From LHC to CLIC and FCC: some common issues in the study of future large accelerator projects

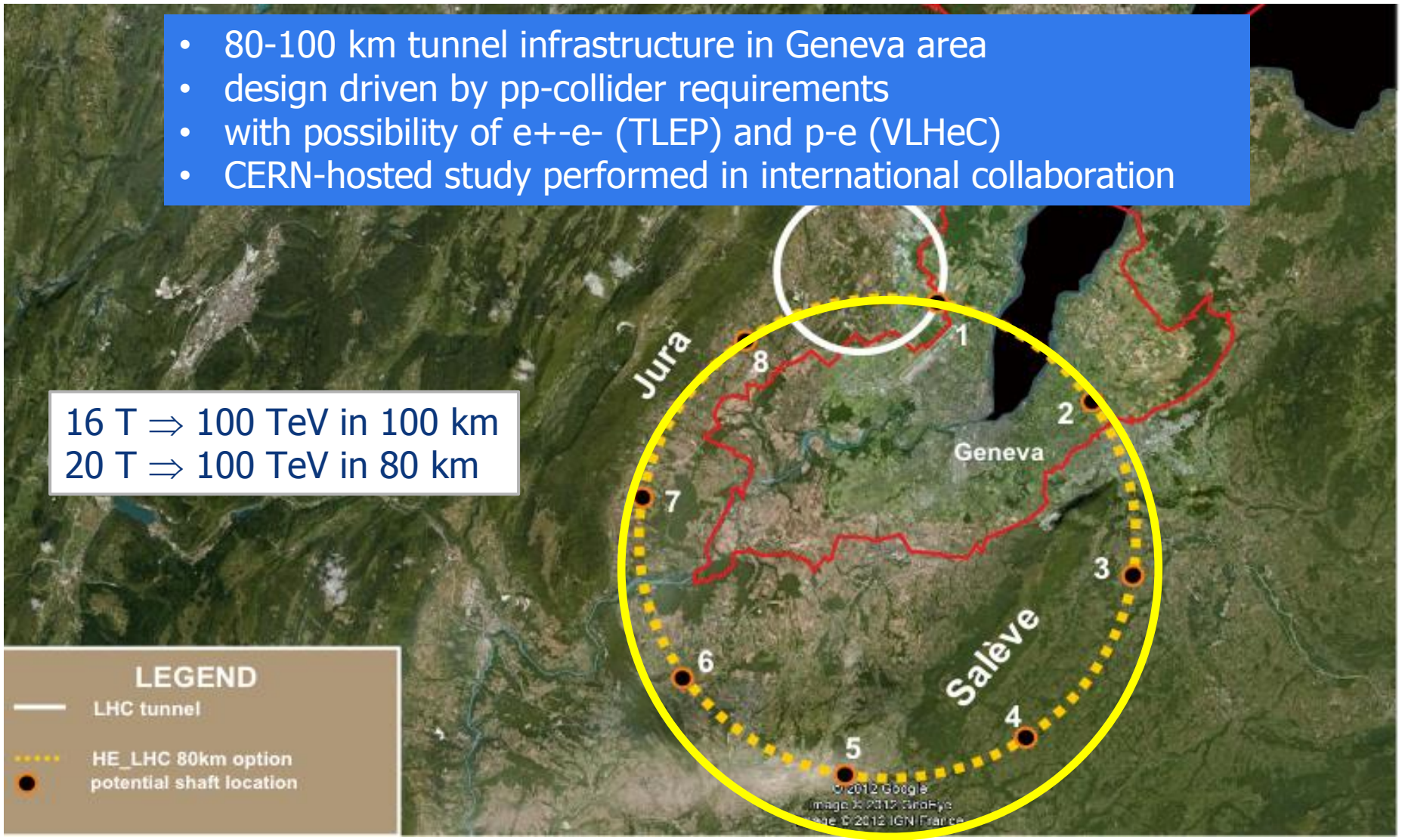
Philippe Lebrun

CLIC Workshop 2014
CERN, 3-7 February 2014

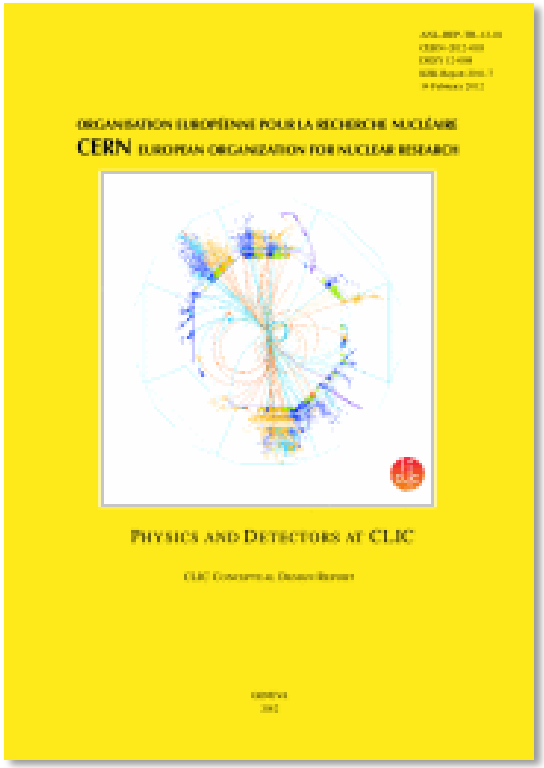
The Future Circular Colliders (FCC) design study

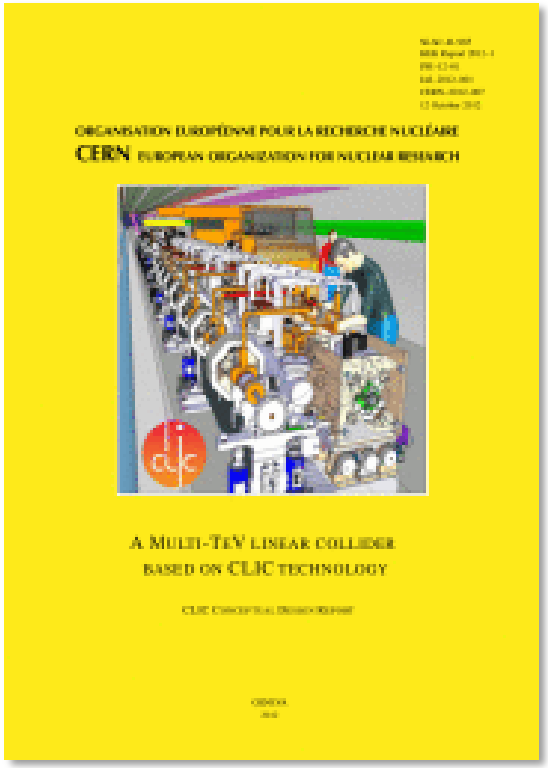
Aiming for CDR and Cost Review for the next ESU (2018)

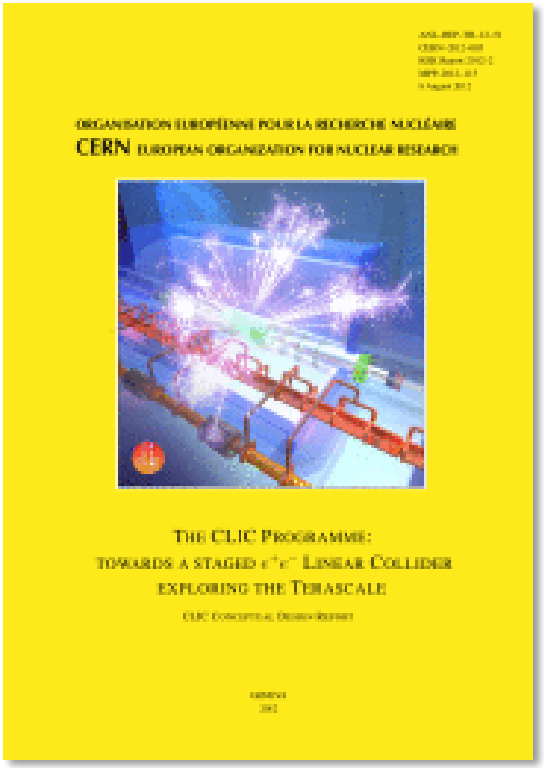
- 80-100 km tunnel infrastructure in Geneva area
- design driven by pp-collider requirements
- with possibility of e+-e- (TLEP) and p-e (VLHeC)
- CERN-hosted study performed in international collaboration



CLIC CDR and cost study (2012)

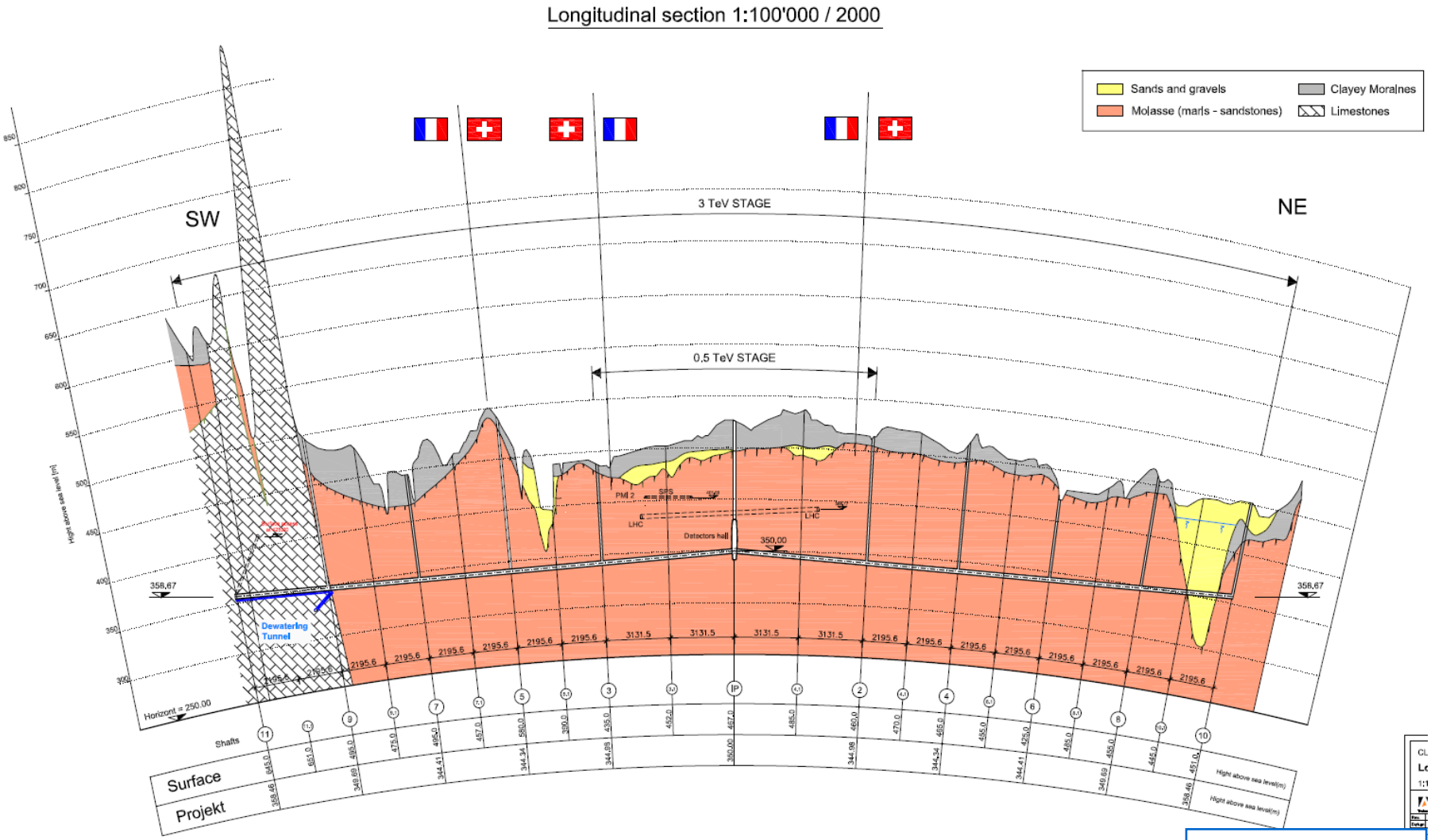






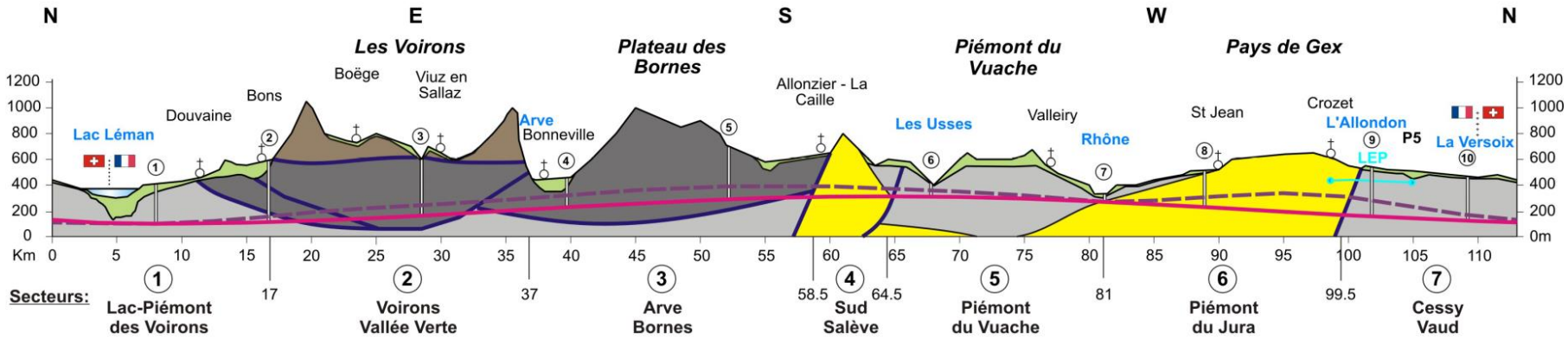
- 3 volumes: physics & detectors, accelerator complex, strategy, cost & schedule
- Collaborative effort: 40+ institutes worldwide
- May be used as model for FCC CDR

