MasterClass

Looking for strange particles in ALICE

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12th Zimányi Winter School on Heavy Ion Physics

Outline

1. Masterclass
   - MC
   - ALICE MC
2. Lecture
   - CERN
   - LHC
   - ALICE
   - Strange Particles
3. Analysis
   - Visual analysis
   - Large statistics analysis
   - Centralities
4. Conclusion

MasterClass

MasterClass

ALICE MasterClass is a part of International Particle Physics Outreach Group called Physics MasterClasses

International MasterClasses

- provide an opportunity for 15- to 19-year old students to discover particle physics
- take place in more than 130 places in 28 countries with more than 6000 participants worldwide
- are organized every year in March

Discover the world of Quarks and Leptons with real data

- get out of school for one day and come to a nearby university or research centre
- get insight into topics and methods of basic research at the fundaments of matter and forces
- perform measurements on real data from particle physics experiments at CERN
- participate in an international video conference for discussion of results

Looking for strange particles in ALICE

Hands on Particle Physics Masterclasses
SEARCH FOR STRANGE PARTCLES IN ALICE

The aim of the exercise is to identify strange particles. Some of the goals are:

- give pupils a flavour of data analysis with real analysis tools
- introduce them to the concept of particle decays and particle identification based on the V0 (and cascade) decay patterns, the concept of invariant mass, introduce efficiency and calculate yields, introduce errors, histograms.
- introduce the concept of background and background subtraction

http://physicsmasterclasses.org

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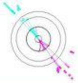

Hands on Particle Physics Masterclasses

ORGANISATION

Welcome in the organisation section of the IPPOG Masterclasses!
Here, we hope to provide you with all that you'll need in order to organise an event that students, teachers and staff will never forget.
Therefore, you can find:

- an **introduction** to the overall organising scheme including a step-by-step list for preparation
- some example **lectures**
- information on the **measurements**
- a **manual** for the video conference, including information on the new quiz
- **corporate material** to prepare e.g. invitation letters or participation certificates
- english **press release**
- german **press release**

We also provide information how we would like to

- present participating institutes on our website or how you can
- contribute in translating the exercises.

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Hands on Particle Physics Masterclasses

PARTICLE PHYSICS INSTITUTES

- Seeking more insight into fundamental particle physics?
- Even interested to study (particle) physics Yourself?
- Visit Your nearest Particle Physics Lab to find out more!

Use the menu on the left to find short records for all of the about 150 particle physics research institutes from 32 countries participating in the IPPOG Particle Physics Masterclasses. The collection in English and local language comprises descriptions of research and teaching, and information about local outreach activities, links, and downloads.

General Particle Physics Links:

- The Particle Adventure (13 languages)
- Antimatter webcasts: mirror of the universe
- www.interactions.org - particle physics news and resources
- CERN educational resources
- DESY research
- Science at SLAC
- Fermilab education office
- Contemporary physics education project - Posters, Charts and more
- Particle Physics Education Sites Worldwide
- CERN Courier - Latest news on Particle Physics
- Symmetry - A magazine from SLAC and Fermilab
- Labs and experiments in particle physics
- International Particle Physics Outreach Group
- String Theory
- Quantum Universe
- Taking a closer look at LHC

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Participating Institutes
HUNGARY

Institutes

- Szekesfehervar: Obuda University
- Budapest: KFKI Research Institute for Particle and Nuclear Physics
- Debrecen: University of Debrecen

National Responsible

Dezso Horváth

KFKI Research Institute for Particle and Nuclear Physics

H-1121 Budapest
Konkoly-Thege 29-33
Hungary

+36 1 392-2755

+36 1 392-2598

horvath@mail.kfki.hu

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  - Italy
  - New Zealand
  - Netherlands
  - Norway

Participating Institutes
POLAND

Institutes

Katowice:	University of Silesia - Institute of Physics
Krakow:	The Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences
Lodz:	National Centre for Nuclear Research - Cosmic Ray Laboratory
Poznan:	Uniwersytet im. Adama Mickiewicza w Poznaniu Wydzial Fizyki
Warsaw:	National Centre for Nuclear Research
Warsaw:	University of Warsaw - Faculty of Physics

