

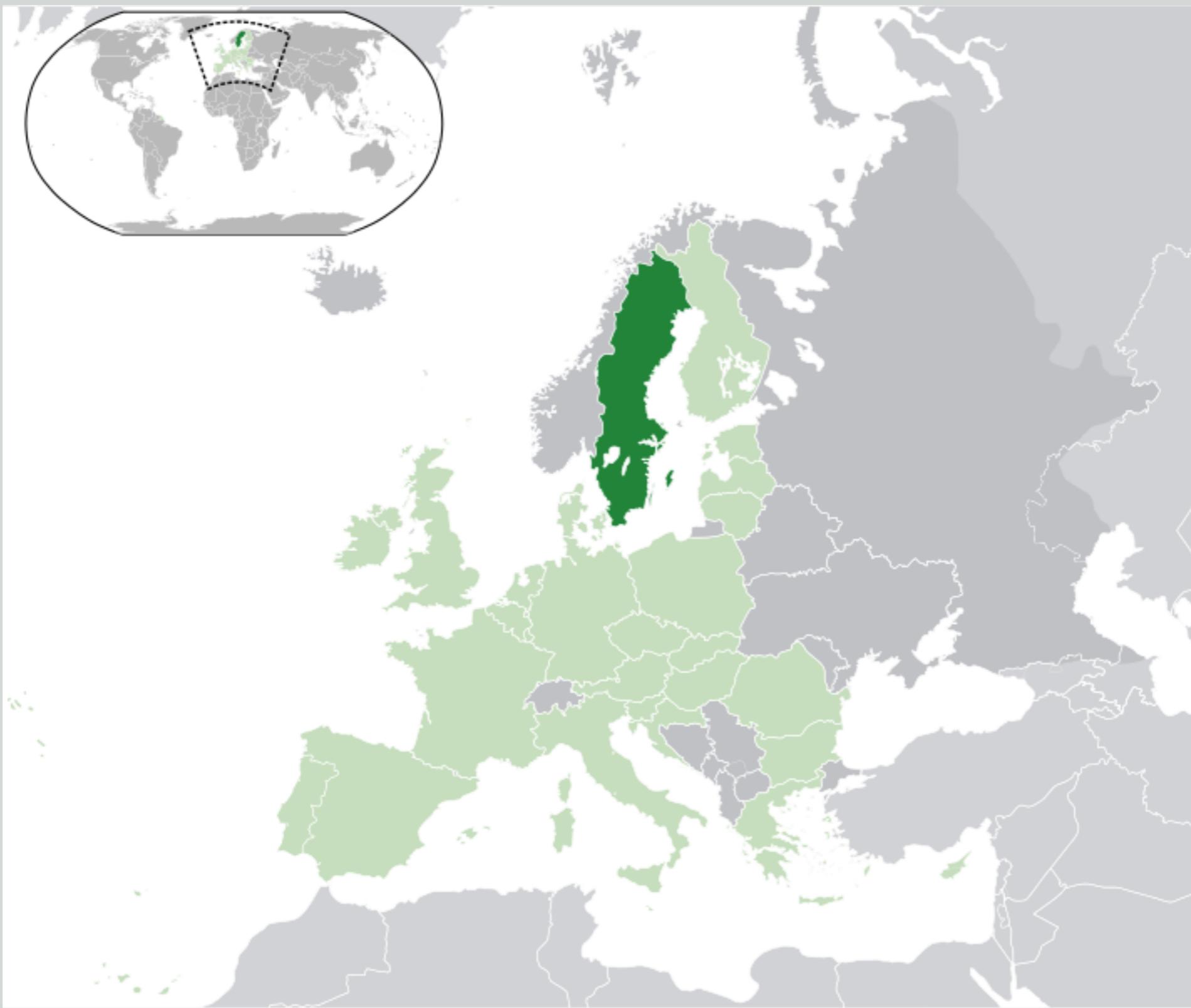
EUROSCHOOL ON EXOTIC BEAMS

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NUCLEAR THEORY AND PREDICTIVE POWER

