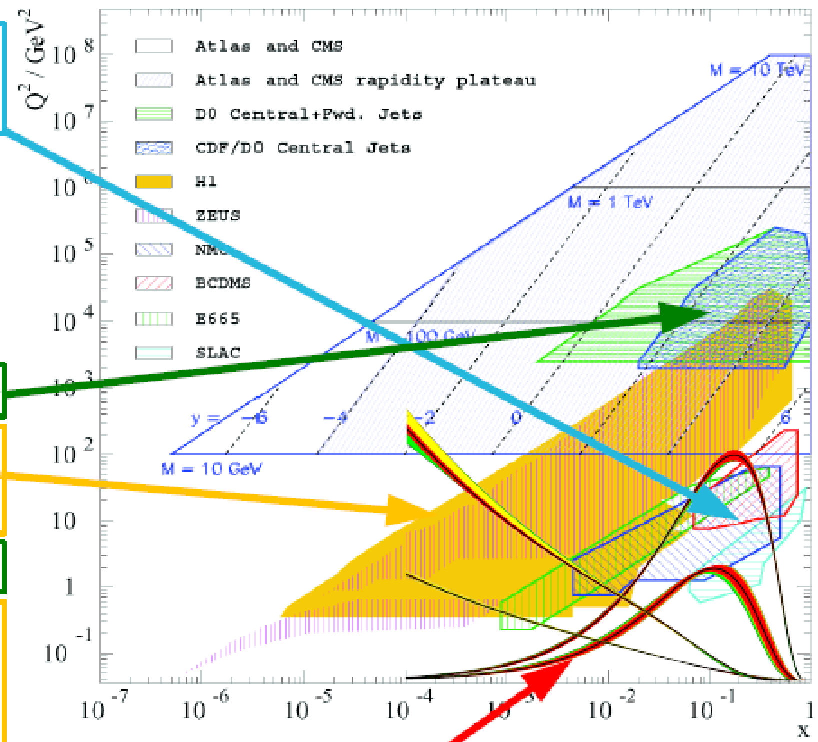
Selected Summer Conference Results In Particle Physics

Viatcheslav Sharyy

September 27, 2010

PDF: experimental information

Process	Experiments	Partons
DIS Fixed target	BCDMS, NMC, E665, SLAC	q, g
DIS $\nu - N$	NuTeV, CHORUS, CCFR	q, s
pp, pN Drell Yan	E605, E772, E866/NuSea	q, g at high x
W, Z in $p\bar{p}$ collisions	CDF, D0	$d, u, d/u$ at medium x
DIS collisions	HERA	q, g
Jets in ep collisions	HERA	g, q
Jets in $p\bar{p}$ collisions	CDF, DO	g, q at high x
F_L in DIS	HERA	g
$c\bar{c}$ in ep collisions	HERA	g, c
$b\bar{b}$ in ep collisions	HERA	g, b



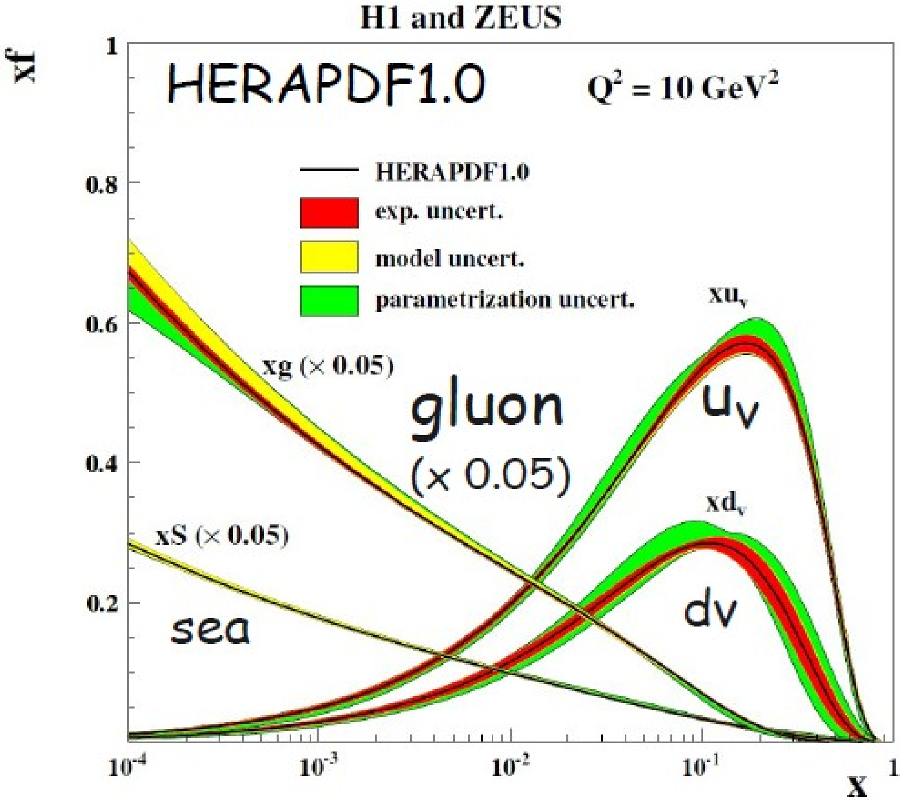
- Global fits: PDFs determination using available data sets
  - ➔ Different extractions, based on different data sets
  - ➔ Differences in theoretical treatments (α_s, heavy flavours, ...)
  - ➔ "Global": MSTW, CTEQ, NNPDF
  - ➔ DIS + DY: AKP, JR
  - ➔ HERA only: HERAPDF

E. Sauvan – LAPP Annecy   ICHEP10, Paris – Experimental QCD Results and Impact on LHC Physics - 5

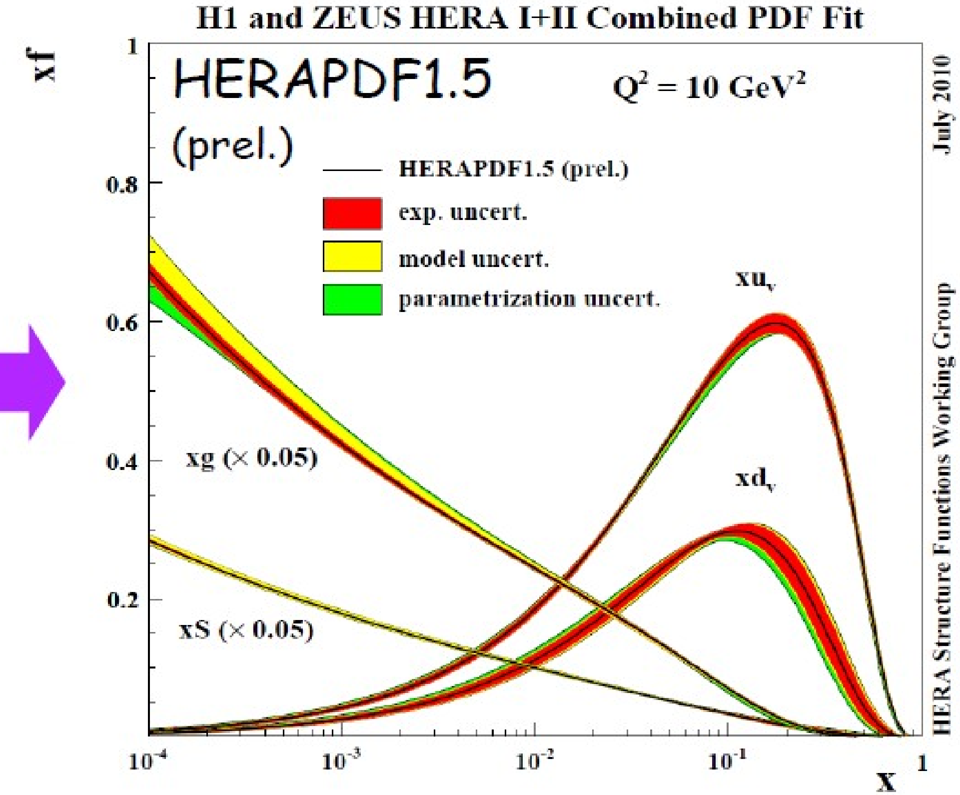
PDF: determination from HERA alone

→ HERA data are enough to determine PDFs of good precision

- HERA I combined data



- Including HERA II



- Advantage: controlled systematics
  - → Errors estimated using $\Delta\chi^2 = 1$
  - → Parametrisation error addressed

→ Errors reduced at high x, mainly visible on valence distributions

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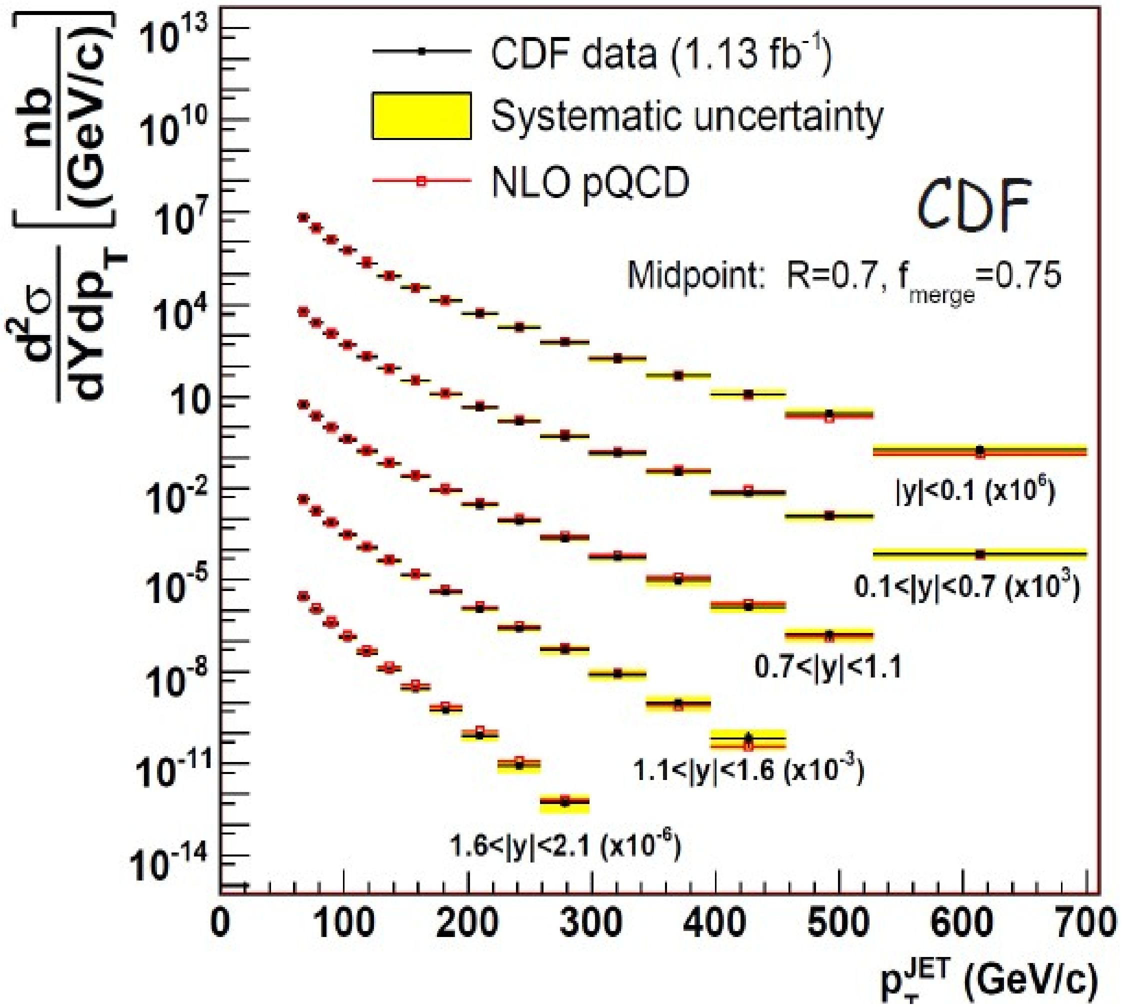
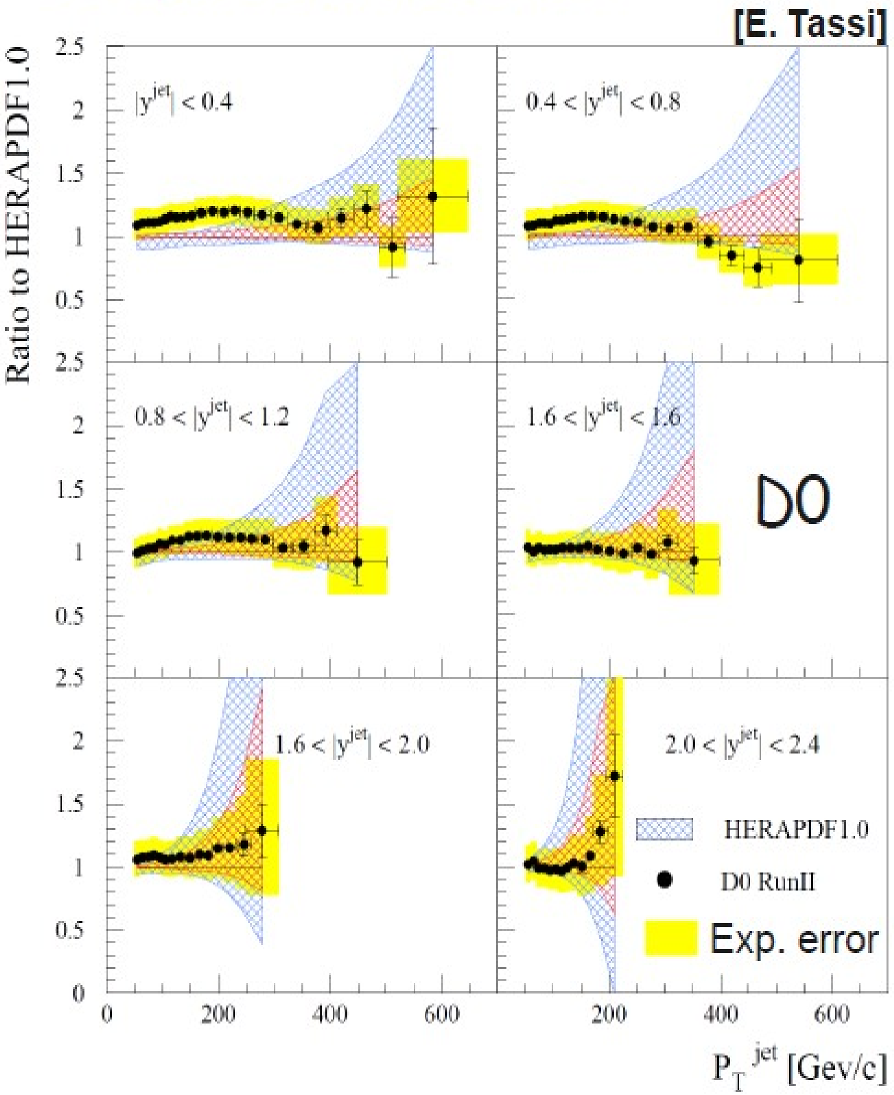
PDF: gloan from jets at Tevatron

- Tevatron jets: constraint the gluon at high x
- Dominant exp. error:
  jet energy scale, now 1%



- Compared to HERAPDF:



PDF: Status

- QCD dynamics of the proton plays a central role in LHC physics
  - ➔ Hard cross sections calculation, underlying event, soft physics, ...
  - ➘ Understanding of its structure being tighten up by HERA and Tevatron colliders

