Sprawozdanie z konferencji EPS 2009 w Krakowie (16-22 lipca 2009)

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Uniwersytet Warszawski

Plan seminarium

1. Krótki przegląd konferencji
2. Fizyka **kwarku *t*** [Tevatron]
3. Fizyka **bozonów *W* i *Z*** [Tevatron, Hera]
4. Wyniki **QCD** [Tevatron, Hera]
5. Fizyka **kwarku *b*** [Fabryki B, Tevatron]
6. Poszukiwania **bozonu Higgsa** [Tevatron]

Przegląd konferencji

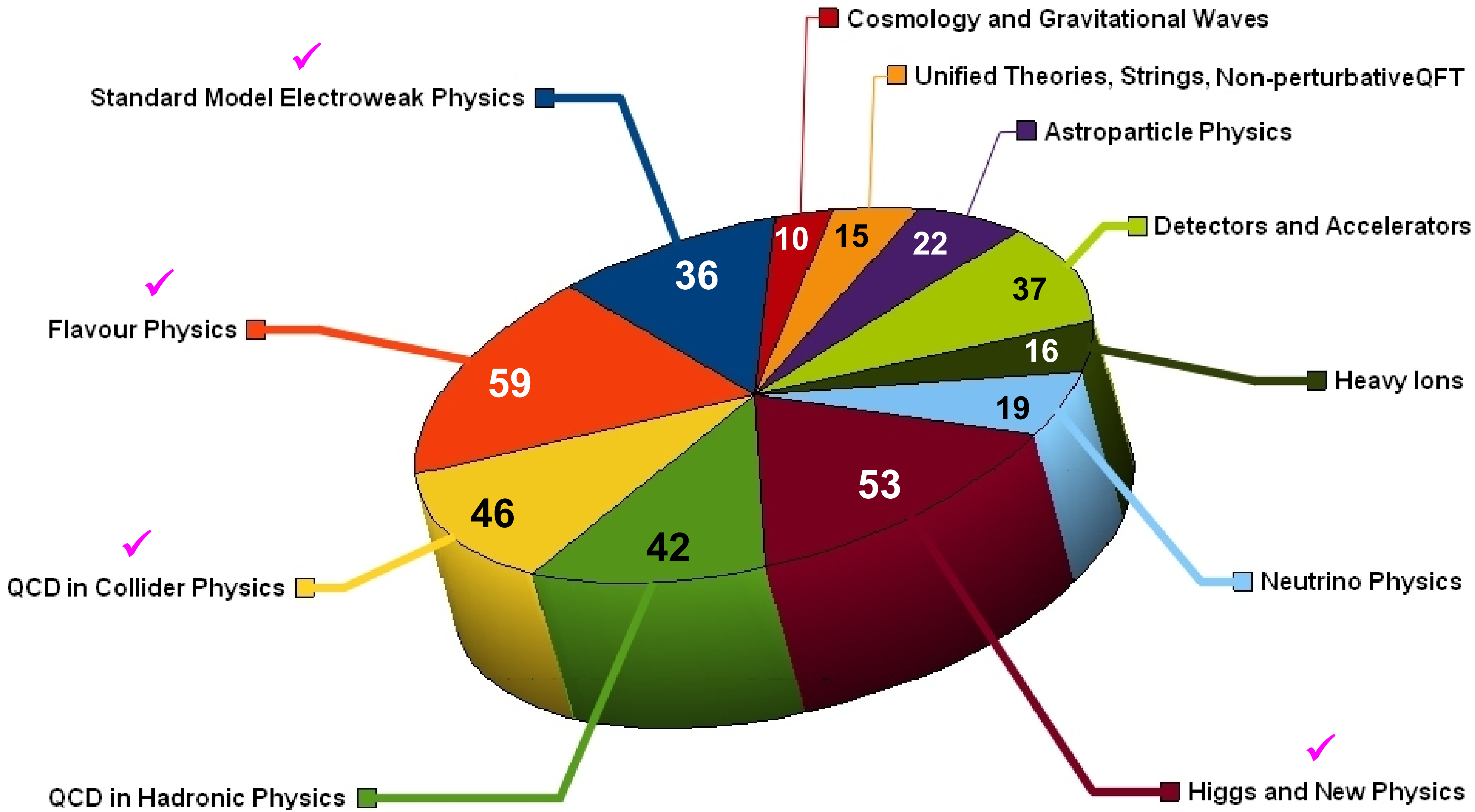
649 zarejstrowanych **uczestników** z 45 krajów

388 prezentacji + **75 plakatów**

	# prezentacji
Sesje plenarne (3 dni)	33
11 sesji równoległych (3 dni):	
• Standard Model Electroweak Physics	36
• Flavour Physics	59
• QCD in Collider Physics	46
• QCD in Hadronic Physics	42
• Higgs and New Physics	53
• Neutrino Physics	19
• Heavy Ions	16
• Detectors and Accelerators	37
• Astroparticle Physics	22
• Cosmology and Gravitational Waves	10
• Unified Theories, Strings, Non-perturbative QFT	15

Tematyka konferencji

Liczba prezentacji na sesjach równoległych (w sumie 350):



Fizyka kwarku *t*

Highlights of top quark physics:

- single top observation + direct measurement of V_{tb}
- precision measurements
  top mass with 0.75% uncertainty
- top properties
  new analyses possible such as spin correlation
- searches for new physics in top sector
  general agreement with SM
- excellent prospects for top physics at the LHC

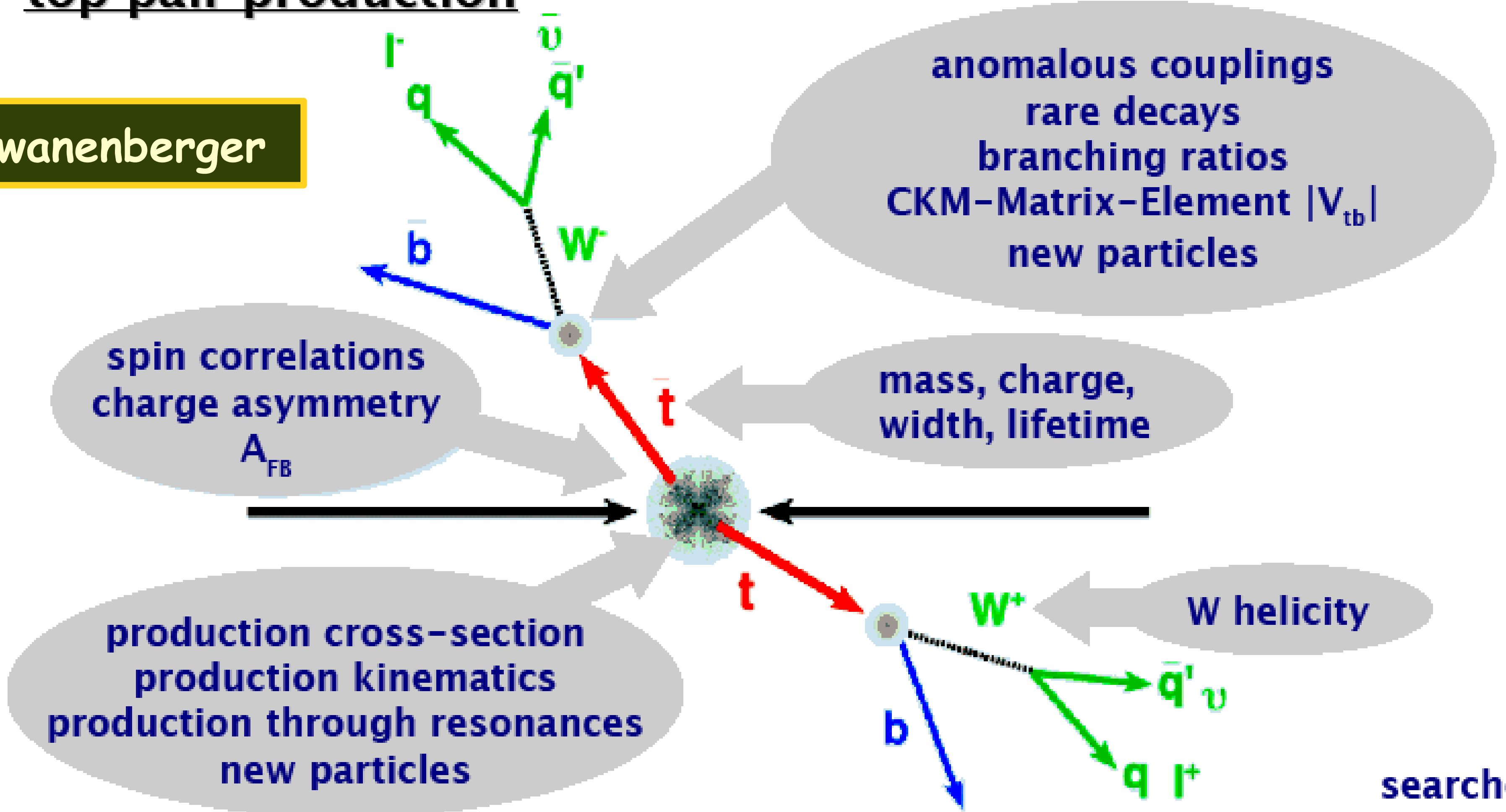
C.Schwanenberger

Top Quark Analyses at the Tevatron

analyses with up to 4 fb^{-1} of data:
several thousand top candidate events per experiment

top pair production

C.Schwanenberger



single top production

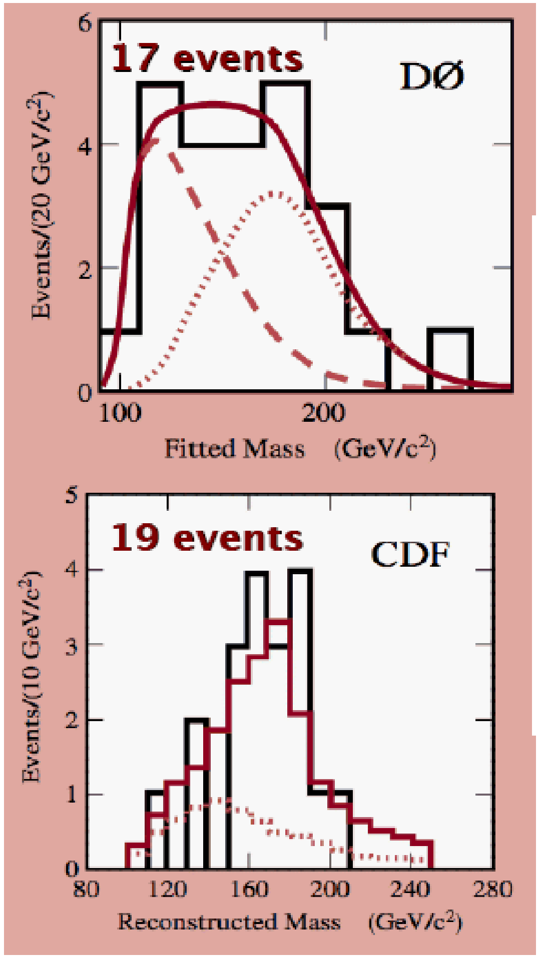
observation by CDF and DØ!

searches for new particles

Top History

discovery

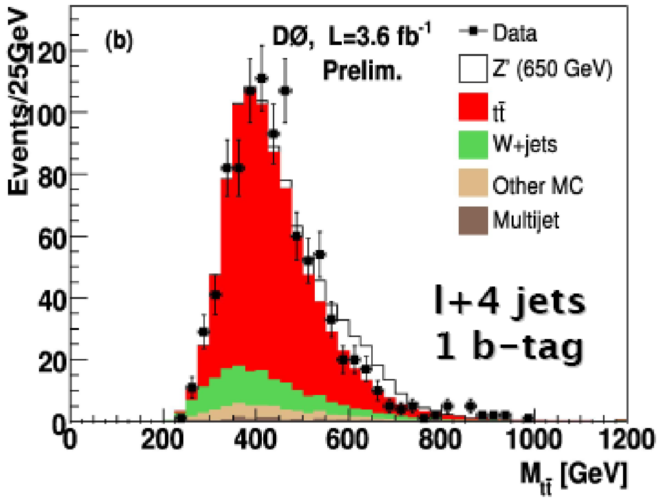
PRL 74, 2632 (1995)
PRL 74, 2626 (1995)



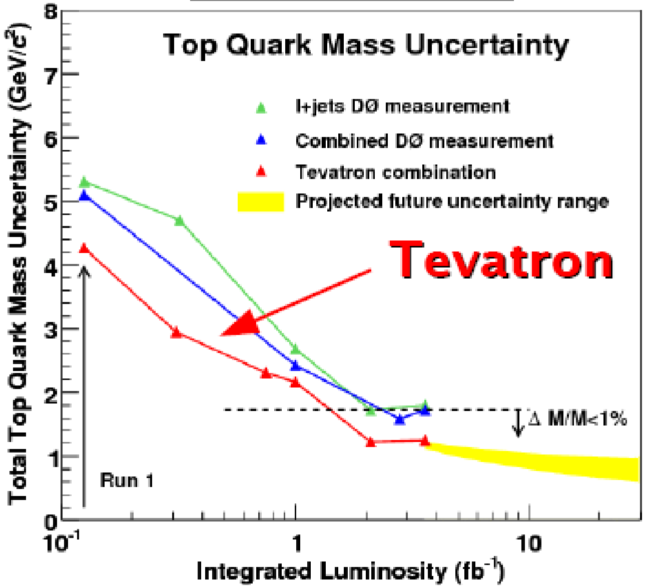
1995, CDF and DØ experiments, Fermilab

today

~1000 events



precision



10 top pairs per day @ Tevatron ↔ 1 top pair per second @ LHC

4 single tops per day @ Tevatron ↔ 30 single tops per minute @ LHC

C.Schwanenberger

Tevatron combination

CDF + DØ

- Combine CDF and DØ measurements, taking correlations into account

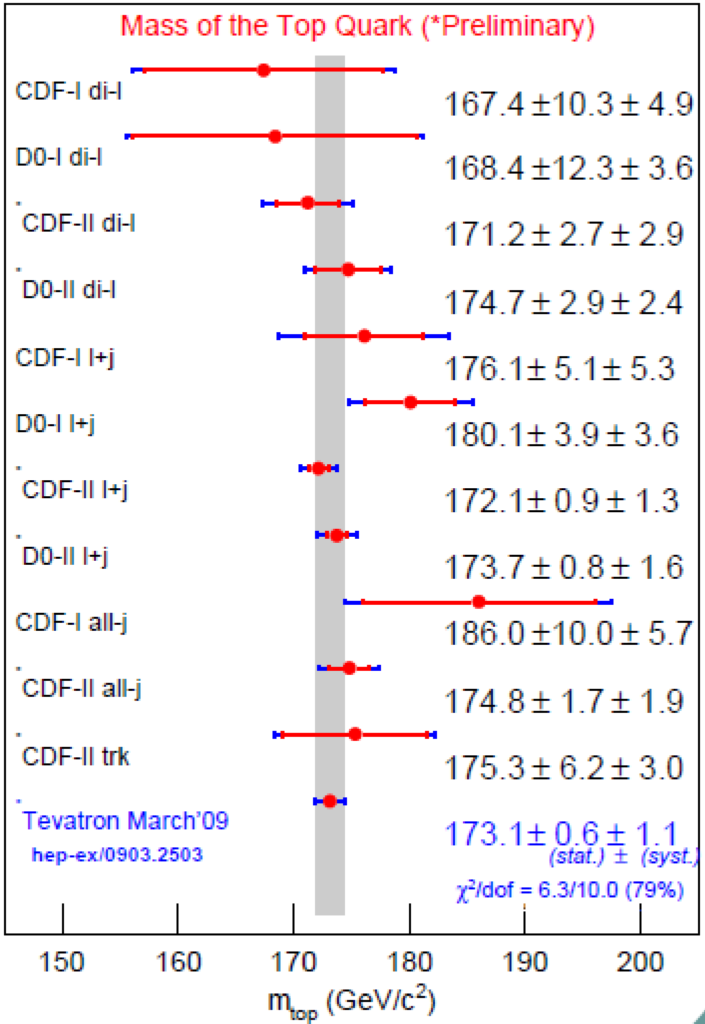
Parameter	Value (GeV/c^2)	Correlations		
$M_t^{\mathrm{all-j}}$	175.1 ± 2.6	1.00		
$M_t^{\mathrm{l+j}}$	172.7 ± 1.3	0.20	1.00	
$M_t^{\mathrm{di-l}}$	171.4 ± 2.7	0.19	0.50	1.00

- Results are all consistent (χ^2 prob 79%)

$$m_t = 173.12 \pm 0.65\ (\mathrm{stat}) \pm 1.07\ (\mathrm{syst})\ \mathrm{GeV/c^2}$$

$$m_t = 173.12 \pm 1.25\ (\mathrm{total})\ \mathrm{GeV/c^2}$$

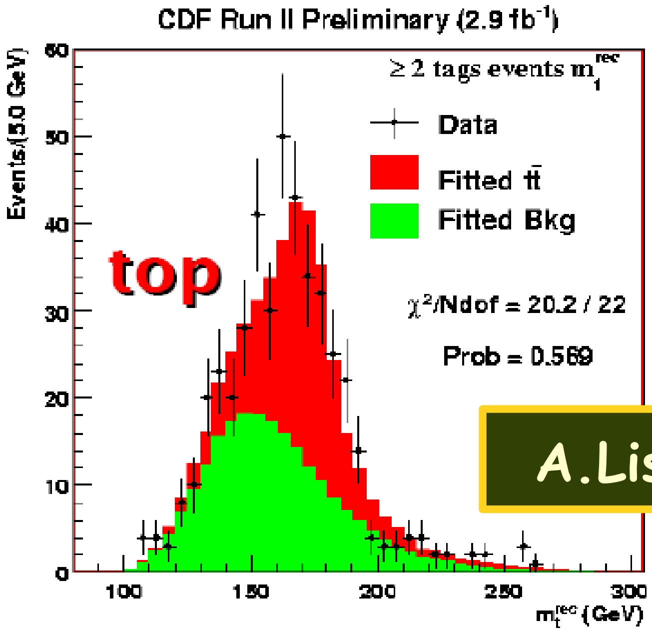
- m_t known within 0.7%
- Total uncertainty approaching 1 GeV/c^2



J.Linacre

15

all hadronic channel:
b-tagging



A.Lister

$\sigma_{t\bar{t}}$ =
7.2 ± 0.5 (stat) ± 1.4 (syst) ± 0.4 (lumi) pb

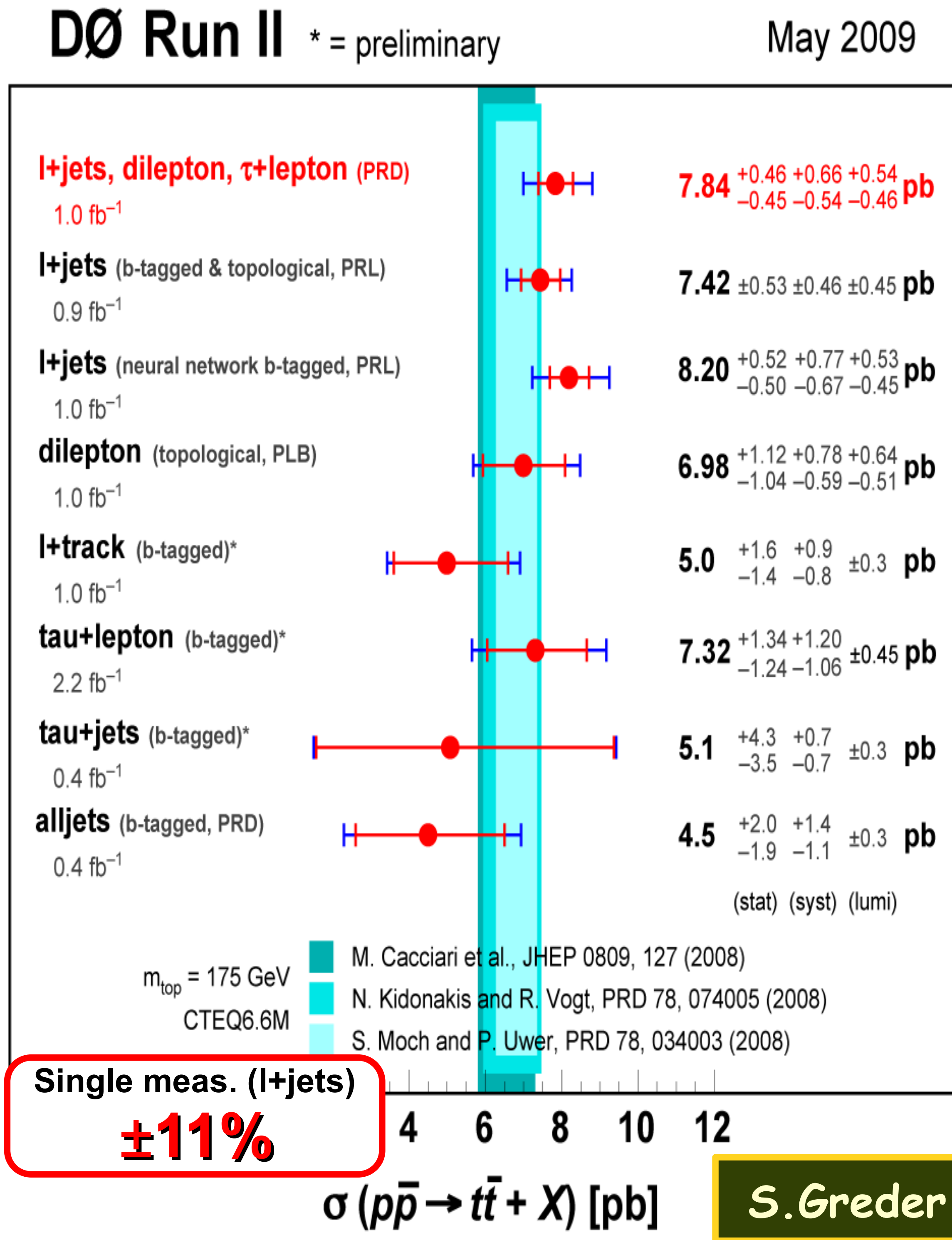
m_{top} = 172.5 GeV **±21%**

$t\bar{t}$/Z+jets cross section ratio

$\sigma_{t\bar{t}}$ =
6.9 ± 0.4 (stat) ± 0.4 (syst) ± 0.1 (Z theo) pb

m_{top} = 175 GeV **±8%**

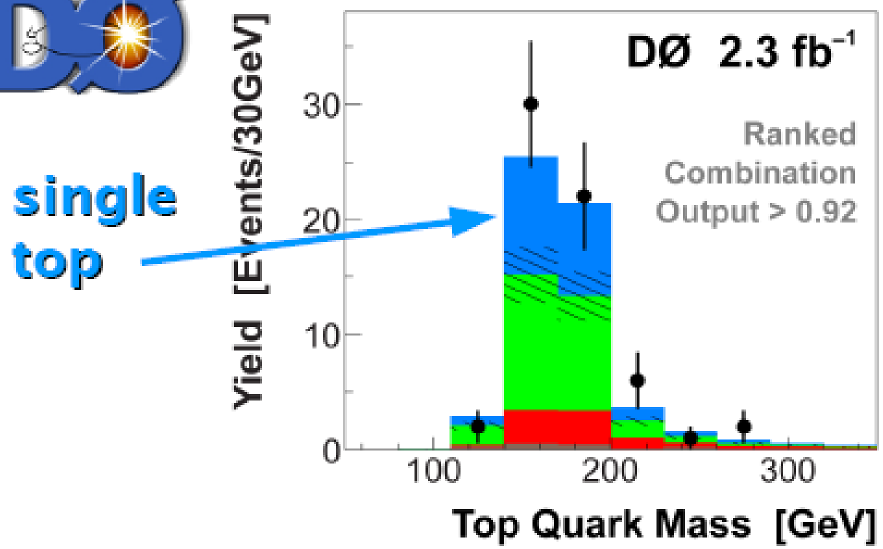
Luminosity uncertainty cancels out in ratio of ttbar to Z cross section if use same triggers and data periods

