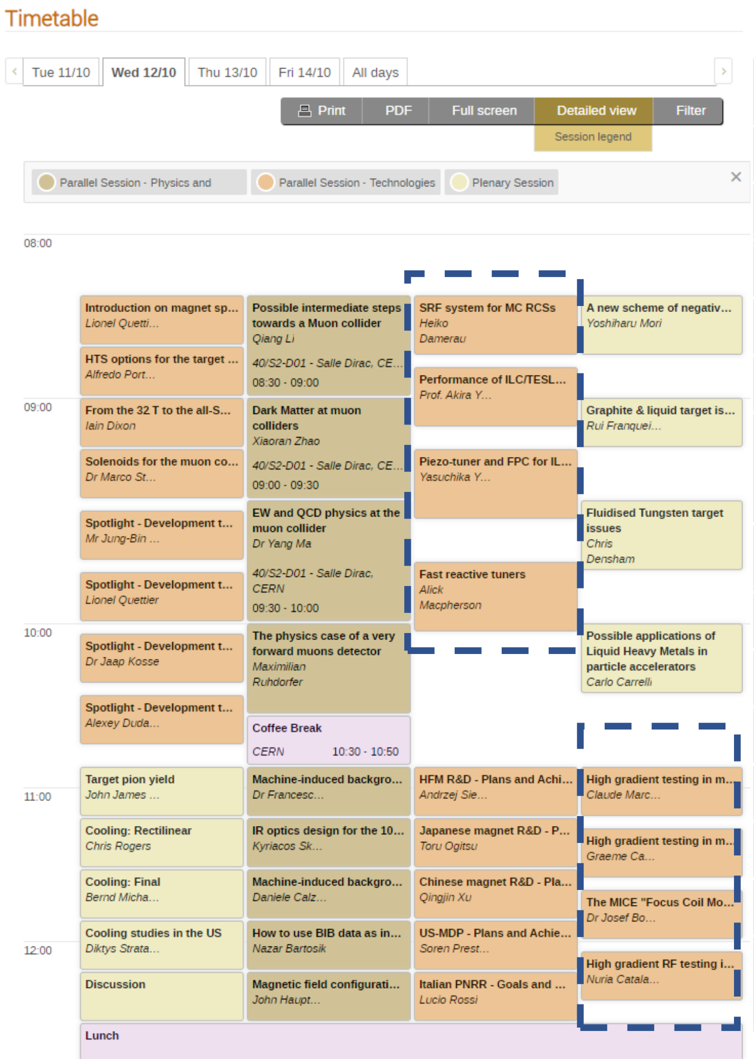
RF session summary

Alexej Grudiev (CERN)
On behalf of MC RF WG
14/10/2022
Muon Collider Annual meeting

RF session: Wednesday morning, B30/7-010



Timetable

Introduction on magnet sp... *Lionel Quetti...*

HTS options for the target ... *Alfredo Port...*

From the 32 T to the all-S... *Iain Dixon*

Solenoids for the muon co... *Dr Marco St...*

Spotlight - Development t... *Mr Jung-Bin ...*

Spotlight - Development t... *Lionel Quettier*

Spotlight - Development t... *Dr Jaap Kosse*

Spotlight - Development t... *Alexey Duda...*

Target pion yield *John James ...*

Cooling: Rectilinear *Chris Rogers*

Cooling: Final *Bernd Micha...*

Cooling studies in the US *Diktys Strata...*

Discussion

Possible intermediate steps towards a Muon collider *Qiang Li* *40/S2-D01 - Salle Dirac, CE...* 08:30 - 09:00

Dark Matter at muon colliders *Xiaoran Zhao* *40/S2-D01 - Salle Dirac, CE...* 09:00 - 09:30

EW and QCD physics at the muon collider *Dr Yang Ma* *40/S2-D01 - Salle Dirac, CERN* 09:30 - 10:00

The physics case of a very forward muons detector *Maximilian Ruhdorfer*

Coffee Break *CERN* 10:30 - 10:50

Machine-induced backgro... *Dr Francesc...*

IR optics design for the 10... *Kyriacos Sk...*

Machine-induced backgro... *Daniele Calz...*

How to use BIB data as in... *Nazar Bartosik*

Magnetic field configurati... *John Haupt...*

SRF system for MC RCSs *Heiko Damerau*

Performance of ILC/TESL... *Prof. Akira Y...*

Piezo-tuner and FPC for IL... *Yasuchika Y...*

Fast reactive tuners *Alick Macpherson*

HFM R&D - Plans and Achi... *Andrzej Sie...*

Japanese magnet R&D - P... *Toru Ogitsu*

Chinese magnet R&D - Pla... *Qingjin Xu*

US-MDP - Plans and Achie... *Soren Prest...*

Italian PNRR - Goals and ... *Lucio Rossi*

A new scheme of negativ... *Yoshiharu Mori*

Graphite & liquid target is... *Rui Franquei...*

Fluidised Tungsten target issues *Chris Densham*

Possible applications of Liquid Heavy Metals in particle accelerators *Carlo Carrelli*

High gradient testing in m... *Claude Marc...*

High gradient testing in m... *Graeme Ca...*

The MICE "Focus Coil Mo... *Dr Josef Bo...*

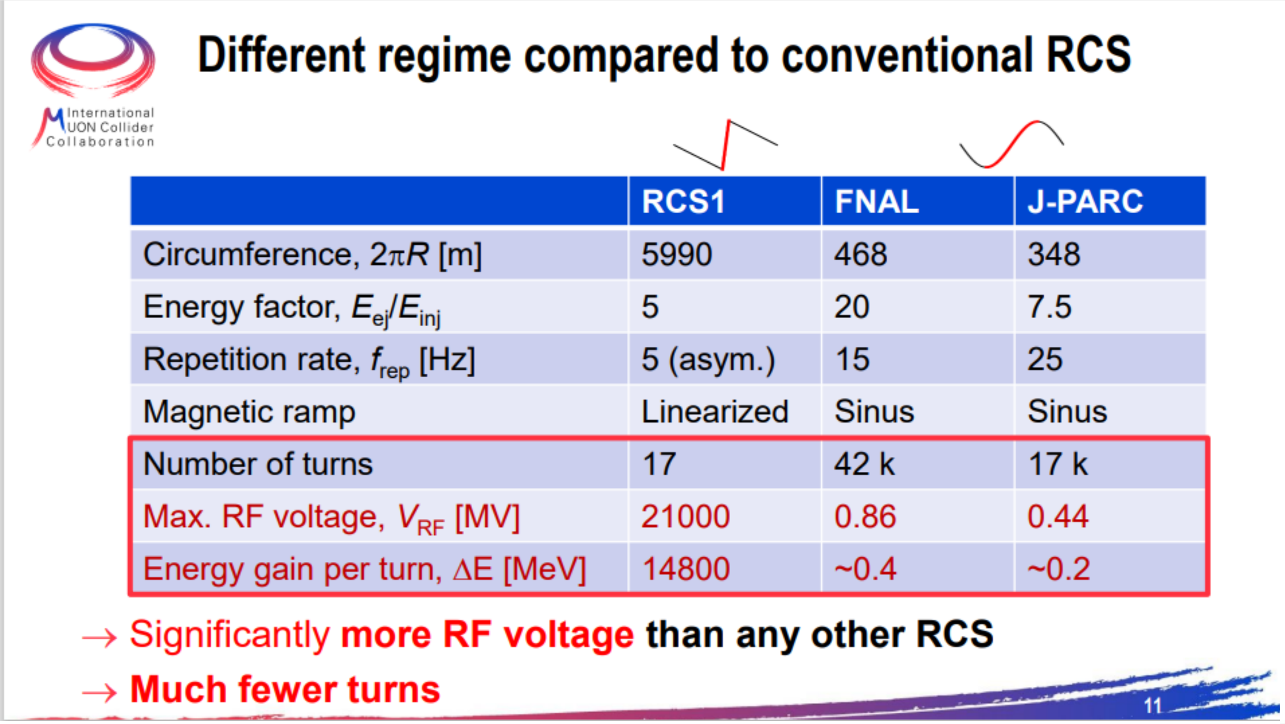
High gradient RF testing i... *Nuria Catala...*

Lunch

Time	Title	Name	Affiliation	Participation
Wednesday, 12 October, 2022				
	RF session			
08:30	**SRF**			
20+5	**SRF system for MC RCSs**	**Heiko Damerau**	CERN	in person
20+5	**Performance of ILC/TESLA-type cavities for future MC RCS application**	**Akira Yamamoto**	KEK	remote
20+5	**Piezo-tuner and FPC for ILC/TESLA type cavities**	**Yasuchika Yamamoto**	KEK	remote
20+5	**Fast reactive tuners**	**Alick Macpherson**	CERN	in person
10:50	**NRF**			
20+5	**High gradient testing in magnetic field at CEA**	**Claude Marchand**	CEA	in person
20+5	**High gradient testing in magnetic field in UK**	**Graeme Burt**	U.Lancaster	remote
20+5	**The MICE "Focus Coil Module"**	**Josef Boehm**	STFC	remote
20+5	**High gradient RF testing infrastructure and MgB2 solenoid at CERN**	**Nuria Catalan**	CERN	in person

SRF system in RCS: Huge RF voltage

Heiko Damerau

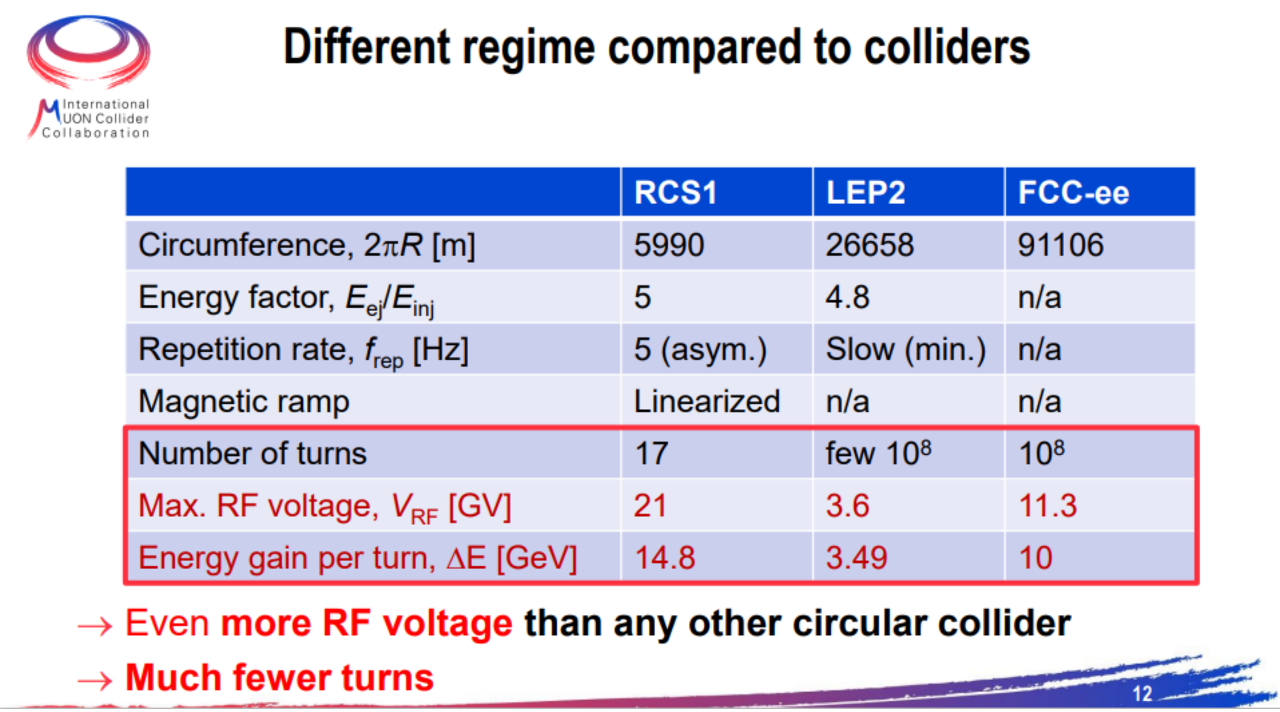


Different regime compared to conventional RCS

	RCS1	FNAL	J-PARC
Circumference, $2\pi R$ [m]	5990	468	348
Energy factor, E_{ej}/E_{inj}	5	20	7.5
Repetition rate, f_{rep} [Hz]	5 (asym.)	15	25
Magnetic ramp	Linearized	Sinus	Sinus
Number of turns	17	42 k	17 k
Max. RF voltage, V_{RF} [MV]	21000	0.86	0.44
Energy gain per turn, ΔE [MeV]	14800	~0.4	~0.2

→ Significantly **more RF voltage** than any other RCS

→ **Much fewer turns**



Different regime compared to colliders

	RCS1	LEP2	FCC-ee
Circumference, $2\pi R$ [m]	5990	26658	91106
Energy factor, E_{ej}/E_{inj}	5	4.8	n/a
Repetition rate, f_{rep} [Hz]	5 (asym.)	Slow (min.)	n/a
Magnetic ramp	Linearized	n/a	n/a
Number of turns	17	few 10^8	10^8
Max. RF voltage, V_{RF} [GV]	21	3.6	11.3
Energy gain per turn, ΔE [GeV]	14.8	3.49	10