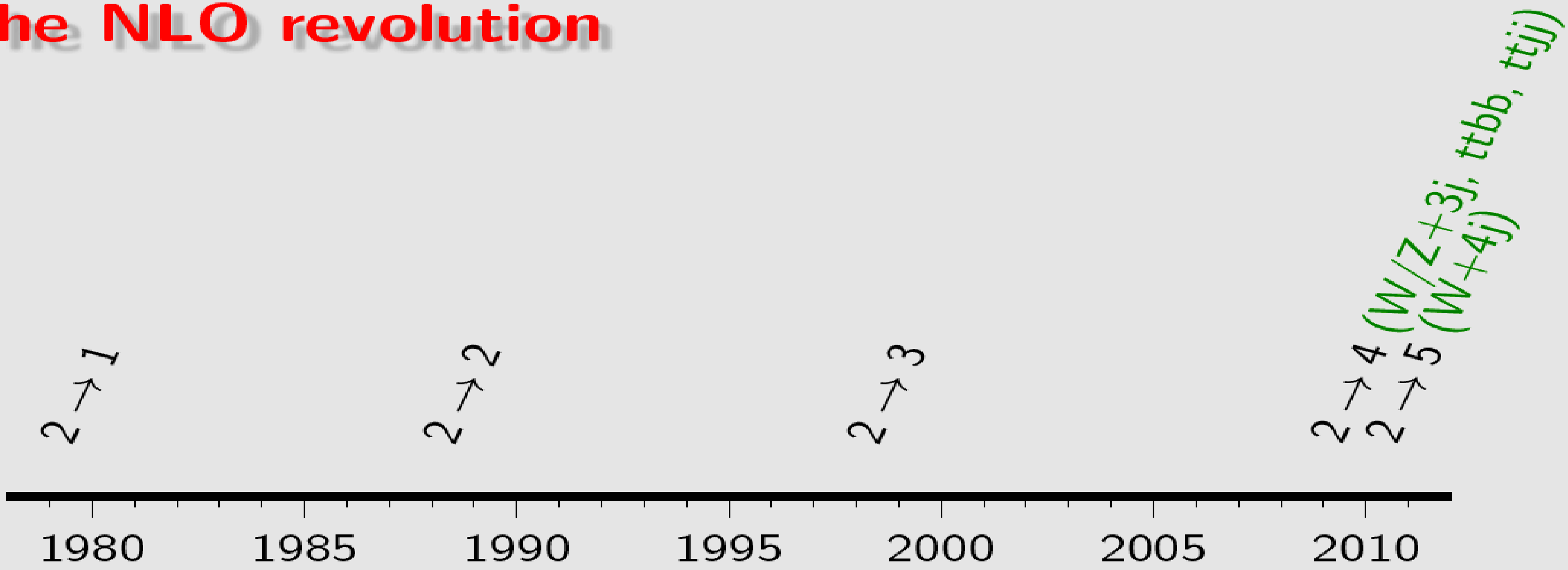
    (PDFs can only be measured and not predicted)

- Increased precision of data
  - ➔ HERA is delivering its final data with optimal precision
  - ➔ More exclusive observables: jets, heavy flavours, ...
  - ➔ Diffractive measurements now entering the precision era

➘ Numbers of measurements now challenging the theory precision

Progress in MC tools

The NLO revolution



2009: NLO W+3j [Rocket: Ellis, Melnikov & Zanderighi] [unitarity]

2009: NLO W+3j [BlackHat: Berger et al] [unitarity]

2009: NLO $t\bar{t}b\bar{b}$ [Bredenstein et al] [traditional]

2009: NLO $t\bar{t}b\bar{b}$ [HELAC-NLO: Bevilacqua et al] [unitarity]

2009: NLO $q\bar{q}\to b\bar{b}b\bar{b}$ [Golem: Binoth et al] [traditional]

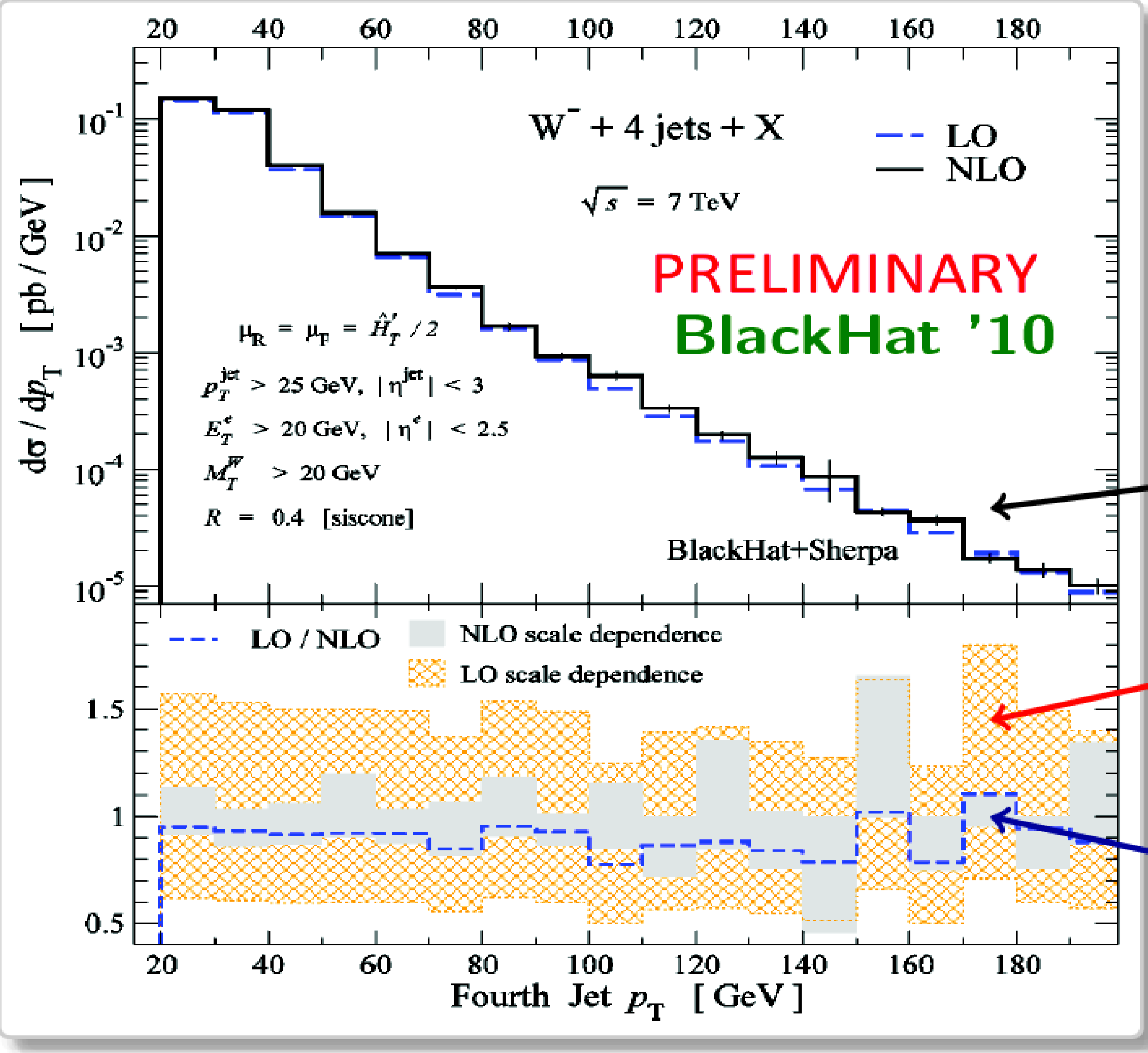
2010: NLO $t\bar{t}jj$ [HELAC-NLO: Bevilacqua et al] [unitarity]

2010: NLO Z+3j [BlackHat: Berger et al] [unitarity]

2010: NLO W+4j [BlackHat: Berger et al, preliminary] [unitarity]

[NLO]

NLO $pp \to W + 4$ jets



First (nearly) complete $2 \to 5$ computation
(as needed in our SUSY example)

NLO spectrum of 4th jet!

LO uncertainty

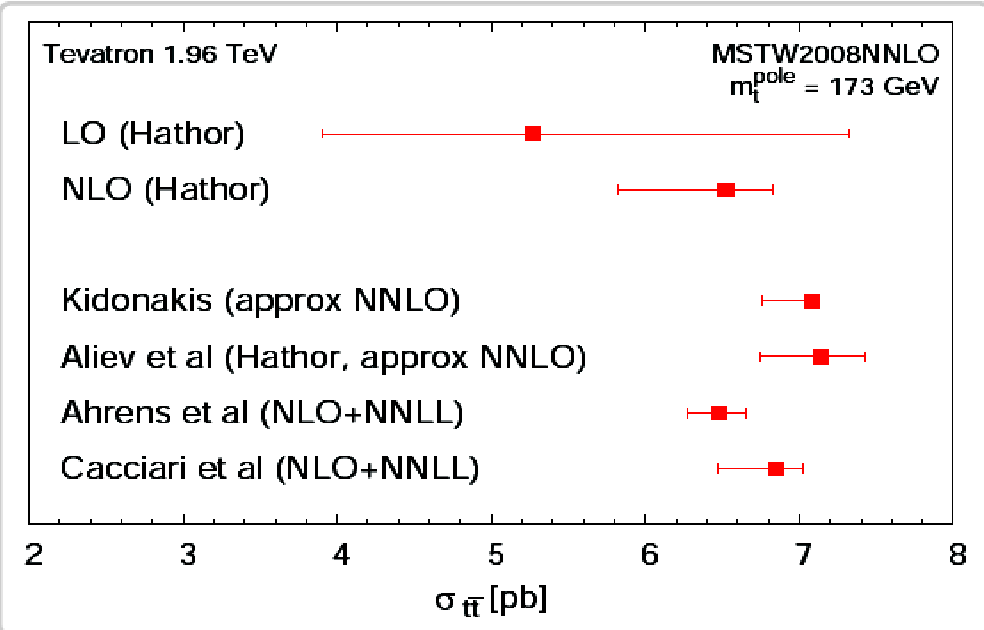
NLO uncertainty

[Currently, leading colour & missing W+6q diags]

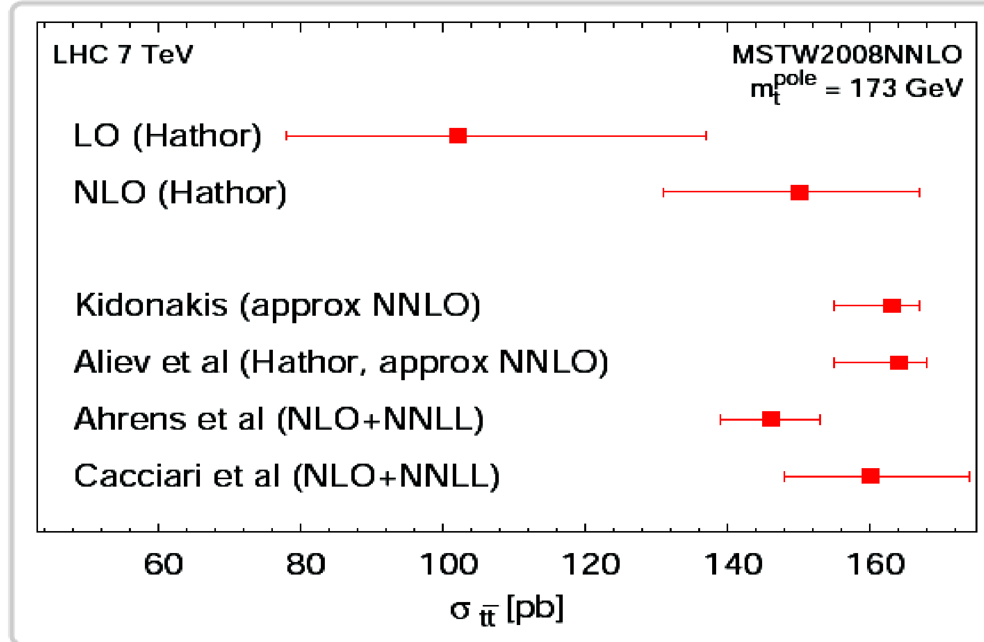
Progress in NNLO calculation

$t\bar{t}$ cross sections

Tevatron 1.96 TeV



LHC 7 TeV



Uncertainties shown are theory (scale) only; no PDF uncertainties

The kinds of differences that are present:

Ahrens et al '10, NNLL+NLO: threshold around $m_{t\bar{t}}$
Aliev et al '10 (Hathor), NNLO approx: threshold around $2m_t$
Procedures for scale dependence and estimating unknown NNLO terms

Much has been learnt about $t\bar{t}$ near threshold

But consensus on cross section & errors not yet reached.

QCD calculation and MC tools status

Several major long-term projects now close to maturity

- The C++ event generators: Herwig++, Sherpa and Pythia 8
- NNPDF global fit with robust error estimates

Breakthroughs:

- NLO calculations, first $2 \to 5$ results (W+4j) Next step: automation
- Jet finding — IR safety; pulling out hadronic signals previously thought impossible

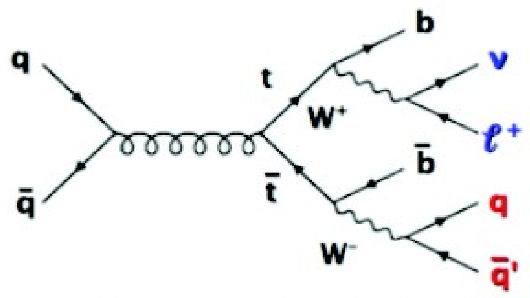
High accuracy:

- Much work on NNLO $t\bar{t}$ and (NNLL) approximations

  And several other processes, e.g. Z/W/H, γj, jj, Vj
- Open questions: estimation of uncertainties; impact of hadronisation

And much else that could not be covered in 30 minutes!

