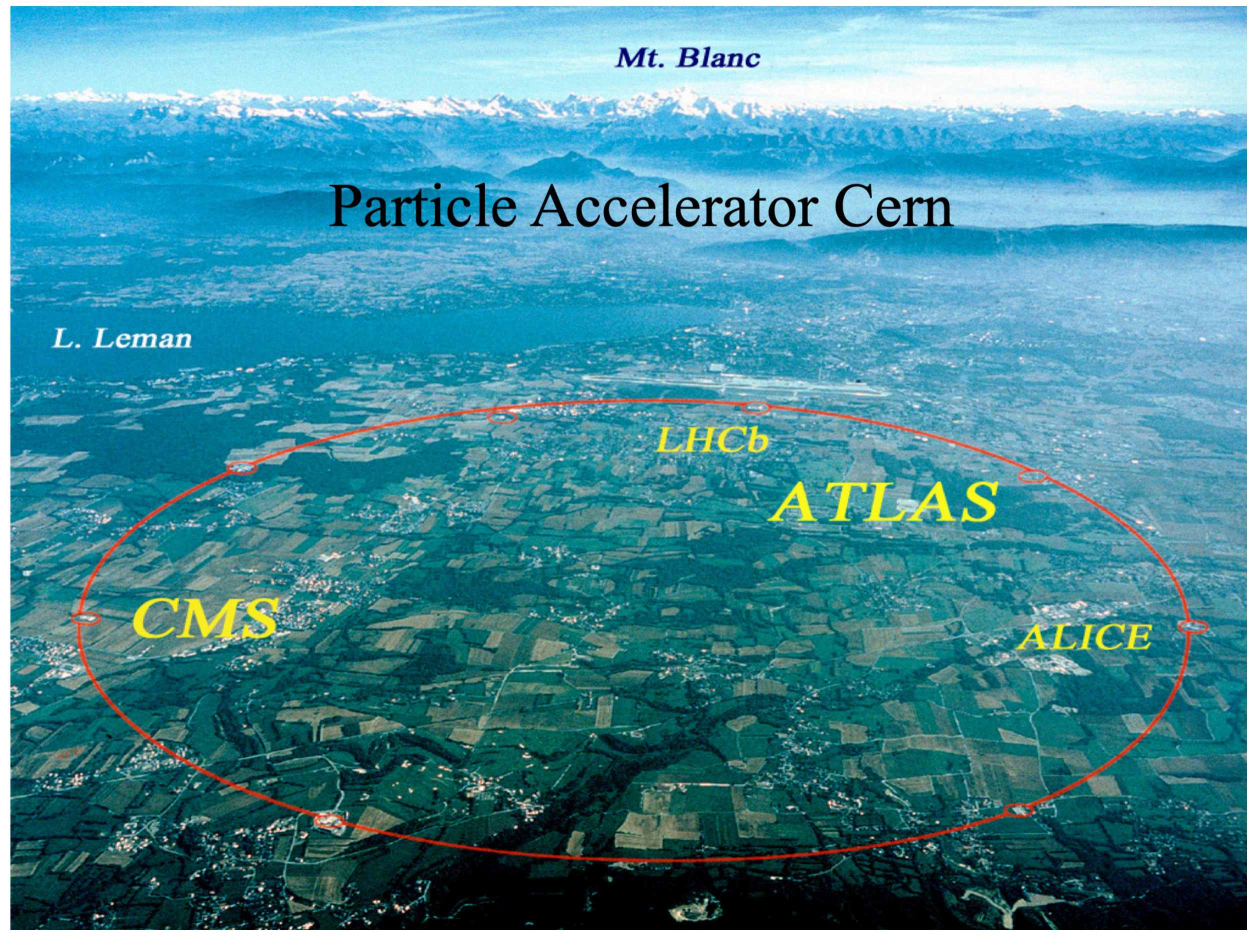
STRING 2024-WELCOME TO CERN



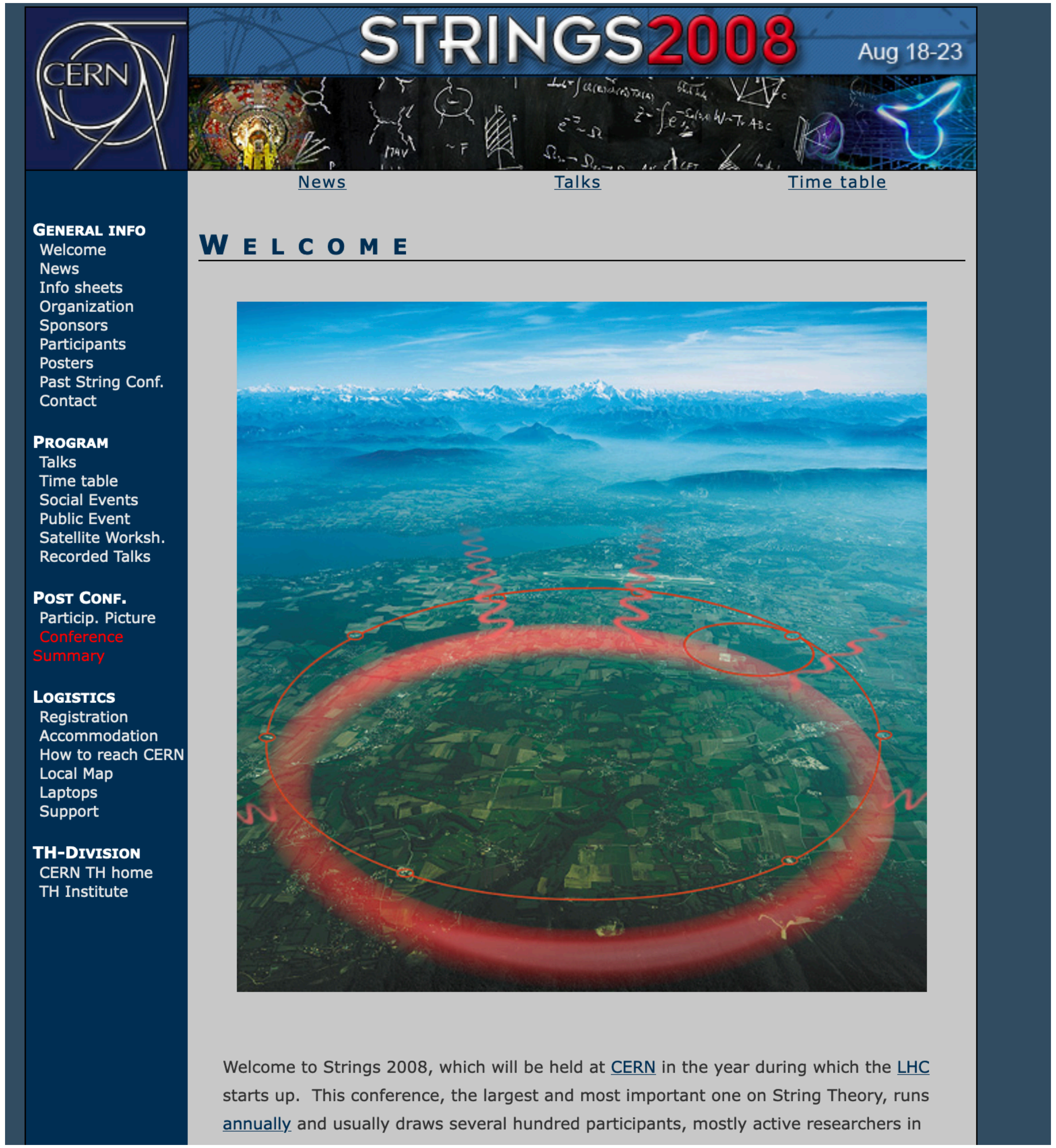
VIEW FROM THE CERN COUNCIL

ELIEZER RABINOVICI

HEBREW UNIVERSITY, JERUSALEM, ISRAEL

PRESIDENT OF THE CERN COUNCIL

STRING 2024-WELCOME TO CERN



STRING 2024-WELCOME TO CERN

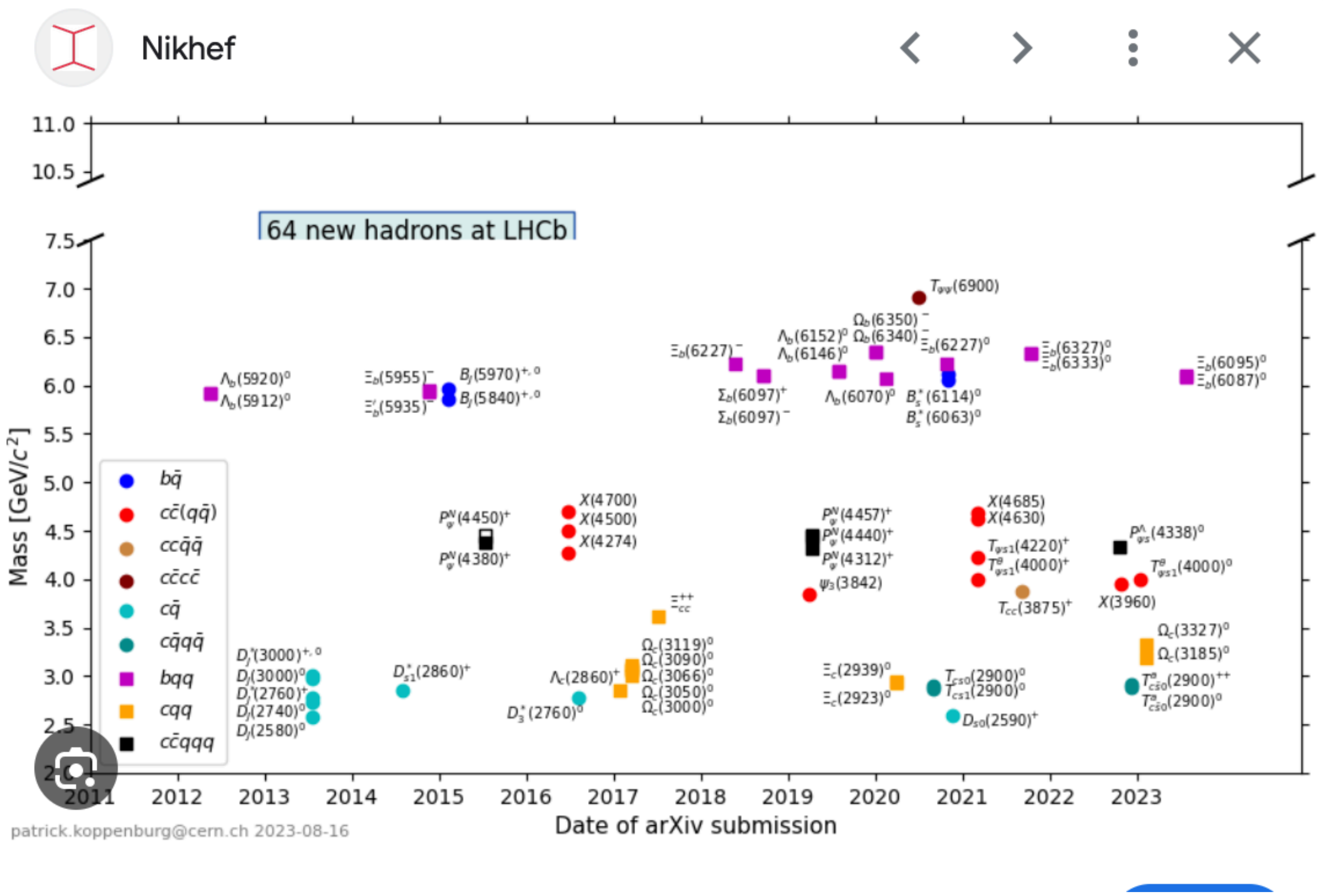
Thanks to all

the organizers

WHAT PARTICLES WERE DISCOVERED?

New fundamental particles

Counter	Experiment	Particle	Mass [GeV]	Date	Reference	Note
1.	ATLAS	Higgs Boson	126.0 ± 0.6	31 Jul 2012	Phys. Lett. B716 (2012) 1	
1.	CMS	Higgs Boson	125.3 ± 0.7	31 Jul 2012	Phys. Lett. B716 (2012) 30	



72 new so far conventional and exotic.

