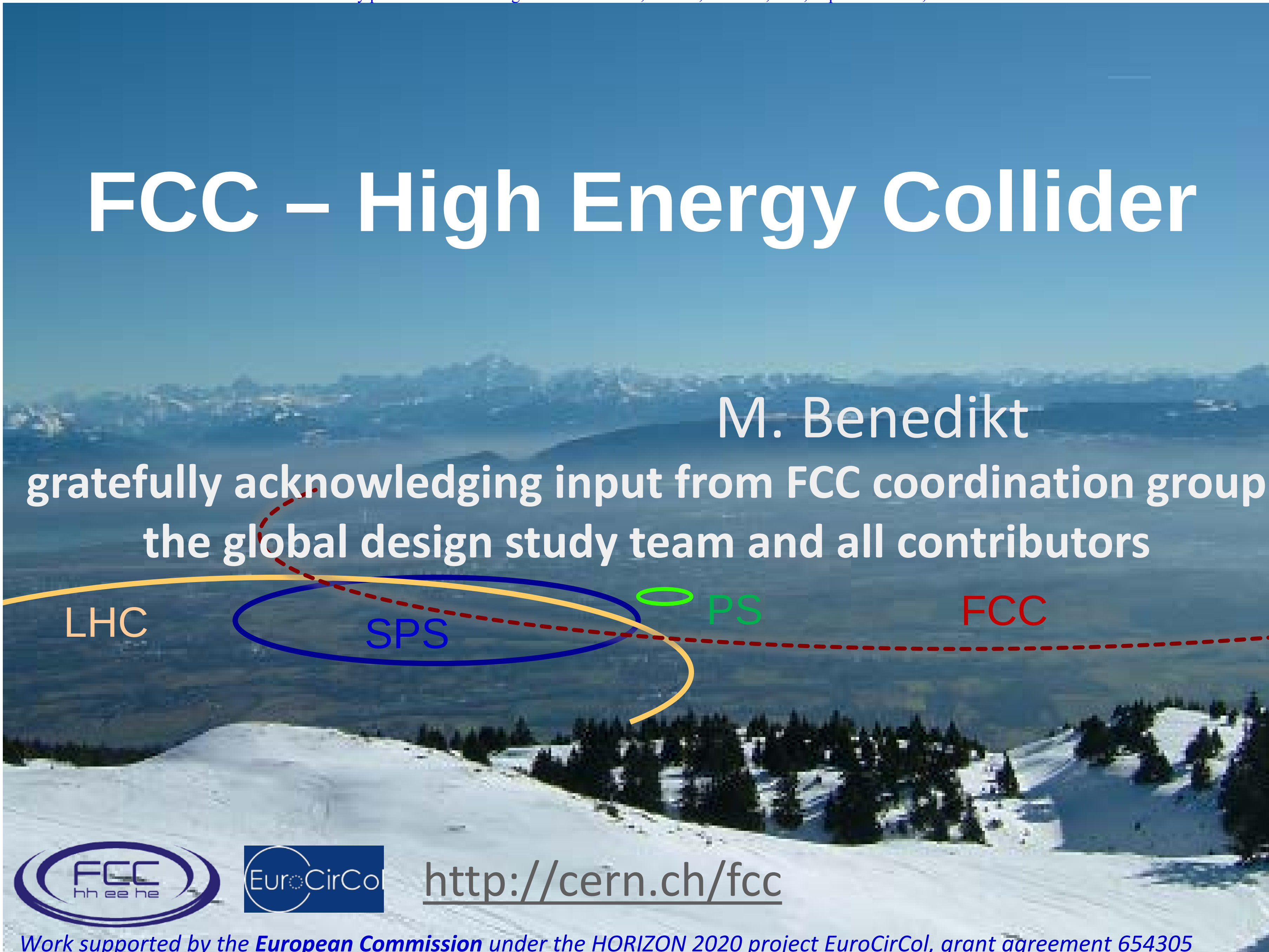
IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.



Acknowledgements

- ASC program committee for the opportunity to present the FCC study to this audience.
- The contents of this presentation is based on the work of many colleagues in the FCC collaboration. Many thanks to all of them for their excellent contributions.
- Particular thanks for provision of slides and detailed discussions to M. Atanasov, A. Ballarino, L. Bottura, S. Calatroni, J. Osborne, L. Rossi, H. Ten Kate, D. Tommasini and F. Zimmermann.

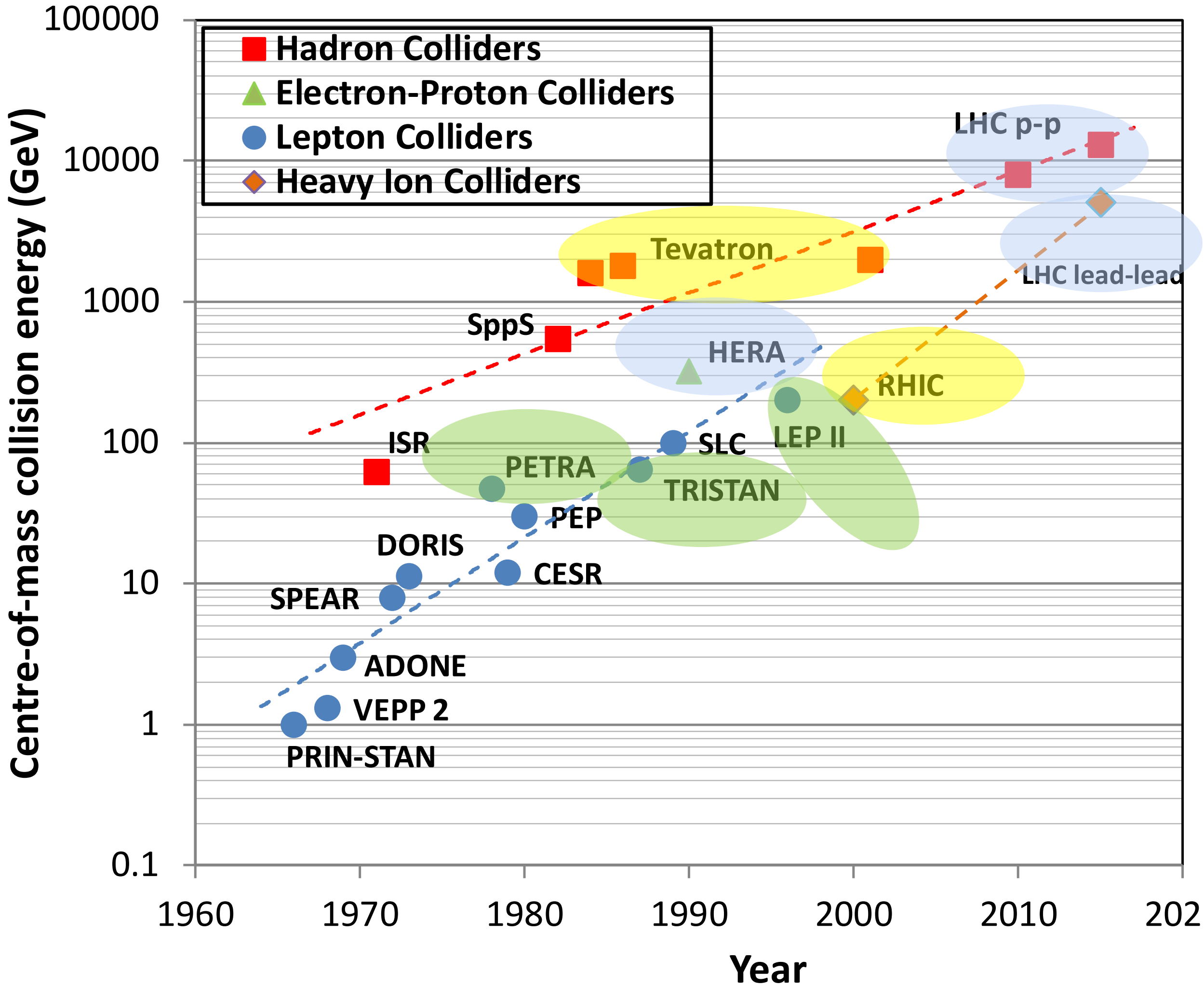
High energy accelerators & colliders

- Using **electrical fields (RF cavities)** to accelerate **and magnetic fields (accelerator magnets)** to guide and collide **charged particle beams** (electrons, protons & anti-particles)

- **Aim at higher energy accelerators for 2 reasons:**
  - **Production of new heavier particles (according to Einstein):** $\mathbf{E} = \mathbf{m}c^2 \leq 2E$ beam (collider)
  - **Resolving smaller distances (according to de Broglie):** **Wavelength** $\lambda = hc/E$ **for LHC** $\sim 2 \cdot 10^{-18}$ cm

Higher energy $\rightarrow$ **Increased potential for discoveries**

Colliders constructed and operated

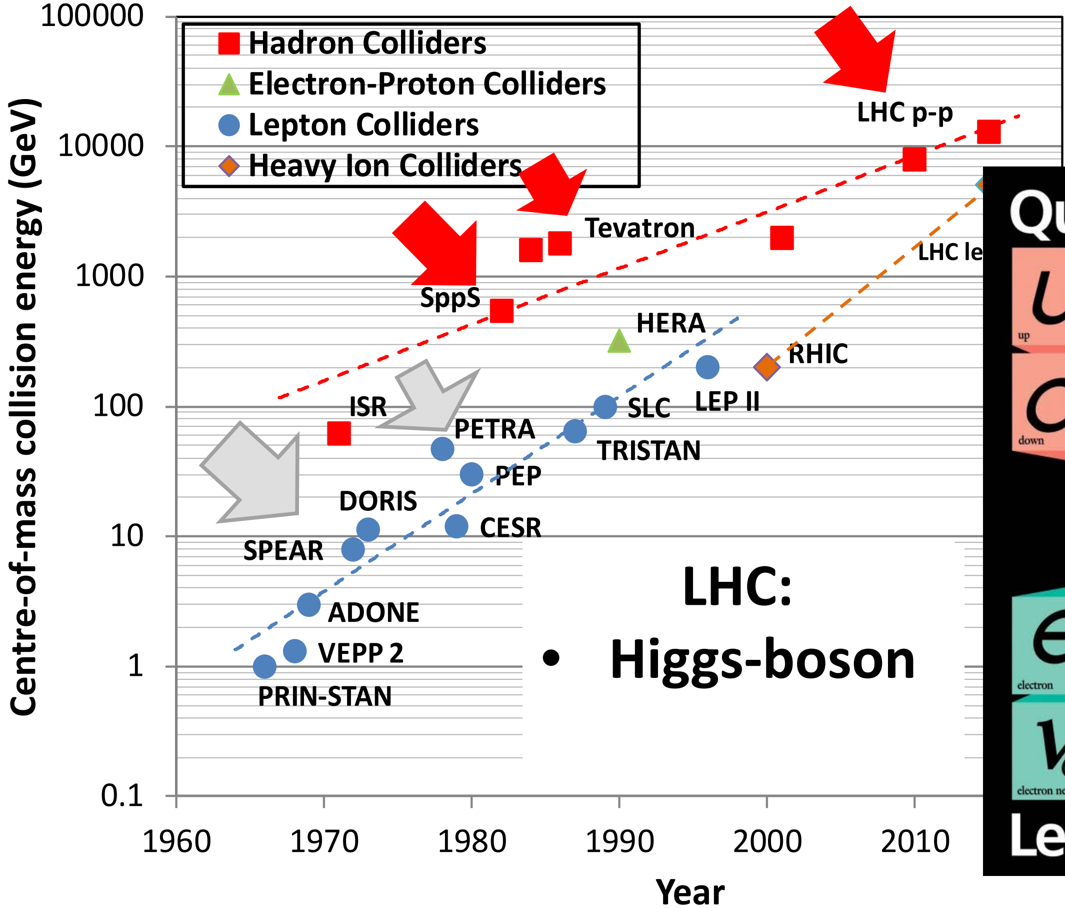


Colliders with superconducting RF system

Colliders with superconducting arc magnet system

Colliders with superconducting magnet & RF

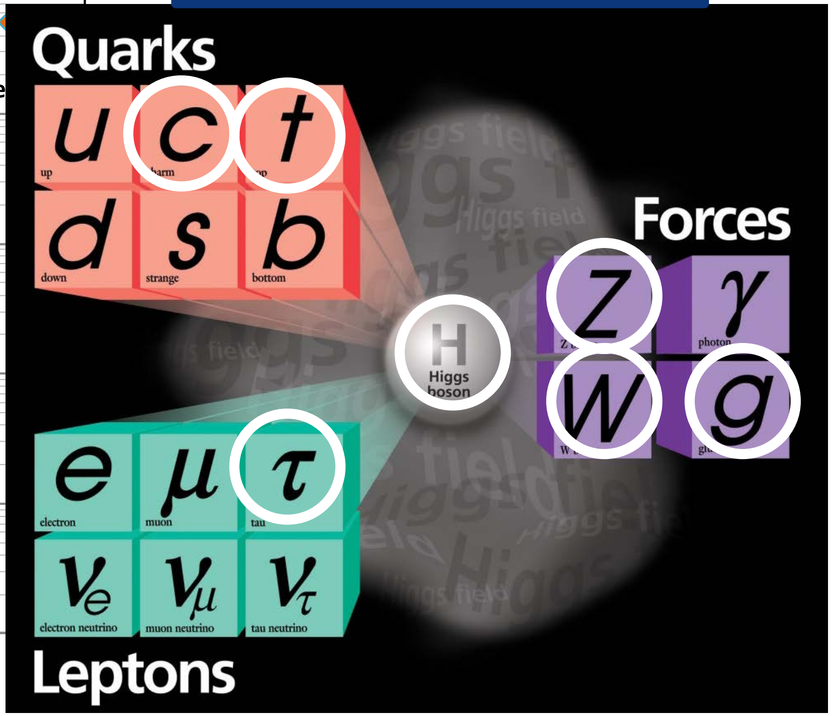
Discoveries by colliders



LHC:

- **Higgs-boson**

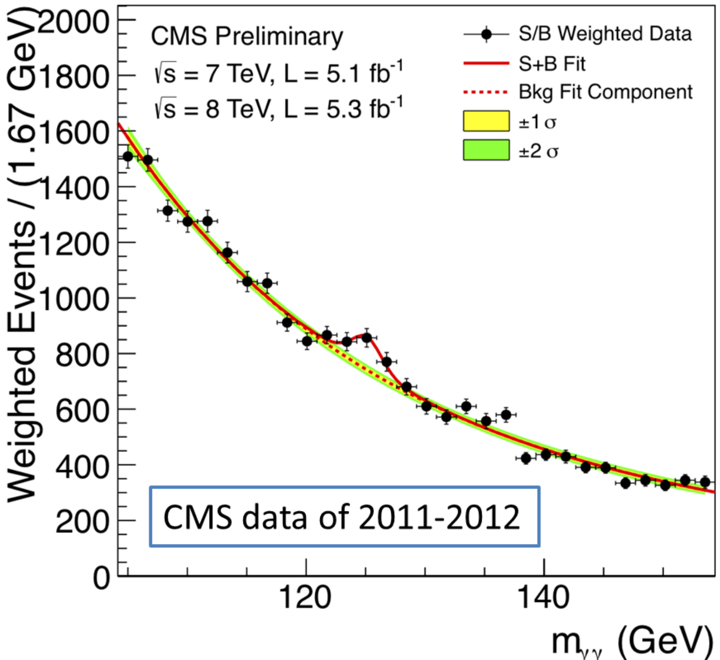
Standard Model Particles and forces

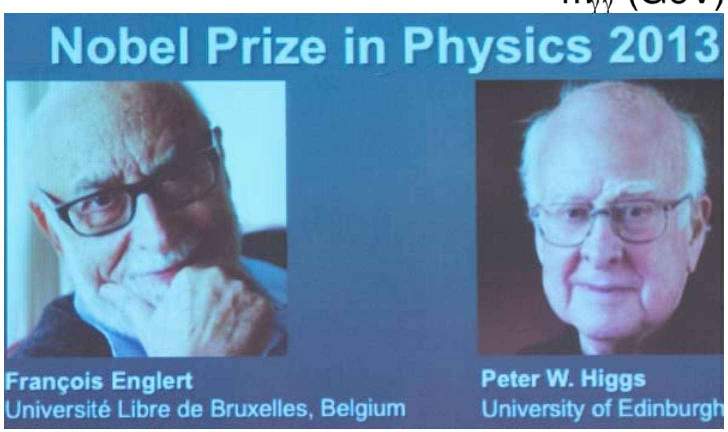


Colliders are powerful instruments in High Energy physics for particle discoveries and precision measurements

