FCC Accelerator Timeline and Goals

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ABP Day, December 2, 2021

U.S. DEPARTMENT OF ENERGY | Stanford University

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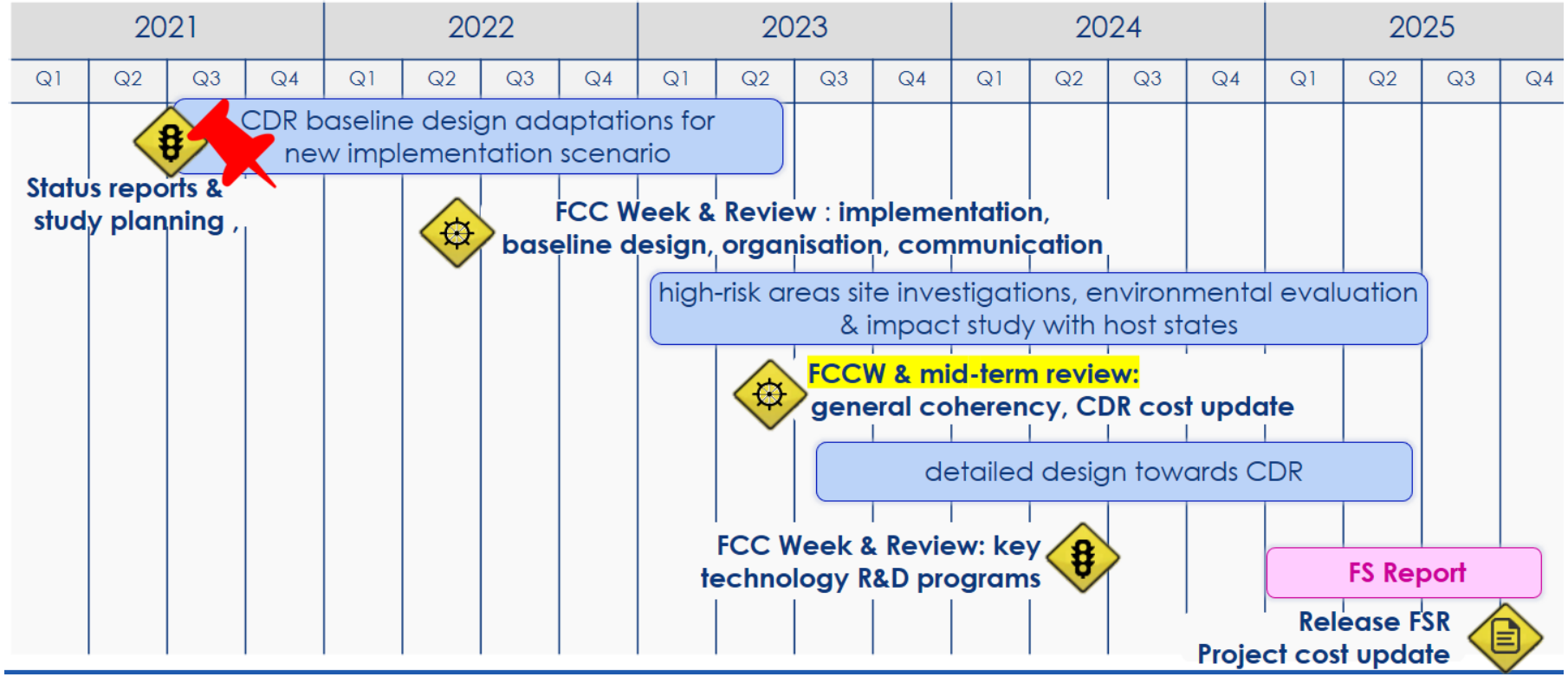
Goals for the FCC