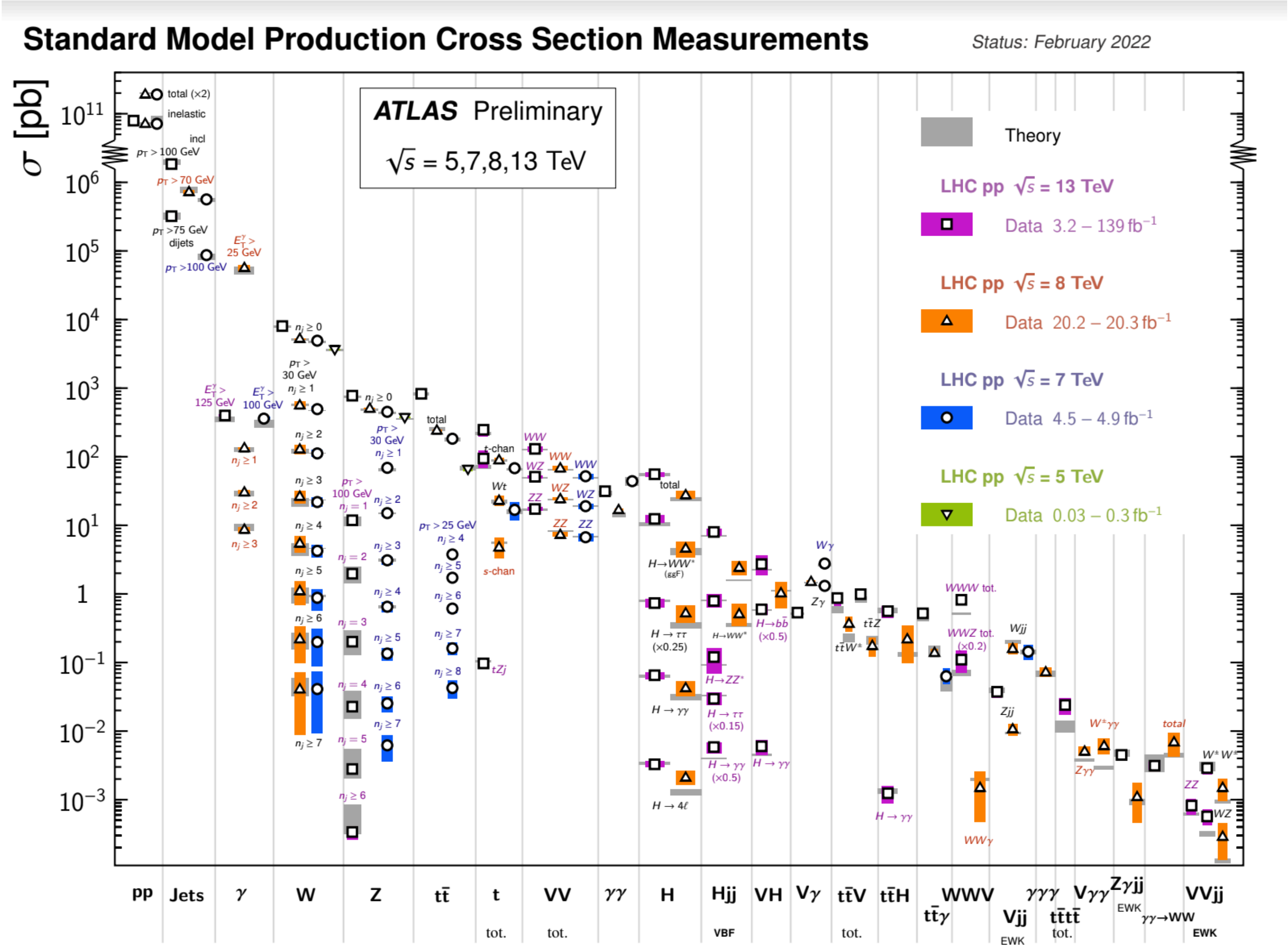
ATLAS and CMS

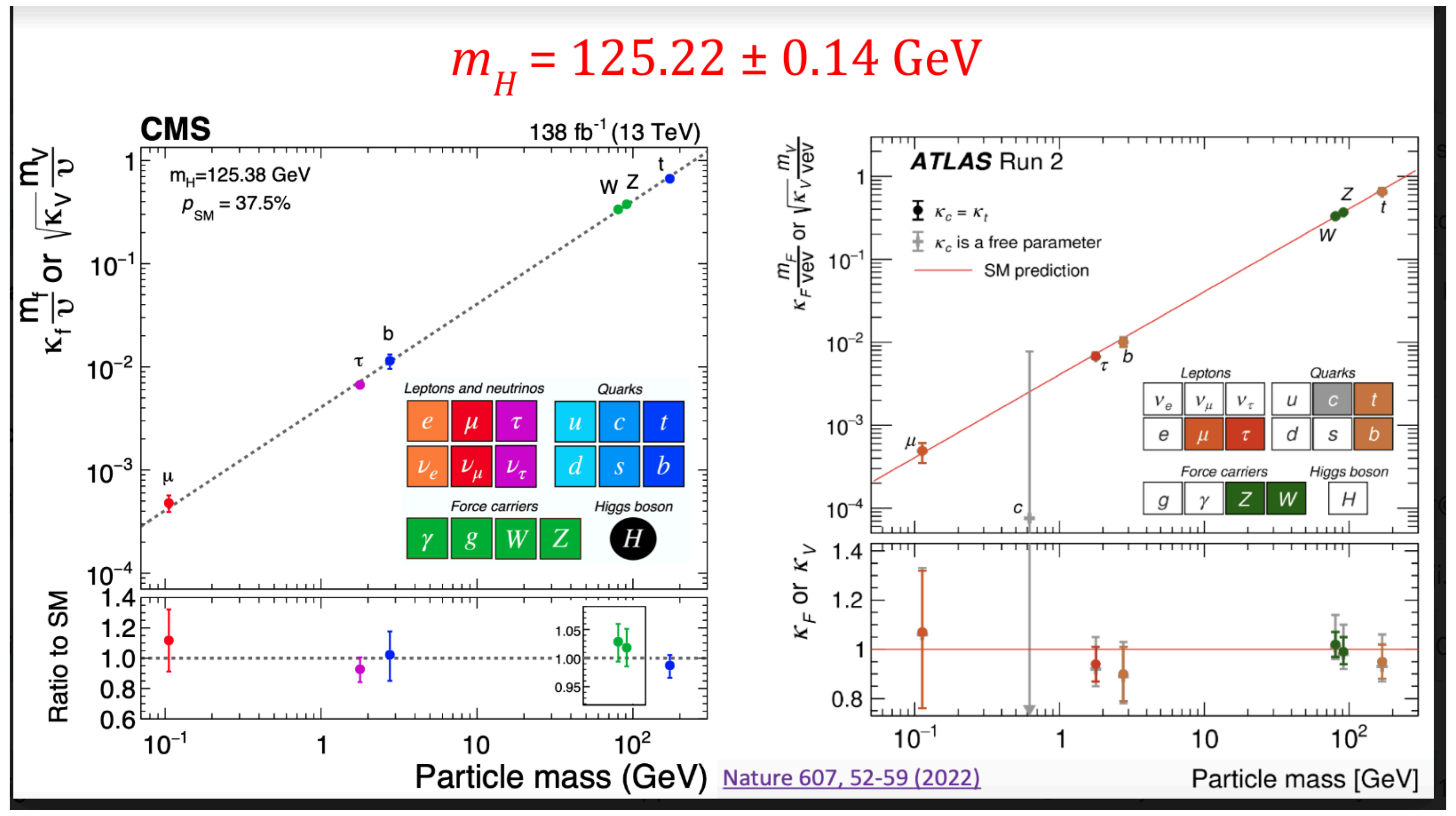
From: Nature

To: Physicists

Subject: Standard Model Status

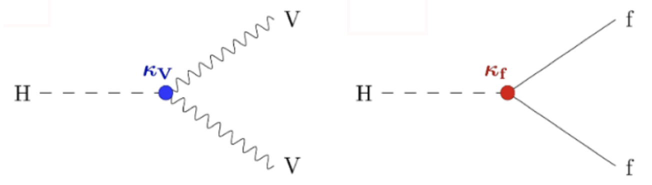
Via: LHC

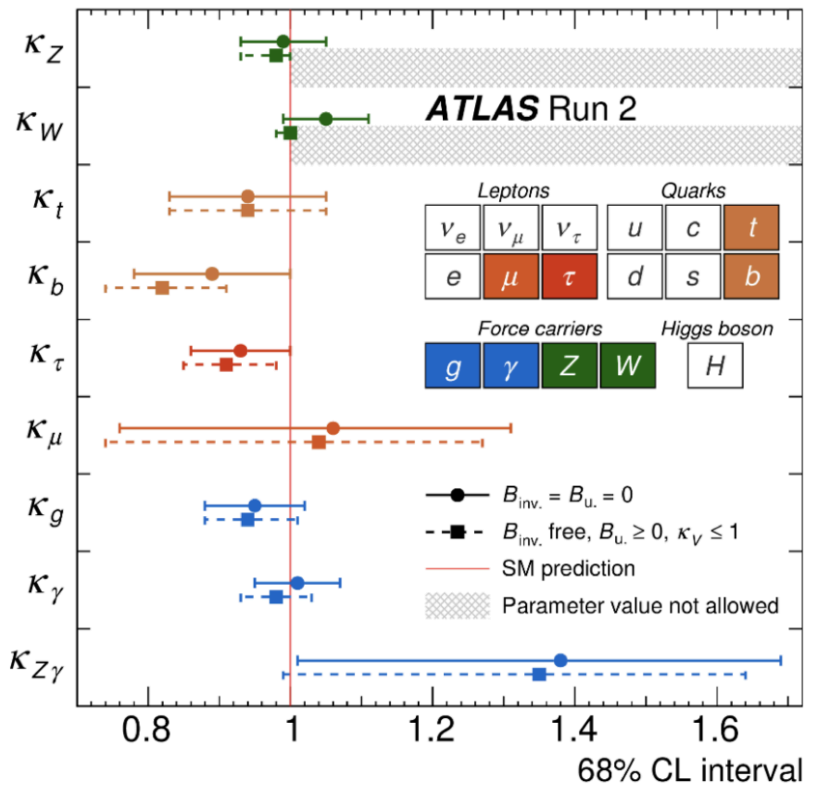




Precision in the measurements of Higgs couplings:

- Gauge bosons (below 10%)
- 3rd gen. fermions (below 20%)





WHAT PARTICLES WERE NOT DISCOVERED?

Shortly Before arriving in Stockholm, Klein received a letter from his good friend Pauli which reads in part:

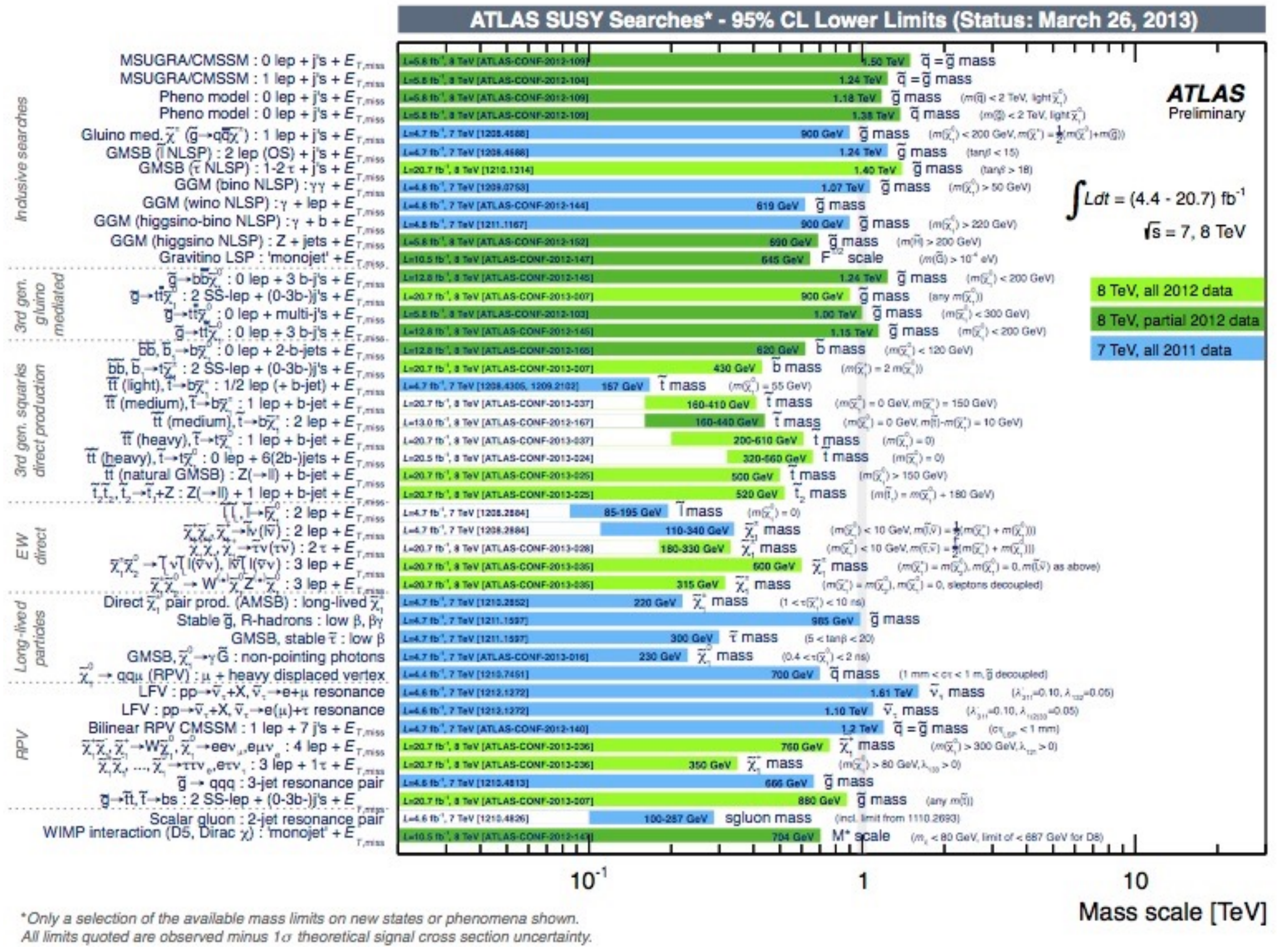
….I am not of the opinion that finding new laws of nature and indicating new directions of research is one of your great strengths,
although you have always developed a certain ambition in that direction…
I find much more beautiful those of your papers which deal with applications of known theories such as for example…
the paper with Nishina about the new scattering formula etc.…

