FCC hh ee he

A summary Report of the FCC Study Kick-off meeting

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Rome University La Sapienza
and INFN Section of Rome 1

http://tlep.web.cern.ch

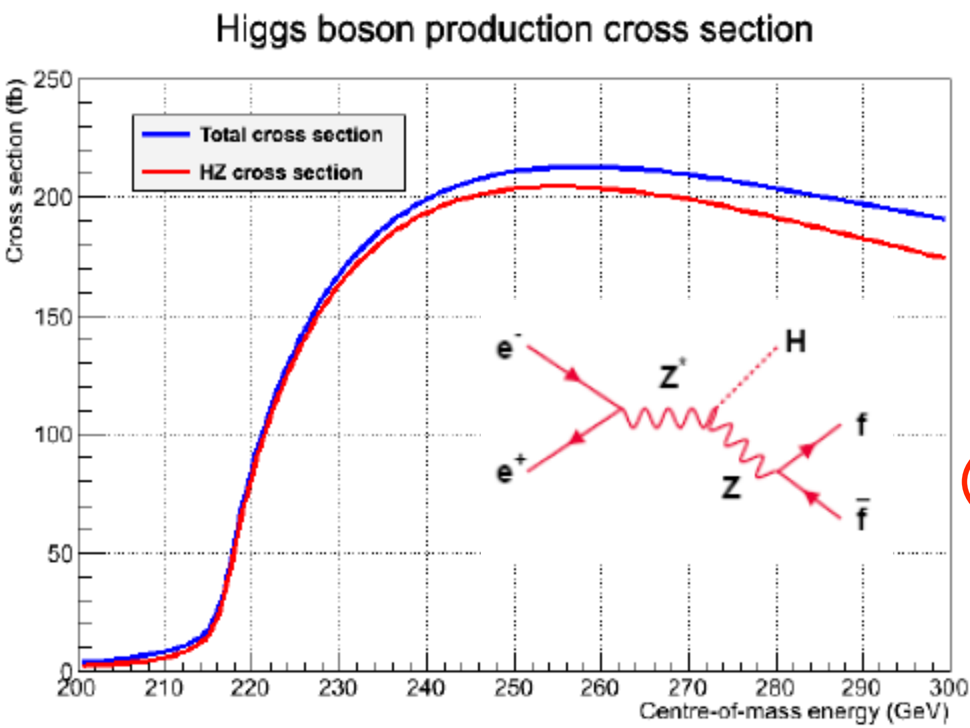
Picture by Jorge Wenninger

Outline

- A bit of history
- Scope of the Workshop
- The Tunnel
- The Accelerators
- The Detectors
- News from China
- Timeline
- Physics Motivations and Implications: see Barbara's talk.

A bit of history

- In July 2011 a proposal was made to (re)install a 120 GeV / beam e^+e^- collider in the LEP-LHC tunnel – named LEP3. Work on LEP3 started in a series of workshops.



LEP3: A HIGH LUMINOSITY E+E- COLLIDER TO STUDY THE HIGGS BOSON

Submitted to the European Strategy Preparatory Group

A. Blondel, U. Geneva, Switzerland;

M. Koratzinos, Geneva, Switzerland;

A. Butterworth, P. Janot, J. M. Jimenez, C. Grojean, A. Milanese, M. Modena, J.A. Osborne, F. Zimmermann, CERN, Geneva, Switzerland;

H. Piekarz, FNAL, U.S.A.;

K. Oide, K. Yokoya, KEK Japan;

J. Ellis, King's College London and CERN, Geneva, Switzerland;

M. Klute, M. Zanetti, MIT, Cambridge, Massachusetts, USA;

M. Velasco, Northwestern U., U.S.A.;

V. Telnov, Budker INP, Novosibirsk, Russia;

L. Rivkin, EPFL, Lausanne and PSI, Villigen, Switzerland;

Y. Cai, SLAC National Accelerator Laboratory, Stanford, U.S.A.

A bit of history

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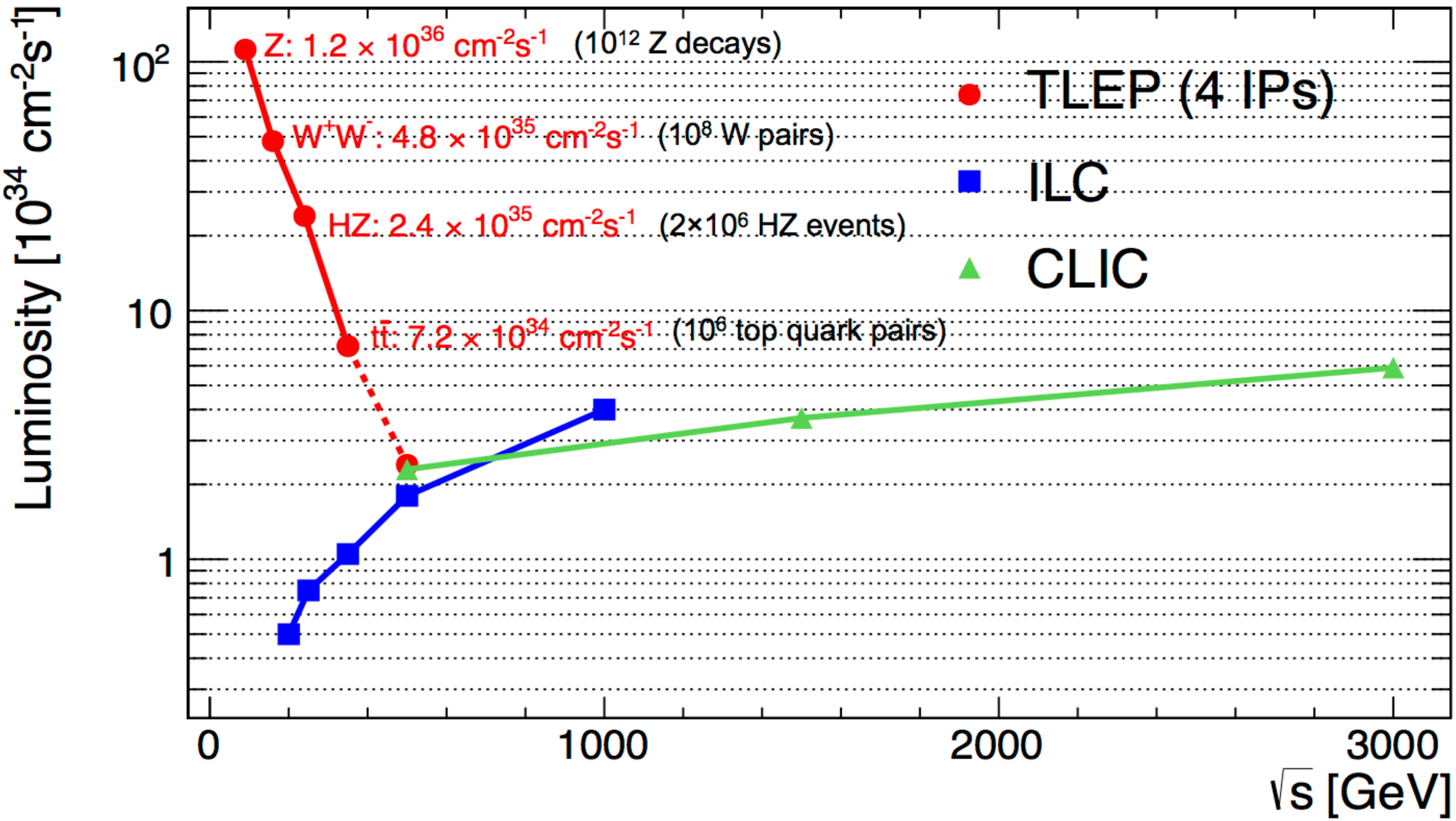
- In May 2013 was presented the Summary of the European Strategy for Particle Physics Update, to be adopted by the CERN

- In October 2013 TLEP was integrated into the FCC study and is now known as FCC-ee.

A bit of history: TLep



When the study of a 80-100 km tunnel was undertaken at CERN, it was soon realized that the e^+e^- collider that would fit in there is just remarkable: 1) the luminosity scales proportionally to the accelerator radius; 2) a centre-of-mass energy in excess of the top-pair threshold can be reached allowing this machine to produce all standard model particles with unequalled statistics; 3) the energy spread is reduced, hence beam transverse polarization can be envisioned at least up to the WW threshold; 4) by using all the RF power of 100 MW, the machine performance at the Z peak is simply mind-boggling – a Tera-Z factory becomes realistically feasible.

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A bit of history: ESU

CERN-Council-S/106
Original: English
7 May 2013

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

Action to be taken *Voting Procedure*

For Approval	EUROPEAN STRATEGY SESSION OF COUNCIL 16th Session - 30 May 2013 European Commission Berlaymont Building - Brussels	Simple Majority of Member States represented and voting

The European Strategy for Particle Physics
Update 2013

Having finalised its text by consensus at its Session of 22 March 2013, the Council is now invited to formally adopt the Update of the European Strategy for Particle Physics set out in this document.

- http://cds.cern.ch/record/1567258/files/esc-e-106.pdf

Summary: European Strategy Update 2013

Design studies and R&D at the energy frontier

….“to propose an ambitious **post-LHC accelerator project at CERN** by the time of the next Strategy update”:

d) ***CERN should undertake design studies for accelerator projects in a global context,***

- *with emphasis on* ***proton-proton and electron-positron high-energy frontier machines****.*
- *These design studies should be coupled to a vigorous accelerator* ***R&D programme, including high-field magnets and high-gradient accelerating structures****,*
- ***in collaboration with national institutes, laboratories and universities worldwide.***

- **http://cds.cern.ch/record/1567258/files/esc-e-106.pdf**

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330 registered participants

Scope of the meeting

Talk by R.Heuer

- Need to go beyond present energy frontier
  → circular high energy collider

- Exploitation of **all options** for such a project (hh – ee – ep) **within one study**

- Global Collaboration for the **Study of Future Circular Colliders** (similar to the CLIC collaboration)

- Hosted by CERN

R. Heuer: Scope

- A conceptual design study of options for a future high-energy frontier circular collider at CERN for the post-LHC era shall be carried out, implementing the request in the 2013 update of the European Strategy for Particle Physics.

- Many results of the study will be site independent.

- The design study shall be organised on a world-wide international collaboration basis under the auspices of the European Committee for Future Accelerators (ECFA) and shall be available in time for the next update of the European Strategy for Particle Physics, foreseen by 2018.

R. Heuer: Scope

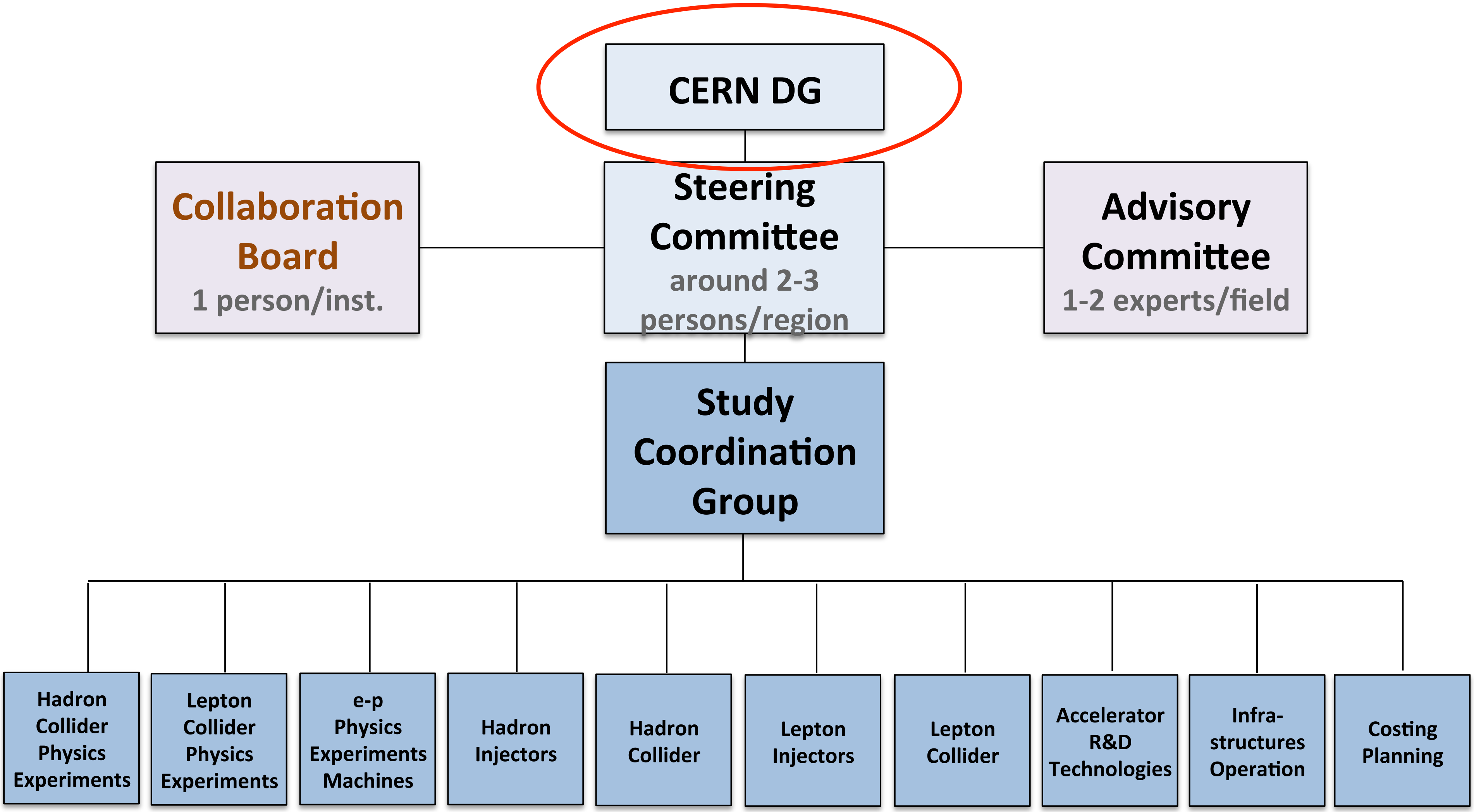
- ❑ The main emphasis of the conceptual design study shall be the long-term goal of a hadron collider with a centre-of-mass energy of the order of 100 TeV in a new tunnel of 80-100 km circumfe-rence for the purposes of studying physics at the highest energies.

- ❑ The conceptual design study shall also include a lepton collider and its detectors, as a potential intermediate step towards realization of the hadron facility. Potential synergies with linear collider detector designs should be considered.

- ❑ Options for e-p scenarios and their impact on the infrastructure shall be examined at conceptual level.

- ❑ The study shall include cost and energy optimisation, industrialisation aspects and provide implementation scenarios, including schedule and cost profiles.

