PAUL SCHERRER INSTITUT

PSI

FUTURE CIRCULAR COLLIDER

CHART Swiss Accelerator Research and Technology

Paolo Craievich (PSI) on behalf of the FCCee Injector collaboration

The FCC-ee Pre-injector studies and the PSI Positron Production at SwissFEL

ICHEP 2022, Bologna (Italy), 7 July

Outline

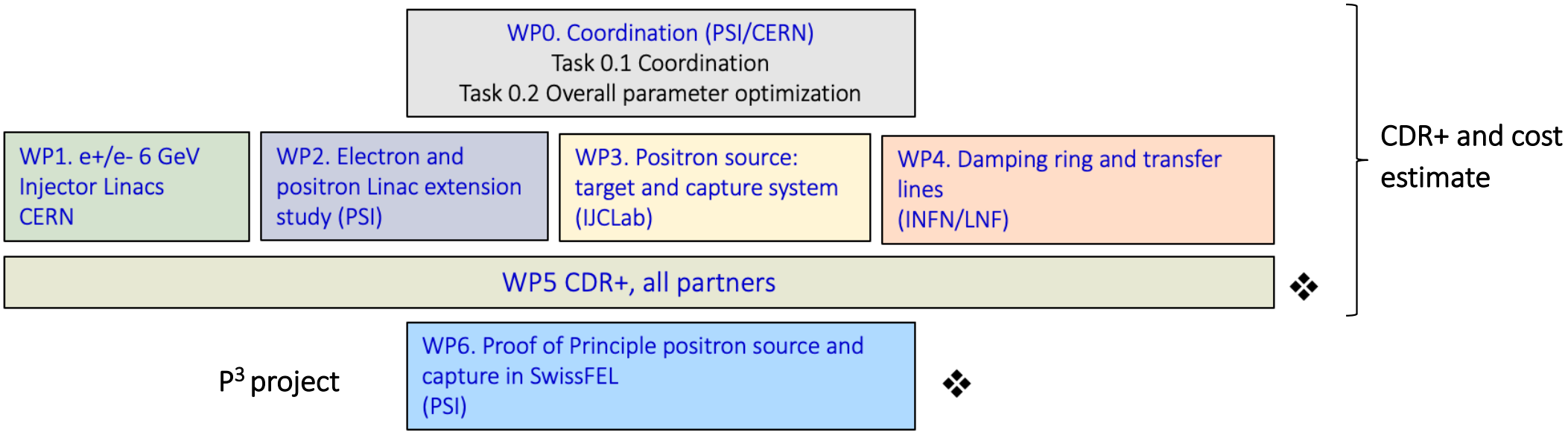
- **Organization**
- **Where are we in FCC-ee?**
- **Pre-Injector: Linacs, Positron source and DR**
- **Pre-Injector parameters for Z-mode**
- **PSI Positron Source (P^3) project**
  - Novel components under development
- **Concluding remarks**

