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CERN Geneva
June 2009

Experimentalism @ EDS09

John Dainton

Cockcroft Institute and Univ Liverpool, UK

1. Pedigree and Context
2. Exclusive Diffraction
3. Inclusive Diffraction
4. Experiment
5. Conclusion

With thanx to very very many, too many to mention!
With apologies to very very many, too many all to include!
With the risk of the prejudice ingrained in me!

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1.Pedigree and Context?

Pedigree

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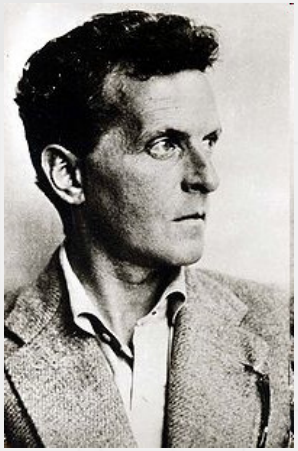
- natural cromophilosophy

400BC

1921AD



By convention there is colour,
by convention sweetness,
by convention bitterness,
but in reality
there are atoms, and space.

Democritus ~400BC

In a manner of speaking,
objects are colourless

L Wittgenstein 1921AD
Tractatus Logico-Philosophicus

Pedigree

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- photon (quantum) interaction
  - elastic scattering
    → size and shape
  - inelastic scattering
    → constituents

what you see is what you get

$$\lambda = \frac{h}{p}$$

- diffractive horizons

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Context

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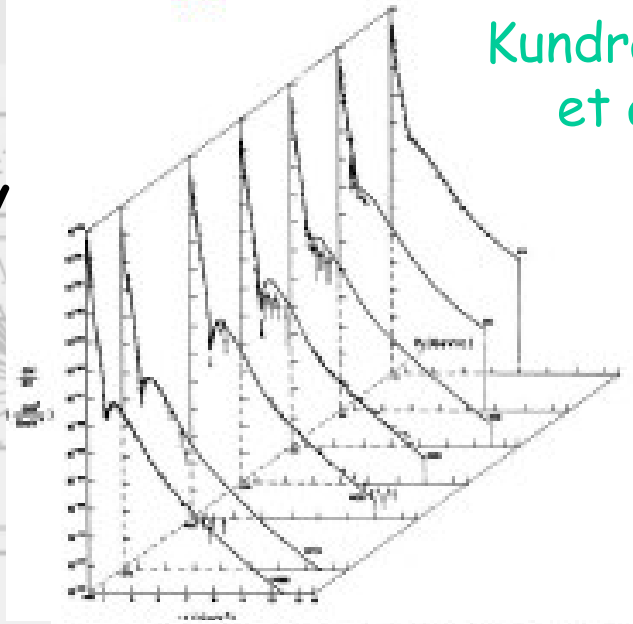
- hadron-hadron (*pp*) elastic scattering
  - "clean" defined environment
    (manifestly) "diffractive"
  - rigours of unitarity+analyticity
    $\leftrightarrow$ total x-section $\leftarrow$ QCD?
  - amplitude analysis
    (real Coulomb+hadronic)

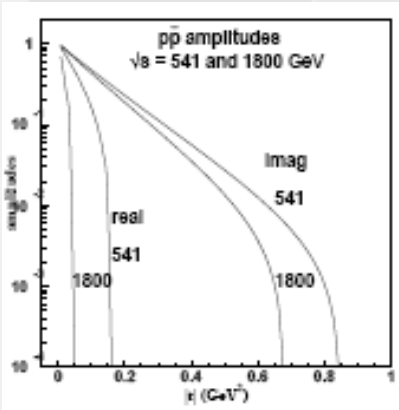
FT+ISR+TeV

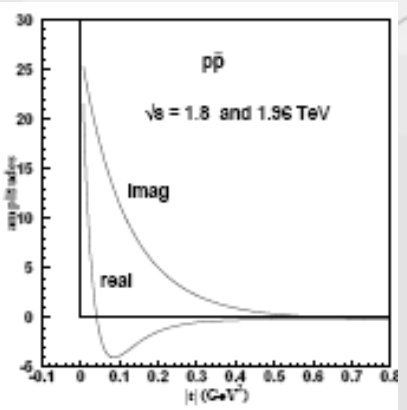
pp at $p_{lab} = 24 \div 2900$ GeV/c

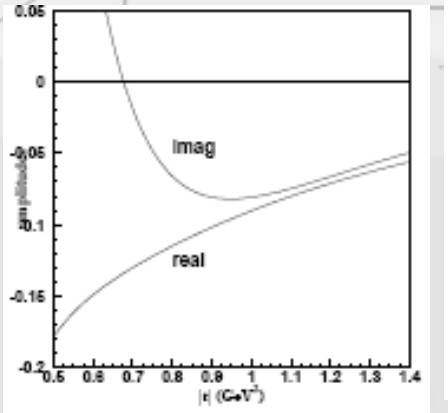
Kundrat et al.

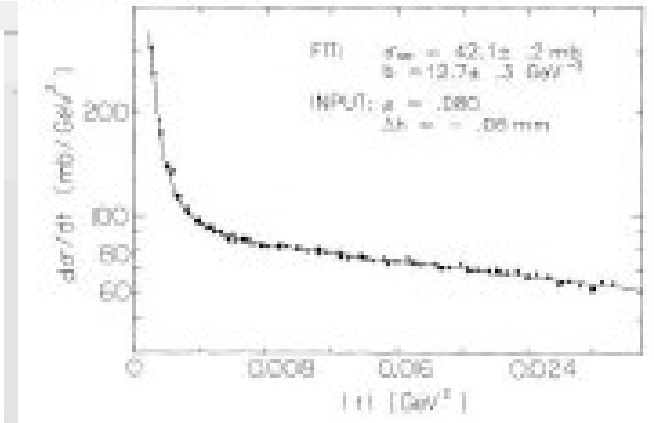


Ferreira



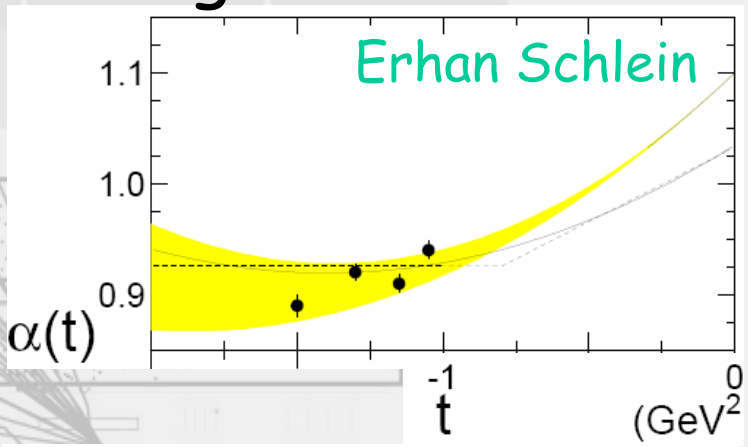


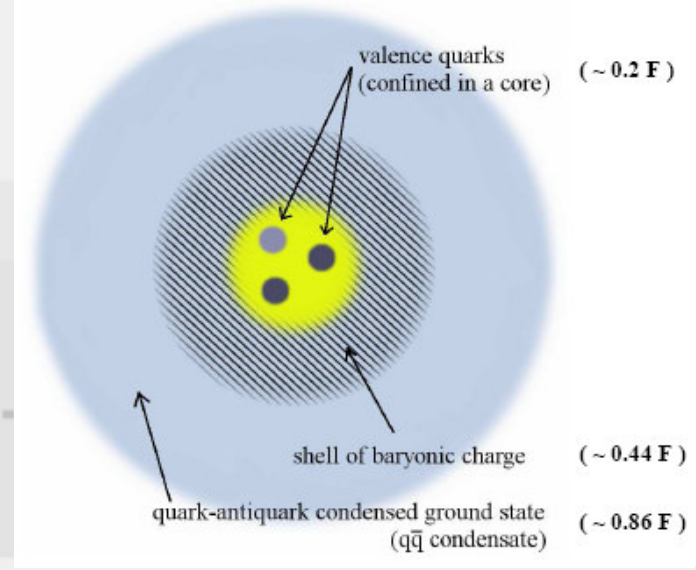


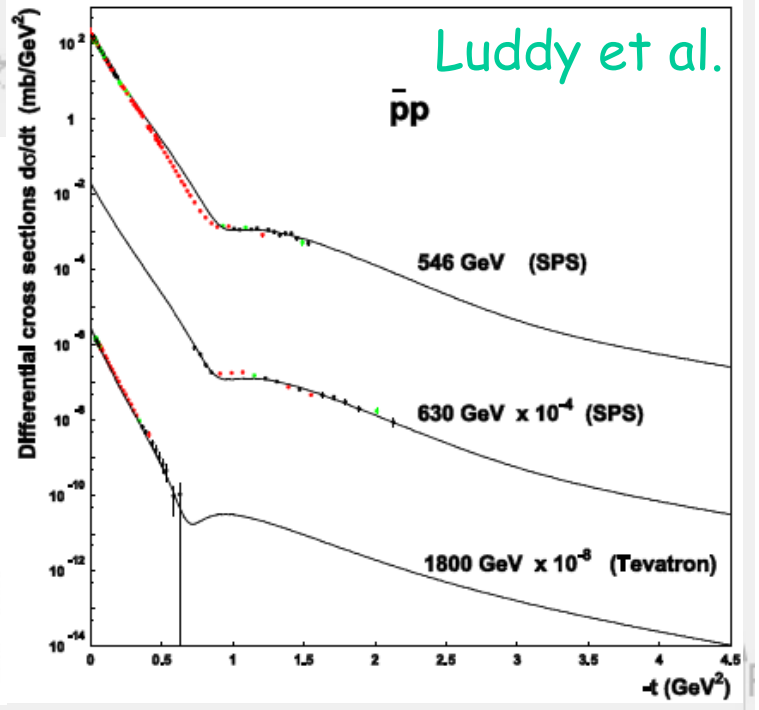


Context

- hadron-hadron (*pp*) elastic scattering
  - "clean" defined environment
  - (lack of) *s* dependence
    Regge asymptopia → QCD?
  - geometrical analysis
    Chou-Yang (1968) to now
    → hadron structure
    → QCD?







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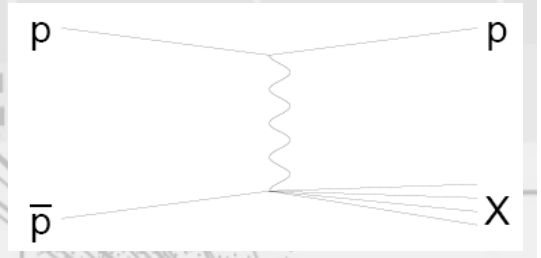
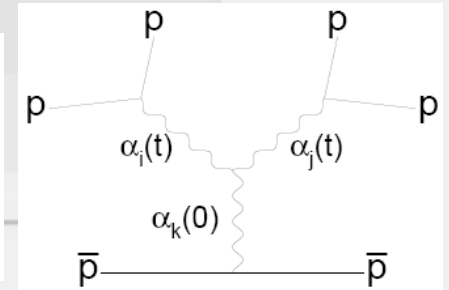
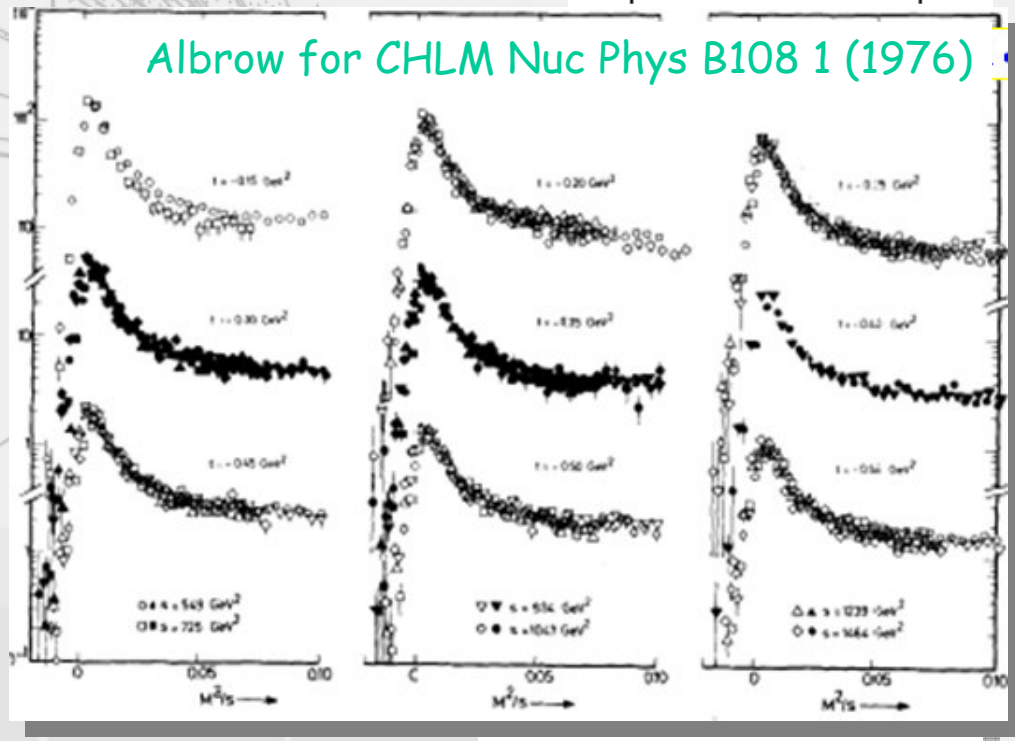
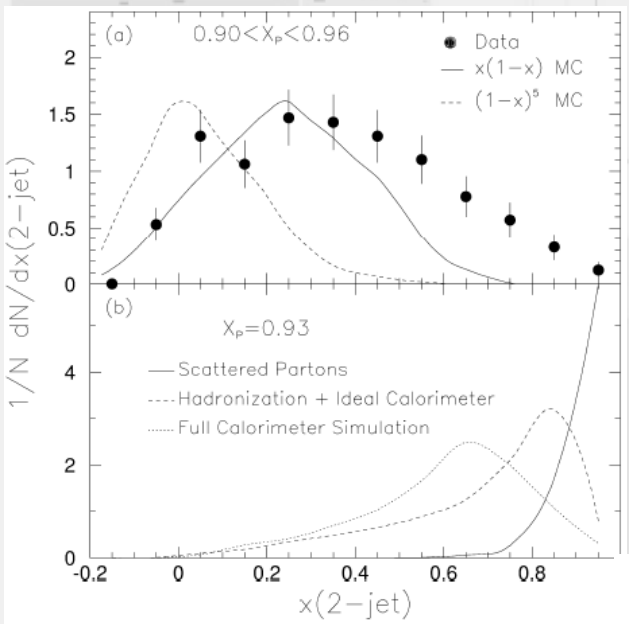
Context

- hadron-hadron (*pp*) *in*elastic scattering
  - ISR pioneer → UA
  - Regge asymptopia → unitarity → QCD? triple pole $I\!P I\!P I\!P$ $I\!P M M$
  - UA4/8 to TeVatron to hard dynamics?









Erhan Ingelmann Schlein UA8

Cross sections !

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Context

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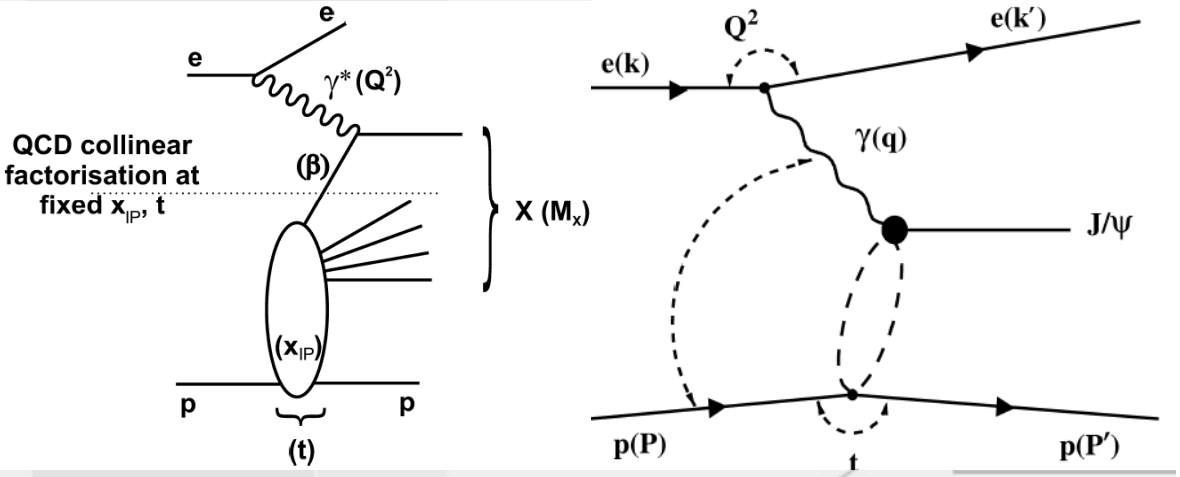
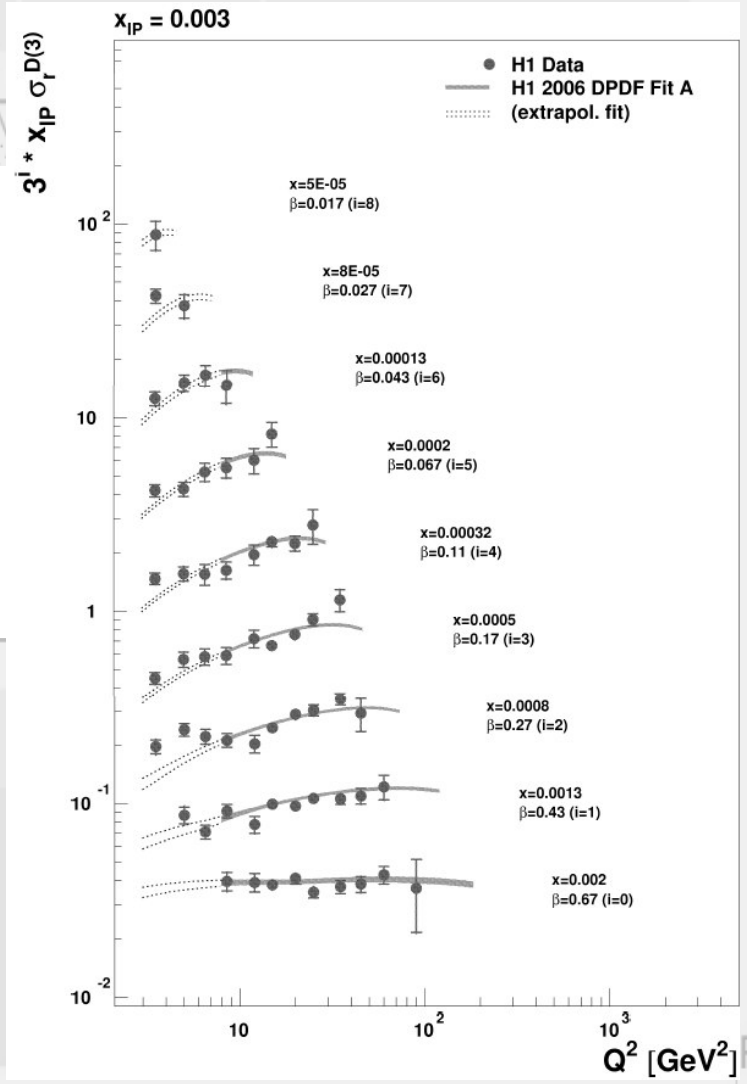
- lepton-hadron ($e^{\pm}p$) *in*elastic (pseudo-elastic)
  - HERA: scale to partons $0 \leq Q^2$
    γ and γ^* *in*elastic diffraction





  - long $\leftrightarrow$ short distance
    hard $\mathbb{P}$
    $\mathbb{P}$ $\mathbb{R}$ structure
    pQCD $\leftrightarrow$ npQCD

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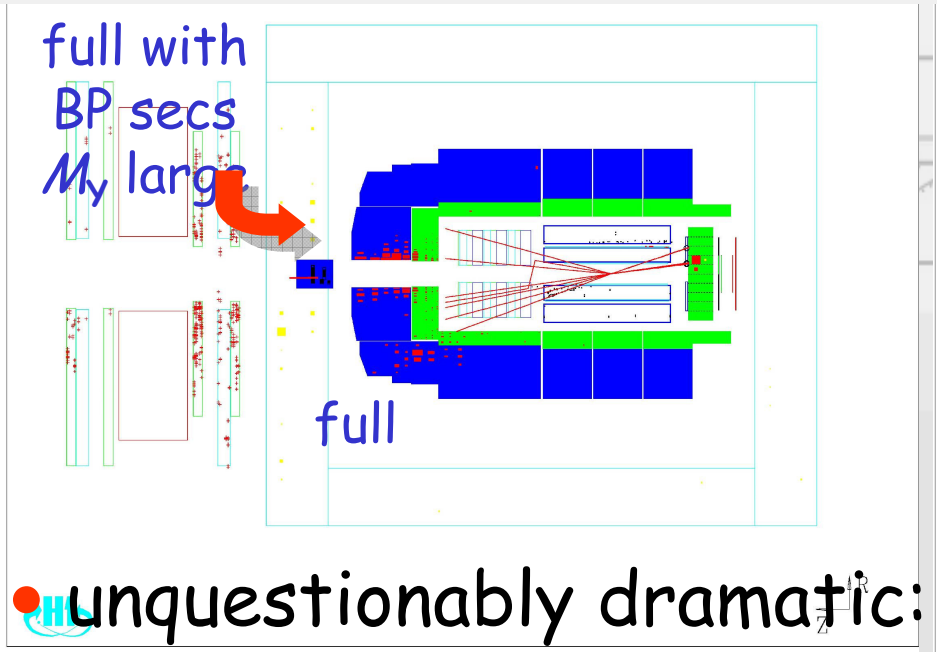
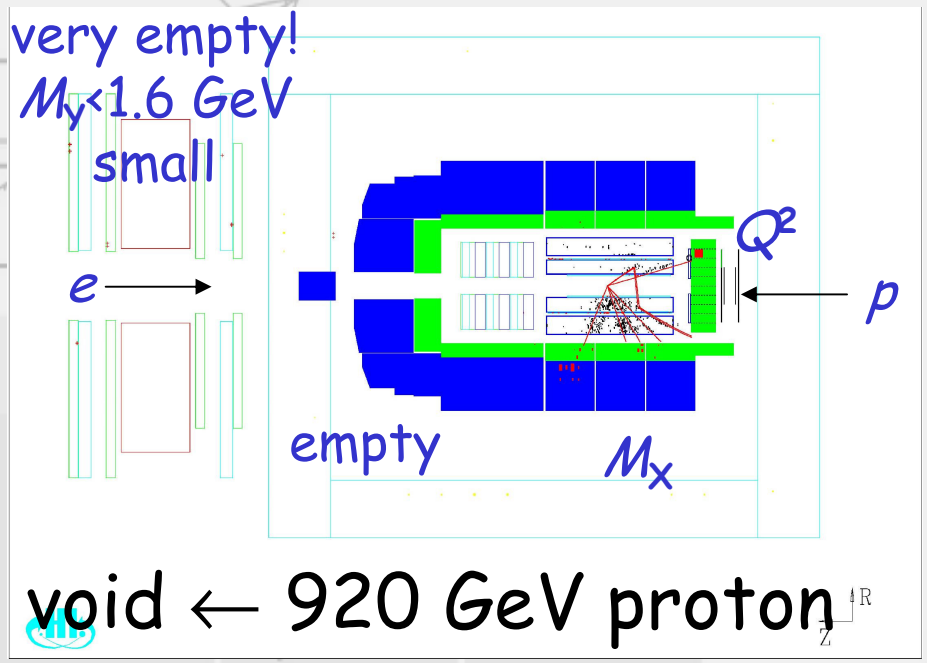
- experiment
  - p isolated in rapidity
  - forward hadrons $M_Y^2 < 2.5$ GeV^2 isolated in rapidity

} gap ➡ precisely defined x-section



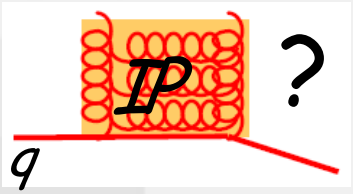


- unquestionably dramatic: void ← 920 GeV proton

Reminder (Discipline!)

