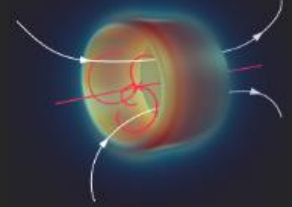


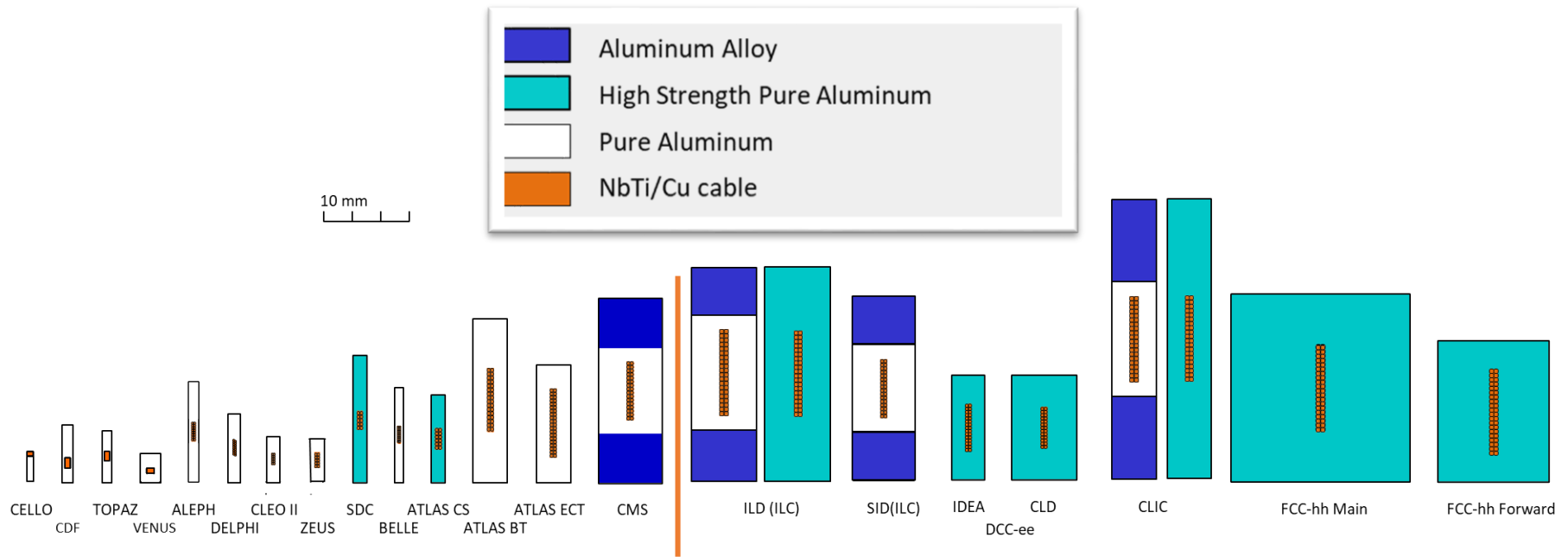
12–14 Sept 2022  
CERN  
Europe/Zurich timezone



