Introduction to LHC Experiments

1. The criteria for theoretical physics
   - Prediction
   - Explanation
2. Abilities in judging experimental results
   - Necessary knowledge about experimental principle and detectors
   - Make experimentalist friends
3. LHC detectors
   - ATLAS
   - CMS
   - LHCb
   - ALICE
4. A necessary process for LHC
   - Accelerator (Collider)
   - Detectors

1. The Criteria for theoretical physics

- **Predictions**

  Proved by experiments and/or observations

- **Explanation**

  Results given by experiments and/or observations

The key is

“ experiments and/or observations ”

2. Abilities in judging experimental results

- **Necessary knowledge about experimental principles & detectors**
  - **how to identify the particles?**
  - **how to measure cross-sections?**
    (total, inclusive, exclusive)
  - **how to measure lifetime & partial widths etc?**
  - **how do the detectors work?**
    (abilities of the detectors & their shortcomings)

a. To identify the particles:

'Long life' charged particles: $e, \mu, \pi^{\pm}, K^{\pm}, P, \Sigma^{\pm}, \Xi$ etc

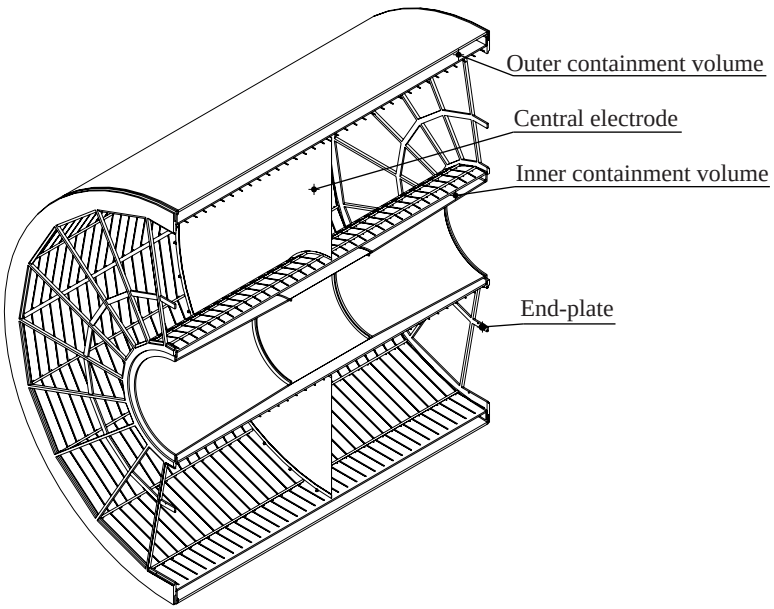
mass: $m^2=E^2-P^2$ (measure P, v, E)

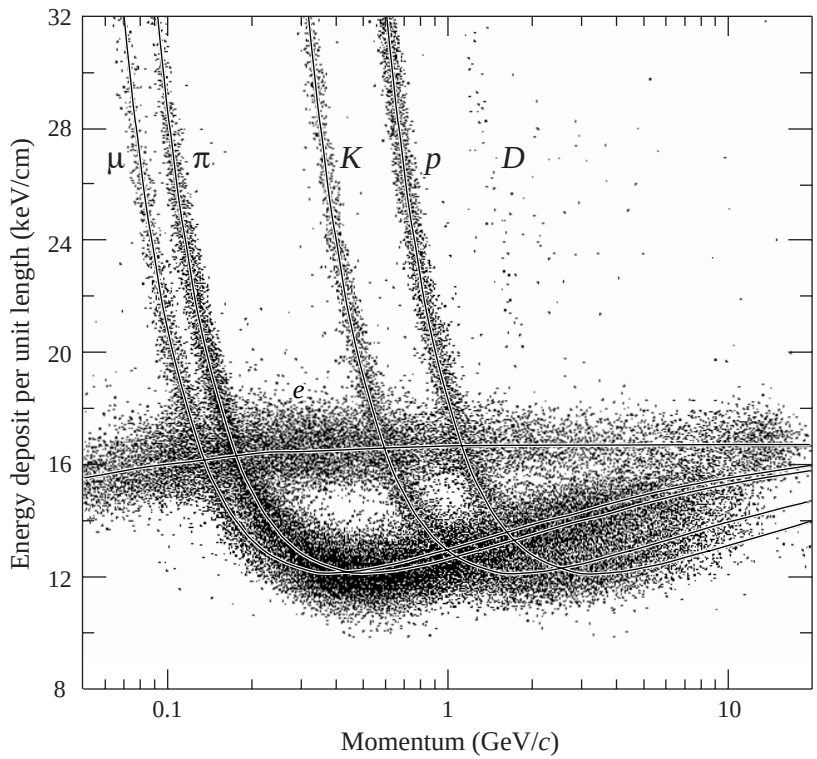
2. Abilities in judging experimental results

