Summary of HERA-LHC Meeting

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October 10th, 2008

University College London

In May 2008 final stage of a 4 year series of meetings at DESY and CERN.

Designed to increase interaction between HERA and LHC communities.

startup meeting:	26-27	March	2005	CERN	(~ 250-300 participants)
2nd meeting:	6 - 9	June	2006	CERN	(~150 participants)
3rd meeting:	12-16	March	2007	DESY	(~160 participants)
4th meeting:	26-30	May	2008	CERN	(~190 participants)

With lots of additional smaller meetings, e.g. working weeks and working group meetings.

Attended majority of these, including initial and final (few) meetings, and various offshoots (later), although no formal involvement in organization.

5 core working groups.

– **Parton density functions**

– **Multi-jet final states and energy flows**

– **Heavy quarks (charm and beauty)**

– **Diffraction**

– **Monte Carlo tools**.

Have been rather more involved with some of these than others, and am more qualified to talk on some than others.

Summary will obviously reflect this, and will largely be highlights rather than a list. No apologies to those not mentioned – default state.

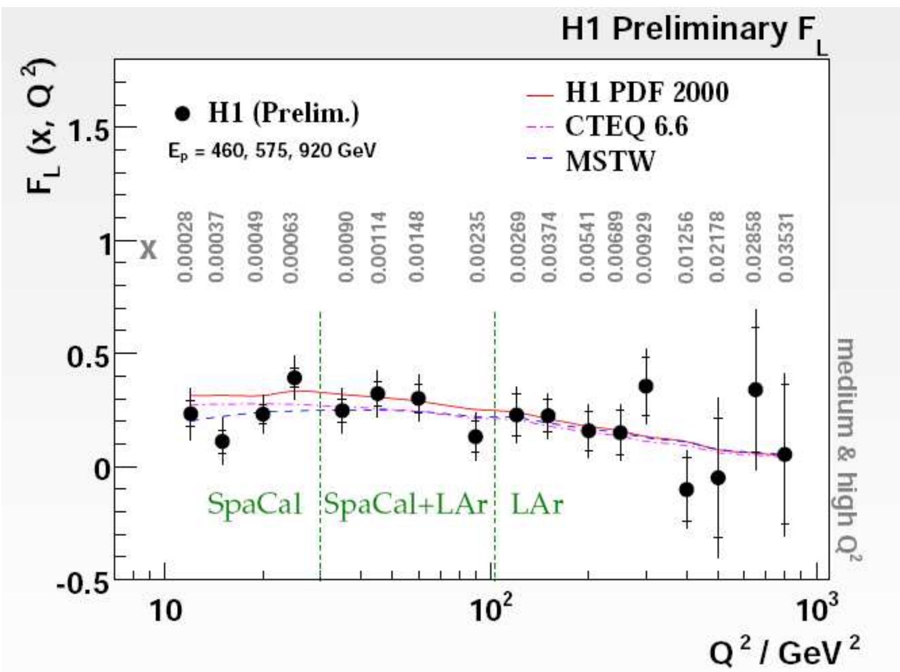
Will order roughly by topic, but not always Working Group (many overlapping sessions).

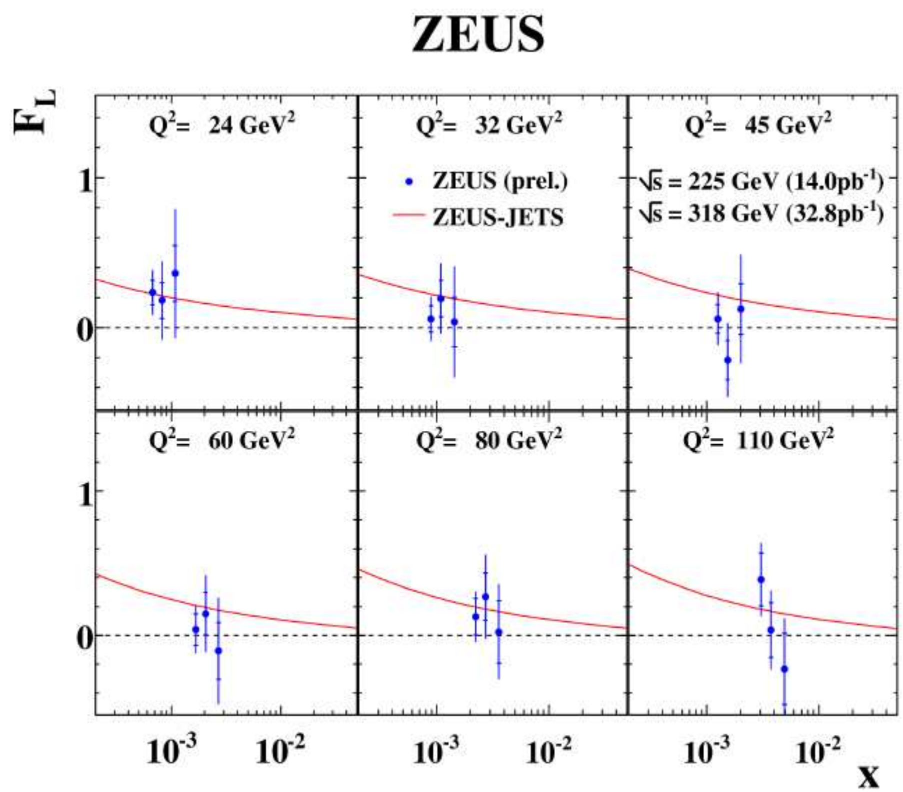
(Also try not to dwell on topics covered in detail in past few days.)

Parton Distribution Functions

At core a session acting as a PDF4LHC meeting, focusing on central topic of most recent data and fits.

Most interesting “new” data clearly that on $F_L(x, Q^2)$ (Grebenyuk, Lenderman).



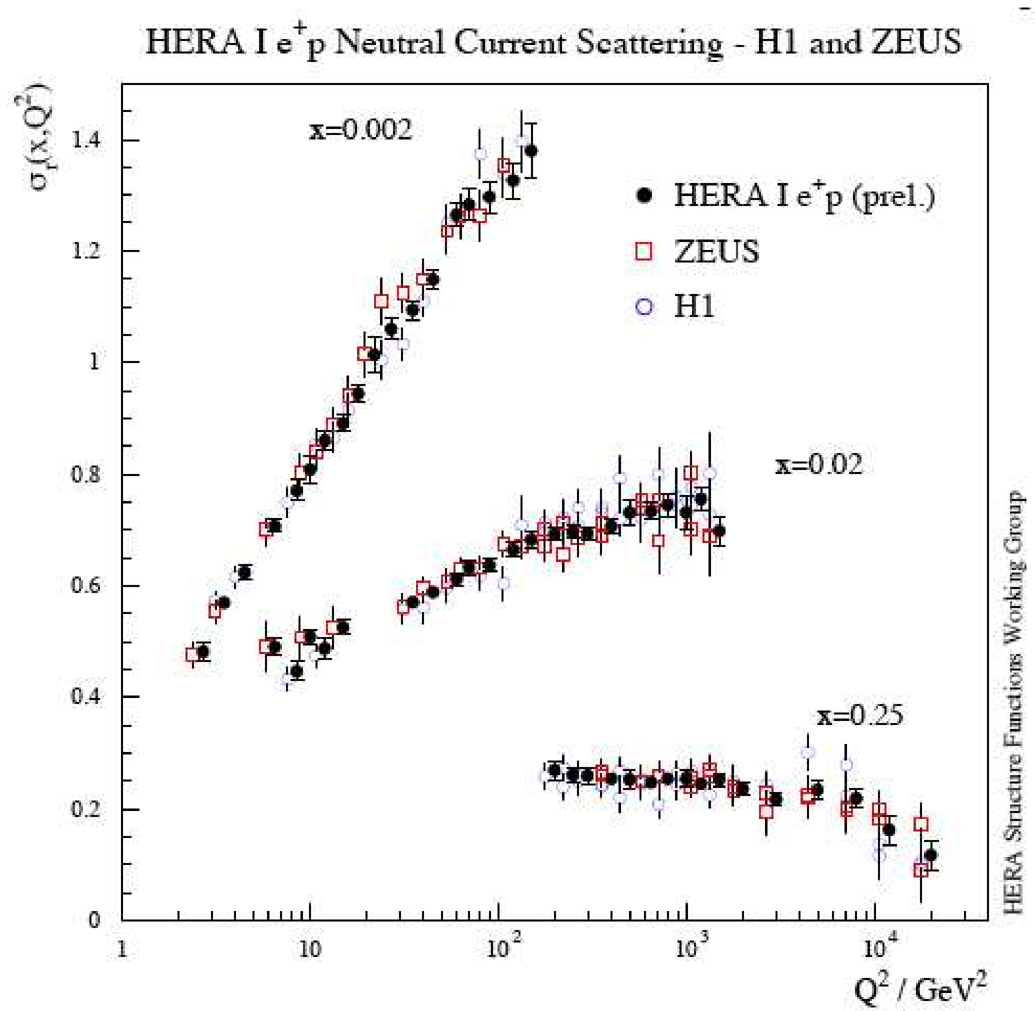


Data from earliest analysis consistent with NLO predictions from various groups.

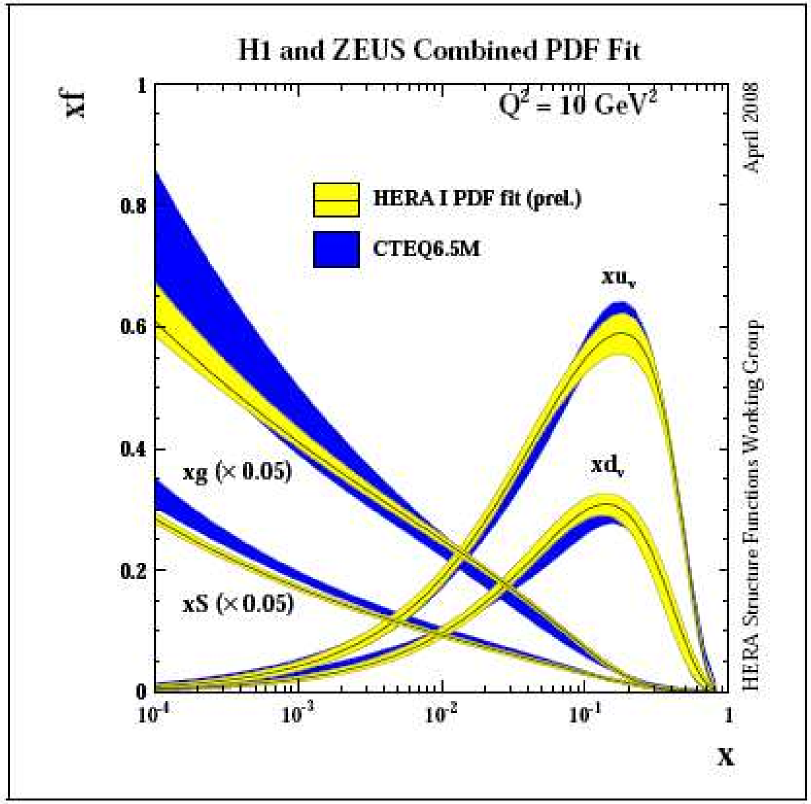
Potentially the most important data presented (probably at whole meeting) the averaged HERA measurement of total inclusive cross-section (Li).

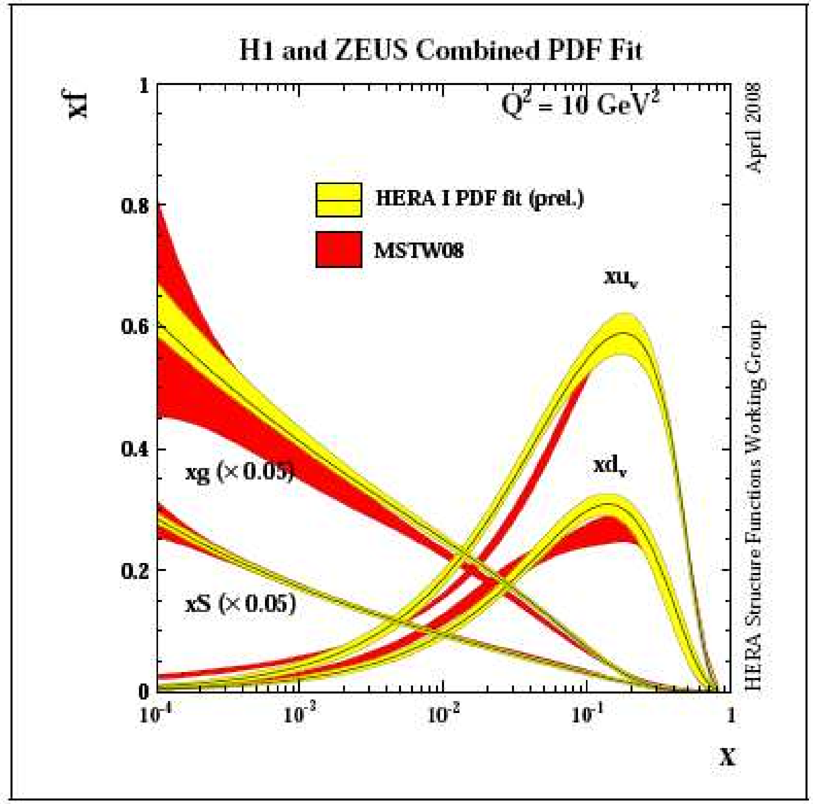
Significant elimination of correlated errors. Accuracy of $1-2\%$ over enormous range of both x and Q^2. The best test of factorization and perturbative QCD that we have.

However, data still preliminary, and at the meeting far more attention paid to presenting



Fit by HERA groups to this (still preliminary!) data





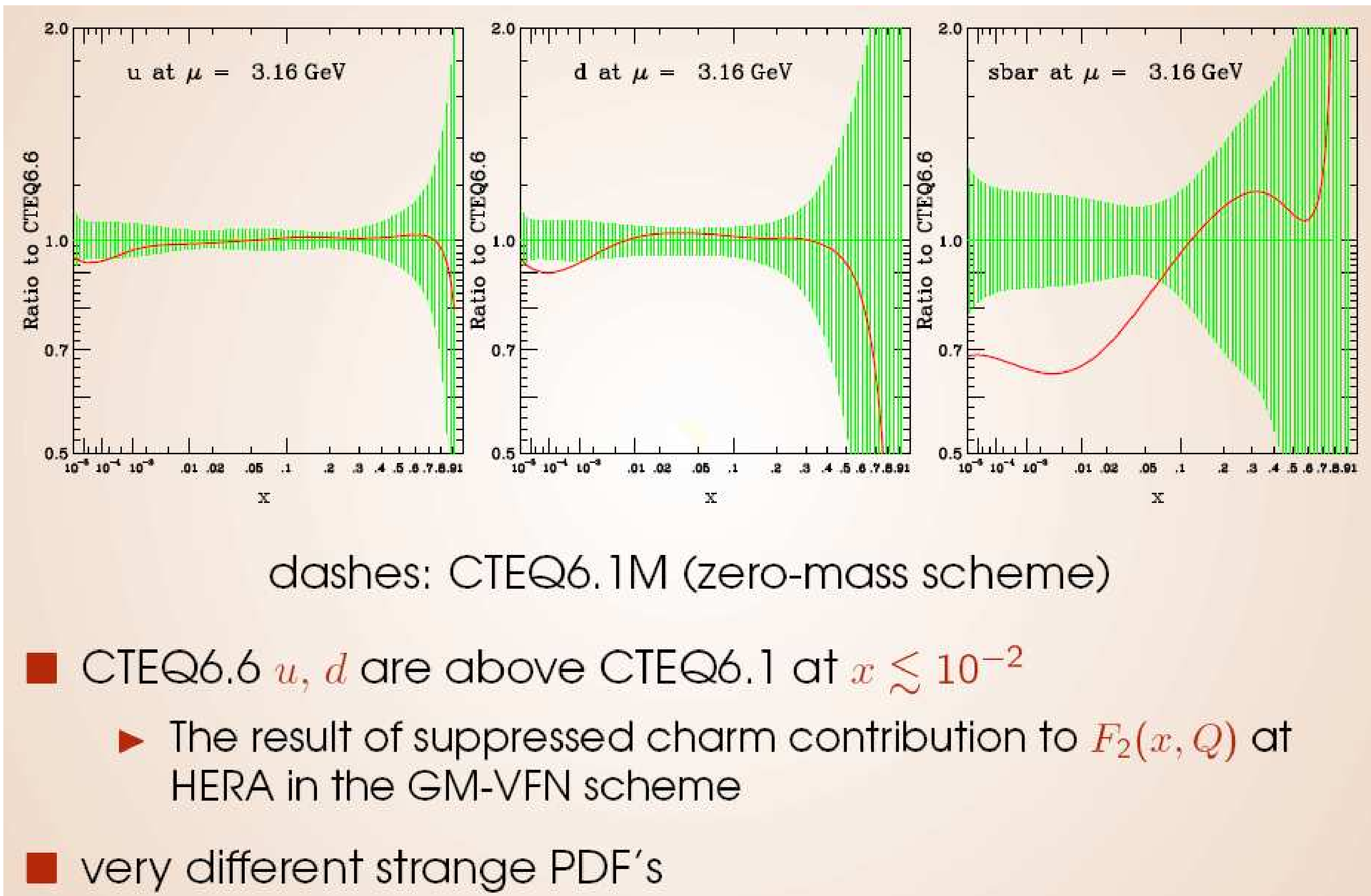
Note MSTW08 is as yet unpublished, we have a pre-release

Impressive reduction in uncertainties. However, in comparing with CTEQ and MSTW there are lots of things to consider – heavy flavour treatments, and particularly number of parameters. Much smaller in these fits with unseen constraints

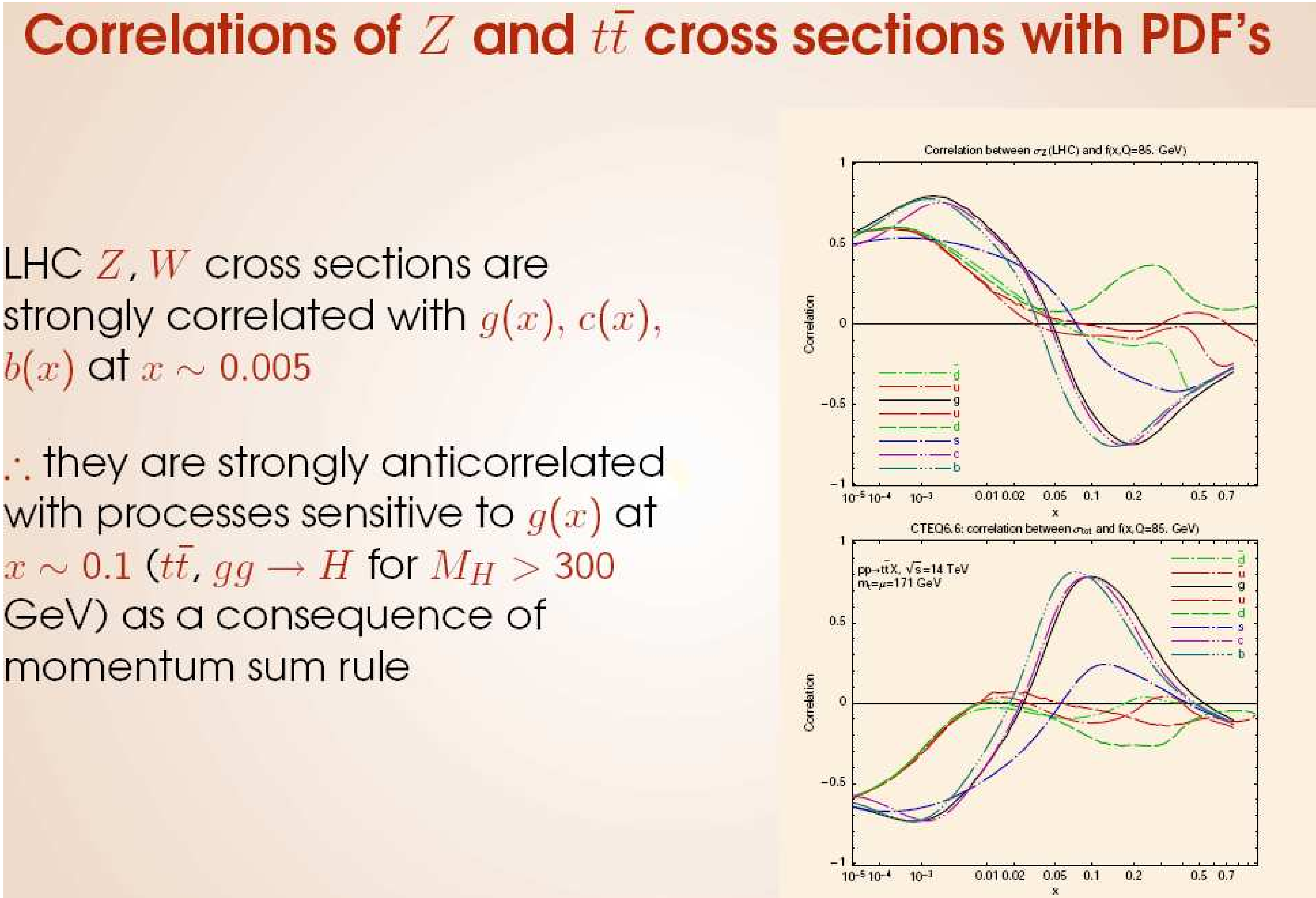
Personally would rather like to see the real final data.

