INTERNATIONAL MASTERCLASSES HANDS ON PARTICLE PHYSICS

ALICE Masterclass

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Before we start….

- Do you have the ALICE Masterclass files on your computer?
  - If not, please copy them from USB stick to your local machine NOW!
  - If you don't have ALICE software on the system you are working on right now, please also install Virtualbox!
    - For Windows & Mac there are Virtualbox installation files on the USB stick
    - For Ubuntu try
      - sudo apt-get install virtualbox-*

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International MasterClasses

A wealth of results!!

Higgs !!! QGP !!!

Excitement in the field!!

How to best share this excitement with the broader public ?

In particular with the new generation, students, high-school children…

The "International Masterclasses" project is

an educational activity that brings the excitement of cutting-edge particle physics research into the classroom !!

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Program of the day

- Introductory lectures
- Visit of a lab or experiment

CERN-PHOTO-201404-070-14

- Hands-on session
  - Instructions and interactive demo
  - Perform measurements on real data from LHC experiments
  - Merge and discuss results locally
  - Prepare presentation
- Participate in an international video conference

Videoconference

Features:

- Moderators lead discussion

- Icebreaker questions
- Presentation
- Discussion of results

- Use Indico

Even with this simple procedure pupils get the message that this is not one person's job….
….and statistics matters!!

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Materials and Information

- **Package you downloaded**
  - MasterClass-BNL-June-2016.pdf file – 54 slides explaining where to find information and help
- **Masterclasses Web page:** http://physicsmasterclasses.org/
- **ALICE Masterclasses:** http://alice.physicsmasterclasses.org/MasterClassWebpage.html

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ALICE measurements

Physics Motivation: Looking for Quark-Gluon Plasma

- How to create it? In high energy collisions of Lead-on-Lead
- How to “see it”? Look for signatures

Signatures of QGP: special features in PbPb compared to “normal matter” (pp)

- Huge temperature and density
- Strange particle production
- Nuclear modification factor R_{AA}

ALICE measurements

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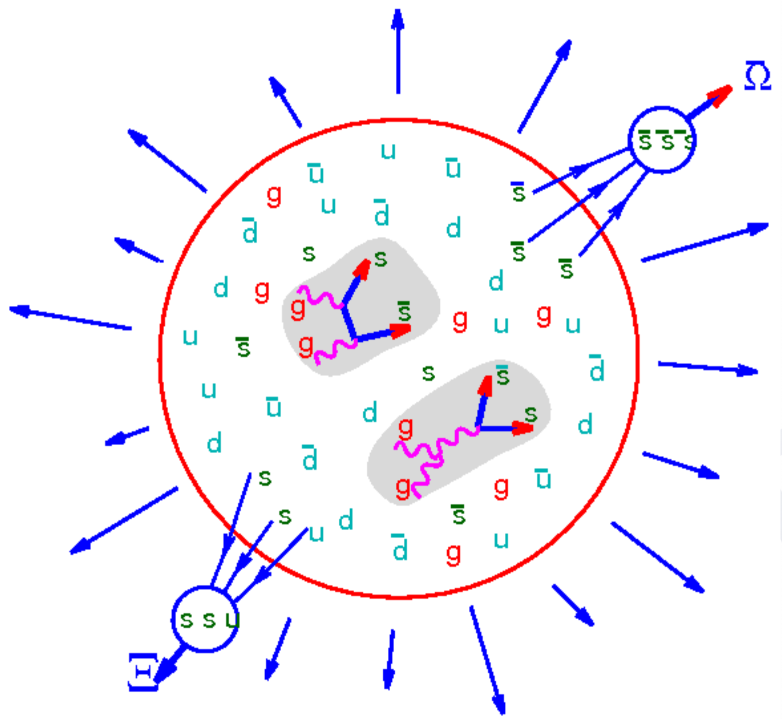
Strangeness Enhancement

- **TASK:** **compare number of strange particles produced in Pb-Pb to these in pp (approprietly normalized)**

$$gg \rightarrow s\bar{s}$$



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ALICE MasterClass project

Tools

- Simplified event display, close to the real one used at the experiment
- Visual analysis of small event sample (10-15 events)
- Large statistics analysis including background subtraction (strangness production) and “writing code” (R_{AA})
- Strangeness production: http://aliceinfo.cern.ch/public/MasterCL/MasterClassWebpage.html
- R_{AA}: http://www-alice.gsi.de/masterclass/

ALICE MasterClass

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; 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.

