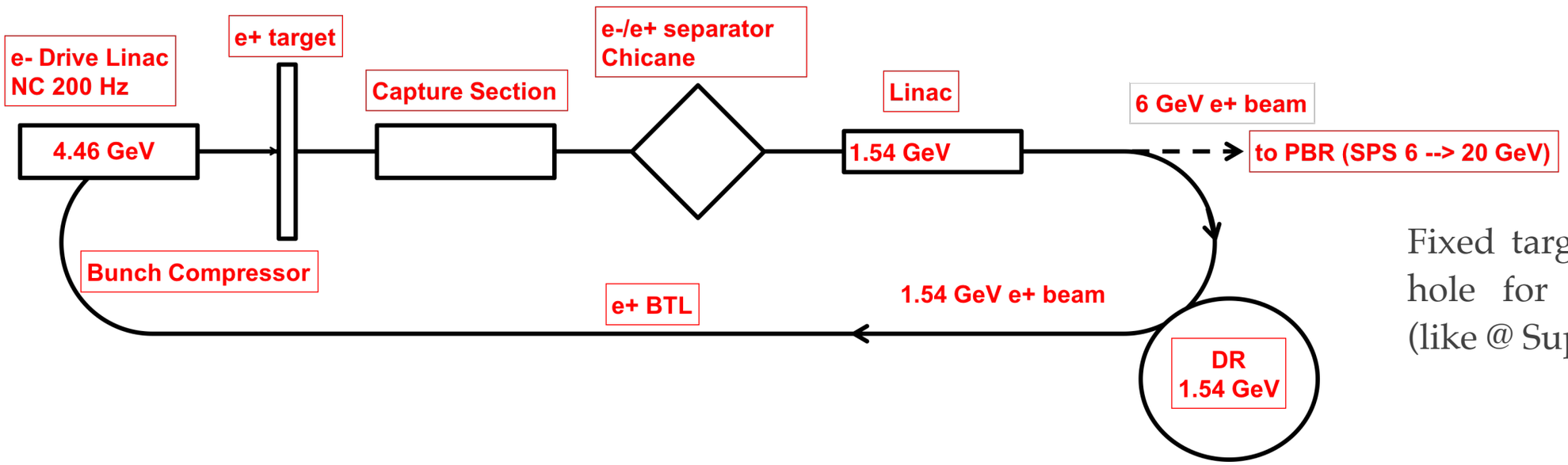
Positron source activities on FCC-ee @LAL