## Summary of the Al-stabilized SC requirements

Y. Makida

# Summary of Al stabilized superconductor for detector magnets in energy frontier colliders



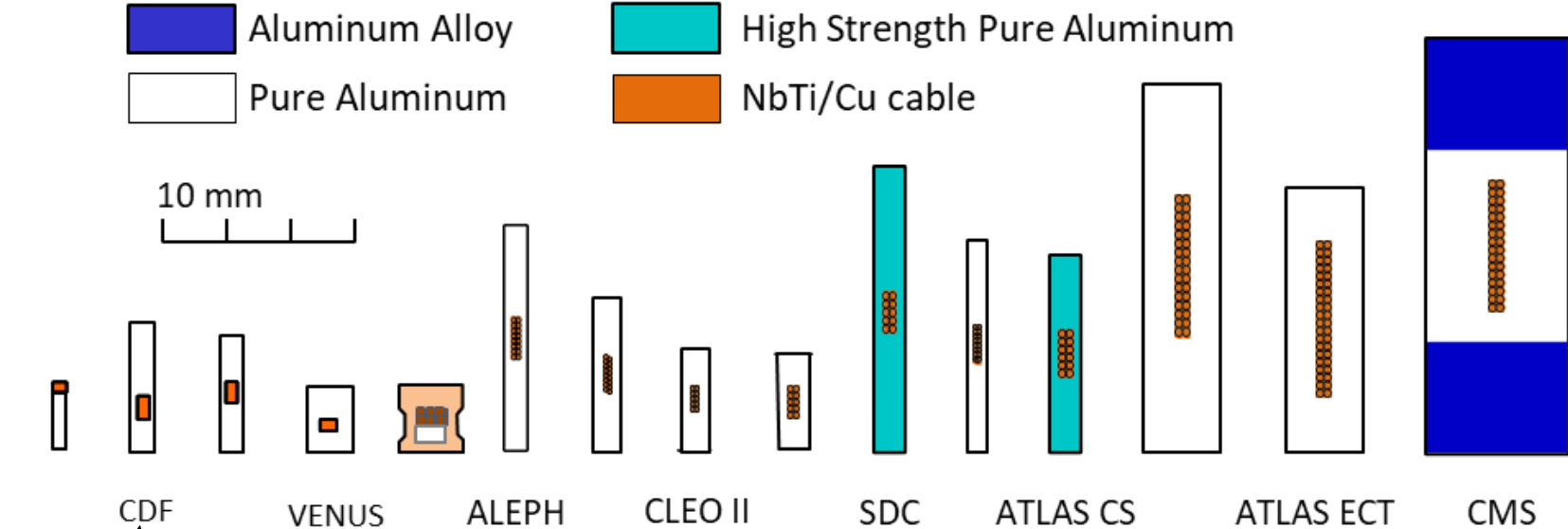
Pioneer

Now

Future

	Experiments	Site	B	Size ID x L	Energy (MJ)	Note	Fabrication Expected
Collider	EIC-Detector	BNL	1.5~3	2.5~3.2 x 8.5	45.7	Cu only	2025 ~
	ILC-ILD	Japan	4	6.88 X 7.35	2300		2030 ~
	ILC-SiD	Japan	5	5 X 5	1400		2030 ~
	CLICdet	CERN	4	7 X 8.3	2320		2035 ~
	FCC-ee IDEA	CERN	2	4.2 X 6.0	170		2035 ~
	FCC-ee CLD	CERN	2	7.4 X 7.4	600		2035 ~
	FCC-hh	CERN	4	10 X 20	13800		2040 ~
Others	BabyAXIO	DESY	2	0.7 X 10	38	Racetrack	~2024
	AXIO	DESY	5 - 6	5 X 25	500	Toroid (Racetrack)	2024~

# Development of aluminum stabilized SC



CELLO → CDF → TOPAZ → VENUS → AMY → ALEPH → DELPHI → CLEO II → ZEUS → SDC → BELLE → ATLAS CS → ATLAS BT → ATLAS ECT → CMS

Zn doped + 15 % cold work → SDC, BELLE  
 Al clad by HOLTON in UK → SDC, BELLE  
 Ni doped + 21 % cw → ATLAS CS, ATLAS BT  
 AA6082 by EB → CMS

NbTi/Cu core is clad with pure aluminum by using a co-extrusion.

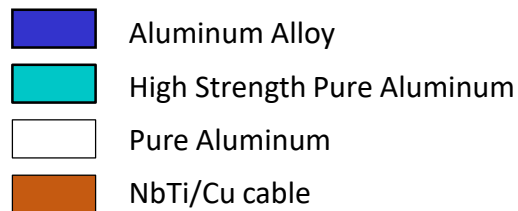
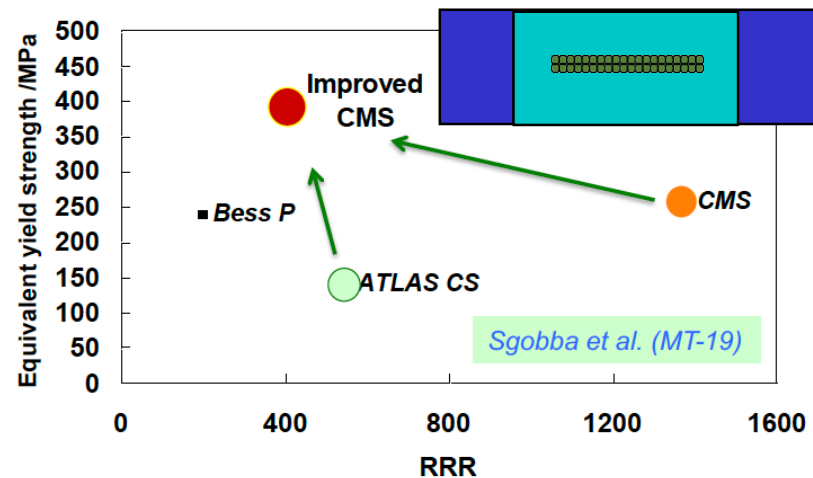
- Interface resistance b/w Cu and Al is  $\sim 10^{-11} \Omega \cdot m$  (1/10 of soldering) and shearing strength is  $> 30 \text{ MPa}$ .
- Diffusion depth is  $\sim 1 \mu m$ , avoiding AlCu formation and  $I_c$  degradation due to NbTi annealing..