- we have (expensive) and ingenious experiments !
  - measured cross sections (structure functions) as a function of appropriate variables
- we have a field theory of the strong interaction !
  - predicted cross sections (structure functions) as a function of appropriate variables
  - comparison
    - comprehension
      phenomenology
      improved prediction
      improved experiment

} progress



- theory changes – (corrected) measurements don't!

Experimental Formalism

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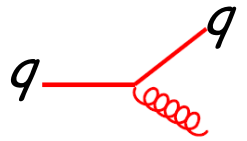
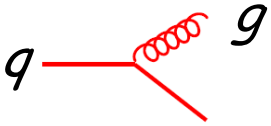
- QCD splitting functions … at high energy (low x)

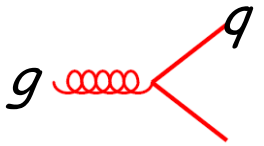
$$P_{qq} = \frac{4}{3}\left[\frac{1+x^2}{(1-x)_+} + \frac{3}{2}\delta(1-x)\right] + o(\alpha_s) \quad \rightarrow \frac{4}{3}\mathbf{dx}\frac{\mathbf{dt}}{t}$$



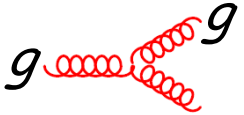
$$P_{gq} = \frac{4}{3}\frac{1+(1-x)^2}{x} + o(\alpha_s) \quad \rightarrow \frac{4}{3}\frac{\mathbf{dx}}{x}\frac{\mathbf{dt}}{t}$$



$$P_{qg} = \frac{1}{2}\left[x^2+(1-x)^2\right] + o(\alpha_s) \quad \rightarrow \frac{1}{2}\mathbf{dx}\frac{\mathbf{dt}}{t}$$



$$P_{gg} = 6\left[\frac{x}{(1-x)_+} + \frac{1-x}{x} + x(1-x)\right] + \frac{33-2n_f}{6}\delta(1-x) + o(\alpha_s) \quad \rightarrow 6\frac{\mathbf{dx}}{x}\frac{\mathbf{dt}}{t}$$



$$x = \frac{parent_\mu \cdot reference^\mu}{daughter_\mu \cdot reference^\mu}$$

dynamics at high energy

Experimental Formalism

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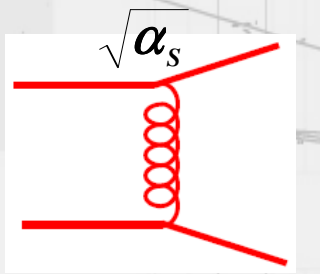
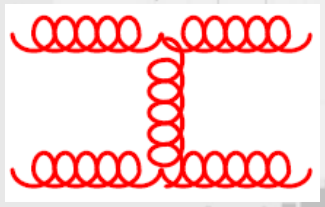
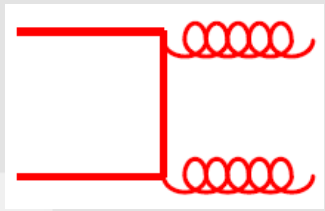
- QCD at high energy
  - (LO) splitting functions → rules of thumb

$qq \to qq$ 

$$d\sigma \sim \frac{dt}{t^2}$$

$gg \to gg$ 

$$d\sigma \sim \frac{dt}{t^2}$$

$qq \to gg$ 

$$d\sigma \sim \frac{dt}{st}$$

0 t-channel fermions

s^0 no s dependence (off-shell g)

declining s^{-1} dependence (off-shell q)

≥1 t-channel fermions

Experimental Formalism

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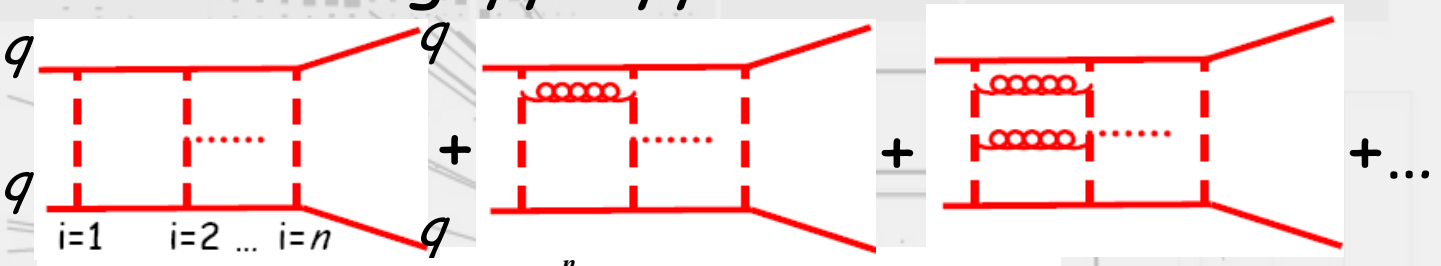
- pQCD at high energy: HO splitting + BFKL ingenuity
  → eg elastic scattering $qq \to qq$

n parton

$$\frac{d\sigma}{dt} \sim s^{2\alpha_n - 2} = s^{2\varepsilon_n}$$



"trajectory" $\alpha_n = \sum_{i=1}^{n} j_i - (n-1) + O(\alpha_s) + ..$

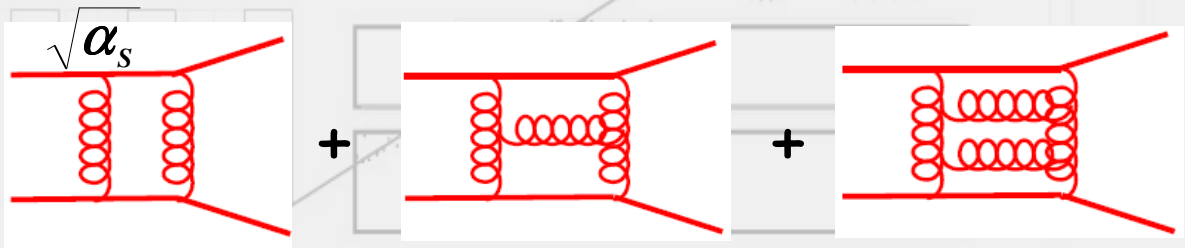
2*g*

$$\frac{d\sigma}{dt} \sim s^{2\varepsilon}$$

0 *t*-channel fermions

$\varepsilon > 0$

small~0 shrinkage



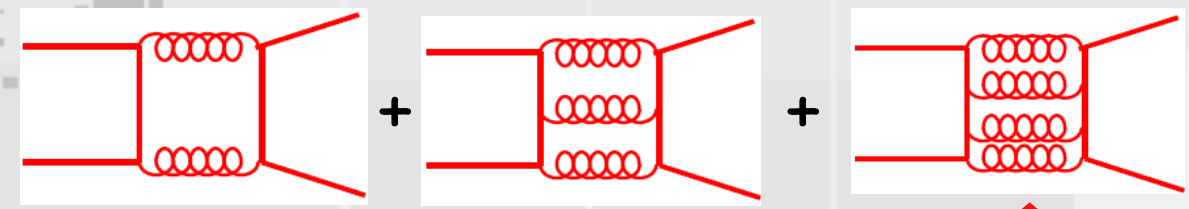
2*q*

$$\frac{d\sigma}{dt} \sim s^{2\varepsilon}$$

≥1 *t*-channel fermions

$\varepsilon \sim -1$

Small~0 shrinkage



evolving "hard" Regge leading behaviour → meson

Experimental Formalism

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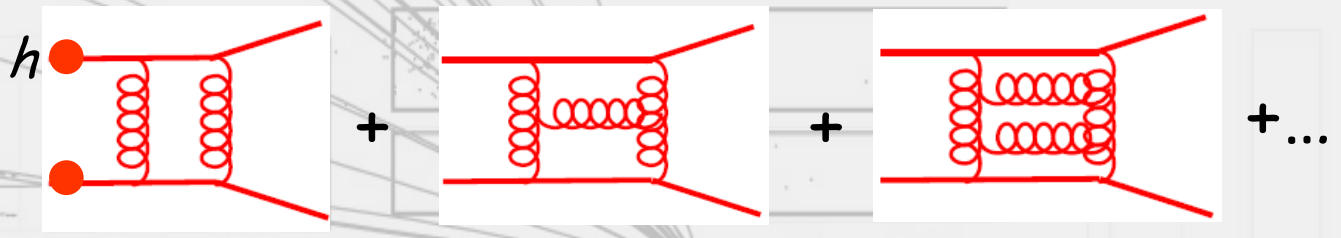
- ⊄QCD at high energy: hadron Regge phenomenology
  - Regge ← crossing/analyticity at high energy (low x_P)

$I\!P$

$$\frac{d\sigma}{dt} \sim s^{2\varepsilon} \qquad \varepsilon(t) = 0.25t$$

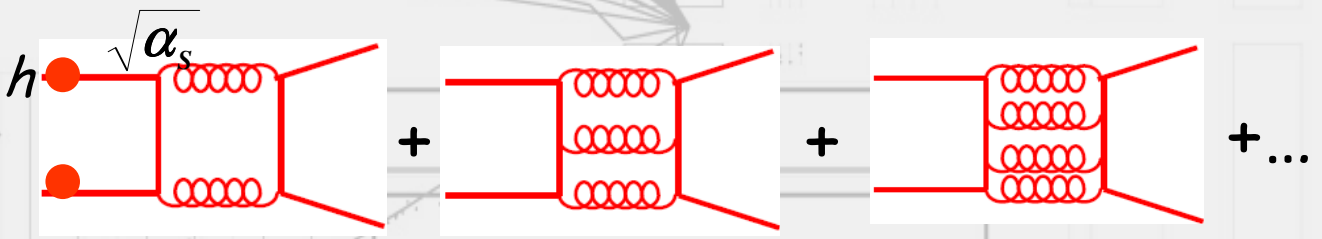
shrinkage



$I\!R$ ≥1 t-channel fermions

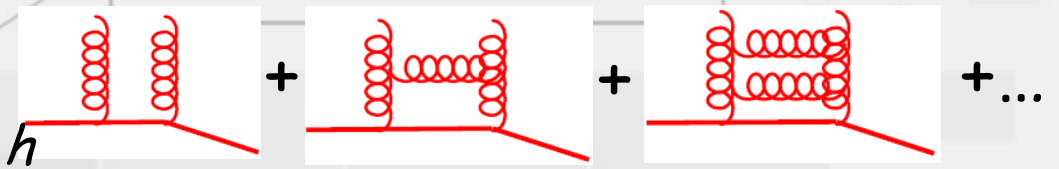
$$\frac{d\sigma}{dt} \sim s^{2\varepsilon} \qquad \varepsilon(t) \le -0.5 + t$$

shrinkage

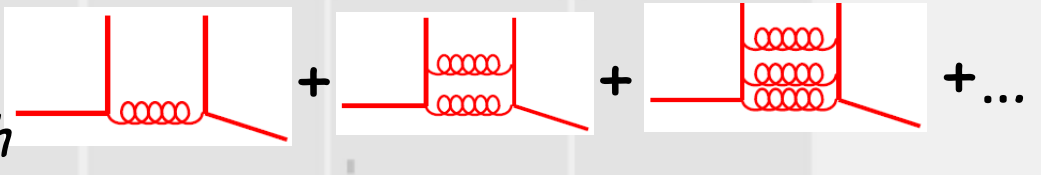


$$P_{/P} \sim \frac{1}{\xi^{2\alpha(t)-1}} = \frac{1}{\xi^{2\varepsilon(t)+1}} \qquad (\xi = x_{IP} = x_{\mathrm{ex/i}})$$

$I\!P$



$I\!R_h$



- (approx.) Regge h phenomenology in $x_{ex/i}$ (x_{IP} ξ) t

Experimental Formalism

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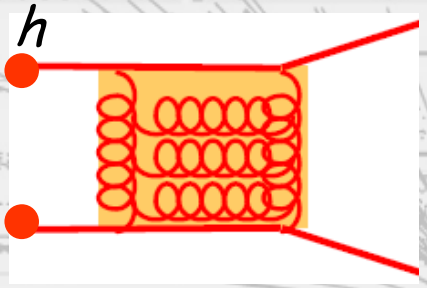
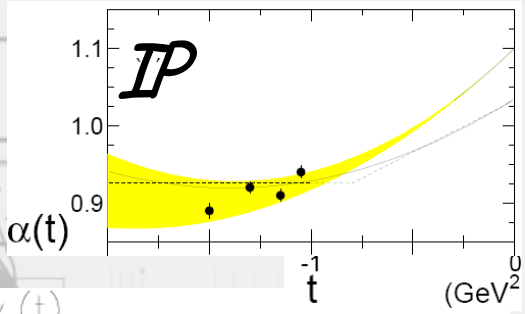
- ø QCD at high energy: Regge hadron phenomenology
  - Regge "splitting" … … at high energy (low $x_{ex/i}$)

$I\!P$

$$\frac{d\sigma}{dt} \sim s^{2\varepsilon} \qquad \varepsilon(t) = 0.25t$$

shrinkage

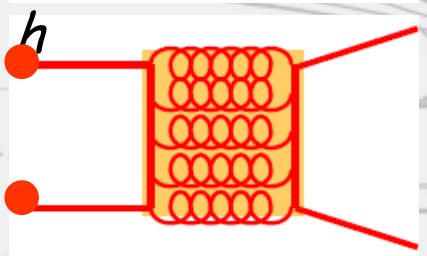


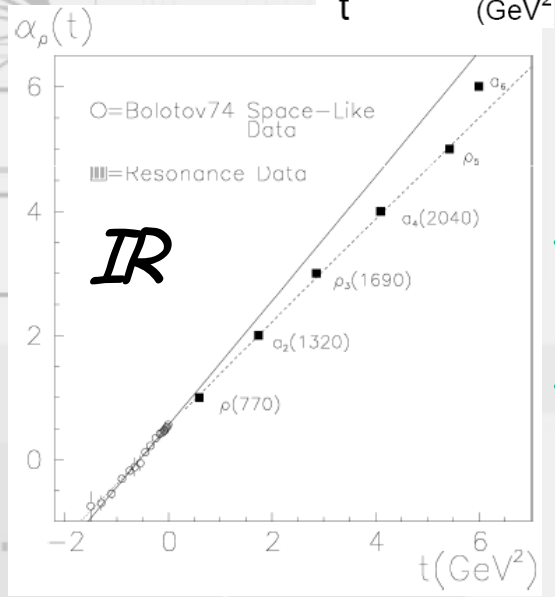


$I\!R$ ≥1 t-channel fermion

$$\frac{d\sigma}{dt} \sim s^{2\varepsilon} \qquad \varepsilon(t) \le -0.5 + t$$

shrinkage



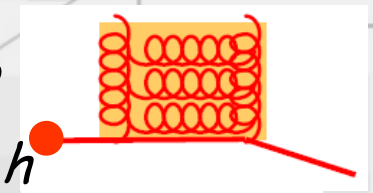


≥1 t-channel hadron

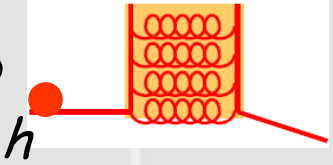
$$P_{/P} \sim \frac{1}{\xi^{2\alpha(t)-1}} = \frac{1}{\xi^{2\varepsilon(t)+1}}$$

$$(\xi = x_{IP} = x_{ex/i})$$

$I\!P$



$I\!R$



- soft Regge h phenomenology in $x_{ex/i}$ (x_{IP} ξ) t

Crossing

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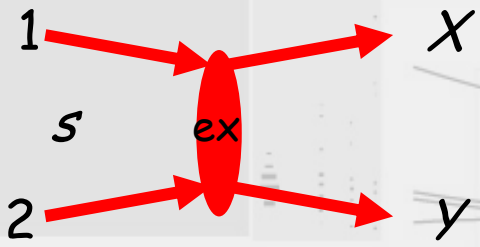
- 2 noteworthy points: analyticity → crossing
  - *s*-channel hadrons (resonances) ↔ *t*-channel $I\!R$

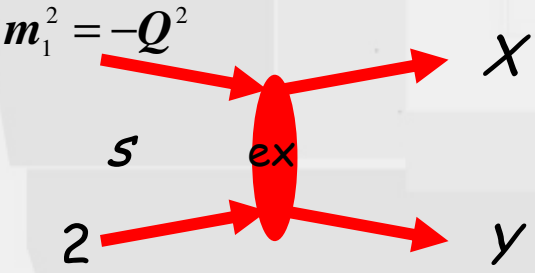


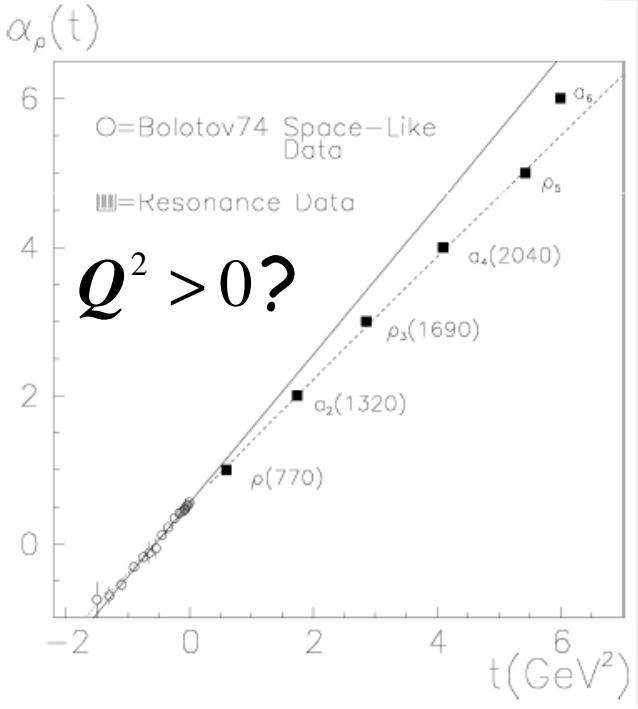
$$(\cos\theta_{CM})_{crossed} = \frac{2t}{s - m_1^2 - m_2^2} \cdot \frac{1}{x_{ex/2}} \cdot \frac{1}{x_{ex/1}} \xrightarrow[M_Y^2 \to m^2]{} \frac{-2}{x_{ex/2}}$$

crossing: $\cos\theta_{CM} \leftrightarrow 1/x_{ex/1}$

  - analyticity depends *also* on any initial mass scale

$m_1^2 = -Q^2 \sim s$





↳ natural variables

$x_{ex/I}$ (x_{IP} ξ) mass² *t*

Reminder (Discipline pays off!)