National Responsible

Jacek Szabelski

National Centre for Nuclear Research
Division for Cosmic Ray Physics

NCBJ, Zaklad BP4
ul. Uniwersytecka 5
PL-90-950 LODZ 1, P.O.Box 447
Poland

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- ELISA - Experimental LHC Interactive Students Analysis
  Konrad Jende, Michael Kobel, Gesche Pospiech, Uta Bilow (all Technical University Dresden); Maiken Pedersen, Farid Ould-Saada, Eirik Gramstad (all University of Oslo)
  The authors gratefully acknowledge the help of Pete Watkins and Tom McLaughlan (University of Birmingham) for contributing to the work of creating and optimising these pages.
  - HYPATIA Event Display
    Christine Kourkoumelis, Dimitros Fassouliotis, Stelios Vourakis (all Univ Athens); Dusan Vudragovic (Institute of Physics, Belgrade)
  - MINERVA Tool
    Peter Watkins, Mark Stockton, Tom McLaughlan (all University of Birmingham); Monika Wielers (Rutherford Appleton Laboratory)
- CMS Masterclass: Discovering our Detector by Rediscovering Standard Model Particles
  Mihael Hategan (University of Chicago and University of California, Davis), Phong Nguyen (Fermilab), Thomas McCauley (Fermilab), George Alverson (Boston University), Kenneth Cecire (University of Notre Dame), Marge Bardeen (Fermilab), Michael Fetsko (Mills Godwin High School), Liz Quigg (Fermilab), Dave Trapp (Sequim Science), Michael Wadness (Medford High School), Shane Wood (Irondale High School)
- Looking for Strange Particles in ALICE
  Pawel Debski (Warsaw University of Technology), Yiota Foka (GSI-Darmstadt), Despina Hatzifotiadou (INFN Bologna), Rafael Sarnecki, Katarzyna Surma (both Warsaw University of Technology), Matevz Tadel (UCSD)
- Hands On Cern
  Erik Johansson et al., Stockholm
- A Keyhole to the Birth of Time
  James Gillies, Richard Jacobsson, CERN
- Identifying Particles
  Terry Wyatt, Univ Manchester (Java Version)
- BaBar Particle Physics Teaching Package

ALICE MC

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

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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. In the end the method of collecting and merging all the results is presented and some possible discussion topics are proposed.

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

ALICE MasterClass Installation

NOTE!

The ALICE MasterClass application runs on systems:

- Linux

- Mac

Windows - NOT AVAILABLE AT THE MOMENT

To copy the ALICE Masterclass to your computer, click on the link below:

ALICE MasterClass application

Then, you get the MasterClass2011.zip file. Unzip it in the local directory.

(new version of 20.3.2012 : the extended analysis has two data files, number 5 proton-proton and number 8 lead-lead

ALICE MasterClass application version of 20.3.2012

Then, you get the MasterClass2011b.zip file. Unzip it in the local directory)

If You have the ROOT environment installed on your computer, go to the direcotry *MasterClass2011* (by typing : *cd MasterClass2011*) and run the application by typing (still in the terminal) *root masterclass.C.*

Then, follow the instructions.

If you don't have the ROOT installed, you have to do it using the instructions available for:
MAC OS X
LINUX UBUNTU
OTHER LINUX (for example, SLC)

Note : The data files have been created using version of root : root v5-28-00f

You need version of root ≥ 28 .

European Organization for Nuclear Research

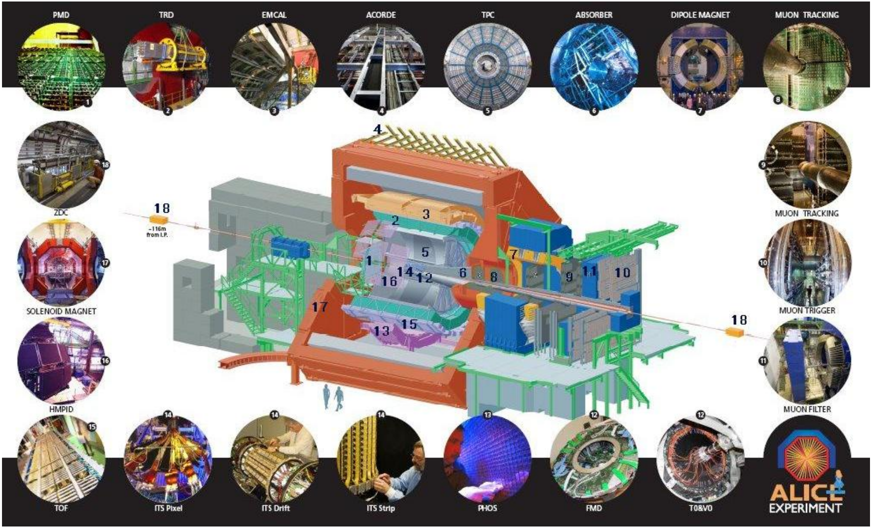
CERN is one of the world's largest and most respected centres for scientific research.

Its business is fundamental physics, finding out what the Universe is made of and how it works.

At CERN, the world's largest and most complex scientific instruments are used to study the basic constituents of matter — the fundamental particles.

LHC is a gigantic scientific instrument near Geneva, where it spans the border between Switzerland and France about 100m underground.
It is a particle accelerator used by physicists to study the smallest known particles – the fundamental building blocks of all things.
It will revolutionise our understanding, from the minuscule world deep within atoms to the vastness of the Universe.

