Program Overview

Superconducting Detector Magnet Workshop for Future Colliders & Physics Experiments

Program Committee:

***Akira Yamamoto** (Chair, KEK-CERN),*

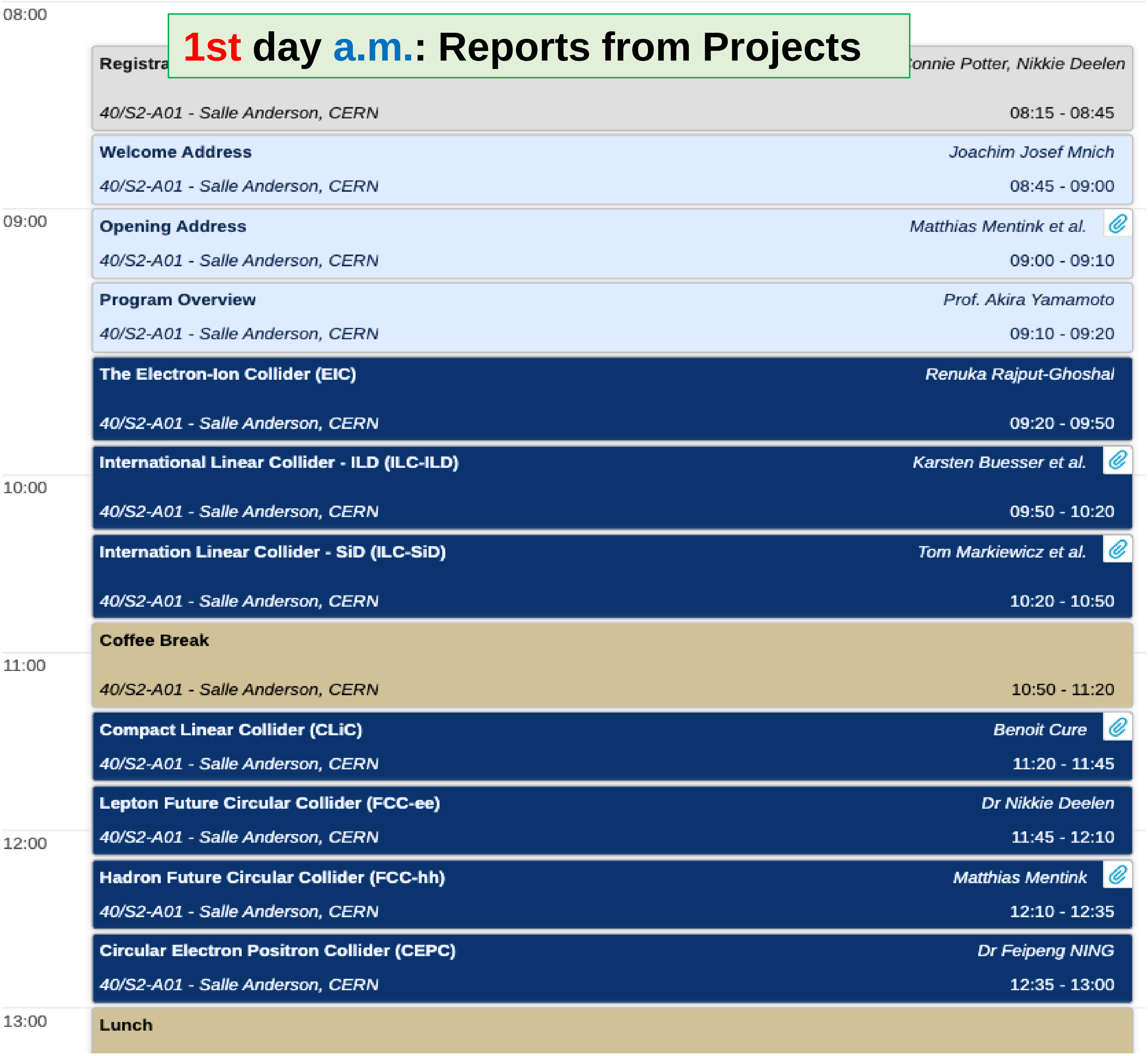
***Benoit Cure** (CERN), **Lionel Quettier** (CEA),*
***Renuka Rajput-Ghoshal** (JLab/BNL), **Vadim Kashikhin** (Fermilab),*
***Ken-ichi Sasaki** (KEK), and **Yasuhiro Makida** (KEK),*

12 Sept. 2022

General Agenda

Date	Agenda
Sept. 12th	**Opening remark:** **Reports from Laboratories:** Requirements from Physics Experiments - Colliders: EIC, ILC, CLIC, FCC-ee. –hh, Alice-3, CEPC, SPPC, MC, and others - Non-colliders: BabyIAXO, Panda, MadMax, Muon experiments, and others
13th	**Reports from Industry:** Experiences and Future Scope - Superconductor (with Al/Cu stabilizer) - Coil winding and magnet assembly, including cryostating - Specific technology Discussions --- Dinner ---
14th	**Discussions:** Laboratory and Industry cooperation to be re-established - Al-stabilized superconductor and alternate conductor (CICC, HTS and ….) - - Next actions **Summary**

1st day a.m.: Reports from Projects



08:00

Registra | onnie Potter, Nikkie Deelen
40/S2-A01 - Salle Anderson, CERN | 08:15 - 08:45

Welcome Address | *Joachim Josef Mnich*
40/S2-A01 - Salle Anderson, CERN | 08:45 - 09:00

09:00

Opening Address | *Matthias Mentink et al.*
40/S2-A01 - Salle Anderson, CERN | 09:00 - 09:10

Program Overview | *Prof. Akira Yamamoto*
40/S2-A01 - Salle Anderson, CERN | 09:10 - 09:20

The Electron-Ion Collider (EIC) | *Renuka Rajput-Ghoshal*
40/S2-A01 - Salle Anderson, CERN | 09:20 - 09:50

10:00

International Linear Collider - ILD (ILC-ILD) | *Karsten Buesser et al.*
40/S2-A01 - Salle Anderson, CERN | 09:50 - 10:20

Internation Linear Collider - SiD (ILC-SiD) | *Tom Markiewicz et al.*
40/S2-A01 - Salle Anderson, CERN | 10:20 - 10:50

Coffee Break
40/S2-A01 - Salle Anderson, CERN | 10:50 - 11:20

11:00

Compact Linear Collider (CLiC) | *Benoit Cure*
40/S2-A01 - Salle Anderson, CERN | 11:20 - 11:45

Lepton Future Circular Collider (FCC-ee) | *Dr Nikkie Deelen*
40/S2-A01 - Salle Anderson, CERN | 11:45 - 12:10

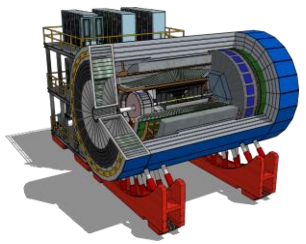
12:00

Hadron Future Circular Collider (FCC-hh) | *Matthias Mentink*
40/S2-A01 - Salle Anderson, CERN | 12:10 - 12:35

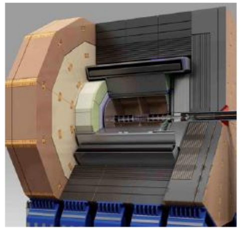
Circular Electron Positron Collider (CEPC) | *Dr Feipeng NING*
40/S2-A01 - Salle Anderson, CERN | 12:35 - 13:00

13:00

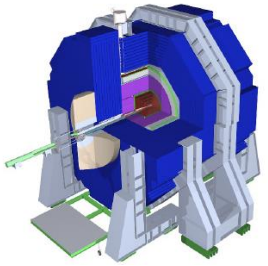
Lunch



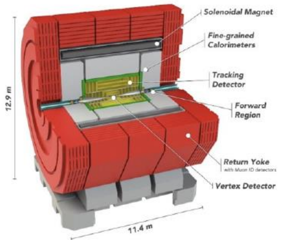
EIC



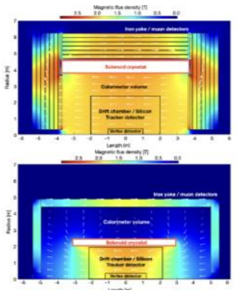
ILC-ILD



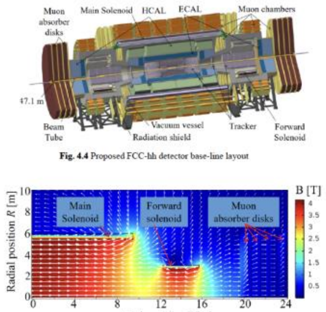
ILC-SiD



CLIC



FCC-ee



FCC-hh

CEPC

1st day, p.m.: Reports from Projects

14:00

CERN 13:00 - 14:15

A Large Ion Collider Experiment 3 (ALICE-3) *Werner Riegler*
40/S2-A01 - Salle Anderson, CERN 14:15 - 14:40

Mu2e *Michael Lamm*
40/S2-A01 - Salle Anderson, CERN 14:40 - 15:05

15:00

Muon experiments in Japan *Ken-ichi Sasaki et al.*
40/S2-A01 - Salle Anderson, CERN 15:05 - 15:30

antiProton ANihilation at DArmstadt (PANDA) *Lars Schmitt*
40/S2-A01 - Salle Anderson, CERN 15:30 - 15:55

16:00

Coffee Break
40/S2-A01 - Salle Anderson, CERN 15:55 - 16:15

Baby International Axion Observatory (BabyIAXO) *Uwe Schneekloth*
40/S2-A01 - Salle Anderson, CERN 16:15 - 16:40

