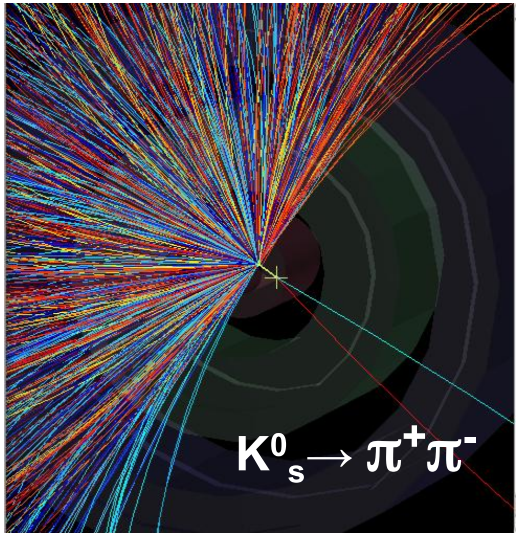
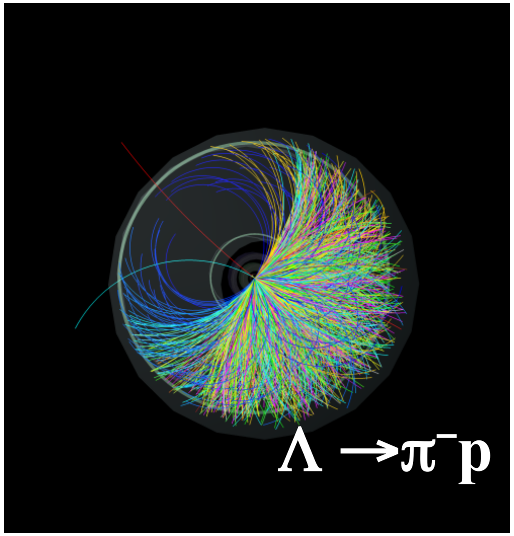
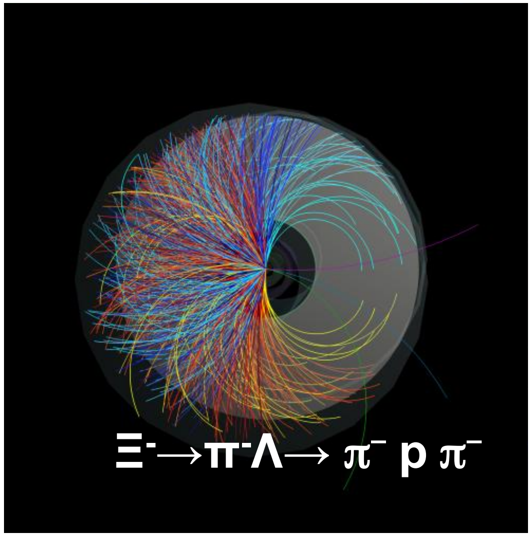
Exploring particles at school with ALICE
(Looking for strange particles in ALICE)







What are strange particles ?

Hadrons (baryons or mesons) containing at least one strange quark (s)

We will be looking for neutral strange particles, which travel some distance (mm or cm) from the point of production before they decay

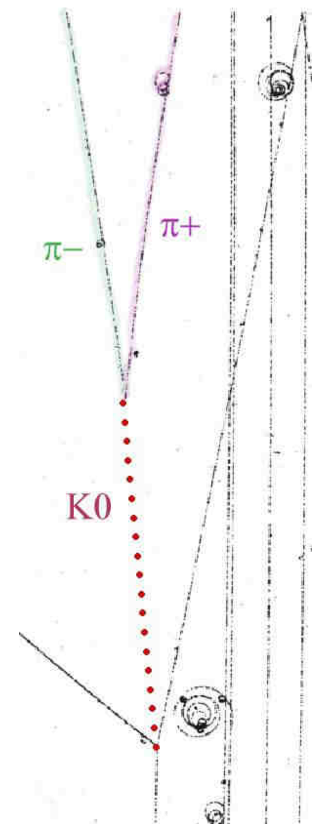
$K^0_s \rightarrow \pi^+\pi^-$

$\tau = 0.89 \times 10^{-10}$ s
$c\tau = 3 \times 10^{10}$ cm s^{-1} $\times 8.9 \times 10^{-11}$ s
2.67 cm from the point of interaction

