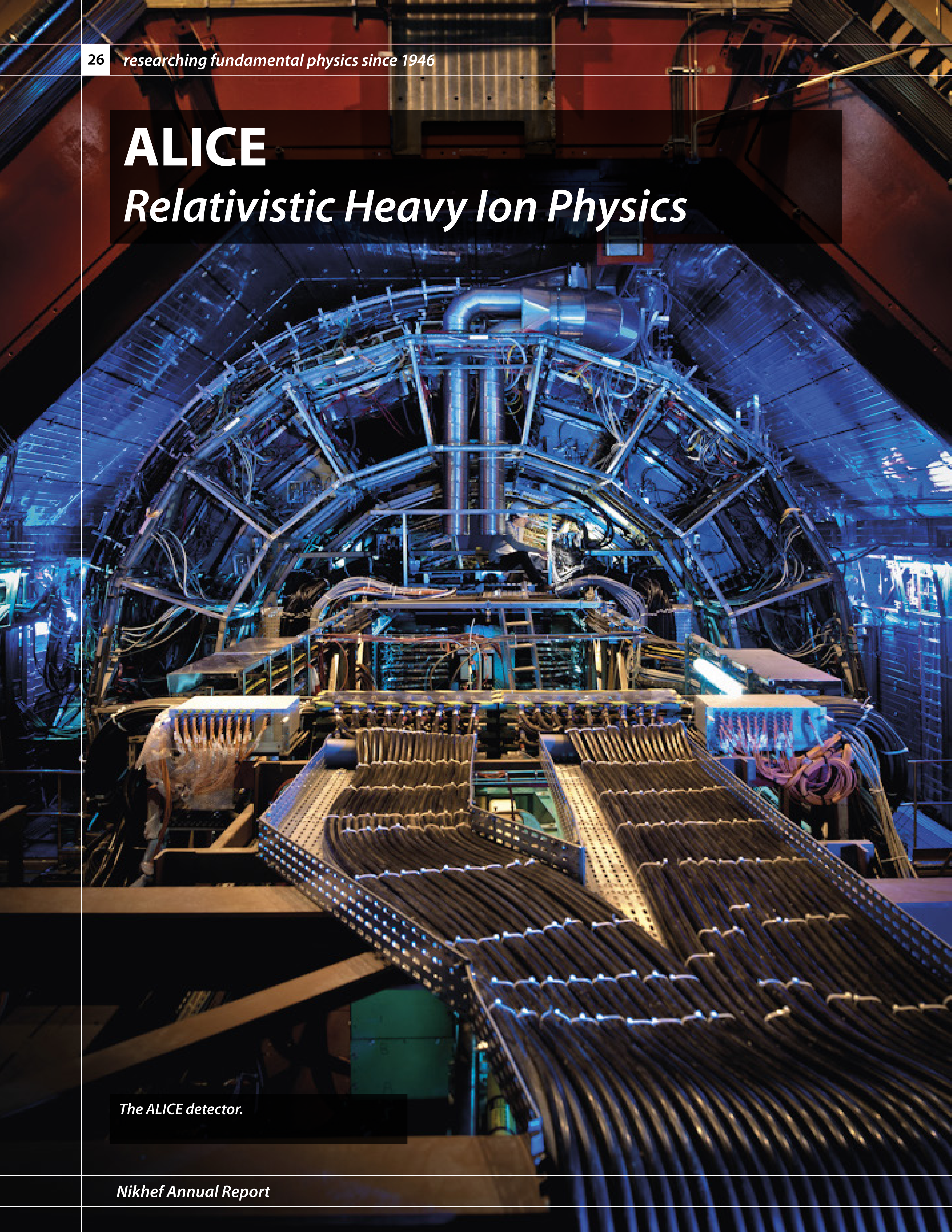
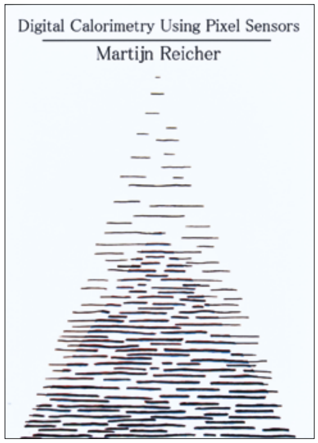
ALICE
Relativistic Heavy Ion Physics

