ECFA DESY

Linear Collider Workshop

The Loop–Verein

Higher Order Corrections for standard e^+e^-– Annihilation Processes at High Energies

Convener SM: F. Jegerlehner, DESY Zeuthen

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ECFA-DESY

Linear Collider Study Group Meeting

– 14./18. September 2001 –

at Krakow Poland

The Loop–Verein: Future Plans

- **Motivation**

The main aim are precision calculations of processes within the Standard Model and super symmetric extensions of it

field which got a lot of momentum from precision physics at LEP/SLC

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we must keep momentum and improve calculations to meet TESLA requirements of HIGHER ENERGY **and** HIGHER LUMINOSITY

- **Coordination**

by a theoretical working group, called "The Loop-Verein".
Coordinate activities, identify problems and their solution.
Time scale: a long term project.

- **Invitation**

Everybody is invited to contribute to progress in this field (http://www-zeuthen.desy.de/theory/TLV/TheLoopVerein.html).

Theory coordinators:

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Experimental advice:

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- **Typical progress required:**

- go from 2 $\to$ 2 processes to 2 $\to$ 4(6) processes
  (plus γ radiation)
  at 0.2% level or better

- go to next order for 2 $\to$ 2 processes
  (plus γ radiation)
  increase precision by factor 10 relative to LEP-I

Note: complexity of calculations grows factorial
(a battle against combinatorics)
SM in renormalizable gauge without fermion doublet multiplicity
11 types of lines , 57 types of vertices !
more loops and/or more legs
become a true challenge

Key processes:

- **Bhabha scattering:** for luminosity monitoring,
  full 2–loop needed
  in massless approximation:
  substantial progress the last two years

- **all kind of boson production, top production:**

$$e^+e^- \to (2f), 4f, 6f, \ldots \text{ plus } \gamma\text{'s}$$

$$\uparrow$$

$$(\gamma,\ Z),\ ZH, WW,\ ZZ,\ Z\gamma,\ \gamma\gamma,\ \cdots, t\bar{t}$$

instable particles $\to$ theoretical problems
(resummation near resonances, order by order perturbation theory breaks down)
problems with unitarity and/or gauge invariance

$\Rightarrow$ masses, widths, couplings, ...

- **Alternative initial states**

$$\gamma\gamma,\ \gamma e,\ e^-e^- \to \cdots$$

as well as perturbative QCD calculations for hadron–hadron (LHC) and/or lepton–hadron colliders

$$\updownarrow$$

share experience with groups working on hadron collider physics

Radiative corrections in high energy processes:

- radiative corrections grow dramatically with energy

Leading EW Sudakov Logs

$$c_{\mathrm{SD}}^{e^+e^-\to X}\ \frac{\alpha}{\pi}\ \ln^2\left(s/M_W^2\right)$$

coefficient depends strongly on observable !

required talking to experimentalists

- what can experiments measure at what accuracy
- from which observable can we learn what
- jet physics and hadronization problems
- exclusive versus inclusive measurements
- etc.

at the end we need efficient event generators

in order to get a real feeling for the problems

- the high precision challenge: GigaZ:

  2 $\longrightarrow$ 2 full 2–loop + leading 3–loop

Altogether: new technical challenge

going from a few 100 to several 10000 diagrams !

Computational physics aspects:

How to beat factorial growth in complexity of calculations?

Memory problems, performance problems, software problems

Levels: analytic (formulae manipulating programs, memory and speed problems), numerical (stability and efficiency problems)

- **parallelization**
- **new algorithms**
- **automatic calculations**
- **standardization**

❏ **need flexible software packages which can easily accommodate new physics: SM $\rightarrow$ MSSM, SSM,..., GUTs,... general: new fields, new vertices, anomalous couplings, extra dimensions, etc.**

Sociological aspects:

we need collective effort in larger collaborations !

man-power problem, attractiveness of field, social prestige etc.

so far more on the individual level

(citation habits favors/requires? this approach!)

indispensable to have competing groups!

How do we organize a different collective behavior?

SUMMARY:

TESLA

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high luminosity at higher energies

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precision physics on a new level of complexity

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substantially enhanced effort by theoreticians

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will work only if community gets more support by our experimental colleagues

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needed:

positions

equipment

A challenging future ahead !