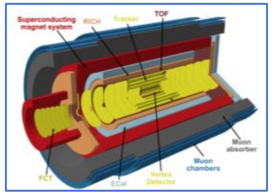
MAgnetized Disc and Mirror Axion eXperiment (MADMAX) *Walid ABDEL MAKSOUD*
40/S2-A01 - Salle Anderson, CERN 16:40 - 17:05

17:00

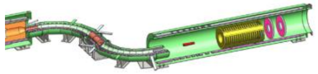
Alpha Magnetic Spectrometer 100 - (AMS-100) *Dr Tim Mulder et al.*
40/S2-A01 - Salle Anderson, CERN 17:05 - 17:30

General Discussion *Lionel Quettier et al.*
40/S2-A01 - Salle Anderson, CERN 17:30 - 18:00

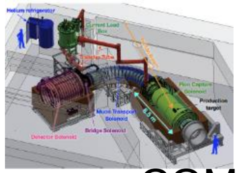
18:00



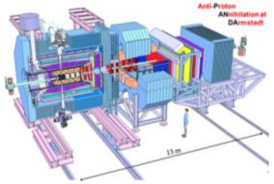
ALIICE-3



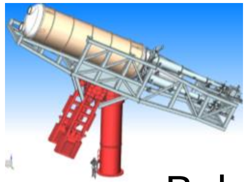
Mu2e



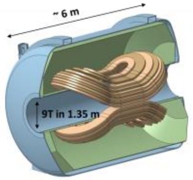
COMET



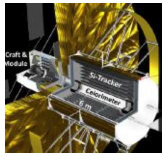
PANDA



BabyIAX0



MadMAX



AMS100

2nd day, a.m.: Reports from Industry

Furukawa Electric *Hisaki Sakamoto et al.*
40/S2-A01 - Salle Anderson, CERN 08:30 - 08:50

~~Luvata (TO BE CONFIRMED)~~
40/S2-A01 - Salle Anderson, CERN 08:50 - 09:10

09:00

The European industrial status on the superconductor manufacturing - Discussion *Dr Amalia Ballarino*
40/S2-A01 - Salle Anderson, CERN 09:10 - 09:30

ICAS *Dr Luigi Muzzi*
40/S2-A01 - Salle Anderson, CERN 09:30 - 09:50

Wuxi Toly Electric Works Co.,Ltd. *Yu Zhao*
40/S2-A01 - Salle Anderson, CERN 09:50 - 10:10

10:00

Coffee Break
40/S2-A01 - Salle Anderson, CERN 10:10 - 10:30

Status Report on Coextrusion Facilities in Europe for Detector Magnet Superconductors *Benoit Cure*
40/S2-A01 - Salle Anderson, CERN 10:30 - 10:50

Techmeta *Peter Oving*
40/S2-A01 - Salle Anderson, CERN 10:50 - 11:10

11:00

Hitachi *Tomoyuki Semba*
40/S2-A01 - Salle Anderson, CERN 11:10 - 11:30

Toshiba *Shohei Takami*
40/S2-A01 - Salle Anderson, CERN 11:30 - 11:50

Mitsubishi Electric *Hiroyuki Horii*
40/S2-A01 - Salle Anderson, CERN 11:50 - 12:10

12:00

Lunch

p.m.: Reports from Industry + a Proposal

14:00

GE Alstom *Marc Nusbaum*
40/S2-B01 - Salle Bohr, CERN 14:00 - 14:20

Bilfinger Noell *Mr Michael Gehring*
40/S2-B01 - Salle Bohr, CERN 14:20 - 14:40

ASG *Antonio Pellecchia*
40/S2-B01 - Salle Bohr, CERN 14:40 - 15:00

15:00

SAES RIAL *Carlo Santini*
40/S2-B01 - Salle Bohr, CERN 15:00 - 15:20

Group photograph and Coffee Break
40/S2-B01 - Salle Bohr, CERN 15:20 - 15:50

16:00

Sigma-Phi *Frederick Forest*
40/S2-B01 - Salle Bohr, CERN 15:50 - 16:10

MgB2 *Riccardo Musenich*
40/S2-B01 - Salle Bohr, CERN 16:10 - 16:30

Discussion session *Prof. Akira Yamamoto*

17:00

40/S2-B01 - Salle Bohr, CERN 16:30 - 17:30

3rd day, a.m.: Strategic Discussions for Future

Development of advanced Al stabilized SC - Part 1	*Dr Stefano Sgobba*	*40/S2-B01 - Salle Bohr, CERN*	08:30 - 08:50
Development of advanced Al stabilized SC - Part 2	*Benoit Cure*	*40/S2-B01 - Salle Bohr, CERN*	08:50 - 09:10
Summary of the Al-stabilized SC requirements	*Yasuhiro Makida*	*40/S2-B01 - Salle Bohr, CERN*	09:10 - 09:30
Comments and advice from Industry: Furukawa	*Hisaki Sakamoto*	*40/S2-B01 - Salle Bohr, CERN*	09:30 - 09:50
Comments and advice from industry: Techmeta	*Peter Oving*	*40/S2-B01 - Salle Bohr, CERN*	09:50 - 10:10
Coffee break		*40/S2-B01 - Salle Bohr, CERN*	10:10 - 10:30
Discussions on alternative SC : CICC experiences in ITER	*Neil Mitchell*	*40/S2-B01 - Salle Bohr, CERN*	10:30 - 10:50
Comments and advice from Industry		*40/S2-B01 - Salle Bohr, CERN*	10:50 - 11:00
Discussions and comments on HTS	*Toru Ogitsu*	*40/S2-B01 - Salle Bohr, CERN*	11:00 - 11:15
Challenge of HTS for future accelerator magnets	*Dr Amalia Ballarino*	*40/S2-B01 - Salle Bohr, CERN*	11:15 - 11:30
General Discussions on Future Prospect and global cooperation	*Prof. Akira Yamamoto et al.*	*40/S2-B01 - Salle Bohr, CERN*	11:30 - 12:20
Closing remarks	*Toru Ogitsu*	*40/S2-B01 - Salle Bohr, CERN*	12:20 - 12:30

← (to be added) Comment and Discusssion on aa aternate: Soldering …. CERN-MME

Al-stabilized SC:

- No industrial production available, as current status,
- Development to be resumed
  - Urgent requests from EIC, BabyIAXO, …
- Laboratory-Industry cooperation inevitable. For
  - **Co-extrusion** technology and/or
  - Soldering technology as backup

Alternate SC:

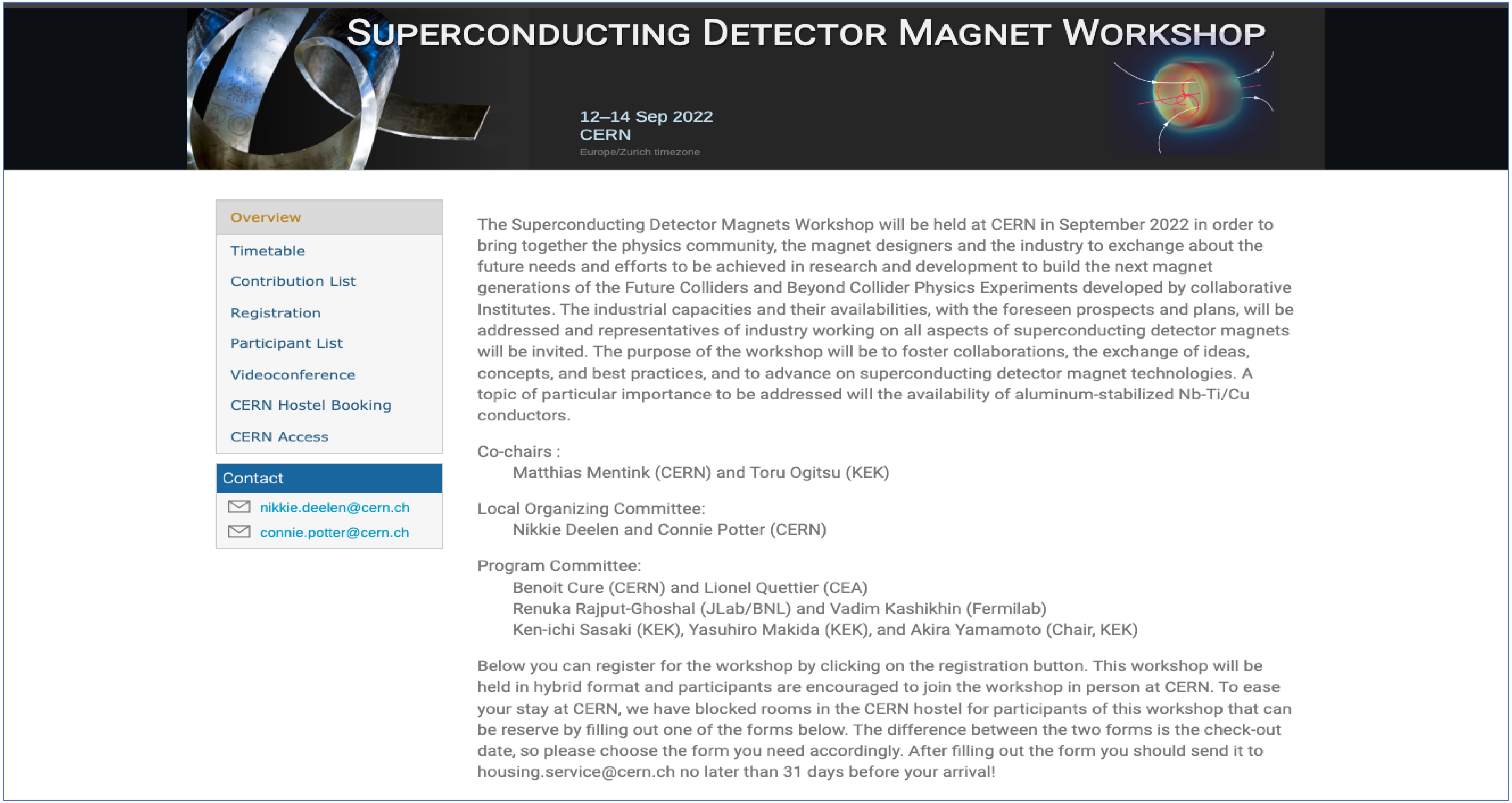
- **CICC**
  - It may be applicable in most detector solenoid design, if no request of "transparency".
  - A proposal to apply CICC to ILC-SiD, with no request for "transparency.
  - It is Important to study the feasibility, and to learn experiences integrated in the ITER project.
- **HTS**
  - HTS application proposed by AMS-100,
  - The feasibility to be investigated.

