Physics at Colliders
HPRN-CT-2000-00149

Midterm Meeting

Durham, April 9, 2002

Torino

http://www.to.infn.it/giampier/net.html

Period: August 1, 2000 - March 31, 2002

Elena Accomando (2003 Post - Doc from PSI)
Andrej Arbuzov (Post - Doc till 31/1/2001)
Alessandro Ballestrero (staff)
Lee Garland (after 1/10/2002 Post - Doc)
Ezio Maina (staff)
Giampiero Passarino (staff - scientist in charge)
Roberto Pittau (staff)
Sandro Uccirati (Ph.D.)

First Graduate School in Physics at Colliders Turin, October 2-6, 2001

- **W. Beenakker**: Sudakov logarithms in the Standard Model
- **F. Feruglio**: Selected Topics in Physics beyond the Standard Model
- **S. Jadach**: Monte Carlo techniques in High Energy Physics
- **J.J. van der Bij**: Selected Topics in Higgs Physics
- **P. Zerwas**: An Introduction to SUSY

Torino funding (no money from EU)

Joint Publications

Precision Electroweak Physics

- 1 (see midterm report)
- 5 (see midterm report)
- + (see next slides)

Milestones - Teams

We have done **a lot more** than it seems. . .

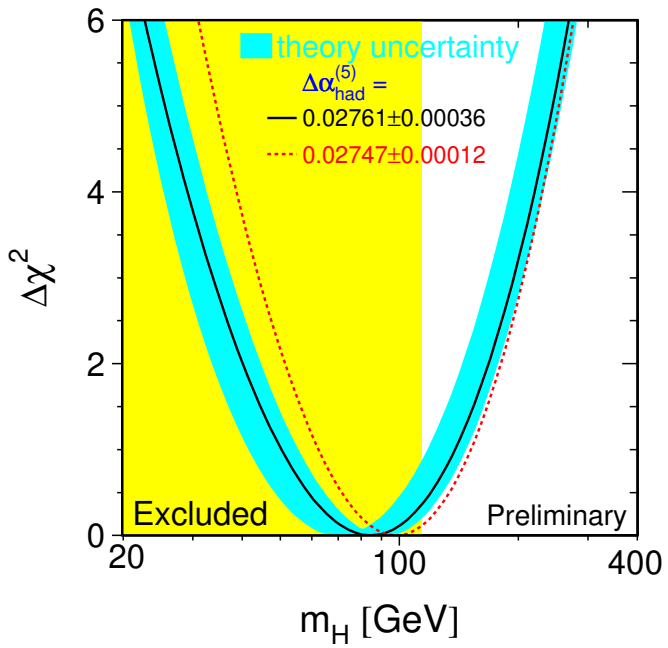

Figure 1: Milestones: *TOPAZ0 - ZFITTER* based

TOPAZ0 © TORINO

The most *celebrated* figure of the Lep era

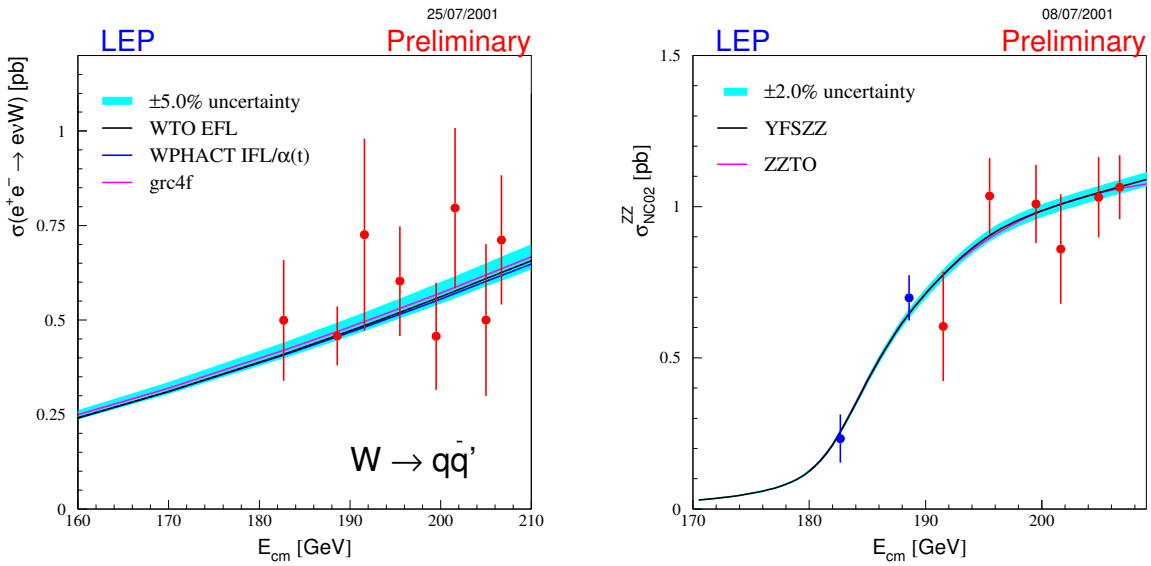

Figure 2: Milestones

WPHACT, WTO, ZZTO © **TORINO**

Addressed Milestones

EW (higher order) corrections in e^+e^-, W and 4-fermion production, constraints on the **SM**

$\nabla\nabla\nabla$

THERE ARE SEVERAL

well-defined PROJECTS,

we are (re)-bulding interlinks

$\nabla\nabla\nabla$

Algebraic - Numerical Evaluation of Multi - Loop Feynman Diagrams

$\Longrightarrow$ *fallout* in all five areas

▷ Papers:

1. **AN APPROACH TOWARD THE NUMERICAL EVALUATION OF MULTILOOP FEYNMAN DIAGRAMS**
   G. Passarino, Nucl.Phys.B619:257-312,2001, e-Print Archive: hep-ph/0108252
2. **ALGEBRAIC NUMERICAL EVALUATION OF FEYNMAN DIAGRAMS: TWO LOOP SELFENERGIES**
