

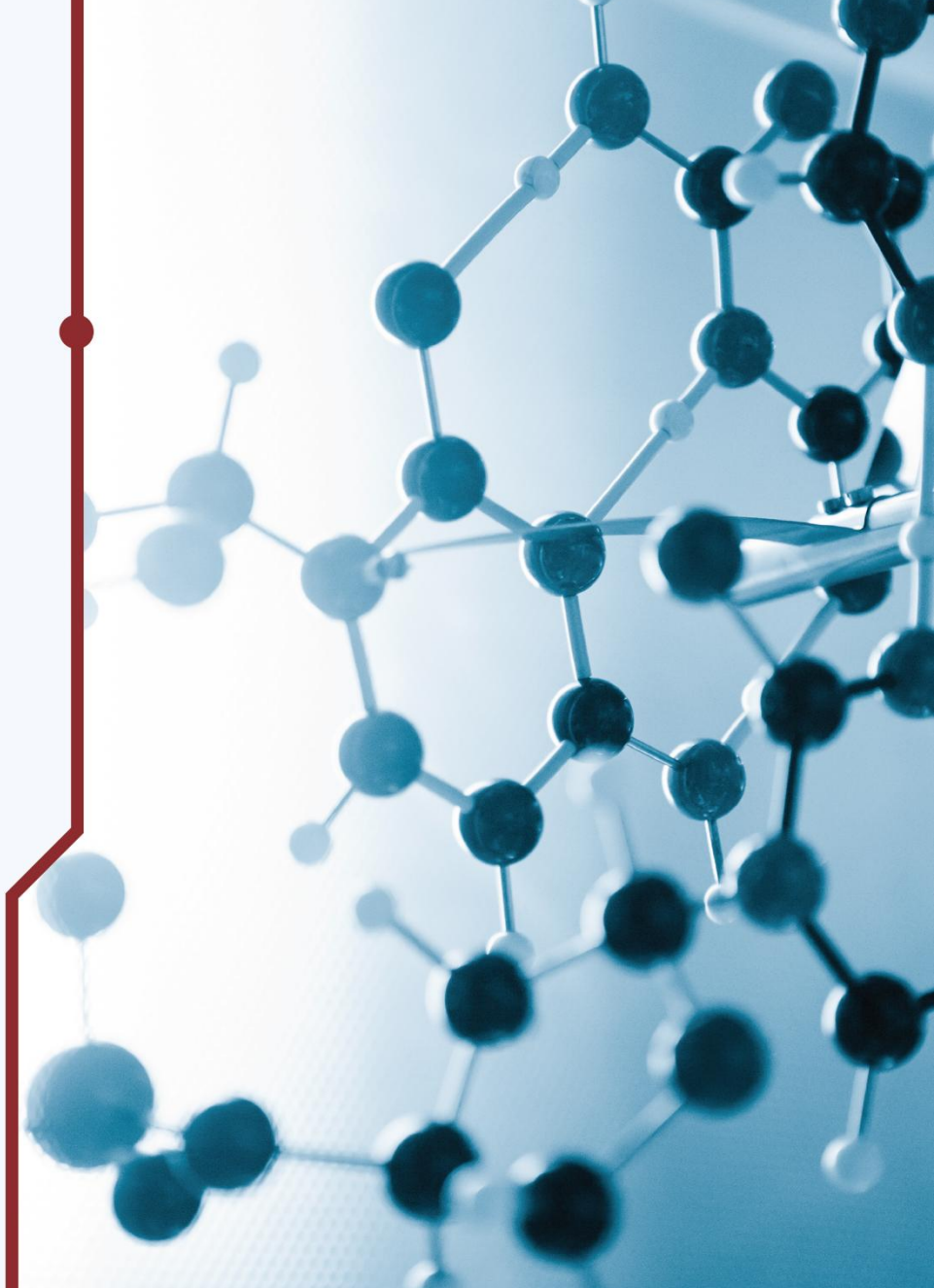


REINFORCE

REsearch INfrastructures FOR Citizens in Europe

WP5 webinar: **Higgs Studies and** **Long-Lived particles**

Dimitris Fassouliotis
NKUA

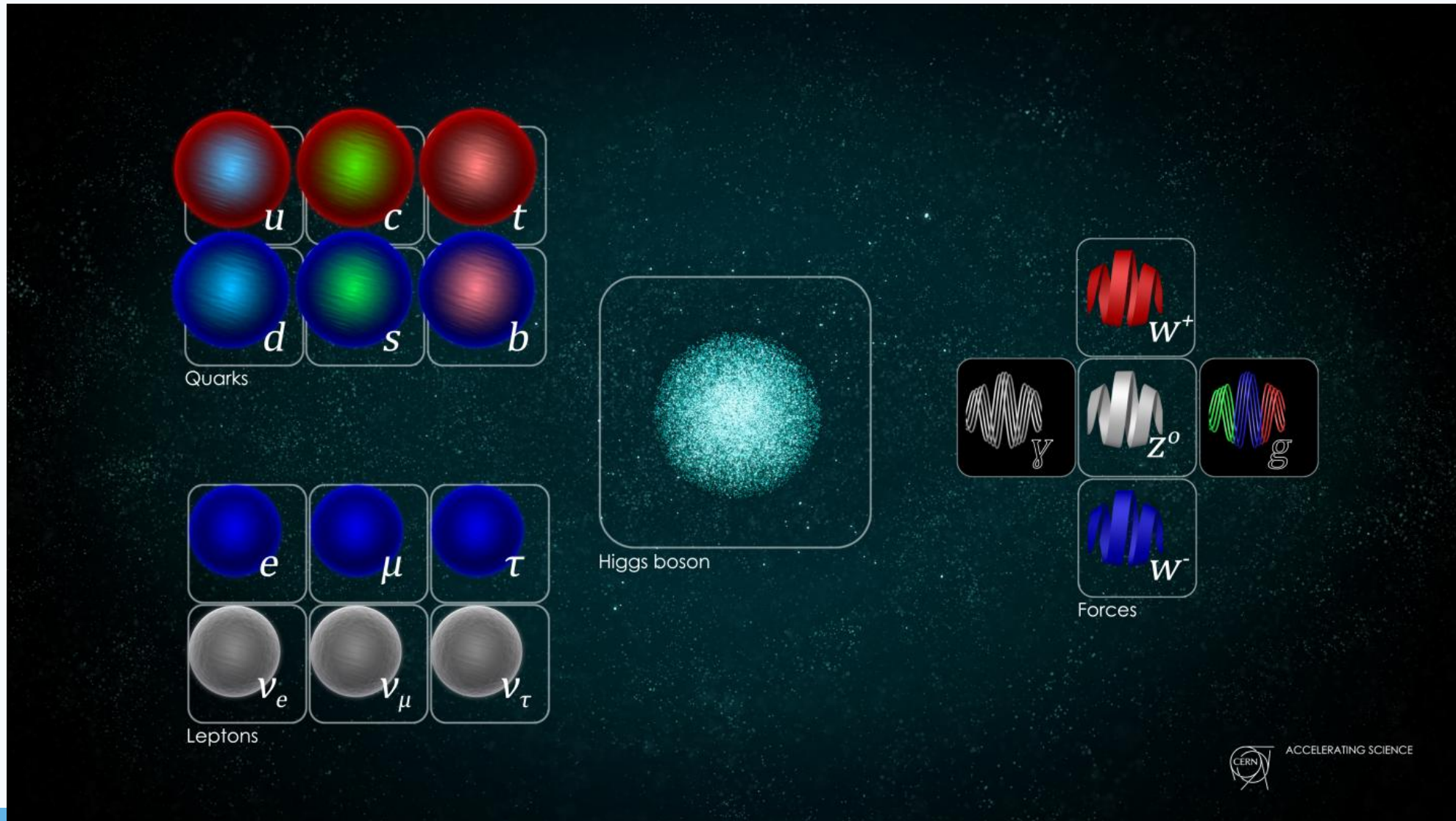




Standard Model of Elementary Particles

Particles of matter - fermions

Carriers of forces - bosons

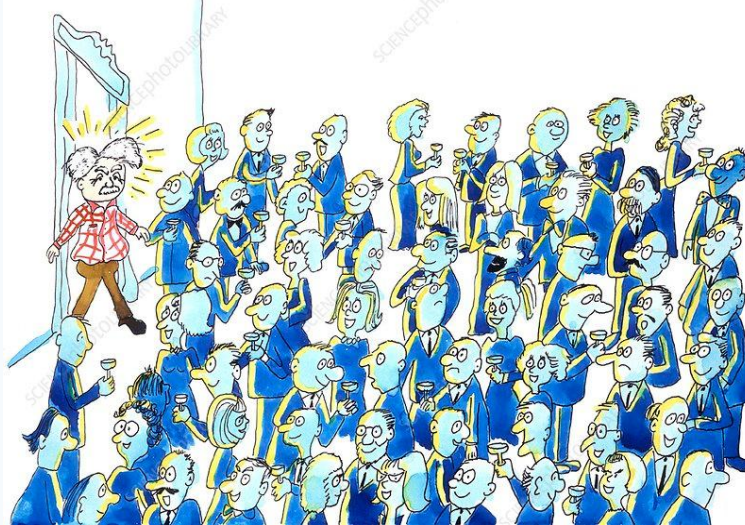


Higgs boson Search

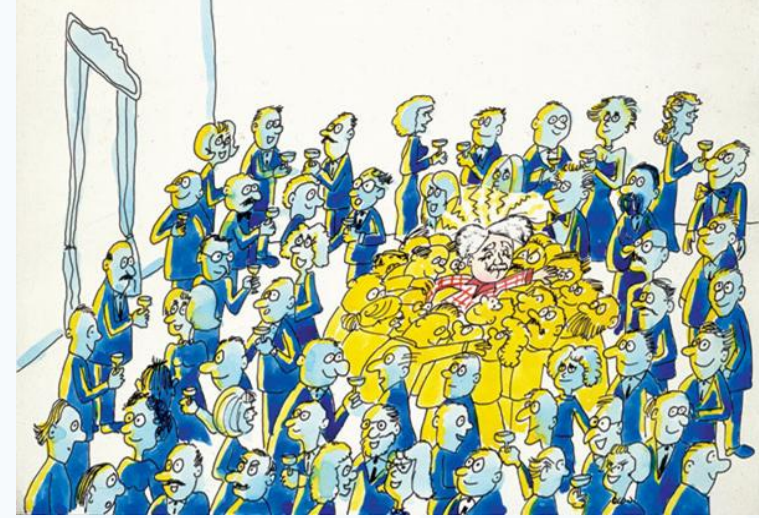
