European Strategy and CERN Medium Term Plan (MTP)

2014年7月29日

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CERN

- 1954年に発足した、欧州の素粒子原子核研究のための欧州を中心とした国際研究所。

（加盟国は欧州に限らないということを2010年に確認）

- 現在の加盟国：　２1カ国（昨年イスラエルが加盟）
- 2012年に国連総会（UN　General Assembly) のObserver status を得た。
- 年間予算：　約1,000 億円
- 職員：　約2,500 人
- ユーザー：　約10,000人（世界71カ国から）

European Strategy for Particle Physics

- 高エネルギー分野の欧州のロードマップといえるもの。
- CERN Councilがとりまとめを行い、初回は2006年に制定。5年を経過したらUpdateを考えるとしてあったが、LHCの初期の結果を見てからということで2012年から見直しが始まり、2013年の6月に、ブリュッセルにおける特別のCERN Councilで承認した。
- 見直しにあたっては、ローザンヌスイス連邦工科大の中田達也氏がChairpersonを勤めた。メンバー国から1人ずつ＋欧州の大きな研究所の代表が中心。非加盟国からもオブザーバーが出席、日本からは浅井祥仁氏（東大）、さらにFALCの議長として岡田安弘氏（KEK）が参加。また、Preparatory Groupに久野良孝氏（阪大）も加わった。

European Strategy Update for Particle Physics

- レポートは http://cds.cern.ch/record/1551933/files/Strategy_Report_LR.pdf にて公開。
- a-q の17のRecommendation
- 2つの一般的なものあと、四つのHigh Priority条項を上げている。

- 以下4ページは中田さんからのコメント

European Strategy

- Just three A4 pages, 1 preamble and 17 statements
  http://council.web.cern.ch/council/en/EuropeanStrategy/esc-e-106.pdf
  - General issues
  - High priority large scale scientific activities
    - LHC, accelerator R&D, e^+e^- (ILC), neutrinos
  - Other scientific activities essential to the particle physics programme
    - theory, small scale precision physics, detector R&D and engineering infrastructure, computing, relation with nuclear and astroparticle physics
  - Organisational issues
    - role of CERN and relation with EU
  - Wider impact of particle physics
    - Outreach, education and knowledge transfer

ヨーロピアンストラテジーはA４で３ページの非常にコンパクトなもの。ヨーロッパのアジアやアメリカで行われるプロジェクトへの参加も積極的に議論されている。科学項目以外に、アウトリーチやノレッジトランスファーにも触れている。

Deliberation Paper

- Deliberation Paper by the ESG is to provide
  - rationale behind the scientific issues
    ⇒ partly in this presentation
  - recommendations of the ESG Working Groups on the non-scientific issues
    ⇒ Council may consider taking up for future consideration

now finalised and available for public.
http://council.web.cern.ch/council/en/EuropeanStrategy/esc-e-S-103Rev.pdf

ストラテジーの基本となった科学の議論はDeliberation Paperに記されている。

Strategy Background

- Reflecting the scientific status
  - Successful HLC operation and Higgs discovery
  - Measurement of θ_{13}, a larger end of the expected value range
  - Non observation of physics beyond the Standard Model
- European geopolitical environment
  - LHC expensive European flag machine, used also for flavour physics and heavy ion physics
  - While CERN is the European central place for particle physics, there are many national laboratories, with particle physics accelerator for some cases
  - Europe acknowledges that Europe cannot host all the important facilities and must be ready to support facilities outside of Europe
- European Strategy does not aim for a concrete programme for given budget scenario but describes strategy and policy

ヨーロピアンストラテジーは、セルンジュネーヴ研究所での大型計画だけでなく各国の国立研究所でもできる中、小型の研究も含めた大局的な将来を語るものなので、特定な予算を想定したプログラムではない。

Four High Scientific Priority

- Exploitation of LHC as much as possible, i.e. including the High Luminosity Upgrade, for precision studies of Higgs and flavour physics, heavy ion physics, and direct search for physics beyond that Standard Model. This is the European top priority.
- Ensure ability to build the next high energy frontier machines: high field magnet, high gradient acceleration, conceptual design studies to estimate costs.
- Acknowledging complementarity between the hadron machines and e^+e^- machines for precision Higgs studies and New Physics search. If an ILC will be hosted in Japan, Europe intends to participate.
- CERN should provide infrastructure and technical support for the neutrino detector R&D for the future long baseline experiments in the US or Japan.

European Strategy (High priority抜粋)

c. The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

(top priorityは upgradeを含めたLHC)

European Strategy (High priority抜粋)

d. To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available. *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.*

(LHC 14TeVの結果が出たところでヨーロッパの次の計画を出す → そのための加速器のR&D)

European Strategy (High priority抜粋)

e. There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. *Europe looks forward to a proposal from Japan to discuss a possible participation.*

(ILCの物理的意義を認め、日本政府の提案を待つ)

European Strategy （High priority抜粋）

f. Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baselineneutrino projects in the US and Japan.*

(ニュートリノは米国・日本のプロジェクトへの参加を検討)

CERN- Medium-Term Plan (MTP)

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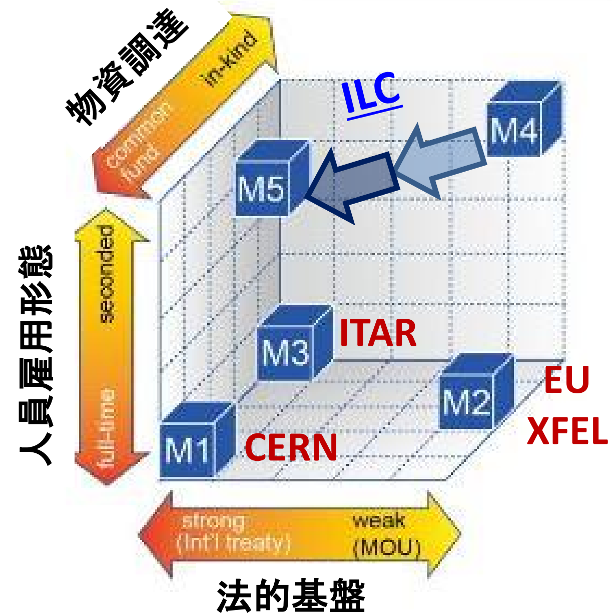
- 例年、6月のCERN　Councilでは、来年の予算案と今後の5年計画（MTP）を議論して承認する。
  - Draft を5月のSPCで議論、Revised versionを6月のSPCでさらに議論、Finance Committee(FC)で承認の上Councilで承認　（6月19日承認済）
- MTPは公開文書（ CERN/3117 ）