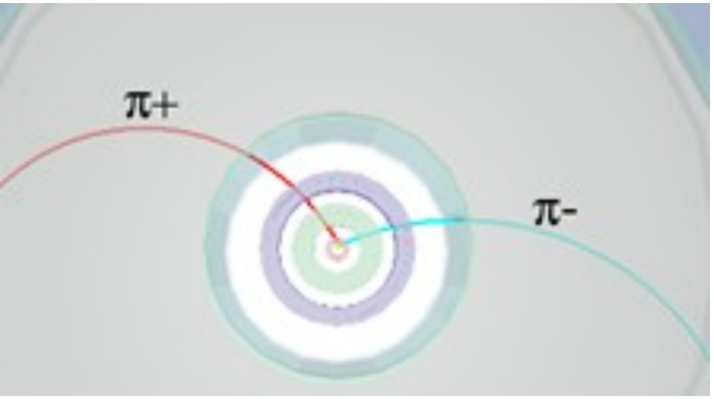
$\Lambda \rightarrow \pi^- p$

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

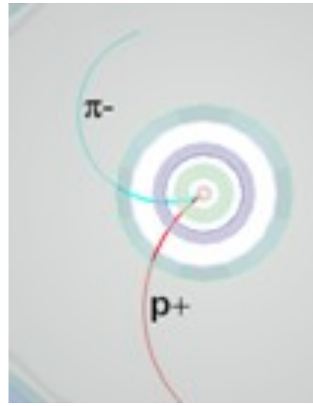
$\tau = 2.6 \times 10^{-10}$ s
$c\tau = 3 \times 10^{10}$ cm s^{-1} $\times 2.6 \times 10^{-10}$ s
7.2 cm distance from the point of interaction



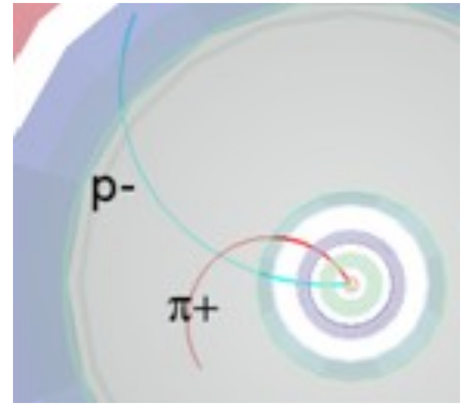
Weak deacays : strangeness is not conserved