→ Even **more RF voltage** than any other circular collider

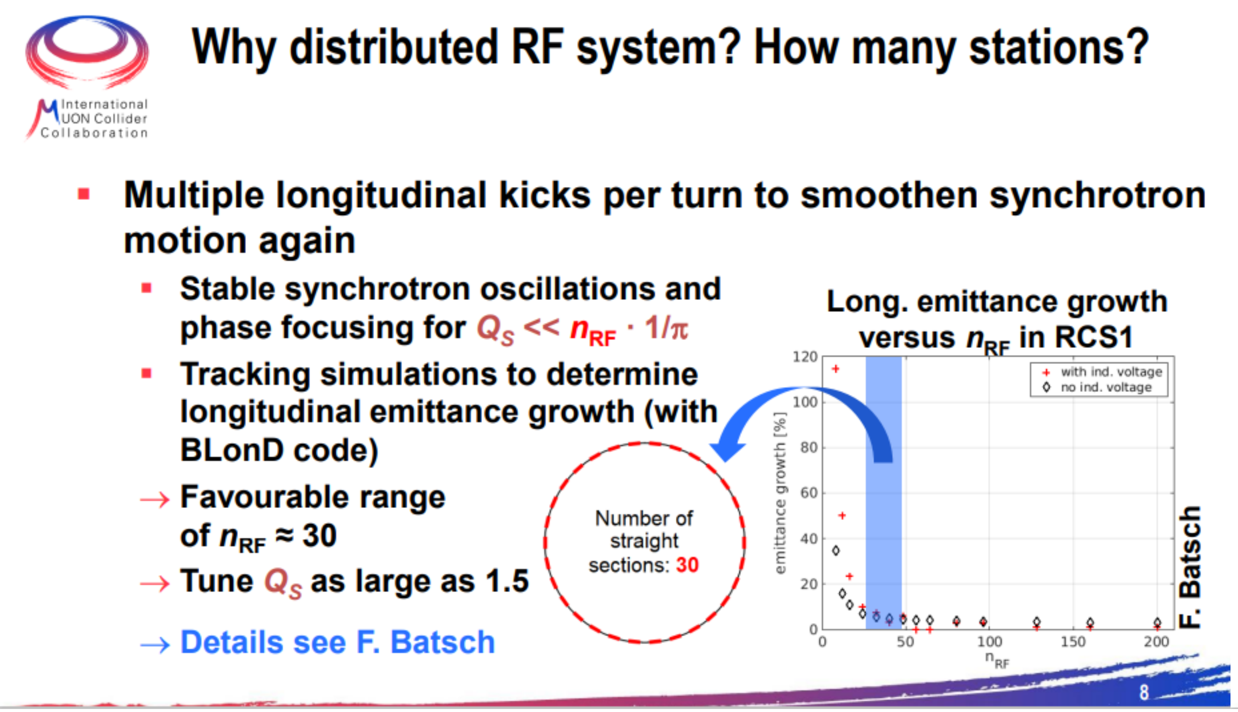
→ **Much fewer turns**

RF system must have huge voltage of 10-20 GV

ILC/TESLA type cavity are attractive since they show highest SRF gradient

SRF system in RCS: Peculiarities

Heiko Damerau

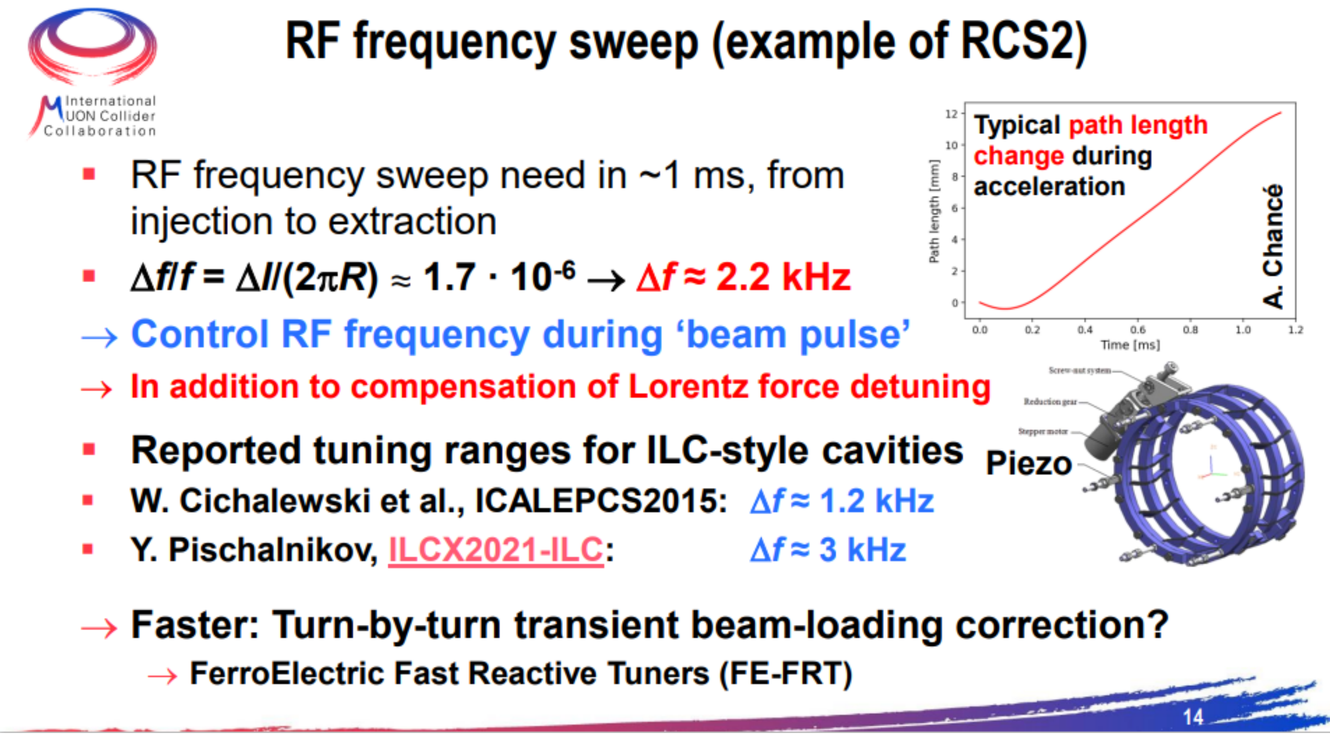


Why distributed RF system? How many stations?

- **Multiple longitudinal kicks per turn to smoothen synchrotron motion again**
  - **Stable synchrotron oscillations and phase focusing for $Q_S \ll n_{RF} \cdot 1/\pi$**
  - **Tracking simulations to determine longitudinal emittance growth (with BLonD code)**
  - → **Favourable range of $n_{RF} \approx 30$**
  - → **Tune Q_S as large as 1.5**
  - → **Details see F. Batsch**

Number of straight sections: 30

Long. emittance growth versus n_{RF} in RCS1



RF frequency sweep (example of RCS2)

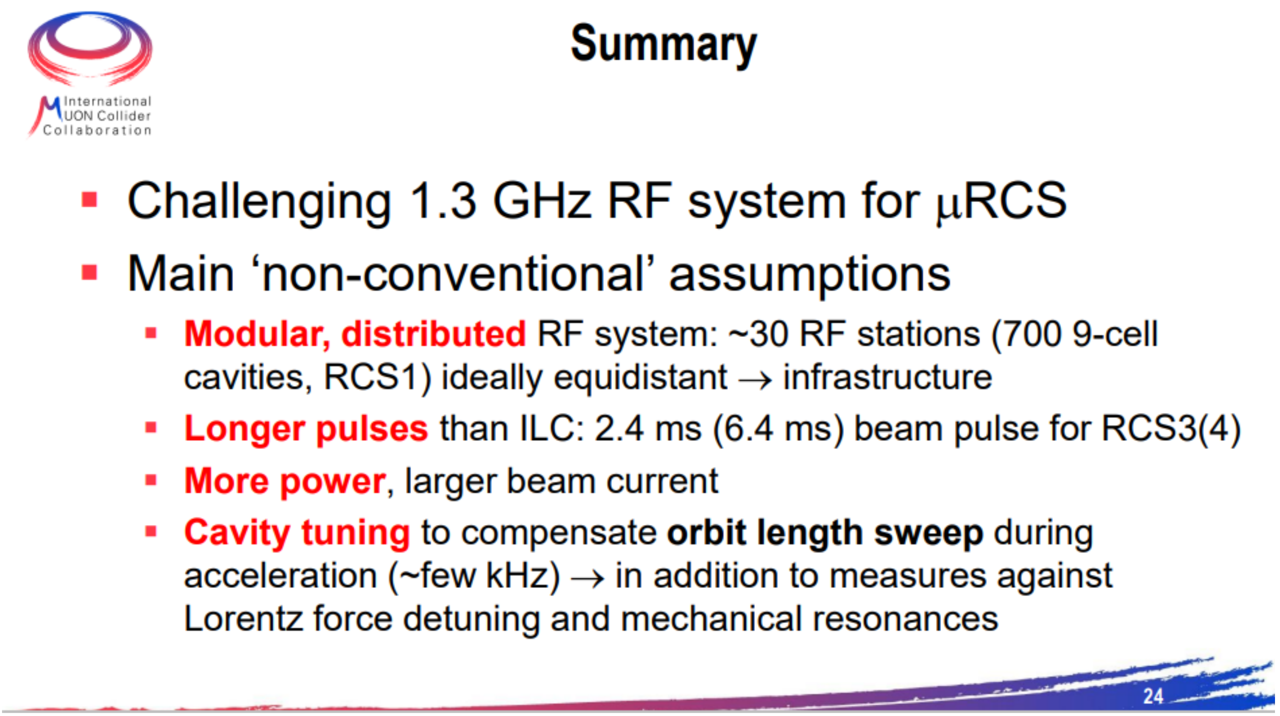
- RF frequency sweep need in ~1 ms, from injection to extraction
- **$\Delta f/f = \Delta l/(2\pi R) \approx 1.7 \cdot 10^{-6} \rightarrow \Delta f \approx 2.2$ kHz**
- → **Control RF frequency during 'beam pulse'**
- → **In addition to compensation of Lorentz force detuning**
- **Reported tuning ranges for ILC-style cavities**
- **W. Cichalewski et al., ICALEPCS2015: $\Delta f \approx 1.2$ kHz**
- **Y. Pischalnikov, ILCX2021-ILC: $\Delta f \approx 3$ kHz**
- → **Faster: Turn-by-turn transient beam-loading correction?**
  - → **FerroElectric Fast Reactive Tuners (FE-FRT)**

Typical path length change during acceleration

- RF system must be distributed over 30-50 location around the ring
- RF frequency must follow the path length change in the hybrid RCS

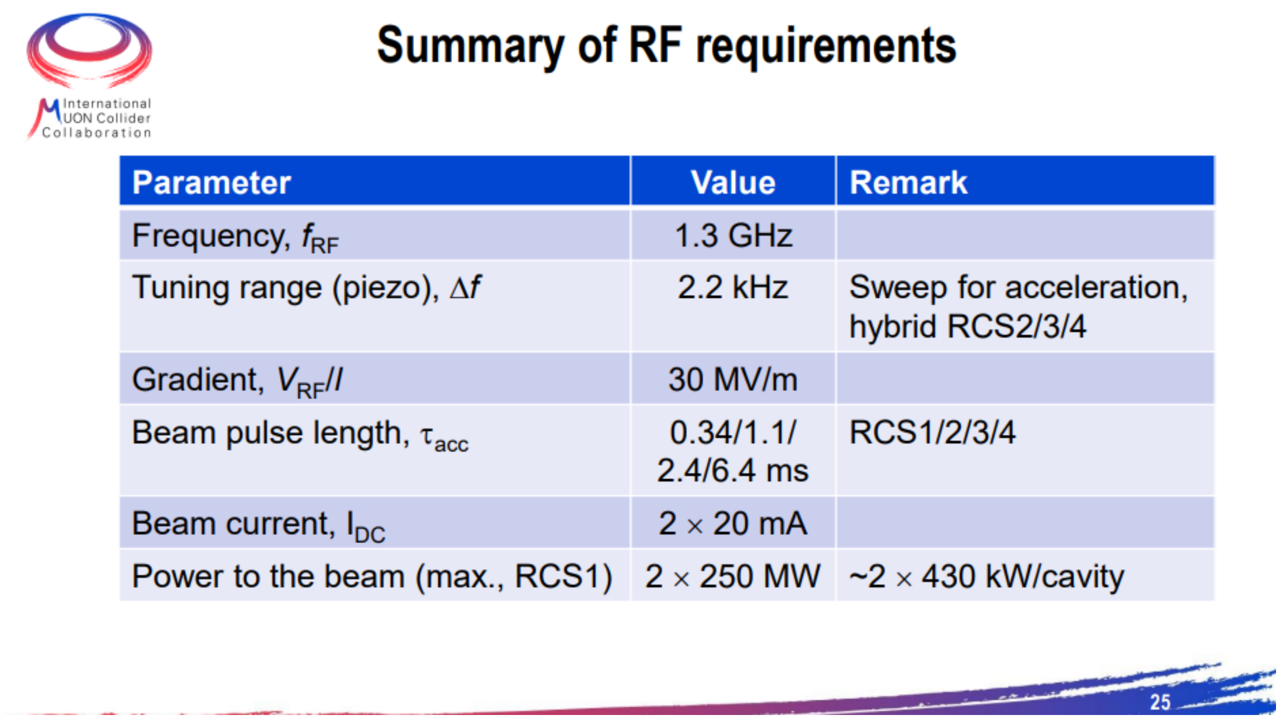
SRF system in RCS: Summary

Heiko Damerau



Summary

- Challenging 1.3 GHz RF system for μRCS
- Main ‘non-conventional’ assumptions
  - **Modular, distributed** RF system: ~30 RF stations (700 9-cell cavities, RCS1) ideally equidistant → infrastructure
  - **Longer pulses** than ILC: 2.4 ms (6.4 ms) beam pulse for RCS3(4)
  - **More power**, larger beam current
  - **Cavity tuning** to compensate **orbit length sweep** during acceleration (~few kHz) → in addition to measures against Lorentz force detuning and mechanical resonances



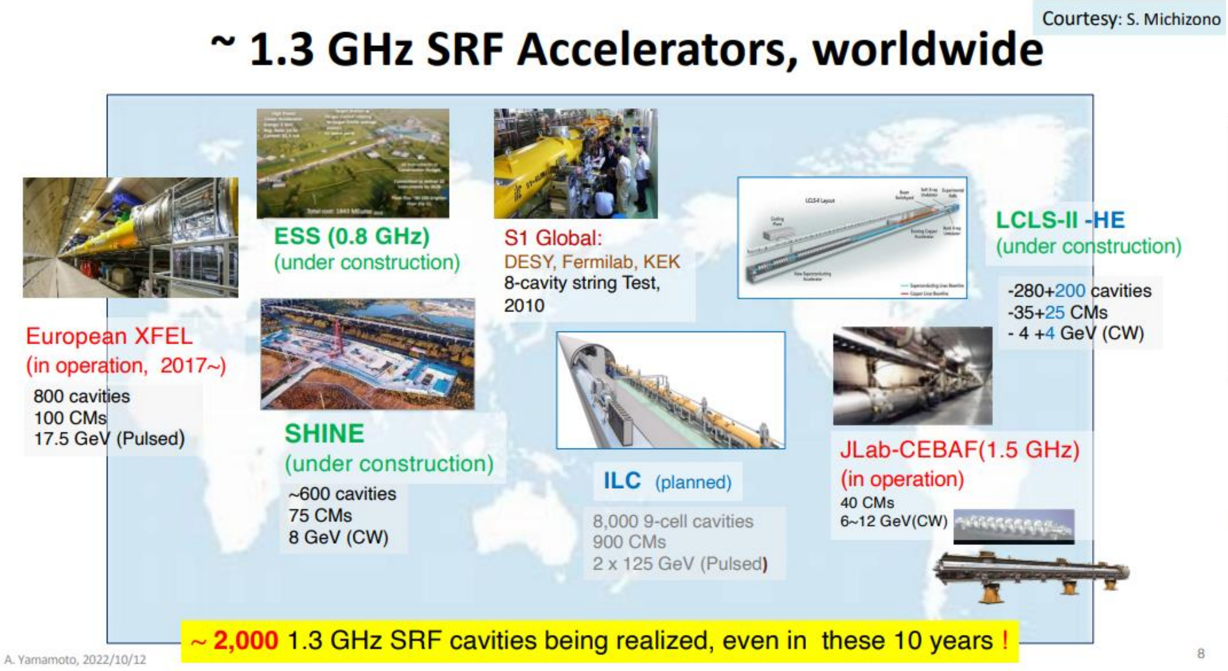
Summary of RF requirements

Parameter	Value	Remark
Frequency, f_{RF}	1.3 GHz	
Tuning range (piezo), Δf	2.2 kHz	Sweep for acceleration, hybrid RCS2/3/4
Gradient, V_{RF}/l	30 MV/m	
Beam pulse length, τ_{acc}	0.34/1.1/ 2.4/6.4 ms	RCS1/2/3/4
Beam current, I_{DC}	2 × 20 mA	
Power to the beam (max., RCS1)	2 × 250 MW	~2 × 430 kW/cavity

Summary of requirements and parameter table is very important input for the SRF experts to access applicability of ILC/TESLA cavities to MC accelerators

State-of-the-art for ILC/TESLA type SRF cavities

Akira Yamamoto



Courtesy: S. Michizono

~ 1.3 GHz SRF Accelerators, worldwide

European XFEL
(in operation, 2017~)
800 cavities
100 CMs
17.5 GeV (Pulsed)

ESS (0.8 GHz)
(under construction)

SHINE
(under construction)
~600 cavities
75 CMs
8 GeV (CW)

