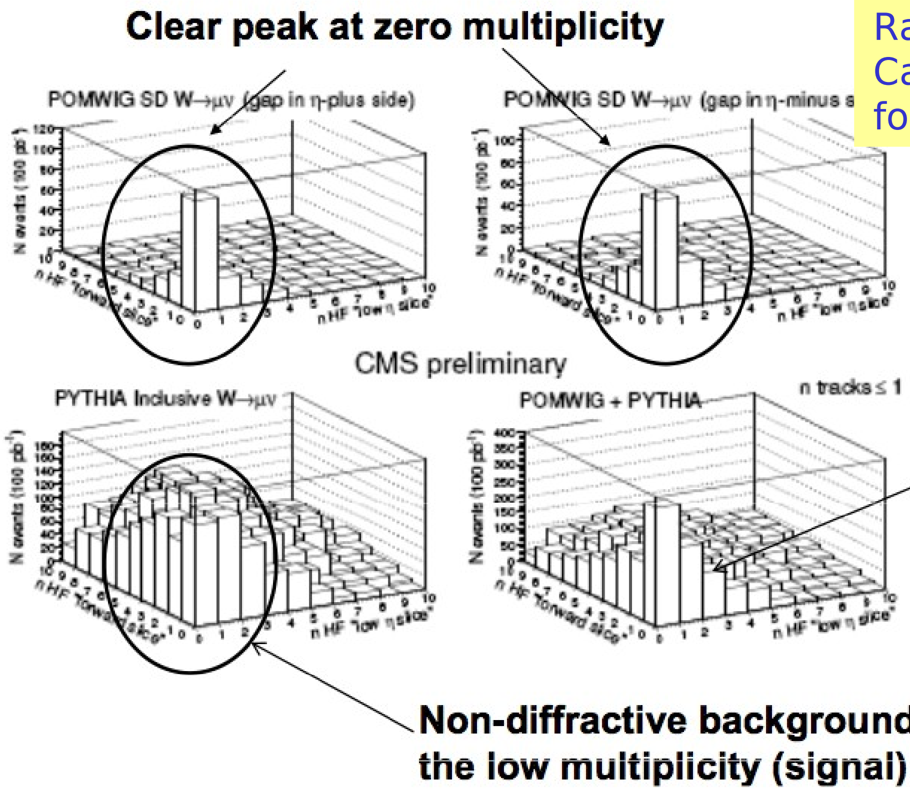


$$IP + IP \rightarrow \chi_C \rightarrow (J/\psi + \gamma)$$





- **Diffractive W (and jet) production**



Rapidity gap:
Calorimeter towers in the CMS forward calorimeter (HF)

"low η": $3.0 < |\eta| < 4.0$

"high η": $4.0 < |\eta| < 5.0$

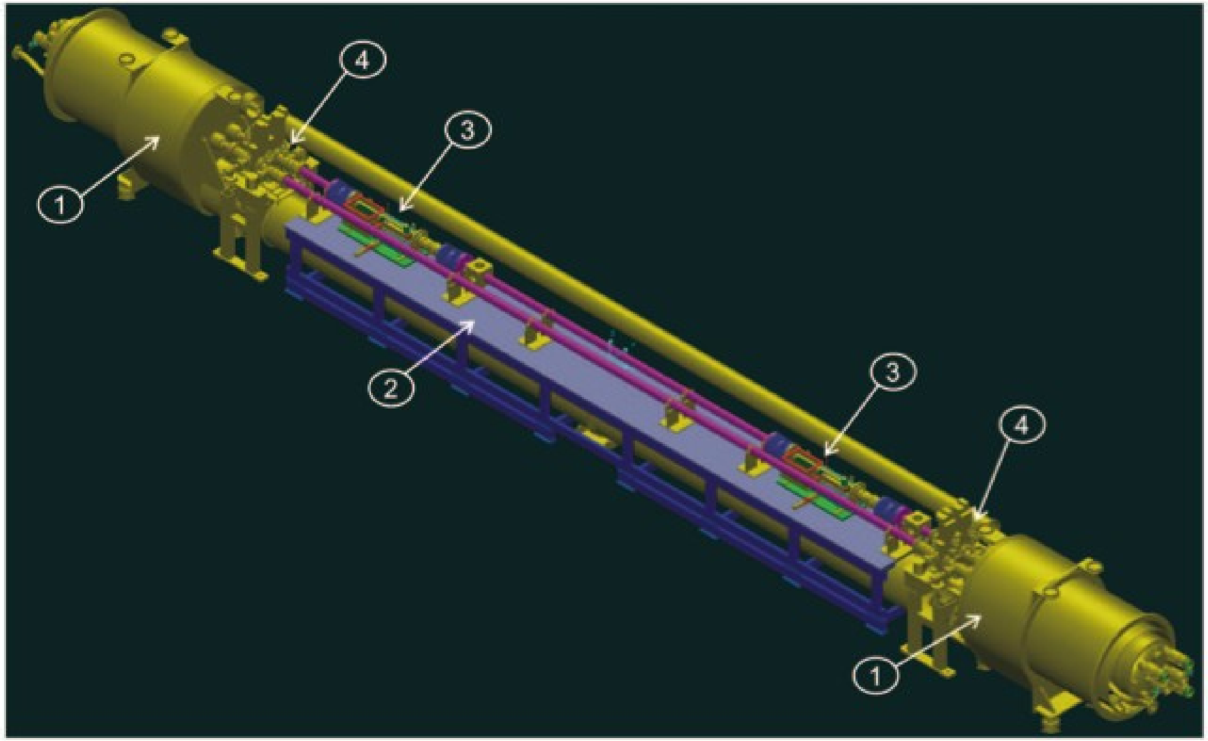
Excess in low multiplicity visible

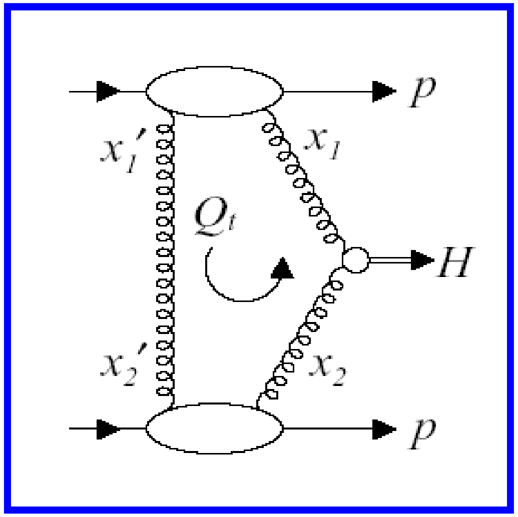
CASTOR forward calorimeter will further increase rapidity gap tagging efficiency

Expect O(100) signal events for 100 pb^{-1} assuming 0.05 gap survival probability

Diffraction @ LHC
A. De Roeck

- **FP420**





- The physics case for forward proton tagging spans central exclusive production (Higgs mass, quantum numbers, discovery in certain regions of MSSM / NMSSM), γγ and γP, diffractive physics, gap survival / underlying event, study of gluon jets, precision jet energy calibration at

→ **extension of baseline detector with FP420 under consideration by ATLAS/CMS**

Dense systems

- Probing the matter created at RHIC
- Saturation in heavy ion collisions from RHIC to LHC
- Hadron multiplicities from RHIC to LHC
- Light/strange/charm hadrons in ep collisions

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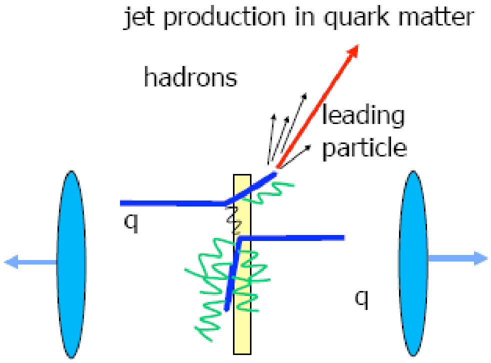
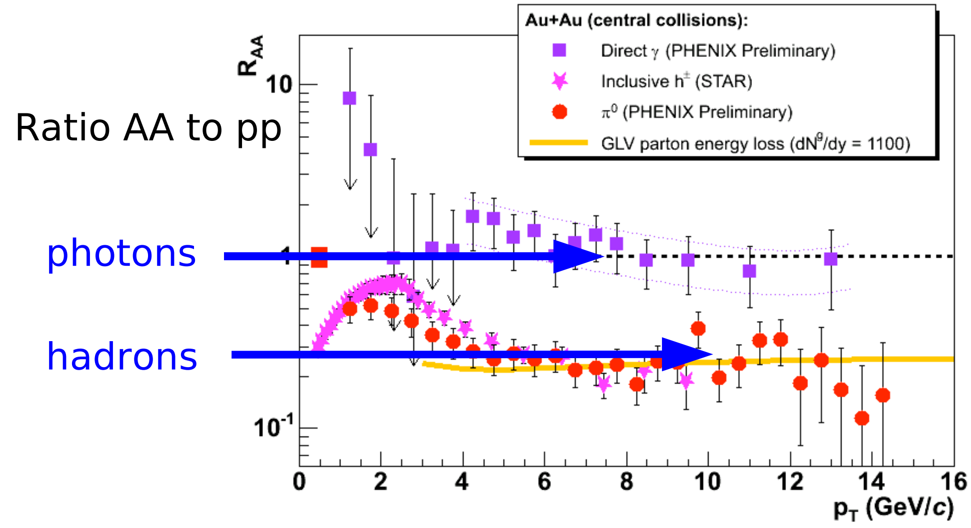
Probing the matter created at RHIC

