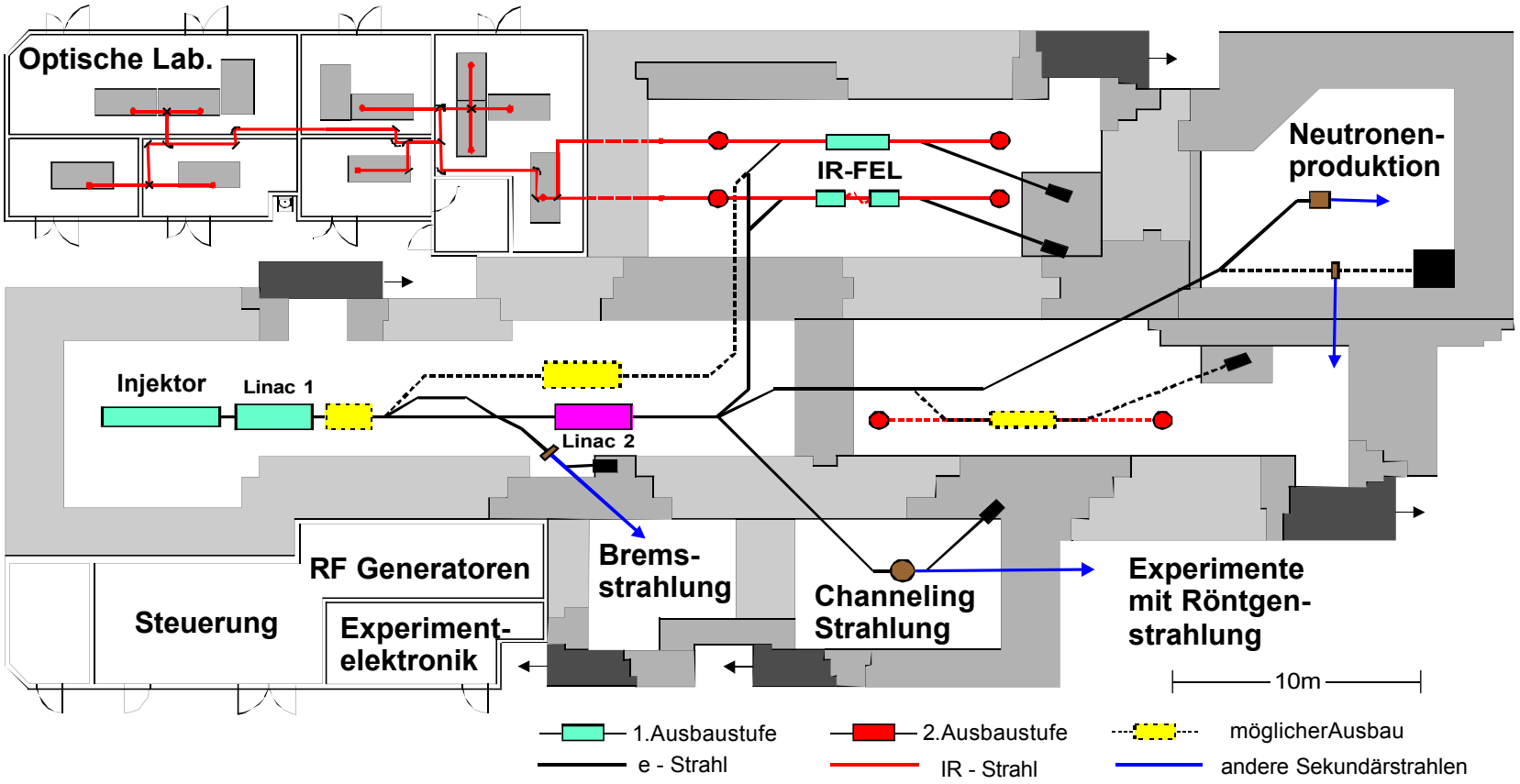
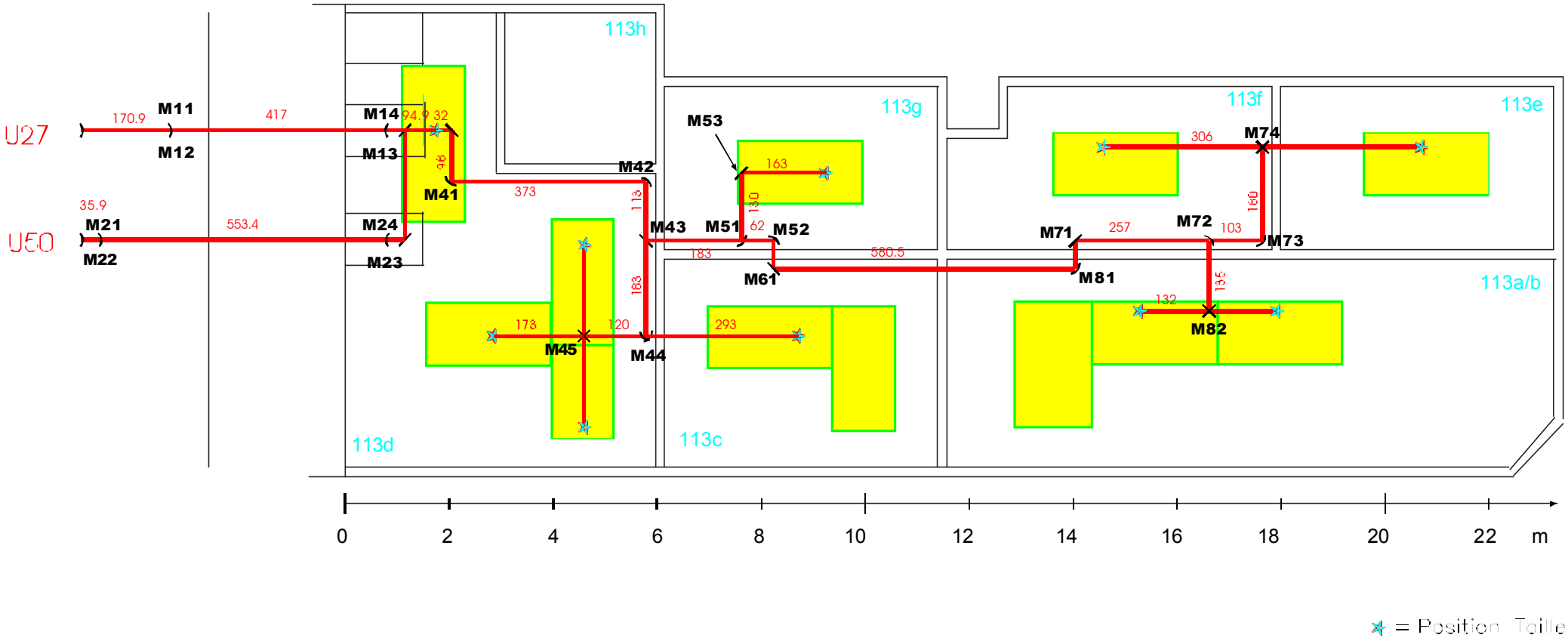
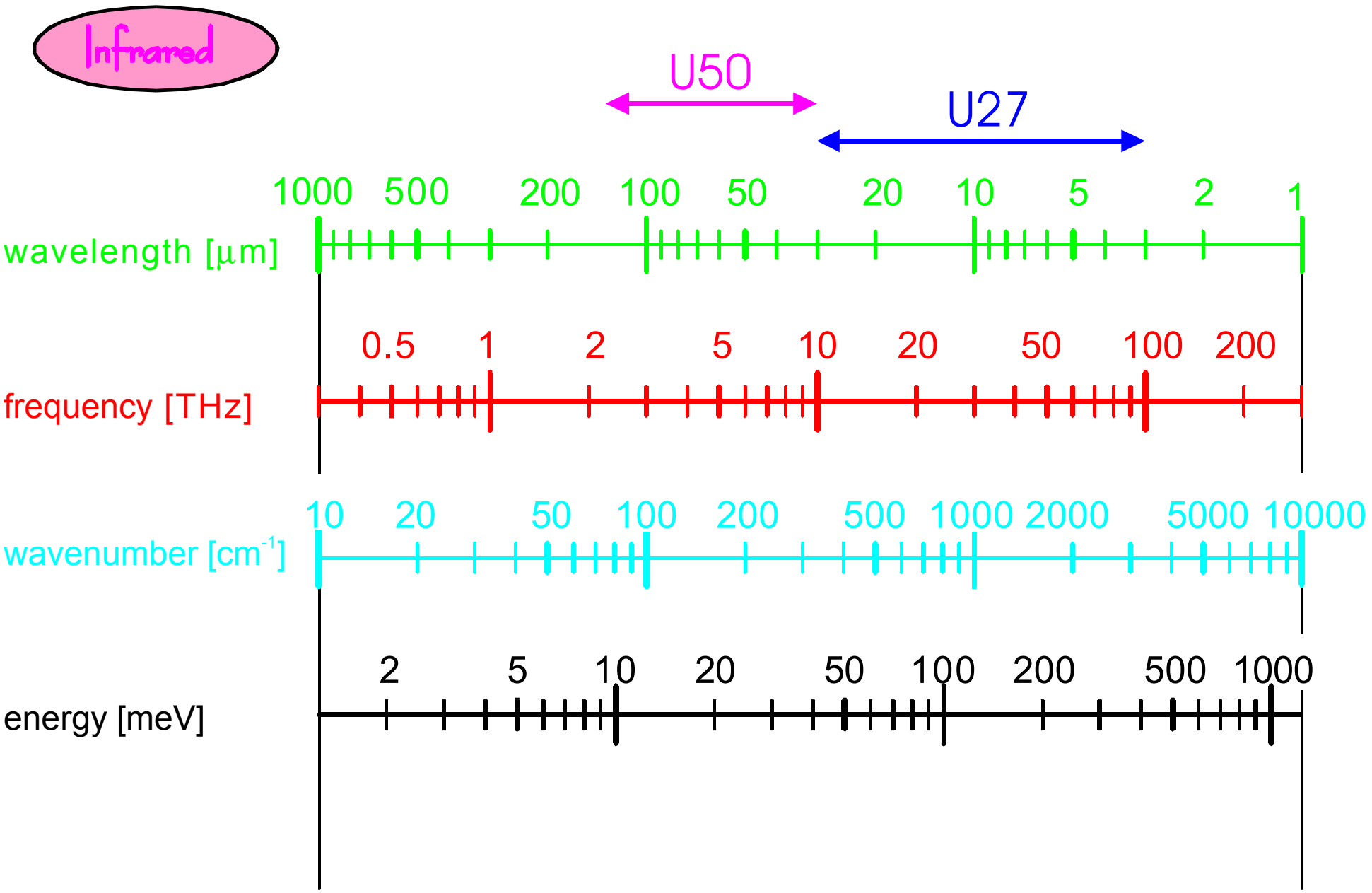