The Higgs vacuum (distributed in the universe)



Imagine a famous scientist enters the party



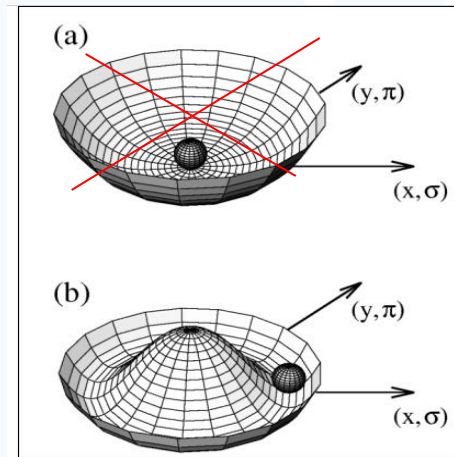
Particles coupled with Higgs gain their masses



A fluctuation in Higgs vacuum



Condensation of Higgs Boson

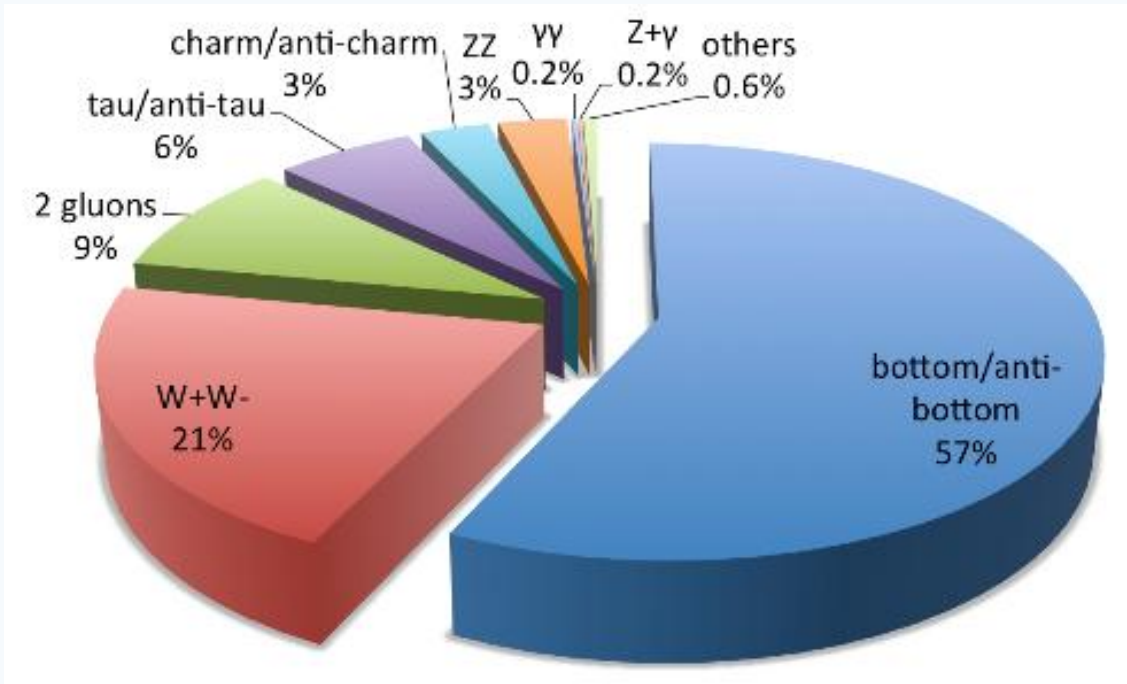
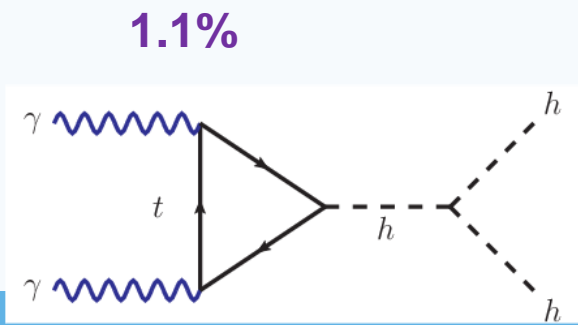
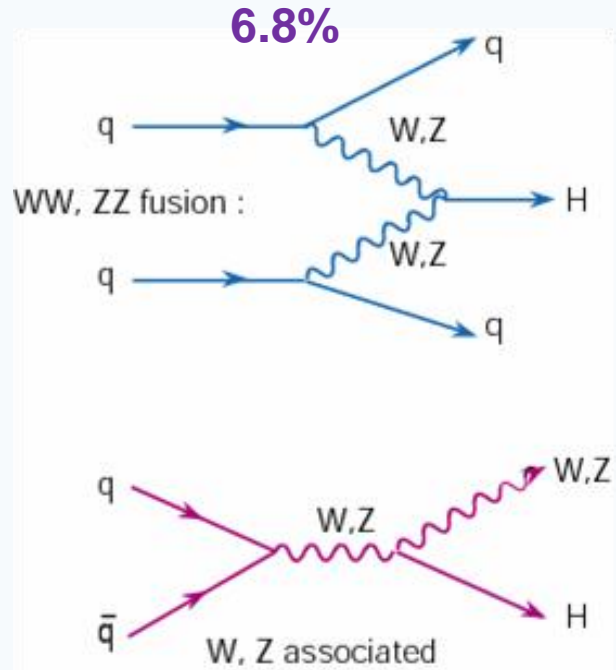
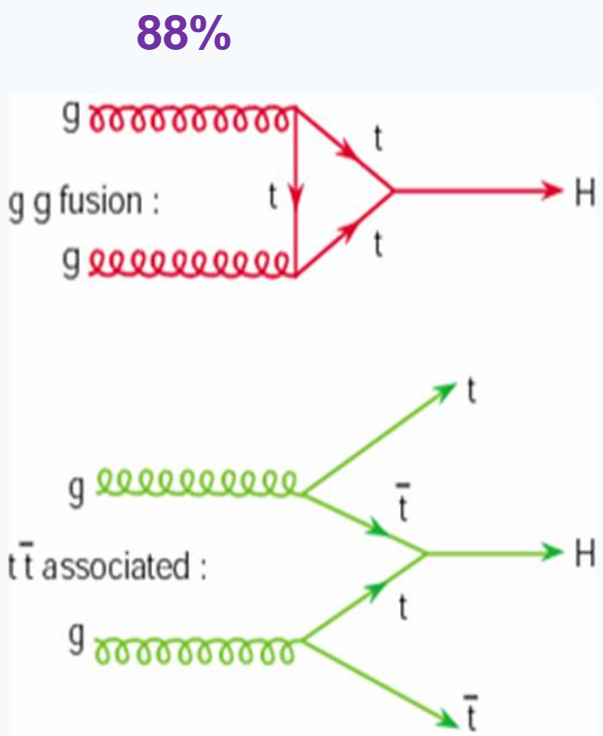


