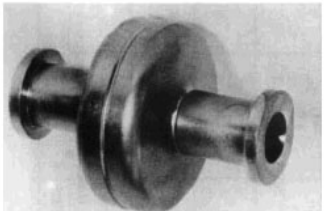
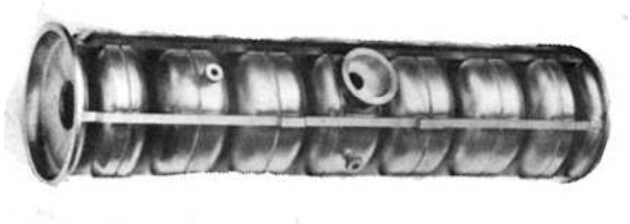
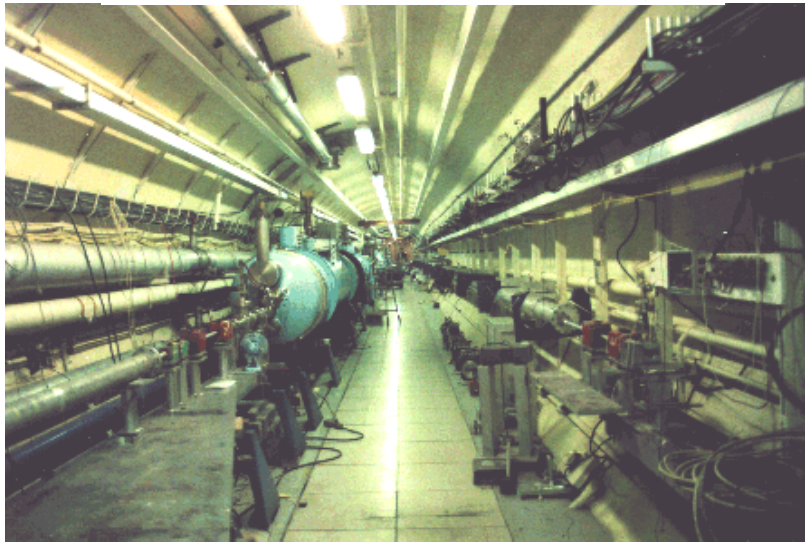
A Little Bit of History

RF Superconductivity Pioneered at Stanford U.





- First SC Cavities
- First SC Structures
- First Recirculating Accelerator
- First FEL