Session conveners

-

Day 1:	AM	1st session:	Benoit Cure
		2nd session:	Ken-ichi Sasaki
	PM	1st session:	Renuka Rajput-Ghoshal
		2nd session:	Lionel Quettier
Day 2:	AM	1st session:	Yasuhiro Makida
		2nd session:	Nikkie Deelen
	PM	1st session:	Vadim Kashkhin
		2nd session:	Toru Ogitsu
Day 3:	AM	1st session:	Matthias Mentink
		2nd session:	Akira Yamamoto

Bakup



SUPERCONDUCTING DETECTOR MAGNET WORKSHOP

12–14 Sep 2022
CERN
Europe/Zurich timezone

The Superconducting Detector Magnets Workshop will be held at CERN in September 2022 in order to bring together the physics community, the magnet designers and the industry to exchange about the future needs and efforts to be achieved in research and development to build the next magnet generations of the Future Colliders and Beyond Collider Physics Experiments developed by collaborative Institutes. The industrial capacities and their availabilities, with the foreseen prospects and plans, will be addressed and representatives of industry working on all aspects of superconducting detector magnets will be invited. The purpose of the workshop will be to foster collaborations, the exchange of ideas, concepts, and best practices, and to advance on superconducting detector magnet technologies. A topic of particular importance to be addressed will the availability of aluminum-stabilized Nb-Ti/Cu conductors.

Co-chairs :
Matthias Mentink (CERN) and Toru Ogitsu (KEK)

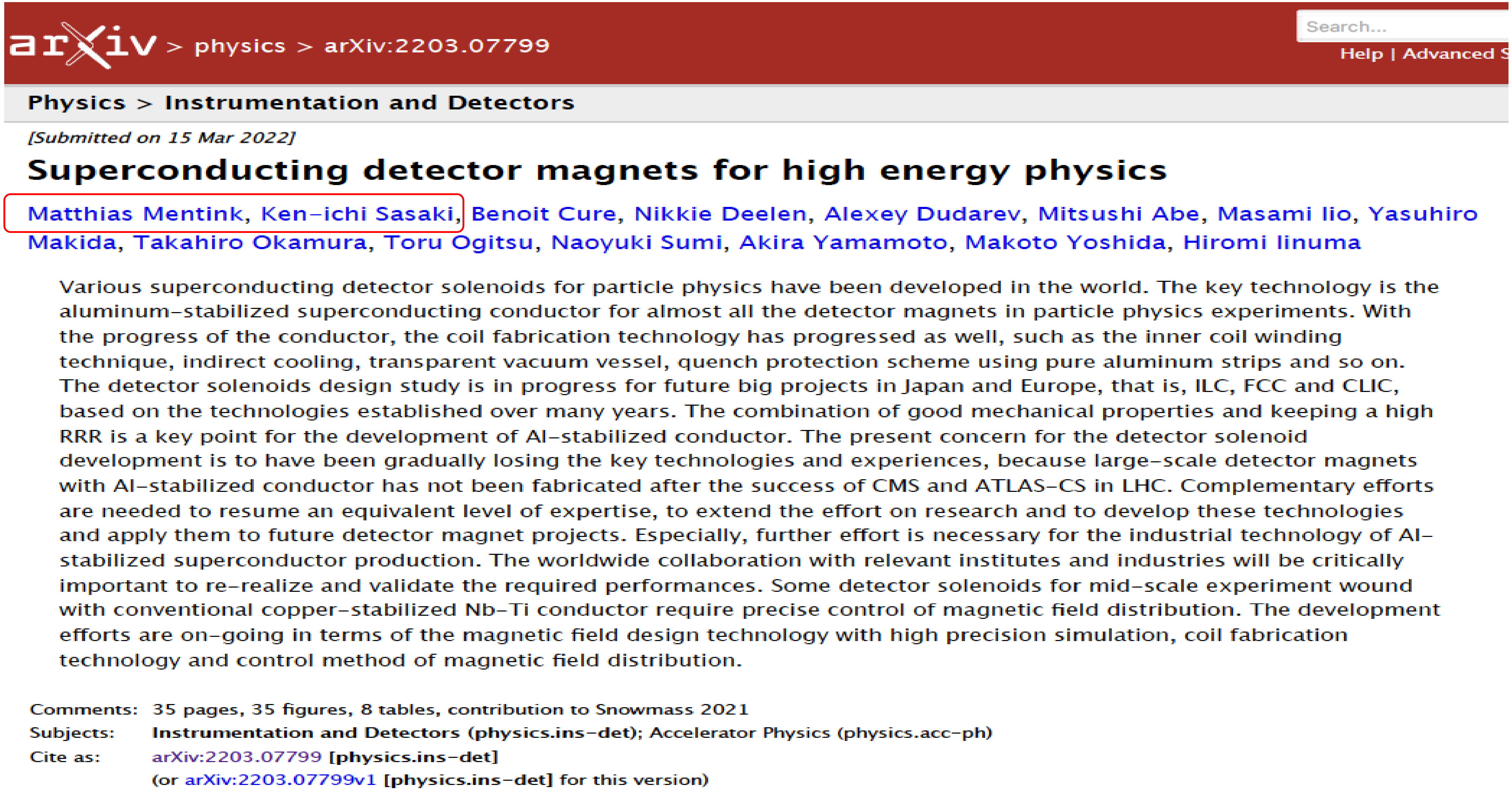
Local Organizing Committee:
Nikkie Deelen and Connie Potter (CERN)

Program Committee:
Benoit Cure (CERN) and Lionel Quettier (CEA)
Renuka Rajput-Ghoshal (JLab/BNL) and Vadim Kashikhin (Fermilab)
Ken-ichi Sasaki (KEK), Yasuhiro Makida (KEK), and Akira Yamamoto (Chair, KEK)

Below you can register for the workshop by clicking on the registration button. This workshop will be held in hybrid format and participants are encouraged to join the workshop in person at CERN. To ease your stay at CERN, we have blocked rooms in the CERN hostel for participants of this workshop that can be reserve by filling out one of the forms below. The difference between the two forms is the check-out date, so please choose the form you need accordingly. After filling out the form you should send it to housing.service@cern.ch no later than 31 days before your arrival!

https://indico.cern.ch/event/1162992/

SnowMass White Paper Submission



Physics > Instrumentation and Detectors

[Submitted on 15 Mar 2022]

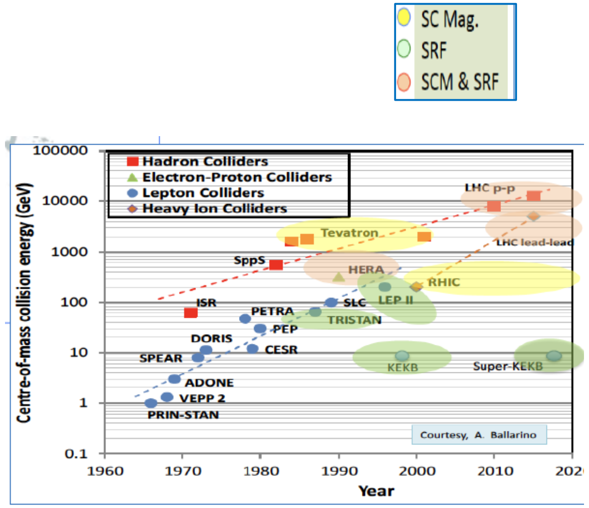
Superconducting detector magnets for high energy physics

Matthias Mentink, Ken-ichi Sasaki, Benoit Cure, Nikkie Deelen, Alexey Dudarev, Mitsushi Abe, Masami Iio, Yasuhiro Makida, Takahiro Okamura, Toru Ogitsu, Naoyuki Sumi, Akira Yamamoto, Makoto Yoshida, Hiromi Iinuma

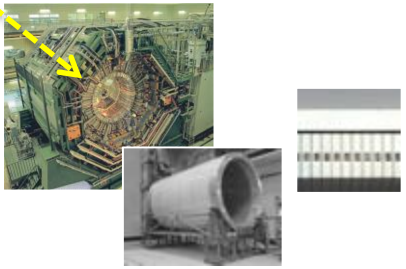
Various superconducting detector solenoids for particle physics have been developed in the world. The key technology is the aluminum-stabilized superconducting conductor for almost all the detector magnets in particle physics experiments. With the progress of the conductor, the coil fabrication technology has progressed as well, such as the inner coil winding technique, indirect cooling, transparent vacuum vessel, quench protection scheme using pure aluminum strips and so on. The detector solenoids design study is in progress for future big projects in Japan and Europe, that is, ILC, FCC and CLIC, based on the technologies established over many years. The combination of good mechanical properties and keeping a high RRR is a key point for the development of Al-stabilized conductor. The present concern for the detector solenoid development is to have been gradually losing the key technologies and experiences, because large-scale detector magnets with Al-stabilized conductor has not been fabricated after the success of CMS and ATLAS-CS in LHC. Complementary efforts are needed to resume an equivalent level of expertise, to extend the effort on research and to develop these technologies and apply them to future detector magnet projects. Especially, further effort is necessary for the industrial technology of Al-stabilized superconductor production. The worldwide collaboration with relevant institutes and industries will be critically important to re-realize and validate the required performances. Some detector solenoids for mid-scale experiment wound with conventional copper-stabilized Nb-Ti conductor require precise control of magnetic field distribution. The development efforts are on-going in terms of the magnetic field design technology with high precision simulation, coil fabrication technology and control method of magnetic field distribution.