FCC-ee (Pre-)Injector study

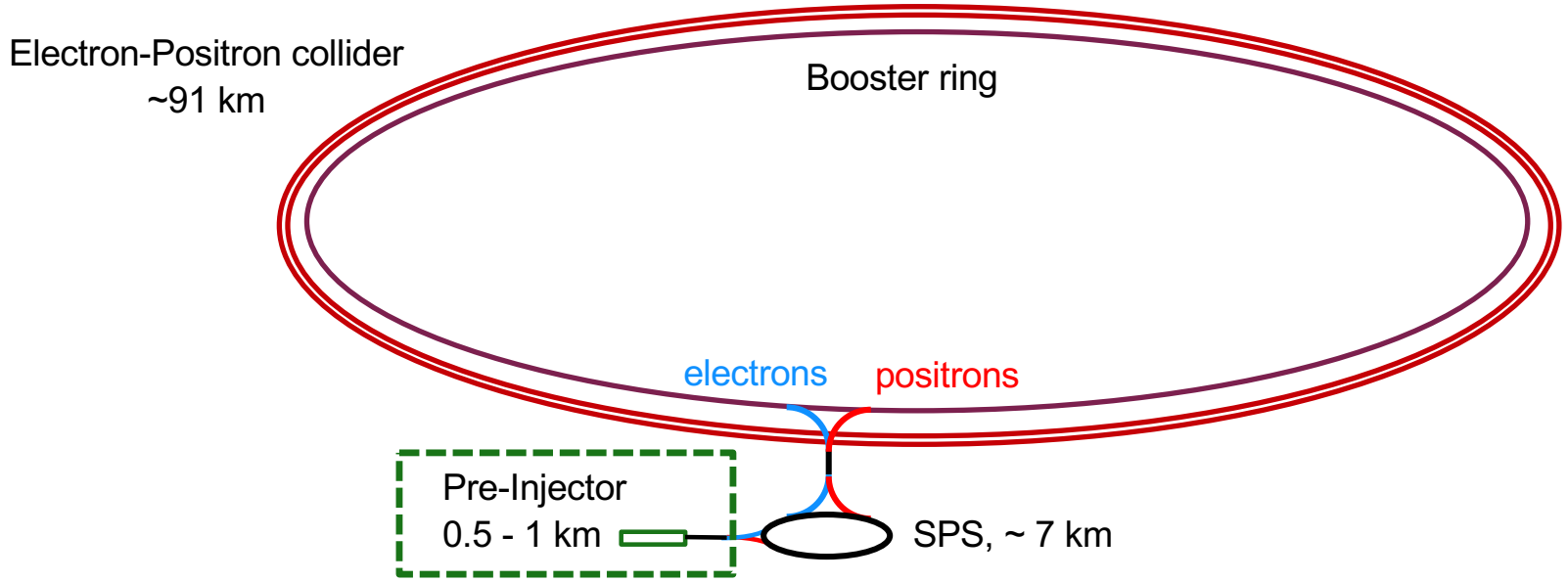
Collaboration between PSI and CERN with external partners:

CNRS-IJCLab (Orsay), INFN-LNF (Frascati), SuperKEKB as observer (also interested in the P³ project), INFN-Ferrara – radiation from crystal

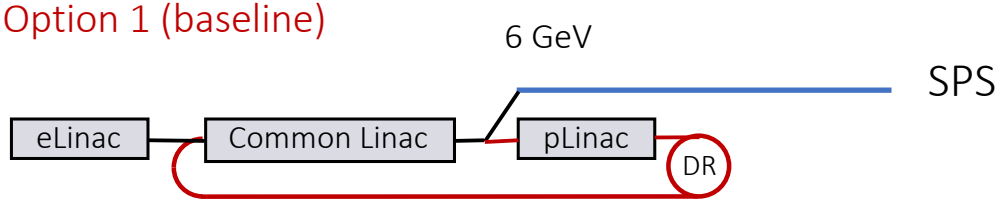
Financed by the CHART.CH programme and part of the FCC feasibility study



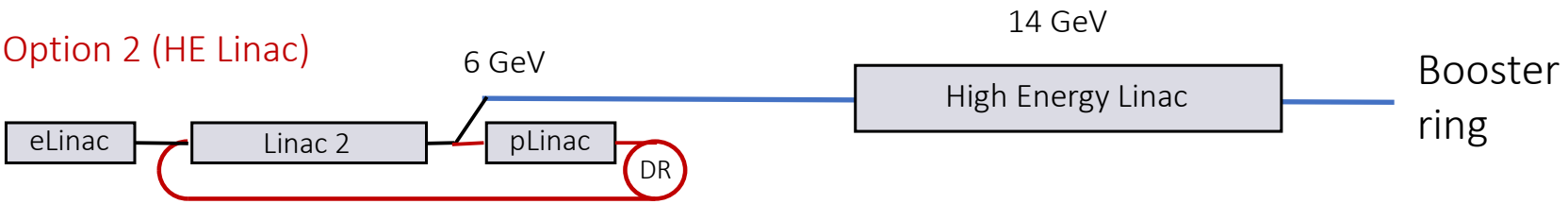
Where are we in FCC-ee?