Optische Lab.
IR-FEL
Neutronen-
produktion
Injektor
Linac 1
Linac 2
Brems-
strahlung
RF Generatoren
Steuerung
Experiment-
elektronik
Channeling
Strahlung
Experimente
mit Röntgen-
strahlung
10m
1.Ausbaustufe
2.Ausbaustufe
möglicherAusbau
e - Strahl
IR - Strahl
andere Sekundärstrahlen

Führung des optischen Strahls vom Resonatorspiegel in dieNutzerlabors

26.02.2002




Infrared
U50
U27
1000 500 200 100 50 20 10 5 2 1
wavelength [μm]
0.5 1 2 5 10 20 50 100 200
frequency [THz]
10 20 50 100 200 500 1000 2000 5000 10000
wavenumber [cm-1]
2 5 10 20 50 100 200 500 1000
energy [meV]

Ziele:

- geringe Verluste beim Strahltransport
  - Anzahl und Abmessung der verwendeten Spiegel
  - Durchmesser des Rohrsystems
  - Strahlquerschnitt

- vom Experiment gewünschte Strahlparameter auf den Experimentiertischen
  - von der Wellenlänge unabhängige Strahldimensionen auf den Experimentiertischen (Strahltaille in Größe und Position unabhängig von λ)
  - nicht zu divergenten Strahl (Rayleighlänge > 1 m)
  - nur 2'-Spiegel innerhalb 1 m um die Strahltaille
  - keine zur Strahlführung gehörenden fokussierenden Spiegel auf den Tischen
  - polarisierten Strahl

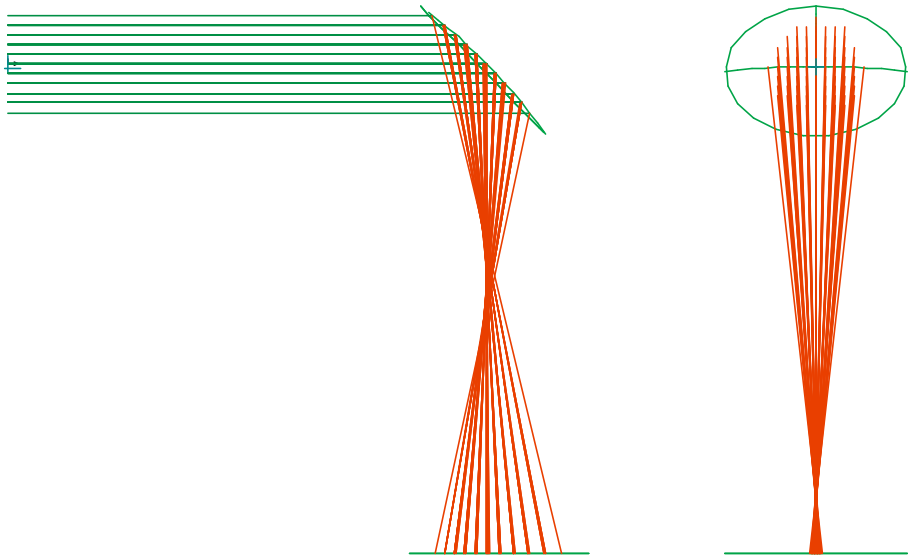
- praktikables Regime der Umschaltung des Strahles von einem Labor in ein anderes
  - möglichst wenige Spiegel bewegen
  - besser raus- und reinfahren als drehen
  - zu bewegende Spiegel am Ende des Strahlenganges

Methoden:

- Methode des äquivalenten Gaussstrahls in kollinearer Geometrie
- wellenoptische Beschreibung auf einem Gitter
  mit Hilfe des Codes GLAD in kollinearer Geometrie
- strahlenoptische Rechnungen mit Hilfe des Codes OptiCAD
- diverse Abschätzungen

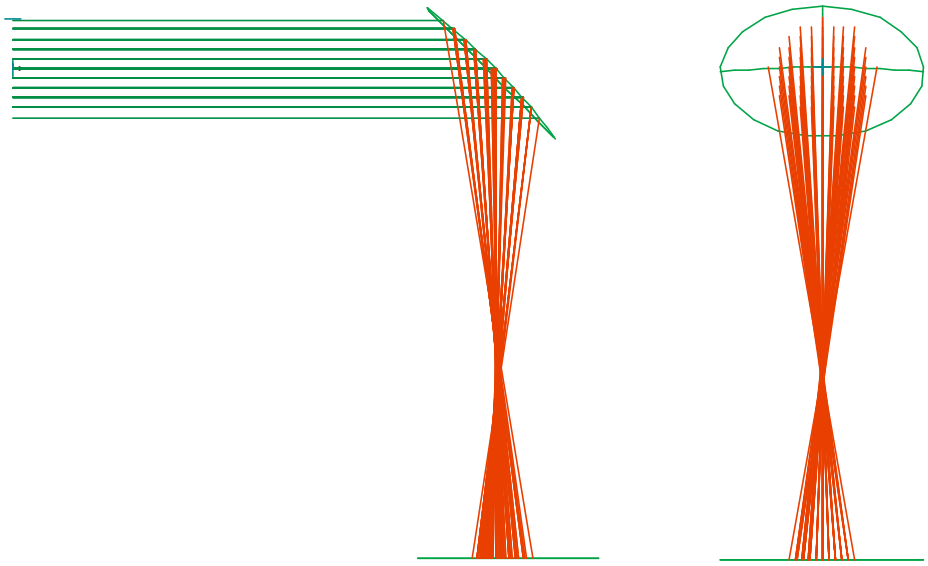
Warum toroidale Spiegel?

