Report on 2-lens focusing system for DMC

This document summarizes some information on the simulation and design phases of a coupled 2-lens neutron focusing system, to be used/tested on the DMC instrument at SINQ. The two lenses are a so-called "quasiadaptive" lens (the main focusing lens), to be placed outside (and as close as possible to) the cryostat (which also includes a pressure cell), and a second, smaller in size, so-called "cryo" lens, to be placed inside the cryostat and right before the sample that resides in the cryostat. In agreement with the DMC instrument scientinst, it was decided that the set up has to be optimized for a <u>wavelength of 4.5 Å.</u>

We decided to investigate both elliptic and parabolic shapes for the lenses, in order to compare their performances. Constraints, coming mainly from the space available on the instrument/beamline where the lenses would be mounted, put some geometrical restrictions on the designing of the lenses. In particular, because of the internal and external dimensions of the cryostat, the length of the cryo lens could not be larger than 115mm (inner diameter of the pressure cell shell), and the distance between the two lenses could not be smaller than ~68.5mm. In detail, the radius of the inner shell is 115mm and the radius of the exterior of the cryostat is 158.5mm. In addition, the minimum distance between the quasilens exit and the cryostat out shell is ~25mm.

Also, due to the size of the pressure cell, the cryo lens exit should be of about 1.5mm, and the sample position fixed at 13mm after the cryo lens's exit. Moreover, the entrance of the quasiadaptive lens should be around 26mm, due to the size of the monochromator's crystals and the critical angle of the mounted supermirror.

With all the above in mind, we first started by designing two parabolic lenses, that would fullfill the above criteria and furthermore produce a focused beam with highest possible intensity on a sample of $1x1mm^2$. It should be mentioned here that the length of the quasiadaptive lens was fixed to 0.5m (this is the set by manufacturing constraints of some main components of the lens).

Despite the various restrictions mentioned above, we were left with many free parameters that needed optimization, and for each of these optimization steps we had to perform series of "scanning" simulations:

1) Should the two parabolic lenses be two separate parabolas, or should they be parts of one common parabola? We tried out both cases.
2) The focal length of the quasiadaptive lens: for a given entrance height (of 26-30mm) we optimized for a focal length that would give the highest intensity on the sample position, without the presence of the cryo lens. That of course fixed the exit size of the quasiadaptive lens.

3) The focal length of the cryo lens was optimized also by a series of scans, to determine the highest intensity at sample position, given its fixed length and exit size.
4) We had a small freedom of moving the cryo lens by a few mm (~5mm) along the neutron beam and towards the direction of the quasiadaptive lens. That was definitely used in our optimization procedure.
5) Investigate whether a flat or curved monochromator should be used.
6) In the case of a curved monochromator, optimize its curvature radius on the vertical plane.

The above mentioned procedure was followed when we switched to designing elliptic lenses. After comparing the best-performing parabolic case with the best-performing elliptic case, we desided to use elliptical lenses. The reason for that was not only the small increase in gain factor, but also the fact of obtaining a nicer defined intensity peak right on the sample position (see Figures 1 and 4).

In the following Tables and Figures we present our optimized designs both for parabolic and elliptic lenses.

Optimized parabolic lenses

Tables 1 and 2 summarize the lenses' characteristics and some relevant distances in the setup. Figure 1 show 2D neutron instensity distributions of the beam before and after the lenses-system. Based on our simulations, the gain factor (i.e., ratio of intensity on a 1x1mm sample, with and without lenses) of the two-lens system is ~3.2 (assuming an optimaly focusing monochromator).

