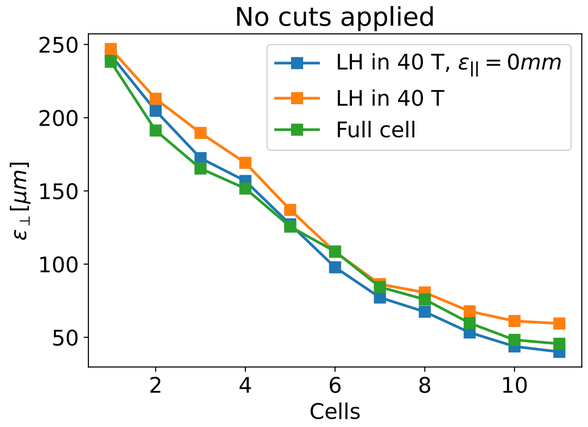
Work in progress: current state of the Final cooling optimisation

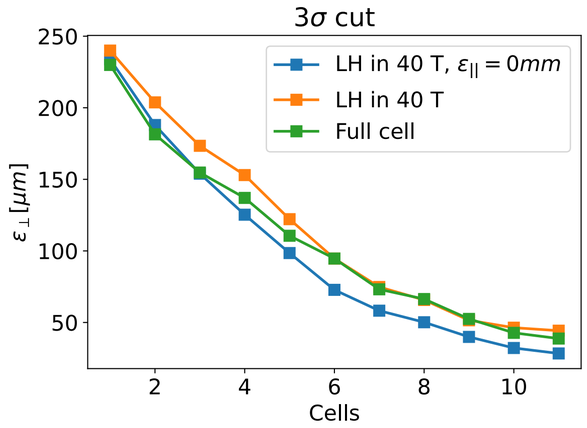
Cell	LH_2 [m]	Drift [m]	N_{RF} rot.	N_{RF} accel.	f_{RF} [MHz]	G [MV/m]	$\phi_{RF,rot.}$ degrees
2	0.466	0.3238	5	5	111.06	19.81	-180
3	0.46958	1.363	10	7	56.85	14.17	90
4	0.4	2.5	9	8	40.13	11.9	51
5	0.3	1.8358	7	2	34.91	11.11	-10
6	0.25	2.0	5	10	30.61	10.4	-54
7	0.3	0.984	5	14	11.637	6.823	-82
8	0.1	3.6464	2	7	16.17	8.04	67
9	0.17	3.64	2	11	13.38	7.32	67
10	0.08	2.555	11	2	8.226	5.39	-6
11	0.0541	2.895	11	4	5.676	4.48	-96
12	0.1	3.016	15	1	5.0145	4.21	-99

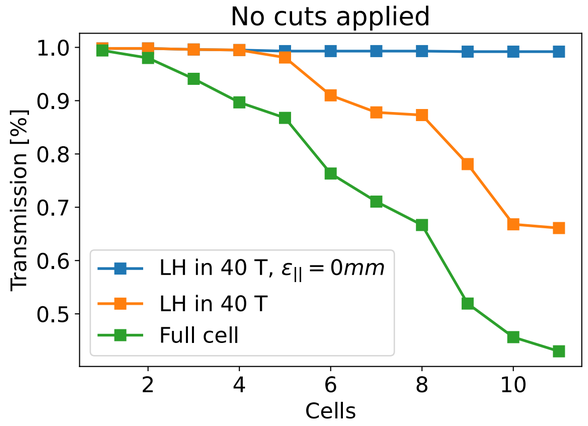
$P_{z,start}$ [MeV/m]	σE_{start} [MeV]	σt_{start} [mm]	$P_{z,end}$ [MeV/m]	σE_{end} [MeV]	σt_{end} [mm]	$\epsilon_{\parallel}$ [mm]	$\epsilon_{\perp}$ [μm]	N [%]
145.0	3.2	50.0	100.0	4.3	125.2	2.1	221.2	95.5
118.8	2.0	201.9	89.0	2.4	130.7	2.9	177.2	87.3
118.9	2.7	192.8	89.2	3.0	268.2	4.0	151.0	81.5
114.5	2.5	399.7	87.4	3.4	173.7	5.0	137.2	71.9
92.9	2.9	209.5	62.0	4.4	592.6	9.2	109.9	65.6
84.9	3.7	1625.8	57.4	1.6	911.6	13.1	93.2	56.3
89.8	1.5	916.6	55.2	2.7	926.9	22.3	69.3	52.5
71.8	2.4	1354.7	57.7	2.9	1365.3	28.0	63.8	48.2
77.2	2.2	1774.2	53.5	3.1	1695.2	40.5	51.0	43.2
61.5	1.8	2561.5	43.5	2.8	2398.1	59.3	42.2	39.0
60.5	2.2	3101.1	49.2	2.8	2954.3	77.3	37.2	36.4
65.8	2.5	3404.7	46.0	3.8	3506.9	117.9	32.1	32.4

