HIGHLIGHTS FROM HG2023

David Alesini– INFN Frascati

The 2023 International Workshop on the High Energy Circular Electron Positron Collider

Oct 23 – 27, 2023

Asia/Shanghai timezone

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GENERAL OVERVIEW

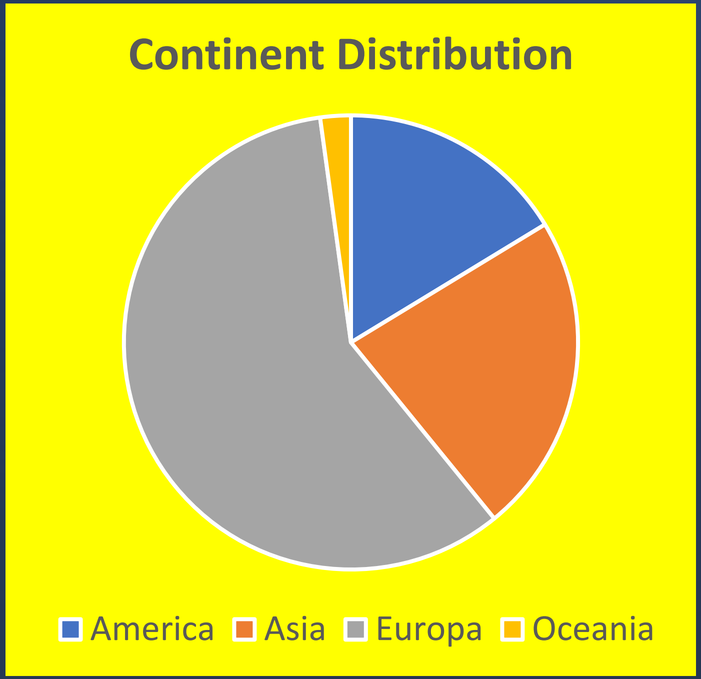
- 15th Workshop on breakdown science and high gradient technology HG2023
- the **HG sector showed to be alive and full of initiatives, vibrant community**
- the HG sector is at **forefront of applied physics, industrial applications and HEP**

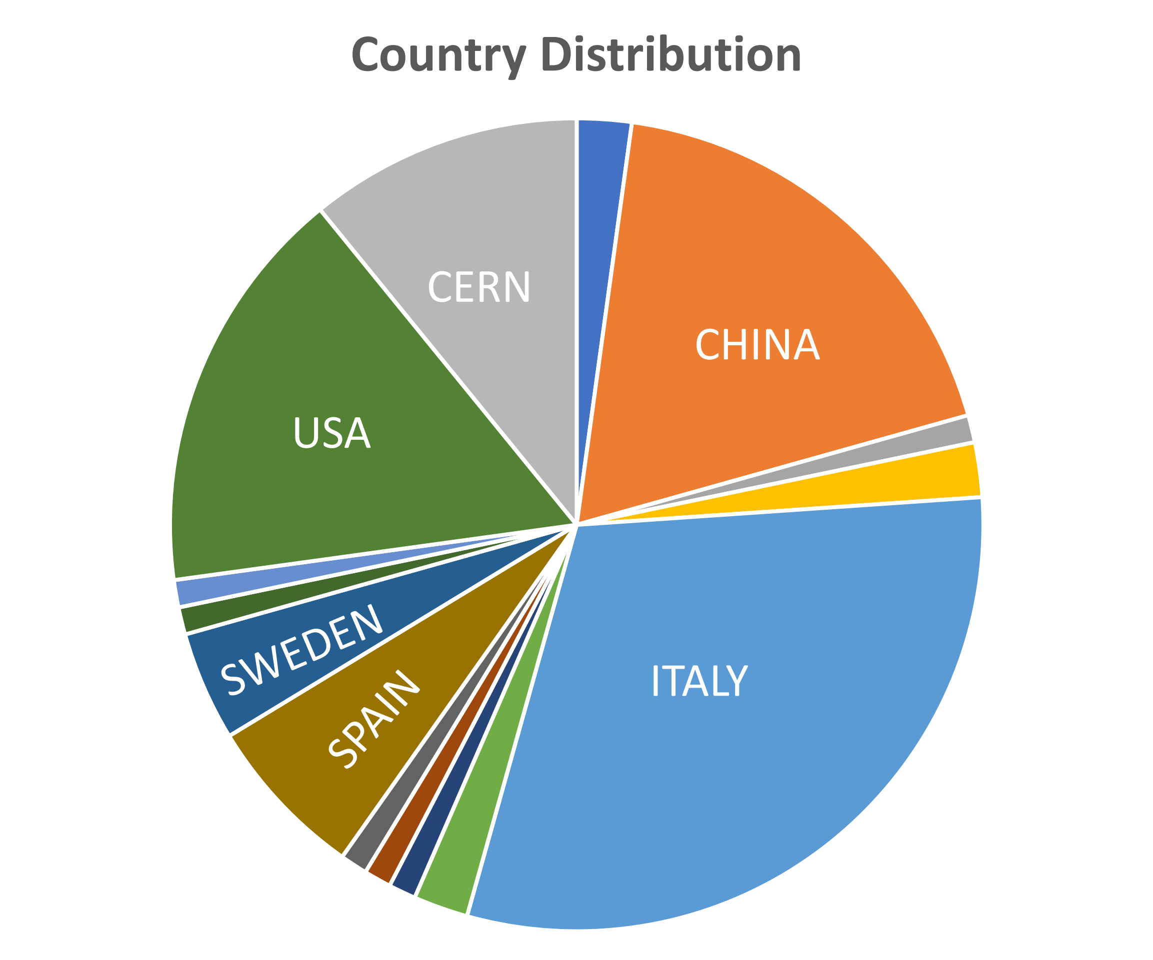
https://agenda.infn.it/event/34253/

- 11 Plenary Sessions;
- 56 Oral presentations;
- 21 Posters;
- 3 Industrial Exhibitors (Scandinova, CPI, TSC)

INTERNATIONAL PARTICIPATION

- 92 registered participants
  - ✓ from 28 scientific institutions + 7 companies;
  - ✓ from 14 countries + CERN;
  - ✓ from 4 continents





Australia	2
China	17
France	1
Iran	2
Italy	28
Japan	2
Nederland	1
Norway	1
Slovenia	1
Spain	6
Sweden	4
Switzerland	1
United Kingdom	1
USA	15
CERN	10

STUDENTS AND GRANTS

INFN
LNF
Istituto Nazionale di Fisica Nucleare

- **15 students supported by grants**

We are especially proud of them!

About **20%** of the whole audience

Contrary to the statistical trend for the general audience, **none of them is Italian!**

SCIENTIFIC PROGRAM

INFN LNF Istituto Nazionale di Fisica Nucleare

	TUESDAY October 17		WEDNESDAY October 18	THURSDAY October 19	FRIDAY October 20
9.00	General & Highlights 1 Alessandro Gallo - INFN	9.00	Projects Walter Wuensh - CERN	Injectors & C-band Tetsuo Abe - KEK	X-band and beyond Emilio Nanni - SLAC
11.00	Coffee break	11.00	Coffee break	Coffee break	Coffee break
11.30	General & Highlights 2 Jiaru Shi - Tsinghua Univ.	11.30	Klystrons, LLRF and equipment Gerardo D'Auria - Sincrotrone Trieste	C-band & Cryogenics Luigi Palumbo - Rome Univ. La Sapienza	HG in the context of the European Strategy Accelerator R&D CONCLUSIONS Valery Dolgachev - SLAC
13.20	Lunch	13.20	Lunch	Lunch	Farewell Buffet Lunch
14.45	Test Stands Wencheng Fang - SARI	14.45	Breakdown and theory I Evgenya Simakov Smirnova - LANL	Visit to LNF Facilities	
16.45	Coffee break	16.30	Coffee break	Coffee break	
	Poster session	17.00	Breakdown and theory II Matteo Volpi - Melbourne Univ.	***Free Time***	
	Wine&Cheese	18.30	*Tranfer to banquet*		
20.00		19.00	***BANQUET***		
		22.00			

- 11 Plenary Sessions;
- 56 Oral presentations;

International Organising Committee

- Alesini David (INFN-LNF)
- D'Auria Gerardo (Sincrotrone Trieste)
- Dolgachev Valery (SLAC)
- Fang Wencheng (SARI)
- Faus-Golfe Angeles (IJCLAB)
- Gallo Alessandro (INFN-LNF)
- Higo Toshi (KEK)
- Jing Chunguang (ANL)
- Nanni Emilio (SLAC)
- Shi Jiaru (Tsinghua Univ.)
- Simakov Smirnova Evgenya (LANL)
- Wuensh Walter (CERN)

X BAND-BASED FACILITIES

15th Workshop on breakdown science and High Gradient Technology
October 16 - 20, 2023 INFN-LNF, Frascati, Italy

