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Advanced Virgo design: Layout for the non-degenerate Recycling Cavities

VIR-xxxA-09

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0.1 Common parameters

In all cases the input mirror substrate is 20 cm thick, the BS substrate is set to be 5 cm thick. Further, the beam parameter given below have been computed from the eigenmode of the PRC in sagittal direction (the tangential parameters are in general different).

The eigenmode is matched to the eigenmode of the arm cavity which is given by: $L = 3000$ m, IM-ROC= 1416 m, EM-R2= 1646 m which yields $q = 1382.573 + 214.9768i$ inside the arm cavity inpinging on IMX and $q = 1399.894 + 150.1556i$ just inside the IMX substrate.

It should be noted that all the following values for radii of curvatures and the respective beam parameters are example solutions. We have used to following criteria for choosing these over many possible others:

- the eigenmode of the NDPRC is matched to the arm cavity eigenmode (in the sagittal plane at least)
- the absolute radii of curvatures of PRM2 and PRM1 are to be as large as possible
- the beam size on PRM1 is to be as large as possible

1 NDPRC Option 1: preliminary design, lenses in input mirror substrates

Design as published in VIR-089A-08. The angle at PRM3 is about 2.5 deg. The angle of PRM2 is about 3.5 deg.

Space	rough distance [m]
IMx - BS	6.26
BS - PRM3	10.7
PRM3 - PRM2	4.5
PRM2 - PRM1	4.5
TOTAL	25

Table 1: Lengths in the preliminary NDPRC design.

Please note the fact that the angles are different occurs from the wish to displace PRM2 as little as possible from the center of the PR-tank.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10.80	NaN	33.00	-1.95	1.96
w [mm]	55.4	41.2	17.1	2.36	1.67
w0 [mm]	0.151	0.151	0.103	0.386	0.386
z [m]	-24.6	-18.3	-5.22	-2.65	-1.85

Table 2: Option 1: Mirror curvatures and beam parameters for Gouy phase of 160 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10.80	NaN	38.50	-2.16	-5.59
w [mm]	55.6	41.4	17.2	3.04	1.6
w0 [mm]	0.15	0.15	0.107	0.952	0.952
z [m]	-24.6	-18.3	-5.46	-8.11	3.61
	IMX AR	BS	PRM3	PRM2	PRM1

Table 3: Option 1: Mirror curvatures and beam parameters for Gouy phase of 20 deg.