sphärischer Spiegel



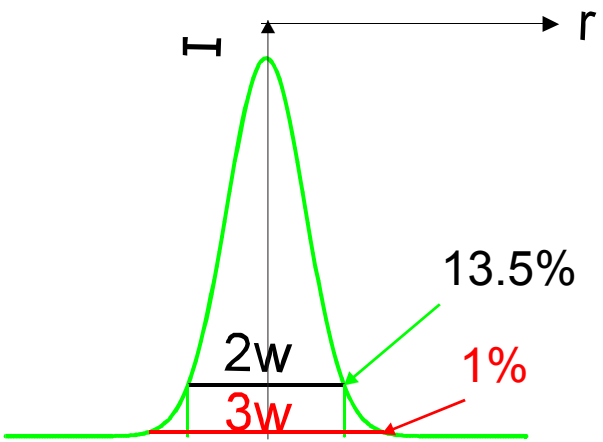
toroidaler Spiegel

$R_t = 2*R_s$

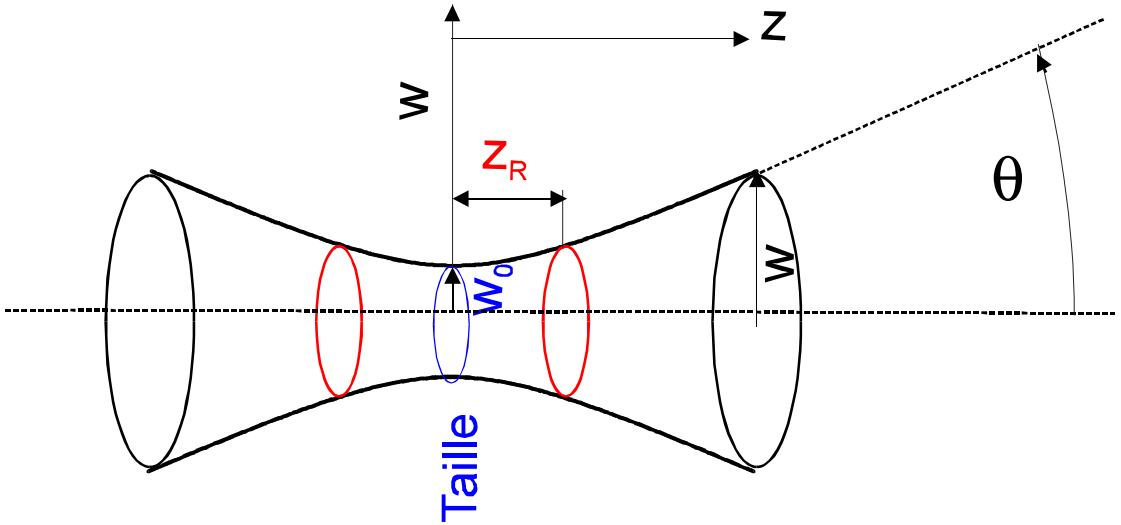


Der Gaussstrahl

transversal



longitudinal



$$I(r) = \frac{2\,P_0}{\pi\,w^2}\,e^{-2r^2/w^2}$$

rund

höhere Moden

$$w(z) = w_0\sqrt{1+(z/z_R)^2}$$

$$z_R = \pi w_0^{\,2} / \lambda$$

$$w_0 * \theta = \lambda/\pi$$

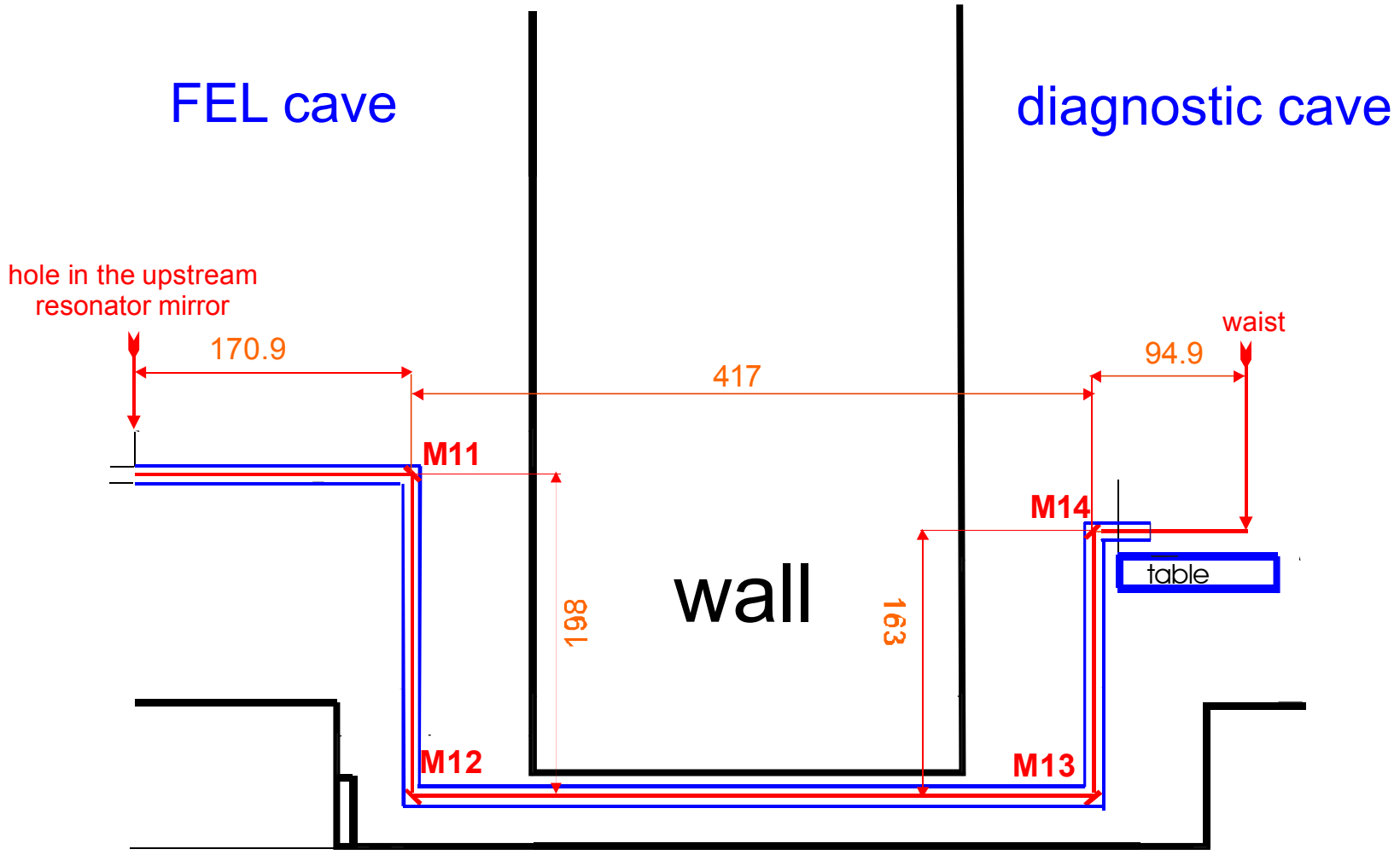
4 unabhängige Parameter

λ

