CERN future projects,

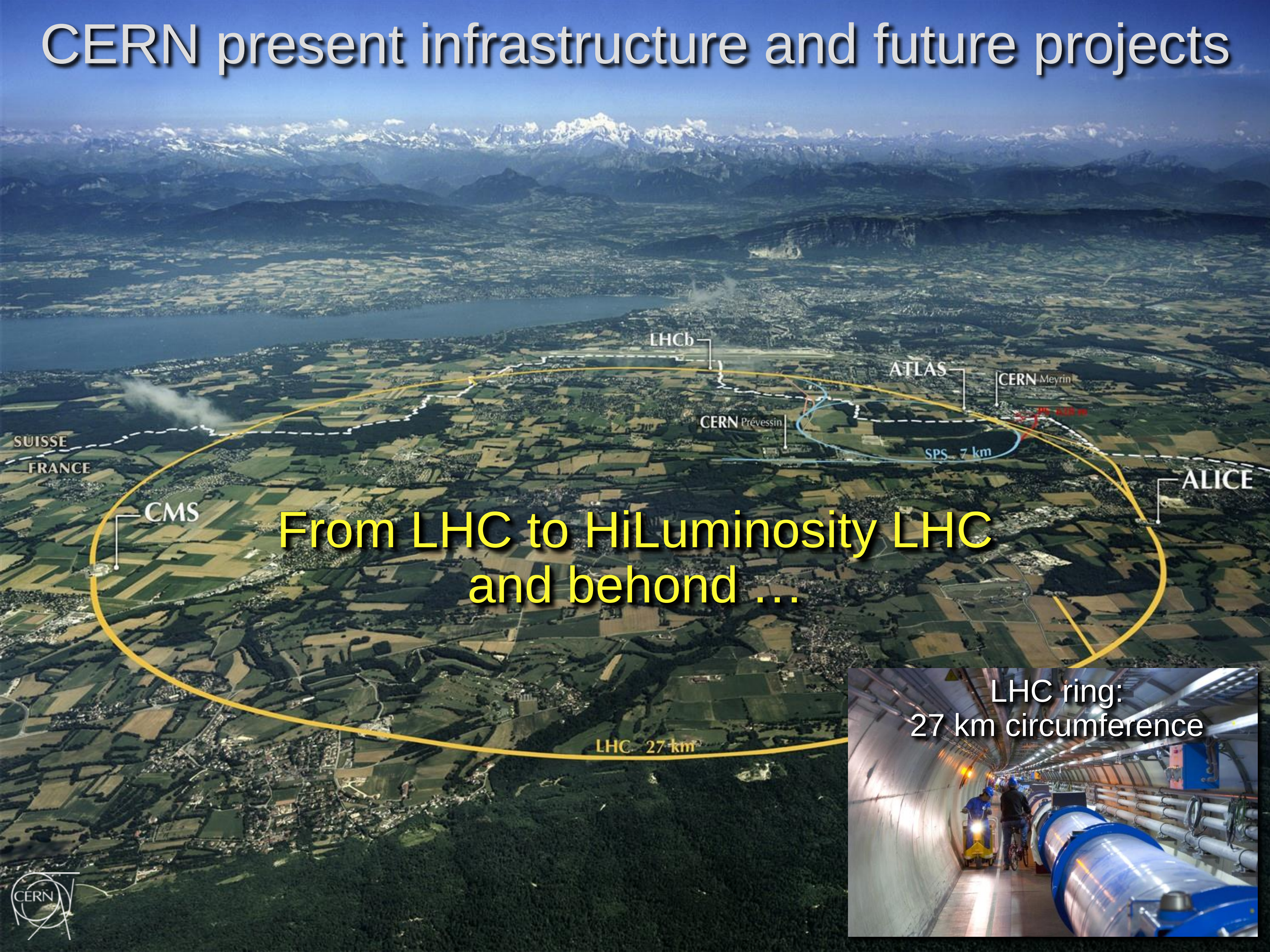
Cryogenics for superconductivity

Serge CLAUDET, *as deputy Cryogenic group leader & HiLumi Cryo WP leader*

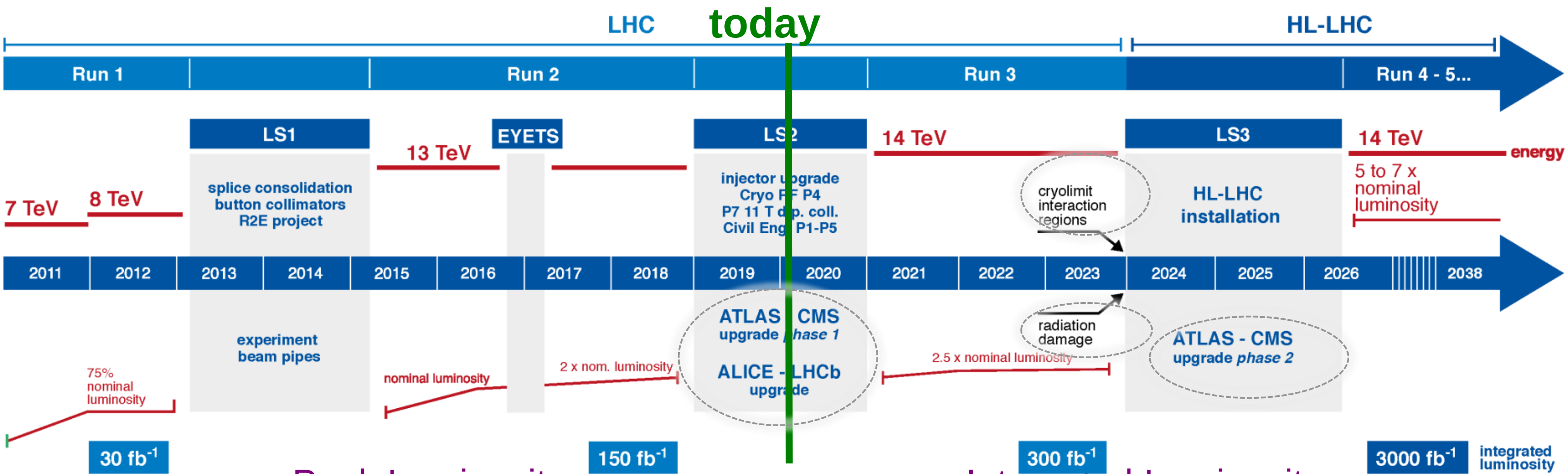
CERN, 29th Jan'20

CERN present infrastructure and future projects

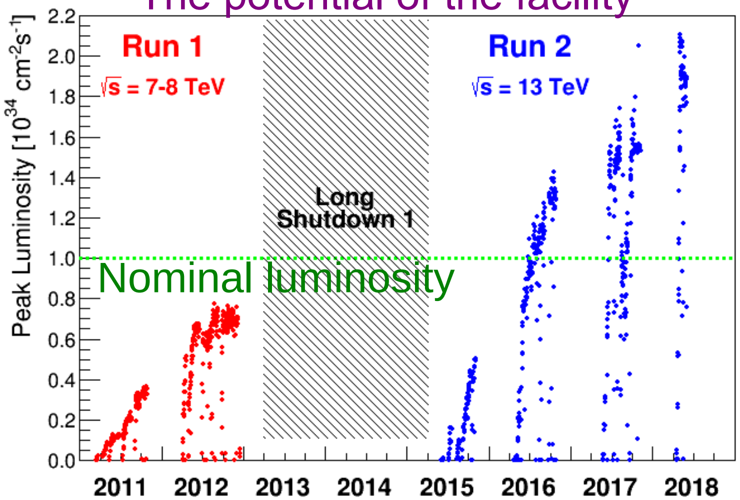
From LHC to HiLuminosity LHC
and behond …



LHC / HL-LHC Plan

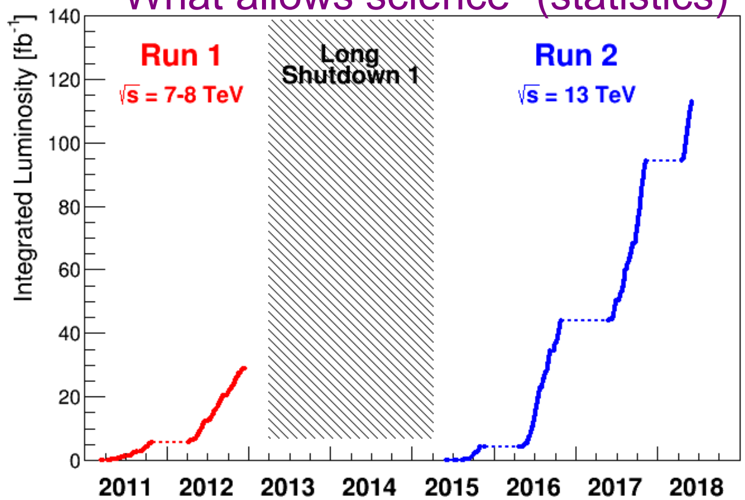


Peak Luminosity
" The potential of the facility"



Performance

Integrated Luminosity
"What allows science" (statistics)