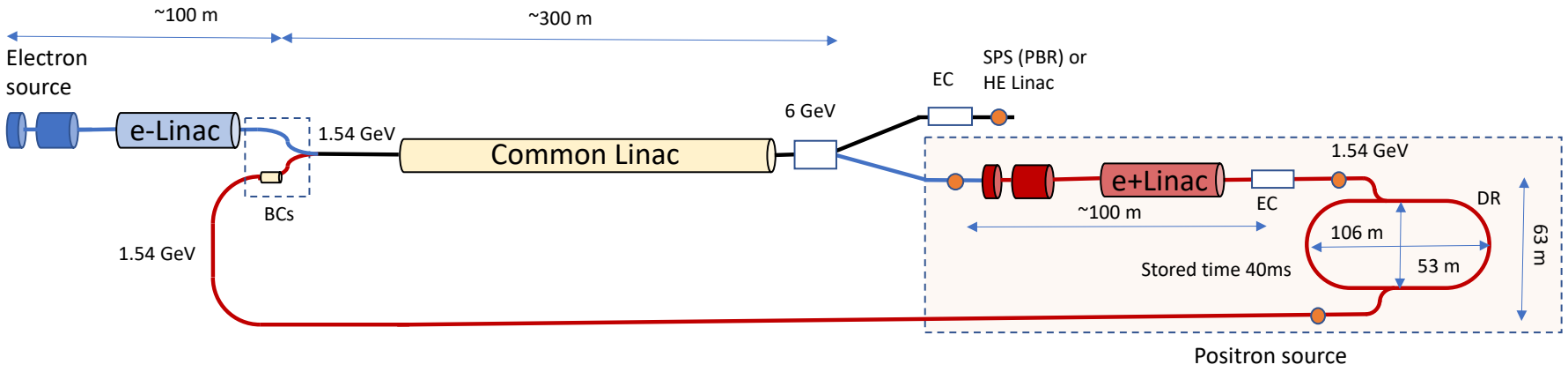
Option 1 (baseline)



Option 2 (HE Linac)

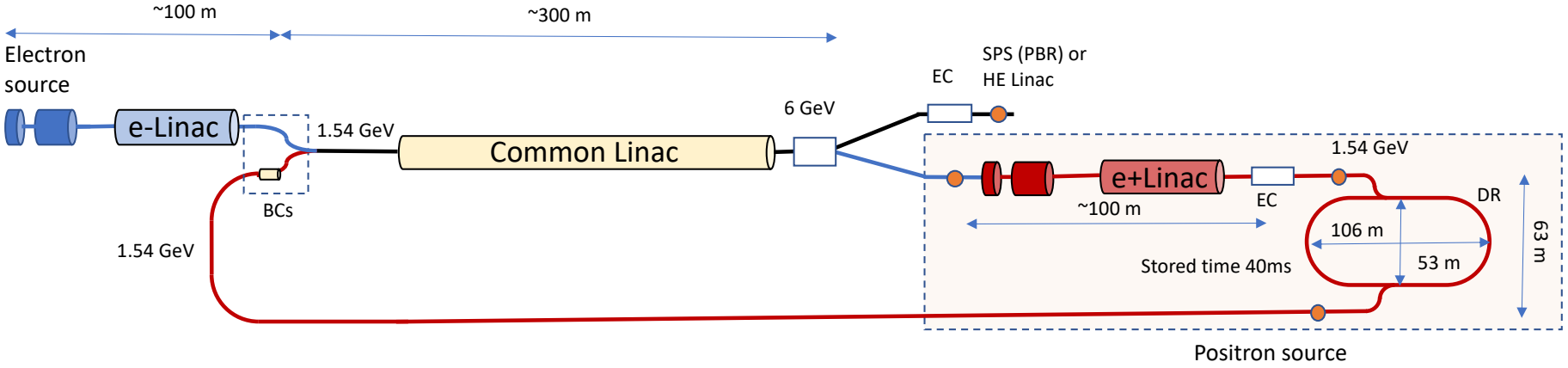


Pre-injector (up to 6 GeV)



