FCC status

F. Zimmermann on behalf of the FCC Collaboration

LHeC Coordination Group

2 October 2015

YEARS/ANS CERN

FCC hh ee he

many thanks to
M. Benedikt and J. Gutleber

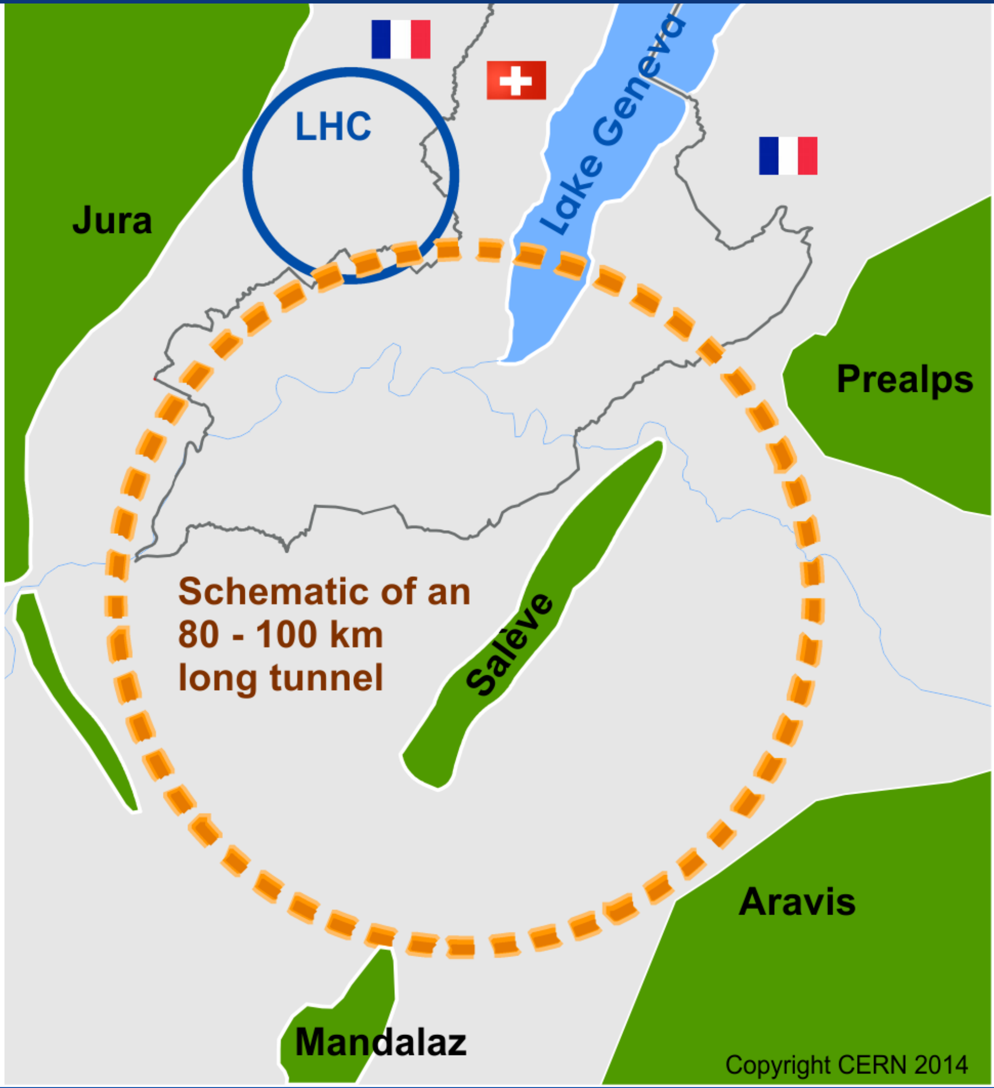
Future Circular Collider Study
GOAL: CDR and cost review for the next ESU (2018)

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

- ***pp*-collider (*FCC-hh*)**
  → main emphasis, defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **80-100 km infrastructure** in Geneva area
- ***e⁺e⁻* collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (FCC-he) option**
- **HE-LHC** with FCC-hh technology



Hadron collider parameters

Parameter	FCC-hh		SPPC	LHC	HL LHC
collision energy cms [TeV]	100		71.2	14	
dipole field [T]	16		20	8.3	
# IP	2 main & 2		2	2 main & 2	
bunch intensity [10^{11}]	1	1 (0.2)	2	1.1	2.2
bunch spacing [ns]	25	25 (5)	25	25	25
luminosity/Ip [10^{34} cm^{-2}s^{-1}]	5	25	12	1	5
events/bx	170	850 (170)	400	27	135
stored energy/beam [GJ]	8.4		6.6	0.36	0.7
synchr. rad. [W/m/apert.]	30		58	0.2	0.35