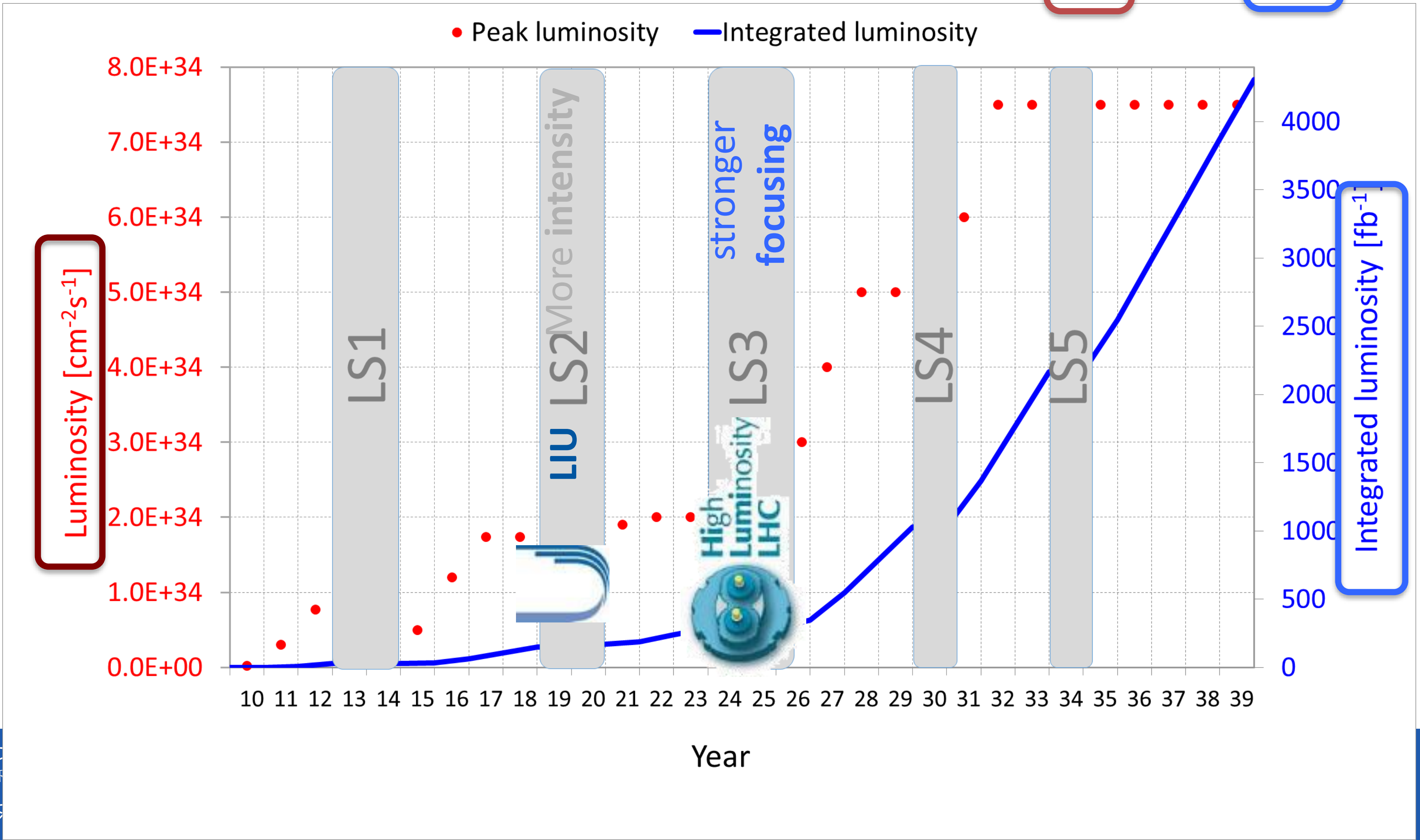


Qualification – Global availability - Time

Towards higher collision rates

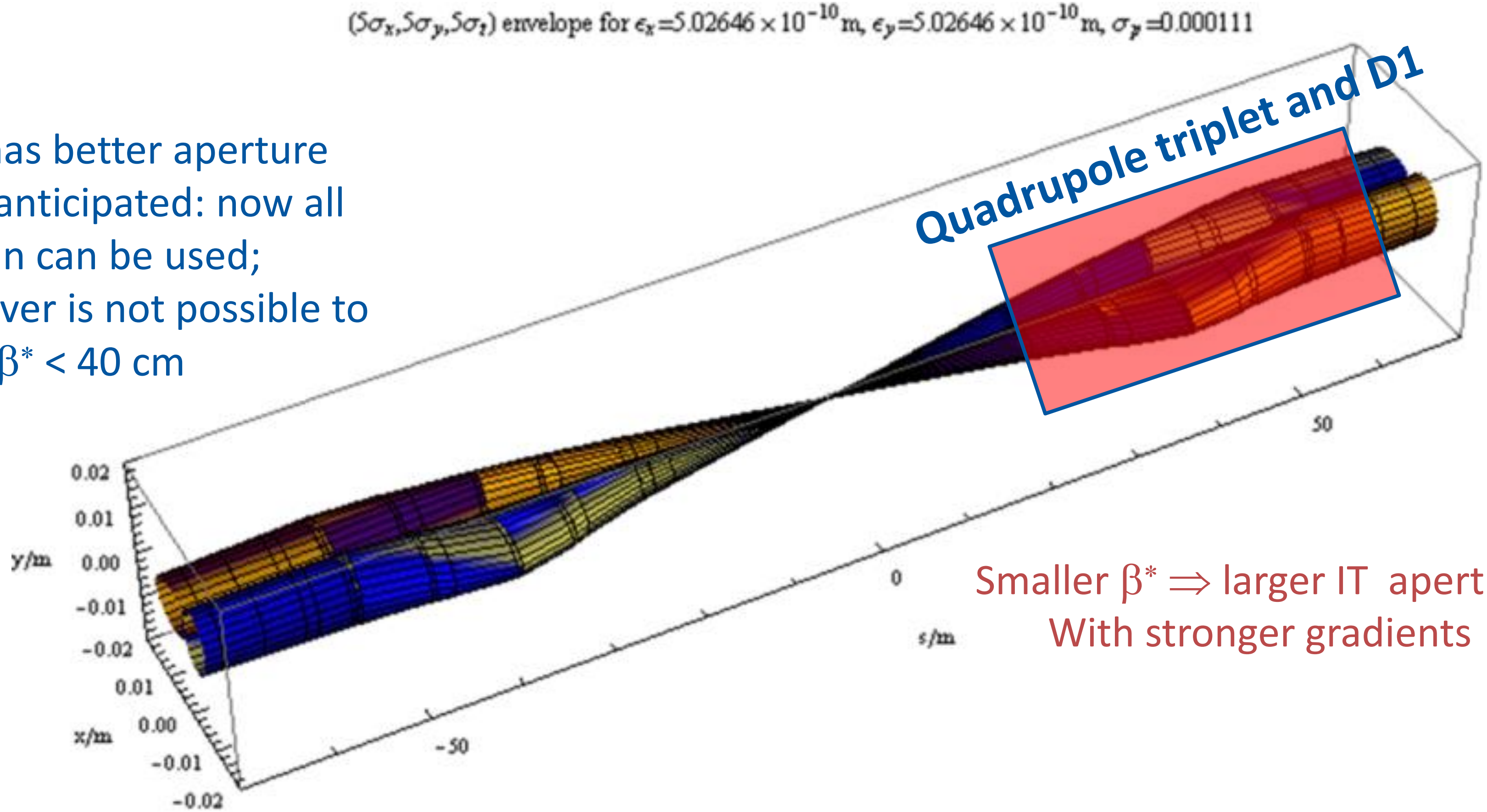
New discoveries or precision measurements need integrated luminosity !!!

Luminosity = f * N² / 4π σ²



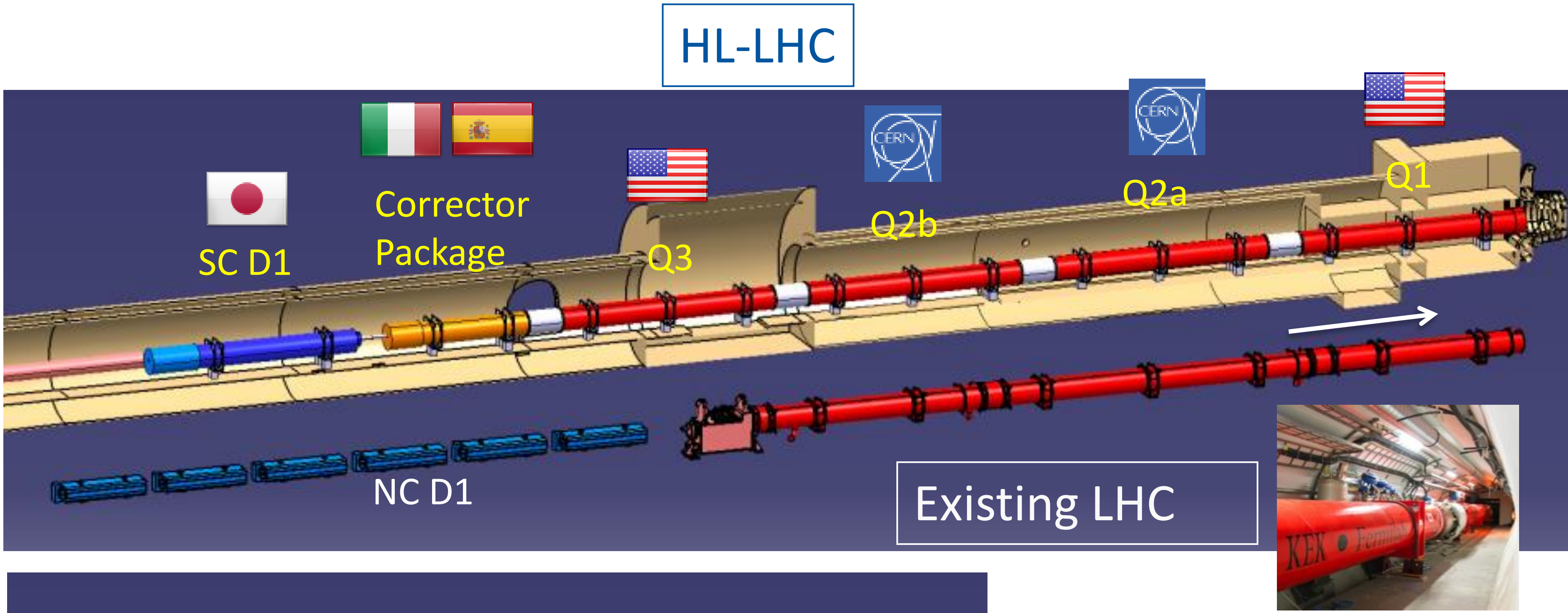
The most straight forward action: reducing beam size with a «local» action