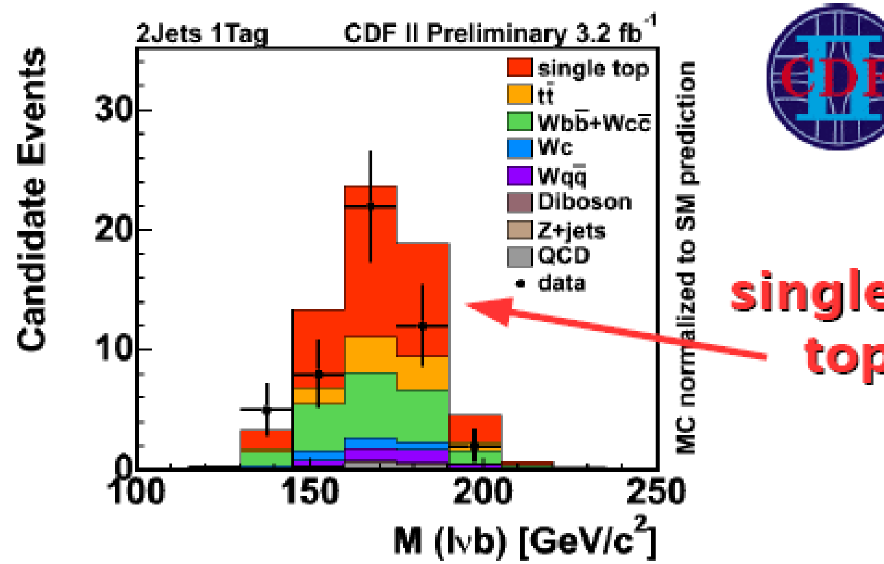


Single meas. (l+jets)
±11%

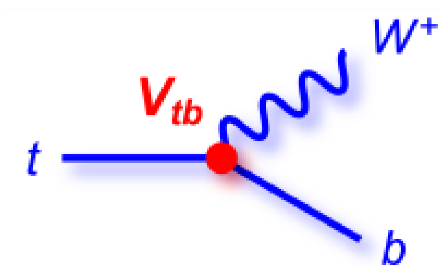
S.Greder

Single Top Observation





Single Top Cross Section	Signal Significance Expected	Signal Significance Observed
DØ 2.3 fb^{-1} arXiv:0903.0850 m_{top} = 170 GeV		
3.94 ± 0.88 pb	4.5 σ	5.0 σ
CDF 3.2 fb^{-1} arXiv:0903.0885 m_{top} = 175 GeV		
2.3 $^{+0.6}_{-0.5}$ pb	>5.9 σ	5.0 σ



DØ: $|V_{tb}| = 1.07 \pm 0.12$

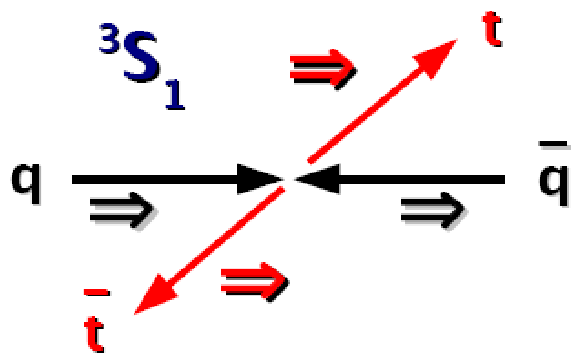
CDF: $|V_{tb}| = 0.91 \pm 0.13$

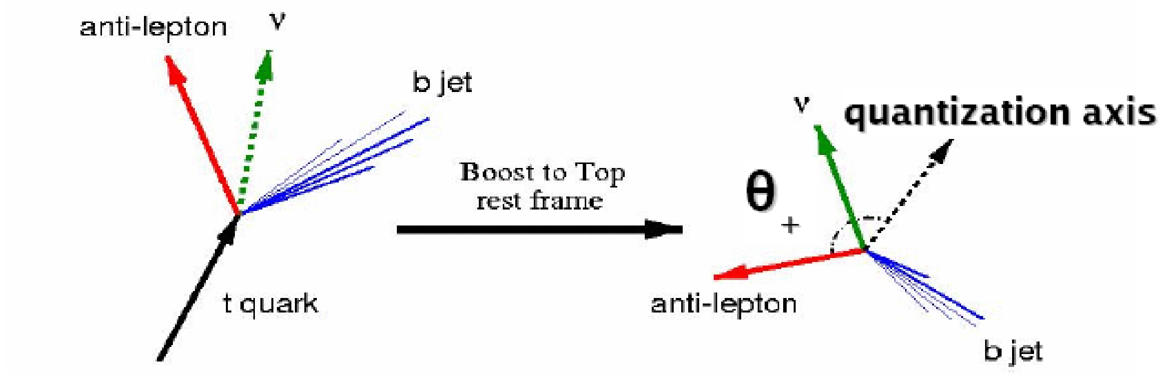
⇒ observation with 5.0σ!

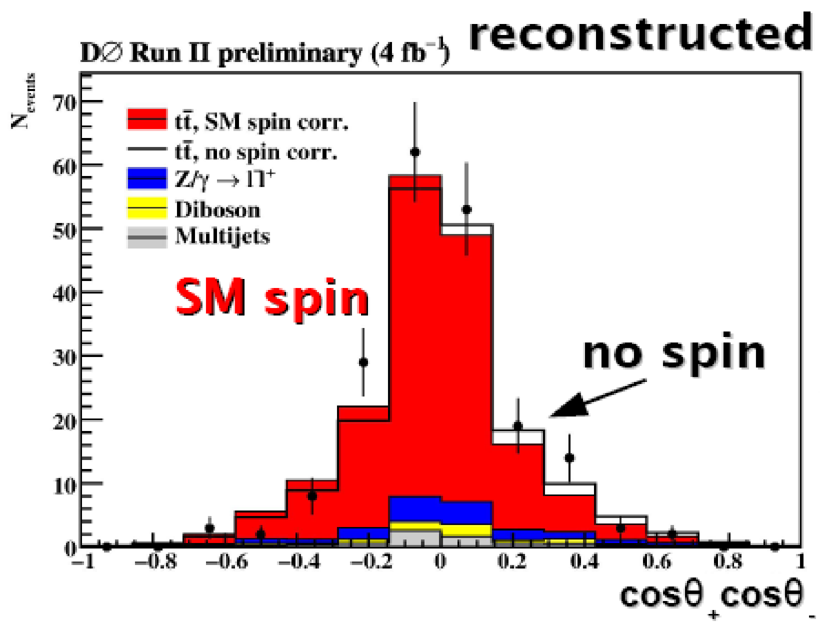
C.Schwanenberger

Spin Correlation in Dilepton Channel

- spins correlated only if top lives short enough







$$\kappa = \frac{N(\uparrow\uparrow)+N(\downarrow\downarrow)-N(\uparrow\downarrow)-N(\downarrow\uparrow)}{N(\uparrow\uparrow)+N(\downarrow\downarrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)}$$

NLO QCD: $\kappa \approx 0.78$

Nucl.Phys.B690, 81 (2004)

DØ: $\kappa = -0.17^{+0.64}_{-0.53}$
- beam axis
- 4.2 fb^{-1}

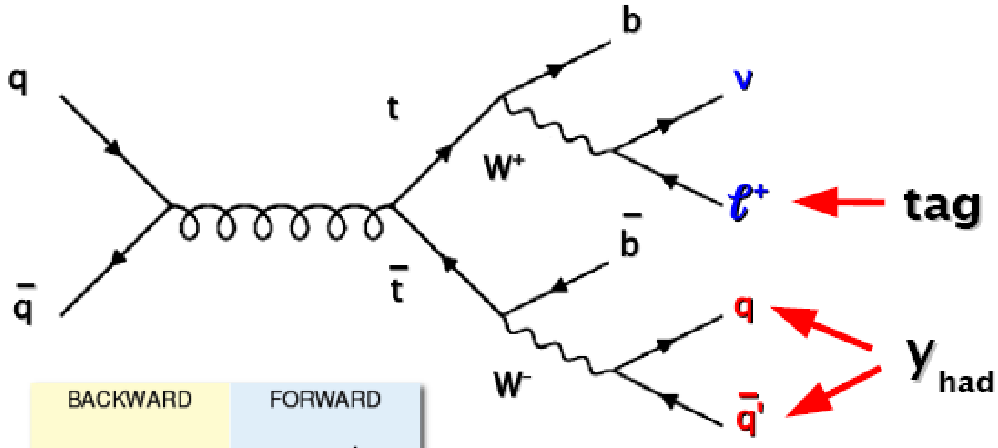
CDF: $\kappa = 0.32^{+0.55}_{-0.78}$
- off diag. axis
- 2.8 fb^{-1}
- $\cos\theta_b$

⇒ first results in Run-II, agreement with SM within 1σ (CDF), 2σ (DØ)

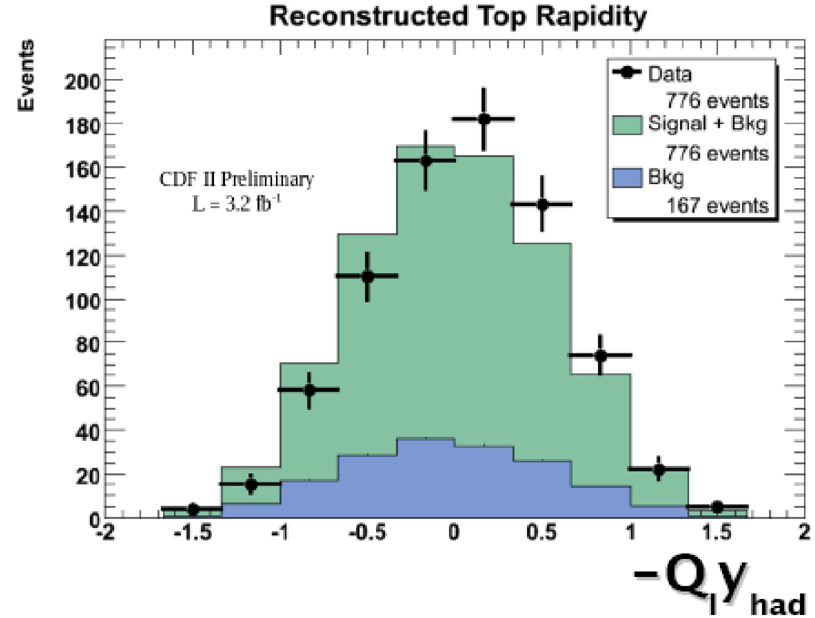
C.Schwanenberger

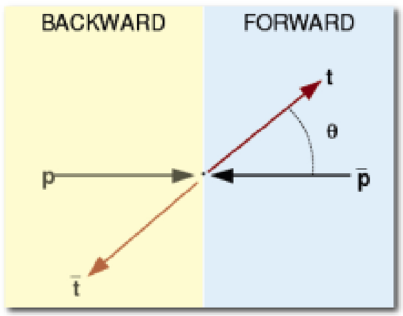
Forward Backward Asymmetry

- **test coupling to top pairs**



detector level:





$$A_{fb} = \frac{F - B}{F + B}$$

template fit, corrected:

A_{fb} = 0.193 ± 0.065 (stat) ± 0.024 (syst)

NLO QCD in $O(\alpha_s^3)$: A_{fb} = 0.05 ± 0.015 ⇒ agrees within 2σ

A^{det}_{fb} = 0.12 ± 0.08 (stat) ± 0.01 (syst) with 1 fb^{-1}

PRL 100, 062004 (2008)

C.Schwanenberger

Fizyka bozonów **W** i **Z**

Fizyka bozonów ***W*** i ***Z***

C.Hays

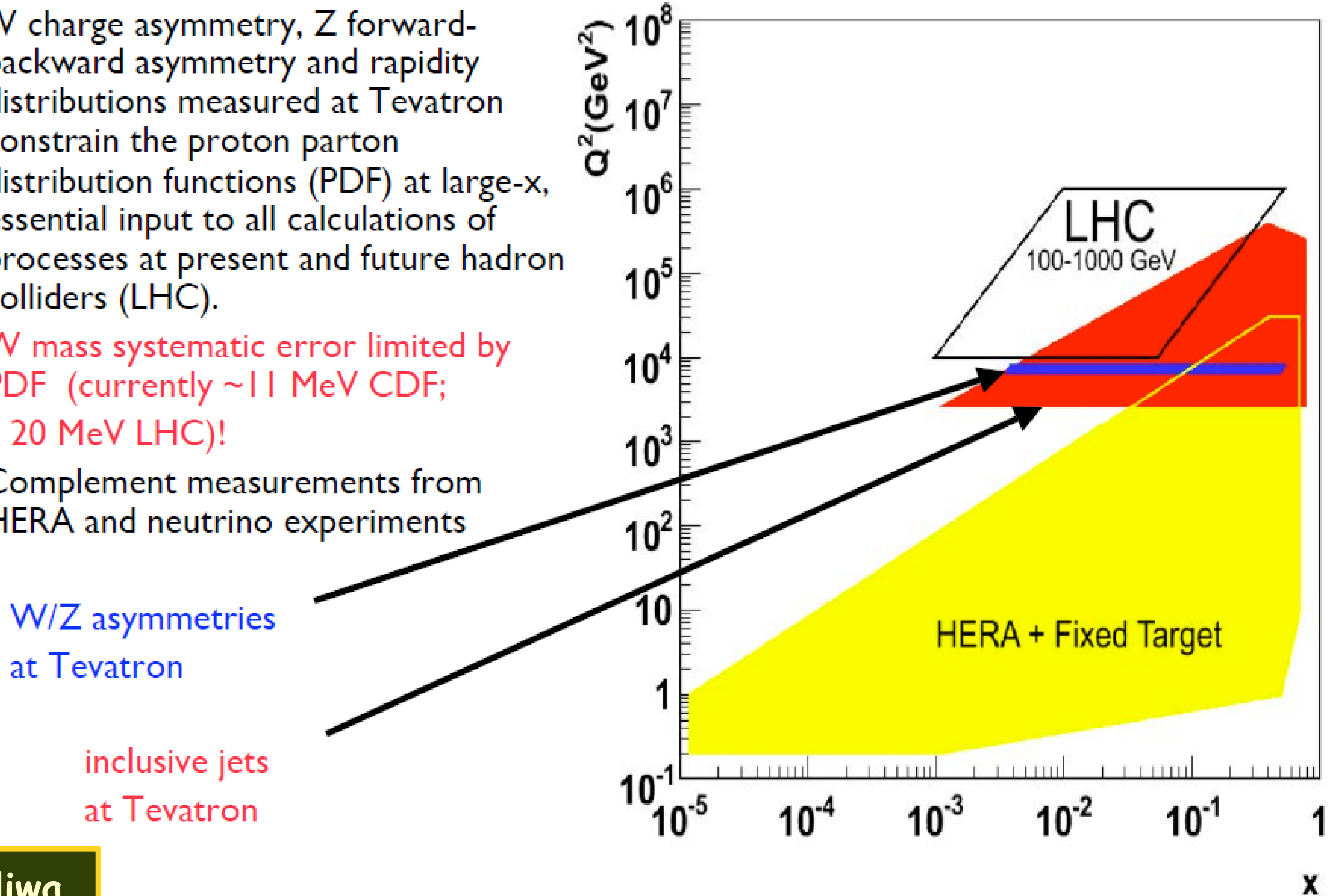
- Steadily improving precision on m_W
  - *CDF and DØ have the two best measurements in the world*
  - *Pieces coming together to allow single measurements with $\delta m_W < 25$ MeV*
  - *Expect ultimate hadron-collider precision of $\delta m_W < 10$ MeV*
- Precision measurement of $\sin^2\theta_W$ possible with full Run 2 data set
  - *CDF and DØ have initial measurements using A_{FB} in electron data*
- HERA producing best measurements of NC quark couplings
  - *Now also able to observe triple-gauge couplings*
- Tevatron experiments probing TGC with unprecedented precision
  - *New hadronic channels an important step on the road to the Higgs*

Fizyka bozonów **W** i **Z** **(1/8)**

W charge asymmetry, Z forward-backward asymmetry and rapidity distributions measured at Tevatron constrain the proton parton distribution functions (PDF) at large-x, essential input to all calculations of processes at present and future hadron colliders (LHC).

W mass systematic error limited by PDF (currently ~11 MeV CDF; ~ 20 MeV LHC)!

Complement measurements from HERA and neutrino experiments



K.Śliwa

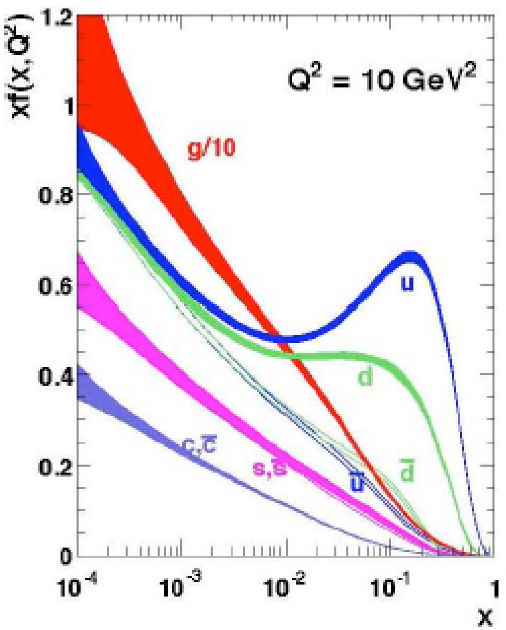
W-asymmetry in rapidity distribution

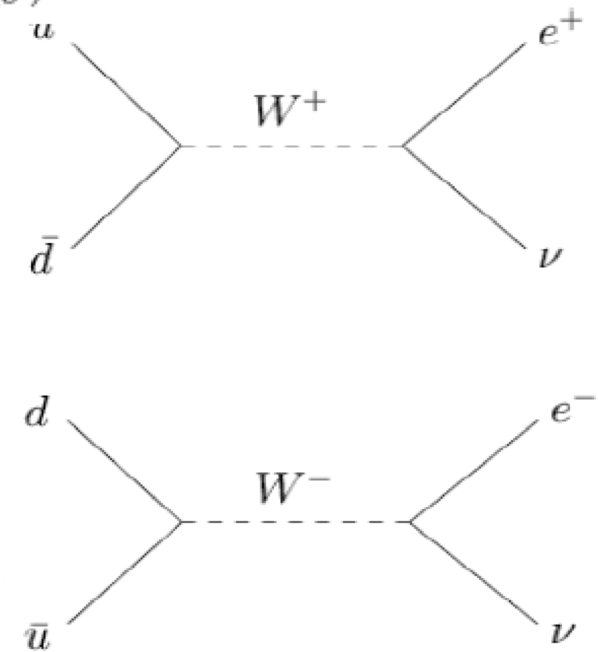
At Tevatron (pp̄) at √s=1.96 TeV, $W^+(W^-)$ are produced predominantly by the weak interaction of u(d) quarks and d̄(ū) antiquarks. Since u quarks carry (on average) larger fraction of proton's momentum than d quarks, W^+ is boosted along the proton direction (W^- is boosted in the antiproton direction). The difference in the respective rapidity distributions gives rise to a charge asymmetry:

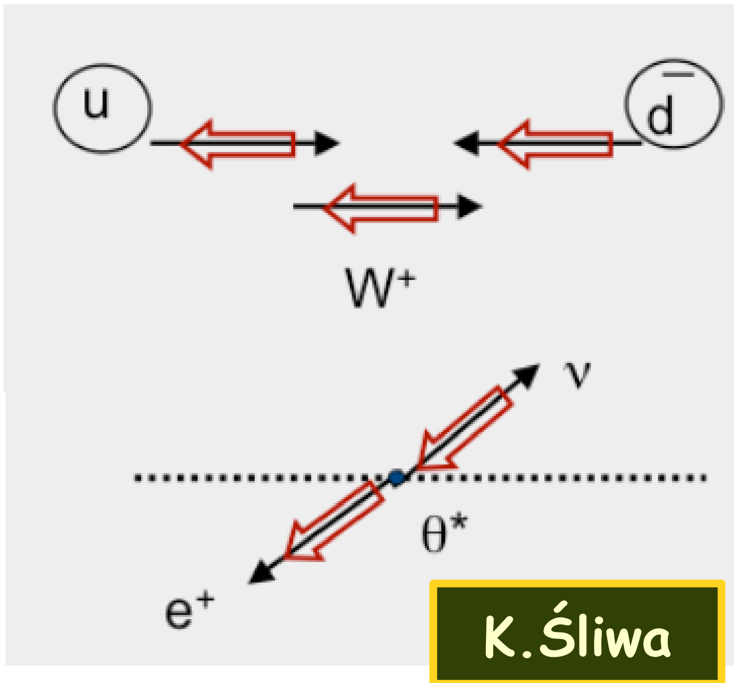
Charge Asymmetry:

Boson $$A_{W^+}(\sqrt{s},y) = A_{W^-}(\sqrt{s},-y) \equiv \frac{\sigma_{W^+}(\sqrt{s},y) - \sigma_{W^+}(\sqrt{s},-y)}{\sigma_{W^+}(\sqrt{s},y) + \sigma_{W^+}(\sqrt{s},-y)}; \qquad y = \frac{1}{2}\ln\left(\frac{E+p_{\parallel}}{E-p_{\parallel}}\right).$$

