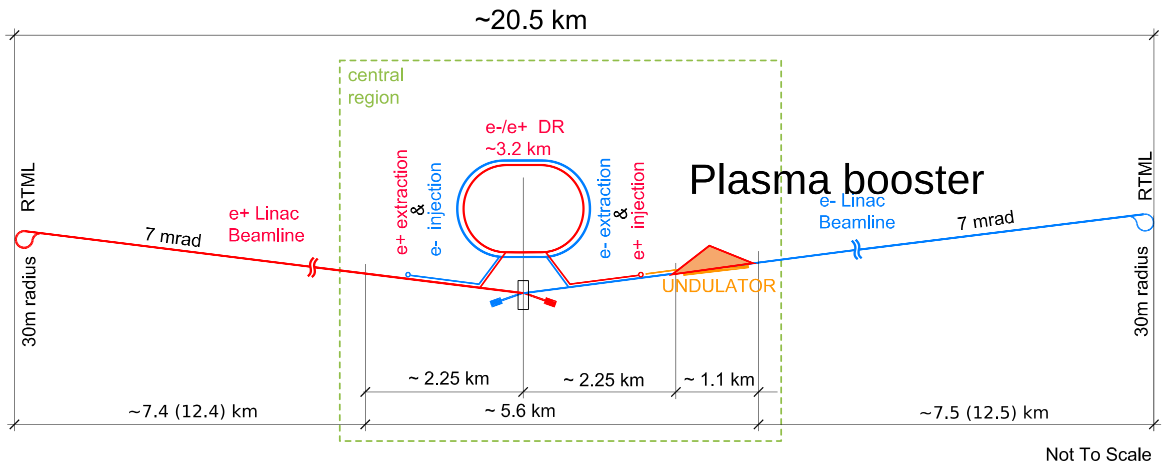
Plasma upgrade for the ILC.

Using the HALHF concept to double the ILC energy



Benno List, DESY

LC Vision Item 6 Meeting
5.6.2024

HELMHOLTZ

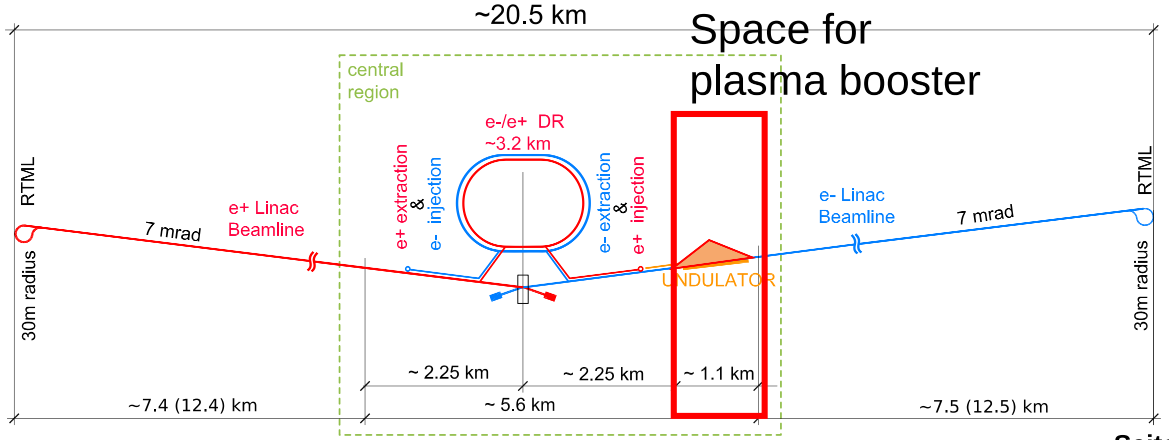
DESY.