- 今回の特徴
  - European Strategy Update (ESU)が出たあと最初のMTP
  - USのP5レポートも反映

グローバル・プロジェクトにおけるガバナンス

鈴木　KEK機構長　ILC有識者会議（６月２４日）でのスライドより



1. Revenues plan

Figure 1: Anticipated revenues

(in MCHF, 2014 prices, rounded off)	Revised 2014 Budget	2015	2016	2017	2018	2019	**Total 2014-2019**	2020	2021	2022	2023	2024	2025	**Total 2014-2025**
REVENUES	**1,220.2**	**1,209.1**	**1,200.7**	**1,206.3**	**1,204.0**	**1,225.8**	**7,266**	**1,256**	**1,255**	**1,256**	**1,231**	**1,206**	**1,206**	**14,675**
Member States' contributions	1,099.6	1,099.6	1,099.6	1,099.6	1,099.6	1,099.6	6,598	1,100	1,100	1,100	1,100	1,100	1,100	13,196
Additional contributions from Host States	1.9						2							2
In-kind [1]	*1.9*						*2*							*2*
Additional contribution from Romania as a Candidate for Accession [2a]	7.9	10.5	10.5	10.5	10.5	10.5	60	11	11	11	11	11	11	124
Special contribution from Israel [2b]	9.5	0.4	0.4	0.4	0.4	0.4	12	0						12
Additional contribution from Serbia as an Associate Member State [2c]	1.0	1.0	1.2	2.5	2.5	2.5	11	3	3	3	3	3	3	26
Contributions anticipated from new Associate Member States		5.0	15.0	25.0	25.0	25.0	95	30	30	30	30	30	30	275
Non-Member States contributions to HL-LHC						25.0	25	50	50	50	25			200
EU contributions	21.6	15.3	10.2	8.0	8.0	8.0	71	8	8	8	8	8	8	119
Additional contributions	9.8	14.7	3.9	4.7	3.2	0.3	37							37
for LINAC4, HIE-ISOLDE, ELENA, CLIC, IdeaLab, R&D neutrinos, FAIR, CESSAMag	*9.8*	*14.7*	*3.9*	*4.7*	*3.2*	*0.3*	*37*							*37*
Personnel paid on team accounts	13.3	9.9	7.9	7.8	7.5	7.3	54	7	8	8	8	8	8	101
Personnel on detachment	1.1	0.4	0.1	0.0			2							2
Internal taxation	28.5	28.4	28.5	28.5	28.2	28.1	170	28	28	28	28	28	28	339
Knowledge transfer	1.3	1.1	1.1	1.1	1.1	1.1	7	1	1	1	1	1	1	14
Other revenues	24.7	22.6	22.1	18.1	17.9	17.9	123	18	18	18	18	18	18	231
Sales and miscellaneous	*9.9*	*9.4*	*9.2*	*5.2*	*5.0*	*5.0*	*44*	*5*	*5*	*5*	*5*	*5*	*5*	*74*
OpenLab revenues [3]	*2.0*	*0.3*					*2*							*2*
Financial revenues	*2.0*	*2.0*	*2.0*	*2.0*	*2.0*	*2.0*	*12*	*2*	*2*	*2*	*2*	*2*	*2*	*24*
In-kind [4]	*4.9*	*4.9*	*4.9*	*4.9*	*4.9*	*4.9*	*29*	*5*	*5*	*5*	*5*	*5*	*5*	*59*
Housing fund	*6.0*	*6.0*	*6.0*	*6.0*	*6.0*	*6.0*	*36*	*6*	*6*	*6*	*6*	*6*	*6*	*72*

[1] The 2014 amount comprises the remaining in-kind contributions from France based on the expected LINAC4 in-kind contributions.

[2a] Romania as a Candidate for Accession will pay 75% of its theoretical Member State contribution in 2014 and 100% as of 2015, as defined in Council Resolution CERN/2829 and updated by the Agreement signed by CERN and Romania on 11 February 2010.

[2b] In line with Council Resolution CERN/3079/RA entitled "Amount and payment modalities of the special contribution by Israel", Israel has already sent an amount of 9,035 kCHF towards its special contribution as a Member State and this amount has been included in the budget for 2014. An additional amount of around 500 kCHF should be paid in cash in 2014.

[2c] Serbia became an Associate Member State on 15 March 2012. As defined in Council Resolution CERN/2999/RA, Serbia will pay the statutory minimum contribution of 1 MCHF until 2015 and either 50% of its theoretical Member State contribution or the statutory minimum contribution of 1 MCHF in 2016. It is assumed that Serbia will become a Member State in 2017 and will pay 100% of its contribution as of 2017.

[3] Including in-kind contributions from OpenLab partners.

[4] Theoretical interest of the FIPOI loan and advantage from free use of land.

Explanations to Figure 1:

The overview of the various revenues headings is shown in Figure 1 in constant 2014 prices. The Member States' contributions include the contribution from Israel, which became a Member State in January 2014 as defined in Council Resolution CERN/3094/RA. Due to the new LINAC4 construction schedule, the in-kind contribution from France continues until 2014 inclusive. The contributions from Romania as a Candidate for Accession and from Serbia as an Associate Member State in the pre-stage to Membership are added. The other headings are updated based on the latest information available and on the 2013 budget out-turn.

As explained in fact sheet 37 on revenues, assumptions are made for contributions from additional Associate Member States and non-Member States to HL-LHC construction.

