# WP8 – Tracking detector power distribution

*Text taken from "description of work" (Annex 1 of the proposal)*

Full exploitation of the physics potential of the SLHC project requires very significant changes, improvements and upgrades of the two large multipurpose detector systems at LHC. This is needed to be able to handle a factor 10 more luminosity and because the lifetime of the current systems is limited due to radiation damage. The changes involve all parts of the detector systems, but mostly affect the replacement of the large central tracking systems, comprising several hundred million particle detection elements, designed in state-of-the-art solid-state sensor technologies coupled to deep-submicron radiation-hard electronics. Sensitive elements (pixels and strips) will be as small as 80*80 μm2 in the inner regions, going up to 3 $mm^2$ in the outer regions. Each individual sensitive element is coupled directly on the detector to its own electronics amplifier and address logic. The SATLAS and CMS2 central trackers will be subject to high radiation levels and will be housed in strong magnetic fields of up to 4 Tesla. They will represent materials investments above 60 M€ each. Once designed and financially approved, they will take approximately 5 years to be constructed.

The distribution of power to the readout electronics of the SLHC trackers poses a huge technical challenge, which strongly affects the overall design of the tracker. The highly segmented independent powering presently adopted for the LHC trackers becomes impractical at the SLHC for a number of reasons including: 1) there is no space for large increase in the number of power cables (which would correspond to the much increased number of electronic channels); 2) power losses in the power cables lead to a poor power efficiency and causes heat dissipation; 3) the material represented by the power cables and additional cooling leads to increased multiple scattering and limits the resolution of the tracking detectors. Therefore, novel solutions to the power distribution challenge must be identified and developed to maturity.

Two main approaches shall be investigated. One consists in exploring ***DC-DC conversion*** to bring higher voltages and lower currents inside the tracker volume, and the other in exploring ***serial powering schemes***. Both approaches address their implementation directly into the on-detector electronics, and therefore mainly involve microelectronics developments. The radiation hardness criterion is not fulfilled by commercially available components and forms the principal reason for dedicated development. For the DC-DC conversion, the incompatibility with commercial products is enhanced by the presence of a large magnetic field inside the detectors, which renders the conventionally used magnetic components (inductors with ferromagnetic core) unsuitable. Prior to SLHC-PP no collaboration framework existed for detector powering studies. The SLHC-PP project forms a crystallisation centre around which a large new collaboration is expected to grow.

**Objectives**

- Evaluation of various *DC-DC conversion* options as well as *serial powering schemes*
- Integration of the most promising solutions into dedicated Application Specific Integrated Circuits (ASICs)
- Tests in full-scale S-ATLAS and CMS2 detector module prototypes
- Delivery of a fully qualified technical solution, ready for use in the implementation phase, at the end of SLHC-PP

**Description of work**

**Task 8.1: DC-DC conversion**

The development aims for radiation-hard components operating in magnetic fields up to 4 Tesla. The following alternative solutions will be explored: buck converters based on air core inductors and on-chip conversion for small current applications. The R&D program shall be structured as follows:

*"Evaluation phase"*

An evaluation of different conversion approaches will be made, singling out the critical difficulties and developing conceptual solutions to overcome them. Exploration of partnerships with industry. Commercially available air-core converters (while not being radiation-hard) will be used to study the behavior and characteristics of detector systems powered through DC-DC conversion. This will include studies on the electromagnetic interference between the converters and the sensors with their read-out electronics

*"Prototype phase"*

Development of custom prototype converters for the alternative solutions. Although this generation of prototypes is intended to be demonstrators only, the air-core inductor converter will have the same level of integration as the final product. All active components will be embedded in ASICs and the number of passive components shall be minimized to be compatible with the real application. The on-chip DC-DC converter, integrated in modern CMOS technologies, will also be prototyped to assess the feasibility of this solution. Prototypes will be integrated in detector modules and multi-module structures and be tested at the system level. A report will detail the performance of the prototypes, with conclusions on the final viability of each conversion approach and recommendation for LHC upgrades.

CERN will play the major role in the inductor-based converter development, with contributions from RWTH Aachen in device testing and integration and contributions from STFC and RWTH Aachen in the system-level testing. PSI will be in charge of the evaluation and first prototyping of the onchip DC-DC conversion.

**Task 8.2: Serial Powering**

Serial powering is a novel and highly promising concept for power distribution in silicon particle detectors. It involves a constant current source feeding a chain of silicon strip or pixel modules combined with shunt and linear voltage regulators on the module. This

reduces the number of cables, minimizes the total current brought into the detector volume and therefore the power losses in the cables.
In serial powering schemes, each module sits at a different potential; thus control, clock and data signals must be AC-coupled or use optical signal transmission. Apart from the challenges of designing radiation-hard power electronics, serial powering systems require the development of over-current protection and redundancy schemes and exploration of grounding and shielding techniques.
The serial powering R&D programme consists of three phases:
*" Generic studies"*
*S*pecification and development of AC-coupling or opto-decoupling elements; investigation of grounding and shielding techniques for serial powering schemes; system evaluation of serial powering systems based on commercial shunt regulators.
*"Development of custom radiation-hard power electronics"*
Design, submission and characterization of custom radiation-hard shunt regulators, power devices and AC–coupling circuitry. Several design iterations in different technologies are foreseen. The concept of a generic high-current serial powering ASIC, with various protection and slow-control features, capable of powering S-ATLAS and CMS2 pixel and strip detectors, will be evaluated.
*"System design and characterization of super-modules"*
Implementation of custom electronics in tracking detector super-modules. A super-module will consist of a significant number of detector modules powered in series. The super module performance will be fully characterized.
AGH-UST, RAL and UBONN will be responsible for this task. AGH-UST will contribute predominantly to the design of the radiation-hard electronics. STFC and UBONN will work on all sub-tasks.