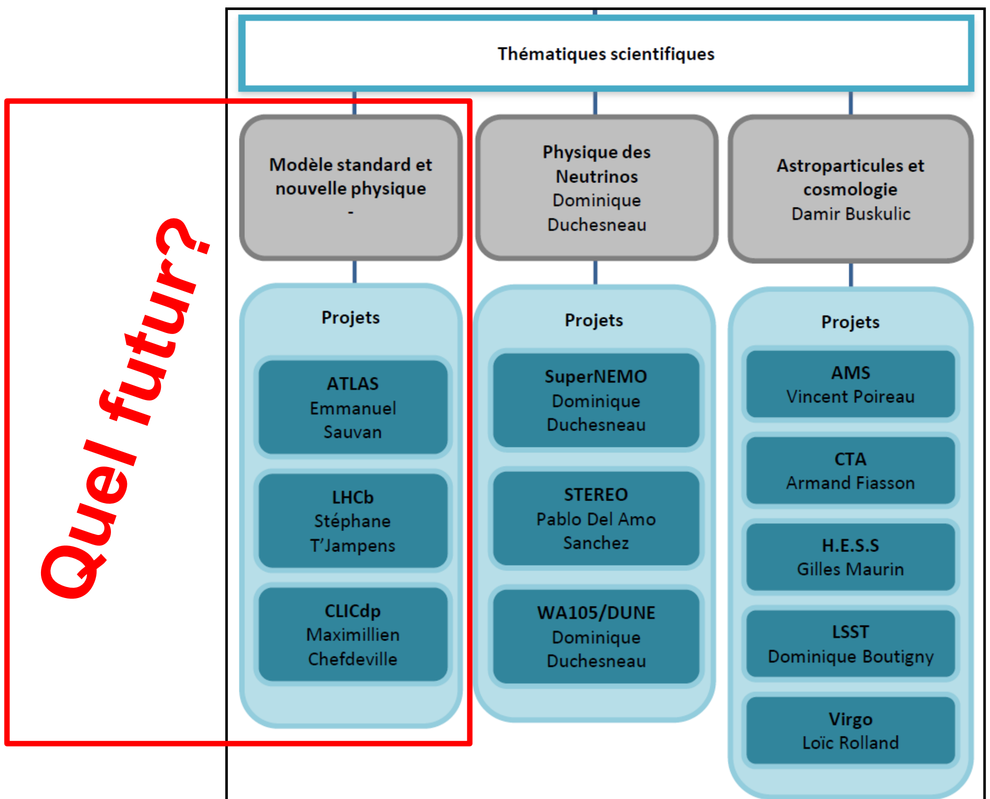
La physique sur collisionneur au-delà de HL-LHC: quelle stratégie pour le LAPP?



Thibault Guillemin

LAPP

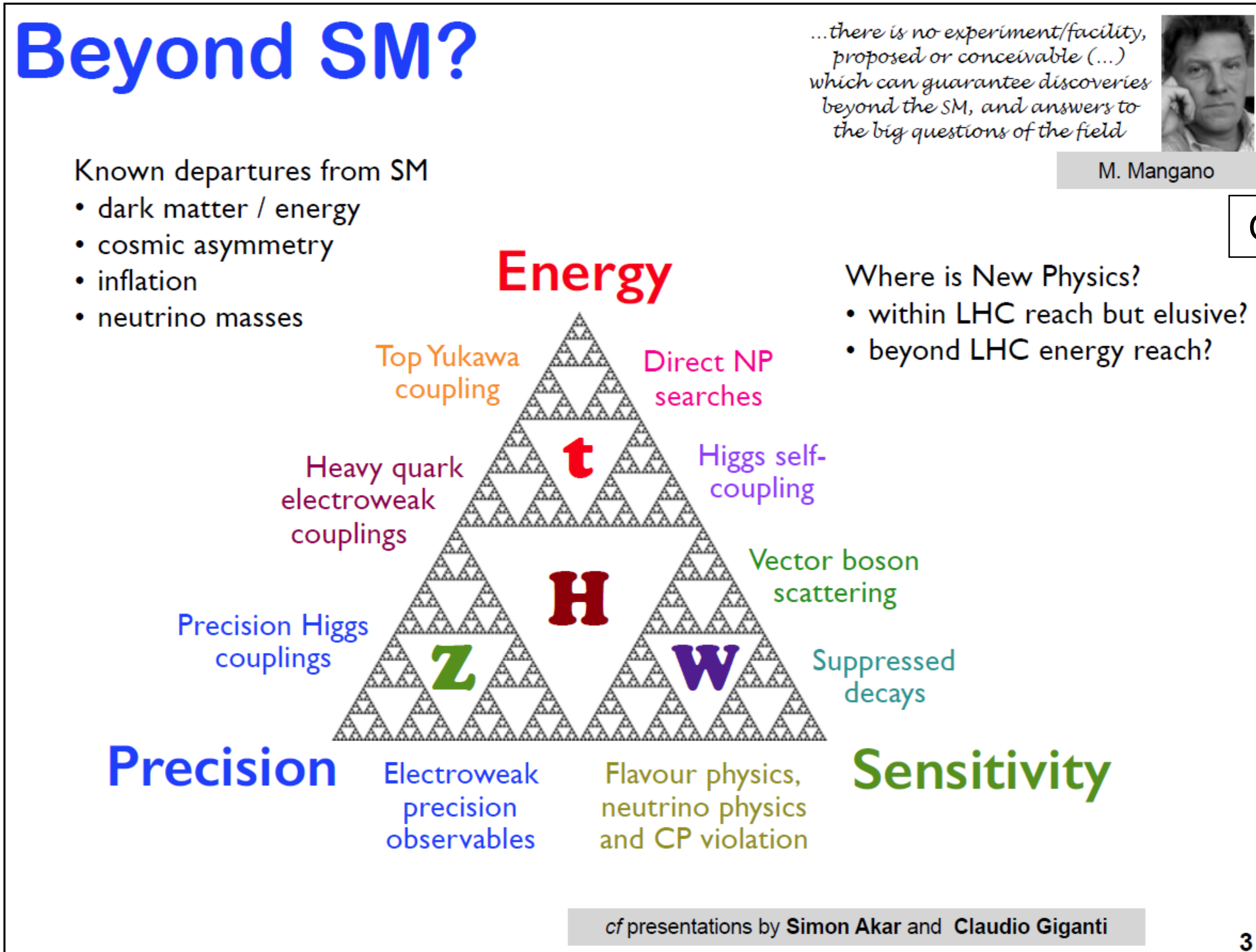
8 février 2019

Plan

- Les futures machines
- Mise à jour de la stratégie européenne
- Situation au LAPP
- Quelques questions pour la discussion

De nombreux slides pris à la présentation de Gautier Hamel de Monchenault à la journée de la SFP (lien)