LECTURE 1

SWEDEN



SWEDEN — FROM NORTH TO SOUTH

Stora Sjöfallet



West coast

East coast



Midsommar

Öresund bridge





Swedish moose



Swedish lynx



Swedish pig



Swedish lawn after visit of Swedish pigs



Swedish herring



Swedish mosquito

Drunken moose ends up stuck in Swedish apple tree

By Per Nyberg, CNN

September 9, 2011 -- Updated 0108 GMT (0908 HKT)



COURTESY OF PER JOHANSSON

A moose got stuck in a tree after eating fermented apples in Saro, Sweden, Wednesday night.

STORY HIGHLIGHTS

- "I saw something really big up in a tree," Per Johansson says, "and it was a moose"

(CNN) -- It was a dark, windy and rainy night when Per Johansson returned from work to his home in Saro just south of Gothenburg, Sweden.

CHALMERS UNIVERSITY OF TECHNOLOGY



Chalmers

students ~11,000
phd students ~1,200
faculty ~1,800



Theoretical Subatomic Physics @ Chalmers

- ▶ From QCD to nuclear interactions
- ▶ Nuclear structure
- ▶ Few-body physics
- ▶ Effective field theory
- ▶ Astroparticle physics, dark matter phenomenology
- ▶ Physics beyond the standard model

Gothenburg, Sweden
pop. ~600,000

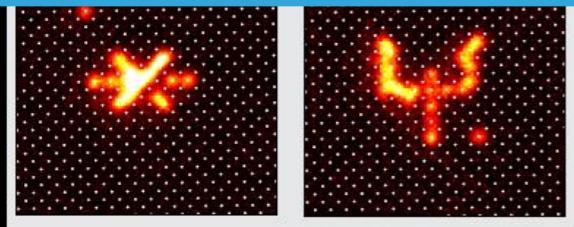
LECTURE PLAN

- ▶ **Lecture 1: Learning from data and predictive power**
 - Theoretical models and predictability
 - Learning from data / Bayesian statistics
- ▶ **Lecture 2: From nucleons to nuclei**
 - Strong QCD
 - Effective theories / Chiral Effective (Field) Theory
 - NN scattering
 - *Ab initio* nuclear theory

PROFOUND INTERSECTIONS

- Can we solve QCD to describe hadronic structures and interactions?
- Can we employ the separation of scales to build successful effective field theories?
- What is the new standard model of particle physics?

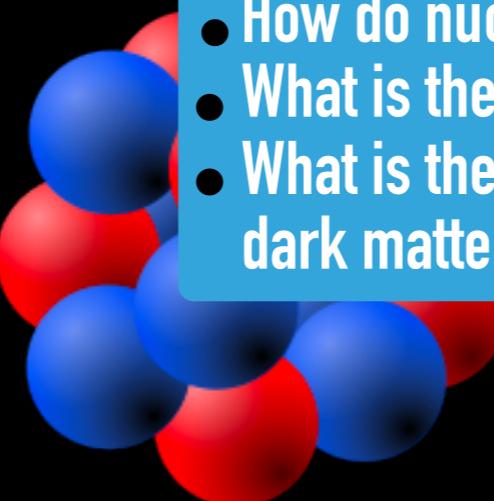
- What controls nuclear saturation?
- What are the properties of nuclei with extreme neutron/proton ratios?
- Can we predict useful cross sections that cannot be measured?
- Can nuclei provide precision tests of fundamental symmetries?



QUANTUM MANY-BODY PHYSICS

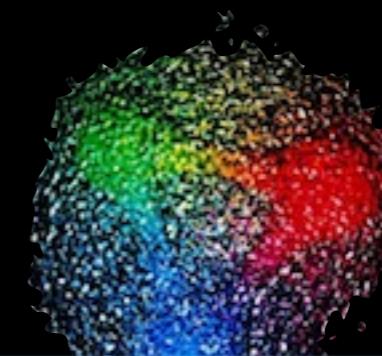
- How do collective phenomena emerge from simple constituents?
- How can complex systems display astonishing simplicities?
- What are unique properties of open quantum systems?

femtophysics



PHYSICS OF NUCLEI

subfemto...



