A new Heavy-Ion Masterclass

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J/ψ Measurement with ALICE

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International Masterclasses

Steering Group Meeting

EMMI

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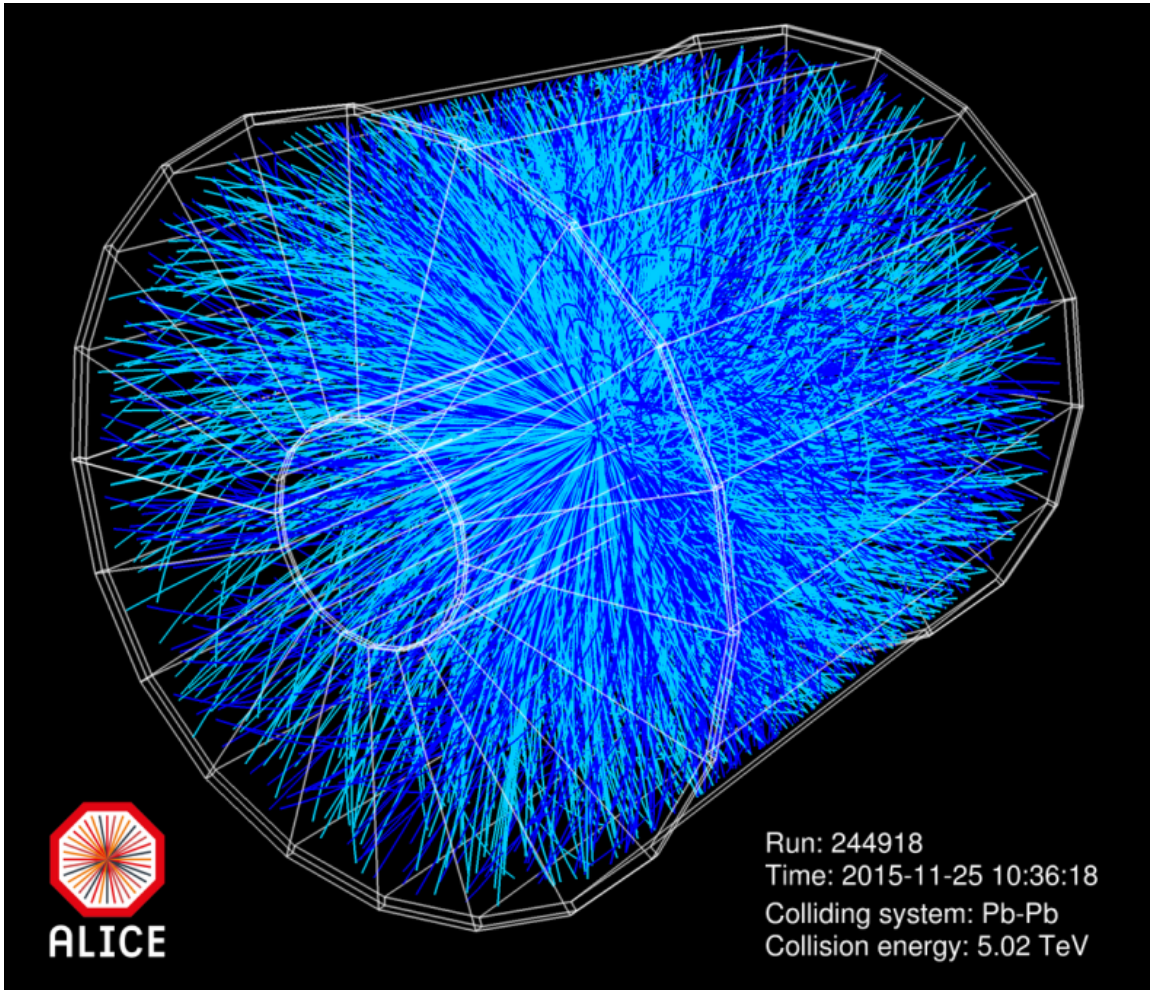
GSI

ALICE

- heavy-ion experiment at the LHC

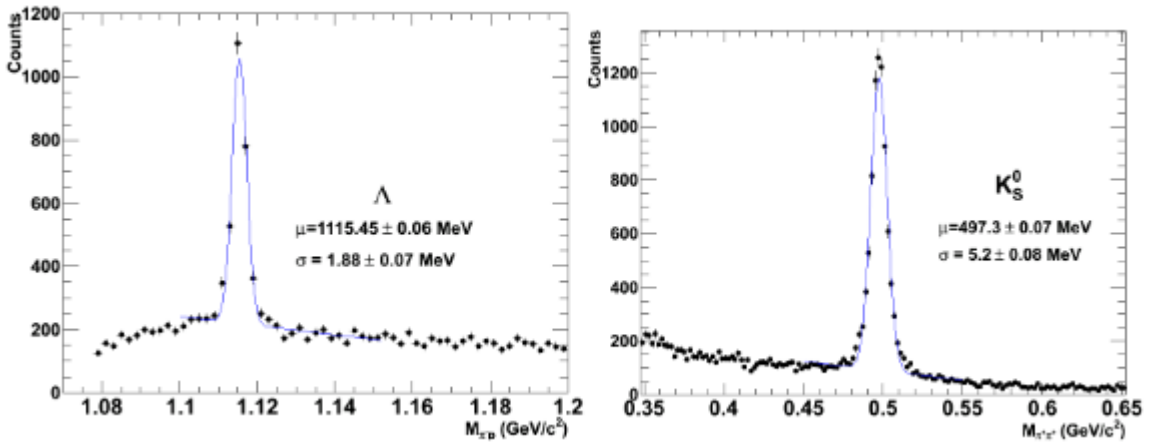
→ investigation of quark-gluon plasma properties



- central Pb-Pb collision with total collision energy above 1 PeV:
  ~3200 primary, charged particle tracks in $|\eta|<0.9$

ALICE Masterclasses

- looking for strange particles in ALICE → Despina Hatzifotiadou
  - is strangeness production different in pp and Pb-Pb collisions due to the presence of a QGP in the latter?

