A NEW PROCESS FOR CALCULATING BEAM OFFSETS DURING ALIGNMENT

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INTRODUCTION

The alignment of a particle accelerator depends on various geometrical data, which are combined to align the machine components.

The beam trajectory is calculated by beam physicists, providing information on the position and orientation of the start and end of each component in the accelerator. This trajectory serves as the objective for the alignment performed by CERN surveyors.

Socket Points coordinates

The survey database computes the theoretical position of equipment by fitting the fiducialization data, the equipment's position along the beam trajectory, and the beam trajectory data.

Beam Points offsets

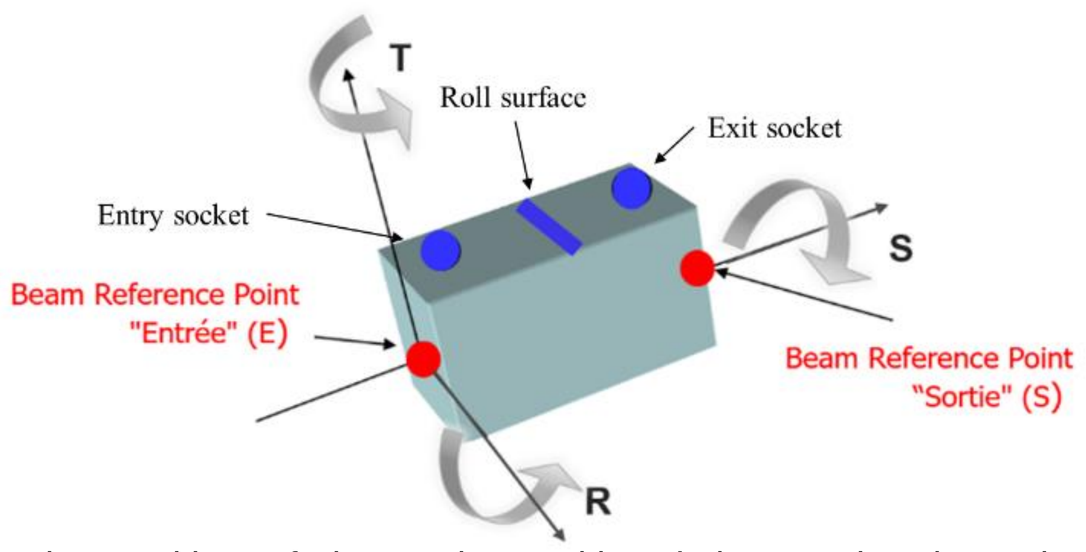
Beam Points Coordinates

The fiducialization data of an equipment represent the positions of external reference points (also named socket or fiducial) according to reference points inside the equipment, which are accessible only before installation.

Aligned Socket Points

CERN surveyors align the equipment to its theoretical position. The alignment in the field is performed at the socket position rather than at the beam position.

Fiducialization Data



The position of the sockets with relation to the theoretical equipment axis can be obtained from diverse sources: drawings, magnetic or mechanical fiducialization and metrology measurement from a CMM. All these sources vary in quality, which may be unknown to the survey team in the field.

Input Quality Limitation

The RST coordinates provided by fiducialization are expected at 0.1 (1σ) mm, but a lot of equipment has not been fiducialized due to the associated costs and time constraints. For this reason, parameters from drawings are used for equipment that does not require as precise positioning. This means that the accuracy of the socket coordinates remains unknown.

As an example, the longitudinal error for the Injection Tunnel 2 of LHC (part of the SPS complex) is 3.55 mm (1σ).