2. Estimated budget balances

Figure 2: Estimated budget balances

(in MCHF, 2014 prices, rounded off)	Revised 2014 Budget	2015	2016	2017	2018	2019	**Total 2014-2019**	2020	2021	2022	2023	2024	2025	**Total 2014-2025**
EXPENSES	**1,286.7**	**1,229.8**	**1,177.1**	**1,176.0**	**1,184.7**	**1,127.7**	**7,182**	**1,164**	**1,148**	**1,127**	**1,097**	**1,005**	**1,012**	**13,734**
Running of scientific programmes and support	**1,053.0**	**987.4**	**940.5**	**936.3**	**947.7**	**907.8**	**5,773**	**950**	**906**	**904**	**904**	**865**	**899**	**11,200**
Scientific programmes	**555.9**	**472.9**	**473.7**	**488.9**	**517.6**	**487.3**	**2,996**	**487**	**474**	**473**	**495**	**483**	**473**	**5,880**
LHC (machine, detectors, computing, including spares and consolidation)	*347.9*	*279.3*	*272.7*	*281.9*	*306.0*	*293.4*	*1,781*	*284*	*282*	*282*	*304*	*292*	*282*	*3,506*
Non-LHC physics and scientific support	*59.2*	*52.5*	*52.3*	*52.3*	*54.7*	*56.0*	*327*	*56*	*56*	*56*	*56*	*56*	*56*	*664*
Accelerators and areas (including consolidation)	*148.8*	*141.2*	*148.8*	*154.8*	*156.8*	*138.0*	*888*	*147*	*136*	*135*	*135*	*135*	*135*	*1,711*
Infrastructure and services	**329.6**	**308.4**	**273.6**	**262.0**	**263.3**	**264.8**	**1,702**	**263**	**261**	**261**	**261**	**261**	**261**	**3,270**
General infrastructure and services (including administration, outreach)	*272.4*	*259.9*	*251.0*	*242.7*	*244.4*	*243.8*	*1,514*	*242*	*240*	*240*	*240*	*240*	*240*	*2,957*
Infrastructure consolidation, buildings and renovation	*57.1*	*48.5*	*22.6*	*19.3*	*18.8*	*21.0*	*187*	*21*	*21*	*21*	*21*	*21*	*21*	*313*
Centralised expenses	**167.5**	**206.1**	**193.2**	**185.4**	**166.9**	**155.7**	**1,075**	**200**	**171**	**170**	**148**	**121**	**165**	**2,049**
Centralised personnel expenses	*34.6*	*35.4*	*35.7*	*35.7*	*35.7*	*35.7*	*213*	*36*	*36*	*36*	*36*	*36*	*36*	*427*
Internal taxation	*28.5*	*28.4*	*28.5*	*28.5*	*28.2*	*28.1*	*170*	*28*	*28*	*28*	*28*	*28*	*28*	*339*
Personnel internal mobility, on detachment, teams, paid but not available	*14.7*	*10.5*	*8.8*	*8.6*	*8.4*	*8.2*	*59*	*8*	*8*	*9*	*9*	*9*	*9*	*111*
Budget amortisation of staff benefits accruals	*17.3*	*17.3*	*17.3*	*17.3*	*17.3*	*17.3*	*104*	*17*						*121*
Energy and water, insurances and postal charges, miscellaneous	*53.7*	*96.5*	*85.8*	*79.2*	*62.2*	*52.3*	*430*	*97*	*86*	*86*	*65*	*40*	*85*	*891*
Interest, bank and financial expenses, in-kind [1]	*18.8*	*17.9*	*17.0*	*16.1*	*15.1*	*14.1*	*99*	*13*	*12*	*11*	*10*	*9*	*7*	*161*
Projects and studies	**233.7**	**242.4**	**236.7**	**239.8**	**237.0**	**219.9**	**1,409**	**214**	**242**	**223**	**193**	**139**	**112**	**2,534**
LHC upgrades	**123.4**	**136.3**	**153.6**	**167.5**	**169.5**	**162.6**	**913**	**159**	**186**	**166**	**141**	**86**	**58**	**1,709**
LINAC4	*24.3*	*11.6*	*3.8*	*0.8*	*0.1*		*41*							*41*
LHC injectors upgrade	*31.9*	*42.6*	*54.9*	*48.4*	*38.7*	*25.9*	*242*	*3*						*246*
HL-LHC construction	*38.0*	*58.2*	*69.1*	*88.7*	*94.2*	*98.5*	*447*	*115*	*148*	*132*	*117*	*66*	*44*	*1,068*
LHC detectors upgrade (Phase 1) and consolidation	*18.7*	*15.6*	*17.5*	*16.6*	*13.2*	*9.6*	*91*	*11*	*11*	*11*	*11*	*11*	*11*	*158*
HL-LHC detectors, including R&D (Phase 2)	*10.5*	*8.3*	*8.3*	*13.0*	*23.4*	*28.6*	*92*	*30*	*27*	*23*	*13*	*8*	*3*	*196*
Energy frontier	**37.4**	**34.5**	**36.1**	**35.9**	**36.0**	**32.7**	**213**	**30**	**31**	**32**	**33**	**34**	**35**	**408**
Linear collider studies (CLIC, ILC, detector R&D)	*34.4*	*28.0*	*27.0*	*24.9*	*23.7*	*20.4*	*158*							*158*
Future Circular Collider study	*3.0*	*6.5*	*9.1*	*11.0*	*12.3*	*12.3*	*54*							*54*
High-energy frontier								*30*	*31*	*32*	*33*	*34*	*35*	*196*
Diversity activities	**73.0**	**71.6**	**47.0**	**36.3**	**31.5**	**24.6**	**284**	**25**	**25**	**25**	**20**	**20**	**20**	**417**
ELENA	*9.5*	*11.8*	*6.9*	*1.6*	*0.3*		*30*							*30*
HIE-ISOLDE	*24.1*	*9.0*	*4.9*	*2.6*	*2.7*	*0.5*	*44*							*44*
TSR@ISOLDE						*2.0*	*2*	*5*	*5*	*5*				*17*
CERN neutrino platform	*11.1*	*15.9*	*10.3*	*7.6*	*6.8*	*3.0*	*55*	*3*	*3*	*3*	*3*	*3*	*3*	*73*
R&D (incl. EU support) for accelerators, detectors, medical applications	*28.2*	*35.0*	*25.0*	*24.6*	*21.7*	*19.1*	*154*	*17*	*17*	*17*	*17*	*17*	*17*	*253*
BALANCE														
Annual balance	-66.5	-20.7	23.5	30.2	19.3	98.1		92	108	129	134	201	194	
Capital repayment allocated to the budget (Fortis, FIPOI 1, 2 and 3, SIG)	-26.2	-27.1	-28.0	-28.9	-29.9	-30.9		-32	-33	-34	-35	-36	-34	
Recapitalization pension fund	-60.0	-60.0	-60.0	-60.0	-60.0	-60.0		-60	-60	-60	-60	-60	-60	
Annual balance allocated to budget deficit	-152.7	-107.8	-64.5	-58.7	-70.6	7.3		0	15	35	39	105	101	
-Cumulative Balance [2]- - 86.1	**-238.8**	**-346.6**	**-411.0**	**-469.7**	**-540.3**	**-533.0**		**-533**	**-519**	**-484**	**-446**	**-341**	**-240**	

[1] Including theoretical interest of the FIPOI loan and advantage from free use of land (compensated by a corresponding heading in the revenues).

[2] The cumulative balance of -86.1 MCHF is the accumulated budget deficit as stated in the Financial Statements for 2013 (CERN/FC/5818, page 13). It does not contain 2013 open commitments and reprofiled projects of 99.6 MCHF carried forward to 2014 and later years (of which 92.9 MCHF announced in the Final Budget 2014).

The annual balance is given by the difference between revenues and expenses. Its positive balance increases over time with new Associate Member States joining and the peak expenses of LS2 and HL-LHC construction ending in the early 2020. Adding the capital repayment and recapitalisation of the pension fund yields the balance allocated to the budget deficit.

