INTERNATIONAL MASTERCLASSES HANDS ON PARTICLE PHYSICS

Yiota Foka (GSI)

on behalf of the

Working Groups

IMC Steering 4.10.2018 CERN

http://physicsmasterclasses.org/

INTERNATIONAL MASTERCLASSES

hands on particle physics

International MasterClasses

International Particle Physics Outreach Group

Challenges, feedback, support

Students Day, Demos: get to know !

ROOT2018: https://indico.cern.ch/event/697389/timetable/#20180910.detailed

Registration		
Academy of Sciences and Arts (Akademija nauka i umjetnosti Bosne i Hercegovine)		08:30 - 09:00
Welcome	*TBD*	
Academy of Sciences and Arts (Akademija nauka i umjetnosti Bosne i Hercegovine)		09:00 - 09:10
ROOT State of the Union and vision for 2020	*Axel Naumann*	
Academy of Sciences and Arts (Akademija nauka i umjetnosti Bosne i Hercegovine)		09:10 - 09:45
Thoughts and ideas of a previous actor and now project's observer about ROOT's future	*Rene Brun*	
Academy of Sciences and Arts (Akademija nauka i umjetnosti Bosne i Hercegovine)		09:45 - 10:05
Particle physics MasterClasses and future developments	*Yiota Foka*	
Academy of Sciences and Arts (Akademija nauka i umjetnosti Bosne i Hercegovine)		10:05 - 10:30

Welcome and introduction		
Sala Grande, Palazzo del Cinema		10:00 - 10:10
The Quark-Gluon Plasma: a historical overview	*Reinhard Stock*	
Sala Grande, Palazzo del Cinema		10:10 - 10:50
Coffee break		
Sala Grande, Palazzo del Cinema		11:00 - 11:30
Open heavy flavours	*Andrea Rossi*	
Sala Grande, Palazzo del Cinema		11:30 - 12:10
Quarkonia	*Alexander Rothkopf*	
Sala Grande, Palazzo del Cinema		12:15 - 12:55
The Masterclasses: a powerful outreach tool for secondary school students	*Yiota Foka*	
Sala Grande, Palazzo del Cinema		13:00 - 13:15

QM2018 https://indico.cern.ch/event/656452/timetable/#20180513.detailed

International MasterClasses 2018

International Particle Physics Outreach Group

15 Feb – 28 Mar 2018

52 countries

225 institutes

14 000 students

Coordination : Fermilab,QuarkNet / TU Dresden

- 48 institutes
- 50 Masterclasses
  - 31 CMS
  - 19 ATLAS

- 177 institutes
- 257 Masterclasses
  - 35 ATLAS W
  - 104 ATLAS Z
  - 58 CMS
  - 39 LHCb
  - 18 ALICE Strangeness
  - 3 ALICE RAA

ROOT based

Usual feedback: we do NNN because ALICE needs ROOT Installation

International MasterClasses

International Particle Physics Outreach Group

Challenges, feedback, support

Students Day, Demos: get to know !

Motivate the next generations of scientists !

EXPAND: newcomers, school level, scope

MasterClasses expanding:

Applications: plans for hadron therapy

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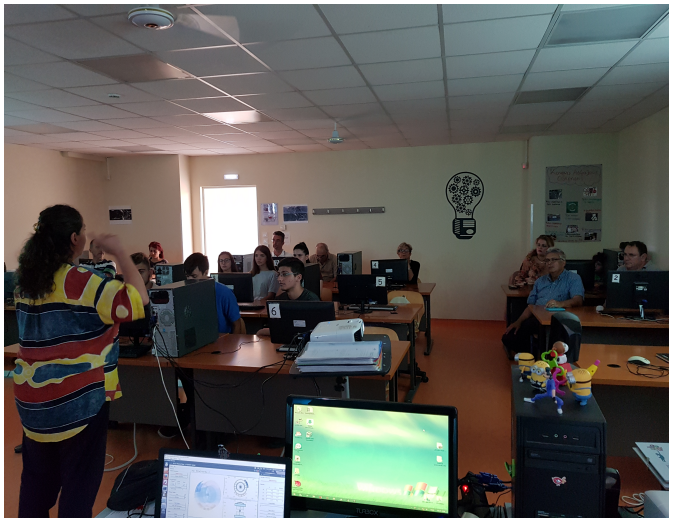


From primary school (St. Petersburg) to Gymnasium (Crete) to Uni (Sarajevo)

Sarajevo

Gazi, Crete

MasterClasses expanding:

Applications: plans for hadron therapy

From: Mirsad Tunja <mirsad.tunja@gmail.com>
Subject: Thanks for masterclass
Date: 17 September 2018 at 17:13:12 CEST
To: <Yiota.Foka@cern.ch>

Dear Yiota,

I am one of students from Bosnia who you met at ROOT conference and I was part of video chat this morning We were able to install masterclass (some with virtual machine, others directly with root) by following instructions you sent.

From this academic year I am starting job as teaching assistant at University of Sarajevo and one of subjects I will teach is Introductory nuclear physics. Some younger students you met will attend that course, and I already have idea to incorporate ALICE Masterclass as part of course. Students you met and I will help other students during class to analyze tracks with your software (maybe I will forbid using built in calculator :)).

.....I see this as great opportunity for our students to "taste" of real research in area of particle physics, improve their knowledge, enjoy classroom activities and expand their horizons.

We will be of course in contact for future Masterclass for high schools, but I just wanted to thank you because you already did a lot for our University (and country).

Masterclass methods

Example: CMS W/Z Investigation
web based

Main features of all measurements

First a visual analysis

Students get easily an impression of how particles
and decays are seen by detectors

What is the effect of magnetic field etc

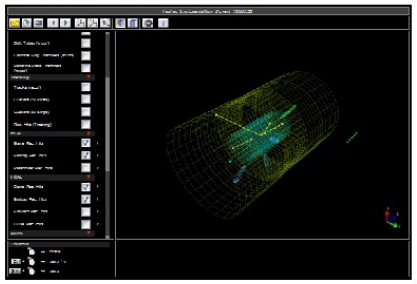
Then run “offline” on a “large statistics sample”
fill histograms, perform fits…
calculate particle yields, ratios…

Given needed (correction) factors
letting them know that this is the work a PhD student!

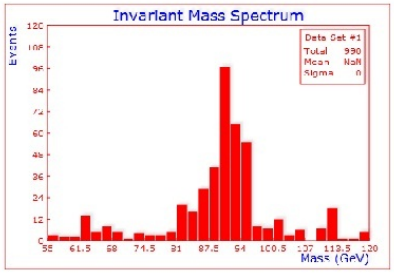
Final results close to the published results

**One of the requirements was
that it should be as close as possible
to the real experiment
And have discovery potential !**

Get the data and tasks



Inspect visualy



**Run algorithms
Fill histograms**

**Deliver results
and interpretation!!**

ALICE measurements

The tools: Based on ROOT, as the real data

- Simplified event display, **close to the real one used at the experiment**
- Visual analysis of small event sample (50 events)
- Large statistics analysis including background and “writing code”

Measurement 1: decay patterns of strange particles (V0)
developed 2010-11, by Pawel Debski at CERN

Measurement 2: momentum spectra of unidentified particles (RAA)
developed 2012, by Frederike Bock at GSI

Measurement 3: J/Psi in progress, by Steffen Weber at GSI
particle identification

V0 measurement adapted by LHCb for D0 studies

“Upgrades“ Plans : To ROOT or NOT To ROOT !?

develop new observables

use for other HI experiments (including HI CMS, ATLAS…)

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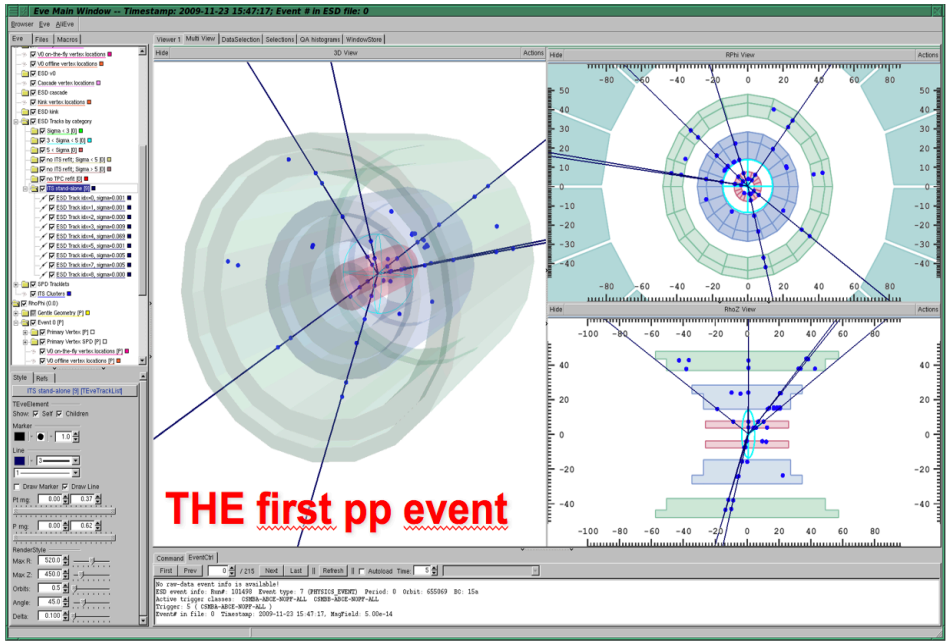
First LHC collisions in ALICE

First paper at LHC on multiplicity measurement

Published on Monday, 14 December 2009 16:00



At 17:21 the beams were dumped and the run closed with 284 events

At 17:28 the first mails with the first online reconstructed event were sent to the institutes

On 23rd November 2009, during the early commissioning of the CERN Large Hadron Collider (LHC), two counter-rotating proton bunches were circulated for the first time concurrently in the machine, at the LHC injection energy of 450 GeV per beam, allowing all LHC experiments to report first collision candidates.

