CERN

and

knowledge transfer for the benefit of medical applications

Frédérick Bordry
Director for Accelerators and technology
Chair of CERN Medical Applications Steering Committee (CMASC)

Innovation Education CERN uniting people Research

The Mission of CERN

- **Push back** the frontiers of knowledge

  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe's existence?

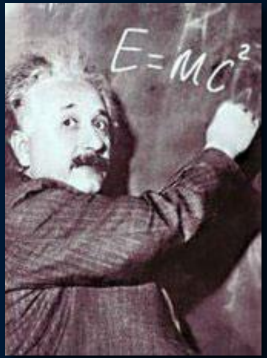
- **Develop** new technologies for accelerators and detectors

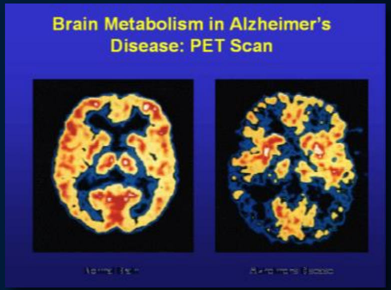
  Information technology - the Web and the GRID

  Medicine - diagnosis and therapy

- **Train** scientists and engineers of tomorrow

- **Unite** people from different countries and cultures





CERN: founded in 1954: 12 European States
Science for Peace and Development
Today: 23 Member States

~ 2600 staff
~ 1800 other paid personnel
~ 14000 scientific users

Budget (2019) ~ 1200 MCHF

Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

Associate Members in the Pre-Stage to Membership: Cyprus, Slovenia

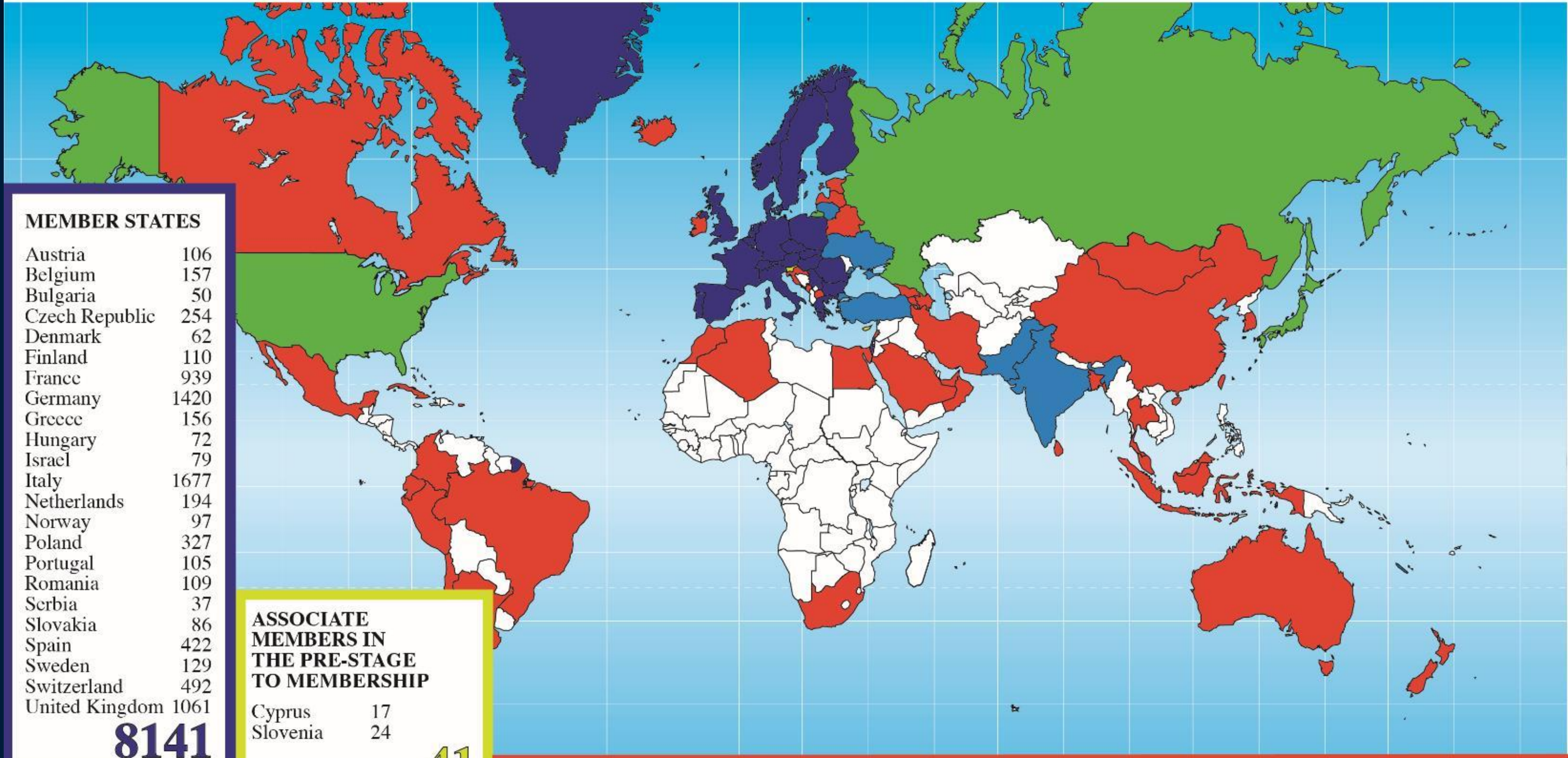
Associate Member States: India, Lithuania, Pakistan, Turkey, Ukraine

Applications for Membership or Associate Membership: Brazil, Croatia, Estonia

Observers to Council: Japan, Russia, United States of America; European Union, JINR and UNESCO

Science is getting more and more global

Distribution of All CERN Users by Location of Institute on 9 April 2019



MEMBER STATES

Austria	106
Belgium	157
Bulgaria	50
Czech Republic	254
Denmark	62
Finland	110
France	939
Germany	1420
Greece	156
Hungary	72
Israel	79
Italy	1677
Netherlands	194
Norway	97
Poland	327
Portugal	105
Romania	109
Serbia	37
Slovakia	86
Spain	422
Sweden	129
Switzerland	492
United Kingdom	1061