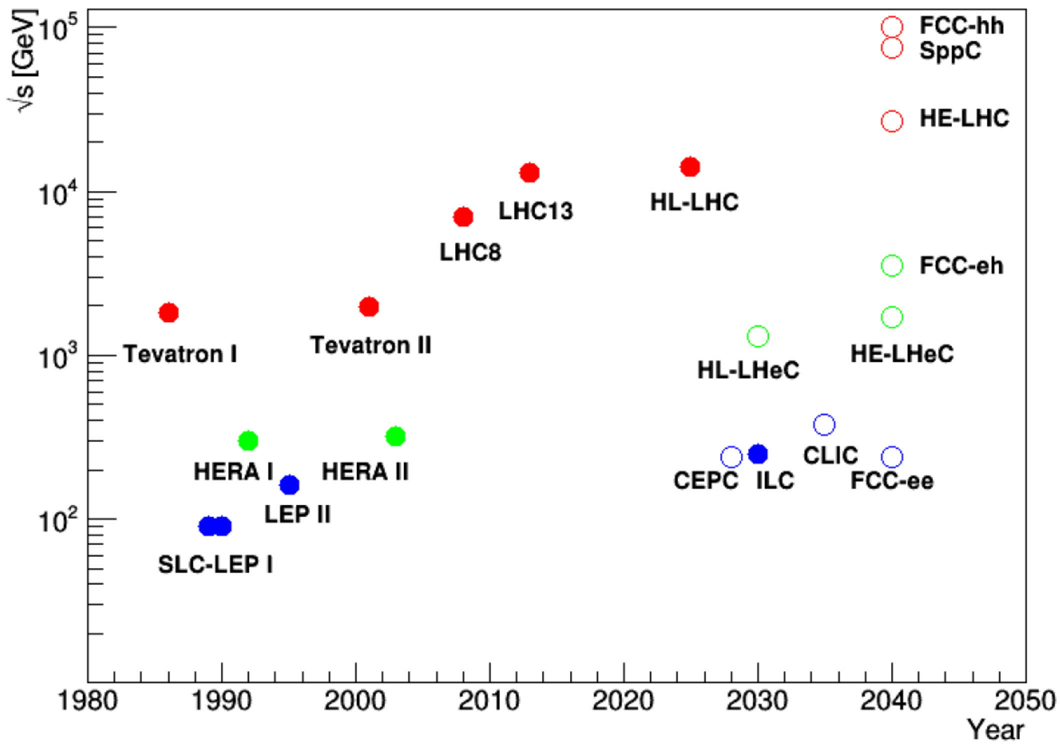
Le panorama HEP actuel



Gautier

Projets de collisionneur

No clear idea about the scale of new physics (naturalness gives some possible guidance)…



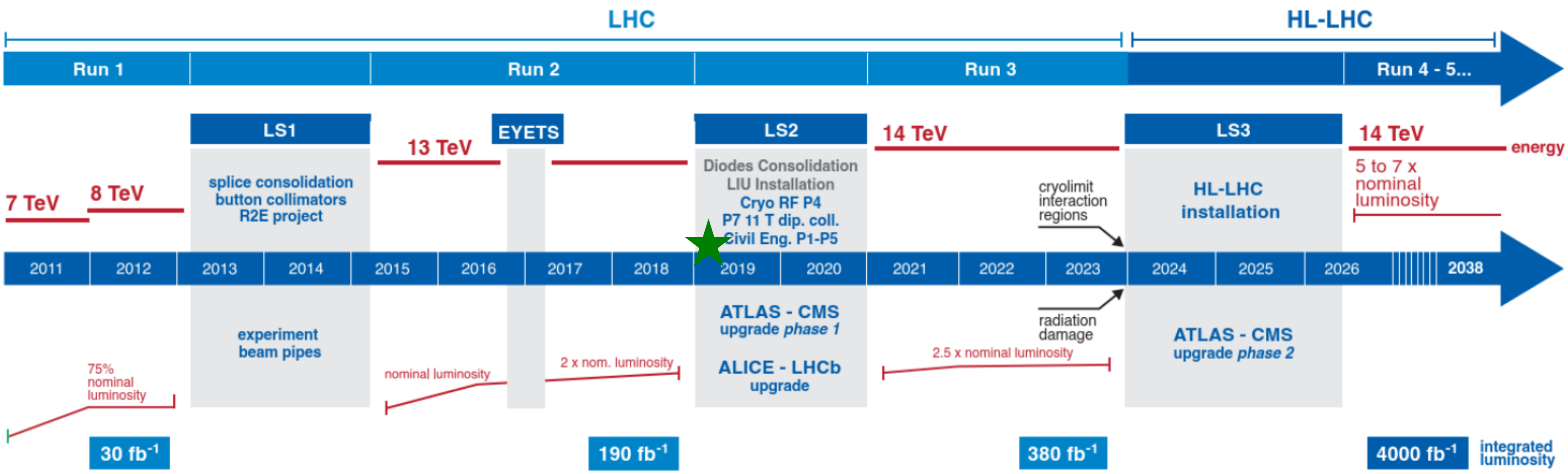
arXiv:1809.10426v2

HL-LHC: the only approved project

Linear colliders:
e^+e^- for Higgs and 'LHC-reachable' new physics
➔ ILC, CLIC

Circular colliders:
- e^+e^- for Higgs and EW precision observables
➔ FCC-ee, CEPC
- pp for Higgs and highest energy new physics
➔ HE-LHC, FCC-hh, SPPC
- ep: pdf's
➔ LHeC, FCC-eh

HL-LHC


LHC
HL-LHC
Run 1
Run 2
Run 3
Run 4 - 5...
LS1
EYETS
LS2
LS3
7 TeV
8 TeV
13 TeV
14 TeV
14 TeV
energy
splice consolidation
button collimators
R2E project
Diodes Consolidation
LIU Installation
Cryo RF P4
P7 11 T dip. coll.
Civil Eng. P1-P5
cryolimit
interaction
regions
HL-LHC
installation
5 to 7 x
nominal
luminosity
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2038
experiment
beam pipes
ATLAS - CMS
upgrade phase 1
ALICE - LHCb
upgrade
radiation
damage
ATLAS - CMS
upgrade phase 2
75%
nominal
luminosity
nominal luminosity
2 x nom. luminosity
2.5 x nominal luminosity
30 fb-1
190 fb-1
380 fb-1
4000 fb-1
integrated
luminosity

