

Updates on Final Cooling



Cooling Working Group meeting, 01.12.2022
Bernd Stechauner

Palmer et al. 2011

MUON COLLIDER FINAL COOLING IN 30-50 T SOLENOIDS*

Robert B. Palmer, Richard C. Fernow, BNL, Upton, New York, USA
Jon Lederman, UCLA, Los Angeles, California, USA

PHYSICAL REVIEW SPECIAL TOPICS—ACCELERATORS AND BEAMS **18**, 091001 (2015)

High field – low energy muon ionization cooling channel

Hisham Kamal Sayed and Robert B. Palmer
Brookhaven National Laboratory, Upton, New York 11973, USA

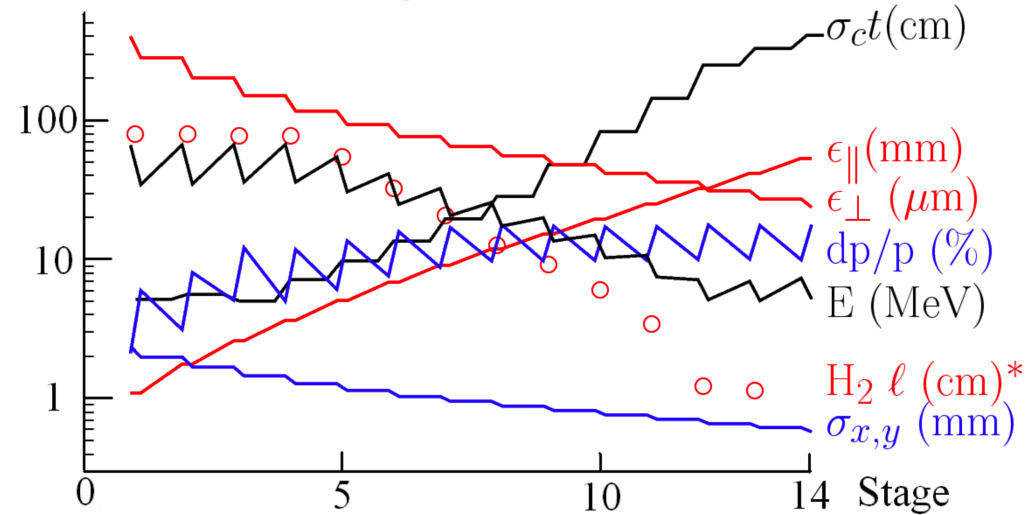
Sayed et al. 2015

David Neuffer
Fermi National Laboratory, Batavia, Illinois 60510, USA
(Received 27 April 2015; published 4 September 2015)

Table 1: Rf Parameters of 40 T Example

	E1 MeV	E2 MeV	freq MHz	grad MV/m	acc L m
NCRF	34.6	66.6	201	15.5	2.1
NCRF	34.8	66.9	201	15.5	2.1
NCRF	36.0	67.1	201	15.5	2.0
NCRF	36.0	54.5	153	11.1	1.7
NCRF	30.6	41.3	110	7.4	1.5
NCRF	24.9	32.4	77	4.7	1.6
NCRF	20.7	25.7	53	2.9	1.7
NCRF	17.4	20.0	31	1.5	1.7
Induction	13.6	15.0	18	1.0	1.4
Induction	10.3	10.7	10	1.0	0.4
Induction	7.5	7.2	6	1.0	0.7
Induction	5.1	7.0	5	1.0	1.8
Induction	5.1	7.4	4	1.0	2.3