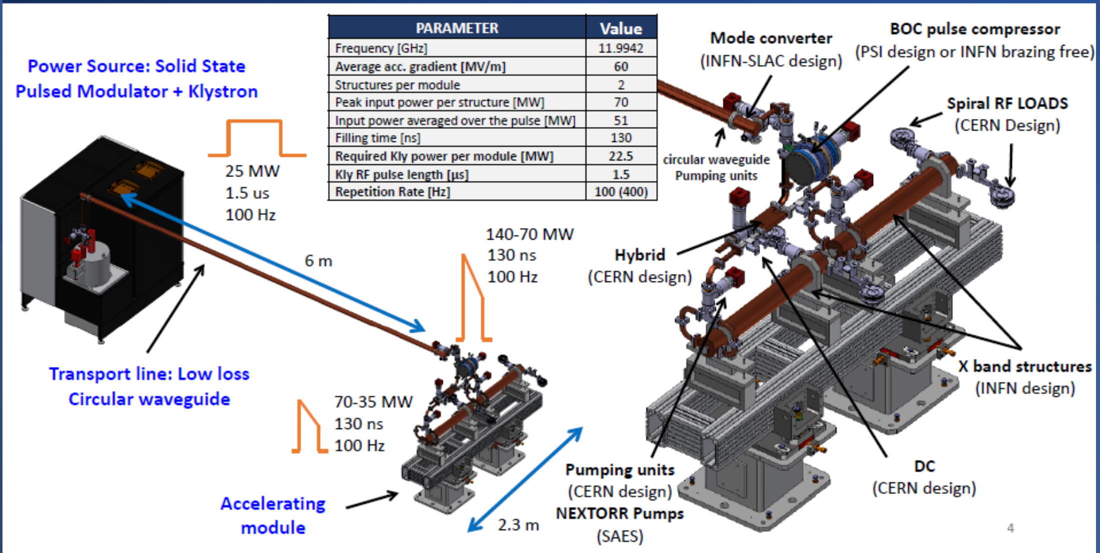
RF Structure for Eupraxia@SPARC_LAB: accelerating sections and waveguide components

Fabio Cardelli and Claudio di Giulio

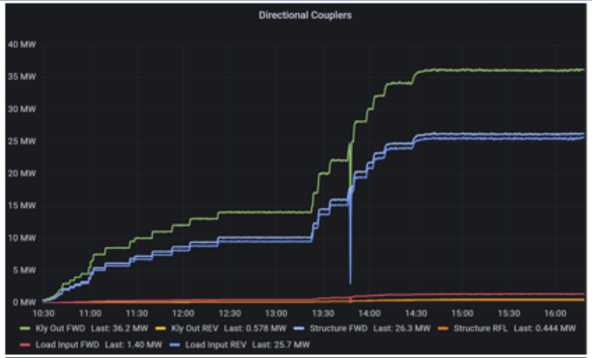
INFN Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati

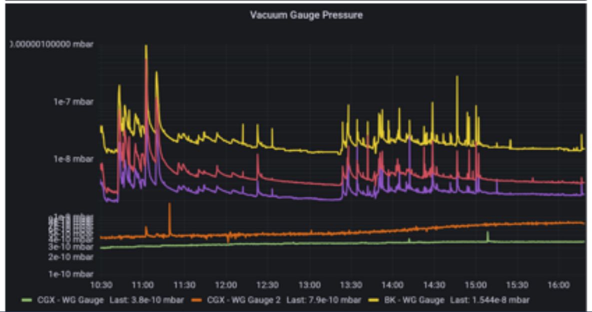
X-band RF Module Layout

PARAMETER	Value
Frequency [GHz]	11.9942
Average acc. gradient [MV/m]	60
Structures per module	2
Peak input power per structure [MW]	70
Input power averaged over the pulse [MW]	51
Filling time [ns]	130
Required Kly power per module [MW]	22.5
Kly RF pulse length [µs]	1.5
Repetition Rate [Hz]	100 (400)



- Modified version of the "wrap around" mode converter from TE_{10} to TE_{01} developed at SLAC [7] and pumping port for circular waveguide
- EM and mechanical design: *done*
- Machining by a private company (TSC): *done*
- Brazing at INFN-LNF: *done*
- Low Power RF test: *done*
- High Power test: *Ongoing (Started yesterday)*



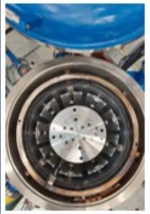


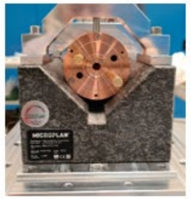
[7] S. Tantawi, et al. (2000), Reviews of Modern Physics, doi: 10.1103/PhysRevSTAB.3.082001

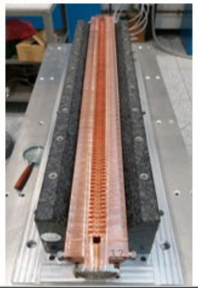
Full-Scale Mechanical Prototype Brazing

Full scale mechanical prototype brazing

To maintain the alignment and cell to cell straightness during and after the brazing process, each cell is fixed to the next one by means of screws and mounted on a very precise granite support. This ease also the cells assembly







Results on the brazed structure

- **Vacuum test OK** (except one coupler for a miss-positioning of the brazing alloy)
- **Straightness ±15 µm** obtained after brazing (±30 µm required by BD)

NEW RESULTS

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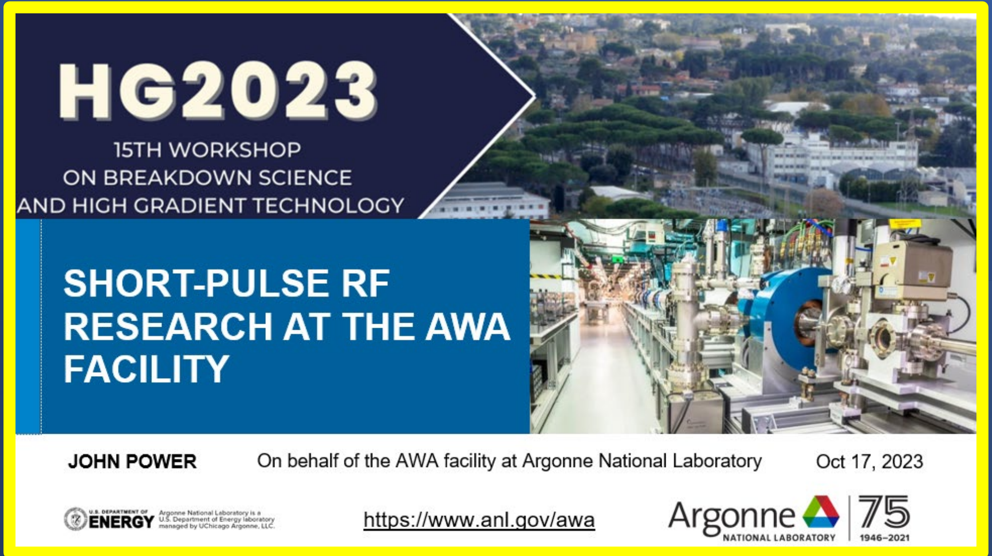

