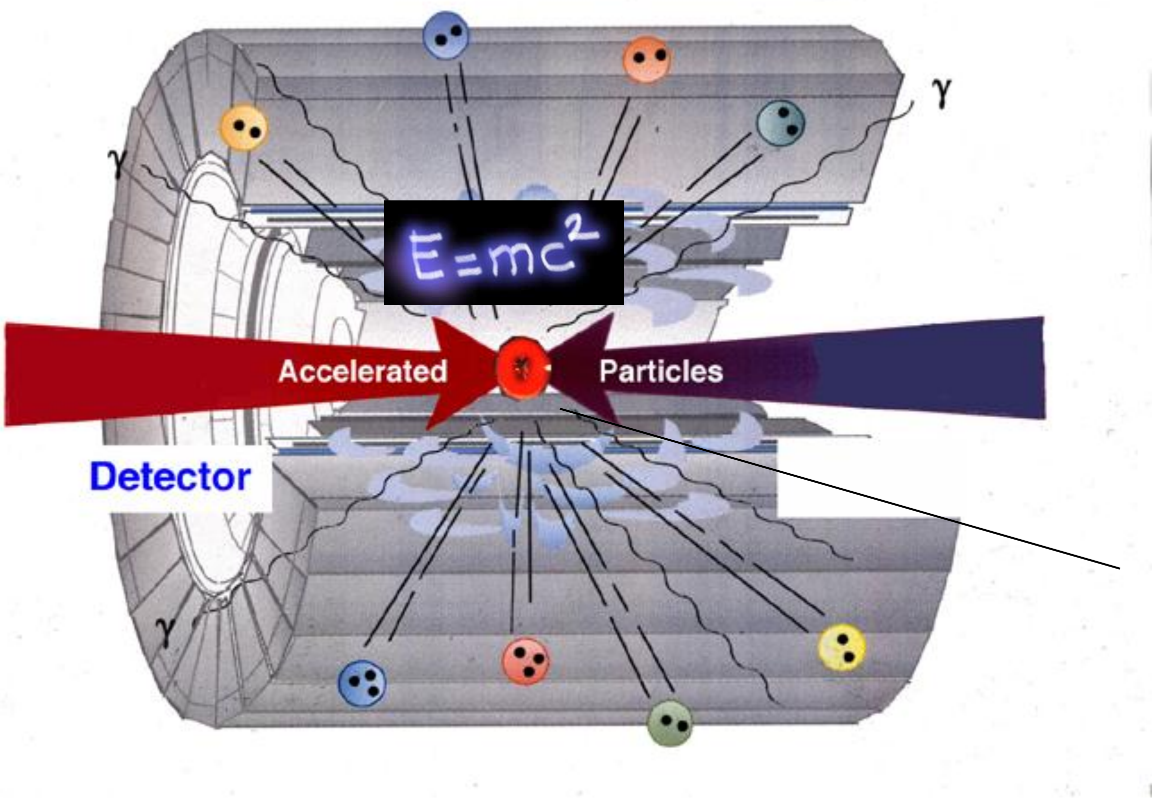
Search for strange particles in ALICE

Reminder : collision - production of particles
Role of detectors in their identification / detection
Result of a collision in ALICE
What are strange particles
Why are they interesting
How do we look for them - V0 / cascades
Topology -
    symmetric - asymmetric decay
    magnetic field - momentum
Kinematics - invariant mass
Concepts of : momentum, energy, mass
Particle ID : measurement of its mass

