Instructions for tutors / moderators

1. **Name of the measurement:** Measurement of the nuclear modification factor R_{AA} with ALICE
2. **Authors:** Ralf Averbeck, Friederike Bock, Benjamin Doenigus, Yiota Foka, Philipp Luettig, Silvia Masciocchi, Kilian Schwarz, Reinhard Simon, Jochen Thaeder
3. **Supported languages:** English
4. **Short description:**
   - students use the ALICE event display to familiarize themselves with transverse momentum and centrality measurements and to determine the mean multiplicity of primary charged particles in pp and Pb-Pb collisions
   - students calculate the nuclear modification factor R_{AA} 'by hand' based on their results from the visual analysis
   - based on a simple example macro students write/edit code to do a ROOT based large scale analysis
   - students measure R_{AA} and R_{CP} as a function of the charged particle's transverse momentum p_T and for various Pb-Pb collision centralities
5. **Prerequisites (Browser, Software ...:)**
   - ROOT as available for download from `http://root.cern.ch/`
   - the software package of the measurement itself, including all datasets, can be downloaded from `http://www-alice.gsi.de/masterclass/`
6. **Datasets:**
   - all data are from real ALICE events measured at 2.76 TeV
   - visual analysis: 10 datasets, each including 1 pp event without magnetic field, 30 pp events with nominal magnetic field, and three Pb-Pb events with different centralities (peripheral, semi-central, and central)
   - large scale analysis: ≈120000 minimum bias Pb-Pb events
7. **Proposed outline for the day:**
   - 09:00 - 09:30: arrival and welcome
   - 09:30 - 11:30: lectures (two times 45 minutes plus questions/discussion)
     - introduction to particle physics
     - introduction to quark-gluon plasma physics and ALICE
   - 11:30 - 12:00: visit of facilities/labs
   - 12:00 - 13:00: lunch
   - 13:00 - 15:30: introduction to the measurement and the measurement itself
   - 15:30 - 16:00: preparation for the video conference
   - 16:00 - 16:30: video conference
   - 16:30 - 17:00: evaluation and summing up

8. **Students' tasks:**

   - students work in groups of two
   - each group visually analyzes a few events and calculates the corresponding nuclear modification factor R_{AA} for various centralities
   - with the help of the tutors the students' results are averaged
   - in a large scale analysis the students determine R_{AA} or the similar quantity R_{CP} as function of the charged particles' transverse momentum p_T in one of nine Pb-Pb centrality classes
   - with the help of the tutors the measurements by all student groups are combined in one plot (a combination of the results from the student groups is not required).
   - the students discuss how their measurement can be interpreted. They prepare (with tutor help) a short common presentation for the video conference and they collect questions they would like to ask during this conference.

9. **How they do it (step by step):**

   - a detailed step by step description of the measuerement as well as a brief introduction into the relevant physics can be found on the web page for this measurement: `http://www-alice.gsi.de/masterclass/`
   - during the first part of the measurement (visual analysis) each group analyzes one of the ten available data sets
   - tutors explain the analysis GUI on screen to the students
   - with the GUI the students count primary charged particle tracks in the 30 pp events they have in their data set
   - after the analysis of 30 pp events the students read off the mean charged particle multiplicity from the GUI
   - the results from all student groups are collected by the tutors (on the black board) and a final average multiplicity is calculated
   - the students use the GUI to count charged particle tracks in the three Pb-Pb events with different centralities provided in each data set
   - from the mean multiplicity in pp collisions, the number of charged particle tracks in each Pb-Pb collisions, the relative efficiency in pp and Pb-Pb collisions (provided in the student handout), and the equivalent number of binary collisions N_{coll} (explained and provided in the handout as well) each group of students calculates the nuclear modification factor R_{AA} for their three Pb-Pb collisions.
   - the tutors collect the measurements from the different groups on the blackboard and average R_{AA} values are calculated. The meaning of those are discussed with the help of the tutors.
   - in the second part of the measurement (large scale analysis) all students analyze the same dataset to determine R_{AA} in a much more differential way which is not doable with the limited statistics available in the visual analysis. The goal is to measure R_{AA} as a function of the charged particle transverse momentum p_T in various Pb-Pb centrality classes.
   - the tutors show the students on screen how to open a text editor and walks them through the first analysis macro they are working on.
   - each group of students works on the measurement of R_{AA} in one of nine Pb-Pb centrality class.
   - following the examples provided in the first analysis macro the students write (via cut & paste) code to create a transverse momentum histogram for a given Pb-Pb centrality, fill it in an event loop, plot it with proper axis labels and figure legend, and write it to an output file. The latter serves as input for the second analysis macro the students work on.
   - the tutors walk the students through the second analysis macro in which, as an example, R_{CP} is calculated for a given centrality class.
   - each group of students edits this macro (again mostly cut & paste) to calculate either R_{CP} or R_{AA} in one of 9 Pb-Pb centrality classes. The reference p_T distribution from pp collisions is given to the students. The students produce properly labeled plots to be collected by the tutors.
   - the students' results are discussed, questions are collected, and with the help of the tutors a short presentation is prepared for the video conference.

10. **Gaining and presentation of results (plot, table, histogram ...:**

    - during the large scale analysis the student groups produce the plots with their results automatically.
    - tutors should collect these plots. Alternatively, the tutors can themselves go through the macros of the large scale analysis in parallel with the students and prepare a complete set of plots. It is actually highly encouraged that tutors do that already before the measurement. On request tutors can receive from us ready-to-run macros for the large scale analysis.

11. **What can be discussed (proposed questions):**

    - visual analysis: where do the clusters come from that are not associated with a reconstructed track?
    - visual analysis: did you observe more positively or negatively charged particle tracks? Why is this so?
    - visual analysis: why do most of the produced particles have low momenta?
    - what is a reconstruction efficiency and why is it important?
    - what is the difference between R_{CP} and R_{AA}?
    - why is $R_{AA} < 1$ consistent with energy loss in a quark-gluon plasma?

12. **<u>For Moderators:</u> Details on combination:**

    - moderators should agree with the institutions before the video conference on who presents what. Each institution should report a measurement not reported by anybody else. Depending on the number of participating institutions the moderators can ask for reports on the measurements of R_{CP} or R_{AA} in different centrality classes.
    - once all institutions have reported their results the moderator discusses the complete picture and puts it into context.
    - tutors from the different institutions could contribute to the video conference with additional short presentations, e.g. what other R_{AA} measurements exist from other experiments, how does R_{AA} look for identified particles, with which other observables can one look the difference between pp and Pb-Pb collisions at the LHC and elsewhere.

13. **Supporting material for students (cheat sheets ...):**

    - a hand out for students, tutors, and moderators is available at the web page for this measurement: `http://www-alice.gsi.de/masterclass/`

14. **Supporting material in general (talks, films, animations, documentations ...:**

    - in addition to the hand out mentioned above, we will provide further material at the web page. In particular, example introductory lectures as well as example presentations to put the students' results into context will be available there.