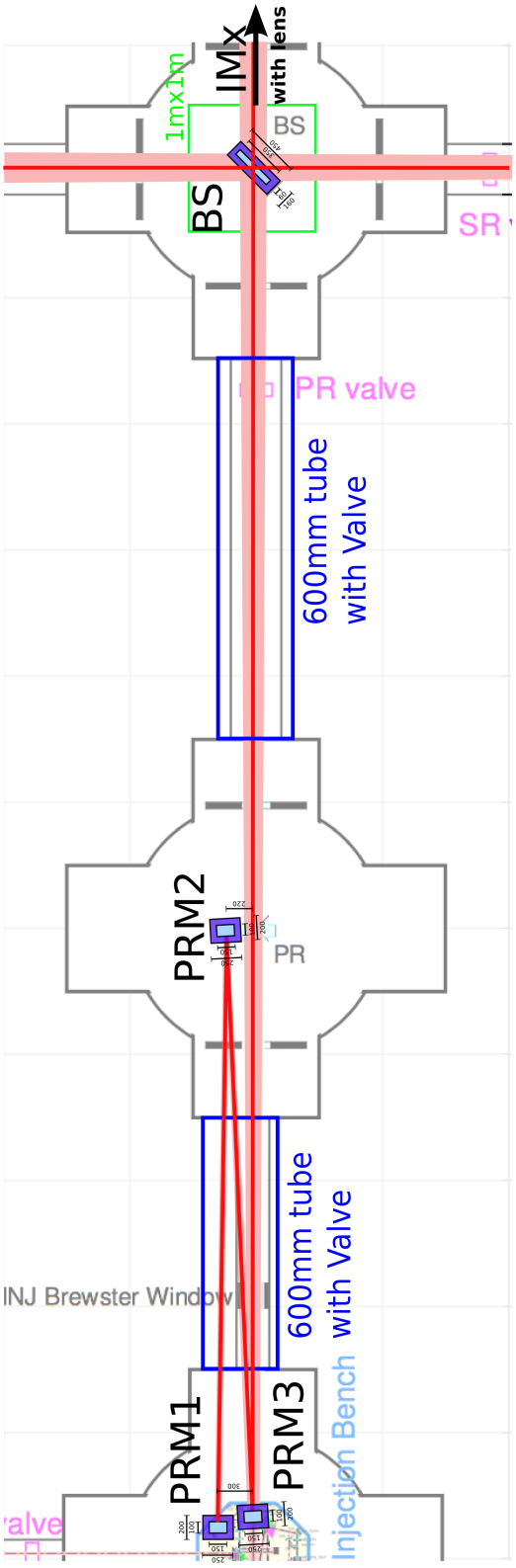


Figure 1: NDPRC preliminary design

2 NDPRC Option 2: no lenses, PRM2 in BS tank

Space	rough distance [m]
IMx - BS	5.5
BS - PRM3	6
PRM3 - PRM2	5.5
PRM2 - PRM1	10.5
TOTAL	28

Table 4: Lengths in the NDPRC design with PRM2 in the BS tank.

The angle for both PRM3 and PRM2 is about 3.3 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10000.00	NaN	12.55	-1.79	1.81
w [mm]	55.5	55.8	56.2	7.24	1.42
w0 [mm]	6.19	6.19	0.0381	0.414	0.414
z [m]	1.01e+03	1.01e+03	-6.31	-8.84	-1.66

Table 5: Option 2: Mirror curvatures and beam parameters for Gouy phase of 160 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10000.00	NaN	12.80	-2.04	-2.03
w [mm]	55.5	55.8	56.2	8.2	1.25
w0 [mm]	6.19	6.19	0.0388	0.505	0.505
z [m]	1.01e+03	1.01e+03	-6.44	-12.2	1.7

Table 6: Option 2: Mirror curvatures and beam parameters for Gouy phase of 20 deg.

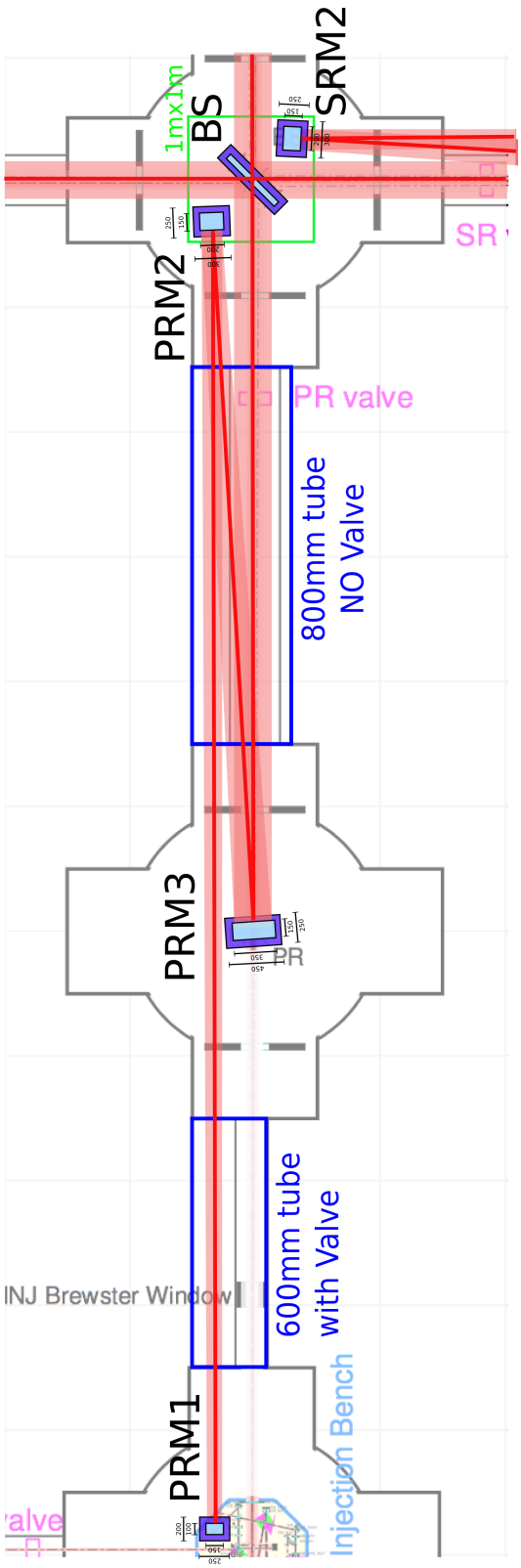


Figure 2: NDPRC design with PRM2 in the BS tank

3 NDPRC Option 3: no lenses, PRM2 in input tanks

Space	rough distance [m]
IMx - BS	6.23
BS - PRM3	6
PRM3 - PRM2	12.05
PRM2 - PRM1	16.87
TOTAL	41

