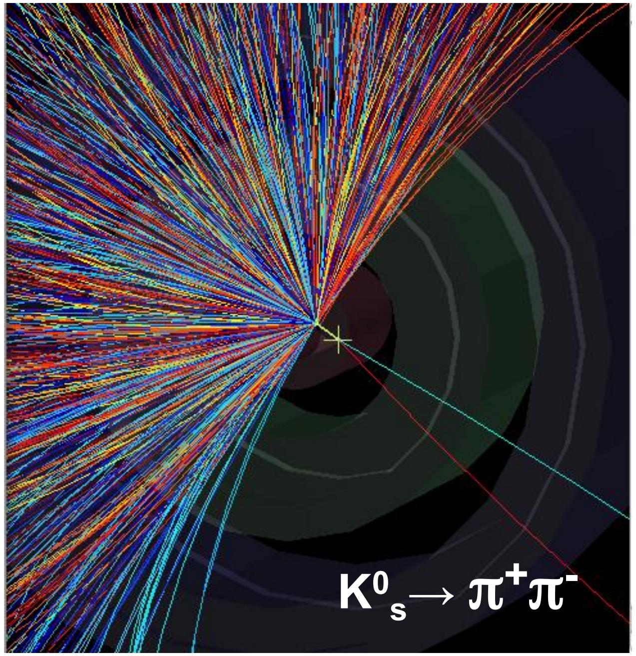
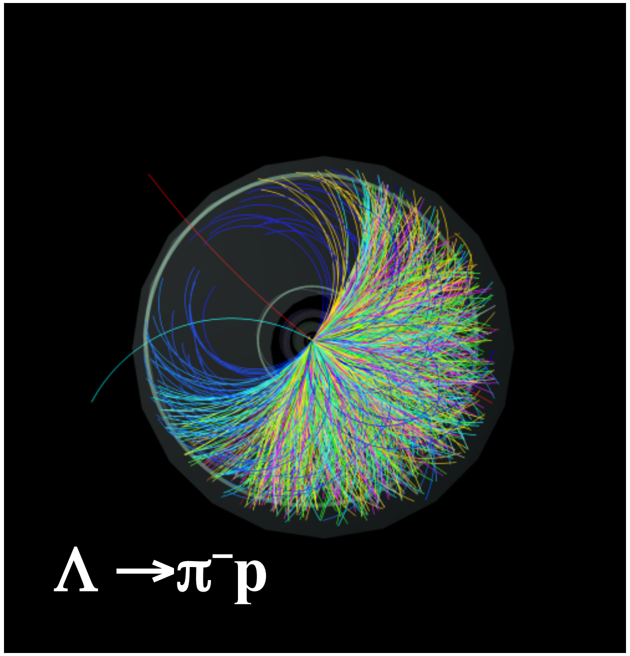
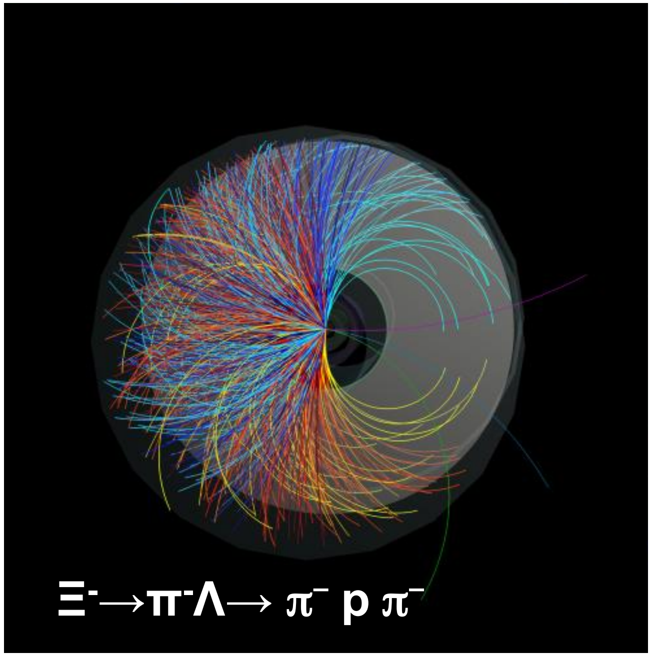