From: Nature

To: Physicists

Subject: SUSY Particles and more

Via: LHC



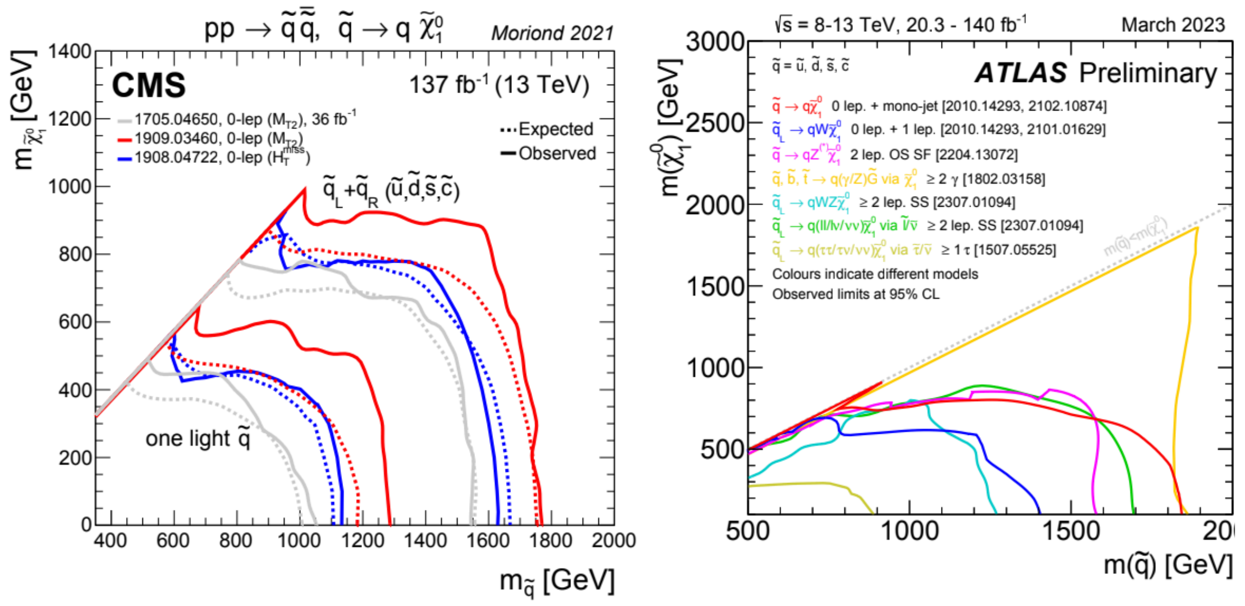


Figure 89.5: Left: 95% C.L. exclusion contours in the framework of simplified models assum a single decay chain of $\tilde{q} \to q\tilde{\chi}_1^0$, obtained by the CMS collaboration. Right: Assuming m complicated decay chains including W or Z bosons, obtained by the ATLAS collaboration.

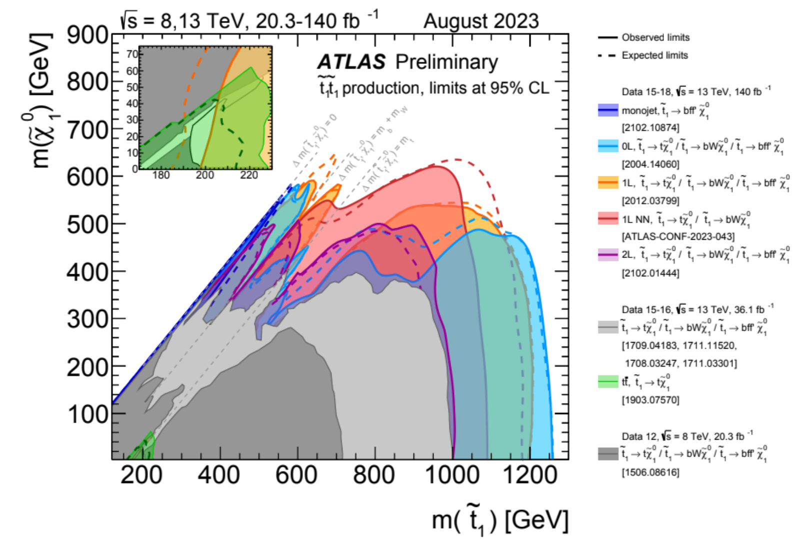


Figure 89.6: A summary of the 95% C.L. exclusion contours in the stop-neutralino mass plane for various possible decay chains, including two-, three- and four-body decays, as obtained in dedicated analyses by ATLAS.

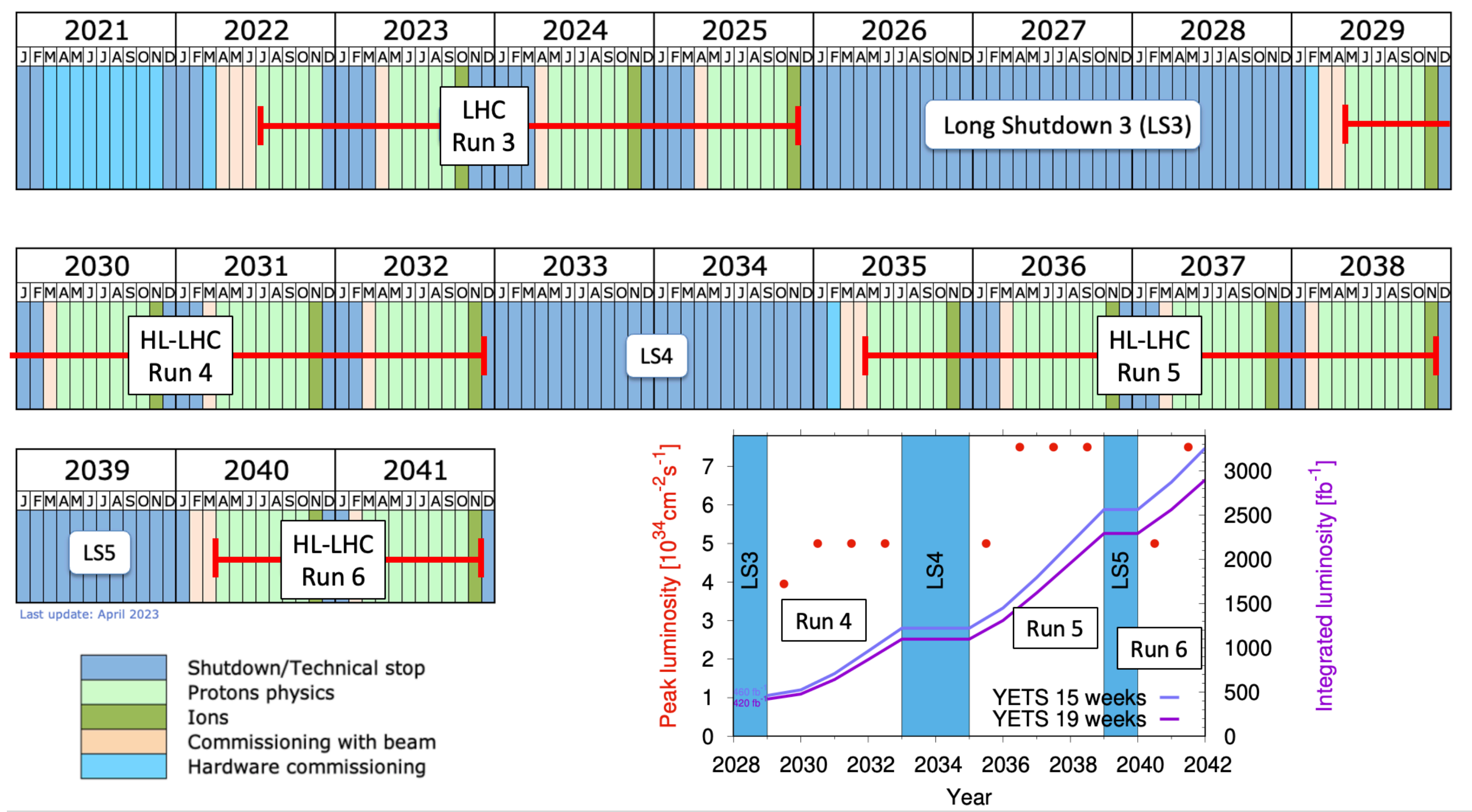
Table 89.1: Summary of squark mass and gluino mass limits using different interpretation approaches assuming R-parity conservation. Masses in this table are provided in GeV. Further details about the assumptions and analyses from which these limits are obtained are discussed in the corresponding sections of the text.