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Best resource

Youtube tutorials

- Visual analysis: https://www.youtube.com/watch?v=vzj9LRzs7VA

- Large scale analysis: https://www.youtube.com/watch?v=eoBpAyOd2wM

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Event Display Mode

The exercise is done in the ROOT framework

Simplified version of ALICE Event Display, based on ROOT

Demonstration mode

Student mode for event analysis

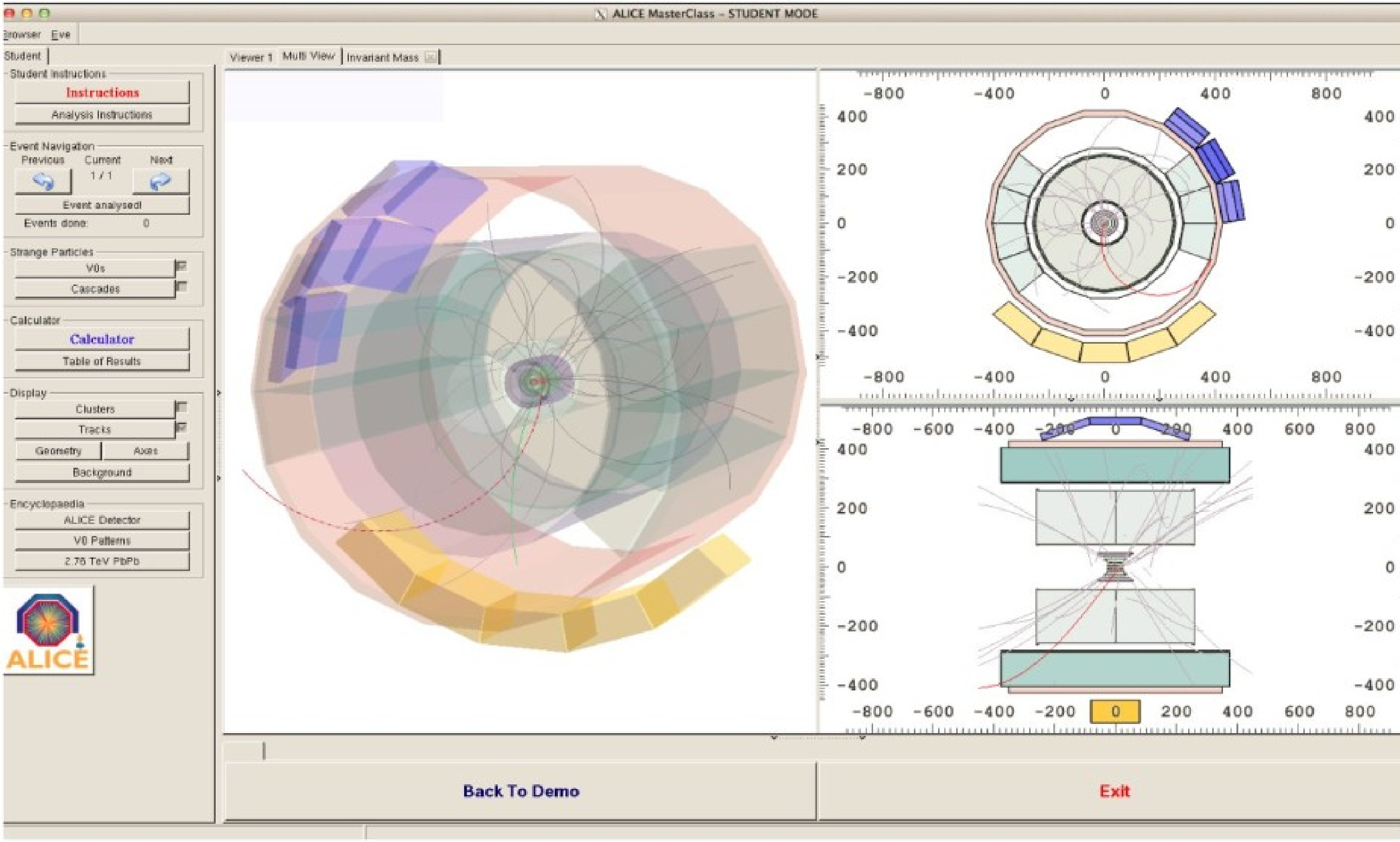
Teacher mode: tips on merging data

Visual analysis

Proton-proton event

Introduce concepts and visual analysis tools, fill histograms

Interactive!!!
Grab and rotate



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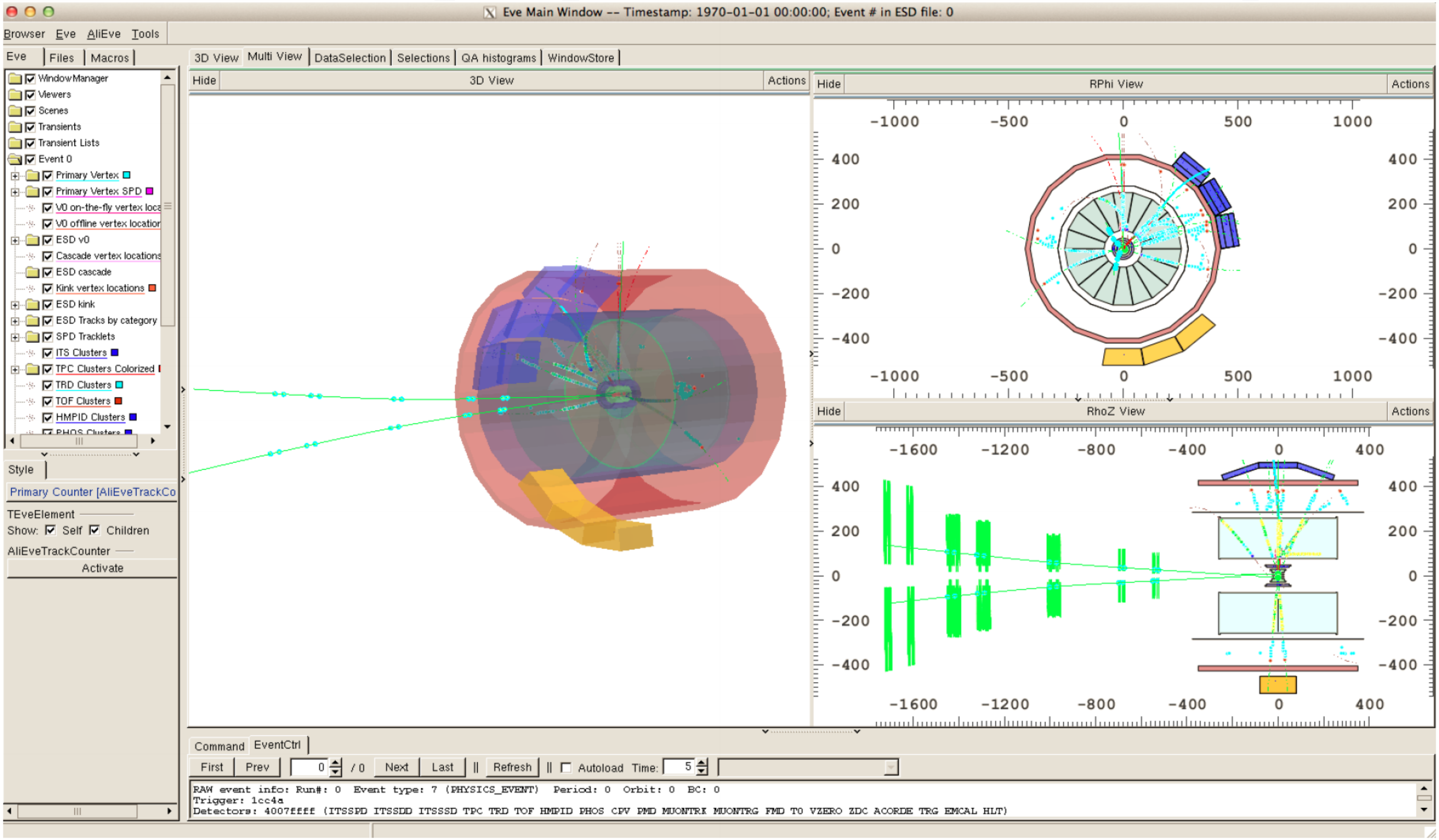
Use of Event Display at the Control Room



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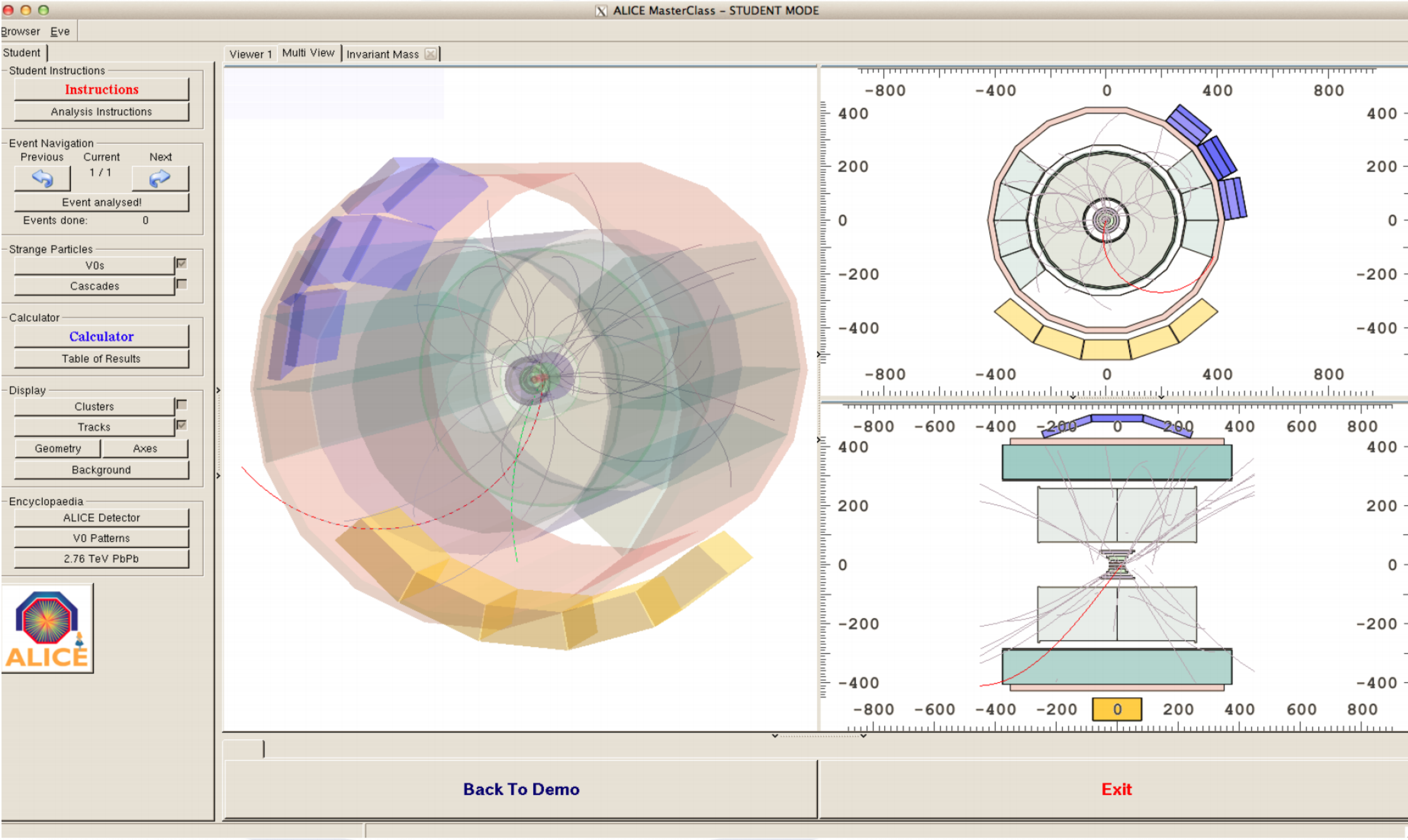