PDF Fitting Groups

Detailed presentation of the CTEQ6.6 PDFs for the first time (Nadolsky). Major changes, adoption of general-mass heavy flavour scheme as as default (also in 6.5) and fit to strange quarks directly (using complicated parameterization). Now 44 (previously 40) eigenvector sets.



Also a major emphasis on presenting the correlation between different PDFs and consequently physical quantities, e.g. anti-correlation between relatively light W, Z production where $x \sim 0.005$ and heavy $t\bar{t}$ production where $x \sim 0.1$.

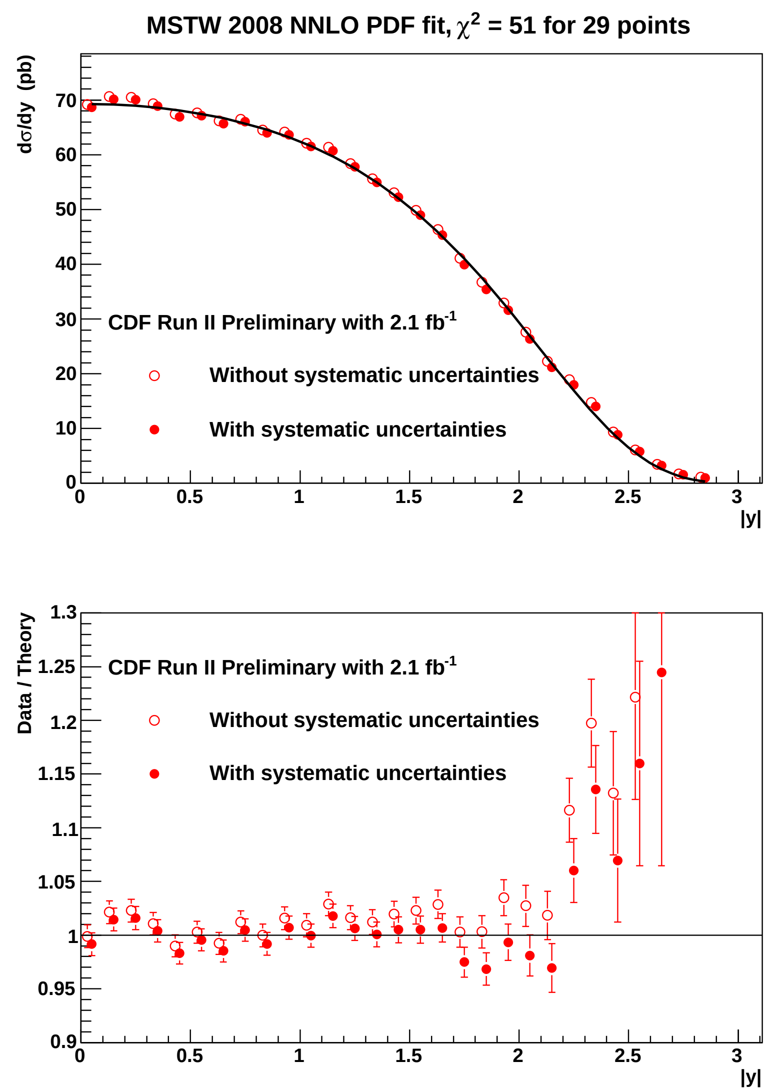


MSTW have preliminary 2008 set based on a fit to a very wide variety of new data. Also have strange as free parameter, but closer to previous distribution (increases uncertainties). Now 40 (previously 30) eigenvector sets.

Most important inclusion of lots of new Tevatron data which gives detailed information of quark decomposition since it probes different weightings than structure functions.

Also new *dynamical* determination of tolerance. No fixed $\Delta\chi^2$ – analysis eigenvector by eigenvector.

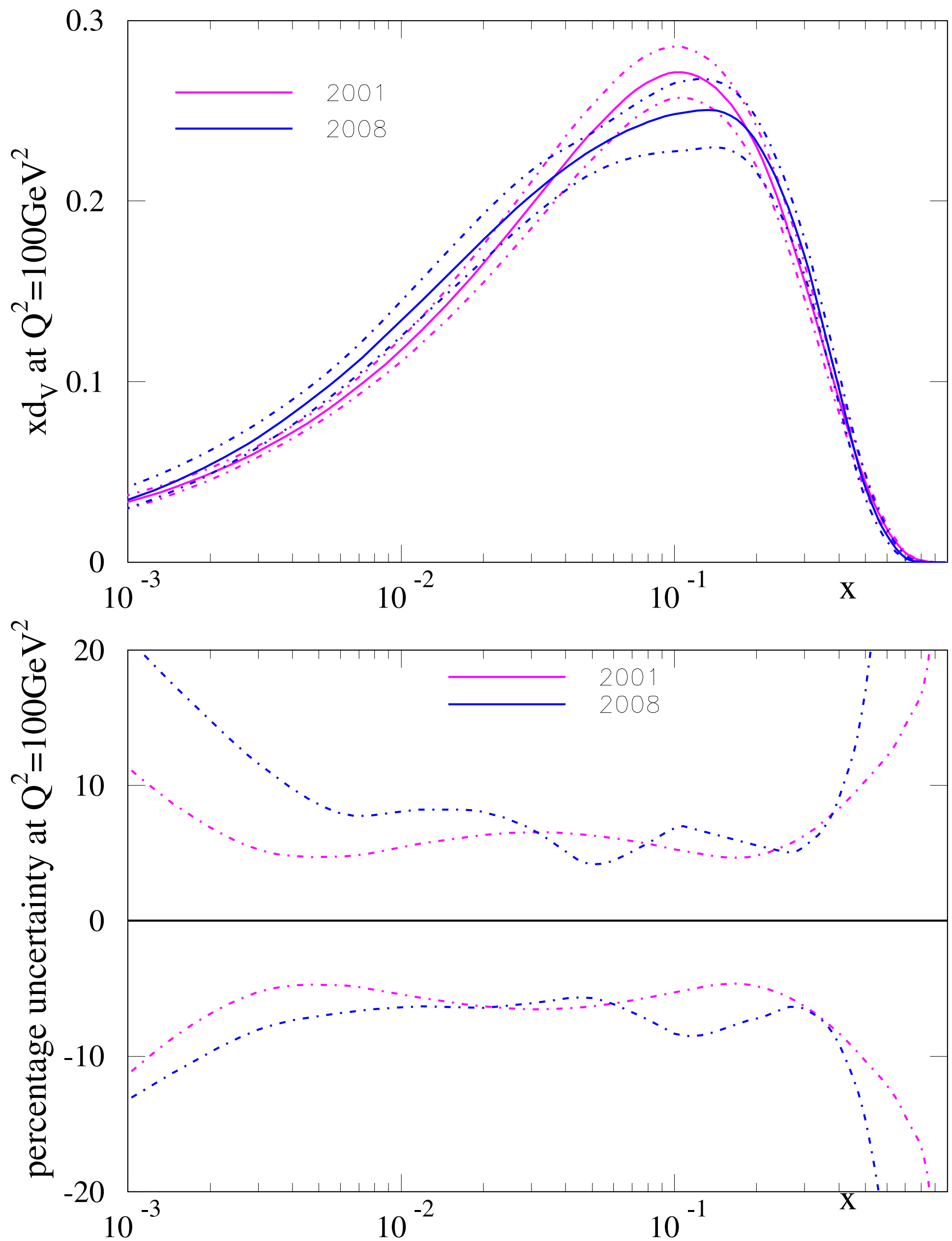
Z/γ^* rapidity distribution from CDF



For example, $d_V(x, Q^2)$ now chooses a different type of shape.

Mainly changed by new Tevatron W-asymmetry data and new neutrino structure function data.

Uncertainty growing more quickly as $x \to 0$ and $x \to 1$ than before due to better parameterisation in determining uncertainty eigenvectors.



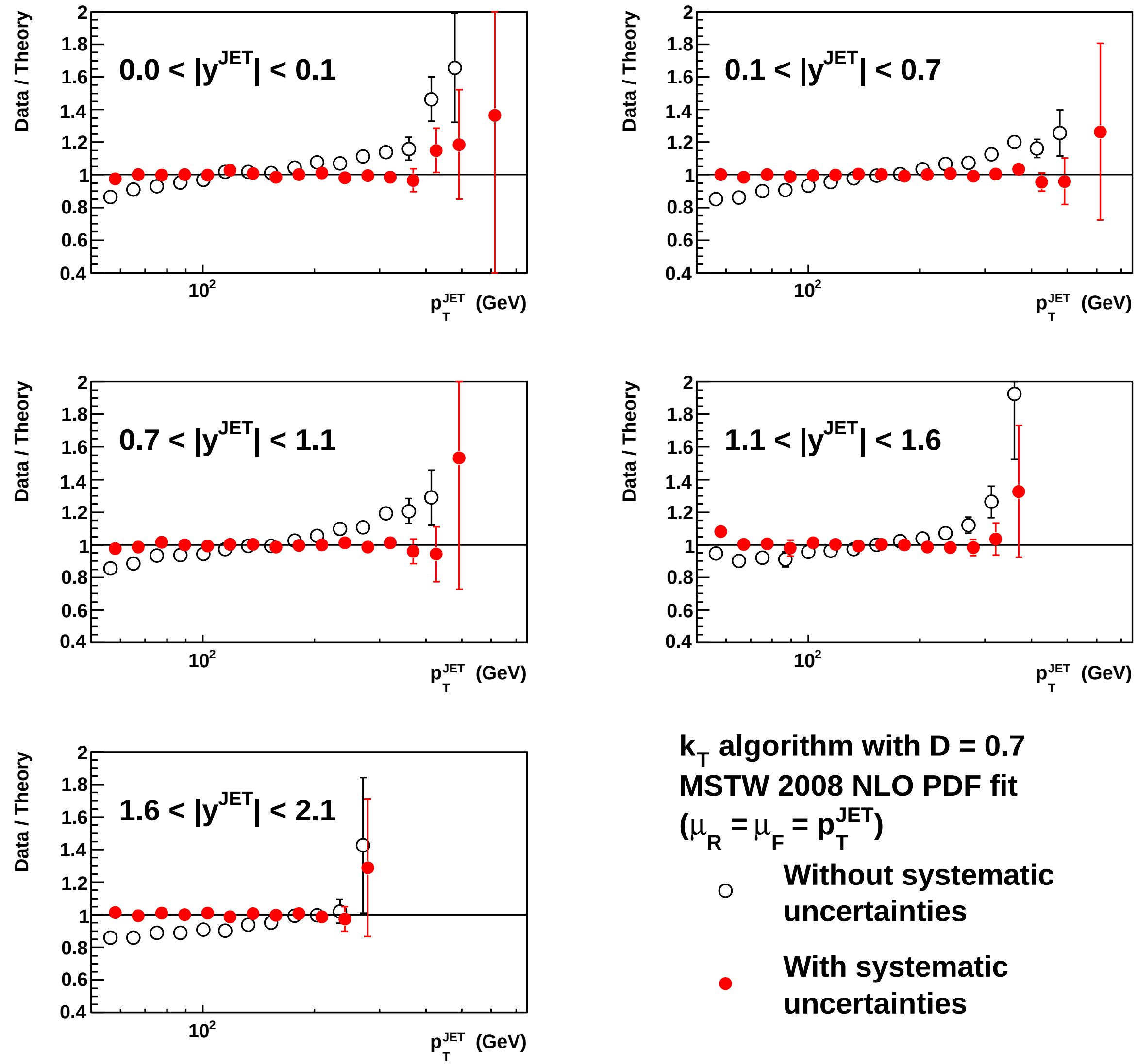
Include CDF Run II inclusive jet data in different rapidity bins using k_T jet algorithm and D0 Run II mid-point cone algorithm data.

Very good fit – $\chi^2 = 55/76$ and $\chi^2 = 115/110$.

CTEQ reported inconsistencies in preliminary fits to jet data, but mainly due (as I understand) to CDF Run II mid-point cone algorithm data.

MSTW find much softer high-x gluon with new data.

CDF Run II inclusive jet data, χ^2 = 55 for 76 pts.



Now much more stability in **predictions for W and Z cross-sections** for LHC and Tevatron (in brackets) with common fixed order QCD and vector boson width effects, and common branching ratios.

Ratio to MSTW 2008 (prel.)	σ_W	σ_Z
MRST 2006 NLO (unpublished)	1.002 (0.995)	1.009 (1.001)
MRST 2006 NNLO	0.995 (1.004)	1.001 (1.010)
MRST 2004 NLO	0.974 (0.990)	0.982 (1.000)
MRST 2004 NNLO	0.936 (0.991)	0.940 (1.003)
CTEQ6.6 NLO	1.019 (0.978)	1.022 (0.987)

Increases from MRST2006 compared to MRST2004 due to improved (NLO) or completed (NNLO) heavy flavour prescription.

Virtually no change from MRST2006 $\rightarrow$ MRST2008. Not guaranteed to be true for all quantities.

Consistent with CTEQ6.6, but systematic differences mirror shape of gluon/quarks.

Appearance of a new set of PDFs – presentation of those from the NNPDF group. (Final at July PDF4LHC meeting.)

Attempt to lose restriction in uncertainty due to fixed parameterization limitations.

- Monte Carlo sampling of data (generation of replicas of experimental data)

$$\mathcal{D}_i^{(art)(k)} = \left(1 + r_N^{(k)}\sigma_N\right)\left[\mathcal{D}_i^{(exp)} + r_i^s\sigma_i^{stat} + \sum_{l=1}^{N_{sys}} r^{l,(k)}\sigma_i^{sys,l}\right]$$

where σ_i are the experimantal errors, and r_i are random numbers choosen accordingly to the experimental correlation matrix.

- Expectation values:

$$\langle \mathcal{F}\left[g(x)\right]\rangle = \frac{1}{N_{rep}}\sum_{k=1}^{N_{rep}} \mathcal{F}\left(g^{(fit)(k)}(x)\right)$$

- Errors:

$$\sigma_{\mathcal{F}[g(x)]} = \sqrt{\langle \mathcal{F}\left[g(x)\right]^2\rangle - \langle \mathcal{F}\left[g(x)\right]\rangle^2}$$

- Correlations between pairs of different parton distributions at different points:

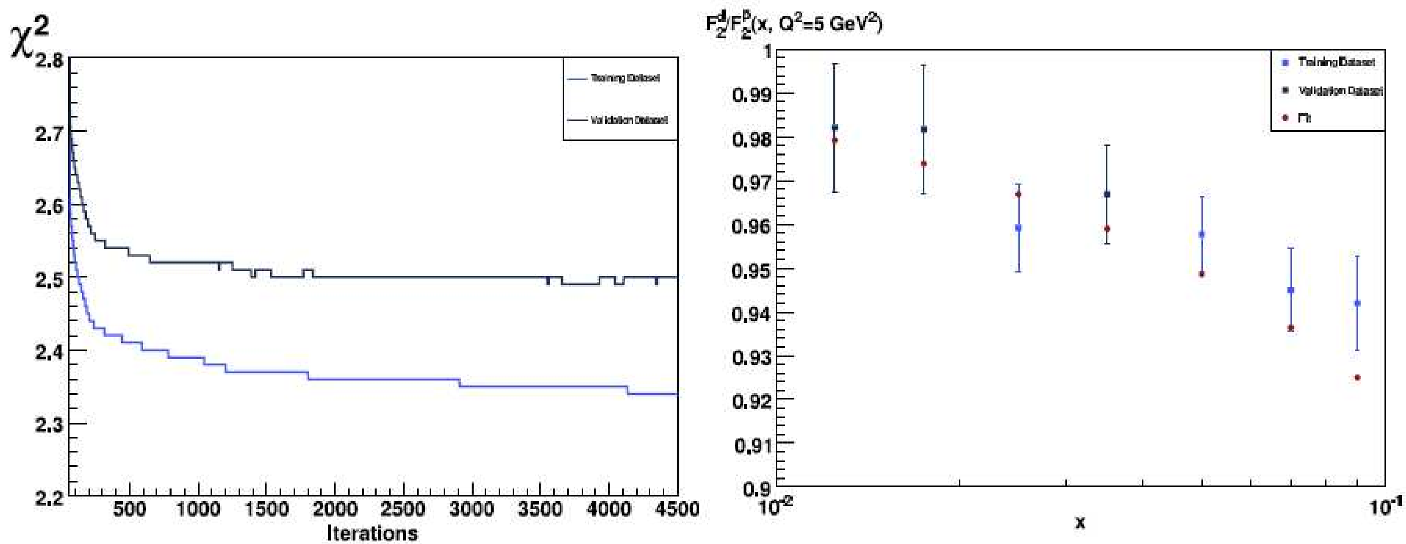
$$\langle u(x_1)d(x_2)\rangle = \frac{1}{N_{rep}}\sum_{k=1}^{N_{rep}} u^{(fit)(k)}(x_1)d^{(fit)(k)}(x_2)$$

Data split into training and validation sets for each copy, and χ^2 for one monitored while other minimized.

- OPTIMAL FIT OBTAINED WHEN QUALITY OF FIT TO VALIDATION (CONTROL) DATA STOPS IMPROVING
- POSSIBILITY OF OVERFITTING GUARANTESS THAT MINIMUM NOT DRIVEN BY PARAMETRIZATION

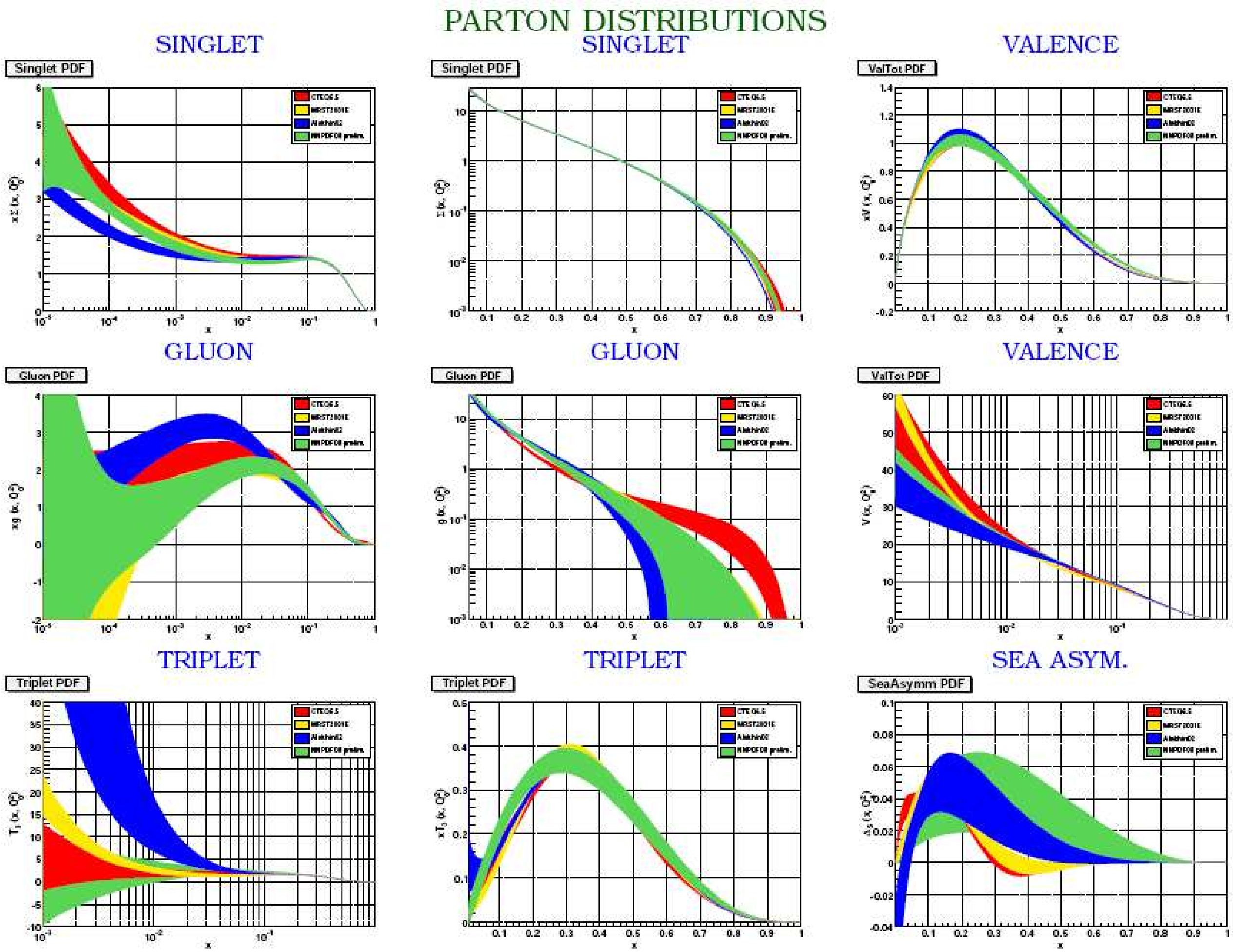
OVERFITTING

χ^2 FIT TO DATA



Avoid overcomplicating input PDFs by stopping when fit to validation sets stops improving. Some judgement required. Fit quality seems slightly worse at best than global fits.