a. To identify the particles:

'Long life' charged particles: e, μ, $\pi^{\pm}$, $K^{\pm}$, P, $\Sigma^{\pm}$, Ξ etc

mass: $m^2=E^2-P^2$ (measure P, v, E)





2. Abilities in judging experimental results

Some 'long life' neutral particles: γ , η , K_s , Λ etc

mass: $m^2=E^2-P^2$ (measure P, v, E) but

$$K_s \to \pi^{\pm}\pi^{\mp} \qquad \Lambda \to P\pi^{-}$$

Some 'short life' particles: D, B mesons etc

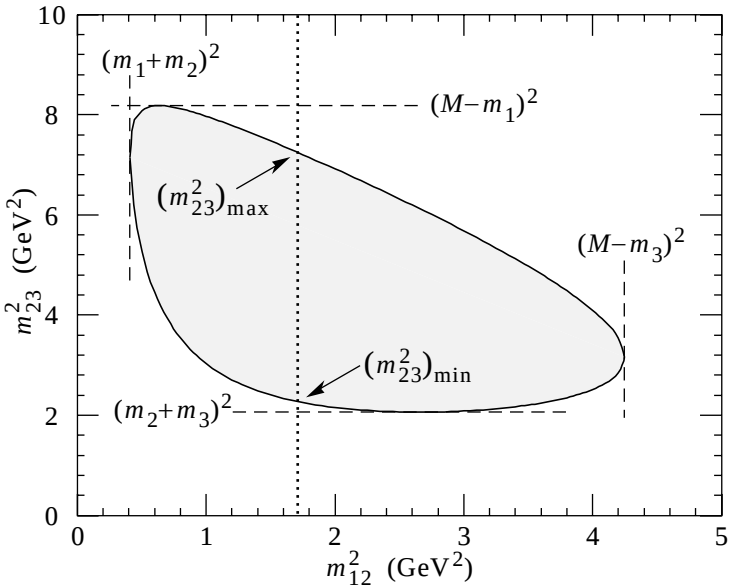
τ ~ ps, (vertex detector)

mass: $m^2=E^2-P^2$ (measure P, v, E) but

Some resonance particles: ρ , K^*, Δ etc

Dalitz plot $\psi \to \rho\ \pi \to \pi^+\pi^-\pi^0$

2. Abilities in judging experimental results



Dalitz plot $\psi \rightarrow K^{*+}K^- \rightarrow K^+K^-\pi^0$

To identify W, Z, Higgs, SUSY particle etc

$Z \rightarrow \mu\mu$, bb, etc

$H \rightarrow \mu\mu$, bb, $\tau\ \tau$, $\gamma\ \gamma$, W‘W’ etc, (discovery)

2. Abilities in judging experimental results

b. To measure cross-sections:

#(event number)= L (luminosity)• σ (cross-section)

difficulty → luminosity measurement

c. To measure τ (lifetime) or Γ (total width):