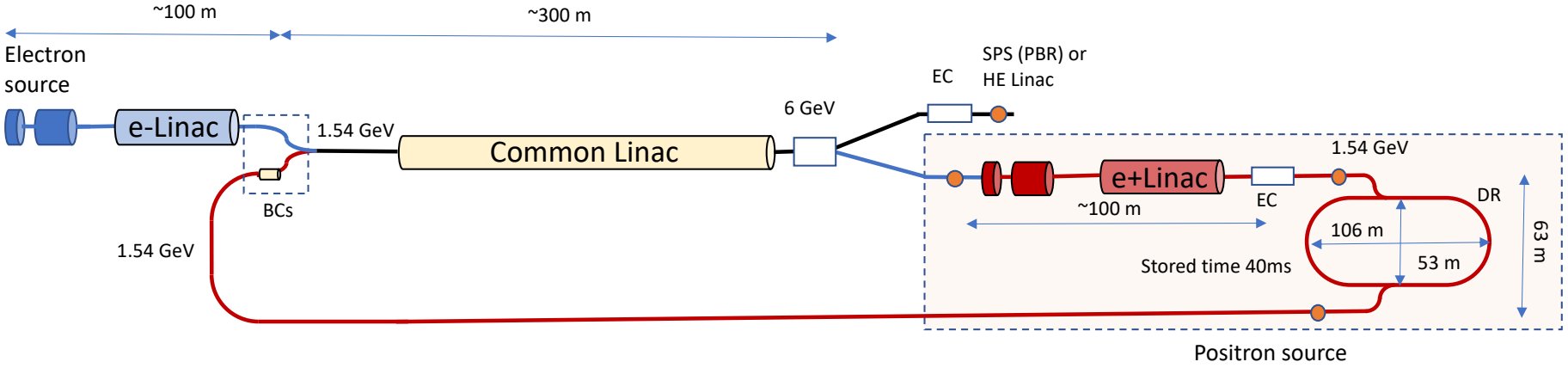
- **Injector is splitted in WPs:**
  - **WP1: Electron source, e-Linac, e+Linac, HE linac (A. Grudiev CERN et al.)**
  - **WP3: Positron generation and capture (I. Chaikovska et al.)**
  - **WP4: DR and return lines with positron bunch compression (C. Milardi et al.)**
- **Linac efficiencies optimized: electron/positron beam with same energy, main and drive electron beam with same final energy**
- **2-bunches at 200 Hz, time separation few tens of ns (minimum 17.5 ns), can fullfill the specification for the collider rings**

Pre-injector – Linacs



- **Specifications are fullfilled for the electron bunch (beam dynamics for the e-linac and common linac well advanced)**
  - **Common linac: Frequency 2.8 GHz, repetition rate 200 Hz+200 Hz when positron are generated (klystron at 400 Hz from CETD could be feasible), optimization of the RF structures well advanced**
- **DR has to provide a delay of 2.5 ms to allocate the positron bunches on the on the right rf bucket in the common linac**
- **e+ linac: rf design well advanced 2 GHz, 200 Hz, large iris aperture, beam dynamics on-going (solenoidal channel up to 1.54 GeV vs quadrupoles under investigation)**

Pre-injector – e+ source and DR



- **Simulation for the positron production showed yield > 7 BUT DR acceptance to be reviewed and energy compression to be investigated**
- **Two options still open for the AMD: HTS solenoid or Flux concentrator**
- **Target: Engineering, intergration and radiation losses on-going for the SC/AMD based on HTS tape. We fixed the aperture for the SC/AMD (key parameter).**
- **The concepts for the DR and the return transfer line are well established, to be decided the RF systems**

Injector parameters for the Z-mode

	Baseline	HE Linac	Unit
Ring for injection	SPS/PBR	BR	
Injection energy	6	20	GeV
Bunch population both species	3.47 (5.55)	3.12 (5.0)	1E10 (nC)
Repetition rate	200	200	Hz
Number of bunches	2	2	
Bunch spacing	17.5-50	17.5-50	ns
Normalized emittance (x, y) (rms)	50, 50	50, 50	mm.mrad
Bunch length (rms)	~1	~1	mm
Energy spread (rms)	<0.1	<0.1	%

