Electroweak Aspects of the Standard Model

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Lecture III: Weak Gauge Bosons

Stefan Dittmaier

Albert-Ludwigs-Universität Freiburg

Overview

1 Electroweak precision physics at e^+e^- colliders

2 Cross sections at hadron colliders

3 W- and Z-boson production at hadron colliders

Electroweak precision physics at e^+e^- colliders

Features of the electroweak Standard Model

- Higgs boson not yet found, particle content verified otherwise
- No really significant contradictions of GSW model with experiment
- Input parameters:

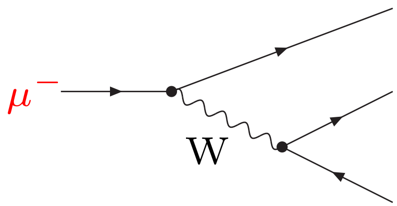
$$\alpha = \frac{e^2}{4\pi} \approx 1/137, \; M_{\mathrm{W}} \approx 80\,\mathrm{GeV}, \; M_{\mathrm{Z}} \approx 91\,\mathrm{GeV}, \; M_{\mathrm{H}} \gtrsim 100\,\mathrm{GeV}, \; m_f, \; V$$

- GSW model = consistent quantum field theory
  - ◇ matrix elements respect unitarity
  - ◇ renormalizability

$\Rightarrow$ evaluation of higher perturbative orders possible
(and phenomenologically necessary !)

Important electroweak experiments

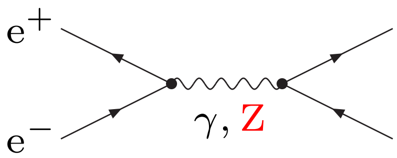
- Muon decay: $\mu^- \to \nu_\mu e^- \bar{\nu}_e$



determination of the Fermi constant

$$G_\mu = \frac{\pi \alpha M_Z^2}{\sqrt{2} M_W^2 (M_Z^2 - M_W^2)} + \dots$$

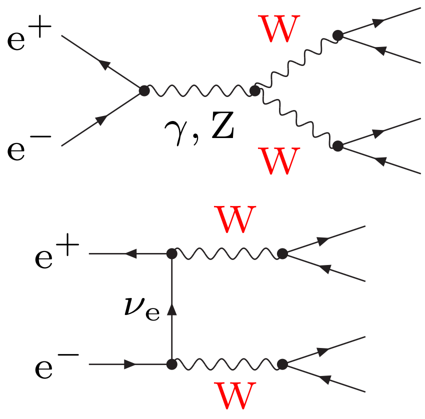
- Z production (LEP1/SLC): $e^+e^- \to Z \to f\bar{f}$



various precision measurements at the Z resonance: $M_Z, \Gamma_Z, \sigma_{had}, A_{FB}, A_{LR}, \text{etc.}$

$\Rightarrow$ good knowledge of the $Zf\bar{f}$ sector

- W-pair production (LEP2/ILC): $e^+e^- \to WW \to 4f(+\gamma)$



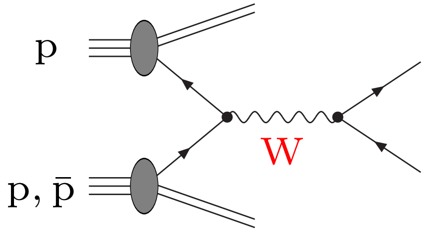
– measurement of M_W

– γWW/ZWW couplings

– quartic couplings: $\gamma\gamma WW$, γZWW
(via $e^+e^- \to WW + \gamma$)

Important electroweak experiments (continued)

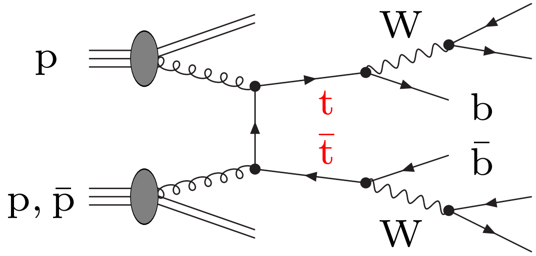
- W production (Tevatron/LHC): $\mathrm{pp}, \mathrm{p\bar{p}} \to \mathrm{W} \to l\nu_l(+\gamma)$



– measurement of M_W

– bounds on $\gamma\mathrm{WW}$ coupling

- top-quark production (Tevatron/LHC): $\mathrm{pp}, \mathrm{p\bar{p}} \to \mathrm{t\bar{t}} \to 6f$



– measurement of m_t

Theoretical predictions

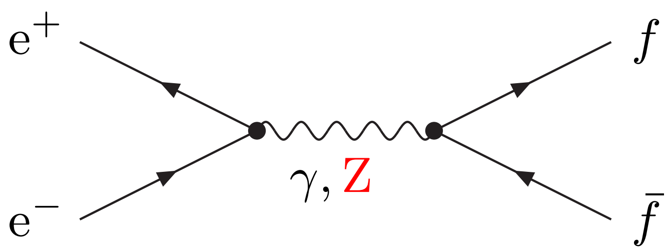
parametrized by $\alpha(M_\mathrm{Z})$, M_W, M_Z, m_t, m_f, $\alpha_\mathrm{s}(M_\mathrm{Z})$ and M_H

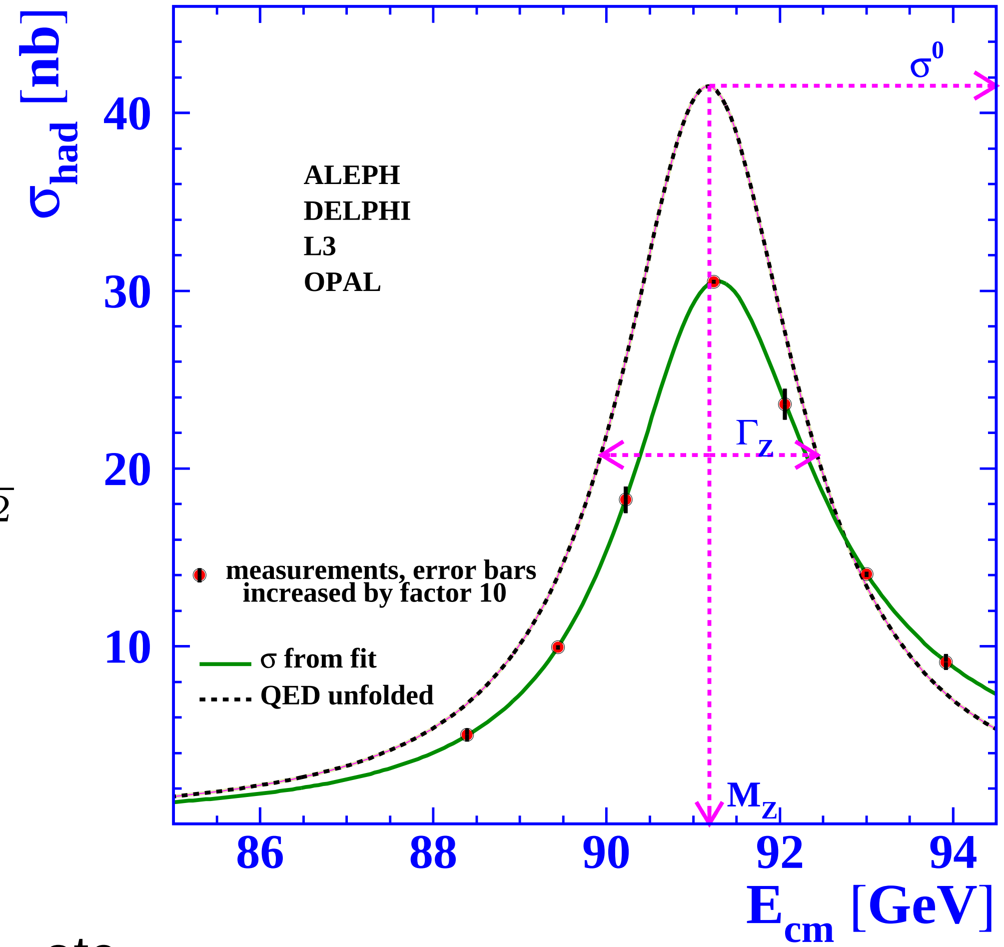
$\hookrightarrow$ global fit of SM to data yields bounds on M_H

But: high precision necessary,
since M_H sensitivity weak $\sim \frac{\alpha}{\pi}\log(M_\mathrm{H}/M_\mathrm{W})$

(in contrast to top-loops where sensitivity $\sim G_\mu m_\mathrm{t}^2$)

Precision study of the Z line shape





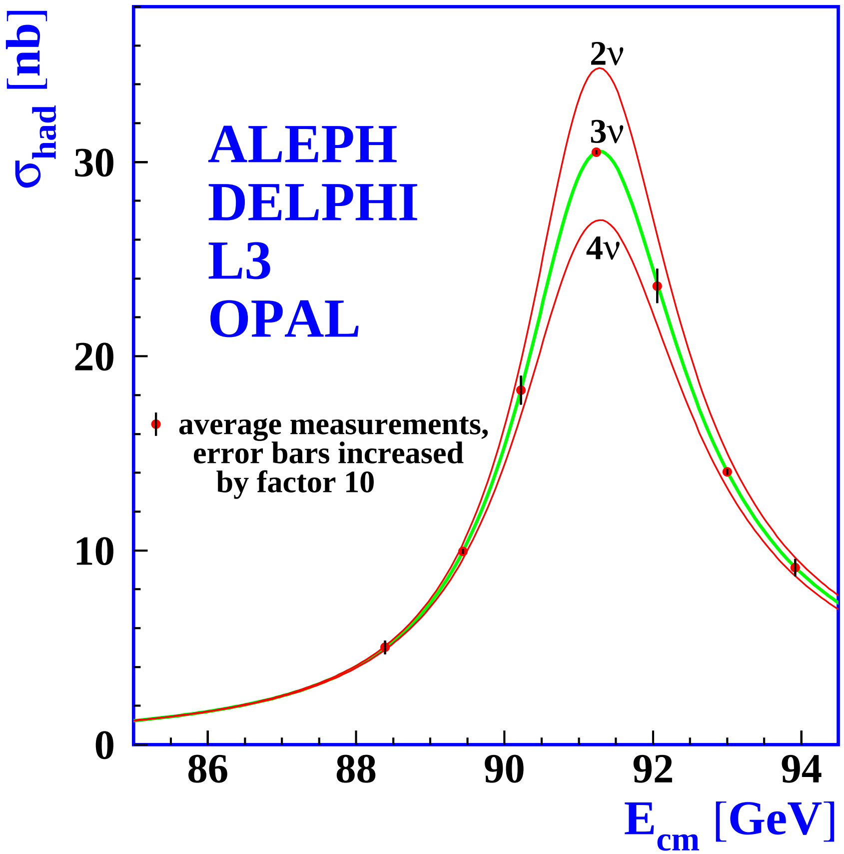
Unfolded resonance:

$$\sigma_{\mathrm{res}}(s) = \sigma^0 \frac{s\,\Gamma_Z^2}{\left|s - M_Z^2 + \mathrm{i} M_Z \Gamma_Z \frac{s}{M_Z^2}\right|^2}$$

Resonance observables:

- Z mass and width: M_Z, Γ_Z
- peak cross section: σ^0_{had}
- various asymmetries: $A_{\mathrm{FB}}, A_{\mathrm{LR}}$, etc.
- ratios of decay widths: $R_l = \frac{\Gamma_{\mathrm{had}}}{\Gamma_l}$, etc.

