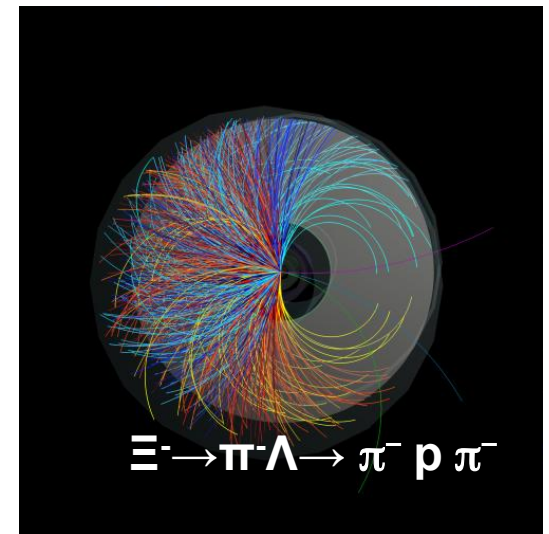
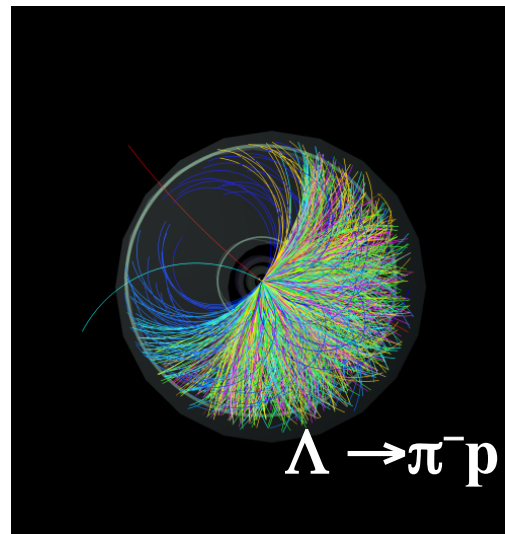
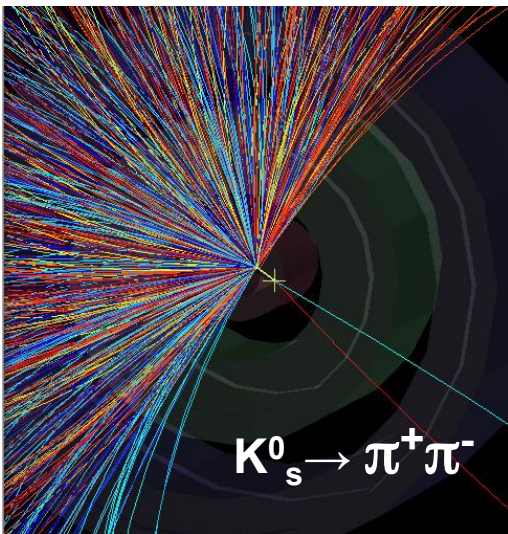


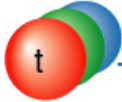



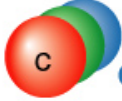







Looking for strange particles in ALICE

Despina Hatzifotiadou
INFN Bologna



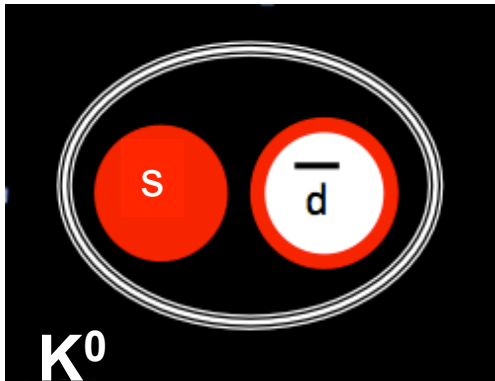
30.07.2024

Today's periodic system of the fundamental building blocks

	<i>Quarks</i>		<i>Leptons</i>	
<i>Generation 3</i>	 t Top	 b Bottom	 τ Tau	 ν_τ Tau-neutrino
<i>Generation 2</i>	 c Charm	 s Strange	 μ Muon	 ν_μ Muon-neutrino
<i>Generation 1</i>	 u Up	 d Down	 e Electron	 ν_e Electron-neutrino

