The 2025 International Workshop on the High Energy Circular Electron Positron Collider

November 5 – 10, 2025 - Guangzhou Dongfan Hotel

A forward looking strategical view on SRF technologies

Guangzhou, 7 November 2025

Institute of High Energy Physics
Chinese Academy of Sciences

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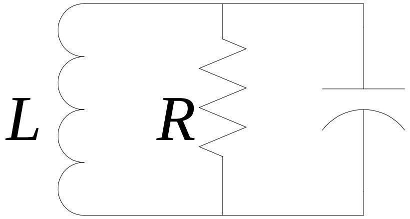
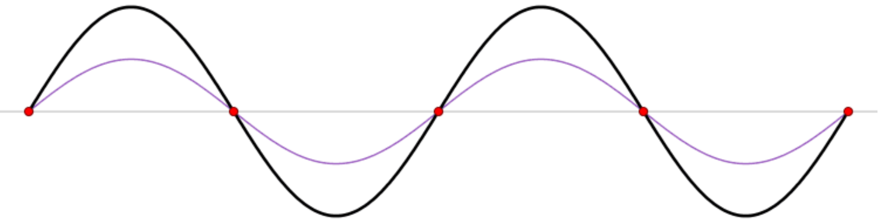
INFN LASA

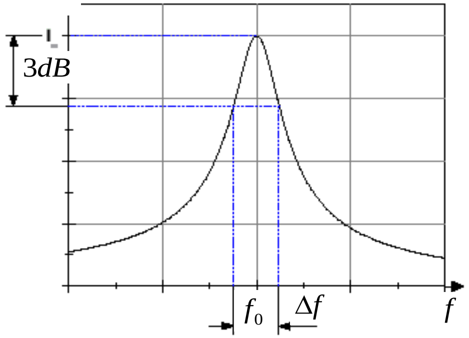
Superconducting RF resonators (cavities)

An RF cavity, the accelerating element, is a container in which a non-conservative electric field is stored or travelling. When a bunched particle beam passes through it, the field has to be properly oriented.





High Q for low losses → **Small R_s for high Q**



$$Q = \omega \frac{U}{P_{diss}}$$

U = stored energy
P_{diss} = dissipated power

$$Q = \frac{G}{R_s}$$

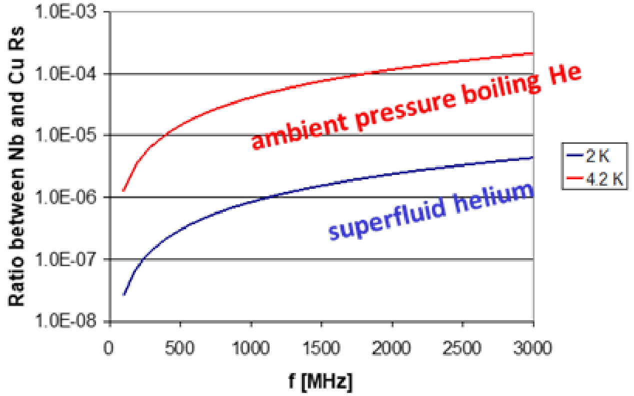
R_s = surface resistance
G = cavity geometrical factor

SC cavities still dissipate power, since not all electrons are in Cooper pairs. Dissipation is at cryogenic temperature

$$P_{diss} = \frac{R_s}{2} \int_S H^2 dS$$

Nb: $R_s[\mathrm{n\Omega}] = 9 \times 10^4 \frac{f^2[\mathrm{GHz}]}{T[\mathrm{K}]} \exp\left(-\frac{a}{T[\mathrm{K}]}\right)$ → **SC** SuperConducting

Cu: $R_s[\mathrm{m\Omega}] = 7.8 f^{\frac{1}{2}}[\mathrm{GHz}]$ → **NC or RT** NormalConducting



SRF Workshops since 1980

1st SRF Workshop 1980

Karlsruhe, Germany
July 2-4 1980

22nd

SRF2025 TOKYO

22ND INTERNATIONAL CONFERENCE ON RF SUPERCONDUCTIVITY

September 21-26, 2025

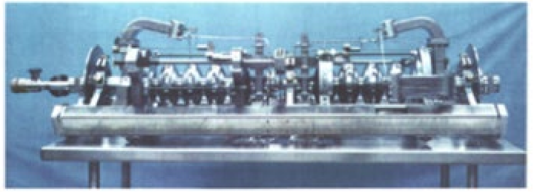
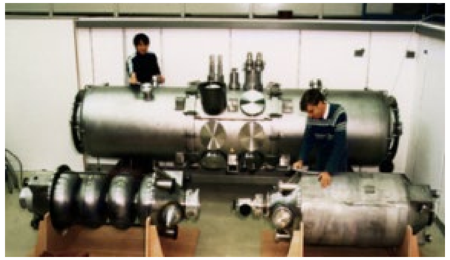
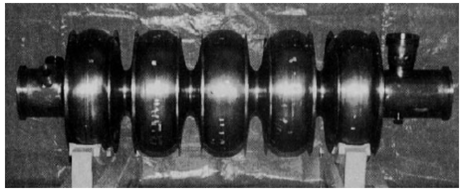
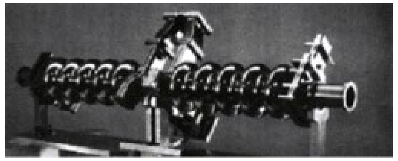
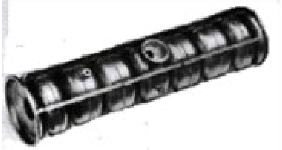
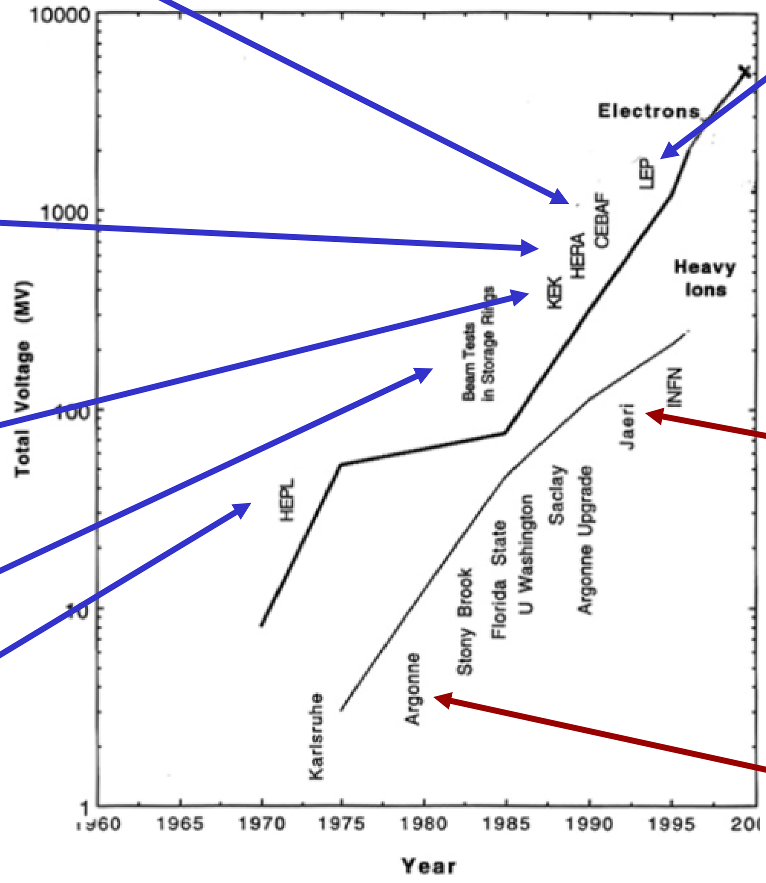
SRF2025 - 22nd International Conference on RF Superconductivity

LIST OF PARTICIPANTS

1.	G. Arnolds	GHS	Wuppertal
2.	B. Aune	CEN	Saclay
3.	W. Bauer	KfK	Karlsruhe
4.	F. Baumann	Uni	Karlsruhe
5.	M. Baye	IEF	Orsay
6.	R. Blaschke	GHS	Wuppertal
7.	A. Brandelik	KfK	Karlsruhe
8.	P. Breitfeld	KfK	Karlsruhe
9.	W. Buckel	Uni	Karlsruhe
10.	R. Calder	CERN ISR	
11.	G. Cavallari	CERN EF	
12.	J. Chelius	Kawecki Lakewood	
13.	E. Chiaveri	CERN EF	
14.	A. Citron	KfK	Karlsruhe
15.	M. Dwersteg	DESY	Hamburg
16.	D. Farkas	SLAC	Stanford
17.	O. Fischer	Uni	Genf
18.	J. Fouan	CEN	Saclay
19.	H. Gerke	DESY	Hamburg
20.	G. Geschonke	CERN	
21.	W. Giebeler	Interatom Bergisch Gladbach	
22.	H.D. Graef	GSI	Pfungstadt
23.	J. Griffin	Fermi-Lab. Batavia	
24.	Th. Grundey	GHS	Wuppertal
25.	E. Haebel	CERN EF	
26.	H. Hahn	BNL	Brookhaven
27.	J. Halbritter	KfK	Karlsruhe
28.	J. Hasse	Uni	Karlsruhe
29.	H. Heinrichs	CERN/Wuppertal	
30.	W. Herz	KfK Karlsruhe	
31.	B Hillenbrand	FL Siemens, Erlangen	
32.	N. Hilleret	CERN ISR	
33.	H. Hogg	SLAC	Stanford
34.	H. Hübner	KfK	Karlsruhe
35.	S. Isagawa	CERN	
36.	U. Klein	GHS	Wuppertal
37.	P. Kneisel	KfK	Karlsruhe
38.	Y. Kojima	KEK	Japan
39.	W. Krause	FL Siemens Erlangen	
40.	M. Kuntze	KfK	Karlsruhe
41.	R.M. Laszewski	Univ.	Illinois
42.	R. Lehm	KfK	Karlsruhe
43.	W. Lehmann	KfK	Karlsruhe
44.	H. Lengeler	CERN EF	
45.	G. Loew	SLAC	Stanford
46.	Cl. Lyneis	HEPL	Stanford
47.	A. Mathewson	CERN ISR	
48.	R. Meyer	GHS	Wuppertal
49.	G. Müller	GHS	Wuppertal
50.	R. Delesclefs	Uni	Genf
51.	V. Nguyen Tuong	IEF	Orsay
52.	Sh. Nogushi	Uni INS	Tokyo
53.	H. Padamsee	Univ.	Cornell
54.	C. Pagani	Univ.	Milano
55.	A. Palussek	Interatom Bergisch Gladbach	
56.	R. Parodi	INFN	Genoa
57.	C. Passow	KfK	Karlsruhe
58.	J. Peters	DESY	Hamburg
59.	M. Pham Tu	IEF	Orsay
60.	A. Philipp	KfK	Karlsruhe
61.	H. Piel	GHS	Wuppertal
62.	J. Sayag	IEF	Orsay
63.	F. Schürrer	KfK	Karlsruhe
64.	A. Septier	IEK	Orsay
65.	R. Sundelin	Univ.	Cornell
66.	L. Szecsi	KfK	Karlsruhe
67.	M. Tigner	Univ.	Cornell
68.	J. Vetter	KfK	Karlsruhe
69.	R. Vincon	KfK	Karlsruhe
70.	L. Wartskj	IEF	Orsay
71.	W. Weingarten	GHS	Wuppertal