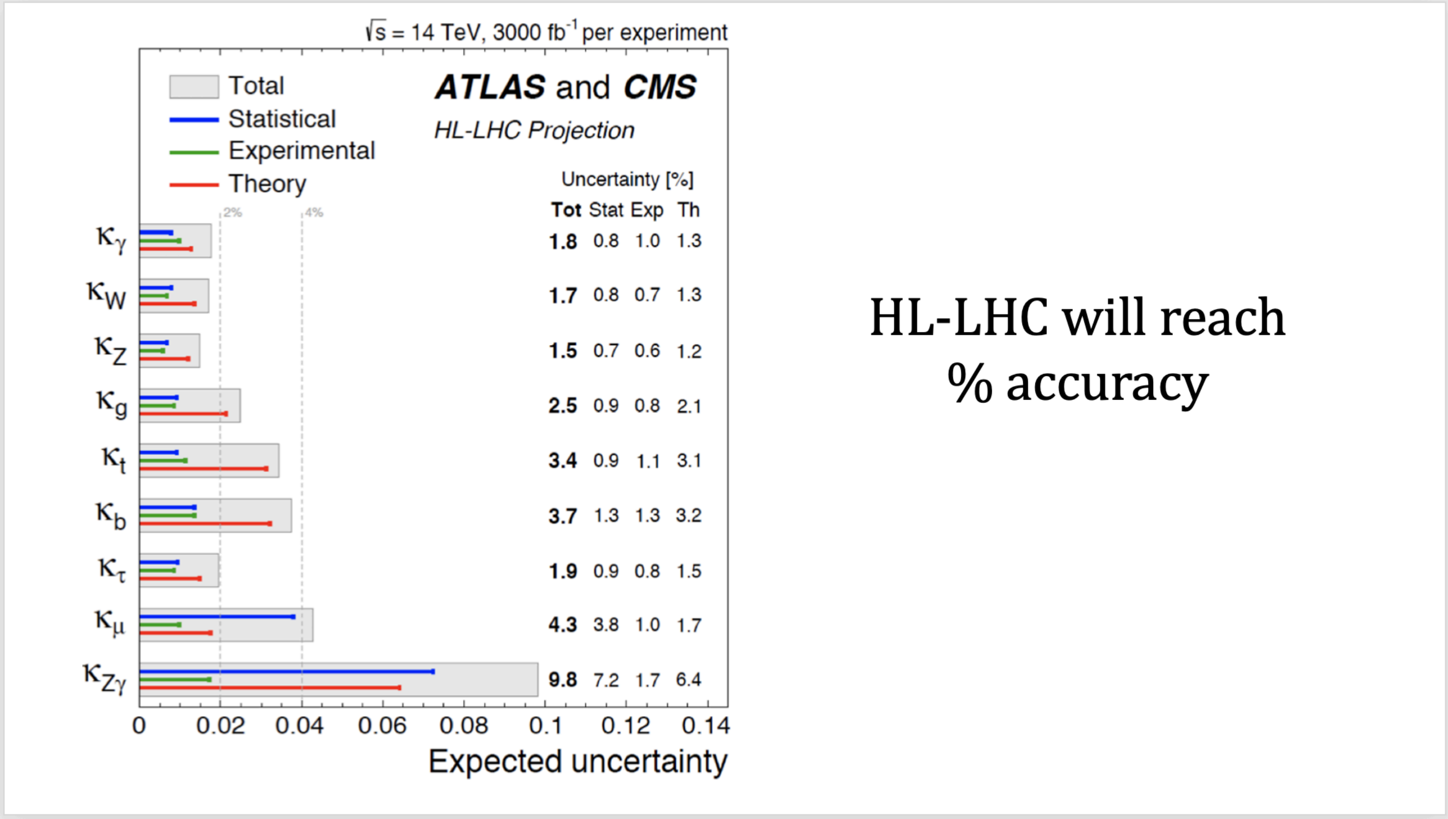
Model	Assumption	$m_{\tilde{q}}$	$m_{\tilde{g}}$
Simplified models $\tilde{g}\tilde{g}$			
$\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$	$m_{\tilde{\chi}_1^0}$ =0	-	≈ 2300
	$m_{\tilde{\chi}_1^0}$ >≈ 1200	-	no limit
$\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$	$m_{\tilde{\chi}_1^0}$ =0	-	≈ 2440
	$m_{\tilde{\chi}_1^0}$ >≈ 1600	-	no limit
$\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$	$m_{\tilde{\chi}_1^0}$ =0	-	≈ 2400
	$m_{\tilde{\chi}_1^0}$ >≈ 1400	-	no limit
Simplified models $\tilde{q}\tilde{q}$			
$\tilde{q} \to q\tilde{\chi}_1^0$	$m_{\tilde{\chi}_1^0}$ =0	≈ 1900	-
	$m_{\tilde{\chi}_1^0}$ >≈ 800	no limit	-
$\tilde{u}_L \to q\tilde{\chi}_1^0$	$m_{\tilde{\chi}_1^0}$ =0	≈ 1300	-
	$m_{\tilde{\chi}_1^0}$ >≈ 600	no limit	-

WHAT NEXT?

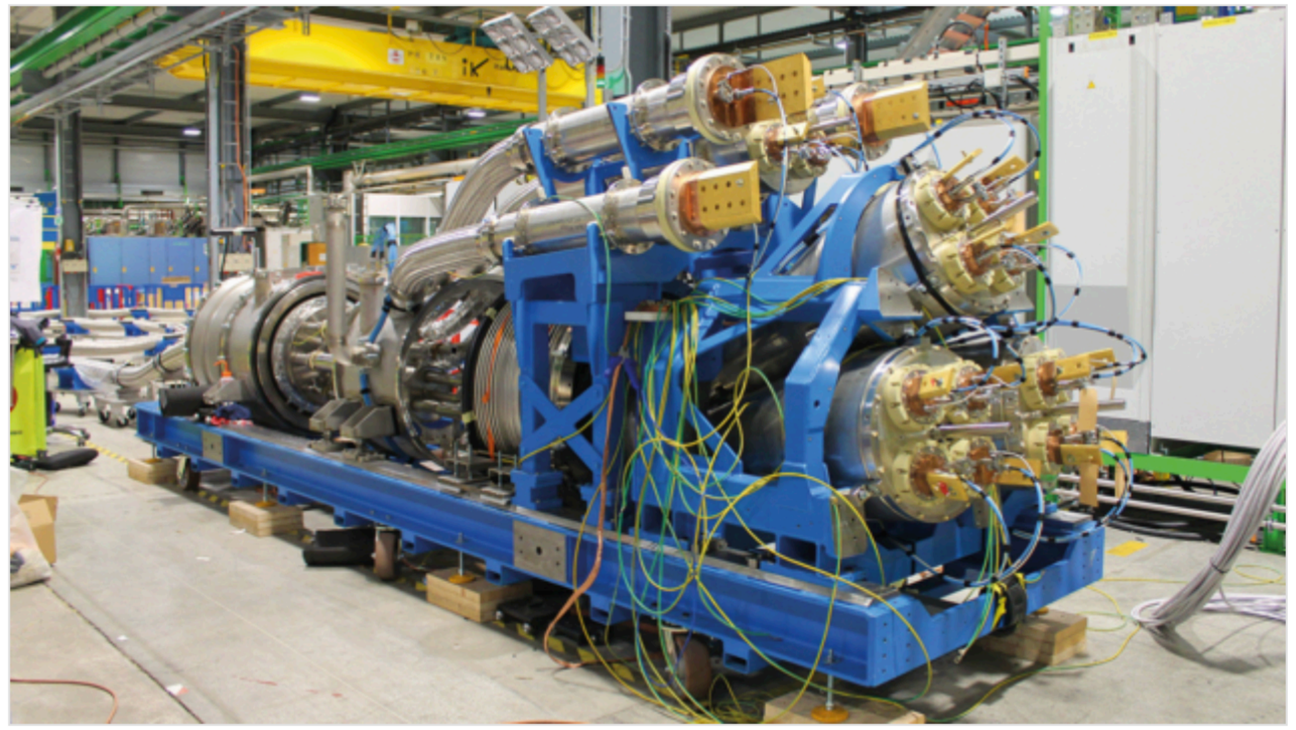
NEAR TERM : 2029(?)-2041(?)

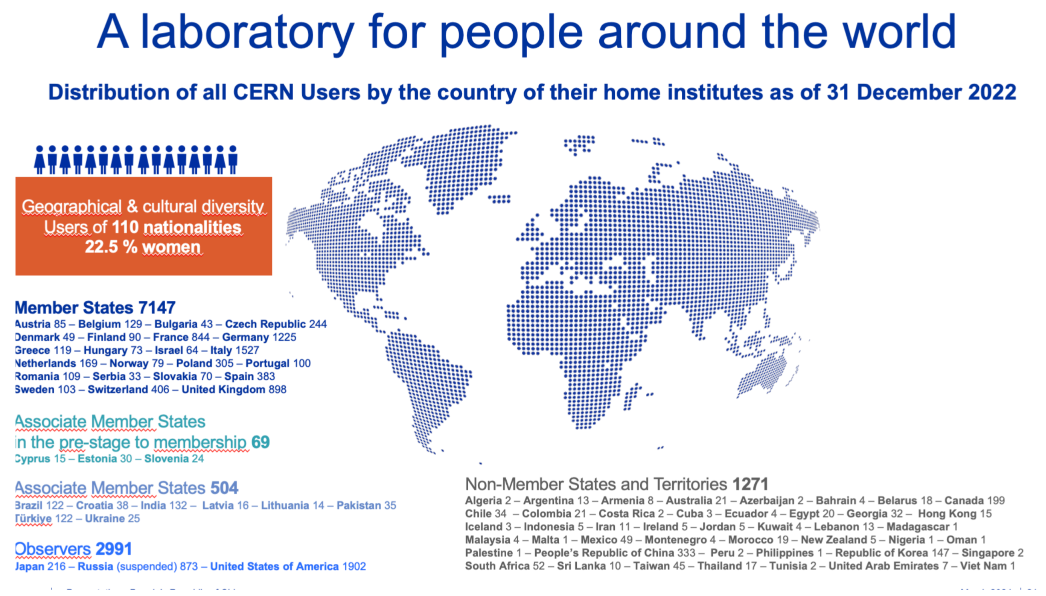
HIGH LUMINOSITY LHC- HL-LHC





HL-LHC will reach
% accuracy





CERN’s governance organs

CERN is governed by **two main organs** (Article IV, Convention)

- the **Council**
  - ➢ supreme decision-making authority
  - ➢ advised by specialised subordinate bodies, the Scientific Policy Committee, the Finance Committee, the Pension Fund Governing Board, the Audit Committee

- the **Director-General,** who is the Chief Executive Officer and legal representative of the Organization

