Computer tools in particle physics

- Introduction -

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Dear radioactive Ladies and Gentlemen...

December 4th, 1930
Letter to his colleagues in Tübingen

1930
Pauli's neutrino hypothesis
Zürich, Dec. 4, 1930

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Dear Radioactive Ladies and Gentlemen,

As the bearer of these lines, to whom I graciously ask you to listen, will explain to you in more detail, because of the "wrong" statistics of the N- and Li-6 nuclei and the continuous beta spectrum, I have hit upon a desperate remedy to save the "exchange theorem" of statistics and the law of conservation of energy. Namely, the possibility that in the nuclei there could exist electrically neutral particles, which I will call neutrons, that have spin 1/2 and obey the exclusion principle and that further differ from light quanta in that they do not travel with the velocity of light.

(.../...)

But so far I do not dare to publish anything about this idea, and trustfully turn first to you, dear radioactive people, with the question of how likely it is to find experimental evidence for such a neutron if it would have the same or perhaps a 10 times larger ability to get through [material] than a gamma-ray.

I admit that my remedy may seem almost improbable because one probably would have seen those neutrons, if they exist, for a long time. (.../...) Thus, dear radioactive people, scrutinize and judge. - Unfortunately, I cannot personally appear in Tübingen since I am indispensable here in Zürich because of a ball on the night from December 6 to 7. With my best regards to you, and also to Mr. Back, your humble servant

signed W. Pauli
... and now!

Today in hep-ph:

   The ATLAS Z + MET Excess in the MSSM
   M. Cahill-Rowley, J.L. Hewett, A. Ismail, T.G. Rizzo
   → 22 new particles

   New Minimal SO(10) GUT : A Theory for All Epochs
   Charanjit S. Aulakh
   → ~ 600 new particles

   Focus Point Gauge Mediation with Incomplete Adjoint Messengers and Gauge Coupling Unification
   Gautam Bhattacharyya, Tsutomu T. Yanagida, Norimi Yokozaki
   → ~ 40 new particles

   Vector-like $W^\pm pm$-boson coupling at TeV and fermion-mass hierarchy (two boson-tagged jets vs four quark jets)
   She-Sheng Xue
   → 1 new particle

   Neutrino Mixing with Non-Zero $\theta_{13}$ and CP Violation in the 3-3-1 Model Based on $S_4$ Flavor Symmetry
   Vo Van Vien, Hoang Ngoc Long, Dinh Phan Khoi
   → 30 new particles
Many new models and particles

An “explosion” of new models and particles. **Strategy:**

- **Analytical** derivation of particle masses and vertices, minimization of the scalar potential, renormalization group equations, ...
- **Numerical** routines: diagonalization, resolution of differential equations, phase space integration...
- Mass spectrum, loop corrections, flavor observables and decay rates
- **Dark matter** properties: relic density, direct and indirect detection rates, ...
- **Collider** simulations
- Other
Usual approach

Compute! Compute! Compute!!!
Usual approach

Let's automatize the process!

Compute! Compute! Compute!!!
SARAH

SARAH is a Mathematica package for analyzing SUSY and non-SUSY models.

It calculates analytically all vertices, mass matrices, tadpoles equations, 1-loop corrections for tadpoles and self-energies and 2-loop RGEs.

SARAH is also a spectrum-generator-generator: based on the derived analytical expressions it creates Fortran source code for SPheno.

SPheno

SPheno is a Fortran code. It provides routines for the numerical evaluation of all vertices, masses and decay modes in a given model.
MicrOmegas [Bélanger, Boudjema, Pukhov, Semenov]

Computer code for the study of dark matter.
First developed to compute the relic density of a stable massive particle, the current version also computes direct and indirect dark matter detection rates.
Written in C and Fortran.

MadGraph [The MadTeam]

MadGraph is a Monte Carlo event generator for collider simulations. It allows for a complete simulation of a new physics model at the LHC, from events at the parton level to detector response.
It is written in Python.
Message 1

It is not so hard!

What people think about SARAH, micrOmegas, MadGraph...

What they really are
Message 2

Do no trust (too much) in codes!
Plan

- **Lecture 1**: Exploring new models with SARAH
- **Lecture 2**: Computing dark matter properties with MicrOmegas
- **Lecture 3**: LHC physics with MadGraph
- **Lecture 4**: Final exercise
Let's get started!

Rules:

- You can interrupt and ask questions at any moment
- Suggestion: you can emulate what I do with your own laptop
- I will assume that you already have all the prerequisites installed