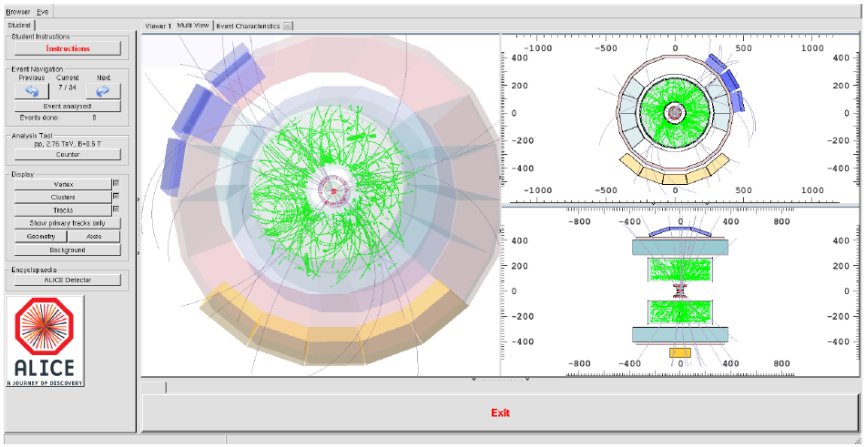


→ not discussed further today

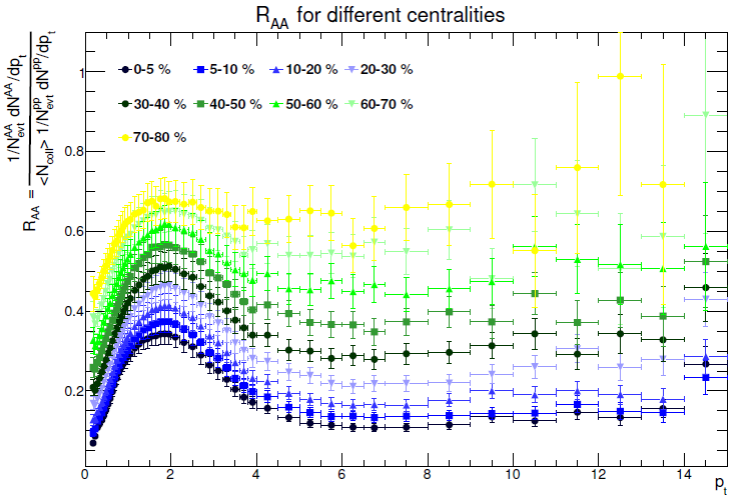
- measurement of the nuclear suppression factor R_{AA} for charged particles
  - can we witness quarks interacting strongly and, thus, loosing energy when propagating through a QGP?
    → current Masterclass workhorse at GSI

Nuclear modification factor R_{AA}

- $R_{AA} = \frac{yield\ (Pb-Pb)}{\langle N_{coll} \rangle\ yield\ (pp)}$
  - ratio of transverse-momentum distributions of charged particles in Pb-Pb and pp collisions, taking into account the collision geometry
  - R_{AA}<1 implies jet suppression in the quark-gluon plasma



- **measurement**
  - necessary concepts: measurement of
    - charged particle momentum
    - collision centrality
  - event-display based visual analysis
    → R_{AA} simply via counting of tracks
  - ROOT based large scale analysis
    → R_{AA} as a function of momentum and collision centrality
    → students discover jet suppression!



R_{AA} measurement: pros & cons

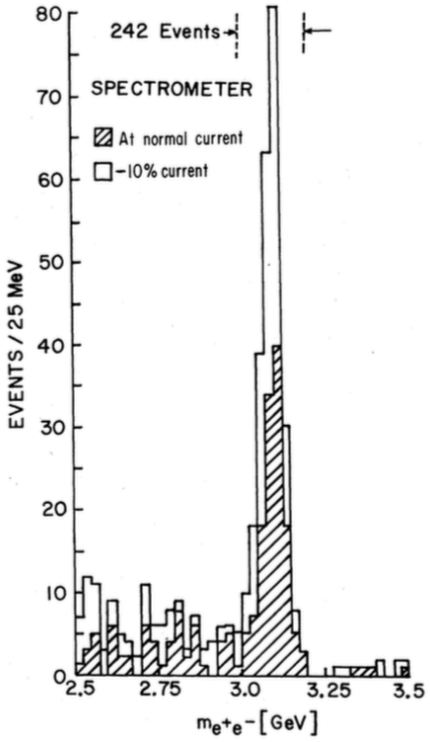
- advantages
  - genuine heavy-ion physics observable
  - doesn't need any difficult concepts (only tracking and centrality)
  - teaches the value of collaborative work
- disadvantages
  - large-scale analysis difficult without programming experience
  - challenging to complete the full measurement in time
  - no use of particle identification techniques
- measures
  - various versions (all work well for their purpose)
    - "full", "copy and paste", "demonstration" version

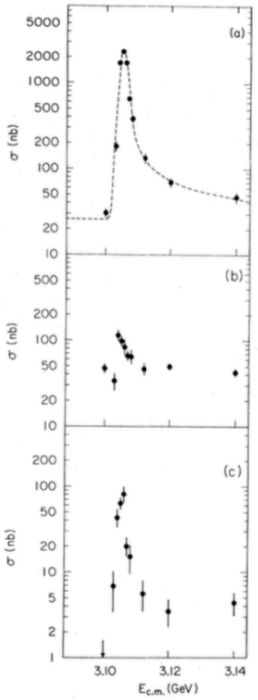
→ development of a new ALICE Masterclass on J/ψ

- main emphasis: particle (electron) identification
- other necessary concepts: decay, invariant mass, combinatorial background
- no programming skills needed

J/ψ measurement with ALICE

- **J/ψ**
  - **bound state of charm quark and antiquark, m ~ 3.1 GeV/c^2**
  - **discovered in 1974 at BNL and SLAC ("November revolution")**
  - **usually reconstructed via e^+e^- or $\mu^+\mu^-$ decay (BR ~ 6%)**