FCC-hh luminosity goals & phases

- **Two parameter sets for two operation phases:**

  - **Phase 1 (baseline): 5 x 10^{34} $cm^{-2}s^{-1}$ (peak),**
    250 fb^{-1}/year (averaged)
    2500 fb^{-1} within 10 years (~HL LHC total luminosity)

  - **Phase 2 (ultimate): ~2.5 x 10^{35} $cm^{-2}s^{-1}$ (peak),**
    1000 fb^{-1}/year (averaged)
    ➔ 15,000 fb^{-1} within 15 years

  - **Yielding total luminosity O(20,000) fb^{-1} over ~25 years of operation**

Luminosity goals for a 100-TeV pp collider

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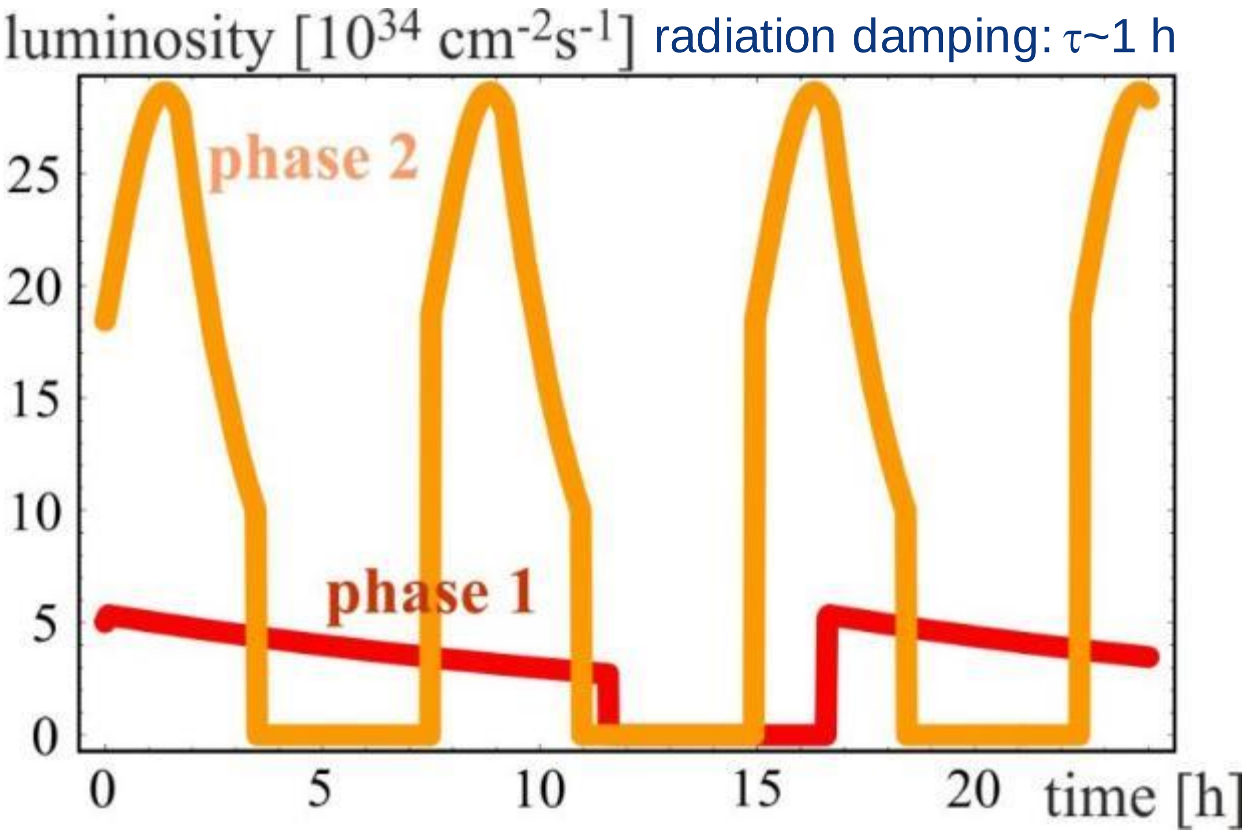
April 24, 2015

Abstract

We consider diverse examples of science goals that provide a framework to assess luminosity goals for a future 100-TeV proton-proton collider.

20 ab^{-1} OK for physics

Luminosity evolution



for both phases:

beam current 0.5 A unchanged!

total synchrotron radiation power ~5 MW.