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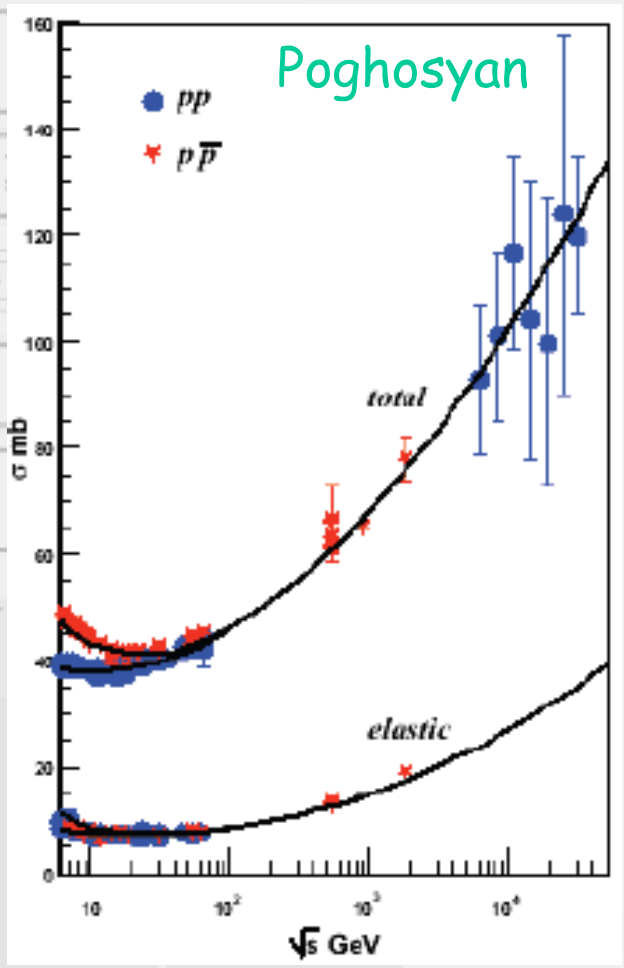
- only data cannot be changed
  - let data speak for themselves
  - analyse data as they deserve
  - leave results for posteriority

for

- QCD is difficult
- analytic approaches are
  only approximately rigorous
  more or less valid models
  even outrageous

unitarity



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2. Exclusive Diffraction

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June 2009

Pushing Elastic Scattering

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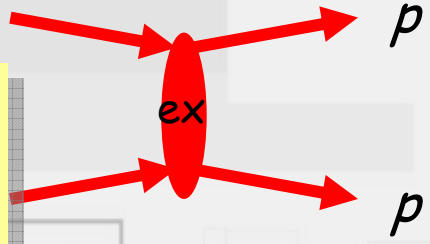
- improving technology
- experience → new understanding
  → better prediction (LHC!)
  → better LHC extraction



Ferreira et al

Usually B_R and B_I are treated as having equal values. We allow

$$s,t)e^{i\alpha\Phi(s,t)} + F^N(s,t)$$

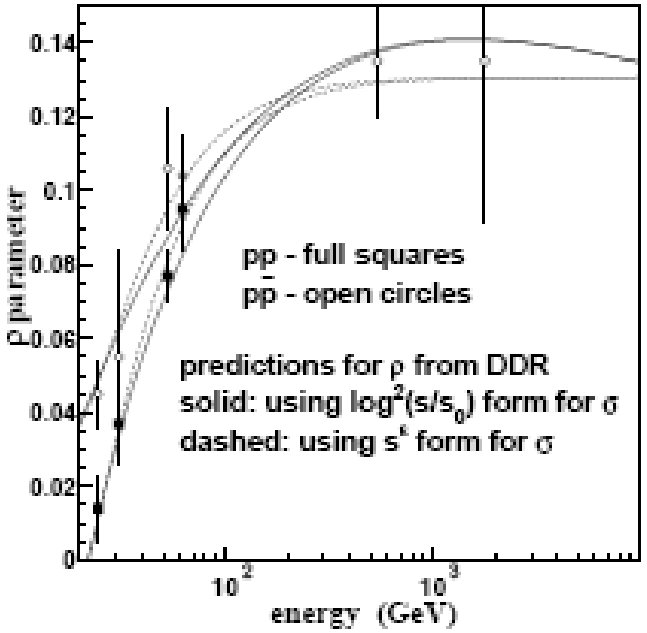
$$B_R \neq B_I$$

For low $|t|$, the strong differential cross section has appro
form with single exponential slope

$$\frac{d\sigma}{dt} = \left|\frac{d\sigma}{dt}\right|_{t=0} e^{Bt}$$

with

$$B = \frac{\rho^2 B_R + B_I}{1+\rho^2}$$



Forecasting σ_{tot}

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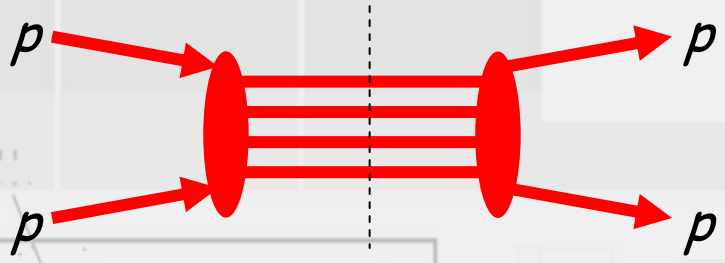
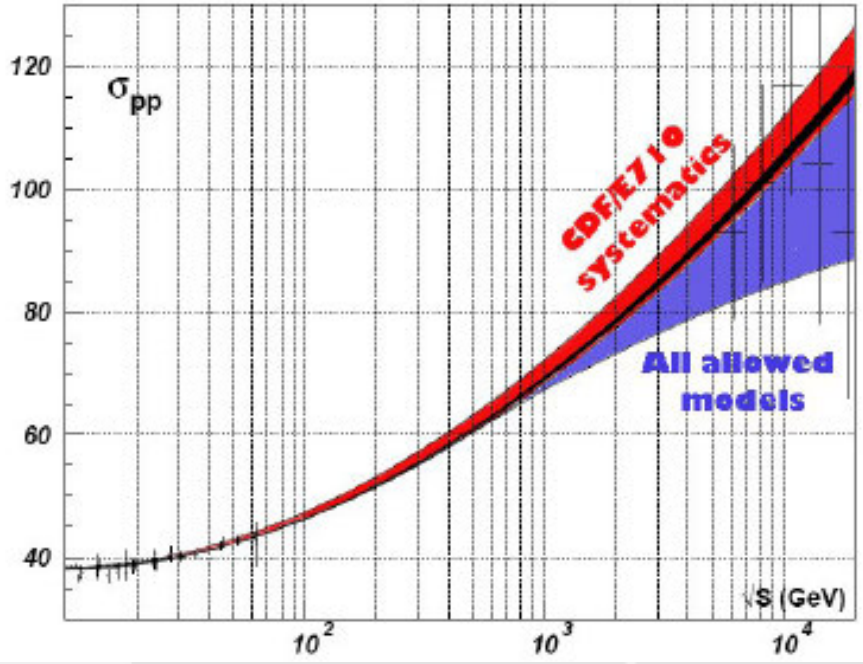
- unitarity $\frac{1}{p_{CM}} \mathrm{Im} T_{elastic}(t=0) = \sigma_{tot}$



and analyticity of $T_{elastic} \rightarrow \sigma_{tot}$

double poles ($\log(s)$)/ triple poles ($\log^2(s)$)
+ 2 undegenerate lower trajectories

Cudell et al



$\sigma_{tot}^{pp}(10\ \mathrm{TeV})$
84 – 112 mb
$\sigma_{tot}^{pp}(14\ \mathrm{TeV})$
90 – 117 mb

Vector Electroproduction

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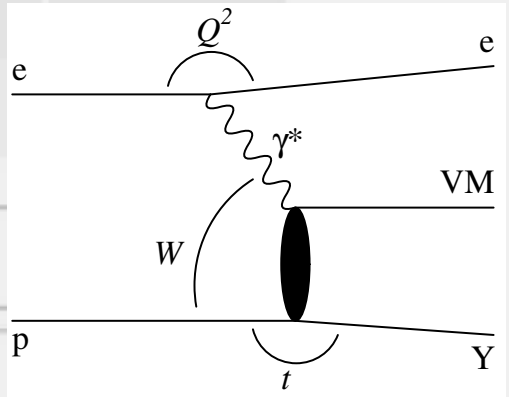
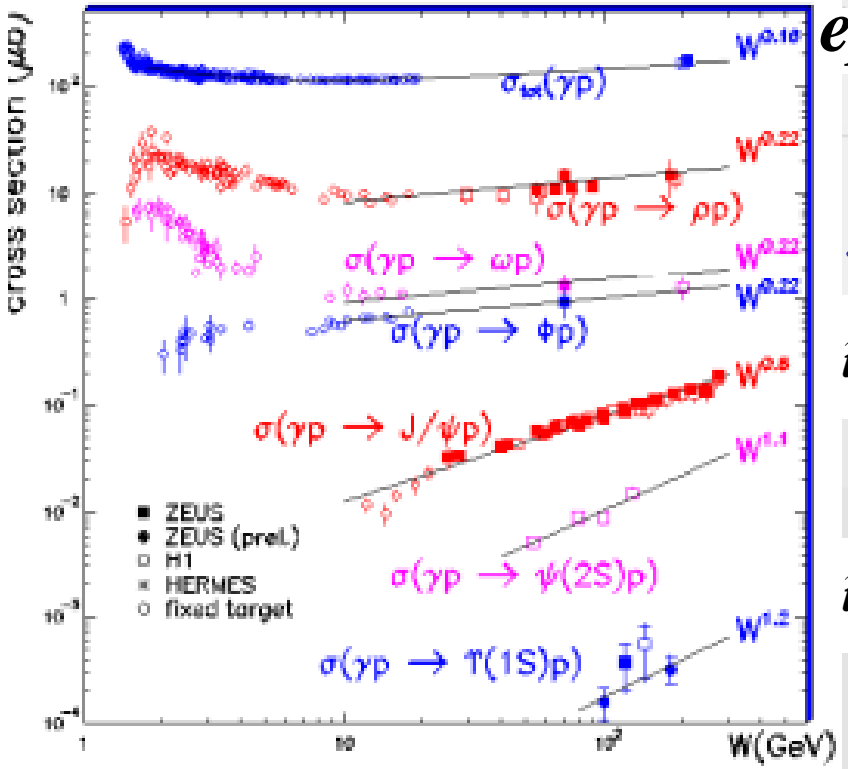
- scale dependence of diffraction
  - dimension of $I\!P$ probe

Marage

$$\hat{t}_{\substack{\min\\ \max}} = m_q^2 - \frac{Q^2 + M^2 - t}{2}\left(1 \mp \sqrt{1 - \frac{4m_q^2}{M^2}}\right)$$





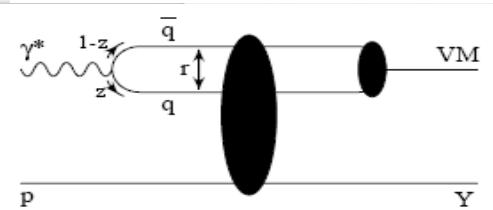
$$ep \to e\rho p$$

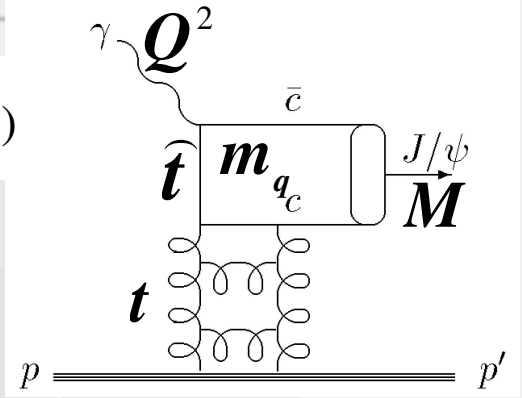
small < r < large

$$\hat{t} \to m_q^2 - \frac{M^2}{2}\left(1 \mp \sqrt{1 - \frac{4m_q^2}{M^2}}\right)$$

r small

$$\hat{t} \to m_c^2 - \frac{M_{J/\Psi}^2}{2} \to -\frac{M_{J/\Psi}^2}{4}$$





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Vector Electroproduction

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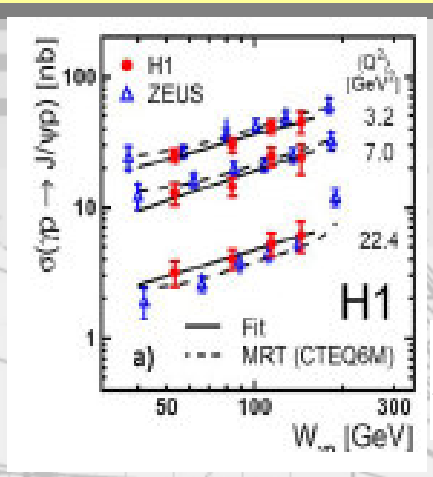
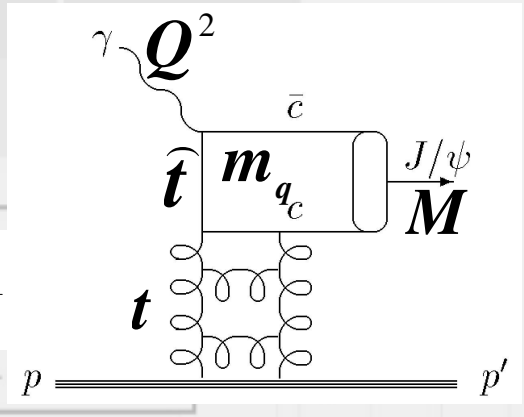
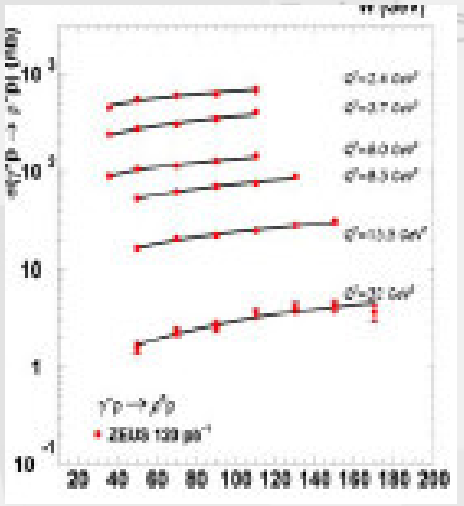
- scale variable
  - quark virtuality $\hat{t}$ → dipole size



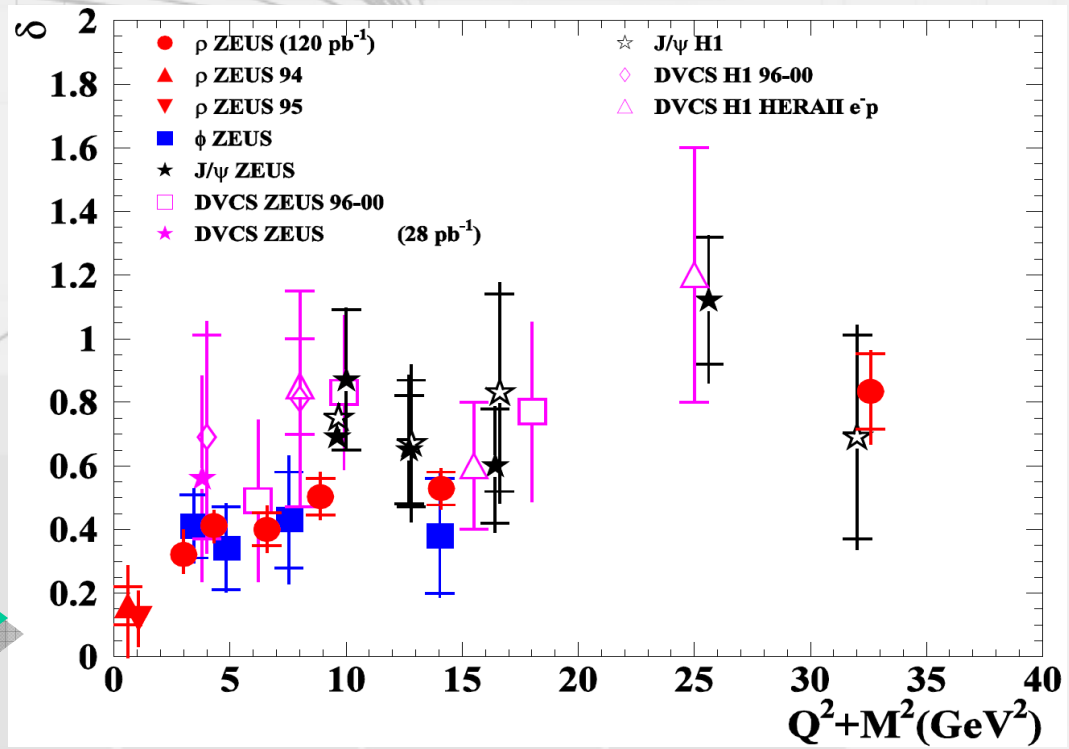
$$\hat{t} \to -\frac{Q^2 + M_{J/\Psi}^2}{2}$$





$$0 \geq \hat{t} \geq Q^2 + M_\rho^2$$

- scale variable $\hat{t}$?



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Vector Electroproduction

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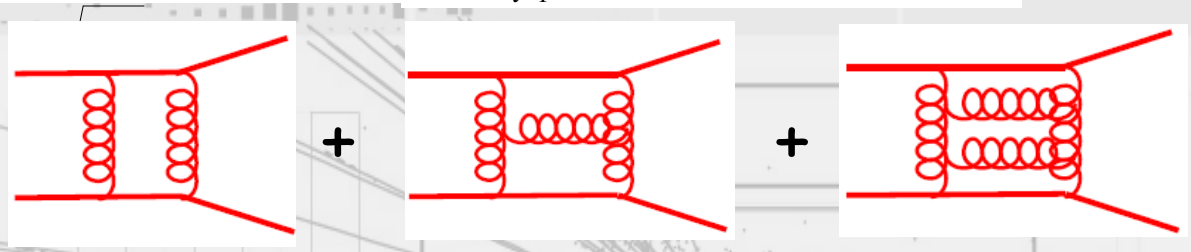
- evolution to hard pomeron

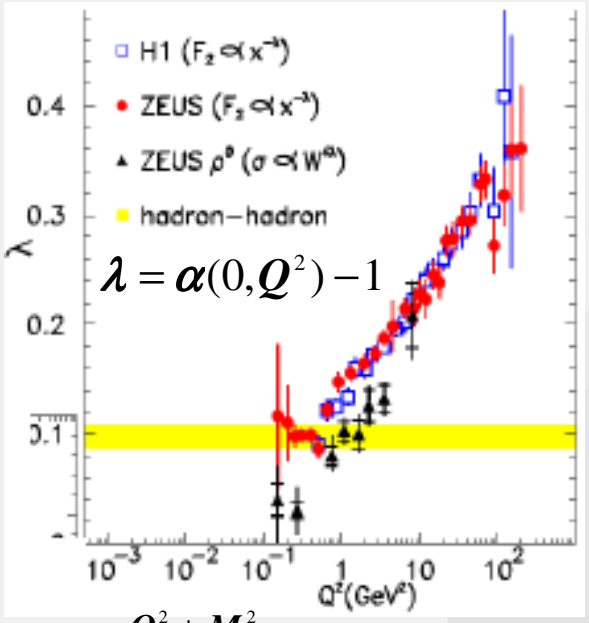
$ep \to e\rho p$

"trajectory" $\alpha_n = \sum_{i=1}^{n} j_i - (n-1) + O(\alpha_s) + ..$

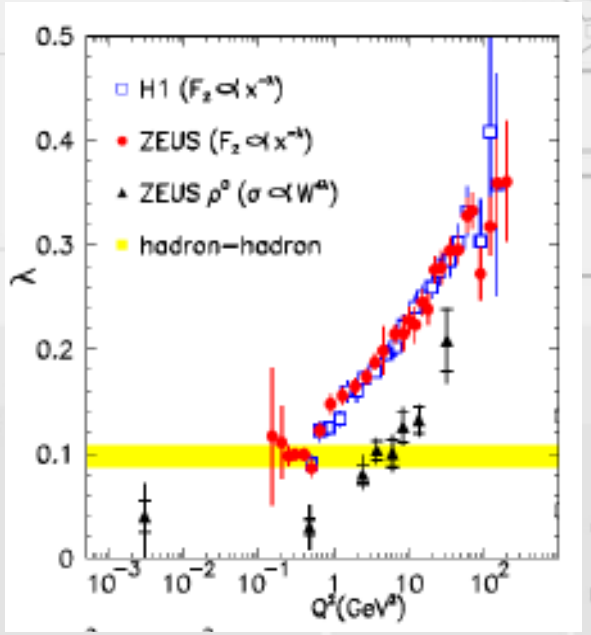
$0 \geq \hat{t} \geq Q^2 + M_\rho^2$



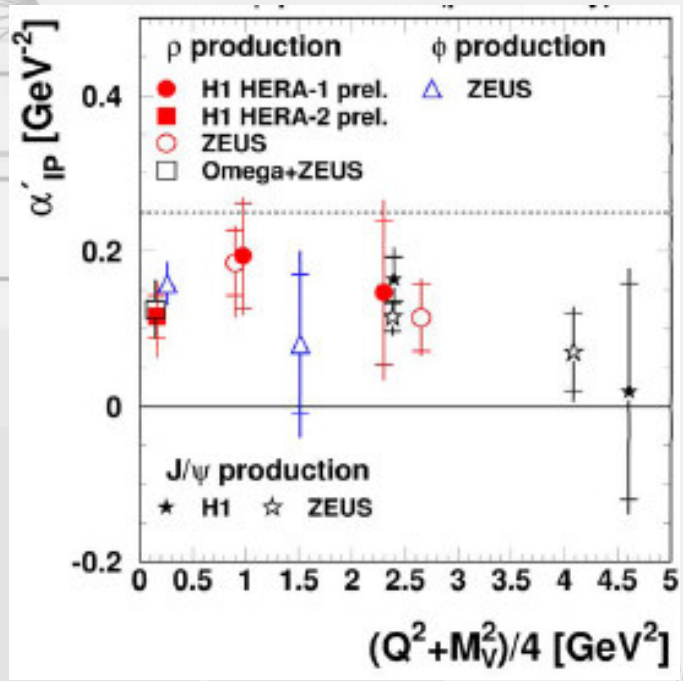
- trajectory $\alpha(t,Q^2) = \alpha(0,Q^2) + \alpha'(t,Q^2) + ...$



