FCC-ee Pre-Injector study coordination meeting #20

P. Craievich – 05.12.2024

Agenda

- WP0 - General information (P. Craievich)
- HE Linac to Booster ring (LTB) transfer line (P. Arrutia)
- WP1 - e+/e- Injector Linacs: electron-, positron- and HE-linac (A. Grudiev)
- WP3 - Positron source and capture system (I. Chaikovska)
- WP4 - DR at 2.86 GeV: status and outlook (A. De Santis)
- WP6 - P-cubed experiment at PSI (R. Zennaro)
- WP6 - Target development at CERN (J.-L. Grenard)

SAC meeting, 18-20 November 2024

- Slides on the Indico.
- Green light to proceed with the FS report, slides are also the guideline for the FS report
- Some topics discussed during SAC:
  - Length of injector and DR siting, length for FS report is 1.2 km. Further discussion in post-FS.
  - Compensation scheme for beam loading and rf pulse shape with ‘golden’ pulse. Well received.
  - DA at the injection into the booster: this point should be further explored. Input (‘real’) distribution from injector for booster simulations.
  - Place the HE Compressor (HEC) just before booster injection to control parameter changes in the TL and eventually use R56 of the transfer line. Decision: The HEC remains at the HE linac end for the FS report.
  - Iryna’s statement on positron source: “we expect the positron flux to be twice the current world record of SLC”. Comment: however, it remains one of the most challenging parameters for the project (Paolo: together with the overall transmission efficiency).
  - DR: positron acceptance should be included in the FS report. Strong impact on the overall positron production. Presently we have a margin of ~2.5 on the positron production.

Final Report of the FCC Feasibility Study

Volume 2: Accelerators, TI and Safety

IV, Chapter 7: Injector complex

Submission Timeline for Vol. 2

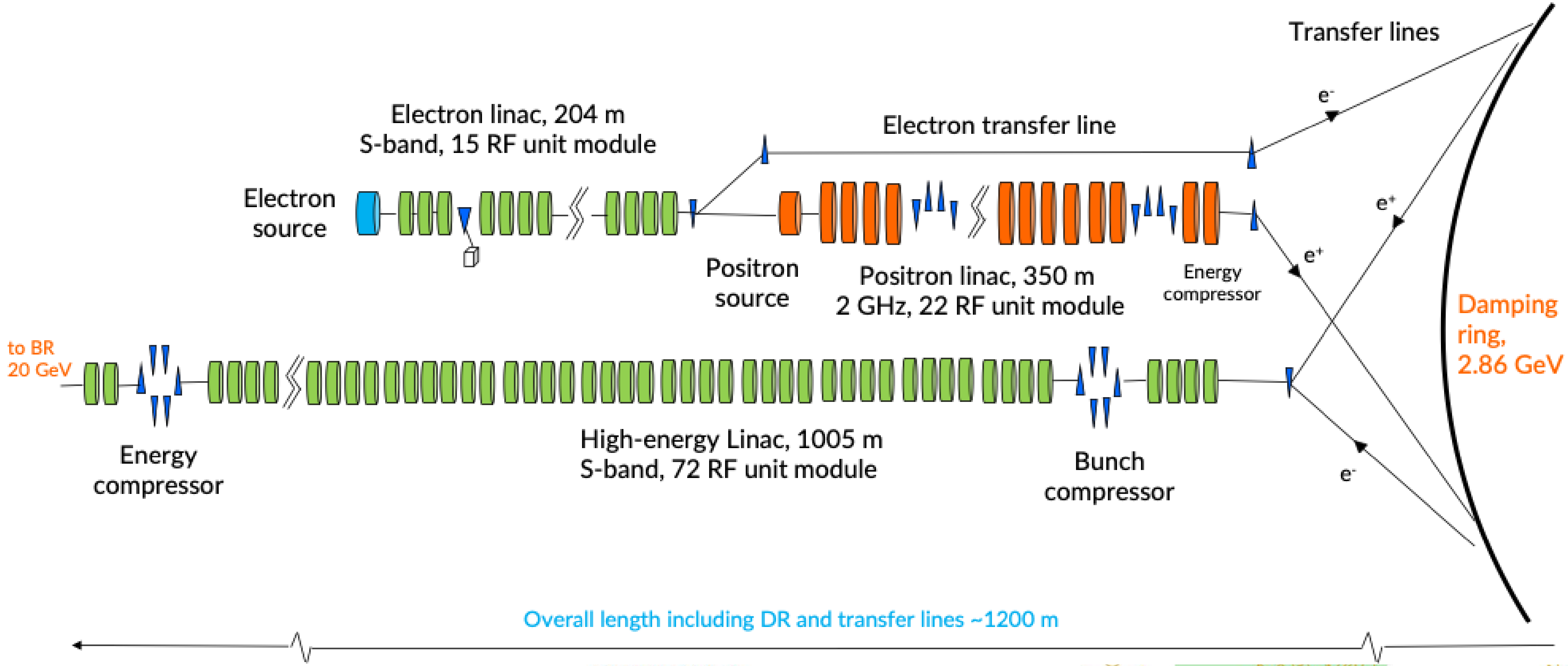
- First draft by 20.12.2024
- Submission to FCC (main) editors by 3.2.2025
- Submission to Directorate by 25.2.2025
- Collect comments by Directorate by 7.3.2025
- Finalize volumes for publication/submission to European Strategy by 17.3.2025
- Circulate to editors for any final remarks by 24.3.2025
- Submit to the European Strategy Update: 31.3.2025