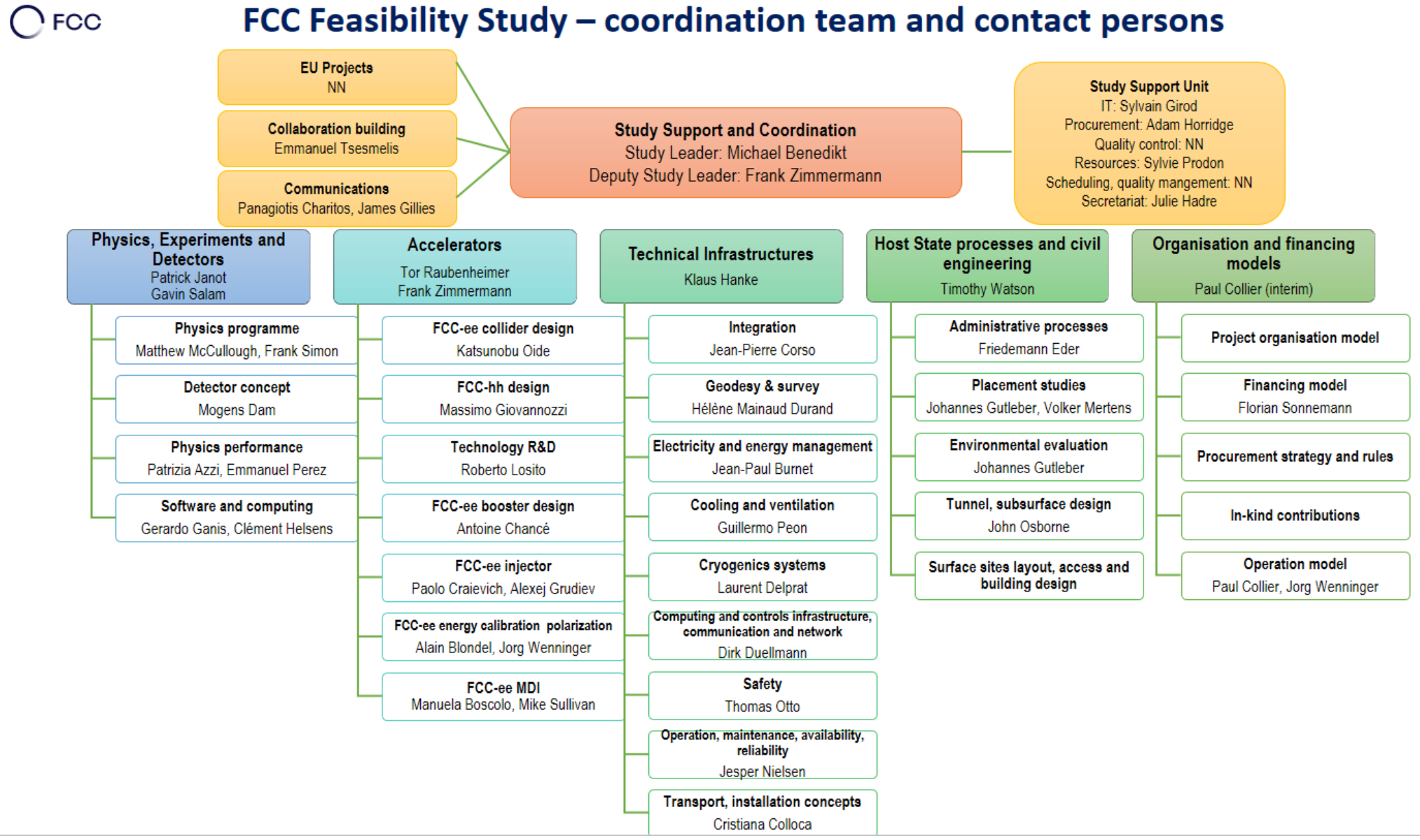
The FCC CDR was developed for the 2020 European Strategy (ESPP)

Now push the design further with detailed placement options to a pre-TDR level for the next ESPP in 2026.