Complex	AD	ISOLDE	LEIR	LHC	PS	SPS
Fiducialized equipment (%)	33	100	32	85	44	5

New Methodology

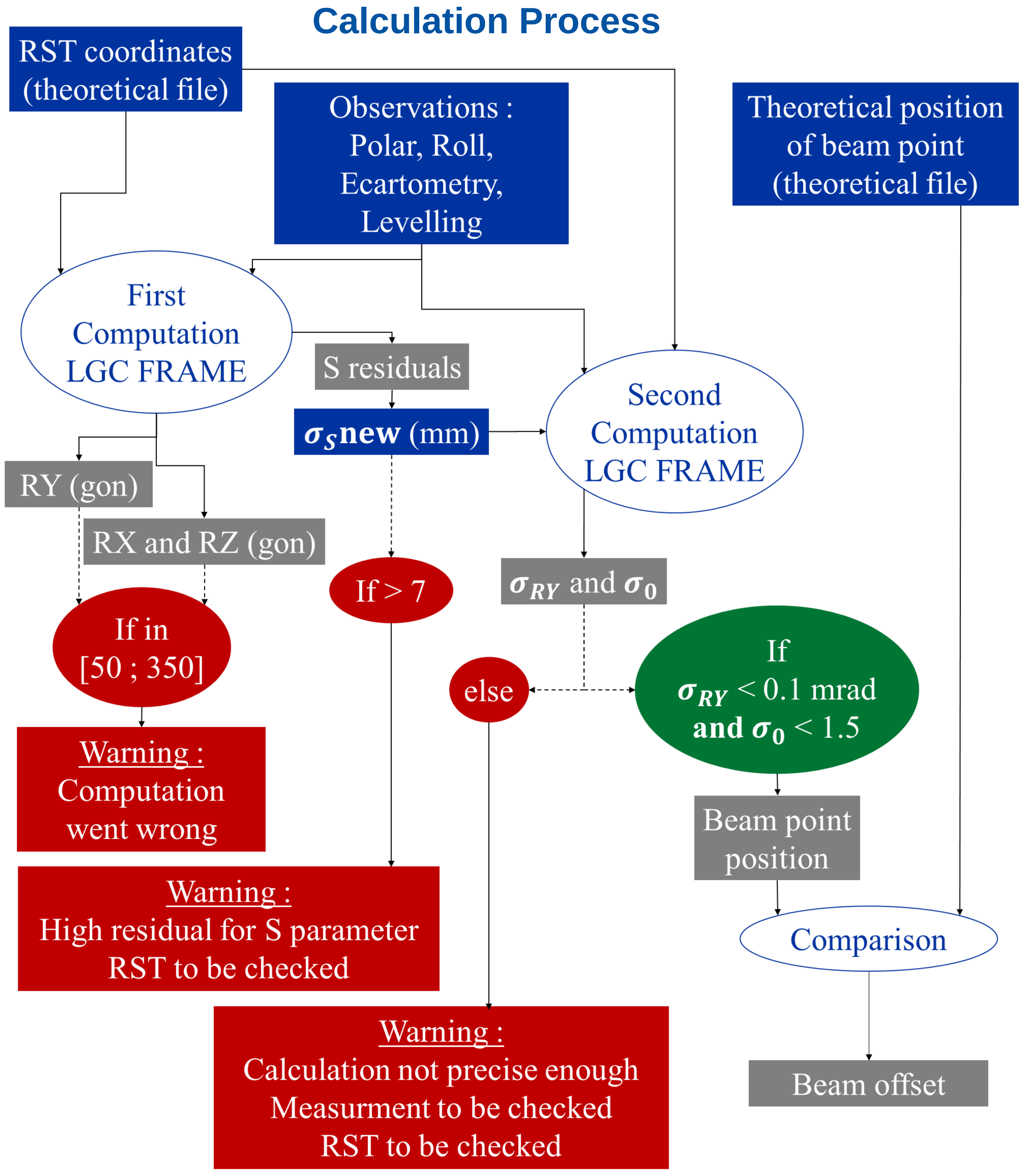
To compute beam offsets during alignment, the frame concept introduced in least square adjustment software LGC (Logiciel General de Compensation) is used. A frame is defined by a standard Helmert transformation and can contain points, measurements and other frames moving together.

The fiducialization geometry is incorporated as a measurement in the calculation and adjusted in bloc with the field measurement.

The challenge lies in evaluating the accuracy of the fiducialization observations. By default, the RST coordinates are known at 0.1 mm (1σ). As previously mentioned, the quality of the longitudinal parameter may be degraded. This is why two computations are performed. The first one enables to compute a new accuracy, σS new, to be used for the longitudinal coordinate S in the second calculation.

Several checks are conducted on the calculation to validate it and detect common mistakes throughout the process.

