Funding options and integration of the FCC ee construction and operation in CERN's financial plan

FCC week London, 6 June 2023

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Financial planning at CERN

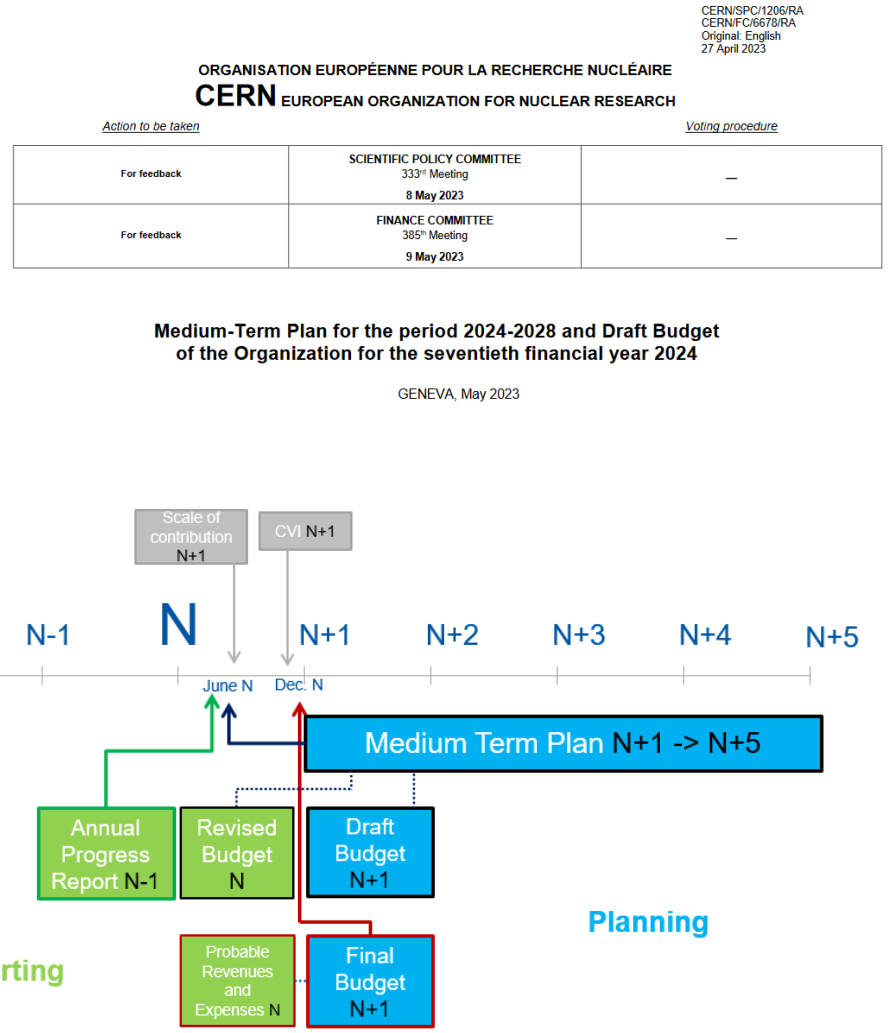
The financial planning at CERN is updated annually, usually asking for approval of the CERN Council in June every year.

This plan includes budget estimates detailed for the following 5 years (including the draft budget) as well as a financial outlook for 10 years.

Since the LEP project, the financing of new projects and facilities at CERN has essentially been done with a constant level of revenues meaning

- **A separation of matching revenues to expenses**
- **A need to have an accrual budget and to separate cash flow considerations**
- **The need to use financial elements to ease the cash-flow burden during the construction (deficit) – repaid over the operation period**

A key indicator is the cumulative budget deficit – it is the net assets of the financial statements without the impact of postemployment benefits and expensing investments in the budget year.