8141

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

Cyprus	17
Slovenia	24

41

ASSOCIATE MEMBERS **440**

India	212
Lithuania	25
Pakistan	43
Turkey	126
Ukraine	34

OBSERVERS

Japan	277
Russia	1125
USA	2073

3475

OTHERS

Algeria	3
Argentina	19
Armenia	16
Australia	30
Azerbaijan	5
Bahrain	1
Bangladesh	2
Belarus	21
Brazil	122
Canada	213
Chile	19
China	341
Colombia	27
Croatia	39
Cuba	4
Ecuador	4
Egypt	17
Estonia	18
Georgia	33
Hong Kong	20
Iceland	3
Indonesia	6
Iran	21
Ireland	11
Korea	170
Latvia	2
Lebanon	17
Malaysia	13
Malta	8
Mexico	59
Mongolia	2
Montenegro	7
Morocco	15
New Zealand	8
North Macedonia	1
Oman	4
Peru	3
Puerto Rico	1
Saudi Arabia	1
Singapore	5
South Africa	84
Sri Lanka	8
Taiwan	62
Thailand	19
U.A.E.	2

1486

High Energy Physics Roadmap:
3 pillars: based on the 2013 European Strategy for Particle Physics

Full exploitation of the LHC:

- successful operation of the nominal LHC until end 2023
- construction & installation of LHC upgrades: LIU (LHC Injectors Upgrade) and **HL-LHC**

Scientific diversity programme serving a broad community:

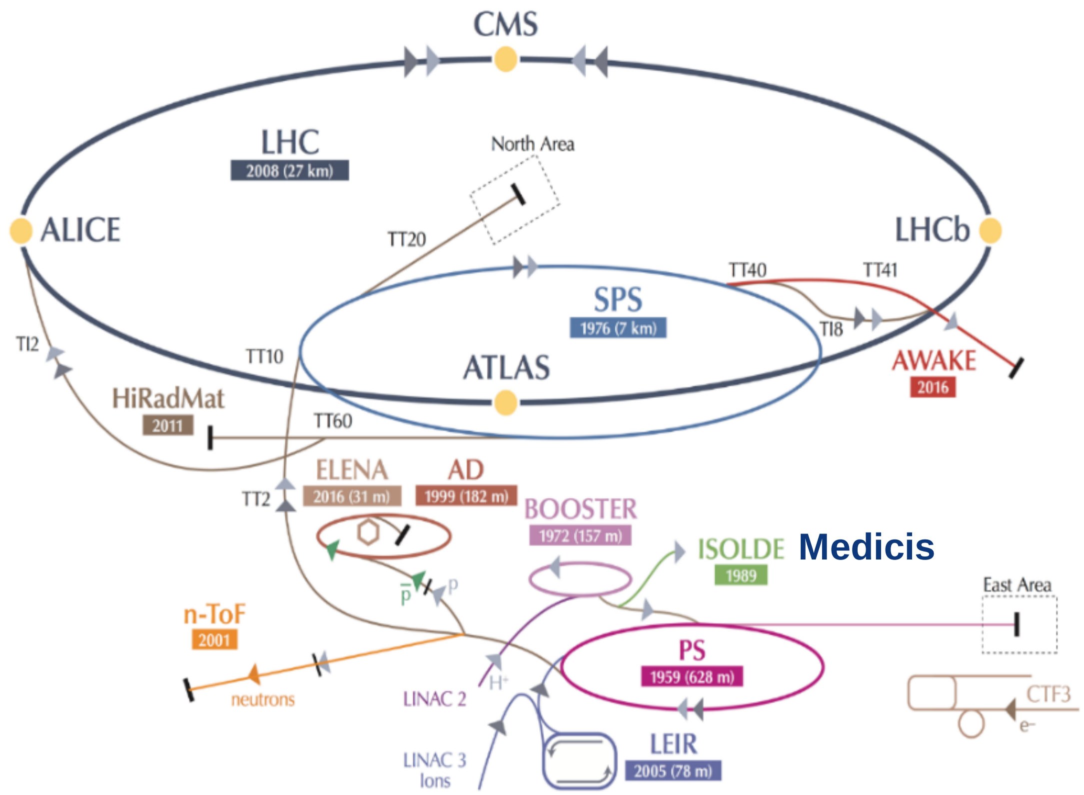
- ongoing experiments and facilities at Booster, PS, SPS and their upgrades (HIE-ISOLDE, ELENA)
- participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in the US) through CERN Neutrino Platform

Preparation of CERN's future:

- vibrant accelerator R&D programme exploiting CERN's strengths and uniqueness (including superconducting high-field magnets, plasma wakefield acceleration, etc.)
- design studies for future high-energy accelerators: **CLIC, FCC (includes HE-LHC)**
- future opportunities of diversity programme: Physics Beyond Colliders Study Group

Important milestone:
update of the European Strategy for Particle Physics (ESPP)
to be completed in May 2020