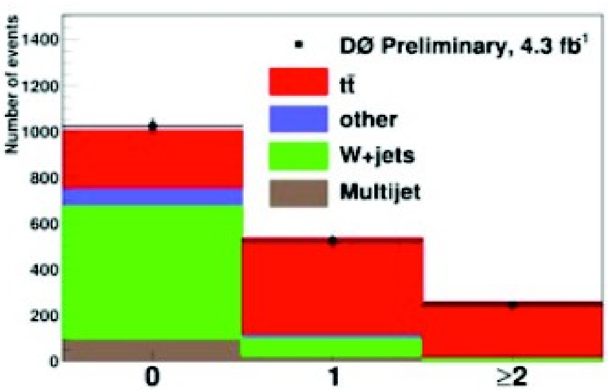
Top: pair cross-section



l+jets channel

Methods:

- kinematical information
- b-jet identification



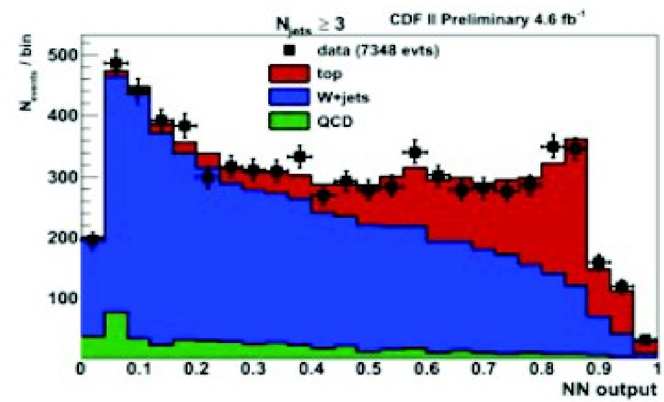
$$\sigma_{t\bar{t}} = 7.70^{+0.79}_{-0.70}(\text{total})\text{pb}$$

Total uncertainty ~10-12%

- First step in understanding selected top quark sample
- Test of theoretical QCD calculations

- Limited by systematics, luminosity dominates at ~6%.
- Take ratio to Z cross section: trade for Z theory uncertainty

4.6 fb-1 PRL 105:012001,2010



Combined topological and b-tagged

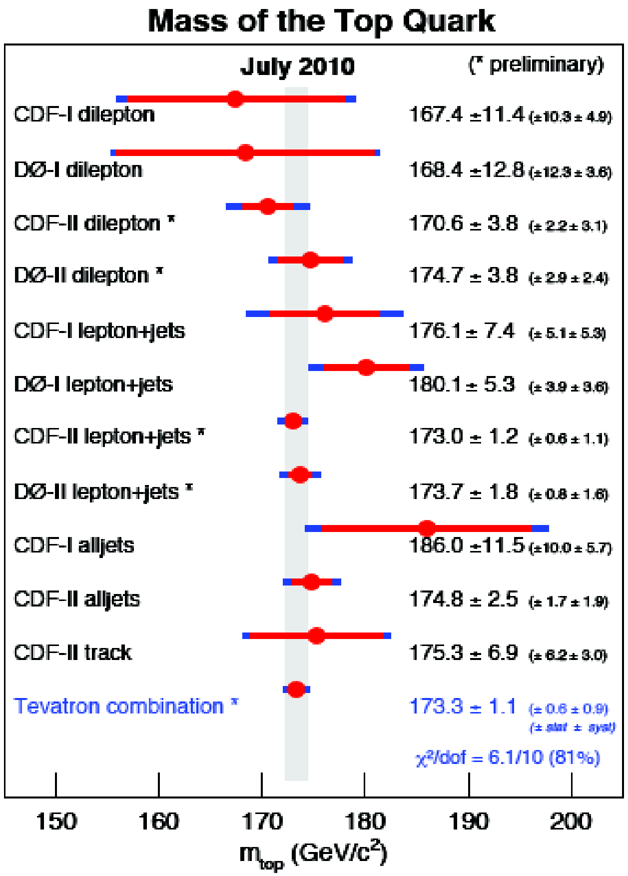
$$\sigma_{t\bar{t}} = 7.70 \pm 0.52(\text{total})\ \text{pb}$$

7% relative precision, 9% with luminosity uncertainty

CDF combination: 6% precision!

July 26, 2010 E.Shabalina -- The physics of top, W and Z -- ICHEP 2010 - Paris 23

Top: Tevatron mass combination



new

0.6% relative uncertainty

m_{top}=173.3±1.1(total) GeV

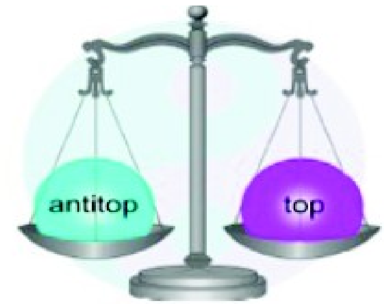
- Measurement in different channels consistent with each other
- Different methods produce consistent results

statistical component of JES
b-jet response
b-jet energy scale
modeling uncertainties
residual JES
detector response
ISR/FSR, PDF, NLO
showering model

Systematic source	δm_{top} (GeV)
iJES	0.46
aJES	0.21
bJES	0.20
cJES	0.13
dJES	0.19
rJES	0.15
Lepton p_T	0.10
Signal model	0.19
Background	0.23
Fit	0.11
MC generator	0.40
Color reconnection	0.39
Multiple interactions	0.08
Total	1.06

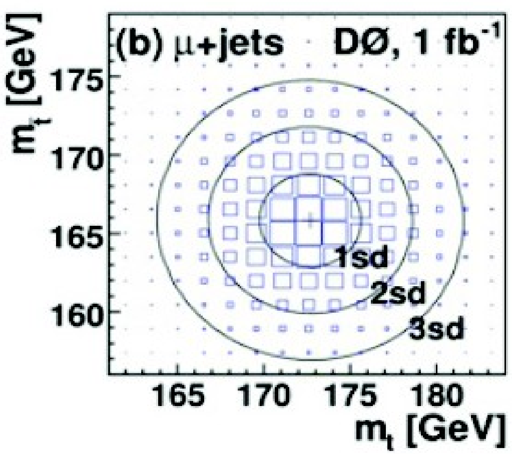
Is top quark mass equal to anti-top quark mass?

Drop assumption $m_t = m_{\bar{t}}$ in top mass measurement



DØ

- Extension of ME mass analysis
- m_t, JES → m_t, $m_{\bar{t}}$



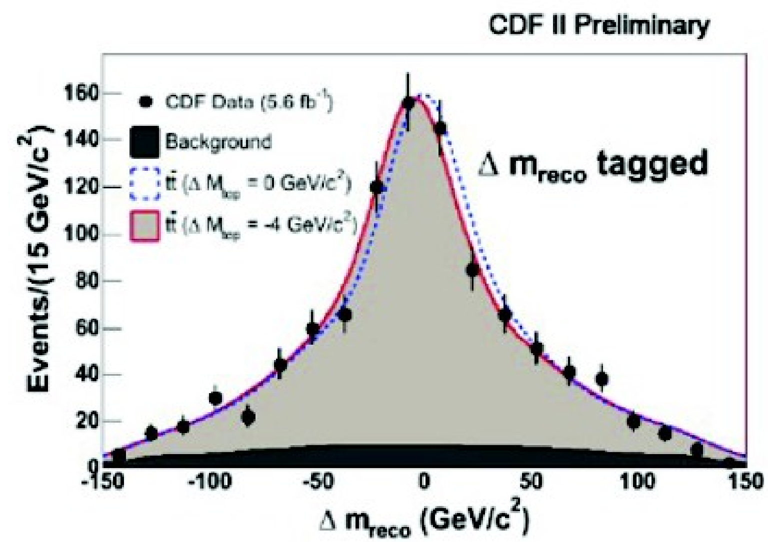
ΔM_{top} = 3.8 +/- 3.7 GeV/c²

PRL 103, 132001 (2009)

First measurements of mass difference of bare quarks

CDF

- Template method
- variables: Δm_{reco} and $\Delta m_{reco(2)}$



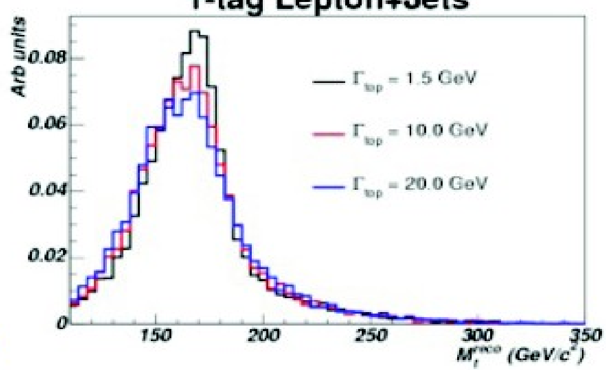
ΔM_{top} = -3.3 +/- 1.4(stat.) +/- 1.0 (syst.) GeV/c² 5.6 fb^{-1}

Top: width

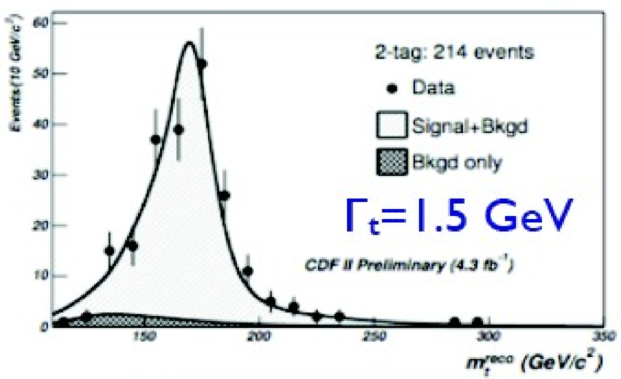
Standard Model: $\Gamma_t \sim 1.5$ GeV at NLO for $m_t = 172.5$ GeV

Additional decay modes: $t \rightarrow H^+b$, $t \rightarrow dW^+$, $t \rightarrow sW^+$?

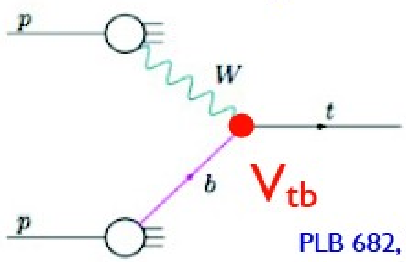
- Direct measurement
- use dependence of the reconstructed m_{top} on Γ_t

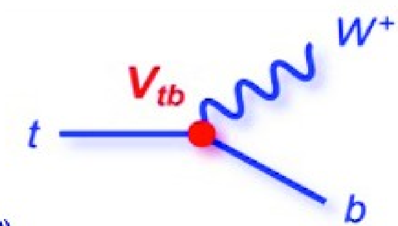


$\Gamma_t < 7.5$ GeV at 95% CL



- Indirect measurement
- use single top t-channel cross section
- combine with measured branching ratio
- assumption: coupling in top production and decay is the same





PLB 682, 363 (2010)

$$\Gamma_t = \frac{\sigma(t-ch)}{\mathcal{B}(t \rightarrow bW)} \times \frac{\Gamma(t \rightarrow bW)_{\rm SM}}{\sigma(t-ch)_{\rm SM}}$$

PRL 100, 192003 (2008)

$$\Gamma_t = (2.05^{+0.57}_{-0.52})\,\text{GeV}$$

$$\tau_t = (3.2^{+1.1}_{-0.7}) \times 10^{-25}\,s$$

Consistent with the standard model

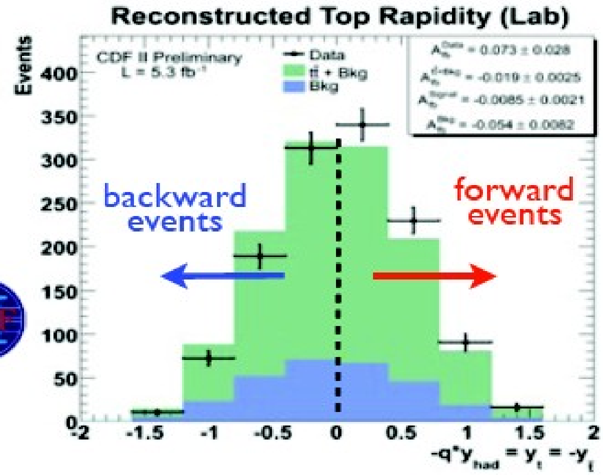
Top: forward-backward asymmetry

- LO: top quark production angle is symmetric with respect to beam direction
- NLO: asymmetry due to interference effects

l+jets events, $p\bar{p}$ rest frame

$$A_{fb} = \frac{N(-Q \times Y_{had} > 0) - N(-Q \times Y_{had} < 0)}{N(-Q \times Y_{had} > 0) + N(-Q \times Y_{had} < 0)}$$

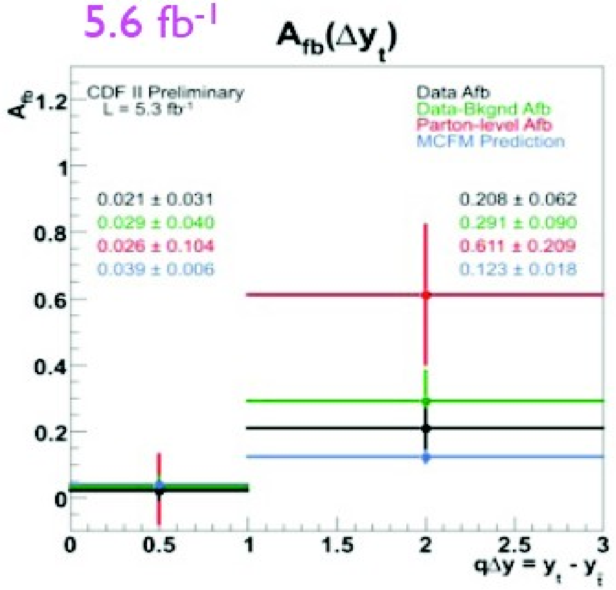
Q - lepton charge, Y_{had} - rapidity of hadronic top



unfolded: A_{fb} ($p\bar{p}$) = 15.0 ± 5.0 (stat) ± 2.4 (syst) %

2.7σ deviation from 0

5.6 fb^{-1}

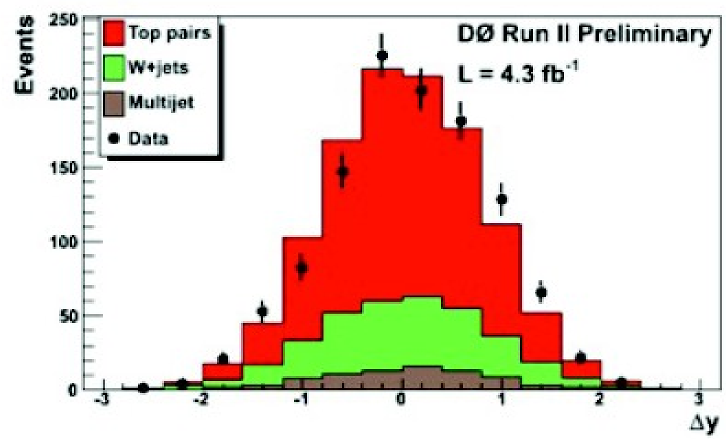


new

2.4 σ deviation from 0

A_{fb} (|Δy|<1.0)= 2.6 ± 10.4(stat) ± 5.5(syst) %
A_{fb} (|Δy|>1.0)= 61.1 ± 21.0(stat) ± 14.1(syst) %

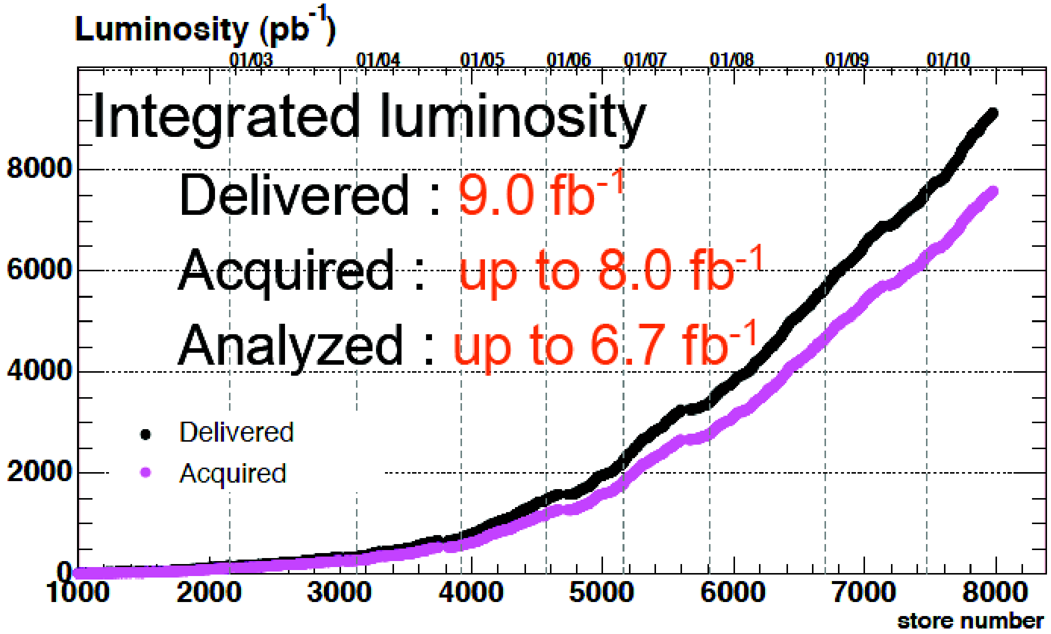
~30 theory papers in last 2 years!



