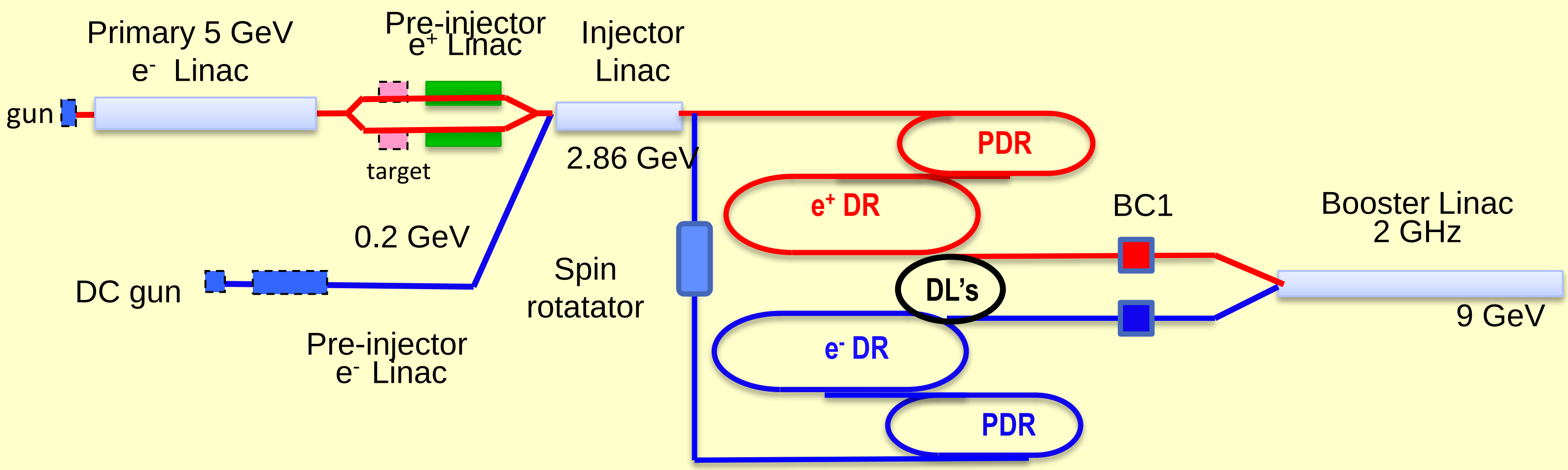
CLIC source update

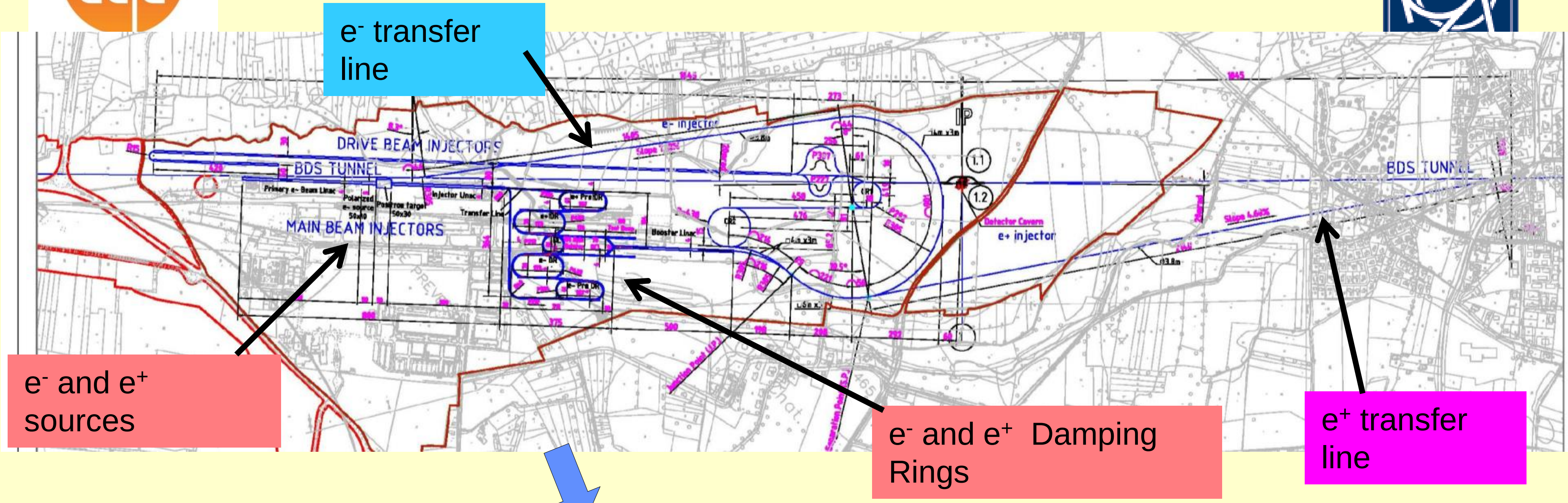
- CLIC main beam injectors reminder
- Recent interest, cost savings improving efficiencies
- Positron production using undulator

Layout

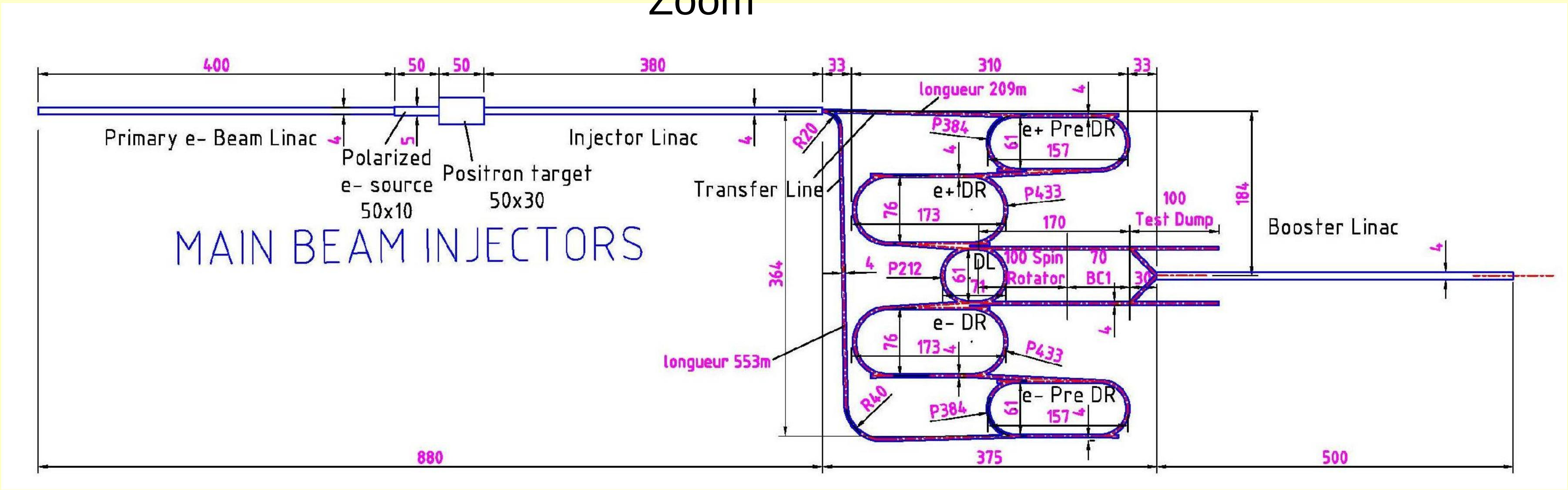


- Two hybrid positron sources (only one needed for 3 TeV)
- Common injector linac
- All linac at 2 GHz , bunch spacing 1 GHz before the damping rings