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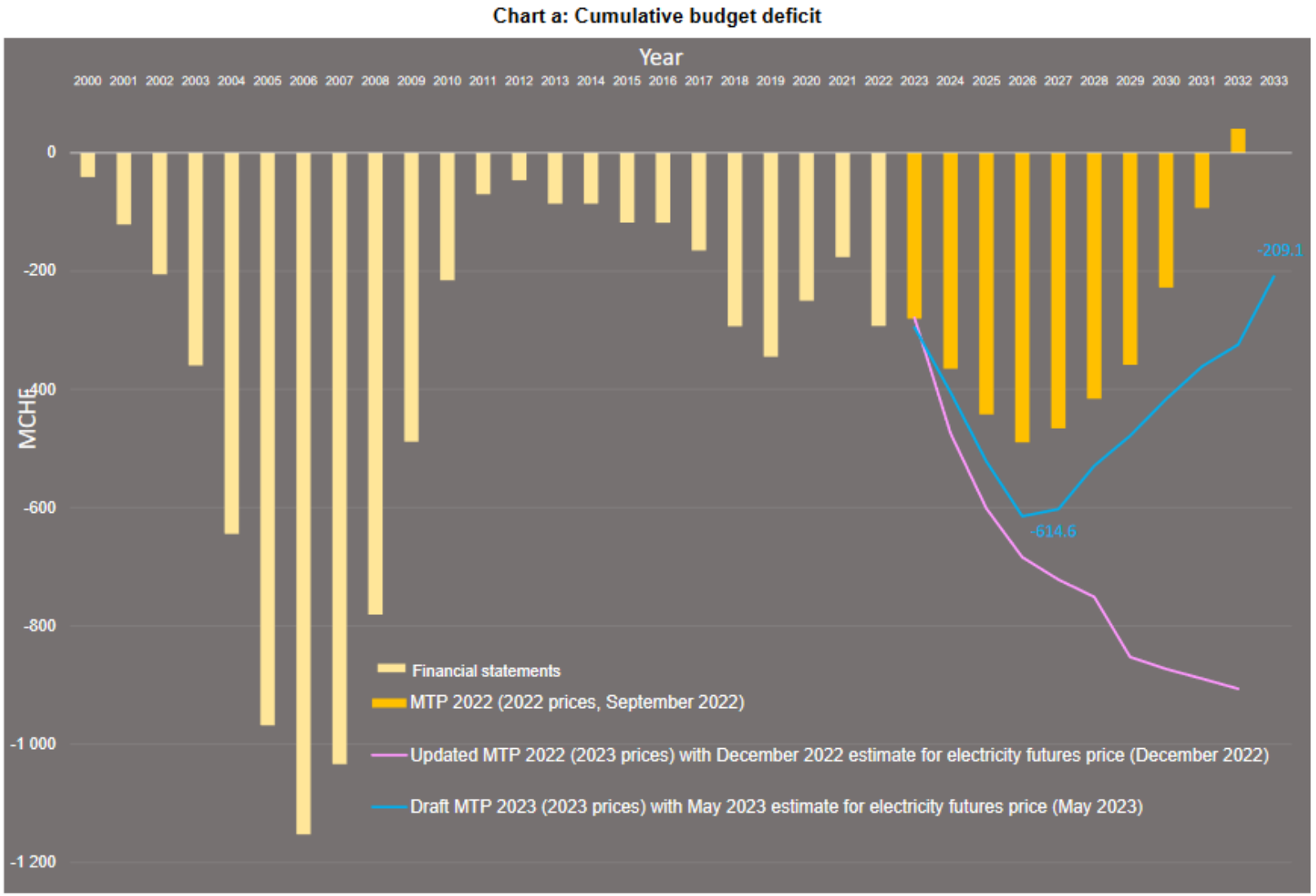
ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		Voting procedure
For feedback	SCIENTIFIC POLICY COMMITTEE 333rd Meeting 8 May 2023	–
For feedback	FINANCE COMMITTEE 385th Meeting 9 May 2023	–

Medium-Term Plan for the period 2024-2028 and Draft Budget of the Organization for the seventieth financial year 2024

GENEVA, May 2023

Financial planning and reporting cycle



Aim: to be close to zero in the beginning of the 2030ties such as to be able to afford starting the construction of the next large facility (i.e. post HL-LHC).

Funding model and affordability as part of the feasibility study

FCC Feasibility Study (geological, environmental, technological, financial, administrative feasibility):

- ❑ mid-term review: autumn 2023 → discussion at special Council session 2 Feb 2024
- ❑ final report end 2025

Financial feasibility is important part of the Feasibility Study, with 2 main components:

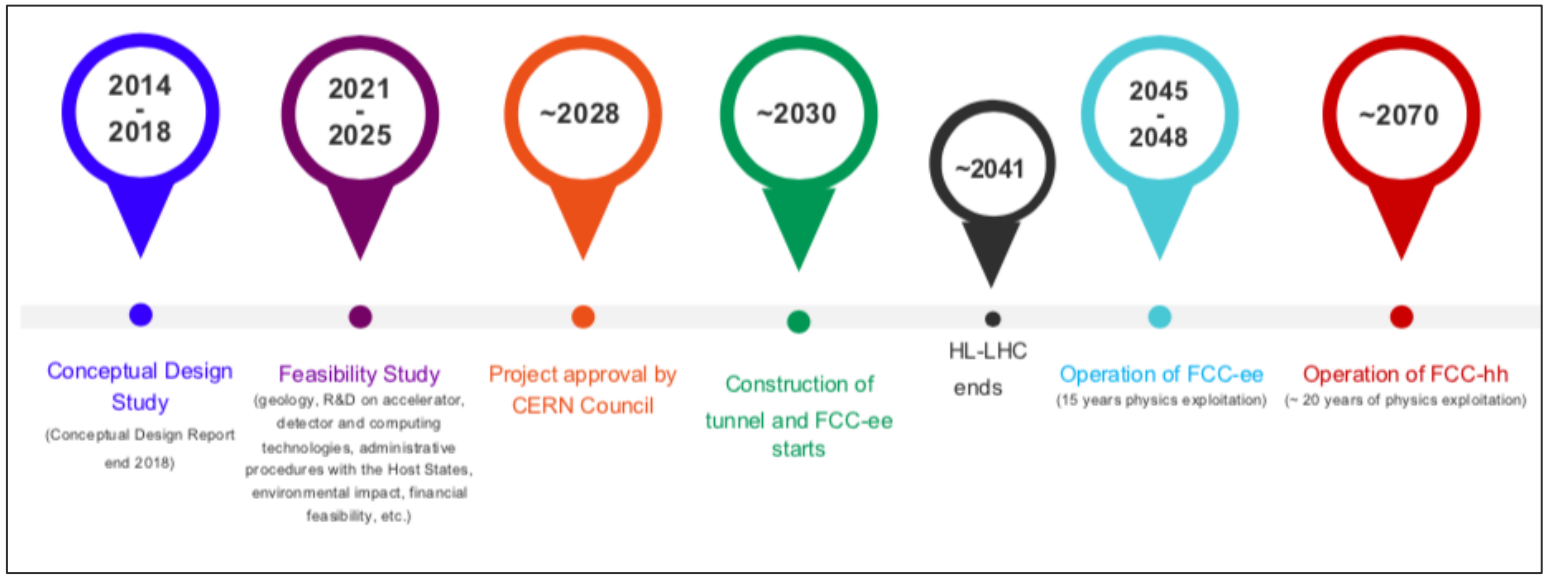
1) Updated assessment FCC cost throughout project's lifetime (i.e. including investment and operating costs) and its uncertainty,
2) (Affordable) funding model to cover above costs.