S1 Global:
DESY, Fermilab, KEK
8-cavity string Test, 2010

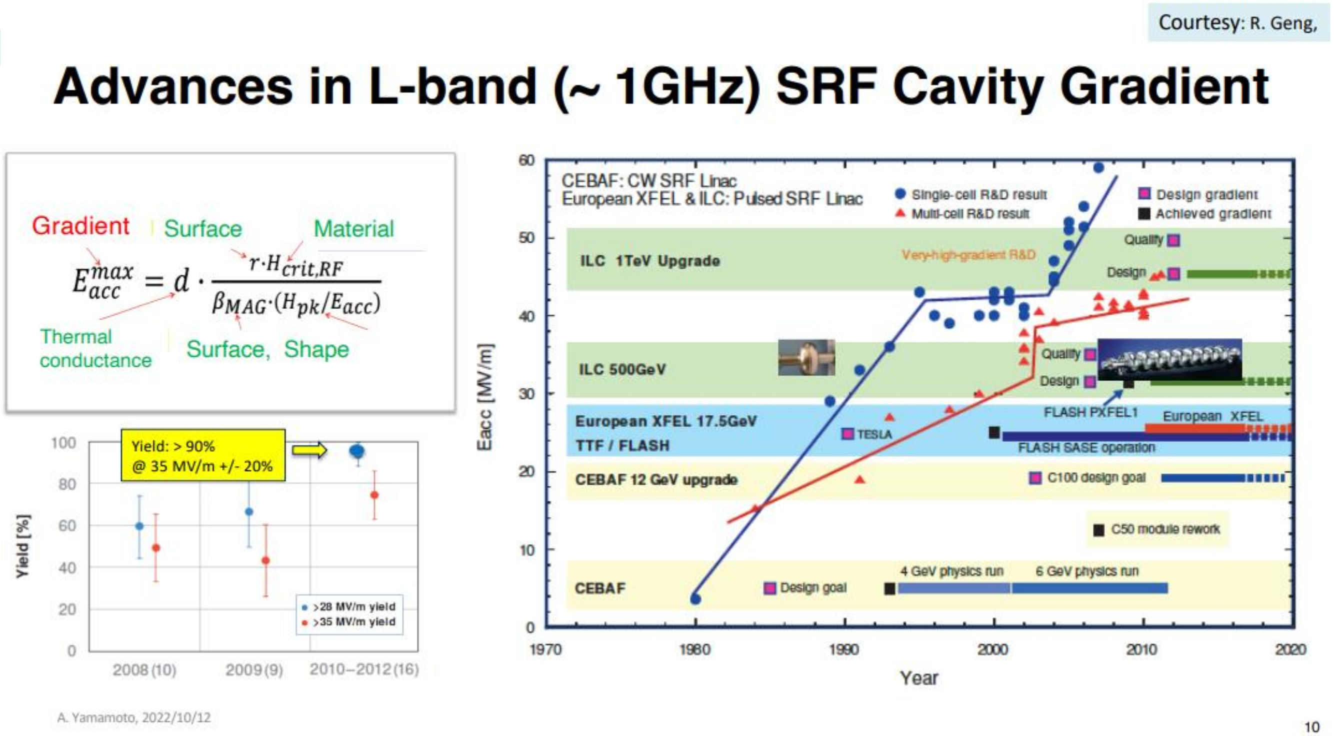
ILC (planned)
8,000 9-cell cavities
900 CMs
2 x 125 GeV (Pulsed)

LCLS-II -HE
(under construction)
-280+200 cavities
-35+25 CMs
- 4 +4 GeV (CW)

JLab-CEBAF(1.5 GHz)
(in operation)
40 CMs
6~12 GeV(CW)

~ **2,000** 1.3 GHz SRF cavities being realized, even in these 10 years !

A. Yamamoto, 2022/10/12



Courtesy: R. Geng,

Advances in L-band (~ 1GHz) SRF Cavity Gradient

Gradient | Surface | Material

$$E_{acc}^{max} = d \cdot \frac{r \cdot H_{crit,RF}}{\beta_{MAG} \cdot (H_{pk}/E_{acc})}$$

Thermal conductance | Surface, Shape

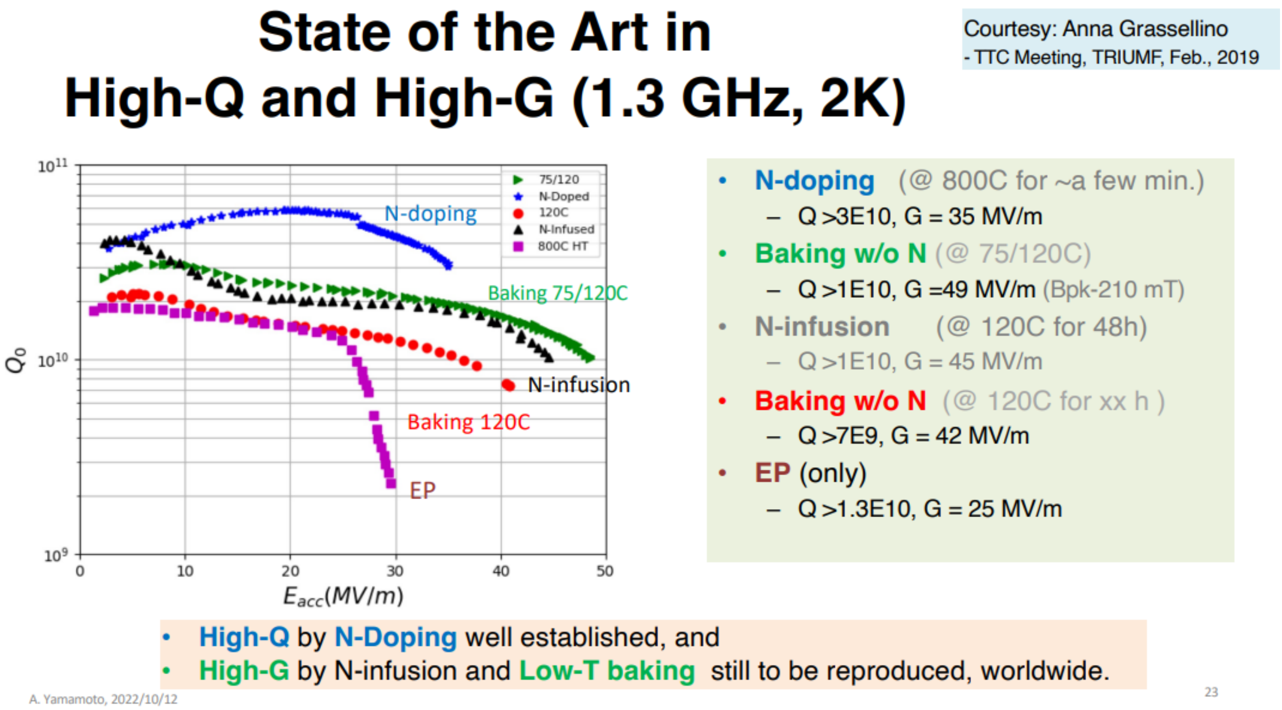
Yield: > 90%
@ 35 MV/m +/- 20%

A. Yamamoto, 2022/10/12

ILC/TESLA type cavities is mature and most developed SRF technology

State-of-the-art for ILC/TESLA type SRF cavities

Akira Yamamoto



State of the Art in High-Q and High-G (1.3 GHz, 2K)

Courtesy: Anna Grassellino
- TTC Meeting, TRIUMF, Feb., 2019

- **N-doping** (@ 800C for ~a few min.)
  - Q >3E10, G = 35 MV/m
- **Baking w/o N** (@ 75/120C)
  - Q >1E10, G =49 MV/m (Bpk-210 mT)
- **N-infusion** (@ 120C for 48h)
  - Q >1E10, G = 45 MV/m
- **Baking w/o N** (@ 120C for xx h)
  - Q >7E9, G = 42 MV/m
- **EP** (only)
  - Q >1.3E10, G = 25 MV/m

- **High-Q** by **N-Doping** well established, and
- **High-G** by N-infusion and **Low-T baking** still to be reproduced, worldwide.

A. Yamamoto, 2022/10/12

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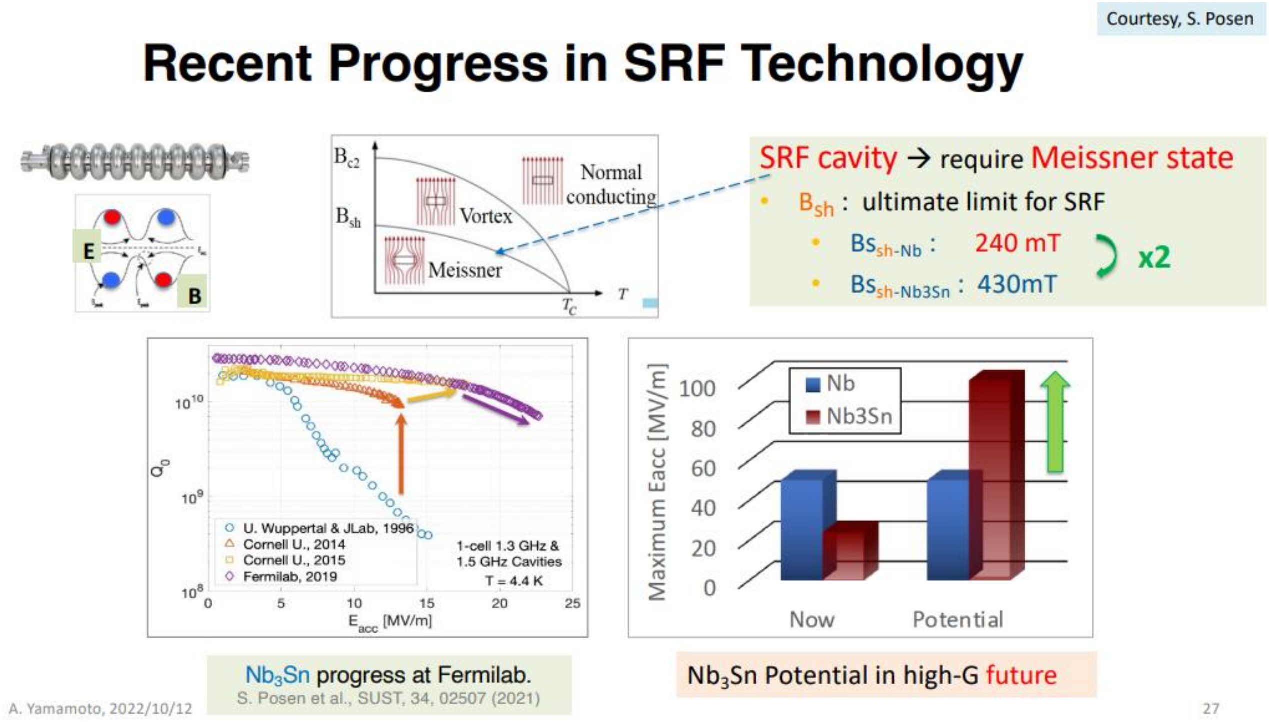

Courtesy, S. Posen

Recent Progress in SRF Technology

SRF cavity → require Meissner state

- B_{sh} : ultimate limit for SRF
  - $Bs_{sh\text{-}Nb}$: 240 mT
  - $Bs_{sh\text{-}Nb3Sn}$: 430mT

x2

Nb_3Sn progress at Fermilab.
S. Posen et al., SUST, 34, 02507 (2021)

Nb_3Sn Potential in high-G future

A. Yamamoto, 2022/10/12

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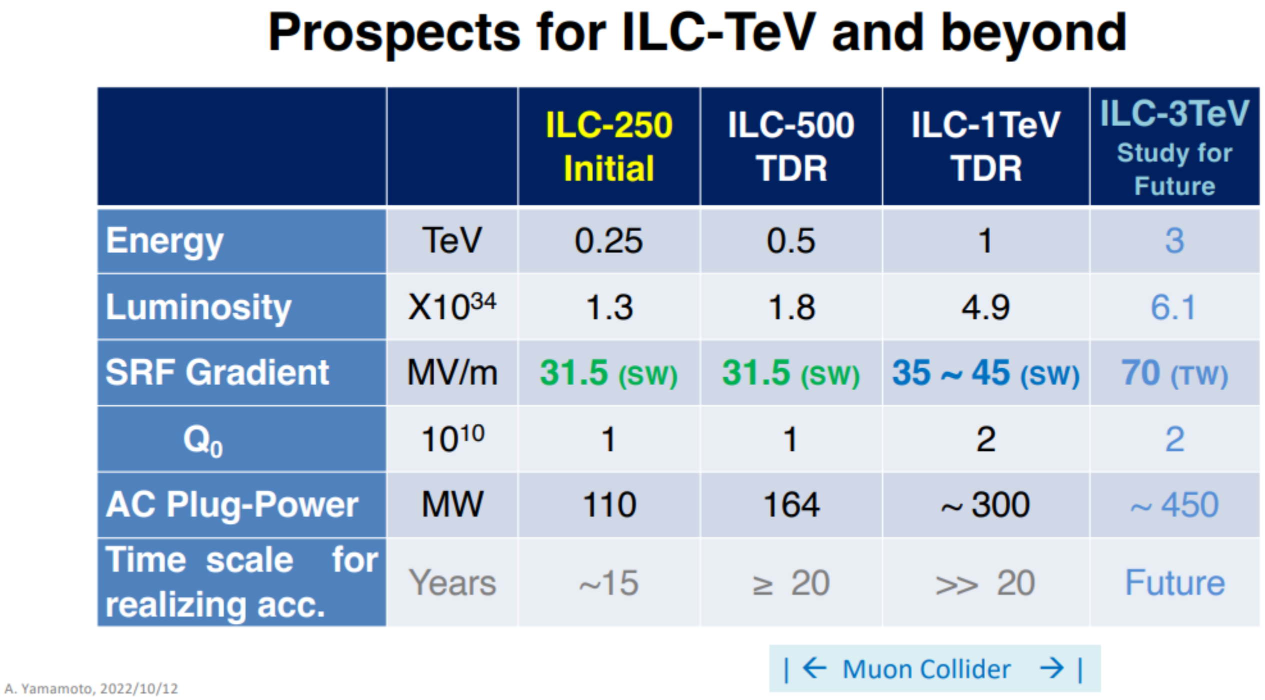
There are several ways to improve high-gradient and high-Q performance in the next decade both for bulk-Nb and new materials