Geology
Longitudinal section along CLIC tunnel



J. Osborne

Geology
Longitudinal section along large ring in Geneva basin



MORAINES

MOLASSE EN PLACE

MOLASSE CHARRIEE

CALCAIRES

FLYSCH des VOIRONS

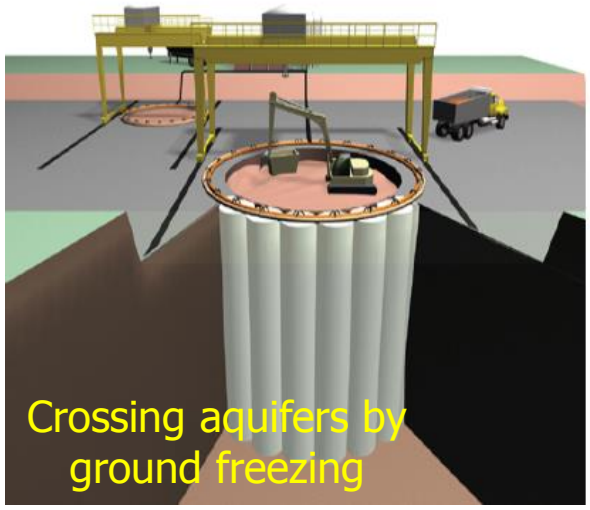
FAILLES OU SURFACES DE CHARRIAGE

TUNNEL - Tracé plan

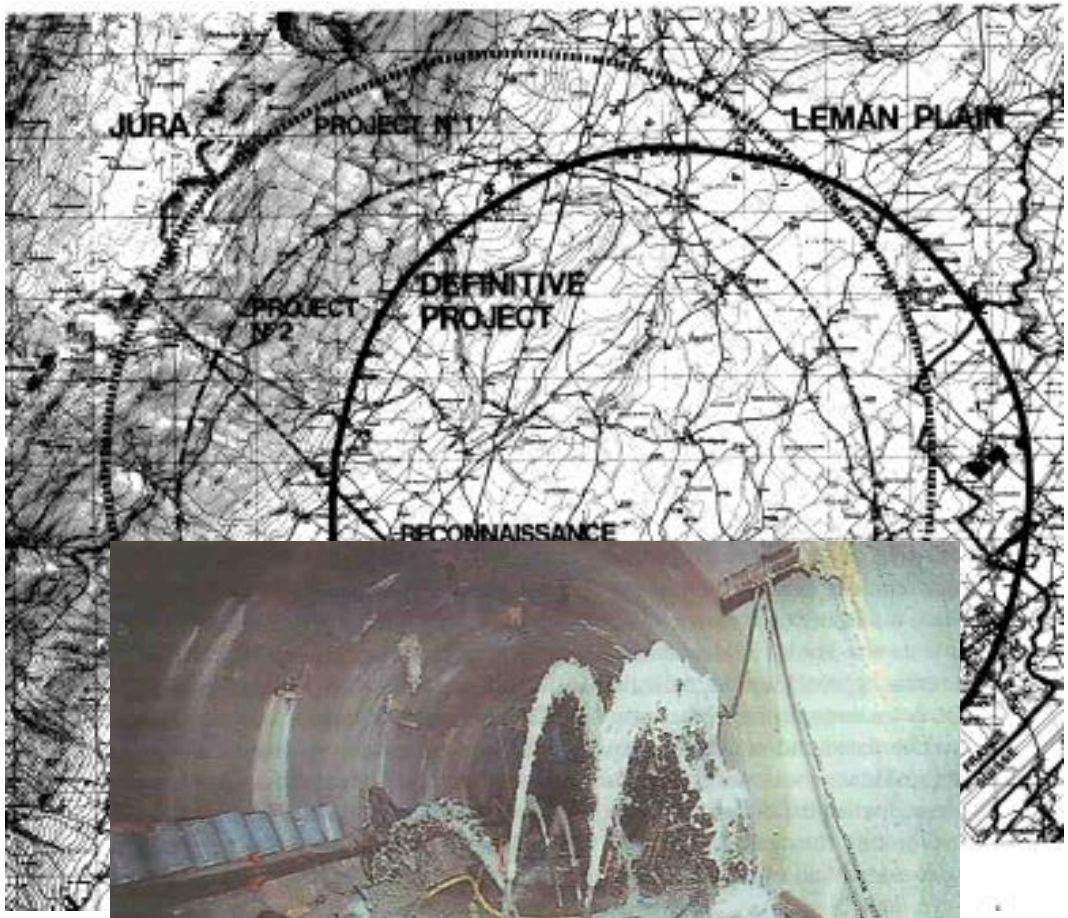
TUNNEL - Tracé adapté à la topo

GADZ GEOTECHNIQUE APPLIQUEE DERIAZ S.A.

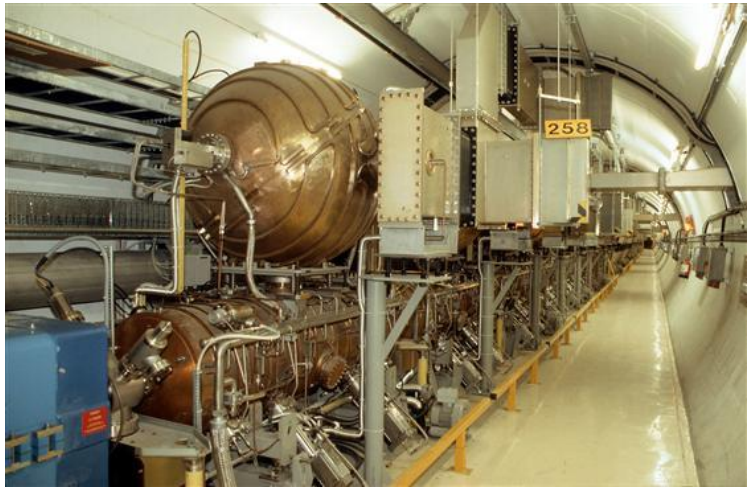
Geotechniques for LEP & LHC
Applicable to CLIC and FCC



Site/size optimization: the case of LEP

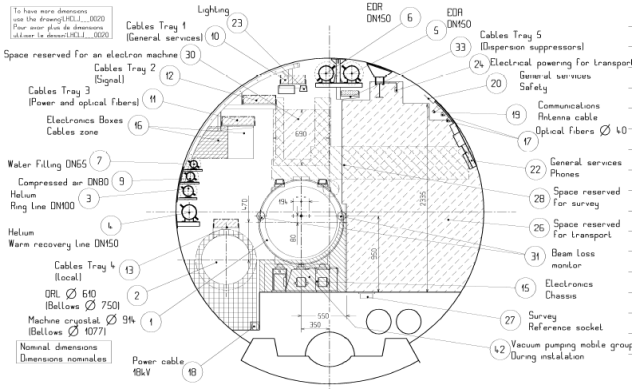


- **Geology**: stay out of Trias
- **Hydrology**: preserve springs at piedmont of Jura
- **Geotechnical**: maximize tunnel in "molasse" (1.41 % slope)
- **Topography**: limit overburden
- **Neighbourhood**: integration of surface buildings, noise, road traffic
- **Cost**
- **Performance**: trade-off CE vs accelerator technology



Tunnel cross-section
Accelerator components only

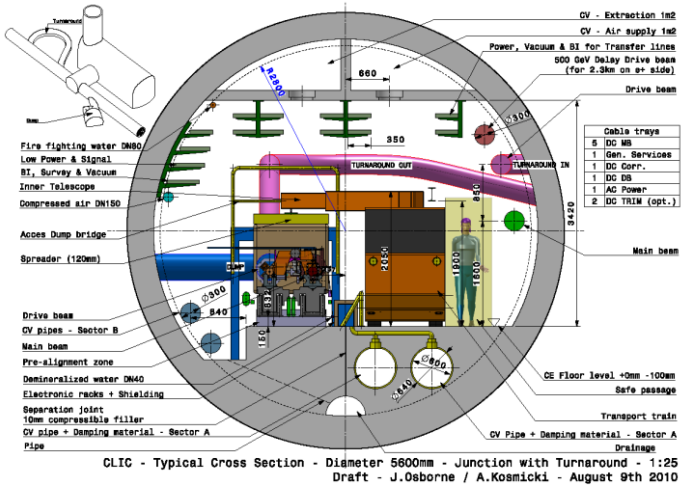
LEP/LHC



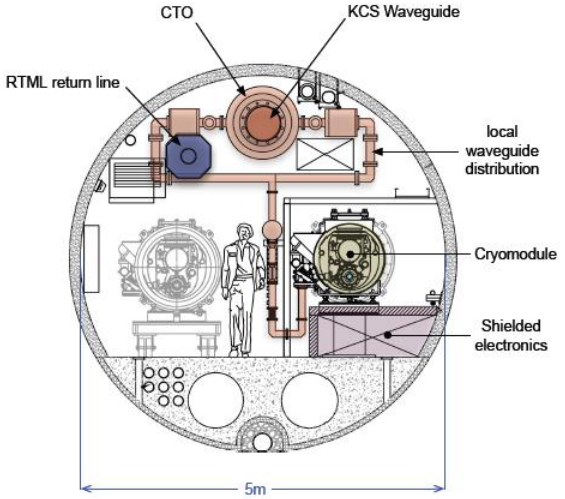
All tunnels drawn at same scale

2 m

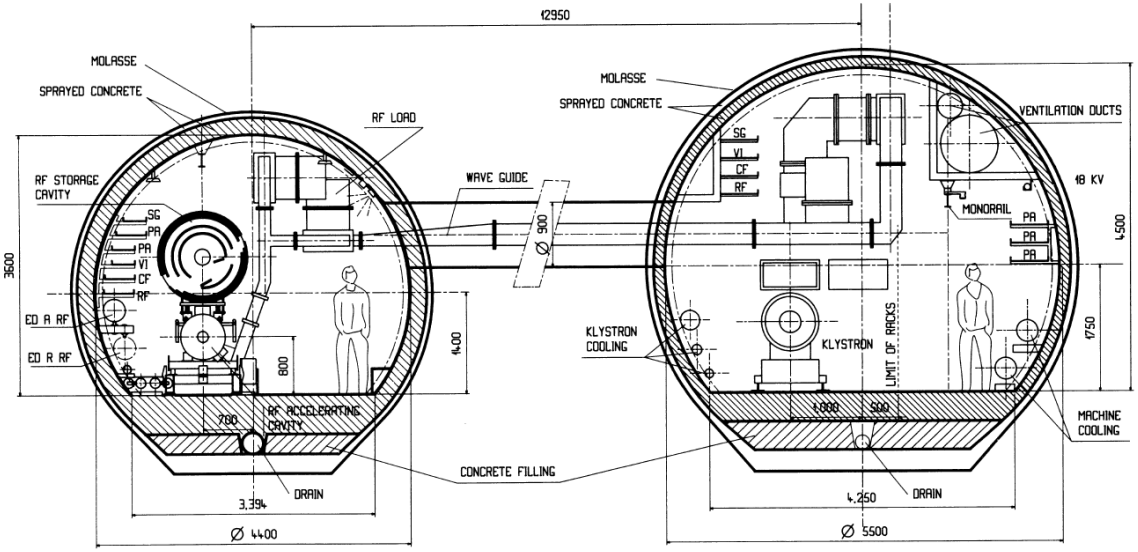
CLIC



ILC "klystron cluster"



