ALICE proposal for MasterClass based on visual identification of strange particles in pp LHC data

work by

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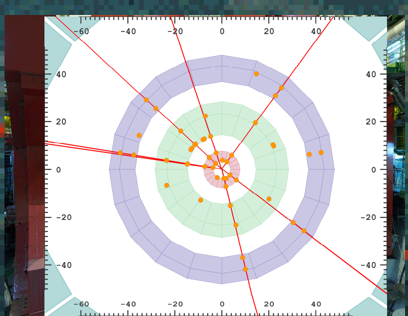


Contents

Basic idea

-variants

First implementation

- prototype exercise, web page, accompanying material

Data samples

- real collisions (and MC data) in pp and later in PbPb

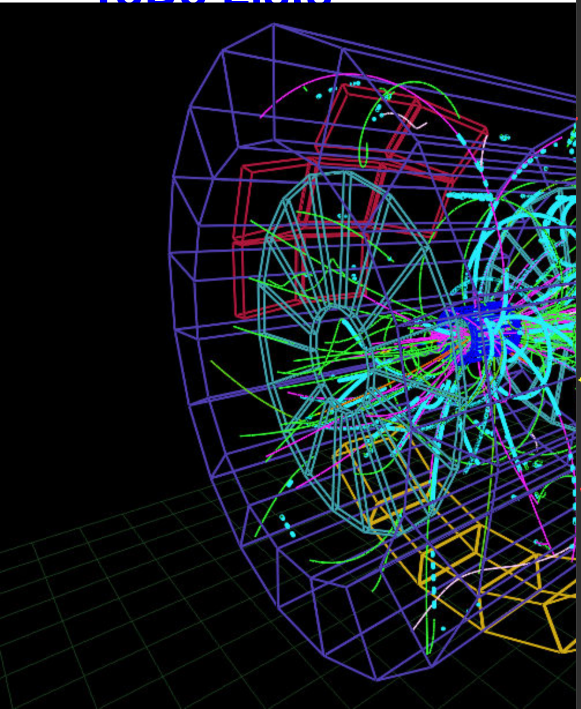
Tools

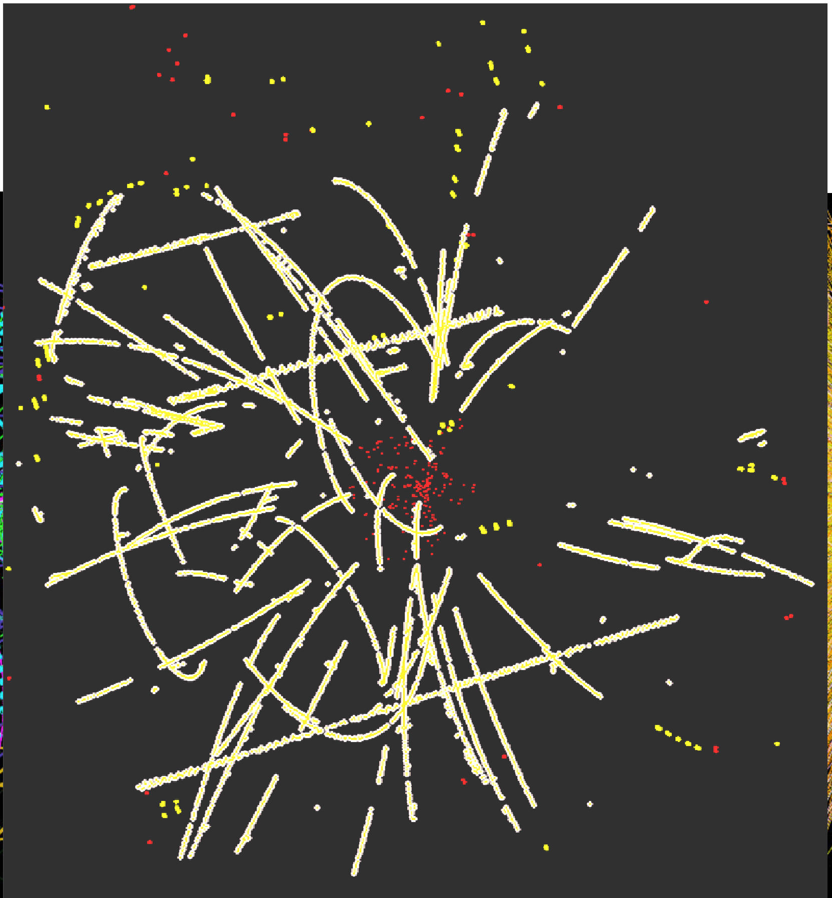
“Pilot” tests

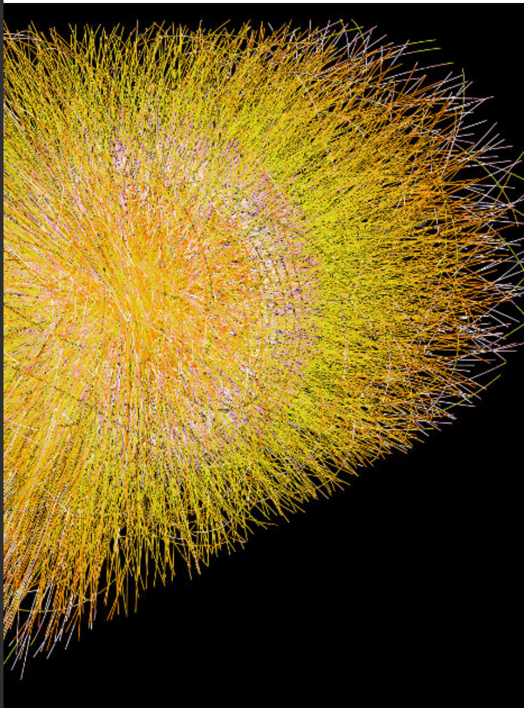
ToDo Lists

Proposals and ideas for discussion

Start with pp go to PbPb







Basic idea

Identify strange particles through their decay pattern using visualisation tools

Measurement: count n. of different species of strange particles

Aim: Variant A

Count strange particles, compare to MC

Aim: Variant B

Count strange particles, make ratios: strange/non-strange particles

Check QGP signature (strangeness enhancement)

Aim: Variant C and D (for uni level)

Count strange particles, make ratios of different particles

Measure characteristics of phase transition

To Be Given

n. of non-strange particles in real and MC data

Works for pp and PbPb

Cascade topology reconstruction in PbPb

Tracking challenge but it works!!

MC PbPb event

Cascade: Ξ,Ω

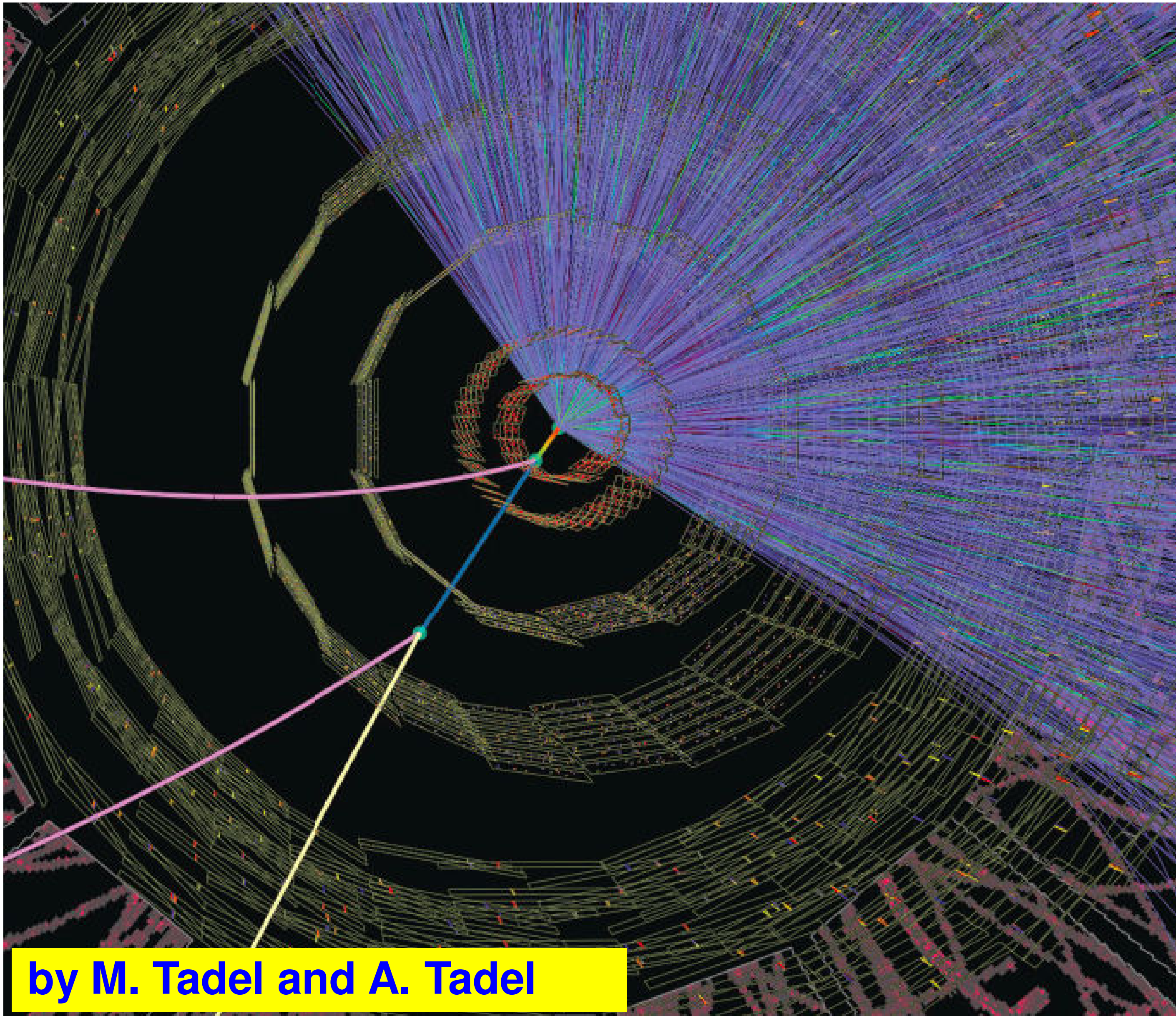
with part of the event removed displaced vertices can be seen

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

10^7 events:

p_t reach Ξ,Ω

~ 9-12 GeV



by M. Tadel and A. Tadel

Basic idea

Identify strange particles through their decay pattern using visualisation tools

Measurement: count n. of different species of strange particles

Correctness of MC underlying event

Aim: Variant A

Count strange particles

Compare measured counts (“yield”) to MC (Pythia)

Outcome: strangeness production; confirm or not the MC

Example of reporting table

Particle species	Real	Pythia
K^0	**measured**	given (or measured)
Λ (anti Λ)	**measured**	given (or measured)
Ξ	**measured**	given (or measured)
π	given	given
N_{ch}	given	given

possibility to measure in MC too or give pre-calculated values

Basic idea

Identify strange particles through their decay pattern using visualisation tools

Measurement: count n. of different species of strange particles

Discovery potential QGP-like pattern in (high multiplicity) pp

Aim: Variant B

Count strange particles, get n. of non-strange particles

make ratios: strange/non-strange particles

Compare ratios in real pp data and reference (Pythia, or **pp low multiplicity**)

Outcome: confirm or not strangeness enhancement (predicted as QGP

particle species	real	Pythia	Ratio strange/π	real	Pythia
K^0	**measured**	given	K^0/π	**deduced**	given
Λ	**measured**	given	Λ/π	**deduced**	given
Ξ	**measured**	given	Ξ/π	**deduced**	given
π	given	given			
N_{ch}	given	given			

Ratio of total strange to non-strange (proper normalisation)

Basic idea

Identify strange particles through their decay pattern using visualisation tools

Measurement: count n. of different species of strange particles

for university level

First physics PRL in 900 GeV from ALICE

Aim: Variant C

Count strange particles and make ratio: **Λ / antiΛ**

Outcome: Baryon-antibaryon asymmetry : baryon transfer mechanism

Aim: Variant D

Count strange particles, get n. of non-strange and make ratios of different particles

Give the ratios as input to chemical models

Outcome: characteristics of phase transition: μ and T (baryon density, Temperature)

Nail down properties of hadronisation

First implementation

- **Introduction**
  - ⇨QGP physics, strangeness as signature
  - ⇨Experiment
  - ⇨Detector principle
  - ⇨From signal recording to visualisation
  - ⇨Tracking and PID **(π, K, p)**
  - ⇨Strange particles decay patterns **(K^0, Λ, Ξ,)**
- **Exercise**
  - ⇨Examples of decay patterns and kinematical characteristics
  - ⇨Demo, “guided tour”
  - ⇨On your-self
- **Individual measurements**
  - ⇨Students work on their data sample: identify, count and report
- **Analysis by the class**
  - ⇨Teacher collects individual reports: data analysis, conclusions (ToBe Done)

data samples: 100 real pp per student
possibility that half of the class has real and half MC data without telling them in advance ??

First implementation

- **Visualisation tools and functionality of AliEVE V0**

  Implemented by A. Maire and B. Hipollyte, simplified by P. Debski

  - ⇨From AliRoot to ROOT
  - ⇨Experiment independent
  - ⇨No need of heavy installation
  - ⇨Runs in PC and mac laptop

- **Needed files**
  - ⇨VizDB with geometry and reconstructed objects definitions
  - ⇨Xi.root with the data of strange particle candidates

Support material

- **Web page and animations (version 0)**
  - ⇨ QGP physics, strangeness as signature

    Text and simplified slides

    animation of heavy-ion collision

    QuickTime™ and a
    Cinepak decompressor
    are needed to see this picture.

  - ⇨ Experiment

    Text, experimental set up and photos

    animation of the experiment and detectors

    animation of collision in the centre of experiment

    and particle propagation in the detectors

  - ⇨ Detector (emphasis on TPC)

    animation for TPC principle of operation

  - ⇨ From signal recording to visualisation

    animations of events 900 GeV and 7 TeV pp

    use of visualisation in every day life

  - ⇨ Tracking strategy and Strange particles decay patterns **(π, K, p), (K^0, Λ, Ξ,)**

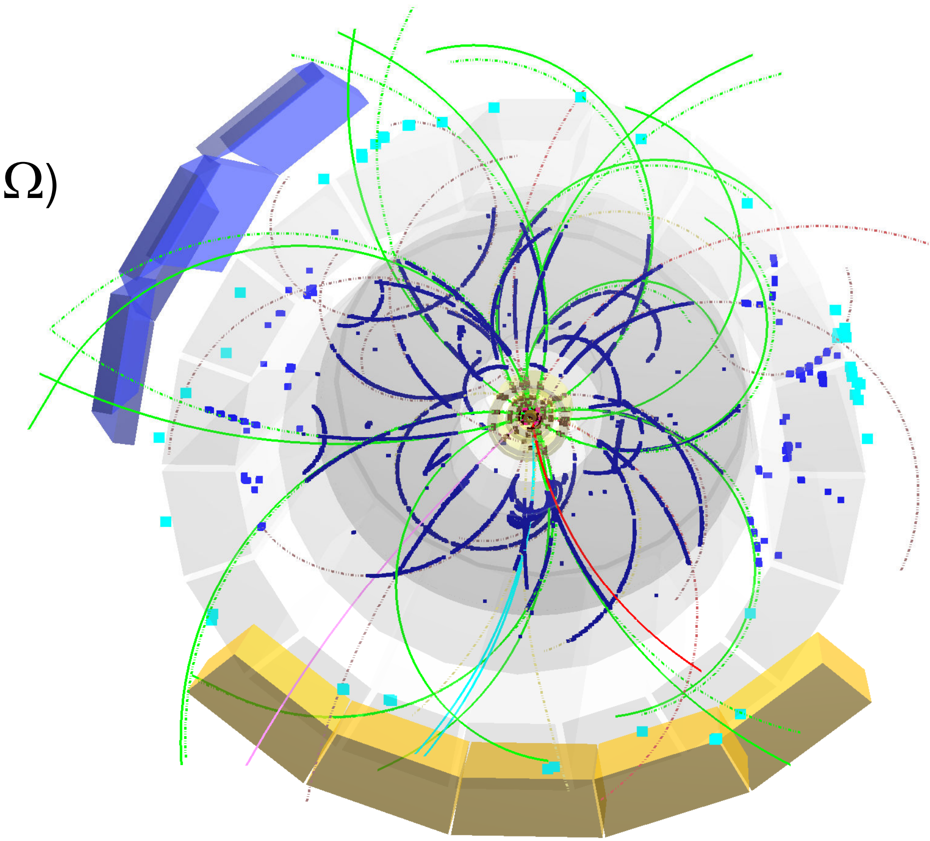
    views of V0s and Cascades in 900 GeV and 7 TeV pp

Data samples

- **Some 10ths of V0s and Ξ in pp at 900 GeV and 7 TeV**
  - ⇨ **Used for demo of prototype and web**
- **Existing lists of good V0s and Ξ in pp at 900 GeV**
  - ⇨ Used for strangeness production paper

    (200 Ξ in 500 K pp at 900 GeV)
- **Existing lists of Ξ and Ω at 7 TeV**
  - ⇨ Analysis in progress (~ 1000 Ξ, ~70 Ω)

We have enough real pp data to prepare data samples



Data samples

ToDo: (in July)

"automatise" the method to extract

from real and MC pp data

the necessary sub-samples

from which to create input data

for the MasterClass

QuickTime™ and a Cinepak decompressor are needed to see this picture.

- **Sub-samples: filter out of data the run, event, topology ID numbers**
  - ⇨ of **"golden"** candidates (preliminary version)
  - ⇨ of **"bad"** candidates which failed geometrical criteria
  - ⇨ of events with **no strange** particle candidates
- **Mix them to create input file to MasterClass**
  - ⇨ Students should not wait for ever to find a Ξ (200 Ξ in 500 K in 900 GeV)
  - ⇨ **Mixing should preserve the observed in reality strange/non-strange ratios**

    (i.e. no artificial strangeness enhancement)

Expose to real life tests

ToDo:

1. Pilot MasterClass

(CERN training centre; September)

2. Scrutiny test by “alternative teaching” teachers

(laptop demo; Greece June)

3. University exercise (Warsaw univ; October)

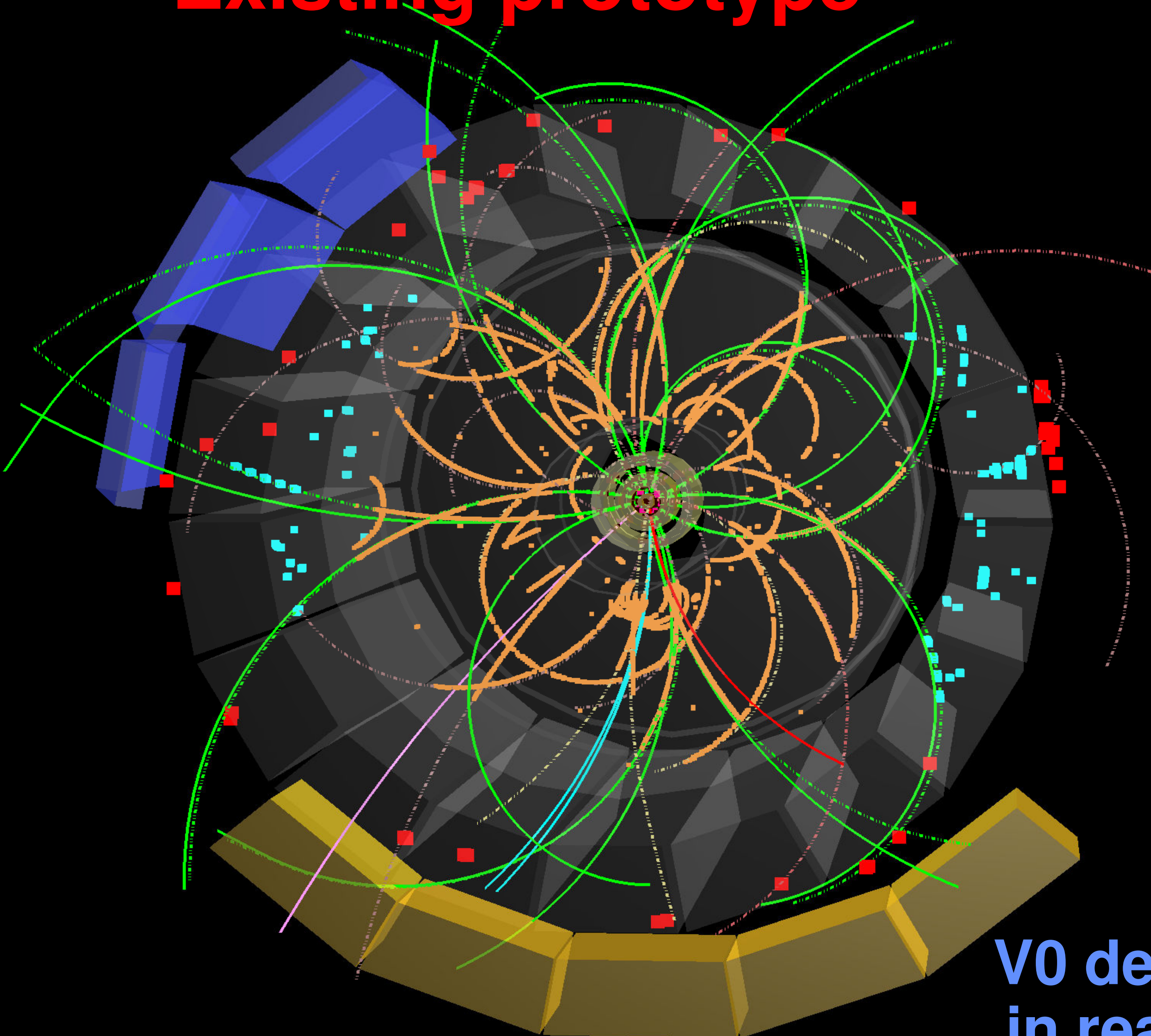
Aim:

1. Realise the “holes” (what we assume and we need to explain)

2. …what is too complex, what is boring….