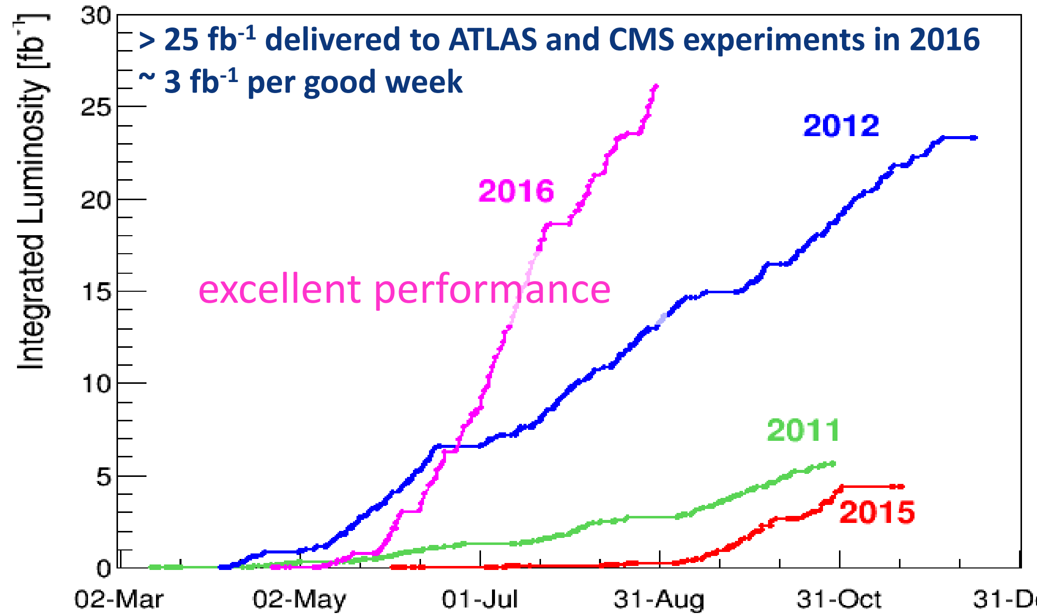
LHC: present collider flagship

2012: Higgs boson discovery





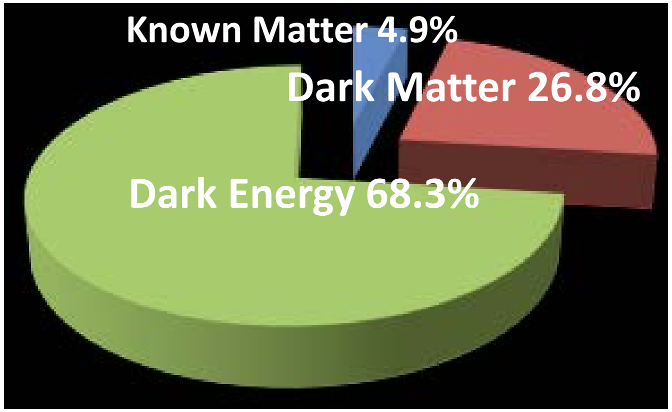
2016 performance: LHC design luminosity (data-rate) reached!

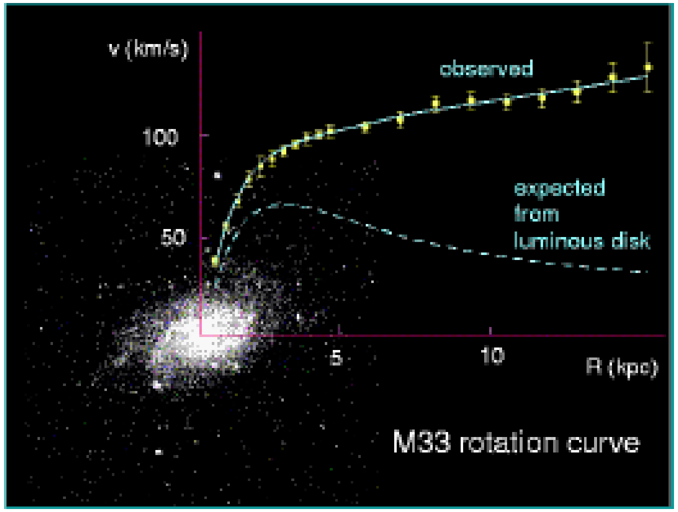


So far the accumulated data do not yet show signs for new physics beyond standard model.

Many open questions remaining

- Standard model describes known matter, i.e. 5% of the universe!



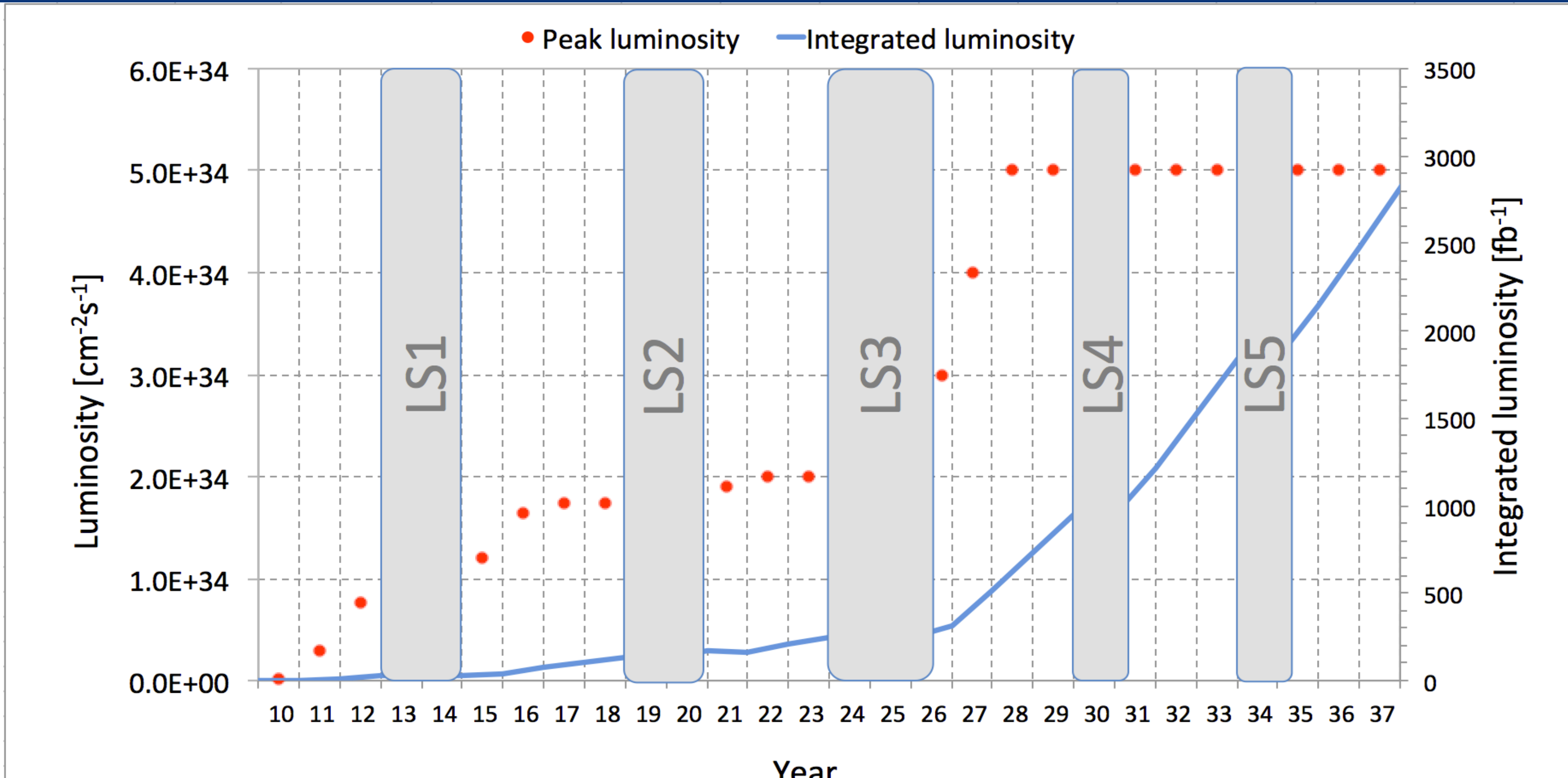


galaxy rotation curves, 1933 - Zwicky

- what is dark matter?
- what is dark energy?
- why is there more matter than antimatter?
- why do the masses differ by more than 13 orders of magnitude?
- do fundamental forces unify in single field theory?
- what about gravity?
- Is there a "world equation – theory of everything"? ...

K. Borras

Step 1: HL-LHC upgrade – ongoing

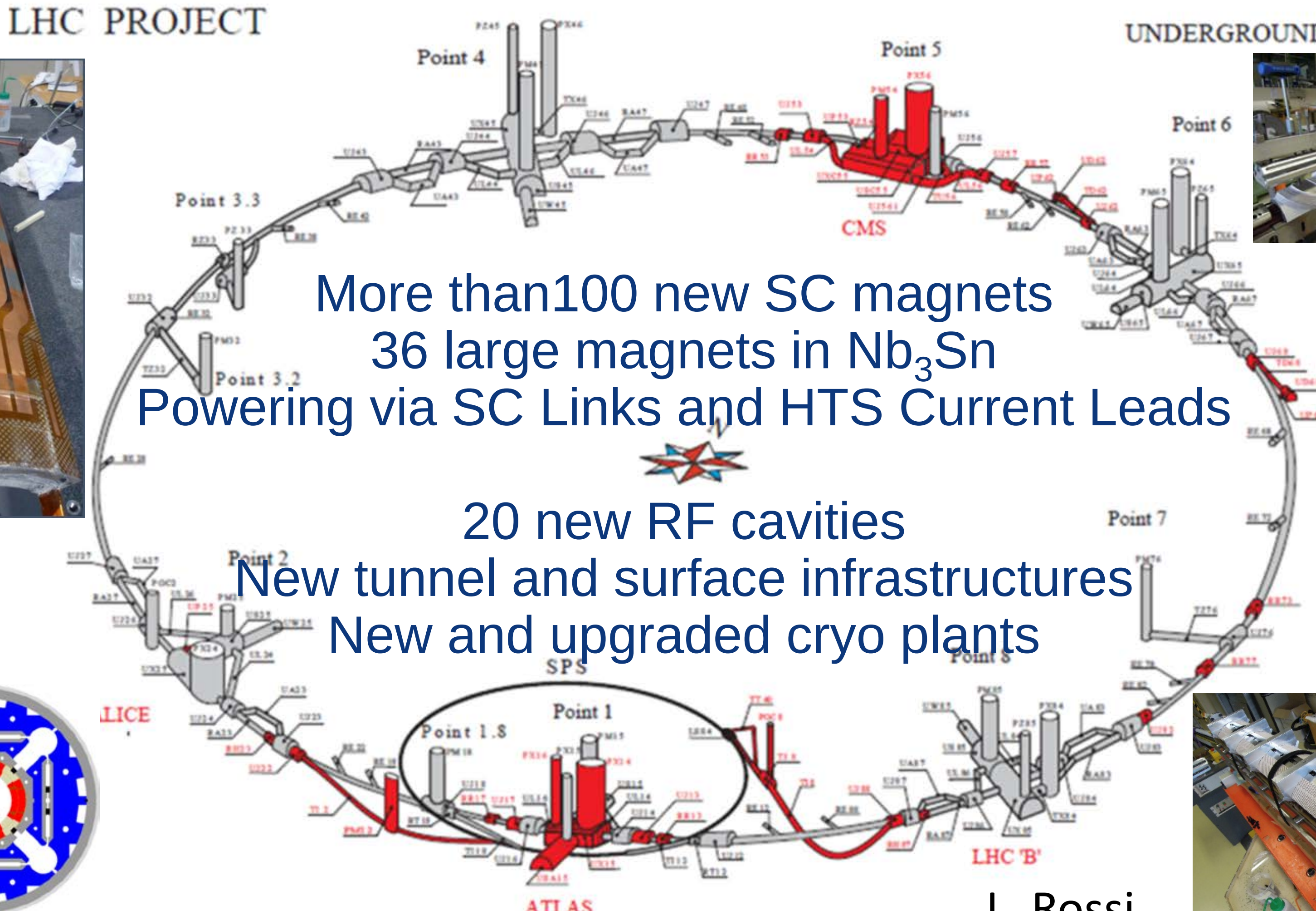


HL-LHC significantly increases data rate to improve statistics, measurement precision, and energy reach in search of new physics

Gain of a factor 5 in rate, factor 10 in integral data wrt initial design

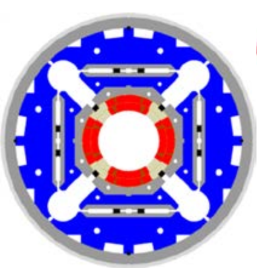
IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

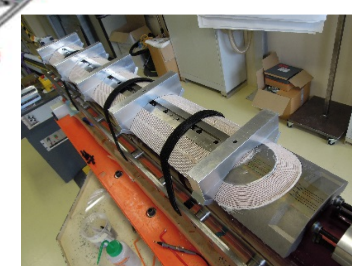
High Luminosity LHC project scope



More than100 new SC magnets
36 large magnets in Nb_3Sn
Powering via SC Links and HTS Current Leads

20 new RF cavities
New tunnel and surface infrastructures
New and upgraded cryo plants