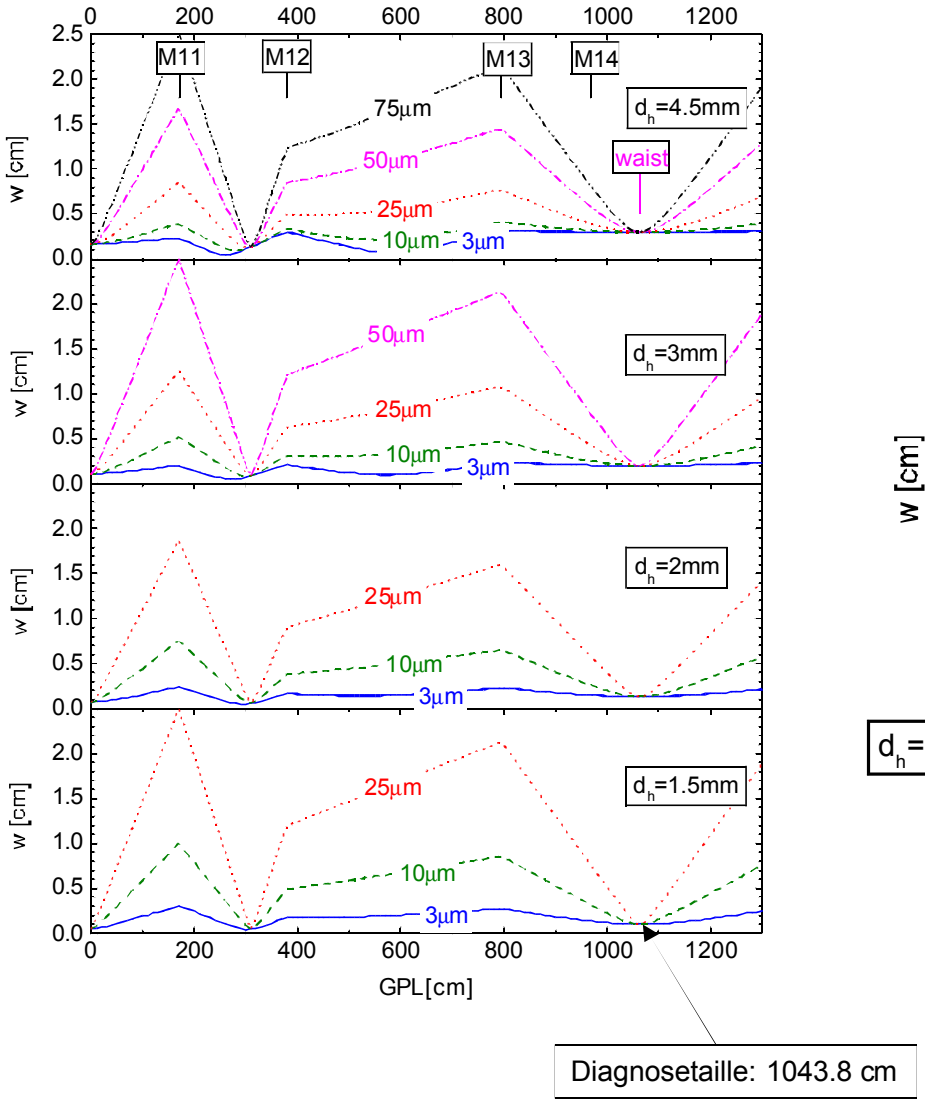
P_0 oder $I^{peak}(z_w)$

z_w

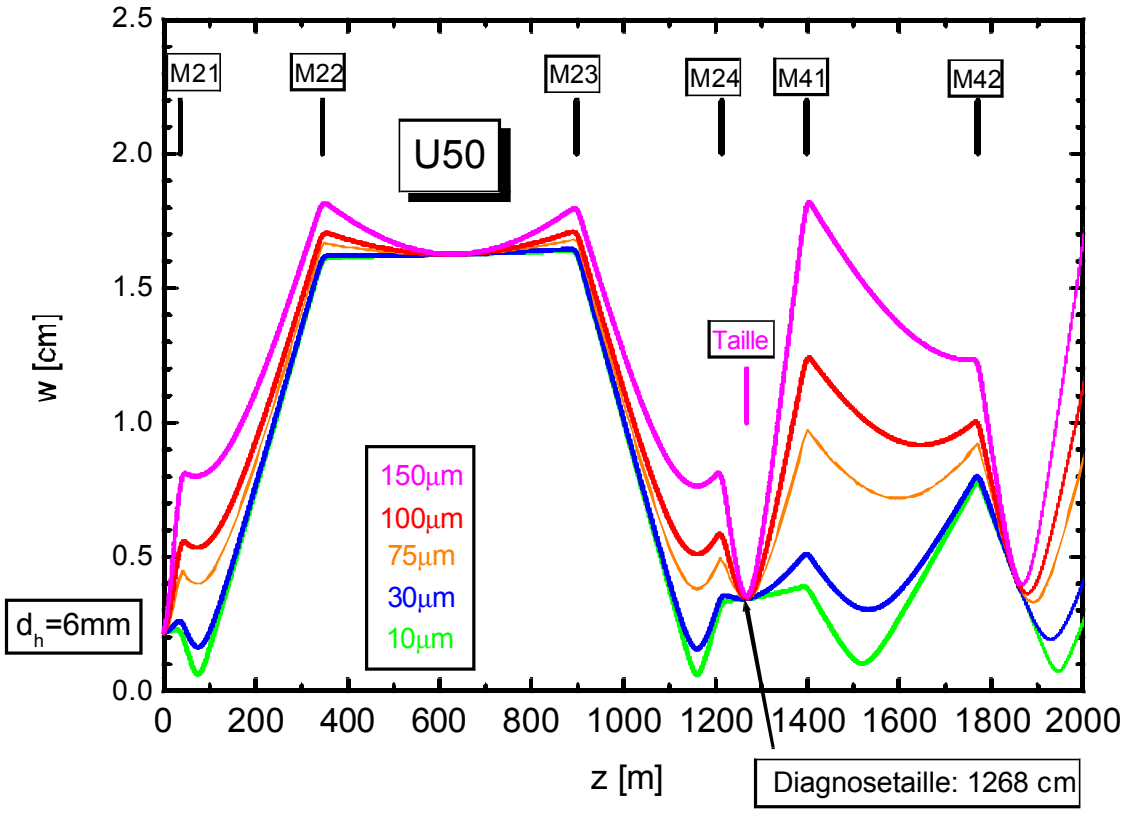
w_0 oder z_R

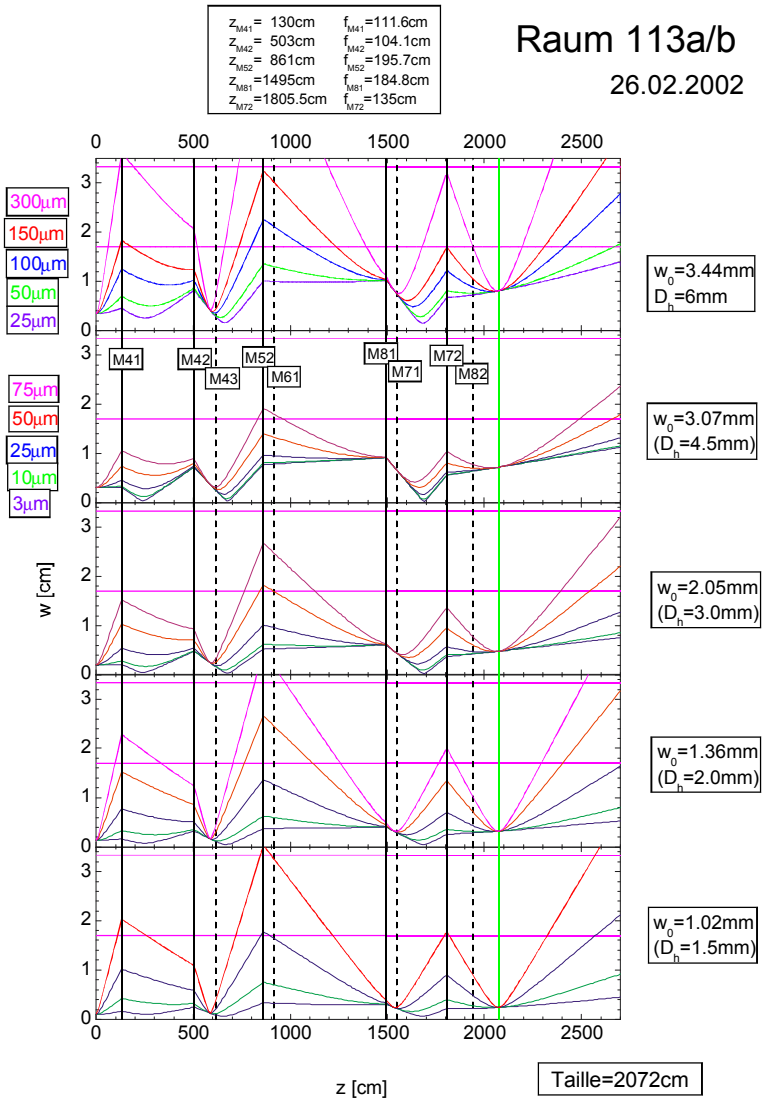

FEL cave
diagnostic cave
hole in the upstream
resonator mirror
170.9
417
94.9
waist
M11
M14
wall
198
163
table
M12
M13

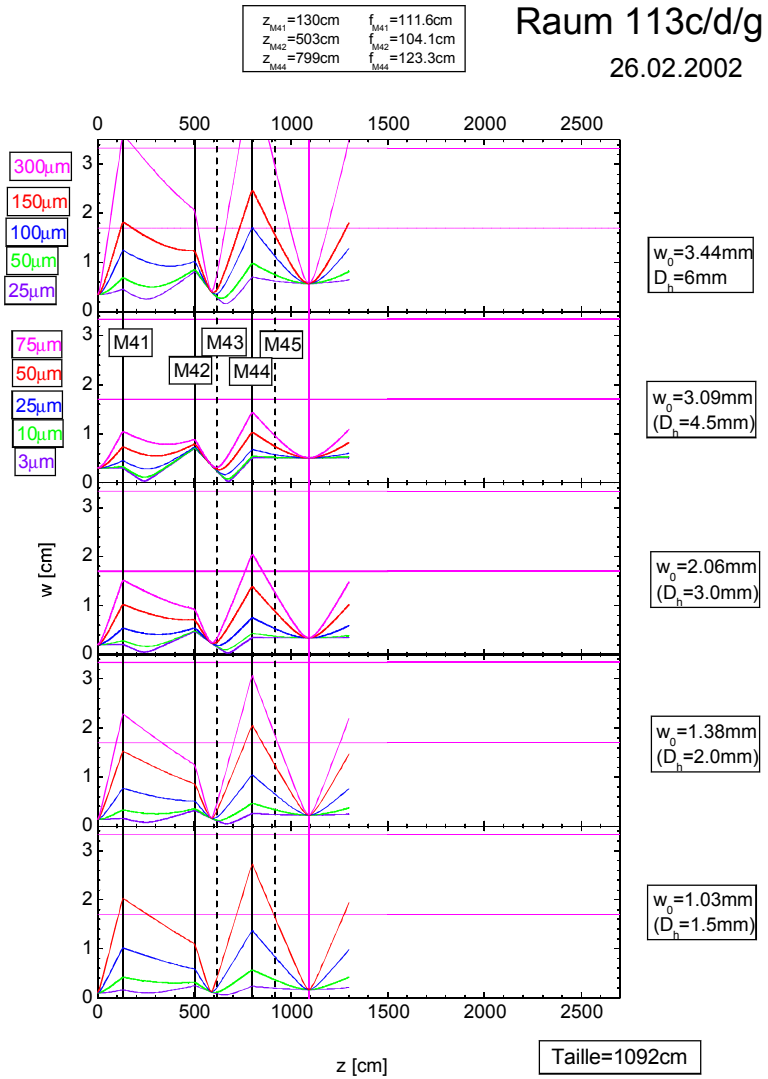
U27


M11
M12
M13
M14
75µm
50µm
25µm
10µm
3µm
waist
d_h=4.5mm
d_h=3mm
d_h=2mm
d_h=1.5mm
w [cm]
GPL[cm]
Diagnosetaille: 1043.8 cm