Table 1: Parabolic lenses' characteristics

	Quasiadaptive Lens	Cryo Lens
length [mm]	500	105
y_{entr} [mm]	27	6.6737.04
y_{exit} [mm]	15.38	1.5
f_2 [mm]	240	5

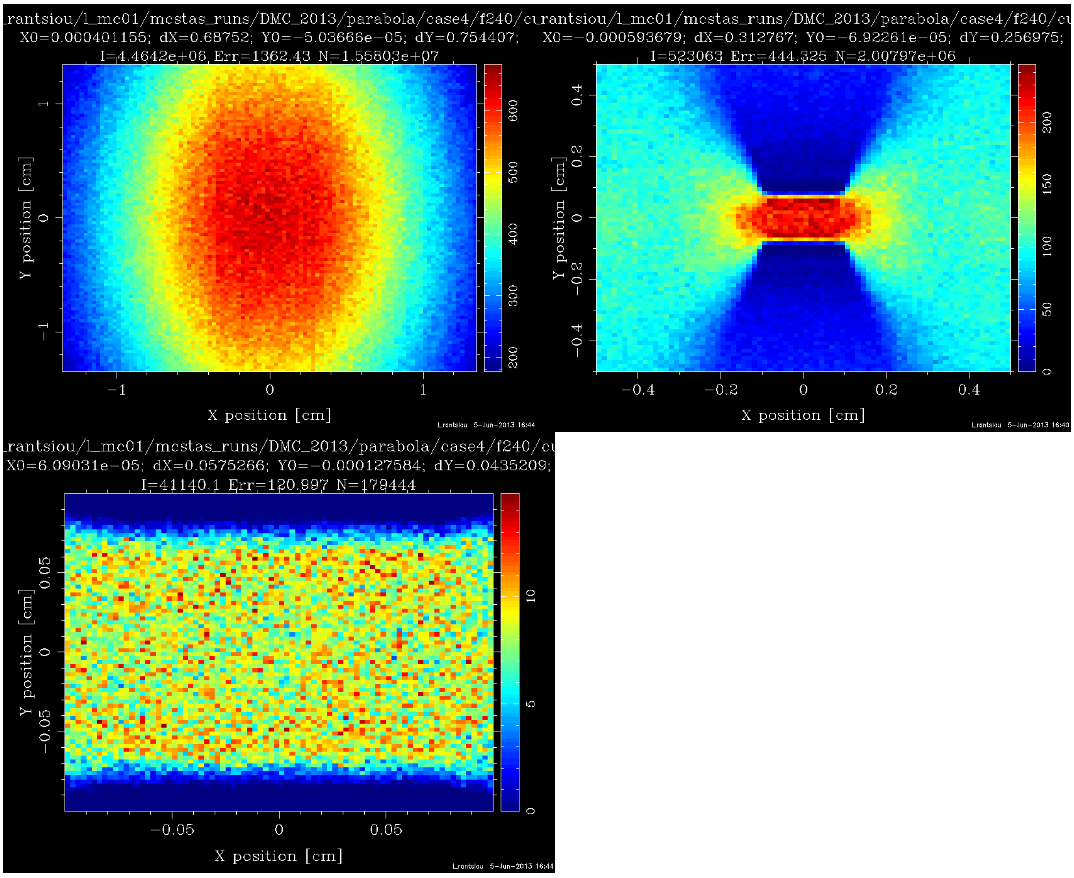
Table 2: Relevant distances for optimized parabolic lenses setup

Relevant distances [mm]

monochromator center to quasi entrance	1340
quasi exit to cryo entrance	82
cryo exit to sample center	13

Figure 1

Upper left: 2D Neutron intensity distribution at the entrance of the quasiadaptive lens. Upper right: 2D neutron intensity distribution of $1x1cm^2$ area at the sample position. Lower left: 2D neutron intensity distribution of $2x2mm^2$ area at the sample position.



Optimized elliptic lenses

After thorough examination and a series of simulations, we ended up with the following set-up for DMC's lenses: two elliptic lenses with characteristics as summarized in Table 3.

A schematic representation of the set-up is given in Figures 2 and 3, and some information on the positions of the two lenses are given in Table 4. Figure 4 show 2D neutron intensity distributions of the beam before and after the lenses-system.

Based on our simulations, the gain factor (i.e., ratio of intensity on a 1x1mm sample, with and without lenses) of the two-lens system is ~3.5 (assuming an optimal focusing monochromator).

