Non Linear Gauge Fixing for FeynArts

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1. Why FeynArts?
2. Non Linear Gauge Fixing in the SM
3. Non Linear Gauge Fixing in the MSSM
4. Outlook

1. Why FeynArts?

There are so many other codes, too . . .

- It is free of charge.
- It is open sourced.
- It has a great support. (Thomas Hahn)
- It is easily customized.
- The user has full control.

2. Non Linear Gauge Fixing in the SM

Gauge fixing is necessary for gauge theories, so also for the SM.

- Why nonlinear gauge fixing?
  - Parameters provide a test for the correctness (of the code):
  - Result not gauge invariant $\Rightarrow$ errors in the code.

- Introduced more than 20 years ago; used then also by
  - F. Boudjema and E. Chopin,
    Z. Phys. C **73** (1996) 85 [arXiv:hep-ph/9507396].

- Then why the talk here?
  - There was no FeynArts model file.
  - The actual messy calculations are "left as exercises for the reader".

2. Non Linear Gauge Fixing in the SM

- What is so messy?
  - To get the conventions consistent
    - in your own calculation,
    - between your prefered reference papers and your own calculation,
    - between FeynArts and your own calculation.

- Download `Lorentznlg.gen` and `SMnlg.mod` from

  `http:\\terra.ar.fi.lt\~garfield\SM\`

- Difficulties and Problems
  - We had to change the existing Lorentz files.
    - `Lorentz.gen` does not support the extended couplings.
    - `Lorentz.gen` has a wierd definition for the ghost propagator $\frac{i\sqrt{\xi}}{p^2-\xi m^2}$.
    - `Lorentzbgf.gen` does not support all counter terms: ghost wfr and mass.

3. Non Linear Gauge Fixing in the MSSM

Also proposed by F. Boudjema and implemented in Grace:

G. Belanger, F. Boudjema, J. Fujimoto, T. Ishikawa, T. Kaneko, K. Kato and Y. Shimizu, Phys. Rept. **430** (2006) 117 [arXiv:hep-ph/0308080].

The gauge fixing conditions are defined for the mass bases $\{A_\mu, Z_\mu, W_\mu^\pm\}$ and $\{H_h, H^\pm, G^0, G^\pm\}$, $h = 1, 2, 3$:

$$F^A = \partial^\mu A_\mu \quad , \qquad F^Z = \partial^\mu Z_\mu + \xi_Z m_Z G^0 + \tfrac{1}{2} g_Z \xi_Z \tilde{\epsilon}_h H_h G^0 \quad ,$$

$$F^\pm = \partial^\mu W_\mu^\pm \pm i \xi_W [m_W G^\pm + e(\tilde{\alpha} A^\nu + \tfrac{1}{2}\tfrac{s_W}{c_W} \tilde{\beta} Z^\nu) W_\nu^\pm + \tfrac{g}{2}(\tilde{\kappa} G^0 \mp i \tilde{\delta}_h H_h) G^\pm] \, ,$$

with the additional 9 parameters $\tilde{\alpha}, \tilde{\beta}, \tilde{\delta}_h, \tilde{\epsilon}_h, \tilde{\kappa}$ (only 7 for CP conserving).

- Gauge invariance of the MSSM is easy in the interaction basis,
- but non trivial in mass eigenstates.
- Parameters can be used to check gauge invariance numerically.
- It is hopefully useful for checks in the Complex Mass Scheme (CMS).
  A. Denner, S. Dittmaier,
  Nucl. Phys. Proc. Suppl. **160** (2006) 22 [arXiv:hep-ph/0605312].

3. Non Linear Gauge Fixing in the MSSM

- Download `Lorentznlgf.gen` and `MSSMnlgf.mod` from

  `http:\\terra.ar.fi.lt\~garfield\MSSM\`

- Features
  - `Lorentzbgf.gen` with an added coupling for ghost counter terms.
  - The Higgs mixing is included with `Ohiggs`:
    - rename to `Uhiggs` (or `Zhiggs`) when linking to FeynHiggs.
    - That is now somewhat outdated, as it appeared in the original distribution. See the talk by Thomas Hahn from Saturday.
  - The Lagrangian is calculated and transformed to mass eigenstates.
    - But the programming is not elegant and has no documentation.

- Difficulties and Problems
  - There was little time for checks and no numeric check **yet** .

Outlook . . . or what we plan to do

- Checks of the model file
  - analytic and numeric.
- Cleanup and provide a documentation for the Lagrangian(s)
  - depending on the time we can afford.
- Include counter terms for the MSSM.
  - But this will be a slow progress.
- Calculate processes for the LHC
  - to get students in Lithuania interested in particle physics.

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