8 Girder system

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8.1 Introduction

The cross-sections of the beam in the straight sections are $\sigma(x)$ = 51.2 µm and $\sigma(y)$ = 4.7 µm. The user requirement for beam stability is one-tenth of the beam size; hence the stability has to be in the sub-micrometre range. The beam stability is determined by the stability of the magnets as provided by the girder system supporting the magnets. For a 4th generation light source, a very stable girder system with 'eigen-frequencies' greater than 50 Hz is required. Furthermore, some movements of the girders should be adjusted in real time. A new type of girder system has been introduced at the Swiss light source [8.1] that involves: 1) fixing up to six magnets on the very well machined top plate of the girder system; and 2) installing a so-called mover system for real-time adjustment of the girder. Roughly the same system with some modifications and improvements has been used for the most recently built synchrotron light sources. The girder system should have the following properties:

– easy to install (in terms of handling, pre-alignment, and magnet disassembly for service);
– fast, accurate, and easy to align (not only with three-point support; minimization of clamping effect);
– *Y* and *Z* independent adjustments;
– high stiffness and rigidity;
– the design goal of having the first frequency greater than 50 Hz requires multiple support points (more than three).

All the requirements can be met with the girder system designed for the upgrade of the ESRF, and so it is proposed to make a copy of this system.

The supports of the storage ring magnets and vacuum chambers rely on 85 girders (84 plus one for the injection straight section), including four girders for each of the 16 storage ring cells. Each girder has to support seven to nine magnets, with a layout that can cope with the space constraints and the necessity of having flanges and bellows between the vacuum chambers supported by adjacent girders. The girders are all identical with a length of about 5.1 m.

The girder alignment requirements are 50 µm in both the vertical and the transverse directions; to respect the inter-girder alignment tolerances, a realignment of the girders in the vertical direction will be necessary every six months because of the medium-term displacements of the storage ring floor. For this purpose, each girder should be equipped with a ±5 mm motorized vertical adjustment and a ±5 mm manual transverse adjustment with 5 µm resolution.

Initial efforts have been made to develop a motorized girder system with optimum stability for the new girder systems.

8.2 General design

The girder that meets all the above requirements is based on the concept of the orthogonal heptagon, derived from the orthogonal hexapod. A body in space has six degrees of freedom, so by putting it on six supports, for each of them blocking movement of a point in only one direction and ensuring no rotations, an easily adjustable isostatic system is obtained.

This is the concept used in commercial hexapods on six articulated jacks and in the cam system of Diamond, SLS, Petra III, etc. Unfortunately, this system is not sufficiently stiff to meet our stability requirement. So it was decided to modify it by introducing a supplementary leg in the vertical direction, losing the perfect isostativity but greatly increasing the stiffness. Four motorized supports in the vertical direction, instead of three, permit the adjustment of height, pitch, and roll.

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The two jacks in the transverse direction allow translation in Y, and the yaw and one jack are used for longitudinal adjustment. The hyper-stativity of the system must be managed by adjusting carefully the four vertical legs to ensure that each of them carries its load correctly. The girder itself is made of normal carbon steel. Special attention is given to the welding, which should be continuous and of nearly full penetration type. The layout of the girder system is presented in Fig. 8.1.

