Computer tools in particle physics

- Introduction -

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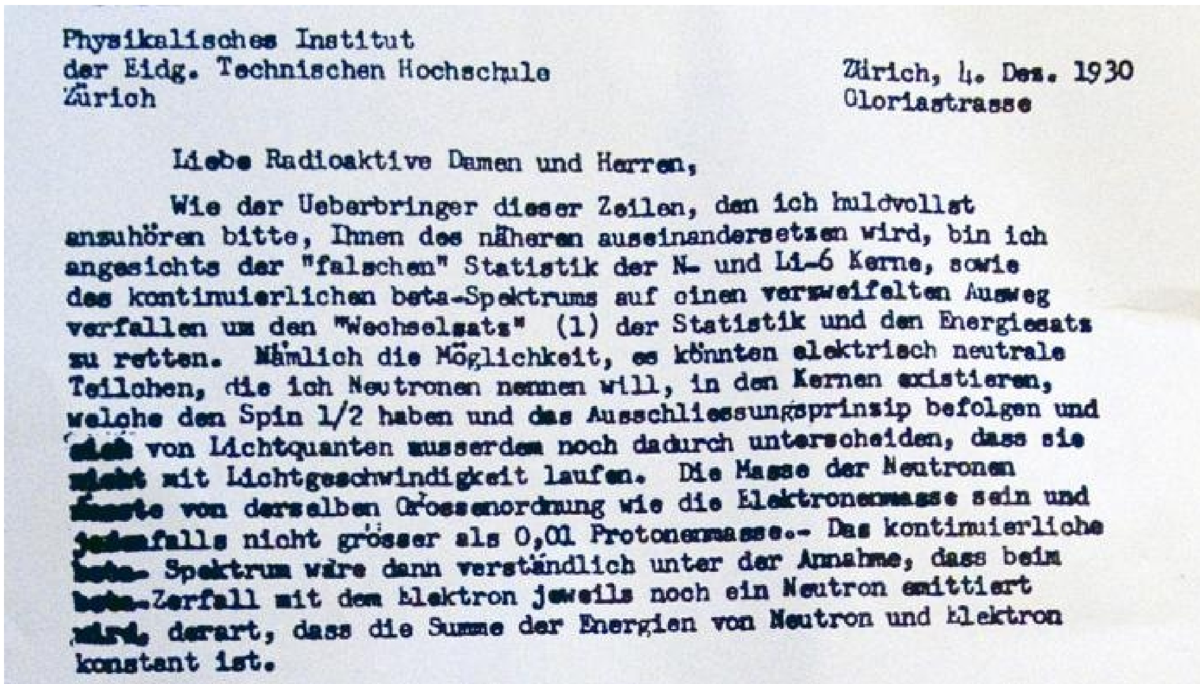
Dear radiactive Ladies and Gentlemen...



Physikalisches Institut
der Eidg. Technischen Hochschule
Zürich

Zürich, 4. Dez. 1930
Gloriastrasse

Liebe Radioaktive Damen und Herren,

Wie der Ueberbringer dieser Zeilen, den ich huldvollst anzuhören bitte, Ihnen des näheren auseinandersetzen wird, bin ich angesichts der "falschen" Statistik der N- und Li-6 Kerne, sowie des kontinuierlichen beta-Spektrums auf einen verzweifelten Ausweg verfallen um den "Wechselsatz" (1) der Statistik und den Energiesatz zu retten. Nämlich die Möglichkeit, es könnten elektrisch neutrale Teilchen, die ich Neutronen nennen will, in den Kernen existieren, welche den Spin 1/2 haben und das Ausschliessungsprinzip befolgen und sich von Lichtquanten ausserdem noch dadurch unterscheiden, dass sie nicht mit Lichtgeschwindigkeit laufen. Die Masse der Neutronen dürfte von derselben Grossenordnung wie die Elektronenmasse sein und jedenfalls nicht grösser als 0,01 Protonenmasse.- Das kontinuierliche beta- Spektrum wäre dann verständlich unter der Annahme, dass beim beta-Zerfall mit dem Elektron jeweils noch ein Neutron emittiert wird, derart, dass die Summe der Energien von Neutron und Elektron konstant ist.

December 4th, 1930
Letter to his colleagues in Tübingen

1930
Pauli's neutrino hypothesis

Back in the good old times...