ALICE has been designed to measure, in the most complete way possible, the particles produced in the collisions which take place at its center, so that the evolution of the system in space and time can be reconstructed and studied.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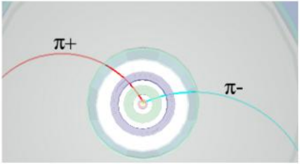
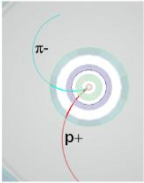
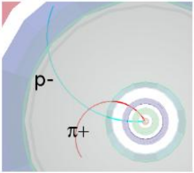
- Strange particles are hadrons containing at least one strange quark.
- Here we will be studying their decays. In these decays the quantum number of strangeness is not conserved, since the decay products are only composed of up and down quarks.
- The decays we will be looking for are:



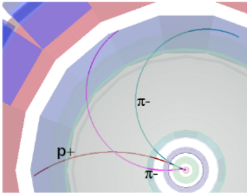
$K_S^0 \rightarrow \pi^+ \pi^-$



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



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



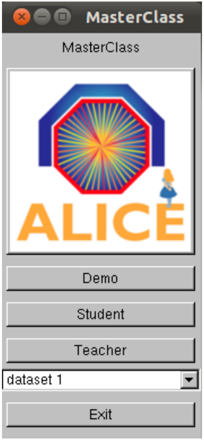
$\Xi^- \rightarrow \pi^- \Lambda \rightarrow \pi^- p + \pi^-$

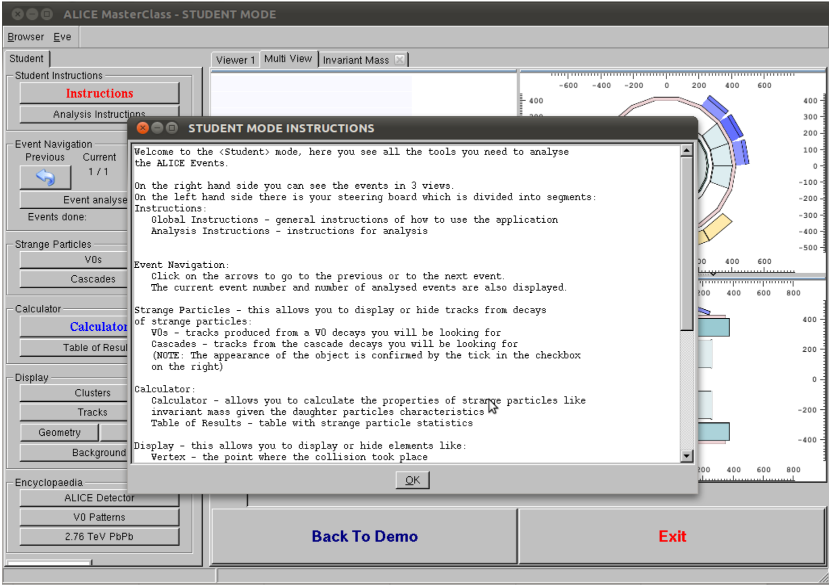
Visual analysis

- Pupils work by themselves at computers, in groups of 2 or 3; supervisors help them.
- analyse 30 events
- update tables and histograms
- save results file

The tools and how to use them

- the exercise is done in the ROOT framework
- simplified version of the ALICE event display
- demonstration mode
- student mode for the event analysis
- teacher mode for the collection and merging of the results.