$(\tau \bullet \Gamma = \hbar)$

Modern techniques : $\Gamma > 10$ keV $(< 6.6 \bullet 10^{-20}$s)

$\tau > 0.1$ ps $(< 6.6 \bullet 10^{-3}$eV)

Therefore there is a blank gap

$0.1 \text{ ps} > \tau > 10^{-7}$ps (or 10 keV > $\Gamma > 10^{-2}$eV)

Note: lifetime is a statistics quantum number (proper time)!

d. To measure a partial width $\Gamma_i = \Gamma Br_i$:

Exp.:

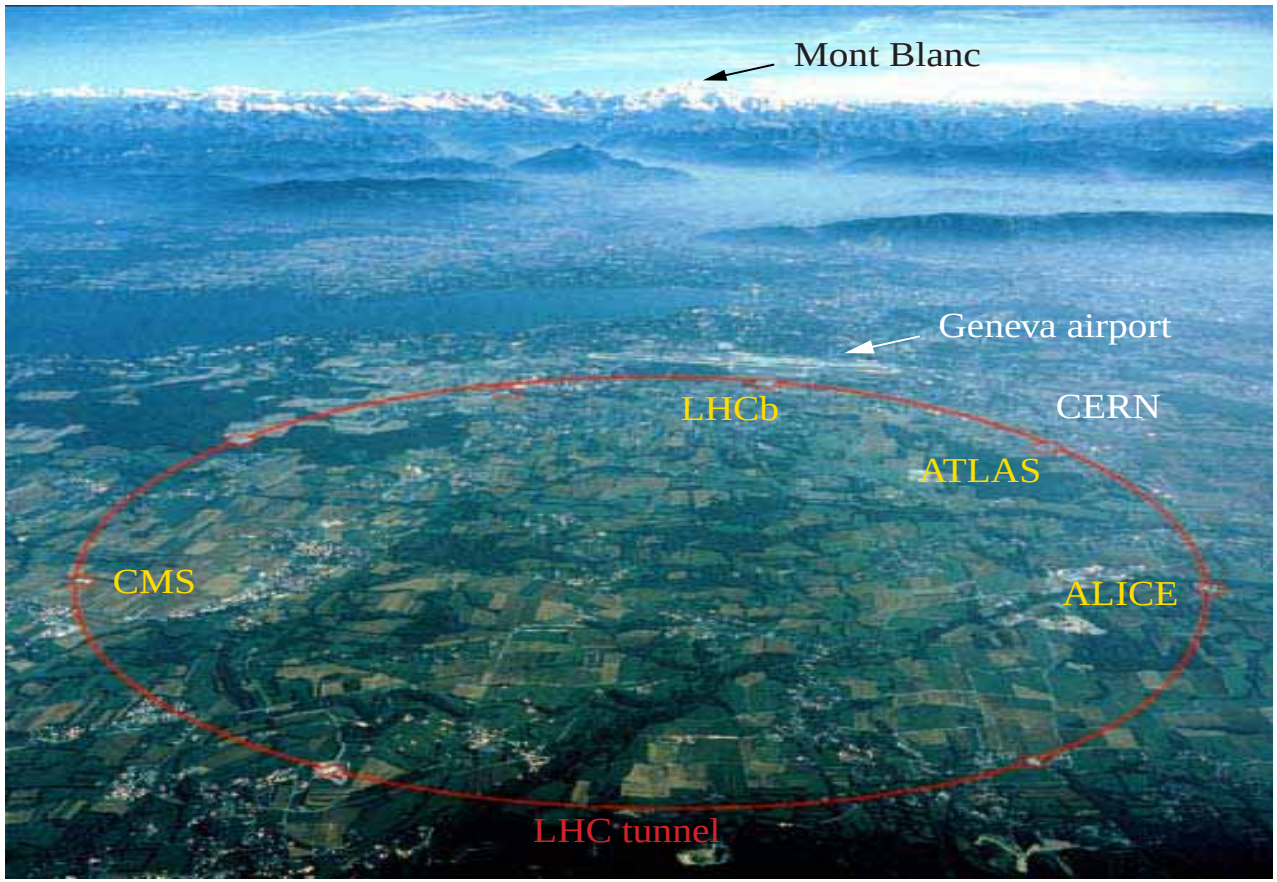
relative branching ratio Br_i/Br_0 **→ branching ratio** Br_i

2. Abilities in judging experimental results

- **Make experimentalist friends**

  Very important !

