CLIC Main Beam generation

Baseline configuration only

L. Rinolfi

for the CLIC Injector complex team

R&D program for the CDR

The CLIC Main Beams generation is focused on 3 studies to produce the bunch charge at the entrance of the Pre-Damping Ring (PDR) :

1) Base Line configuration:

3 TeV (c.m.) - polarized electrons (4.4×10^9 e^-/bunch) and unpolarized positrons (6.7×10^9 e^+/bunch).

2) Polarized positron configuration:

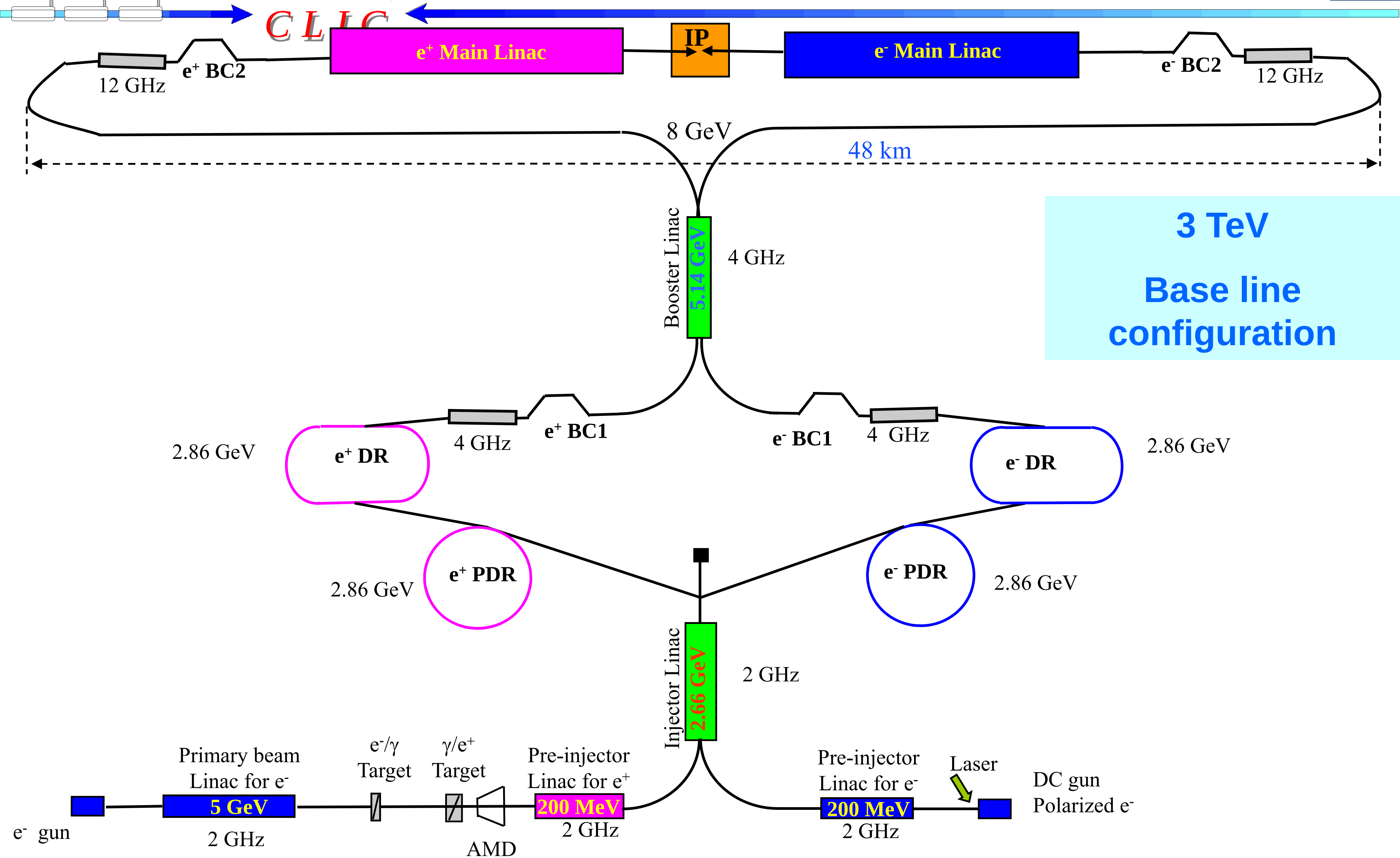
3 TeV (c.m.) - polarized e^- and e^+ with same charge as above