ALICE MasterClass - STUDENT MODE
Browser Eve
Student
Student Instructions
Instructions
Analysis Instructions
Event Navigation
Previous Current
1 / 1
Event analysed
Events done:
Strange Particles
V0s
Cascades
Calculator
Calculator
Table of Results
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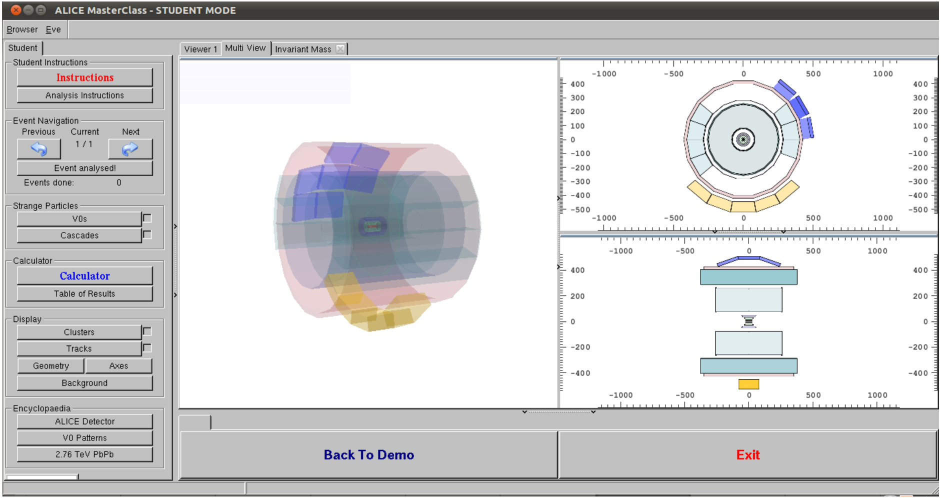
Clusters
Tracks
Geometry
Background
Encyclopaedia
ALICE Detector
V0 Patterns
2.76 TeV PbPb
Viewer 1
Multi View
Invariant Mass
STUDENT MODE INSTRUCTIONS
Welcome to the <Student> mode, here you see all the tools you need to analyse the ALICE Events.
On the right hand side you can see the events in 3 views.
On the left hand side there is your steering board which is divided into segments:
Instructions:
Global Instructions - general instructions of how to use the application
Analysis Instructions - instructions for analysis
Event Navigation:
Click on the arrows to go to the previous or to the next event.
The current event number and number of analysed events are also displayed.
Strange Particles - this allows you to display or hide tracks from decays of strange particles:
V0s - tracks produced from a V0 decays you will be looking for
Cascades - tracks from the cascade decays you will be looking for
(NOTE: The appearance of the object is confirmed by the tick in the checkbox on the right)
Calculator:
Calculator - allows you to calculate the properties of strange particles like invariant mass given the daughter particles characteristics
Table of Results - table with strange particle statistics
Display - this allows you to display or hide elements like:
Vertex - the point where the collision took place
OK
Back To Demo
Exit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Event analysed!
Events done: 0
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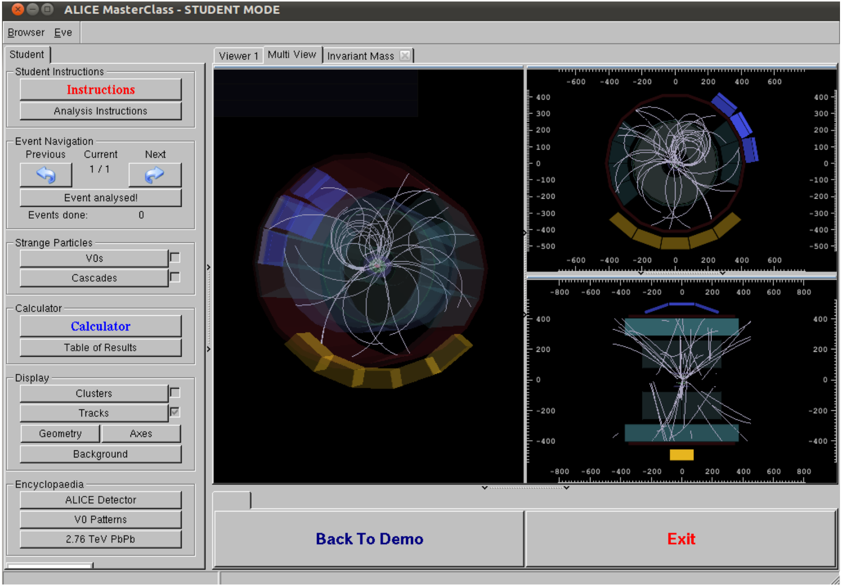
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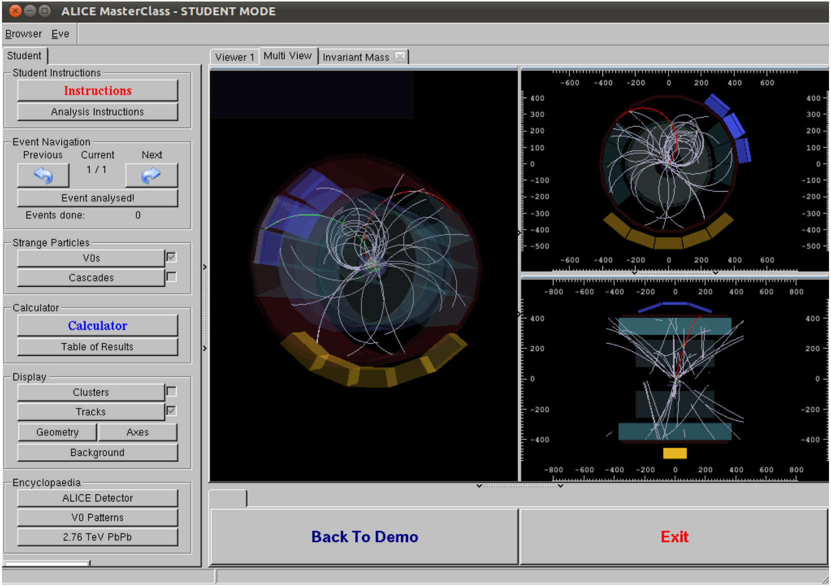
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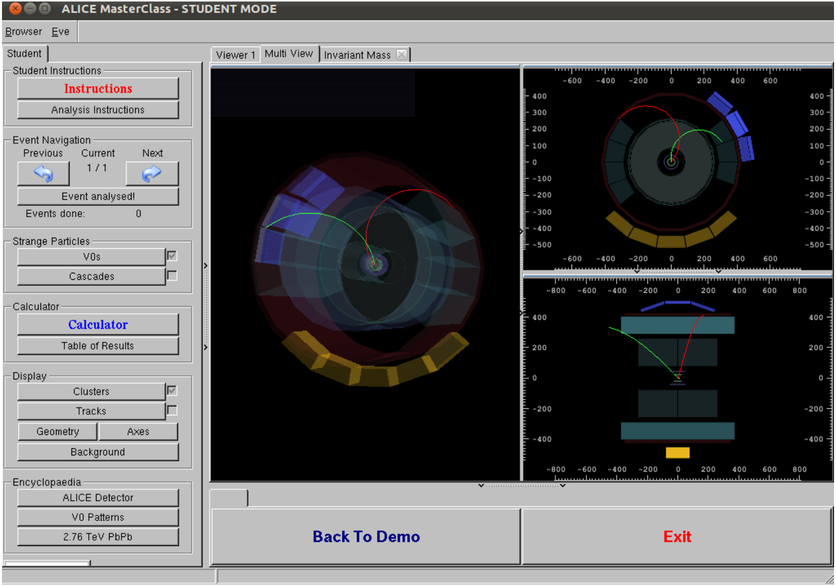
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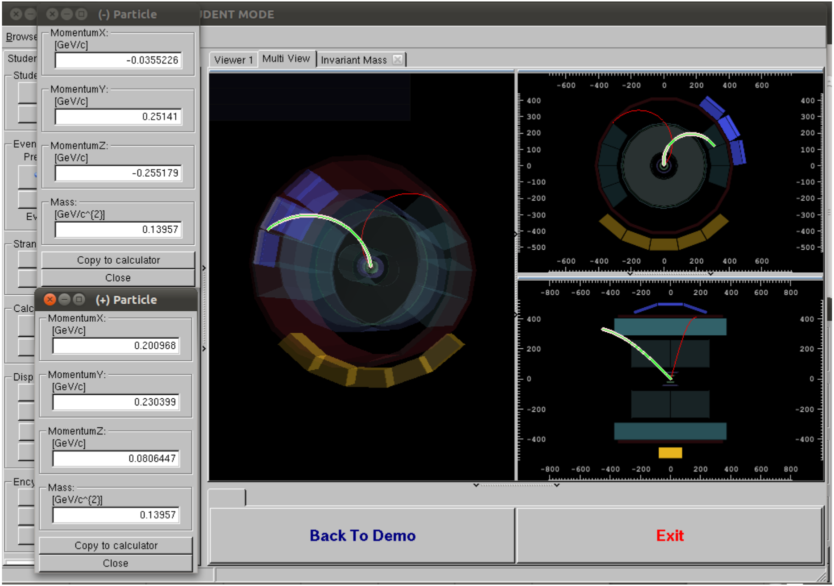
(-) Particle
DENT MODE
Browse
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Stude
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Pre
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Stran
Calc
Disp
Ency
MomentumX:
[GeV/c]
-0.0355226
MomentumY:
[GeV/c]
0.25141
MomentumZ:
[GeV/c]
-0.255179
Mass:
[GeV/c^{2}]
0.13957
Copy to calculator
Close
(+) Particle
MomentumX:
[GeV/c]
0.200968
MomentumY:
[GeV/c]
0.230399
MomentumZ:
[GeV/c]
0.0806447
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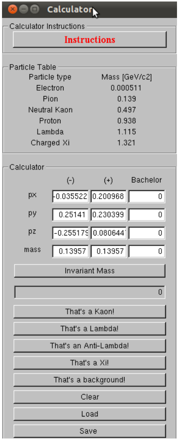
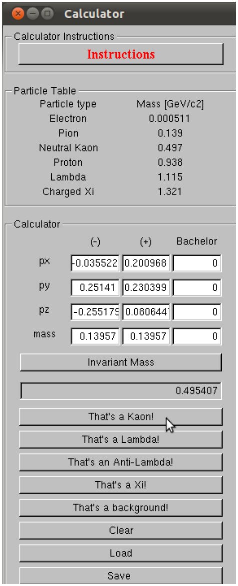