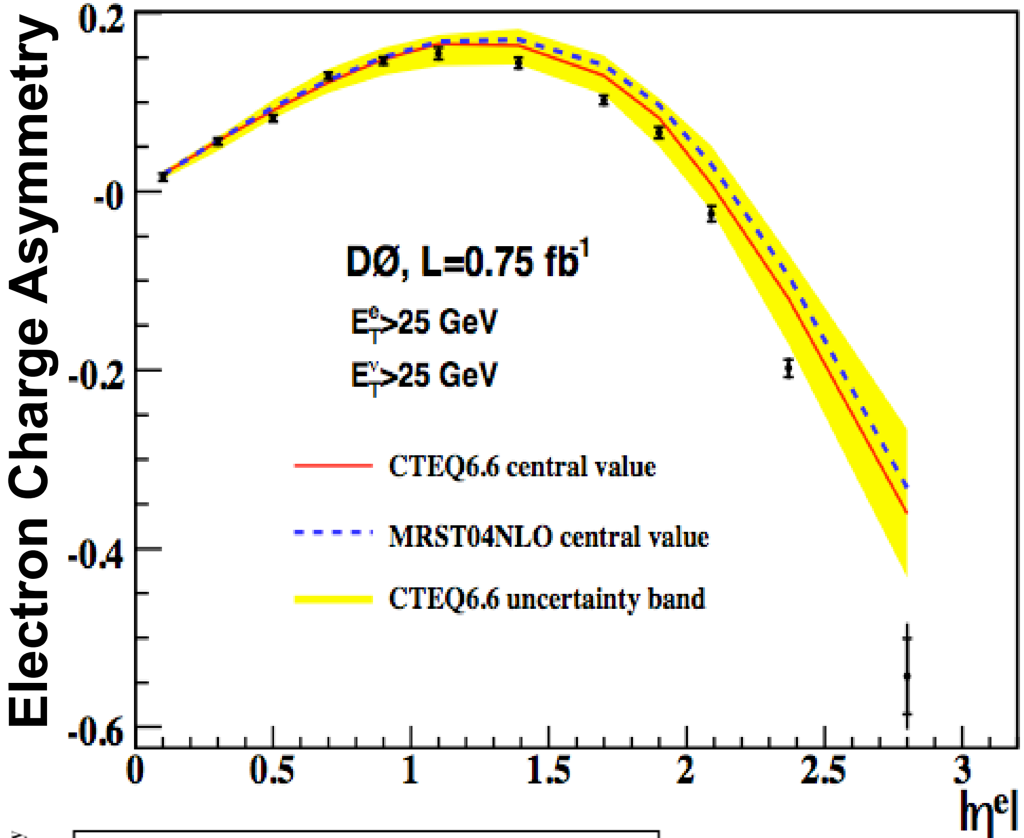
Electron $$A(y_e) = \frac{N_{e^+}(y) - N_{e^-}(y)}{N_{e^+}(y) + N_{e^-}(y)}$$

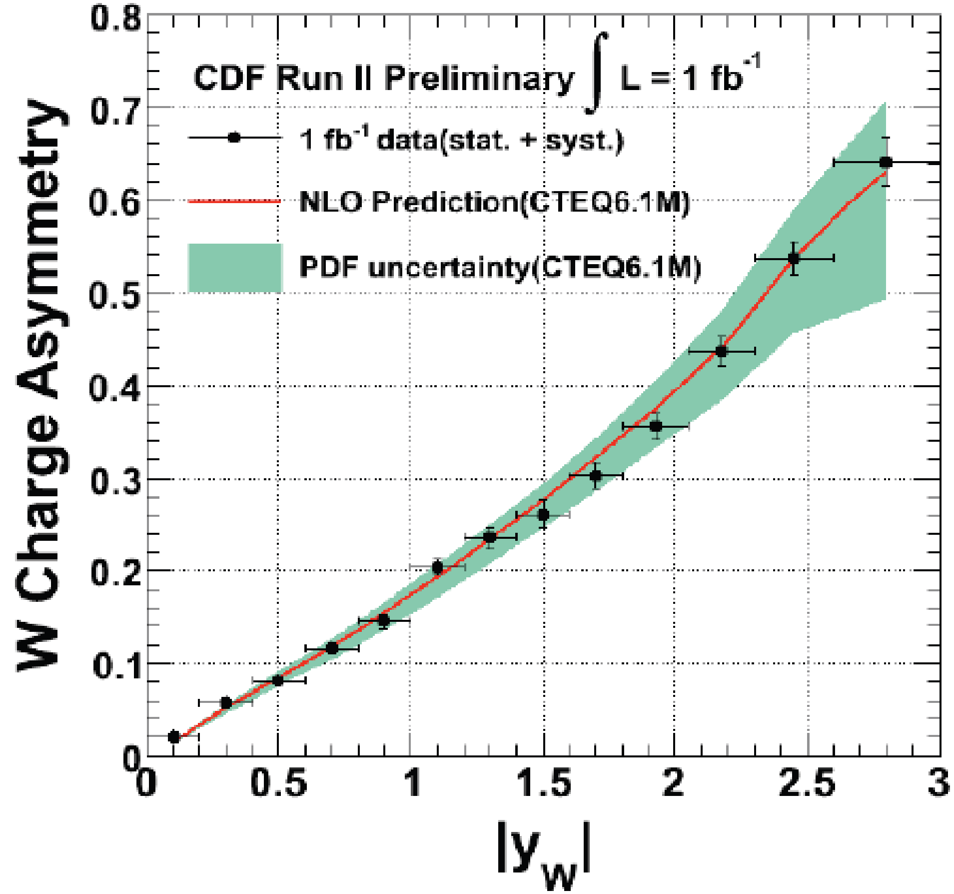


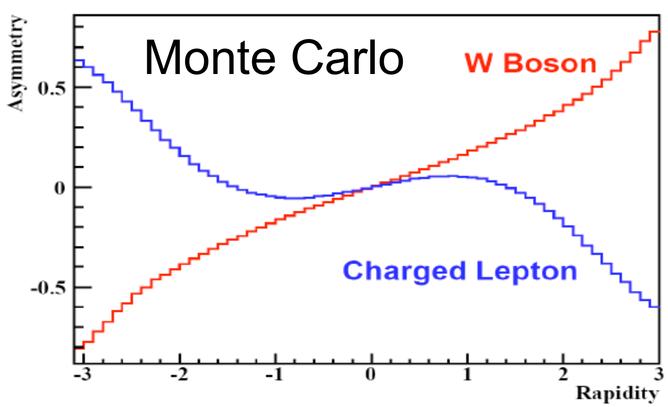




Fizyka bozonów **W** i **Z** **(3/8)**





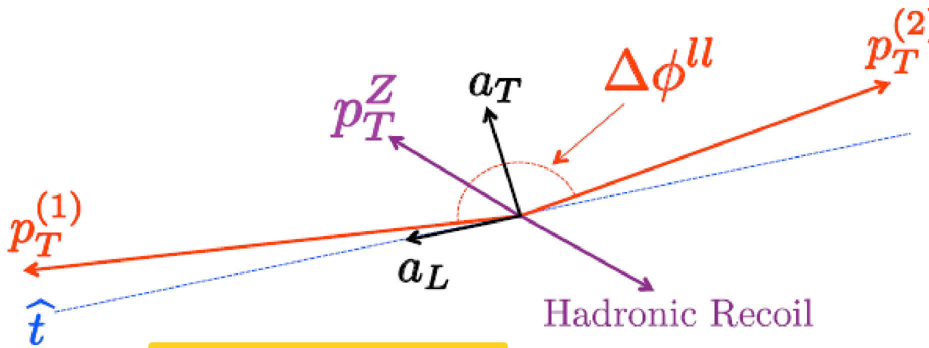


D.Khatidze

K.Śliwa

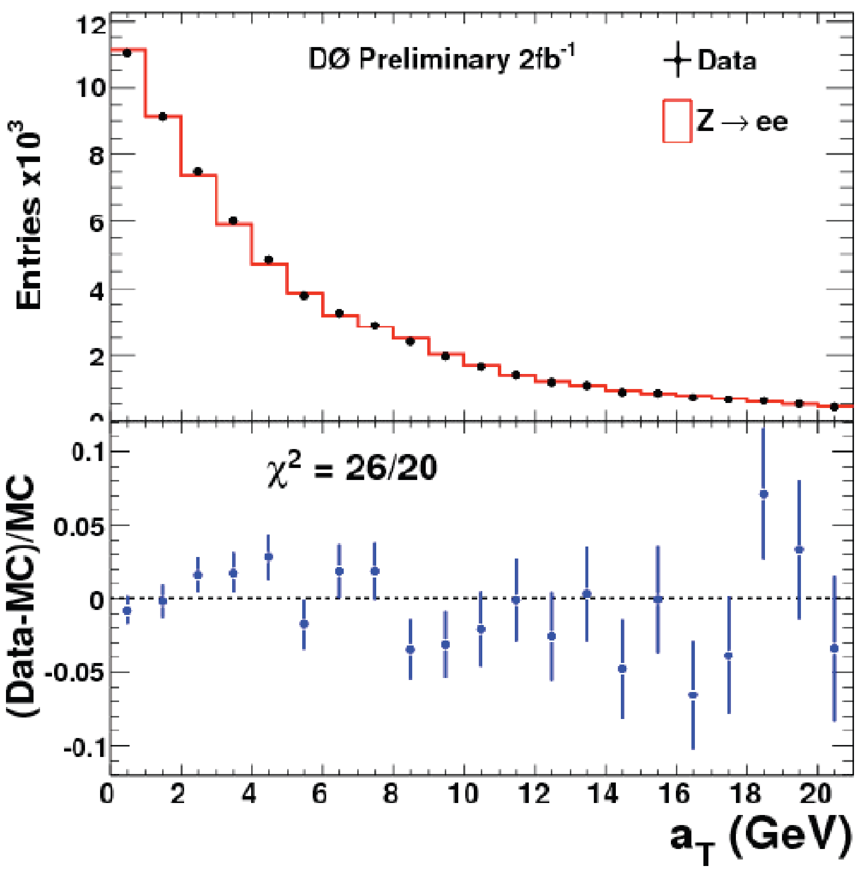
Z Boson Production

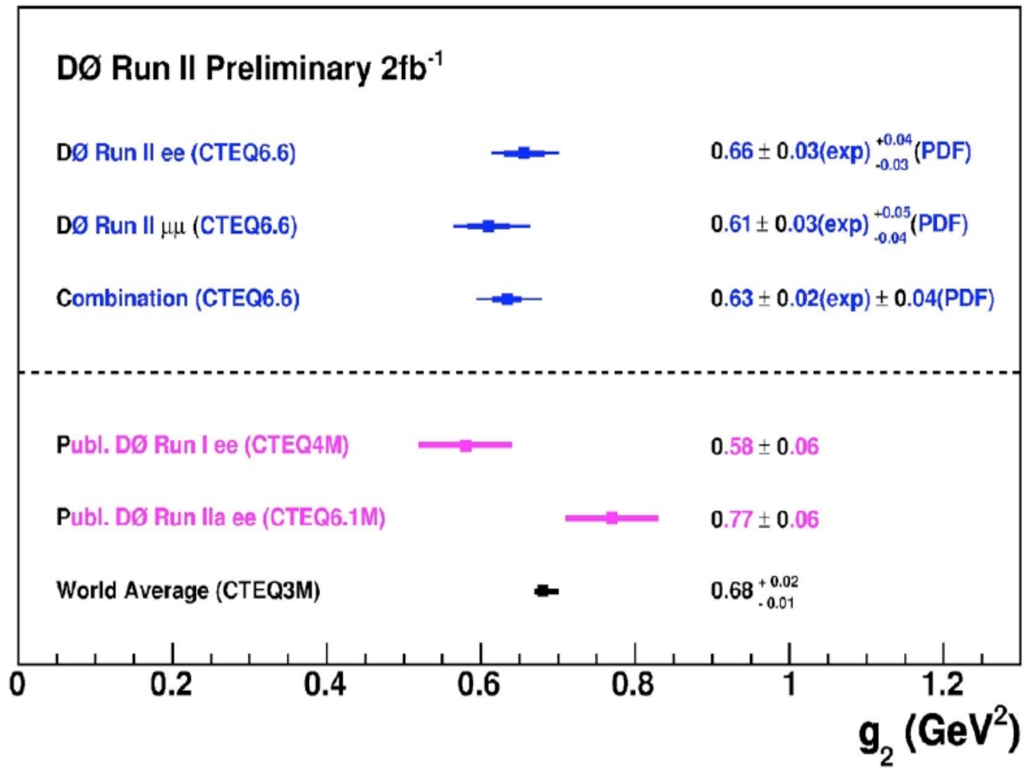
- Boson transverse momentum
  - *Dominant production in non-perturbative regime*
  - *Parameters motivated by theory, measured with Z boson data*
  - *Experimentally more precise to measure projected boson p_T*



C.Hays

D.Khatidze





$$\frac{d\sigma}{dy\,dq_T^2} = \frac{\sigma_0}{S}\int \frac{d^2b}{(2\pi)^2} e^{-i\vec{q_T}\cdot\vec{b}}\,\tilde{W}^{\rm PERT} e^{-S^{\rm NP} b^2} + Y$$

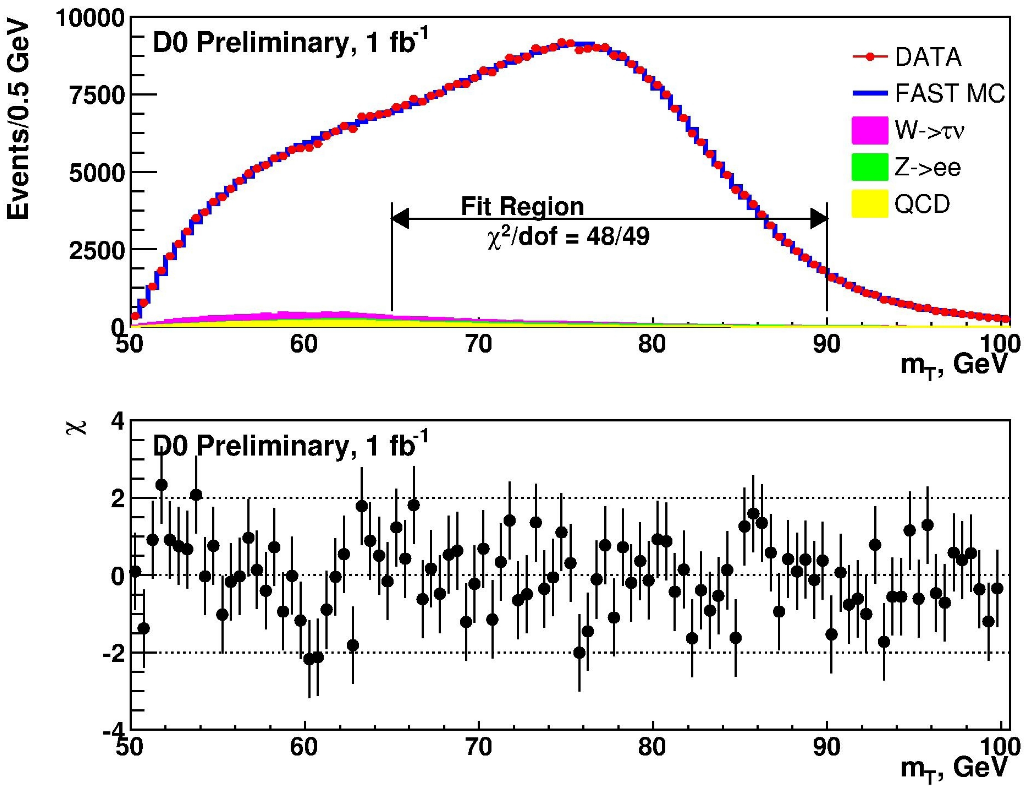
$$S^{\rm NP}_{\rm BLNY}(b, Q^2) = -g_1 - g_2 \ln\left(\frac{Q^2}{Q_0}\right) - g_1 g_3 \ln(100 x_A x_B)$$

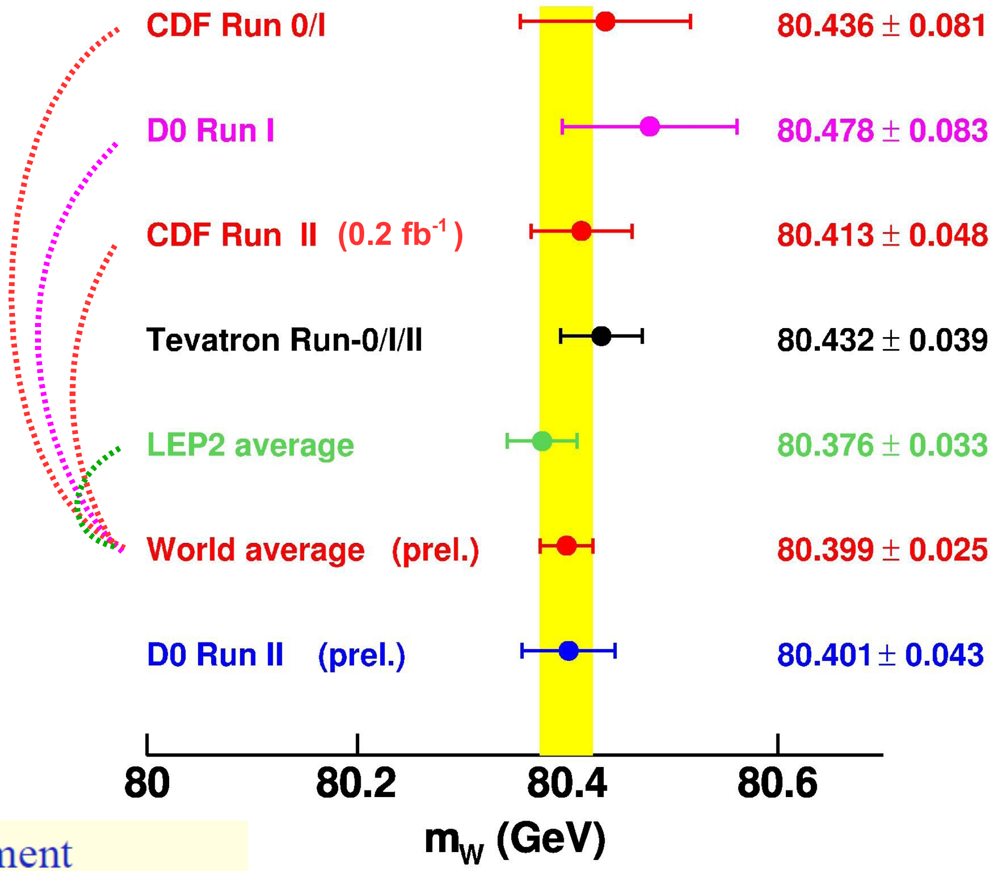
Single most precise measurement of m_W to date:

$$m_W = 80.401 \pm 0.021_{stat} \pm 0.038_{syst} \text{ GeV} = 80.401 \pm 0.043 \text{ GeV}$$

M.Ć.

– In good agreement with previous measurements: **CDF Run II (0.2 fb^{-1}), LEP2 average**





- Expect $\delta m_W < 25$ MeV from next Tevatron measurement
  - *CDF: 2.3 fb^{-1}, DØ: 5 fb^{-1}*

C.Hays

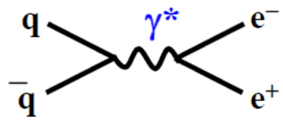
- Tevatron average not yet available
- Gfitter group has calculated its own world-average m_W
  - *$m_W = 80.399 \pm 0.023$ GeV (~10% reduction in uncertainty)*

Measurement of $\sin^2\theta_W$

C.Hays

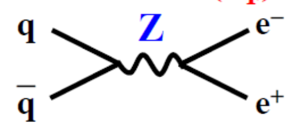
Chiral weak coupling produces angular asymmetry in Drell-Yan

- $d\sigma / d\cos\theta \propto 1 + \cos^2\theta + A_{FB}\cos\theta$ $[\, A_{FB} = f(v_f, a_f, s)\,]$
- *Vector & axial couplings:*
  - $\mathbf{v_f} = I^3_L - 2e\sin^2\theta_W$; $\mathbf{a_f} = I^3_L$
- *Measurement provides sensitivity to* $\sin^2\theta_W$



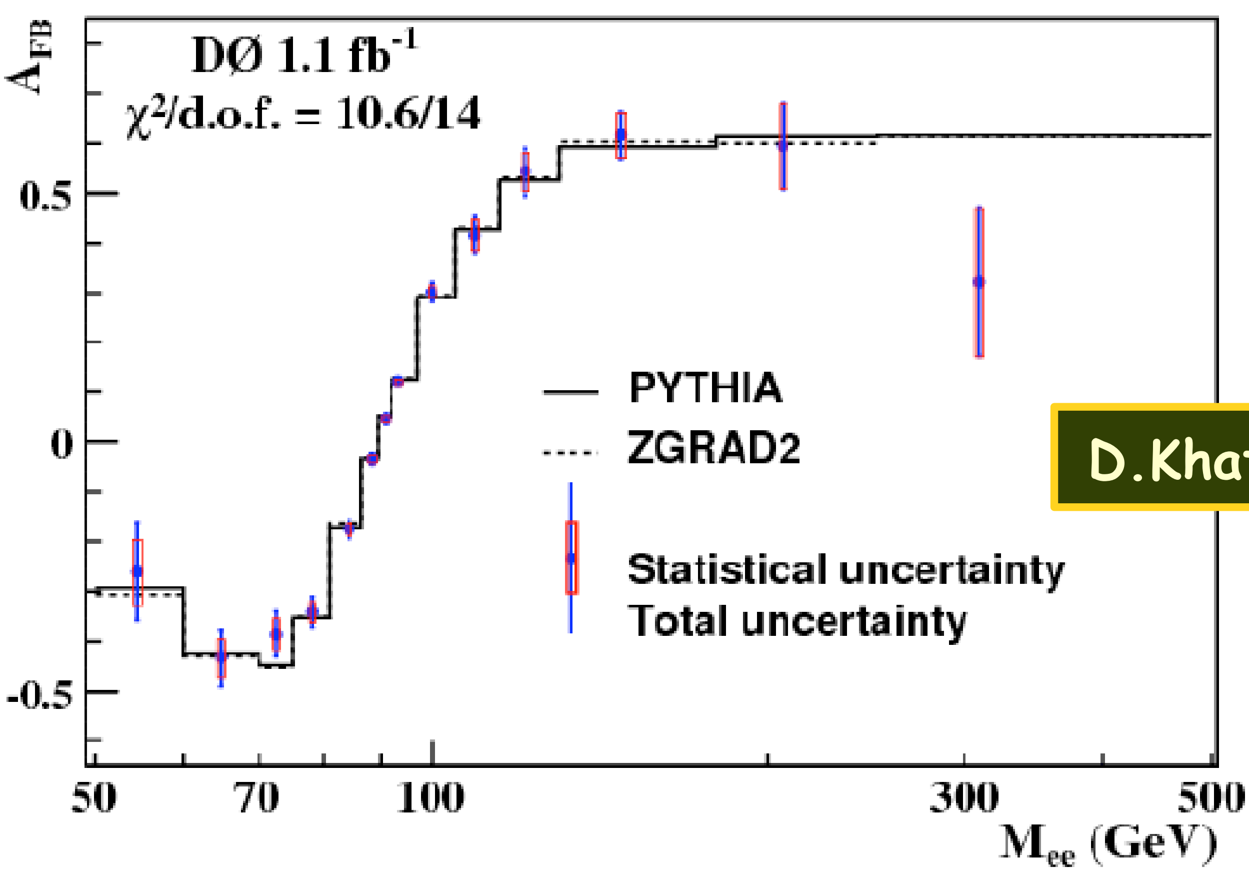
Vector coupling

FORWARD (σ_F) ($\cos\theta^* > 0$)



