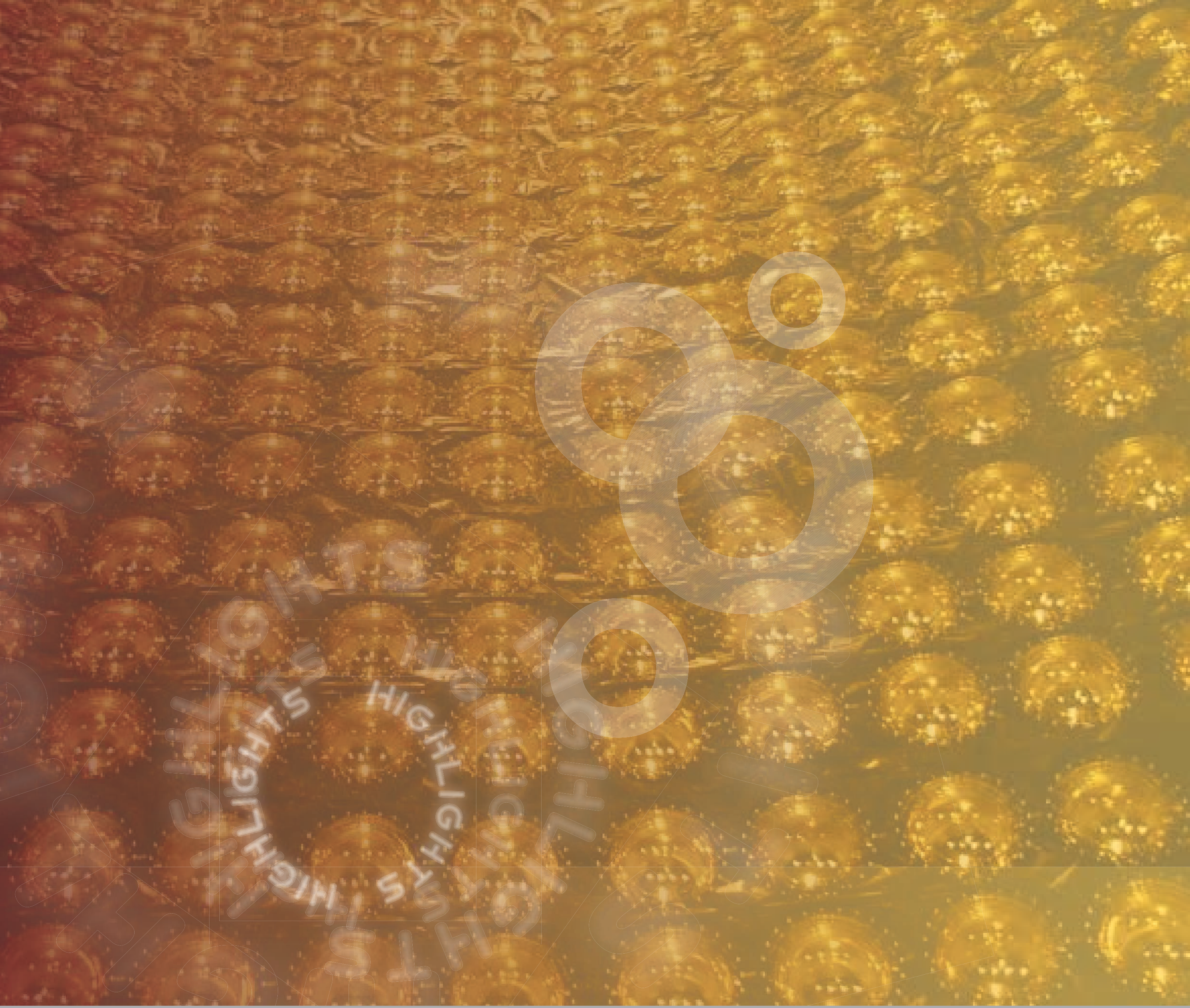

DEPARTMENT

OF FUNDAMENTAL RESEARCH

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DEPARTMENT

OF FUNDAMENTAL RESEARCH

The scientific activity of DBP in 2014 is presented in detail in the sections devoted to its four Divisions: Nuclear Physics Division (BP1), Theoretical Physics Division (BP2), High Energy Physics Division (BP3) and Astrophysics Division (BP4) (this is a new division including the former Division of Cosmic Ray Physics and the astrophysical section from the BP3 division). Here I shall present only a short overview referring to the specialized sections presented by the Divisions for details and further references. The main achievements selected as the achievements of the whole Institute to be presented to the broad public are:

