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CLIC Note 277

Travel report

Linear Collider Workshop LC95

27-31 March 1995, Tsukuba (Japan)

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A technical review committee mandated by the Linear Collider Collaboration Council is editing a report which critically reviews all the schemes. The report is expected to be available by Summer 95. It will provide together with the proceedings of the workshop detailed information on the status of the different schemes and the many questions still open.

This note gives a brief account of the highlights of the workshop with emphasis on the achievements and findings since the last workshop which took place at SLAC in October 1993.

1. Parameters at E_{cm} = 500 GeV and 1000 GeV

Table 1, 2 compiled by G.A. Loew gives the latest lists of parameters. Most of the 1 TeV parameters are new. Comparing the 0.5 TeV versions with the previous sets, the following comments can be made.

- **TESLA** (1.3 GHz, Supercond.; DESY, FNAL, INFN, Saclay...)
  Emittances and final spot size reduced to allow for reduction of beam power at constant luminosity; easier but still very demanding positron production.

- **SBLC** (3 GHz; DESY, Darmstadt)
  No change.

- **JLC** (3, 6, 11 GHz; KEK)
  Virtually no change in the parameter sets for all three frequencies where 3 and 6 GHz are the favourites for 2 x 250 GeV, 6 and 11 GHz for 2 x 500 GeV, and 11 GHz for beyond 2 x 500 GeV. However, for the next two years, main effort continues on 11 GHz; very limited effort (one engineer) for 6 GHz, just sufficient to develop a few small components. Choice of frequency in 2 to 3 years (Takata).

- **NLC** (11 GHz; SLAC)
  Number of klystrons doubled; klystron power 50 MW.
  Hope for 100 MW klystrons abandoned. Other parameters unchanged.

- **VLEPP** (14 GHz; BINP, Russia)
  No longer a project, only technology development.

Parameters for a $\gamma\gamma$ collider with $L = 1.5 \times 10^{36}$ at $E\gamma = 120$ GeV based on two 100 GeV electron linacs were presented.

- CLIC
  New parameters providing a small energy spread as all other schemes. Highest luminosity (1×10^{33}) of all schemes in single bunch operation, but multi-bunch operation required for desired luminosity (4 to 5×10^{33}) still considered more difficult than in other schemes.

Table 3 gives a summary of the most basic pros and cons for each scheme.

2. Upgrading from 2 x 250 to 2 x 500 GeV

- **TESLA**: Either total length (ℓ) increased or exchange of old (25 MV/m) against new (40 MV/m) cavities.

- **SBLC**: Number of klystrons 2517 → 5034 and SLED lead to $4 \times P_{rf}$ doubling the gradient.

- **JLC**: ℓ doubled, gradient constant.

- **NLC**: Number of klystrons 3940 → 9456 and increase of klystron power from 50 → 72 MW leads to about $4 \times P_{rf}$ doubling the gradient.
  Length of interaction region between the 2 linacs ("beam delivery length") compatible with 1 TeV right from the start.

  Possible variant for rf power source (LBL & LLNL & SLAC): TBA scheme with 10 MeV chopped drive beam running for 300 m along main linac providing 360 MW at 11 GHz every 2 m. "A 300 m long 11 GHz klystron".

- **CLIC**: ℓ doubled, gradient constant; second drive beam pulse required because reacceleration of first drive beam pulse not feasible due to its strong degradation as a consequence of maximum deceleration chosen to enhance efficiency.

3. News from test facilities

- **SBLC**: Injector operational by end of 95; design of 6 m acceleration section started; klystron 150 MW, 1.5 μs worked at SLAC. Ready beginning 97.

- **TTF of TESLA**: Cavity (no couplers) in vertical cryostat: 25 MV/m, $Q = 3 \times 10^9$ obtained. Dornier delivered 6 cavities (8 required per cryomodule). Beam tests: end 95 with first module; mid 97 with all modules.

- **ATF of JLC**: S-band linac nearly installed, injector operational, beam tests in Sept. 95. Damping ring: vacuum and magnets complete by January 96; commissioning with beam December 96.

- **FFTB of NLC**: A spot size of 70 nm at 47 GeV with SLAC beam achieved after 320 x demagnification (50 nm expected). This is order of magnitude of SBLC and TESLA spot size in interaction point.

- **NLCTA of NLC**: Sledded 50 MW klystron yielded 205 MW x 150 ns (200 MW x 250 ns design); accelerating structure: detuned and damped, design in progress. Four sections operational end of 96, last two in mid 97.

- **TBA model for NLC**: 30 m long test set-up planned at LBL; request for 5 M$ materials budget submitted to DOE; ready in 5 years.