Table 7: Lengths in the NDPRC design with PRM2 in input mirror tank

The angle for both PRM3 and PRM2 is about 1.9 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10000.00	NaN	27.00	-3.75	4.78
w [mm]	55.5	55.9	56.2	6.69	2.49
w0 [mm]	6.19	6.19	0.0824	0.63	0.63
z [m]	1.01e+03	1.02e+03	-13.7	-12.4	-4.48

Table 8: Option 3: Mirror curvatures and beam parameters for Gouy phase of 160 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10000.00	NaN	27.60	-4.23	-7.02
w [mm]	55.5	55.9	56.2	7.78	2.15
w0 [mm]	6.19	6.19	0.0843	0.983	0.983
z [m]	1.01e+03	1.02e+03	-14	-22.4	5.55

Table 9: Option 3: Mirror curvatures and beam parameters for Gouy phase of 20 deg.

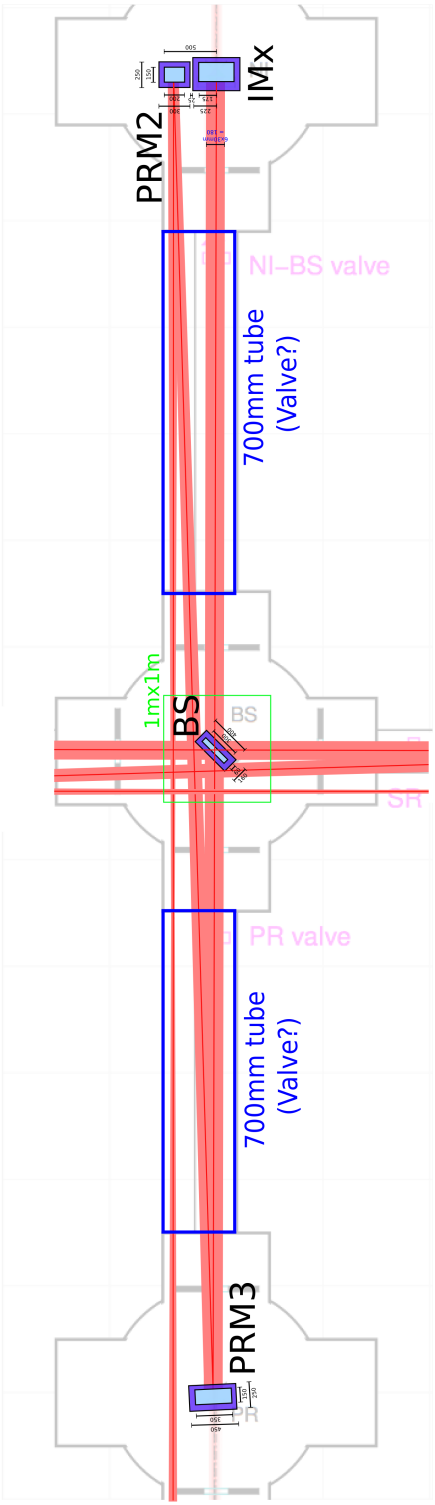


Figure 3: NDPRC design with PRM2 in input mirror tank.

4 NDPRC option 4: the small BS

Space	rough distance [m]
IMx - PRM3	12
PRM3 - PRM2	12
PRM2 - BS	6.5
BS - PRM1	10.5
TOTAL	41

Table 10: Lengths in the NDPRC design featuring a small BS.

The angle for both PRM3 and PRM2 is about 1.9 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10000.00	NaN	27.50	-4.53	4.11
w [mm]	52.5	3.78	53.2	7.39	2.2
w0 [mm]	6.54	0.609	0.0888	0.609	0.609
z [m]	1.01e+03	-6.7	-13.9	-13.2	-3.8

Table 11: Option 4: Mirror curvatures and beam parameters for Gouy phase of 160 deg.

	IMX AR	BS	PRM3	PRM2	PRM1
ROC [m]	10000.00	NaN	28.00	-4.89	-4.84
w [mm]	58.4	6.33	59.1	9.14	1.91
w0 [mm]	5.89	0.783	0.0813	0.783	0.783
z [m]	1.01e+03	-14.5	-14.2	-21.1	4.02

Table 12: Option 4: Mirror curvatures and beam parameters for Gouy phase of 20 deg.