(*) **Evidence for High Energy Resummation Effects in Mueller-Navelet Jets at the LHC** *by the international research group lead by Prof. L. Szymanowski from BP2 DBP NCBJ; main results were presented in Phys. Rev. Lett. 112, 082003 (2014).*

(*) ***Precise Measurement of the Neutrino Mixing Parameter ϑ23 from Muon Neutrino Disappearance in an Off-Axis Beam*** *by the Warsaw Neutrino Group lead by Prof. E.Rondio (M. Kabirnezhad, J. Łagoda, P. Mijakowski, P. Przewłocki, E. Rondio, J. Zalipska) under the aegis of the world-wide neutrino research collaboration T2K; main results were presented in Phys. Rev. Lett. 112, 181801 (2014).*

The Nuclear Physics Division (BP1) concentrates on low energy nuclear physics (mostly in collaboration with the Heavy Ion Laboratory, University of Warsaw). Its activity in high energy nuclear physics connected with the Hermes collaboration at the Deutsches Elektronen Synchrotron (DESY) in Hamburg was limited to preparation of some final publications because the experiment has been definitively closed. Also activity connected with the large-scale international collaboration PANDA in the FAIR project was very limited and most probably will be closed due to serious problems and delays in work on this project experienced recently at the GSI laboratory. The attempts to renew the activity of the BP1 division in true nuclear physics, undertaken by hiring Prof. H. Mach, seemed very promising, but, unfortunately, they came to naught due to his unexpected death at the end of December 2014. At the end of 2014 the BP1 division moved to new quarters in the pavilion section of Hoża 69 and its main scientific equipment, the Van de Graaff accelerator, has finished its activity. New plans concerning the future of this division are now under consideration.

The Theoretical Physics Department (BP2) works in close collaboration with experimental groups in CERN, GSI, Kamiokande and Frascatti and in collaborations with the Universities of Warsaw, Kielce, Paris, Liege, London and such institutes as PAN, CERN, GSI, JINR, RIKEN. It concentrates on the properties of heavy and superheavy nuclei; properties of nuclear matter and nuclear collisions; exotic atoms; phenomenology of collisions of hadrons and leptons; supersymmetry and cosmology, nonlinear effects in extended media and the Bayesian approach to multi-parameter problems in physics and beyond. In all of these areas interesting results were found. Its main achievement was already mentioned above. The others are mentioned in the report by the division leader.

The High Energy Physics Division`s (BP3) activity concentrated mostly on the LHC experiments ALICE, CMS, and LHCb and on neutrino physics. Because of the shutdown of the LHC accelerator no new data were collected, all groups analyzed previously taken data (whch resulted in a number of valuable results presented in many publications involving to NCBJ) and very actively participated in upgrading their detectors. It was chosen as one of the two biggest achievements of NCBJ in 2013, as mentioned before. This year special emphasis should be put on the work of our Neutrino Physics group performed within the K2K collaboration, which was mentioned before as one of the main achievements of the DBP NCBJ.

….. The Division of Astrophysics, (BP4), now consists of two separate branches: the cosmic ray physics group located in Łódź, and the astrophysical group in Warsaw. The cosmic ray physics group concentrates mostly on the future JEM-EUSO experiment planned to be installed at the International Space Station and on the EUSO-Ballon test experiment; in both cases we are responsible for some dedicated, very sophisticated, pieces of hardware. The long lasting collaboration with the KASKADE-Grande experiment is approaching its end due to the shutdown, only some remaining data are still being analysed. The astrophysics group is vigorously developing. It specializes mainly in investigations of the large scale of the Universe by very actively (and successfully at the same time) participating in many world wide projects in this domain.