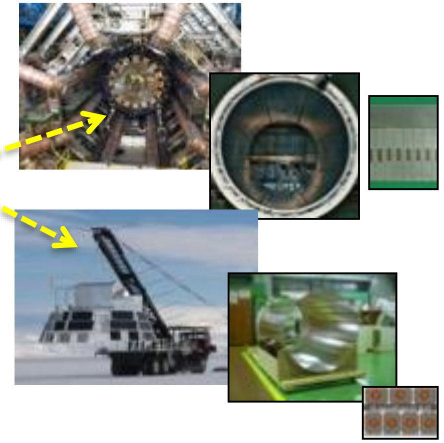
Comments: 35 pages, 35 figures, 8 tables, contribution to Snowmass 2021
Subjects: Instrumentation and Detectors (physics.ins-det); Accelerator Physics (physics.acc-ph)
Cite as: arXiv:2203.07799 [physics.ins-det]
(or arXiv:2203.07799v1 [physics.ins-det] for this version)

History of Detector Solenoids

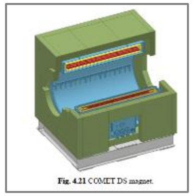


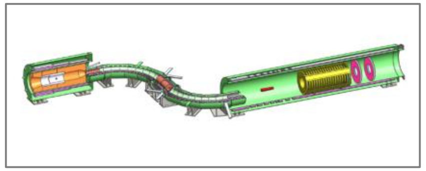
Experiment	Laboratory	R (m)	B (T)	I (kA)	X (X_0)	E/M (kJ/kg)	E (MJ)	Year
PLUTO	DESY	0.75	2.2	1.3	4.0	2.3	4.1	1972
ISR point 1	CERN	0.85	1.5	2	1.1	1.8	3.0	1977
CELLO	Saclay/DESY	0.85	1.5	3	0.6	5.0	7.0	1978
PEP4/TPC	LBL/SLAC	1.1	1.5	2.27	0.83	7.6	11	1983
CDF	KEK/FNAL	1.5	1.6	5	0.84	5.4	30	1984
TOPAZ	KEK	1.45	1.2	3.65	0.70	4.3	19	1984
VENUS	KEK	1.75	0.75	4	0.52	2.8	11.7	1985
AMY	KEK	1.2	3	5	N/A	N/A	40	1985
CLEO-II	Cornell	1.55	1.5	3.3	2.5	3.7	25	1988
ALEPH	Saclay/CERN	2.75	1.5	5	2.0	5.5	136	1987
DELPHI	RAL/CERN	2.8	1.2	5	1.7	4.2	110	1988
ZEUS	INFN/DESY	1.5	1.8	5	0.9	5.2	10.5	1988
H1	RAL/DESY	2.8	1.2	5	1.8	4.8	120	1990
BESS	KEK	0.5	1.2	0.38	0.2	6.6	0.25	1990
WASA	KEK/Uppsala	0.25	1.3	0.9	0.18	6	0.12	1996
BABAR	INFN/SLAC	1.5	1.5	6.83	0.5	N/A	27	1997
D0	FNAL	0.6	2.0	4.85	0.9	3.7	5.6	1998
BELLE	KEK	1.8	1.5	4.16	N/A	5.3	37	1998
ATLAS-CS	KEK/CERN	1.25	2.0	7.8	0.66	7.1	38	2001
BESS-polar	KEK	0.45	1.0	0.48	0.156	9.2	0.34	2005
CMS	CMS/CERN	3.0	4.0	19.5	N/A	12	2600	2007
BESIII	IHEP (China)	1.45	1.0	5	N/A	2.6	9.5	2008
CMD-3	BINP	0.35	1.5	1	0.085	8.2	0.31	2009



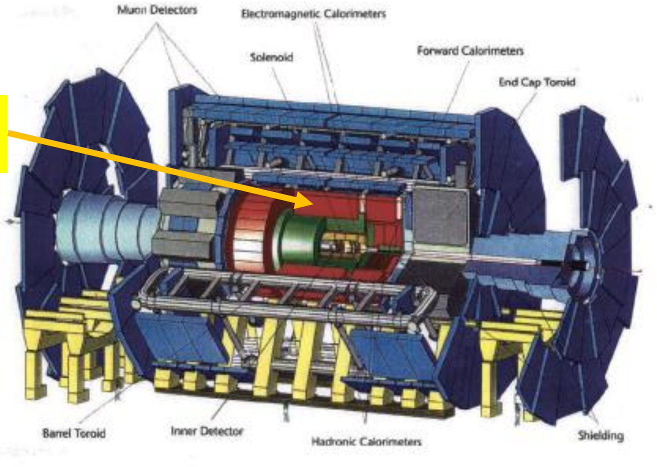


COMET (KEK) --- under construction, AL-stab. SC in 2013-2015
Mu2e (Fermilab) --- under construction, Al-stab SC in same time





Solenoid

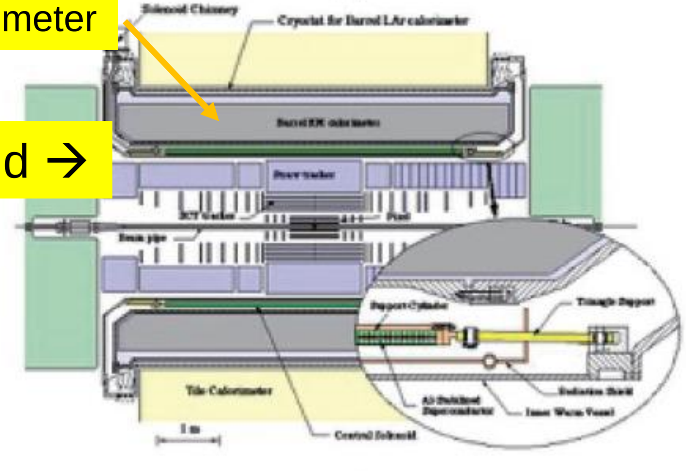


(a)

(b)

Calorimeter

Solenoid →



(c)

ATLAS-CS, placed inside Calorimeter

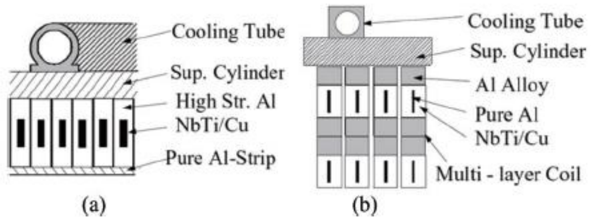


図 19　ATLAS および CMS 超伝導ソレノイドコイル断面図.

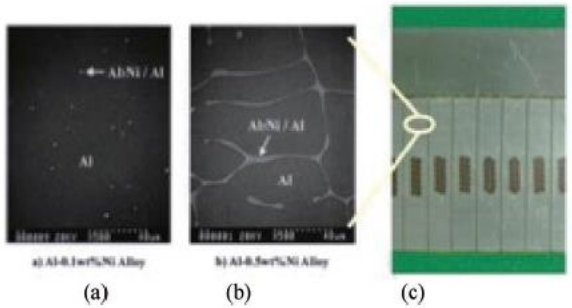
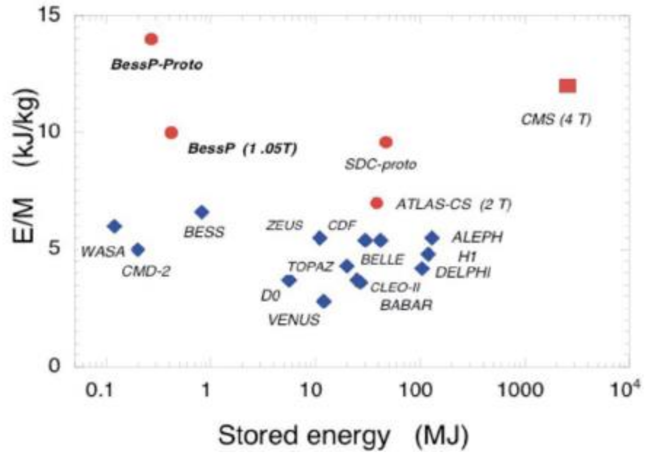


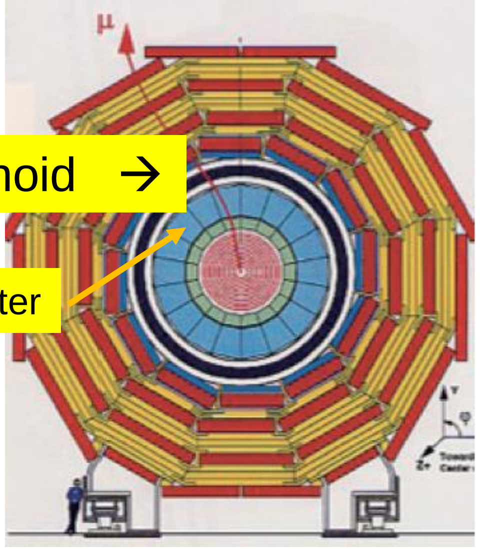
図 20　Ni 添加による Al-Ni 析出（(a) 100 ppm,（b) 500 ppm), および ATLAS アルミ安定化超伝導コイル断面.



