CHART Collaboration

Lenny Rivkin

PSI and **EPFL**

Balsthal



www.chart.ch



Swiss Accelerator Research and Technology





CHART Applied Superconductivity

FUTURE

CIRCULAR

LIDER



- "CHART, the Swiss Center for Accelerator Research and Technology, was founded to support the future oriented accelerator project Future Circular Collider (FCC) at CERN and the development of advanced accelerator concepts in Switzerland beyond the existing technology. [...] The high field magnet R&D has strong synergies with PSI projects [...]"
- ~50% of the effort directed to Applied Superconductivity for accelerators.



PSI: MagDev FCCee HTS4

ETHZ: MagRes MagComp MagNum MagAM FCCee CPES

UniGE WireDev HFM WireChar

Bernhard Auchmann

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• Topics and FTEs of ongoing **HFM projects** in CHART:

Name	🖵 Institute	Description	🖵 FTE	🚽 FTE 🗖 % Suisse National Funds 🚽		
MagAM	ETHZ	Additive manufacturing for coil components		1	100	
MagComp	ETHZ	Coil composite characterization and constitutive modeling		1	100	
MagNum	ETHZ	Model-based systems engineering for magnets		1	100	
MagRes	ETHZ	Crack-resistant resin development		1	51	
MagDev1	PSI	SC magnet development		8	73	
MagDev2	PSI	SC magnet development		8	54	
WireChar	UniGE	SC wire and tape characterization		1	50	
WireDev	UniGE	Nb₃Sn wire development		3	53	
			Tot 2	4		

- FCC Feasibility Study and other CHART projects:
 - FCC / LHC Lumi
 - FCCee Beam Dynamics Simulation
 - FCChh Stability
 - FCCEe SPIN POL
 - FCCee Lumi
 - Muon Collider Feasibility Studies
 - FCCee Injector
 - FCC Geodesy
 - FCCee CPES cryogenic power supply development (1 FTE)
 - FCCee HTS4 HTS Short Straight Section Demo for FCCee (4 FTE)
 - HTS Bulk Undulator bulk REBCO undulator technology (2 FTE)
 - FCC Geology 3D Model









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CHART 2 Projects

	2019	2020	2021	2022	2023	2024	2025	2026
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Nb3Sn Development			tirst j		prototype wires			
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2 WireChar		campaign	measurement campaign	measurement campaign	measurement campa	inc Final Teport		
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3 Resins (MagRes)		experimen	ntal		and constitutive modelling	and report		
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4 HTS Bulk Undulator		Signature con	tract LSS End short samp	ne program - Cambridge	Ist cold test of End of	tardwore End of the Test	& Optmisation of the HTSU	
4 HTS BUIK UNdulator		with Perm	hiab Derivery of the	HTSI @ PSI A	▲ (LSS+HTSI) ◆	sioning 🔹	•	
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5 FCC LHC-Lumi		correction startegy	in operational scans	Data analysis	nalysis Benertine			
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		Laboratory Decision of th	e technology demonstrator	Design and Conceptual	eports,			
6 MagDev1		building		Construction Design	Final			
		finished 🔷 🔶 🔷	•	BigBOX Demo	teprane e			
-		Experimental	Concept Digital On	timization of Adaptive Enspacers	Final Report			
7 MagAM		Investigation in	Workflow V1 Ac	besive_oints				
8 FCChh stability		Develop FCC-hh Sync	hrotron raciation effects and coupling	to Integration of FCC-nh	Benchmark to LHC RUN3	Reporting:		
,						POC-EE CRUTT		
		Physics	design positron	RF module design		Installation P. Cubed	Report on the positron source	
9 FCCee Injector		sou roe ar	nd capture system	and costs	CDR+CDR+_		P_Cubed experiment	2
			ready 🛇 🔸	• • •	\diamond	↓	Extension	
FCCee-beam dynami	cs	Codes Review an	d FW strategy 1st FW with	basic modules Integ	ration of Optics + BB modules	Simulation campaign for	Reporting:	~
10 simulations					+ multi-IP stucies	FCC-ee design	FCC-ee CDR++	
		\	Surface encodesis	Call	bration,	Integration of a		
11 ECC Geodesy			reference network mo	del for the ECC region test	facility of Gravity field mode	Is 3D gravity field Dyn	amic gravity field	
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12 Geology 3D model		ofhi	gh y critical building					
			areas	• •				
			Framework architecture Red	uced vector-potential REBC	0 workflow			
13 MagNum			and Nb35n workflow tools	FEM software and t	framework			
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14 Muon Colliders Feasi	bility			Impecance model of r	nachine Develop theory and mo	el for Extensive numerical simu	ations for the Propose opti-	mai prio acci
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15 FCC-ee SPIN-POL				benchmark	FCC ee	Framework C	ompaign for FCC-ee scenarios fi	prenergy
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16 MagComp				Rutherford	cables Apple an sotropic mechanica	mechanical implomentation		
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17 ECCop HTS4				Concer	Subscale Testing Radiation	Management, Reports, Eccee Feas	ibility Study,	
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18 FCCee CPES				orequalification	Eval. Demonstrator	Demonstrator		
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19 FCCee Lumi				Beam Optics 0	ptimisation Sensitivity	& Lumnosity of IP Tuni	ig Process Tuning Scheme Up	A ignment report
有效的变形,通过使用的变形 。					 Anaiysis 	Related Signals	a Performance	