MTP-Highlight-1

- LHC-Upgrade (HL-LHC)をフルに入れた10年計画を提示した。（通常は5年計画）
- これのMTPがCouncilで承認されたということは、CERNがHL-LHCを進めることを承認したと言うこと。
- 昨年までは、LHCのアップグレードは「Performance Improving Consolidation(465MCHF)」と「HL-LHC (385MCHF)」とに分けて書かれていたが、今回は合体して表示、これも欧州戦略で第一優先度となったことから、LHCから最大限のOutputを得るオプションを選択したことになる。
- LHCの実験のアップグレードに関する費用もCERN分担分を全部計上してある。
- ただし、財政状況を鑑みて、加速器、実験とも現在の見積もりより10%削減した予算しかつけていない。

MTP-Highlight-2

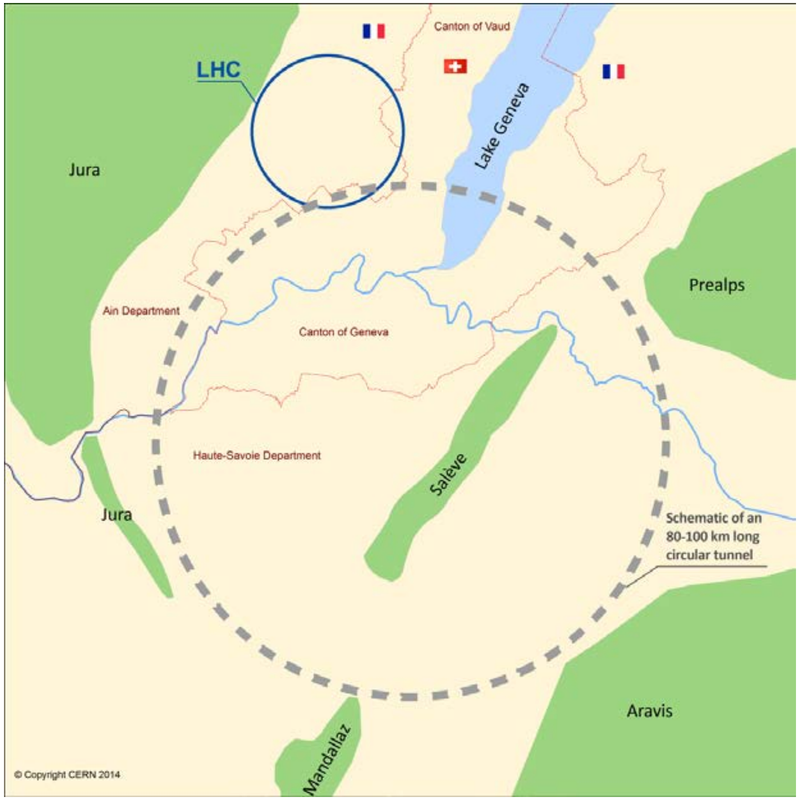
- Non-member国(NMS)からのLHCアップグレードに関する貢献の期待額を収入に組み込んでいる。ここでは、米国がP5で最優先課題にあげていること、日本がD1磁石の設計・製作を担当していることなどからの算定。
- NMSからの寄与は全部で200MCHFで、2023年で終わっている。これは、つまり、NMSの貢献は建設に対してで、運転に関しては期待していないことを反映している。

MTP-Highlight-3

- 将来のエネルギーフロンティアのR&DとしてLinear collider studies (CLIC, ILC, detector R&D)及びFCCに予算をつけている。”CERN has launched the FCC study in addition to its leading role in the CLIC collaboration and participation in the ILC. ”
- 両方合わせて毎年30MCHF強であり、FCCの予算が少しずつ増えていく。
- 2020年には将来の方向性が定まっていると考えてそこからの予算は両者を一本化してある。しかし、その額は年間30MCHF程度であり、今後10年間にR&D以上の進展はとりあえず考えていない。

FCC
Kick-off meeting 12-15/Feb/2014

- http://cern.ch/fcc
- **http://indico.cern.ch/e/fcc-kickoff**



- 100km 16T磁石→　100TeV
  （現在開発中のNb_3Snなど）
- 80km　20T磁石→　100TeV
  （高温超伝導磁石の開発）

Cf.

LHC: 27km 8.33T 磁石→　14TeV
（NbTi　磁石）

MTP-Highlight-4

- LC　Studies の予算のほとんどはCLICに関連したものであり、2015年に関して言えば人件費10MCHF、物件費12MCHF。
- ILCに関しては特に独立した予算化はされていないがILCとCLIC研究とのSynergyが強調され、共通な加速器開発や、測定器開発がうたわれている。
- ESUを受けて以下のような表現の記述が有り、日本の出方を待つということ。"CERN, together with national institutes, laboratories and universities in Europe, looks forward to a proposal from Japan to discuss possible participation."

MTP-Highlight-5

- ニュートリノに関しては、欧州戦略と米国P5を受けて、CERNがニュートリノ研究のR&Dを進めるための基地となることを提案。
- ここではCERNでニュートリノ実験をやるのではなく、ニュートリノの検出器（特に液体アルゴン）の開発のための、テストファシリティを整えるのが中心。今後5年間で55MCHF程度。
- CERNにおいて欧州チームが開発した液体アルゴン検出器が、米国Fermi研究所のビームをつかった、長基線ニュートリノ、及び短基線ニュートリノの実験に使われることになる。

（F）

MTP-Highlight-6

- 昨年で、LHC建設の借金をほぼ返済し終えたが、今後10年間は、HL-LHCを進めるために、再び借金が増えることになる。
- 2018年頃に540MCHFの赤字になり、その後、徐々に回復して2025年には240MCHFの赤字になる見通し。（ちなみに、CERNの年間予算は1200MCHF程度）

参考資料

- European Strategy Update
- MTP (抜粋）

Accelerating science and innovation

Societal benefits of European research in particle physics

The European Strategy for Particle Physics

Update 2013

Prepared by the European Strategy Group for Particle Physics for the special European Strategy Session of Council in Brussels on 30 May 2013.

Preamble

Since the adoption of the European Strategy for Particle Physics in 2006, the field has made impressive progress in the pursuit of its core mission, elucidating the laws of nature at the most fundamental level. A giant leap, the discovery of the Higgs boson, has been accompanied by many experimental results confirming the Standard Model beyond the previously explored energy scales. These results raise further questions on the origin of elementary particle masses and on the role of the Higgs boson in the more fundamental theory underlying the Standard Model, which may involve additional particles to be discovered around the TeV scale. Significant progress is being made towards solving long-standing puzzles such as the matter-antimatter asymmetry of the Universe and the nature of the mysterious dark matter. The observation of a new type of neutrino oscillation has opened the way for future investigations of matter-antimatter asymmetry in the neutrino sector. Intriguing prospects are emerging for experiments at the overlap with astroparticle physics and cosmology. Against the backdrop of dramatic developments in our understanding of the science landscape, Europe is updating its Strategy for Particle Physics in order to define the community's direction for the coming years and to prepare for the long-term future of the field.