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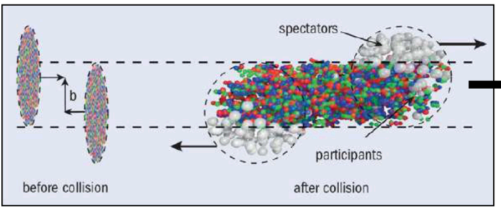
Strangeness enhancement

New Year CERN DG 2018

ALICE

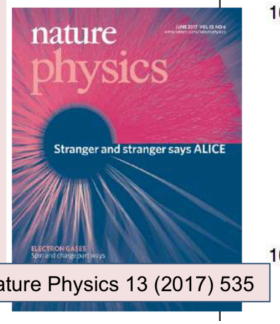


Heavy Ion collisions: conditions of high density and temperature of nuclear matter → formation of a plasma of deconfined quarks and gluons (QGP).

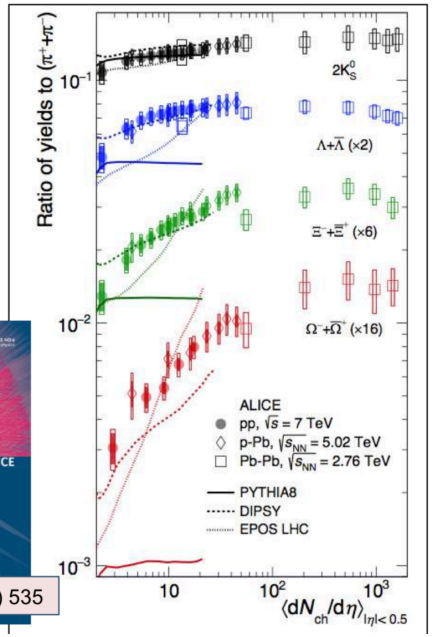
Enhanced production of strange particles historically considered to be one of the manifestations of QGP formation

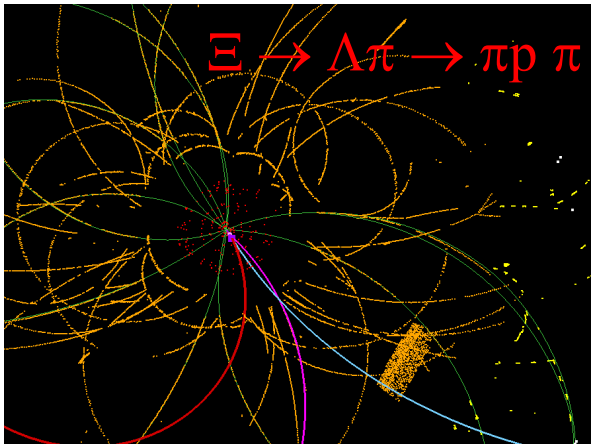
First observed at CERN in the 90's (WA97, NA57, NA49). Later at RHIC and by ALICE

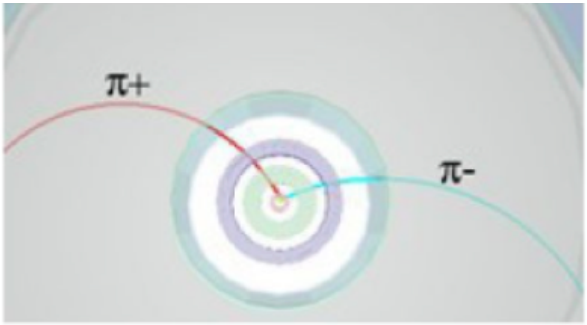
Now observed by ALICE also in **high-multiplicity pp interactions**
→Is this due to QGP formation in "small systems" (pp, p-Pb) at high multiplicity (already hinted by particle correlations, so-called "ridge")**?**
Observation not reproduced by pp MC models → opens new directions of (joint) theoretical and experimental studies in pp and HI



Nature Physics 13 (2017) 535







K0s→ π+π-

Measurement 1: decay patterns of strange particles with First pp Run1 Data

Test models and explore high-multiplicity pp events

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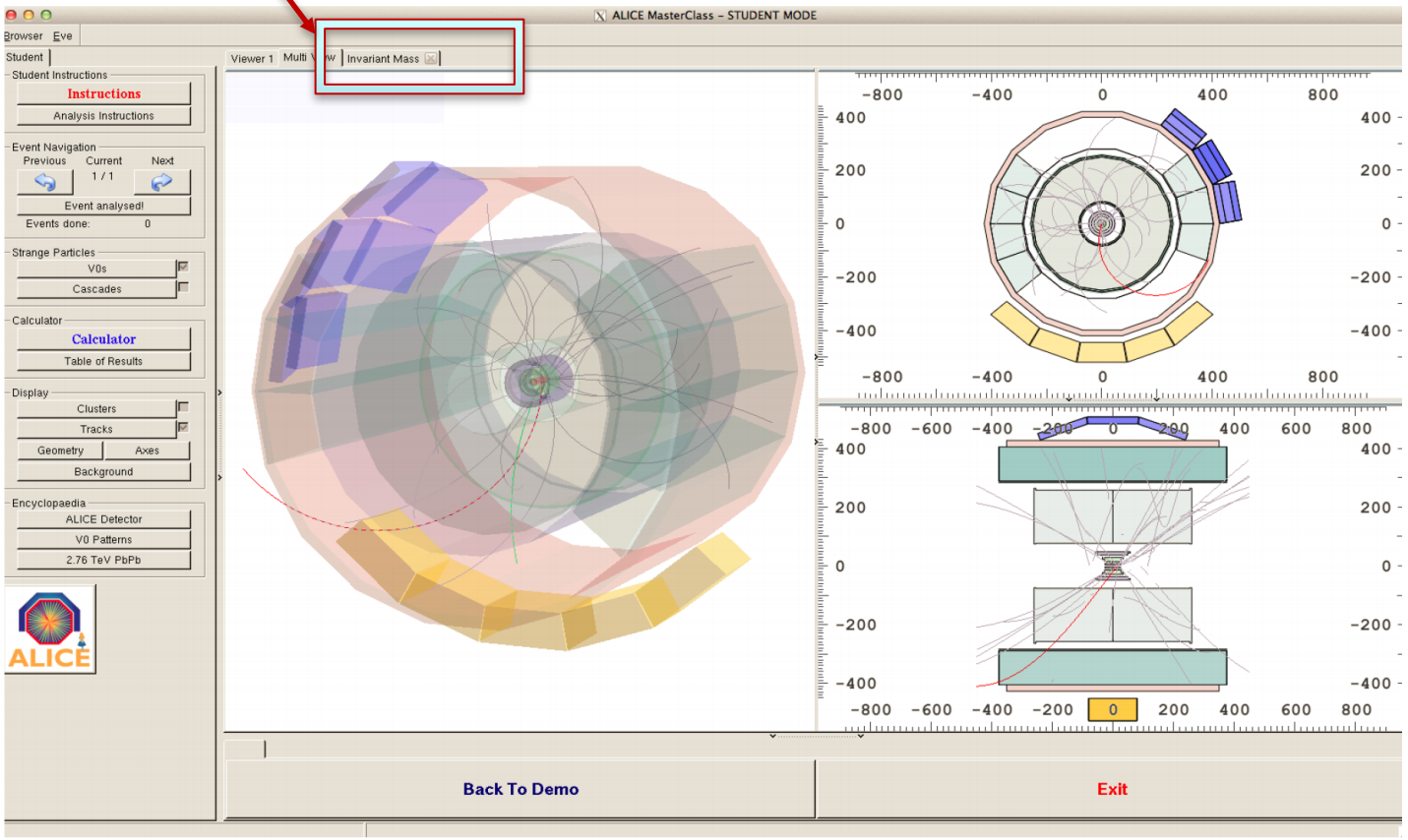
Visual analysis

Proton-proton (pp) event

Introduce concepts and visual analysis tools.

Interactive!
Grab and Rotate

Fill histograms while clicking on decay patterns



Clusters, Track reconstruction, Decay vertices, products…
effects of magnetic field… relate curvature with momentum…