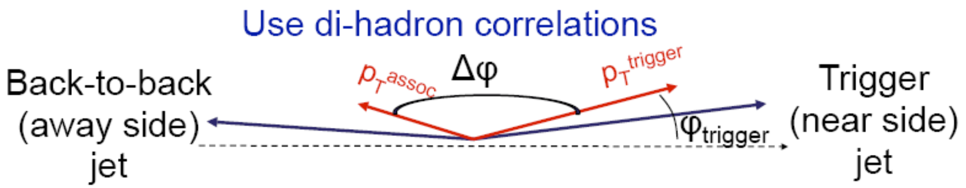
H. Caines

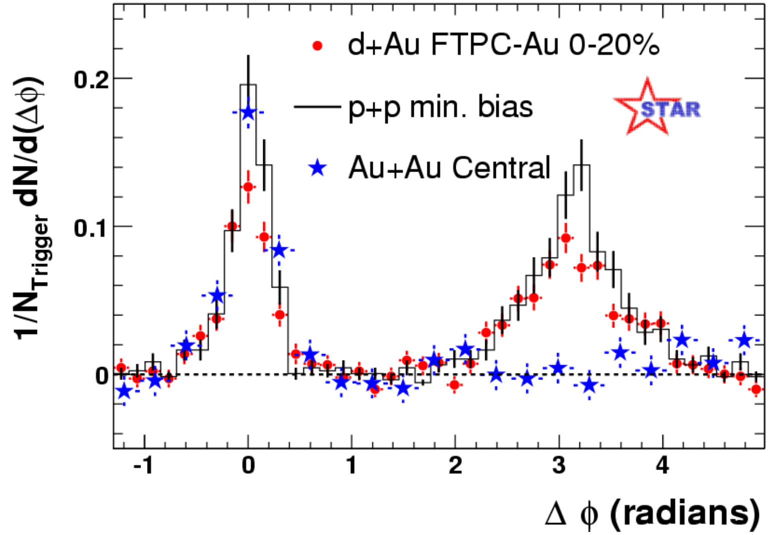
- **Suppression of high pT hadrons**





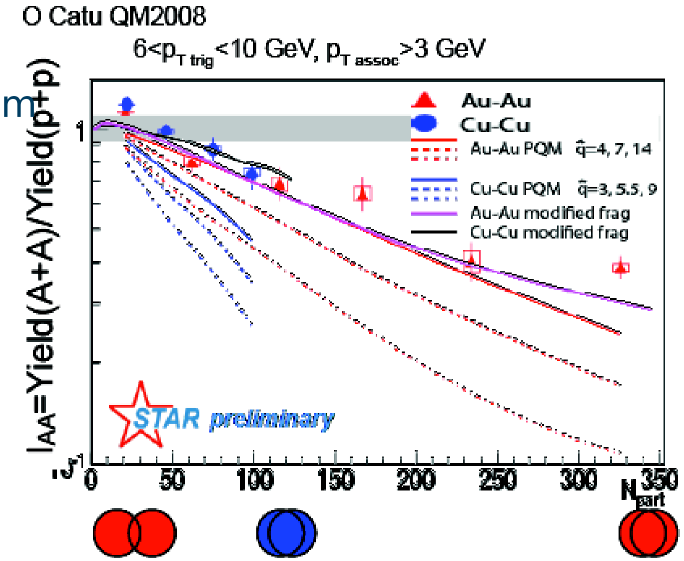
- **Suppression of away-side jet**





Probing the matter created at RHIC

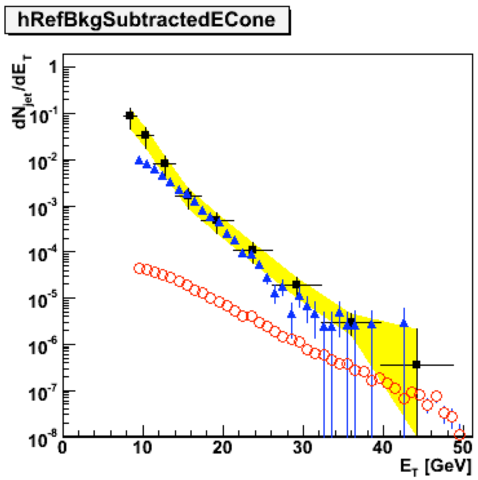
H. Caines

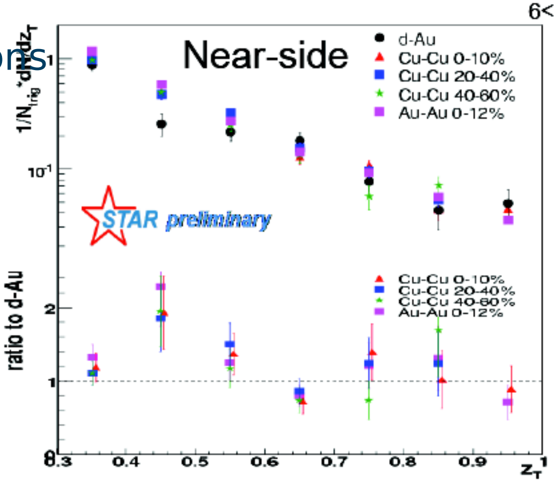


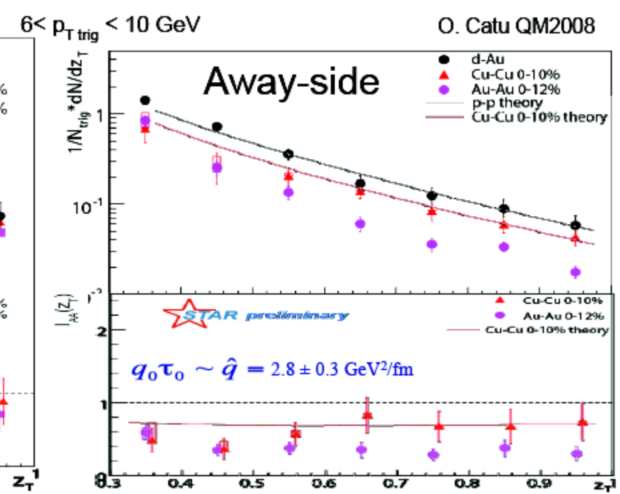
- Past discovery stage → on to characterization of the medium
  - transport coefficient
  - gluon density

  } **constraining models**

- Experimental observables
  - **jet yield** = number of associated particles in jet/trigger cone
  - di-hadron **fragmentation function**
    → consistent with vacuum fragmentation after energy loss
  - first **jets** in central HI collisions



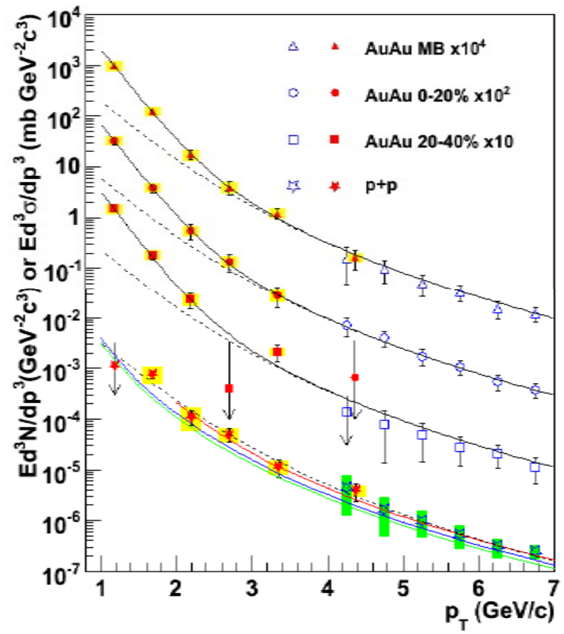


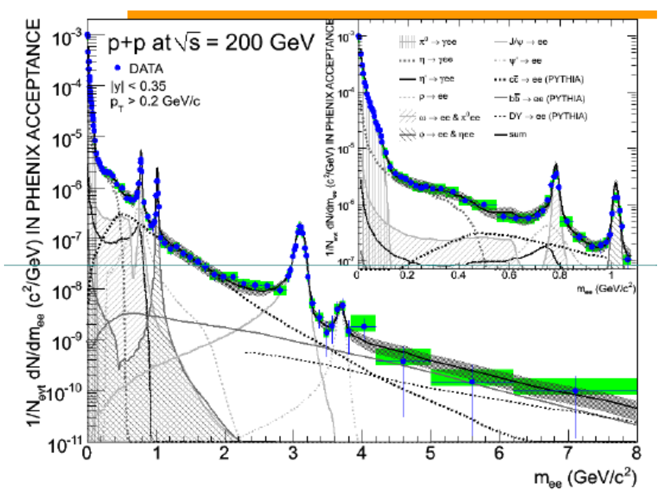


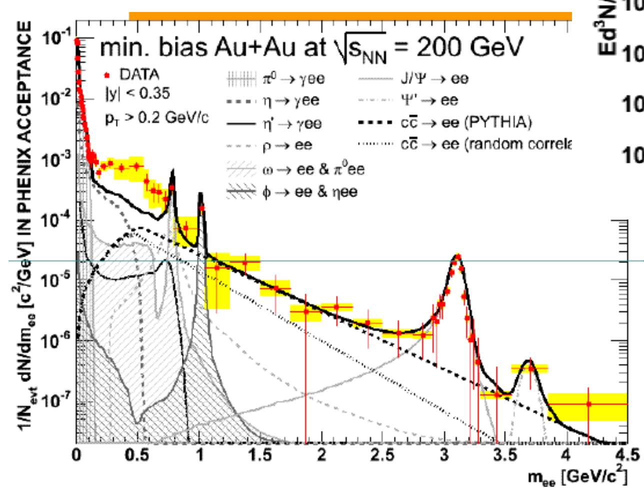
Probing the matter created at RHIC

H. Buesching

- Attempt to measure thermal photons in Au+Au collisions with PHENIX:
  - advantage: sQGP transparant to photons
  - difficulty: many photon sources
- Solution: measure virtual photons decaying to e^+e^-
  - excess in Au+Au over hadronic cocktail us assumed to be due to internal conversion of direct photons
- Fit of p_T spectrum
  - → T = 221 +/- 23 (stat) +/-18 (sys) MeV, in qualitative agreement with hydrodynamical models







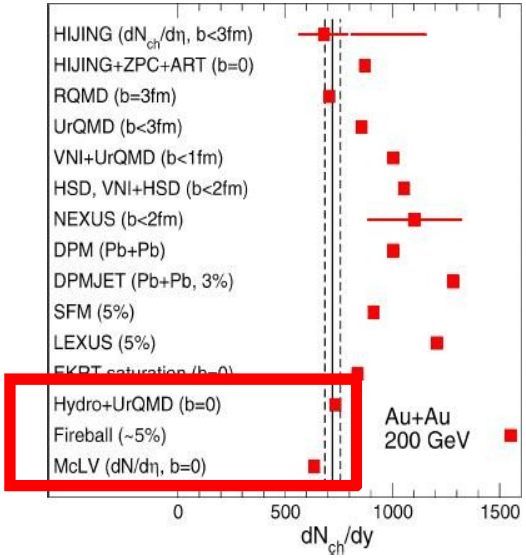
Saturation in heavy ion collisions from RHIC to LHC

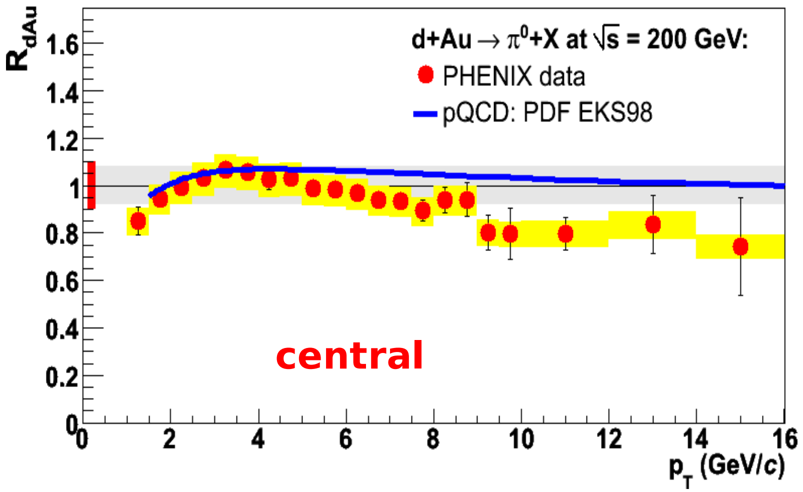
A. Dainese

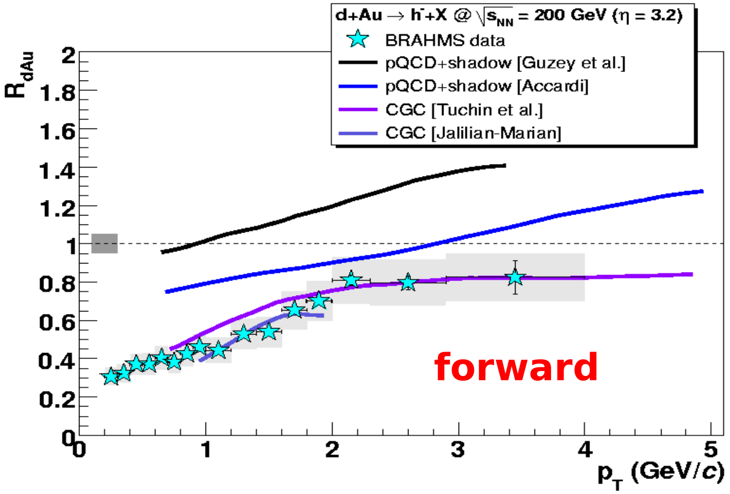
- Saturation scale in heavy ion collisions

$$Q_s^2 \sim \alpha_S \frac{xG_A(x, Q_s^2)}{\pi R_A^2} \sim A^{1/3} x^{-\lambda}$$