$$E_1 = \sqrt{(px_1 * px_1 + py_1 * py_1 + pz_1 * pz_1 + mass_1 * mass_1)}$$

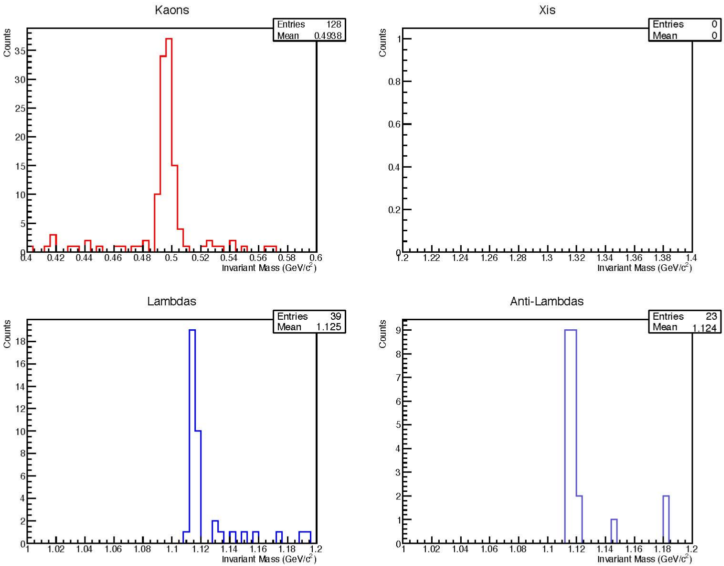
$$minv = \sqrt{((E_1 + E_2 + E_3) * (E_1 + E_2 + E_3) - (px_1 + px_2 + px_3) * (px_1 + px_2 + px_3) - (py_1 + py_2 + py_3) * (py_1 + py_2 + py_3) - (pz_1 + pz_2 + pz3) * (pz_1 + pz_2 + pz_3))}$$

Invariant mass calculation

- 497 MeV $\pm$ 13 MeV it is a K_0^s
- 1115 MeV $\pm$ 5 MeV and the daughter particles are a proton and a negative pion then it is a Λ.
- 1115 MeV $\pm$ 5 MeV and the daughter particles are an antiproton and a positive pion then it is an anti-Λ.
- For a cascade decay, if the mass calculated from the 3 tracks is 1321 $\pm$ 10 MeV then it is a Ξ.

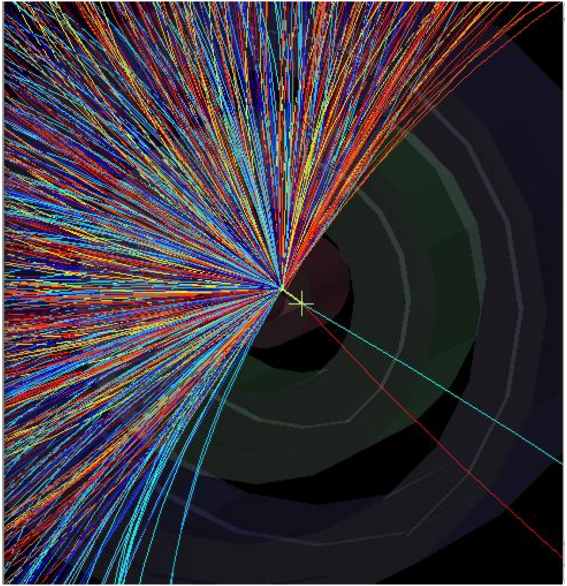


Histograms

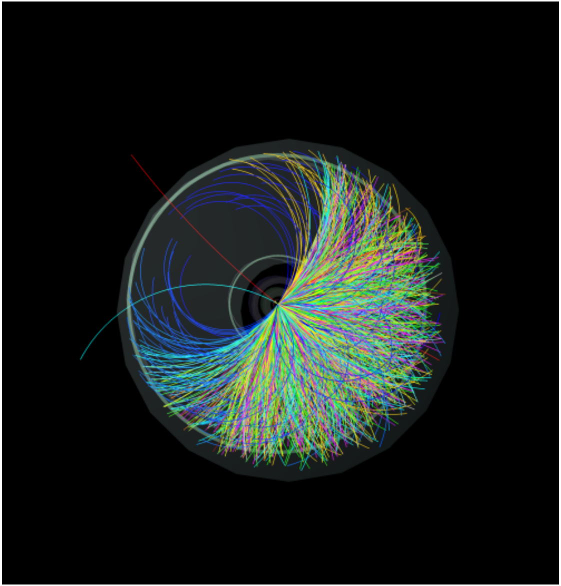


Kaons
Entries 128
Mean 0.4938
Counts
Invariant Mass (GeV/c^2)
Xis
Entries 0
Mean 0
Counts
Invariant Mass (GeV/c^2)
Lambdas
Entries 39
Mean 1.125
Counts
Invariant Mass (GeV/c^2)
Anti-Lambdas
Entries 23
Mean 1.124
Counts
Invariant Mass (GeV/c^2)

