2014/06/19

1 Loki Bender Optimization summary / status update

1.1 Default guide (proposal)

The Loki guide as described in the proposal (and the given McStas file), named *default* in the following, consists of a 4 m long bender between 2 m and 6 m from the source, with 4 channels and m=4 coating, followed by a 0.25 m constant guide, a 0.45 cm chopper gap, another 2.9 m long constant guide and another 0.6 m chopper gap, 7.8 m exchangable guide (collimation region) and a 2 m gap up to the sample position at 20 m from the source. The guide cross-section is 3x3 cm^2, the coating in the constant guide sections is m=1 or in case of a collimation length L_c >2 m m=0 in the respective last guide section. Apertures are placed at 10 m, 15 m and 18 m from the source as well as directly at the sample position to enable collimation lengths L_c of 10 m, 5 m and 2 m.

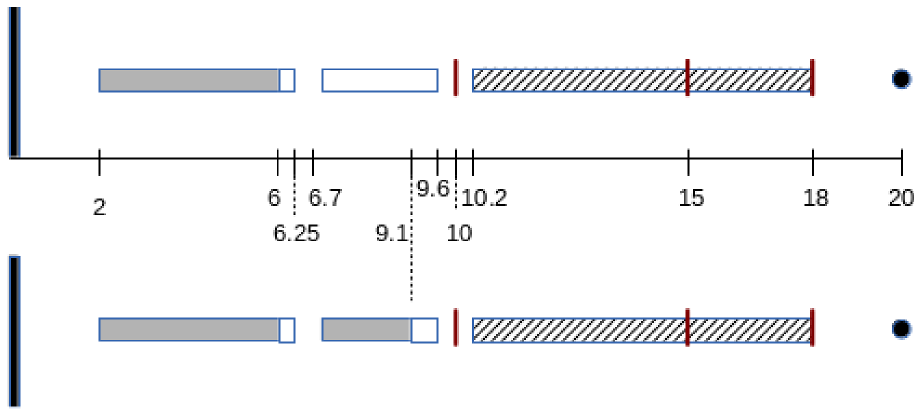


Figure 1: Schematic drawing of default (top) and double bender (bottom): gray sections are bent, striped sections are exchangable m=1 (m=2) or m=0 guide sections.

1.2 Guidelines and simulation details

1.2.1 Line of sight calculation

In the calculation of direct line of sight, the guide width is increased by 5 mm as safety margin. As (super)mirror substrate, copper or comparable material which is intransparent for high energy background is planned to be used at key positions to block direct line of sight, therefore no additional substrate width is taken into account. Following these assumtions, the default Loki guide is out of direct line of sight at 81 cm behind the bender, i.e. 6.8 m from the source.

1.2.2 Assumptions and simplifications used in the simulation

In all simulations and calculations, the substrate width dividing the bender channels (*bladewidth*) was set to 0.5 mm. Note that a this value is the dominant factor in decreasing transmission of long wavelengths.

Guide sections were simulated with pieces as large as possible, and no misalignement was taken into account at this point, nor any other imperfections (e.g. waviness).

1.2.3 Cost estimation

The cost of the benders and guide sections was calculated from the area coated with different supermirrors assuming a radiation hard substrate, the price of which was estimated to be 67.6 kEUR per m^2 for m=1. Higher m values result in the following scaling factors: 1.15, 1.47, 2.0, 2.77, 3.82 for m=2...6, respectively.

The default 4 m long bender with 4 (double-coated) channels and a 3x3 cm^2 cross-section thus results in 162 kEUR, plus a 10.95 m long straight m=1 guide section in total for 90 kEUR.

1.3 Performance avoiding 2x line of sight

Two bender sections are used such that line of sight is avoided once directly after the first, 4 m long bender at 6 m from the source, and a second time at 9.1 m from the source in order to keep a 50 cm long straight guide section after the second bender to remedy potential asymmetries caused by the bending. This leaves 2.4 m of guide length for the second bender section. The radii of the 3 cm wide benders (again including a 5 mm margin) then calculate to R_1=57 m and R_2=37.7 m.

In the following, a given sample size corresponds to the diameter of the sample aperture, and the preceding aperture in use has a diameter twice as large.

For the case of a 1 cm sample size and 2 m collimation length, the maximum intensity on the sample as well as the maximum intensity per cost are optimized both for the whole wavelength band 2-22 Å and for 3 Å (2.5-3.5)[1]. The result for maximum intensity of the whole waveband is the same as for the maximum intensity at 3 Å per Euro (option 1). The maximum intensity

[1]Previously: 2 Å

per Euro for the whole waveband shows a very asymmetric divergence distribution and hence is discarded. The optimization for maximum intensity of 3 Å neutrons is option 2. The third option shown is the optimization of 2 Å neutrons per cost.