3. LHC detectors



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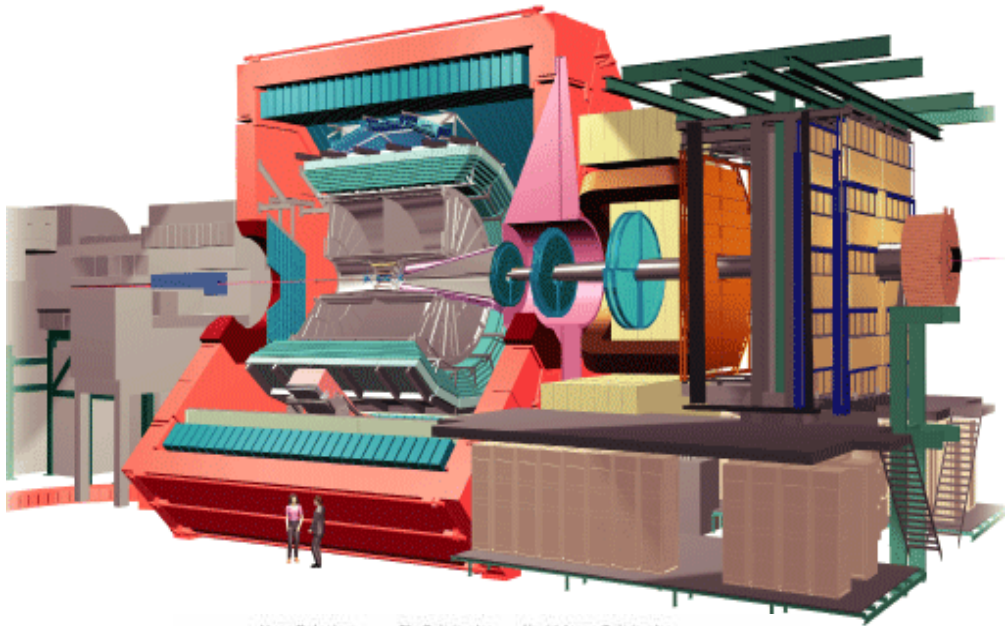
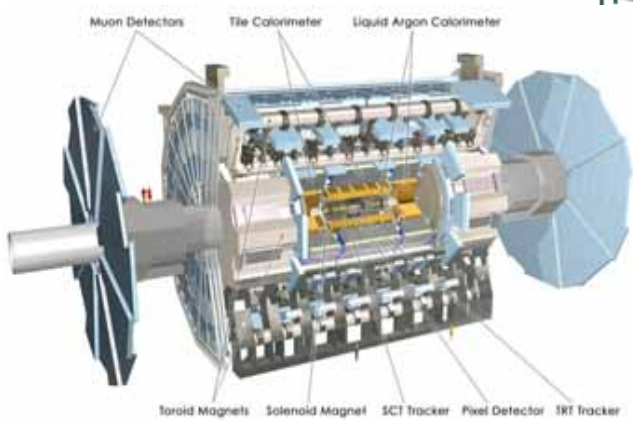
3. LHC detectors

ATLAS:

- **Higgs**
- **New particles**
- **New couplings**
- **etc**
- **(luminosity high)**