FCC-ee Positron Injector

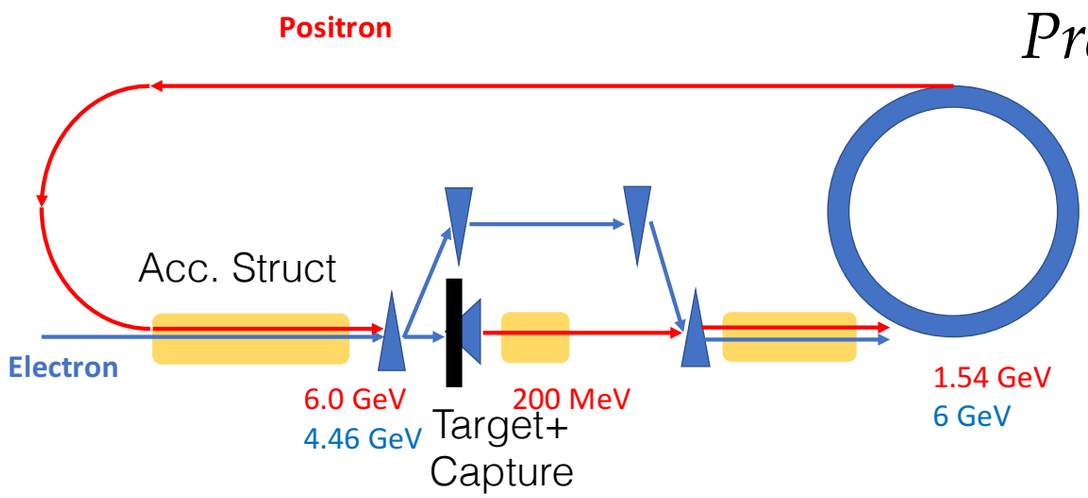
Current scheme

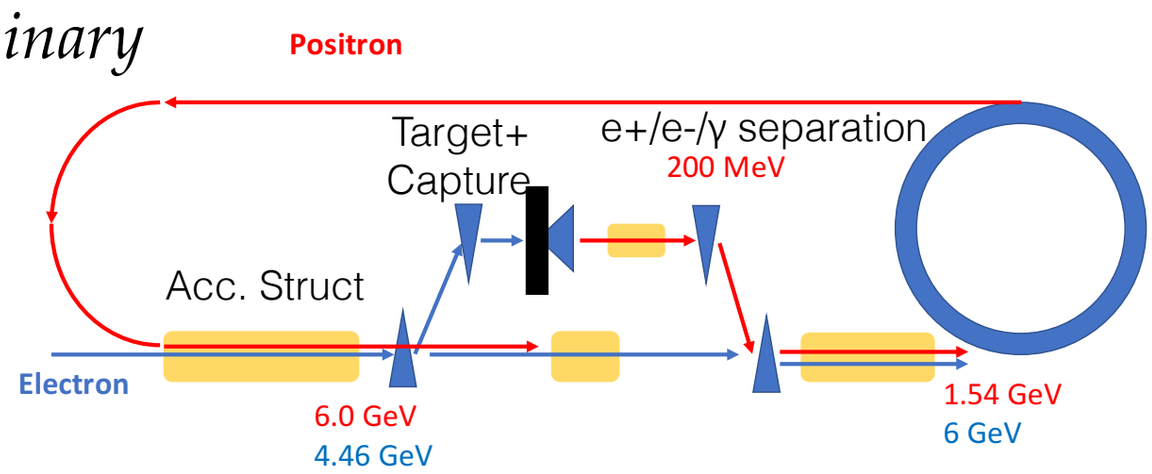


Fixed target-converter has a hole for e- beam passage (like @ SuperKEKB)

Schemes with the bypass under consideration in the framework of PhD thesis of Bowen Bai (supervised by A. Faus-Golfe)

