Radius/Momentum Calculation for S444 Experiment February 2020 - Overview

Tobias Jenegger

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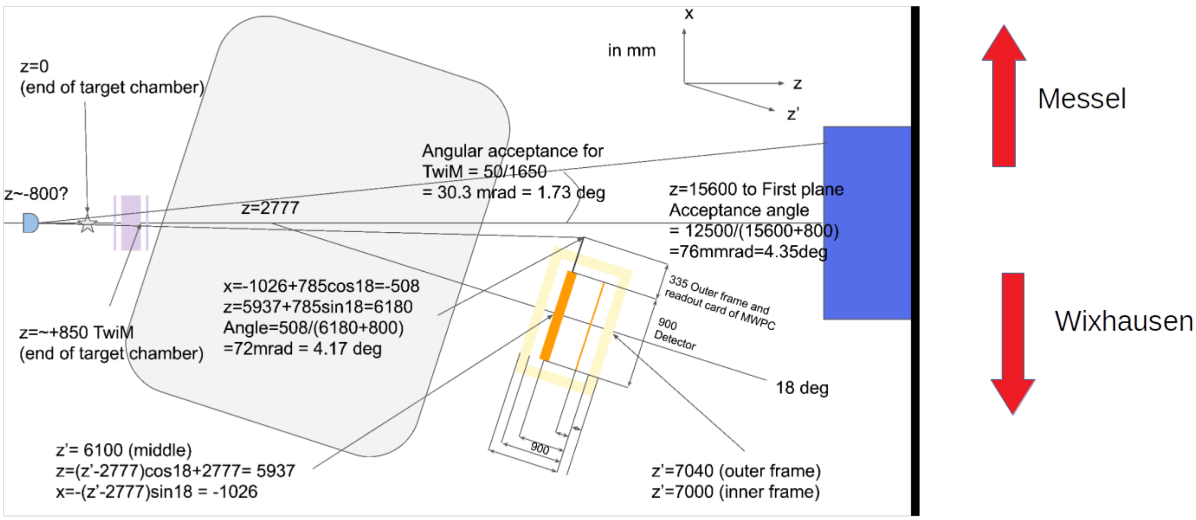
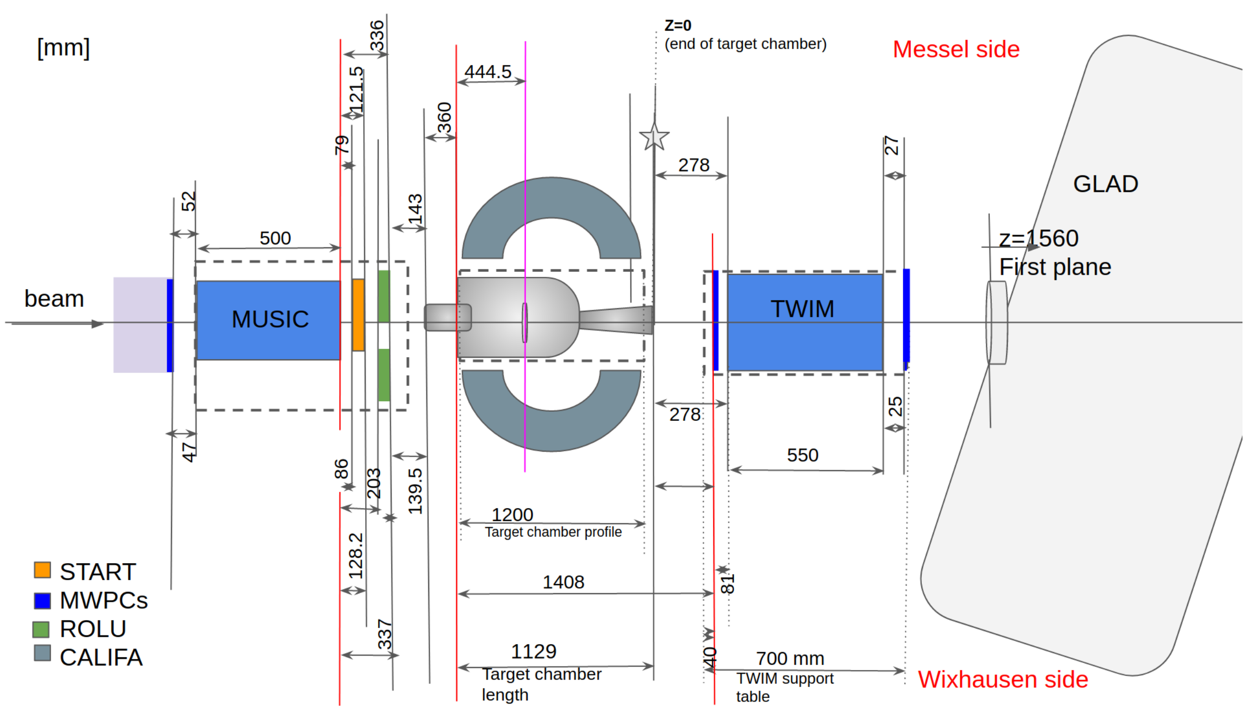
0.1 The Setup