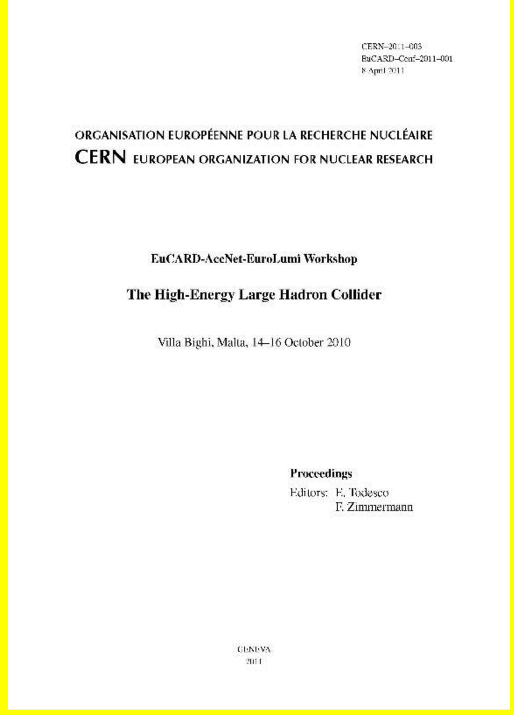
phase 1: β*=1.1 m, ΔQ_{tot}=0.01, t_{ta}=5 h

phase 2: β*=0.3 m, ΔQ_{tot}=0.03, t_{ta}=4 h

High-Energy LHC

FCC study continues effort on **high-field collider in LHC tunnel**

2010 EuCARD Workshop Malta;
Yellow Report CERN-2011-1



CERN–2011–003
EuCARD–Conf–2011–001
8 April 2011

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

EuCARD-AccNet-EuroLumi Workshop

The High-Energy Large Hadron Collider

Villa Bighi, Malta, 14–16 October 2010

Proceedings
Editors: E. Todesco
F. Zimmermann

GENEVA
2011

EuCARD-AccNet-EuroLumi Workshop: The High-Energy Large Hadron Collider - HE-LHC10, E. Todesco and F. Zimmermann (eds.), EuCARD-CON-2011-001; arXiv:1111.7188; CERN-2011-003 (2011)

- based on 16-T dipoles developed for FCC-hh
- extrapolation of other parts from the present (HL-)LHC and from FCC developments

LEP – highest energy e^+e^- collider so far

circumference 27 km
in operation from 1989 to 2000
maximum c.m. energy 209 GeV
maximum synchrotron radiation power 23 MW