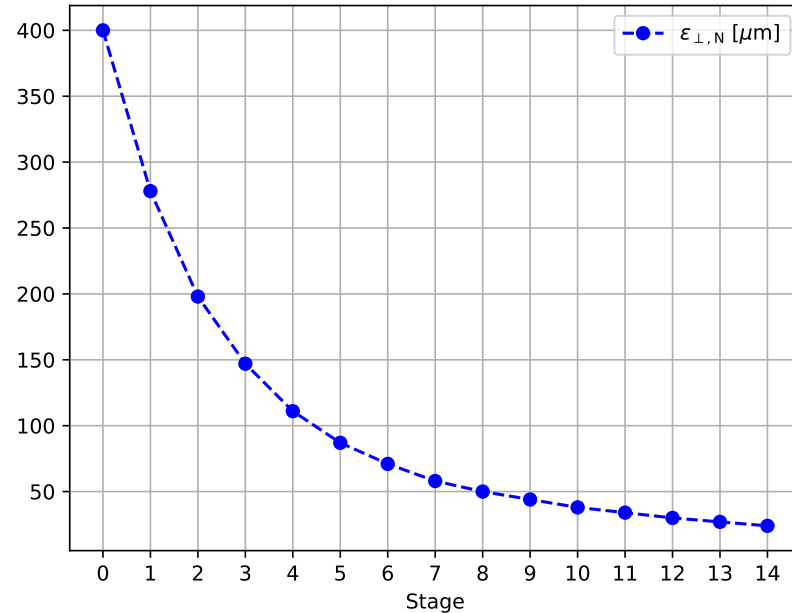
Parameters vs. stage for the 40 T sequence



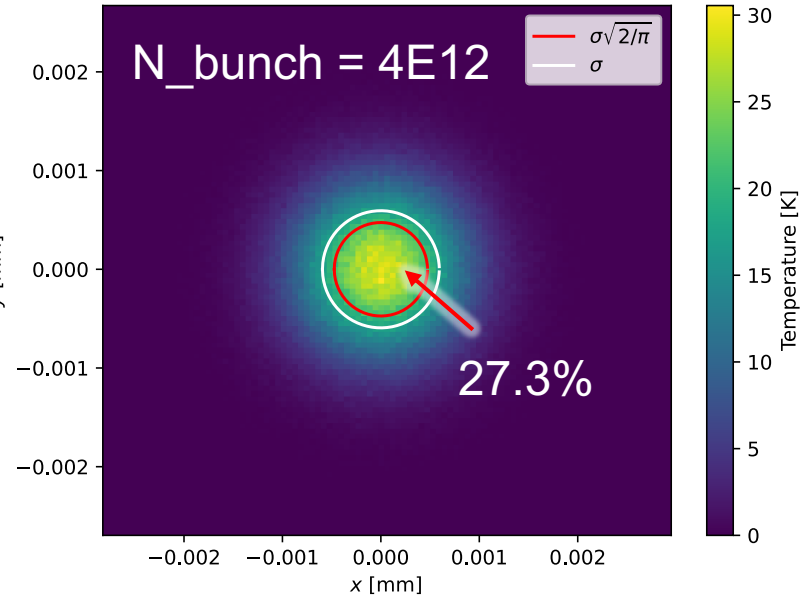
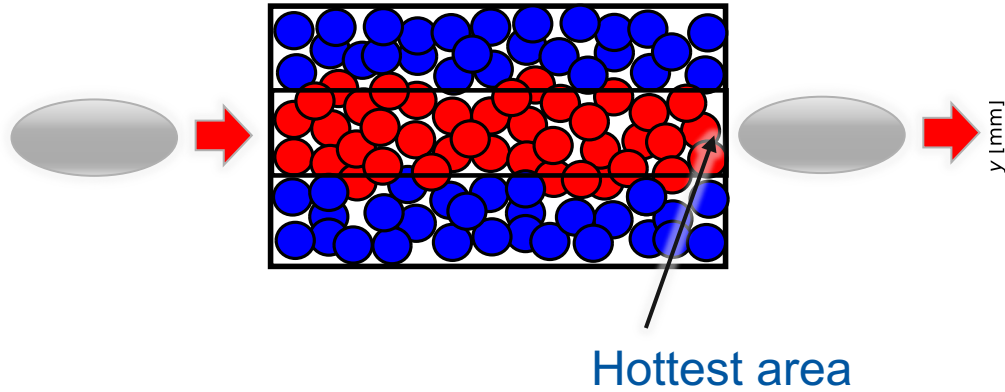
Stage	E_{Enter} MeV	E_{Exit} MeV	decel %	Abs len cm	$\epsilon_{L,N}^{\text{Exit}}$ μm
1	67.0	34.6	48.4	77.4	278
2	66.6	34.8	47.7	75.9	198
3	66.9	36.0	46.2	74.3	147
4	67.1	36.0	46.4	74.4	111
5	54.5	30.6	43.9	52.5	87
6	41.3	24.9	39.7	31.5	71
7	32.4	20.7	36.1	19.8	58
8	25.7	17.4	32.3	12.2	50
9	20.0	13.6	32.0	8.0	44
10	15.0	10.3	31.3	4.9	38
11	10.7	7.5	29.9	2.6	34
12	7.2	5.1	29.2	1.3	30
13	7.0	5.1	27.1	1.1	27
14	7.4	5.4	32.4	1.5	24