State and institutional participation in CERN

23 Member States:

1954 Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom, Yugoslavia

1959 Austria, **1983** Spain, **1986** Portugal, **1991** Finland, Poland,

1992 Hungary, **1993** Czech Republic, Slovakia, **1999** Bulgaria,

2014 Israel, **2016** Romania, **2019** Serbia 2024(?) Estonia

Pre-Stage to Membership: Cyprus (2016), Slovenia (2017), Estonia (2020)

Associate Member States: Turkey (2015), Pakistan (2015), Ukraine (2016), India (2017), Lithuania (2018), Croatia (2019), Latvia (2020)

Applications: Brazil

Observer States: Japan, United States of America (Russian Federation suspended March 2022)

Observer institutions: UNESCO, European Union, JINR


0.0000000000001
or
0.0000000000002

BOTTOM UP APPROACH

European Strategy for Particle Physics(ESGPP)

- First adopted by the Council in 2006 – Non Brainer - bottom up Orsay-Zeuthen- Lisbon
- Adopted in 2013 Bottom Up Krakow- Erice- CERN
- HL-LHC , Future vision (fcc ilc clic and others)

- Updated 2020 –BOTTOM-UP – POINT-LINE-CIRCLE
- Granada-Bad Honnef -CERN(Budapest) HL LHC the rest Complex

- The update of the ESGPP by the Council in June 2020 called for:

"a technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update"

A few holiday snaps…

FCC Feasibility Study Mid-Term Status

Restricted Council

2 February 2024

Michael Benedikt, CERN

on behalf of the FCC collaboration

progress with implementation baseline PA31 90.7 km

FUTURE CIRCULAR COLLIDER

Meetings with municipalities concerned in France (31) and Switzerland (10)

PA – Ferney Voltaire (FR) – site experimental

PB – Présinge/Choulex (CH) – site technique

PD – Nangy (FR) – site experimental

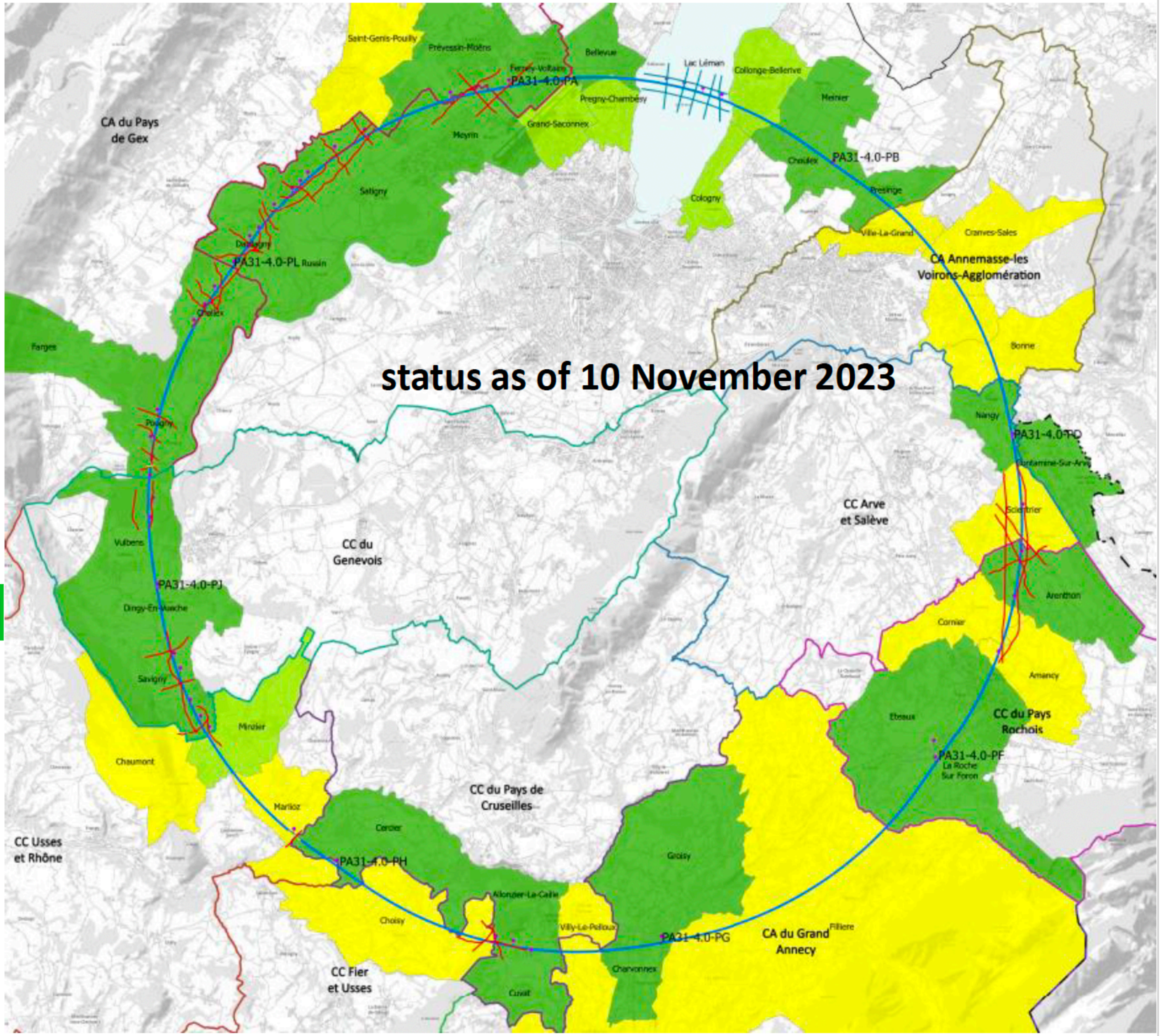
PF – Roche sur Foron/Etaux (FR) – site technique

PG – Charvonnex/Groisy (FR) – site experimental

PH – Cercier (FR) – site technique

PJ – Vulbens/Dingy en Vuache (FR) site experimental

PL – Challex (FR) – site technique



Individual meeting

Individual meeting planned

Collective meeting

The support of the host states is greatly appreciated and essential for the study progress!

FUTURE CIRCULAR COLLIDER

FCC-ee: main machine parameters

Parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45.6	80	120	182.5
beam current [mA]	1270	137	26.7	4.9
number bunches/beam	11200	1780	440	60
bunch intensity [10^{11}]	2.14	1.45	1.15	1.55
SR energy loss / turn [GeV]	0.0394	0.374	1.89	10.4
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.1/0	2.1/9.4
long. damping time [turns]	1158	215	64	18
horizontal beta* [m]	0.11	0.2	0.24	1.0
vertical beta* [mm]	0.7	1.0	1.0	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.71	1.59
vertical geom. emittance [pm]	1.9	2.2	1.4	1.6
horizontal rms IP spot size [μm]	9	21	13	40
vertical rms IP spot size [nm]	36	47	40	51
beam-beam parameter ξ_x / ξ_y	0.002/0.0973	0.013/0.128	0.010/0.088	0.073/0.134
rms bunch length with SR / BS [mm]	5.6 / 15.5	3.5 / 5.4	3.4 / 4.7	1.8 / 2.2
luminosity per IP [10^{34} $cm^{-2}s^{-1}$]	140	20	5.0	1.25
total integrated luminosity / IP / year [ab^{-1}/yr]	17	2.4	0.6	0.15
beam lifetime rad Bhabha + BS [min]	15	12	12	11
	4 years 5×10^{12} Z LEP x 10^5	2 years > 10^8 WW LEP x 10^4	3 years 2×10^6 H	5 years 2×10^6 tt pairs

currently assessing technical feasibility of changing operation sequences (e.g. starting at ZH energy)

- x 10-50 improvements on all EW observables
- up to x 10 improvement on Higgs coupling (model-indep.) measurements over HL-LHC
- x10 Belle II statistics for b, c, τ
- indirect discovery potential up to ~ 70 TeV
- direct discovery potential for feebly-interacting particles over 5-100 GeV mass range

Up to 4 interaction points → robustness, statistics, possibility of specialised detectors to maximise physics output

F. Gianotti

FUTURE CIRCULAR COLLIDER

FCC-hh parameters

parameter	FCC-hh	HL-LHC	LHC
collision energy cms [TeV]	81 - 115	14	
dipole field [T]	14 - 20	8.33	
circumference [km]	90.7	26.7	
arc length [km]	76.9	22.5	
beam current [A]	0.5	1.1	0.58
bunch intensity [10^{11}]	1	2.2	1.15
bunch spacing [ns]	25	25	
synchr. rad. power / ring [kW]	1020 - 4250	7.3	3.6
SR power / length [W/m/ap.]	13 - 54	0.33	0.17
long. emit. damping time [h]	0.77 – 0.26	12.9	
peak luminosity [10^{34} $cm^{-2}s^{-1}$]	~30	5 (lev.)	1
events/bunch crossing	~1000	132	27
stored energy/beam [GJ]	6.1 - 8.9	0.7	0.36
Integrated luminosity/main IP [fb^{-1}]	20000	3000	300

With FCC-hh after F
significantly
more time for high-
magnet R&D
aiming at highest p
energies

Formidable challenges:

- ❑ high-field superconducting magnets: 14 - 20 T
- ❑ power load in arcs from synchrotron radiation: 4 MW → cryogenics, vacuum
- ❑ stored beam energy: ~ 9 GJ → machine protection
- ❑ pile-up in the detectors: ~1000 events/xing
- ❑ energy consumption: 4 TWh/year → R&D on cryo, HTS, beam current, …