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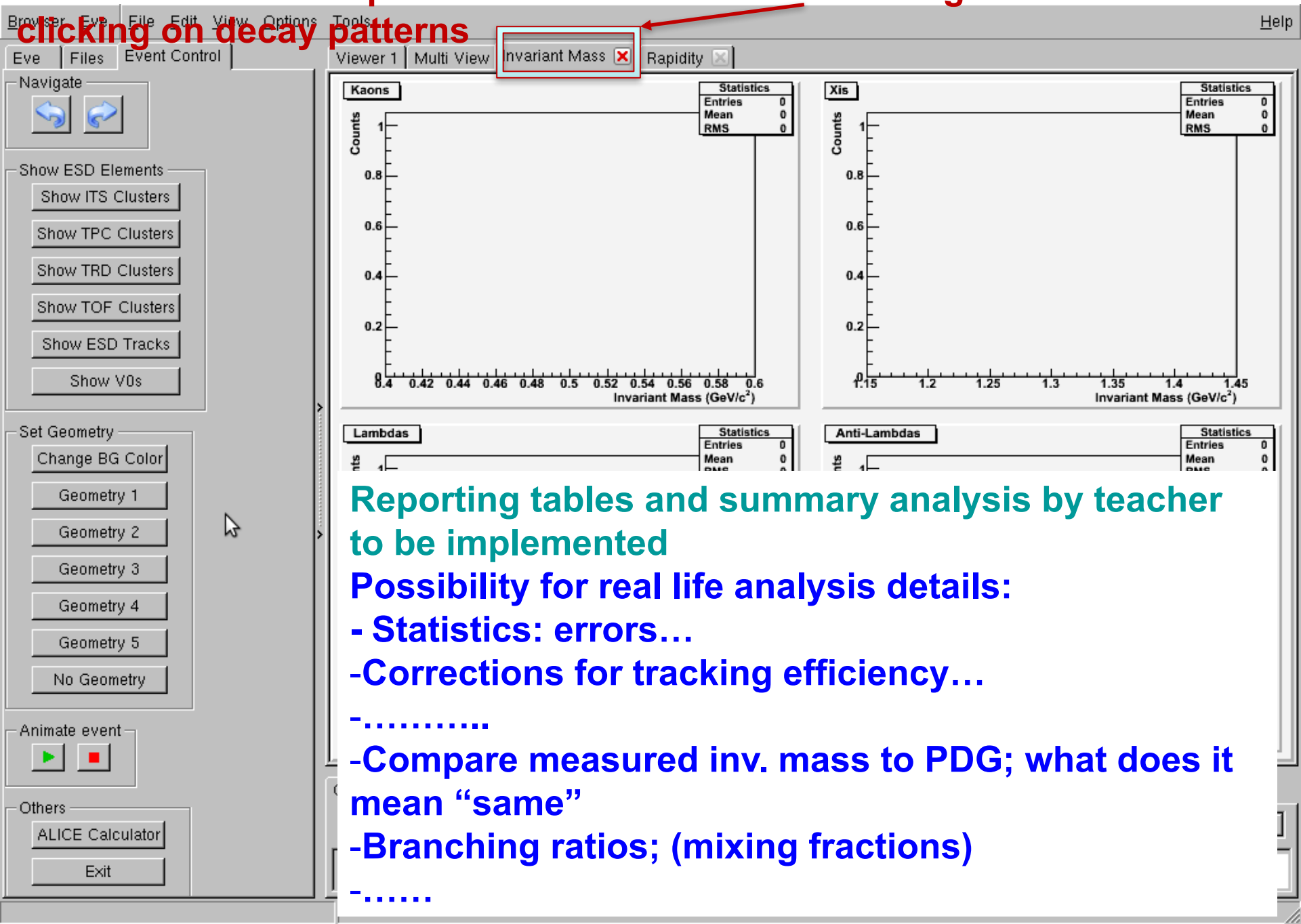
Slide from Initial Proposal NOT TO GIVE UP ! Fill histograms while clicking on decay patterns



Reporting tables and summary analysis by teacher to be implemented

Possibility for real life analysis details:

- Statistics: errors…

-Corrections for tracking efficiency…

-……..

-Compare measured inv. mass to PDG; what does it mean “same”

-Branching ratios; (mixing fractions)

-……

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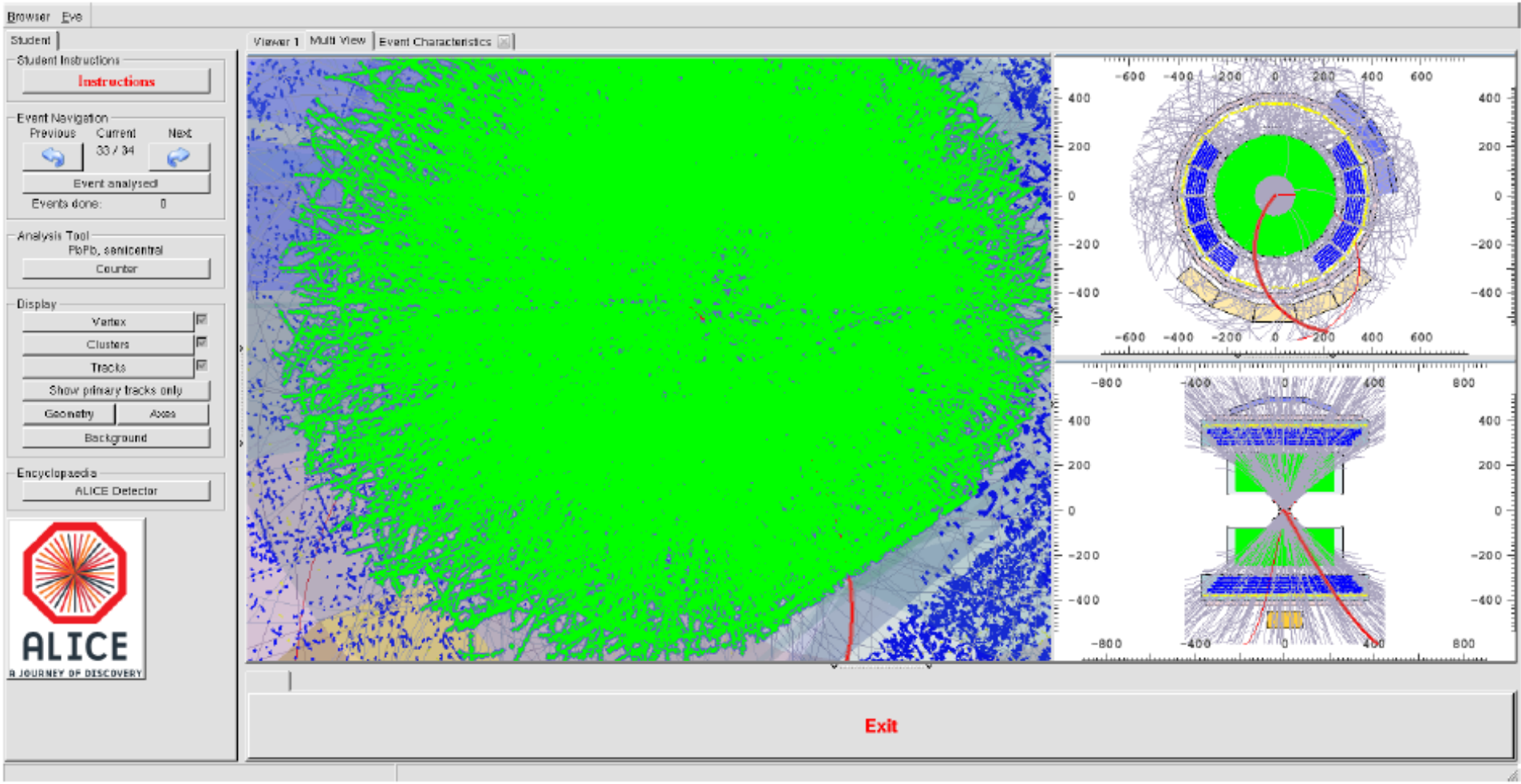
Visual analysis

Lead-Lead (PbPb) event

Visual impressions: PbPb is different than pp

Visual analysis has limits



relate multiplicity with centrality

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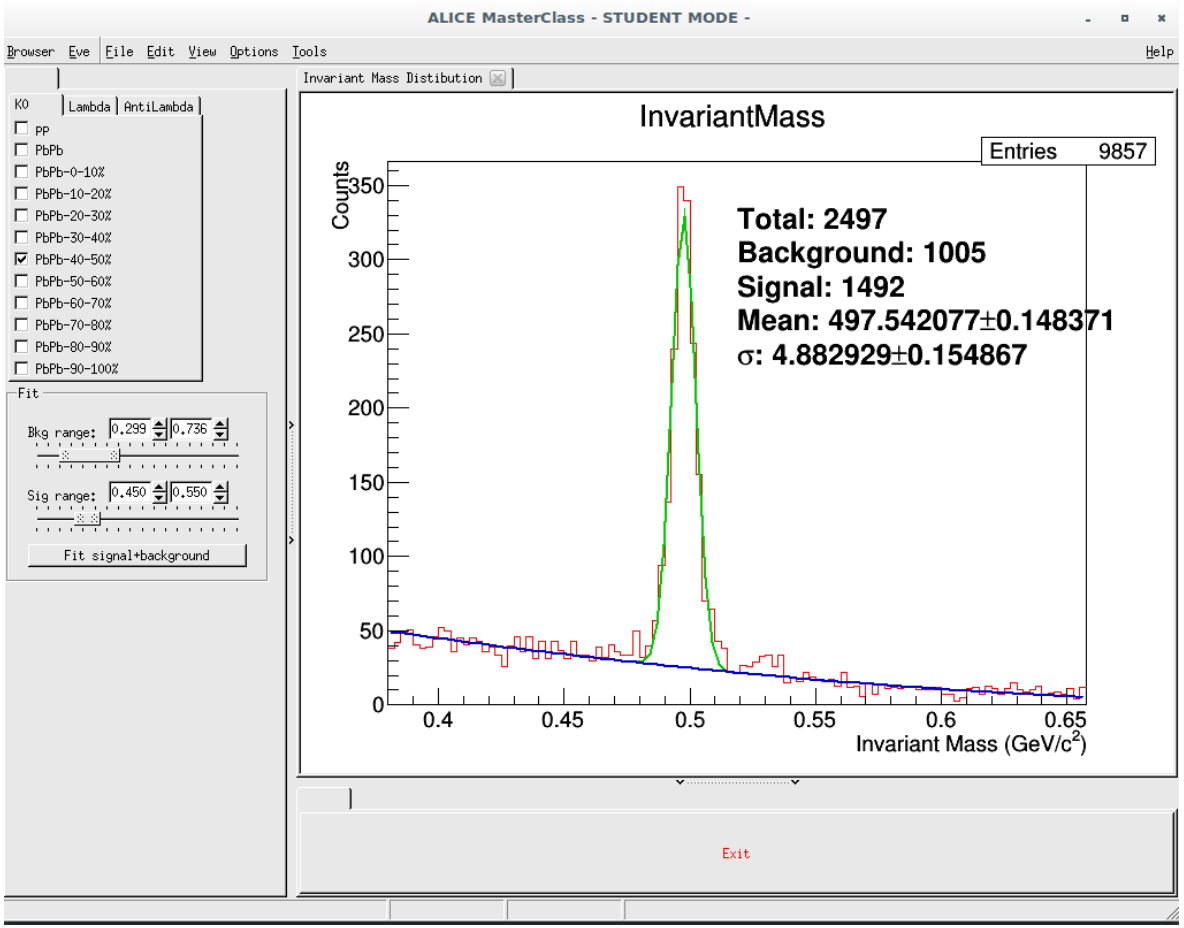
Large statistics analysis

Final results similar to publications !