PDFs seem rather similar to existing global fit sets (note at present ZM-VFNS and more limited quark decomposition.



Uncertainties generally only much bigger when there is a lack of data constraint compared to global fits. However, method of determination completely different. Interesting to see developments.

Standard Candles

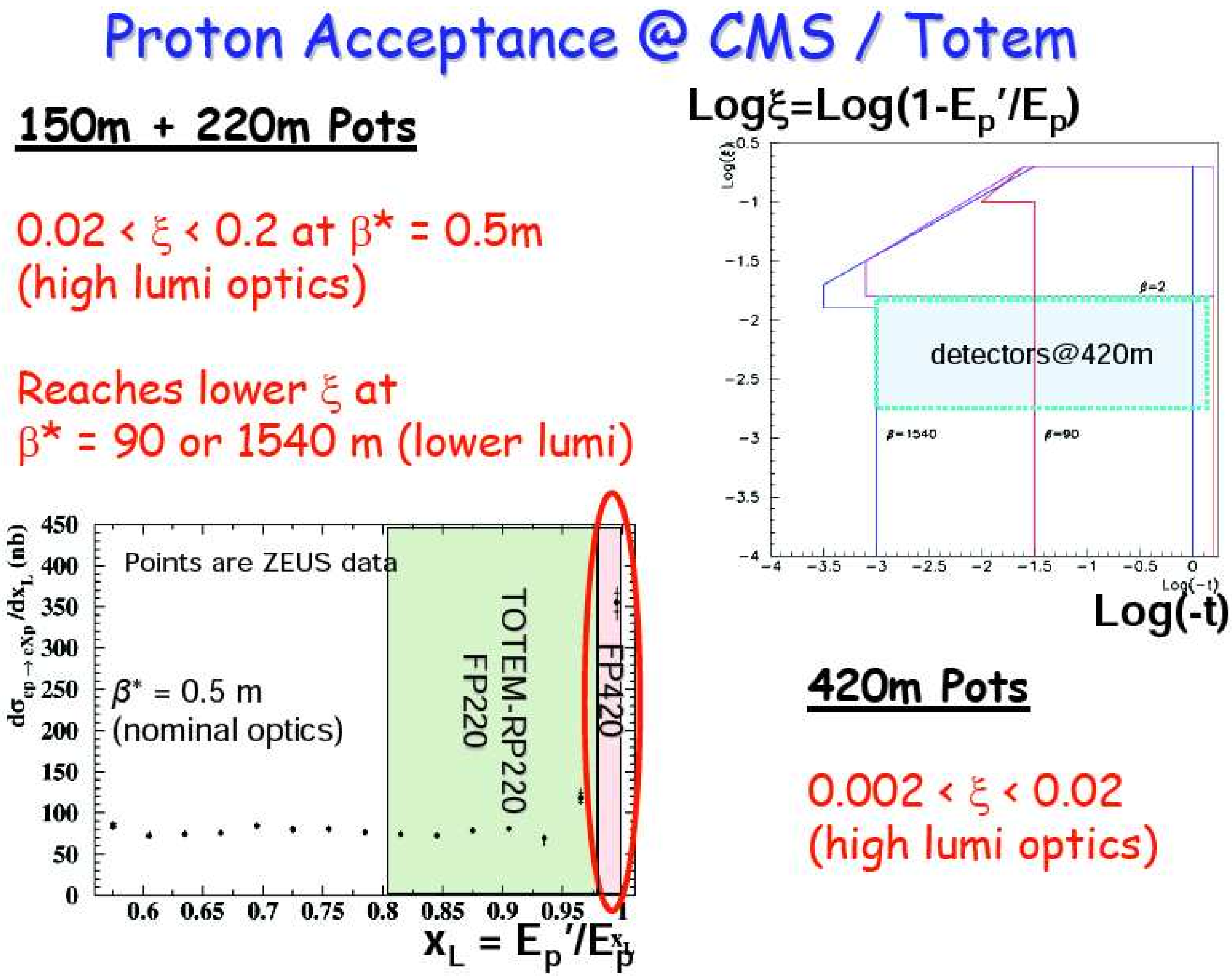
A special session on this. Question of possible luminosity determinations.

Luminosity measurements at LHCb: summary

	2008 (5pb^{-1})	2009 (0.5fb^{-1})	2010 (2fb^{-1})
Van Der Meer	20%	5 -10%	5 -10%
Beam-Gas	10%	< 5%	< 5%
$Z \longrightarrow \mu\mu$	5%	4%	4%
$pp \rightarrow pp + \mu^+\mu^-$	20%	2.5%	1.5%

At LHCb (and ATLAS and CMS) in early running Z production probably best (limited by fairly realistic $4-5\%$ theory error). Later $pp \rightarrow pp + \mu^+\mu^-$ good at LHCb but total and elastic cross-section measurements using forward detectors better at ATLAS (ALFA) and CMS (TOTEM).

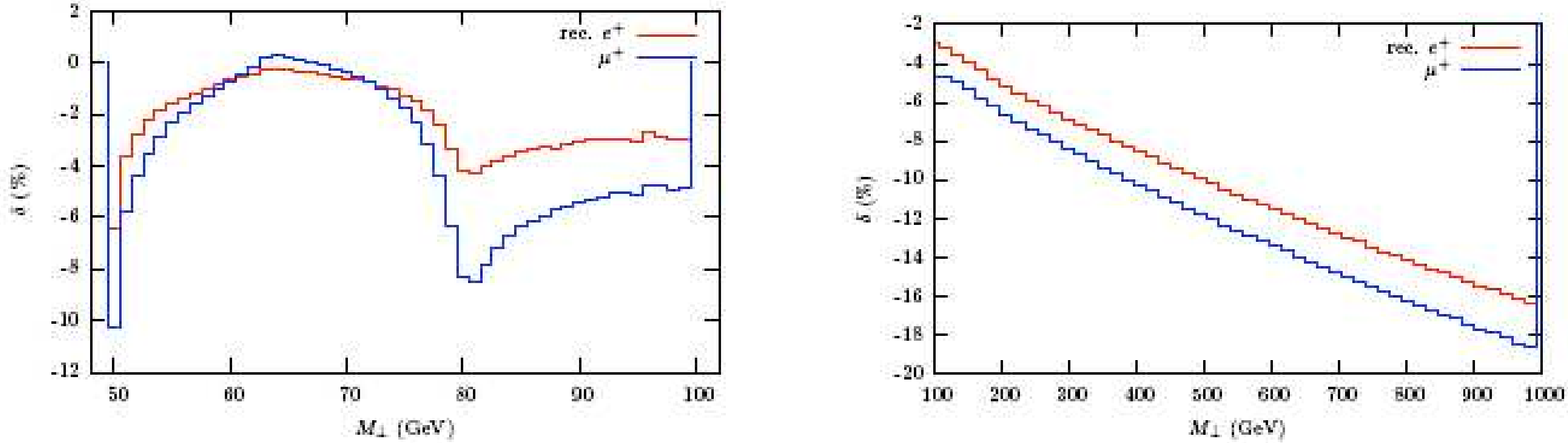
I.e use TOTEM with coverage as shown.



Get about 5% precision after 1year – 3% claimed for ALFA. Of course TOTEM and FP420 will add much more than this to physics reach.

Note that it is certainly necessary to include electroweak effects to get maximum precision on W, Z cross-sections (Piccini).

- LHC, $pp \to W^+ \to \ell^+ \nu_\ell$, $p_{\perp,\ell}$ and $p_{\perp,\nu} > 25$ GeV, $|\eta_\ell| < 2.5$
- $\mathcal{O}(\alpha)$ EW corrections to the M_T distribution



EW corrections to total cross-sections only a couple of percent (depends on EW renormalization scheme – careful when looking at predictions).

Larger corrections in M_T tail due to EW Sudakov terms $\alpha_W \ln^2(M_T^2/m_W^2)$.

Issue with EW corrections whenever a scale $\gg m_{W,Z}$ in the calculation. Much more work on combining EW and QCD corrections needed for LHC.

$\sigma_{t\bar{t}}$ also proposed as a standard candle by CTEQ. Both theory and data uncertainties may approach 5%?

PDF Uncertainties

Tevatron

CTEQ6.5 $\sigma = 7.61\,^{+0.38(5.1\%)}_{-0.80(10.9\%)}\,(\text{scales})\,^{+0.49(6.6\%)}_{-0.34(4.6\%)}\,(\text{PDFs})$ pb

MRSTW-06 $\sigma = 7.93\,^{+0.34(4.3\%)}_{-0.56(7.1\%)}\,(\text{scales})\,^{+0.24(3.1\%)}_{-0.20(2.5\%)}\,(\text{PDFs})$ pb.

MRST–CTEQ = 0.32 ± 0.45 pb

LHC

CTEQ6.5 $\sigma = 908\,^{+82(9.0\%)}_{-85(9.3\%)}\,(\text{scales})\,^{+30(3.3\%)}_{-29(3.2\%)}\,(\text{PDFs})$ pb

MRSTW-06 $\sigma = 961\,^{+89(9.2\%)}_{-91(9.4\%)}\,(\text{scales})\,^{+11(1.1\%)}_{-12(1.2\%)}\,(\text{PDFs})$ pb

MRST–CTEQ = 53 ± 33 pb

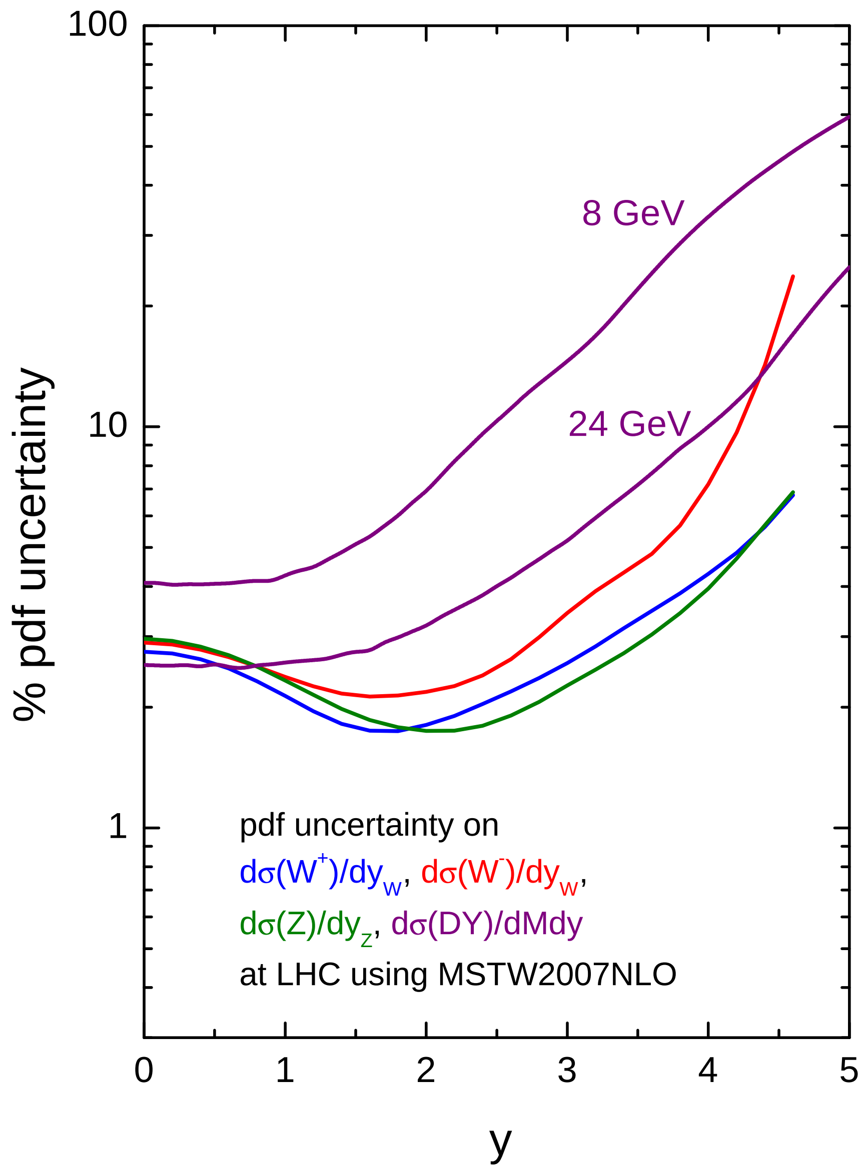
Not there at present with theory (Mangano) due to PDF and cross-section uncertainty (PDF difference likely ok, old certainties underestimated). Doubts raised on data. Could maybe be future PDF constraint.

However, most obvious constraint in immediate term are vector boson production.

Uncertainty on $\sigma(Z)$ and $\sigma(W^+)$ grows at high rapidity.

Uncertainty on $\sigma(W^-)$ grows more quickly at very high y – depends on less well-known down quark.

Uncertainty on $\sigma(\gamma^\star)$ is greatest as y increases. Depends on poorly know (even after HERA) partons at extremely small x.



Measurements of all these bosons (and their ratios) good enough in one detector or another to put new constraints on PDFs quite quickly.

Most dramatic high rapidity, low mass Drell-Yan. Possible at LHCb (Anderson).

$\gamma^* \longrightarrow \mu\mu$ After selection

Mass range (GeV)	Efficiency	Purity
$5 < M_{\mu\mu} < 8$	10%	80%
$8 < M_{\mu\mu} < 10$	10%	90%
$10 < M_{\mu\mu} < 15$	15%	95%
$15 < M_{\mu\mu} < 20$	30%	95%
$20 < M_{\mu\mu} < 80$	50%	95%

Stat. uncertainty is 1% with 100pb^{-1} (independent of mass)

“ “ 0.3% with 1000pb^{-1}

This will not only constrain the PDFs within a fixed order though.

Small-x resummations - talk by Forte here but my quick summary

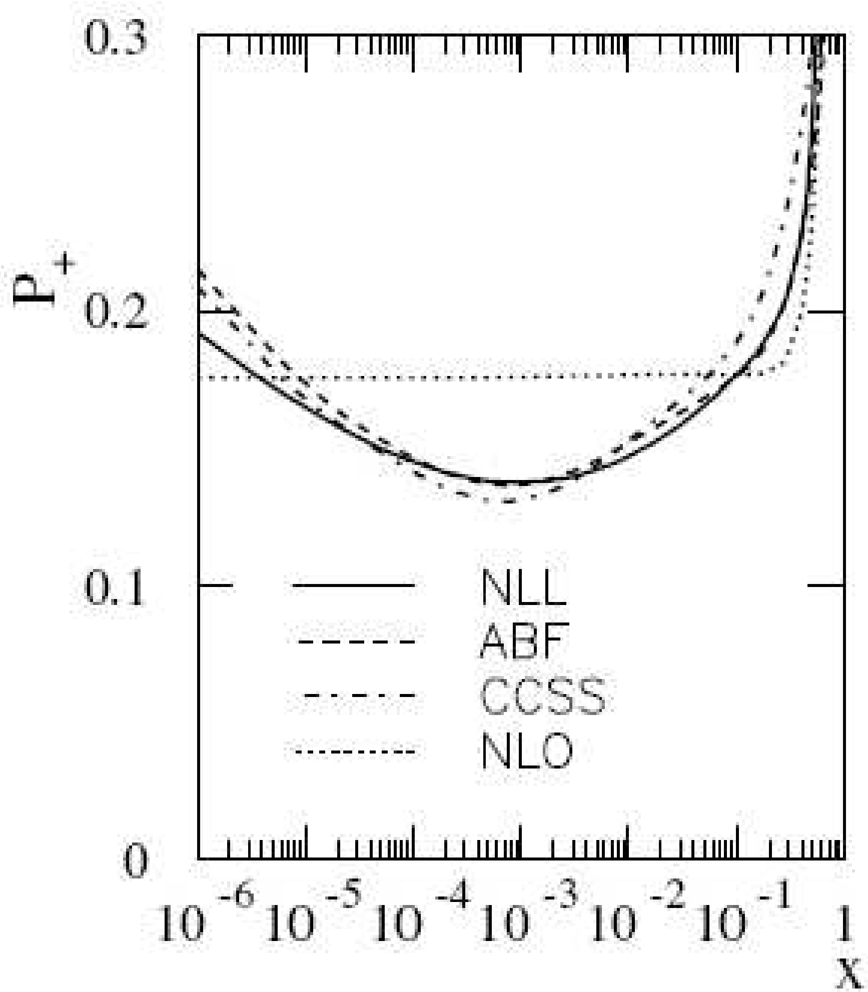
Now similar results coming from the White-RT, Ciafaloni-Colferai-Salam-Stasto and Altarelli-Ball-Forte procedures, despite some differences in technique.

Full set of coefficient functions still to come in some cases. Fit to data only in White-RT approach.