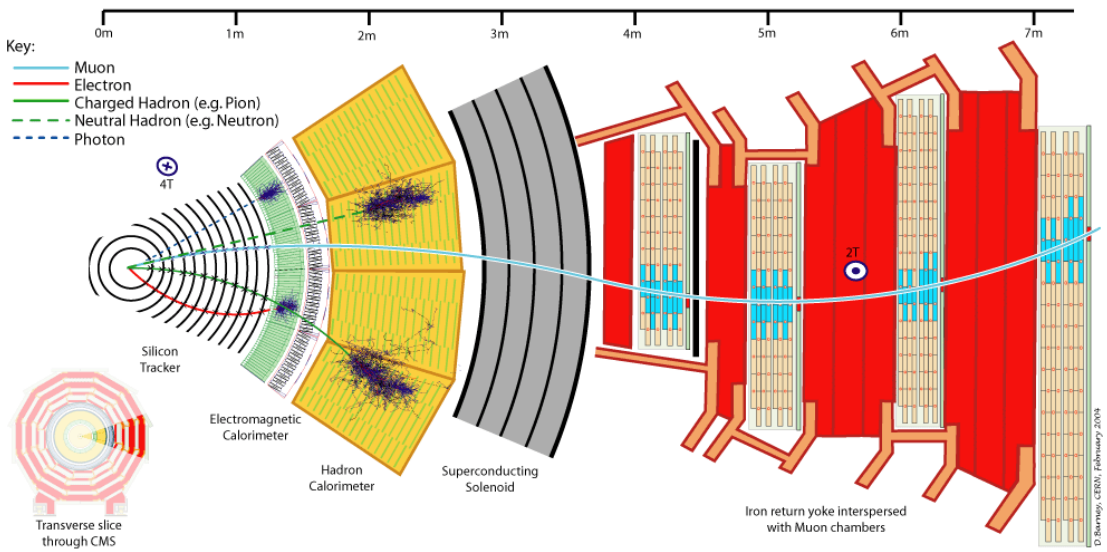


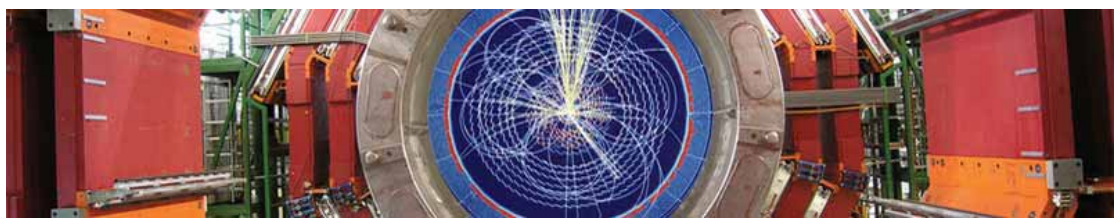
3. LHC detectors

CMS:

- Higgs
- New particles
- New couplings
- etc

(luminosity high)