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Event display: Visual identification of V0 decays

The signature

V0 (and cascade) decays of strange hadrons (K^0_s, Λ, Ξ)

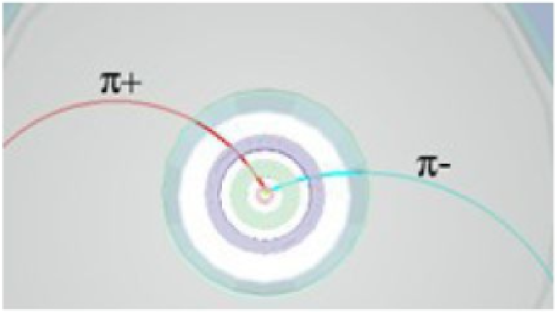
Use Event Display

to visually identify strange particles through the reconstruction of their decay patterns

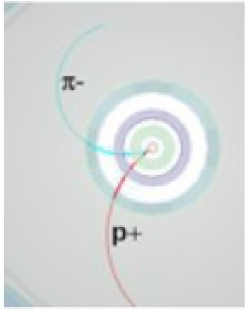
Didactic messages:

- Easy to understand and communicate some basic concepts (i.e. behaviour of charged particles in magnetic field, particle identification techniques etc.)

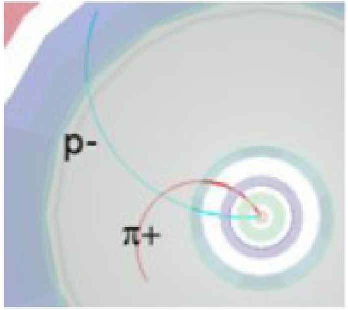
- Easy to explain how you "see the strange particles"