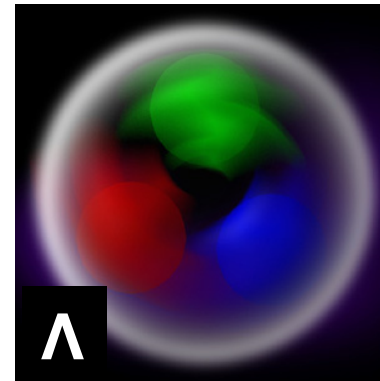
What are strange particles ?

meson



$\bar{d}s, ds$

baryon



uds

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

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

$$K_s^0 \rightarrow \pi^+\pi^- \quad \tau = 0.89 \times 10^{-10} \text{ s}$$

$$c\tau = 3 \times 10^{10} \text{ cm s}^{-1} \times 8.9 \times 10^{-11} \text{ s}$$

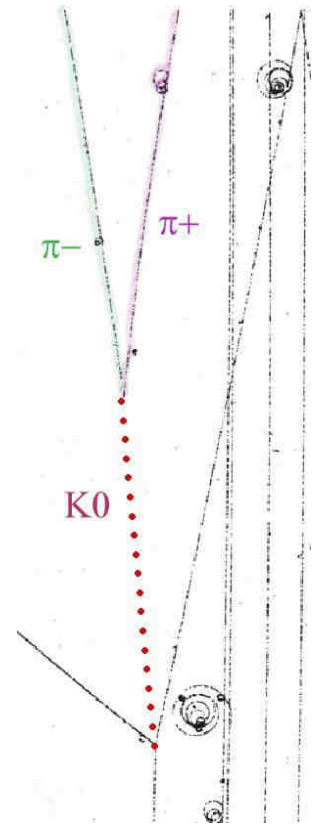
2.67 cm from the point of interaction

$$\Lambda \rightarrow \pi^- p \quad \tau = 2.6 \times 10^{-10} \text{ s}$$

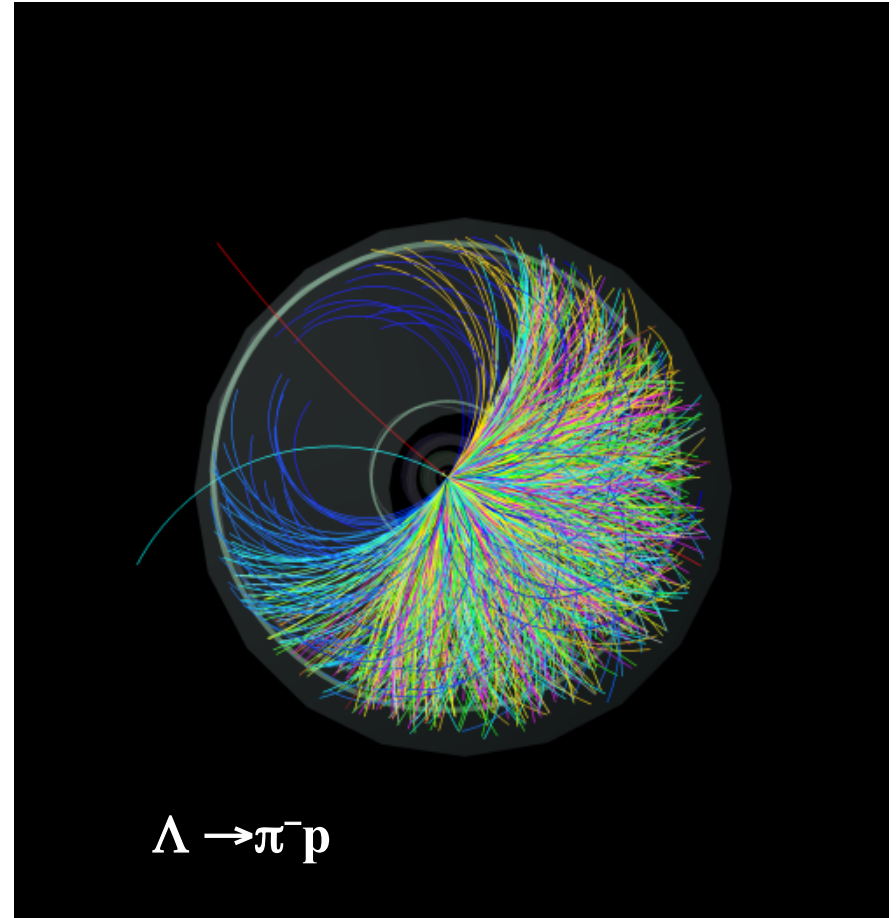
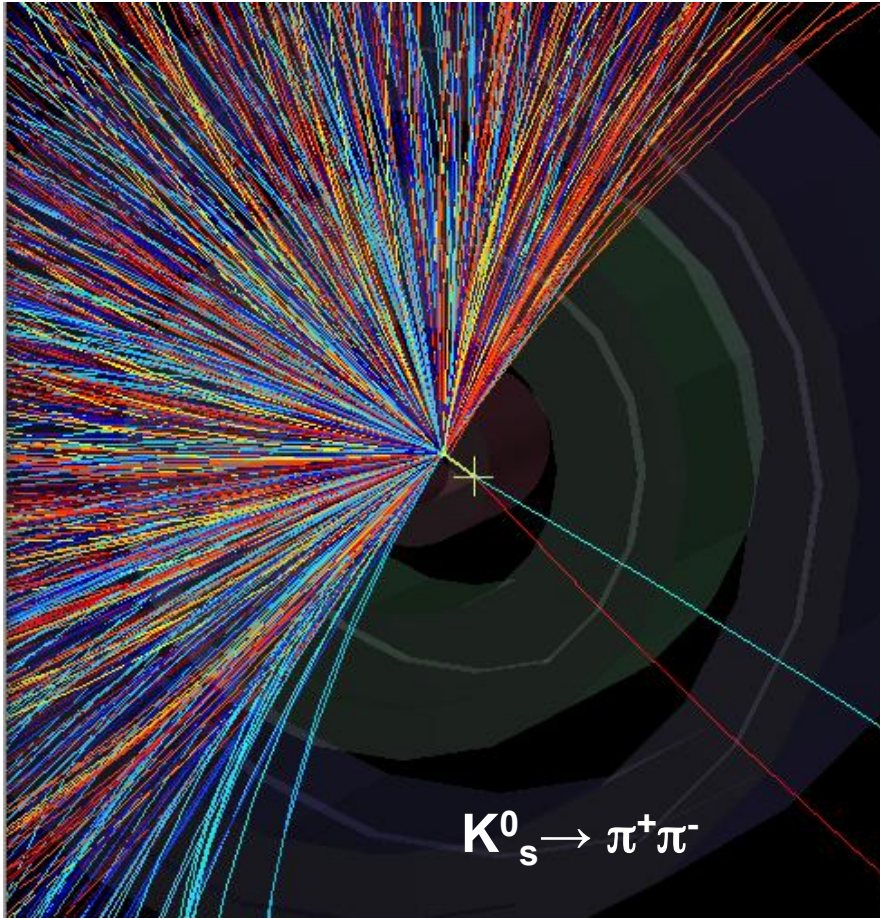
$$\bar{\Lambda} \rightarrow \pi^+ \bar{p} \quad c\tau = 3 \times 10^{10} \text{ cm s}^{-1} \times 2.6 \times 10^{-10} \text{ s}$$