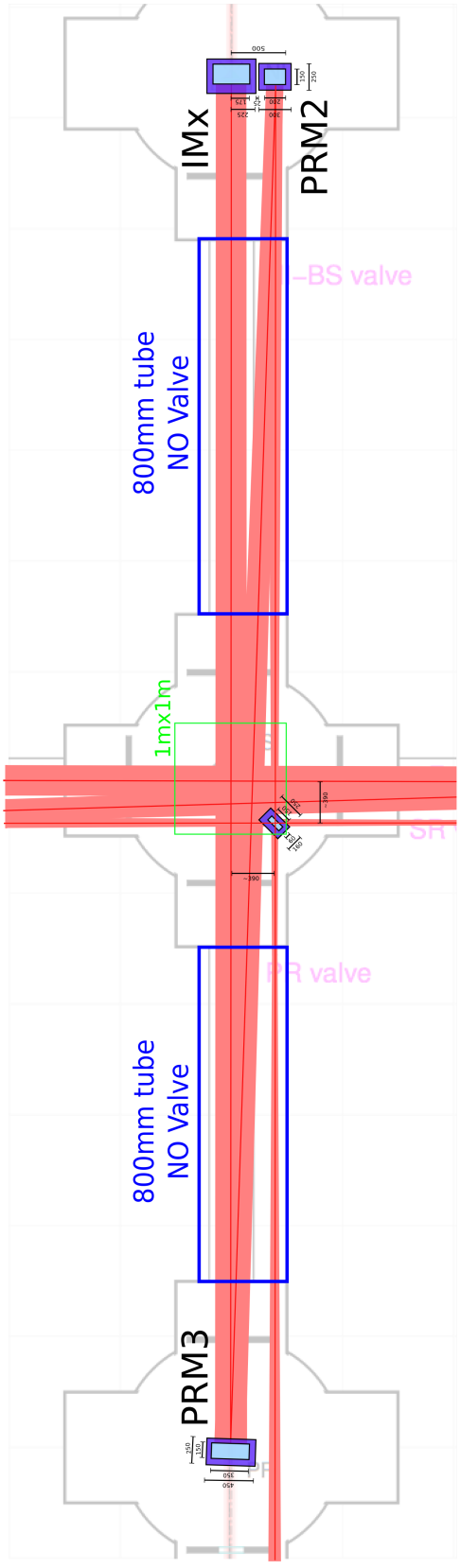


Figure 4: NDPRC design featuring a small BS.

A Tolerancing analysis

The tolerances for length and radii of curvatures listed in the following sections have been computed for the case of a Gouy phase of the eigenmode in the sagittal plane of 160°. The tolerances refer to the change of a *single* parameter such that the Gouy phase remains within the bounds $[150°, 170°]$.

A.1 Option 1

```
      lx L=      6.26, tol=  0.047 ( 0.75%)
   lprm3 L=     10.70, tol=  0.047 ( 0.44%)
   lprm2 L=      4.50, tol=  0.022 ( 0.49%)
   lprm1 L=      4.50, tol=  0.305 (  6.8%)
  prm1 Rcy=      1.96, tol=  0.331 (   17%)
  prm2 Rcy=     -1.95, tol=  0.079 (  4.1%)
  prm3 Rcy=     33.00, tol=   0.43 (  1.3%)
 imxAR Rcy=     10.80, tol=   0.02 ( 0.19%)
   imx Rcy=   1416.00, tol= 102.95 (  7.3%)
```

A.2 Option 2

```
      lx L=      5.50, tol=  38.14 (693.45%)
   lprm3 L=      6.00, tol=  38.36 (639.33%)
   lprm2 L=      5.50, tol=  0.003 ( 0.05%)
   lprm1 L=     10.50, tol=  0.355 ( 3.38%)
  prm1 Rcy=      1.75, tol=  0.413 (23.54%)
  prm2 Rcy=     -1.79, tol=  0.008 ( 0.45%)
  prm3 Rcy=     12.55, tol=  0.007 ( 0.06%)
   imx Rcy=   1416.00, tol= 102.49 ( 7.24%)
```