Spontaneous
electroweak
symmetry breaking

Higgs boson Search

Main Higgs boson Production Mechanisms at LHC

Decays of the Standard Model Higgs boson

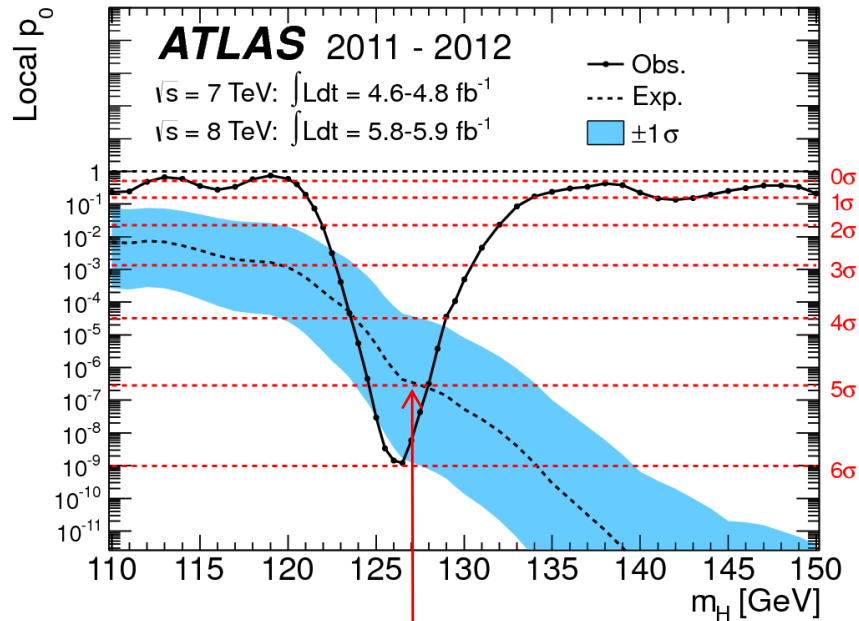


Unfortunately, the higher rate decays have enormous backgrounds and / or not fully reconstructed final state. So two of the most promising channels for the study of the Higgs boson properties:

- $H \rightarrow \gamma\gamma$ 2%
- $H \rightarrow ZZ(*) \rightarrow l^+ l^- l^+ l^-$ 0.14%



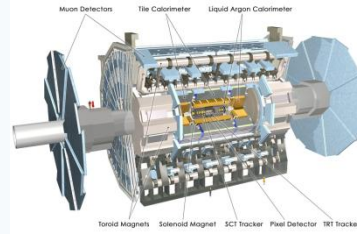
Higgs boson Search



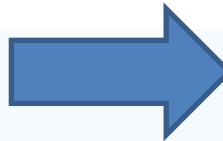
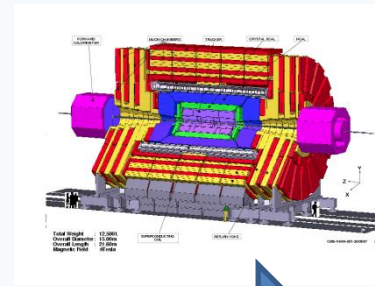
< 1/3,000,000 probability of background

After discovery → Measure properties:

- Mass **125.25 ± 0.17 GeV**
- Spin **0**
- **Couplings with other particles**
- Width **3.2 +2.8 -2.2 MeV**
- Differential distributions