A Plasma Booster for ILC250

Using the HALHF concept to double the ILC energy

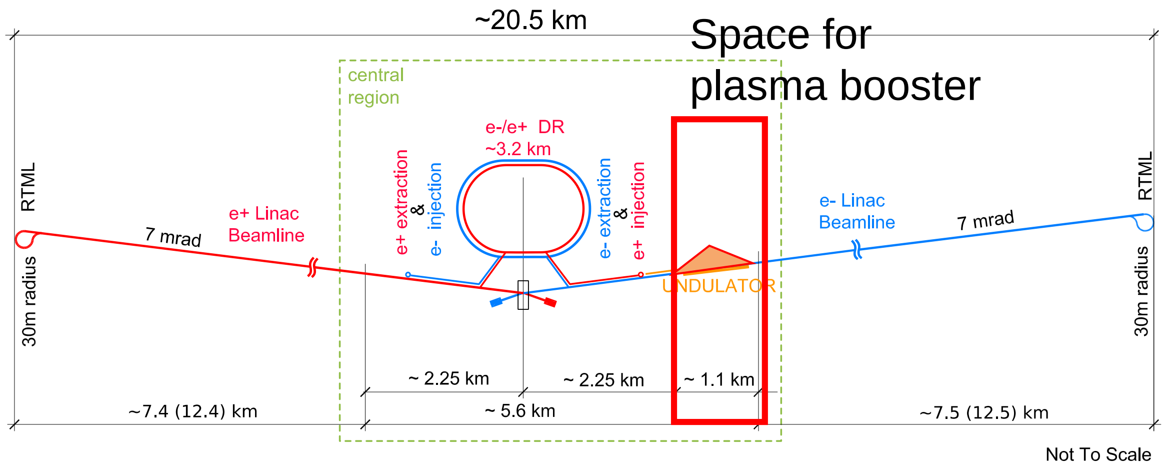
- Basis: ILC250 Higgs factory ⇒ 2x125GeV linacs available
- Apply HALHF concept:
  Collide plasma accelerated electrons with conventionally accelerated positrons
- Upgrade **electron arm** to 500GeV with plasma
  ⇒ 137.5 x 550GeV ⇒ 550 GeV CME
  ⇒ upgrade a higgs factory to a tth / Zhh factory
  - Reduce electron linac energy by 4 to 34.4GeV
  - Drive 16 stage plasma accelerator
- Use space for undulator source between electron ML and BDS to install plasma booster
- Feed boosted electrons into existing BDS (already laid out for 500GeV)

		E- (drive)	E- (Collide)	E+
Beam energy	GeV	34.4	34.4 → 550	137.5
Linac Gradient	MV/m	8.7		35
CoM energy	GeV	550		
Bunch charge	nC	4.3	1.6	6.4
Bunches/pulse		10496	656	656
Rep rate	Hz	5		
Beam power	MW	8.0	0.18 → 2.9	2.9
Lumi (approx.)	$cm^{-2}s^{-1}$	$\sim 1 \cdot 10^{34}$		



Basic idea

- Assume: ILC has been built,
  -> 2x125GeV linacs available
- Goal: upgrade electron arm to 500GeV with plasma
  -> 125x500GeV -> 500GeV COM
  -> upgrade a higgs factory to a tth / Zhh factory
- Use electron linac for drive and witness beam:
  run a lower gradient but higher current, upgrade RF on electron arm
- Use space for undulator source between electron ML and BDS to install plasma booster
- Feed boosted electrons into existing BDS (laid out for 500GeV)



Double the energy, halve the beam intensity

- ILC 250 in baseline configuration has a lumi upgrade option: Install 50% more klystrons for twice as many bunches (more bunches per pulse reduce losses from fill time)
- To double CoM energy, halve the beam intensity to keep RF power reasonable (compared to nominal
  -> halve number of colliding bunches per pulse
- Positron arm: half number of bunches at twice the bunch intensity -> RF power ~constant
- Electron arm:
  halve number of colliding bunches
  halve intensity per bunch
  quadruple beam energy
  -> RF power for colliding bunches ~constant
- But: drive beam power is 2.7 higher (37% eff)
  -> overall, electron arm needs about 2.7 times more RF power than in baseline configuration (8.2MW)
  -> 60% increase over lumi upgrade scenario

- Or go to 10Hz?
  - **Cryo on e+ side needs upgrade** (10Hz at full gradient not foreseen in baseline)
  - Cryo on e- side no problem (low gradient)