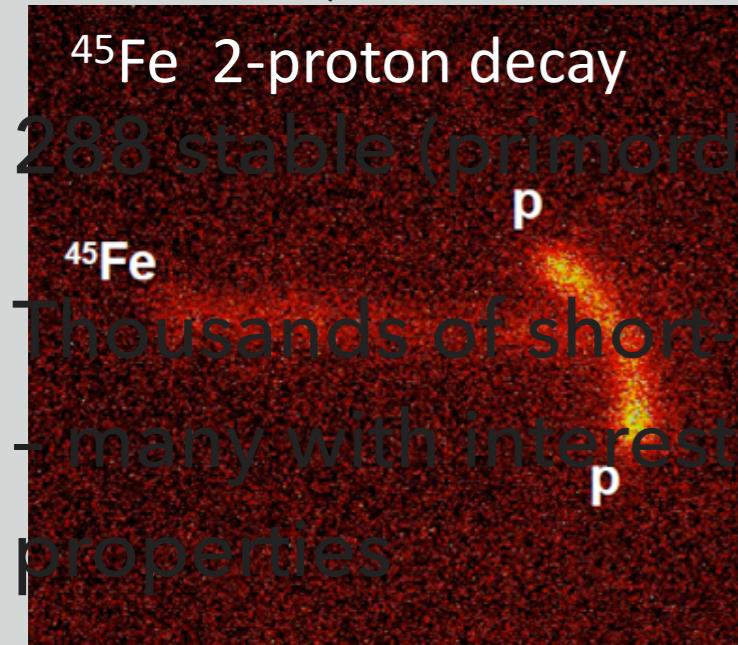
ARTICLES

giga...