ATLAS - CMS



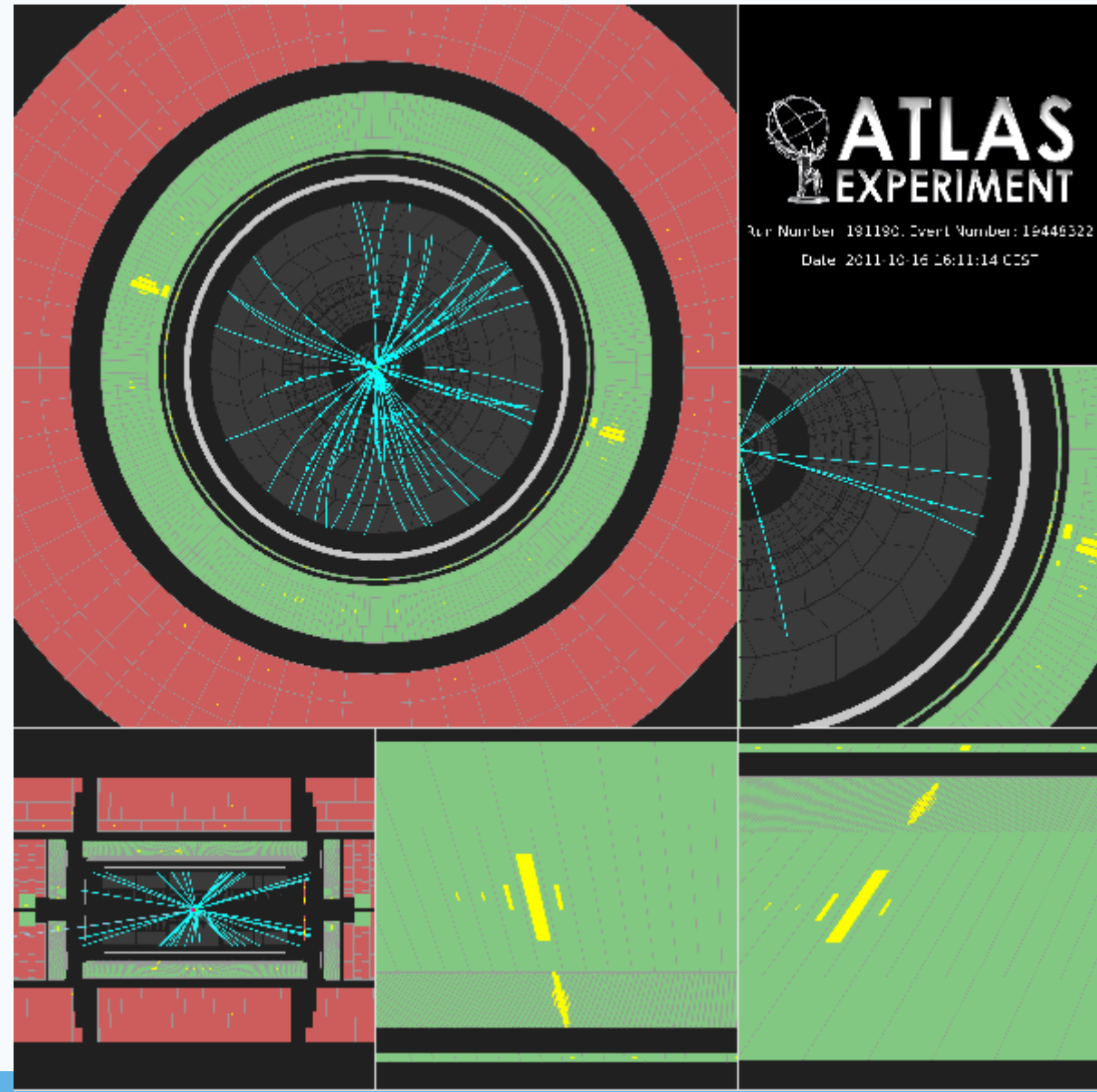
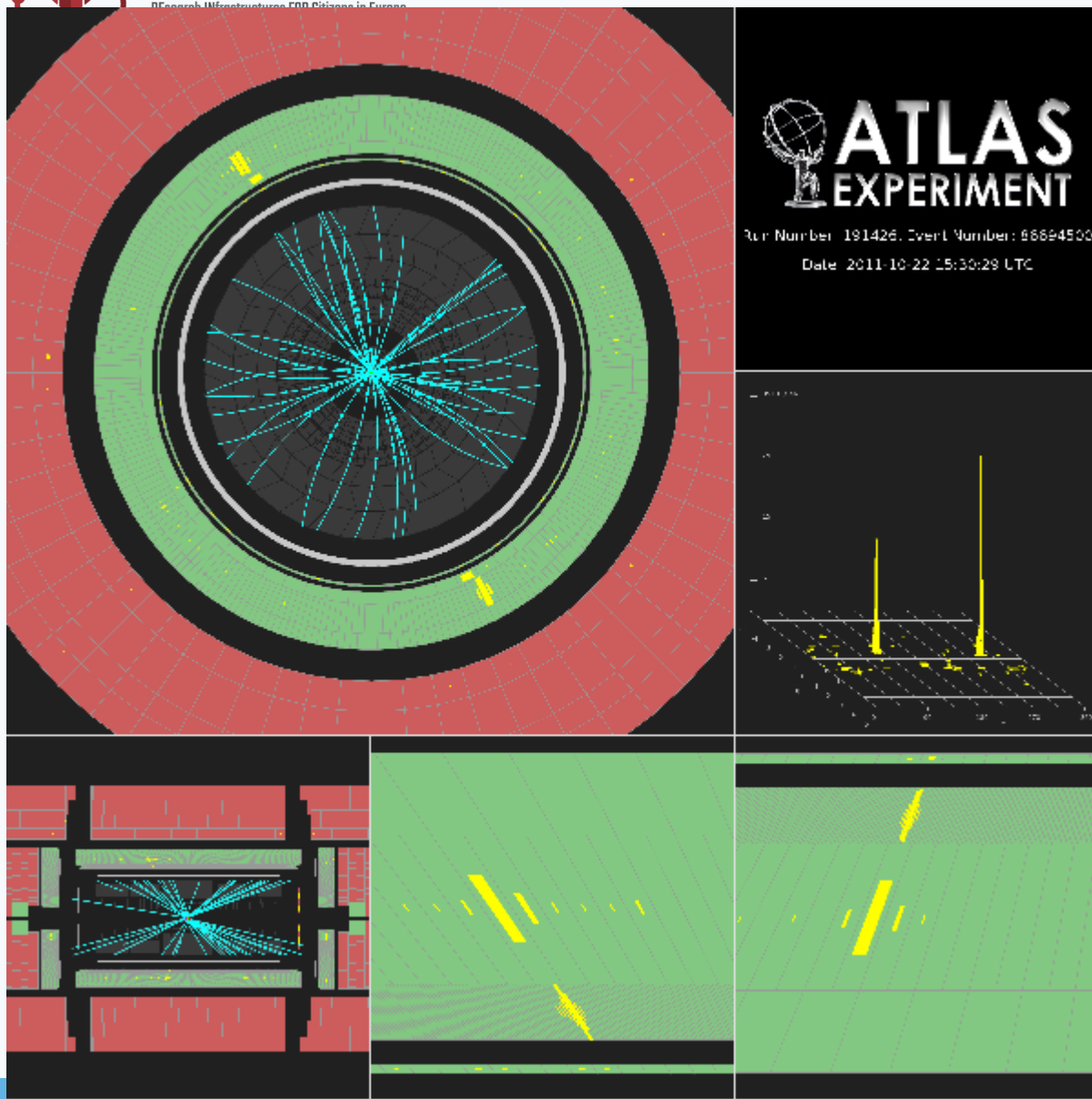
The Nobel Prize in Physics 2013