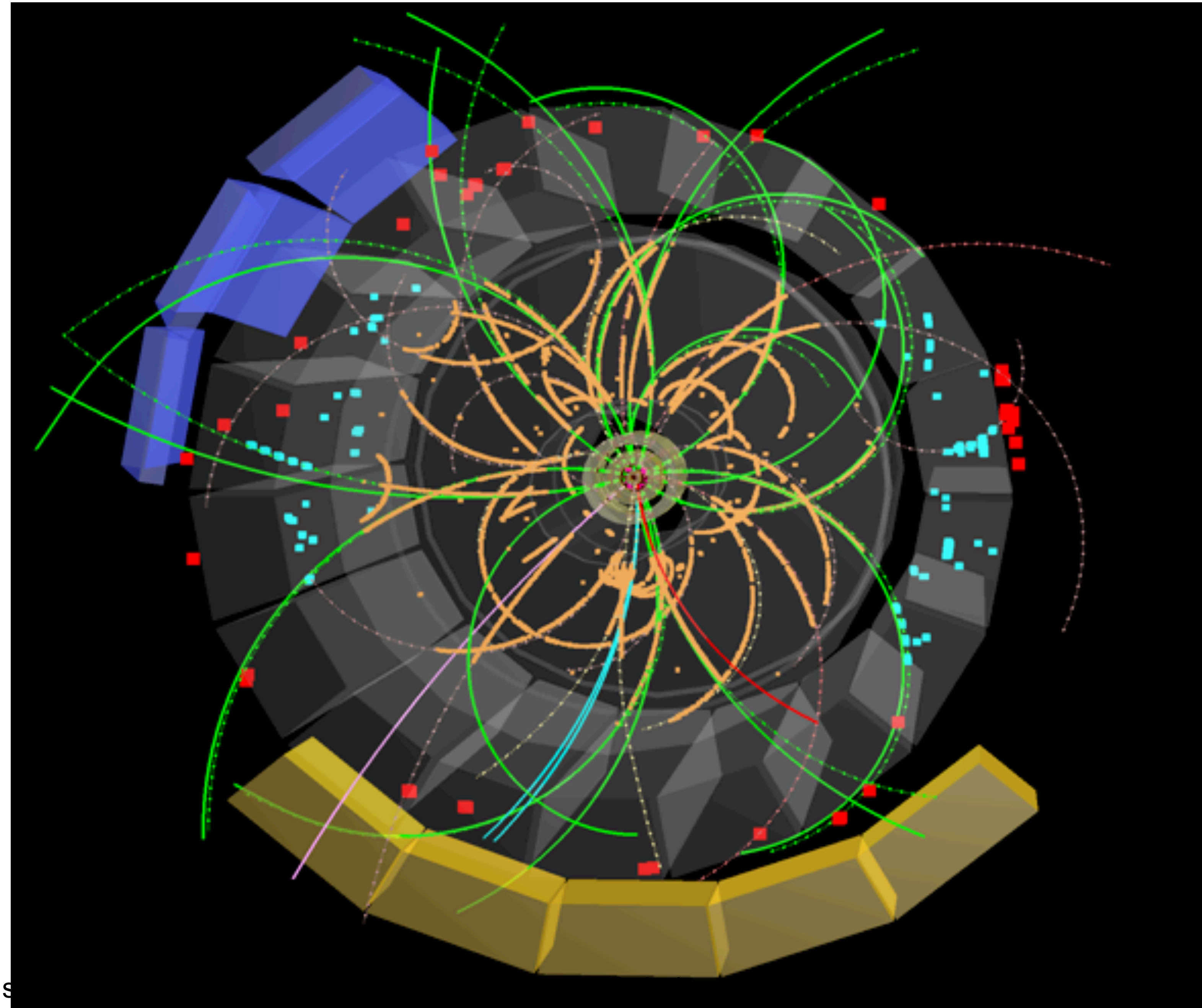
# Search for strange particles in ALICE