Preliminary

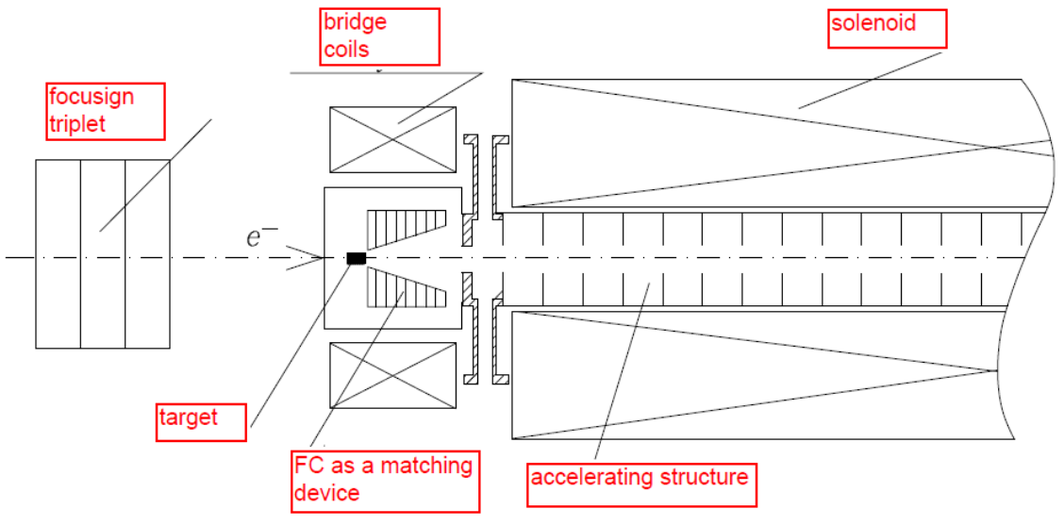




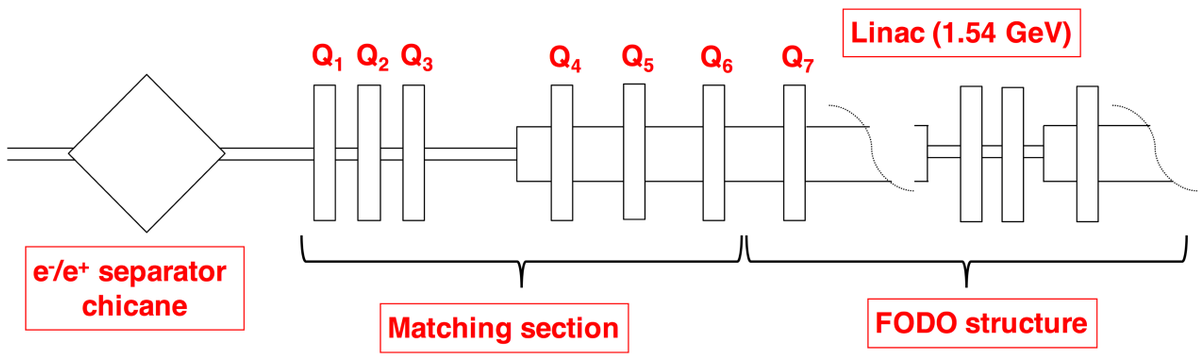
Beam parameters

☞ Parameters used are from the FCC CDR

e+ production and capture section



e+ acceleration up to 1.54 GeV



<u>Primary e- beam</u>

4.46 GeV

3×10^{10} e^-/bunch ~ 5 nC
(main e- beam)

4.2×10^{10} e^-/bunch ~ 7 nC
(for e+ production)

2 bunches/pulse spaced by ~60 ns

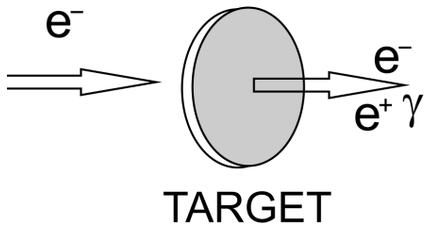
The complete filling for Z running (most demanding) => requires a linac bunch intensity of 2.1×10^{10} particles for both species

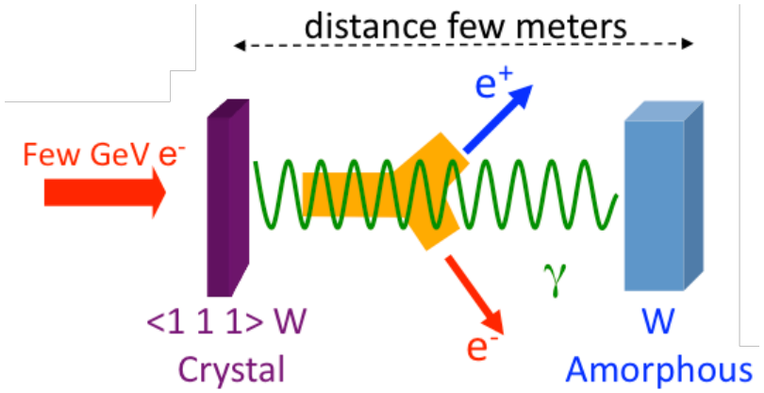
Requirement @ DR:
2.1×10^{10} e^+/bunch (4.3 nC)
~0.5 e+/e- without safety factor

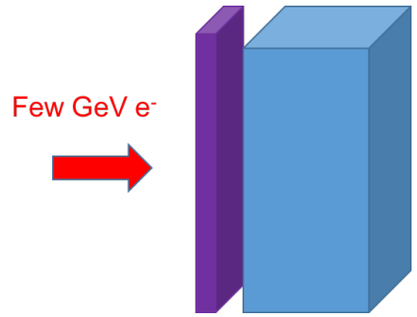
A safety factor of at least 2 should be considered

Activities ongoing

1) **<u>Conventional positron target:</u>** bremsstrahlung and pair conversion.
2) **<u>Hybrid positron target:</u>** Two-stage process to generate positron beam. Channeling (crystal target) and pair conversion (amorphous target).