U50


M21
M22
M23
M24
M41
M42
U50
Taille
150µm
100µm
75µm
30µm
10µm
d_h=6mm
w [cm]
z [m]
Diagnosetaille: 1268 cm


z_{M41}= 130cm f_{M41}=111.6cm
z_{M42}= 503cm f_{M42}=104.1cm
z_{M52}= 861cm f_{M52}=195.7cm
z_{M81}=1495cm f_{M81}=184.8cm
z_{M72}=1805.5cm f_{M72}=135cm
Raum 113a/b
26.02.2002
300µm
150µm
100µm
50µm
25µm
75µm
50µm
25µm
10µm
3µm
M41
M42
M43
M52
M61
M81
M71
M72
M82
w_0=3.44mm D_h=6mm
w_0=3.07mm (D_h=4.5mm)
w_0=2.05mm (D_h=3.0mm)
w_0=1.36mm (D_h=2.0mm)
w_0=1.02mm (D_h=1.5mm)
w [cm]
z [cm]
Taille=2072cm


z_{M41}=130cm f_{M41}=111.6cm
z_{M42}=503cm f_{M42}=104.1cm
z_{M44}=799cm f_{M44}=123.3cm
Raum 113c/d/g
26.02.2002
300µm
150µm
100µm
50µm
25µm
75µm
50µm
25µm
10µm
3µm
M41
M42
M43
M44
M45
w_0=3.44mm D_h=6mm
w_0=3.09mm (D_h=4.5mm)
w_0=2.06mm (D_h=3.0mm)
w_0=1.38mm (D_h=2.0mm)
w_0=1.03mm (D_h=1.5mm)
w [cm]
z [cm]
Taille=1092cm

Spiegel der optischen Strahlführung vom Diagnosetisch in die optischen Labors

Spiegel #	Position im Strahlengang [cm]	eff. Brennweite [cm]	Spiegeldurch-messer* [cm]	Besonderheiten
M41	130	111.6	7.5	auf Tisch
M42	503	104.1	7.5	
M43	616	plan	7.5	herausfahrbar
M44	799	123.3	10	180^0 drehbar
M45	919	plan	2'	auf Tisch, drehbar, kann verschoben werden
M51	799	123.3	10	herausfahrbar
M52	861	195.7	10	
M53	929	plan	2'	kann verschoben werden
M61	914.5	plan	10	
M71	1548.5	plan	5	
M72	1805.5	135.0	7.5	herausfahrbar
M73	1908.5	212.3	7.5	
M74	2088.5	plan	7.5	180^0 drehbar, kann längs der Wand verschoben werden
M81	1495	184.8	7.5	
M82	1940.5	plan	2'	auf Tisch, drehbar, kann verschoben werden

Strahlradien w an den Arbeitspunkten

Loch	113a/b	113e & f	113 c, d & g
1.5 mm U27	2.4 mm	3.2 mm	1.8 mm
2.0 mm U27	3.2 mm	4.2 mm	2.3 mm
3.0 mm U27	4.8 mm	6.4 mm	3.5 mm
4.5 mm U27	7.2 mm	9.6 mm	5.2 mm
6.0 mm U50	8.1 mm	10.7 mm	5.8 mm

General
Laser
Analyses and
Design

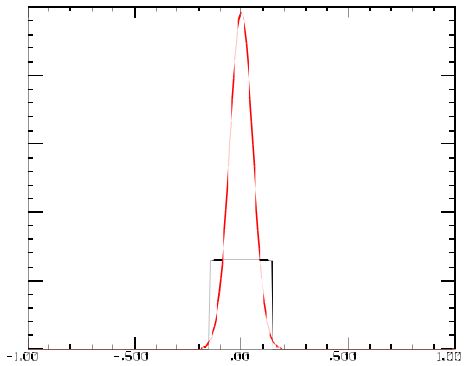
- Code zur Berechnung der Ausbreitung elektromagnetischer Felder auf der Grundlage der Maxwellgleichungen mit einer Vorzugsrichtung
- Wellenoptik mit dominierender Strahlrichtung und Beugung
- senkrecht zur Strahlrichtung mitgeführtes Gitter
- vordefinierte optische Elemente wie Blenden, Linsen, Spiegel, ..., Gain- Medien

- mitgeführtes Gitter hat konstante Anzahl von Punkten (2^n x 2^m) und ist nicht immer optimal angepasst
- keine fokussierenden Elemente unter endlichem Winkel
- keine Wellenleiter