Vector & axial-vector coupling

BACKWARD (σ_B) ($\cos\theta^* < 0$)



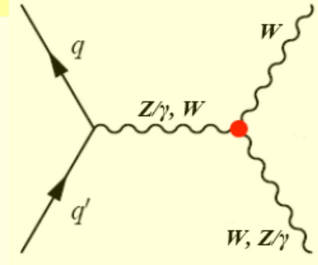
D.Khatidze

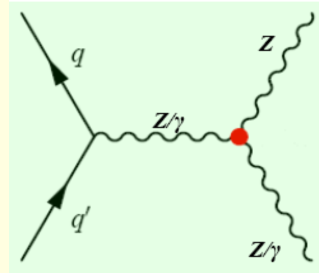
$\sin^2\theta_W = 0.2326 \pm 0.0018_{stat} \pm 0.0006_{sys}$

c.f. SM prediction:

$\sin^2\theta_W = 0.23149 \pm 0.00013$

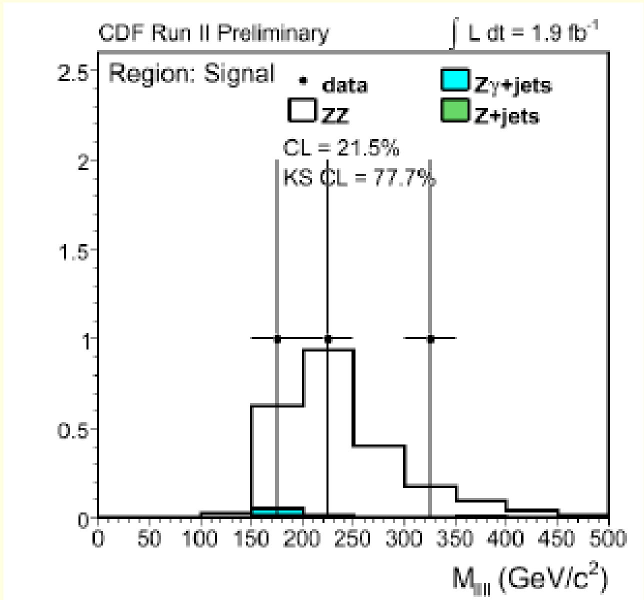
Triple-Gauge Couplings



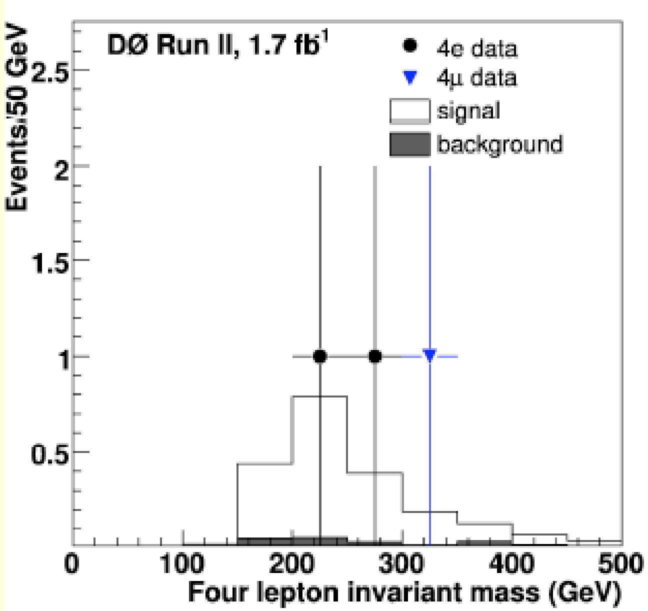


Non-abelian electroweak structure tested in detail

- *Tevatron results complementary to LEP*
  - Sensitive to deviations at higher Q^2
  - Separately probe WWZ and $WW\gamma$ vertices
- *Continue to add final states to probe triple-gauge couplings*
  - $W\gamma \to l\nu\gamma$
  - $Z\gamma \to ll\gamma$
  - $Z\gamma \to \nu\nu\gamma$
  - $WW \to ll\nu\nu$
  - $WW \to l\nu qq$
  - $WZ \to l\nu qq$
  - $WZ \to lll\nu$
  - $WZ \to qq\nu\nu$
  - $ZZ \to qq\nu\nu$
  - **$ZZ \to llll$**
  - **$ZZ \to ll\nu\nu$**
  - $ZZ \to llqq$



CDF Collaboration,
PRL 100, 201801 (2008)
4.4σ evidence



DØ Collaboration,
PRL 101, 171803 (2008)
5.7σ observation

C.Hays

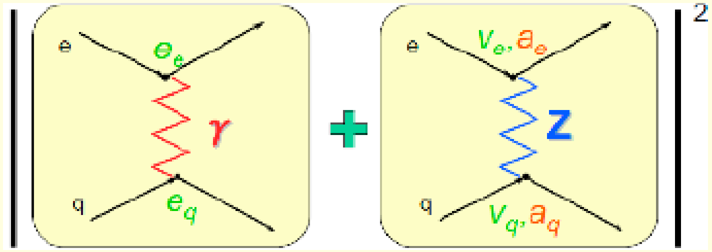
V.Cavaliere

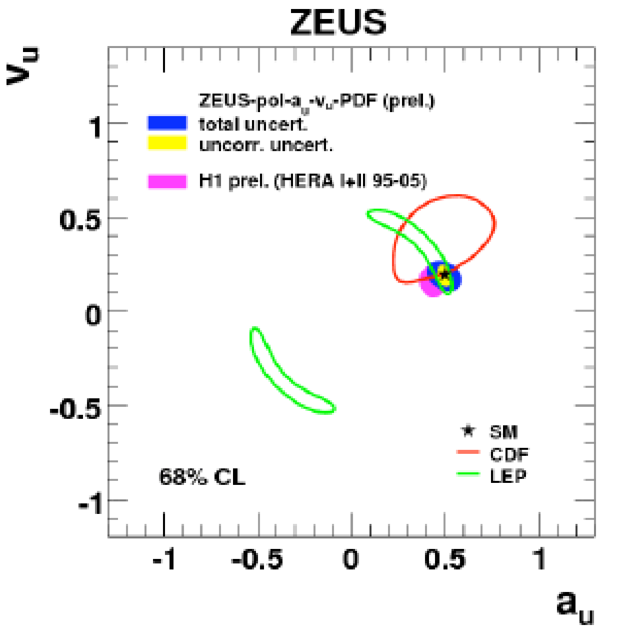
J.Haley

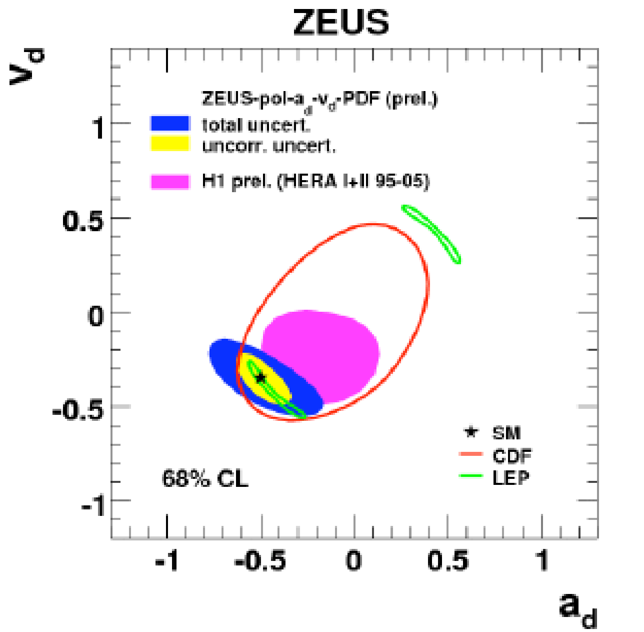
Quark Couplings to Neutral Current

Ambiguity in LEP measurement of quark electroweak couplings

- *HERA and Tevatron data resolving ambiguity*
- *Up and down quark couplings to neutral current*
  - Vector coupling:
    - $v_q = I^3_L - 2e \sin^2\theta_W$ = **0.203 (u), -0.351 (d)**
  - Axial coupling:
    - $a_q = I^3_L$ = **1/2 (u), -1/2 (d)**







Fit to v_q, a_q using NC data from HERA

Factor of two more data available for analysis

H1 Collaboration, PLB 632, 35 (2006)

C.Hays **E.Rivizi**

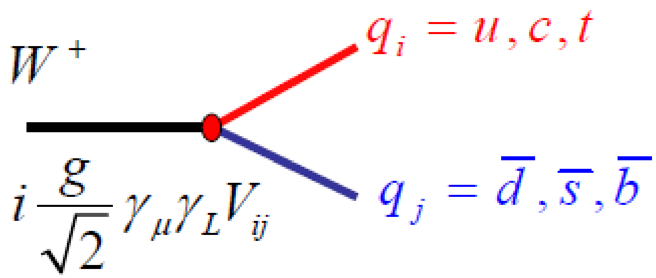
Fizyka kwarku *b*

Fizyka kwarku *b*

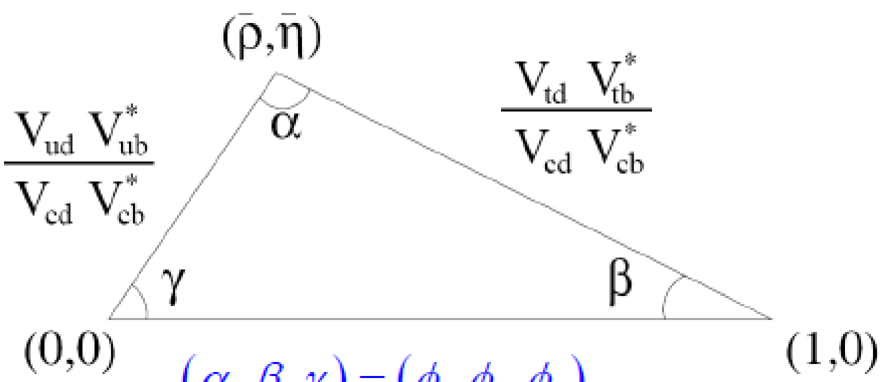
A.Bevan

- The B-Factories measure some tension with the SM:
  - $\sin 2\beta$
    - 2.1 - 2.7σ discrepancy between SM and measurements in Charmonium and (theoretically clean) s-penguins.
  - V_{ub}
    - Inclusive and exclusive measurements not in good agreement.
  - $A_{K\pi}$: the $K\pi$ puzzle
    - >5σ discrepancy between theory and measurement: is this real, or are there large corrections needed for theory (see S. Mishima).
  - The polarization puzzle persists.
- They also continue to constrain New Physics parameter space with rare B and τ decays.
  - $B^{\pm}\to\tau^{\pm}\nu$, $s\ell^{+}\ell^{-}$, $\tau\to 3\ell$, …
- Υ(NS) physics potential to constrain lepton universality and search for dark matter and light Higgs particles.

CKM and the unitarity triangle



$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



$$(\alpha, \beta, \gamma) = (\phi_1, \phi_2, \phi_3)$$

$$\alpha \equiv \arg\left[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*\right]$$
$$\beta \equiv \arg\left[-V_{cd}V_{cb}^*/V_{td}V_{tb}^*\right]$$
$$\gamma \equiv \arg\left[-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*\right]$$

$$\mathcal{A}(\Delta t) = \frac{\Gamma(\Delta t) - \overline{\Gamma}(\Delta t)}{\Gamma(\Delta t) + \overline{\Gamma}(\Delta t)}$$

$$\mathcal{A}(\Delta t) = S\sin(\Delta m_d \Delta t) - C\cos(\Delta m_d \Delta t)$$

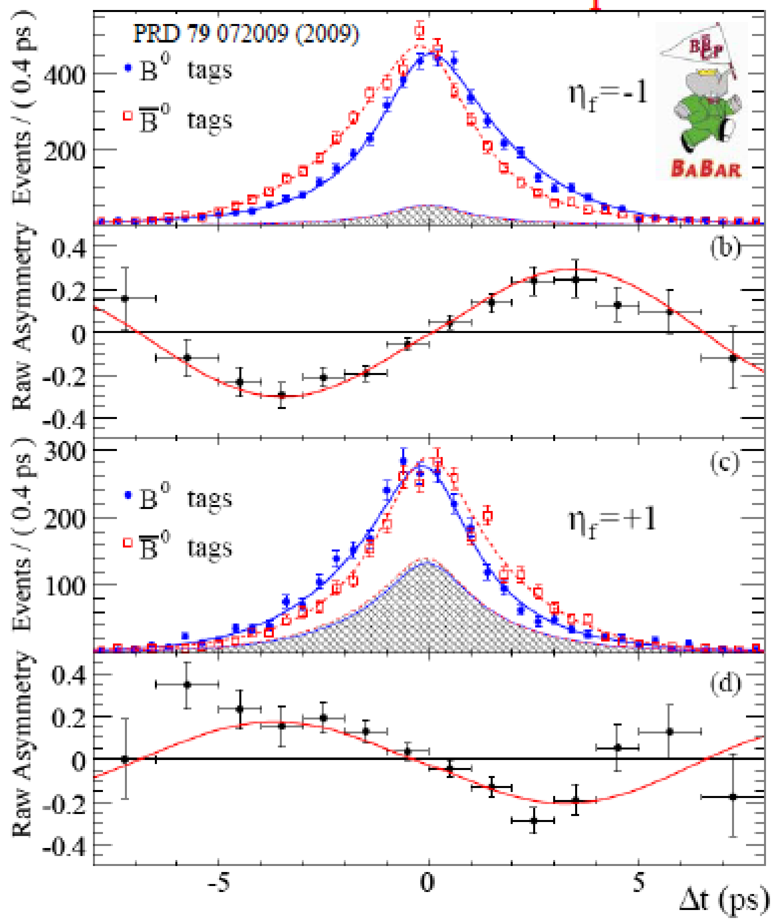
A.Bevan

Adrian Bevan 55

CP Violation: β (ϕ_1) from $c\bar{c}s$ decays

- Using $B \to J/\psi K^0$, $J/\psi K^*$, $\psi(2S)K_S$, $\eta_c K_S$, & $\chi_{c1}K_S$ decays.

BaBar's final result has been published:

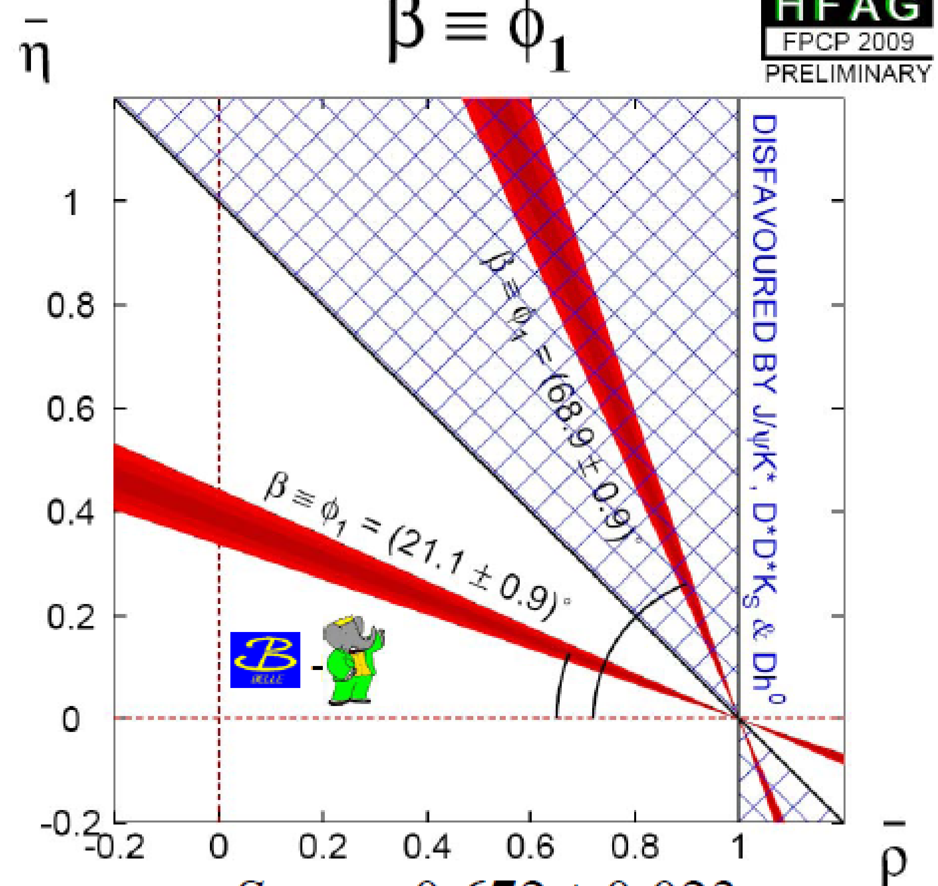


$$S = -0.687 \pm 0.028 \pm 0.012$$

$$C = 0.024 \pm 0.020 \pm 0.016$$

$\beta \equiv \phi_1$

HFAG FPCP 2009 PRELIMINARY



$$S_{WA} = -0.672 \pm 0.023$$

$$C_{WA} = 0.004 \pm 0.019$$

Still limited by statistics!

A.Bevan

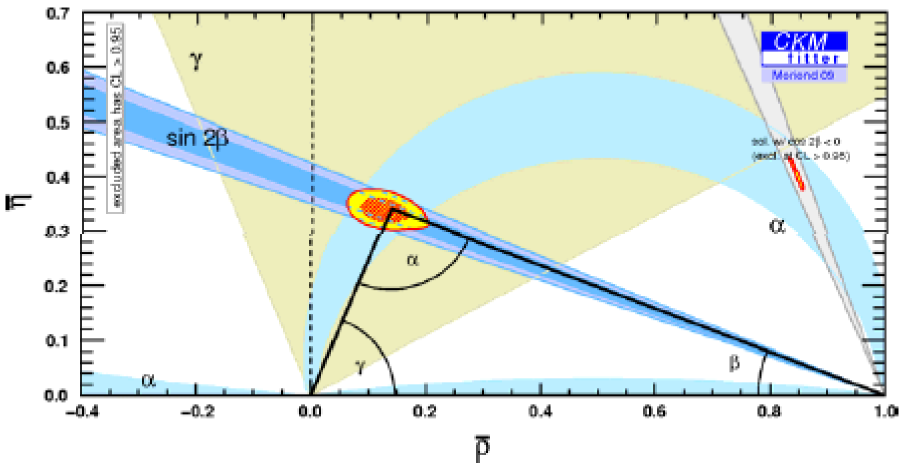
Adrian Bevan 5

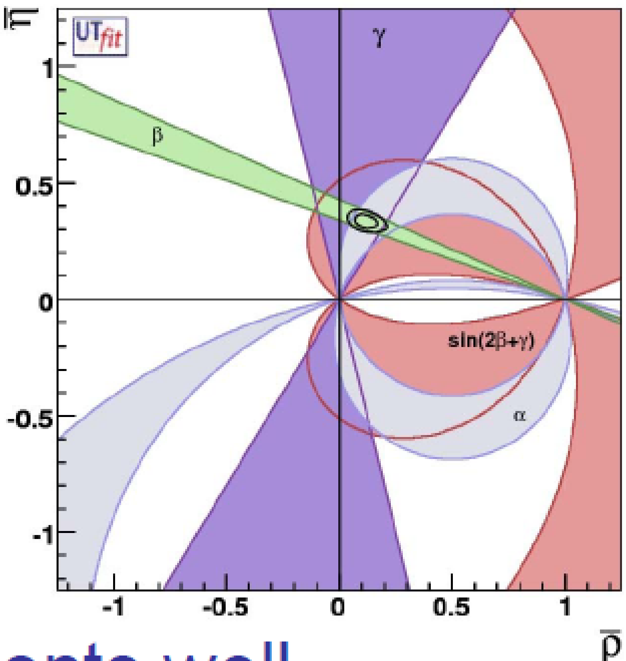
Testing the Standard Model

- $\alpha+\beta$ constrained Unitarity Triangle to 5°!

$$\alpha+\beta+\gamma=\left(180^{+27}_{-30}\right)^{\circ}\ /\ \left(191\pm14\right)^{\circ}$$ CKM fitter / UT fit

- But poor precision on over-constraint.





- CKM describes measurements well.
- Still plenty of room for new physics!

A.Bevan

Adrian Bevan 9

Testing the Standard Model

- We were reminded that we should be careful with what we compare:
  - NP could affect $c\bar{c}s$ sin2β.