- **The bunch by bunch intensity will randomly vary from 0 to 100%, depending on the intensity balance between the collider rings**
- **Bunch-by-bunch injection intensity stability: 3%**

→ **Electron source: an injector based on a photocathode RF gun can provide electrons for both ring injection and positron production AND the laser system can provide the bunch-to-bunch intensity modulation and stability required**

PSI Positron Source Experiment at PSI

P³ project funded by the CHART program

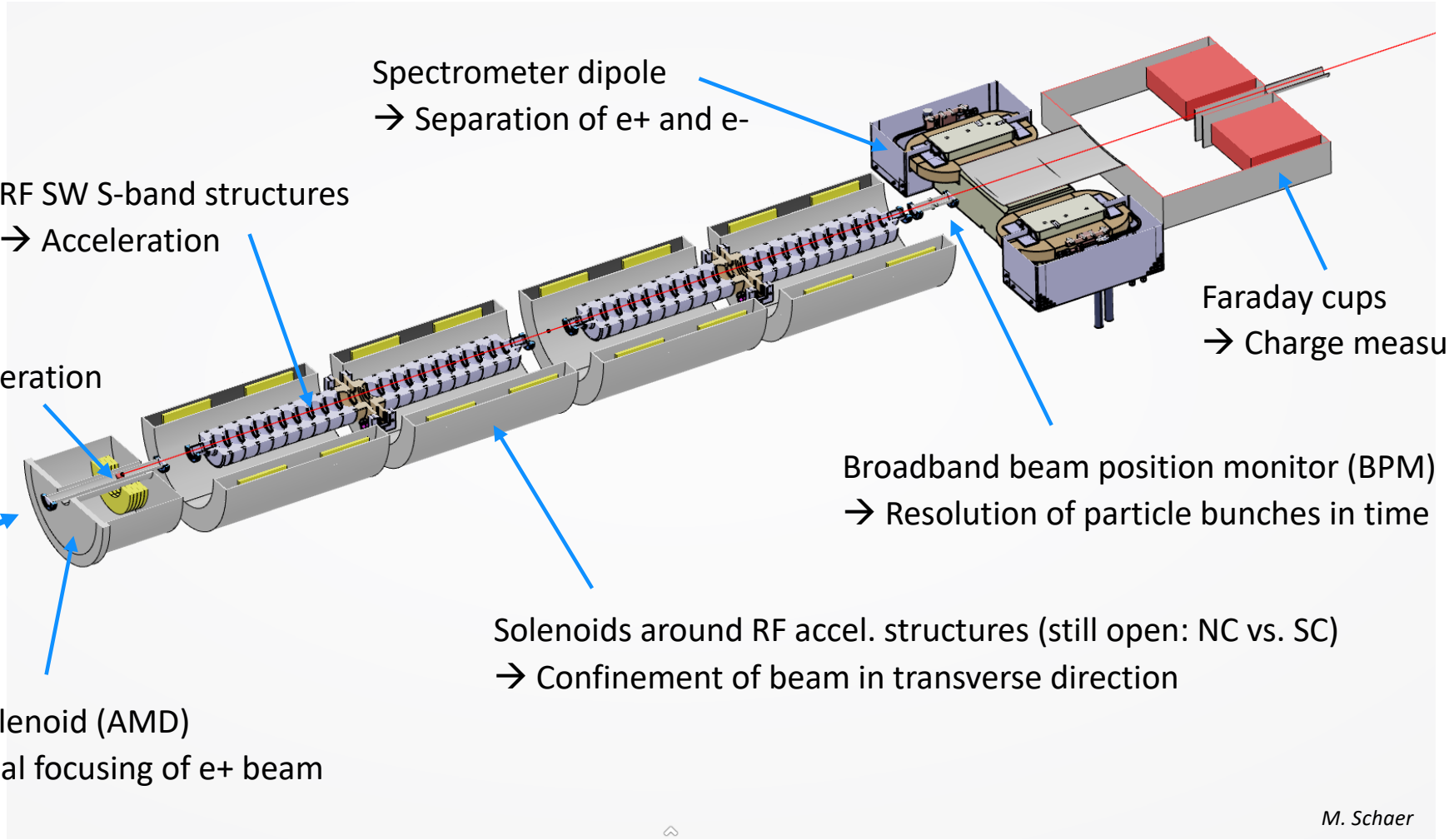
	FCC-ee	SwissFEL
Beam energy	6 GeV	
RMS beam size	~ 0.5 mm	
Rep. rate	200 Hz	1 Hz
Bunch charge	~ 1.5 nC	≤ 0.2 nC
Bunches/pulse	2	1

