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PHYSICS REACH OF THE ATLAS EXPERIMENT DURING THE FIRST LHC RUN

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We discuss the ATLAS physics programme for the first year of LHC operation. The layout of the initial (staged) detector will be described, as well as the impact of staging on the physics reach. The main data samples and strategies which will be used to calibrate, align and understand the detector response will be presented. Finally, the physics channels which will be addressed in the first months of operation will be discussed. These include a low-mass Higgs boson, for which a striking signal might be observed after only a few months of data taking. The impact of a realistic non-optimal detector performance, as expected at the beginning, will be illustrated in some cases.

Keywords: ATLAS, LHC, comissioning, Higgs, SUSY

1. ATLAS layout and comissioning

ATLAS is one of the two multi-purpose detectors for new physics in the TeV-mass range which are being constructed for operation at the LHC [1,2]. The LHC will collide two proton beams at a centre-of-mass energy of 14 TeV. The initial delivered peak luminosity is designed to be $10^{33}\text{cm}^{-2}\text{s}^{-1}$. LHC is scheduled to start beam operation in spring 2007 and provide collisions later in 2007.

ATLAS comprises several layers, extending from the Inner Detector (ID), to the super-conducting solenoid magnets with a 2 T field, calorimeters, muon chambers, and an air-toroid with a 4 T field. The ID combines tracking straw tubes in the outer transition-radiation tracker with silicon microstrip detectors in the middle and silicon pixel detectors in the innermost component to achieve an impact-point resolution of 50μm at 20 GeV and a momentum resolution of $\sigma/p_T = 0.05\% \cdot p_T \oplus 1\%$ (p_T in GeV). The calorimeter is composed of liquid argon-lead, -tungsten or -copper cells for both electromagnetic and parts of the hadronic calorimeter, and the barrel-hadronic steel-scintillator tile calorimeter, providing energy measurements with a precision of $\sigma/E = 10\%/\sqrt{E} \oplus 0.7\%$ for electrons and photons, and $\sigma/E = 50\%/\sqrt{E} \oplus 3\%$ for hadrons (E in GeV). The muon spectrometer combines drift tubes and cathode strips for precision tracking with resisitive plate chambers and thin gap chambers for triggering. The relative momentum resultion ranges from 2%

to 7%. The overall ATLAS detector covers a rapidity region of $|\eta| < 2.5$, although individual components extend even further in η.

Before the start of LHC, during the pre-collision phase and with the first collision events, ATLAS will undergo calibration and alignment procedures. For example, the Inner Detector will use tracks from first LHC events, combined with an initial survey and metrology, to perform an alignment procedure. This procedure will result in a statistical error on the position of individual modules of appeox. 1μm already after one day of data taking. Additional information will be drawn from comparison to the energy of $e^{\pm}$-clusters in the electromagnetic calorimeter and from decay products of well-known resonances such as J/ψ. An 1μm-precision in the alingment will be crucial for a precise measurement of the W-mass (see below). Similarly, the electromagnetic calorimeter will use a combination of monitoring data taken during production for cell calibration and $Z \to e^+e^-$ decays for calibrating long-range non-uniformities to achive the precision neccessary for e.g. measurements of the Higgs-mass in the decay $H \to \gamma\gamma$. Commissioning of other detector components will follow equivaltent strategies.

2. Early physics with ATLAS

This section focusses entirely on the reach of ATLAS during the first year of operation, corresponding to a luminosity of up to 10 fb^{-1}. Details of the respective analyses touched here are discusses elsewhere [2,3,4,5,6,7,8].

SUSY searches are amongst the most promising for early data taking with ATLAS: assuming a squark or gluino mass of around 1 TeV, SUSY events will be seen at a rate of about 100 events per day. Using the most efficient and general signature, that of missing transverse energy, a discovery of SUSY is already possible with an integrated luminosity of 1 fb^{-1}, a tenth of what is expected in the first year.

The Standard Model Higgs can be discovered with a 5σ signal in the mass range $120 < m_H < 200$ GeV with an integrated luminosity of 10 fb^{-1} as shown in figure 1. It should be noted that a combination of several analyses using different Higgs decay and production modes is neccessary since one mode alone does not neccessarily reach beyond the 5σ level. Similarly, an MSSM Higgs can be discovered over a large part of the (m_A,$\tan\beta$) parameter space with an integrated luminosity of 10 fb^{-1}, again using a combination of several modes.

Many electroweak processes at ATLAS will have large production rates such that the measurements will not be limited by statistical errors even during low luminosity running. Some measurements are actually more favourable at lower luminosities due to lower pile-up effects. Two examples for such measurements are those of the W and top mass, which yield a precision in mass of $\Delta m_W < 20$ MeV or $\Delta m_t \approx 1$ GeV, respectively.

Due to financial and time constraints, some of the detector components will not be ready on the first day of ATLAS operation. The guiding principle for staging certain detector parts were the necessity to have all sub-components in operation

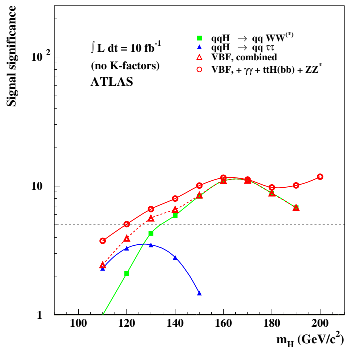

Fig. 1. Significance of Higgs signals from different decay and production mechanisms as function of the Higgs mass m_H.

from the start, with the need to cover the full η-range such as to not strongly reduce sensitivity to new physics. Instead, radial redundancy was reduced which has a less critical impact on physics. The most serious effect on physics is expected from the deferrals to high-level trigger and data acquisition processors, resulting in the need to limit the output rate at the first trigger level. As a consequence, many physics channels will suffer in a notable loss in statistics, but under current background assumption this loss will be modest and acceptable for most channels. Only the B-physics trigger will be strongly reduced. Options for partial recovery are under investigation.

3. Summary

It was briefly described how first pre-collision and collision data from ATLAS will be used to align and calibrate the detector. Since data samples needed for this process are large a fast commissioning is expected.

Already the first year of ATLAS operation will have the potential for discoveries, such as a general signal for SUSY and the discovery of the Standard Model Higgs. Staging of some detector components will affect physics performance, but for most analyses only a modest degradation is expected.

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