		Nom / Lup	E- (drive)	E- (Collide)	E+
Beam energy	GeV	125	34.4	34.4 → 550	137.5
Linac Gradient	MV/m	31.5	8.7	8.7 + plasma	35
CoM energy	GeV	250	550		
Bunch charge	nC	3.2	4.3	1.6	6.4
Bunches/pulse		1312 / 2625	10496	656	656
Rep rate	Hz	5	5		
Beam power	MW	2 x 2.6 / 2 x 5.2	8.0	0.18 → 2.9	2.9
Lumi (approx.)	$cm^{-2}s^{-1}$	$1.35 / 2.7 \cdot 10^{34}$	$\sim 1 \cdot 10^{34}$		

Bunch Pattern and RF supply in Drive Beam Linac

- Rep-rate: 5Hz (ILC baseline)
- Time between colliding bunches: 1.6us (3 x ILC)
- In drive beam linac: mini-trains: 16 db bunches + witness bunch in ~80ns, then gap
  -> pulse length: 1.1ms
- Average current in pulse: 46mA
  -> 4x ILC at ¼ gradient
  -> cavity fill time: 32us – very short
- Power 1.5 cryomodules (13 cavities) with one klystron -> **9.8MW** matched power per klystron
- Requires 3x more klystrons than in baseline configuration (baseline: 2 klystrons for 9 cryomodules) -> fits RF cell structure
  -> next slide

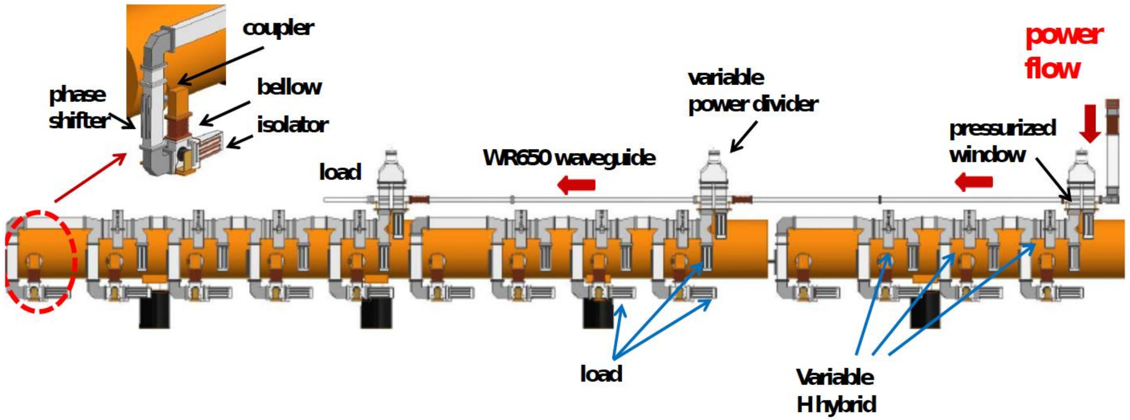
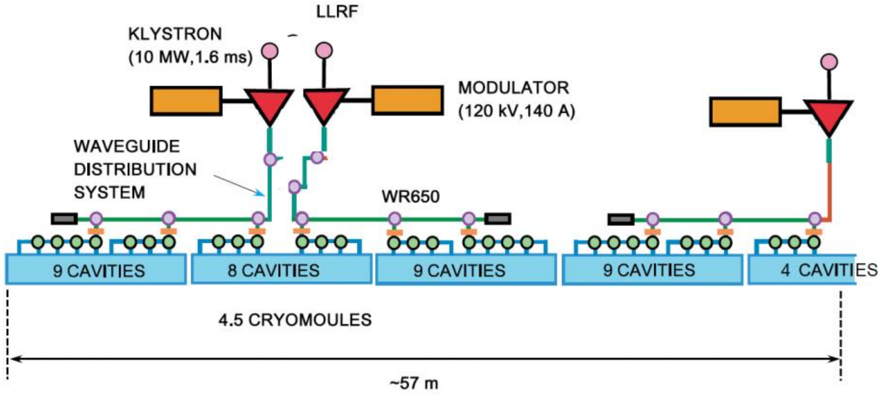