CLIC Main Beam complex



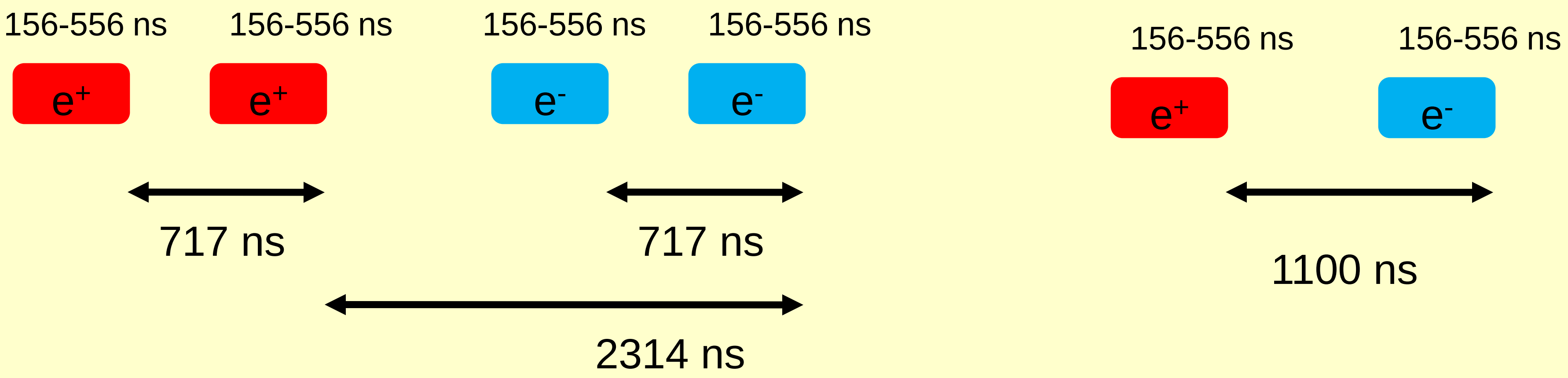
Zoom



Beam timing and operational modes

Before damping ring
(1 GHz bunch spacing)

After damping ring
(2 GHz bunch spacing)



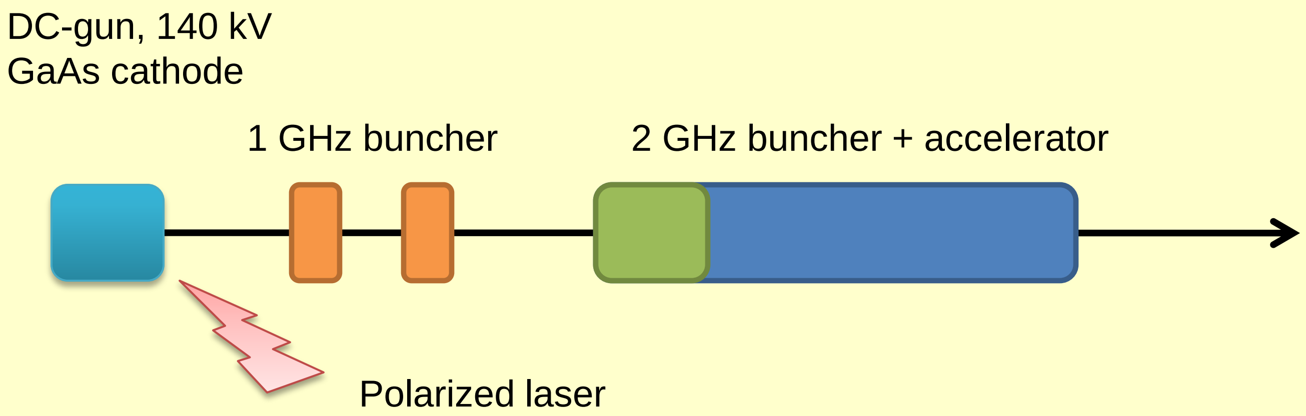
Operational mode	Charge per bunch (nC)	Number of bunches
Nominal	0.6	312
500 GeV	1.2	312
Low energy scans	0.6, 0.45, 0.4, 0.3, 0.23	312, 472, 552, 792, 1112

Beam parameters

Parameter	Unit	CLIC polarized electrons	CLIC positrons	CLIC booster
E	GeV	2.86	2.86	9
N	10^9	4.3	4.3	3.75
n_b	-	312	312	312
Δt_b	ns	1	1	0.5
t_{pulse}	ns	312	312	156
$\varepsilon_{x,y}$	μm	< 100	7071, 7577	$600{,}10 \cdot 10^{-3}$
σ_z	mm	< 4	3.3	$44 \cdot 10^{-3}$
σ_E	%	< 1	1.63	1.7
Charge stability shot-to-shot	%	0.1	0.1	0.1
Charge stability flatness on flat top	%	0.1	0.1	0.1
f_{rep}	Hz	50	50	50
P	kW	29	29	85

Polarized electron source

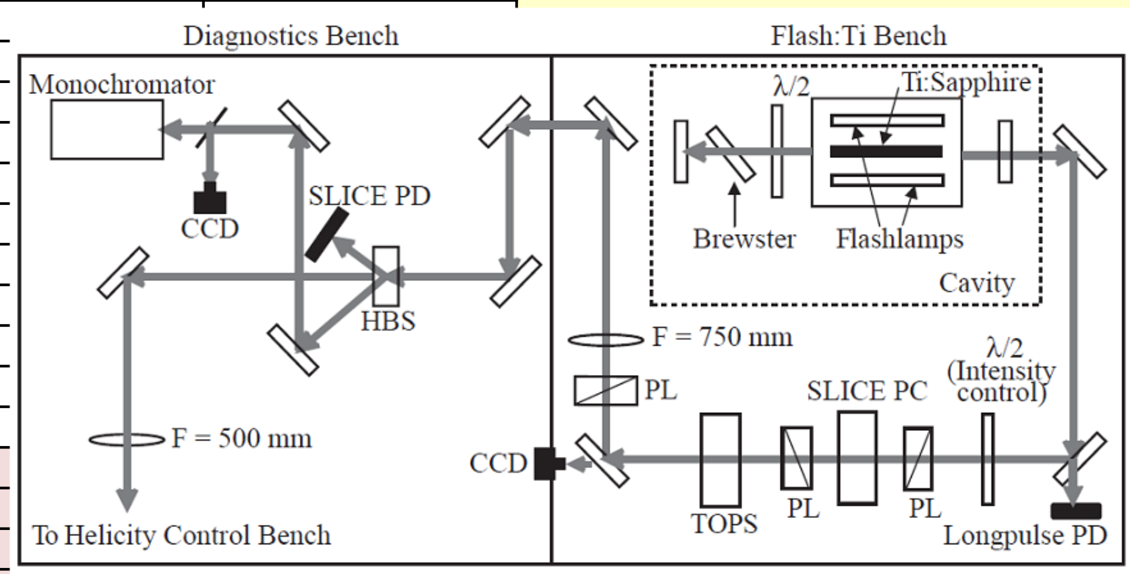
- Classical polarized source wit bunching system
- Charge production demonstrated by SLAC experiment
- Simulations showed 87 % capture efficiency (F. Zou, SLAC)



