

# Some activities of the « high-energy » component of the theory group

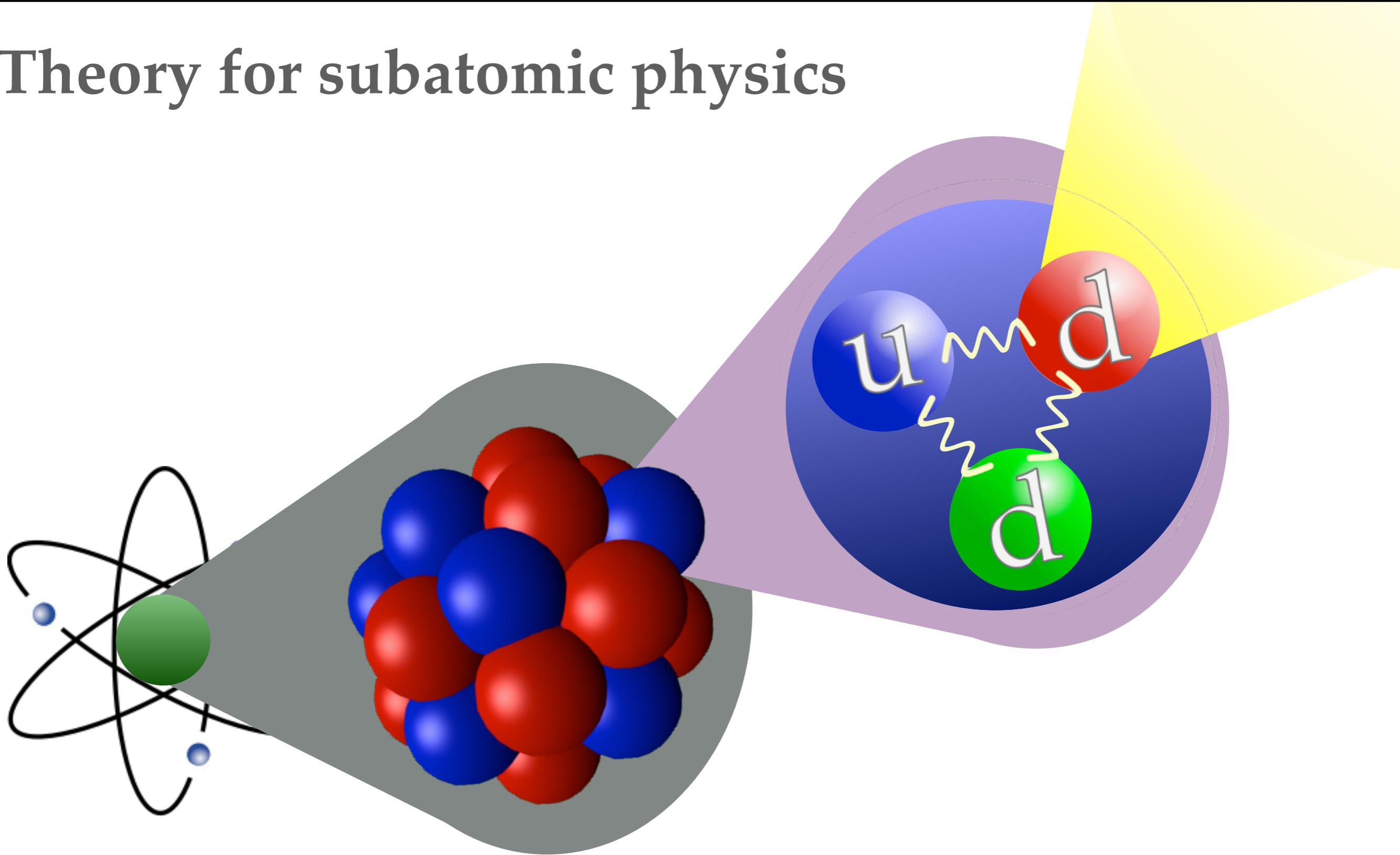
Quentin Bonnefoy  
*U. of Strasbourg & IPHC*

Journée scientifique  
et technique de l'IPHC  
14/10/2024

# The theory group at IPHC

# The theory group at IPHC

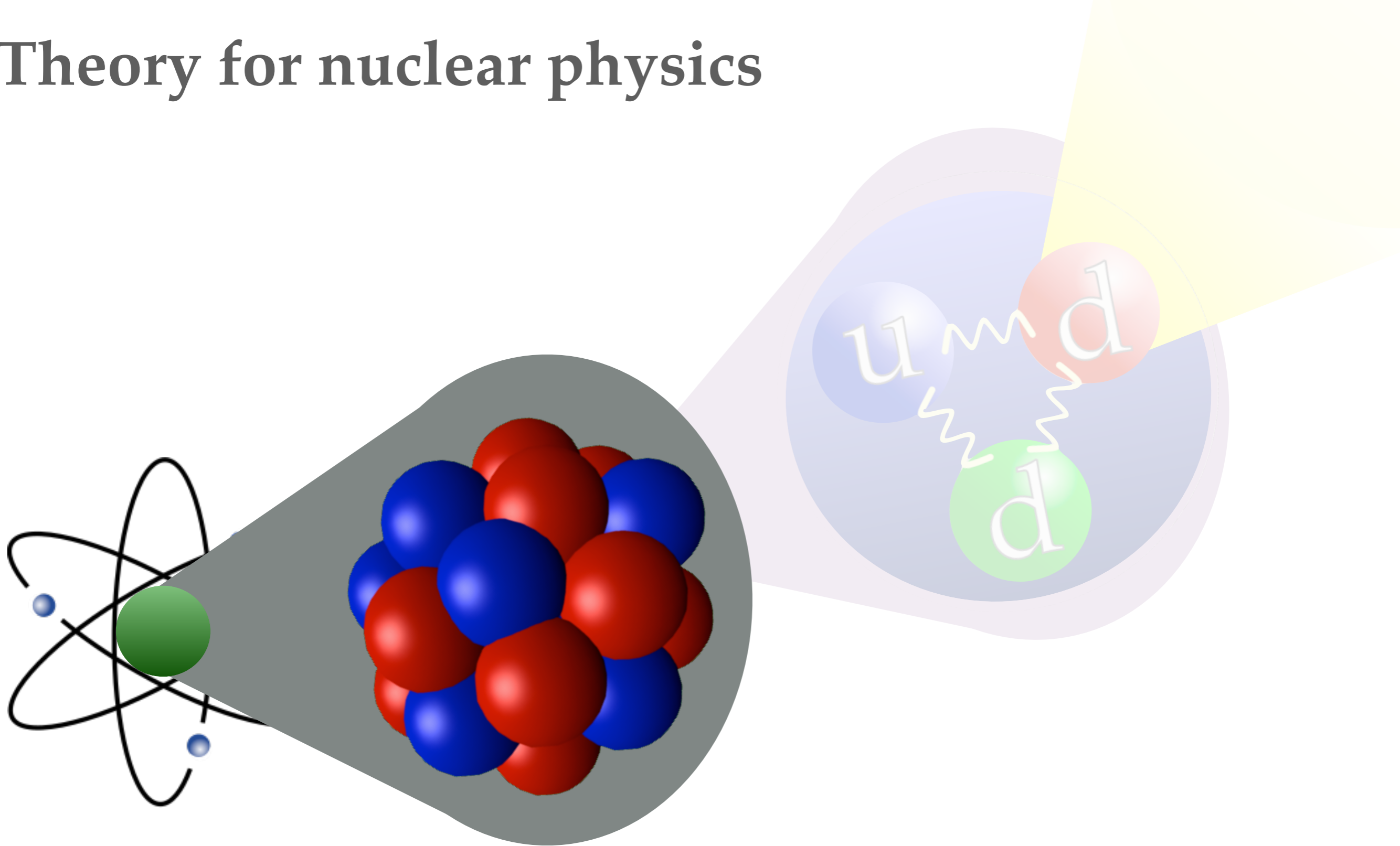
## Theory for subatomic physics



*[I recycled many visual elements from Wikipedia in this presentation]*

# The theory group at IPHC

## Theory for nuclear physics

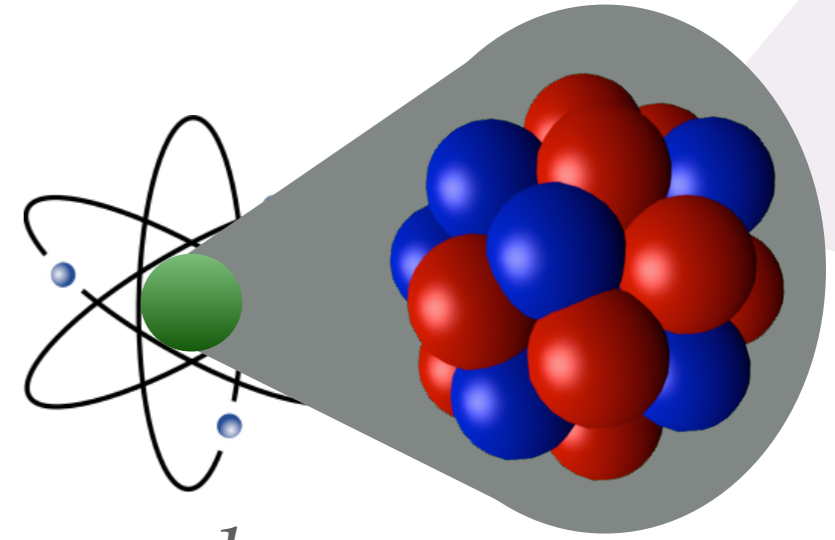


# The theory group at IPHC

## Theory for nuclear physics

Main expertise of the theory group

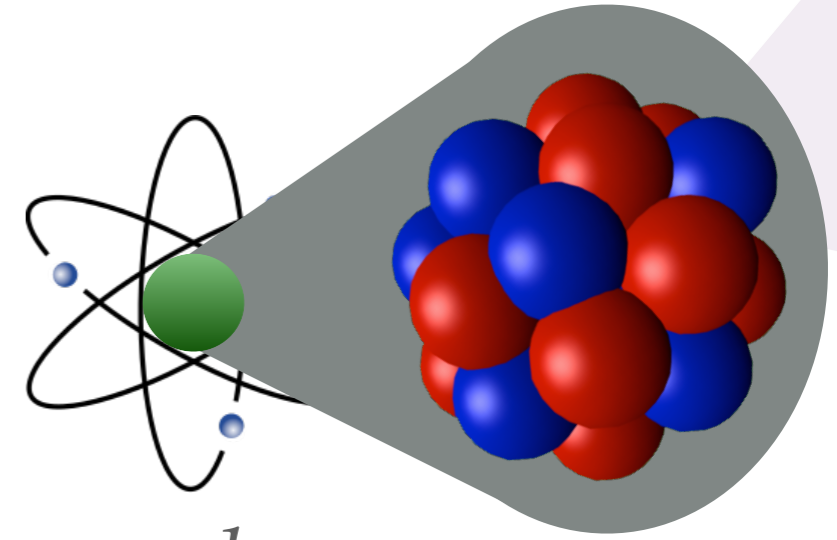
*J. Bartel, D. D. Dao, J. Dudek, M. Dufour, R. Lazauskas,  
H. Molique, F. Nowacki, K. Sieja + P-Y. Duerinck, O. Le Noan*



# The theory group at IPHC

## Theory for nuclear physics

Main expertise of the theory group



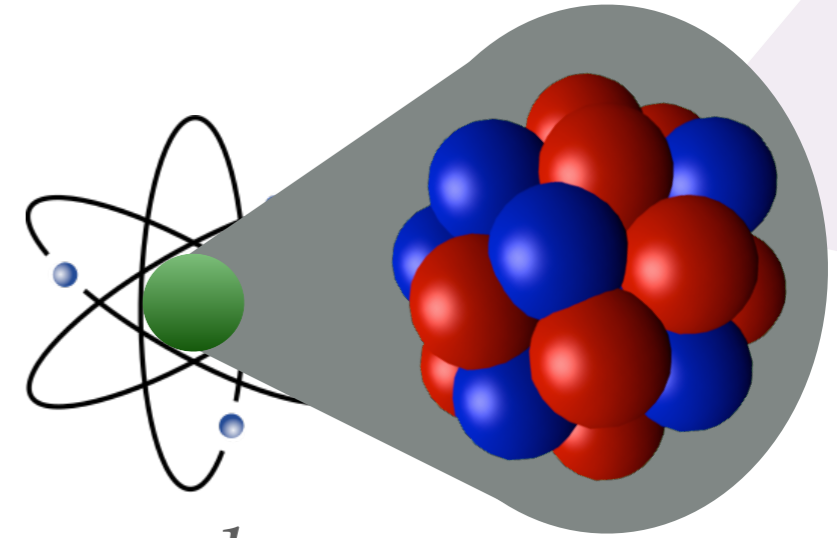
*J. Bartel, D. D. Dao, J. Dudek, M. Dufour, R. Lazauskas,  
H. Molique, F. Nowacki, K. Sieja + P-Y. Duerinck, O. Le Noan*

- Description of nuclear structure and of nuclear reactions from first principles or effective approaches
- Development and applications of analytical and numerical methods
- Interpretation of remarkable nuclei or nuclear phenomena
- Link with nuclear physics experiments and astrophysics
- ...

# The theory group at IPHC

## Theory for nuclear physics

Main expertise of the theory group

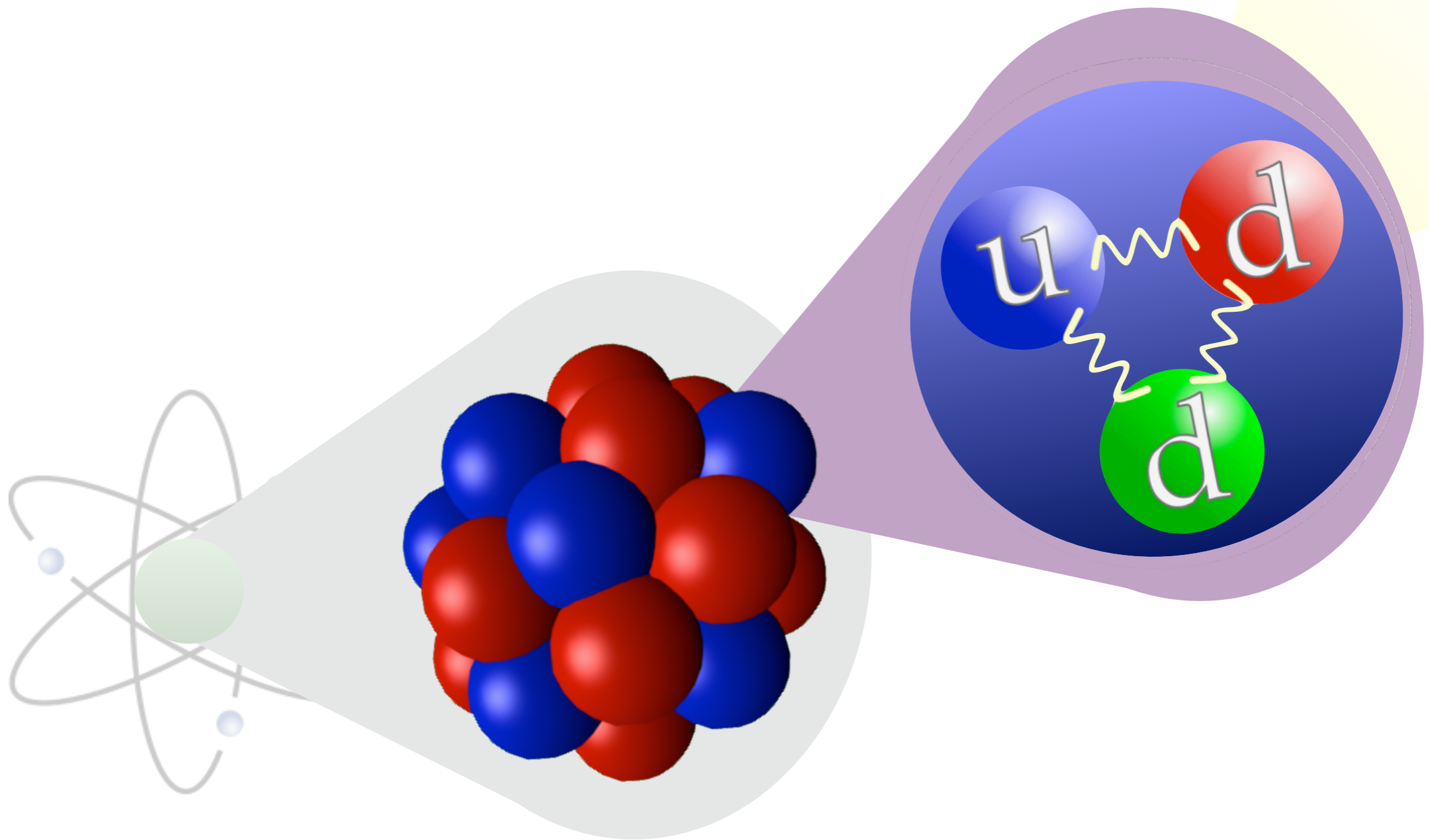


*J. Bartel, D. D. Dao, J. Dudek, M. Dufour, R. Lazauskas,  
H. Molique, F. Nowacki, K. Sieja + P-Y. Duerinck, O. Le Noan*

- Description of nuclear structure and of nuclear reactions from first principles or effective approaches
- Development and applications of analytical and numerical methods
- Interpretation of remarkable nuclei or nuclear phenomena
- Link with nuclear physics experiments and astrophysics
- ... *(let me stop here to avoid making mistakes, let's hear them next year !)*