Focus on the FCC-ee to address Z, W, Higgs, and t-tbar before an FCC-hh



FCC-ee Design Study Contacts



FCC FS overall timeline and main deliverables

main deliverables and timelines of the FCC Feasibility Study	2021				2022				2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
technical design work and R&D in all relevant areas																				
progress review on key technology R&D programs																				
development and documentation of implementation scenario																				
design update for preferred implementation variant																				
communications plan development and implementation																				
development of funding models and concepts																	update			
development of project organisation and operation models																	update			
CDR cost update with external review																				
general coherence review (mid-term)																				
detailed design for Feasibility Study Report																				
environmental evaluation process and impact study with host states					preparation															
high-risk areas site investigations					preparation															
project cost update with external review																				
Feasibility Study Report																				

- Pre-decision on placement of the ring (geology, surface areas, etc.): mid-2022
- High-risk area site investigations for selected placement: mid-2023 to mid-2025
- Design update for preferred placement scenario: mid-2023
- General coherence review across all work packages: mid-2023 (FS mid-term review)

- Cost reviews with external expert review committee: 2023 and 2025

Accelerator Development Goals and Timeline

- Self-consistent Baseline configuration for Feasibility Study by end of 2025
- Support mid-term and final costing exercises in June 2023 and December 2025
  - Complete beam optics aligned to the present tunnel placement and initial component specification by January 2023 to allow cost development through May 2023 **for mid-term FCC review in June 2023**
    - Optics specifications with correction elements, RF, collimation and injection systems
    - Beam dynamics calculations to include initial studies: tuning and correction; dynamic aperture with errors; beam-beam with errors; collective effects.
    - FCCee Injector and Booster optics and layouts completed with tradeoff studies documented
    - FCChh optics layout in consistent layout
    - Technology R&D specification with milestones
- Iterate to support the Feasibility Study costing exercise from January 2025 through December 2025

FCC Accelerator Status

Placement updated with slightly smaller footprint (91 km) and 8 accesses

Updating main ring optics for 4 IPs with new placement for 4 energies

Selected baseline high-level parameters (mostly)

Working on MDI, RF layout, collimation, and injection/extraction

Many outstanding physics and tuning questions

Developing Booster and Injector configurations

Working to ensure compatibility with FCC-hh

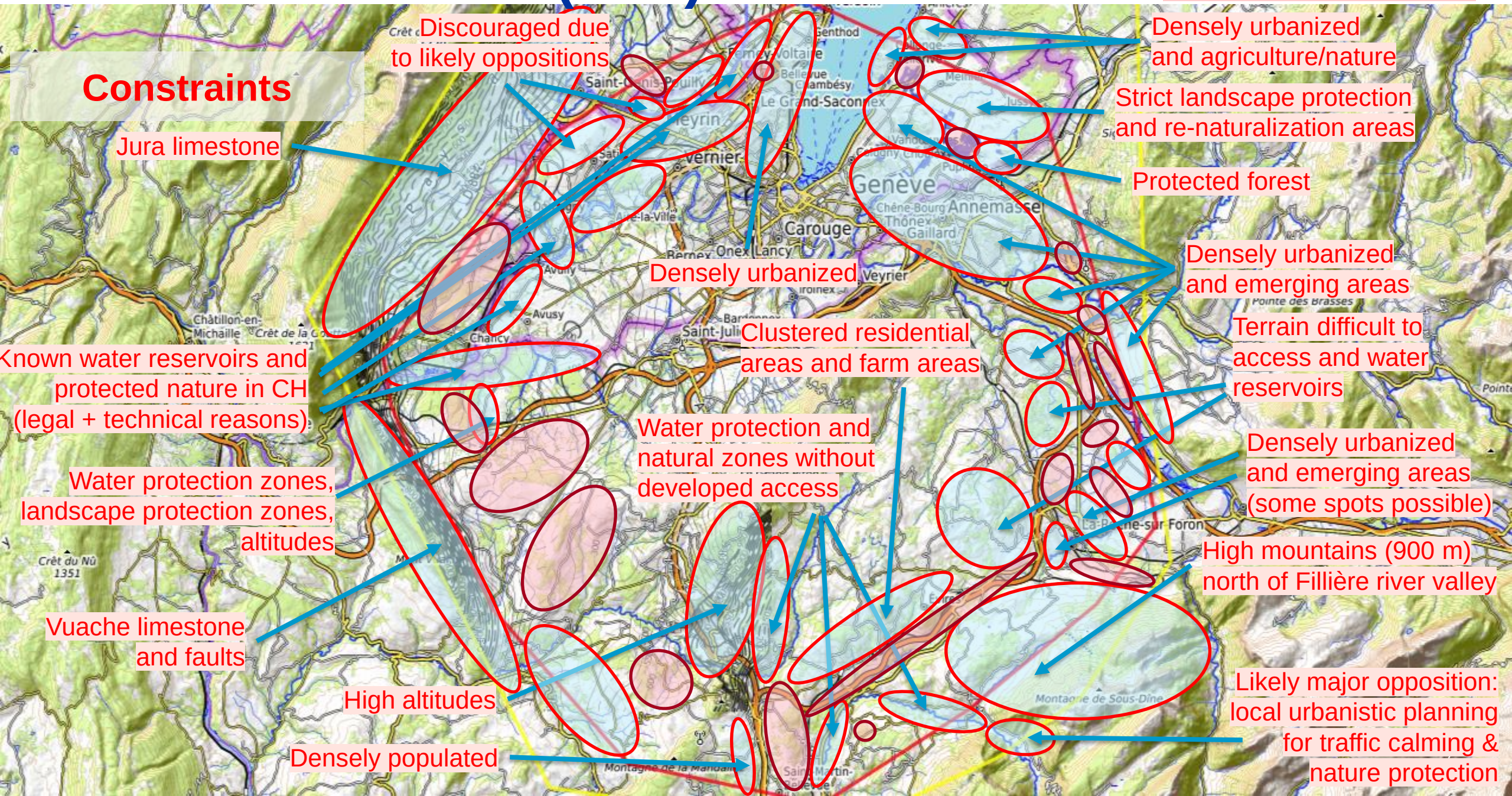
Technical R&D program is beginning to prioritize tasks