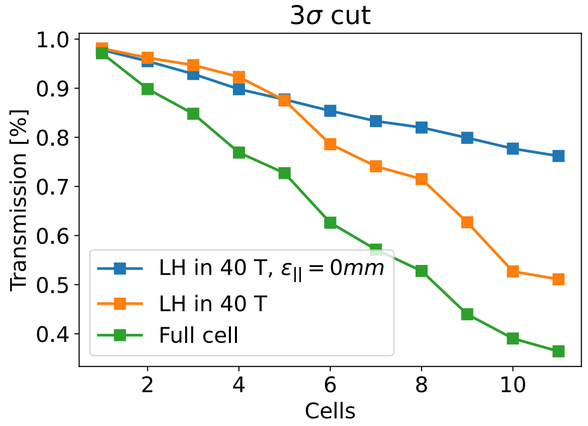
=> Re-optimizing, minimizing the energy spread further:
currently, in cell 10:
transv. = 47 micron, long. = 48 mm, 47% transmission, E-spread: 2.3 MeV

Simplified cooling (tracking in static 40 T and LH) vs. Cooling and acceleration in integrated full cells









Using 11 cells, integrated cell, optimising RF:

Preliminary

	$\epsilon_\perp [\mu m]$	$\epsilon_{||}$ [mm]	N [%]
3σ-cut	35	132	34
IF	35	131	35
MCD	32	117	32
No cuts	39	157	39

IF: Isolation Forest algorithm for outliers detection
MCD: Minimum covariance determinant
3 sigma cut is applied iteratively

=> result as in analytical estimation is achievable when tracking in simple 40 T, LH cell, applying 3sigma cut , with no longitudinal spread (transverse emittance 28 micron)

Transmission losses along the channel vs. Energy Spread

Transmission (applying 3 sigma cut)

After cooling	After cooling, cut	After drift and RF	σE_{accel}[%]
99.42	97.12	96.88	5.8
96.11	89.84	88.98	4.4
88.2	84.8	83.88	5.8
83.17	76.9	76.43	7
75.66	72.71	71.81	14.4
65.87	62.62	61.84	7.6
60.13	57.14	56.5	8.4
55.49	52.79	52	14
46.47	44	43	13.9
40.56	40	39	16.7
38	37	36	18
35	34		21

Radiation load relevant parameters:

Cell	Bz peak [T]	Solenoid Length [m]	Bz low [T]	Beam size, max [mm]	Beam size, min [mm]	E (before LH) [MeV]	LH thickness [m]	E (after LH) [MeV]	Total cell length [m]
1	43	1.48	4.75	42.6	11.8	74	0.85	40	4.0
2	43	1.75	4.75	31.5	9.7	53	0.466	32	6.82
3	43	1.0	4.7	31.3	9.99	53	0.47	32	9.61
4	43	1.0	4.7	37.2	14.5	50	0.4	32	10.75
5	43	1.0	4.7	32.3	9.5	35	0.3	18	8.09
6	43	1.11	4.7	30.8	24	30	0.25	15	9.75
7	41	1.33	2.1	42.3	21	33	0.3	14	9.73
8	41	1.0	2.0	32	23	22	0.1	15	9.9
9	41	1.4	1.1	36.8	24	25	0.17	13	10.89
10	39	1.0	0.86	40.8	26	16	0.08	9	9.8
11	39	1.0	0.86	43.4	27	16	0.054	11	10.64
12	40	1.5	0.9	39.2	27	19	0.1	10	11.02

Solenoid field in RF-Track:

$$B(z) = 0.5 \cdot B_0 \left(\frac{L - z}{\sqrt{R^2 + (L - z)^2}} + \frac{z}{\sqrt{R^2 + z^2}} \right)$$

(Radius = 0.16 m in all cells)