z=0
(end of target chamber)
z~-800?
z=2777
z=~+850 TwiM
(end of target chamber)
x=-1026+785cos18=-508
z=5937+785sin18=6180
Angle=508/(6180+800)
=72mrad = 4.17 deg
z'= 6100 (middle)
z=(z'-2777)cos18+2777= 5937
x=-(z'-2777)sin18 = -1026
Angular acceptance for
TwiM = 50/1650
= 30.3 mrad = 1.73 deg
in mm
x
z
z'
z=15600 to First plane
Acceptance angle
= 12500/(15600+800)
=76mmrad=4.35deg
335 Outer frame and readout card of MWPC
900 Detector
900
18 deg
z'=7040 (outer frame)
z'=7000 (inner frame)
Messel
Wixhausen


[mm]
beam
MUSIC
500
52
47
336
121.5
79
86
203
128.2
337
143
139.5
360
444.5
Z=0
(end of target chamber)
1200
Target chamber profile
1408
1129
Target chamber
length
278
278
81
40
TWIM
550
27
25
700 mm
TWIM support
table
Messel side
Wixhausen side
GLAD
z=1560
First plane
START
MWPCs
ROLU
CALIFA

1 Geometry and relative position of the detectors in the beam direction

Here, the positions are given for the s444 and s467 experiments

z position of the MWPC0: zMW0 = -2520 mm
z position of the target: zT = -684.5 mm
z position of the MWPC1 in front of the Twin-MUSIC: zM1 = 279 mm
z position of the middle of the Twin-MUSIC: zTwin = 553 mm
z position of the MWPC2 after the Twin-MUSIC: zM2 = 854 mm
α tilted angle of GLAD (14 degrees): = 0.244 rad
effective length of GLAD: L_eff = 2067 mm
z middle of GLAD zGm = 2577mm
horizontal of the central path (18 degree) θ_out0 = pi/10 rad
z position of the MWPC3 after GLAD zM3 = 5937 mm
z position of the ToFwall zToFW = 6660.2 mm

Correspondence between the GLAD current and the magnetic field: I = 3584 A, B = 2.2 T