SRF Evolution in Particle Accelerators

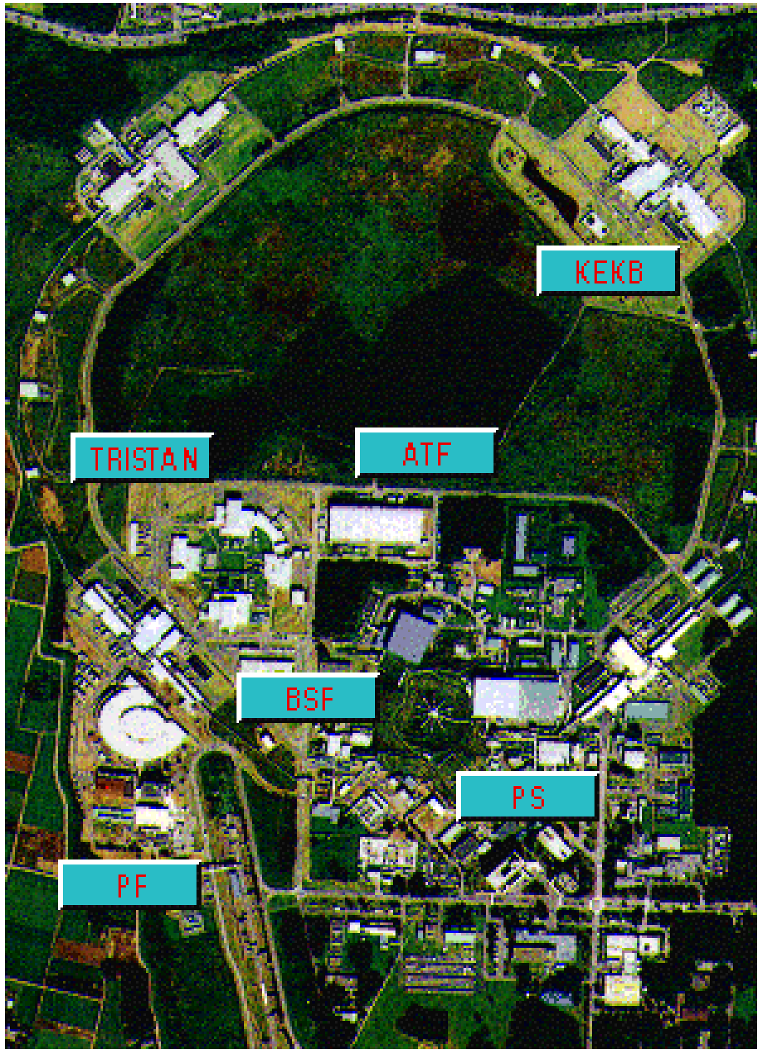
SRF before TESLA

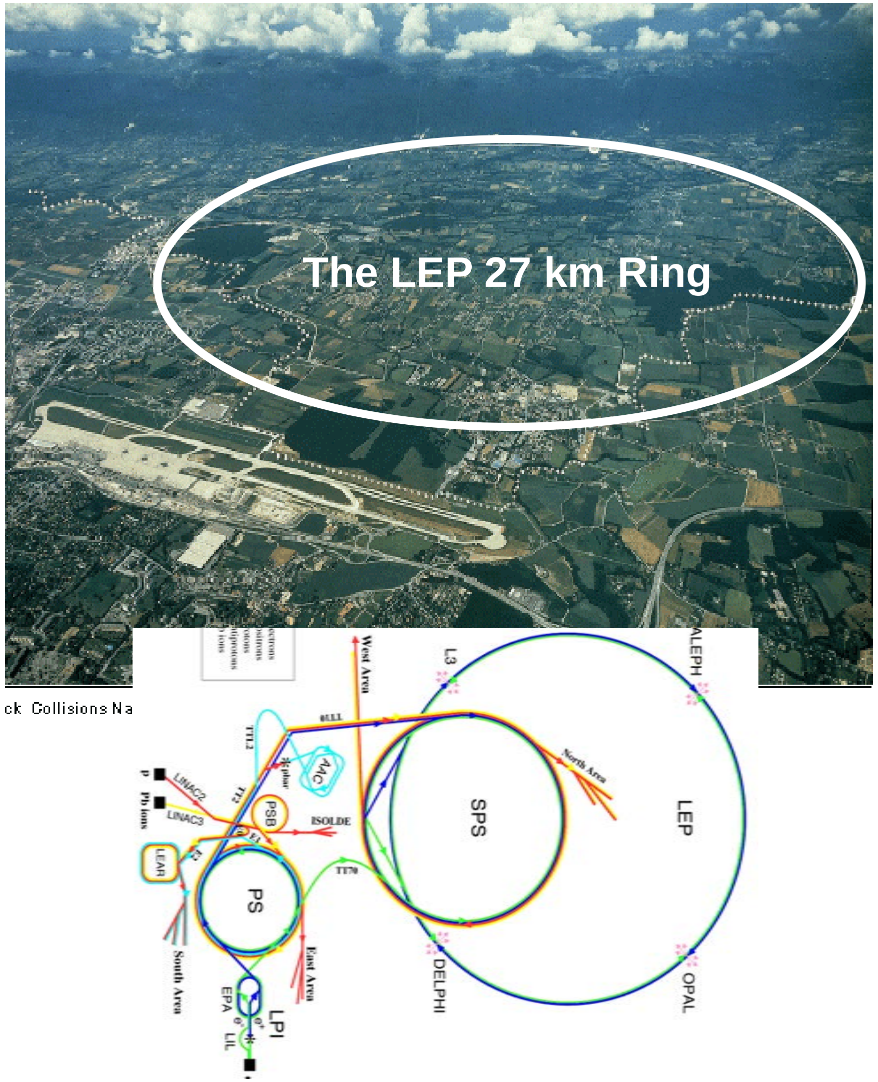


Since 1980s Large HEP Projects bet on SRF

TRISTAN at KEK

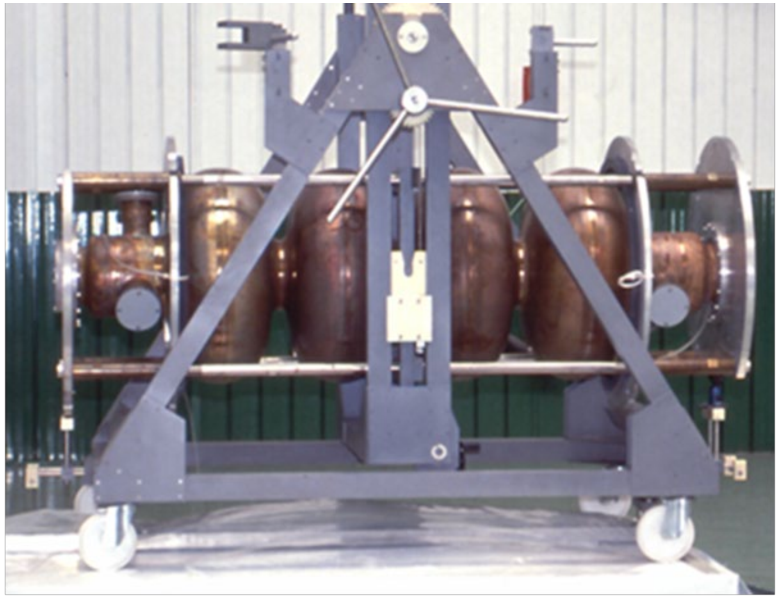


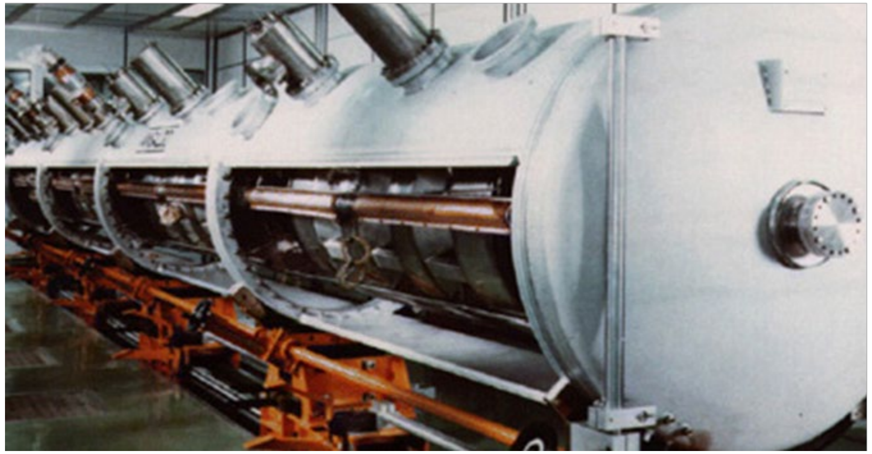
LEP2 at CERN



CEBAF at TJNAF

LEP-II: Production and Performances





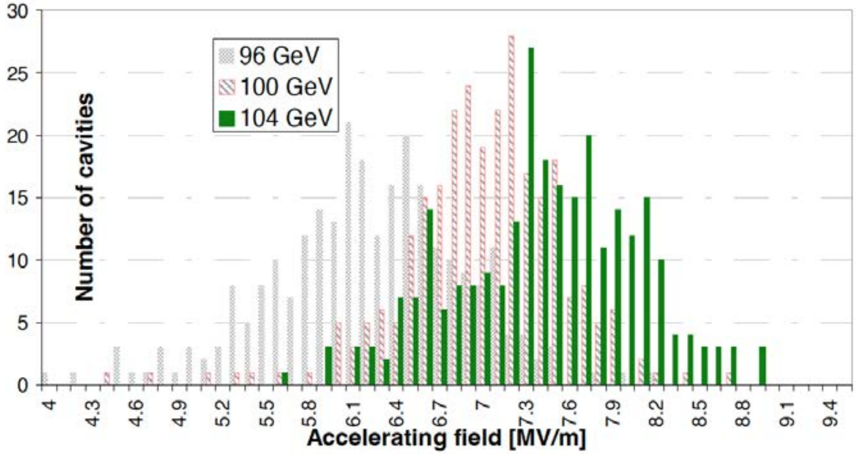
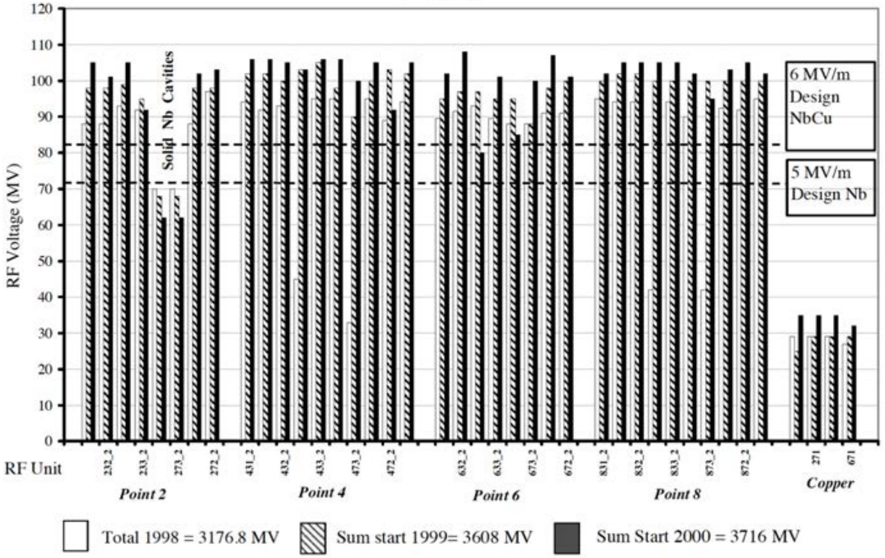
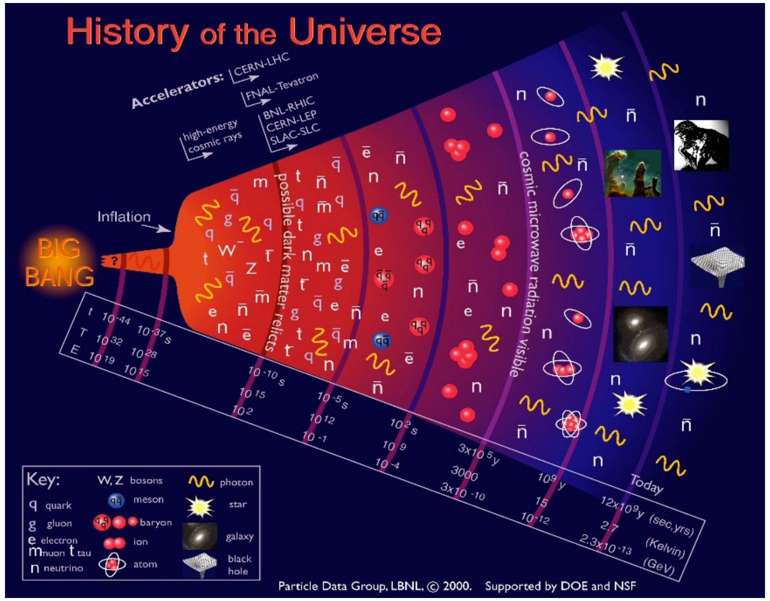
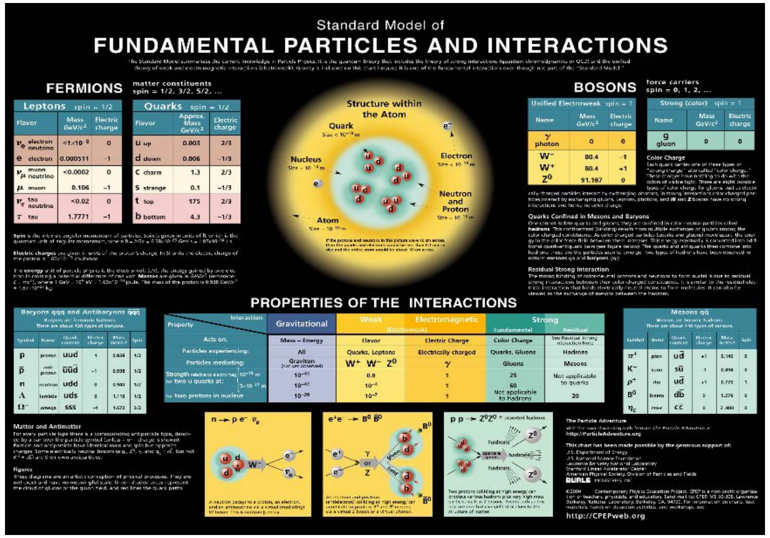


Figure 3.: Histogram of cavity gradient distribution for three different maximum beam energies in 1999 and 2000.



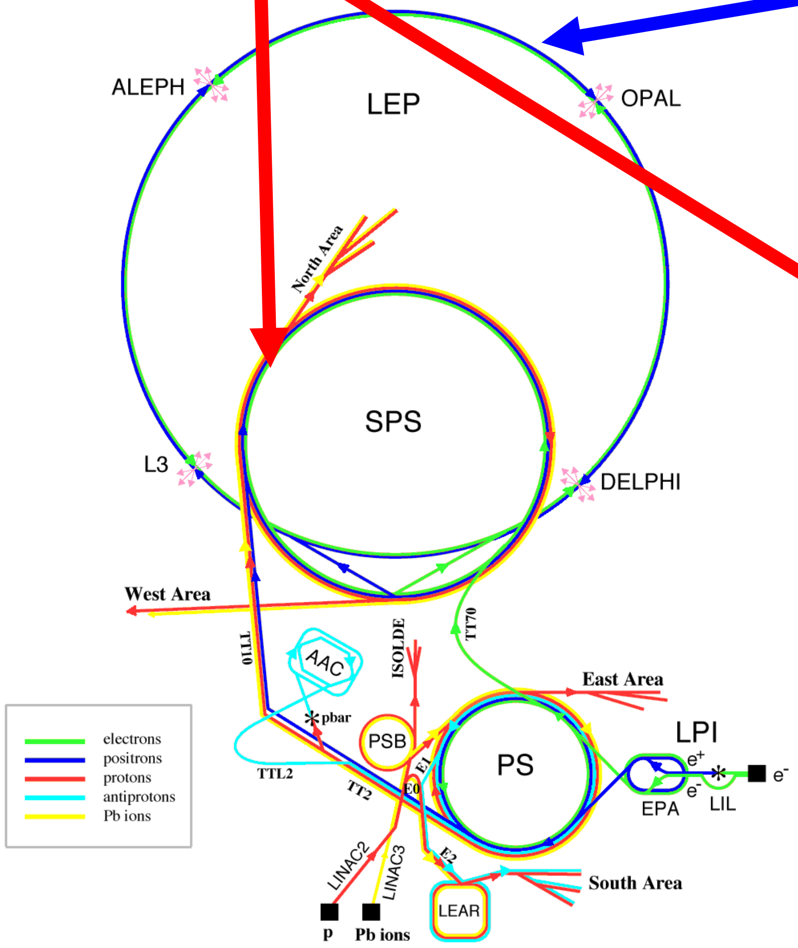
A complete picture was in progress

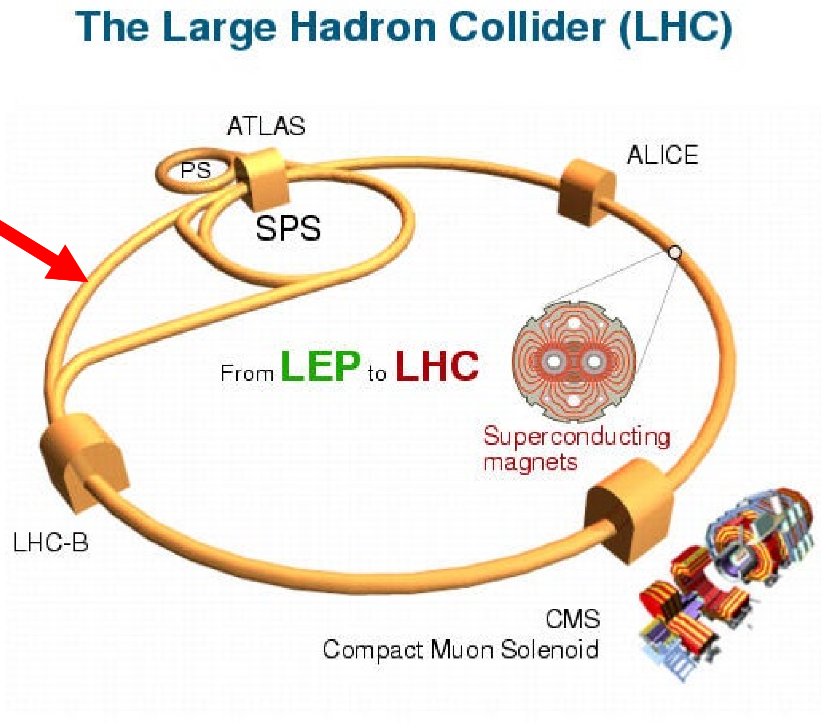




Hadrons for discovery

Leptons for understanding

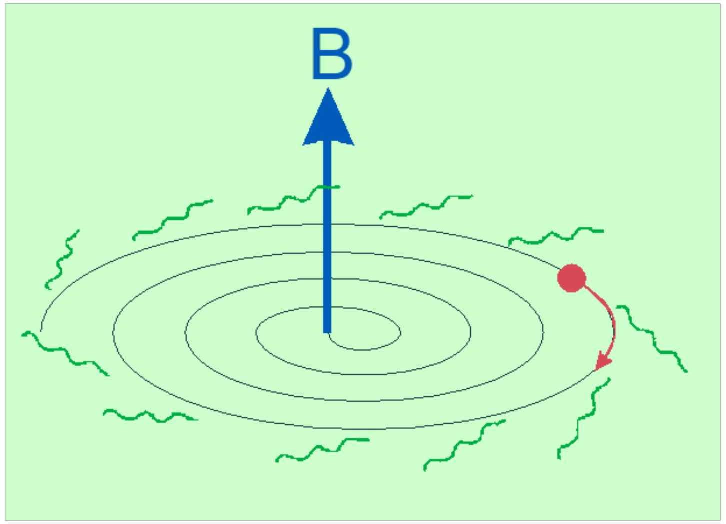




	Beams	Energy		Luminosity
LEP	e+ e-	200	GeV	10^{32} cm^{-2}s^{-1}
LHC	p p	14	TeV	10^{34}
	Pb Pb	1312	TeV	10^{27}

Next Lepton Collider should be Linear, LC

Synchrotron Radiation
From an electron in a magnetic field:

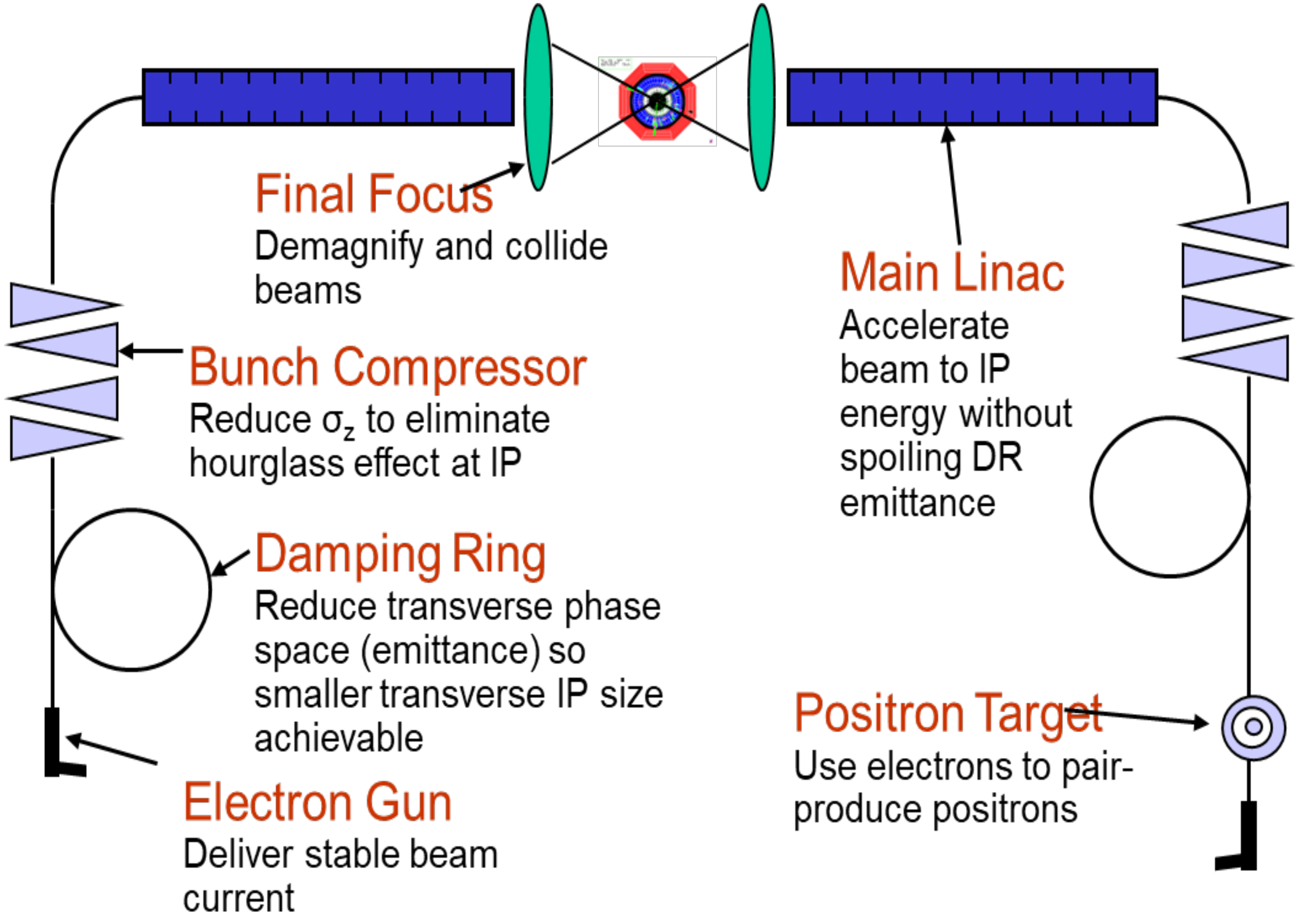


Energy loss must be replaced by RF system

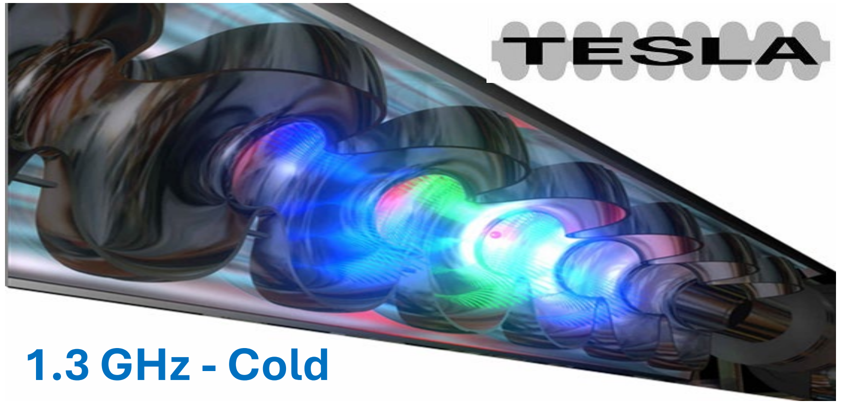
$$U_{SR}\,[\mathrm{GeV}] = 6 \cdot 10^{-21} \cdot \gamma^4 \cdot {}^{1}\!/_{r[km]}$$

$$\$ \propto E_{cm}^{\;2}$$

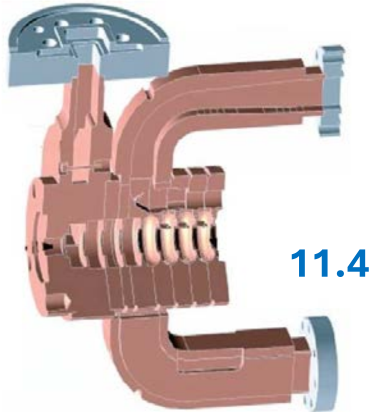
Linear Collider Schematics



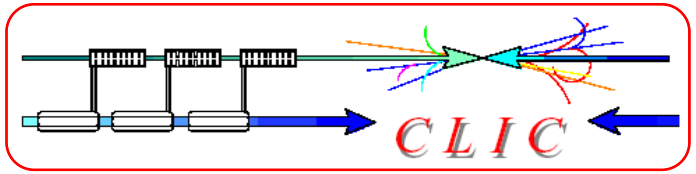
LC competition and the TESLA Collaboration



1.3 GHz - Cold



11.4 GHz



30 GHz

Ph. Institute Yerevan

IHEP Beijing
Tsinghua University

IN2P3/LAL Orsay
IN2P3/IPN Orsay
DSM/DAPNIA Saclay

INFN LNF
Univ. Roma II
INFN LNL
INFN Milano - LASA

Argonne/APS
Cornell University
Fermilab
UCLA Dep. Of Physics
Thomas Jefferson Lab

RWTH Aachen
BESSY Berlin
Max-Born Institut Berlin
Hahn-Meitner- Institut Berlin
TU Berlin
TU Darmstadt
TU Dresden
Frankfurt University
GKSS Research Center
DESY
Hamburg University
FZ Karlsruhe
Rostock University
Wuppertal University

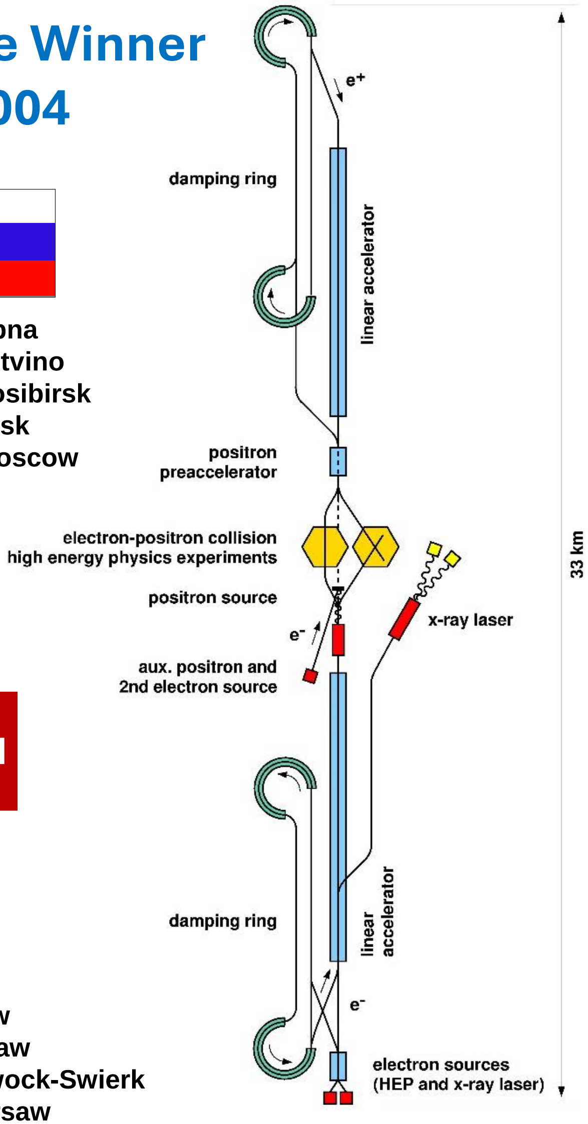
Ph. Institute Helsinki

Polish Acad. Of Science
Warsaw University
Inst. Of Nuclear Physics, Cracow
Univ. Of Mining & Metallurgy, Cracow
Polish Atomic Energy Agency, Warsaw
Soltan Inst. For Nuclear Studies, Otwock-Swierk
High Pressure Research Center, Warsaw

TESLA, the Winner in 2004

JINR Dubna
IHEP Protvino
INP Novosibirsk
INR Troitsk
MePhI Moscow

PSI



TESLA Collaboration: Intellectual Property

Article 11 - Intellectual Property

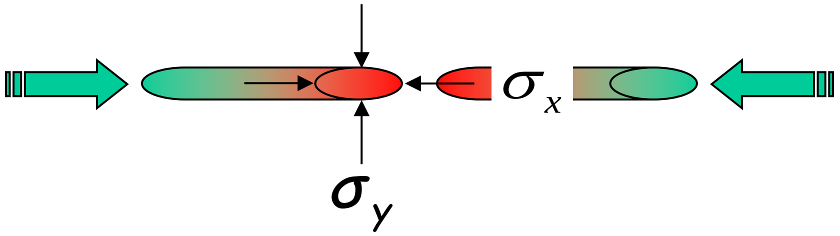
All technical know-how (including inventions) gained and procedures developed in the course of the project by any of the partners, whether protected or not, will be available to all partners free of cost, who can use them for their own research projects and for the purpose of the project.

If possible industrial contracts should reflect these guidelines.

Luminosity is Proportional to Beam Power

C. Pagani - ISLC08 - Lecture 1
Oak Brook, October 20, 2008

$$L \propto \frac{N_e^2}{\sigma_x \sigma_y}$$



$$L \propto n_b \times f_{rep}$$

L = Luminosity

N_e = # of electron per bunch

$\sigma_{x,y.}$ = beam sizes at IP

IP = interaction point

$$L \propto \frac{P_b}{E_{c.m.}} \times \frac{N_e}{\sigma_x \sigma_y}$$

n_b = # of bunches per pulse

f_{rep} = pulse repetition rate

P_b = beam power

$E_{c.m.}$ = center of mass energy

Parameters to play with

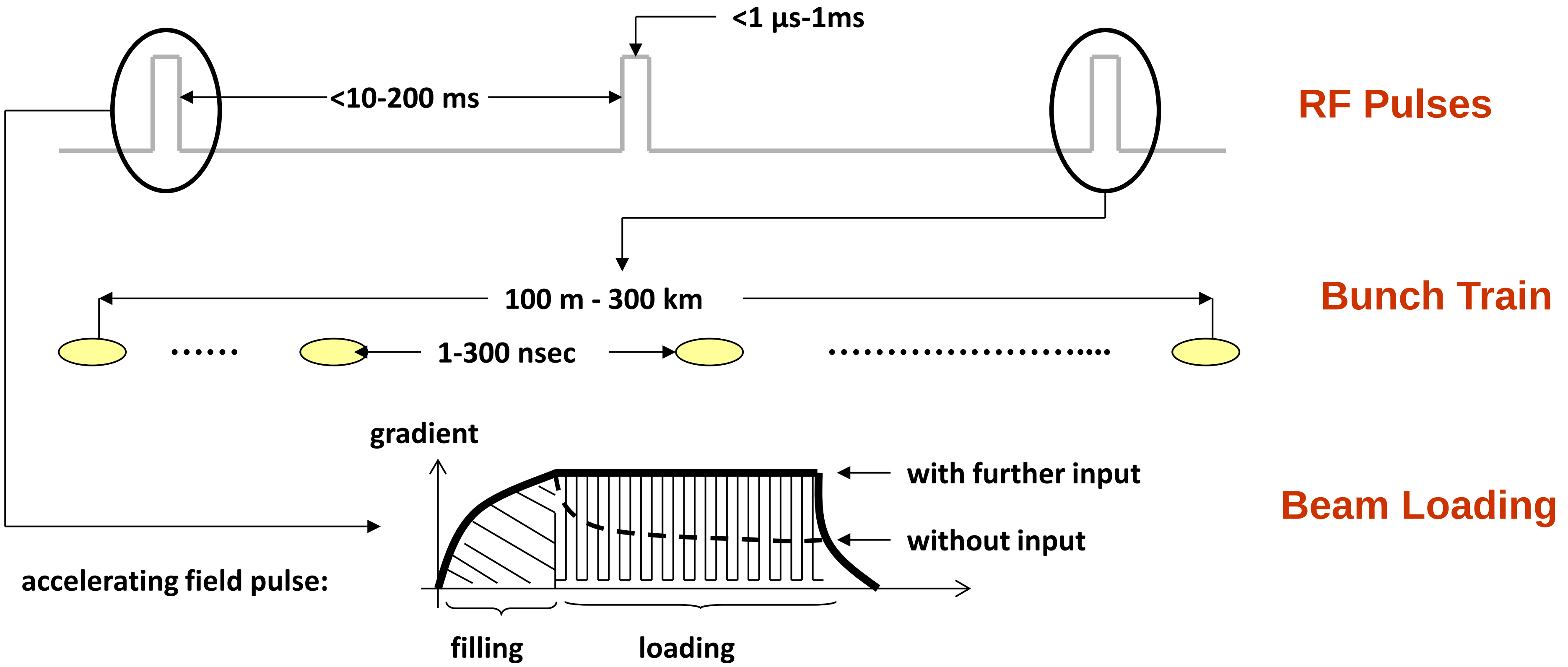
- ↓ **Reduce beam emittance ($\varepsilon_x \cdot \varepsilon_y$)** for **smaller beam size ($\sigma_x \cdot \sigma_y$)**
- ↑ **Increase bunch population (N_e)**
- ↑ **Increase beam power** $\left(P_b \propto N_e \times n_b \times f_{rep}\right)$
- ↑ **Increase beam to-plug power efficiency for cost**

LC are Pulsed for Conversion Efficiency

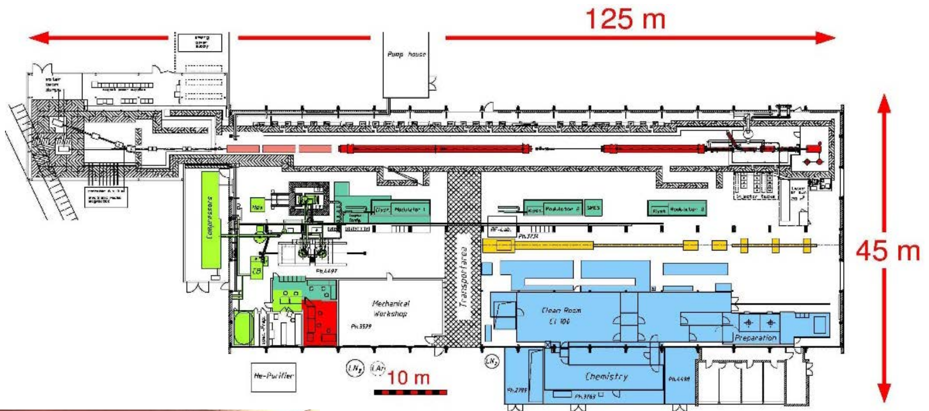
All the LCs must be pulsed machines to improve Plug Power to Beam Power conversion efficiency. As a result:

- duty factors are small
- pulse peak powers can be very large

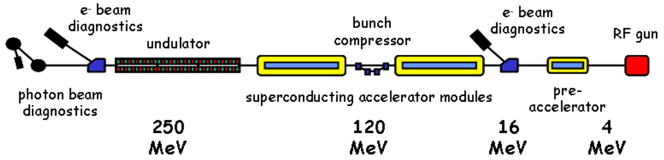
C. Pagani - ISLC08 - Lecture 1
Oak Brook, October 20, 2008



The path to a new SRF standard for TESLA



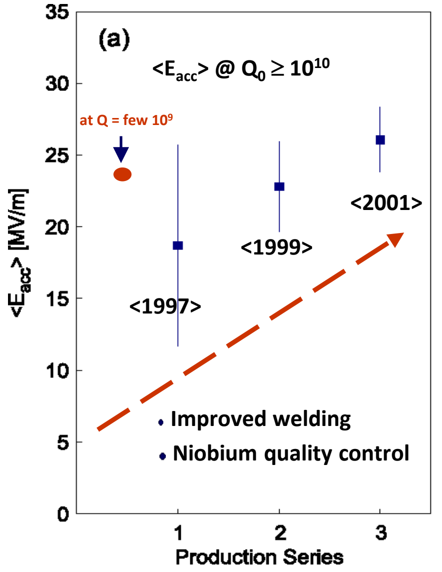
TTF as operated for SASE FEL

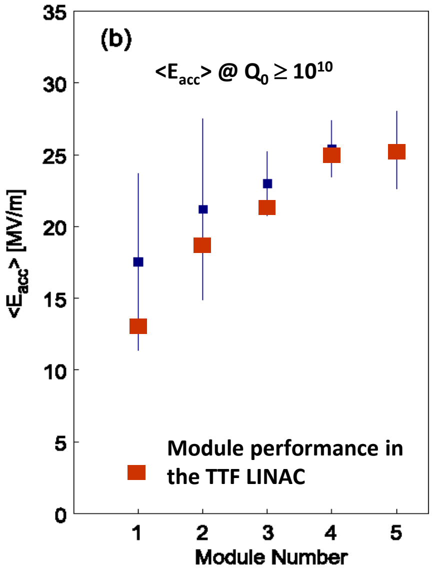


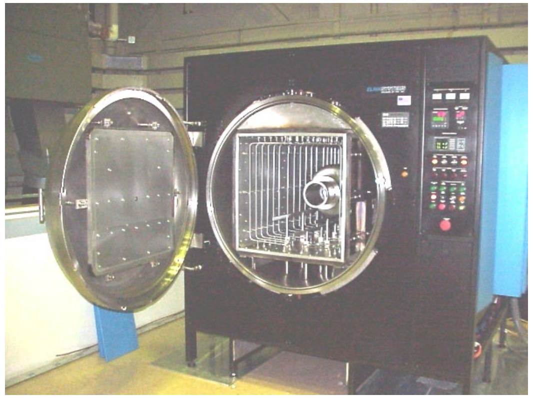
3 cavity productions from 4 European industries: Accel, Cerca, Dornier, Zanon