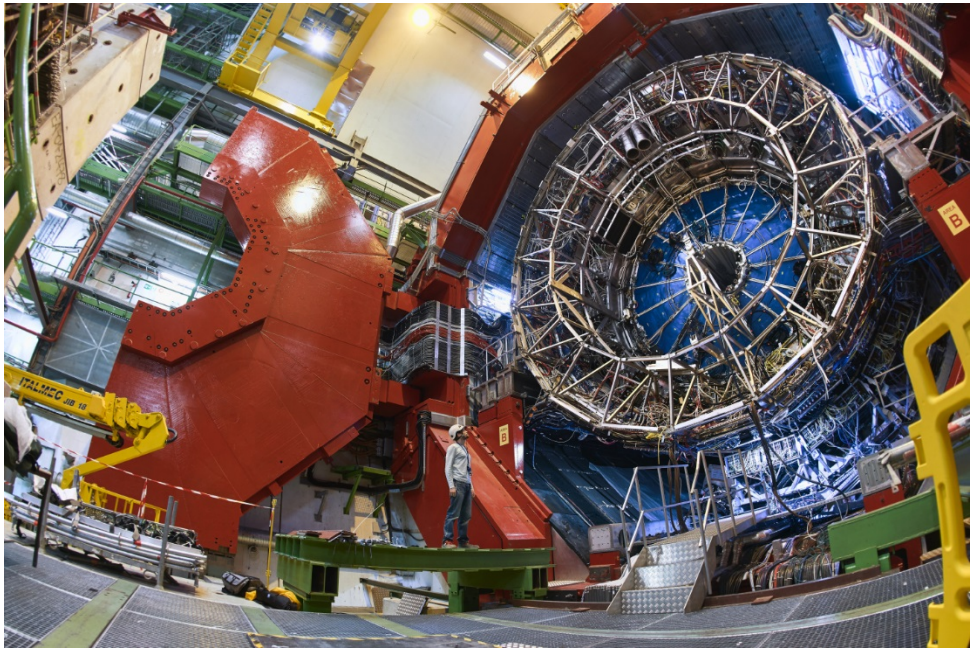


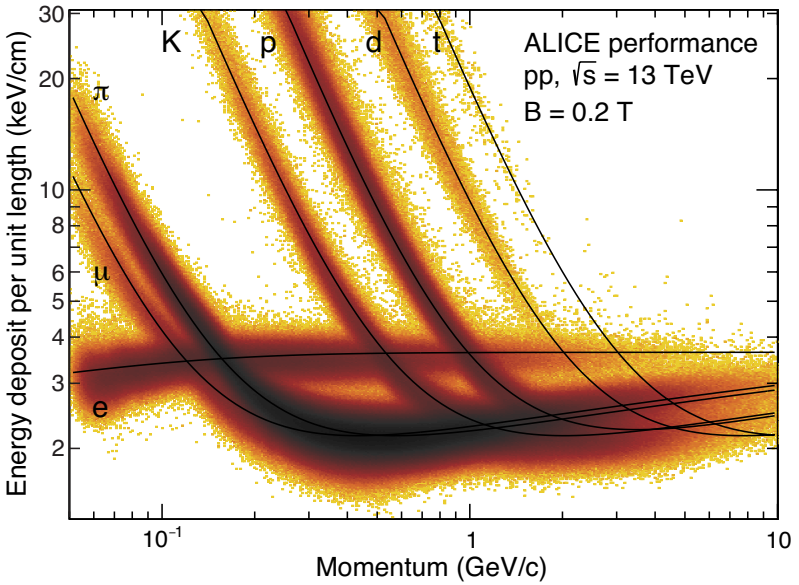


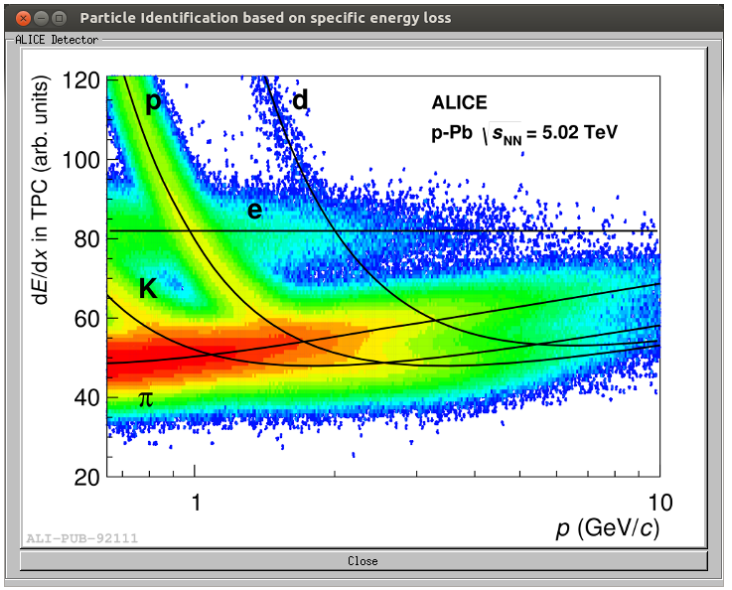
Nobel prize for S. Ting and B. Richter (1976)
Rev. Mod. Phys. 49 (1977) 235 & 251

- **in ALICE**
  - **J/ψ measured in dimuon and dielectron channel**
  - **electron identification via specific energy loss dE/dx measured in the ALICE Time Projection Chamber (calorimetry and time-of-flight ignored for simplicity)**
  - **Masterclass package mainly developed by Steffen Weber (WWU Münster)**