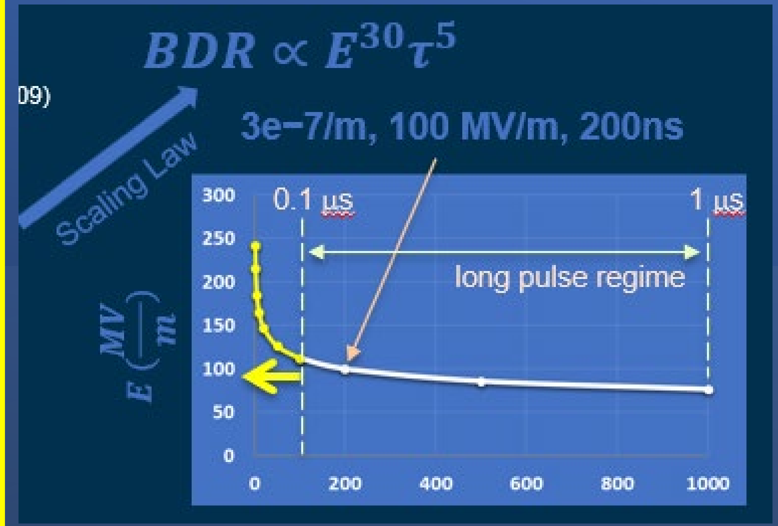

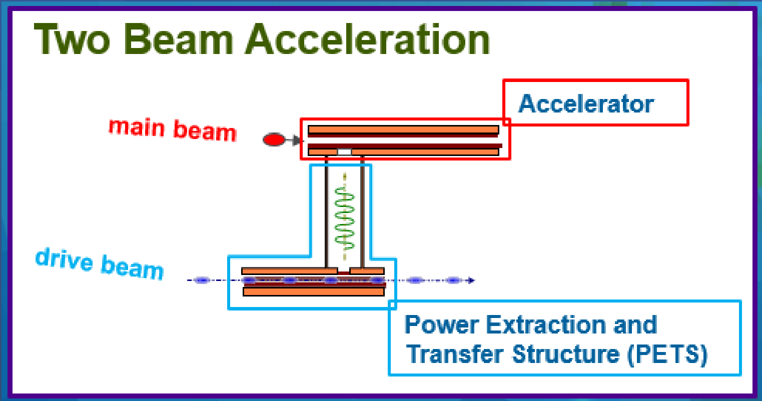

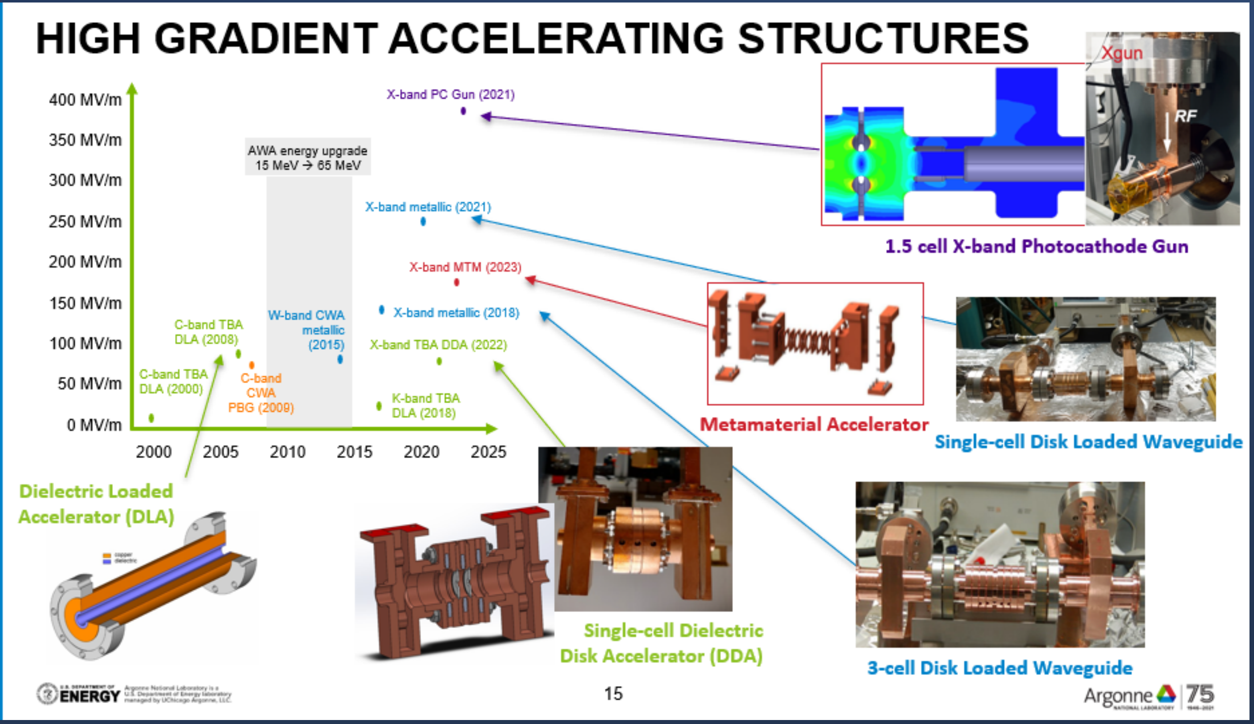

SHORT-PULSE REGIME

SUMMARY

- X-band RF test stand (500 MW, 2 Hz)
- RF power generation
  - 565 MW metamaterial PETS
  - 400 MW metallic PETS
  - 200 MW dielectric PETS
- High-gradient structures
  - 300 MV/m X-band TW accelerating metallic accelerator
  - 400 MV/m X-band photocathode gun
  - 100 MV/m X-band TW dielectric disk accelerator
  - 100 MV/m X-band transverse deflector
  - Discovery of BIAR regime (see HG2022 Jiahang Shao)
- Next Steps
  - Test Xgun V1 to higher gradients … once Xgun V2 is working
  - Generate higher-charge drive dunch trains
  - Demonstrators
    - 100 MeV high-brightness Xgun photoinjector beamline
    - 500 MeV demonstrator
  - Upgrade AWA drive beam energy from 65 MeV to ~130 MeV

NEW HEP PROJECT: COOL COPPER COLLIDER (C^3)

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Cool Copper Collider

Emilio Nanni
HG 2023
10/18/2023

SLAC NATIONAL ACCELERATOR LABORATORY — Stanford University — U.S. DEPARTMENT OF ENERGY

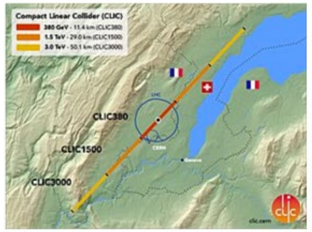
C^3 Parameters

Collider	C^3	C^3
CM Energy [GeV]	250	550
Luminosity [x10^{34}]	1.3	2.4
Gradient [MeV/m]	70	120
Effective Gradient [MeV/m]	63	108
Length [km]	8	8
Num. Bunches per Train	133	75
Train Rep. Rate [Hz]	120	120
Bunch Spacing [ns]	5.26	3.5
Bunch Charge [nC]	1	1
Crossing Angle [rad]	0.014	0.014
Site Power [MW]	~150	~175
Design Maturity	pre-CDR	pre-CDR

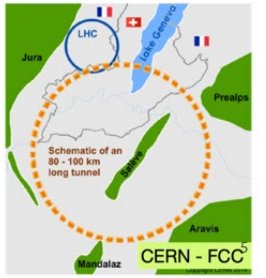
ous Proposals

CEPC
240 GeV

CLIC 380/1000/3000 GeV

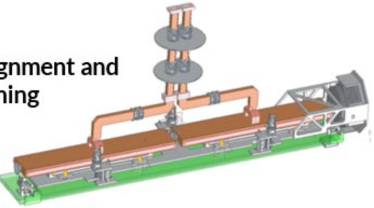


FCC-ee
240/365 GeV

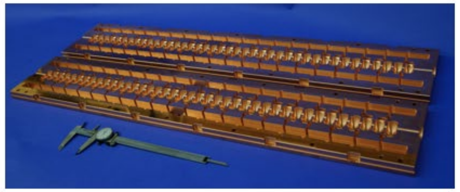


Ongoing Technological Development

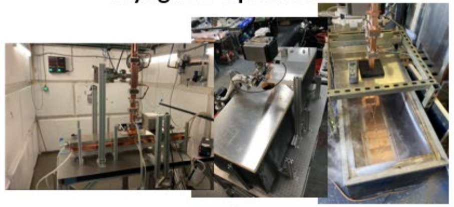
Preliminary Alignment and Positioning



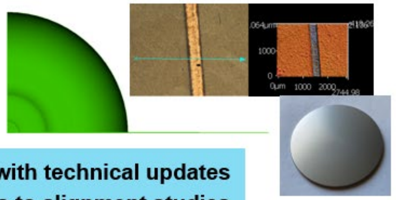
Modern Manufacturing Prototype One Meter Structure



High Accelerating Gradients Cryogenic Operation



Integrated Damping with NiChrome Coating

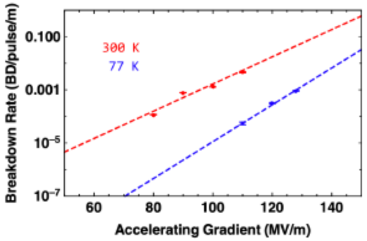


LCWS 2023 - Twelve C^3 presentation with technical updates from detector background simulations to alignment studies

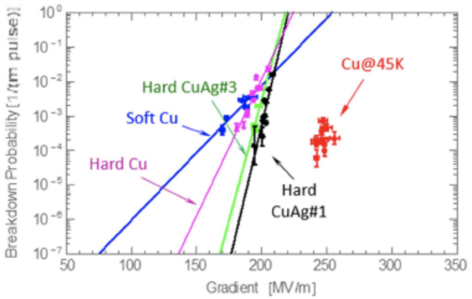
Cryo-Copper: Enabling Efficient High-Gradient Operation

Cryogenic temperature elevates gradient
- Increased material strength is key factor
- Increase electrical conductivity reduces pulsed heating in the material

Operation at 77 K with liquid nitrogen
- Large heat capacity, simple handling
- Small impact on electrical efficiency

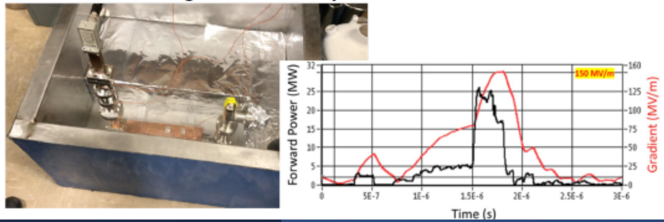


Nasr, et al. PRAB 24.9 (2021): 093201



Cahill, A. D., et al. *PRAB* 21.10 (2018): 102002.

High Gradient Operation at 150 MV/m



DEVELOPMENTS FOR FACILITIES

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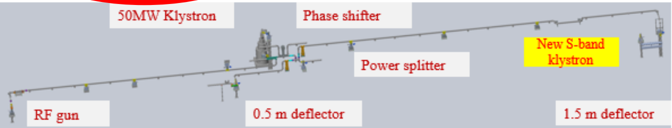
Recent RF activities on high gradient technology at SSRF

Jianhao Tan on behalf of the team
Wencheng Fang, Xiaoxia Huang, Cheng Wang、 Hanyu Gong, Zihe Gao

S-band high power test platform



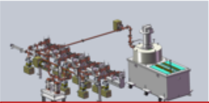
Now SXFEL facility has completed the national acceptance, we have plenty of time and space to do more research.
Right now, the power source is still use Toshiba 50 MW klystron, the … divided into three structures, including the rf gun, short s-ba… end of injector and long deflector in the down stream of X-b… system by power splitter and phase shifter.
The waveguides is too complicated and long, recently, we h… klystron from a China company, it will be installed near the… of the power will be used for S-band deflector, while meetin… test the s-band rf structures.

SSRF

Research and development of MW team

Project

SSRF
SXFEL
SHINE



X-band deflector on SHINE

Satisfy the operation of SSRF and SXFEL, and construction of SHINE normal conducting rf system, including several S-band and X-band deflectors

Normal conducting RF system

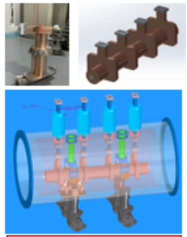
X-band accelerating structure
X-band deflecting structure
Dual-mode deflecting structure
S-band accelerating structure for proton therapy

X-band RF system on SXFEL

Responsible for high gradient technology research, such as X-band accelerating structures and deflecting structures, new technology about two modes operation deflecting structure, we begin cryogenic RF structures and systems development in recent years.