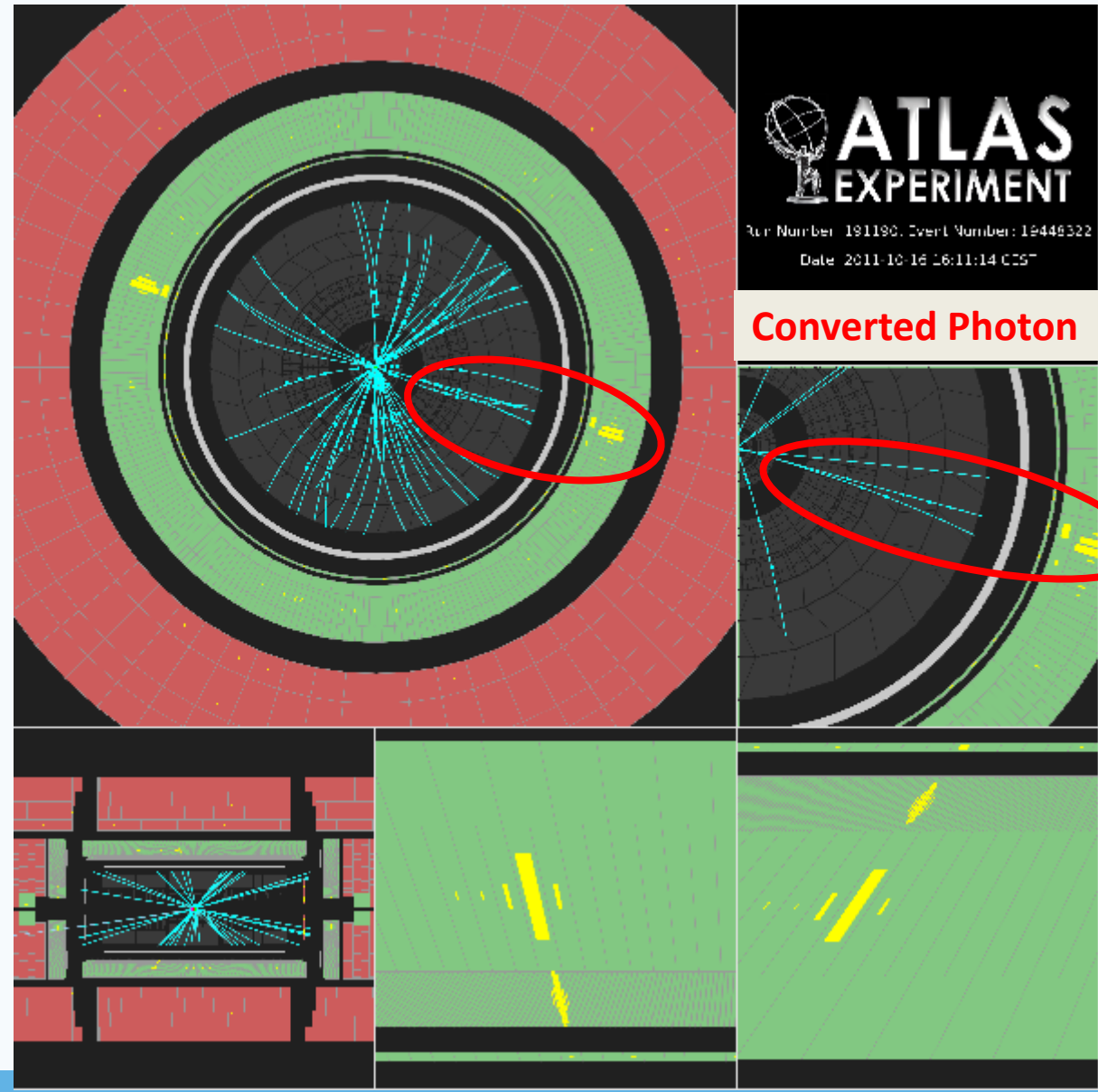
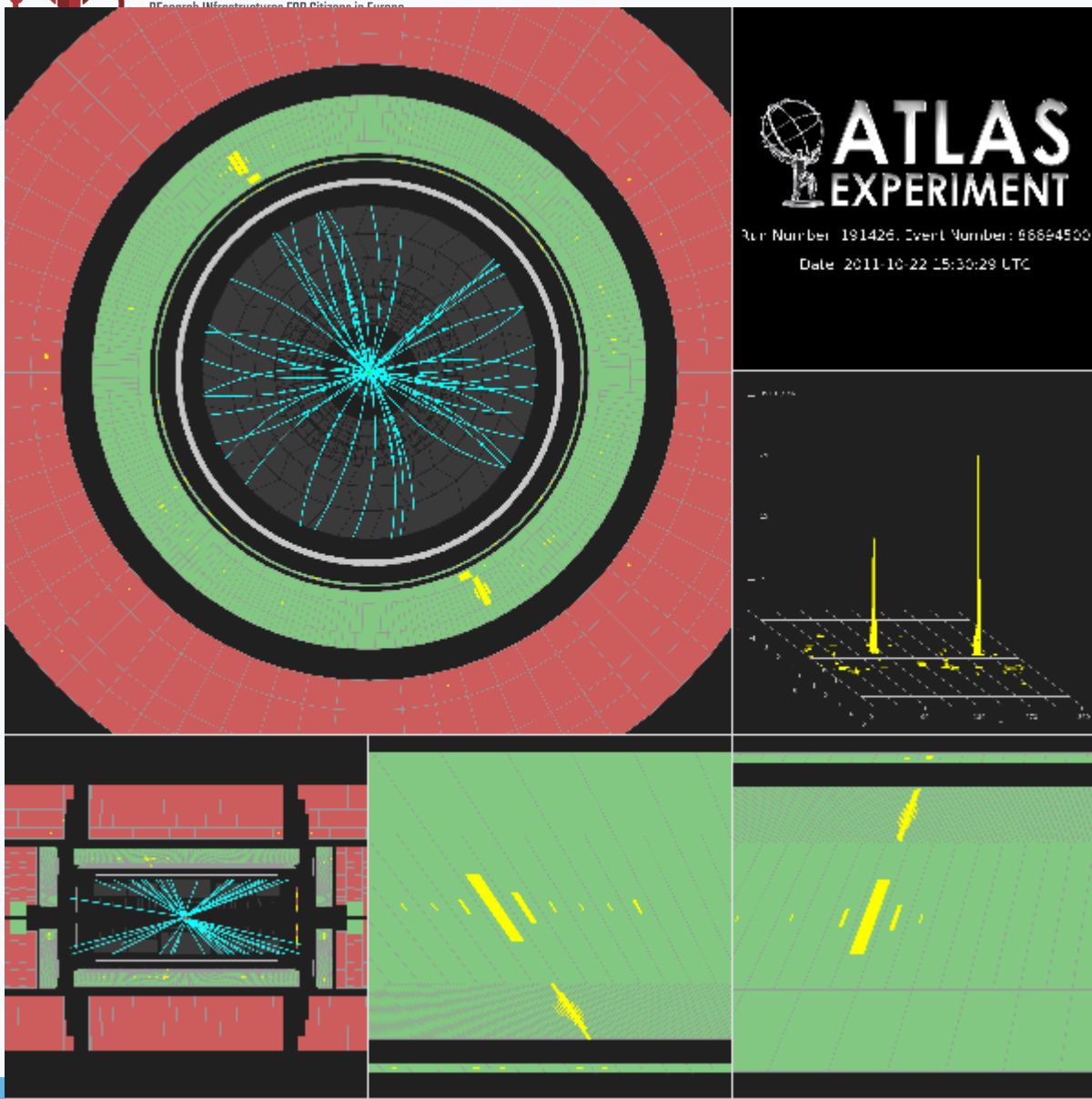
François Englert

Peter W. Higgs

Higgs boson Study $H \rightarrow \gamma\gamma$



Higgs boson Study $H \rightarrow \gamma\gamma$



➤ **Converted photons**

- e^+e^- tracks very close to each other
- e^+e^- originate from instrumented part of inner detector
- Non trivial identification → Automated machine learning algorithms

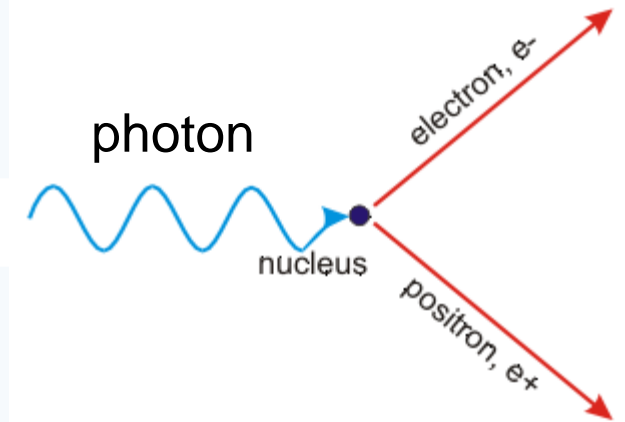
➤ **Challenge 1 “Can human brain compete (or even overpass) automatic algorithms?”**

❖ Proportion of converted photons in $H \rightarrow \gamma\gamma$ decays

➤ **Challenge 2 “Can human brain identify any of the very rare Higgs boson production mechanisms?”**

- $qqH \rightarrow \gamma\gamma$ + activity in forward region
- $VH \rightarrow \gamma\gamma$ + additional lepton(s) (e or μ)
- $bbH \rightarrow \gamma\gamma$ + a lot of activity in central region
- $ttH \rightarrow \gamma\gamma$ + a lot of activity in central region + additional lepton(s)

❖ Identify rare final states and rate them accordingly



Why is there the need for theories Beyond the Standard Model (BSM) ?

Several open questions:

- **Dark matter**
- «Empty» space is unstable
- Flavor & origin of matter
- Masses of neutrinos
- Hierarchy problem
- Inflation
- Quantum gravity
- Dark energy
- . . .