Grzegorz Wilk

EVIDENCE FOR HIGH ENERGY RESUMMATION EFFECTS IN MUELLER-NAVELET JETS AT THE LHC

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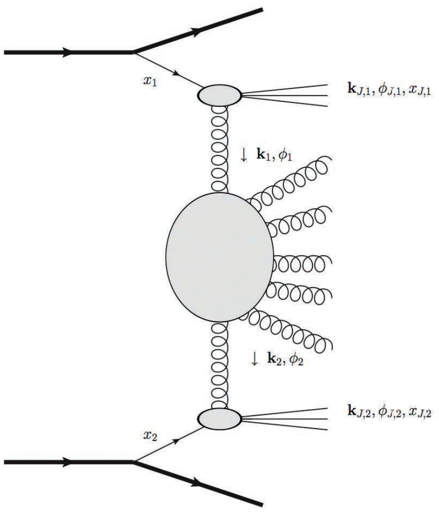
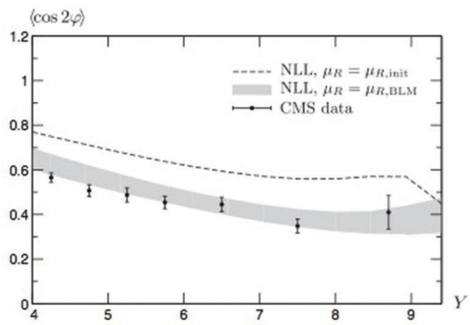
Many processes have been proposed as a way to probe the high energy dynamics of Quantum Chromodynamics (QCD) described by the Balitsky-Fadin-Kuraev-Lipatov (BFKL) approach [1]. The most promising is the hadroproduction of two forward jets separated by a large interval of rapidity at hadron colliders, proposed by Mueller and Navelet [2], as shown on the figure below.

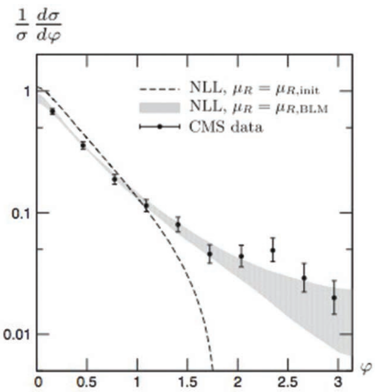


In the study [3] we derive predictions for the observables which can be measured at LHC experiments performed by the CMS collaboration for the azimuthal correlations of these jets. The main prediction based on the BFKL dynamics is a strong decorrelation of the relative azimuthal angle phi between two produced jets: a fixed order calculation implies that the two jets would be emitted back-to-back, but when more and more (untagged) gluons can be emitted between them when increasing their relative rapidity this fact should lead to a decorrelation in this azimuthal angle. We analyze this process within a complete next-to-leading BFKL framework supplemented by the use of the Brodsky-Lepage-Mackenzie (BLM) procedure to find the optimal renormalisation scale.

The decorrelation effects are described by calculation of averaged cos(n πηι) for different integer values n, where the case with n=0 corresponds to the cross section. This harmonic analysis is confronted with experimental data from LHC experiments. Theoretical predictions are more stable for the ratios of decorrelation coefficients cos(n πηι)/cos(m πηι).

The following figures show two examples of the predictions obtained: for the decorrelation coefficient cos (2 phi) and for the azimuthal distribution 1/sigma d sigma/d phi. We see that the BLM procedure of fixing the optimal renormalisation scale is crucial for obtaining very good agreement between the predictions and the data, much better than for predictions obtained using the natural scale and drawn with dashed curves.





References

[1] V.S. Fadin, E.A. Kuraev, L.N. Lipatov Phys. Lett. 60B 50 (1975); E.A. Kuraev, L.N. Lipatov, V.S. Fadin Sov. Phys, JETP 44, 443 (1976); 45, 199 (1977); I.I. Balitsky, L.N. Lipa-tov, Sov. J. Nucl. Phys. 28, 822 (1978).