Zürich, Dec. 4, 1930

Physics Institute of the ETH

Gloriastrasse

Zürich

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 amindispensable 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

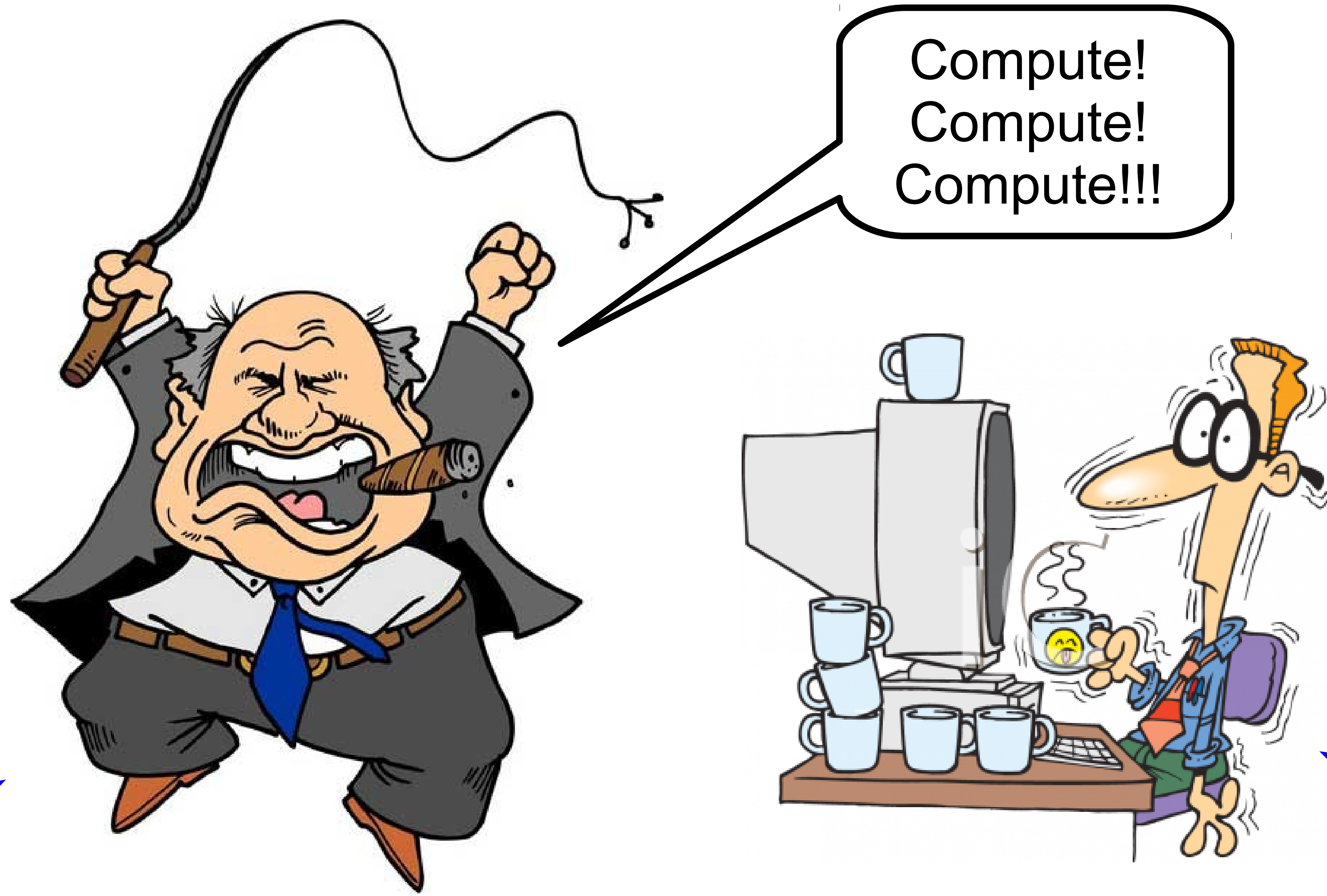
signed W. Pauli

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

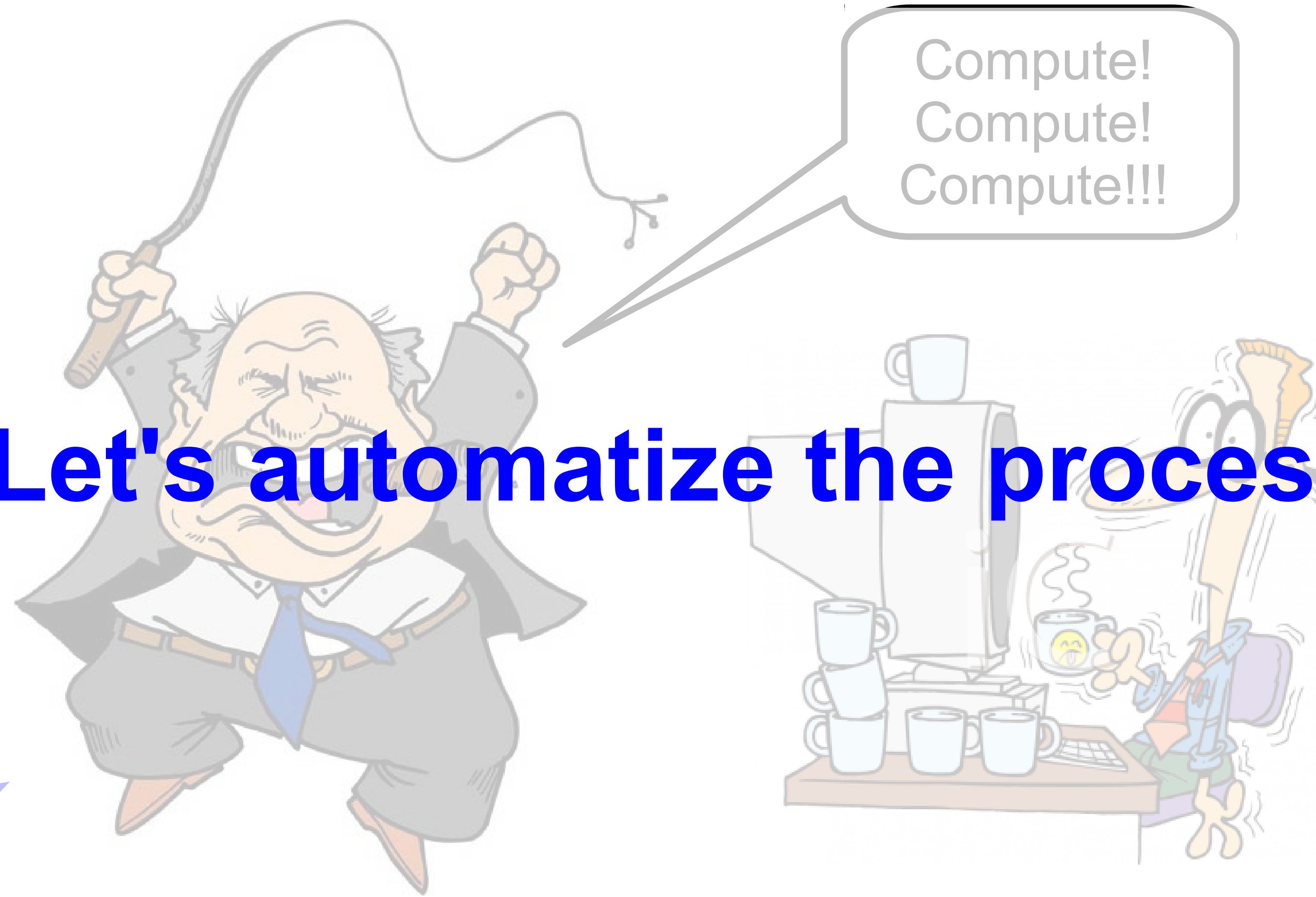
Usual approach



Professor

Poor student

Usual approach



Let's automatize the process!

Professor

Poor student

SARAH and SPheno

SARAH

[Staub]

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

[Porod, Staub]

SPheno is a Fortran code. It provides routines for the numerical evaluation of all vertices, masses and decay modes in a given model.

MicrOmegas and MadGraph

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
- **Lecture 5** : Introduction to FlavorKit, questions and conclusion

References

Lectures

"Computer tools in particle physics", A. Vicente,
[arXiv:1507.06349]

Practical introductions

"Exploring new models in all detail with SARAH", F. Staub,
[arXiv:1503.04200]

(Only for SUSY)

Manuals

SARAH: arXiv:1309.7223
Spheno: arXiv:1104.1573
MicrOmegas: arXiv:1407.6129
MadGraph: arXiv:1405.0301

Websites

All links can be found in
http://ific.uv.es/~montesin/computer_tools.html

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