CERN's accelerators / CERN's scientific diversity programme



Medicis

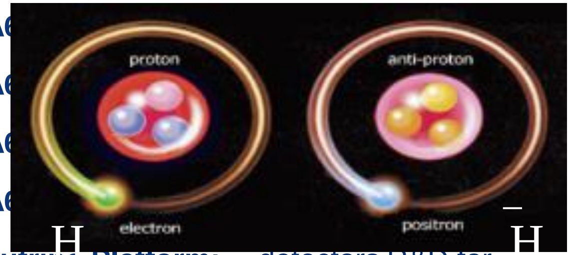
~20 experiments,
> 1200 physicists

CLOUD:
Study effect of cosmic rays on cloud formation

spectroscopy

Matter-Antimatter comparison

ISOLDE: radioactive nuclei facility



NA6

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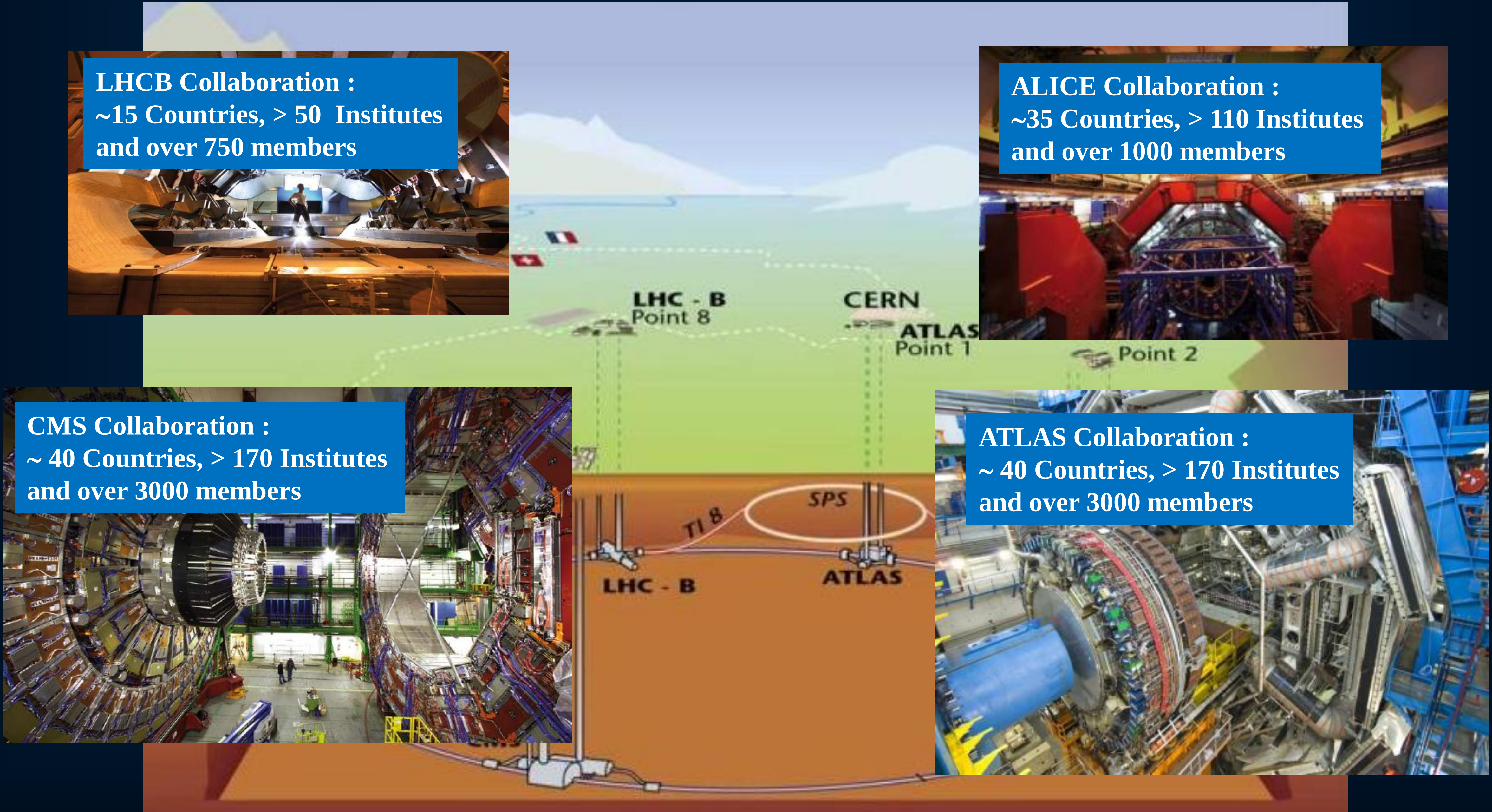
Neutrino Platform: ν detectors R&D for experiments

n-TOF: n-in

UA9: crysta

LHC: accelerator of 27 km
Four experiments: the coopetition



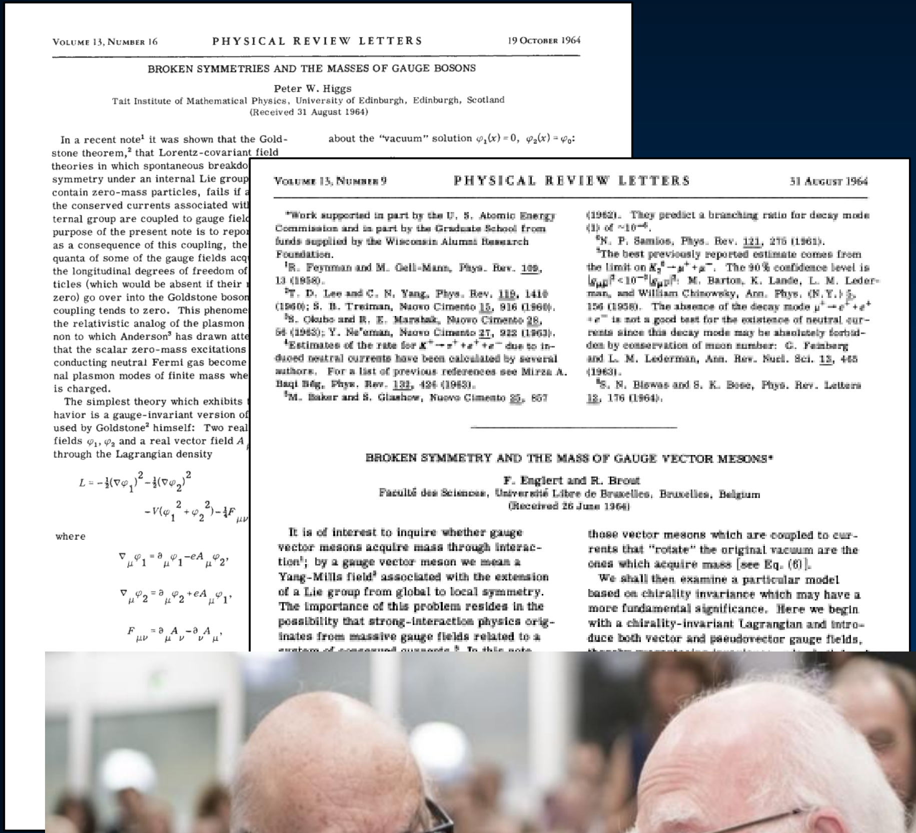
LHCB Collaboration :
~15 Countries, > 50 Institutes
and over 750 members

ALICE Collaboration :
~35 Countries, > 110 Institutes
and over 1000 members

CMS Collaboration :
~ 40 Countries, > 170 Institutes
and over 3000 members

ATLAS Collaboration :
~ 40 Countries, > 170 Institutes
and over 3000 members

From **individual** theoretical physicist **idea**….


Volume 13, Number 16 PHYSICAL REVIEW LETTERS 19 October 1964

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

In a recent note[1] it was shown that the Goldstone theorem,[2] that Lorentz-covariant field theories in which spontaneous breakdo symmetry under an internal Lie group contain zero-mass particles, fails if a the conserved currents associated wit ternal group are coupled to gauge field purpose of the present note is to repor as a consequence of this coupling, the quanta of some of the gauge fields acq the longitudinal degrees of freedom of ticles (which would be absent if their zero) go over into the Goldstone boson coupling tends to zero. This phenome the relativistic analog of the plasmon non to which Anderson[3] has drawn atte that the scalar zero-mass excitations conducting neutral Fermi gas become nal plasmon modes of finite mass whe is charged.