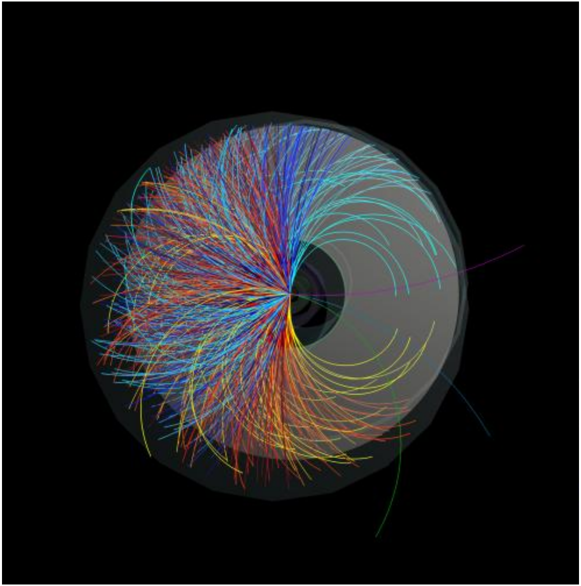
K_0^s



Λ

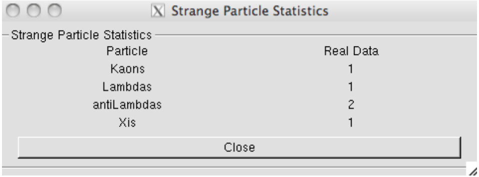


Ξ



Presentation of the results

This table summarises the results. The column **real data** contains the numbers of K_0^s, Λ, anti-Λ and Ξ found by student



Strange Particle Statistics

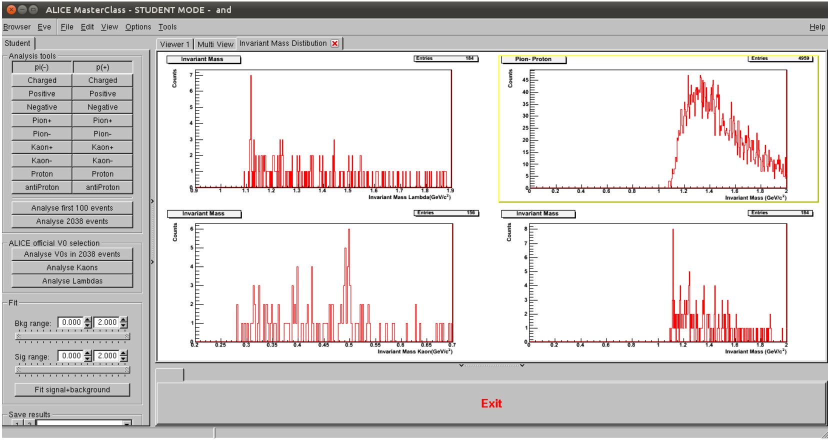
Strange Particle Statistics

Particle	Real Data
Kaons	1
Lambdas	1
antiLambdas	2
Xis	1

Close

Large statistics analysis

- analyse 2000 events /observe the mass distribution of the combinatorial background.
- analyse 2000 events looking for K_0^s / fit background / fit peak
- analyse 2000 events looking for Λ and anti-Λ / fit background / fit peak.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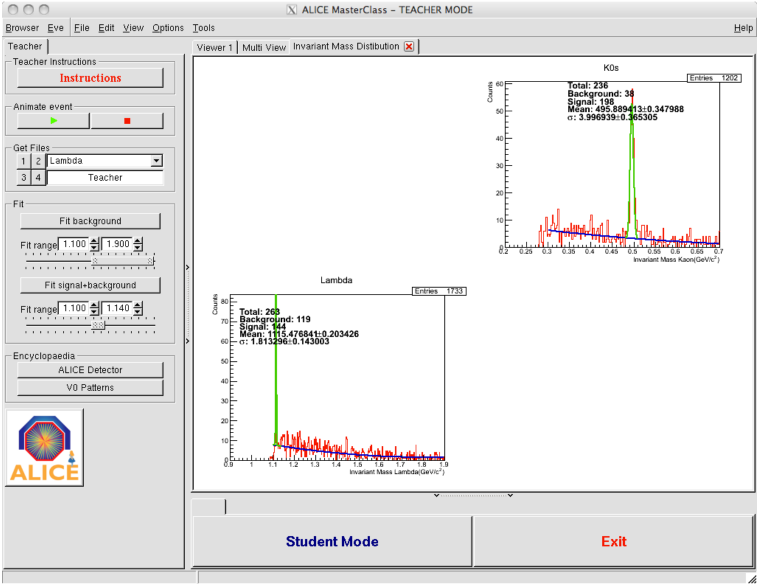
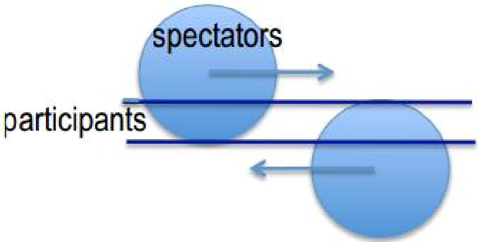
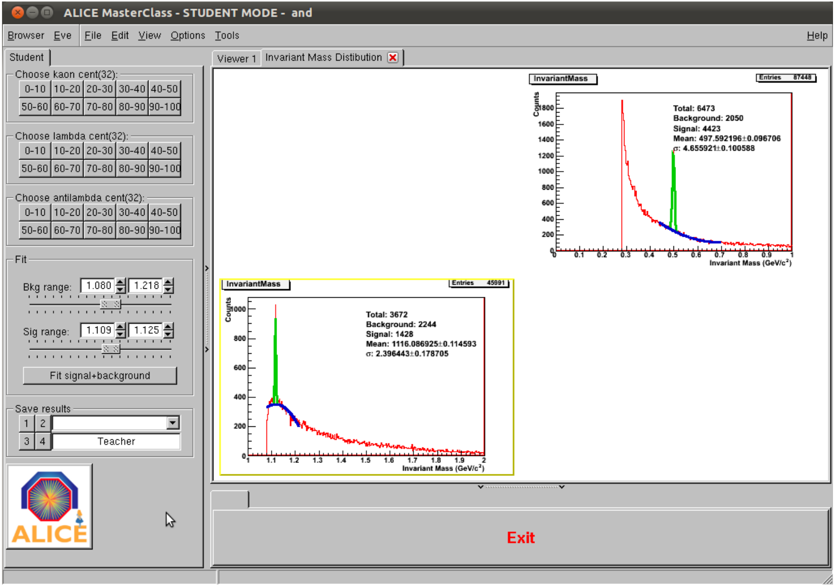
Charged Charged
Positive Positive
Negative Negative
Pion+ Pion+
Pion- Pion-
Kaon+ Kaon+
Kaon- Kaon-
Proton Proton
antiProton antiProton
Analyse first 100 events
Analyse 2038 events
ALICE official V0 selection
Analyse V0s in 2038 events
Analyse Kaons
Analyse Lambdas
Fit
Bkg range: 0.000 2.000
Sig range: 0.000 2.000
Fit signal+background
Save results
Invariant Mass
Pion- Proton
Counts
Invariant Mass Lambda(GeV/c²)
Invariant Mass (GeV/c²)
Invariant Mass Kaon(GeV/c²)
Exit