Proposed international organization structure

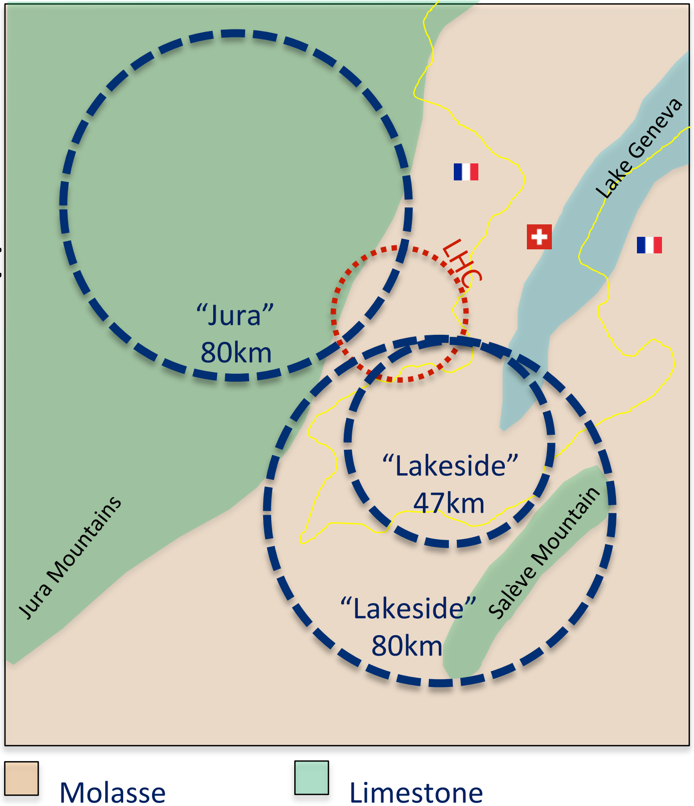


The Tunnel

Potential locations

- Several locations have been studied for the possibility to construct an 80km ring tunnel in the CERN area.
  - Location constraints
    - CERN area
    - Connected to LHC/SPS at one point
    - Depth (access shafts)

	Circumference	Average Depth	Max Depth below surface
LEP/LHC	27 km	100 m	170m
Jura	80 km	590 m	1270 m
Lakeside	80 km	280 m	690 m
Lakeside	47 km	220 m	320 m



John Osborne (CERN GS-SE)

Potential locations

- Location 1:

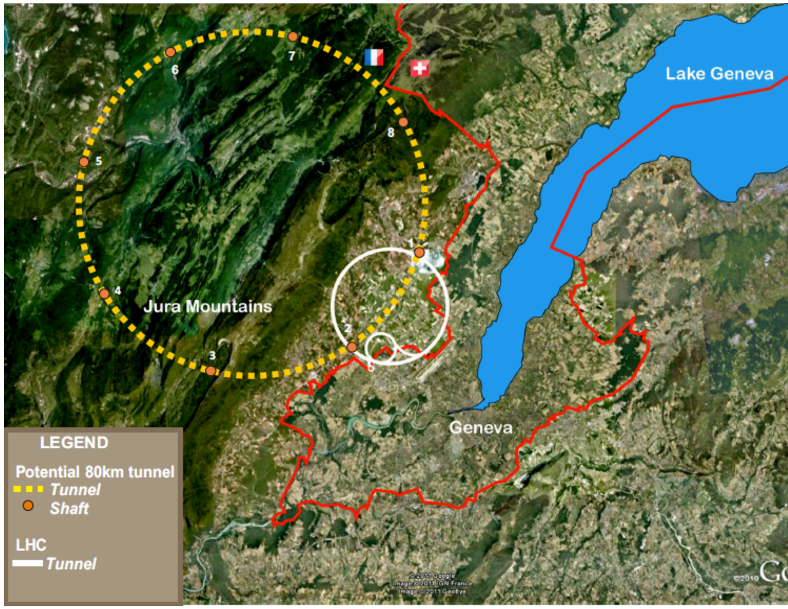
  80km Jura option

  – Fully housed in France
  – 90% in Jura Limestones (roccia calcarea)
  – 10% in Molasse (arenaria)
  – Connected to LHC
  – Shafts every 10km

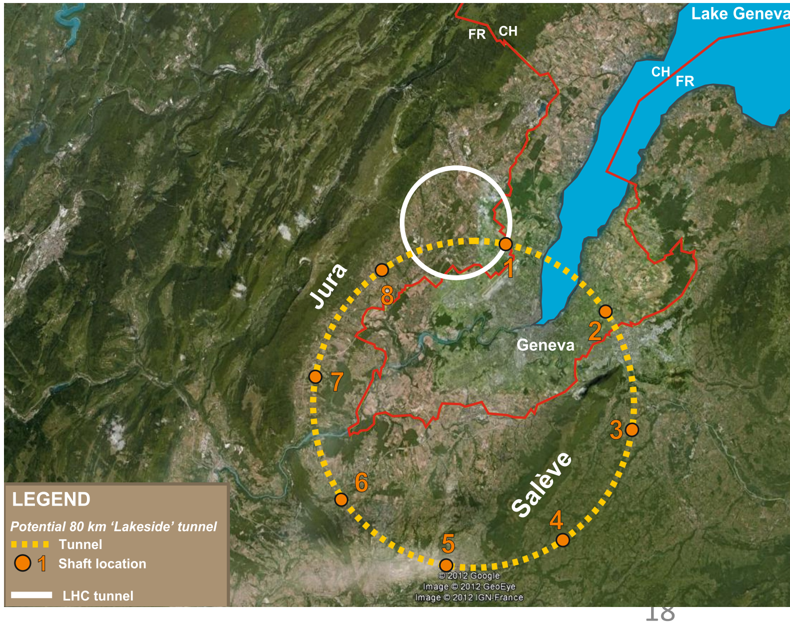
- Location 2:

  80km Lakeside option

  – Housed in France and Switzerland
  – 10% in Limestones (Jura, Salève)
  – 90% in Molasse
  – Passes under Lake Geneva
  – Around the back of the Salève
  – Connected to LHC
  – Shafts every 10km



Option 1: 80km Jura



Option 2: 80km Lakeside

John Osborne (CERN GS-SE)

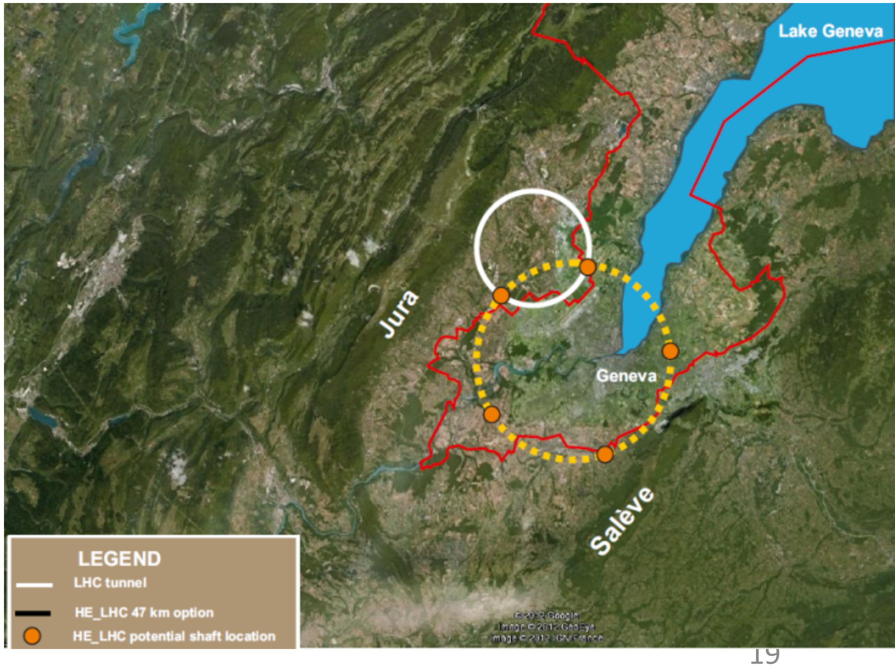
Potential locations

- Location 3:

  47km Lakeside option

  Studied from geotechnical viewpoint

  - Fully housed in the Molasse rock (preferred excavation rock in the Geneva area)
  - Under Lake Geneva
  - In front of Salève and Jura
  - Housed in France and Switzerland
  - Connected to LHC
  - Shafts every 10km
    - Too short for physics goal?



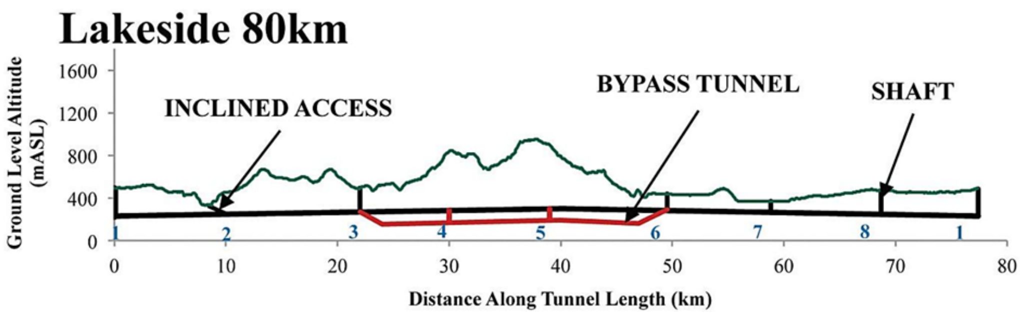
Option 3: 47km Lakeside

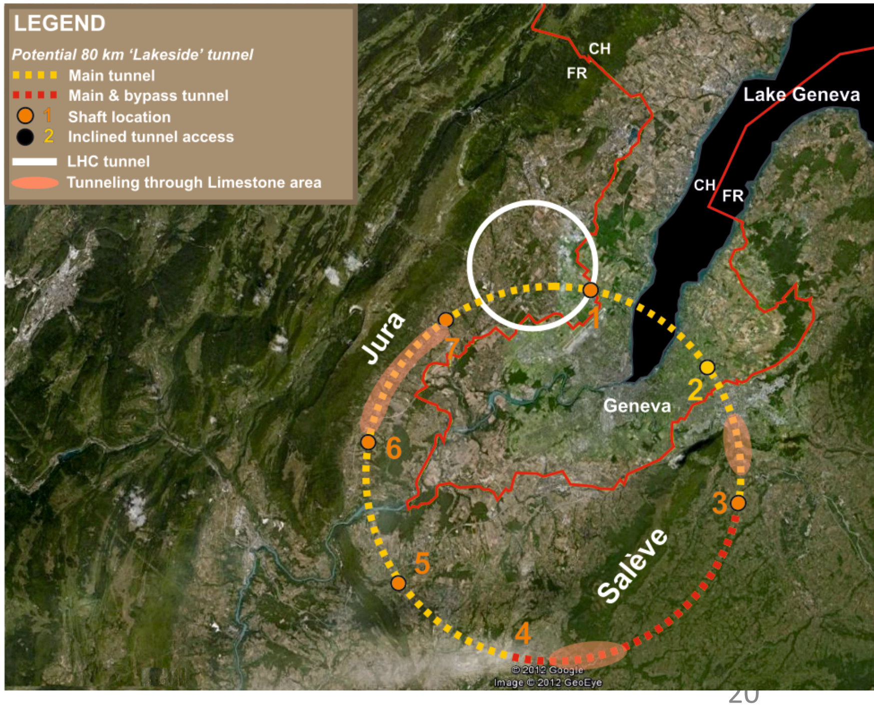
John Osborne (CERN GS-SE)

CE considerations and Optimization

- Optimization studies for the project configuration have been started
  - Bypass tunnel in geological and environmental sensitive area
  - Inclined access tunnel in urban area

- More optimization studies needed
  - Incline tunnel?
  - More bypass tunnels?





John Osborne (CERN GS-SE)

FUTURE CIRCULAR COLLIDER

WORKSHOP 13. / 14. FEBRUAR 2014, GENEVA

Gotthard Basetunnel

Aspects of Long Tunnels

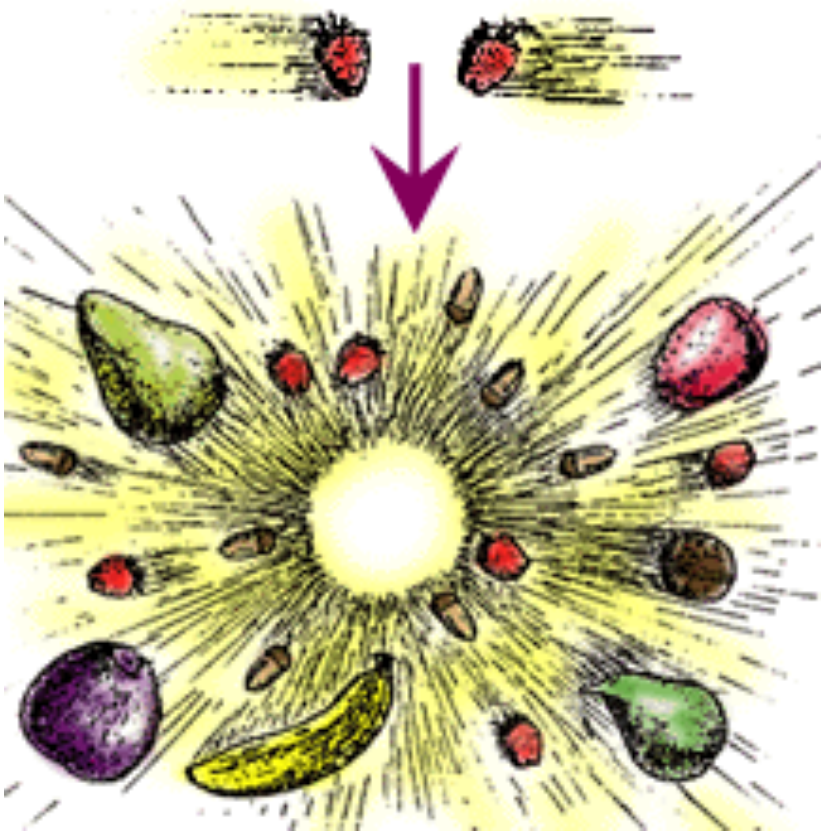
The Tunnel is not a problem

presented by:

M.Sc. F Amberg

Amberg Engineering Ltd., Regensdorf, Switzerland

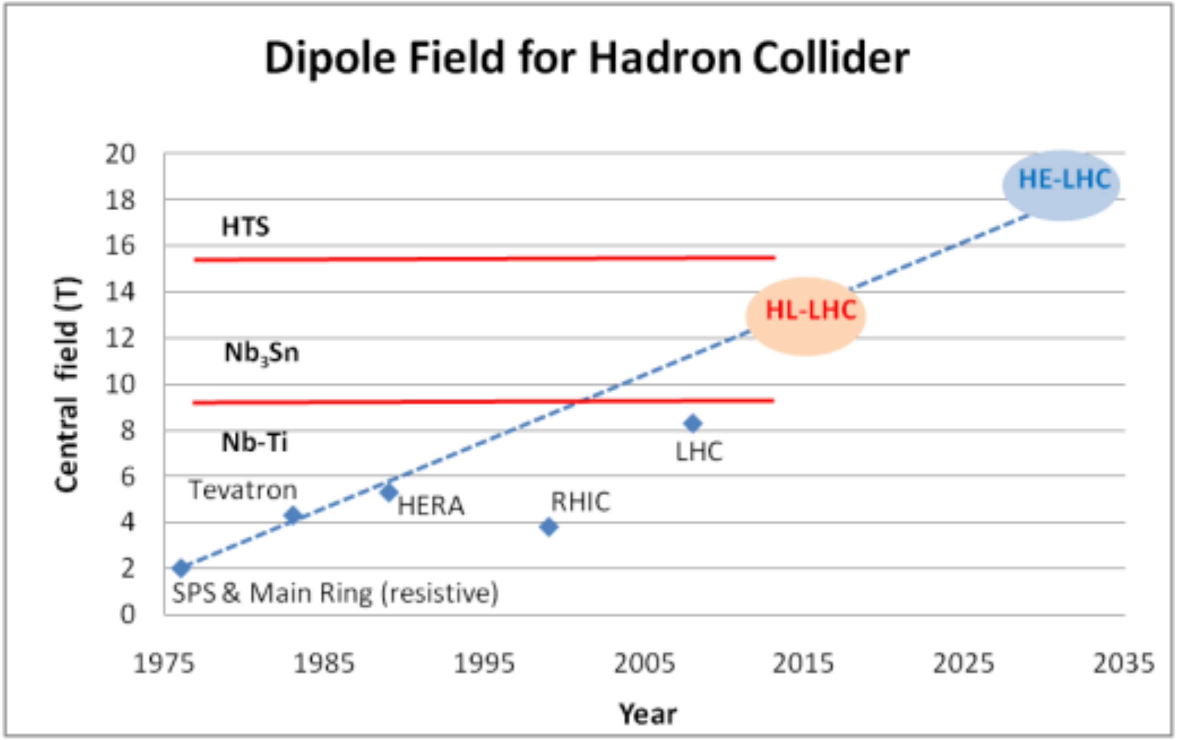
The accelerators



Malta Workshop: **HE-LHC @ 33 TeV c.o.m.**

14-16 October 2010

Material	N. turns	Coil fraction	Peak field	$J_{overall}$ (A/mm^2)
Nb-Ti	41	27%	8	380
Nb3Sn (high Jc)	55	37%	13	380
Nb3Sn (Low Jc)	30	20%	15	190
HTS	24	16%	20.5	380



Magnet design (20 T): very challenging but not impossible.

300 mm inter-beam

Multiple powering in the same magnet (and more sectioning for energy)

Work for 4 years to assess HTS for 2X20T to open the way to 16.5 T/beam .

Otherwise limit field to 15.5 T for 2x13 TeV

Higher INJ energy is desirable (2xSPS)

Nb-Ti: Niobium – Titanium

Nb_3Sn: TriNiobium – Tin

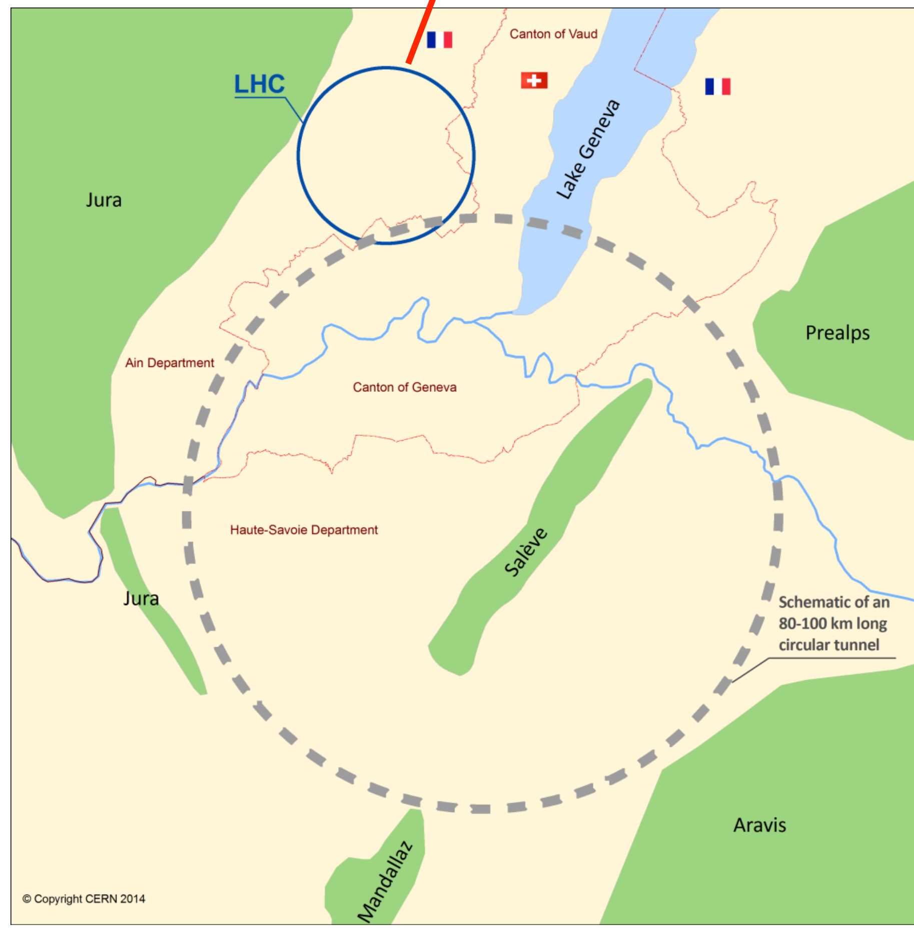
HTS: High Temperature Superconductor

"High Energy LHC"

First studies on a new 80 km tunnel in the Geneva area

- **42 TeV with 8.3 T using present LHC dipoles**
- **80 TeV with 16 T based on Nb_3Sn dipoles**
- **100 TeV with 20 T based on HTS dipoles**

HE-LHC :33 TeV with 20T magnets



FCC-hh parameters – starting point

Michael Benedikt, Frank Zimmermann

Energy	**100 TeV c.m.**
Dipole field	**~ 16 T (Nb_3Sn), [20 T option HTS]**
Circumference	**~ 100 km**
#IPs	**2 main (tune shift) + 2**
Luminosity/IP_{main}	**$5x10^{34}$ $cm^{-2}s^{-1}$**
Stored beam energy	**8.2 GJ/beam**
Synchrotron radiation	**26 W/m/aperture** (filling fact. ~78% in arc)
Long. emit damping time	**0.5 h**
Bunch spacing	**25 ns [5 ns option]**
Bunch population (25 ns)	$1x10^{11}$ p
Transverse emittance	2.2 micron normalized
#bunches	10500
Beam-beam tune shift	0.01 (total)
β*	1.1 m (HL-LHC: 0.15 m)

already available from SPS for 25 ns

FCC-hh design challenges

Michael Benedikt, Frank Zimmermann

Optics and beam dynamics

- IR design, dynamic aperture studies, SC magnet field quality

Impedances, instabilities, feedbacks

- Beam-beam, e-cloud, resistive wall, feedback systems design

Synchrotron radiation damping

- controlled blow up, luminosity levelling, etc…

Energy in beam & magnets → dump, collimation, quench protection

- **Stored beam energy critical: 8 GJ/beam (0.4 GJ LHC)**
- Beam losses, radiation effects → collimation, shielding
- Synergies intensity frontier (**SNS, J-PARC, PSI, PIP, FRIB, ESS, FAIR**)

High synchrotron radiation load on beam pipe

- **Up to 26 W/m/aperture in arcs, total of ~5 MW for FCC-hh**
- (LHC has a total of 1W/m/aperture from different sources)
- Heat extraction: photon stop, beam screen temperature, cryo load,
- Synergies with **SSC,VLHC, LHC, light sources, SppC, …**

FCC-hh: Physics Parameters

Daniel Shulte

	LHC	HL-LHC	HE-LHC	FCC-hh
Cms energy [TeV]	14		33	100
Luminosity [$10^{34}cm^{-2}s^{-1}$]	1	5	5	5
Bunch distance [ns]	25			25 (5)
Background events/bx	27	135	147	170 (34)
Bunch length [cm]	7.5	7.5	7.5	8

- Two main experiments sharing the beam-beam tuneshift
  - Two reserve experimental areas not contributing to tuneshift
- Currently assume 25ns as baseline
  - May be able to reduce bunch spacing and background
- Might be able to increase bunch length
  - Will explore this if experiments find it useful
- 80% of circumference filled with bunches

High-field magnet R&D targets

Michael Benedikt, Frank Zimmermann

FCC-hh **baseline 16T Nb_3Sn technology for ~100 TeV c.m. in ~100 km**

Develop Nb_3Sn-based 16 T dipole technology,

- with sufficient aperture (~40 mm) and
- accelerator features (field quality, protectability, cycled operation).
- In parallel conductor developments

Possible goal:

- **16T short dipole models by 2018 (America, Asia, Europe)**

In parallel HTS development targeting 20 T:

- HTS insert, generating *O*(5 T) additional field
- in large aperture *O*(100 mm, 15 T)

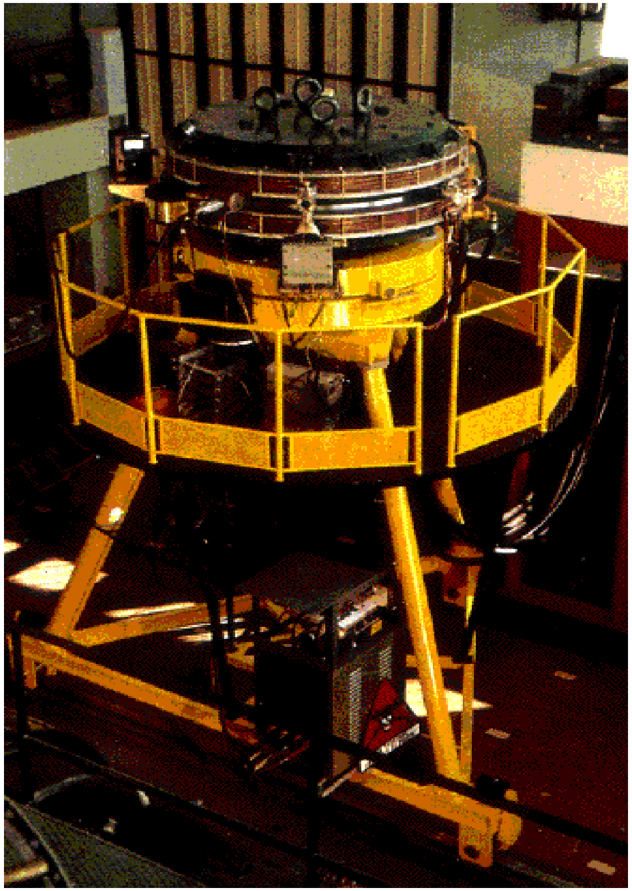
Possible goal:

demonstrate HTS/LTS 20 T technology in two steps

- a field record attempt to break the 20 T barrier (no aperture), and
- a 5 T insert, with sufficient aperture (40 mm) and accel. features

FCC-ee alias TLEP

ADA – 1961 - LNF



$\sqrt{s}$ = 500 MeV

FCC-ee parameters – starting point

Michael Benedikt, Frank Zimmermann

Design choice: max. synchrotron radiation power set to 50 MW/beam

- **Defines the maximum beam current at each energy**
- **4 physics operation points (energies) foreseen *Z, WW, H, ttbar***
- **Optimization at each operation point, mainly via bunch number and arc cell length**

Parameter	*Z*	*WW*	*H*	*ttbar*	*LEP2*
E/beam (GeV)	**45**	**80**	**120**	**175**	**105**
L (10^{34} $cm^{-2}s^{-1}$)/IP	**28.0**	**12.0**	**5.9**	**1.8**	**0.012**
Bunches/beam	**16700**	**4490**	**1330**	**98**	**4**
I (mA)	1450	152	30	6.6	3
Bunch popul. [10^{11}]	1.8	0.7	0.47	1.40	4.2
Cell length [m]	300	100	50	50	79
Tune shift / IP	0.03	0.06	0.09	0.09	0.07

FCC-ee design challenges

Michael Benedikt, Frank Zimmermann

Short beam lifetime from high luminosity (radiative Bhabha scattering)

- **Top-up injection** (single injector booster in collider tunnel)

Additional lifetime limit from beamstrahlung at top operation energy

- Flat beams (small vertical emittance, small vertical β^* ~ 1 mm)
- Final focus with large (~2%) energy acceptance to reduce losses

Machine layout for high currents, large #bunches at *Z* pole, *WW*, *H*

- **Two ring layout and configuration of the RF system.**

Polarization for high precision energy calibration at *Z* pole and *WW* with long natural polarization times (*WW*: ~10 hours, *Z*: ~200 hours)

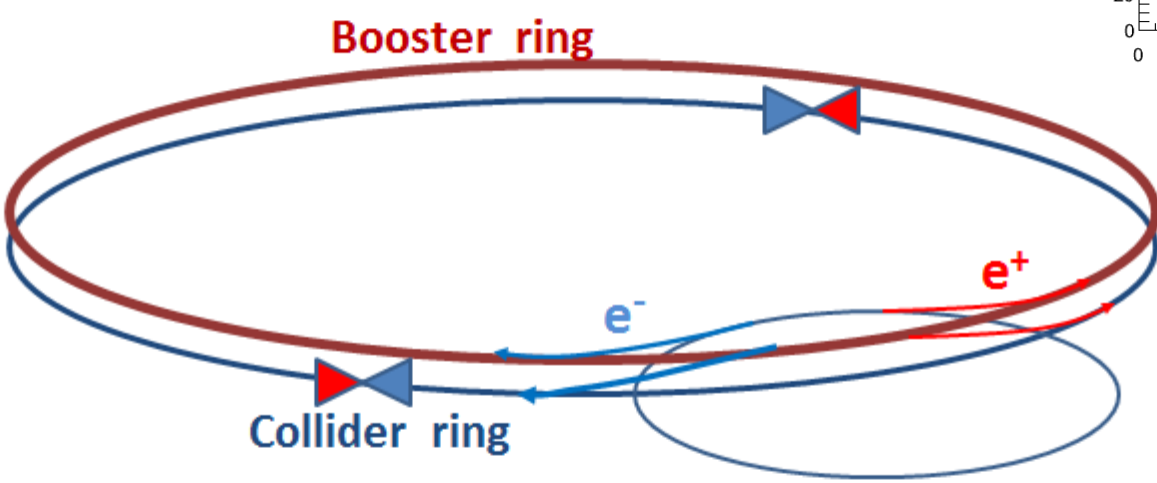
Important expertise available worldwide and potential synergies:

- **IR design, experimental insertions, machine detector interface, (transverse) polarization**

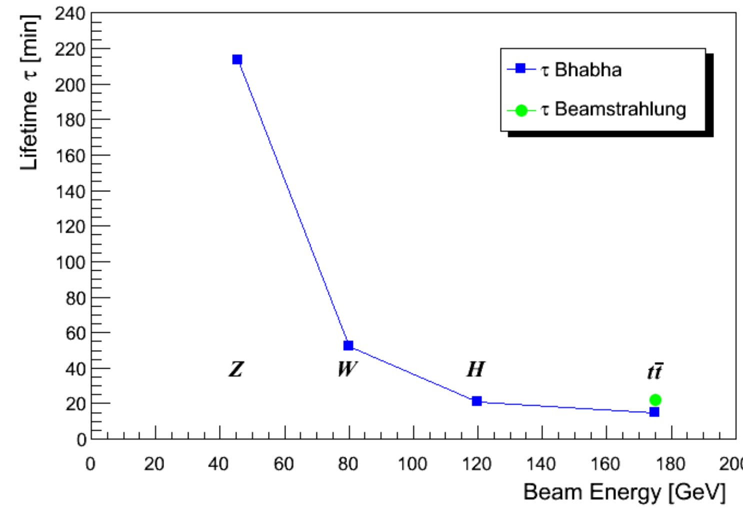
RHIC, VEPP-2000, BEPC-II, SLC, LEP, *B*- and Super-*B* factories, CEPC, ILC, CLIC

FCC-ee: injection

- Besides the collider ring(s), a booster of the same size (same tunnel) must provide beams for top-up injection.
  - *Same size of RF system, but low power (~ MW).*
  - *Top up frequency ~0.1 Hz.*
  - *Booster injection energy ~20 GeV.*
  - *Magnetic coupling between collider and booster !*
- Injector complex for e^+ and e^- beams of ~20 GeV.