Strange particles : particles containing strange quark(s)

We will be looking for neutral strange particles

| Meson | Baryon | |
|---|---|---|
| $\pi(u\overline{u})$ | $p(uud)$ | |
| $Ks(d\overline{s})$ | $n(udd)$ | |
| | $\Lambda(uds)$ | (Hyperon) |

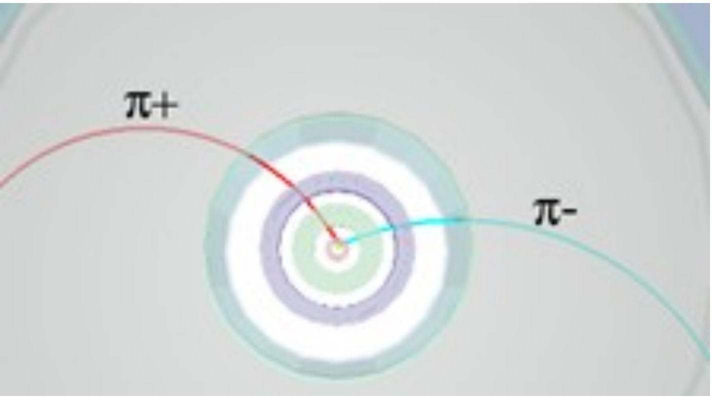
These particles travel some distance from the point of production before they decay

$$Ks \rightarrow \pi + \pi -$$
$$\Lambda \rightarrow p\pi -$$
$$\overline{\Lambda} \rightarrow \overline{p}\pi +$$

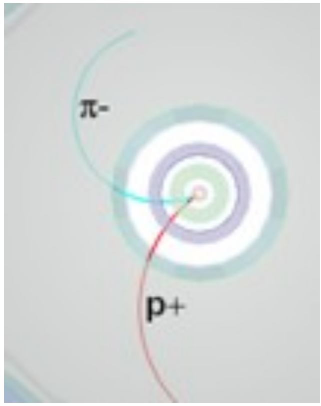
$\Lambda$ : $\tau = 2.6 \times 10^{-10}$ s; $c\tau = 3\times10^{10}$ cm $s^{-1}$ $\times 2.6\times10^{-10}$ s = 7.8 cm
$c\tau = 3\times10^{10}$ cm $s^{-1}$ $\times 10^{-9}$ s = 3 cm distance from interaction point
$c\tau = 3\times10^{10}$ cm $s^{-1}$ $\times 10^{-9}$ s = 3 cm

these decays are weak decays

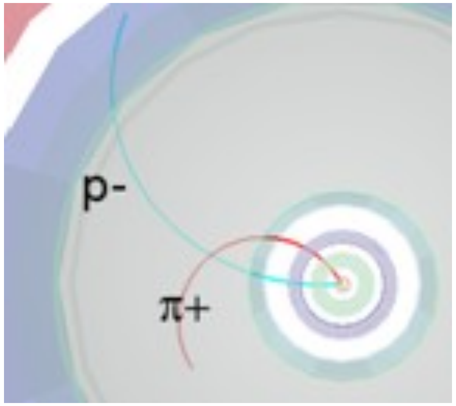
Conservation laws
electric charge q conserved
strangeness conserved in strong decays ( $\Delta S = 0$) $\tau = 10^{-23}$ s
$\Delta S = 0$ or $\Delta s=1$ in weak decays : (here $\Delta S=1$) $\tau = 10^{-8}$ s - $10^{-10}$ s
Baryon number is conserved




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

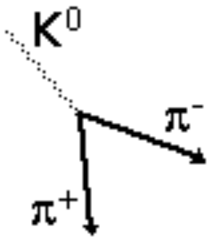



$\Lambda \to \pi p$

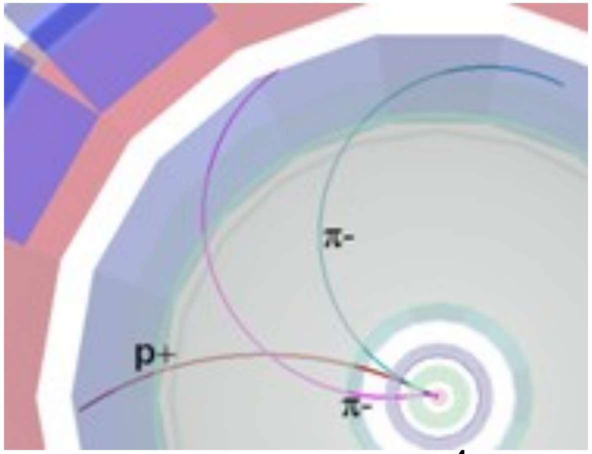



anti $\Lambda \to p^- + \pi^+$

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




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




Cascade : A charged particle followed by a V0

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

# Invariant mass

Conservation of energy $E = E_1 + E_2$

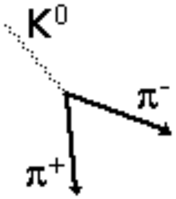
Conservation of momentum $\mathbf{p} = \mathbf{p}_1 + \mathbf{p}_2$ **p** ; vector p=|**p**| vector length