   G. Passarino and S. Uccirati, e-Print Archive: hep-ph/0112004

▷ Collaborations:

1. **Andrea Ferroglia**, NYU $\rightarrow$ Freiburg;
2. **Massimo Passera**, Padova.

A **systematic** evaluation of

ALL two-loop diagrams

with

special emphasis to **SM** applications

including **QED**

Methodology

▷ **analysis** of Landau equations

▷ **BT** functional relations

▷ identification of **sectors** in **physical** cases

▷ **threshold behavior** through Mellin transforms

▷ Mellin - Barnes splitting

Actual Ward-identity restoration through finite counter-terms

The **Landau equations** for some topology are as follows:

$$\alpha_1\,(q_1^2+m_1^2)=0, \qquad \alpha_2\,((q_1-q_2)^2+m_2^2)=0,$$
$$\alpha_3\,((q_2-p_2)^2+m_3^2)=0, \qquad \alpha_4\,((q_2-P)^2+m_4^2)=0, \tag{1}$$

$$\alpha_1 q_{1\mu}+\alpha_2(q_1-q_2)_\mu=0,$$
$$-\alpha_2(q_1-q_2)_\mu+\alpha_3\,(q_2-p_2)_\mu+\alpha_4\,(q_2-P)_\mu=0.$$

The **leading** Landau singularity occurs for
$\alpha_i \neq 0, \forall i,$
for arbitrary masses it occurs for:

$$\begin{aligned} P^2 &= \frac{1}{2\,m_3^2}\,[(-p_2^2-(m_1+m_2)^2+m_3^2)\,(-p_1^2+m_3^2-m_4^2) \\ &+ 2\,m_3^2\,(p_1^2+p_2^2)\pm(\lambda_1\,\lambda_2)^{1/2}] \end{aligned}$$

$$\lambda_1 = \lambda(-p_1^2,m_3^2,m_4^2) \qquad \lambda_2=\lambda(-p_2^2,(m_1+m_2)^2,m_3^2)$$

An k/n **defoliation** is defined by the following relation

$$\int_0^1 \prod_{i=1}^{k} dx_i \prod_{j=k+1}^{n} dy_j \, F(\{x\}\,;\,\{y\}) = \sum_{l=1}^{k} \int_0^1 \prod_{i=1}^{k} dx_i \, x_l^{k-1} \prod_{j=k+1}^{n} dy_j \, F(x_l\, x_1, \ldots, x_l, \ldots x_l\, x_k\, \{y\}). \tag{2}$$

▷ A chain will stop when **all the singularites** of F which are at the **vertices of the simplex** $[0,1]^n$ have been factorized.

▷ The original integral is therefore decomposed into a **set** of N **sectors** and the **infrared divergences** have been disentangled.