[2] A.H. Mueller, H. Navelet, Nucl. Phys. B282, 727 (1987).

[3] B. Ducloue, L. Szymanowski, S. Wallon, Phys. Rev. Lett. 112 (2014) 096.

PRECISE MEASUREMENT OF THE θ23 MIXING PARAMETER IN THE T2K EXPERIMENT

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Much effort has been put into measuring the neutrino mixing parameters within the last decade of neutrino experiments. All mixing angles (θ_{23}, θ_{12}, θ_{13}) of the Pontecorvo-Maki-Nakagawa-Sakata mixing matrix, which describes the relation between neutrino mass eigenstates and neutrino flavour states, have already been measured [1,2,3]. The first known and the largest mixing angle is θ_{23}~45°. However, it still remains unsure whether θ_{23} is maximal or not.

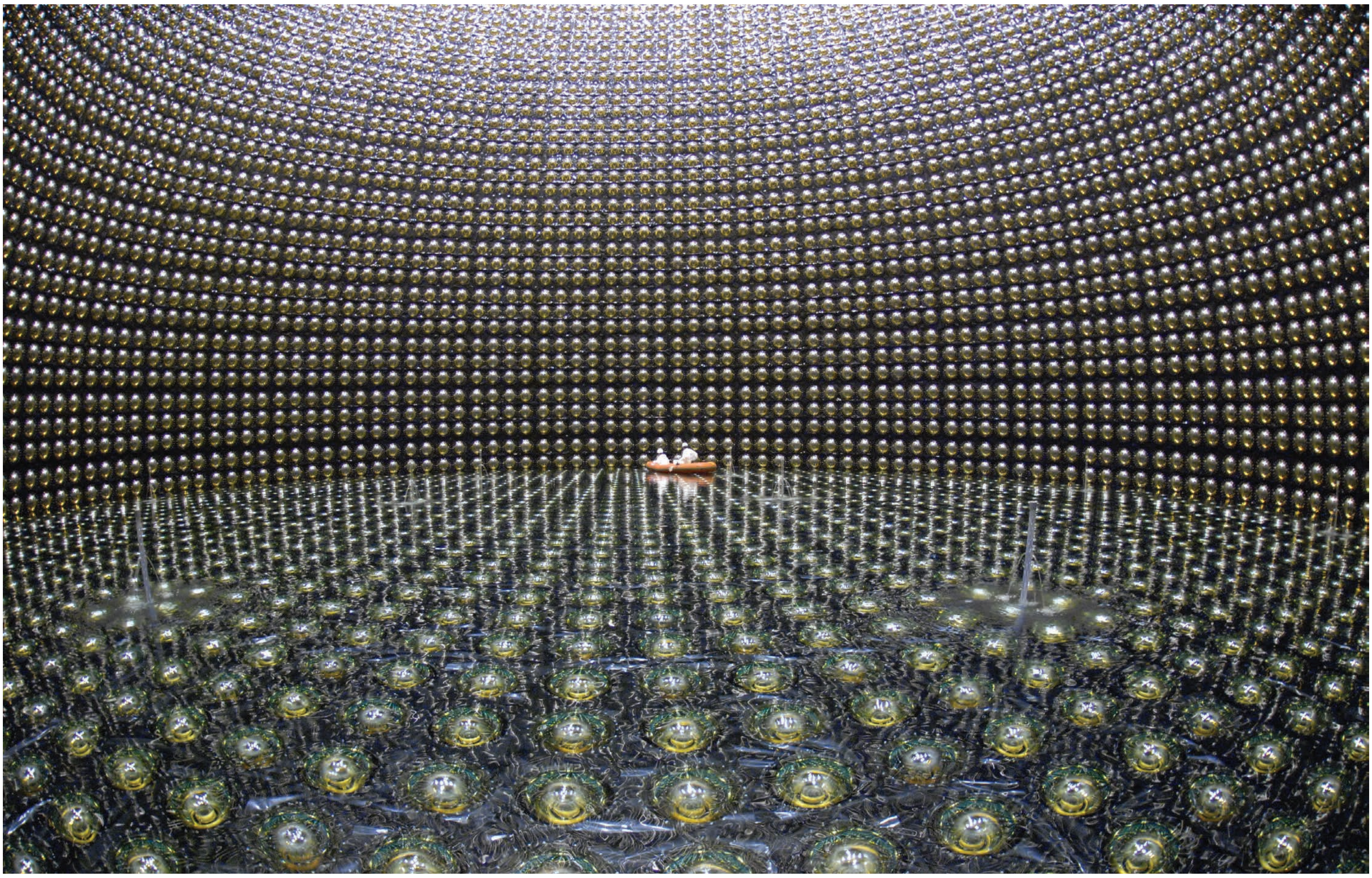

Fig. 1 Photograph of the Super-Kamiokande detector with half filled with water.

The T2K experiment [4] is designed to probe neutrino mixing parameters through measurement of neutrino oscillations. An almost pure ν_μ beam is produced by the JPARC accelerator in Japan and sent 295km away towards the far detector Super-Kamiokande (SK), Fig.1. On the way the neutrino beam and interaction cross sections are measured by the Near Detector system ND280 located 280m from the neutrino production point. Thanks to the ability of that SK to distinguish muons from electrons T2K can study the appearance of electron neutrinos as well as the disappearance of muon neutrinos from the beam. From the beginning of operation of T2K in 2010 both oscillation analysis: ν_μ–>ν_e and ν_μ–>ν_μ have been performed. The results have already been published in previous years [5,6] and as the greatest achievement we were able to report the measurement of θ_{13} mixing parameter for the first time in ν_μ–>ν_e appearance mode .