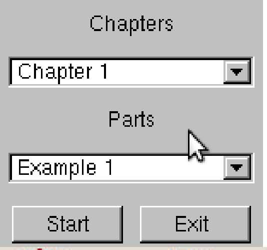
- **Given feedback, advices, to keep in mind, to consider….**
  - ⇨ **Start from more complete (complex), reduce and simplify on the way**
  - ⇨ Students that participate are by default interested and of certain level?
  - ⇨ Different level at different countries?…. What else…

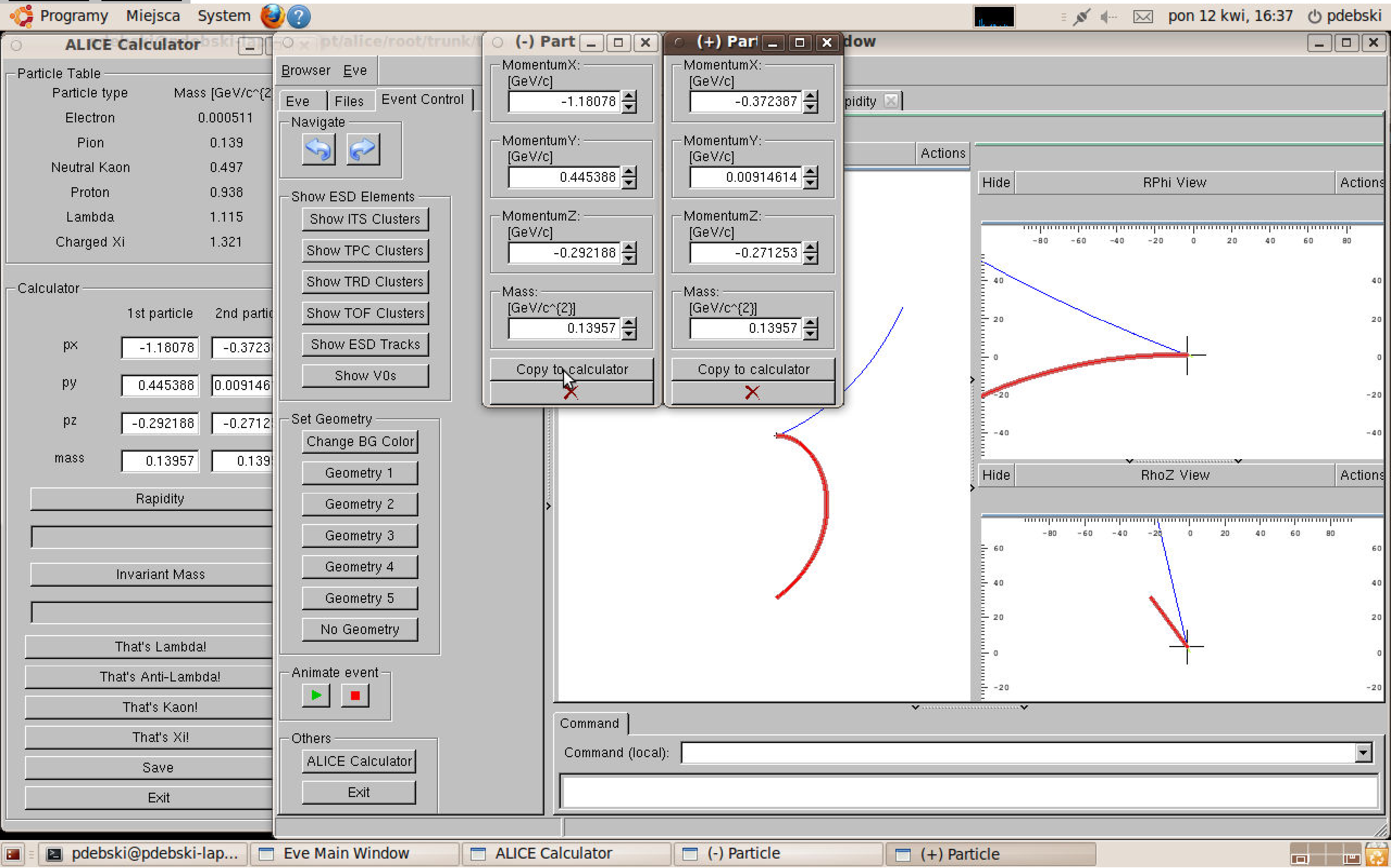
Existing prototype

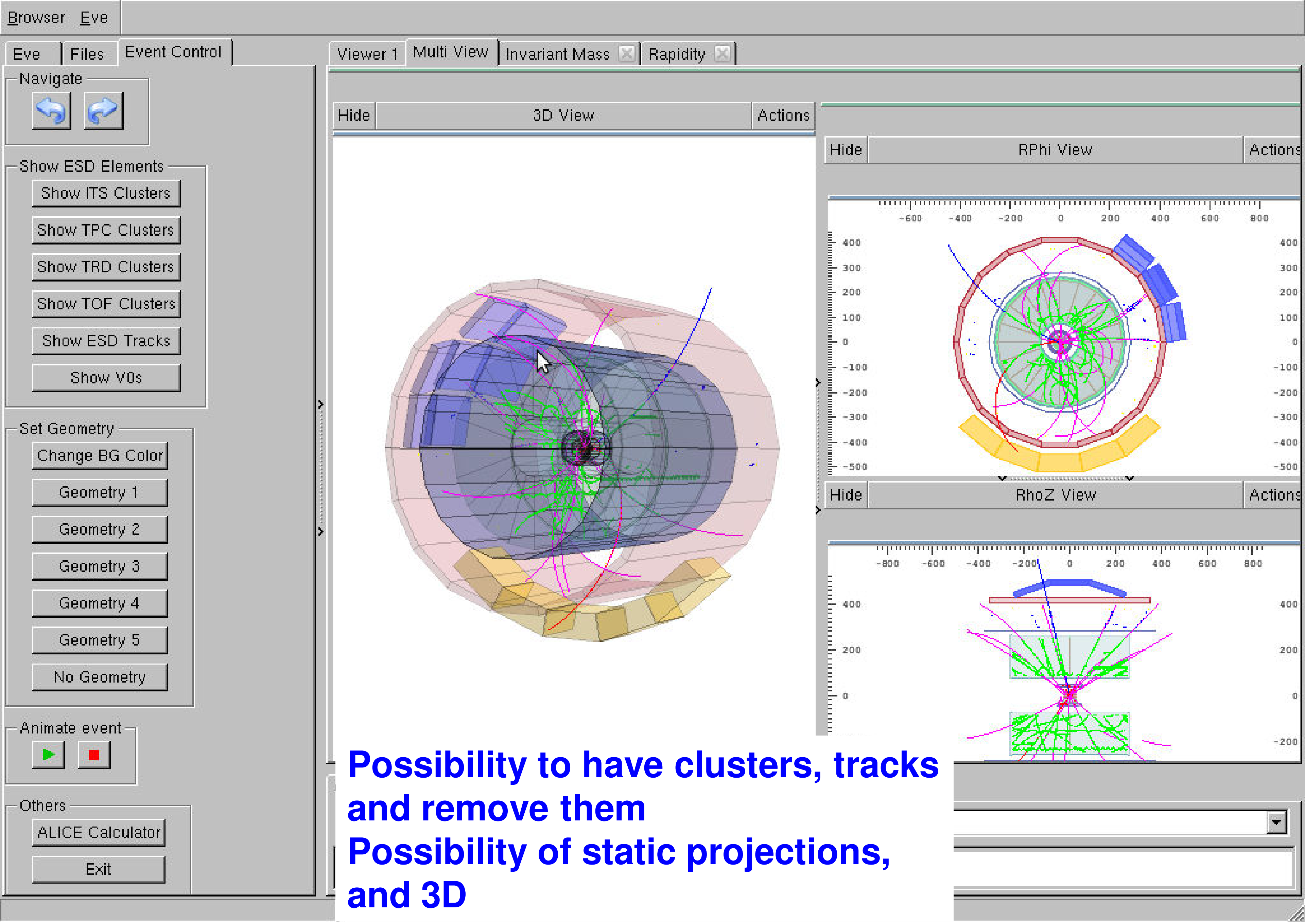


V0 decay pattern in real pp events

Existing prototype

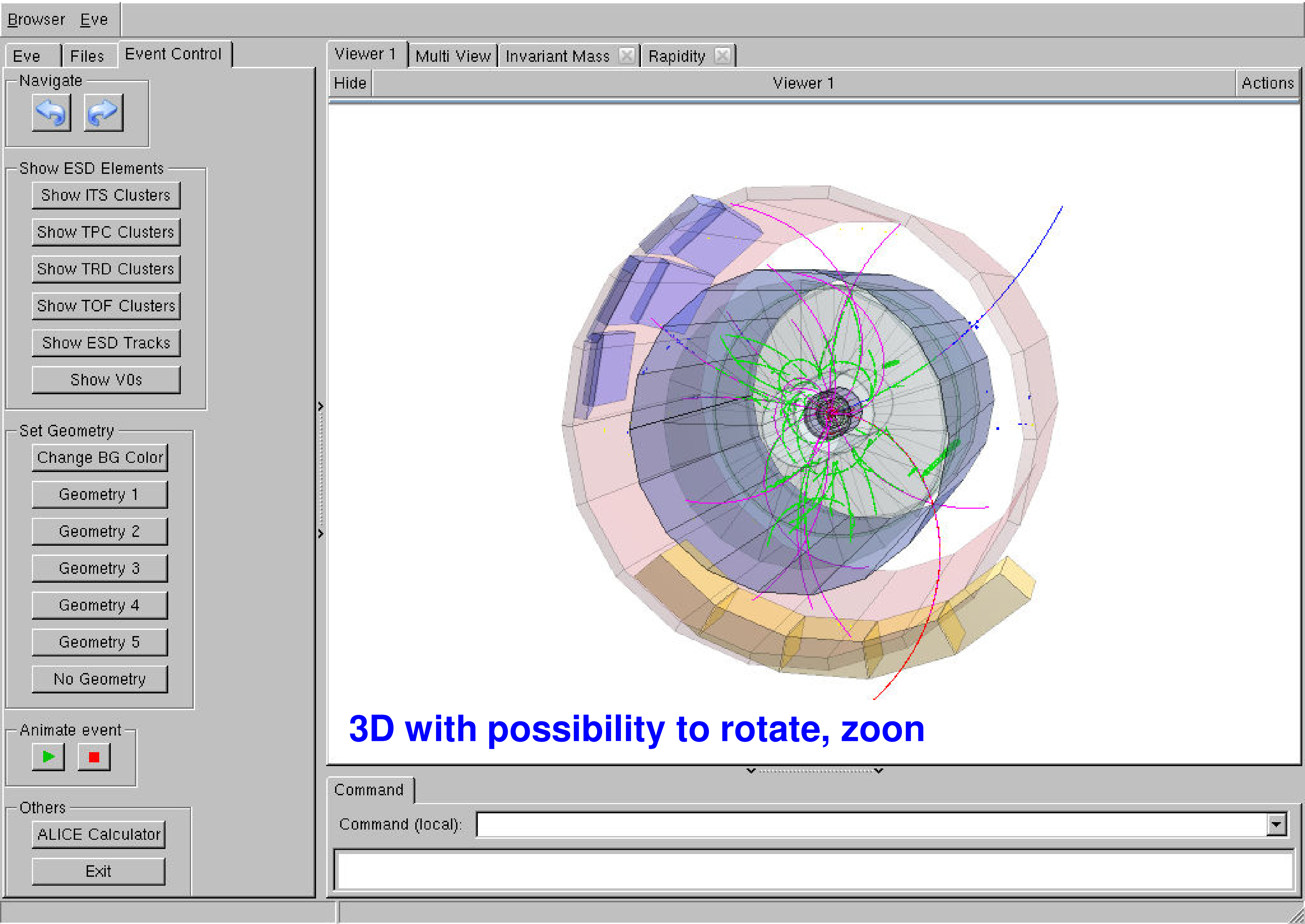




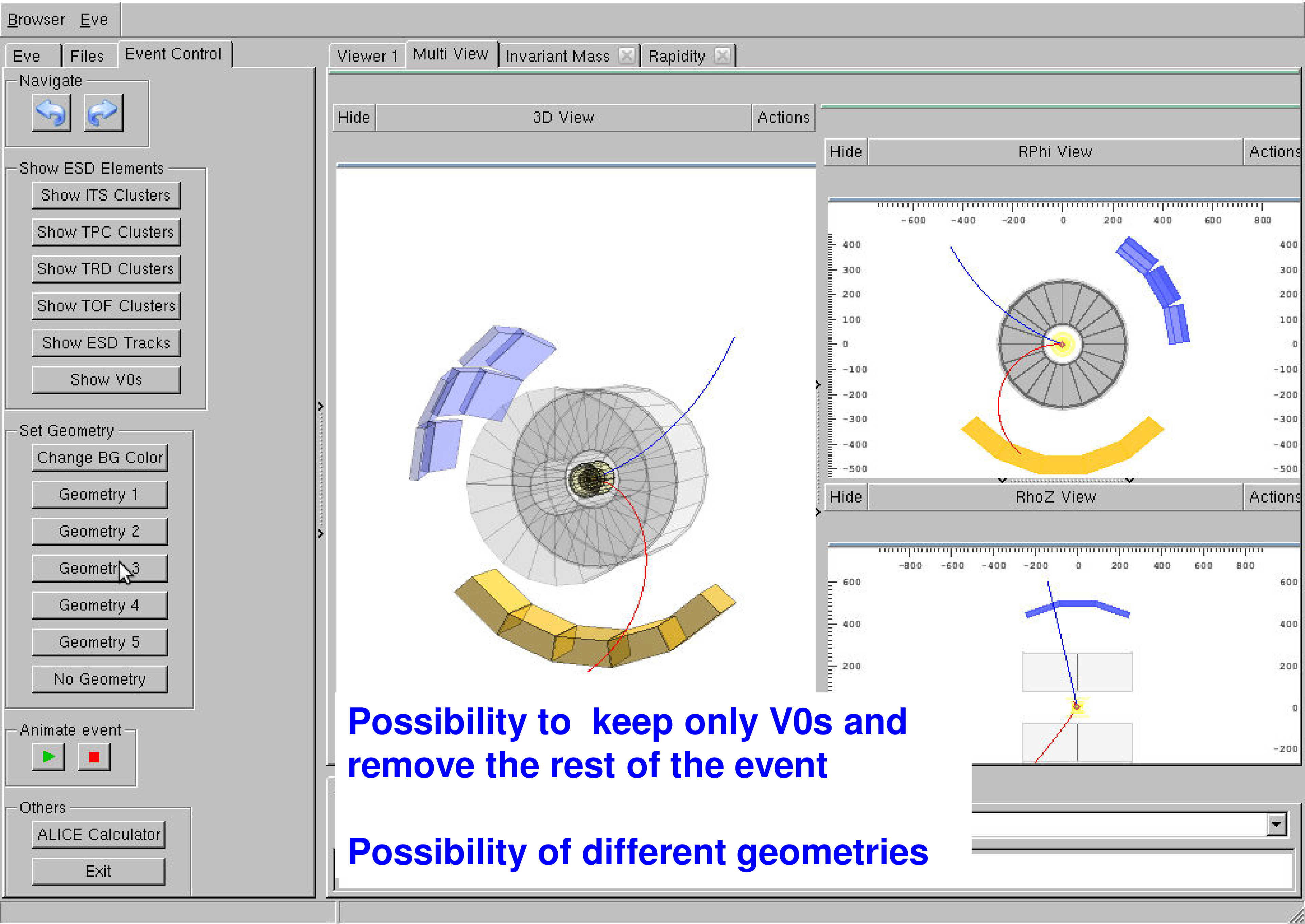


Possibility to have clusters, tracks and remove them

Possibility of static projections, and 3D

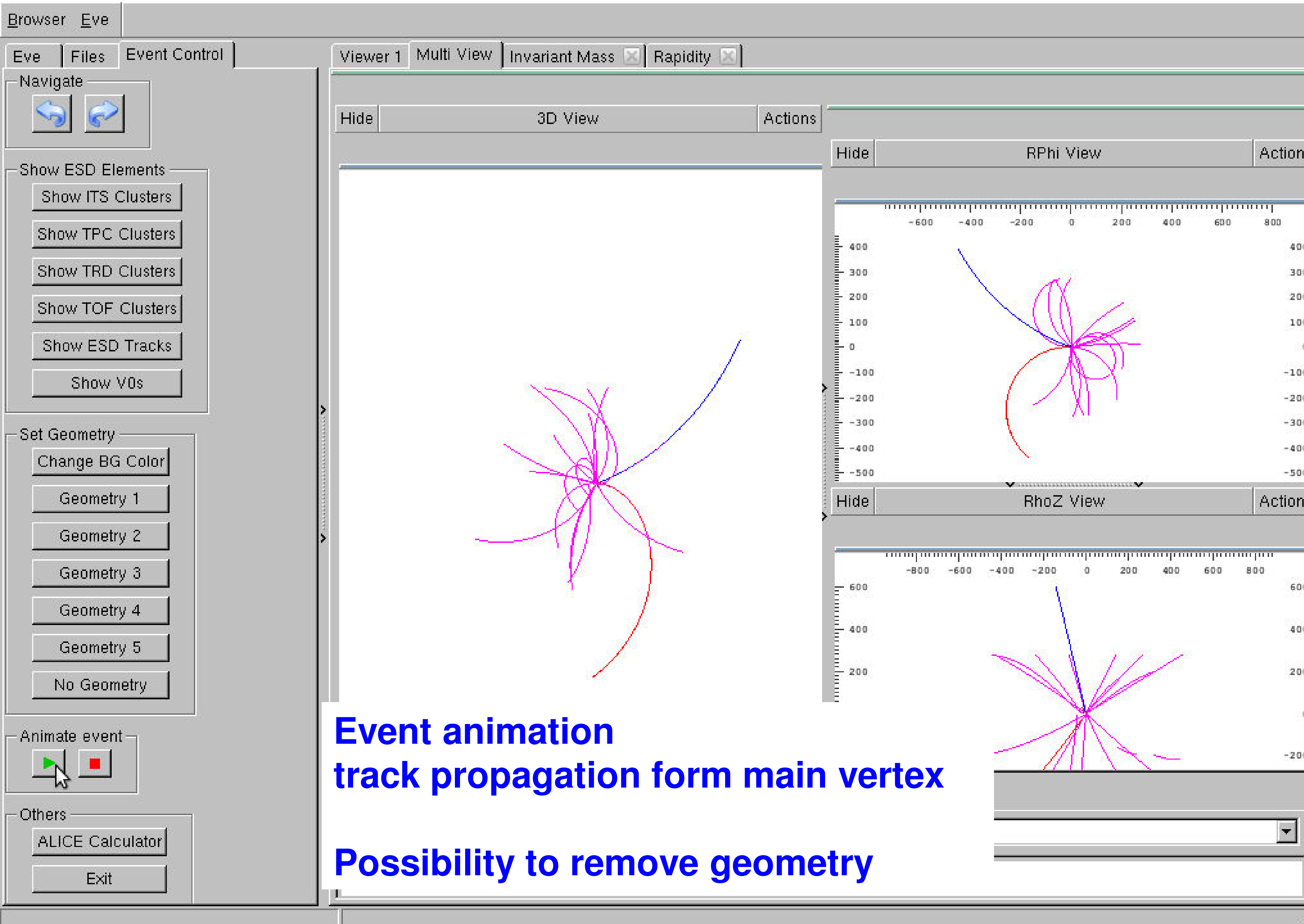


3D with possibility to rotate, zoon



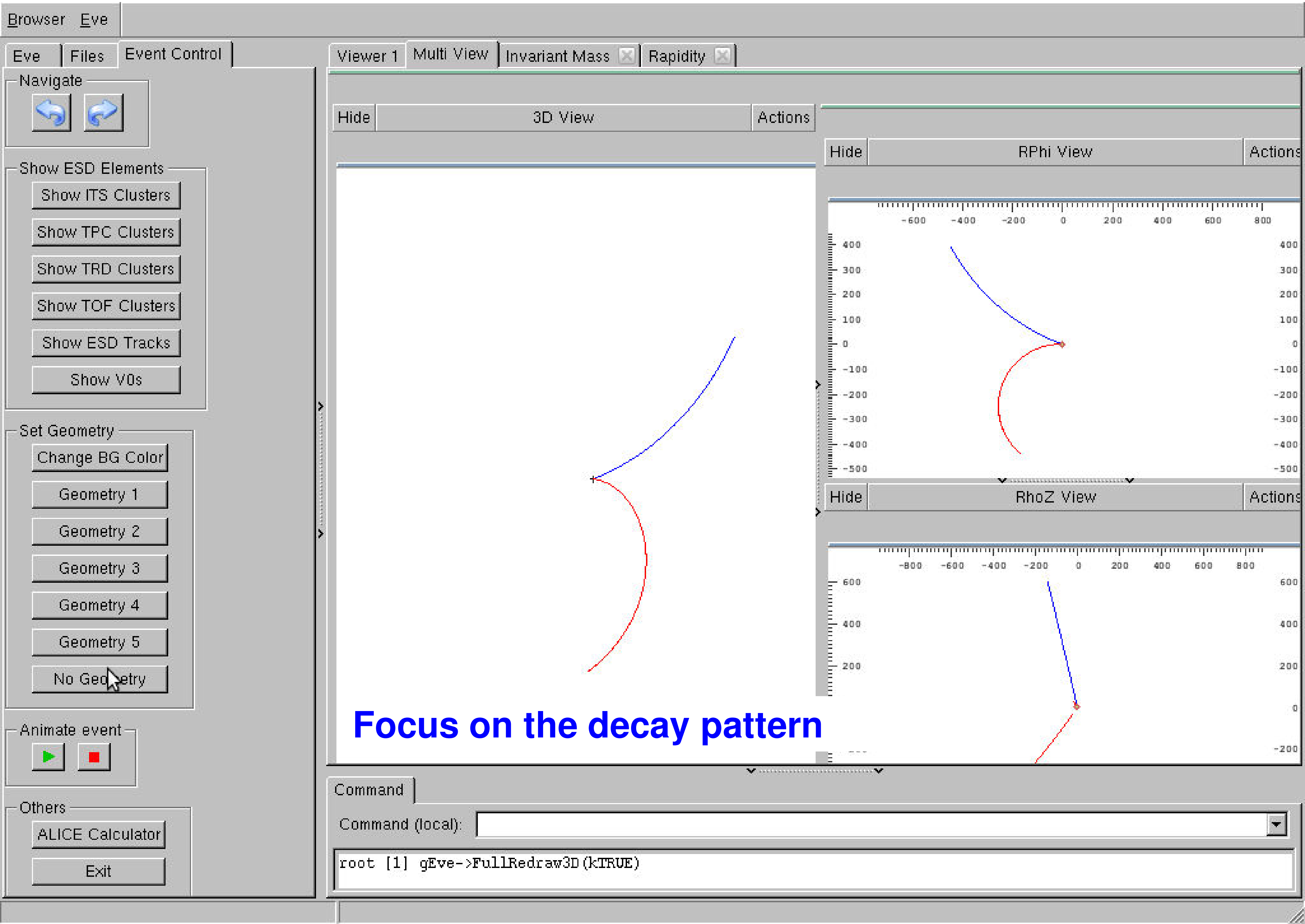
Possibility to keep only V0s and remove the rest of the event

