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Custom ultrasonic instrumentation for flow measurement and real-time binary gas analysis in the CERN ATLAS Experiment

The development of a custom ultrasonic instrumentation was motivated by the need for continuous real-time monitoring of possible leaks and mass flow measurement in the evaporative cooling systems of the ATLAS silicon trackers. The instruments use a pairs of ultrasonic transducers transmitting sound bursts and measuring transit times in opposite directions. The gas flow rate is calculated from the difference in transit times, while the sound velocity is deduced from their average. The gas composition is then evaluated by comparison with a sound velocity/composition database, based on the direct dependence between sound velocity and component molar concentration in a gas mixture at a known temperature and pressure. The instrumentation has been developed in several different geometries.
Five instruments are now integrated in the ATLAS Detector Control System (DCS). Three of these monitor C3F8 and CO2 coolant leaks into N2 envelopes of the SCT, IBL and Pixel detectors. Resolutions better than 2.10-5 and 10-4 are respectively seen for C3F8 and CO2 leak concentrations in N2. A fourth instrument detects sub-percent levels of air ingress into the C3F8 condenser of the new thermosiphon coolant recirculator. Following extensive CFD studies a fifth instrument was built as an angled sound path flowmeter to measure the high returning C3F8 vapour flux (~1.2 kg.s-1) to the thermosiphon condenser. A precision of < 2.3% F.S. for flows up to 10 m.s-1 was demonstrated. This instrument should also be capable of determining the concentrations of C3F8 and C2F6 to better than ±3·10-3 should such blends be needed to reduce the operating temperature of the SCT and Pixel detectors for enhanced radiation tolerance. Custom microcontroller-based readout has been developed for the instruments, allowing readout into the ATLAS DCS via Modbus TCP/IP on Ethernet. These instruments have many potential applications where continuous binary gas composition measurement is required, including hydrocarbon and anaesthetic gas mixtures.

Autore principale: ROSSI, Cecilia (INFN Genova, Via Dodecaneso 33, 16146 Genova, Italy)

Coautore: BITADZE, A. (School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK); MADSEN, A. (Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany); O'ROURKE, A. (Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany); ROZANOV, A. (Centre de Physique des Particules de Marseille, 163 Av. de Luminy, 13288 Marseille, France); DI GIROLAMO, B. (CERN, 1211 Geneva 23, Switzerland); PEARSON, B. (Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA); DEGEORGE, C. (Physics Department, Indiana University, Bloomington, IN 47405, USA); DETERRE, C. (Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany); LOMBARD, D. (CERN, 1211 Geneva 23, Switzerland); ROBINSON, D. (Department of Physics and Astronomy, Cavendish Laboratory, University of Cambridge, CB3 0HE, UK); STANECKA, E. (Institute of Nuclear Physics PAN, ul. Radzikowskiego 152, 31-342 Kraków, Poland); BOYD, G. (Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA); FAVRE, G. (CERN, 1211 Geneva 23, Switzerland); HALLEWELL, G. (Centre de Physique des Particules de Marseille, 163 Av. de Luminy, 13288 Marseille, France); YOUNG, J. (Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA); NAGAI, K. (Department of Physics, Oxford University, Keble Road, Oxford, OX1 3RH, UK); ZWALINSKI, L. (CERN, 1211 Geneva 23,

Switzerland); ALHROOB, M. (Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA); BATTISTIN, M. (CERN, 1211 Geneva 23, Switzerland); DOUBEK, M. (Czech Technical University, Technická 4, 166 07 Prague 6, Czech Republic); STRAUSS, M. (Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA); CRESPO-LOPEZ, O. (CERN, 1211 Geneva 23, Switzerland); BONNEAU, P. (CERN, 1211 Geneva 23, Switzerland); VAGLIO, R. (CERN, 1211 Geneva 23, Switzerland); BERRY, S. (CERN, 1211 Geneva 23, Switzerland); KATUNIN, S. (B.P. Konstantinov Petersburg Nuclear Physics Institute (PNPI), 188300 St. Petersburg, Russia); MCMAHON, S. (Rutherford Appleton Laboratory, Harwell Science and Innovation Campus, Didcot, OX11 OQX, UK); VACEK, V. (Czech Technical University, Technická 4, 166 07 Prague 6, Czech Republic)

Relatore: ROSSI, Cecilia (INFN Genova, Via Dodecaneso 33, 16146 Genova, Italy)