State-of-the-art for ILC/TESLA type SRF cavities

Akira Yamamoto

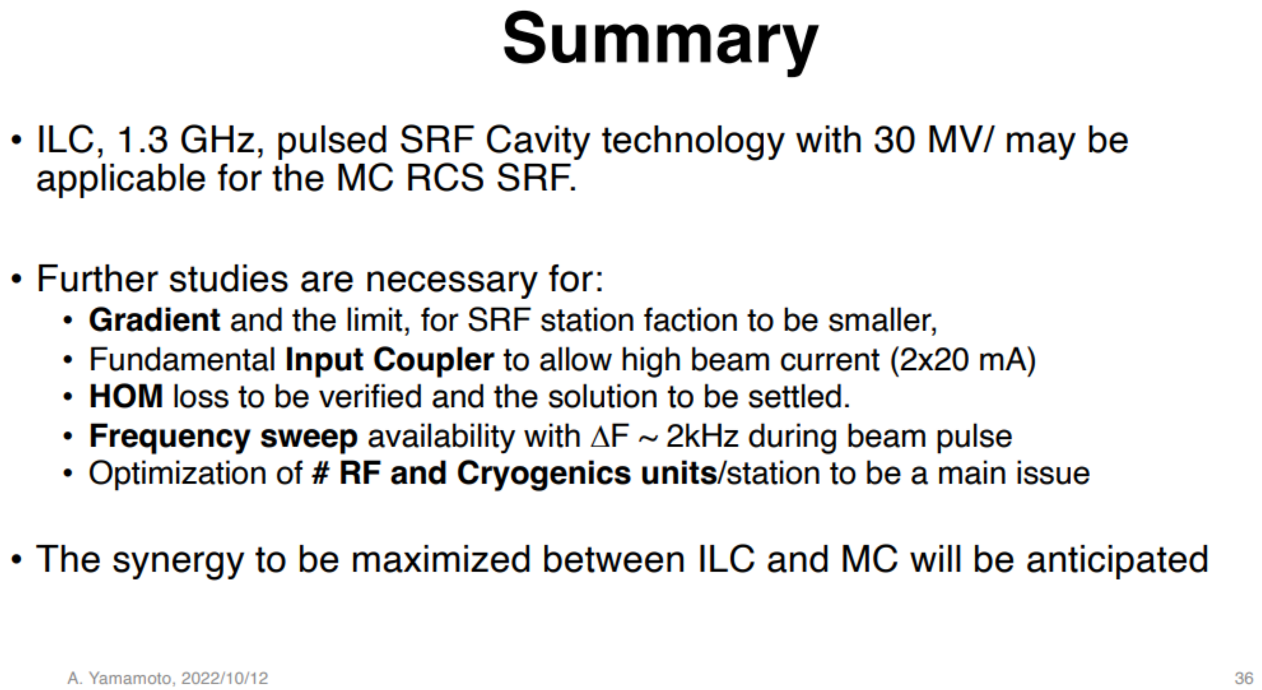


Prospects for ILC-TeV and beyond

		ILC-250 Initial	ILC-500 TDR	ILC-1TeV TDR	ILC-3TeV Study for Future
Energy	TeV	0.25	0.5	1	3
Luminosity	X10^{34}	1.3	1.8	4.9	6.1
SRF Gradient	MV/m	**31.5** (SW)	**31.5** (SW)	**35 ~ 45** (SW)	**70** (TW)
Q_0	10^{10}	1	1	2	2
AC Plug-Power	MW	110	164	~ 300	~ 450
Time scale for realizing acc.	Years	~15	≥ 20	>> 20	Future

| ← Muon Collider → |

A. Yamamoto, 2022/10/12



Summary

- ILC, 1.3 GHz, pulsed SRF Cavity technology with 30 MV/ may be applicable for the MC RCS SRF.
- Further studies are necessary for:
  - **Gradient** and the limit, for SRF station faction to be smaller,
  - Fundamental **Input Coupler** to allow high beam current (2x20 mA)
  - **HOM** loss to be verified and the solution to be settled.
  - **Frequency sweep** availability with ΔF ~ 2kHz during beam pulse
  - Optimization of **# RF and Cryogenics units**/station to be a main issue
- The synergy to be maximized between ILC and MC will be anticipated

A. Yamamoto, 2022/10/12

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ILC/TESLA technology is applicable to MC. More studies are necessary

Piezo tuners and power couplers

Kirk

Tuners serving *(significant amount of)*1.3GHz elliptical cavities

XFEL/Saclay I
N=800 units

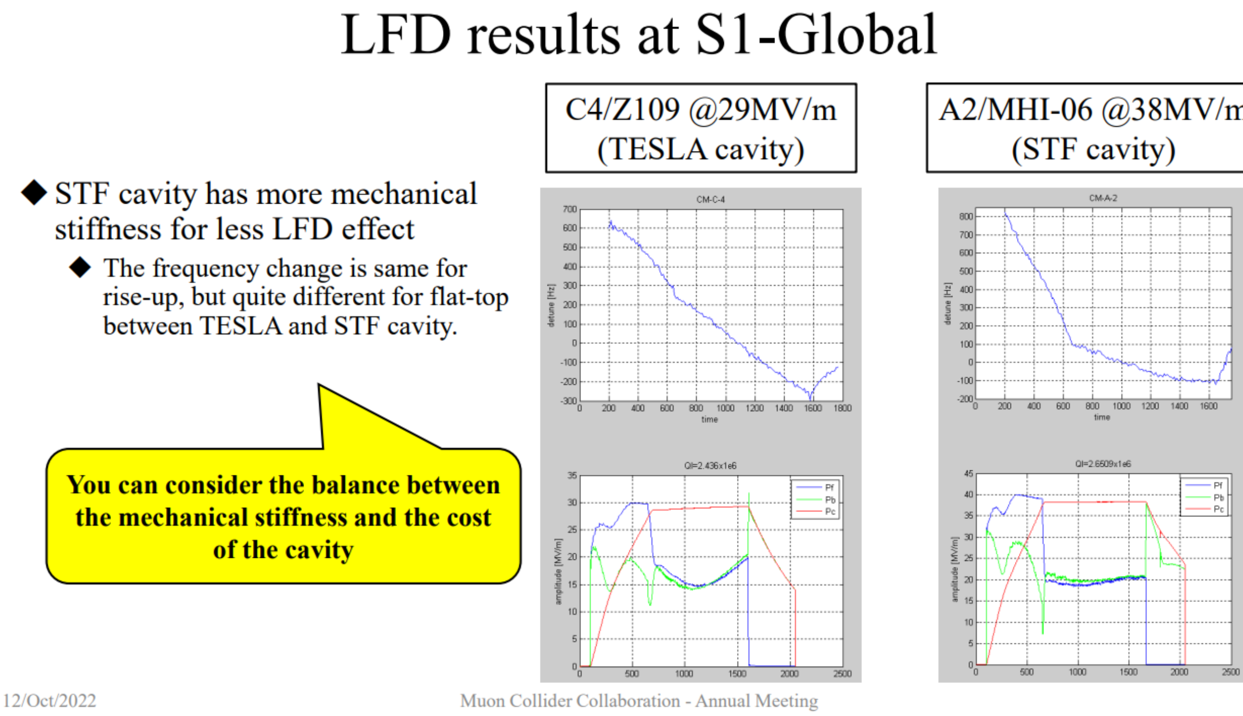
LCLS II (HE)/FNAL's
N=320 units+ 180units

SLIM Blade Tuner
(N=10 units at FNAL's CM2/FAST)

KEK/Slide Jack/
N~10 units

Length difference between TESLA and ILC cavities

3 Yuriy Pischalnikov, FNAL's design compact SRF Cavity Tuners for ILC



LFD results at S1-Global

- STF cavity has more mechanical stiffness for less LFD effect
  - The frequency change is same for rise-up, but quite different for flat-top between TESLA and STF cavity.

You can consider the balance between the mechanical stiffness and the cost of the cavity

C4/Z109 @29MV/m
(TESLA cavity)

A2/MHI-06 @38MV/m
(STF cavity)

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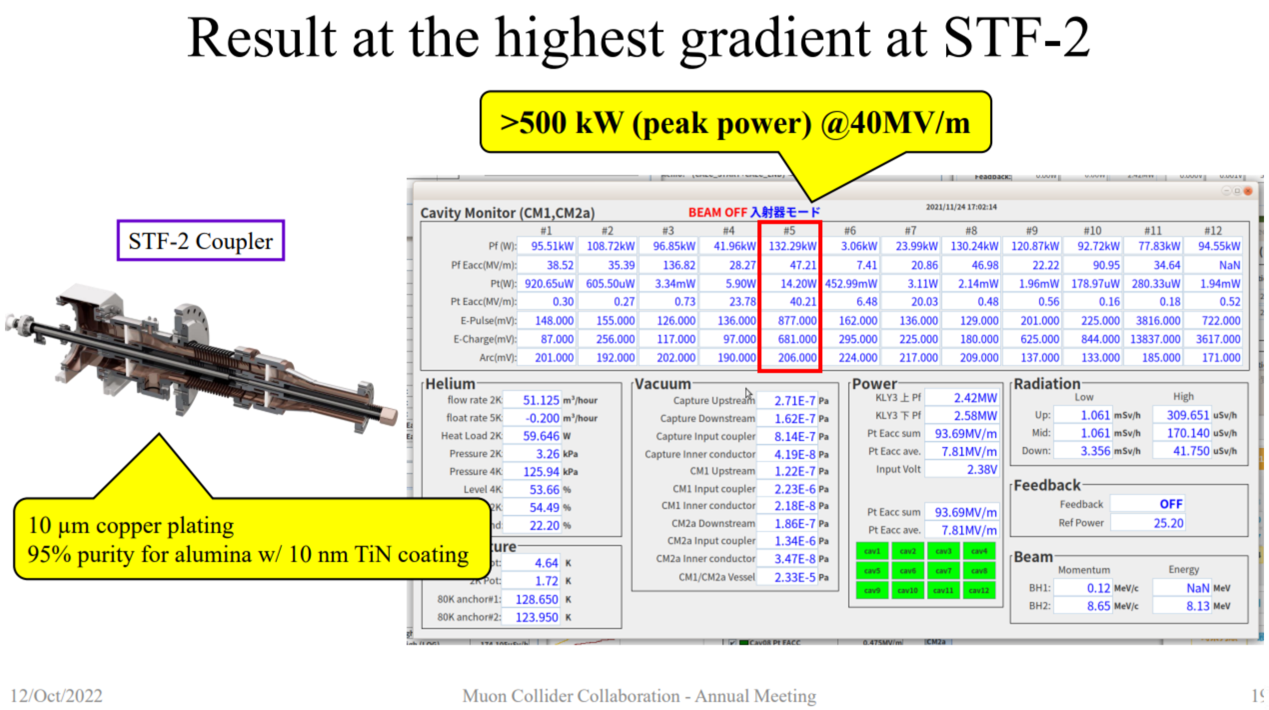
Number of Piezo-tuner solutions developed for ILC/TESLA cavities
Demonstrated performance is close to the MC needs

Piezo tuners and **power couplers**

Kirk



Result at the highest gradient at STF-2

>500 kW (peak power) @40MV/m

STF-2 Coupler

10 µm copper plating
95% purity for alumina w/ 10 nm TiN coating

Cavity Monitor (CM1,CM2a) BEAM OFF 入射器モード 2021/11/24 17:02:14

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Pf (W):	95.51kW	108.72kW	96.85kW	41.96kW	132.29kW	3.06kW	23.99kW	130.24kW	120.87kW	92.72kW	77.83kW	94.55kW
Pf Eacc(MV/m):	38.52	35.39	136.82	28.27	47.21	7.41	20.86	46.98	22.22	90.95	34.64	NaN
Pt(W):	920.65uW	605.50uW	3.34mW	5.90W	14.20W	452.99mW	3.11W	2.14mW	1.96mW	178.97uW	280.33uW	1.94mW
Pt Eacc(MV/m):	0.30	0.27	0.73	23.78	40.21	6.48	20.03	0.48	0.56	0.16	0.18	0.52
E-Pulse(mV):	148.000	155.000	126.000	136.000	877.000	162.000	136.000	129.000	201.000	225.000	3816.000	722.000
E-Charge(mV):	87.000	256.000	117.000	97.000	681.000	295.000	225.000	180.000	625.000	844.000	13837.000	3617.000
Arc(mV):	201.000	192.000	202.000	190.000	206.000	224.000	217.000	209.000	137.000	133.000	185.000	171.000

Helium

flow rate 2K:	51.125	m³/hour
float rate 5K:	-0.200	m³/hour
Heat Load 2K:	59.646	W
Pressure 2K:	3.26	kPa
Pressure 4K:	125.94	kPa
Level 4K:	53.66	%
2K:	54.49	%
nd:	22.20	%

ture

ot:	4.64	K
2K Pot:	1.72	K
80K anchor#1:	128.650	K
80K anchor#2:	123.950	K

Vacuum

Capture Upstream	2.71E-7	Pa
Capture Downstream	1.62E-7	Pa
Capture Input coupler	8.14E-7	Pa
Capture Inner conductor	4.19E-8	Pa
CM1 Upstream	1.22E-7	Pa
CM1 Input coupler	2.23E-6	Pa
CM1 Inner conductor	2.18E-8	Pa
CM2a Downstream	1.86E-7	Pa
CM2a Input coupler	1.34E-6	Pa
CM2a Inner conductor	3.47E-8	Pa
CM1/CM2a Vessel	2.33E-5	Pa

Power

KLY3 上 Pf	2.42MW
KLY3 下 Pf	2.58MW
Pt Eacc sum	93.69MV/m
Pt Eacc ave.	7.81MV/m
Input Volt	2.38V
Pt Eacc sum	93.69MV/m
Pt Eacc ave.	7.81MV/m

cav1	cav2	cav3	cav4
cav5	cav6	cav7	cav8
cav9	cav10	cav11	cav12

Radiation

	Low		High	
Up:	1.061	mSv/h	309.651	uSv/h
Mid:	1.061	mSv/h	170.140	uSv/h
Down:	3.356	mSv/h	41.750	uSv/h

Feedback

Feedback	OFF
Ref Power	25.20

Beam

	Momentum		Energy	
BH1:	0.12	MeV/c	NaN	MeV
BH2:	8.65	MeV/c	8.13	MeV

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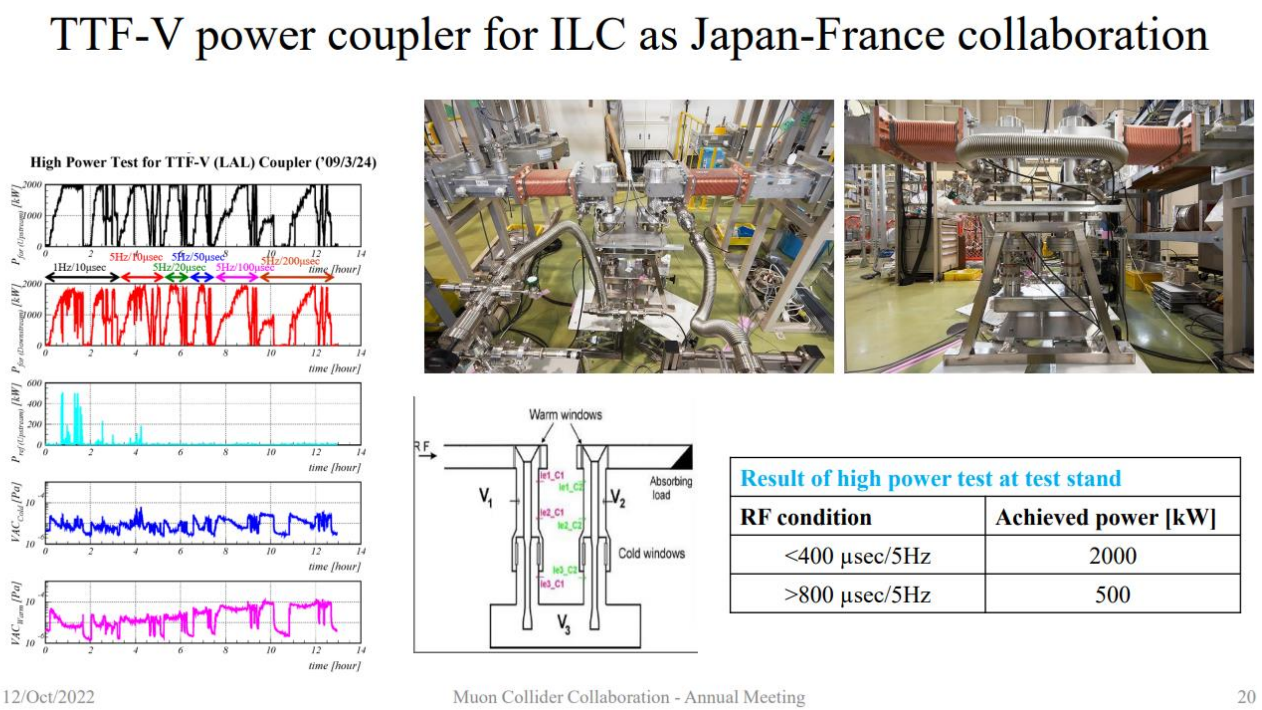

TTF-V power coupler for ILC as Japan-France collaboration

High Power Test for TTF-V (LAL) Coupler ('09/3/24)