A.3 Option 3

```
      lx L=      6.23, tol=  37.84 (607.38%)
   lprm3 L=      6.00, tol=  37.39 (623.17%)
   lprm2 L=     12.05, tol= 0.0138 ( 0.11%)
   lprm1 L=     16.87, tol=   0.81 ( 4.80%)
  prm1 Rcy=      4.78, tol=  0.897 (18.76%)
  prm2 Rcy=     -3.75, tol=  0.037 ( 0.99%)
  prm3 Rcy=     27.00, tol=  0.028 ( 0.10%)
   imx Rcy=   1416.00, tol= 102.24 ( 7.22%)
```

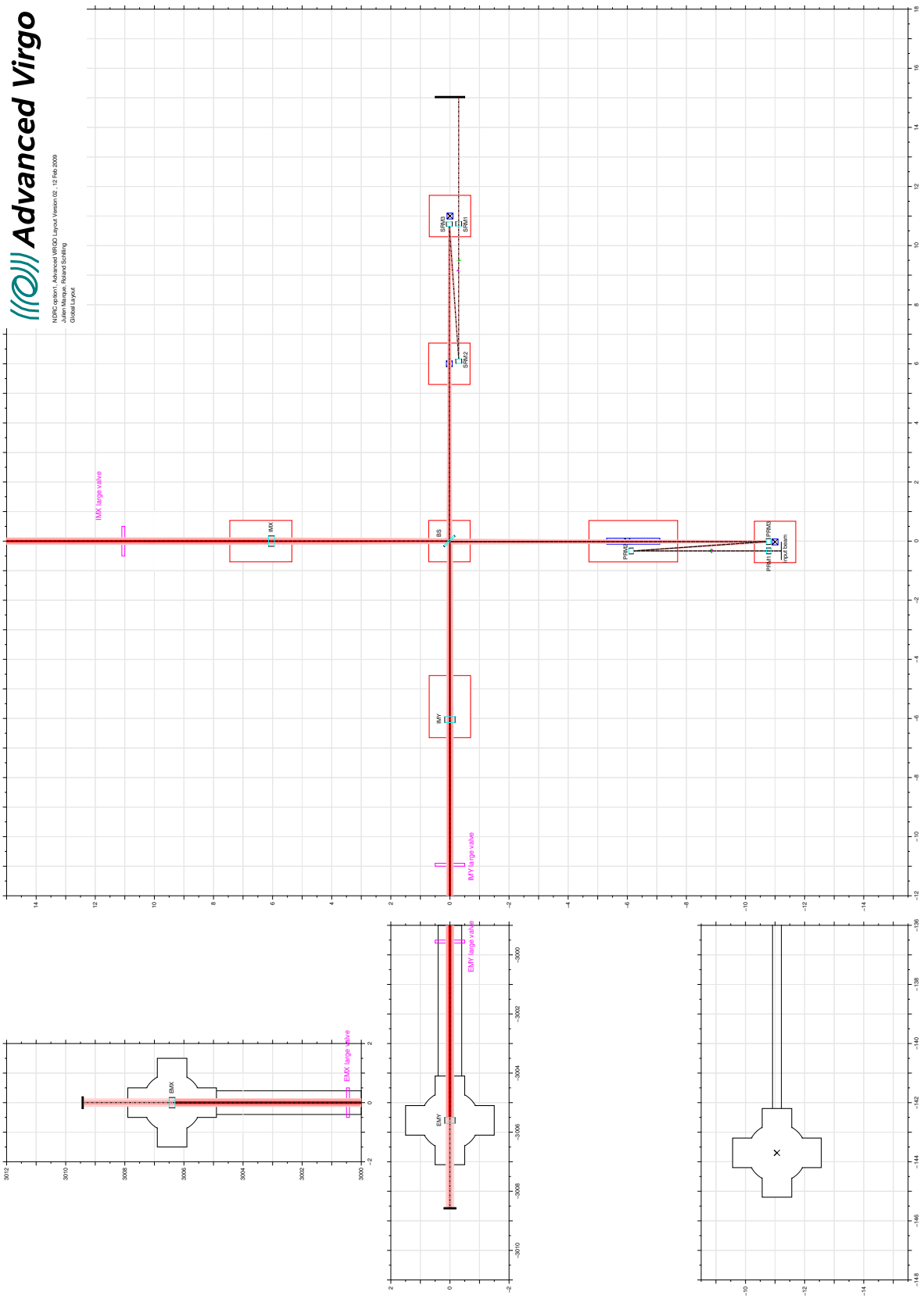
A.4 Option 4

```
      lx L=      6.50, tol=     ??
   lprm3 L=     12.00, tol=     ??
   lprm2 L=     12.00, tol=     ?? These gave <mm tolerances
   lprm1 L=     10.50, tol=     ?? might be an error
  prm1 Rcy=      4.11, tol=  0.856 (20.82%)
  prm2 Rcy=     -4.53, tol=  0.045 ( 0.99%)
  prm3 Rcy=     27.50, tol=  0.032 ( 0.12%)
   imx Rcy=   1416.00, tol= 114.36 ( 8.08%)
```

B OptoCad plots

The following pages show CAD sketches of the design options, created using OptoCad. You can zoom in to see details.