By the end of 2013 T2K chadollected a data set corresponding to 6.57×10^{20} protons on target. These new data allow us to provide the most precise measurement of the neutrino mixing angle θ_{23} ever [1]. The disappearance of ν_μ from the beam is clearly visible when the number of observed muon events in the far detector Super-Kamiokande (120) is compared to the predicted number of events in the case of no neutrino oscillation, which equals 445.98+-22.49.

In estimating of the expected neutrino spectrum and the uncertainty in the number of events in Super-Kamiokande the measurement performed by the near detector ND280 plays an important role. ND280 measured about 25000 selected ν_μ interactions through charged current processes. These data were used to perform a fit of the neutrino energy spectrum and cross section parameters used to model neutrino interactions in a Monte Carlo simulation. In order to be sensitive to various processes the selected data sample was further split into sub samples according to the number of observed pions. For selected samples the fit to the data was performed based on distributions of reconstructed muon angle and momenta. As a result parameters describing neutrino beam flux and cross sections were constrained. One can for example consider axial mass parameters for quasi elastic and resonant processes, the values of which prior to the ND280 fit were equal to 1.21+-0.45 and 1.41+-0.22 respectively. After the fit their precision was significantly improved, achieving values of 1.223+-0.072 and 0.963+-0.063. As a consequence of the ND280 measurement we can predict the expected neutrino spectra at the Super-Kamiokande far detector more precisely. With current analysis the error on the number of expected events in SK associated with the flux and cross section parameters is 2.7%. Without the ND280 constraint this uncertainty would be as large as 21.8%. Our group participated in the analysis performed by ND280. We were responsible for the estimation of the external background and some of the systematic errors.