Number of light neutrinos



$$\Gamma_Z = \Gamma_{had} + \Gamma_e + \Gamma_\mu + \Gamma_\tau + \Gamma_{inv}$$

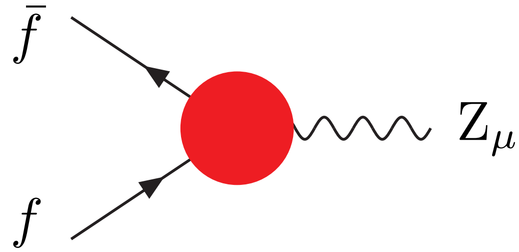
- Γ_Z measured from Z line shape
- Γ_{had} and $\Gamma_{l=e,\mu,\tau}$ from

  $R_l = \frac{\Gamma_{had}}{\Gamma_l}$ and $\sigma^0_{had} = \frac{12\pi}{M_Z^2} \frac{\Gamma_e \Gamma_{had}}{\Gamma_Z^2}$

Fit of Γ_Z, R_l, and σ^0_{had} yields invisible Z-decay width: $\Gamma_{inv} = N_\nu \, \Gamma^{theory}_{Z\to\nu\bar{\nu}}$

$\hookrightarrow \; N_\nu = 2.9840 \pm 0.0082$

Effective Z-boson–fermion couplings



$$= \mathrm{i}e\gamma_\mu(g_{Vf} - g_{Af}\gamma_5)$$

Leptonic couplings from LEP1 asymmetry measurements, e.g.:

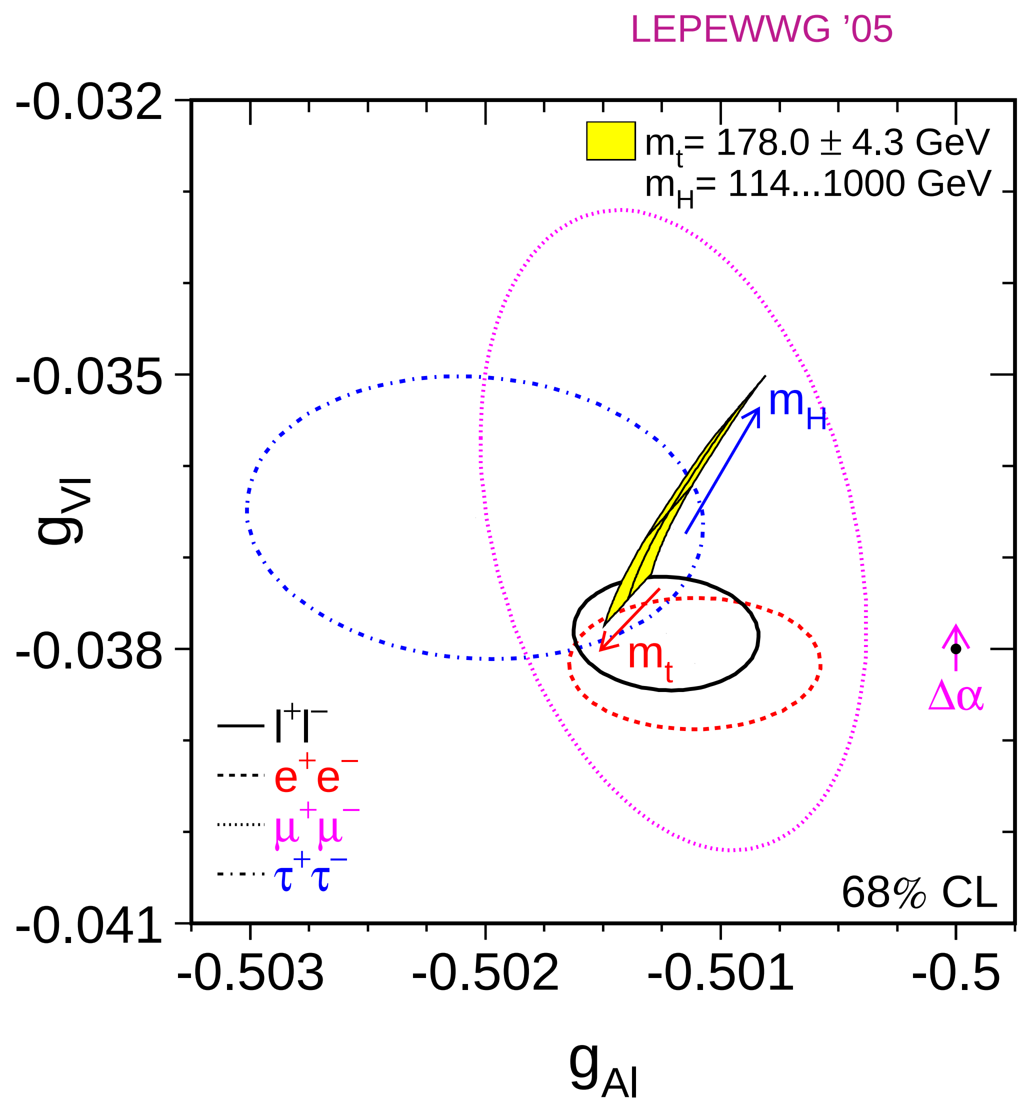
$$A_{\mathrm{FB}}^{0,f} = \frac{\sigma^0_{f,\mathrm{F}} - \sigma^0_{f,\mathrm{B}}}{\sigma^0_{f,\mathrm{F}} + \sigma^0_{f,\mathrm{B}}} = \frac{3}{4}\mathcal{A}_\mathrm{e}\mathcal{A}_f$$

$(\mathrm{F/B} =$ For/Backward hemisphere)

with $\mathcal{A}_f = \dfrac{2g_{Vf}g_{Af}}{g_{Vf}^2 + g_{Af}^2}$

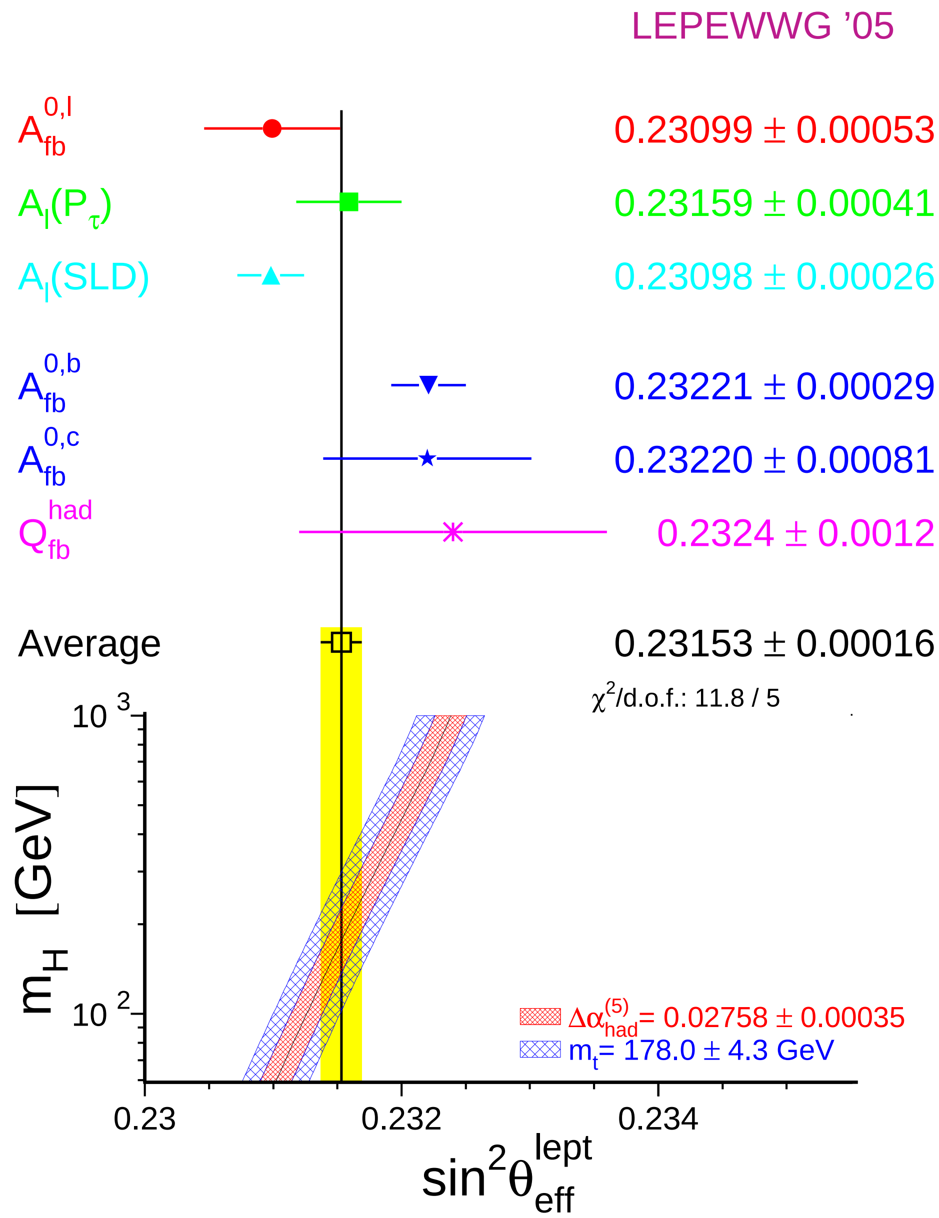
Good agreement with SM

- lepton universality confirmed
- constraints on m_t and M_H



Translation of effective couplings into effective weak mixing angle

$$\sin^2\theta_{\rm eff}^{\rm lept} = \frac{1}{4}\left(1 - \mathrm{Re}\left\{\frac{g_{Vl}}{g_{Al}}\right\}\right)$$



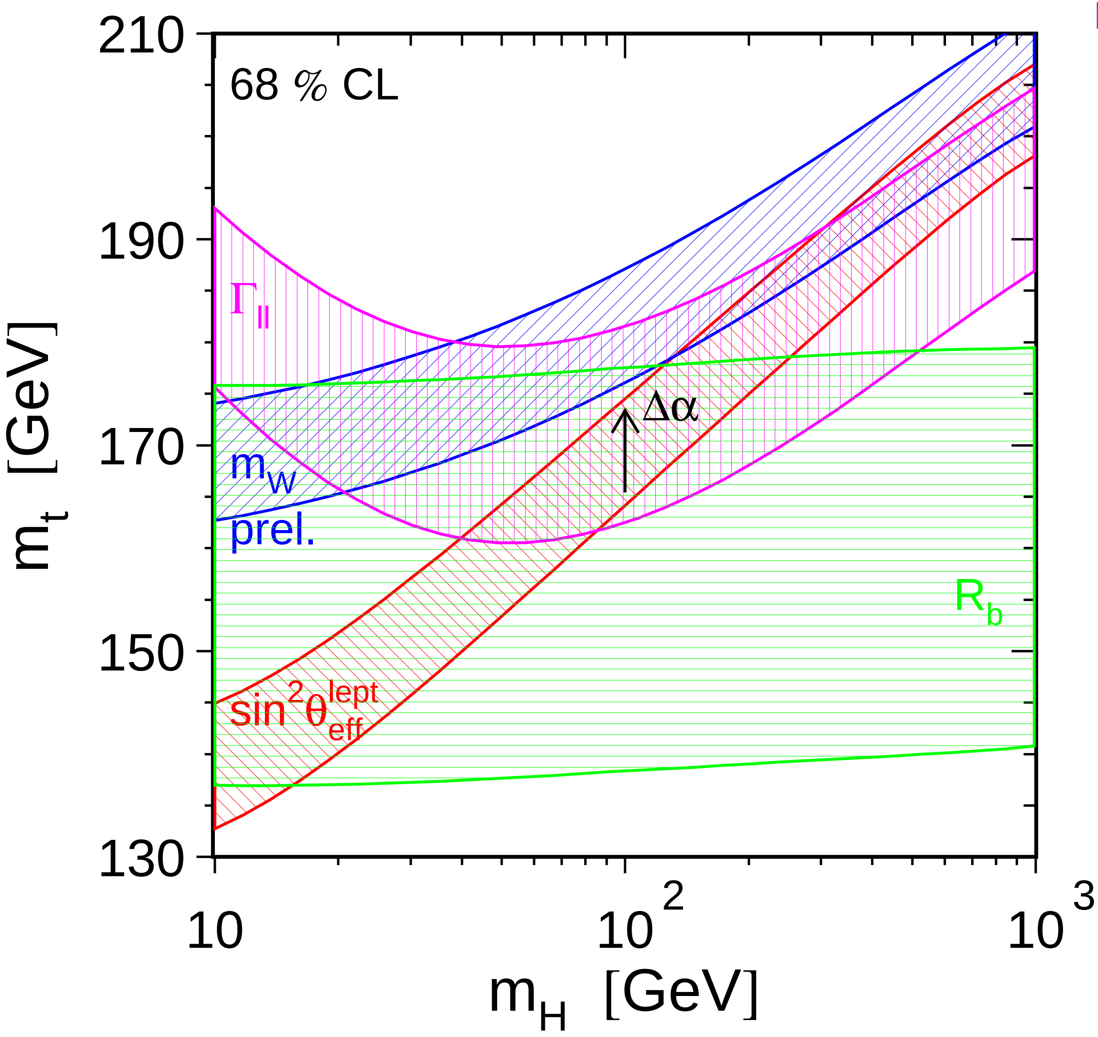
Important features:

- high sensitivity to $M_{\rm H}$
- combination of very different observables
- $\sim 3\sigma$ difference between $A_{\rm FB}^{0,b}$(LEP) and $A_{\rm LR}^{0,l}$(SLD)

  with the initial-state pol. asymmetry

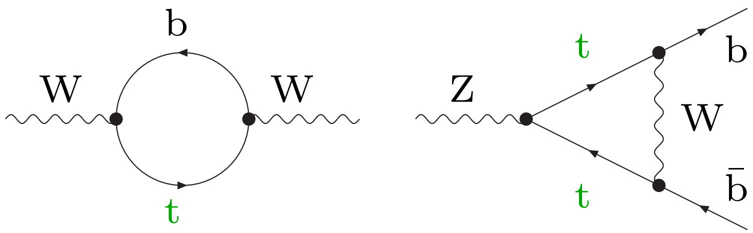
$$A_{\rm LR}^{0,l} = \frac{\sigma_{\rm L}^0 - \sigma_{\rm R}^0}{\sigma_{\rm L}^0 + \sigma_{\rm R}^0}\,\frac{1}{\langle|\mathcal{P}_{\rm e}|\rangle}$$

Observables most sensitive to m_t and M_H

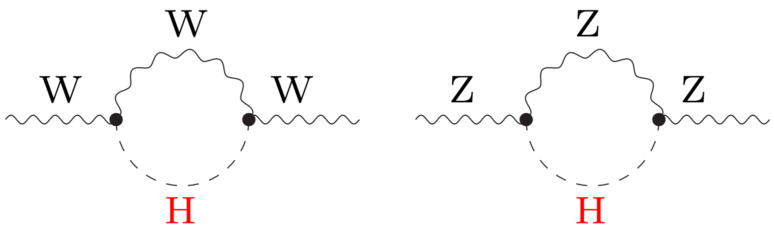


LEPEWWG '05

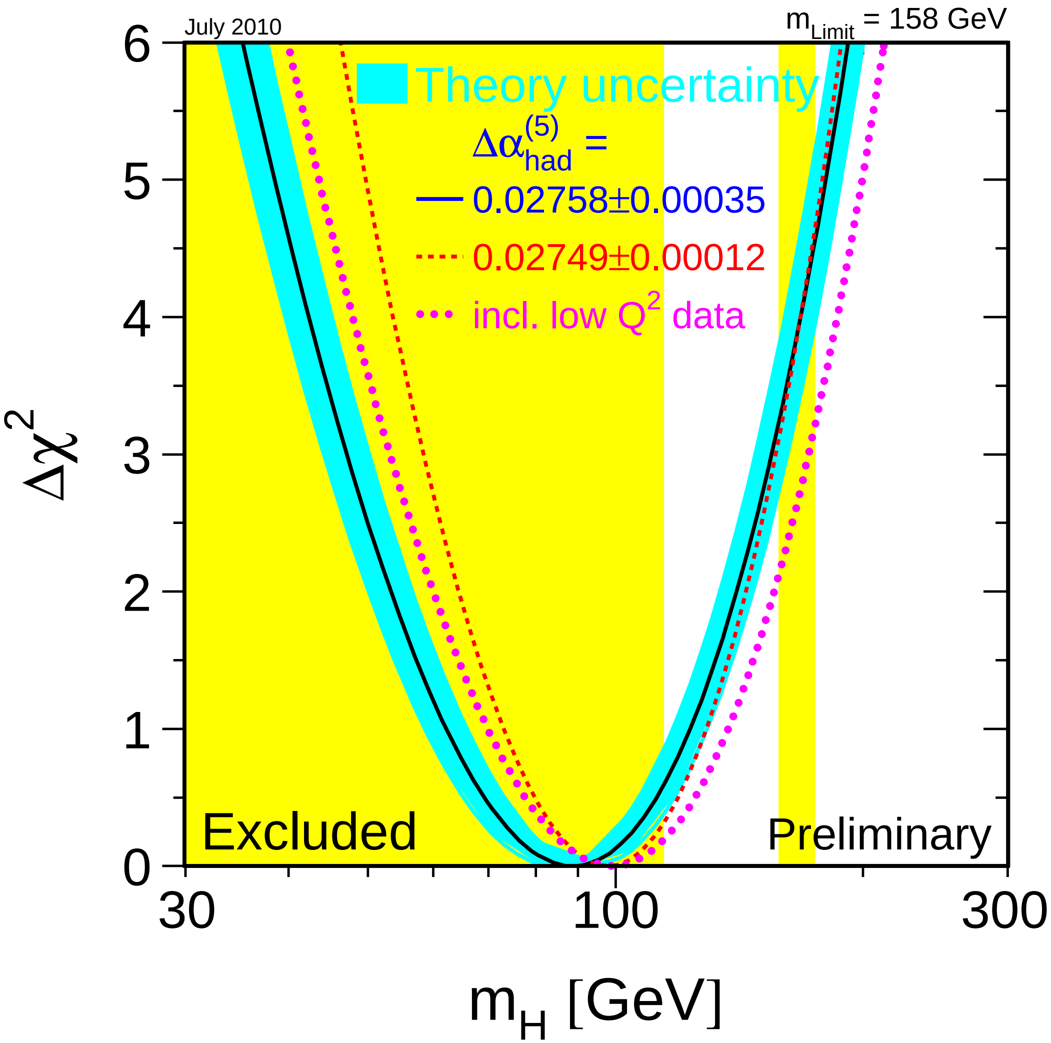
main sensitivity to m_t via



main sensitivity to M_H via



Bounds on $M_{\rm H}$ (95% C.L.)

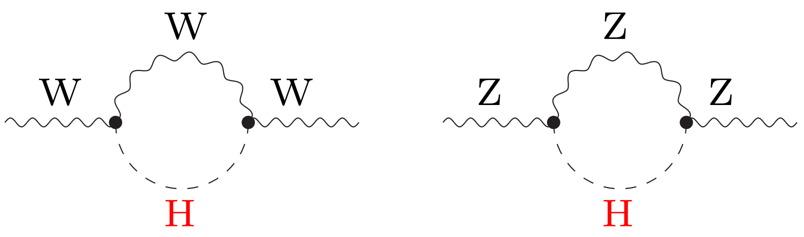


– $M_{\rm H} > 114.4\,{\rm GeV}$ (LEPHIGGS '02)

$e^+e^- \not\to {\rm ZH}$ at LEP2

– $M_{\rm H} < 158\,{\rm GeV}$ (LEPEWWG '10)

fit to precision data,
i.e. via quantum corrections



Sensitivity via "high-precision observables": $m_{\rm t}$, $M_{\rm W}$, $\sin^2\theta^{\rm lept}_{\rm eff}$, etc.

$\hookrightarrow$ precise measurement is possible at future ILC !

$\Rightarrow$ stronger bounds on $M_{\rm H}$

W-pair production $e^+e^- \to WW \to 4f(+\gamma)$

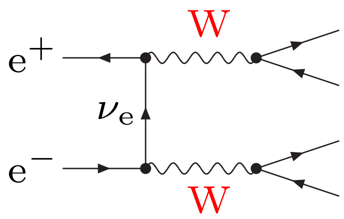


diagram dominates near W-pair threshold

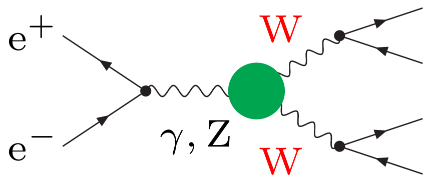


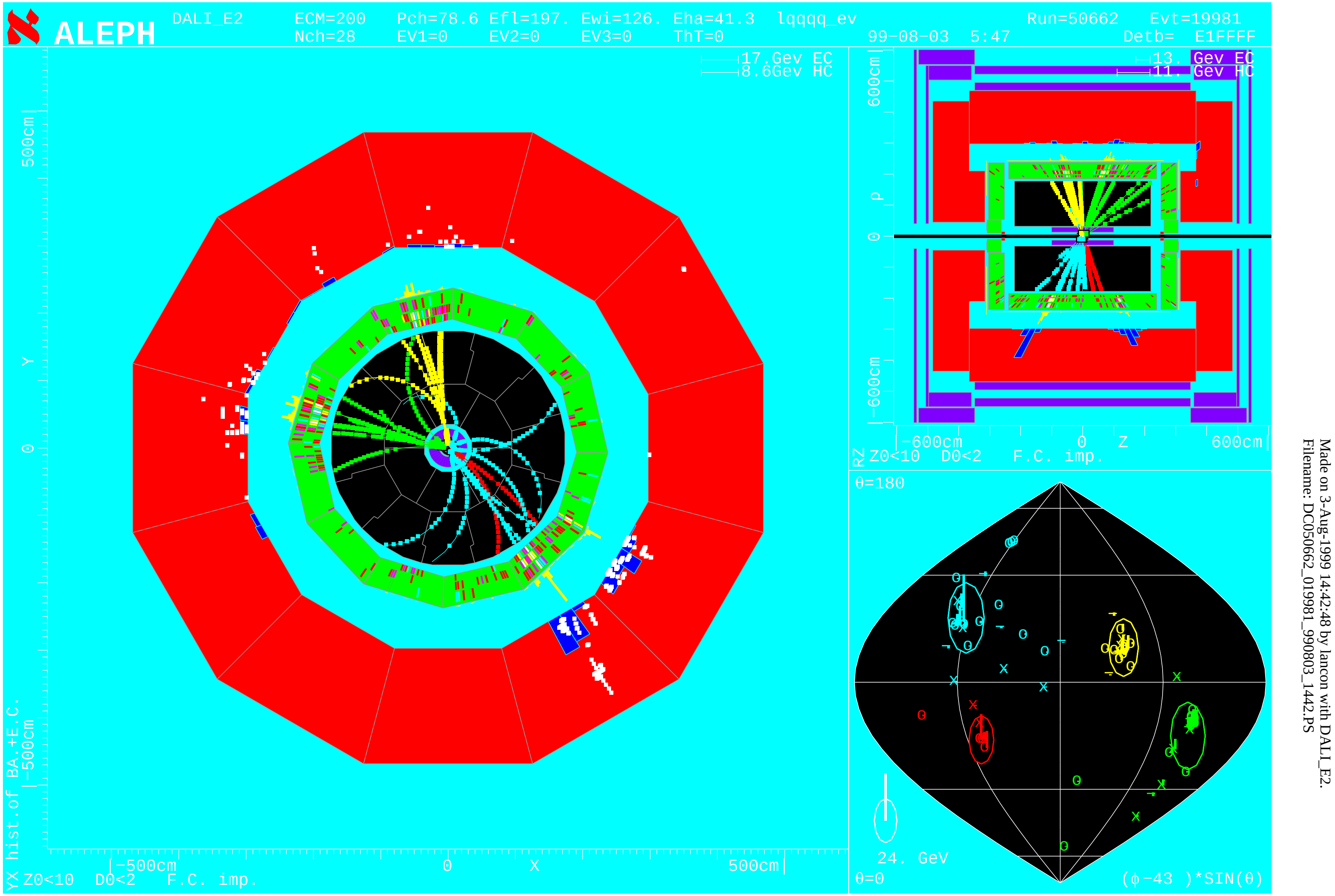
diagram contains γWW/ZWW couplings

Physics issues:

- test of non-abelian structure of triple gauge-boson couplings (TGCs)
  $\hookrightarrow$ constraint on non-standard $\gamma WW/ZWW$ couplings
- precision measurement of W-pair cross section
- precision measurement of W mass M_W
- first bounds on non-standard quartic gauge-boson couplings (QGCs)

$\Rightarrow$ Theoretical requirement:
precise understanding of $2 \to 4$ process (0.5% level for cross section)

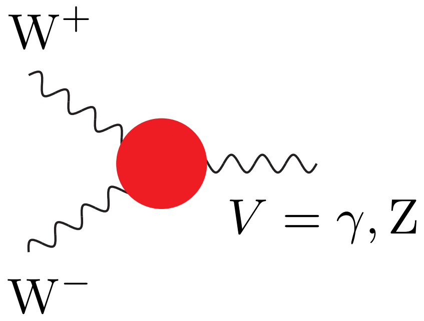
A typical 4-jet event observed at ALEPH



(Non-)standard TGCs

Gaemers, Gounaris ’79; Hagiwara, Hikasa, Peccei, Zeppenfeld ’87; Bilenky, Kneur, Renard, Schildknecht ’93; etc.