ALICE: dE/dx in the TPC



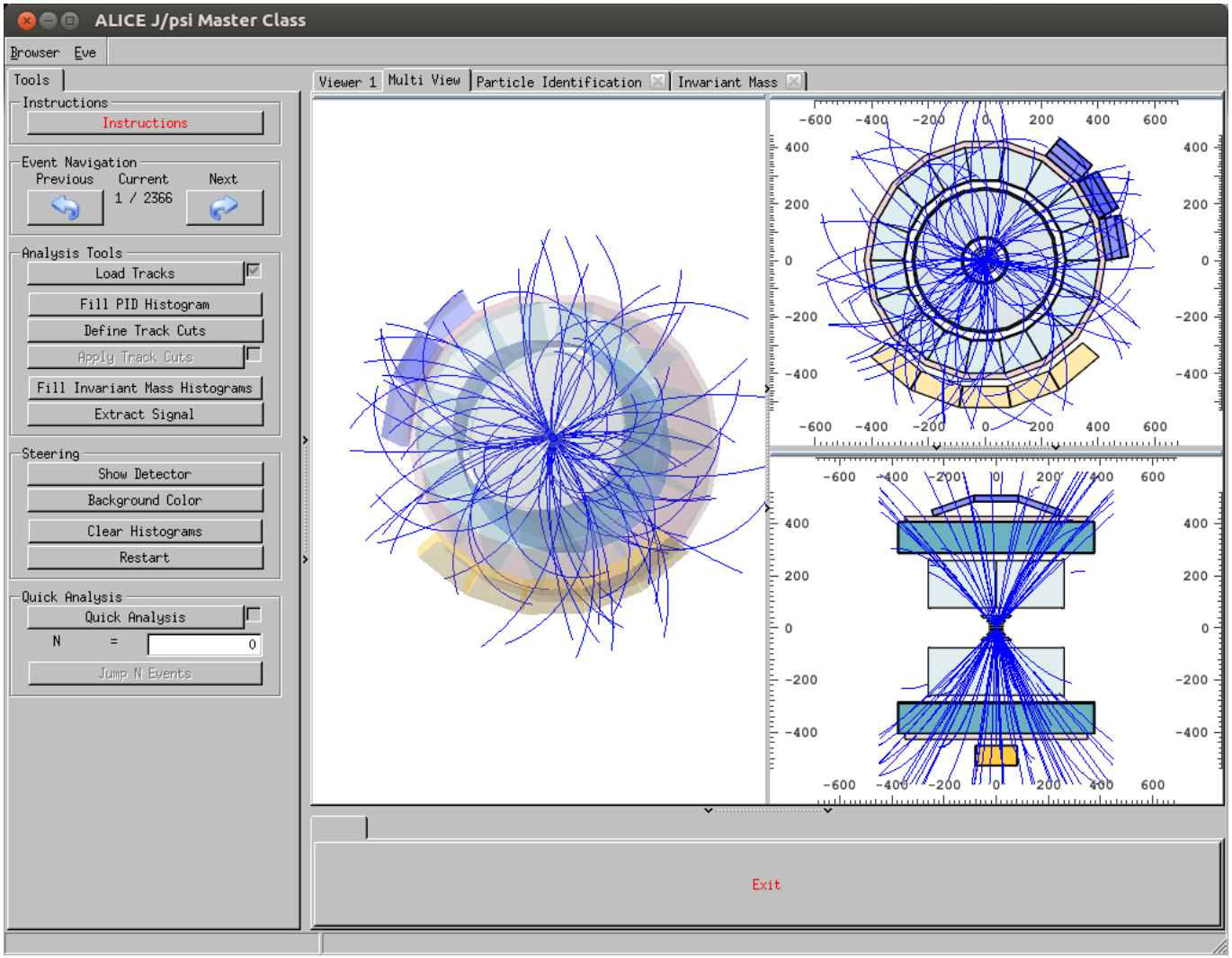




- dE/dx performance as published by the PDG vs. Masterclass version

J/ψ Masterclass: the GUI

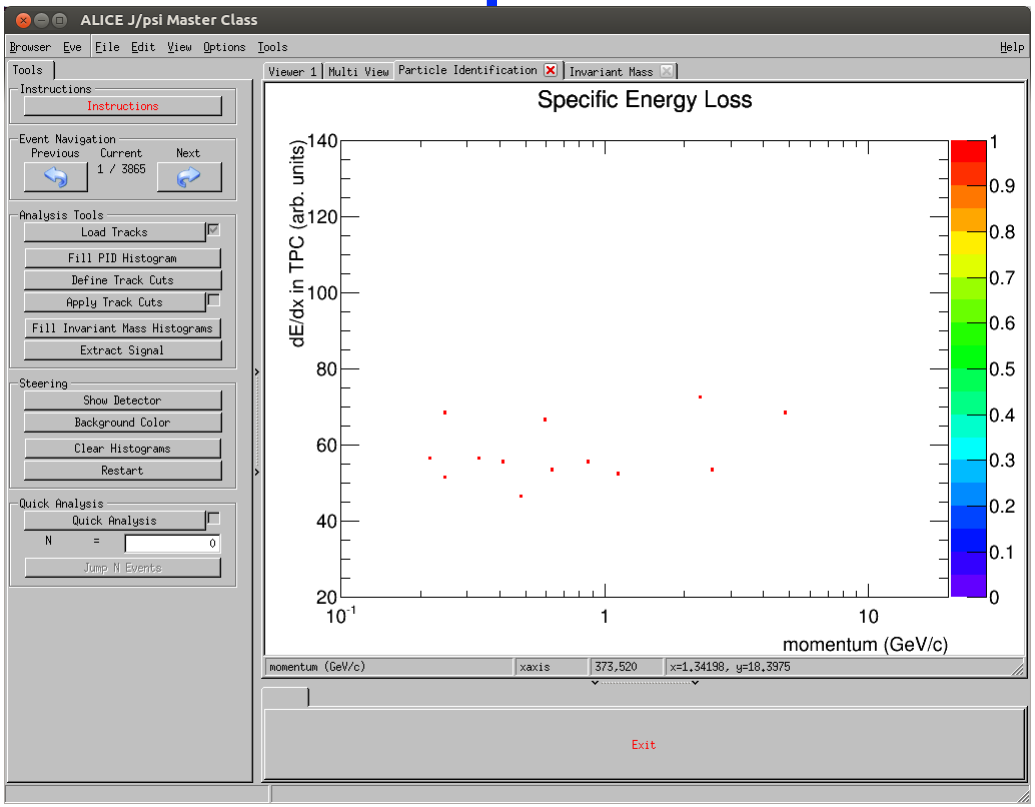
- inspired from R_{AA} Masterclass



- workflow
  - load charged-particle tracks
  - fill PID histogram
  - define PID selection
  - fill inv. mass histograms
  - extract J/ψ yield

J/ψ Masterclass: PID in pp

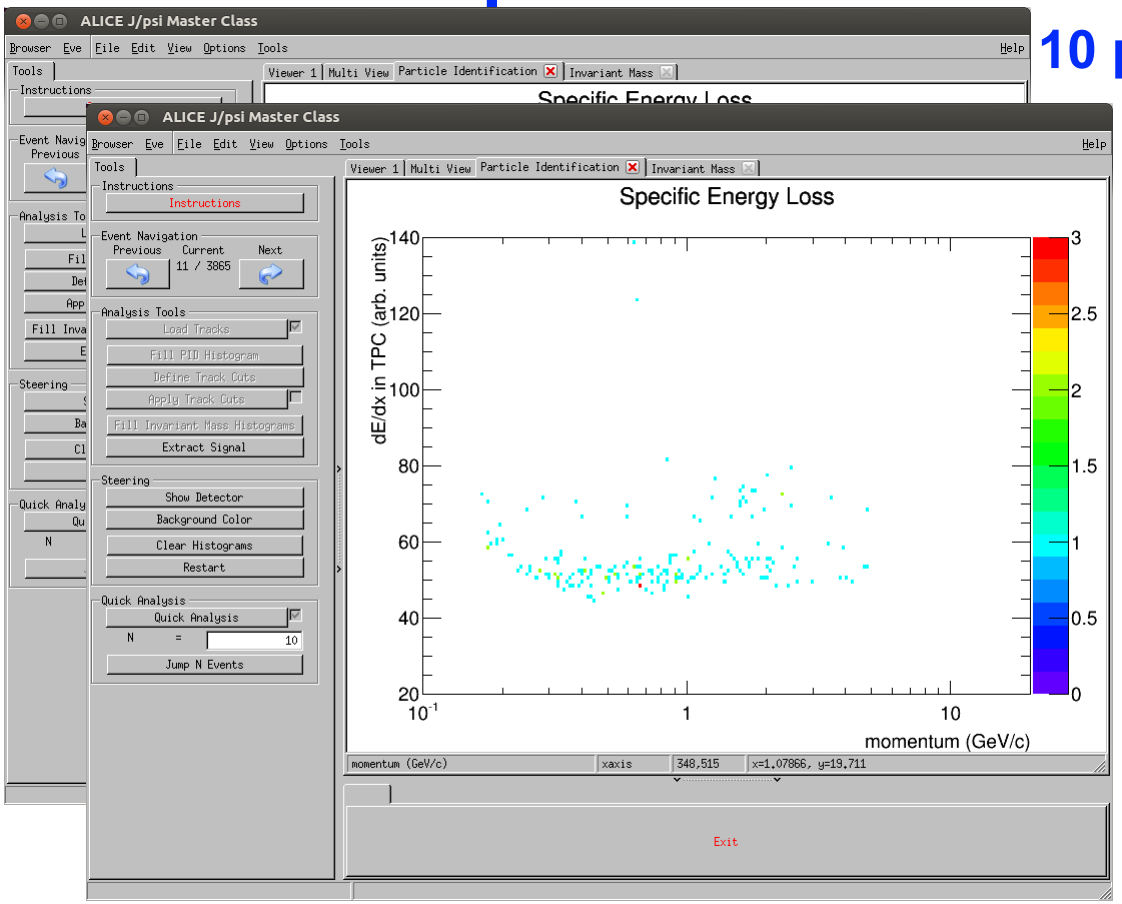
- with a bit of patience the electrons emerge