Earliest Nb Cavity

1968 HEPL Stanford U

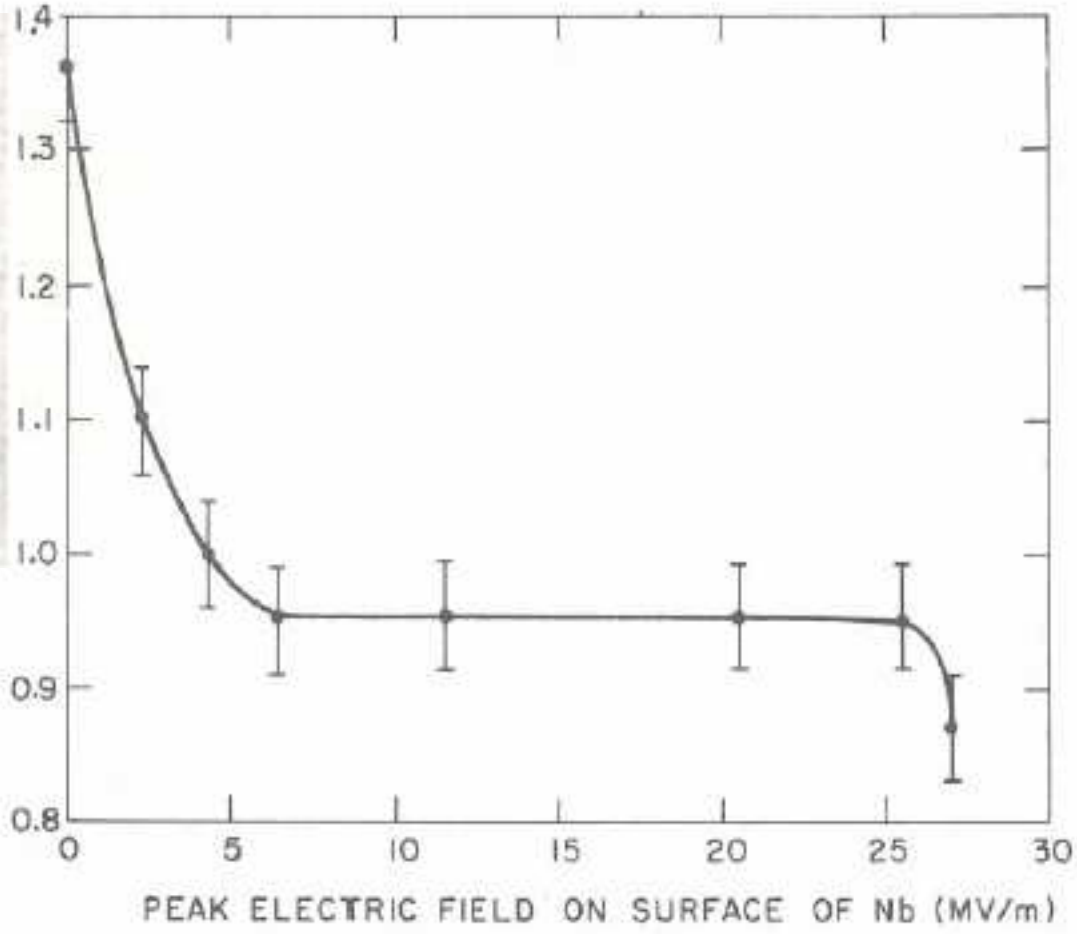
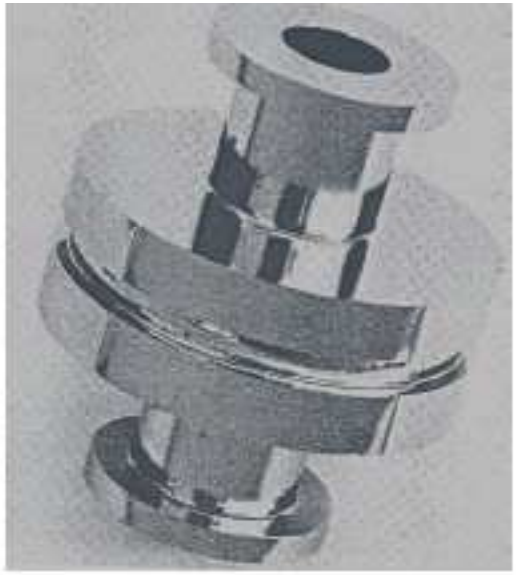


Figure 1: Results from the first solid niobium cavity [3].