Cryogenic RF system

Cryogenic RF structures and system



Cryogenic RF system

Technology Application

S/C/X-band RF system, including accelerating structure, deflecting structure, pulse compressor on different facility or application

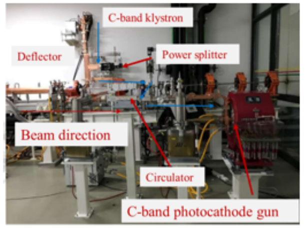
C-band RF system on SXFEL

Responsible for mature technology application, including S-band and C-band accelerating structures, deflecting structures, pulse compressor and waveguide components.

SSRF

C-band high power test platform

In the end of the linac, c-band deflector is powered by a Mitsubishi 50 MW klystron, and it is not need to operation all the time.
Separated from c-band deflector's klystron by a power splitter, and it will not influence the operation of SXFEL.
High power test of C-band photocathode gun has finished, and the maximum gradient is 180 MV/m.
A new klystron from Institute of Electrics of CAS has been installed, the maximum power is 50 MW.
Cryogenic RF gun has completed cold test and installation, and preparing to test when klystron is ready.
The structures to be tested is not on the beam line.

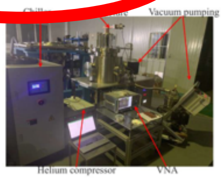


SSRF

New C-band klystron made by Institute of Electrics, CAS

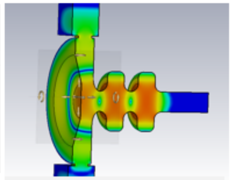
Cryogenic RF gun

Cryogenic RF gun

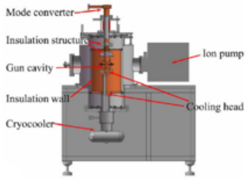


Prototype test in cryogenic platform

	Room temp.	Cryo temp.	
π mode	5692.9	5712	MHz
1/2π mode	5674.5	5693.6	MHz
0 mode	5647	5666	MHz
Q0	9852.46	54000	
Esmax/Ec	0.914		
Shunt impendance	6.285	34.455	Mohm
Target gradient	200		MV/m
Peak RF power	16.773	3.07	MW
RF pulse	2		μs
Peak temperature rise	75.45	7.8	K



New TM02 mode coupler gun



Layout of cryogenic platform

Cryogenic rf structure is a hotspot field in recent years.
The first prototype of cryogenic RF gun and platform for high power test are completed, and preparing to do high power test in a few months later.
A new cryogenic RF gun with TM02 mode coupler design has finished, and getting ready to fabricate.
The first prototype of cryogenic platform is only used for high power test.

SSRF

Nuclear Inst. and Methods in Physics Research, A 1010 (2021) 165488
NUCL SCI TECH (2021) 32:97 https://doi.org/10.1007/s41365-021-00925-8

Thursday presentation by Cheng Wang

NEW TEST STAND IN OPERATION

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Istituto Nazionale di Fisica Nucleare

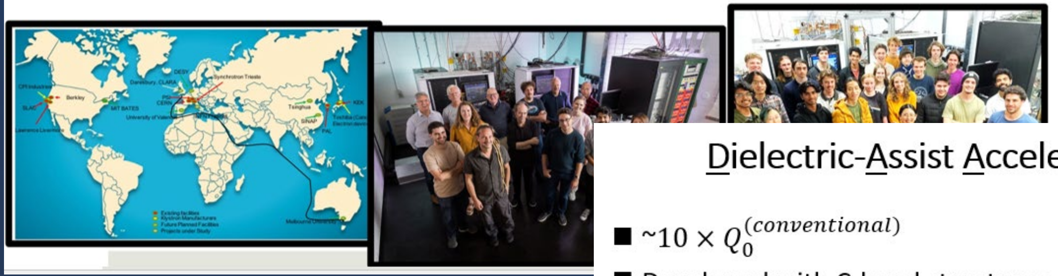
X-LAB
X-BAND LABORATORY FOR ACCELERATORS AND BEAMS

Matteo Volpi on behalf of the X-LAB group

X-band Laboratory for Accelerators and Beams (X-LAB)

THE UNIVERSITY OF MELBOURNE · CERN · ANSTO

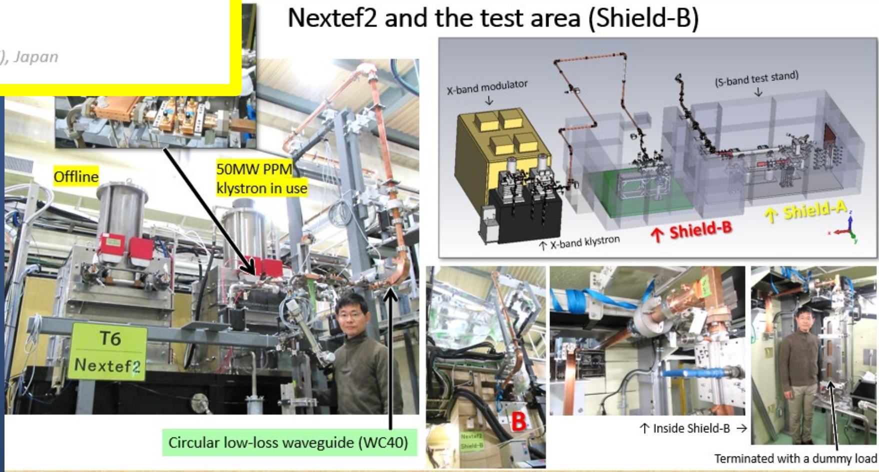
- A new laboratory is currently operational at the University of Melbourne (UoM)
  - This facility represents the first high-power, high-frequency accelerator laboratory in the Southern Hemisphere. It is dedicated to testing high-gradient structure prototypes and RF components for CLIC, as well as engaging in ultra-precision manufacturing.
  - The primary objectives include designing and developing more widely available, high-quality x-ray sources. This project aims to provide local researchers and students with the opportunity to make significant advances in accelerator design.



Status of Nextef2 at KEK

Tetsuo ABE
<tetsuo.abe@kek.jp>
High Energy Accelerator Research Organization (KEK), Japan

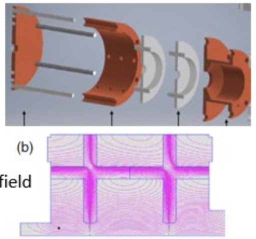
Nextef2 and the test area (Shield-B)

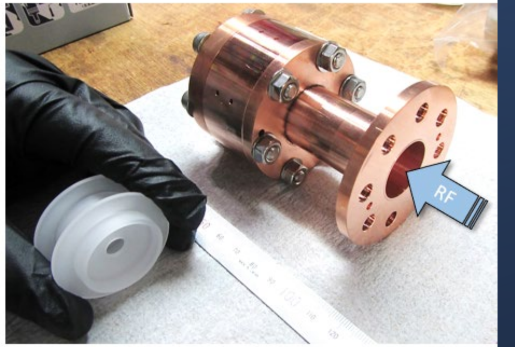


Dielectric-Assist Accelerating (DAA) test structure
for X-band (11.4 GHz)

- $\sim 10 \times Q_0^{(conventional)}$
- Developed with C-band structures so far at KEK

✓ Being HG tested at Nextef2 / Shield-B



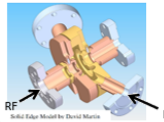


Courtesy of Mitsuhiro YOSHIDA (KEK)

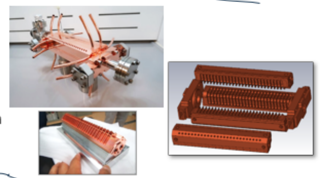
Figures excerpted from
Shingo Mori, Mitsuhiro Yoshida, and Daisuke Satoh,
"Multipactor suppression in dielectric-assist accelerating structures via diamondlike carbon coatings",
Phys. Rev. Accel. Beams 24, 022001 – Published 12 February 2021

Other near-future test structures

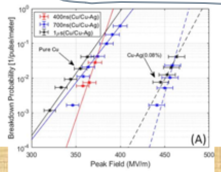
1. **SLAC full-choke cavity**
   - Basic study of the breakdown mechanism using a high-power pulsed laser or high-spec. cameras.



2. **Quadrant-type WG-Damped CLIC prototype structure TD24_QUAD**
   - Using one klystron,
     - E_{acc} = 100 MV/m (P_{in} = 45MW : $P_{kly\text{-}out}$ = 60 MW) *impossible*
     - E_{acc} = 90 MV/m (P_{in} = 36MW : $P_{kly\text{-}out}$ = 48 MW) *difficult*
     - E_{acc} = 80 MV/m (P_{in} = 30MW : $P_{kly\text{-}out}$ = 38 MW) *maybe possible*
     - E_{acc} = 70 MV/m (P_{in} = 22MW : $P_{kly\text{-}out}$ = 30 MW) *possible*
   - Need the modulator upgrade to drive two klystrons for E_{acc} > ~100 MV/m
   - The previous version: TD18_QUAD reached E_{acc} < 60 MV/m.



3. **Cavity made of CuAg alloy**
   - Higher HG performance than pure Cu?
   - With various alloy composition ratios
     - Can be available using spin-coating technology



E.g. M. Schneider *et al.*, *Appl. Phys. Lett.* 121, 254101 (2022)

APPLICATIONS: NEW HIGH GRADIENT INJECTORS

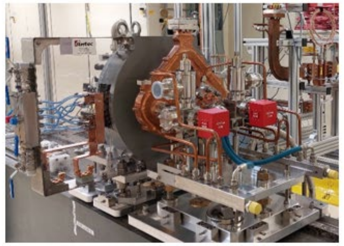
Istituto Nazionale di Fisica Nucleare
LNF

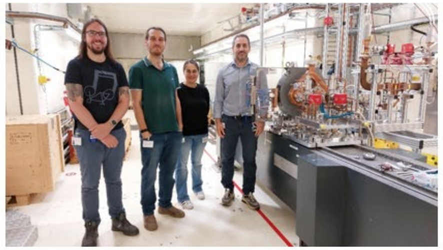
Construction and test of a high-gradient, high rep rate C-band RF Gun

David Alesini
INFN-LNF (Frascati, Italy)

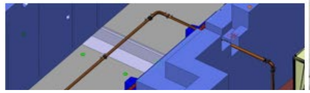
FINAL GUN ASSEMBLY AND TESTS

The cells have been clamped and finally also the cathode is mounted. The assembly has been vacuum tested and then characterized and tested at low RF power.