Positions of the TOFWPads:
1 ⇒ Messel
27⇒ Wixhausen

2 RUNS used for calibration = SWEEP RUNS without target

RUN	Beam ion	Beam Energy [AmeV]	GLAD current [A]	Comments
36	12C primary	400	1444	before broken motor, here we see that tof is about 5ns faster. So they probably changed the position of the TOFW afterwards
37	12C primary	400	1444	it has be seen that motor drive not working
38	12C primary	400	1444	tof is back with new gates *magnet sweep 1444A
39	12C primary	400	1498	
40	12C primary	400	1501	
41	12C primary	400	1501	stopped with 1558 A
42	12C primary	400	1558	
43	12C primary	400	1558	stopped with 1653 A
44	12C primary	400	1653	
45	12C primary	400	1653	stopped with 1748 A
46	12C primary	400	1748	
47	12C primary	400	1748	stopped with 1843 A
48	12C primary	400	1843	
49	12C primary	400	1843	stopped with 1938 A
51	12C primary	400	1938	
52	12C primary	400	1938	stopped with 1444 A
53	12C primary	400	1444	
54	12C primary	400	1444	stopped with 1349 A
55	12C primary	400	1349	
56	12C primary	400	1349	stopped with 1254 A
57	12C primary	400	1254	
58	12C primary	400	1254	stopped with 1159
59	12C primary	400	1159	
60	12C primary	400	1159	stopped with 1064
61	12C primary	400	1064	
62	12C primary	400	1064	stopped with 1444 A
123	12C primary	650	1748	stopped with 1957
124	12C primary	650	1957	

(red)	=	sweeping
(green)	=	stable GLAD current

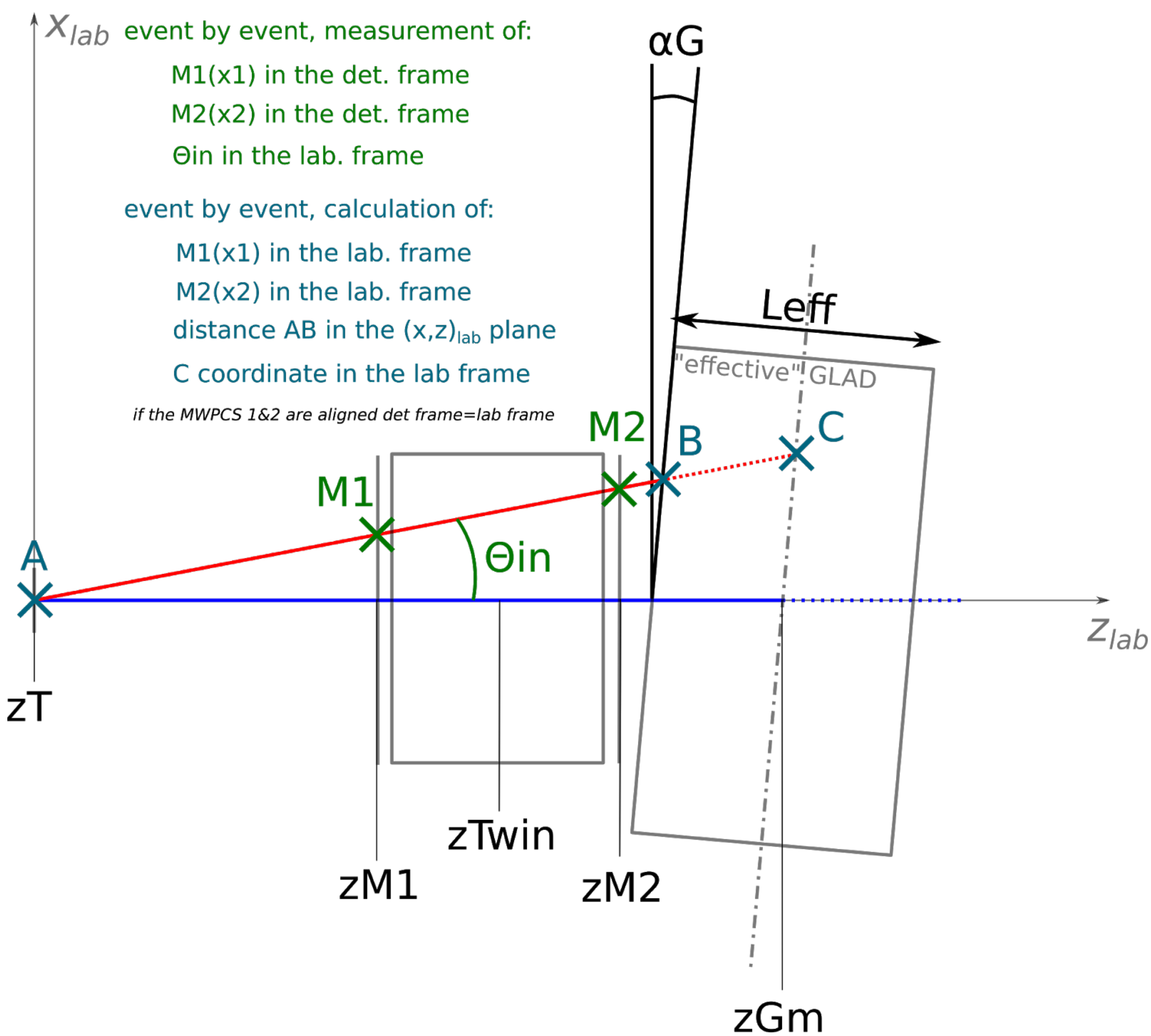
2.0.1 Other RUNS used for various checks:

RUN 70: 2 cm C target
RUN 80: 10.86 mm C target
RUN 81: 24.53 mm CH2 target
RUN 67: 24 mm CH2 target
RUN 68: 1 cm C target
RUN 79: 12.29 mm CH2 target
RUN 75: 21.98mm C target

3 Methods for flightpath reconstruction in the (x,z) plane

3.1 The "Kickplane" method

3.1.1 From MW0 to the entrance of GLAD, the ion is following a straight line



The straight line trajectory from MW0 to entrance before glad is defined by:

⇒ **one absolute value before GLAD**

absolute = calibrated position in mm in the laboratory frame

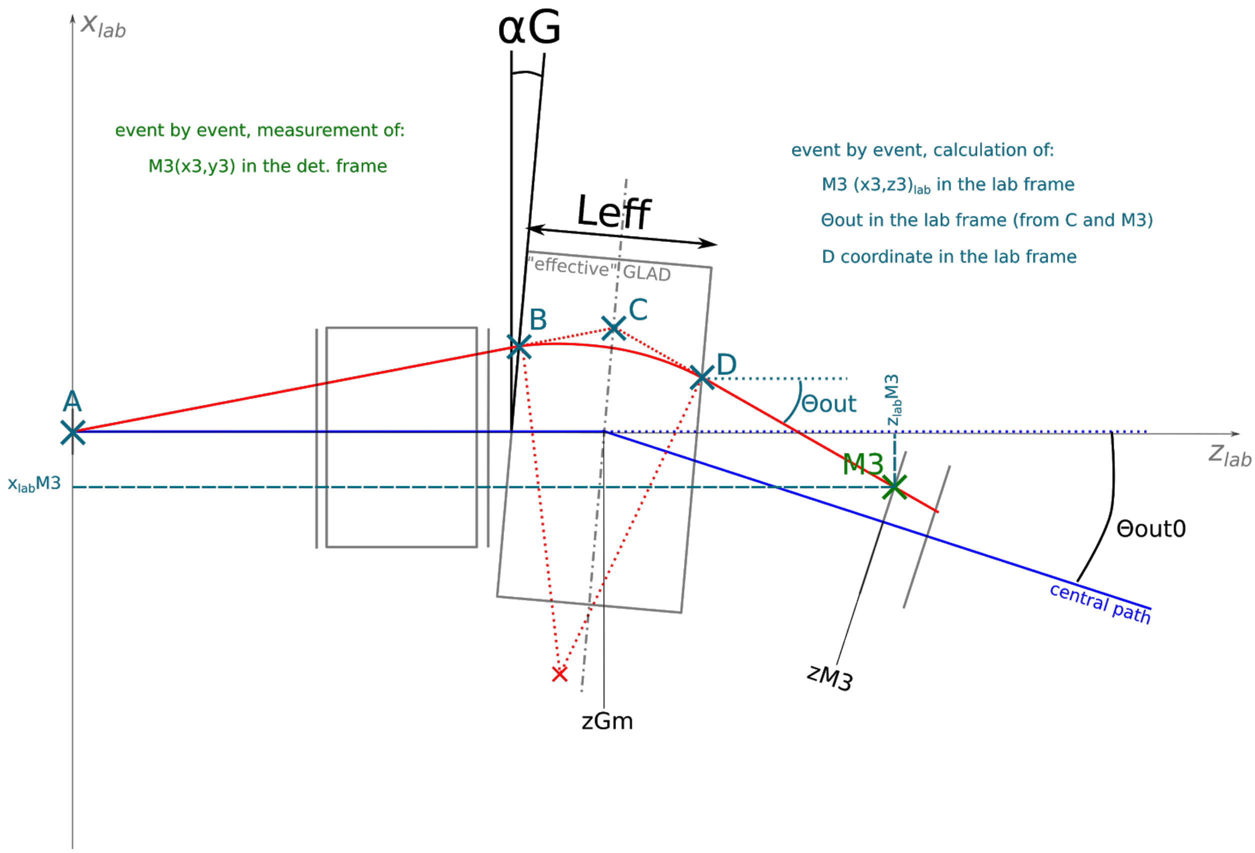
To get the position, use the position given by one MWPCs (1 or 2)