1) FCC cost
   - Investment cost: current assessment is from FCC Conceptual Design Report (CDR, https://fcc-cdr.web.cern.ch, end 2018).
     It will be reviewed twice:
     -- autumn 2023, in the context of mid-term review of the FCC Feasibility Study
     -- second half of 2025, as final input to the Feasibility Study Report
     Review done by Cost Review Panel (CRP) of external experts: Council consulted recently on membership, appointment of being finalised by FCC Steering Committee.
     → For the preliminary financial analyis presented here: CDR cost is used → this analysis will be updated when new assessment reviewed by CRP available in autumn 2023.
   - Operating costs: operating model for FCC and operating costs are being developed in the context of the Feasibility Study.
     Assumptions used here (see later) based on experience with LHC, will be updated for Final Report, after review by CRP.

2) Funding model: preliminary analysis presented here is first step towards establishing financial feasibility of the project in the context of Feasibility Study. Iterations with Council and its subordinate bodies in the coming 2.5 years are crucial to develop a solid, affordable model acceptable for the Member States with a view to the Feasibility Study Report in 2025.

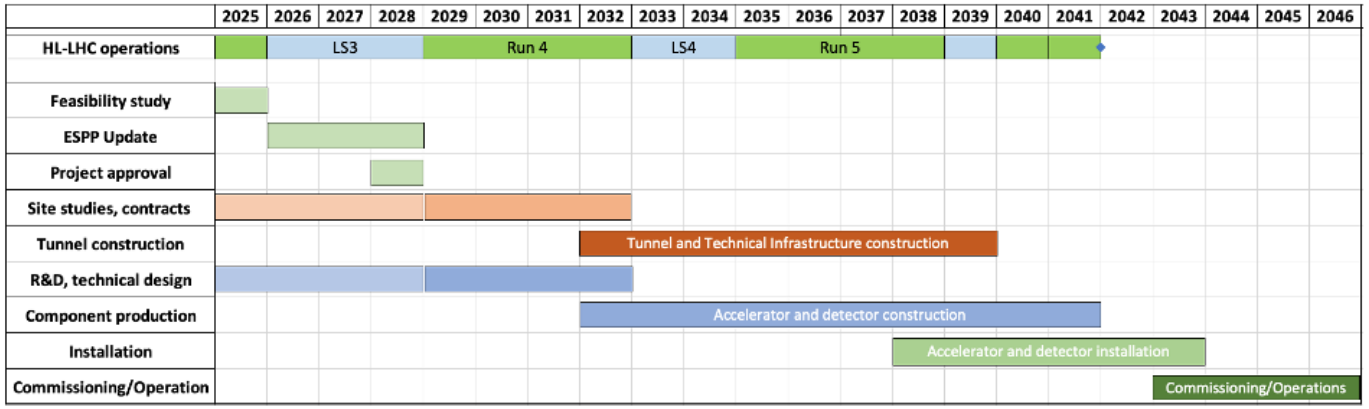
Timeline of the FCC facility

Highest energy and highest intensity of all proposed facilities; ee, pp, ion-ion, e-p, e-ion; multiple experiments → immense physics potential
Here emphasis is on FCC-ee given shorter timescale and much lower cost and technology uncertainties than FCC-hh



This schedule takes into account:
- ❑ past experience in building colliders at CERN
- ❑ that HL-LHC will run until ~ 2041
- → **ANY future collider at CERN cannot start physics operation before 2045-2048** (but construction will proceed in parallel to HL-LHC operation)

Indicative timeline



FCC-ee offers highest luminosities at Z, W, ZH of all proposed Higgs and electroweak factories; indirect discovery potential up to ~ 70 TeV

Operation mode	Z	W^+W^-	ZH	ttbar
$\sqrt{s}$ [GeV]	~91.2	~160	~240	~360
Run time [years]	4	2	3	5
L/IP [10^{34} cm^{-2}s^{-1}]	182	19.4	7.3	1.33
Events [4 IPs]	5×10^{12}	$>10^8$	2×10^6	2×10^6

Cost and funding scenarios

Project cost up to ZH energy : 11 BCHF
Upgrade to ttbar (additional superconducting radiofrequency - SRF – cavities) : 1.1 BCHF
Construction over 15 years

→ see later for more detail

2 funding scenarios considered here:

1) Constant revenues from Member and Associate Member States (with indexation according to corridor principle, up to 2%)
   → out of 11 BCHF for first-stage machine: 5.5. BCHF can be covered from CERN's budget, and 5.5 BCHF would come from outside CERN budget. The latter may include: additional contributions from Member and Associate Member States, contributions from non-Member States, a possible contribution from the European Commission, possible contributions from private donors.
   The additional 1.1 BCHF for the upgrade to ttbar would come from (constant) CERN's budget.

2) Revenues from Member and Associate Member States increase by 1% from 2029 to 2040 → total of 12.5% by 2040
   → "only" 2 BCHF would be needed in this case from outside CERN's budget

Many possible scenarios between (and beyond) these two "extreme" cases can obviously be considered.