# The theory group at IPHC

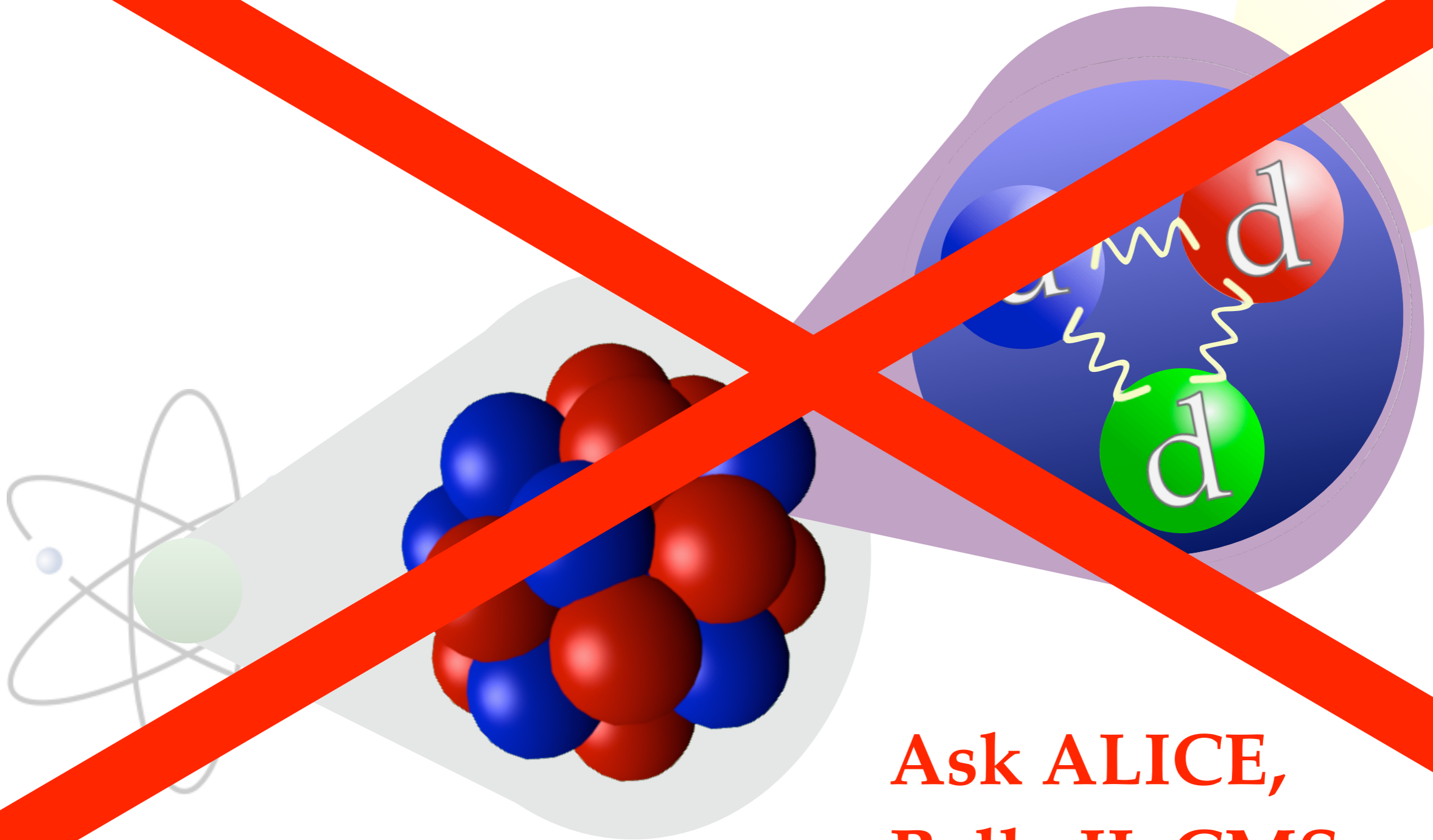
Theory for hadron physics ?





# The theory group at IPHC

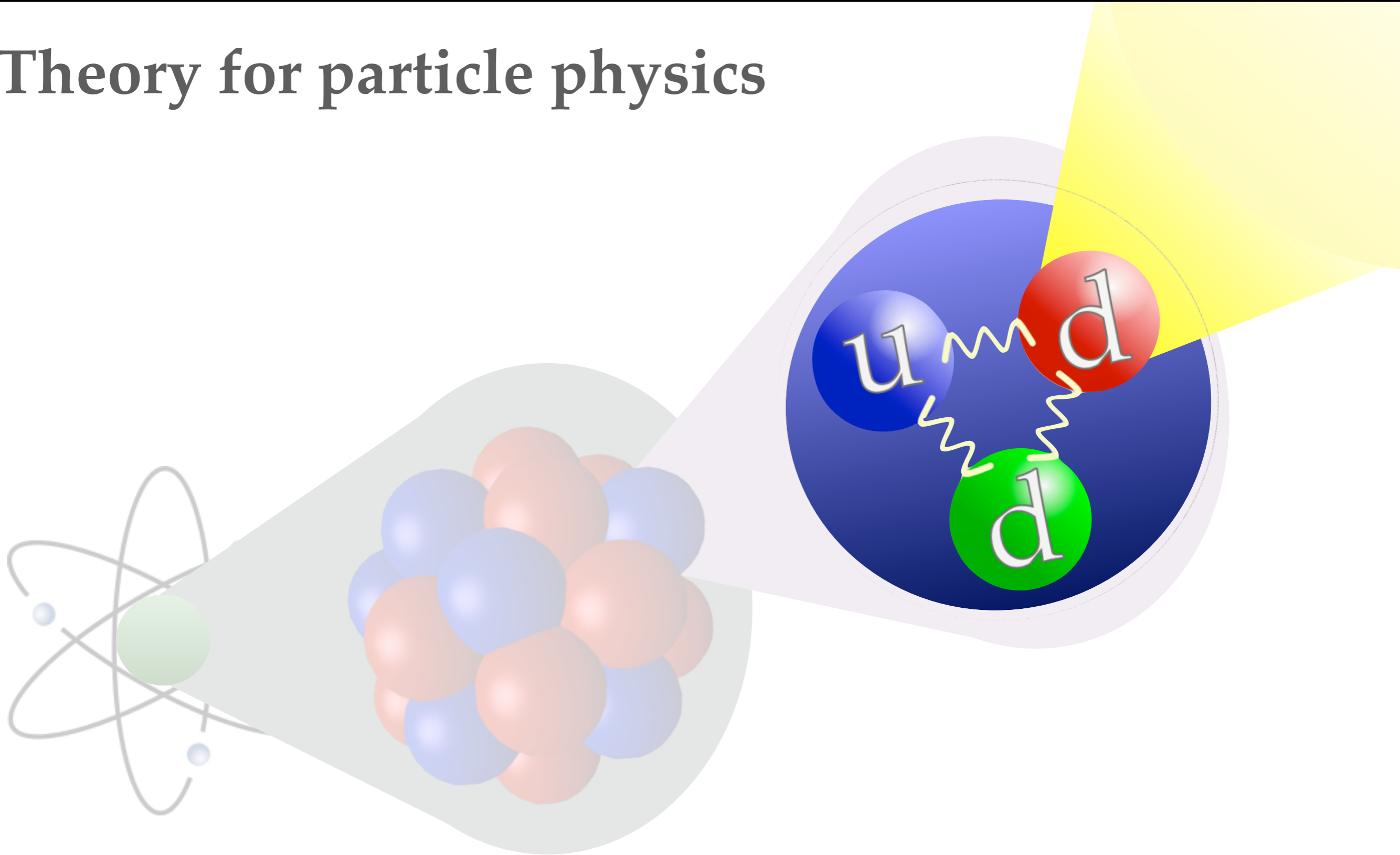
Theory for hadron physics ?



**Ask ALICE,  
Belle II, CMS, ...**

# High-energy physics theory at IPHC

## Theory for particle physics

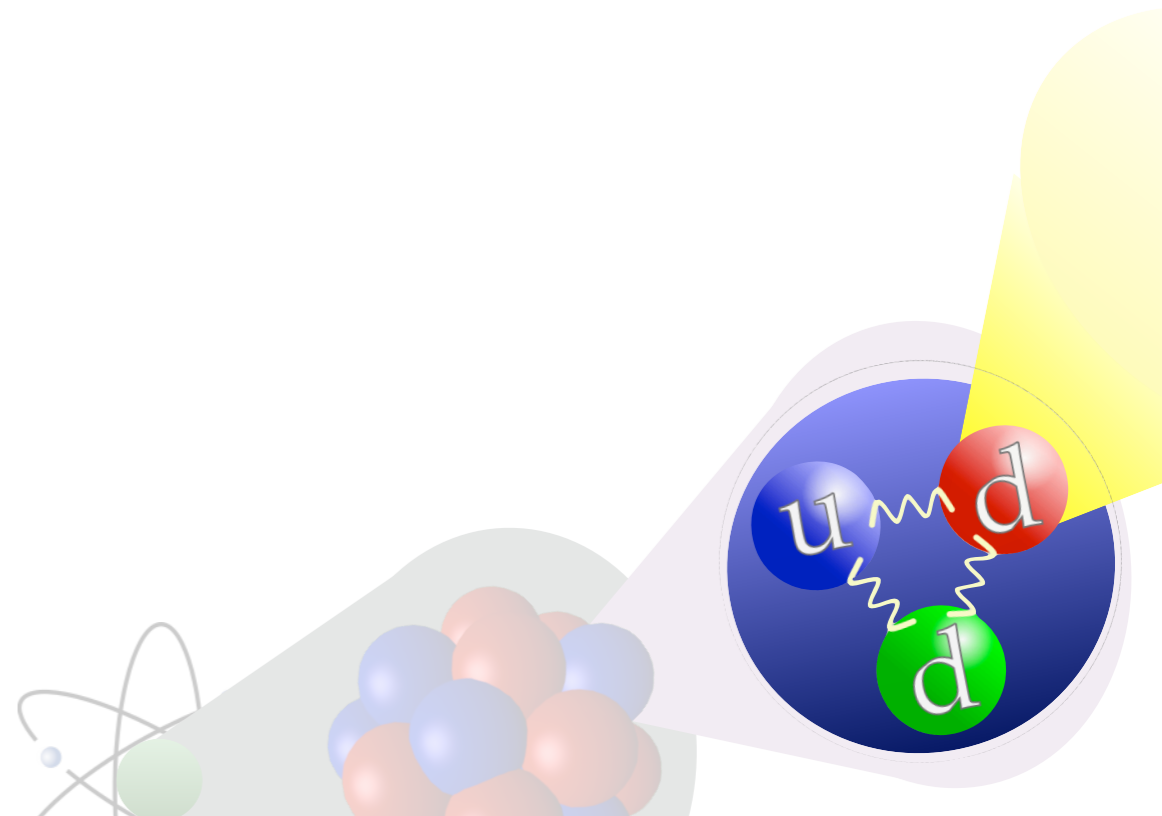


# High-energy physics theory at IPHC

Theory for particle physics ...

... and associated formal branches of mathematical physics

*J. Polonyi, M. Rausch de Traubenberg, QB*



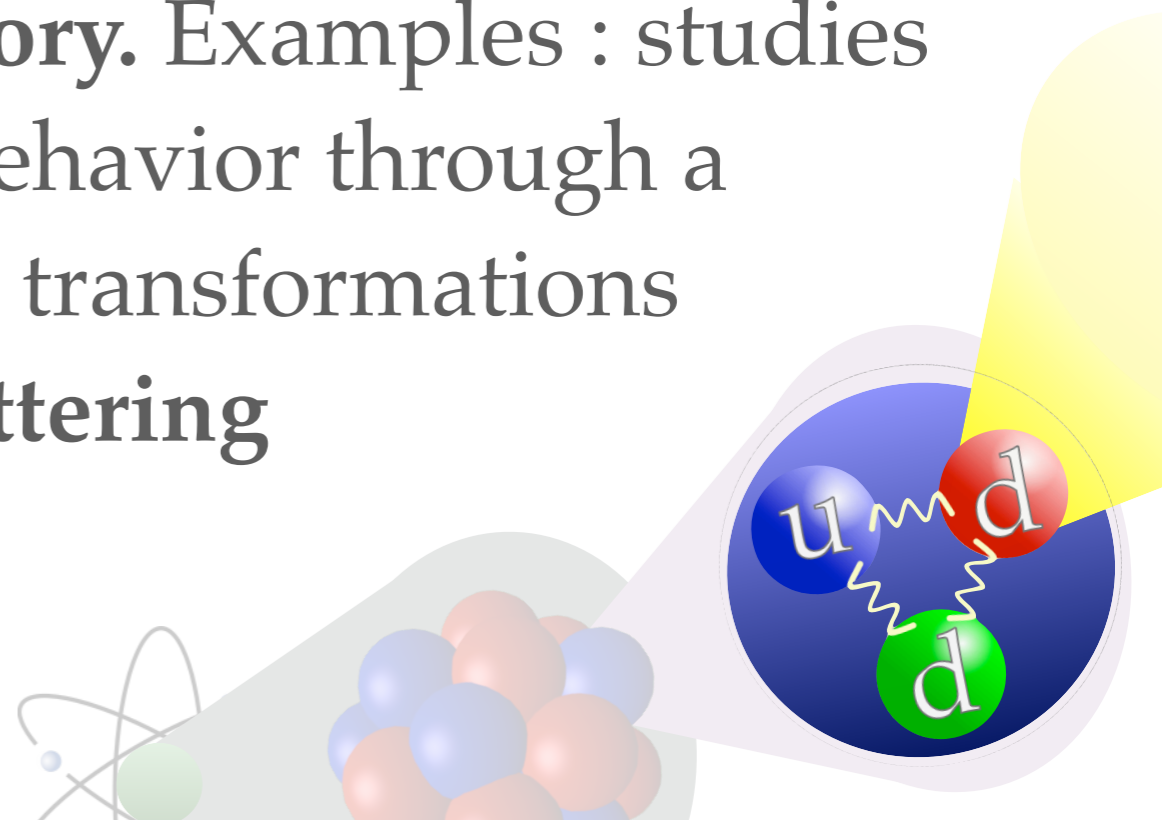
# High-energy physics theory at IPHC

## Theory for particle physics ...

... and associated formal branches of mathematical physics

*J. Polonyi, M. Rausch de Traubenberg, QB*

- Development of the tool used to describe particle physics (or any system whose description requires the concepts of quantum mechanics and special relativity), namely **quantum field theory**. Examples : studies of **renormalization** (= change of behavior through a change of scale), of **symmetries** (= transformations that do not affect a system), of **scattering**



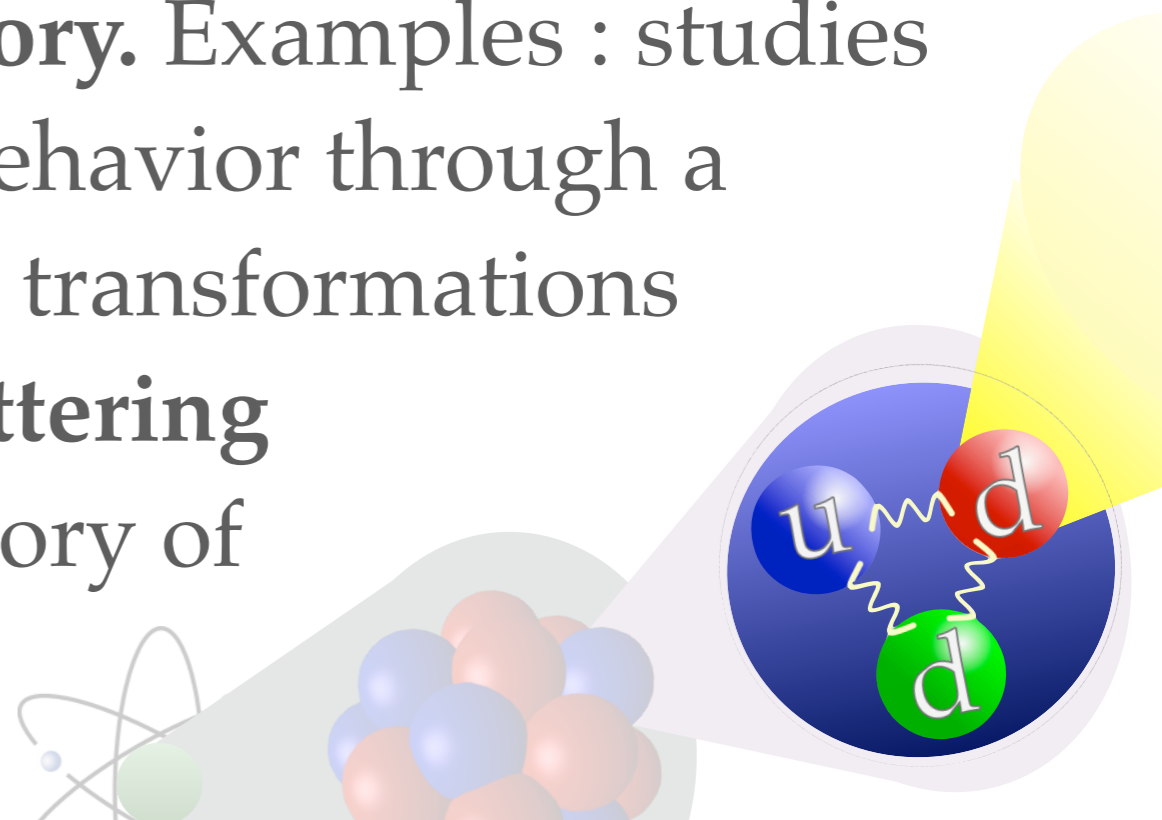
# High-energy physics theory at IPHC

## Theory for particle physics ...

... and associated formal branches of mathematical physics

*J. Polonyi, M. Rausch de Traubenberg, QB*

- Development of the tool used to describe particle physics (or any system whose description requires the concepts of quantum mechanics and special relativity), namely **quantum field theory**. Examples : studies of **renormalization** (= change of behavior through a change of scale), of **symmetries** (= transformations that do not affect a system), of **scattering**
- Development of an alternative theory of gravitation, called **supergravity**