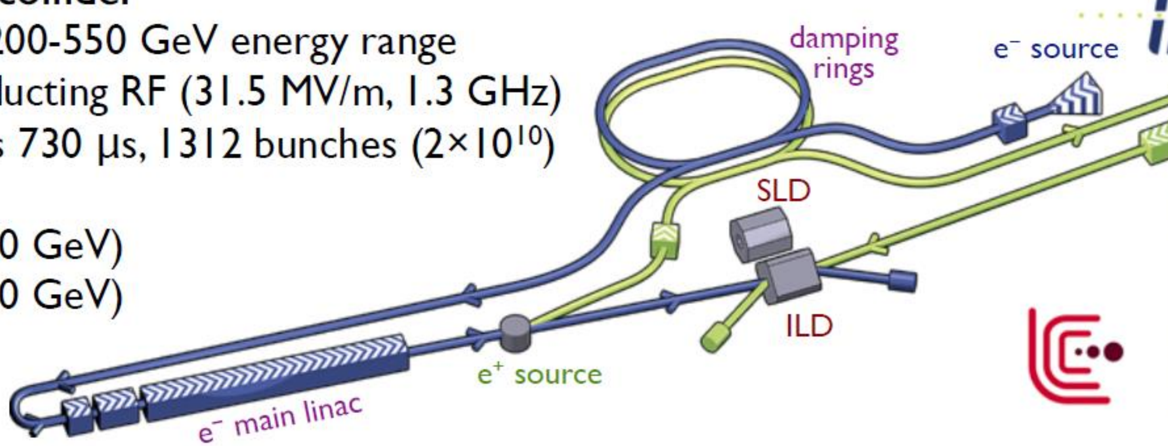
ILC

Gautier

Linear e^+e^- collider

in the 200-550 GeV energy range

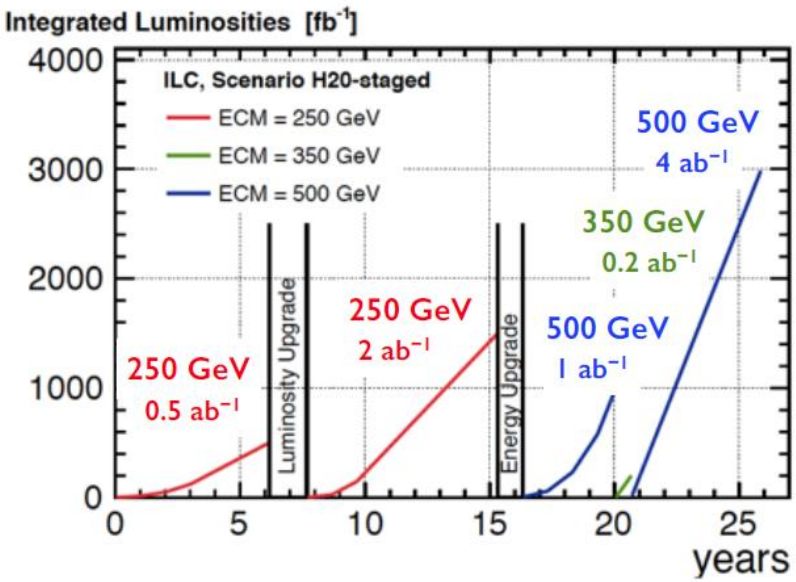
- super conducting RF (31.5 MV/m, 1.3 GHz)
- 5 Hz, trains 730 μs, 1312 bunches (2×10^{10})
- footprint:
  20 km (250 GeV)
  31 km (500 GeV)



ILC TDR (2013)
ILC-250 Physics Case (2017)

Staging scenario

- $\sqrt{s}$ = 250 GeV
- optimised luminosity: $\mathcal{L} = 1.5\times10^{34}\ cm^{-2}s^{-1}$
- ±80% (±30%) e^- (e^+) beam polarisation
- (LR, RL, LL, RR) = (45%, 45%, 5%, 5%)



Strong effort by Japanese community to host ILC
☛ political decision expected by ~~end of 2018~~ **Début mars 2019**

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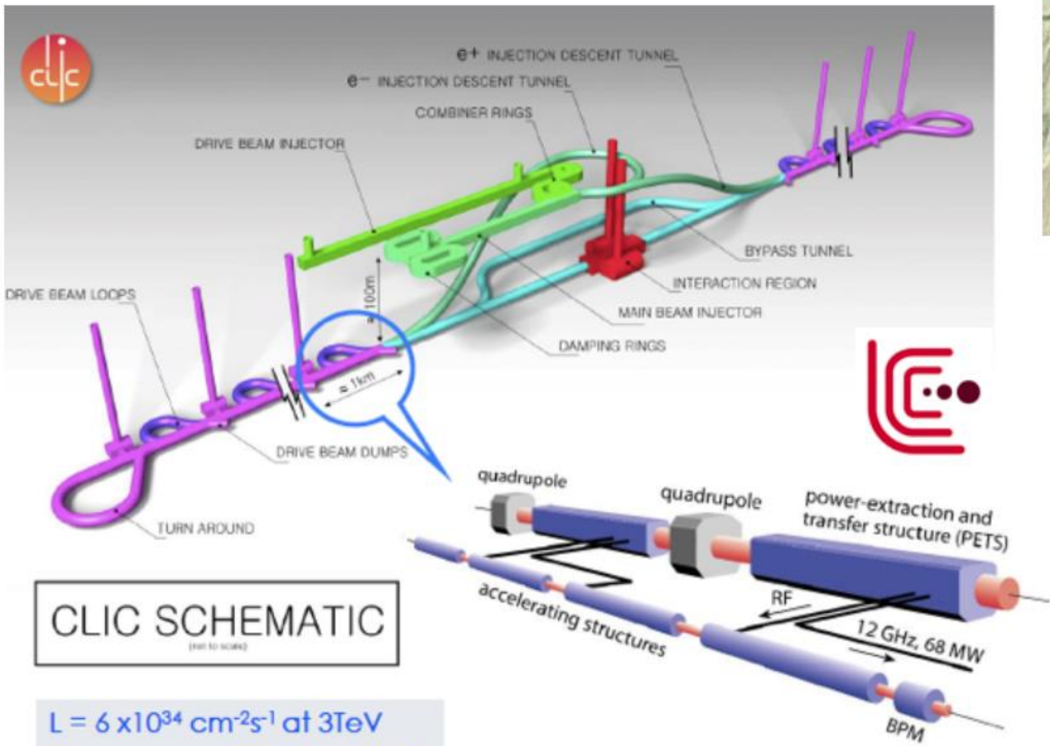
CLIC

Gautier

Linear e⁺e⁻ collider at CERN

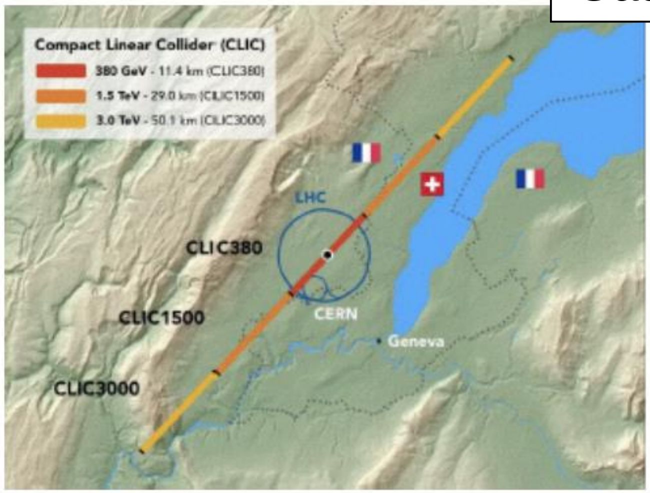
in the up-to multi-TeV energy range

- normal conducting high-frequency RF (X-band, 12 GHz)
- e⁻ drive beam for RF power generation

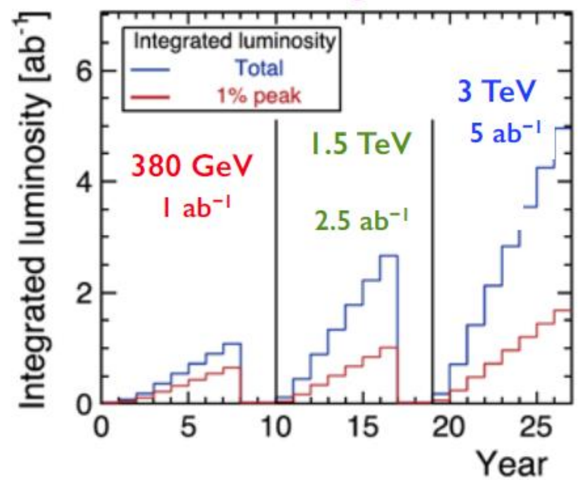


CLIC SCHEMATIC

$L = 6 \times 10^{34}$ cm^{-2}s^{-1} at 3TeV
Beam power 30MW at 3TeV



Scenario in 3 stages



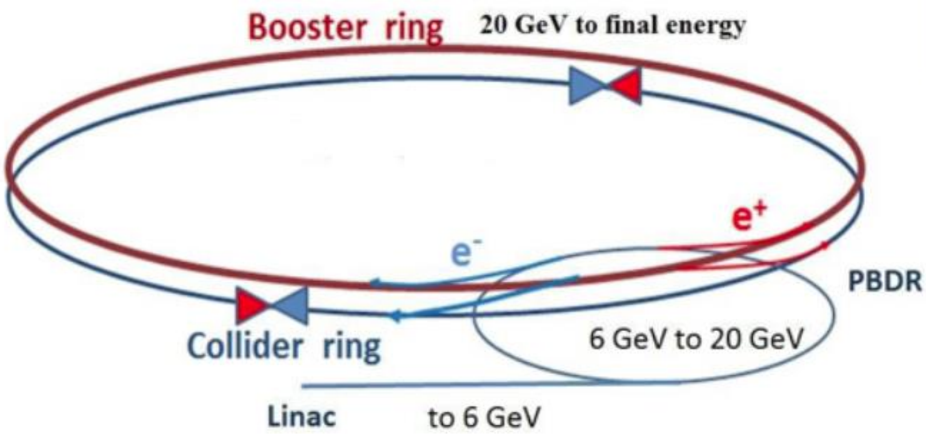
Beam polarisation: (±80%, ∓80%)
LR / RL = 50% / 50%