Possibility of different geometries



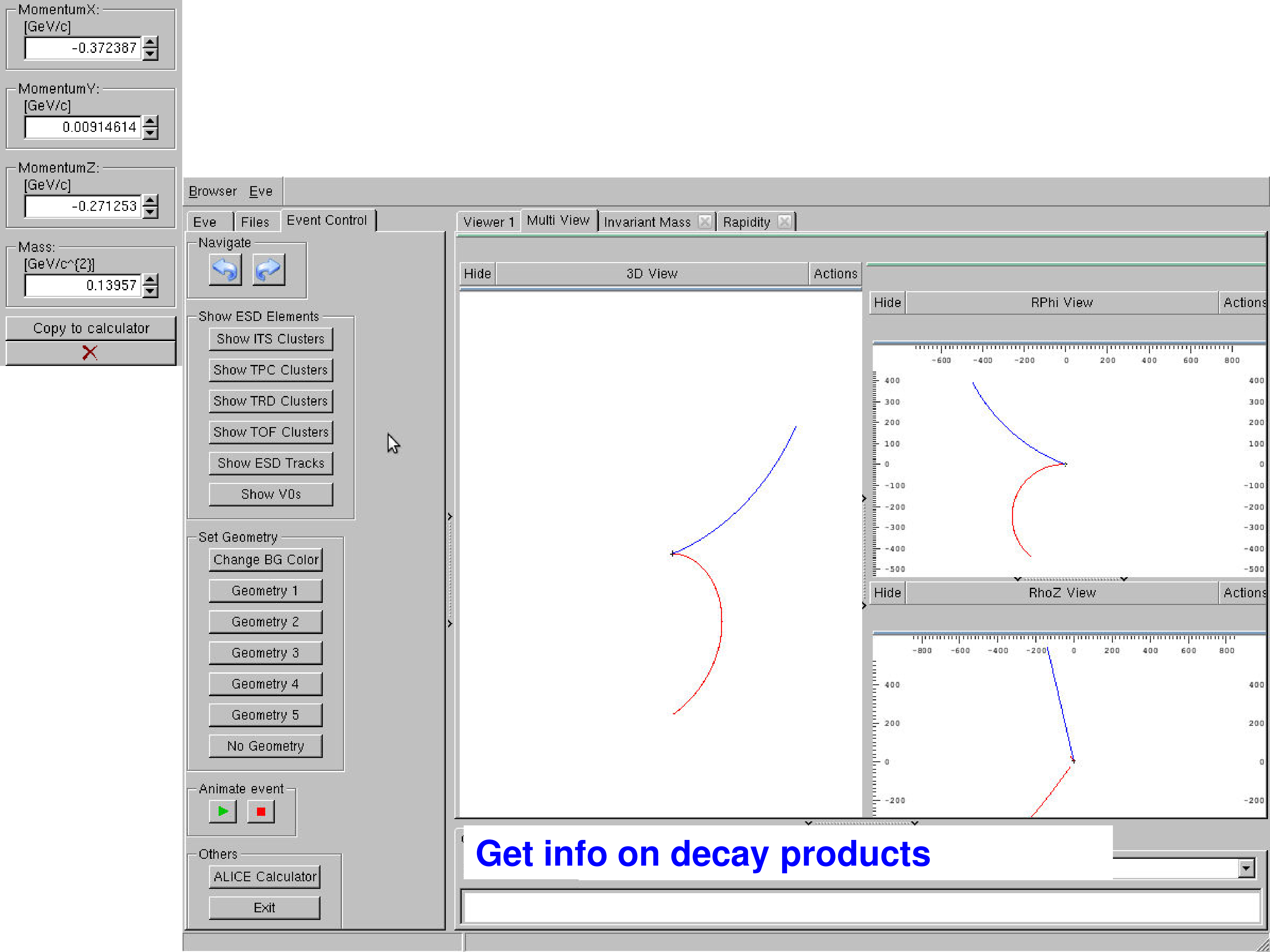
Event animation
track propagation form main vertex

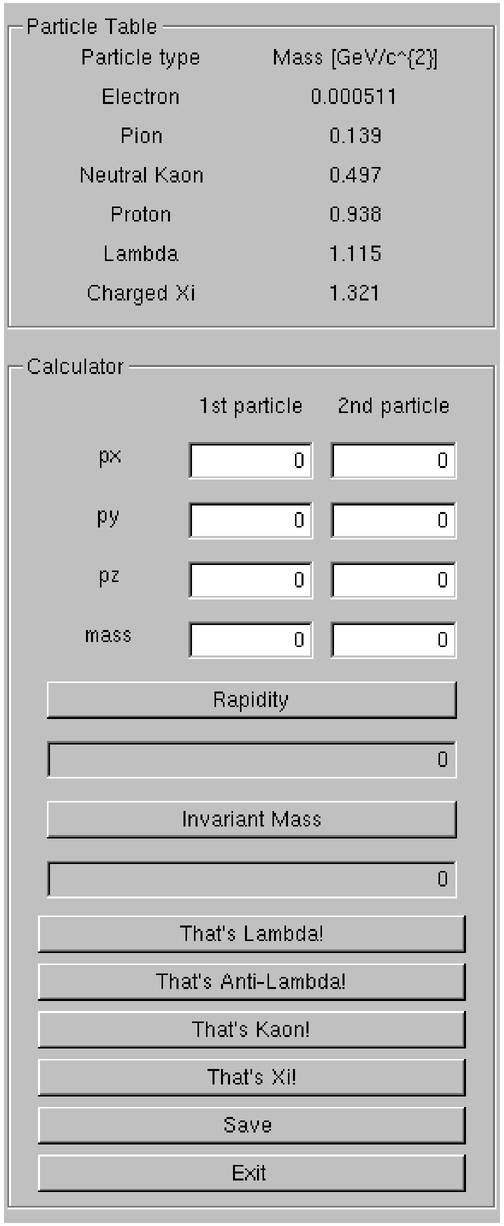
Possibility to remove geometry

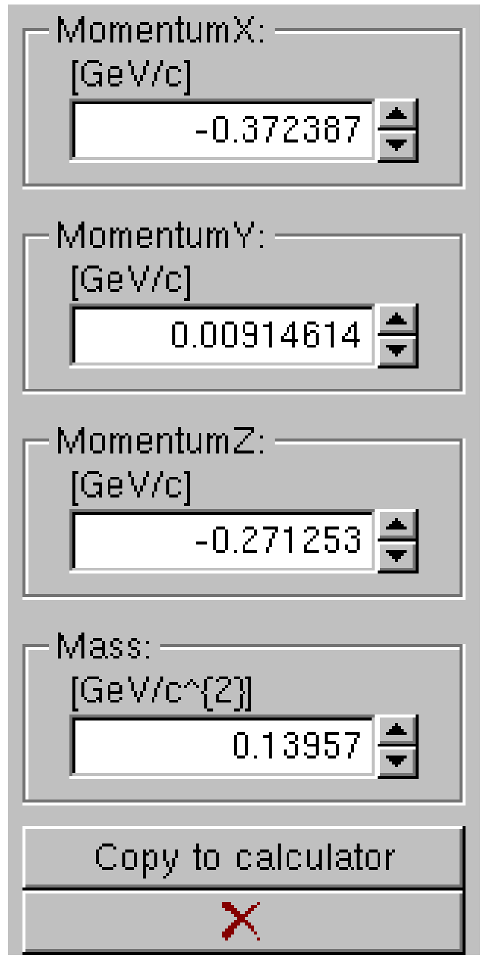


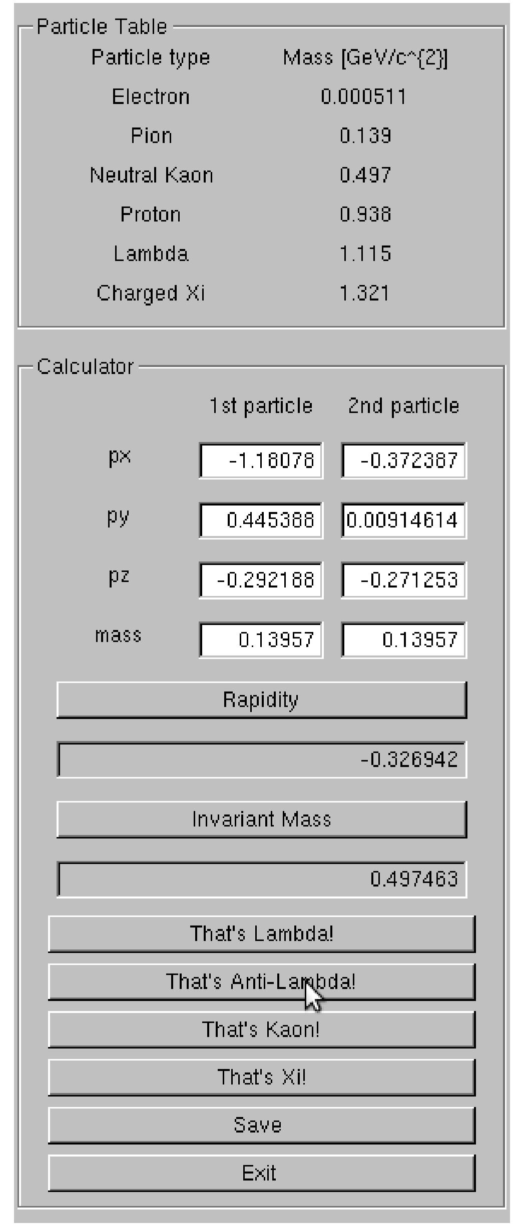
Focus on the decay pattern

Get info on decay products

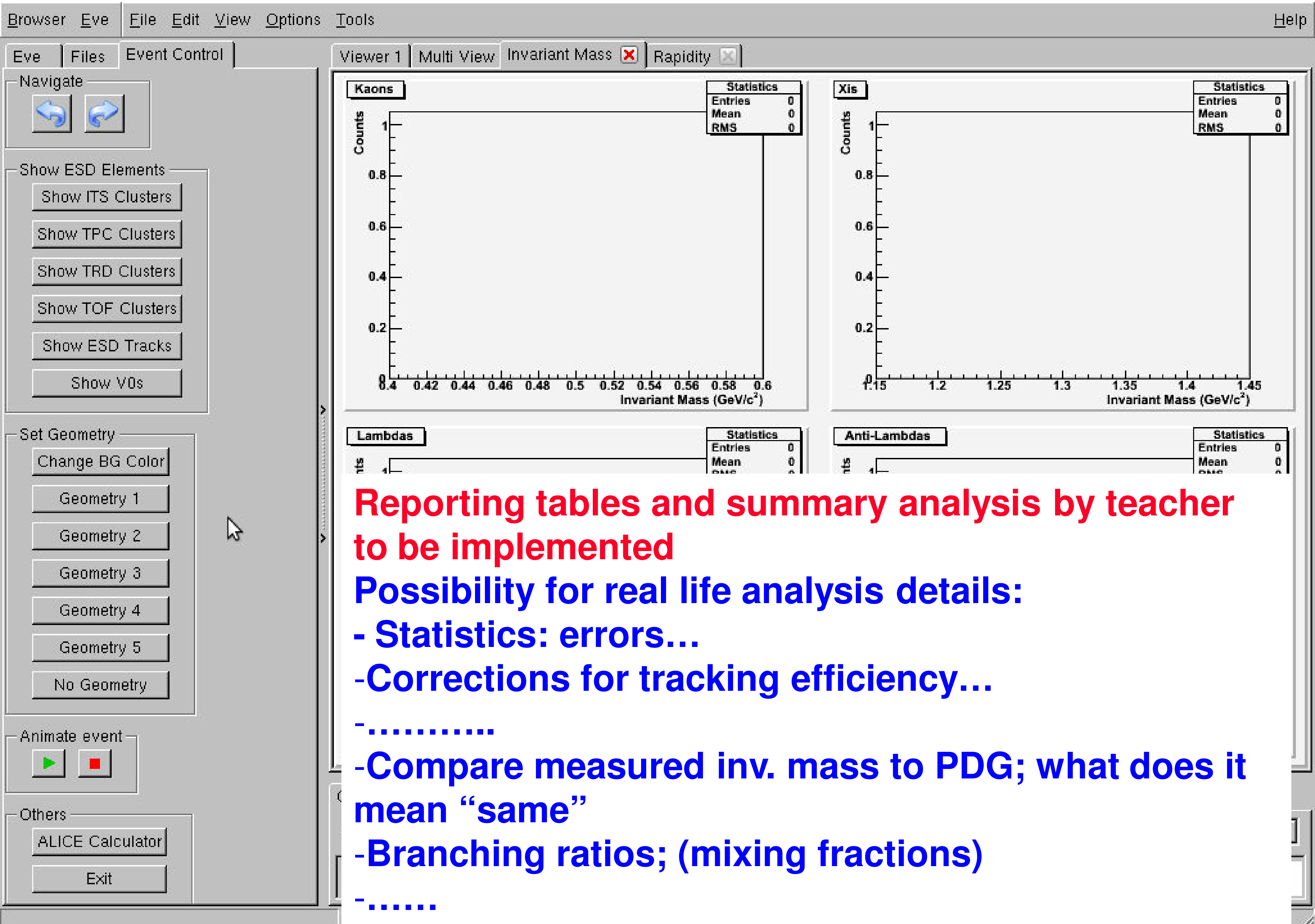








copy info on decay products into calculator; check, decide, report
(increase counter and histos)



Reporting tables and summary analysis by teacher to be implemented

Possibility for real life analysis details:

- Statistics: errors…

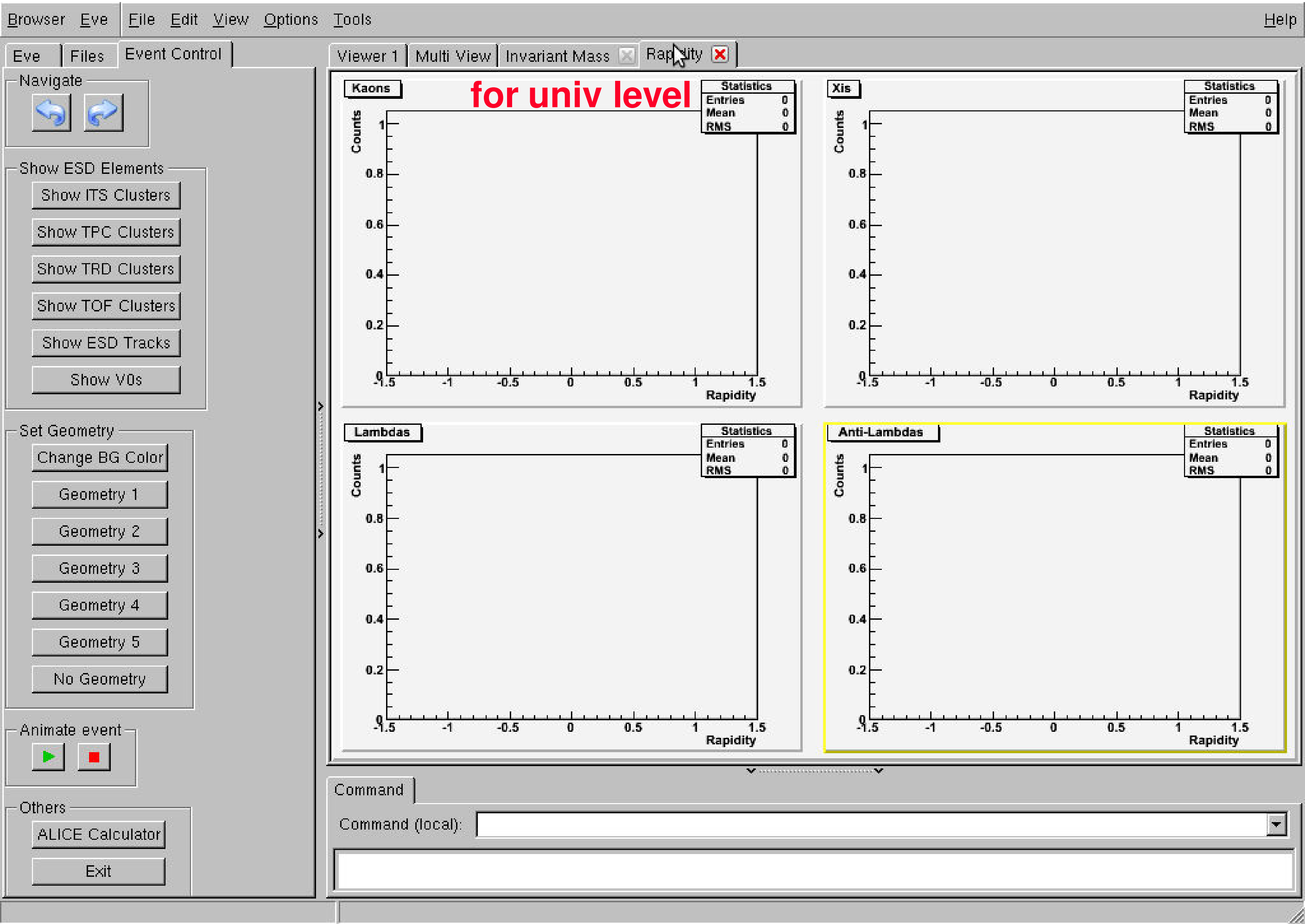
-Corrections for tracking efficiency…

-………..

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

-Branching ratios; (mixing fractions)

-……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Show TOF Clusters
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Show V0s
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Geometry 2
Geometry 3
Geometry 4
Geometry 5
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Others
ALICE Calculator
Exit
Viewer 1 Multi View Invariant Mass Rapidity
for univ level
Kaons
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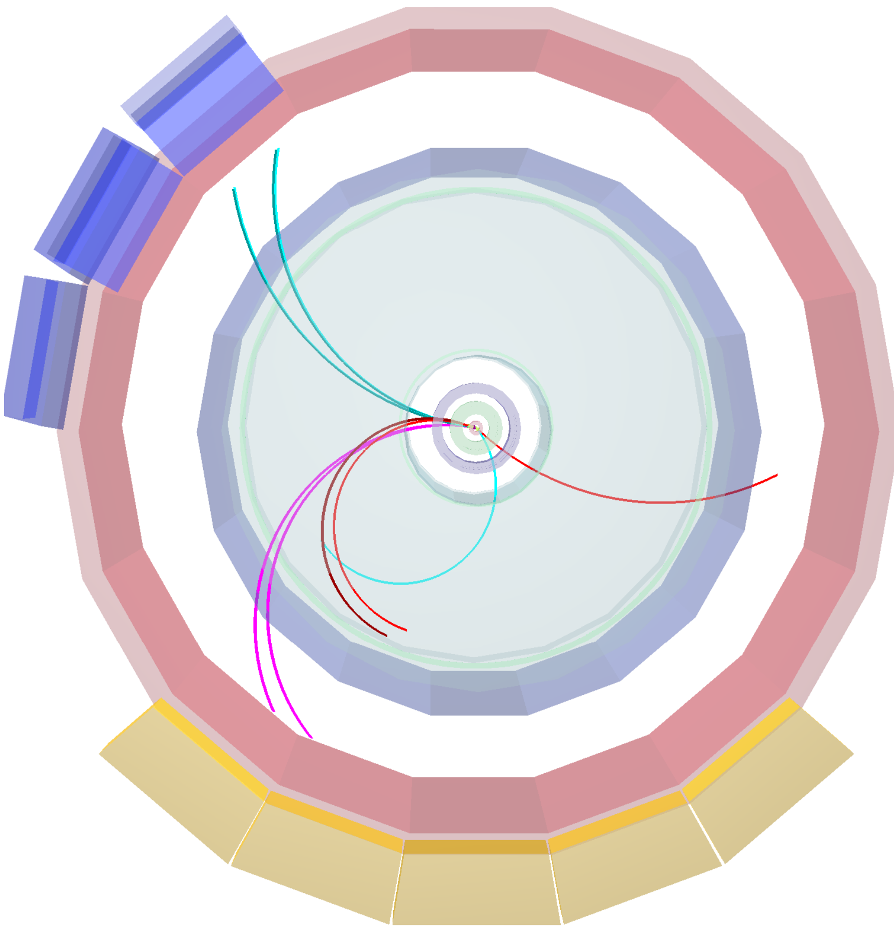
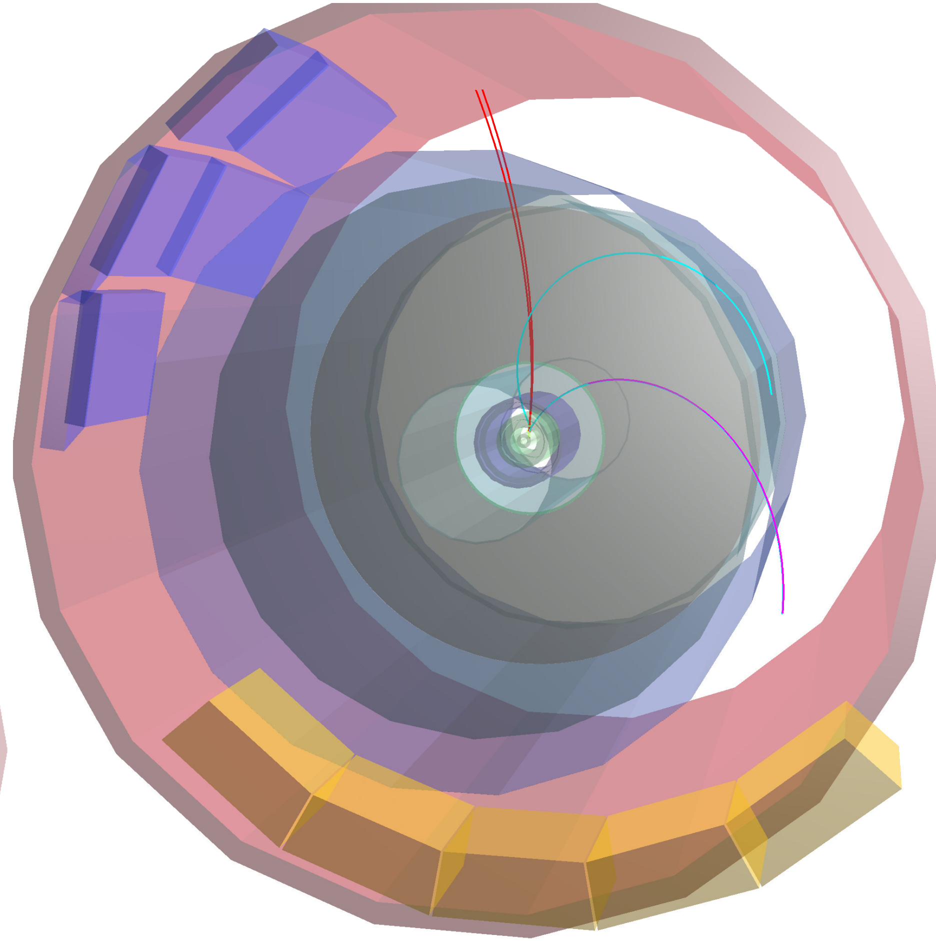
Lambdas
Anti-Lambdas
Statistics
Entries 0
Mean 0
RMS 0
Counts
Rapidity
Command
Command (local):