General parametrization (C- and P-conserving):



$$\mathcal{L}_{VWW} = -\mathrm{i}eg_{VWW}\Big\{ g_1^{\mathrm{V}}(W^+_{\mu\nu}W^{-,\mu}V^\nu - W^{-,\mu\nu}W^+_\mu V_\nu) + \kappa_{\mathrm{V}} W^+_\mu W^-_\nu V^{\mu\nu} + \frac{\lambda_{\mathrm{V}}}{M_{\mathrm{W}}^2} W^+_{\rho\mu} W^{-,\mu}_{\nu} V^{\nu\rho}\Big\}$$

Meaning for static W^+ bosons:

$$Q_{\mathrm{W}} = eg_1^\gamma = \text{electric charge } (= e \text{ by charge conservation})$$

$$\mu_{\mathrm{W}} = \frac{e}{2M_{\mathrm{W}}}(g_1^\gamma + \kappa_\gamma + \lambda_\gamma) = \text{magnetic dipole moment}$$

$$q_{\mathrm{W}} = -\frac{e}{M_{\mathrm{W}}^2}(\kappa_\gamma - \lambda_\gamma) = \text{electric quadrupole moment}$$

Standard Model values:

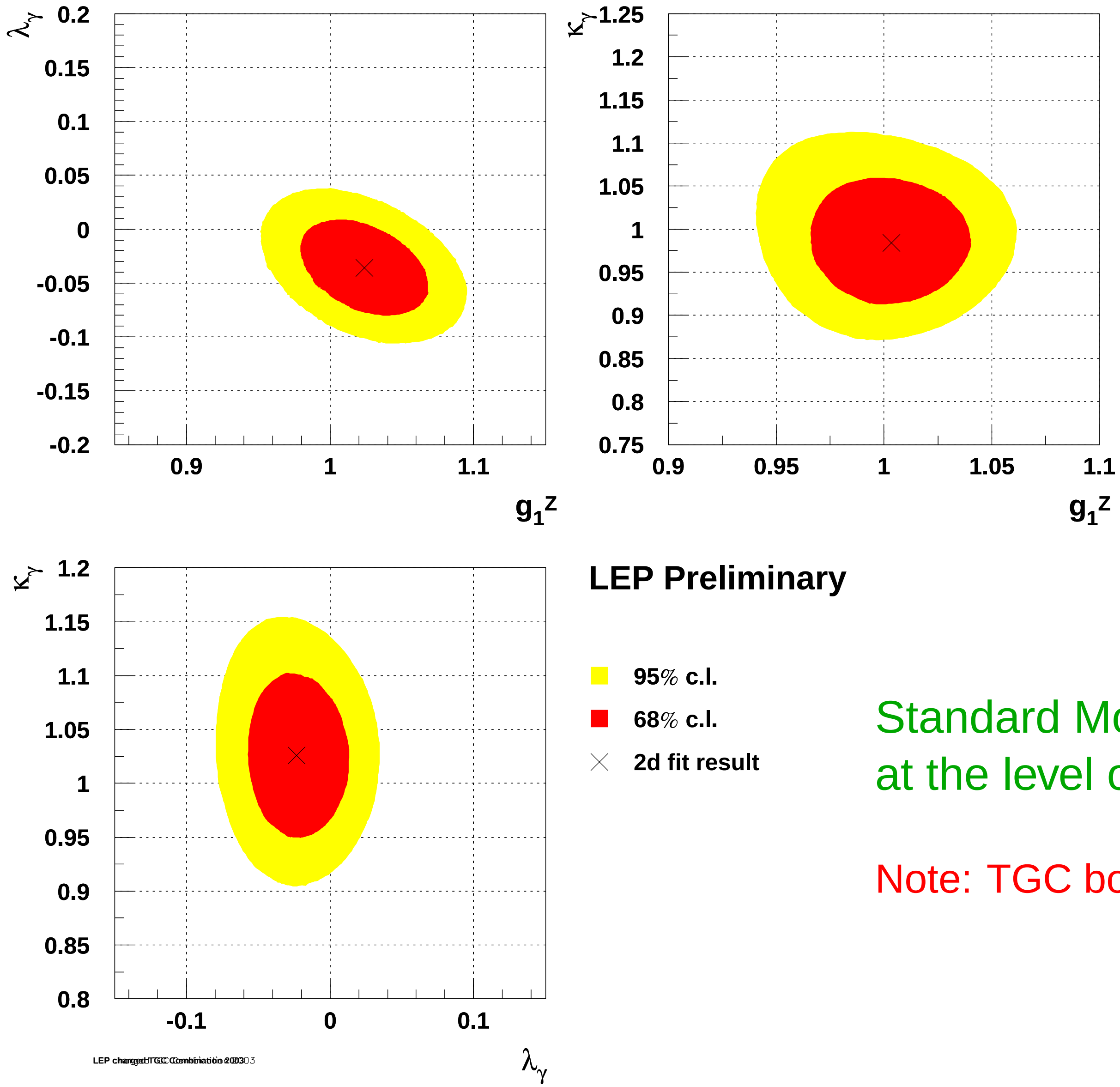
$$g_1^{\mathrm{V}} = \kappa_{\mathrm{V}} = 1, \qquad \lambda_{\mathrm{V}} = 0$$

Restriction to SU(2)×U(1)-symmetric dim-6 operators:

$$\kappa_{\mathrm{Z}} = g_1^{\mathrm{Z}} - (\kappa_\gamma - 1)\tan^2\theta_{\mathrm{W}}, \qquad \lambda_{\mathrm{Z}} = \lambda_\gamma$$

LEP2 constraints on charged TGCs

LEPEWWG '04



$$\Delta g_1^Z = -0.009^{+0.022}_{-0.021}$$

$$\Delta\kappa_\gamma = -0.016^{+0.042}_{-0.047}$$

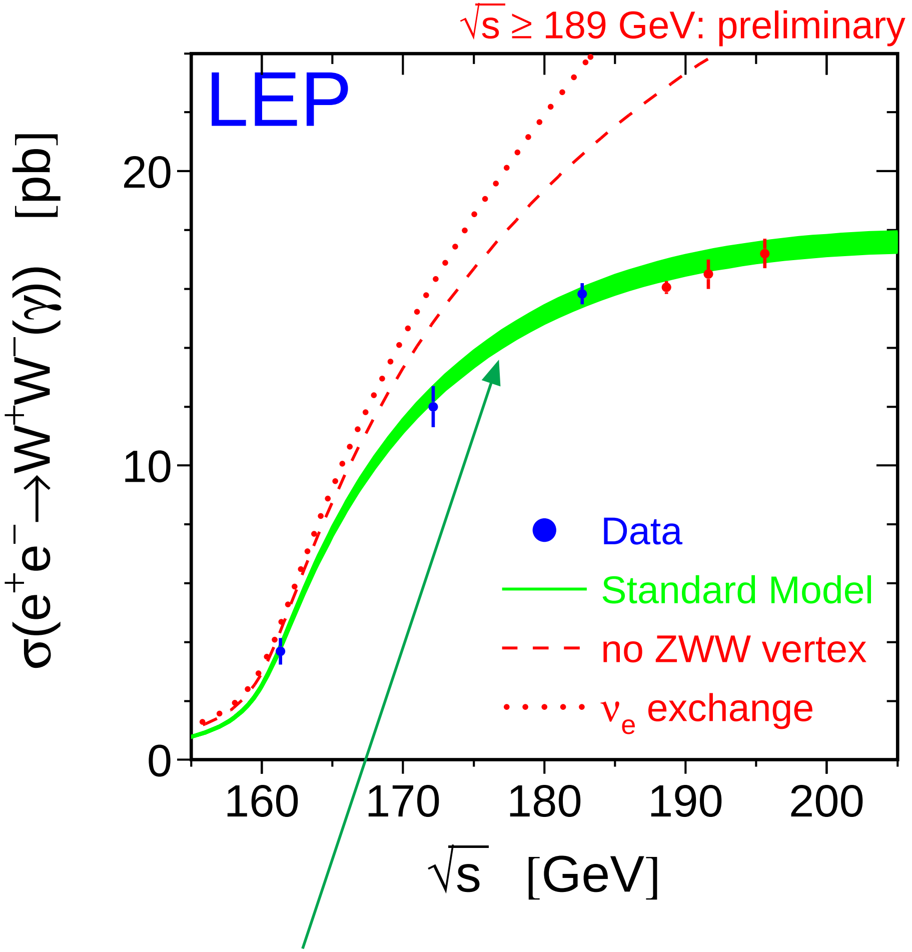
$$\lambda_\gamma = -0.016^{+0.021}_{-0.023}$$

Standard Model values verified at the level of 2–4%

Note: TGC bounds $\sim$ $\mathcal{O}$(EW corrections)

Total WW cross section at LEP2

Status of 1999: (LEPEWWG ’99)

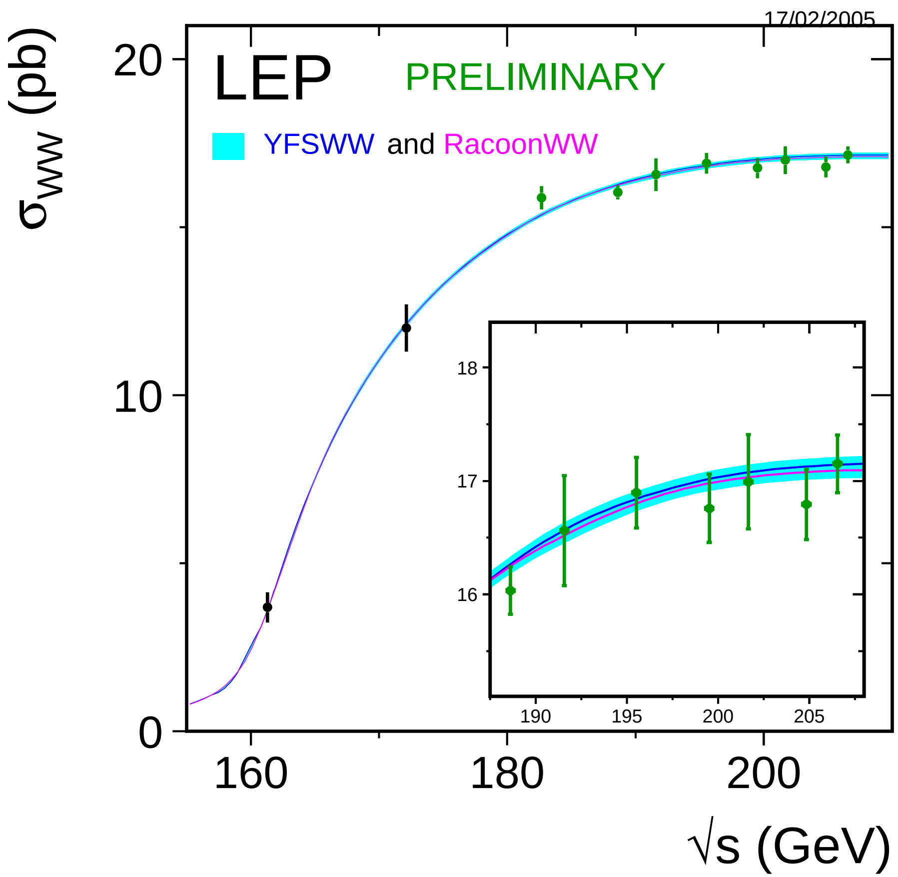


GENTLE (Bardin et al.)

only universal EW corrections

$\hookrightarrow$ theoretical uncertainty $\sim \pm 2\%$

Final result: (LEPEWWG ’05)



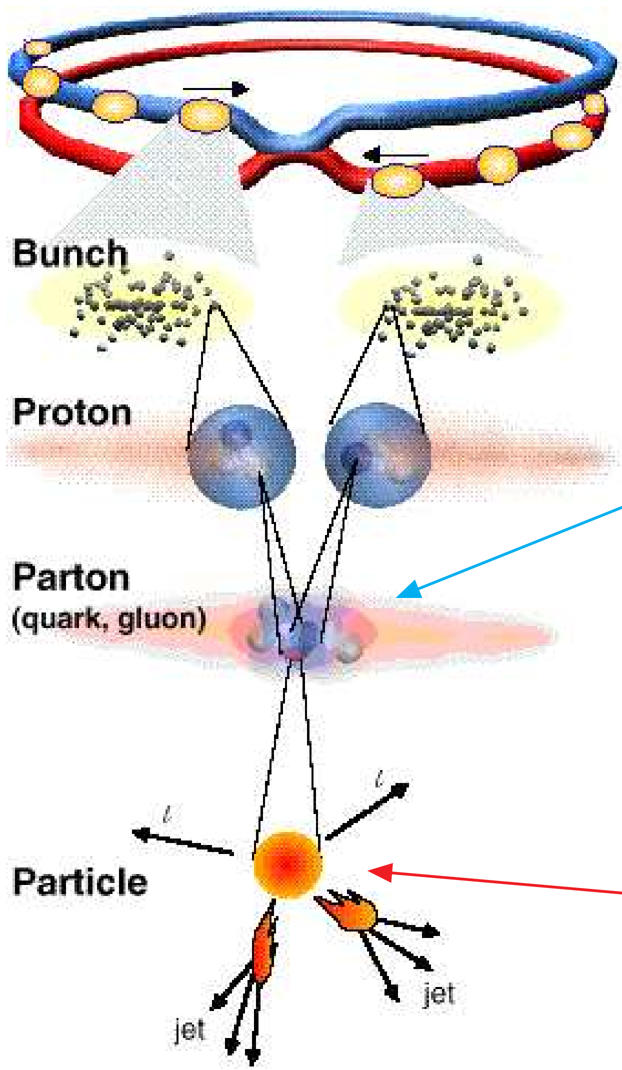
YFSWW (Jadach et al.) / RacoonWW (Denner et al.)