The simplest theory which exhibits havior is a gauge-invariant version of used by Goldstone[2] himself: Two real fields φ_1, φ_2 and a real vector field A through the Lagrangian density

$$L = -\tfrac{1}{2}(\nabla\varphi_1)^2 - \tfrac{1}{2}(\nabla\varphi_2)^2 - V(\varphi_1^2 + \varphi_2^2) - \tfrac{1}{4}F_{\mu\nu}$$

where

$$\nabla_\mu\varphi_1 = \partial_\mu\varphi_1 - eA_\mu\varphi_2,$$

$$\nabla_\mu\varphi_2 = \partial_\mu\varphi_2 + eA_\mu\varphi_1,$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu,$$

about the "vacuum" solution $\varphi_1(x) = 0$, $\varphi_2(x) = \varphi_0$:

Volume 13, Number 9 PHYSICAL REVIEW LETTERS 31 August 1964

*Work supported in part by the U. S. Atomic Energy Commission and in part by the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

[1]R. Feynman and M. Gell-Mann, Phys. Rev. 109, 13 (1958).

[2]T. D. Lee and C. N. Yang, Phys. Rev. 119, 1410 (1960); S. B. Treiman, Nuovo Cimento 15, 916 (1960).

[3]S. Okubo and R. E. Marshak, Nuovo Cimento 28, 56 (1963); Y. Ne'eman, Nuovo Cimento 27, 922 (1963).

[4]Estimates of the rate for $K^+ \to \pi^+ + e^+ + e^-$ due to induced neutral currents have been calculated by several authors. For a list of previous references see Mirza A. Baqi Bég, Phys. Rev. 132, 426 (1963).

[5]M. Baker and S. Glashow, Nuovo Cimento 25, 857 (1962). They predict a branching ratio for decay mode (1) of $\sim 10^{-6}$.

[6]N. P. Samios, Phys. Rev. 121, 275 (1961).

[7]The best previously reported estimate comes from the limit on $K_2^0 \to \mu^+ + \mu^-$. The 90 % confidence level is $|g_{\mu\mu}|^2 < 10^{-2}|g_{\mu\nu}|^2$: M. Barton, K. Lande, L. M. Lederman, and William Chinowsky, Ann. Phys. (N.Y.) 5, 156 (1958). The absence of the decay mode $\mu^+ \to e^+ + e^+ + e^-$ is not a good test for the existence of neutral currents since this decay mode may be absolutely forbidden by conservation of muon number: G. Feinberg and L. M. Lederman, Ann. Rev. Nucl. Sci. 13, 465 (1963).

[8]S. N. Biswas and S. K. Bose, Phys. Rev. Letters 12, 176 (1964).

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

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Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

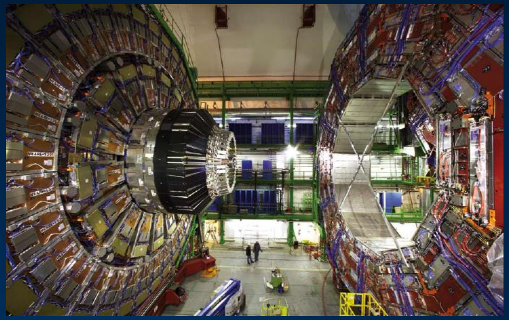
It is of interest to inquire whether gauge vector mesons acquire mass through interaction[1]; by a gauge vector meson we mean a Yang-Mills field[2] associated with the extension of a Lie group from global to local symmetry. The importance of this problem resides in the possibility that strong-interaction physics originates from massive gauge fields related to a

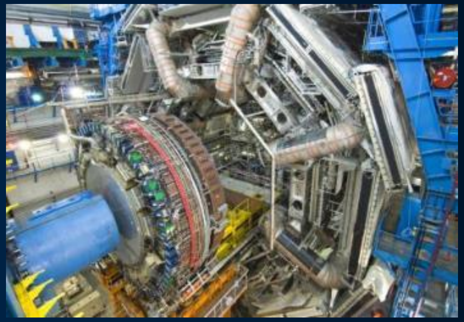
those vector mesons which are coupled to currents that "rotate" the original vacuum are the ones which acquire mass [see Eq. (6)].

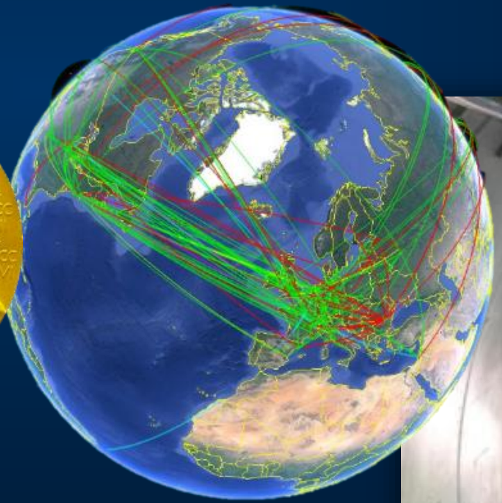
We shall then examine a particular model based on chirality invariance which may have a more fundamental significance. Here we begin with a chirality-invariant Lagrangian and introduce both vector and pseudovector gauge fields,

Discovery 2012, Nobel Prize in Physics 2013

…to **collective innovation** !







1964-2012

LHC (Large Hadron Collider)

1983	First studies for the LHC project
1988	First magnet model (feasibility)
1994	Approval of the LHC by the CERN Council
1996-1999	Series production industrialisation
1998	Declaration of Public Utility & Start of civil engineering
1998-2000	Placement of the main production contracts
2004	Start of the LHC installation
2005-2007	Magnets Installation in the tunnel
2006-2008	Hardware commissioning
2008-2009	Beam commissioning