- **CTF of CLIC**:
  i) CTF 1 results: generated 76 MW at 30 CHz and obtained 32 nC in single bunch and 450 nC in 48 bunches; 90 MV/m in accelerating section (80 MV/m design)* and 60 MW in transfer structure (45 MW design).
  ii) CTF 2 construction in 95-97 in stages; final 500 MeV beam commissioning in 98.

4. Other notable points

4.1 Technical

- X-band klystrons: SLAC apparently gave up R&D for 100 MW and concentrates on 50 MW; KEK still believes that 130 MW version could be ready in 2 years (problem mainly in output cavity);

- Approach to ground stability and trajectory correction has been much rationalized;

- Detector aspects (energy spread, background due to beamstrahlung and mini-jets): all schemes about equivalent.

4.2 KEK matters

- JCL: not mentioned as domestic project by Sugawara though he had been quite firm about this in 1994;

- KEK/JCL: strong interest in continuing and extending collaboration with CLIC; request for help when turning on ATF;

- R&D on SC rf (TESLA) continues (35 MV/m obtained in 1 cell, 9 cell structure in preparation);

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* It is up till now the only accelerating section which has demonstrated beam acceleration. The gradient was 63 MV/m indirectly limited by the magnets which turn the spent drive beam into the probe beam.

- TBA/FEL R&D at KEK stopped this year and team will be dispersed.

4.3 General

- Increasing weight on E_{cm} = 1.0 TeV and interest for 1.5 TeV stressing complementarity to LHC; however, initial phase 0.5 TeV maintained;

- Interest in $\gamma\gamma$, $e\gamma$, e^-e^- colliders; needs a second interaction point; physics case strong enough?

- No discussion on cost as no new estimates available except for tunnelling where SLAC and KEK had new numbers (CLIC uses LEP unit cost);

- Interest in $\mu\mu$ colliders (talk by Palmer); announcement of strong activity in US (collaboration meeting in FNAL 11-18 July 95, workshop in Montauk 10-20 Oct. 95 and conference 13-15 Dec. 95).

4.4 Next workshop

Spring 97 in the region of Moscow organized by Balakin / BINP.

5. Acknowledgements

I discussed the note with J.-P. Delahaye and I. Wilson who made many valuable suggestions.

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Linear Collider: Overall and Final Focus Parameters Available at LC95

500 GeV (center of mass)

	TESLA	SBLC	JLC-I(S)	JLC-I(C)	JLC-I(X)	NLC	VLEPP	CLIC
Initial energy (c. of m.) (GeV)	500	500	500	500	500	500	500	500
RF frequency of main linac (GHz)	1.3	3	2.8	5.7	11.4	11.4	14	30
Nominal luminosity (10^{33} $cm^{-2}s^{-1}$)	3.6	2.2	5.2	10.9	5.1	5.3	12	0.7-3.4
Luminosity w/pinch (10^{33} $cm^{-2}s^{-1}$)	6	3.75	4.3	9.1	5.2	7.1	15	1.0-~~4.7~~ 4.8
Linac repetition rate (Hz)	5	50	50	150	150	180	300	2530-1210
No. of particles/bunch at IP (10^{10})	3.6	2.9	1.44	1.0	.63	.65	20	.8
No. of bunches/pulse	1130	125	50	72	85	90	1	1-10
Bunch separation (ns)	708	16.0	5.6	2.8	1.4	1.4	----	.66
Beam power/beam (MW)	8.2	7.26	1.3	4.3	3.2	4.2	2.4	0.8-3.9
Damping ring energy (GeV)	4.0	3.15	2.0	2.0	2.0	2.0	3.0	2.15
Two-linac lengh (km)	30	30.2	22.1	19.6	11.4	15.6	10	6.8
Total beam delivery length (km)	3	3	3.6	3.6	3.6	4.4		3
$\gamma\varepsilon_x/\gamma\varepsilon_y$ (mrad x 10^{-8})	1400/25	1000/50	330/4.8	330/4.8	330/4.8	500/5	2000/7.5	300/15
β_x^*/β_y^* (mm)	25/0.7	22/0.8	10/0.1	10/0.1	10/0.1	10/0.1	100/0.1	10/0.18
σ_x^*/σ_y^* (nm) before pinch	845/19	670/28	260/3.0	260/3.0	260/3.0	320/3.2	2000/4	247/7.4
σ_z^*(μm)	500	500	120	120	90	100	750	200
Crossing angle at IP (mrad)	0	3	6.4	6.0	6.1	20	--	1
Disruptions D_x/D_y	0.4/11	.36/8.5	.29/25	.20/18	.096/8.2	.07/7.3	.4/215	.29/9.73
H_D	1.7	1.7	1.6	1.6	1.6	1.34	1.26	1.42
Upsilon sub-zero	.02	.04	.21	.14	.12	.089	.059	
Upsilon effective	.03	.041				.090	.074	.075
δB (%)	2.9	2.8	9.6	5.3	3.2	2.4	13.3	3.5
n_γ (no. of γ per e)	1.9	1.8	2.1	1.5	.96	.79	5.0	1.35
N_{pair} (p_T^{min}=20MeV/c, θ_{min}=0.15)	26	16	30	12	4	3.9	1700	5.1
$N_{hadrons/crossing}$	.17	.1				.04	45.9	
N_{jet} x 10^{-2} (p_T^{min}=3.2GeV/C)	.38	.21				.10	56.4	