$K0s \rightarrow \pi+\pi-$



$\Lambda \rightarrow \pi-p$

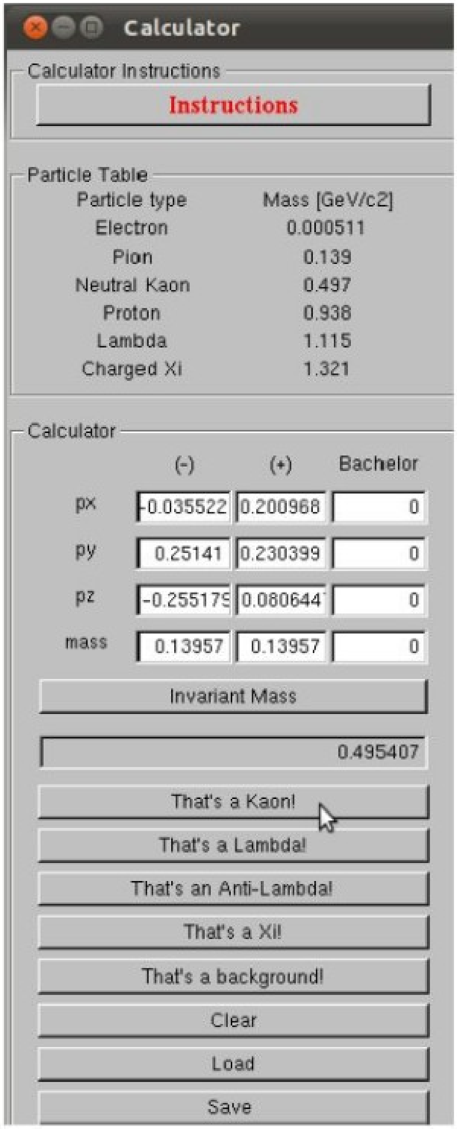


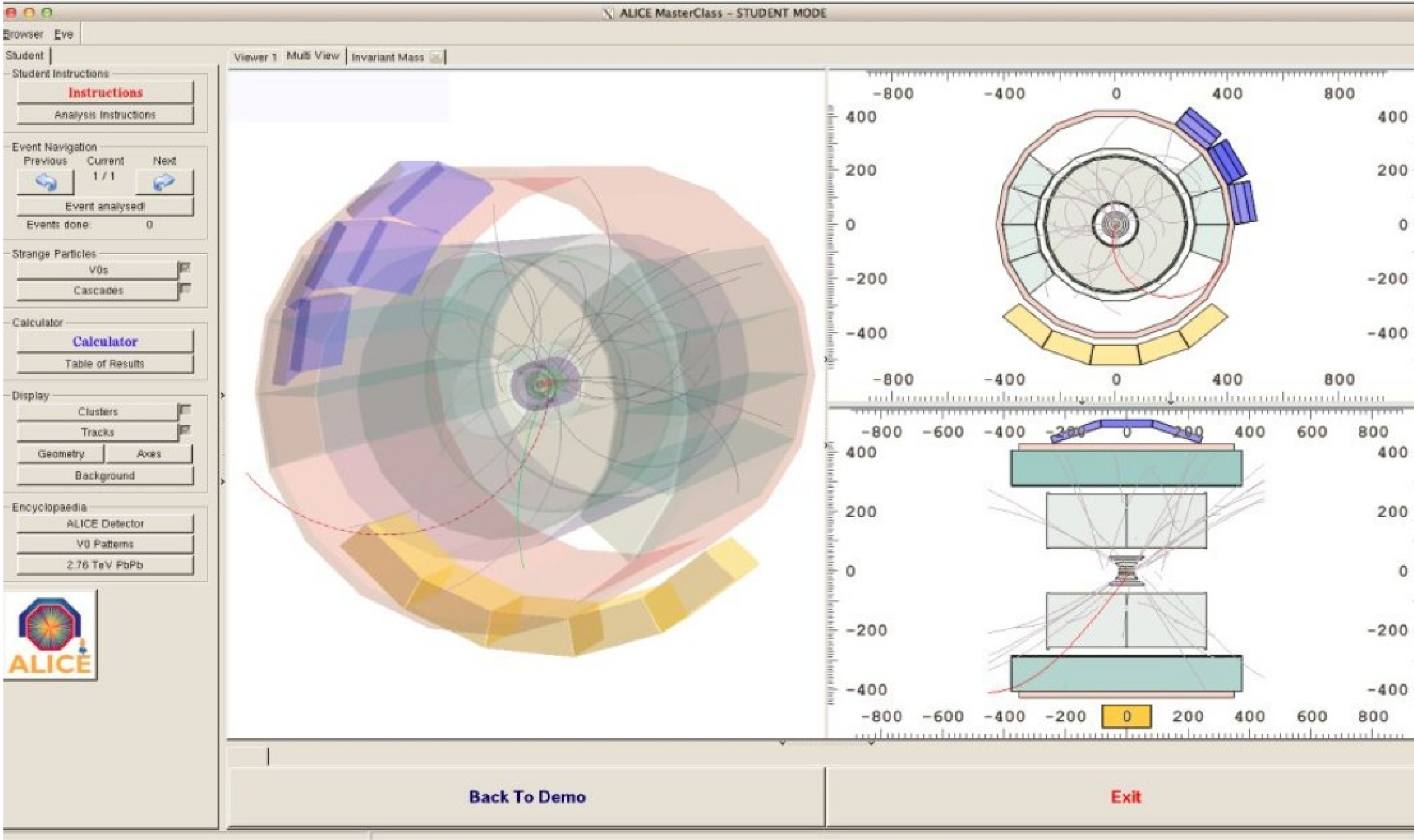
anti $\Lambda \rightarrow p-\pi+$

Two opposite tracks from a secondary vertex

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.