$\frac{Q^2 + M_\rho^2}{4}$



$Q^2 + M_\rho^2$



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Compton Scattering

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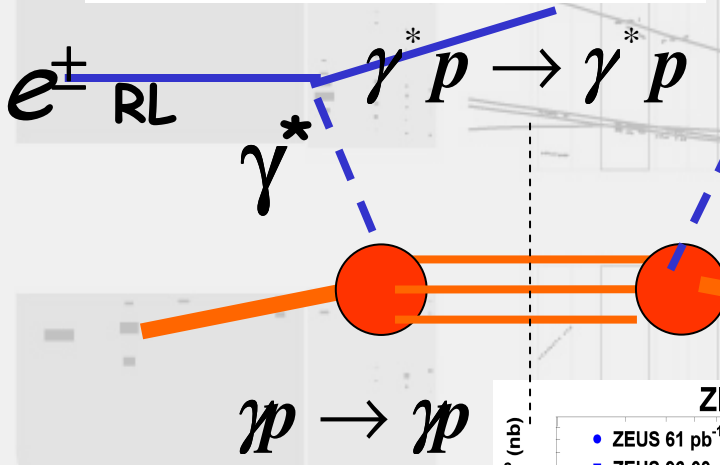
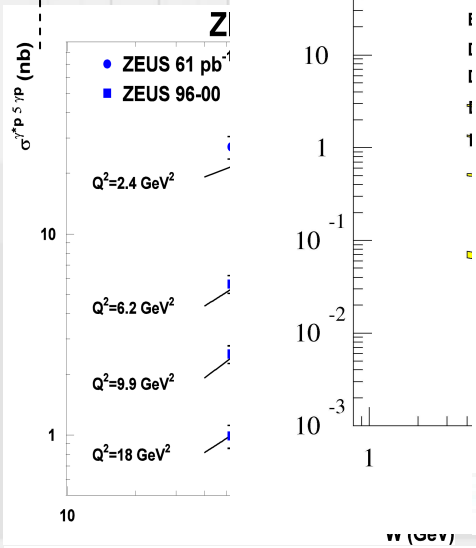
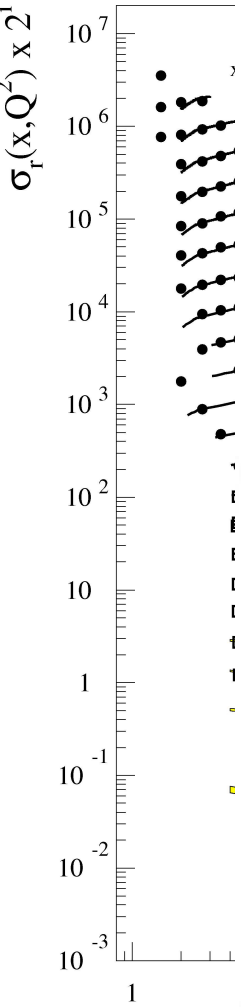
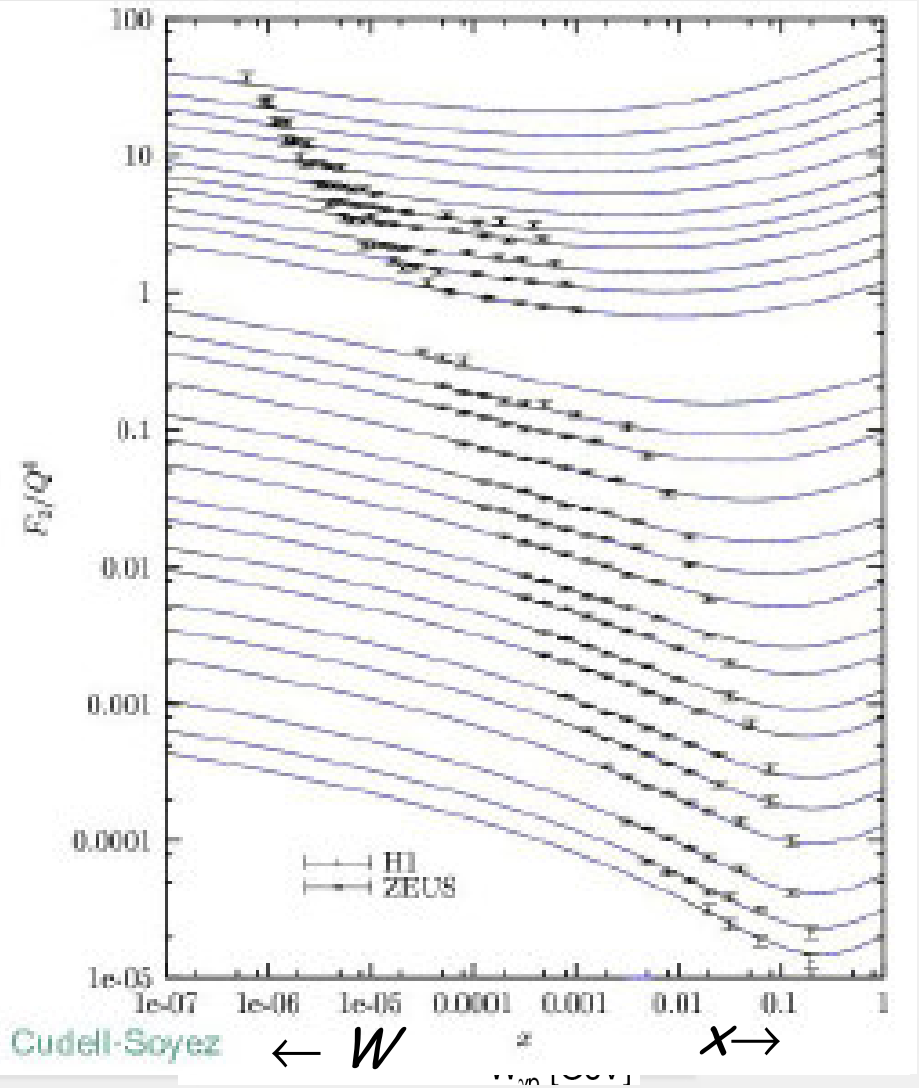
- unitarity and analyticity of $T_{elastic} \rightarrow \sigma_{tot}$

$$\frac{1}{p_{CM}} \mathrm{Im} T_{elastic}(t=0) = \sigma_{tot}$$









Cudell poles

- analyticity ↔ pQCD

Vector Electroproduction

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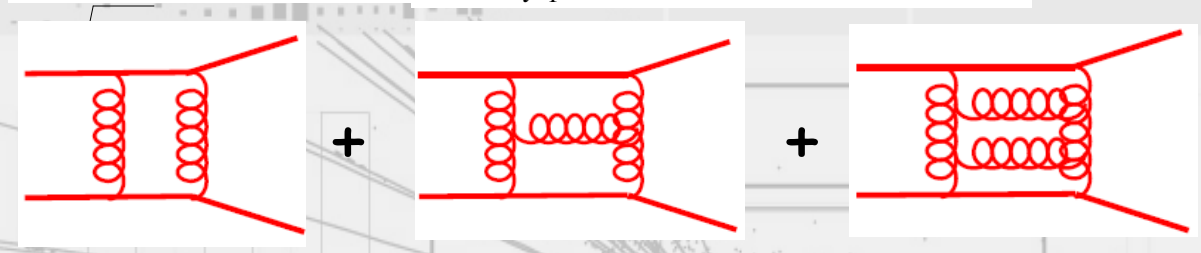
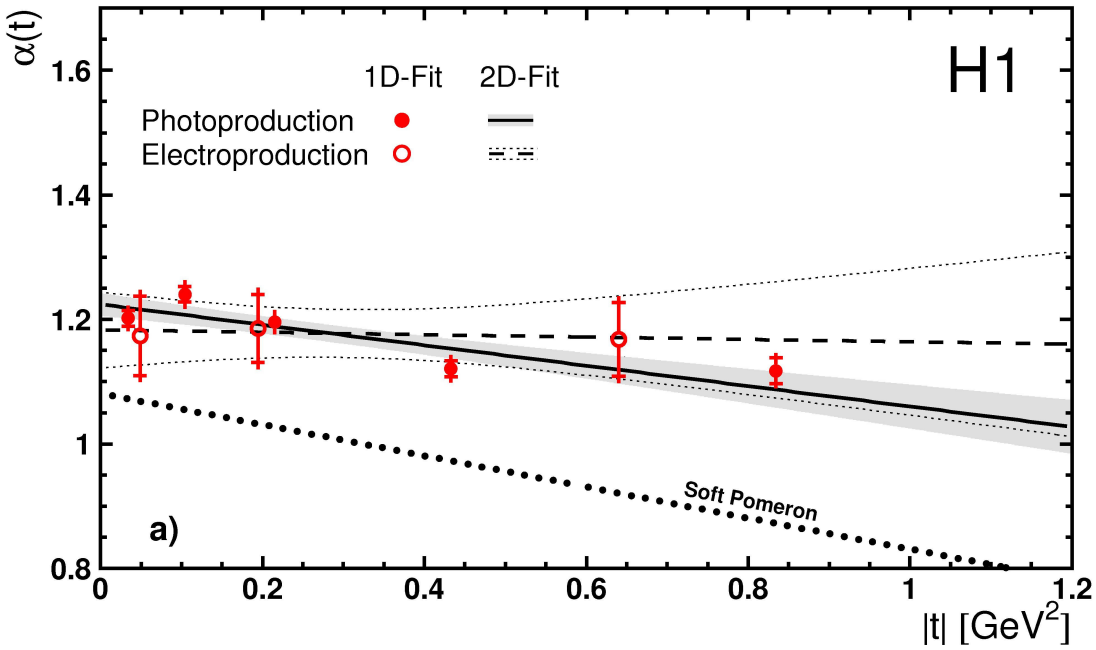
- evolution to hard pomeron

$ep \to eJ/\Psi p$ "trajectory" $\alpha_n = \sum_{i=1}^{n} j_i - (n-1) + O(\alpha_s) + ..$

$\hat{t} \to -\frac{M_{J/\Psi}^2}{2}$



- trajectory $\alpha(t,Q^2) = \alpha(0,Q^2) + \alpha'(t,Q^2) + ...$



"Higgs with no mess"!

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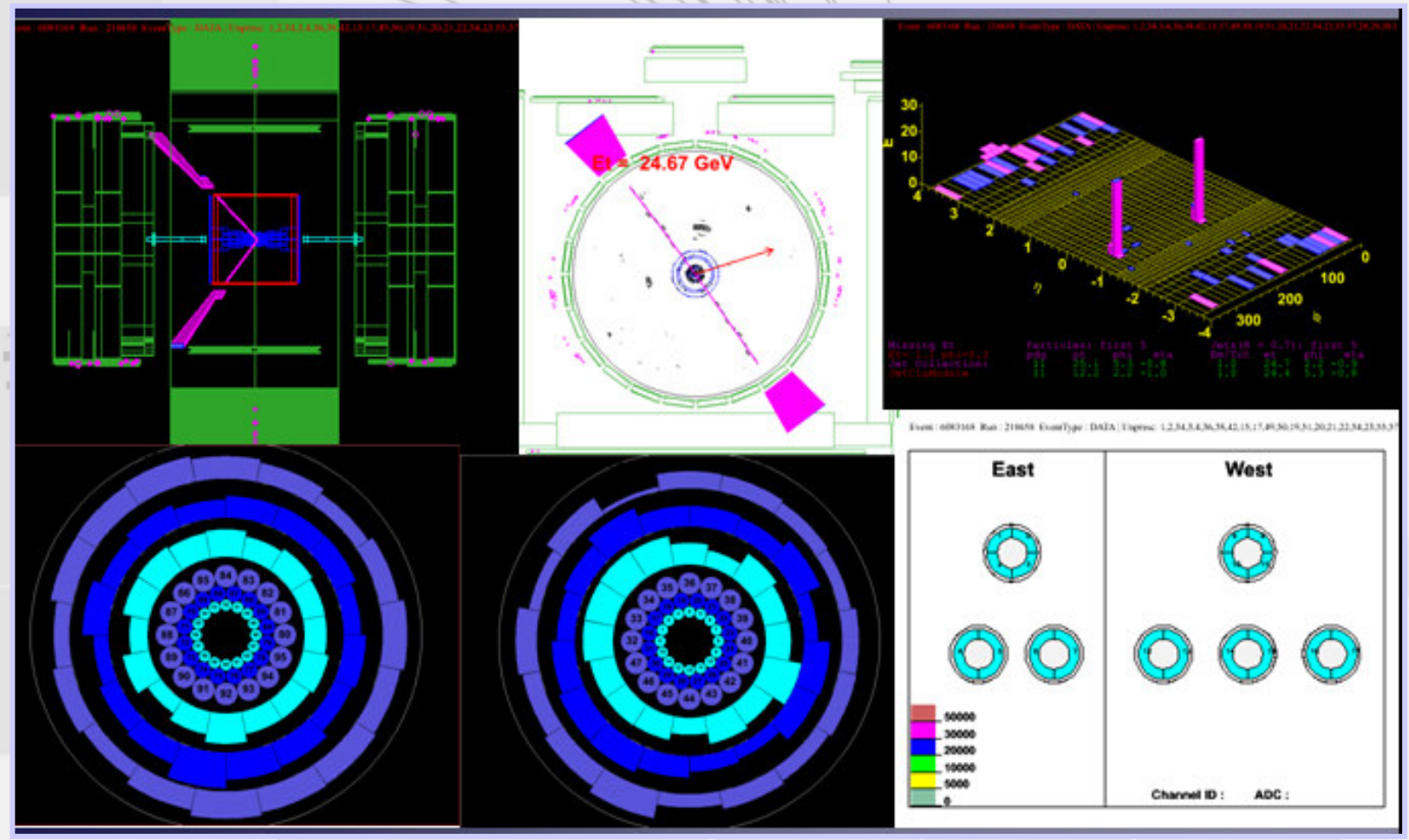
- amazing idea now maturing with data

  Terascale $pp \rightarrow ppe^+e^-$

Albrow



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Towards "Higgs with no mess"?

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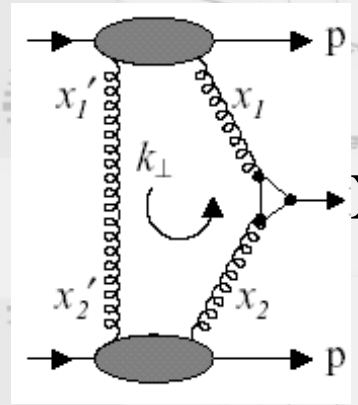
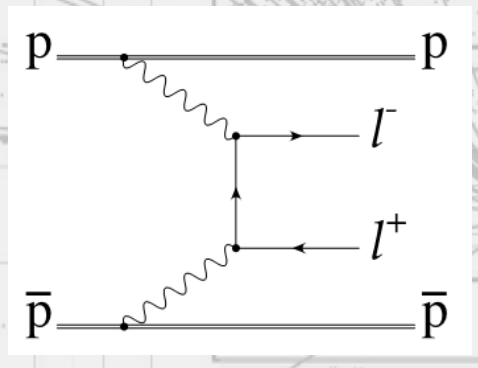
Central Exclusive Production

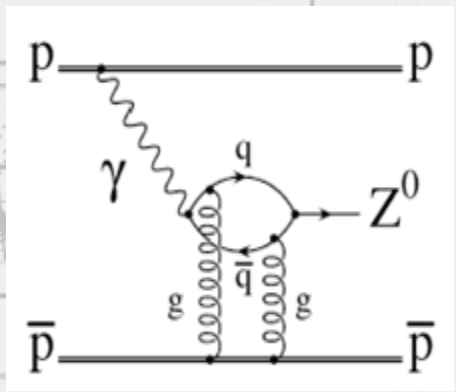
$$p + \bar{p} \rightarrow p + X + \bar{p}$$

where X is a simple state fully measured, and no other particles produced.

(Cannot detect p/pbar, down beam pipe, but BSC → η = 7.4 empty)







(& VM)

Motivation:

In CDF, sophisticated tests of QCD with large rapidity gaps Δy

Looking forward to LHC:

Interesting examples →

$$X = h, H, W^+W^-, \tilde{l}^+\tilde{l}^-, \ldots$$

If see h, H : **Mass, width, spin J, C = +1, Couplings H – gg, …**

in a unique way, even if e.g. $h(140) \rightarrow b\bar{b}$ & $H(150) \rightarrow b\bar{b}$

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Towards "Higgs with no mess"?

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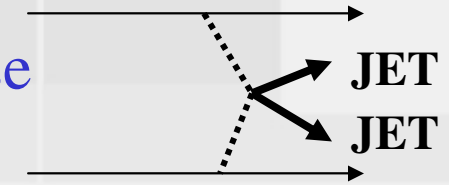
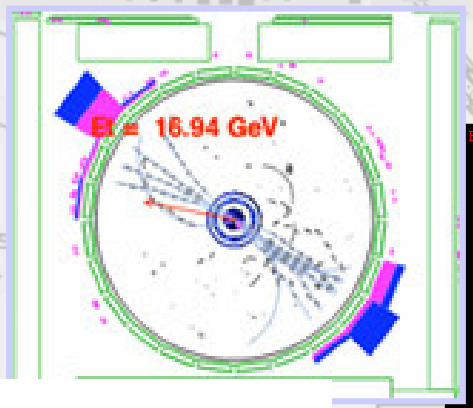
- $pp \rightarrow pp$ +2jets

$$p + \bar{p} \rightarrow p + JJ + \bar{p} + \sim \text{nothing else}$$

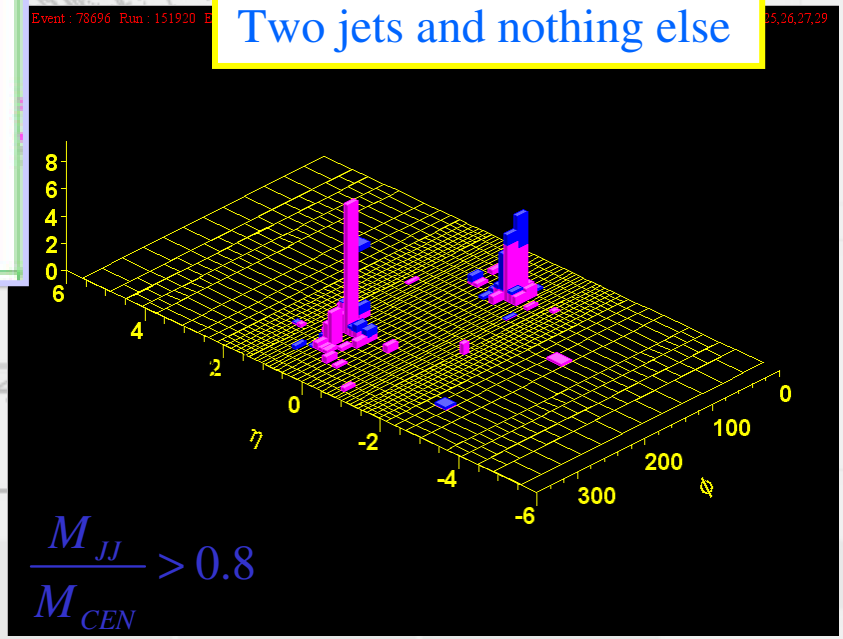


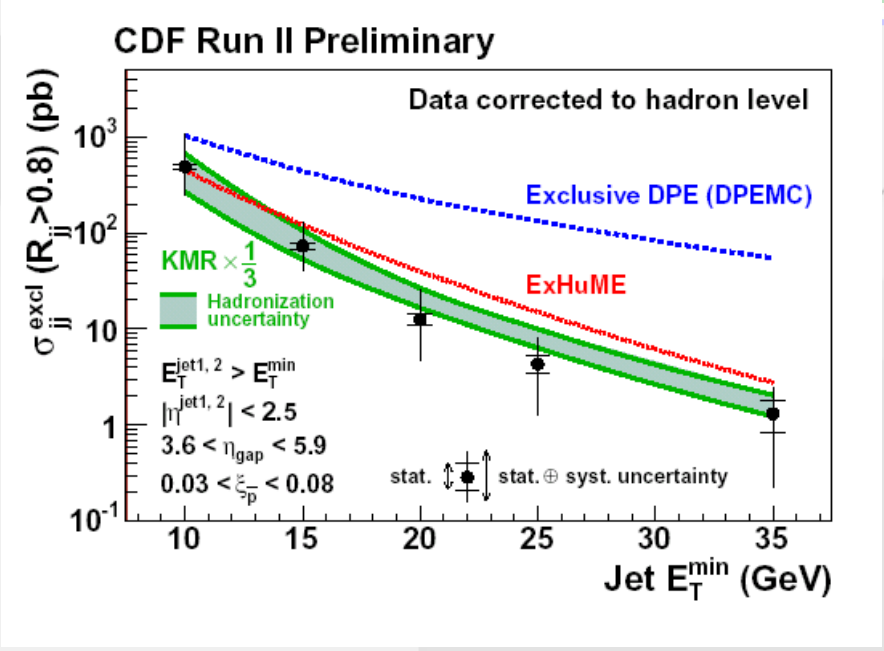
Observed in CDF, QCD tests
& related to p+H+p

$$R_{JJ} = \frac{M_{JJ}}{M_X} \approx 1.0$$



"Almost" exclusive di-jet,
Two jets and nothing else





- "direct" $I\!P$?

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Towards "Higgs with no mess"?

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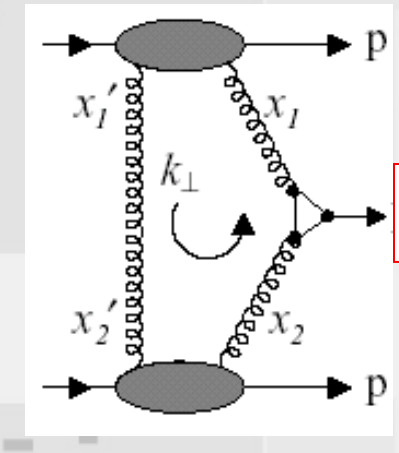
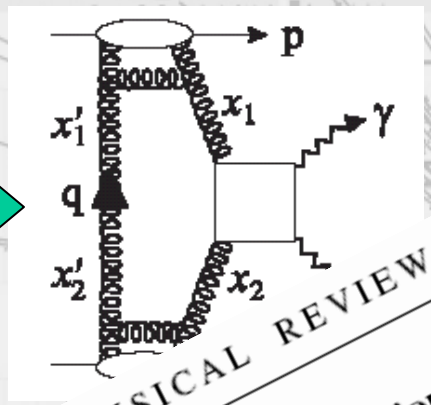
- result $pp \to pp\,\gamma\gamma$ ……

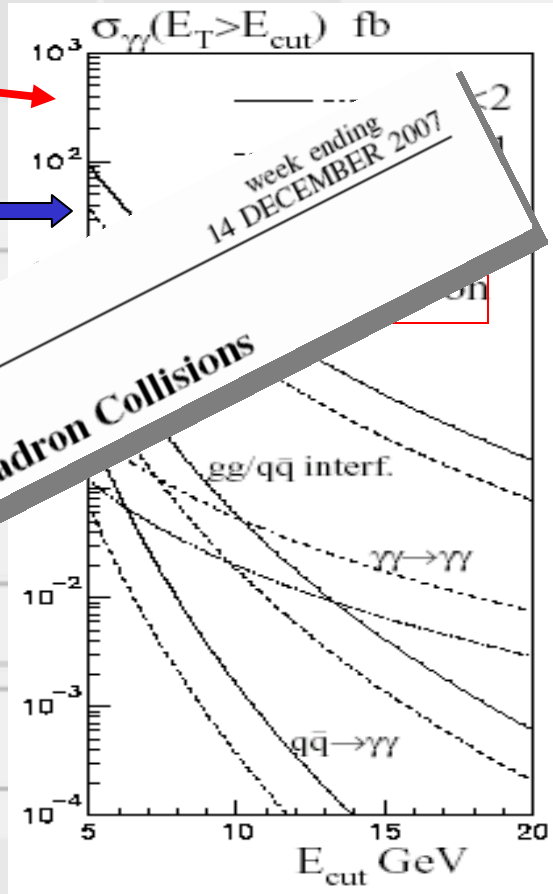
Claim factor ~ 3 uncertainty ; Correlated to p+H+p



H



36 fb



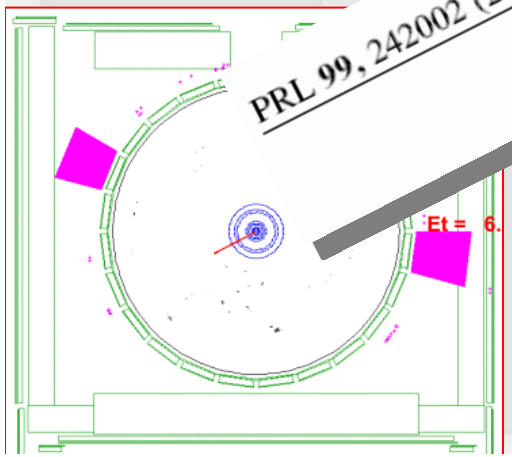
PHYSICAL REVIEW LETTERS
week ending 14 DECEMBER 2007
Search for Exclusive γγ Production in Hadron-Hadron Collisions
PRL 99, 242002 (2007)

$\gamma\gamma \to \gamma\gamma$?