An huge R&D work is ongoing for polarized e^+ but not presented in this talk

3) Double charge configuration:

500 GeV (c.m.) - polarized electrons (8×10^9 e^-/bunch) and unpolarized positrons (13×10^9 e^+/bunch).

CLIC Main Beam Injector Complex in 2009



3 TeV

Base line configuration

CLIC Main Beam nominal parameters

At the entrance of the Main Linac for e^- and e^+

		NLC (1 TeV)	CLIC 2008 (3 TeV)	CLIC 2008 (0.5 TeV)	ILC (0.5 TeV)
E	GeV	8	8	8	15
N	10^9	7.5	4	7	20
n_b	-	190	312	354	2625
Δt_b	ns	1.4	0.5 (6 RF periods)	0.5	369
t_{pulse}	ns	266	156	177	968925
$\varepsilon_{x,y}$	nm, nm	3300, 30	600, 10	2300, 10	8400, 24
σ_z	µm	90-140	43 - 45	72	300
σ_E	%	0.68 (3.2 % FW)	1.5 - 2	2	1.5
f_{rep}	Hz	120	50	50	5
P	kW	219	90	180	630

CERN manpower

for the beam generation studies

0.5 FTE (Staff)

+

0.2 FTE (Fellow)

External collaborations

Alphabetic order for countries

Countries	Institutes	Contact person	Subject	Status	Date
France	LAL	A. Variola	e+ studies	Formal agreement	September 2008
Germany	FZR Rossendorf	J. Teichert	Compton sources	In preparation	November 2008
Japan	KEK	T. Omori	e+ studies	Informal agreement	October 2007
Japan	KEK	J. Urakawa	R&D on targets systems and experiments at KEKB	In preparation	January 2009
Turkey	Ankara University	A.Kenan Çiftçi	FLUKA simulations	Informal agreement	April 2009
Ukraine	Kharkov Institute	E. Bulyak	Compton Rings	Informal agreement	April 2006
United Kingdom	Cockcroft Institute	J. Clarke	e+ studies	Formal agreement	October 2008
USA	Argonne Laboratory	W. Gai	e+ studies	In preparation	January 2009
USA	Jefferson Laboratory	M. Poelker	Polarized e-	Formal agreement	September 2007
USA	SLAC	J. Sheppard	Polarized e-	In preparation	August 2008

Generation of polarized electron

Specific issues for polarized e^- source

Parameter	Symbol	0.5 TeV	3 TeV
Number Electrons per microbunch	N_e	**10×10^9**	**6×10^9**
Number of microbunches	n_b	354	312
Width of microbunch	t_b	~ 100 ps	~ 100 ps
Time between microbunches	Δt_b	0.5002 ns	0.5002 ns
Microbunch rep rate	f_b	1999 MHz	1999 MHz
Width of macropulse	T_B	177 ns	56 ns
Macropulse repetition rate	F_B	50 Hz	50 Hz
Charge per micropulse ($e \times N_e$)	C_b	1.6 nC	0.96 nC
Charge per macropulse ($C_b \times n_b$)	C_B	566 nC	300 nC
Average current from gun ($C_B \times F_B$)	I_{ave}	28 µA	15 µA
Average current in macropulse (C_B / T_B)	I_B	3.2 A	1.9 A
Duty Factor w/in macropulse ($t_b/\Delta t_b$)	DF	0.2	0.2
Peak current of micropulse (I_B / DF)	I_{peak}	16 A	9.6 A
Current density (I_{peak} / σ) [spot size radius 1 cm]	D	5 A/cm^2	3 A/cm^2

laser & gun

photo cathode

One of the critical issues is the Surface charge limit => needs demonstration => depends on laser system

ILC and CLIC e^- sources

Parameters	ILC	CLIC 0.5 TeV	CLIC 3 TeV
Electrons/microbunch	~3E10	10E9	6E9
Number of microbunches	2625	354	312
Width of Microbunch	1 ns	~100 ps	~100 ps
Time between microbunches	~360 ns	500.2 ps	500.2 ps
Width of Macropulse	1 ms	177 ns	156 ns
Macropulse repetition rate	5 Hz	50 Hz	50 Hz
Charge per macropulse	~12600 nC	566 nC	300 nC
Average current from gun	63 μA	28 μA	15 μA
Peak current of microbunch	4.8 A	16 A	9.6 A
Current density (1 cm radius)	1.5 A/cm^2	5 A/cm^2	3 A/cm^2
Polarization	>80%	>80%	>80%

J. Sheppard/SLAC at TILC09 workshop

Goals:

The major goals for photocathode development at SLAC for the ILC and CLIC are:

1) demonstration of full charge production without space charge and surface charge limitation;

2) >85% polarization;

3) ~1% QE and long QE lifetime.

