Overview of HEMC Scheme

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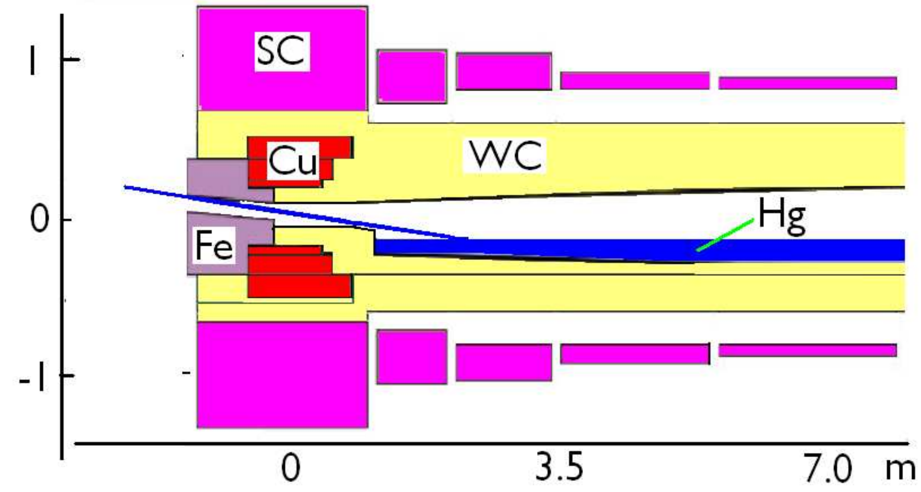
JLab

2/28/2011 My birthday

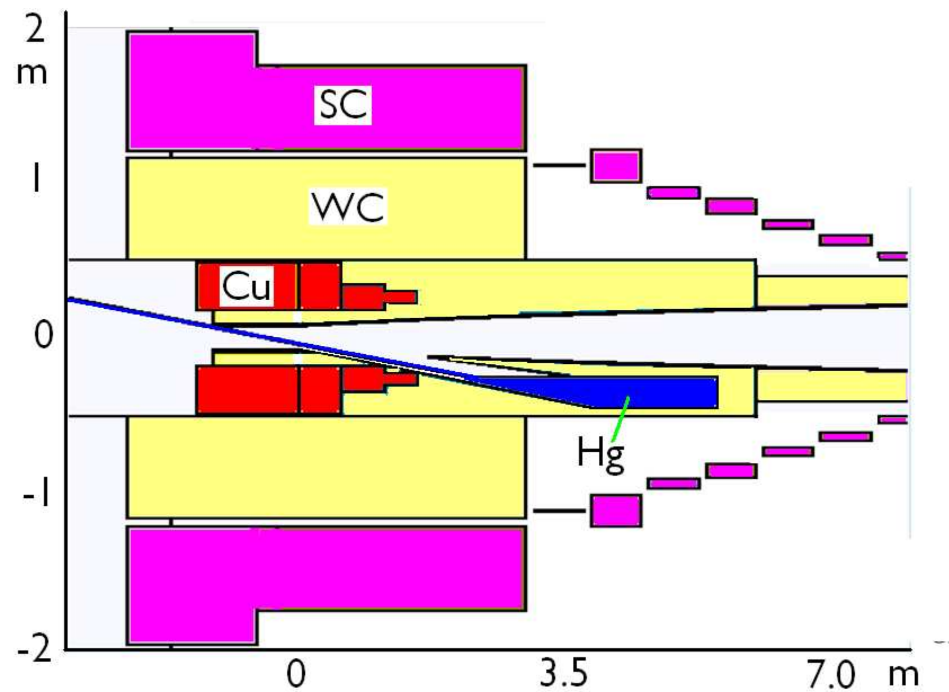
- Progress on Cooling simulations
- New Acceleration sequence with higher transmission
- New System transmission estimate
- New Wall power requirement estimate

Target Collection (Kirk, Bing)

- Study II was for 1 MW
  Collider uses 4 MW
- Study II used 24 GeV
  Collider uses 8 MW
- Radiation from target
  $\approx 8 \times$ higher
- Study II SC OD $\approx$ 2.6 m
  New design OD $\approx$ 4 m
- Study II 6 T Cu power = 12 MW
  New 6 T Cu power = 15 MW