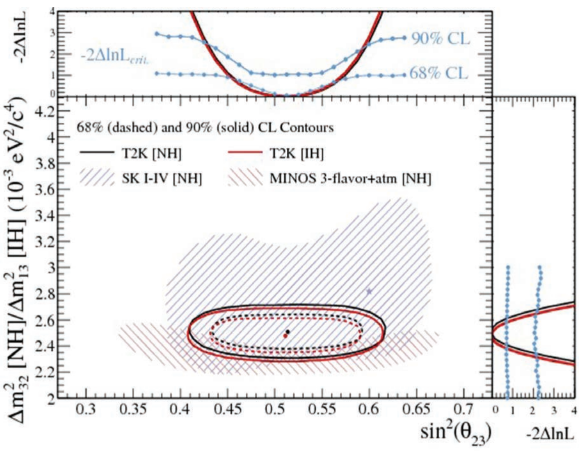

Fig. 2 The T2K 2014 results for ν_μ–>ν_μ analysis. The loops show the allowed regions of $\sin^2\theta_{23}$ and Δm^2_{23} at 68% (dashed line) and 90% (solid line) confidence level. The solid black line represents the result for normal mass hierarchy, while the red line for inverted hierarchy. The shaded regions show Super-Kamiokande and MINOS 90% C.L. regions for comparison.

The oscillation parameters of ν_μ–>ν_μ such as $\sin^2\theta_{23}$ and Δm^2_{23} are estimated using a maximum likelihood fit to the measured event rate and the reconstructed neutrino energy spectrum at Super-Kamiokande. Measurements of other oscillation parameters are assumed to be known from other experiments or T2K analysis and are allowed to change within their errors. As a result we obtained the confidence region in the plane of Δm^2_{23} and $\sin^2\theta_{23}$ shown in Fig.2 in comparison to other experiments. We can conclude that we measured $\sin^2\theta_{23}$ =0.514+0.055/-0.056 for normal mass hierarchy and 0.511+-0.055 for inverted mass hierarchy. The result obtained is consistent with maximal mixing. So far this is the most precise measurement of θ_{23}.

In the future T2K will try to improve the analysis and use more of the accumulated statistics when data taking continues. On the other hand T2K is now focused on collecting data in anti-neutrino mode. This will lead us to search for oscillations of ν_μ–>ν_e and search for a signal of CP violation in the neutrino sector which has not yet been observed by any experiment.

References

[1] K. Abe et al, . Phys.Rev.Lett. 112(2014), 181801
[2] K. Able et al., Phys.Rev.Lett. 112 (2014), 061802
[3] A. Gando et al., Phys.Rev. D88 (2013),033001
[4] K. Abe et al., Nucl.Instrum.Meth. A659 (2011), 106
[5] K. Abe et al., Phys.Rev.Lett. 111 (2013), 211803
[6] K. Abe et al., Phys.Rev. D88 (2013), 032002

PI OF THE SKY CONTRIBUTION TO FIRST SEARCHES FOR OPTICAL COUNTERPARTS TO GRAVITATIONAL-WAVE CANDIDATE EVENTS

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The Pi of the Sky [4] telescope has taken part, among other invited instruments, in the LSC -Virgo Looc-Up project [1,2]. The aim of the Looc-Up project was to search for electromagnetic (EM) counterparts to gravitational wave transient candidates in the joint LIGO-Virgo detectors science runs, S6VSR2-3, in 2009-2010. A successful observation of an astrophysical event in the optical and gravitational bands could possibly bring significant scientific results and could raise the confidence in a GW event candidate. During the science run no possible EM counterpart to gravitational wave transient event was found. The LSC-Virgo and astronomical partners published the results of the project as [1] and the methodology used during the search was described in detail in [2].

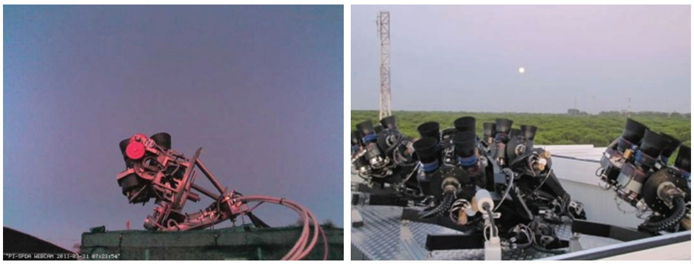

Fig. 1. (Left) Pi of the Sky South, San Pedro the Atacama, Chile. (Right) Pi of the Sky North, INTA, Spain.