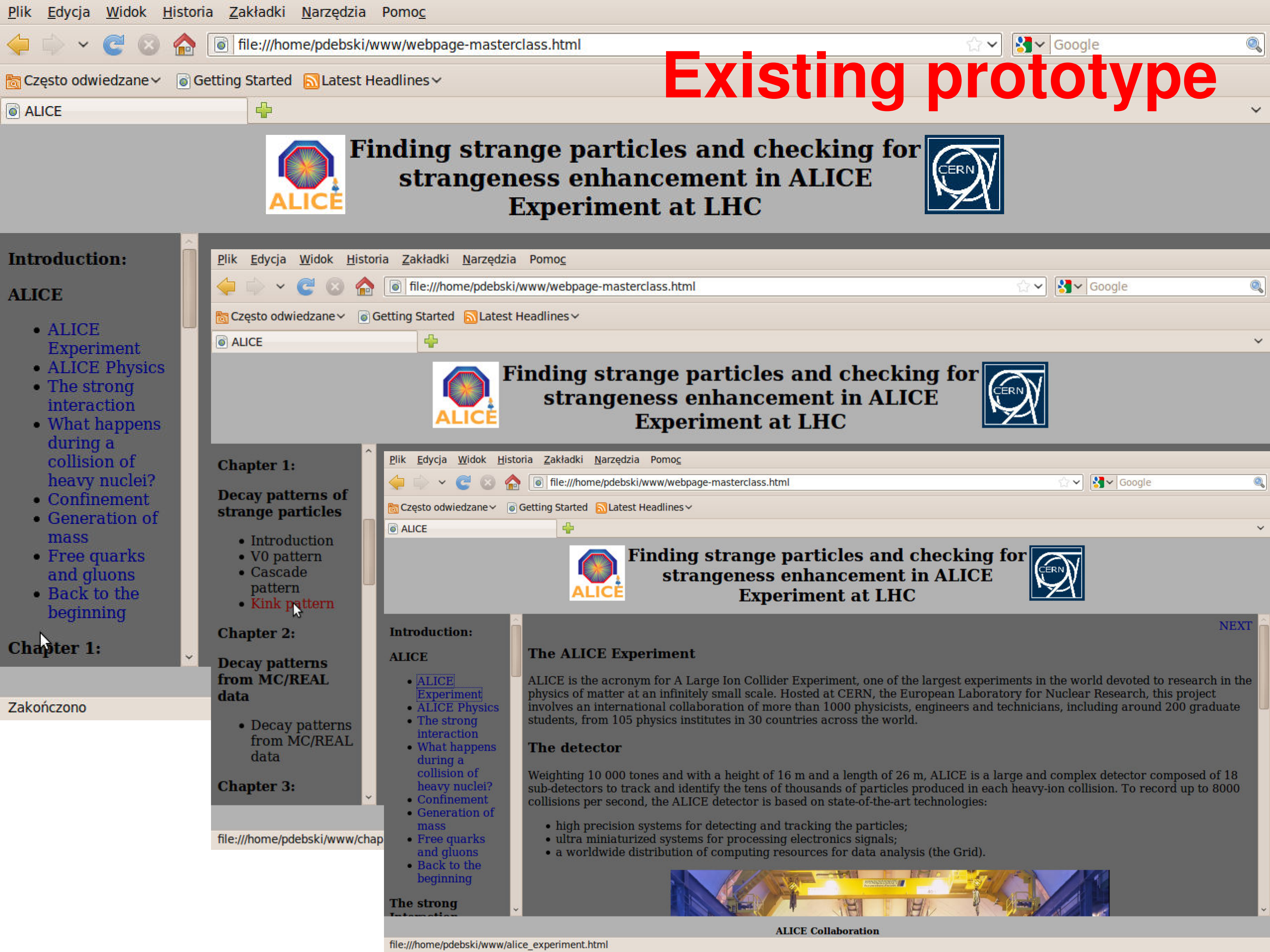
Ξ do be done

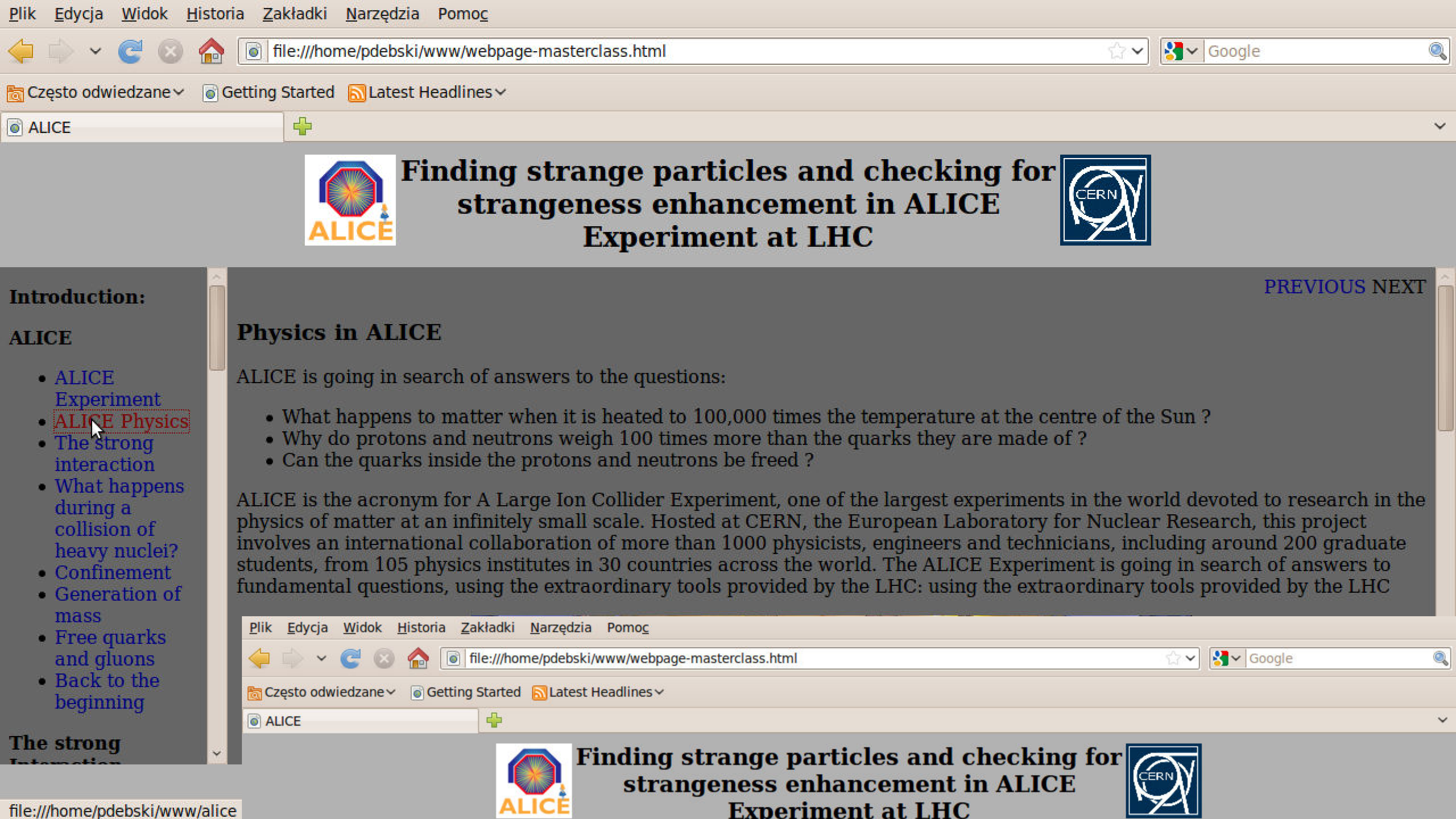




Ξ decay patterns
in real 7 TeV pp events

Existing prototype





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ALICE

Finding strange particles and checking for strangeness enhancement in ALICE Experiment at LHC

Introduction:

ALICE

- ALICE Experiment
- ALICE Physics
- The strong interaction
- What happens during a collision of heavy nuclei?
- Confinement
- Generation of mass
- Free quarks and gluons
- Back to the beginning

The strong

PREVIOUS NEXT

Physics in ALICE

ALICE is going in search of answers to the questions:

- What happens to matter when it is heated to 100,000 times the temperature at the centre of the Sun ?
- Why do protons and neutrons weigh 100 times more than the quarks they are made of ?
- Can the quarks inside the protons and neutrons be freed ?

ALICE is the acronym for A Large Ion Collider Experiment, one of the largest experiments in the world devoted to research in the physics of matter at an infinitely small scale. Hosted at CERN, the European Laboratory for Nuclear Research, this project involves an international collaboration of more than 1000 physicists, engineers and technicians, including around 200 graduate students, from 105 physics institutes in 30 countries across the world. The ALICE Experiment is going in search of answers to fundamental questions, using the extraordinary tools provided by the LHC: using the extraordinary tools provided by the LHC

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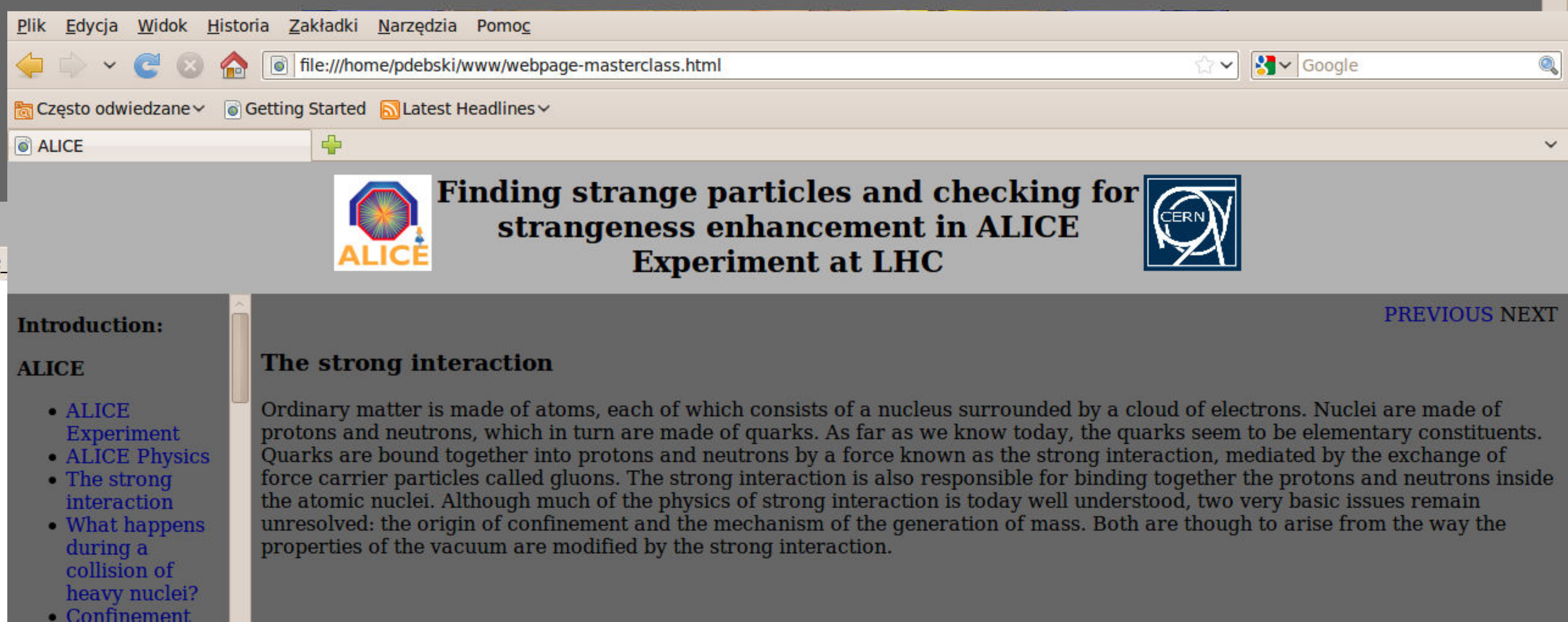

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The strong interaction

Ordinary matter is made of atoms, each of which consists of a nucleus surrounded by a cloud of electrons. Nuclei are made of protons and neutrons, which in turn are made of quarks. As far as we know today, the quarks seem to be elementary constituents. 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 the atomic nuclei. 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 though to arise from the way the properties of the vacuum are modified by the strong interaction.

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Google

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The strong Interaction

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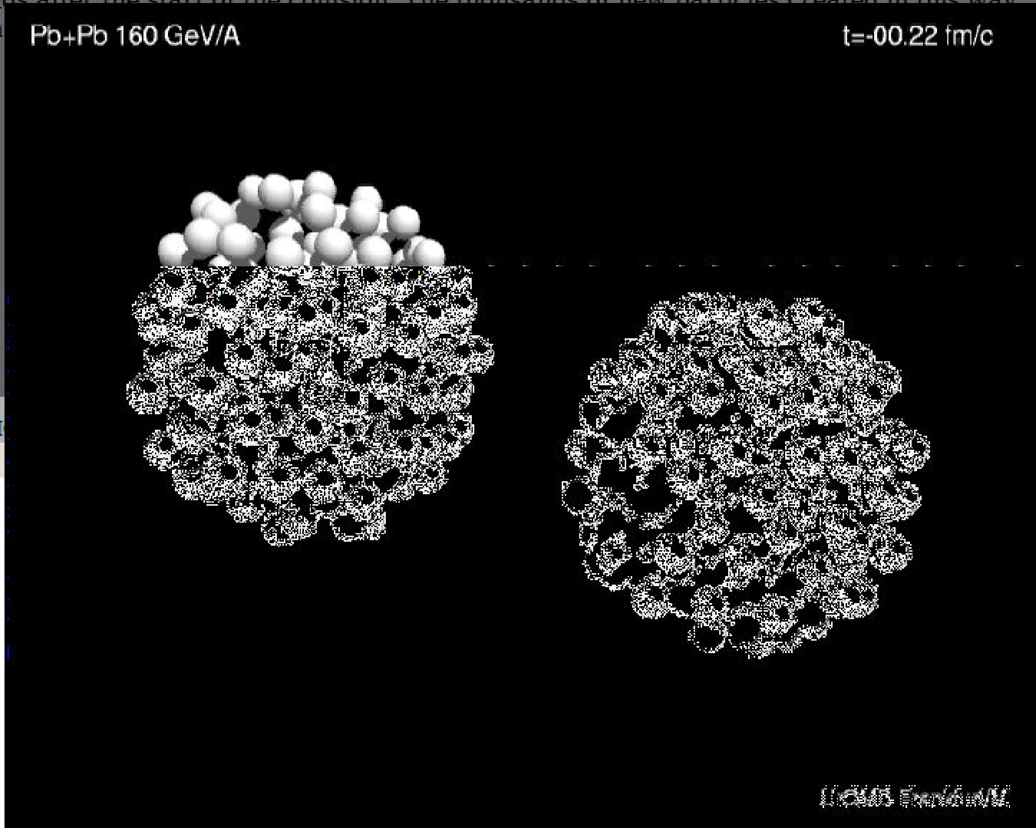
What happens during a collision of heavy nuclei?

The two heavy nuclei approach each other at a speed close to that of light. According to Einstein's theory of relativity, they appear as very thin disks. The two nuclei collide and the extreme temperature that is generated during the collision releases the quarks (red, blue and green) and gluons. Quarks and gluons collide with each other creating a thermally equilibrated environment: the quark-gluon plasma. The plasm expands and cools down to the temperature (10 to 12 degrees) at which quarks and gluons regroup to form ordinary matter, barely 10 to -23 seconds after the start of the collision. The thousands of new particles created in this way move towards the detection system. (simulation



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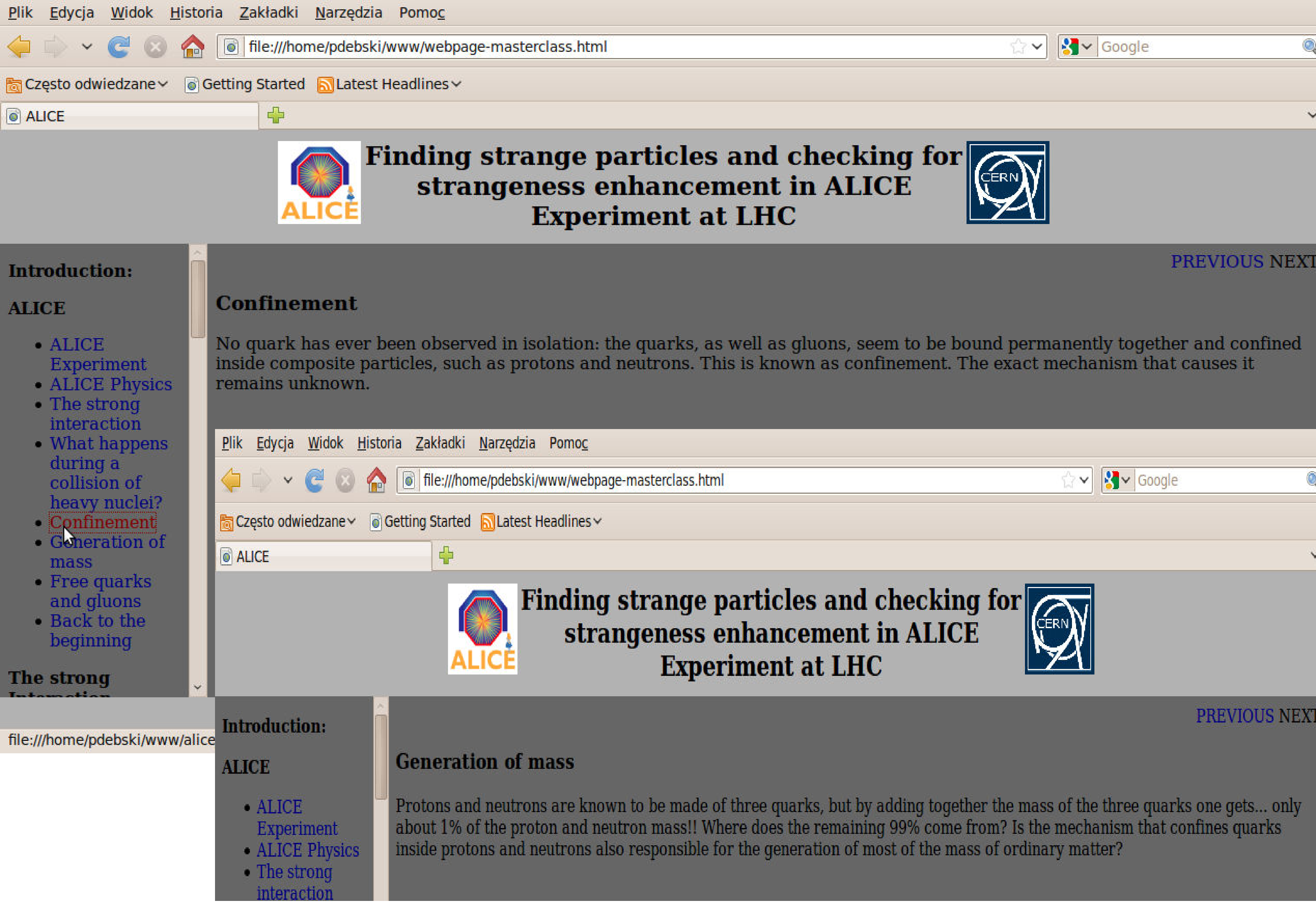
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Confinement
No quark has ever been observed in isolation: the quarks, as well as gluons, seem to be bound permanently together and confined inside composite particles, such as protons and neutrons. This is known as confinement. The exact mechanism that causes it remains unknown.
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Generation of mass
Protons and neutrons are known to be made of three quarks, but by adding together the mass of the three quarks one gets... only about 1% of the proton and neutron mass!! Where does the remaining 99% come from? Is the mechanism that confines quarks inside protons and neutrons also responsible for the generation of most of the mass of ordinary matter?

Finding strange particles and checking for strangeness enhancement in ALICE Experiment at LHC

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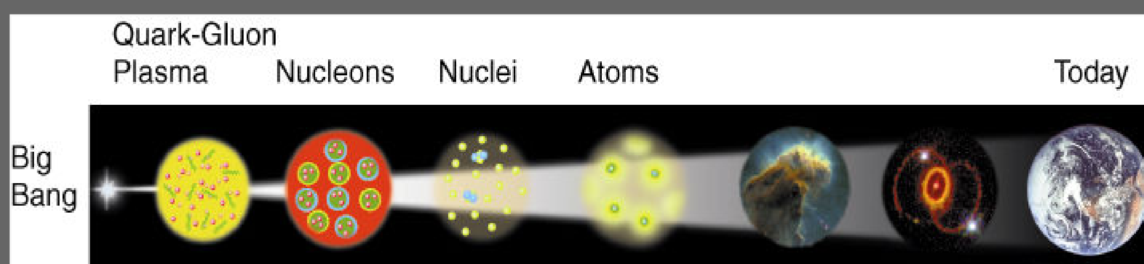
Free quarks and gluons

The current theory of the strong interaction (called quantum chromodynamics QCD) predicts that at very high temperatures and very high densities, quarks and gluons should no longer be confined inside composite particles. Instead they should exist freely in a new state of matter known as quark-gluon plasma. Such a transition should occur when the temperature exceeds a critical value estimated to be around 2000 billion degrees.... about 100 000 times hotter than the core of the Sun!! Such temperatures have not existed in Nature since the birth of the Universe. We believe that for a few millionths of a second after the Big Bang the temperature was indeed above the critical value, and the entire universe was in a quark-gluon plasma state.

PREVIOUS NEXT

Back to the beginning

Can this scenario be studied experimentally? Can such extreme conditions be recreated in the laboratory? By inducing head-on collisions of heavy nuclei (such as nuclei of lead atoms) accelerated by the LHC to a speed close to the speed of light, we should be able to obtain -albeit over a tiny volume, only about the size of a nucleus- and for an exceedingly short instant, a drop of such primordial matter and observe it as it reverts to ordinary matter through expansion and cooling. By studying such collisions at the LHC, ALICE should be able to explore deep into the physics of confinement, to probe the properties of the vacuum and the generation of mass in strong interactions- and to get a glimpse of how matter behaved immediately after the Big Bang.