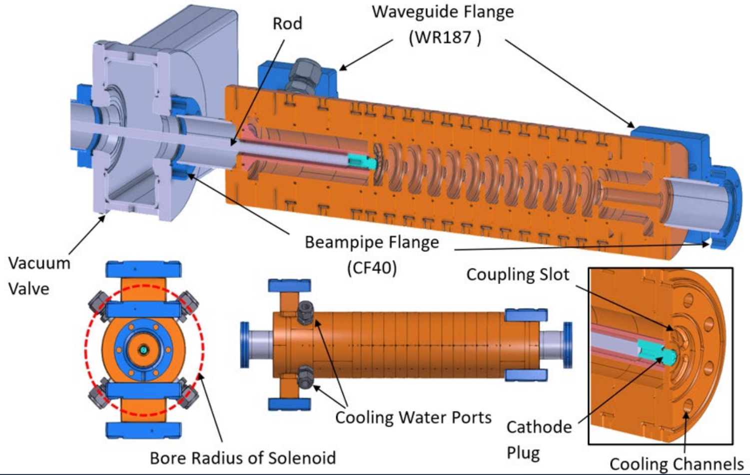


- The **bunker has been refurbished** with the addition of a new wall and preparation for the high power tests of the gun have begun.
- The **waveguide network** and the C-band Gun has been installed in July 2023.



PAUL SCHERRER INSTITUT PSI

Mechanical Design of TW RF Photogun



Los Alamos NATIONAL LABORATORY

Update on the High Gradient C-band project at LANL

Evgenya Simakov, Anna Alexander, Petr Anisim[...]
Haynes, Dongsung Kim, Sergey Kurennoy, Dee[...]
Xu, MD Zuboraj

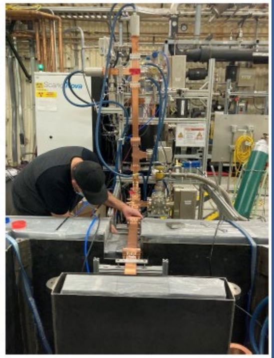
The goals for LANL's high gradient project are

- To build a C-band (5.712 GHz) high gradient rf breakdown study facility (2019-2022).
- To build a C-band cryo-cooled photoinjector study facility (2022-2025).
- To conduct material studies.
- To develop C-band compact accelerator facility for X-ray production or UED (future).

LANL C-band Engineering Research Facility (CERF-NM)

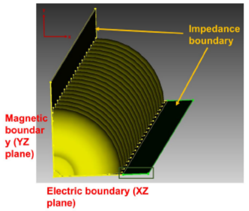
CERF-NM was built with $3M of LANL's internal infrastructure investment.

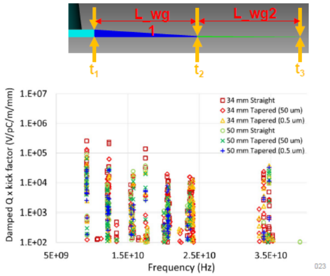
- Powered with a C-band Canon klystron
- Conditioned to 50 MW
- Frequency 5.712 GHz
- 300 ns – 1 μs pulse length
- Rep rate up to 200 Hz (typical 100 Hz)
- Nominal bandwidth 5.707-5.717 GHz

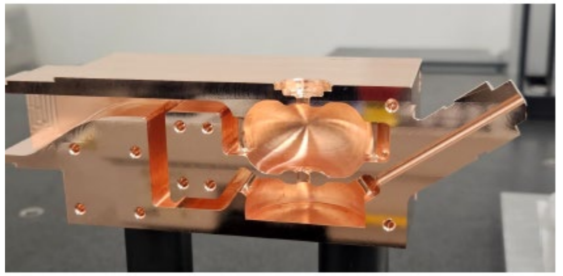


NiCr absorbers for HOM suppression

We conducted extensive optimizations of HOM suppression in a 20-cell C-band accelerating structure with NiCr absorbers.







UPGRADE OF EXISTING FACILITIES AND HG APPLICATIONS

INFN LNF Istituto Nazionale di Fisica Nucleare

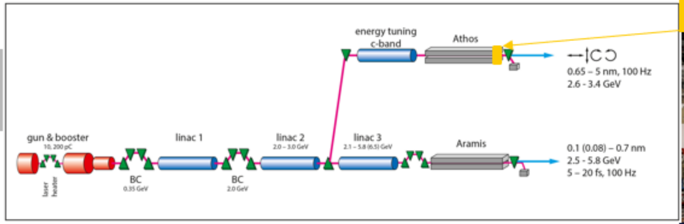
Fabio Marcellini on behalf of the PolariX team:: Paul Scherrer Institute

Studies and commissioning results of the PolariX TDS system at SwissFEL

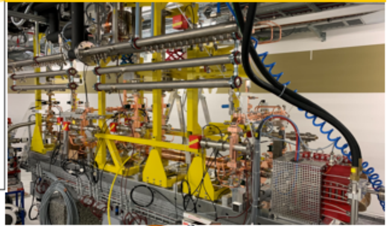
15th Workshop on Breakdown Science and High Gradient Technology (HG2023)

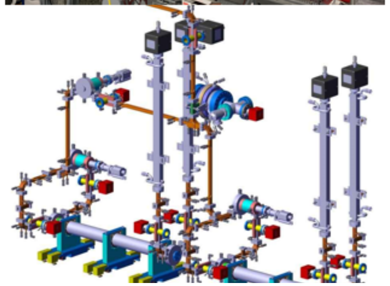
PAUL SCHERRER INSTITUT PSI

PolariX in ATHOS



PolariX TDS placed downstream the ATHOS undulators





PSI HV modulator: develop and built in-house (400 kV, 3 us)
- based on the Linac 1 and 2 design (Ampegon)
- Investment for future renewal of the injector modulators (S-band and X-band)

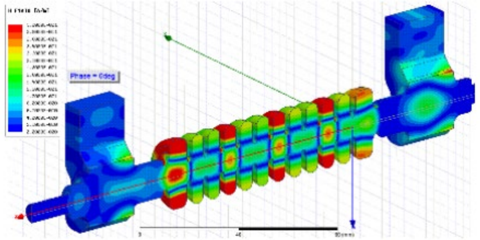
Klystron: CPI VKK-8311 50 MW X-band.

Waveguide RF components including the XBOC, phase shifters and directional couplers designed and built at PSI.

Two TDSs (120 cells version) built at PSI.

Key Technology:

PSI high-precision tuning-free assembly procedure



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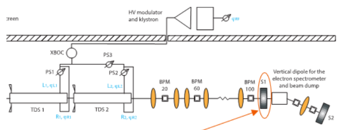
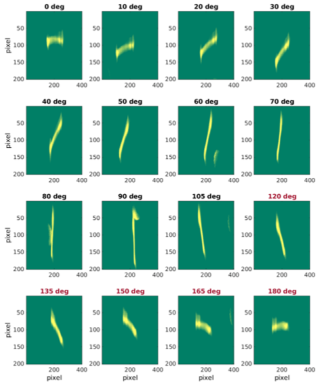
Variable polarization – first measurements

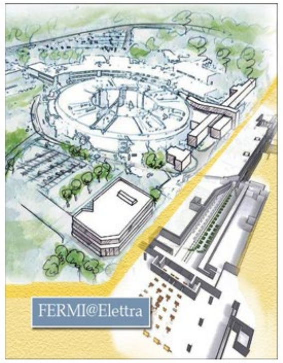


Images on screen S1, just upstream the spectrometer, showing that the streaking is actually performed on the different polarization planes.

Polarization angles in black: integrated deflecting voltage 85 MV Polarization angles in red: 72.8 MV. System not yet fully conditioned, need to reduce klystron output power for some polarization angles.