In ALICE : dE/dx, TOF, TRD, HMPID, muon chambers

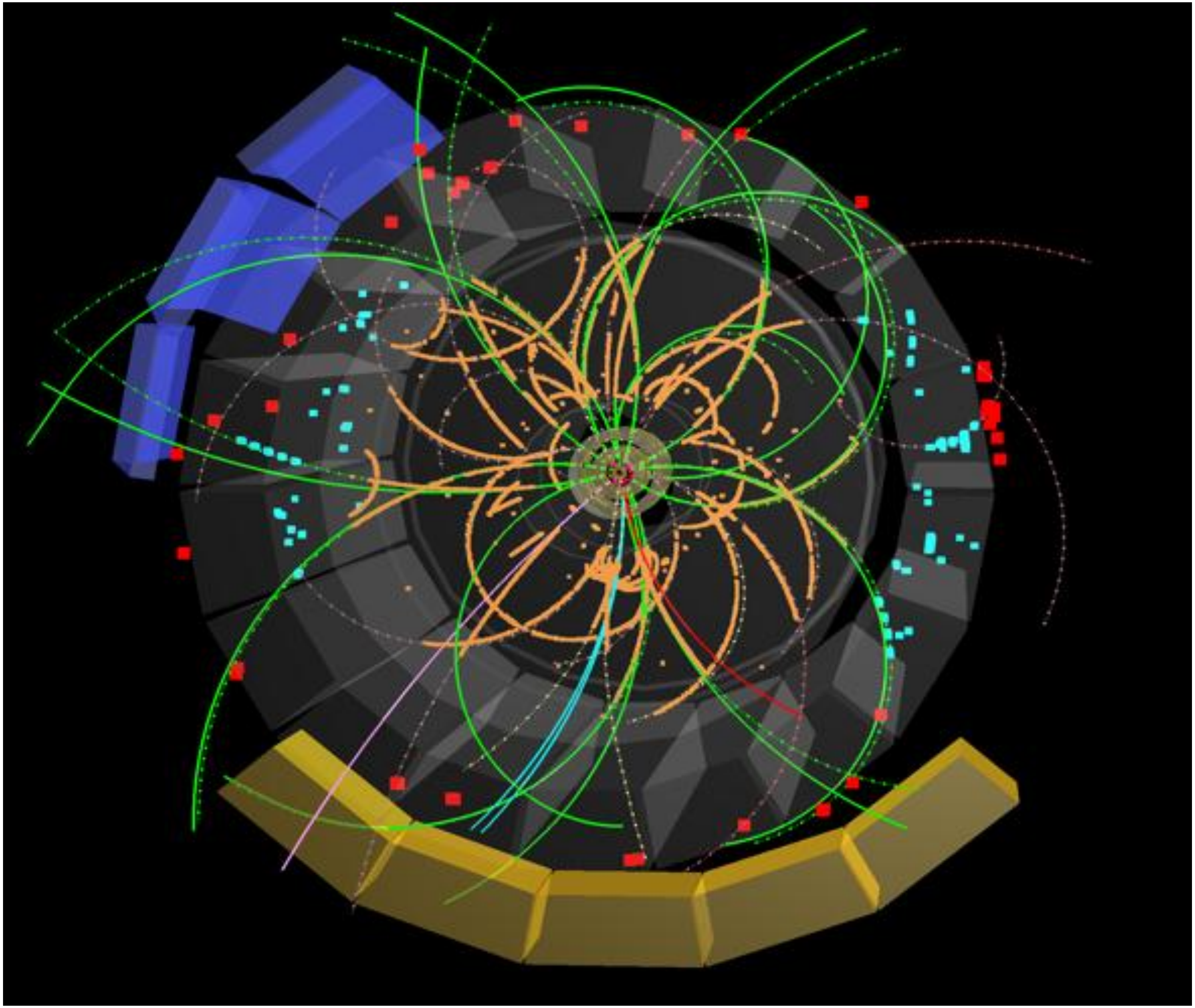
In particle physics we….



1) Concentrate energy on particles (**accelerator**)

2) **Collide** particles (recreate conditions after Big Bang)

3) Identify created particles in **Detector** (search for new clues)



Strange particles : particles containing strange quark(s)

We will be looking (mainly) for neutral strange particles

Meson☐

p$(u\bar{u})$

$Ks(d\bar{s})$

Baryon

$p(uud)$

$n(udd)$

L (uds) (Hyperon)

These particles travel some distance from the point of creation before they decay

$Ks \rightarrow \pi + \pi -$

$\Lambda \rightarrow p\pi -$

$\bar{\Lambda} \rightarrow \bar{p}\pi +$

Λ : $\tau = 2.6 \times 10^{-10}$ s; $c\tau = 3\times10^{10}$ cm $s^{-1} \times 2.6\times10^{-10}$ s = 7.8 cm