Result of high power test at test stand

RF condition	Achieved power [kW]
<400 µsec/5Hz	2000
>800 µsec/5Hz	500

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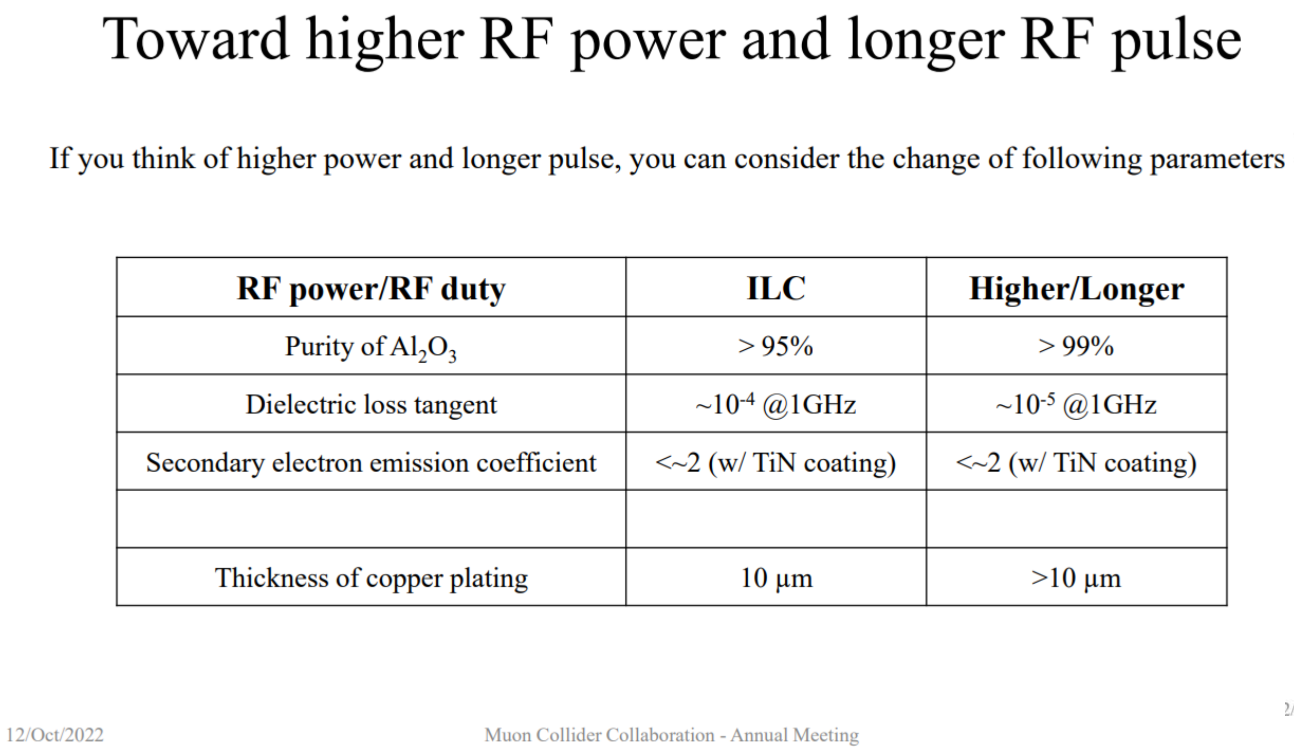
Fundamental power coupler demonstrated ~0.5 MW peak power

MC needs about 2 times more peak power and longer pulses.

Piezo tuners and **power couplers**

Kirk



Toward higher RF power and longer RF pulse

If you think of higher power and longer pulse, you can consider the change of following parameters

RF power/RF duty	ILC	Higher/Longer
Purity of Al_2O_3	> 95%	> 99%
Dielectric loss tangent	$\sim 10^{-4}$ @1GHz	$\sim 10^{-5}$ @1GHz
Secondary electron emission coefficient	<~2 (w/ TiN coating)	<~2 (w/ TiN coating)
Thickness of copper plating	10 μm	>10 μm

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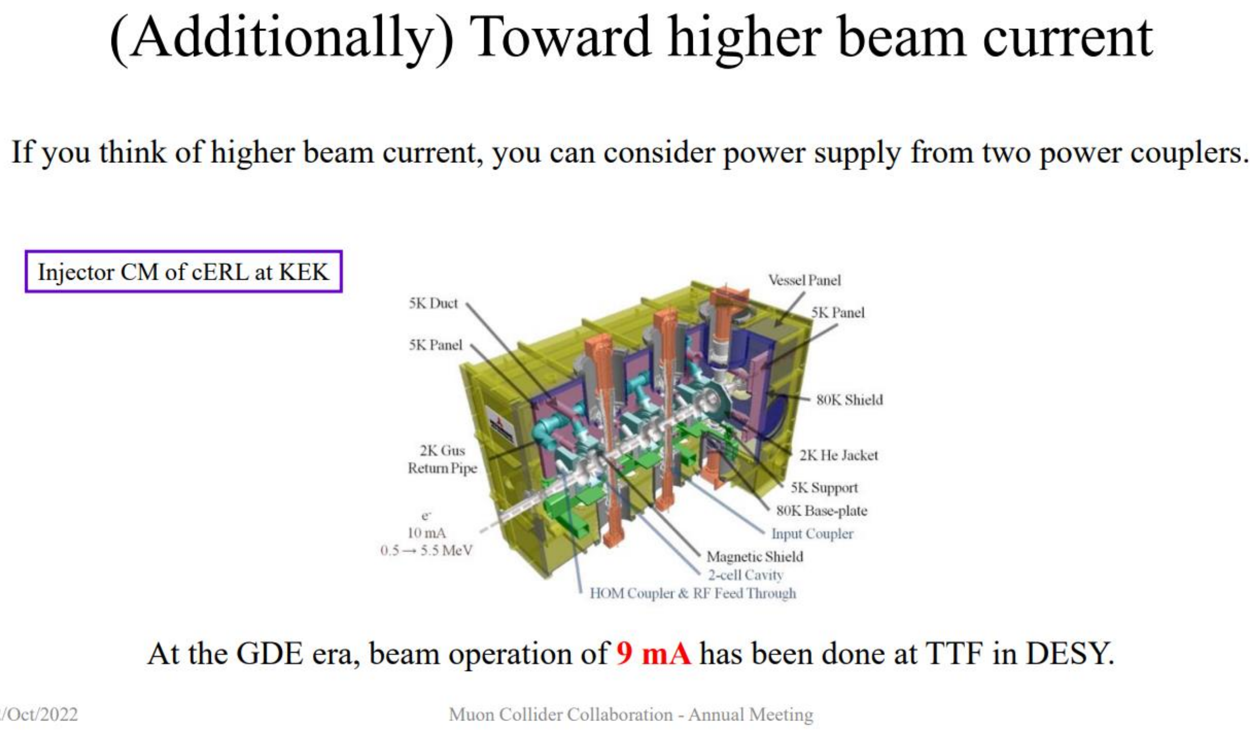

(Additionally) Toward higher beam current

If you think of higher beam current, you can consider power supply from two power couplers.

Injector CM of cERL at KEK

At the GDE era, beam operation of **9 mA** has been done at TTF in DESY.

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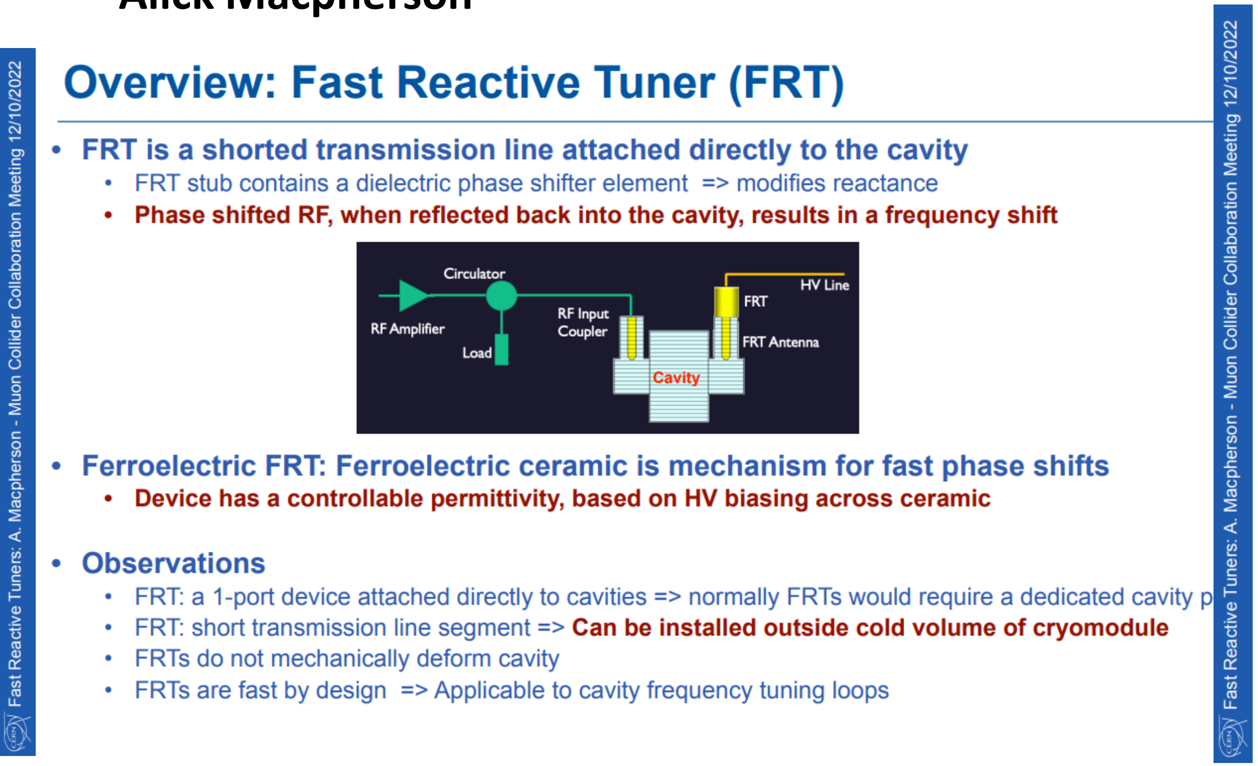
There are ways to improve further towards higher peak power and longer pulse operation necessary for MC.

Ferro-electric fast reactive tuners

Alick Macpherson



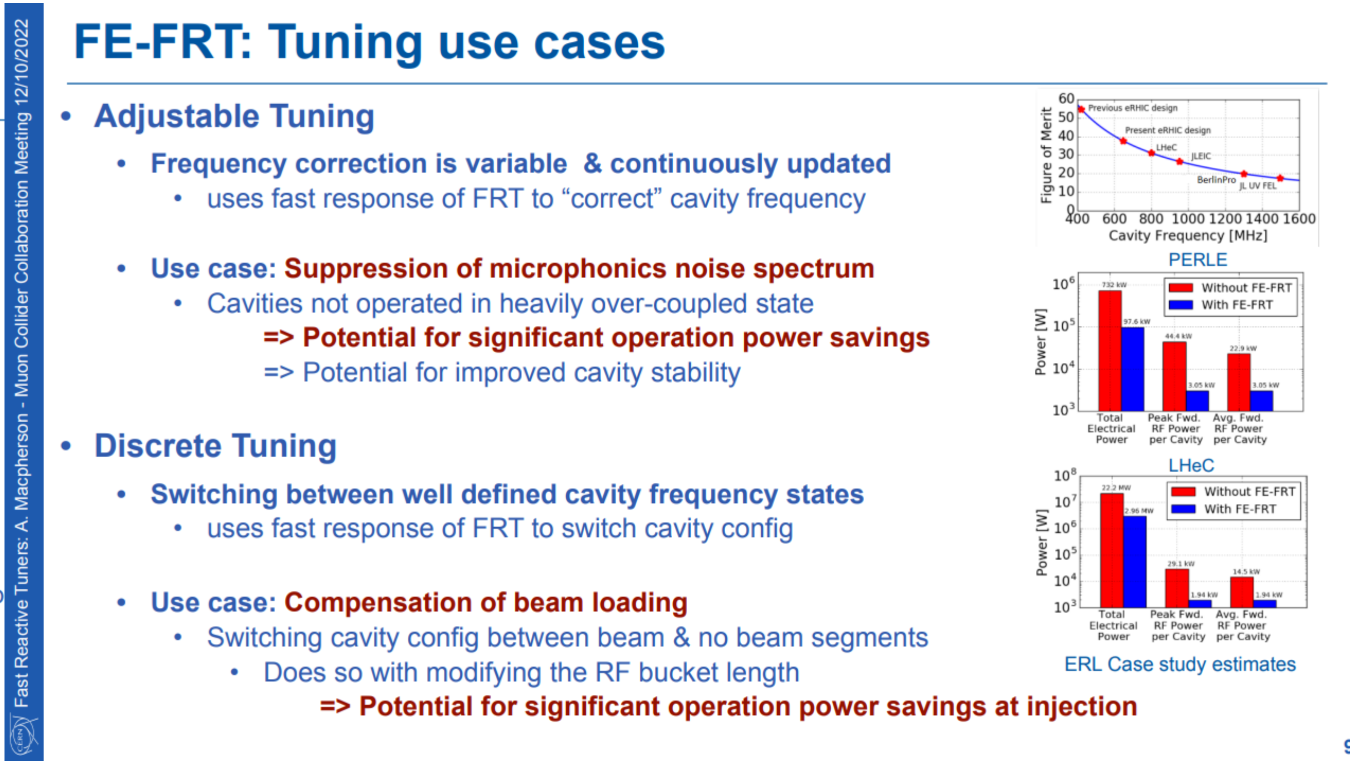
Fast Reactive Tuners: A. Macpherson - Muon Collider Collaboration Meeting 12/10/2022

Overview: Fast Reactive Tuner (FRT)

- **FRT is a shorted transmission line attached directly to the cavity**
  - FRT stub contains a dielectric phase shifter element => modifies reactance
  - **Phase shifted RF, when reflected back into the cavity, results in a frequency shift**

- **Ferroelectric FRT: Ferroelectric ceramic is mechanism for fast phase shifts**
  - **Device has a controllable permittivity, based on HV biasing across ceramic**

- **Observations**
  - FRT: a 1-port device attached directly to cavities => normally FRTs would require a dedicated cavity p
  - FRT: short transmission line segment => **Can be installed outside cold volume of cryomodule**
  - FRTs do not mechanically deform cavity
  - FRTs are fast by design => Applicable to cavity frequency tuning loops



Fast Reactive Tuners: A. Macpherson - Muon Collider Collaboration Meeting 12/10/2022