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

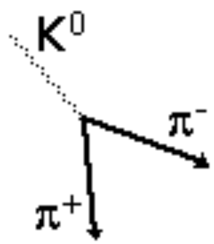


$\Lambda \to \pi^- p^+$



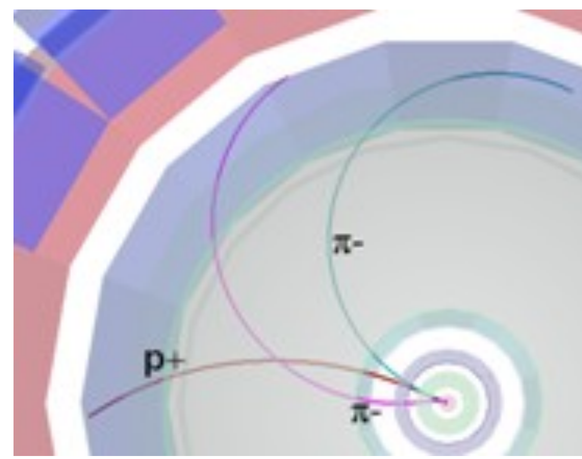
anti $\Lambda \to p^- \pi^+$

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



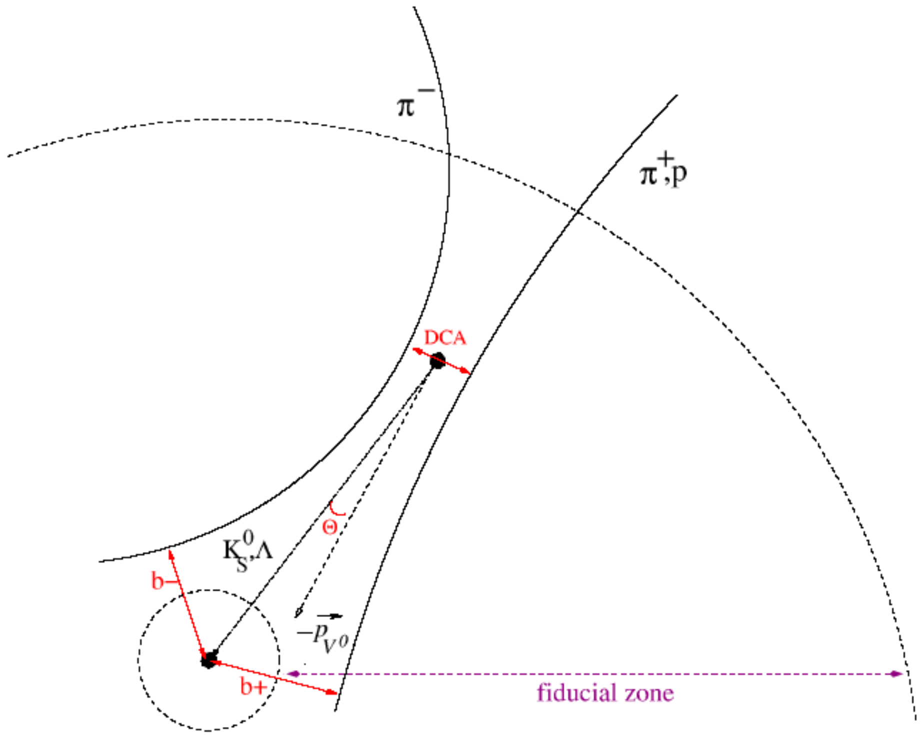
V0 decay :
a neutral particle (no track) gives suddenly two tracks

Cascade : A charged particle followed by a V0



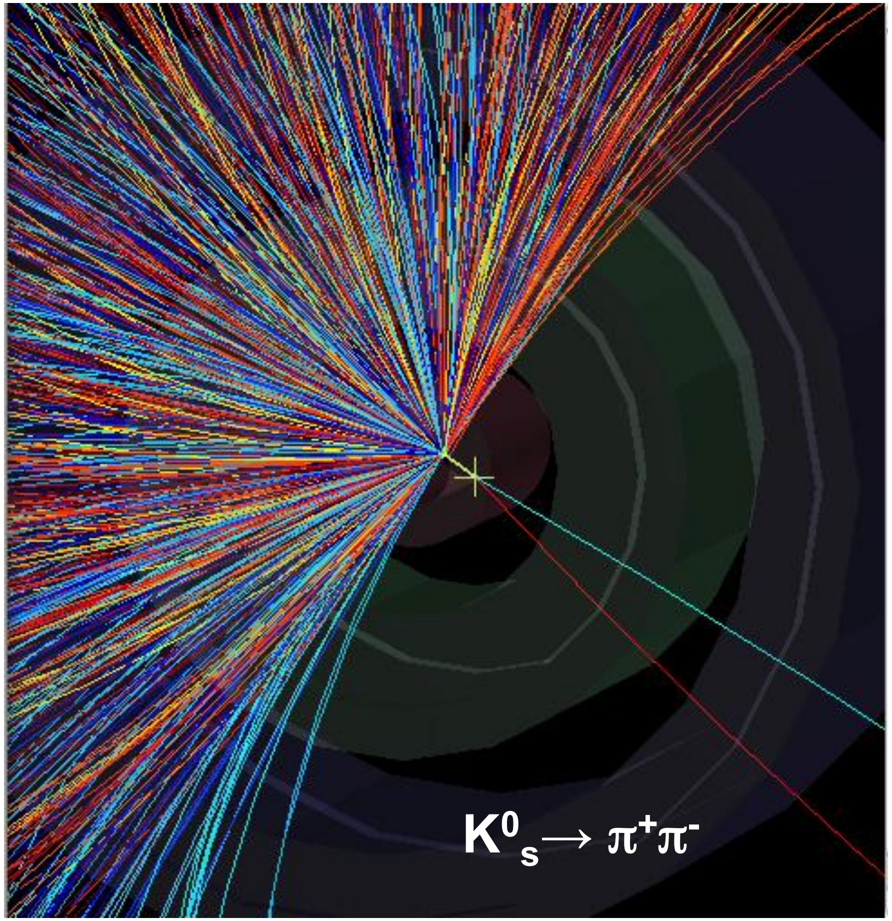
$\Xi^- \to \pi^- \Lambda \to \pi^- \; p + \pi^-$