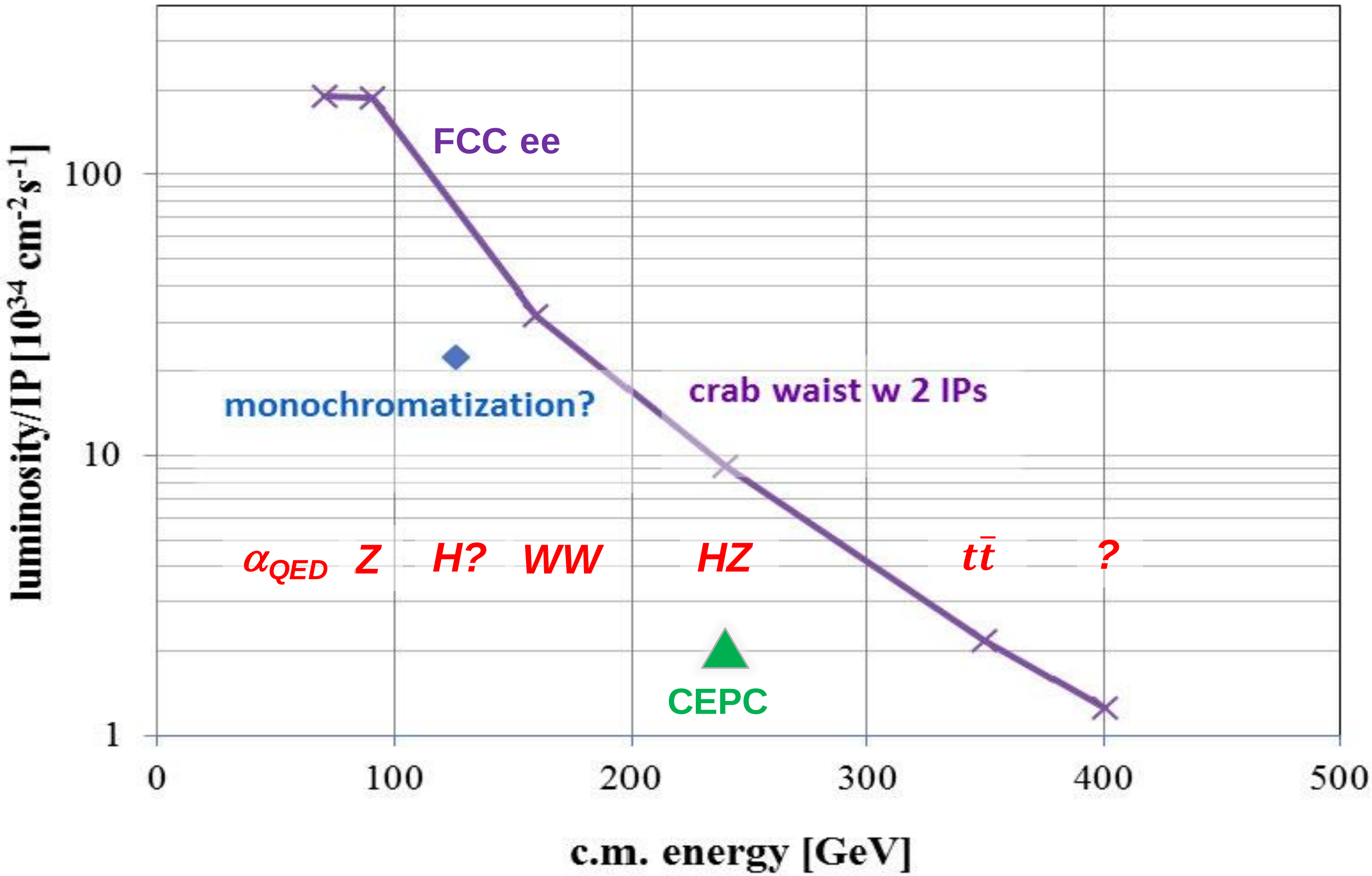
Lepton collider key parameters

parameter	FCC-ee			CEPC	LEP2
energy/beam [GeV]	**45**	**120**	**175**	**120**	105
bunches/beam	13000-60000	500-1400	51- 98	50	4
beam current [mA]	1450	30	6.6	16.6	3
luminosity/IP x 10^{34} $cm^{-2}s^{-1}$	**21 - 280**	**5 - 11**	**1.5 - 2.6**	**2.0**	0.0012
energy loss/turn [GeV]	0.03	1.67	7.55	3.1	3.34
synchrotron power [MW]	100			103	22
RF voltage [GV]	0.2-2.5	3.6-5.5	11	6.9	3.5

FCC-ee: 2 separate rings **CEPC baseline: single beam pipe like LEP**

Dependency FCC-ee: crab-waist vs. baseline optics and 2 vs. 4 IPs

e^+e^- luminosity vs. c.m. energy



Site investigations

Alignment | Shaft Tools

Choose alignment option

93km quasi-circular ▾

Tunnel depth at centre: 299mASL