1 pp collision

J/ψ Masterclass: PID in pp

- with a bit of patience the electrons emerge

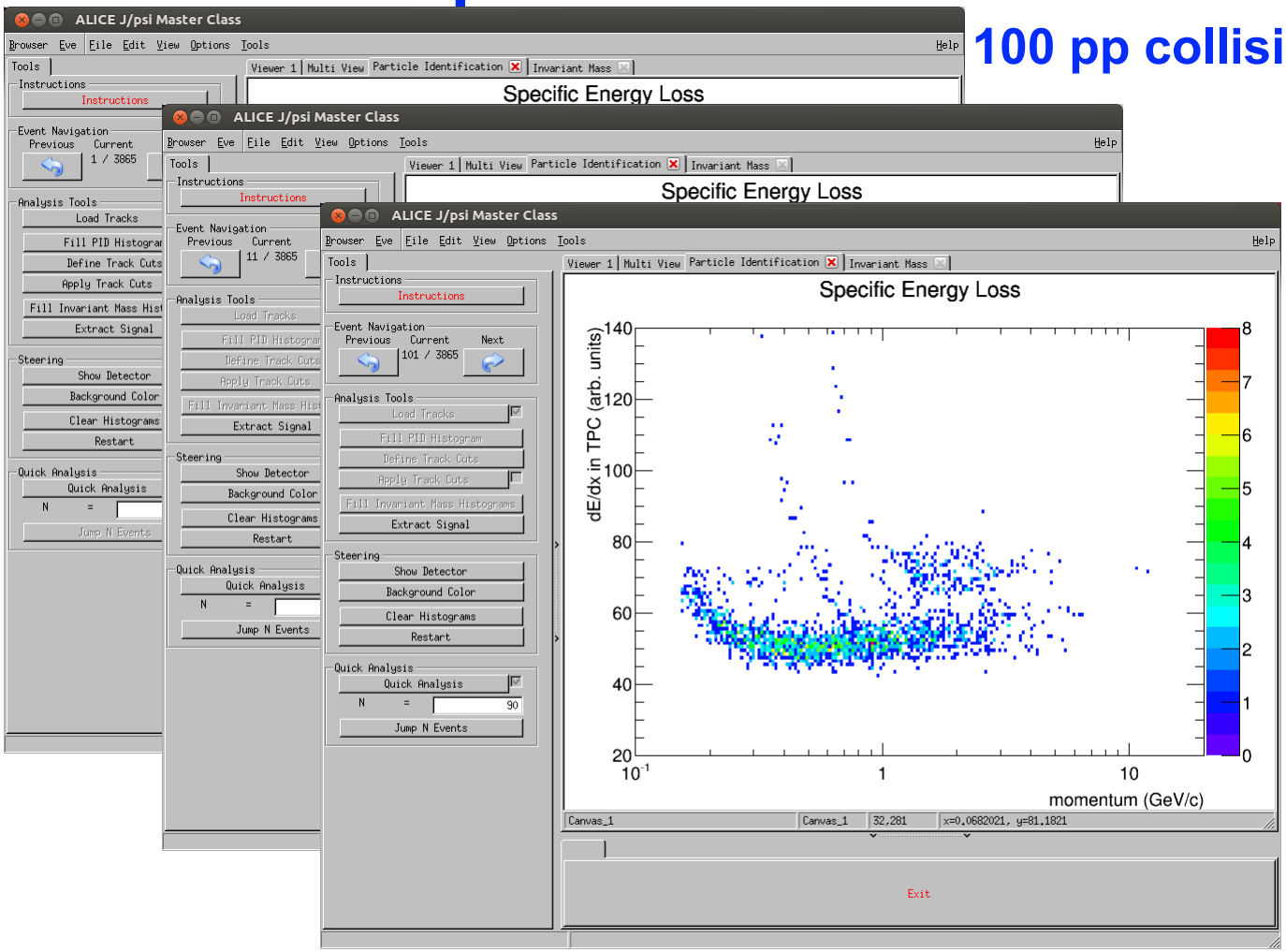


10 pp collisions

J/ψ Masterclass: PID in pp

- with a bit of patience the electrons emerge

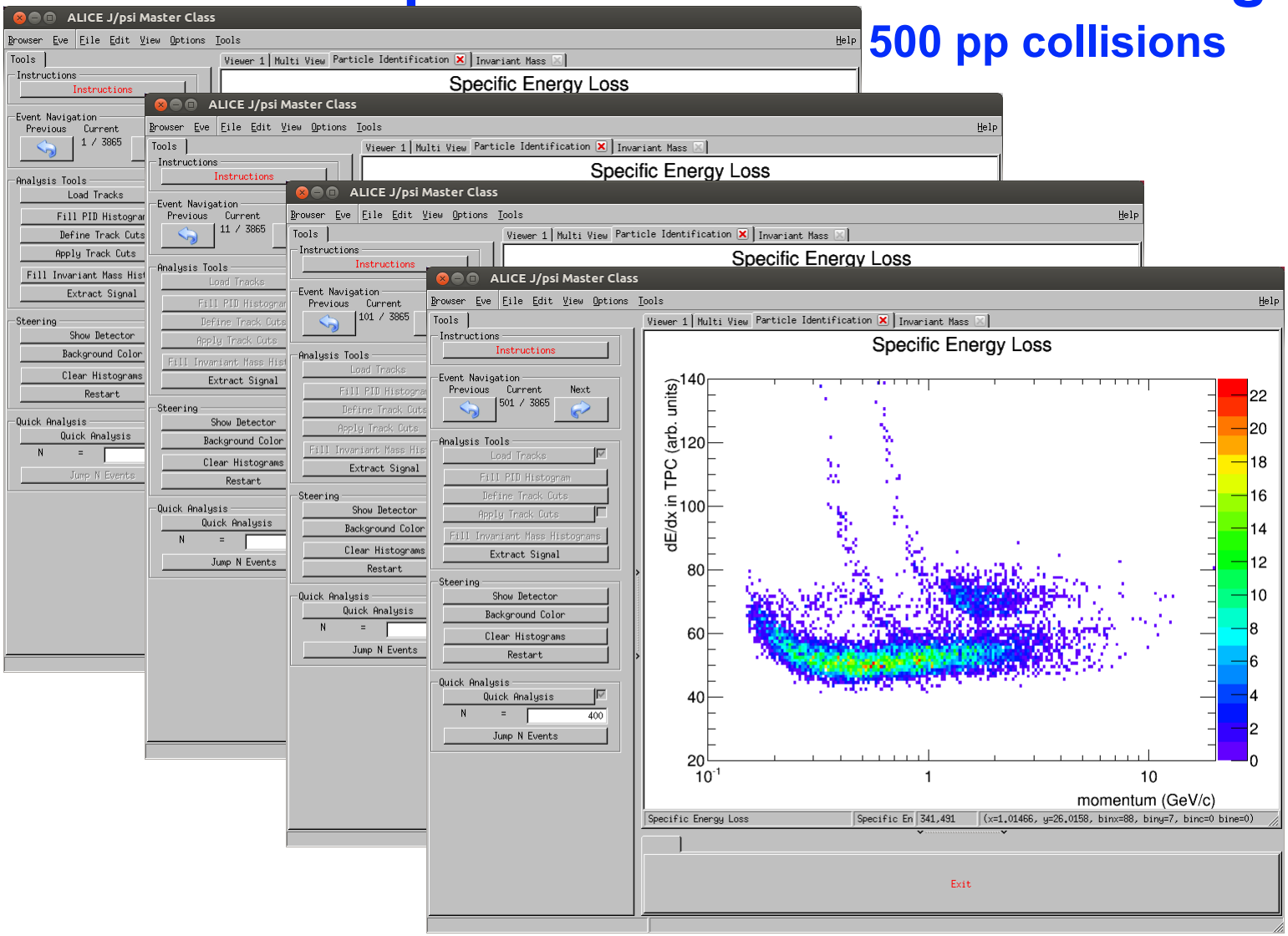
100 pp collisions



J/ψ Masterclass: PID in pp

