QED radiative corrections for electroproduction: modernising the COMPASS code

Barbara Latacz
supervised by Barbara Badelek and Yann Bedfer

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Program TERAD is a well known tool to calculate radiative corrections for an inclusive lepton-nucleus deep inelastic scattering. It was originally written in FORTRAN 77. Several collaborations were using it for many yearsw adding corrections using the Patchy package. After years of using Patchy and TERAD together it needed to be reordered. The new version, called Terad15, is described in this report. It has the same functionality as the old TERAD but is written only in FORTRAN 77.

1 Introduction

In the Born approximation a charged lepton scattering off a nucleus occurs via single photon exchange, Figure. 1*a*. In an experiment one can observe not only that ideal process but also many others with e.i. an additional photon exchange or a vacuum polarisation, Figure 1*b*-*e*. As a result, to obtain a cross-section for the Born approximation $\sigma_{1\gamma}$ from the measurement σ_{total}, it is needed to take into account *radiative corrections*.

Definition of a radiative correction (in inclusive reaction $lA \rightarrow l'X$ for given input energy of the lepton E):

$$\eta(x, y) = \frac{\sigma_{1\gamma}(x, y)}{\sigma_{total}(x, y)},$$

where $x = Q^2/2M\nu$, $y = \nu/E$, $Q^2 \approx 4EE' \sin^2\theta/2$, $\nu = E - E'$, E' - energy of scattered lepton, θ - lepton scattering angle, M - proton mass.

COMPASS experiment uses two different programs to calculate electrodynamic radiative corrections:

- TERAD - a program which calculates exact values of $\eta(x, y)$;
- RADGEN - a Monte-Carlo generator.

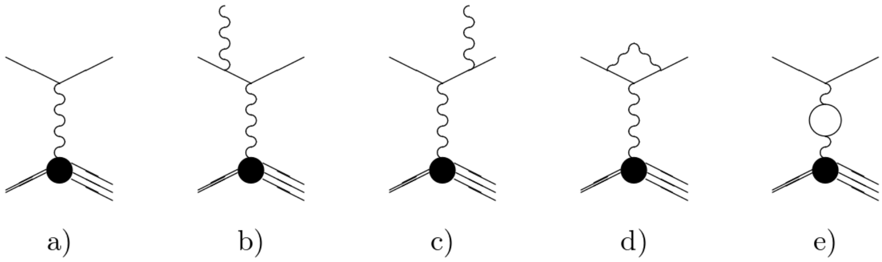

Figure 1: Feynman diagrams for *a)* the Born approximation, *b-e)* radiative corrections in lepton-nucleus scattering.

Both programs where created by independent groups, uses different approaches and give results in agreement with each other within 2% accuracy.

2 TERAD program

Program TERAD [1] was written in FORTRAN 77 using the Patchy package (*Source Code Control System - SCCS*). It is used to calculate exact values of radiative corrections for inclusive, non-polarised deep inelastic charged lepton scattering (DIS) off a nucleus, Figure. 2.

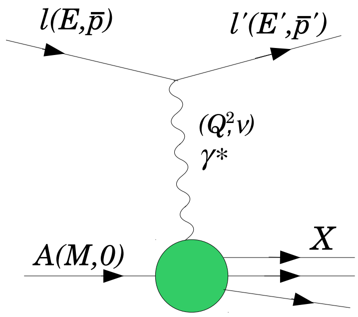

Figure 2: Deep inelastic charged lepton scattering off a nucleus in the Born approximation.

To obtain $\sigma_{1\gamma}$ and σ_{total} one needs following input data:

- elastic form factors F_{el} for proton, deuteron and heavier targets;
- quasi-elastic form factors F_{qel} for deuteron and heavier targets;
- structure function F_2 for proton, deuteron and heavier targets; if for a given target there are no measurements, F_2 function is created using results for other nuclei multiplied by a proper EMC factor;
- structure function R, assumed to be identical for all processes.

TERAD calculates radiative corrections for given values of (x, y) variables in the range: $0.00005 \leq \ x \ \leq \ 0.9$, $0.05 \leq y \leq 0.95$.

The result of TERAD is a table of numbers with the most important variables: x, y, $total$. From values of $total$ one can obtain radiative correction using formula:

$$\frac{total(x, y)}{100} + 1 = \frac{1}{\eta(x, y)}.$$

If $total = 9999.998$ then program went beyond selected kinematic range.

3 Student work - Terad15

Program TERAD was modified by several CERN's collaborations (i.e. NMC, SMC) and therefore needed to be ordered and modified. The main task of the student was to remove all commands associated with Patchy (CERN no longer provides support for this package), and make it easy to use for all members of the COMPASS collaboration.

3.1 General description of a student's task

During Summer Programme Student created a new version of a program TERAD named Terad15. This version is written completely in FORTRAN 77.

Student's work:

- Old version of TERAD was supposed to run on Student's computer. It had to be modified to work properly.
- All commands associated with the Patchy package were removed. It was the most complicated and time-consuming task.
- The code was reordered and some comments were added.
- All used parameters were organised and added to the program. Also some forgotten parameters were found (in the code of old TERAD). They might be useful in future to compare results from different experiments.
- Terad15 was neatly tested whether it agrees with the original one.
- Documentation of the new program was written: *Terad15 - user guide*.

3.2 Input parameters - a brief description

Terad15 uses an input file to enter external parameters in order to be accessible and easy-to-use for all members of the collaboration. There are 74 input parameters which define calculations conditions. General subject classification of parameters:

- Basic options
  - Type of a particle - defines a particle which collide with a target (electron or muon).
  - Energy of a scattered lepton. One can choose between: 90, 100, 120, 160, 200, 280 [GeV].
  - Choice between initial particles and antiparticles.
  - Target definition. There are 14 different targets.
  - Nuclear suppression factor (3 possible options).
  - Semiinclusive cuts.
  - Size of the radiative correction table. One can choose for how many (x, y) points the calculation is performed.
- Form Factors
  - Nucleon form factor - 4 parametrisations available.
  - Nuclear form factor for deuteron - 5 parametrisations.
  - Nuclear form factor for different targets - several options defined for every target.
- F2 functions
  - F2 parametrisation - 6 parametrisations available.
  - Switches optional for f2 parametrisation. These are additional corrections for given parametrisations.

- EMC effect for nuclear targets
    - ∗ Transform an isoscalarity corrected nuclear structure function in a true one.
    - ∗ Nuclear ratio.
- R functions. There are three R parametrisations.

Most of them have only *“use”* (=1) or *“do not use”* (=0) options. For more detailed description one can look into *Terad15 - user guide*.

3.3 New parametrisation of nucleons form factors

In recent years, it turned out that different methods of nucleon form factors measurements give inconsistent results. That is why new calculations shows a large discrepancy between old and new parametrisations. Therefore a new form factor's parametrisation, based on Kelly's formula [2], was added to Terad15. Exact values of used parameters can be found in the following publications: proton electric and magnetic form factors [3], neutron electric [5] and magnetic form factors [4].

4 Summary

Program TERAD used by the COMPASS collaboration is now modernised and can be run on every computer which has access to cernlib. The new version is called Terad15 and has the same functonality, but works differently: instead of using the Patchy package it uses input file to read parameter values. The fortran code was ordered and therefore some forgotten options were found. Also usless parts of code were removed. To improve the calculations new nucleons' form factors were added.

References

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