Solenoid

Solenoid →

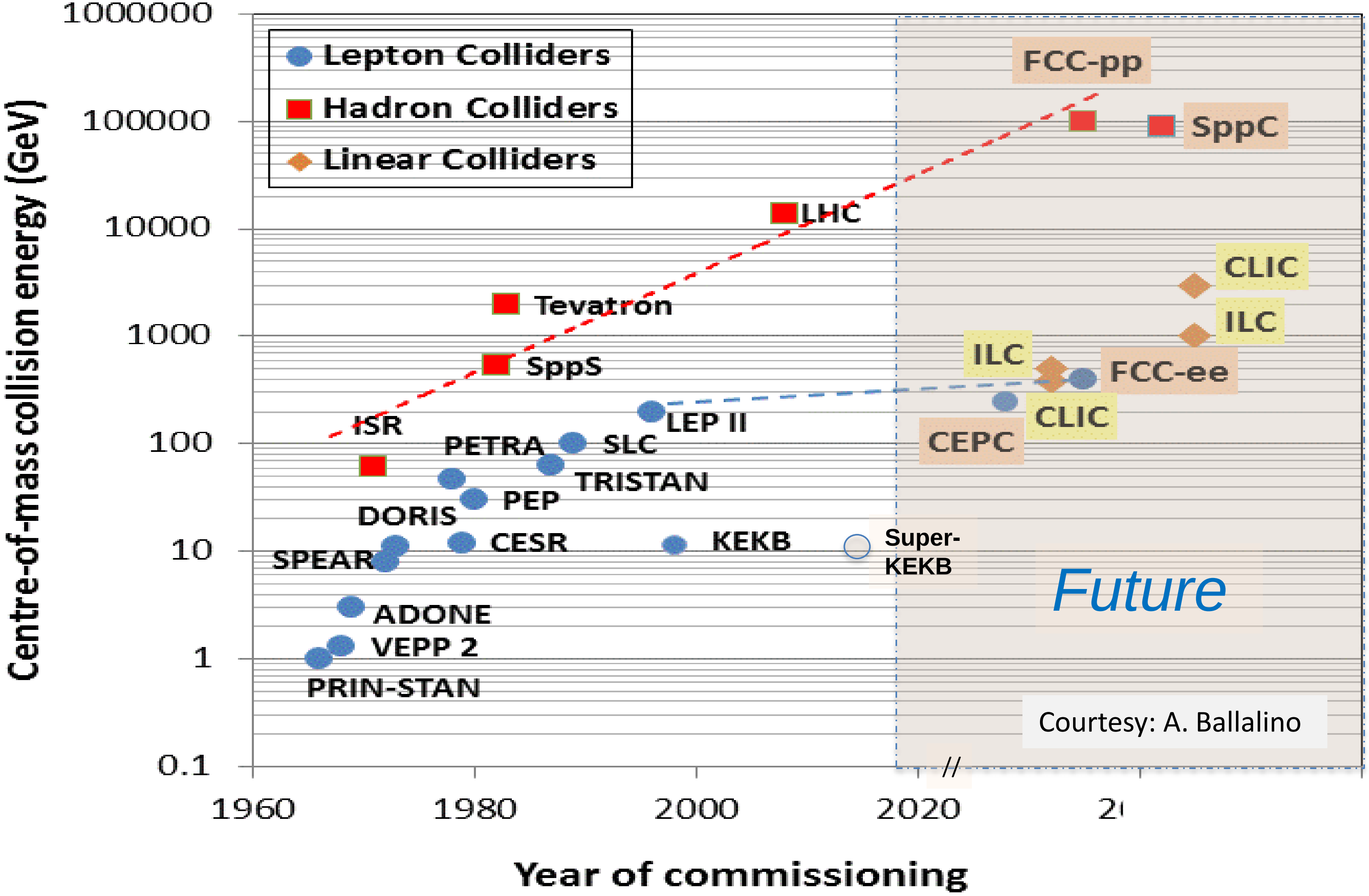
Calorimeter



CMS Solenoid placed outside alorimeter

Future Energy-Frontier Colliders expected

粒子加速器の将来計画



Courtesy: A. Ballalino

A. Yamamoto, 2022/9/7

Future Colliders based on SC Technology (See full list in next pages)

Linear Colliders:

ILC e+e- (250 GeV → 1 TeV) :

- **SRF:** for High-Q (10^{10}) and high-G (31.5 MV/m)
- Highest efficiency and AC-power balance

CLIC e+e- (380 GeV → 3 TeV) :

- **NRF:** Very high G (100 MV/m) for energy frontier with compactness

Circular Colliders :

FCC-e+e- (90 → 350 GeV):

- **SRF:** with staging for efficient energy extension
  - Synchrotron radiation (SR) to determine the energy
- Highest luminosity at Z and H,

FCC-pp (2 x 50 TeV):

- High-field SC magnets (SCM: 16 T) for energy frontier
- **SRF:** for acceleration for good energy balance w/ SR

CEPC e+e- (2 x 120 GeV):

- **SRF:** for acceleration,
  - Synchrotron radiation to determine the energy

SPPC- pp (75 TeV):

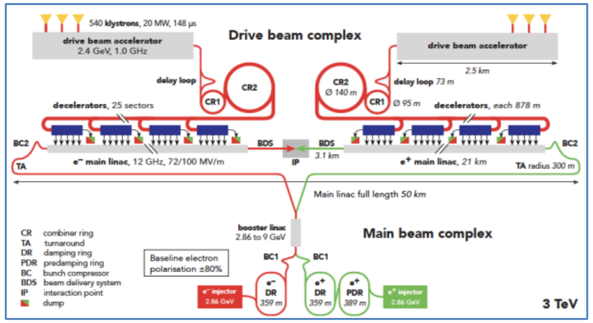
- High-field SCM (12 T) for energy frontier
- **SRF:** beam acceleration

(EIC Ion•e-(275/100 GeV/n v.s. 18 GeV, under constr.)

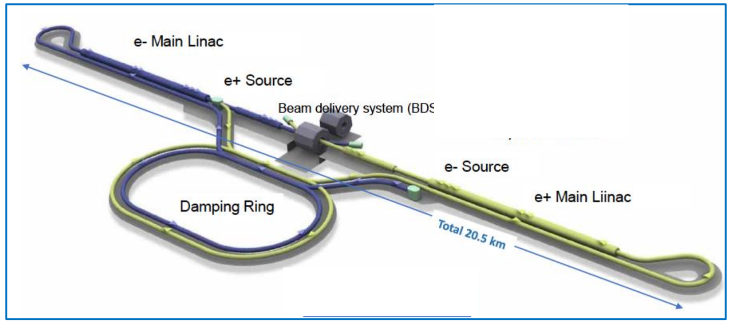
- **SCM and SRF**

MC μ+μ– (3 – 14 TeV)

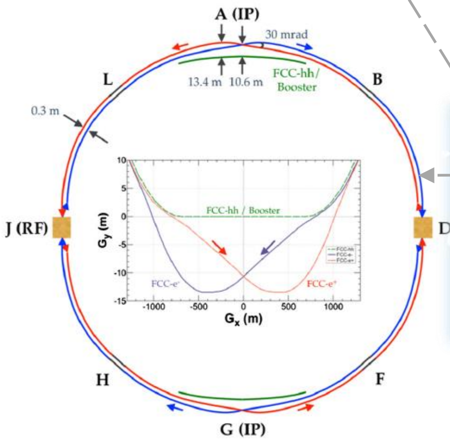
- SRF and NRF with very high-field SCM
- Higher efficiency at > 3 TeV, although short life-time.