Remarks:

- ❑ Choice of funding scenario, in particular amount of resources from outside CERN's budget and how these external resources are shared among the various potential contributors, is a "political"/strategic one, which has implications for the governance of the project.
  → Directorate stands ready to support the Council in the discussions of these matters
- ❑ Directorate started informal discussion with some of potential contributors: US-DOE, President of European Commission, private donors

Cost components and analysis

FCC-ee: key numbers for construction costs and dates

Cost-to-completion of 11 BCHF:

- **civil engineering : 5.4 BCHF;**
- **technical infrastructure : 2.0 BCHF;**
- **Accelerators (collider and injectors) : 3.1 BCHF;**
- **CERN's contribution to the two detectors : 130 MCHF. This contribution was not included in the CDR*;**
- **other infrastructure for the facility (roads, high-voltage power lines, land, etc.) that would be necessary for the FCC construction and operation : 300 MCHF.****
- **Upgrade of superconducting RF cavities of 1.1 BCHF**

Assumptions on key dates and timeline

2028: project approval

2033: construction start

2041: end of HL-LHC operation

2048: FCC-ee operation start (Z, W, HZ, energies)

2058: upgrade of SRF cavities completed and operation at ttbar energy starts

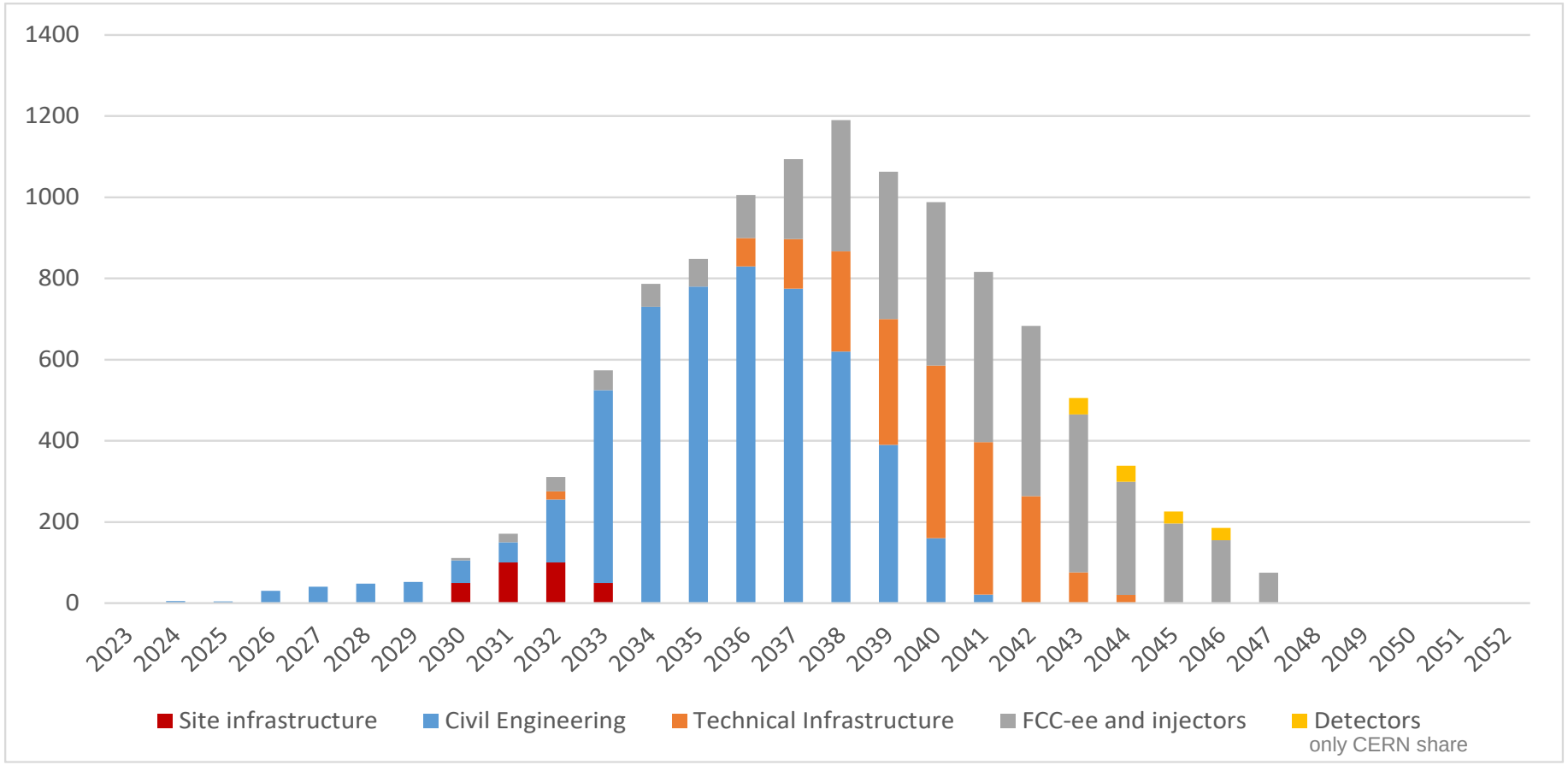
2063: FCC-ee operation end

*** In this model CERN bears 10% of the cost of detectors, expected to be 350 MCHF each plus host lab costs.**

**** This is a preliminary assessment that needs to be verified by a more detailed study to be carried out together with the Host States.**

Population in our MS (not AMS): 527 Mill. (Wikipedia, 2021): so 11 BCHF means 21 CHF per person, i.e. 1.4 CHF pa per inhabitant for the construction.
The ongoing Social Economic Impact Study shows that the population is ready to pay much more.