B.1 Option 1



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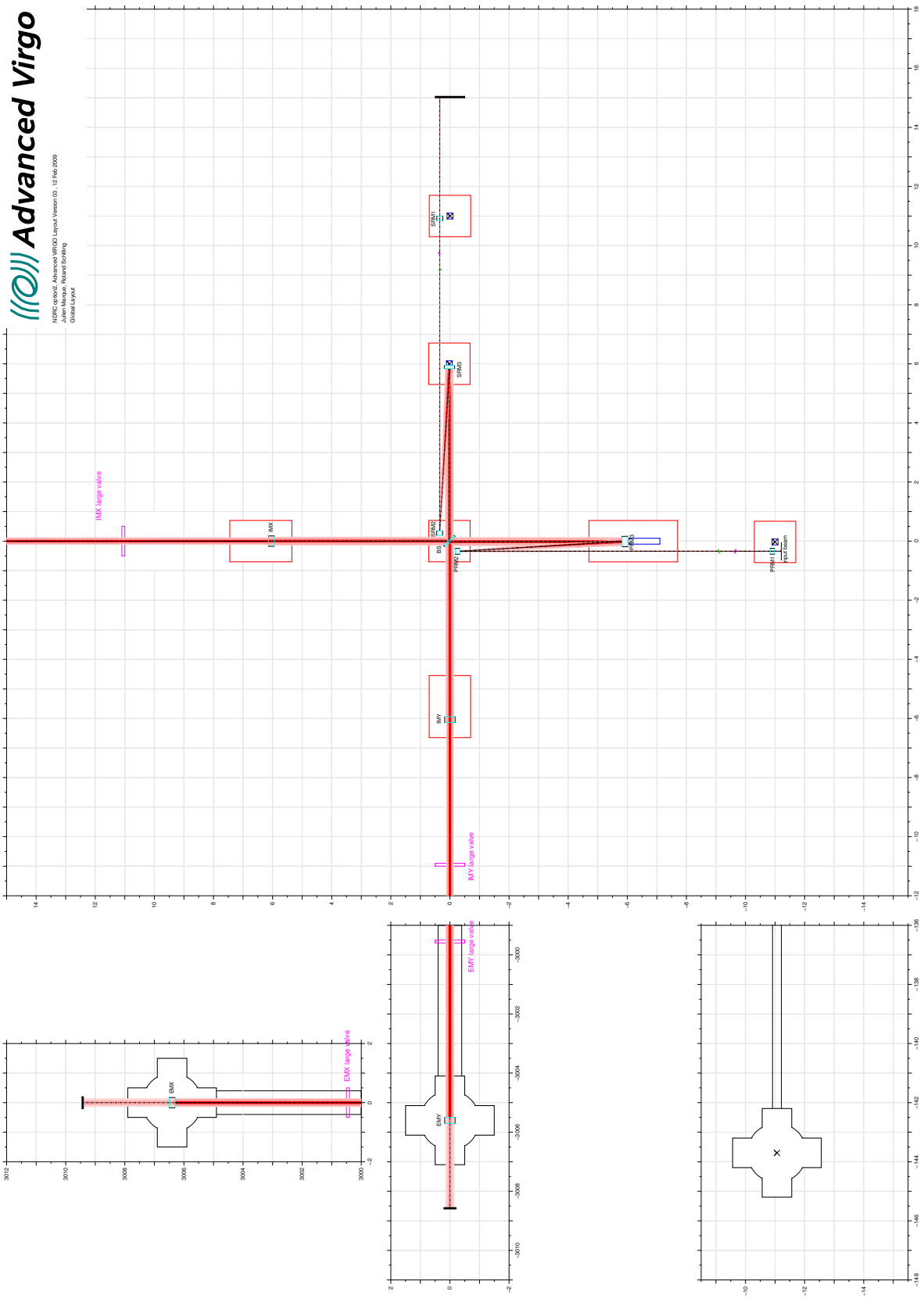
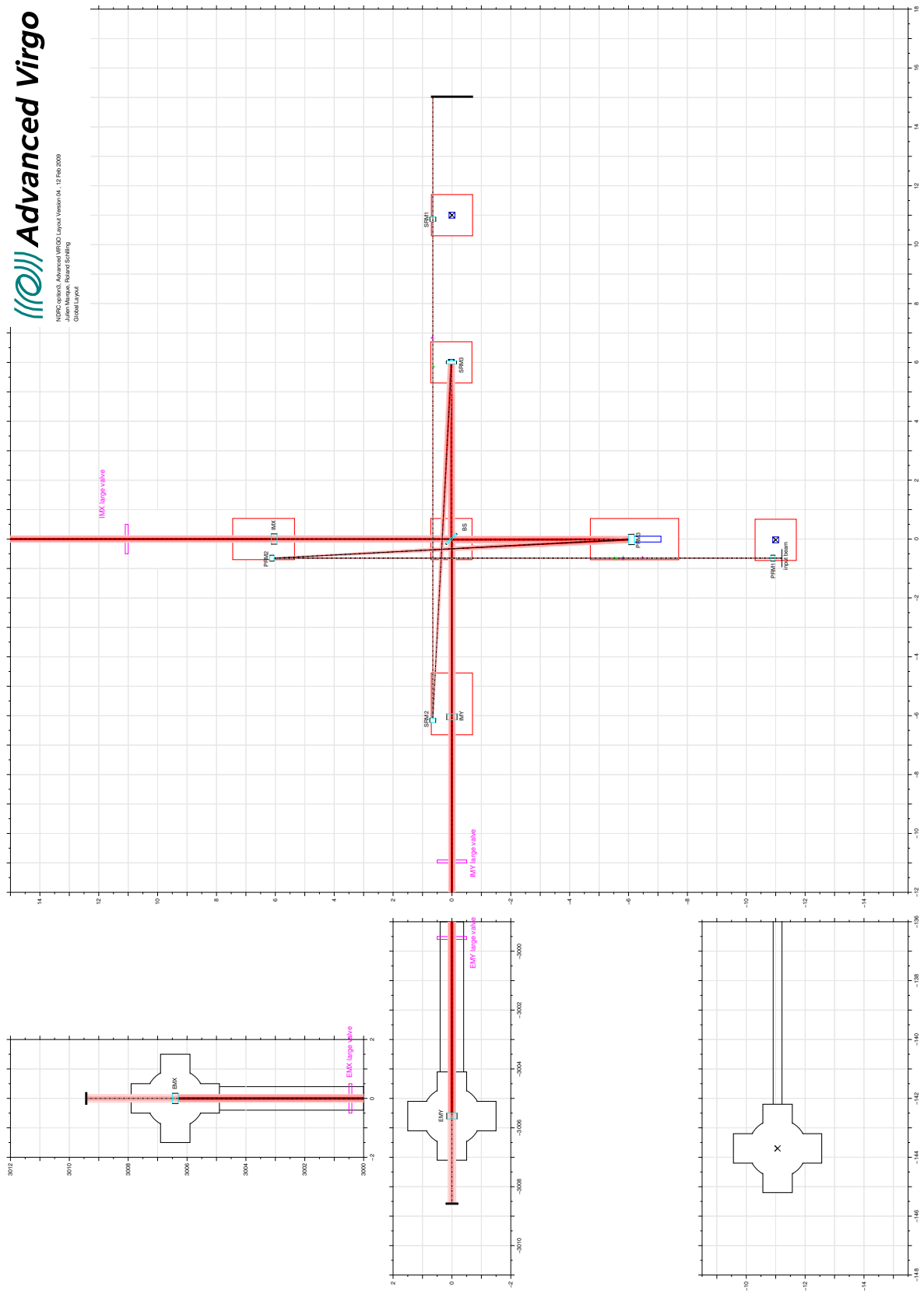
B.2 Option 2


Advanced Virgo
NDRC option2, Advanced VIRGO Layout Version 03. - 12 Feb 2009
Julien Marque, Roland Schilling
Global Layout
IMX large valve
IMY large valve
EMX large valve
EMY large valve
IMX
IMY
BS
PRM2
PRM3
PRM1
SRM1
SRM2
SRM3
Input beam
EMX
EMY