Polarized electron source parameters

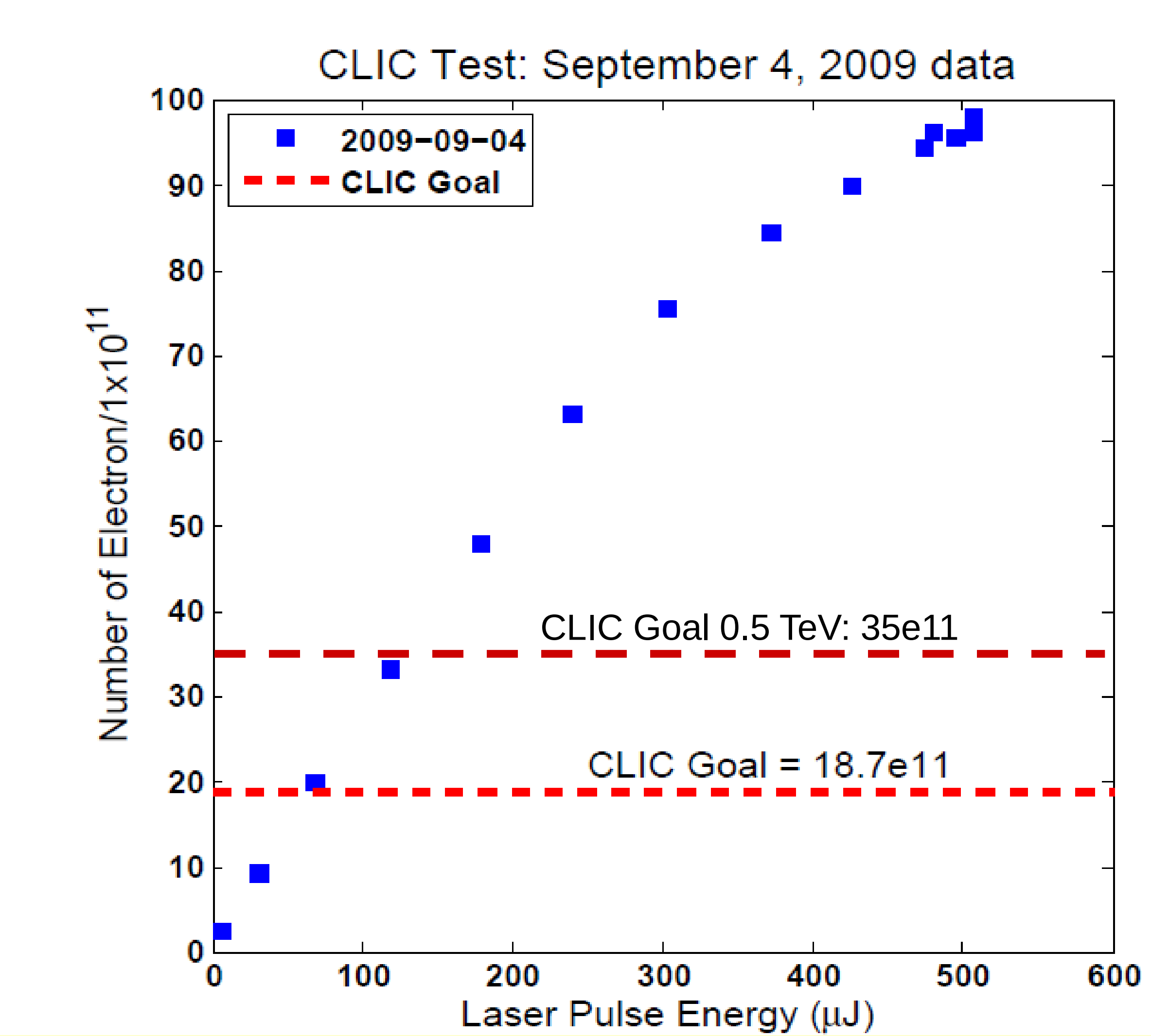
		POLARIZED SOURCE FOR CLIC	
		CLIC 1 GHz	CLIC DC/ SLAC Demo
Number of electrons per bunch (*10^9)	Electrons		
Charge/single bunch (nC)			
Charge/macrobunch (nC)			
Bunch spacing(ns)			
RF frequeny (GHz)			
Bunch length at cathode (ps)			
Number of bunches			
Repetition rate (Hz)			
QE(%)			
Polarization			
Circular polarization			
Laser wavelength (nm)	Laser		
Energy/micropulse on cathode (nJ)			
Energy/macropulse on cathode (µJ)			
Energy/micropulse laser room (nJ)		1526	NA
Energy/macrop. Laser room (µJ)		476	633
Mean power per pulse (kW)		1.5	2
Average power at cathode wavelength(mW)		8	9.5

Laser scheme



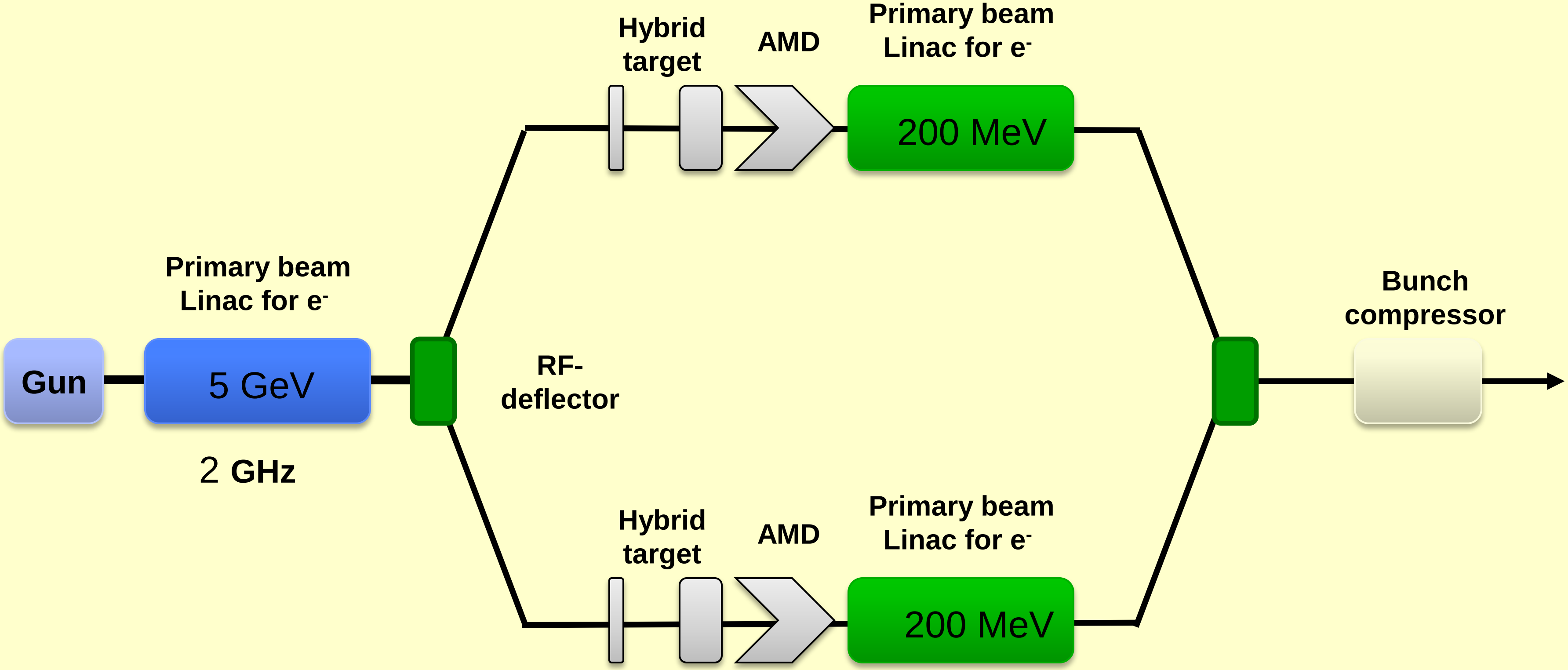
For the 1 GHz approach cathode current densities of 3-6 A/cm^2 would be needed, the dc approach uses < 1 A/cm^2