Lifetimes down to ~15 minutes



$$\tau_{ee} \propto \frac{I}{L\sigma_{ee} n_{ip}}$$

$$\sigma_{ee} \approx 0.21 \text{ (b)}$$

SC-RF main R&D areas

SC cavity R&D

- **Large Q_0 at high gradient and acceptable cryogenic power**
  - Recent results at 4 K with Nb_3Sn coating on Nb at Cornell
  - 800 ℃ ÷ 1400 ℃ heat treatment at JLAB
  - Beneficial effect of impurities observed at FNAL
- **Relevant for many other accelerator applications**

High efficiency RF power generation from grid to beam

- Power converter technology
- Klystron efficiencies beyond 65%, alternative RF sources as Solid State Power Amplifier or multi-beam IOT (inductive output tube), etc.
- **Relevant for all high power accelerators, intensity frontier (drivers):**
  J-PARC, SNS, νstorm, LBNE, XFEL, μcoll, ESS, MYRRHA, …

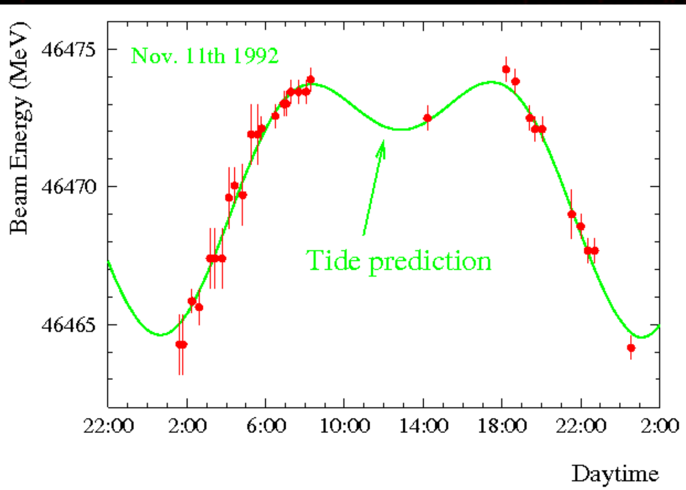
Overall RF system reliability → relevant for *FCC-hh* and *FCC-ee*

R&D Goal is optimization of overall efficiency, reliability and cost!

- Power source efficiency, low-loss high-gradient SC cavities, operation temperature vs. cryogenic load, total system cost and dimension.

When the moon hits your eye…

J. Wenninger



Moon Found Behind Particle-Accelerator Puzzle

In Physics, the Moon Factor

GENEVA (IHT) — Scientists at the European Laboratory for Particle Physics will have to consult the phase of the moon in future before calibrating instruments on the Large Electron Positron collider outside Geneva.

Long puzzled by variations in the energy of the circulating beam made up of hundreds of millions of subatomic particles, physicists have now discovered that these correspond exactly to minute deformations in the Earth's crust caused by lunar attraction. Over the 27 kilome-

SCIENCES

Au LEP, près de Genève

Les effets de Lune dévoilés par les physiciens

Physicists look to the moon for atomic answers

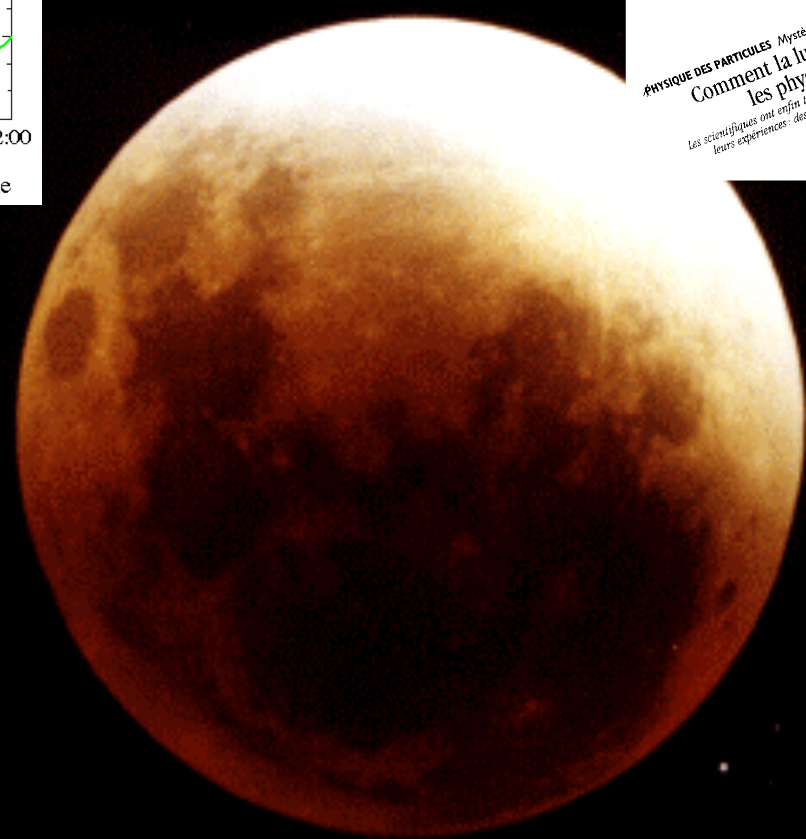
PHYSIQUE DES PARTICULES Mystère élucidé

Comment la lune a trompé le CERN : les physiciens expliquent

La lune trouble le CERN

L'énergie des particules circulant dans l'anneau du LEP se modifie en fonction des phases lunaires.

November 1992

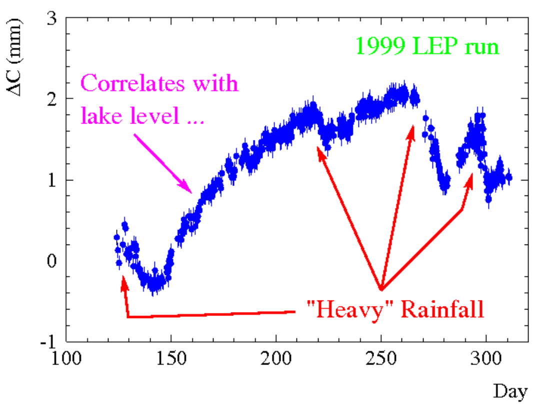


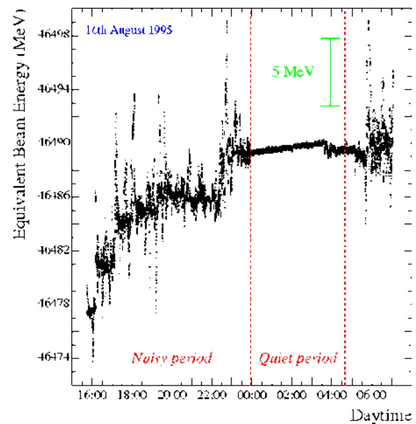
Energy swing

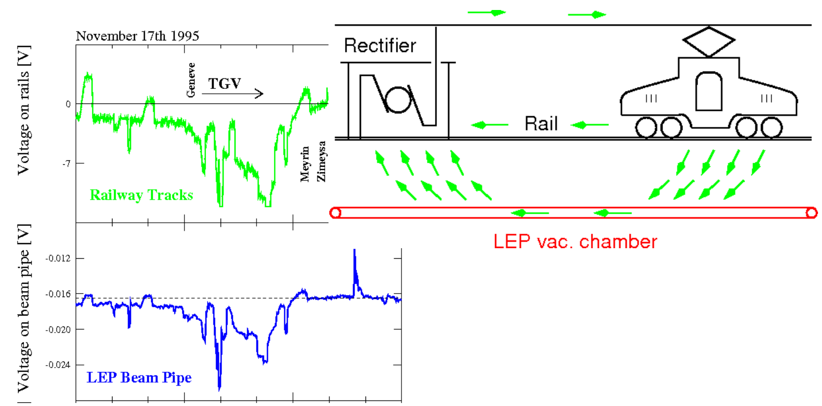
LEP	10 MeV at Z
FCC-ee	1.5 GeV at t
	10 - 400 MeV at Z
	(function of optics !)

Energy Calibration

- The average beam energy can be obtained to ~100 keV precision from resonant depolarization.
  - *Local energy offsets at the IPs must be modelled !*
- At LEP energy calibrations could not be performed continuously, a model had to be build for interpolation (up to few days). The final accuracy on the energy was limited by the energy model.







- LEP lesson: to achieve sub-MeV accuracy at FCC-ee the energy must be measured **continuously**.
  - *Use a few non-colliding bunches to monitor the energy.*

J. Wenninger

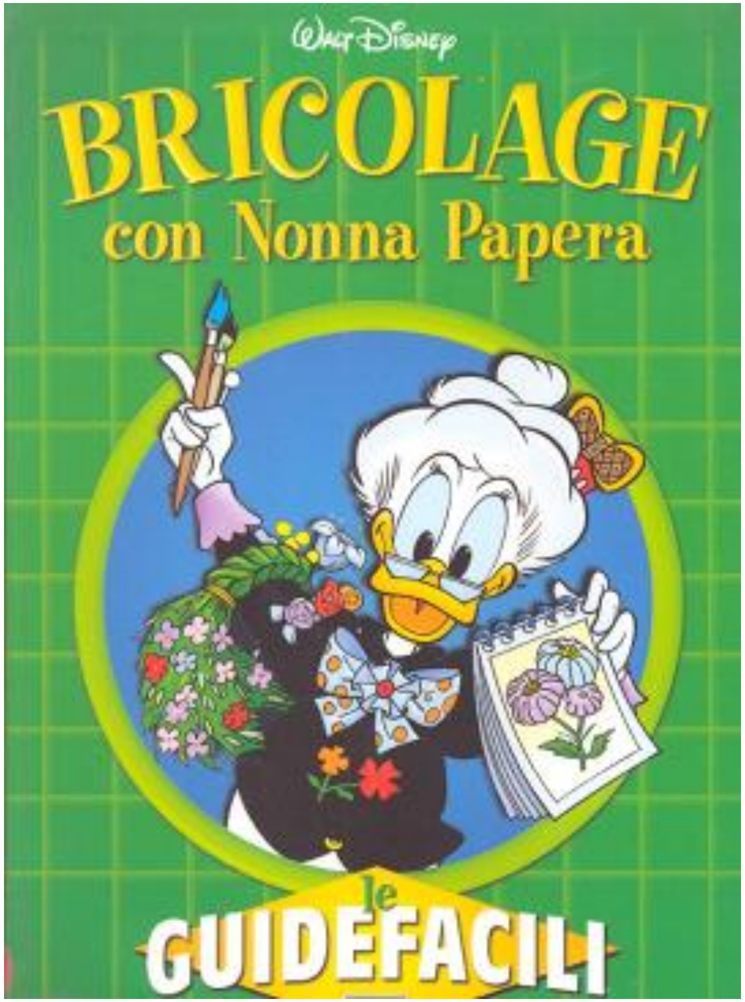
FCC-he parameters – starting point

Michael Benedikt, Frank Zimmermann

- **Design choice: beam parameters as available from *hh* and *ee***
  - Max. $e^{\pm}$ beam current at each energy determined by 50 MW SR limit.
  - **1 physics interaction point, optimization at each energy**

collider parameters	**$e^{\pm}$ scenarios**			**protons**
species	***$e^{\pm}$*** (polarized)	***$e^{\pm}$***	***$e^{\pm}$***	***p***
beam energy [GeV]	**80**	**120**	**175**	**50000**
luminosity [$10^{34}cm^{-2}s^{-1}$]	**2.3**	**1.2**	**0.15**	
bunch intensity [10^{11}]	0.7	0.46	1.4	1.0
#bunches per beam	4490	1360	98	10600
beam current [mA]	152	30	6.6	500
$\sigma_{x,y}$* [micron]	4.5, 2.3			

The Detectors



A.Ball, F. Gianotti, D. Fournier

Preliminary considerations about general purpose....

Detectors
for ~100 TeV p-p collisions

F.Gianotti, A.Henriques, H.TenKate,
L.Pontecorvo, DF
and informally many other colleagues

FCC-hh: driving requirements

A.Ball, F. Gianotti, D. Fournier

(1) Discovery of « high-mass » phenomena at the « Lσ »limit

- From « Drell-Yan » Limit m(Z') ~ 30 TeV

Z'→μμ : muon spectrometer (resolution,acceptance)

Z'→ee : EMcal (thickness, resolution-constant term- ,dynamic range,..)

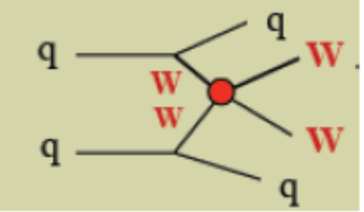
- From QCD: q* Limit m(q*) ~ 50 TeV

  -jet resolution, linearity

-SUSY

  -complex signatures ETmiss, jets, leptons, taus,...