Tunnel cross-section
Accelerator components & technical systems

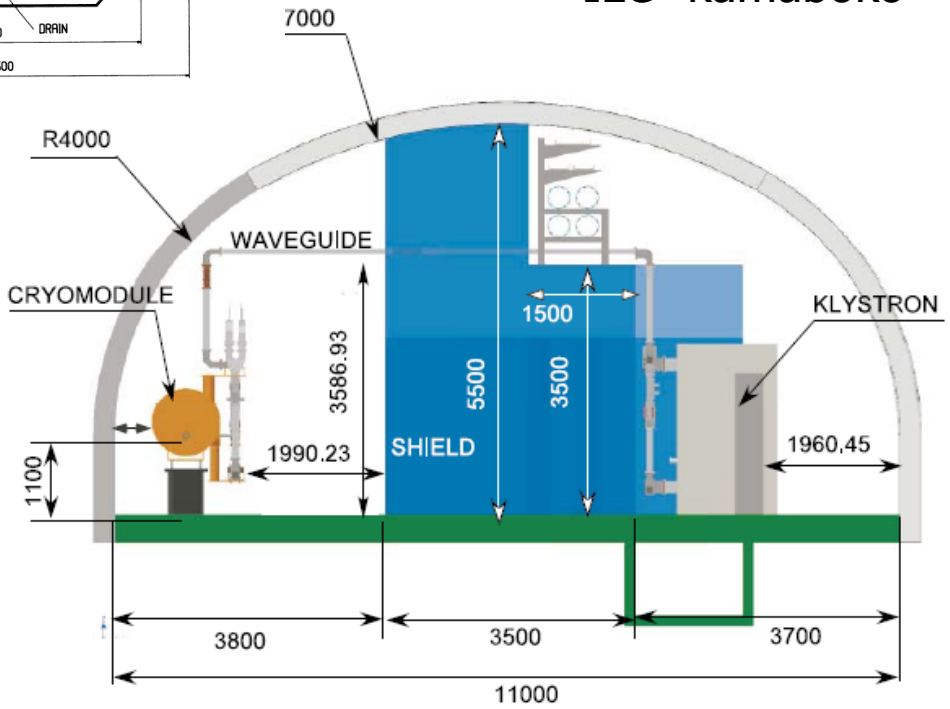


LEP

All tunnels drawn at same scale

2 m

ILC "kamaboko"

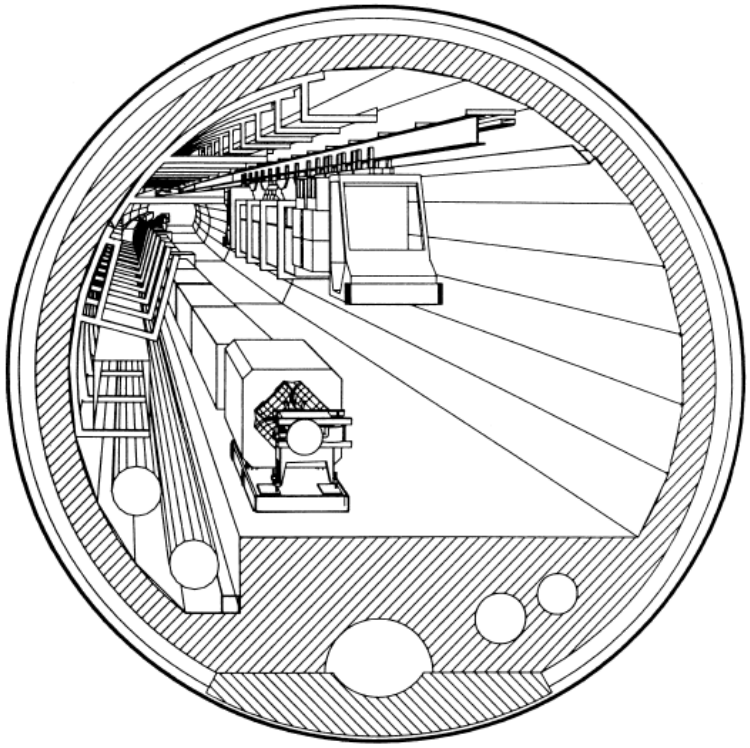


Need for a technical service tunnel?

Ph. Lebrun

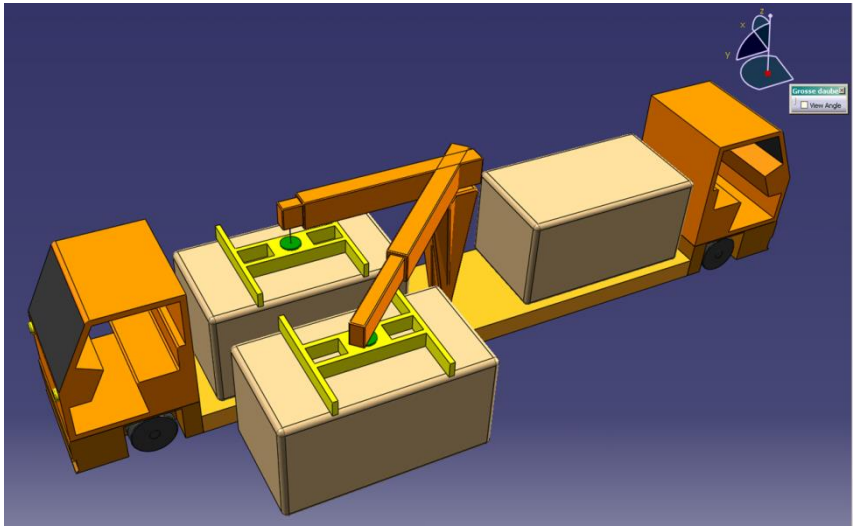
Underground transport & installation

LEP monorail



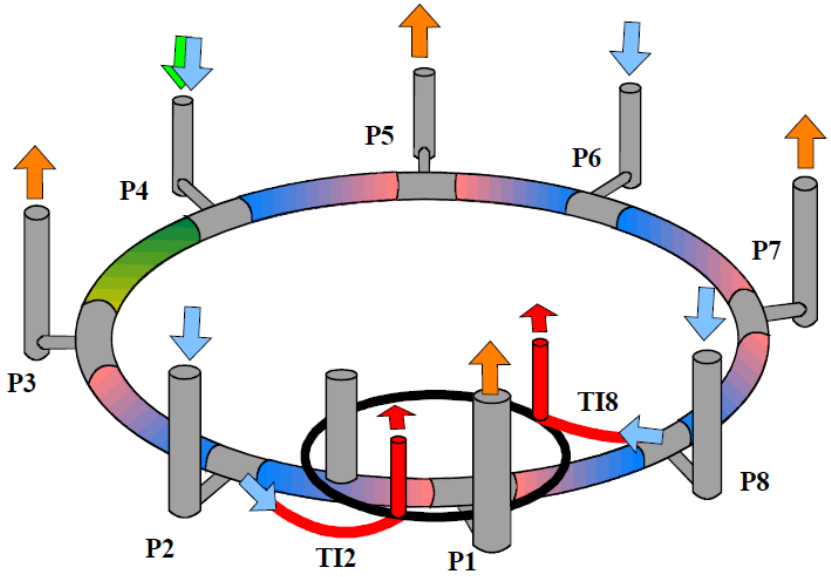
LHC

CLIC

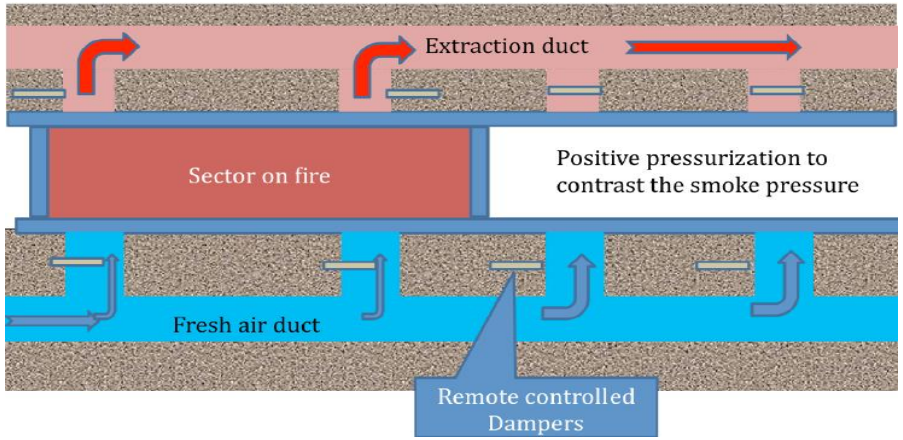


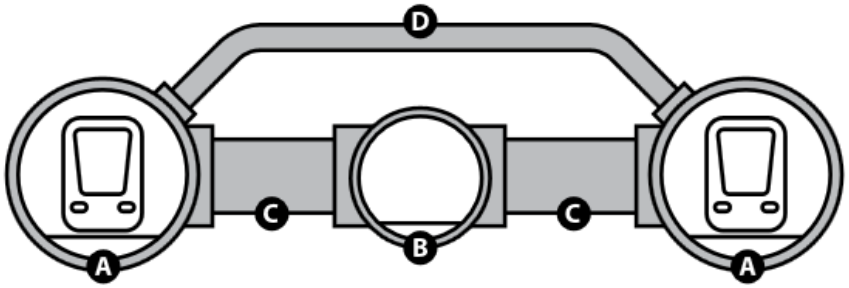
- Floor or ceiling?
- Personnel & equipment
- Co-activities & safety

A case in tunnel safety: the ventilation scheme



- Longitudinal
  - Tunnel is the air duct
  - Safety not guaranteed downstream of danger area
- Transverse
  - Need (protected) fresh-air & extraction ducts in tunnel (larger X-section)
  - Danger area can be segmented
- Separate service/safety tunnel
  - Also used for ventilation & pressure equalization





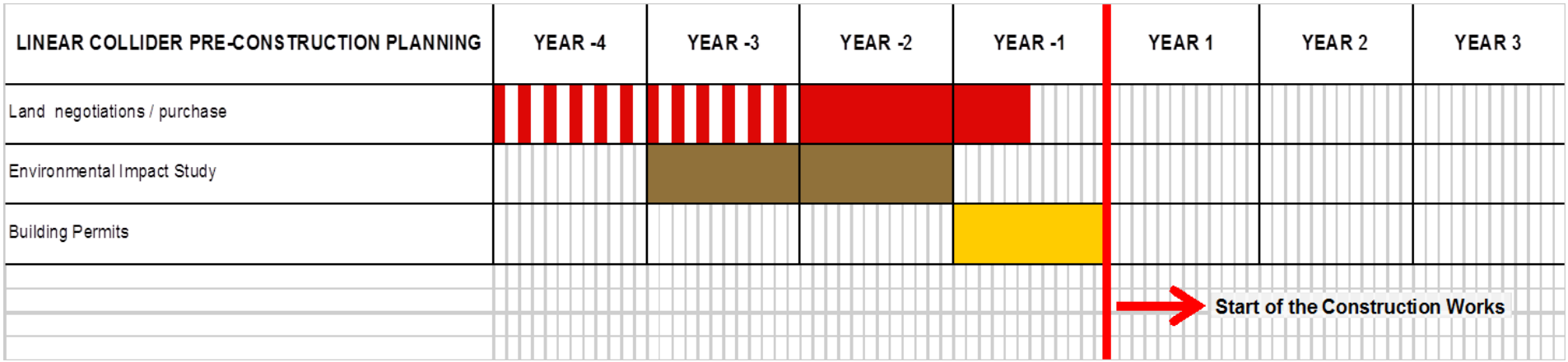
Environment impact assessment
Requirements

- EIA (World Bank OP 4-01, 1999 rev. 2011)
  - *An instrument to identify and assess the potential environmental impacts of a proposed project, evaluate alternatives, and design appropriate mitigation, management, and monitoring measures*

- Large projects require EIA
  - French law:
    - Article R 122-8I du Code de l'Environnement
    - Décret 77-1141 du 12 October 1977
  - Swiss federal law:
    - Ordonnance relative à l'étude de l'impact sur l'environnement (OEIE)
  - EU:
    - Directive 85/337/EEC
    - Updated in 1997 (directive 97/11/EC), 2003 (directive 2003/35/EC), 2009 (directive 2009/31/EC)

C. Waaijer

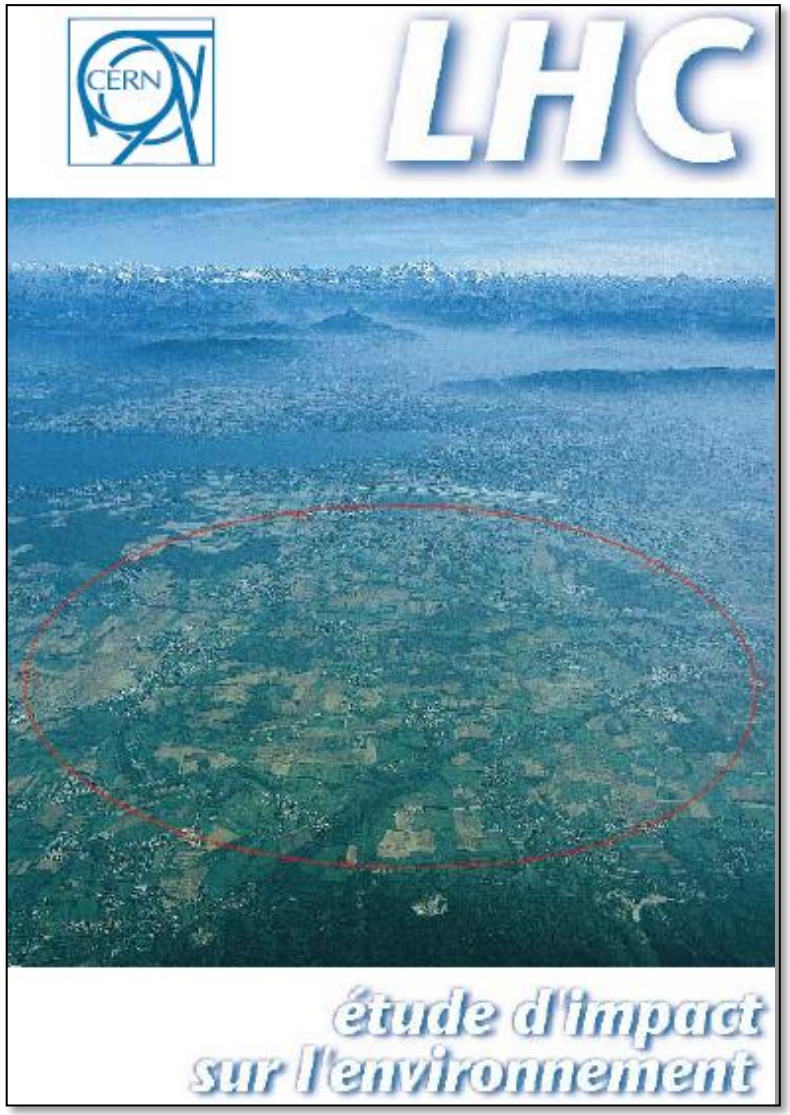
Environmental impact assessment
Process



- Environmental Impact Study
  - Survey of initial state
  - Description of maximum impacts for all phases of construction & operation
  - Environmental Management Plan for each phase
- Involvement of the public
  - Information sessions
  - Public enquiry
- Déclaration d'Utilité Publique

C. Waaijer

Environmental impact assessment
LHC impact study



Le Conseil du CERN a décidé à l'unanimité, le 16 décembre 1994, de construire le grand collisionneur de hadrons (LHC), qui donne aux physiciens des particules européens et du monde un instrument exceptionnel pour la poursuite de leurs travaux.