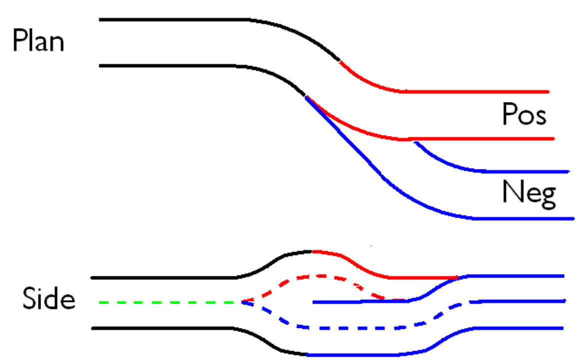
Old design

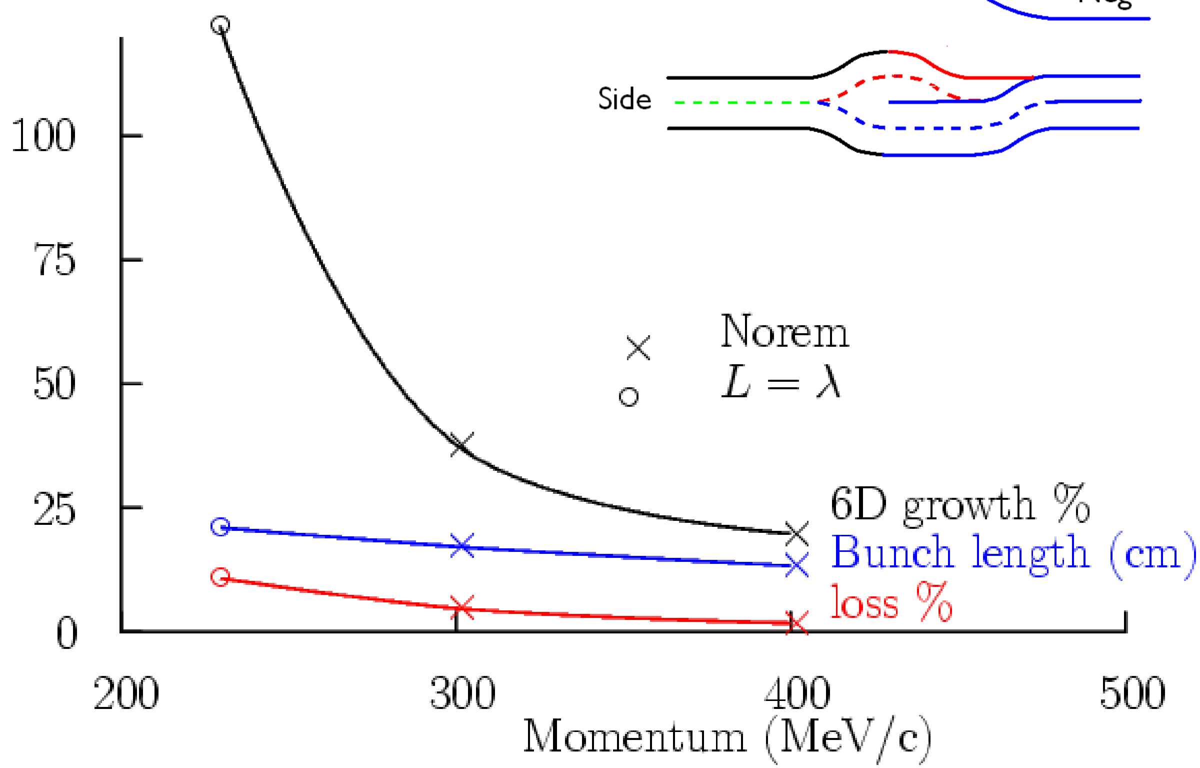


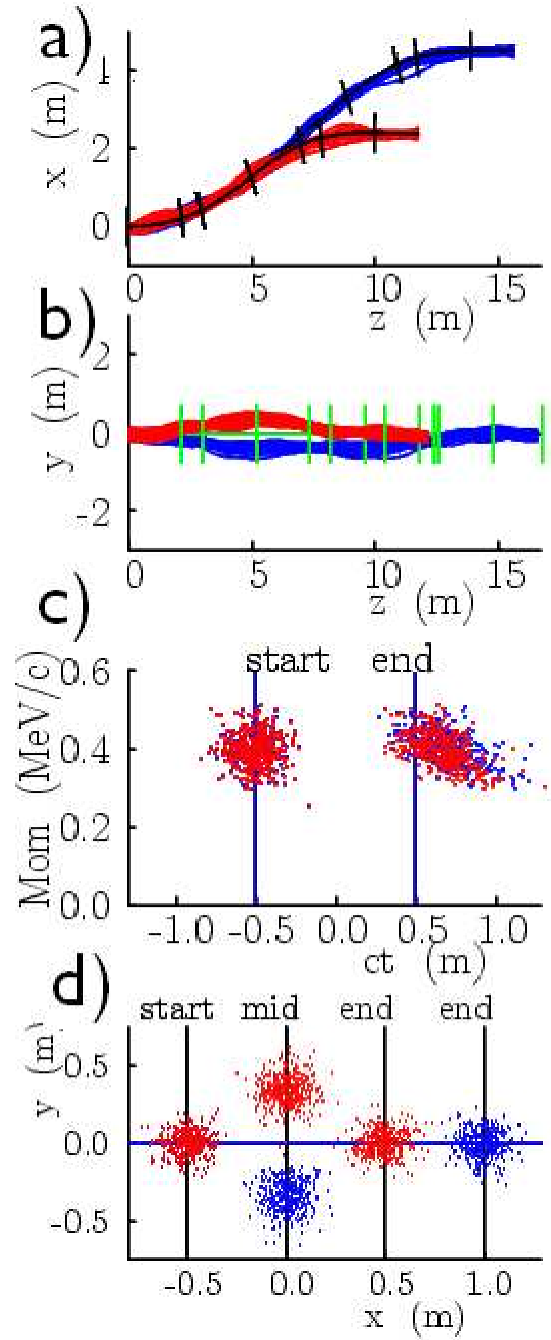
New design

Charge Separation (Fernow,Palmer)