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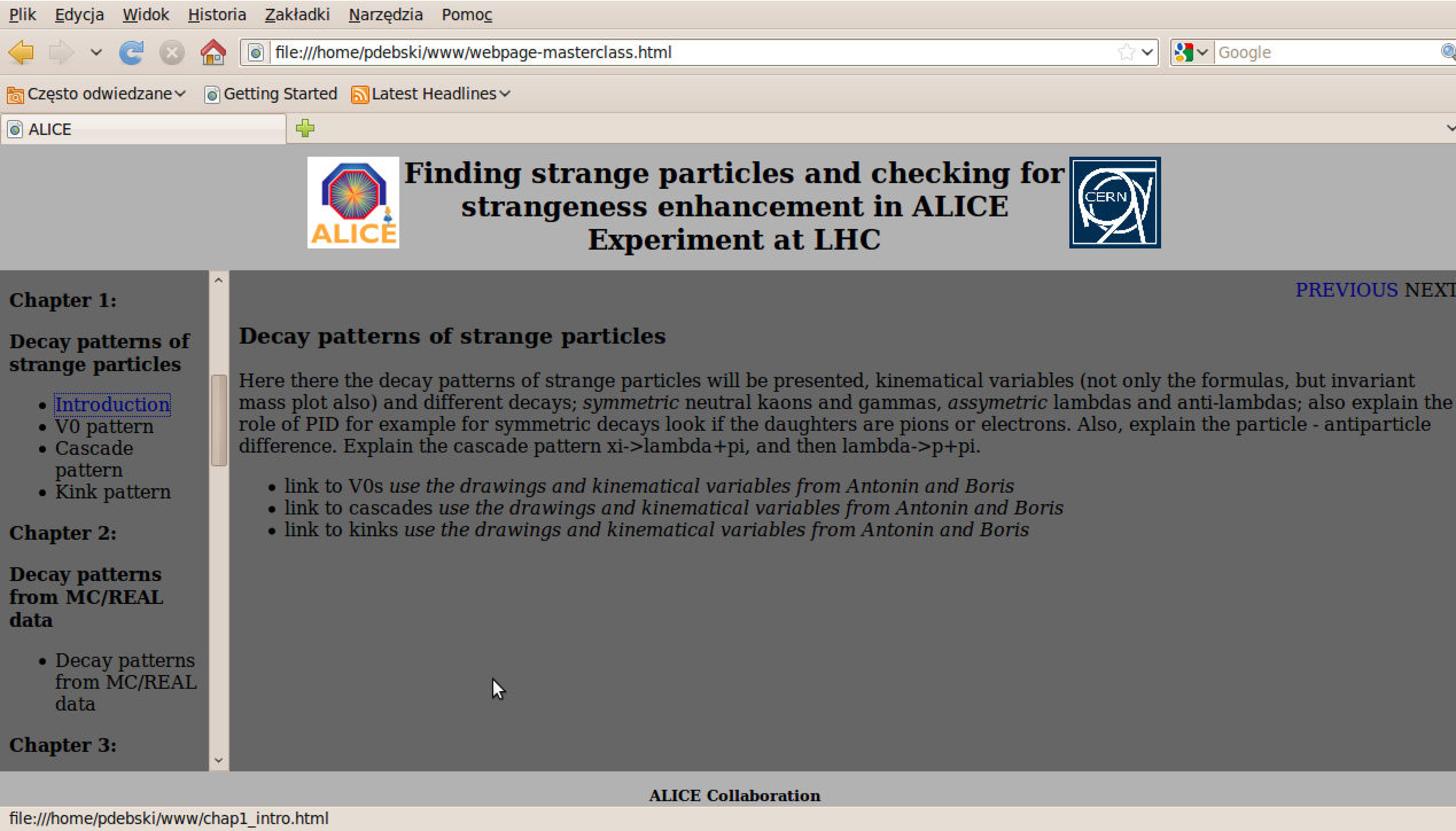
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Decay patterns of strange particles

Here there the decay patterns of strange particles will be presented, kinematical variables (not only the formulas, but invariant mass plot also) and different decays; *symmetric* neutral kaons and gammas, *assymetric* lambdas and anti-lambdas; also explain the role of PID for example for symmetric decays look if the daughters are pions or electrons. Also, explain the particle - antiparticle difference. Explain the cascade pattern xi->lambda+pi, and then lambda->p+pi.

- link to V0s *use the drawings and kinematical variables from Antonin and Boris*
- link to cascades *use the drawings and kinematical variables from Antonin and Boris*
- link to kinks *use the drawings and kinematical variables from Antonin and Boris*

ALICE Collaboration

file:///home/pdebski/www/chap1_intro.html

To add existing material by A. Maire and B. Hippolyte

V0 analysis basics

Λ^0(uds)

m = 1115.683 ± 0.006 MeV

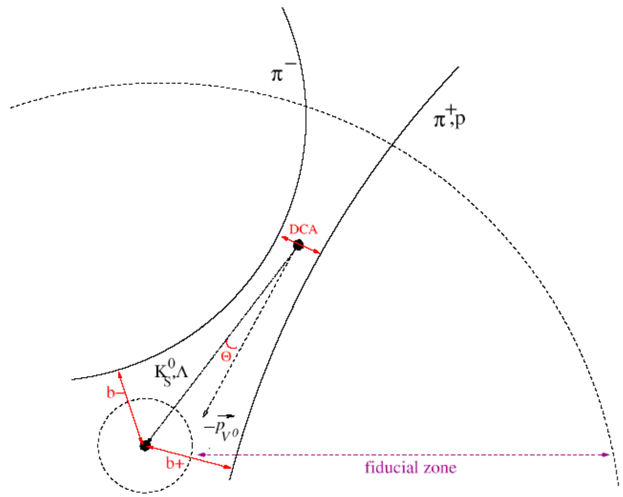
<τ> = (2.632 ± 0.020)x10^{-10} s

cτ = 7.89 cm

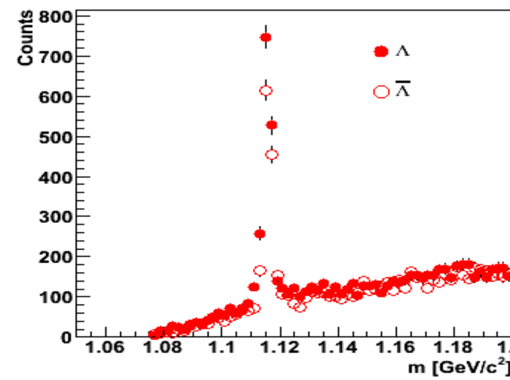
Λ -> pπ$^-$ (~64 %)

-> Nπ^0 (~35.8 %)

-> nγ (~1.75x10^{-3} %)

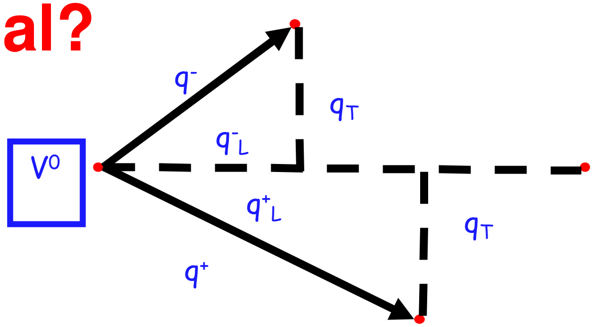


$$m_{inv} = \sqrt{(E_1 + E_2)^2 - \left(\vec{p}_1 + \vec{p}_2\right)^2}$$

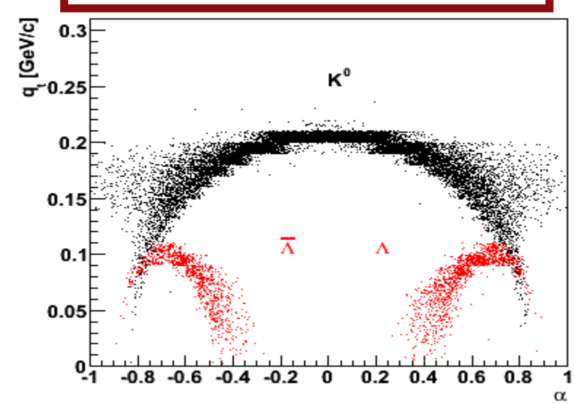


$$\alpha = \frac{q_L^+ - q_L^-}{q_L^+ + q_L^-}$$

Univ level, if at al?



Armenteros - Podolanski space



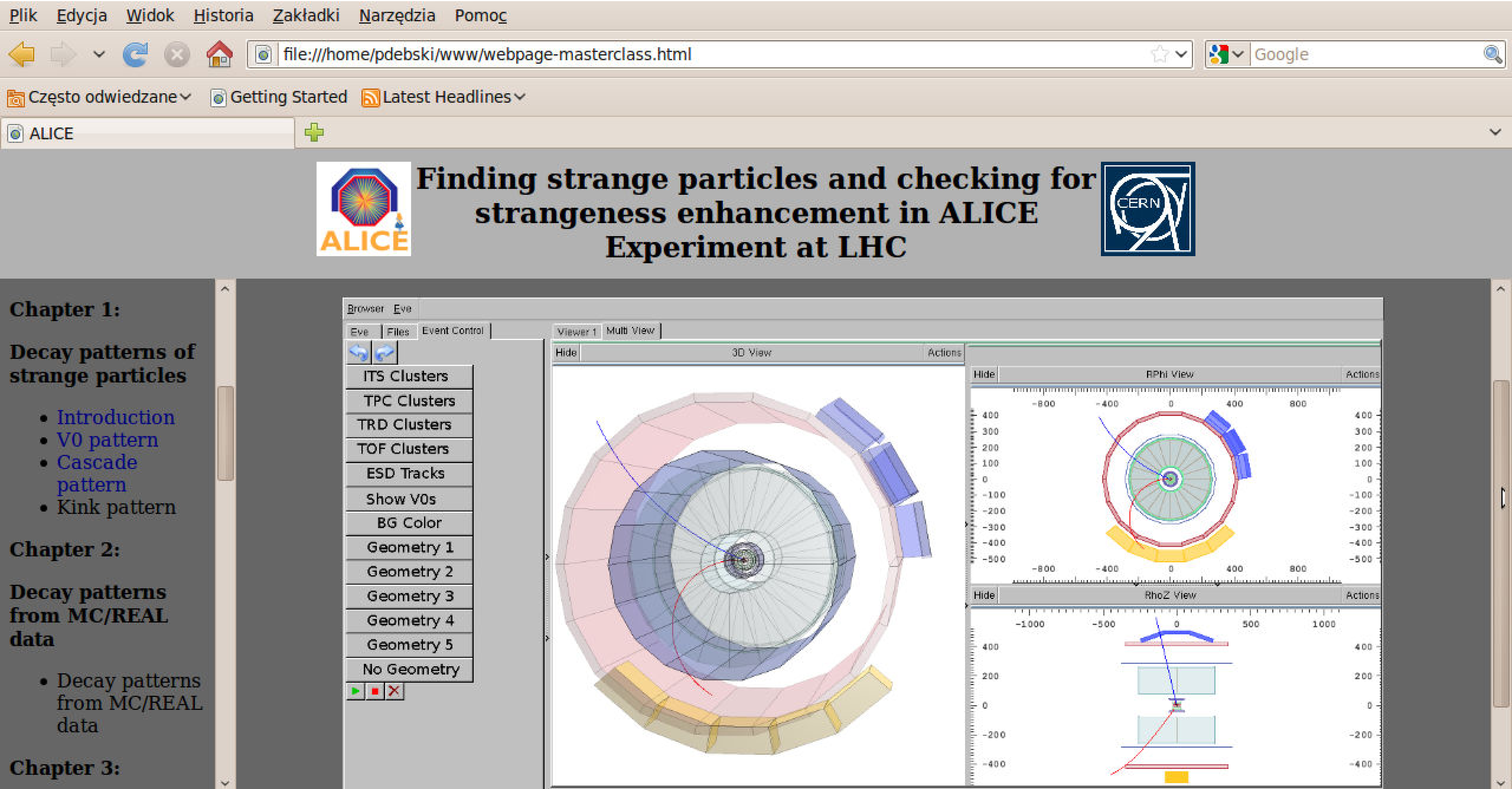
To Consider: Use of geometrical (DCA) and kinematical (inv. mass) variables to decide correctness of candidate ???

Analysis experience

- Visual patterns

  Symmetric **(K0s, γ)**, not symmetric (**Λ, anti Λ)**

  V0 or Cascade

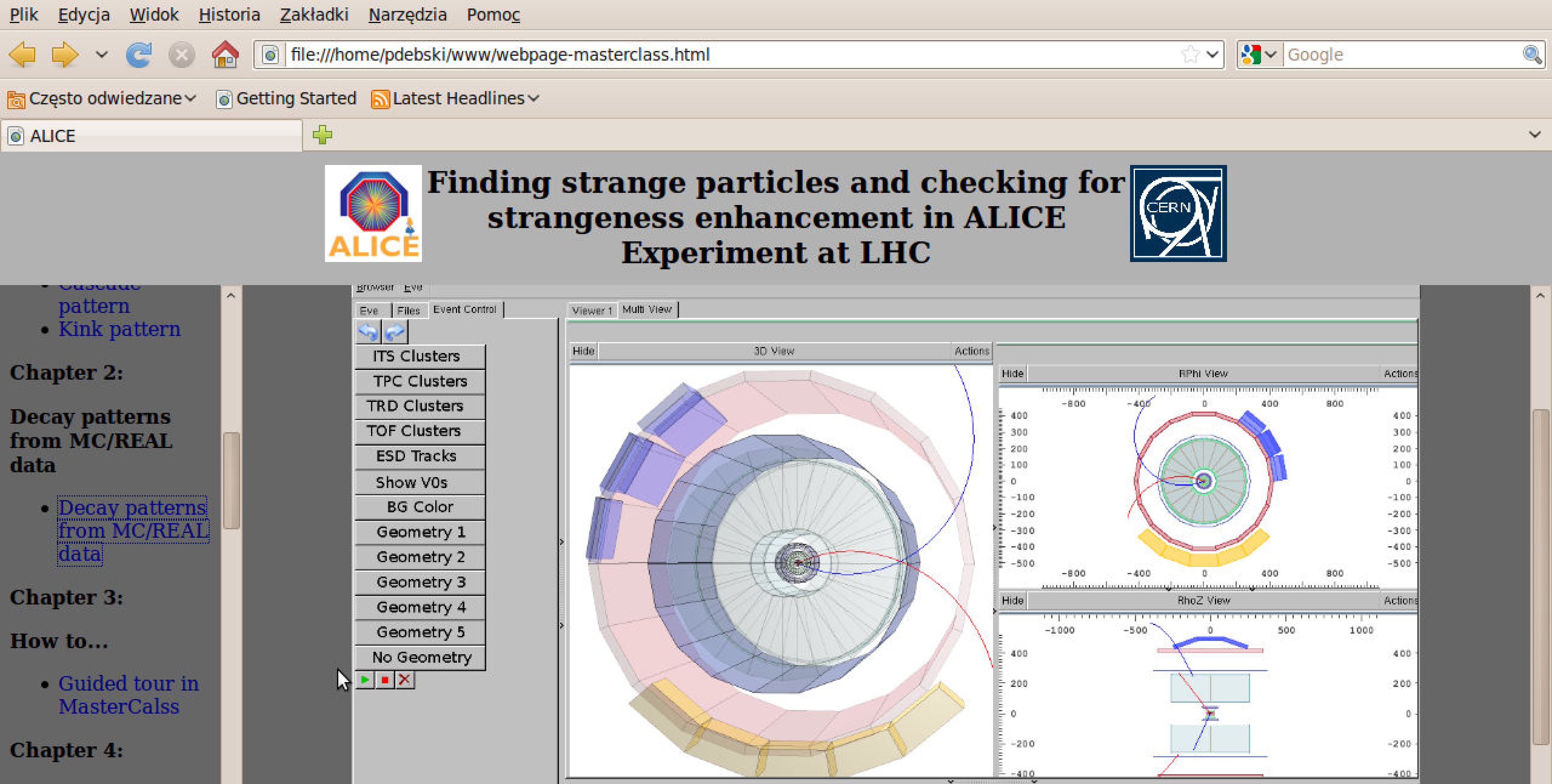


Analysis experience

- Magnetic field

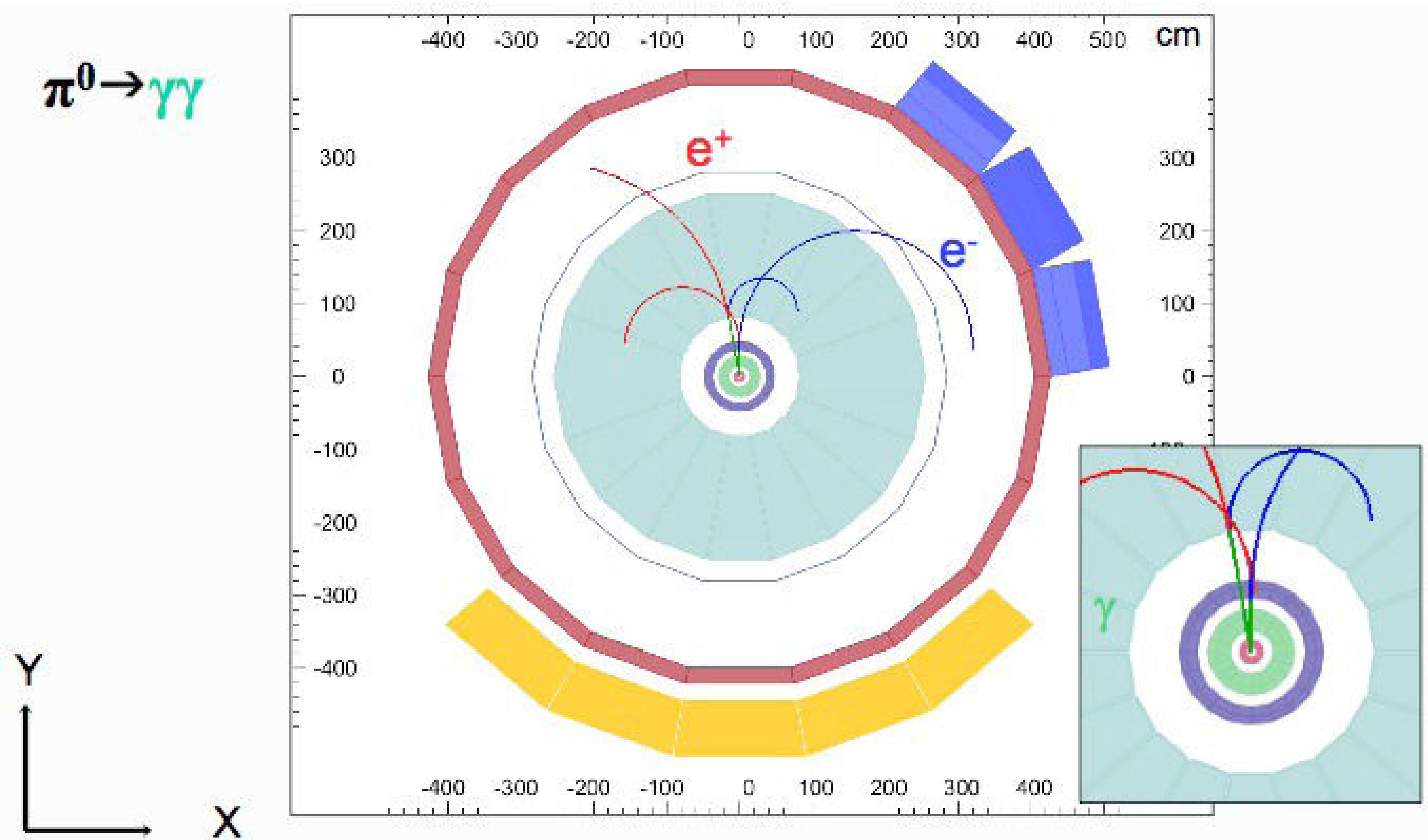
  particles/anti-particles; orientation in magnetic field

  “sailor” topology



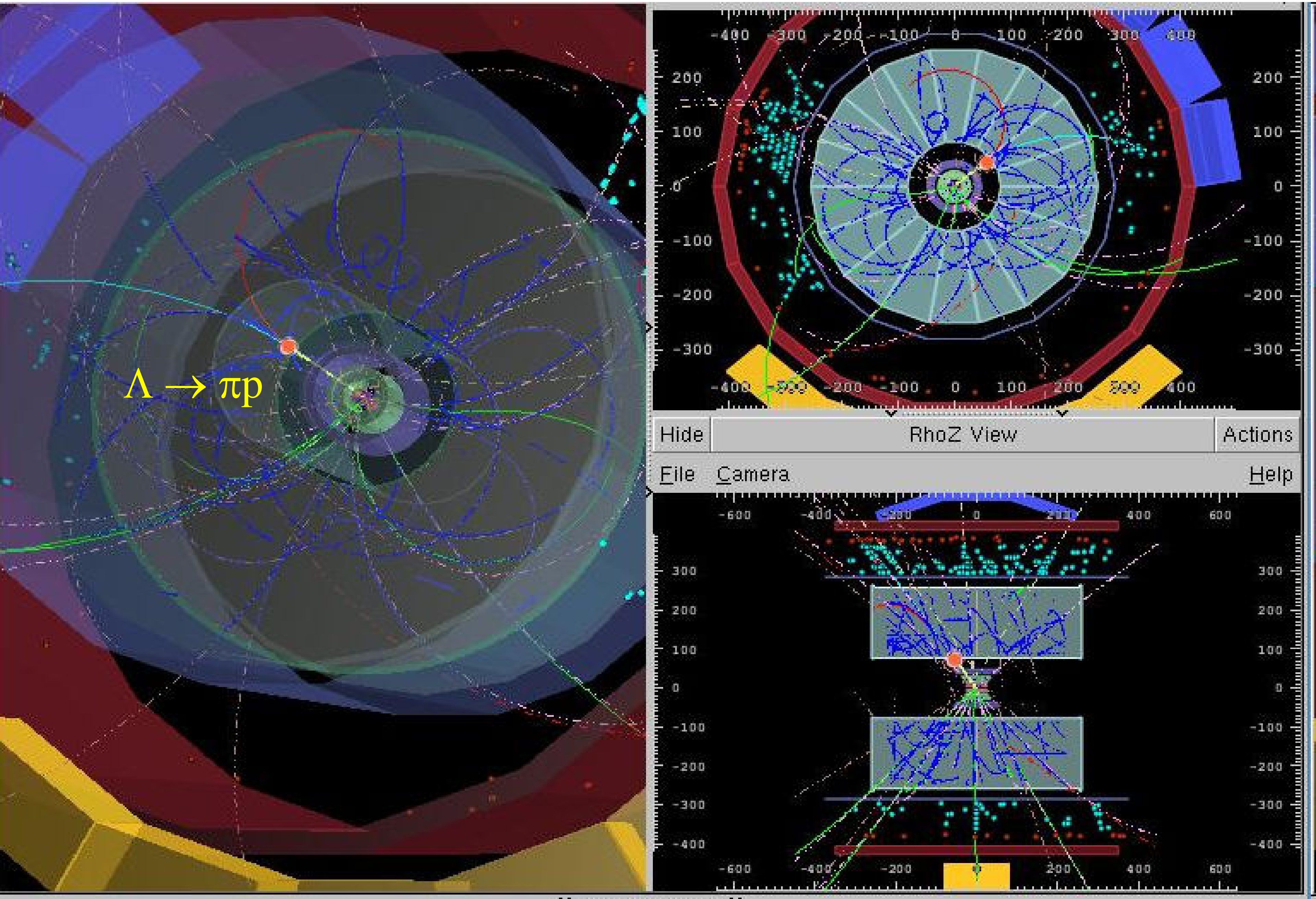
gamma conversions

$\pi^0 \rightarrow \gamma\gamma$

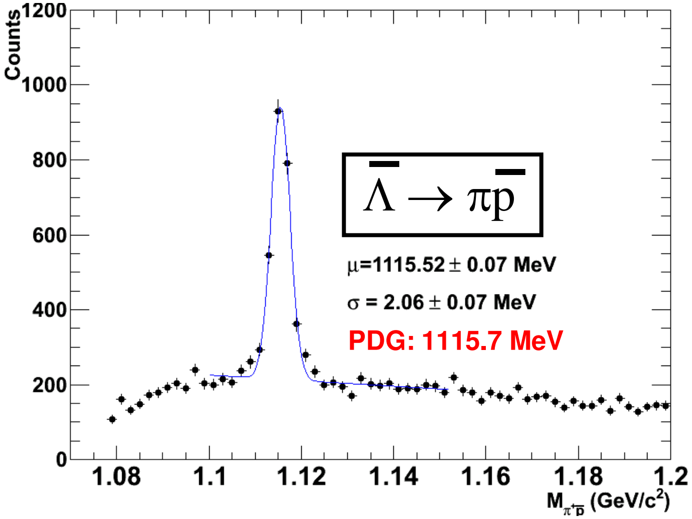


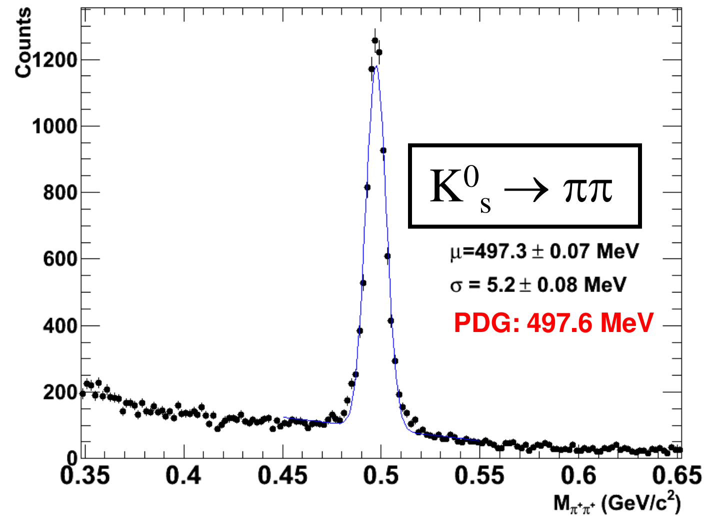
Symmetric, looks like K0s: look at PID of daughters (e or π)