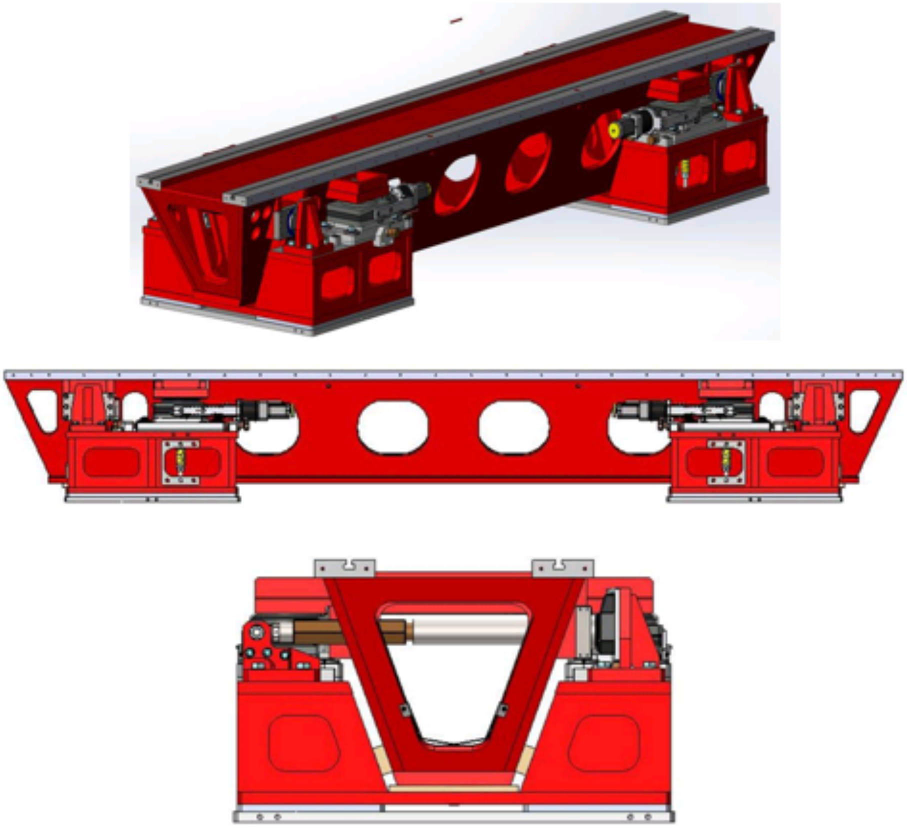

Fig. 8.1: Layout of the ESRF-EBS girder, which would be used for the SEE-LS too

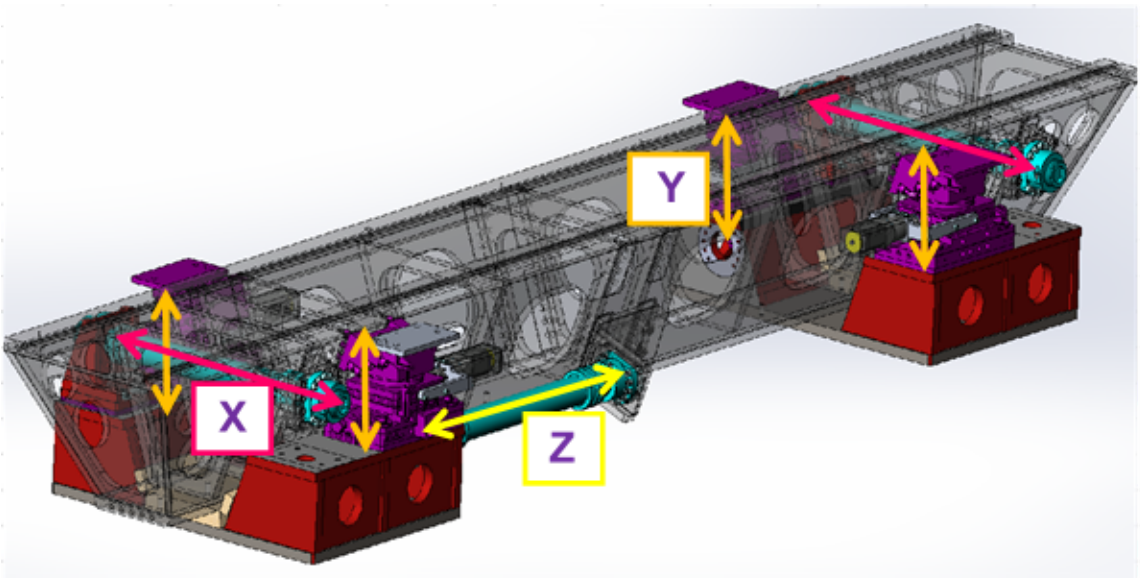

Fig. 8.2: The movement system for adjustments in the three directions

Figure 8.2 shows how the positions in the three directions can be changed with a total of six moving systems. For movement in the vertical system a motorized system is used. More details are presented in Figs. 8.3 and 8.4.