FE-FRT: Tuning use cases

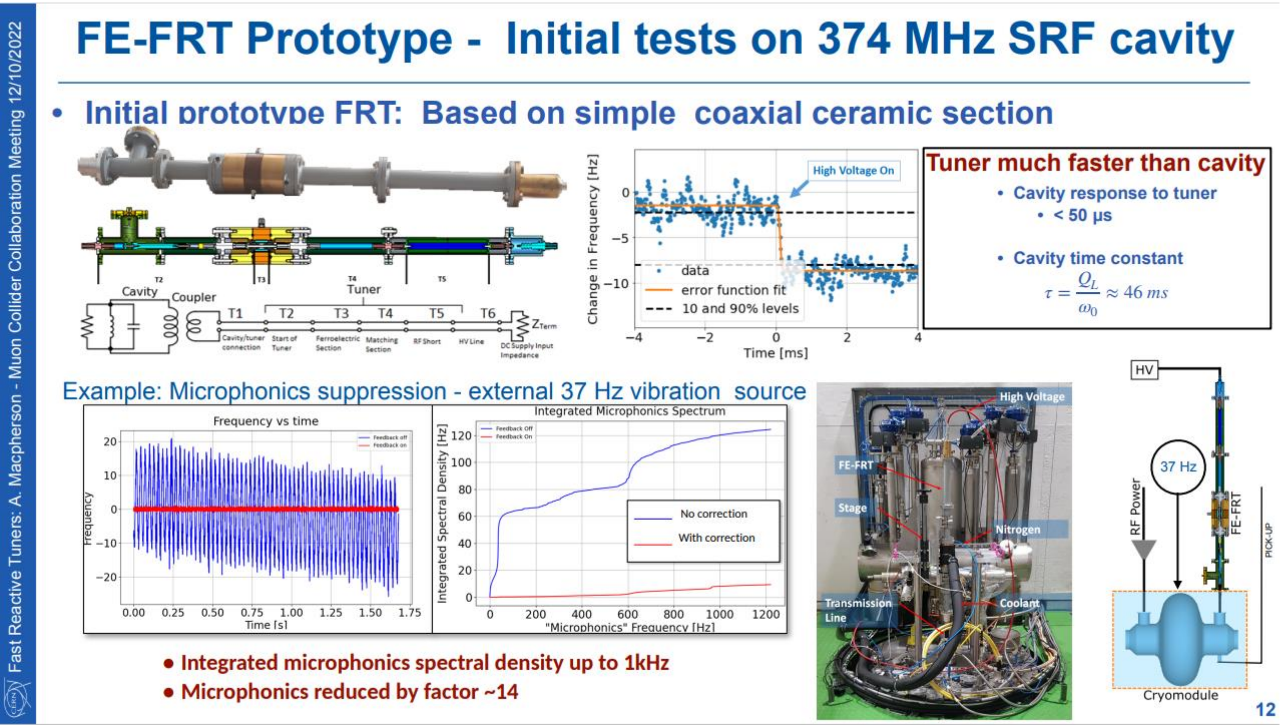
- **Adjustable Tuning**
  - **Frequency correction is variable & continuously updated**
    - uses fast response of FRT to "correct" cavity frequency
  - **Use case: Suppression of microphonics noise spectrum**
    - Cavities not operated in heavily over-coupled state
      - **=> Potential for significant operation power savings**
      - => Potential for improved cavity stability
- **Discrete Tuning**
  - **Switching between well defined cavity frequency states**
    - uses fast response of FRT to switch cavity config
  - **Use case: Compensation of beam loading**
    - Switching cavity config between beam & no beam segments
      - Does so with modifying the RF bucket length
        - **=> Potential for significant operation power savings at injection**

ERL Case study estimates

Fast reactive tuners is promising new technology for many different applications

Ferro-electric fast reactive tuners

Alick Macpherson



FE-FRT Prototype - Initial tests on 374 MHz SRF cavity

- Initial prototype FRT: Based on simple coaxial ceramic section

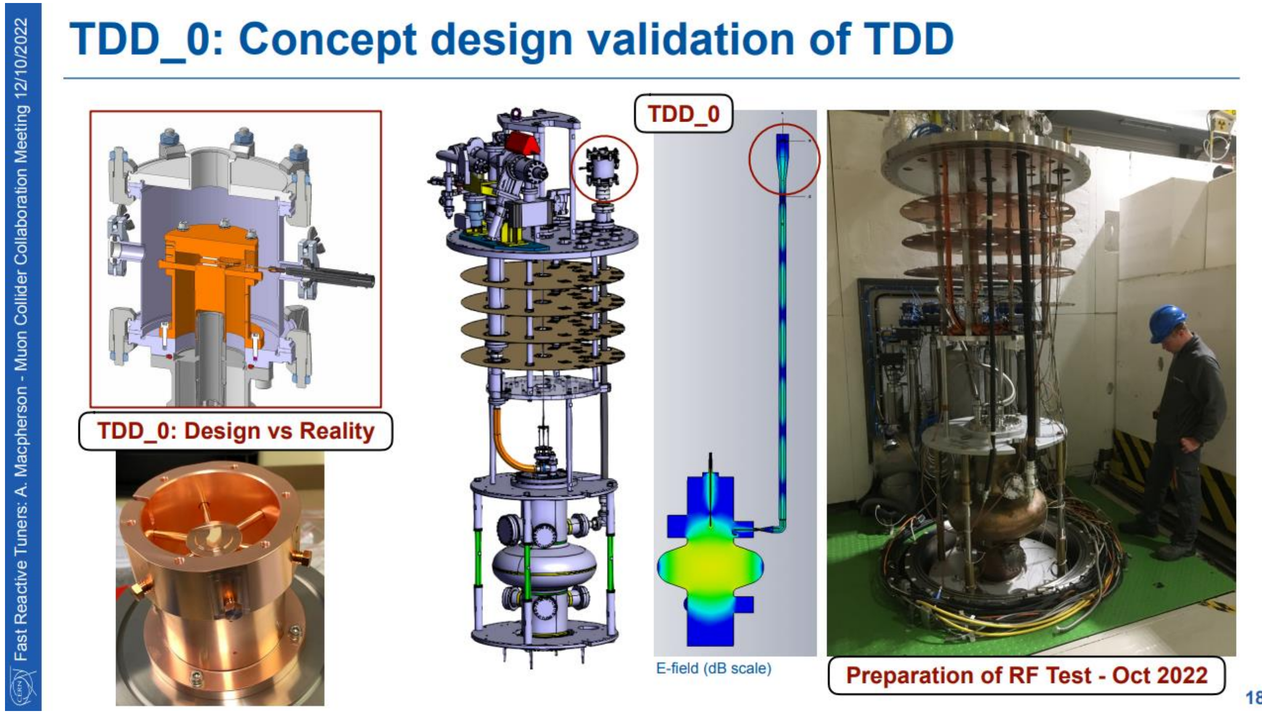
Tuner much faster than cavity

- Cavity response to tuner
  - < 50 μs
- Cavity time constant

$$\tau = \frac{Q_L}{\omega_0} \approx 46\,ms$$

Example: Microphonics suppression - external 37 Hz vibration source

- Integrated microphonics spectral density up to 1kHz
- Microphonics reduced by factor ~14



TDD_0: Concept design validation of TDD

TDD_0: Design vs Reality

TDD_0

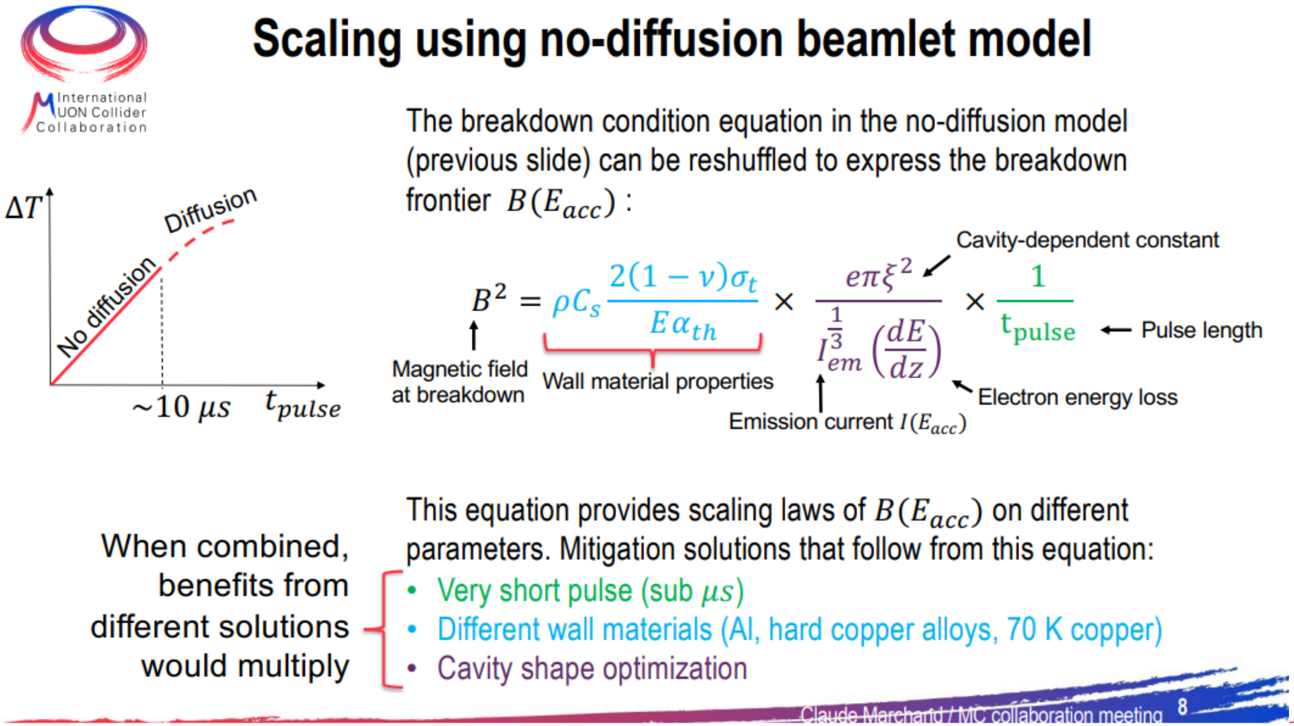
E-field (dB scale)

Preparation of RF Test - Oct 2022

Prototypes have been built and tested at CERN paving the way towards application in LHC RF cavities for transient BL compensation

High gradient in strong B-fields, CEA prospects

Claude Marchand



Scaling using no-diffusion beamlet model

The breakdown condition equation in the no-diffusion model (previous slide) can be reshuffled to express the breakdown frontier $B(E_{acc})$:

$$\underset{\uparrow}{B^2} = \underbrace{\rho C_s \frac{2(1-\nu)\sigma_t}{E\alpha_{th}}}_{\text{Wall material properties}} \times \frac{e\pi\xi^2}{I_{em}^{\frac{1}{3}}\left(\frac{dE}{dz}\right)} \times \frac{1}{t_{pulse}}$$

Magnetic field at breakdown

Cavity-dependent constant

Pulse length

Electron energy loss

Emission current $I(E_{acc})$

This equation provides scaling laws of $B(E_{acc})$ on different parameters. Mitigation solutions that follow this equation:

When combined, benefits from different solutions would multiply

- Very short pulse (sub μs)
- Different wall materials (Al, hard copper alloys, 70 K copper)
- Cavity shape optimization

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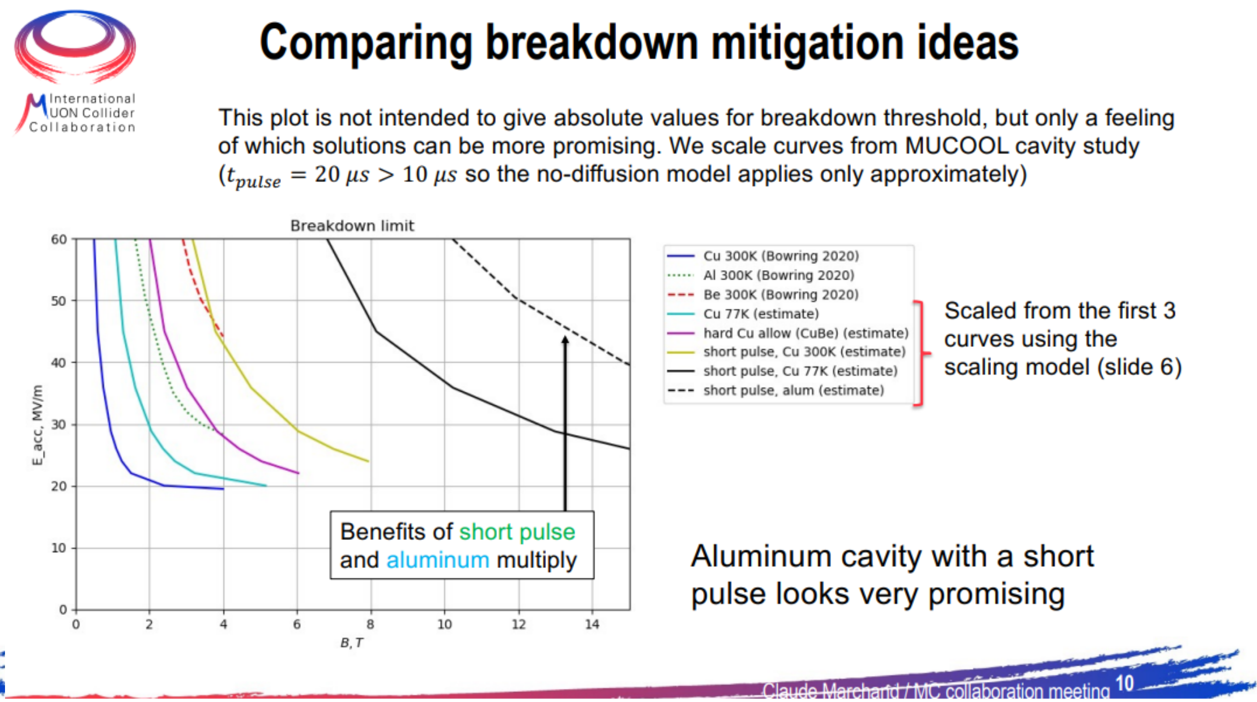

Comparing breakdown mitigation ideas

This plot is not intended to give absolute values for breakdown threshold, but only a feeling of which solutions can be more promising. We scale curves from MUCOOL cavity study ($t_{pulse} = 20\ \mu s > 10\ \mu s$ so the no-diffusion model applies only approximately)

Scaled from the first 3 curves using the scaling model (slide 6)

Benefits of short pulse and aluminum multiply

Aluminum cavity with a short pulse looks very promising

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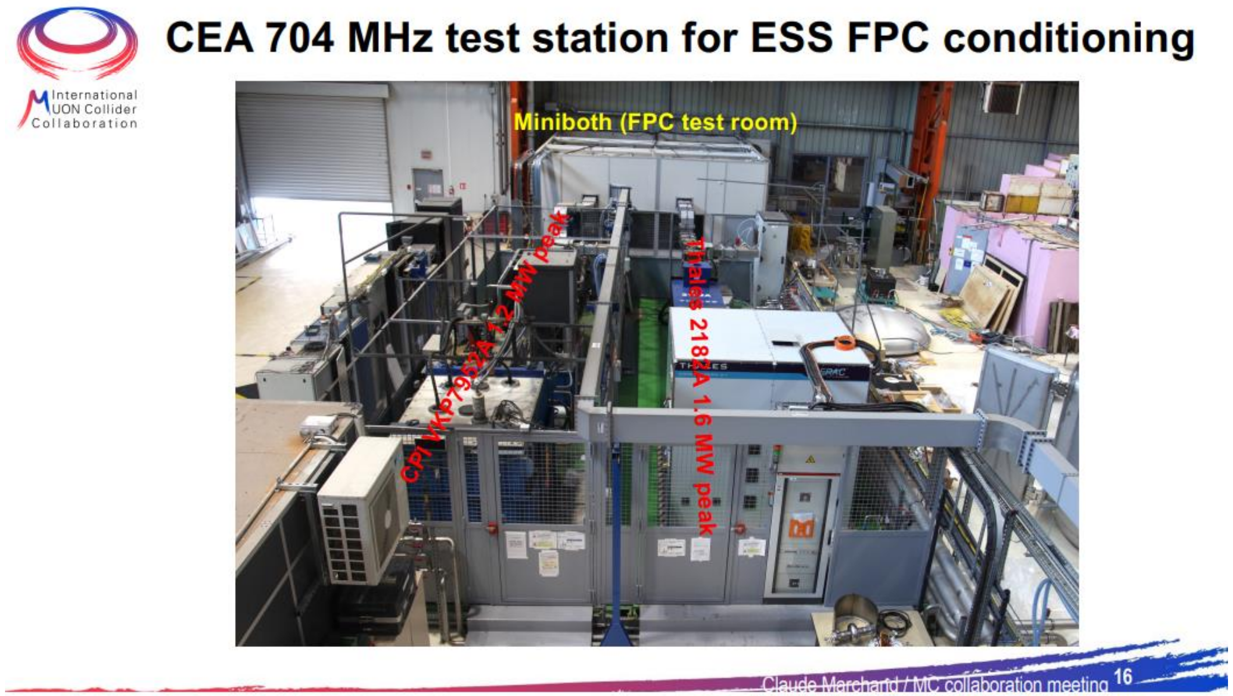
Scaling of the high-G limit using existing model has been described