L. Rossi

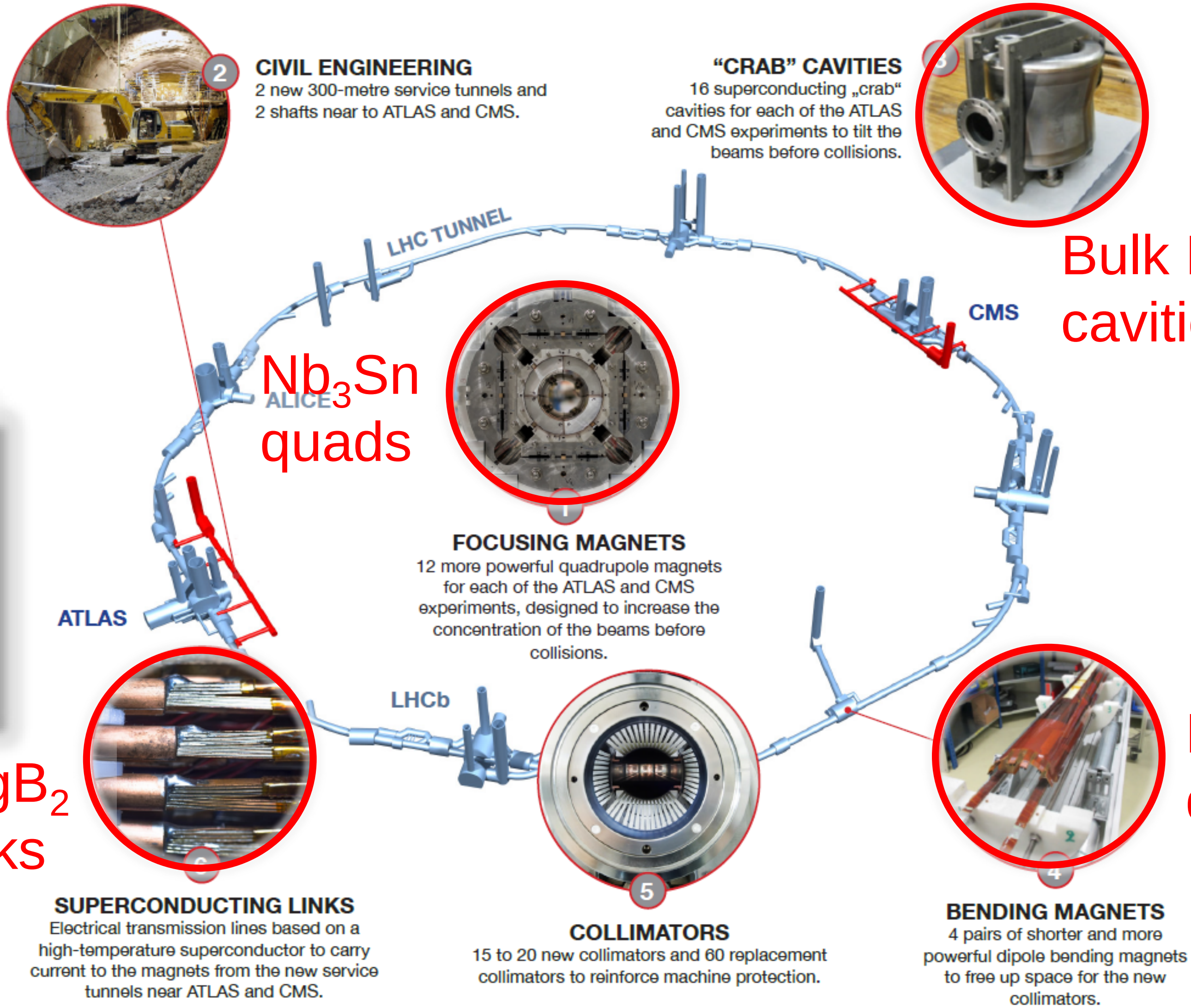
IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

FCC hh ee he

HL LHC project landmarks

Cryo@P4

2MOr1B-01
3LPo2L-08
3MPo2C-08
5LOr1B-01
5LOr1B-03
5LOr1B-05



Cryo@P1-P5

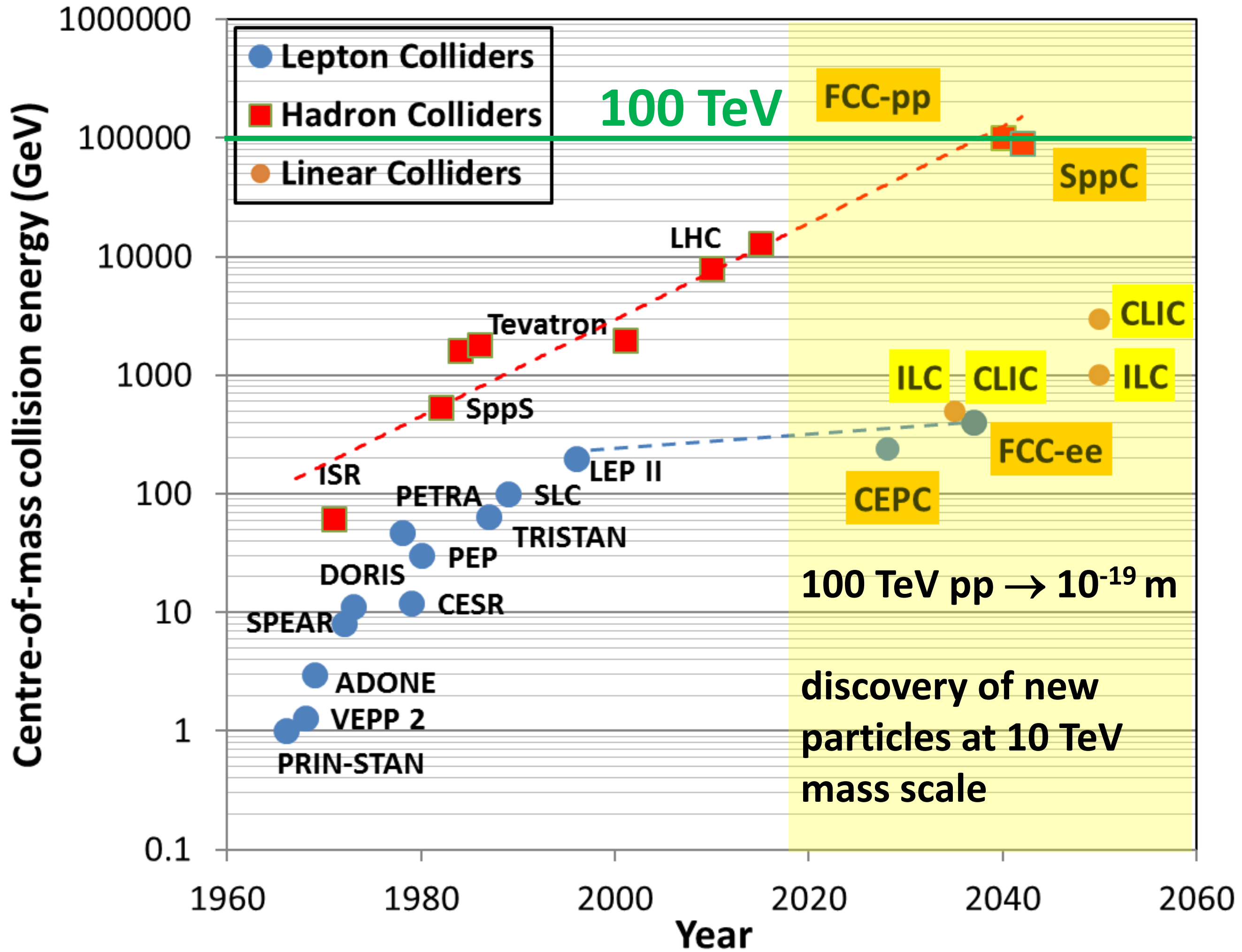
Nb_3Sn for the first time in an operating accelerator (~ 30 tons)

Step 2: Future high energy colliders

For physics beyond the LHC and beyond the Standard Model, under study (synergy of):

- **Linear e^+e^- colliders** (CLIC, ILC)
  E_{CM} up to ~ **3 TeV**
- **Circular e^+e^- colliders** (CepC, FCC-ee)
  E_{CM} up to ~ **400 GeV** - limited by $e^\pm$ synchrotron radiation. Ideal for **precision measurements**
- **Circular p-p colliders** (SppC, FCC)
  E_{CM} up to ~ **100 TeV**
  Ideal for **discoveries at higher energy frontiers**

High Energy Colliders under study



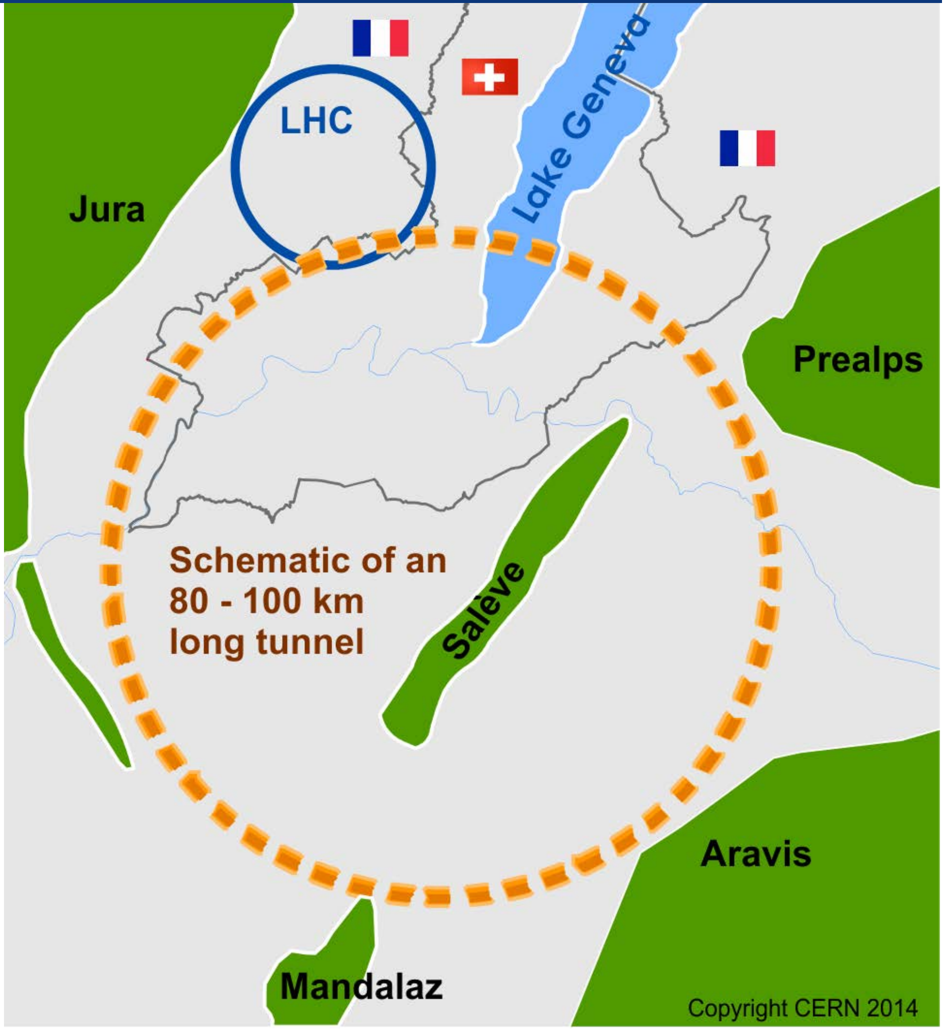
Future Circular Collider Study
GOAL: CDR and cost review for the next ESU (2019)

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 tunnel infrastructure** in Geneva area, site specific
- ***e^+e^-* collider (*FCC-ee*),** as potential first step
- ***p-e* (*FCC-he*) option,** integration one IP, FCC-hh & ERL
- **HE-LHC** with *FCC-hh* technology



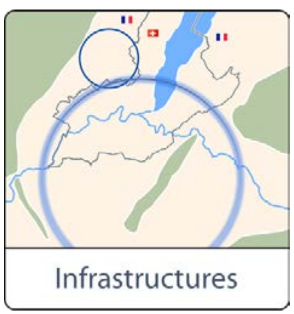
FCC Scope: Accelerator and Infrastructure

FCC-hh: **100 TeV pp collider as long-term goal**
→ defines infrastructure needs

FCC-ee: **e^+e^- collider**, potential intermediate step

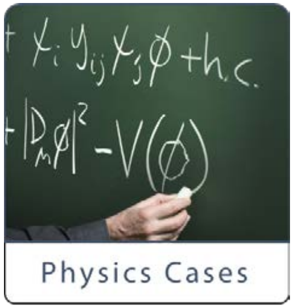
HE-LHC: **based on FCC-hh technology**

Launch R&D on key enabling technologies in dedicated R&D programmes, e.g.
16 Tesla magnet program, cryogenics, SRF technologies and RF power sources

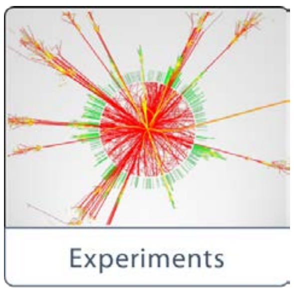


Tunnel infrastructure in Geneva area, linked to CERN accelerator complex;
site-specific, as requested by European strategy

FCC Scope: Physics & Experiments



Elaborate and document
- **Physics opportunities**
- **Discovery potentials**

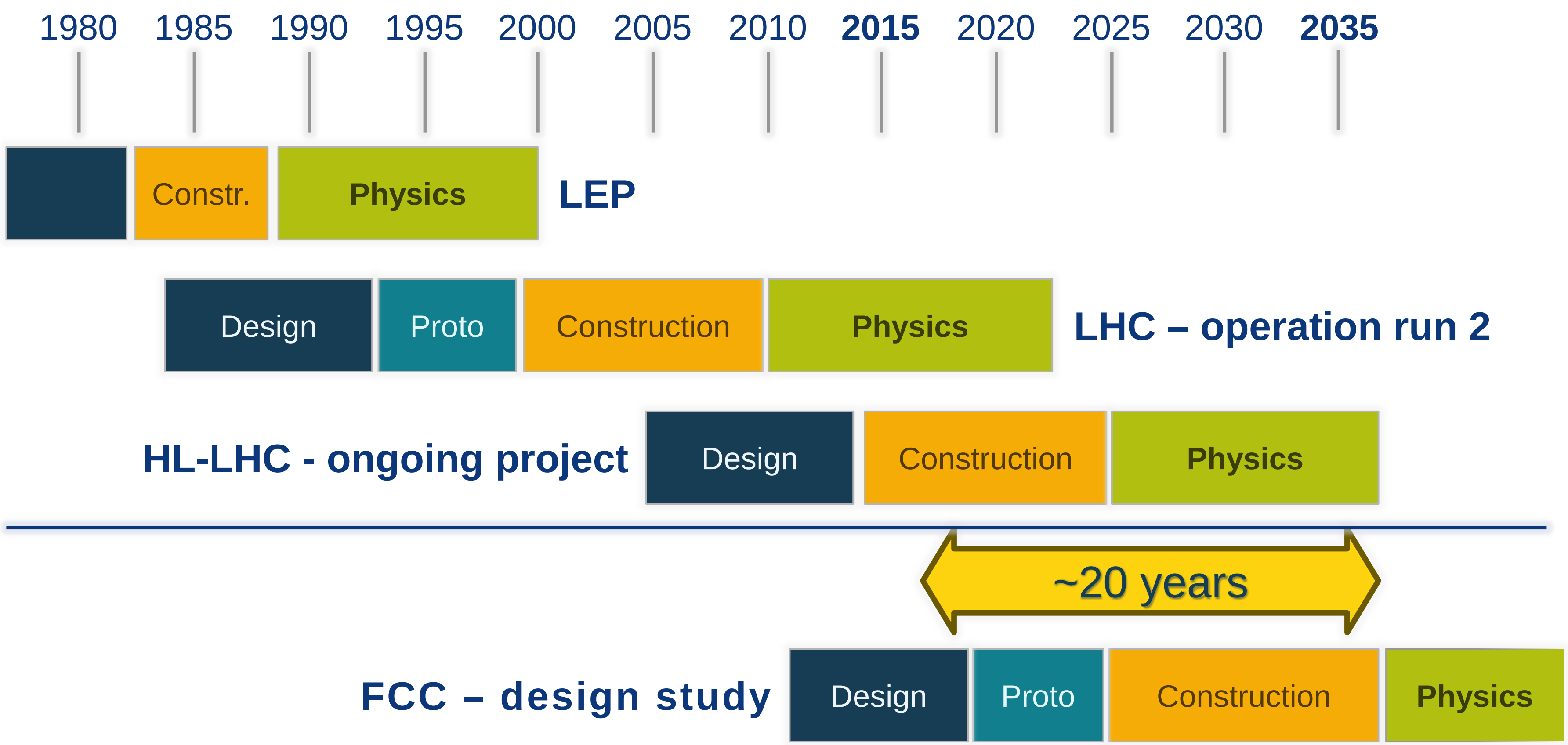


Experiment concepts for hh, ee and he
Machine Detector Interface studies
R&D needs for **detector technologies**

Overall **cost model for collider scenarios** including infrastructure and injectors
Develop **realization concepts**
Forge **partnerships with industry**