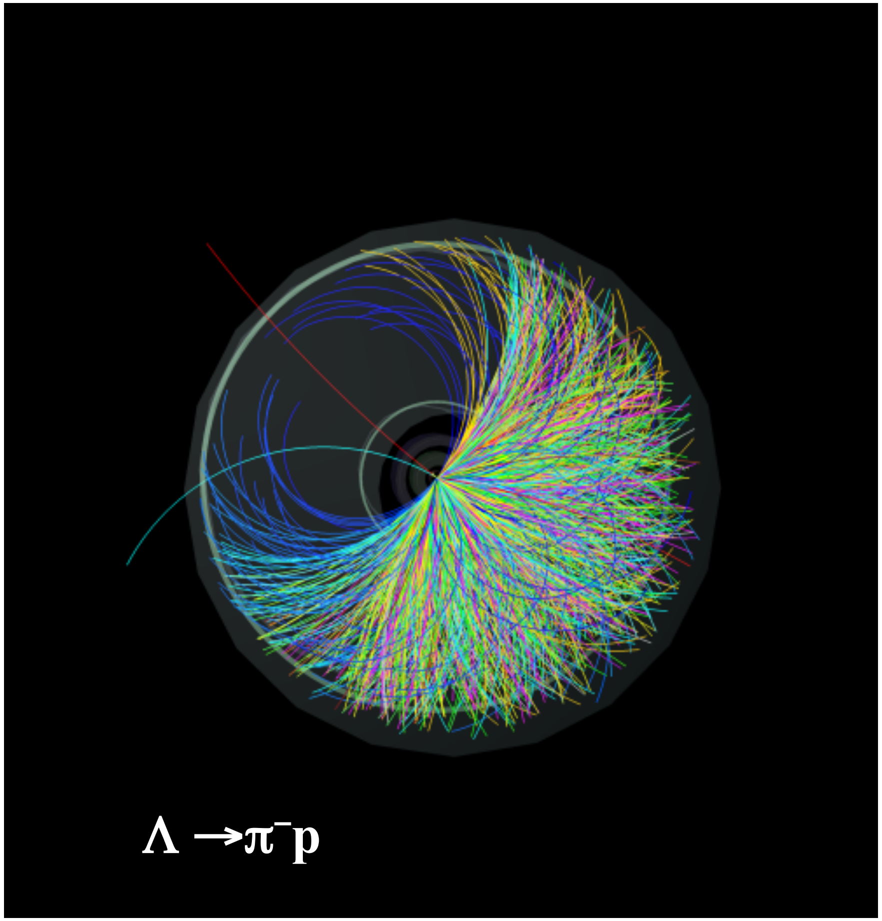
How do we find V0s ?



We look for two opposite tracks, having the same origin, which is not the interaction (collision) point

How do we find V0s ?

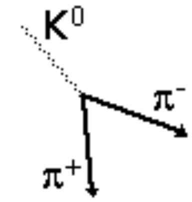




We look for two opposite tracks, having the same origin, which is not the interaction (collision) point

How do we identify each V0?