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

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




$m^2 = E^2 - p^2 = (E_1+E_2)^2 - (p_1+p_2)^2$

$= \; = m_1^2 + m_2^2 + 2E_1E_2 - 2\,\mathbf{p}_1 . \mathbf{p}_2$

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 = mυ

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

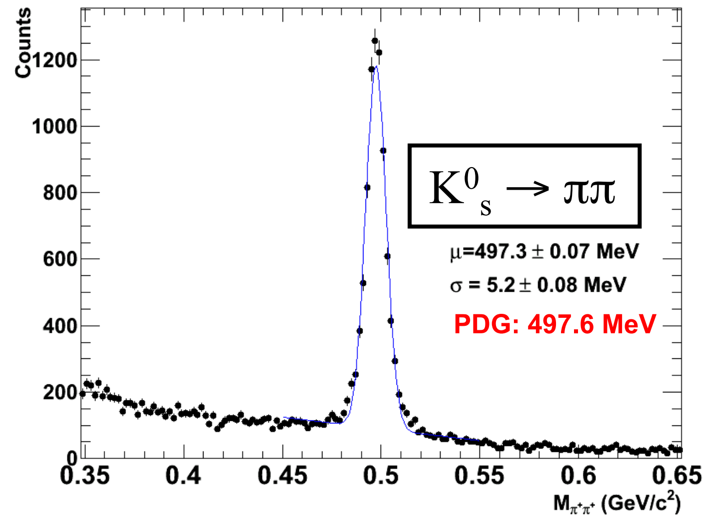
C=1 $E^2 = p^2 + m^2$

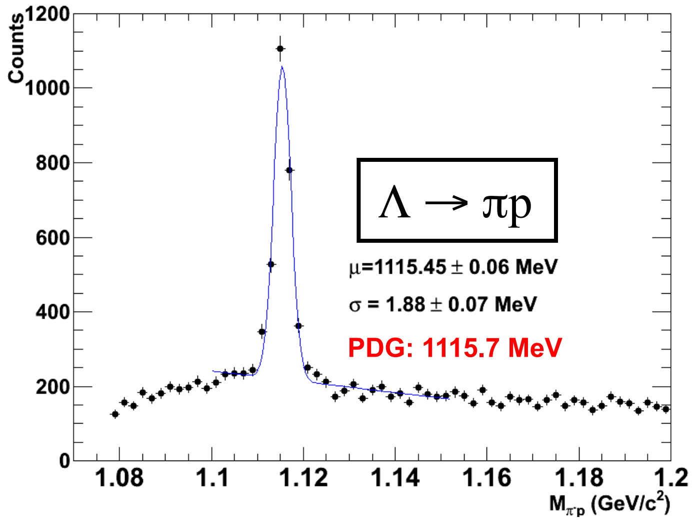
Units

Kinetic energy of an electron accelerated by a potential difference of 1 Volt.
E = qV = 1 (elementary charge; 1.6 $\times10^{-19}$ Cb) x 1 V = 1 eV = 1.6$\times10^{-19}$ 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



# V0 analysis basics

**$\Lambda^0$(uds)**

m = 1115.683 ± 0.006 MeV

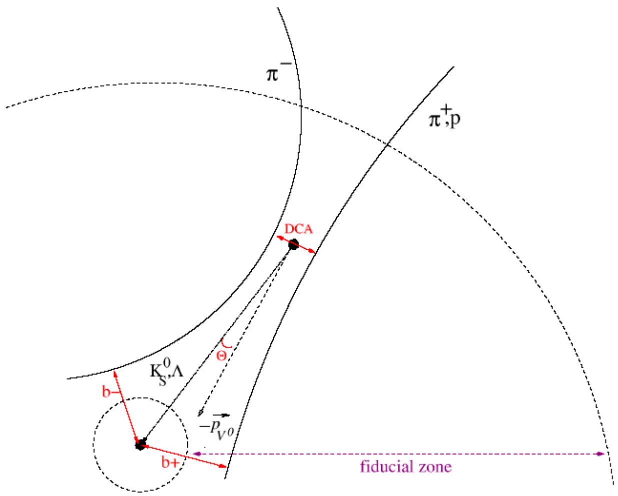
<τ> = (2.632 ± 0.020)x$10^{-10}$ s

cτ = 7.89 cm

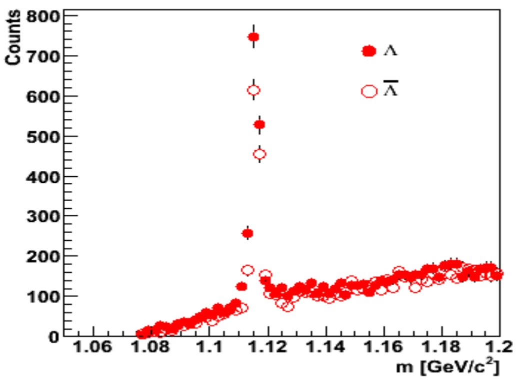
$\Lambda \to p\pi^-$ (~64 %)