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

CERN Circular Colliders & FCC



Must advance fast now to be ready for the period 2035 – 2040
Goal of phase 1: CDR by end 2018 for next update of European Strategy

Progress on site investigations

Alignment | Shafts | Query

Choose alignment option: 100km quasi-circular

Tunnel elevation at centre:261mASL

Grad. Params

Azimuth (°): -20
Slope Angle x-x(%): 0.65
Slope Angle y-y(%): 0

LOAD | SAVE | CALCULATE

Alignment centre

X: 2499731   Y: 1108403

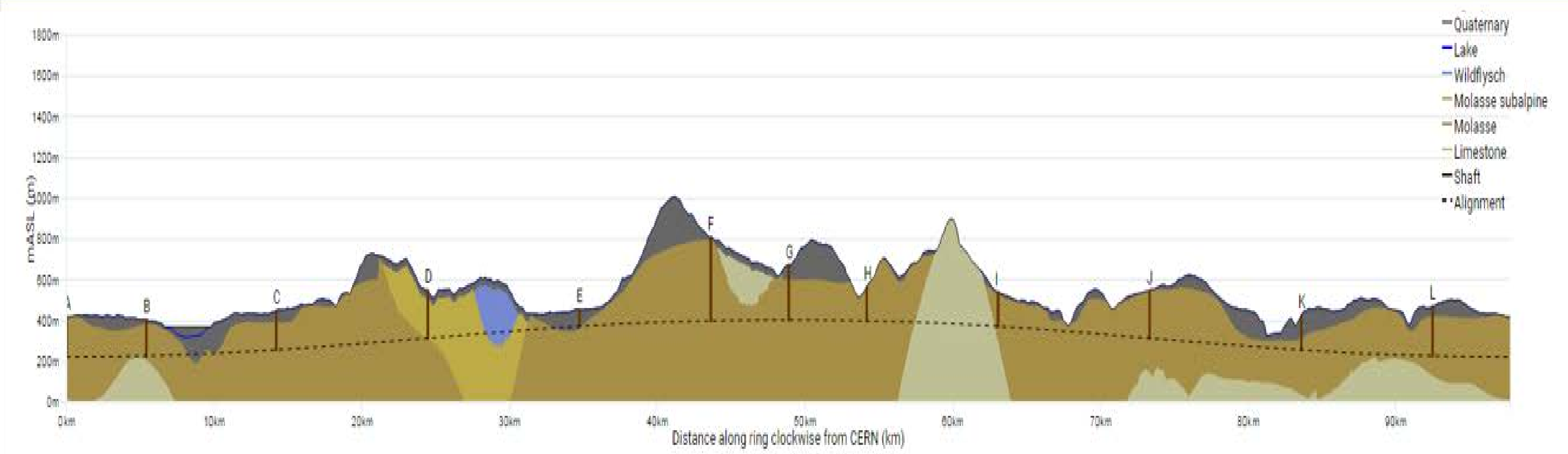
	CP 1		CP 2	
	Angle	Depth	Angle	Depth
LHC	-64°	220m	64°	172m
SPS		242m		241m
TI2		235m		241m
TI8		242m		170m

Alignment Location

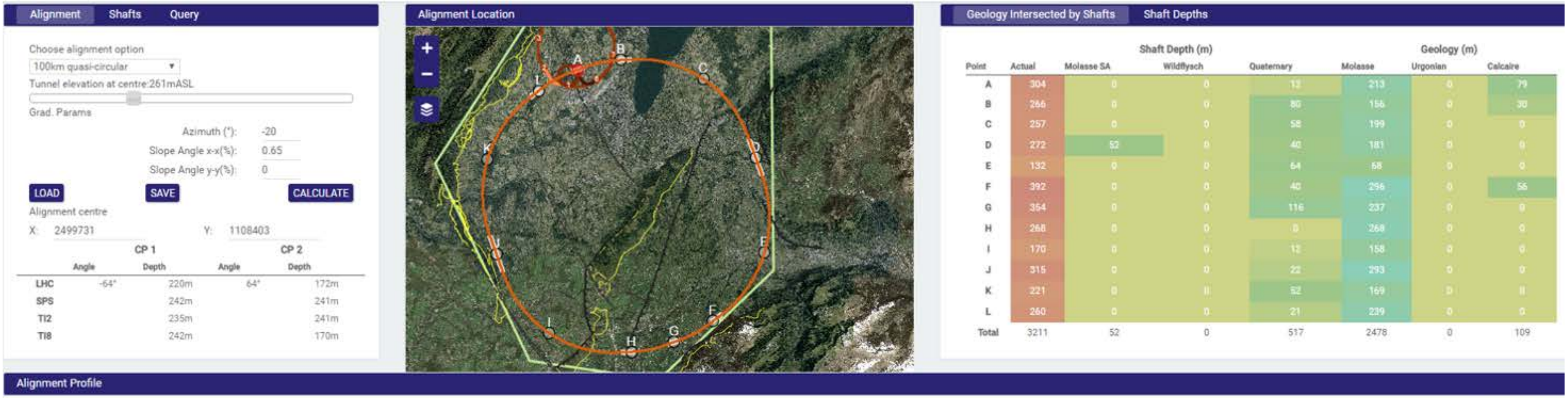
Geology Intersected by Shafts | Shaft Depths

Point	Shaft Depth (m)			Geology (m)			
	Actual	Molasse SA	Wildflysch	Quaternary	Molasse	Urgonian	Calcaire
A	304	0	0	12	213	0	79
B	266	0	0	80	156	0	30
C	257	0	0	58	199	0	0
D	272	52	0	40	181	0	0
E	132	0	0	64	68	0	0
F	392	0	0	40	296	0	56
G	354	0	0	116	237	0	0
H	268	0	0	0	268	0	0
I	170	0	0	12	158	0	0
J	315	0	0	22	293	0	0
K	221	0	0	52	169	0	0
L	260	0	0	21	239	0	0
Total	3211	52	0	517	2478	0	109

Alignment Profile



Progress on site investigations



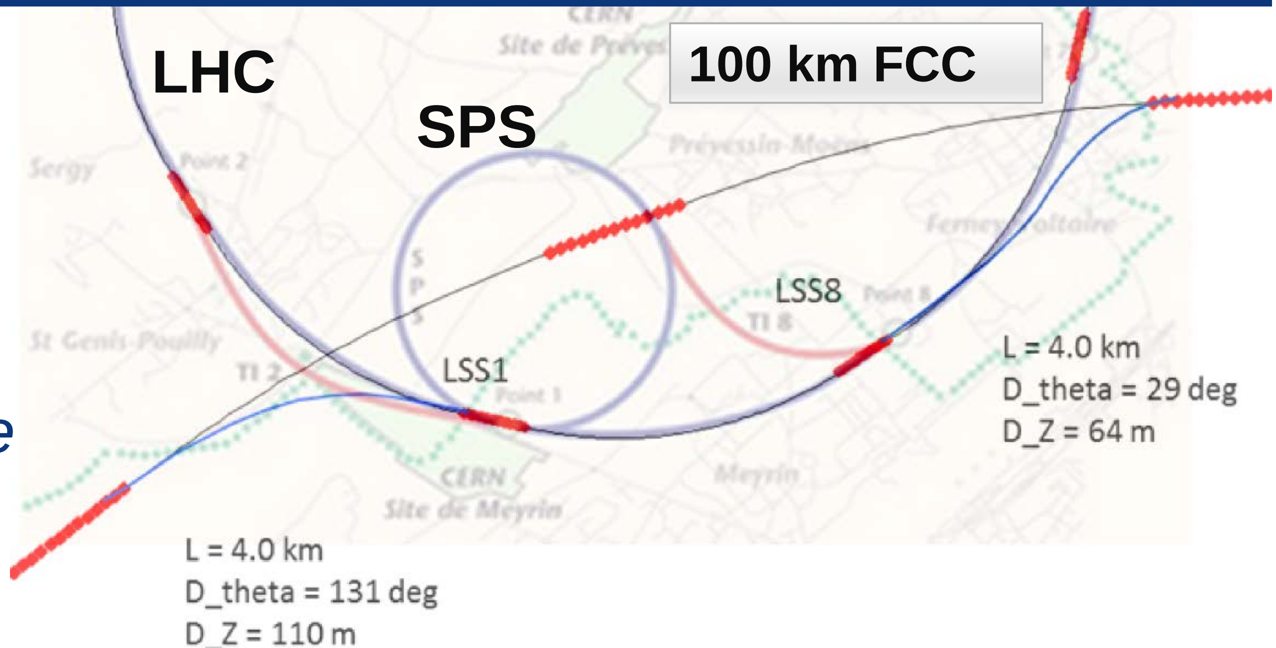
- 90 – 100 km fits geological situation well
- LHC suitable as potential injector
- The 100 km version, intersecting LHC, is now being studied in more detail

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

FCC-hh injector considerations

High energy and large size of the ring requires a pre-injector chain:

"gear-box" principle



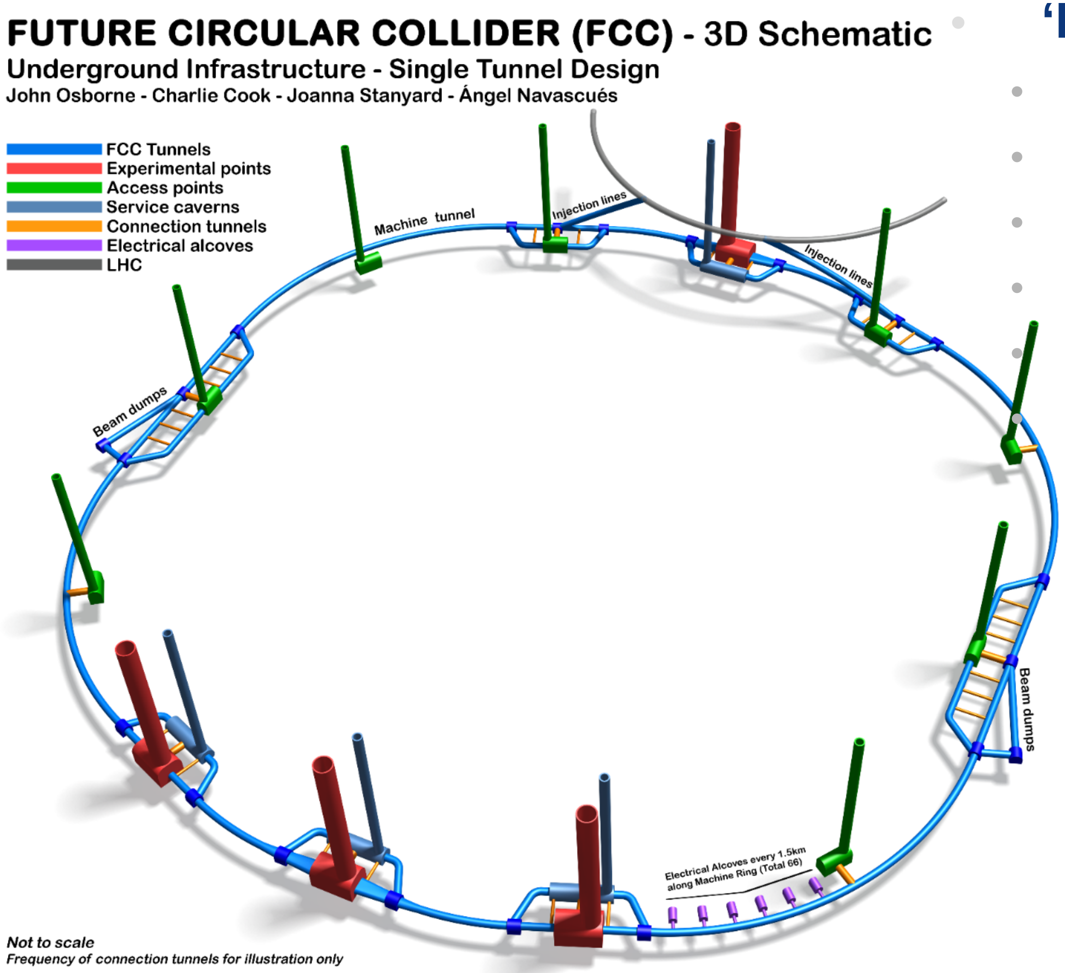
Baseline:

- **3 TeV, directly from LHC, reusing the whole CERN complex**

Alternative:

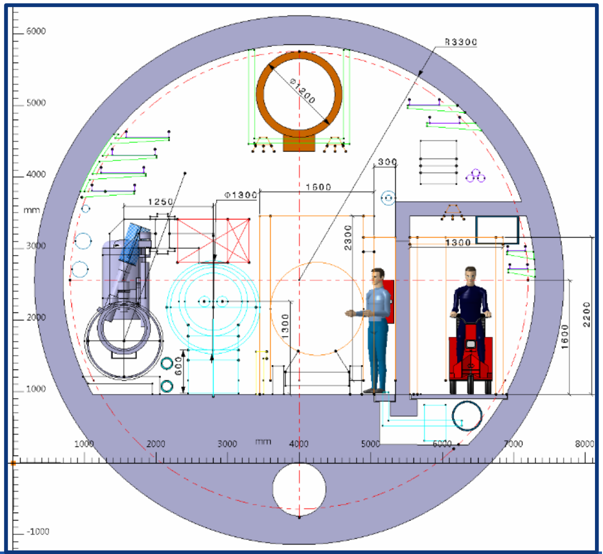
- **1.5 TeV with new SPS (7 km machine circumference) based on fast-cycling SC magnets, 6-7T, ~ 1T/s ramp**

FCC Tunnel Layout



'Baseline' Layout

- 100 km tunnel 6 m inner diameter
- 4 large experimental caverns
- 8 service caverns for infrastructure
- 12 & 4 vertical shafts (3 km integral)
- 2 transfer tunnels (10 km)
- 2 beam dump tunnels (4 km)



Hadron collider parameters

parameter	FCC-hh		HE-LHC* (*tentative)	(HL) LHC
collision energy cms [TeV]	100		>25	14
dipole field [T]	16		16	8.3
circumference [km]	100		27	27
# IP	2 main & 2		2 & 2	2 & 2
beam current [A]	0.5		1.12	(1.12) 0.58
bunch intensity [10^{11}]	1	1 (0.2)	2.2	(2.2) 1.15
bunch spacing [ns]	25	25 (5)	25	25
beta* [m]	1.1	0.3	0.25	(0.15) 0.55
luminosity/IP [10^{34} $cm^{-2}s^{-1}$]	5	20 - 30	>25	(5) 1
events/bunch crossing	170	<1020 (204)	850	(135) 27
stored energy/beam [GJ]	8.4		1.2	(0.7) 0.36
synchrotron rad. [W/m/beam]	30		3.6	(0.35) 0.18