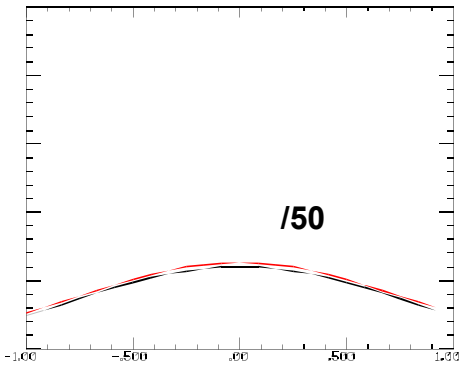
beam profiles

λ = 30 µm d_h = 3 mm

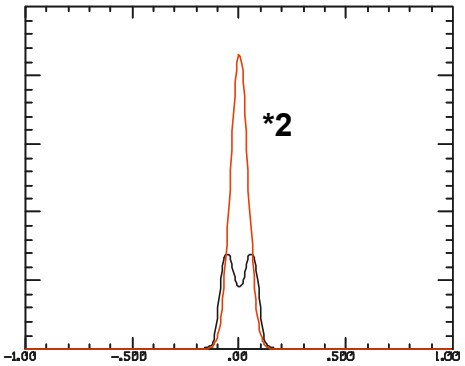
hole



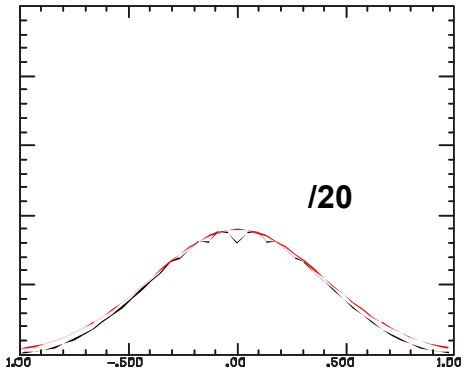
M11



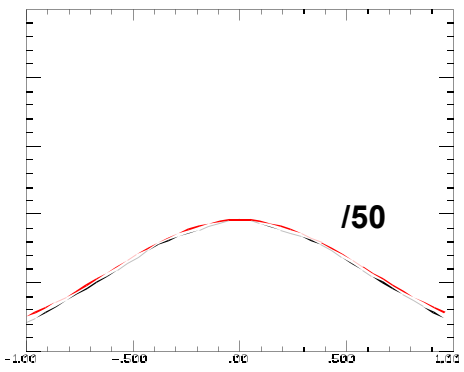
w11



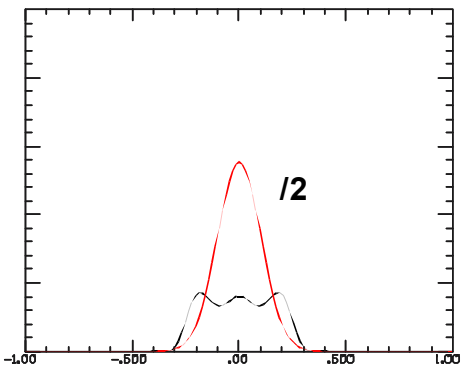
M12



M13



w_{diag}

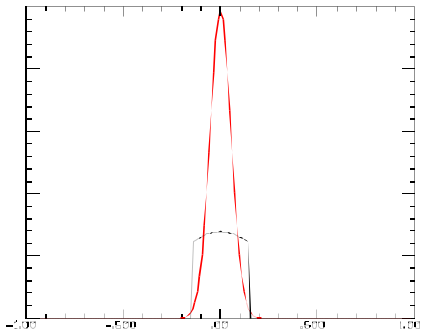


—— "true" --- equiv. Gauss

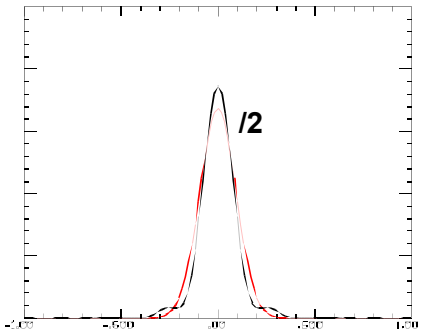
beam profiles

λ = 3 µm d_h = 3 mm

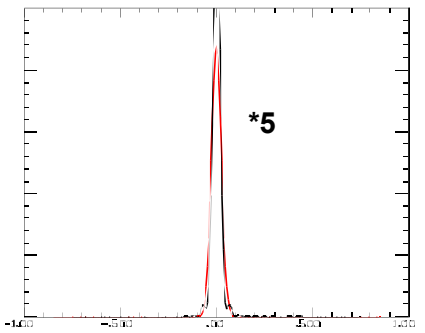
hole



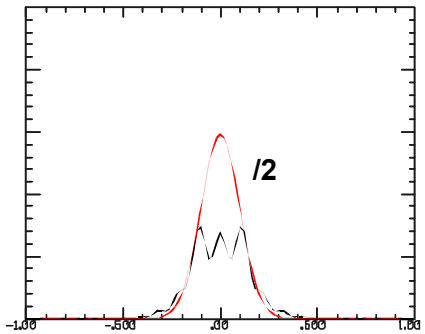
M11



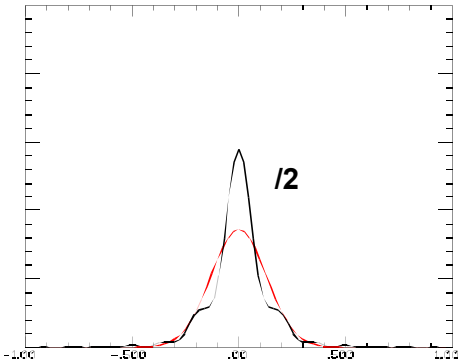
w11



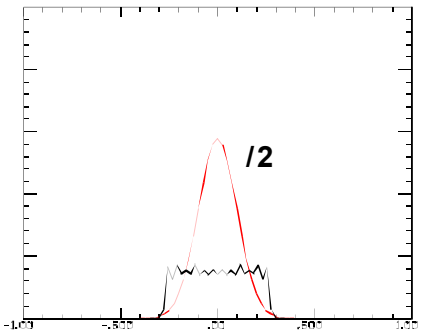
M12



M13

