JLC Accelerator Overview

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Accelerator Description of JLC	
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X-band Rf	Y. Chin
X-band structure	T. Higo
C-band Accelerator	H. Matsumoto
C-band SASE FEL at SPring8	T. Shintake
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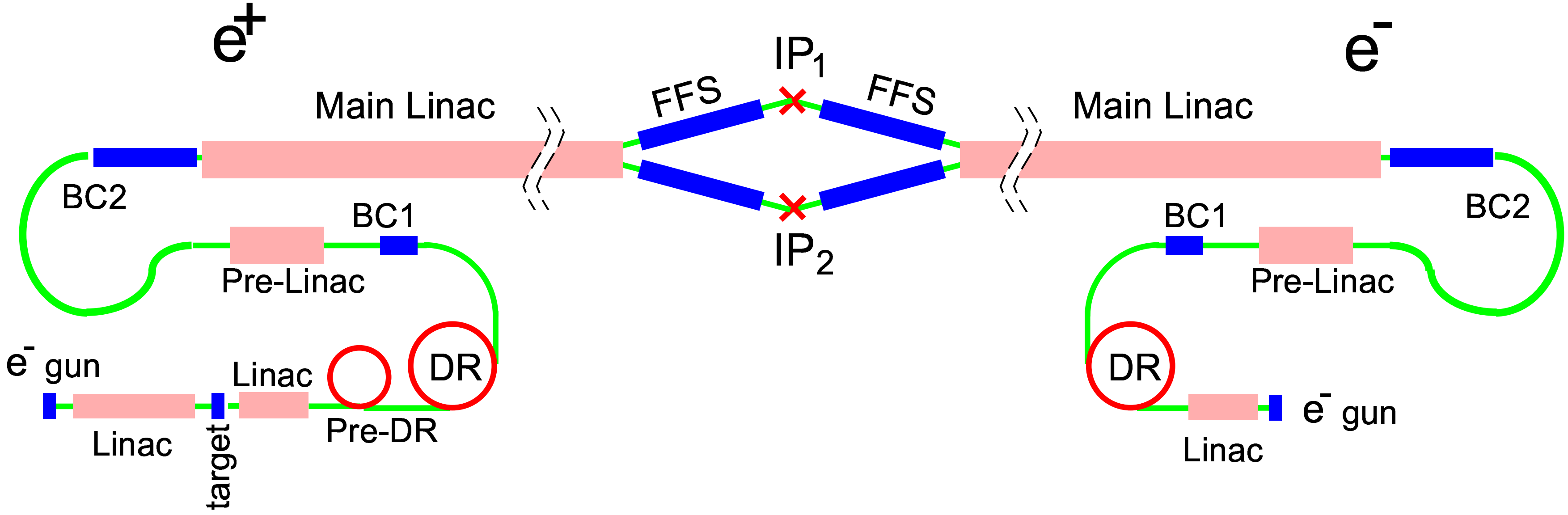


e+
e-
IP1
IP2
FFS
FFS
Main Linac
Main Linac
BC2
BC1
BC1
BC2
Pre-Linac
Pre-Linac
e- gun
Linac
target
Linac
Pre-DR
DR
DR
e- gun
Linac

JLC

- Up to $E_{CM} \sim$ 1TeV
- Normal conducting RF linac
- Main linac frequency (no major difference in other parts)
  - X-band 11.424GHz. Main scheme
  - C-band 5.712GHz. Backup scheme
- Close collaboration with NLC on X-band
  - Nearly identical beam parameters
  - Some differences in RF components
  - ISG8 (International Study Group) held right after the last ACFA workshop at Beijing (Nov.2001)

$\Rightarrow$ Minor parameter change.
Hi-Lum parameter set is now the standard set