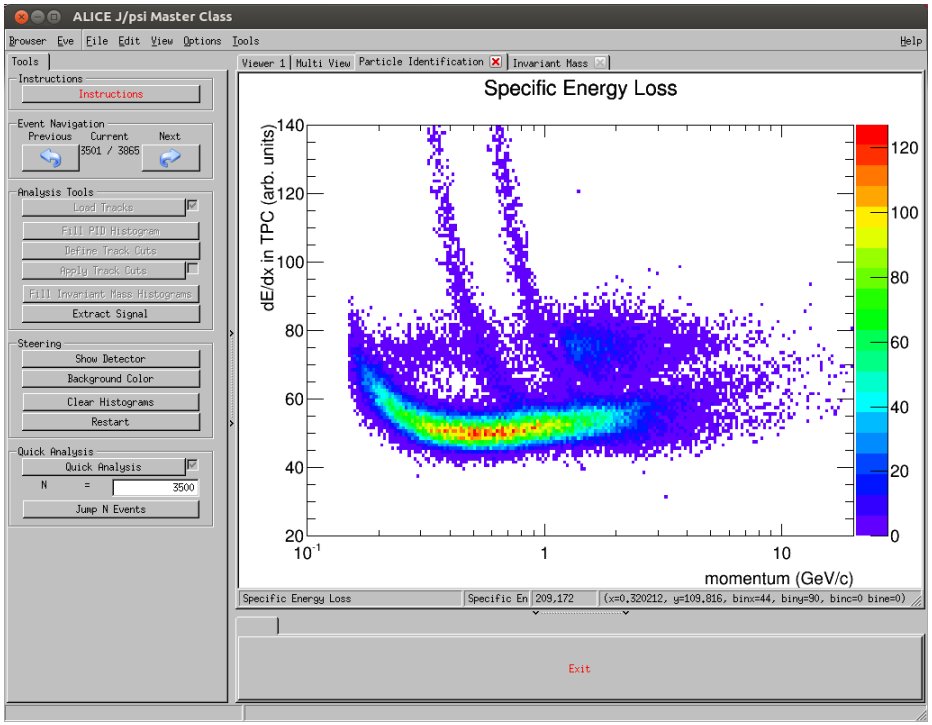
- with a bit of patience the electrons emerge

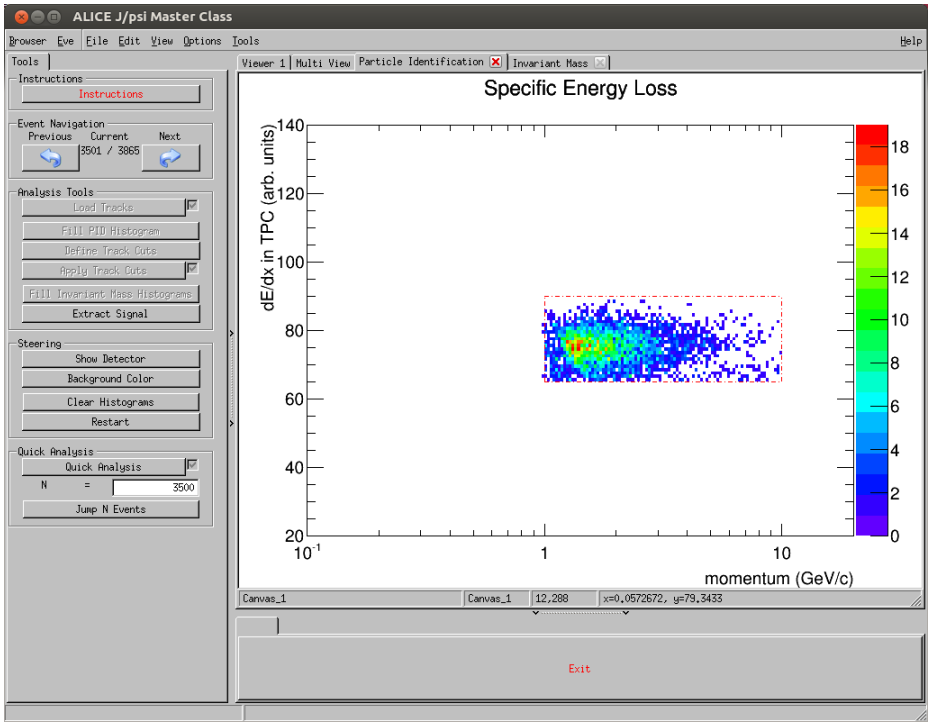
500 pp collisions



J/ψ Masterclass: PID in pp

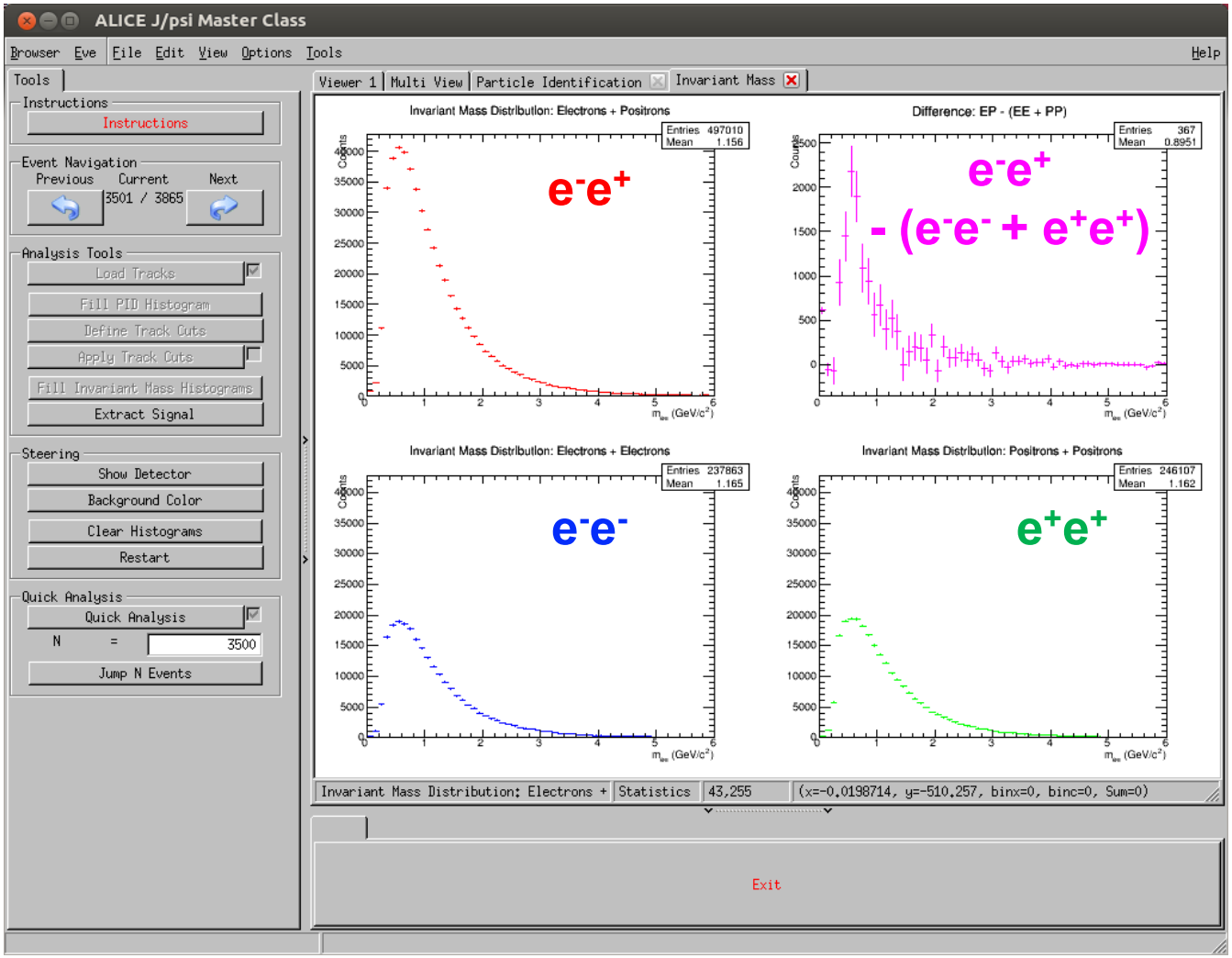
- with a bit of patience the electrons emerge and can be selected