-> $N\pi^0$ (~35.8 %)

-> nγ (~1.75x$10^{-3}$ %)




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



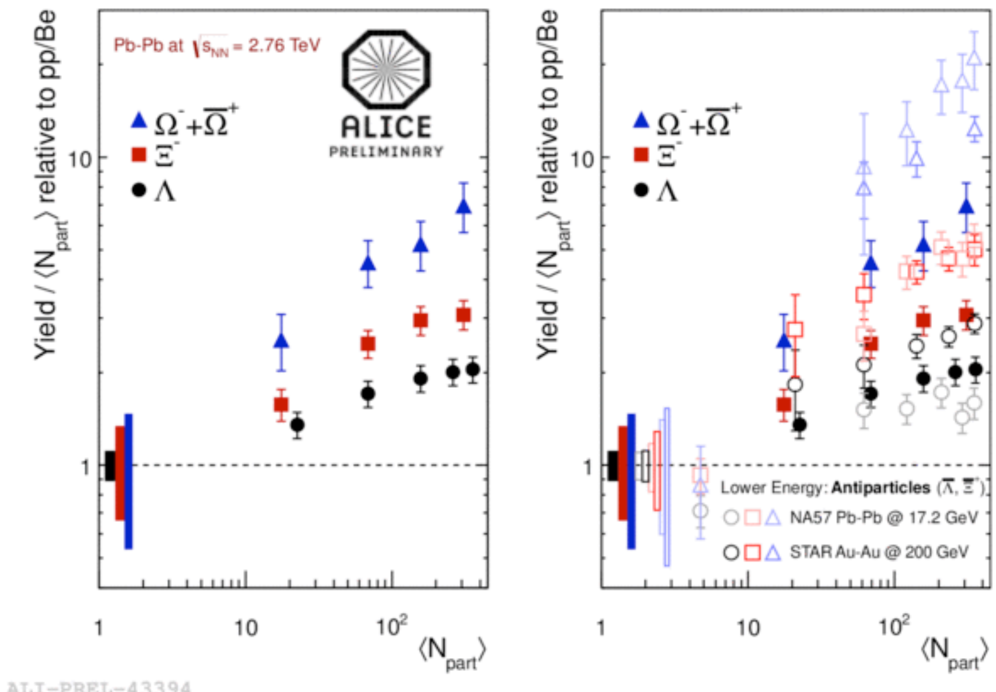

Analyse some events

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?

