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TITLE NEW RESULTS ON (LAMPF II) SUPERCONDUCTING LINAC COST

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

MASTER

Paper presented at the
15th EHF Workshop, Lecco (I), Oct. 9-14, 1989

October 2, 1989

NEW RESULTS ON
(LAMPF II) SUPERCONDUCTING LINAC COST

by

G. Schaffer
Los Alamos National Laboratory
MP-14, MS H847

Summary:

A consolidated cost estimate for a superconducting 800 MeV extension of the LAMPF I linac is presented in this note. Based on recent CERN-LEP tender results for 20 superconducting cavities, the cost of a superconducting linac structure (402.5 MHz) can be projected with much better accuracy than so far.

The total construction cost for an 800 MeV extension amounts to 99.5 M$, buildings, cryoplant etc. included. The corresponding figure for a normalconducting structure (1207.5 MHz, on-axis coupled) is 104.6 M$.

Outline:

Paper presented at the
15th EHF Workshop, Lecce (I), Oct. 9-14, 1989

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Results
NEW$/ON

(LAMPF II) SUPERCONDUCTING LINAC COST

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A consolidated cost estimate for a superconducting 800 MeV extension of the LAMPF I linac is presented in this note. Based on recent CERN-LEP tender results for 20 superconducting cavities, the cost of a superconducting linac structure (402.5 MHz) can be projected with much better accuracy than so far.

The total construction cost for an 800 MeV extension amounts to 99.5 M$, buildings, cryoplant etc. included. The corresponding figure for a normalconducting structure (1207.5 MHz, on-axis coupled) is 104.6 M$.

Pulsed-beam operation of a superconducting cavity has been proven sucessfully at the CERN-SPS for beam injection into LEP.

Outline:

Comments on Linac Cost

News on Cost Estimates
for 800 MeV Linac Extensions

G. Schaffer, MP-14
12-Jul-89

New Information obtained from various Laboratories (CERN, CEBAF)
is summed up in the following:

1) On RF Cost

In an interview at CERN in June, Wolfgang Schnell pointed out to me that the cost of the LEP 1 RF system is now estimated to amount to 62 MSF (in 1989 prices).

60 % of the total cost will be caused by the RF power part (16 MW CW).

If we evaluate this with the present exchange ratio of 1.60 SF per $, the cost of a 1 MW CW power unit results in 1.46 M$.
- -

This means an increase of the unit cost by about 20 %, compared to the figure in my note "RF Power Cost 4" from Jan. 1989.