Resulting spending profile for the construction



Peak expenses in Civil Engineering and its related technical infrastructure appear in the first years of the construction

Further key parameters for the FCC-ee: expenses summary

CtC 11 BCHF CAPEX

- Construction period 15 years
- Additional 1.1 BCHF for the SRF upgrade to ttbar energy

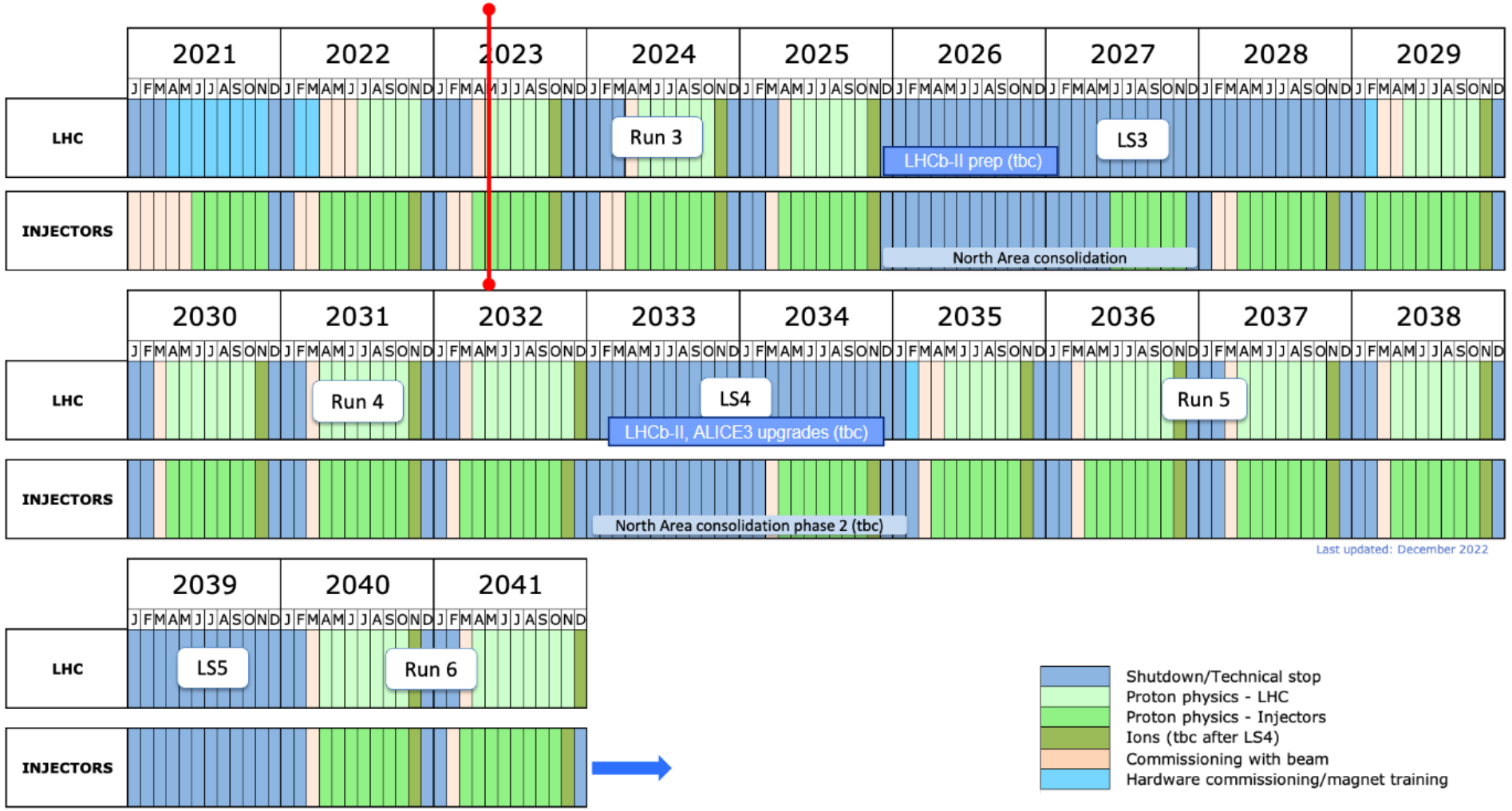
OPEX

- Operation & maintenance costs P+M assumed (without electricity) at 6%, i.e. 660 MCHF, based on experience with LHC (about 5%)
- Electricity consumption at 2.2 to 2.7 TWh p.a. at 90€/MWh => 180 to 240 MCHF p.a. in total, considering :
  1. current consumption at 1.25 TWh during LHC run 3 and 1.52 TWh during HL-LHC
  2. R&D work ongoing to reduce consumption for cooling and SRF, etc.

Other assumptions

- **Apply constant prices starting from the MTP 2022**
- **Maintaining fix target physics after HL-LHC stops, maintain R&D on other technologies than FCC**
- **Provision for de-commissioning LHC (100 MCHF) included**
- **Workforce analysis ongoing – here we assume a five-year stop after HL-LHC for full personnel reallocation to FCC-ee**
- **Ramp up of commissioning to operation as of 2042**

For information - overall schedule of current facilities



As part of the savings measures proposed by the Management, the LS3 shutdown for the injectors could be extended throughout 2027.

It is assumed that the PS and SPS complexes and their scientific facilities will continue operating AFTER the LHC era.