non-universal corrections included

$\hookrightarrow$ th. uncertainty $\sim \pm 0.5\%$ for $\sqrt{s} > 170\,\mathrm{GeV}$

Cross sections
at hadron colliders

Inelastic hadronic collisions:



Parton content of the proton:

valence quarks uud,

sea quarks $\mathrm{u, d, c, s,} (+\mathrm{b},)$

gluons g (+photons γ)

"Parton distribution functions" (PDF) $f_{i/\mathrm{p}}(x, Q)$

determine fraction x of the p momentum

carried by parton i at "factorization scale" Q

= non-perturbative input (from exp.),

but process independent

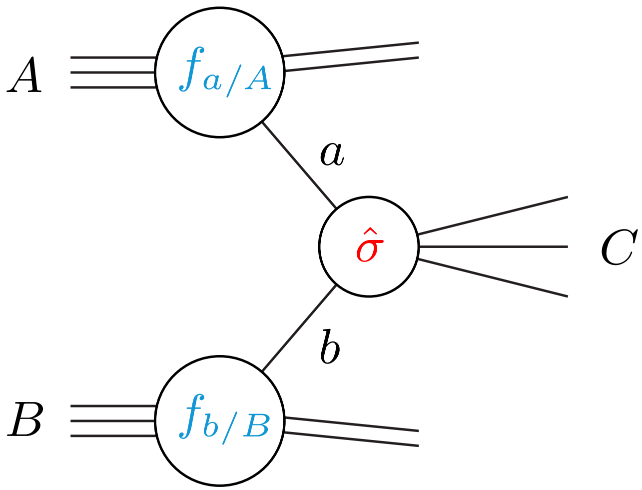
Hard interaction of partons

$\hookrightarrow$ perturbative QCD applicable,

model for hard interactions

(apart from QCD/QED) enters only here

Parton model description of hadronic collisions



hadronic momenta: p_A, p_B

hadronic CM energy: $\sqrt{s} = E_A + E_B$

partonic momenta: $p_a = x_A p_A$, $p_b = x_B p_B$

partonic CM energy: $\sqrt{\hat s} = \sqrt{x_A x_B s}$

Hadronic cross section for $AB \to C + X$: ($X =$ any hadronic remnant/activity)

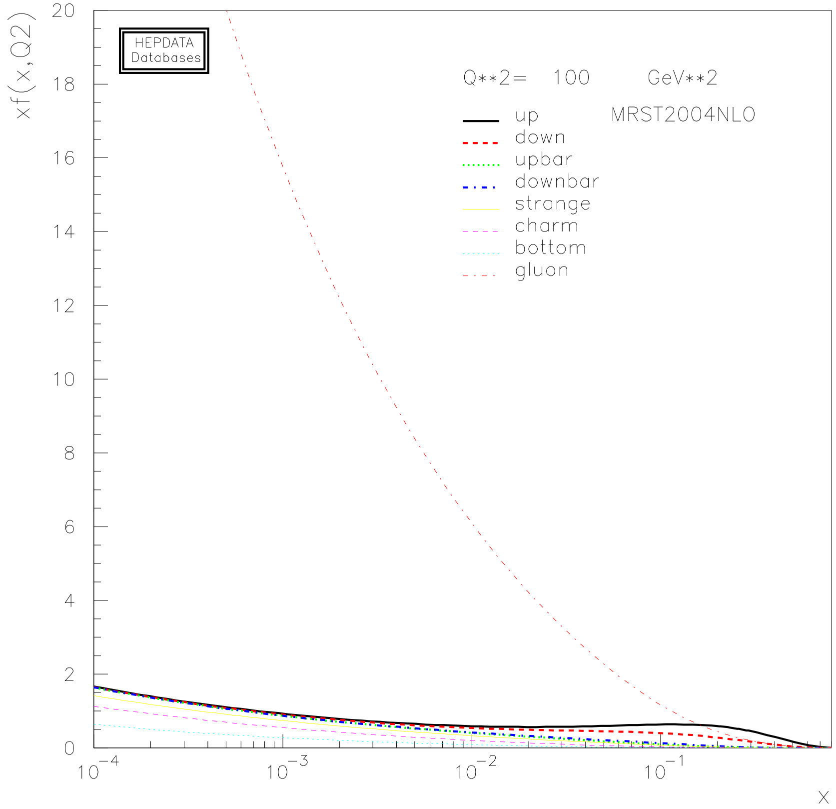
$$\sigma_{AB\to C+X}(s) = \int_0^1 \mathrm{d}x_A \int_0^1 \mathrm{d}x_B \sum_{a,b} f_{a/A}(x_A,Q)\, f_{b/B}(x_B,Q)\, \hat\sigma_{ab\to C}(\hat s, Q)$$

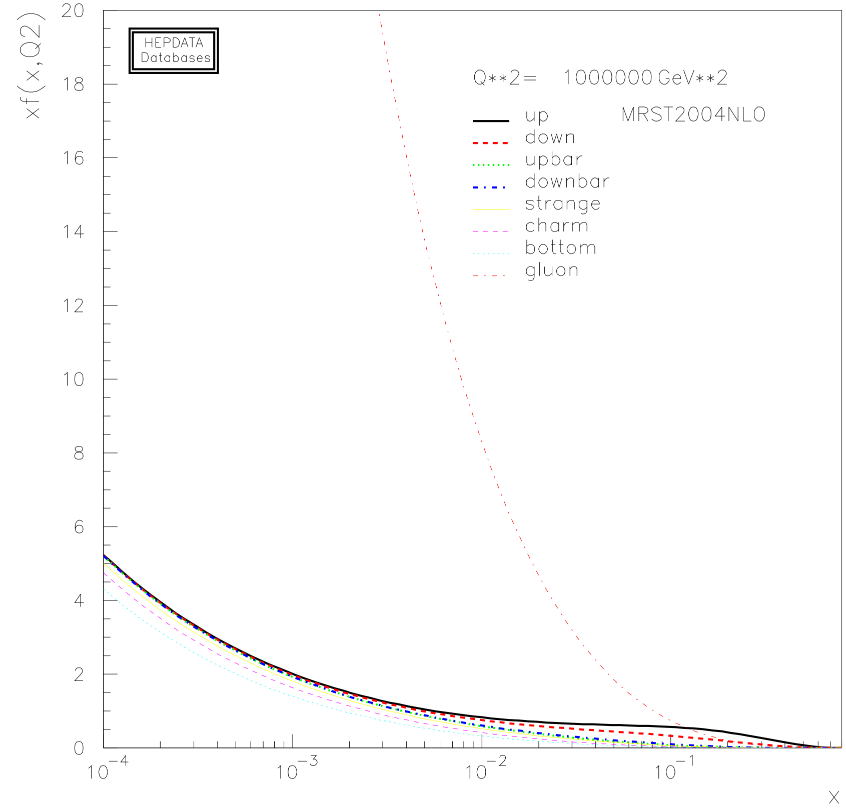
Factorization scale Q separates soft from hard contributions.

- Q dependence of PDFs $f_{a/A}(x_A,Q)$ ruled by DGLAP evolution equations
- Q dependence of hard scattering cross section $\hat\sigma_{ab\to C}(\hat s, Q)$ universal
- Q drops out in “all-order” calculations for $\sigma_{AB\to C+X}(s)$

$\hookrightarrow$ residual Q dependence in finite-order predictions reflects theoretical uncertainty

Parton distribution functions





- DGLAP evolution to larger Q shifts PDFs to lower x

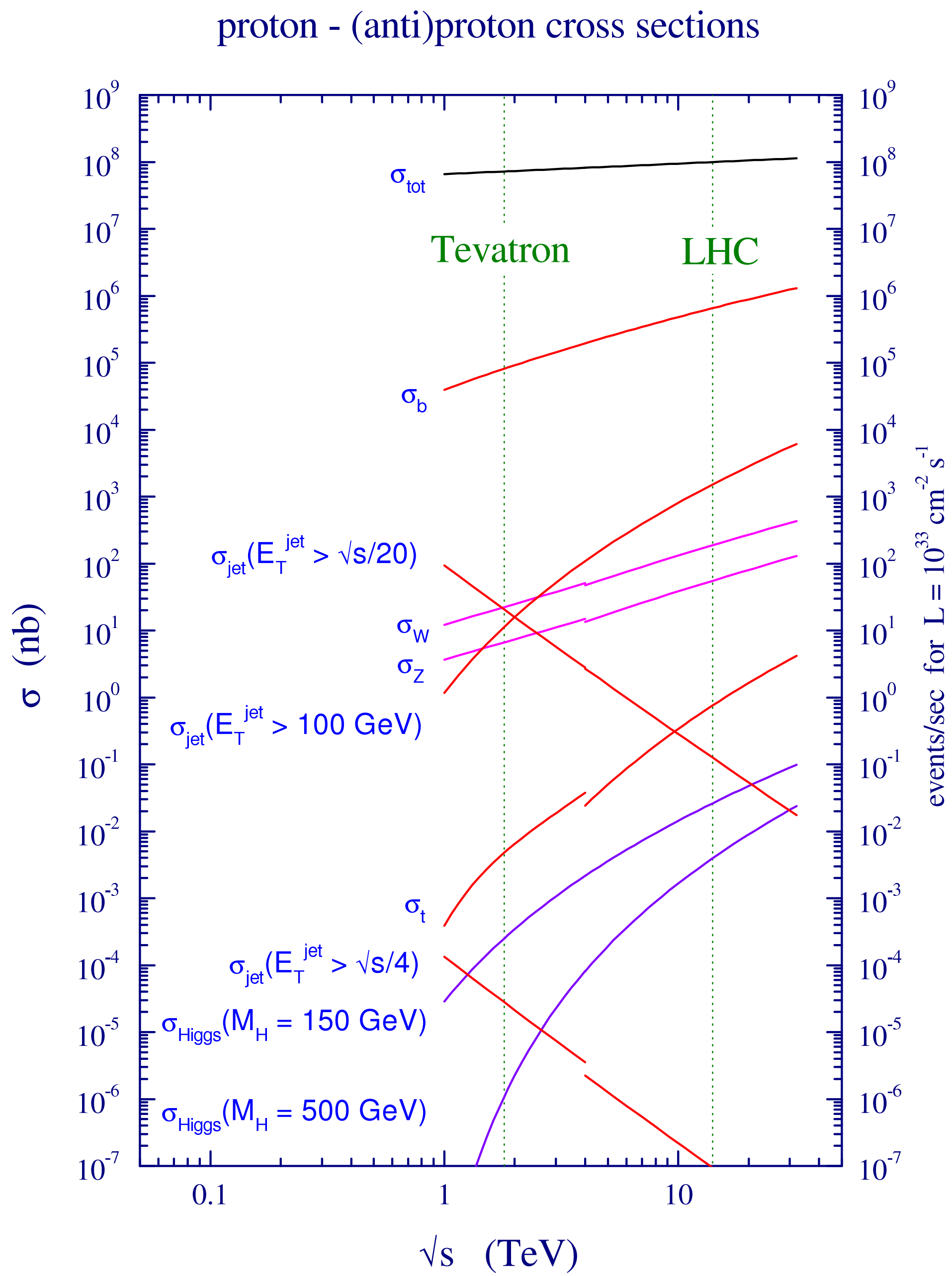
  $\hookrightarrow$ enhancement of sea-quark and gluon PDFs

- Processes with both gg and $q\bar{q}$ channels (e.g. $\mathrm{t\bar{t}}$ production)

  Tevatron: $q\bar{q}$ often dominates by $\sim 90\%$

  LHC: gg often much more important than $q\bar{q}$

Some Standard Model cross sections at the Tevatron ($p\bar{p}$) and the LHC (pp)



events $= \sigma \times$ luminosity

design luminosity: $100\,\mathrm{fb}^{-1}\mathrm{a}^{-1}$/exp.