What we want to validate with the experiment

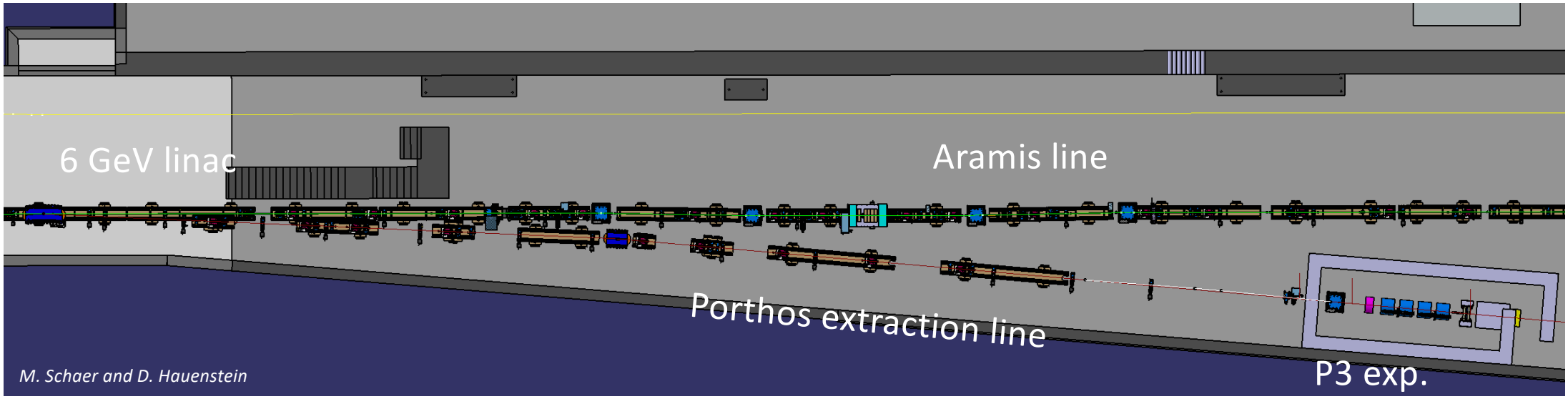
- ✓ Positron Yield > 3 (simulation showed > 7) with conventional scheme (simulation vs measurement)
- ✓ AMD: SC Solenoid with HTS technology including mech. and thermal (cryostat) concept
- ✓ RF structures: large iris aperture
- ✓ NC versus SC solenoids around the rf structures
- ✓ Phase 2: hydride scheme with crystal

…BUT repetition rate 1 Hz with 200 pC@6GeV (due to radiation losses in SwissFEL) → the dissipated power on the target less than in the FCCee target (~W against few kW)