Physics prospects

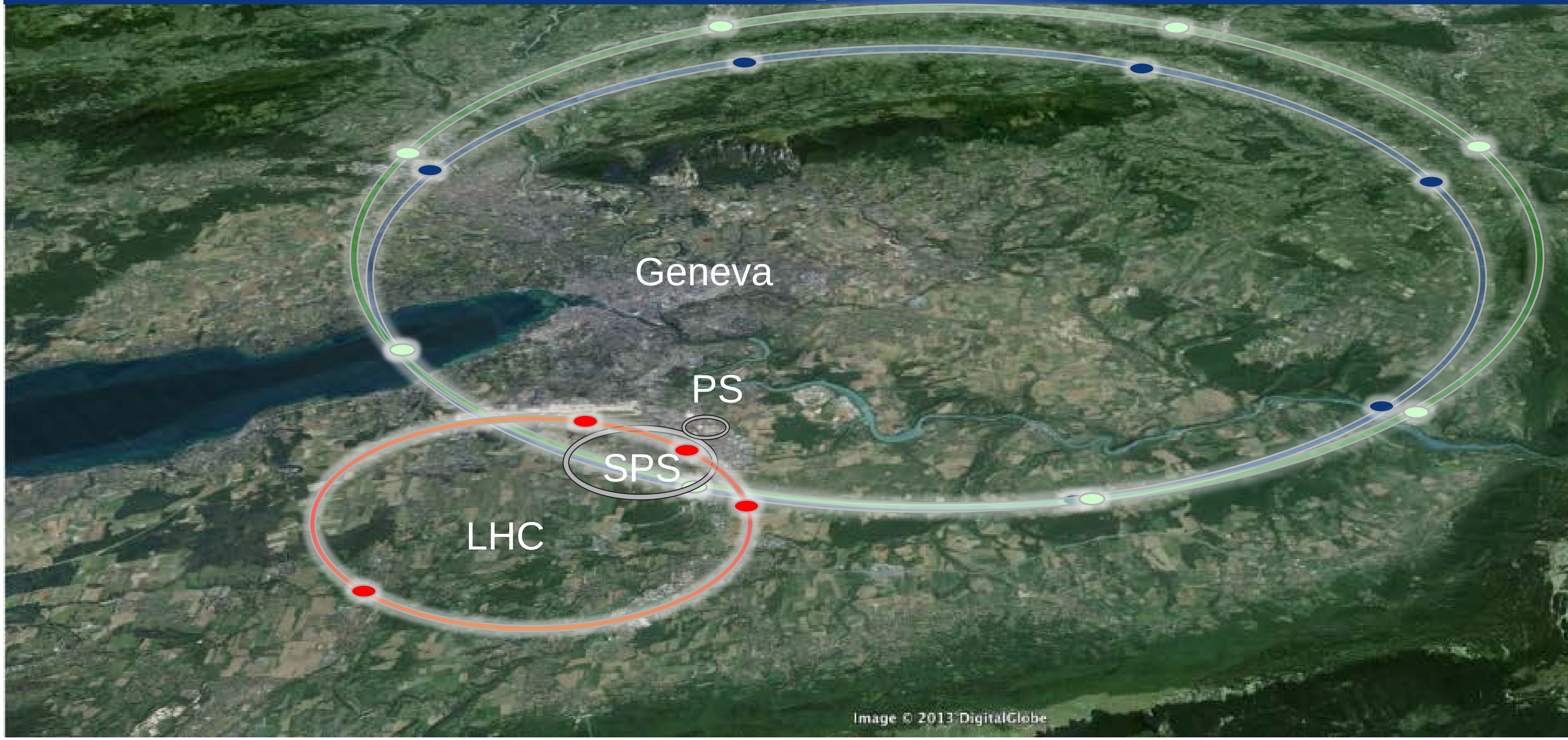
Physics at the FCC-hh

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/FutureHadroncollider

- **Volume 1: SM processes** (238 pages)
- **Volume 2: Higgs and EW symmetry breaking studies** (175 pages)
- **Volume 3: beyond the Standard Model phenomena** (189 pages)
- **Volume 4: physics with heavy ions** (56 pages)
- **Volume 5: physics opportunities with the FCC-hh injectors** (14 pages)

- **Being published as CERN yellow report**

FCC SC main magnet options and requirements



LHC	HE-LHC baseline	FCC-hh baseline	FCC-hh
27 km, 8.33 T	**27 km, 16 T**	**100 km, 16 T**	80 km, **20 T**
14 TeV (c.o.m.)	26 TeV (c.o.m.)	100 TeV (c.o.m.)	100 TeV (c.o.m.)
1300 tons NbTi	**2500 tons Nb_3Sn**	**10000 tons Nb_3Sn**	2000 tons HTS 8000 tons LTS

Main SC Magnet system FCC (16 T) vs LHC (8.3 T)

FCC

Bore diameter: 50 mm

Dipoles: $4578\ units, 14.3\ m\ long, 16\ T \Leftrightarrow \int Bdl \sim 1\ MTm$

Stored energy ~ 200 GJ (GigaJoule) ~44 MJ/unit

Quads: $762\ magnets,\ \ 6.6\ m\ long, 375\ T/m$

LHC

Bore diameter: 56 mm

Dipoles: $1232\ units, 14.3\ m\ long, 8.3\ T \Leftrightarrow \int Bdl \sim 0.15\ MTm$

Stored energy ~ 9 GJ (GigaJoule) ~7 MJ/unit

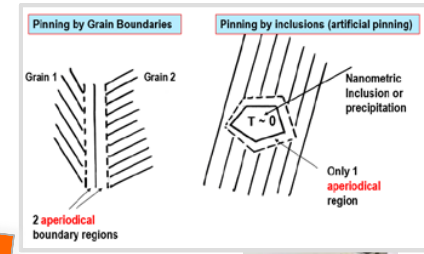
Quads: $392\ units,\ \ 3.15\ m\ long, 233\ T/m$

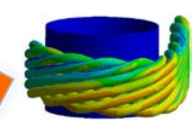
FCC Technology program 2016-2020

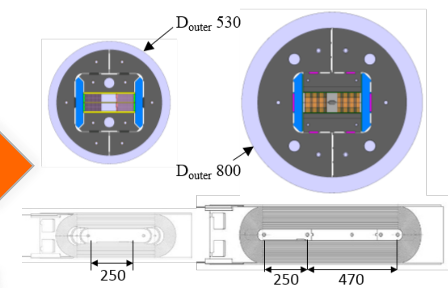
FCC-ST-0001

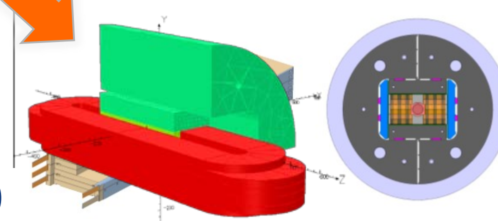
Page 3 of 16

Table of Contents





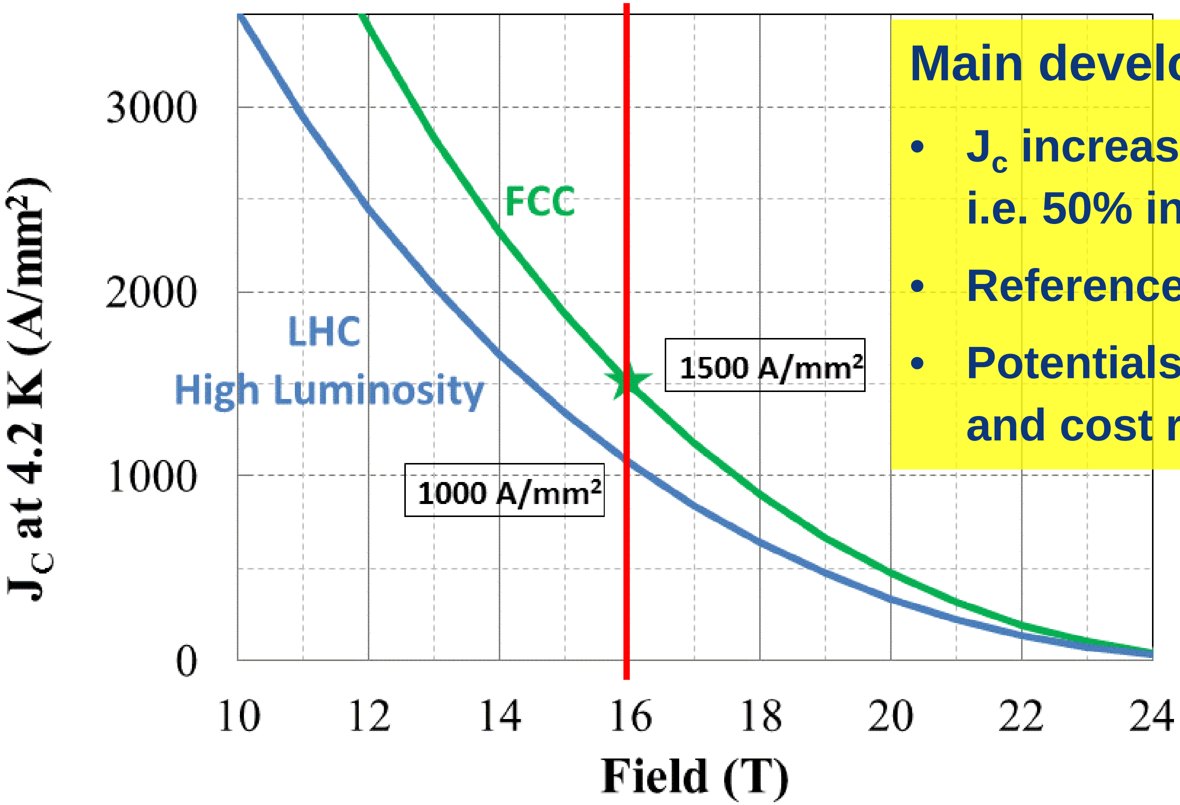




15 MCHF material over 4 years (8 MCHF on conductor R&D)

Nb_3Sn conductor program

Nb_3Sn is one of the major cost & performance factors for FCC-hh and must be given highest attention



Main development goals until 2020:

- J_c increase (16T, 4.2K) > 1500 A/mm^2 i.e. 50% increase wrt HL-LHC wire
- Reference wire diameter 1 mm
- Potentials for large scale production and cost reduction

Collaborations FCC Nb_3Sn program

Procurement of state-of-the-art conductor for protoyping:

- Bruker– European
- OST – US

Stimulate conductor development with regional industry:

- CERN/KEK – Japanese contribution. Japanese **industry** (JASTEC, Furukawa, SH Copper) and laboratories (Tohoku Univ. and NIMS).
- CERN/Bochvar High-technology Research Inst. – Russian contribution. Russian **industry** (TVEL) and laboratories
- CERN/KAT – Korean **industrial** contribution
- CERN/Bruker– European **industrial** contribution

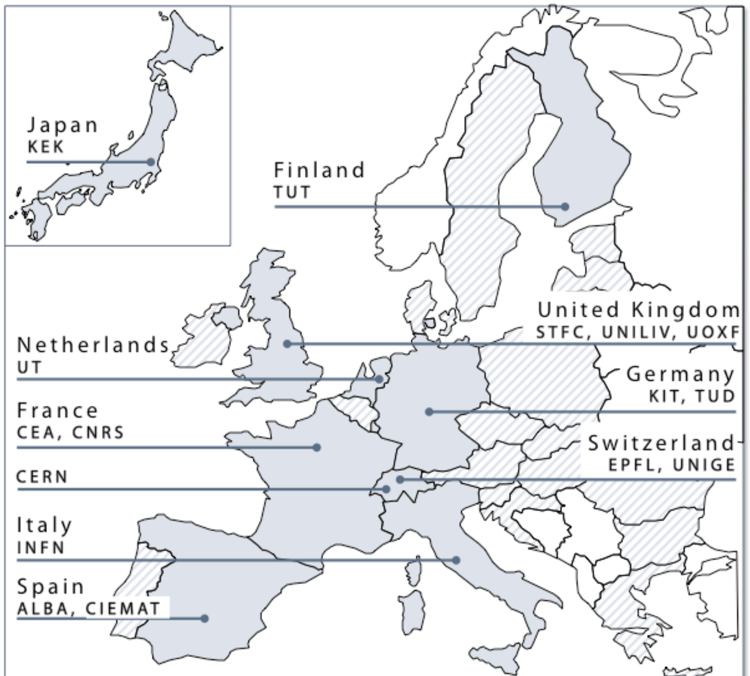
Characterisation of conductor & research with universities:

- **Europe: Technical Univ. Vienna, Geneva University, University of Twente**
- **Applied Superconductivity Centre** at Florida State University

New US DOE MDP effort – US activity with **industry** (OST) and labs

CERN-EU program ‘EuroCirCol’ on 16 T dipole design

UNIVERSITY OF TWENTE. INFN TAMPERE UNIVERSITY OF TECHNOLOGY



EuroCirCol consortium, federating 16 partners, 1 from Japan and 1 IEIO

TECHNISCHE UNIVERSITÄT DARMSTADT
KIT Karlsruher Institut für Technologie
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
UNIVERSITY OF LIVERPOOL
UNIVERSITÉ DE GENÈVE
ALBA
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
MANCHESTER 1824

European Union Horizon 2020 program

- Support for FCC study
- Grant agreement 654305
- 3 MEURO co-funding

Scope:

FCC hadron collider

- Optics Design
- Cryo vacuum design
- 16 T dipole design, construction folder for demonstrator magnets

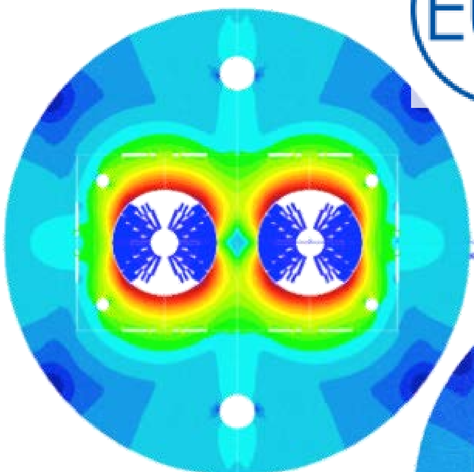
IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