Gradient Parameters

Azimuth (°):	-15
Slope Angle x-x(%):	.5
Slope Angle y-y(%):	0

CALCULATE

Alignment centre

X: 2499812 Y: 1106889

LHC Intersection	CP 1	CP 2
Angle		
Depth	589m	589m

Alignment Location

Geology Intersected by Shafts | Shaft Depths

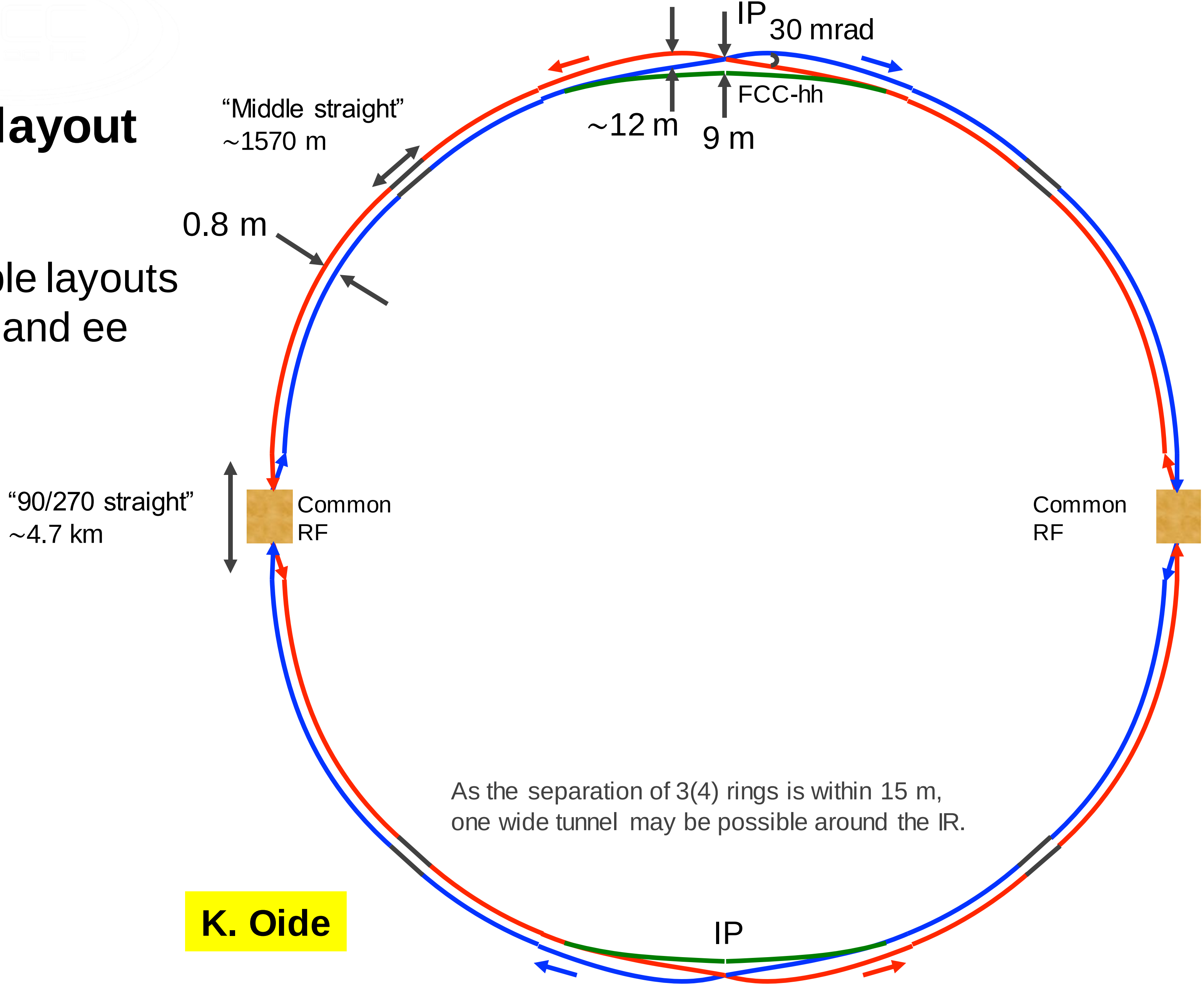
Point	Shaft Depth (m) Actual	Min	Mean	Max	Geology (m) Quaternary	Molasse	Urgonian	Calcaire
A	203	200	204	212	93	111	0	0
B	227	219	226	231	41	185	0	0
C	218	208	217	225	75	143	0	0
D	153	150	154	158	19	134	0	0
E	247	233	249	261	24	223	0	0
F	262	251	269	304	32	230	0	0
G	396	392	393	396	177	220	0	0
H	266	231	274	322	0	325	0	0
I	146	141	144	149	26	120	0	0
J	248	247	251	258	6	242	0	0
K	163	153	159	164	76	87	0	0
L	182	182	184	187	17	165	0	0
Total	2711	2607	2724	2867	585	2185	0	0