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



Calculate the (invariant) mass

Energy conservation $E = E_1+E_2$

Momentum conservation $\mathbf{p} = \mathbf{p}_1+\mathbf{p}_2$

Total energy $E^2 = p^2c^2 + m^2c^4$

c=1 $E^2 = p^2 + m^2$

$E = E_1+E_2$ $E_1^2 = p_1^2 + m_1^2$ $E_2^2 = p_2^2 + m_2^2$

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

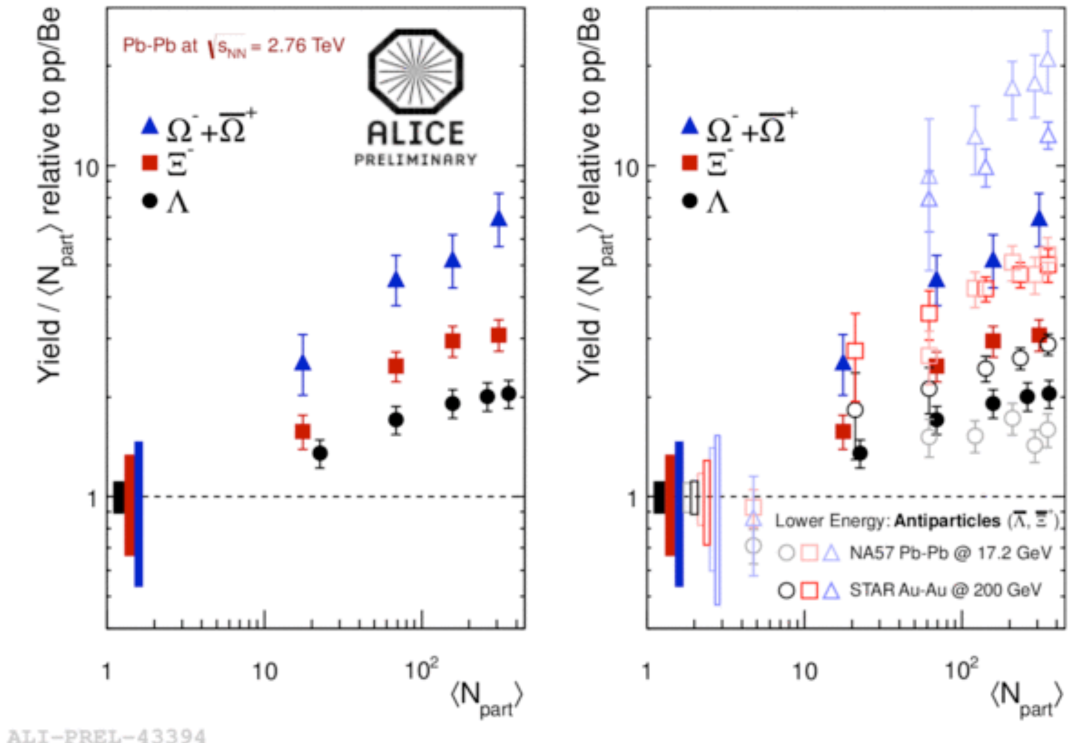
Calculate the mass of the initial particle from the values of the mass and the momentum of the final particles

Particle Identification (done by a number of PID detectors) ⟹ m_1 m_2

Radius of curvature of the particle tracks due to magnetic field ⟹ p_1 p_2

$P = Q \cdot B \cdot R$ (P momentum, Q electric charge, R radius of curvature)

Strangeness enhancement : one of the first signals of QGP

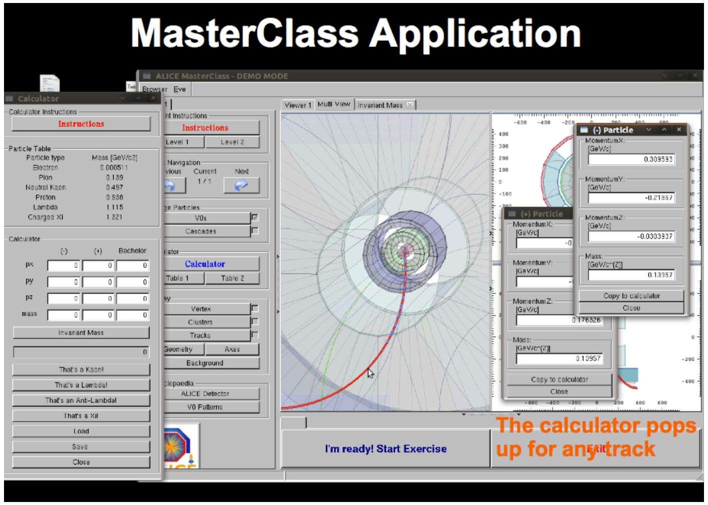


Enhancement increases with number of strange quarks in the hadron (Ω has 3, Ξ has 2, Λ has 1)
Enhancement decreases with collision energy (going from SPS to RHIC)..and at the LHC?