X-Band Overall and IP Parameters

Center-of-mass energy	E_{cm}	500	1000	GeV
Linac repetition rate	f_{rep}	150	100	Hz
Number of particles / bunch	N	0.75	0.75	$\times 10^{10}$
Number of bunches / pulse	n_b	192	192	
Bunch separation	t_b	1.4	1.4	ns
Bunch train length	$n_b t_b$	0.267	0.267	μs
Bunch length	σ_z	110	110	μm
Beam power / beam	P_B	8.6	11.5	MW
Unloaded gradient	G_0	70		MV/m
Loaded gradient[1)]		54.7		MV/m
Effective gradient[2)]		47.9		MV/m
Total two linac length[3)]		12.6	25.8	km
Total beam deliverly length		3.7	3.7	km
Normalized emittance at DR exit	$\gamma\epsilon_x/\gamma\epsilon_y$	3.0/0.02		$\times 10^{-6}$m $\cdot$ rad
Normalized emittance at IP	$\gamma\epsilon_x^*/\gamma\epsilon_y^*$	3.6/0.04	3.6/0.04	$\times 10^{-6}$m $\cdot$ rad
Beta function at IP	β_x^*/β_y^*	8/0.11	13/0.11	mm
Beam size at IP	σ_x^*/σ_y^*	243/3.0	219/2.3	nm
Full crossing angle		7	7	mrad
Disruption parameters	D_x/D_y	0.16/12.9	0.08/10.0	
Pinch enhancement factor	H_D	1.52	1.47	
Average beamstrahlung parameter	Υ	0.14	0.29	
Average energy loss by beamstrahlung	δ_B	4.7	8.9	%
Number of photons per electron	n_γ	1.3	1.3	
Nominal luminosity[4)]	$\mathcal{L}_0$	15.2	15.7	10^{33}cm^{-2}s^{-1}
Peak luminosity	$\mathcal{L}$	25.0	25.0	10^{33}cm^{-2}s^{-1}

1) Includes single- and multi-bunch loading
2) Includes $\cos\phi$ and 8% overhead for BNS, failure, and feedback.
3) Includes diagnostics sections
4) $\mathcal{L}_0 = f_{rep} n_b N^2 / 4\pi\sigma_x^*\sigma_y^*$

X-Band Main Linac Parameters

Center-of-mass energy	E_{cm}	500	1000	GeV
Active two linac length		10.1	20.2	km
Total two linac length[1)]		12.6	25.8	km
Total AC power into modulators		121.4	161.9	MW
Total AC power[2)]		132.4	176.5	MW
Wall-plug-to-rf efficiency		37.4		%
RF-to-beam efficiency		26.7		%
Number of mudulators		468	936	
Number of klystrons		3744	7488	
Number of accelerating structures		11232	22464	
Modulator				
Efficiency		80		%
Klystron				
Peak output power		75		MW
Pulse length		1.59		μs
Efficiency		55		%
DLDS				
Pulse compression ratio		4		
Pulse compression effciency		85		%
Switching time	T_{sw}	10		ns
RF group velocity in delay lines	$v_{g,DL}$	0.984		$\times c$
Distance between adjacent feeds[3)]		59.105		m
Acceleratng structure				
Length		0.90		m
Phase advance per cell		150		deg
Iris radius	a/λ	0.210-0.148		
Group velocity	v_g/c	5.1-1.1		
Filling time	T_f	120		ns
Attenuation parameter	τ	0.510		
Unloaded Q	Q	9055-8093		
Shunt impedance	r	81.2		MΩ
RF pulse length		396		ns

1) Includes the focusing elements and diagnostics sections
2) Includes the cooling system
3) $cv_{g,DL}[T_f + (n_b - 1)t_b + T_{sw}]/(c + v_{g,DL})$.

C-Band

Advantages of C-band

- RF components ready or nearly ready
  - Modulator and (solenoid) klystron shown to be stable for thousands of hours at full spec.
  - Pulse compressor and acc.structure wait for high power test

$\Rightarrow$ Reliable. Can start earlier

- Alignment tolerances (cavities and quads) looser by factor $\lesssim$2 than with X-band

$\Rightarrow$ Actual integrated luminosity may even be higher than X-band

!! SLC design and its actual luminosity

But the quoted luminosity is lower

C-band : X-band $\approx$ 1 : 3

$$\frac{\mathcal{L}}{P_{AC}} = \frac{C}{E} \times \eta_{AC\to RF} \times \eta_{RF\to beam} \times \left(\frac{\delta_B}{\epsilon_y^*}\right)^{1/2}$$

C	universal constant
δ_B	beamstrahlung loss
ϵ_y^*	normalized vertical emittance at IP

Why?

- Conservative design of RF system
  (assumed lower efficiency $\eta_{AC\to RF}$)
- Short beam train (lower $\eta_{RF\to beam}$)
  Can be cured by much bigger compressor,
  but we do not want

Possible Operation of Hybrid C and X

- Start as early as possible with C up to 400 GeV (CM)
  - Choice of '400GeV' is tentative
  - Depends on physics of 1st stage
  - Lower the better for the site length and total power consumption in the 2nd stage
- After $\gtrsim 5$ years of operation and X-band R&D
- Add X-band to reach 1TeV
- Luminosity/power slightly lower than X-alone senario (Factor $\sim$2 at 400GeV, $\sim$1.5 at 1TeV)
- A disadvantage of this senario is the discontinuity of R&D

But does the beam property match?