FCC hh ee he

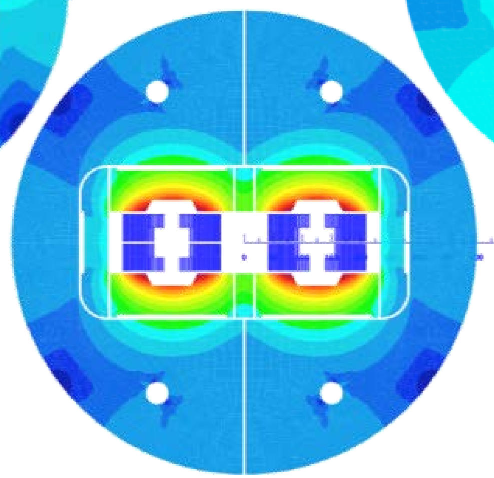
16 T dipole options under consideration

EuroCirCol
A key to New Physics

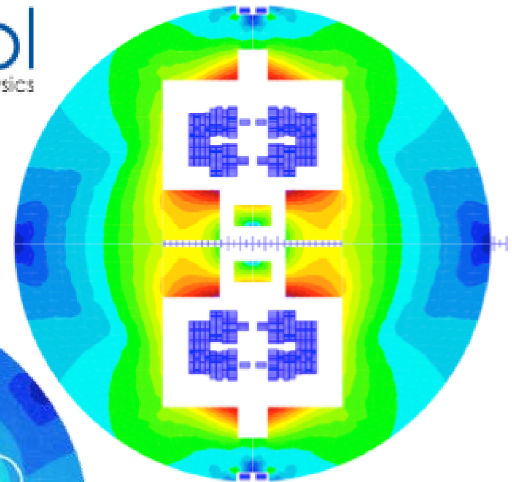
Cos-theta



Blocks

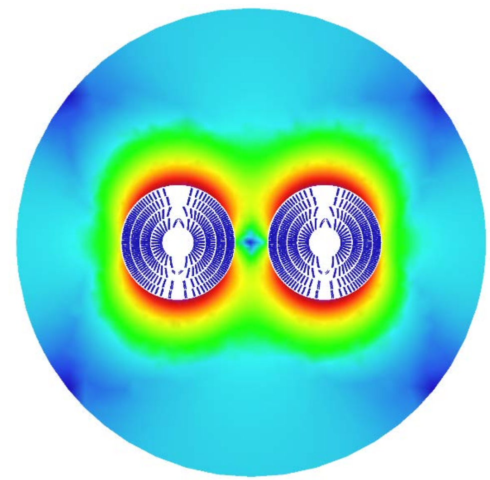


Common coils



Swiss contribution
via PSI

Canted
Cos-theta



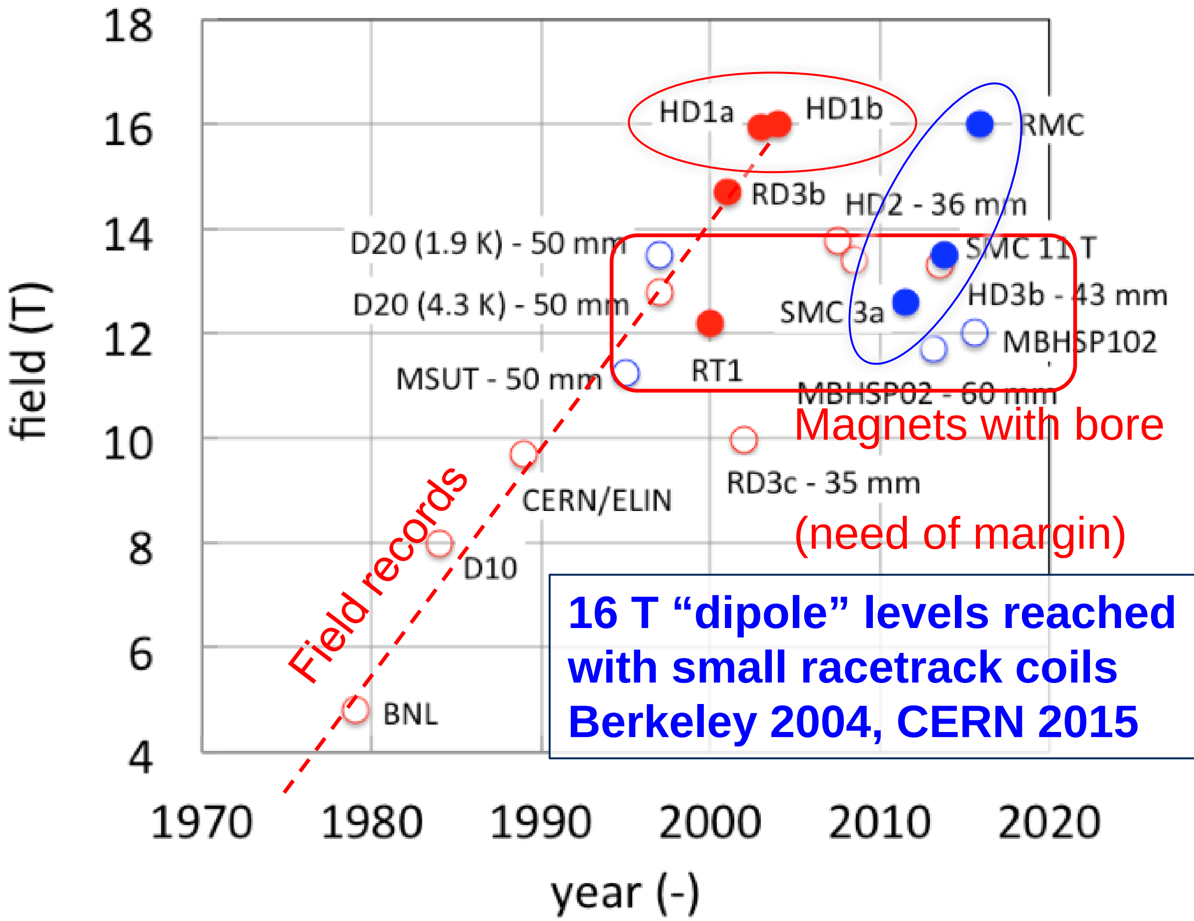
1LOr3C-02, 2PL-01, 2LPo1A-10, 2LPo1D-02, 2LPo1D-03, 2LPo1D-05, 2LPo1D-07, 2LPo1D-08

Down-selection of options end 2016 for more detailed design work

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

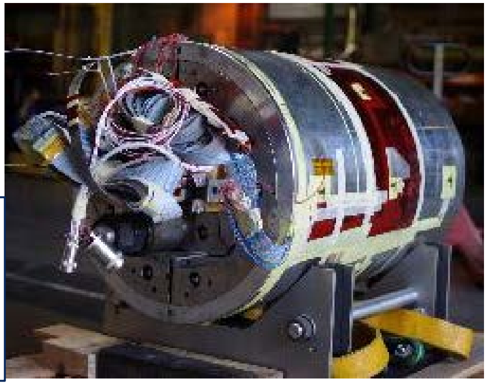
Towards 16T magnets

Record fields for SC magnets in “dipole” configuration



16 T “dipole” levels reached with small racetrack coils Berkeley 2004, CERN 2015

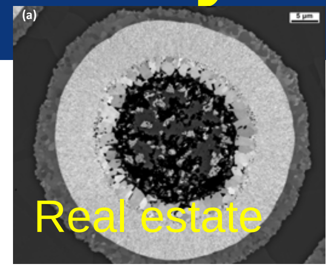
LBNL HD1

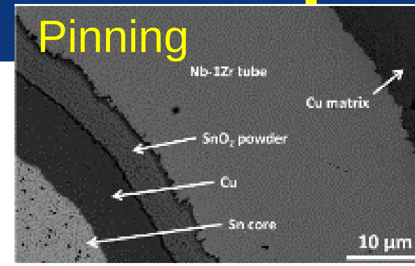


CERN RMC

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

Summary FCC 16 T planning

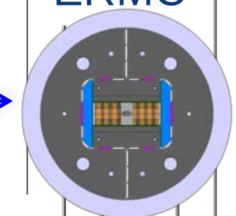




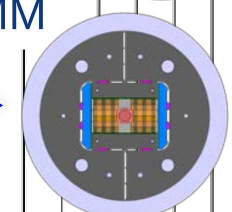
Activity	Begin	End	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
FCC EuroCirCol	01.05.2015	30.04.2019																
EuroCirCol concepts	01.05.2015	31.12.2016																
EuroCirCol design	31.12.2016	31.12.2017																
EuroCirCol engineering	31.12.2017	31.12.2018																
FCC Conductor Program	01.05.2015	31.12.2024																
wire and material R&D	30.06.2016	30.06.2021																
state-of-the-art wire for demonstrators	30.06.2016	31.12.2017																
high Jc wire for 16 T models	30.06.2017	30.06.2020																
high performance wire for 16 T models and prototypes	30.06.2020	31.12.2024																
Core magnet technology R&D	01.01.2015	30.06.2021																
Design, manufacture and test of ERMC	30.06.2015	30.06.2018																
Design, manufacture and test of RMM	01.01.2016	30.06.2019																
FCC 16 T Models	30.06.2018	31.12.2022																
FCC 16 T Prototypes	01.01.2023	31.12.2025																
FCC Production	01.01.2026	31.12.2033																

EuroCirCol
A key to New Physics

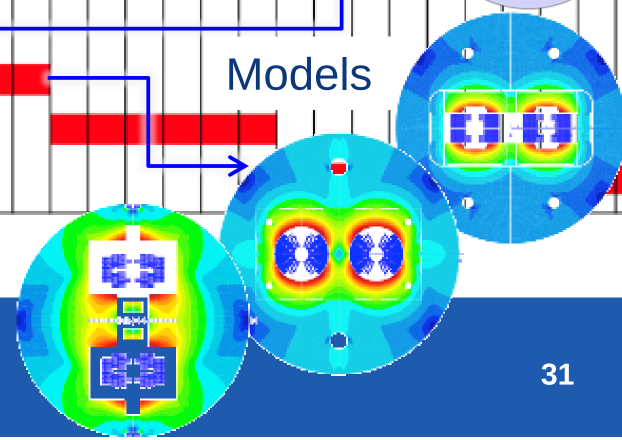
ERMC



RMM

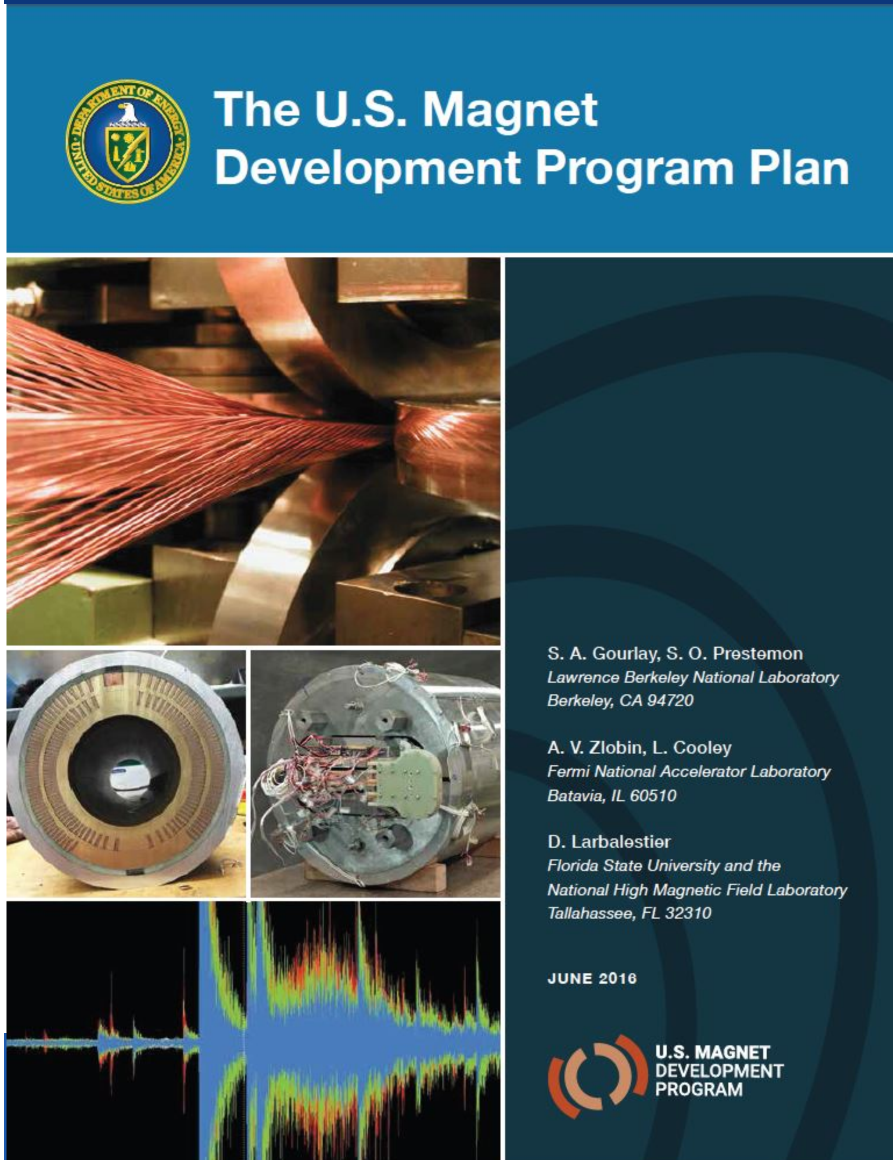


Models



FCC hh ee he

US Program


The U.S. Magnet Development Program Plan

S. A. Gourlay, S. O. Prestemon
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

A. V. Zlobin, L. Cooley
Fermi National Accelerator Laboratory
Batavia, IL 60510

D. Larbalestier
Florida State University and the
National High Magnetic Field Laboratory
Tallahassee, FL 32310

JUNE 2016

U.S. MAGNET DEVELOPMENT PROGRAM

Program (MDP) Goals:

GOAL 1:

Explore the performance limits of Nb_3Sn accelerator magnets with a focus on minimizing the required operating margin and significantly reducing or eliminating training.

GOAL 2:

Develop and demonstrate an HTS accelerator magnet with a self-field of 5 T or greater compatible with operation in a hybrid LTS/HTS magnet for fields beyond 16 T.

GOAL 3:

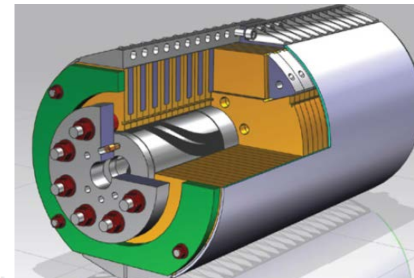
Investigate fundamental aspects of magnet design and technology that can lead to substantial performance improvements and magnet cost reduction.

GOAL 4:

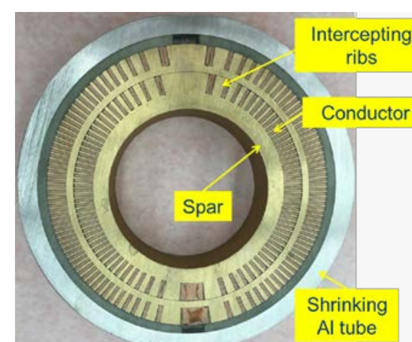
Pursue Nb_3Sn and HTS conductor R&D with clear targets to increase performance and reduce the cost of accelerator magnets.

Under Goal 1:

16 T cos theta dipole design



16 T canted cos theta (CCT) design



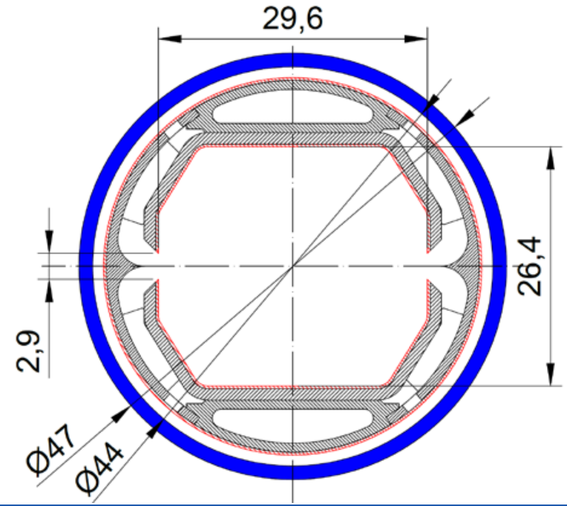
Synchrotron radiation beam screen prototype

High synchrotron radiation load of proton beams @ 50 TeV:

- **~30 W/m/beam (@16 T)** (LHC <0.2W/m)
- **5 MW total in arcs (@1.9 K!!!)**

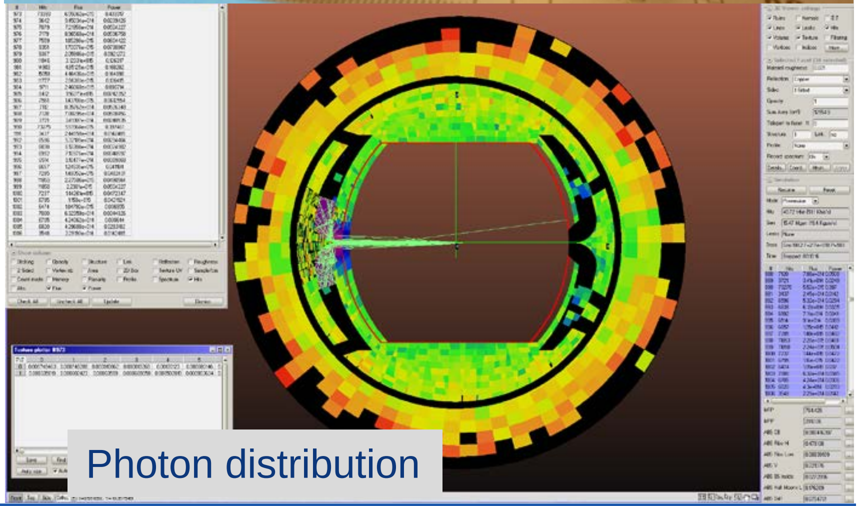
New Beam screen with ante-chamber

- absorption of synchrotron radiation at 50 K to reduce cryogenic power
- factor 50! reduction of power for cryo system