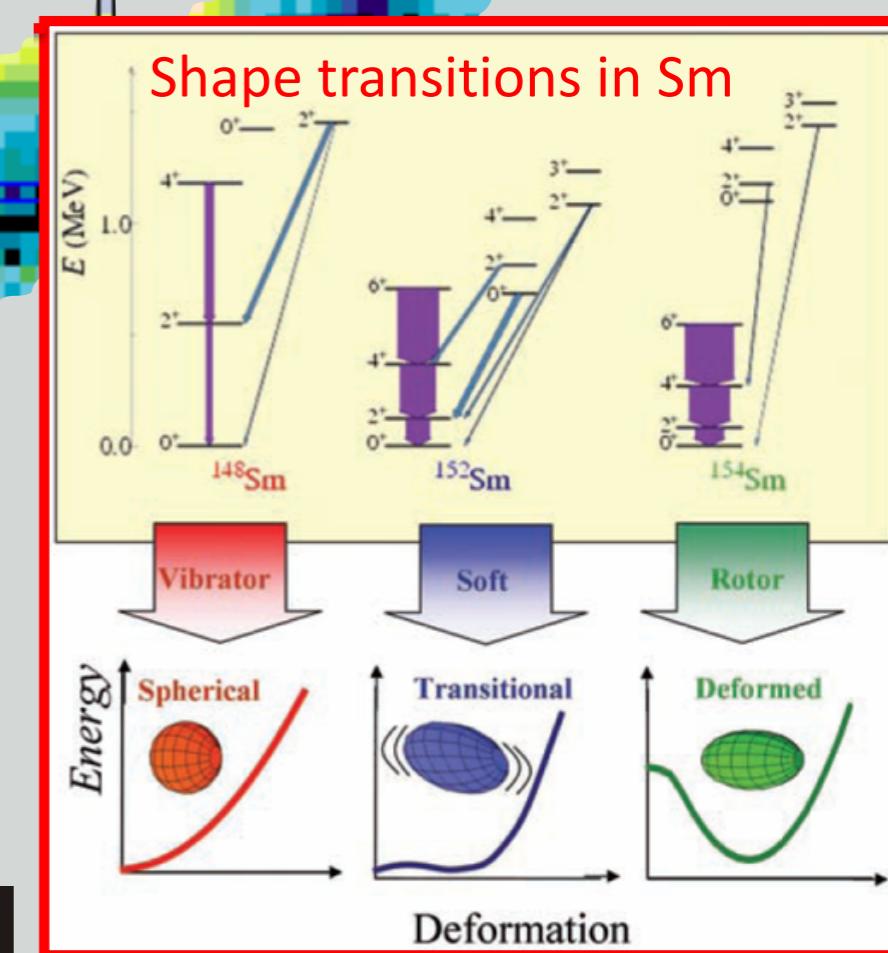
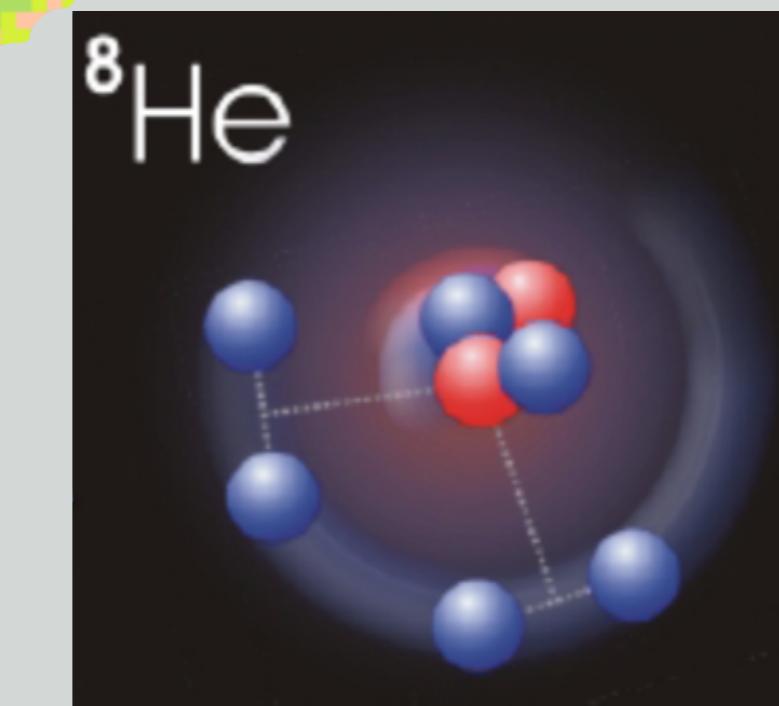
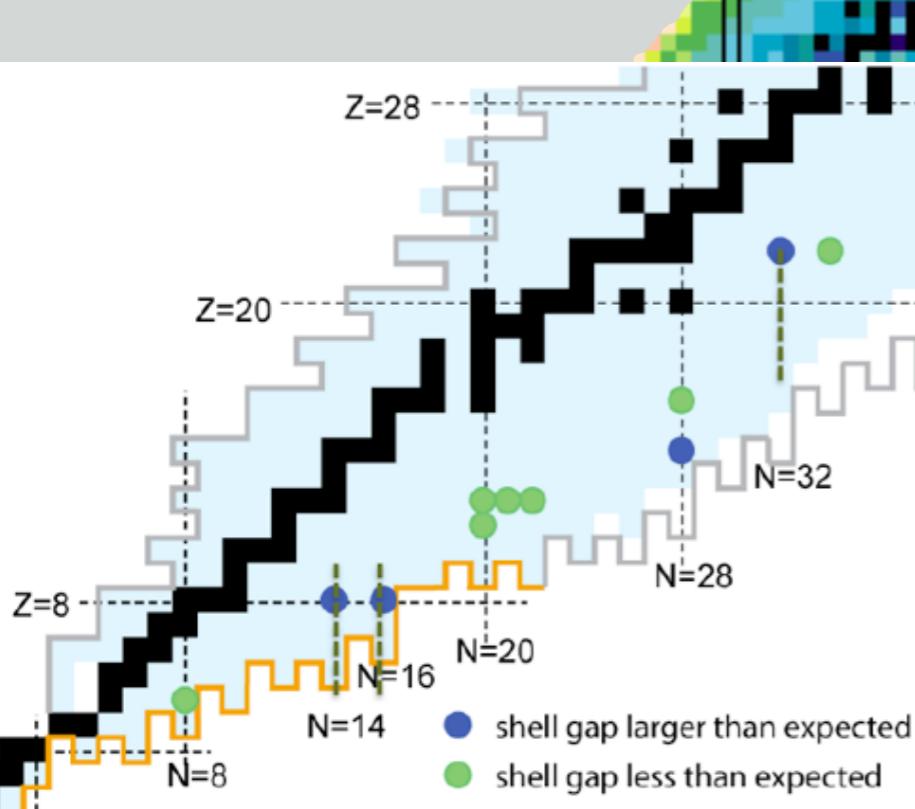
PHYSICS AND COSMOLOGY