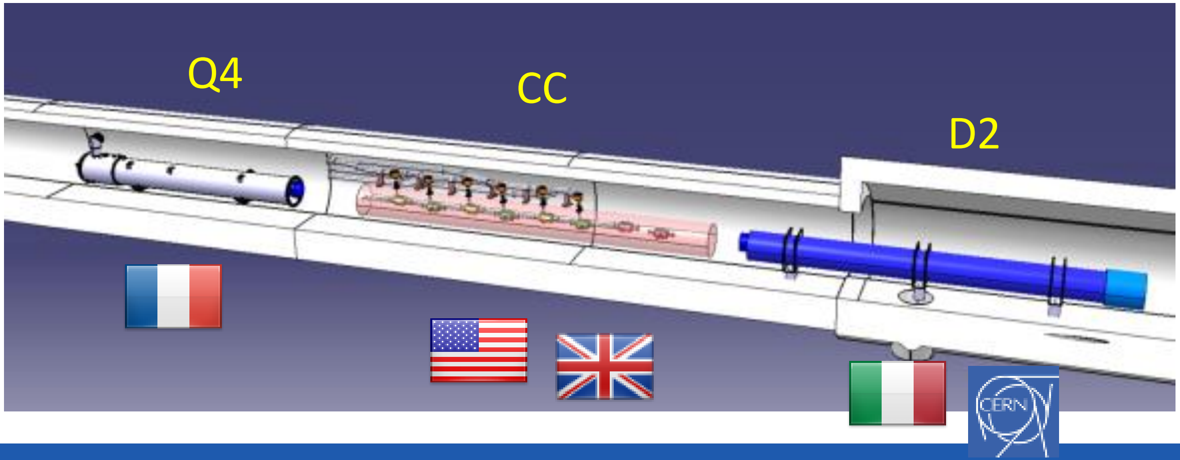
LHC has better aperture than anticipated: now all margin can be used; however is not possible to have $\beta^* < 40$ cm



Smaller $\beta^* \Rightarrow$ larger IT aperture
With stronger gradients

HL-LHC configuration

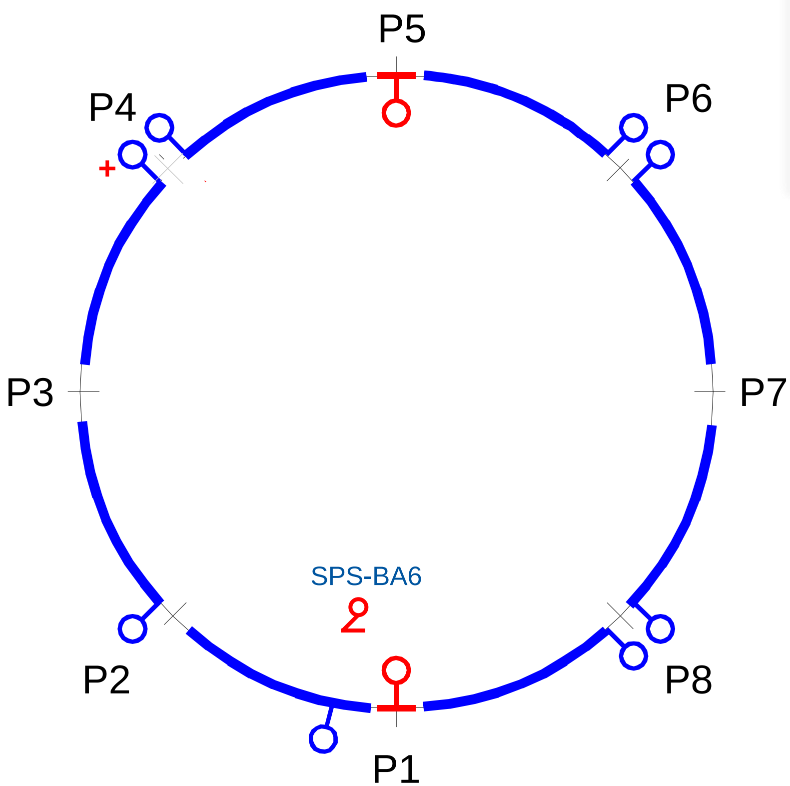




HL-LHC relies on more powerful final focussing quadrupoles, associated recombination dipoles and crab cavities,

Local heat loads expected x5 w.r.t LHC

HL-LHC cryogenic upgrade

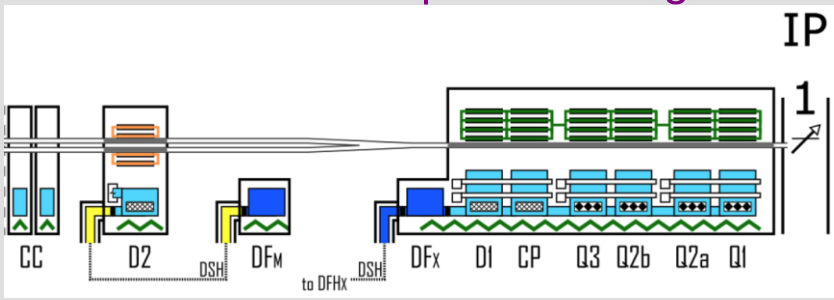


Existing cryoplant

New HL-LHC cryoplant

- P1-P5: 2 new cryoplants (~15 kW @ 4.5 K incl. ~3 kW @ 1.8 K) and 2 x 750m cryo-distribution for high-luminosity insertions
- P4: upgrade (+2 kW @ 4.5 K) of an existing LHC 18 kW @ 4.5K cryoplant
- *SPS-BA6: SRF test facility with beam primarily for Crab-Cavities*

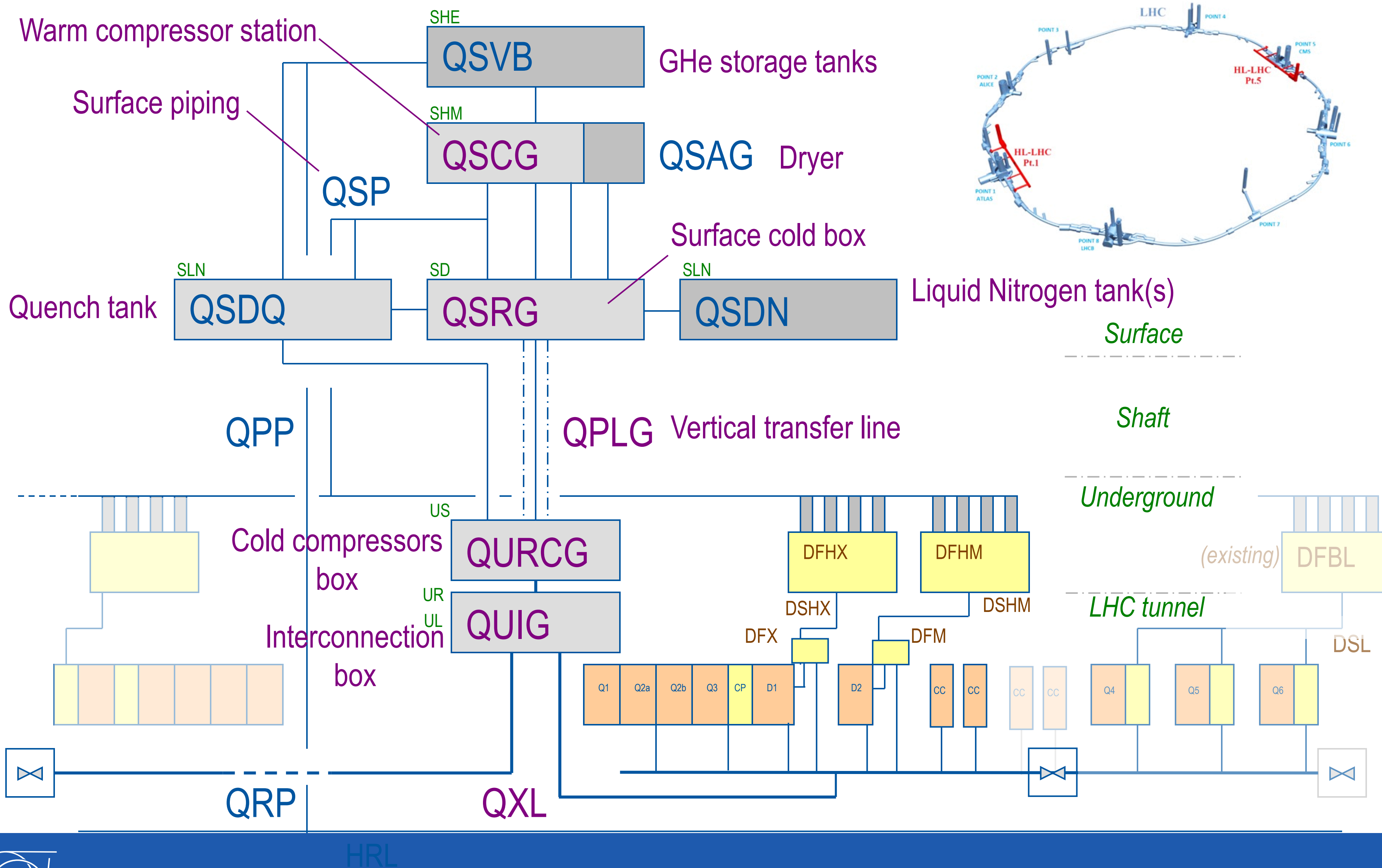
P1/P5: Provide adequate cooling for this