Cet instrument sera réalisé sur le domaine que la Suisse et la France, Etats-hôtes de l'Organisation, ont mis à la disposition de celle-ci.

Comme il l'a fait pour ses grands accélérateurs antérieurs, en particulier le SPS et le LEP, le CERN réalisera le LHC en concertation avec les autorités nationales et les élus locaux.

Hubert Curien
Président du Conseil du CERN
lors de l'approbation du projet LHC
Ancien Ministre de la Recherche
du Gouvernement français

Environmental impact assessment
Survey initial state

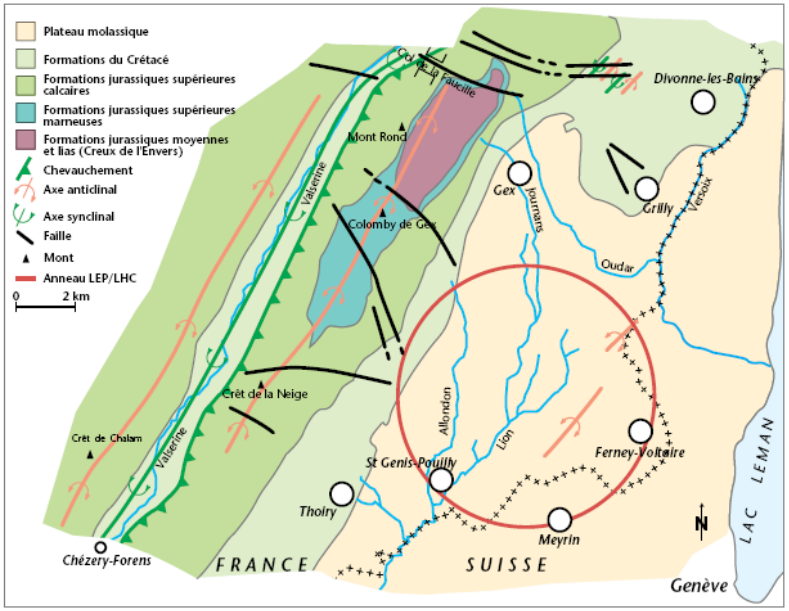
Fauna

Grand tétras

Flora

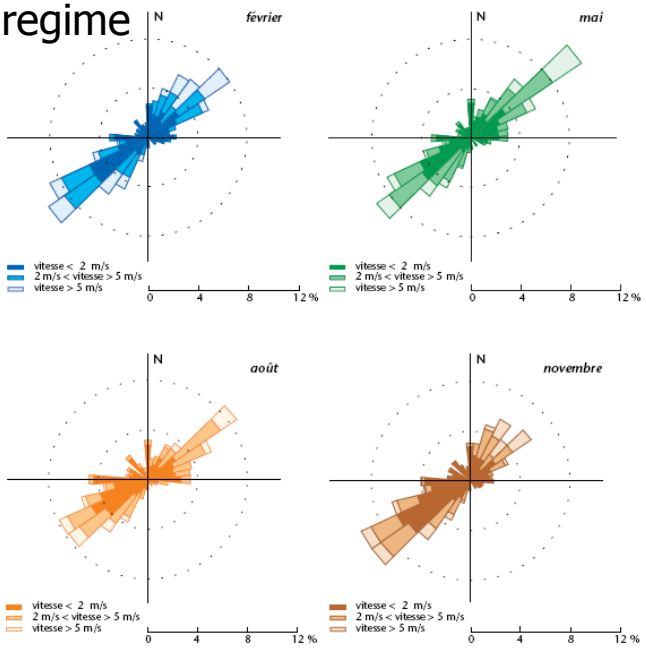
Gentiane jaune sur le Jura

Geology & hydrology



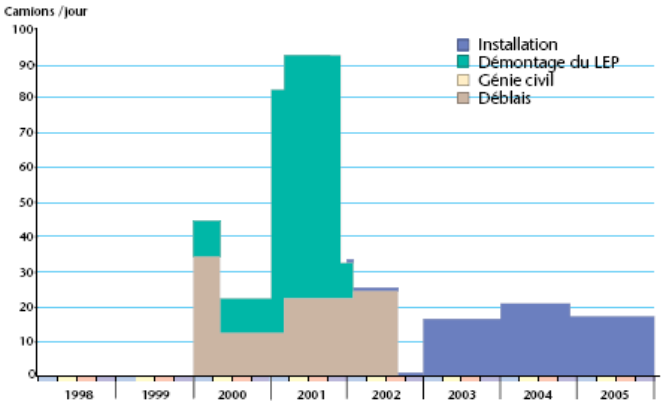
igure 6.6 Schéma structural et géologie simplifiée

Wind regime



4 Vents enregistrés à Genève-Cointrin de 1982 à 1995

Environmental impact assessment
Minimize impacts



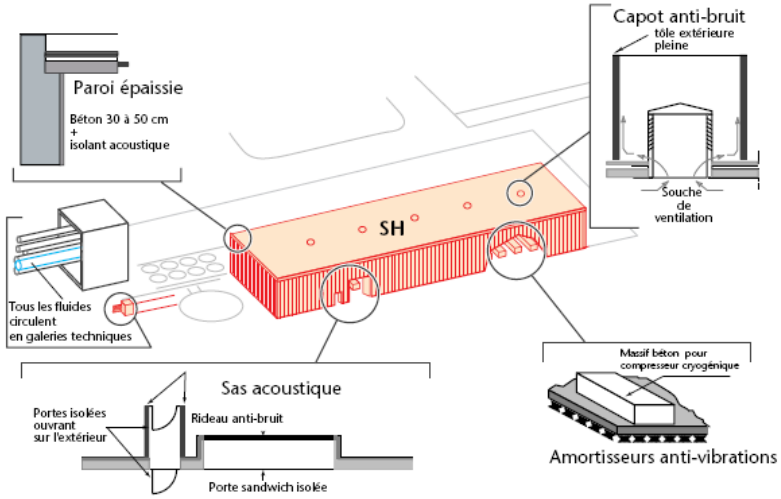
Trafic LHC sur la RD 984 entre le rond-point et la route VC 5 de Prévessin

Road traffic

Vue du Point 5 côté village : de la phase 1 ...

Visual impacts

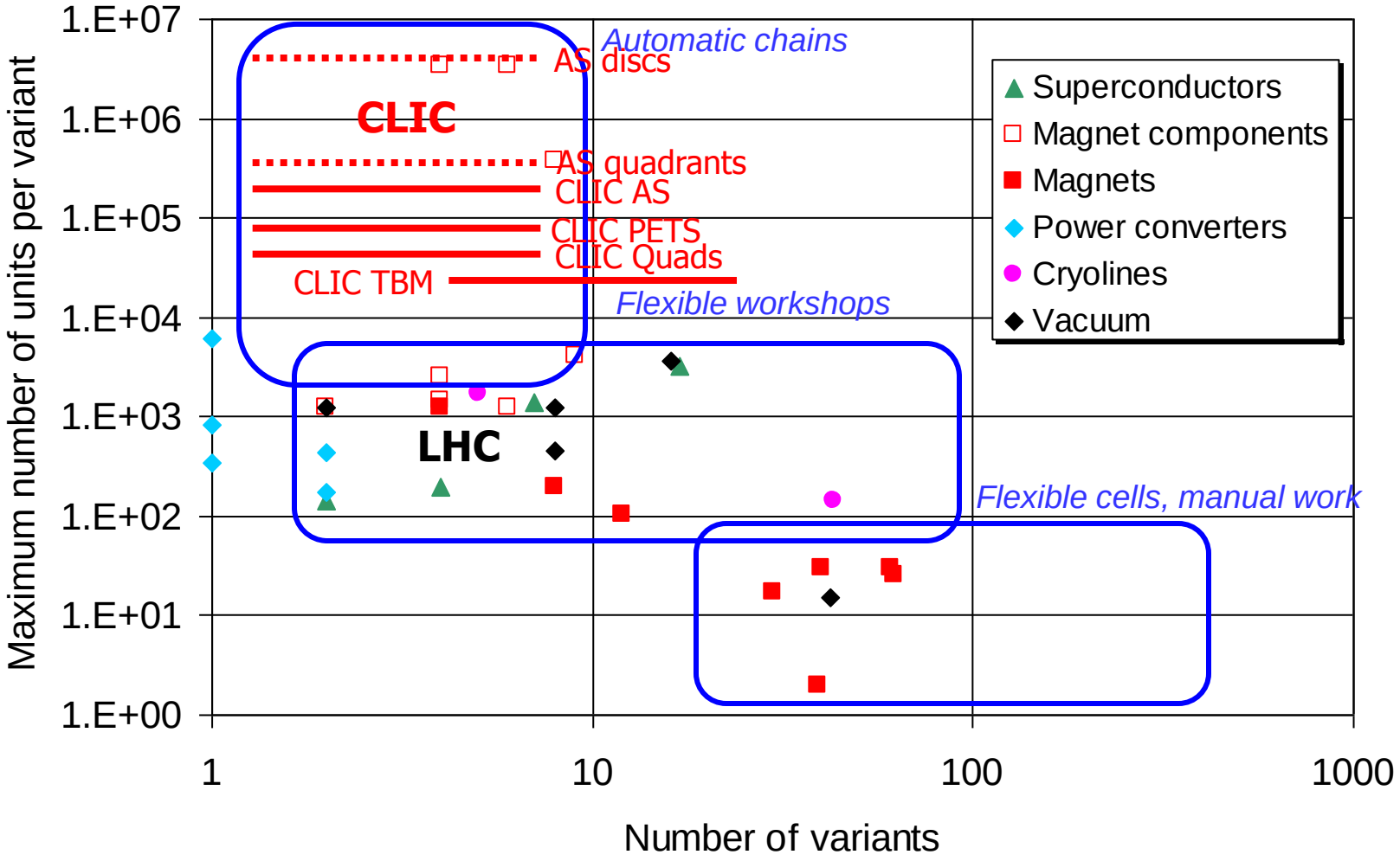
Vue du Point 5 côté village : ... à la phase 2



e 8.7 Isolation phonique des bâtiments de type SH

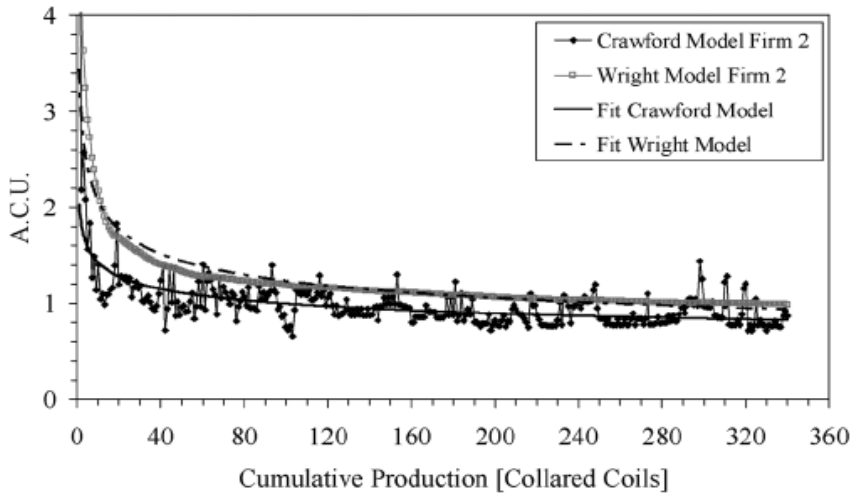
Noise

Industrial production of accelerator components
CLIC vs LHC series numbers



Industrial production of accelerator components
Measured learning curves of LHC SC dipoles