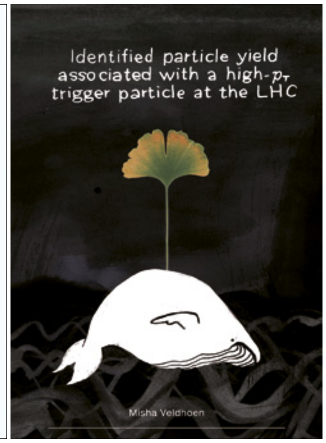


The ALICE detector.

You Zhou
6 January 2016



Martijn Reicher
7 March 2016



Misha Veldhoen
14 March 2016

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6 April 2016

Management
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In the Standard Model of particle physics Quantum Chromodynamics (QCD) predicts, in case the density and/or temperature exceed a critical value, a phase transition from colourless hadronic matter to the so-called Quark Gluon Plasma (QGP), a plasma where the quark and gluon degrees of freedom are not anymore confined. The main goal of the ALICE experiment is to determine the properties of this newly formed hot and dense matter. Furthermore, ALICE is well suited for a precision test of QCD at central and forward rapidity and down to the ~ 0 p_T regime in pp, p–Pb and Pb–Pb collision systems.

Higher flow harmonics in Pb–Pb collisions

In a semi-central Pb–Pb collision (*i.e.* collisions with a large impact parameter), the initial spatial anisotropy of the overlap region between the two nuclei was conjectured to be smooth and almond shaped. The aforementioned conjecture went under scrutiny in the past few years, when experimental measurements and hydrodynamic calculations have pointed out that such region must have an irregular shape originating from the initial random distribution of the gluons and nucleons in the nuclei, which fluctuates from one event to the next.

These event-by-event fluctuations in the initial spatial anisotropy can be investigated by studying the azimuthal correlations between final-state particles relative to the symmetry plane of the system and quantified by a Fourier series of the azimuthal distribution of particle production relative to the aforementioned symmetry plane.

The elliptic-flow coefficient v_2, representing the second harmonic of the Fourier expansion, has been one of the main focus of the heavy-ion community in the last few years. Elliptic-flow measurements, both at RHIC and LHC colliders, contributed to the revelation that the Quark-Gluon-Plasma (QGP) generated in heavy-ion collisions behaves as an almost perfect liquid. The ratio of shear viscosity to entropy density (η), which is a measure of its fluidity, is very close to the lower bound of $\hbar/4\pi k_B$ conjectured by the anti-de-Sitter/conformal field theory (AdS/CFT) correspondence. The higher-order harmonics $v_{n, n>2}$, representing modulations to smaller spatial scales, are more sensitive to the value of ηS of the QGP. In addition, since they mainly originate from the initial state and its fluctuations, $v_{n, n>2}$ are a unique tool to constrain them. Furthermore, if studied for different particle species, they can also probe the effect of the dissipative, late-stage hadronic re-scattering on the flow coefficients.

Recently, the ALICE collaboration has used Pb–Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV to measure the elliptic (v_2), triangular (v_3), quadrangular (v_4) and pentagonal (v_5) flow coefficients of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ for different centrality intervals. For central collisions (0–1%), in which the initial spatial anisotropy is predominantly driven by the initial-state fluctuations, one observes significant non-zero values for all harmonics and particle species (see Fig. 1 for pions).