2 experiments in 5 years:

$\sigma \sim 1\,\mathrm{pb} \quad \rightarrow \quad \sim 10^6$ events

$\hookrightarrow$ precision physics
(systematics dominates uncertainty)

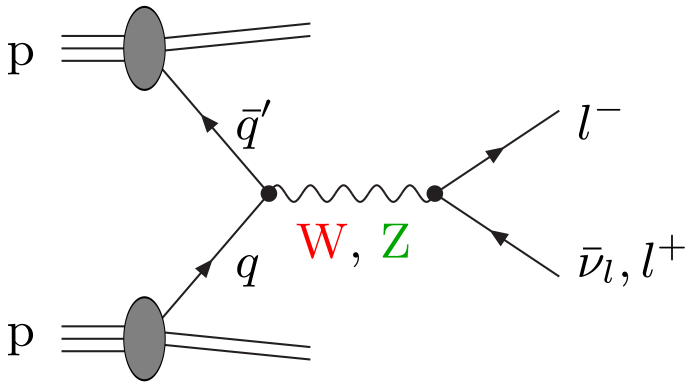
$\sigma \sim 1\,\mathrm{fb} \quad \rightarrow \quad \sim 10^3$ events

$\hookrightarrow$ good prospects for searches
(statistics dominates uncertainty)

BUT:
inclusive cross sections reduced by branching ratios, event selection, experimental efficiencies, etc.

W- and Z-boson production at hadron colliders

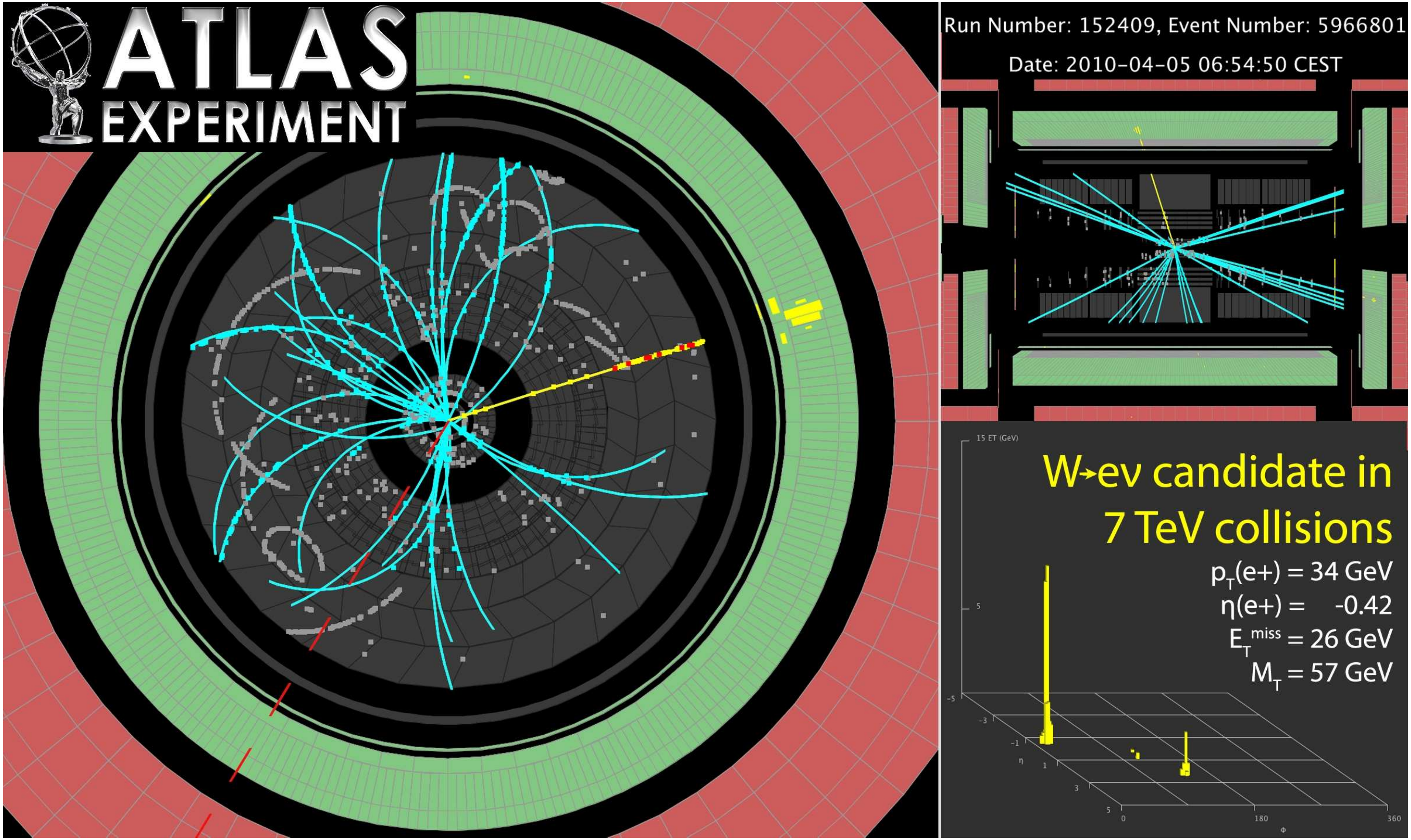
W- and Z-boson production at hadron colliders



Physics goals:

- M_Z $\rightarrow$ detector calibration by comparing with LEP1 result
- $\sin^2\theta_{\rm eff}^{\rm lept}$ $\rightarrow$ comparison with results of LEP1 and SLC
- M_W $\rightarrow$ improvement to $\Delta M_W \sim 15\,\mathrm{MeV}$, strengthen EW precision tests
  ($\mathrm{W/Z}$ shape comparisons even sensitive to $\Delta M_W \sim 7\,\mathrm{MeV}$ at LHC)
  Besson et al. '08
- decay widths Γ_Z and Γ_W from M_{ll} or $M_{\mathrm{T},l\nu_l}$ tails
- search for Z' and W' at high M_{ll} or $M_{\mathrm{T},l\nu_l}$
- information on PDFs or parton–parton luminosities

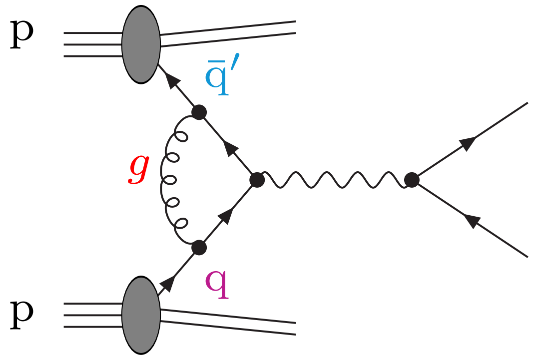
A W-boson event at the LHC



W/Z production in the QCD-improved parton model

$\hookrightarrow$ inclusion of higher-order corrections in α_s:

- virtual corrections: diagrams with loops

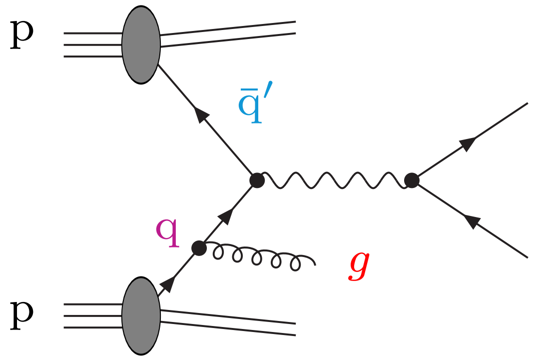


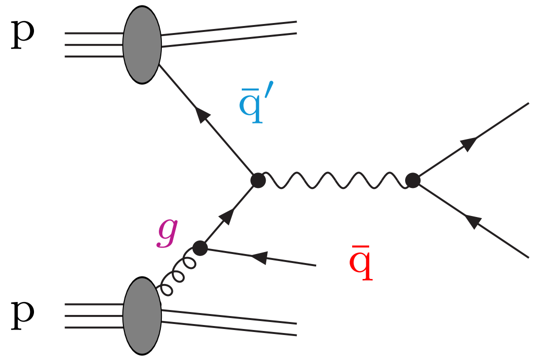
◇ UV divergences
$\hookrightarrow$ absorbed by renormalization ($\alpha_s(\mu_{ren})$, etc.)

◇ soft IR divergences

◇ collinear divergences

- real corrections: diagrams with additional external partons

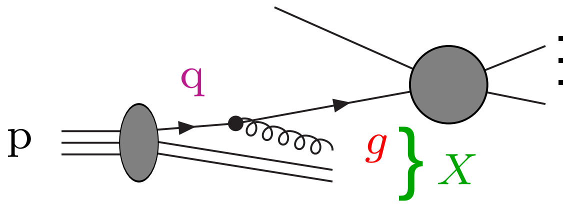


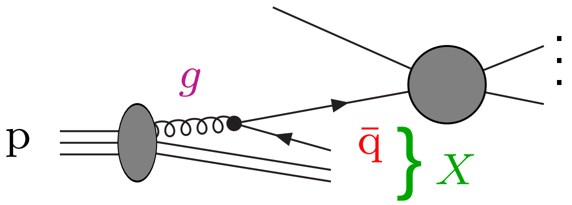


◇ soft IR divergences $\longrightarrow$ compensate soft IR divergences of virtual corrections

◇ collinear divergences $\longrightarrow$ not completely compensated

Collinear divergences in initial state and factorization





g, $\bar{\mathrm{q}}$ have transverse momenta $\mathrm{k_T} \to 0$

- process-independent divergence in $\int \mathrm{d}\mathbf{k}_\mathrm{T}^2$
- g, $\bar{\mathrm{q}}$ are part of proton remnant X

$\hookrightarrow$ singularity belongs to proton $\Rightarrow$ absorption into renormalized parton densities

$$q(x,Q) = q(x) + \left\{ \text{divergent part from} \int_0^{Q^2} \mathrm{d}\mathbf{k}_\mathrm{T}^2 \right\}, \text{ etc.}$$

$Q =$ "factorization scale"; Q dependence ruled by DGLAP evolution

pp cross section:

$$\sigma_{\mathrm{pp}} = \sum_{f_1 f_2} \int_0^1 \mathrm{d}x_1\, f_1(x_1,Q) \int_0^1 \mathrm{d}x_2\, f_2(x_2,Q)\, \hat{\sigma}_{f_1 f_2}(x_1 x_2 s, Q)$$

$$(f_1 f_2 = \bar{\mathrm{q}}'\mathrm{q},\ \mathrm{q}\bar{\mathrm{q}}',\ g\mathrm{q},\ g\bar{\mathrm{q}}',\ \bar{\mathrm{q}}'g,\ \mathrm{q}g,\ gg)$$

Note: incomplete compensation of Q dependence in finite perturbative orders
$\hookrightarrow$ measure of missing corrections

QCD corrections to W/Z production:

- NNLO QCD corrections
  - ◇ total cross sections — Hamberg, v.Neerven, Matsuura ’91; v.Neerven, Zijlstra ’92; Harlander, Kilgore ’02
  - ◇ W/Z rapidity distributions — Anastasiou et al. ’03
  - ◇ fully differential — Melnikov, Petriello ’06; Catani et al. ’09
- soft-gluon resummation (partially combined with γ emission) — Balazs, Yuan ’97; Landry et al. ’02; Cao, Yuan ’04

EW corrections to W/Z production:

- NLO EW correction to W production — Baur, Keller, Wackeroth ’98; S.D., Krämer ’02; Baur, Wackeroth ’04; Arbuzov et al. ’05; Carloni Calame et al. ’06
- NLO EW correction to Z production — Baur, Keller, Sakumoto ’97; Baur, Wackeroth ’99; Brein, Hollik, Schappacher ’99; Arbuzov et al. ’06; S.D., Huber ’09
- multi-photon radiation via leading logs — Baur, Stelzer ’99; Carloni Calame et al. ’03; Placzek, Jadach ’04; Brensing et al. ’07

Corrections beyond the SM:

- NLO SUSY corrections in the MSSM — Brensing et al. ’07; S.D., Huber ’09

$\hookrightarrow$ negligible near W/Z resonances $\Rightarrow$ standard candles !