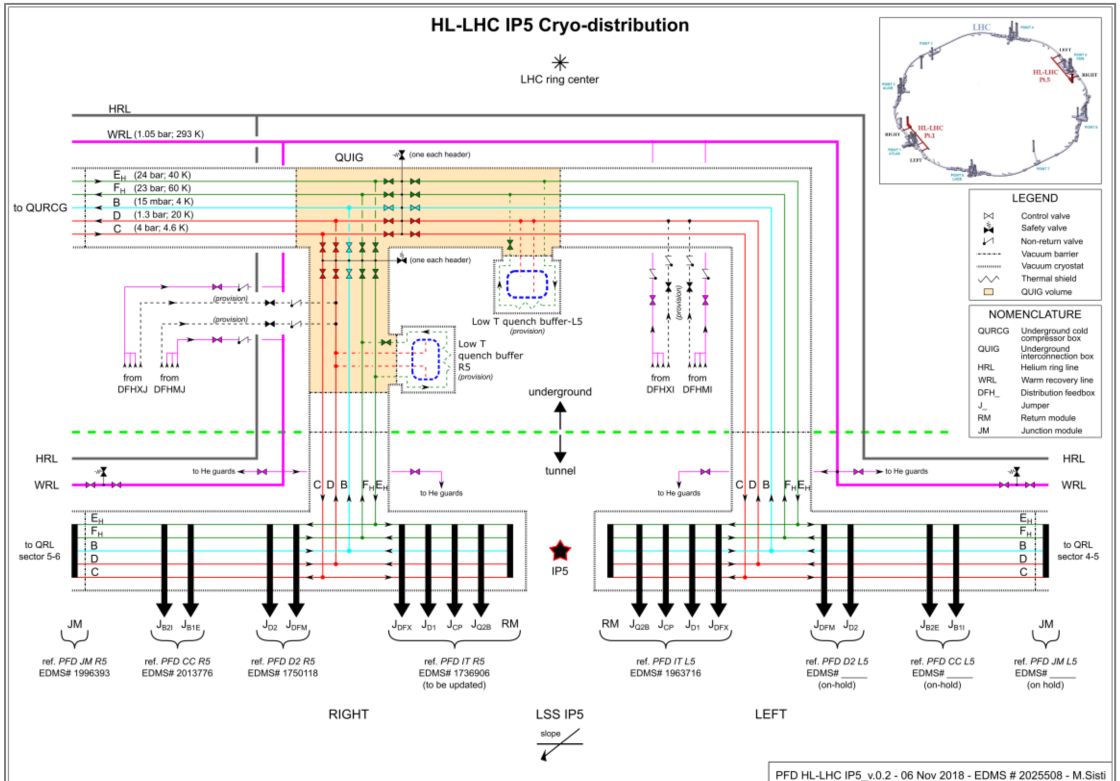
Other test facilities related activities not reported here

P1/P5 Cryogenic architecture

15 kW equivalent at 4.5 K, including 3 kW at 1.8 K



Cryo-distribution reference

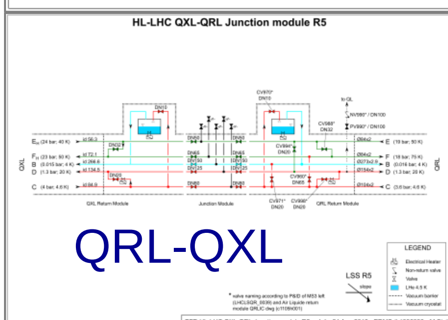


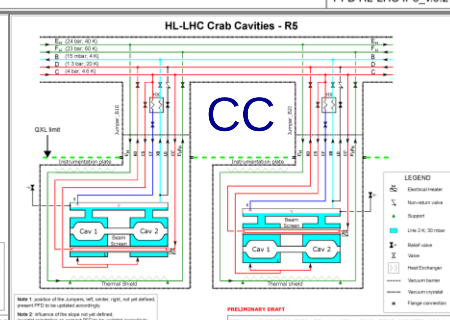
Identification of needs,

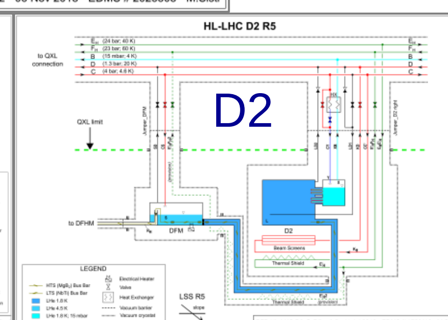
Proposal of a possible architecture

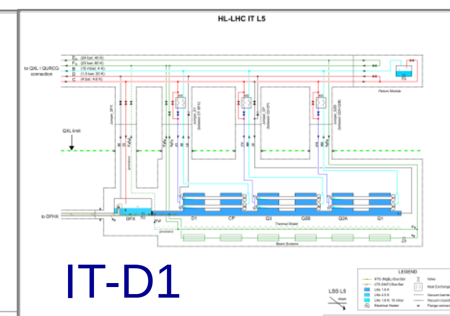
Proposal of a reference configuration with size

3D models





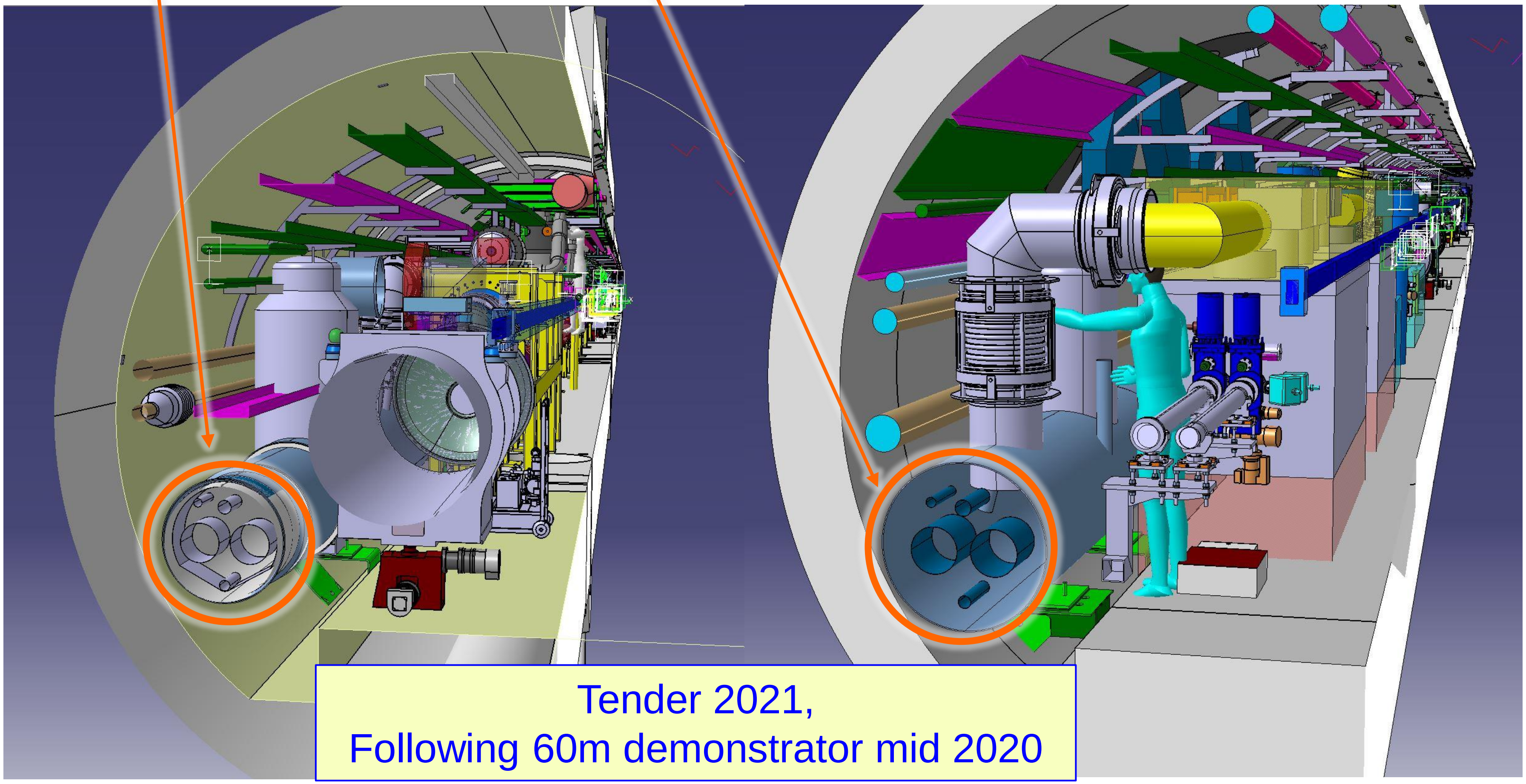




Reference established, optimised considering project requirements and CRG expertise