$c\tau = 3\times10^{10}$ cm $s^{-1} \times 10^{-9}$ s = 3 cm distance from interaction point

$c\tau = 3\times10^{10}$ cm $s^{-1} \times 10^{-9}$ s = 3 cm

these decays are weak decays

Conservation laws

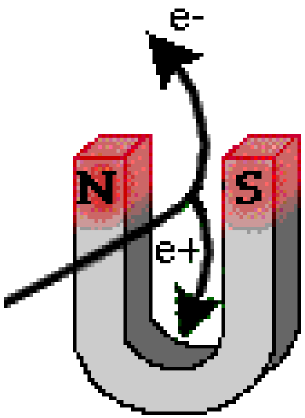
electric charge q conserved

strangeness conserved in strong decays ($\Delta S = 0$) $\tau = 10^{-23}$ s

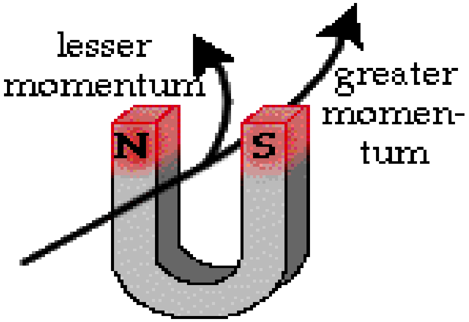
$\Delta S = 0$ or $\Delta s=1$ in weak decays : (here $\Delta S=1$) $\tau = 10^{-8}$ s - 10^{-10} s