CERN/SPC/1114 (2018)

11

FCC-ee

Gautier



First-phase machine in the **100-km tunnel** built to host eventually FCC-hh

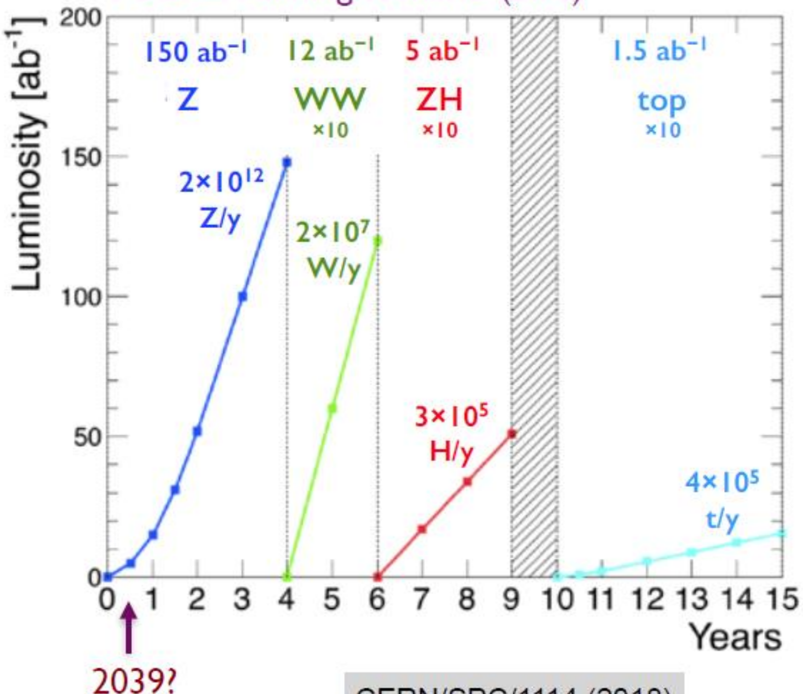
Luminosity limited by SR
- top-up injection (once per minute)
- 50 MW power/beam
- 2 interaction points

RF system: high-current → high gradient
3 sets of RF cavities

	V_{rf} [GV]	#bunches	I_{beam} [mA]
Z	0.1	16640	1390
WW	0.44	2000	147
ZH	2.0	393	29
top	10.9	48	5.4

Asymmetric optics with beam crossing angle of 30 mrad

FCC-ee running scenario (2IPs)



FCC-ee CDR fall 2018

CERN/SPC/1114 (2018)

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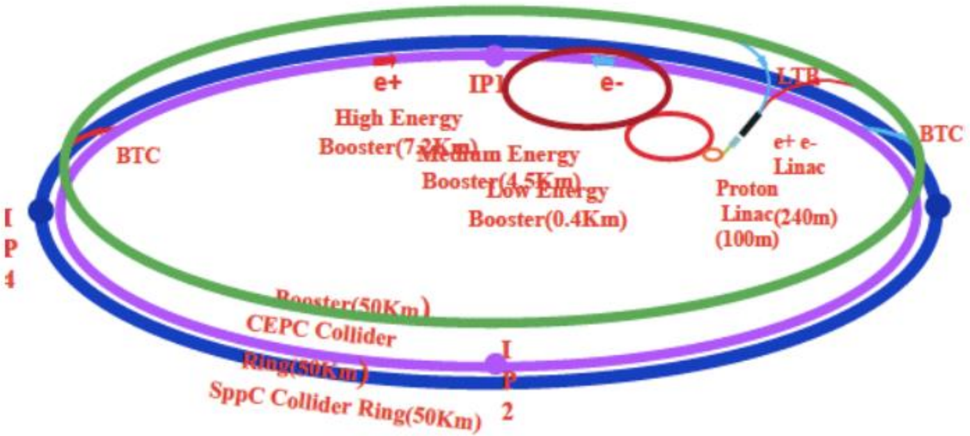
CepC

Gautier



Project similar to FCC-ee in China
- two colliding rings and a booster
- $\sqrt{s}$ = 90-240 GeV

- Hosted in a 100-km tunnel which could eventually host a 70-TeV pp collider
- several possible sites

Peak luminosity (2 IPs) (CDR parameters)
- at the Z: 1.7×10^{35} $cm^{-2}s^{-1}$ (3T)
- at the W: 1.0×10^{35} $cm^{-2}s^{-1}$
- at the H: 3×10^{34} $cm^{-2}s^{-1}$

Physics goals:
- $>3\times10^{11}$ Z bosons (8 ab^{-1})
- 2×10^{7} W pairs (2.6 ab^{-1})
- 10^{6} Higgs bosons (5.6 ab^{-1})

Timeline

2013-2015	pre-studies
2016-2022	R&D Engineering Design
2022-2030	Construction
2030-2040	data taking

- Starts before the end of the HL-LHC
- possibly concurrent with the ILC

CEPC CDR in preparation (2019)

CEPC symposium (Nov. 2018)

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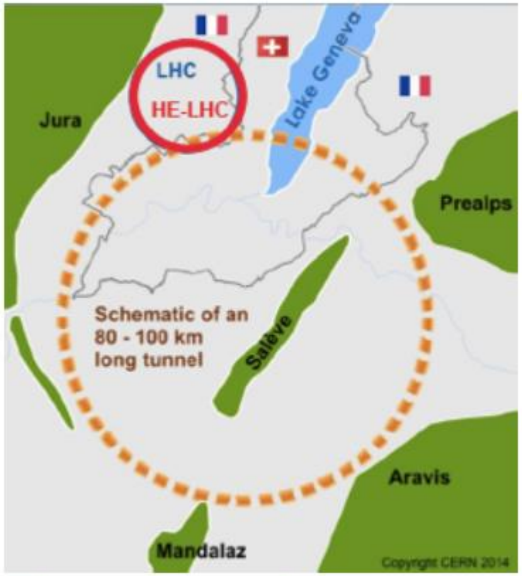
FCC: vue générale

Gautier



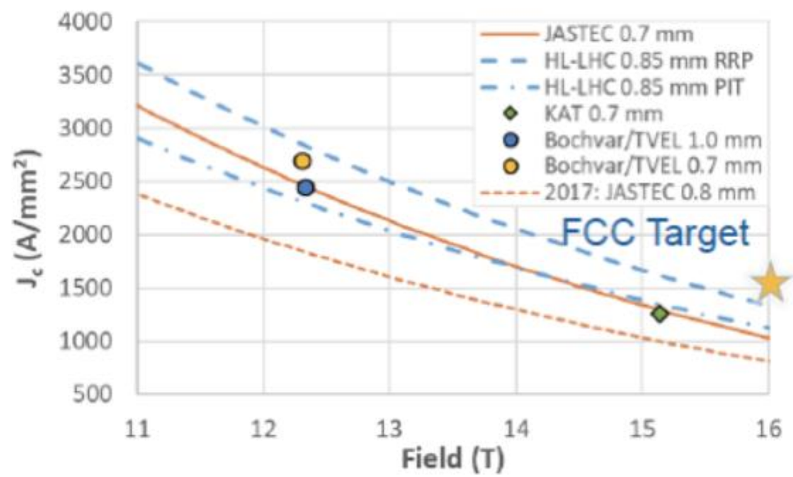
100-km tunnel in Geneva area

	$\sqrt{s}$	$\mathcal{L}$ $(cm^{-2}s^{-1})$	first beams (technically)	tunnel
HE-LHC	27 TeV	1.6×10^{35}	2040	LHC
FCC-ee	90-365 GeV	$200\text{-}1.5\times10^{34}$	2039	
FCC-eh	3.5 TeV	1.5×10^{34}	2043	100-km
FCC-hh	100 TeV	3×10^{35}	2043	

cf backup slide

	$\sqrt{s}$	L (ab^{-1})	years
HE-LHC	27 TeV	12	20
FCC-hh	100 TeV	30	25

Major focus at CERN:
development of 16-T Nb_3Sb SC magnets
- on-going R&D on SC high-field magnets
- prepare industrialisation