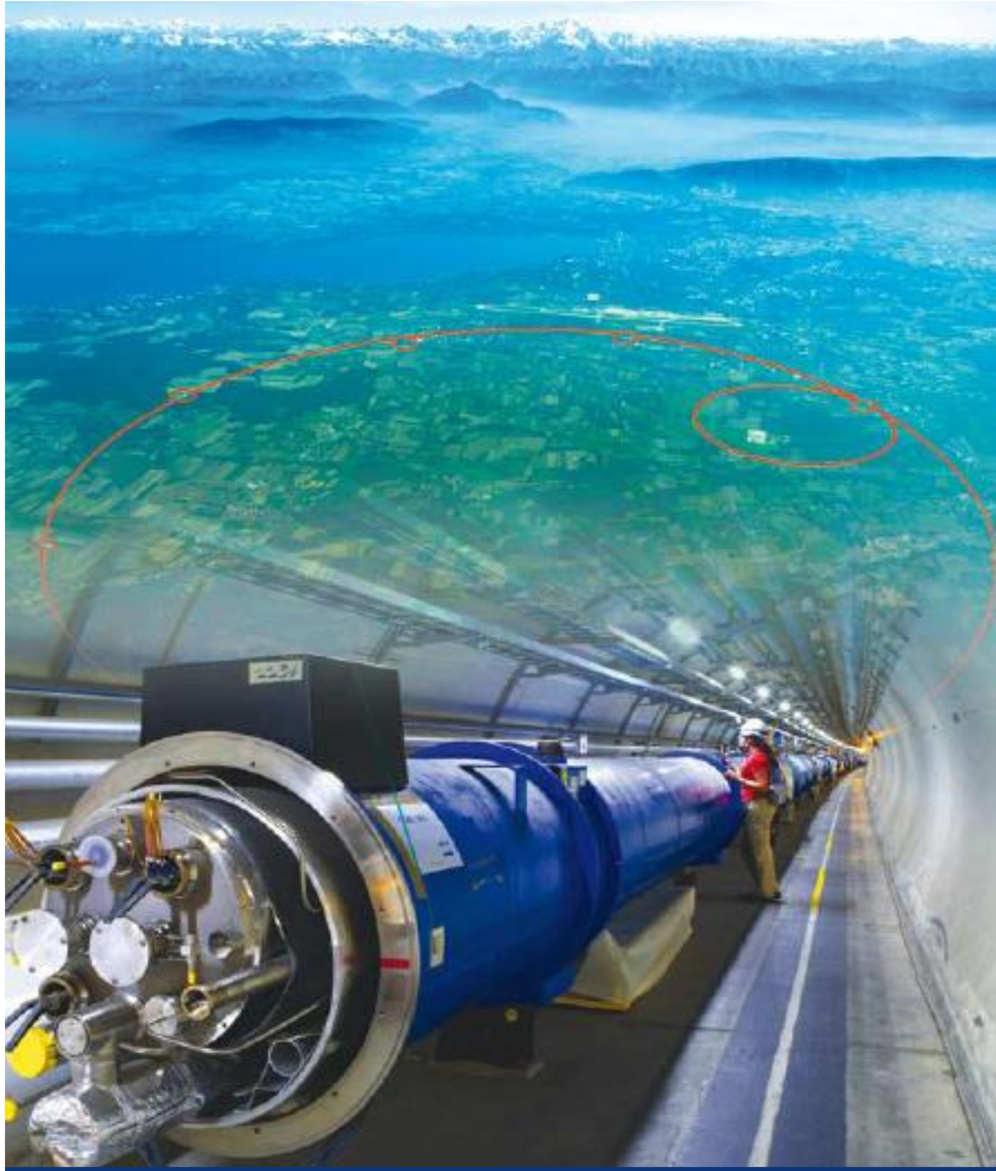
~ 25 years

2010-2037… **Physics exploitation**

2010 – 2012	Run 1 ;7 and 8 TeV
2015 – 2018	*Run 2 ; 13 TeV*
2021 – 2023	Run 3 (14 TeV)
2024 – 2025	HL-LHC installation
2026 – 2037…	HL-LHC operation

~ 30 years

HiLumi HL-LHC PROJECT



A 27 km circumference collider…

Standard Model

Only 4%

is ordinary (visible) matter

The DARK Universe

96%

~ 73% Dark Energy

~ 23% Dark Matter

DARK …. MATTERS !

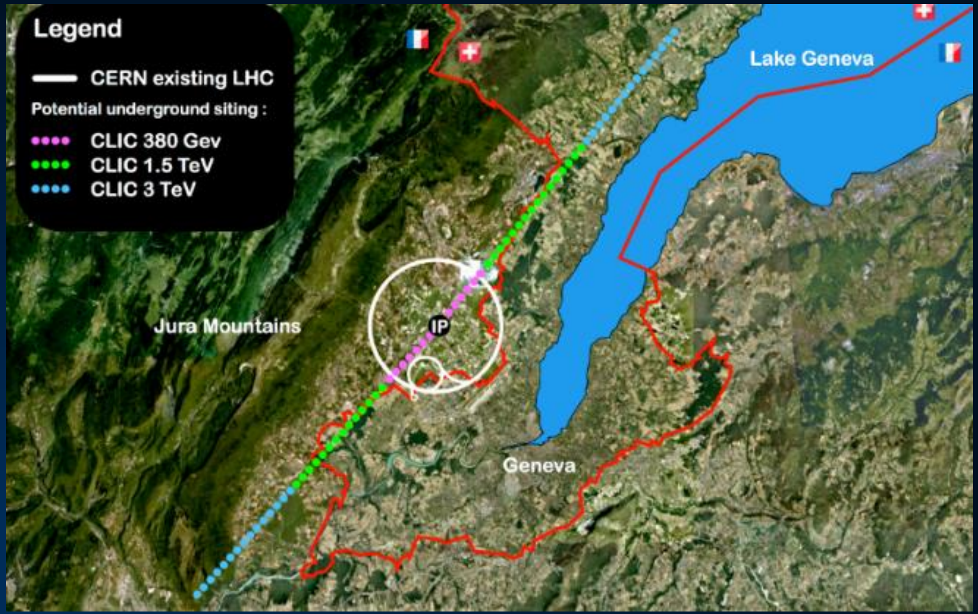
What is the cause of the Universe’s accelerated expansion (today: dark energy ? primordial: inflation ?)
Why is there so little antimatter in the universe ?
What is the origin of the matter-antimatter asymmetry in the Universe ?
What is the origin of neutrino masses and oscillations ?
How many dimensions are there in our universe?Why is Gravity so weak ?
Are there other forces in addition to the known four ?
…

Post LHC accelerator studies

Compact Linear Collider (CLIC)

Linear e^+e^- collider $\sqrt{s}$ up to 3 TeV

100 MV/m accelerating gradient needed for compact (~50 km) machine
→ based on normal-conducting accelerating structures and a two-beam acceleration scheme