Table 3: Elliptic lenses' characteristics

	Quasiadaptive Lens	**Cryo Lens**
length [mm]	500	90
y_{entr} [mm]	26	6.673
y_{exit} [mm]	14.8099	1.545
f_1 [mm]	2e6	7e3
f_2 [mm]	240	5

Figure 2: Schematic DMC set-up, from monochromator to detector. The two lenses are also in green (quasiadaptive lens) and light blue (cryo lens).

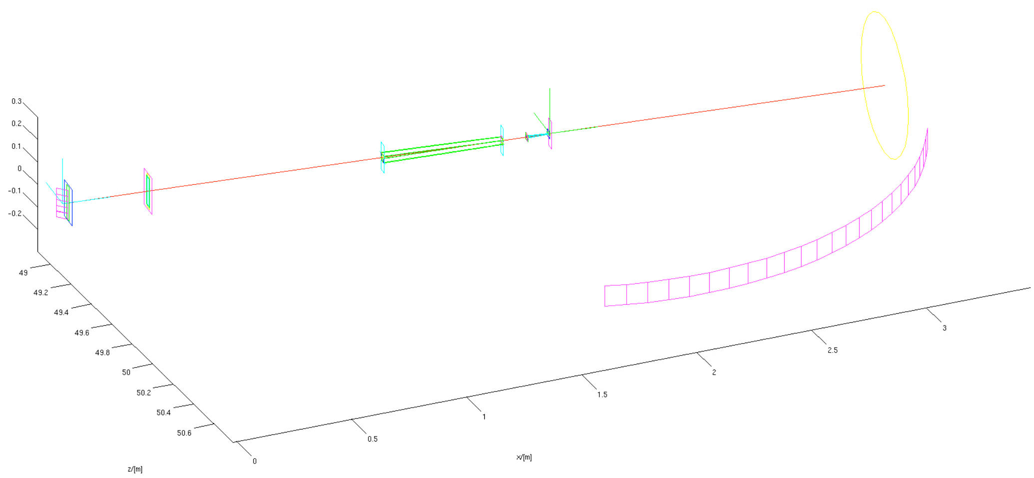


Figure 3: A close up on the two lenses from Figure 1

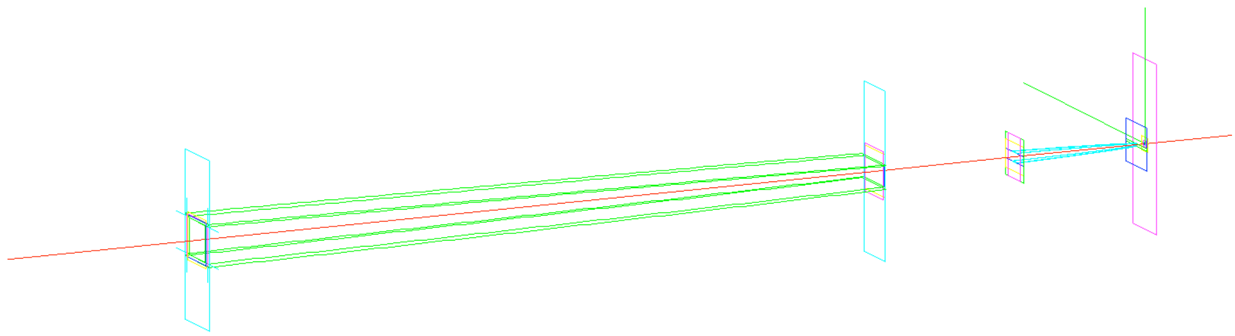
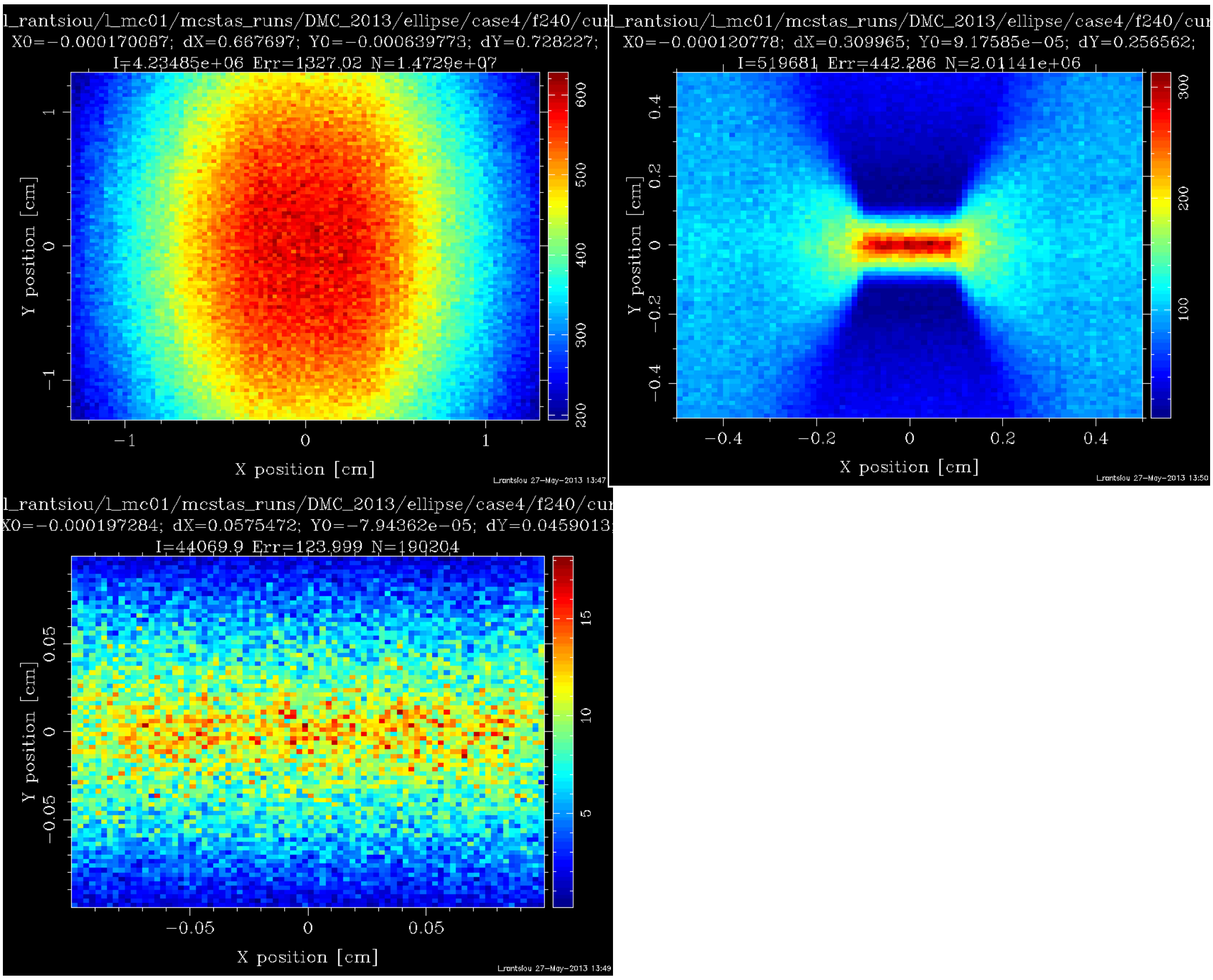


Table 4: Relevant distances for optimized elliptic lenses setup

Relevant	distances [mm]
monochromator center to quasi entrance	1340
quasi exit to cryo entrance	92
cryo exit to sample center	18

Figure 4

Upper left: 2D neutron intensity distribution at the entrance of the quasiadaptive lens. Upper right: 2D neutron intensity distribution of $1x1cm^2$ area at the sample position. Lower left: 2D neutron intensity distribution of $2x2mm^2$ area at the sample position.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