⇒ **the theta angle (theta_in) before GLAD**

Angle obtained from comining MWPC1 and MWPC2

(to get higher precision the drift time in TWIM MUSIC could be used)

3.1.2 From entrance to the exit of GLAD, the effective trajectory is circular



The circular trajectory is defined by:

⇒ **one absolute position before GLAD B and angle theta_in (see: 3.1.1)**
⇒ **one absolute position at MWPC3**

From this information the angle theta_out is constructed in follwing steps:

1. Extend the line of flight of the ion before the GLAD.
2. The point of intersection with the "kickplane" (symmetry axis line of GLAD magnet) is the kickpoint C.
3. Draw a straight line between C and the absolute position at MWPC3 = M3.
4. theta_out is the positive angle between the z-beam direction and the line between C and M3.

The curvature radius ρ is given by[1]:

$$\rho = \frac{\mathrm{L\_eff}}{2\cdot\sin\left(\frac{theta\_in}{2}+\frac{theta\_out}{2}\right)\cdot\cos(\delta)}$$

With δ:

$$\delta = \arctan\left(\left|\frac{\frac{cos(theta\_out)-\cos(theta\_in)}{\sin(theta\_out)+\sin(theta\_in)}+\tan(\alpha)}{1-\frac{cos(theta\_out)-\cos(theta\_in)}{\sin(theta\_out)+\sin(theta\_in)}\cdot\tan(\alpha)}\right|\right)$$

The full derivation can be found in the appendix.