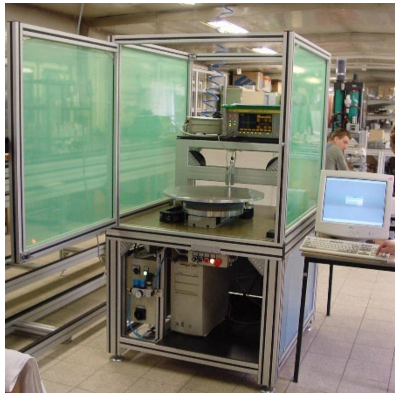
Cornell 1995

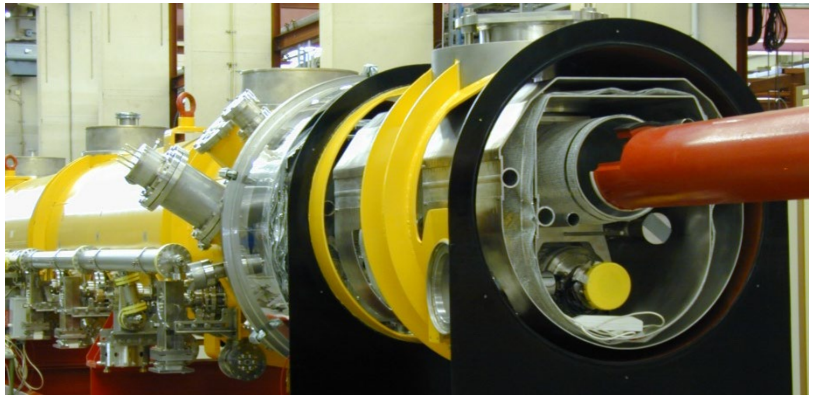
5-cell











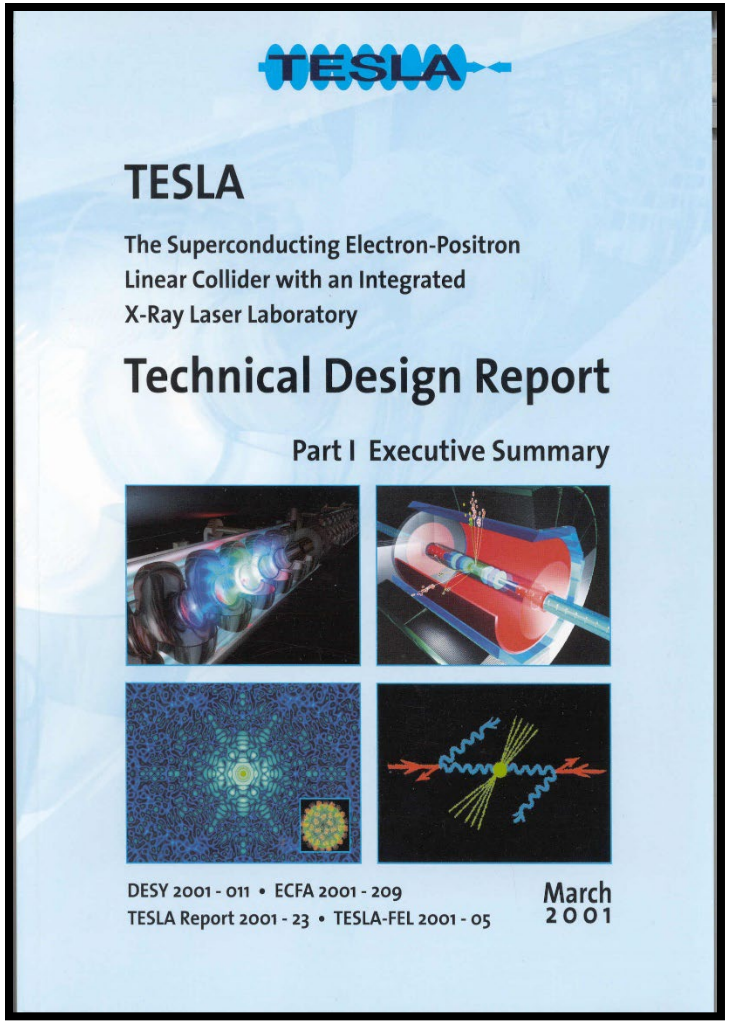
TESLA TDR: Presentation and Reactions

TESLA TDR kick-off meeting March 2001

1000 participants, 40% from abroad

- Cold reaction from German Government to the proposal to host the TESLA inear collider
- Insufficient momentum from the HEP international community, inspired by CERN
- Understanding of the potentiality opened by the TESLA driven SRF technology
- Endorsement of the science prospectives coming from the realization of an X-Ray Free-Electron Laser
- Interest for a stand alone X-Ray FEL

From TESLA TDR to an independent XFEL



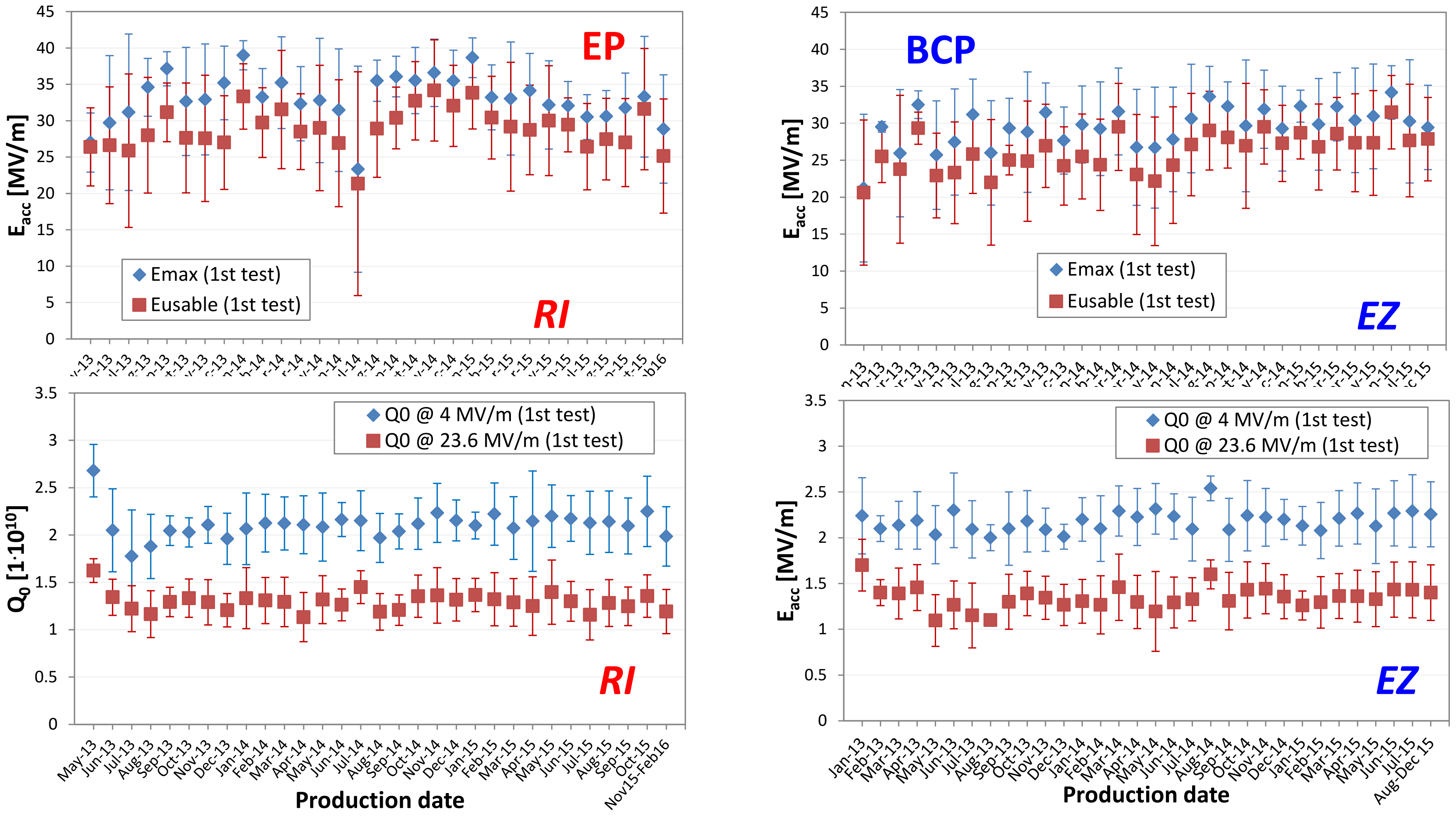
On request of German Science Council

Feb 2003 - **Decision by German Government:**

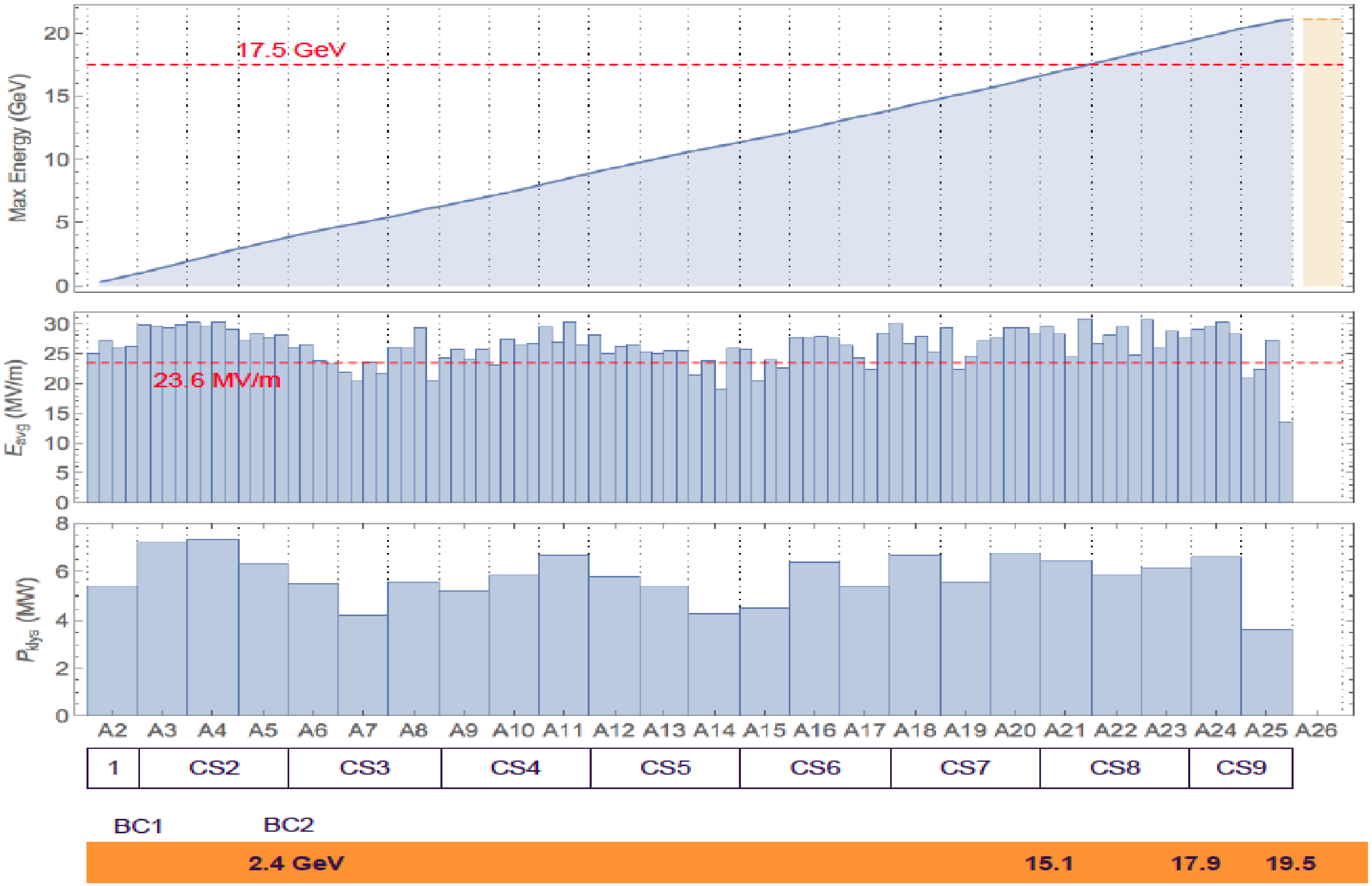
Germany will cover half of the cost of the free-electron laser facility proposed by DESY, which has to be **realized in a European collaboration**.

E-XFEL: 800 cavities at the State of the Art

1.3 GHz Eu-XFEL cavities «as received»



E-XFEL: Usable Installed Voltage



From TESLA to TESLA Technology Coll.-TTC

TESLA Technology Collaboration

Mission Statement

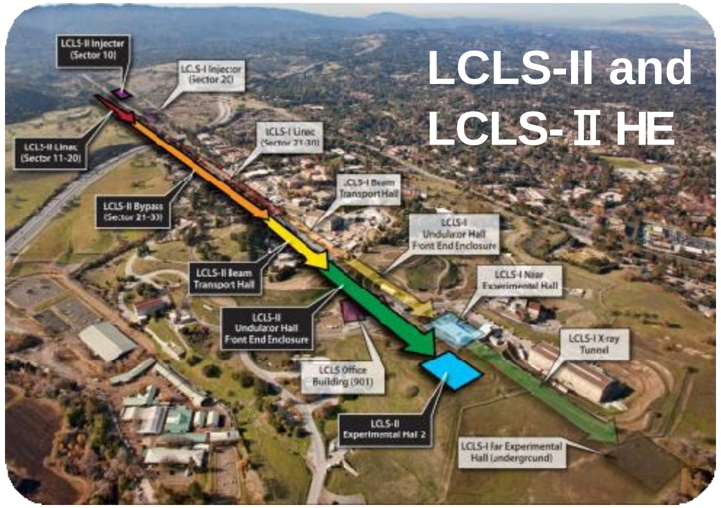
The mission of the TESLA Technology Collaboration (TTC) is to advance superconducting RF accelerator R & D and related accelerator studies across the broad diversity of scientific applications, and to keep open and provide a bridge for communication and sharing of ideas, developments, and testing across associated projects.

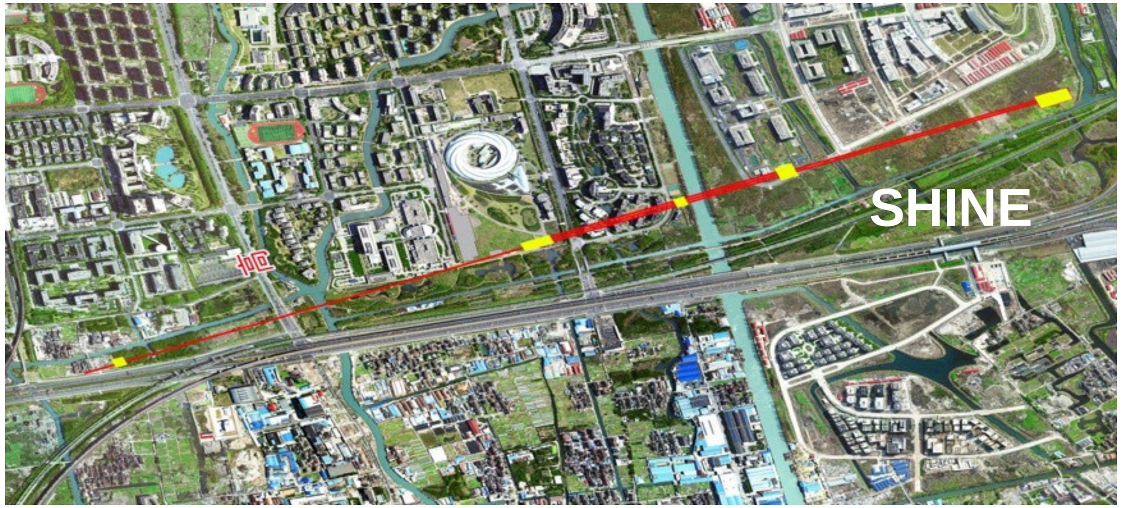
To this end the Collaboration supports and encourages free and open exchange of scientific and technical knowledge, expertise, engineering designs, and equipment.