- Fernow's method
- Palmer vs. momentum

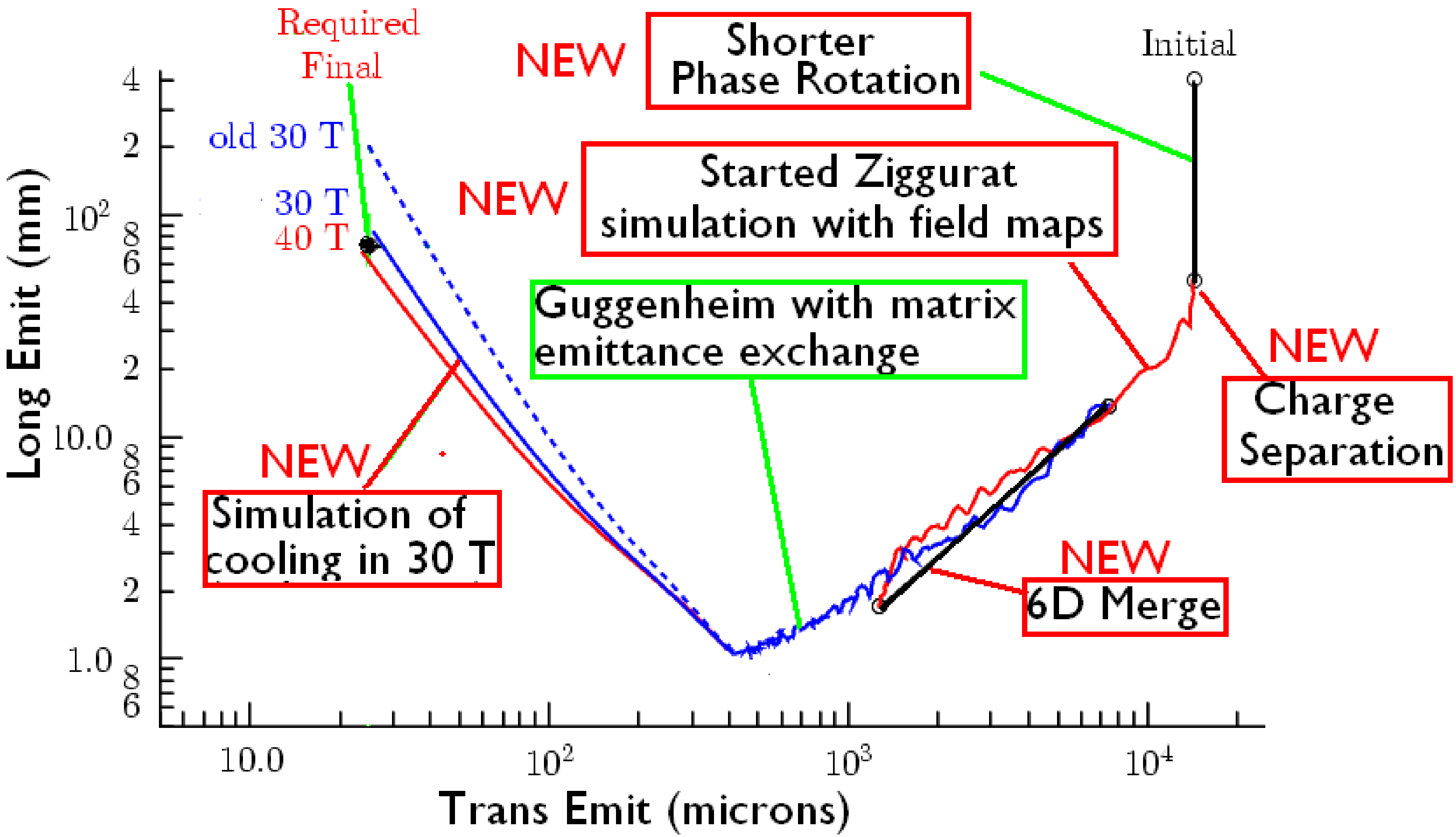






- Use of Snake cooling would delay charge separation to lower emittances and not require higher momenta

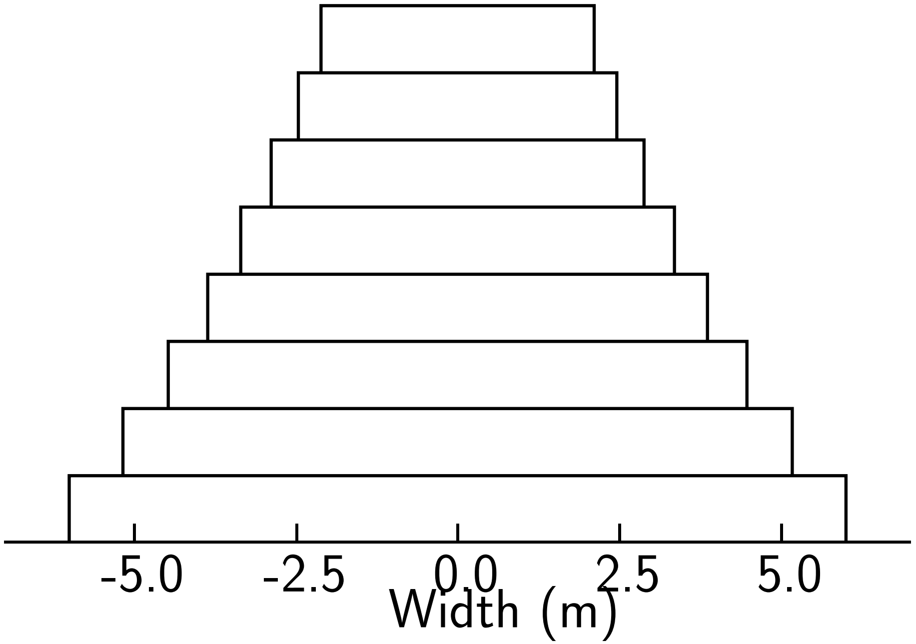
Simulation of cooling



- New corrected Final Cooling with 30 T 30 T now ok (Palmer)
- 6D cooling before merge now with real coils and field map (Fernow)
- 6D merge is more efficient than old 2D merges (Palmer)

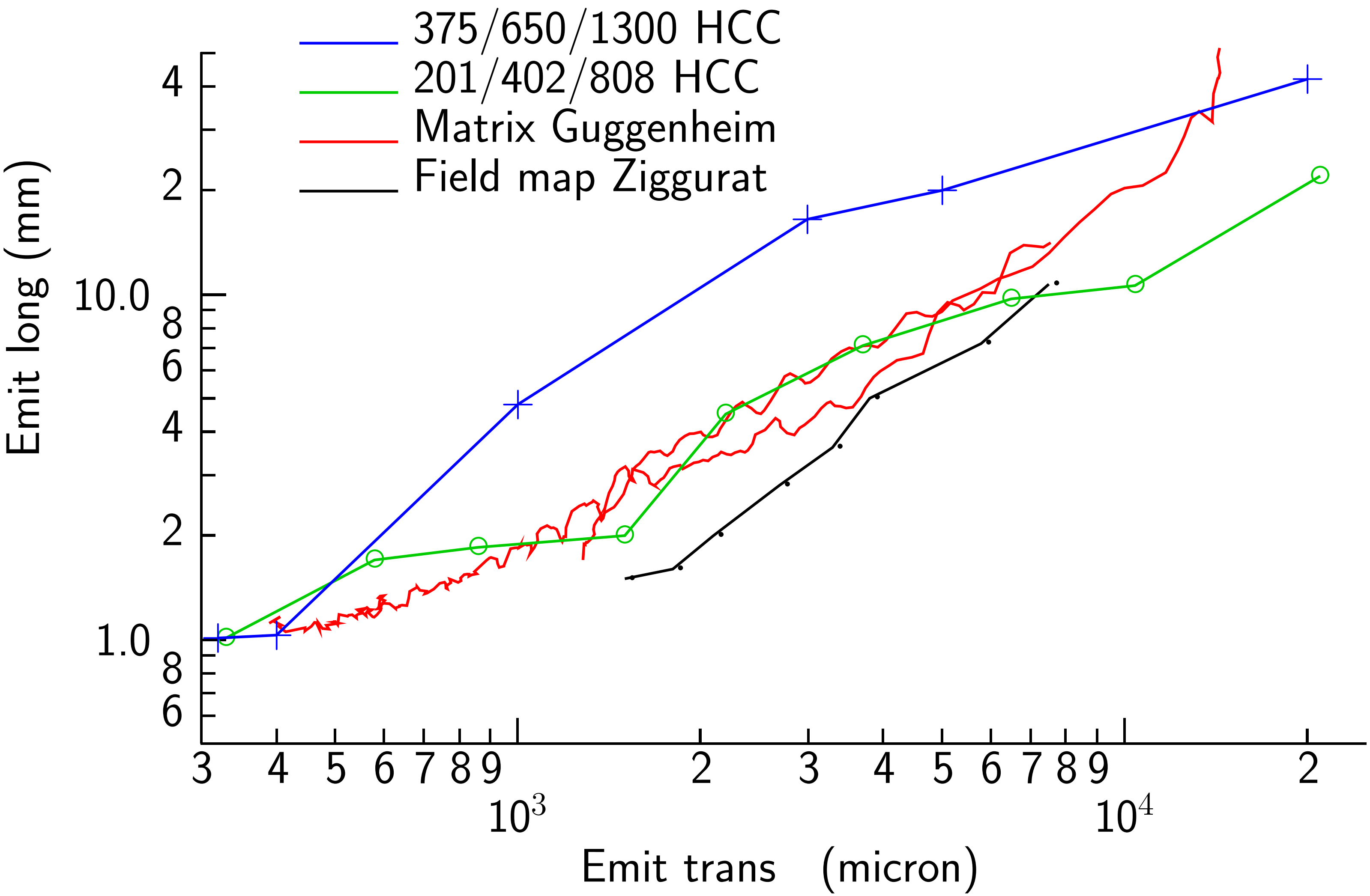
Simulation with field map (Fernow)