(2) Study of VV scattering by « VBF mechanism »

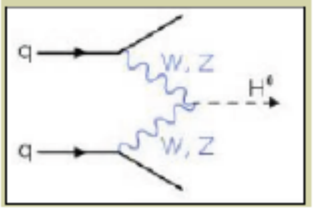


- VBF jets between η~2 and η~6

  need to be well measured and separated from pile-up

- muons (and electrons) around ~1 TeV pT

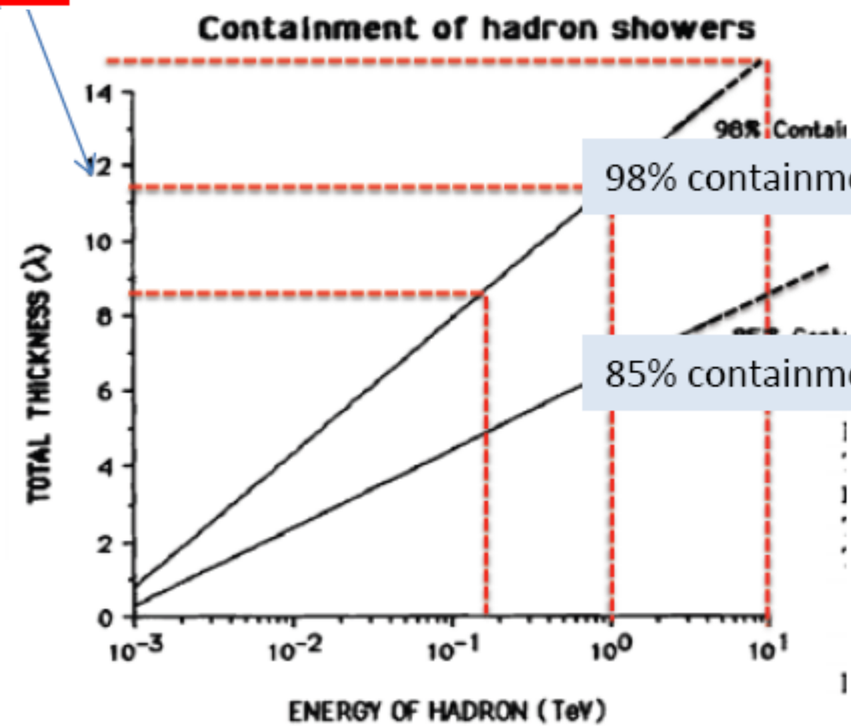
  need to be triggered, identified, precisely measured



Example: hcal depth

A.Ball, F. Gianotti, D. Fournier

12 λ



"Common understanding"
10 λ at LHC→12λ at 100 TeV
(including ~1λ EM in front)

- SSC study confirmed by TileCal measurements (up to 20λ)
  - -A 20TeV jet has 1→several 1 TeV hadrons
  - -require ~98% containment of 1 TeV hadrons

Detector line guide

A.Ball, F. Gianotti, D. Fournier

Very preliminary sketches, to stimulate discussions…

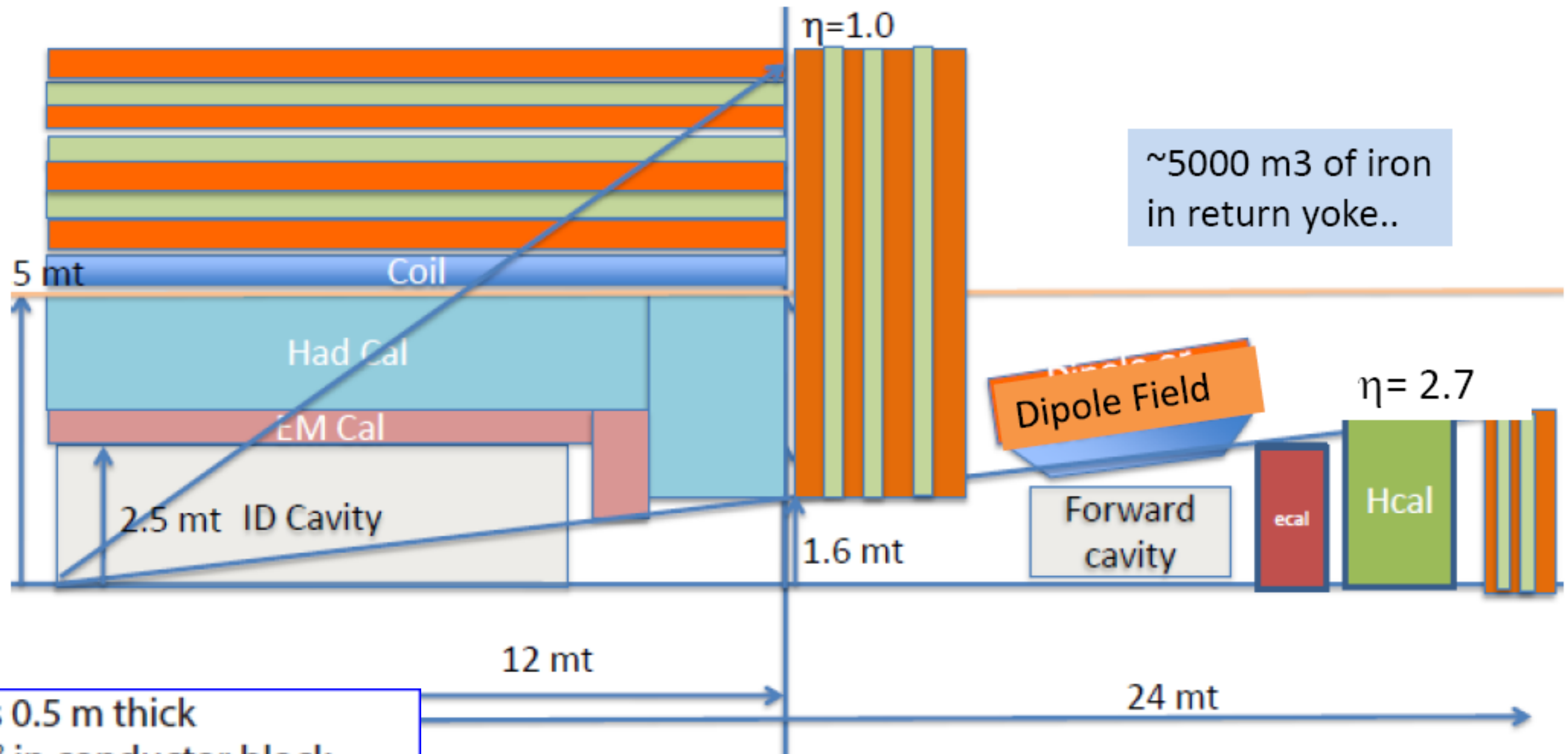
- Increase central bending power (muons)
- Extend coverage of tracking in B–field (up to ~η=5?)
- Increase thickness of calorimeters
- Move EC calorimeters away from collision point

CMS-like

LARGE SOLENOID :
coil : 24 m long and 5 m radius

ALTERNATIVES:

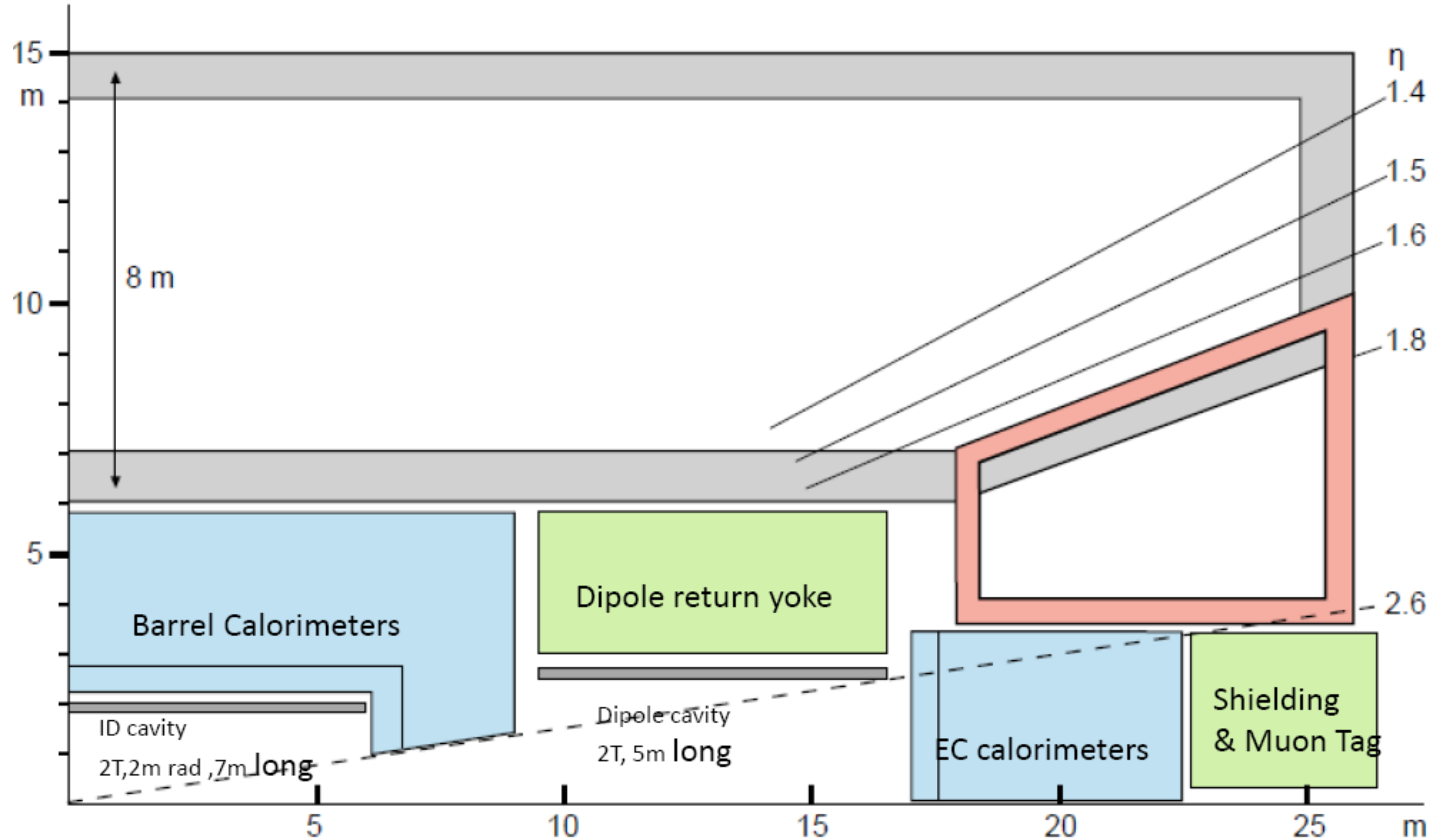
- increase R_coil up to 6m
(to accomodate >12 λ calorimeter depending on absorber choice)
- Replace Iron return by large SC coil (~10 m radius) and « low »field



- 5m radius 0.5 m thick
- 10 A/mm² in conductor block
- 5.5 T peak field on conductor
- 20 GJ stored energy (without iron)
- 5 T central bending field

CMS : 22 m x 15 m
Solenoid: 6 m x 4 T

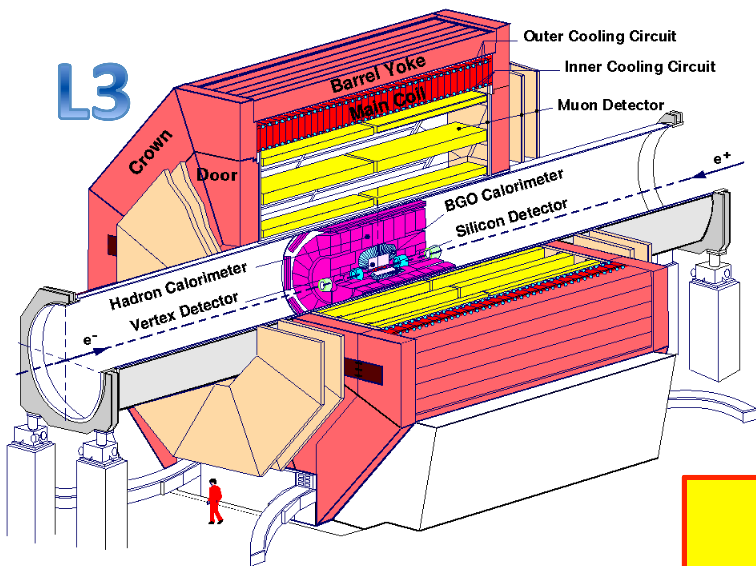
Atlas-like

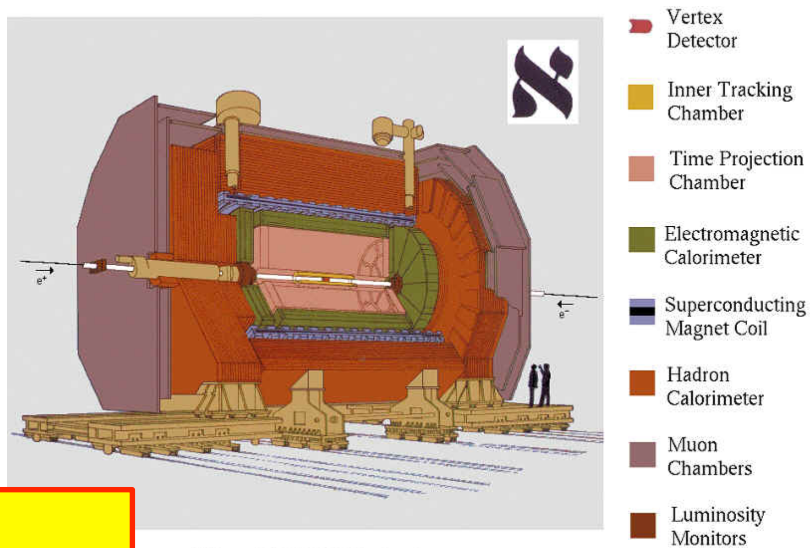


Radially: ~20Tm
against 2.4 in ATLAS

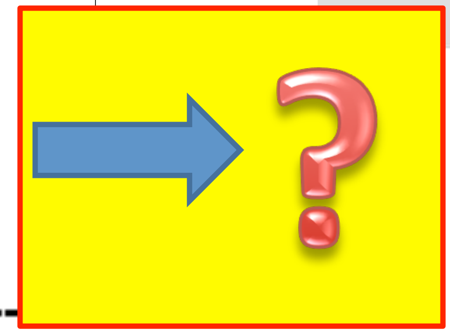
- Peak field on conductor up to ~8 T (to be minimized)
- Stored energy > 50 GJ