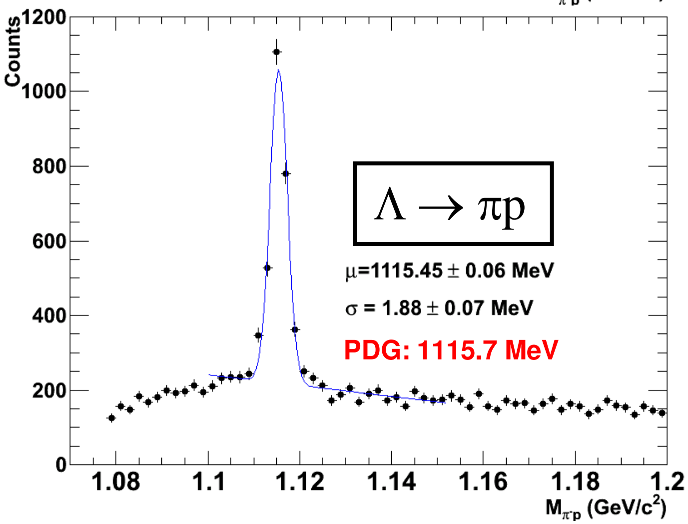
Strange particle (V0) reconstruction



Strange particle (V0) reconstruction





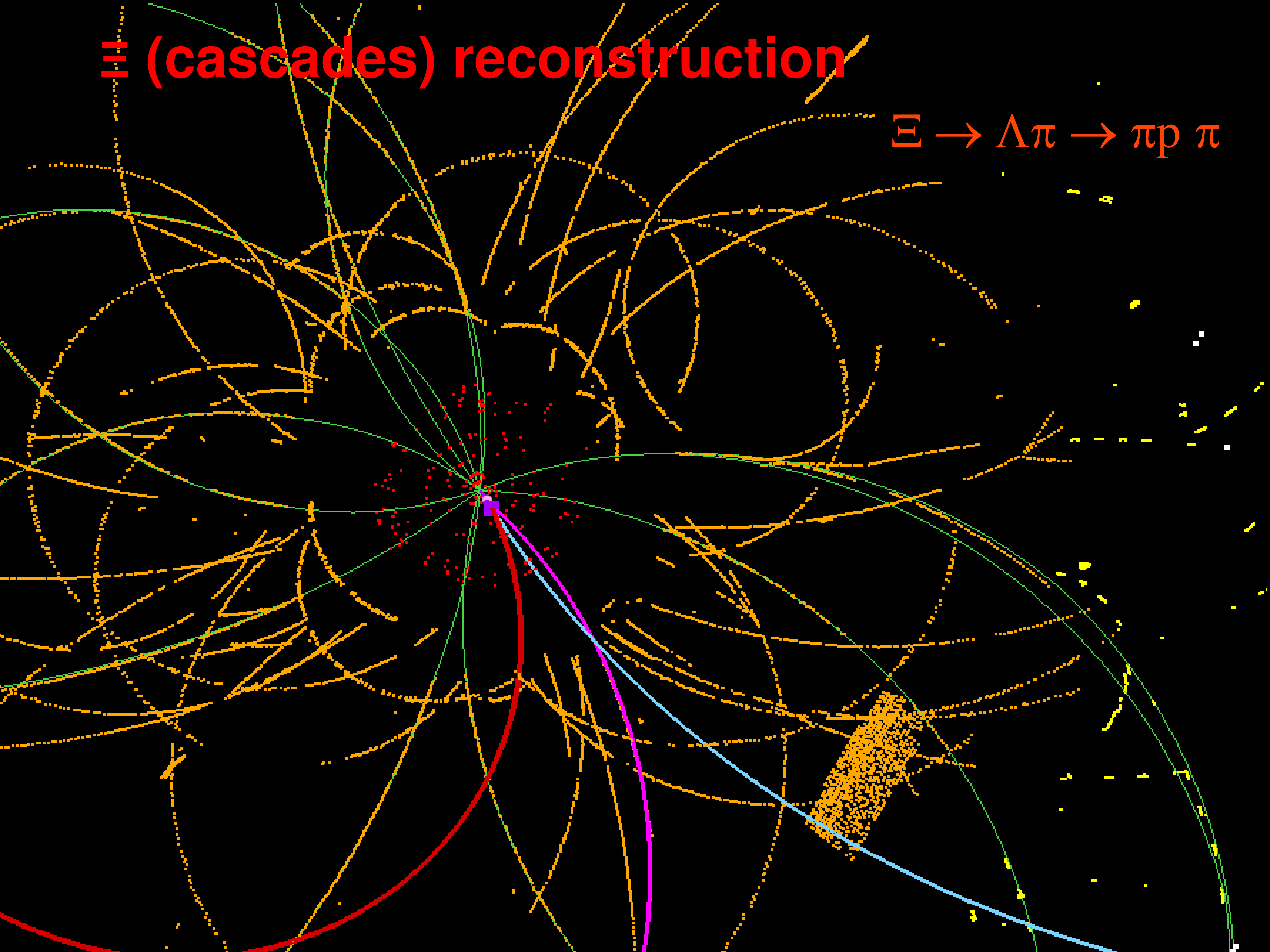


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

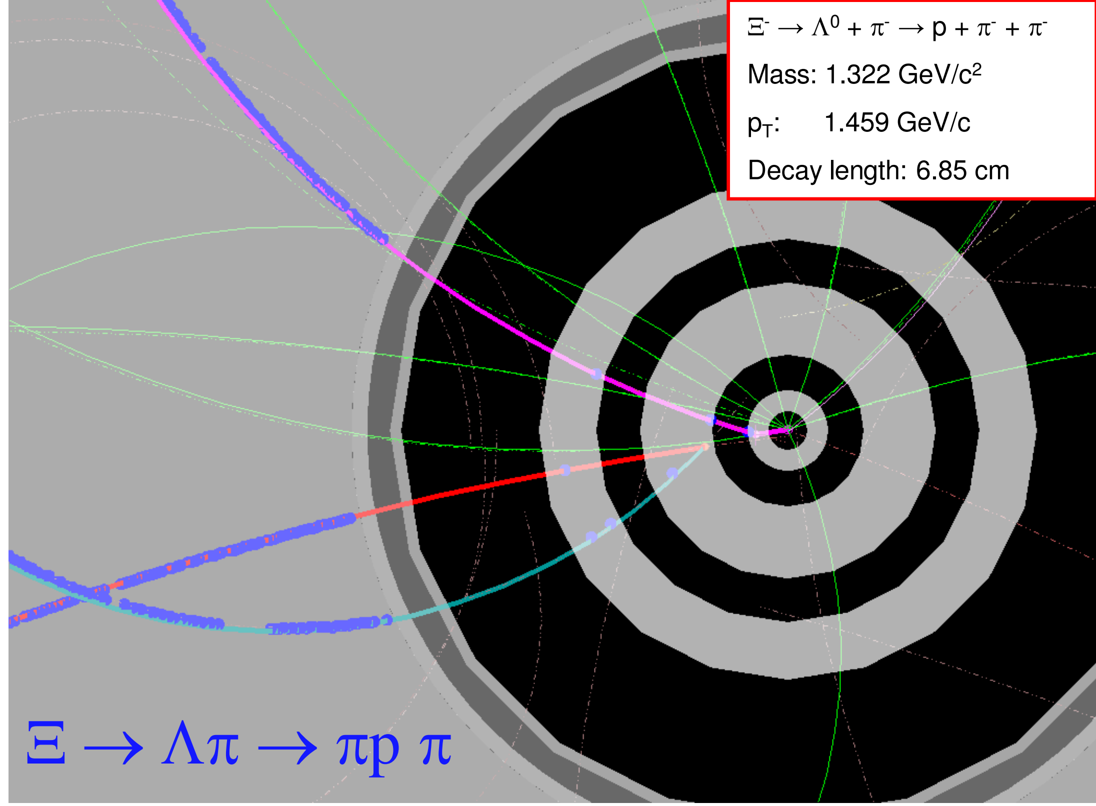
Univ level, if at al?

Ξ (cascades) reconstruction

$\Xi \rightarrow \Lambda\pi \rightarrow \pi p\ \pi$

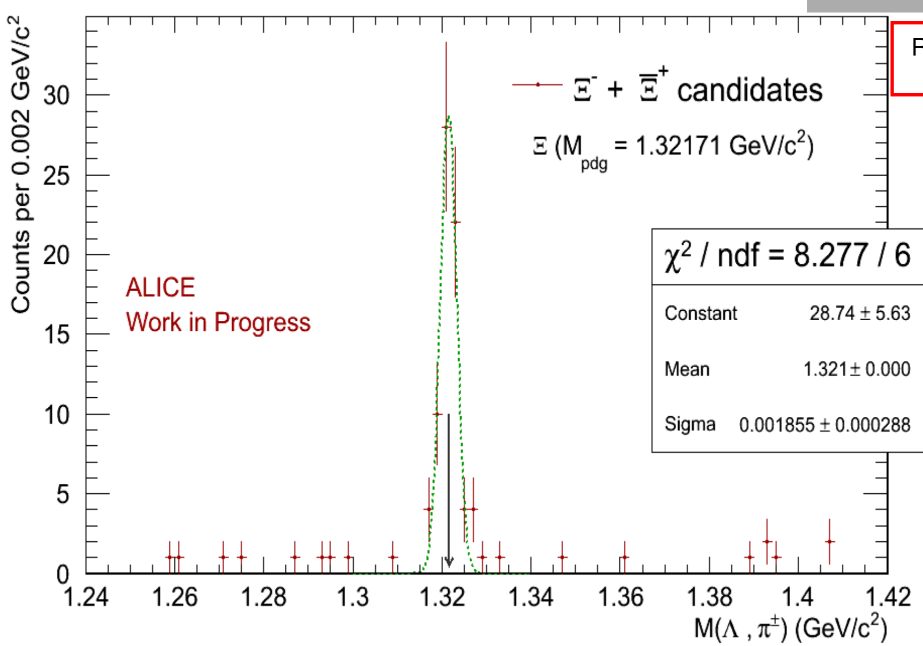


Ξ reconstruction



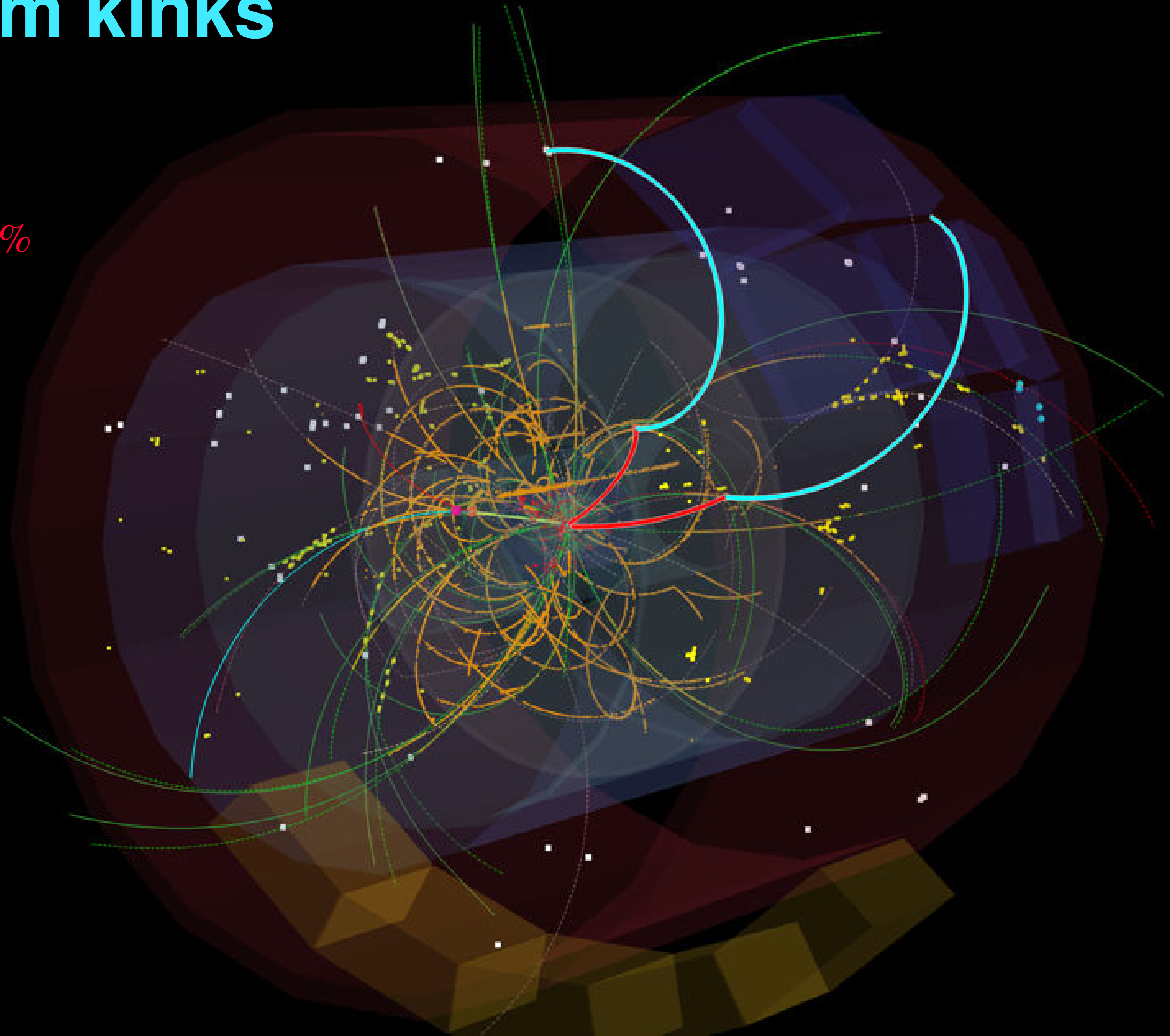
Run 104892, chunk 09000104892020.130, event in chunk 1840

ALICE data, p-p at 900 GeV



- Strangeness production paper:
  - K^0, Λ, Φ p_T spectra
  - Ξ^- yield

K from kinks



K – kinks

$K \rightarrow \pi\pi^0$ 21.13%

π - kinks

$\pi \rightarrow \mu\nu$ 99%

K decays

$K \rightarrow \mu\nu$ 63.43%

$K \rightarrow \varepsilon\pi^0\nu$ 4.87%

$K \rightarrow \mu\pi^0\nu$ 3.27%

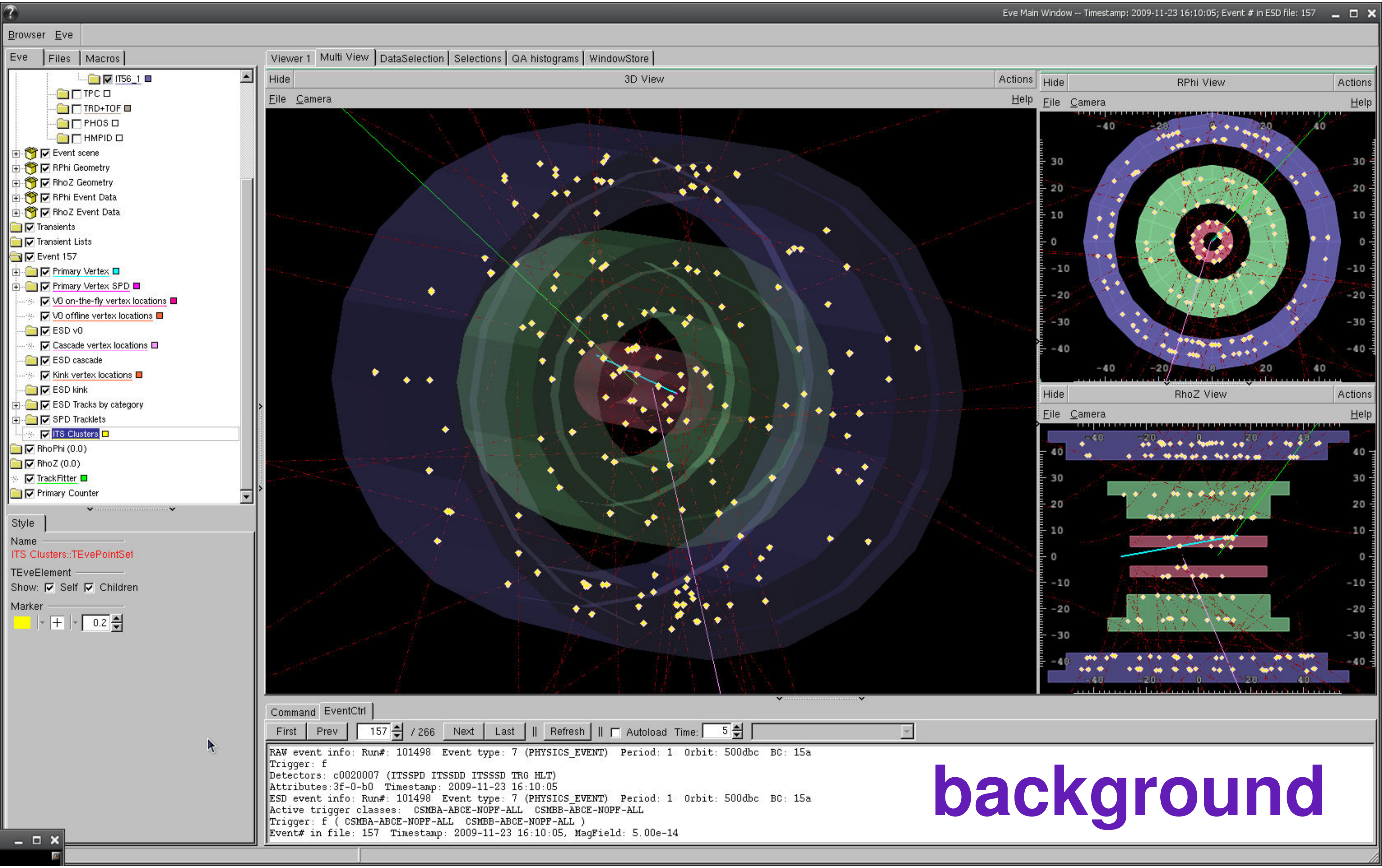
$K \rightarrow \pi\pi^0\pi^0$ 1.73%

Analysis experience

Emphasis on
tracking and PID, main and secondary vertices reconstruction,

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Visual inspection and verification

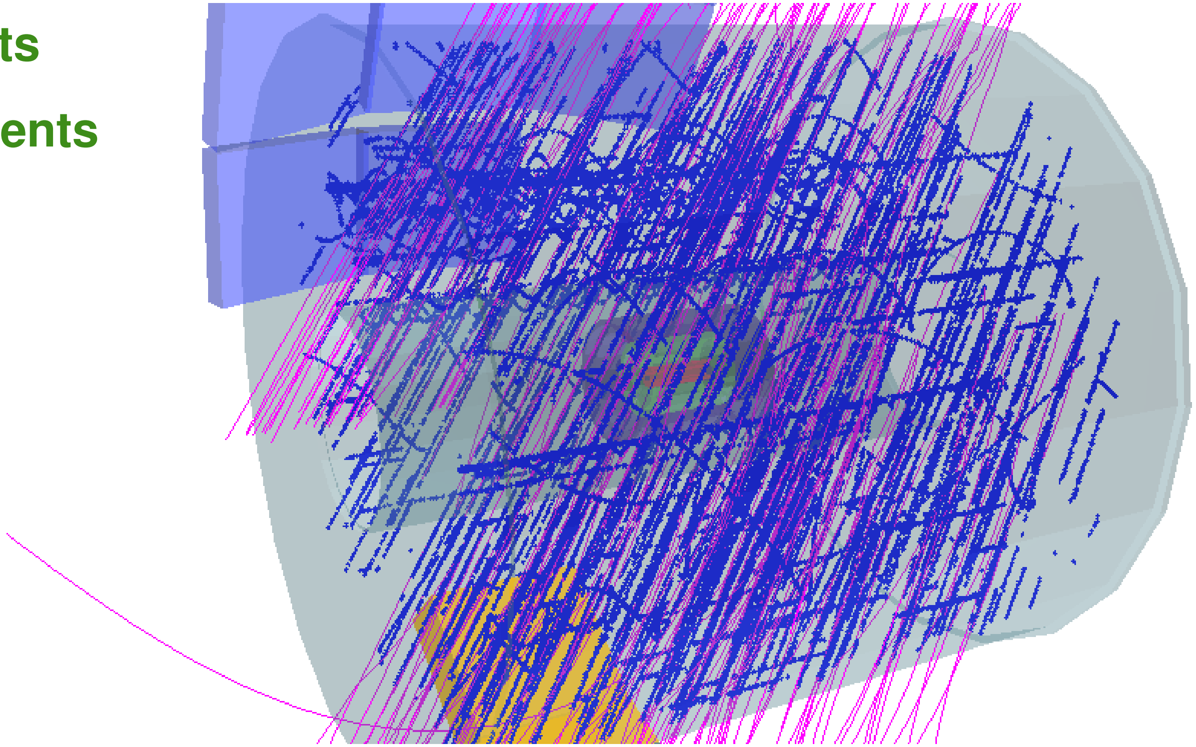


background

Visualisation in real life

- **Visualisation used in real life**
  - ⇨ First look in ACR; online
  - ⇨ Inspect, identify patterns,
  - ⇨ Optimise, verify
  - ⇨ Suspect events
  - ⇨ Interesting events