The joint LIGO-Virgo science runs took place in 2009-2010. Nine astronomical teams (including QUEST, TAROT, Zadko, Pi of the Sky...) and the Swift satellite took part in the Looc-Up project. Instruments used by the astronomical team were placed in various parts of the world and have different specifications. During the science run, gravitational wave data from three interferometer detectors was analysed in low-latency in order to select gravitational wave transient candidates (triggers) and infer their possible sky localizations. Information about GW candidate events and their apparent sky coordinates was provided to astronomical groups in order to perform follow-up observations. Astronomical images were taken for eight GW candidate events. No optical transient was found that might possibly link to any of the candidates. None of the GW candidates showed evidence of being astrophysical in nature.

Pi of the Sky, operated by NCBJ, CFT PAS and the Faculty of Physics of UW, is a network of robotic telescopes aimed at searching for short optical transients between seconds up to months. The network is currently composed of two observatories Pi of the Sky South (San Pedro de Atacama, Chile), with a Field of View (FoV) of 400 square degrees, and Pi of the Sky North, (INTA El Arenosillo Test Center, southern Spain), with a FoV bigger than 5000 square degrees. Telescopes in both observatories operate with limiting magnitude 12m 13m and time resolution 12s. The main goal of the Pi of the Sky network is to search for prompt optical counterparts of Gamma Ray Bursts (GRBs). The very wide FoV and high time resolution of the system have proven to be very useful on numerous occasions, possibly the most famous were the observations of GRB 080319B.

During the Looc-Up project, Pi of the Sky followed a trigger sent by LSC-Virgo – G23004. For observations Pi of the Sky used an auxiliary site located in Koczargi Stare near the Kampinos Forest in Poland. The telescope used had a camera with 400 degrees FoV and limiting magnitude between 10-11.5m due to weather conditions. Pi of the Sky began searching for an EM counterpart to gravitational wave transient candidate G23004, 6h56m after the trigger and covered more than 40% of the 4 possible sky positions in 10 minutes. The area of the possible sky locations of the trigger was observed for the next few days and a month after. No possible EM counterpart was found.

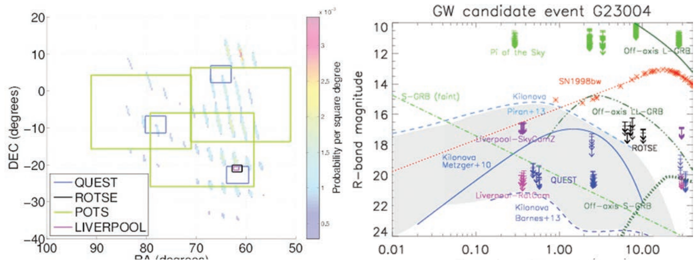

Fig. 2. (Left) Parts of sky position probability map of G23004 imaged by Pi of the Sky (light green boxes) compared with other telescopes. Image taken from [1]. (Right) Upper limits estab-lished by each telescope versus time on observed area. Typical light curves of theoretical models of possible EM astrophysical events that might produce gravitational waves are plotted for comparison. Image taken from [1]

Upgraded gravitational wave detectors, Advanced LIGO and Advanced Virgo, are planned to start operating in 2015-2016. Pi of the Sky has enlisted to take part in the LSC-Virgo EM Follow-up project that would aim at searching for EM counterparts to gravitational wave transient candidates. The first EM Follow-up observational run is planned in the autumn/winter of 2015 [5].

References

[1] J. Aasi et al. (LSC-Virgo Collaboration with astronom-ical partners) 2014 ApJS 211 7
[2] J. Abadie et al. (LSC-Virgo Collaboration with as-tronomical partners) A&A 539, A124 (2012)
[3] A. Zadrożny et al. (Pi of the Sky) Proc. SPIE 8903 (2013), 890310
[4] G. Wrochna et al. (Pi of the Sky) Proc. SPIE 5125, p. 359–363 (2003)
[5] J. Aasi et al. (LSC-Virgo Collaboration), arXiv:1304.0670