Contents

Other documents to be submitted

- Risk management
  - Excel file (for the risk register) with the identified risks related to the injector complex including proposal for mitigation measures for further discussions.
  - First draft submitted.
- Update of the cost estimate, with a view of reducing the uncertainty level from cost class 4 to cost class 3, when relevant;
  - First draft almost ready, to be submitted in the next days.
- Environment aspect report for the FS also needs to feature a chapter describing the injector complex
  - Report for non-technical readers and authorities
  - not started yet

Recap: Baseline layout: 4 ASs for module, 4 bunches (25 ns), 100 Hz



The schematic will be changeg to reproduce the CE

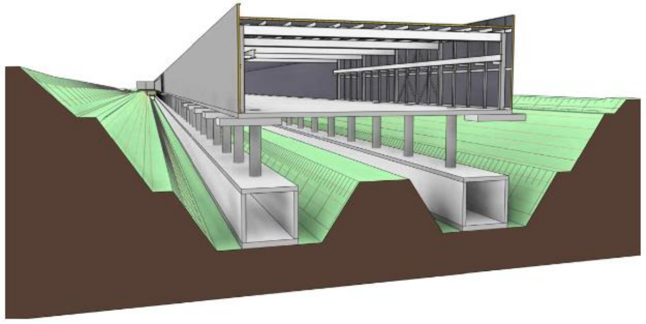
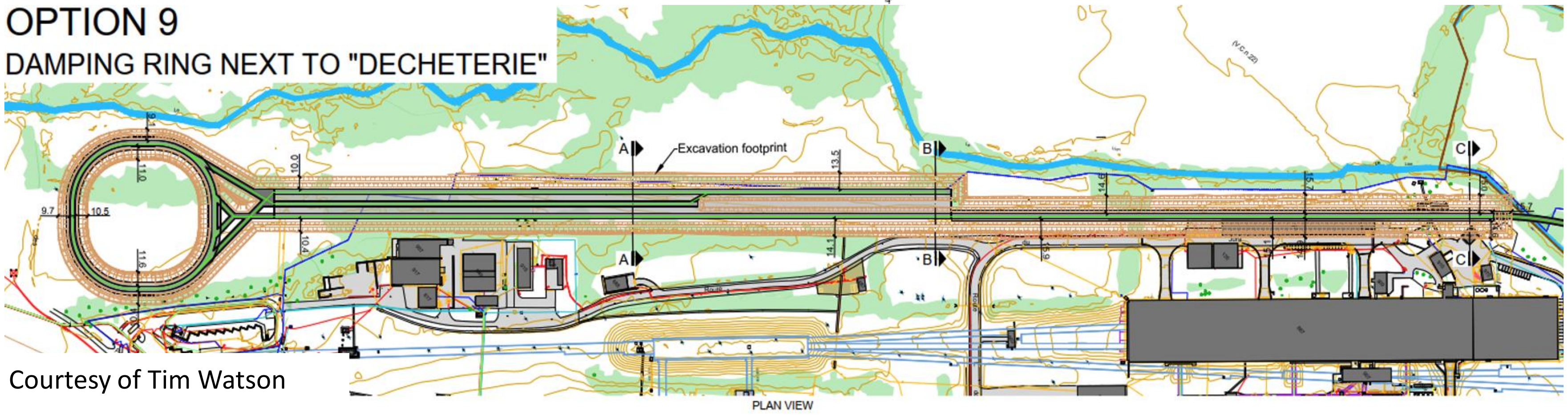
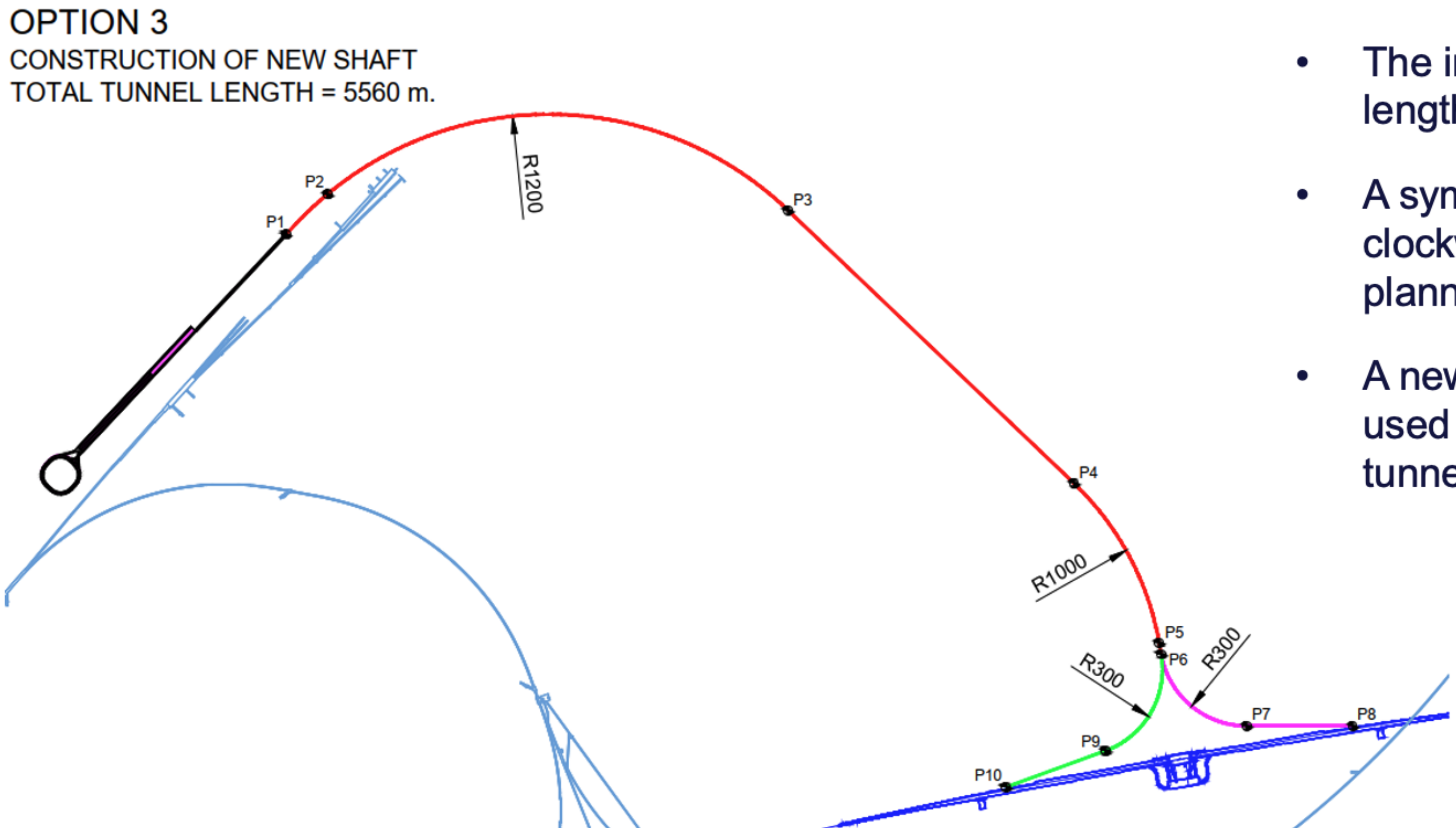