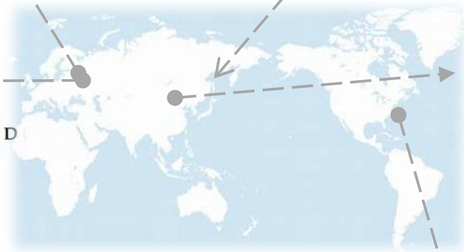
CLIC

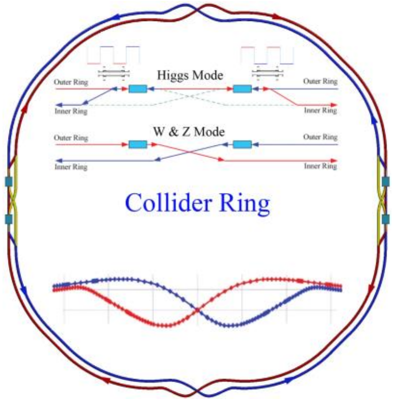


ILC

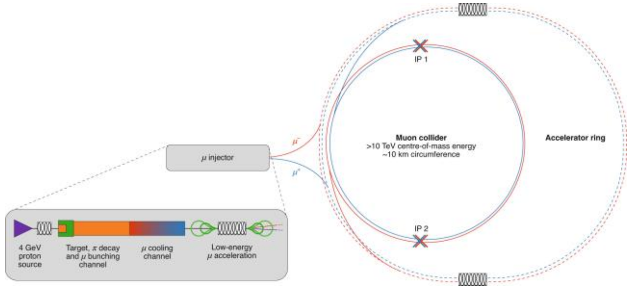


FCC-ee/-hh

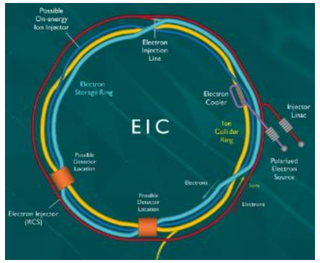




CEPC/SPPC



MC



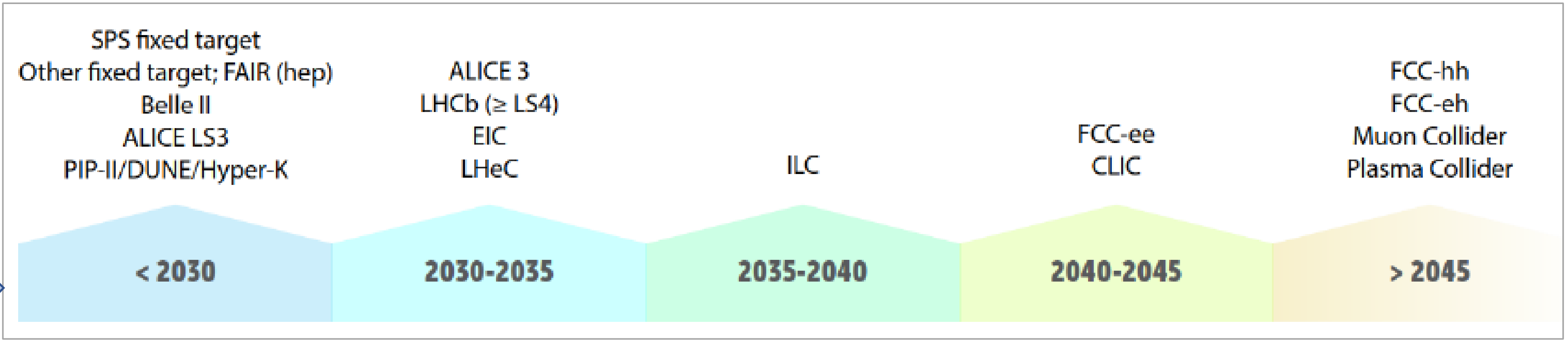
EIC

<u>Future</u> Colliders and Physics Experiments anticipated

Future particle physics experiments being studied: from LDG Accelerator R&D Report, CERN 2022-001

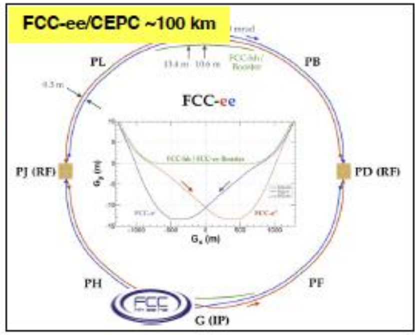
COMET
Mu2e

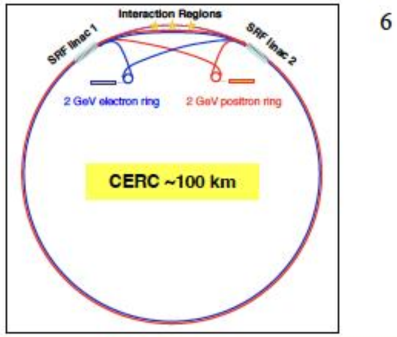
2007 ～ 2022

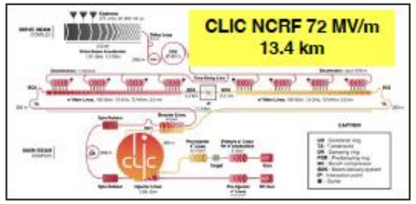


Other phys. Experiments: Mu2e, G-2 (fnal), Comet, G-2)J-Parc), BabyAXIO, AXIO (desy)

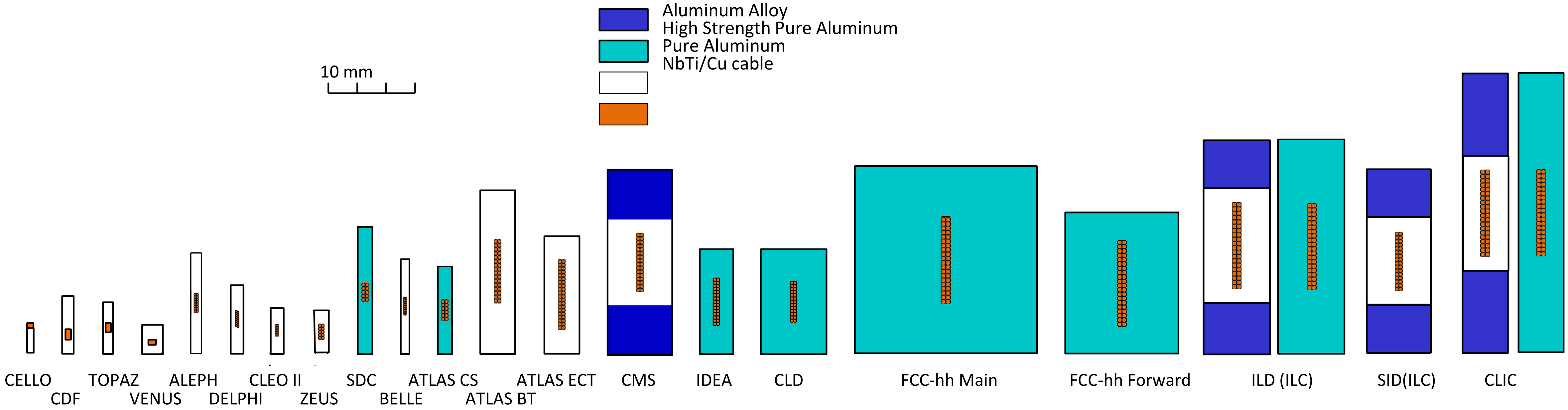
- **Colliders:** <u>ILC</u>, <u>CLIC</u>, <u>FCC-ee</u>, <u>-hh</u>, -eh, Panda (?), <u>EIC</u>, MC, and others (CEPC, SPPS, …)
- **Non-Colliders;** <u>Muon Beam</u> Experiments, <u>Axion-Observatory</u> (BabyIAXO), and others (….)
- Others ?