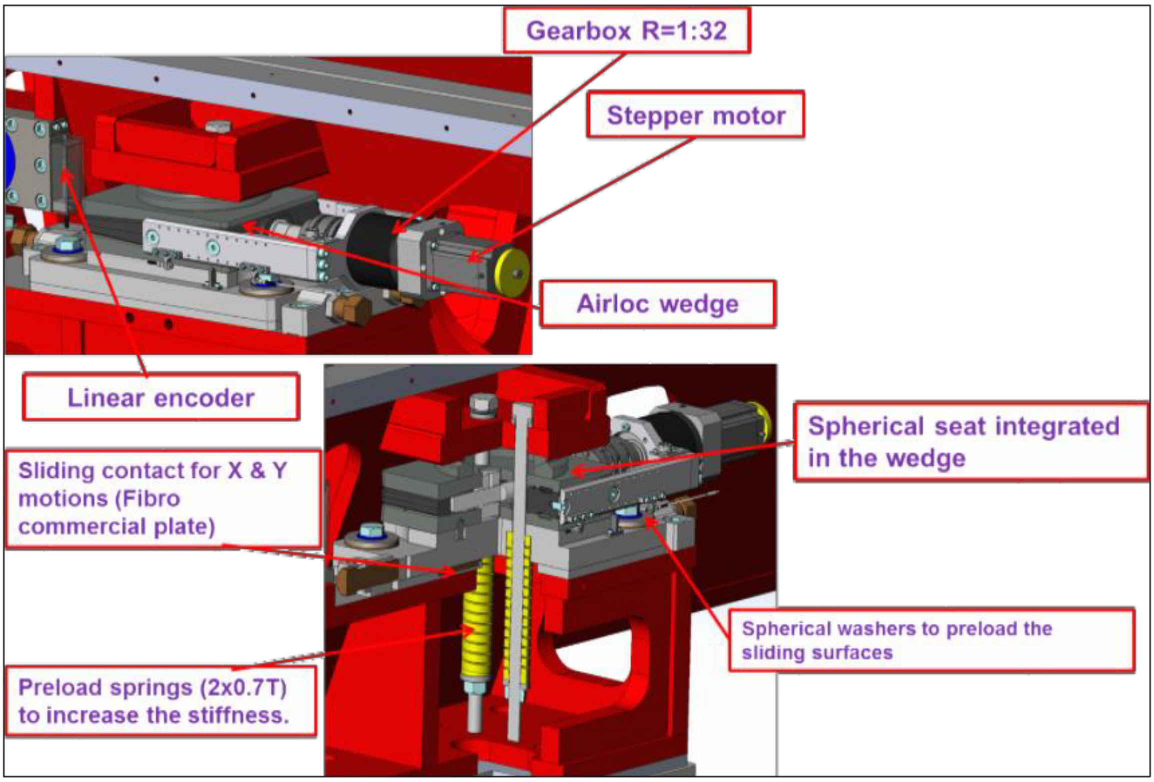

Fig. 8.3: Vertical foot design

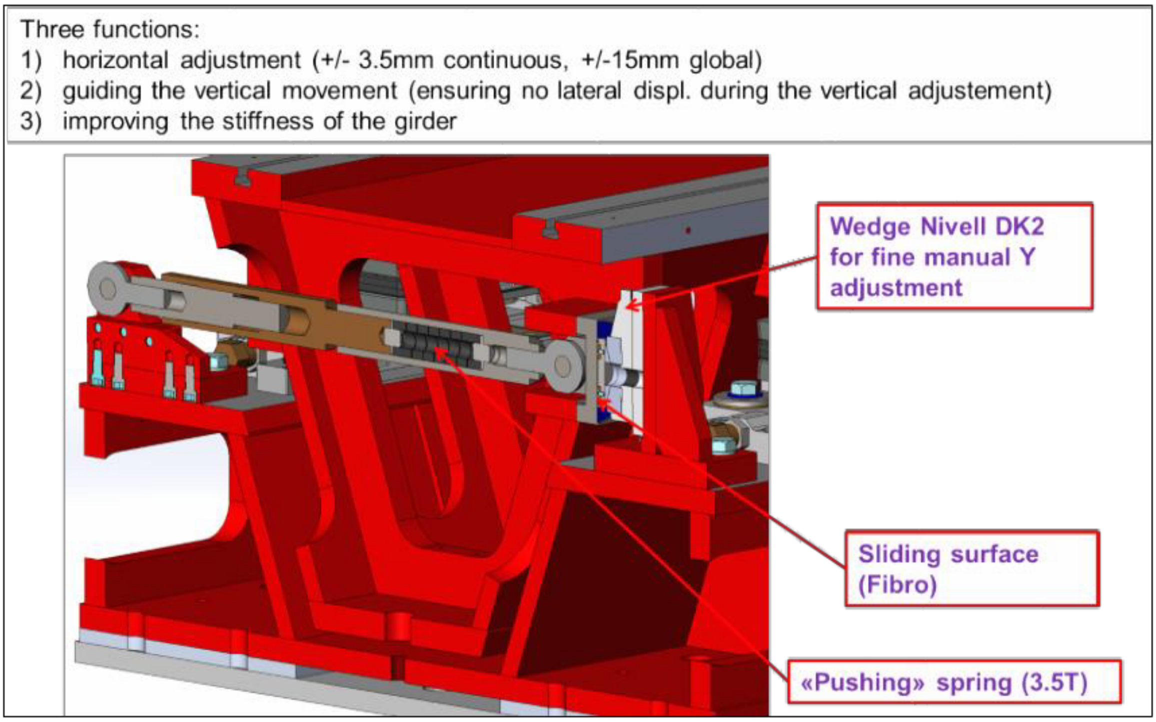

Fig. 8.4: Horizontal foot design

8.3 Girder performance

Vibration measurements and analysis were undertaken on a prototype girder installation (see Fig. 8.5). The initial test was performed on four feet without magnets. Since the results obtained were satisfactory, as the first horizontal mode was above 80 Hz, the tests carried on with measurements on the girder with dummy magnets. In this configuration, the first magnet mode was found at 42 Hz, while the more global first girder mode dropped to 51 Hz. The amplification with respect to the floor vibration level is weak and does not exceed 1 µm peak to peak. Therefore, the prototype girder's behaviour complies with the vibration specifications.