Formal CERN/SLAC collaboration under discussion for this topic

Possible schedule

1) Assuming that SLAC management would agree with the proposed demonstration and provides support, then preliminary tests are expected before September 2009.

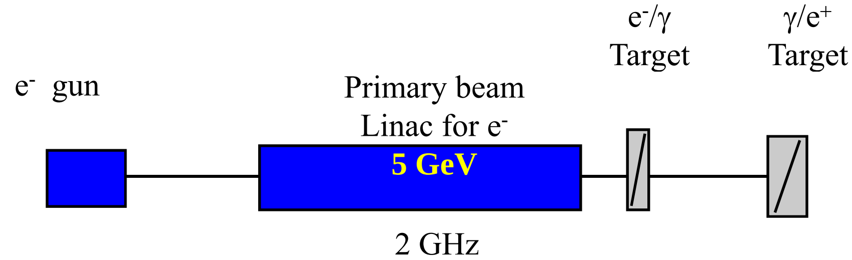
If existing equipments show some limitations, the idea is to make the appropriate corrections in 2010.

In this case, results and relevant issues will be included in the CDR.

2) Further along (2011-2012), the SLAC cathode and laser would be installed together with JLab HV gun.

Generation of unpolarized positron

Primary electron beam



Parameter	Unit	
Primary e⁻ Beam		
Energy	GeV	5
N e⁻ /bunch	10^9	7.5
N bunches / pulse	-	312
N e⁻ / pulse	10^{12}	2.34
Pulse length	ns	156
Repetition frequency	Hz	50
Beam power	kW	94
Beam radius (rms)	mm	2.5
Bunch length (rms)	mm	0.3

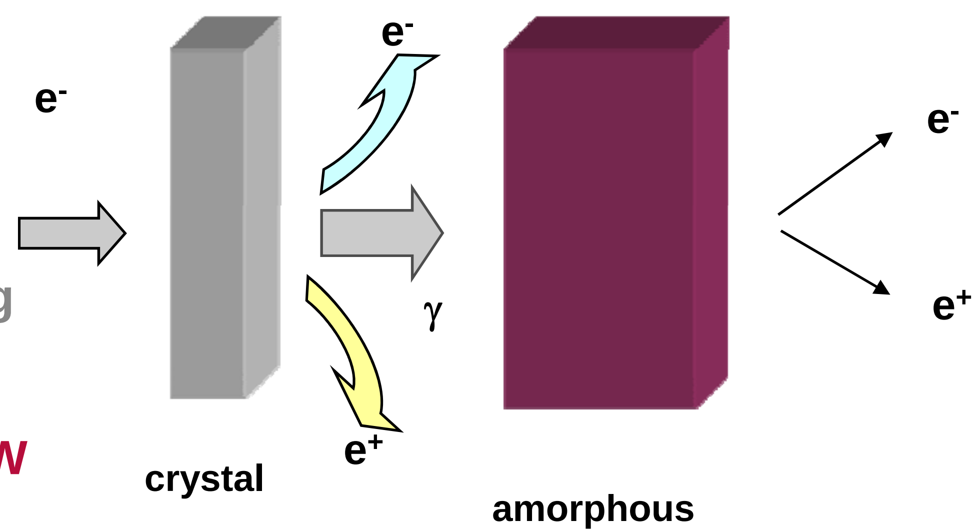
Unpolarized e+ based on hybrid targets

After several simulations, an optimized configuration is given below:

Electron beam on the crystal:
- energy = 5 GeV
- beam spot size = 2.5 mm

First target is a crystal: 1.4 mm thick W oriented along <111> axis where channeling process occurs