…smaller

…eV; $|\eta(\gamma)|<1.0$

… candidates, 2 golden, 1 ? $\pi^0\pi^0$



36 fb → 0.8 events

Note : $\sigma_{MEAS} \approx 2\times10^{-12}\,\sigma_{INEL}$!

…… CDF = SM(QED) LHC=SM(Higgs)?

Exclusive Diffraction

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- elastic hadron-hadron
  - the aristocrat of sub-nuclear physics
  - rigorous forward amplitude analysis
    critical for first measurements at LHC
    underpins precision understanding of strong interaction = diffraction
- electroproduction
  - unique probe of scale interplay
  - pQCD $\leftrightarrow$ ~~p~~QCD laboratory
- exclusive electroweak production
  - now SM(QED)
  - tomorrow SM(EW)

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3. Inclusive Diffraction

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Inclusive Diffraction

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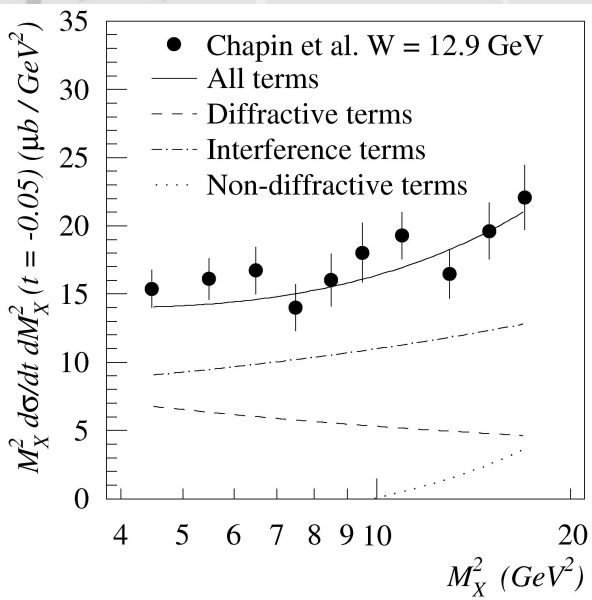
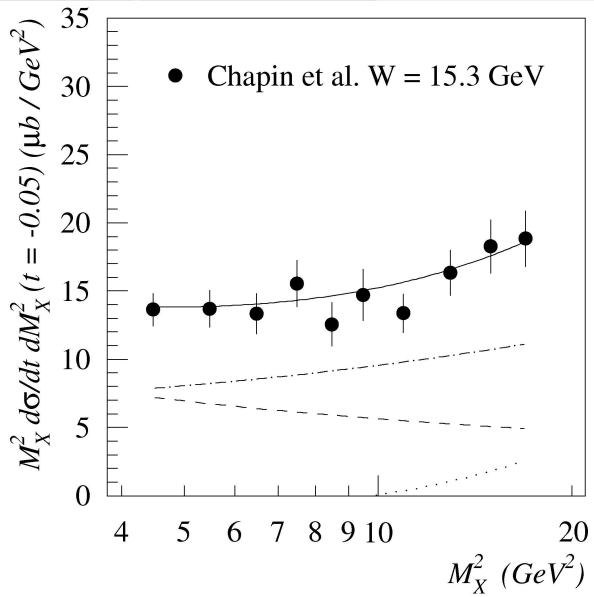
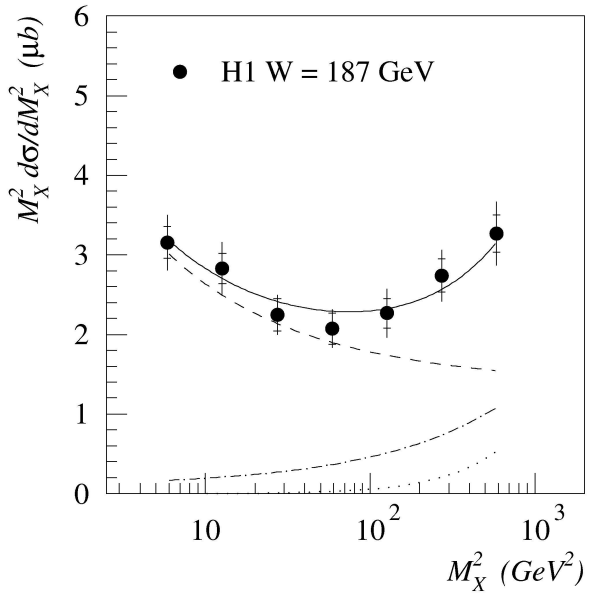
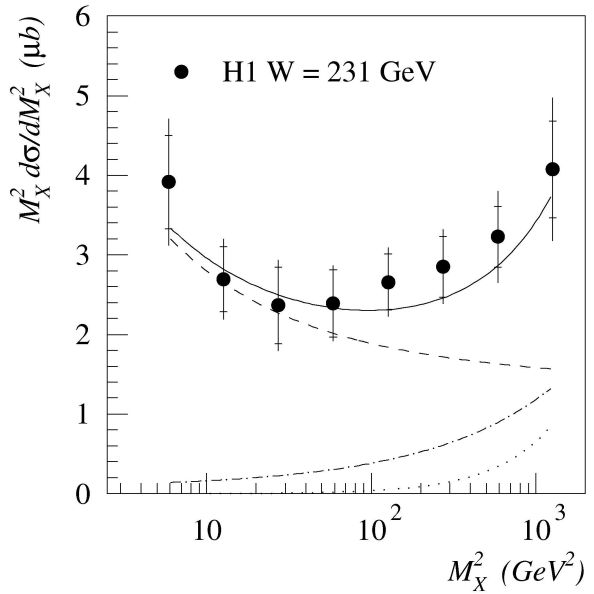
- $pp \to pX$
  - CERN ISR 1997
  + Chapin et al.
    Fermilab 1974
  + triple Regge









→ precision measurements (archive)
→ precision phenomenology

Inclusive Diffraction

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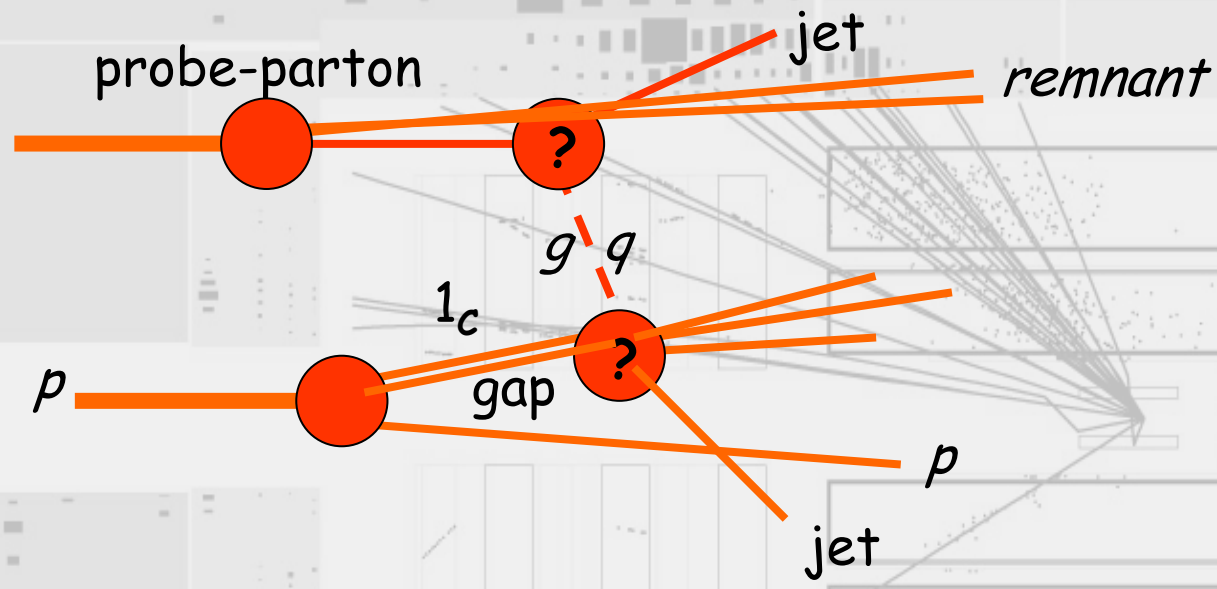
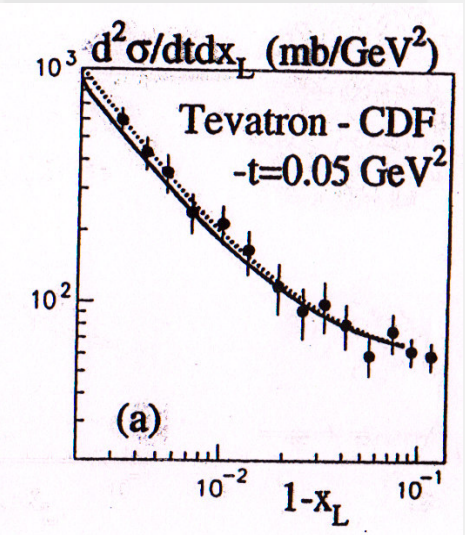
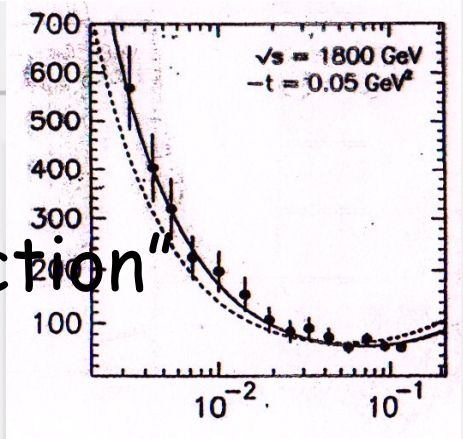
- TeVatron $pp \rightarrow pp$ +jets

Goulianos et al







β = Bjørken-x of 1_c exchange

$1-x_L = x_{IP}$

- deep-inelastic structure of "diffraction"
  - q sensitive and g sensitive probe
  - target = $I\!P + I\!R + \ldots$?

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Inclusive Diffraction

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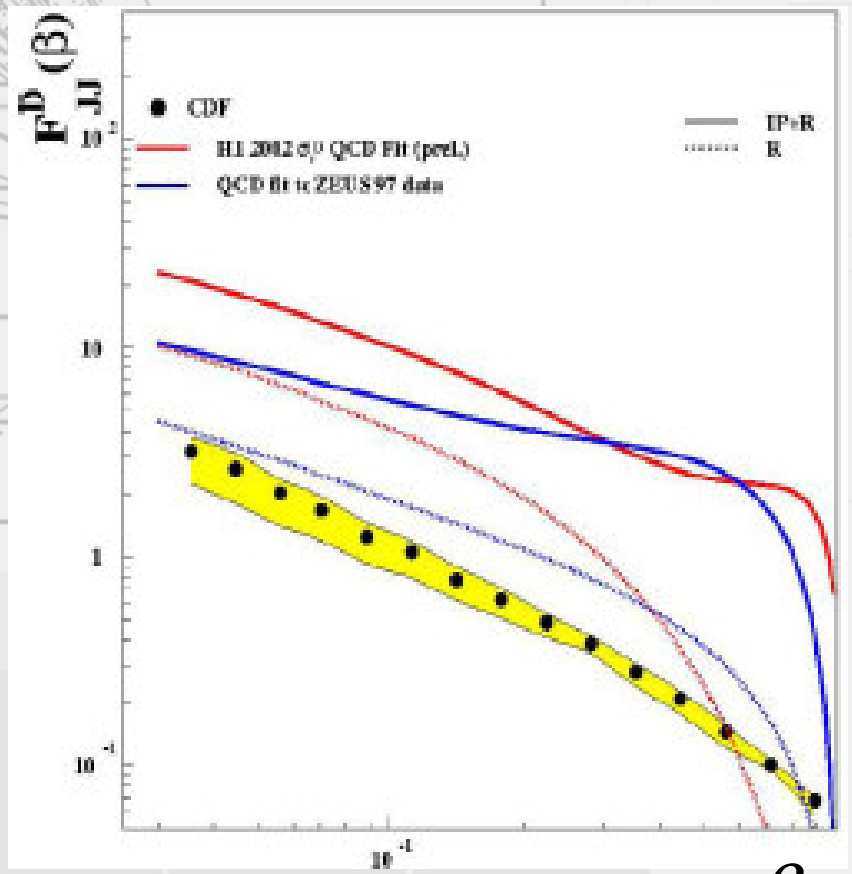
Goulianos
Mesropian

- deep-inelastic structure of "diffraction"
  - q sensitive and g sensitive probe
  - target = $I\!P + I\!R + \ldots$?

$$R^{SD}_{ND}(x,\xi) = \frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F^D_{jj}(x,Q^2,\xi)}{F_{jj}(x,Q^2)}$$

Data known PDF



QCD factorisation fails

Inclusive Diffraction

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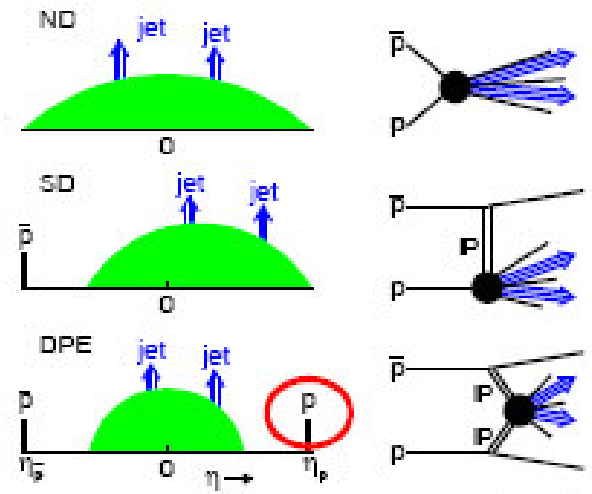
Goulianos

- factorisation restored when probe parton from 1_c ($I\!P + I\!R + \ldots$)
  - $I\!P$ probe ?

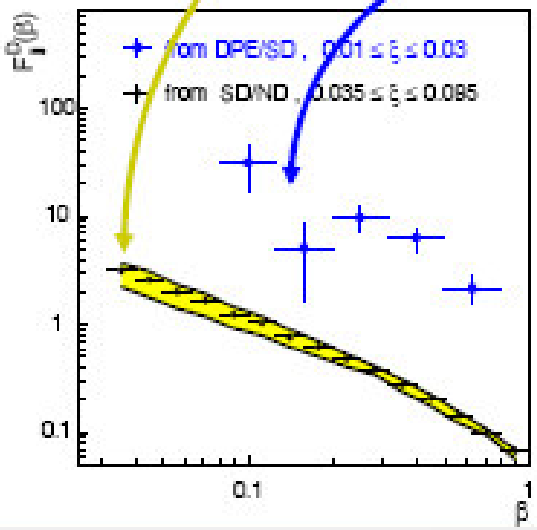
How?

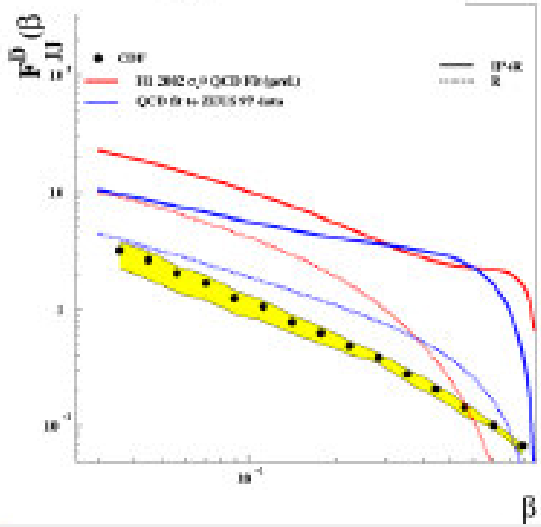


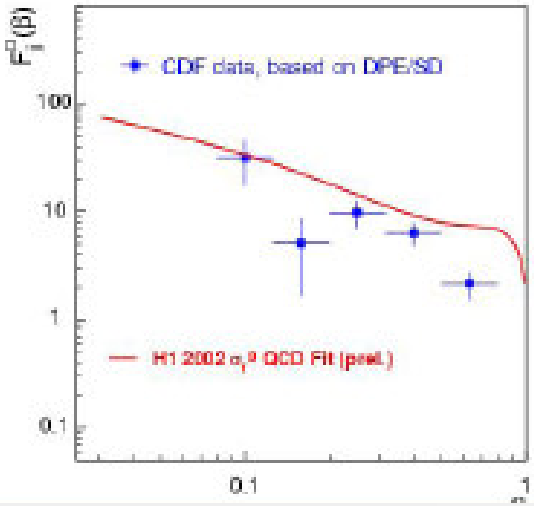
R(SD/ND)

R(DPE/SD)

DSF from ratio of two/one gap: factorization restored!







Inclusive Diffraction

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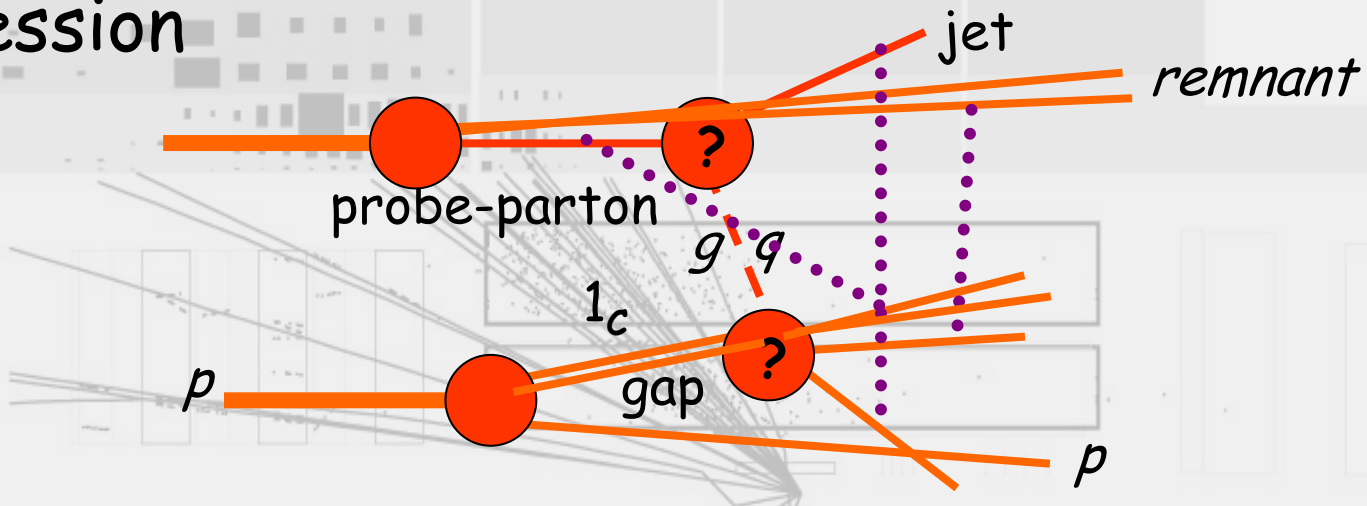
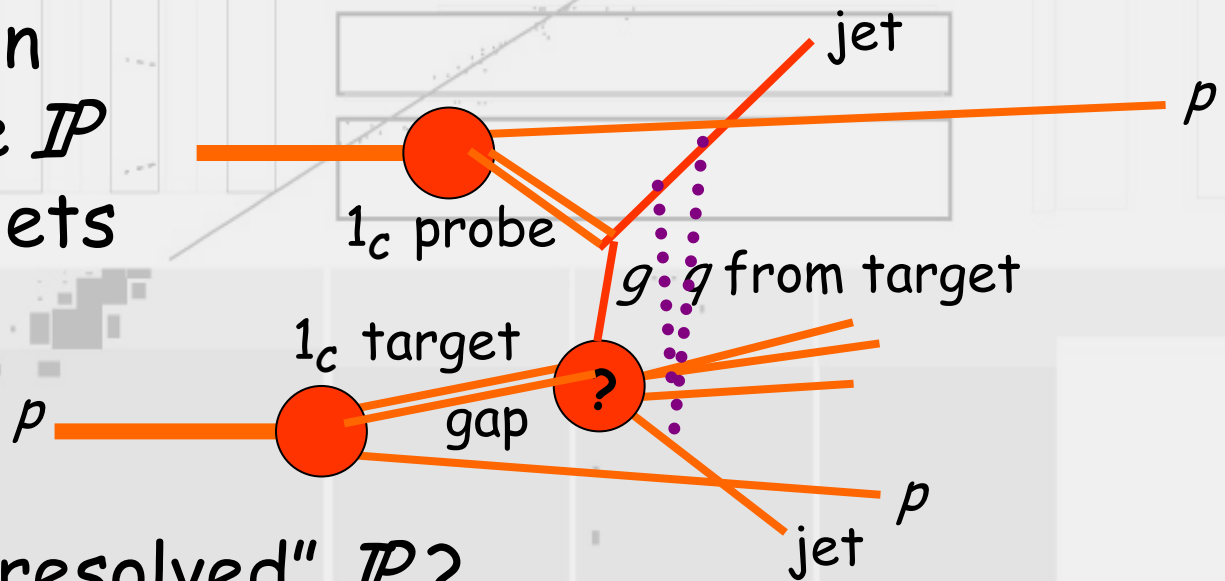
- gap suppression



- gap restoration
  - remnant free $I\!P$ cf exclusive jets



- "direct" and "resolved" $I\!P$?