First part of measurement
Visual analysis of ~15 events

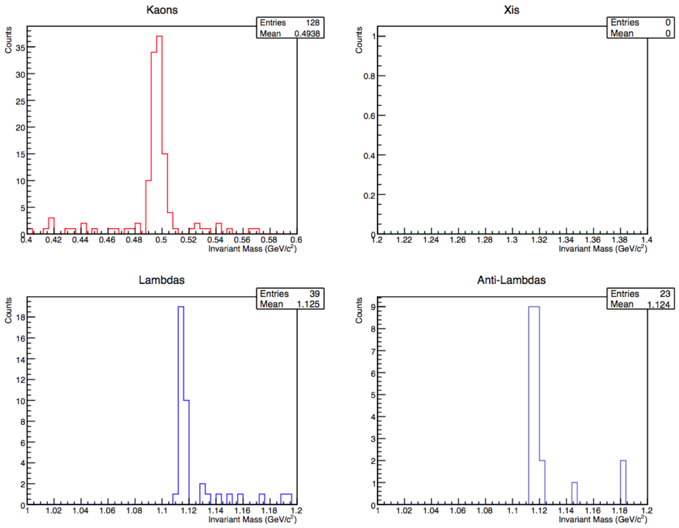
- Find V0s (K^0_s, Λ, anti-Λ) from decay pattern
- (V0 : two tracks with opposite charge,

  coming from a common secondary vertex)
- Calculate invariant mass
- Classify according to invariant mass value and daughter particle type (K^0_s,Λ, anti-Λ)
- Fill histograms and tables



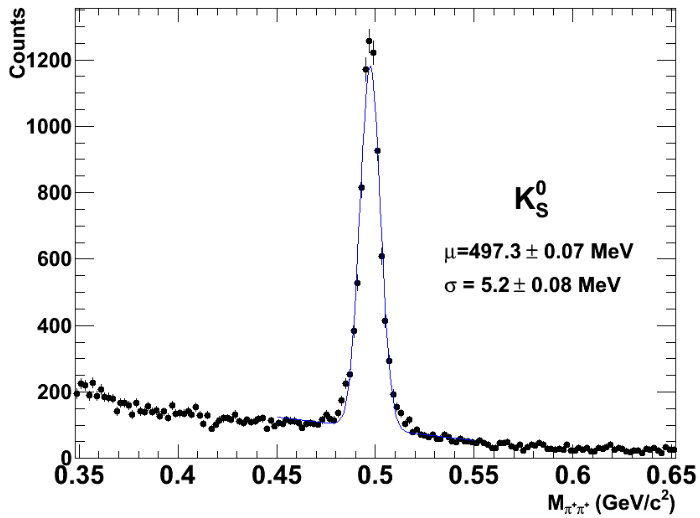
Discuss

- Value of mass peak
- Width of mass peak
- Background events

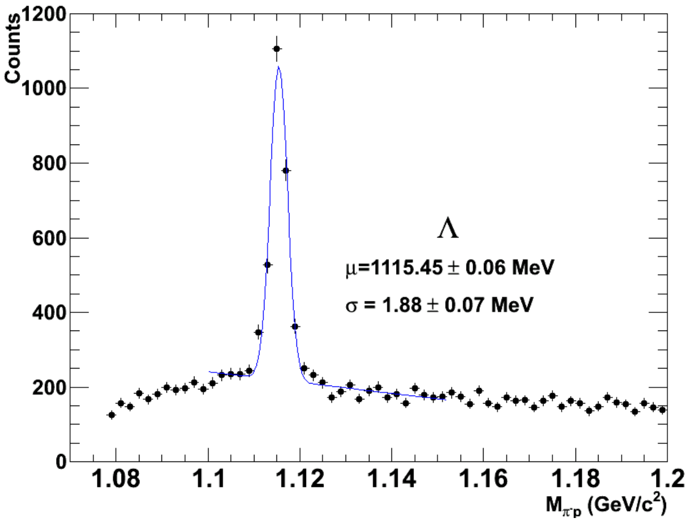


Second part of measurement
Analysis of a large event sample (thousands of events)

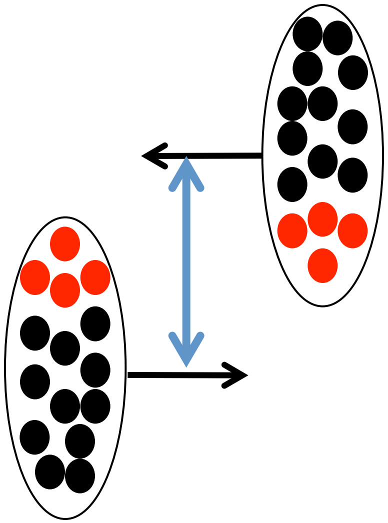
- Fill invariant mass histograms for K_s, Λ anti-Λ
- Fit curves to background (2nd degree polynomial) and peak (gaussian)
- Find number of K_s, Λ, anti-Λ after background subtraction