Polarized electron source



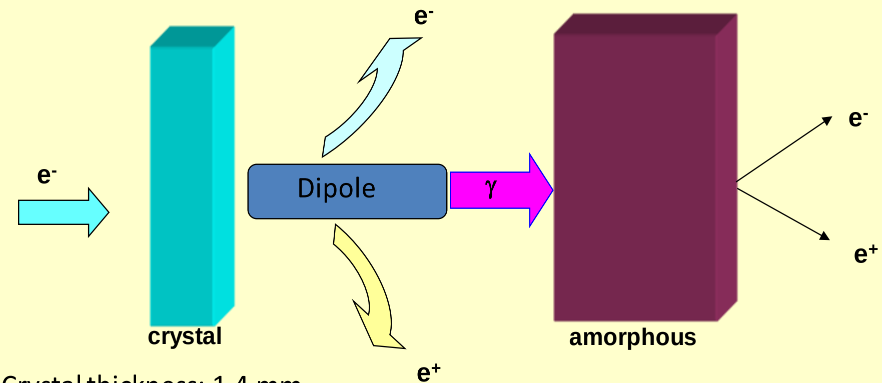
J. Shepard

Positron source conventional ?



AMD: 200 mm long, 20 mm radius, 6T field

Hybrid target



Crystal thickness: 1.4 mm
Oriented along the <111> axis

Distance (crystal-amorphous) d = 2 m

Amorphous thickness e =10 mm

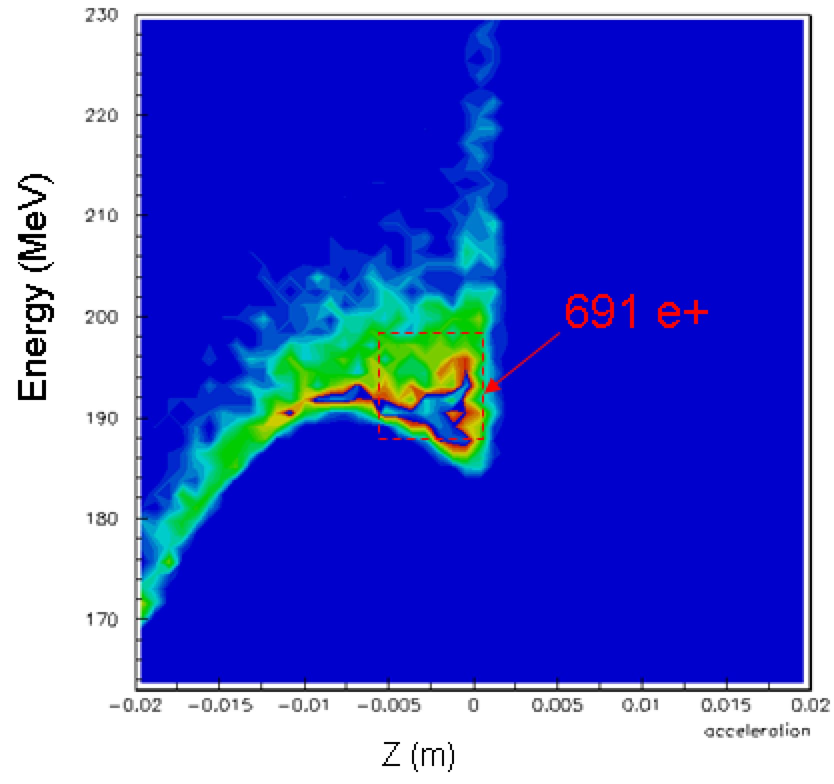
Target Parameters Crystal		
Material	**Tungsten**	**W**
Thickness (radiation length)	**0.4**	χ_0
Thickness (length)	**1.40**	**mm**
Energy deposited	**~1**	**kW**

Target Parameters Amorphous		
Material	**Tungsten**	**W**
Thickness (Radiation length)	**3**	χ_0
Thickness (length)	**10**	**mm**
PEDD	**30**	**J/g**
Distance to the crystal	**2**	**m**

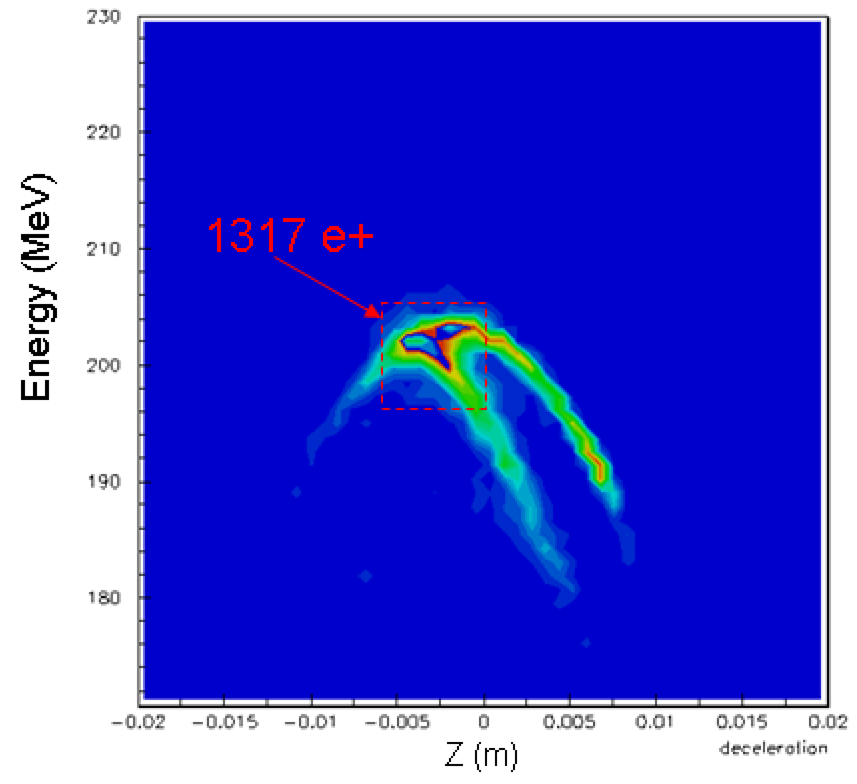
Yield simulations
capture and pre-injector linac