Baryon number is conserved

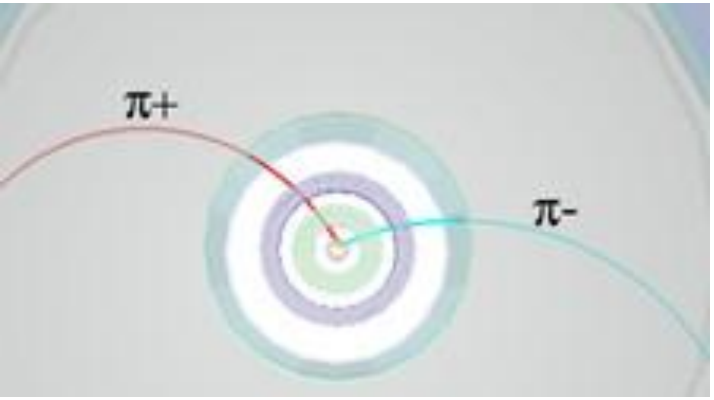
Charge inside a magnetic field



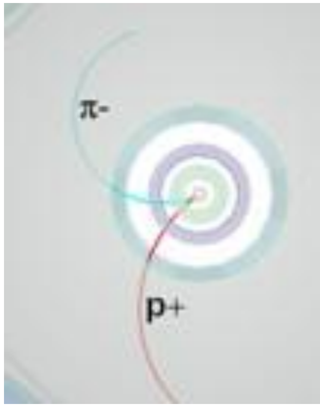
Identify the charge



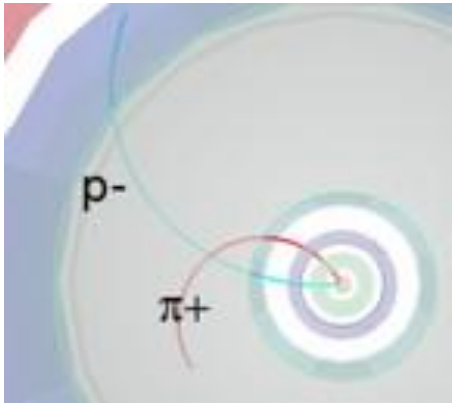
Measure the momentum



$K^0_s \rightarrow \pi^+\pi^-$

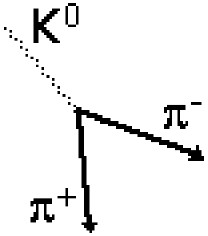


$\Lambda \rightarrow \pi p$



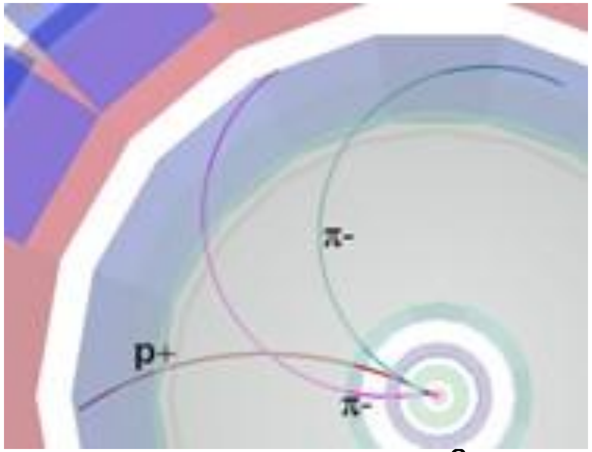
anti $\Lambda \rightarrow p^- + \pi^+$

$K^0 \rightarrow \pi^+ + \pi^-$

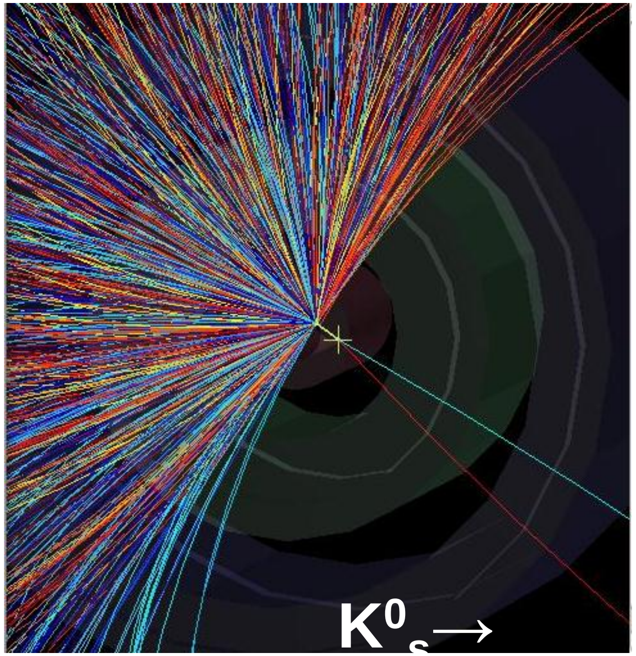


V0 decay :
a neutral particle (no track) gives suddenly two tracks

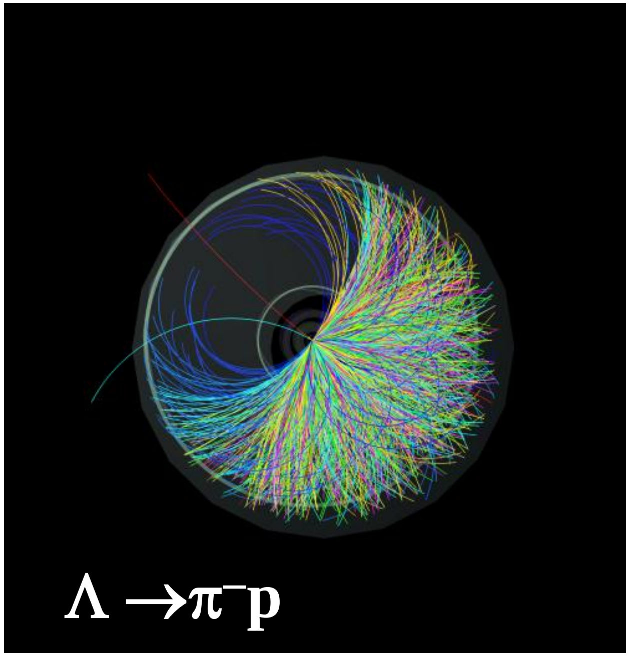
Cascade : A charges particle followed by a V0