Alignment Profile

- 90 – 100 km fits geological situation well
- LHC suitable as potential injector

FCC layout

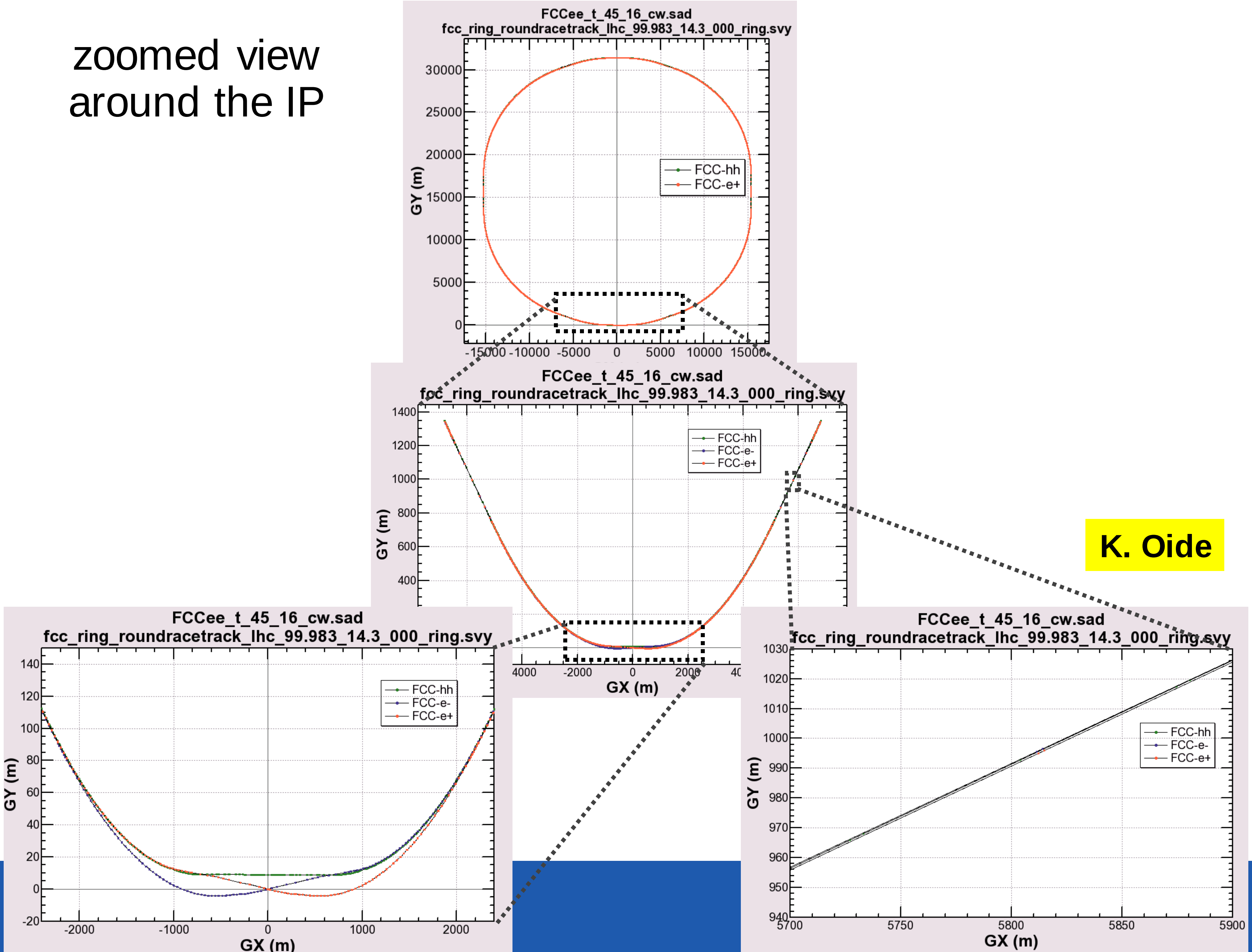
compatible layouts for hh and ee



As the separation of 3(4) rings is within 15 m, one wide tunnel may be possible around the IR.