General issues

a. The success of the LHC is proof of the effectiveness of the European organizational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN. *Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.*

b. The scale of the facilities required by particle physics is resulting in the globalisation of the field. *The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.*

High priority large-scale scientific activities

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

c. The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC,* *including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

d. To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available. *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.*

e. There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. *Europe looks forward to a proposal from Japan to discuss a possible participation.*

f. Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.*

Other scientific activities essential to the particle physics programme

g. Theory is a strong driver of particle physics and provides essential input to experiments, witness the major role played by theory in the recent discovery of the Higgs boson, from the foundations of the Standard Model to detailed calculations guiding the experimental searches. *Europe should support a diverse, vibrant theoretical physics programme, ranging from abstract to applied topics, in close collaboration with experiments and extending to neighbouring fields such as astroparticle physics and cosmology. Such support should extend also to high-performance computing and software development.*

h. Experiments studying quark flavour physics, investigating dipole moments, searching for charged-lepton flavour violation and performing other precision measurements at lower energies, such as those with neutrons, muons and antiprotons, may give access to higher energy scales than direct particle production or put fundamental symmetries to the test. They can be based in national laboratories, with a moderate cost and smaller collaborations. *Experiments in Europe with unique reach should be supported, as well as participation in experiments in other regions of the world.*

i. The success of particle physics experiments, such as those required for the high-luminosity LHC, relies on innovative instrumentation, state-of-the-art infrastructures and large-scale data-intensive computing. *Detector R&D programmes should be supported strongly at CERN, national institutes, laboratories and universities. Infrastructure and engineering capabilities for the R&D programme and construction of large detectors, as well as infrastructures for data analysis, data preservation and distributed data-intensive computing should be maintained and further developed.*

j. A range of important non-accelerator experiments take place at the overlap of particle and astroparticle physics, such as searches for proton decay, neutrinoless double beta decay and dark matter, and the study of high-energy cosmic-rays. These experiments address fundamental questions beyond the Standard Model of particle physics. The exchange of information between CERN and ApPEC has progressed since 2006. *In the coming years, CERN should seek a closer collaboration with ApPEC on detector R&D with a view to maintaining the community's capability for unique projects in this field.*

k. A variety of research lines at the boundary between particle and nuclear physics require dedicated experiments. *The CERN Laboratory should maintain its capability to perform unique experiments. CERN should continue to work with NuPECC on topics of mutual interest.*

Organizational issues

l. Future major facilities in Europe and elsewhere require collaboration on a global scale. *CERN should be the framework within which to organise a global particle physics accelerator project in Europe, and should also be the leading European partner in global particle physics accelerator projects elsewhere. Possible additional contributions to such projects from CERN's Member and Associate Member States in Europe should be coordinated with CERN.*

m. A Memorandum of Understanding has been signed by CERN and the European Commission, and various cooperative activities are under way. Communication with the European Strategy Forum on Research Infrastructures (ESFRI) has led to agreement on the participation of CERN in the relevant ESFRI Strategy Working Group. The particle physics community has been actively involved in European Union framework programmes. *CERN and the particle physics community should strengthen their relations with the European Commission in order to participate further in the development of the European Research Area.*

Wider impact of particle physics

n. Sharing the excitement of scientific discoveries with the public is part of our duty as researchers. Many groups work enthusiastically in public engagement. They are assisted by a network of communication professionals (EPPCN) and an international outreach group (IPPOG). For example, they helped attract tremendous public attention and interest around the world at the start of the LHC and the discovery of the Higgs boson. *Outreach and communication in particle physics should receive adequate funding and be recognised as a central component of the scientific activity. EPPCN and IPPOG should both report regularly to the Council.*

o. Knowledge and technology developed for particle physics research have made a lasting impact on society. These technologies are also being advanced by others leading to mutual benefits. Knowledge and technology transfer is strongly promoted in most countries. The HEPTech network has been created to coordinate and promote this activity, and to provide benefit to the European industries. *HEPTech should pursue and amplify its efforts and continue reporting regularly to the Council.*

p. Particle physics research requires a wide range of skills and knowledge. Many young physicists, engineers and teachers are trained at CERN, in national laboratories and universities. They subsequently transfer their expertise to society and industry. Education and training in key technologies are also crucial for the needs of the field. *CERN, together with national funding agencies, institutes, laboratories and universities, should continue supporting and further develop coordinated programmes for education and training.*

Concluding recommendations

q. This is the first update of the European Strategy for Particle Physics. It was prepared by the European Strategy Group based on the scientific input from the Preparatory Group with the participation of representatives of the Candidate for Accession to Membership, the Associate Member States, the Observer States and other organizations. Such periodic updates at intervals of about five years are essential. *Updates should continue to be undertaken according to the principles applied on the present occasion. The organizational framework for the Council Sessions dealing with European Strategy matters and the mechanism for implementation and follow-up of the Strategy should be revisited in the light of the experience gained since 2006.*

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Observations of the Director-General

Introduction

After the excellent first LHC run period (Run I), CERN moved into a phase of extensive maintenance and consolidation work for the machine, detectors and infrastructure in 2013. This long shutdown for the LHC and its injector chain, which is now coming to an end on schedule, is preparing CERN to enter the next exciting LHC run period at high energy and increasing luminosity in the years 2015 to 2018.

In line with the European Strategy for Particle Physics, CERN is also enhancing its efforts on focused R&D at the high-energy frontier. These initiatives include the launch of the Future Circular Collider (FCC) study, including the option for a Higher-Energy LHC (HE-LHC), and the kick-off event for this study took place in Geneva in February 2014. The aim is for CERN to be in a position, at the time of the next European Strategy Update, to take on major roles in new emerging and truly global projects beyond 2030, i.e. beyond the lifetime of the LHC and its luminosity upgrade.

During the upcoming period, covered by this MTP, CERN will pursue its diversification activities by supporting a world-class fixed-target programme, including a neutrino physics platform to be established at CERN. Subject to adequate external manpower being made available, the Management proposes to start integration of the Test Storage Ring (TSR) at HIE-ISOLDE, a new facility that will provide unique opportunities.

Following an extensive review of the High Luminosity LHC (HL-LHC) project in autumn 2013, this year's MTP includes a more quantitative long-term outlook up to 2025, i.e. incorporating the construction and commissioning of the HL-LHC and the completion of the detector upgrades by the end of Long Shutdown 3 (LS3), scheduled for the years 2023 to 2025.