- ▶ 118 chemical elements (94 naturally found on Earth)



- ▶ 288 stable (primordial) isotopes

▶ Thousands of short-lived isotopes
– many with interesting properties



What should be the goal for our theoretical understanding of atomic nuclei?

- A. To find a “standard model” of nuclear physics that both explains and predicts all properties of atomic nuclei from fundamental principles.
- B. Same as A, but let us not be greedy. We should aim to reproduce gross properties, but not necessarily fine details.
- C. Developing a number of different nuclear models that explains observed nuclear properties in specific regions of the nuclear chart.
- D. Same as C, but aiming for predictive power.
- E. I don’t really care. I just need a theory curve with my experimental data to satisfy the referee and publish my paper.

The first, the basic approach, is to study the elementary particles, their properties and mutual interaction. Thus one hopes to obtain knowledge of the nuclear forces.

M. Goeppert-Mayer (Nobel Lecture)

[...] If the forces are known, one should, in principle, be able to calculate deductively the properties of individual nuclei. Only after this has been accomplished can one say that one completely understands nuclear structure.

M. Goeppert-Mayer (Nobel Lecture)

[...] The other approach is that of the experimentalist and consists in obtaining by direct experimentation as many data as possible for individual nuclei. One hopes in this way to find regularities and correlations which give a clue to the structure of the nucleus .

M. Goeppert-Mayer (Nobel Lecture)

[...]

The shell model, although proposed by theoreticians, really corresponds to the experimentalist's approach.

M. Goeppert-Mayer (Nobel Lecture)

CLASSIFICATION OF THEORIES

Classification of theories (from Kitaigorodskii):

- ▶ A third rate theory explains after the facts (postdictive);
- ▶ A second rate theory forbids;
- ▶ A first rate theory predicts (predictive).

All three categories are needed!

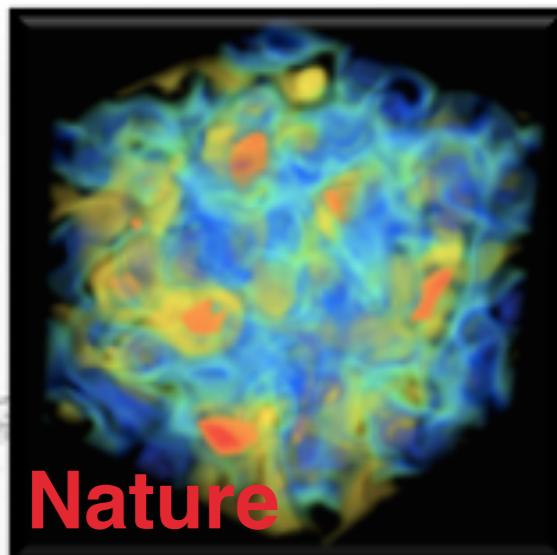
What property is absolutely critical for achieving predictive power?