Fabrication & Commissioning of 1st HG Module

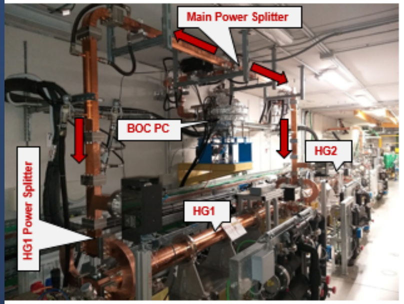


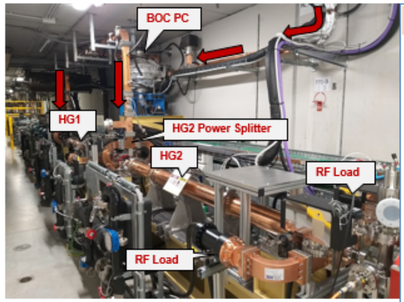
Nuaman Shafqat
on behalf of
FERMI Team

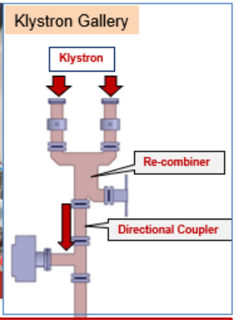
Elettra Sincrotrone Trieste

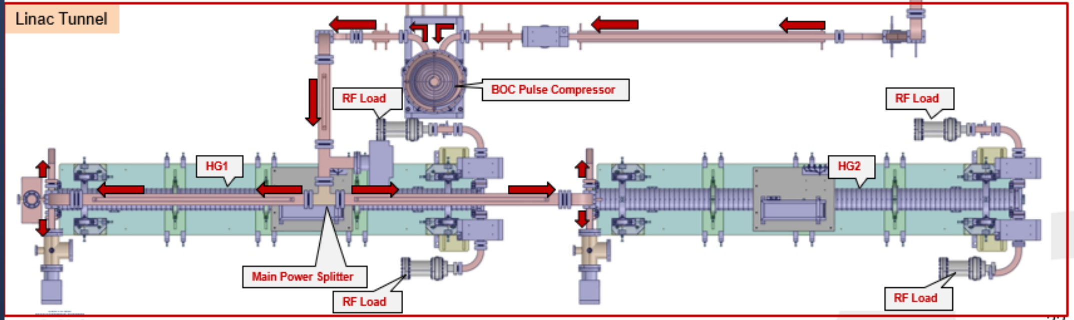
THE FIRST HG MODULE INSTALLATION IN THE FERMI TUNNEL

HG2023









TECHNOLOGY AND TEST FACILITIES CONSOLIDATION

Istituto Nazionale di Fisica Nucleare

Band Prototypes Production

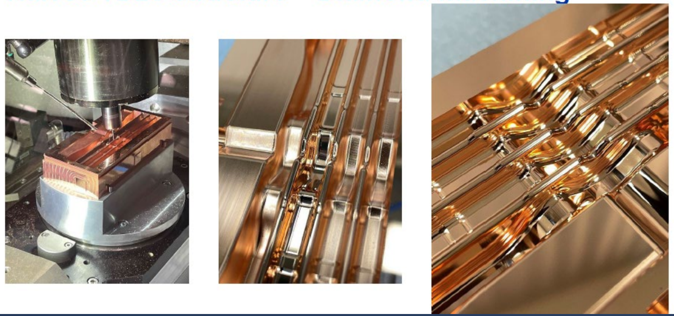
CERN Xband Acc. structure update

HG2023

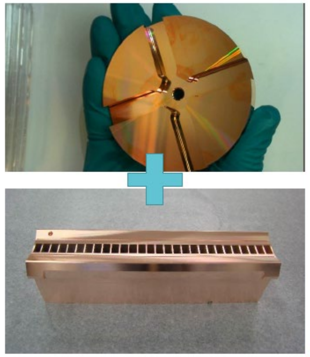
Pedro Morales Sánchez

17/10/2023

Halves TD26 structure – Diamond machining

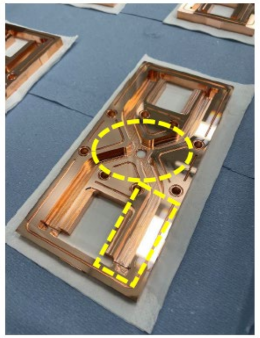


Structure design



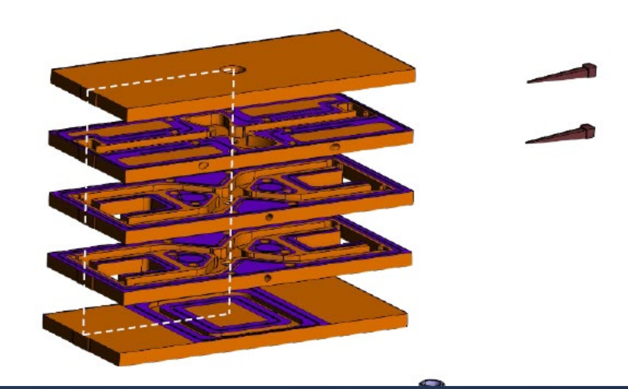
There are two main reasons for this redesign. The transition from bonding to bonding + brazing and avoiding many parts and steps to get the full structure

The new design integrates the RF area, cooling circuits, HOM loads and part of the vacuum system in one part



Halves TD26 structure – Lessons learnt

- The machining of this small mock-up has been a great exercise to test the capabilities of the industry on this kind of complex machining.
- With the current state of the art in UP-Machining a larger structure will require some attention and maybe some re-design since the parts will be heavier and longer.
- There is a risk intrinsic to machining such a large part. If you make a mistake with one part, you loose half of the structure.
- From the point of view of the assembly process, the method has been validated and could be implemented in a longer structure.



HG2023. Frascati 16-20 Oct 2023

UPDATE OF THE CERN X-BAND TEST FACILITY

N. Catalan Lasheras, P. Alonso Arias, M. Boronat Arevalo, M. Wendelmuth

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

EURO-LABS

EURO-LABS EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

GOALS

1. Provide efficient transnational access to the available resources at a major fraction of EUROpean Laboratories for Accelerator Based Sciences (EURO-LABS) at a network including the major European laboratories
2. Enhance collaborative targeted improvements for the existing services that will lead to an increase of the scientific and technical opportunities at various RIs
3. Make the results from the tests conducted at the RIs of EURO-LABS during the period of the project freely available to the scientific community and manage the experimental data, when relevant, through a Data Management Plan (DMP) in line with the FAIR principles (Findable, Accessible, Interoperable, Reusable).
4. Organize the training of the new generation of researchers and young technical staff to best exploit the RIs, through workshops and hands-on experience at specifically chosen RIs

EURO-LABS OFFERS

- Reimbursement of travel and accommodation costs for using the facilities at the Research Infrastructures
- Technical Support and expertise at the laboratories hosting the RI
- Service improvement at the RI
- Training for new users and young researchers

MULTI-DISCIPLINARY APPLICATIONS

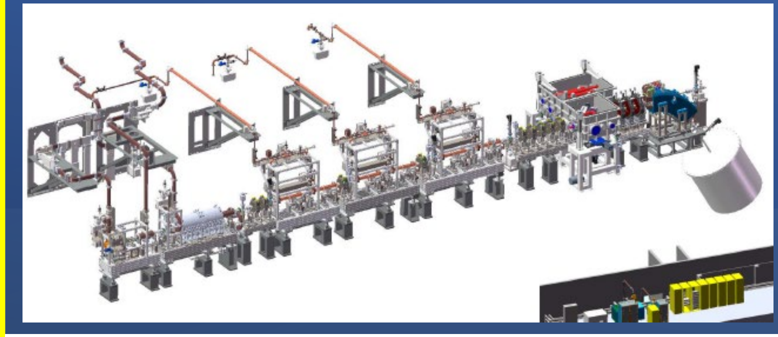
INFN LNF
Istituto Nazionale di Fisica Nucleare

NSFC
清華大學 Tsinghua University

Progress of the VIGAS Project in Tsinghua University

VIGAS: Very compact Inverse-compton-scattering GAmma-ray Source

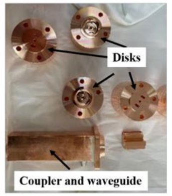
Jiaru Shi
on behalf of VIGAS team in THU
2023.10.18



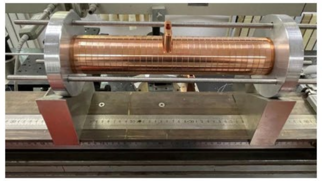
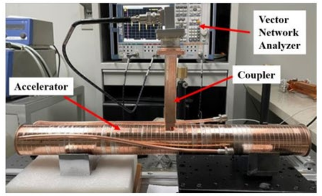
Developing New X-band Linac Tubes
Main Concerns - Manufacturing

- Micron precision turning on diameter of the disks
- RF measurement of individual cells requires accurate positioning
- Control the detuning of cells during brazing and welding of e-gun/target

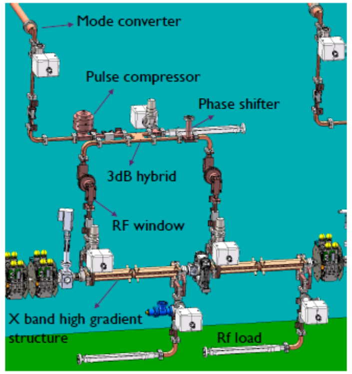
(a)



(b)

X BAND MODULE



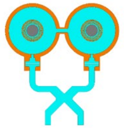
- One klystron
  - 50 MW, 1.5us
- One pulse compressor (SLED I type)
- Two X band high gradient structures
  - Average gradient >= 80 MV/m
  - Energy gain per structure > 50 MeV
  - Filling time < 150 ns
- rf loss from klystron to Xacc ~ 0.9dB
- 91 MW at Xacc w/ PC gain factor as 4.5

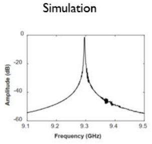
XT72	6	P.C.	3
mode convrt.	6	phase shifter	3
circ. wg	6	D.C.	24
RF window	6	pump. port	21
E-bend (90)	20	RF load	9
H-bend (U+90)	24+6	straight wg	30
H-T	12	3dB hybrid	3

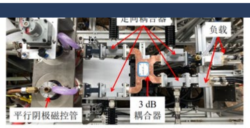
20

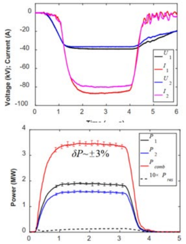
COMBINING RF POWER OF MAGNETRONS

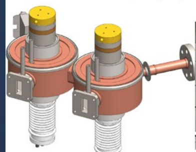
- two in one
- π-like mode in outer cavity: 9.300 GHz
- Compact
- Stable at 3.4MW 3μs
- Efficiency P/(I*V) 54%

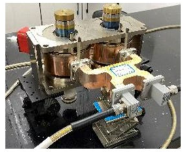












Design and Prototyping of **high-gradient C-band** accelerating structures for a Very High Electron Energy linac for **FLASH radiotherapy**

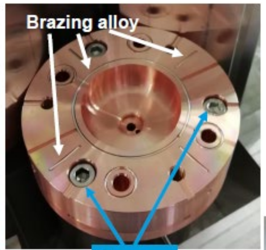
Lucia Giuliano
Sapienza University of Rome
SBAI Department

SAPIENZA Università di Roma — INFN Roma

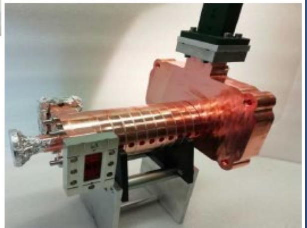
FLASH Radiotherapy with high Dose-rate particle beAms — HEAL ITALIA — Finanziato dall'Unione europea NextGenerationEU — MUR — Italiadomani

Prototyping phase

1. **Pre-prototypes** on 5-cells **without couplers** to test the brazing procedure, vacuum sealing and the **in-house** mechanical design.
2. **Prototype of 12 cells** with couplers has been **brazed** @INFN LNF –FRASCATI oven to perform low-power RF tests.