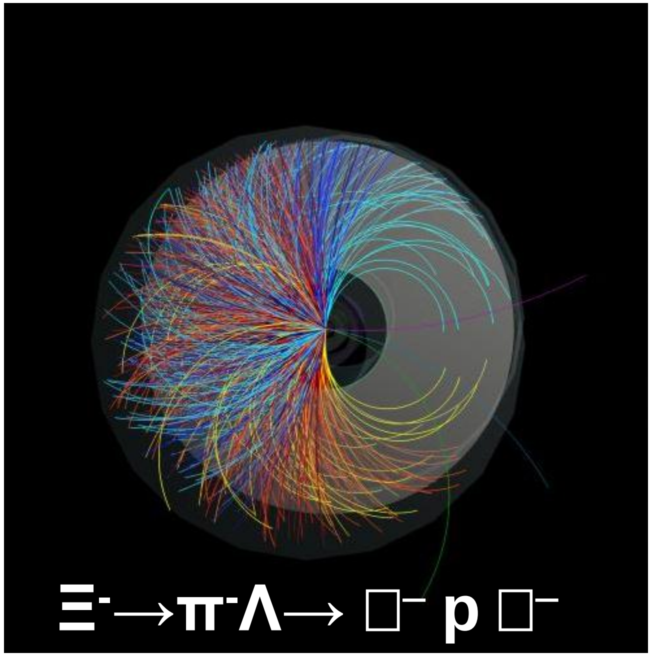
$\Xi^- \rightarrow \pi^-\Lambda \rightarrow \pi^- p + \pi^-$



$K^0_s \rightarrow$



$\Lambda \rightarrow \pi^- p$



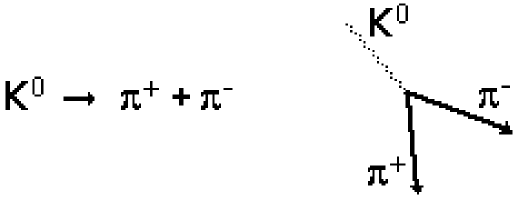
$\Xi^- \rightarrow \pi^- \Lambda \rightarrow$ □⁻ p □⁻

event displays from lead lead collisions

Invariant mass

Conservation of energy $E = E_1+E_2$
Conservation of momentum $\mathbf{p} = \mathbf{p}_1+\mathbf{p}_2$ **p** ; vector p=|**p**| vector length
Total energy of moving particle $E^2 = p^2c^2 + m^2c^4$
with the assumption that c=1 $E^2 = p^2 + m^2$

We can calculate the mass of the mother particle from



$$m^2 = E^2 - p^2 = (E_1+E_2)^2 - (p_1+p_2)^2$$
$$= \quad = m_1^2 + m_2^2 + 2E_1E_2 - 2\,\mathbf{p}_1 . \mathbf{p}_2$$

Find mass of mother particle from masses and momenta of decay products

How do we know the momentum?

Measure from curvature of track in magnetic field

How do we know the mass?
Particle identification done by a number of detectors

In case you want to explain what momentum is..

Supposing a mosquito approaches you with the velocity of 40 km/h. Even a collision would hardly affect you. However, if a truck was to approach you with the same velocity, it could be fatal. It naturally, is because of the truck's mass. However, it is not only mass that plays a role here. If it were, a truck standing still would've scared you too. Hence, an important property here is the product of mass and velocity. This product is known as momentum.