Second target is amorphous: 10 mm thick W

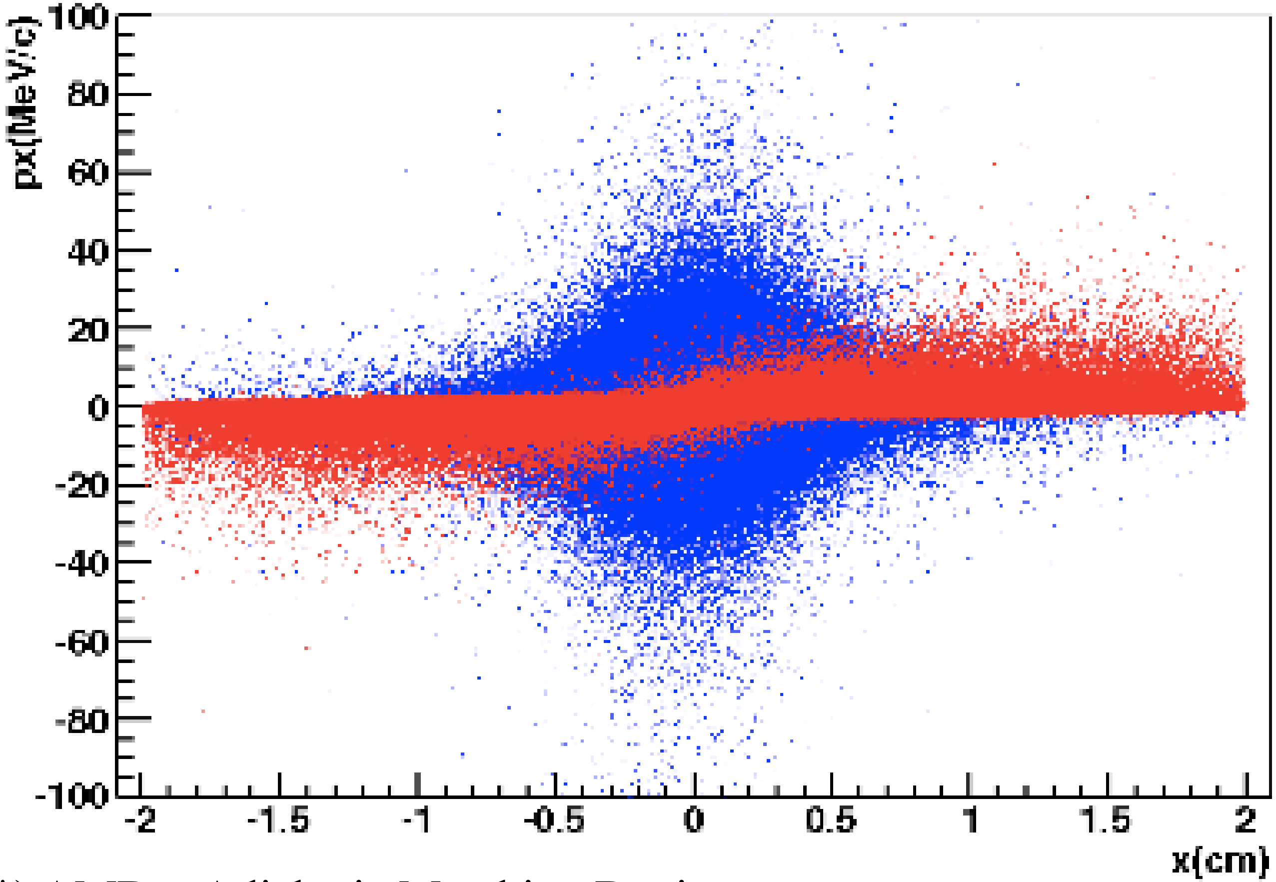


Charged particles are swept off after the crystal: only γ (> 2MeV) impinge on the amorphous target.

The distance between the two targets is 3 meters

Results just downstream the e^+ target

O. Dadoun / LAL



Blue: after the target

Red: after the AMD (*)

Yield = 2.1 e^+ / e^-

Max energy = 1.9×10^9 GeV / mm^3

Peak Energy Density Deposition

PEDD = 15.5 J/g

(*) AMD = Adiabatic Matching Device:

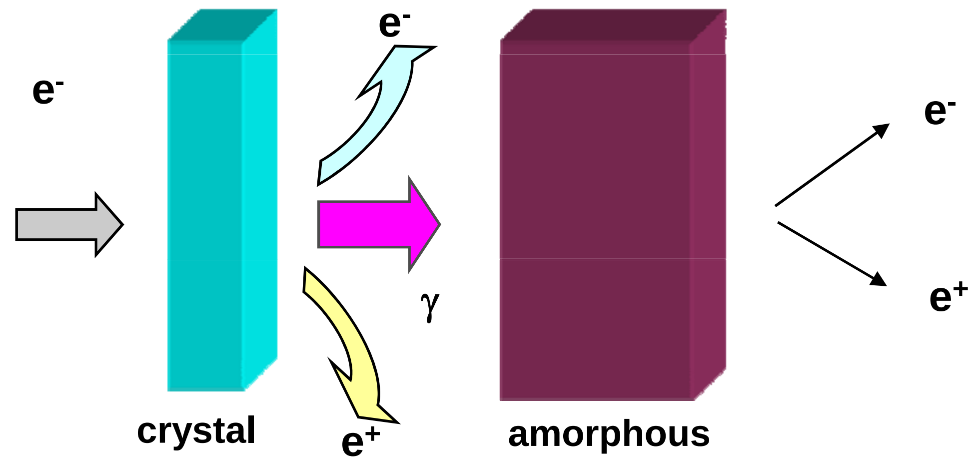
B_0 = 6 T, L = 50 cm, α = 22m^{-1}

$$B = \frac{B_0}{1+\alpha z}$$

Experimental limit found at SLAC: with a PEDD $\geq$ 35 J/g

=> target does not survive

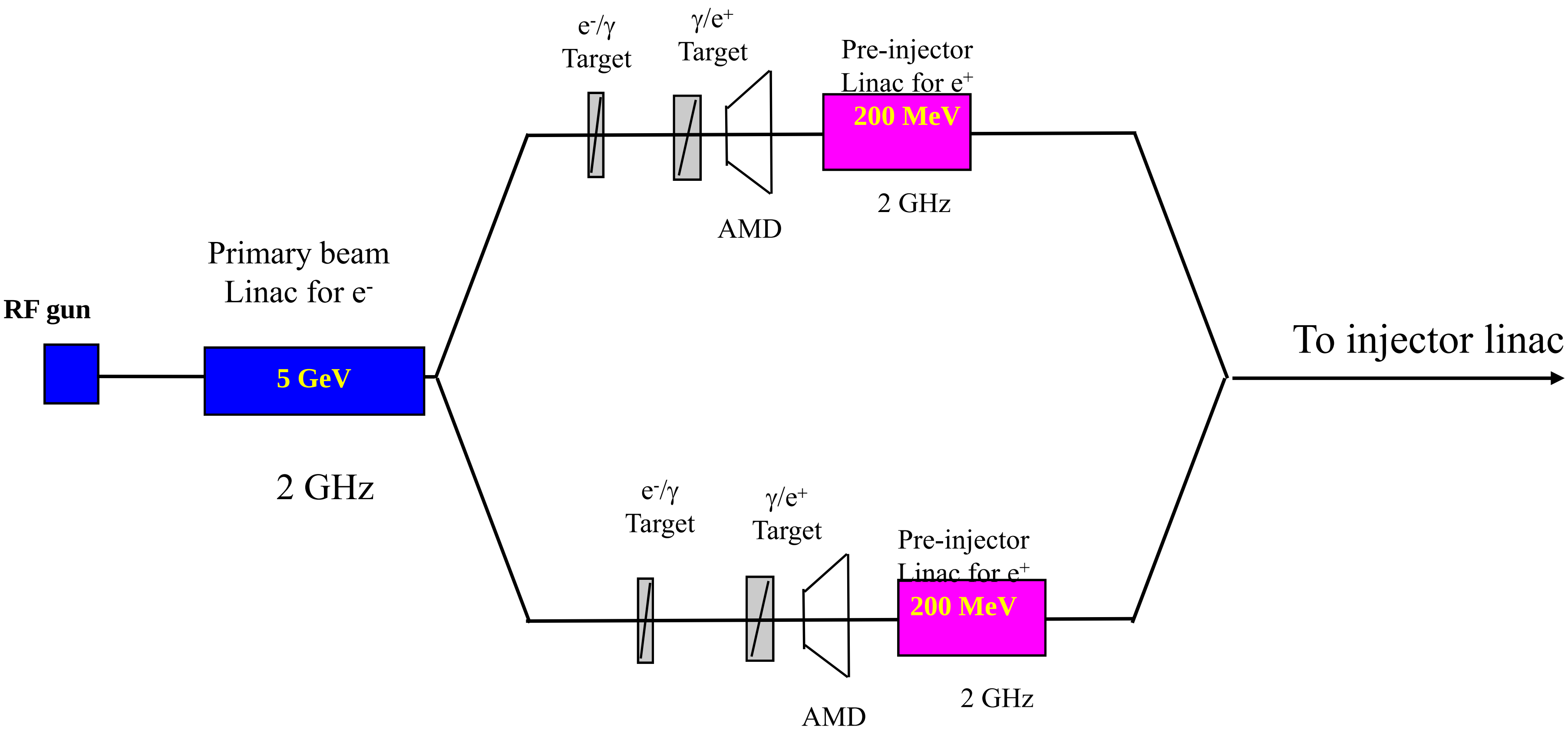
Beam power and PEDD



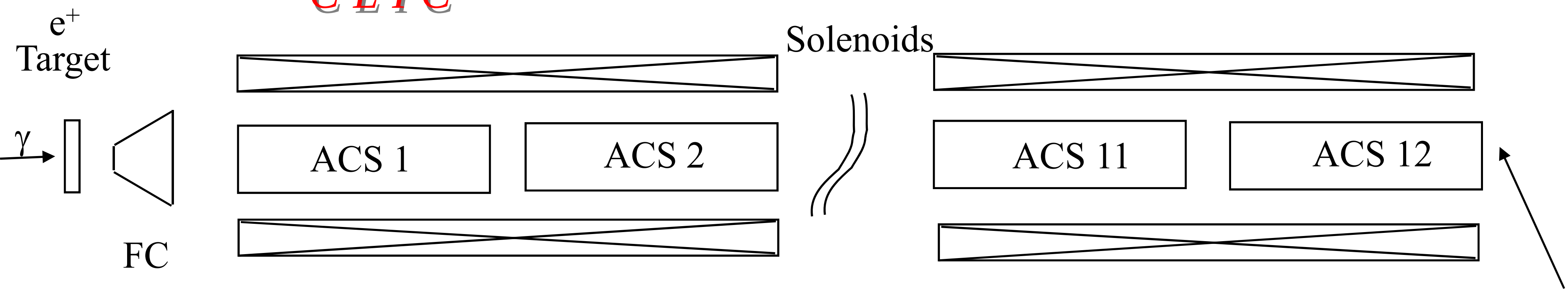
Parameter	Unit		
Target		Crystal	Amorphous
Material		W	W
Length	mm	1.4	10
Beam power deposited	kW	0.2	7.5
Deposited P / Beam Power	%	0.2	8
Energy lost per volume	10^9 GeV/mm^3	0.8	1.9