For the MTP period, the scientific programme will comprise the ongoing projects described in detail in the Annual Progress Report and the fact sheets, fully in line with the updated European Strategy for Particle Physics. The presentation of the R&D and Projects programme has been updated accordingly in order to show the priorities more clearly:

1. Exploit the full potential of the LHC and the high-luminosity upgrade project of the accelerator and experiments. This includes the R&D, construction and commissioning of the HL-LHC and CERN's share as the host Laboratory towards the Phase 2 upgrade of the detectors until 2025 and operation of HL-LHC thereafter.
2. Position and maintain CERN as the Laboratory at the energy frontier through accelerator design studies and a vigorous accelerator R&D programme. This includes reviving core technologies such as superconducting RF cavities and superconducting magnet R&D as well as alternative acceleration concepts. These initiatives will prepare CERN to bid for a future large project in particle physics. In addition to the Compact Linear Collider (CLIC) collaboration and participation in the International Linear Collider (ILC) study, the international FCC study has been launched and is included in this MTP.
3. Develop a neutrino programme to pave the way for a substantial European role in a future long-baseline experiment. This MTP proposes the establishment of a neutrino platform at CERN by enhancing the North Area to allow for R&D for neutrino physics detectors (notably based on liquid argon technology).
4. Broaden the vibrant and unique fixed-target programme. The Management is committed to completing the initial phase of the HIE-ISOLDE construction, the ELENA project including the necessary consolidation of the AD facility, the commissioning of NA62 and n_TOF-EAR2. The financial plan also earmarks the estimated funding needed to implement the TSR at HIE-ISOLDE subject to the availability of adequate manpower, which will have to be provided by the collaboration and external institutes.

1) The Plan for the LHC

The research programme until around 2035 is primarily driven by the full exploitation of the LHC's physics potential broken down in the following timeline.

- The LHC long shutdown in 2013-2014 (LS1) is progressing according to schedule and includes the repair and consolidation of the inter-magnet copper stabilisers, the installation of the pressure rupture disks (DN200), an exchange of main magnets to ensure operation at high energy and overall consolidation of the LHC injectors, its technical infrastructure, the machine and detectors (as described in fact sheets 1 to 7).

  Physics operation will resume in 2015 following an initial period of commissioning. In the years 2015 to 2018 (LHC Run II), the LHC will be operated starting with an initial energy of 6.5 TeV/beam to deliver physics data quickly, limiting the number of retraining quenches, and will be progressively increased to 7 TeV/beam with increased intensities and luminosities. Short technical stops are scheduled for the end of each year.

- During the next long shutdown in 2018-2019 (LS2), it is planned to connect LINAC4, complete the PS Booster energy upgrade and extensively reconfigure radiofrequency systems in the SPS (LHC injectors upgrade, LIU), as well as finalising the enhancement of the collimation system and carry out LHC detector improvements.
- LS2 will be followed by the LHC Run III until about 2022.
- Maintenance and improvements will need to be carried out after Run III in 2023, including modifications to components in the insertion regions of the machine, whose performance will have deteriorated due to radiation effects, such as the inner triplet quadrupole magnets. For this reason, this MTP and its financial long-term outlook include the construction of the HL-LHC and CERN's share towards the mandatory LHC detector upgrades in the years 2023 to 2025. Among the many improvements brought by the HL-LHC upgrade, superconducting magnet studies and developments are in progress to provide magnetic fields of about 11 T in dipoles (for new collimation in the DS region) and 13 T equivalent (nominal gradient of 140 T.m) in quadrupoles of large aperture (150 mm) to allow for low-beta inner triplets. Improvements on the cryogenics, collimation and RF systems for integrated luminosity maximisation are also planned.
- The HL-LHC upgrade is expected to be partly funded by important external contributions in the framework of an international collaboration as shown in the anticipated revenues in Figure 1. It should be noted that the availability of personnel to ensure, simultaneously, the operation of the machine run, the maintenance of the LHC and its infrastructure as well as the construction of items for the luminosity upgrade will be particularly challenging.
- This high-luminosity upgrade HL-LHC will allow the LHC to reach a peak luminosity of 5×10^{34} $cm^{-2}s^{-1}$ (ultimate 7×10^{34} $cm^{-2}s^{-1}$) and an integrated luminosity of 250 fb^{-1} per year (ultimate 300 fb^{-1} per year), more than five times the annual integrated luminosity that will be achieved before 2023. This performance will make it possible to accumulate a total integrated luminosity of some 3000 fb^{-1} (on tape) by 2035, in line with the highest-priority item of the European Strategy for Particle Physics.

2) High-Energy Frontier

The two most promising lines of accelerator development are proton-proton and electron-positron colliders. In line with the European Strategy's second highest priority, CERN has launched the FCC study in addition to its leading role in the CLIC collaboration and participation in the ILC.

The main emphasis of the FCC conceptual design study will be the long-term goal of a hadron collider with a centre-of-mass energy of the order of 100 TeV (FCC-hh) in a new tunnel of 80-100 km circumference for the purposes of studying physics at the high-energy frontier. The corresponding hadron injector chain will be included in the study, taking into account the existing CERN accelerator infrastructure and long-term accelerator operation plans.

The FCC study will also cover the performance and cost analysis of a HE-LHC, housed in the LHC tunnel, and based on the same high-field magnet technology as the FCC-hh collider.

As a potential intermediate step, the FCC study will also include a high-luminosity electron-positron collider (FCC-ee), operating at centre-of-mass energies up to 350 GeV, and examine options for lepton-hadron scenarios (FCC-he).

The new FCC study had its official launch with the kick-off meeting in Geneva in February 2014, aiming to establish an international collaboration and looking forward to obtaining contributions in cash and in kind, especially concerning the availability of experts in sufficient numbers.

Studies and R&D for very high field superconducting magnets for FCC will be a natural continuation of developments in the context of LHC upgrades (HL-LHC) and will fully exploit the available synergies. The need to retain and develop competencies in the field of high-gradient and high-power superconducting RF systems is also addressed in this MTP. The following technological developments will be required:

- developing superconducting magnet technology beyond HL-LHC requirements. Long-term objectives will be the production of short-magnet models reaching 16 T, as well as demonstrating 20 T magnet technology of collider quality, based on new types of superconductors;
- optimising the technology for large superconducting RF systems determining the optimum cavity technology, balancing complexity and power consumption of the cryogenic system against the difficulty of reliably reaching large quality factors and accelerating gradients.

This MTP presents dedicated fact sheets relating to superconducting RF and superconducting magnet R&D. These fact sheets cover generic requirements relating to the installation, upgrade, operation and maintenance of the necessary infrastructure for material testing and characterisation, as well as to exploring alternatives for material, design and fabrication techniques in these key technologies. Applications of these technologies could, for example, be in superconducting proton linacs, for which CERN has ongoing collaborations and obligations towards the European Spallation Source (ESS) *inter alia*.

The resources headings for these R&D activities and the FCC study are to be understood as global headings, for which some materials to personnel transfer will be needed.

Options for linear electron-positron colliders include CLIC and ILC. CLIC, for which a Conceptual Design Report has already been published, could, in stages, reach a centre-of-mass energy up to 3 TeV. The ILC Technical Design Report has been completed and the Japanese particle physics community has launched an initiative to host such a facility in Japan. CERN, together with national institutes, laboratories and universities in Europe, looks forward to a proposal from Japan to discuss possible participation.