Beam train length

- Must not change the train length in going from C to C+X
- The optimum beam train length is usually longer for lower frequency (optimum $\eta_{RF\rightarrow beam}$)
- But our C-band up to now adopts short train
  Nearly the same as (even shorter than) X, accidentally

$\Rightarrow$ Only a small change from present train length

$\circ$ disadvantage $\rightarrow$ advantage

Bunchlength

- Bunchlength normally longer in C
  (Energy slope/spread control hard with X-band bunchlength)

- adopt $\sigma_z = 200\mu$m for 400GeV

- and 110μm for 1TeV

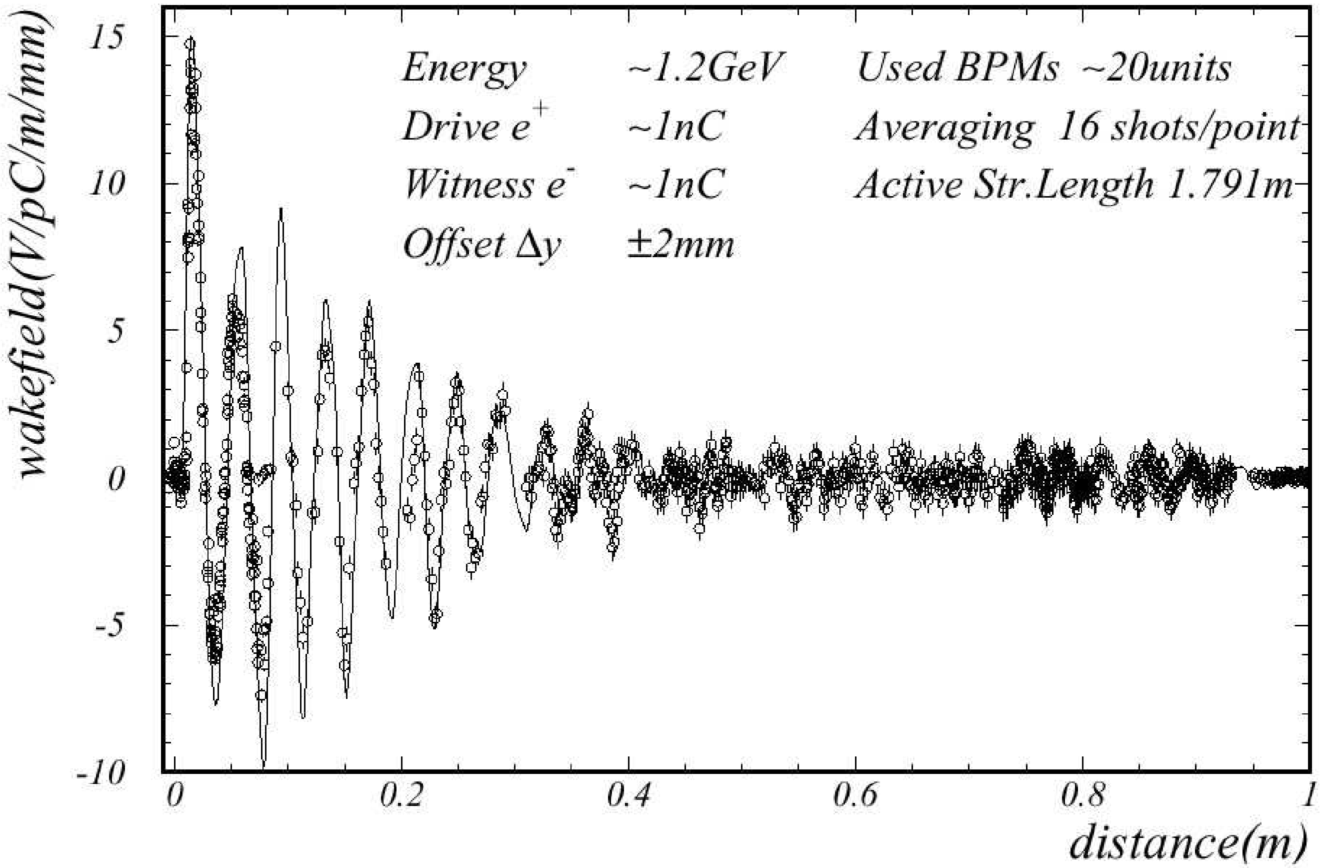
  - BNS damping at C-band section (9 degree behind the crest)
  - energy spread compensation at X-band section

- Somewhere between 200μm-110μm for 400-1000GeV

- Wait for beam dynamics study

Bunch-to-bunch distance

- Wake still sizable at 1.4ns
- But can be fine-adjusted to place a node at 1.4ns
- Does not cause tigher fabrication tolerance (looser than 1/500)



Injector Systems for C-X Hybrid

- Injection energy to C-band linac not studied yet but will be lower (6GeV?) than in X-alone case