High purity aluminum has 6 times longer radiation length, higher electrical and thermal conductivity than those in copper at low temperature. Attached by soft soldering.

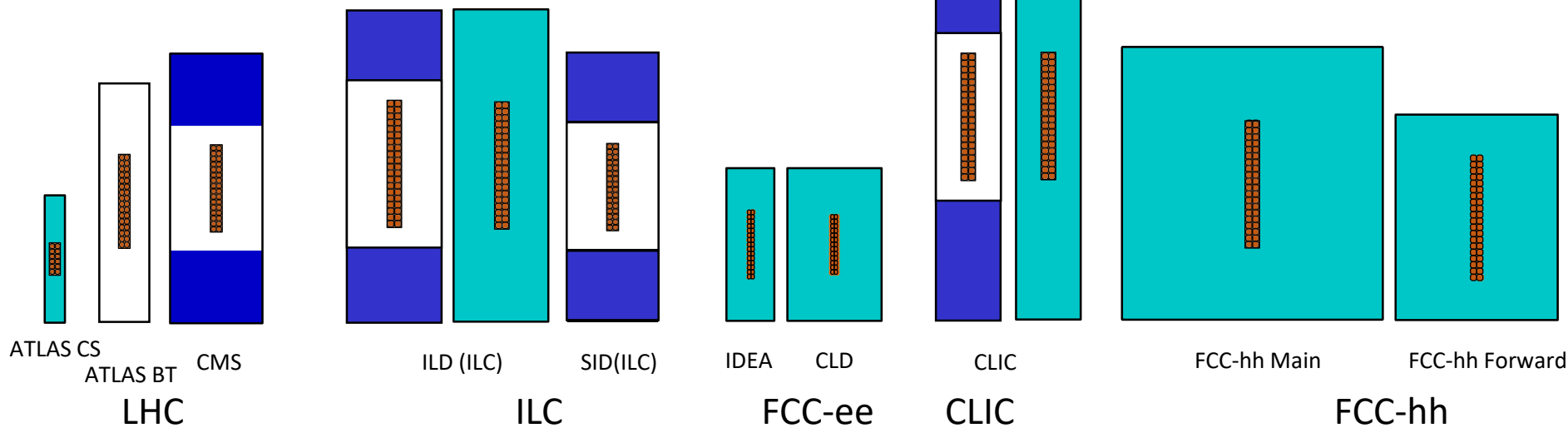
# Proposed SC in future detector & Improvement

Toward an Improved High Strength, High RRR CMS Conductor (MT-19)

- Toward 400 MPa yield strength by ATLAS CS and CMS together.
  - Pure AL -> AL + 0.1 w%Ni
  - AW6082 -> AW-7020



10 mm



# Look at real industry! Withdraw from Al clad process

Currently, makers said to their customer that **they could not produce Al-stabilized NbTi conductor.**

This means that they could not find a way to produce large amount of Al-stabilized conductor comply with the specification with foreseeable cost and lead time because of instability in the co-extrusion process which is currently usable.

**Sporadic demand of Al-stabilized NbTi conductor makes it inviable business.**

Combining machines used for former Al-stabilized NbTi conductor production became decrepit and were scrapped.

# Future Colliders and Conductor Demand

## Can we get makers' interest?

### Future particle physics experiments being studied

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

ALICE 3  
LHCb ( $\geq$  LS4)  
EIC  
LHeC

ILC

FCC-ee  
CLIC

FCC-hh  
FCC-eh  
Muon Collider  
Plasma Collider

2030-2035

2035-2040

2040-2045

> 2045

### Conductor Demand

2025-2030

2030-2035

>2035



EIC

10

17

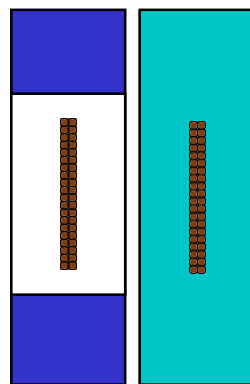
Cu stab.