Solenoid fields: 40T, Absorber: LH



Thermodynamics



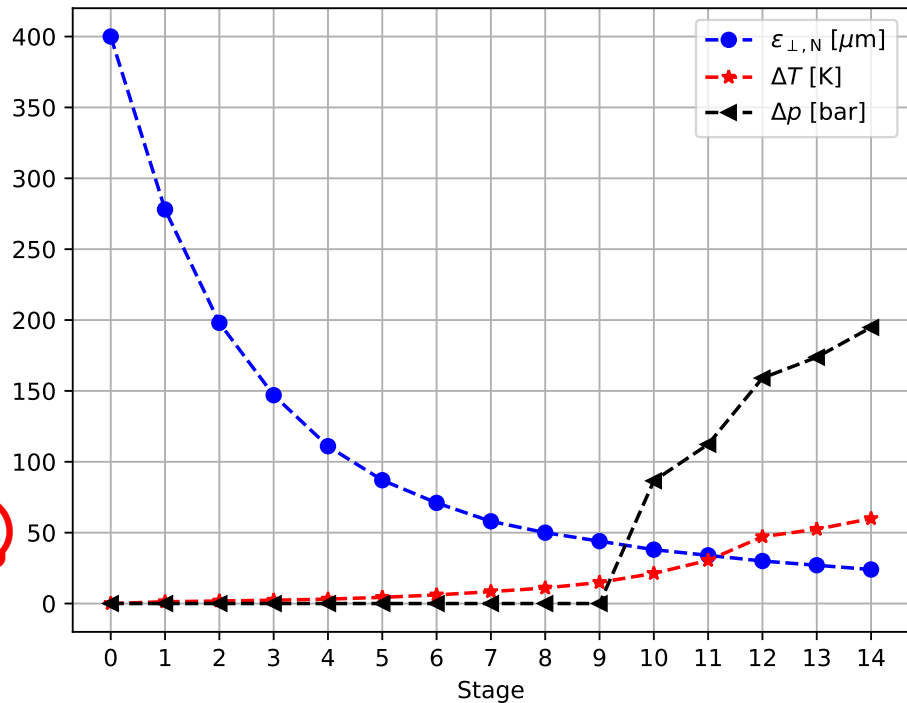
$$\Delta T = \beta\gamma \frac{\langle \frac{\partial E}{\partial s} \rangle}{2\beta_{\perp}\epsilon_{\perp,N} \cdot c_T} N_{\text{Bunch}} \cdot 0.273$$

Stage	E_{Enter} MeV	E_{Exit} MeV	decel %	Abs len cm	$\epsilon_{\perp,N}^{\text{Exit}}$ μm	ΔT K	Δp bar
1	67.0	34.6	48.4	77.4	278	1	0
2	66.6	34.8	47.7	75.9	198	2	0
3	66.9	36.0	46.2	74.3	147	2	0
4	67.1	36.0	46.4	74.4	111	3	0
5	54.5	30.6	43.9	52.5	87	4	0
6	41.3	24.9	39.7	31.5	71	6	0
7	32.4	20.7	36.1	19.8	58	8	0
8	25.7	17.4	32.3	12.2	50	11	0
9	20.0	13.6	32.0	8.0	44	15	0
10	15.0	10.3	31.3	4.9	38	21	87
11	10.7	7.5	29.9	2.6	34	30	112
12	7.2	5.1	29.2	1.3	30	47	160
13	7.0	5.1	27.1	1.1	27	52	173
14	7.4	5.4	32.4	1.5	24	60	195