- Hints for saturation at RHIC:
  - reduced charged hadron multiplicity $dn_{ch}/d\eta$ at $y=0$
  - geometrical scaling of $dn_{ch}/d\eta$
  - forward hadron suppression







Saturation in heavy ion collisions from RHIC to LHC
A. Dainese

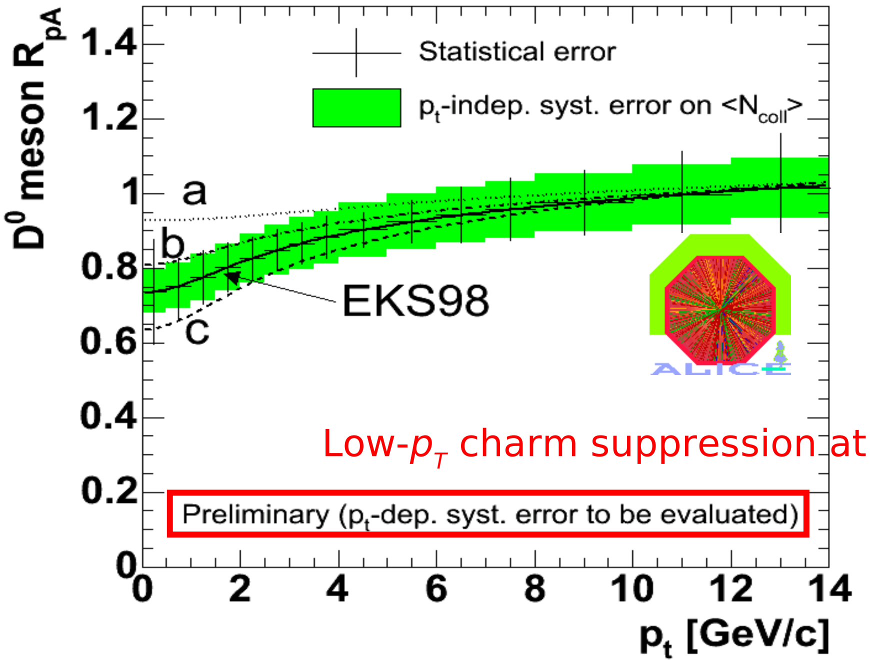
- Saturation scale at the LHC

$Q_s^2 \sim 2$ GeV^2 (RHIC, dAu @ 200 GeV)

$Q_s^2 \sim 5$ GeV^2 (LHC, pPb @ 8.8 TeV)

→ LHC will study saturation with perturbative probes

- Forward jets
- Charm



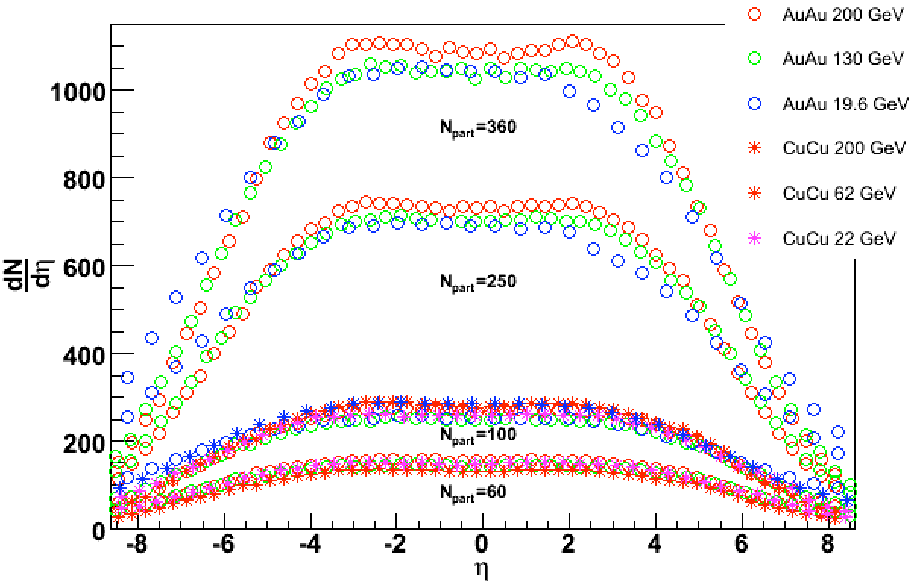
Low-p_T charm suppression at ALICE

Multiparticle production in e^+e^-, pp, pA and AA

W. Busza

- Rapidity spectra scale for very different kind of interactions

ln √s scaling in η and dN/dη



The logarithmic scaling in η and dN/dη is nothing other than extended longitudinal scaling (a.k.a. Limiting fragmentation), plus logarithmic rise of multiplicity at mid rapidity

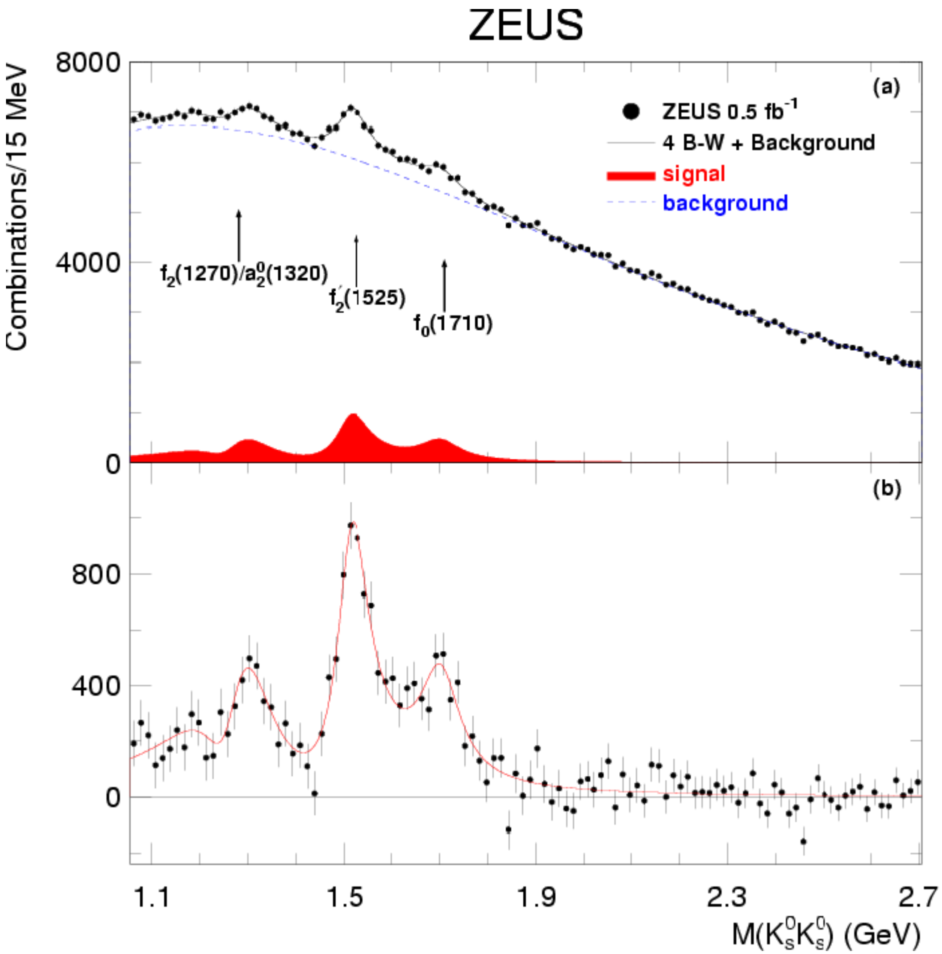
- Prediction for LHC:
  - Total charged multiplicity in central (NPART =386) PbPb collisions at (√s = 5.5 TeV) = 15000 +/- 1000
  - Total charged multiplicity in NSD pp collisions at (√s = 14 TeV) = 72 +/- 8

➔ **Why is it that, while the intermediate states are very different, there is no evidence for this in the final state?**

Light/strange/charm hadrons in ep collisions

A. Kropivnitskaya

- Detailed information about ρ, K^{*0}, $K^{*\pm}$, φ, K^0_S, Λ, D*, D_s than can be used as baseline for heavy ion collisions
- **Glueball candidate**



- f0(1710) is observed with 5 sigma effect
- this state is considered to be a glueball candidate

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Strategies and analysis methods

- Bose-Einstein correlations @ LEP
- Underlying event and multi-parton interactions
- Forward detectors

BEC @ LEP

W. Metzger, C. Ciocca

- Bose-Einstein correlations:

$$R_2 = \frac{\rho_2(p_1,p_2)}{\rho_1(p_1)\rho_1(p_2)} = \frac{\rho_2(Q)}{\rho_0(Q)}$$

$$R_2(Q) = 1 + \lambda|\widetilde{S}(Q)|^2$$

$$\widetilde{S}(Q) = \int dx\, e^{iQx} S(x)$$

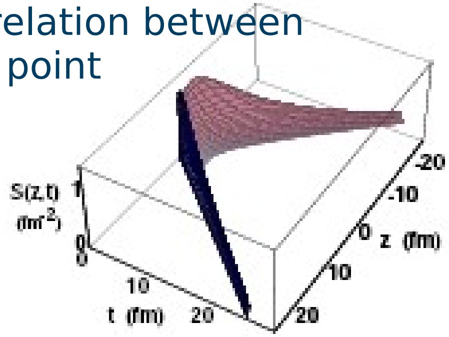
S(x): emission source density
→ Gaussian, Levy, Edgeworth parametrizations
for R_2 not very successful ..