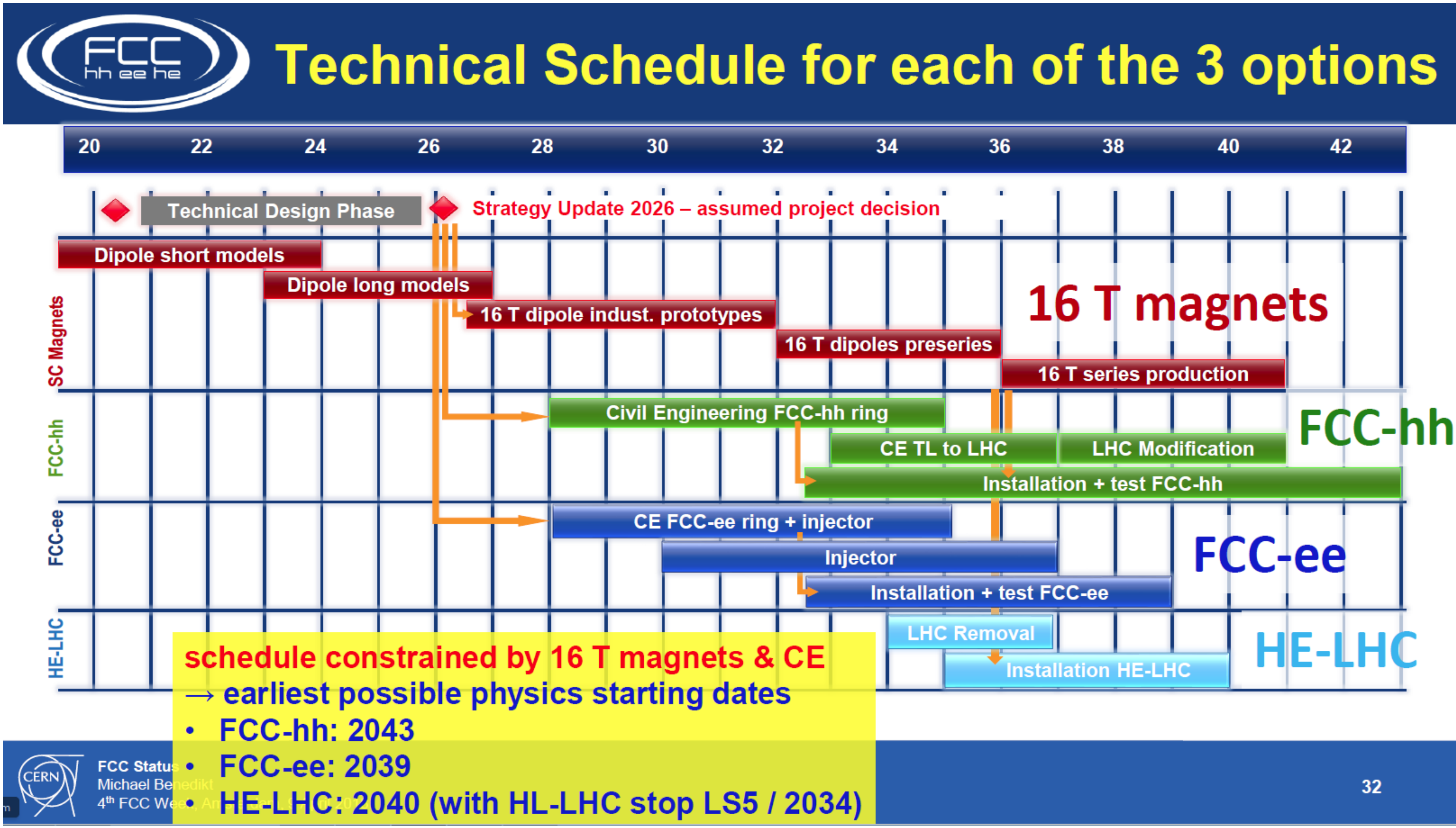
FCC CDR fall 2018

CERN/SPC/1114 (2018)

cf presentation by **Barbara Dalena**

5

Planning FCC



Si FCC-ee: date FCC-hh décalée (~20 ans) Coût FCC-hh (seul): 24 G€

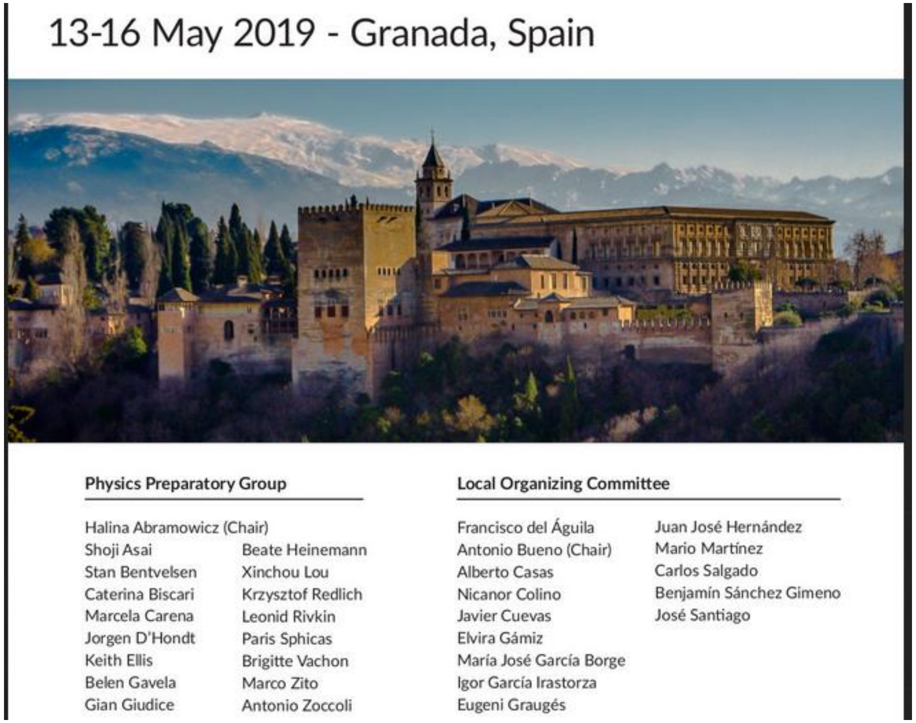
La mise à jour de la stratégie européenne

- December 2018: deadline for contribution submission

- The Open Symposium: Granada, Spain (13-16 May 2019)

- The Strategy Drafting Session: Bad Honnef, Germany (20-24 January 2020)

- May 2020: approval of the updated strategy by the CERN council



CEA: Marco Zito (neutrinos accélérateur)
IN2P3: personne

La contribution de l'IN2P3

SM and BSM physics at the high energy frontier:

- Ensure the success of the HL-LHC, i.e., the upgrade of the machine, the detectors and the exploitation of the data, including especially computing aspects.
- Support the need for an e^+e^- collider running at the Higgs production resonance. This machine should be upgradable to higher energies in order to reach the top pair production, as well as the associated top and Higgs production thresholds. IN2P3 is supporting the ILC proposal in Japan.
- Support of accelerator R&D for a project at CERN after the HL-LHC. In order to plan for a FCC-hh, it is essential to continue high field magnets R&D in particular high temperature superconducting magnets. Further R&D on improved accelerating concepts should be part of the strategy (muon colliders, plasma).