First FCC-hh beam screen prototype

Testing 2017 in ANKA within EuroCirCol

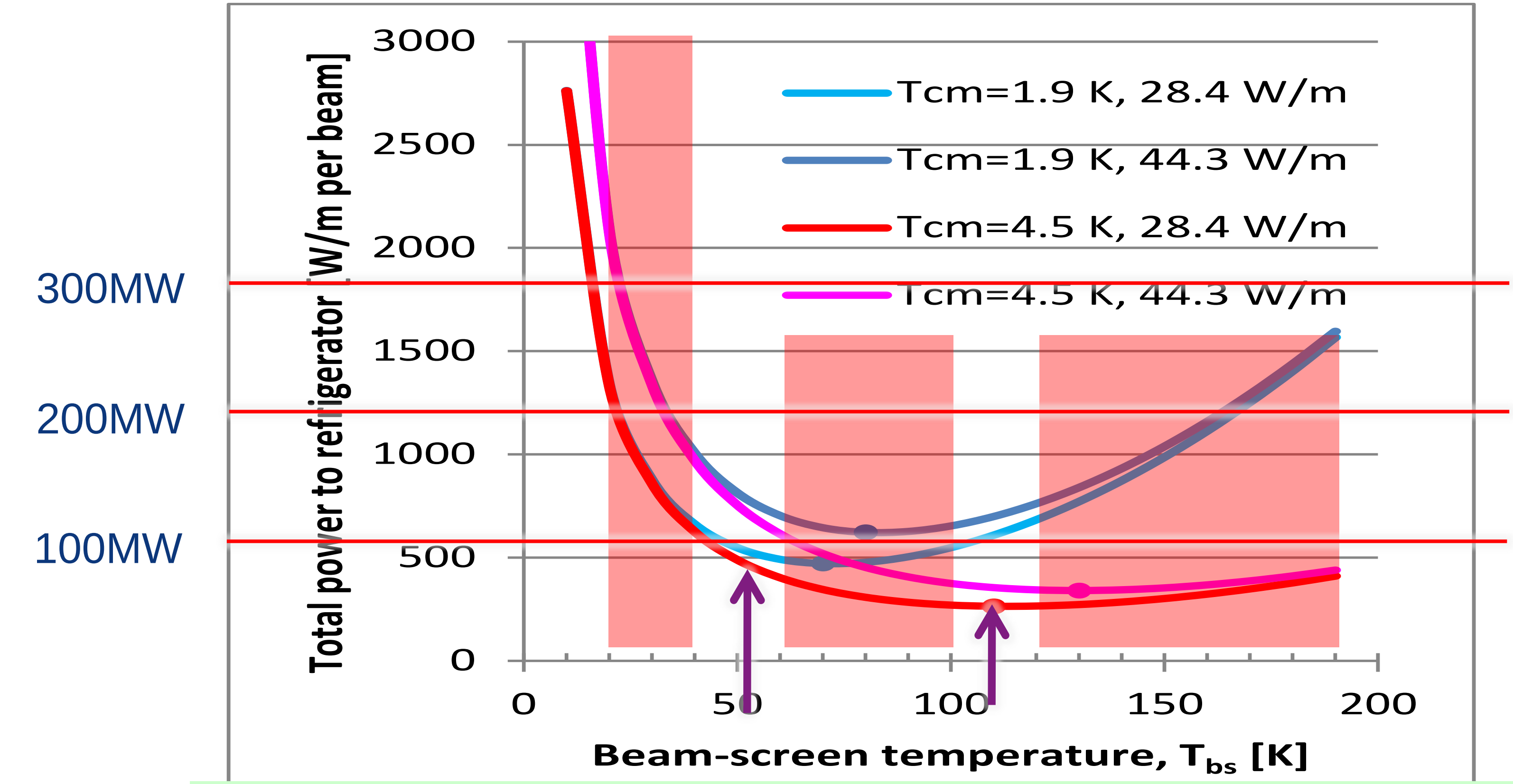


Photon distribution

Cryo power for cooling of SR heat

Overall optimisation of cryo-power, vacuum and impedance

Termperature ranges: <20, 40K-60K, 100K-120K



Multi-bunch instability growth time: 25 turns 9 turns (ΔQ=0.5)

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

HTS coating for beam screen

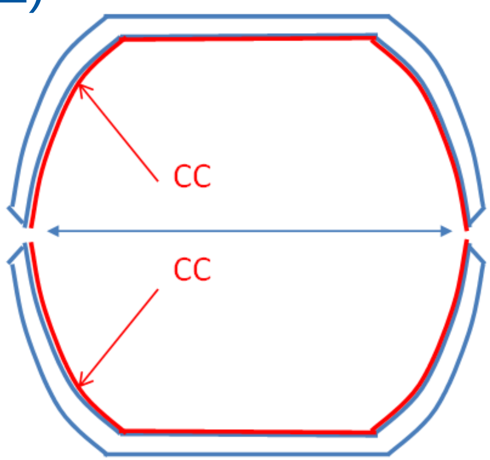
Goals: lower FCC-hh beam impedance for stability, while allowing higher beam-screen temperature for efficency

Candidate materials:

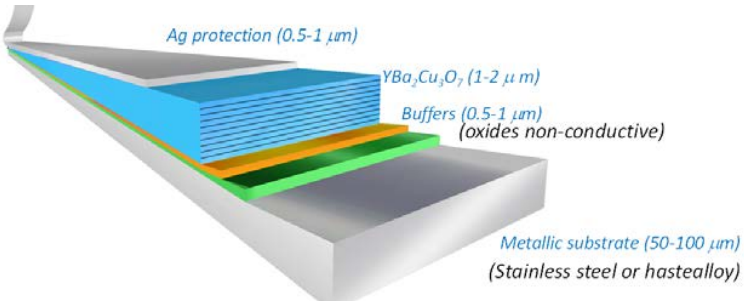
Tl-1223 (promising performance, opens up >100 K temperature window, scalable coating, R&D with CNR-SPIN and TU-Vienna)

YBCO (proven performance, requires forming technology, R&D with ICMAB-ALBA-IFAE)

HTS can have surface resistance lower than Cu at T< 77 K and f < 10 GHz



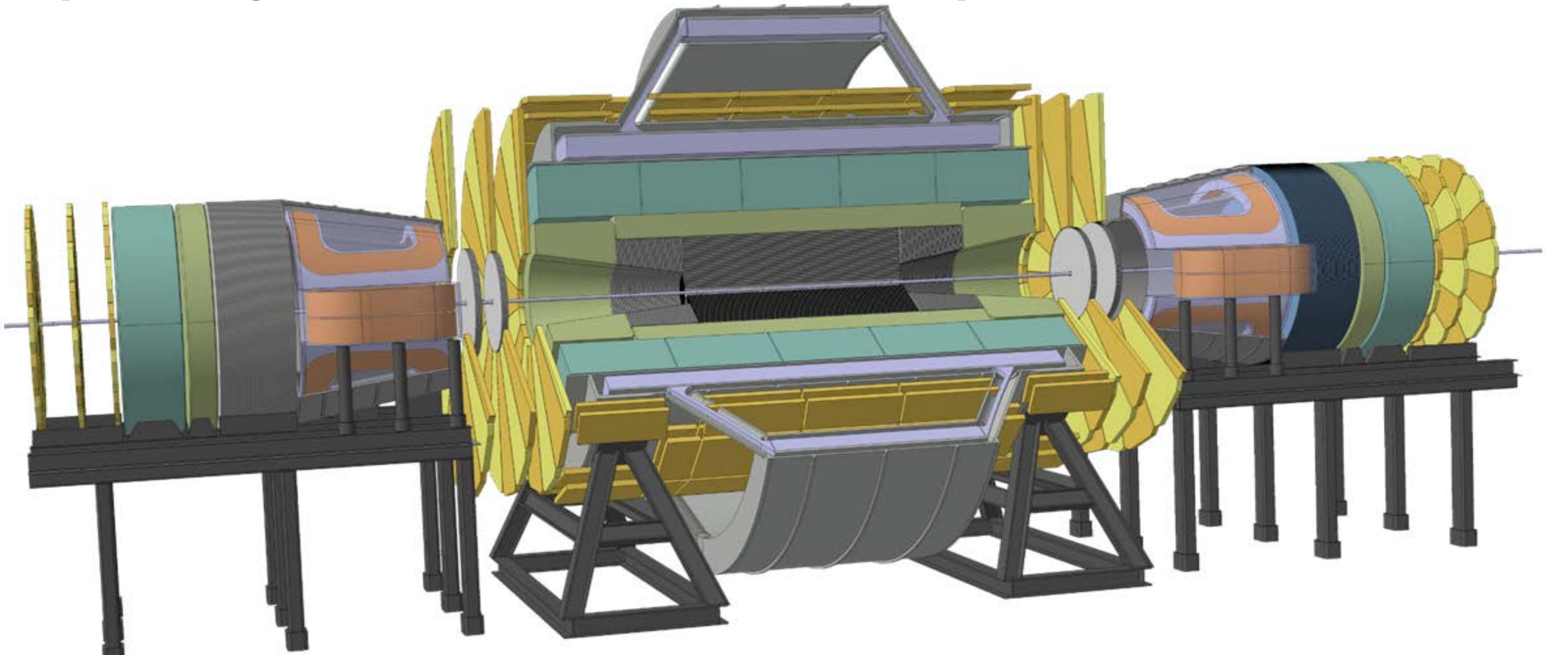
CC: coated conductor



Detector Concepts for 100 TeV pp

Very large volume of high magnetic field needed to measure momentum of charged particles.

Expanding from LHC detector concepts:



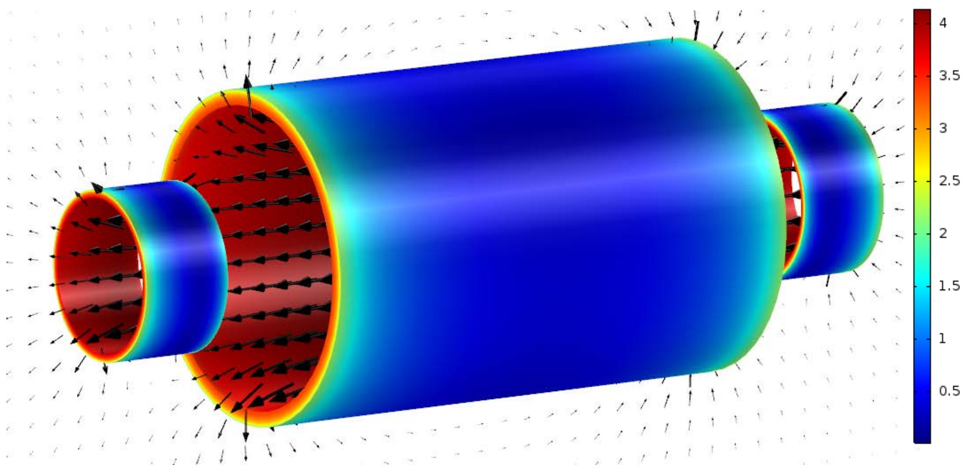
B=6 T, 12 m bore, solenoid with shielding coil and 2 dipoles 10 Tm.

Length 64 m, diam. 30 m, magnet 7000 tons, stored energy 50 GJ

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

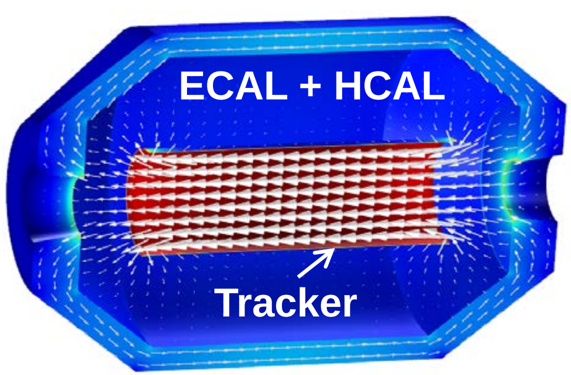
Detector Magnet Studies

Designs for physics-performing and cost-efficient magnet systems



Today's baseline:

4T/10m bore 20m long Main Solenoid
4T Side Solenoids – all unshielded
14 GJ stored energy, 30 kA and
2200 tons system weight



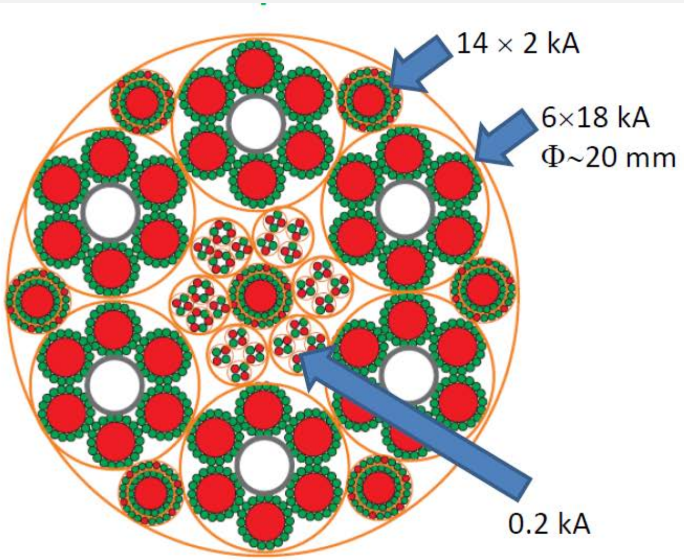
Alternative challenging design:

4T/4m Ultra-thin, high-strength Main Solenoid
allowing positioning inside the e-calorimeter,
280 MPa conductor (side solenoids not shown)
0.9 GJ stored energy, elegant, 25 t only,
but needs R&D!