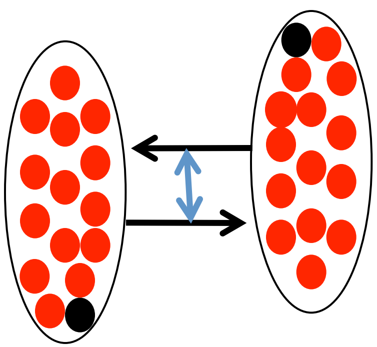
This analysis is done for different centrality bins for Pb-Pb collision data



Geometry of a Pb-Pb collision



- Peripheral collision
  - Large distance between the centres of the nuclei
  - Small number of participants
  - Few charged particles produced (low multiplicity)

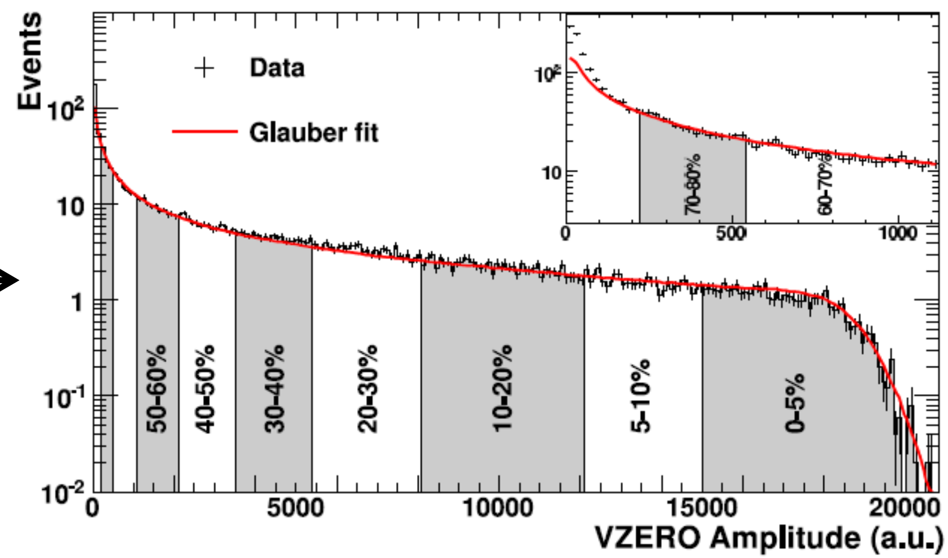


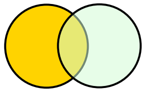
- Central collision
  - Small distance between the centres of the nuclei
  - Large number of participants
  - Many charged particles produced (high multiplicity)

Centrality of Pb-Pb collisions

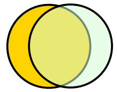
Distribution of the signal amplitude of V0 (plastic scintillators)

red line : described by model (Glauber)





périphériques



centrales

Centrality	$dN_{ch}/d\eta$	$\langle N_{part} \rangle$	$(dN_{ch}/d\eta)/(\langle N_{part} \rangle/2)$
0%–5%	1601 ± 60	382.8 ± 3.1	8.4 ± 0.3
5%–10%	1294 ± 49	329.7 ± 4.6	7.9 ± 0.3
10%–20%	966 ± 37	260.5 ± 4.4	7.4 ± 0.3
20%–30%	649 ± 23	186.4 ± 3.9	7.0 ± 0.3
30%–40%	426 ± 15	128.9 ± 3.3	6.6 ± 0.3
40%–50%	261 ± 9	85.0 ± 2.6	6.1 ± 0.3
50%–60%	149 ± 6	52.8 ± 2.0	5.7 ± 0.3
60%–70%	76 ± 4	30.0 ± 1.3	5.1 ± 0.3
70%–80%	35 ± 2	15.8 ± 0.6	4.4 ± 0.4