A_{fb}^{raw}(Δy)=8±4(stat)±1(syst) %

4.3 fb^{-1}

predicted MC@NLO: $A_{fb}=1^{+2}_{-1}$ %



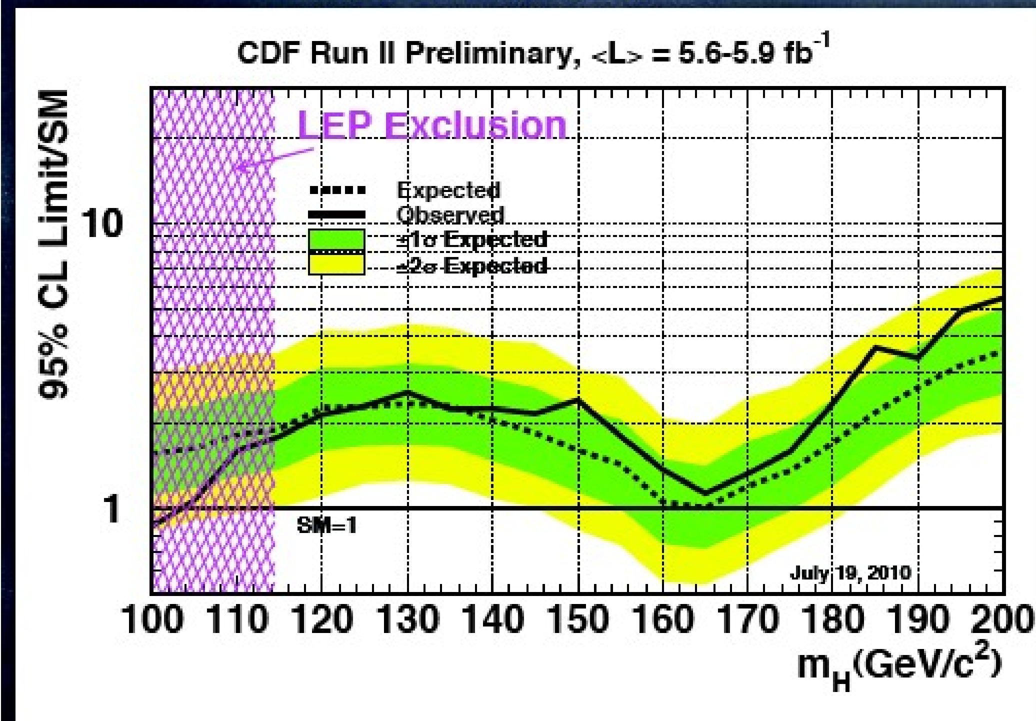
Channel	Expt	Dataset now	Increase since Nov. 2009 combination
H → WW	D0	6.7	24%
H → WW	CDF	5.9	23%
WH → lνbb	CDF	5.7	30%
WH → lνbb	D0	5.3	6%
ZH/WH→METbb	CDF	5.7	60%
ZH/WH→METbb	D0	6.4	23%
ZH → llbb	CDF	5.7	40%
ZH → llbb	D0	6.2	45%
H → γγ	CDF	5.4	New!
H → γγ	D0	4.2	0%
H → ττ	CDF	2.3	15%
H → ττ	D0	4.9	0%
ZH/WH→qqbb	CDF	4	100%
ttH	D0	2.1	0%

Ben Kilminster, ICHEP 2010

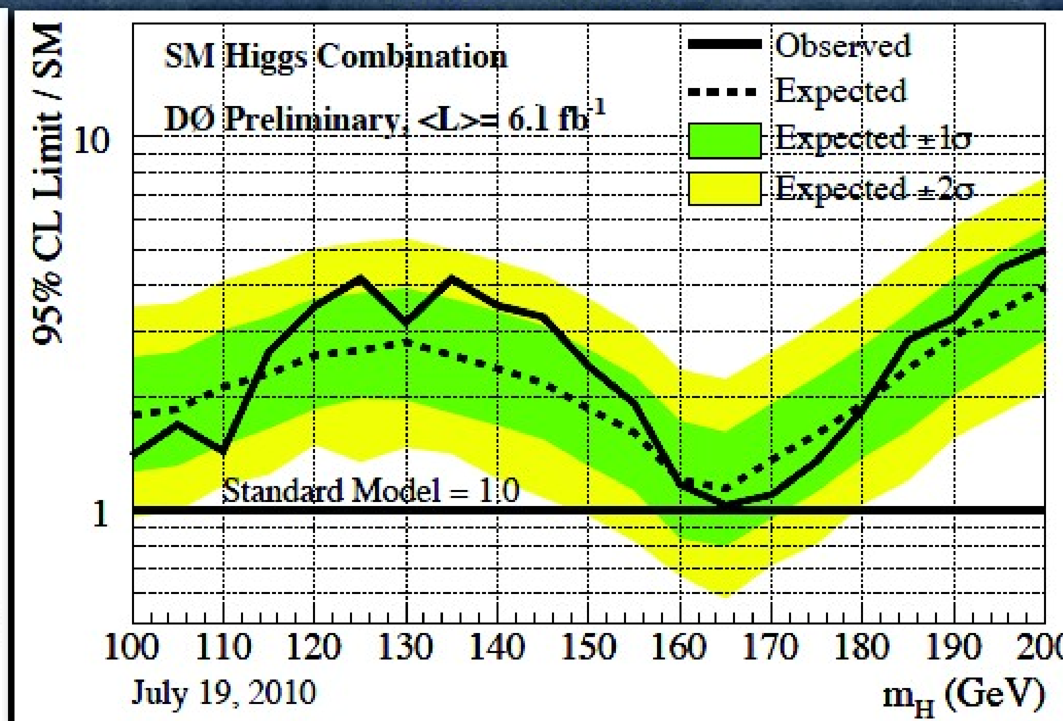
CDF & D0 combinations

Shown first on July 23, 2010

CDF's limits



D0's limits



CDF achieves expected exclusion at 165 GeV

D0 almost achieves observed exclusion at 165 GeV

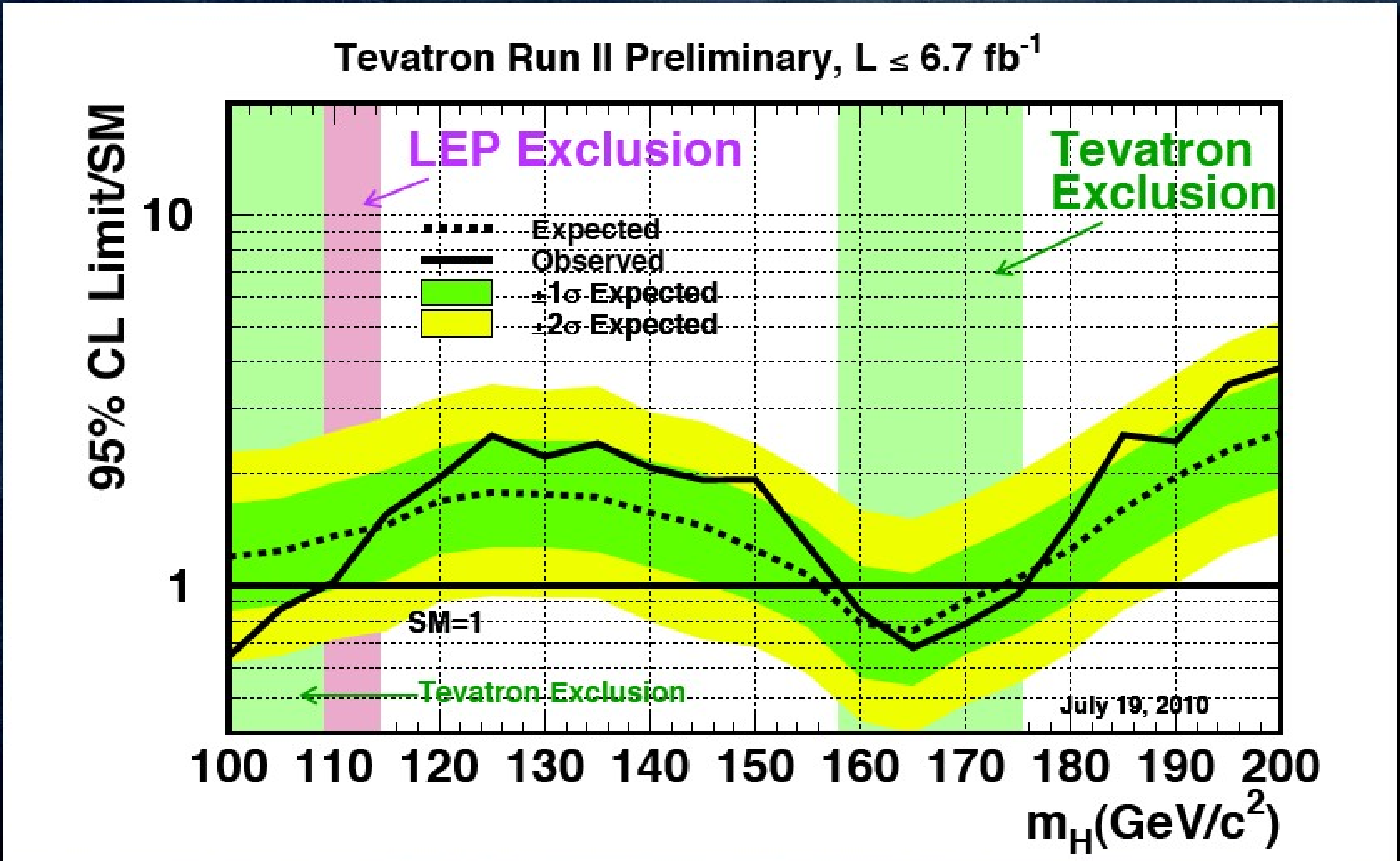
@ m_H = 100 GeV, both set observed limits below expected

Closing in on low mass LEP exclusion

Ben Kilminster, ICHEP 2010 23

Tevatron combination

"Expected sensitivity"



- Low mass sensitivity approaching LEP exclusion :
  - Expected 1.45*SM @ 115 GeV
  - Expected 1.24*SM @ 105 GeV
- High mass 95% CL exclusion :
  - $158 < m_H < 175$ GeV
    - 4 times previous (162 - 166 GeV)
    - Expected ($156 < m_H < 175$ GeV)

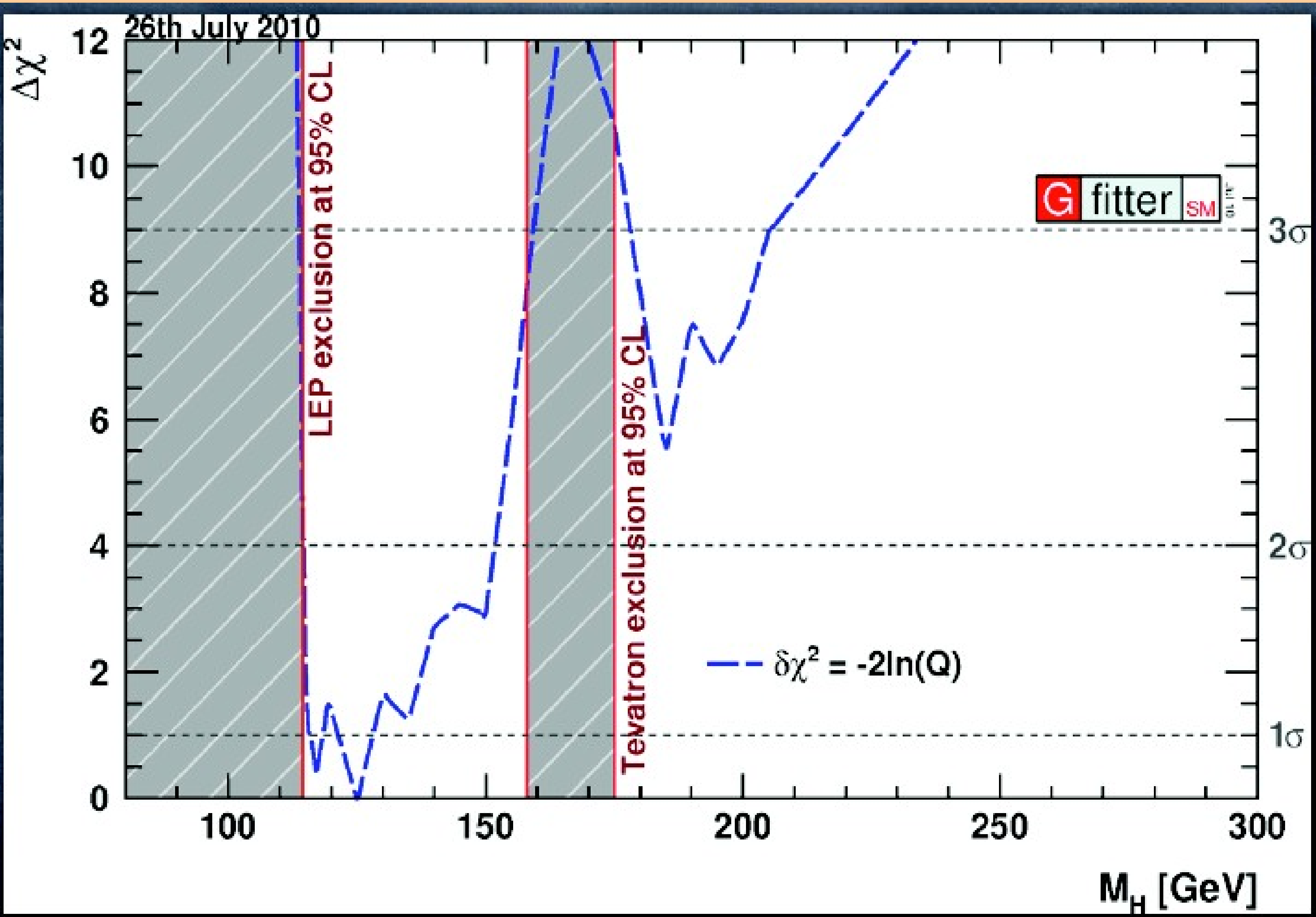
minimum:

$m_H = 125.029$ GeV

1 sigma range(s):
[115.752, 118.411]
[121.342, 128.053]

2 sigma range(s):
[114.577, 151.804]

3 sigma range(s):
[113.81, 159.307]
[178.124, 205.285]



95 % CL upper Limit is 151.537 GeV !!!
99 % CL upper Limit is 155.988 GeV !!!