87
112
160
173
195



Solenoid fields: 40T, Absorber: LH



Assumption: Window deformation @ 10 bar

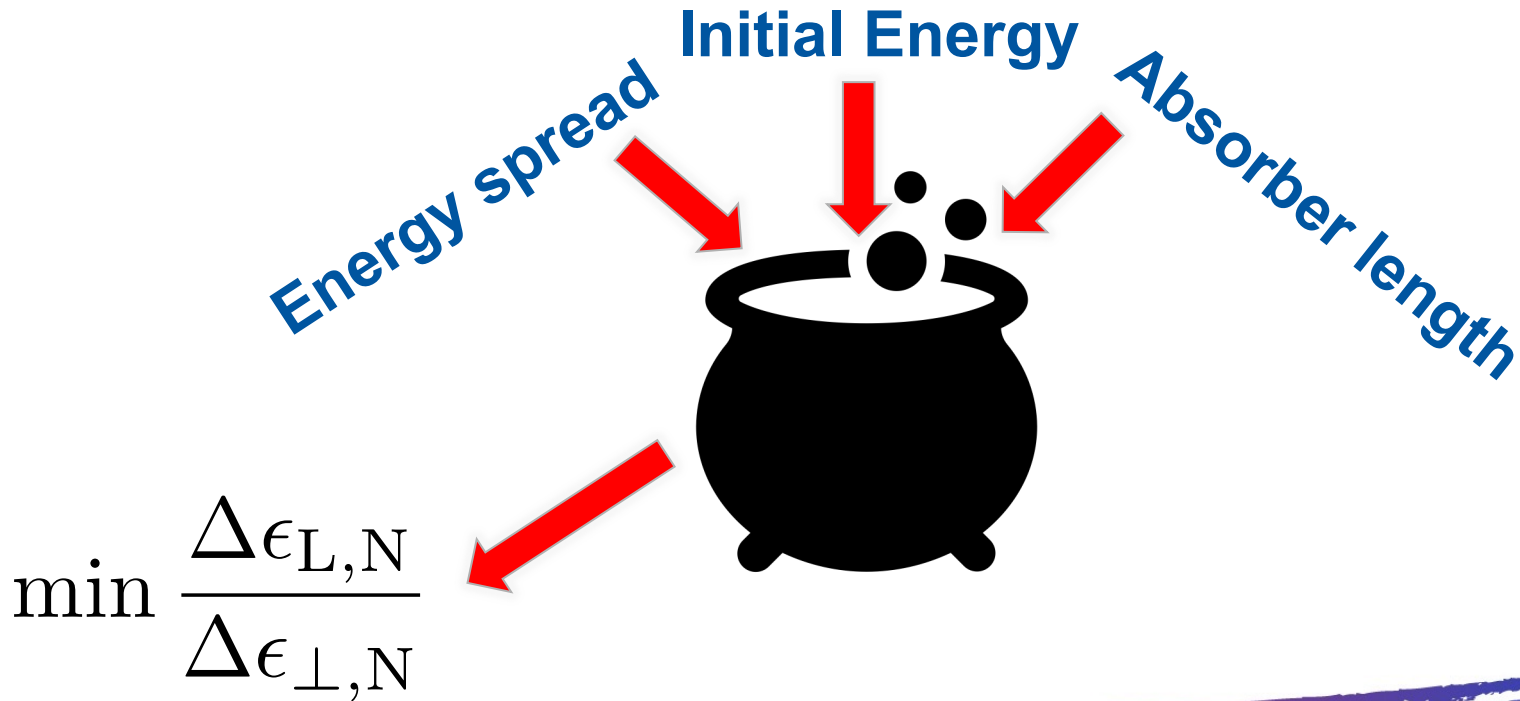
Hydrogen Gas

Stage	E_{Enter} MeV	E_{Exit} MeV	decel %	Abs len cm	Abs pres bar	$\epsilon_{L,N}^{\text{Exit}}$ μm	ΔT K	Δp bar
1	67.0	34.6	48.4	77.4	1	278	1	0
2	66.6	34.8	47.7	75.9	1	198	2	0
3	66.9	36.0	46.2	74.3	1	147	2	0
4	67.1	36.0	46.4	74.4	1	111	3	0
5	54.5	30.6	43.9	52.5	1	87	4	0
6	41.3	24.9	39.7	31.5	1	71	6	0
7	32.4	20.7	36.1	19.8	1	58	8	0
8	25.7	17.4	32.3	12.2	1	50	11	0
9	20.0	13.6	32.0	8.0	1	44	15	0
10	15.0	10.3	31.3	37.6 (gas)	1.6	38	21	10
11	10.7	7.5	29.9	27.4 (gas)	1.2	34	30	10