BabyIAXO

17

20



ILD (ILC)

168

32

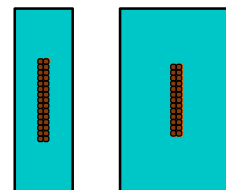
SID (ILC)

99

27

##: Demand (ton)

##: (km)



FCC-ee

IDEA

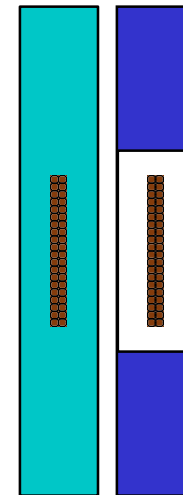
10

10

CLD

39

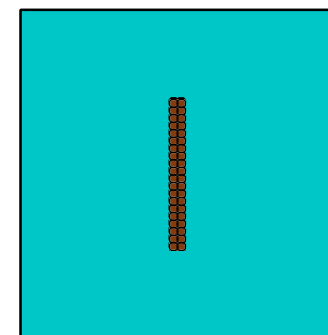
18



CLIC

210

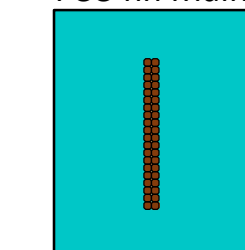
40



FCC-hh Main

1015

93



FCC-hh Forward

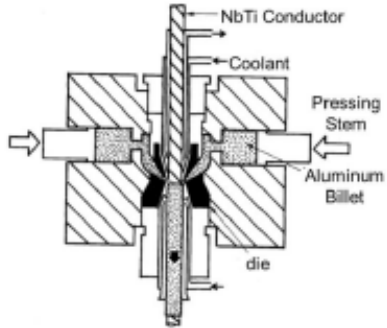
92 19

# How take over extrusion process ?

## Process Condition

1. Keep NbTi temperature  $< 350$  °C (instantaneously 400 °C).
  - Brazing or welding SC cable and Al are excluded.
2. Interface resistance from NbTi/Cu cable to Al  $< 1 \times 10^{-9} \Omega \cdot \text{m}$ .
3. Shear strength  $> 20$  MPa.
4. ...

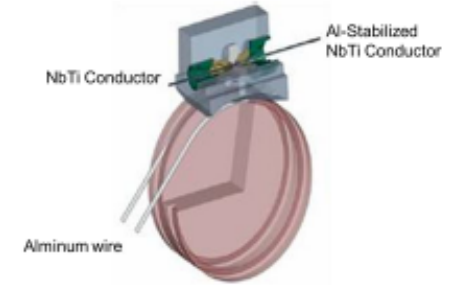
# How take over extrusion process ? Conform (Conclad) machine



Schematic view of Schloemann's cable cladding press

K.Saito et al.,  
J. JILM, Vol. 35, No. 5 (2020), 297-303  
in Japanese

Item	Schloemann	Conforming
Al Source	Billet	Wire
Machine Size	Large	Small
Application	Clad wires	OPGW, AS
Al-stabilized NbTi conductor		
Cross Section of Al	Large	Small -170mm <sup>2</sup> (Max 300mm <sup>2</sup> )
Length	Limited by Billet	Continuous



Schematic view of conforming machine  
<https://bwe.co.uk/conklad/>

From FEC talk



Pre-processing equipment



Extrusion machine

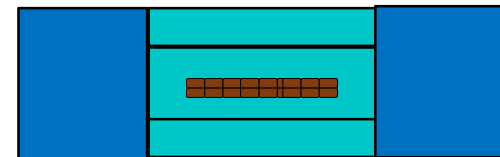
BWE Ltd. is supplier of Conklad™ machine contacted by CERN

From Benoit's talk

Rod diameter 2 x 9.5 ~ 12 mm  
Cable thickness 3~30 mm  
Cable width 10 ~ 70 mm

From TOLY's talk

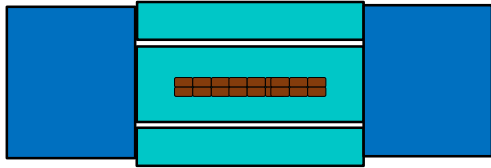
If Max 300 mm<sup>2</sup> -> 30 x 10 mm<sup>2</sup>