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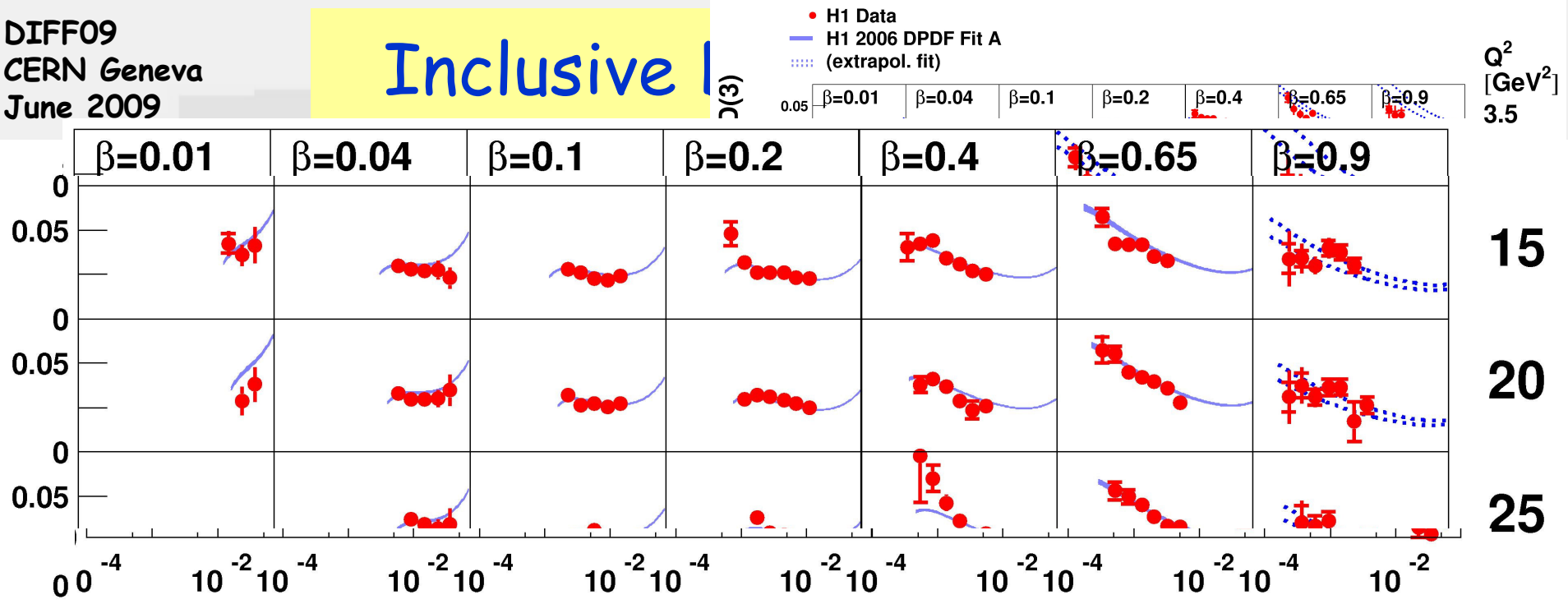
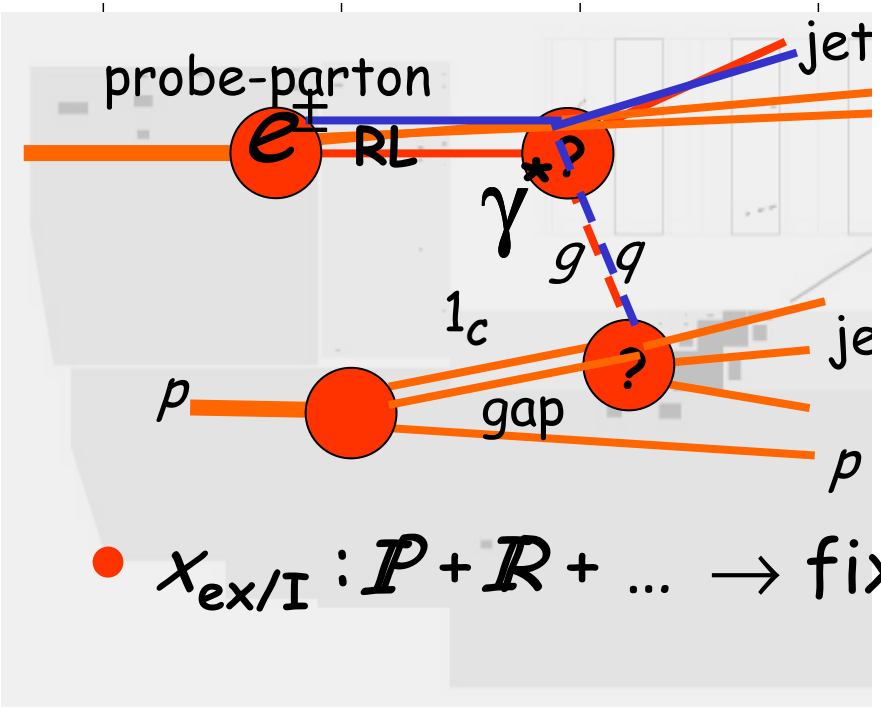
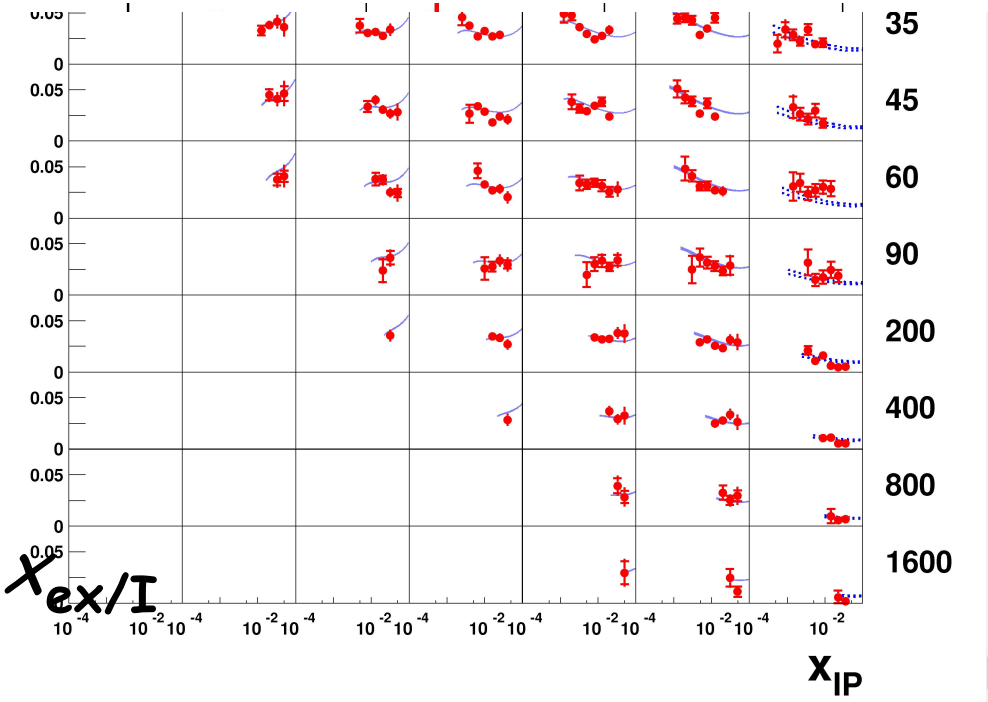
Inclusive I





- $x_{ex/I} : \mathbb{P} + \mathbb{R} + \ldots \rightarrow$ fix $x_{ex/I}$



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Deep-Inelastic 1_c Structure

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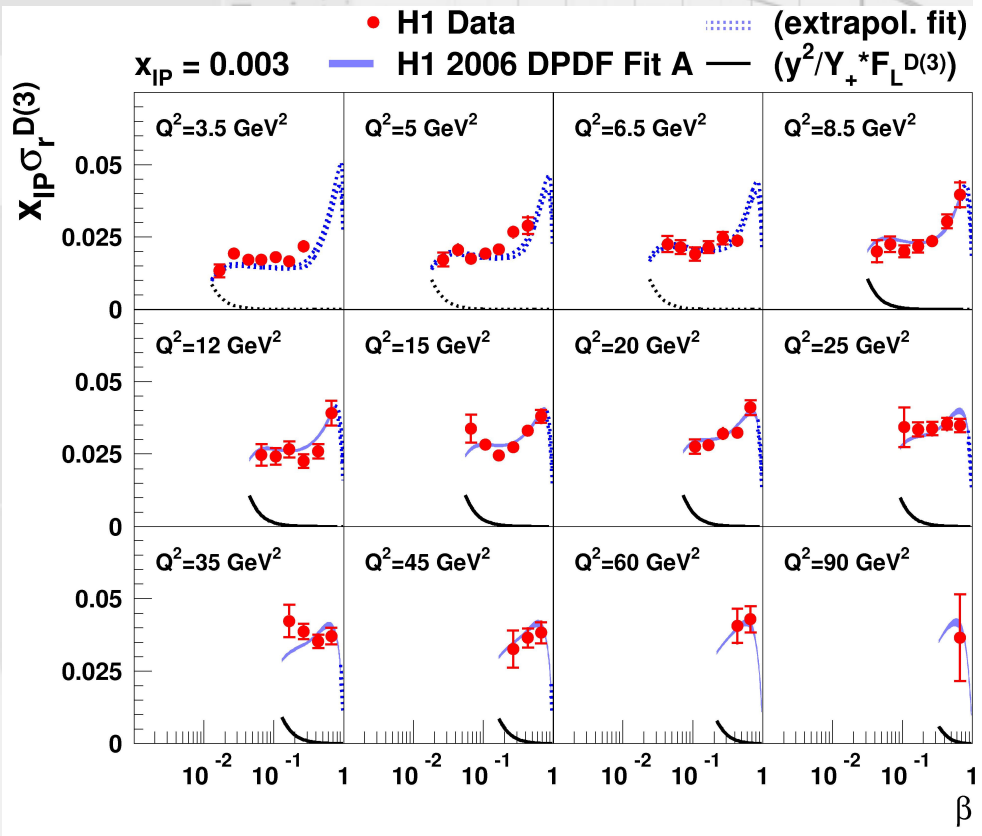
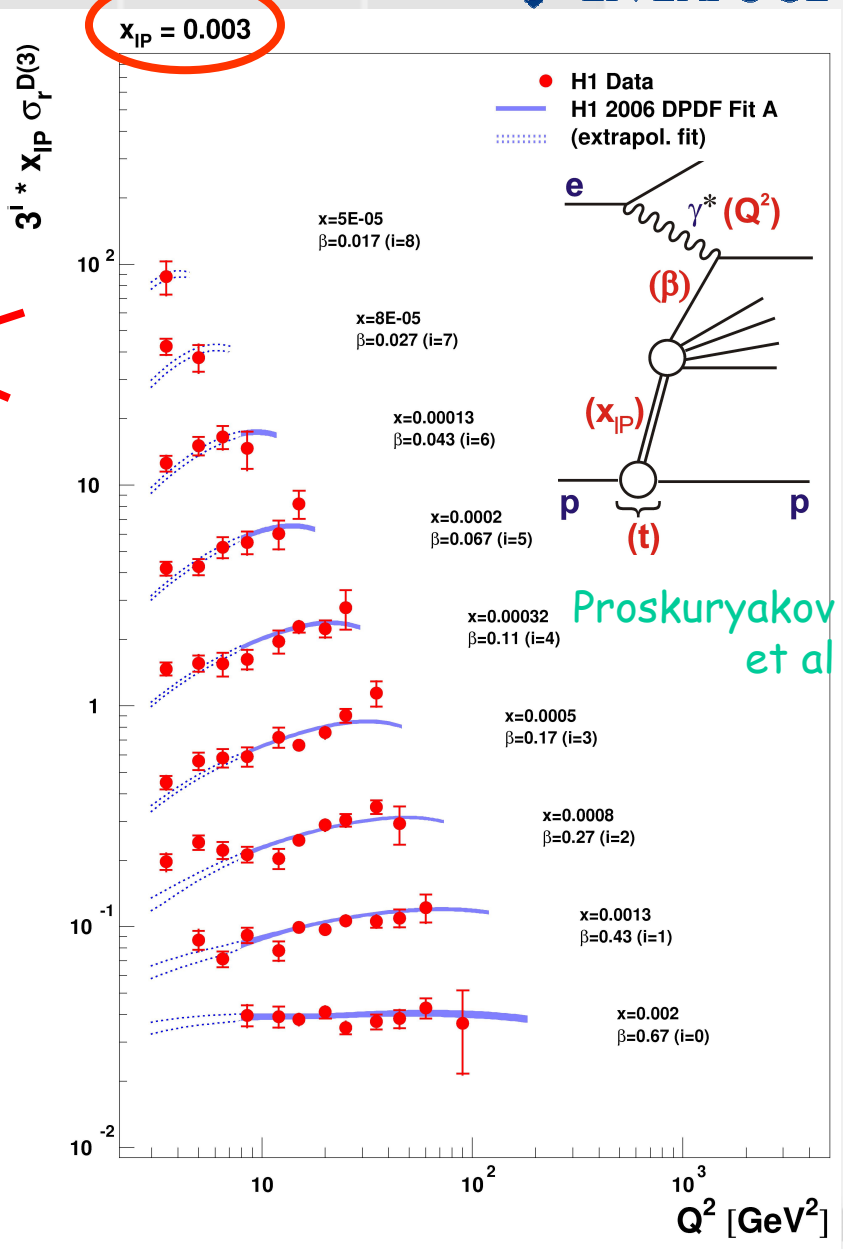
- x-section $\not{x}_{I\!P}\,\sigma_r$
  - scaling violations → flavour singlet q_s evol^n
  - β dep^c ~ $g/I\!P \to q\bar{q}$





Proskuryakov et al

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Deep-Inelastic 1_c Structure

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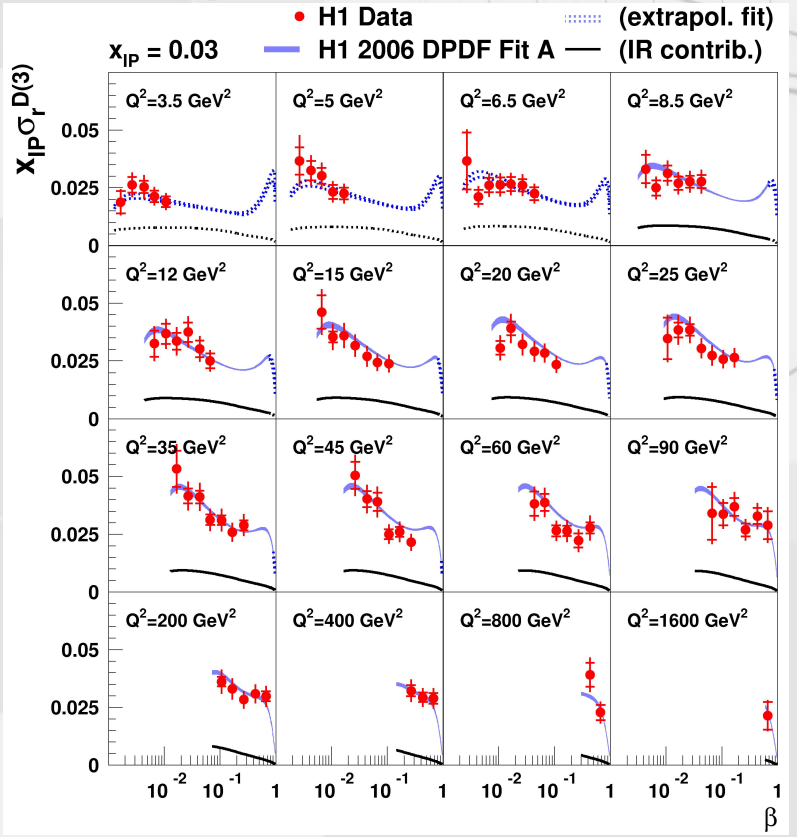
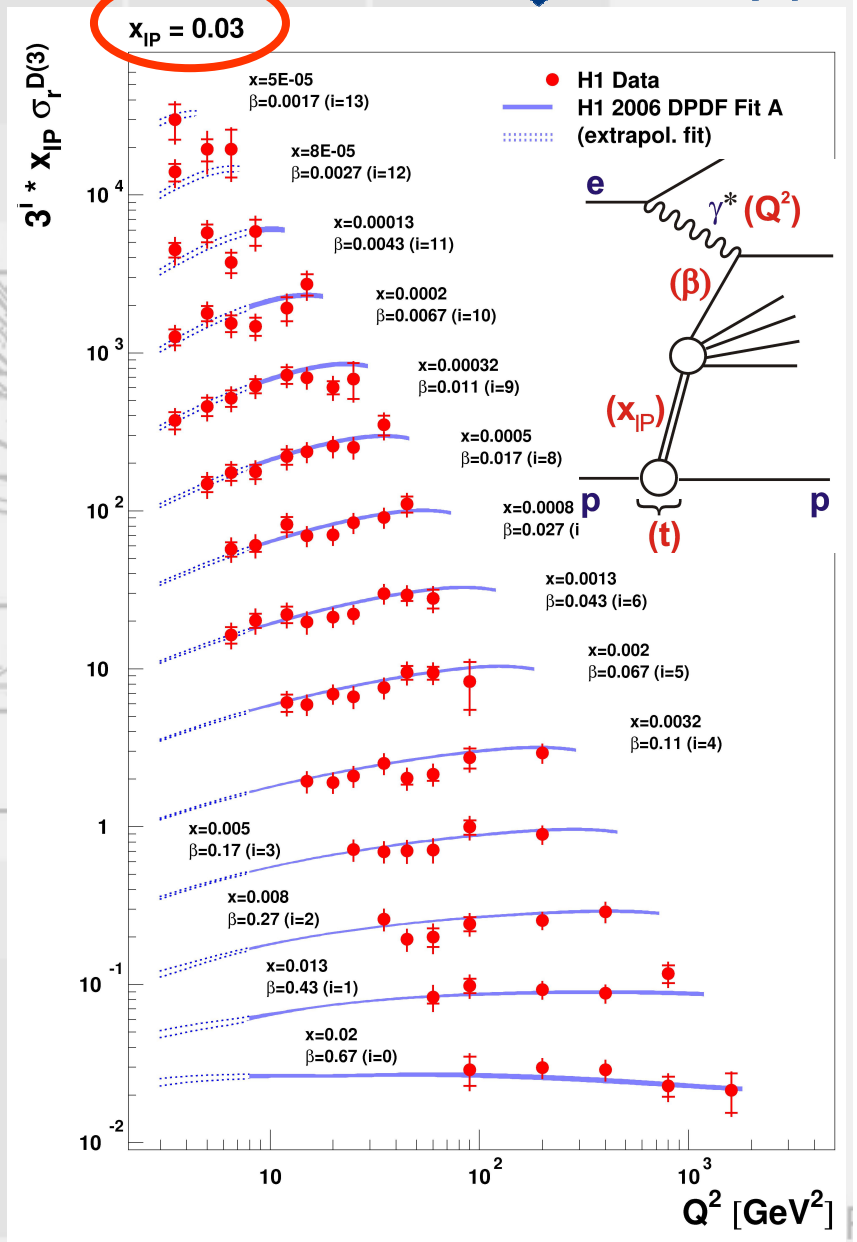
- x-section $x_{I\!P}\sigma_r$ @ larger $x_{I\!P}$
  - scaling violations → flavour singlet q_s evol^n
  - β dep^c ~ $g \to q\bar{q}$ + meson





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Deep-Inelastic 1_c Structure