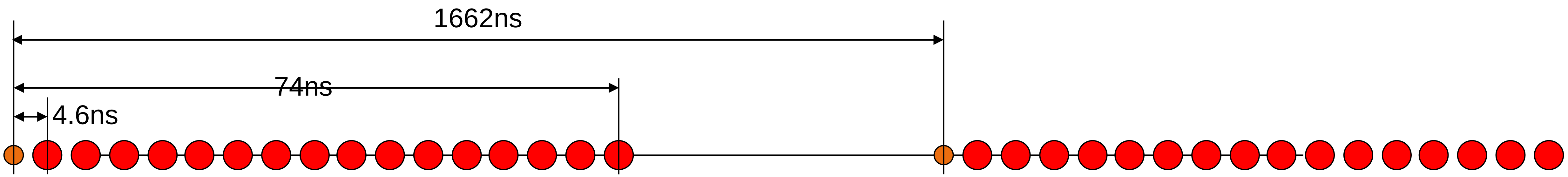
Figure 3.33. CAD model of a 13-cavity local power-distribution system (LPDS)

TDR, Vol 3.II



Bunch Pattern

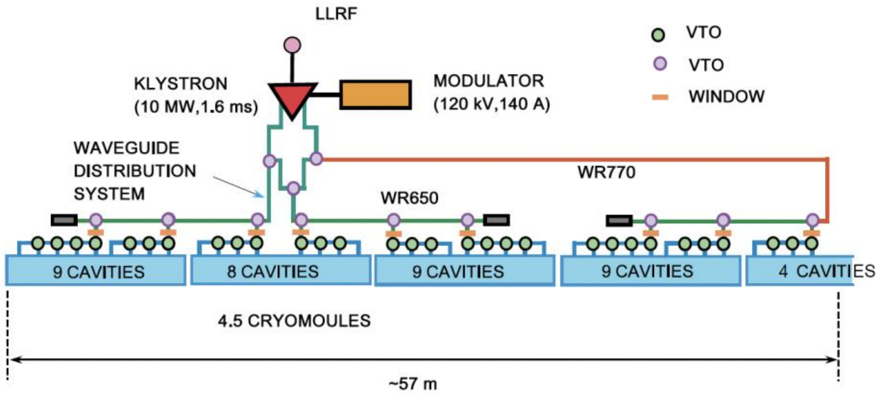
Not to scale



Overall: 656 mini trains in pulse -> pulse length 1090us

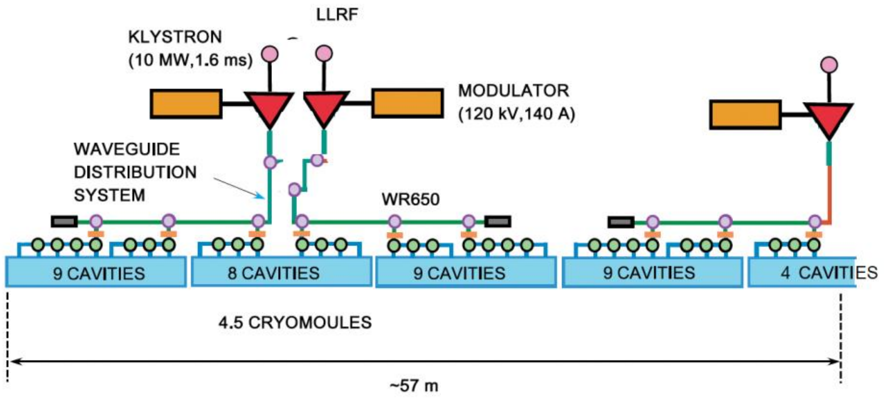
RF Upgrade on e- side: 6 klystrons per 9 modules

Figure 3.41
Schematic layout of a DKS RF unit, showing a single klystron driving 39 cavities (1-1/2 ML units).