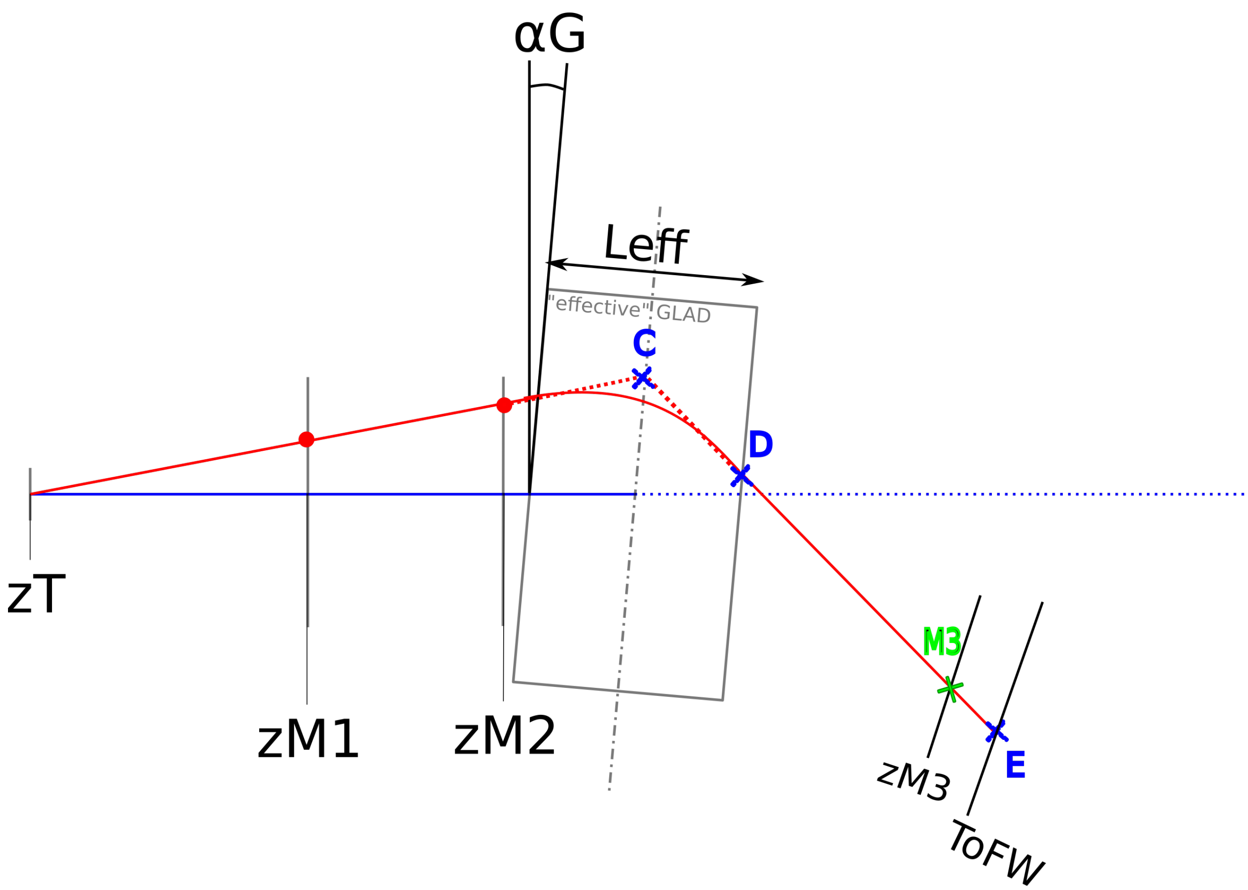
The circular trajectory is then given by:

$$\omega = 2 * \left|\arcsin\left[\frac{BD}{2\cdot\rho}\right]\right|$$

with BD = length of the BD segment

[1] for consistency checks the $\cos(\delta)$ term can be omitted, as it plays a minor role

3.1.3 After GLAD up to the TOFW, the trajectory is a straight line



The straight line trajectory from D to E is definded by:

⇒ the output angle from GLAD theta_out
⇒ one absolute position after GLAD in the laboratory frame M3

With this information the straight line trajectory lenght after GLAD can be measured. It starts at the exit point of GLAD D and follows the straigh line (characterized by the angle theta_out and the absolute position at MWPC3) until the intersection with the TofW (middle position of the ToFWall zToFW= $6660.2mm$, tilted angle= $18°$).