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

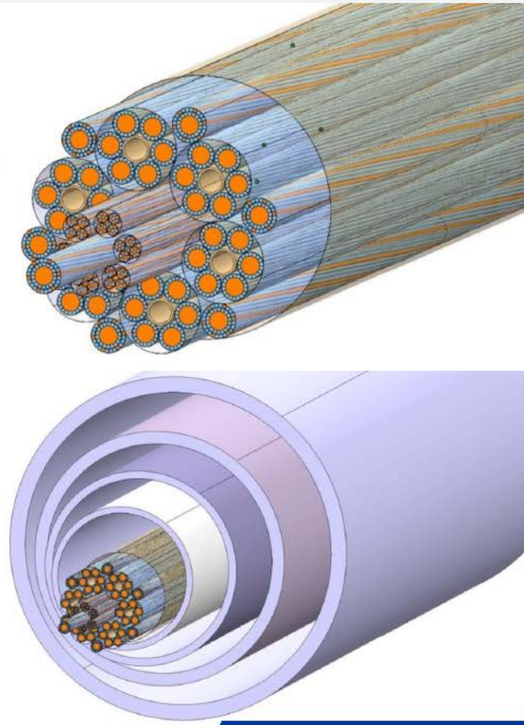
SC links for circuit powering

MgB_2 industrial conductor, He gas cooled
Example HL-LHC (I_{tot} up to ~|150 kA| @ 25 K)
All circuits in single cryostat – compact & efficient



Φext ~ 65 mm
|Itot| ~ 150 kA

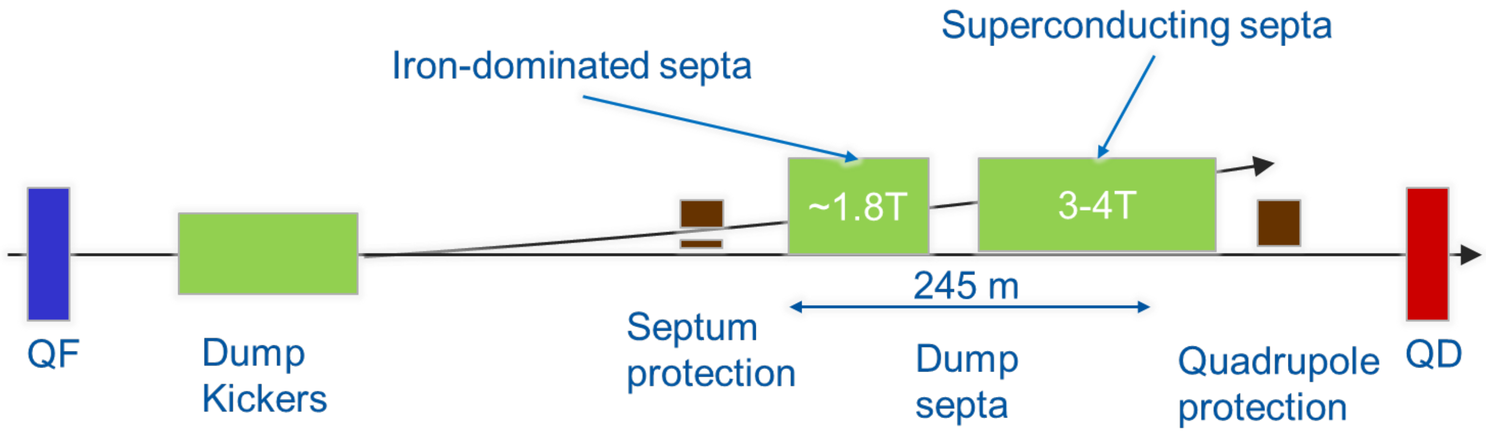
Mass ~ 11 kg/m



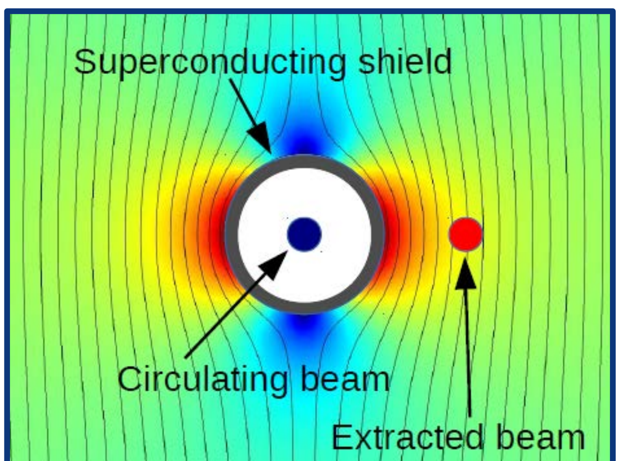
Φext ~ 220 mm

R&D on Superconducting Septa

Need an extraction system for safely removing the beam from the collider hybrid system: short overall length with **high robustness & availability**



SuShi concept:
SC shield creates field-free region inside strong dipole field



3 candidate technologies:
(1) NbTi/Nb/Cu multilayer sheet
(2) HTS tape/coating
(3) Bulk MgB_2

IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2016.
Plenary presentation 2PL-01 given at ASC 2016; Denver,Colorado,USA, September 4 – 9, 2016.

lepton collider parameters

parameter	FCC-ee (400 MHz)				LEP2
Physics working point	**Z**	**WW**	**ZH**	**tt_{bar}**	
energy/beam [GeV]	**45.6**	**80**	**120**	**175**	105
bunches/beam	**91500**	**5260**	**780**	**81**	4
bunch spacing [ns]	**2.5**	**50**	**400**	**4000**	22000
bunch population [10^{11}]	**0.33**	**0.6**	**0.8**	**1.7**	4.2
beam current [mA]	**1450**	**152**	**30**	**6.6**	3
luminosity/IP x $10^{34}cm^{-2}s^{-1}$	**90**	**19**	**5.1**	**1.3**	0.0012
energy loss/turn [GeV]	**0.03**	**0.33**	**1.67**	**7.55**	3.34
synchrotron power [MW]	**100**				22
RF voltage [GV]	**0.2**	**0.8**	**3.0**	**10**	3.5

Limitation: synchrotron radiation - strong dependency on beam energy

FCC hh ee he

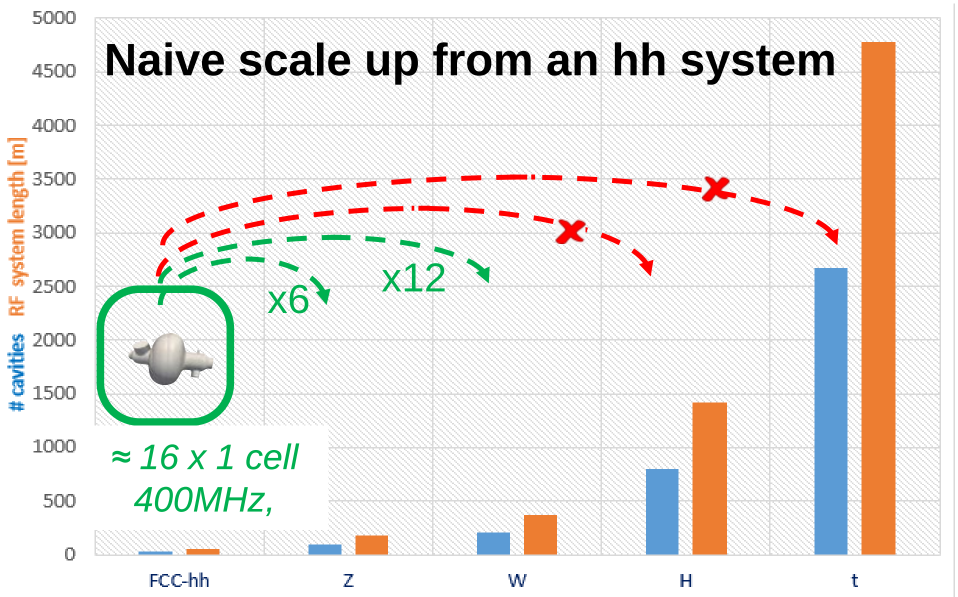
SRF system requirements

Very large range of operation parameters

"Ampere-class" machines

	V_{total} GV	$n_{bunches}$	I_{beam} mA	ΔE/turn GeV
hh	0.032		**500**	
Z	0.4/0.2	30000/90000	**1450**	0.034
W	0.8	5162	152	0.33
H	**5.5**	770	30	1.67
t	**10**	78	6.6	7.55

"high gradient" machines

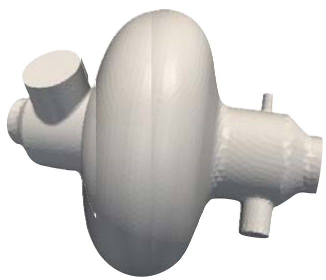


- Voltage and beam current ranges span more than factor > 10^2
- No well-adapted single RF system solution satisfying requirements

SRF system R&D lines

400 MHz single-cell cavities preferred for hh and ee-Z (few MeV/m)

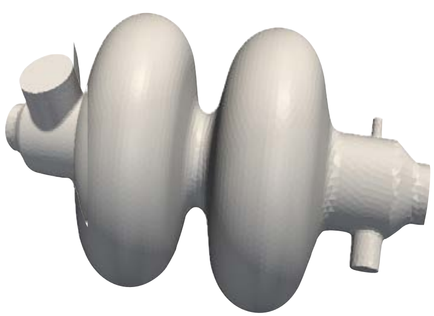
- Baseline Nb/Cu @4.5 K, development with synergies to HL-LHC, HE-LHC
- R&D: power coupling 1 MW/cell, HOM power handling (damper, cryomodule)



hh	Z	W
≈ 16 cells per beam	≈ 100 per beam (+ 100 for booster ring)	(≈ 210 per beam (+ 210 for booster ring))

400 or 800 MHz multi-cell cavities preferred for ee-H, ee-tt and ee-W

- Baseline options 400 MHz Nb/Cu @4.5 K, ◄—► 800 MHz bulk Nb system @2K
- Long-term R&D: Nb_3Sn like components

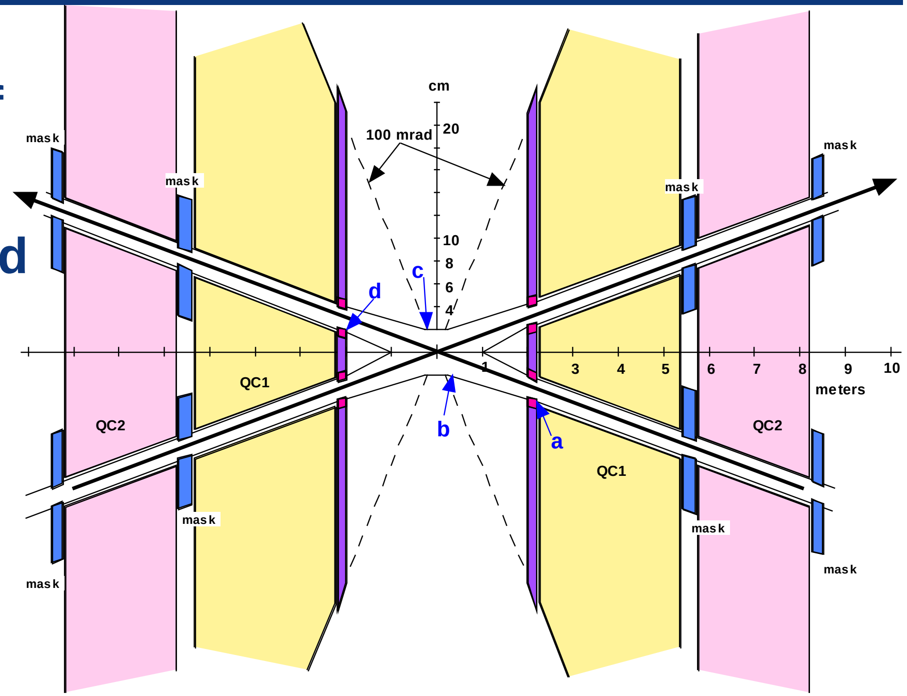


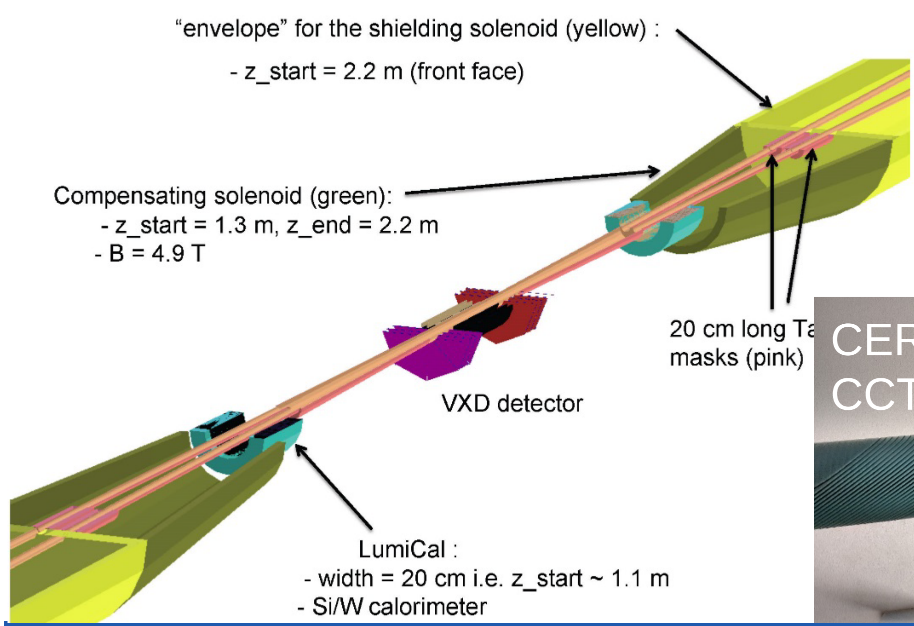
W	H	t
≈ 200 per beam (+ 200 for booster)	≈ 800 per beam (+ 800 for booster)	≈ common 2600 cells for both beams (+ 2600 for booster)

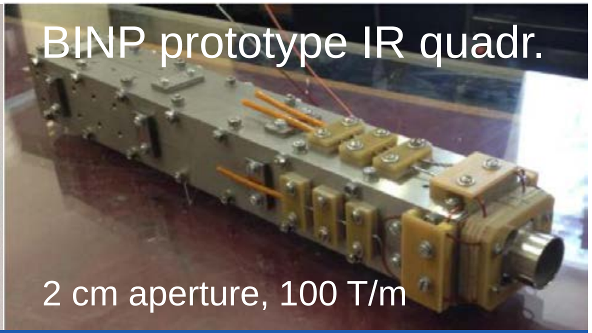
FCC-ee MDI optimisation

MDI work started with optimization of

- ***l****, **IR quadrupole design**
- **compensation & shielding solenoid**
- **SR masking and chamber layout**







FCC International Collaboration

- 88 institutes
- 28 countries + EC

Status: August, 2016

FCC Collaboration Status

87 collaboration members + EC + CERN as host

ALBA/CELLS, Spain
Ankara U., Turkey
Aydin U, Istanbul, Turkey
U Belgrade, Serbia
U Bern, Switzerland
BINP, Russia
CASE (SUNY/BNL), USA
CBPF, Brazil
CEA Grenoble, France
CEA Saclay, France
CIEMAT, Spain
Cinvestav, Mexico
CNRS, France
CNR-SPIN, Italy
Cockcroft Institute, UK
U Colima, Mexico
UCPH Copenhagen, Denmark
CSIC/IFIC, Spain
TU Darmstadt, Germany
TU Delft, Netherlands
DESY, Germany
DOE, Washington, USA
TU Dresden, Germany
Duke U, USA
EPFL, Switzerland
UT Enschede, Netherlands
ESS, Sweden
U Geneva, Switzerland
Giresun U. Turkey
Goethe U Frankfurt, Germany
GSI, Germany
GWNU, Korea
U. Guanajuato, Mexico
Hellenic Open U, Greece
HEPHY, Austria
U Houston, USA
ISMAB-CSIC, Spain
IFAE, Spain
IFIC-CSIC, Spain
IIT Kanpur, India
IFJ PAN Krakow, Poland
INFN, Italy
INP Minsk, Belarus
U Iowa, USA
IPM, Iran
UC Irvine, USA
Isik U., Turkey
Istanbul University, Turkey
JAI, UK
JINR Dubna, Russia
Jefferson LAB, USA
FZ Jülich, Germany
KAIST, Korea
KEK, Japan
KIAS, Korea
King's College London, UK
KIT Karlsruhe, Germany
KU, Seoul, Korea
Korea U Sejong, Korea
U Liverpool, UK
U Lund, Sweden
U Malta, Malta
MAX IV, Sweden
MEPhI, Russia
UNIMI, Milan, Italy
MIT, USA
Northern Illinois U, USA
NC PHEP Minsk, Belarus
OIU, Turkey
Okan U, Turkey
U Oxford, UK
PSI, Switzerland
U. Rostock, Germany
RTU, Riga, Latvia
UC Santa Barbara, USA
Sapienza/Roma, Italy
U Siegen, Germany
U Silesia, Poland
Stanford U, USA
U Stuttgart, Germany
TAU, Israel
TU Tampere, Finland
TOBB, Turkey
U Twente, Netherlands
TU Vienna, Austria
Wigner RCP, Budapest, Hungary
Wroclaw UT, Poland

Summary

- Superconductivity is the key enabling technology for FCC in many areas. In particular the Nb3Sn program towards building 16 T model magnets is of prime importance.
- International collaboration is essential to advance with this study on all the challenging subjects and the community is warmly invited to join the FCC efforts.
- HL-LHC is the first step towards future circular colliders
- Next milestone is the FCC Week 2017 in Berlin, to review and confirm baseline design and technology choices.


FCCWEEK2017
Future Circular Collider Conference
BERLIN, GERMANY
29 MAY - 02 JUNE
fccw2017.web.cern.ch
IEEE
CSC
DPG
DESY