J/ψ Masterclass: m_{ee} in pp

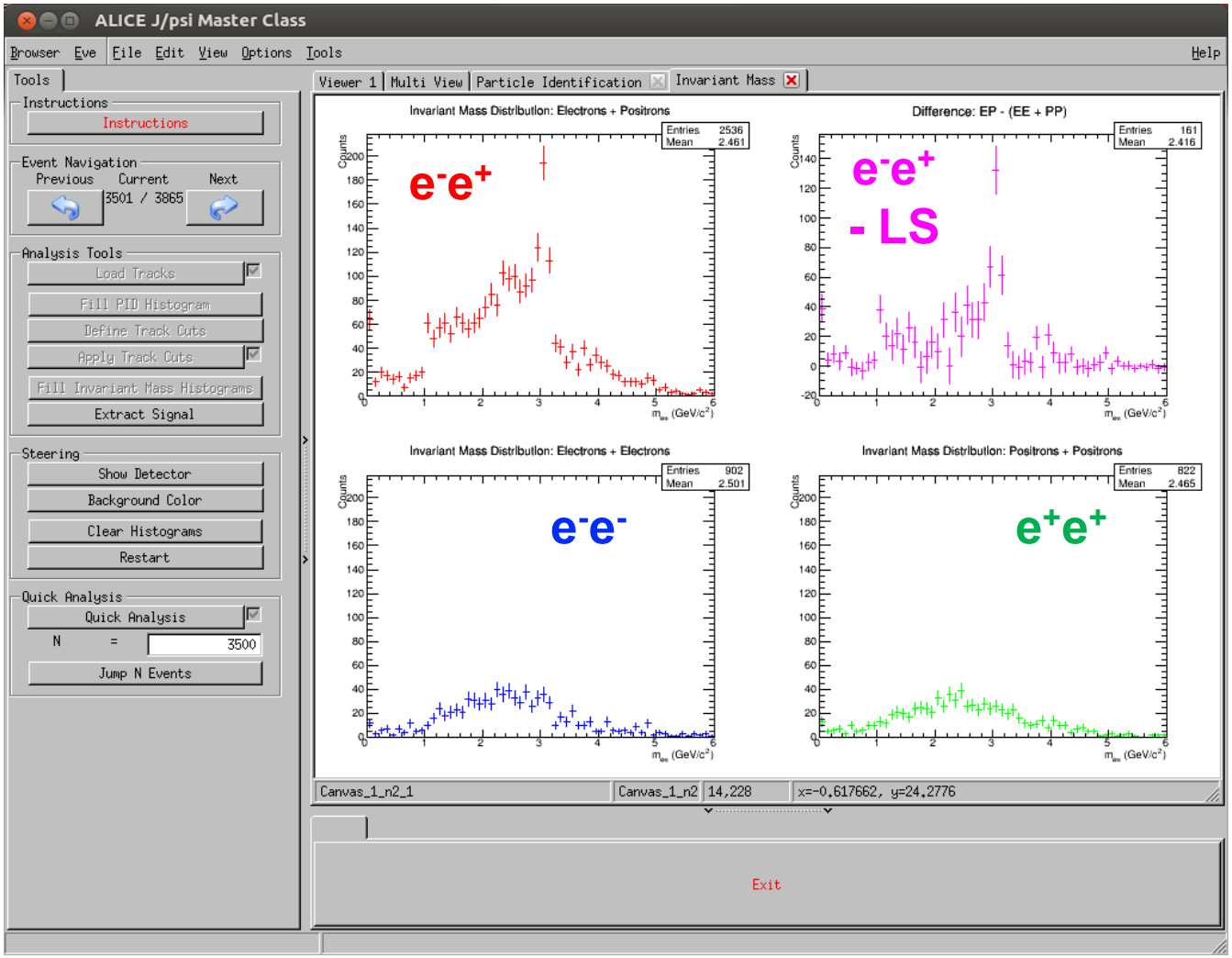
- without electron identification



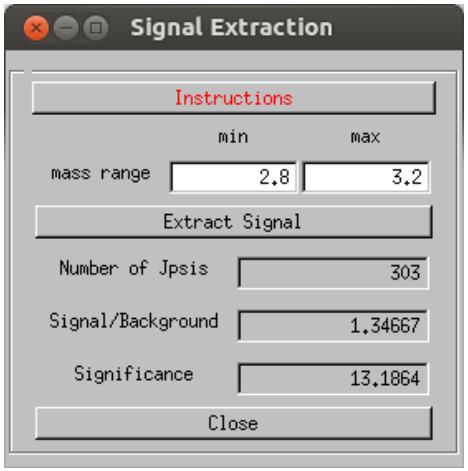
- observations
  - no signal visible on top of combinatorial background (CB)
  - like-sign pairs: a good (not perfect) estimate for CB