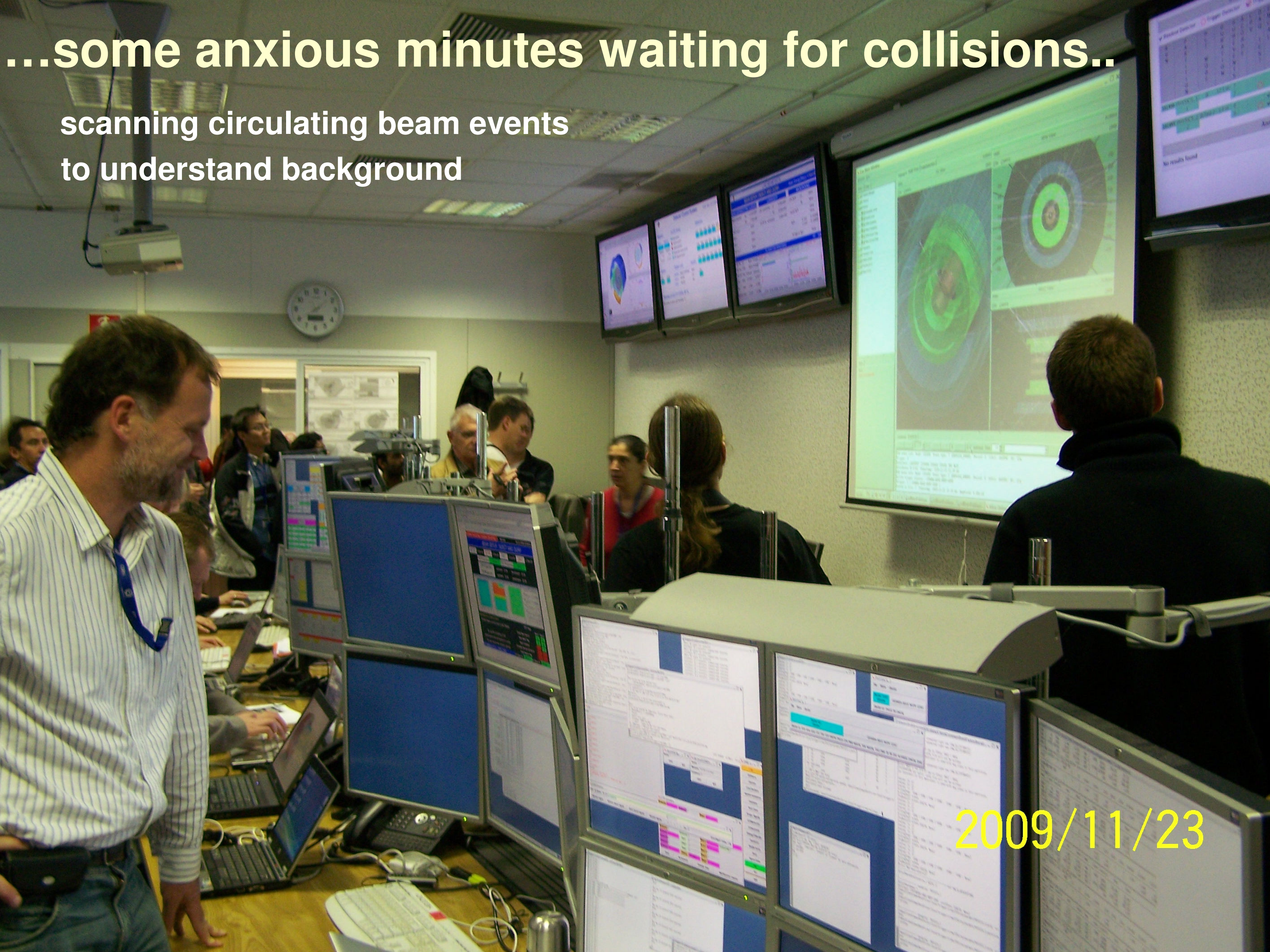
…expect the unexpected…



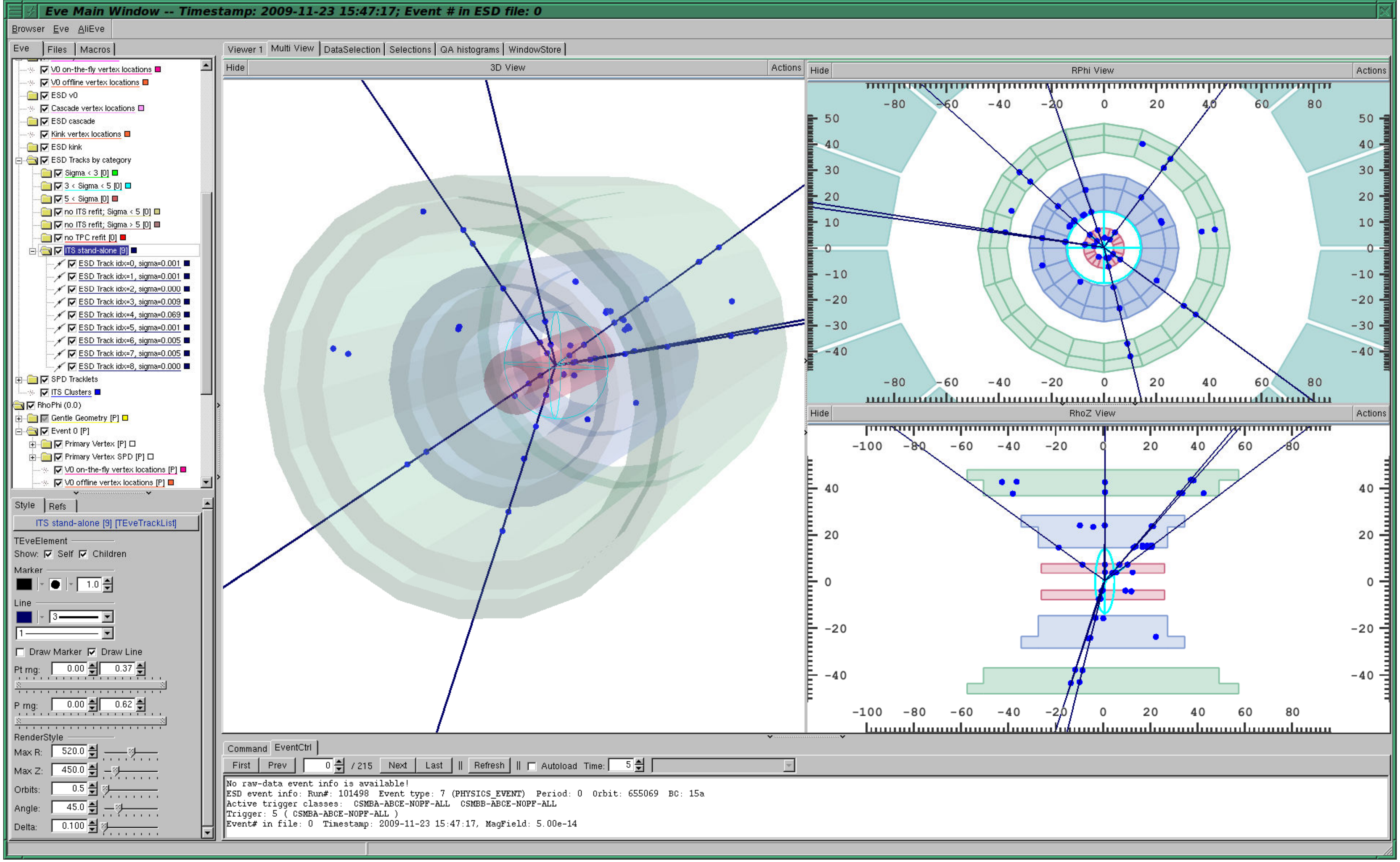
RUN 109547 chunk 20.10 ev 3723

...some anxious minutes waiting for collisions..

scanning circulating beam events
to understand background



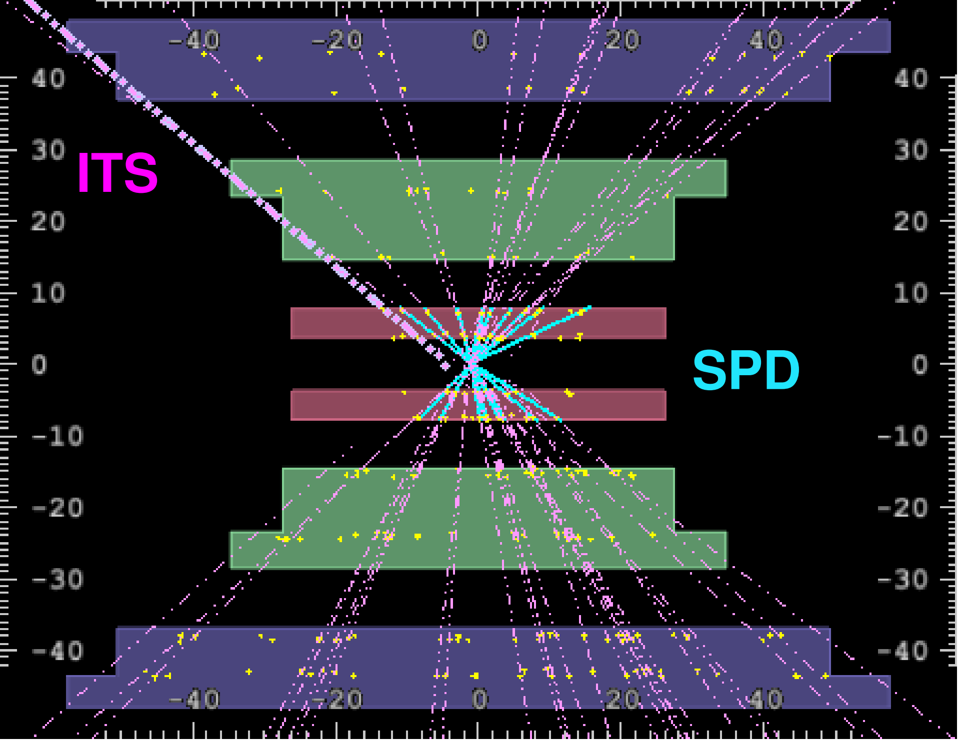
…some "happy minutes" watching collisions…



Immediate feedback

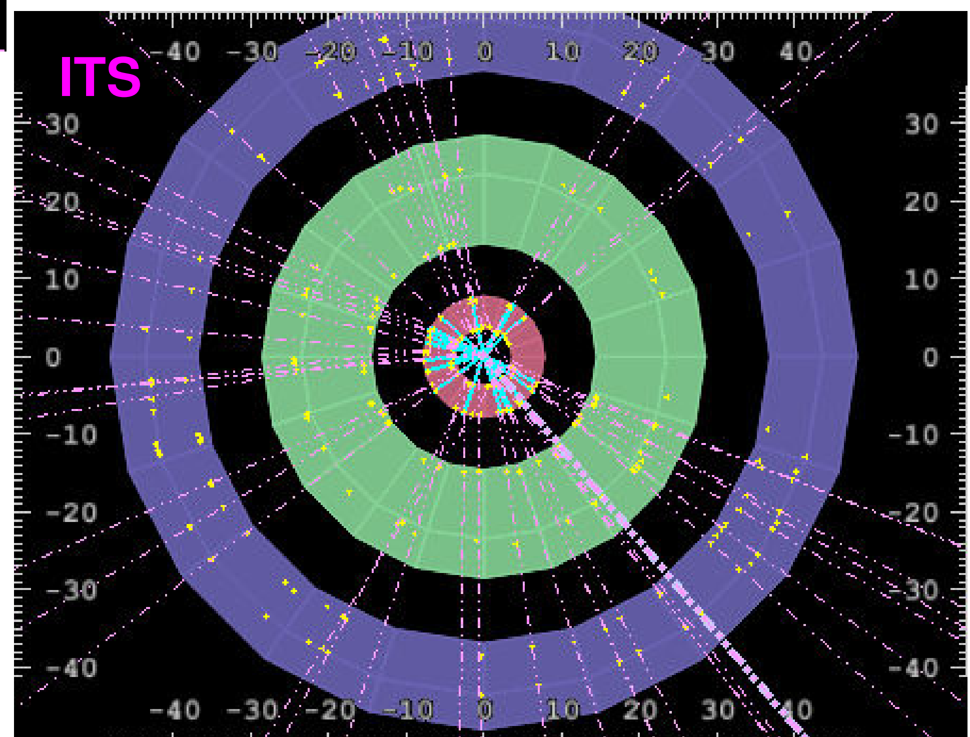
At 17:21 the beams were dumped and the run closed with 284 events

At 17:28 THE first online reconstructed event



consistency checks

main vertex reconstruction



high multiplicty

1. tracklets reconstracted by SPD
2. global ITS tracks recostructed by whole ITS !!!

they match!!

Analysis details

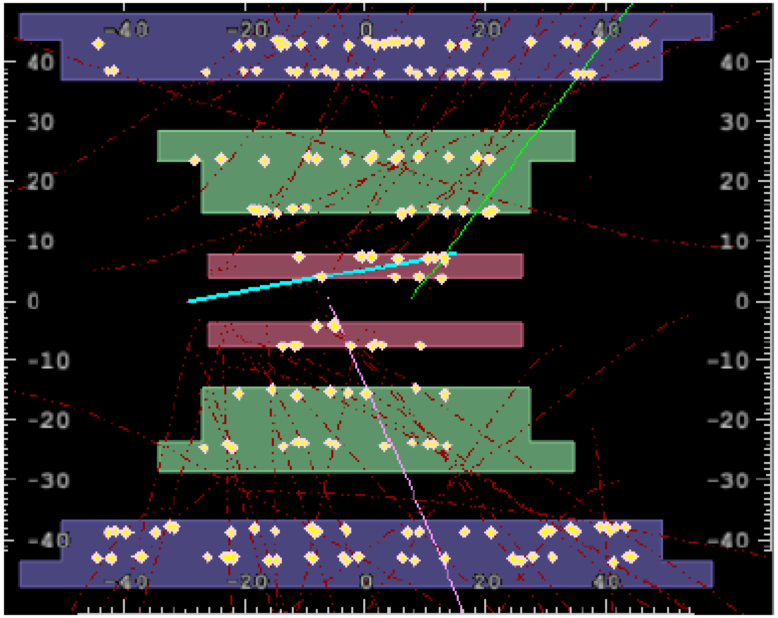
Out of a total of 284 events,
227 events
were used for the analysis.

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

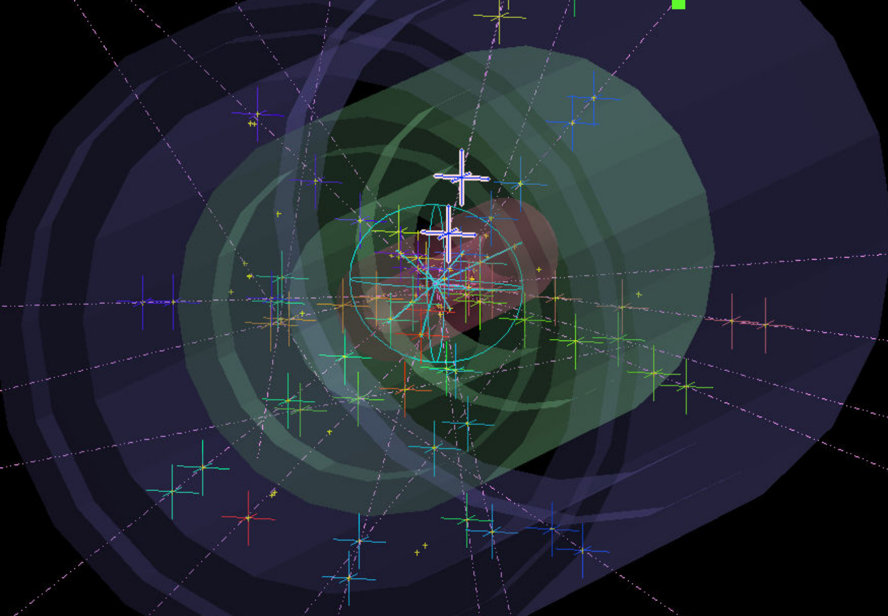
Remainder was rejected due to:

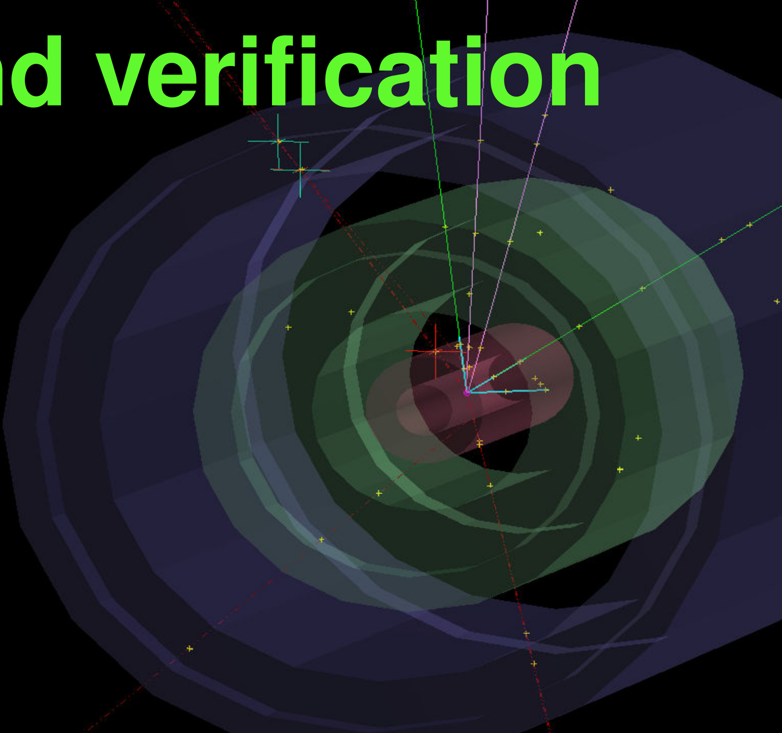
- timing information in V0
  (beam induced background)
- no tracklets found
- no vertex found
- $|z_{vtx}| > 10$ cm
- clusters vs. tracklets correlation
  in SPD