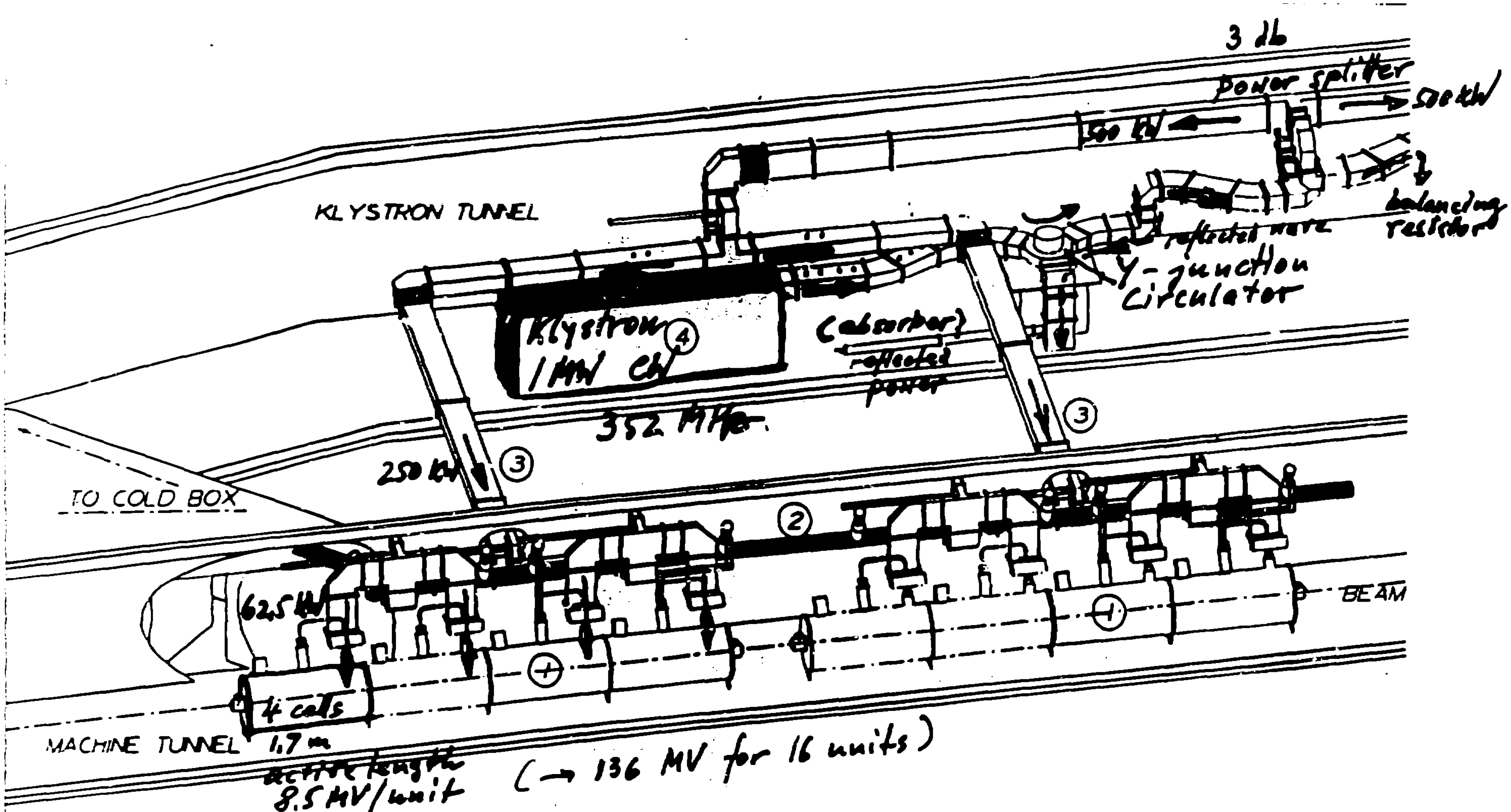
2) On Cost of Superconducting Structures:
- -

CERN has placed the order for 20 cavities (352 MHz) to be used for LEP, for an amount of 10 MSF. This is about 25 % more compared to the original estimate.

CEBAF has proposed to order their cavities (1500 MHz) from Interatom, but another tenderer has formulated objections with the General Accounting Office.

More details on these cases will be reported separately.

In summary, it appears that superconducting structures remain very competitive from the point of view of cost, and that our studies should continue how to use them for LAMPF Linac Extensions.



LEP Supercond. Cavity Installation

① CAVITY + CRYOSTAT
② LHE DISTRUBUTION LINE
③ WAVE GUIDE
④ KLYSTRON

Structure Cost 4

LINAC STRUCTURE COST					
Information from various sources					
				G. Schaffer, MP-14	
					Jul-89
Cost Results for Superconducting Structures					
- -					
frequency & type	352 MHz	manufacturers recent quotations, based on 20 units,			
	4-cell	active length 1.7 m per unit			
	CERN-LEP				
guaranteed RF properties:					
		resonance frequency		at room	
		field flatness		temperature	
		accelerating field		at 4.5 K	
		unloaded quality factor Qo		at 4.5 K	
		tuning range		at 4.5 K	
		values according to CERN Specification I-1771/LEP			
		e.g. Qo min 3 x 10^9 for Eacc = 5 MV/m.			
guaranteed mechanical					
and thermal properties:		leak tightness for vacuum tank		at 4.5 K	
		leak tightness for helium tank		at 4.5 K	
		cryogenic losses		at 4.5 K	
The following cost estimates were given by 3 (out of 7) tenderers					
(CERCA, DORNIER, INTERATOM). The individual items are sorted from lower to higher					
figures and cannot be systematically allocated to these 3 manufacturers.					
Conversion used: 0.62 $/SF.					
item	quotation	lowest	second	higher	
cavity		62	77	98	k$/m
niobium		41	50	50	
tuners		22	22	24	
rad. shield		10	11	13	
test		3	4	6	
He-tank		14	16	33	
vacuum tank		18	38	39	
		- - - - - - -	- - - - - - -	- - - - - - -	
	sum	170	218	263	k$/m
Lowest offer:		182	k$/m		
		- - - - - - -	- - - - - - -		