Clearly, we need more statistics → x 10 000 000

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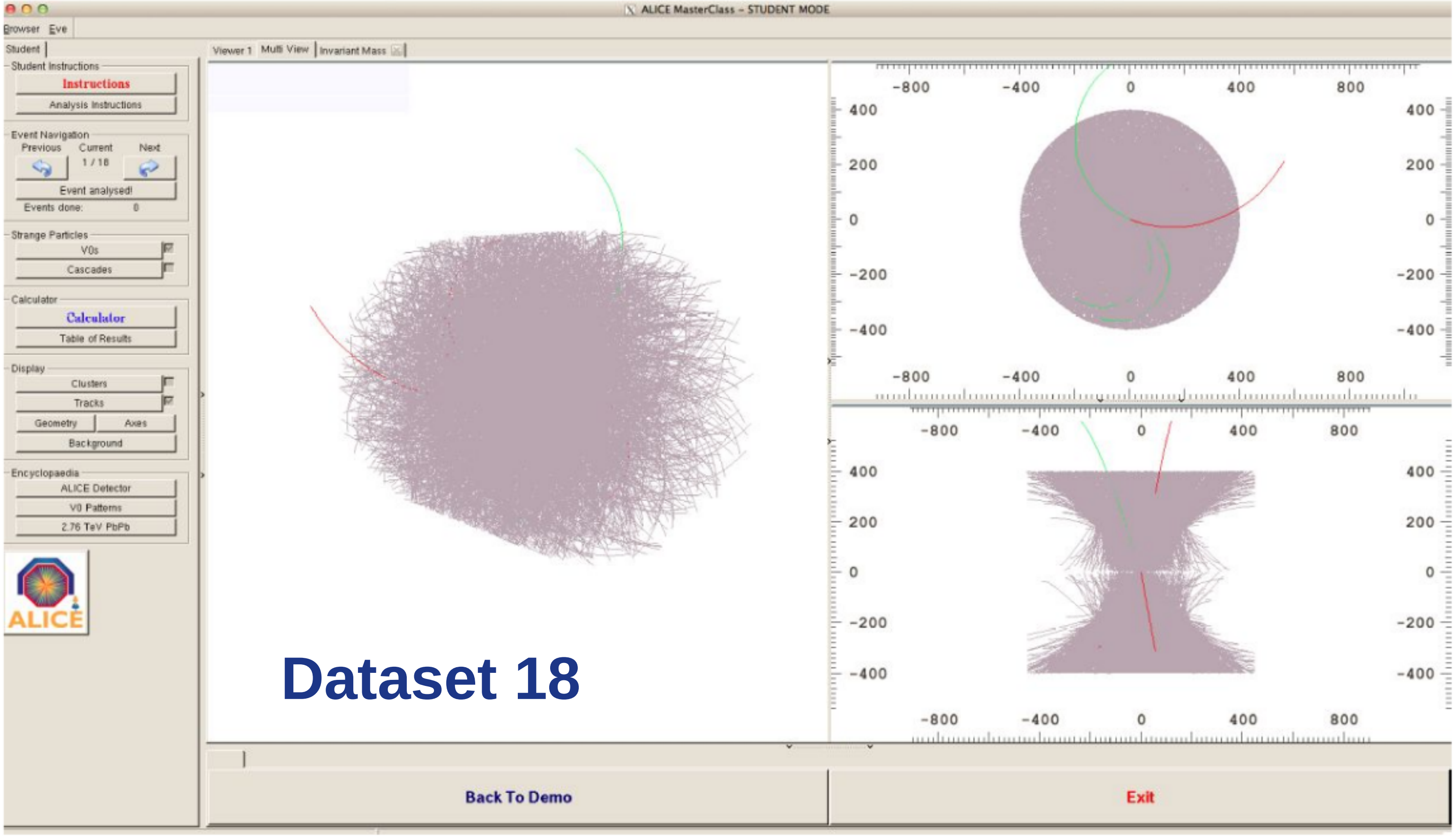
Lead-Lead event