Energy density at 200 MeV

Accelerating mode



decelerating mode



Positron yield: after target: ~8 e^+/e^-

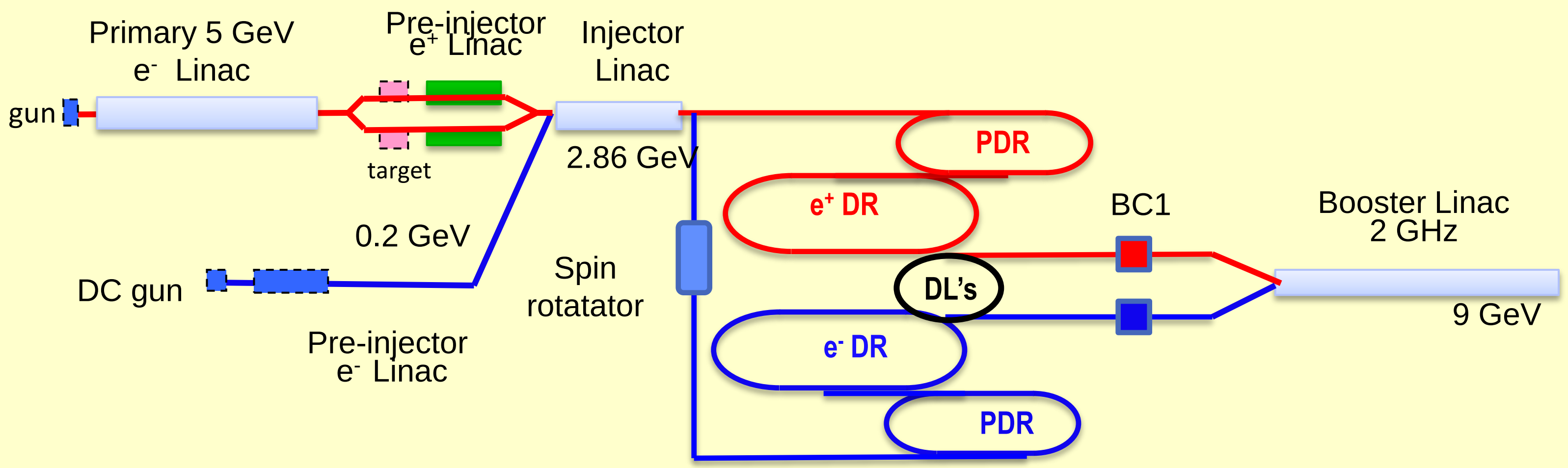
at 200 MeV: 0.9 e^+/e^-

into PDR: 0.39 e^+/e^-

O. Dadoun

Linac Parameters

LINAC	Energy Gain (MeV)	Bunch charge (10^9)	rf pulse length (ns)	Power per structure (MW)	Loaded gradient (MV/m)	Configuration (struct/klyst)	No of rf stations	pulse compressor gain	No of structures	Length (m)
e- pre-injector	200	4.3	1300-1700	54	18	2	4	2.3-2.5	7	30
e+ pre-injector	200	11	1300-1700	56	15	2	4	2.3-2.5	9	40
injector linac	2660	6	3600-4000	44	15	1	118	1	118	300
positron drive linac	5000	11	1300-1700	56	15	2	111	2.3-2.5	222	400
booster linac	6140	4	1700-2000	44	16	2	128	2-2.3	256	473



Cost reduction for the main injectors

- CDR design was focused on low risk, conventional, state of the art facility to guarantee excellent beam quality and not worry about cost or feasibility
- It turned out that the injectors have a significant cost impact even on CLIC

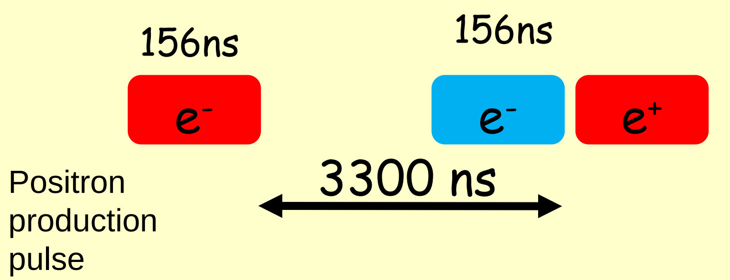
→ In the frame work of the new base-line for CLIC, in particular optimizing a low energy first stage we decided to focus as well on cost and efficiency

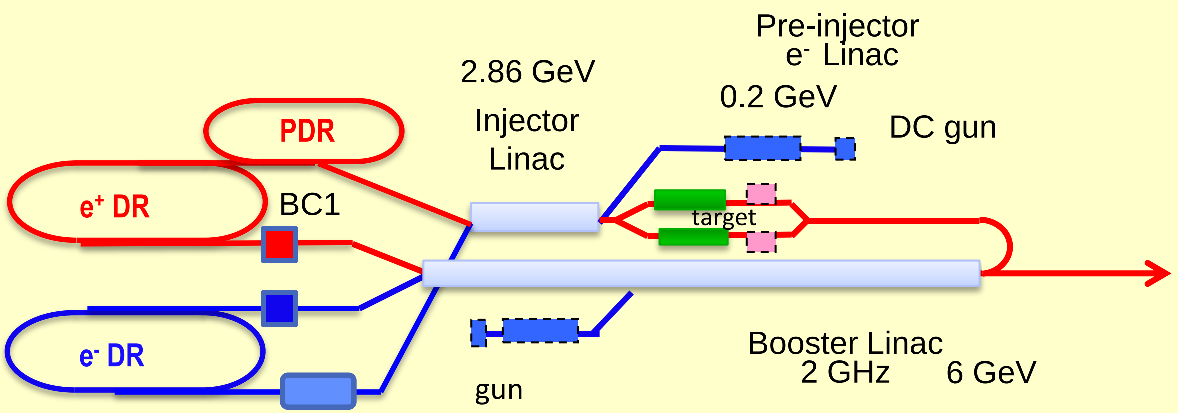
Main proposals:

- ❑ PDR for electrons not needed
- ❑ Use 2 GHz bunch spacing through out the complex, shorter rf pulses in linac's and no need for delay loop
- ❑ Optimise timing of the beams to gain efficiency (PC optimisation)
- ❑ Investigate to use booster linac as positron driver (saves positron driver)
- ❑ Provide cost model for optimization

Alternative layout

Without positron driver linac and e^- PDR, 2 GHz bunch spacing everywhere





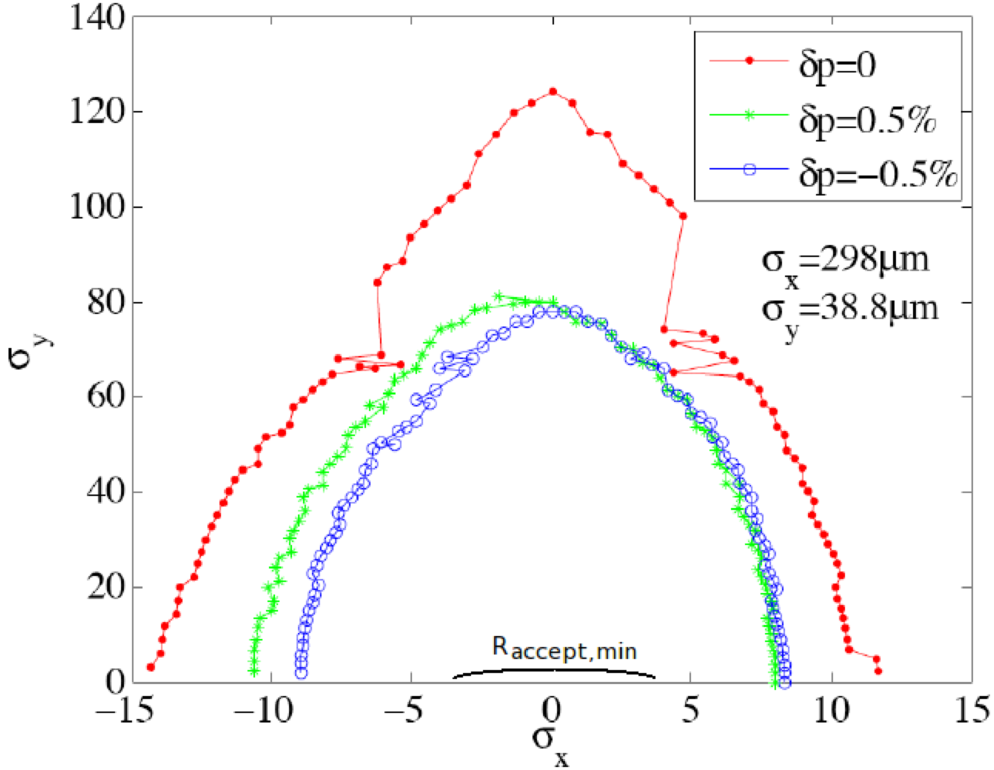
Save two rings, positron driver linac, and tunnel length (saving potential 200 MCHF)