- BEC-analyses evolved from static, 1-dim to dynamic multi-dim sources:

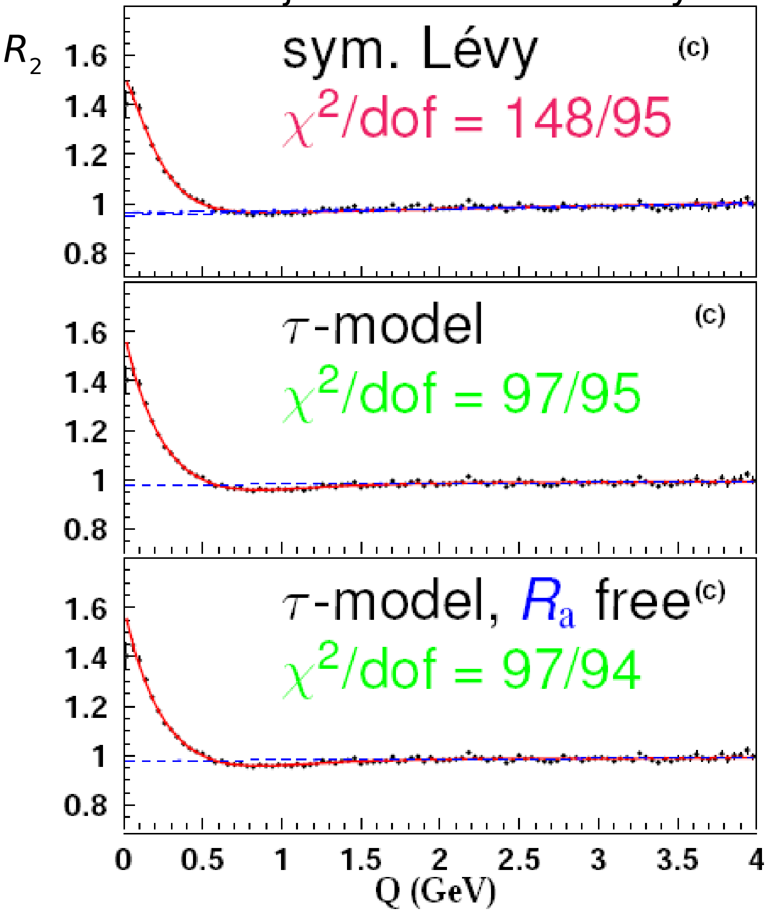
E.g. **τ-model** based on correlation between momentum and production point

→ emission function

→ particle production is close to the light cone



2-jet events in Z^0 decays

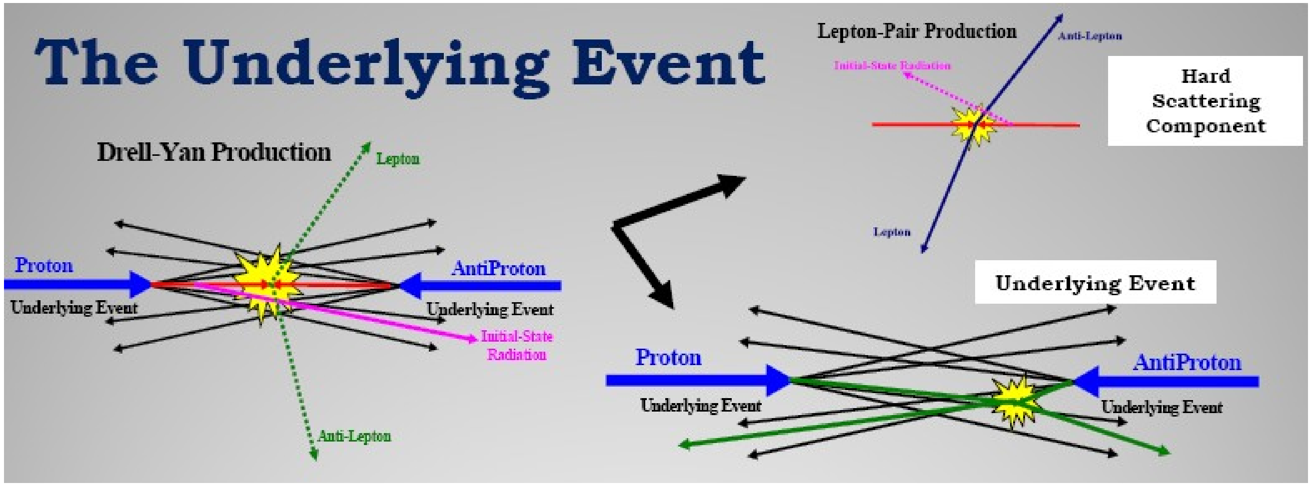


BEC are a basic tool to study parton-hadron phase transitions in QGPs

Multi-parton interactions and underlying events

P. Bartalini, D. Kar, A. Bunyatian

- **Knowledge about the UE and MPI is crucial for discovery physics!**



→ Jet pedestals
→ missing energy
→ isolation

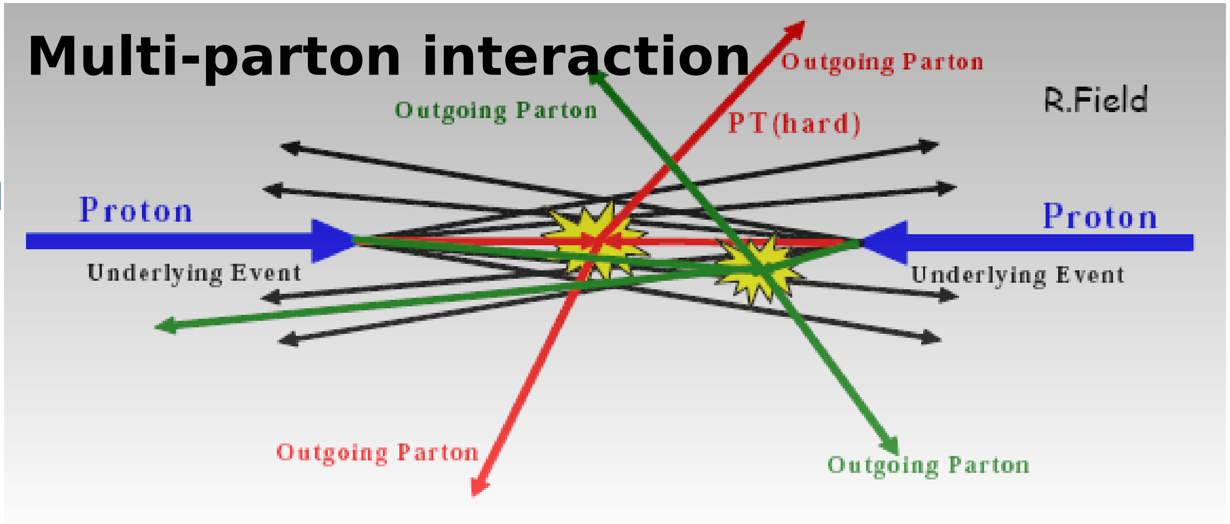
→ MPI may fake a discovery signal e.g.:

pp→WHX, W→lv and H→bb

versus

pp→WX and pp→bbX

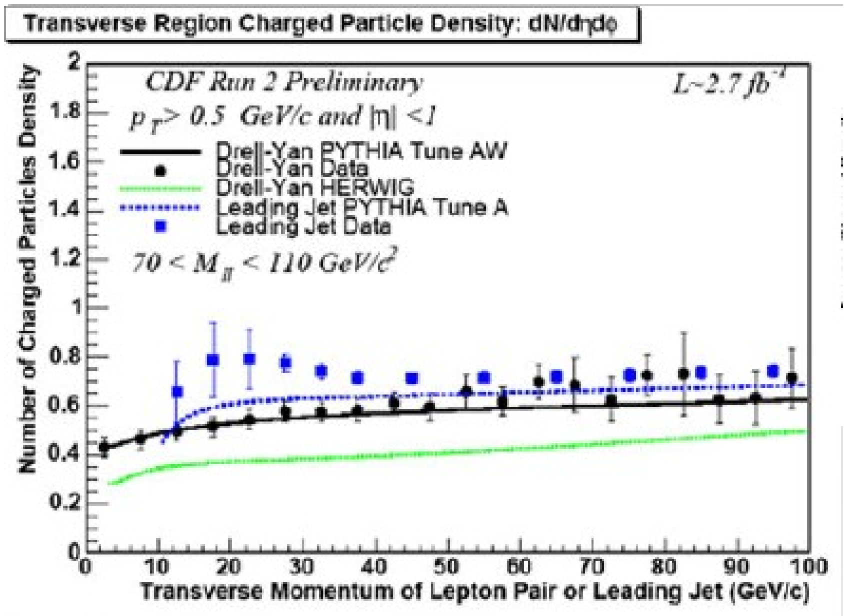
without any Higgs!

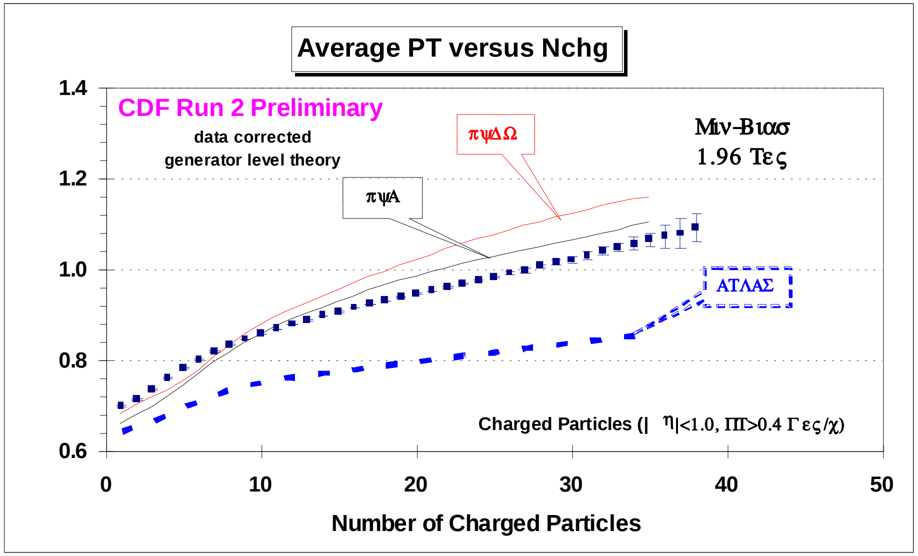


Multi-parton interactions and underlying events

P. Bartalini, D. Kar, A. Bunyatian

- **Observables for UE/MPI tuning:**
  - $\langle p_T \rangle$ vs n_{ch}
  - n_{ch} in transverse region vs. p_T
  - $\Sigma\, p_T$ in transverse region vs. p_T
  - ...

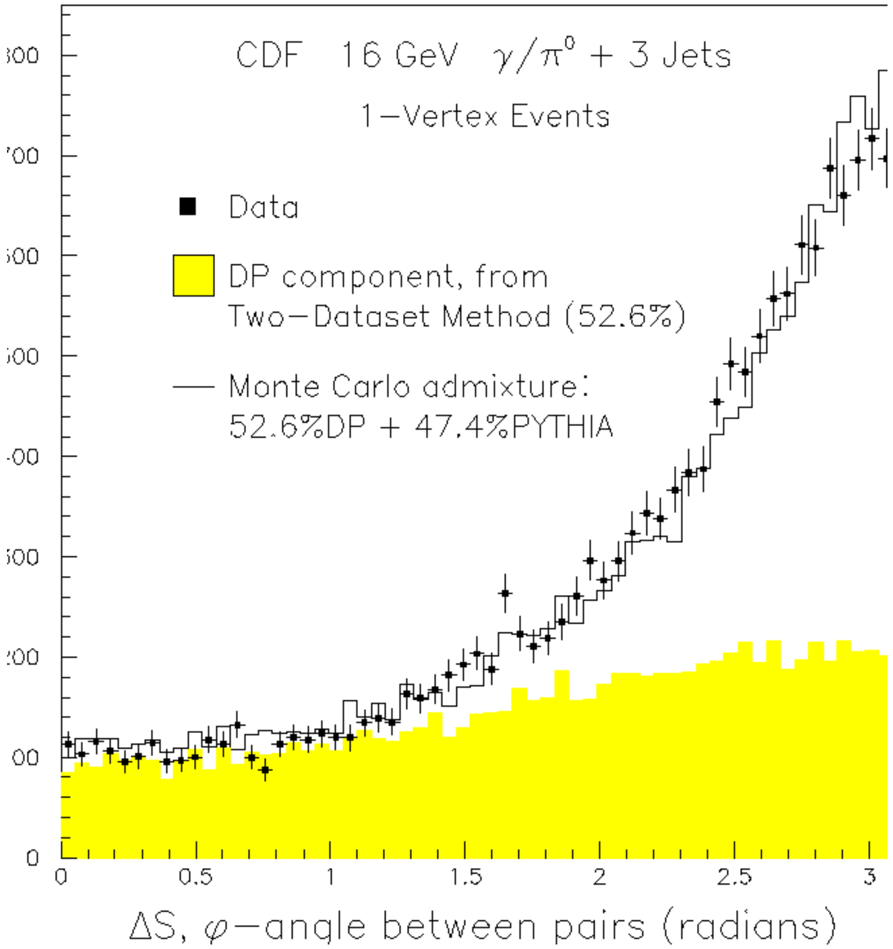




Multi-parton interactions and underlying events

P. Bartalini, D. Kar, A. Bunyatian

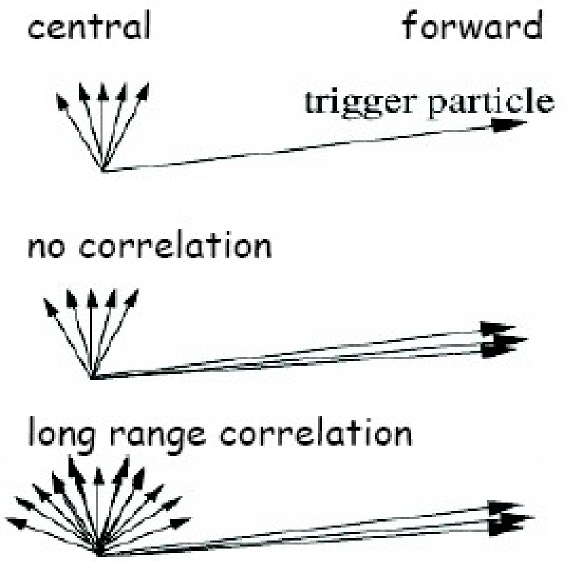
- **Observables for MPI tuning:**
  - 3 jet+γ: Δφ between dijet en jet+γ