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



We put results into appropriate cells

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

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MasterClass Youtube tutorials

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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ALICE MasterClass Upgrades

Main Aim: strengthen and facilitate HI communities

Possibility to implement Masterclass measurements for different experiments
re-use of existing MC or develop new in flexible and economic way
- introduce data (particles, decays)
- introduce geometry

Facilitate installation and use

Summer Student Proposal from ALICE

Supervisors: Redmer Alexander Bertens, Friederike Bock
Summer 2018

This summer student project is aimed at improving and expanding the current ALICE MC and at developing a **general, experiment independent framework**

Contacts and Task Force

coordination with HI communities:
- at LHC (CMS, ATLAS, LHCb), RHIC (STAR), GSI/FAIR (CBM, HADES)

ROOT and Open Data Groups

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Examples of possible developments

Development of Masterclass for CBM
(future experiment at GSI/FAIR)

Development of Masterclass for HADES
(running experiment at GSI, sister of CBM)

Development of further Masterclasses for ALICE
e.g. LHCb Do re-implement for ALICE (started from ALICE Vo)

Development of CMS Do Masterclasses

Development of ATLAS RAA Masterclass
possibility to combine it with ALICE RAA (and cover low and high pt range)

Development of J/Psi ALICE, CMS….

Development of similar observables for STAR at RHIC etc

Based on tracks, decays and invariant mass analysis

Need well structured modular framework
And common definition of data format

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Heavy-ion Physics

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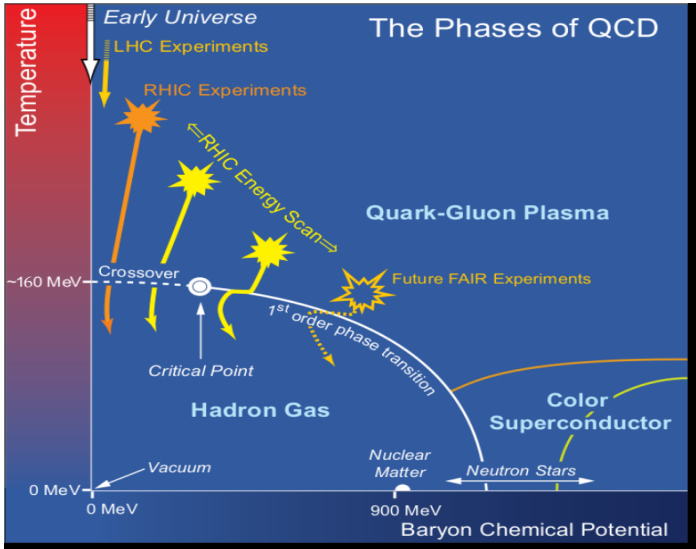
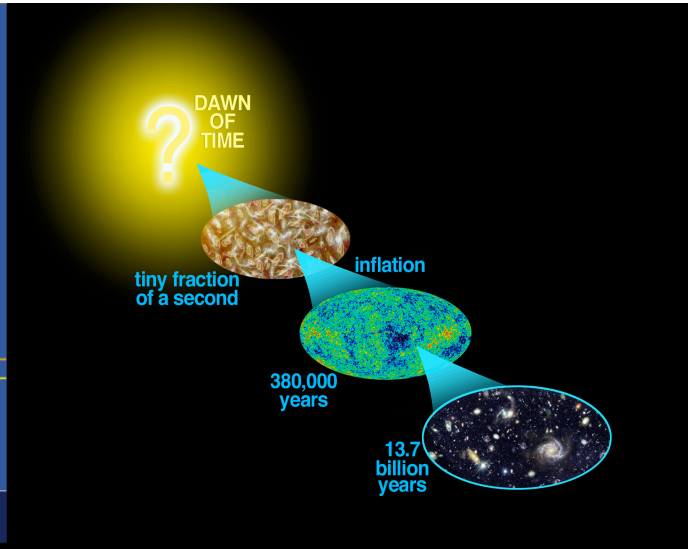
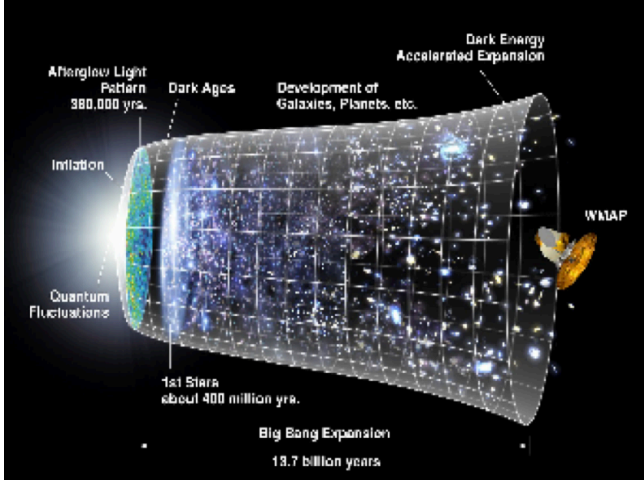
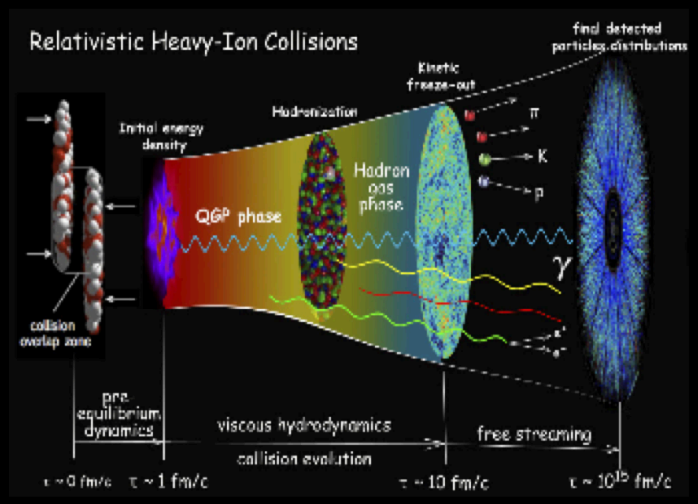
Analogies of Little and Big Bang See for instance here







our Universe



a heavy-ion collision

ALICE Masterclass Upgrades

Starting from unified package:

by Christian Holm Christensen Niels Bohr Institute

Jonas Toth (programmer)
CERN Summer Student

Towards a framework:

all ALICE MasterClasses in one single package

Uploaded to GitLab
https://gitlab.cern.ch/tothjo/alice-masterclasses

ROOT6: providing compiled package
Providing ready-to-use virtual machine

Follow up and Feedback:

Active Follow up also CMS and STAR

Schools in Crete (September, October)

ALICE Juniors….

Dedicated Presentation and Tutorial
for Summer Students from ALICE and Montenegro, Sarajevo
Open Data, participation
https://indico.cern.ch/event/751662/

ALICE Physics Forum

ALICE MasterClass Upgrades

Global work plan discussed with IMC Steering and IPPOG

https://indico.cern.ch/event/735959/
https://indico.cern.ch/event/703335/timetable/?print=1&view=standard

Translations:

Start with providing methods to easily add a new language

Semi-automatic snippet translation through Google Translate

```
/// translation/EntryPoint/keys_gui_trans.txt.de

/// Key-Value store for German translation.
/// This translation can be generated semi-automatically.
RegisterText("GUISettings", "Einstellungen ...");
RegisterText("GUIDataSource", "Waehlen Sie eine Datenquelle (optional) ...");
RegisterText("GUILabelClassConfig", "Hier gehts los ...");
RegisterText("GUIChooseLanguage", "Waehle Sprache ...");
RegisterText("GUIChooseClass", "Waehle Meisterklasse ...");
RegisterText("GUIChooseExercise", "Waehle eine Uebung aus ...");
RegisterText("GUIExitButton", "Beenden");
```

Refactoring: structural changes, not affecting behaviour

Extract building blocks from existing code

Implement easy-to-use-hard-to-misuse interfaces

Test points in the code

Decouple GUI

MasterClass Framework Outlook

Web-based MasterClasses

jsROOT implements Event Display for browser

Basic code, structure could be reused

code reuse possible e.g. WebAssembly, ASM.js, Emscripoten

Work Plan To be Continued:

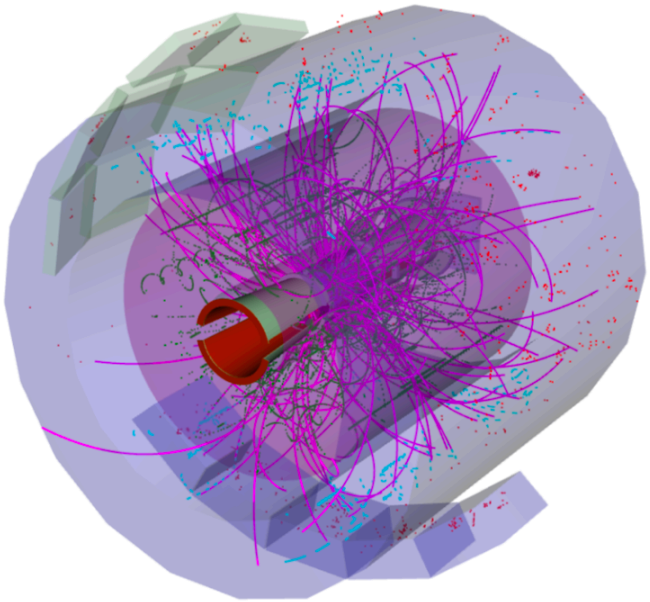
Google Summer of Coding

In the ToDo List: use by other HI experiments

Data format
Collect “proof of principle” data from experiments
Testing and Training

HI Groups: new physics observables

Physics message
Generating data sets



Need decay history

Data for MasterClasses and Open Data Portal

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CERN Open Data portal

Can CERN open source software handle. . .