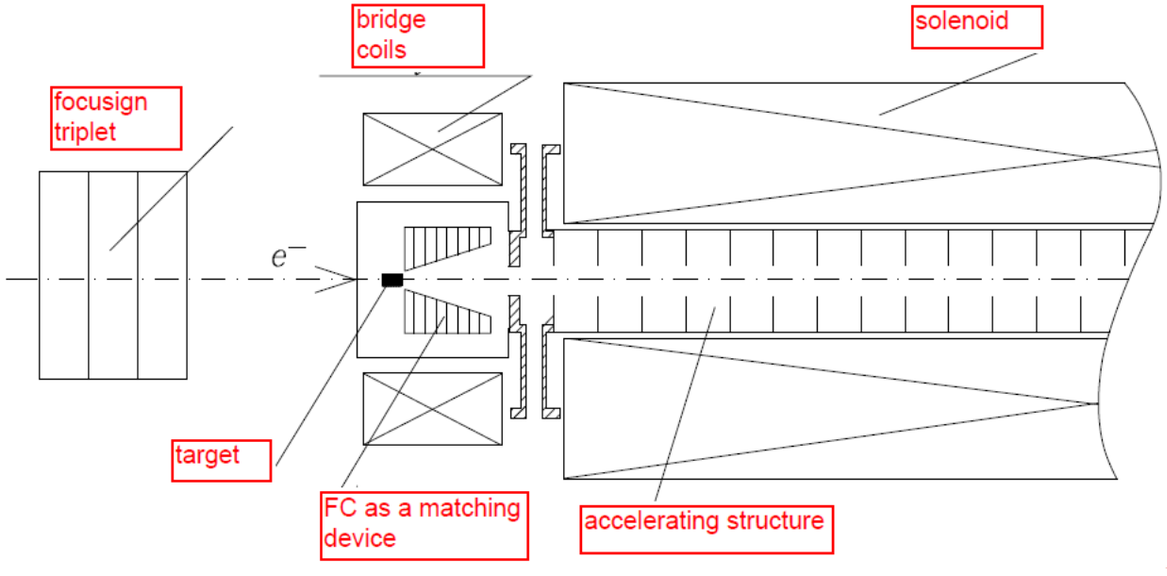




The capture linac is encapsulated inside a solenoid with the axial magnetic field of 0.5-0.7 T.

☞ **Hybrid scheme:** 1.5 meter long 17 MV/m, 2 GHz L-band structures.

☞ **Conventional scheme:** 3 meter long 20 MV/m 2856 MHz large aperture S-band structures.



Activities ongoing

☞ All studies up to now have been done with the parameters from the FCC CDR(4.46 GeV, ~7 nC, two bunches, 200 Hz).

- Simulation and optimization of the production for the conventional/ hybrid positron source (LAL, BINP).
- Simulation of the positron capture up to 200 MeV with the FC and SC-solenoid. S- and L-band structures (LAL, BINP).
- Design of the FC (BINP) .
- Design studies of the BC + DC solenoid have been started (BINP).

After Kick-Off meeting @PSI

☞ Program until 2023 ?