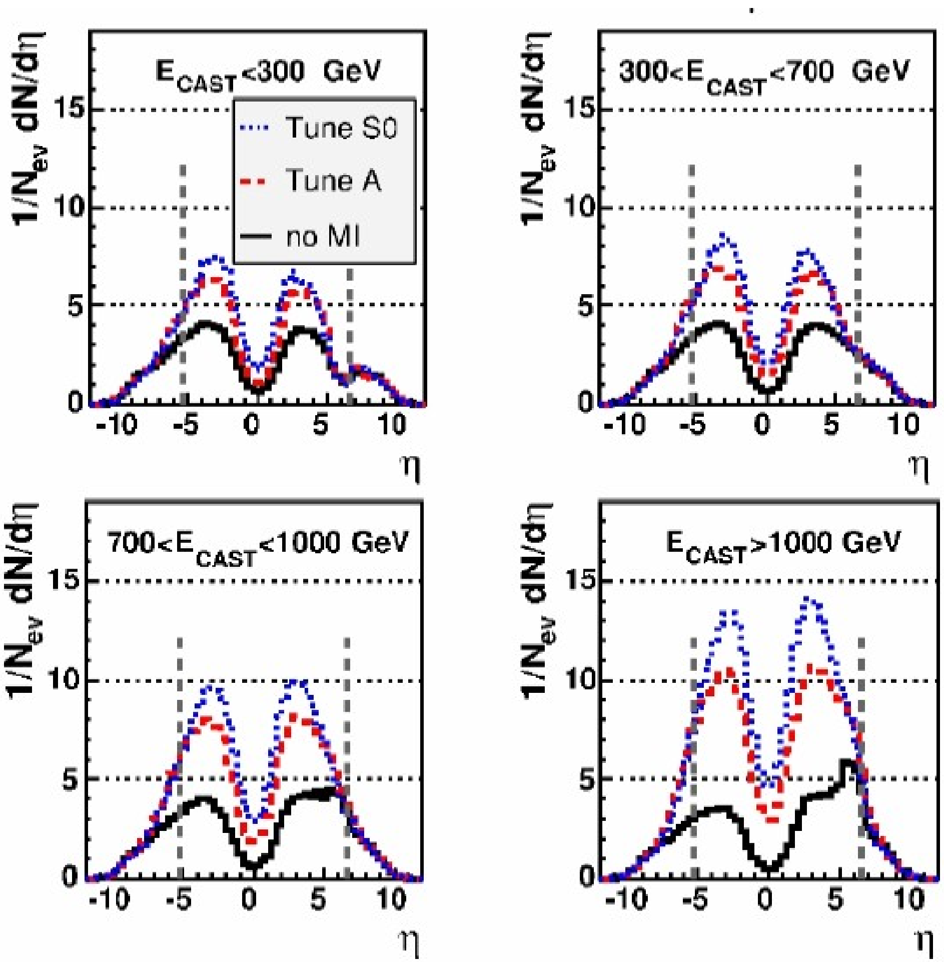


Multi-parton interactions and underlying events

P. Bartalini, D. Kar, A. Bunyatian

- **Observables for MPI tuning:**
  - Long range correlations

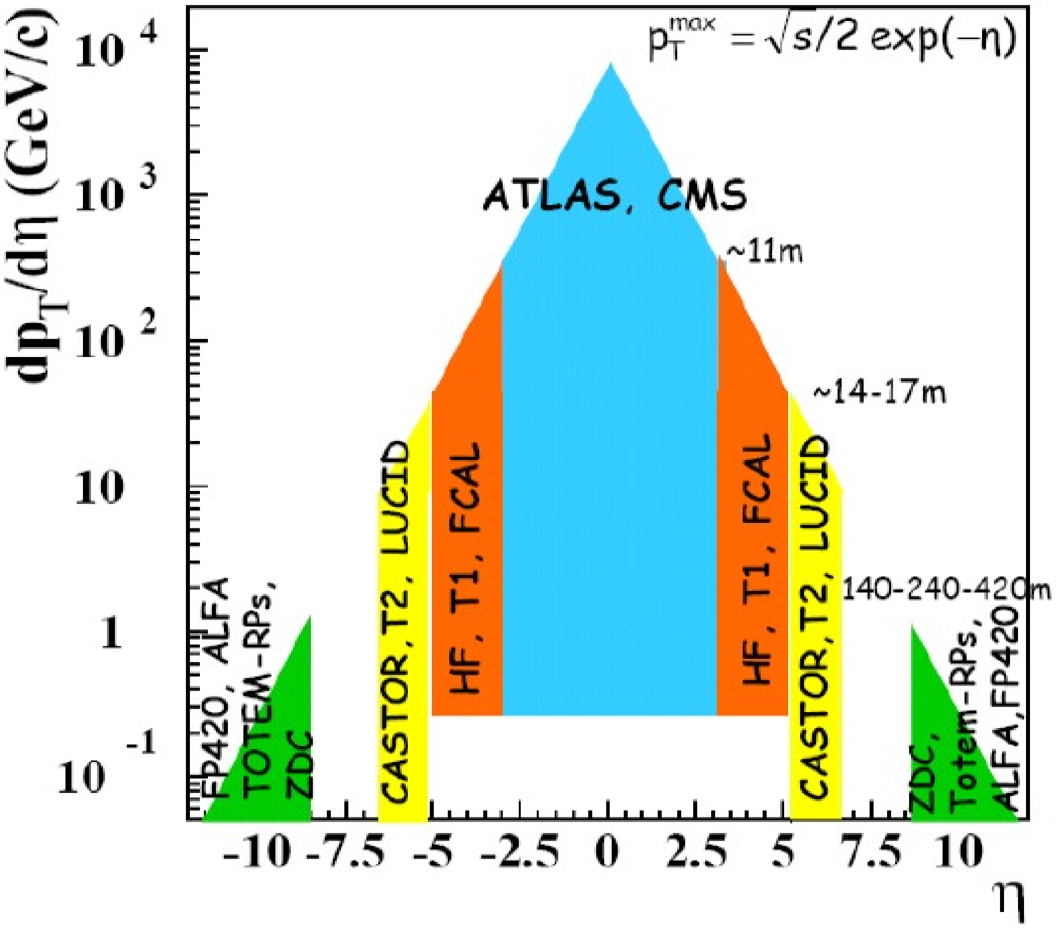




Forward detectors

A. Bunyatian

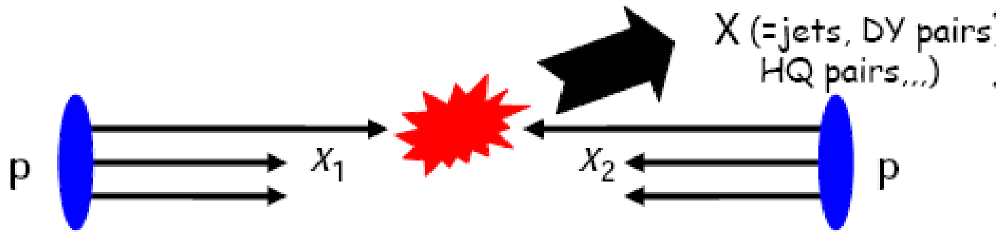
- **Forward physics programme:**
  - Low-x QCD dynamics
  - Elastic & diffractive scattering
  - Forward energy and particle flow in cosmic ray models
  - Two-photon interactions and peripheral collisions
  - QED processes to determine luminosity
  - Forward physics in pA and AA collisions
  - New physics phenomena
  - ...



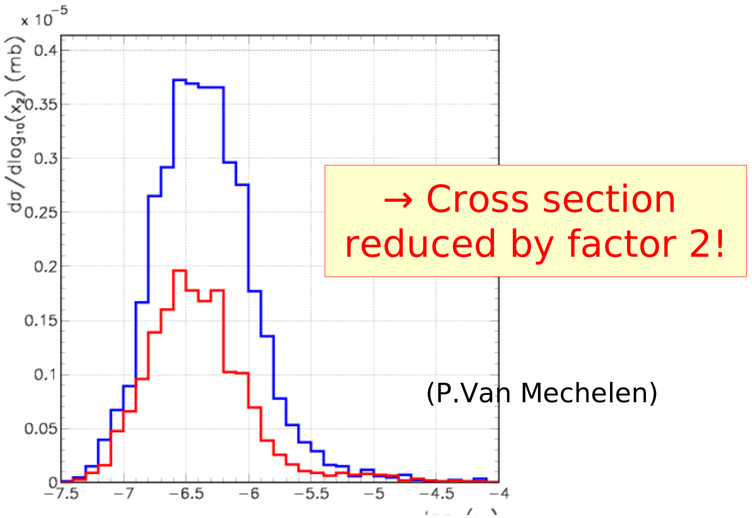
Forward detectors

A. Bunyatian

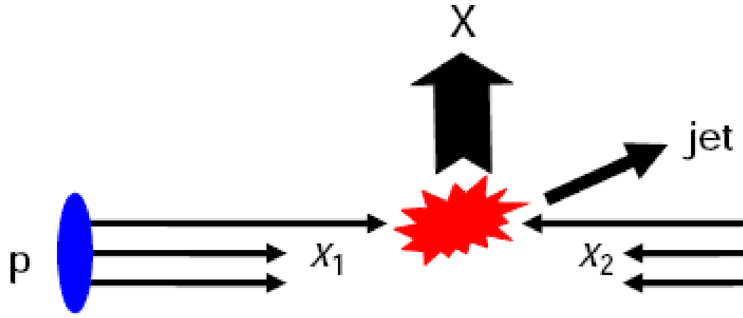
- **Low-x QCD dynamics**
  - Forward jets, DY pairs, … (saturation)