Finally the pathlength in the (x,z) plane from the target position to the ToFW is given by:
P = AB + $\rho \cdot \omega$ +DE

where:
A = (x,z) position at the target point
B = (x,z) position at the GLAD entry point
D = (x,z) position at the GLAD exit point
E = (x,z) position where the constructed trajectory line hits the ToFW

The assumption for the "Kickplane" method is that the kickpoint for each event lies on the predefinded Kickplane, the symmetry axis line of the GLAD magnet.

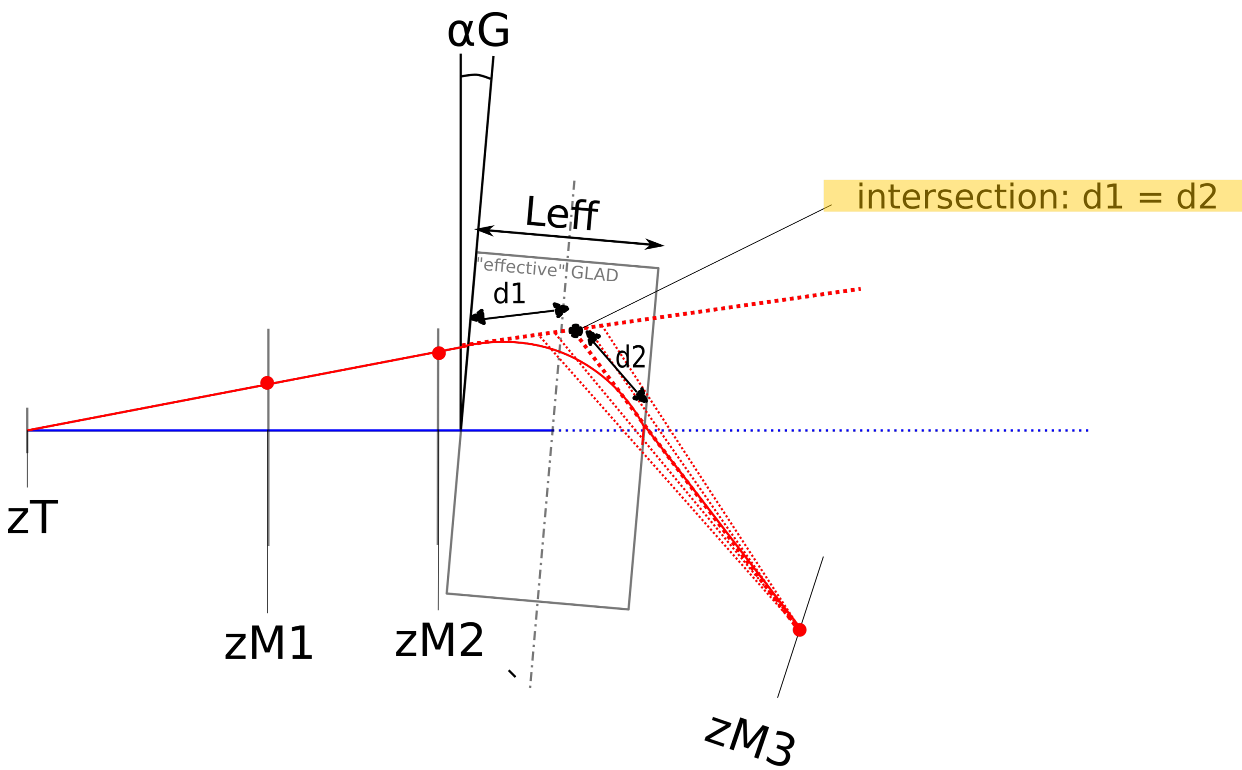
3.2 The "Fit-Track" method

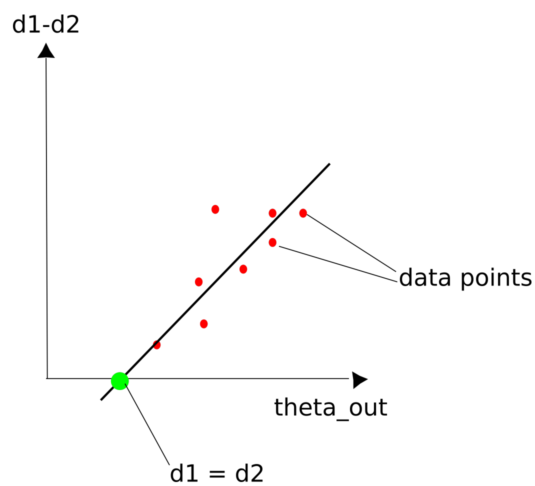
For the "Fit-Track" method the assumption that the kickpoint C lies on the symmetry axis line of the GLAD magnet is rejected. Instead following algorithm is applied: [2]

1. Extend the line of flight of the ion before the GLAD.
2. Draw a line from the point MW3 to C (as constructed with the "Kickplane" method).
3. Now sweep the straight line after the kickpoint, leaving the position MW3 unchanged but sweeping the intersection point along the inline beam.
4. For each sweeping step plot theta_out versus (d1-d2) where d1 is the distance betweeen B and the point of intersection and d2 the distance between D and the intersection point accordingly.