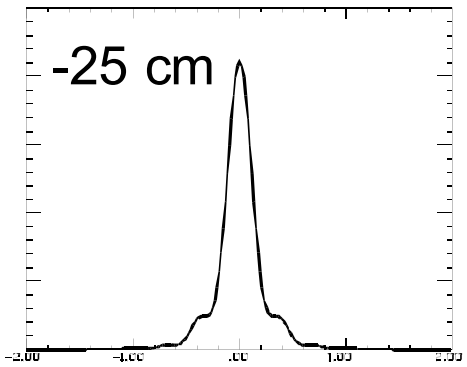


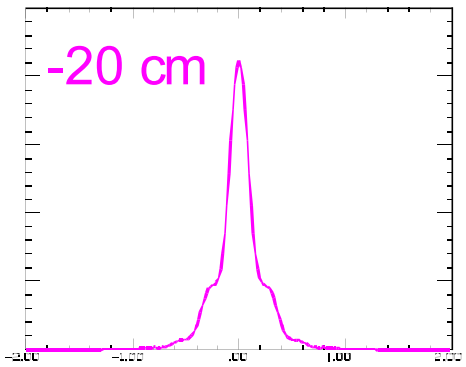
w_{diag}

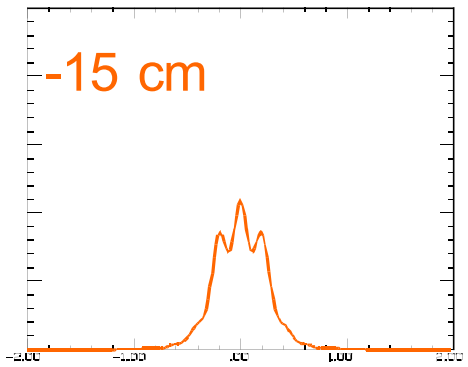


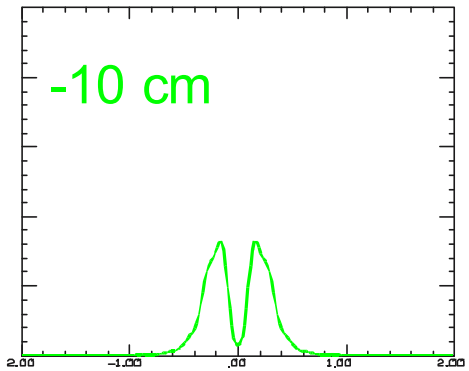
—— “true” --- equiv. Gauss

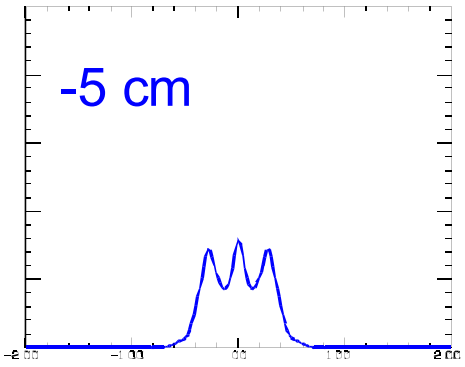
λ = 100 µm D_h = 6 mm z_R = 24.5 cm

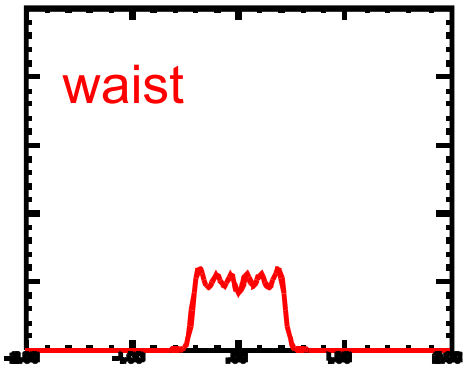


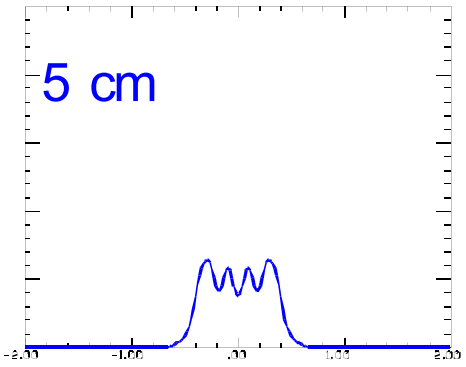


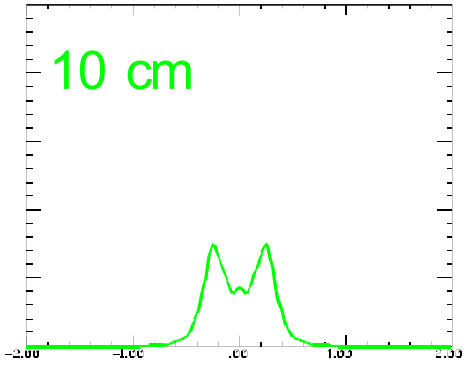


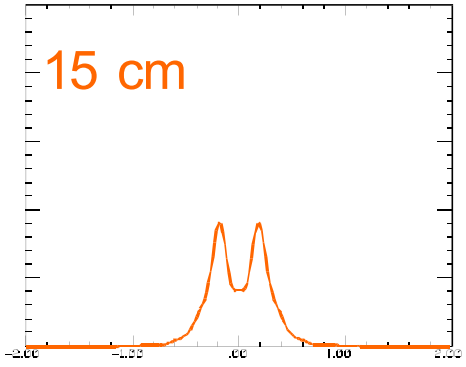


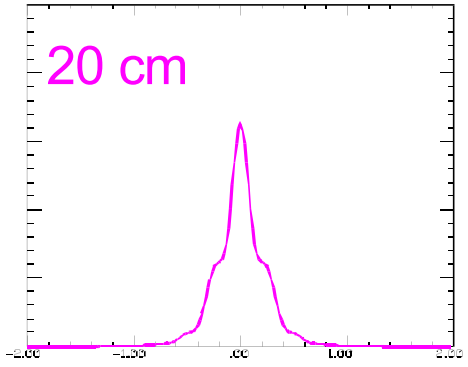


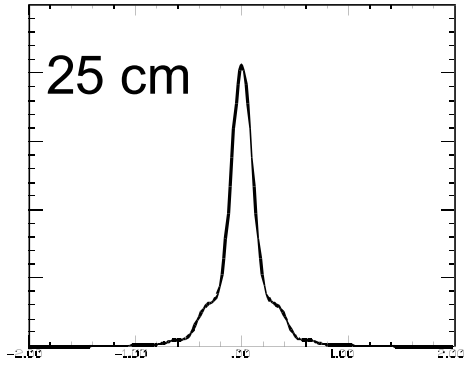




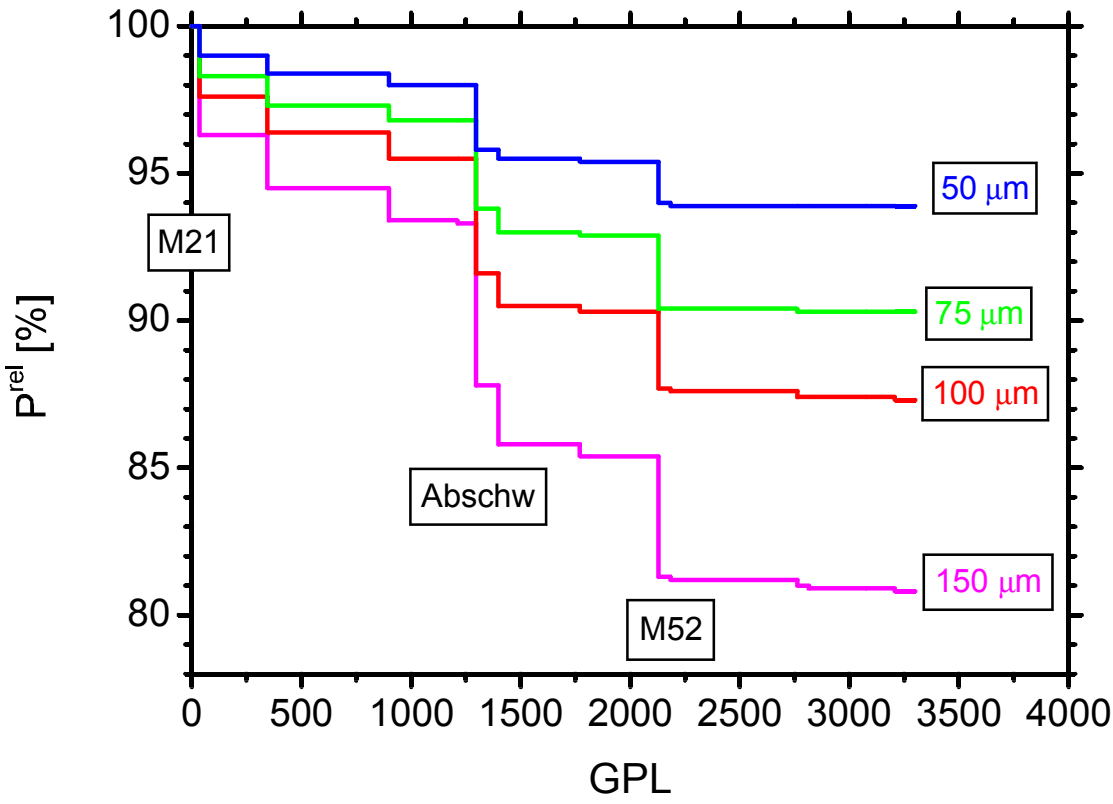




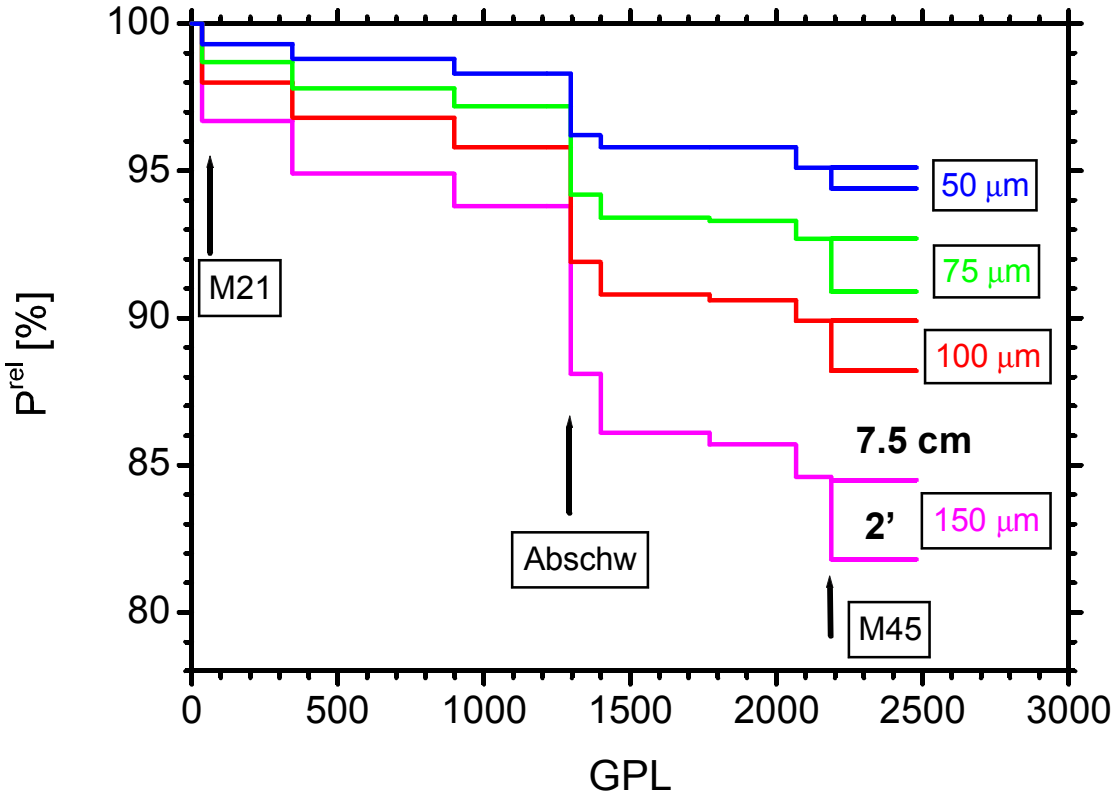