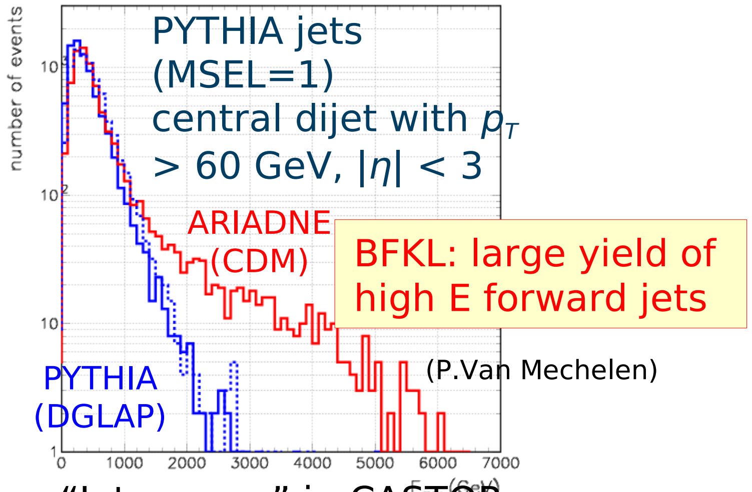


$$x \sim \frac{Q}{\sqrt{s}} e^{-\eta} \qquad Q \equiv p_T, M, \ldots$$



  - Central+forward jets (BFKL dynamics)





"Jet energy" in CASTOR

New Physics

- Beyond the Standard Model
- Higgs at TEVATRON and LHC

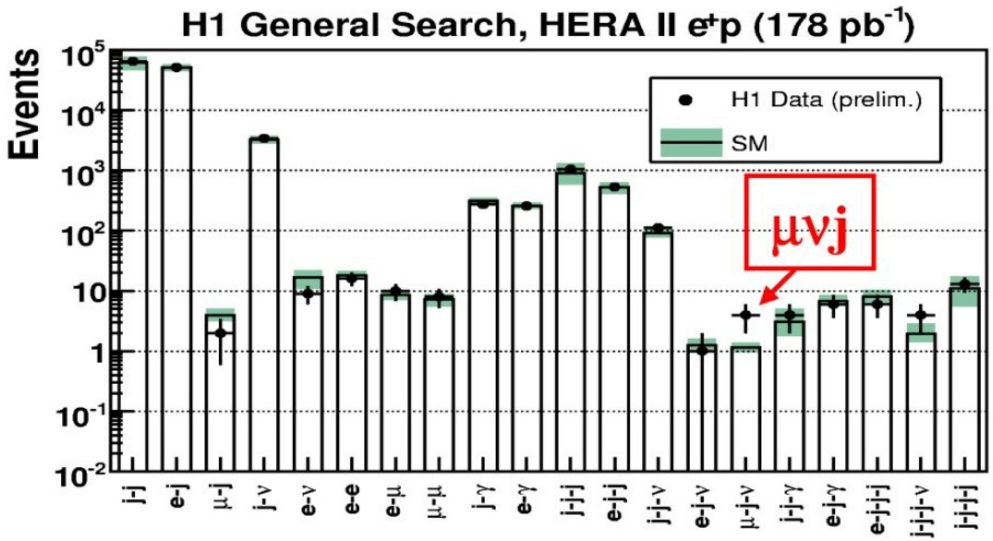
Supersymmetry, etc.

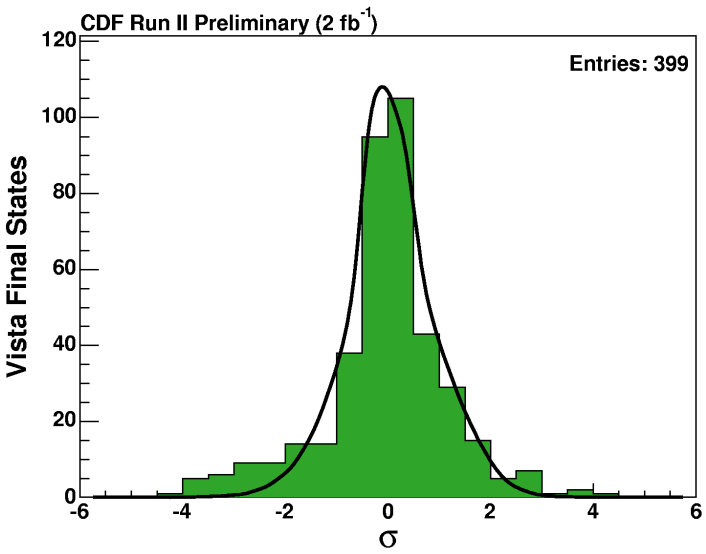
A. Meyer

- Excited fermions, leptoquarks, W'/Z', supersymmetry, large extra dimensions, gravitons, ...

  → **no excesses found...**

- Generic searches:





→ **no more deviations than expected from statistics**

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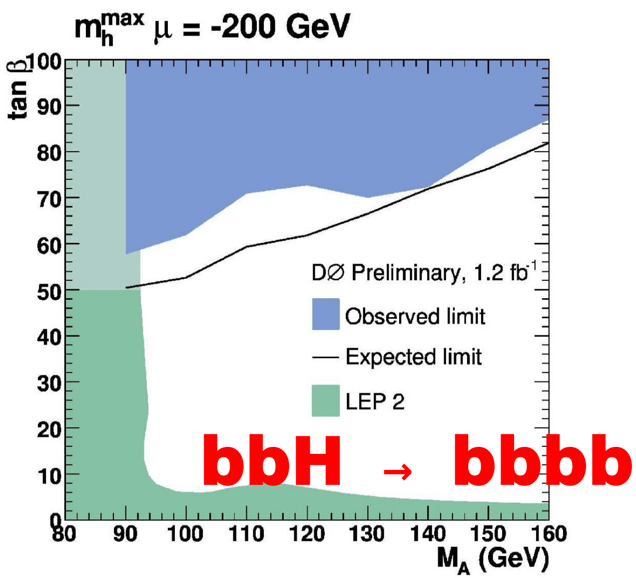
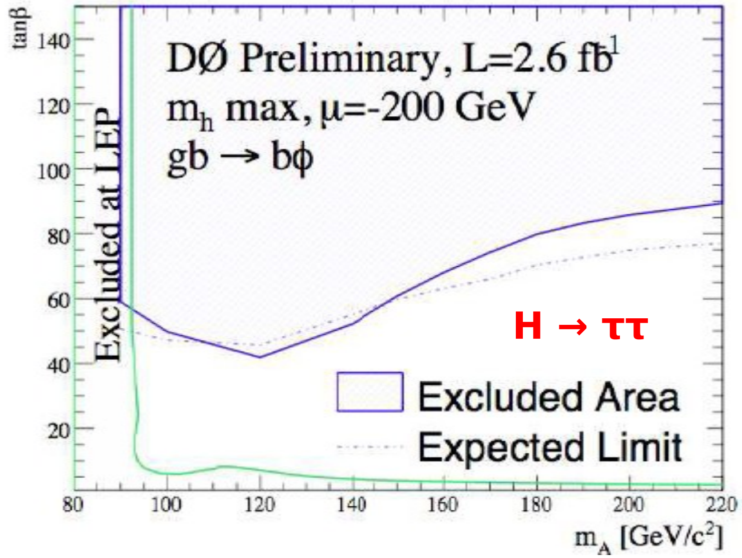
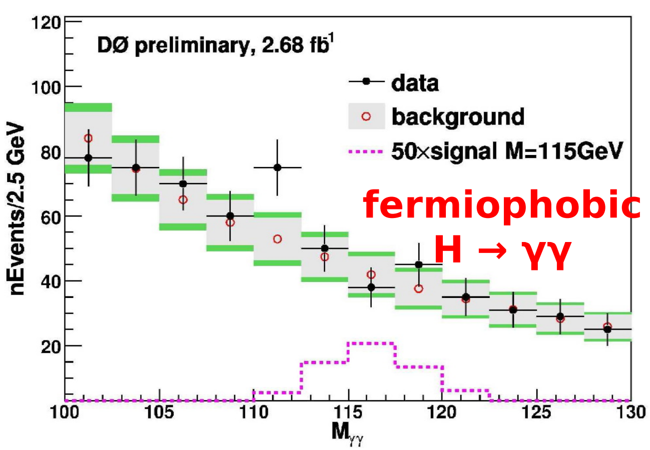
Higgs searches at the TEVATRON