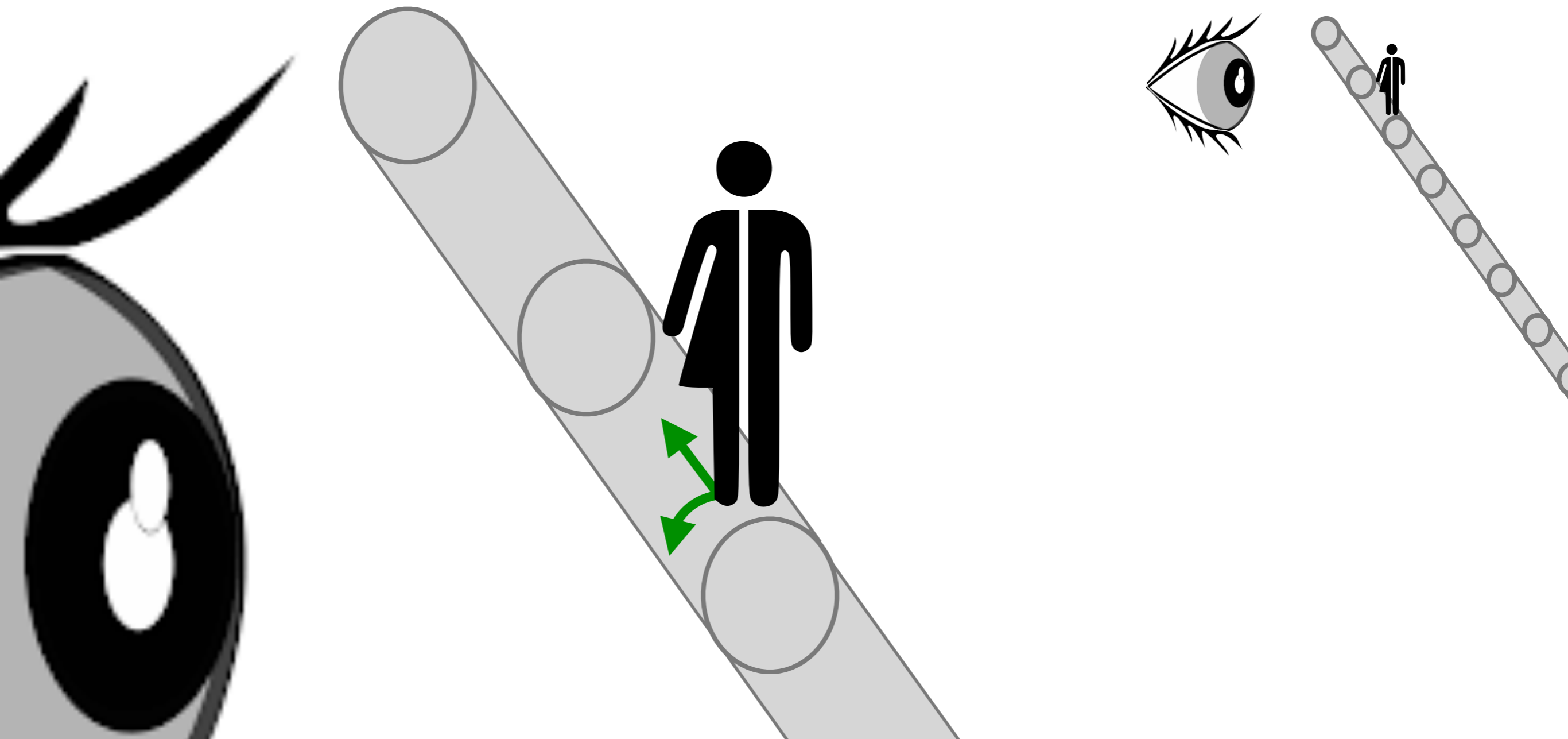
# High-energy physics theory at IPHC

- **Group theory** (= mathematical structures associated to symmetries)

# High-energy physics theory at IPHC

- **Group theory** (= mathematical structures associated to symmetries)

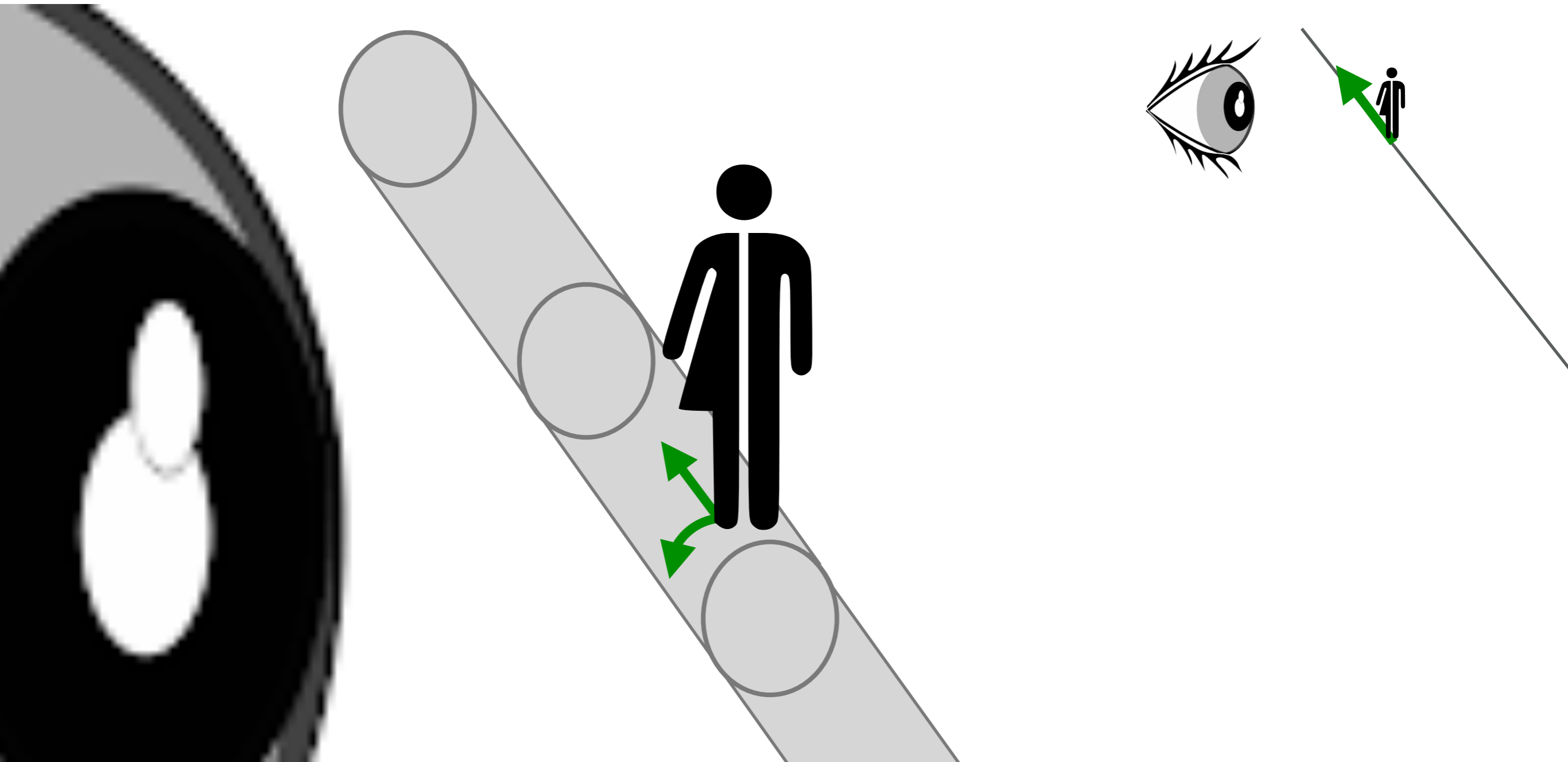
A recent example :



# High-energy physics theory at IPHC

- **Group theory** (= mathematical structures associated to symmetries)

A recent example :

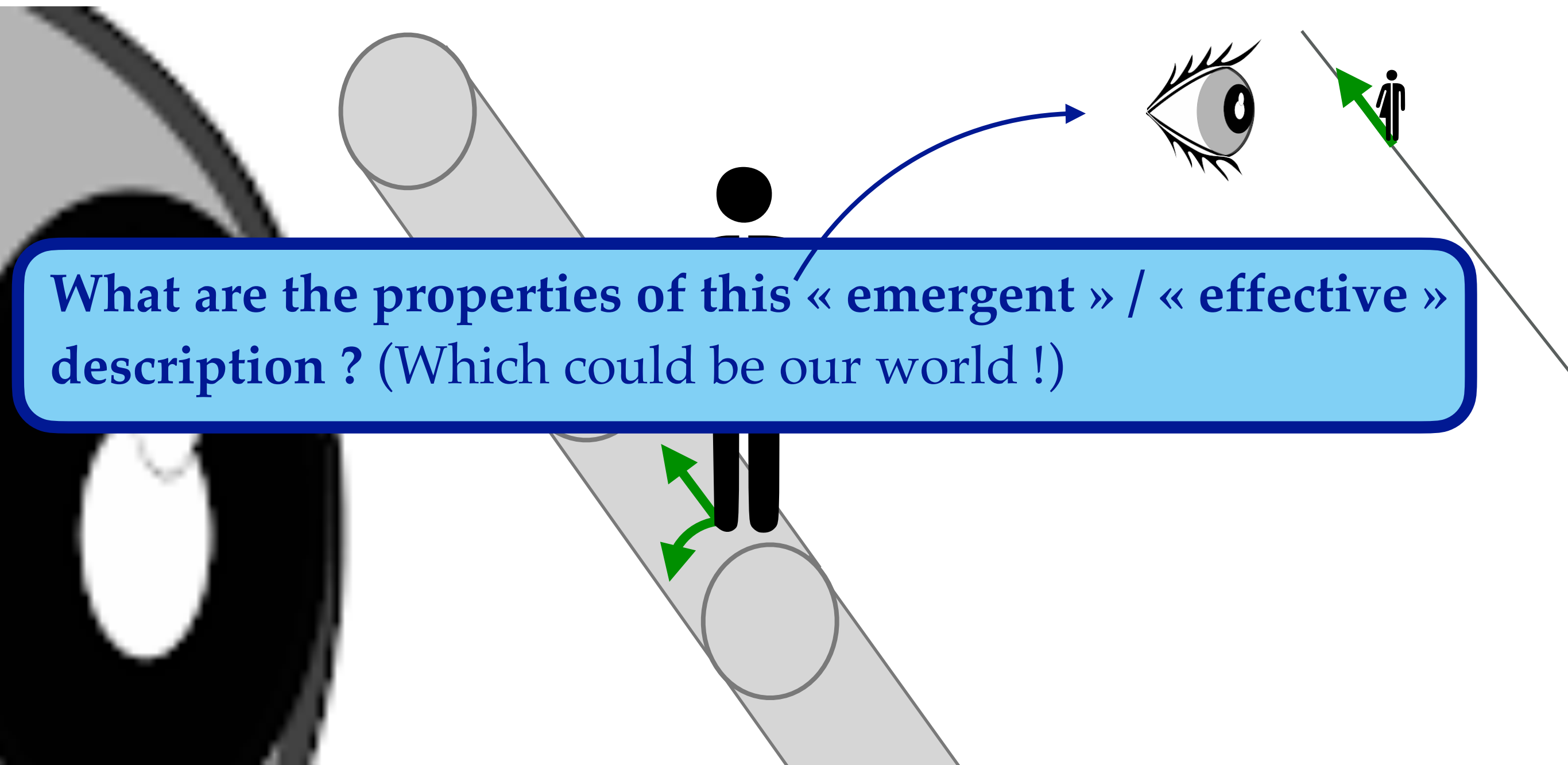




# High-energy physics theory at IPHC

- **Group theory** (= mathematical structures associated to symmetries)

A recent example :

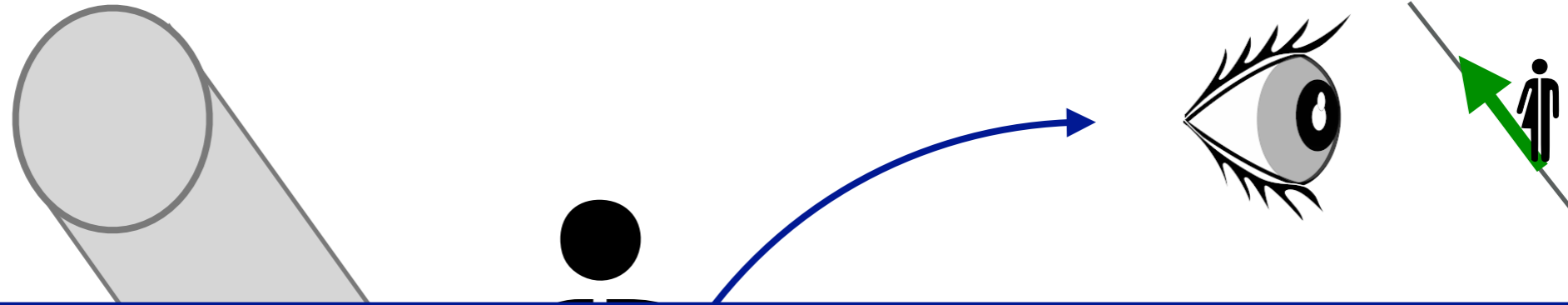


**What are the properties of this « emergent » / « effective » description ? (Which could be our world !)**

# High-energy physics theory at IPHC

- **Group theory** (= mathematical structures associated to symmetries)

A recent example :



**What are the properties of this « emergent » / « effective » description ? (Which could be our world !)**

**Many things to observe ... such as emergent symmetries !**

**Several papers on the mathematics of these symmetries (and ongoing work on applications)**

[R. Campoamor-Stursberg, M. de Montigny, **M. Rausch de Traubenberg** '21]

[R. Campoamor-Stursberg, A. Marani, **M. Rausch de Traubenberg** '24]

# Theoretical particle phenomenology at IPHC

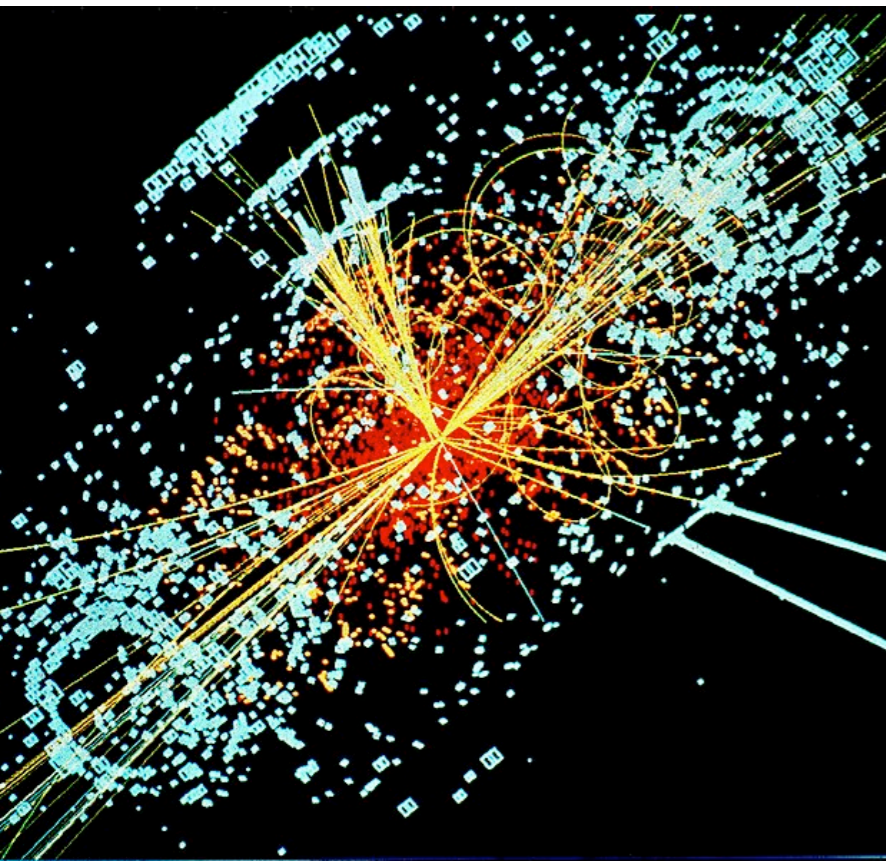
# Theoretical particle phenomenology at IPHC

**Particle physics phenomenology** = interpretations or predictions of observable phenomena (in particle physics or related systems)

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?