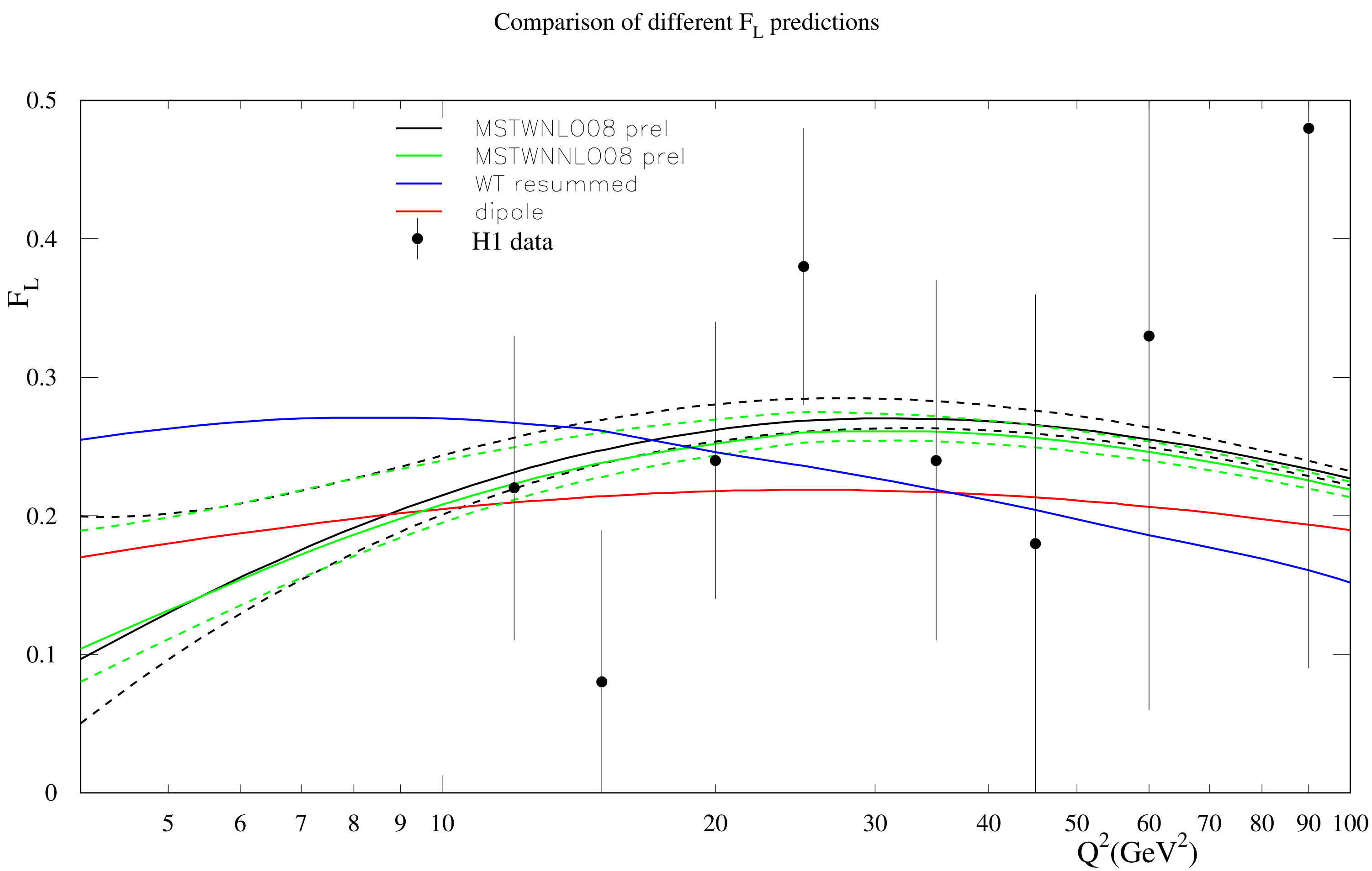
Note NLO corrections lead to dip in functions below fixed order values until slower growth (running coupling effect) at very small x.

May possibly be significant to small x details, and spoil $3-4\%$ theoretical accuracy.

Back to $F_L(x, Q^2)$ measurements.



So far consistent with standard predictions – NLO, NNLO, a dipole model prediction and resummed fit. Some possibilities (LO QCD) ruled out.



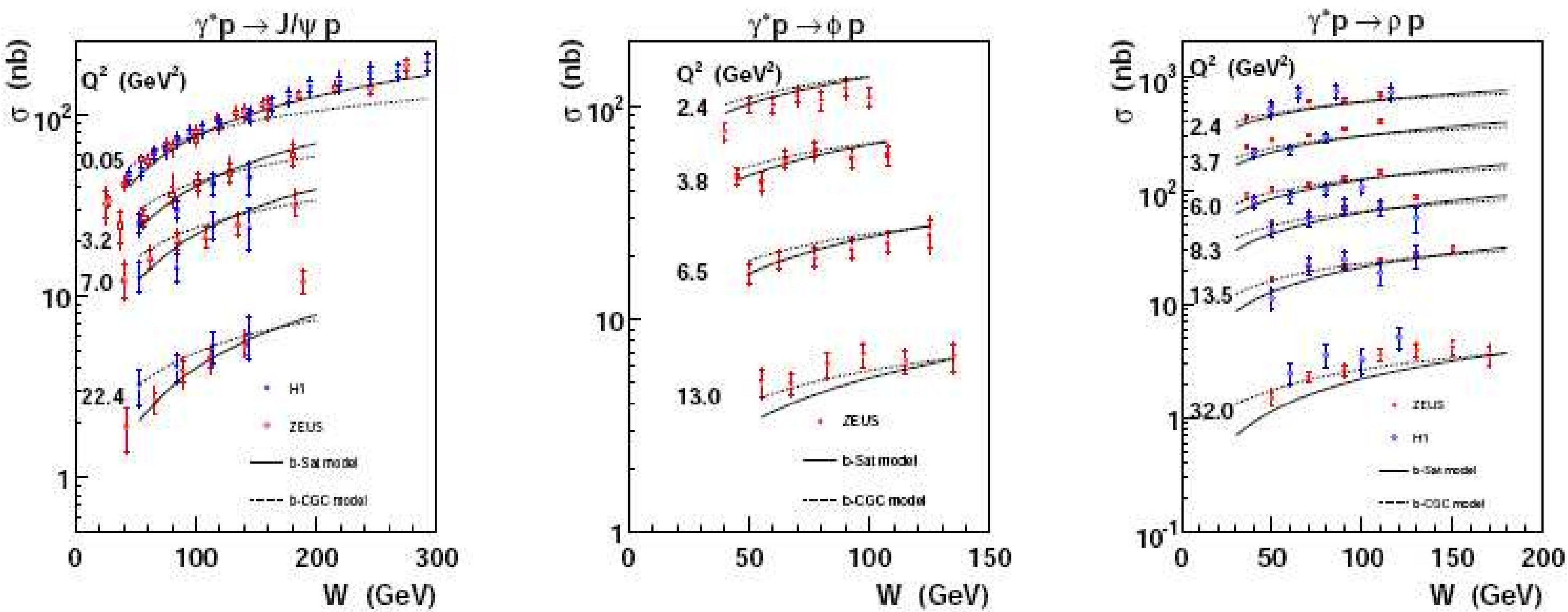
Good measurements at lower Q^2 may give an idea of how well to trust precision QCD. Very interesting to combine these with high rapidity, low mass, Drell-Yan at LHC.

Dipole Models, Saturation

As seen on last page, small-x automatically takes us to dipole models, saturation and overlap with **Diffraction** session.

Watt presented extended dipole model with impact parameter b dependence,

Free parameters determined by fit to $F_2(x, Q^2)$ and results compared to variety of exclusive processes with good results.

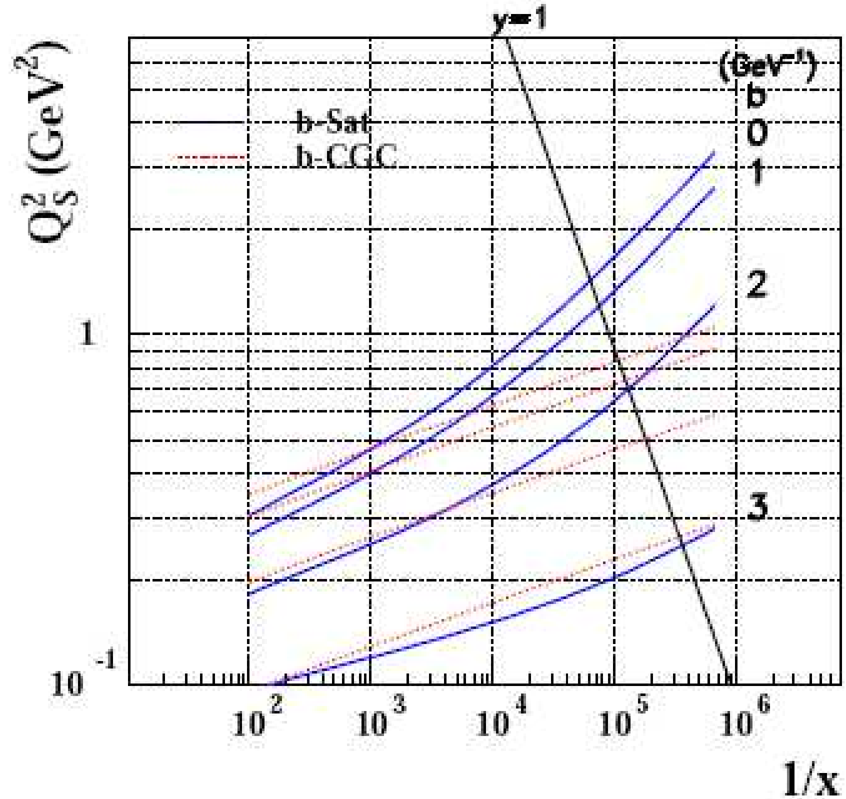


Saturation scale at very low x even for $b = 0$ – falling to lower x as b rises.

Average for inclusive processes $b \sim 2 - 3\mathrm{GeV}^{-1}$.

Similar results from most sophisticated and recent determinations of parameters using saturation based dipole models.

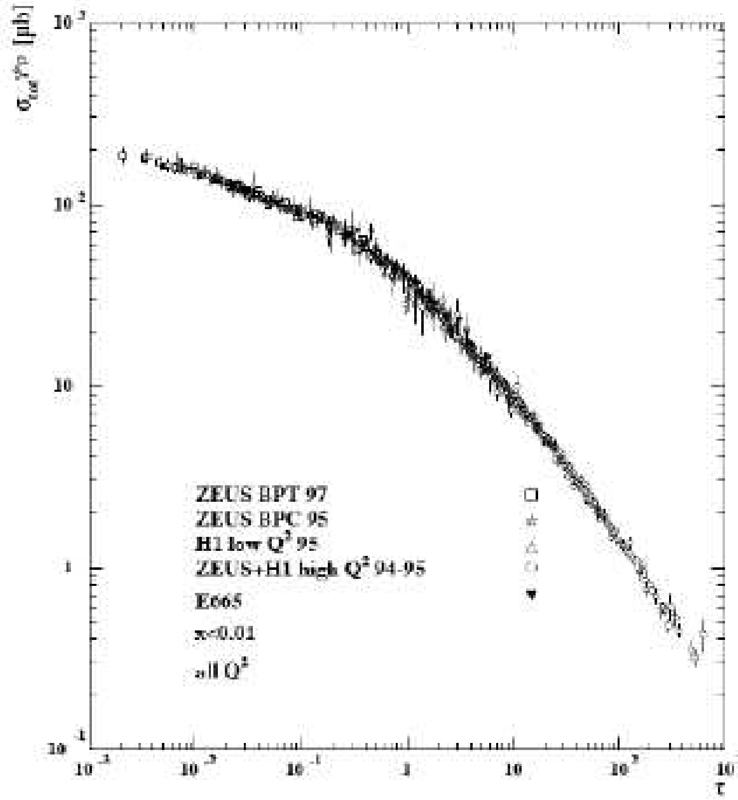
At HERA impact of saturation on inclusive quantities seems minimal.



Geometric scaling often cited as *evidence* for saturation effects.

- $\sigma(\gamma^* p)$ as a function of τ
- A. M. Stasto, K. Golec-Biernat, J. Kwiecinski, Phys. Rev. Let. 86 (2001) 596

$$\boxed{\tau = Q^2 (x/x_0)^\lambda}$$

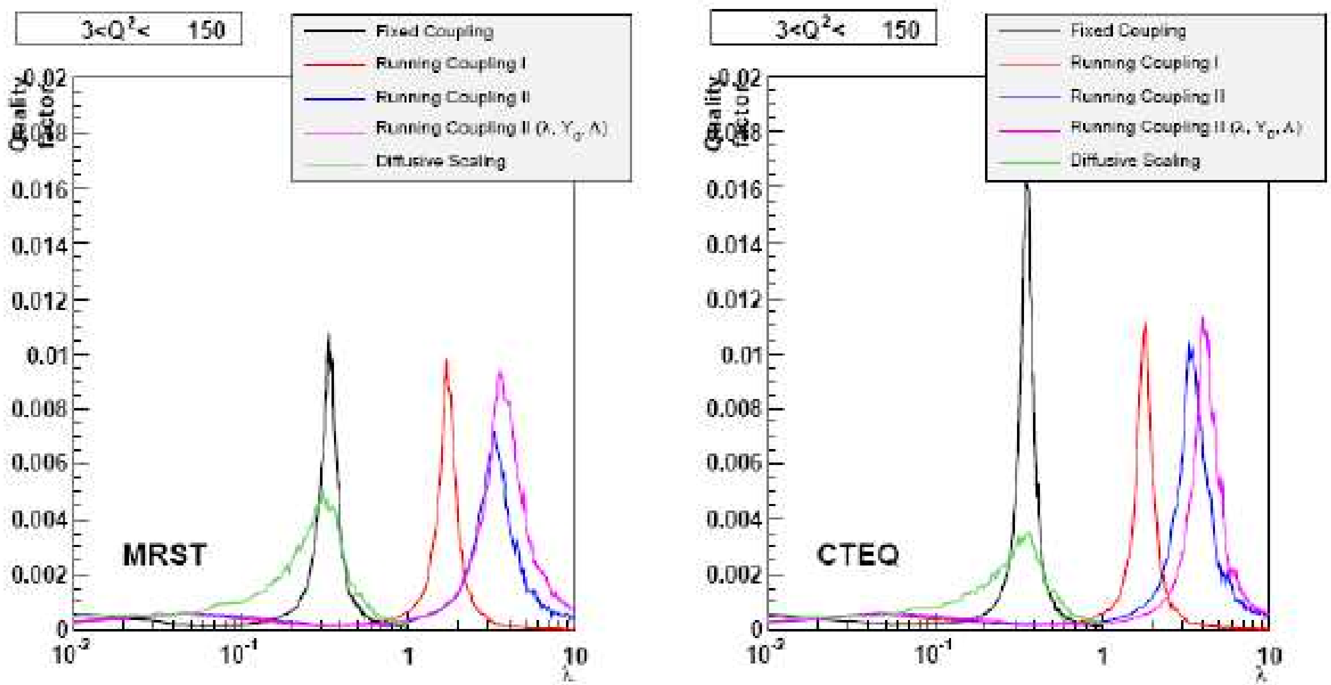


Simplest model shown. However, always going to be broken (higher orders, quark masses, ...) by more than size of error bars.

Now lots of variations on the type of geometric scaling depending on sophistication.

Theoretical evidence that geometric scaling can appear from DGLAP evolution (Caola).

More revealingly demonstrated that $F_2(x, Q^2)$ generated from MRST and CTEQ PDFs display *all* types of geometric scaling with good quality factors (Salek).



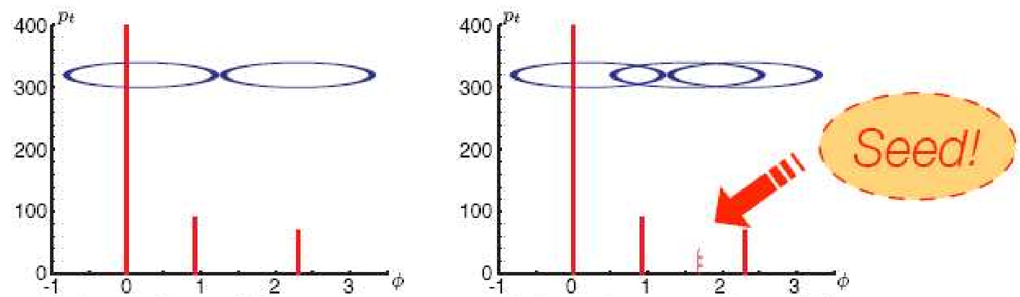
In this case there is no saturation in the input at all, yet is displayed by output.

Results suggest saturation effects in inclusive quantities at HERA are at very low scales. Dipole approach and very probably saturation more important for understanding exclusive quantities. Not convinced that geometric scaling (which type?) is evidence.

Developments in Perturbative QCD - Jets.

Long known that initial cone-based jet algorithms are generally infrared unsafe

Mid-point algorithm   Soyez



3 h ⇒ 2 stable cones   3 h + 1 s ⇒ 3 stable cones

with quantitative finite consequences

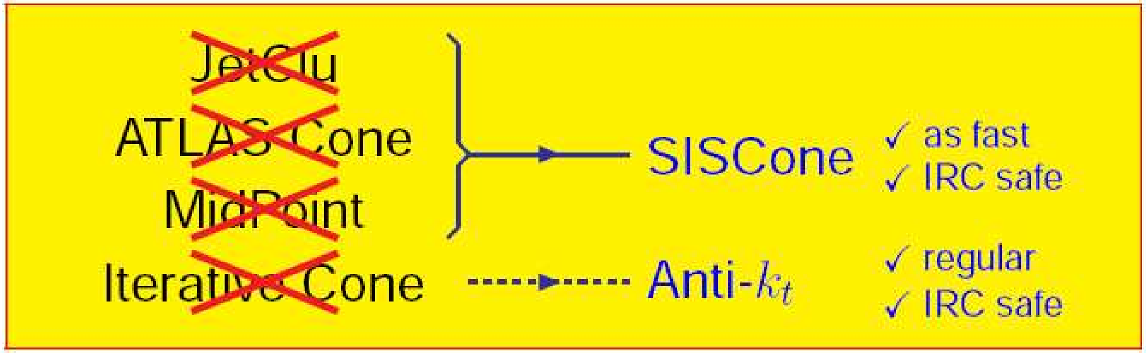
Real life does not have infinities, but pert. infinity leaves a real-life trace

$$\alpha_s^2 + \alpha_s^3 + \alpha_s^4 \times \infty \to \alpha_s^2 + \alpha_s^3 + \alpha_s^4 \times \ln p_t/\Lambda \to \alpha_s^2 + \underbrace{\alpha_s^3 + \alpha_s^3}_{\text{BOTH WASTED}}$$

Among consequences of IR unsafety:

	Last meaningful order			
	JetClu, ATLAS cone [IC-SM]	MidPoint [IC_{mp}-SM]	CMS it. cone [IC-PR]	Known at
Inclusive jets	LO	NLO	NLO	NLO ($\to$ NNLO)
$W/Z + 1$ jet	LO	NLO	NLO	NLO
3 jets	none	LO	LO	NLO [nlojet++]
$W/Z + 2$ jets	none	LO	LO	NLO [MCFM]
m_{jet} in $2j + X$	none	none	none	LO

Soyez presented improvements with properties similar to older algorithms.



Both available from FastJet (http://www.lpthe.jussieu.fr/~salam/fastjet)

Correspondingly strong statement in introduction – Salam

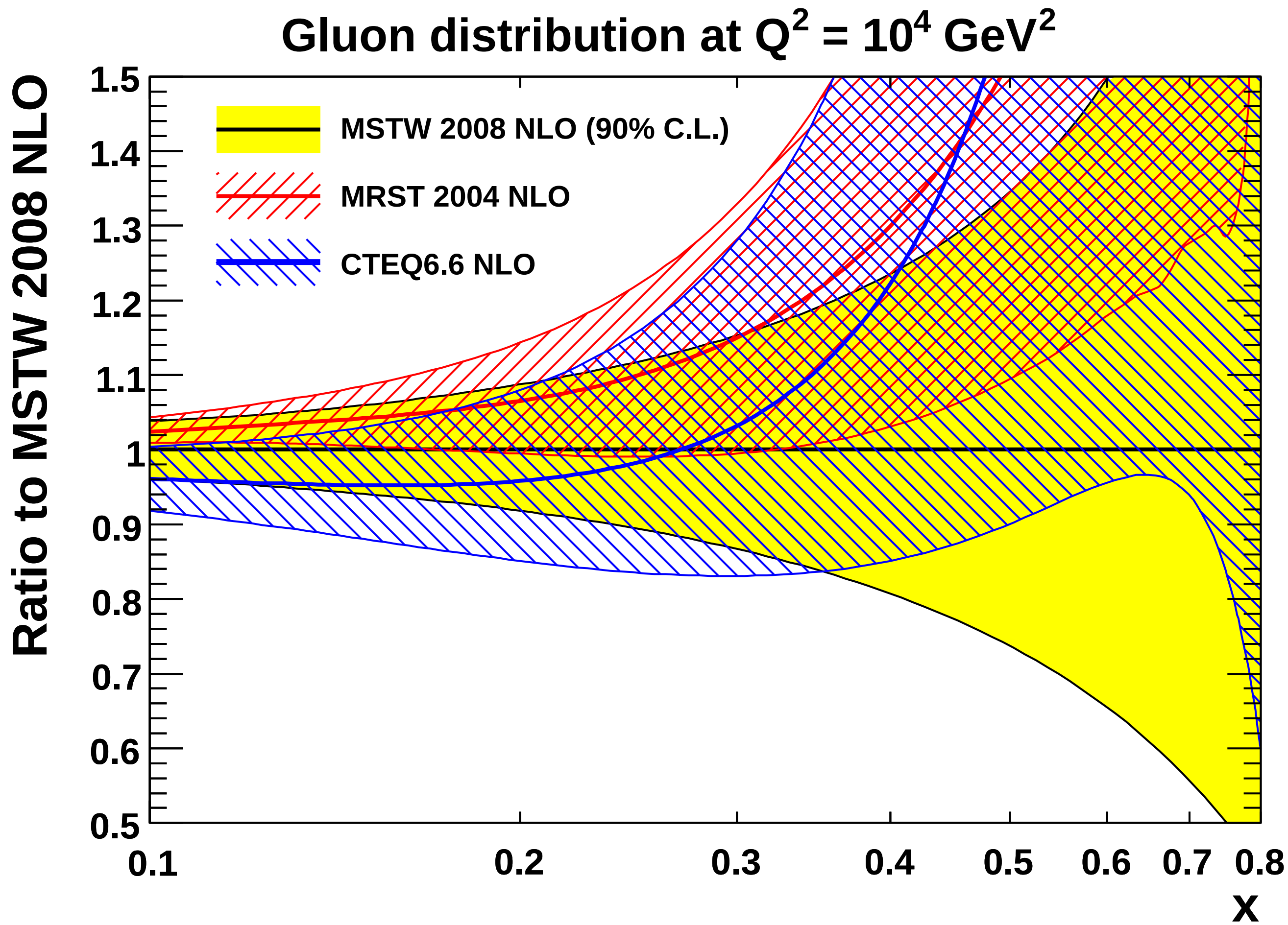
1. Infrared and Collinear unsafe jet algorithms have been with us for a long time

It's time to relegate them to where they belong

20th century history

Difficult not to agree.