J/ψ Masterclass: m_{ee} in pp

- with electron identification

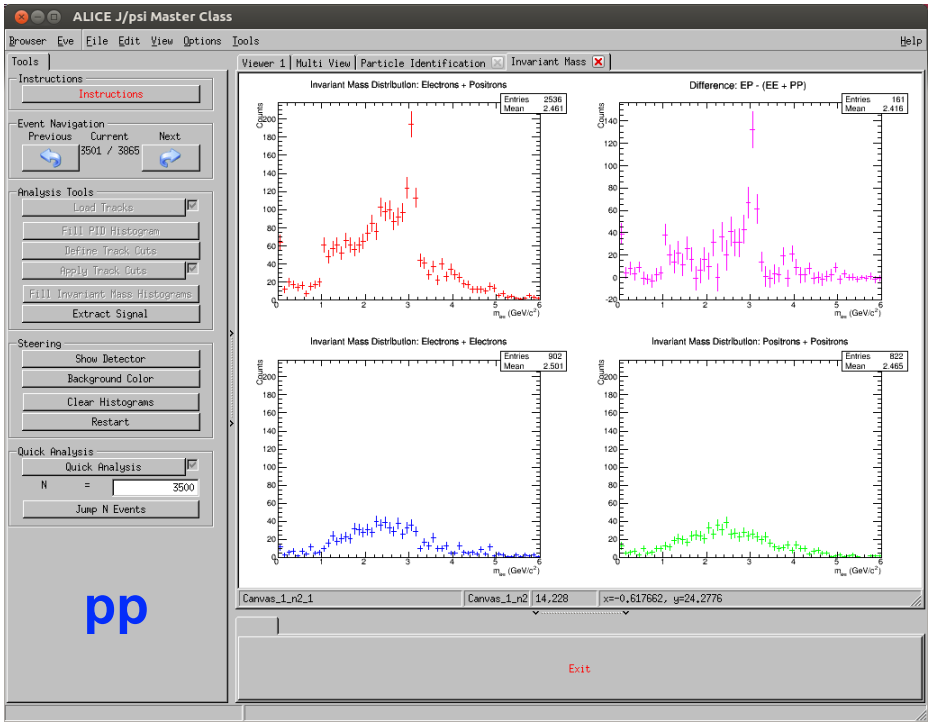


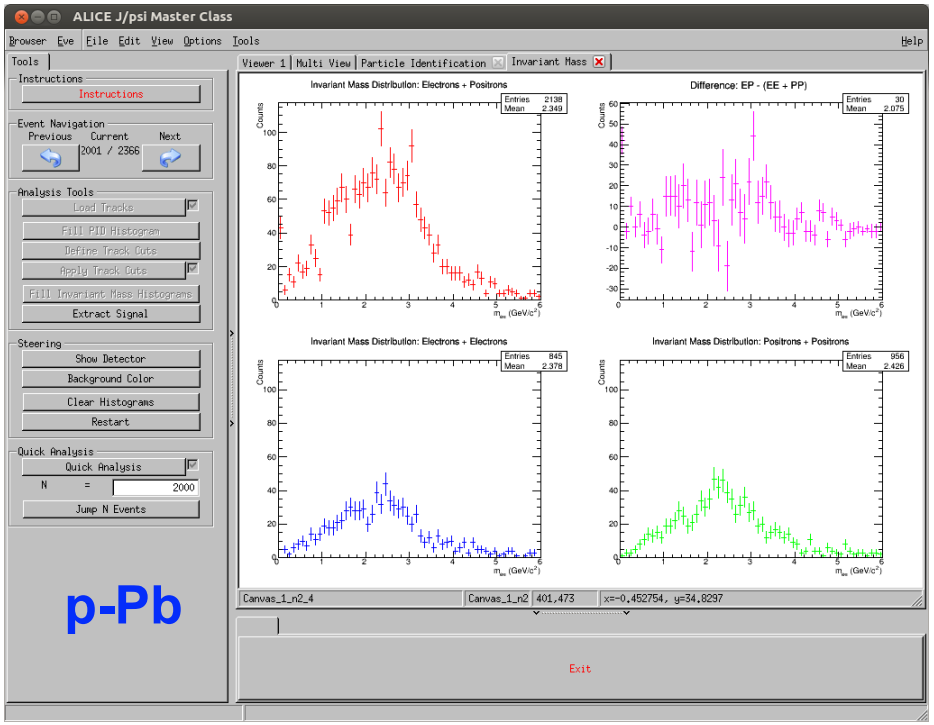
- observations
  - signal emerges and can be quantified
    - yield
    - S/B
    - significance



J/ψ Masterclass: pp vs. p-Pb

- combinatorial background grows with multiplicity

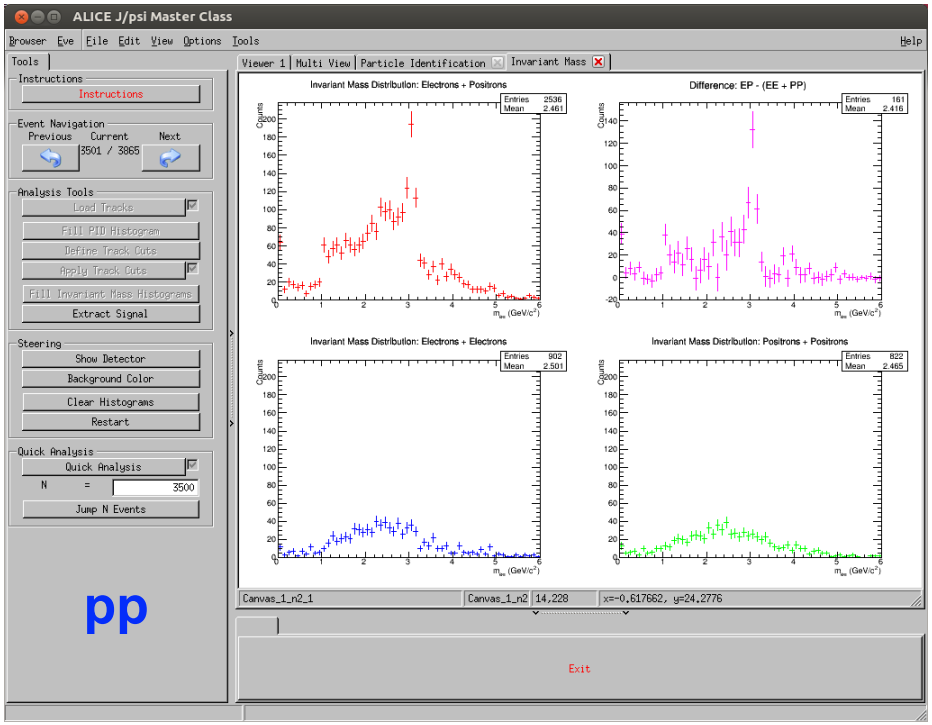


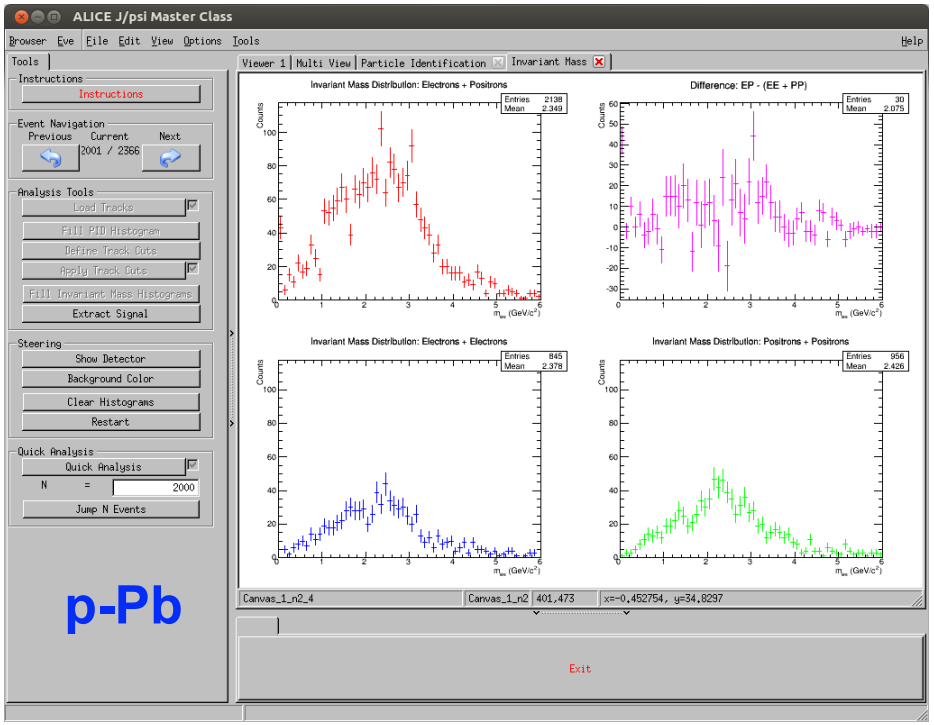


- signal extraction much more difficult
- no good idea yet on how to add Pb-Pb collisions

J/ψ Masterclass: pp vs. p-Pb

- combinatorial background grows with multiplicity





- signal extraction much more difficult
- going to Pb-Pb collisions to make connection with heavy-ion physics
  - being discussed
  - not with signal extraction
  - not with large-scale analysis a la R_{AA} measurement

J/ψ Masterclass: next steps

- signal extraction part is ready

→ will be tested in a pilot run on June 7, 2019

  - physics class from Eleonorenschule, Darmstadt
  - 6 out of 22 students have experience with the ALICE R_{AA} Masterclass!

- QGP connection is being explored …

- want to try (manual available in German only for the moment)?

  → https://github.com/zwound40/JpsiMasterclass.git