Threshold behavior and Mellin-Barnes transforms

$$I(\alpha) \;=\; \int_0^1 dx\,[\chi_B(x) - i\,\delta]^{-\alpha}.$$

$$\begin{aligned}
\chi_B(x) \;&=\; s\,(x-a)^2 + \frac{\lambda}{4\,P^2} - i\,\delta, \\
a \;&=\; \frac{1}{2}\,\frac{s - m_2^2 + m_1^2}{s}, \\
\lambda \;&=\; \lambda(s, m_1^2, m_2^2) = 0, \quad \rho = -4\,s^2/\lambda.
\end{aligned}$$

$$I(\alpha) \;=\; (\frac{\rho}{s})^{\alpha} \sum_{X=a}^{1-a} \int_0^X dx\,(1+\rho\,x^2)^{-\alpha} = (\frac{\rho}{s})^{\alpha} \sum_{X=a}^{1-a} J_X(\alpha,\rho),$$

$$\begin{aligned}
J_X(\alpha,\rho) \;&=\; \frac{1}{2}\,B(\frac{1}{2}, \alpha - \frac{1}{2})\,\rho^{1/2} + J_X^{\rm reg}(\alpha,\rho), \\
J_X^{\rm reg}(\alpha,\rho) \;&=\; \sum_{k=0}^{\infty} (-1)^{k+1}\,\frac{\Gamma(\alpha+k)}{\Gamma(k+1)}\,\frac{X^{1-2\,(\alpha+k)}}{1-2\,(\alpha+k)}\,\rho^{-\alpha-k}.
\end{aligned}$$

CALCULUS FOR PRECISION HIGH-ENERGY PHYSICS

▷ Papers:

1. **PROJECT CALCPHEP: CALCULUS FOR PRECISION HIGH-ENERGY PHYSICS**
   D. Bardin, G. Passarino, L. Kalinovskaya, P. Christova, A. Andonov, S. Bondarenko and G. Nanava
   hep-ph/0202004
2. **A PRACTICAL APPROACH FOR EXPONENTIATION OF QED CORRECTIONS IN ARBITRARY PROCESSES**
   G. Passarino, Nucl.Phys.B619:313-358,2001, hep-ph/0108255
3. **ATOMIC PARITY VIOLATION AND PRECISION PHYSICS**
   D. Bardin, P. Christova, L. Kalinovskaya and G. Passarino, Eur.Phys.J.C22:99-104,2001, hep-ph/0102233

CALCULUS FOR PRECISION HIGH ENERGY PHYSICS

- ▷ Papers

1. **TESLA Technical Design Report Part III: Physics at an e^+e^- Linear Collider**
   R.D. Heuer et al.
   hep-ph/0106315
2. **WPHACT 2.0 A fully massive Monte Carlo generator for four fermion physics at e^+e^- colliders.**
   E. Accomando, A. Ballestrero, E. Maina
   hep-ph/0204052
3. **FOUR-FERMION SIMULATION AT LEP2 IN DELPHI.**
   A. Ballestrero, R. Chierici, E. Migliore, F. Cossutti
   in preparation

▷ Collaborations

- Elena Accomando, PSI

▷ Projects

1. Improvements for future n-fermion MonteCarlos on: integration, unweighted generation, ISR for multi scale processes, radiative corrections.

2. Phenomenology of six fermion at LHC for WW scattering and **Higgs** physics

3. New code for semi-automatic helicity amplitude computations

Closed Project:

Fully massive $4 - f(\gamma)$ production at $e + e-$ colliders, including: Leading Higher order contributions (Fermion Loop, p_t spectrum)

Produced Paper:

- "NEXTCALIBUR: A FOUR FERMION GENERATOR FOR ELECTRON POSITRON COLLISIONS",
  F. A.Berends, C.G. Papadopoulos and R. Pittau,
  Comput. Phys. Commun. 136: 148-172, 2001.

Partecipants:

- NCSR-D (Demokritos)
- Torino
- KUN (Leiden)

Running Projects:

1– Gauge invariant treatment of instable particles preserving Unitarity (merging of BBC approach + Fermion Loop)

Partecipants:

- Wim Beenakker (Nijmegen)
- Alexander Chapovsky (Aachen)
- Costas Papadopoulos (Demokritos)
- Roberto Pittau (Torino)

2– MC Techniques for Multi Particle production at Hadron Colliders

Partecipants:

- Roberto Pittau (Torino)
- Everyone interested (parallel activity by the Nijmegen and Demokritos groups)

EW CORRECTIONS TO QCD DOMINATED PROCESSES

- **EFFECTS OF JET ALGORITHMS FROM HIGHER ORDER QCD IN $W^{\pm}$ MASS DETERMINATIONS AT LEP-2**
  E. Maina, S. Moretti, hep-ph/0109180

▷ Partecipants:

1. **D. Ross** Southhampton,
2. **E. Maina** Torino,
3. **S. Moretti** Durham - Cern