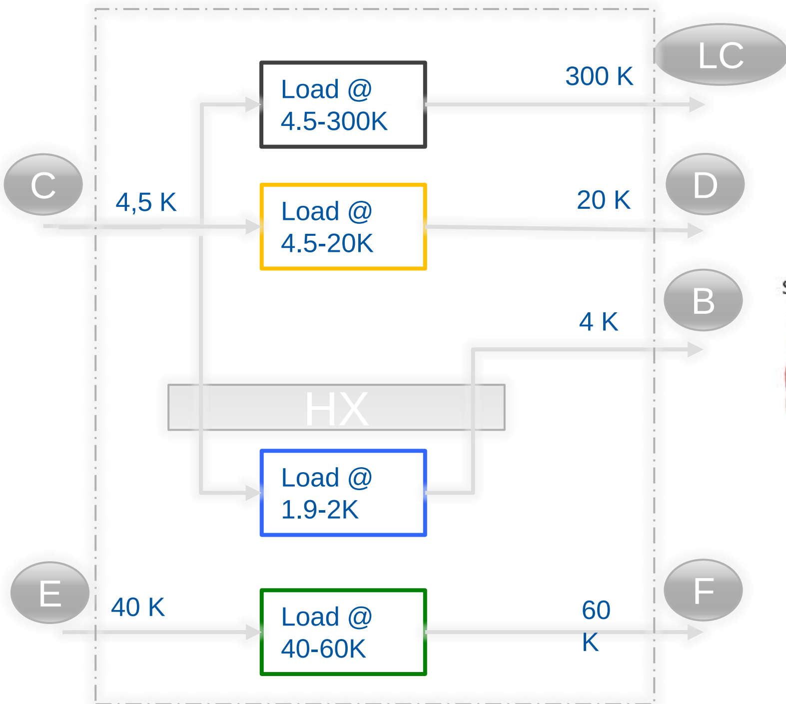
QXL cryoline, 3D models and integration

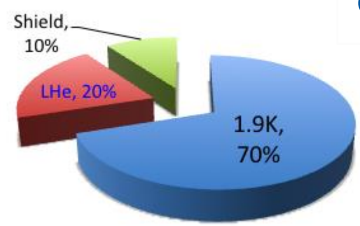
1’500m, 5 tubes in a shell diam 650-800mm, similar to existing LHC QRL cryoline

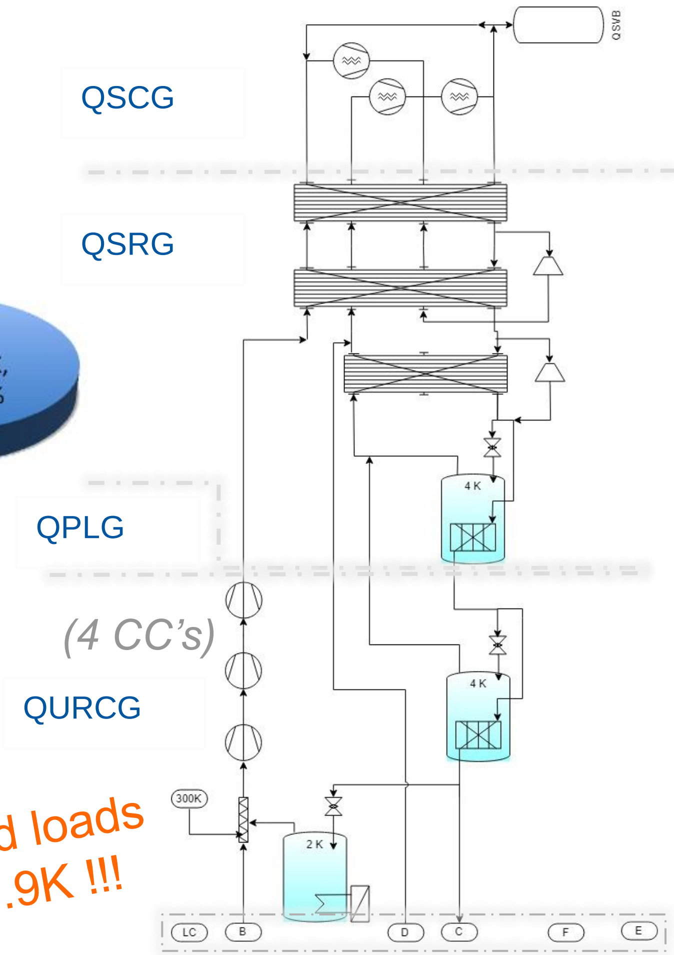


Tender 2021,
Following 60m demonstrator mid 2020

From cooling requirements to Refrigeration capacity and process







Pulsed loads @ 1.9K !!!

Obvious need for 15mbar header (1.8K cold source),
no special need for 4.5K loads

Process options now under study

2 x 15 kW eq. @ 4.5K He Refrigerators, *incl 3kW @ 1.8K*

Best Capex + Opex offer matching specified requirements

Compressors, dryers, cold box(es), vertical cryoline, cold compressors

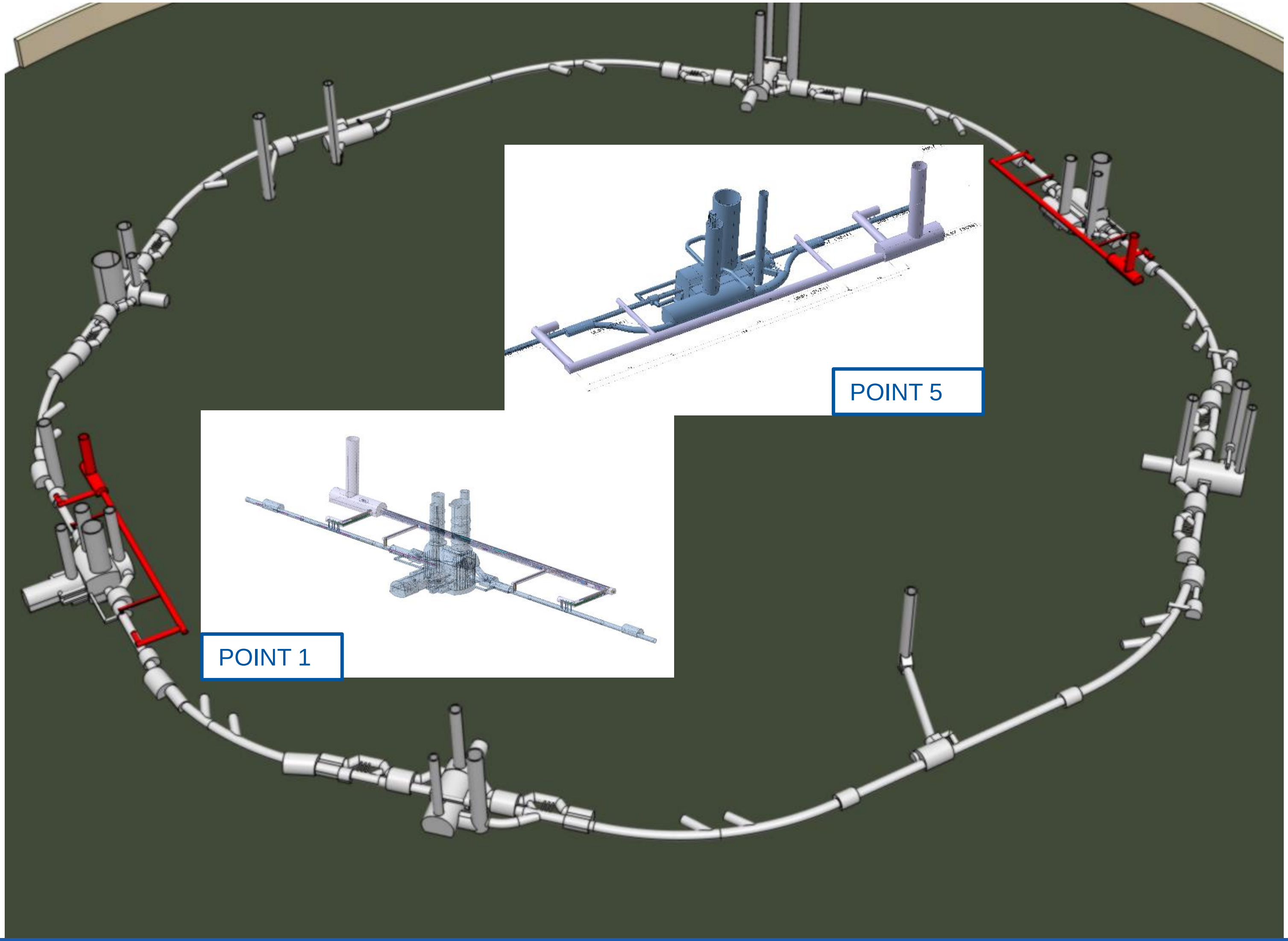
Tender Q1 2021

Complementary infrastructure

- Valve boxes (2): 25 valves in a 2m Diam & 8-10m long box
- GHe storage tanks (4): 250 Nm3 – PN25
- LN2 storage tanks (2): 50’000 l + vaporiser
- Interconnecting piping: 2’000m Diam 250 eq. stainless steel
- Instrumentation for tunnel equipment (accuracy, radiation)
- Controls (integration with existing LHC infrastructure)