Couplers:						
In a separate tender, main input couplers and higher-order-mode couplers were						
offered by CERCA, DORNIER, INTERATOM and PHILIPS.						
1 main coupler + 2 HOM couplers per cavity are needed.						
Again, without specific allocation to tenderers, the offers are:						
couplers		8	15	20	23	k$/m
Lowest sum for						
structure incl. couplers		190	k$/m			
		- - - - - -	- - - - - -			
Other items belonging to our category "Structure Cost" are estimated in analogy to						
normalconducting structures:						
vacuum						
quadrupoles						
quad power supplies						
beam instrum. & controls,						
subtotal all others		26	k$/m			
		- - - - - -	- - - - -			
Completed Structure Cost		216	k$/m	(352 MHz)		
		- - - - - -	- - - - -			
Extrapolation to 402.5 MHz:						
- - - - - - - - - - - - - - - - - - - -						
The material required is roughly inversely proportional to the square of the frequency.						
This would justify a deduction of 10 k$/m for the niobium. With all other items						
unchanged, the extrapolated structure cost for 402.5 MHz would be:						
Structure Cost (402.5 MHz)		206	k$/m			
		- - - - - -	- - - - -			
Cost of Cryogenic Equipment:						
- - - - - - - - - - - - - - - - - - - -						
H. Lengeler proposes to use this formula for the cost of cryogenic equipment (4.2 K):						
Cost of Cryoplant		2.5 x (P in kW)^0.6			in MSF	
or, with our conversion		1.55 x (P in kW)^0.6			in M$	
P is the sum of static and dynamic losses.						
Static thermal losses are specified not to exceed 10 W/m (including couplers).						
We may assume 10... 20 W/m dynamic losses at 5 MV/m.						
The total losses for 160 m active length (800 MeV @ 30 degree synchronous phase)						
would then be between 3.7 and 5.9 kW.						
Resulting Cryo-System Cost			3.4	to 4.5	M$	

Worksheet 800.1sr

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Superconducting Linac Cost Spreadsheet 3/31/89 (Sc), Revision 7/26/89																			
2	Headroom	1.1																		
3	Pmax	1	MW																	
4	Pavg	0.12	MW													Linac Building Length				
5	eff	0.3														equals 1.85*Struct.Length				
6	RFcost	0.55	M$/module		hrspyea	4000	hrs/yr													
7	Life	25	Years		kwh	0.05	$/kW-hr													
8	Str	0.206	M$/meter		Power	0.2	M$/MWyear													
9	Zshunt	2500	GOhm/meter																	Linac
10	dE	800	MeV		Loss	0.01	kW/m at 5 MV/m+10 W/m													Constr.
11	ibeam	0.022	Amps		Conversi	330									Installed				Total	Cost +
12	duty	0.12						Linac	Lifetime						Linac		Electr.+		Linac	Lifetime
13		Struct.	PeakRF			LifetimeRF		Compon	Cryo		Install.	EDI	Proj.	Contin	Equipm.	Linac	Cooling	Cryo	Constr.	Power
14	Grad	Length	Power	RF Cost	Str.Cost	Power Cost		Cost	Cost		Cost	Cost	Manag.	gency	Cost	Buildg	Plant	Plant	Cost	Cost
15	(MeV/m)	(meter	(MW)	(M$)	(M$)	(M$)		(M$)	(M$)		(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)
16	1	800	17.6	10.65	164.8	35.201		175.4	13.9		17.54	39	23.2	63.69	318.44	57.4	2.544	9.7	388.1	437.2
17	2	400	17.6	10.65	82.4	35.202		93.05	8.009		9.305	20	12.3	33.78	168.88	28.7	2.625	6.97	207.2	250.4
18	3	266.7	17.6	10.65	54.933	35.203		65.58	6.513		6.558	14	8.66	23.81	119.03	19.1	2.705	6.15	147	188.7
19	4	200	17.6	10.65	41.2	35.203		51.85	6.117		5.185	11	6.84	18.82	94.106	14.4	2.785	5.93	117.2	158.5
20	5	160	17.6	10.65	32.96	35.204		43.61	6.162		4.361	9.6	5.76	15.83	79.151	11.5	2.866	5.95	99.45	140.8
21	6	133.3	17.6	10.65	27.467	35.205		38.12	6.426		3.812	8.4	5.03	13.84	69.181	9.57	2.946	6.1	87.8	129.4
22	7	114.3	17.6	10.65	23.543	35.206		34.19	6.816		3.419	7.5	4.51	12.41	62.06	8.2	3.026	6.32	79.61	121.6
23	8	100	17.6	10.65	20.6	35.207		31.25	7.285		3.125	6.9	4.13	11.34	56.719	7.18	3.107	6.58	73.58	116.1
24	9	88.89	17.6	10.65	18.311	35.208		28.96	7.806		2.896	6.4	3.82	10.51	52.565	6.38	3.187	6.86	68.99	112
25	10	80	17.6	10.65	16.48	35.209		27.13	8.363		2.713	6	3.58	9.848	49.242	5.74	3.267	7.15	65.4	109