Baseline configuration:
2 klystrons for 9 cryomodules

Lumi upgrade would be 3 klystrons per 9 modules

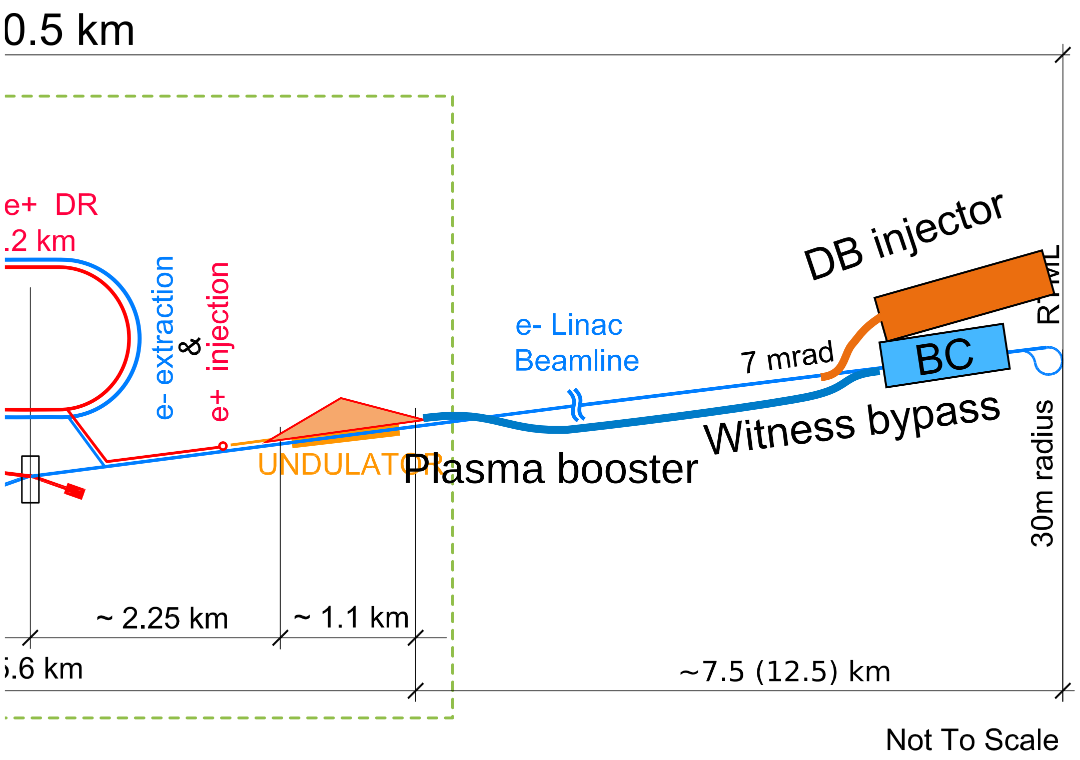


Upgrade configuration
6 klystrons / modulator units for 9 cryomodules (1 RF unit)
-> 1 klystron per 13 (9 + 4) cavities

Overall number of klystrons / modulators is the same as for a full 500 GeV ILC

Separating Drive and Witness Beam on e- side?

- ILC uses 2-stage bunch compressor at 5 and 15 GeV, ”Main Linac” accelerates only from 15 to 125GeV
- Bunch compressor 2 accelerates bunches from 5 to 15 GeV. Could not handle drive beam
- Injecting drive beam at 15GeV too expensive, want to use existing Main Linac for drive beam
- Possible solution: Separate drive and witness beams!
  - Take witness beam out after bunch compressor at 15GeV, build transfer line to start of plasma section
  - Use Main Linac only for drive beam acceleration -> reduce injection energy from 5 to 2GeV?



Summary

- A “HALHF” type plasma booster for ILC 250 could boost the CoM energy to ~550 GeV
  -> enough to reach tth threshold
- Overall beam intensity would be half compared to ILC250 or full ILC500
  -> half of luminosity
- Compared to full ILC500 further luminosity reduction from larger emittance / asymmetric beams -> needs to be studied
- BDS of ILC designed for 500GeV beams
  -> should work
- Bunch Compressors are an issue

Kontakt

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