stage	ρ [m]	f [MHz]	α_W [deg]	cells
5	6.00	201	90	18
6	5.17	201	90	23
7	4.47	201	100	31
8	3.86	402	110	33
9	3.35	402	110	35
10	2.88	402	120	45
11	2.46	402	120	38
12	2.11	402	130	48



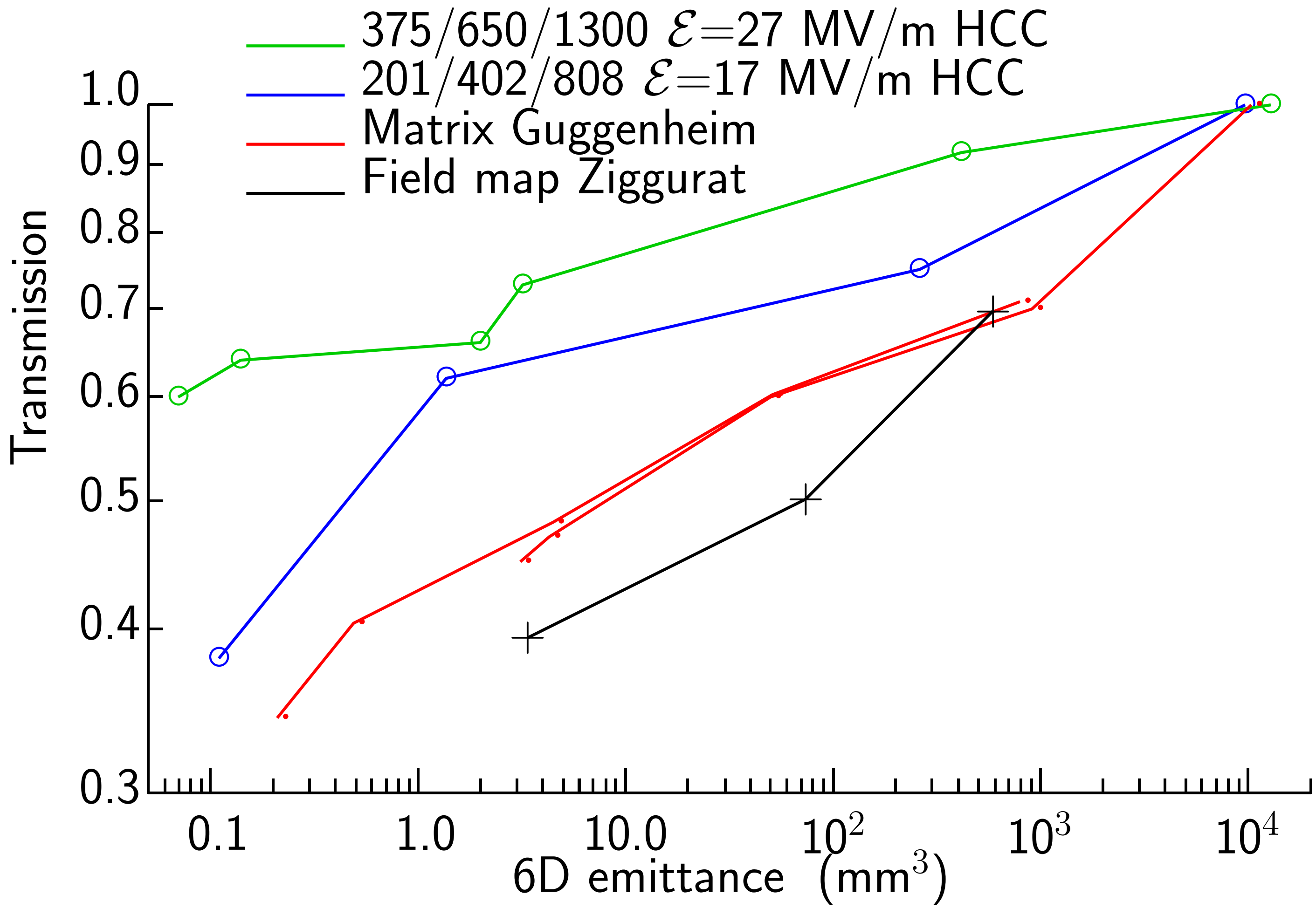
- Current simulation uses rings (Pavel has shown Guggenheim similar)
- Simulation used tilted coils - separate bend will give greater dispersion
  This will allow smaller apex angles and better performance

Compare Slopes



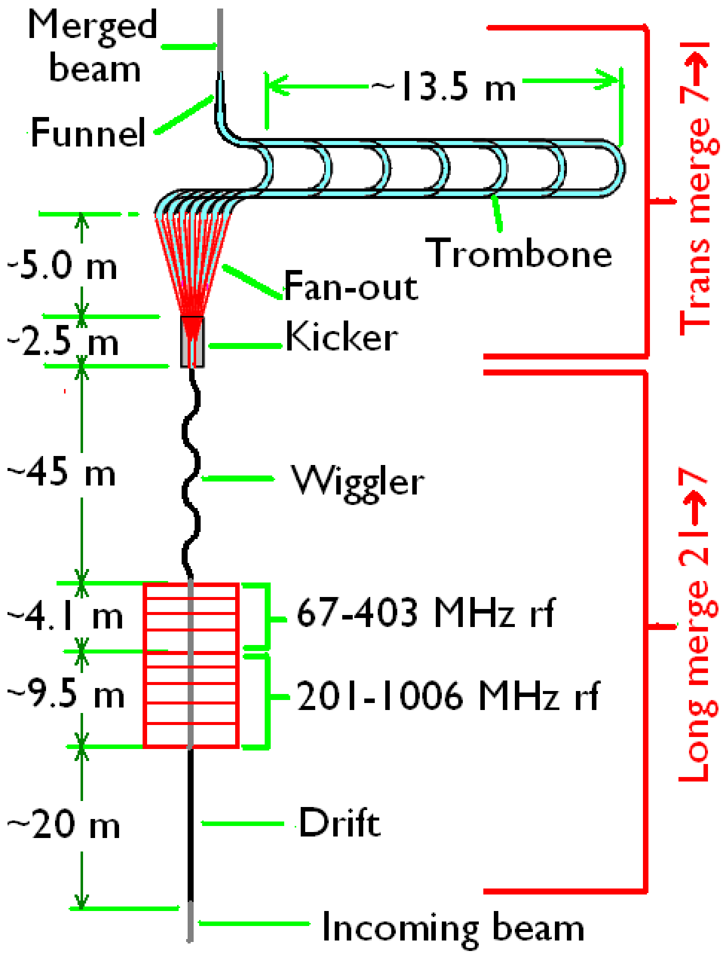
- Similar slopes
- 325 MHz HCC delays long cooling