Structure of EW corrections: example of W production

Born amplitude:

$$\mathcal{M}_0 = \frac{e^2}{2s_W^2} \left[\bar{v}_d \gamma^\mu \tfrac{1}{2}(1-\gamma_5) u_u\right] \frac{1}{\hat{s} - M_W^2 + \underbrace{\mathrm{i} M_W \Gamma_W}} \left[\bar{u}_{\nu_l} \gamma_\mu \tfrac{1}{2}(1-\gamma_5) v_l\right]$$

results from (partial) Dyson summation of W self-energy

Virtual corrections:

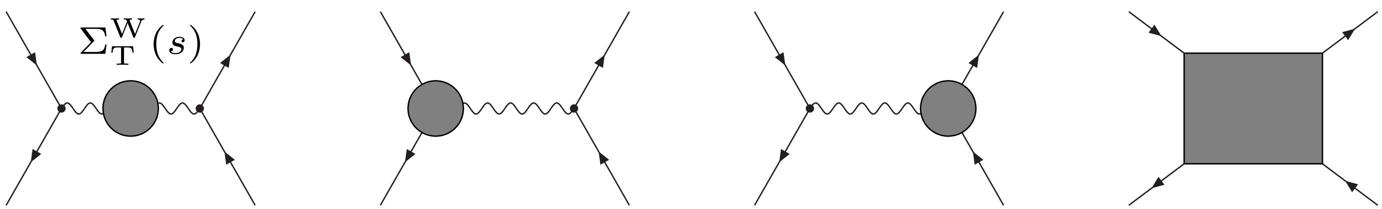
consistent gauge-invariant treatment of W resonance required

$\hookrightarrow$ solutions: pole scheme, factorization schemes, complex-mass scheme

see S.D., Huber '09 and refs. therein

$$\mathcal{M}_1 = \delta^{\mathrm{virt}} \mathcal{M}_0$$

$$\delta^{\mathrm{virt}} = \delta_{WW}(\hat{s}) + \delta_{Wdu}(\hat{s}) + \delta_{W\nu_l l}(\hat{s}) + \delta_{\mathrm{box}}(\hat{s}, \hat{t})$$



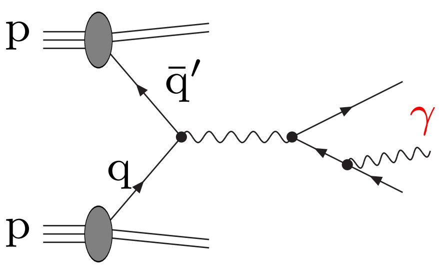
W self-energy — Wud and $\mathrm{W}l\nu_l$ vertex corrections — box diagrams

Note: δ^{virt} is not analytic at $\hat{s} \to M_W^2$,
but contains terms $\propto \alpha \ln(\hat{s} - M_W^2 + \mathrm{i} M_W \Gamma_W)$

Real photon corrections:

consistent treatment of W resonance with correct IR (soft and collinear) limits

- final-state radiation:

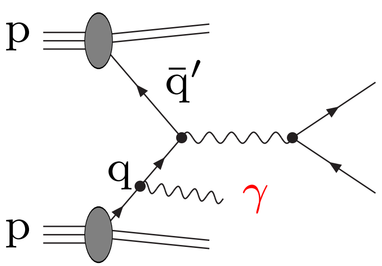


$$\sigma_{\mathrm{FSR}} = \sigma_0 \int_0^1 \mathrm{d}z \, \frac{Q_l^2 \alpha}{2\pi} \ln\left(\frac{M^2}{m_l^2}\right) \left(\frac{1+z^2}{1-z}\right)_+ \Theta_{\mathrm{cut}}(k_l = z\hat{k}_l) + \ldots$$

$\hookrightarrow$ large mass-singular correction if $\int \mathrm{d}z$ restricted

Note: singularity vanishes after "photon recombination"
due to full z integration (inclusiveness $\to$ KLN theorem)

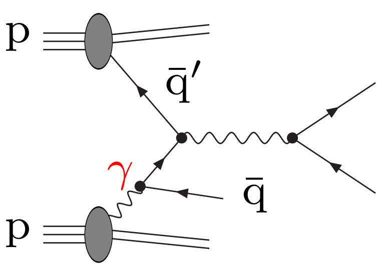
- initial-state radiation:



Mass singularity absorbed via PDF redefinition as in QCD
$\hookrightarrow$ remaining ISR corrections not enhanced
and depend on factorization scale Q

But: QED-corrected PDFs required (corrections $\sim 1\%$)
only old set MRST2004qed available $\to$ update necessary

- photon-induced processes:



PDF redefinition necessarily includes photon PDF
$\hookrightarrow$ $\gamma\mathrm{q}$ processes deliver real corrections,
effects typically $\lesssim 1\%$

γ PDF measureable via $\gamma\gamma \to l^+ l^-$ via special cuts ?

Observables for W/Z production at hadron colliders

Momentum/energy measurements:

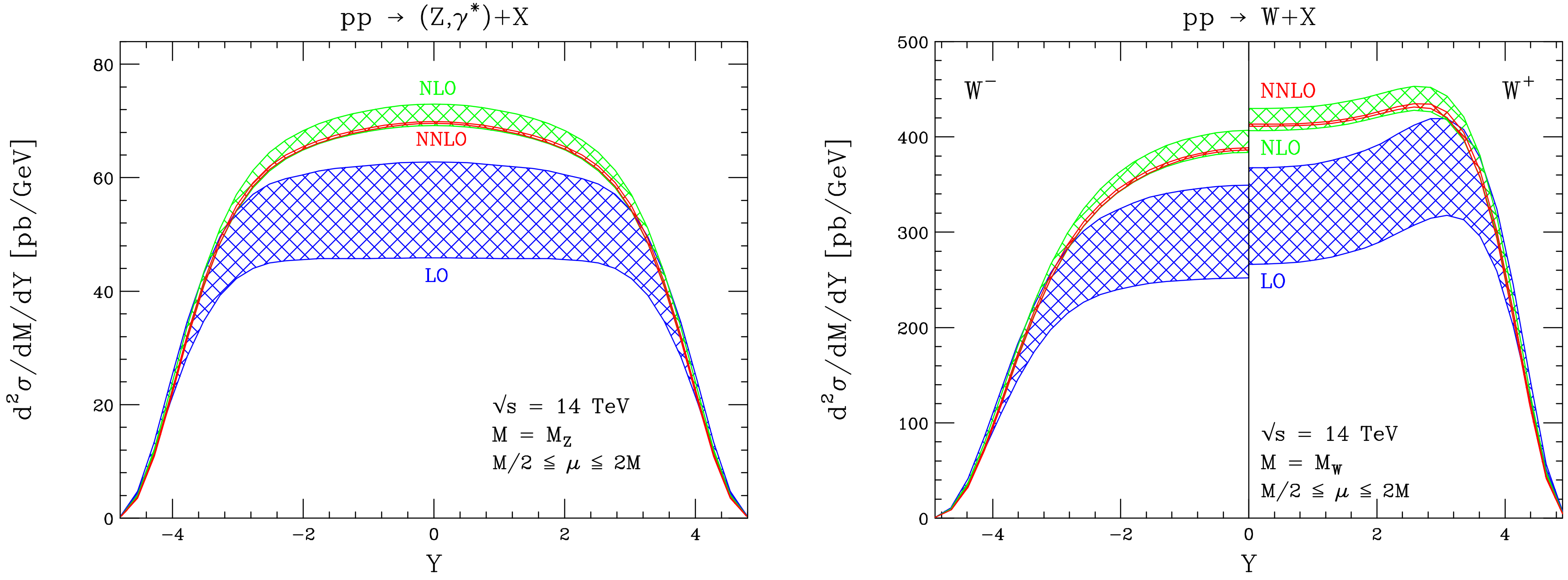
- $p_{\mathrm{T},l} =$ lepton transverse momenta
- $p_{\mathrm{T,miss}} =$ missing transverse momentum (or energy)
- $y_l = \frac{1}{2}\ln\left(\frac{p_l^0+p_l^3}{p_l^0-p_l^3}\right) =$ lepton rapidities

"Derived" observables:

- $M_{ll} = \sqrt{(p_{l^+}+p_{l^-})^2} =$ dilepton invariant mass for Z production
  $\hookrightarrow$ important for calibration
- $M_{\mathrm{T},\nu l} = \sqrt{2p_{\mathrm{T},l}p_{\mathrm{T,miss}}(1-\cos\phi_{\nu l})} =$ transverse invariant mass for W production
  $\hookrightarrow$ measurement of M_{W}
- $p_{\mathrm{T,W/Z}} = p_{\mathrm{T},\nu/l} + p_{\mathrm{T},l'} =$ transverse W/Z momenta
  $\hookrightarrow$ induced by QCD radiation (jets)
- various asymmetries

W/Z rapidity distributions

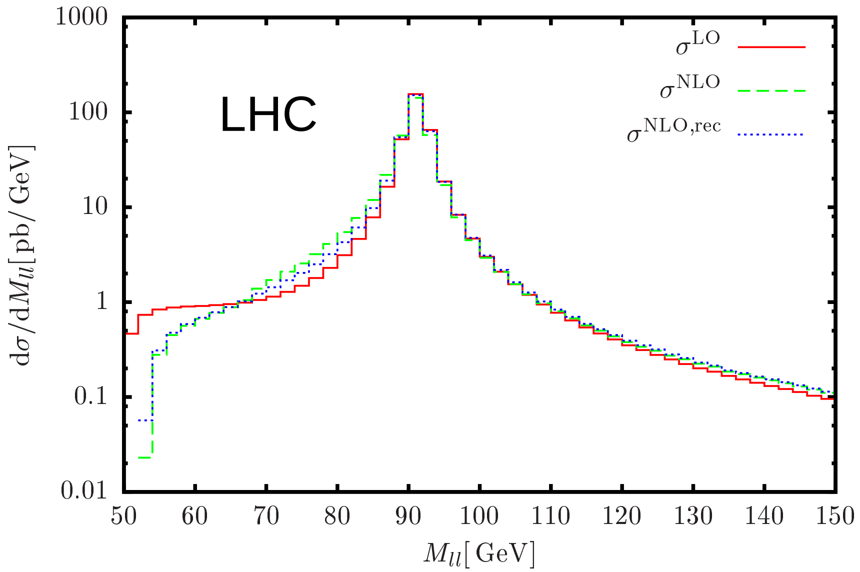
Anastasiou et al. '03



- LHC:
  - ◇ all rapidity distributions are forward–backward (FB) symmetric (see plot)
  - ◇ FB asymmetry defined wrt boost direction of Z boson

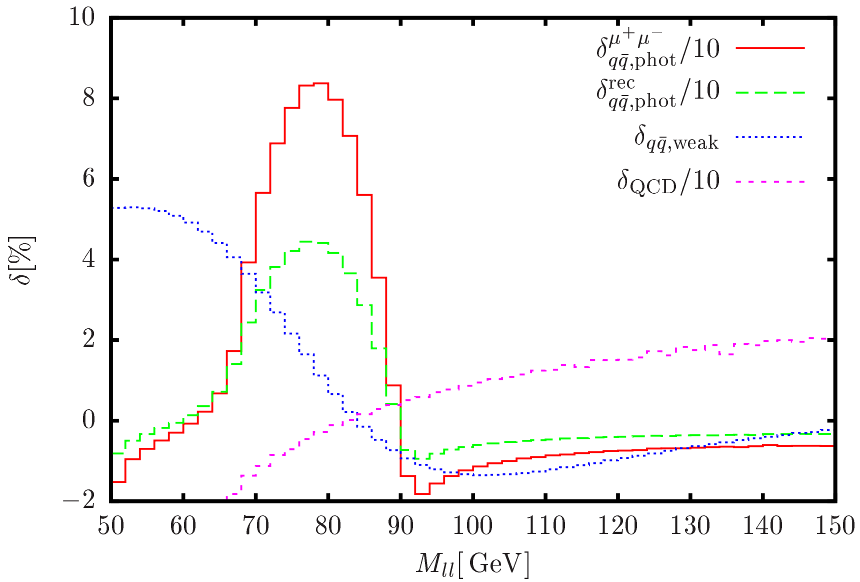
    $\hookrightarrow$ $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ measureable with precision competitive to LEP/SLC ?
- Tevatron:
  - ◇ FB asymmetry defined wrt p direction $\rightarrow$ $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ in progress
  - ◇ W (charged lepton) rapidity constrains PDF ratio $\mathrm{u}(x)/\mathrm{d}(x)$
- QCD predictions show nice convergence in LO $\longrightarrow$ NLO $\longrightarrow$ NNLO
- EW corrections at the level of few % (not shown)

Dilepton invariant-mass distribution (at intermediate M_{ll} values)