Cost of 1 vs. 2GHz system

- The cost of the DR RF system was scaled with the total voltage
- For the PDR the total voltage is 10MV in both options, so no potential cost saving
- For the DR, the total voltage at 1GHz is 5.1MV, whereas it is 4.5MV for 2GHz. Taking 850kCHF/MV, the reduction for 2GHz is 0.5MCHF
- At 2GHz, there is not delay loop necessary, and there is a reduction of around 9.8MCHF
- The technological risk of choosing the 2GHz option, after Alexej's conceptual design, seems equivalent with the train recombination for the 1GHz option

Electron linac requirements

DA of the main DR



- For non-Gaussian beams the minimum required acceptance:

$$R_{\min} = \sqrt{2\beta\varepsilon_{\max}} + D(\delta p/p_0)_{\max}$$

- To avoid an e^- PDR:
  - In horizontal $R_{min} < 1$ mm-rad
  - In vertical $R_y^{min} < 1.2$ mm-rad

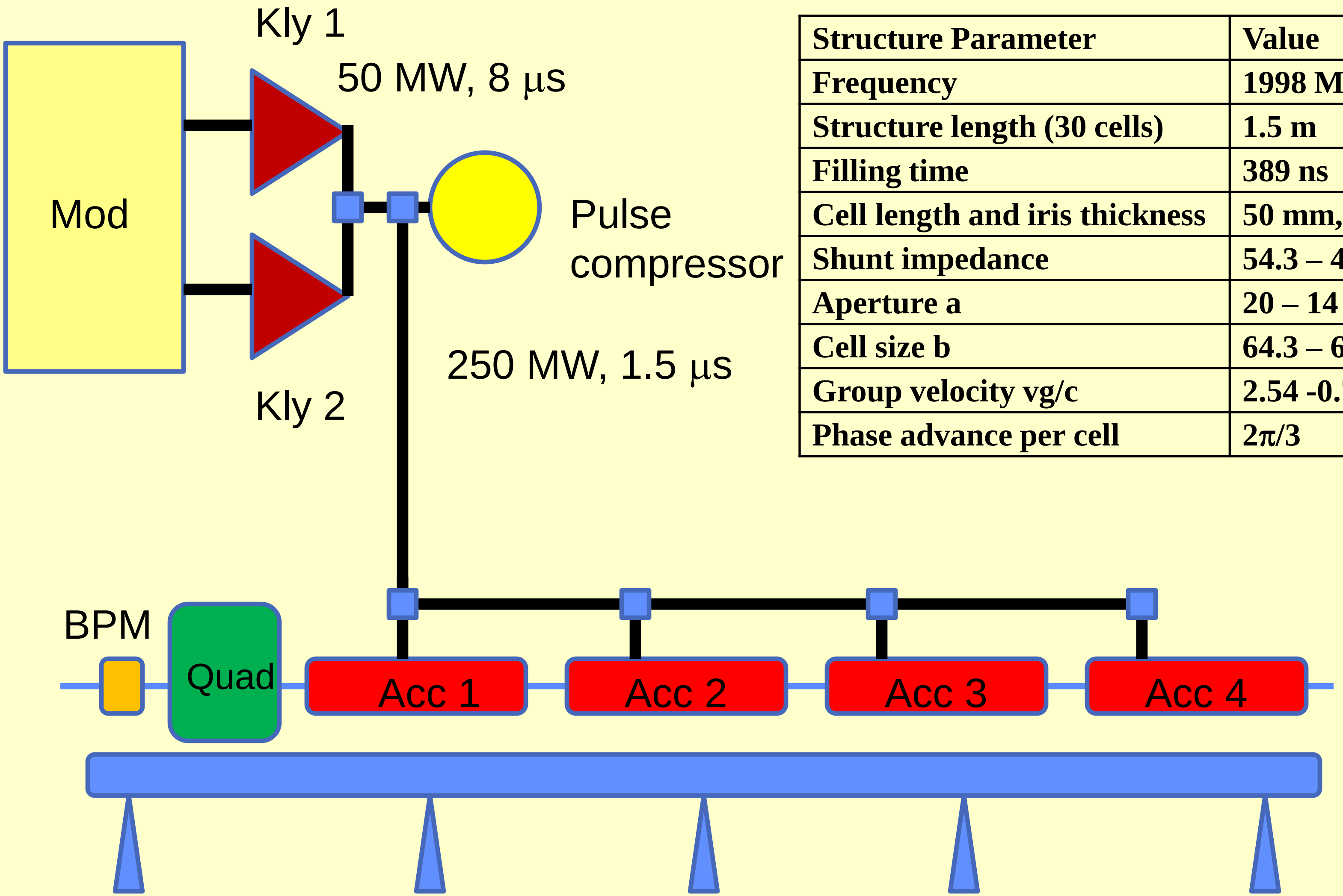
- Required emittances from the electron injection linac **in order to remove electron PDR**

$\varepsilon_x^{rms} = 25$ μm-rad

$\varepsilon_y^{rms} = 50$ μm-rad

F. Antoniou

Injector linac rf system



Structure Parameter	Value
Frequency	1998 MHz
Structure length (30 cells)	1.5 m
Filling time	389 ns
Cell length and iris thickness	50 mm, 8 mm
Shunt impedance	54.3 – 43.3 MΩ/m
Aperture a	20 – 14 mm
Cell size b	64.3 – 62.9
Group velocity vg/c	2.54 -0.7 %
Phase advance per cell	$2\pi/3$

Cost per linac

Cost estimate per linac (1.5 TeV parameters)

LINAC	Energy Gain (MeV)	Bunch charge (10^9)	rf pulse length (ns)	Power per structure (MW)	Loaded gradient (MV/m)	Configuration (structure/2 klystrons)	No of rf modules	pulse compressor gain	No of structures	Length (m)	Energy gain per module (MeV)	Cost	Efficiency (%)	Structure efficiency for 312 bunches (%)
e- pre-injector	200	4.3	1300-1700	54	18	4	2	2.3-2.5	8.0	30	108	5830	2.68	
e+ pre-injector	200	11	1300-1700	56	15	4	3	2.3-2.5	9.0	40	90	8745	4.58	
injector linac	2660	6	3600-4000	44	15	2	60	1	119.0	300	45	127950	6.64	31
positron drive linac	5000	11	1300-1700	56	15	4	56	2.3-2.5	223.0	400	90	163240	6.13	32
booster linac	6140	4	1700-2000	53	16	4	64	2-2.3	256.0	473	96	186560	4.79	27