1 PB of LHC data?

- disseminating public particle physics data
  - –datasets, software, VMs, configuration, documentation, and more
- **LHC collaboration data policies**
  - **–restricted → embargo period (~5 years) → open**
- users
  - **–education: general public, high-school students, masterclasses**
  - –research: data scientists, physicists
- timeline
  - –launched in November 2014 (Invenio v2)
  - –major upgrade in December 2017 (Invenio v3)

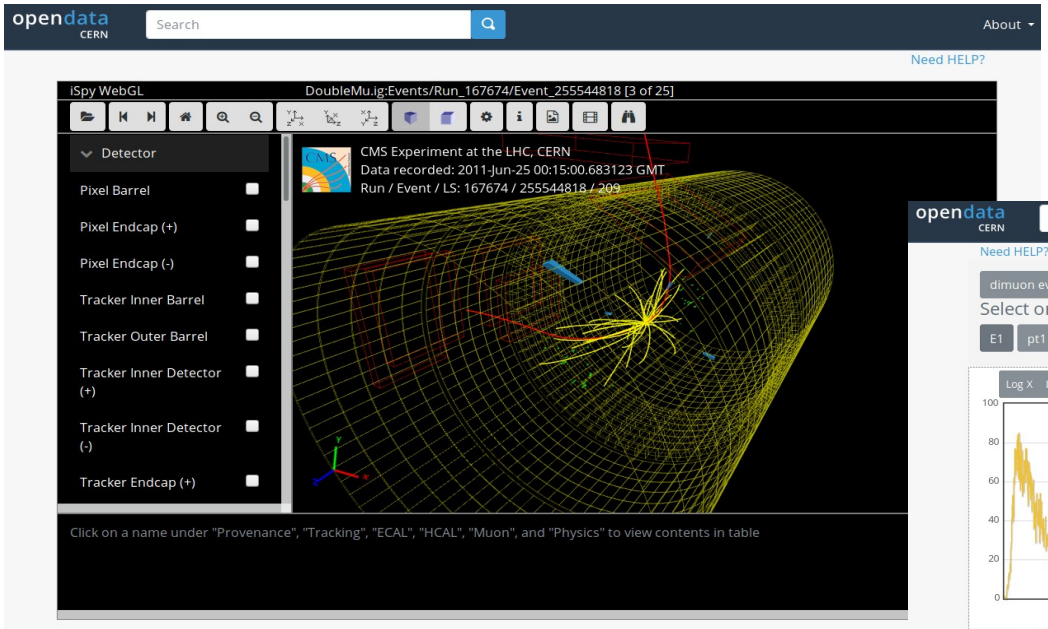
Developed by CERN-IT and CERN-SIS in close collaboration with LHC experiments

Tibor Šimko

@tiborsimko

ITTF · 16 March 2018

Visualise detector events

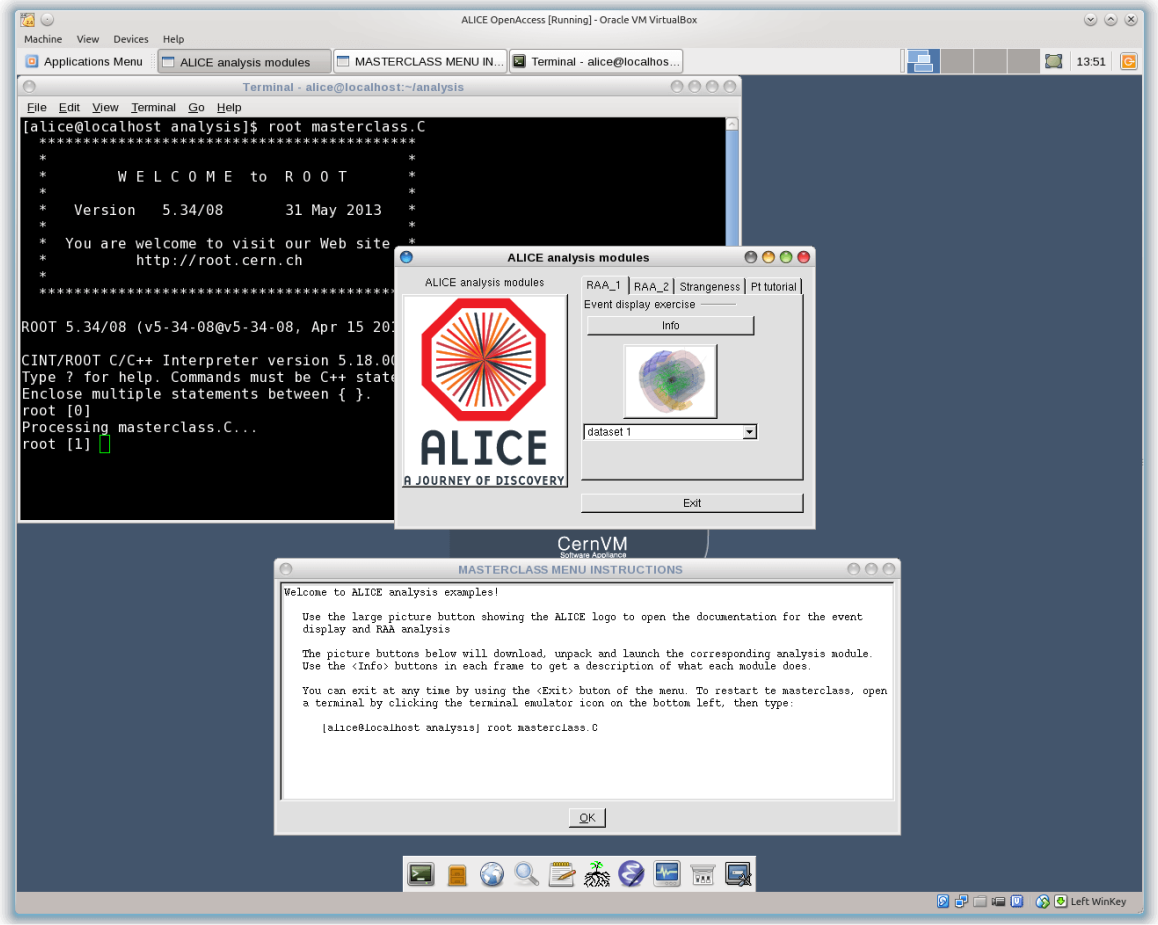


Interactive event display for high-level derived datasets

Interactive histogram plotting for high-level derived datasets

@tiborsimko

Virtual machines



Install CernVM virtual machines to explore primary datasets

@tiborsimko

ROOT 6.15/01
Reference Guide

ROOT Home | Main Page | Tutorials | Functional Parts | Namespaces | All Classes | Files | Release Not

Search

tutorials > dataframe

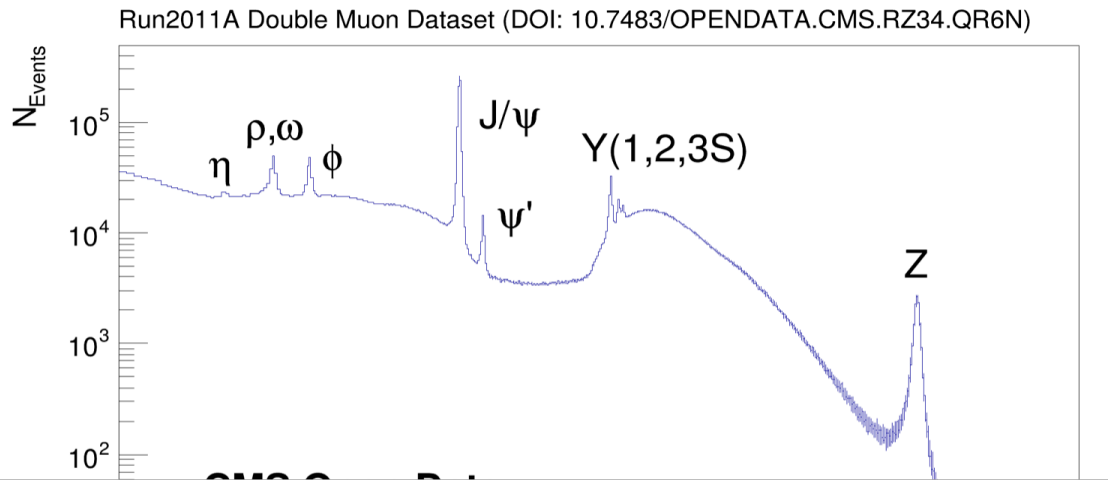
df102_NanoAODDimuonAnalysis.C File Reference

Tutorials » Data Frame tutorials

Detailed Description

View Notebook | Open in SWAN This tutorial illustrates how NanoAOD files can be processed with **ROOT** dataframes.

The NanoAOD-like input file is filled with events from CMS OpenData containing muon candidates from 2011 data (DOI: 10.7483/OPENDATA.CMS.RZ34.QR6N). The script matches muon pairs and produces an histogram of the dimuon mass spectrum showing resonances up to the Z mass.