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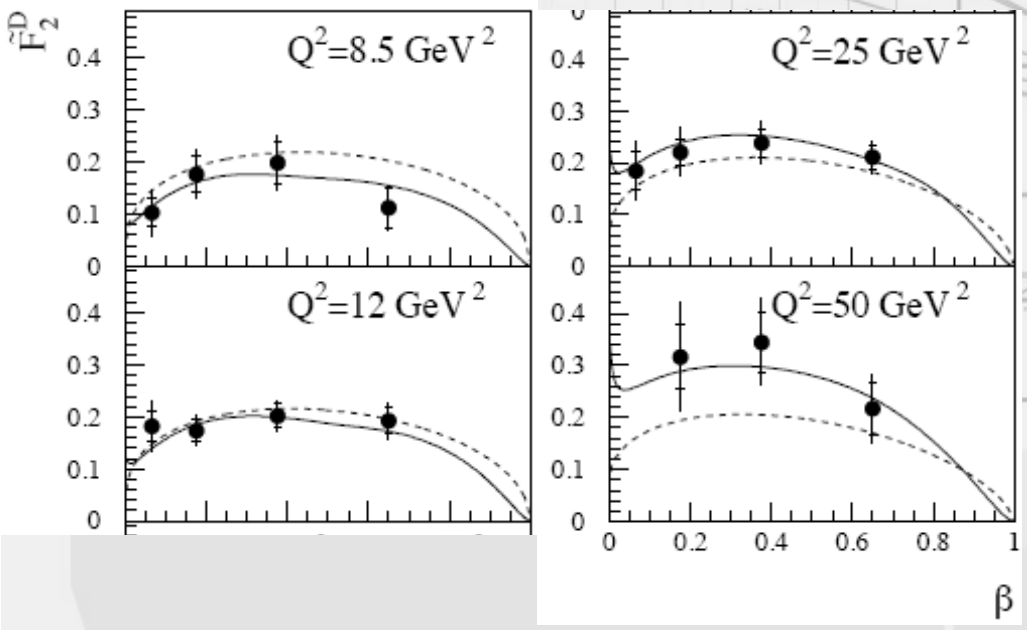
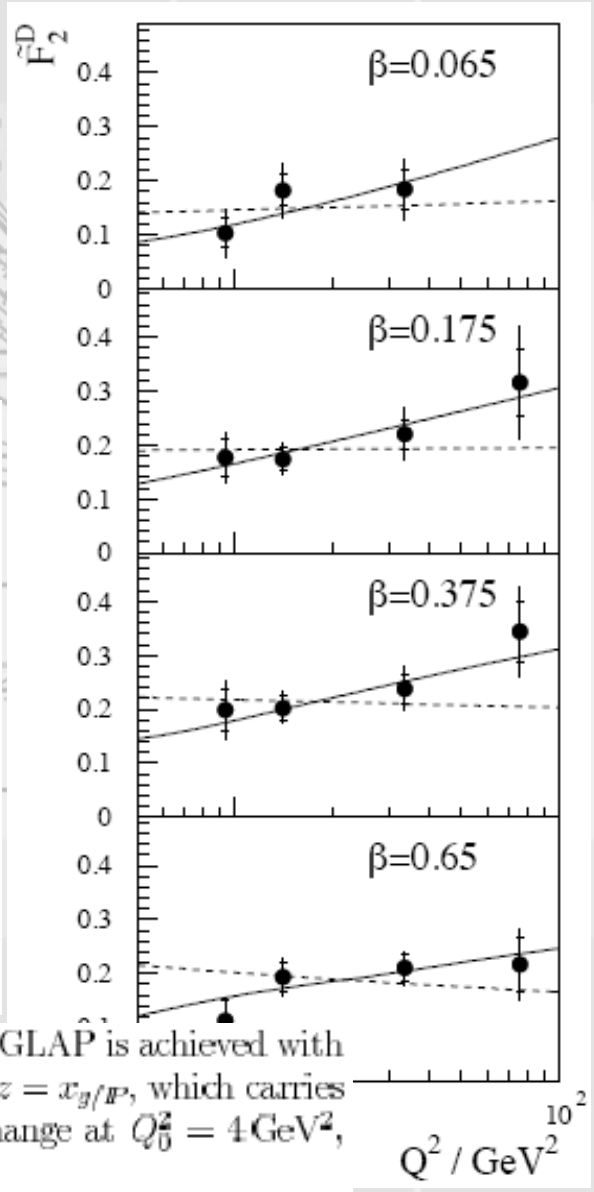
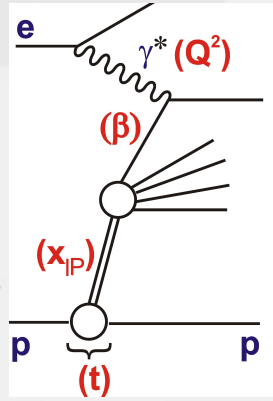
- H1 $\tilde{F}_2^D$ 1996 (Brussels)
  - scaling violations → flavour singlet q_s evolⁿ
  - β depᵉ ~ $g \to q\bar{q}$







An excellent description of $\tilde{F}_2^D$ in the framework of LO DGLAP is achieved with a gluon density which predominates at larger fractional momenta $z = x_{g/I\!P}$, which carries approximately 80% to 90% of the momentum in diffractive exchange at $Q_0^2 = 4\,\mathrm{GeV}^2$, and which supports a leading gluon interpretation.

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Deep-Inelastic 1_c Structure

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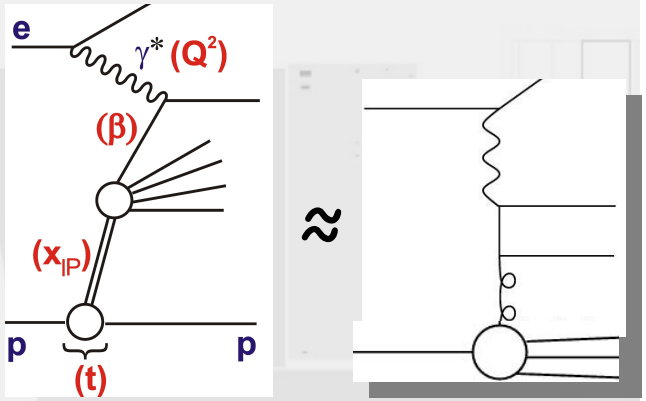
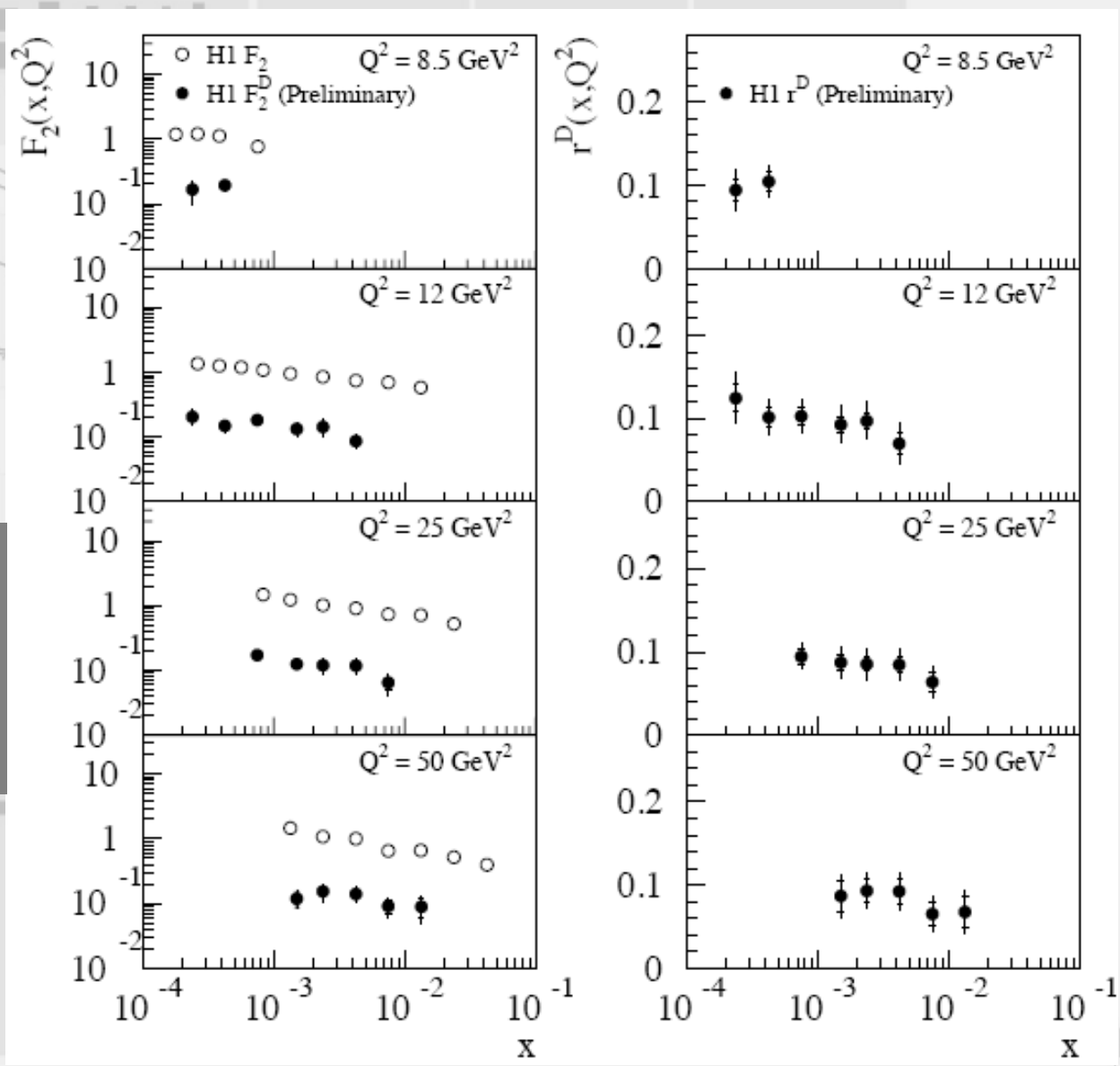
- H1 $F_2^{D(3)}$ 1995
  - F_2^D evolution ≈ F_2 evolution
  - F_2^D evolution ≈ boson-gluon



g in $\mathbb{P}$ in p look like g in p



DGLAP on 1_c Structure

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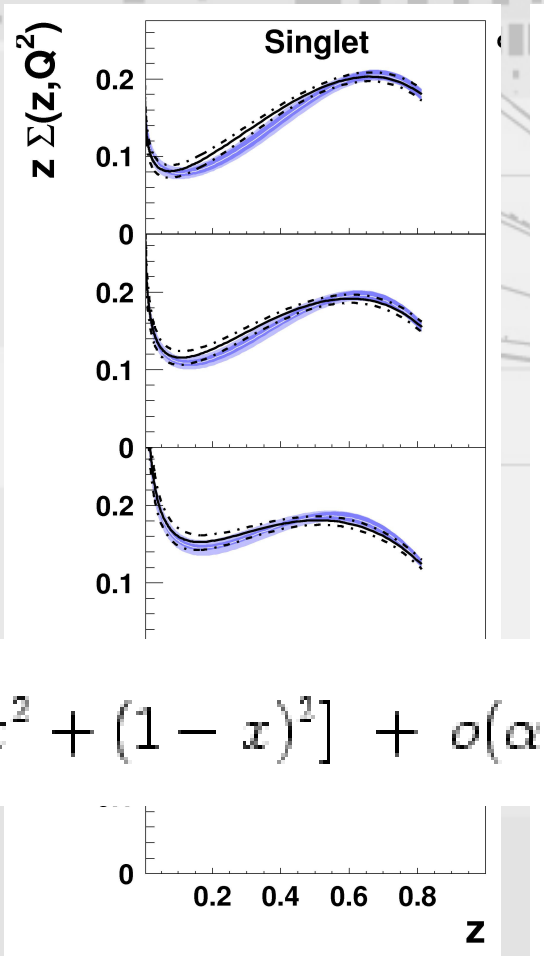
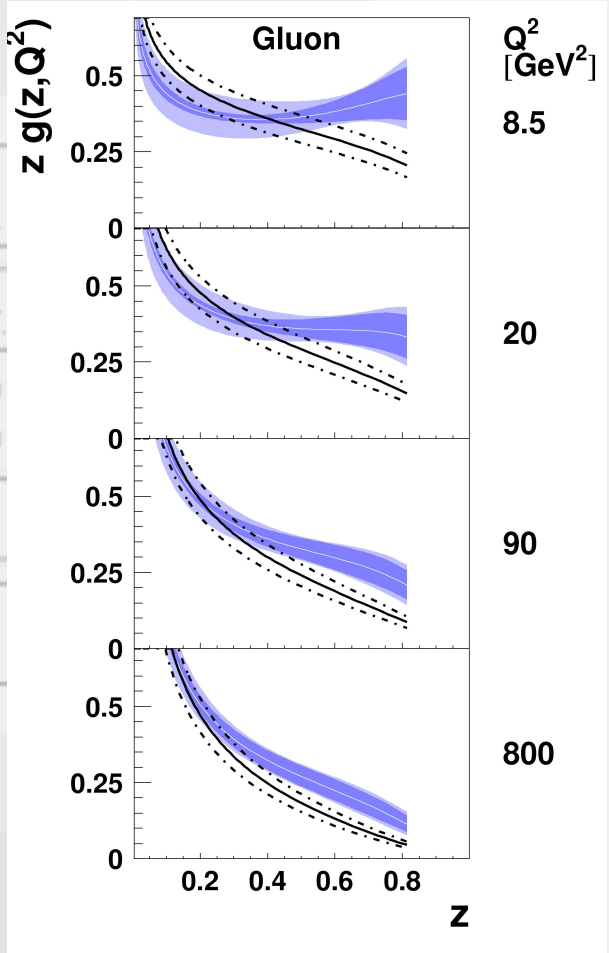
- H1 2008 → pdfs for diffractive dynamics

- q and $\bar{q}$ in F_s = $g \to q\bar{q}$ + $g \to qqg$ + ...



$$P_{qg} = \frac{1}{2}[x^2 + (1-x)^2] + o(\alpha_s)$$

- g in F_s = g + $g \to gg$ + ...



"hard" (~70%) g and $g \to gg$ $g \to q\bar{q}$ splitting

DGLAP on 1_c Structure

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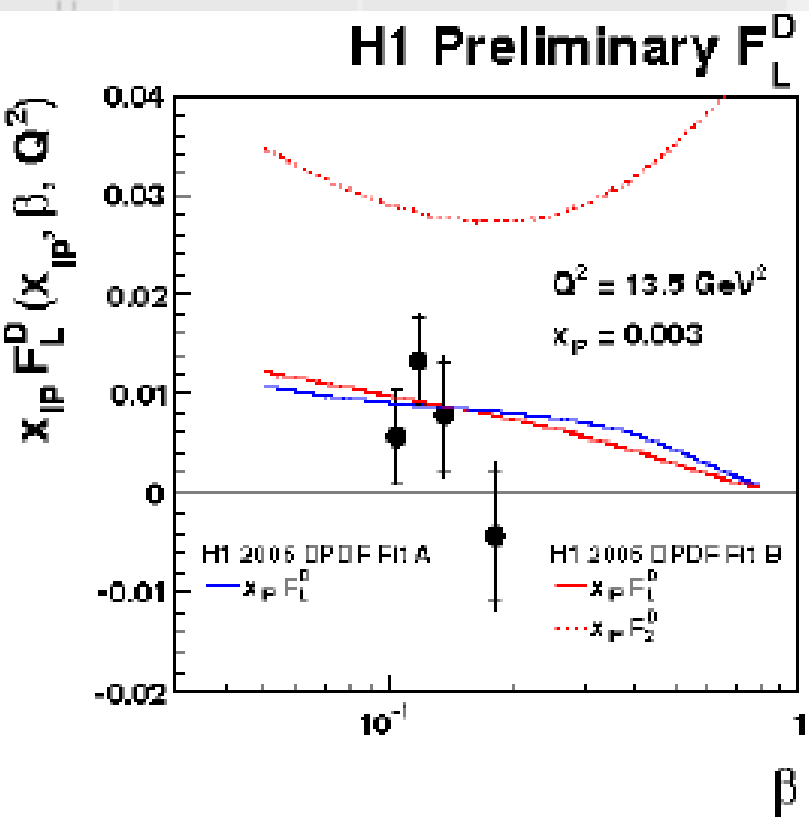
- direct test of *g* component of structure

$$\sigma_r^{D(3)}(Q^2,\beta,x_{IP}) = F_2^{D(3)} - \frac{y^2}{2(1-y+y^2/2)} F_L^{D(3)}$$

Three proton beam energy:
920 GeV (21 pb^{-1})
575 GeV (11 pb^{-1})
460 GeV (6 pb^{-1})

Measure $\sigma_r^{D(3)}$ at fixed Q^2, β, x_{IP} and different y



Results compatible with QCD fit predictions
$\sigma_L/\sigma_T \sim 0.5$

Further 1_c Structure

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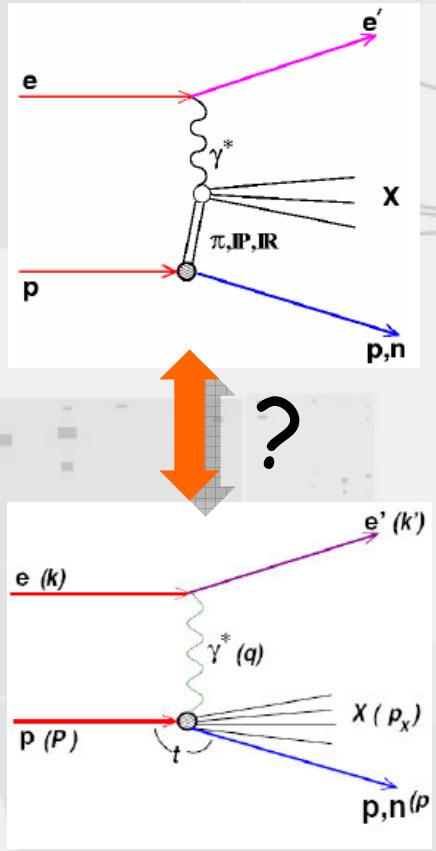
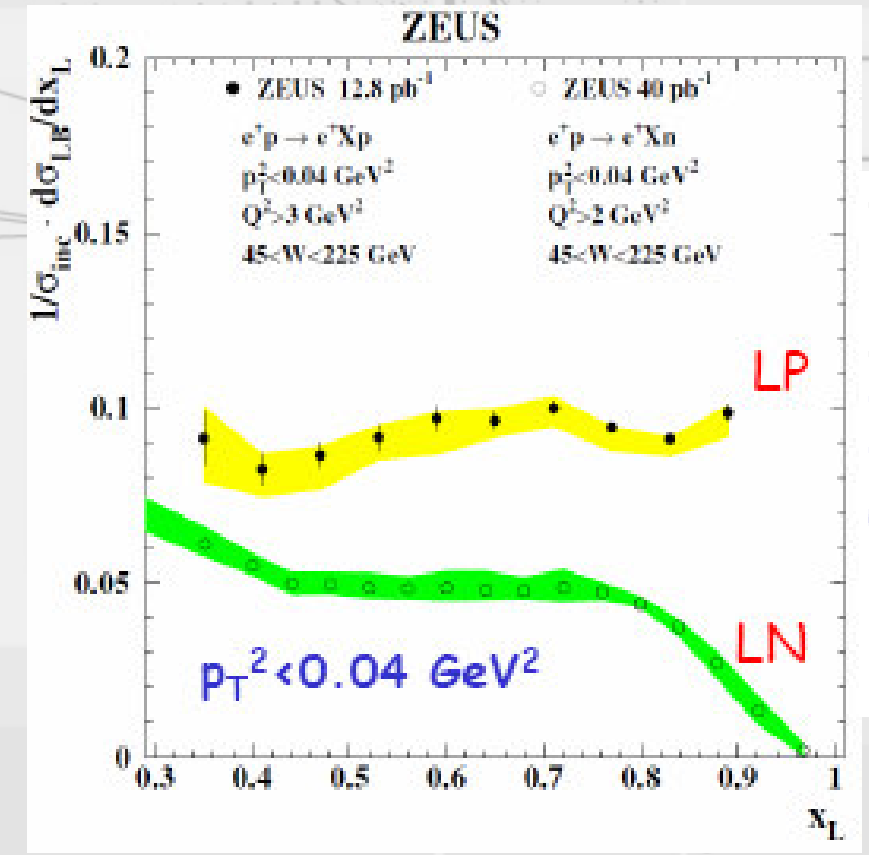
- eliminate dominant $I\!P$ with t-channel flavour
  - leading fragmentation ↔ leading neutron/N^*?





$ep \rightarrow eXn$

- measurement: LP ~ 2·LN
- for pure isovector particle exchange (e.g. pion) one expects LP = ½·LN

  → more isoscalar exchanges contribute to the LP rates

- Q^2 → "soft" and "hard" mesons ?