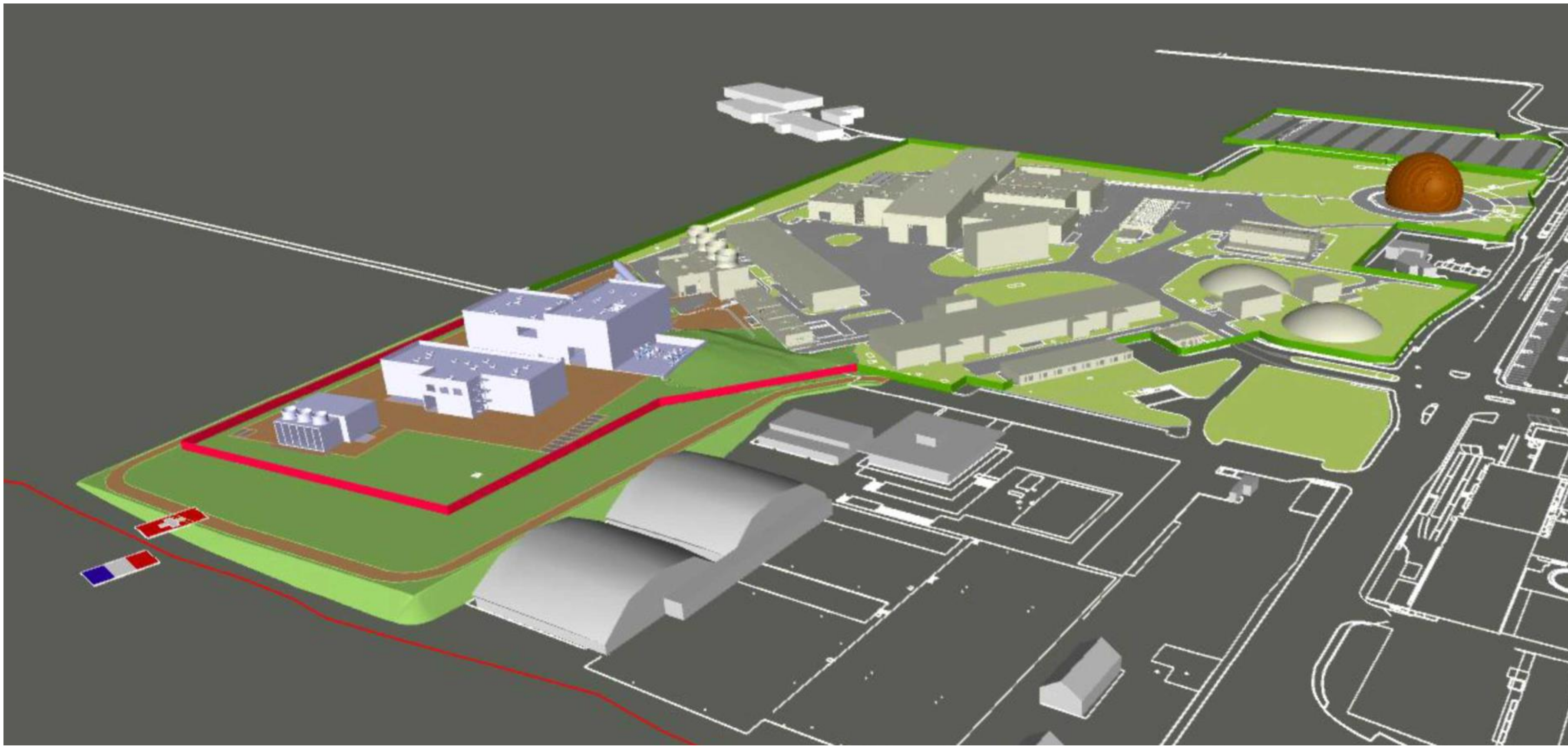
Major civil engineering required at P1-P5

All underground infrastructure being prepared during LS2



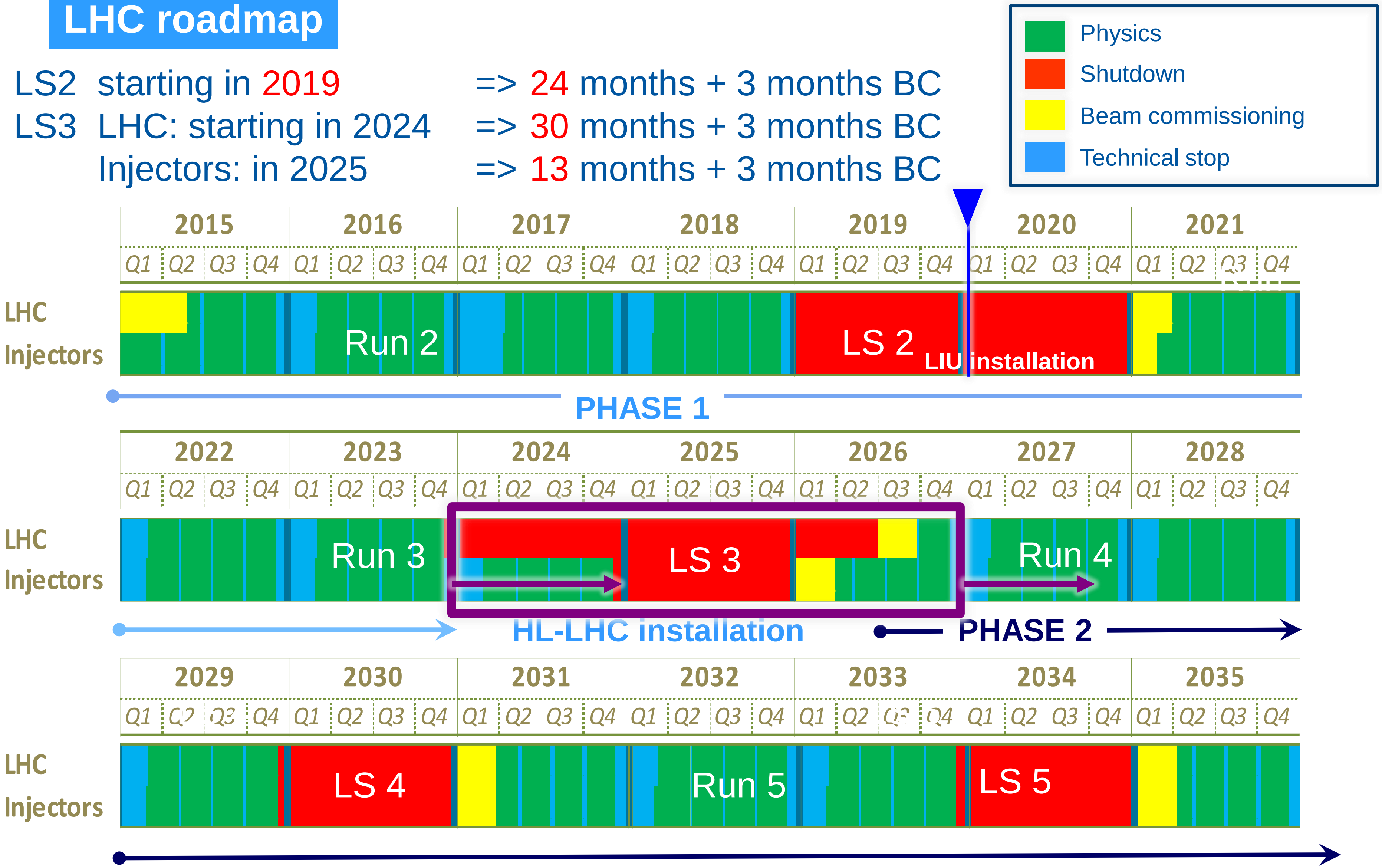
Inventory of the surface works (P1, ATLAS)

All surface buildings during Run3



LHC roadmap

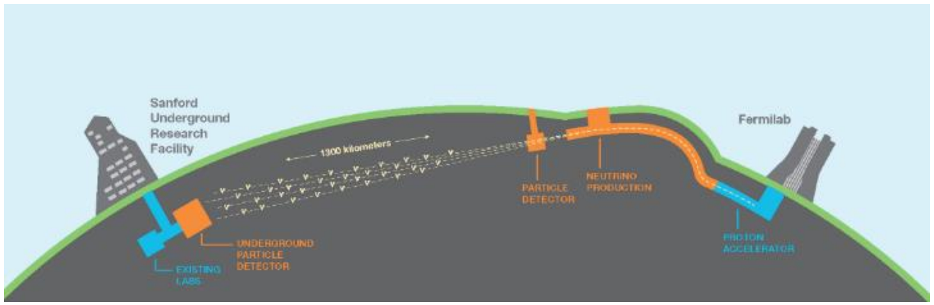
LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC

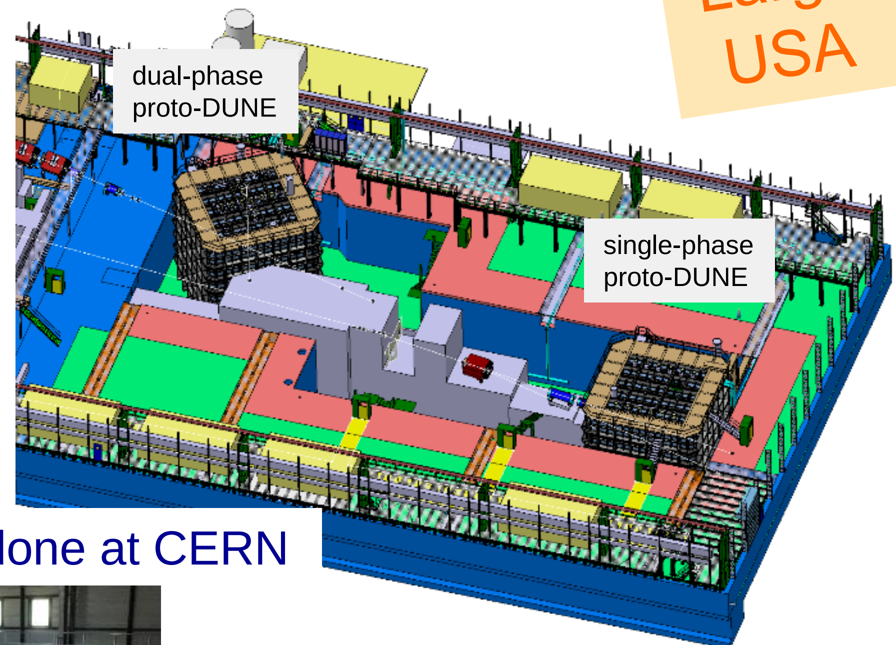


Neutrino Platform (new extension of North Area)

Larg., USA

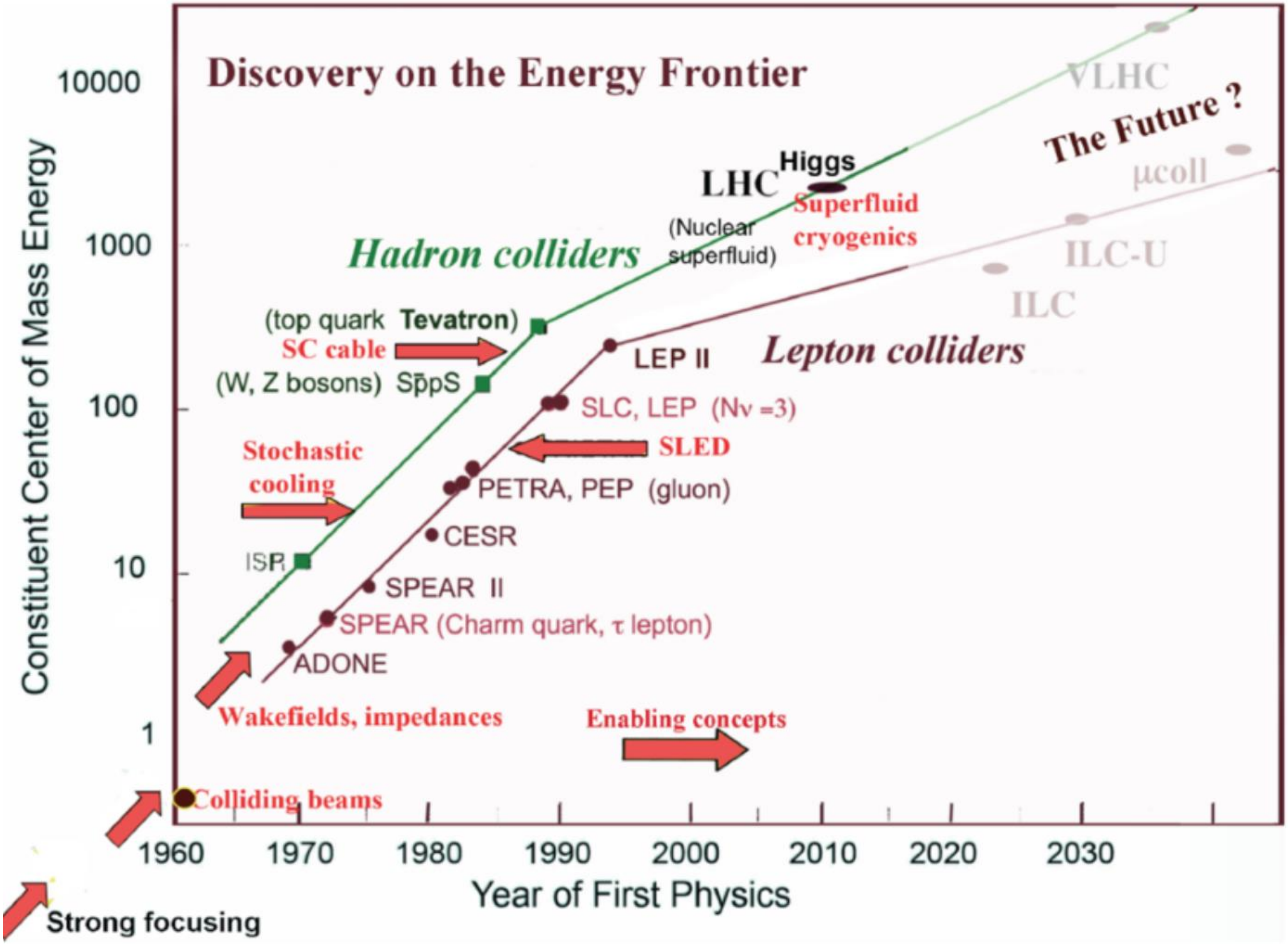
LBNF/DUNE project in USA:





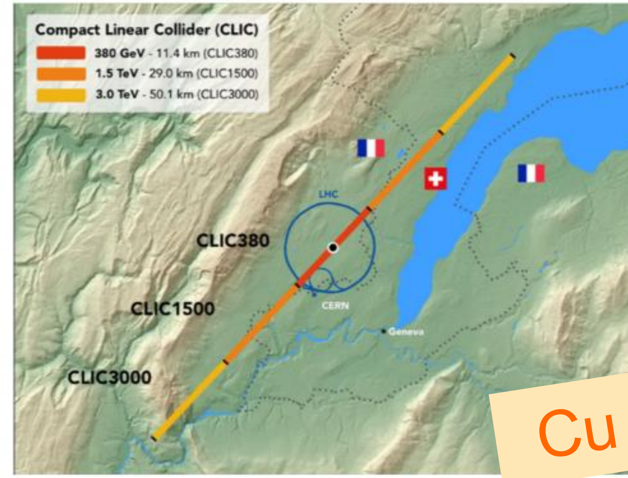
Recently done at CERN

Neutrino platform as a test area with charged beams for neutrino detectors (e.g. R&D for large liquid argon detectors).



Discovery on the Energy Frontier
Constituent Center of Mass Energy
Year of First Physics
10000
1000
100
10
1
1960
1970
1980
1990
2000
2010
2020
2030
Hadron colliders
Lepton colliders
The Future ?
VLHC
μcoll
ILC-U
ILC
LHC
Higgs
Superfluid cryogenics
(Nuclear superfluid)
(top quark Tevatron)
SC cable
(W, Z bosons) SppS
LEP II
SLC, LEP (Nν =3)
SLED
Stochastic cooling
PETRA, PEP (gluon)
CESR
ISR
SPEAR II
SPEAR (Charm quark, τ lepton)
ADONE
Wakefields, impedances
Enabling concepts
Colliding beams
Strong focusing

CLIC: multi-TeV e^+e^- linear collider

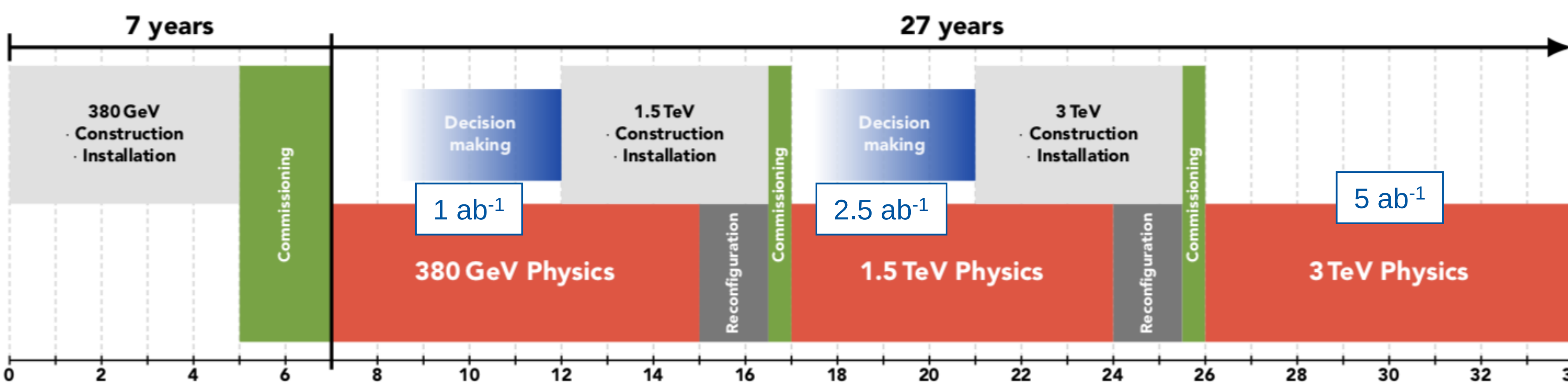


Cu !