Collared coils



Cold masses

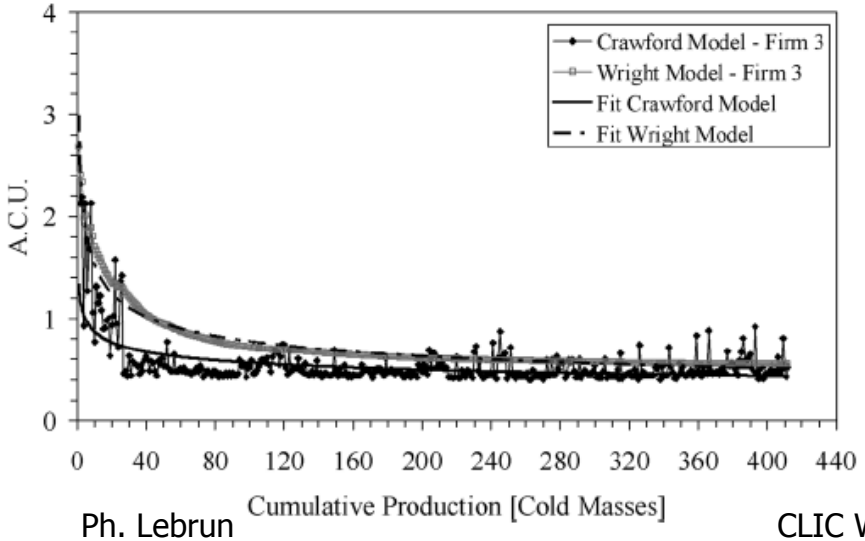
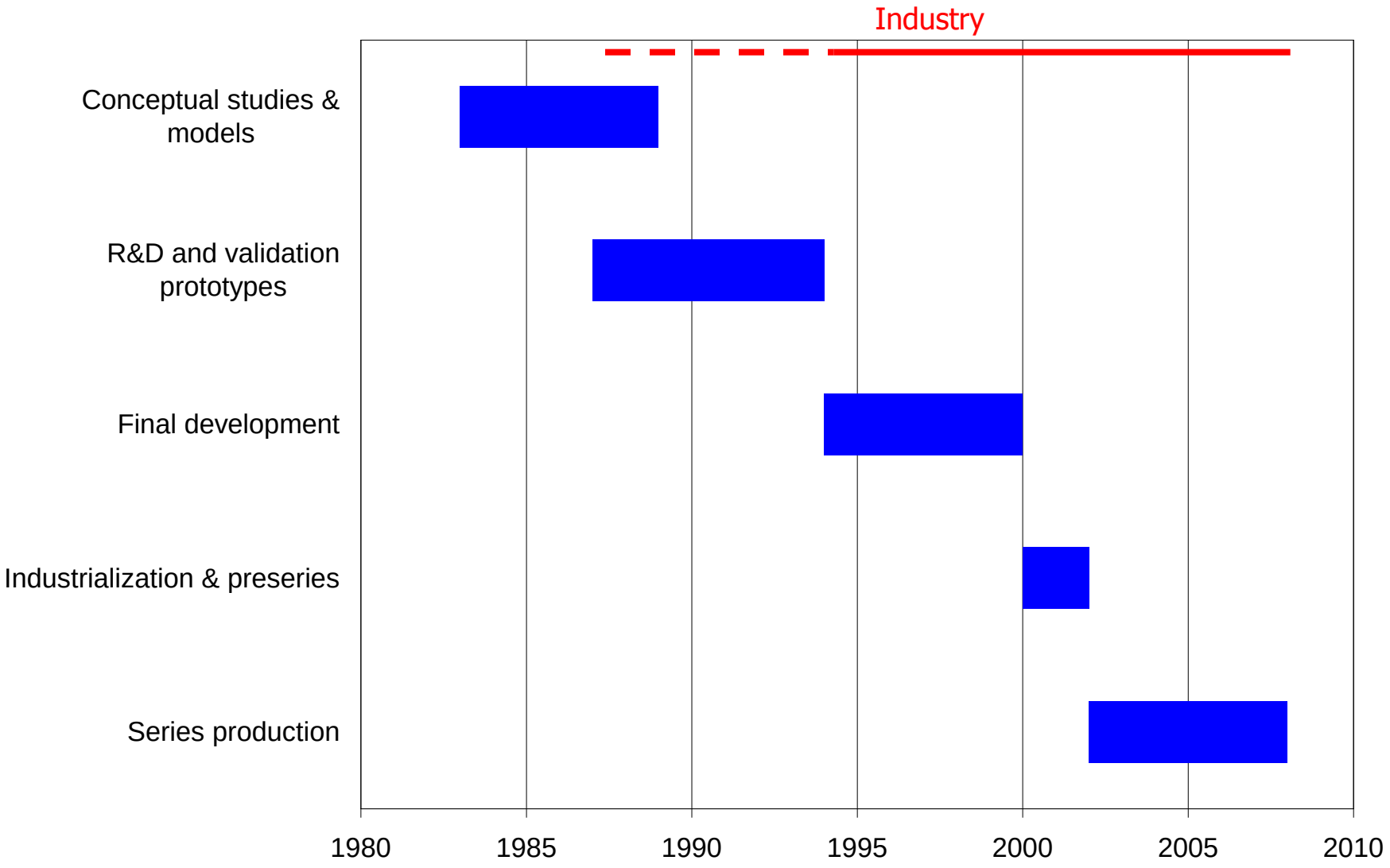


TABLE IV
LEARNING PERCENTAGE OF SELECTED REFERENCE INDUSTRIES

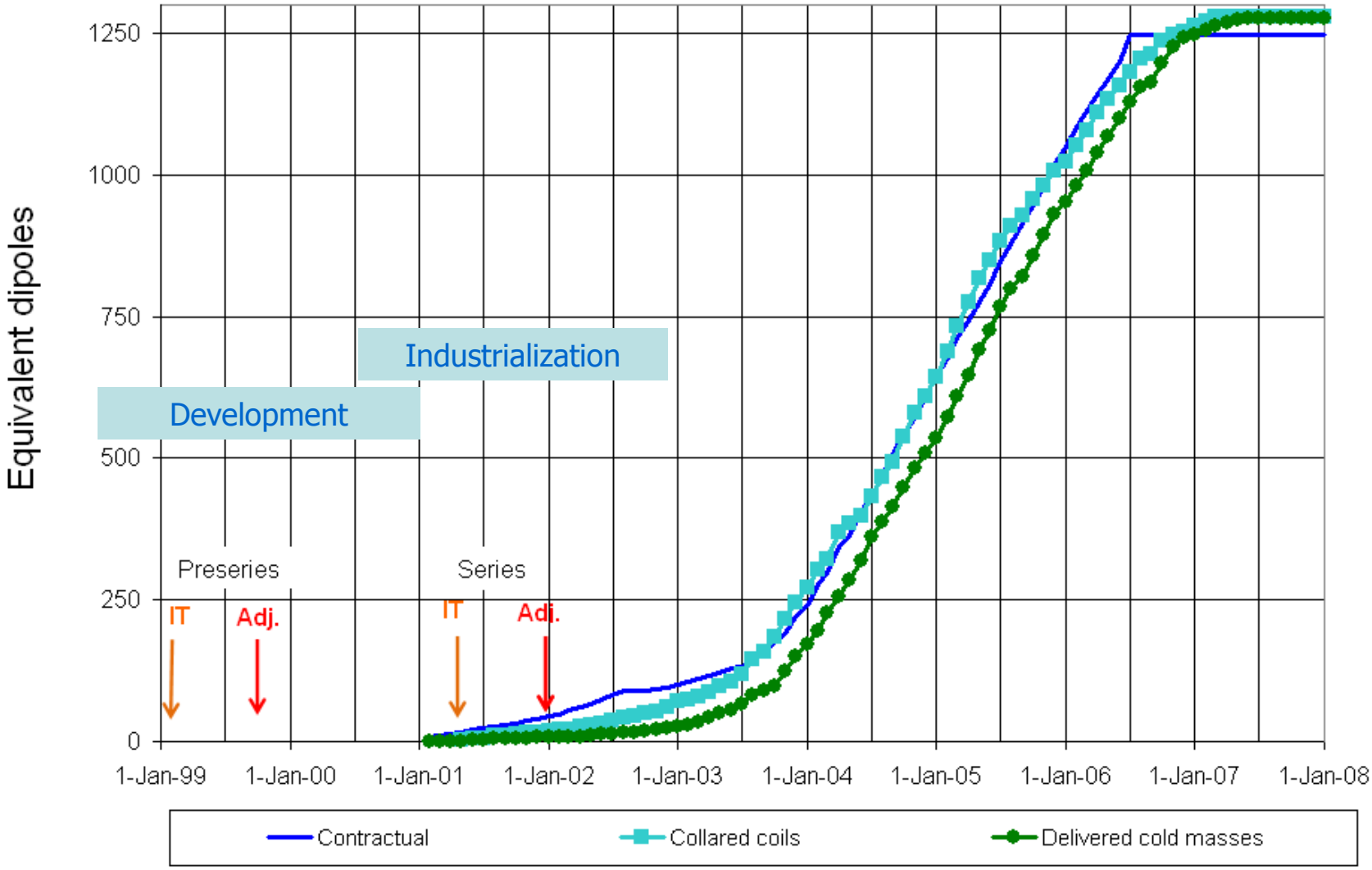
Industry	ρ
Complex machine tools for new models	75%-85%
Repetitive electrical operations	75%-85%
LHC magnets	80%-85%
Shipbuilding	80%-85%
Aerospace	85%
Purchased Parts	85%-88%
Repetitive welding operations	90%
Repetitive electronics manufacturing	90%-95%
Repetitive machining or punch-press operations	90%-95%
Raw materials	93%-96%

P. Fessia

Industrial production of accelerator components
Early involvement of industry in LHC SC dipoles



Industrial production of accelerator components
Industrialization & production ramp-up of LHC SC dipoles



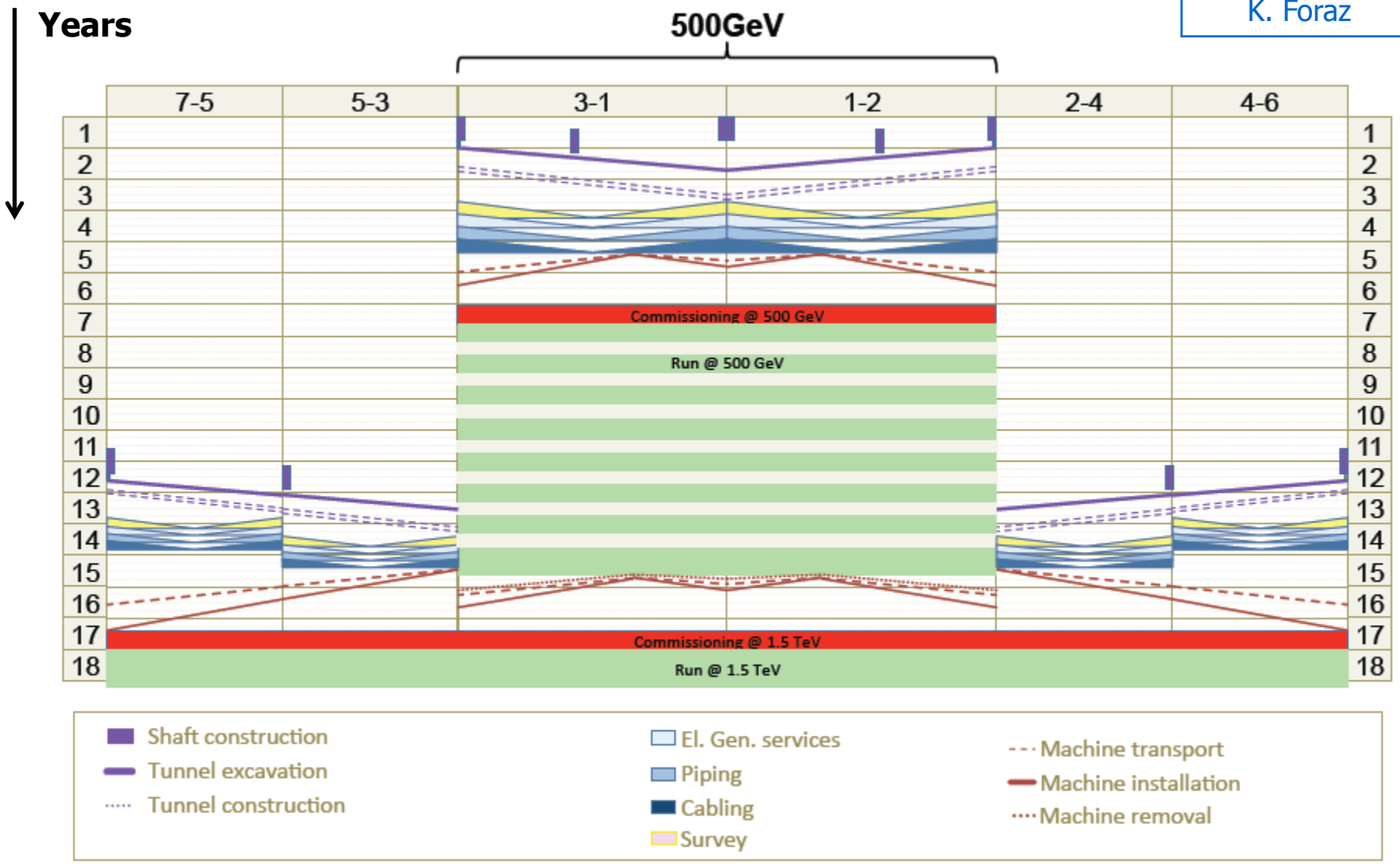
Schedule
Progress rate assumptions for CLIC