# How take over extrusion process ?

If Max 300 mm<sup>2</sup> -> 30 x 10 mm<sup>2</sup>

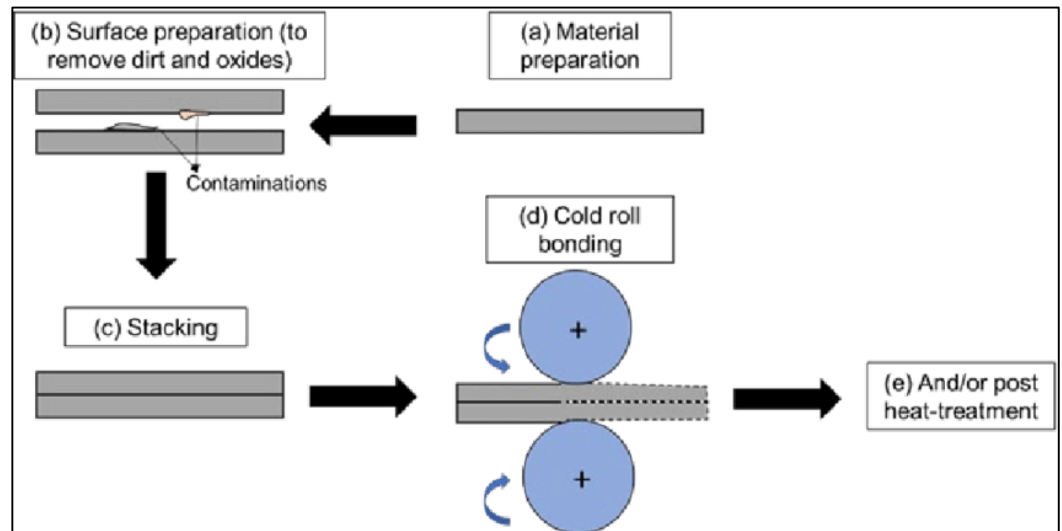
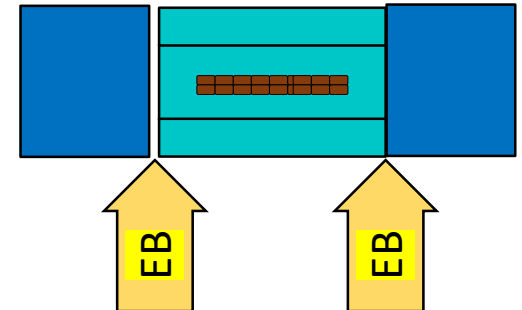
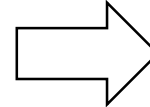
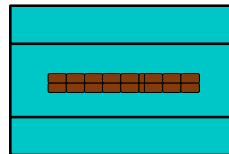
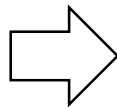
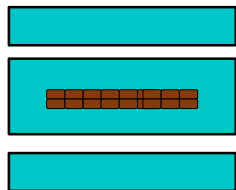


## 2022 - 2023 – CONTINUOUS STRIP WELDING

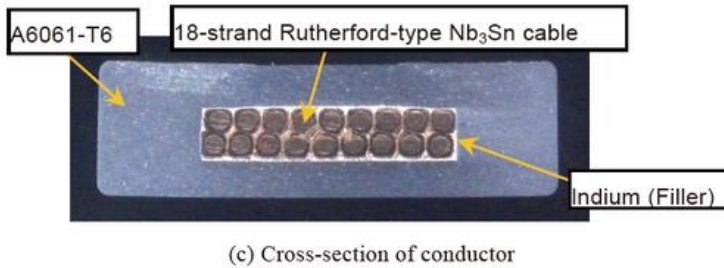
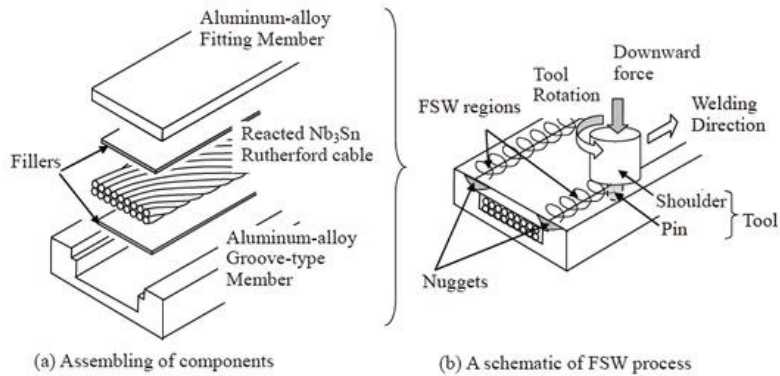
- [TECHMETA Strips](#)
- **New jobshop** entity on separate production site
- Dedicated to continuous strip welding > 2 **Production Units**
- Operational > Begin 2023
- Market > Automobile industry / Electrical cars



From TECHMETA's talk



# How take over extrusion process ? Setting SC cable into grooved Al rod



**Fig. 9** Aluminum jacketed Nb<sub>3</sub>Sn conductor using the FSW technique.<sup>24)</sup>