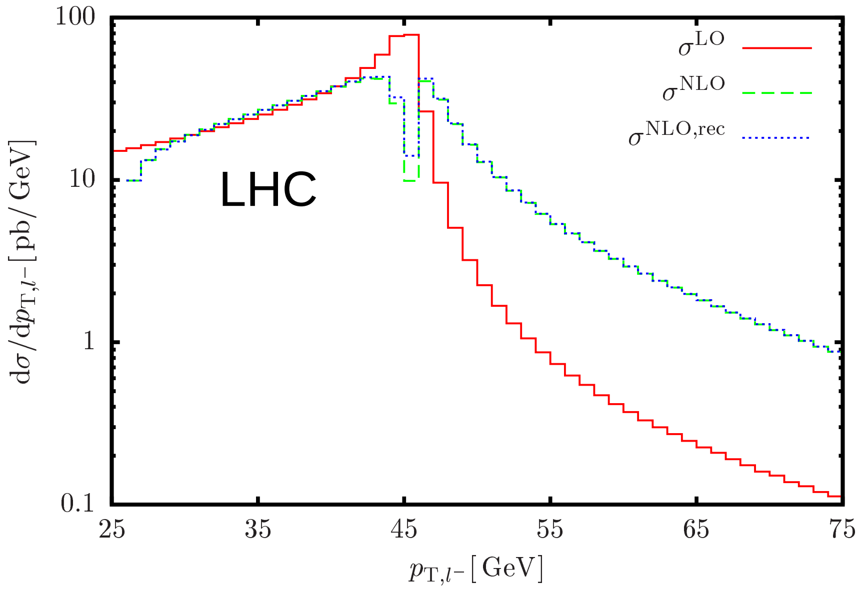
S.D., Huber '09

Relative corrections:



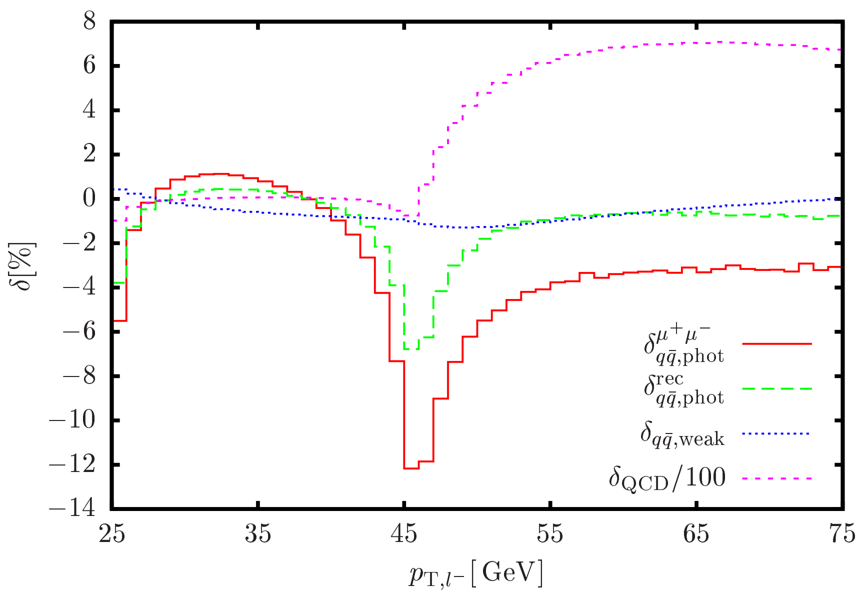
- QCD corrections of $\mathcal{O}(20\%)$, but very little resonance distortion
- photonic corrections very large due to FSR ("inverse radiative tail") $\hookrightarrow$ resonance distortion
  - ◇ "bare muons": enhanced by mass sing. $\propto \alpha \ln m_\mu$
  - ◇ "photon recombination" ($\mathrm{e}^\pm$ case): mass sing. canceled due to KLN
- weak corrections (loops with W's, Z's, fermions) at the order of $\lesssim 5\%$

Lepton transverse-momentum distribution for Z-boson production



S.D., Huber '09

Relative corrections:

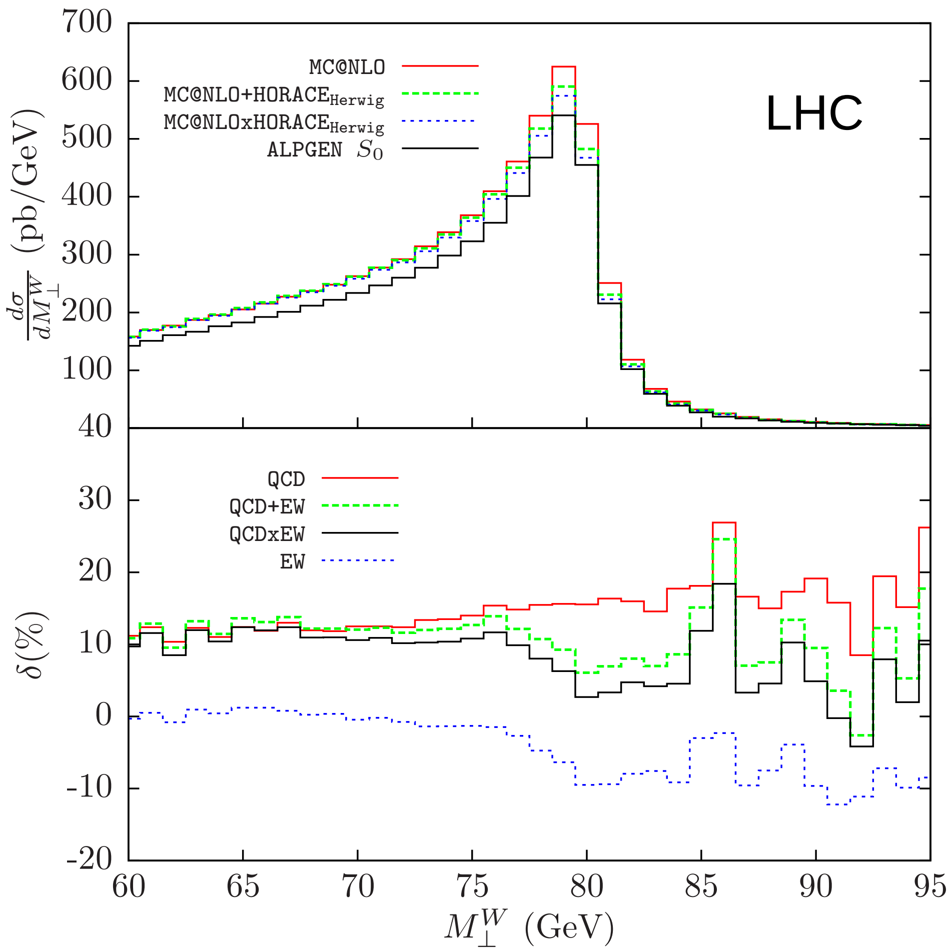


- "Jacobian peak" near $p_{T,l} \approx M_Z/2$, resonant Z's contribute only to $p_{T,l} \lesssim M_Z/2$
- patterns of corrections similar for Z and W production
- size of photonic and weak corrections qualitatively similar to M_{ll} distribution
- QCD corrections extremely huge for $p_{T,l} \gtrsim M_Z/2$ because of jet ISR: LO process becomes Z+jet prod.

  $\hookrightarrow$ no good perturbative control of QCD

  $\Rightarrow$ M_W measured better from $M_{T,\nu l}$!

Transverse-mass distribution for W production



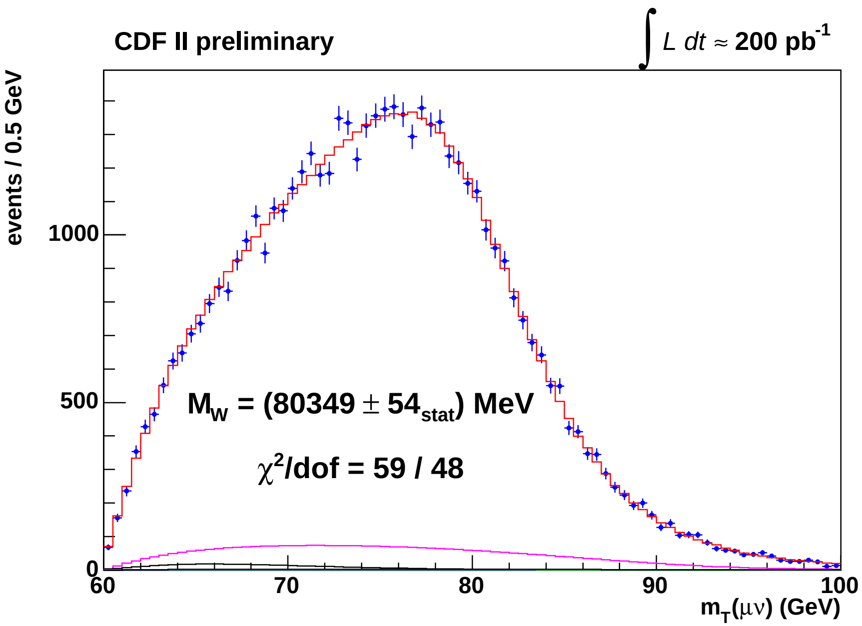
Balossini et al. '09

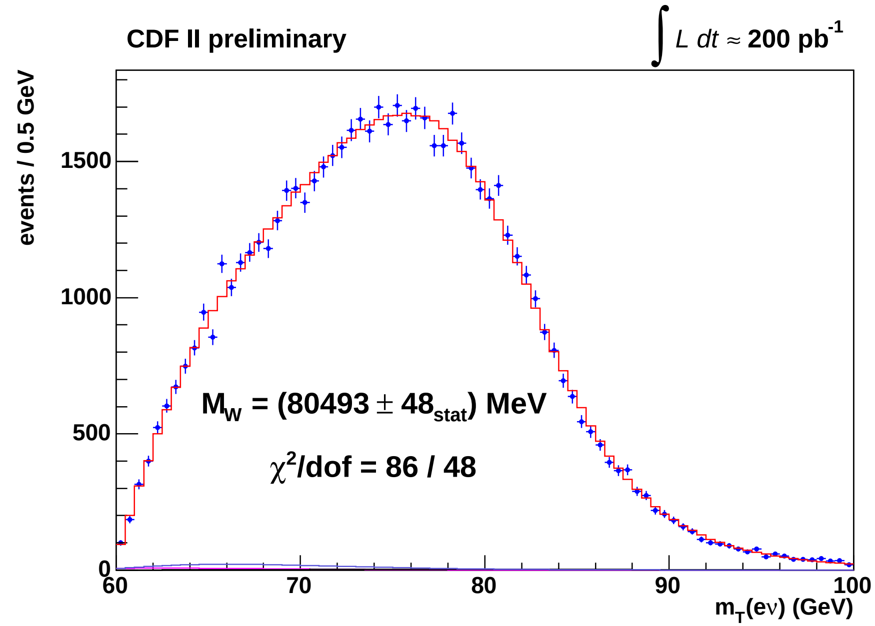
- QCD corrections moderate and flat near the peak
- EW corrections (mainly FSR) shift peak by about $\mathcal{O}(100\,\mathrm{MeV})$
- different ways of combining QCD and EW corrections $(1+\delta_{\mathrm{QCD}}+\delta_{\mathrm{EW}})$ vs. $(1+\delta_{\mathrm{QCD}})\times(1+\delta_{\mathrm{EW}})$ differ at %-level
  $\hookrightarrow$ $\mathcal{O}(\alpha\alpha_{\mathrm{s}})$ calculation needed ...

W-mass reconstruction from "Jacobian peak" near $M_\perp^W \equiv M_{\mathrm{T},\nu l} \approx M_{\mathrm{W}}$:

- resonant W bosons contribute only for $M_{\mathrm{T},\nu l} < M_{\nu l} \approx M_{\mathrm{W}}$
- the tail $M_{\mathrm{T},\nu l} \gtrsim M_{\mathrm{W}}$ can be used to fit the W width Γ_{W}

Fits of M_W to W transverse mass at the Tevatron





Theory prediction based on QCD resummations (improved by some EW corrections)

Result from CDF Run II: $M_\mathrm{W} = 80.413 \pm 0.048\,\mathrm{GeV}$

Result from D0 Run II: $M_\mathrm{W} = 80.402 \pm 0.043\,\mathrm{GeV}$

CDF/D0 combination 2009: $M_\mathrm{W} = 80.420 \pm 0.031\,\mathrm{GeV}$ (from Fermilab homepage)

Result from LEP: $M_\mathrm{W} = 80.376 \pm 0.033\,\mathrm{GeV}$

World average 2009: $M_\mathrm{W} = 80.399 \pm 0.023\,\mathrm{GeV}$