Parameter	Unit	Stage 1	Stage 2	Stage 3
$\sqrt{s}$	GeV	380	1500	3000
Tunnel length	km	11	29	50
Gradient	MV/m	72	72/100	72/100
Pulse length	ns	244	244	244
Luminosity (above 99% of $\sqrt{s}$)	10^{34} $cm^{-2}s^{-1}$	1.5 0.9	3.7 1.4	5.9 2
Repetition frequency	Hz	50	50	50
Bunches per train		352	312	312
Bunch spacing	ns	0.5	0.5	0.5
Particles/bunch	10^9	5.2	3.7	3.7
Beam size at IP (σ_y/σ_x)	nm	2.9/149	1.5/60	1/40
Annual energy consumption	TWh	0.8	1.7	2.8
Construction cost	BCH	5.9	+5.1	+7.3

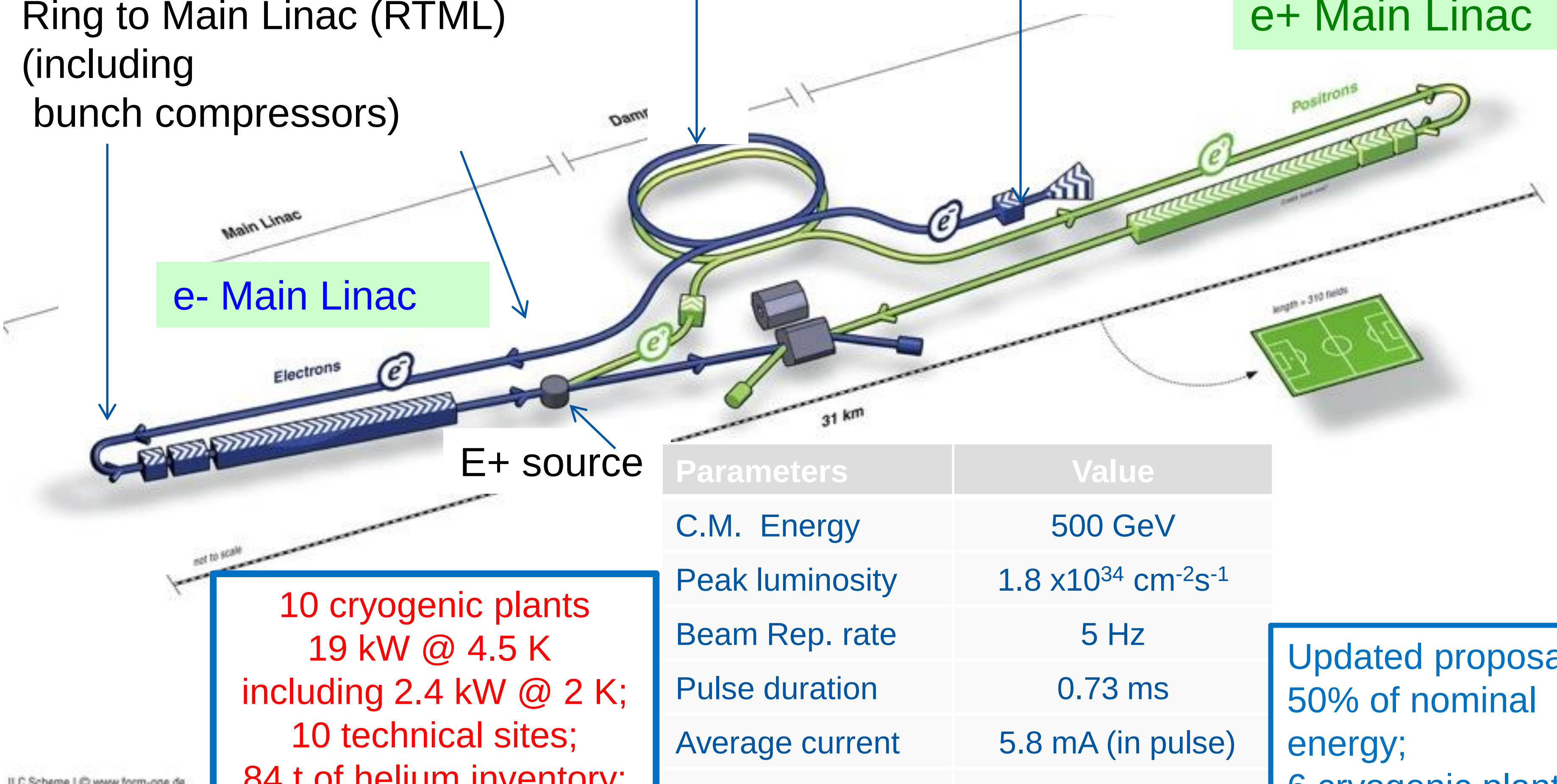
100 MV/m accelerating gradient needed for compact (~50 km) machine at 3 TeV
→ based on normal-conducting accelerating structures and a two-beam acceleration scheme

Technically, construction could start in ~2026 (TDR in 2025) → first collisions at $\sqrt{s}$=380 GeV in ~2035 → 25-30 years of physics exploitation



Cryogenics for ILC; TDR Design

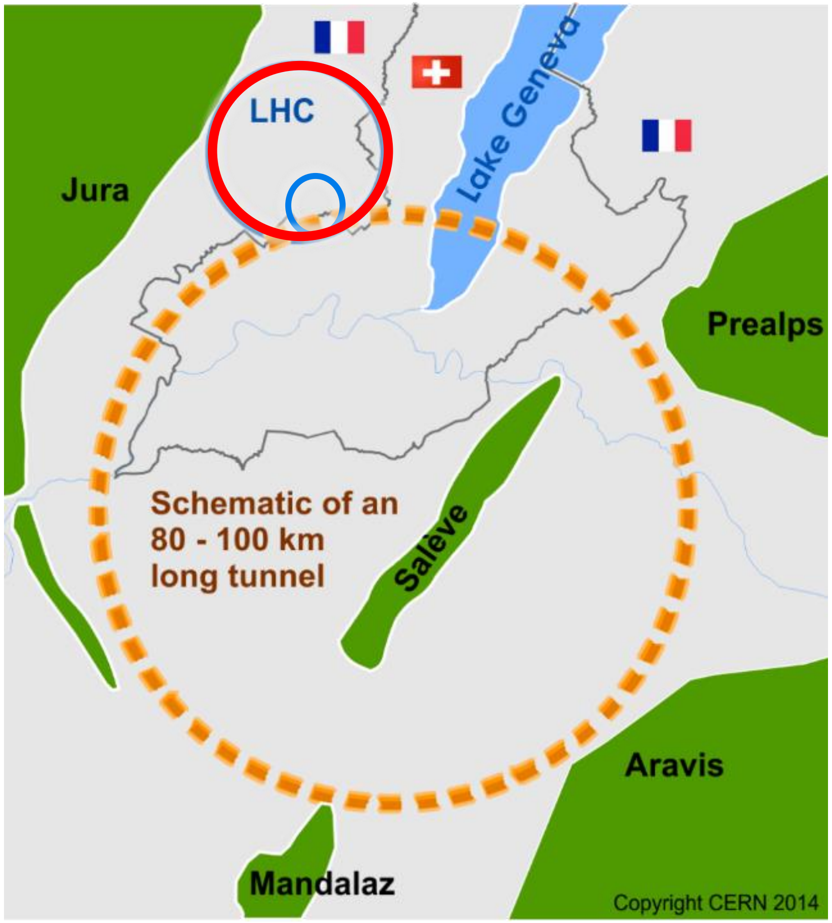
Hell, JP



Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8 x10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
E gradient in SCRF acc. cavity	31.5 MV/m +/-20% Q_0 = 1E10

10 cryogenic plants
19 kW @ 4.5 K
including 2.4 kW @ 2 K;
10 technical sites;
84 t of helium inventory;
cryogenic distribution line

Updated proposal:
50% of nominal energy;
6 cryogenic plants in 1st phase

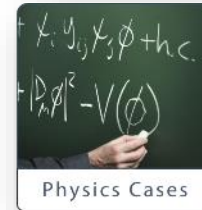


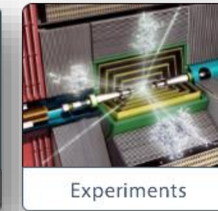
International FCC collaboration (CERN as host lab) to study:

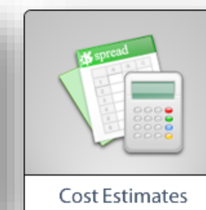
- **~100 km tunnel infrastructure** in Geneva area, linked to CERN
- ***e⁺e⁻* collider (*FCC-ee*),** as potential first step
- ***pp*-collider (*FCC-hh*)** → long-term goal, defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **HE-LHC** with *FCC-hh* technology







- 2018 CDR (studies involving industry)
- 2020 European Strategy (discussion)

Up to 1’000 kW eq. @ 4.5K
800 t He

Les accélérateurs sont notre coeur de métier

Merci pour votre attention!

L'électricité est notre énergie,

L'Hélium est notre sang !