From personal experience, fitting to Run II Tevatron high-E_T jet data, with improved jet algorithms (k_T algorithm for CDF) results in a significant change in the gluon.



Due to improvements in algorithms?

Particularly struck by new "anti-k_t algorithm" which combines all soft partons within "cone" with hard parton to produce "cone-like" jet definition.

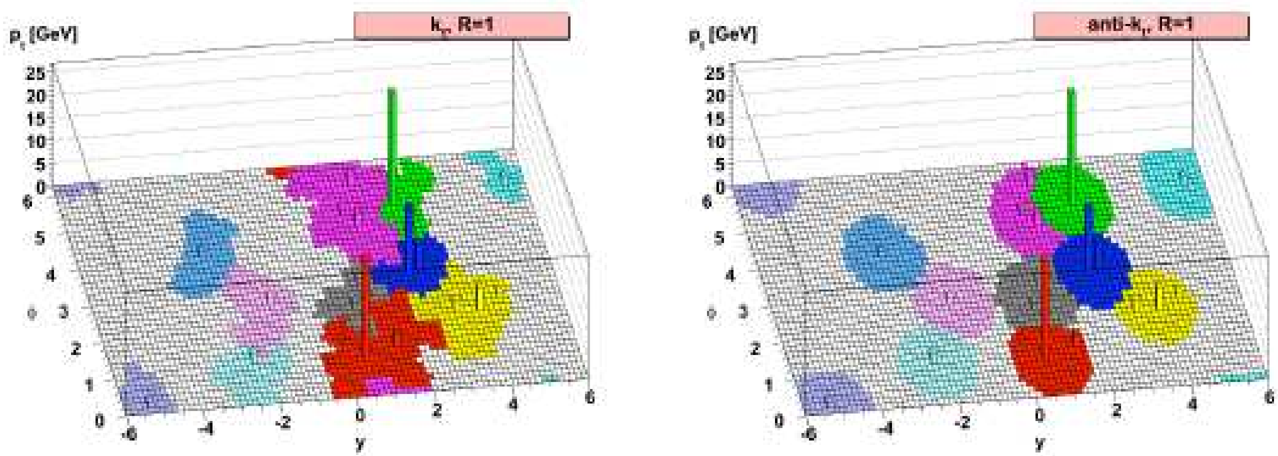
Come back to recombination-type algorithms:

Soyez

$$d_{ij} = \min(k_{t,i}^{2p}, k_{t,j}^{2p})\ (\Delta\phi_{ij}^2 + \Delta\eta_{ij}^2)$$

- $p = 1$: k_t algorithm
- $p = 0$: Aachen/Cambridge algorithm
- $p = -1$: anti-k_t algorithm [M.Cacciari, G.Salam, G.S.,JHEP 04 (08) 063]

Hard event + homogeneous soft background



Useful when using jet area to subtract underlying event and pile up, where P_T/A is fairly constant except for hard jets (Cacciari).

Developments in Perturbative QCD - Calculations.

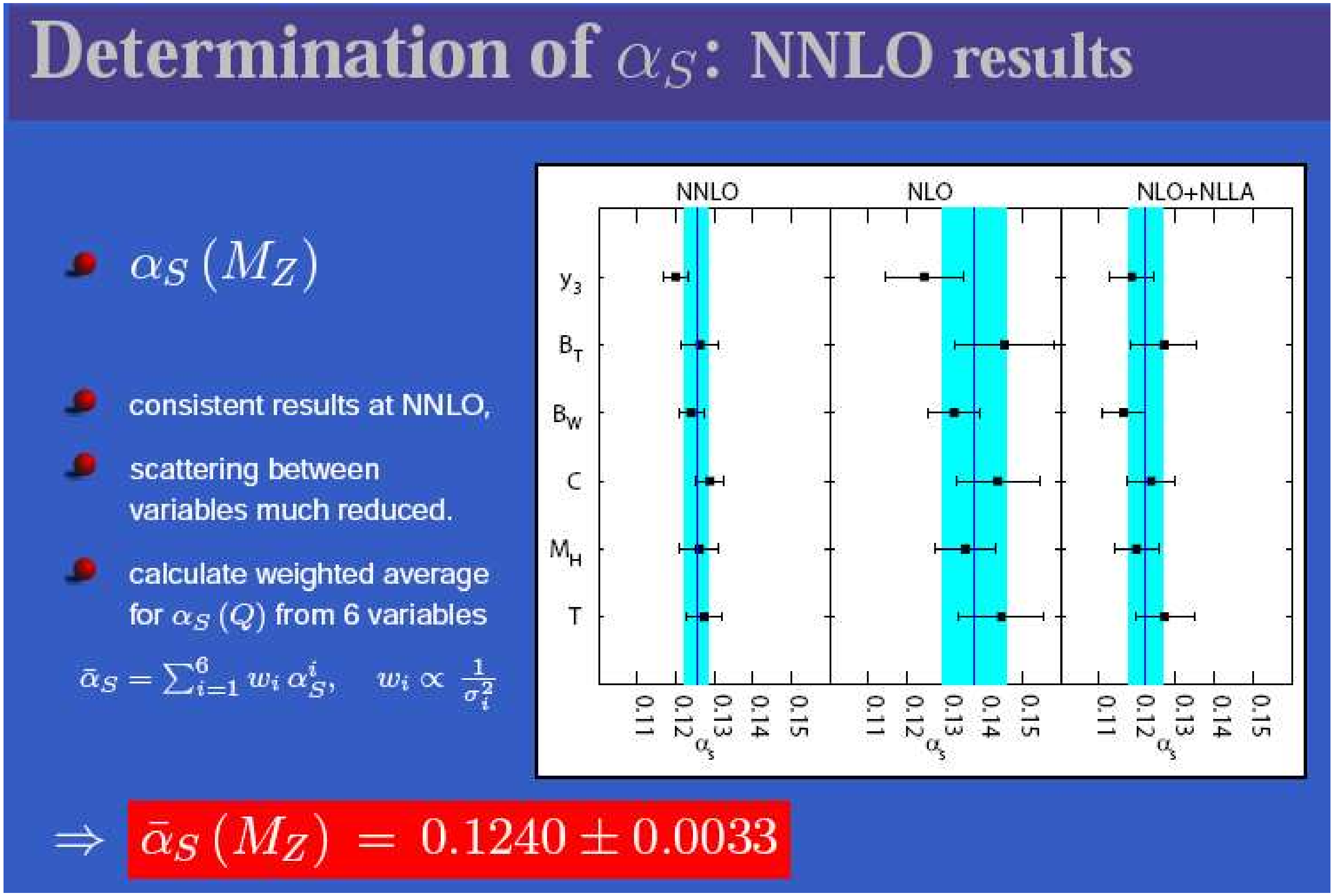
As presented by Zanderighi, lots of developments in NLO calculations.

Automation & improving performance of NLO

Want Alpgen/Sherpa@NLO $\Rightarrow$ fully automated NLO calculations

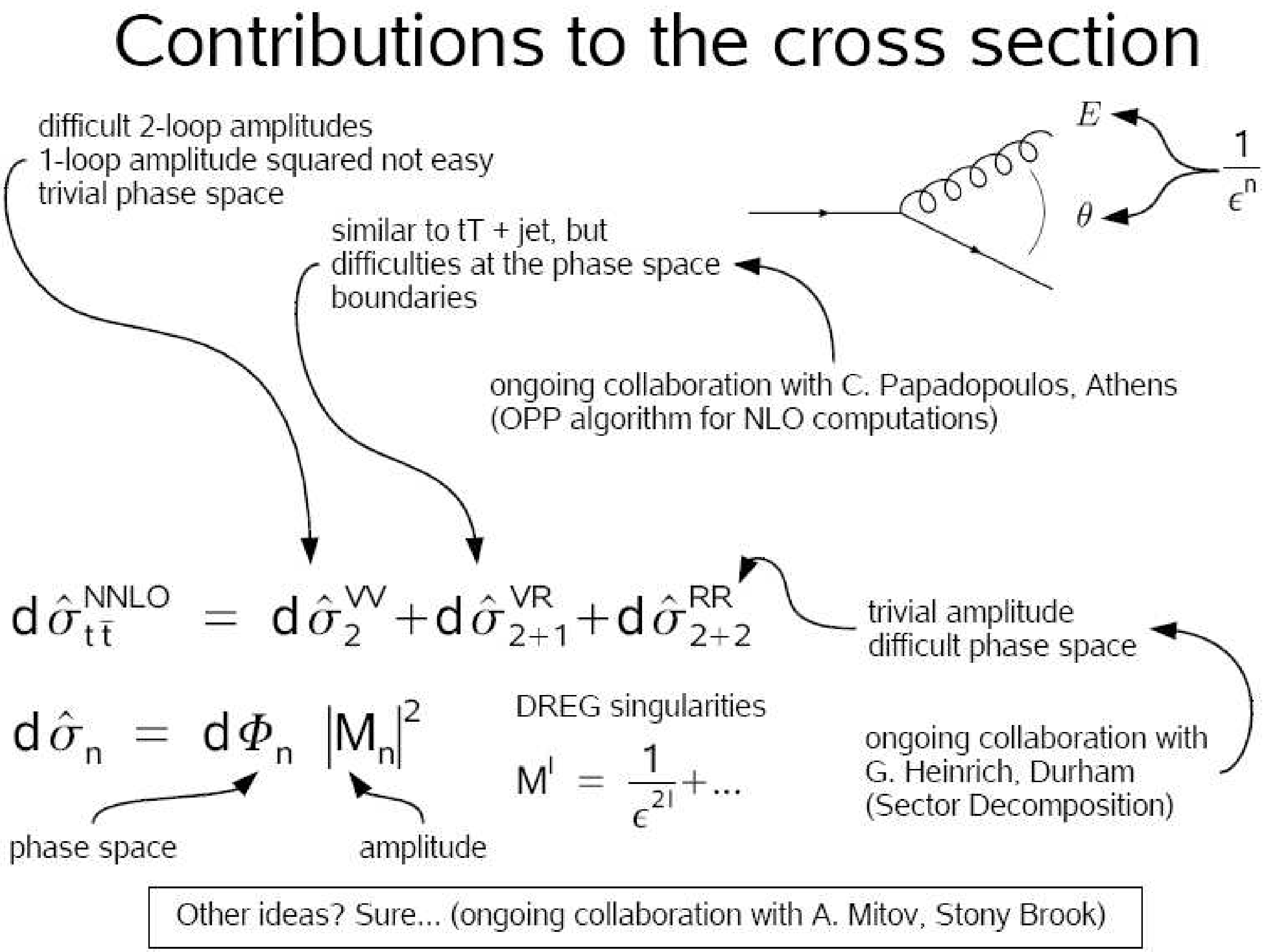
- towards automation of NLO calculations
  Van Hameren
- NLO + parton shower
  Nagy
- duality between one-loop and single-cut phase space integrals
  Rodrigo
- automated one-loop N-gluon amplitudes via unitarity ➠ **Rocket**
  Zanderighi
- automated implementation of dipole-subtraction ➠ **TevJet**
  Seymour, Tevlin
- fast-NLO, NLOgrids, event weight grids
  Kluge, Clements, Sutton

Developments at NNLO. Particularly full calculations of jet event shapes (Luisoni).



Reduces uncertainty in extraction of $\alpha_S(M_Z^2)$ compared to NLO, but high value. Combination with additional resummations necessary. Nearing (reaching) completion – (JADE – 0.1210 NNLO$\rightarrow$ 0.1172 NNLO$+$NLLA).

Even major progress in full NNLO calculation of heavy quark production in hadron-hadron collisions (Czakon).



Exact contributions for virtual corrections to quark annihilations. Total quark contributions in sight?

Heavy Flavour

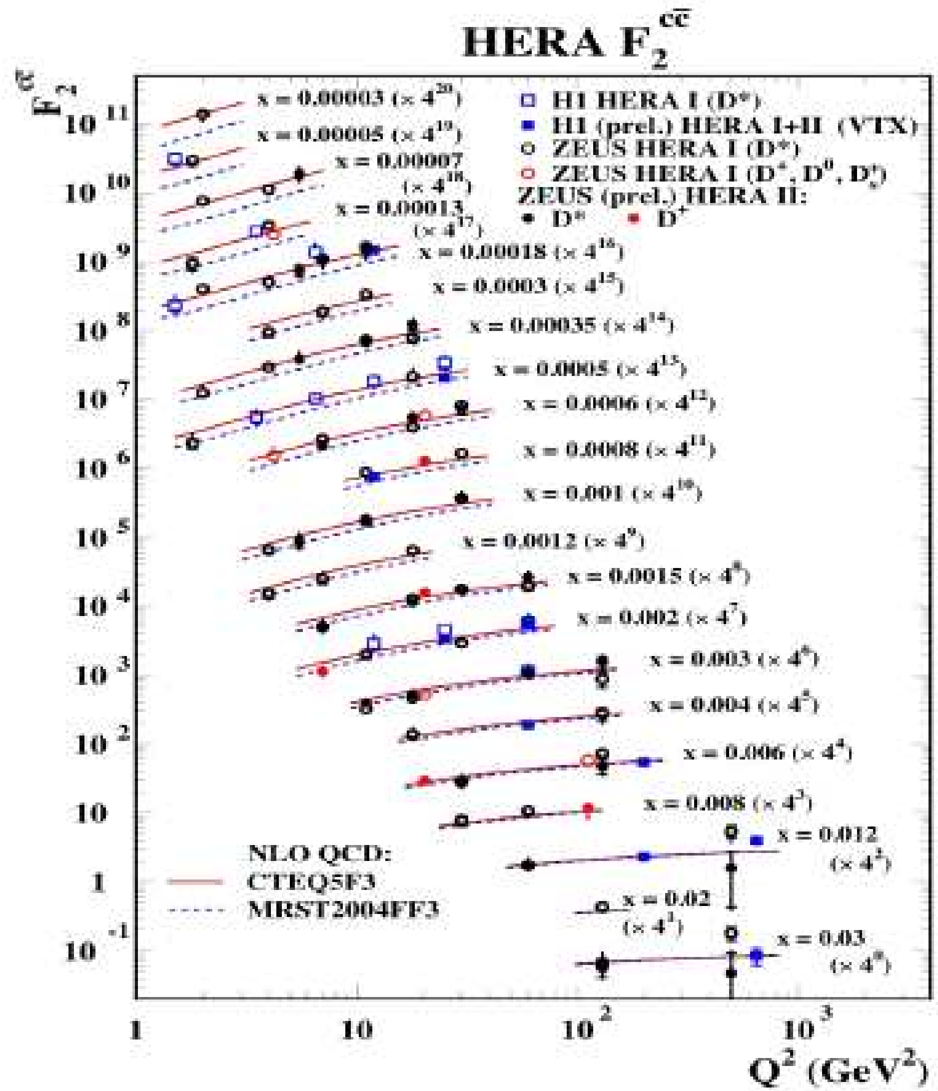
Already heard easily enough on calculating $F_i^H(x,Q^2)$ this week.

Upshot – MSTW and ACOT definitions of GM-VFNS not very different.

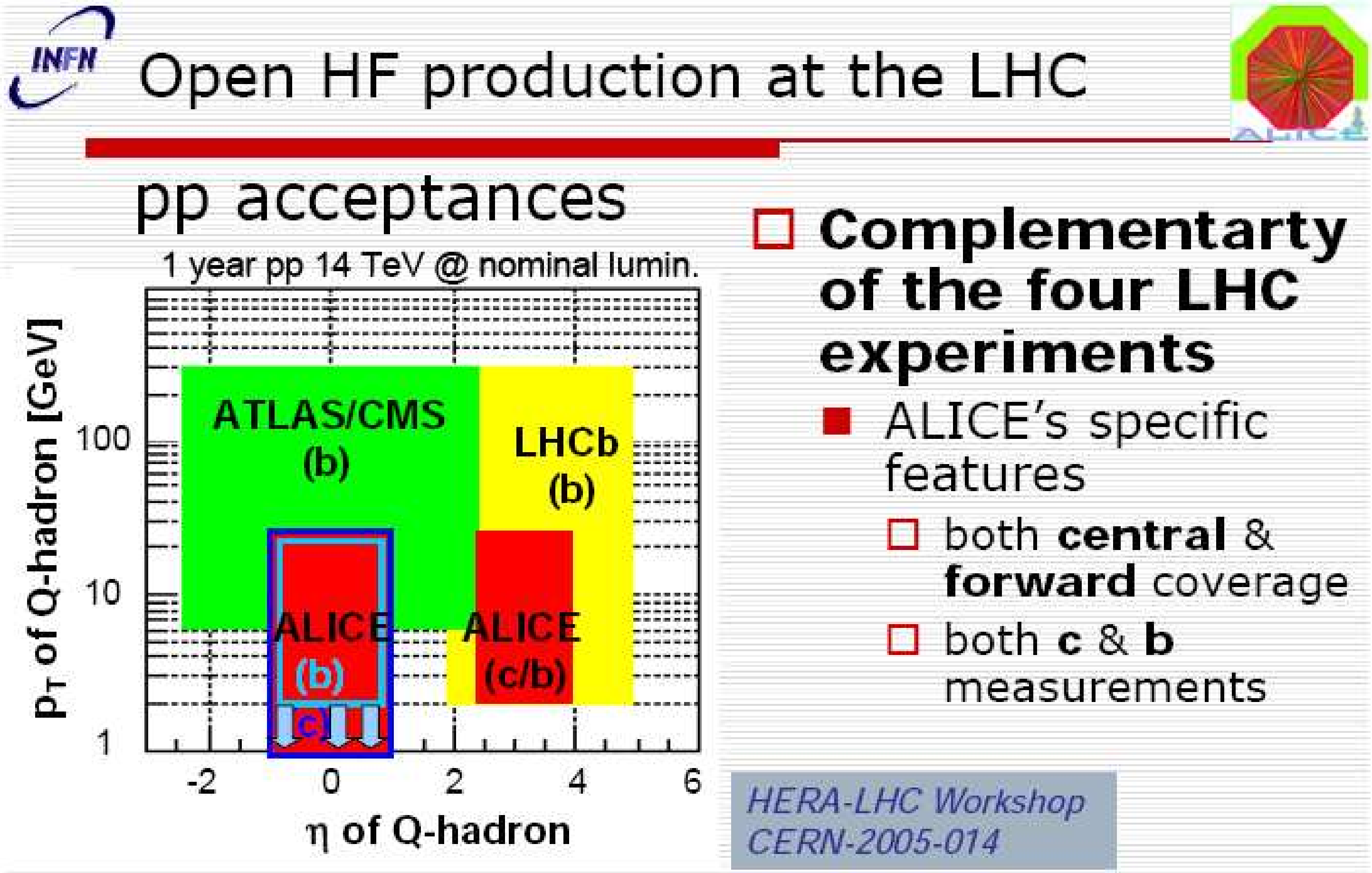
Note easier to define at NNLO in GM-VFNS than in FFNS.