7.2 cm distance from the point of interaction

Weak decays : strangeness is not conserved

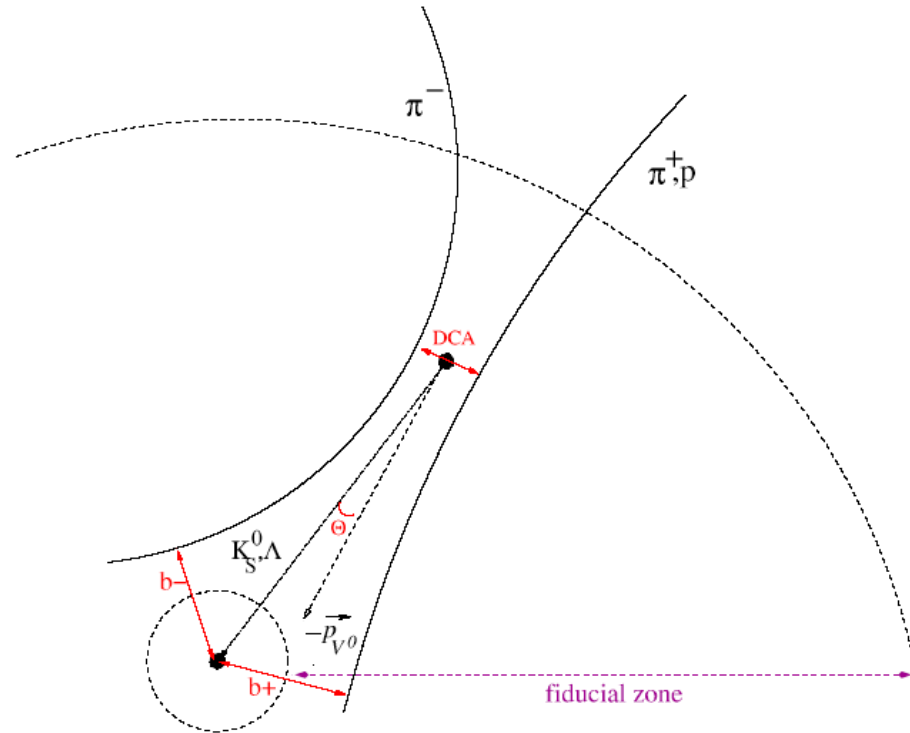


How do we find V0s ?



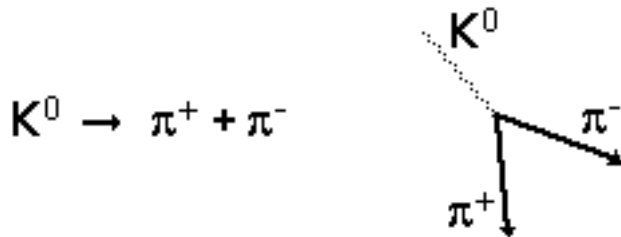
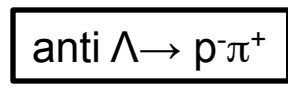
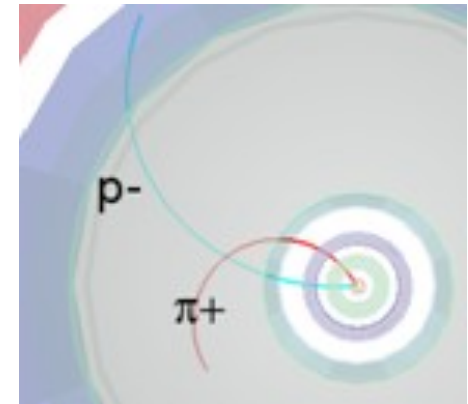
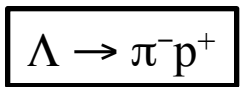
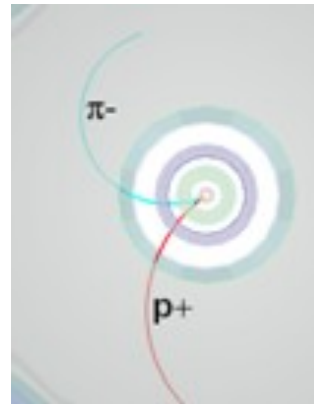
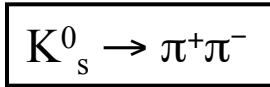
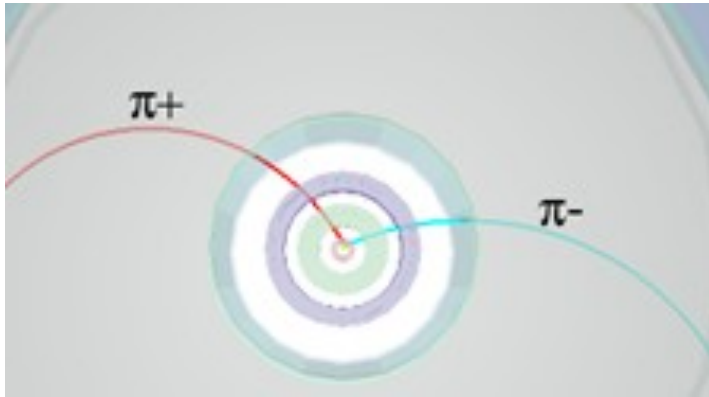
We look for two opposite tracks, having the same origin, which is not the interaction (collision) point