12	7.2	5.1	29.2	19.9 (gas)	0.8	30	47	10
13	7.0	5.1	27.1	19.6 (gas)	0.7	27	52	10
14	7.4	5.4	32.4	28.4 (gas)	0.6	24	60	10

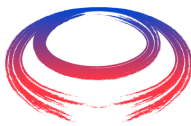
- Absorber length reduction at the first stages with Li ?
- Window modifications to avoid H-gas ?



Free parameters

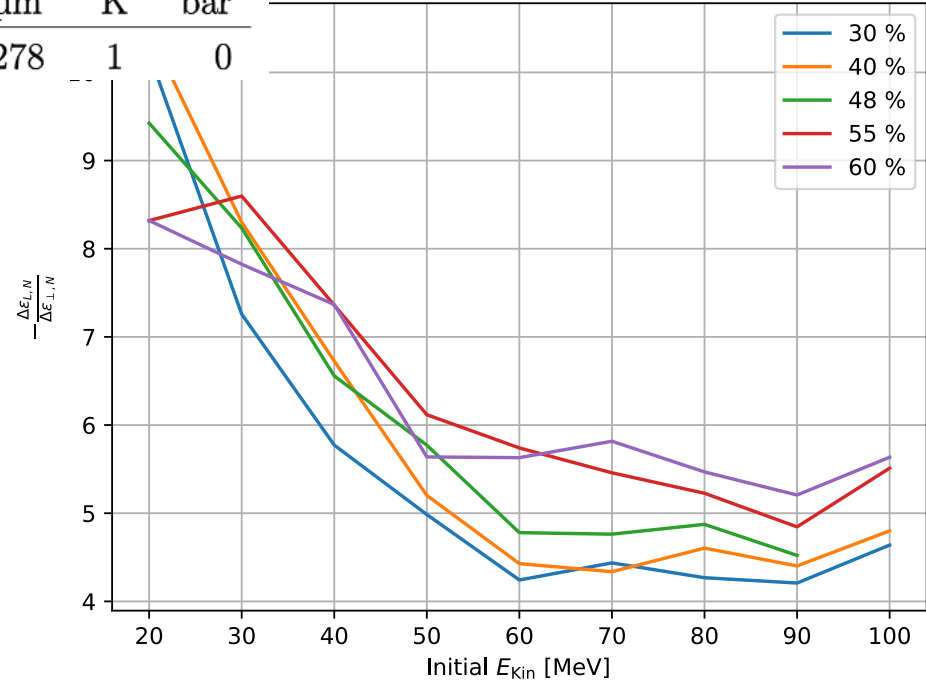


Effective cooling



Stage	E_{Enter} MeV	E_{Exit} MeV	decel %	Abs len cm	Abs pres bar	$\epsilon_{L,N}^{\text{Exit}}$ μm	ΔT K	Δp bar
1	67.0	34.6	48.4	77.4	1	278	1	0

ICool simulation



- Initial momentum spread: 2%
- Initial norm trans emit: 400 mm mrad
- Initial norm long emit: 1 mm