Energy calibration and polarization studies beginning

Need to develop tools and simulations

Placement studies (1 / 2)

J. Gutleber, V. Mertens

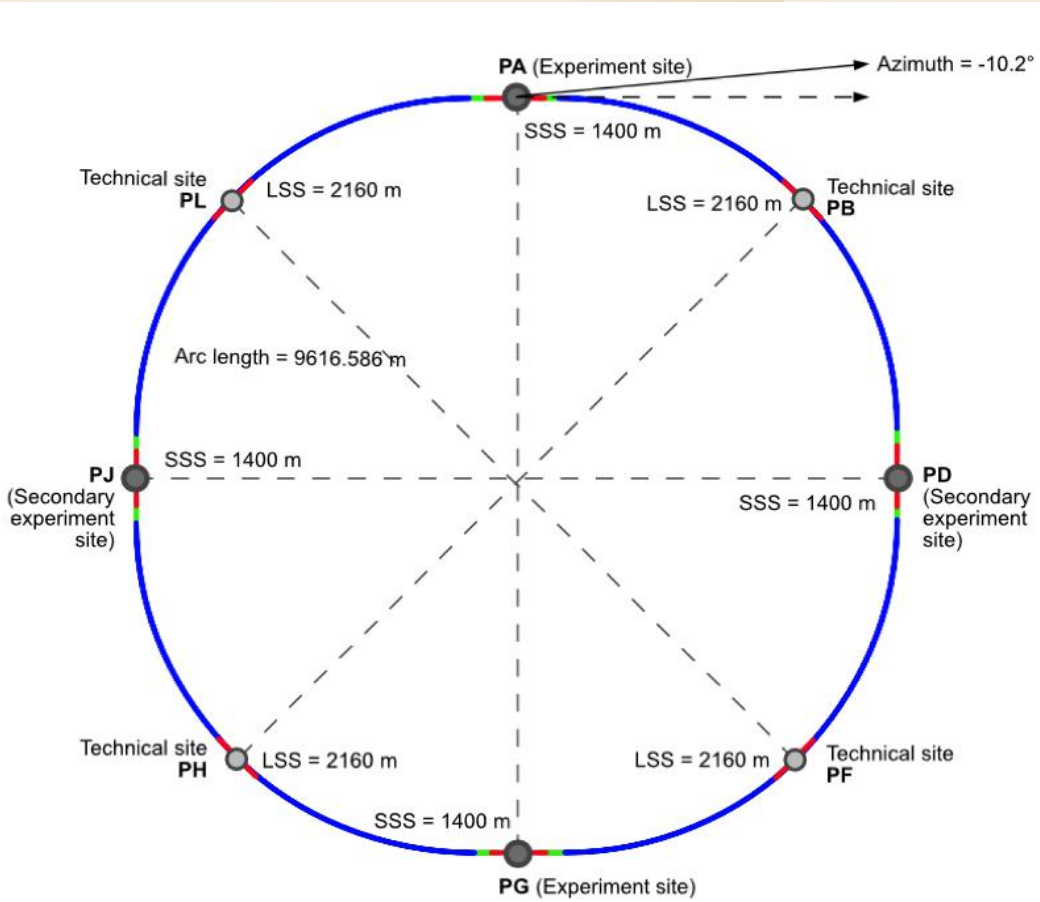


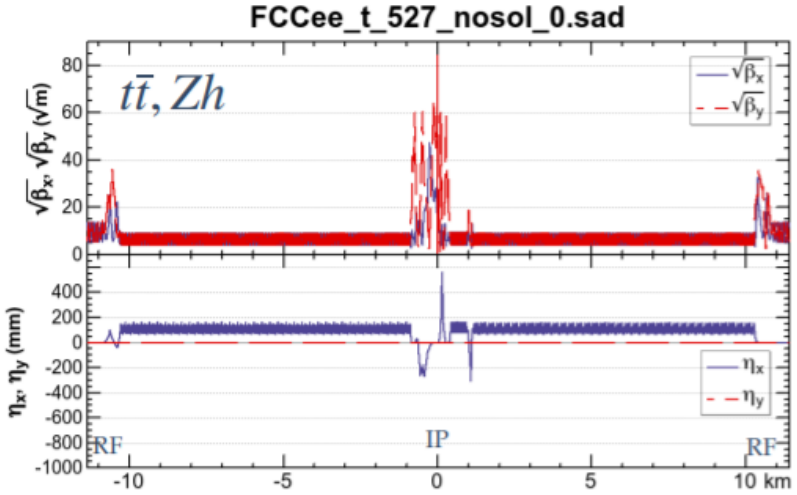
Placement Studies (2 / 2)

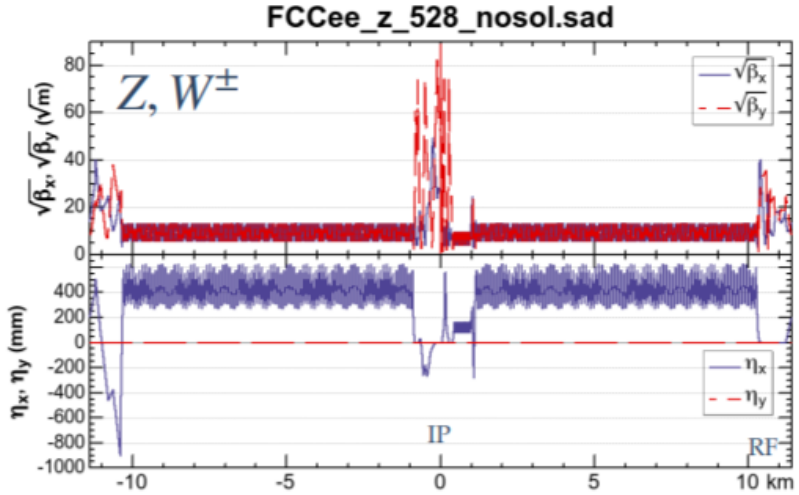
Looked in detail at placement options.