Possible mitigation measures have been proposed

High gradient in strong B-fields, CEA prospects

Claude Marchand



CEA 704 MHz test station for ESS FPC conditioning

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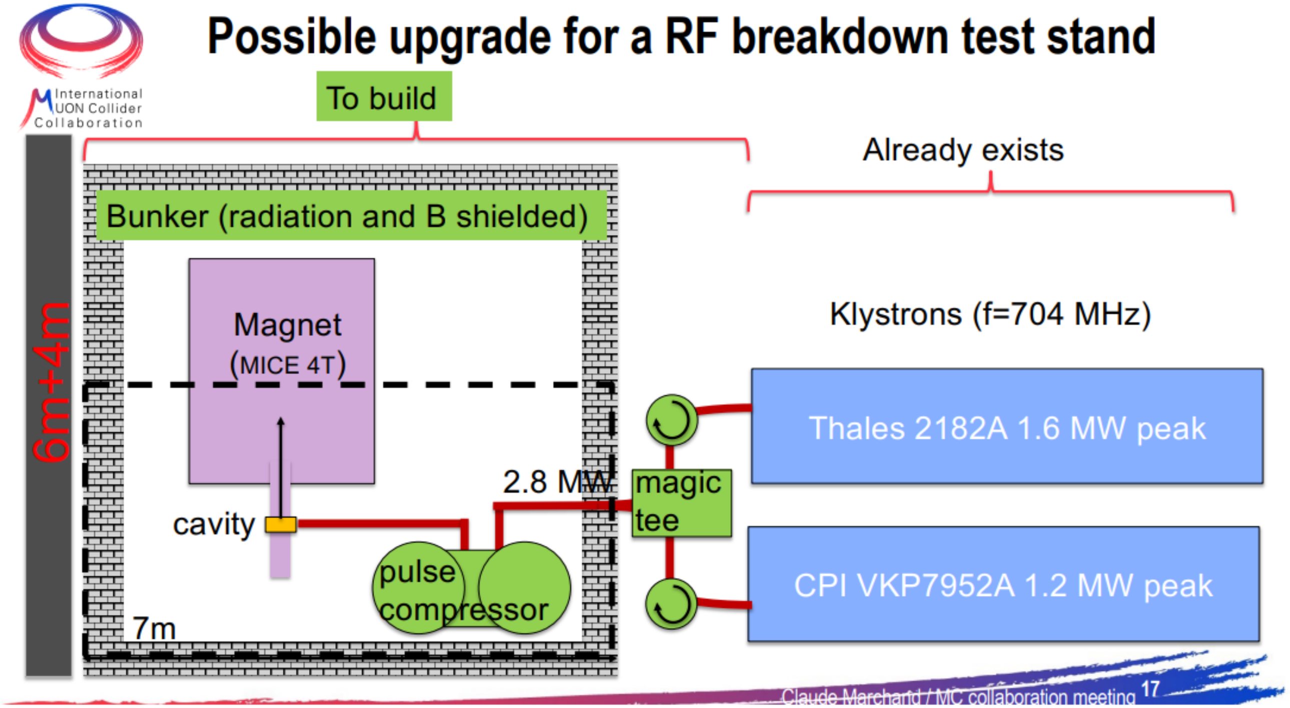

Possible upgrade for a RF breakdown test stand

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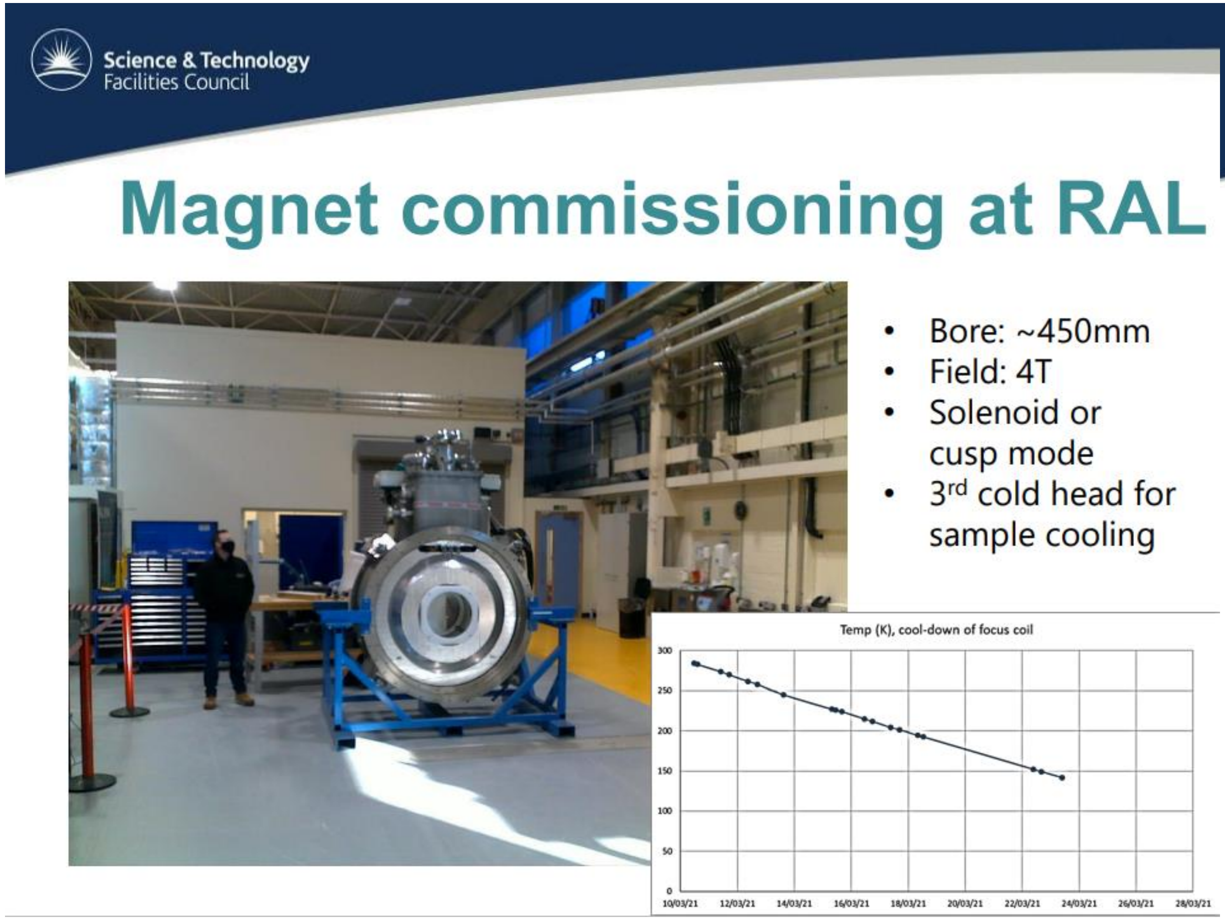
Available infrastructure at CEA has been shown and possible implementation plan towards RF test stand has been discussed

The MICE “focus coil module”

Josef Boehm

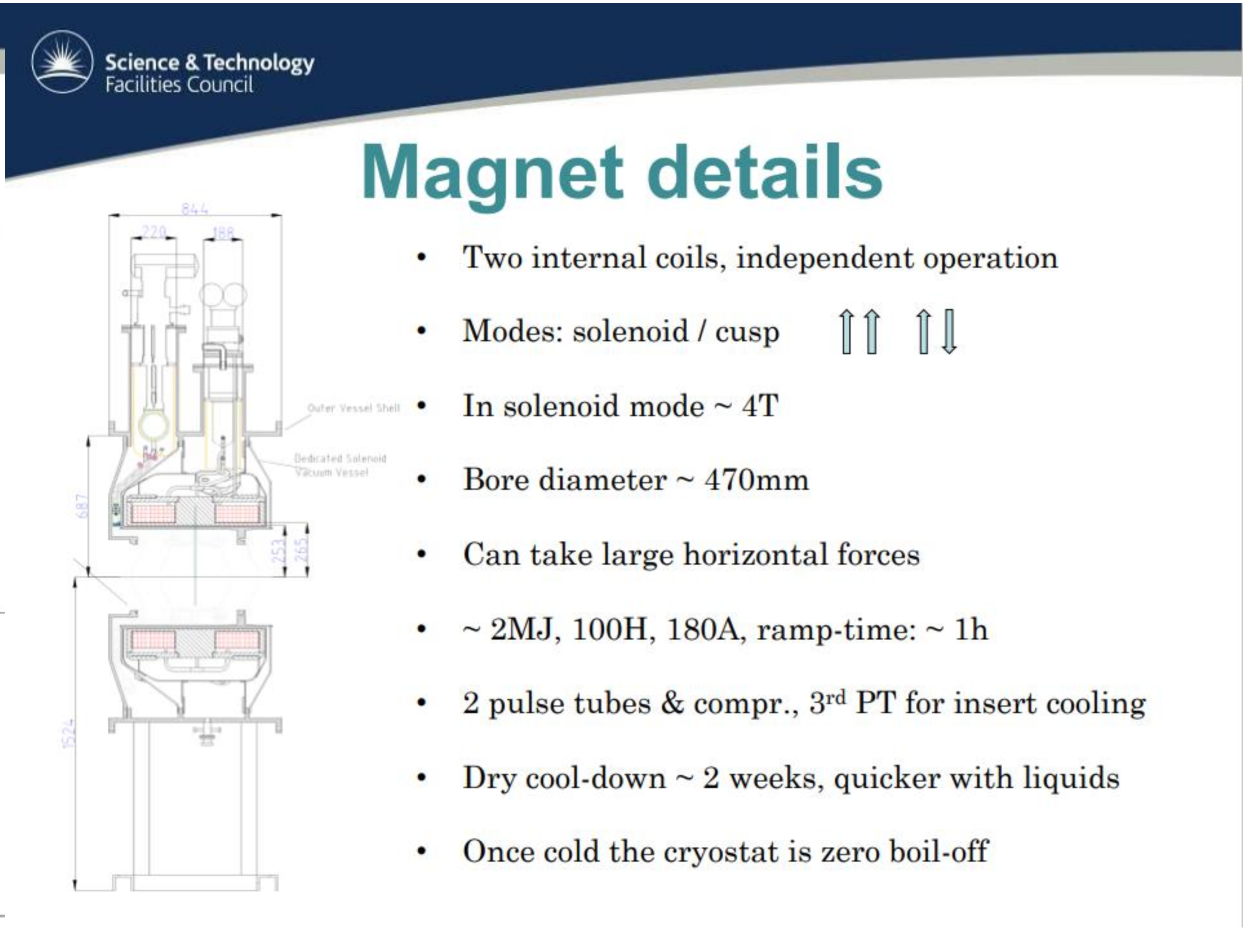


Science & Technology Facilities Council

Magnet commissioning at RAL

- Bore: ~450mm
- Field: 4T
- Solenoid or cusp mode
- 3rd cold head for sample cooling

Temp (K), cool-down of focus coil



Science & Technology Facilities Council

Magnet details

- Two internal coils, independent operation
- Modes: solenoid / cusp ⇈ ⇅
- In solenoid mode ~ 4T
- Bore diameter ~ 470mm
- Can take large horizontal forces
- ~ 2MJ, 100H, 180A, ramp-time: ~ 1h
- 2 pulse tubes & compr., 3rd PT for insert cooling
- Dry cool-down ~ 2 weeks, quicker with liquids
- Once cold the cryostat is zero boil-off

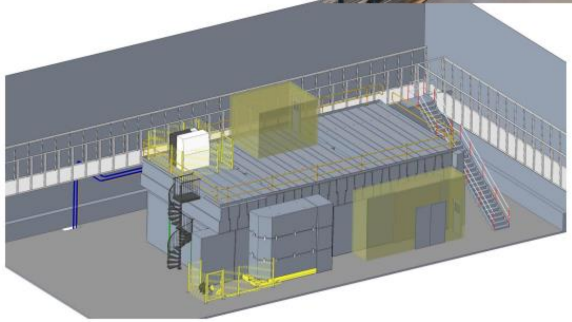
Important ingredient of the possible RF test stand is SC 4T solenoid available at RAL.

Muon RF activities in the UK

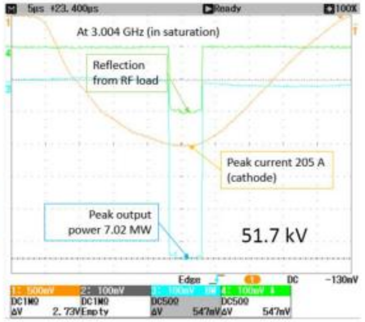
Graeme Burt

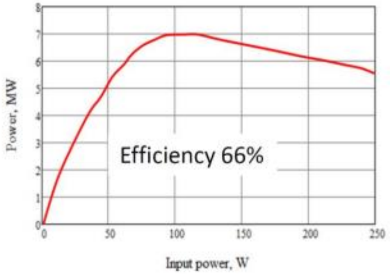
CI RF Bunker

- Have started putting the concrete in place with handover expected mid 2022
- S-band 7 MW klystron and LLRF control being shipped/procured



BAC MBK factory test results





The achieved S-band BAC MBK klystron performance confirmed the excellent potential of the new bunching technology. In this case by 'simply' replacing the klystron RF circuit (retrofit), the peak output RF power was boosted by almost 50%!

CLIC project meeting, 26 April 2016

Igor Syratchev, CERN

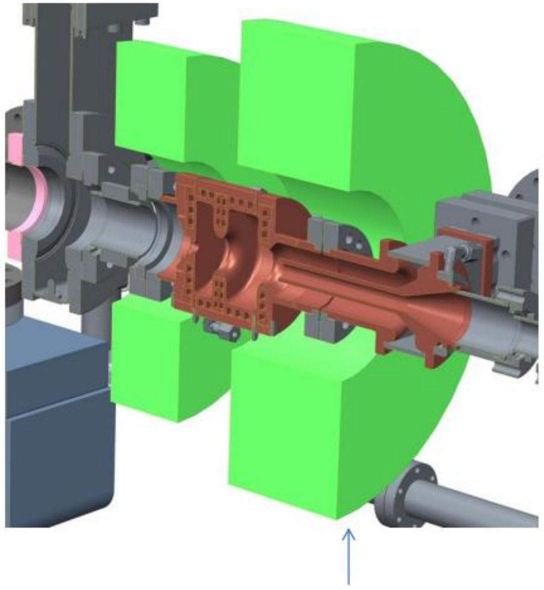
RF test stand is under construction. Bunker is in place.

S-band high efficiency MBK is provided by CERN.