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~16 fb^{-1} :*

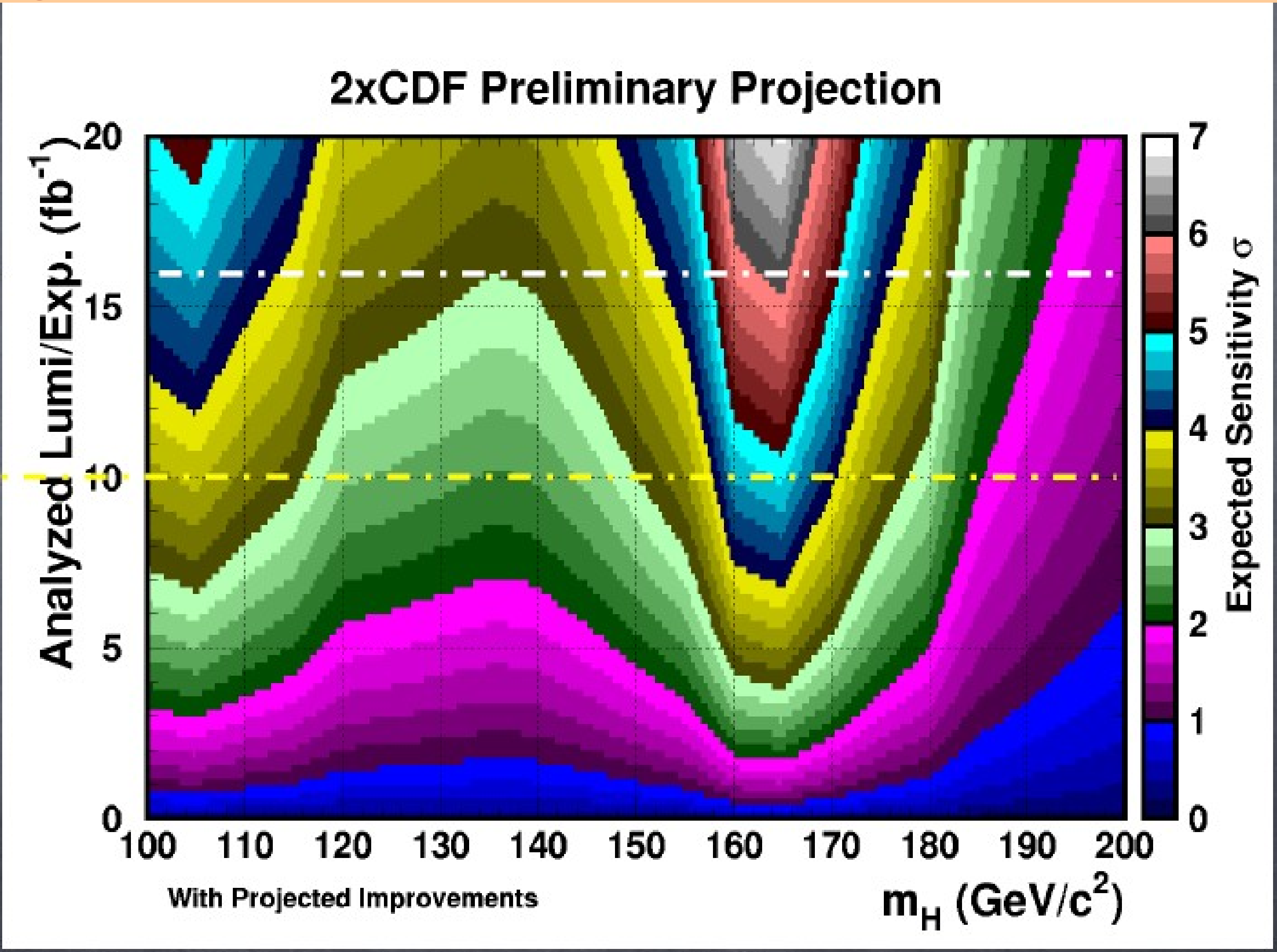
> 3 σ expected sensitivity from 100 – 185 GeV

4 σ @ 115 GeV

End of 2011:

> 2.4 σ expected sensitivity across mass range

3 σ at 115 GeV



* 16 fb^{-1} : based on "Run III" proposal to run 3 more years

Ben Kilminster, ICHEP 2010 37

Higgs: Prospects for Evidence

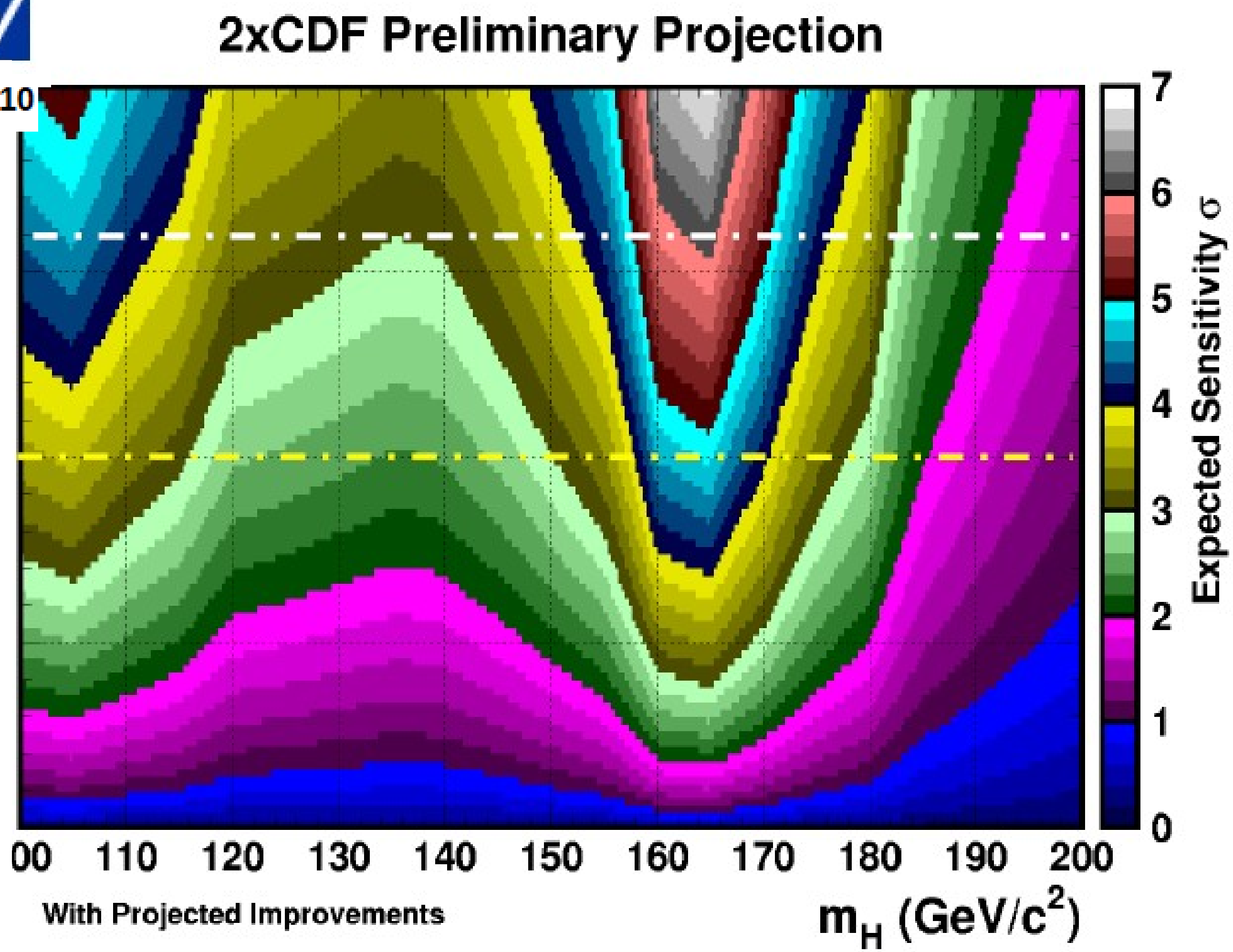
Fermilab Today

Director's Corner **Tuesday, Sept. 21, 2010**

Tevatron

Fermilab Director
Pier Oddone

As described in my column of September 1, the Fermilab Physics Advisory Committee recommended a three-year extension for the Tevatron beyond FY11. We will proceed with the recommendation *provided* we can secure additional resources to continue running the Tevatron while minimizing damage to our Intensity Frontier experiments and avoiding damage to the national high energy physics program beyond Fermilab. Securing additional resources in the present funding climate is a tall order, and it will take some time. However, additional funding is absolutely essential for Tevatron operation beyond FY11. It is also important that we at Fermilab take responsibility for providing some of the needed resources out of our own hide.



III" proposal to run 3 more years

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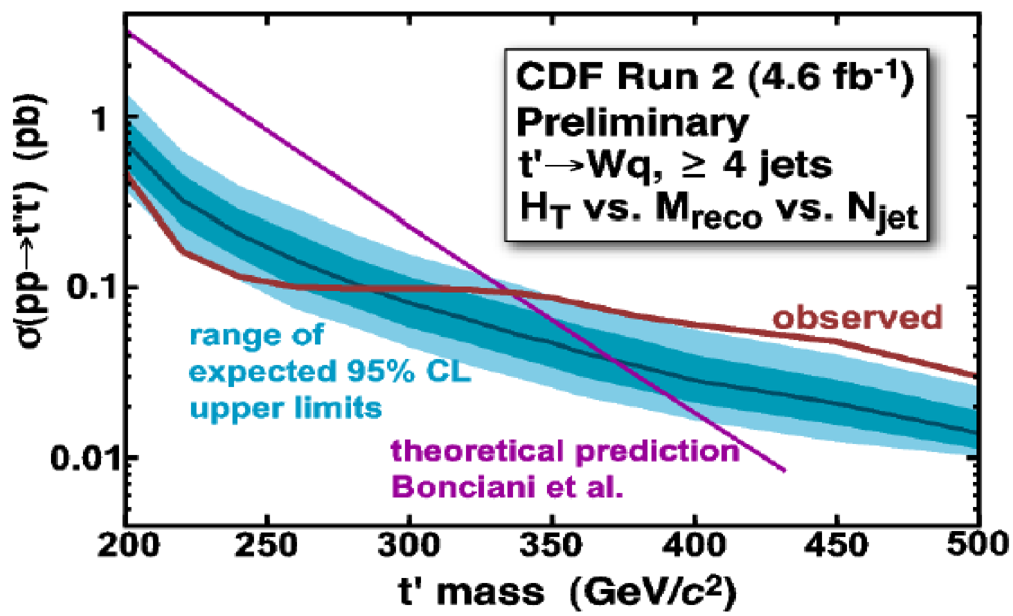
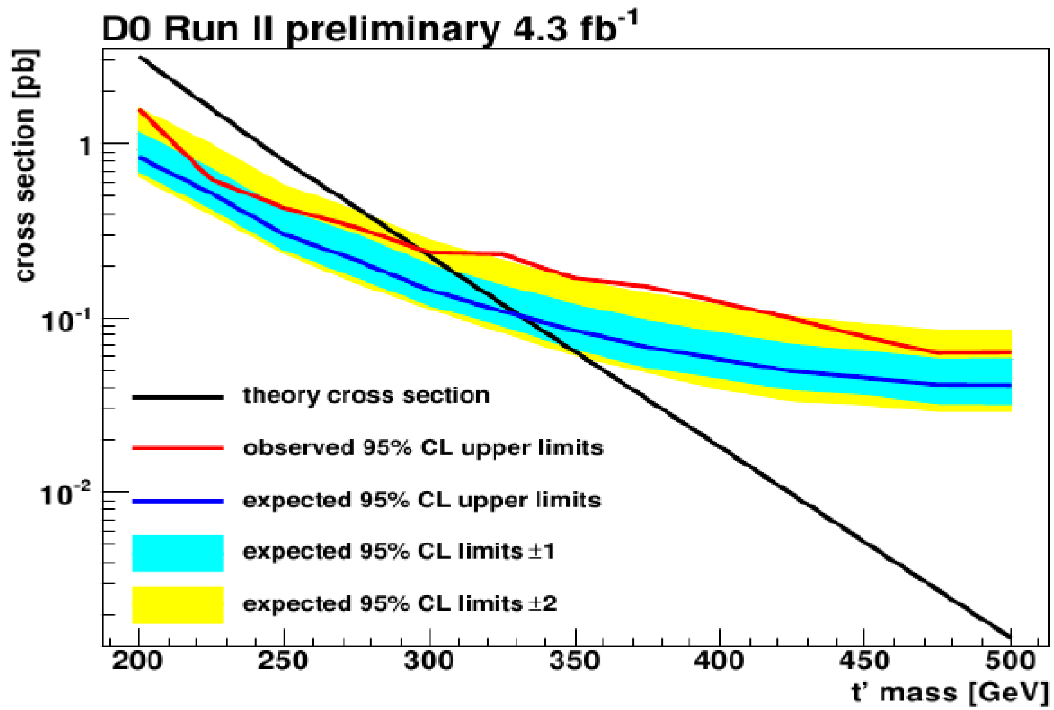
4-th Generation Quarks: Search for Heavy t'

- 4th generation of fermions arises in a set of models
- if mass splitting is small, $M(t') - M(b') < M(W)$, $B(t' \to Wq) = 100\%$
- search for a pair-produced heavy top-like quark





- excluded at 95% CL: $M_{t'} < 335\,GeV$ (CDF'2010) , $M_{t'} < 296\,GeV$ (D0'2010)

$A^b_{sl} = (-0.957 \pm 0.251\ (\text{stat}) \pm 0.146\ (\text{syst})\ )\%$

- This result differs from the SM prediction by ~3.2 σ
- A^b_{sl} produces a band in a^d_{sl} v.s. a^s_{sl} plane:

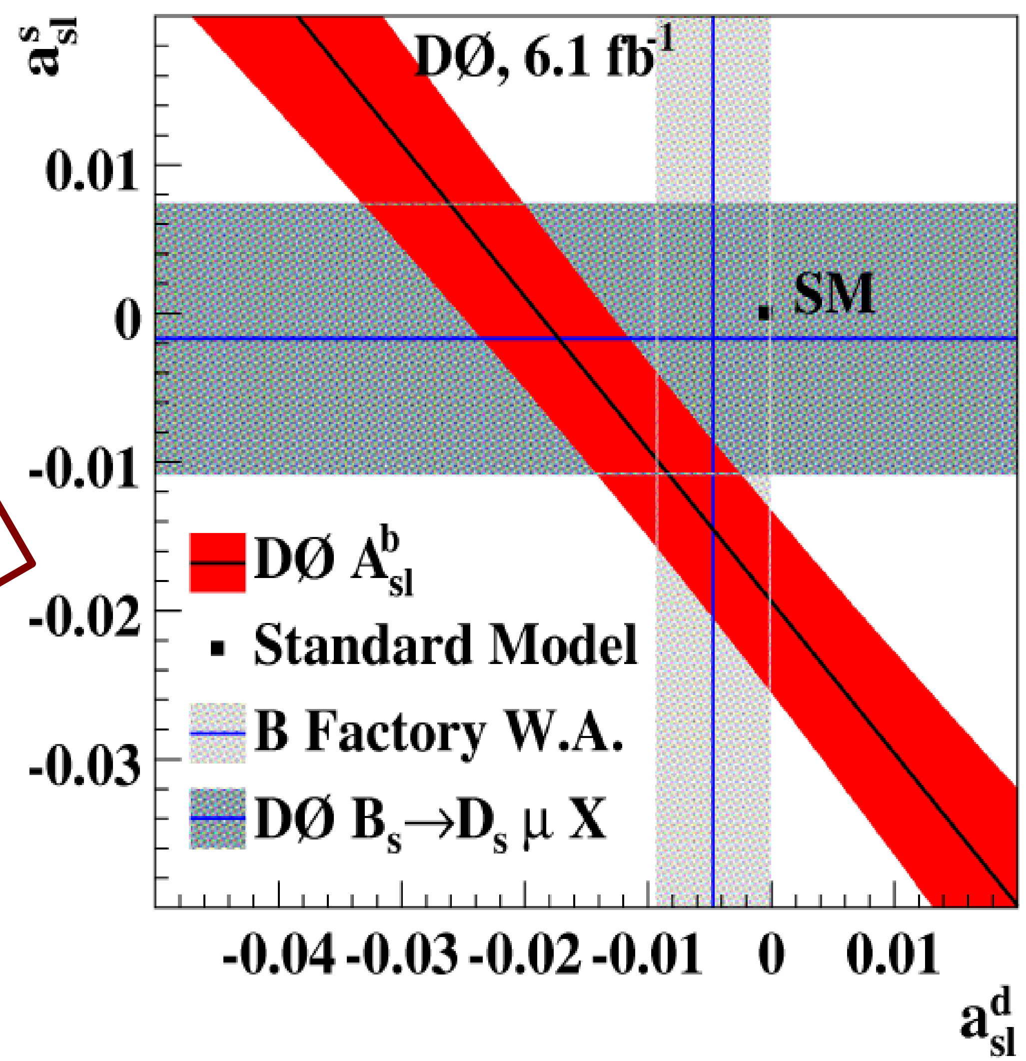
$A^b_{sl} = (0.506 \pm 0.043)\, a^d_{sl} + (0.494 \pm 0.043)\, a^s_{sl}$