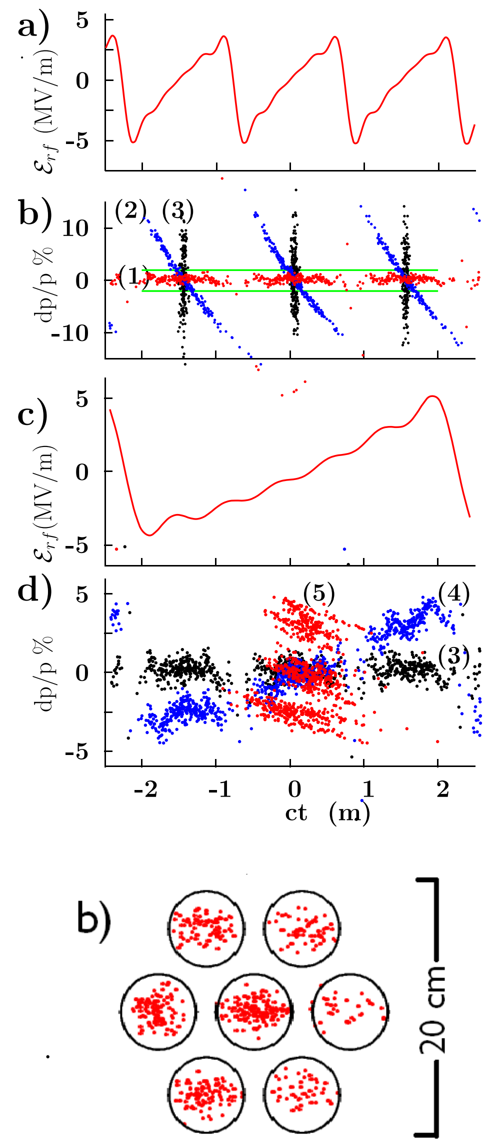
Compare Losses

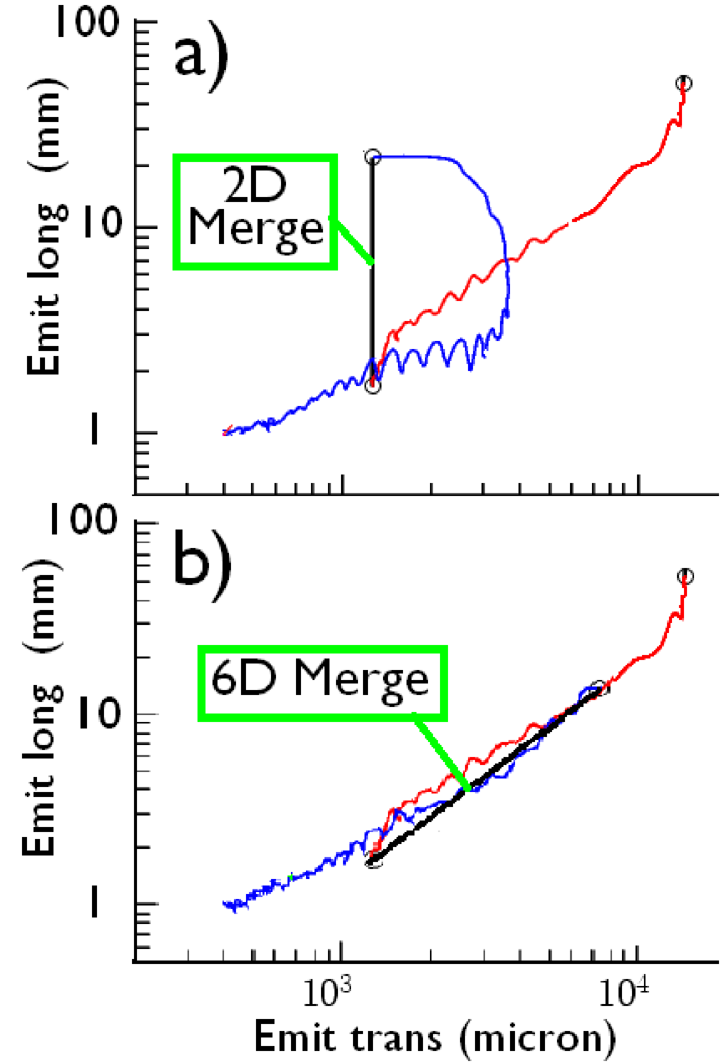


- 325 MHz HCC with 27 MV/m has least losses
  but would meet specifications set by Matrix Guggenheim
- Guggenheim using field map slightly worse than with Matrices
  but should be improved with greater dispersion

6D merge (Palmer)