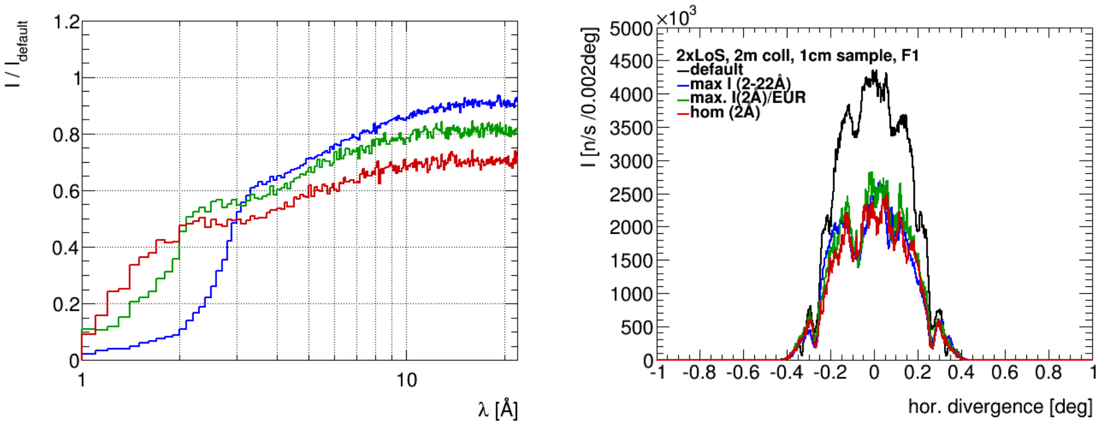
The bender specifications are summarized in table 1, the wavelength and divergence spectra are shown in figure 2 in comparison with the default guide. In general, a higher intensity at short wavelengths has to be paid for by a loss of long wavelength as well as a higher cost.

The spatial beam profile at the sample position is shown in figure 3 (integrated over the whole waveband). A $1\times1\,\mathrm{cm}^2$ square is drawn for orientation, but the sample aperture used is circular with a radius of 5 mm. For both 2 m and 10 m collimation length, the sample area is approximately uniformely illuminated, while for 5 m collimation, a significant displacement of the maximum beam intensity is seen. This has to be further investigated. In the simulation results shown here, the 50 cm long constant guide section after the second bender has been changed to be slightly diverging (linear, guide exit: 3.2 cm) to decrease the divergence, since this has been seen to slightly increase the intensity in the sample area while reducing the background around the sample are.

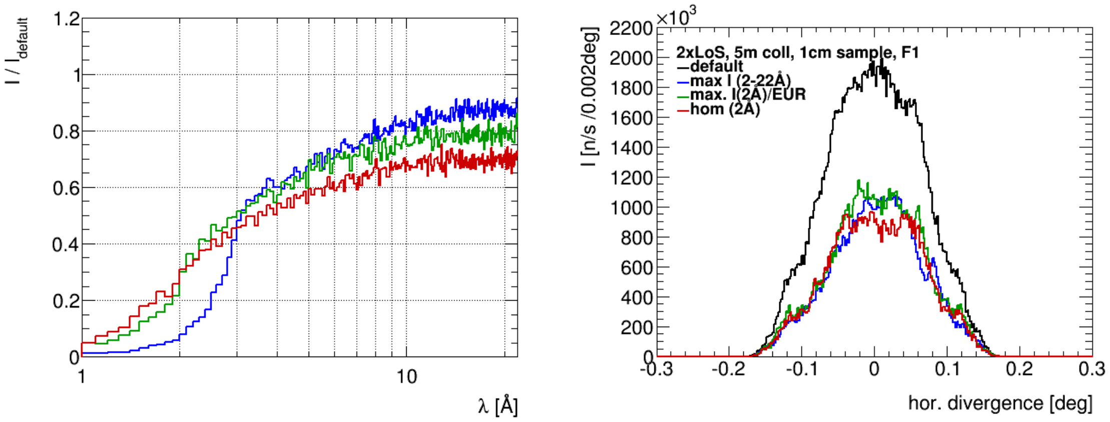
The sample aperture is generally over-illuminated, therefore as an additional option/modification, the last 3 m long guide section used in case of a 2 m collimation length has been changed to be elliptically focussing with a guide exit of 2.1 cm and a focal point at the sample position. The resulting performance is shown in figure 4: the intensity on the sample is increased without significant distortion of the phase space. However, the background hitting the sample aperture is increases as well.