$p = m\upsilon$

$$E = \sqrt{(mc^2)^2 + (pc)^2}$$

C=1

$E^2 = p^2 + m^2$

Units

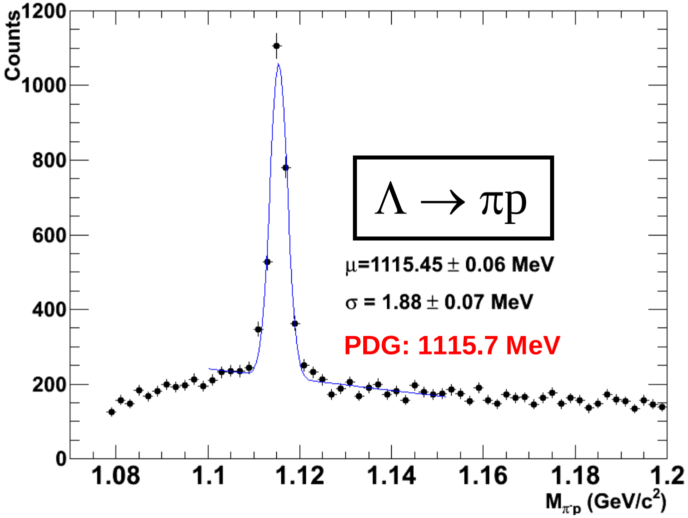
Kinetic energy of an electron accelerated by a potential difference of 1 Volt.
E = qV = 1 (elementary charge; 1.6 x10^{-19} Cb) x 1 V = 1 eV = 1.6x10^{-19} Joule

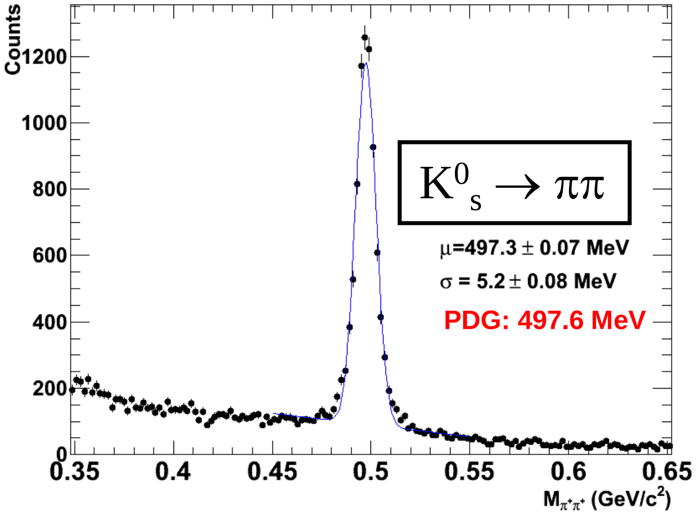
Energy E : (eV, keV), MeV, GeV, TeV
Mass (mc^2) : (eV, keV), MeV, GeV, TeV
Momentum (pc) : (eV, keV), MeV, GeV, TeV

Invariant mass distributions

Natural width
Heisenberg’s uncertainty principle
(quantum mechanics)

$$\Delta x \, \Delta p \geq \frac{\hbar}{2} \qquad \Delta E \Delta t \gtrsim h,$$





Width due to limits of the measurements

Momentum resolution
Energy resolution

V0 analysis basics

Λ^0(uds)

m = 1115.683 ± 0.006 MeV

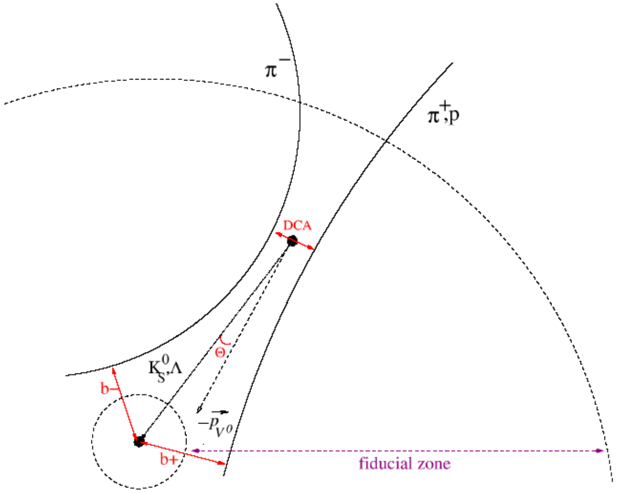
<τ> = (2.632 ± 0.020)x10^{-10} s

cτ = 7.89 cm

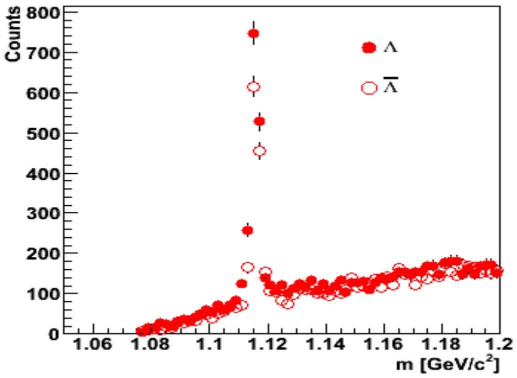
Λ -> pπ^- (~64 %)