- Obtained result agrees well with other measurements of a^d_{sl} and a^s_{sl}

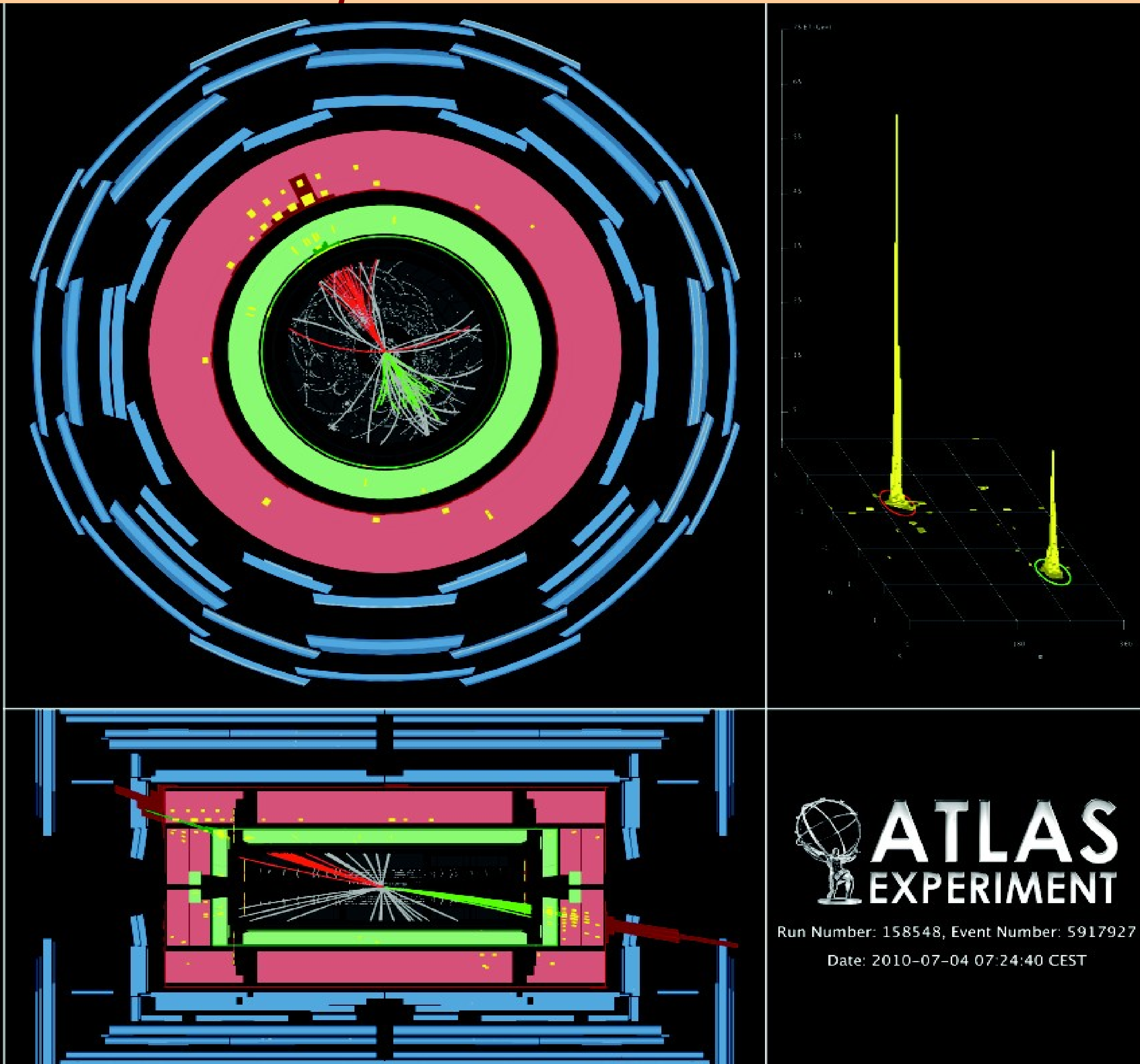
See slides from SPP seminar by G.Borissov,
20 September 2010

2010/07/2 BSM searches through B

B. Hoeneisen, ICHEP-2010,
DØ Collab., arXiv:1005.2757 accepted by PRD
DØ Collab., arXiv:1007.0395 accepted by PRL



LHC Start-up



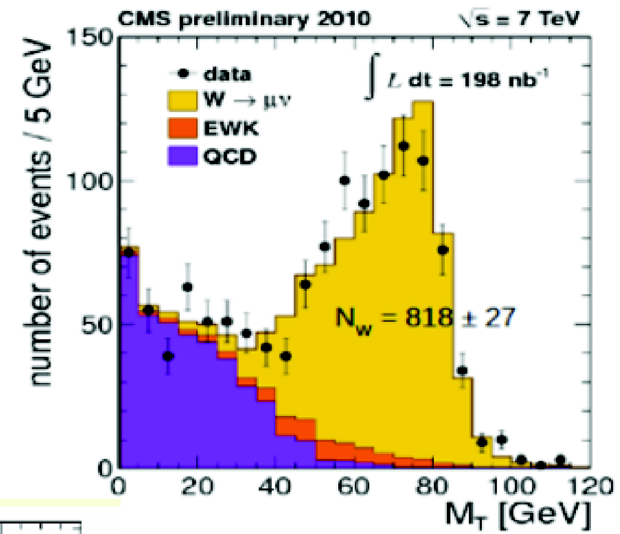
m^{j1j2} =2.55 TeV

p_T (j_1)= 420 GeV

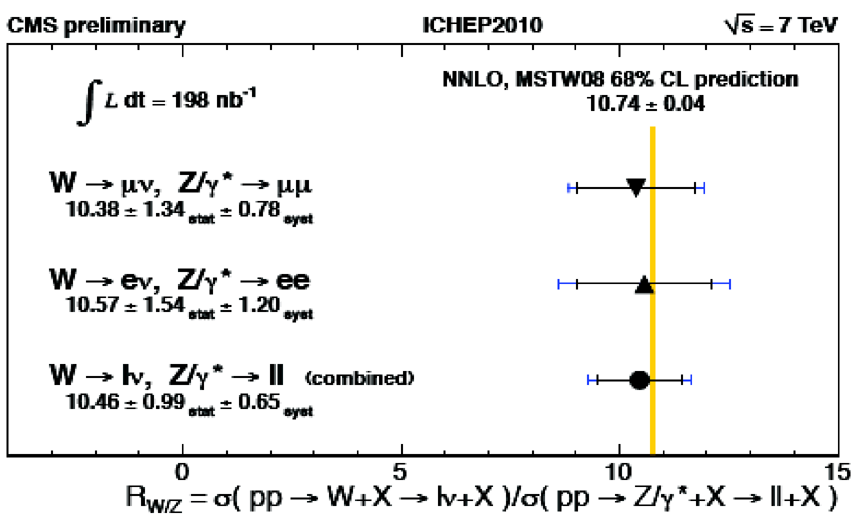
p_T (j_2)= 320 GeV

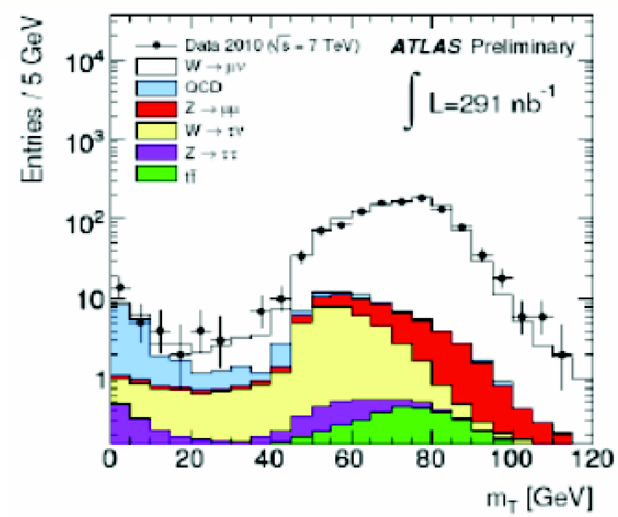
LHC: W and Z boson observation

- W inclusive cross section
  - CMS: L=196 nb^{-1}, Atlas: 17 nb^{-1}
- Z inclusive cross section
  - CMS: L=196 nb^{-1}, Atlas: ~225 nb^{-1}
- W/Z ratios (CMS)



W to Z ratios





Transverse W mass

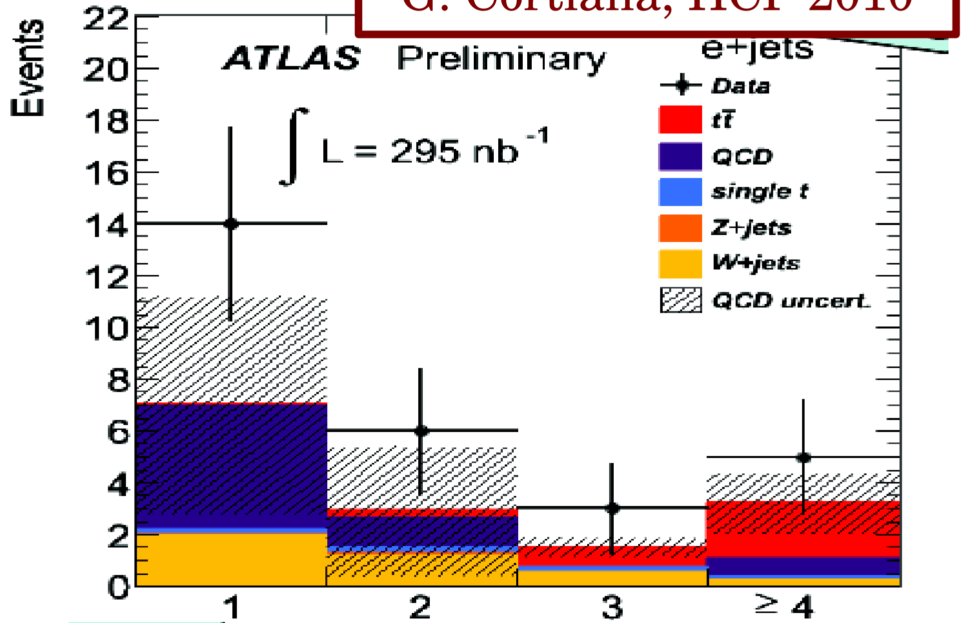
$W \to \mu\nu$

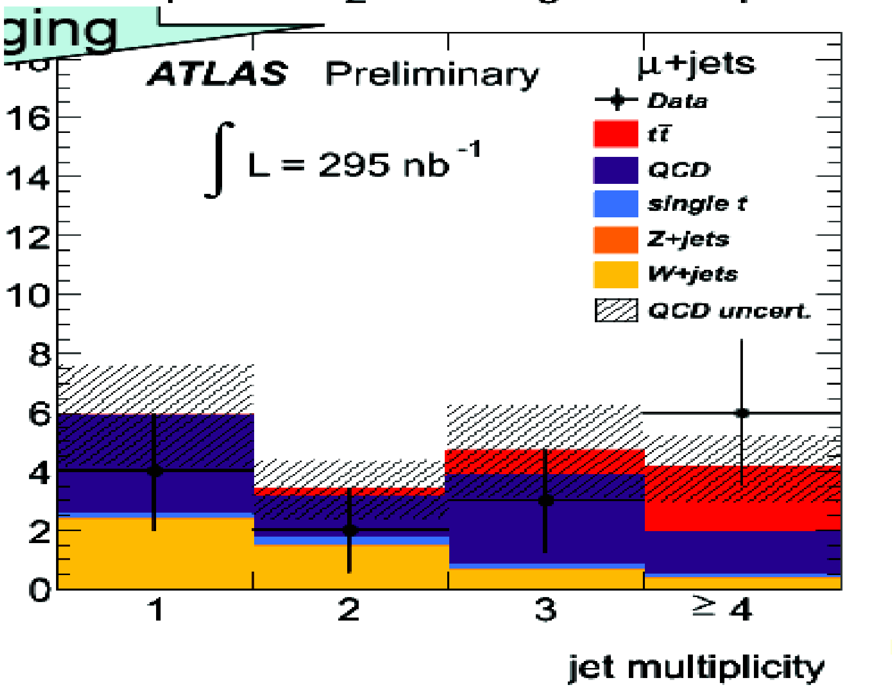
← candidates in 291 nb^{-1} of data

Measurements agree between electron and muon channels and with the NNLO calculation