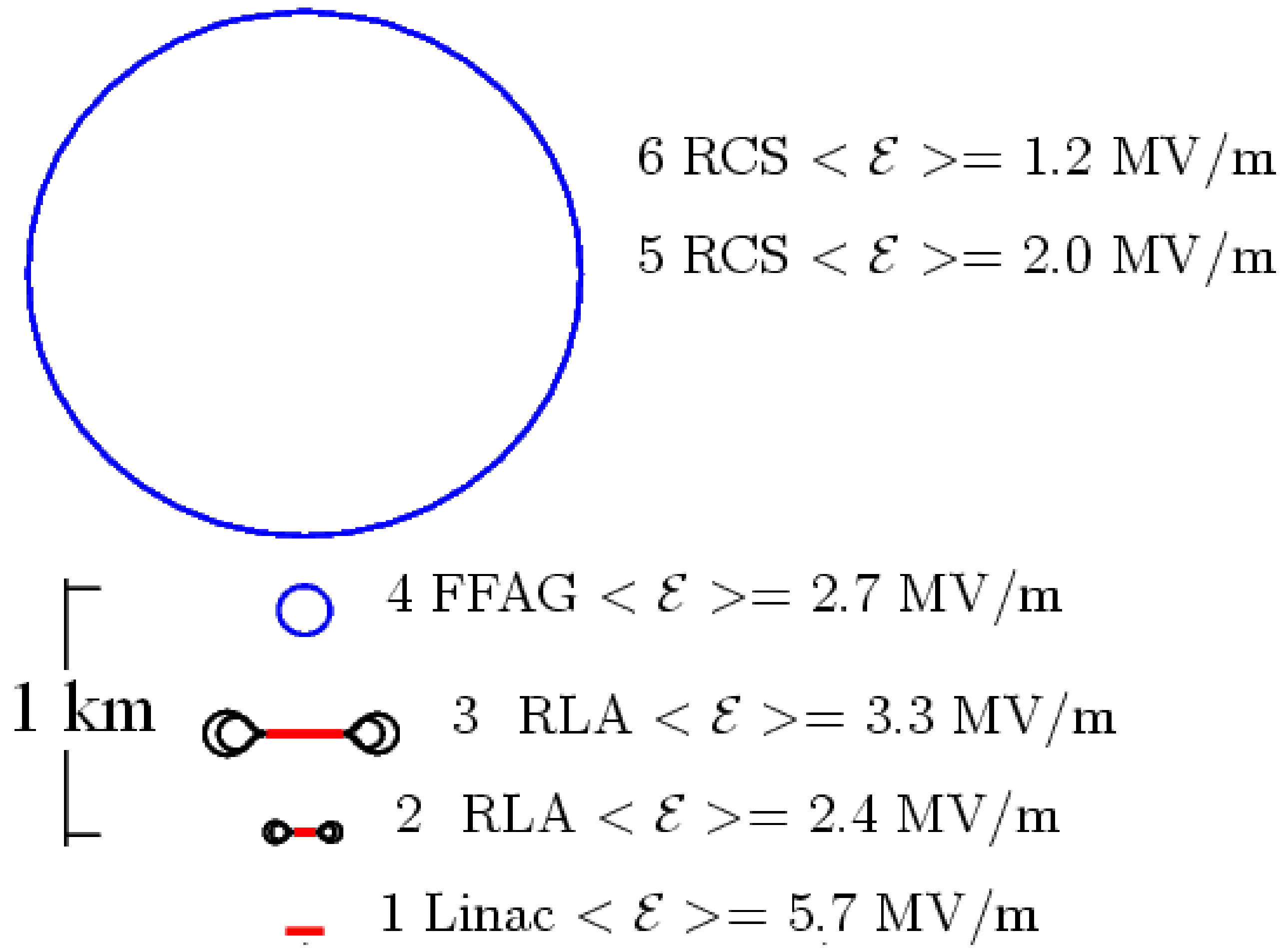




- Cooling after merge is more efficient with 6D merge
- Trombone will be much easier for 3(longitudinal) $\times$ 2(x) $\times$ 2(y) $=$ 12
- It can also be made shorter using wiggler with higher fields

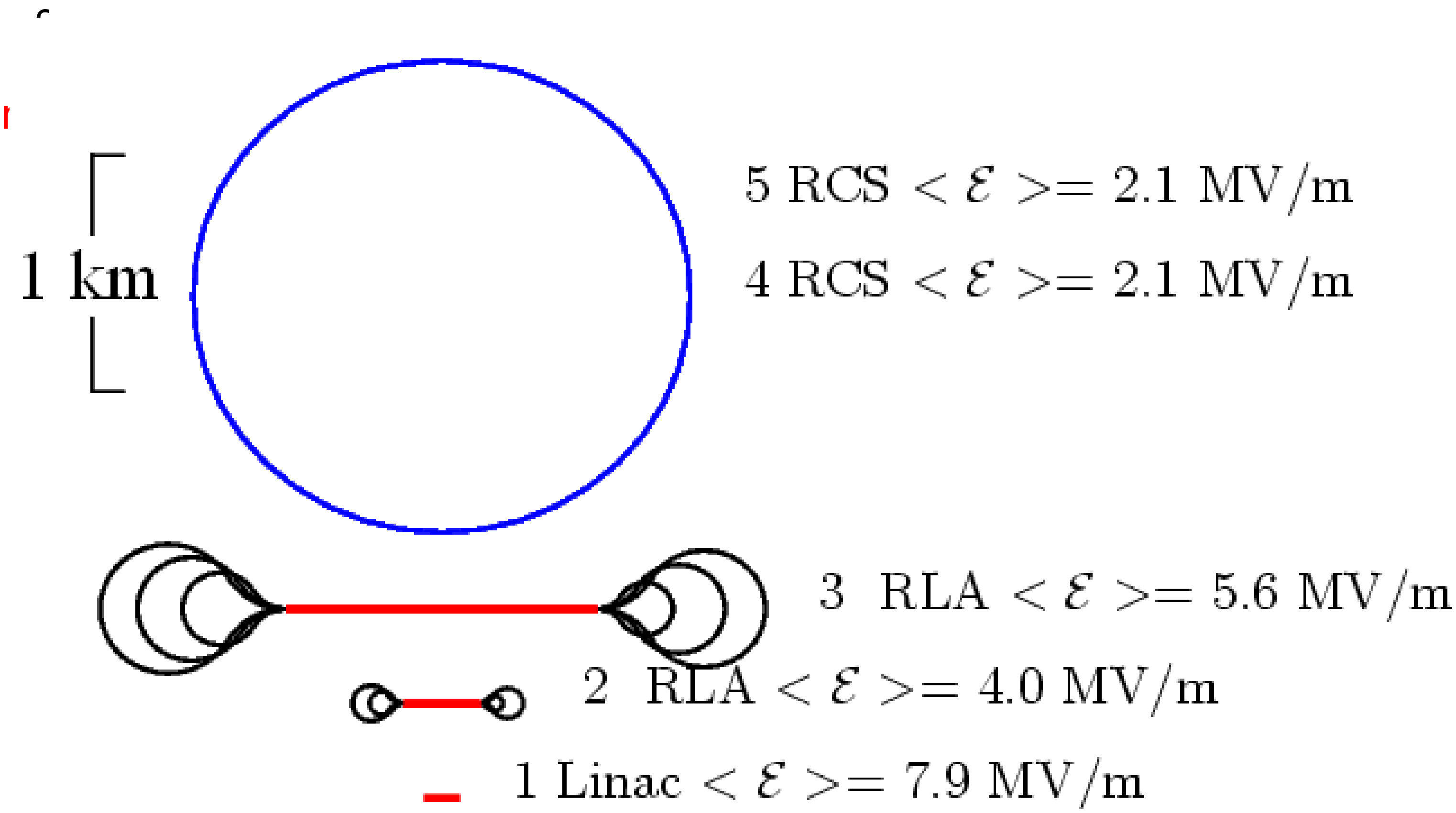
Acceleration (Berg)