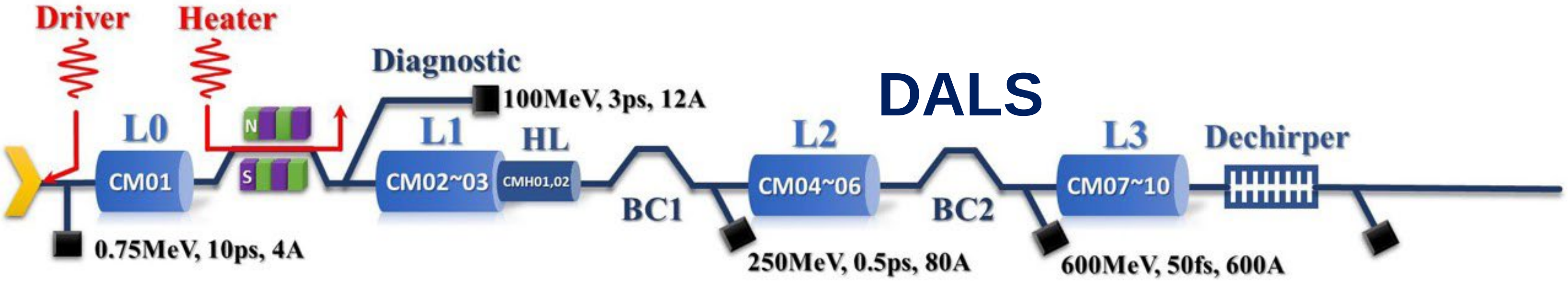
	• CANDLE, Yerevan • Yerevan Physics Institute, YerPhI	CANDLE Coordinator website under construction
	• TRIUMF, Canada's particle accelerator centre	ARIEL
	• Institute for High Energy Physics, IHEP • Tsinghua University • Peking University • Institute of Modern Physics, IMP, Lanzhou • Shanghai Institute of Applied Physics, SARI • Institute of Advanced Science Facilities – Shenzhen, IASF	Accelerator Technology and Science Department of Engineering Physics link will be added soon LINAC Center CAS
	• Commissariat à L'Energie Atomique, CEA/DSM, Saclay • Centre national de la recherche scientifique, CNRS, Paris • LAL became part of IJCLab, Orsay • Institut de Physique Nucléaire, IPN, Orsay • Synchrotron SOLEIL	IRFU DACM link will be added soon Accelerator Department SUPRATECH link will be added soon
	• Helmholtz-Zentrum Berlin, HZB • Technische Universität Darmstadt • Universität Frankfurt am Main • Helmholtz-Zentrum Geesthacht, HZG • Deutsches Elektronen-Synchrotron, DESY • Universität Hamburg • Helmholtz-Zentrum Dresden-Rossendorf, HZDR • Universität Rostock • Bergische Universität Wuppertal • Johannes Gutenberg Universität Mainz	SupraLab S-DALINAC & TEMF Accelerator Physics Institute of Materials Research FLASH & XFEL & MKS & MSL Accelerator Physics ELBE Electromagnetic Field Theory Field Emission MESA
	• Science and Technology Facilities Council, STFC • Royal Holloway, University of London • University College London • The John Adams Institute for Accelerator Science	Accelerator Science SuperFab UK-CSQS Department of Physics and Astronomy link will be added soon
	• Raja Ramanna Centre of Advanced Technology, RRCAT • Bhabha Atomic Research Centre, BARC • Inter-University Accelerator Centre, IUAC & Delhi University, DU • Variable Energy Cyclotron Centre, VECC	Superconducting Cavities Development Division Physical Science Superconducting Linear Accelerator Superconducting Cyclotron Beam Development Section
	• INFN, Laboratori Nazionali di Frascati • INFN, Laboratori Nazionali di Legnaro • INFN, Laboratori Acceleratori e Superconduttività Applicata, Milano • INFN Roma Tor Vegata • Elettra Sincrotrone Trieste	COLD Lab Superconductivity LASA Rome II & ATLAS Sincrotrone Trieste
	• Kō-Enerugī Kasokuki Kenkyū Kikō, KEK • Rikagaku Kenkyūjo, RIKEN • Institute for Quantum and Radiological Science and Technology, QST • Japan Atomic Energy Agency JAEA	Accelerator Laboratory RNC Rokkasho Fusion Institute
	• The Henryk Niewodniczanski Institute of Nuclear Physics • AGH University of Science and Technology • National Centre for Nuclear Research, NCJB, Swierk • Institute of High Pressure Physics, Warsaw • Uniwersytet Warszawski • Lodz University of Technology, TUL • Warsaw University of Technology, ISE	IFJ PAN Department of Solid State Physics Accelerator physics NCBiR Faculty of Physics Institute of Physics The Faculty of Electronics and Information Technology & The Faculty of Physics
	• Moscow Engineering Physics Institute, MEPhI • Budker Institute for Nuclear Physics, BINP • Institute of High Energy Physics, IHEP-Protvino • Institute for Nuclear Research, INR	Institute of Nuclear Physics and Engineering Russian Academy of Sciences (BINP SB RAS) Department of High Energy Physics FFPF MIPT link will be added soon
	• Institute for Basic Science, IBS	Rare Isotope Science Project
	• Uppsala University	FREIA
	• Argonne National Laboratory, ANL • Fermi National Accelerator Laboratory, FNAL • Cornell University, Ithaca NY • Thomas Jefferson National Accelerator Facility • Stanford Linear Accelerator Center, SLAC • Lawrence Berkeley National Laboratory, LBNL • Michigan State University, MSU • Oak Ridge National Laboratory, SNS • Brookhaven National Laboratory, BNL	Accelerator Development FAST CLASSE Jefferson Lab LCLS-II Accelerator Technology and Applied Physics Division Accelerator Science and Engineering Research Accelerator Division RBRC

European Organisations		
	• European Spallation Source, ESS	ESS Accelerator Division & LINAC
International Organisations		
	• European Council for Nuclear Research, CERN	CERN's accelerator complex
	• Joint Institute for Nuclear Research, JINR, Dubna	Research Facilities

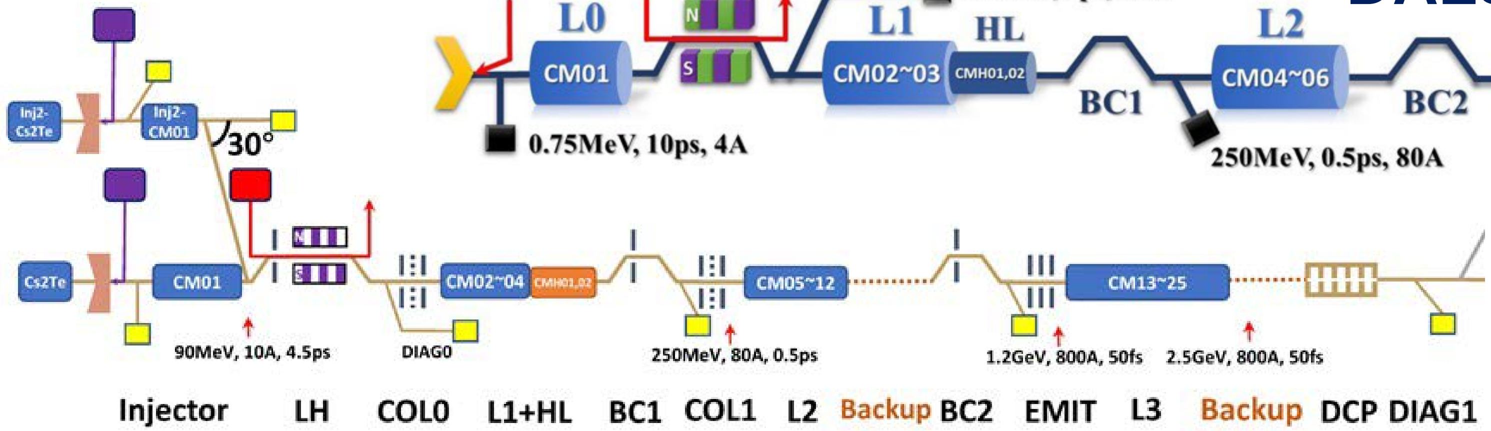
New CW XFEL from TESLA Technology





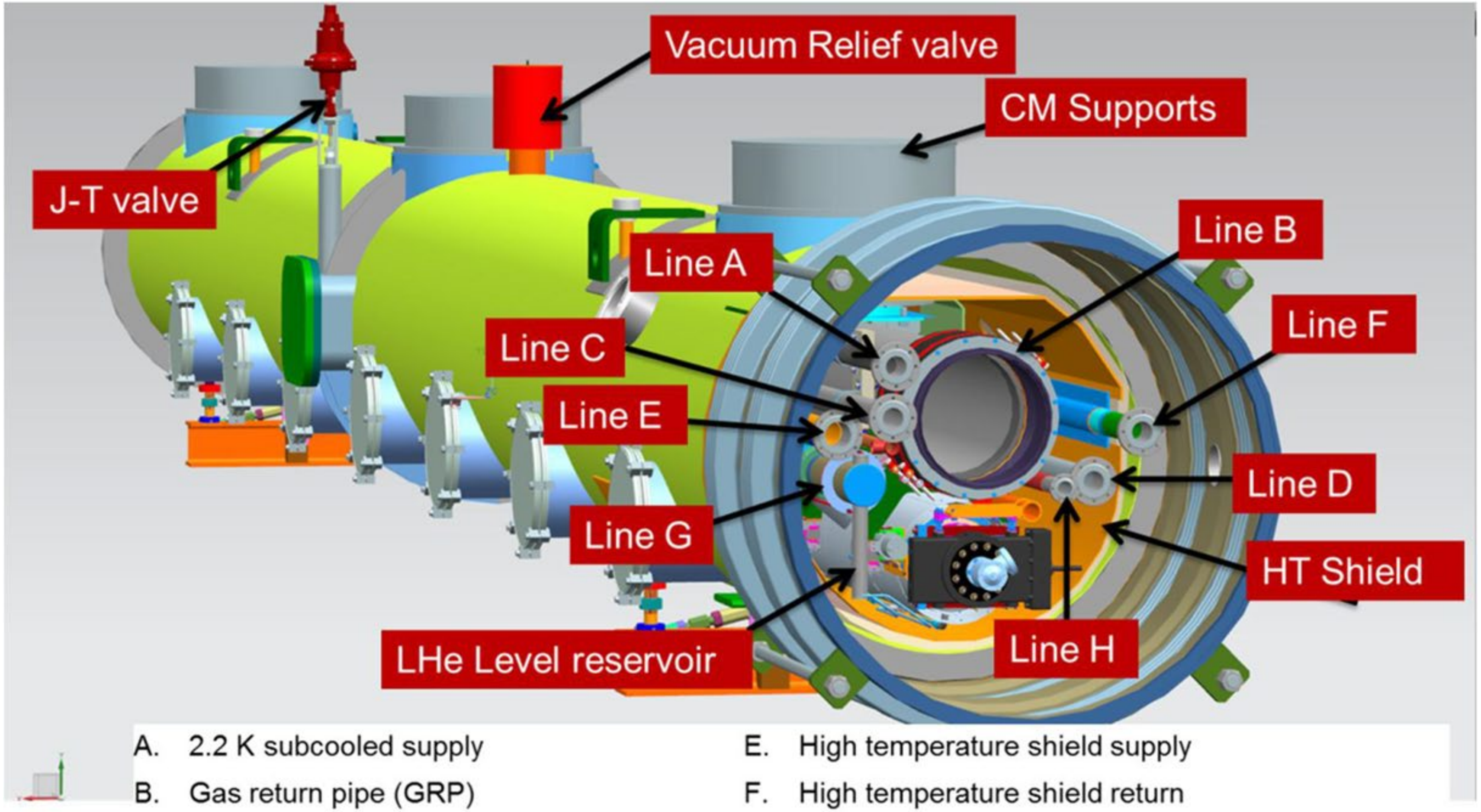


DALS



S3FEL

TTC: US modifications for CW and High Q



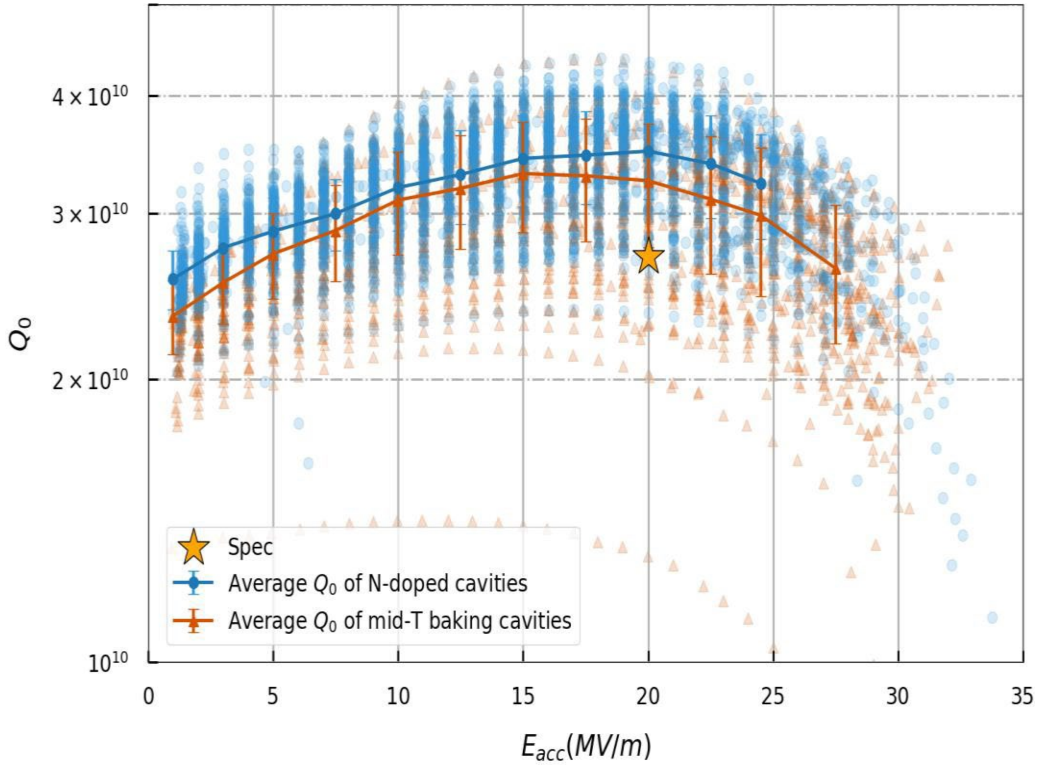
A. 2.2 K subcooled supply
B. Gas return pipe (GRP)
C. Low temperature intercept supply
D. Low temperature intercept return
E. High temperature shield supply
F. High temperature shield return
G. 2-phase pipe
H. Warm-up/cool-down line