THEORETICAL ERRORS

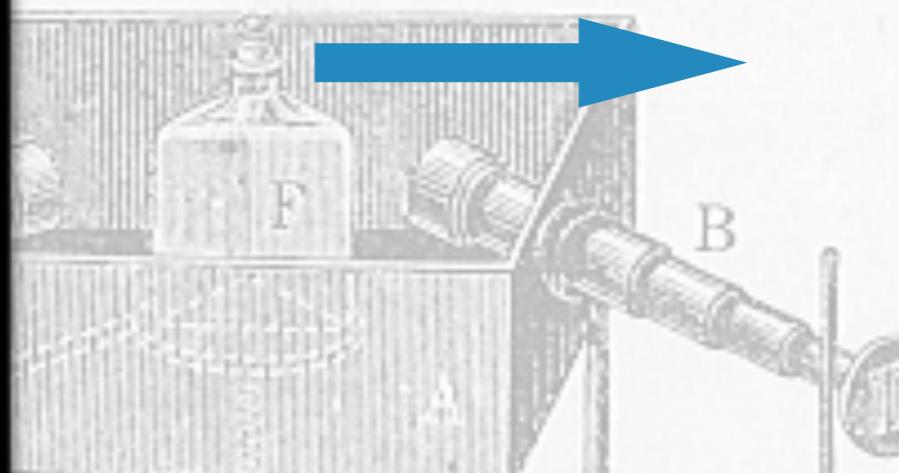
What kinds of theoretical errors
can one encounter?

- ▶ Statistical errors
 - ▶ Model parameter uncertainties
 - ▶ Monte Carlo method statistics
- ▶ Systematic errors
 - ▶ Method uncertainties (convergence)
 - ▶ Model uncertainties (missing physics)
 - ▶ Unknown physics

THE SCIENTIFIC METHOD



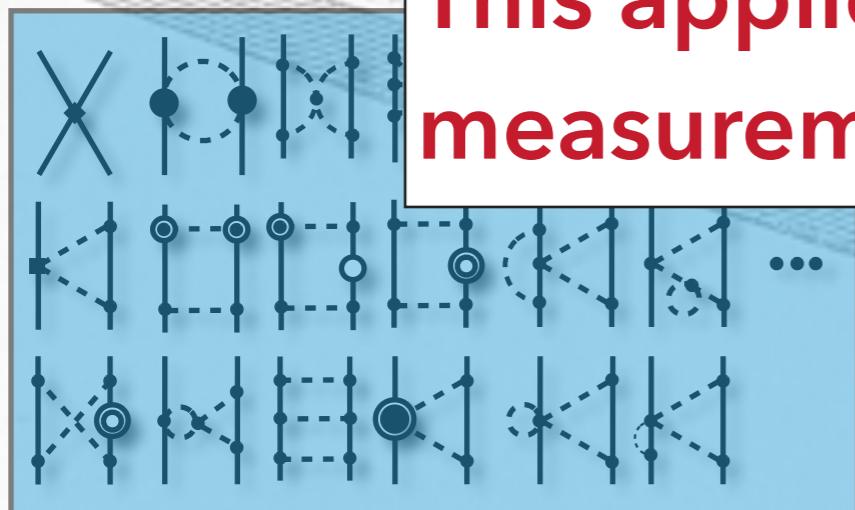
Manifests itself in



Reactions



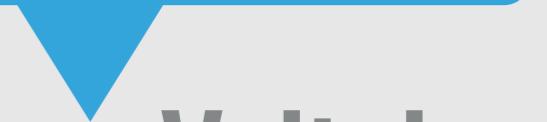
The quantification of uncertainties
is absolutely critical for progress.
This applies BOTH to the
measurement and to the theory.



inspire



**'UNCERTAINTY IS AN
UNCOMFORTABLE POSITION.
BUT CERTAINTY IS AN ABSURD ONE.'**



Voltaire

USEFUL THEORIES

- ▶ It makes no sense to improve a model below model's resolution.
- ▶ Statistical tools can be used to both improve and eliminate a model.

Next: "*Learning from data*"

See: https://github.com/cforssen/Euroschool2018_Forsseen.git