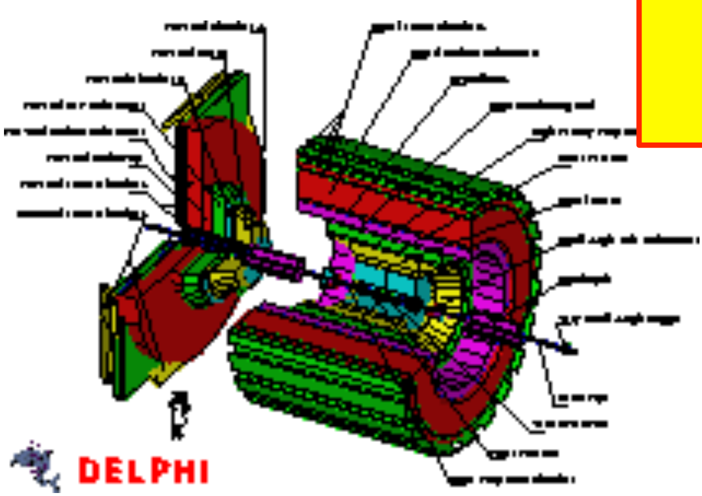
FCC-ee Detectors

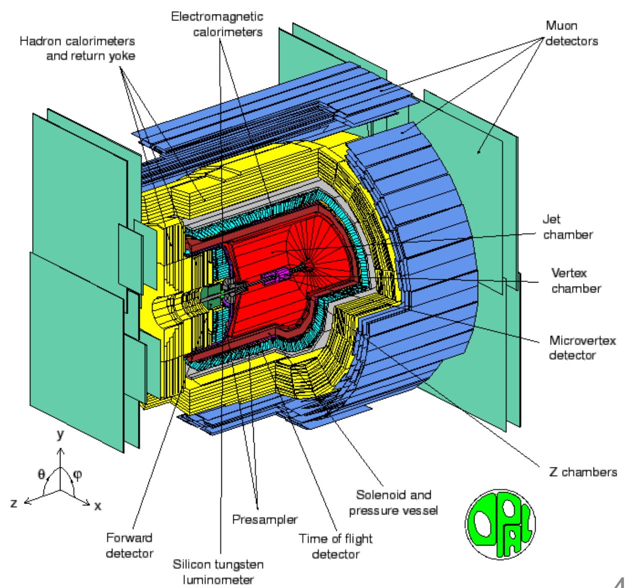




The ALEPH Detector







Some Physics cases

G. Rolandi

- Precise measurement (0.1% to 1%) of the Higgs Couplings
- Improve precision (statistics x 10^5) on the measurements of the Z parameters [M_Z, Γ_Z , R_ℓ, R_b, R_c, Asymmetries & weak mixing angle]. Z rare decays.
- Scan W threshold (aiming at 0.5 MeV precision). W rear decays
- Scan ttbar threshold (aiming at 10 MeV)

Measurements dominated by systematics

All masses measured from a scan of the cross section what matters is energy calibration of the accelerator.

General detector requirements

G. Rolandi

- Be suitable for high precision measurement
- Large Magnetic Field
- Excellent lepton id and lepton/photon momentum resolution
- Adequate calorimeter granularity [Particle Flow Friendly]
- Precise angular (and energy) jet measurement
- High granularity vertex detector with b and c tagging capabilities
  - …. in a low occupancy environment

The Detector is not a big problem

The FCC-ee program

G. Rolandi

16700 bunches: 62.5-50 MHz bunch crossing rate

Challenge for the DAQ/Trigger system and Inner Detector

√s (GeV)	<L >(ab-1/year)*	Rate (Hz) ee—>hadrons	Years	Statistics
90	5.6	$2\ 10^4$	1	$2\ 10^{11}$ Z decays
160	1.6	25	1-2	$2\ 10^7$ W pairs
240	0.5	3	5	$5\ 10^5$ HZ events
350	0.13	1	5	$2\ 10^5$ ttbar

* each interaction point

Rare Z "Decays", for example: $O(150)\ B_s \rightarrow \mu\mu$, $O(20)\ B_d \rightarrow \mu\mu$ → **Very good tracking system**

The Working Groups have to spot critical issues for the detector

FCC-ee Design study: Physics WBS

- **Experimental Physics WBS (coordinators A. Blondel, P. Janot)**
  - Study the properties of the Higgs and other particles with unprecedented precision

Electroweak Physics at the Z pole	Di-boson Physics m_W measurement	H(126) Properties	Top Quark Physics
R. Tenchini	R. Tenchini	TBA	P. Azzi

QCD and γγ Physics	Flavour Physics	Exp'tal signatures of New Physics
D. d'Enterria	S. Monteil	TBA

  - Develop the necessary tools
  - Understand the experimental conditions

Offline Software and Computing	Online Software and Computing	Exp'tal Environment
TBA	C. Leonidopoulos	N. Baccheta
Synergy with FCC-hh		Synergy with FCC-hh

  - Set constraints on the possible detector designs to match statistical precision

Detector Designs
G. Rolandi

Synergy with linear collider detectors

conveners jobs is to assemble collaborators and find co-conveners in a global way

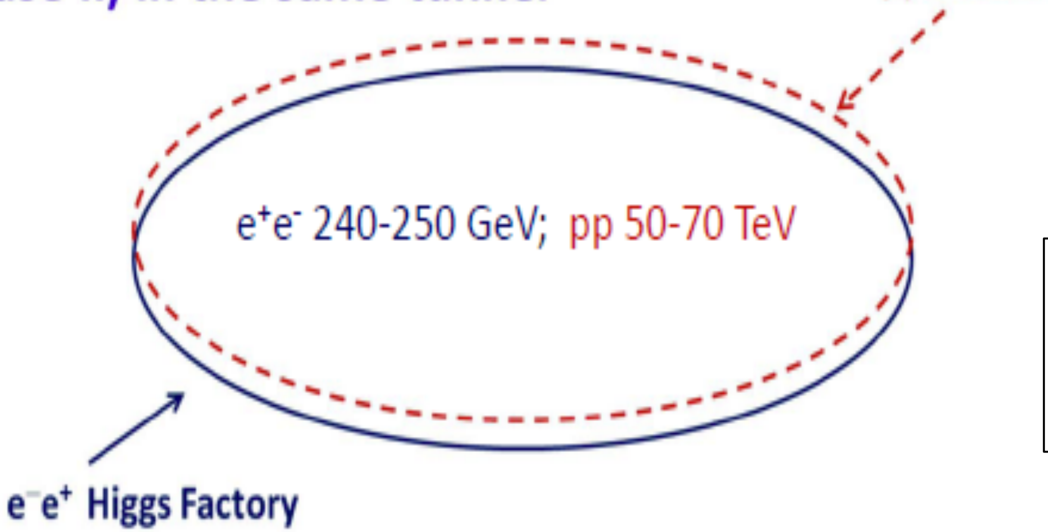
News from China

CEPC+SppC

Yifang Wang

- For about 8 years, we have been talking about “What can be done after BEPCII in China”
- Thanks to the discovery of the low mass Higgs boson, and stimulated by ideas of Circular Higgs Factories in the world, CEPC +SppC configuration was proposed in Sep. 2012

- Circular Higgs factory (phase I) + super pp collider (phase II) in the same tunnel



A 50-70 km tunnel is very affordable in China NOW

The site: Qinhuangdao

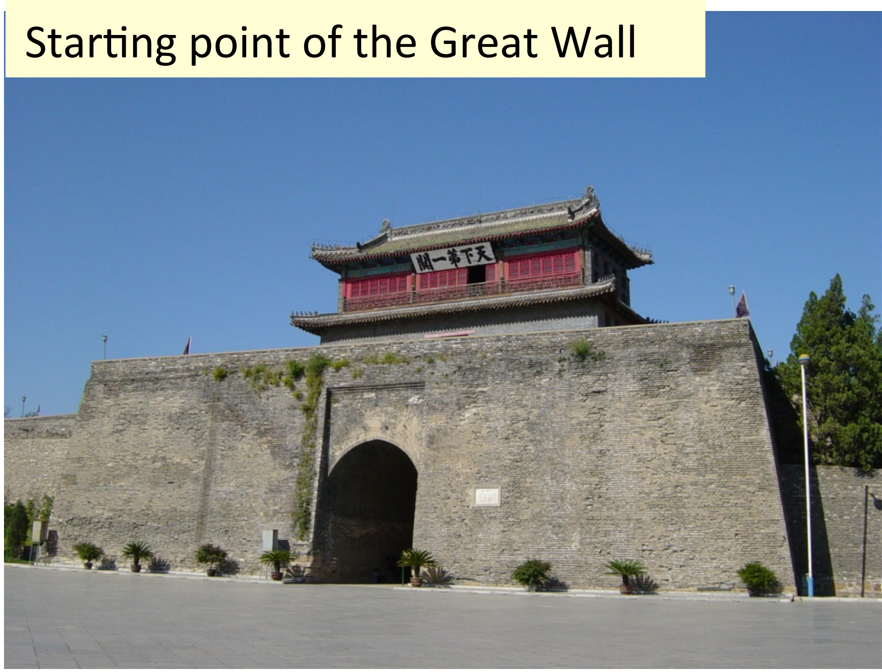
Yifang Wang

- 300 km from Beijing
- 3 h by car
- 1 h by train

Beautiful Place for a Science Center

Best beach & cleanest air
Summer capital of China

Starting point of the Great Wall

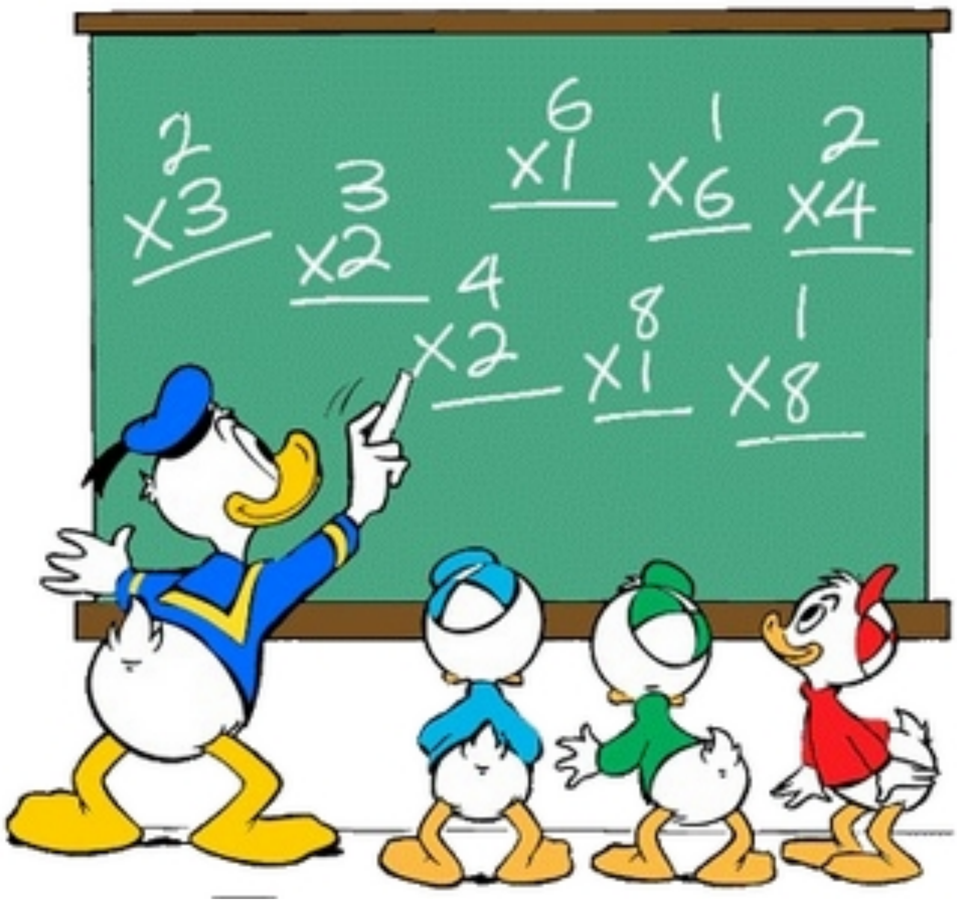


Wine yard

Yifang Summary

- It is difficult
- But it is very exciting
- Even if it is not in China, it is still very beneficial to our field and to the Chinese HEP & Science community
- We fully support a global effort
- Let's us work for our dream

The “burocracy”



FCC Kick-Off & Study Preparation Team

Future Circular Colliders - Conceptual Design Study
Study coordination, **M. Benedikt, F. Zimmermann**

Hadron collider
D. Schulte

Hadron injectors
B. Goddard

e+ e- collider and injectors
J. Wenninger

Infrastructure, cost estimates
P. Lebrun

Technology

High Field Magnets
L. Bottura

Supercon-ducting RF
E. Jensen

Cryogenics
L. Tavian

Specific Technologies
JM. Jimenez

Physics and experiments

Hadrons
A. Ball,
F. Gianotti,
M. Mangano

e+ e-
A. Blondel
J. Ellis, P. Janot

e- p
M. Klein

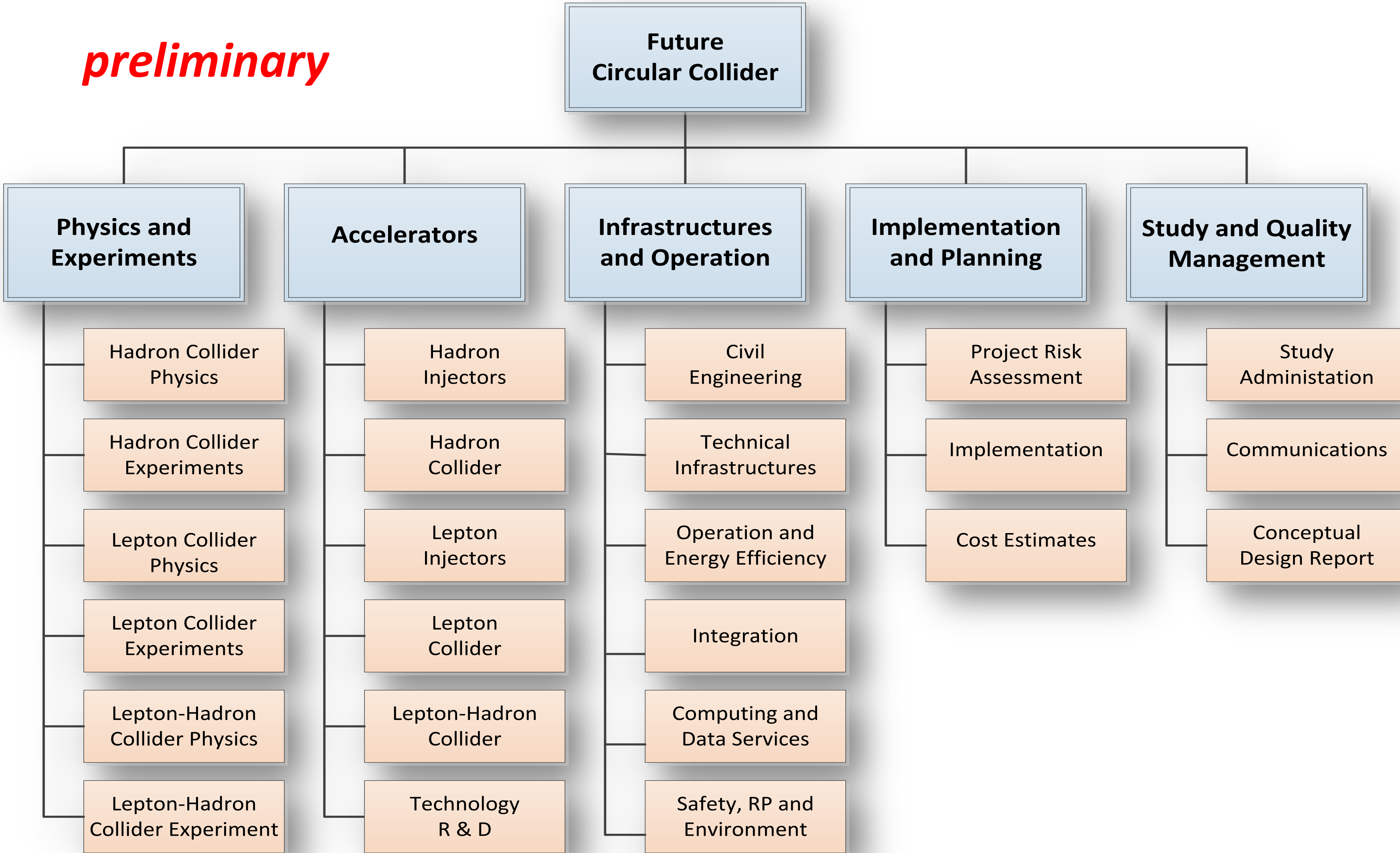
e- p option
Integration aspects **O. Brüning**