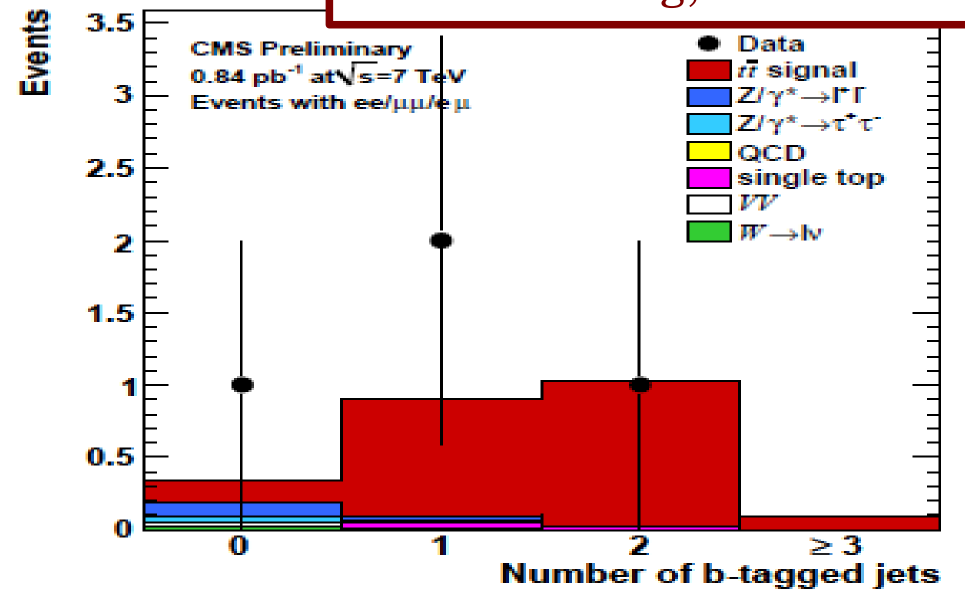
LHC: top quark

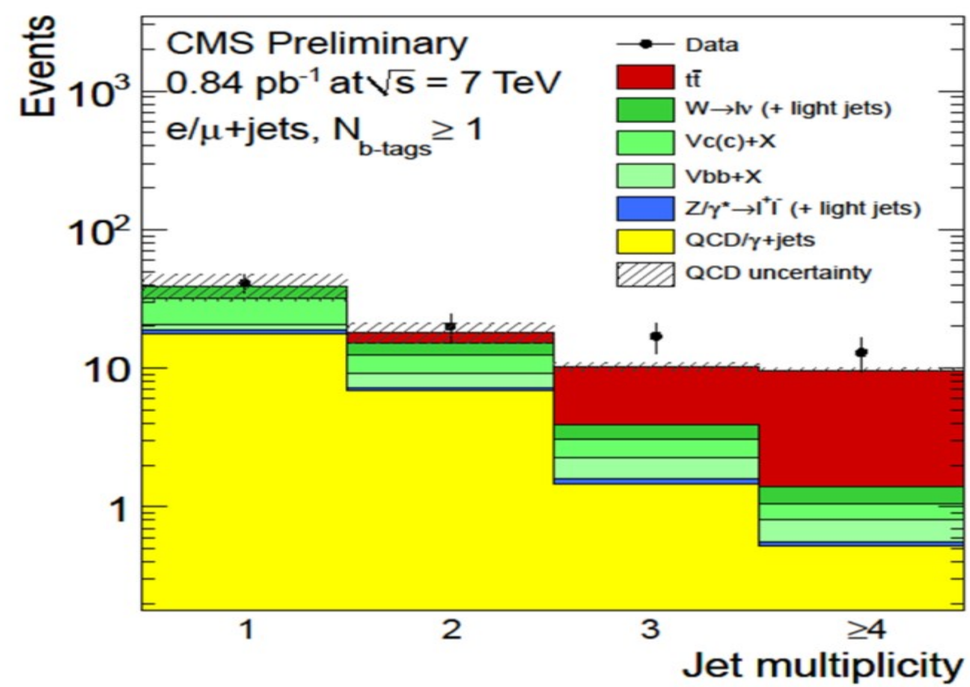
G. Cortiana, HCP 2010





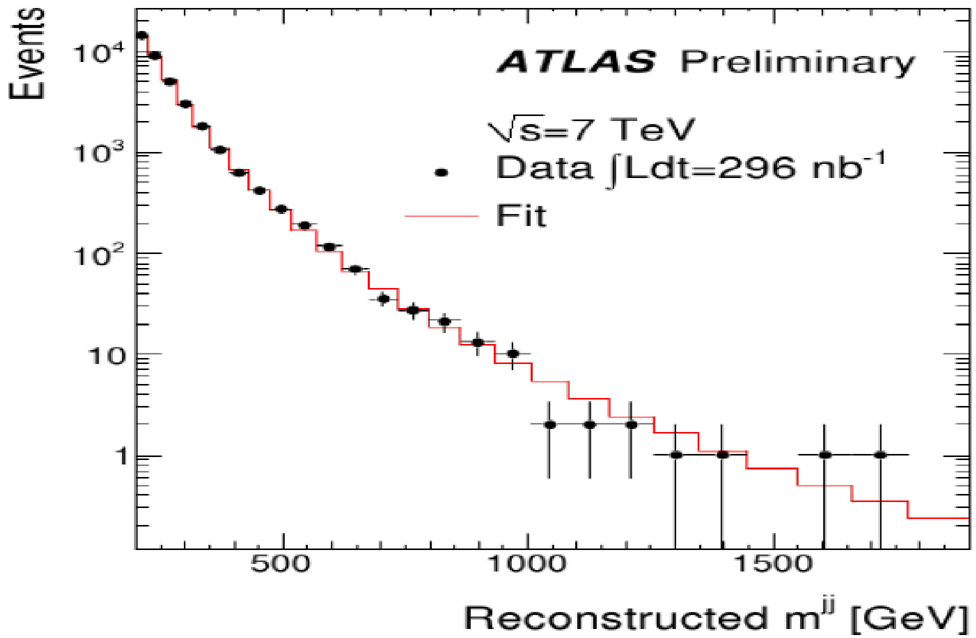
F.-P. Schilling, HCP 2010

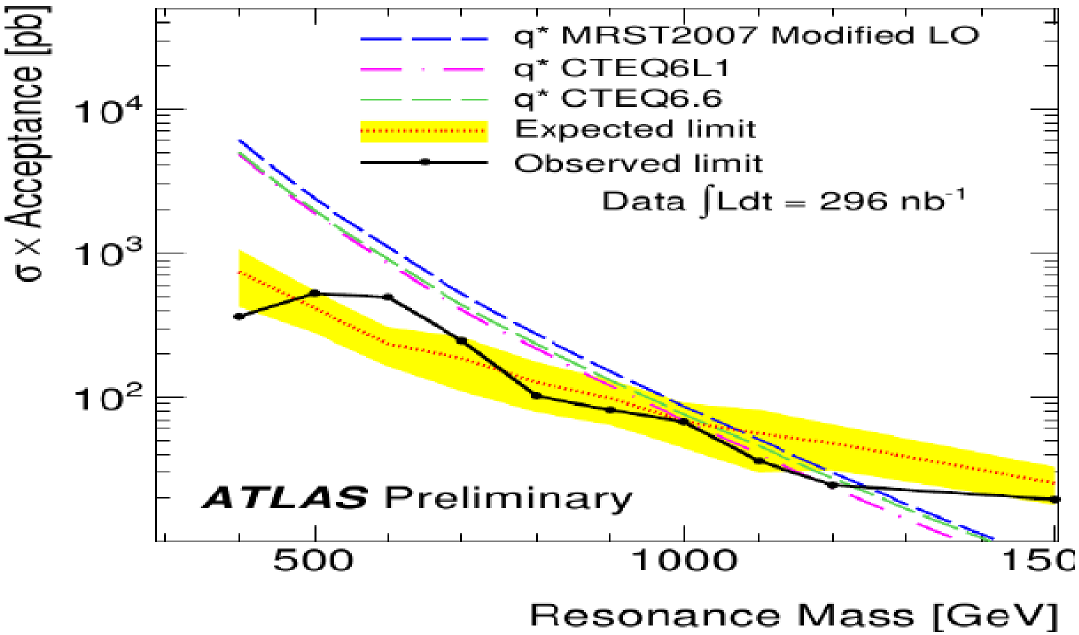




First Search for Excited Quarks

- select event with 2 or more jets
- require $|\Delta\eta_{12}| < 1.3$ to improve sensitivity to the high-mass signal



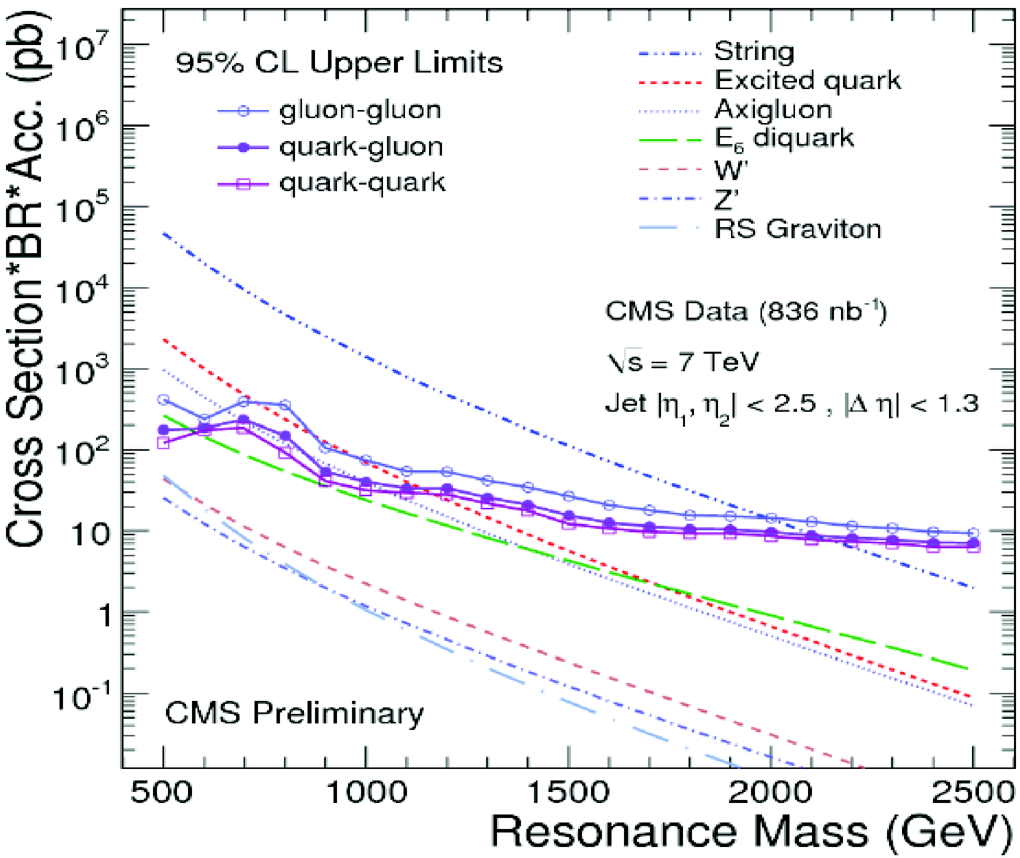


- ATLAS'2010 excluded @ 95% CL
  - M_{Q*} in [400 GeV, 1180 GeV] with CTEQ6 L1 PDF's
  - M_{Q*} in [400 GeV, 1290 GeV] with MRST'2007 PDF's

improving best published limit $M_{Q*} > 870 GeV$ (CDF, $1.1 fb^{-1}$, PRD79(2009)112002)

Model-Independent Cross Section Limits

We obtain generic cross section limits on qq, qg, gg resonances. The upper limits are compared to the predicted cross sections for 7 models.



Model	95% C.L. Mass Limit (TeV) using CTEQ6L		
	CMS 836 nb^{-1}	CDF 1.13 fb^{-1}	ATLAS** 315 nb^{-1}
String	2.10	1.4	---
q*	1.14	0.87	1.20
Axigluon	1.06	1.25	---
E_6 Diquark	0.58	0.63	---

- CMS now well beyond the Tevatron for both string resonances and q*
- CMS competitive with ATLAS q* limits** (arXiv:1008.2461)

Sung-Won Lee HCP 2010, Toronto 14

Conclusion

- Improving precision on different SM processes from Tevatron (top, electro weak, QCD)
- Improved precision from B-factories and Tevtaron in B-physics field
  - 3.2 difference from SM prediction observed by D0 in dimuon charge assymetry
- Higgs limited are tightened by Tevatron
  - Tevatron could find Higgs boson with significant probability after additional 3 years run (to be approved).
- LHC start-up: very rapid and fruitful
  - W and Z benchmark signals are observed
  - Very close to the top cross-section measurement
  - First limits on non SM processes, beyond the Tevatron ones.

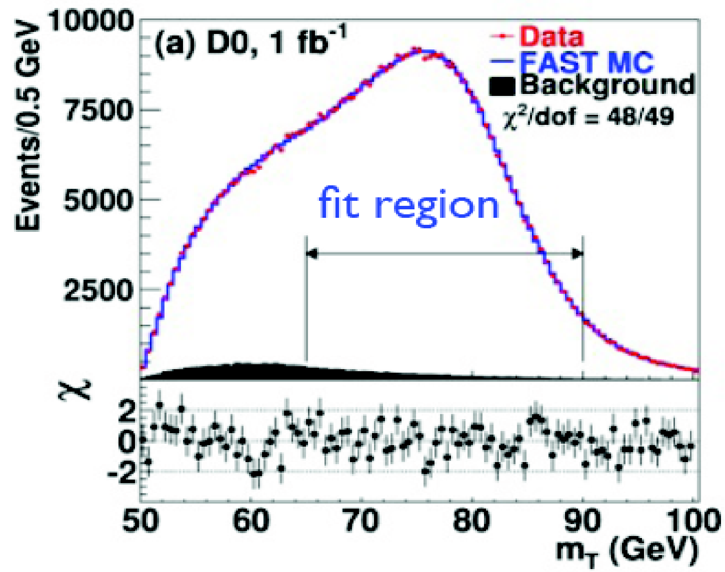
Back-up

- ~499,830 $W\rightarrow e\nu$ candidates — 1 fb^{-1}
- Many systematic uncertainties are due to limited statistics of calibration data samples

M_W=80.401±0.043 GeV

Single most precise measurement

World average **M_W=80.399±0.023 GeV**

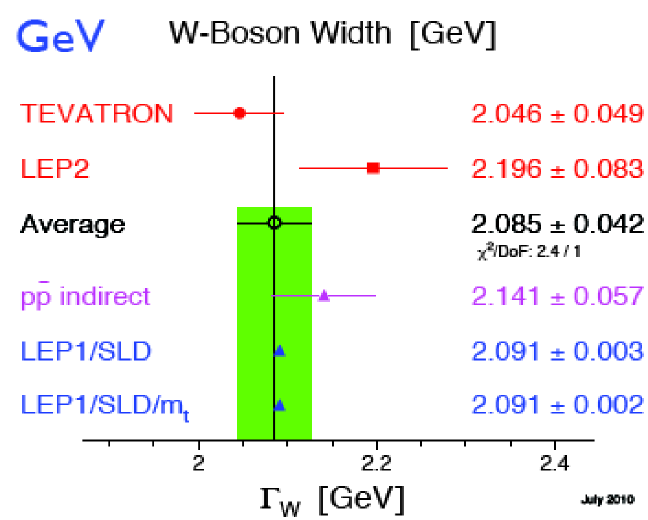


- Measure W width from the shape of transverse mass distribution

Γ_W=2.028±0.072 GeV

SM: Γ_W=2.093±0.002 GeV

World average **Γ_W=2.085±0.042 GeV**



- study of $W\rightarrow\pi\gamma$ — 4.3 fb^{-1}

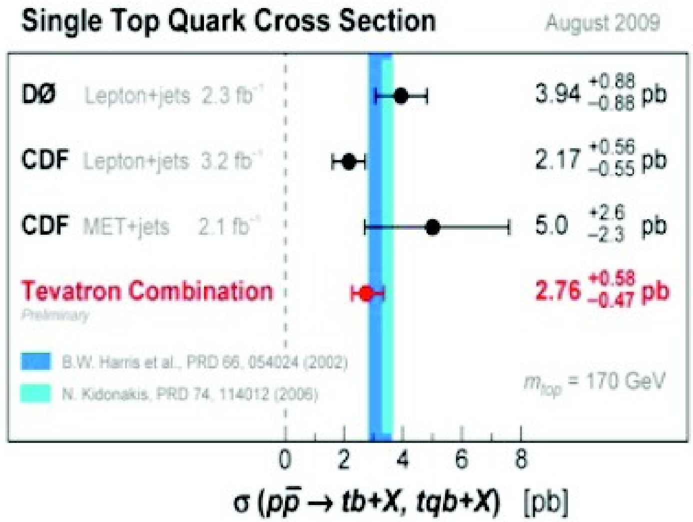
SM: $BR(W\rightarrow\pi\gamma)/BR(W\rightarrow e\nu) = 10^{-6}-10^{-8}$

$BR(W\rightarrow\pi\gamma)/BR(W\rightarrow e\nu) < 6.4 \times 10^{-5}$ at 95% CL

Top: electroweak production

- Predicted 10 years before top discovery
  - s- and t-channels
- Observed by CDF and D0 in 2009, 14 years after top discovery
  - small cross section
  - large background with large uncertainties
  - multivariate techniques necessary

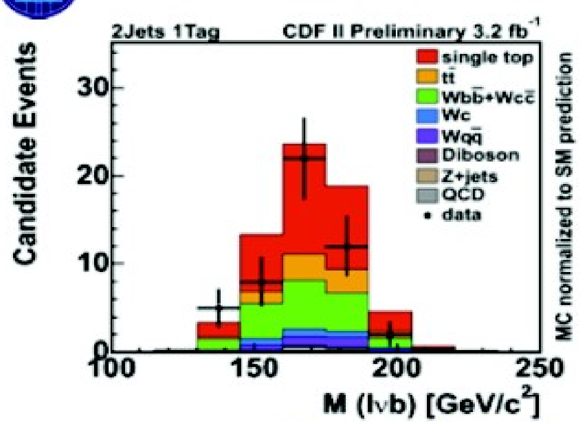
S.Willenbrock, D. Dicus, Phys. Rev. D34, 155 (1986); S Cortese and R Petronzio, PLB 253, 494 (1991)