LCLS-II Director's Review, August 19-21, 2014

J.N. Galayda @ Linac2014

Impressive results at SHINE

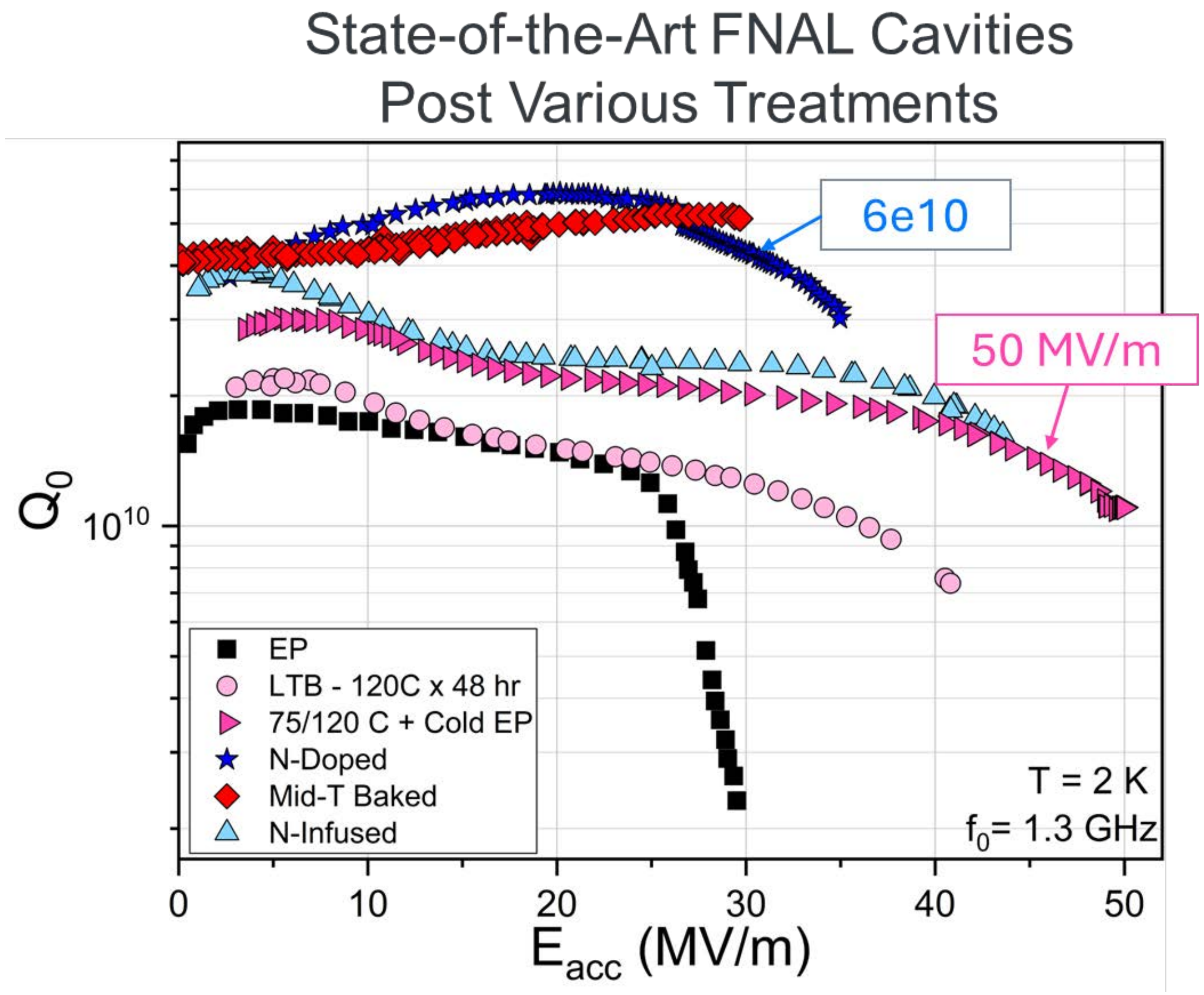
- **252 dressed cavities are tested** including:
  - 126 mid-T baked cavities
  - 126 N-doped cavities
- **192 cavities qualified (76%)**
  - 152 qualified as received
  - 30 with FE, qualified after HPR
  - 10 with Q-switch or low Q, qualified after retest
- **36 concessionally accepted for CM assembly (14%)**
  - Eacc≥ 19 MV/m, or Q0≥2.5E+10@20MV/m
- **24 cavities still unqualified (10%)**
  - 4 with FE, awaiting further HPR
  - 20 with too low Eacc or Q0, need repair (on going)



Recipes	Ave. max Eacc (MV/m)	Ave. Q_0
Mid-T	27.5	3.2E+10
N-doping	24.5	3.5E+10

Hongtao HOU @ SRF 2025

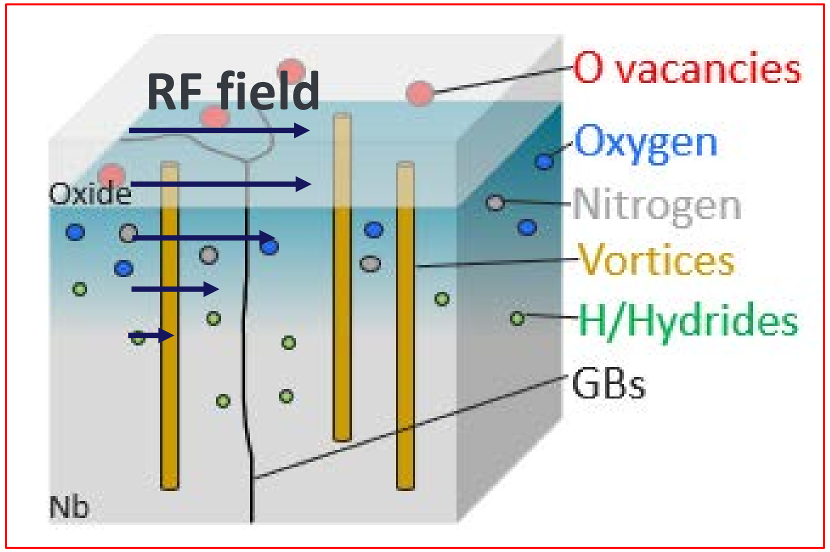
Great Progress on SRF Understanding



Daniel Bafia @ LCWS 2025

Conclusions

- Coupled **RF and materials science** studies advance microscopic understanding of SRF materials, **revealing how impurities and defects govern performance.**
- Impurity (N or O) tailoring tunes SRF properties
  - N is ~10× more effective than O at lowering R_{BCS}.
- Optimized EP is critical to realize impurity-tailoring benefits
  - Minimizes H uptake, smooths surface and removes lossy inclusions.
- H and lattice defects identified as key loss sources in Nb films
  - Annealing mitigates these losses and improves film performance.



SRF Accelerators for Free-Electron Lasers

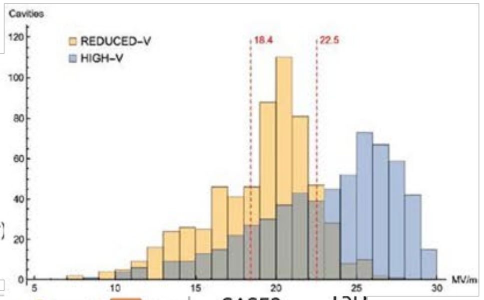
European XFEL (DESY)

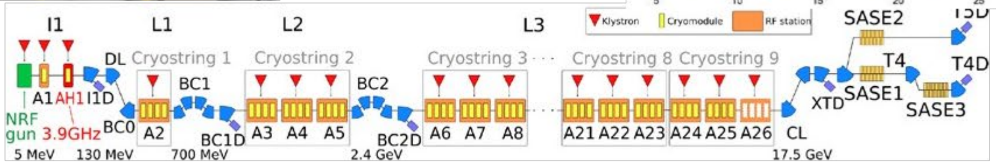
Cavity operation

776x 1.3 GHz TESLA cavities

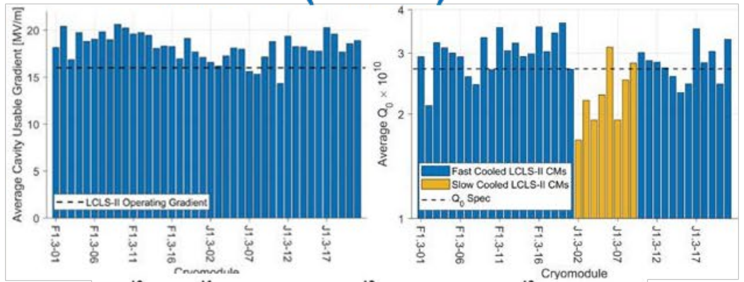
Typical operation conditions

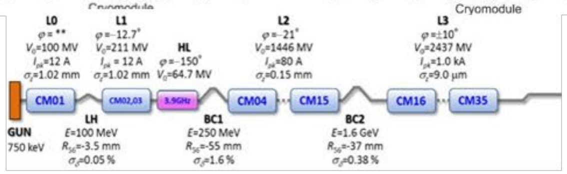
- Average gradient + spread
- Coupler power (x4 for peak power)
- Measured Q_0 = 1 x 10^{10}



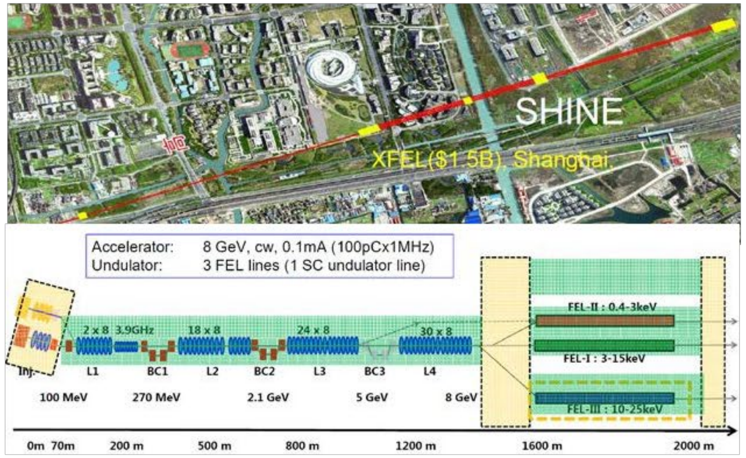


LCLS-II (SLAC)

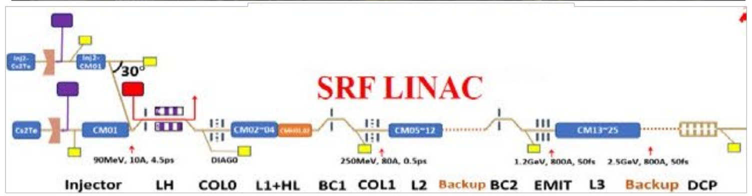




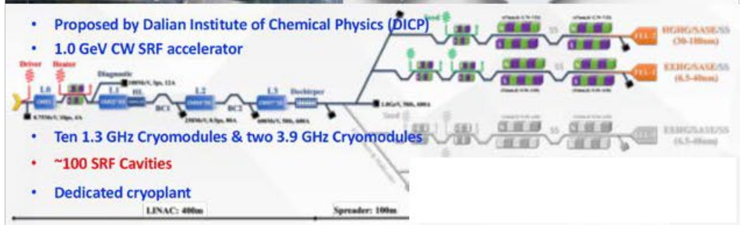
SHINE (Shanghai)



S3FEL (Shenzhen)



DALS (Dalian)



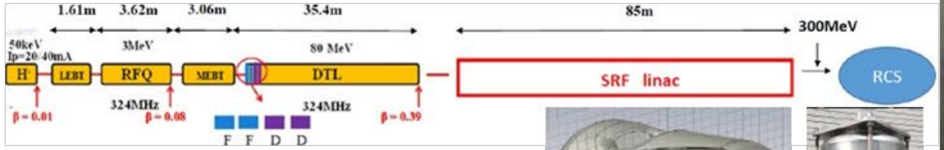
SRF Based Spallation Neutron Sources

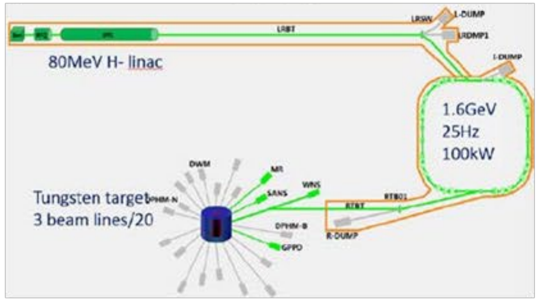
● **SNS-PPU (ORNL)** (Proton Power Upgrade)

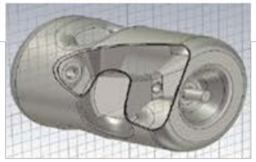
[by SNS/ORNL Home page]

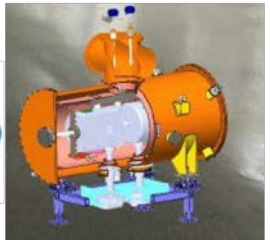
32 x 805 MHz, 6-cell cavity $\beta = 0.81$

● **CSNS-II / CAS** [H. Liu (IHEP/CSNS) in HPPA-WS2019]



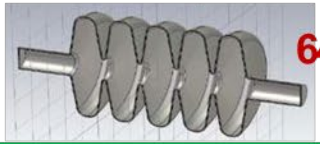






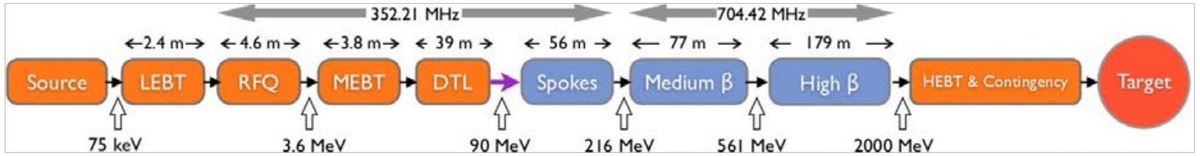
CSNS-II double -spoke module

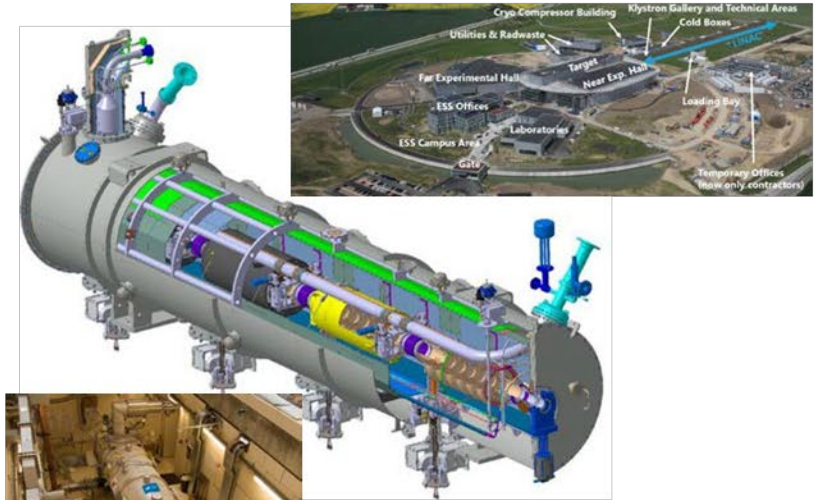
324 MHz, Double-Spoke, $\beta = 0.50$

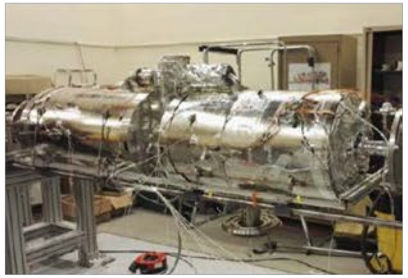


648 MHz, 5-cell cavity $\beta = 0.67$

● **ESS (Lund)** (European Spallation Source) [G. Devanz (CEA) in SRF19]







26 x 325.2 MHz, Double-Spoke $\beta = 0.50$

36 x 704.4 MHz, Med-β, 6-cell cavity $\beta = 0.67$

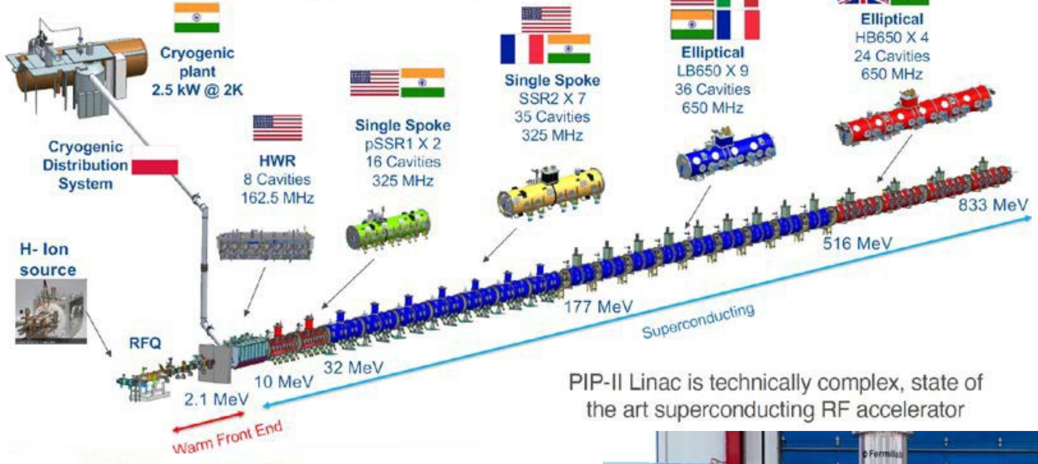
84 x 704.4 MHz, High-β, 5-cell cavity, $\beta = 0.86$

Proton and Deuteron SRF Accelerators

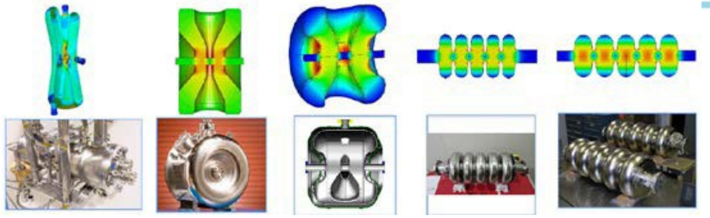
PIP-II (FNAL) (Proton Improvement Plan – II)