Muon RF activities in the UK

Graeme Burt

High Repetition Rate RF Gun

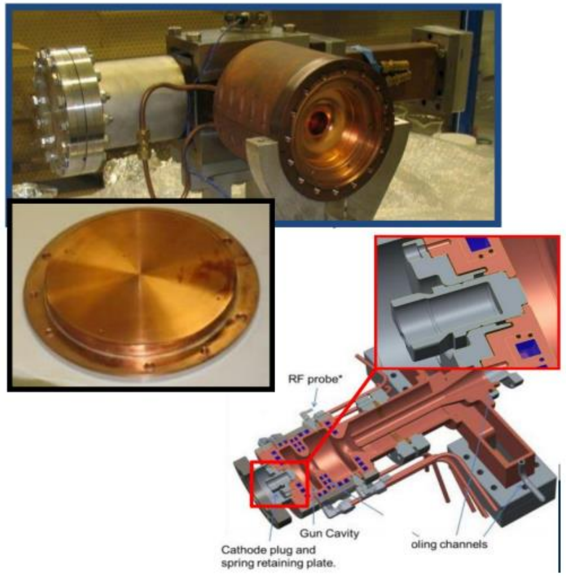


- ASTeC in collaboration with Lancaster University has developed a High Repetition Rate Gun for CLARA.
- The gun has a solenoid on it allowing some testing with lower magnetic fields (0.2 - 0.3 T)
- May be partially relevant for muons in the short term to validate models.
- Testing gradients of 80/100/120 MV/m
- Is being conditioned now and we ae very interested in the effect of B field on conditioning

Science and Technology Facilities Council

RF sample testing

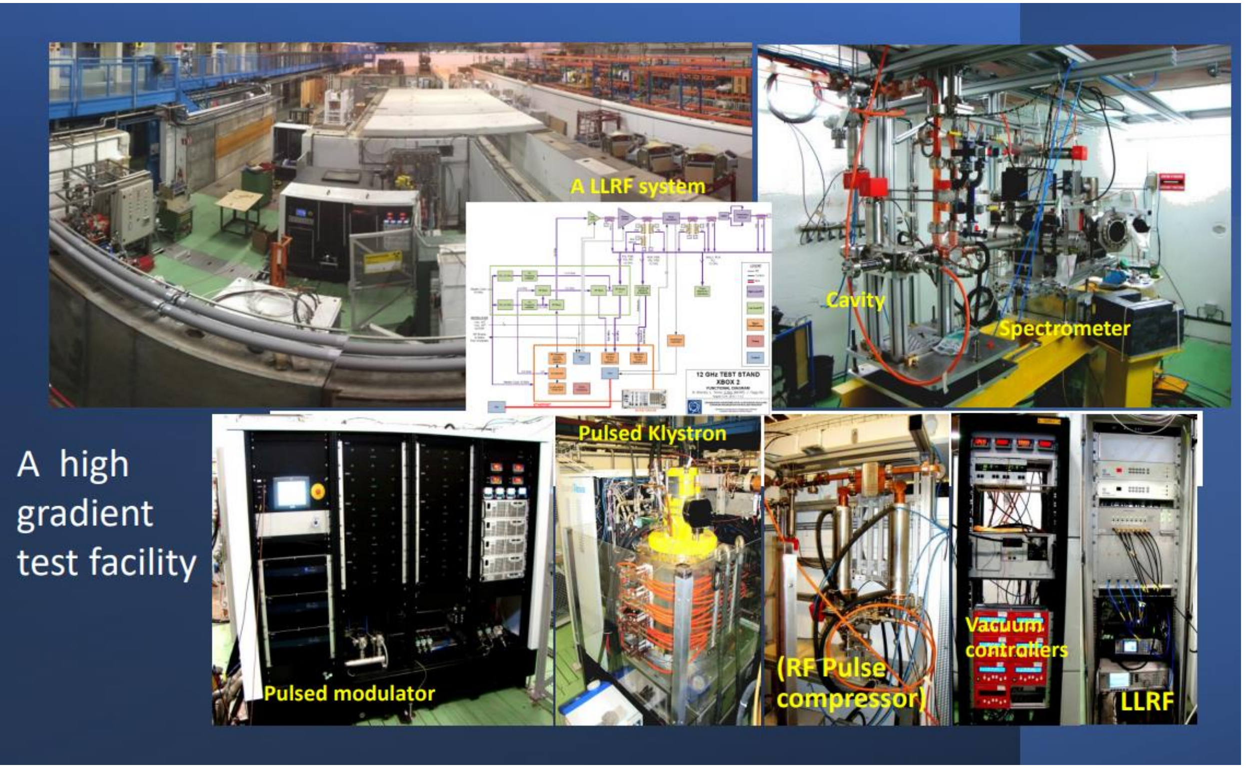
- Plan to replicate something like our RF guns where we have removable back plates or plugs
- Can design to maximise peak fields on the removable part while keeping most of the cavity the same
- Can test different materials
- Possibility to test same sample with DC
- Southampton could design a solenoid to go around this cavity
- As its only 3 GHz we can use a smaller bore (~10-15 cm)
- Can couple via an axial coax line similar to our RF gun to avoid having large waveguide feed go through the coil



Investigation of the effect of magnetic field (~0.3T) on high gradient performance of an S-band RF gun is planed.

High gradient RF testing infrastructure and MgB2 solenoid at CERN

Nuria Catalan



A high gradient test facility

Xbox1

- 50 MW/1.5 ms
- 120 MW/250 ns
- 50Hz
- RF signals
- Dark current
- Accurate phase
- Spectrometer
- E-beam capabilities
- Connects to CTF3/CLEAR

Xbox2

- 50 MW/1.5 ms
- 120 MW/250 ns
- 50Hz
- RF signals
- Dark current
- Accurate phase
- Radiation
- Two DUT feeding with variable power splitting
- Input phase variation

Xbox3

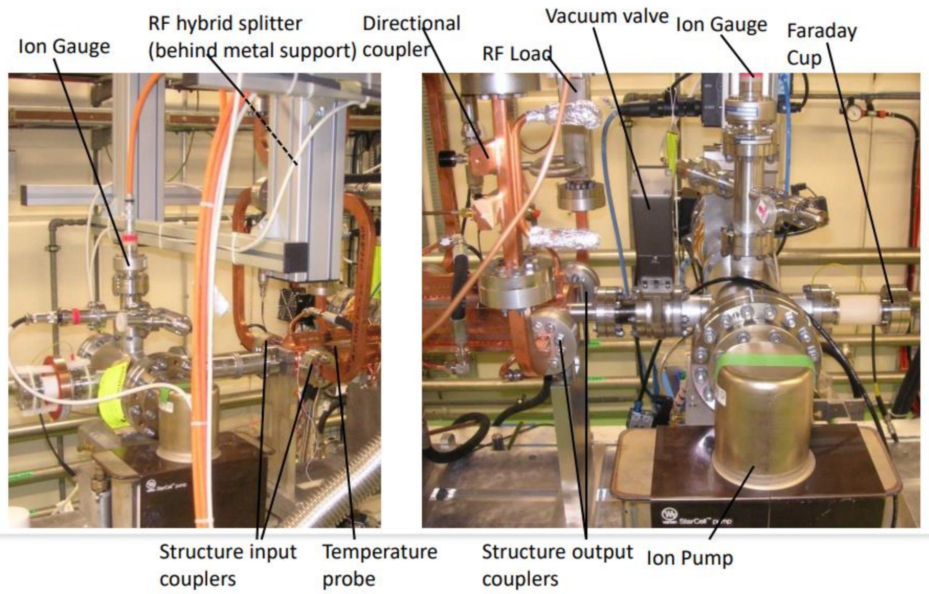
- 6-10 MW/5 ms
- 40-60 MW/100 ns
- Up to 400Hz
- 2 DUT
- RF signals
- Dark current
- Accurate phase
- Radiation monitors

High gradient RF testing infrastructure has been presented

High gradient RF testing infrastructure and MgB2 solenoid at CERN

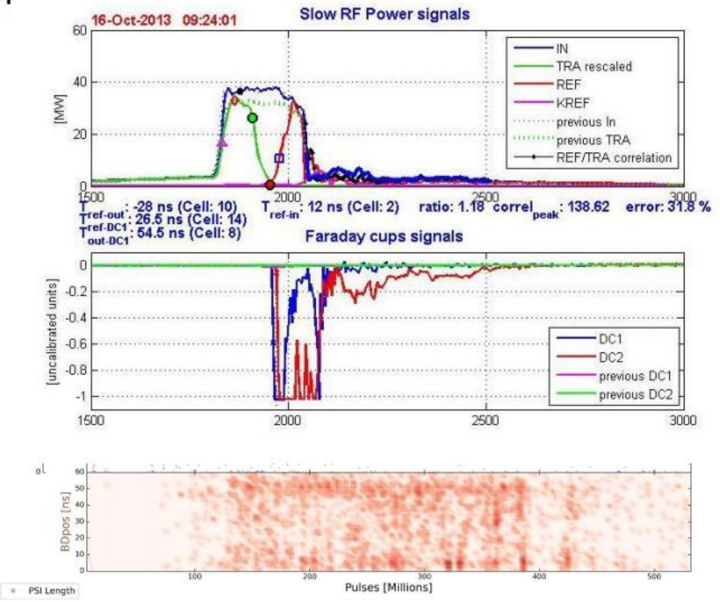
Nuria Catalan

Accelerating Structure Diagnostics



BD Detection: Breakdown

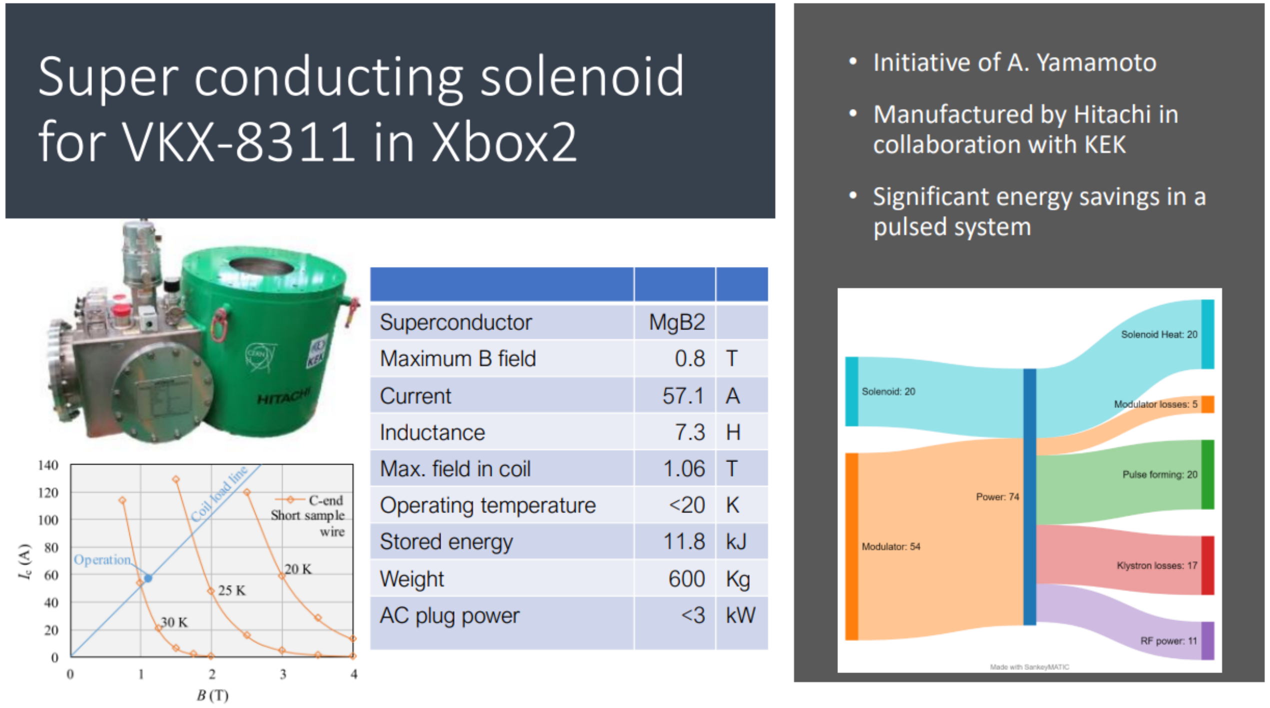
- Transmitted pulse drops as the arc is established.
- Reflected power increases to the same order as the incident pulse.
- Faraday cup voltages are saturated: 100-1000x increase in charge emitted.
- We can use the difference in time between the transmitted power falling and the reflected power increasing to find the BD cell location.
- The phase of the reflected signal is used to pinpoint cell location.



Required diagnostic and BD detection tools have been described sharing decades of CERN experience.

High gradient RF testing infrastructure and **MgB2 solenoid** at CERN

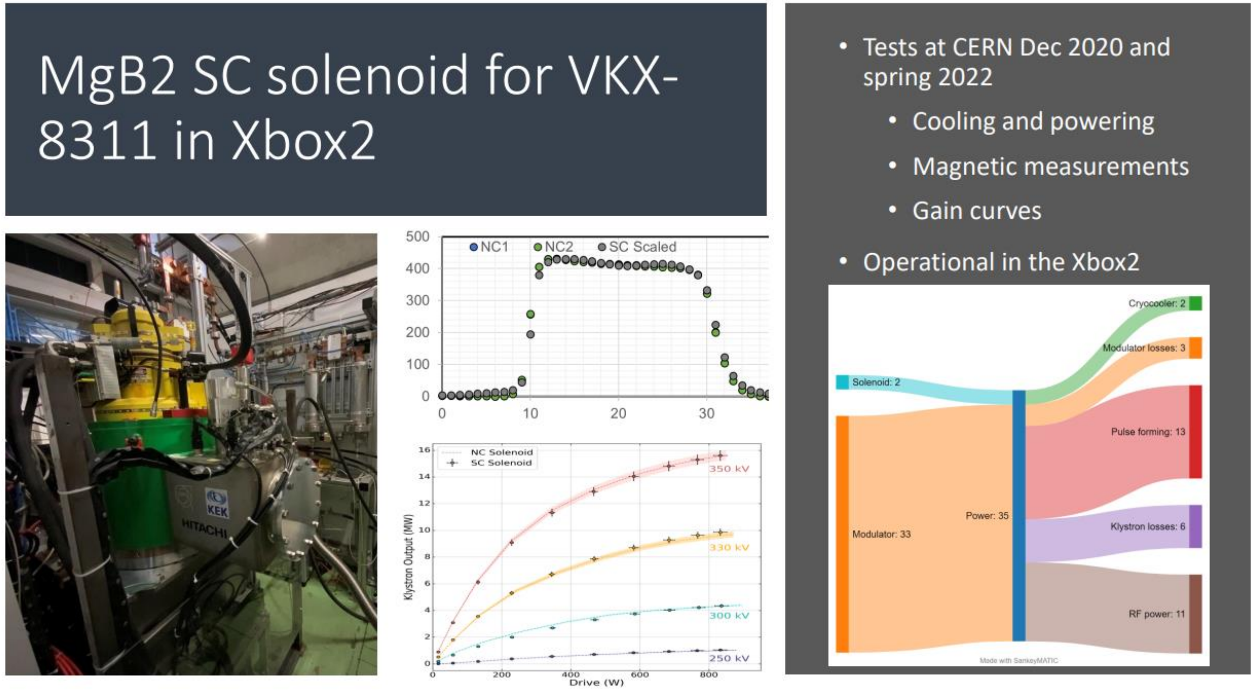
Nuria Catalan



Super conducting solenoid for VKX-8311 in Xbox2

Superconductor	MgB2	
Maximum B field	0.8	T
Current	57.1	A
Inductance	7.3	H
Max. field in coil	1.06	T
Operating temperature	<20	K
Stored energy	11.8	kJ
Weight	600	Kg
AC plug power	<3	kW

- Initiative of A. Yamamoto
- Manufactured by Hitachi in collaboration with KEK
- Significant energy savings in a pulsed system



MgB2 SC solenoid for VKX-8311 in Xbox2

- Tests at CERN Dec 2020 and spring 2022
  - Cooling and powering
  - Magnetic measurements
  - Gain curves
- Operational in the Xbox2

MgB2 SC solenoid have been commissioned at CERN for X-band klystron application. Solenoid power reduced from 20 to 2 kW.

Thank you for your attention