Next (uni level) Use of notebooks to see and interactively execute code

https://root.cern/doc/master/df102__NanoAODDimuonAnalysis_8C.html

From clicking buttons to seeing what is happening !

```
#include "ROOT/RDataFrame.hxx"
#include "ROOT/RVec.hxx"
#include "TCanvas.h"
#include "TH1D.h"
#include "TLatex.h"
#include "TLorentzVector.h"
#include "TStyle.h"

using namespace ROOT::VecOps;

void df102_NanoAODDimuonAnalysis()
{
   // Enable multi-threading
   ROOT::EnableImplicitMT();

   // Create dataframe from NanoAOD file
   ROOT::RDataFrame df("Events",
       "http://root.cern.ch/files/NanoAOD_DoubleMuon_CMS2011OpenData.root");

   // Select events with more than two muons
   auto df_filtered = df.Filter("nMuon>=2", "More than two muons");

   // Find muon pair with highest pt and opposite charge
   auto find_pair = [](const RVec<float> &pt, const RVec<int> &charge) {
      // Get indices that sort the muon pts in descending order
      const auto idx = Reverse(Argsort(pt));

      // Find muon with second-highest pt and opposite charge
      const auto i1 = idx[0];
      for (size_t i = 1; i < idx.size(); i++) {
         const auto i2 = idx[i];
         if (charge[i1] != charge[i2]) {
            return RVec<size_t>({i1, i2});
         }
      }

      // Return empty selection if no candidate matches
      return RVec<size_t>({});
   };
   auto df_pair = df_filtered.Define("Muon_pair", find_pair, {"Muon_pt", "Muon_charge"})
                             .Filter("Muon_pair.size() == 2", "Found valid pair");

   // Compute invariant mass of the di-muon system
   auto compute_mass = [](RVec<float> &pt, RVec<float> &eta, RVec<float> &phi,
                          RVec<float> &mass, RVec<size_t> &idx) {
      // Compose four-vectors of both muons
      TLorentzVector p1;
      const auto i1 = idx[0];
      p1.SetPtEtaPhiM(pt[i1], eta[i1], phi[i1], mass[i1]);

      TLorentzVector p2;
      const auto i2 = idx[1];
      p2.SetPtEtaPhiM(pt[i2], eta[i2], phi[i2], mass[i2]);

      // Add four-vectors to build di-muon system and return the invariant mass
      return (p1 + p2).M();
   };
   auto df_mass = df_pair.Define("Dimuon_mass", compute_mass,
                                 {"Muon_pt", "Muon_eta", "Muon_phi", "Muon_mass",
    "Muon_pair"});
```

Next (uni level) Use of notebooks to see and interactively execute code

https://root.cern/doc/master/df102__NanoAODDimuonAnalysis_8C.html

Conferences Demos

International Particle Physics Outreach Group

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Involvement of LHC experiments
Conference Committees, HI conveners
Outreach Coordinators… IPPOG

QM2018 Venice
CONF: Thessaloniki, Dublin

INTERNATIONAL MASTERCLASSES

Hands on Particle Physics

INTRODUCTION

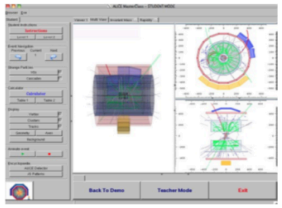
International Masterclasses[1] are a successful tool to engage young people with particle physics. High school students are offered the chance to become scientists for one day and perform a tailor-made physics analysis involving real LHC data under the supervision of physicists. In this way students experience methods and tools used in research and an appreciation for fundamental science is created.

CONCEPT

- High school students (15-19 years old) are invited to a university or research lab
- Introductory talks (standard model, detectors, accelerators)
- Hands-on: measurement with LHC data (ALICE, ATLAS, CMS, LHCb)
- International videoconference (3-5 groups + moderators at CERN / Fermilab)
- Organized by IPPOG[2]

MEASUREMENTS

Measurements[3] with data from ALICE, ATLAS, CMS, and LHCb have been developed for International Masterclasses. Students are introduced to basic concepts of particle identification and event classification. They work with event displays and tools also used by scientists. The basic idea of each measurement is a question related to particle physics. The results lead students to new and fundamental insights in this field. Tasks for students include for example revealing the structure of the proton, rediscovering the Z boson, the search for the Higgs particle or signatures of quark-gluon plasma. All material is free to use for any educational purpose.



ALICE MC measurement based on the Event Display used by the experiment.

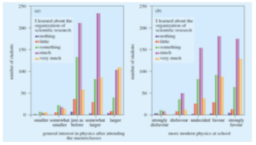
VIDEOCONFERENCE

At the end of their Masterclass, students connect to a videoconference with CERN or Fermilab and groups from other countries. Moderators combine students´ results and discuss them with participants. In addition, the videoconference includes a Q&A session and a quiz.

Videoconference with moderators at CERN (top left) and 5 groups.

EVALUATION

Evaluations have shown that students enjoy Masterclasses. The appreciation is independent of gender and pre-knowledge. Three-quarter of the participants reported that they learned much or very much about the organization of scientific research. In addition, students increase their general interest in physics and wish to have more modern physics at school[4].



After a whole day of particle physics students´motivation is raised.

PARTICIPATION

Since its beginning in 2005, the program has steadily grown[5]. In 2018, more than 220 universities and research labs in 52 countries participated with 14.000 students getting their hands on real data from the LHC. The worldwide participation reflects the international collaboration in particle physics.

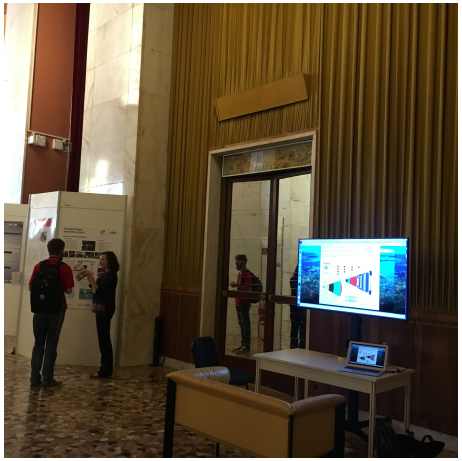
World map (left) and map of Europe (right) showing in green countries participating in International Masterclasses.

ALICE ROOT based

CMS

LHCb ROOT based

ATLAS



International Particle Physics Outreach Group

Public Events

IONS2017, Chania, Crete
https://indico.cern.ch/e/ions2017

ATLAS and ALICE MC

Curiosity Team

more photos

INTERNATIONAL MASTERCLASSES
hands on particle physics

International Particle Physics Outreach Group

Curiosity team, follow up

INTERNATIONAL MASTERCLASSES
hands on particle physics

Different environments, different approaches: web-based, virtual box, USB key... administrators, policies

Chania, conference venue

CERN auditorium

ATLAS MC at Herakleion, school

ALICE MC at CERN P2 and at GAZI

Workshop on Ions

for Cancer Therapy, Space Research and Material Science

SPACE RESEARCH
WORKSHOP
ON IONS FOR CANCER THERAPY
MATERIAL SCIENCE

Chania, Crete, Greece

26 - 30 August 2017

Workshop Main Topics

28-30 of August at Great Arsenali

Particle therapy status
- Centres worldwide
- Treatment planning and imaging novel methods
- Challenges, new R&D directions

Space research and dosimetry
Nanotechnology, electronics and material research
Modelling and benchmarking of experiments
Novel accelerators and training

Public Events

26 of August - science fair at Neorio Moro
27 of August - public talks at Great Arsenali
30 of August - coffee with scientists at Neorio Moro

https://indico.cern.ch/e/ions2017/

Ions for cancer therapy

ENLIGHT, CERN

BIOMAT and BIOPHYSICS, GSI

IONS2017

https://indico.cern.ch/e/ions2017

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https://indico.cern.ch/e/ions2(

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Etiennette Auffray Hillemanns (CERN, Switzerland)
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A. Katanaeva (UB, Spain and SPbSU, Russia)
D. Shukhobodskaia (SPbSU, Russia)

PIMMS2 @CERN

Workshop
Location Archamps, France
Venue: European Scientific institute (ESI)
Dates: 19-21 June 2018

Ideas and technologies for a next-generation facility for medical research and therapy with ions