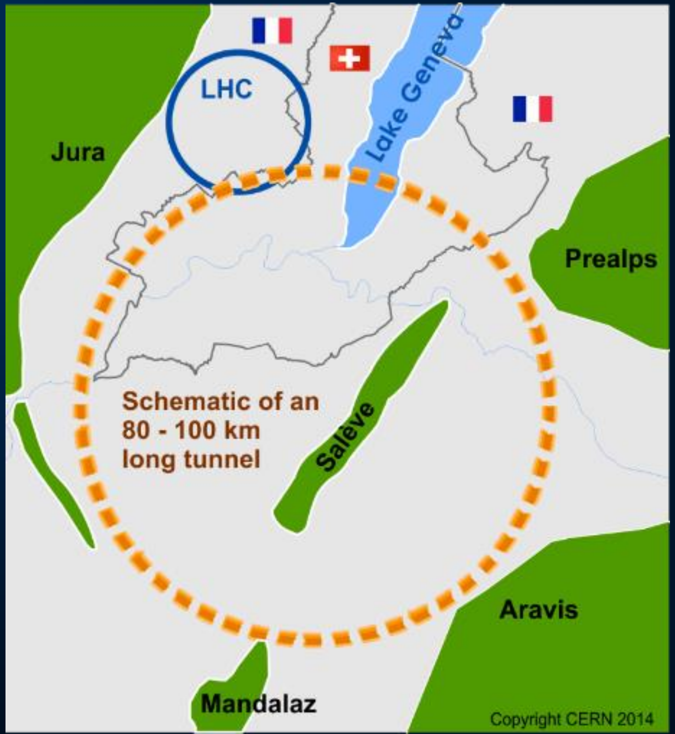
Future Circular Collider (FCC)

hh-collider (FCC-hh)
80-100 km tunnel infrastructure in Geneva area,

~16 T ⇒ 100 TeV *pp* in 100 km

- e+e- collider (FCC-ee) as potential 1st step

- HE-LHC in the present LHC tunnel with FCC-hh technology

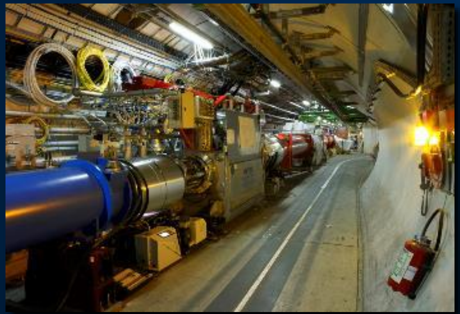


Innovation
CERN
uniting people
Education
Research

CERN: Particle Physics and Innovation

- **Interfacing** between fundamental science and key technological developments

- **CERN Technologies and Innovation**

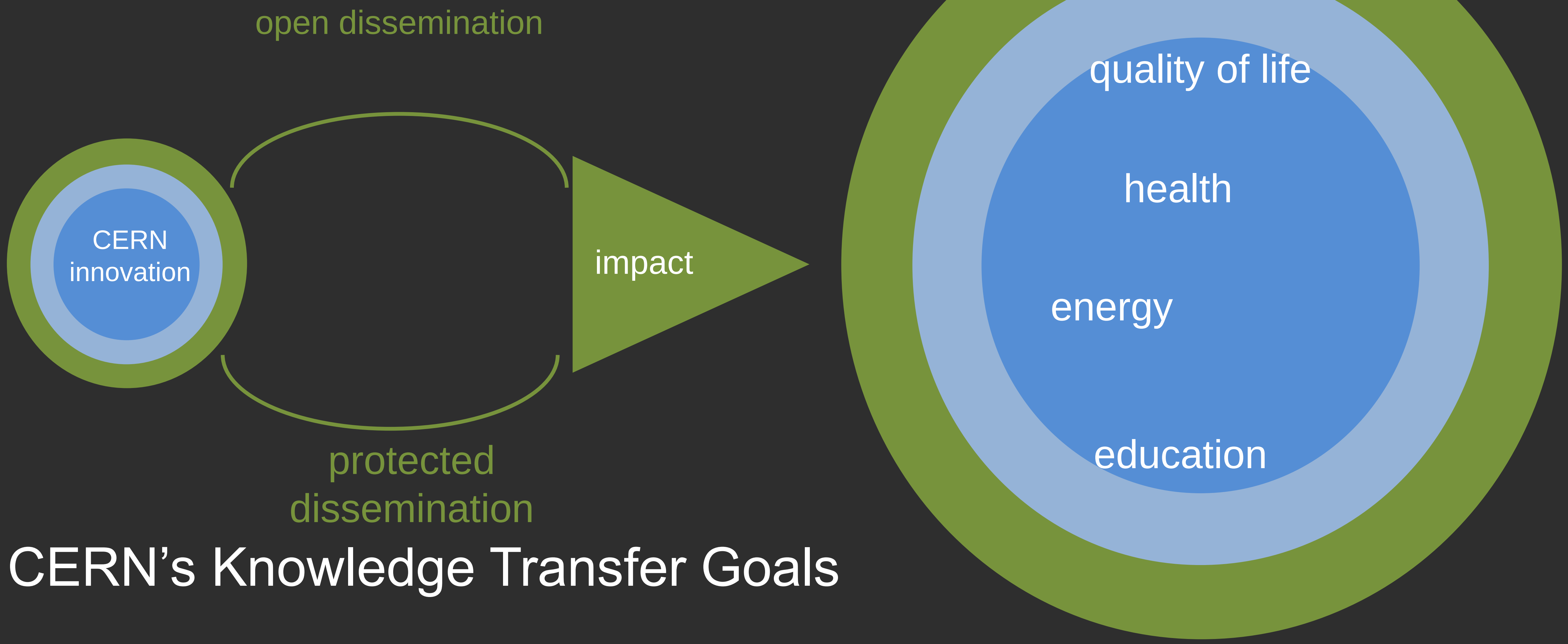


Accelerating particle beams

Detecting particles

Large-scale computing (Grid)

cern.ch/knowledgetransfer



CERN’s Knowledge Transfer Goals

The goal is to maximise the positive impact of CERN innovations on society, with the help of our partners, through both open and protected dissemination.

Knowledge Transfer

Knowledge transfer for the benefit of medical applications

CERN/SPC/1091/RA
CERN/FC/6125/RA
CERN/3311/RA
Original: English
23 May 2017

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		Voting Procedure
For information	SCIENTIFIC POLICY COMMITTEE 304th Meeting 12 & 13 June 2017	-
For information	FINANCE COMMITTEE 360th Meeting 13 & 14 June 2017	-
For approval	RESTRICTED COUNCIL 185th Session 16 March 2017	Simple majority of Member States represented and voting

Strategy and framework applicable to knowledge transfer by CERN for the benefit of medical applications

The Council is invited to approve the strategy and framework set out in this document for medical applications-related activities, and to take note of the information contained in Annexes I and II.

CERN's core mission is basic research in particle physics.

Transferring CERN's know-how and technology to other fields, and thus maximising the societal impact of the Laboratory's research, is an integral part of CERN's mission

Know-how and technologies developed by CERN in the construction of the accelerator, detector and computing infrastructure required for its research.

Strategy underlying CERN's medical applications-related activities

CERN's medical applications-related activities shall focus on R&D projects, using technologies and infrastructures that are uniquely available at CERN.

This approach seeks to minimise any duplication of research efforts taking place in CERN's Member States (MS and AMS) and to avoid overlap with the activities of external service providers, either in the market or otherwise.