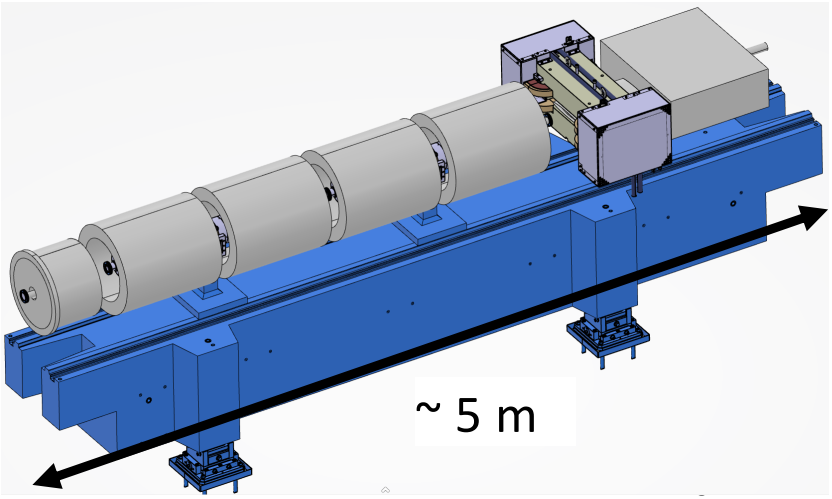
P3 Layout


Spectrometer dipole
→ Separation of e+ and e-
RF SW S-band structures
→ Acceleration
W Target
→ e+ generation
6 GeV drive beam
HTS solenoid (AMD)
→ Initial focusing of e+ beam
Solenoids around RF accel. structures (still open: NC vs. SC)
→ Confinement of beam in transverse direction
Broadband beam position monitor (BPM)
→ Resolution of particle bunches in time
Faraday cups
→ Charge measurement
M. Schaer

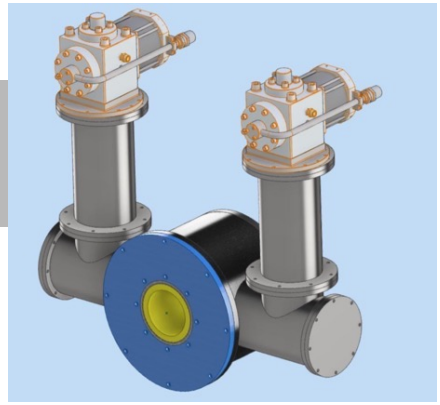
Installation in SwissFEL



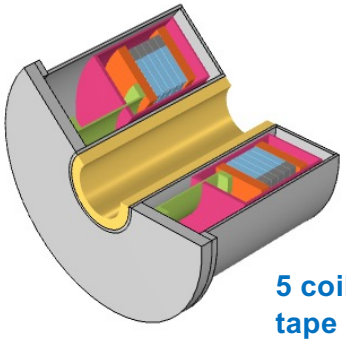
- **P³ experiment will be installed in the extraction line for Porthos (third SwissFEL BL)**
- **3D layout design well advanced**
- **Installation plan based on scheduled shutdowns: 3/year**
- **Radiation losses under estimation to evaluate the additional shielding/bunker**



Novel components under development at PSI

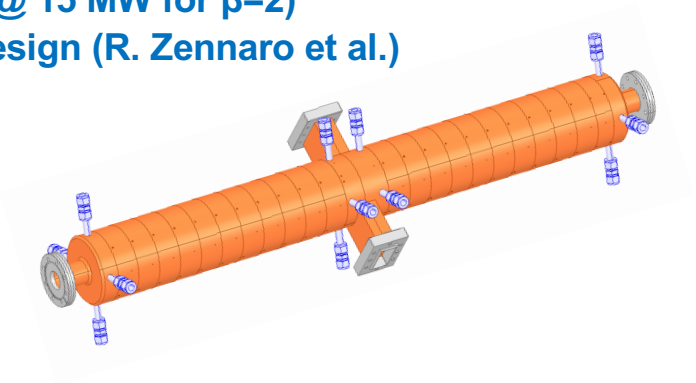


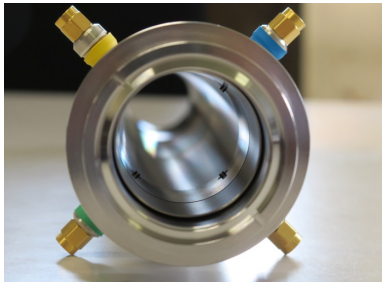
HTS solenoid integrated in the cryostat (M. Duda et al.)
Peak magnetic field: 12 T (test up to 18 T)