	optimized	Bender 1			Bender 2				sum
option	wavelength	m	N	k€	m	N	k€		k€
1	2-22 Å	6	1	59	3	5	75	same curv.	134
2	3 Å	6	1	59	3	9	126	s-bender	185
3	2 Å	6	2	99	3	10	139	s-bender	238
default		4	4	162	-	-	-		162

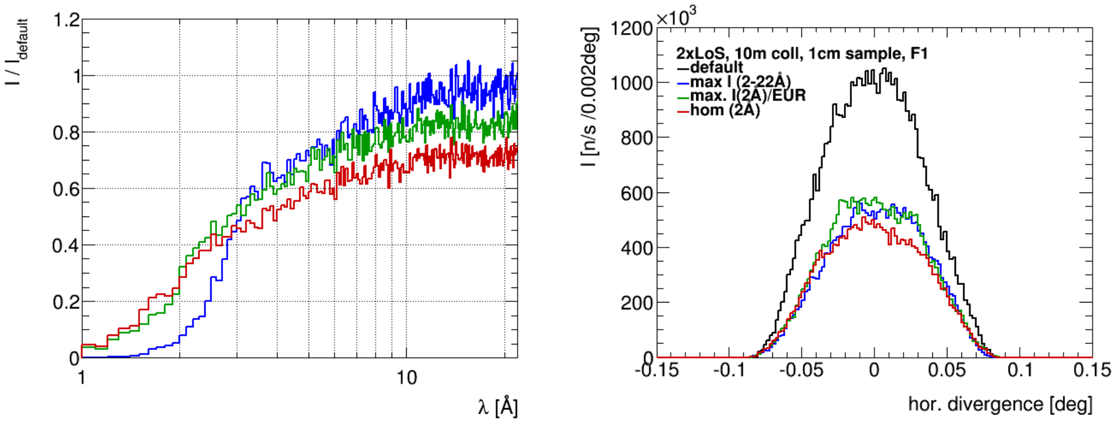
Table 1: Bender costs for selected bender combinations with m-value of coating on top, bottom and outer curved wall reduced to m=2. The default bender has m=4 coating everywhere (which is probably not necesssary). N is the number of channels.



(a) 2 m collimation length

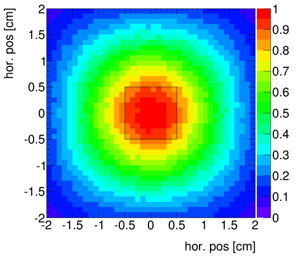


(b) 5 m collimation length

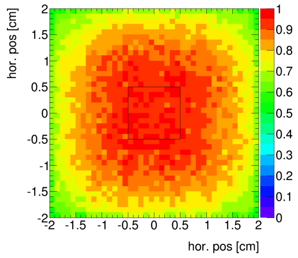


(c) 10 m collimation length

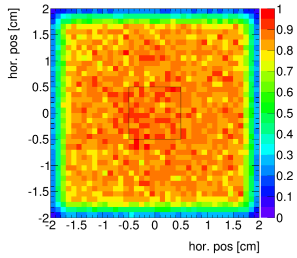
Figure 2: Spectrum wrt default as well as divergence on 1 cm sample for 2, 5 and 10 m collimation