-> Nπ^0 (~35.8 %)

-> nγ (~1.75x10^{-3} %)



$$m_{inv} = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$$



Summary

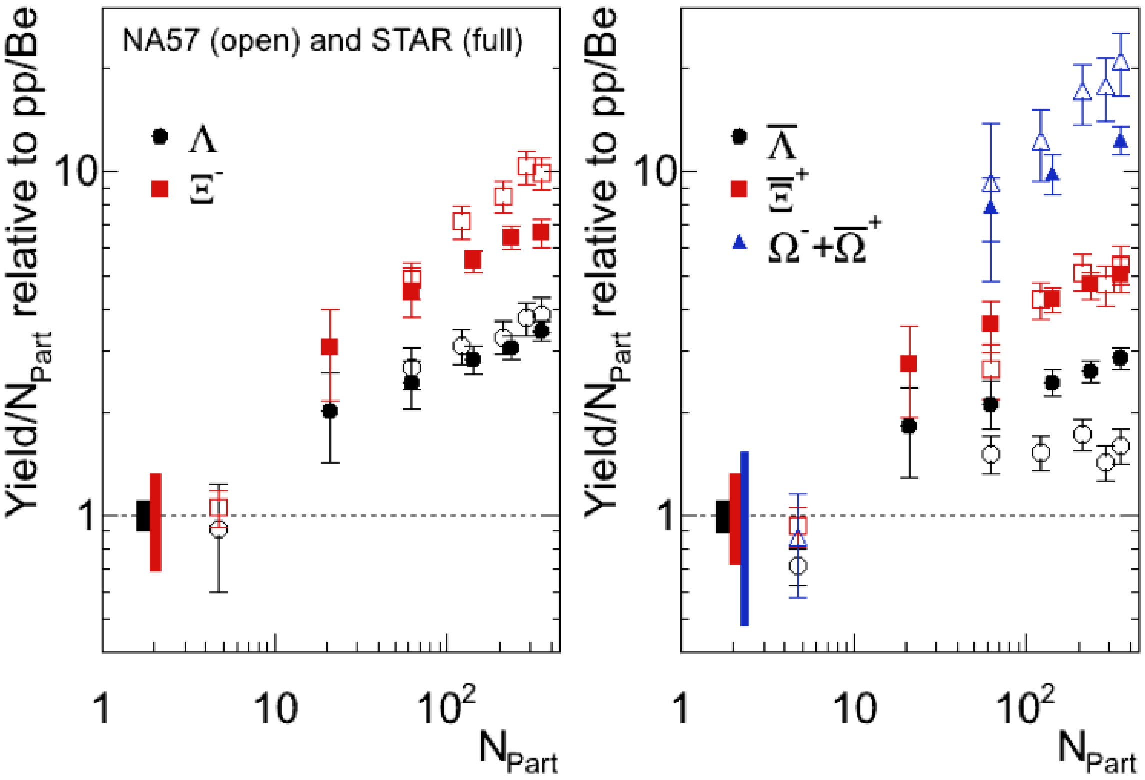
Analyse 30 events

Find the K, Λ, and anti-Λ – and count them(visual identification + invariant mass)

The ratio strange/non strange particles gives us an indication of the creation or not Of the Quark Gluon Plasma

Strangeness enhancement

defined as: the particle yield normalised by the number of participating nucleons in the collision, and divided by the observed yield in proton-beryllium (or proton-proton) collisions



Enhancement increases with number of strange quarks in the hadron (Ω has 3, Ξ has 2, Λ has 1)

Enhancement decreases with collision energy (going from SPS to RHIC)..and at the LHC?