R&D for CLIC will continue in parallel, with emphasis on synergies with the ILC. It should be emphasised that a choice between CLIC and FCC will have to be made by the time of the next European Strategy Update around 2018/2019 in order for the next large-scale facility to embark upon the corresponding project phase. For that reason, these activities are merged under a single heading after the MTP period in the long-term plan.

CERN is supporting and providing its share of funding for the AWAKE Collaboration, which has the aim of demonstrating proton-driven plasma wakefield acceleration as a possible technology that could lead to future colliders of high energy but of a much reduced length compared to currently proposed linear accelerators. AWAKE will use the SPS proton beam at the location of the former CNGS facility. First protons are expected to be delivered to the AWAKE experiment at the end of 2017 and this will be followed by an initial 3-to-4 year experimental programme.

3) Neutrino Platform

Following the European Strategy Update, CERN is also committed to developing a neutrino programme, namely the neutrino platform to pave the way for a substantial European role in a future long-baseline experiment. For this reason, the Management proposes, in this MTP, to enhance and consolidate the existing North Area to allow not only for continued operation of test beams but also to enable dedicated detector R&D for neutrino physics (starting with liquid argon detectors) which could be used in neutrino experiments in the US and Asia. The Management is actively pursuing discussions with US laboratories, particularly Fermilab, to form an umbrella-collaboration for a long-term neutrino programme. The long-term strategy is to allow for an important European role in future long- and, possibly, short-baseline experiments at Fermilab.

4) Fixed-target programme

The fixed-target programmes at the PS Booster (ISOLDE), PS (AD, East Area and n_TOF) and SPS (North Area) will restart this year in June, July and October, respectively.

The Management confirms its support for CERN’s unique, world-class fixed-target programme, which consists of existing or approved experiments at the SPS, PS, AD, n_TOF and ISOLDE. The Management also proposes to install the TSR at HIE-ISOLDE, which will open up unique physics opportunities, provided that adequate external manpower is made available.

5) Reliable and Safe Infrastructure

This MTP is in line with the updated European Strategy for Particle Physics and addresses all CERN’s areas of activity as well as its services, from science and engineering to infrastructure and user-friendliness, aimed at achieving the goals mentioned in the previous four sections. Due to the limited financial resources, the primary focus is clearly on the LHC programme, which requires a reliable and safe infrastructure.

Consolidation of the technical infrastructure, including the accelerator chain, the experimental areas and detectors, and the general infrastructure, is urgently needed. The minimum amounts are ring-fenced in this MTP.

In order to allow for reliable operation of the fixed-target programme, the minimum consolidation requirements of the AD facility, the East Hall and the North Area have been earmarked for funding.

6) Financial Considerations

This MTP differs from last year’s MTP in that it includes the estimated full cost of constructing the HL-LHC and LIU as well as CERN’s share towards the LHC detector upgrades. As this upgrade is scheduled to be completed during LS3 from 2023 to 2025, the financial outlook ends after that period and before the period of operation of the HL-LHC.

The funds needed to arrive at a conceptual design report for the FCC study by the time of the next European Strategy Update, around 2018/2019, and for the implementation of the neutrino platform have been allocated.

Due to the limited financial resources, only part of the urgently-needed funding for the consolidation of the North Area, the East Hall and the AD facility could be allocated. The same applies for the maintenance and repair of the technical and general infrastructure. The need for additional buildings due to increasing space requirements can be partially fulfilled through the creation of some swing spaces. More details are given in fact sheet 20.

In response to the discussion in the Council and its Committees in June 2013, the revenues forecast includes a realistic assumption for new Associate Member States and targets for non-Member State contributions to HL-LHC construction.

The Management is committed to minimising, whenever possible, the cumulative budget deficit and to providing a rolling reporting on the deficit to the Council and its Committees. CERN showed it was capable of reducing a cumulative deficit corresponding to a full year's budget nearly to zero by the end of 2012. Now, with the start of the new HL-LHC project and without increasing Member State contributions, the deficit will increase again.

Important budget expenses are linked to CERN's obligation to fund post-employment benefits, which must be presented in a transparent way. In addition, some infrastructure expenses were funded in the past based on long-term loans (such as buildings, water piping, etc.), involving long-term capital repayment plans. These obligations for capital repayment and for ensuring the stability of CERN's social security system amount to some 8% of the Budget.

In order to limit the unavoidable increase of the cumulative budget deficit, the Management has imposed a 10% cut on the most important construction projects with respect to the reviewed Cost-to-Completion for HL-LHC, LIU and CERN's share of LHC detector upgrades (Phase 1 and Phase 2). Furthermore, operational expenses for goods, consumables and services are under scrutiny with a view to implementing a 5% cut on operations and finding a balance between operational reliability and a sufficient service level under a financial plan which is acceptable to the Member States.

Variations with respect to last year's MTP can be attributed to:

- Additional revenues anticipated from new Associate Member States.
- Adjusted construction estimates for HL-LHC and LIU construction and CERN's share of the LHC detector upgrade, with a limitation on the Cost-to-Completion and without additional personnel.
- Launch of the FCC study and focused accelerator R&D aiming for an international collaboration comprising materials and personnel contributions.
- Implementation of CERN's neutrino platform.
- Ring-fenced funding for technical and general infrastructure repairs and refurbishments, as well as some limited funding for urgently required swing space. This includes some earmarked funding for the North Area, East Hall and AD facility consolidations.
- Funding of CERN's share of HIE-ISOLDE, ELENA, and possibly integration of the TSR at HIE-ISOLDE.
- Scrutinising, de-scoping and therefore cutting materials expenses for operation activities and services by about 5% to constrain as far as possible the unavoidable increase of the cumulative deficit.

7) Additional Information on Possible Budget Scenarios

During the discussion of the MTP White Paper in the SPC, questions were raised about the reasoning behind the choices that led to the financial plan presented in this document. This section provides further clarification on the Management's choices that resulted in the present financial plan:

- HL-LHC Construction versus PIC-LHC

  The most significant change with respect to last year's MTP concerns the implementation of the estimated construction costs for the HL-LHC. Whereas last year's plan only made provision for the maintenance and performance-improving consolidation of the LHC (PIC-LHC), as well as R&D expenses for HL-LHC, this year the Management presents a plan that includes the full HL-LHC construction. It should be noted that the high luminosity LHC is the only option to ensure the full exploitation of the LHC physics potential. It has also been recommended recently by the Particle Physics Project Prioritization Panel (P5) in the US and we look forward to a strong involvement on their part. Therefore, in order to implement the highest priority of the European Strategy for Particle Physics, it is essential to include, in this year's plan, the full HL-LHC construction costs and to update the LHC long-term schedule. The HL-LHC schedule and cost have been optimised as mentioned above and the Management is committed to implementing this highest priority item of the European Strategy for Particle Physics.