1) Predict sin2β from indirect constraints.

$$[\sin(2\beta)]^{\text{prediction}}_{\text{no } V_{ub}} = 0.87 \pm 0.09 \,.$$

2) Compare to $c\bar{c}s$ measurement.

$$[\sin 2\beta]_{c\bar{c}s} = 0.672 \pm 0.023$$

3) Compare to clean penguin measurements.

$$[\sin 2\beta]^{clean}_{b \to s-penguin} = 0.58 \pm 0.06$$

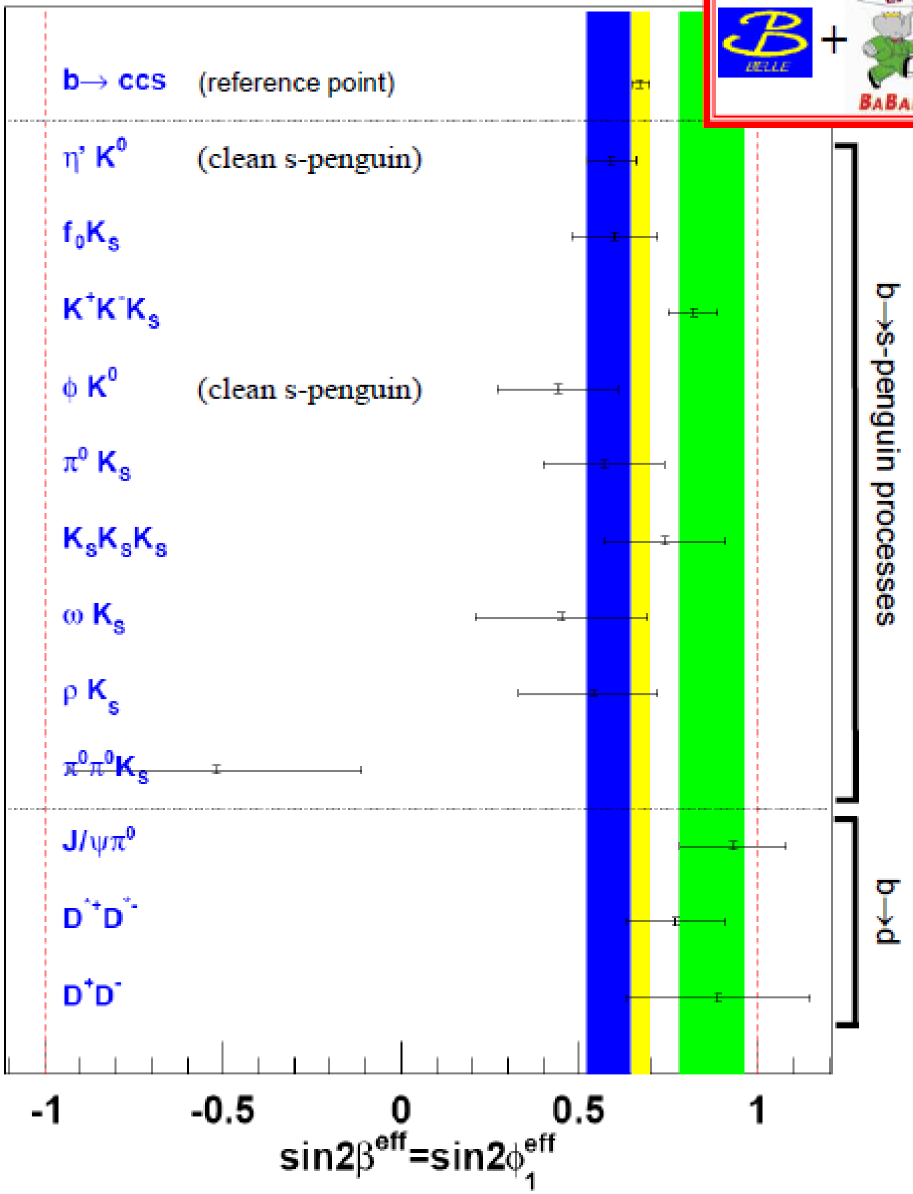
(or the average of the two)

Are these 2.1–2.7σ hints for new physics?

Lunghi and Soni, Phys.Lett.B666 162-165 (2008).
Buras and Guadagnoli Phys Rev D 78 033005 (2008).

- **Can theory error be reduced for other modes?**

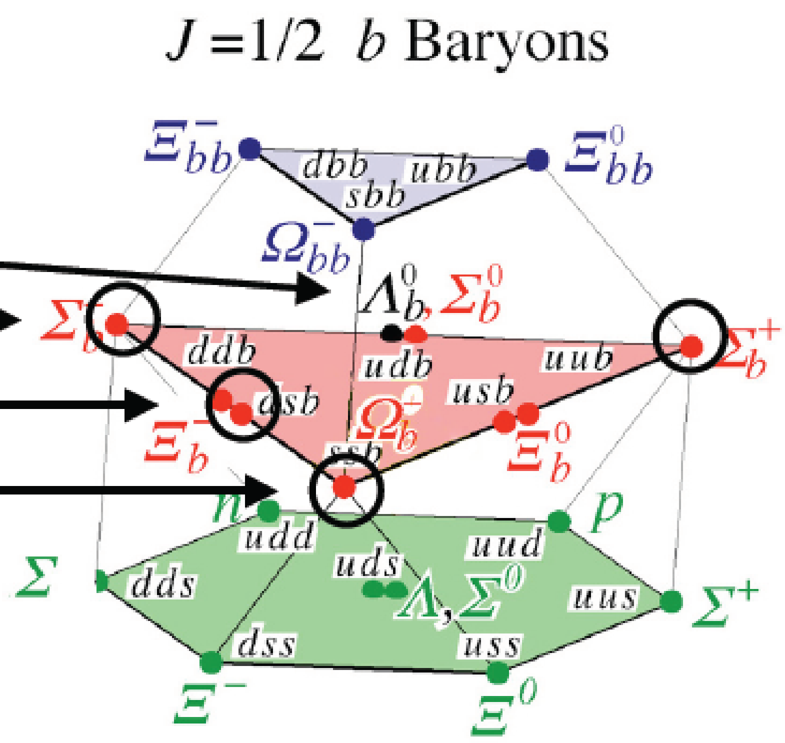
(numbers taken from the HFAG web site)



A.Bevan

Bottom Baryon States

- Our knowledge of *b*-baryons has greatly expanded in the last ~3 years
- This is totally a Tevatron field
  - World's largest samples of Λ_b
  - $\Sigma_b^{(*)+}$ and $\Sigma_b^{(*)-}$ observed by CDF in 2007
  - Ξ_b^-, observed by D0 & CDF in 2007
  - Ω_b^-, observed by D0 in 2008, CDF 2009
- Will mention only the latest results, which are about Ξ_b^- (*usb*) and Ω_b (*ssb*). Both are weakly-decaying as the Λ_b and can be fully reconstructed in J/ψ modes by both experiments.



D0 : $m(\Omega_b) = 6165 \pm 10 \pm 13$ MeV/c^2

?

$M(\Omega_b)_{D0} - M(\Omega_b)_{CDF} = 111 \pm 12 \pm 14$ MeV/c^2

- Significant disagreement (6-sigma)
- Agreement on Ξ_b^- : not a scale problem

G.Punzi

FCNC/LFV

G.Punzi

- Rare in the SM, but can be significantly enhanced by several BSM processes.
- Require large production and large rejection - strong points of Tevatron experiments. Data collected from either dimuon trigger (Pt>1.5 GeV) or (remarkably) track trigger (Pt>2 GeV with impact parameter).
- Modes studied:
  - $B^0 \to K^{0*} l^+l^-$, $B^+ \to K^+ l^+l^-$, $B_s \to \varphi\, l^+l^-$
    - In progress, expect similar resolution to B-factories. Confirm hints of deviation ? *[see talk by T.Hurth]*
  - $D^0 \to \mu\mu$
    - BR <5.3 10^{-7} (0.36fb^{-1}). Best limit until recently.
  - B_s /B_d $\to$ ee, eμ
    Best Pati-Salam leptoquark limits: >48/60 TeV respectively
    [Phys.Rev.Lett.102:201801,2009]
  - $B_d \to \mu\mu$, $B_s \to \mu\mu$

B_s oscillation parameters

G.Punzi

$$i\frac{d}{dt}\begin{pmatrix} B_s^0 \\ \bar{B}_s^0 \end{pmatrix} = \begin{pmatrix} M - \frac{i\Gamma}{2} & M_{12} - \frac{i\Gamma_{12}}{2} \\ M_{12}^* - \frac{i\Gamma_{12}^*}{2} & M - \frac{i\Gamma}{2} \end{pmatrix}\begin{pmatrix} B_s^0 \\ \bar{B}_s^0 \end{pmatrix}$$

Diagonalize

CP Eigenstates: $|B_s^{odd}\rangle = |B_s^0\rangle + |\bar{B}_s^0\rangle$ $|B_s^{even}\rangle = |B_s^0\rangle - |\bar{B}_s^0\rangle$

Mass Eigenstates: $|B_s^H\rangle = p|B_s^0\rangle + q|\bar{B}_s^0\rangle$ (Heavy) $|B_s^L\rangle = p|B_s^0\rangle - q|\bar{B}_s^0\rangle$ (Light)

If CP conserved in mixing, $p=q$

observables

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H \qquad \Gamma_s = \frac{(\Gamma_L + \Gamma_H)}{2}$$

$$\Delta M_s = M_H - M_L$$

$$a^s_{fs} = \frac{\Gamma(\bar{B}_s(t) \to f) - \Gamma(B_s(t) \to \bar{f})}{\Gamma(\bar{B}_s(t) \to f) + \Gamma(B_s(t) \to \bar{f})}$$

$$\Delta M_s = 2|M_{12,s}^{\rm SM}| \cdot |\Delta_s|$$

$$\Delta\Gamma_s = 2|\Gamma_{12,s}| \cdot \cos\left(\phi_s^{\rm SM} + \phi_s^\Delta\right)$$

$$\frac{\Delta\Gamma_s}{\Delta M_s} = \frac{|\Gamma_{12,s}|}{|M_{12,s}^{\rm SM}|} \cdot \frac{\cos\left(\phi_s^{\rm SM} + \phi_s^\Delta\right)}{|\Delta_s|}$$

$$a_{fs}^s = \frac{|\Gamma_{12,s}|}{|M_{12,s}^{\rm SM}|} \cdot \frac{\sin\left(\phi_s^{\rm SM} + \phi_s^\Delta\right)}{|\Delta_s|}$$

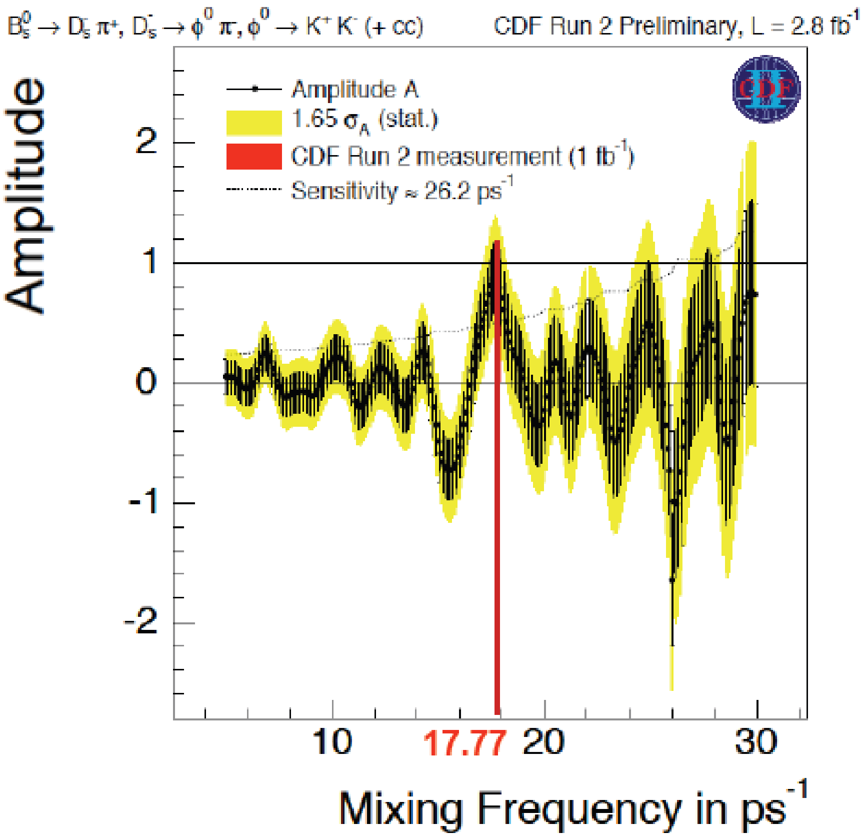
$$\sin(\phi_s^{\rm SM}) \approx 1/240$$

Sensitive to a lot of possible New Physics:
SUSY, 4th generation, GUT, Extended Higgs, MFV, unparticle, …

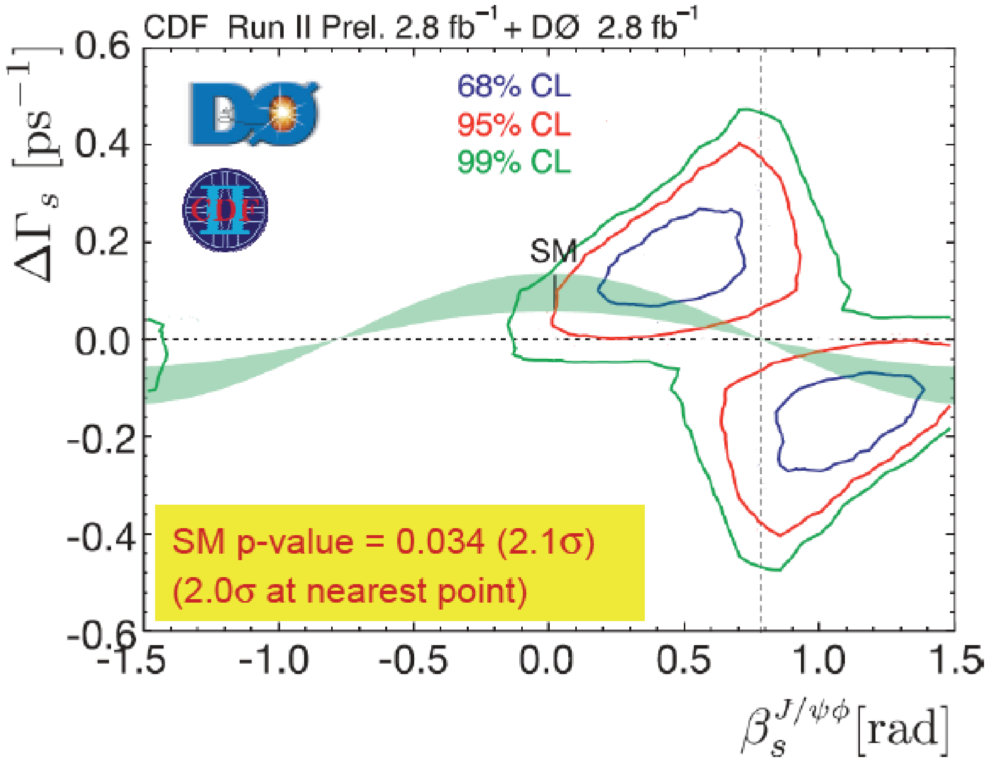
B_s oscillation parameters

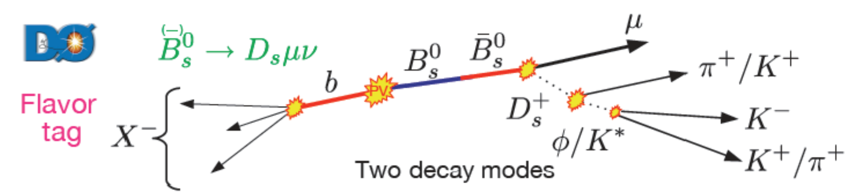
Δm_s - (CDF dominated) agree with SM.

$\Delta m_s = 17.77 \pm 0.10 \pm 0.07$ ps^{-1}



$\phi_s^{J/\psi\phi} \equiv -2\beta_s^{J/\psi\phi}$ results (2.8fb^{-1}/exp.)





arXiv:0904.3907, sub. to PRL

B_s semileptonic asymmetry

$$\mathcal{A}_{SL}^s = -0.0017 \pm 0.0091^{+0.0012}_{-0.0023}$$

Wyniki **QCD**

Wyniki **QCD**

P.Schleper

Parton densities:

- big step seen in HERA-PDF from combining HERA-I data,
- HERA-II will improve at high-x
- major improvement will need NNLO for jets in ep collisions: eq→e jj, also for α_s

Legs and Loops:

- ground breaking new developments for NLO with 3,4 … legs
- tests at Tevatron require (again) change of jet cone algorithms
- physics program of LHC requires excellent understanding of multi-leg (NLO) Monte-Carlos

Soft processes:

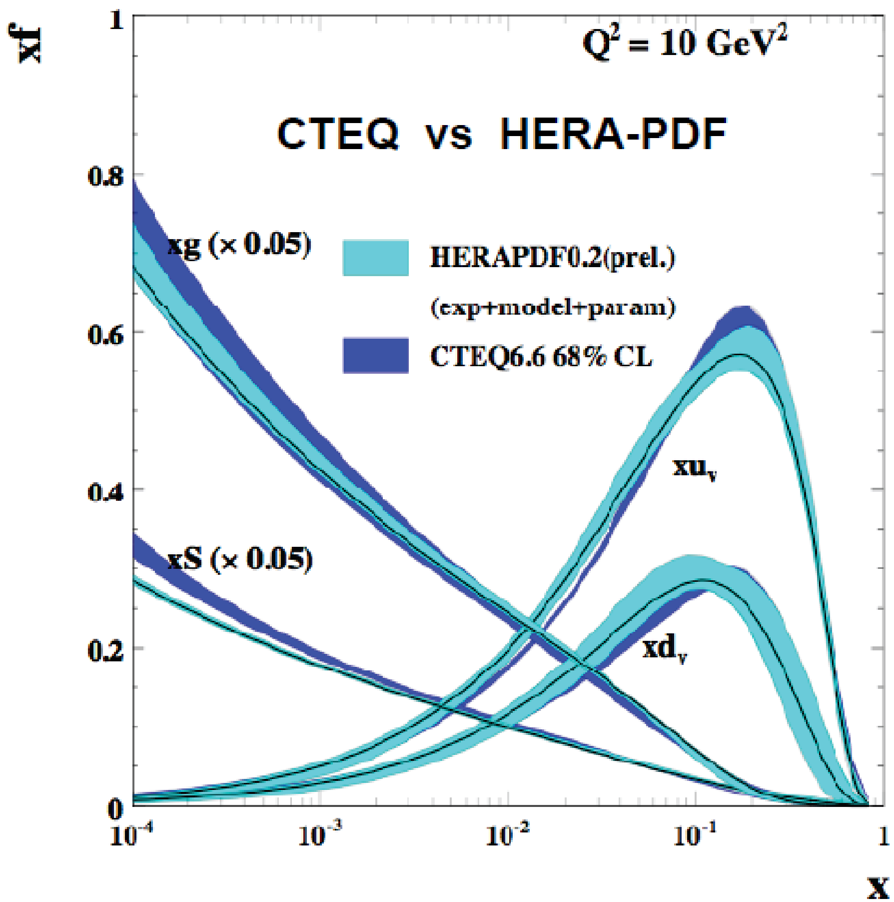
- Underlying event and minimum bias processes poorly modeled
- Hopefully not a bottleneck for understanding first LHC data

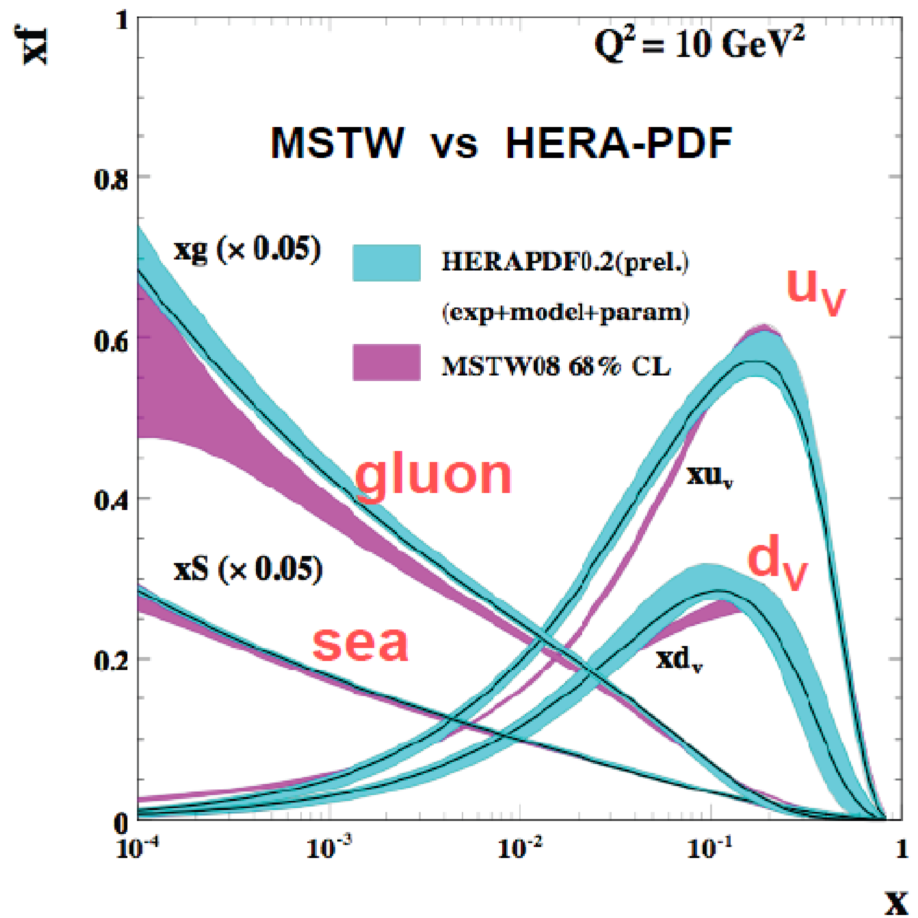
- New QCD toolbox needs to be tested / tuned at Tevatron and HERA
- QCD at LHC will be much more exciting than anticipated with these tools in place

LHC program for start-up

- Underlying Event
- Jet Shapes
- Dijet Angular Decorrelation
- Inclusive Jet Cross Section
- Dijet Mass and Ratio, Angle
- Event Shapes
- Multi-Jets

QCD Fits of Parton Densities I





Errors reflect different treatment of experiments, model uncertainties, $\alpha_{S,}$ …

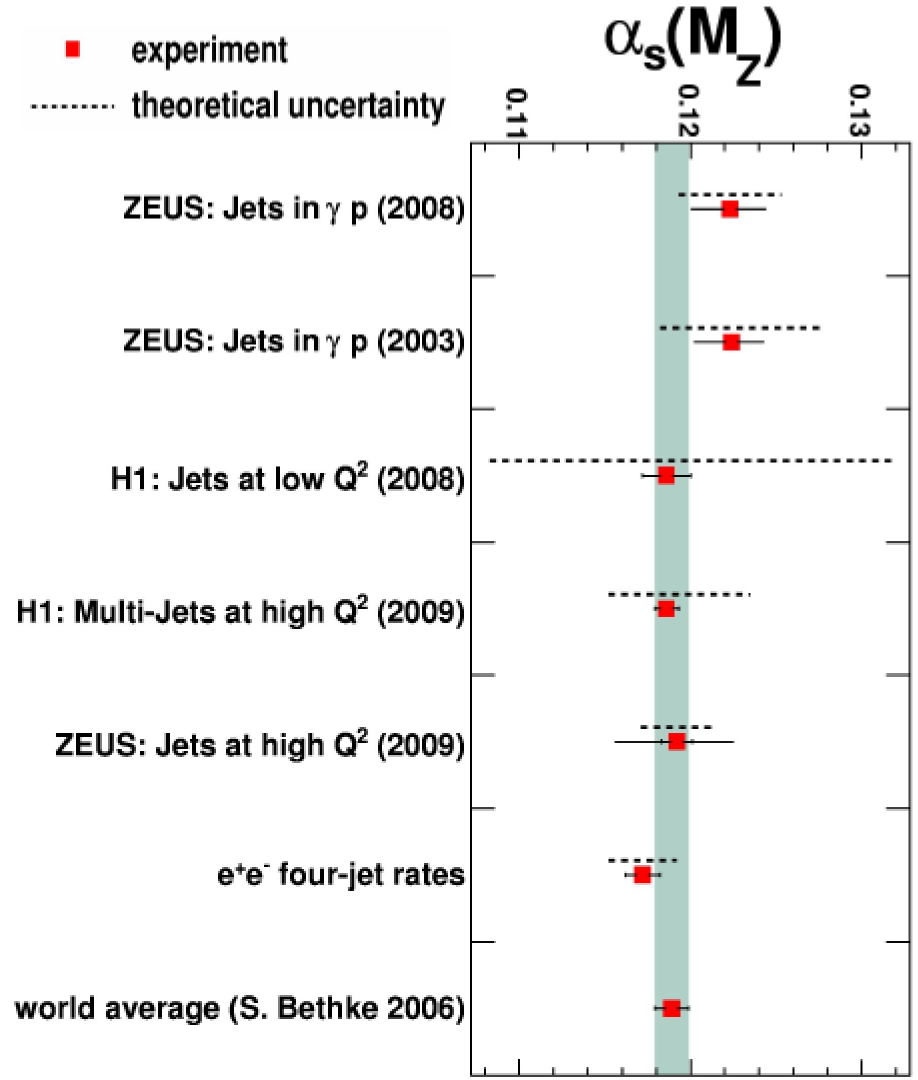
HERA Structure function working group

- Combined cross section: cross calibration of systematics: $\Delta\sigma$ ~ 1 ... 2 %
  H1, ZEUS results are compatible: χ^2/ ndf = 637 / 656
- NLO QCD Fit: HERA-PDF 0.2

P.Schleper

Summary of α_s Extractions

- **extracted α_s values are consistent with the world average!**
- precision is comparable to the values obtained from e^+e^- interactions
- HERA competitive!
- different measurements and environments and processes are consistent
  - $\hookrightarrow$ **great success of QCD!!**



Best value so far

$\alpha_s(M_Z) = 0.1168 \pm 0.0007$ (exp.)