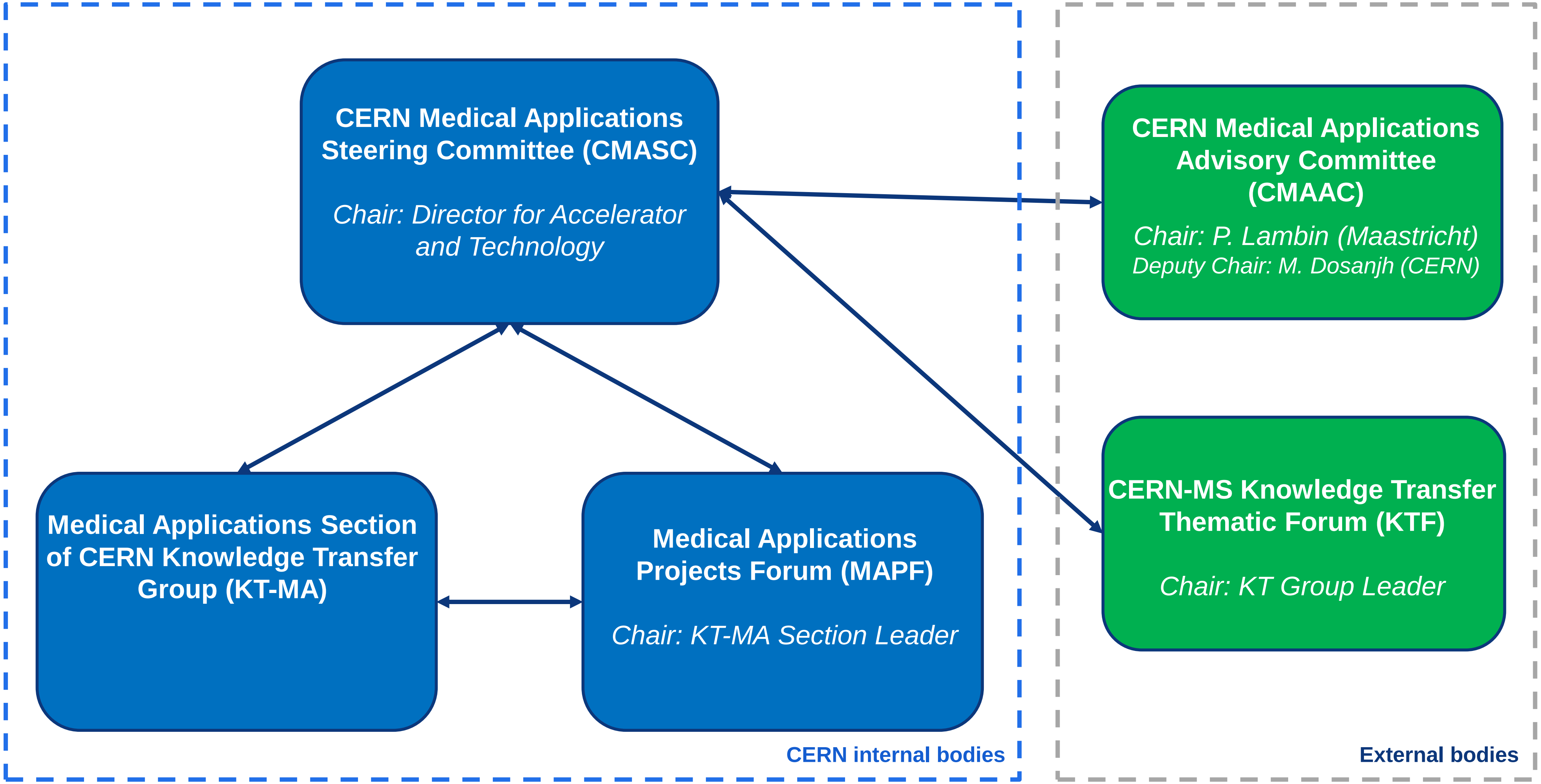
The results of this identification exercise shall be matched with the requirements of the medical research communities, in particular in CERN's MS and AMS, which must always be the drivers of CERN's engagement in this domain.

Projects shall then be identified and established, taking into account, in particular:

- the objective of maximising the impact of CERN's engagement;
- complementarities and synergies with the work in other laboratories in the MS;
- the existence of sufficient external funding to support each project;
- the availability of resources, taking into account that CERN's priority is its core mission of fundamental particle physics research.

The external stakeholders must provide the funding needed to deliver their project. CERN can provide a limited amount of seed funding for medical applications projects.

Organisational structure (established in 2016)



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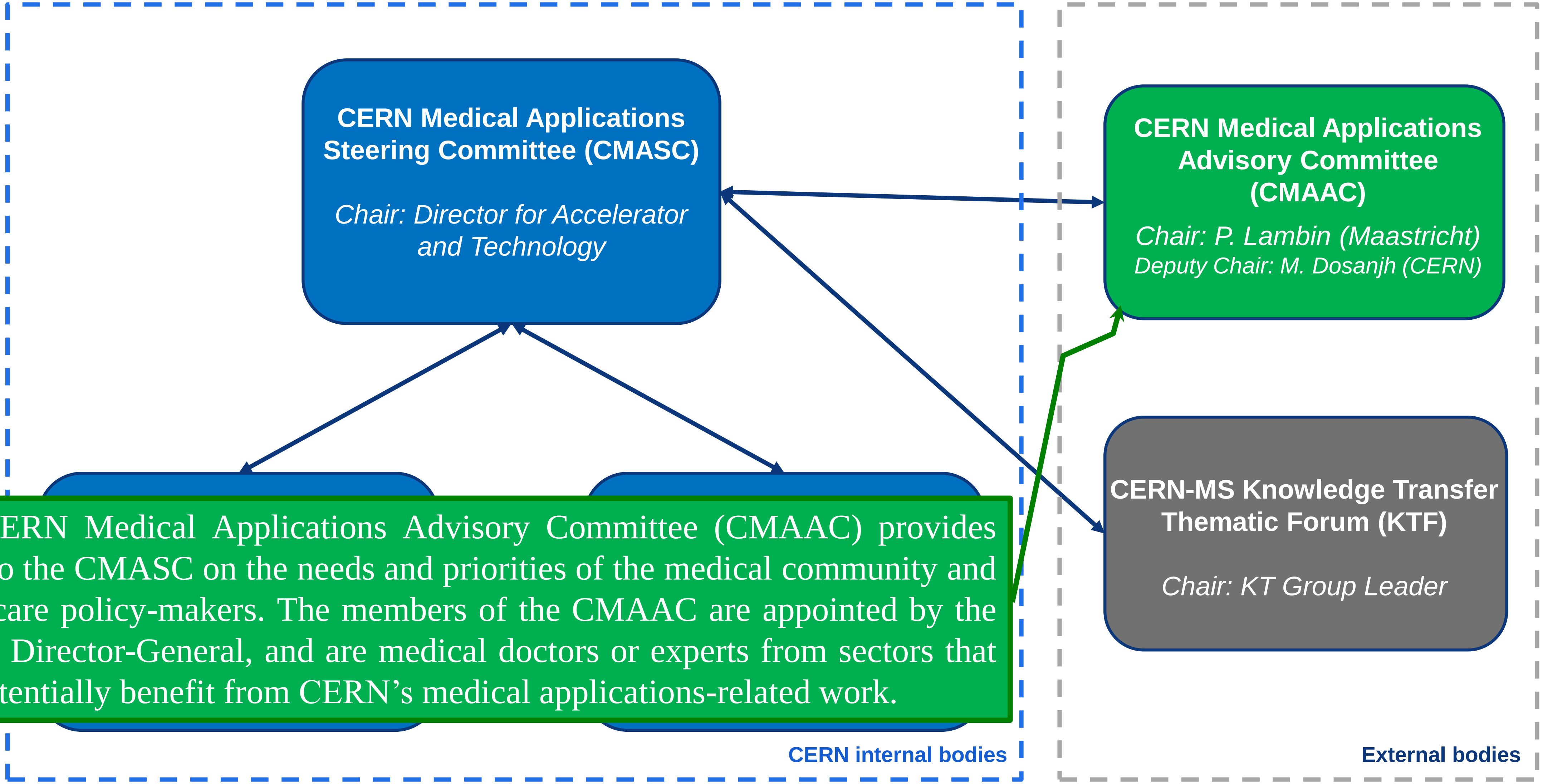