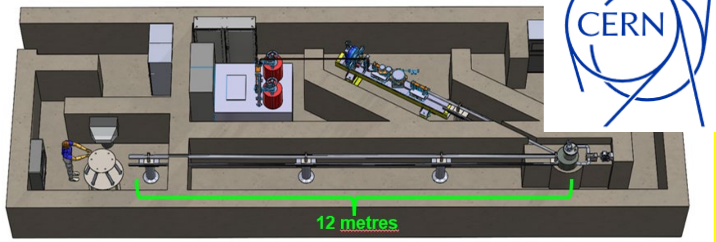
Screws: **prevent external clamping** and ensure alignment and easier assembly

Main contributors: D. Alesini, R. Di Raddo, L. Faillace, L. Giuliano, M. Magi, M. Migliorati

VULCAN Conceptual Layout

CERN



- Small footprint (existing lab)
- Measurements in realistic times
- Operated by local, pre-qualified staff
- Low maintenance
- More specialised than large neutron facilities, but less powerful

Laurence Wroe (Senior Fellow, ATS-DO)

HIGH EFFICIENCY KLYSTRON DEVELOPMENTS

INFN
LNF
Istituto Nazionale di Fisica Nucleare

Testing and Validation of High-Efficiency Klystron Technology: an 8MW X-band klystron

15th Workshop on Breakdown Science and High Gradient Technology

CERN CLIC

Delivered by Paz Alonso-Arias

Anisullah Baig, Marca Boronat Arevalo, Graeme Burt, Nuria Catalan Lasheras, Gerard McMonagle, Zaib Un Nisa Nisa, Igor Syratchev, Mareike Wendelmuth

18 October 2023

Progress on high efficiency klystron for CEPC at IHEP

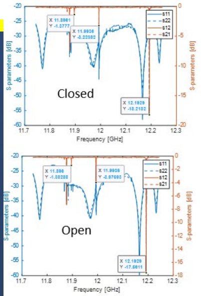
Ouzheng Xiao
IHEP,CAS
Oct.18,2023
On behalf of high efficiency klystron team

High efficiency klystrons projects at CERN

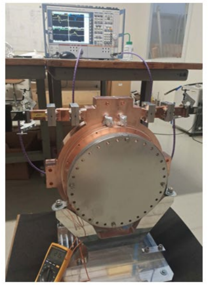
- HE X-band klystron demonstrating >50% efficiency

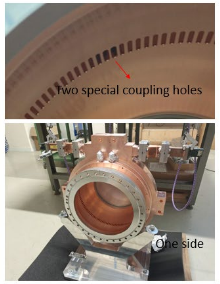
Collaboration with industry Canon

RF measurement of the BOC pulse compressor



S-parameters of the BOC

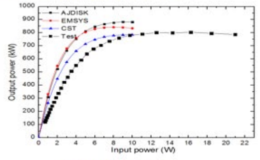




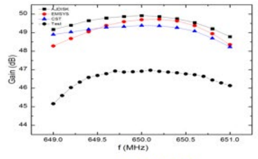
High power test

- High power test has been finished in March 2020.
- Simulation and high power test resulsts are in good agreement.

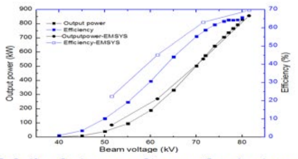
Parameters	Design	Test
Frequency (MHz)	650	650
Voltage (kV)	81.5	80
Perveance(μ A / $V^{3/2}$)	0.65	0.7
Efficiency(%)	65	65
Saturation gain (dB)	49	46.5
Output power (kW)	800	804pulse/700CW
1 dB bandwidth (MHz)	≥1	1.8 MHz



Tranfer curve



Bandwidth



Relation between voltage and output power

Design of the Pulse compression system and measurements of the prototypes for the klystron-based CLIC main linac

Ping Wang, Alexej Grudiev
18.10.2023

Conclusions

Demonstrated improved efficiency of ref

The followed methodology does not provide the reliability and accurac need (lack of experience!)

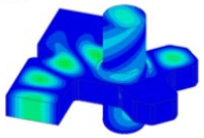
Exciting opportunity to learn in collaboration with Canon and Scandin

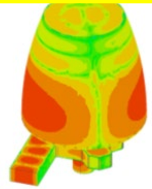
FUTURE \

Development of new methodology and setup that ensure accurate measurements (accuracy in efficiency meas. <5%)

Spectral measurement of klystron output: study of harmonics

RF rotator





Summary

- So far,high efficiency klystron of CEPC has achieved efficiency of 70%.
- Efficiency of 75% is expected to be achieved after refinement of the 2nd prototype by the end of 2023.
- MBK is being manufactured ,which will be tested in the middle of 2024.

NEW FRONTIERS

Developments of Dielectric-Assist Accelerating structure at C-band and beyond

Daisuke Satoh, Chief Researcher.
National Institute of Advanced Industrial Science and Technology (AIST)

Tetsuo Abe, associate professor.
High energy accelerator research organization (KEK)

MeV-scale simulations and fabrication tests of silicon slot and woodpile-based waveguides for Dielectric Laser Accelerators

Giuseppe Torrisi
giuseppe.torrisi@lns.infn.it
On behalf of MICRON collaboration, INFN Comm-V

MIniaturised aCceleRatOrs Network
μICRON

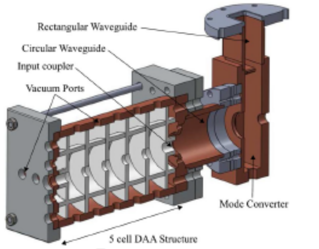
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

Istituto Nazionale di Fisica Nucleare

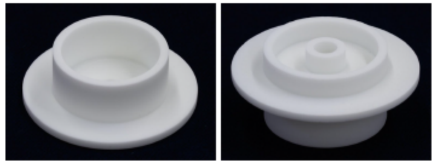
【 Design and Fabrication of prototype 】

AIST

【5 cell DAA structure[2]】



【Dielectric cells[2]】



【DAA structure assembly[2]】

【Cavity parameters[2]】

Parameter	Five-cell DAA structure
Dielectric material	Magnesia
ε_r	9.64
$\tan\delta$	6.0×10^{-6}
Accelerator type	Standing wave type
Accelerating mode	TM_{02}-π mode
Operation frequency	5.712 GHz
Number of accelerating cells	5
Total cavity length	157.5 mm
Q_0	126,400
Z_{sh}	630 MΩ/m
E_{max}/E_0	2.92
H_{max}/E_0	2.74 mA/V

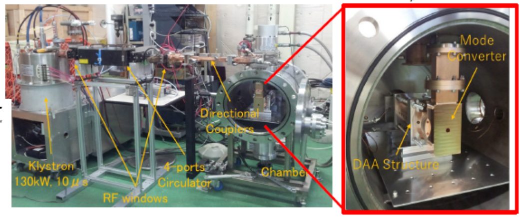
[2] D. Satoh, et. al.,

【 High power test of the prototype】

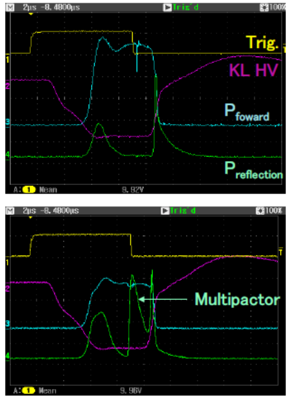
AIST

【Test stand @KEK】

High power tests were performed with pulse width of T_p = 2 – 7.5 μs.



【Results】



$E_{acc,max}$ = 2 MV/m (@ T_p = 2 μs) achieved.

But, it did not rise to any higher $E_{acc,max}$ after operating for more than 6×10^6 shots.

The longer the pulse width, the slower the progress of cavity conditioning and the lower $E_{z,max}$ was.

【 Summary】

AIST

- We proposed the DAA structure and have been performed a proof-of-principle study.
- The DLC coating lowerers the SEY of MgO cells while maintaining a low tanδ. → $E_{acc,max}$ = 11 MV/m (@ T_p = 5.4 μs)
- It is important to understand in detail where and what causes the discharge in the DAA structures in order to further increase the Eacc.
- A new research program is currently underway to develop an X-band DAA structures (2023); short pulse excitation of the DAA structures with step-pulse input and monitoring of the discharge inside the cavity is planned for April 2024.