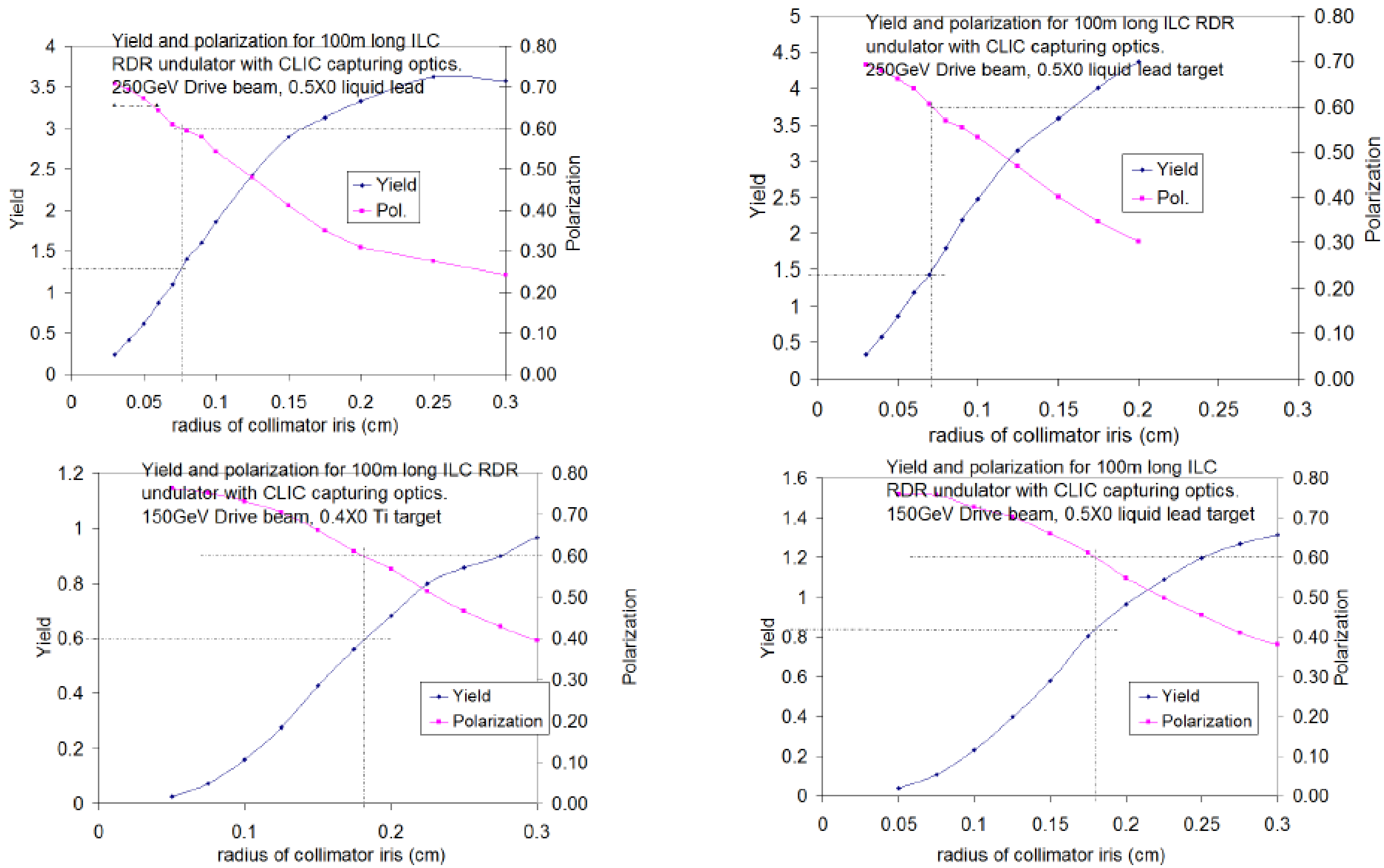
Bunch charge and gradient determine power/structure, optimized for a 2x 50 MW klystron + pulse compressor configuration to feed a maximum of structures

Cost of structure 13%

Cost of high power system 75%, ~ factor 2 of this could hopefully be gained (150M)

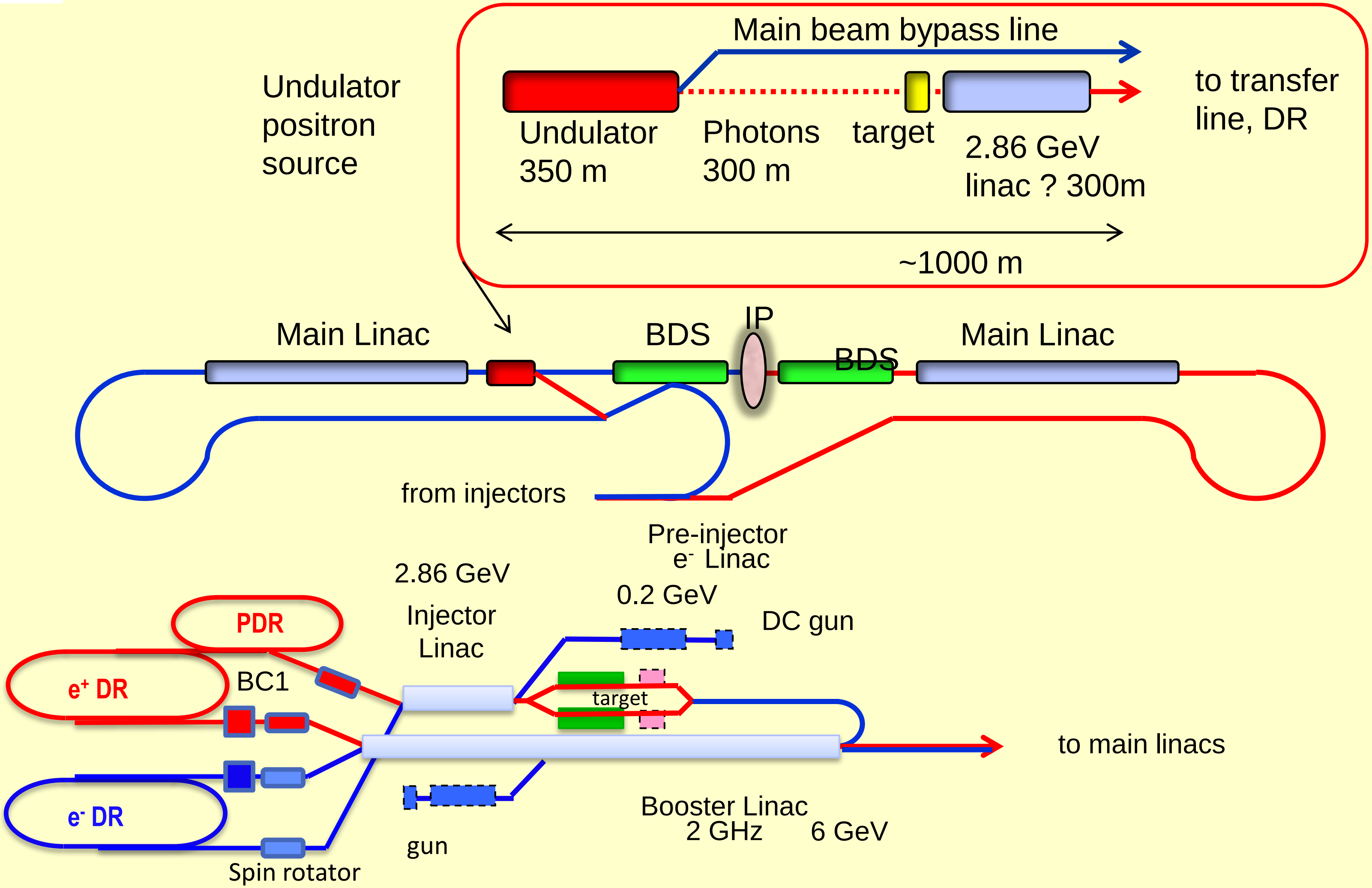
Undulator based positron source for CLIC