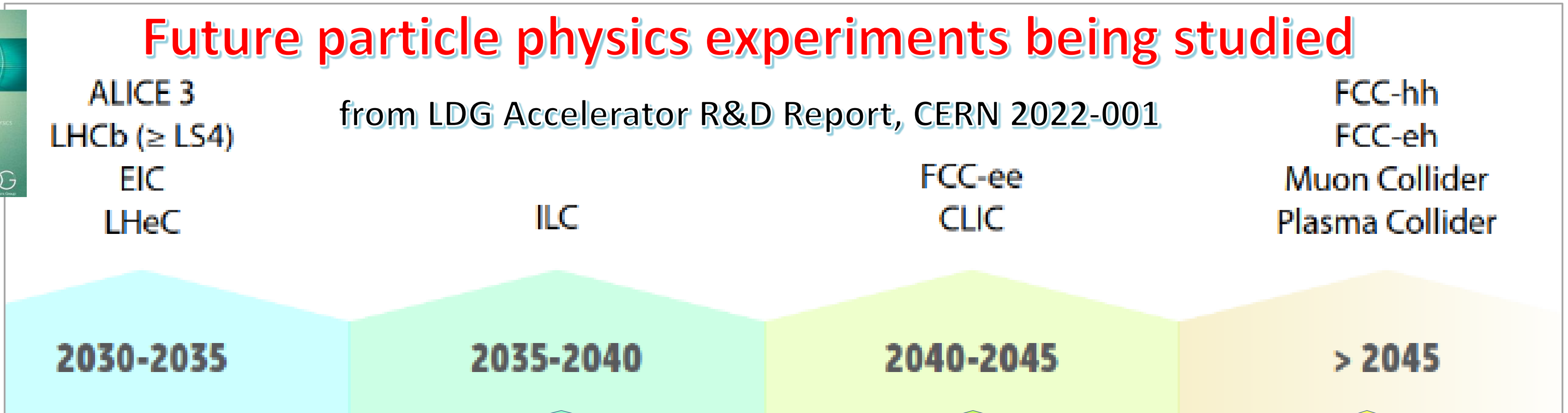


Courtesy: Y. Makida



Future Colliders and Conductor Demand

Courtesy: Y. Makida

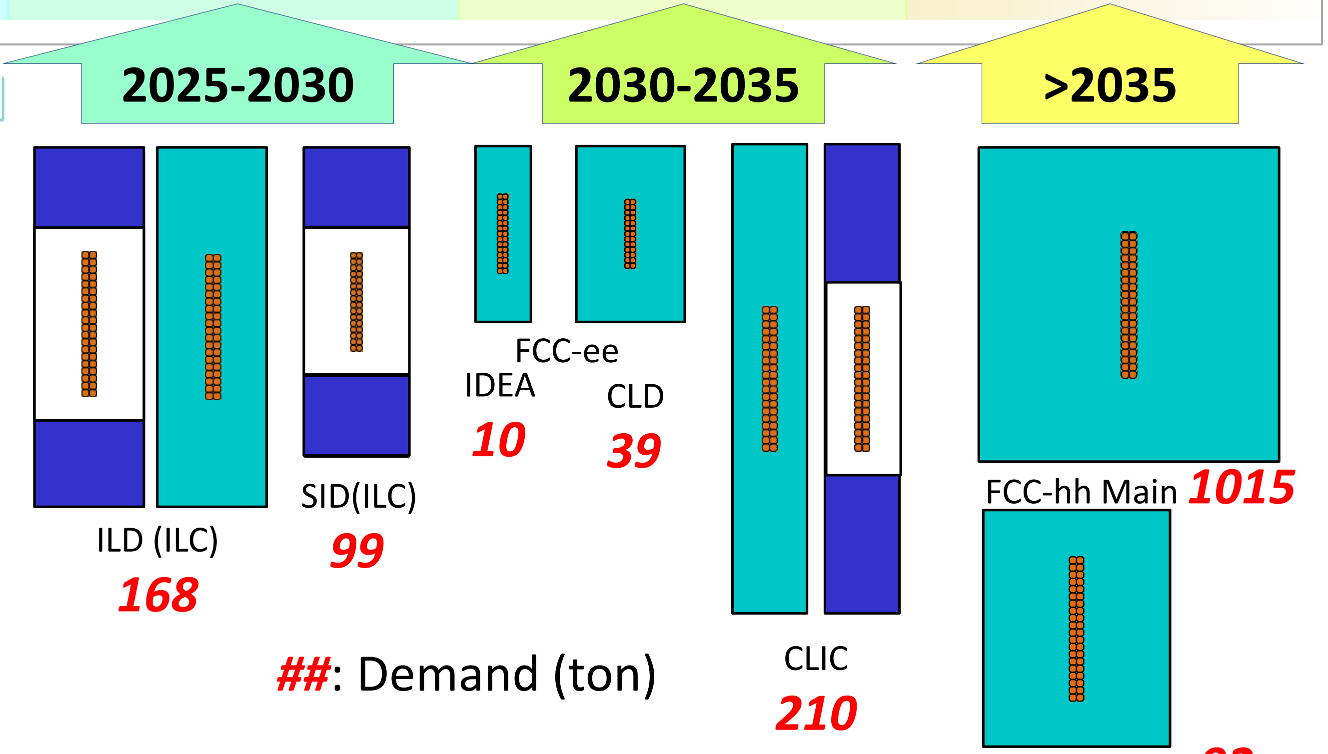


Future particle physics experiments being studied

from LDG Accelerator R&D Report, CERN 2022-001

2030-2035	2035-2040	2040-2045	> 2045
ALICE 3 LHCb (≥ LS4) EIC LHeC	ILC	FCC-ee CLIC	FCC-hh FCC-eh Muon Collider Plasma Collider

Conductor Demand



2025-2030

2030-2035

>2035

ILD (ILC) ***168***

SID(ILC) ***99***

FCC-ee

IDEA ***10***

CLD ***39***

CLIC ***210***

FCC-hh Main ***1015***

FCC-hh Forward ***92***

##: Demand (ton)

A Critical Issue: Al-stabilized Superconductor

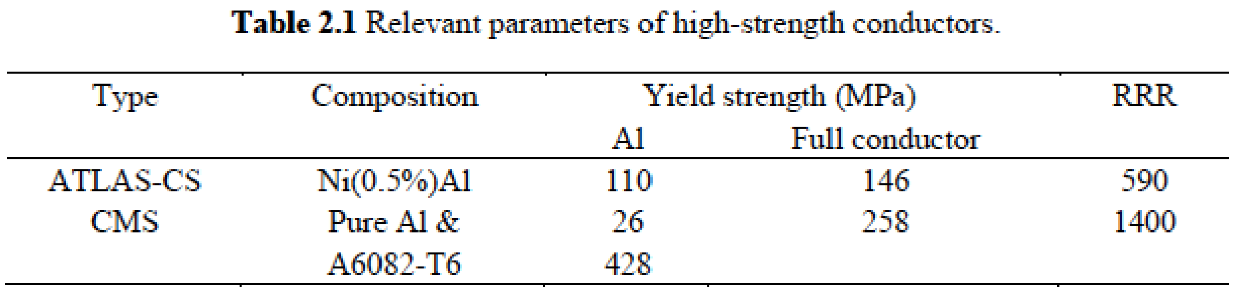
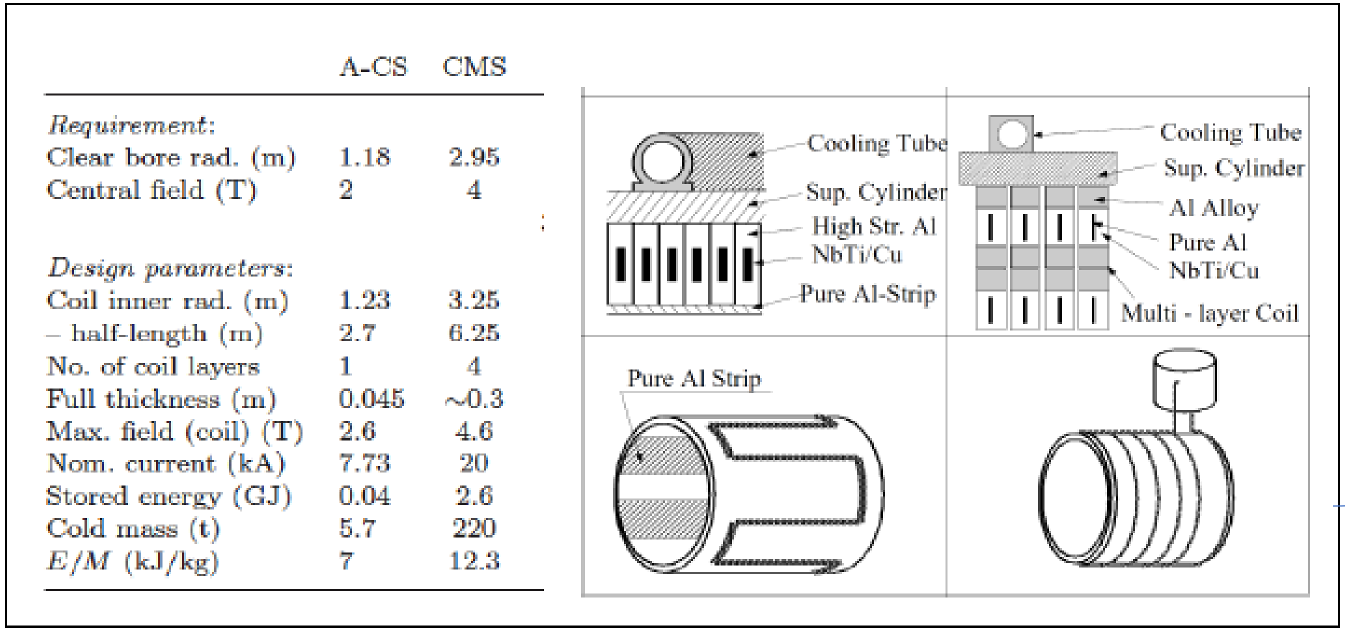


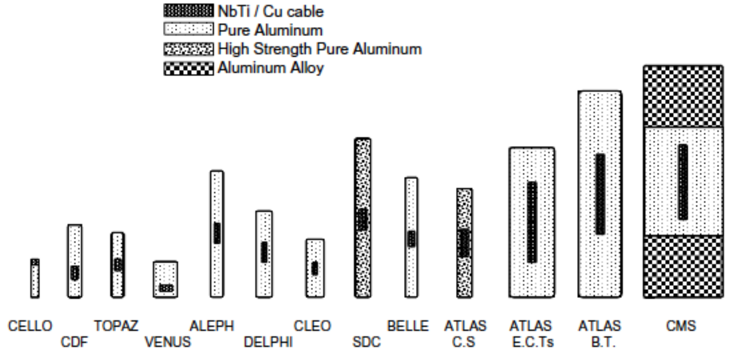
Table 2.1 Relevant parameters of high-strength conductors.

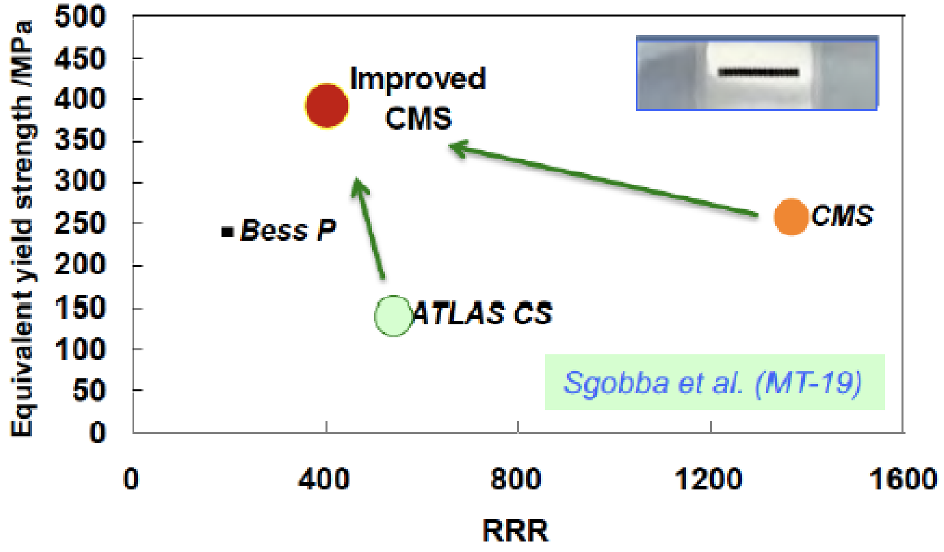
Type	Composition	Yield strength (MPa)		RRR
		Al	Full conductor	
ATLAS-CS	Ni(0.5%)Al	110	146	590
CMS	Pure Al & A6082-T6	26 428	258	1400



	A-CS	CMS
Requirement:		
Clear bore rad. (m)	1.18	2.95
Central field (T)	2	4
Design parameters:		
Coil inner rad. (m)	1.23	3.25
– half-length (m)	2.7	6.25
No. of coil layers	1	4
Full thickness (m)	0.045	~0.3
Max. field (coil) (T)	2.6	4.6
Nom. current (kA)	7.73	20
Stored energy (GJ)	0.04	2.6
Cold mass (t)	5.7	220
E/M (kJ/kg)	7	12.3

Fig. 1.1 Detector solenoids experienced in LHC





Sgobba et al. (MT-19)

Another Alternates?