https://indico.cern.ch/e/ions2018

MAIN TOPICS:
- EXISTING FACILITIES
- CURRENT INITIATIVES
- NEW TECHNOLOGIES
- DESIGN PARAMETERS
- TECHNICAL OPTIONS

ORGANIZATION

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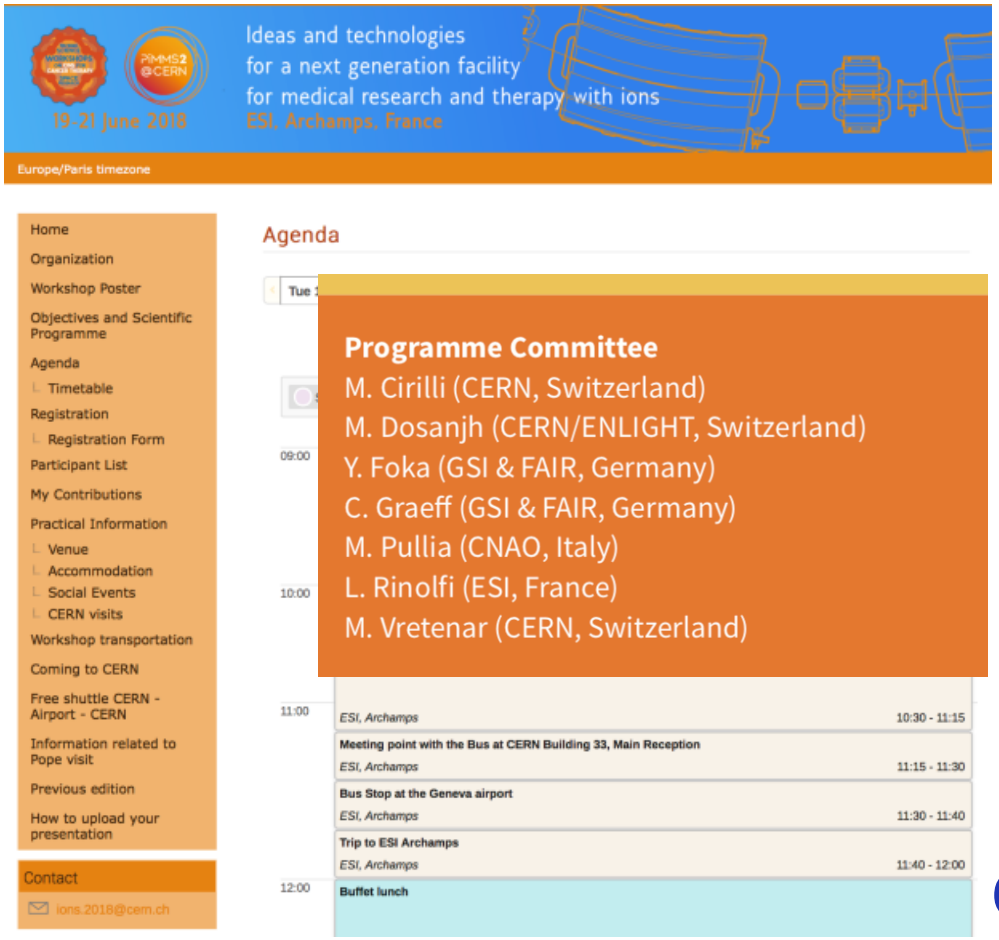
CERN ARIES esi FAIR EMMI GSI ENLIGHT

Scientific programme

Fruitful workshop, concrete outcome, offer to society.



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Continue with design study and applications for EU funds

Implementing MasterClass on hadron therapy

Amer Ajanovic
CERN Summer Student from Sarajevo

Assemble Package and Hands-on !

A lot of support material

From ENLIGHT and EU projects

http://enlight.web.cern.ch/
http://enlight.web.cern.ch/media/highlights

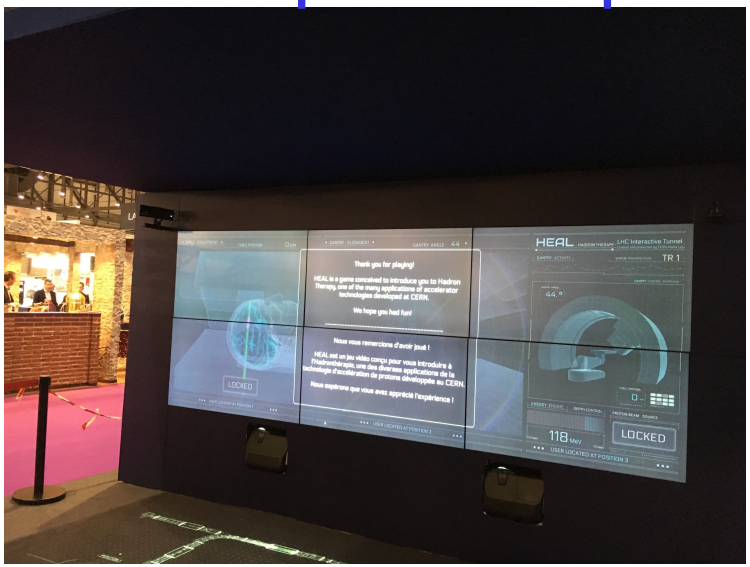
Imaging and hadron therapy animation
http://cds.cern.ch/record/1611721?ln=en
http://cds.cern.ch/record/2002120

Interactive virtual visit to hadrotherapy centre
http://www.cern.nymus3d.nl/maps#

Presentations and e-book open access
"from particle physics to medical applications"
http://iopscience.iop.org/book/978-0-7503-1444-2

Use real data: imaging based on commercial expensive software
(e.g. ROOT used for mamography)

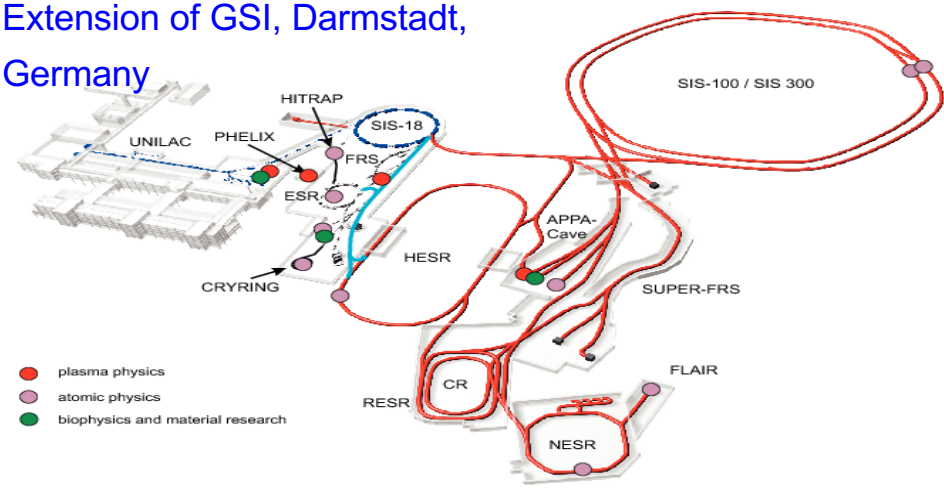
From Palexpo CERN expo

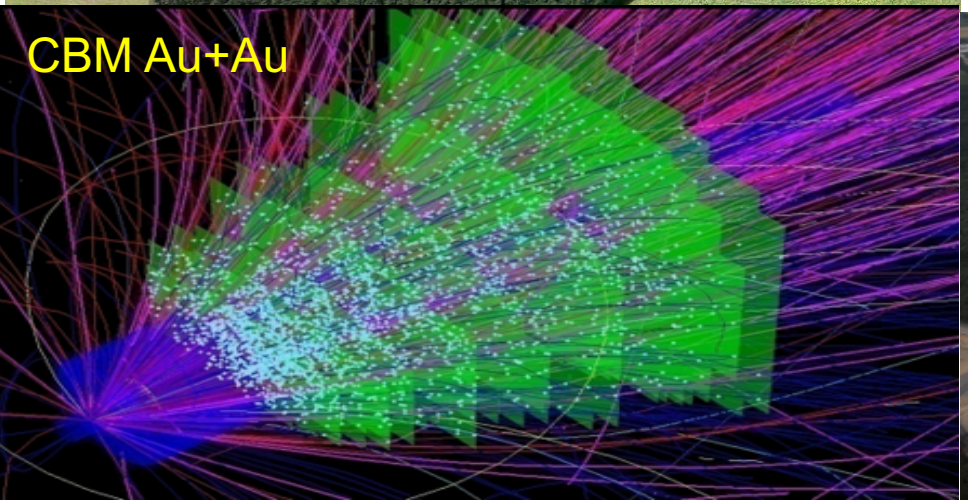


Aim:
to have a common software which is not too complex to use but still accurate and powerful.
Interest of lead author of MatRad, **a matlab based open-source** treatment planning tool.

GSI/FAIR

Extension of GSI, Darmstadt, Germany





Hadron (carbon ion) therapy

Pioneered at GSI

Implemented in hospitals

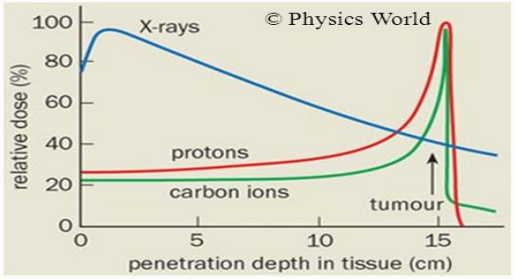
(i.e. Heidelberg…)

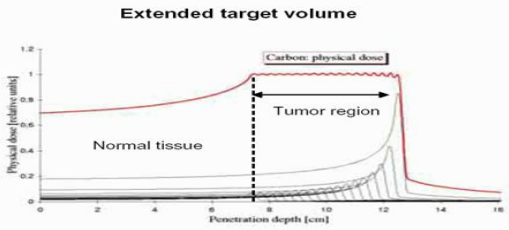
Part of FAIR program

GSI Darmstadt: scanned carbon beam

Clinically relevant properties of heavy-ion beams

- Inverted depth-dose profile (Bragg curve)

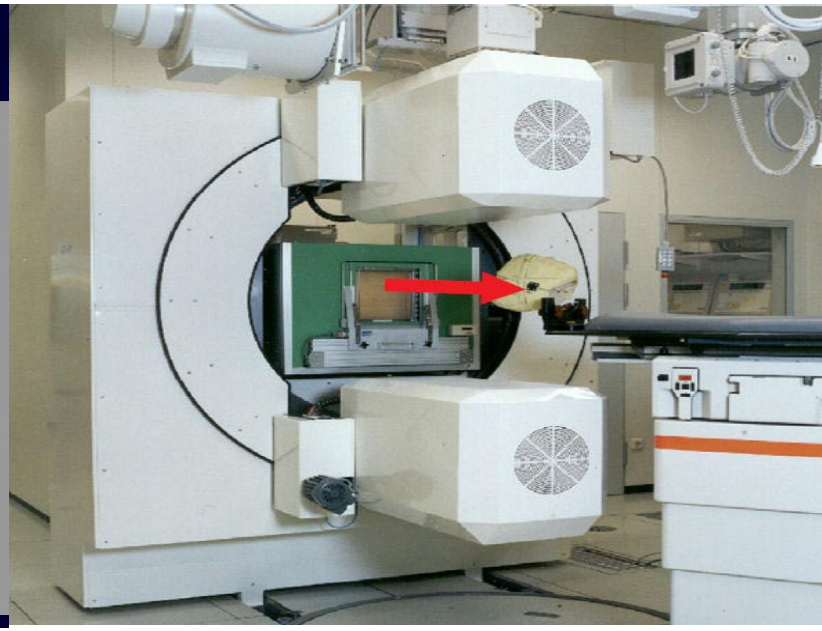




Typically 30 energy steps needed
for a ripple < 5%

D Shardt (GSI)