Flavour physics and the intensity frontier:

- Exploit the two large-scale facilities with a wide flavour physics programme, LHCb and Belle2, which are in particular expected to provide further insights into the nature of the current flavor anomalies.
- Pursue a long-term intensity frontier physics programme with the LHCb upgrade II, a possible Belle II upgrade, a FCC-ee running at the Z pole and beam dump experiments or upgrades to existing experiments searching for long-lived particles.
- Support experiments dedicated to specific measurements of crucial observables, in particular Electric Dipole Moments and Lepton Flavour Violation.

Les détecteurs pour ee: déjà une longue R&D

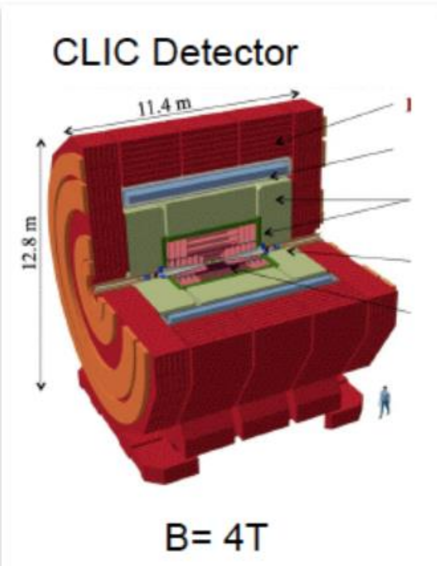
Gautier

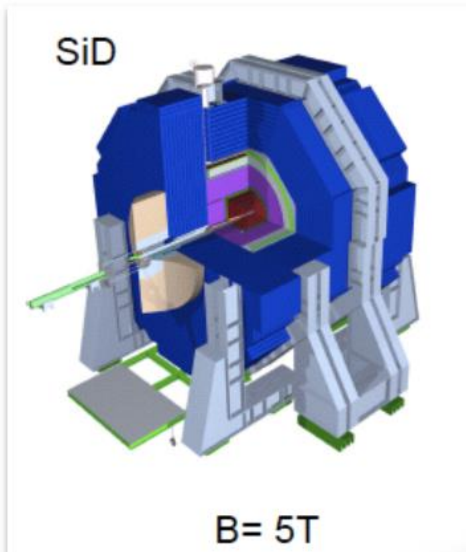
cf. presentation by **Christophe G**

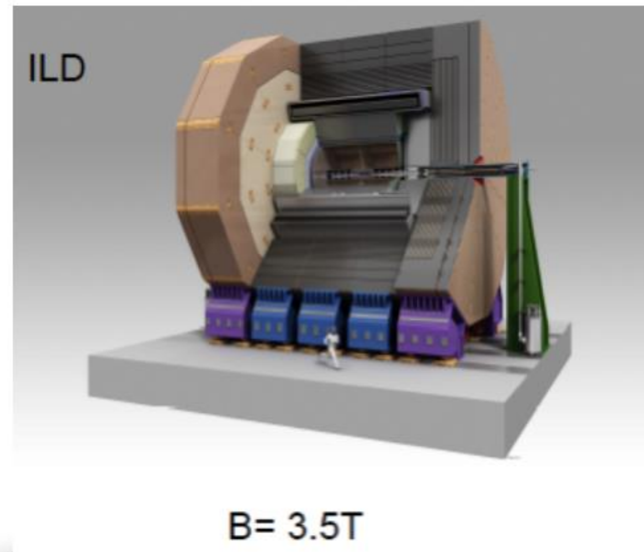
Particle Flow Detectors
- high hermiticity
- high granularity
- momentum resolution
- high separation power

FCC-ee 2 detector concepts
- CLD: inspired from CLIC detector
- IDEA: from present state-of-the-art

CEPC 2.5 detector concepts
- baseline: ILD/SiD concept (3T)
- IDEA concept (2T)







inner tracking with silicon

central tracking with silicon

central tracking with TPC

highly-granular calorimeters

CLIC CDR (2012)
(revised since)

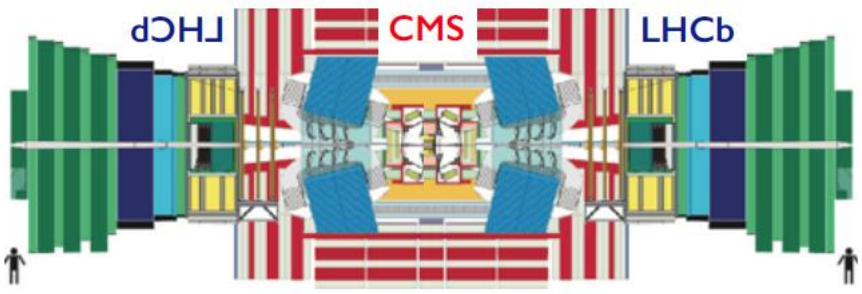
ILC DBD (2013)

14

Les détecteurs pour pp: un territoire inconnu

Gautier

Starting point

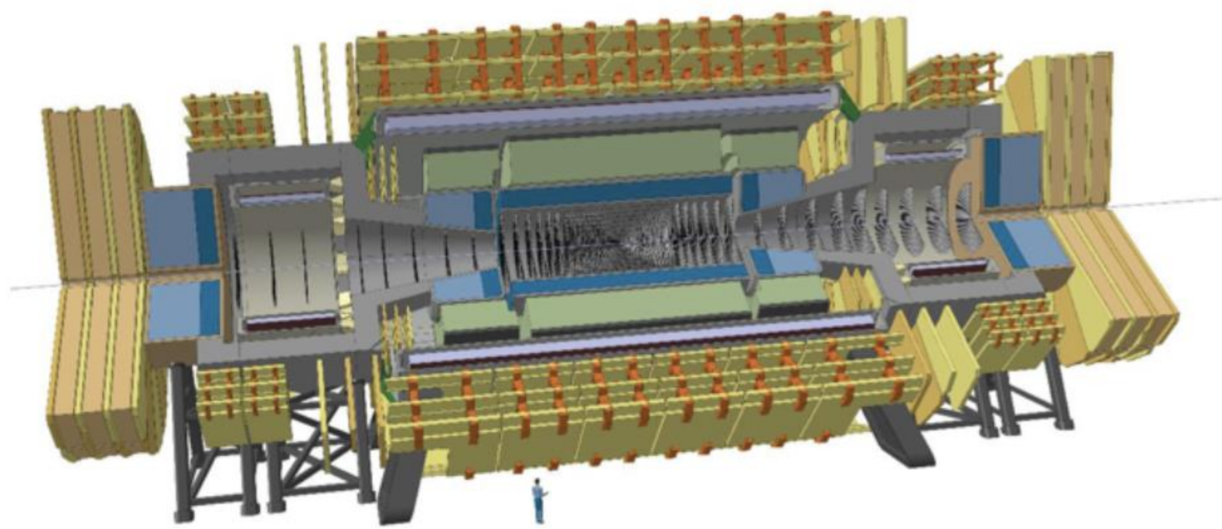


Main features

- 4T solenoid, 10-m bore solenoid
- Two forward 4T, 5-m bore solenoids
- no shielding
- ~14 GJ stored energy
- EM and H calorimetry up to η = 6
- high granularity (×4 ATLAS or CMS)
- trigger includes muon system