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?



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

$$P = Q \cdot B \cdot R$$

P momentum

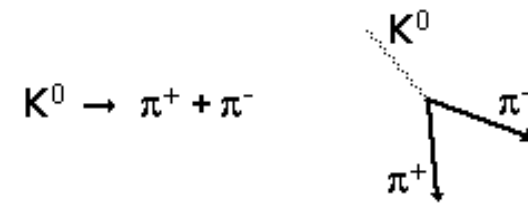
Q electric charge

B magnetic field

R radius of curvature

Identify V0s from the decay topology

How do we identify each V0?



Calculate the (invariant) mass

Energy conservation

$$E = E_1 + E_2$$

Momentum conservation

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

Total energy

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

$c=1$

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

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

$$E^2 = p^2 + m^2 \quad m^2 = E^2 - p^2 = (E_1 + E_2)^2 - (\mathbf{p}_1 + \mathbf{p}_2)^2 = m_1^2 + m_2^2 + 2E_1 E_2 - 2\mathbf{p}_1 \cdot \mathbf{p}_2$$

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) $\Rightarrow m_1 m_2$

Radius of curvature of the particle tracks due to magnetic field $\Rightarrow p_1 p_2$

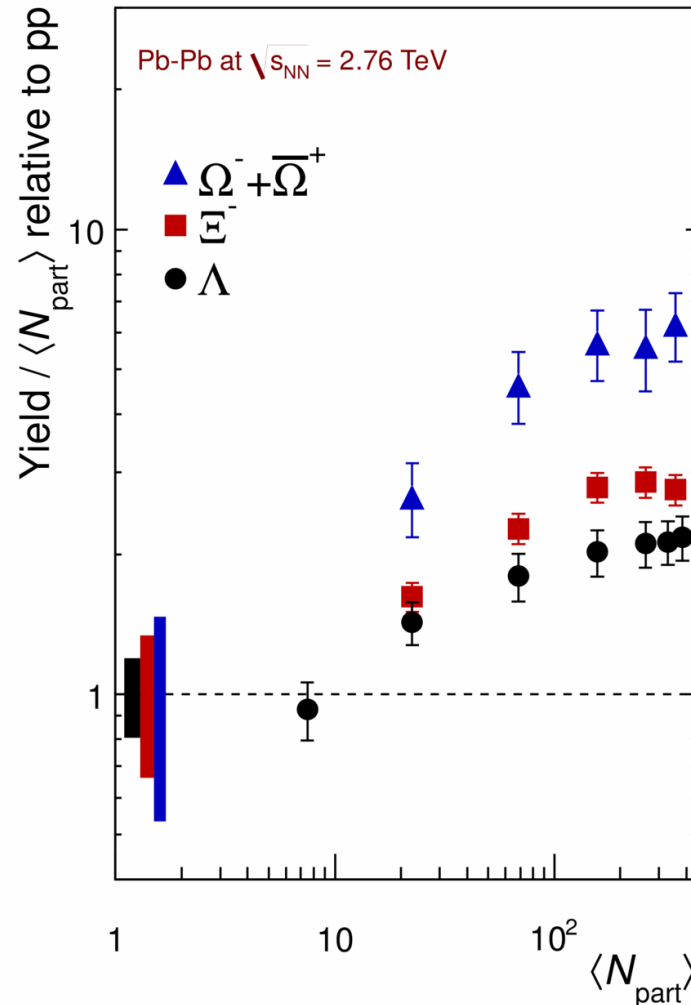
$P=Q \cdot B \cdot R$ (P momentum, Q electric charge, R radius of curvature, B magnetic field)