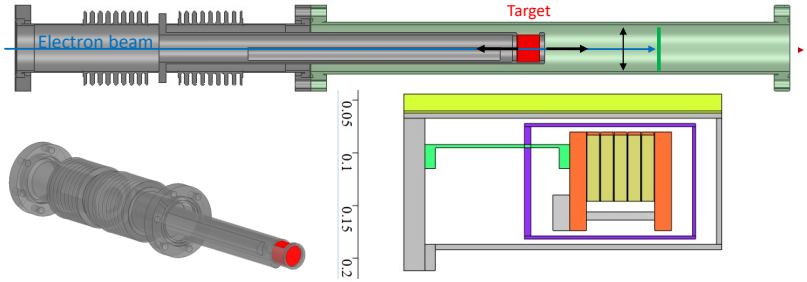
5 coils ReBCO tape

2x SW π-mode cavitiy (18 MV/m @ 15 MW for β=2)
Advanced RF and mechanical design (R. Zennaro et al.)

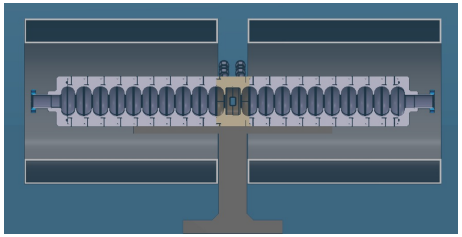




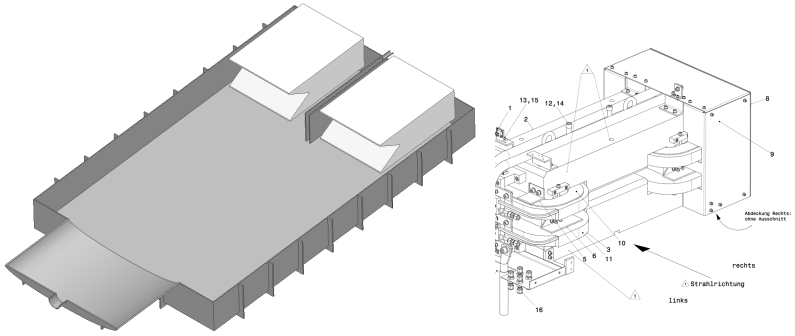
Development of broadband pickup
(E. Ismaili and F. Marcellini)



Movable Target Insertion Device
(R. Zennaro et al.)



SC solenoids (NbTi)
NC (~ 0.4 T) vs. SC (1 – 1.5 T)



Special Faraday cup and spectrometer
(N. Vallis and R. Zennaro)

(Some) Concluding remarks

- **(Pre-)Injector study:**
  - Studies are well advanced on all parts of the injector
  - Still some parameters to be confirmed from the SPS, booster and collider sides
  - General consideration: As deliverable for CHART (and for the FCC feasibility study) we have to provide a cost estimate for the injector. After the design phase we have to start with a cost model for the different part of the injector
  - Next deadline: mid study costing exercise in Summer 2023 with external reviewer
- **P^3 project**
  - Concept and design phase well advanced, engineering ad procurement ongoing
    - But engineering and installation at PSI are strongly influenced by other two major ongoing project (SLS2 and IMPACT)
  - Present schedule: First experiment in 2025
  - The P^3 project will provide a positron beam of nearly 1 nC: some ideas for using it are welcome

Credits

PSI:	R. Zennaro, M. Schaer, N. Vallis, B. Auchmann, M. I. Besana, S. Bettoni, H. Braun, M. Duda, E. Hohmann, D. Hauenstein, R. Ischebeck, P. Juranic, J. Kosse, G. L. Orlandi, M. Pedrozzi, J.-Y. Raguin, S. Reiche, S. Sanfilippo
IJCLab:	I. Chaikovska, S. Ogur, F. Alharthi
CERN:	A. Grudiev, W. Bartmann, M. Benedikt, T. Brezina, M. Calviani, S. Doebert, Y. Duthell, O. Etisken, J.L. Grenard, B. Humann, A. Latina, A. Lechner, A. Marcone, H. Pommerenke R. Ramjiawan, Y. Zhao, F. Zimmermann
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KEK:	K. Oide, Y. Enomoto, K. Furukawa

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