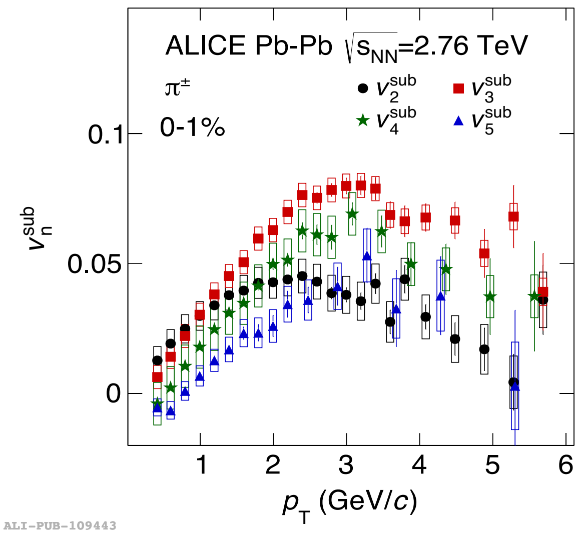


Figure 1. The evolution of the p_T–differential v_n^{sub} for $\pi^{\pm}$ in 0–1% Pb–Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV. The superscript sub stress the removal of non-flow contributions (*i.e.* contributions from jets, resonances and quantum statistics correlations).

The v_3 and v_3 coefficients become progressively dominant with increasing transverse momentum, while even v_5 for p_T > 4 GeV/c is comparable to v_2. For more peripheral collisions, v_2 is the dominant flow harmonic. Higher harmonics also have significant nonzero values with a mild dependence on centrality.

While these observations confirm that v_2 is driven mainly by the anisotropy in the collision geometry, the higher harmonics are mainly describing the initial-state fluctuations. Furthermore, comparison with models highlighted the importance of the late hadronic rescattering stage to the development of the observed mass ordering at low values of p_T and of coalescence as a particle production mechanism for the particle type grouping at intermediate values of p_T for all harmonics.

Silicon tracker upgrade

ALICE completed the installation of current detectors during the first long LHC shutdown (LS1) with the aim to accumulate 1 nb^{-1} of Pb–Pb collisions during Run-2 corresponding to about 10 times the Run-1 integrated luminosity. However, to fully exploit the physics opportunities and challenges of LHC Runs 3 and 4, the collaboration is preparing a major upgrade of its apparatus, planned to take place during LS2, in the years 2018–2019. At present, the ALICE Time Projection Chamber (TPC) readout rate is about 0.5 kHz for Pb–Pb collisions. After the upgrade the TPC will be able to record all Pb–Pb interactions at a rate of ~50 kHz. In addition a new, high-resolution, low-material budget Inner Tracking System (ITS) will improve the tracking precision significantly (see Fig. 2).

These new detectors in combination with upgraded data acquisition, will allow ALICE collecting about $10 nb^{-1} Pb–Pb minimum-bias interactions in the period 2019–2021. This sample represents an increase by a factor of one hundred with respect to the Run-2 collected statistics.

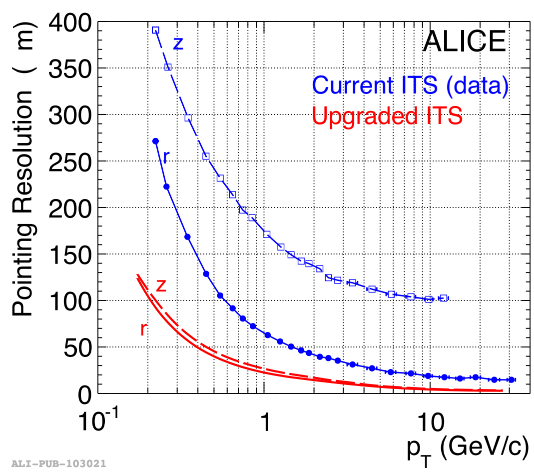


Figure 2. Comparison of the r–φ and z resolutions between the current ITS (blue) and the upgraded ITS (red).

The Nikhef ALICE group holds a major role in the upgrade of the ITS detector. The group had an important role in studying the physics performances of the ungraded detector for D and B mesons studies and, through simulations of the geometry of the upgraded detector, is contributing to the development of the new alignments tools that will be used during commissioning phase. Furthermore, the Nikhef group is responsible for the read-out board, which controls the front-end pixel modules and sends the pixel data to the data acquisition system. This board will also integrate the power regulators for the pixel modules. Since the read-out board will be located at a few meters from the interaction point it will be designed for full compatibility with the magnetic field and the radiation environment. The main task of our group during the production of the ITS will be the assembly staves from individual pixel modules. The assembly involves many steps. Each module will be tested at each step during the assembly procedure.