5. 50 sweeping steps are performed.
6. Fit the final theta_out versus (d1-d2) plot with linear least square fit.

[2]This algorithm is motivated from https://www.blogs.uni-mainz.de/fb08-kernphysik/files/2018/09/PHDThesis_OlgaBertini.pdf, section 3.4

7. Find the intersection of the abscissa. The corresponding theta_out value is now the corrected one which should be used for the calculation of the radius.





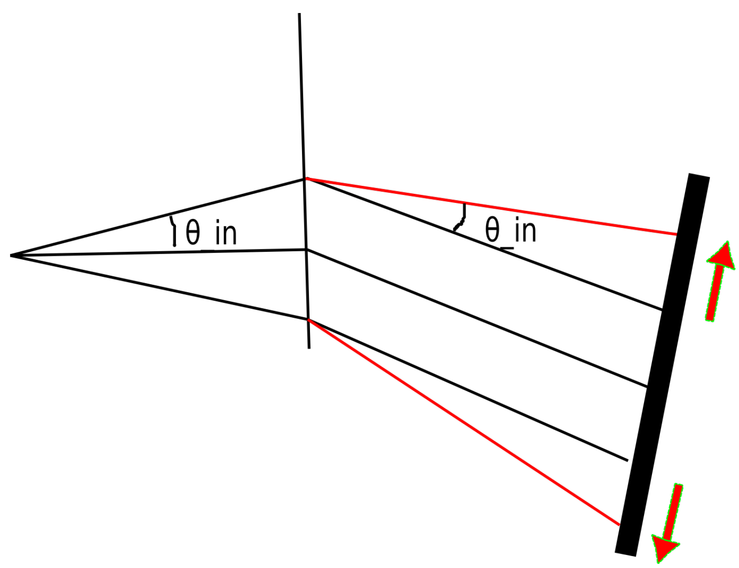
3.3 The "Theta_in correction" method

Here the "Kickplane" method is used and subsequently the theta_out is corrected by theta_in. That means:

theta_out_corr = theta_out - theta_in.

Consequentely the theta_in dependence of ρ vanishes(neglecting the cos(δ) term):

$$\rho = \frac{\text{L\_eff}}{2\cdot\sin\left(\frac{theta\_in}{2}+\frac{theta\_out\_corr}{2}\right)} = \frac{\text{L\_eff}}{2\cdot\sin\left(\frac{theta\_out}{2}\right)}$$



3.4 Optional method: Kickplane method, setting theta_in to 0

4 Plots

In this section all the plots for the various track finding algorithms are presented. For the calculation of the theta_in angle MWPC1 and MWPC2 are used. Alternatively MWPC0 and MWPC2 could be used, to get a longer lever arm (work in progress ...).

4.1 MWPC1 vs MWPC2 - x position