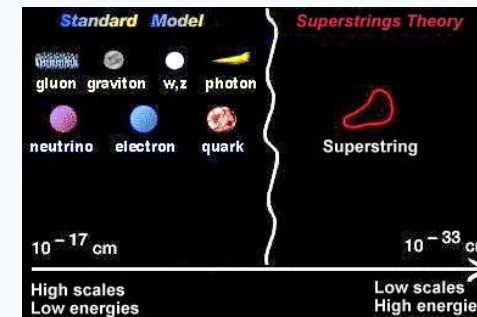
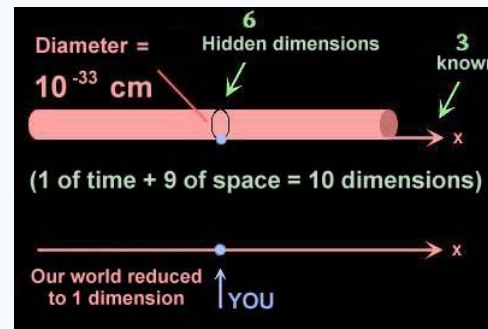
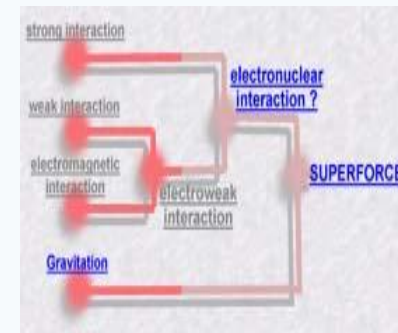
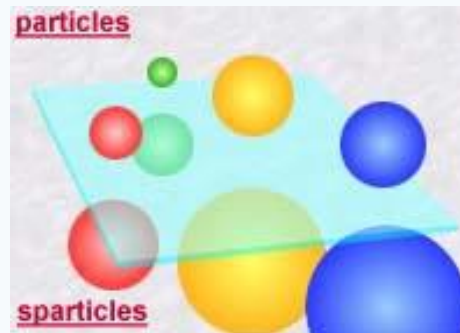
Why is there the need for theories Beyond the Standard Model (BSM) ?

Several open questions:

- Dark matter
- «Empty» space is unstable
- Flavor & origin of matter
- Masses of neutrinos
- Hierarchy problem
- Inflation
- Quantum gravity
- Dark energy
- . . .

Proposals:

- Supersymmetry
- Grand Unified Theories
- Extra dimensions
- String Theories
- . . .



Why is there the need for theories Beyond the Standard Model (BSM) ?

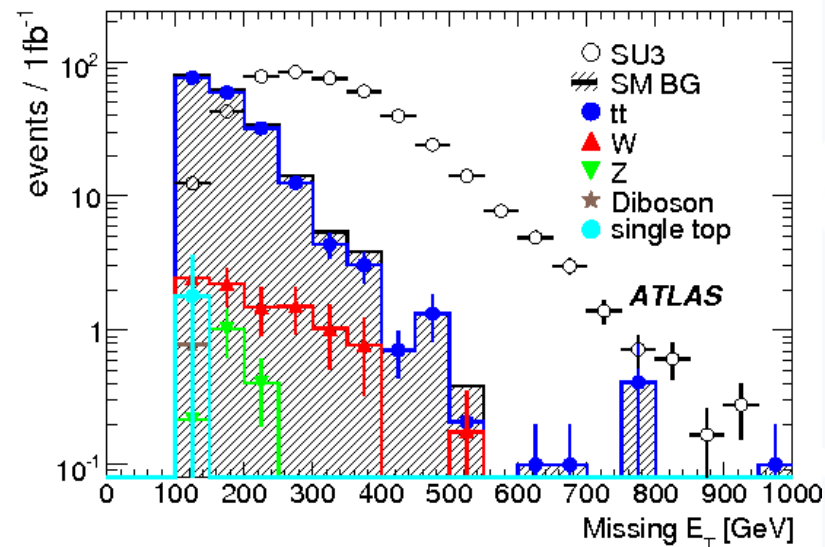
Several open questions:

- Dark matter
- «Empty» space is unstable
- Flavor & origin of matter
- Masses of neutrinos
- Hierarchy problem
- Inflation
- Quantum gravity
- Dark energy
- . . .

Proposals:

- Supersymmetry
- Grand Unified Theories
- Extra dimensions
- String Theories
- . . .

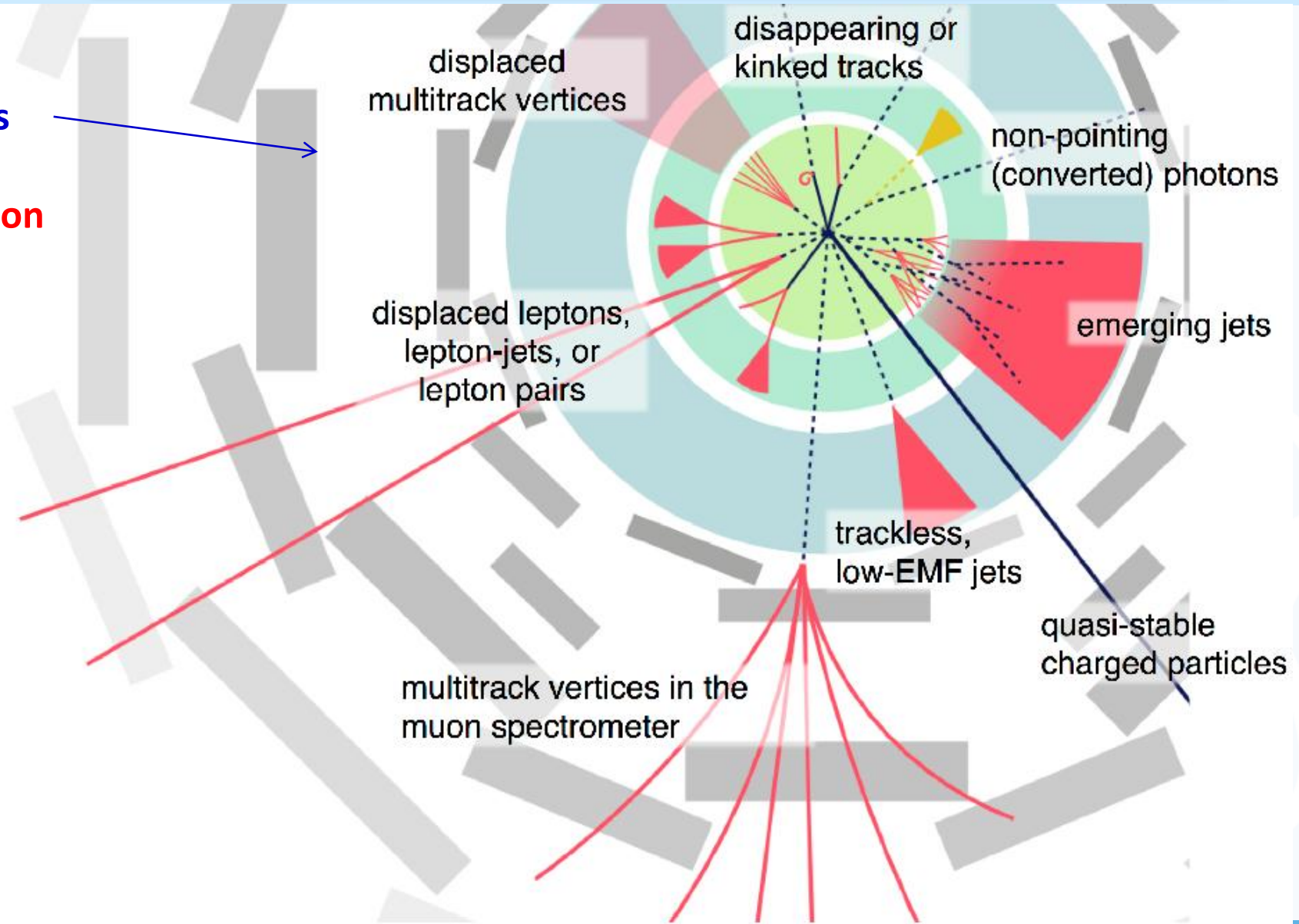
However, **no signs of new physics** in “standard” search scenarios at LHC