Access points are challenging to find
→ layout with slightly smaller (91 km) circumference and 8 access points

2 main optics configurations: Z, W and Zh, ttbar







Parameters

Beam energy	[GeV]	45.6	80	120	182.5
Layout		PA31-1.0			
# of IPs		4			
Circumference	[km]	91.174117		91.174107	
Bending radius of arc dipole	[km]	9.937			
Energy loss / turn	[GeV]	0.0391	0.370	1.869	10.0
SR power / beam	[MW]	50			
Beam current	[mA]	1280	135	26.7	5.00
Bunches / beam		9600	880	248	36
Bunch population	[10^{11}]	2.53	2.91	2.04	2.64
Horizontal emittance ε_x	[nm]	0.71	2.16	0.64	1.49
Vertical emittance ε_y	[pm]	1.42	4.32	1.29	2.98
Arc cell		Long 90/90		90/90	
Momentum compaction α_p	[10^{-6}]	28.5		7.33	
Arc sextupole families		75		146	
$\beta^*_{x/y}$	[mm]	150 / 0.8	200 / 1.0	300 / 1.0	1000 / 1.6
Transverse tunes/IP $Q_{x/y}$		53.563 / 53.600		100.565 / 98.595	
Energy spread (SR/BS) σ_δ	[%]	0.039 / 0.130	0.069 / 0.154	0.103 / 0.185	0.157 / 0.229
Bunch length (SR/BS) σ_z	[mm]	4.37 / 14.5	3.55 / 8.01	3.34 / 6.00	2.02 / 2.95
RF voltage 400/800 MHz	[GV]	0.120 / 0	1.0 / 0	2.08 / 0	4.0 / 7.25
Harmonic number for 400 MHz		121648			
RF freuqeuncy (400 MHz)	MHz	399.994581		399.994627	
Synchrotron tune Q_s		0.0370	0.0801	0.0328	0.0826
Long. damping time	[turns]	1168	217	64.5	18.5
RF acceptance	[%]	1.6	3.4	1.9	3.1
Energy acceptance (DA)	[%]	±1.3	±1.3	±1.7	-2.8 +2.5
Beam-beam ξ_x/ξ_y [a]		0.0040 / 0.152	0.011 / 0.125	0.014 / 0.131	0.096 / 0.151
Luminosity / IP	[10^{34}/cm^{2}s]	189	19.4	7.26	1.33
Lifetime (q + BS)	[sec]	–		1065	2405
Lifetime (lum)	[sec]	1089	1070	596	701