Visual impressions: PbPb is different than pp. Visual analysis has limits



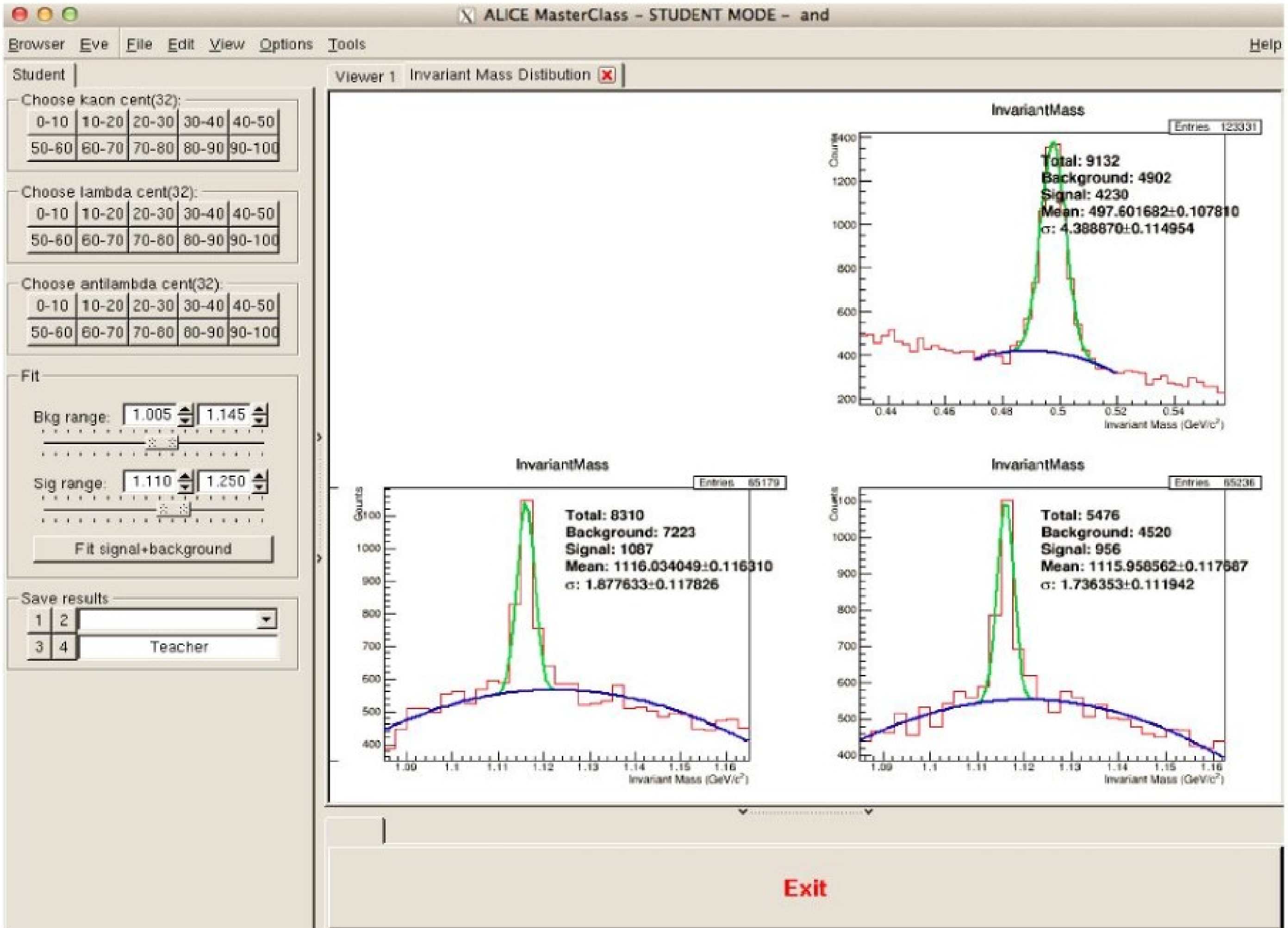
but useful for testing/debugging algorithms

Large Statistics Analysis

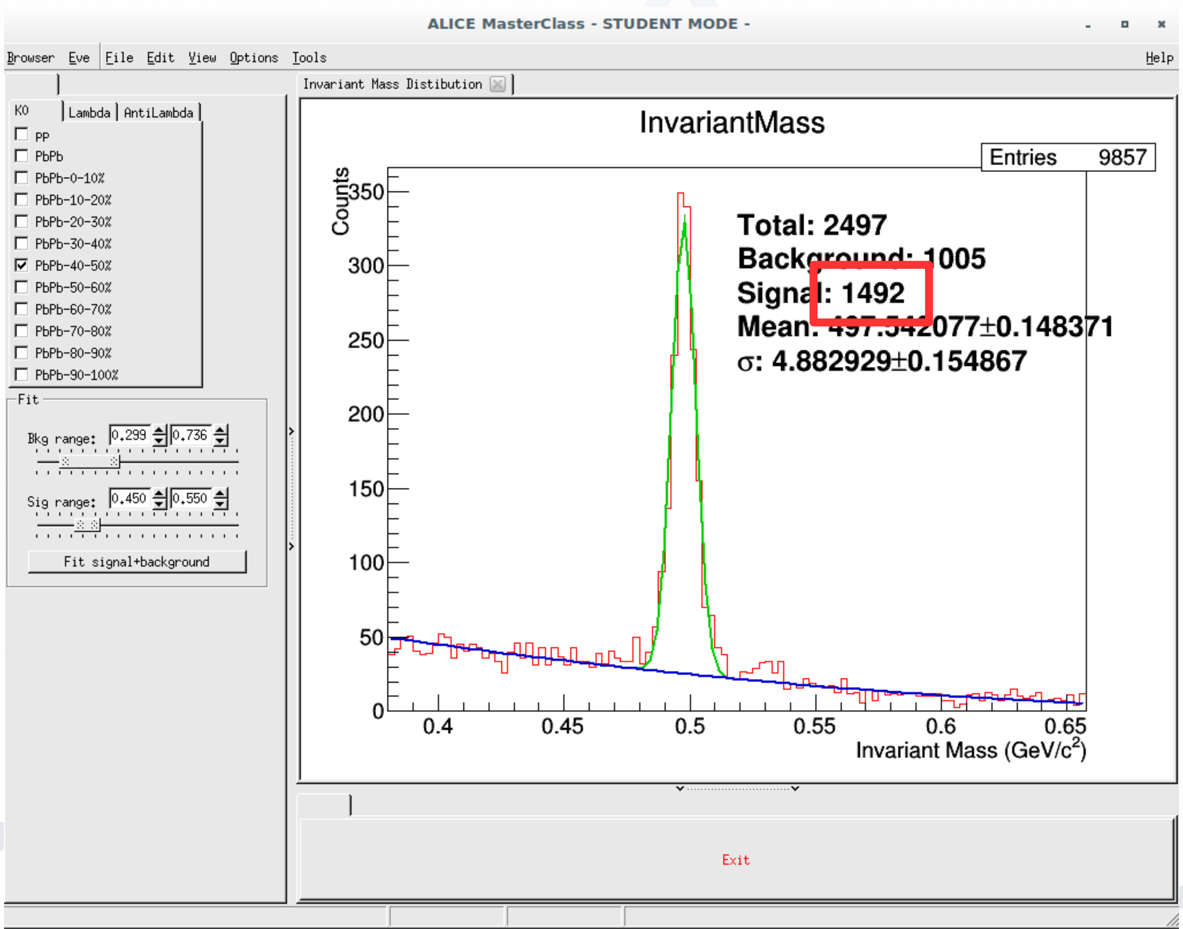
- Analyze 20000 events looking for K^0_s, Lambdas, antilambdas
  Note background!