NNLO FFNS needs new $\mathcal{O}(\alpha_S^3)$ matrix elements even for $Q^2/m_H^2 \to \infty$ limit. Calculation Bierenbaum, Klein.

Excellent new data. Can compare with anything if extracted as $F_2^H(x,Q^2)$, but need better than old (limited) MRST04 and (older) CTEQ5 for best extraction.



There will similarly be excellent coverage of heavy flavour at the LHC (Bruno)



with LHCb and particularly ALICE having triggers to extremely low p_T.

LHCb also measure charm with early running?

Enormous cross-section for heavy flavour production at LHC.

Doesn't really matter that bandwidth for trigger for B physics is only about 5%.

All detectors have a wide ranging heavy flavour physics programme. Measurements of

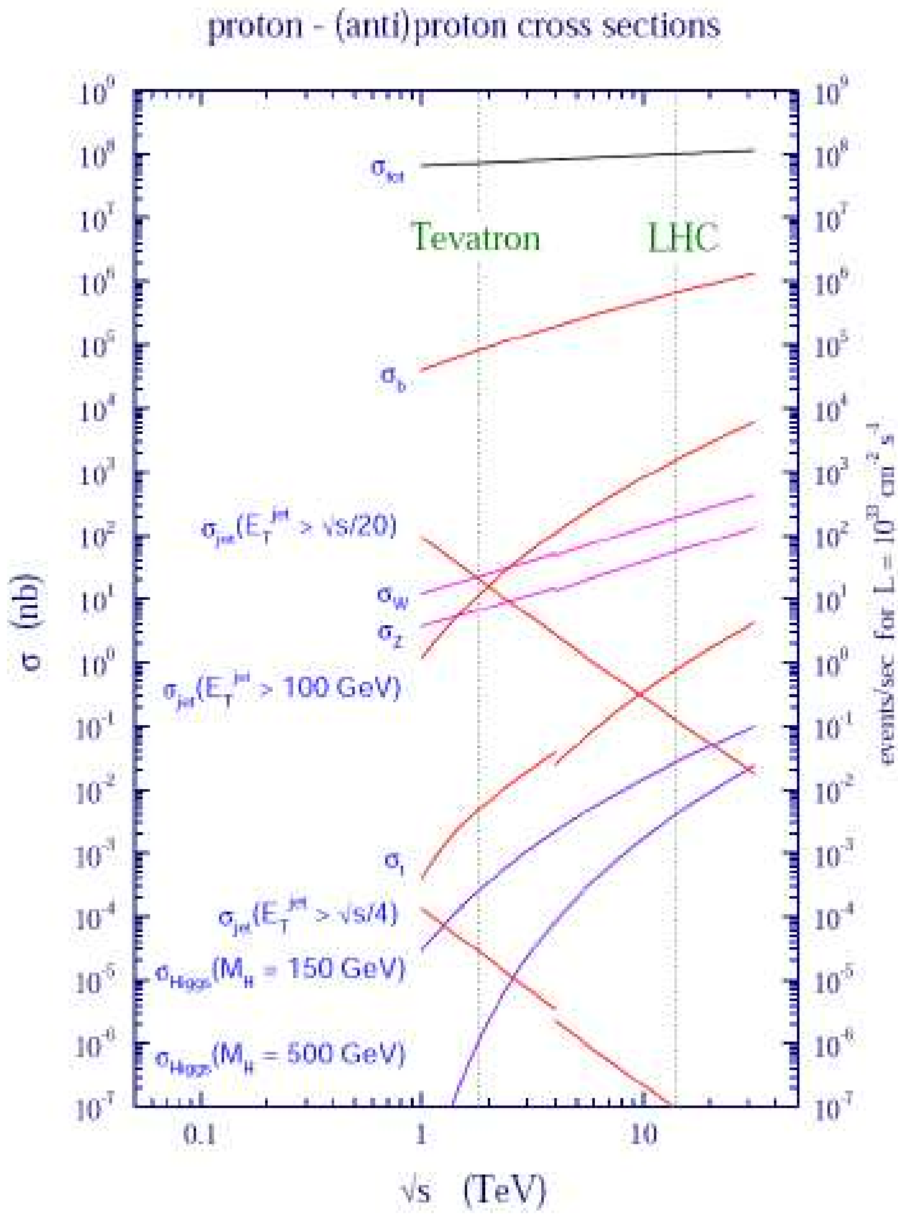
– open heavy flavour production

– heavy flavour jets

– quarkonium production

– oscillations

– rare decays.



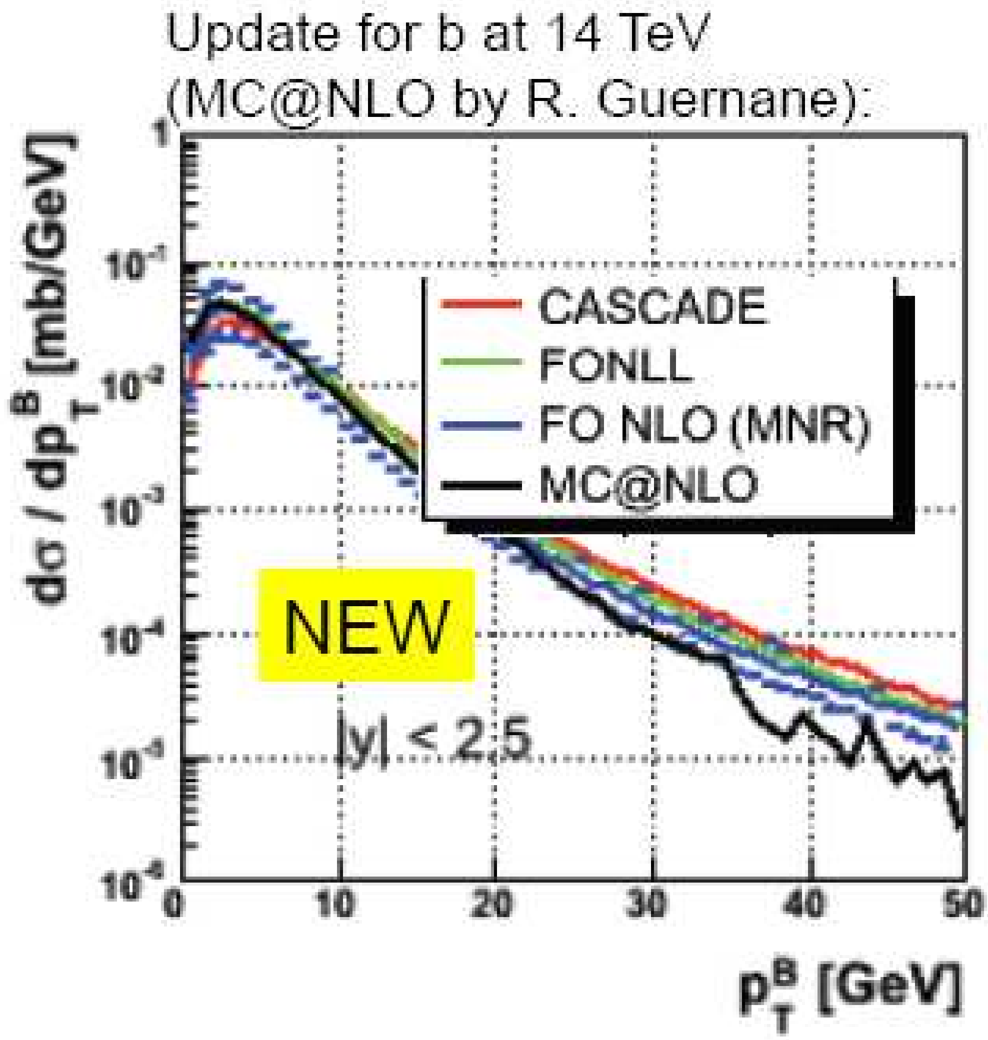
Measurements of heavy flavours down to low p_T and at higher rapidity will test QCD in the same manner as the low-mass Drell-Yan production.

Constrain small-x PDFs, check for small-x resummations, saturation *etc.*

However, theory is even more uncertain in this case. Predictions show uncertainties of factors of 2.

Even more scope for variations.

Lot of work for theorists here.

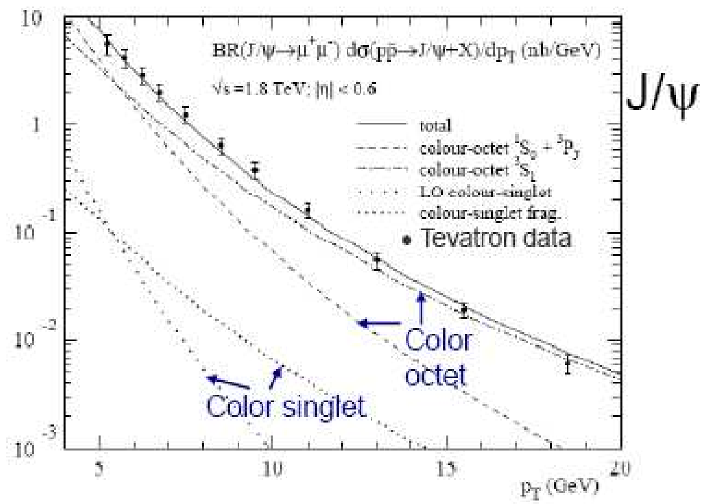


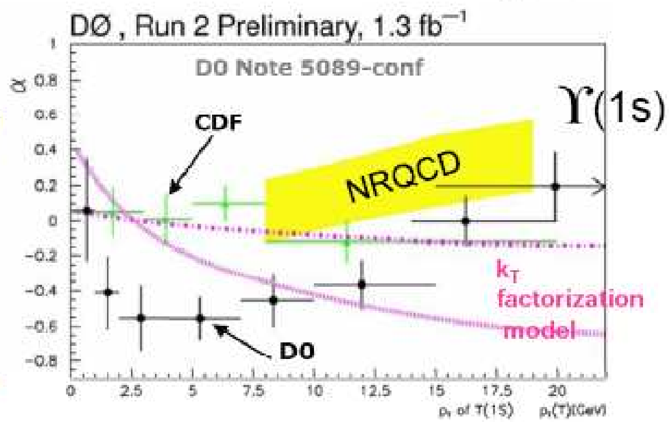
Possibility of very quick results on heavy meson production (Lytken – ATLAS).

Quarkonia

- Among first measurements
  + theoretical interest:
  What is the production mechanism?
- The Color Octet Mechanism agrees well with measured σ shape from Tevatron
  Polarization measurements:
  CDF sees no sign of pol. for J/ψ and DØ $\Upsilon(1S)$ measurements not consistent with predictions.

More data with high-p_T needed!

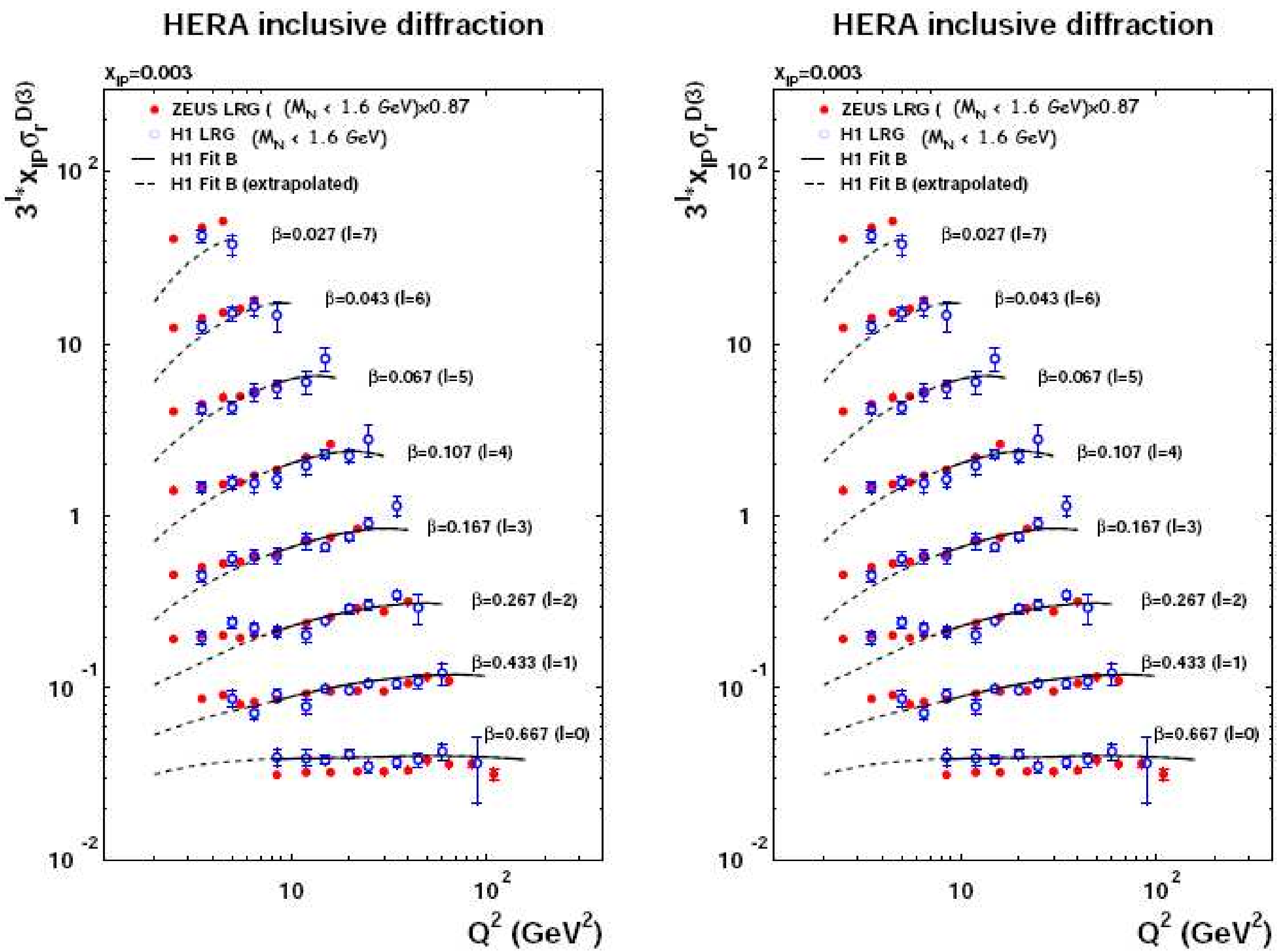




Already with 10 pb^{-1}: measure J/ψ pol. to same precision as TeV with 1.3 fb^{-1} - but with interesting high p_T data!
Same precision for Υ polarization studies can be reached after ~100 pb^{-1}

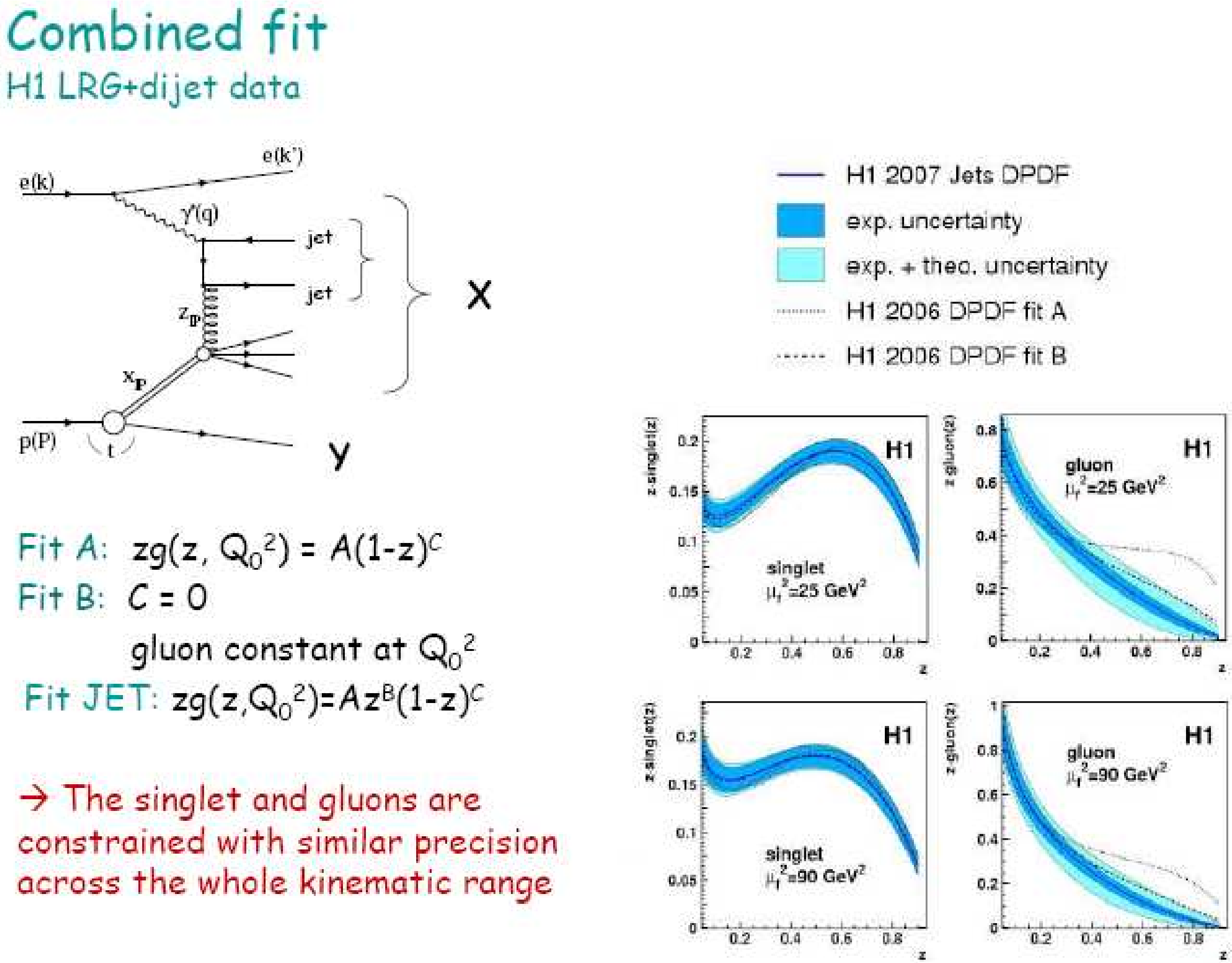
Diffraction at HERA

Major improvements over time in consistency between measurements,



Comparison of inclusive diffraction using Large Rapidity Gap definition (Ruspa).

In addition inclusion of jet production has stabilised results of fit dramatically (near to fit B and MRW results).

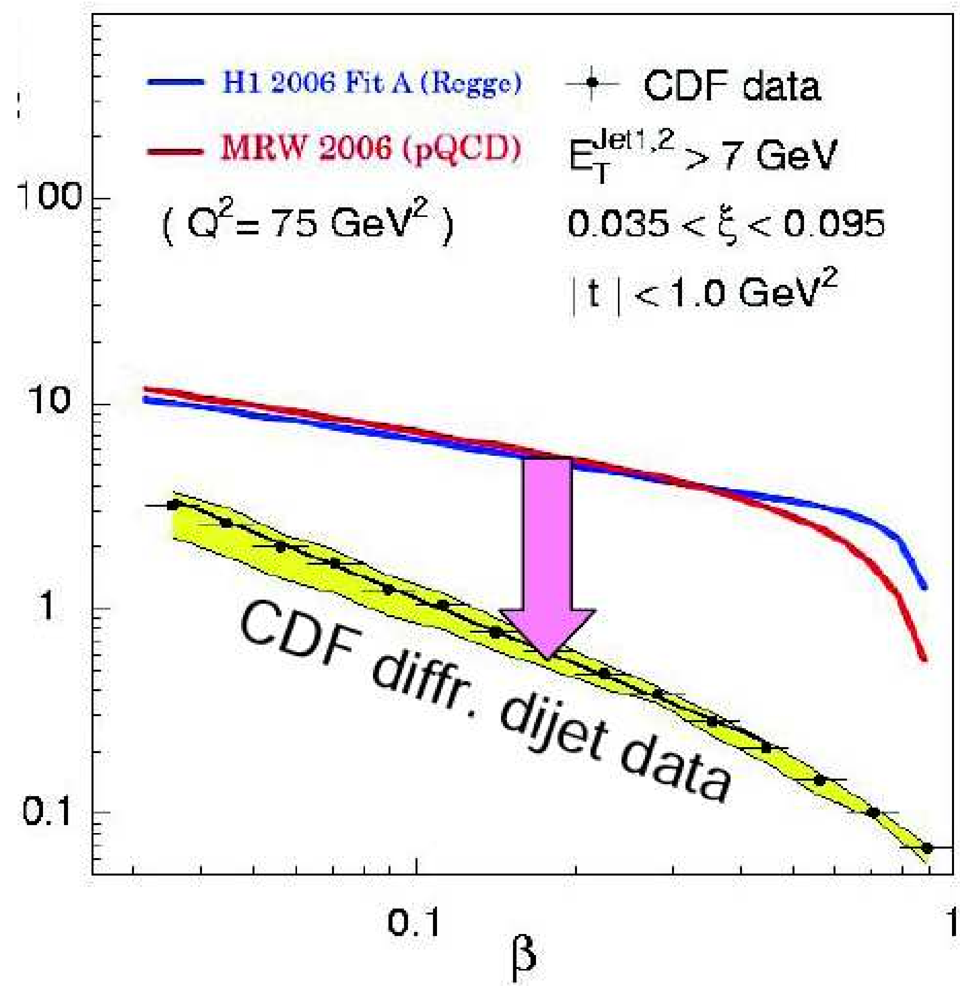


Now time for averaged data, and (subsequently) combined fits.