Operation aspects,
energy efficiency, safety, environment **P. Collier**

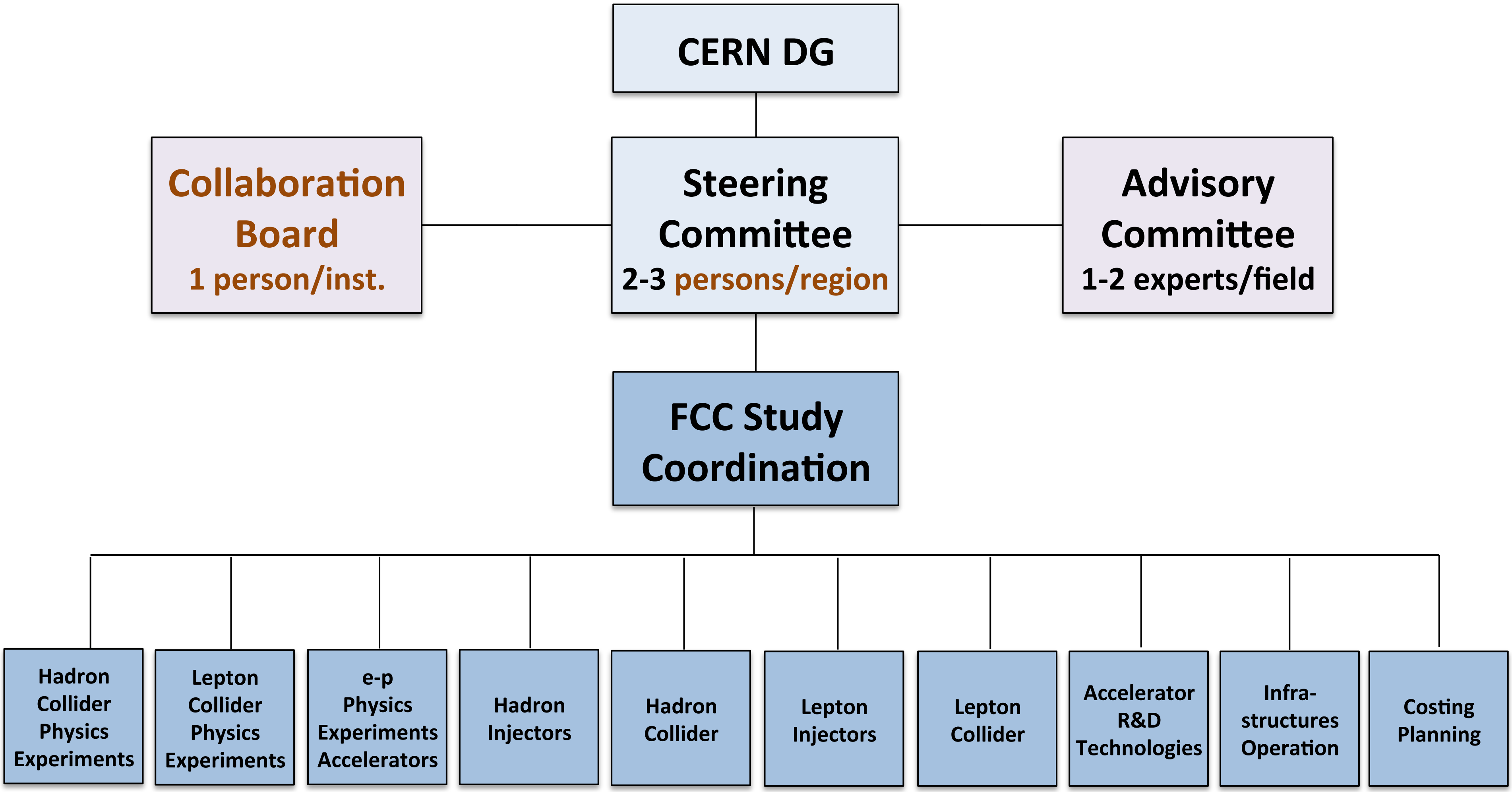
Planning (Implementation roadmap, financial planning, reporting)
F. Sonnemann, J. Gutleber

Proposal for FCC WBS top level

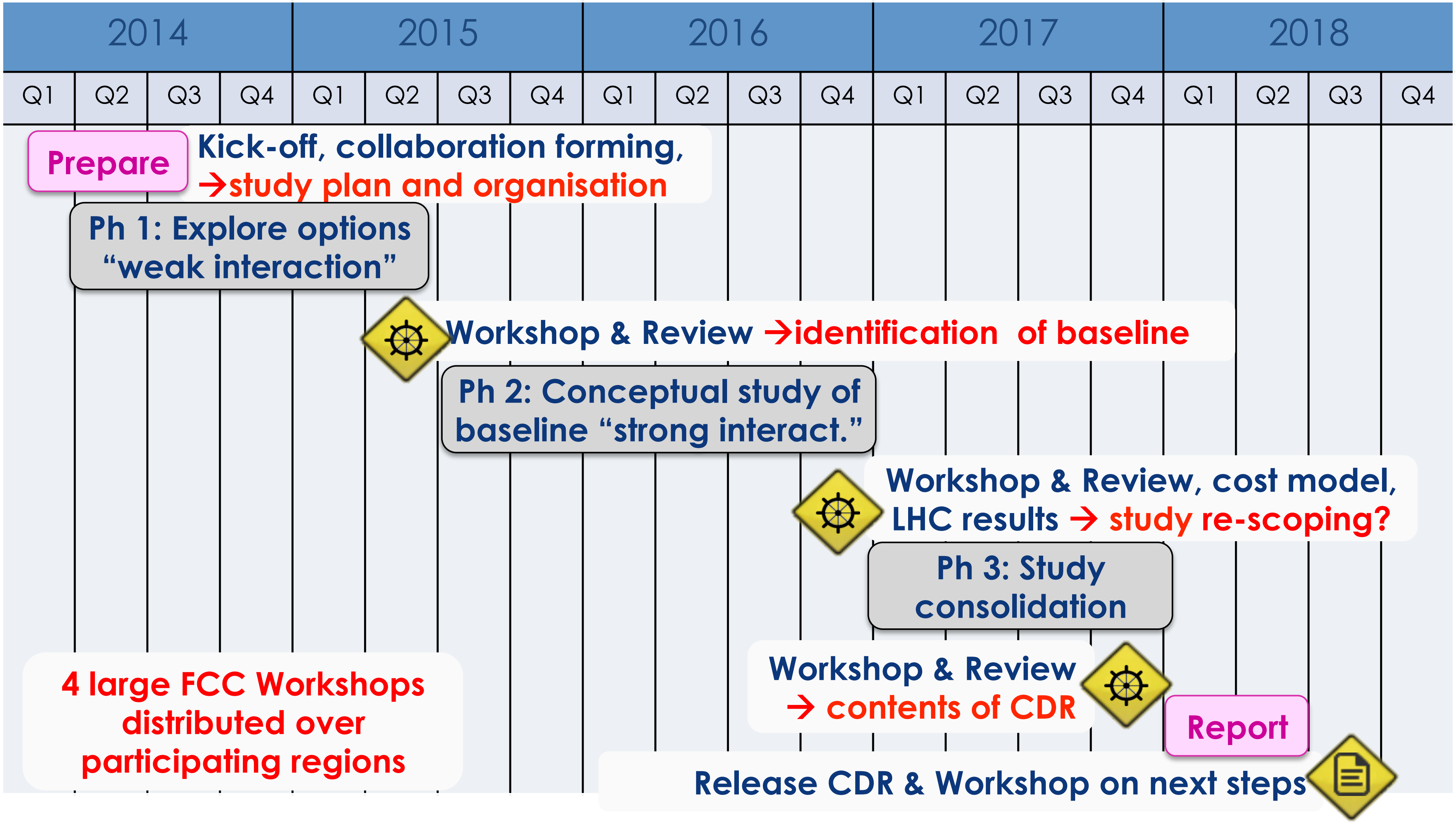
preliminary



Proposed international organization structure



Proposal for FCC Study Time Line



FCC Study - Summary

- In line with the **European Strategy**, CERN is launching a **5-year international design study** for **Future Circular Colliders**;
- **Worldwide collaboration in all areas** - physics, experiments and accelerators – is **essential to reach CDR level by 2018**.
- **FCC R&D areas** e.g. **SC high-field magnets** and **SC RF** are **of general interest & relevant for many other applications**.
- **Significant R&D investments have been made** over last decade(s), e.g. in the framework of LHC and HL-LHC; **further continuation will ensure efficient use of past investments**.
- **Goals of kick-off meeting: Introducing FCC study, discussing study scope and organization, preparing and establishing collaboration!** ***Invitation to join!***

Conclusions

OBVIOUS FUTURE

BIG MACHINES,
BIG PHYSICS IDEAS

LIFEBLOOD OF
FUNDAMENTAL PHYSICS

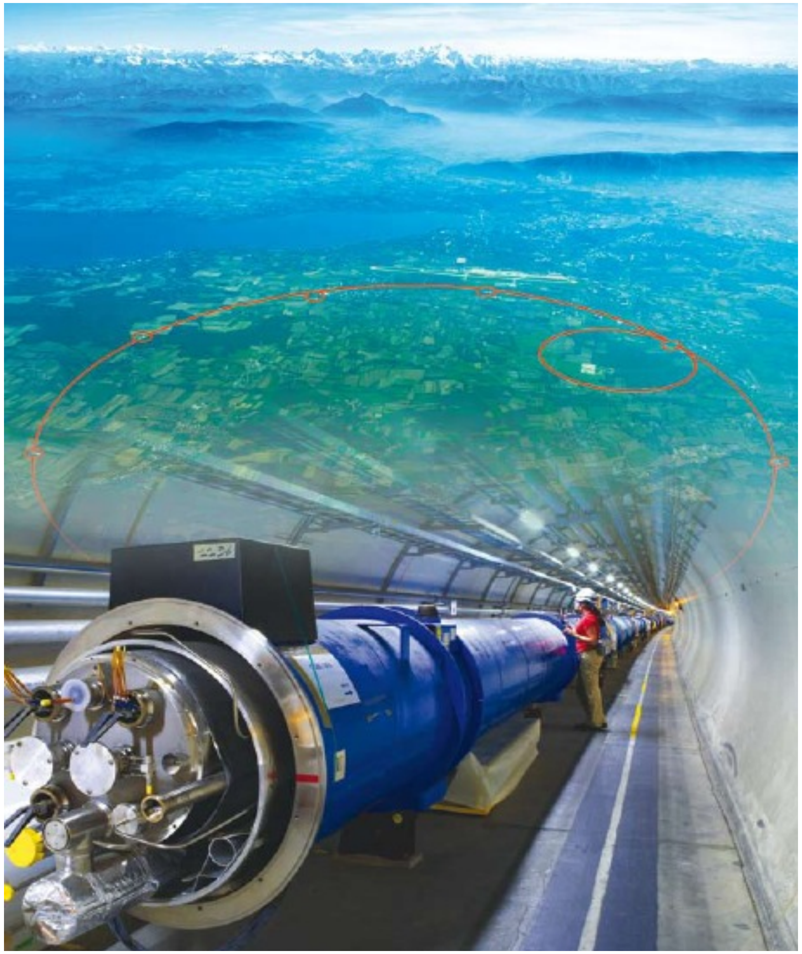
Nima ARKANI-HAMED

Back-up

LHC (Large Hadron Collider)