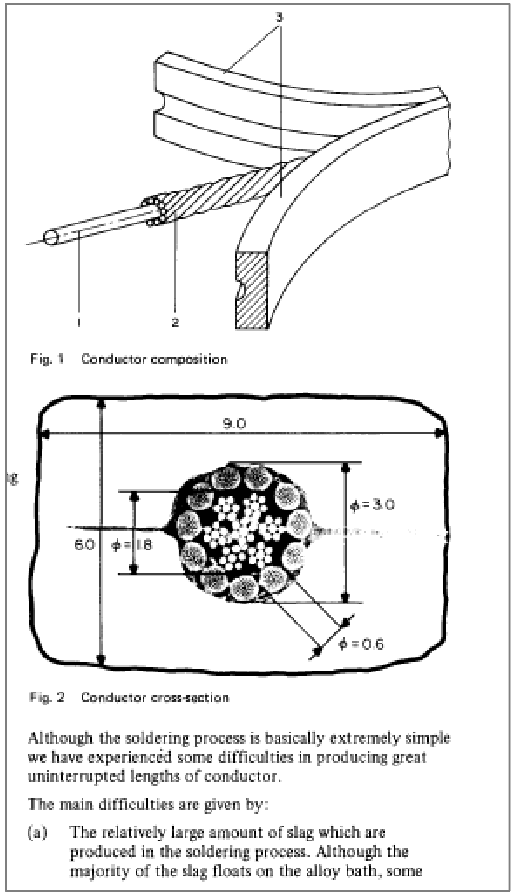


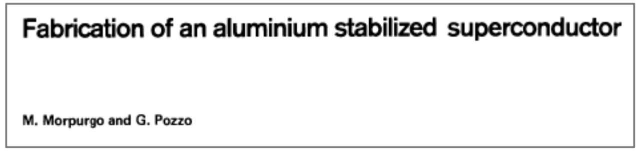
Fig. 1 Conductor composition

Fig. 2 Conductor cross-section

Although the soldering process is basically extremely simple we have experienced some difficulties in producing great uninterrupted lengths of conductor.

The main difficulties are given by:

(a) The relatively large amount of slag which are produced in the soldering process. Although the majority of the slag floats on the alloy bath, some

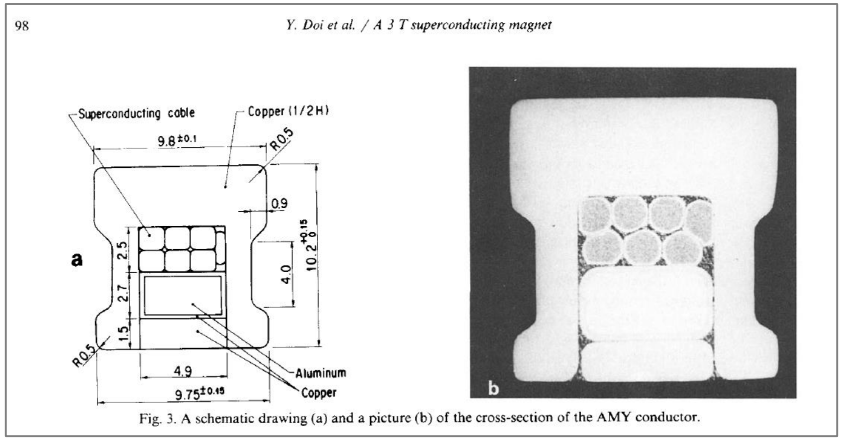


Fabrication of an aluminium stabilized superconductor

M. Morpurgo and G. Pozzo

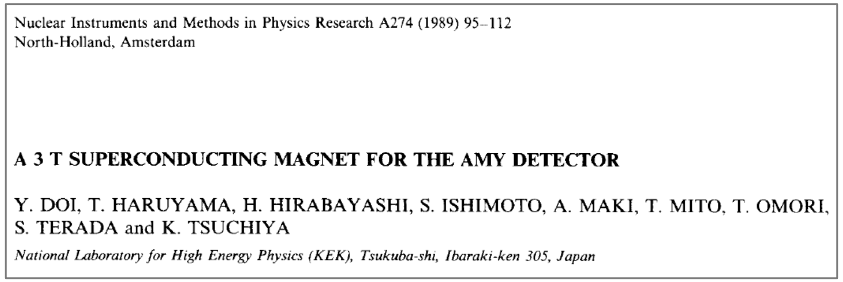
CRYOGENICS . FEBRUARY 1977

p87



98 *Y. Doi et al. / A 3 T superconducting magnet*

Fig. 3. A schematic drawing (a) and a picture (b) of the cross-section of the AMY conductor.

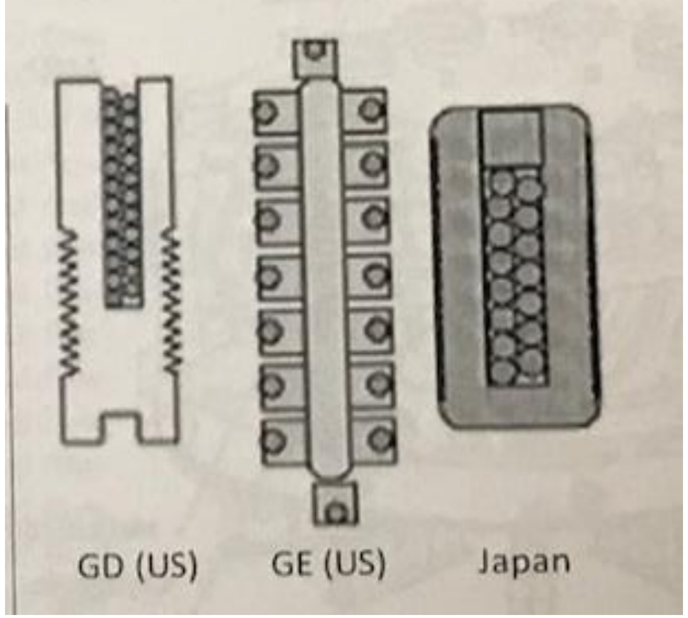


Nuclear Instruments and Methods in Physics Research A274 (1989) 95–112
North-Holland, Amsterdam

A 3 T SUPERCONDUCTING MAGNET FOR THE AMY DETECTOR

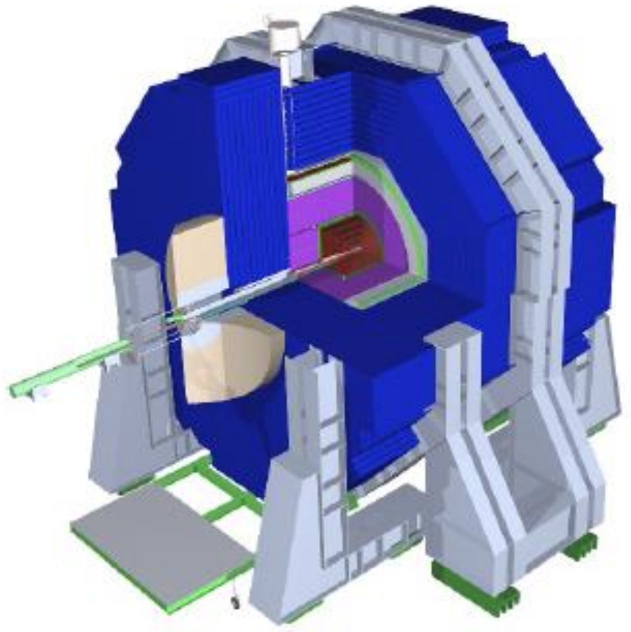
Y. DOI, T. HARUYAMA, H. HIRABAYASHI, S. ISHIMOTO, A. MAKI, T. MITO, T. OMORI, S. TERADA and K. TSUCHIYA

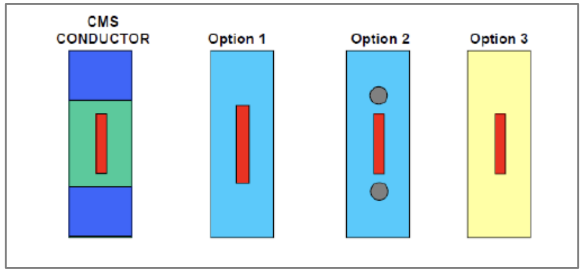
National Laboratory for High Energy Physics (KEK), Tsukuba-shi, Ibaraki-ken 305, Japan



A._Yamamoto and T. Taylor
RAST, V.5 (2012) p91.
(SC for Large Coil Task for Fusion)
Cu-Stabilized SC with soldering

Al-stabilized SC or Alternates for SiD ?





or