Summary of the expenses

The numbers shown are annual expenses in 2022 prices for P+M

- **REVENUES**
- **OPEX**
  - **Figures distinguish operation and shutdown years**
- **CAPEX**
  - **Consolidation of techn.& gen infrastructure**
  - **R&D for technologies other than FCC**
  - **Investment in Scientific diversity programme**
  - **FCC SRF (2048-2057)**
  - **R&D, i.e. HFM for FCC hh (until 2057)**
  - **FCC-hh construction (as of 2058)**

Current annual revenues (mostly from Member and Ass. Member States)	1290	MCHF
Current annual OPEX expenses		
LHC operation	400	MCHF
LHC shutdown	450	MCHF
All accelerators except LHC	100	MCHF
Electricity for LHC, injectors and baseload	120	MCHF
Electricity during shutdowns	40	MCHF
Electricity for injectors and baseload	60	MCHF
Base lab operation	400	MCHF
Central expenses - Pension Fund, capital repayment	61	MCHF
FCC-ee operation	650	MCHF
Electricity for FCC-ee only	120-180	MCHF
Annual CAPEX other than for FCC ee first stage construction		
Base lab consolidation	40	MCHF
R&D (other than for FCC)	15	MCHF
Scientific diversity programme	10	MCHF
FCC-ee SRF upgrade (over 10 years)	110	MCHF
FCC-hh R&D (until construction starts)	30	MCHF
FCC-hh construction as of 2058	250	MCHF

Funding scenarios

Key parameters for the FCC-ee revenues

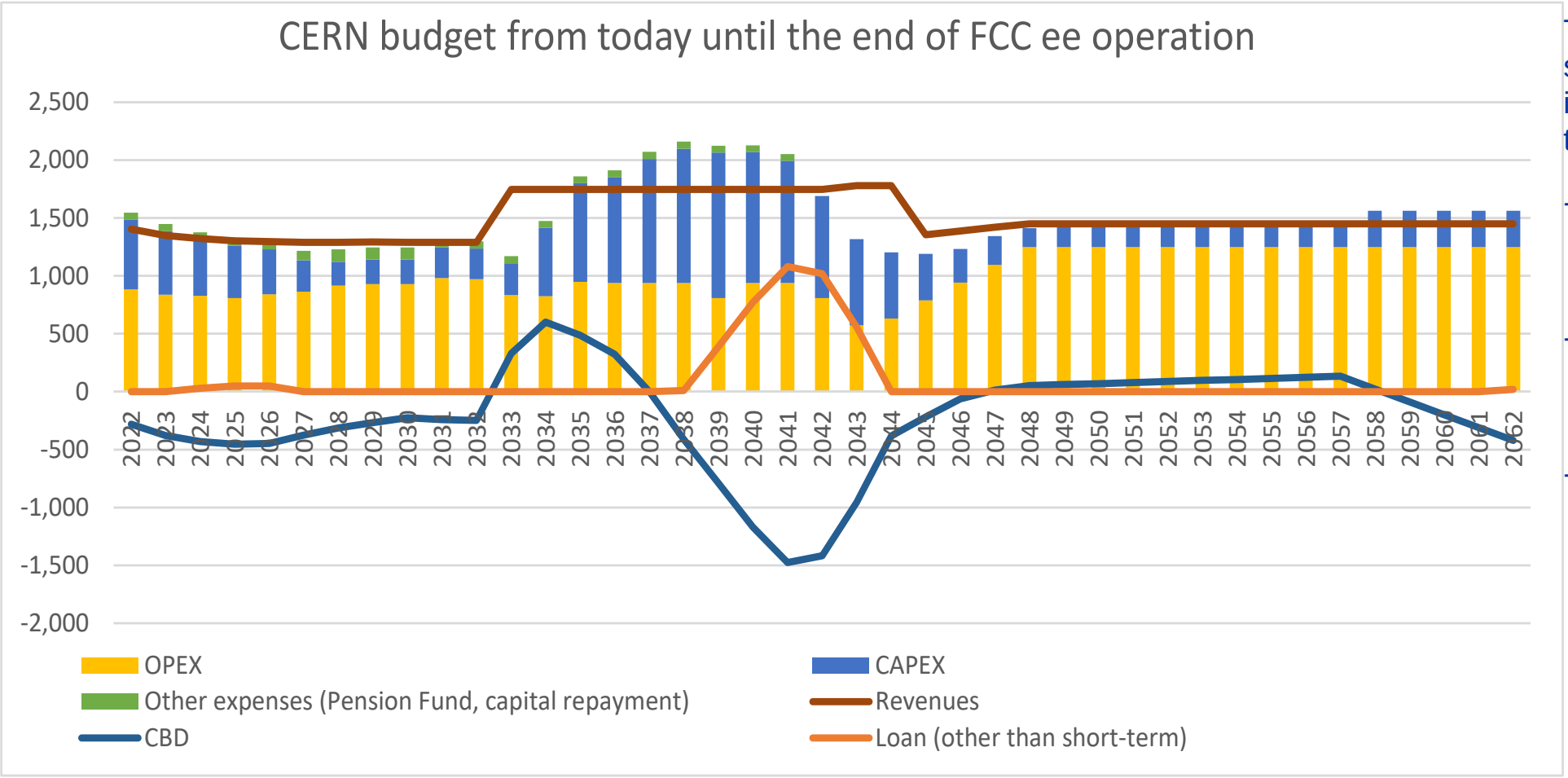
CAPEX REVENUES: Two scenarios for revenues beyond the current CERN budget for the construction are studied here

- Scenario 1 : 5.5 BCHF from outside the CERN Budget (about 2/3 in cash) receivable within 12 years
- Scenario 2 : Budget increase by 1% p.a. between 2029 and 2040 for a total of 12.5% and smaller special contribution of 2 BCHF from outside the CERN Budget.
- There are several possible intermediate scenarios between the two
- This is a political / strategic choice by the Council

OPEX REVENUES

Contributions to the operation of the FCC from non-Member States are assumed here 25% of the total operating costs i.e. 25% of 660 MCHF = 165 MCHF p.a.