Peak energy deposition density (PEDD)	J/g	6.8	15.5

e^+ source for CLIC 500 GeV

Double charge / bunch => Double PEDD => ≈ breakdown limit => Double target station



Pre-Injector Linac for e^+



E = 200 MeV

Accelerating Structures (ACS):

$G \cong 10$ MV/m L = 1.8 m Radius = 0.018 m f = 2 GHz

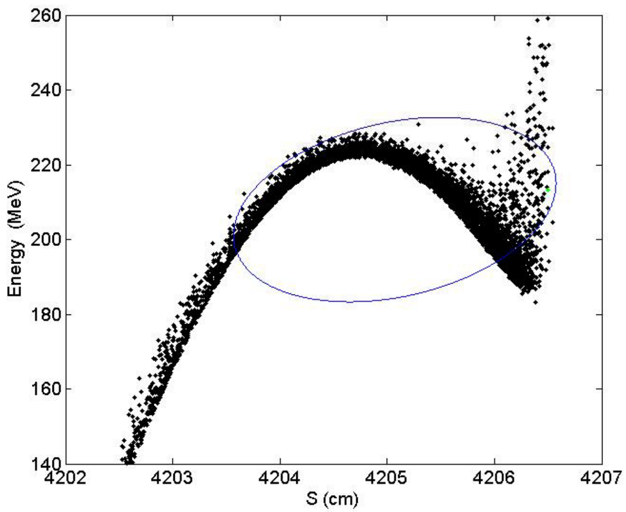
Magnetic Field of Flux Concentrator (FC)	T	6
FC Length	m	0.5
Solenoid Magnetic Field	T	0.5
Length of Pre-Injector Linac	m	42