Originally planned milestones

Extension

Currently planned milestones
 Project delay (main y because of COVID)

+ MagDev2, MagMu (-> 40T HTS solenoid for muon collider, HE MuCol), MagNum2

CHART II commitments & spending (Stand 7.3.2023)





Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera

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(Ĵ) ETH-RAT











SYNOPSIS OF THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP

by the European Committee for Future Accelerators Detector R&D Roadmap Process Group







Accelerator R&D for future colliders 6

FCC integrated program

comprehensive long-term program maximizing physics opportunities

FUTURE

CIRCULAR COLLIDER

- stage 1: FCC-ee (Z, W, H, tt) as Higgs factory, electroweak & top factory at highest luminosities
- stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, pp & AA collisions; e-h option
- highly synergetic and complementary programme boosting the physics reach of both colliders (e.g. model-independent measurements of the Higgs couplings at FCC-hh thanks to input from FCC-ee; and FCC-hh as "energy upgrade" of FCC-ee)
- common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure
- FCC integrated project allows the start of a new, major facility at CERN within a few years of the end of HL-LHC



Needs long term commitment, good roadmap!

CHART: High Field Magnets



- outstanding team effort on a new type of Canted Cosine Theta, high field magnet
- the first magnet from PSI and very fruitful collaboration with LBNL colleagues.
- eventually tested at CERN in Nov 2022: **10.1 T in the bore at 1.9 K**; 9.9 T at 4.5 K.



MagDev Laboratory









Douglas Araujo Engineer LTS



Jaap Kosse Engineer ReBCO



Colin Müller Mechanic LTS



Henrique Rodrigues Process Engineer ReBCO



Dmitry Sotnikovs Design Engineer ReBCO



André Brem *Material Scientist*



Thomas Michlmayr CAD, Technical Design Page 9



CHART has demonstrated rapid entry into the High Field Magnet R&D

Recent difficulties (degradation issues) with the HL-LHC high field magnets development point to the need to re-examine some of the basics

material science input may be urgently needed to understand the conductor robustness under extreme transverse magnetic pressure and longitudinal forces

CHART partners have launched a wide front of such projects

Test facilities, allowing for a rapid turn-around of small samples

CHART: Magnet technology development High Temperature Superconductor (HTS)





B.Auchmann & CHART magnet team

- ReBCO conductor
- 18.2 Tesla solenoid field
- Cryogen free cooled @ 12K

 → makes s.c. technology available for smaller & cost efficient accelerators
 → cryogenic efficiency much improved

→ Applications for light sources and neutron scattering (recent R'Equip)

HTS superconducting magnet technology undulators

Using bulk HTS material: has reached 2 Tesla for very short period magnets Put the structure into a solenoid magnet, cool it and trap the field



Cooling @ 10T / Solenoid @ 0.0T / 10.0K





HTS Magnet technology developments:

- developments for fusion (Tokamak Energy Ltd., UK)
- HTS based undulators for light sources
- HTS based low power consumption magnets



Cost (A.U./ kA m)





CHART 2025 - 2028

The present CHART-2 funding is until 2024. Main lines of development beyond 2024:

- Future CERN projects: FCCee and FCChh
- High Field Magnets
- High-gradient RF: positron source
- Photon science applications: HTS magnets
- High-gradient plasma and laser:

light sources and compact accelerators

- Muon Colliders: beam stability studies, magnets
- Energy efficient accelerators, ERL options



Swiss Accelerator Research and Technology

CHART Roadmap

ACCELERATOR SCIENCE AND TECHNOLOGY RESEARCH AND DEVELOPMENT

January 18, 2022

CHART/RM/02



Collaborating international partners of CHART include:

- <u>TU Twente</u>, Enschede, Netherlands
- <u>TU Darmstadt</u>, Germany
- <u>USMDP</u> Magnet Development Program, Berkeley, USA
- <u>University of Cambridge</u>, UK
- <u>LEAPS</u>, League of European Accelerator based Photon Sources
- <u>BNL</u>, Brookhaven National Laboratory, USA
- <u>KEK</u>, High Energy Accelerator Research Organization, Tsukuba, Japan
- <u>IJCLab</u>, Laboratoire de Physique des 2 infinis Irène Joliot-Curie, Orsay, France
- <u>INFN Frascati</u>, Italy
- <u>SLAC National Accelerator Laboratory</u>, Menlo Park, USA
- <u>University of Oxford</u>, UK
- <u>FERMILAB</u>, Fermi National Accelerator Laboratory, USA
- <u>RIKEN SPring-8 Center</u>, Japan
- <u>Kyoto University</u>, Japan
- <u>ESRF</u>, European Synchrotron Radiation Facility, Grenoble, France

Thank you