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DC-DC converters with reduced mass for trackers at the HL-LHC

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The development at CERN of low noise DC-DC converters for the powering of front-end systems enables the implementation of efficient powering schemes for the physics experiments at the HL-LHC. Recent tests made on the ATLAS short strip tracker modules confirm the full electromagnetic compatibility of the DC-DC converter prototypes with front-end detectors. The integration of the converters in the trackers front-ends needs to address also the material budget constraints. The impact of the DC-DC converters prototypes onto the ATLAS tracker modules material budget is discussed and mass reduction techniques are explored, leading to a compromise between the electromagnetic compatibility and mass. Low mass shield implementations and Aluminum core inductors are proposed. Also, the impact on emitted noise due to a size reduction of critical components is discussed. Finally, material reduction techniques are discussed at the board layout and manufacturing levels.

Summary 500 words

The upgrade of front-end systems at the HL-LHC will result in an increase of the required power, that forces the development of new, more efficient powering schemes. For this, DC-DC converters have been proposed, and specific developments are being carried out to provide custom designed point-of-load converters able to withstand the high levels of magnetic field and of radiation at which the trackers front-ends are exposed, while keeping the noise emissions low enough to maintain the performance of the systems powered by them.

Converter prototypes have been produced and tested with the ATLAS tracker modules equipped with the ABCN25 front-end ASICs. The electromagnetic compatibility between the converters and the system has reached a level that is comparable to that one achieved when powering the system with a linear power supply. The noise performance obtained with different systems will be presented.

The inner detectors impose strong restrictions in terms of material budget contributed by the front-end assemblies, in which the DC-DC modules are included. The converters require the use of components of non negligible mass, such as the output inductor, the decoupling capacitors, the board copper and the shield. The material budget contribution of each of these items has been evaluated and mass reduction strategies have been explored.

The reduction of the inductor mass is achieved using enameled copper cladded aluminum (ECCA) wire. The presence of an aluminum core in the ECCA wire results in an increase of the DC resistance, which is somehow limited with the addition of the copper clad around it. For an equivalent diameter, the DC resistance of the ECCA wire increases by 50% when compared to a standard copper wire. In this way, the mass of copper can be divided by three; the mass of the aluminum core is typically half the one of the copper clad.

The shield enclosure contributes also significantly to the converter material budget, and its effectiveness is directly related to its thickness and to the material used. The shielding effectiveness for different materials and thicknesses will be presented. The simplest solutions consist of coating a plastic substrate with copper, while other techniques allow getting rid of the plastic, for instance the laser YAG soldering of thin aluminum foils. The performance of the different techniques will be compared and a compromise between effectiveness and material will be presented.

To achieve the low levels of noise required for the compatibility with the front-end electronics, low ESL and ESR surface mounting components are used in noise reducing board arrangement. These components contribute significantly to the converter mass. The impact of reducing number of passives or of replacing them with smaller sizes, at expense of emitted noise, is presented.

The mass reduction strategies proposed have, up to some extent, an impact on the noise emitted by the converter. The choice between emitted noise and material budget must result from a compromise to enable the required electrical performance of the front-end system, without compromising the physics resolution of the detector.

Ultimately the option to use aluminum cladded printed circuit boards is also discussed, with emphasis on reliability issues of these technologies.

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