Formidable physics reach, including:

- ❑ Direct discovery potential up to ~ 40 TeV
- ❑ Measurement of Higgs self to ~ 5% and ttH to ~ 1%
- ❑ High-precision and model-indep (with FCC-ee input measurements of rare Higgs decays ($\gamma\gamma$, $Z\gamma$, $\mu\mu$)
- ❑ Final word about WIMP dark matter

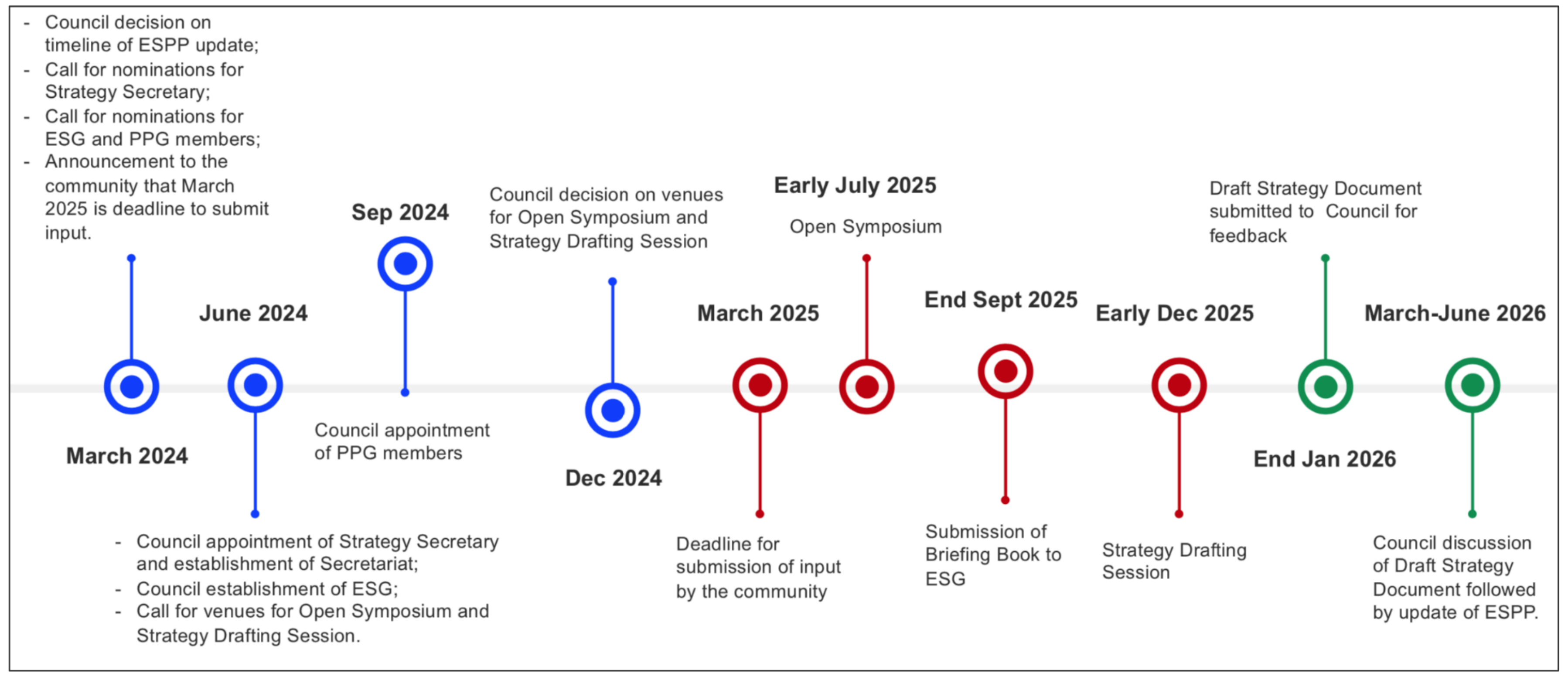
FCC Feasibility Study: the next steps

SPC Meeting, 18 March 2024

Michael Benedikt, CERN
on behalf of FCC collaboration

Proposed general timeline for next ESPP update

- 2024: preparatory year where all committees are established and venues of meetings chosen
- 2025: submission of scientific input by community, community Open Symposium and drafting of Strategy document
- 2026: Council discussion and update of the Strategy

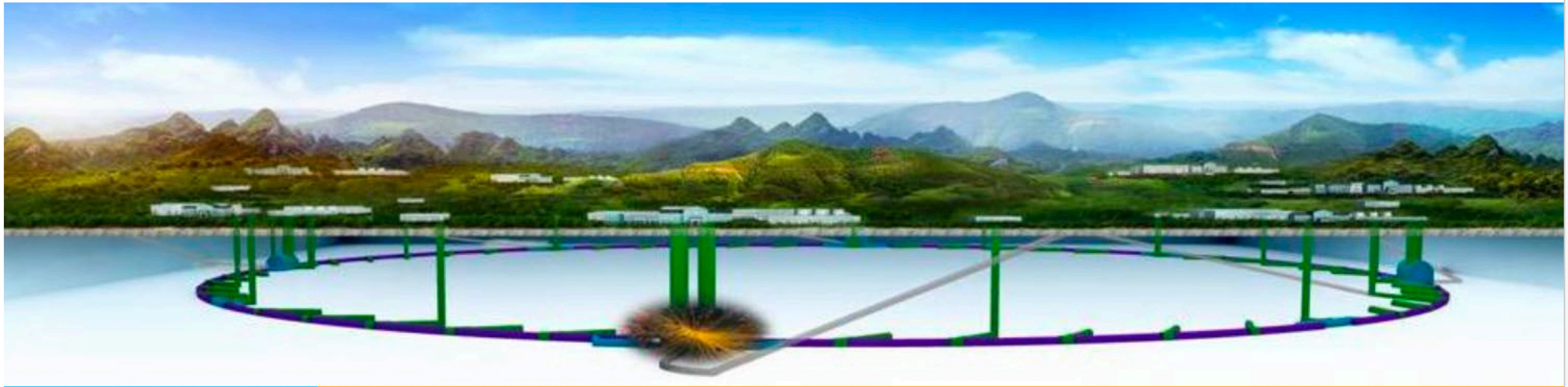


As last time, a more detailed timeline will be presented to Council by the Strategy Secretariat once established

Circular Electron-Positron Collider in China

Yifang Wang， IHEP

CERN, March 19, 2024



Vision of the 2023 Particle Physics Project Prioritization Panel (P5)

We envision a new era of scientific leadership, centered on decoding the quantum realm, unveiling the hidden universe, and exploring novel paradigms. Balancing current and future large- and mid-scale projects with the agility of small projects is crucial to our vision. We emphasize the importance of investing in a highly skilled scientific workforce and enhancing computational and technological infrastructure. Particle physics has a long-proven record of creating new technologies and provides a training ground for a skilled workforce that drives not only fundamental science, but also quantum information science, AI/ML, computational modeling, finance, national security, and microelectronics.

We recommend the following:

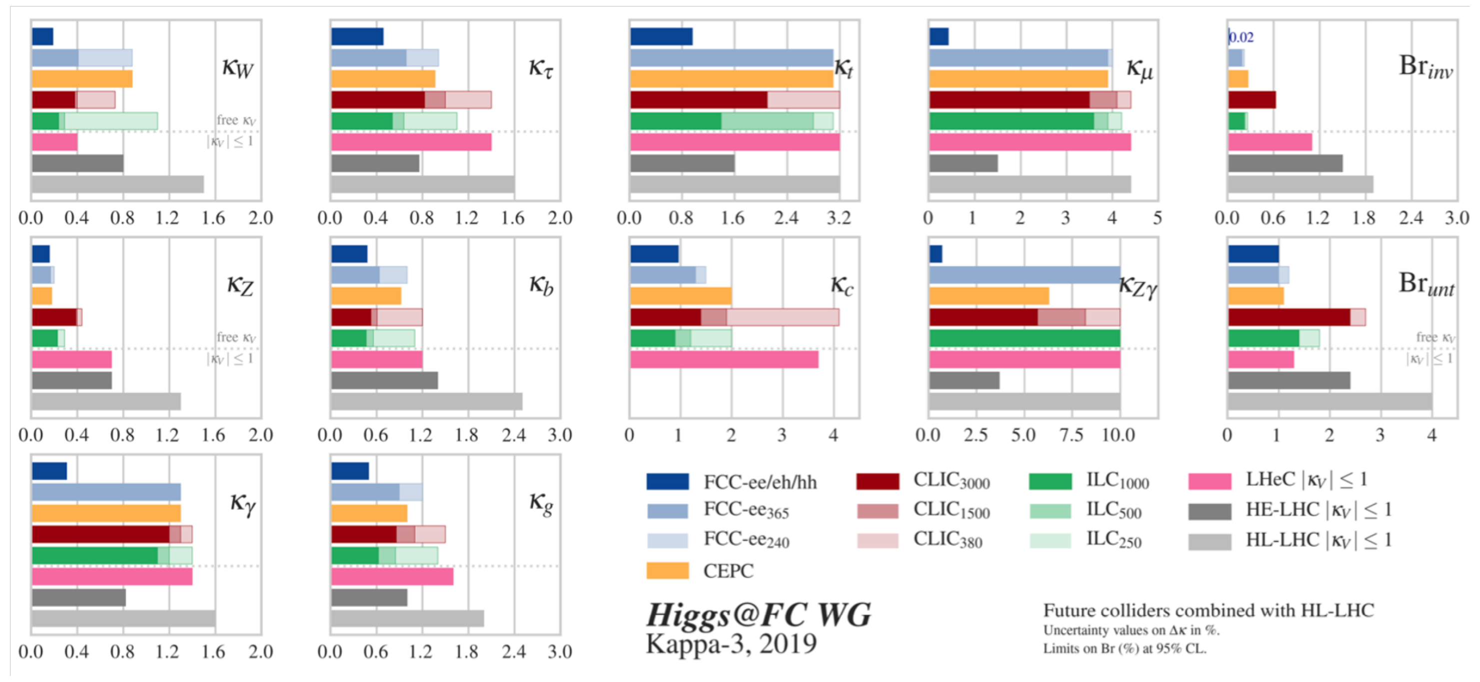
1. As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science. This includes High-Luminosity LHC, the first phase of Deep Underground Neutrino Experiment (DUNE) and Proton Improvement Plan II, the Rubin Observatory to carry out the Legacy Survey of Space and Time (LSST).