- Civil engineering
  - site installation: 15 weeks
  - shaft excavation and concrete:
    - 180 m deep: 30 weeks
    - 150 m deep: 26 weeks
    - 100 m deep: 15 weeks
  - service caverns: 35 weeks
  - excavation by tunnel-boring machine (TBM): 150 m/week
- Installation of general services
  - Survey & floor markings: 9 weeks/km/front
  - electrical general services: 8 weeks/km/front
  - cooling pipes & ventilation ducts: 8 weeks/km/front
  - AC and DC cabling: 8 weeks/km/front
- Installation of main linacs
  - Transport of two-beam modules: 500/month
  - Interconnection of two-beam modules: 300 to 400/month

Schedule

CLIC Main Linac construction schedule – Scenario B

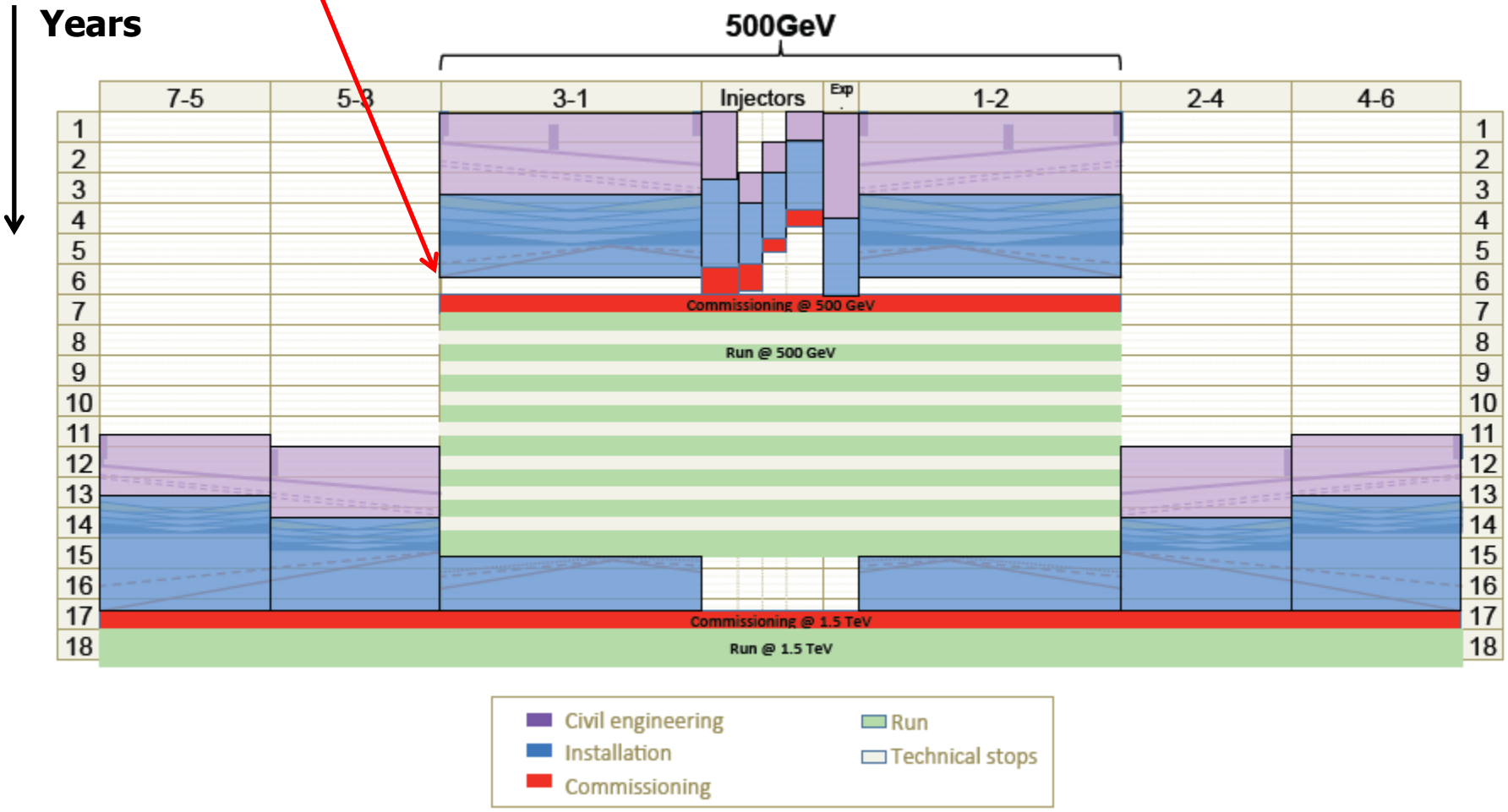
K. Foraz



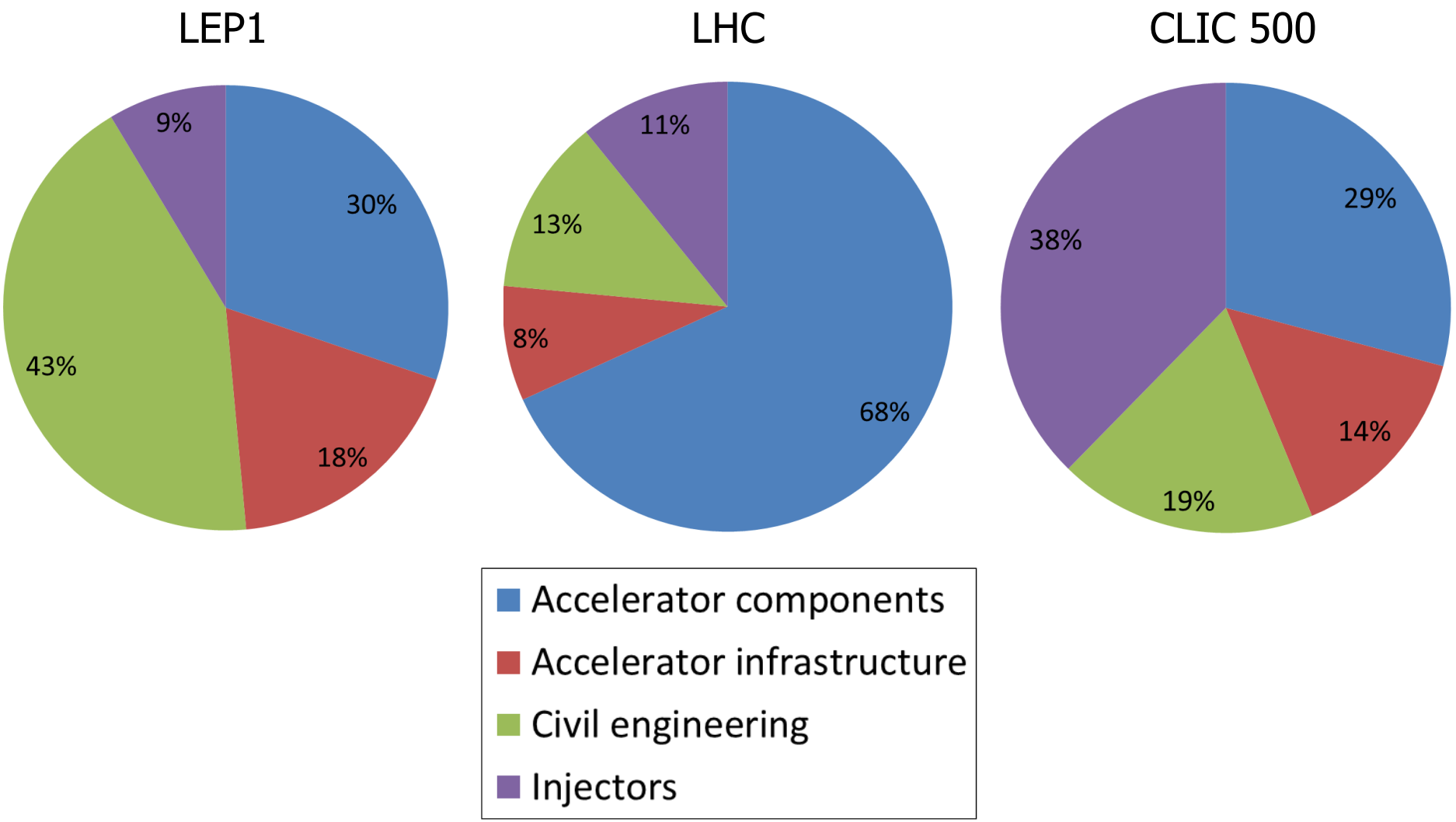
Schedule
CLIC overall construction schedule - Scenario B

Construction of Main Linacs in the shade of injectors & experiments

K. Foraz

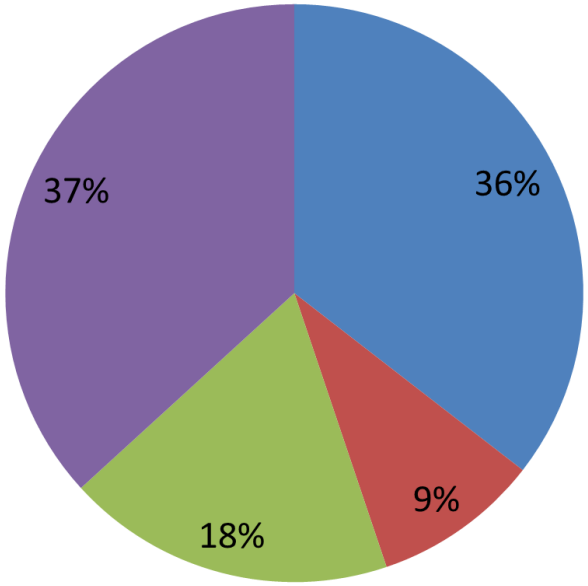


Cost
Cost structure of large accelerator projects

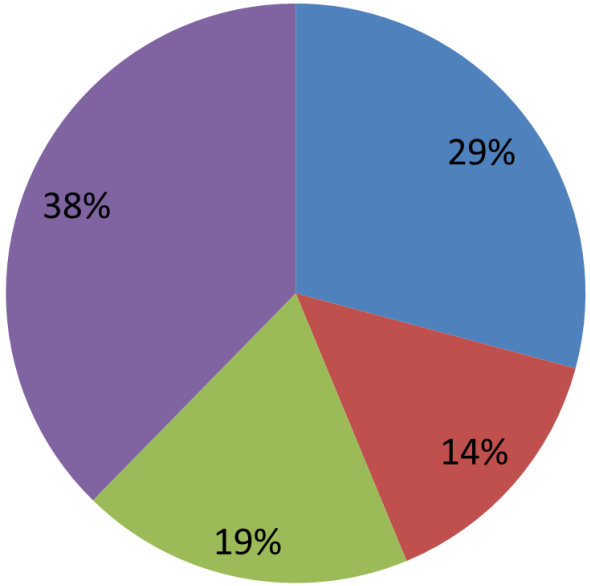


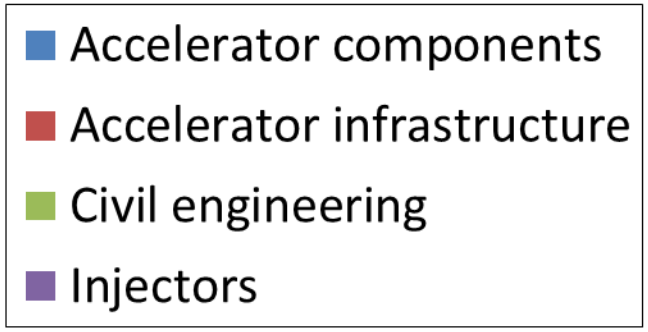
Cost
"Green field" cost of large accelerator projects

LHC "green field" (reconstructed)