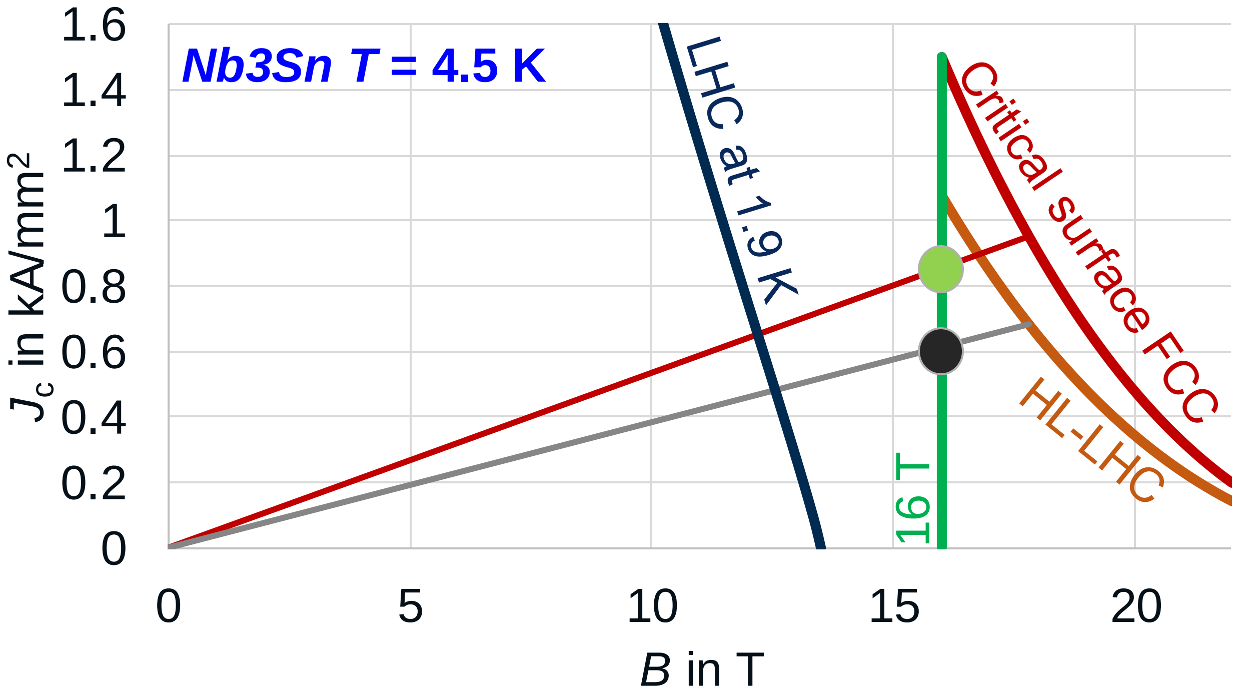
K. Oide

zoomed view around the IP



K. Oide

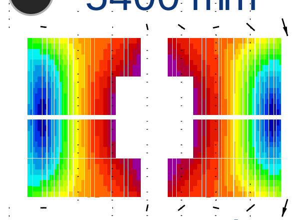
Superconductor performance



Nb-Ti Not possible

Different technology →

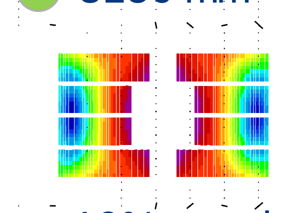
5400 mm²



~10% margin
HL-LHC

~1.7 times less SC →

3150 mm²

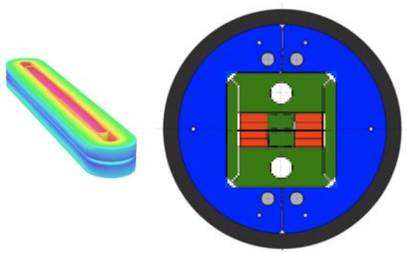


~10% margin
FCC ultimate

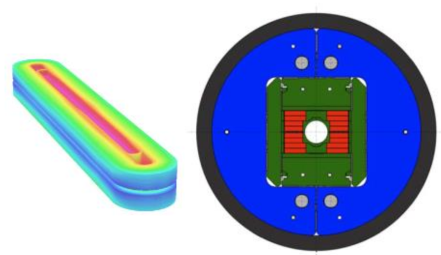
FCC magnet technology program

Main Milestones of the FCC Magnets Technologies

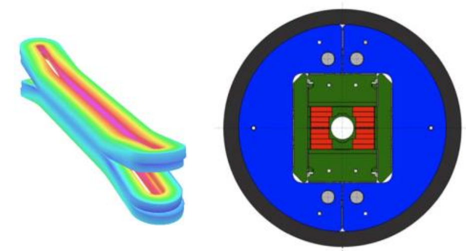
Milestone	Description	15	2016		2017		2018		2019		2020		21
M0	High J_c wire development with industry	■	■	■	■	■	■	■	■	■	■	■	■
M1	Supporting wound conductor test program	■	■	■	■	■	■	■	■	■	■	■	■
M2	Design & manufacture 16T ERMC with existing wire	■	■	■	■								
M3	Design & manufacture 16 T RMM with existing wire		■	■	■	■							
M4	Procurement of 35 km enhanced wire			■	■	■							
M5	Design & manufacture 16T demonstrator magnet			■	■	■	■	■					
M6	Procurement 70 km of enhanced high J_c wire				■	■	■	■	■				
M7	EuroCirCol design 16T accelerator quality model	■	■	■	■	■	■	■	■				
	Manufacture and test of the 16 T EuroCirCol model									■	■	■	■



ERMC (16 T mid-plane field)



RMM (16 T in 50 mm cavity)

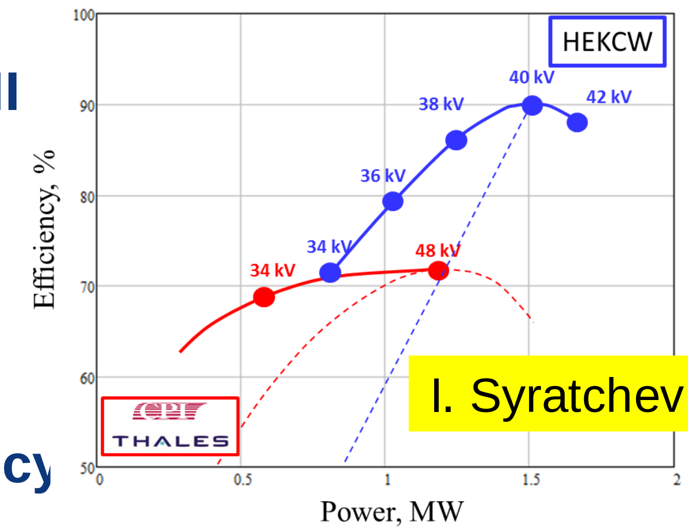


Demonstrator (16 T, 50 mm gap)

SC RF R&D towards FCC

Many pertinent R&D and construction efforts at CERN:

- R&D and production of ***Nb/Cu* sputtered 401- MHz LHC cavities,** and of **HL-LHC 401-MHz crab cavities** (with US-LARP and U. Lancaster),
- fabrication of 802 MHz cavities & CM's for HL-LHC (with JLAB & CEA)
- testing 704-MHz *Nb* cavities, complete string and CM assembly (w ESS)
- continue **R&D on "high-Q" technologies such as "N_2 doping" or Nb_3Sn coating** (with Cornell and FNAL)
- **contributions to int'l projects like ILC & PIP-II**
- optimized cool-down schemes
- **new fabrication techniques**
  (3D-print, rapid forming, seamless cavities…)
- **new materials** (Nb(Ti)N, V_3Si, TBBCO…)
- RF power sources **energy conversion efficiency**
- **more efficient cryogenics** (optimum T?); improved cryomodule design