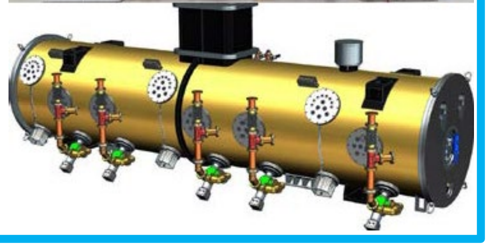
[A. Klebaner (FNAL) in SRF21]

PIP-II Superconducting RF CW Linac, 2mA, 800 MeV
Consists of Five Types of Cryomodules



PIP-II Linac is technically complex, state of the art superconducting RF accelerator

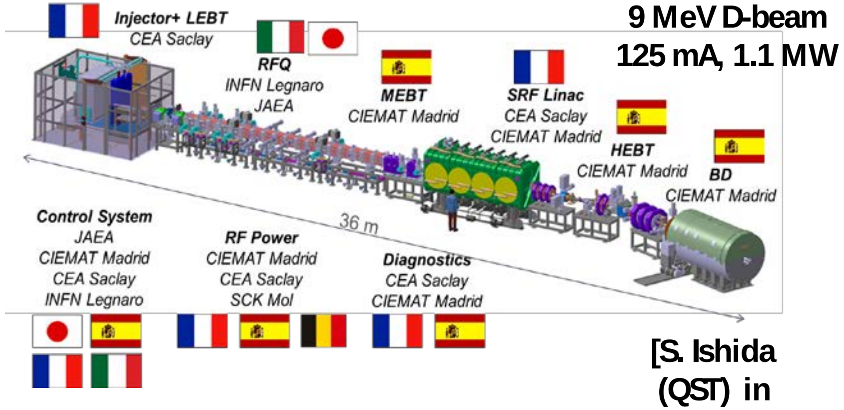




Description	Units	HWR (8)	SSR1 (16)	SSR2 (35)	LB650 (36)	HB650 (24)
Type		Half-Wave	Single Spoke	Single Spoke	Elliptical	Elliptical
β		0.11	0.22	0.47	0.61	0.92
Frequency	MHz	162.5	325	325	650	650
Q_0		$8.5 \cdot 10^9$	$8.2 \cdot 10^9$	$8.2 \cdot 10^9$	$2.4 \cdot 10^{10}$	$3.3 \cdot 10^{10}$
Gradient	MV/m	9.7	10	11.5	16.8	18.7
E_{Peak}	MV/m	44.9	38.4	40.3	40.2	38.8
B_{peak}	mT	48.3	58.1	77.4	75	72.8
N-doped		No	No	No	TBD	Yes

IFMIF-LIPAc (QST/ Rokkasho)

9 MeV D-beam
125 mA, 1.1 MW



[S. Ishida (QST) in SRF19]

A-FNS (QST/Rokkasho) (Advanced Fusion Neutron Source)

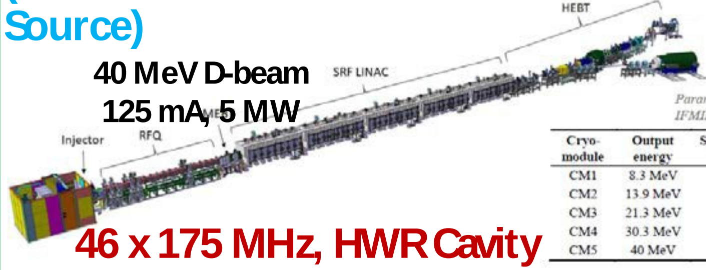
40 MeV D-beam
125 mA, 5 MW

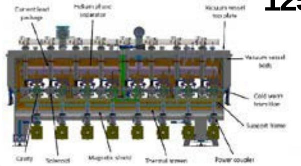
DONES (F4E/CEA) (Demo Oriented Neutron Source)

8+10+12+12 HWR 175MHz

[N. Bazin (CEA) in SRF21]

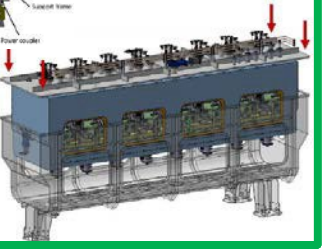
40 MeV D-beam
125 mA, 5 MW





Parameters of the cryomodules of the IFMIF- DONES superconducting linac

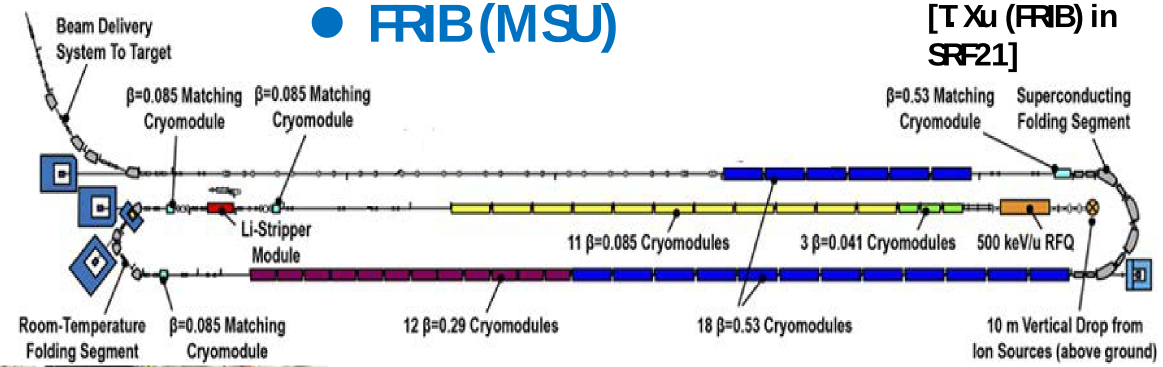
Cryo-module	Output energy	Solenoids	Cavities	Type of cavities
CM1	8.3 MeV	8	8	Low-β
CM2	13.9 MeV	6	11	Low-β
CM3	21.3 MeV	5	9	High-β
CM4	30.3 MeV	5	9	High-β
CM5	40 MeV	5	9	High-β

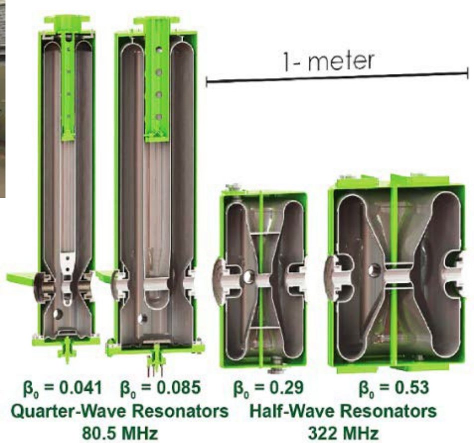


46 x 175 MHz, HWR Cavity

Large Heavy Ion SRF Accelerators

- **FRIB (MSU)** [T. Xu (FRIB) in SRF21]



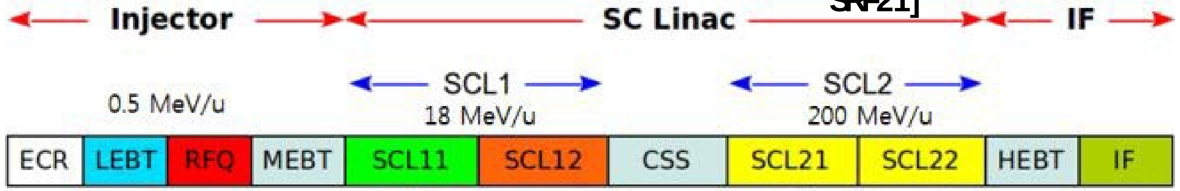


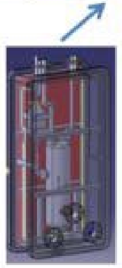
16+104 QWR:
80.5 MHz,
β = 0.041, 0.085

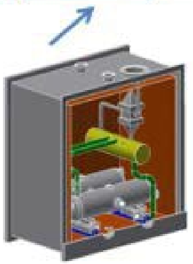
72+148 HWR:
322 MHz,
β = 0.29, 0.53

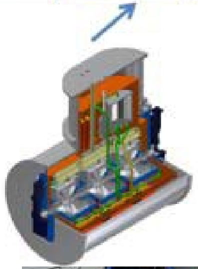
55 5-cell Cavity:
644 MHz,
β = 0.65

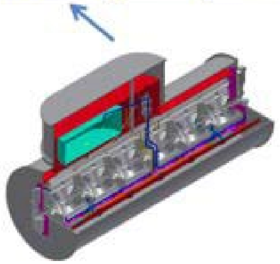
- **RAON (IBS/RISP)** [Y. Sohn (IBS/RISP) in SRF21]











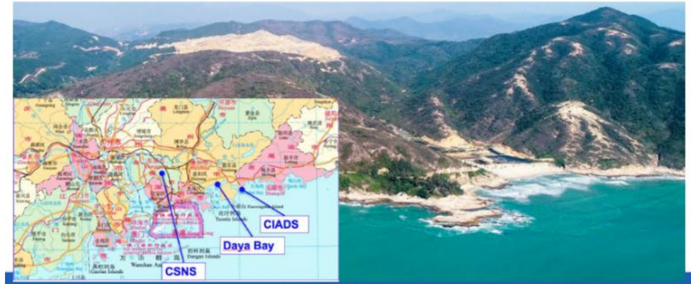
28 QWR: 81.25MHz

76 HWR: 162.5MHz

138 SSR2: 325MHz

69 SSR1: 325MHz

SRF for ADS *(Accelerator Driven System)*

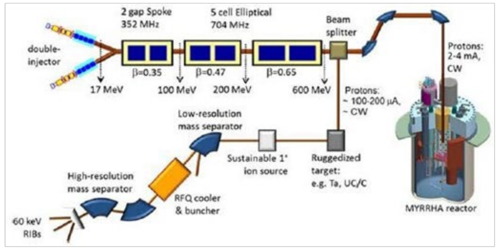


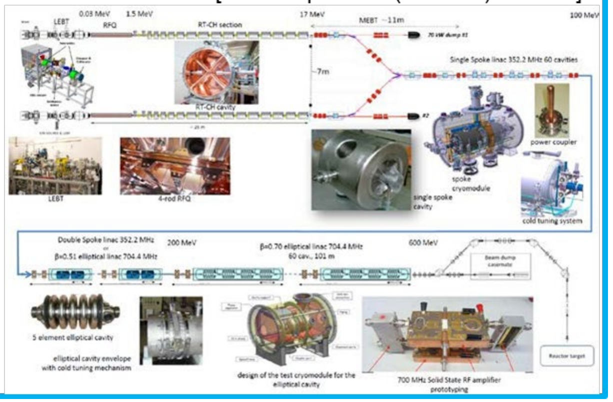
- Approved in Dec. 2015, Ground broke in August 2018, Officially started in July 2021
- Leading institute: IMP
- Budget: ~4 B CNY (Gov. 1.8B + CNNC 1.0 B + Local Gov. 1.2 B)
- Location: Huizhou, Guangdong Prov.
- Partners: CIAE, CGN, IHEP, etc.

CiADS linac: progress and first beam of normal frontend, Zhijun Wang 6

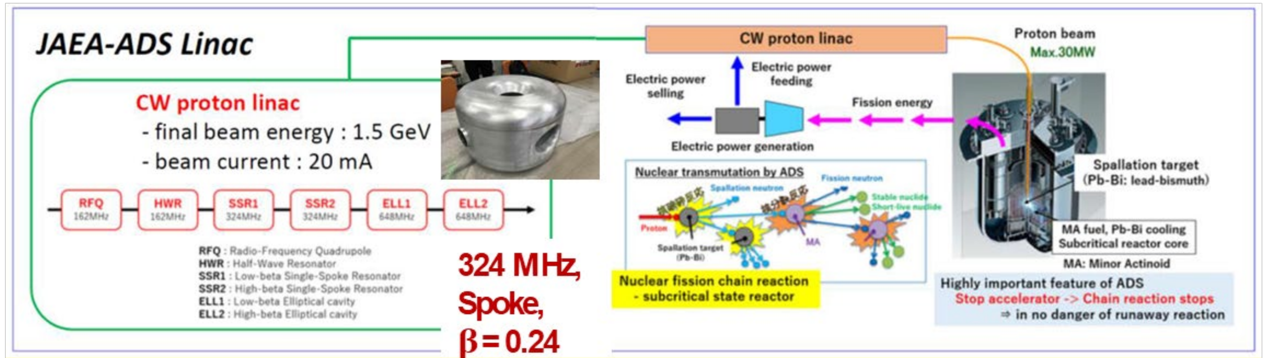
- **MYRRHA (ADS) /SCK-CEN**

[D. Vandeplassche (SCK/CEA) in SRF19]





[J. Tamura (JAEA) in SRF21]



324 MHz, Spoke, β = 0.24

SRF for Dark Matter Search

FERMILAB-SLIDES-24-0106-SQMS

SQMS · Fermilab · U.S. Department of Energy, Office of Science

This material is based upon work supported by the U.S. Department of Energy, Office of Science, National Quantum Information Science Research Centers, Superconducting Quantum Materials and Systems Center (SQMS) under contract number DE-AC02-07CH11359

Application of superconducting cavities as ultra-sensitive RF photon detectors

FRXD3, Friday May 24th, 2024

Bianca Giaccone

Superconducting Quantum Materials and Systems Center (SQMS), Fermilab

SQMS

30 Partner Institutions

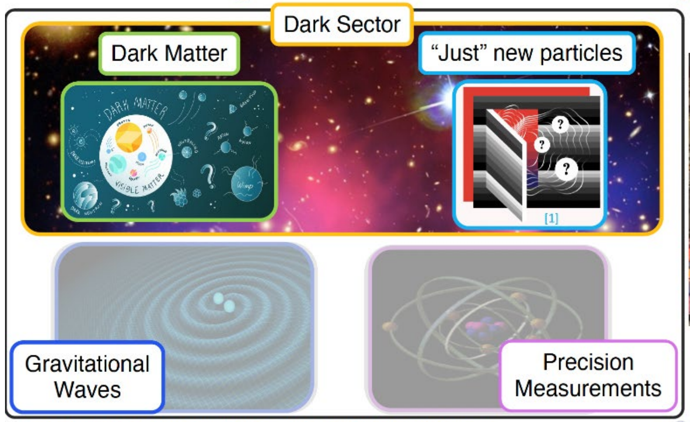
>500 Collaborators

A DOE National Quantum Information Science Research Center

Fermilab · Northwestern University · rigetti · AMES National Laboratory · NASA Ames Research Center · NIST · Colorado School of Mines · FormFactor · Goldman Sachs · Illinois Institute of Technology · INFN · Jefferson Lab · Johns Hopkins University · Lockheed Martin · LSU · NPL National Physical Laboratory · NYU · Royal Holloway University of London · Rutgers · Stanford · Temple University · Unitary Fund · The University of Arizona · University of Colorado Boulder · University of Illinois Urbana-Champaign · University of Minnesota Driven to Discover · Università di Pisa · University of Waterloo · IQC Institute for Quantum Computing

A rich **ecosystem**, multi-institutional and multidisciplinary collaboration **leveraging investments** at DOE national labs, academia, industry and several other federal and international entities

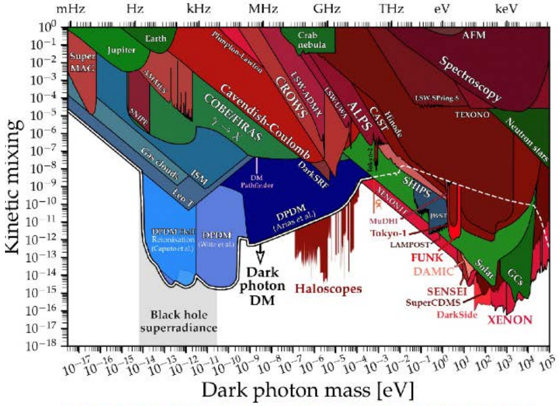
Quantum Sensing: new windows into fundamental physics



Fermilab Dark SRF Experiment

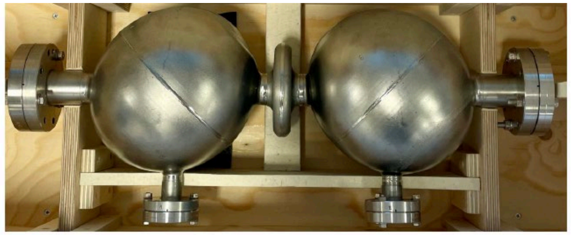
[1] Artwork by Sandbox Studio Chicago with A. Kova symmetrymagazine.org

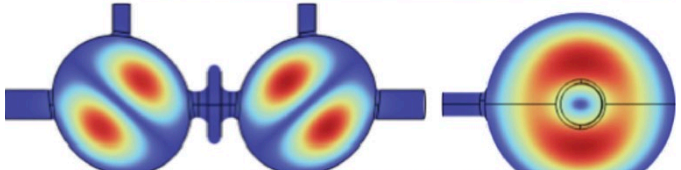
No dark photons (or axions) were found (yet).