Some of the challenges

- pileup = 1000 (×10 / HL-LHC)
- radiation = 10^{18} part (1MeV)/cm2 (×100 / HL-LHC)
- forward SM physics
- high-p_T jets and leptons
- 1-1.5 PB/s



one billion € project

cf. presentation by **Christophe Ochando**

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Programme R&D du CERN 2020-2025

Rapport: https://cds.cern.ch/record/2649646

Working Groups	Convenors
Silicon detectors	Heinz Pernegger, Luciano Musa, Petra Riedler, Dominik Dannheim
Gas detectors	Christoph Rembser, Eraldo Oliveri
Calorimetry and light based detectors	Martin Aleksa, Carmelo d'Ambrosio
Detector Mechanics	Corrado Gargiulo, Antti Onnela
IC technologies	Federico Faccio, Michael Campbell
High Speed Links	Paolo Moreira, Francois Vasey
Software	Graeme Stewart, Jakob Blomer
Detector Magnets	Herman Ten Kate, Benoit Cure

R&D détecteur (rapport ECFA 2018)

Most promising future R&Ds	**# answers (380 total)**
Precision timing	210
Precise position resolution	63
Precise energy measurements	25
Radiation Hardness	29
CMOS HV-MAPS monolithic	24
High granularity imaging calorimetry	21
Artificial intelligence / Machine Learning	16
Fast (tracker) triggers (online)	16
High rate capability	14
Low power consumption in detector systems/electronics,	14
4D tracking	14

Table 11: Perceived most promising future R&D topics (top-11).

Nos activités détecteurs

CLICdp
R&D micromegas
(pour SDHCAL)
Arrêt fin 2018

LHCb
- Upgrade 1 (2019-2020)

Micro-code pour cartes DAQ

- Discussion sur la (quelle?)

participation à la possible upgrade 2 (installation après le Run 4, ~2030)
LHCb EoI soumise en 2017

ATLAS
- Upgrade phase 1 (2019-2020)

- LAr electronics
LATOME, IPMC, code online

- Upgrade phase 2 (jusqu'en 2025)

- ITK
Electronique et mécanique
Flex, refroidissement CO_2, isolateurs, assemblage et tests des modules, simulation
- LAr electronics
Carte calibration, carte TTC et code online

+ R&D computing pour HL-LHC
+ R&D tracking pour HL-LHC

Les équipes techniques (COM 2018)

Bien sûr, ce sont des ressources humaines non étiquetées ‘physique sur collisionneur’, mais cela donne une idée…

ATLAS

6 ETP IT électronique [COM 2018 : 7.2]

Sébastien Cap, Eric Chabanne, Nicolas Chevillot, Pierre-Yves David, Cyril Drancourt, Nicolas Dumont-Dayot, Renaud Gaglione, Richard. Hermel, Nicolas Massol, Jean-Marc Nappa, Sébastien Villalte

3.2 ETP IT mécanique [COM 2018 : 4.2]

Nicolas Allemandou, Pierre Delebecque, Jean-Marc Dubois, Nicolas Geffroy, Fabrice Pelletier, Olivier Prevost, Thibaut Rambure

3.25 ETP IT informatique [COM 2018 : 3.25]

Fatih Bellachia, Thierry Bouedo, Sylvain Lafrasse, Laurent Gantel

LHCb

Équipes techniques :

- **Mécanique** : Bruno Lieunard, Laurent Brunetti, Laurent Journet, Tamer Yildizk
- **Électronique** : Sébastien Cap, Guillaume Vouters, Cyril Drancourt

CLICdp

– COM 2018: C. Drancourt, F. Peltier, G. Vouters (bonus: S. Cap, J. Jacquemier)

Quelques questions (1/2)

Il semble clair que nous devons définir une stratégie scientifique pour aller au-delà (ou en dehors) de HL-LHC (physique, détecteur et accélérateur).

- Intérêts ILC? Position du LAPP en cas d'une décision positive? Qui? Contribution à un détecteur? Electronique/DAQ?

- CLIC: si ILC = non, le projet devient-il prioritaire?

- Intérêts FCC-ee? FCC-hh? Qui? Implication dans la phase post-CDR? TDR pour la prochaine mise à jour de la stratégie européenne?

- CepC / SppC?

- A quel horizon temporel s'impliquer? Davantage côté R&D détecteur ou simulation/software/physics case pour l'instant?

Quelques questions (2/2)

- Privilégier de toute façon des expériences au CERN (l'ADN du LAPP)?

- R&D détecteur: plutôt calorimètre ou détecteur de traces?

- Quelles ressources humaines (chercheurs et ingénieurs) pour mener de front un engagement nouveau et le programme physique/upgrade LHC?

- Après 2025, quels projets pour les équipes techniques?

- Cohérence avec le programme accélérateur du LAPP?

- Participation à d'autres expériences: Belle II? SHIP?

A définir:
- Qui?
- Quel projet R&D détecteur?
- En vue de quel projet scientifique?

Bonus

How the LHC came to be …

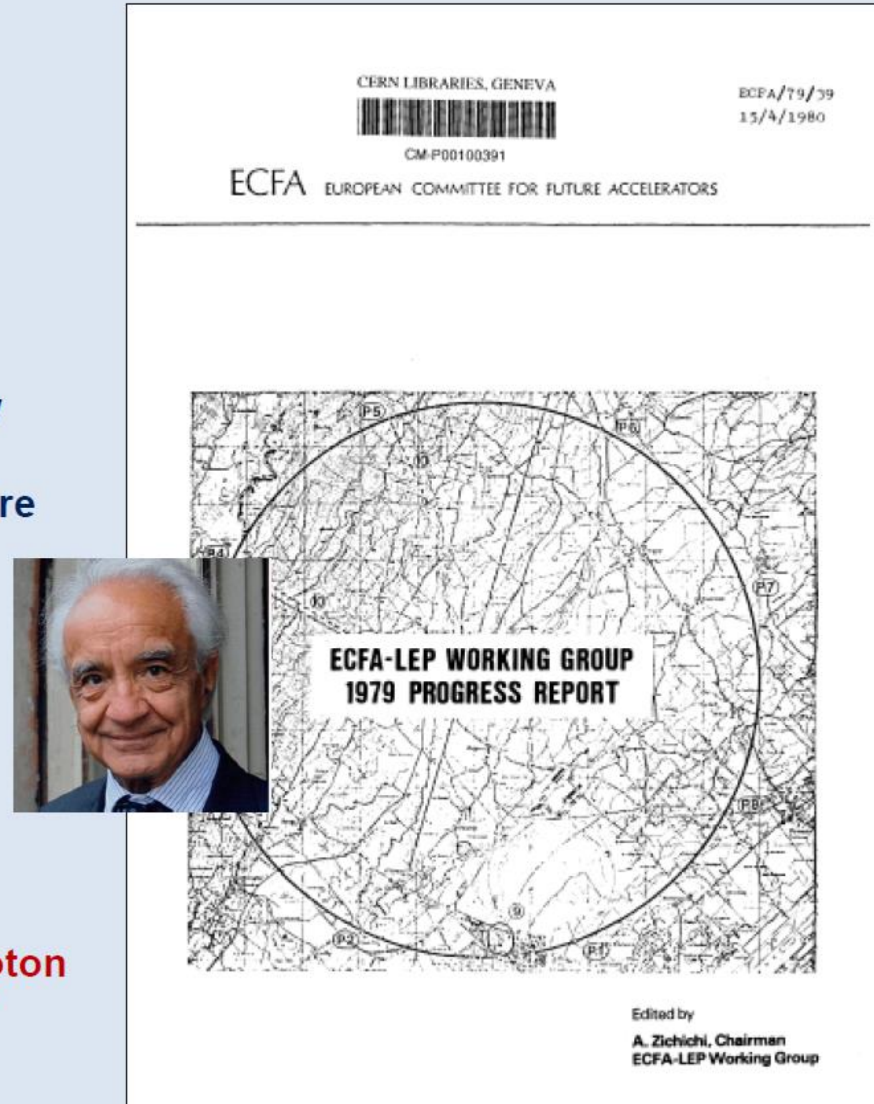
Some very early key dates

1977 The community talked about the LEP project, and it was already mentioned that a new tunnel could also house a hadron collider in the far future