± 0.0016 (PDF)

$+ 0.0046 - 0.0030$ (theo.)

Progress on α_s and PDF requires NNLO

P.Schleper

J.Behr

Collider Jet Data

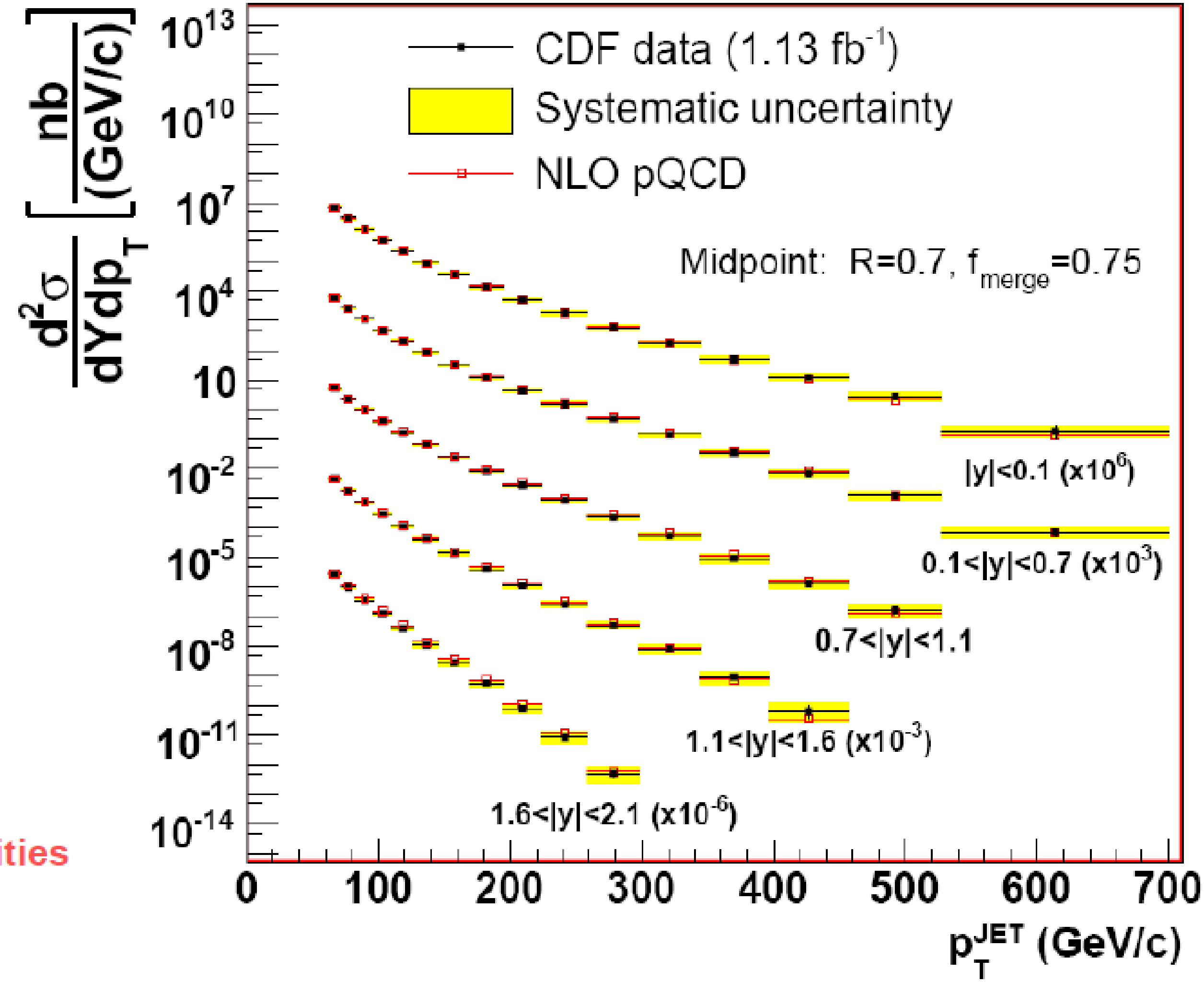
CDF & D0:

- Much improved calibration and error analysis

CDF:

- Inclusive jet cross-section
- Midpoint algorithm for data
- „Similar agreement for Kt and SisCone", dominated by simple 2-jet configurations

➔ Input for fits of parton densities



D0: similar size of experimental error, NLO scale uncertainty, and PDF uncertainty used to constrain new physics

P.Schleper

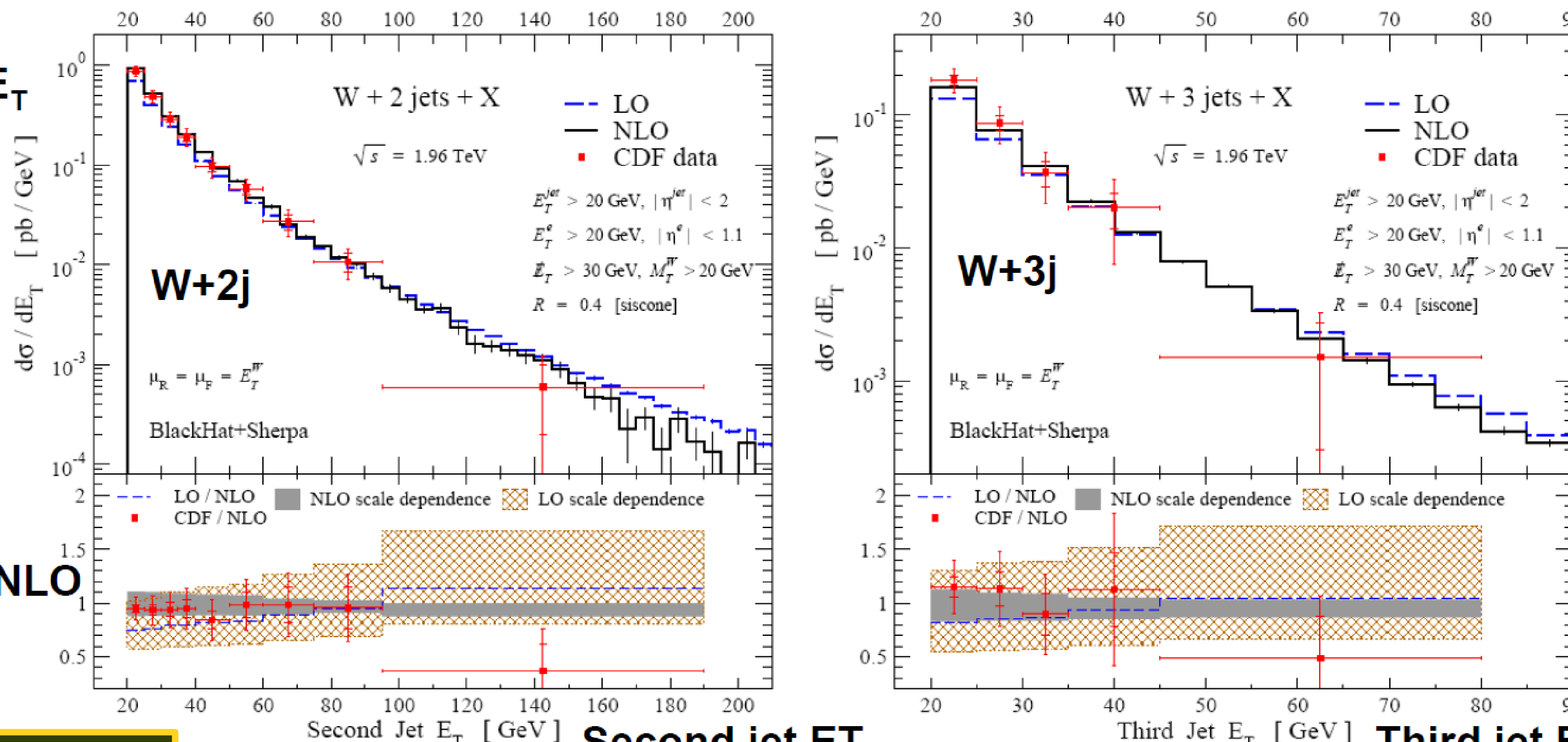
Multi-Leg NLO

New techniques for multi-leg NLO calculations (see talk by Anastasiou)

- full NLO for W+3jet at Tevatron — Berger et al, arXiv:0907.1984
- Much reduced scale uncertainty (~10%)
- NLO: SisCone CDF: JETCLU 0.32 fb^{-1}
- First successful test of NLO automation, much more precise data to come

$d\sigma / dE_T$

data / NLO



Second jet ET   Third jet ET

P.Schleper

Poszukiwania bozonu **Higgsa**

Poszukiwania bozonu **Higgsa**

J.Conway

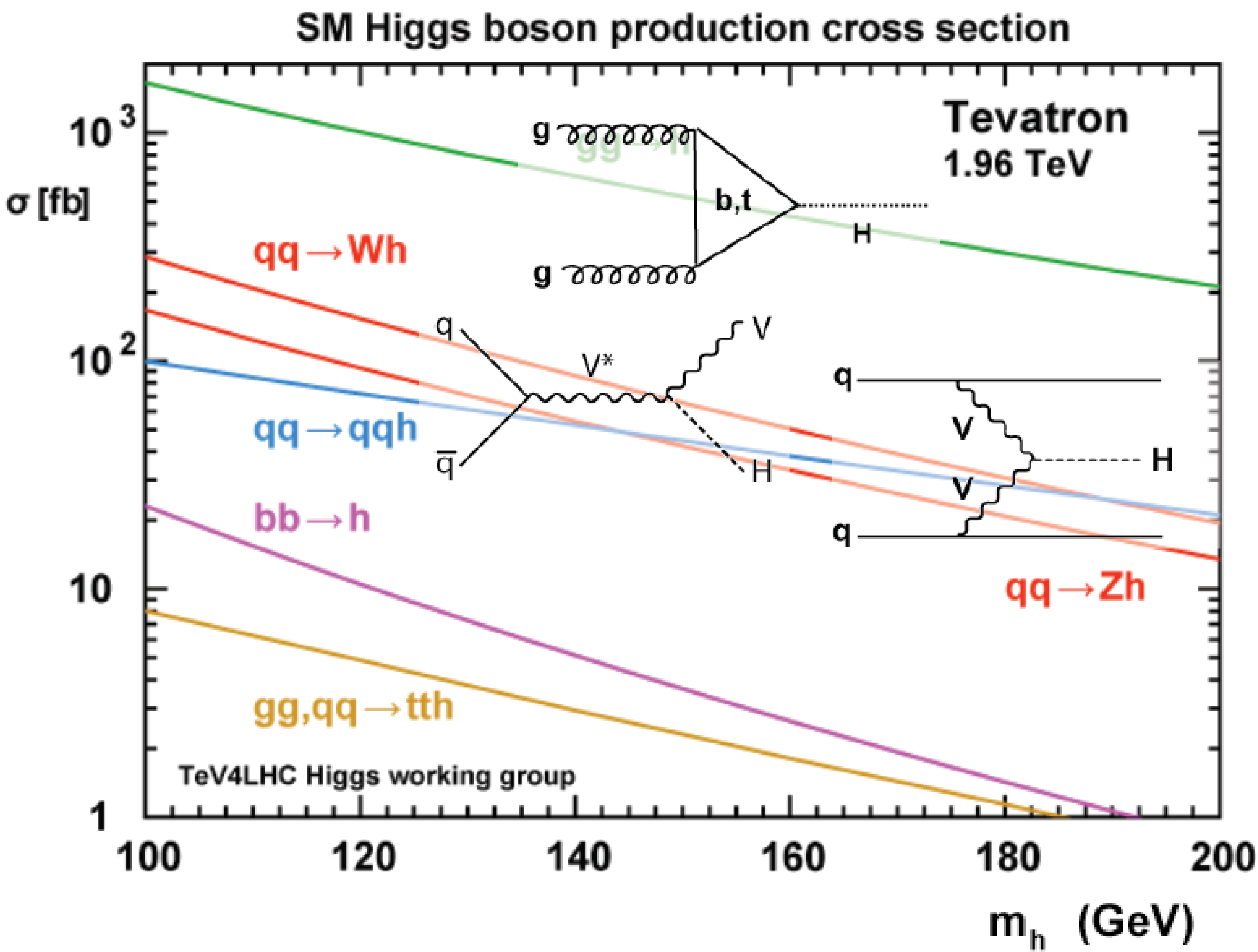
CDF and D0 have drawn first blood in the search for the SM Higgs, excluding the region 160-170 GeV

New combination soon - expand excluded region

MSSM search is statistics limited: new scientific ground broken with every update

An SM Higgs at ~120 GeV is exceedingly difficult to discover and will take a number of years more

A 5-sigma discovery by the Tevatron at low mass is very unlikely, but an exclusion could happen soon!


SM Higgs boson production cross section
σ [fb]
10^3
10^2
10
1
100
120
140
160
180
200
m_h (GeV)
Tevatron
1.96 TeV
g
g
b,t
H
qq→Wh
q
$\bar{q}$
V*
V
H
qq→qqh
q
q
V
V
H
bb→h
qq→Zh
gg,qq→tth
TeV4LHC Higgs working group

