LHC Phenomenology & Physics

17th Intl. Conference on Ion Sources
20 Oct 2017, 11:45 – 12:00

My charge: 15 minutes, only layman language.

My concern: impossible to do justice to the title

My plan: entertain you with a single thought.

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New Title:

How to conclude something from nothing

(one art of particle phenomenology)

$$E = mc^2$$

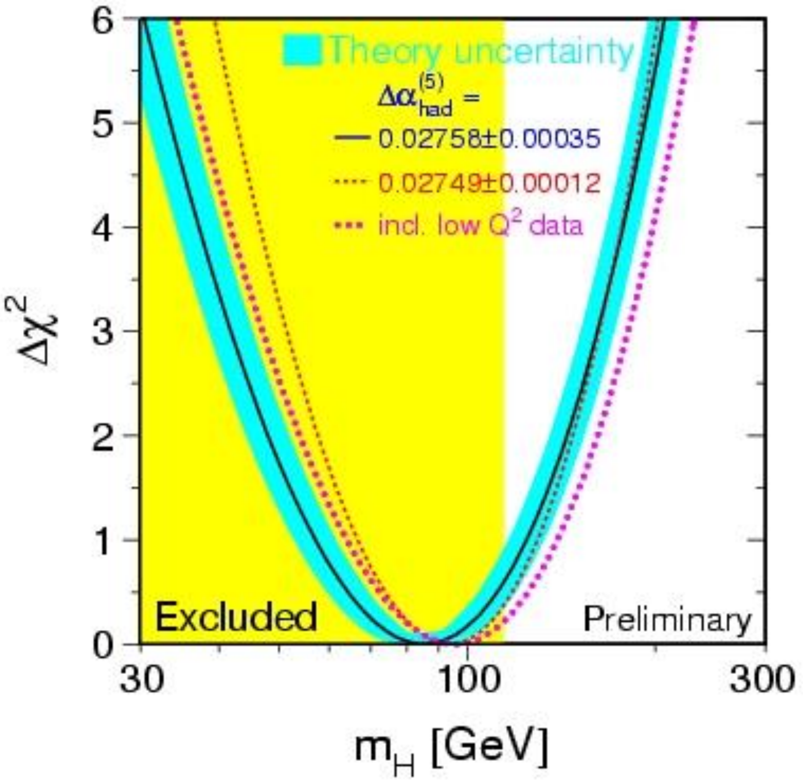
To produce a particle of mass m,
one needs at least the energy E.

The Higgs particle weighs m_H=125 GeV,
which is slightly more than a Xenon nucleus.

The Higgs was searched for at CERN's LEP in 1990s.
It was searched for at Tevatron in the USA till ~ 2012.
It was found at CERN's LHC in 2012.

The center of mass energy at LEPs e^+e^- collider would have been sufficient to produce a detectable Higgs, had the Higgs mass been $m_H < 114$ GeV.

Status around year 2000:



So "**nothing**" was observed at LEP, but "**something**" was concluded:

The Higgs mass must lie "close to" 114 GeV.

How is such a conclusion possible?

Assume that your kid has lost a pair of socks

i) either in the bathroom (LEP)
ii) or in the kid's bedroom (LHC)
iii) or on a week-long school trip (wide region)

Assume that you have searched carefully the bathroom and that you can state with more than 5 sigma confidence that there are no socks in the bathroom.

How can you possibly conclude from this information alone that the socks must be in the kid's bedroom? You can't!

So what makes the search for an elementary particle like the Higgs *conceptually* different from a search for socks?

How can we conclude in which mass region an unknown particle must be before ever having detected it?

Answer:
An unknown particle can reveal its existence via quantum fluctuations, even in situations in which it cannot be produced.

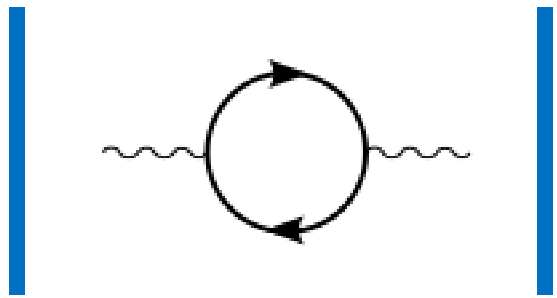
In the following slides, I will try to illustrate to you this answer in a conceptually simple (but a bit crazy and highly impractical) gedankenexperiment.

Consider an experimenter who is only allowed to study empty space (= vacuum). Assume that this experimenter has not even the energy to produce an electron or a positron, and that he does not know yet about their existence. Can this experimenter gather information about the existence of electrons?

The classical answer is: no, since there are no electrons in the vacuum.

The quantum answer is: yes, since the vacuum between charges is not empty but filled with short-lived virtual particle-antiparticle pairs (e^+ e^- pairs, etc)

A vacuum fluctuation of a virtual $e^+ e^-$ pair of energy $2\,m_e$ will live for a short time $\sim h/m_e$.
In an electric field E between condensator plates, the virtual $e^+ e^-$ pairs orient themselves along the field lines



The quantum vacuum behaves therefore like a medium.
It has a finite vacuum polarization

$$\vec{P} = \text{const.} \frac{1}{m_e^4} E^2 \, \vec{E}$$

const. is calculable

The lighter the electron mass, the easier it is to polarize the vacuum. Even without detecting an electron, the measurement of this experimenter is sensitive to the electron mass (at least in principle).

The above was an impractical gedankenexperiment. In practice, its sensitivity is too low, the field strength needed is too high, and electrons are known anyway.

However, the *concept* illustrated here is powerful in particle phenomenology: by calculating quantum corrections to measurable quantities, one gets sensitive to particles that may be too massive to be produced directly.

Such calculations are done by theorists.

I conclude: theorist may not be able to find their socks, but they can help you to look into regions of parameter space that cannot be covered in direct experimental searches.

END