Then can be used at LHC. However, while diffractive PDFs obey factorization, i.e. can determine evolution and combine with hard coefficient functions, the factorization is not universal.

Very simple application of extracted PDFs to Tevatron data does not, and was never expected to work.

Factorization known to be broken in hadronic diffraction due to soft interaction filling in gaps in both initial and final states.

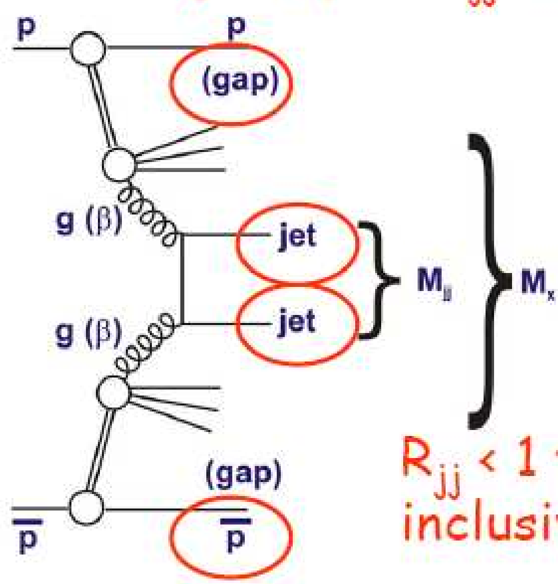


Interpreted as *phenomenological* "gap survival" probability. Can give some reasonable accuracy for prediction of LHC processes.

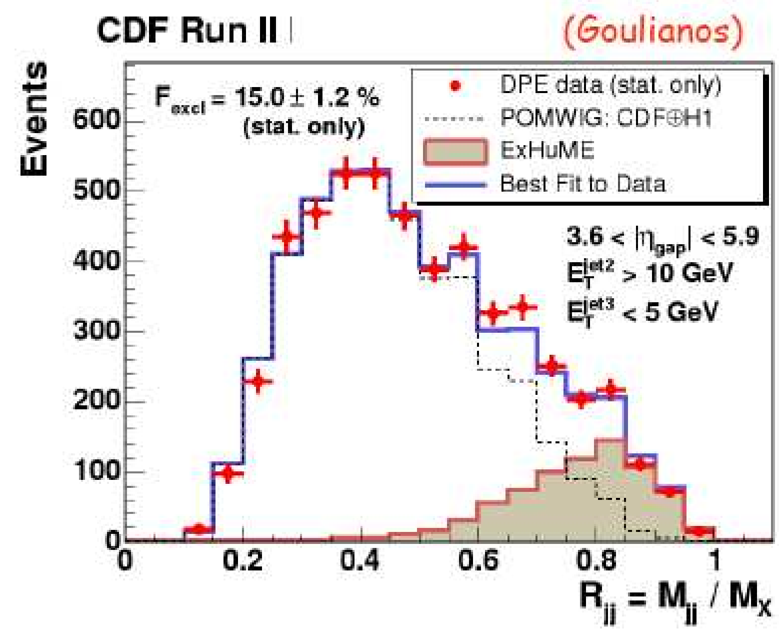
Khoze – " .. not all alike. Dependence on the nature of the basic process, kinematical configuration, cuts ...."

Predictions for Diffractive processes at LHC can be tested at Tevatron.

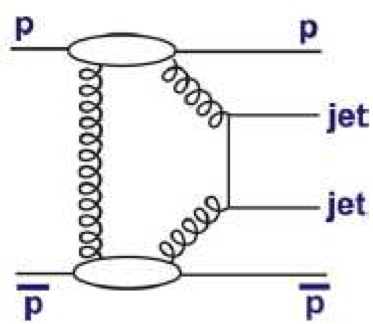
"DPE" dijets, plot $R_{jj}=M_{jj}/M_x$



$R_{jj} < 1$ for inclusive



$R_{jj} \rightarrow 1$ for exclusive (complicated by hadronis^n, higher order QCD ...)



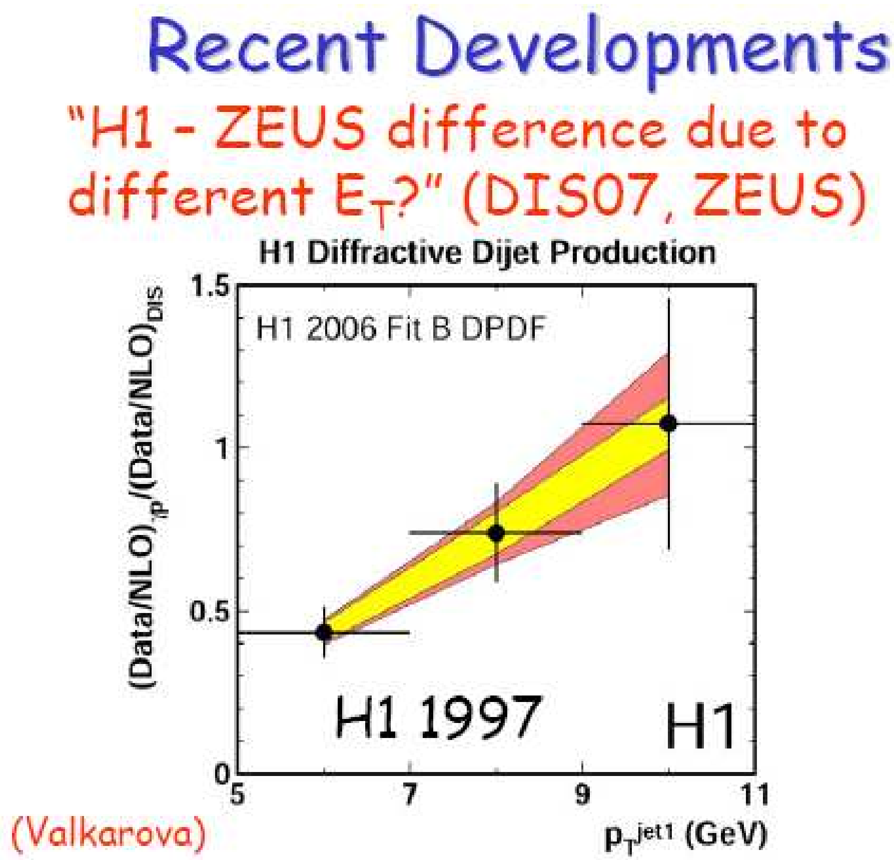
Many comparisons with varying MC modelling and DPDFs ...
...hard to get rid of signal!
Fit with free normalisation of inclusive, exclusive models to quantify exclusive part ...

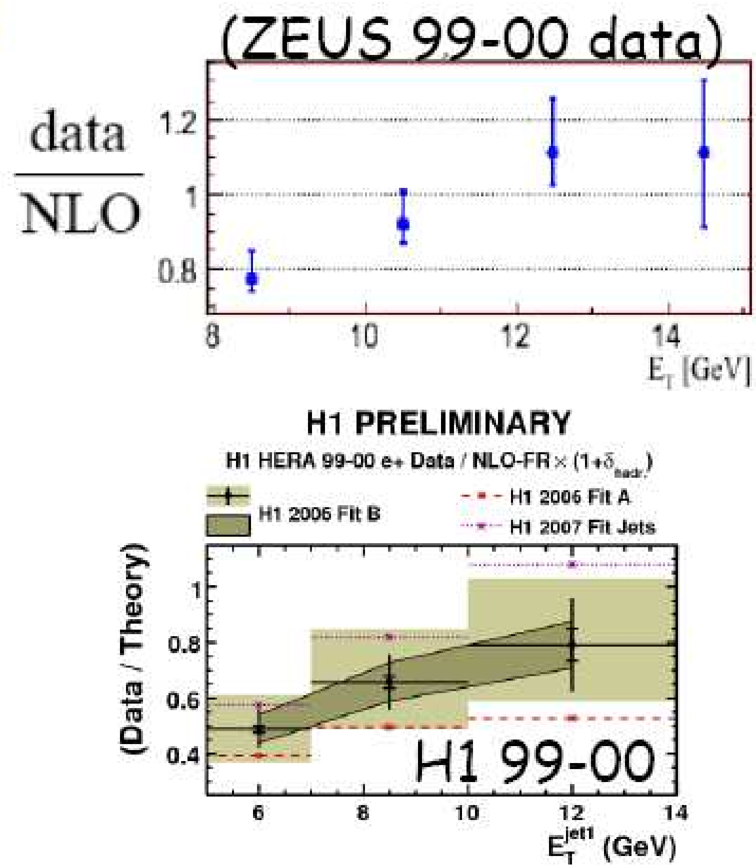
ExHuME (Monk, Pilkington) based on KMR calculation with a 4.5% gap survival probability.

In principle test also in diffractive photoproduction. Naive guess – direct contribution (like DIS) satisfies factorization, resolved (like hadronic) – gap survival ~ 0.3.

Initially ZEUS and H1 data did not agree well, and suggestion of suppression ~ 0.5 at all x_γ.

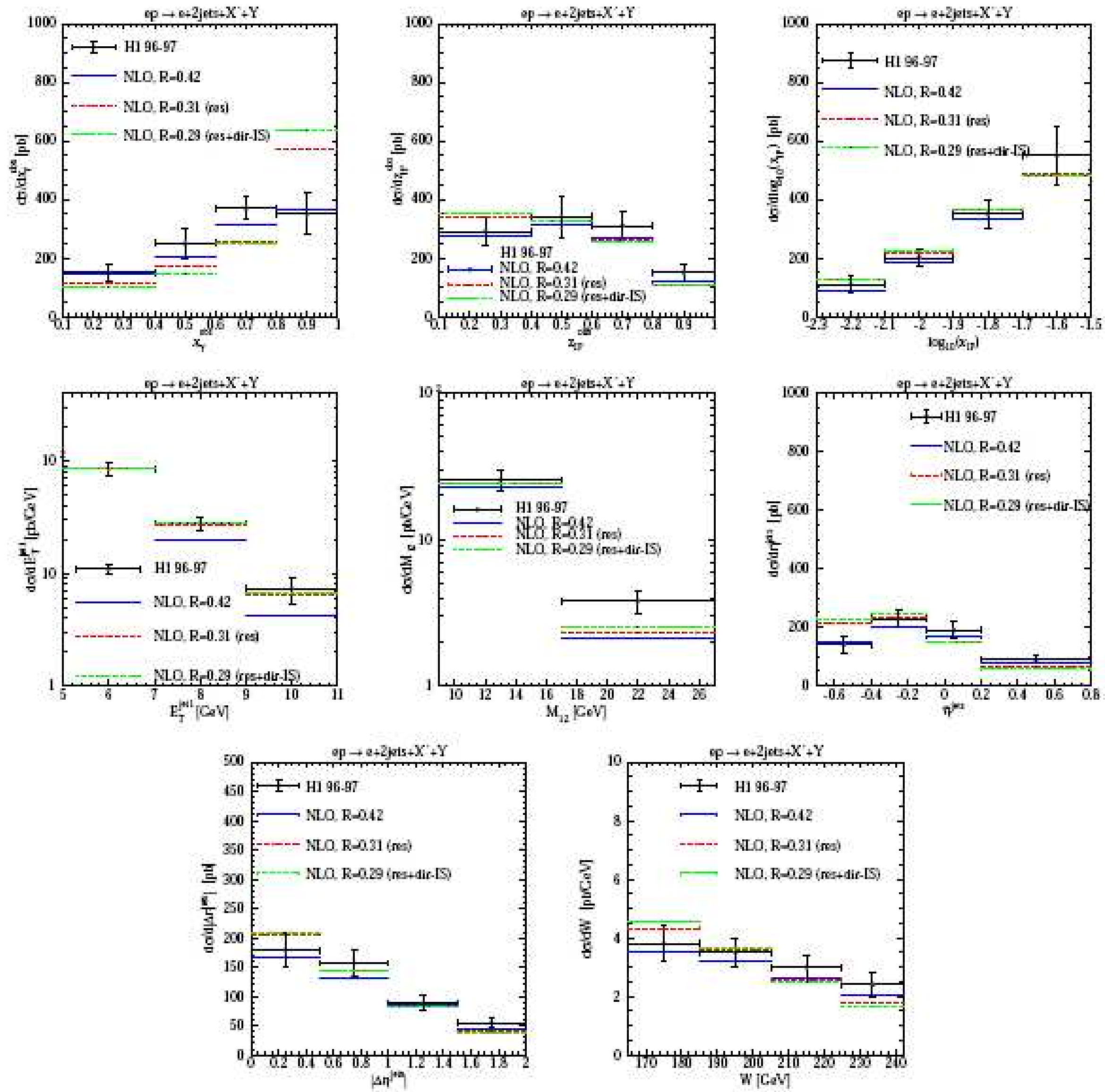
Recent improvements in understanding data differences.





Thorough coverage by Kramer this week.

Suppression (gap survival) factor of ~ 0.4 for all gives best match. Others have problems at highest x_γ – but better at high E_T. Still matter of investigation Klasen, Kramer).



Monte Carlos and related tools

Considerable work on new shower developments noted by Gieseke.

- Nagy, Soper:
  - Beyond 1/Nc
  - with interference beyond soft limit
- KRKMC - Jadach, Skrzypek
  - Constrained Markov Chain
  - MC evolution like PDF evolution
  - Path to NLO

Also new dipole showers in Sherpa – Siegert

CSSHOWER++

- Based on Catani-Seymour dipole subtraction
- Dipole terms can be used to describe splittings
- Correct soft & collinear limits, better treatment of colour coherence

ADICIC++

- Emission off colour dipoles (associated to initial and/or final state colour lines)
- Idea implemented in Ariadne, very good performance for LEP/HERA
- In addition: Initial state emission formulated completely perturbative

Update on status of all the major Monte Carlo generators and associated tools.

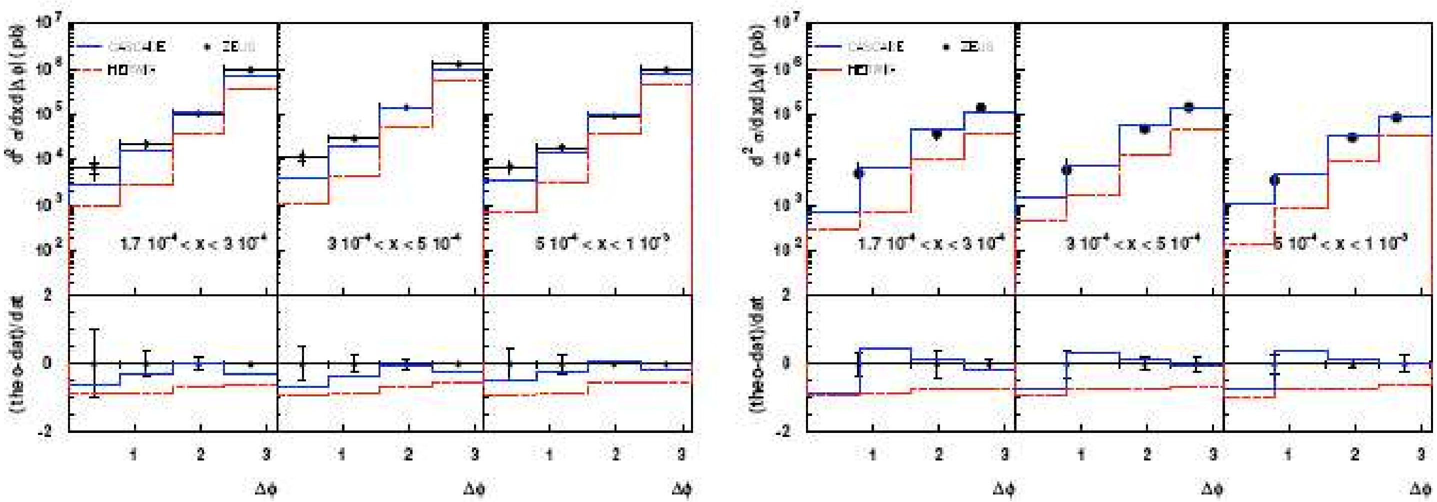
CASCADE – very different to standard MCs, based on generation of unintegrated PDFs via CCFM equation. Advantages (Hautmann)

Advantages over standard Monte-Carlo like PYTHIA or HERWIG:

- better treatment of high-energy logarithmic effects
- likely more suitable for simulating underlying event's $k_\perp$

Seems very successful in some regimes.

Angular jet correlations from CASCADE and HERWIG compared with DIS data



(left) di-jet cross section; (right) three-jet cross section

Also disadvantages

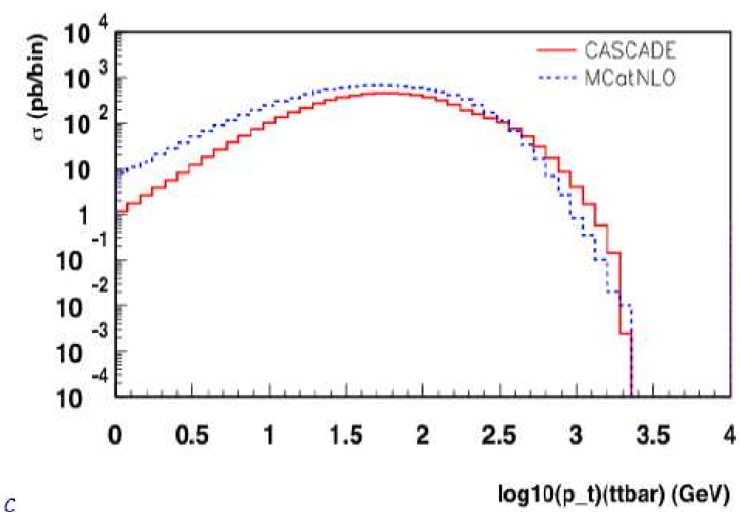
Current limitations:

- radiative terms associated to $x \sim 1$ not automatically included
- procedure to correct for this not yet systematic

  $\hookrightarrow$ e.g.: LO-DGLAP in Höche et al
- quark contributions in initial state included partially

  $\hookrightarrow$ see also: $k_\perp$ kernel for sea-quark evolution [Catani & H]
- limited knowledge of u-pdf's [Jung et al., arXiv:0706.3793; J. R. Andersen et al., 2006]

From experience in similar situations concern that these may be rather important in many cases. Comparison to MC@NLO for top production Jung.



Just starting to add essential corrections, e.g. valence quark contributions (Deak).

ARIADNE - based on colour dipole cascade model Lönnblad.

- Describe gluon emissions in terms of radiation from colour dipoles
- Instead of one parton splitting into two, we have one dipole splitting into two, or two (colour-connected) partons into three.
- $g \to q\bar{q}$ is still treated as normal parton splitting

- Completely rewritten in C++ using THEPEG Main work by Nils Lavesson
- Almost all components are in place
- Simple CKKW(L) matching
- Modified model for initial-state radiation needed
- $q \to g$ splitting included
- String fragmentation with PYTHIA7
- Validated for e^+e^-

But unfortunately...

- ARIADNE will not be ready for LHC startup

Sherpa – various improvements outlined by Seigert.