B.3 Option 3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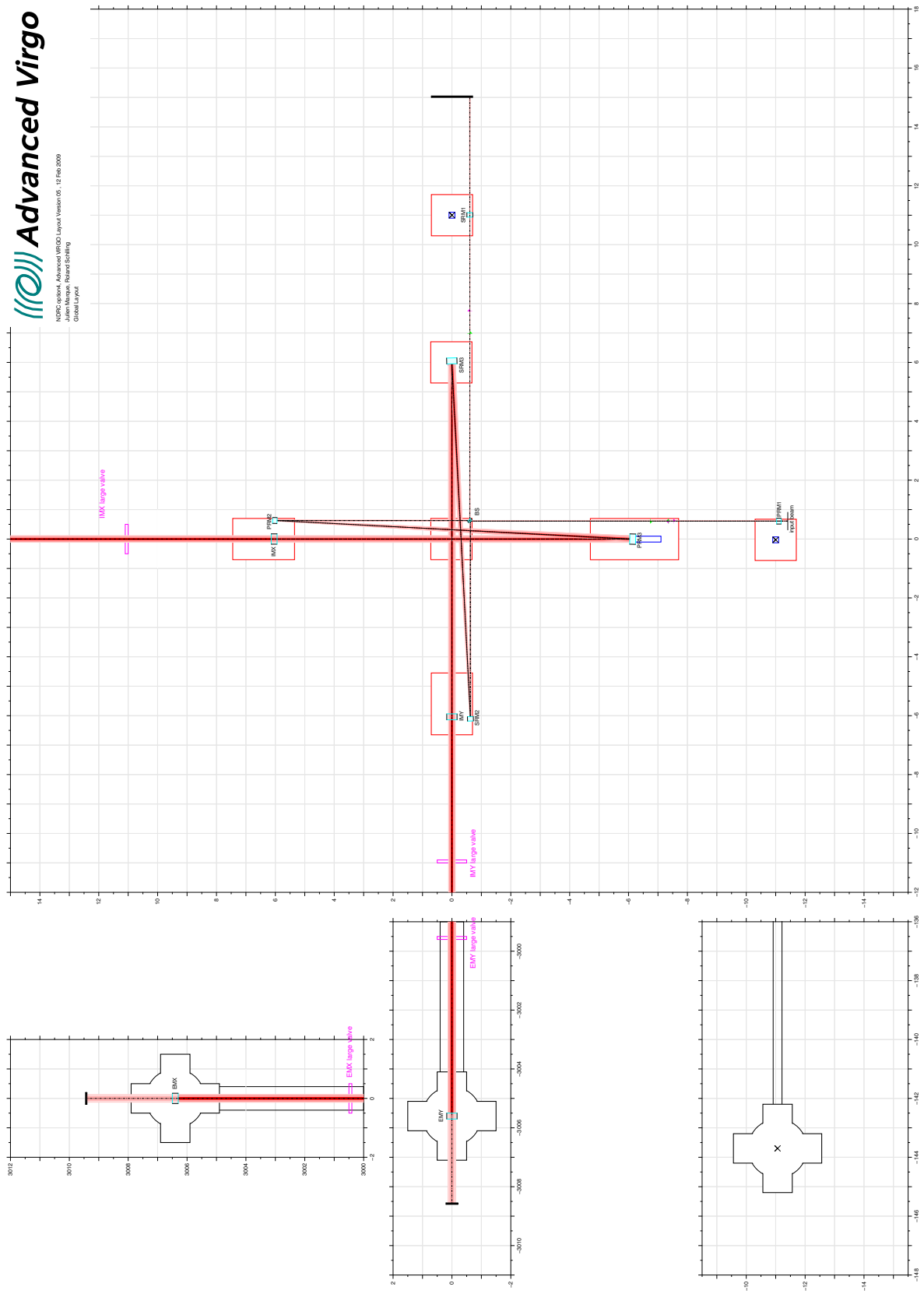
Global Layout
IMX large valve
IMY large valve
EMX large valve
EMY large valve
PRM1
PRM2
PRM3
SRM1
SRM2
SRM3
BS
IMX
IMY
EMX
EMY
input beam

B.4 Option 4


Advanced Virgo
NDRC option4, Advanced VIRGO Layout Version 05 - 12 Feb 2009
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Global Layout
IMX large valve
IMY large valve
EMX large valve
EMY large valve
PRM
PR45
PERM
BS
IMX
IMY
EMX
EMY
SRM1
SRM2
SRM3