Results

Strangeness enhancement: the particle yield normalised by the number of participating nucleons in the collision, and divided by the yield in proton-proton collisions*

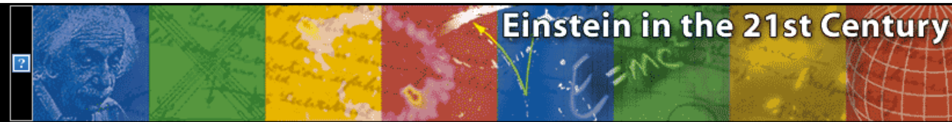
Yield : number of particles produced per interaction
Yield = Nparticles(produced)/Nevents = Nparticles(measured)/(efficiency x Nevents)

K_s-Yield (pp) = 0.25 /interaction ; Λ-Yield(pp) = 0.0617 /interaction ; $\langle N_{part} \rangle = 2$ for pp

Efficiency = Nparticles(measured)/Nparticles(produced)**

*pp yields at 2.76 TeV from interpolation between 900 GeV and 7 TeV
Analysis Note "Ks, Λ and antiΛ production in pp collisions at 7 TeV"

**assumption on efficiency values : to match yields in Analysis Note
Measurement of Ks and Λ spectra and yields in Pb–Pb collisions at √sNN=2.76 TeV with the ALICE experiment



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Looking for strange particles in ALICE

1. Overview

The exercise proposed here consists of a search for strange particles, produced from collisions at LHC and recorded by the ALICE experiment. It is based on the recognition of their V0-decays, such as $K^0_s \rightarrow \pi^+\pi^-$, $\Lambda \rightarrow p + \pi^-$ and cascades, such as $\Xi^- \rightarrow \Lambda + \pi^-$ ($\Lambda \rightarrow p + \pi^-$). The identification of the strange particles is based on the topology of their decay combined with the identification of the decay products; the information from the tracks is used to calculate the invariant mass of the decaying particle, as an additional confirmation of the particle species.

In what follows the ALICE experiment and its physics goals are first presented briefly, then the physics motivation for this analysis. The method used for the identification of strange particles as well as the tools are described in detail; then all the steps of the exercise are explained followed by the presentation of the results; then all the steps of the exercise are explained followed by the presentation of the results as well as the method of collecting and merging all results. In the end the large scale analysis is presented.

2. Introduction.

ALICE (A Large Ion Collider Experiment), one of the four large experiments at the CERN Large Hadron Collider, has been designed to study heavy ion collisions. It also studies proton proton collisions, which primarily provide reference data for the heavy ion collisions. In addition, the proton collision data allow for a number of genuine proton proton physics studies. The ALICE detector has been designed to cope with the highest particle multiplicities anticipated for collisions of lead nuclei at the extreme energies of the LHC.

3. The ALICE Physics

Quarks are bound together into protons and neutrons by a force known as the strong interaction, mediated by the exchange of force carrier particles called gluons. The strong interaction is also responsible for binding together the protons and neutrons inside atomic nuclei.

Even though we know that quarks are elementary particles that build up all known hadrons, no quark has ever been observed in isolation: the quarks, as well as the gluons, seem to be bound permanently together and confined inside composite particles, such as protons and neutrons. This is known as confinement. The exact mechanism that causes it remains unknown.

Although much of the physics of strong interaction is, today, well understood, two very basic issues remain unresolved: the origin of confinement and the mechanism of the generation of mass. Both are thought to arise from the way the properties of the vacuum are modified by strong interaction.

The current theory of the strong interaction (called Quantum Chromo-Dynamics) predicts that at very high temperatures and very high densities, quarks and gluons should no longer be confined inside composite particles. Instead they should exist freely in a new state of matter known as quark-gluon plasma.

http://aliceinfo.cern.ch/public/MasterCL/MasterClassWebpage.html

New portal under construction

http://opendata.cern.ch/ for education and research

Easy procedure to install virtual box; create a VM; configure a VM
http://opendata.cern.ch/VM/ALICE#configure

Once this done, you are in an environment where you have

- both ALICE masterclasses (strangeness and R_{AA})
- a simple program producing P_T distributions using released ALICE data

Alternative solution for running the masterclasses packages independent of operating system and installation of software tools (ROOT)

Thanks for your attention

despina.hatzifotiadou@cern.ch