- Fit background

- Fit peak



We are looking for number of strange particles: result (signal) = total - background



We put results into <u>appropriate</u> cells

http://cern.ch/go/8ZLx

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centrality	<Npart>	Nevents	NKs	efficiency Ks	yield Ks	Ks enhancem
0-10	360	213		0.26	86.963	1.933
10--20	260	290		0.26	61.512	1.893
20-30	186	302		0.29	42.818	1.842
30-40	129	310		0.29	29.032	1.800
40-50	85	302		0.29	17.047	1.604
50-60	52	300		0.29	8.931	1.374
60-70	30	315		0.35	3.710	0.989
70-80	16	350		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 ; $\langle N_{part} \rangle$ = 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"

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How to keep track of results?

Online spreadsheet:

http://cern.ch/go/8ZLx

(students are divided into groups, and they should fill appropriate cell depending on their group number)

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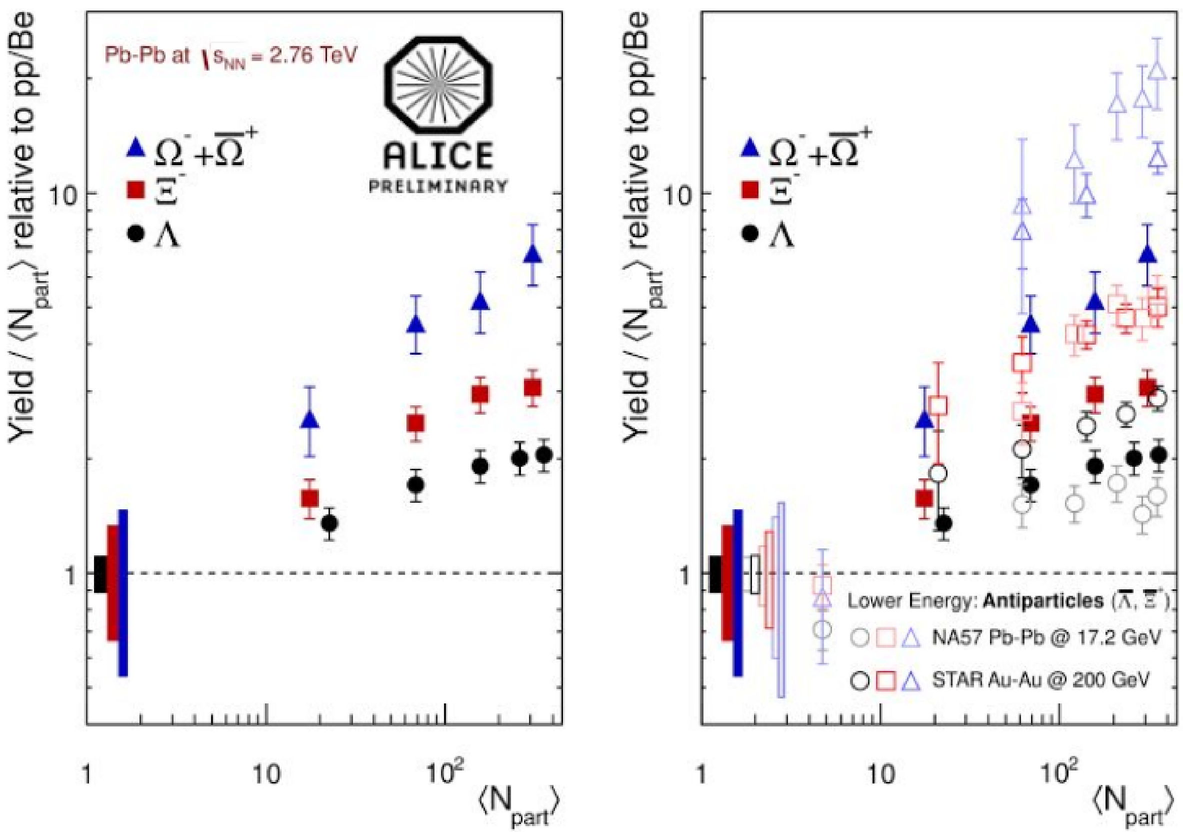
ALICE MasterClass

Strangeness production:

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



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