1st part

Identification of V0s (K_s , Λ , anti- Λ) in pp collisions

- Visual analysis of small samples (~15 events) of pp
- Find V0s with “V0 finder”
- Calculate invariant mass (with “calculator”)
- Classify in corresponding histograms
- Merge all results at the end of the 1st part
- Comment on width of the peak, background events

Strangeness enhancement : one of the first signals of QGP



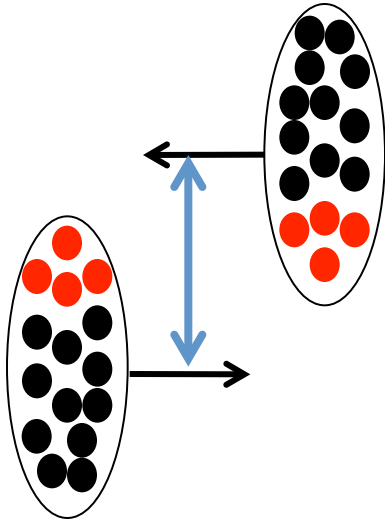
Enhancement increases with number of strange quarks in the hadron (Ω has 3, Ξ has 2, Λ has 1)

ALI-DER-80680

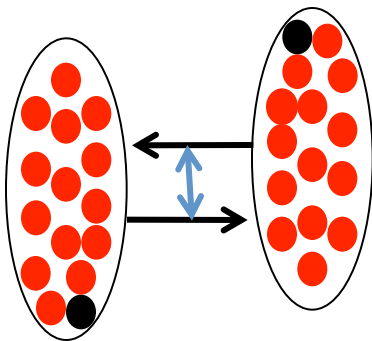
Particle yield for Pb-Pb collisions/ the number of participants