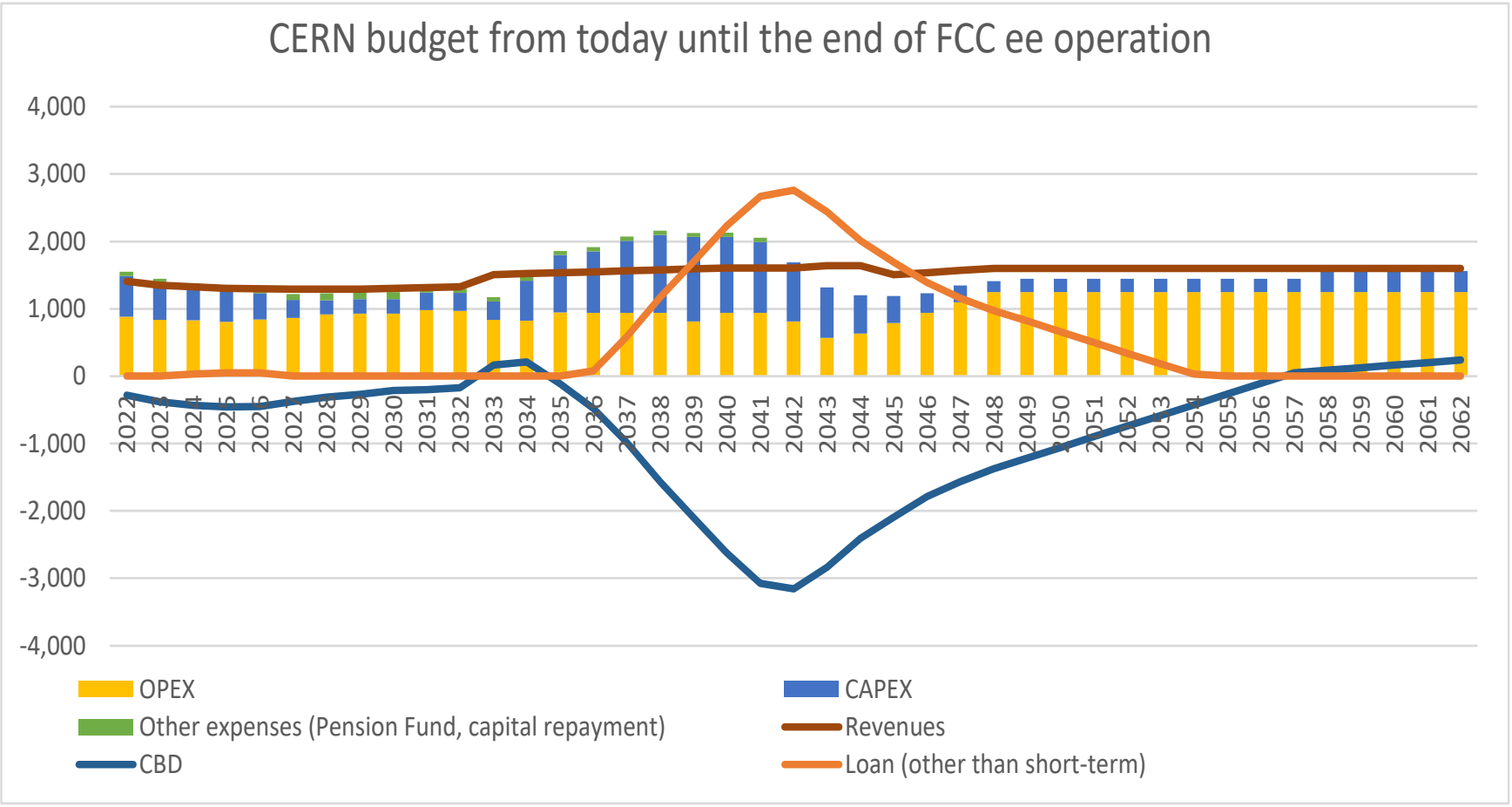
Projections in the case of funding scenario 1 (5.5 BCHF contribution from outside the CERN budget over 12 years)



The special 5.5 BCHF contribution starts in 2033 with constant instalments over the first 12 years of the construction and implies that:

- most of the CE and technical infrastructure costs are covered over the period
- the CBD would be limited to 1.5 BCHF, similar to the times of the LHC construction
- a relatively moderate financial loan -- no costs for servicing the loan are assumed - it would amount to some 80 MCHF with an interest rate at 2% p.a.