The CERN Medical Applications Advisory Committee (CMAAC) provides input to the CMASC on the needs and priorities of the medical community and healthcare policy-makers. The members of the CMAAC are appointed by the CERN Director-General, and are medical doctors or experts from sectors that can potentially benefit from CERN's medical applications-related work.

On-going medical applications-related activities

Main topics :

- MEDICIS: innovative radioisotopes for medical research
- Accelerator design for future hadron (ion) therapy facilities
- Applications of high-field superconducting magnets
- Medical imaging
- Dosimetry

Computing and simulation for health applications

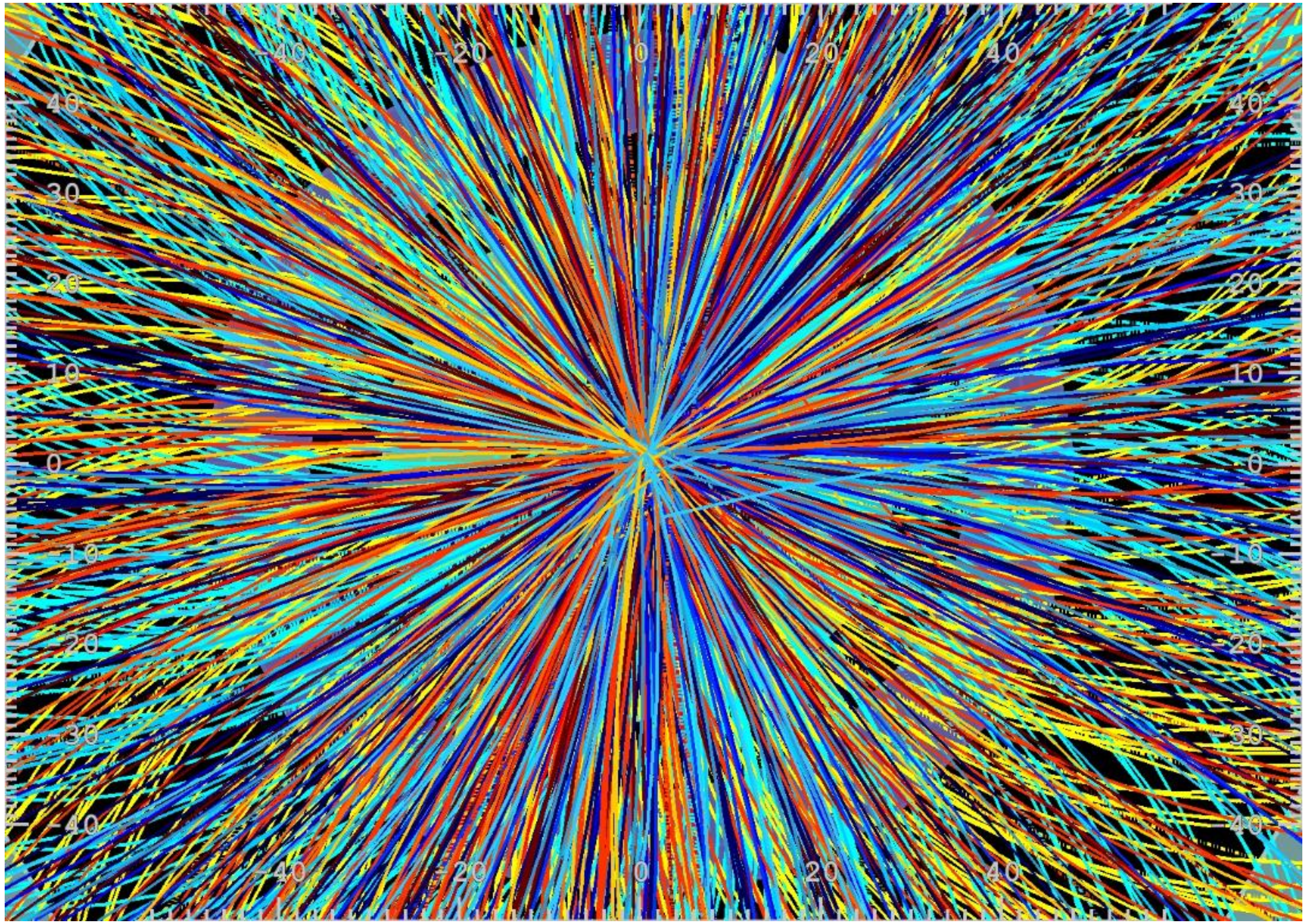
=> Big Data in Medecine

Other project: Medical linacs for challenging environments

Big data, machine learning, deep learning…

From HEP to the medical field

CERN and the
CMAAC
(CERN Medical Applications Advisory Committee)
launch the organization of a
dedicated workshop:
Big Data In Medicine:
Challenges and Opportunities



Thanks for your attention