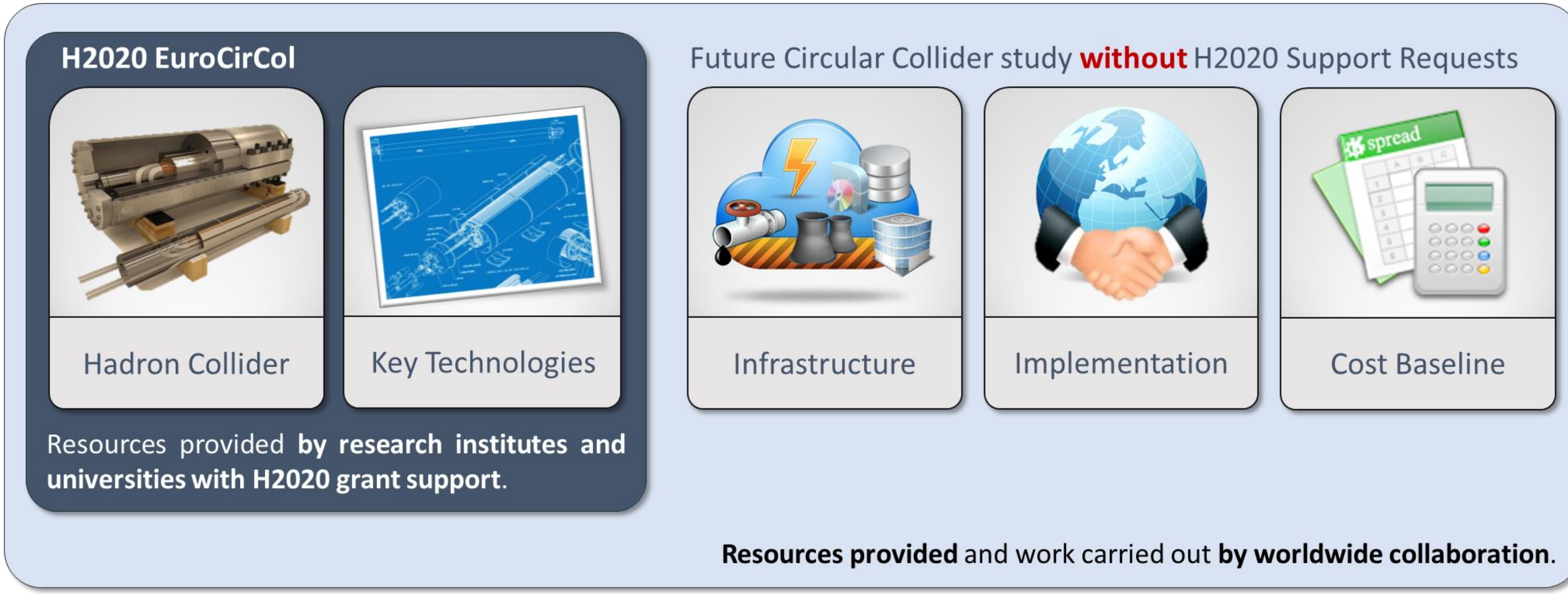


I. Syratchev

Dotted lines – only changing P drive
Solid lines – changing P drive and Voltage

EuroCirCol EU Horizon 2020 Grant

EC contributes with funding to FCC-hh study



- Core aspects of hadron collider design: arc & IR optics design, 16 T magnet program, cryogenic beam vacuum system
- **Recognition of FCC Study by European Commission.**

FCC International Collaboration

- 62 institutes
- 23 countries + EC

Status: 28 September 2015

FCC Collaboration Status

62 collaboration members & CERN as host institute, 28 September 2015

ALBA/CELLS, Spain
Ankara U., Turkey
U Belgrade, Serbia
U Bern, Switzerland
BINP, Russia
CASE (SUNY/BNL), USA
CBPF, Brazil
CEA Grenoble, France
CEA Saclay, France
CIEMAT, Spain
CNRS, France
Cockcroft Institute, UK
U Colima, Mexico
CSIC/IFIC, Spain
TU Darmstadt, Germany
TU Delft, Netherlands
DESY, Germany
TU Dresden, Germany
Duke U, USA
EPFL, Switzerland
GWNU, Korea

U Geneva, Switzerland
Goethe U Frankfurt, Germany
GSI, Germany
U. Guanajuato, Mexico
Hellenic Open U, Greece
HEPHY, Austria
U Houston, USA
IIT Kanpur, India
IFJ PAN Krakow, Poland
INFN, Italy
INP Minsk, Belarus
U Iowa, USA
IPM, Iran
UC Irvine, USA
Istanbul Aydin U., Turkey
JAI/Oxford, UK
JINR Dubna, Russia
FZ Jülich, Germany
KAIST, Korea
KEK, Japan
KIAS, Korea

King's College London, UK
KIT Karlsruhe, Germany
Korea U Sejong, Korea
MEPhI, Russia
MIT, USA
NBI, Denmark
Northern Illinois U., USA
NC PHEP Minsk, Belarus
U. Liverpool, UK
U Oxford, UK
PSI, Switzerland
U. Rostock, Germany
Sapienza/Roma, Italy
UC Santa Barbara, USA
U Silesia, Poland
TU Tampere, Finland
TOBB, Turkey
U Twente, Netherlands
TU Vienna, Austria
Wroclaw UT, Poland

FCC Week 2016

Rome, 11-15 April 2016

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