Using ILC RDR undulator with CLIC capturing optics



Wanming Liu

Layout with undulator based positron source



Minimum scenario for upgrade to positron polarization and fully compatible with conventional layout

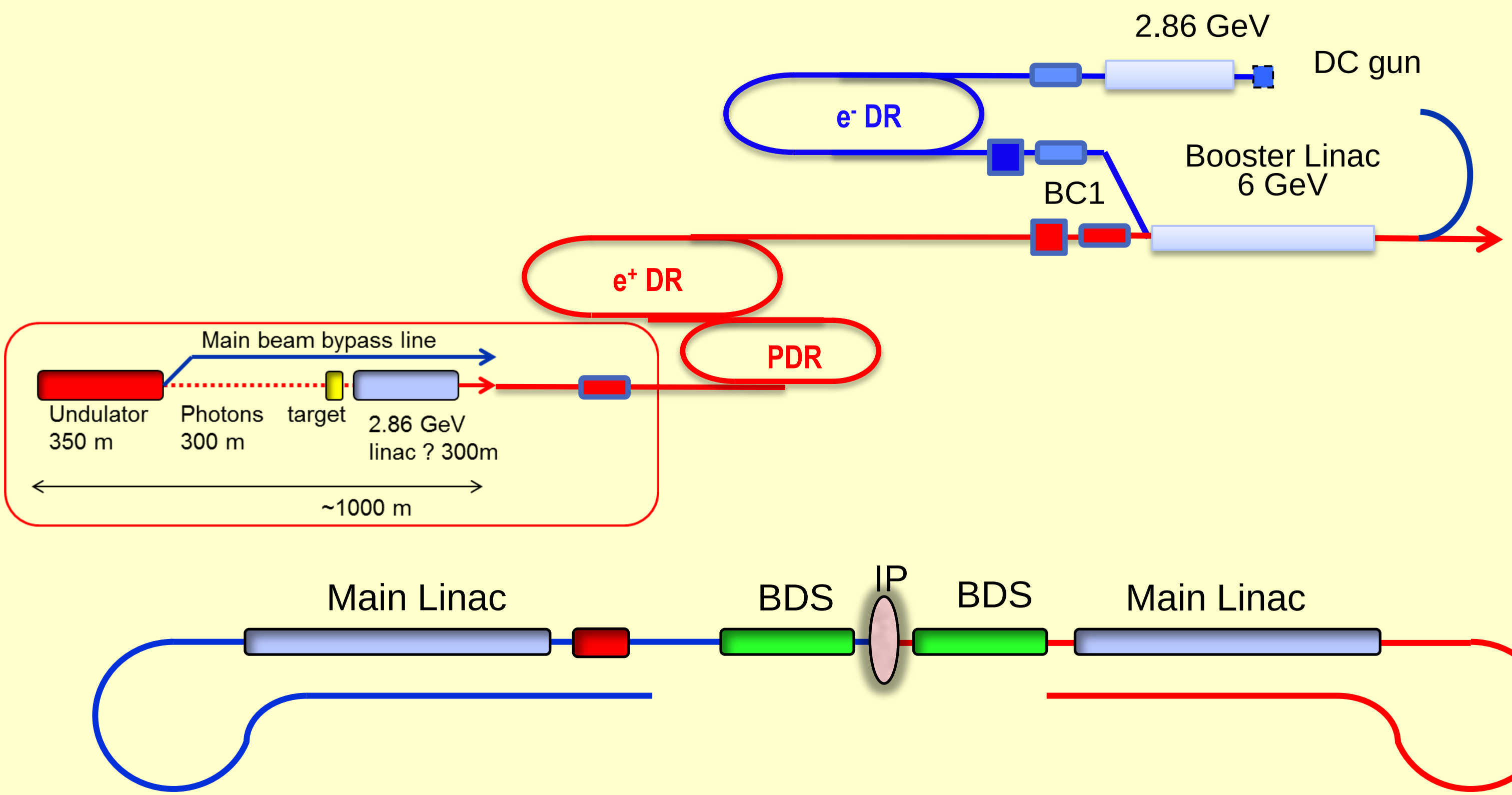
Undulator based positron source

Consequences:

- 400 -1000 m more linac length (both sides ?)
- Separate injector linac for positrons 2.86 GeV
- transfer line from the tunnel to the injector complex
- Spin rotator before and after damping ring (needed anyway for any polarized scheme)
- Gap in damping ring due the delayed beams
- Main beam bypass around positron production
- Coupling of the two beams

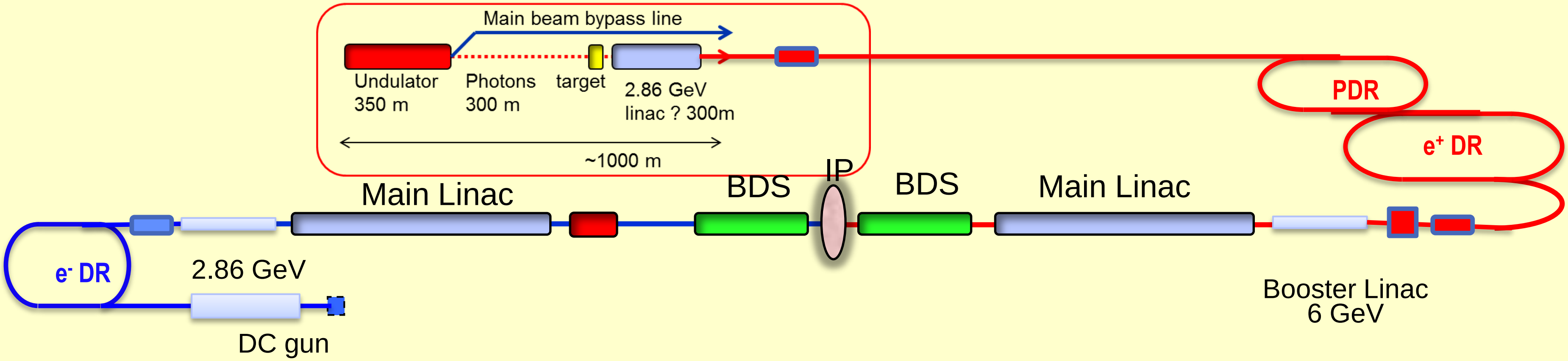
How about a dedicated scheme ?

Central Injectors and DR in deep tunnel



How about a dedicated scheme ?

DR and injector at the end of each side



Undulator based positron source

To be studied

- Impact in cost, length and performance
- Emittance preservation in undulator and bypass
- Beam loading in PDR due to a likely gap of ~ 43 μs (500 GeV)
- General timing consideration
- Upgrade scenarios
- Undulator parameters, can we get 60% polarization

Wei Gai, Wanming Liu and CLIC team

Conclusions

- Small effort for CLIC sources after CDR
- Focus on low energy first stage (375 GeV), cost, performance and efficiency optimization
- Started to study an undulator based positron source for CLIC more seriously with the aim to document that before the end of the year.