Figure 21: Cross-section of High-energy LINAC civil engineering



Courtesy of Tim Watson

Transfer Tunnels



- The injection tunnels will have a total length of 5560m
- A symmetrical arrangement for the clockwise and anticlockwise injection is planned.
- A new shaft on the Prevessin site will be used to construct the injection line tunnels.

Courtesy of Tim Watson and Wolfgang Bartmann (SAC meeting)

Recap: Collider and booster parameters related to the Injector

Sources: C. Carli, SAC meeting (Nov 2024) and H. Bartosik, Other Science Opportunities at the FCC-ee (Nov 2024)

Running mode	Z	W	ZH	tt bar	Unit
Number bunches in collider	11200	1856	300	64	
Nominal bunch charge in collider	34.40	22.08	27.04	23.68	nC
Allowable charge imbalance	5	3	3	3	%
Booster cycle/number of bunches	10x1120	2x928	1x300	1x64	
Injector duty cycle	73%	40%	19%	5%	
Max injected bunch charge	3.43	1.6	1.6	1.6	nC
Number of bunches	4	4	2	2	
Linac rep. rate	100	100	50	50	Hz
Bunch spacing	25				ns
Beam energy at BR	20				GeV
Norm. emittance (x, y) (rms) (BR)	<20,2				mm mrad
Bunch length (rms) (BR)	~4				mm
Energy spread (rms) (BR)	~0.1				%

Open questions for the post-FS

- Working RF frequency for the linacs (from 2.8 GHz to 3 GHz): The power source (klystron) with a commercial S-band frequency can be used if slightly different time separations (presently around 25 ns) between bunches in the injector and booster can be accepted, otherwise, the klystron should be slightly tuned, e.g., from ~2999 to ~3006 MHz.
- Positron capture and linac (from 2.0 GHz to commercial rf frequency): New optimization using commercial frequencies will be performed. Some options to be discussed, i.e., an option could be the re-use low-temperature SC solenoids around the rf structures (also a reduction in energy consumption, currently 4-5MW!) or recovery the yield increasing the drive beam energy (new layout is flexible for this) or using 1.5 GHz frequency for capture rf structures
  - Optimization MUST include dynamic acceptance and aperture in the DR! Start-to-end simulations from target to DR.
- Reliability and availability of the injector complex to be estimated based on high-power rf test on rf prototypes.
- Photocathode RF gun (electron source) for collider top-up operation: some options under discussion between PSI and CERN for the bunch-by-bunch charge variation (4 bunches at 100 Hz) changing the laser intensity on the photocathode
  - DR for electrons → can we exclude the use of another type of electron sources and intensity modulation schemes?
- Polarized positrons (and electrons) from the injector. Impact on the present layout, i.e., dedicated DR?, OR polarized electron source?