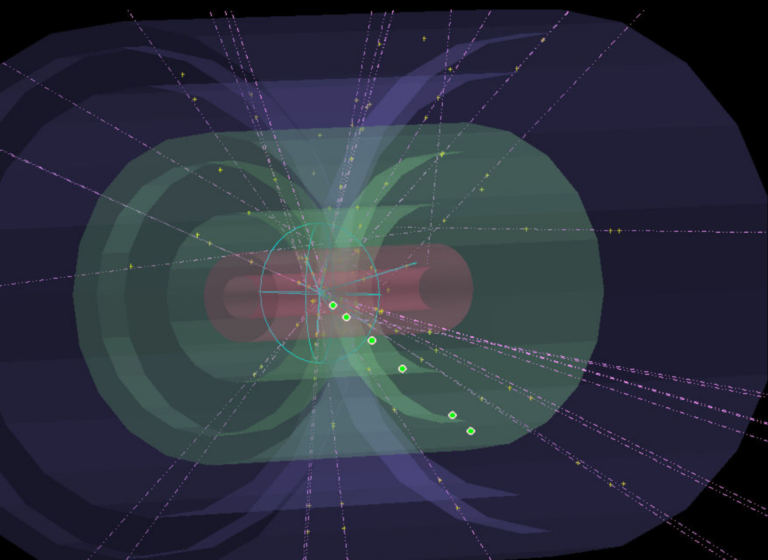
confirmed by visual scan

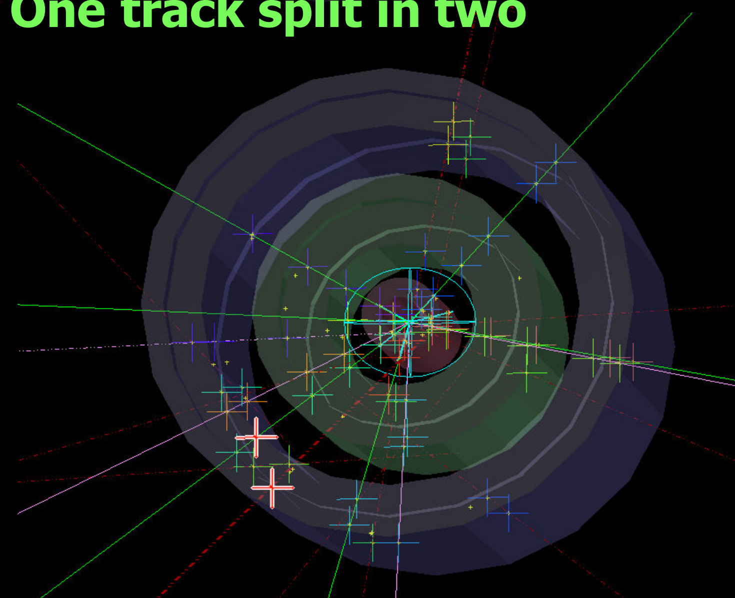


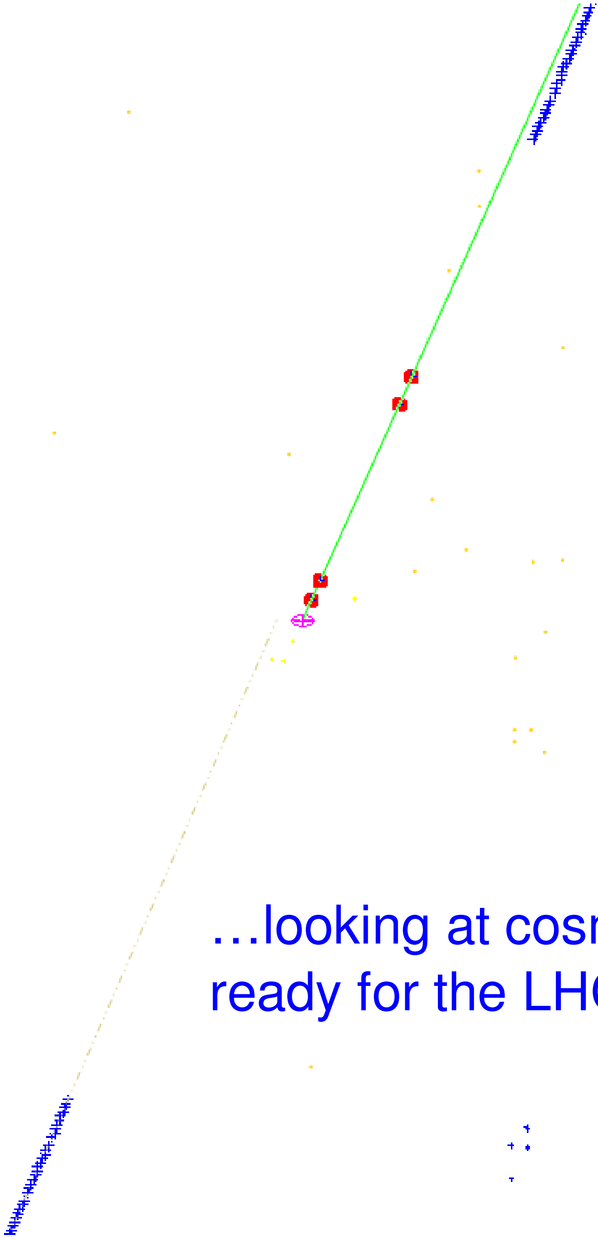
Visual inspection and verification


51. Track splitting

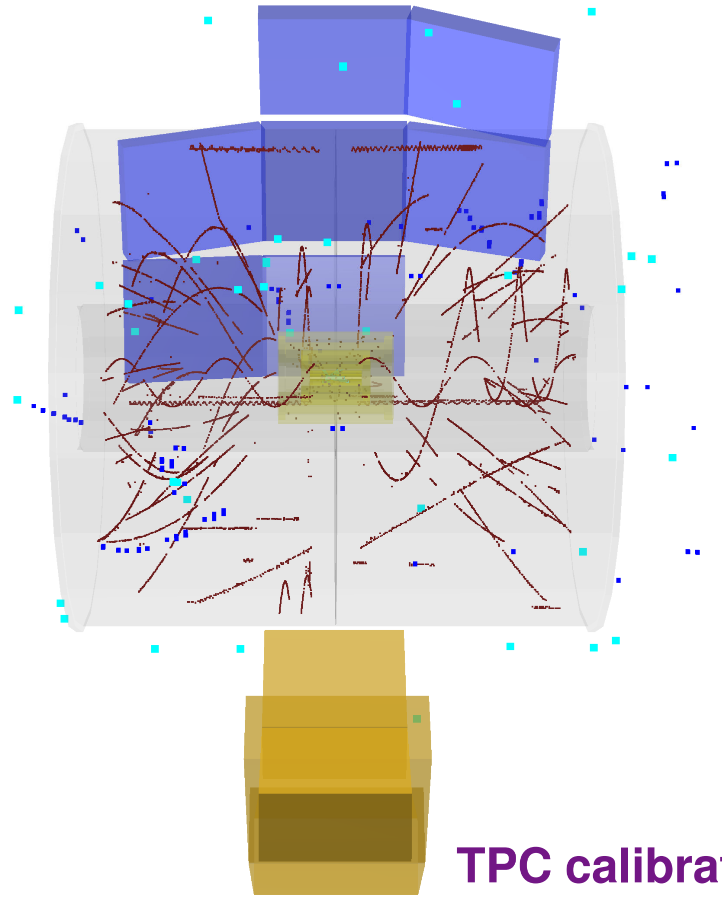

61. One track split in two


50. Good tracklet and clusters, no track


51. Clusters not associated with track



…looking at cosmics to get ready for the LHC beams …

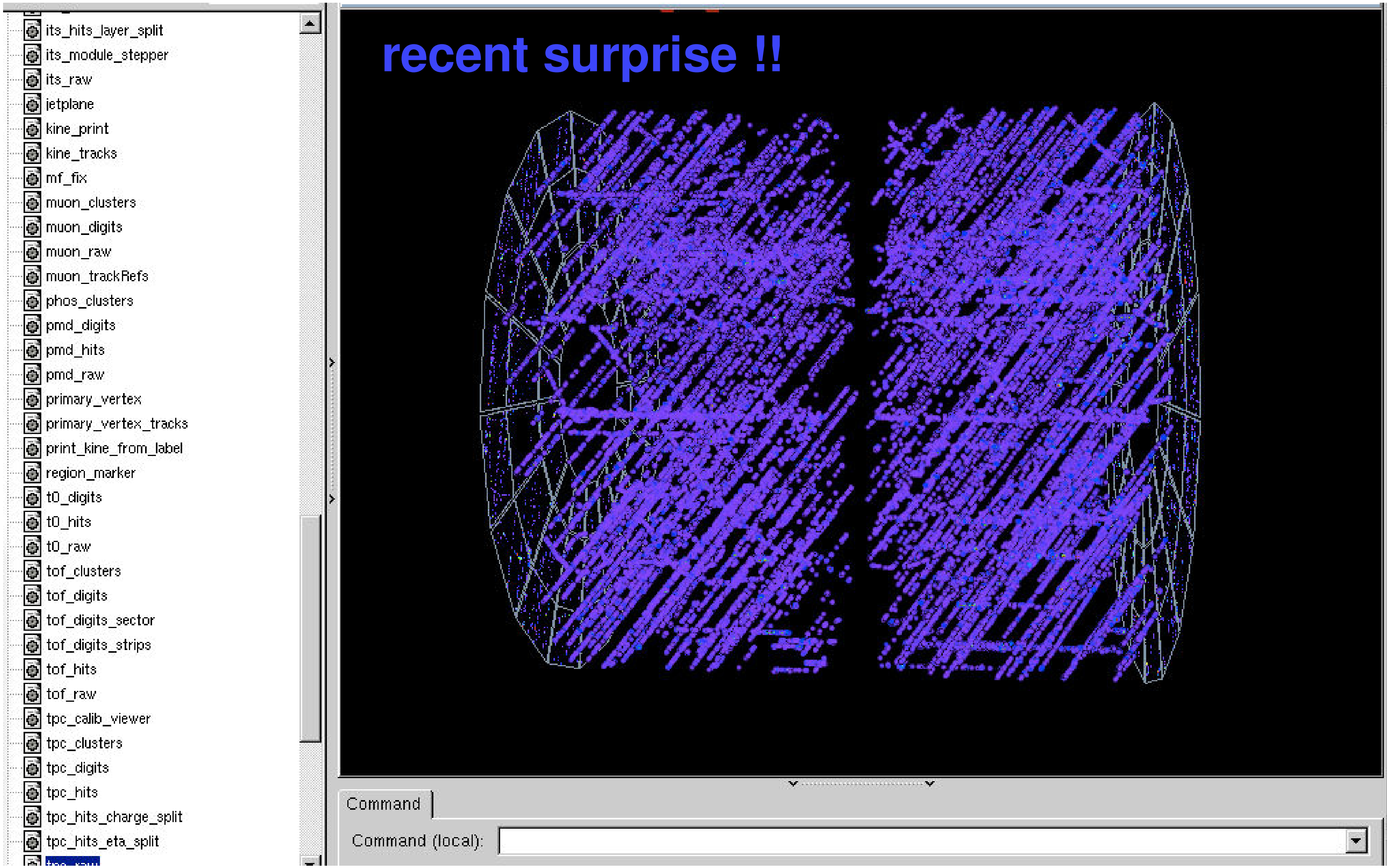


TPC calibration

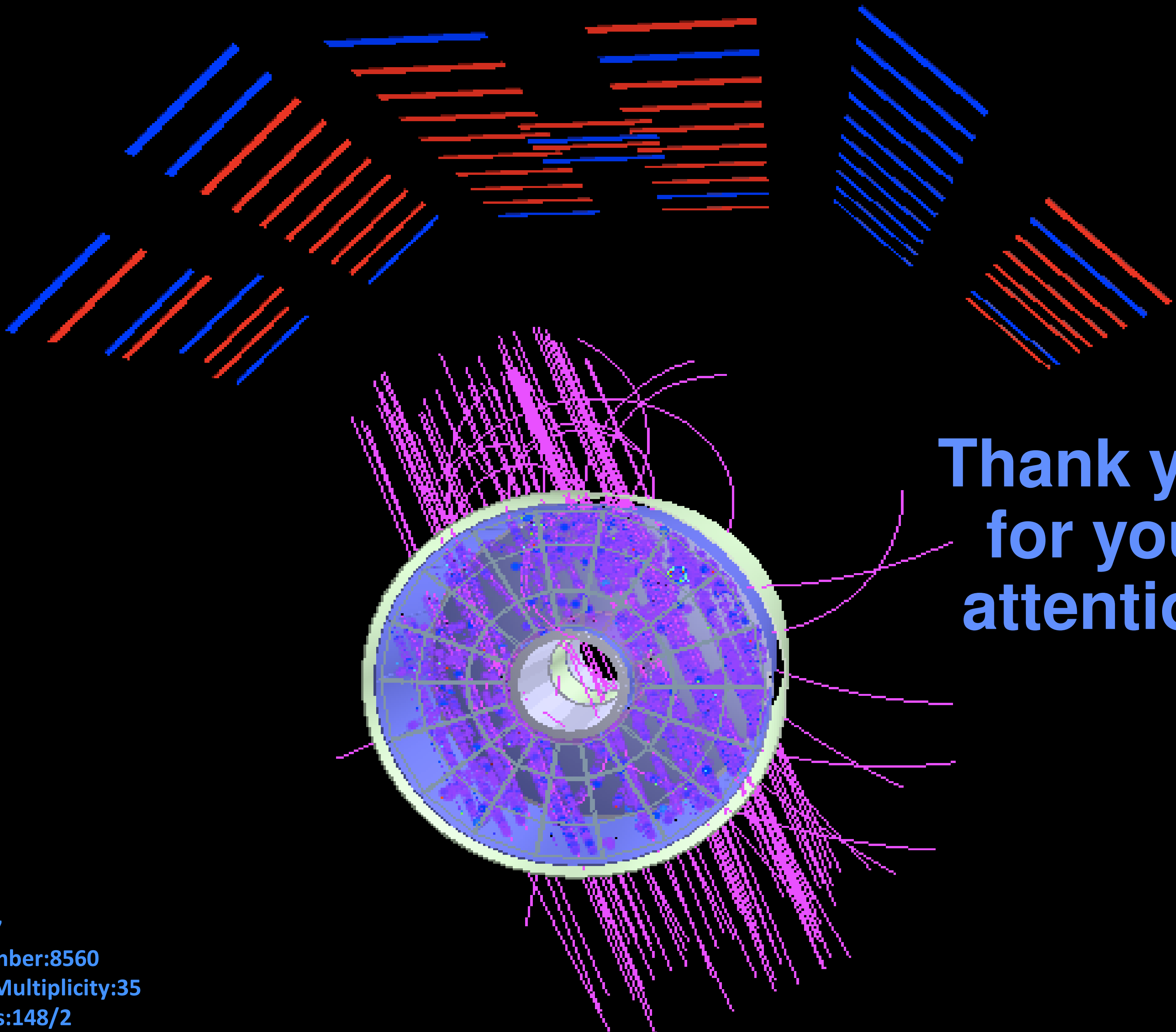
…using cosmics and pp data optimize

detector calibration and performance

…and stay open to surprises !!



RUN 109547 chunk 20.10 ev 3723



Thank you for your attention

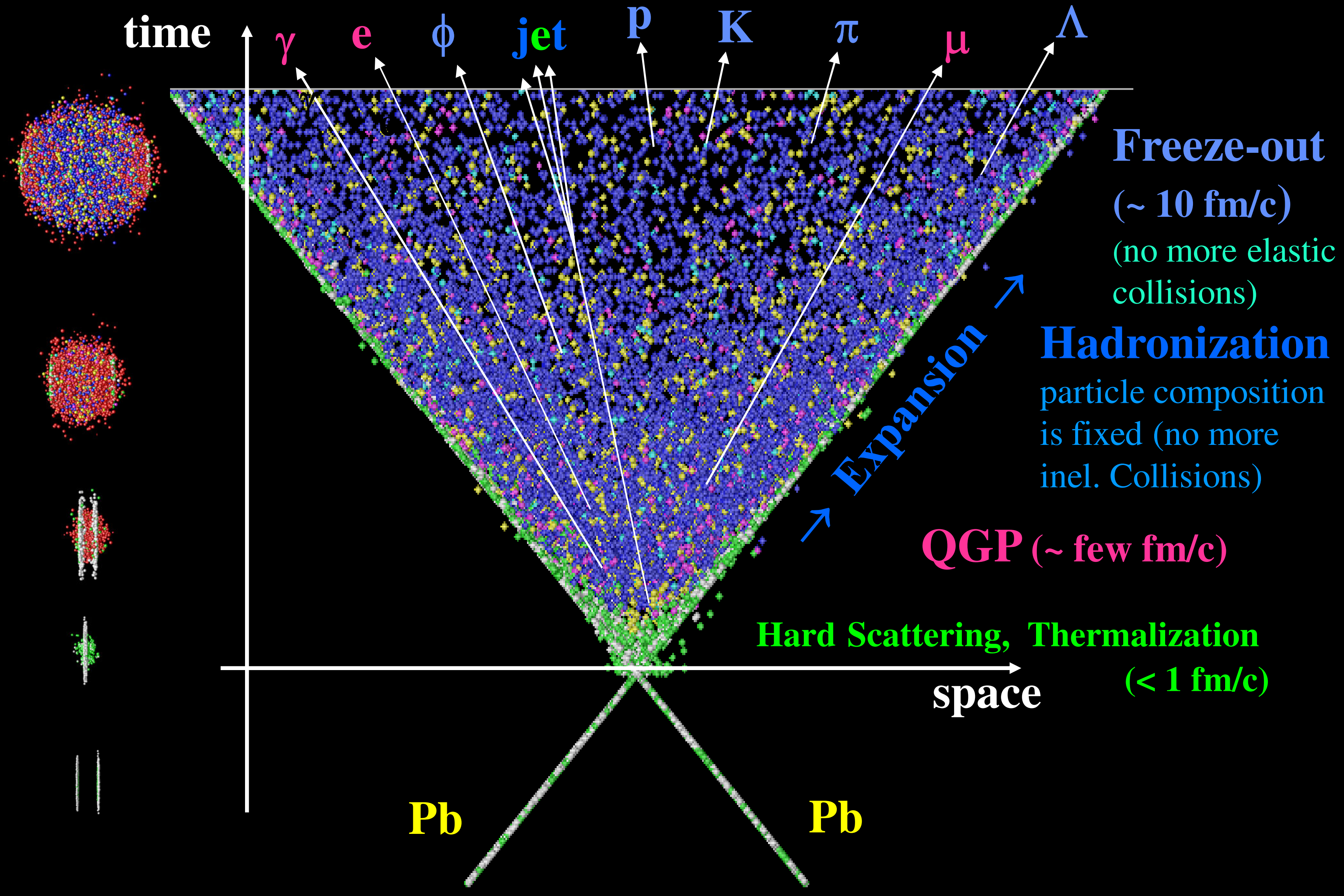
Run62107
Event number:8560
ACORDE Multiplicity:35
TPC tracks:148/2

Extra Material

- URQMD collision
- Evolution of collision
- Signatures and measurements
- Tracking challenge

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Space-time Evolution of the Collisions



Observables – Lattice Thermodynamics

Interferometry

$\pi\pi$, ...

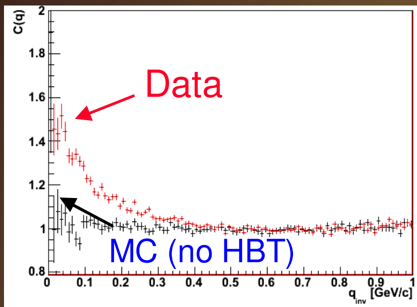
Temperature

120 MeV

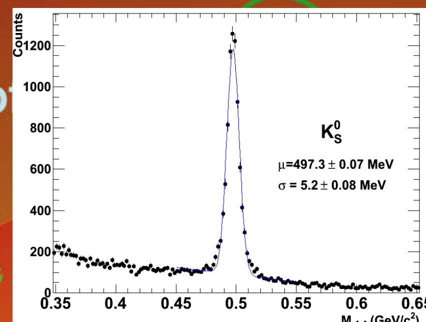
Last scattering

Smeared ρ

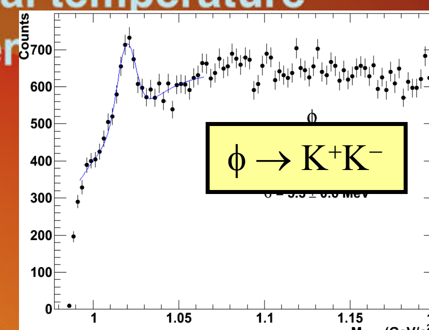
Thermal masses
chiral symmetry restoration



Equation of



Critical temperature
and er



c/2

Strange

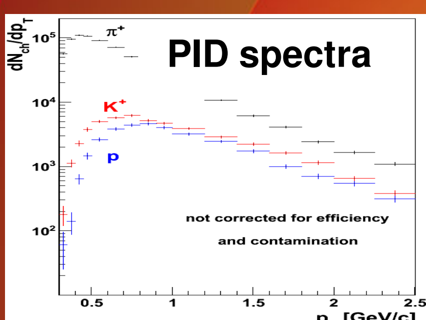
K, Λ, Ω, ...

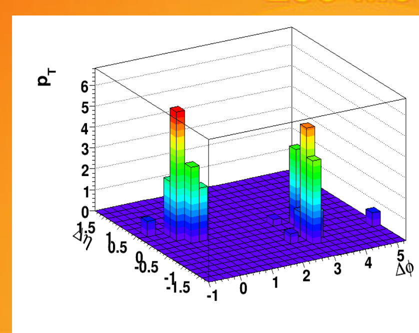
190 MeV

Heavy Quark Potential,
screening

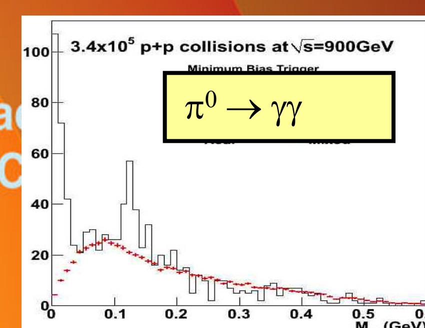
no χ_c

230 MeV





establish conta
perturbative QC



What does it mean “Heavy-Ion Physics” ?

What is ALICE looking for through the Looking Glass

Heavy-Ion Collisions is the tool

that we expect will provide the necessary conditions for the QCD phase transition to QGP to happen.

The physics is the

“physics of hot and dense strongly interacting mattter”

At LHC energies

“high energy density QCD”

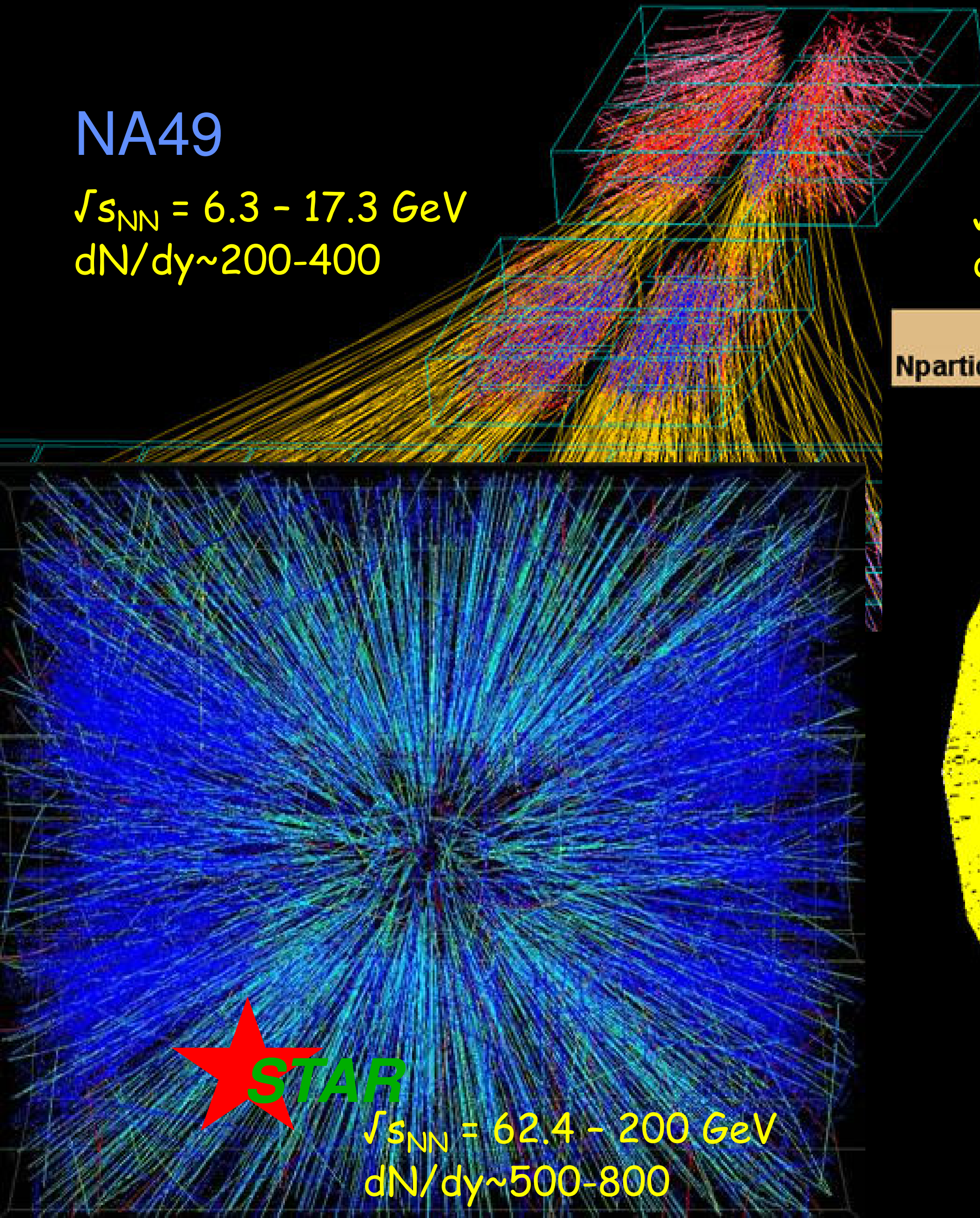
ALICE

Properties of high-multiplicity pp events at LHC energy density?

…with increasing energy tracking challenge..

NA49

$\sqrt{s_{NN}}$ = 6.3 – 17.3 GeV
dN/dy~200-400



$\sqrt{s_{NN}}$ = 62.4 – 200 GeV
dN/dy~500-800

ALICE 'worst case' scenario:

dN_{ch}/dy = 8000

$\sqrt{s_{NN}}$ = 5.5TeV
dN/dy~1500 – 2000 (current estimate)