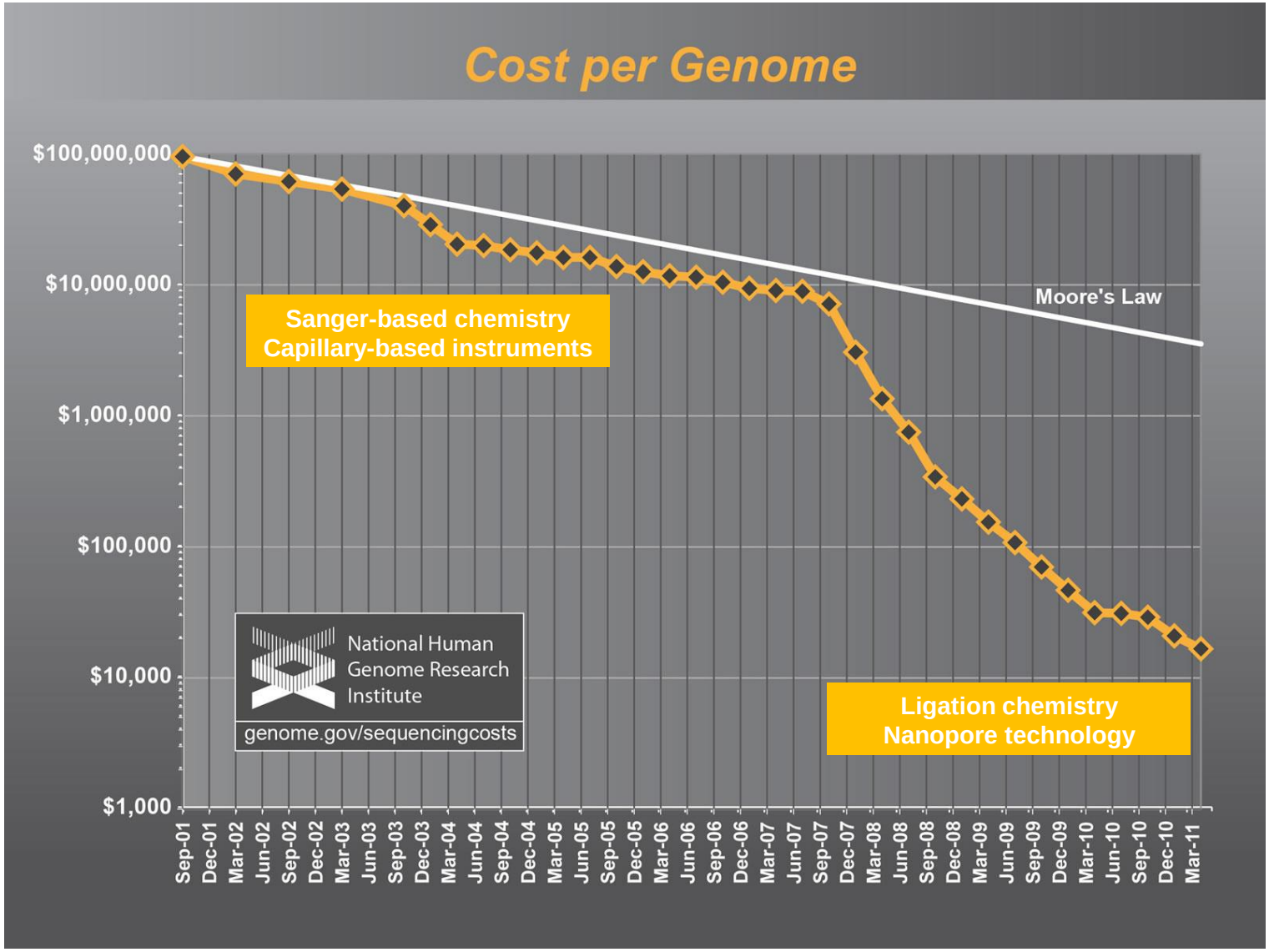
CLIC 500 ≡ "green field"





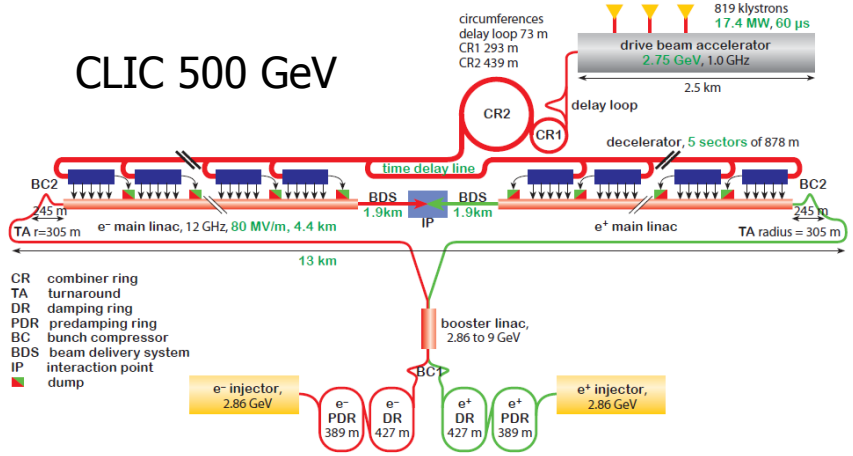
Cost mitigation: breakthrough vs gradual progress

The case of human genome sequencing

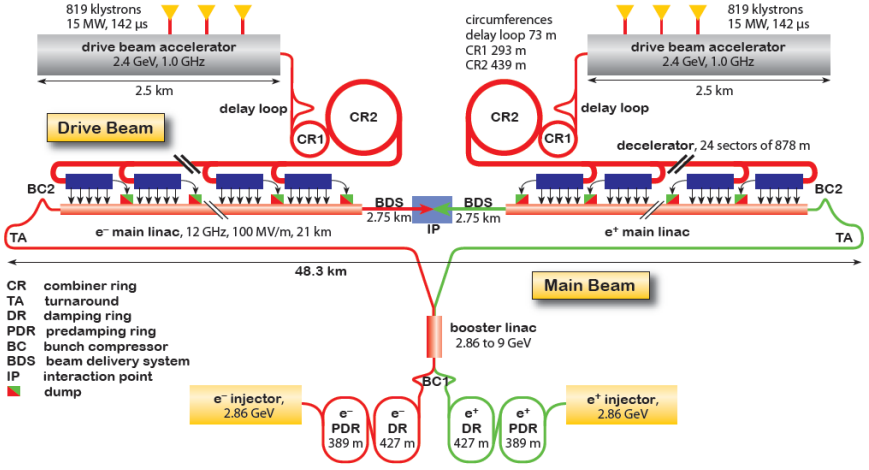


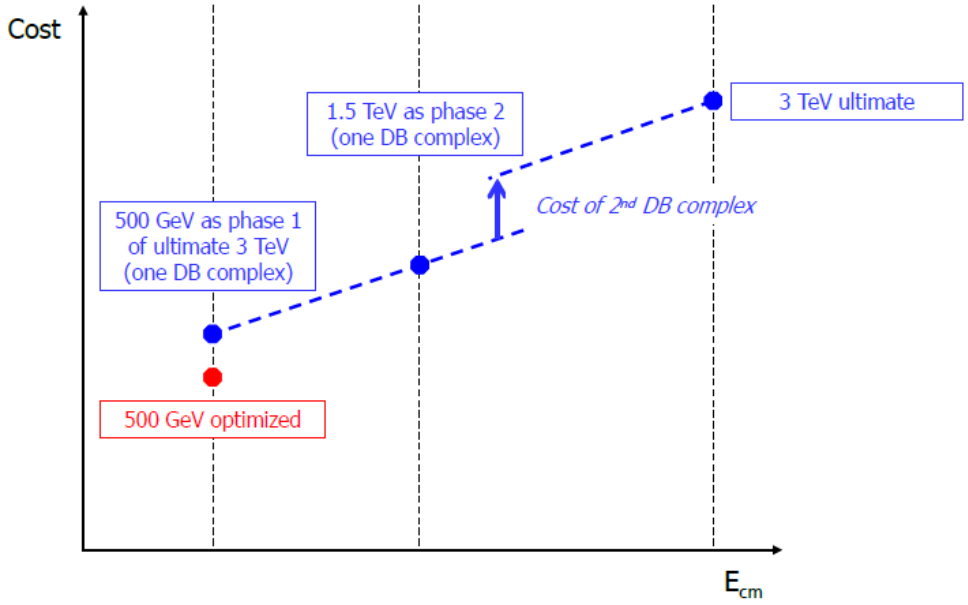
Understanding discontinuities in cost structure
First-order phase transition: CLIC energy stages