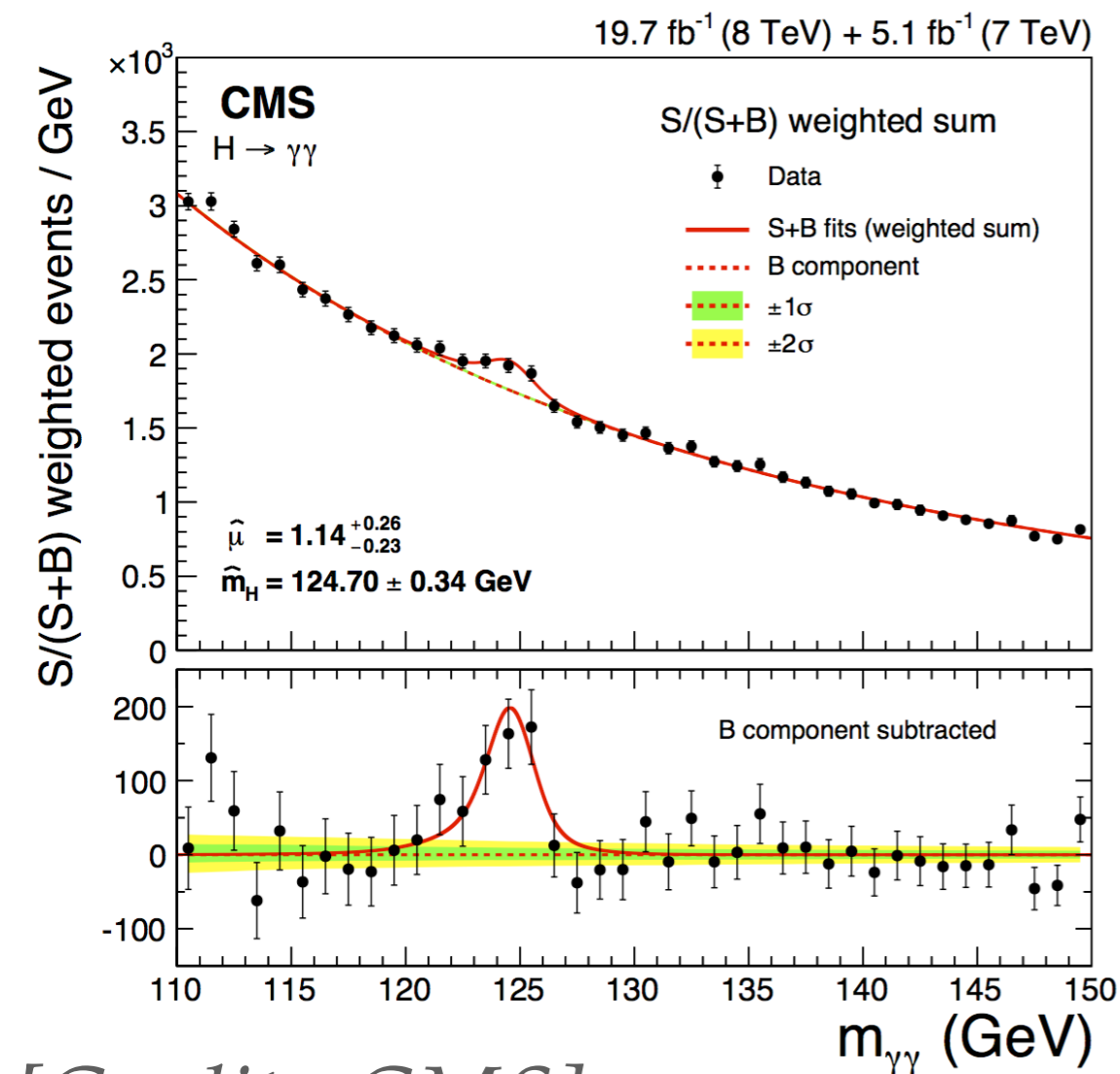


*[Credit : CMS]*

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?

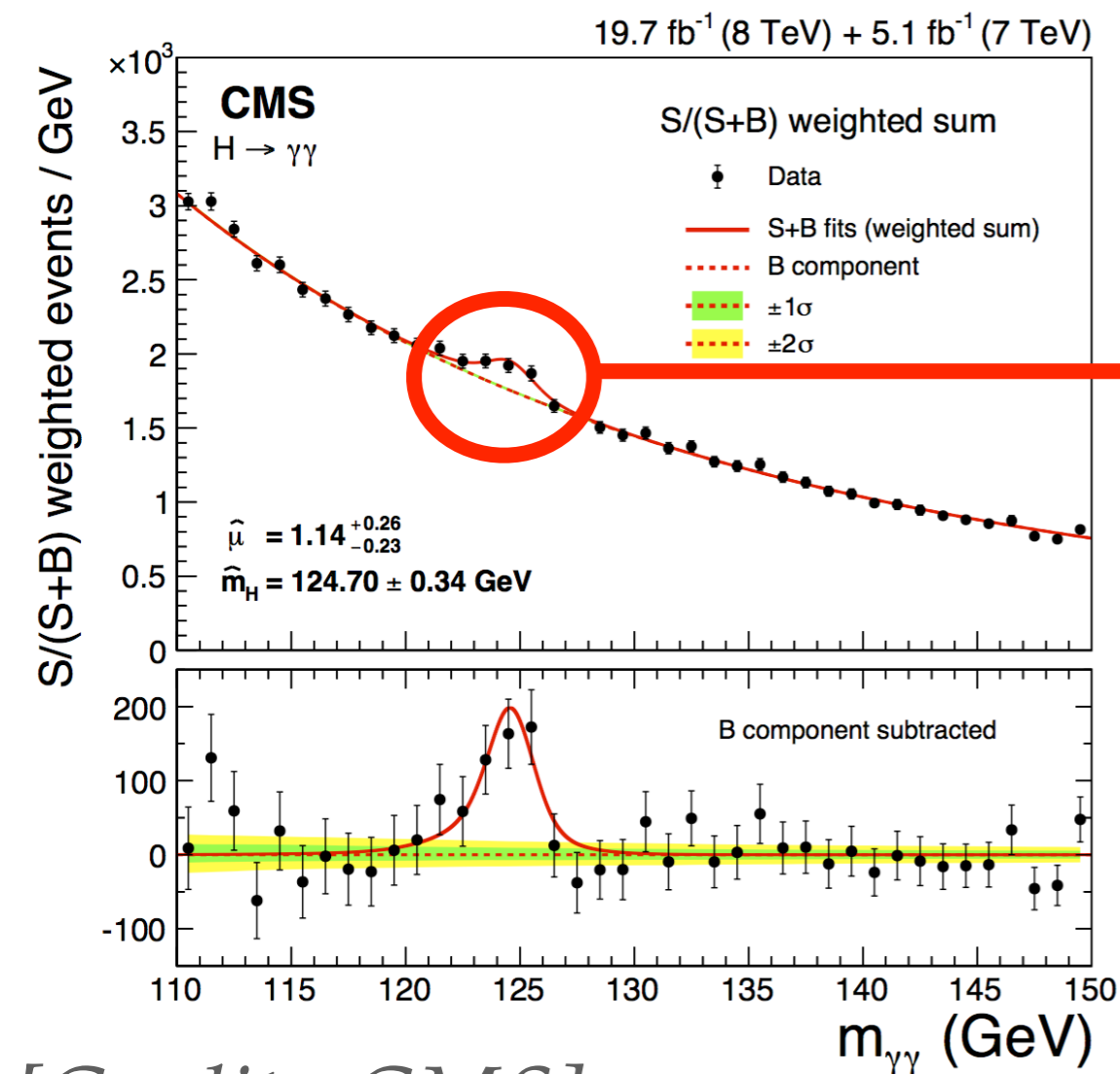


[Credit : CMS]

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = **interpretations** or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?



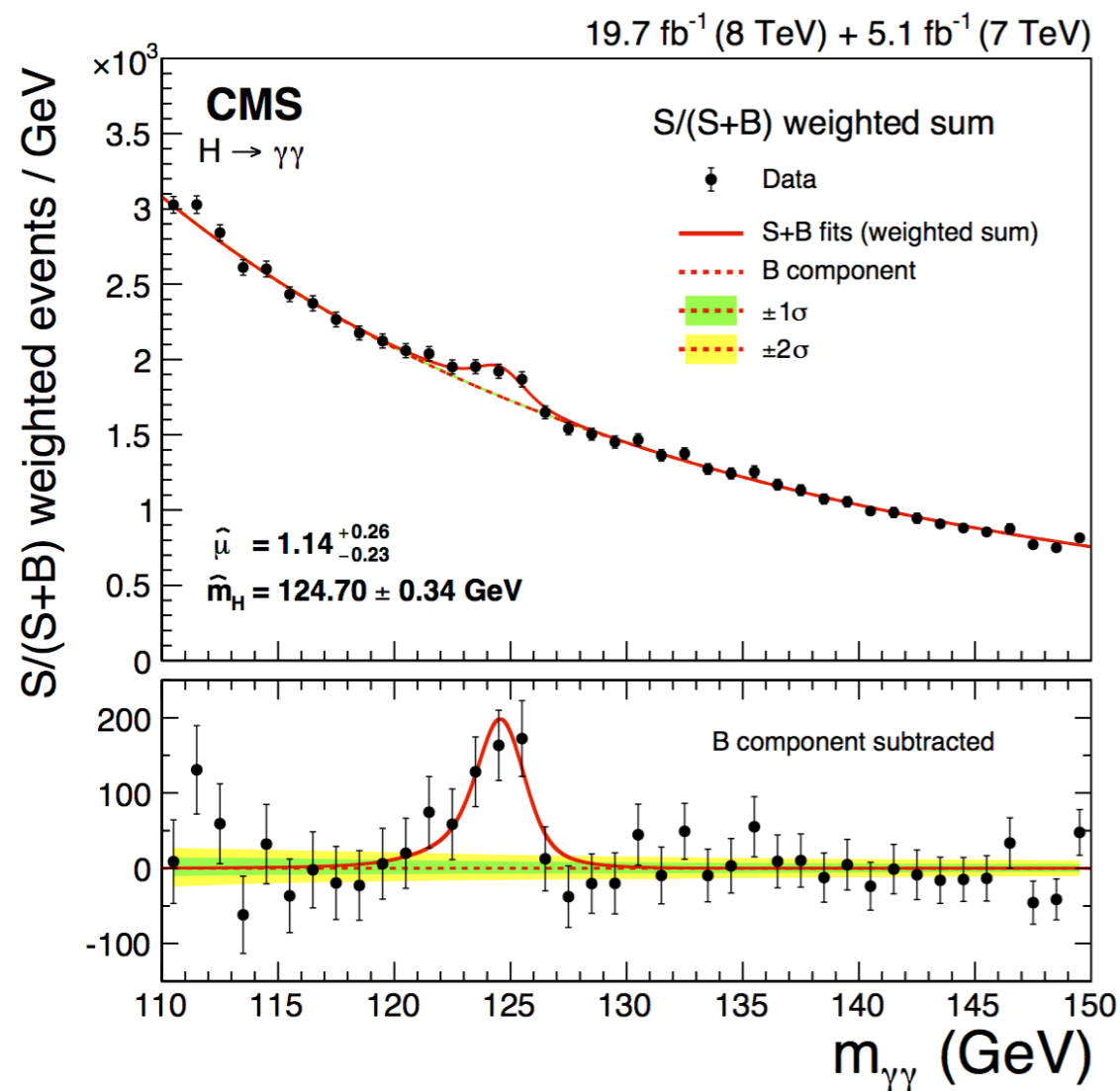
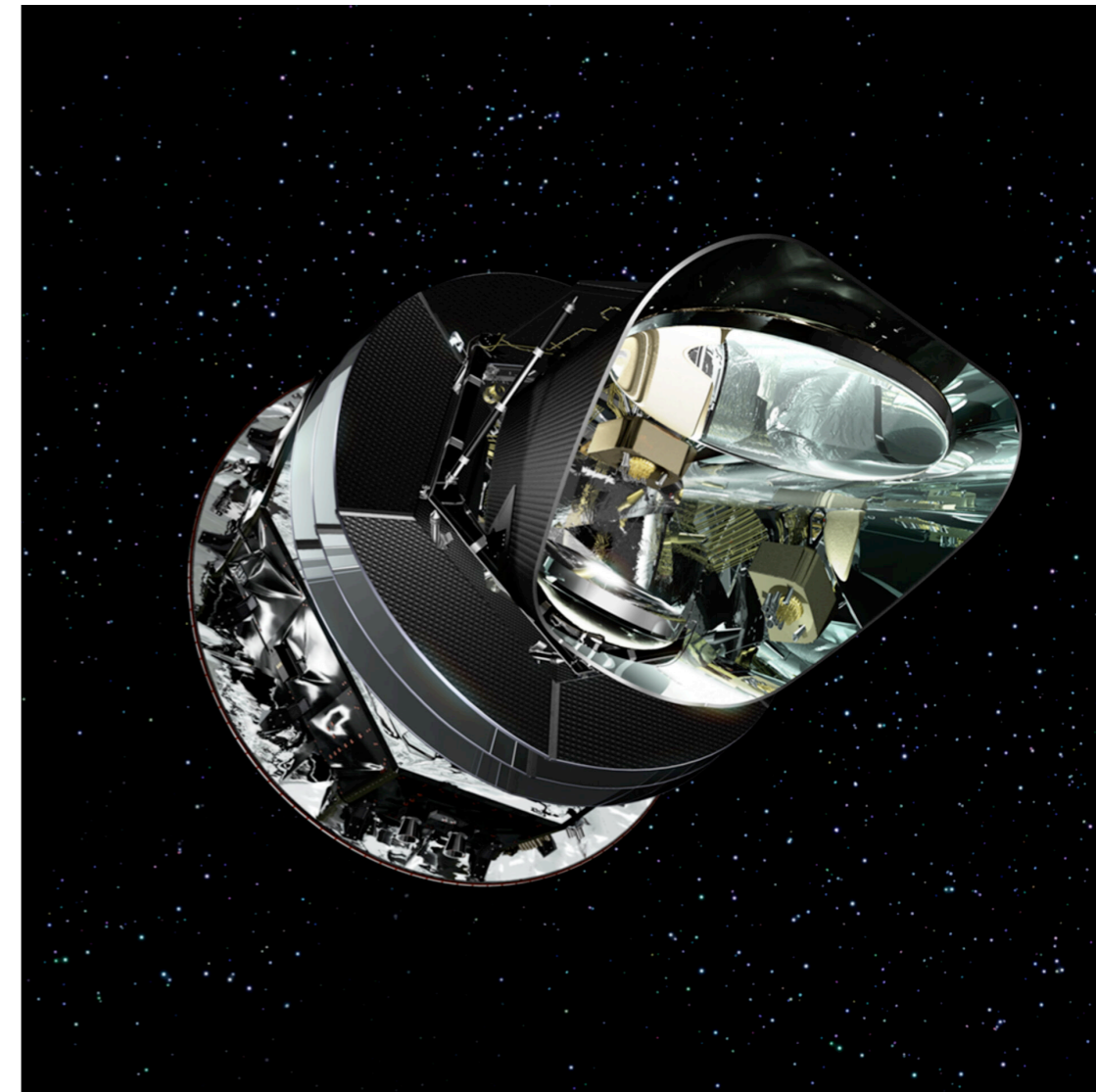
What is it really ?

[Credit : CMS]

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?



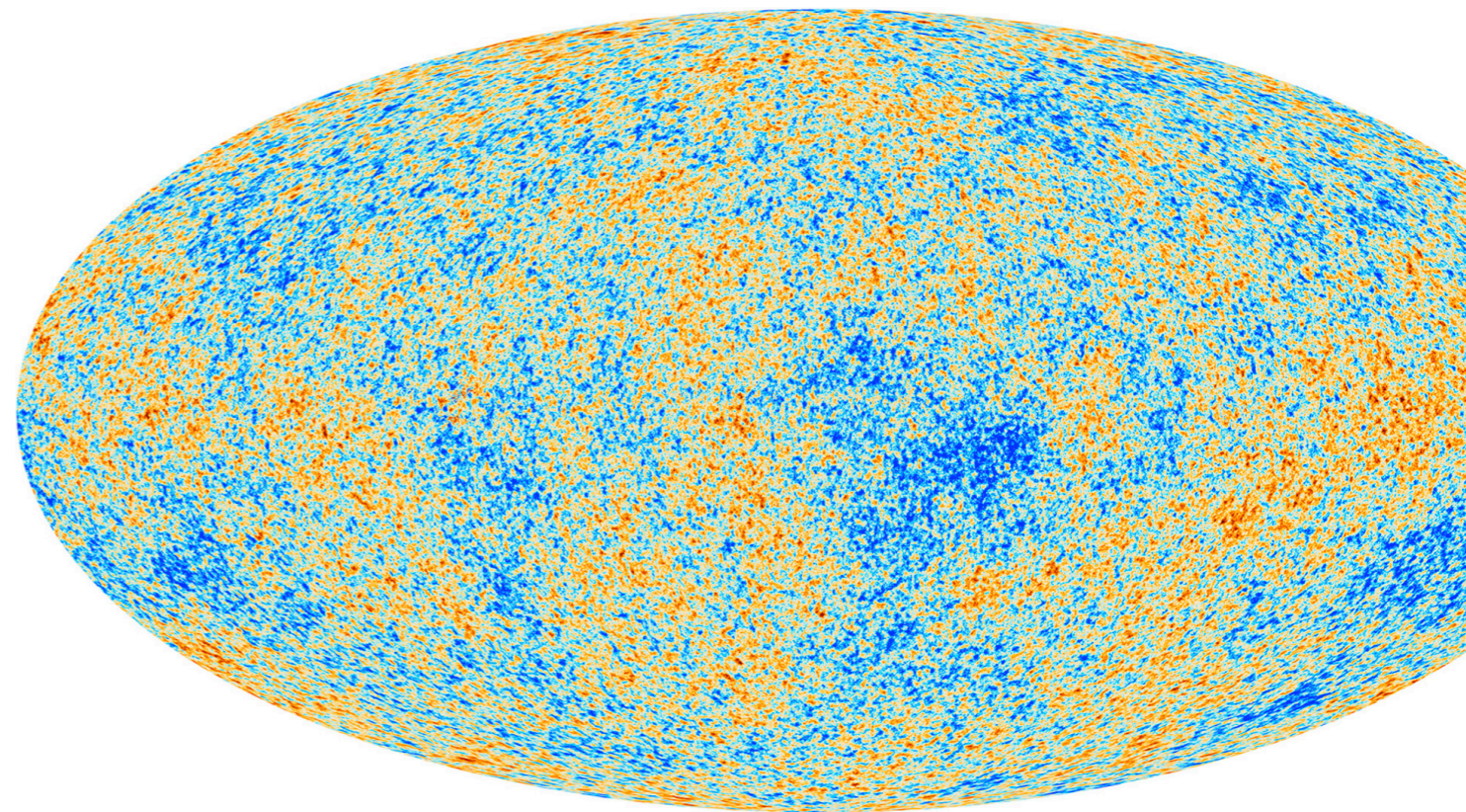
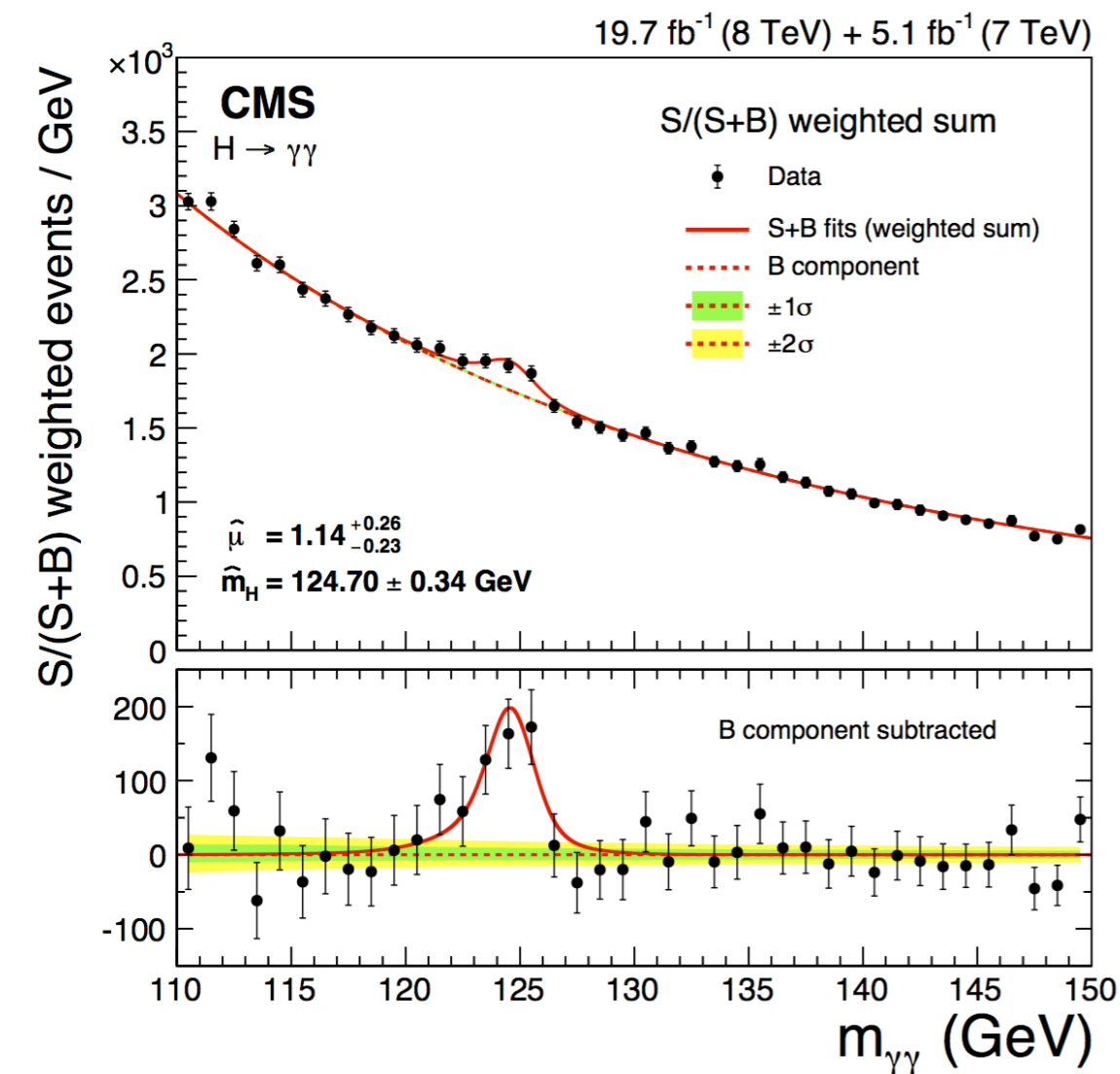
[Credit : ESA]



# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?



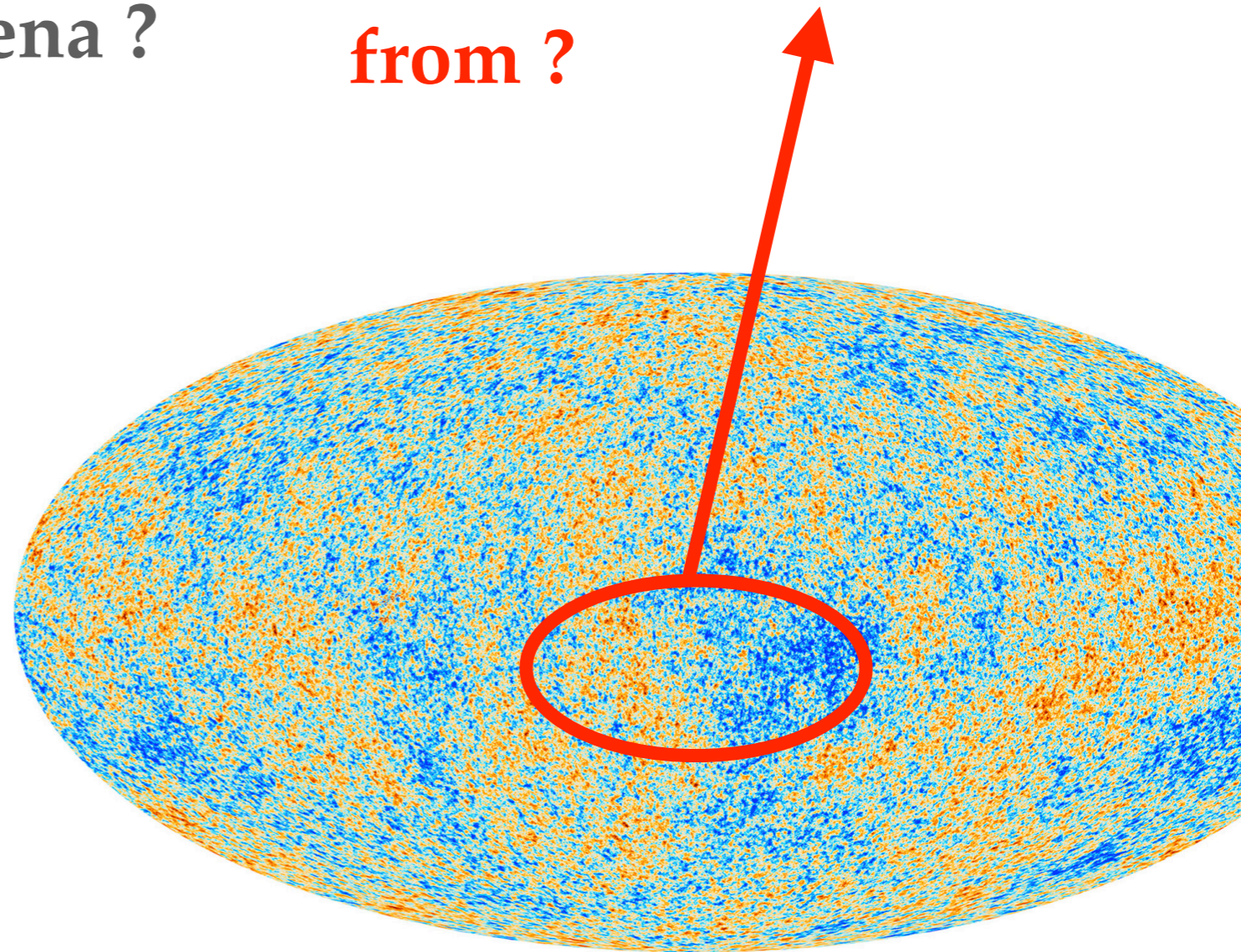
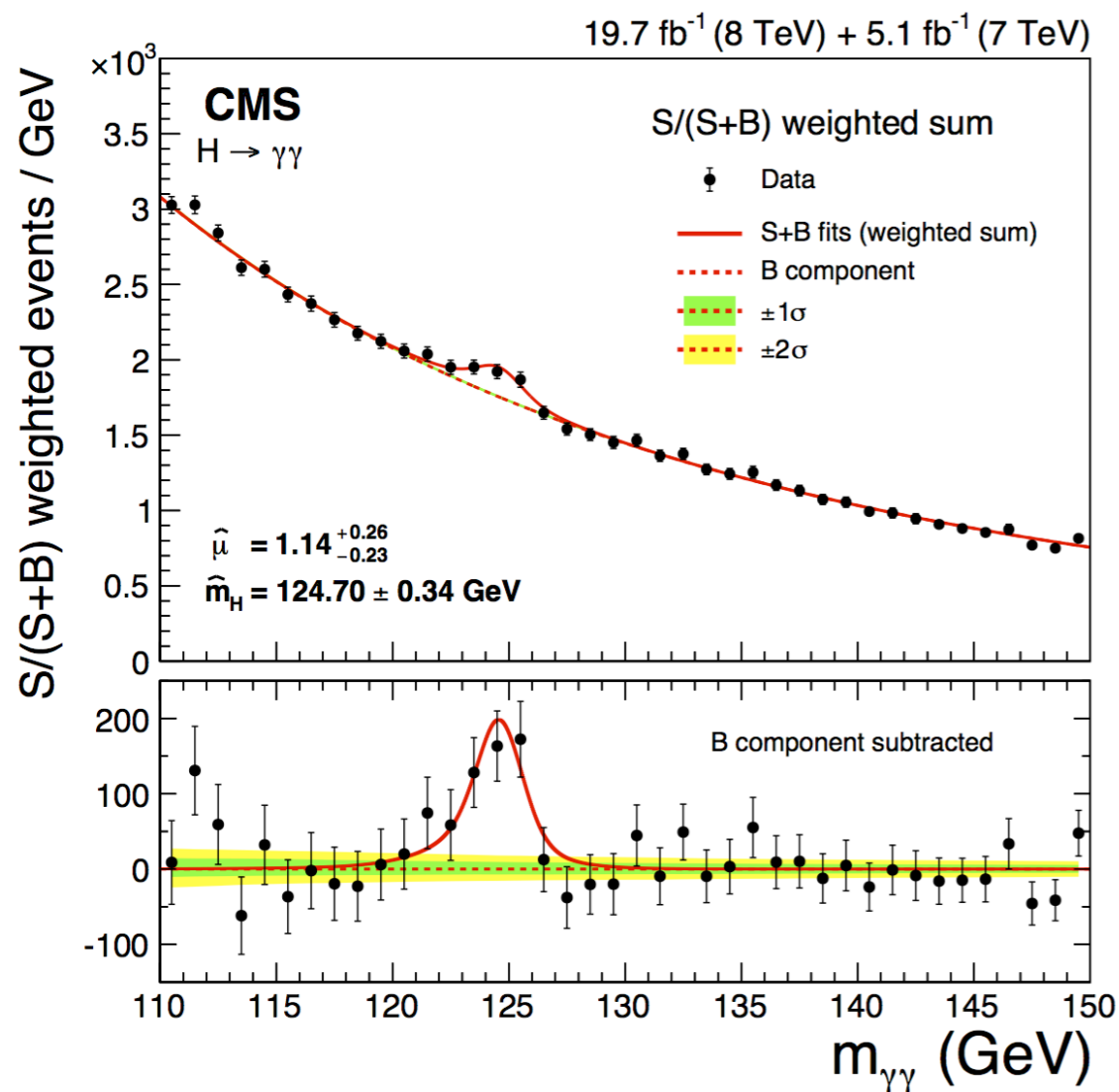
[Credit : ESA]

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = **interpretations** or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?

**Where does this come from ?**

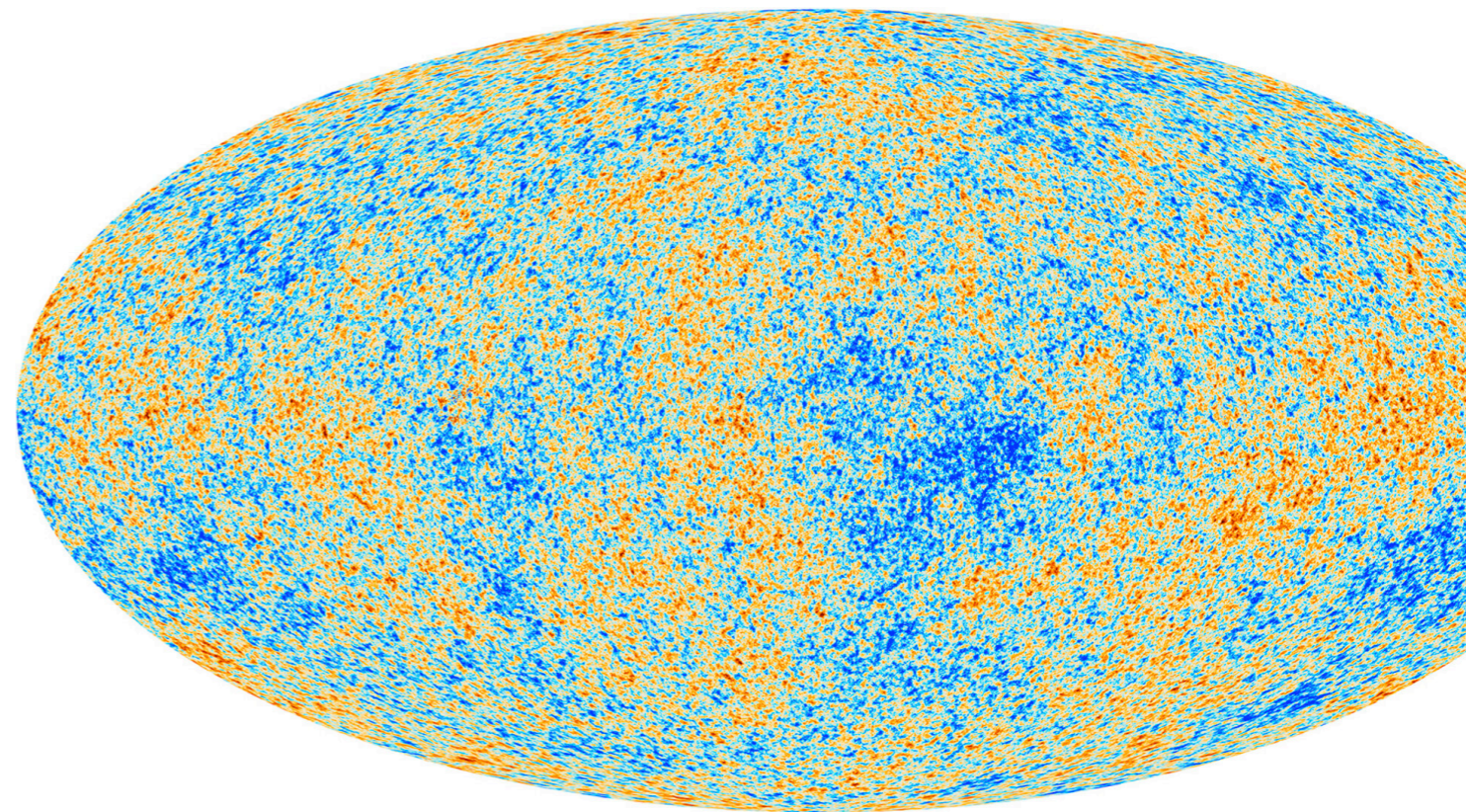
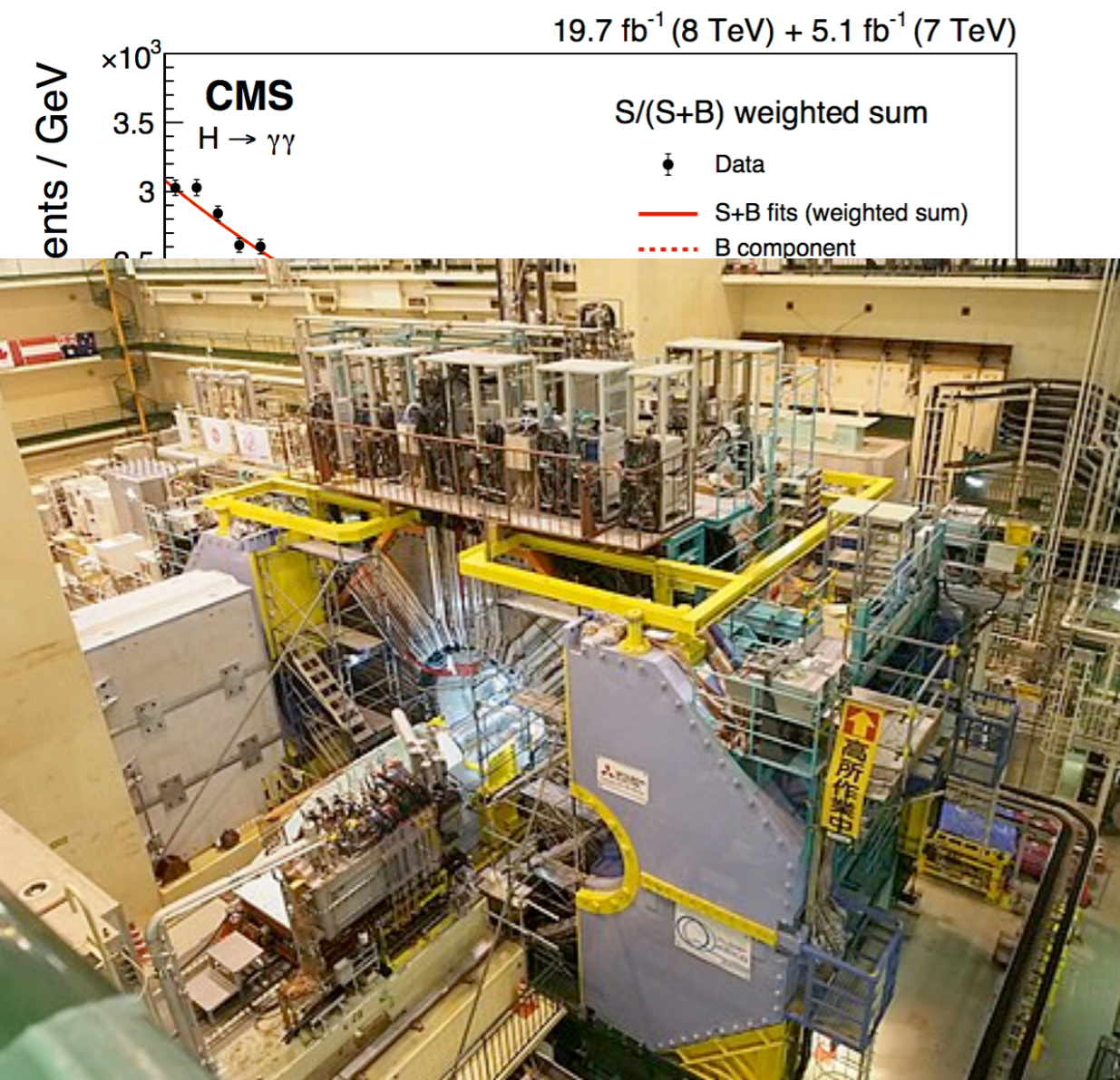


[Credit : ESA]

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or predictions of observable phenomena (in particle physics or related systems)

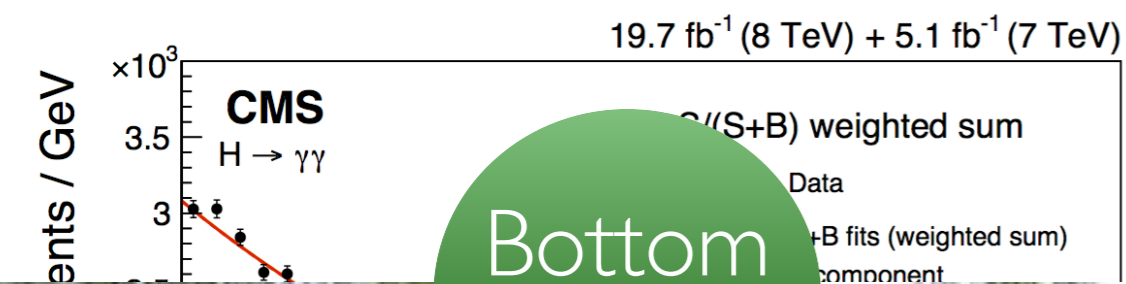
Which observable phenomena ?



# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or predictions of observable phenomena (in particle physics or related systems)

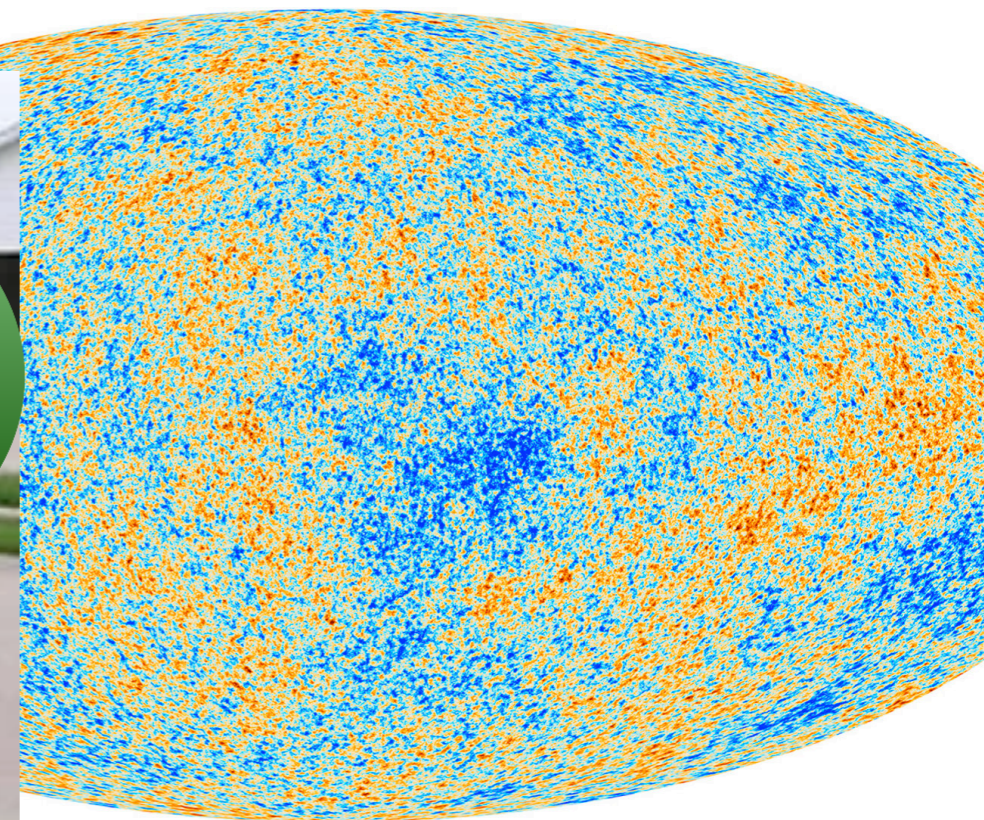
Which observable phenomena ?



Bottom quark

Strange quark

Down quark



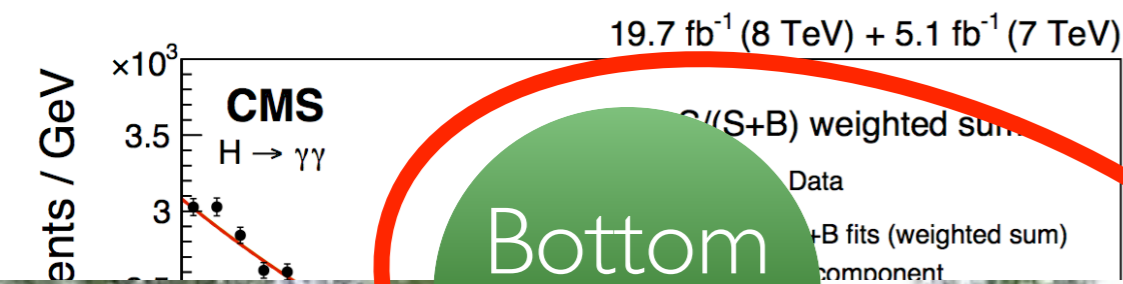
[Credit : Reddit]

# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = **interpretations** or predictions of observable phenomena (in particle physics or related systems)

Which observable phenomena ?

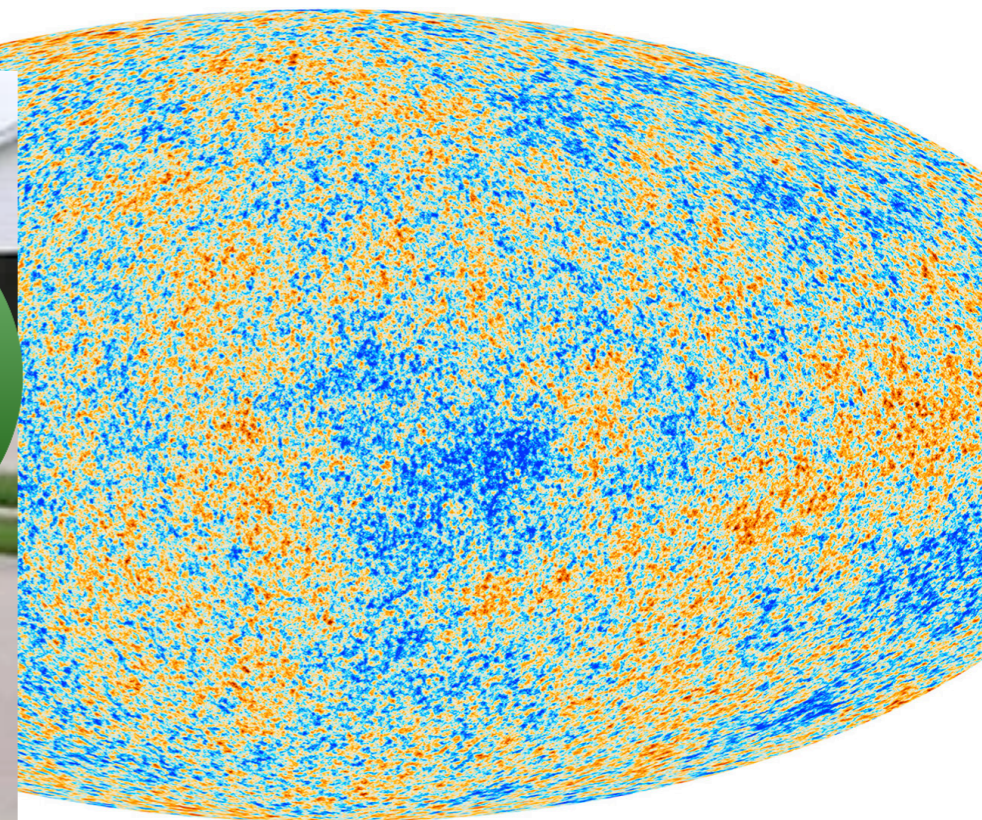
**Why two more ?**



Bottom quark

Strange quark

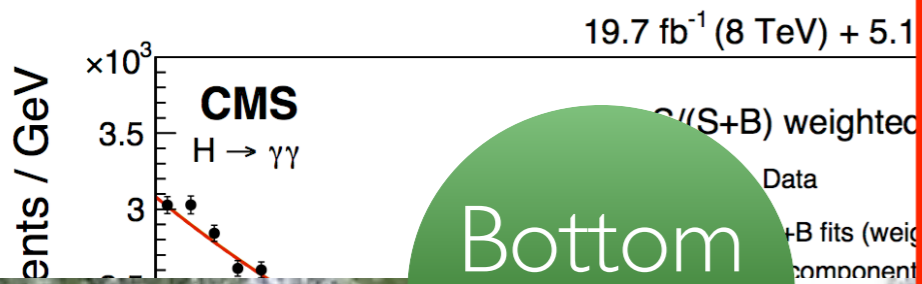
Down quark



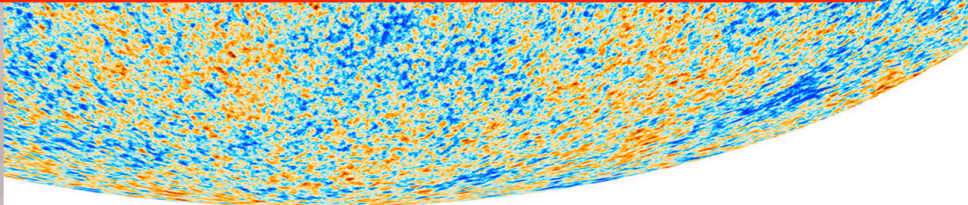
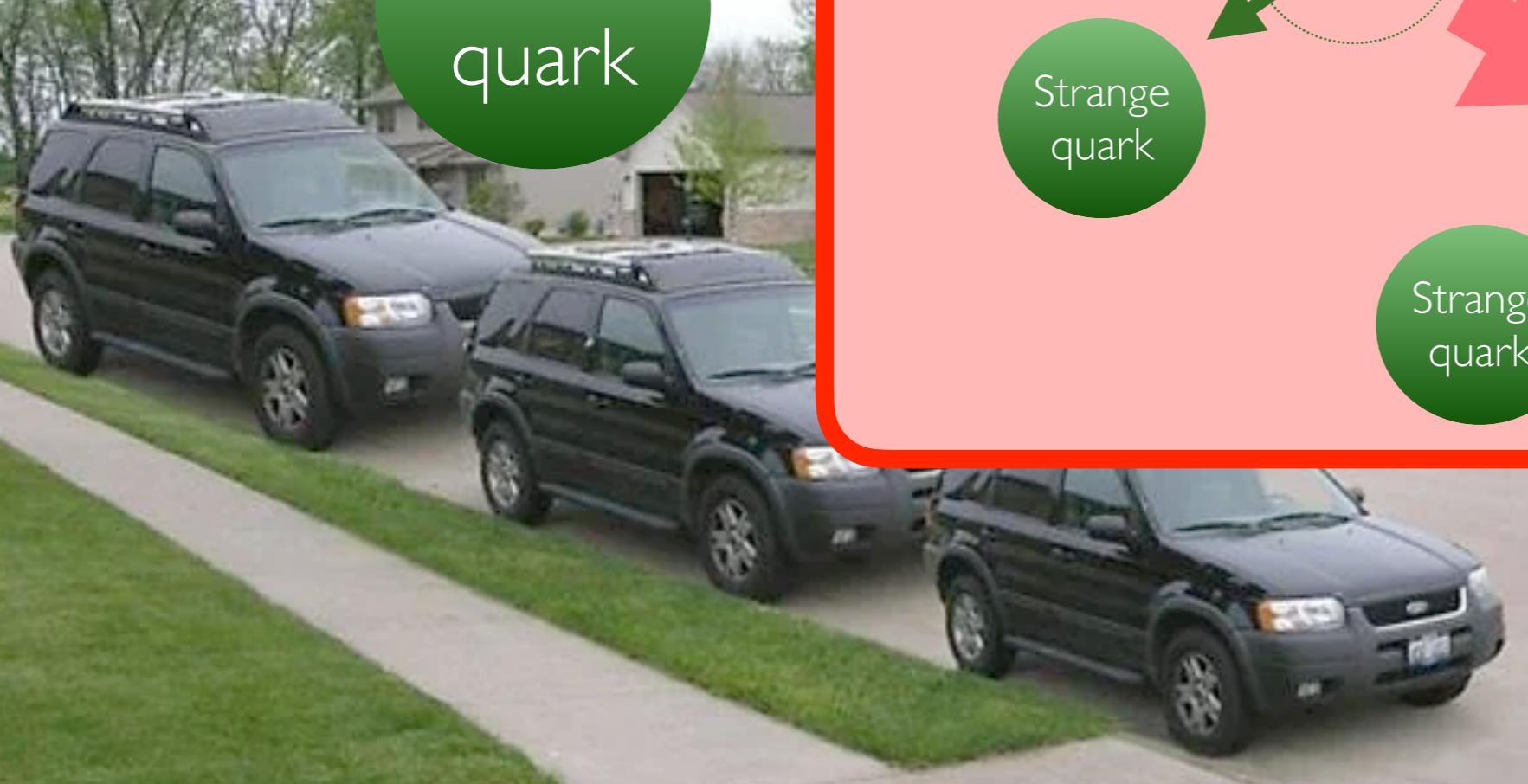
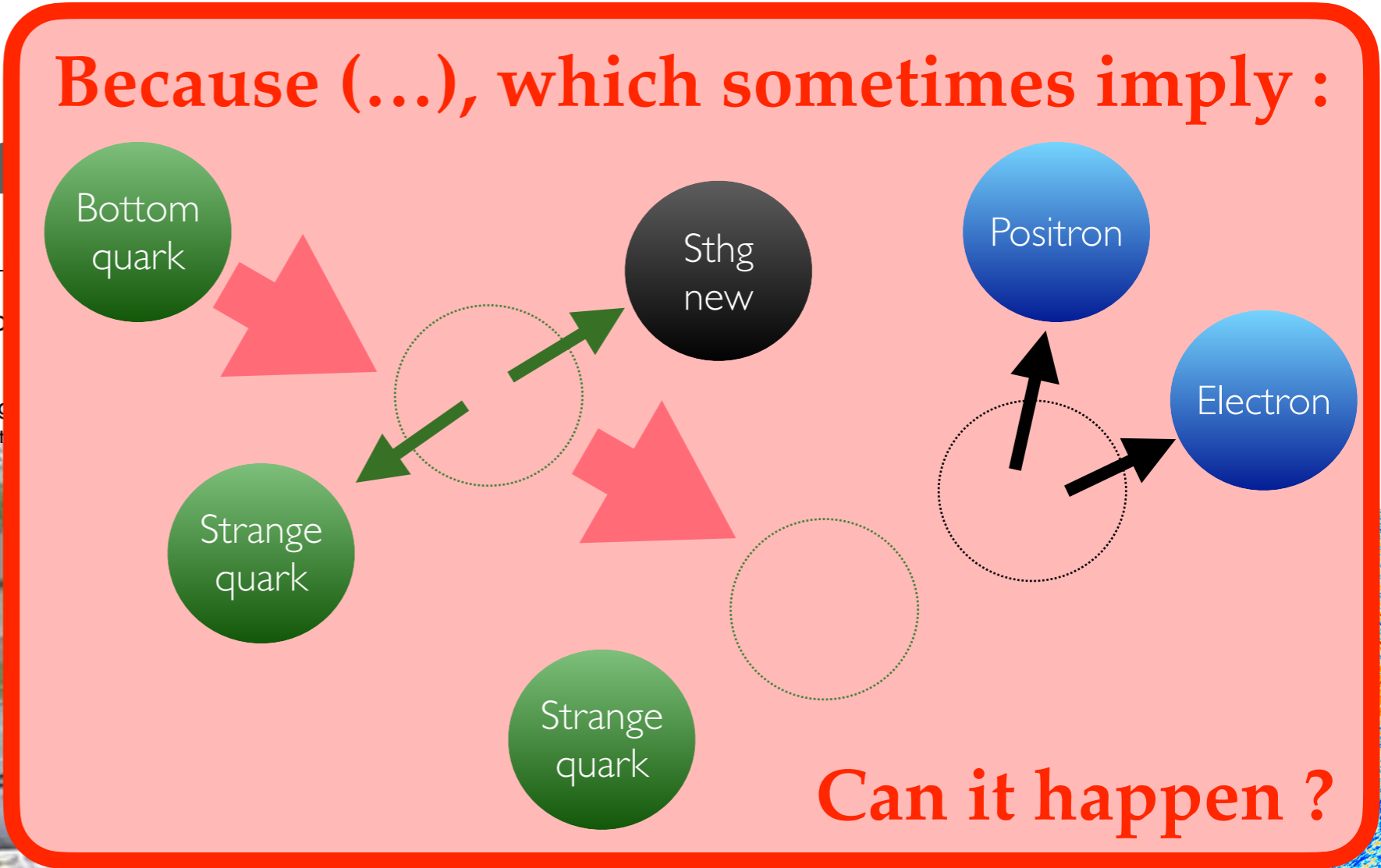
# Theoretical particle phenomenology at IPHC