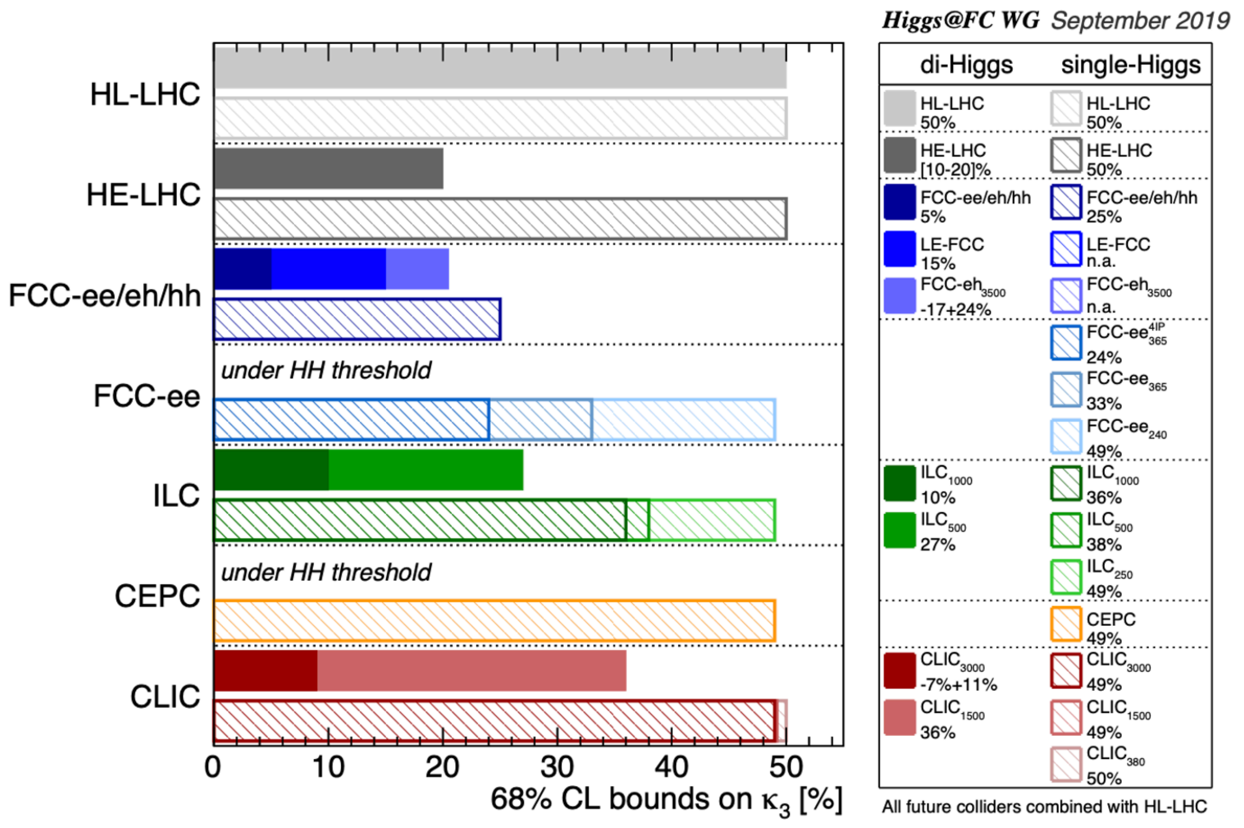
2. Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future.

a. **CMB-S4**, which looks back at the earliest moments of the universe,

b. **Re-envisioned second phase of DUNE** with an early implementation of an enhanced 2.1 MW beam and a third far detector as the definitive long-baseline neutrino oscillation experiment,

c. **Offshore Higgs factory, realized in collaboration with international partners**, in order to reveal the secrets of the Higgs boson,

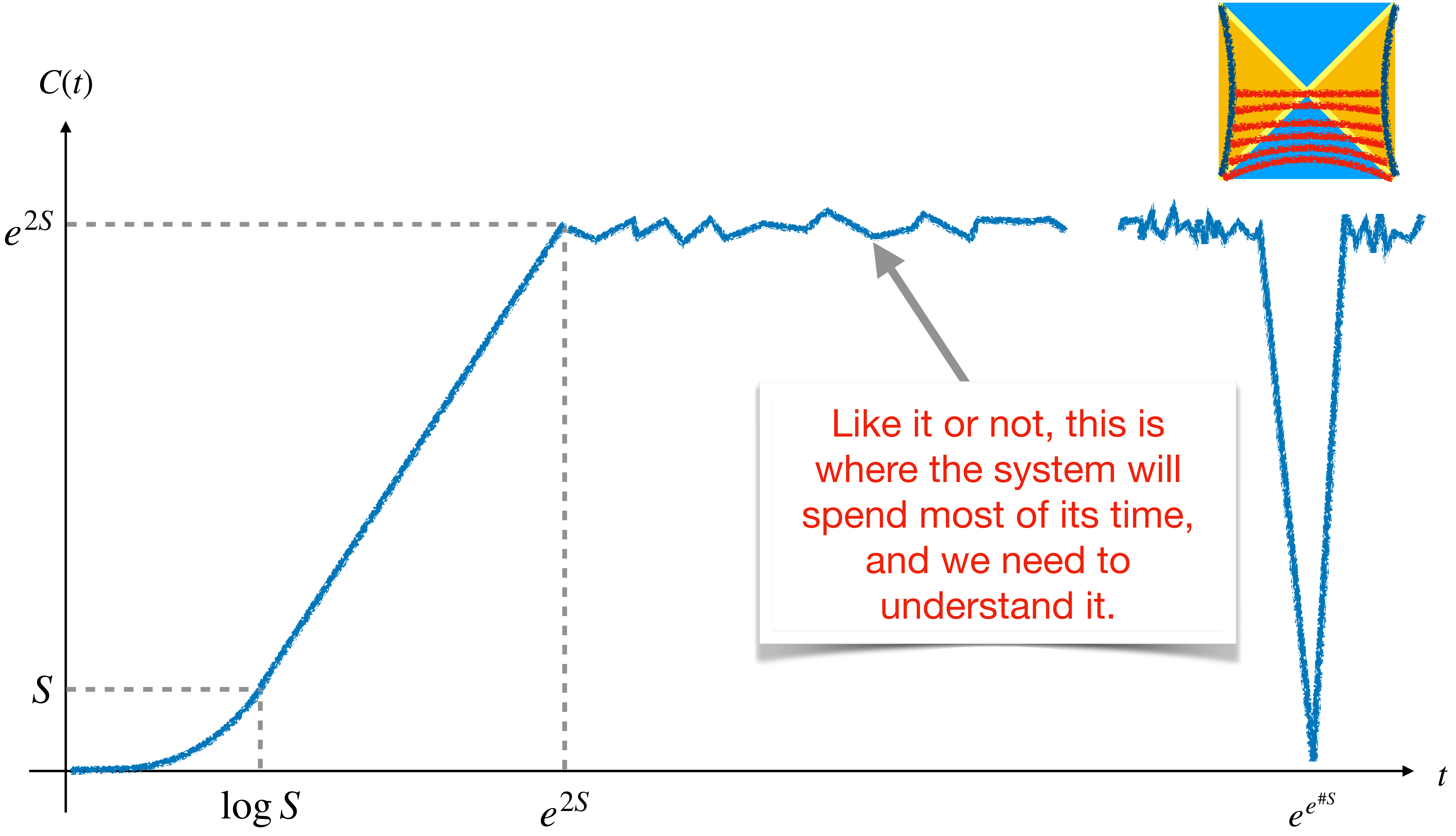




- **AS OF NOW NOT ENOUGH MOTIVATIONAL STRINGS ATTACHED!**

BULK DUAL TO Boundary quantum complexity?

Expectation from a quantum chaotic system with a finite number S of qubits



Complexity time evolution profile for operators

OPEN QUESTION 101 -MAY YOU HAVE 1001 NEW Q&A

FOR STRINGS 20XX@CERN