Search for Long Lived Particles at LHC

Large variety of possible signatures

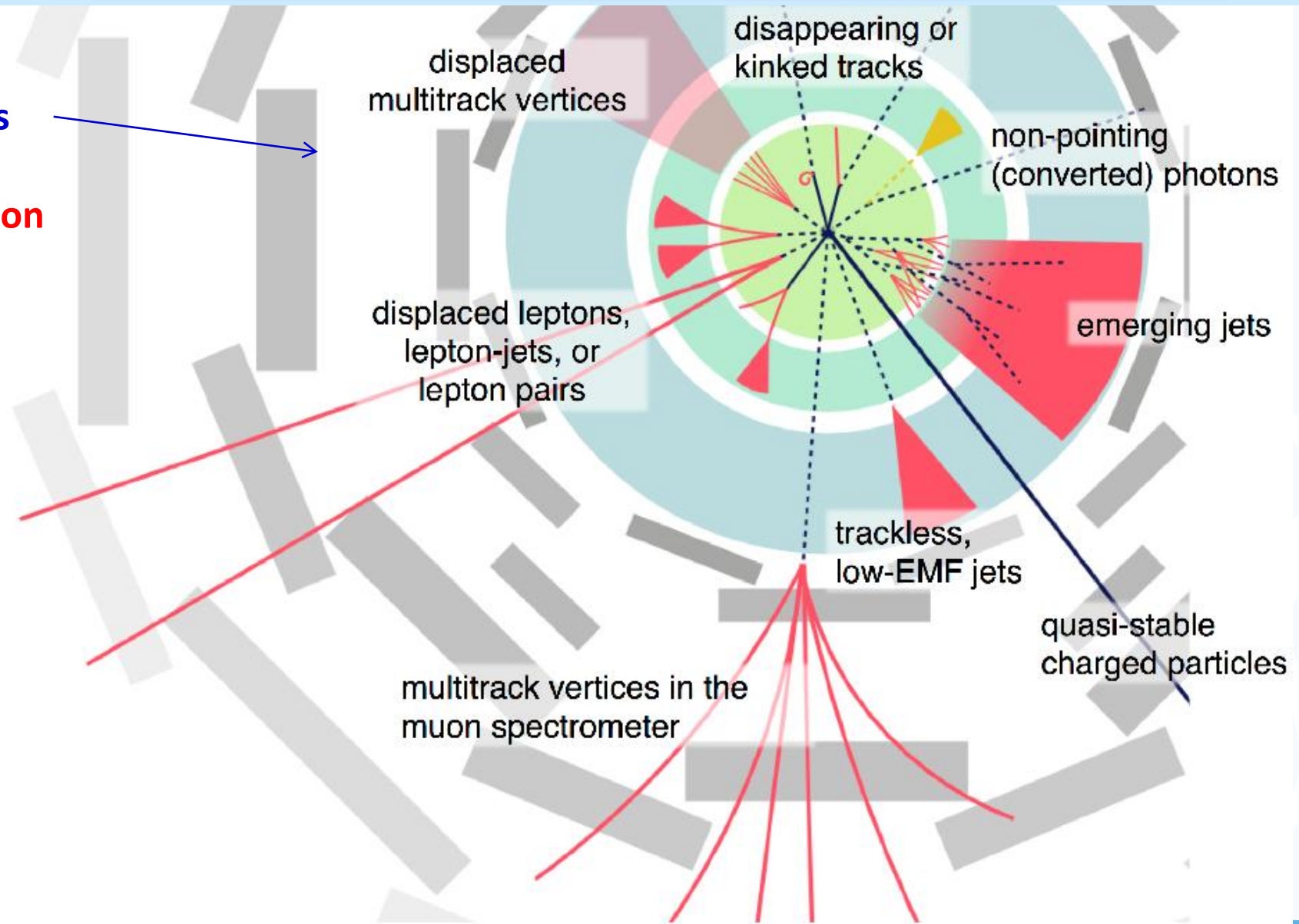
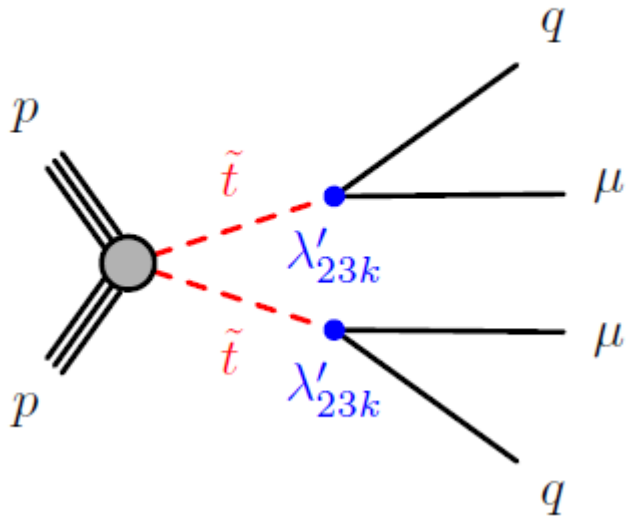
Need of non-standard reconstruction and identification techniques