AC Note (95-05)

Table 1

Final tables by G. Loew, LC95

AC Note (95-05)

Table 2

LC 95 Final tables by G. Loew

Linear Collider: Overall and Final Focus Parameters Available at LC95
1 TeV (center of mass)

	TESLA	SBLC	JLC-I(X)	NLC	CLIC
Initial energy (c. of m.) (GeV)	1000	1000	1000	1000	1000
RF frequency of main linac (GHz)	1.3	3	11.4	11.4	30
Nominal luminosity (10^{33} $cm^{-2}s^{-1}$)	7.48	3.25	10.0	10.4	1.7 - 7.6
Luminosity w/pinch (10^{33} $cm^{-2}s^{-1}$)	12.8	6.3	9.17	14.5	2.2 - 10.0
Linac repetition rate (Hz)	5	50	150	120	4000 - 1800
No. of particles/bunch at IP (10^{10})	1.8	2.9	0.7	1.1	.8
No. of bunches/pulse	2260	50	85	75	1 - 10
Bunch separation (ns)	354	10.0	1.4	1.4	.67
Beam power/beam (MW)	16.5	5.8	6.4	7.9	2.6 - 11.7
Damping ring energy (GeV)	4.0	3.15	2.0	2.0	2.15
Two-linac lengh (km)	56	30.2	21.8	19.5	13.6
Total beam delivery length (km)	4	4	6	3	
$\gamma\varepsilon_x/\gamma\varepsilon_y$ (mrad x 10^{-8})	1400/6	1000/10	330/4.8	500/5	390/20
β_x^*/β_y^* (mm)	25/0.7	32/0.8	10/0.1	25/0.1	10/0.18
σ_x^*/σ_y^* (nm) before pinch	598/6.5	572/9	184/2.2	360/2.3	200/6.0
σ_z^*(μm)	500	500	90	100	200
Crossing angle at IP (mrad)	0	3	5.0	20	1
Disruptions D_x/D_y	0.2/14	.26/16.2	.096/8.0	.07/7.3	.22/7.4
H_D	1.7	1.9	1.54	1.4	1.31
Upsilon sub-zero	.03		.34		
Upsilon effective	.04	.09		.27	.179
δB (%)	2.5	6.3	8.0	7.0	7.5
n_γ (no. of γ per e)	1.3	2.1	1.24	1.1	1.53
N_{pair} (p_T^{min}=20MeV/c, θ_{min}=0.15)	15	46	6.6	14	6.5
$N_{hadrons/crossing}$	.19	.76		.33	
N_{jet} x 10^{-2} (p_T^{min}=3.2GeV/C)	.89	4.2		1.4	

Table 3, Basic Pros and Cons

	Pro	Contra or potential problems
TESLA	Reasonable spot size Zero crossing angle Easy trajectory control High effective rep. rate → performing feedback	High beam power Difficult e^+ production dependent on e^- spent beam Relatively low gradient → length Dark current ? High cost of accelerating structure ?
SBLC	Reasonable spot size Close to present technology Relatively lower wakefields	Thousands of klystrons, Difficult e^+ production dependant on e^- spent beam Impractical single tunnel layout or 2 tunnels Relatively low gradient → length
JLC/NLC (X-band)	Reasonable compact and short; Reduced beam power	Thousands of klystrons and elaborate rf compression Small emittance and spot size.
CLIC	Compact in 1 tunnel Only passive devices in tunnel High single-bunch luminosity High rep. rate → effective feedback	Elaborate injector of drive beam, difficult to test Strong wakefields ($\Delta\varepsilon/\varepsilon$ = 300 %) Multi-bunching → high frequency, low-impedance rf in damping ring.