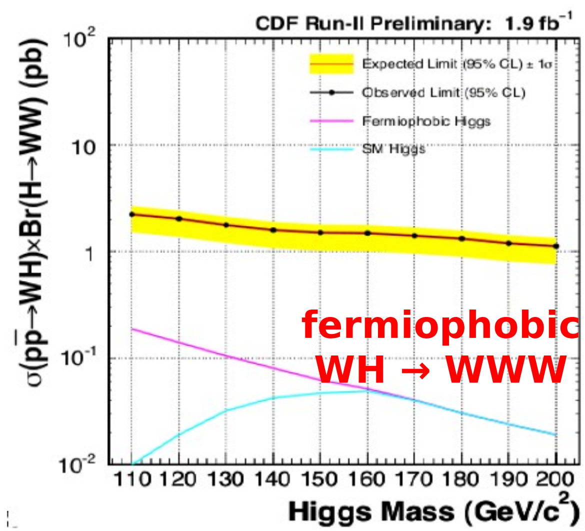
A. Heijboer

- **MSSM Higgs searches**







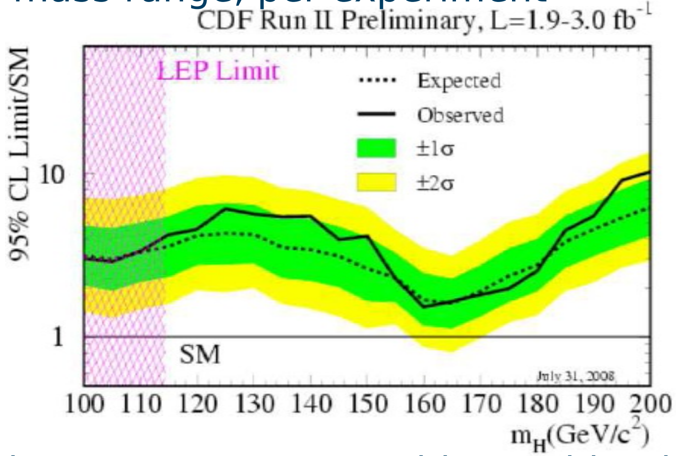


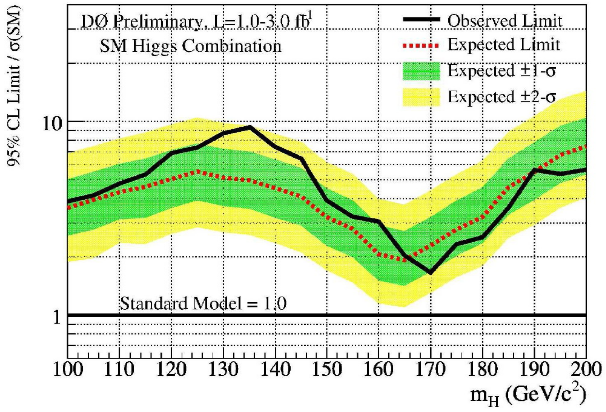
Higgs searches at the TEVATRON

A. Heijboer

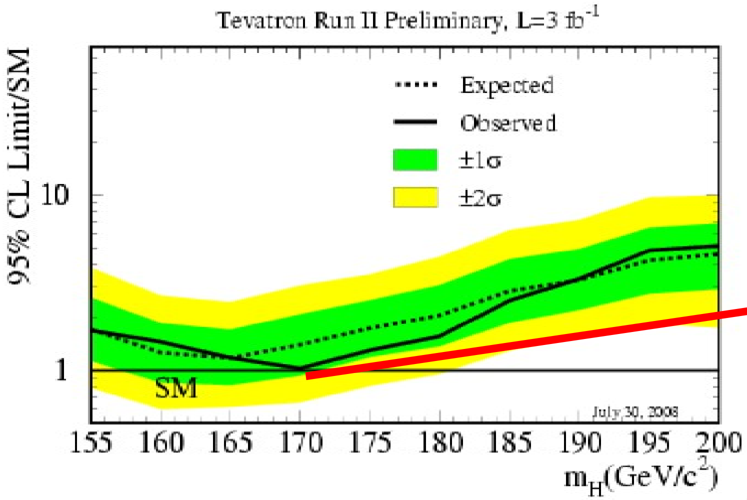
- **SM Higgs exclusion limits**

→ full mass range, per experiment





→ high mass: TEVATRON-wide combination

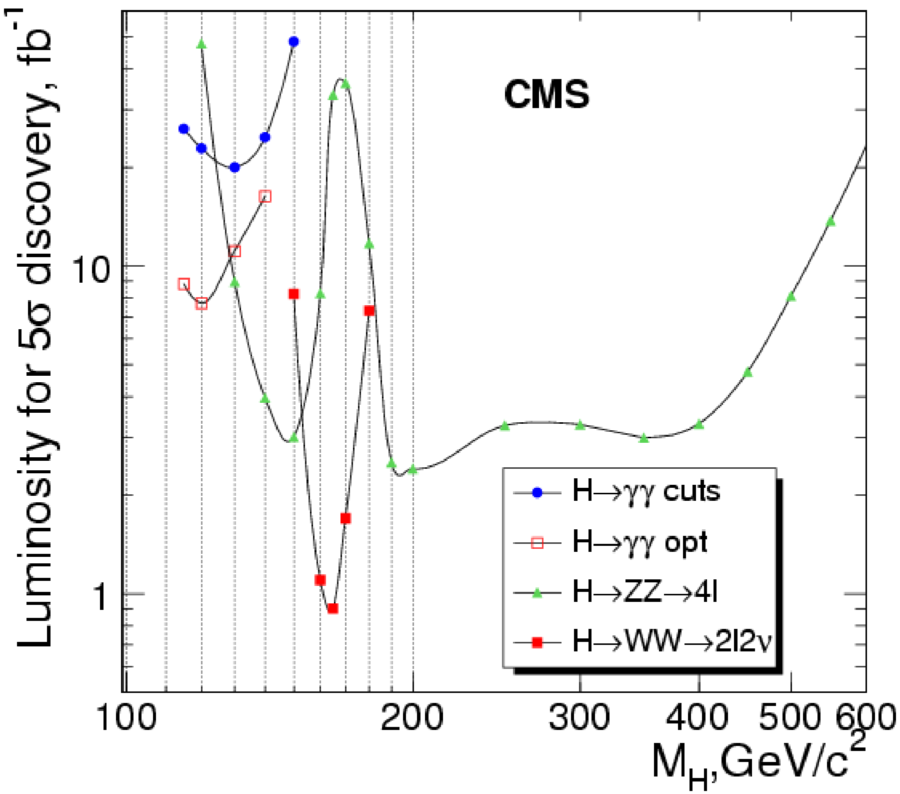


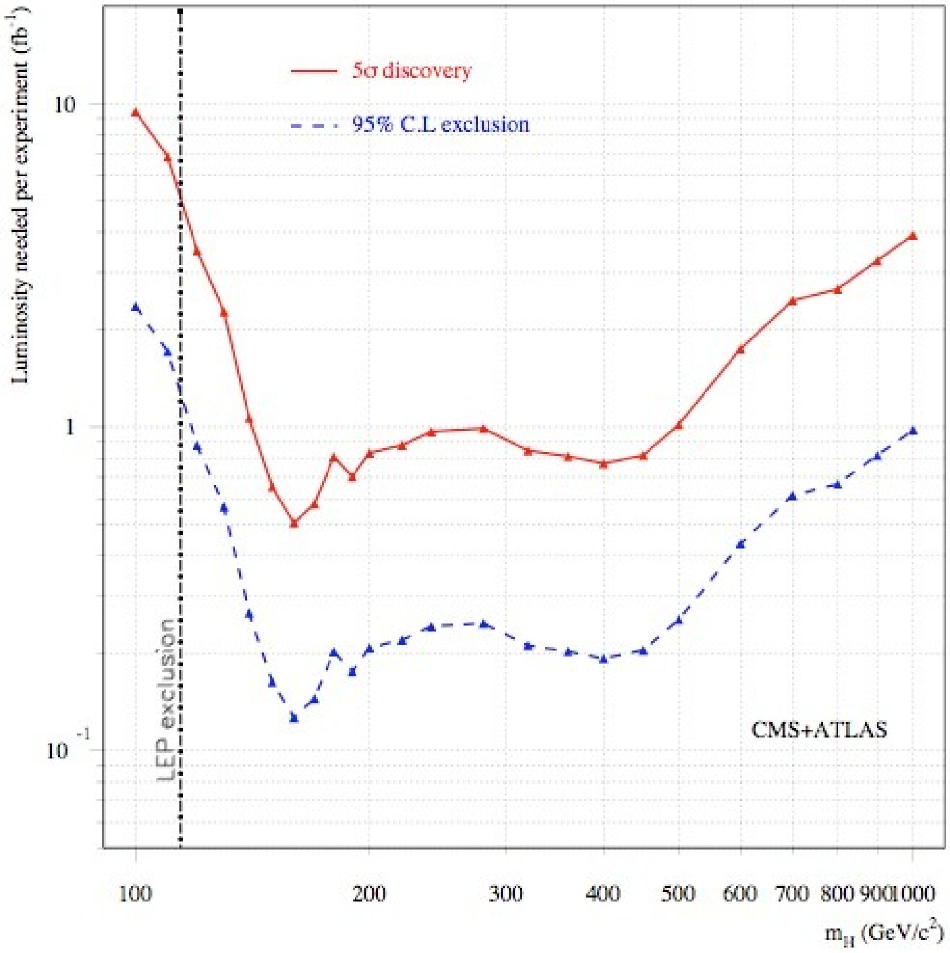
M_H = 170 GeV excluded at 95% CL!

Higgs bosons at the LHC…

I. Tsukerman

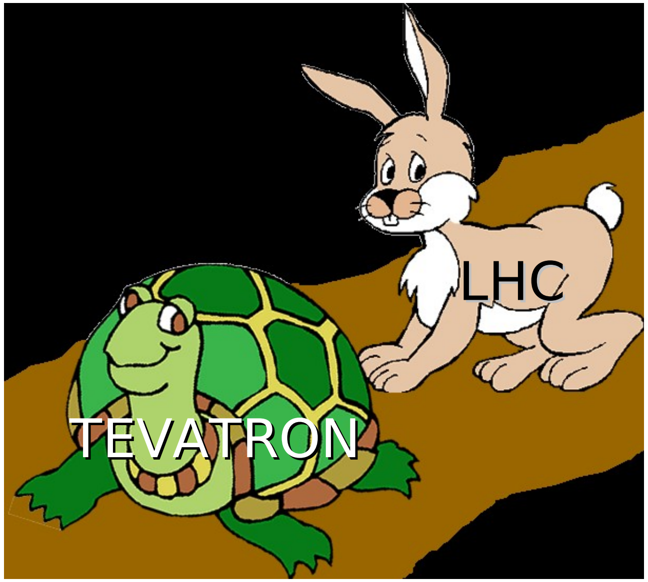
- **Summary of SM Higgs boson discovery potential**



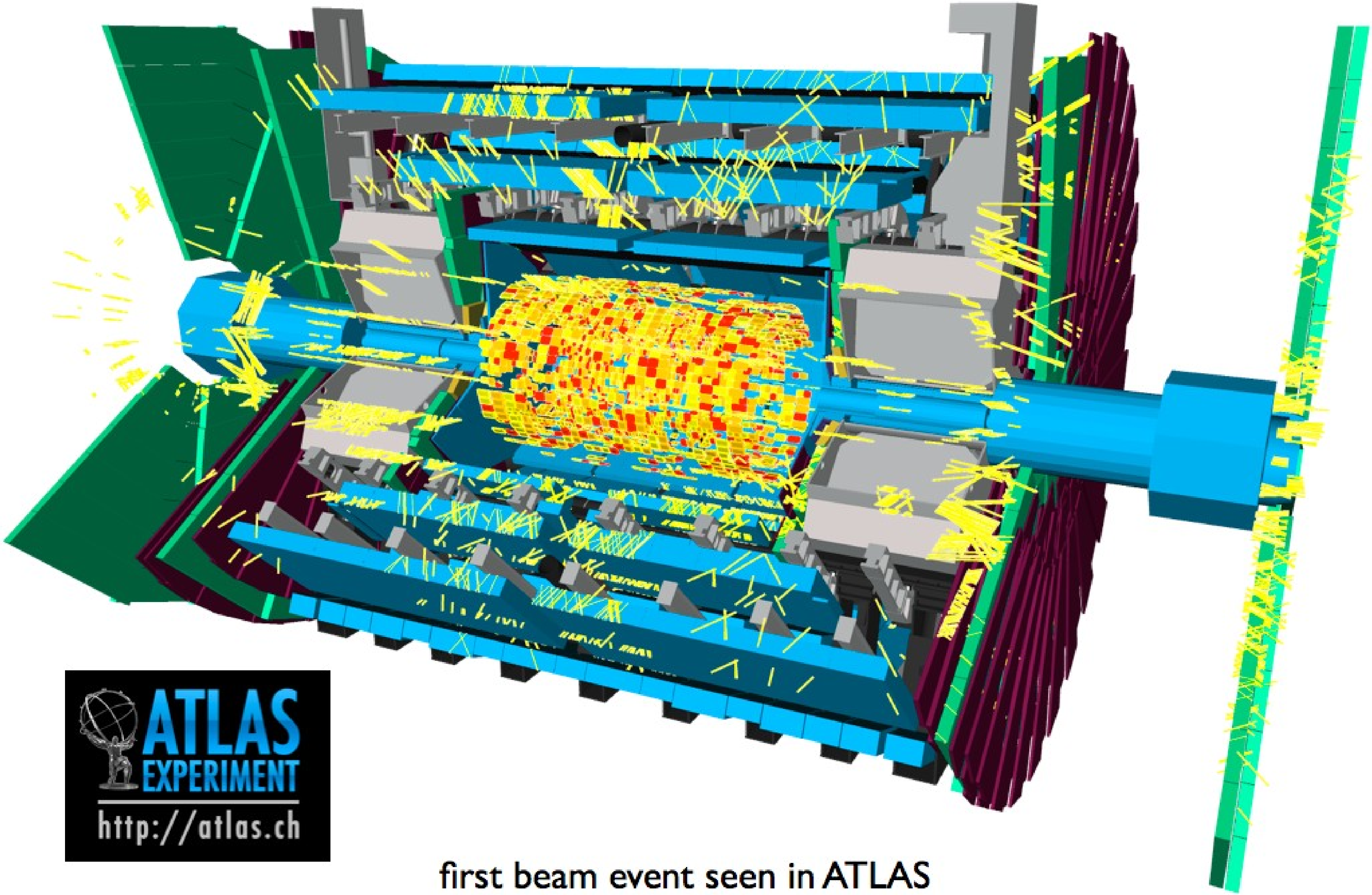


→ about 5 fb^{-1} needed for 5σ discovery
→ less than 1 fb^{-1} needed for 95% CL exclusion