$\Rightarrow$ 2nd bunch compressor slightly easier though still be capable of $\sim$100μm

- Maximum repetition rate 100Hz (150Hz in X-alone)
  $\Rightarrow$ Damping ring slightly easier

- Positron creation same as in X-alone

C-band and C-X Hybrid Parameters

		C alone	Hybrid C	Hybrid X	
Center-of-mass energy	E_{CM}	400	1000		GeV
Beam property					
Initial beam energy	E_i	8	8	200	GeV
Final beam energy	E_f	200	200	500	GeV
Number of particles per bunch	N	0.75	0.75		$\times 10^{10}$
Number of bunches per pulse	n_b	192	192		
Number of particles per pulse	$n_b N$	144	144		$\times 10^{10}$
Bunch spacing	t_b	1.4	1.4		ns
Beam pulse length	$n_b t_b$	268.8	268.8		ns
Repetition frequency	f_{rep}	100	100		Hz
Normalized emittance (DR exit)	$\gamma\epsilon_x$	3×10^{-6}	3×10^{-6}		m·rad
	$\gamma\epsilon_y$	2×10^{-8}	2×10^{-8}		m·rad
R.m.s. bunch length	σ_z	200	110		μm
Main Linac					
Unloaded gradient	G_0	41.8	41.8	70	MV/m
Loaded gradient[1)]	G	31.1	31.1	53.8	MV/m
Active length (each linac)	L_{act}	6.11		6.16	km
Wall plug power	P_{AC}	140	140	122	MW
AC to RF efficiency	$\eta_{AC\rightarrow RF}$	24.12	24.12	37.4	%
RF to beam efficiency	$\eta_{RF\rightarrow B}$	25.9	25.9	26.7	%
Modulator					
Efficiency	η_{mod}	67		80	%
Number of mudulators (/beam)		1696		285	
Klystron					
Peak power		50.12		75	MW
Pulse length		2.762		1.60	μs
Efficiency	η_{kly}	50		60	%
Number of klystrons (/beam)		1696		2280	
Pulse compressor					
Type		Diskloaded		1mode 4/4 DLDS	
Time compression factor		1/5		1/4	
Efficiency (incl. waveguide loss)	η_{cmpr}	72		85	%

1) includes single/multi-bunch loading and $\cos\phi_{rf}$

		C alone	Hybrid C	Hybrid X	
Accelerating structure					
Structure type		CG choke-mode $3\pi/4$		RDDS $5\pi/6$	
Structure length		1.8		0.9	m
Iris radius	a/λ	0.171-0.126		0.210-0.148	
(average)	$\langle a/\lambda \rangle$	0.148		0.18	
Group velocity	v_g/c	3.60-1.14		5.1-1.1	%
(average)	$\langle v_g \rangle /c$	2.12		2.5	%
Filling time	T_f	285		120	nsec
Attenuation parameter	τ	0.524		0.511	
Average Q-factor	Q	9772		8574	
Shunt impedance	r_s	53.7		81.2	MΩ/m
Number of structures (/beam)		3392		6840	
Peak power into a structure		90.2		85	MW
Off-crest angle	ϕ_s	9	$\mp$9	11	deg
Beam Dynamics					
Energy slope $(\sigma_z/E)(dE/dz)$					
BNS required		-1.12	-0.74		
due to wake		-0.39	-0.44		
due to off-crest rf		+0.48	$\mp$0.26		
Interaction point					
Number of particles per bunch	N^*	0.75	0.75		$\times 10^{10}$
Normalized emittance	$\gamma\epsilon_x$	3.6×10^{-6}	3.6×10^{-6}		m·rad
	$\gamma\epsilon_y$	4.0×10^{-8}	4.0×10^{-8}		m·rad
Crossing angle	ϕ_{cross}	7	7		mrad
Beta function	β_x	8	13		mm
	β_y	0.2	0.11		mm
R.m.s. beam size	σ_x	271	219		nm
	σ_y	4.52	2.3		nm
Disruption parameter	D_x	0.289	0.08		
	D_y	17.3	10.0		
Number of beamstr. photons	n_γ	1.30	1.3		
Energy loss by beamstrhlung	δ_{BS}	2.72	8.9		%
Average Upsilon parameter	$\langle \Upsilon \rangle$	0.057	0.29		
Nominal luminosity		7.01	15.7		10^{33}cm^{-2}s^{-1}
Luminosity$^{2)}$	$\mathcal{L}$	10.1	25		10^{33}cm^{-2}s^{-1}
Luminosity / 100MW AC	$\mathcal{L}/P_{AC}$	7.24	9.54		10^{33}