Particle physics phenomenology = interpretations or **predictions** of observable phenomena (in particle physics or related systems)

Which observable p



Bottom quark



# Theoretical particle phenomenology at IPHC

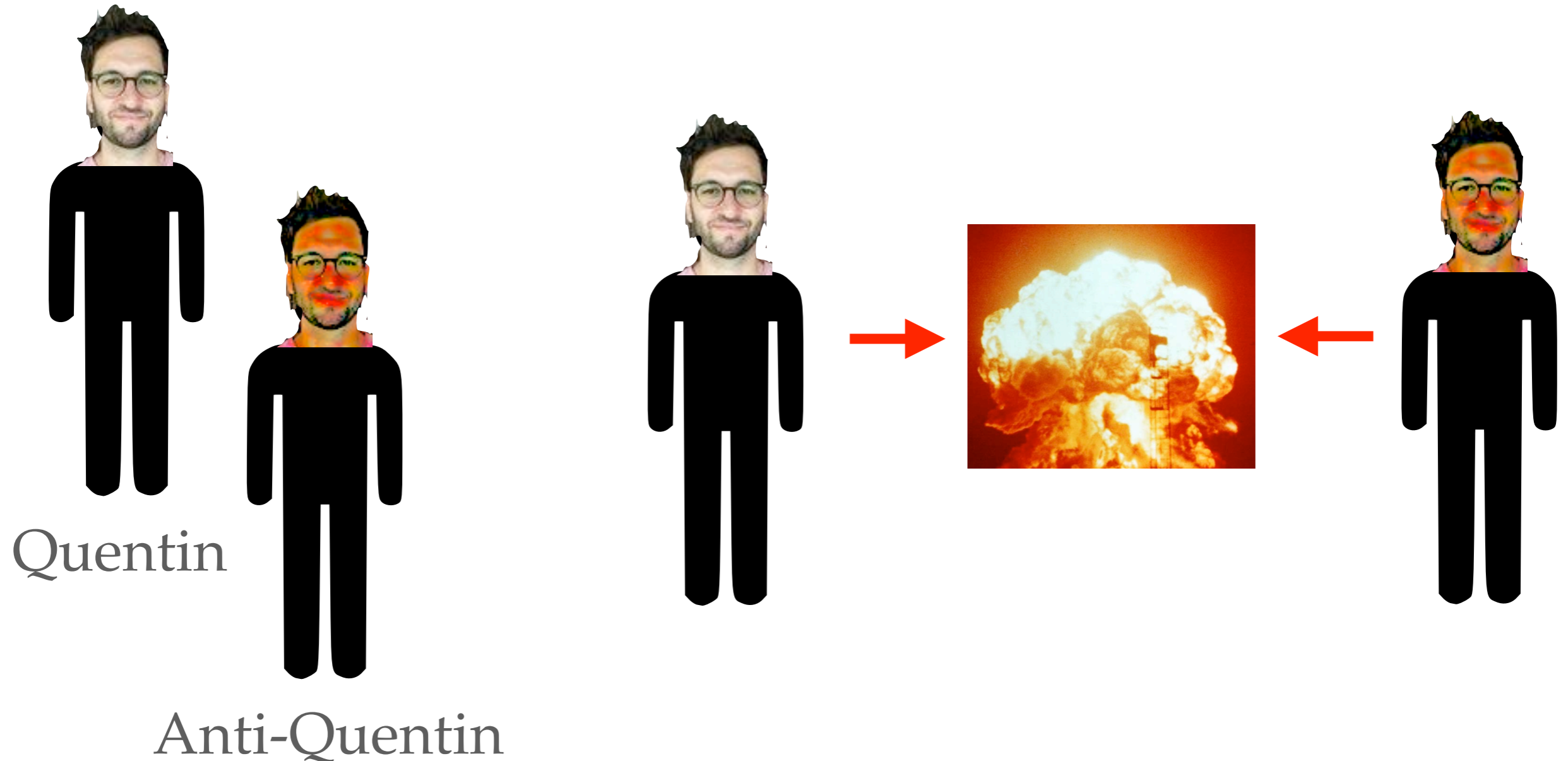
Some ongoing projects :

- 1) consequences of the absence of CP violation  
from strong interactions**

# Theoretical particle phenomenology at IPHC

Some ongoing projects :

1) consequences of the absence of CP violation  
from strong interactions





# Theoretical particle phenomenology at IPHC

Some ongoing projects :

- 1) consequences of the absence of CP violation from strong interactions



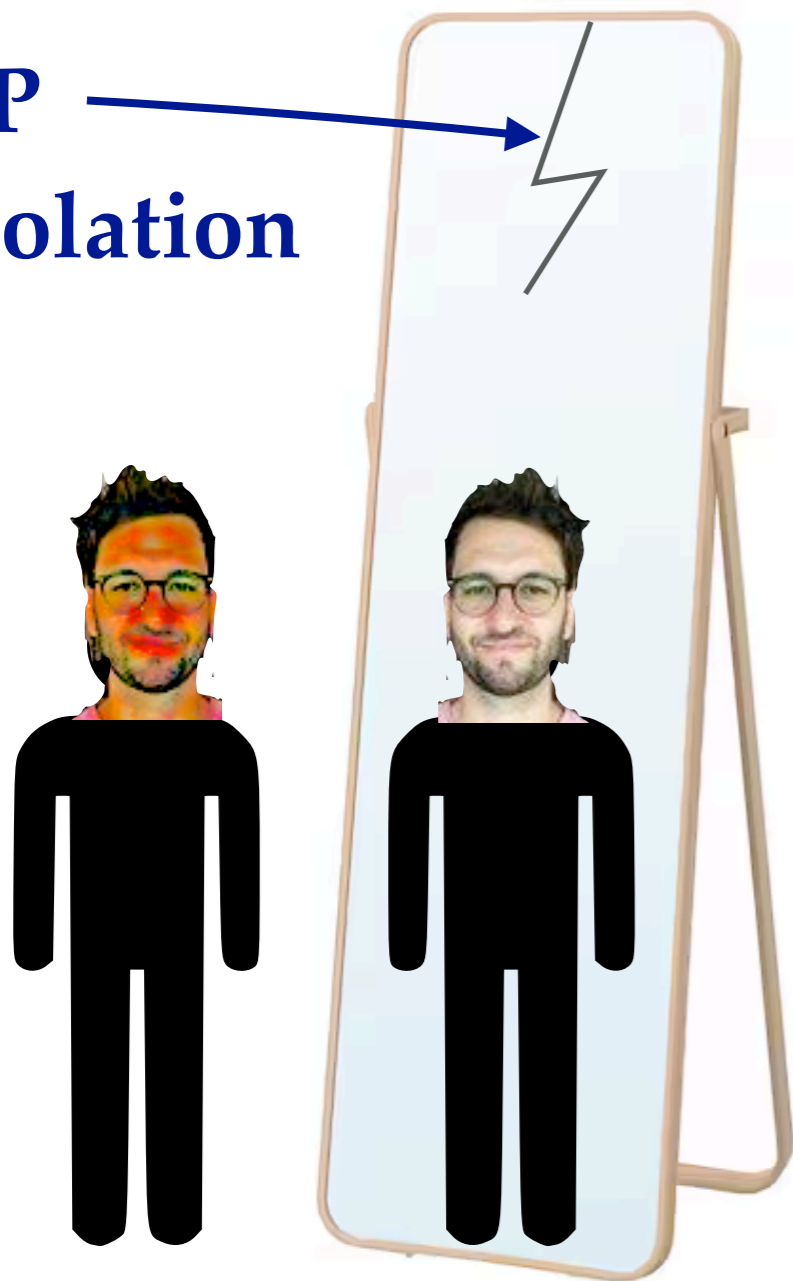
*[Credit : Ikea]*

# Theoretical particle phenomenology at IPHC

Some ongoing projects :

- 1) consequences of the absence of CP violation from strong interactions

**CP  
violation**

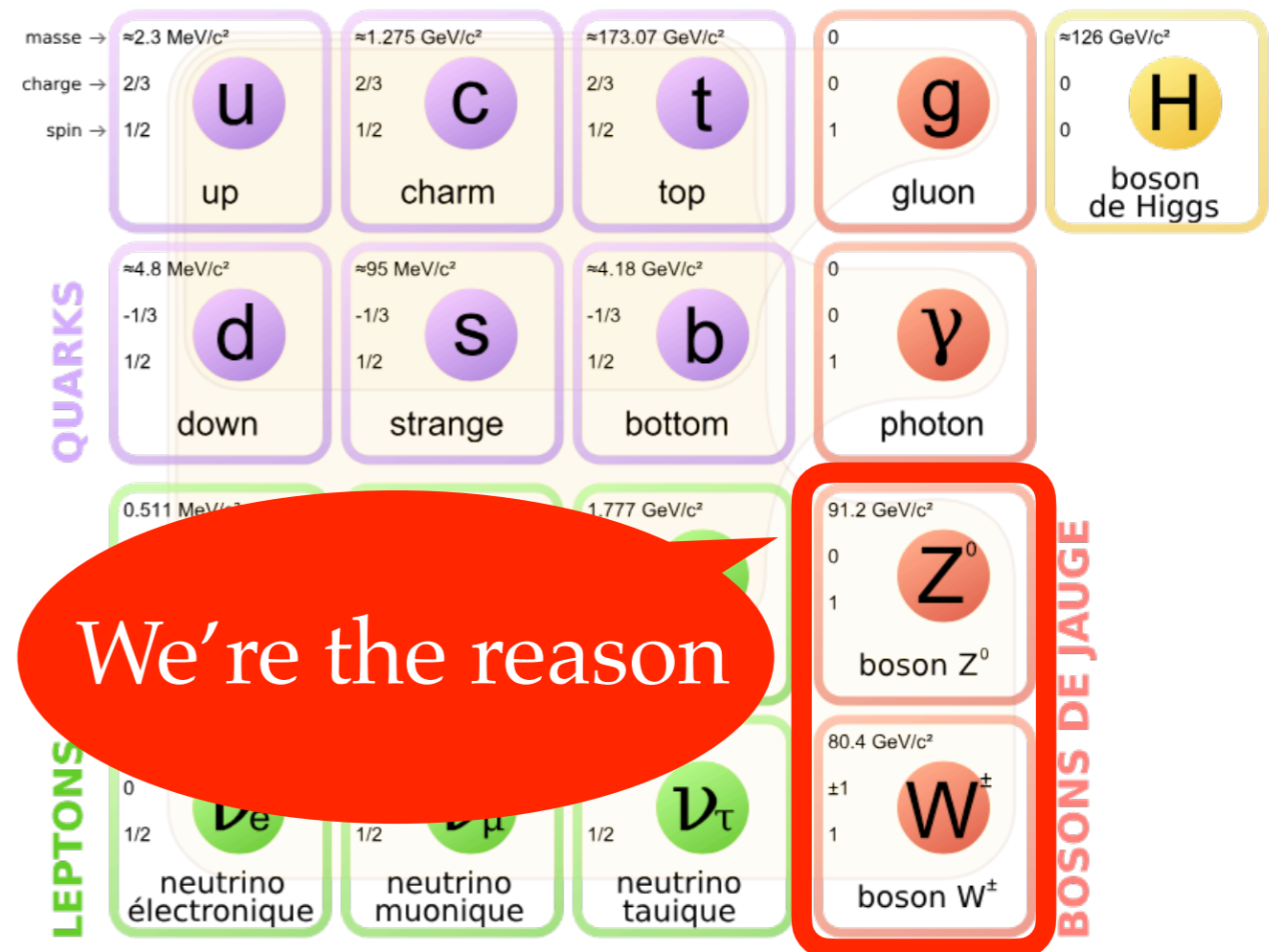


# Theoretical particle phenomenology at IPHC

Some ongoing projects :

- 1) consequences of the absence of CP violation from strong interactions

CP violation



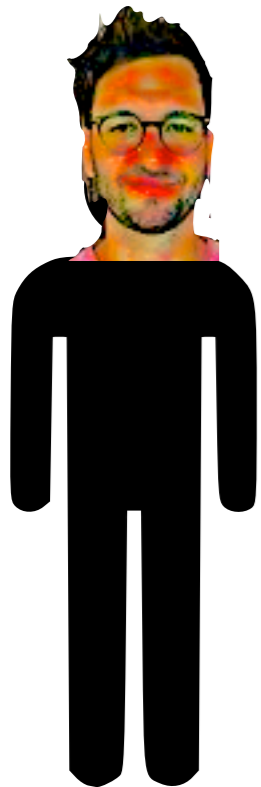
(the Standard Model particles)

# Theoretical particle phenomenology at IPHC

Some ongoing projects :

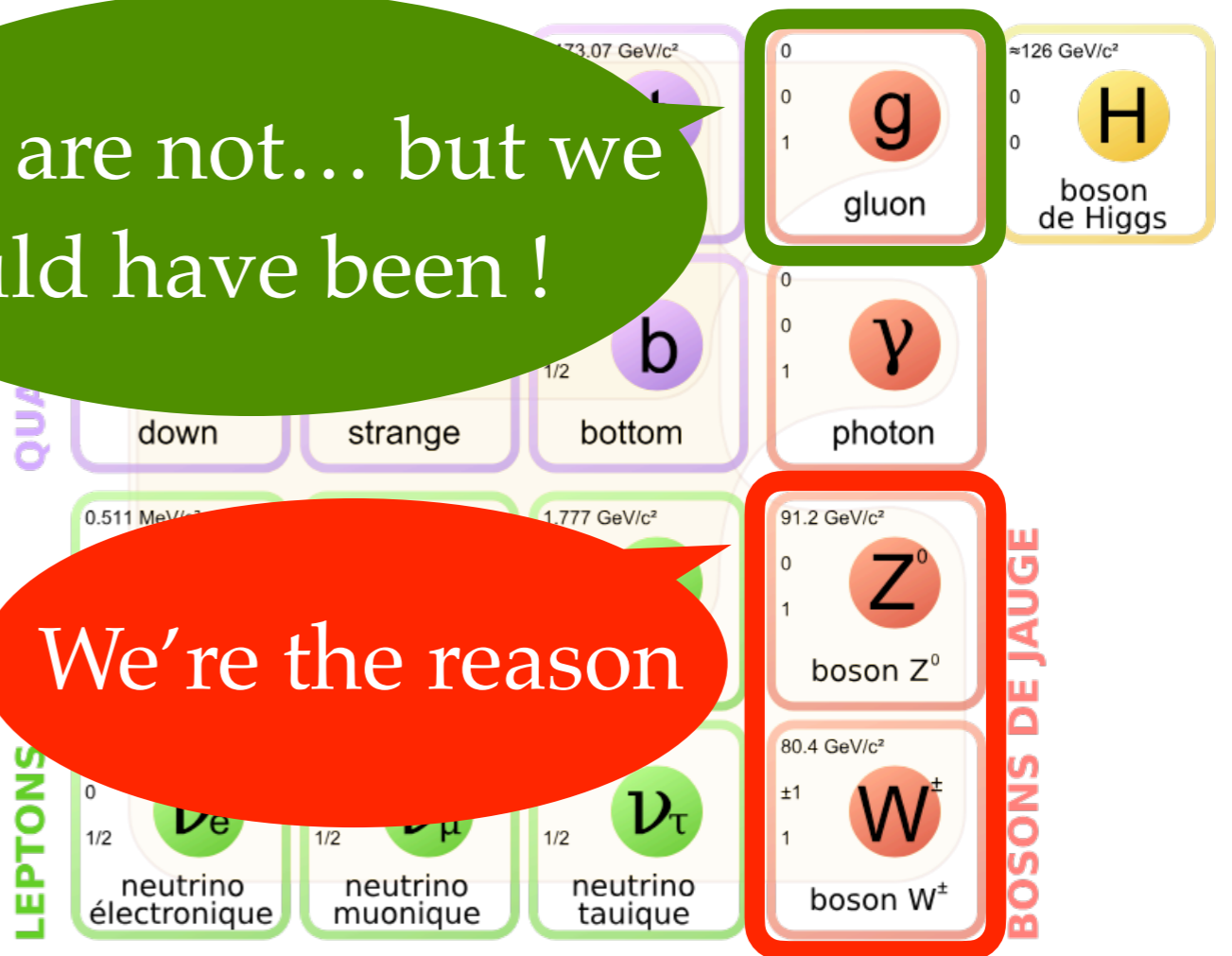
- 1) consequences of the absence of CP violation from strong interactions

CP violation



We are not... but we could have been !