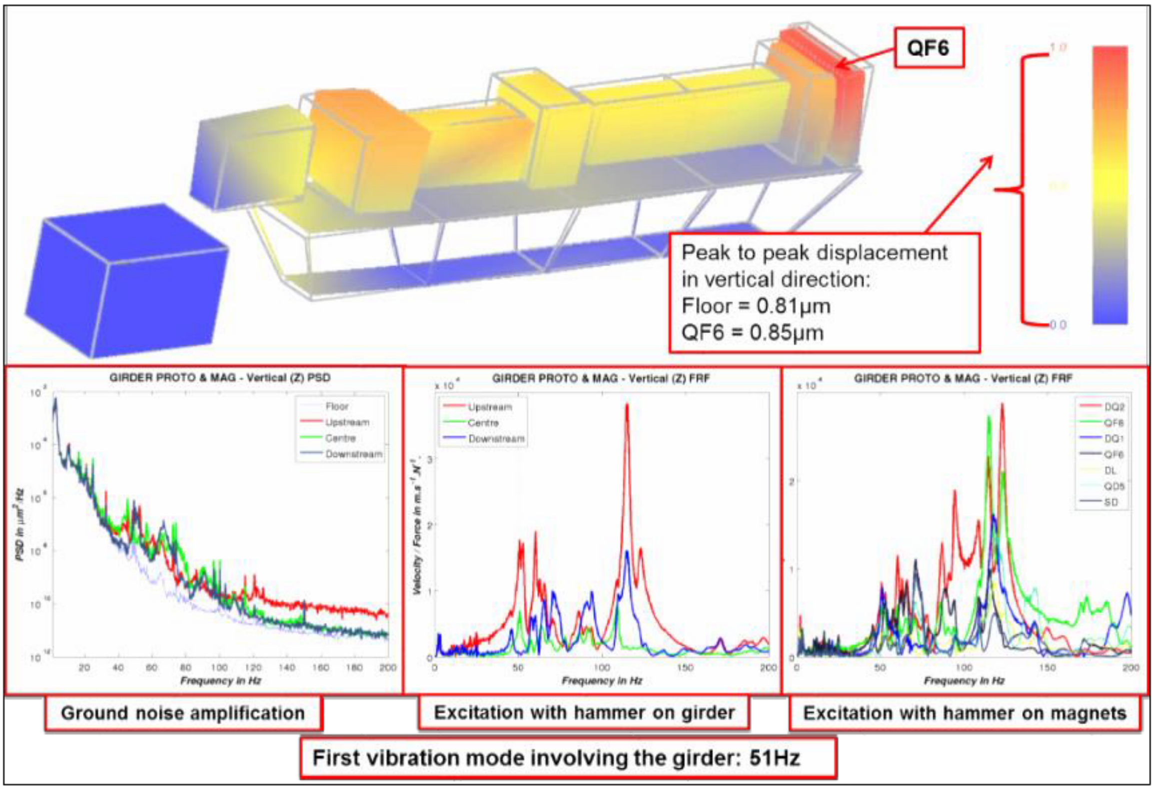

Fig. 8.5: Prototype girder vibration analysis results

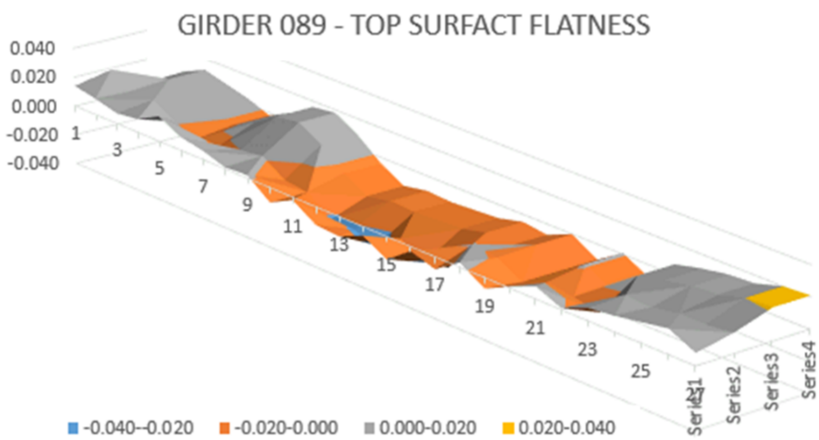

Fig. 8.6: Flatness of the upper plate of the girders

8.4 Locations of magnets on the girders

The locations of the different magnets on the girders are presented in Figs. 8.7–8.10.