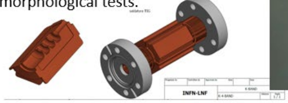
Istituto Nazionale di Fisica Nucleare

The INFN MICRON project at LNF: Development of high-gradient metallic mm-wave accelerating structures

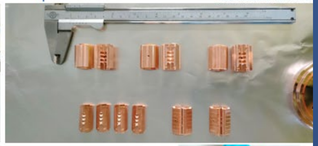
Luigi Faillace,
Fabio Cardelli, Valery Dolgashev, Mauro Migliorati and Brun[redacted]

Ka- band cavity Samples Manufacturing: 2 and 4 sectors

Drawing of the 4-quadrants structure prototype for TIG welding and morphological tests.



Machined sectors for the 4-quadrants Cavities



- ❑ All cavity sectors were manufactured by using a CNC 5-axis milling machine.
- ❑ Machining tool is crucial:
  - ➢ Tungsten-carbide tool → Tolerance = +- 10 μm; Roughness with Ra = 1.6 μm.
  - ➢ Diamond tool with spherical radius < 1 μm → Tolerance = +- 2.5 μm; Roughness with Ra < 80nm.

→ multi-cell cavity with mode launcher (this year)

Machined sectors for the 2-halves Cavities

DISCUSSION ON EUROPEAN STRATEGY

Istituto Nazionale di Fisica Nucleare
LNF

HG in the context of the accelerator R&D for HEP

Giovanni Bisoffi-INFN

HG2023, @ INFN LNF

European Particle Physics Strategy and its updates

"(...) cornerstone of Europe's decision-making process for the long-term future of the field. Mandated by the CERN Council, it is formed through a broad consultation of the grass-roots particle physics community (...) and it is developed in close coordination with similar processes in the US and Japan (...)"

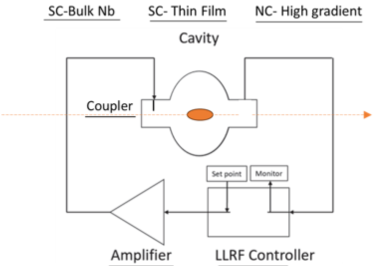
Strategy 14 July 2006

Update 30 May 2013

Update 19 June 2020

5. High gradient RF structures and systems

Topics of the RF theme:



RF Implementation Panel		G. Bisoffi INFN-I, P. McIntosh STFC-UK
WG1	Bulk Nb	M. Baylac CNRS-F, C. Madec CEA-F, L. Monaco INFN-I
WG2	Thin films	C. Antoine CEA-F, O. Malyshev STFC-UK
WG3	Couplers	F. Gerick CERN-CH, E. Montesinos CERN-CH, A. Neumann HZB-D
WG4	NC High gradient	W. Wünsch CERN-CH, D. Alesini INFN-I
WG5	RF Power sources	I. Syratchev CERN-CH, G. Burt ULAN-UK, M. Jensen ESS-SE
WG6	LLRF, AI, ML	Z. Geng PSI-CH, W. Cichalewski U-Lodz-P

GOAL
Per year: 10 M€, 90 FTE (nominal, ~30% higher than actual - ref. Accelerator R&D strategy)

European strategy for particle physics WG5. RF sources and efficiency

I. Syratchev (CERN), G. Burt (ULAN) and M. Jensen (ESS)

NC RF STRUCTURES SURVEY

David Alesini and Walter Wuensch

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	China	Shanghai	fangwencheng@zjlab.org.cn
	China	Dalian	Yelong Wei <wylong@ustc.edu.cn>

26 Laboratories/Universities

Launched survey on week 18-22/9/23

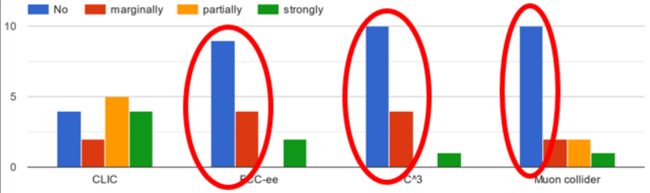
58% received answers up to now

Good participation, more expected

Cockcroft Institute
PSI
Uppsala University
Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud
INFN - National Labs of Frascati - Italy
SLAC
DESY
Elettra - Sincrotrone Trieste
IFIC (CSIC - University of Valencia)
CERN
X-LAB, The University of Melbourne
RIKEN SPring-8 center
High Energy Accelerator Research Organization (KEK)
Tsinghua University
Argonne National Laboratory

INVOLVEMENT IN HE/NON HE PROJECTS

R&D activities in high energy physics projects



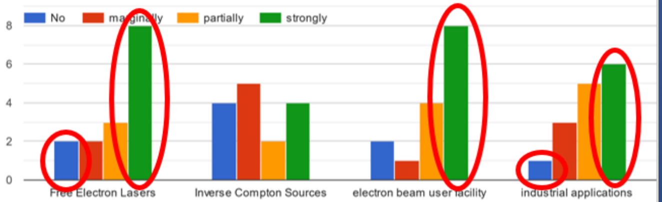
HEP participation: mainly on CLIC with more isolated Muon collider, C3 and FCCee.

Broad coverage of activities

R&D activities in other fields

Development and commissioning of RF and diagnostic active and passive components, HiLumi LHC, ESSnuSB, ESS, laser-plasma interaction for particle production and acceleration I-LUCE, thermonuclear fusion, plasma sterilisation, medical physics, compact accelerators, High gradient linacs, colliders, x-ray sources, ultrafast electron sources, electron beam diagnostics and manipulation, Testing high gradient structure prototype and RF components for CLIC
Axion-like dark matter search using X-band microwave collisions
X-band magnetrons
R&D for a carbon-ion injector for radiobiological studies
Beam manipulation and control and Beam generation

R&D activities in NON high energy physics projects



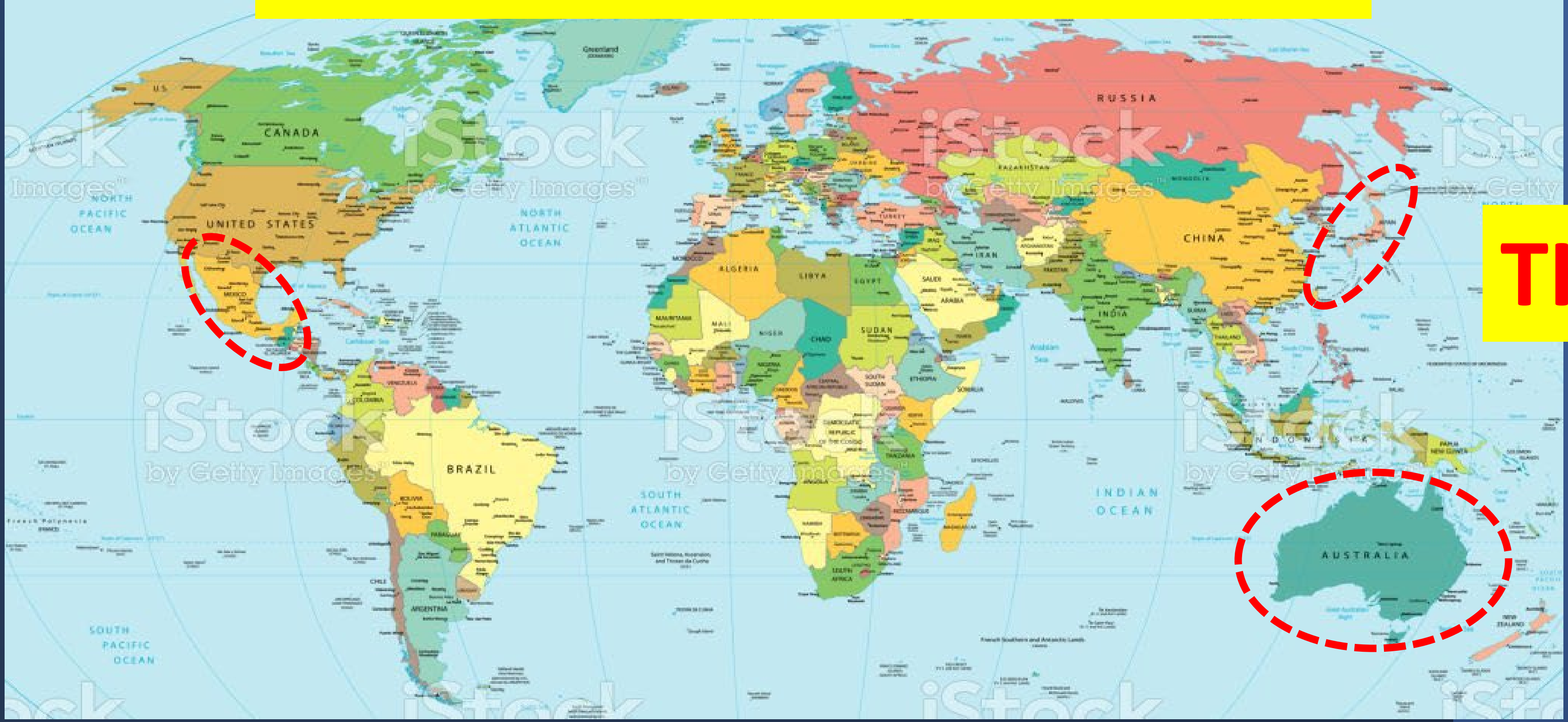
CONCLUSIONS AND PERSPECTIVES

INFN LNF Istituto Nazionale di Fisica Nucleare

- ⇒ **Extremely interesting workshop that illustrates the multi-disciplinarity of the High Gradient Normal Conducting Science and Technology**

- ⇒ **High gradient experiments to overcome the present limits of 100-150 MV/m, new colliders proposals (C3), new facilities based on normal conducting high gradient technology, miniaturization, industrial applications on compact devices,…**

WHAT’S NEXT? TOWARDS AN HG2025 EDITION



THANK YOU!