We're the reason



(the Standard Model particles)



# Theoretical particle phenomenology at IPHC

Some ongoing projects :

- 1) consequences of the absence of CP violation  
from strong interactions

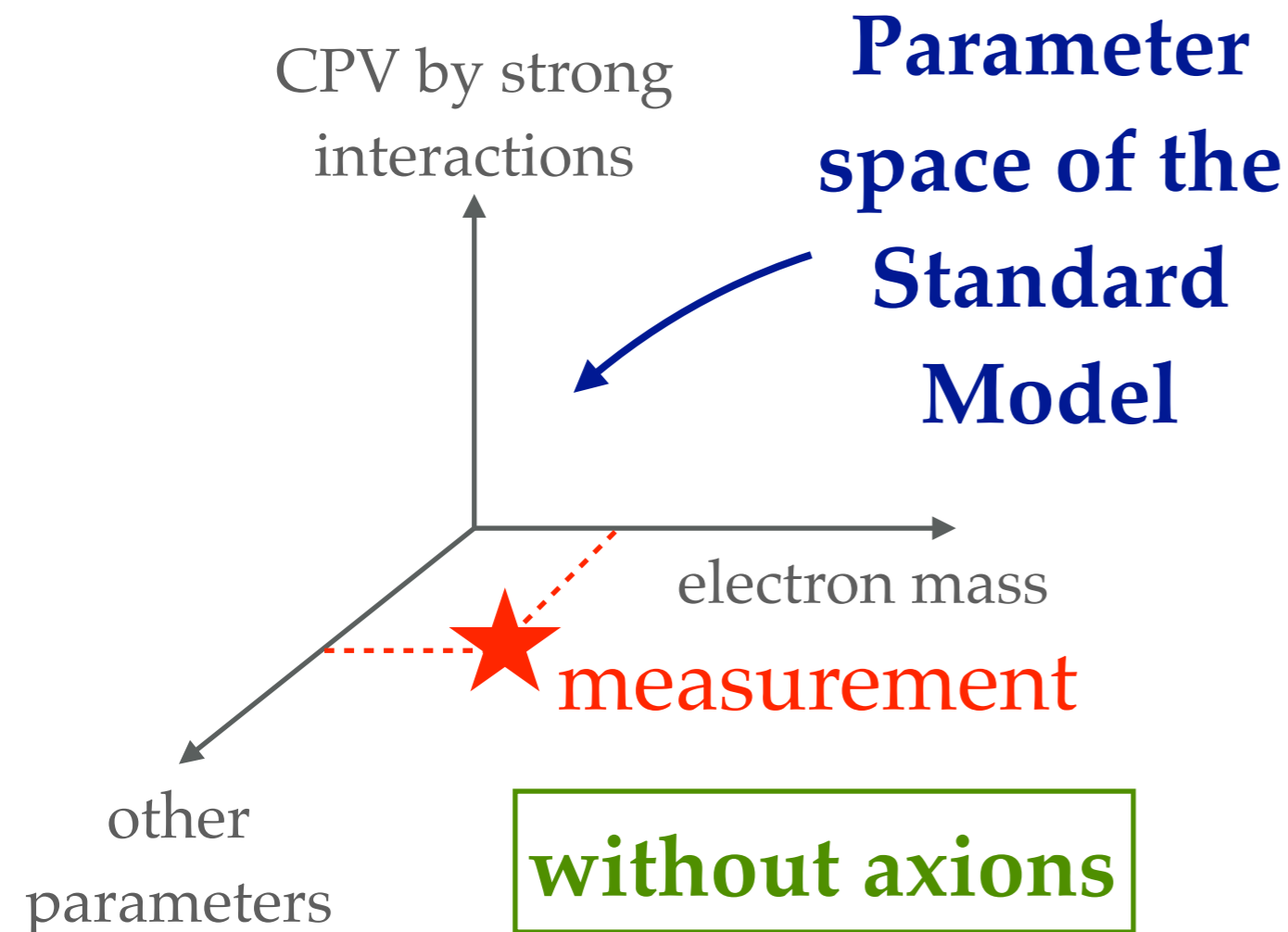
Two scenarios : a) axions

# Theoretical particle phenomenology at IPHC

Some ongoing projects :

- 1) consequences of the absence of CP violation from strong interactions

Two scenarios : a) axions

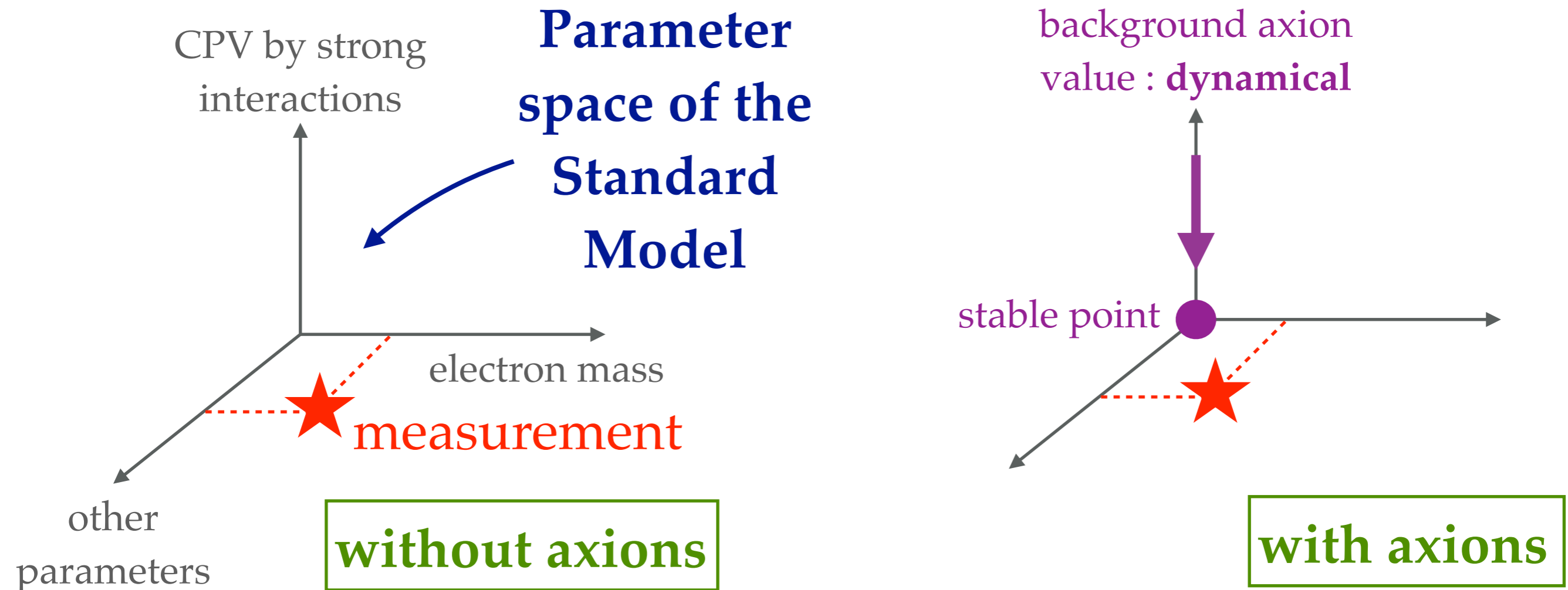


# Theoretical particle phenomenology at IPHC

Some ongoing projects :

1) consequences of the absence of CP violation  
from strong interactions

Two scenarios : a) axions



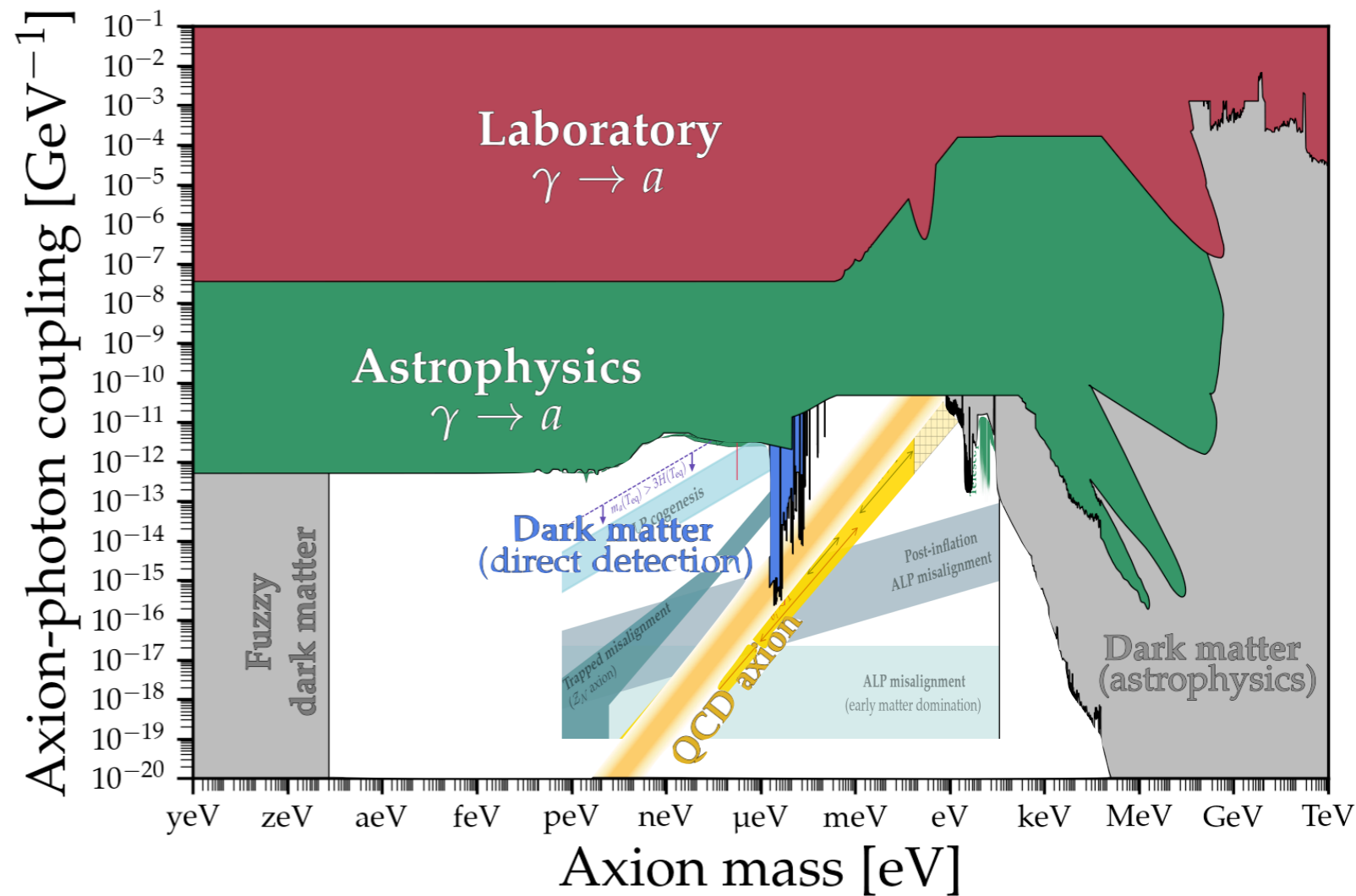


# Theoretical particle phenomenology at IPHC

Some ongoing projects :

1) consequences of the absence of CP violation  
from strong interactions

Two scenarios : a) axions



[Credit : C. O'Hare]

# Theoretical particle phenomenology at IPHC

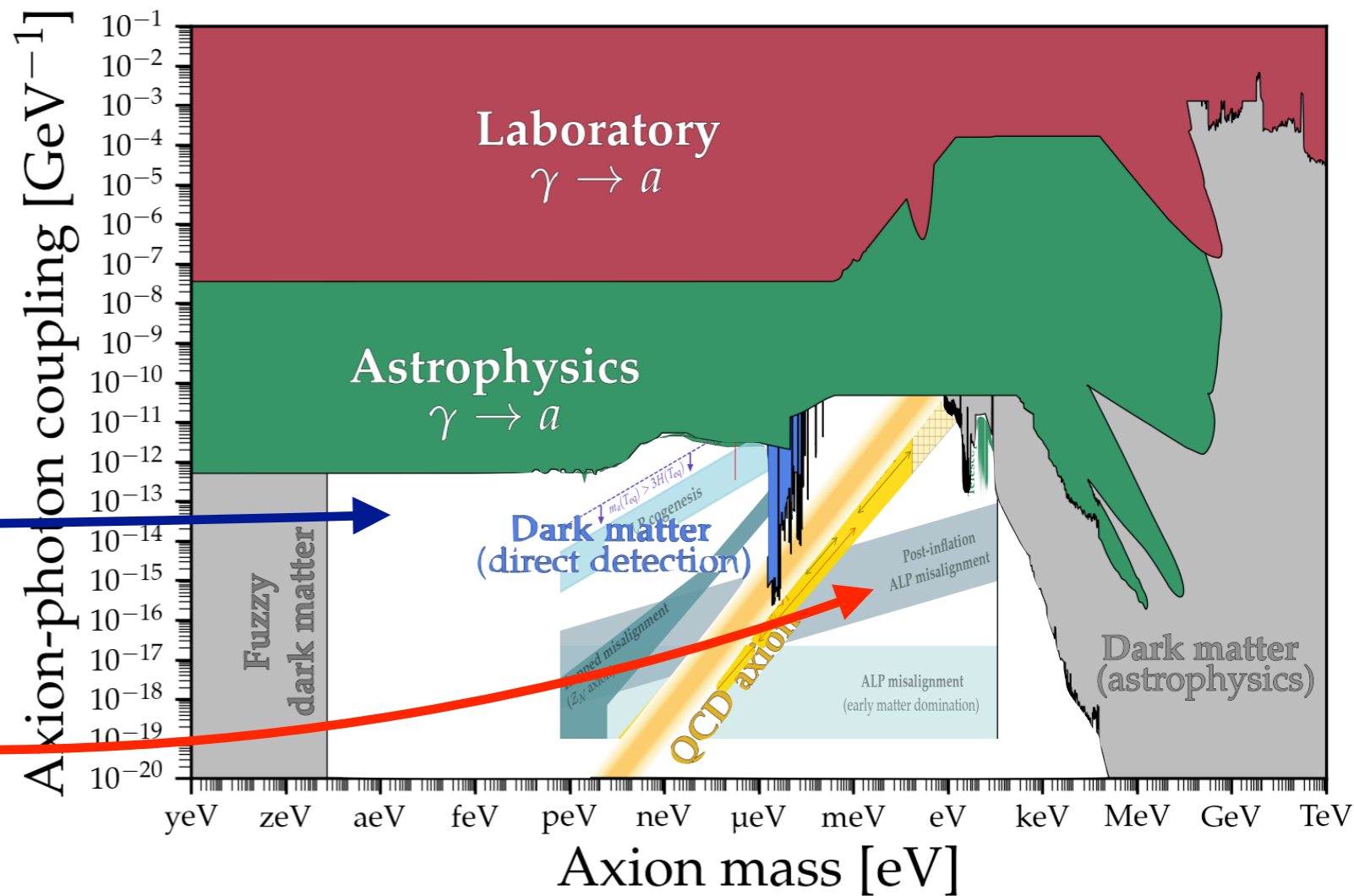
Some ongoing projects :

## 1) consequences of the absence of CP violation from strong interactions

Two scenarios : a) axions

Ex. of questions :

- are there models there ?
- how much larger can I make this region ?
- ...



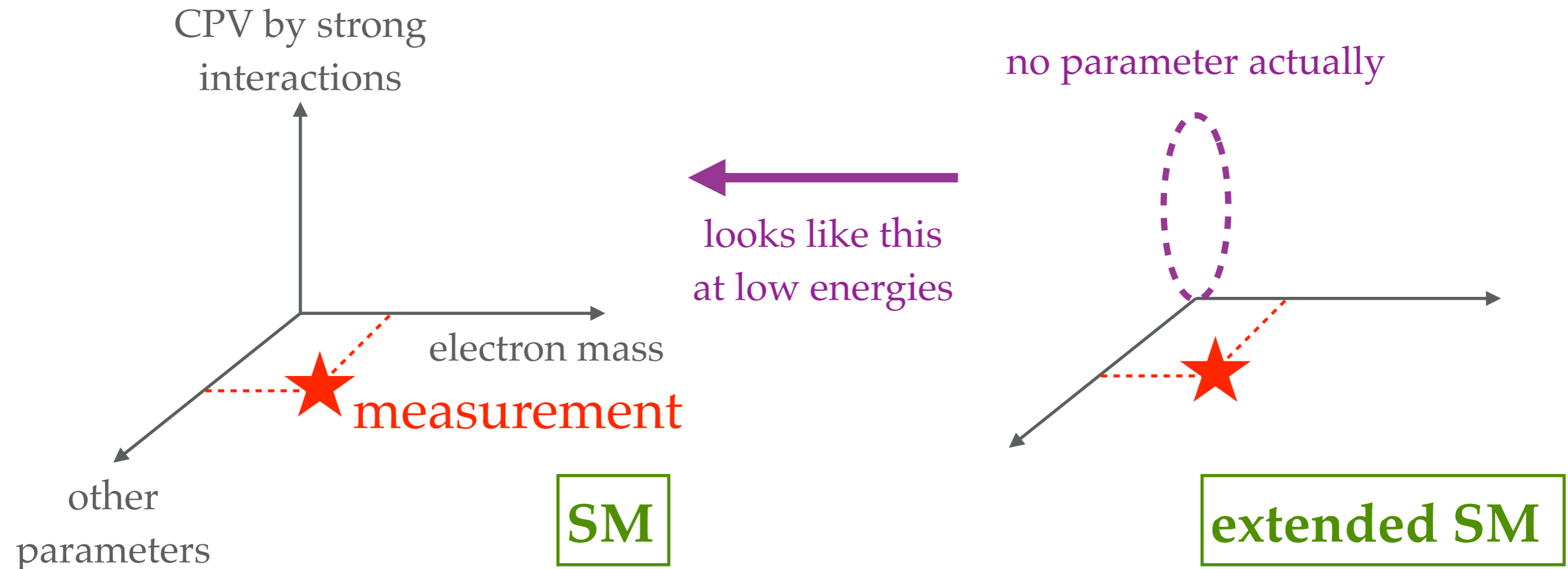
[Credit : C. O'Hare]

# Theoretical particle phenomenology at IPHC

Some ongoing projects :

1) consequences of the absence of CP violation  
from strong interactions

Two scenarios : b) (a kind of) extended Standard Models



# Theoretical particle phenomenology at IPHC

Some ongoing projects :

**1) consequences of the absence of CP violation  
from strong interactions**

Two scenarios : **b) (a kind of) extended Standard Models**

Ex. of questions :

- **new unavoidable collider probes ?**
- **insights on the flavor puzzle ?**
- **dark matter / baryogenesis candidates ?**

# Theoretical particle phenomenology at IPHC

Some ongoing projects :

- 1) consequences of the absence of CP violation  
from strong interactions
- 2) production of axion dark matter in the early universe
- 3) effective field theory parametrizations of  
low-energy phenomena
- 4) new structures in particle scatterings

...

**Questions ?**