Yield: 0.9 e^+ / e^-
@ 200 MeV

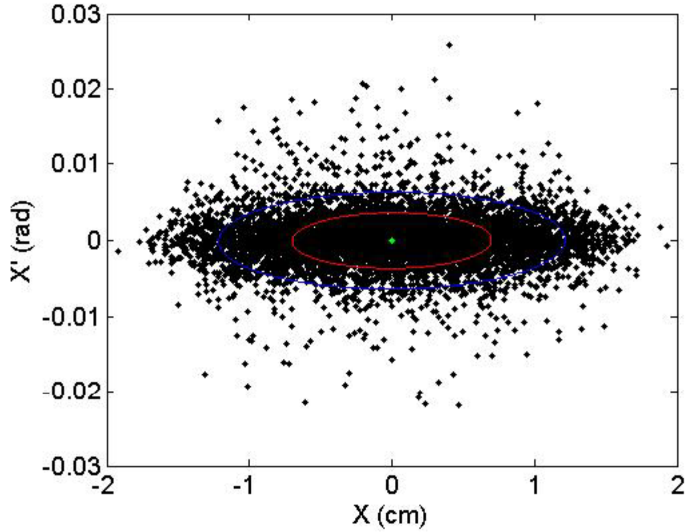
Pre-Injector Linac

Parameter	Unit	CLIC 2009 (A. Vivoli)
		EGS4 + ASTRA
Energy (E)	GeV	0.2
No. of particles/bunch (N)	10^9	6.7
Bunch length (rms) (σ_z)	mm	10
Energy Spread (rms) (σ_E)	%	8
Longitudinal emittance	eV.s	0.5 x 10^{-3}
H and V emittances ($\gamma\varepsilon_x$)	mm. mrad	6700

Longitudinal



Transversal



"ILC/CLIC e^+ generation" working group

J. Clarke (Daresbury), L. Rinolfi (CERN)

The Cockcroft Institute of Accelerator Science and Technology

CERN

Officially set-up at ILC08 workshop
Chicago: 15^{th} - 20^{th} November 2008

CLIC/ILC work plan (1)

Short-term plan 2008 - mid-2009

Undulator-based source
Develop Geant4 model of collimator, target, capture optics, and capture RF assembly.
Optimise parameters wrt yield, polarisation and cost (Collaboration with ANL).
Consider timing constraints issues and upgrade paths.
Consider electron beam quality issues.

Compton source
Design of the Compton ring (Collaboration with NSC KIPT).
Optical stacking cavity (Collaboration with LAL and KEK).
High power lasers.
Stacking simulations.

Lithium lens capture optics
Evaluate suitability for Undulator and Compton schemes (Wide collaboration needed).

Conventional sources (Conventional targets and hybrid targets)
Simulations to optimize the unpolarized e+ yield (Collaboration with LAL).
Evaluate the applicability of the Li lens.

Electron source
Set-up the CERN, CI, JLAB, SLAC collaboration for tracking studies.
Preliminary tests at HV for the DC gun.

CLIC/ILC work plan (2)

Long-term plan mid-2009 - 2010

Undulator-based source
Consider optimal target technology: thermal load, shock waves, activation (Collaboration with LLNL).

Compton source
Extend Geant4 model to Compton source (Collaboration with LAL)
Stacking simulations studied in 6D.

Lithium lens tests
Participate to the BINP tests and CesrTA tests.

Conventional sources
Channelling measurements on NA63 experiment at CERN
Perform experiments at KEKB positron source.

Electron source
Perform tracking studies (Collaboration with JLAB and SLAC).
Hardware tests at JLAB and SLAC for the DC gun at very HV.

Summary

1) For the Base Line configuration at 3 TeV, polarized e^- and unpolarized e^+ would be generated close to the requested performance but extensive simulations for both sources, in parallel with an important R&D program, remain to be done to confirm the present studies.

2) Double charge configuration (0.5 TeV): for the polarized electrons, the space charge limit is a real challenge to provide the requested charge pattern; for the positrons, it would require a double target stations under the present conditions.

3) For polarized positrons, extensive studies are carried on, in collaboration with several institutes. For the 3 TeV, several major issues remain to be investigated and demonstrated by simulations.

4) The beam intensity stability of both sources could be a performance issue.