During 2016 the tools required to test and manipulate the modules were successfully developed (see Fig. 3). Our group will distribute these tools and the testing software among the stave assembly sites.

Outlook

The highlights presented here are a selected summary of results from ALICE in which the Nikhef group played a main role. For the flow higher harmonic measurement, a next step is to study them by using Pb–Pb collisions collected in 2015 that will allow placing more stringent limits on η/s and the initial conditions of a heavy-ion collision. For the ITS upgrade activities the 2017 will be a focal year for the assembly and testing of the modules. In addition to what reported here, our group is involved in several other correlation measurements that address different topics. In the area of hard probes and parton energy loss, the group holds a strong role in heavy-flavour measurements, in measurements of the jet spectrum and modifications of jet fragmentation due to interactions with the medium, and in the measurement of real and virtual photons. The p–Pb runs at $\sqrt{s_{NN}}$=5.01 TeV and $\sqrt{s_{NN}}$=8 TeV collected in November-December of this year will provide the statistics to study in detail the initial state effects, as shadowing and Cronin, that may mimic the signature of the QGP in Pb–Pb collisions.

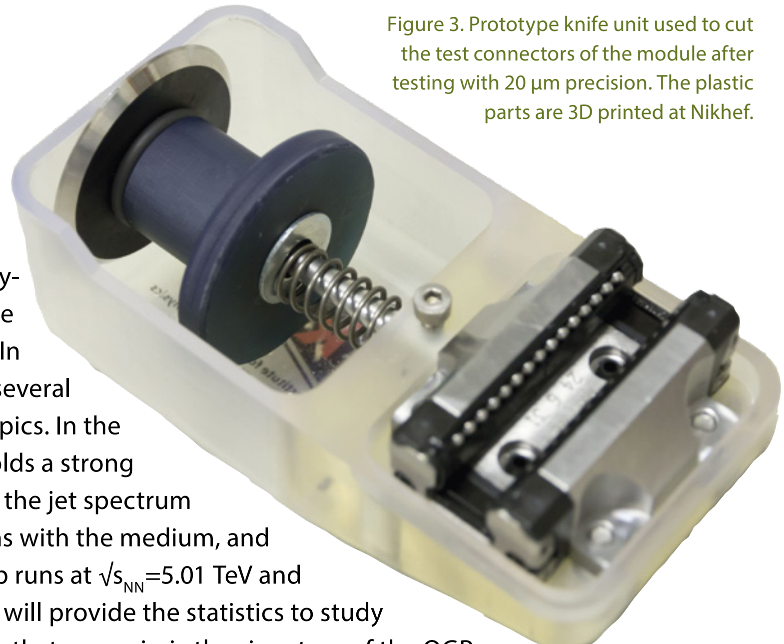
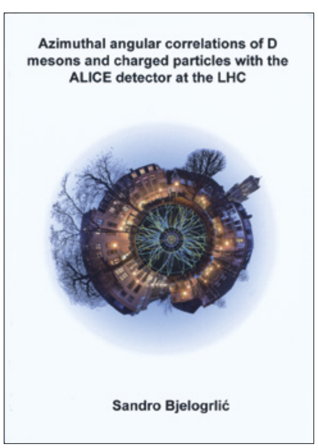
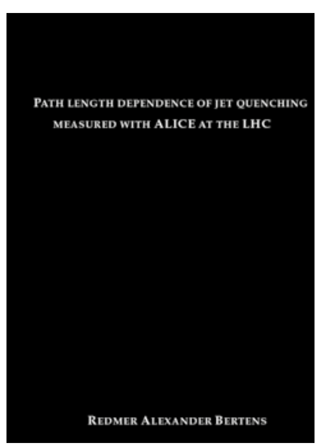


Figure 3. Prototype knife unit used to cut the test connectors of the module after testing with 20 µm precision. The plastic parts are 3D printed at Nikhef.



Sandro Bjelogrlić
4 May 2016



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31 October 2016

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7 December 2016