# Introduction to HEP

CMS Tutorials

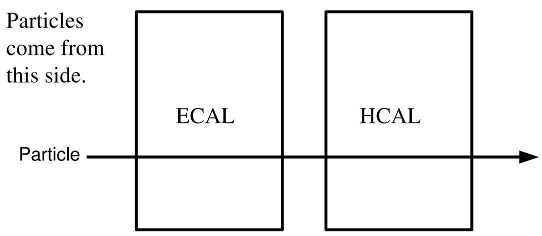
August 10, 2007

1. Why can't one see the "colored" particles, like quarks and gluons? What does the behavior of coupling strenght of the interaction (the "spring strenght") has to do with it?

2. List the possible interactions of each particle (strong, electromagnetic, weal):

   - photon
   - electron
   - muon
   - neutrino
   - gluon
   - quark
   - $Z$ boson
   - $W$ boson
   - $p$ (proton)
   - $n$ (neutron)
   - $\pi^0$ (neutral pion)
   - $\pi^+$ (charged pion)

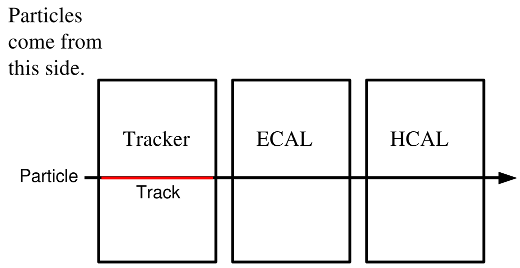
3. Suppose you have an EM calorimeter and a hadronic calorimeter (ECAL and HCAL), in this configuration:

   A particle *passes through* both of them. Which particle can it be?

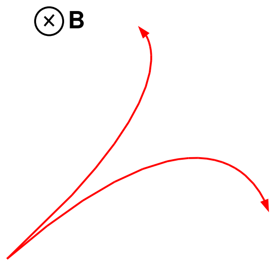
   (HINT: an electromagnetic interacting particle CAN pass through ECAL, if it's heavy enough. On the other hand, if it's too heavy, it is probably too unstable to survive long enough to pass through a calorimeter. No strong interacting particle passes through HCAL.)

   Now you put a Tracker before the ECAL, and the particle leaves a signal, like it is shown below. Can you pinpoint its identity now?




HINT: only charged particles leave a signal in the Tracker.)

4. You see the following signal in your Tracker:




What can you say about this event? (For instance, both tracks seem to be originating from a common point, and they have different senses of rotation. What can you deduce from that?)

5. Let's understand gauge invariance. Let $\phi = \phi(x)$ be a complex function of space

   - Let $H = m^2\phi\phi^* + (\nabla\phi)\cdot(\nabla\phi)^*$. Let $\phi \to \phi' = e^{i\alpha}\phi$, $\alpha$ a real constant. Does $H$ change?
   - Let $\phi \to \phi' = e^{i\alpha}\phi$, $\alpha = \alpha(x)$ a real function of space. Does $H$ change?
   - Suppose that, instead of $(\nabla\phi)\cdot(\nabla\phi)^*$, one had $(D\phi)\cdot(D\phi)^*$, where $D = \nabla + i\,A(x)$, $A(x)$ a real function of space. Let at the same time $\phi \to \phi' = e^{i\alpha}\phi$, $A \to A' = A - \nabla\alpha$, $\alpha = \alpha(x)$ a real function of space again. Does $H$ change? (HINT: try to see how $D\phi$ alone transforms into $D'\phi'$. It should be easy from that point.)
   - Expand the $(D\phi)\cdot(D\phi)^*$ term. Notice that terms including $A$, $\phi$, $\phi^*$ all at once appear. Those are the interaction terms. Notice that, if you were to impose that $H$ is invariant under those transformations (the *gauge transformations*) from the beginning, you could assert the form of the interactions from that invariance alone. Therefore, the presence of the gauge symmetry seems to dictates the dynamics.