CHART 2020-2024

Swiss Accelerator Research and Technology

CHART Scientific Report (Final Report for Phase 2)

FCC-ee Injector Study and the P^3 Project at PSI

PSI:

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CERN:

A. Grudiev, W. Bartmann, H. Bartosik, M. Benedikt, M. Calviani, S. Doebert, Y. Dutheil, J. L. Grenard, B. Humann, A. Kurtulus, A. Latina, A. Lechner, R. Mena Andrade, A. Perillo Marcone, K. Oide, Y. Zhao, T. P. Watson, F. Zimmermann, Z. Vostrel

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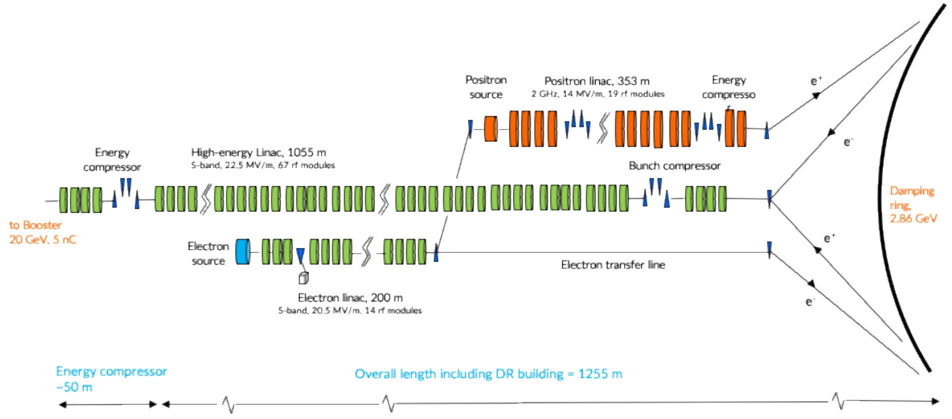
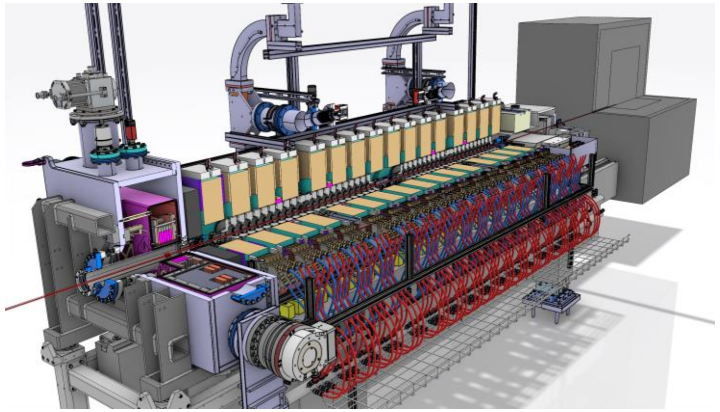
28 October 2024





This work was done under the auspices of CHART (Swiss Accelerator Research and Technology) Collaboration, https://chart.ch - **CHART Scientific Report: https://chart.ch/reports/**

FCCIS: 'This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.'

Post-FS: CHART 2025-2028

FCC-ee Injector: Technical Design Report, 2025-2028:

- Following the completion of the Feasibility Study phase (March 2025), a preliminary technical design report (pre-TDR) will be produced by mid-2027.
- The objective of the pre-TDR is to provide detailed specifications for the accelerator and technical infrastructure requirements necessary for the initial phase of the civil engineering (CE) design.
- By the end of 2028, the final Technical Design Report (TDR) for both the accelerator and the technical infrastructure will have been completed.