Credit: O'Hare, https://cajohare.github.io/AxionLimits/docs/dp.html

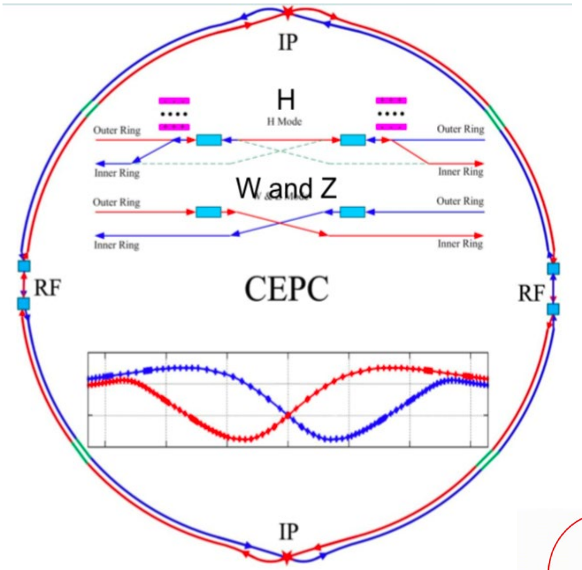
- No discovery, but still progress because of the excluded parameter space.
- But a lot more parameter space left to explore…
- "Mowing the lawn."

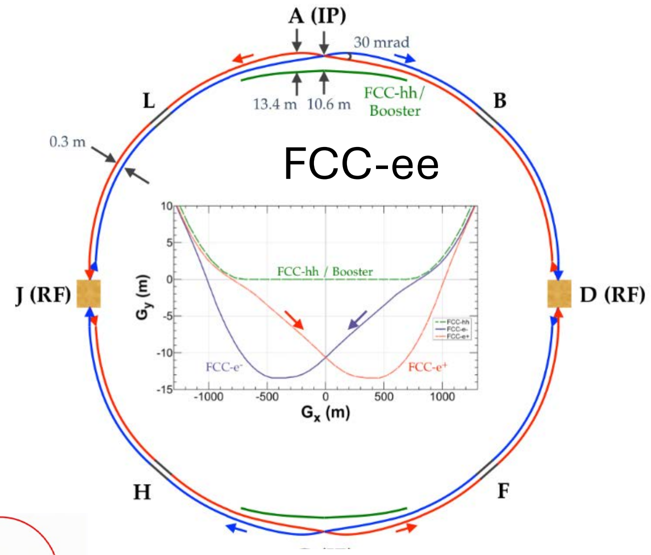


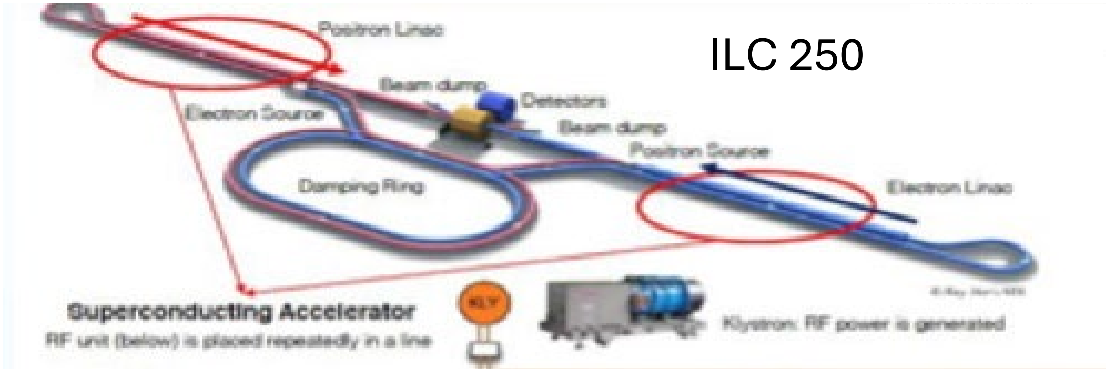


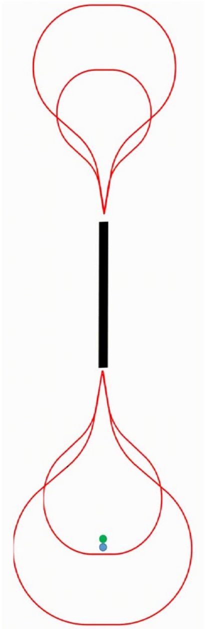
$TE_{011} \rightarrow 2.103$ GHz

Top Level SRF for Future Lepton Colliders



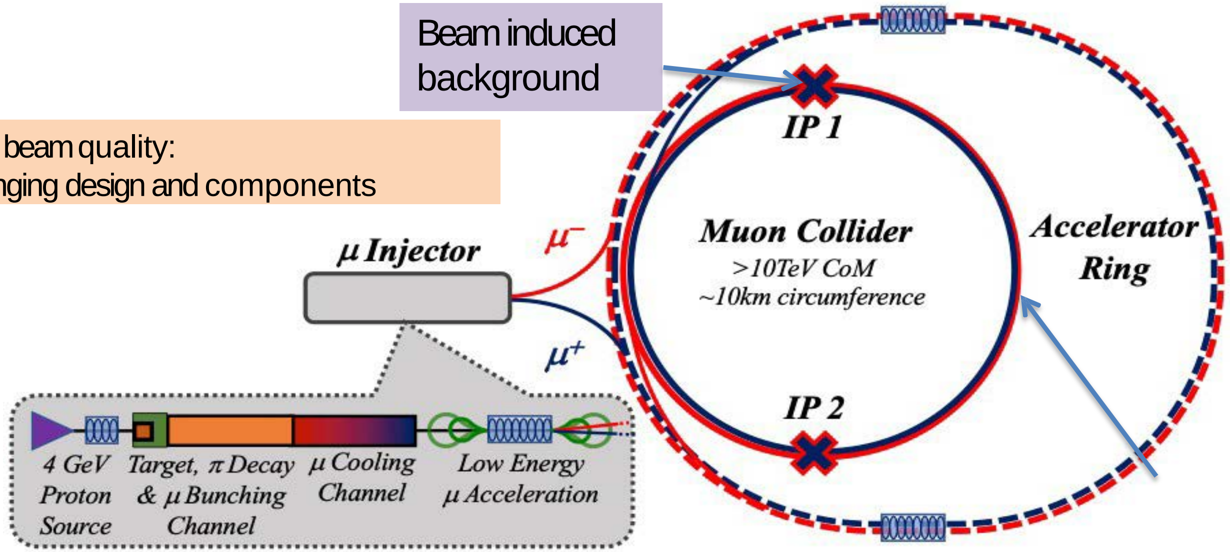




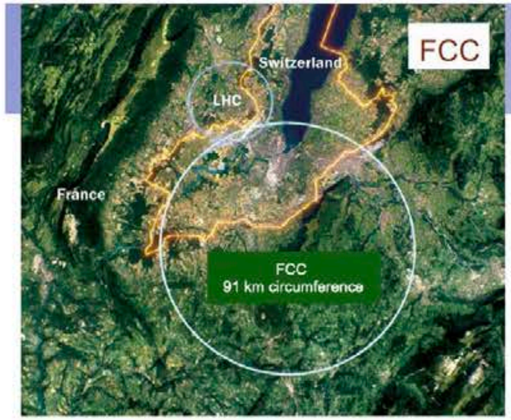


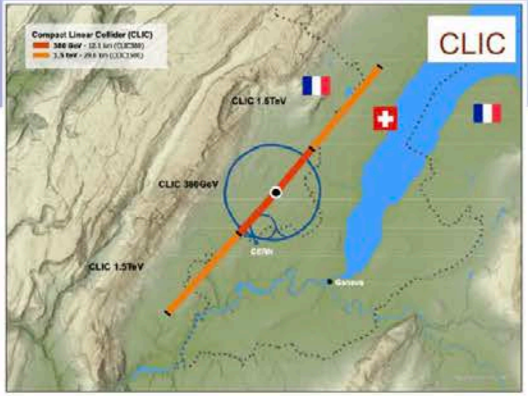
Beam induced background

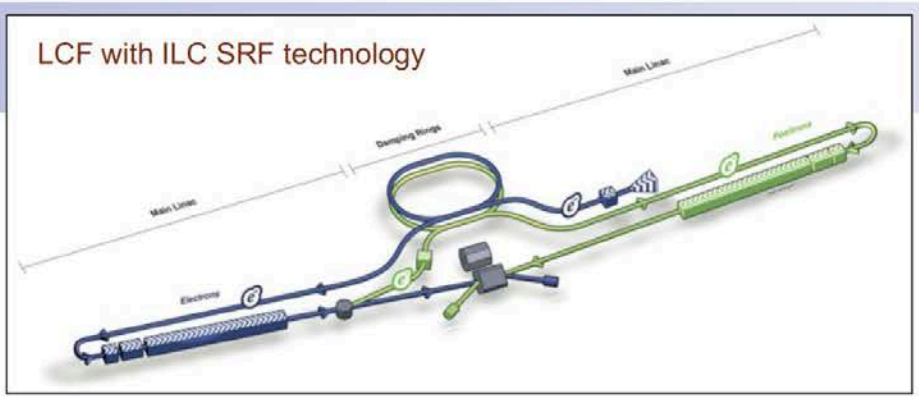
Drives beam quality:
challenging design and components

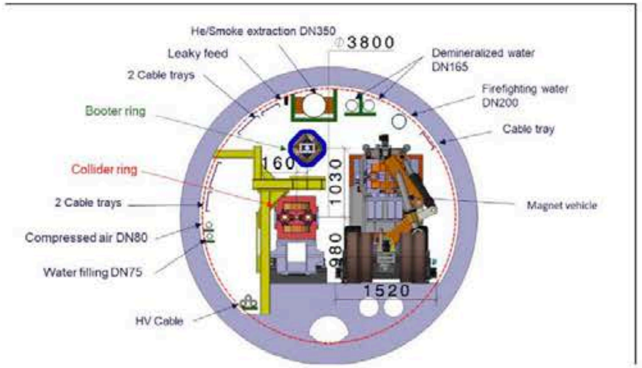


The CERN View *(Venice, June 2025)*

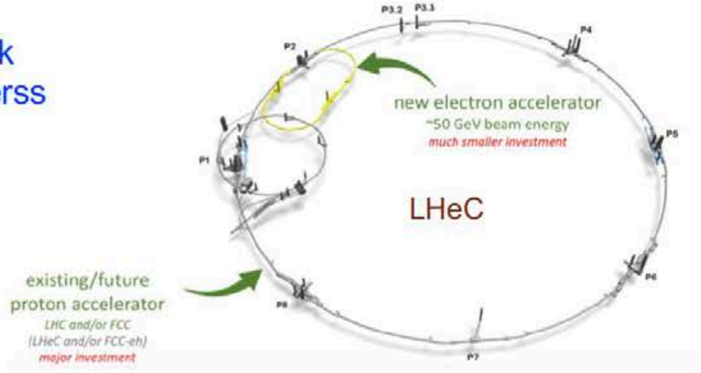




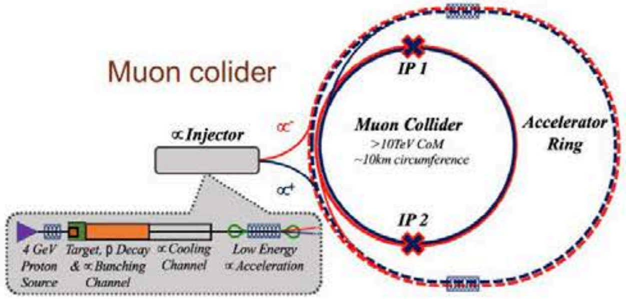


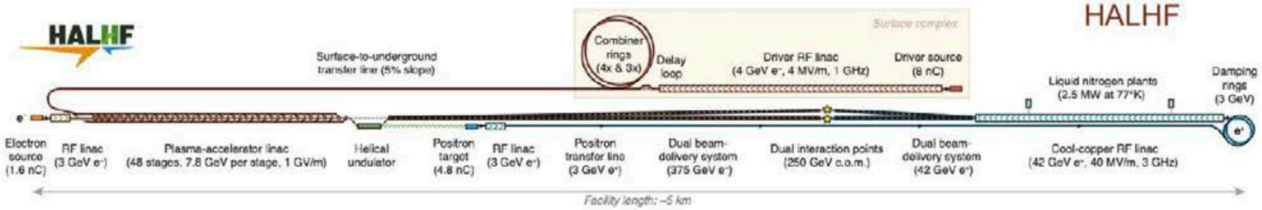


Huge amount of R&D and design work on a variety of proposed future colliderss
(varying levels of maturity, time scale, cost, physics reach/performance)



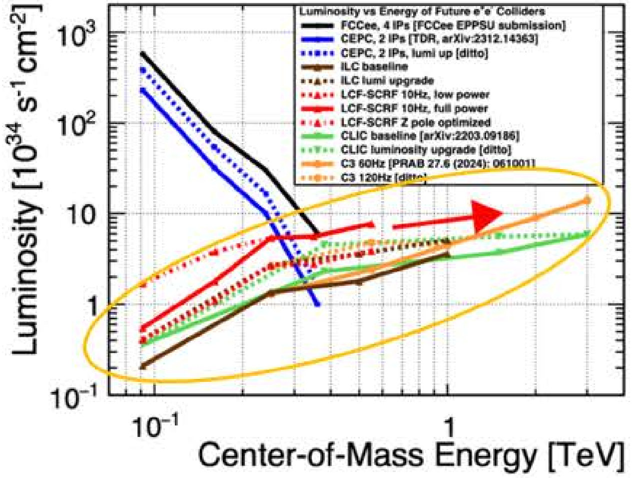
Fabiola Gianotti
Venice 2025





ILC @ CERN

Start with mature technology, can expand in length and/or technology



Energy reach and flexibility:

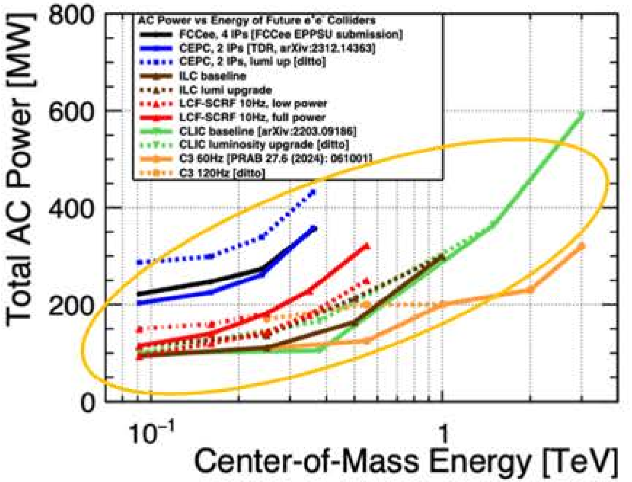
- Physics opportunities from Z-pole to TeV(s)
- Flexible (E,L,cost, power) to adapt to development in physics and technology

Footprint, cost, power – next slides:

- Lower cost to get to Higgs and top than a circular machine (initial machine)
- Power similar to LHC, or lower, for initial configuration
- Footprint (length/location) similar to LHC

Provide many opportunities and increased flexibility for the future:

- Does not determine footprint of future energy frontier machines (hadrons or muons), and it has its own upgrade opportunities
- Encourage accelerator and detector R&D for all these options



Steinar Stapnes @ LCWS 2025

Concluding Remarcs

The great demand for knowledge fueled by nuclear and particle physics has favored the technological **development of magnetic and radiofrequency superconductivity**, through the construction of large accelerators with the involvement of industry.

The fallout on medical devices (MRI, NMR), green energy (ADS) and advanced light sources (SR, XFEL) is currently underway, making conceivable also new huge infrastructures for **fundamental physics (CEPC)**, which **could trigger other future applications**.

The pursuit of pure knowledge, typical of fundamental physics, **has generated large-scale open and global collaborations**, also producing technologies, such as the World Wide Web, accessible to all. **With the TESLA collaboration, SRF has shared this mission**, which today is a precious treasure that we must preserve.

Great Future for SRF in China

Thank you for your attention