light SM Higgs boson

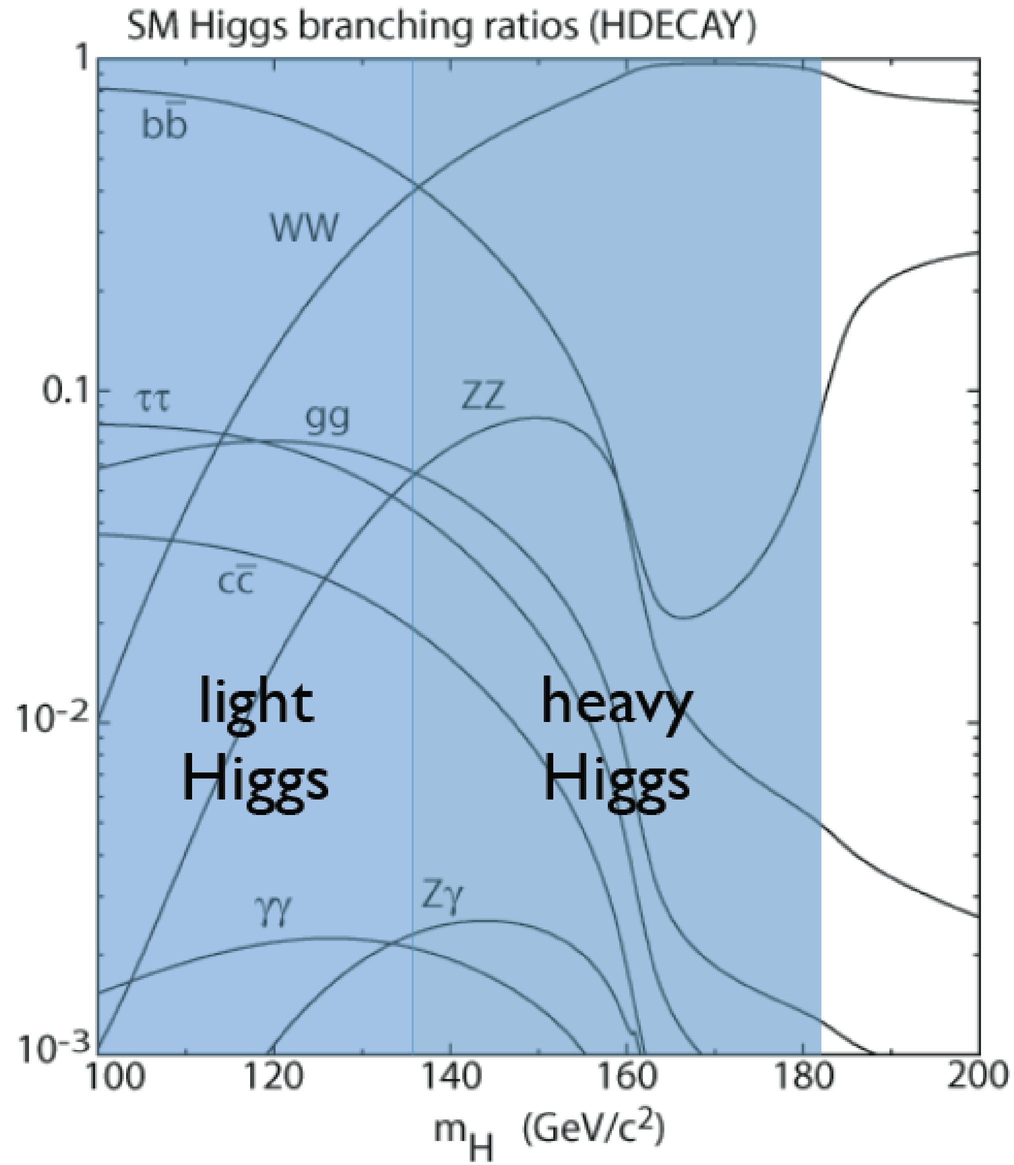
bb decay dominates

ττ plays a role

heavy SM Higgs boson

WW decay dominates

ZZ: ℓℓ BR too small

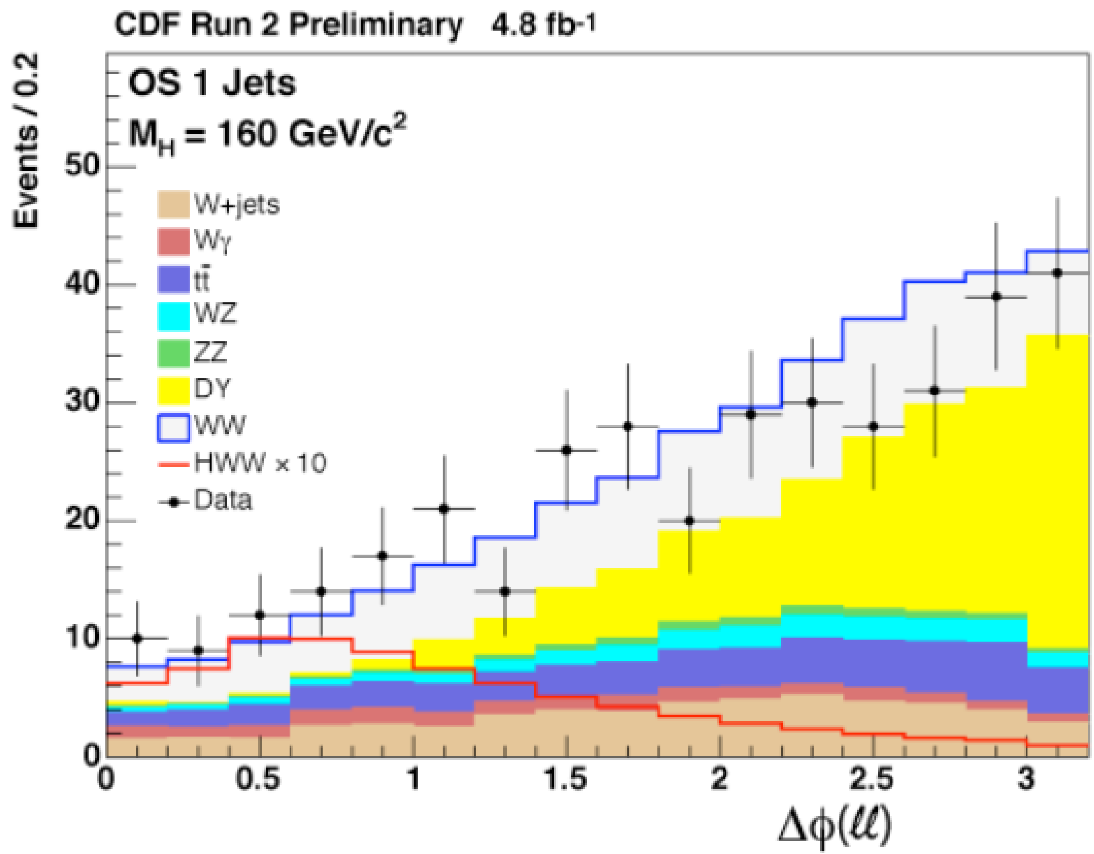


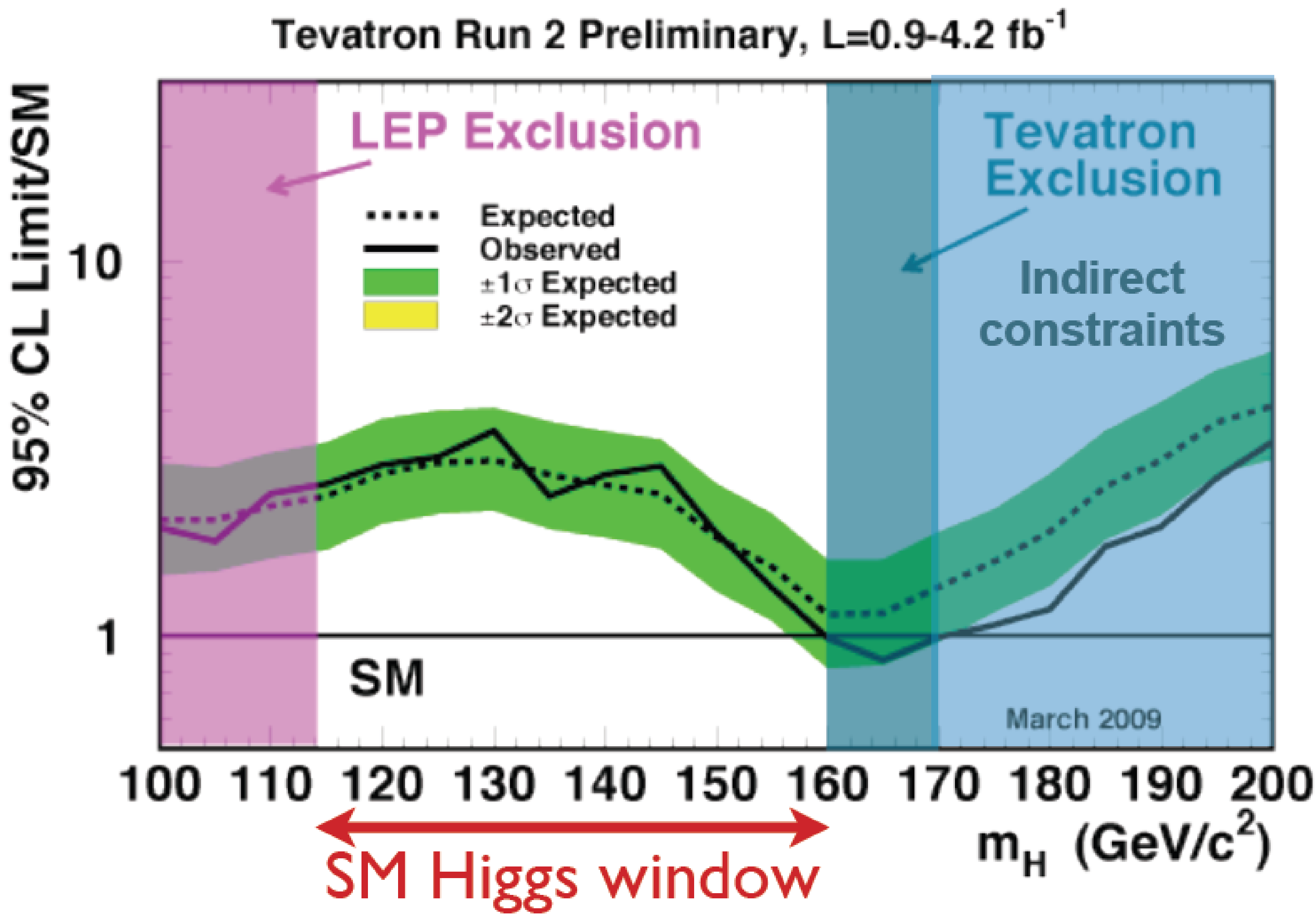
SM Higgs boson decay

New result shown first at this conference: CDF SM H→WW using 4.8 fb^{-1}

$\Delta\phi(\ell\ell)$ distribution shows effect of spin correlations

Use NN discriminator on all four channels





CDF + D0 Exclusion Limits

18 J.Conway - EPS 2009

The "main event" is still the low mass bb channels...

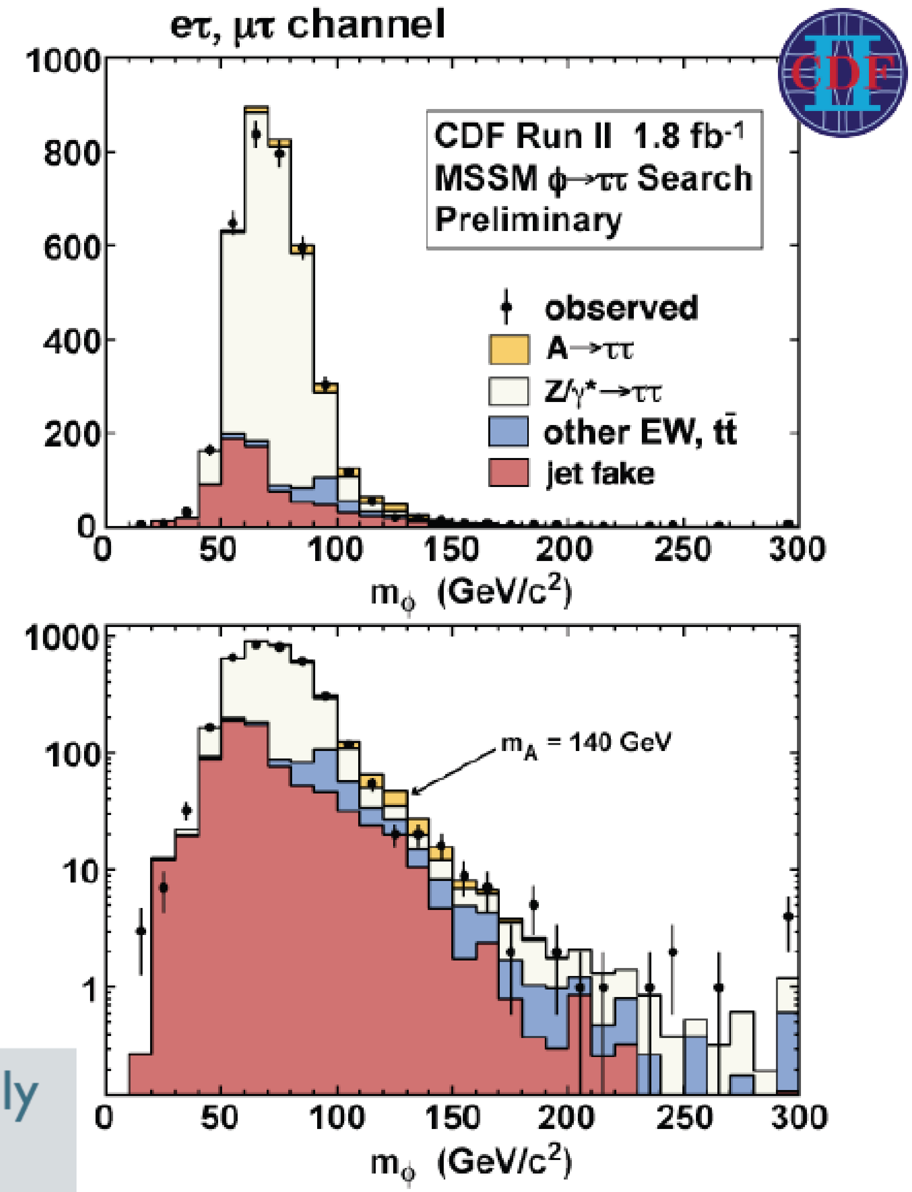
	$\nu\nu bb$	$\ell\nu bb$	$\ell\ell bb$
CDF	2.1 fb^{-1}	2.7 fb^{-1}	2.7 fb^{-1}
D0	1.6 fb^{-1}	2.7 fb^{-1}	4.2 fb^{-1}

We anticipate updates soon in a number of these!

$\nu\nu bb$: expected to be the most sensitive
$\ell\nu bb$: heavily studied final state
$\ell\ell bb$: best m_{bb} resolution, low BR

Tau pair search: demand one e or μ plus one hadronically decaying tau, or another e or μ

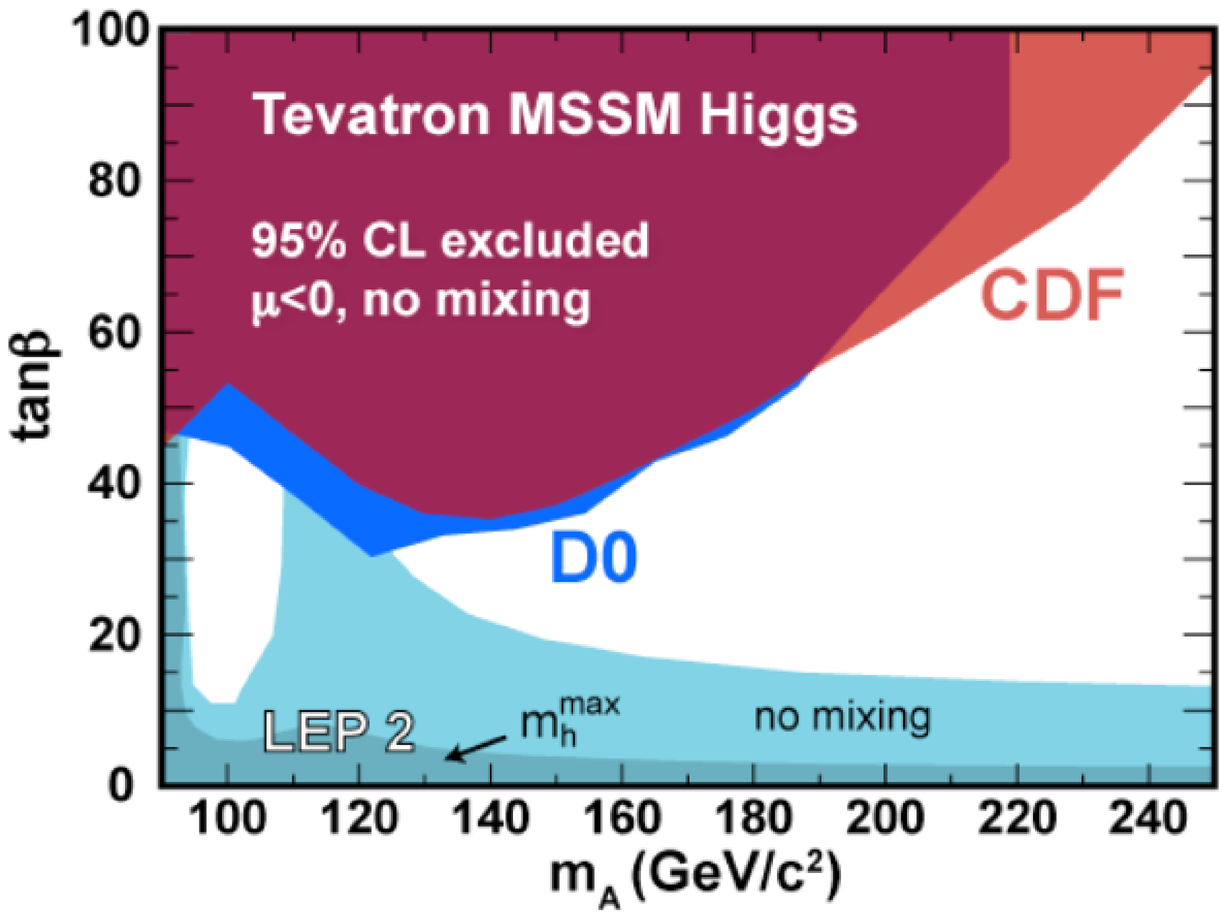
Main background is from Drell-Yan $Z/\gamma^* \to \tau\tau$: use mass to distinguish signal from background



- bb and ττ decay modes dominate experimentally
- ττ is the most sensitive: main background is Z

Tau Pair Search

33 J.Conway - EPS 2009



D0: combine all channels, 1.0-2.6 fb^{-1} CDF: 1.8 fb^{-1}

MSSM Higgs Limits 35 J.Conway - EPS 2009

Podsumowanie

Podsumowanie

Status of the "Standard Models" at this EPS conference:

- Particles: wealth of data, all consistent with the SM
- Astrophysics: no phenomena which are inconsistent with conventional physics
- Cosmology: remarkably precise data, all consistent with cosmological SM

Are there hints for new physics, and if yes, at which energy scale?

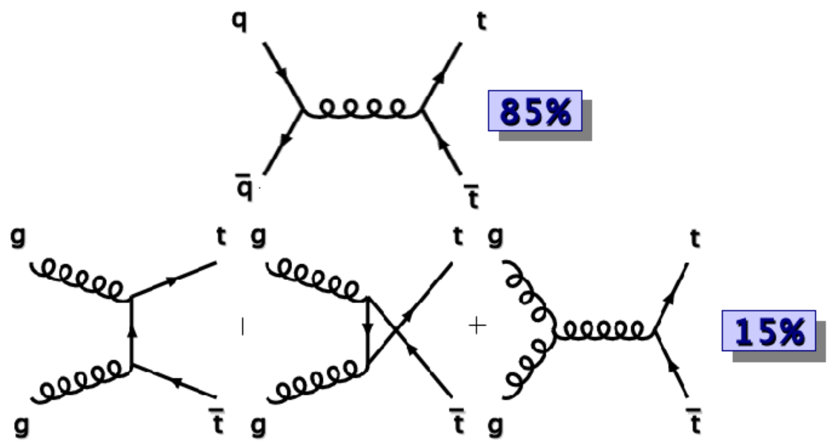
W.Buchmuller

BACKUP

Produkcja **par kwarków t** w Tevatronie

C. Schwanenberger

Top Quark Pair Production

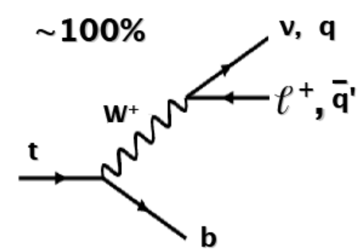


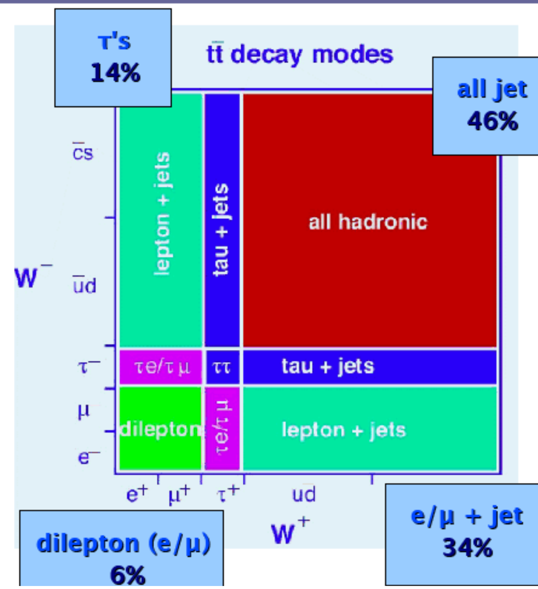
PRD 78, 034003 (2008)

$\sigma_{t\bar{t}} = 7.46\,^{+0.48}_{-0.67}$ pb in NNLO$_{approx}$
(m_{top} = 172.5 GeV)

Top Pair Signatures

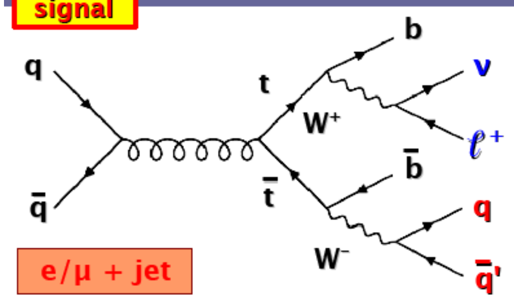
top decay:



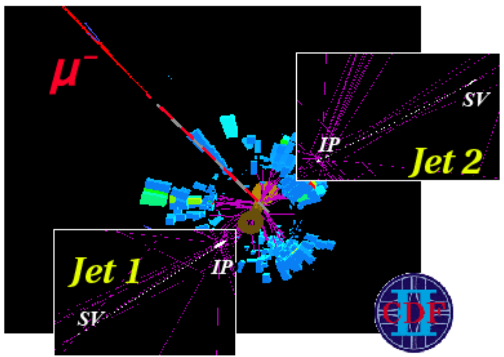


Lepton+jets Signatures

signal

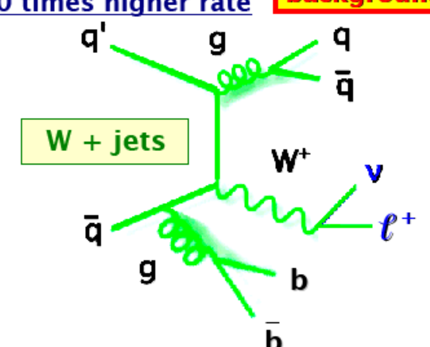


e/μ + jet

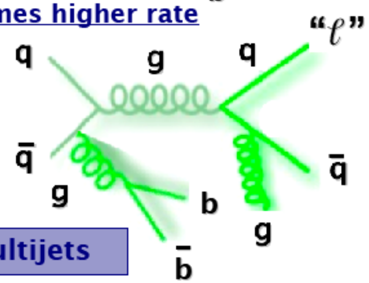


background

3000 times higher rate



10^{10} times higher rate



Methods: overview

Template Methods

- Choose observable(s) X sensitive to m_t
- Create 'templates', **simulated** distributions of X for different true m_t
- Simulated distributions from **M**onte **C**arlo events for predicted signal and background processes
- Measurement based on which m_t template(s) gives best fit to observed data
- Few assumptions

Matrix Element (ME) Methods

- Calculate m_t-dependent p.d.f. for each event i with observables $\vec{x}_i$

$$P_i(\vec{x}_i) = \frac{1}{N}\int \mathrm{TF}(\vec{x}_i \mid \vec{y}_i)\, d\sigma(\vec{y}_i)$$

- LO differential $p\bar{p} \to t\bar{t}$ x-section $d\sigma \propto |\mathcal{M}|^2$
  - $|\mathcal{M}|^2$ sensitive to m_t
- **T**ransfer **F**unction maps measured quantities $\vec{x}_i$ to parton-level quantities $\vec{y}_i$
- m_t from maximisation of the joint likelihood

$$L(\mathbf{x} \mid m_t) = \prod_{\text{events}} P_i(\vec{x}_i \mid m_t)$$

- Better statistical precision achieved by extracting more information from each event

17/07/09

J. Linacre

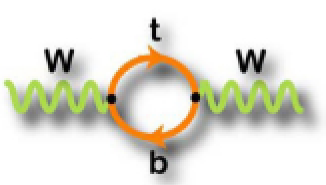
Pomiar masy W

M.Ć.

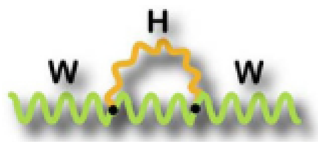
Motivation for precise W mass

- Precise measurements of m_W and m_t can constrain SM Higgs mass

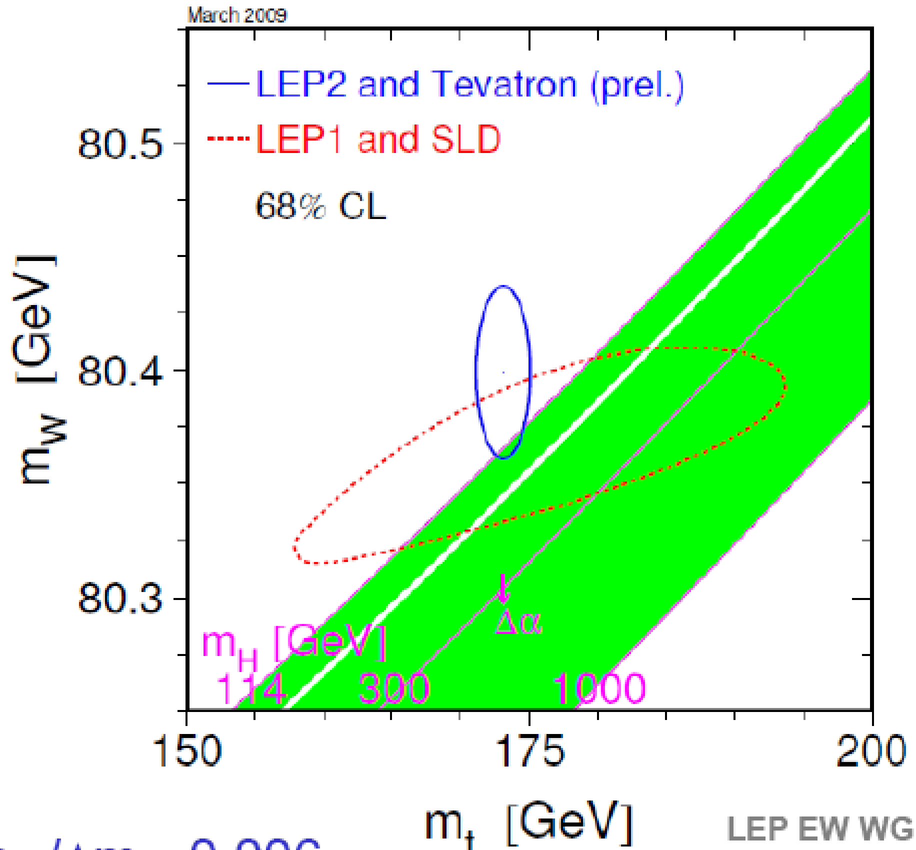
$$m_W = \sqrt{\frac{\pi\alpha}{\sqrt{2}G_F}} \cdot \frac{1}{\sin\theta_W \sqrt{1-\Delta r}}$$



$\Delta r \propto m_t^2$



$\Delta r \propto \log m_H$



LEP EW WG
March 2009

- Δm_W has same impact on Δm_H for $\Delta m_W/\Delta m_t \approx 0.006$
  - for recent Δm_t = 1.3 GeV would need: Δm_W = 8 MeV (0.01%)
  - current world average: Δm_W = 25 MeV (0.03%)
- Additional contributions to $\Delta \mathbf{r}$ arise in SM extensions...

Pomiar masy W

M.Ć.