CLIC 500 GeV

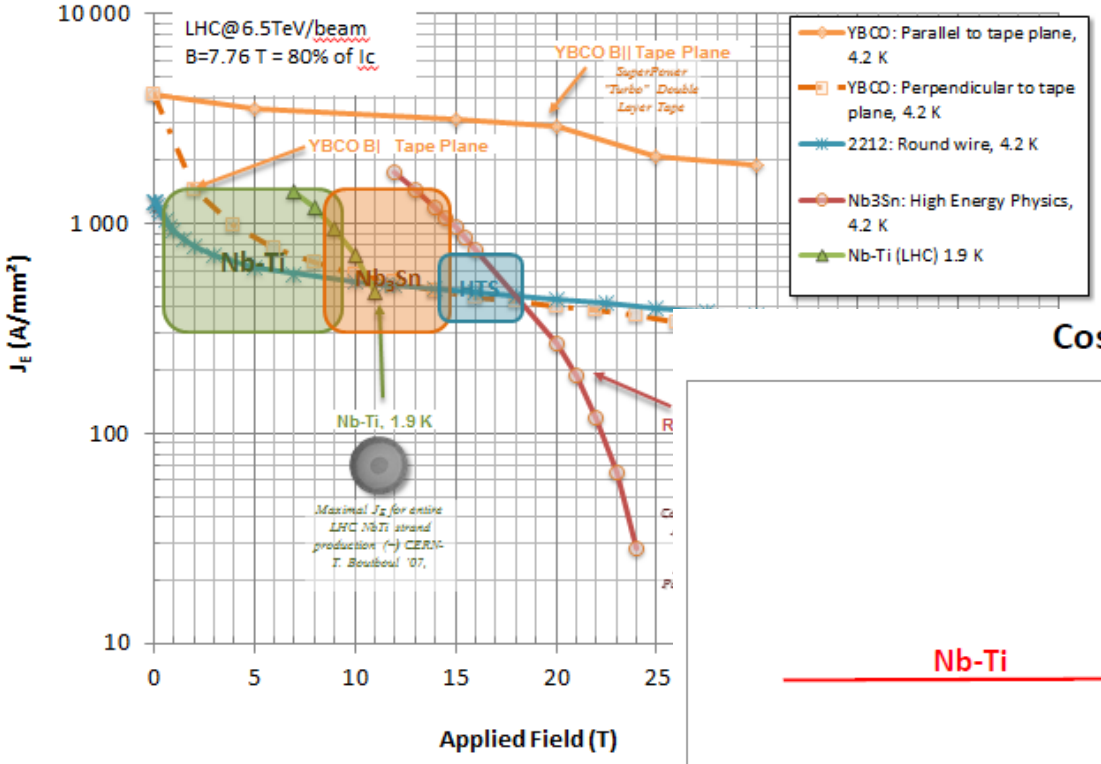


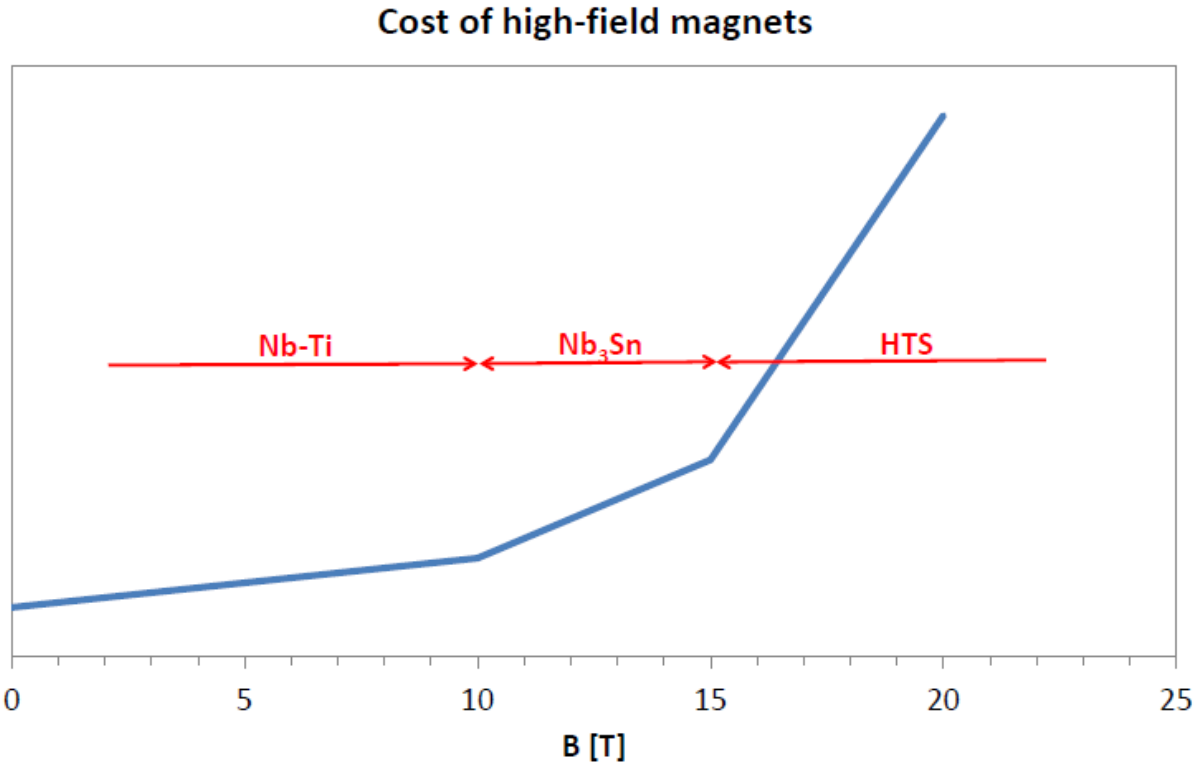
CLIC 3 TeV





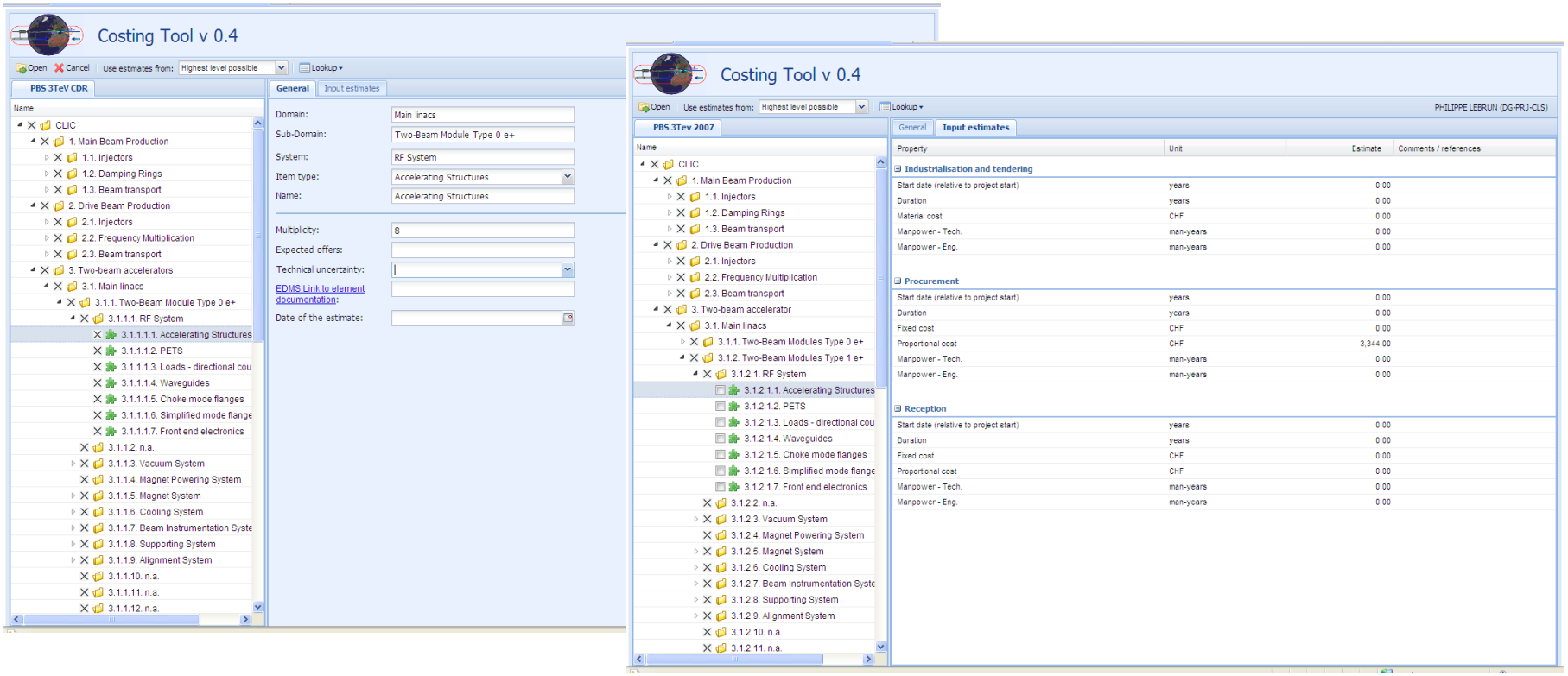
Understanding discontinuities in cost structure
Second-order phase transitions: high-field SC magnets





CLIC Study Costing Tool

- CLIC Study Costing Tool developed & maintained by CERN GS-AIS
- Operational, on-line from C&S WG web page (access protected)
- Includes features for currency conversion, price escalation and uncertainty
- Production of cross-tab reports exportable to EXCEL
- Full traceability of input data



power & energy economy

Electrical power consumption		
Accelerator complex	**Nominal [MW]**	**Standby [MW]**
LHC	122	89
HL-LHC	141	101
CLIC 500 GeV	235	167
CLIC 1.5 TeV	364	190
FCC e+e-	300?	100?
FCC pp	250?	150?

waste heat recovery

sobriety

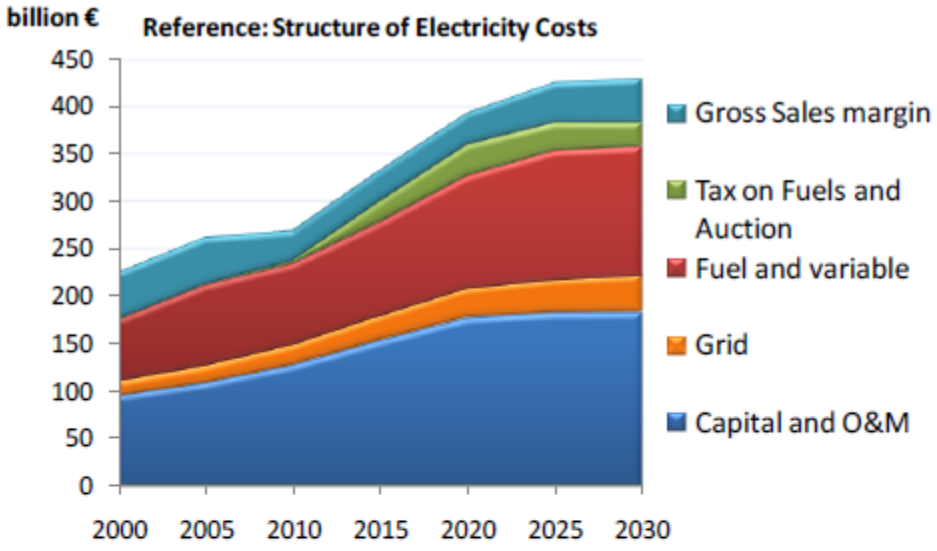
energy management

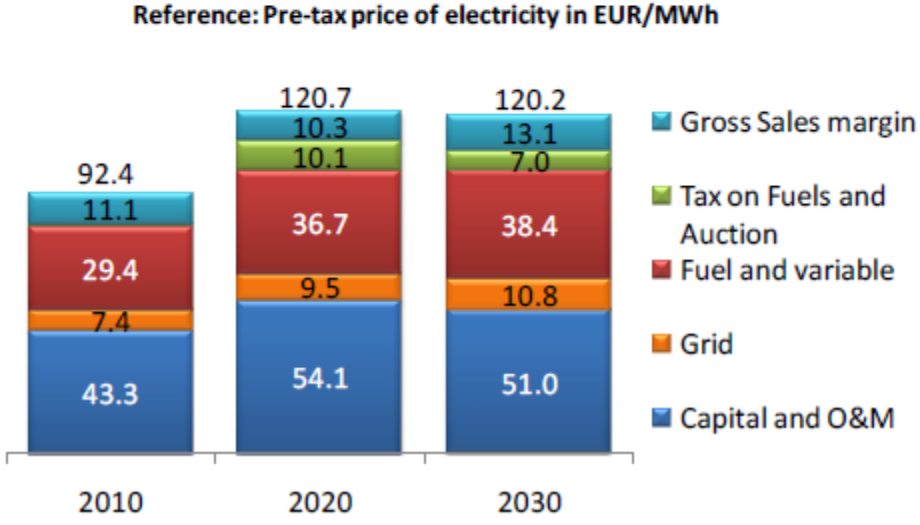
efficiency

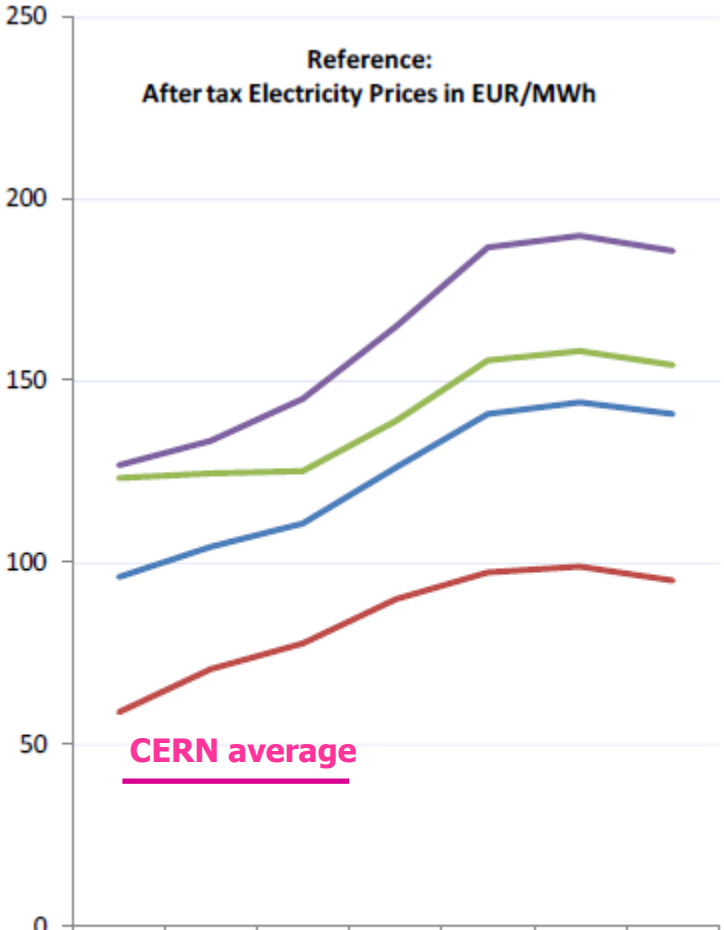
Electricity price projections

European Commission, Directorate-General for Energy

EU energy trends to 2030, Reference Scenario 2010



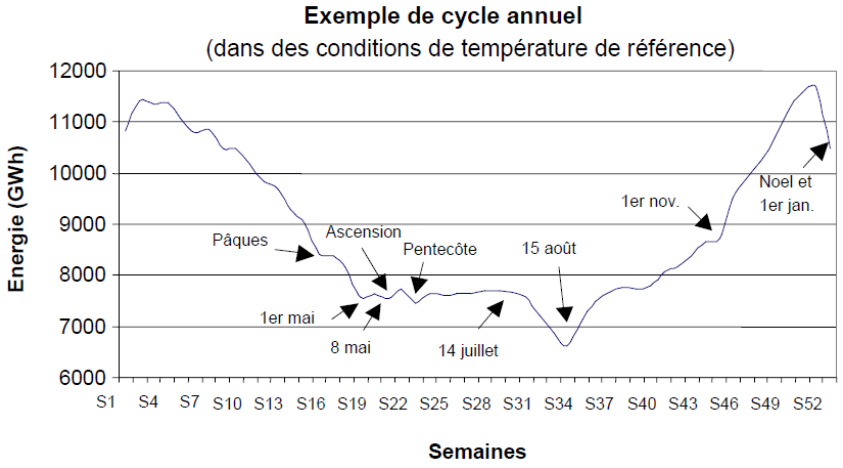


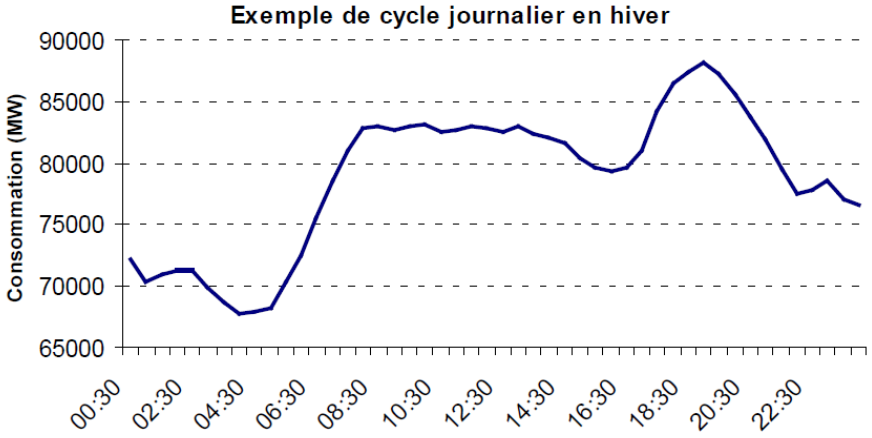


	2000	2005	2010	2015	2020	2025	2030
Average	96	104	110	126	141	144	141
Industry	59	71	78	90	97	99	95
Services	123	124	125	139	155	158	154
Households	127	133	145	165	186	190	186

A path to energy savings
Energy management

- Variation of electricity demand in France (Source: RTE)





- Modulate scheduled operation to match peak electricity demand
  - Shutdown ⇒ Seasonal load shedding
  - Waiting for beam ⇒ Diurnal peak shaving

CLIC

Staging Scenario	E_{CM} [TeV]	$P_{nominal}$ [MW]	$P_{waiting\ for\ beam}$ [MW]	$P_{shutdown}$ [MW]
	0.5	272	168	37
A	1.4	364	190	42
	3.0	589	268	58
	0.5	235	167	35
B	1.5	364	190	42
	3.0	589	268	58

Summary

- CERN's past experience in designing, constructing and operating large accelerator projects at the energy frontier is an essential asset for the study of future such machines, CLIC and FCC
- These project studies raise novel issues not only in accelerator science and technology, but also in infrastructure and technical systems, as well as in the interrelations between them
- Early involvement of stakeholders in all relevant disciplines is necessary to address the resulting complexity and achieve globally optimized solutions

La pensée complexe est, essentiellement, la pensée qui intègre l'incertitude et qui est capable de concevoir l'organisation

Edgar Morin

Introduction à la pensée complexe (1990)

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