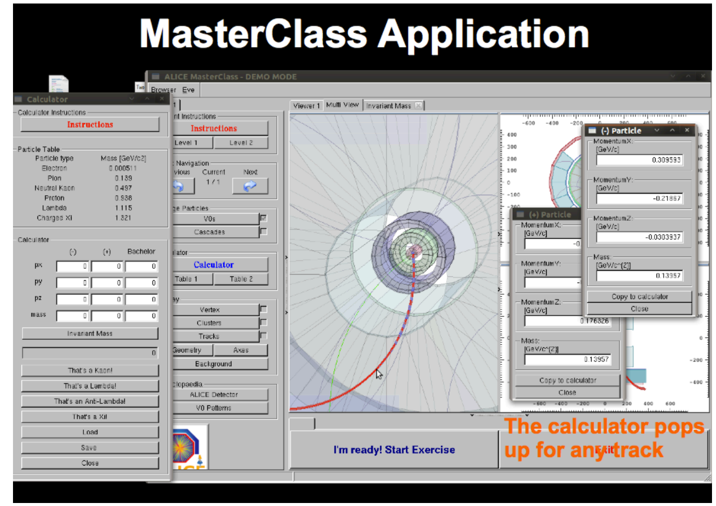
# First part of measurement

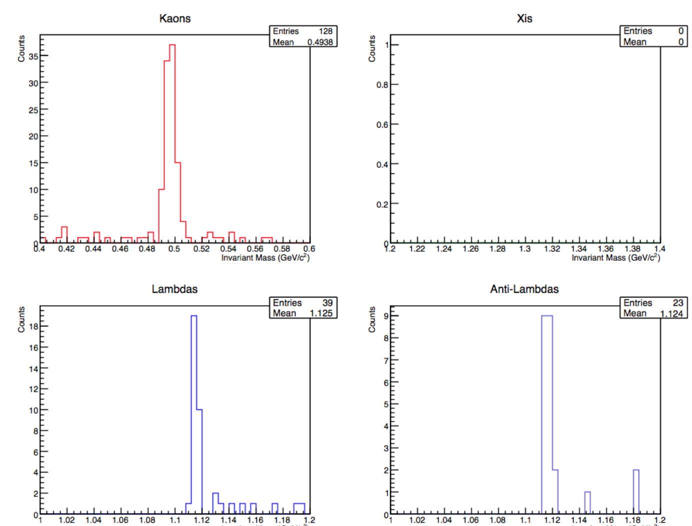
- Find V0s ( $K^0_s$, Λ, anti-Λ) from decay pattern
- (V0 : two tracks with opposite charge,

  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

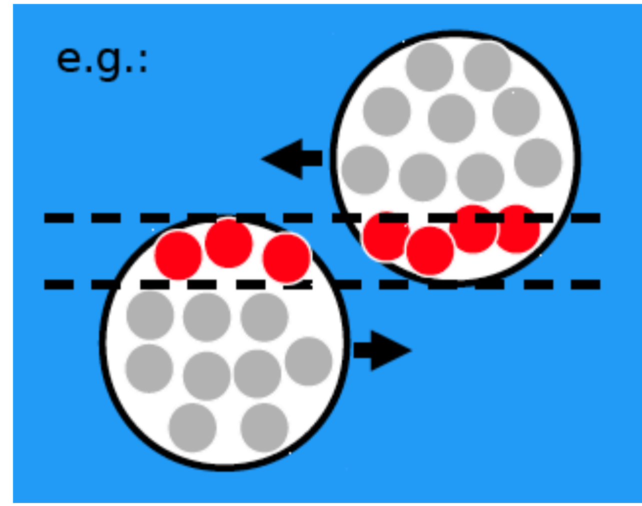
- Value of mass peak
- Width of mass peak
- Background events



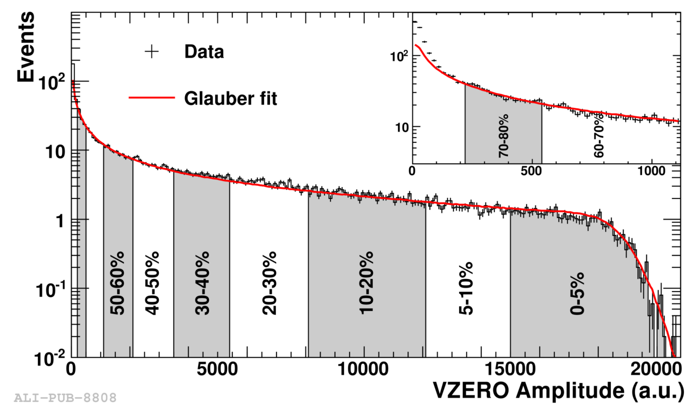



# Second part of measurement

- Analyse 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 in different centrality bins for Pb-Pb collision data




| 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 |



| centrality | <Npart> | Nevents | NKs | efficiency Ks | yield Ks | Ks enhancem |
|---|---|---|---|---|---|---|
| 0-10 | 360 | 213 | 4816 | 0.26 | 86.963 | 1.933 |
| 10--20 | 260 | 290 | 4638 | 0.26 | 61.512 | 1.893 |
| 20-30 | 186 | 302 | 3750 | 0.29 | 42.818 | 1.842 |
| 30-40 | 129 | 310 | 2610 | 0.29 | 29.032 | 1.800 |
| 40-50 | 85 | 302 | 1493 | 0.29 | 17.047 | 1.604 |
| 50-60 | 52 | 300 | 777 | 0.29 | 8.931 | 1.374 |
| 60-70 | 30 | 315 | 409 | 0.35 | 3.710 | 0.989 |
| 70-80 | 16 | 350 | 149 | 0.26 | 1.637 | 0.819 |

known given measured given calculated

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

*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

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

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

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

*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”