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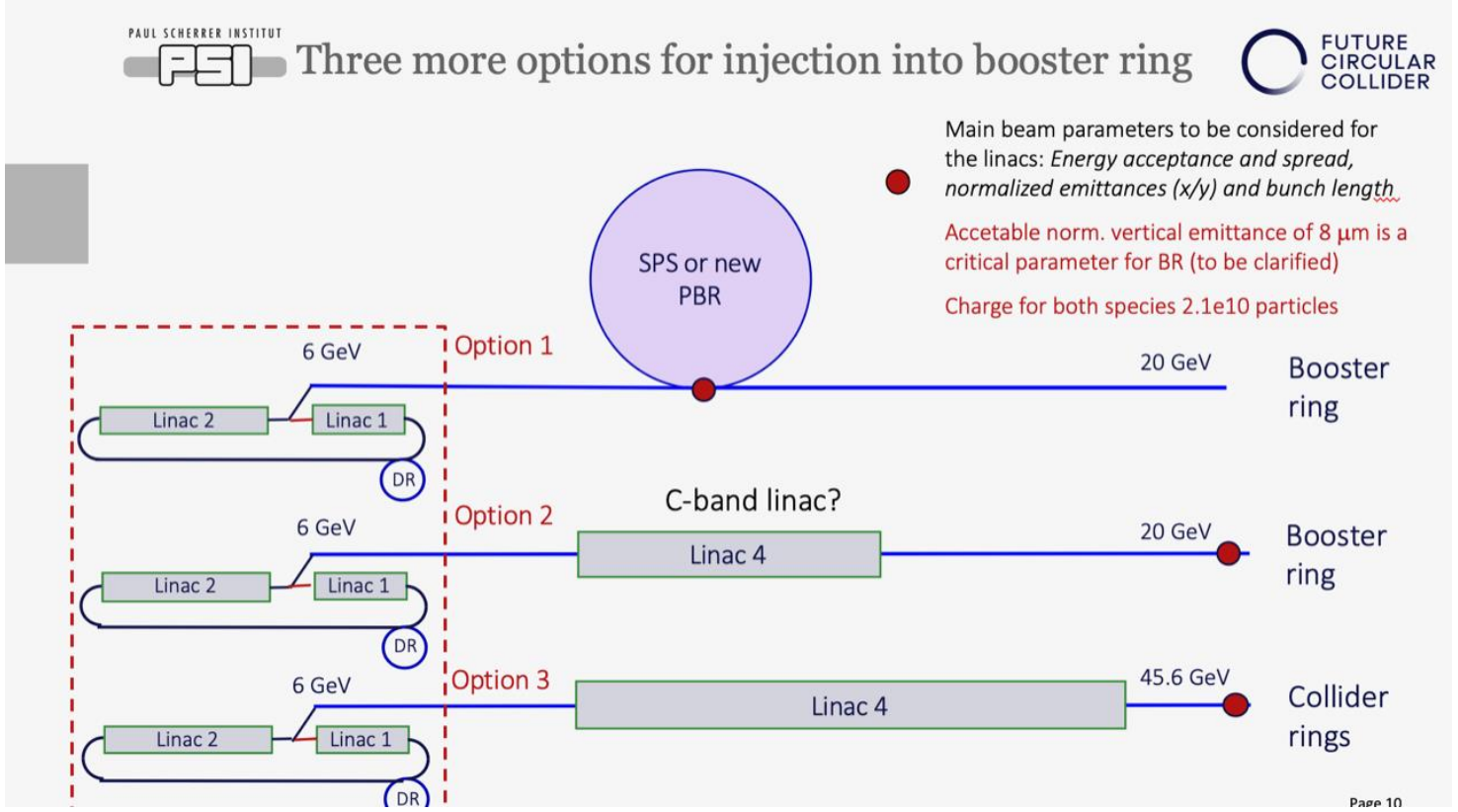
Subsystem Definitions

Along with the main ring placement, major subsystems are being defined and layouts started:

RF, injection/extraction, beam collimation, polarization meas/control, …..

Booster, Injector, Transfer lines

Need iterations on all of these by June 2022 to understand the preliminary civil and infrastructure requirements



Accelerator Baseline Philosophy and Options

- Develop accelerator ‘baseline’ model using relatively conservative accelerator physics and technology choices wherever possible
- Cross-reference technological/physics choices to operating facilities where possible and identify all areas where baseline requires extrapolation
- Start accelerator modeling with established simulation/modeling tools but develop optimized tools for the completion of the Feasibility Study → code workshop, Winter/Spring 2022
- In parallel, develop a list of Alternate options that could potentially lead to a significant improvement in performance or cost
  - Develop the Alternate options in parallel with main project and move them into the baseline as the options mature with an established down select process → schematic
    - Examples might be HTS arc quadrupole/sextupole magnets, the SPS as a pre-booster, positron target using crystal channeling, advanced cooling tower design, etc.

Suggested FCC-ee Design Milestones and Deliverables

Major milestones/deliverables:

- FCCee Parameter update October, 2021
- Specification of RF Baseline configuration, October, 2021
- Collider arc cell and main optics configuration, November, 2021

} Deliverable, January 2022

- Tuning and Simulation tool workshop, Winter, 2022 → broaden to physics modeling

- Tuning, Diagnostic, Tolerance and stability spec → requirements, June 2022
- Collimation system specification, June 2022
- Infrastructure requirements, June 2022
- Tunnel cross-section, June 2022
- Energy calibration update, June 2022