Inclusive Diffraction

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- immense progress in the HERA/TeVatron era
  - diffractive structure is (few) gluon dominated
  - evidence for expected leading $I\!P + I\!R$ + …
  - intriguing factorisation issue ?
    "direct" and "resolved" $I\!P$?
- immense progress in the future
  - on-going HERA analysis
    … t ?
    flavour in t-channel
  - HUGE potential from LHC @ Terascale (x<0.01)
  - HUGE precision potential from LHeC @ Terascale

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4. Experiment

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LHC

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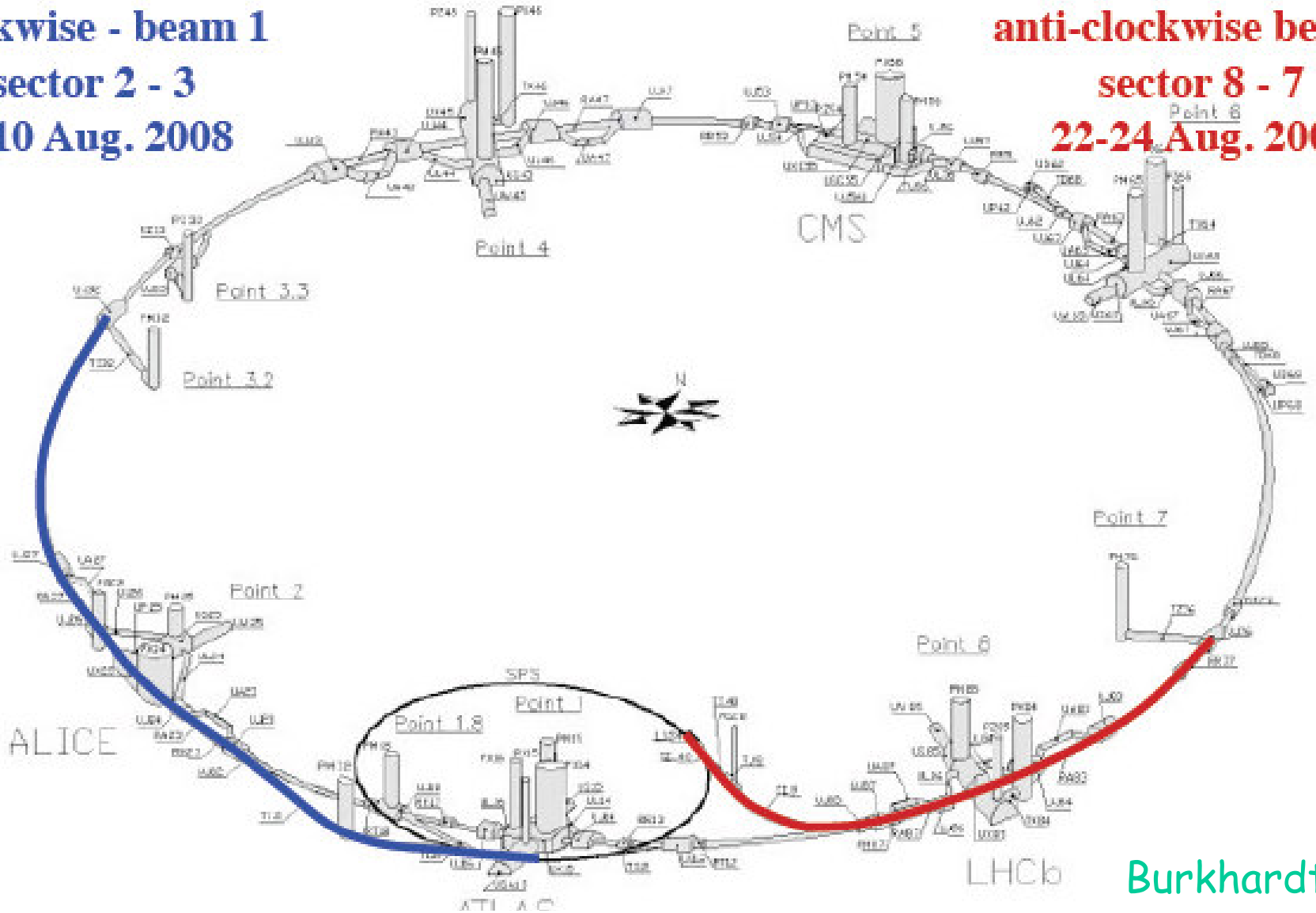
1st Injection
clockwise - beam 1
sector 2 - 3
8-10 Aug. 2008

2nd Injection
anti-clockwise beam 2
sector 8 - 7
22-24 Aug. 2008



Burkhardt

LHC

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- major opportunities for diffractive physics imminent

LHC year 1 : likely to run for month's in steps 5 - 6
No crossing angle. $E_b = 5$ TeV ; $k_b = 156\times156$, $N_p = 5\times10^{10} - 9\times10^{10}$

Run in some fills with $\beta^* = 90$ m in IR5, peak luminosity :
$N_p = 5\times10^{10}$ $L = 5.5\times10^{29}$ cm^{-2}s^{-1} $\sigma_{x,y} = 252$ μm divergence $\sigma'_{x,y} = 2.8$ μrad
$N_p = 9\times10^{10}$ $L = 1.8\times10^{30}$ cm^{-2}s^{-1}
Or also : un-squeeze to 90 m at the end of some fills

Later years
$E_b = 7$ TeV. Dedicated high $\beta^* > 1500$ m runs. No crossing angle, maximum $k_b = 156\times156$
Requires reduced emittance $\varepsilon_N = 1$ μm – which will be difficult and may require scraping
maximum bunch intensity ~ 3×10^{10}
TOTEM $\beta^* = 1535$ m; $N_p = 3\times10^{10}$; $L = 6\times10^{28}$ cm^{-2}s^{-1}; $\sigma_{x,y} = 454$ μm $\sigma'_{x,y} = 0.30$ μrad
ATLAS $\beta^* = 2625$ m; $N_p = 3\times10^{10}$; $L = 4\times10^{28}$ cm^{-2}s^{-1}; $\sigma_{x,y} = 593$ μm $\sigma'_{x,y} = 0.23$ μrad

Experiments

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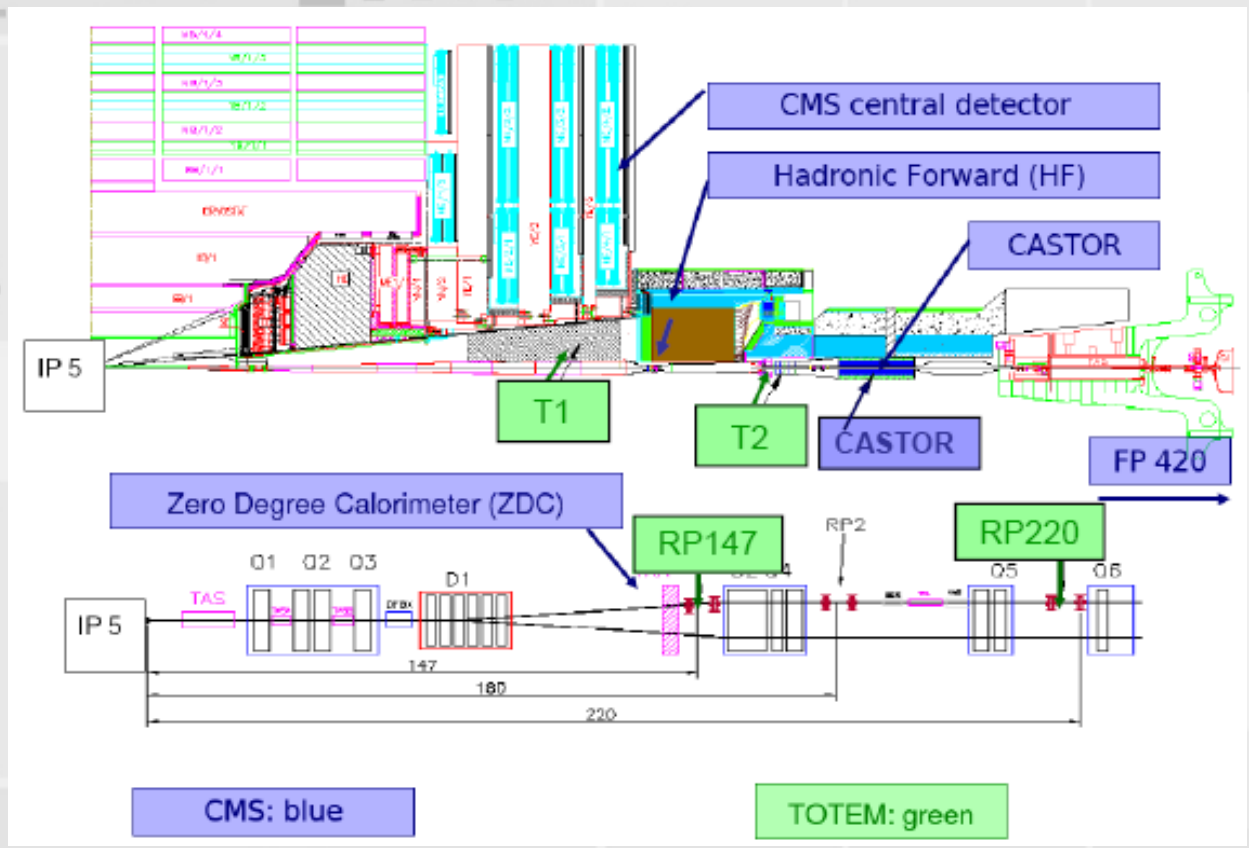
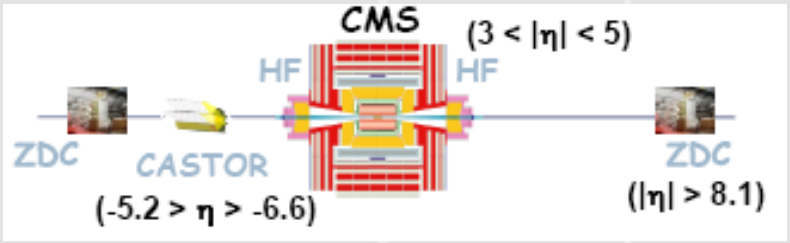
- experiments already impressively instrumented





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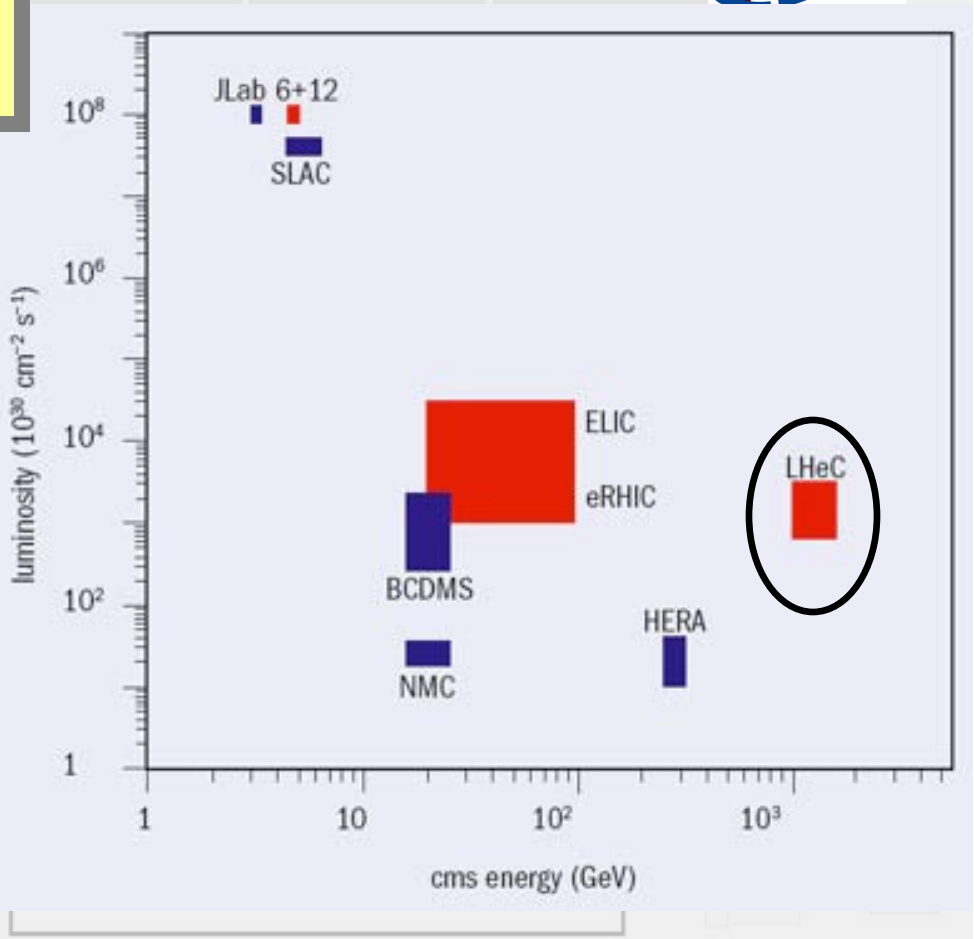
LHeC

The LHeC is not the first proposal for TeV scale DIS, but it is the first with the potential for significantly higher luminosity than HERA …



DESY 06-006
Cockcroft-06-05

Deep Inelastic Electron-Nucleon Scattering at the LHC*

J. B. Dainton[1], M. Klein[2], P. Newman[3], E. Perez[4], F. Willeke[2]

[1] Cockcroft Institute of Accelerator Science and Technology, Daresbury International Science Park, UK
[2] DESY, Hamburg and Zeuthen, Germany
[3] School of Physics and Astronomy, University of Birmingham, UK
[4] CE Saclay, DSM/DAPNIA/Spp, Gif-sur-Yvette, France

… achievable with a new electron accelerator at the LHC …

[JINST 1 (2006) P10001]

LHeC

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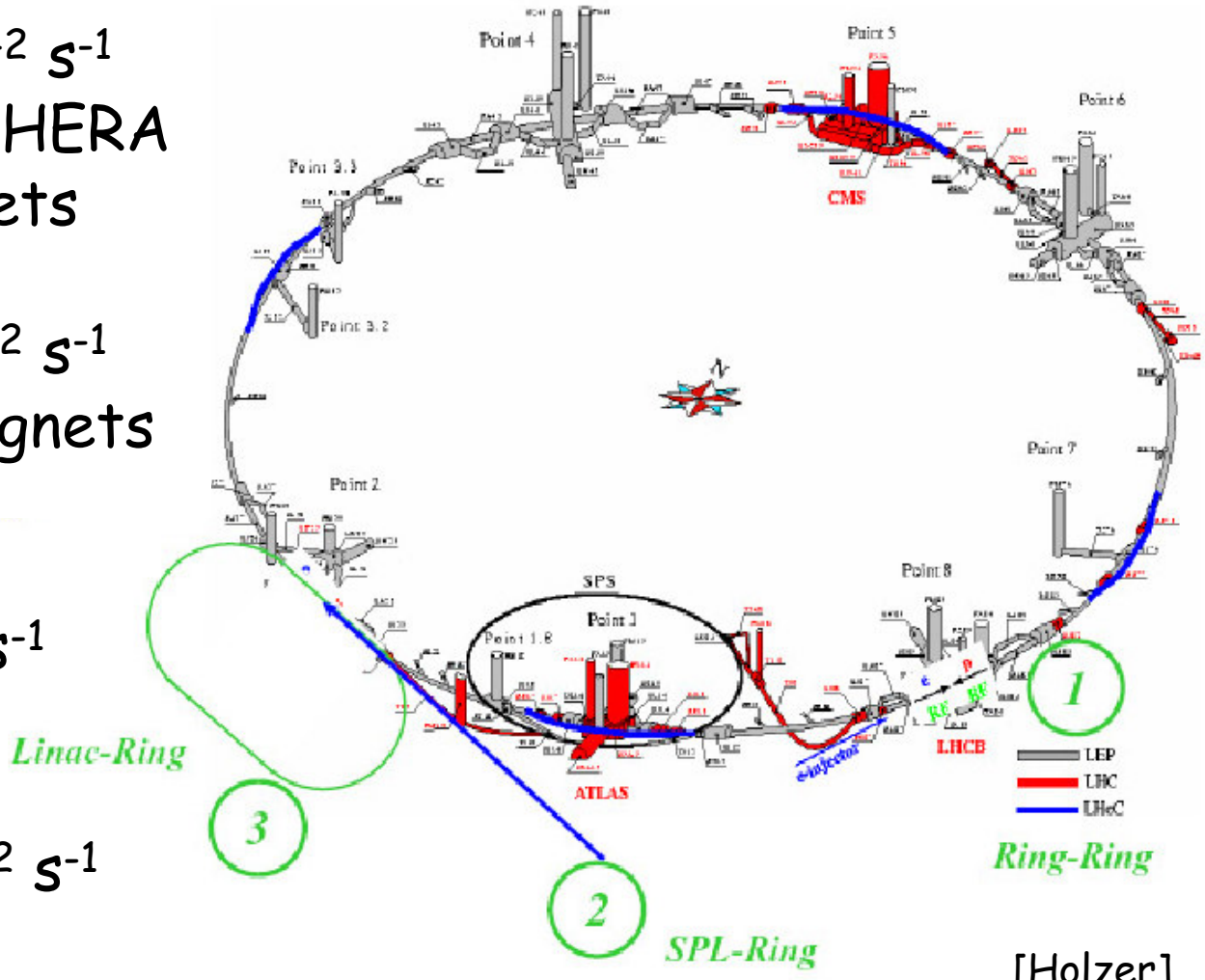
Increasingly detailed design under constraints of simuiltaneous ep (eA) and pp (AA) running at power < 100 MW

1) Lumi ~ 3.10^{33} cm^{-2} s^{-1}
at E_e = 50 GeV with HERA style focusing magnets and 10° acceptance.
… or Lumi ~ 10^{32} cm^{-2} s^{-1}
without focusing magnets and 1° acceptance

2) Lumi ~ 10^{32} cm^{-2} s^{-1}
At E_e = 20 GeV

3) Lumi ~ 3.10^{32} cm^{-2} s^{-1}
at E_e = 100 GeV



[Holzer]

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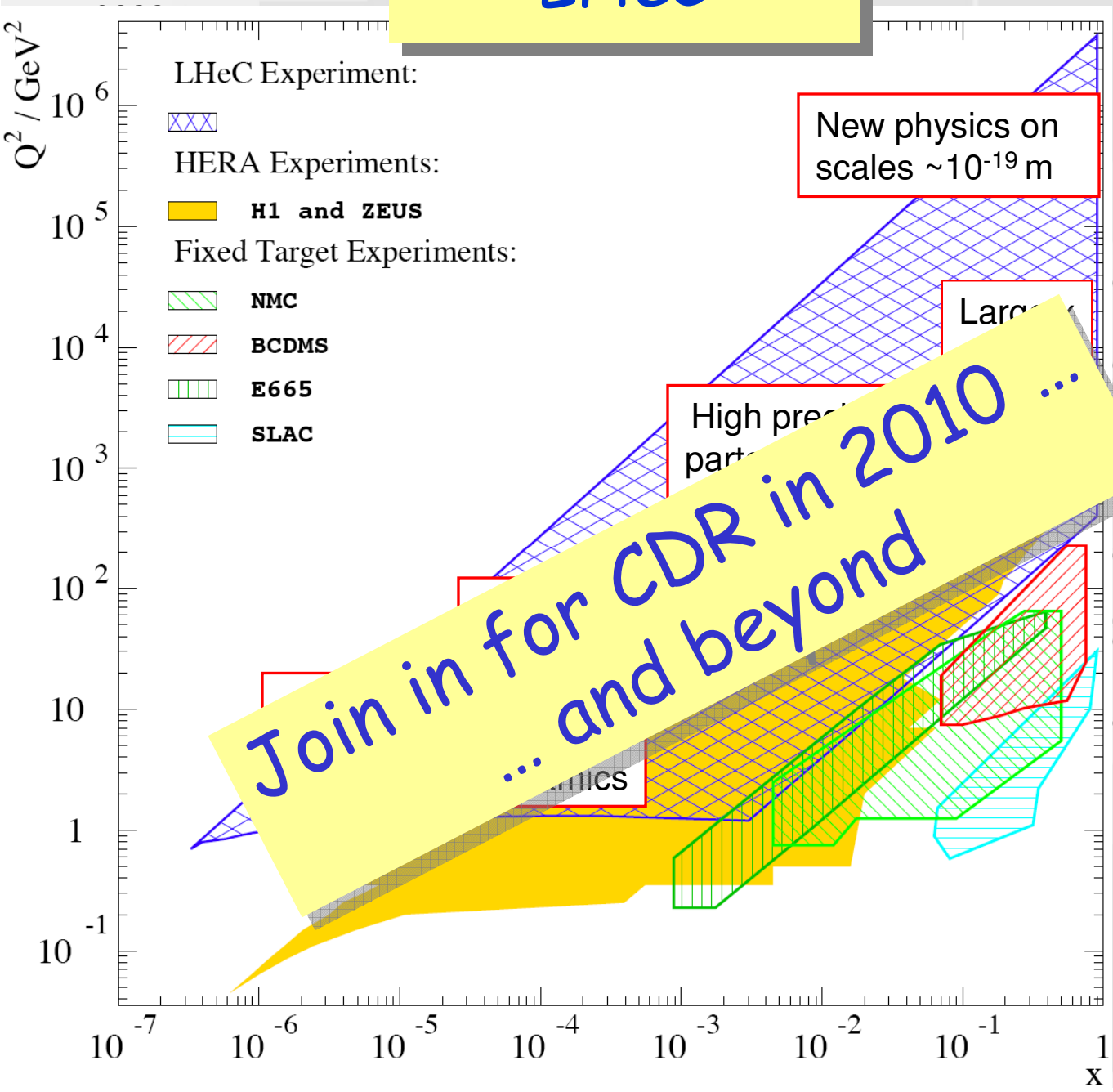

$\sqrt{s} = 2$ TeV

- High mass (M_{eq}, Q^2) frontier
- EW & Higgs
- Q^2 lever-arm at moderate & high x → PDFs
- Low x and eA Frontier → novel QCD …

$x \geq 5.10^{-7}$ at $Q^2 \leq 1\ \mathrm{GeV}^2$

Why: Leptons ↔ Quarks ?

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- how are leptons and quarks related ?

THE UNCONFINED QUARKS AND GLUONS

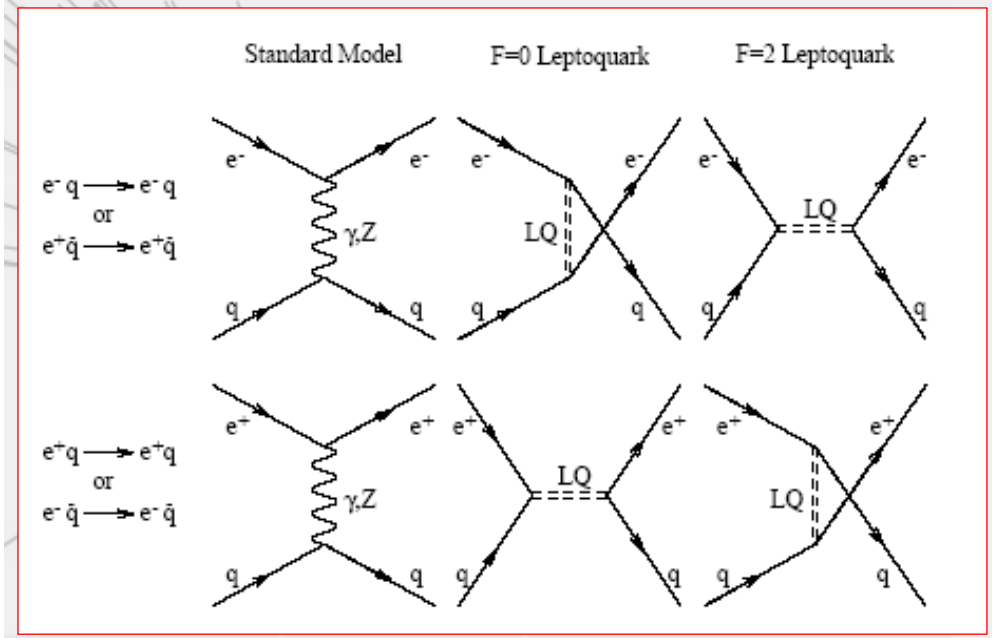
Abdus Salam

International Centre for Theoretical Physics, Trieste, Italy and Imperical College, London, England

1. Introduction

Leptons and hadrons share equally three of the basic forces of nature: electromagnetic, weak and gravitational. The only force which is supposed to distinguish between them is strong. Could it be that leptons share with hadrons this force also, and that there is just one form of matter, not two?

ICHEP86 Berkeley



- put them together at the highest energy at finest detail

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5. Conclusion

Conclusion

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- immense progress in the HERA/TeVatron era
  - diffractive structure is (few) gluon dominated
  - evidence for expected leading $I\!P + I\!R$ + …
  - understanding progressing of pQCD $\leftrightarrow$ pQCD
- immense opportunities in the future
  - LHC: huge increase in all phase space
  - LHeC/EIC/ERHIC: precision with *ep eA* ?

We are making huge progress in understanding the strong sector in the SM ……
…… and soon also beyond SM?

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On behalf of you all please
let me thank all the organisers
of DIFF09.
As always it has been a pleasure to
attend. The science has been gripping
and the hospitality excellent.