- Linac: 0.4-1.2 GeV 140 m
- RLA 1: 1.2-4.2 GeV Linacs 79 m arcs 173-259 m
- RLA 2: 4.2-15 GeV Linacs 288 arcs 362-548
- FFAG: 15-30 GeV 622 m circumference
- RCS1: 30-400 GeV
- RCS2: 400-750 GeV
- Transmission 52.7%



Acceleration with improved transmission (Berg, Palmer)

- Linac 0.4-1.5 GeV 140 m
- RLA 1: 1.5-12.5 GeV Linacs 306 arcs 210-413
- RLA 2: 12.5-100 GeV Linacs 1250 arcs 698-1716
- No FFAG
- RCS1 100-400 GeV
- RCS2 More
- Transmissio
  63.2
  (cf 52.7)



MC Ring Parameters (Y Alexahin)

C of m Energy	1.5	3	TeV
Luminosity	1	4	10^{34} cm^{2}sec^{-1}
Beam-beam Tune Shift	0.087	0.087	
Muons/bunch	2	2	10^{12}
Total muon Power	9	15	MW
Ring <bending field>	6	8.4	T
Ring circumference	2.6	4.5	km
β^* at IP $= \sigma_z$	10	5	mm
rms momentum spread	0.1	0.1	%
RF frequency	805	805	MHz
RF Voltage	20	230	MV
Repetition Rate	15	12	Hz
Proton Driver power	$\approx$4	$\approx$4	MW
Muon Trans Emittance	25	25	pi mm mrad
Muon Long Emittance	72,000	72,000	pi mm mrad

- RF $\mathcal{E}$= 20 MV/m super conducting
  6$\times$18.75 cm=1.12m cells for 1.5 TeV
  61 cells $\times$18.75=11.4 m for 3 TeV

Heat load from Decay in Ring Kirk, Bing

beam power 9 MW

Power to electrons ≈ 3 MW

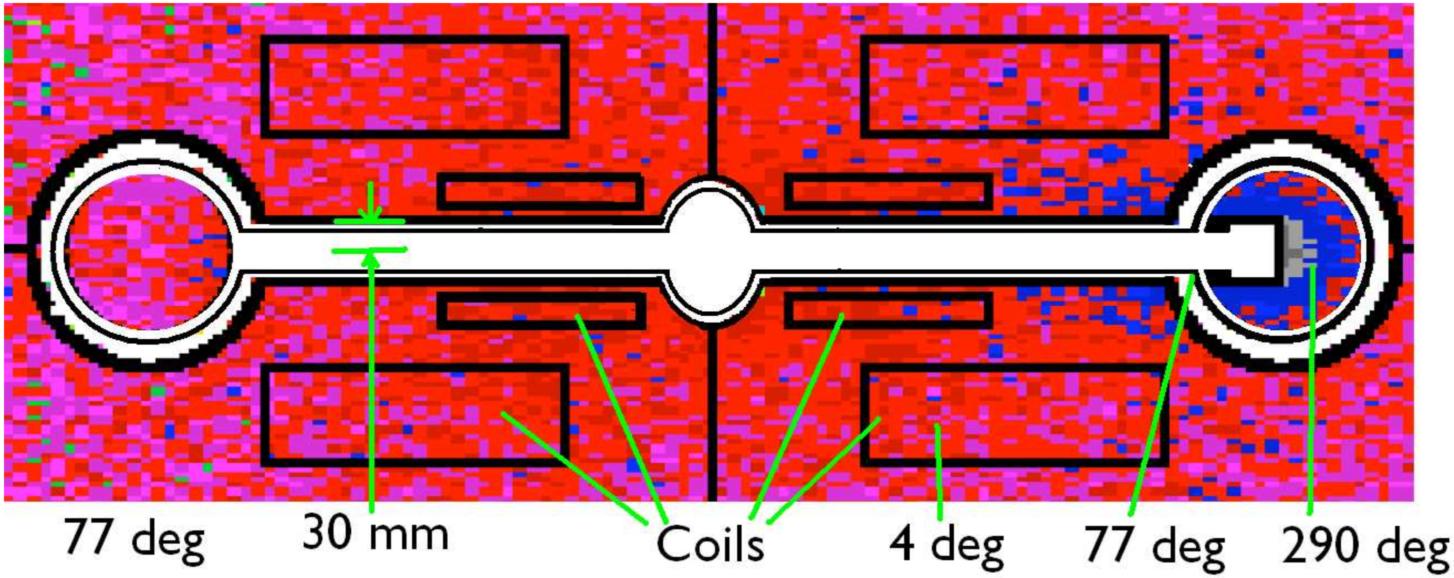
If at 77 deg and 20% of Carno then wall power = $3 \times 3.2 \times 5 =$ 48 MW

Better to take most of heating at room temperature

e.g. 93% at room temp.

and 6 % at 77 deg. giving wall power of 3 MW (Placeholder only)

and 0.6 % at 4 deg. giving wall power of 7 MW (Placeholder only)



New estimates of Transmission

From new acceleration design (not simulated), and cooling simulations

	transmission	cumulative	mu/p	mu/pulse
After rotation			0.334	
Momenta $= 226 \pm 100$ MeV/c	0.654	1.0	0.219	
Best 21 bunches	0.7	0.7	0.153	$2\times27.7\ 10^{12}$
Charge separation	0.85	0.59	0.129	$23.5\times2\ 10^{12}$
6D Cooling before merge	0.468	0.28	0.061	$11.0\ \times2\ 10^{12}$
Merge	0.88	0.25	0.055	$9.7\ \times2\ 10^{12}$
6D Cooling after merge	0.48	0.12	0.026	$4.7\ \times2\ 10^{12}$
50 T Cooling	0.7	0.08	0.018	$3.3\ \times2\ 10^{12}$
RTRF low energy acceleration	0.84	0.067	0.015	$2.7\ \times2\ 10^{12}$
SCRF Acceleration	0.73	0.049	0.011	$2.0\ \times2\ 10^{12}$

- Initial production from 8 GeV and MARS 15:
  For 2 10^{12} muons 1.87 10^{14} protons/bunch
- Power at 12 Hz: $15 \times 1.8710^{14} \times 810^{9} \times 1.610^{-19} \ = \ 3.6$ MW
  $<$ 4 MW $\rightarrow$ still some allowance for increased losses/ lower production.

rf Cavities

	f MHz	n	P(peak) MW
Induction		124$\times$ 1 m	-
NCRF	30	2	3
NCRF	67	5	6
NCRF	110	2	14
NCRF	150	3	17
NCRF	201	344	1160
NCRF	402	426	608
NCRF	805	2252	1283
SCRF	201	206	150
SCRF	402	1900	420
SCRF	805	3500	790

One could estimate the cost of these !