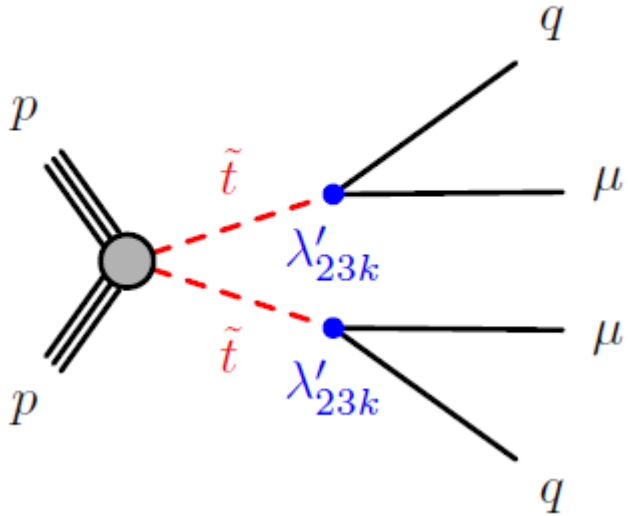
Large variety of possible signatures

Need of non-standard reconstruction and identification techniques

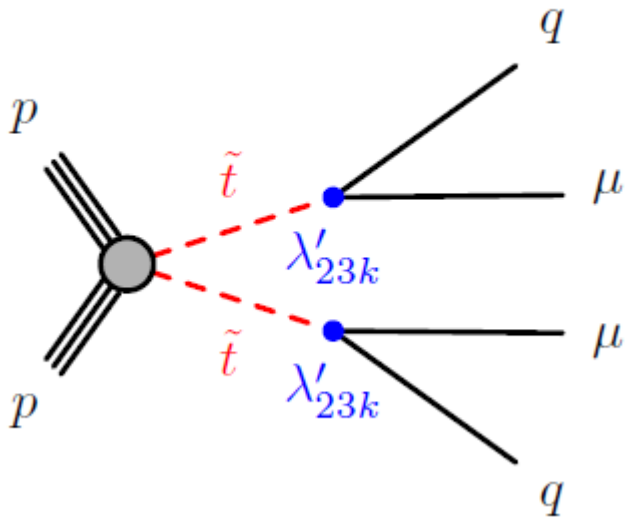
Concentrate on displaced muons + jets



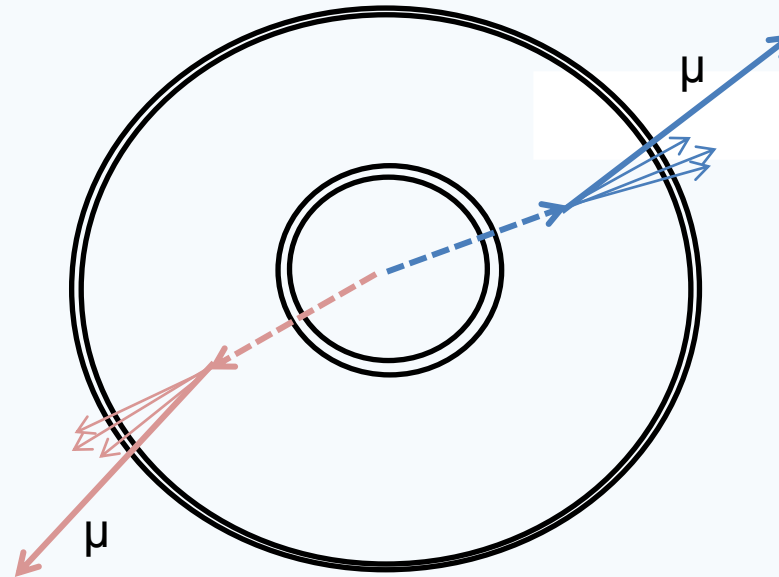
Concentrate on displaced
muons + jets



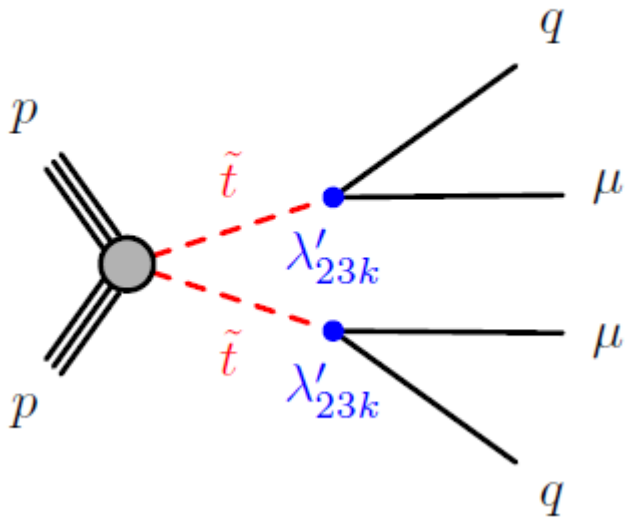
Concentrate on displaced
muons + jets



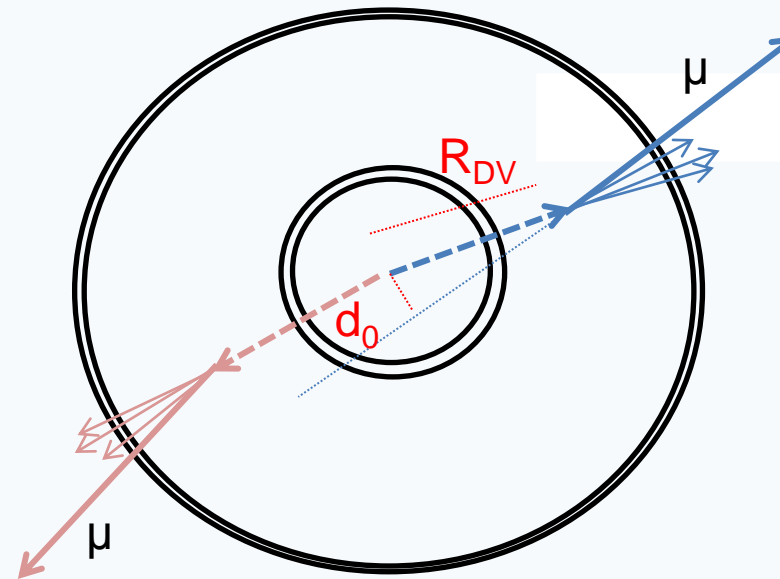
This scenario signature



Concentrate on displaced
muons + jets



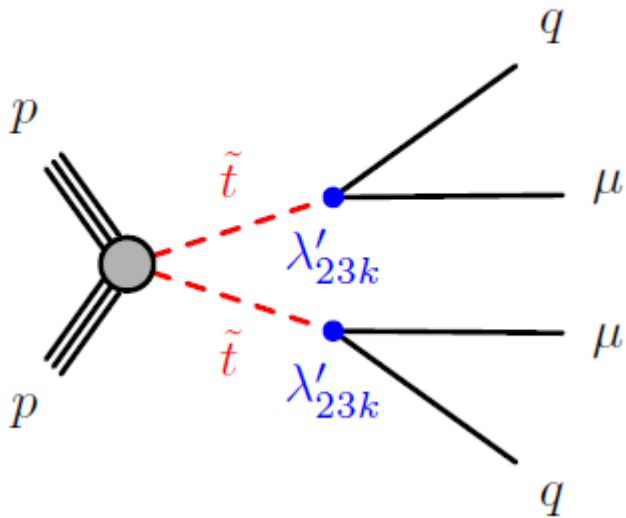
This scenario signature



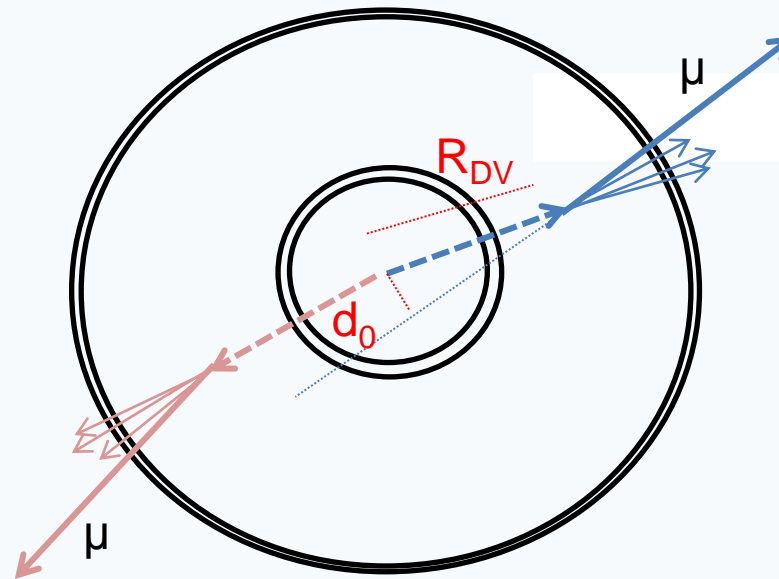
Important Quantities

- Distance of the displaced vertex R_{DV} → Not coincide with detectors radius
- Mass of the particles in the DV → > 10 GeV (The higher the more interesting)
- Muon momentum → > 45 GeV (The higher the more interesting)
- Impact parameter of muon d_0 → The higher the more interesting
- Existence of 2nd displaced muon

Concentrate on displaced
muons + jets



This scenario signature



Challenge:

Can human brain identify cases that escaped unnoticed from automated algorithms and rate them accordingly?

Important Quantities

- Distance of the displaced vertex R_{DV} → Not coincide with detectors radius
- Mass of the particles in the DV → > 10 GeV (The higher the more interesting)
- Muon momentum → > 45 GeV (The higher the more interesting)
- Impact parameter of muon d_0 → The higher the more interesting
- Existence of 2nd displaced muon