} Major Deliverable

- Civil infrastructure requirements, September 2022 → Major deliverable

- Document baseline for costing exercise, December 2022 → Major deliverable

- Begin iteration of parameters, June → December, 2023
- Update Baseline calculations and specifications using new tools over next 1.5 years
- Document Baseline for Feasibility Study costing exercise, June 2025
- Start Feasibility Study baseline documentation, June 2025

Suggested FCC-hh, Tech R&D, and FCC-ee Injector/Booster Design Milestones & Deliverables

Major milestones FCChh and FCCee Injector systems:

- FCC-hh parameter update December, 2021
- FCC-hh specification of RF Baseline configuration, December, 2021

} May be early winter

- FCC-hh collider main optics configuration, June, 2022
- FCC-hh civil infrastructure requirements, September 2022
- FCC-hh injection/extraction optics, December, 2022

- Prioritize technical R&D items, March, 2022 → Reviewed regularly → list of deliverables
- Technical R&D having many parallel programs with established milestones

- FCCee Booster parameter update, December, 2021
- FCCee Booster optics update with main ring injection, June 2022
- FCCee Tunnel cross-section, June 2022 (with main ring)
- FCCee Pre-Injector update, June 2022
- FCCee Booster → Main ring injection, September 2022

- Document baseline for costing exercise, December 2022
- Parameters Iteration, June 2023
- Start Feasibility Study baseline documentation, June 2025

Agenda

08:45 → 10:55 **FCC ABP Day Session 1**

Convener: Edda Gschwendtner (CERN)

08:45 **Welcome and Goals of the FCC ABP Day**
Speakers: Yannis Papaphilippou (CERN) , Frank Zimmermann (CERN)

08:55 **FCC Accelerator Pillar - Plan and milestones**
Speaker: Tor Raubenheimer (SLAC National Accelerator Laboratory (US))

09:15 **ee Collider Design - Open points and where help is needed**
Speaker: Katsunobu Oide (High Energy Accelerator Research Organization (JP))
Optics_openpoints_...

09:35 **Booster Design - Open points and where help is needed**
Speakers: Antoine Chance (CEA Irfu) , Barbara Dalena (CEA-Irfu & Université Paris-Saclay
2021_11_29_Booste... 2021_11_29_Booste...

09:55 **FCC-hh design - Open points and where help is needed**
Speaker: Massimo Giovannozzi (CERN)

10:15 **Collimation for ee and hh, Open points & where help is needed**
Speakers: Roderik Bruce (CERN) , Andrey Abramov (CERN)
FCC_collimation_FC...

10:35 **Collective Effects - Open points and where help is needed**
Speakers: Emanuela Carideo (Sapienza Universita e INFN, Roma I (IT)) , Mauro Migliorati (Sapienza Universita e INFN, Roma I (IT))

11:15 → 13:15 **FCC ABP Day Session 2**

Convener: Yannis Papaphilippou (CERN)

11:15 **MDI - Open points and where help is needed**
Speaker: Manuela Boscolo (INFN e Laboratori Nazionali di Frascati (IT))

11:35 **Pre-injector complex - Open points and where help is needed**
Speaker: Paolo Craievich

11:55 **Energy calibration - Open points and where help is needed**
Speaker: Alain Blondel (Universite de Geneve (CH))

12:15 **Code development**
Speakers: Tatiana Pieloni (EPF Lausanne) , Felix Simon Carlier (EPFL)

12:35 **Other open points**
Speaker: Frank Zimmermann (CERN)

12:55 **FCC FS - Motivations, goals, timeline, organization, etc.**
Speaker: Michael Benedikt (CERN)

Summary

- FCC-ee will address the Higgs/EW physics that has been endorsed worldwide and is very a strong candidate as the next large accelerator in particle physics
- The accelerator will operate in a new regime with very high luminosity at high energy (a merger of the B-factories and LEP) with new physics challenges
- Detailed studies are beginning to understand the placement, infrastructure, and civil engineering as well as the beam physics and accelerator components
- Very exciting time with lots to do to define this new collider!