WP2 e+ production	LAL	Overall target optimization and simulations including variant studies by LAL **BINP for flux concentrator design , bridge coil, long solenoid**	1 postdoc until end 2021 already at LAL, need extension to 2022/23 1 PhD already on the subject until end 2021, new PhD afterwards? 0.6 FTE LAL staff /y, from 2021 0.8 FTE/y **0.5 FTE BINP expert staff**	CDR+ chapters with cost estimate end 2022

<u>Close interaction with (to be discussed)</u>

- CERN on target design/thermal load (depends on the FC design (BINP)
- PSI on RF structures, magnets ?
- LNF on DR (longitudinal phase space acceptance)
- BINP on the FC, BC + long NC solenoid

Activities planned until mid 2022 (to be discussed)

- **Drive beam.** Optimization of the electron drive beam parameters. Bypass.
- **Positron production.** Simulation and optimisation of the positron production including positron yield, target energy deposition and the associated PEDD. Different production schemes (conventional/hybrid target) and target design.
- **Target design and reliability.** Mechanical stress, fatigue limit, shock waves and thermal dynamics. Stationary target or moving target (pendulum, rotating wheel...), target cooling system.
- **Positron capture.** Positron capture and primary acceleration: simulation and optimisation of the positron capture (solenoid, peak field, aperture, length, field profile). SC solenoid as the AMD? Pre-injector linac embedded in the solenoid up to 200 MeV (solenoid field, SC option? acc. gradient, phase, aperture). Different techniques of positron capture.
- **Conceptual design.** Detailed design studies of the FC, BC + DC solenoid.
- **Start-to-end simulations.** Simulations up to the DR and full optimisation.

Discussion

☞**Which criteria can be chosen for positron source (total e+ yield, accepted e+ yield, energy spread and emittance) ?**

☞ **General strategy to be used for the studies.**

- The main parameters for a given/fixed target and capture system designs are electron beam energy and its intensity => make a choice (max 4.2×10^{10} e^-/bunch ~ 7 nC ? Energy ?)
- Conventional or hybrid scheme => decide for the CDR+
- FC or SC solenoid ?
- Choice of the RF structures: large aperture S-band cavities (30 mm diameter) constant impedance ? L-band cavities for the capture linac? TW or SW ?
- Long solenoid: SC option?
- Safety factor 3-4 should be adopted.

Roadmap tp define

Positron source performances

	SLC	LEP (LIL)	KEKB/SKEKB	FCC-ee*
Incident e- beam energy	33 GeV	200 MeV	4.3/3.5 GeV	4.46 GeV
e-/bunch [10^{10}]	3-5	0.5 - 30 (20 ns)	6.25/6.25	4.2
Bunch/pulse	1	1	2/2	2
Rep. rate	120 Hz	100 Hz	50 Hz/50 Hz	200 Hz
Incident Beam power	~20 kW	1 kW (max)	4.3 kW/3.3 kW	12 kW
Beam size @ target	0.6 - 0.8 mm	< 2 mm	/>0.7 mm	
Target thickness	$6X_0$	$2X_0$	$/4X_0$	
Target size	70 mm	5 mm	14 mm	
Target	Moving	Fixed	Fixed/Fixed	
Deposited power	4.4 kW		/0.6 kW	
Capture system	AMD	λ/4 transformer	/AMD	AMD
Magnetic field	6.8T->0.5T	1 T->0.3T	/4.5T->0.4T	
Aperture of 1st cavity	18 mm	25mm/18 mm	/30 mm	
Gradient of 1st cavity	30-40 MV/m	~10 MV/m	/10 MV/m	
Linac frequency	2855.98 MHz	2998.55 MHz	2855.98 MHz	
e+ yield @ CS exit	~4 e+/e-	~3×10^{-3} e^+/e- (linac	~0.1/~0.5 e+/e-	
Positron yield @ DR	~1.2 e+/e-		NO/0.4 e+/e-	
DR energy acceptance	+/- 2.5 %	+/- 1 % (EPA)	+/- 1.5 % (1 σ)	+/- 8 %
Energy of the DR	1.15 GeV	500 MeV	NO/1.1 GeV	1.54 GeV

*FCC-ee under study