Calculation of Wall Power

			Wall power $\longrightarrow$						
	Len	P_{peak}	Static	Dynamic	—	—	—	—	Tot
			4^o	rf	PS	4^o	20^o	70^o	
	m	MW	MW	MW	MW	MW	MW	MW	MW
p Driver (SC linac)									(20)
Target and taper	16				15.0	1.6			16.6
Decay and phase rot	95	220	0.1	0.8		4.5			5.4
Charge separation	14								
6D cooling before merge	222	1420	0.6	7.2		6.8	6.1		20.7
Merge	115	10	0.2	1.4					1.6
6D cooling after merge	428	1350	0.7	2.8			2.6		6.1
Final 4D cooling	78		0.1	1.5			0.1		1.7
NC RF acceleration	104	35	0.1	4.1					4.2
SC RF linac	140	50	0.1	3.4					3.5
SC RF RLAs	10400	570	9.1	19.5					28.6
SC RF RCSs	12566	790	11.3	11.8					23.1
Collider ring	2600		2.3		(3.0)	3		(7)	5.3
Totals	26777	4445	24.6	52.5	18.0	15.9	8.8	7	146.8

Refrigerator costs could also be estimated

Variants:

1) Using MICE spectrometer data to predict cryogenic losses

Of the total wall power estimates for cryogenic cooling, that coming from heat leaking into the 4 degree systems, are given in column 2 of the following table.

If we assume cryostat heat losses taken from the experience of the MICE spectrometer magnet (2 w/m), instead of an earlier estimate (1.2 W/m), then the new total wall power numbers become:

P_{wall} old cryo loss	new cryo loss	Diff	P_{wall} total old	P_{wall} total new		increase	
24.6	32.8	8.2	147	155	MW	5.7	%

2) Magnetic insulation instead of pillbox cavities in fields

The wall power used to power NCRF in the phase rotation and cooling sections where magnetic field is present, are given in column 2 of the following table.

If Magnetic insulation is used, this power will be higher by a factor of ≈2. Columns 3 and 4 give the total wall powers including this factor.

old P_{wall} for NCRF	new P_{wall} for NCRF	diff.	P_{wall} total old	P_{wall} total new		increase	
12.2	24.4	12.2	147	159	MW	8.5	%

3) 3 TeV instead of 1.5 TeV c-of-m

- requires a new RCS for 750-1500 GeV

	E1 GeV	E2 GeV	L m	turns	Cav's	Freq MHz	grad MV/m	<grad> MV/m	Decay %	Pwall MW
RCS	750.00	1500.00	12566	29.0	5724	805	25.0	2.1	5.3	15.9

- Requires a larger collider ring
- Wall power changes:

	old P_{wall} MW	new P_{wall} MW	Diff. MW	total old MW	P_{wall} total new MW	increase %
rf in new RCS	-	15.9	15.9	147	163	11.0
magnet power in RCS	-	3	3	163	166	1.9
Static cryo in RCS	-	11.3	11.3	166	177	6.9
rf in ring	0.01	0.15	0.14	177	177	0.1
static cry for ring	2.3	4.0	1.7	177	179	1.0
Lower rep rate	99	$12/15\times 99$	-20	179	159	-11.4

  – Wall power for 3 TeV only 8.3 % higher than for 1.5 TeV
  – The 3 TeV power of 159 MW is $\approx$ 1/3 of CLIC, & 2/3 of ILC
  – and has (within 1 % E) 2 $\times$ luminosity of CLIC (4 vs. 2 10^{34})
  – This has larger uncertainties since the 3 TeV ring has not been designed

To be done on Current Ideas

- Evaluate space charge and other coherent effects at all locations in scheme
- Final Cooling
  - include windows
  - more and better optimizations
  - match and re-acceleration of an initial, mid, and final stage
  - full simulation
- RFOFO (Guggenheim/Ziggurat) 6D Cooling
  - simulate early 6D using output from new Phase Rotation
  - re-design 6D merge for 12 bunches
  - compare 6D with Neuffer 4D merging using matrix 6D cooling
  - tackle momentum miss-match before final cooling (200 MeV $\rightarrow$ 135 MeV
  - tackle initial momentum miss-match from charge separation to 6D (400 MeV $\rightarrow$ 200 MeV
  - design RFOFO lattice with separate bending for greater dispersion
  - do full simulations of early 6D and 6D after merge

- HCC
  - design initial 201 MHz HCC with specified coils and compatible rf
  - simulate the above using field maps (not helical fields)
  - design final 805 MHz HCC with specified coils and compatible rf
  - Simulate the above using field maps (not helical fields)
  - simulate needed sequences for before and after merge

- Snake Cooling
  - simulate snake for initial 6D with charge separation delayed
  - compare with RFOFO

- Acceleration
  - design and simulate early Normal Conducting for rf after final cooling
  - design RLAs with better transmission
  - design hybrid SC and pulsed 2nd RCS
  - design less challenging 1st RCS

To be done in Exploration of new options

- Explore Non-Flip RFOFO at end of 6D
  - aim to reduce current densities and fields in coils

- Explore REMX using wedges in 30-40 T solenoids
  - this should allow cooling to lower emittances
  - but 2 $d\epsilon_{\parallel}/\epsilon_{\perp}$ probably above 1.0

To be done on system requirements

- Tabulate super-conducting magnets
- Tabulate pulsed magnets
- Tabulate power supplies

Conclusion

- Much simulation progress this year
  - new capture magnet design
  - new shorter phase rotation
  - charge separation
  - 6D Ziggurat with field maps
  - 201/402/805 MHz HCC
  - 6D merge
  - improved final cooling with 30 T
  - sequence of acceleration with better transmission
  - start of design for open mid-plane dipole
- Either HCC or Guggenheim/Ziggurat probably ok
  - question for Ziggurat still rf breakdown in fields although magnetic insulation promising
  - question for HCC still incorporation of rf in helix magnets
- New transmission estimate still ok
- List of all rf for reviewers
- Estimate of wall power 2/3 of ILC 1/3 of CLIC