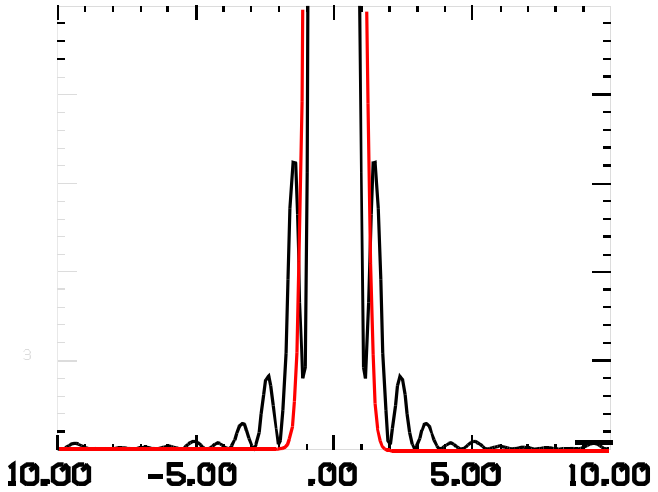
Verluste U50 a/b



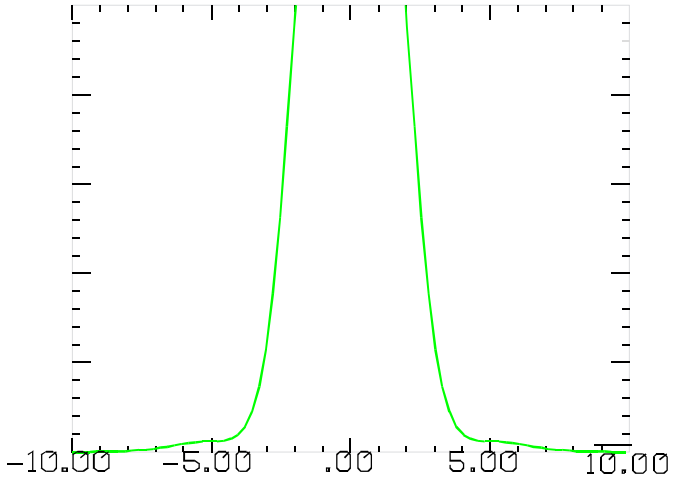
Verluste U50 c d g

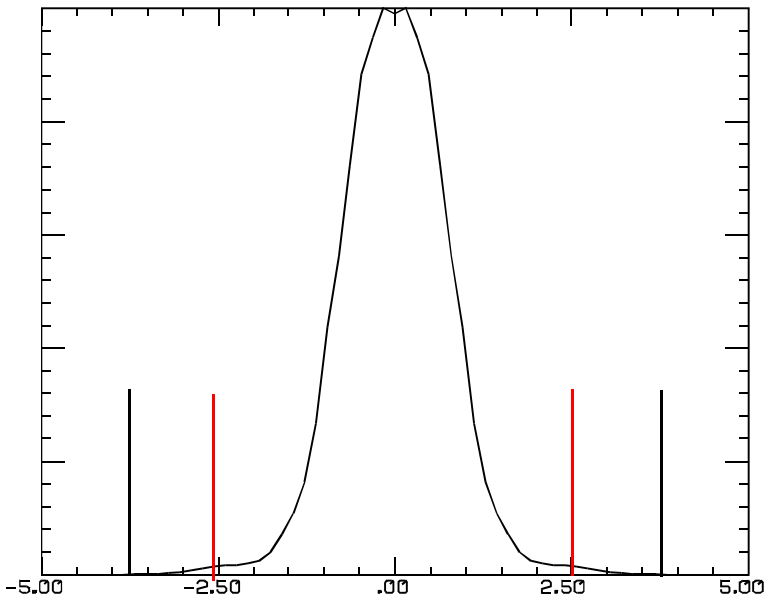


M21

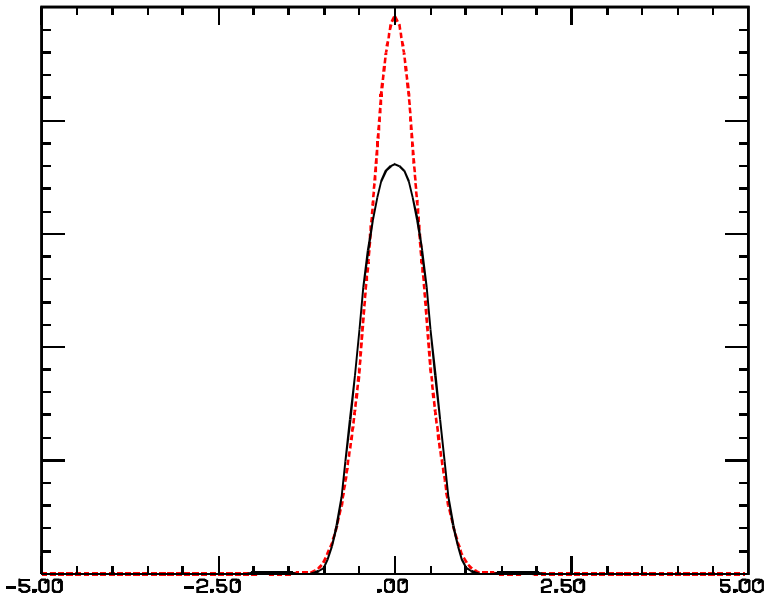


M52



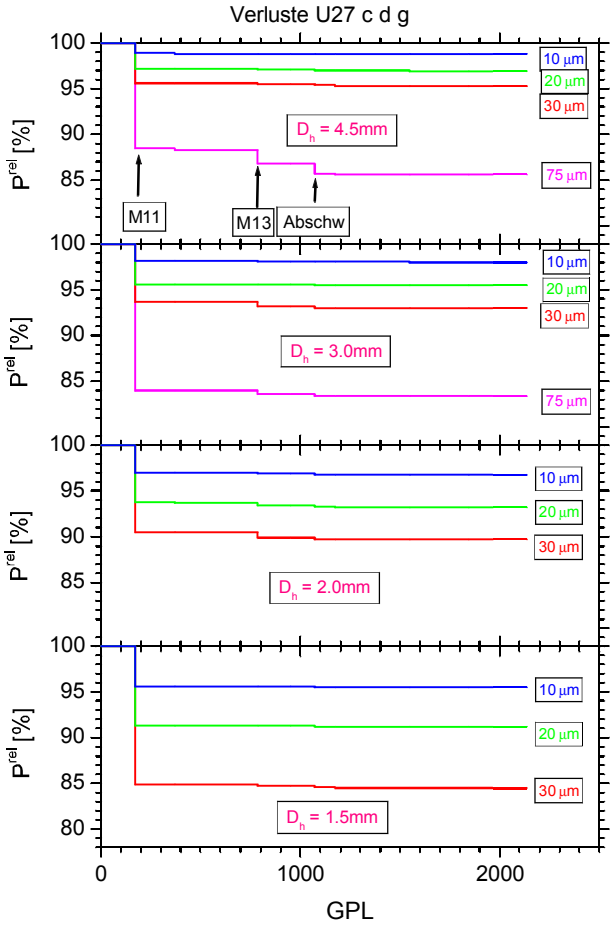


am Spiegel M45

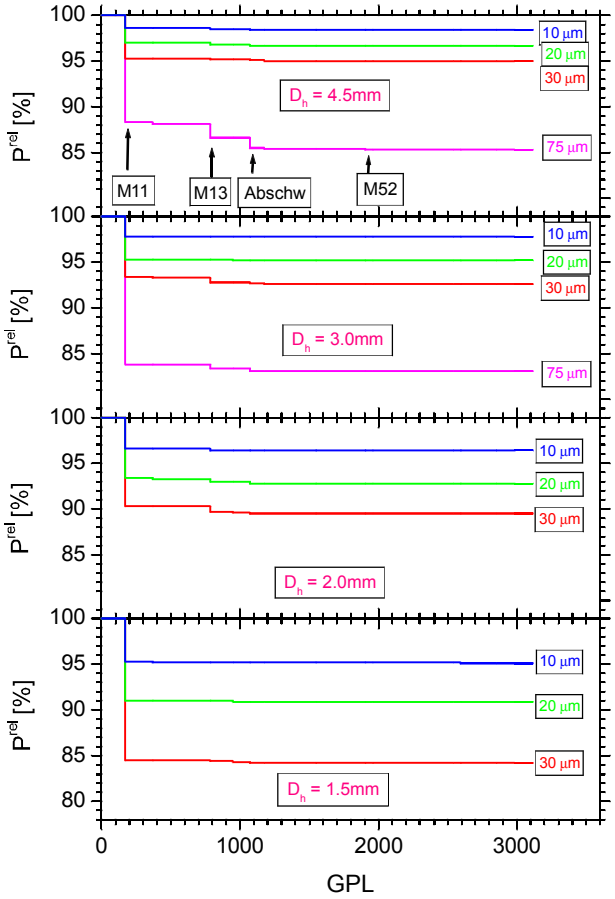


an der Taille

Beugungsverluste beim Transport des U27 Strahles



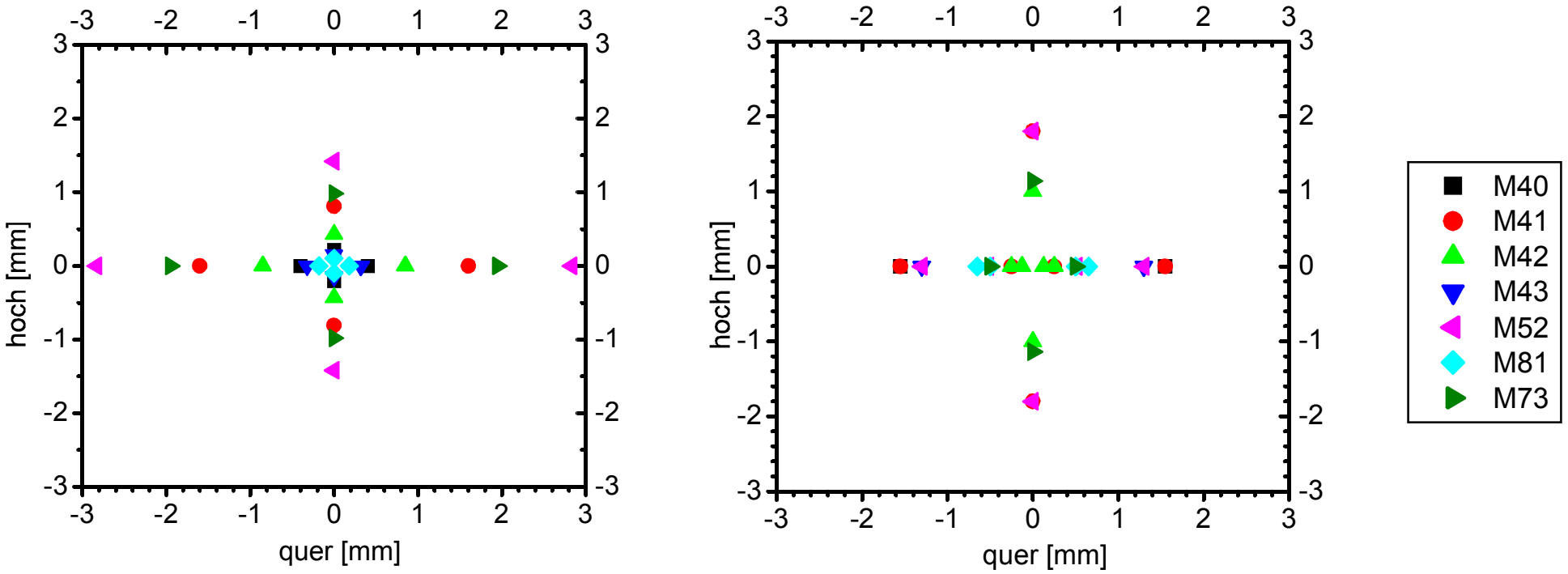
Räume 113 c, d, g



Raum 113 a/b

Toleranzen

Verkippung: 200 μrad Verschiebung 500 μm



Abbildungsfehler:

- **Astigmatismus** durch toroidale Form kompensiert
- **sphärische Aberration** klein, wegen D/f << 1 (~1/30)