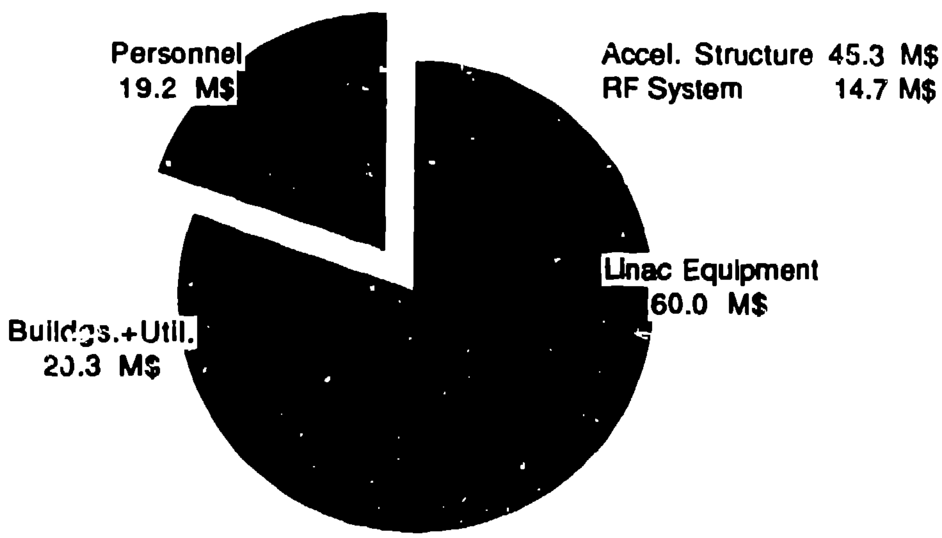
Worksheet 800.1sr

	U	V	W	X
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11		Distribution of Construction Cost		
12		for 5 MeV/m:		
13				
14	Linac Equipment	59.96	(M$)	
15	Buildgs.+Util.	20.3	(M$)	
16	Personnel	19.19	(M$)	
17	Constr. Total	99.45	(M$)	
18				
19				
20	Accel. Structure	45.32	(M$)	
21	RF System	14.64	(M$)	
22				
23				
24				
25				