Fig. 8.7: Placement of the magnets of an achromat on the four girders

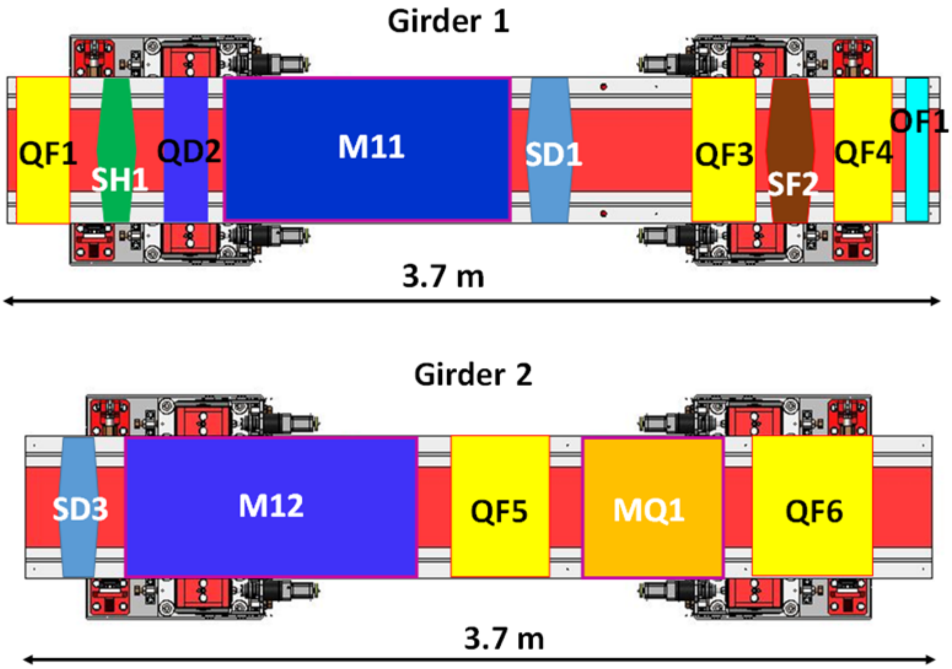

Fig. 8.8: Arrangement of the magnets on girders 1 and 2

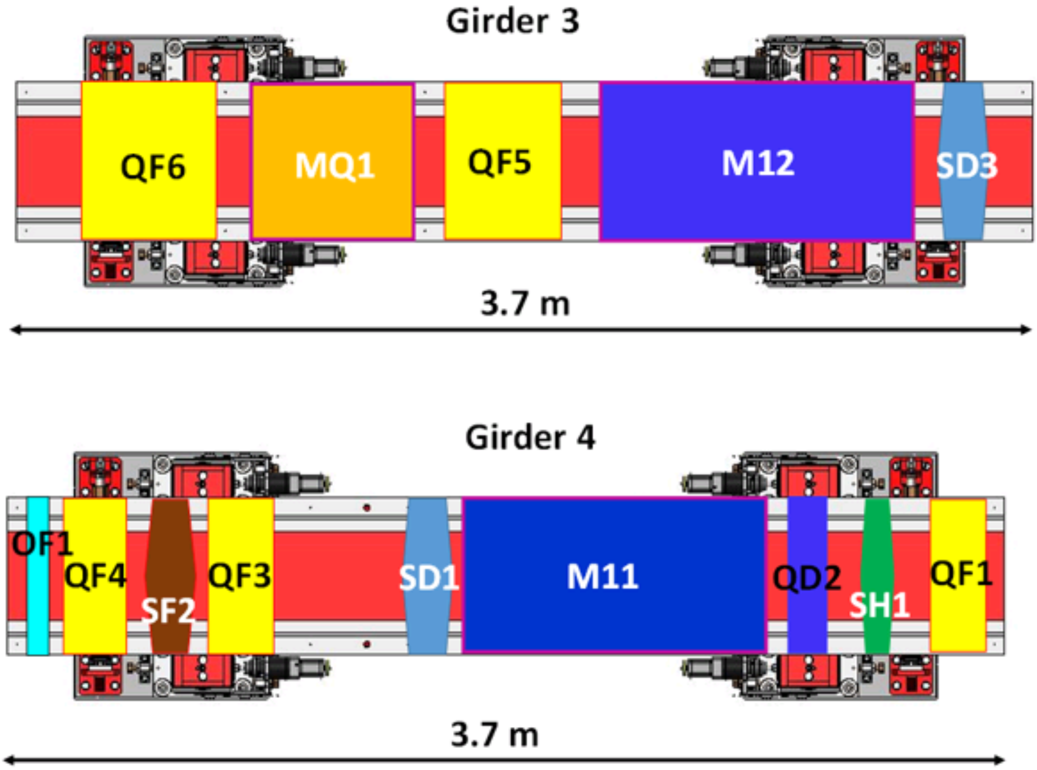

Fig. 8.9: Arrangement of the magnets on girders 3 and 4

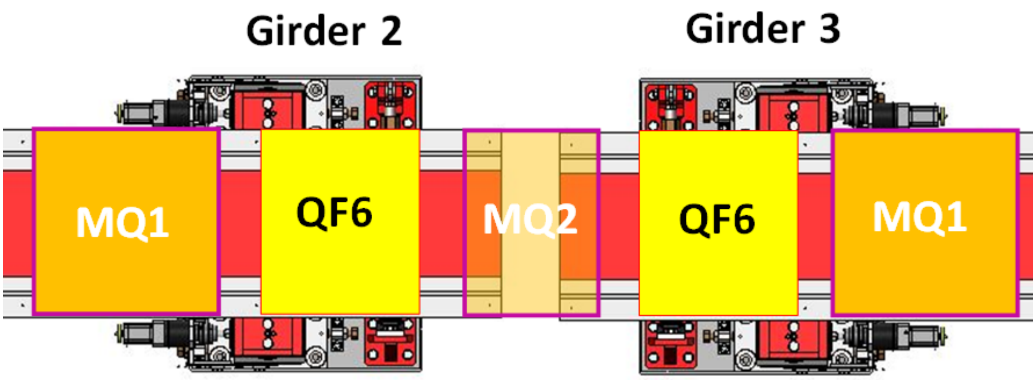

Fig. 8.10: Arrangement of the magnet MQ2 on girders 2 and 3

References

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[8.2] ESRF-EBS project, EBS storage ring technical report (ESRF, Grenoble, 2018), https://web.archive.org/web/20190506105503/https://www.esrf.eu/files/live/sites/www/files/about/upgrade/documentation/Design Report-reduced-jan19.pdf