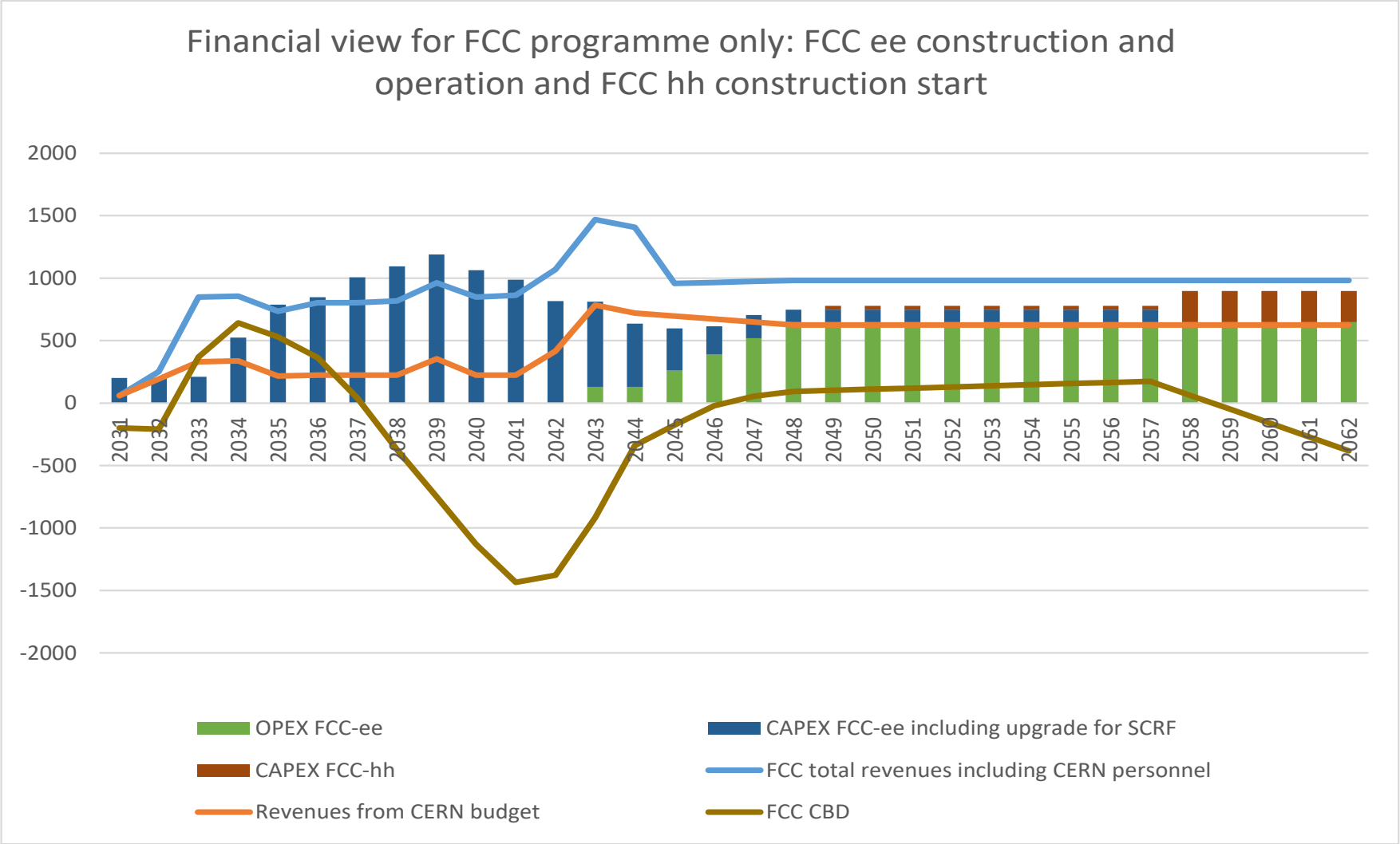
Projections in the case of funding scenario 2
(2 BCHF contribution from outside the CERN Budget over 12 years and increase in revenues from MS and AMS from 2029 to 2040)



A gradual budget increase on top of the corridor principle of 1% p.a. from 2029 to 2040 would:

- yield 3.5 BCHF by 2058
- help in the repayment capacity as well as during the operation phase and for the subsequent construction of FCC-hh
- require a greater loan to cope with the needs for the payment of construction costs.

Financial view for "separate" FCC project (including transfer of budget and personnel from CERN to FCC)



An attempt to present the main financial components from an FCC viewpoint only with a transfer from CERN budget to the materials costs as well as accounting for the personnel detached from CERN to the FCC facility.

Risks assessment and possible mitigation

Parameter	CtC [BCHF]	Peak CBD [BCHF]	Years of loans > 500 MCHF	Comment
Baseline	11	1.5	5	
Increased FCC-ee construction cost by 25%	13.8	3.9	*30*	Can be offset by a longer construction period (3 more years) and a 2 year delay to FCC-ee upgrade to top-antitop
Special contribution of 4 BCHF instead of 5.5 BCHF	11	2.7	18	Can be offset by a longer construction period (2 more years)
Special contribution of 5.5 BCHF paid over 15 years instead of 12 years	11	2.4	9	Can be offset by a longer construction period (2 more years)
Non-Member States contribution to the operating costs of the FCC-ee of 15% instead of 25%	11	1.5	11	
FCC-ee operation costs of 7% instead of 6%	11	1.5	7	

The majority of risks (extra costs for construction and/or operation, less external contributions etc.) can be mitigated by a delay of physics starts.

However, the number of years, during which financial loans are necessary, will increase, and this would impact the later phases of FCC importantly.

Outlook towards FCC-hh

- **Cost to Completion 17 BCHF**
  - Civil Engineering 0.6 BCHF
  - Technical Infrastructure 2.8 BCHF
  - Accelerators 13.6 BCHF (including some 9.4 BCHF for 4700 high-field SC magnets@2MCHF/piece)
- **Funding**
  - 250 MCHF p.a. as of 2058
  - 750 MCHF p.a. as of end of FCC-ee physics until 2072 => 9 BCHF
  - If, due to the R&D on High Temperature Superconductors and the larger time frame allowed by operating FCC-ee first
    - 9.4 BCHF become 6.5 BCHF as a result of this targeted R&D => 5 BCHF contribution from outside the CERN budget are needed
    - If the second funding scenario is chosen for FCC-ee, i.e. a gradual increase of revenues of 1% p.a. between 2029 and 2040, corresponding to additional 150 MCHF p.a. as of 2041 => contribution from outside the CERN budget would reduce to some 2.8 BCHF

Conclusions

This presentation is a preliminary analysis of the cost assessment of a FCC-ee facility with a first stage CtC of 11 BCHF and starting physics exploitation in 2045-2048.

A preliminary outlook for the operation phase of the FCC-ee as well as the later stage construction of the FCC-hh is also given.

The updated CtC will be available in autumn 2023 as the deliverable of the mid-term review of the FCC Feasibility Study.

This analysis will be updated, as and when the input from the FCC Feasibility Study will become available (e.g. operating model and costs).

Two (at least) different funding scenarios have been considered to assess the financial feasibility.

The choice of the funding scenario for the contribution outside the CERN budget is a political/strategic one and might impact the overall governance of the project and facility.

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