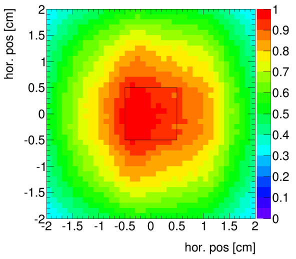
(a) 2 m coll, default



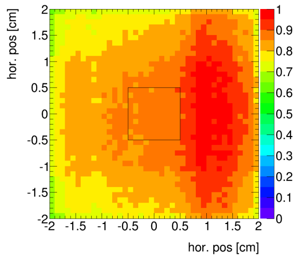
(b) 5 m coll, default



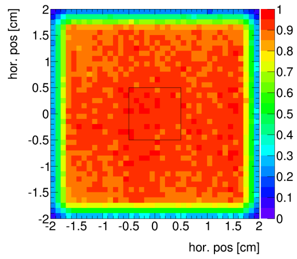
(c) 10 m coll, default



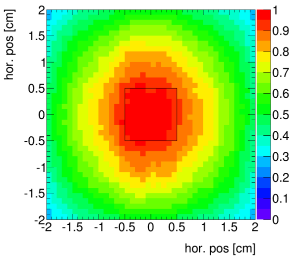
(d) 2 m coll, all



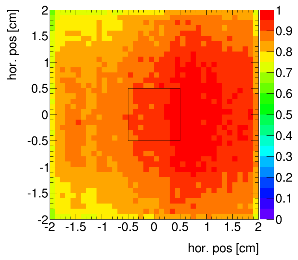
(e) 5 m coll, all



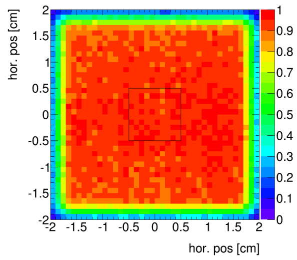
(f) 10 m coll, all



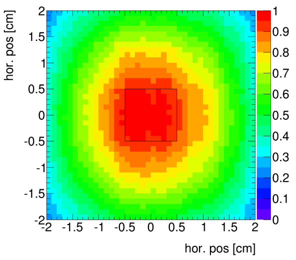
(g) 2 m coll, 3 Å



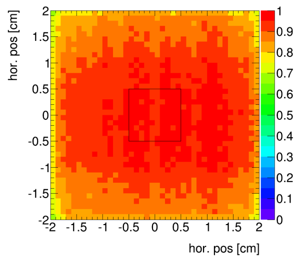
(h) 5 m coll, 3 Å



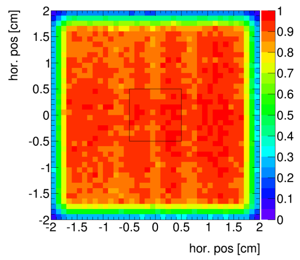
(i) 10 m coll, 3 Å



(j) 2 m coll, 2 Å

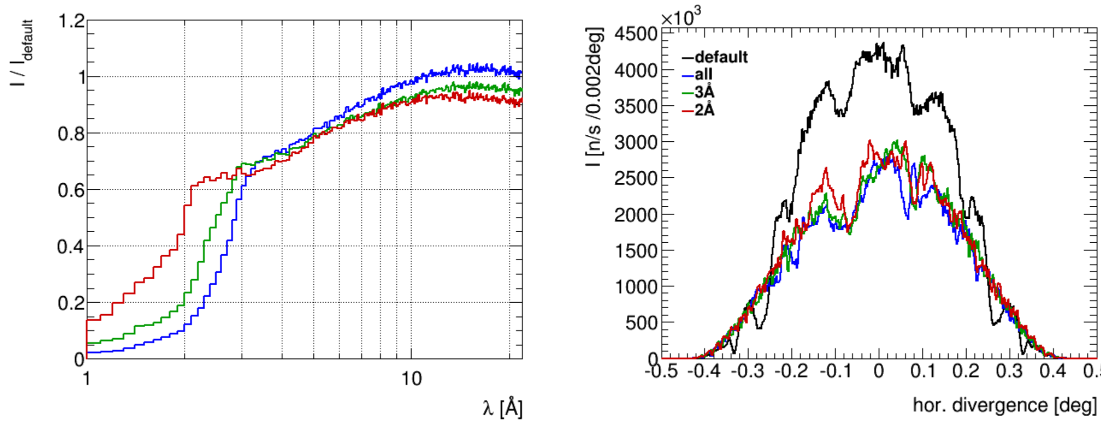


(k) 5 m coll, 2 Å

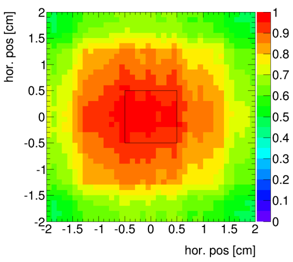


(l) 10 m coll, 2 Å

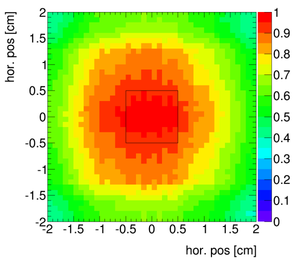
Figure 3: Spatial beam profile at sample aperture for 2, 5 and 10 m collimation (left, center, right) for default (upper line) and with 2x line of sight options