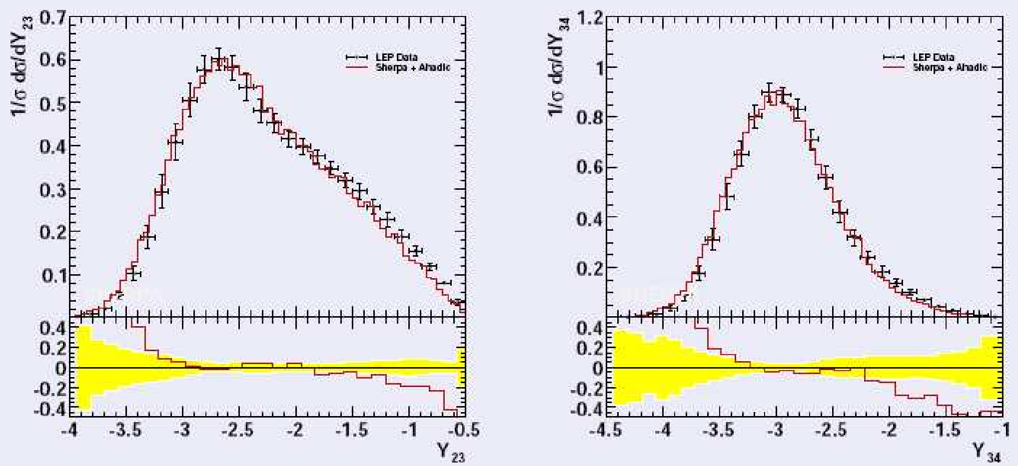
New features

- AHADIC++ – Cluster fragmentation module
- HADRONS++ – Complete hadron and τ decay module
- PHOTONS++ – QED radiation in the YFS formalism

Improvements in other areas

- CKKW merging for processes with decay chains

LEP I data



Along with new method for calculating high multiplicity cross-sections COMIX

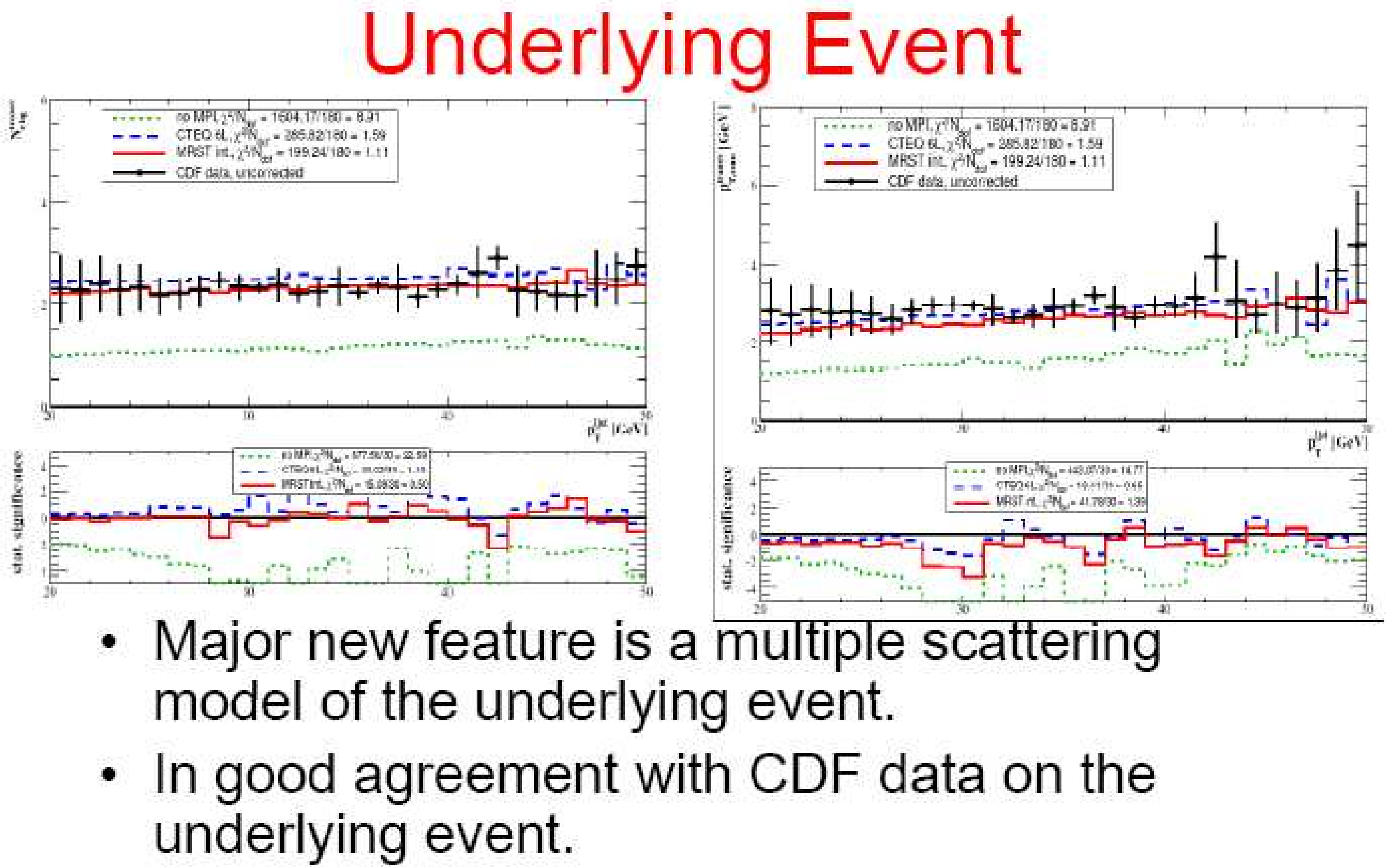
Example from MC4LHC comparison vs. COMIX

σ [pb]	Number of jets						
e^-e^+ + QCD jets	0	1	2	3	4	5	6
COMIX	723.5(4)	187.9(3)	69.7(2)	27.14(7)	11.09(4)	4.68(2)	2.02(2)
ALPGEN	723.4(9)	188.3(3)	69.9(3)	27.2(1)	10.95(5)	4.6(1)	1.85(1)
AMEGIC++	723.0(8)	188.2(3)	69.6(2)	27.21(6)	11.1(1)		

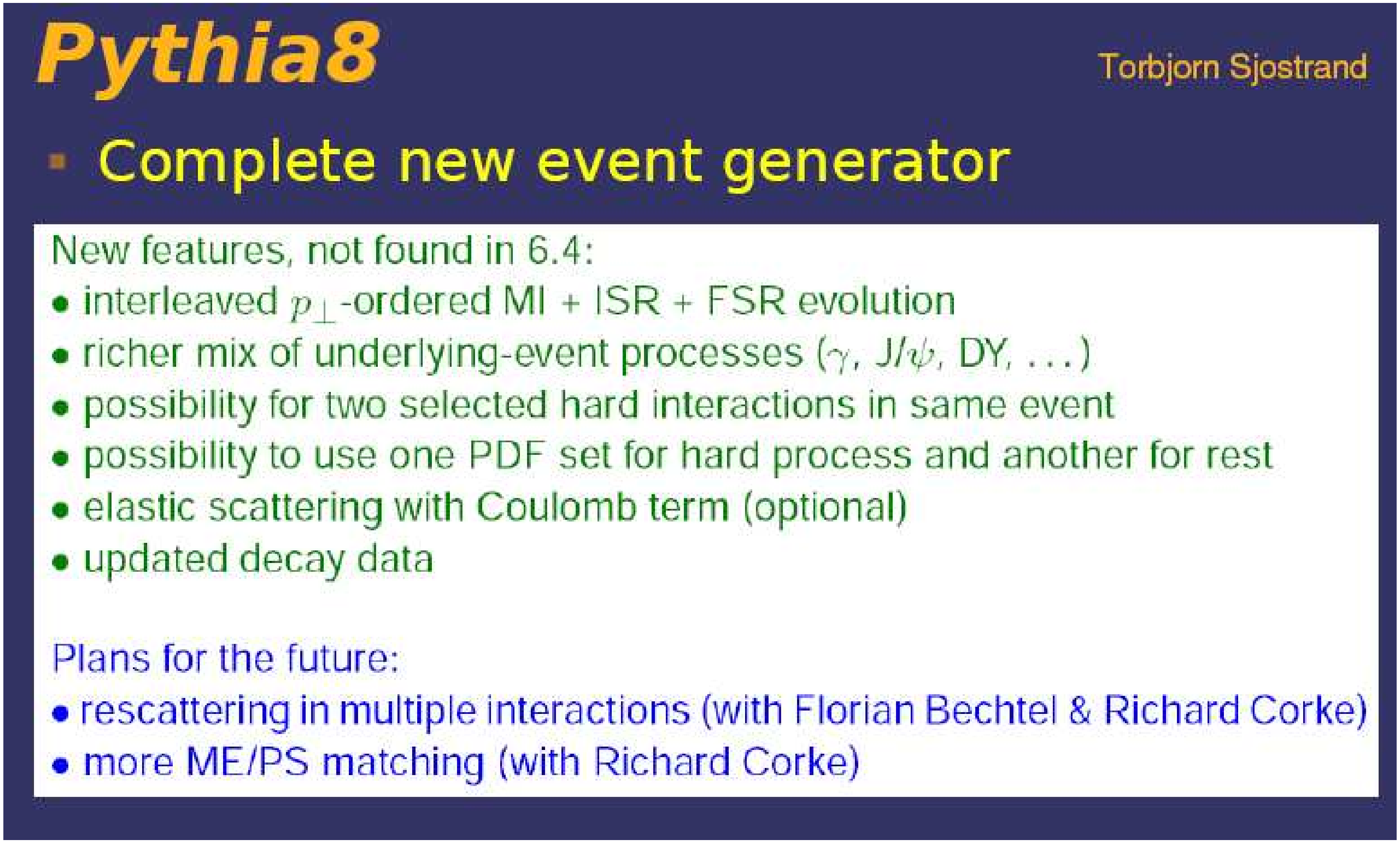
Lots of improvements in new update HERWIG++.

Now available for a lot more people to start using – (Richardson).

Particular improvement in description of underlying event (Bähr).



Lots of improvements in new update PYTHIA8.



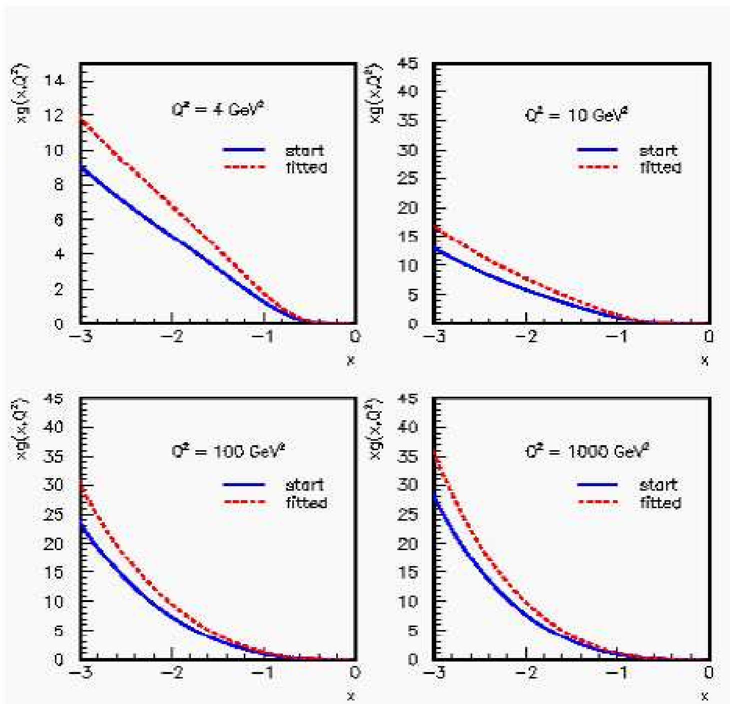
Point 4 due to suggestion that some PDFs, e.g. LO, are appropriate for some process, e.g. underlying event, and others, e.g. NLO for different processes, e.g. W, Z production. Not likely to be used. Full circle to PDF4LHC.

One approach, obtain PDFs by fitting using Monte Carlo – PDF4MC (Jung).

- branch 2: use standard MCEG like PYTHIA/HERWIG/RAPGAP but also ALPGEN/SHERPA etc and obtain PDFs from fits to F_2 and TeVatron data, as done in global analyses
  - neither LO or NLO is appropriate
  - define MC-PDFs, depend on generator, parton showers etc
    - **MC-factorization scheme.... instead of MS bar**
  - include proper treatment of parton showers in initial and final state
  - include all kinematics from full simulation, no approximations

- Use LO fit....
- Fit F_2 by varying $xg(x,\mu) = A_0 x^{A_1} \dots$ and $\alpha_s(\mu)$
- Fit changes normalization and slope of gluon ... as seen in the scan....
- χ^2/ndf improves...., but can still be better....

➔ Not yet the final answer...

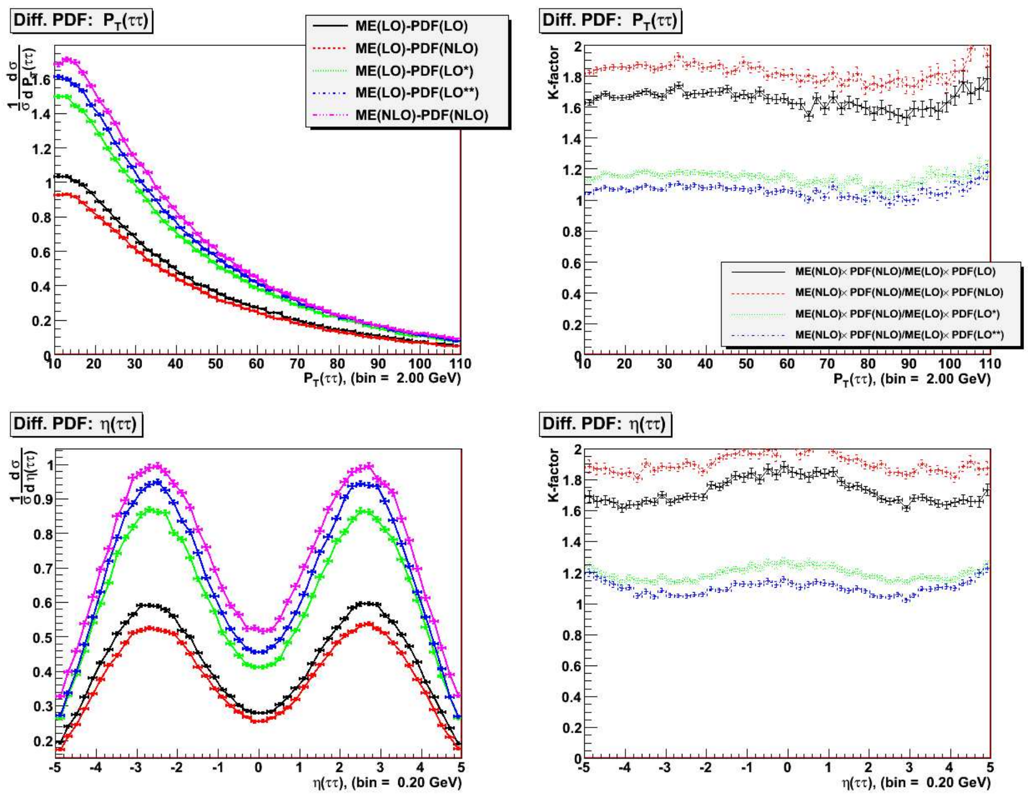


A lot of work to do thoroughly.

My concern that good simultaneous fit will be difficult.

Problem with working entirely at LO, most NLO corrections positive, many large. Global good fit and predictions not possible.

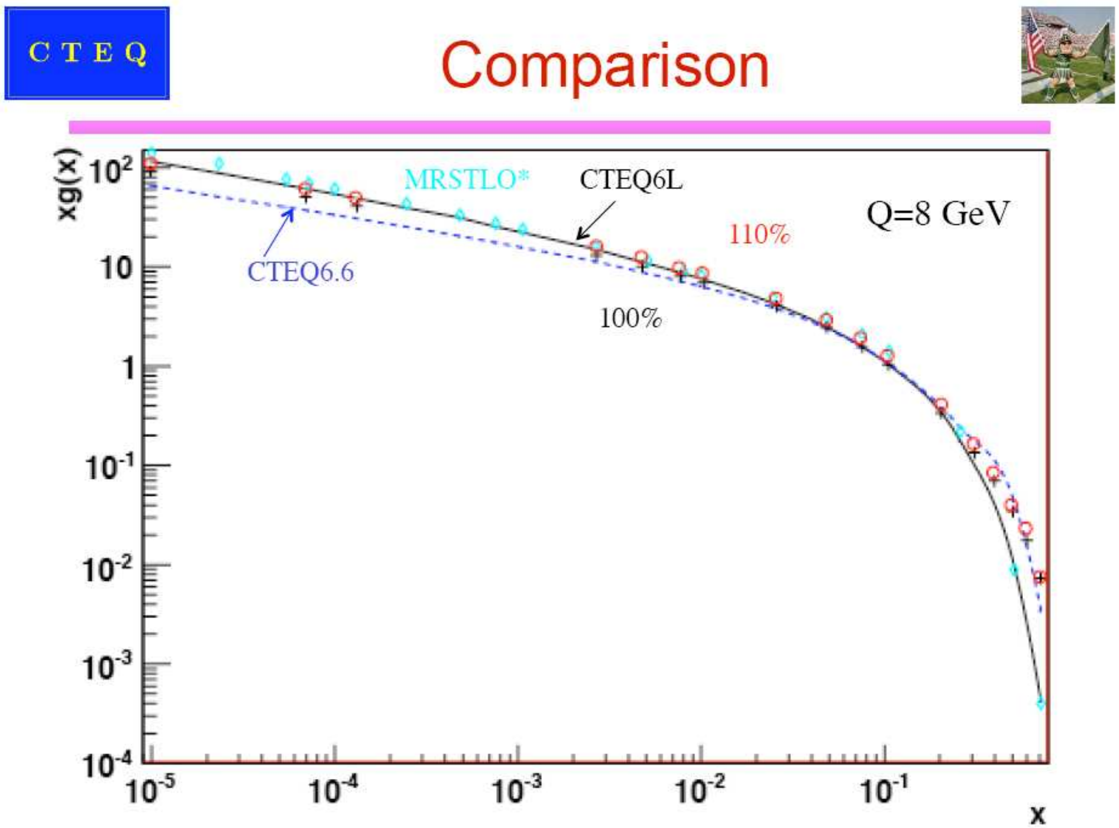
→ **Modified LO partons for LO Monte Carlos** – RT, Sherstnev. Enhancement of LO* partons from momentum violation, plus use of NLO coupling with Monte Carlo inspired scale in α_S generally leads to best match to full NLO predictions.



Leads to much better prediction for Higgs (and many other processes) than LO or NLO PDFs. LO* and LO** available at LHAPDF for a few months.

Similar sets in preparation by CTEQ. Presented at PDF4LHC in June 2008 (Huston).

Based also (sometimes) on momentum violation in input and sometimes in this case fitting to pseudodata.



Similar to MRSTLO* and not CTEQ6.6. Final version to be decided on soon.

PDFs for Monte Carlos (one of many) ongoing project(s).

Conclusions

Consider objectives – as listed by Hannes Jung.

➔ To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.

➔ To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

➔ To encourage and stimulate theory and phenomenological efforts.

➔ To examine and improve theoretical and experimental tools.

➔ To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.

Clearly been very successful in all of these, and Hannes and Albert deserve both congratulations and thanks.

Couple of minor comments:

– As talk shows, despite name of Workshop Tevatron results and people also made big contribution and involved in collaborations.

– Lot of people at LHC who looked in at first meeting decided to forget about importance of QCD. Will be forced to remember when data comes in.

Future

Clearly end of Workshops in this precise form.

However, work started will undoubtedly continue in some form.

From **Parton density functions** working group have developed PDF4LHC committee and series of smaller workshops – February, July and September 2008.

Already been a MC4LHC workshop, and continuing effort in MCNET network.

It would seem as though there is definitely scope for something similar along the lines of Jets4LHC, Diff4LHC, CandB4LHC *etc.*.

Really should build on the good work started and many collaborations established by the HERA-LHC series.