Conclusion



- Thanks to organizers and conveners for the invitation
- Thanks to speakers for many interesting talks
- Congratulations to all for making this a great edition of the ISMD!



first beam event seen in ATLAS

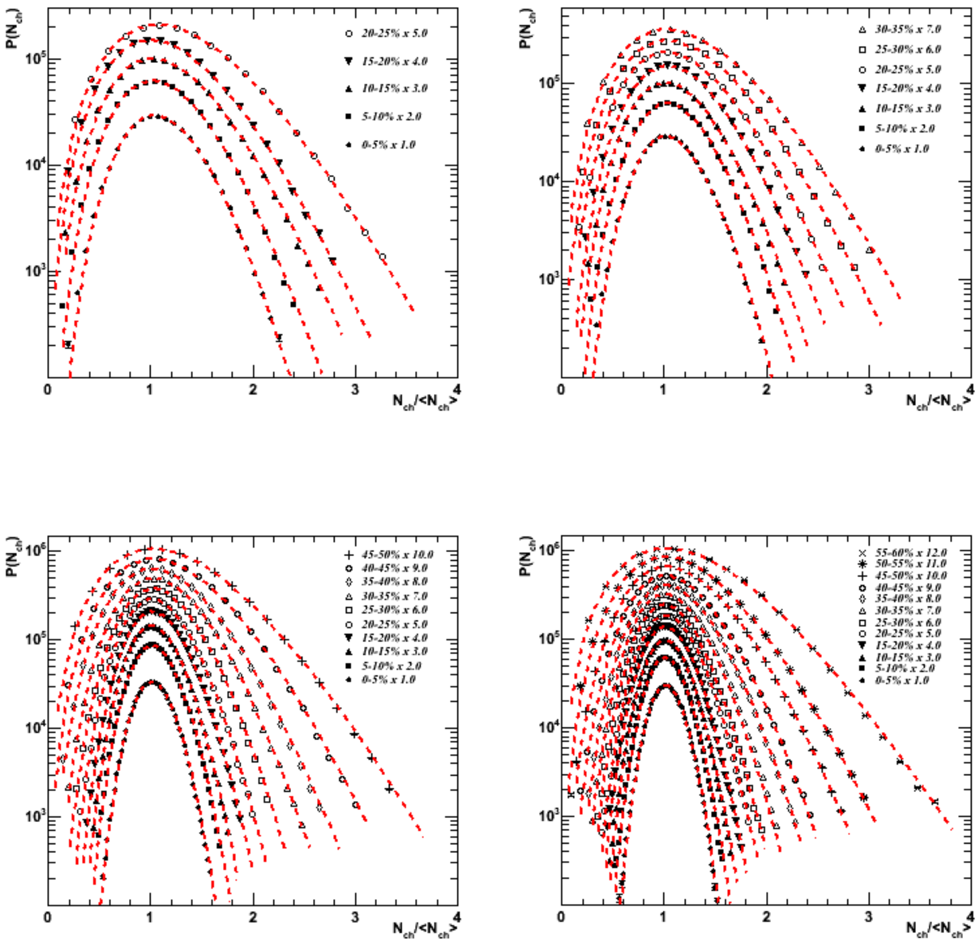
and now.... let's get back to work!
(ok, after the theory summary...)

Correlations and fluctuations in PHENIX

K. Homma

- Correlations and phase transitions

  -> fit NBD to measure correlation strength



Inclusive diffraction and jets

M. Wing

- **H1 2006 DPDF fit**
  NLO QCD fit of $\alpha_{IP}(0)$, n_{IR} + polynomials for DPDF at Q_0^2
  (reggeon flux and pdf is fixed)
  - Fit A

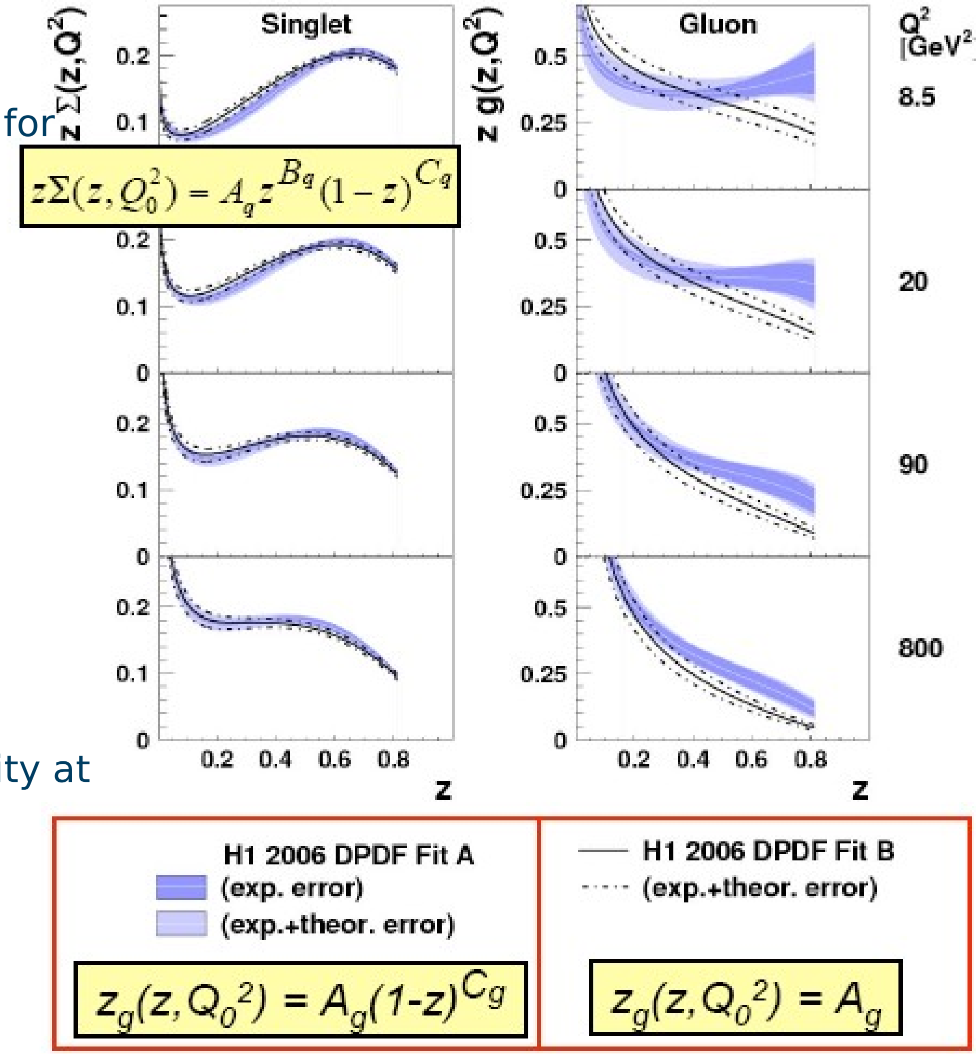
    χ^2 = 158 / 183 d.o.f.

  - Fit B

    χ^2 = 164 / 184 d.o.f.

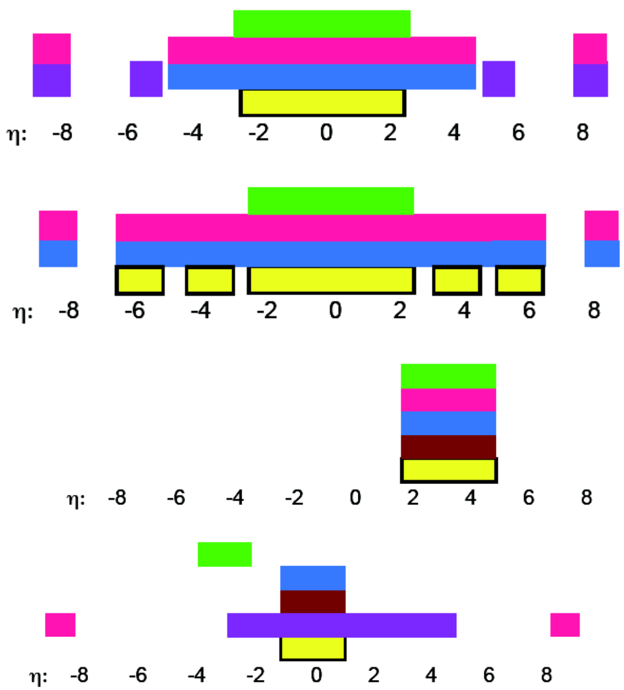
→ Quarks very stable

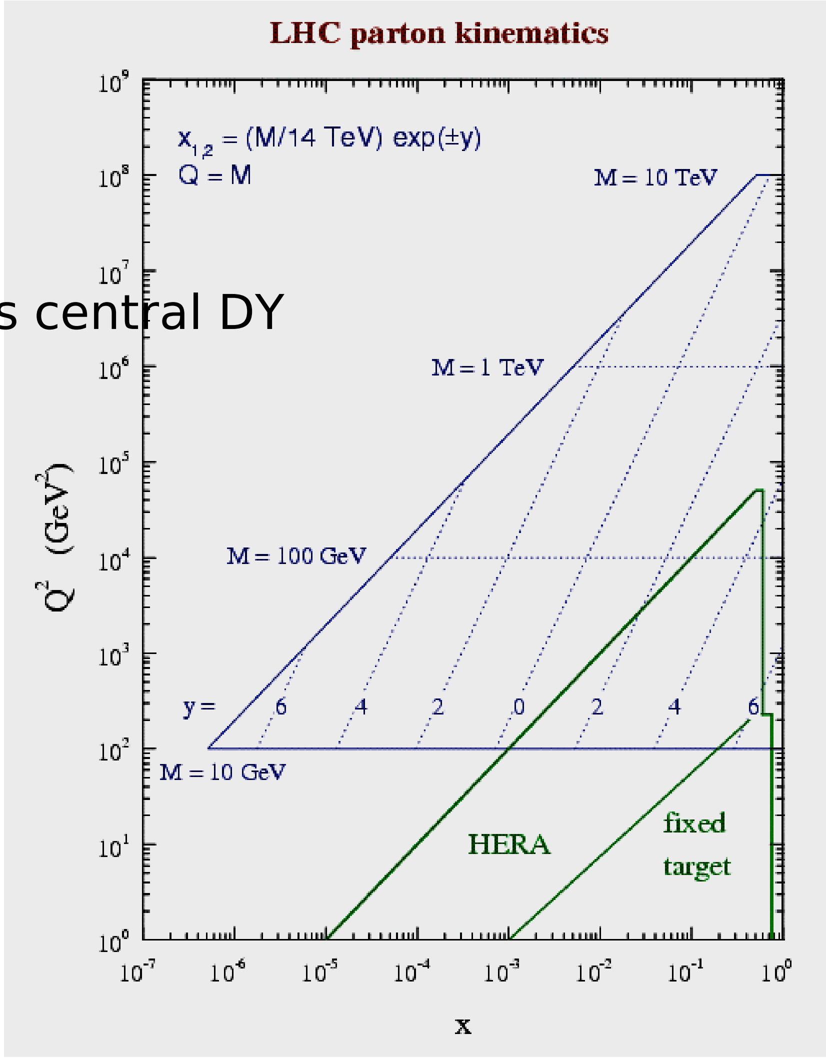
→ Gluons stable a low z, but no sensitivity at high z



Access to low-*x* PDFs at the LHC

T. Shears





Low mass central DY

Low mass forward DY

Forward jets

Forward J/psi