Injector Project schedule (as proposed by Michael Benedikt in preliminary discussion)

- Start 2028 – end 2030 CE design and tendering (3 years)
- Start 2029 – end 2031 Accelerator engineering and technical infrastructure designs
- Start 2030 – end 2033 Civil construction (4 years)
- Start 2031 – end 2040 Component production (assuming similar production rates for RF structures as for SwissFEL)
- Start 2034 – end 2036 Technical infrastructure installation
- Start 2035 – end 2040 Component installation and testing
- Start 2042 beam commissioning

Work packages and tasks		Lead	Collab.	2025 Q1	2025 Q2	2025 Q3	2025 Q4	2026 Q1	2026 Q2	2026 Q3	2026 Q4	2027 Q1	2027 Q2	2027 Q3	2027 Q4	2028 Q1	2028 Q2	2028 Q3	2028 Q4
WP0	Coordination and TDR drafting	PSI/CERN	all	■	■	■	■	■	■	■	■	■	■	■	■ ◇1	■	■	■	■ 1
WP1	Electron source	PSI	CERN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP1.1	Design (RF vs DC gun)	CERN	PSI	■	■	■	■	■	■										
WP1.2	Photocathode RF gun test stand	PSI		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP1.3	Photocatode development	PSI	CERN					■	■	■	■	■	■	■	■	■	■	■	■
WP1.4	Commissioning and measurements	PSI	CERN							■	■	■	■	■	■	■	■	■	■ ◇2
WP2	Electron and positron linac	CERN	PSI/IJCLab	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP2.1	Electron linac	CERN	PSI	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP2.1.1	RF structure design	CERN	PSI	■	■	■	■												
WP2.1.2	Mechanial design and fabrication	PSI	CERN					■	■	■	■								
WP2.1.3	Design and fabrication of the pulse compr.	PSI	CERN							■	■	■	■	■	■				
WP2.1.4	S-band test stand	CERN		■	■	■	■	■	■										
WP2.1.5	Klystron/modulator procurement	CERN		■	■	■	■	■	■										
WP2.1.6	High power test	CERN	PSI							■	■	■	■	■	■	■	■ ◇3		
WP2.2	Positron linac	CERN	PSI	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP2.2.1	RF structure design	CERN	PSI					■	■	■	■	■	■						
WP2.2.2	Mechanial design and fabrication	PSI	CERN											■	■	■	■		
WP2.2.3	Design and fabrication of the solenoids	PSI								■	■	■	■	■	■				
WP2.2.4	High power test	CERN	PSI															■	■ ◇4
WP3	Positron source and capture system	IJCLab	PSI/CERN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP3.1	Beam dynamics studies and specifications	IJCLab	PSI/CERN	■	■	■	■	■	■	■	■ ◇5								
WP3.2	Design and integration of positron target area	CERN	IJCLab/PSI			■	■	■	■	■	■	■	■	■	■				
WP3.3	P-cubed experiment	PSI	CERN/IJCLab	■	■	■	■	■	■	■	■	■	■ ◇6	■	■	■	■	■	■
WP4	Damping ring, injection and extraction lines	INFN	PSI/CERN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■ ◇7
WP4.1	Damping ring	INFN	PSI/CERN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP4.2	Injection and extraction transfer lines	INFN	CERN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP5	Civil enegineering (CE)	CERN	PSI													■	■	■	■
WP6	Technical infrastrcutures (TI)	CERN	PSI	■	■	■	■	■	■	■	■	■	■	■	■				
WP7	Technical system interfaces and integration in CERN enviroment	CERN	PSI/INFN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP8	International collaborations	PSI	all	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Deliverable:
1 TDR ready

Milestones:
◇1 Pre-TDR (ready to start CE design)
◇2 Top-up scheme demostrated
◇3 BDR defined for electron linac
◇4 BDRs defined for positron linac
◇5 Baseline for capture system
◇6 Positron source with conventinal target demostrated
◇7 Damping ring and transfer

Main topics (under discussion):

- Drafting of the TDR
- Proof of principle for the electron source
- Prototype of the RF structures (BDR)
- High power test with power source
- Positron linac at 3 GHz
- Perform the p-cubed experiment
- Design of the DR
- Technical system interfaces and integration in the CERN enviroment

Goals:

- Industralization process for linac production (~ 450 rf structures)
- Start CE design in 2028 (pre-TDR by 2027)
- Final TDR by 2028

Any question?