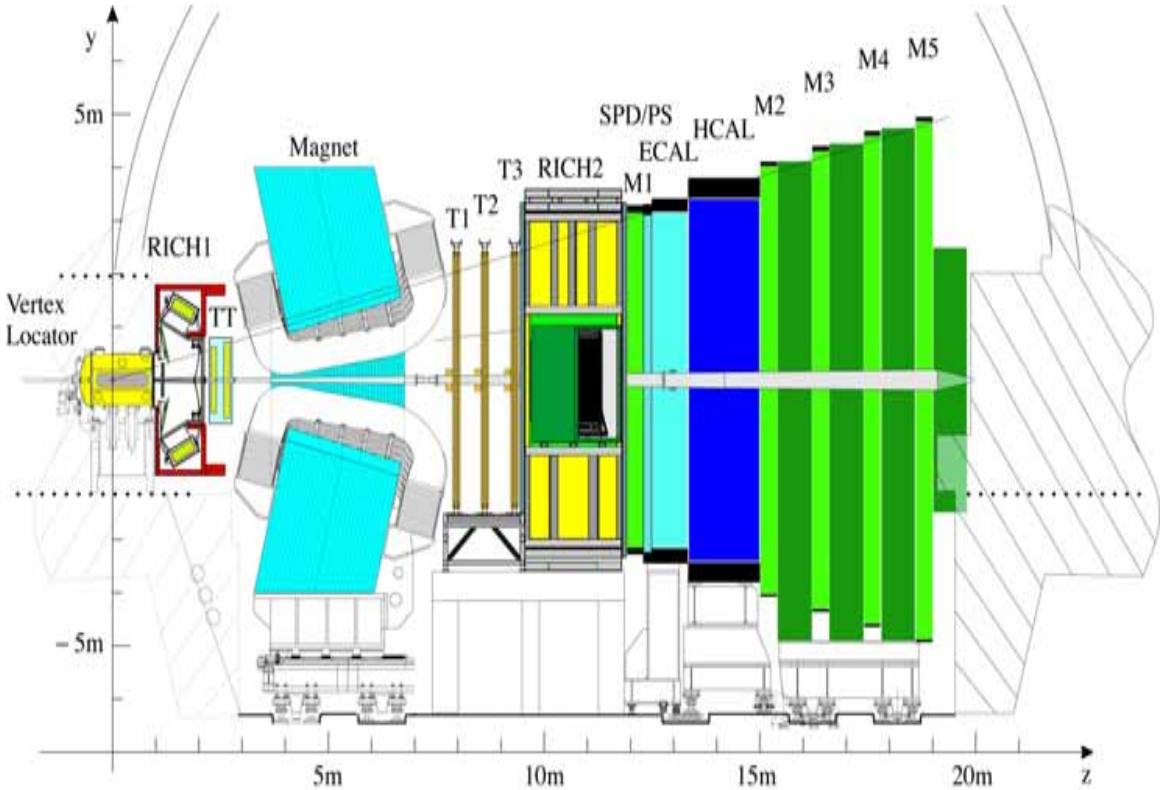




3. LHC detectors

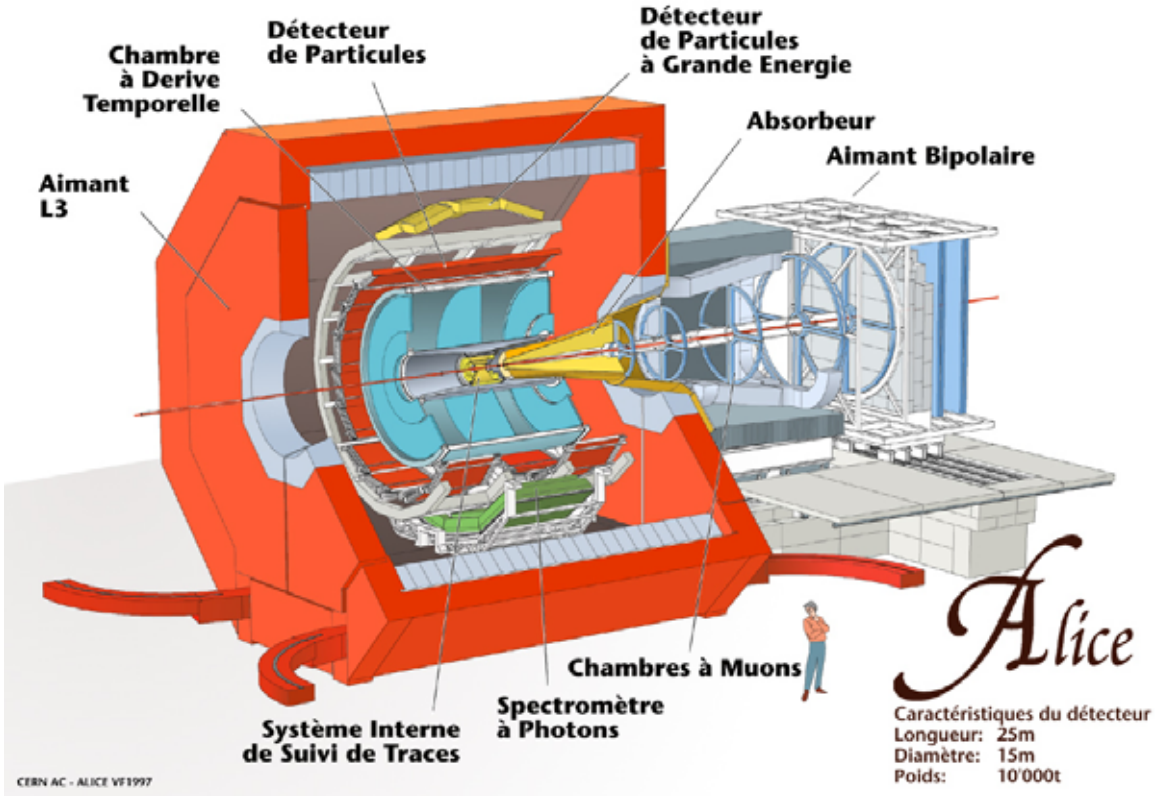
LHCb:

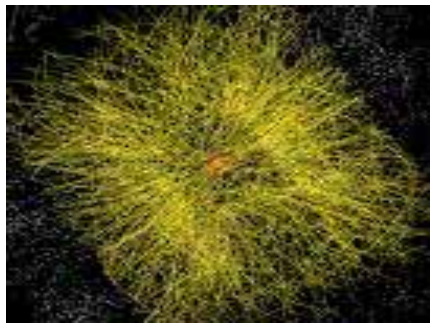
- **b-phys.**
- **CP-violation**
- **Bs**
- **Bc**
- **Λ_b, Ξ_b, etc**
- **Ξ_{cc}, Ξ_{cb}, etc**

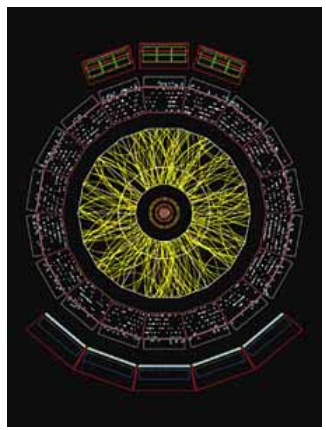


3. LHC detectors

ALICE: relativistic heavy iron, QGP, etc







Pb+Pb collision mode，Energy: 2.76 *TeV*/nucleon

3. LHC detectors

Physics: pQCD

Suppose we are interested in particle ‘c’:

$$d\sigma_{H_1H_2\to cX} = \sum_{ij} \int dx_1 \int dx_2 F^i_{H_1}(x_1,\mu_F^2) \times F^j_{H_2}(x_2,\mu_F^2) d\hat{\sigma}_{ij\to cX}(x_1,x_2,\mu_F^2,\mu^2,Q^2)$$

We do not know the specific C.S. energy and longitudinal momentum of the sub-process, unless we may measure the sub-process exclusively!

Therefore it is a great shortcoming at a hadron collider (as LHC) besides huge background in the environment, and it is why most measurements restrict themselves to observe P_T .

4. A necessary process for LHC

- **Accelerator (collider)**

  设计指标:

  能量14万亿电子伏特(*TeV*)的，高亮度（10^{34}厘米$^{-2}$秒$^{-1}$）

  目前到了12 月1 日，它的能量达到了2•1.18 万亿电子伏(2.36 *TeV*),仅仅能做到质子-质子对撞了。

- **Detectors**

Firstly :

To calibrate the detectors and test the soft ware for event reconstruction and physics analysis etc

4. A necessary process for LHC

- **Detectors (continue)**

To start with known physics at low luminosity so as to confirm the observations elsewhere and to understand the detectors and the soft wares well. Perhaps it takes years!

Then

New physics searches will be started with the energy and luminosity of the collider (LHC) being increased to accumulate enough events for the searches at high luminosity!

Thanks & good luck !