1979 LEP White Book:

ECFA-LEP Working Group 1979 chaired by A Zichichi

'Tunnel with 27 km circumference and a diameter of 5 m, with a view to the replacement of LEP at the end of its activities by a proton-proton Collider using cryogenic magnets'



EMFCSC, Erice, June 2017
P Jenni (Freiburg and CERN) LHC, Higgs and Beyond (ATLAS) 3

Les dates du LHC

1984 **For the community it all started with the CERN - ECFA Workshop in Lausanne on the feasibility of a hadron collider in the future LEP tunnel**

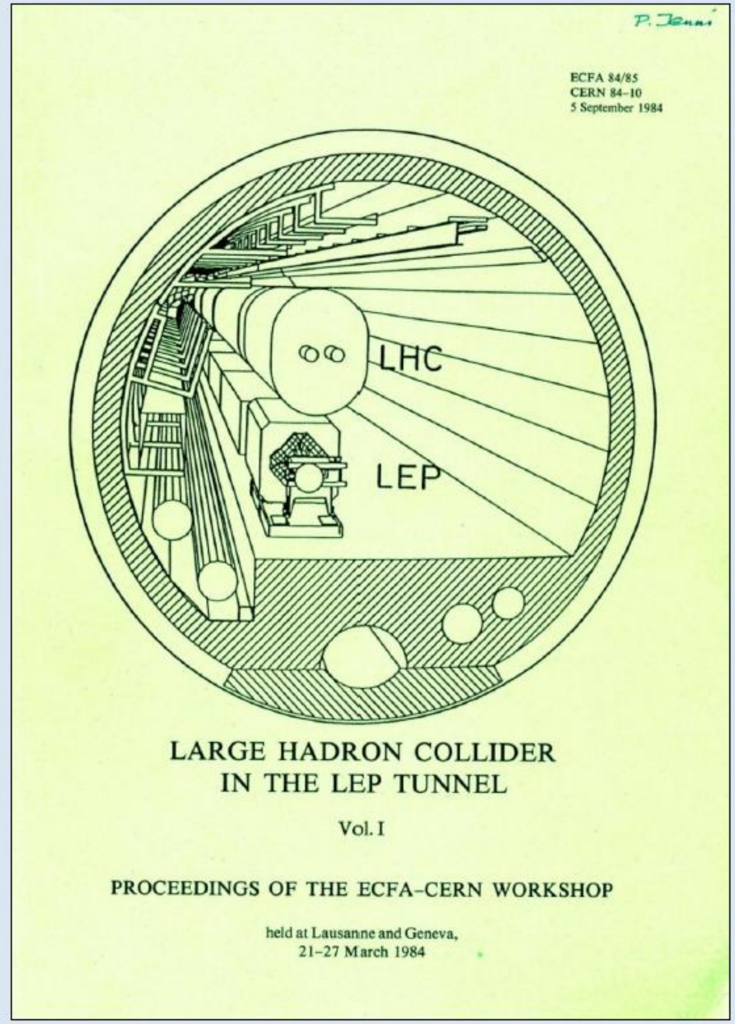
1986 **LAA R&D on new detector technologies started, later followed by the DRDC**

1987 **La Thuile Workshop**

Many LHC colleagues were already involved in this WS set up by Carlo Rubbia as part of the Long Range Planning Committee

1996

December Council approved finally the single-stage 14 TeV LHC for completion in 2005



EMFCSC, Erice, June 2017
P Jenni (Freiburg and CERN)

LHC, Higgs and Beyond (ATLAS)

5

Les dates d'ATLAS

The birth of ATLAS

March 1992 – Summer 1992

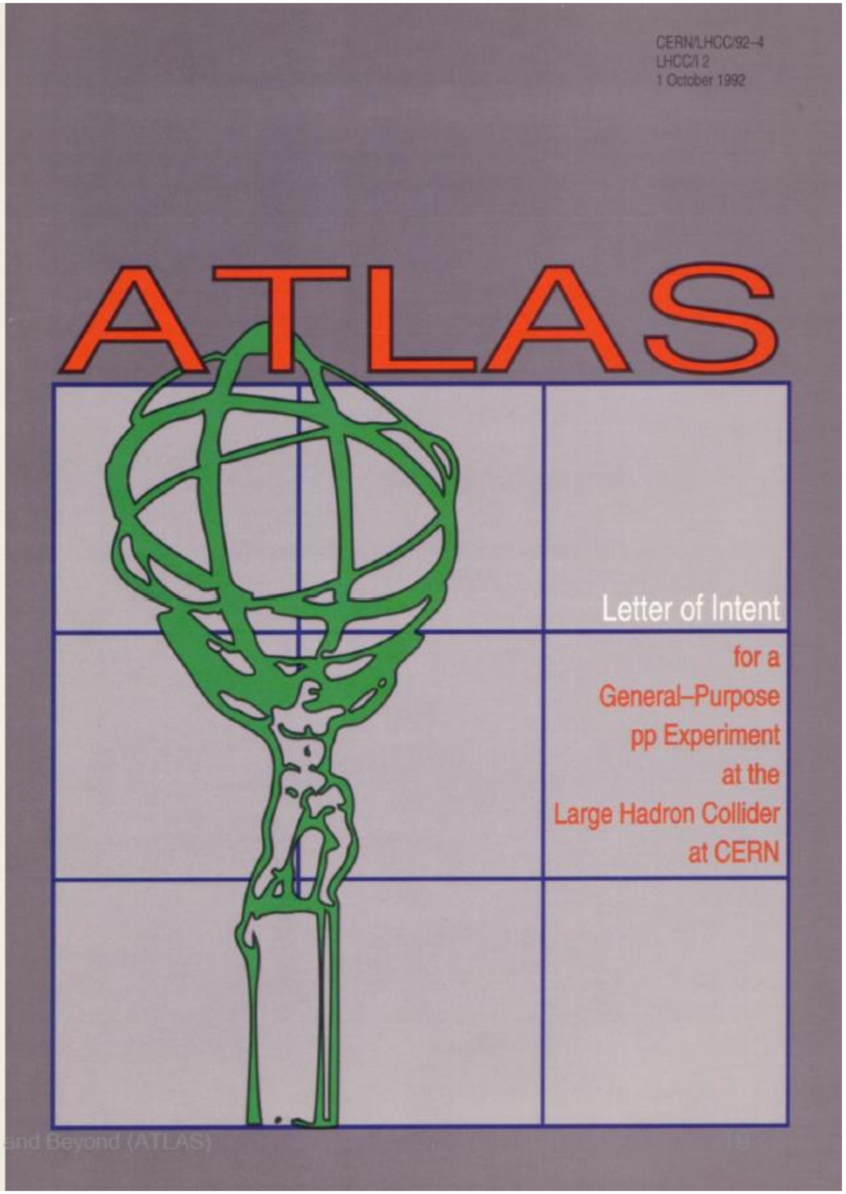
Merging of EAGLE and ASCOT

September 1992: Decision on the name

October 1992:

ATLAS LoI submitted to the LHCC (as well as the CMS LoI)

Approval of the project: 1995



EMFCSC, Erice, June 2017
P Jenni (Freiburg and CERN)

LHC, Higgs and Beyond (ATLAS)

LHCb upgrade II