Worksheet 800.1sr

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
1										
2		Dictionary:								
3		- - - - - - - -								
4										
5		Headroom	-factor indicating safety margin in RF power sources							
6		Pmax/Pavg	-max. pulse/average RF output power per module							
7		eff	-overall efficiency of RF power sources (referring to mains input)							
8		RFcost	-cost of RF power module incl. associated equipment (HV supply, modulator,waveguides, low.-power RF part, controls)							
9		Life	-number of years of accelerator operation, used for power cost calculation							
10		Str	-cost of acc. structure incl. assoc. equipm. (cooling+vacuum syst., beam focus.+meas. equipm., controls)							
11		Zshunt	-resonant impedance of acc. structure per unit length							
12		dE	-energy gain of accelerated particle at synchronous phase							
13		ibeam	-beam intensity during pulse							
14		duty	-duty factor of RF operation							
15		Power	-cost of mains power							
16		Loss	-dynamic and static heat losses in superconducting structure							
17		Conversion	-factor indicating ratio cryo-system input power (mains) to losses in superc. structure							
18		Grad	-mean gradient inside structure at synchronous phase							
19		EDI	-cost of engineering, design, inspection							
20										
21										
22										
23										
24										
25										

Chart 800.1sr



800 MeV Superconducting Linac Extension
Gradient 5 MeV/m
Construction Cost 99.5 M$

Worksheet 800 o.a./1.2 GHz

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	C	P
1	Hi Duty Factor Linac Cost Spreadsheet HAT 1/11/89+GSC 5/23/89															
2	Headroom	1.1														
3	Pmax	3	MW													
4	Pavg	0.36	MW											Linac Building Length		
5	eff	0.5												equals 1.1*Struct.Length		
6	RFcost	0.87	M$/module		hrspyea	4000	hrs/yr									
7	Life	25	Years		kwh	0.05	$/kW-hr									
8	Str	0.0809	M$/meter		Power	0.2	M$/MWyear									
9	Zshunt	54.9	MOhm/meter		Structure type		on-axis coupled									
10	dE	800	MeV													
11	ibeam	0.022	Amps		ibeam average		2.6	mA								Total
12	duty	0.12											Installed		Electr.+	Linac
13		Struct.	Peak RF			Lifetime		Linac	Install.		Proj.	Contin	Linac	Linac	Cooling	Constr.
14	Grad	Length	Power	RF Cost	Str. Cost	Power Cost		Compon.	Cost	EDI	Manag.	gency	Equipm.	Building	Plant	Cost
15	(MeV/m	(meters)	(MW)	(M$)	(M$)	(M$)		(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)
16	1	800	37	11.82	64.72	44.4		76.535	7.65	16.8	10.1	27.78	138.91	34.14	4.928	178
17	2	400	56.5	18.02	32.36	67.8		50.376	5.04	11.1	6.65	18.29	91.432	17.07	7.515	116
18	3	266.67	75.9	24.22	21.57	91.1		45.79	4.58	10.1	6.04	16.62	83.109	11.38	10.1	104.6
19	4	200	95.4	30.42	16.18	114		46.598	4.66	10.3	6.15	16.91	84.575	8.536	12.69	105.8
20	5	160	115	36.62	12.94	138		49.562	4.96	10.9	6.54	17.99	89.956	6.829	15.27	112.1
21	6	133.33	134	42.82	10.79	161		53.606	5.36	11.8	7.08	19.46	97.295	5.691	17.86	120.8

Worksheet 800 o.a./1.2 GHz

	Q	R	S	T	U	V	W	X	Y	Z
1										
2										
3										
4										
5										
6										
7										
8										
9	Linac		Distribution of Construction Cost:							
10	Constr.		- -							
11	Cost +								Total	
12	Lifetime		Linac	Linac			Total		Linac	
13	Power		RF	Acc.	Linac	Buildgs.	Capital	Personnel	Constr.	
14	Cost	Gradient	Syst.	Str.	Equipm.	+Utilit.	Investm.	Cost	Cost	
15	(M$)	MeV/m	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	(M$)	
16	222.43	1	16.2	89	105.2	39.07	144.3	33.675	178	
17	183.79	2	24.8	44.5	69.27	24.59	93.85	22.165	116	
18	195.69	3	33.3	29.7	62.96	21.48	84.44	20.148	104.6	
19	220.22	4	41.8	22.2	64.07	21.22	85.3	20.503	105.8	
20	249.81	5	50.4	17.8	68.15	22.1	90.25	21.807	112.1	
21	281.92	6	58.9	14.8	73.71	23.55	97.26	23.587	120.8	

Chart 800.3-1.2 GHz