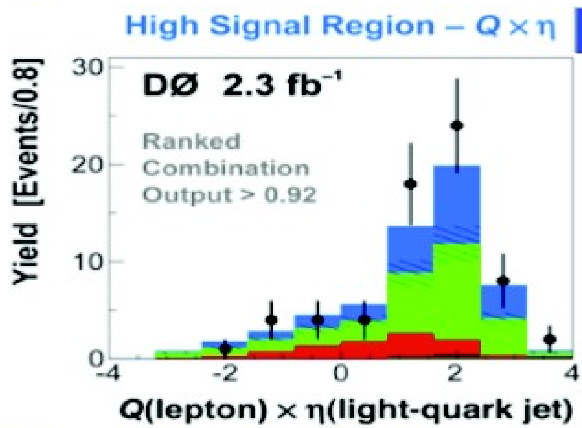


$$\sigma = 2.76^{+0.58}_{-0.47}(\mathrm{stat}+\mathrm{syst})\,\mathrm{pb}$$

$|V_{tb}|=0.91\pm0.08$ (stat+syst)

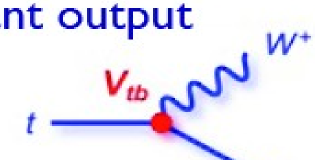
arXiv:0908.2171v1 [hep-ex]





Events with high discriminant output

- Allows to measure $|V_{tb}|^2$
- Sensitive to new physics



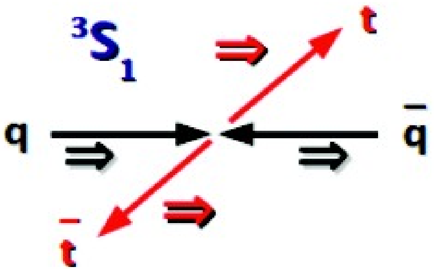
$\sigma \sim |V_{tb}|^2$

- 4.8 σ evidence for t-channel production

PLB 683 363 (2010)

July 26, 2010 E.Shabalina -- The physics of top, W and Z -- ICHEP 2010 - Paris 29

Top: spin correlation

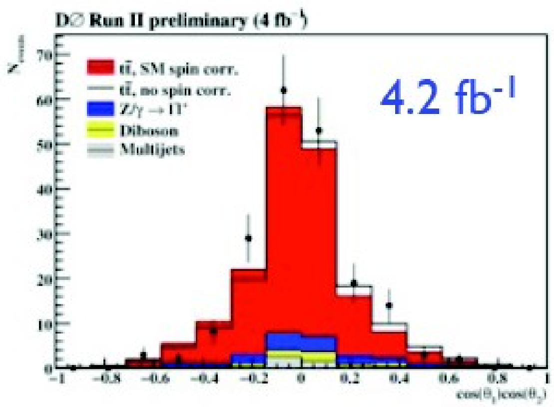


- Short lifetime
- Flight directions of top decay products carry information about top polarization at production

$$\kappa = \frac{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} - N_{\downarrow\uparrow} - N_{\uparrow\downarrow}}{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} + N_{\downarrow\uparrow} + N_{\uparrow\downarrow}}$$

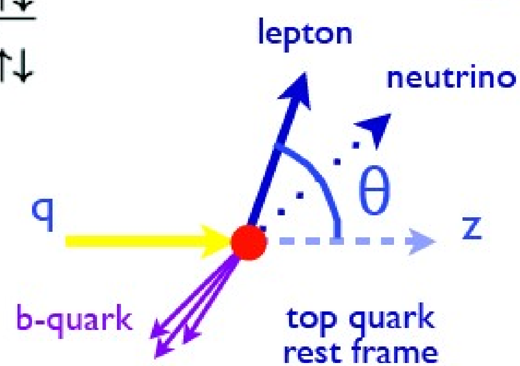
Strength depends on spin quantization axis: beam line, off-diagonal

Dilepton channel



$\kappa = -0.17\ ^{+0.64}_{-0.53}$

beam basis, NLO: κ=0.777

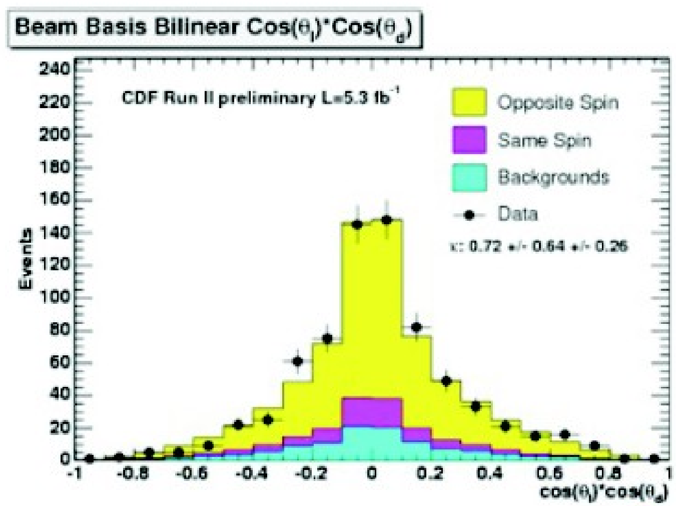


2.8 fb^{-1}

$\kappa = 0.32\ ^{+0.55}_{-0.78}$

off-diagonal basis
NLO: κ=0.782

Lepton+jets channel



5.3 fb^{-1}

new

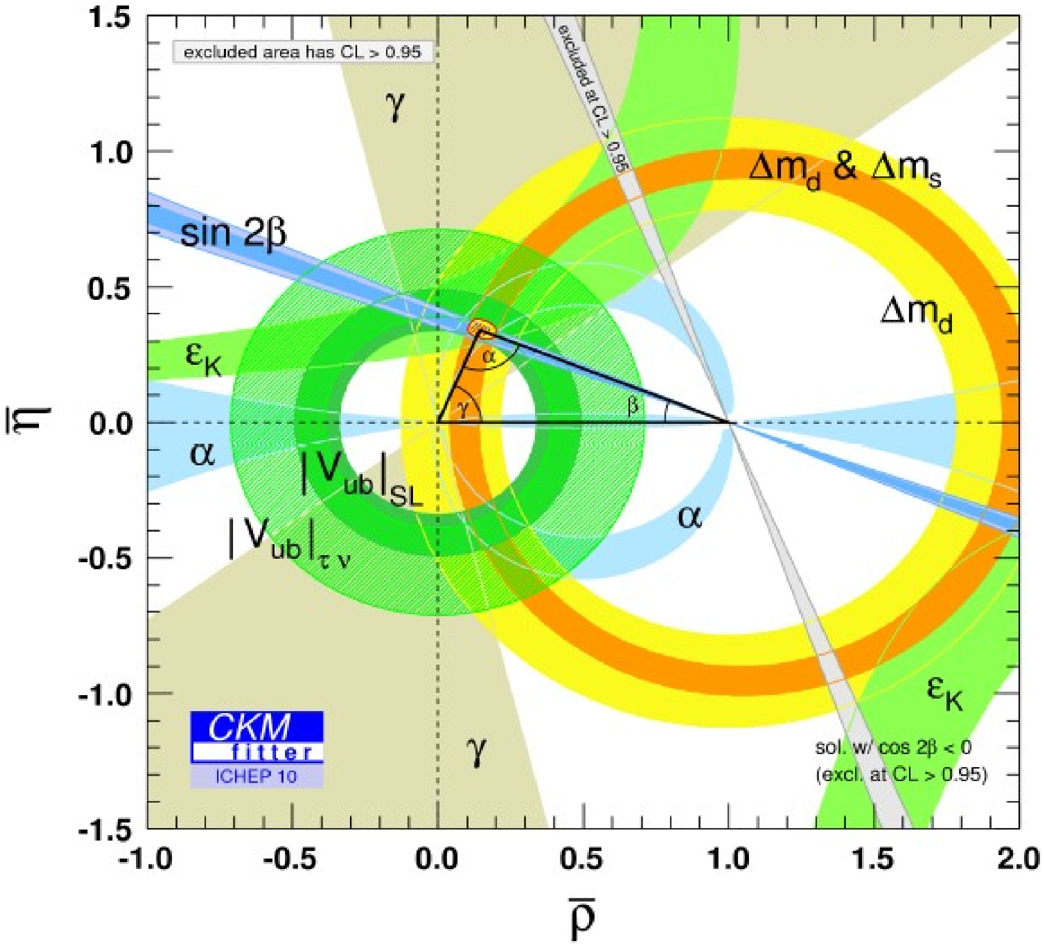
$\kappa = 0.72 \pm 0.64_{stat} \pm 0.26_{syst}$

beam basis

Three measurements in last year!

Which are the sources of flavour symmetry breaking accessible at low energies?

The good overall consistency of the experimental constraints appearing in the so-called CKM fits seems to indicate there is not much room for new sources of flavour symmetry breaking

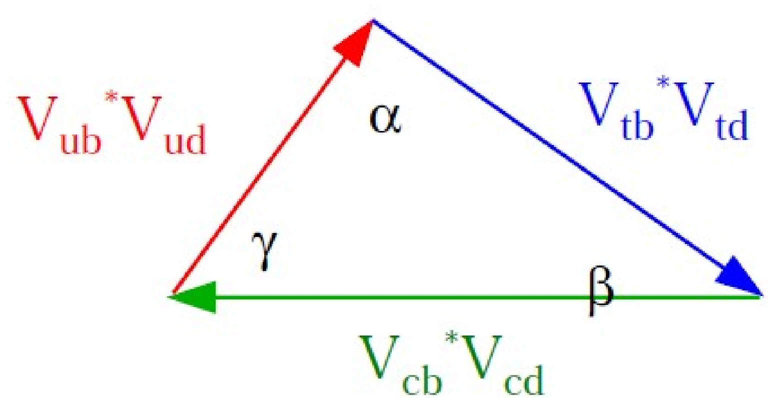


$$V_{CKM} V_{CKM}^{+} = I$$

⬇

triangular relation:

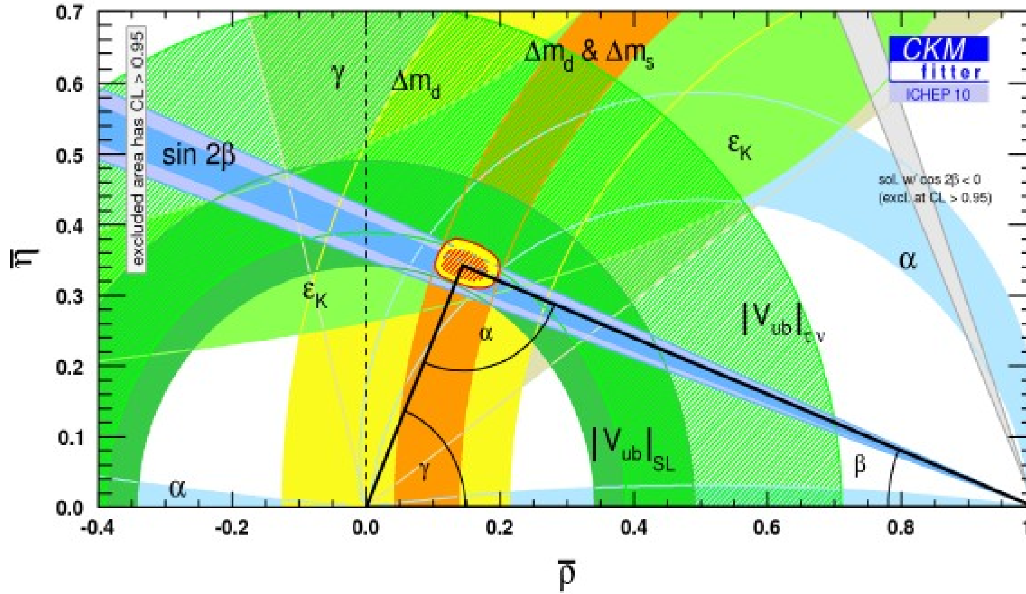
$$V_{ub}^{*} V_{ud} + V_{cb}^{*} V_{cd} + V_{tb}^{*} V_{td} = 0$$



I. The sin(2β) tension in the CKM fit

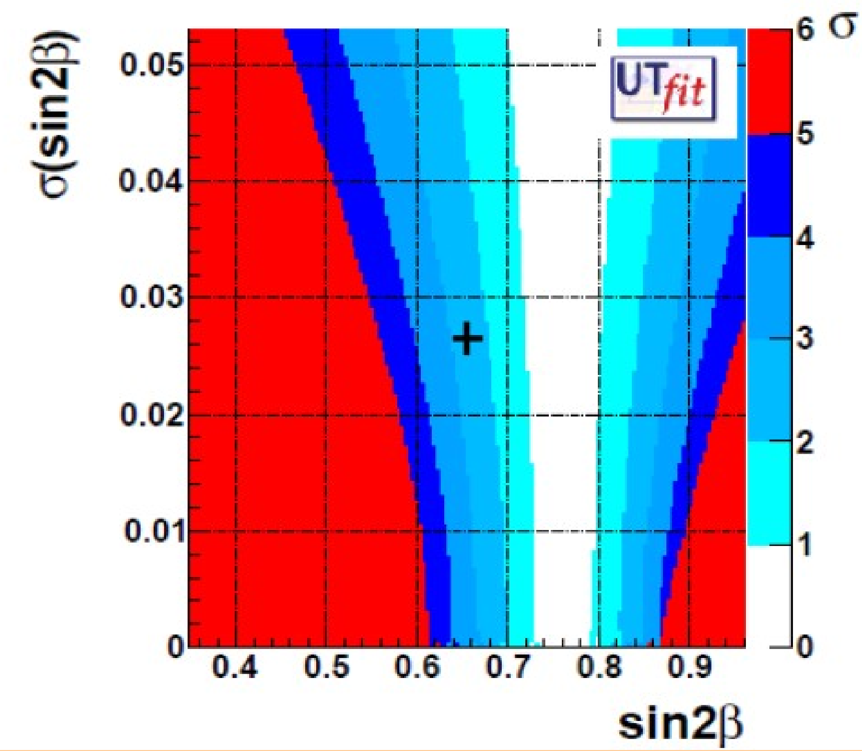
At first sight the global CKM fit shows an excellent consistency. However, a closer inspection shows a tension between $A_{\psi K}=\sin(2\beta)$ and its prediction (via ε_K and V_{ub}).

Buras & Guadagnoli, '08
Soni & Lunghi, '08-'09



This tension becomes quite clear if we take into account only the recent unquenched determinations of B_K

Antonio *et al.* '08
Aubin *et al.* '10



The indirect determination of sin(2β) turns out to be at ~2.6 σ from the experimental measurement

Talk by C. Tarantino

F77 → C++; but also improved physics

Pythia 6.4 → Pythia 8.1

- New p_t ordered shower (mass-ordered shower removed)
- Numerous new features for multiple interactions

Herwig 6.5 → Herwig++ 2.4

- New angular ordered shower, including better mass treatment
- Several processes at NLO with POWHEG
- Incorporates multiple interactions model

[no F77 version] → **Sherpa 1.2**

- Dipole shower
- Efficient multileg matrix-elements (COMIX), CKKW matching
- Now has own multiple interactions, hadronisation, etc.