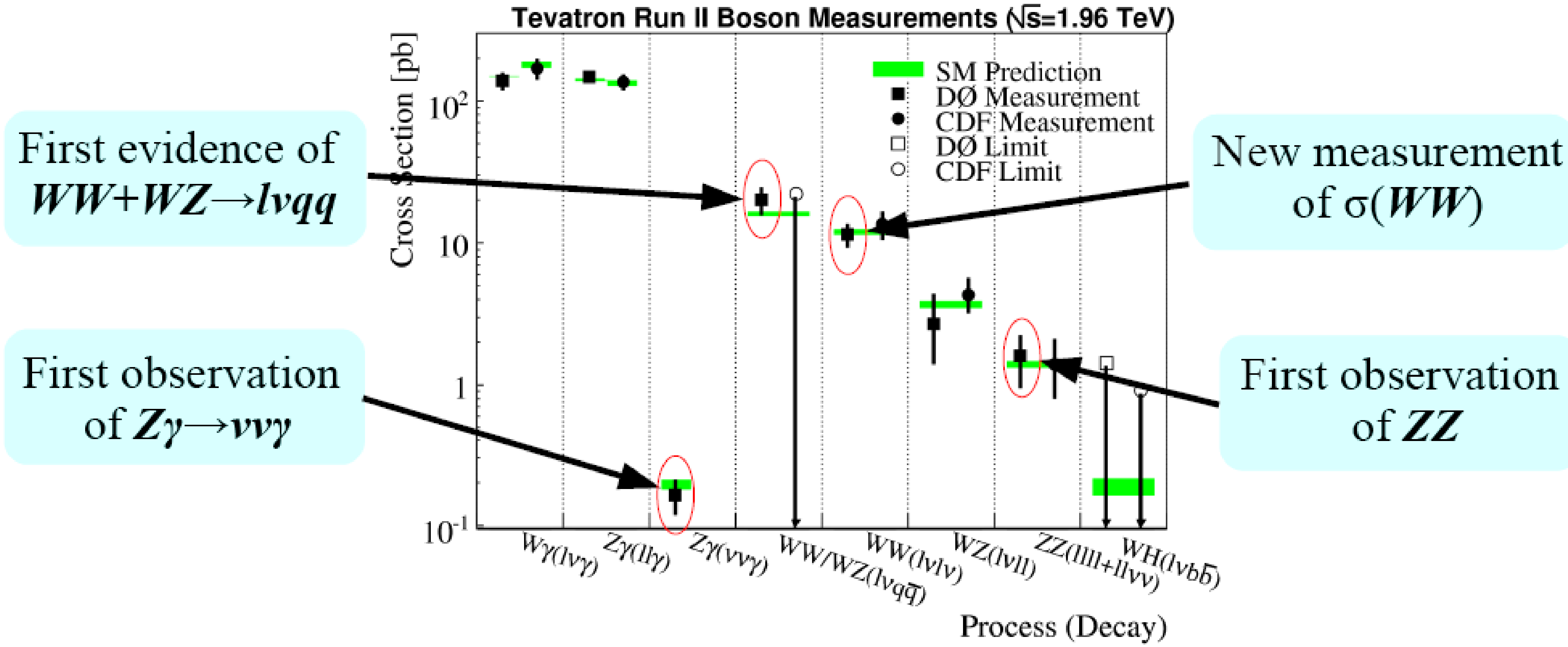
Uncertainties

		m_W uncertainty [MeV]		
	Source	m_T	$p_T(e)$	Missing E_T
	Electron energy response	**34**	**34**	**34**
EXPERIMENT	Electron energy resolution	2	2	3
	Electron energy non-linearity	4	6	7
	Electron energy loss differences for W and Z	4	4	4
	Electron efficiencies	5	6	5
	Recoil model	6	12	20
	Backgrounds	2	5	4
	Subtotal Experimental	**35**	**37**	**41**
THEORY	**PDF** CTEQ6.1M	**9**	**11**	**11**
	QED	7	7	9
	Boson p_T	2	5	2
	Subtotal Theory (W/Z production & decay)	**12**	**14**	**17**
	Total Systematics	**37**	**40**	**44**
	Total Statistics	**23**	**27**	**23**
	TOTAL	**44**	**48**	**50**

Conclusions

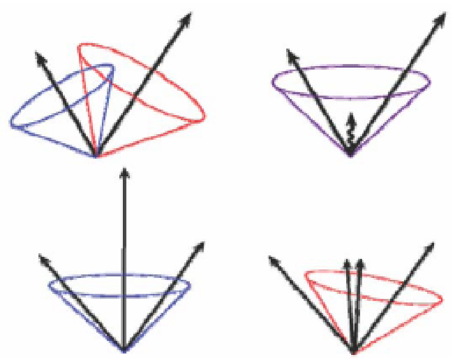
J.Haley

- So far everything agree with the Standard Model
- Many of the measurements are firsts or bests from a hadron collider



- And we now have over 6 fb^{-1} of reconstructed data
  ⇒ The future is bright for Diboson physics at D0!

Jet Algorithms 1/2



Infrared safe

- Jet reconstruction insensitive to emmission of soft gluons
- Experiments: soft energy from noise, underlying event, pile-up supressed by detector thresholds, B-field

Collinear safe

- Jet reconstruction insensitive to collinear splitting of partons
- Experiments: non-linear calorimeters

➔ Yes, for experimental and theoretical reasons for cross sections and for searches:

- discoveries should be safe against noise, underlying event, pile-up, NLO tests

Sequential algorithms: safe — combine particles with min D_{nm}

- Durham (e^+e^-) or k_T (ep, pp) — $D_{nm} = \min(k_{Tn}^2, k_{Tm}^2)\, R/R_0$ — *low-k_T first*
- anti-k_T (Cacciari, Salam, Soyez 08) — $D_{nm} = \min(k_{Tn}^{-2}, k_{Tm}^{-2})\, R/R_0$ — *high-k_T first*

Cone-Algorithms $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$

- SisCone: seedless infrared-safe (Salam, Soyez 07)
- Others: not infrared-safe

Shape ➔ regular is good for pileup, calibration
Split/merge ➔ close-by jets, E-sharing, subjets counting
Best choice depends on application

LEP, HERA: k_T (no pileup, UE)
Tevatron: other cones ☹ ➔ k_T, (SisCone)
ATLAS: first anti-k_T, then k_T, SisCone
CMS: first SisCone, then k_T, anti-k_T
No test yet of SisCone, anti-k_T with real data …

P.Schleper

Multi-Leg Monte Carlos

Top, Higgs, Susy:

- complicated analysis
- very sensitive to proper modelling of kinematics
- Tevatron, LHC potential can only be fully exploited with excellent multi-leg Monte Carlos

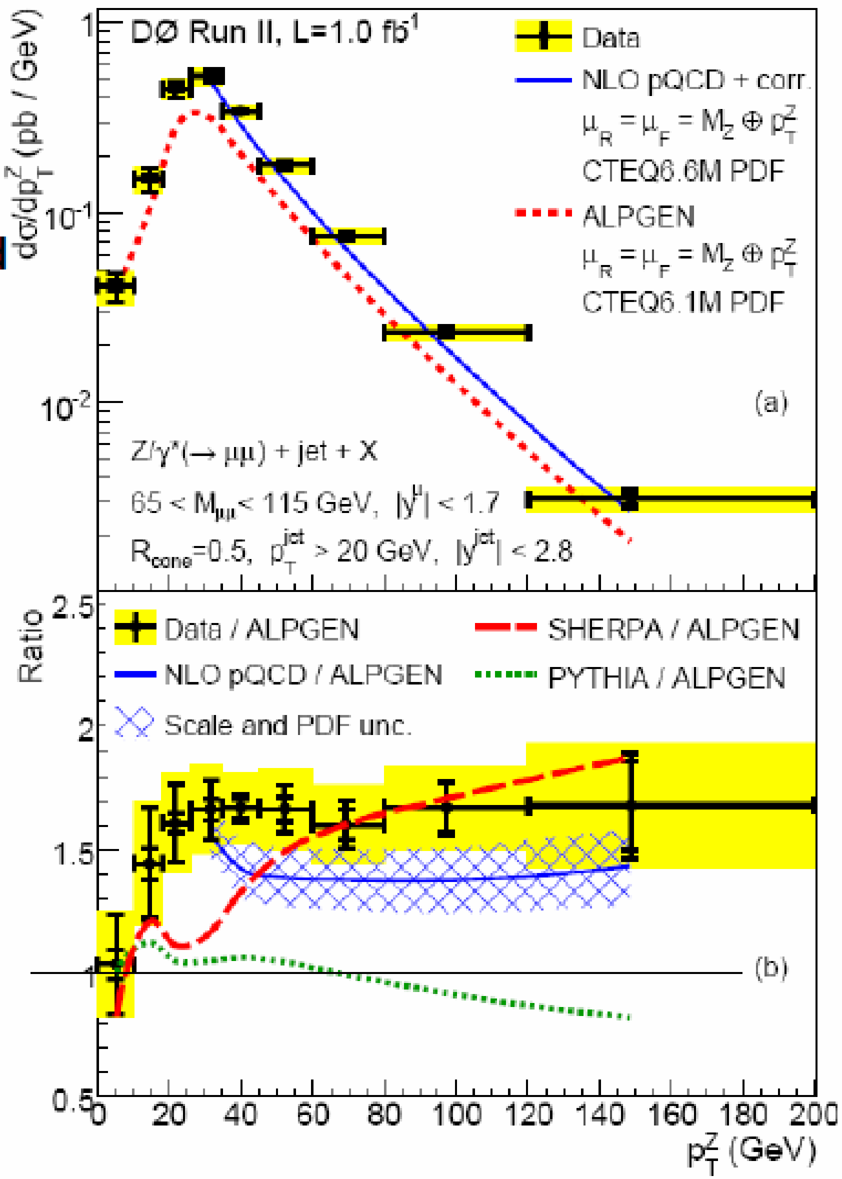
Monte Carlo:

- LO 2 → 2 + PS has dominated the field (Pythia, Herwig)
- LHC: LO multi-leg Monte Carlos widely used (Sherpa, Alpgen, MadGraph, …)
- Interface between Parton-Showers and NLO MC@NLO, …

Tevatron Z + jet analysis

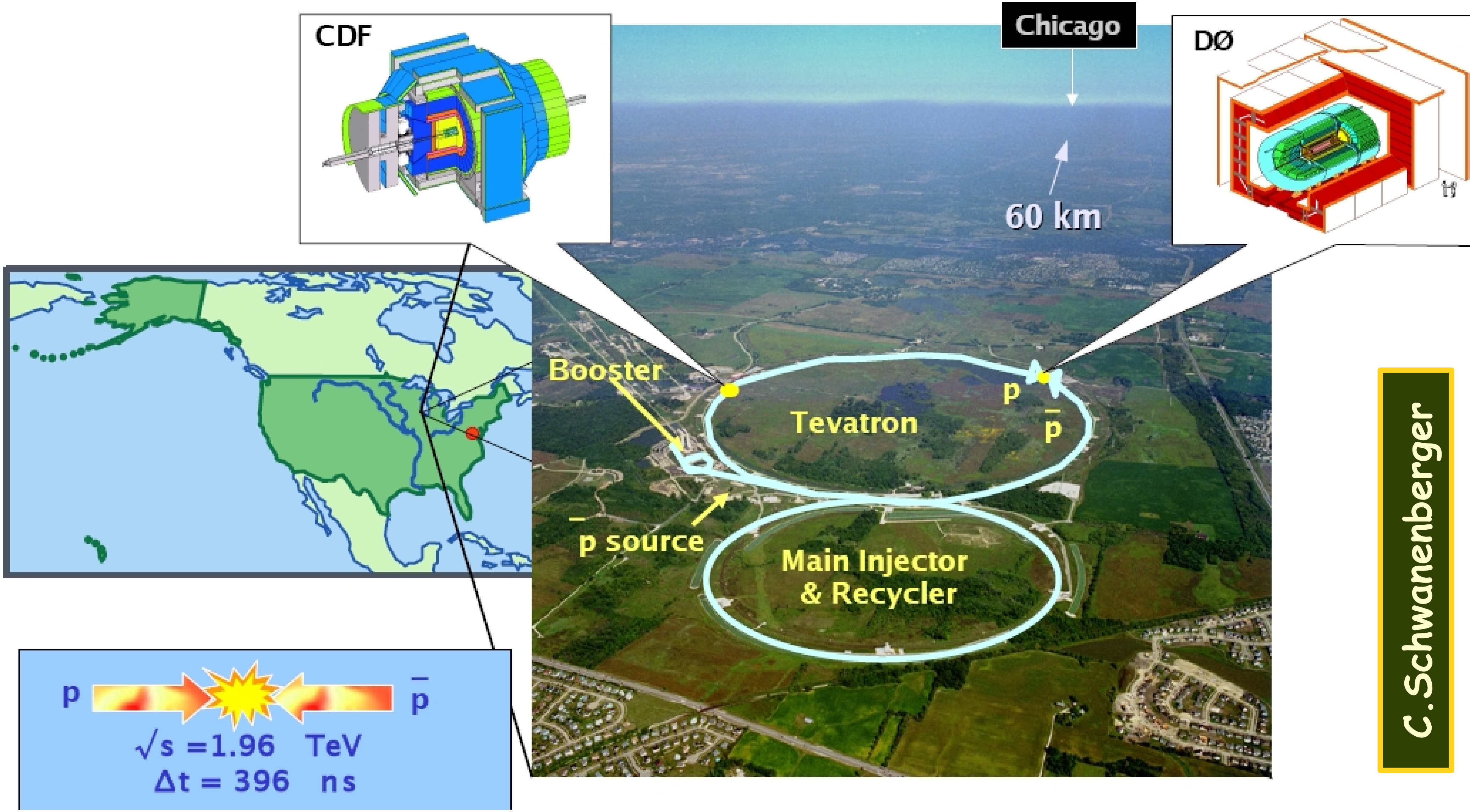
- Midpoint algorithm
- above P_{TZ}>30 GeV

  - NLO agrees within errors
  - Alpgen, Pythia predict lower cross sections (1.7)
  - SHERPA has different slope in PT



P.Schleper

The Tevatron at FERMILAB: $p\bar{p}$ Collisions



C.Schwanenberger

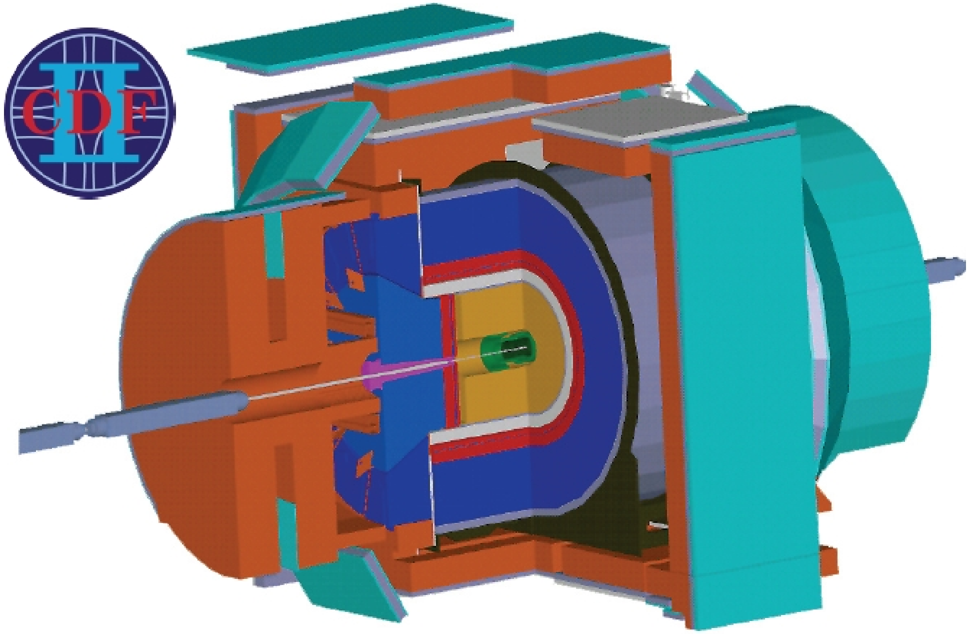
Luminosity delivered up to now: ~6.6 fb^{-1} (>5 fb^{-1} recorded)

running in 2010 approved ⇒ ~9 fb^{-1}

running in 2011 considered ⇒ 12 fb^{-1}

K.Śliwa

C.Schwanenberger



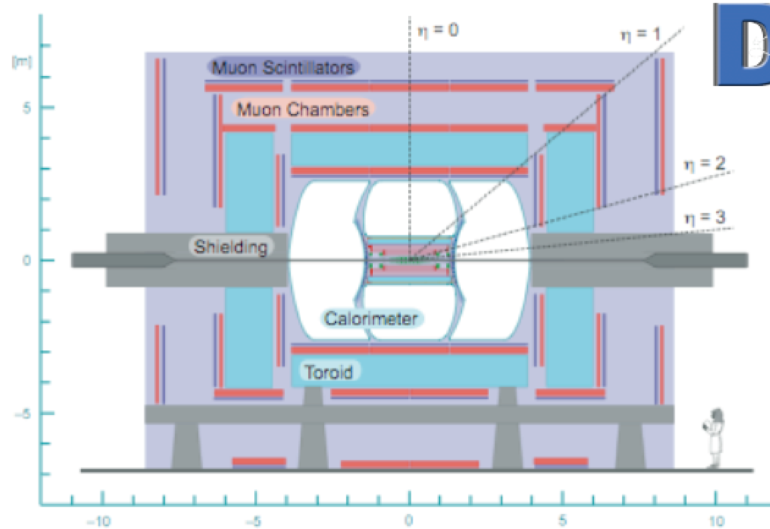
__leptons__

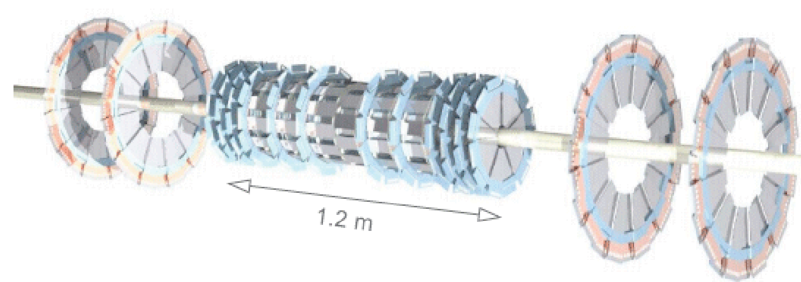
electrons $|\eta| < 2$
muons $|\eta| < 1.5$

__jets__

coverage $|\eta| < 2.8$
b tagging $|\eta| < 1.4$
energy scale ~1%

dijet mass: 16%





__leptons__

electrons $|\eta| < 2.6$
muons $|\eta| < 2$

__jets__

coverage $|\eta| < 3$
b tagging $|\eta| < 2$
energy scale ~1%

dijet mass ~16%

Low mass sensitivity not as good as studies:

- new silicon would have improved b-tag coverage
- MET channel ($\nu\nu bb$) trigger efficiency not 100%
- bb mass algorithms not 10% in all channels

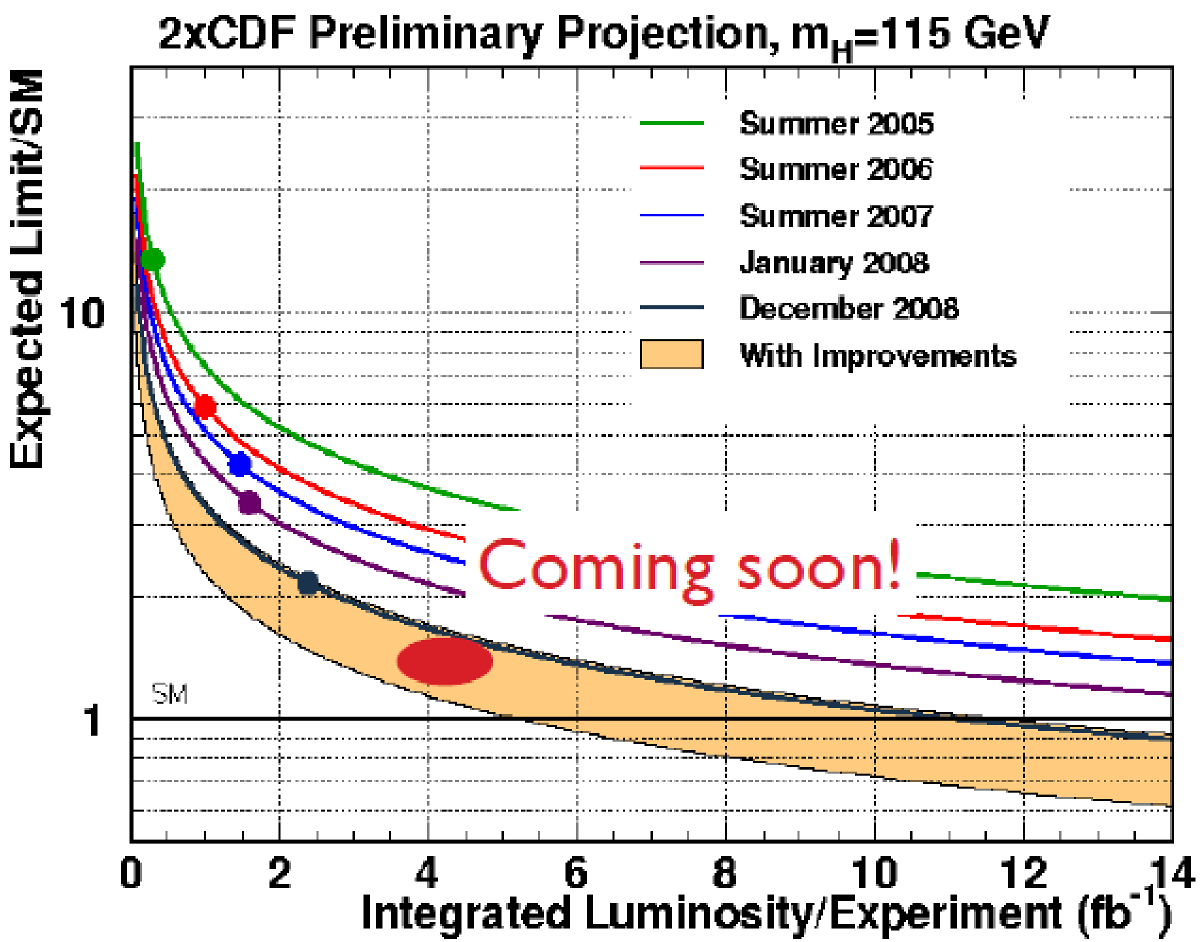
Greatly exceeded expectations in a number of areas:

- added tau channels (~10%)
- $\ell\ell bb$ channel much better than expected
- high-mass channels: more powerful methods
- MVA techniques greatly enhance sensitivity
- can still deploy better bb mass algorithms

Data really do make us smarter

Limit/SM ratio approaching unity!

Tevatron will likely run through 2011



CDF/D0 will likely ultimately have ~10 fb^{-1}/experiment