GSI

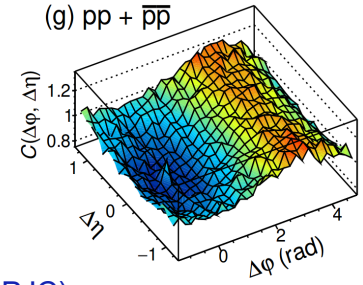


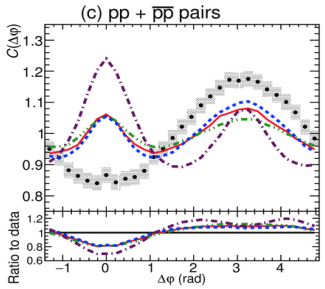
Strong interest discussions, planning on therapy MasterClass: efforts for 2019-2020 ?
GSI/FAIR, CERN, Sarajevo, Montenegro

Open questions

Baryon production mechanisms to be understood

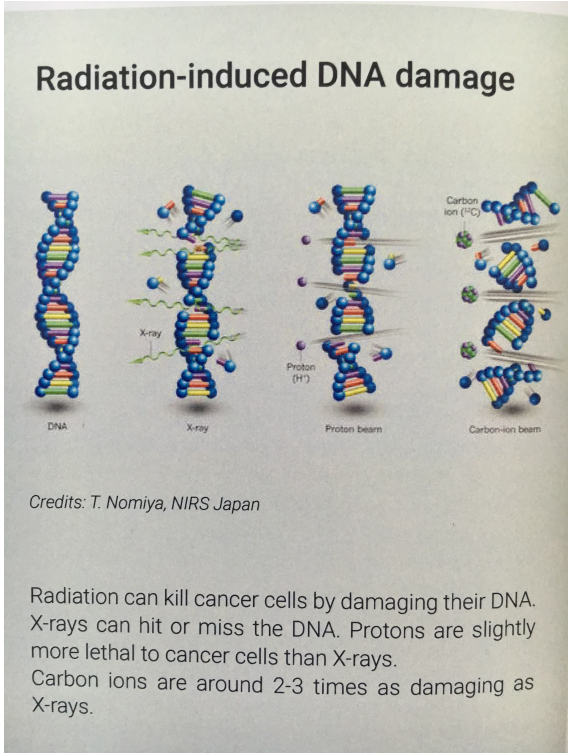
MJ Thesis,
arXiv: 1612.08975 (EPJC)



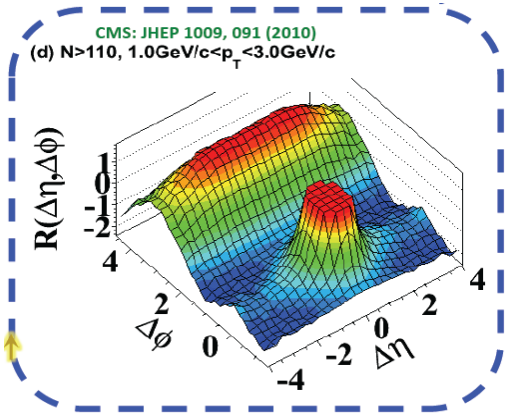


ALICE PID studies: Baryons, protons, in minimum pp events

Understanding biological effects



First discovery at LHC:
CMS "Ridge" in high multiplicity pp



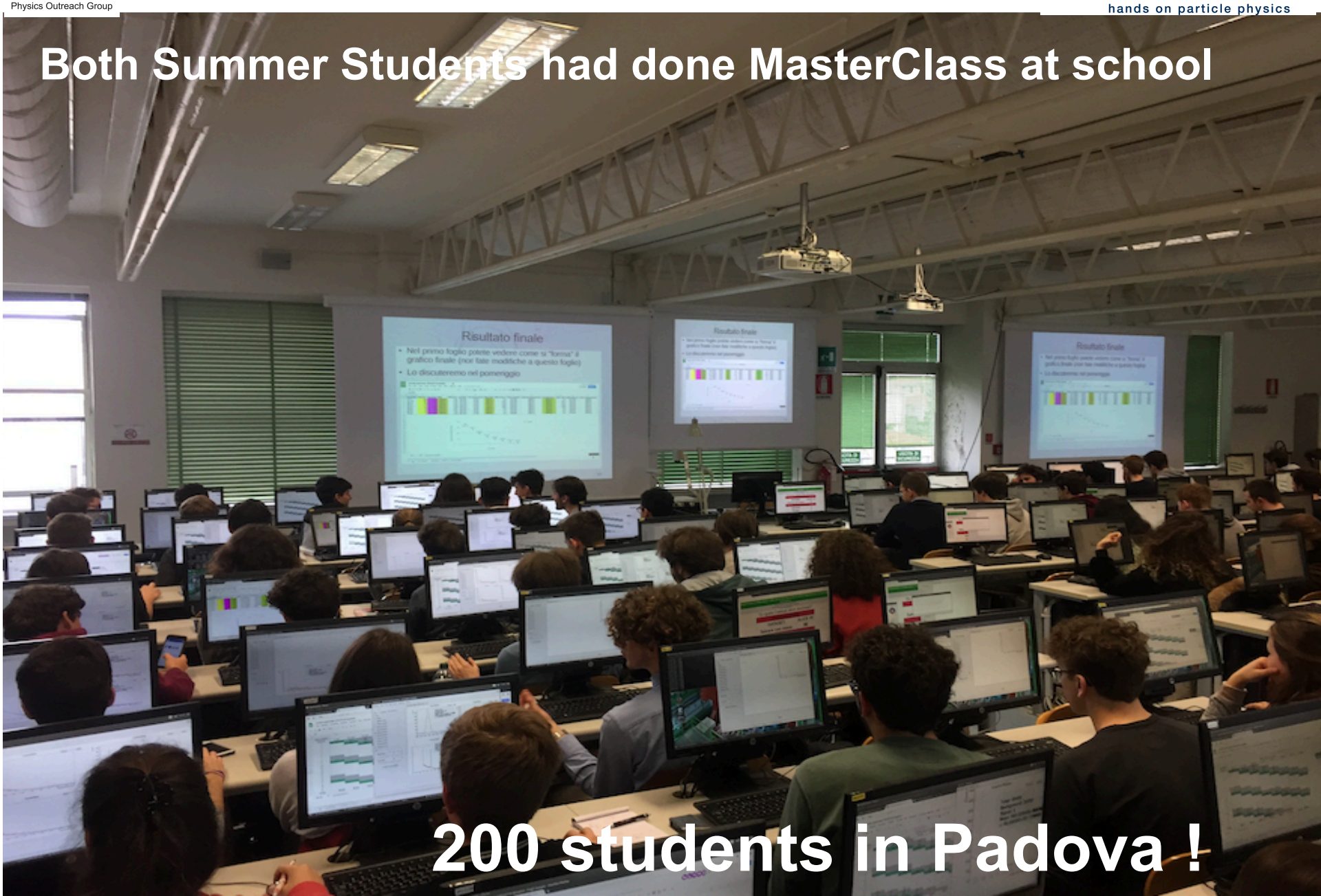
Re-analysis of ALEPH ee
and HERA ep data
to understand
where such patterns appear.

Understanding fundamental interactions !

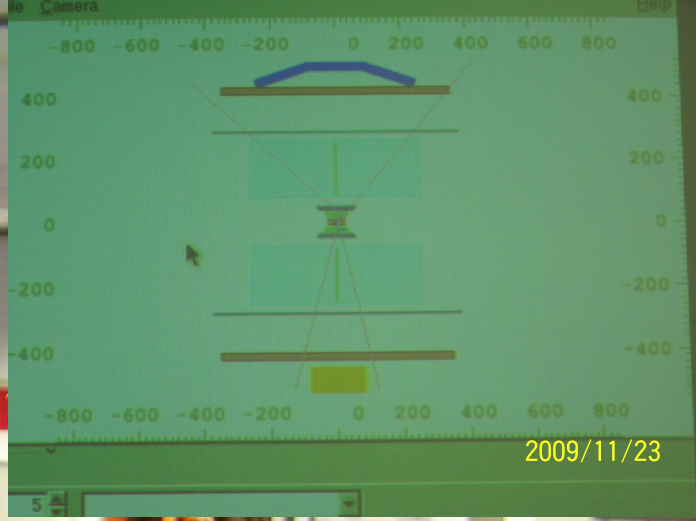
International Particle Physics Outreach Group

Our Reward !

INTERNATIONAL MASTERCLASSES
hands on particle physics



Big Thanks to ROOT Team
Support From
First Collisions at LHC…



To Preparing
Next Generation Projects
And
Next Generation Scientists

2009/11/23

International Particle Physics Outreach Group

Thanks to IMC Demo Contributors

ALICE RAA GSI (Ralf Averbeck) and **IKF** (Henner Buesching)

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Alena Harlenderova
Edgar Perez Lezama
Michael Habib
Jerome Jung
Sebastian Scheid
Fabian Pliquett**f**
Carsten Klein

ALICE Strangeness

Ester Anna Rita Casula
Ramona Lea
Fabio Colamaria
Marianna Mazzilli

Thanks to Conference Committees, Outreach Coordinators…

CMS

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QuarkNet: Frank Geurts, Daniel Brandenburg

ATLAS

Iwona Grabowska-Bold
Klaudia Burka

LHCb

Bartosz Piotr Malecki

INTERNATIONAL MASTERCLASSES
hands on particle physics