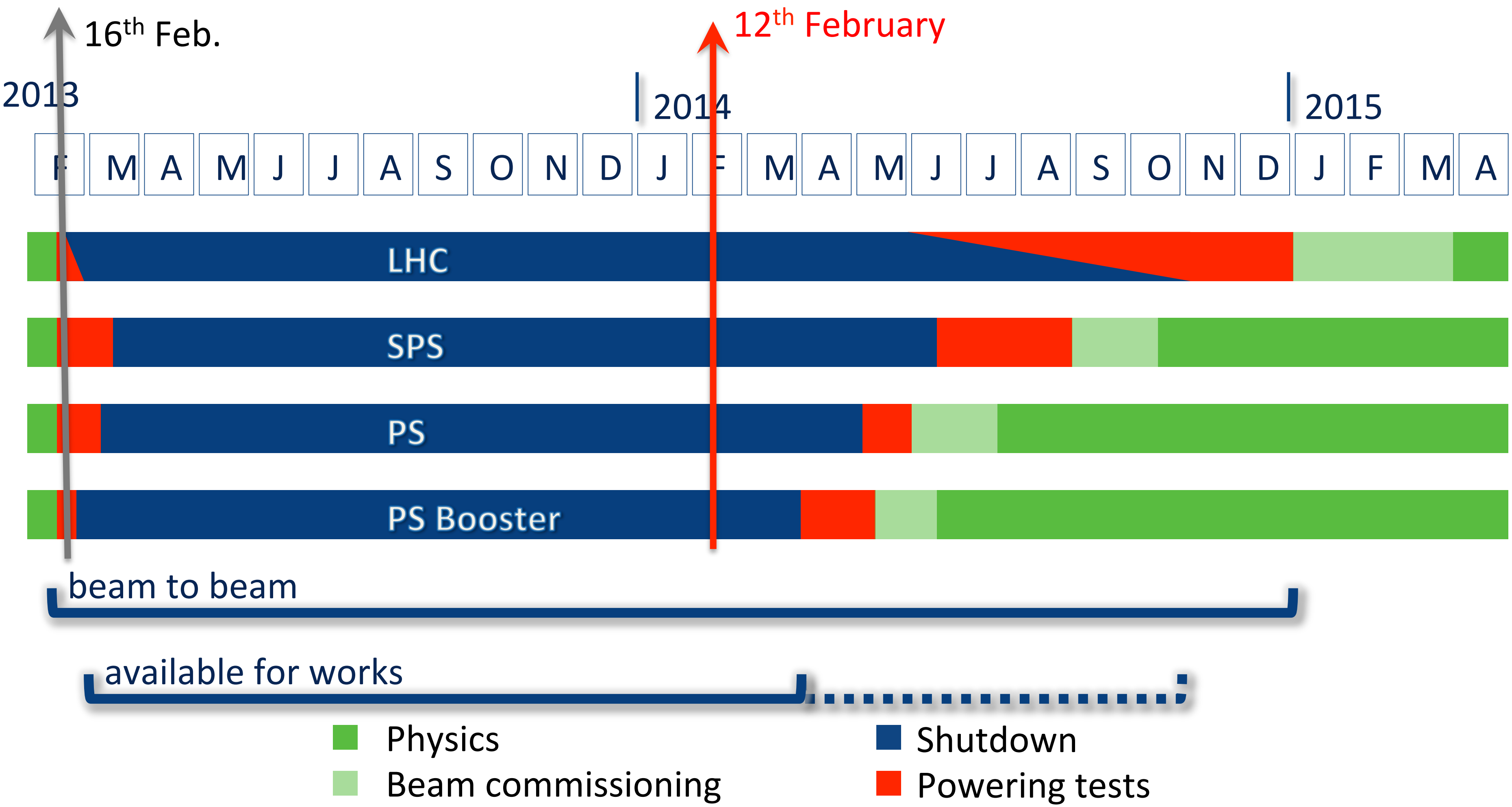
14 TeV proton-proton accelerator-collider built in the LEP tunnel

Lead-Lead (Lead-proton) collisions



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 and repair
2009-2035 : Physics exploitation

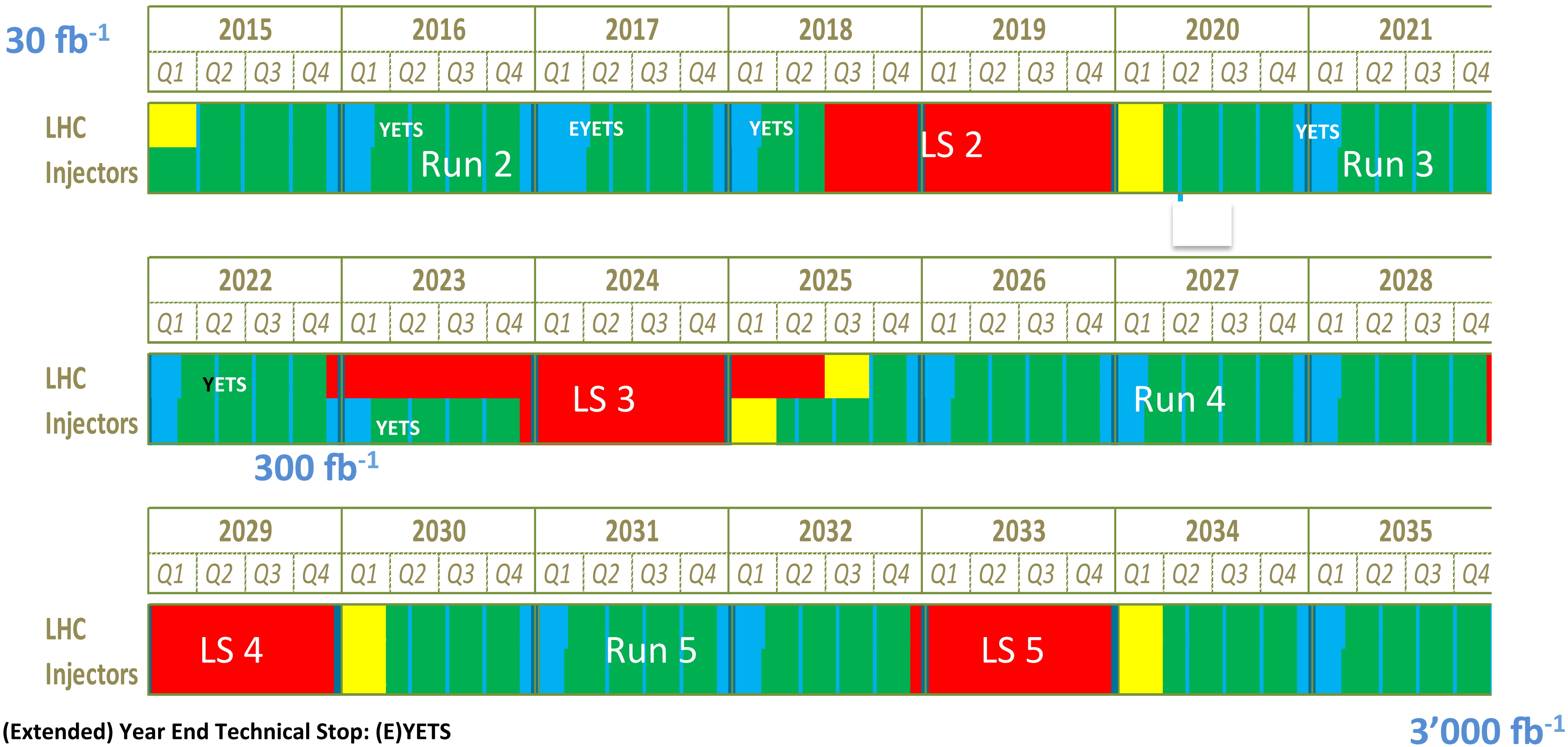
LS 1 from 16th Feb. 2013 to Dec. 2014



LHC schedule beyond LS1

LS2 starting in 2018 (July) => 18 months + 3 months BC
LS3 LHC: starting in 2023 => 30 months + 3 months BC
Injectors: in 2024 => 13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop



The European Strategy for Particle Physics
Update 2013

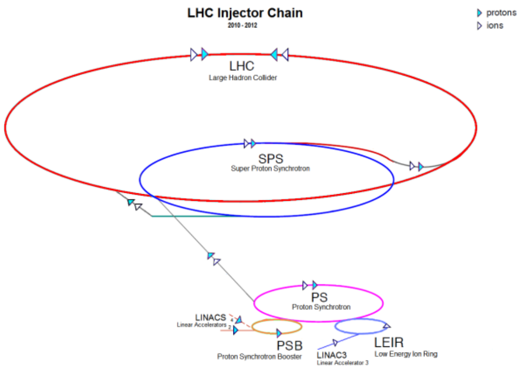
c) *Europe's top priority should be the **exploitation of the full potential of the LHC**, including the high-luminosity upgrade of the machine and detectors with a view to collecting **ten times more data than in the initial design, by around 2030**. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

HL-LHC from a study to a PROJECT

300 fb^{-1} → 3000 fb^{-1}

including LHC injectors upgrade **LIU** (Linac 4, Booster 2GeV, PS and SPS upgrade)

LS2 : (mid 2018-2019), LHC Injector Upgrades (LIU)

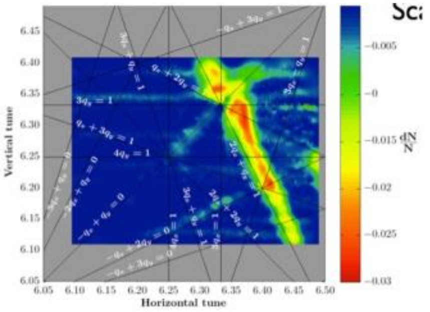


LINAC4 – PS Booster:

- H^- injection and increase of PSB injection energy from 50 MeV to 160 MeV, to increase PSB space charge threshold
- New RF cavity system, new main power converters
- Increase of extraction energy from 1.4 GeV to 2 GeV

PS:

- Increase of injection energy from 1.4 GeV to 2 GeV to increase PS space charge threshold
- Transverse resonance compensation
- New RF Longitudinal feedback system
- New RF beam manipulation scheme to increase beam brightness



SPS

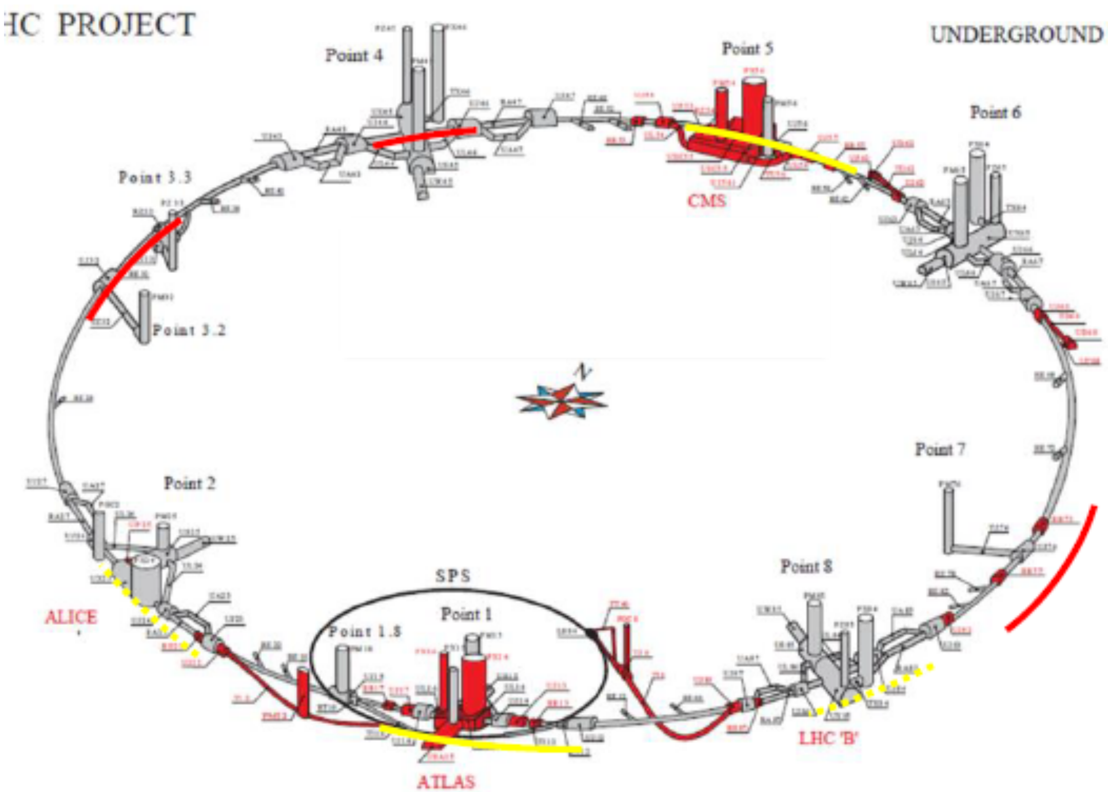
- Electron Cloud mitigation – strong feedback system, or coating of the vacuum system
- Impedance reduction, improved feedbacks
- Large-scale modification to the main RF system

These are only the main modifications and this list is far from exhaustive

Project leadership: R. Garoby and M. Meddahi

The HL-LHC Project

- Obtain about 3 - 4 fb^{-1}/day (40% stable beams)
- About 250 to 300 fb^{-1}/year



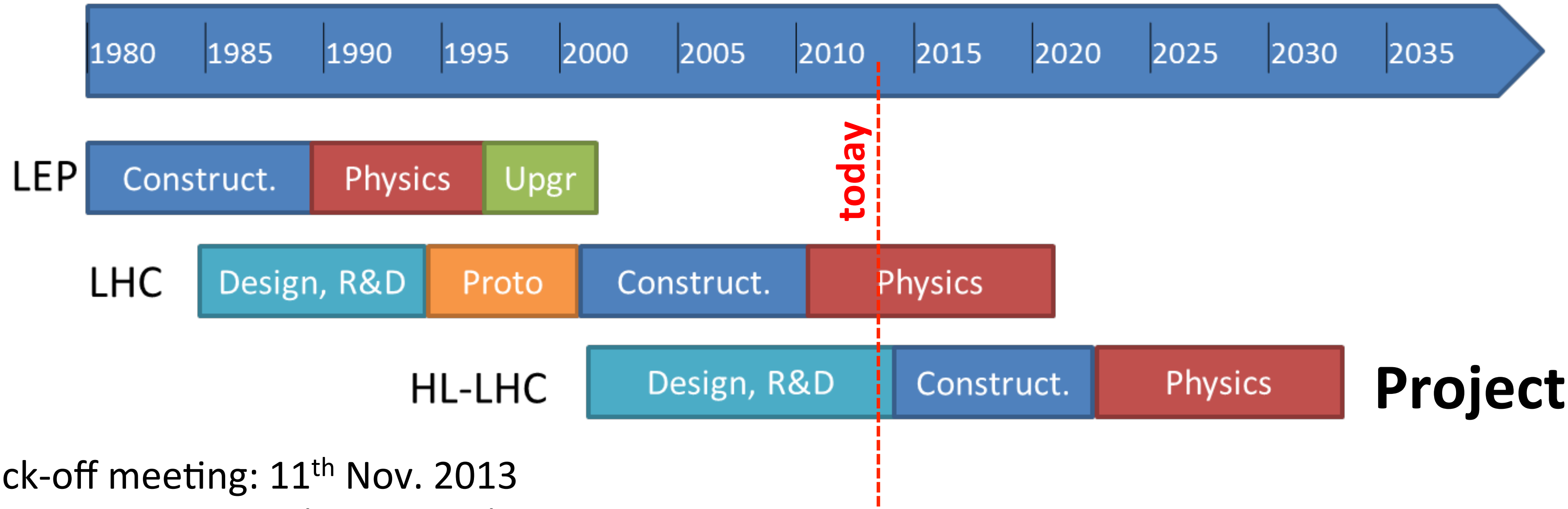
- New IR-quads Nb_3Sn (inner triplets)
- New 11 T Nb_3Sn (short) dipoles
- Collimation upgrade
- Cryogenics upgrade
- Crab Cavities
- Cold powering
- Machine protection
- …

Major intervention on more than 1.2 km of the LHC

Project leadership: L. Rossi and O. Brüning

"…exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors…"

=> High Luminosity LHC project



Kick-off meeting: 11th Nov. 2013 (Daresbury)

http://cern.ch/hilumilhc


UNIVERSITÉ DE GENÈVE
FCC Kick-Off 2014
Future Circular Collider (FCC) Study
FCC
hh ee he
Future Circular Collider Study
FCC Kick-Off 2014
R-D Heuer, CERN
1
“Bière de l'amitié"
maticity correction similar to SuperKEKB,
tum acceptance will be similar, about ±1.4%.