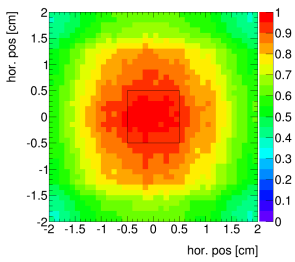
(a) Ff



(b) all



(c) 3 Å

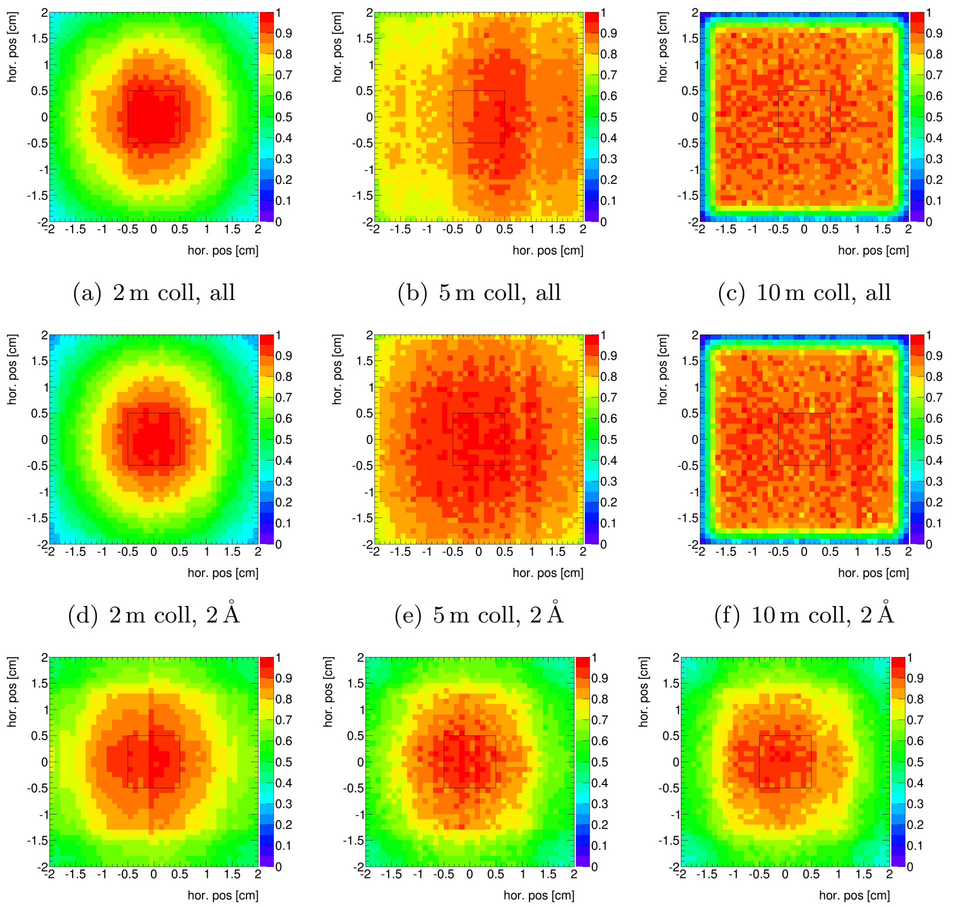


(d) 2 Å

Figure 4: 2 m collimation, with focusing

1.3.1 Spatial displacement for 5 m collimation

The displacements seen in figure 3 have been tried to be corrected for by determining the mean of the divergence distribution after the second bender and inclining the following beamline accordinglty by 0.05°. This procedure improves the spatial distribution for 5 m collimation in case of the first option (whole wavelength band optimization), but does not completely cancel the offset, see first line in figure 5. A further inclination increases the offset again. In case of the 3 Å optimization, such an inclination does not change the result at all (therefore not shown in figure 5), while in case of the 2 Å optimization, the spatial homogeneity also doesn't change much but there is somewhat less background around the sample aperture, see second line in figure 5. A slight asymmetry is introduced if option 1 is used with 2 m collimation and a focusing guide end, see bottom line of figure 5.



(a) 2 m coll, all (b) 5 m coll, all (c) 10 m coll, all

(d) 2 m coll, 2 Å (e) 5 m coll, 2 Å (f) 10 m coll, 2 Å

(g) all, 2 m coll, focusing (h) 3 Å, 2 m coll, focusing (i) 2 Å, 2 m coll, focusing

Figure 5: Spatial beam profile with inclination after second bender.

1.4 Next steps

1. Check what part of the moderator surface is used (how large) in order to determine how much the whole beamline might be inclined (for less horizontal offset of the sample / detector)
2. Show performance loss when an s-bender is used in option 1
3. Effect of misalignment vs. effect of misalignment prevention (backwards height increase)