Particle yield for proton-proton collisions / 2

Geometry of a Pb-Pb collision

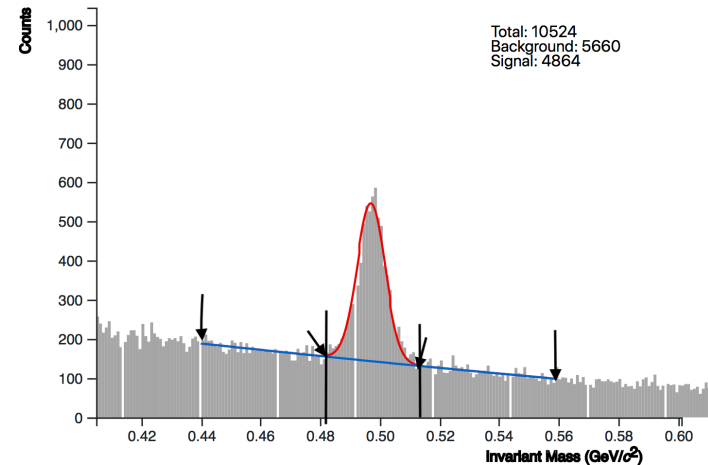
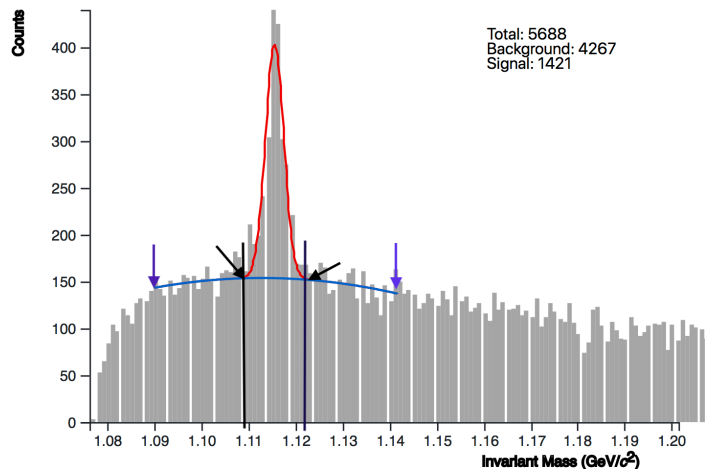
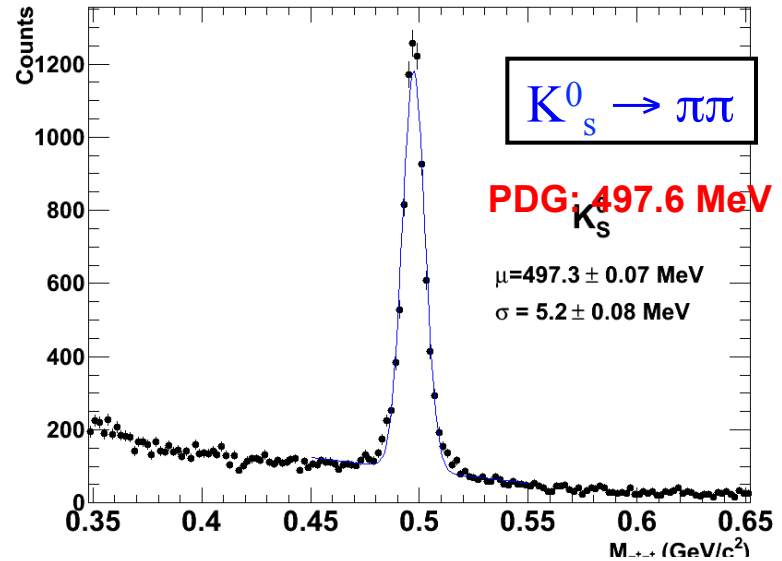
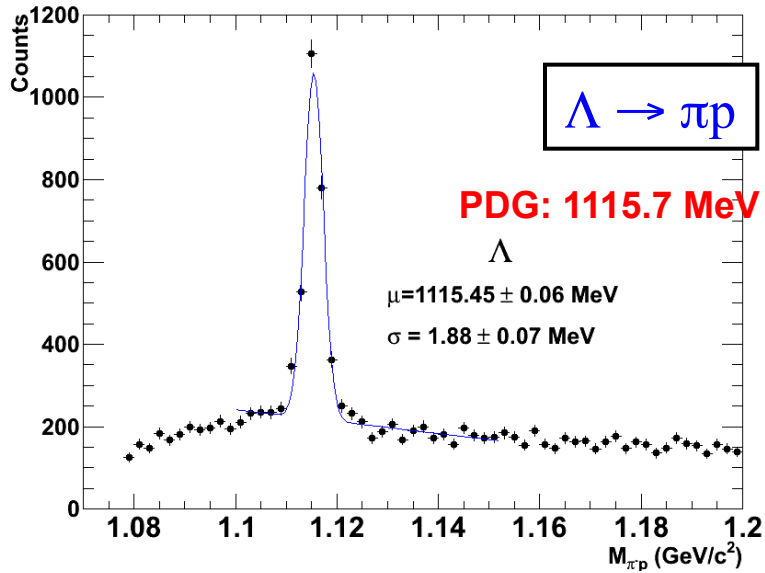