ALICE MasterClass - TEACHER MODE
Browser Eve File Edit View Options Tools Help
Teacher
Teacher Instructions
Instructions
Animate event
Get Files
Lambda
Teacher
Fit
Fit background
Fit range 1.100 1.900
Fit signal+background
Fit range 1.100 1.140
Encyclopaedia
ALICE Detector
V0 Patterns
ALICE
Viewer 1 Multi View Invariant Mass Distibution
K0s
Entries 1202
Total: 236
Background: 38
Signal: 198
Mean: 495.889413±0.347988
σ: 3.996939±0.365305
Counts
Invariant Mass Kaon(GeV/c²)
Lambda
Entries 1733
Total: 263
Background: 119
Signal: 144
Mean: 1115.476841±0.203426
σ: 1.813296±0.143003
Invariant Mass Lambda(GeV/c²)
Student Mode
Exit

Centralities analysis

- create large data samples to do analysis of V0 (K0s and Lambdas) and Cascade reading V0 and Cascade candidates
- create files in different centrality bins for PbPb




ALICE MasterClass - STUDENT MODE - and
Browser Eve File Edit View Options Tools Help
Student
Viewer 1
Invariant Mass Distibution
Choose kaon cent(32):
0-10 10-20 20-30 30-40 40-50
50-60 60-70 70-80 80-90 90-100
Choose lambda cent(32):
0-10 10-20 20-30 30-40 40-50
50-60 60-70 70-80 80-90 90-100
Choose antilambda cent(32):
0-10 10-20 20-30 30-40 40-50
50-60 60-70 70-80 80-90 90-100
Fit
Bkg range: 1.080 1.218
Sig range: 1.109 1.125
Fit signal+background
Save results
1 2
3 4 Teacher
ALICE
InvariantMass
Entries 87448
Counts
Total: 6473
Background: 2050
Signal: 4423
Mean: 497.592196±0.096706
σ: 4.655921±0.100588
Invariant Mass (GeV/c²)
InvariantMass
Entries 45991
Counts
Total: 3672
Background: 2244
Signal: 1428
Mean: 1116.086925±0.114593
σ: 2.396443±0.178705
Invariant Mass (GeV/c²)
Exit

Conclusions

- ALICE MasterClass is a part of International Particle Physics Outreach Group called Physics MasterClasses
- the aim of the exercise is to identify strange particles and give pupils a flavour of data analysis with real analysis tools
- ALICE MC - three parts:
  - Visual Analysis
  - Large Scale Analysis
  - Centrality Analysis
- more info:
  http://physicsmasterclasses.org
  http://aliceinfo.cern.ch/public/MasterCL/MasterClassWebpage.html

Thank you!