- High-Energy Frontier

  Given the long lead time between starting a focused R&D initiative and possible physics data taking, it is vital for CERN to reinforce its technology know-how for the two most important technologies needed for an accelerator, i.e. high-gradient RF and high-field magnet technologies. This MTP allows for focused R&D initiatives for these two core technologies, which are strongly linked to the high-energy frontier initiatives being pursued. Only with such technology options can future colliders at the high-energy frontier be studied.

  The high-energy frontier was earmarked in the European Strategy for Particle Physics as one of the high-priority large-scale scientific activities. It consists of an e^+e^- option – in either linear (ILC or CLIC) or circular collider form – and of a future hadron-hadron collider at energies higher than the LHC. Natural synergies exist among many aspects of these projects: there are connections between the R&D required for the FCC-hh and that for the HL-LHC and HE-LHC, particularly for high-field magnets.

  Reducing the Linear Collider allocation would jeopardise this high-priority activity of the European Strategy for Particle Physics. It is worth noting that the CLIC effort is also a world-wide collaboration, with agreed obligations of CERN.

  On a very limited effort basis, the FCC-he option is also being pursued based on a common R&D platform.

  All these aspects are of considerable interest to many institutes around the globe and this interest must be exploited to the full.

- Neutrino Platform

  A further priority of the European Strategy for Particle Physics is for Europe to play a major role in a future neutrino facility, most likely in the US. A large-scale neutrino facility has been recommended recently by the P5 in the US. The Management has scrutinised the neutrino physics initiatives and proposes in this MTP a neutrino platform for neutrino detector R&D whilst maintaining and enhancing CERN's key North Area role for test beams. In order for Europe to have a coherent and visible contribution to a future global long-baseline neutrino programme, this neutrino platform constitutes a vital minimum effort.

It should be noted that all large-scale programmes presented in this MTP, i.e. LHC, neutrino, LC, and the FCC study, are global in nature and are high-priority items in the European Strategy for Particle Physics as well as in the strategies of the other regions. The Management sees no potential for further savings here unless one of the priority items is cut completely.

- Diversity of Physics Programme (AD, HIE-ISOLDE, TSR)

  A diverse physics programme has been highlighted in the European Strategy for Particle Physics as being essential to the overall particle physics programme. CERN's world-leading diverse physics programme is unique, serves physics communities beyond those at the LHC and is crucial for the training of highly-qualified personnel. This programme also has natural synergies with new facilities planned elsewhere in Europe. Last year's MTP already included the programme for ELENA, requiring the consolidation of the AD complex, the construction of HIE-ISOLDE and the new experimental area for n_TOF. Issues have arisen due to additional costs as well as external contributions that were earmarked but not fully secured. Ending one of these projects would not only result in a major loss of unique physics opportunities for the low- and medium-energy particle physics community, but would also waste the investments made so far.

  From a physics point of view, an early implementation of the TSR at the HIE-ISOLDE facility would be desirable. However, given the shortage of manpower and the need to focus on the LHC programme, this revised plan proposes the completion of HIE-ISOLDE Phase 2 a year later than previously foreseen, provided external funding is secured. This implies physics exploitation of HIE-ISOLDE Phase 2 (10 MeV/n) and the integration of the TSR only after the completion of LS2. The TSR commissioning would be 2.5 years later.

  In addition to a large-scale project such as the HL-LHC, a diverse physics programme is vital for CERN and for European particle physics.

- Other R&D Activities

  In line with CERN's undertaking to support science facilities at other European laboratories, various projects have been launched within existing collaborations on various facilities, for example ESS or FAIR. Reducing the allocations to these projects would put at risk the collaboration with CERN's partners. For some of these activities, CERN receives external contributions.

  Limited funding is included for generic detector technology R&D.

  This heading also includes allocations assuming future EU-supported projects, with matching revenues.

- Medical Applications

  Applications to medical physics have an important and crucial impact directly on society. This has been underlined by several Member States who are keen to see CERN getting involved in this growing field and the Management is fully committed to continuing this activity.

- Outreach Impact

  Explanation of the long-term benefits of basic research, and of science in general, is vital, particularly in times of economic hardship. A more active approach has therefore been implemented to boost CERN's communication and outreach presence. These initiatives aim to engage the general public, address concerns and ensure understanding of the field's funding requirements.

- Training, highly-qualified personnel (HQP)

  As underlined in the European Strategy for Particle Physics, the training of highly-qualified personnel is a key area delivering a wide impact for particle physics. CERN's international and diversified work environment, combined with its leading-edge areas of expertise, is conducive to providing unique opportunities to train highly-qualified personnel. For example, over the last five years, the number of Fellows trained by CERN has essentially doubled for the following reasons:

  - the operation phase of the LHC with data analyses combined with new, focused R&D initiatives and consolidation programmes,
  - flexibility in materials-to-personnel transfers with the GET Fellowship programme in the accelerator and technology areas,
  - successful applications for EU support (e.g. COFUND Fellows, Marie Curie Early Stage Training positions, or general R&D projects).

  Cutting such opportunities would be counterproductive as these trained personnel usually return to their home countries, allowing important knowledge transfer from CERN back to the Member States, and thereby an important return on their contributions.

  In this context, it should be noted that variations on some activity headings, such as subsistence payments for scientific visitors, e.g. in the Theory Unit, are mainly due to the completion of already-signed EU supported projects. The Management is making every effort to obtain at least the same amount of support during the Horizon 2020 programme and to keep the core funding stable.

- EU Involvement

  As mentioned above, CERN has an excellent track record in securing EU support for training purposes. For procurement and other activities, it should be underlined that EU-supported funding requires the availability of matching funds. Thus, the budgetary burden of the Organization can be reduced only if EU-supported projects address work packages which are already part of the programme.

- Operation Expenses

  In order to constrain, as far as possible, the unavoidable increase of the cumulative budget deficit, a cut of 5% will be applied on all materials operation headings. This cut will have unavoidable and severe impacts on service levels and operational reliability:

  - many operation expenses are incompressible such as payments for software licenses (provided to all users), host laboratory contributions to the collaborations, energy costs, etc.,
  - reduced infrastructure maintenance risking the closure of some areas (buildings, workshops, etc.) for safety reasons,
  - fewer training opportunities for students and young scientists receiving limited financial support in the form of subsistence payments,
  - ending stand-by duties to be replaced with "best-effort" arrangements that are likely to increase down-time,
  - increasing the time between maintenance intervals, which would mean falling back into "repair mode" rather than "preventive maintenance mode",
  - longer waiting times and lower service levels for infrastructure services like equipment repairs, cleaning, handling, access, etc. and in particular cuts into user services established during the past years, which relate to CERN's task of serving the community as a whole.

The cumulative budget deficit for the period up to 2025 is primarily driven by the top-priority construction of the HL-LHC and CERN's contributions to the LHC experiment upgrades. Cuts in any other parts of the programme would not change the overall level of the deficit but would, on the other hand, severely impact an important section of the European and worldwide particle physics community and be detrimental to CERN's mission.