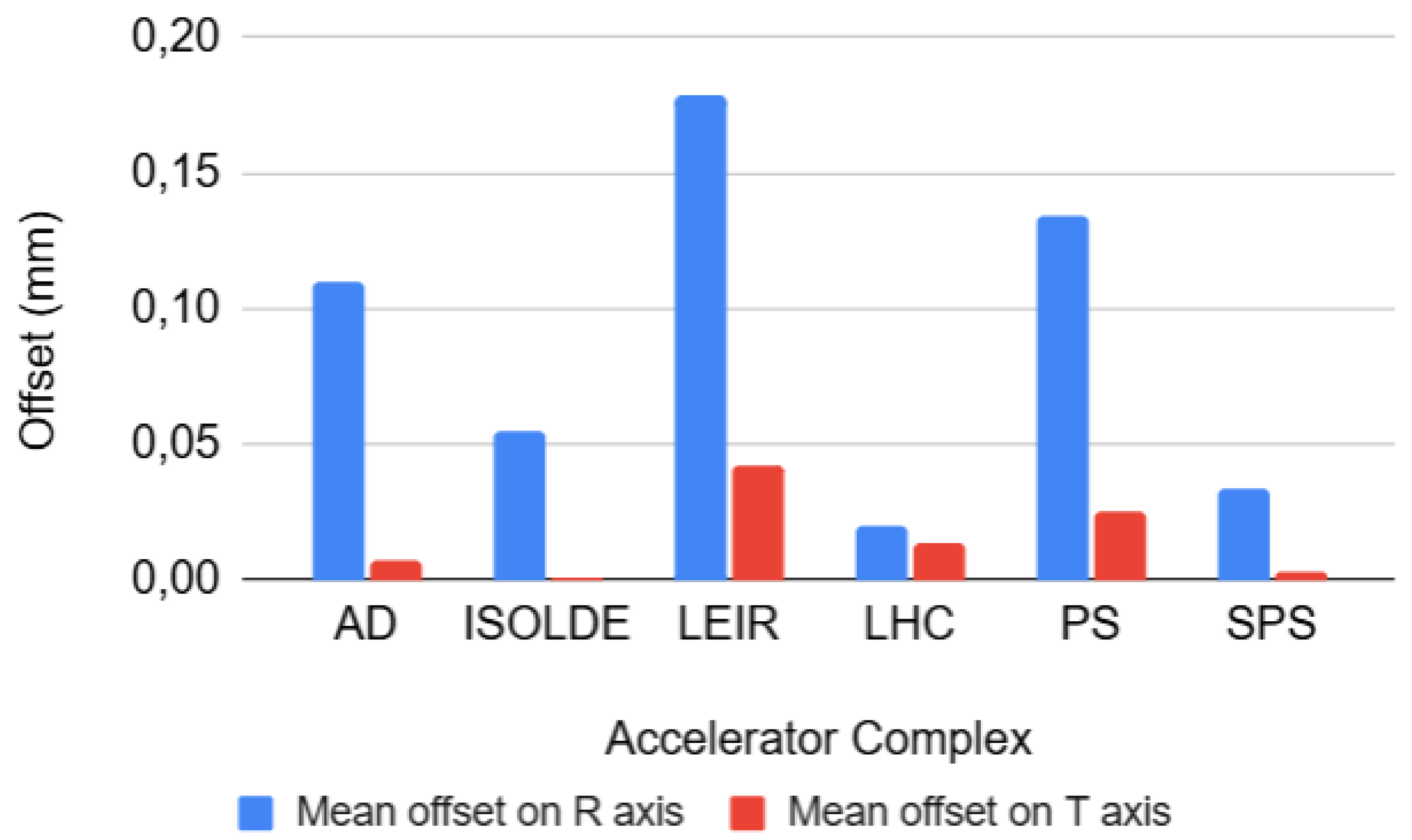
Calculation Process



Compensating Roll angle offset with Radial and vertical

There are various situations in the field where aligning the roll angle of equipment is not feasible or necessary. This can be due to vacuum constraints, limitations of the adjustment system, or equipment that is not sensitive to roll. In such cases, knowing how to compensate for roll angle offsets using radial and vertical adjustments is highly advantageous.

The effect has been evaluated using the current roll deviation of the equipment along with the R and T coordinates of the sockets stored in the database



Conclusion

The new process has several benefits for the field alignment:

- Feedback on the beam position allows the operator to align the equipment according to the needs of both beam physicists and machine operators.
- Understanding the beam offsets on the field allows to compensate some offsets in an easier way. As an example, a roll angle offset could be compensated with a radial and vertical offset.
- The process directly computes the roll angle on the field which is important for magnetic equipment.

Perspectives

The new process facilitates continuous error transmission from surface measurement to machine alignment. One of the mid-term projects focuses on storing precision information from fiducialization in the database in order to integrate it into the frame system, thereby enabling continuous error transmission. This approach would also streamline the process by eliminating the need for iterative adjustment, as the weighing within the least square process would be automated.

The ability to compute the coordinate of the beam points in the field also provides the opportunity to use the beam points of the reference equipment as fixed points in the calculation, rather than relying on the sockets. This approach could address several current issues, such as incorrect distances between reference equipment, incorrect roll angle of a reference, errors in fiducialization data, and deviations in machine slope relative to the nominal geometry. Preliminary tests are showing promising results, but further testing is necessary to fully validate the process.