- Peripheral collision
 - Large **distance** between the centres of the nuclei
 - Small number of **participants**
 - Few charged particles produced (low multiplicity)



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

Fit functions describing the invariant mass distributions



2nd degree polynomial for the background $f(x) = ax^2+bx+c$
 Gaussian for the peak

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

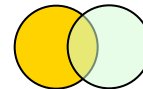
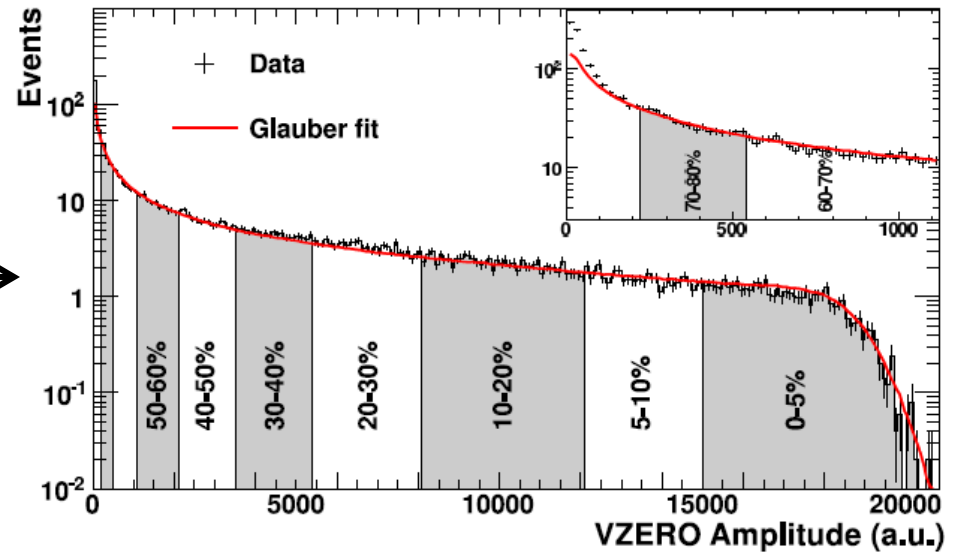
Find the number of K_S , Λ , anti- Λ after subtraction of the background

Centrality of Pb-Pb collisions

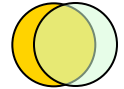
Distribution of the signal amplitude of V0 (plastic scintillators)
 red line : described by model (Glauber)



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



peripheral collisions



central collisions

Strangeness enhancement calculation

Yield : number of particles produced per interaction = $N_{\text{particles(produced)}}/N_{\text{events}}$

Efficiency = $N_{\text{particles(measured)}}/N_{\text{particles(produced)}}$ *

Yield = $N_{\text{particles(measured)}}/(\text{efficiency} \times N_{\text{events}})$

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

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

*assumption on efficiency values : to match yields in Analysis Note
Measurement of K_s and Λ spectra and yields in Pb–Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV with the ALICE experiment

*pp yields at 2.76 TeV from interpolation between 900 GeV and 7 TeV
Analysis Note “ K_s , Λ and anti Λ production in pp collisions at 7 TeV”

2nd part

Strangeness enhancement in lead-lead collisions

- Analysis of “large” event samples from lead collisions
- Find number of K_s , Λ , anti- Λ in different centrality regions
- Students’ job: do appropriate fits to signal and background
- Results are sent to a server; for each case the average of all values corresponding to each case is taken into account
- Particle yields are calculated
- Strangeness enhancement is calculated taking into account particle yields in proton collisions