1970 HEPL Stanford U



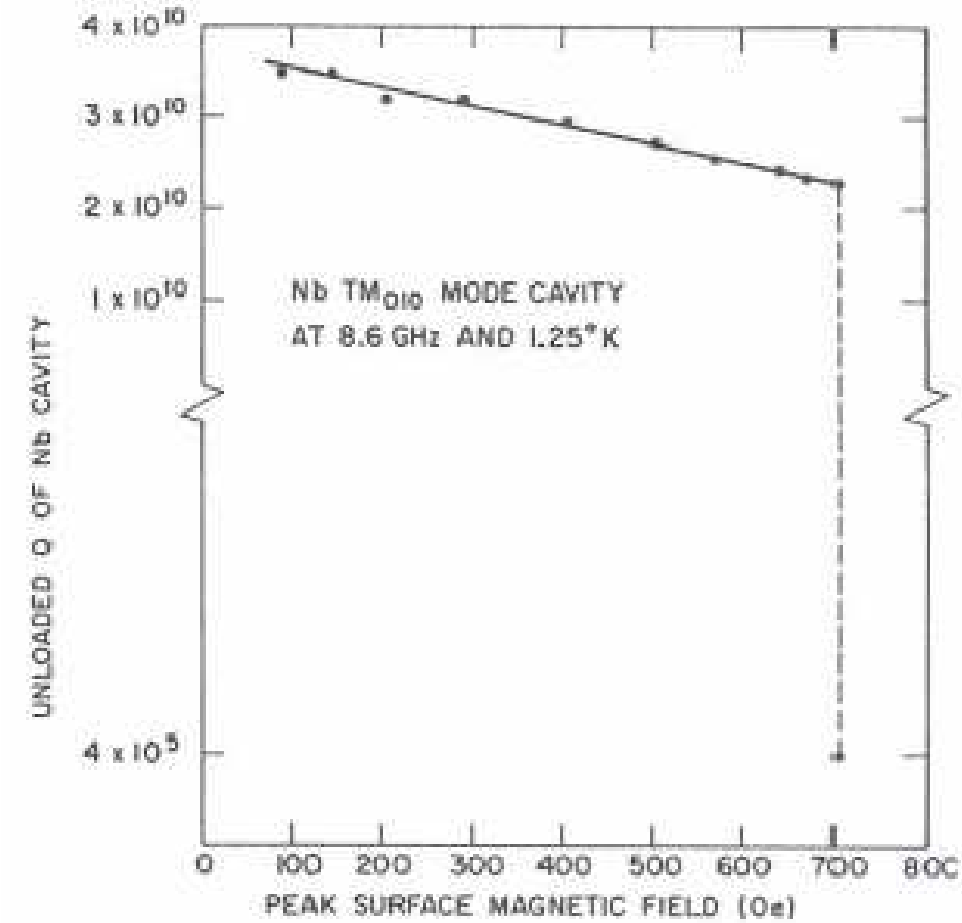
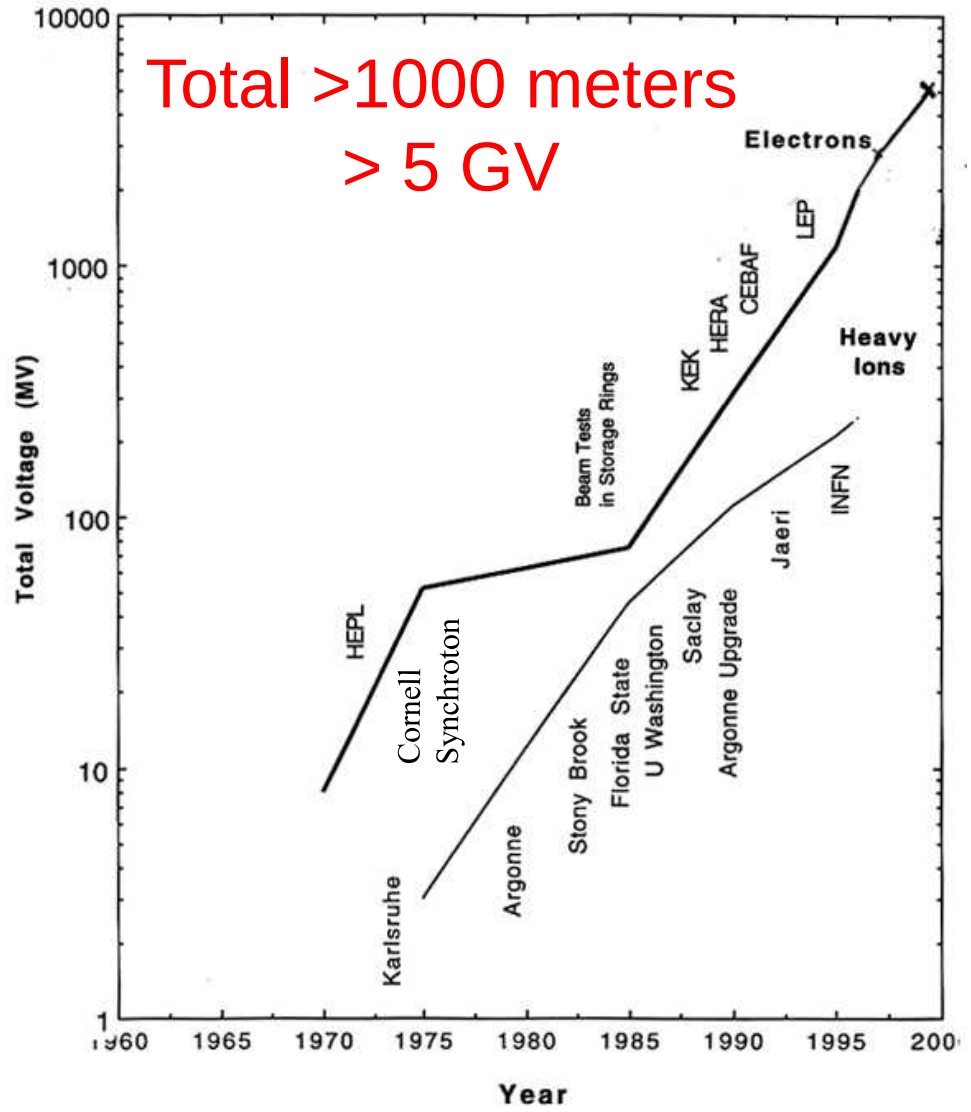


Figure 2: Electron beam welded TM_{010} X-band cavity [4].

Success Story #1, Applications In Place

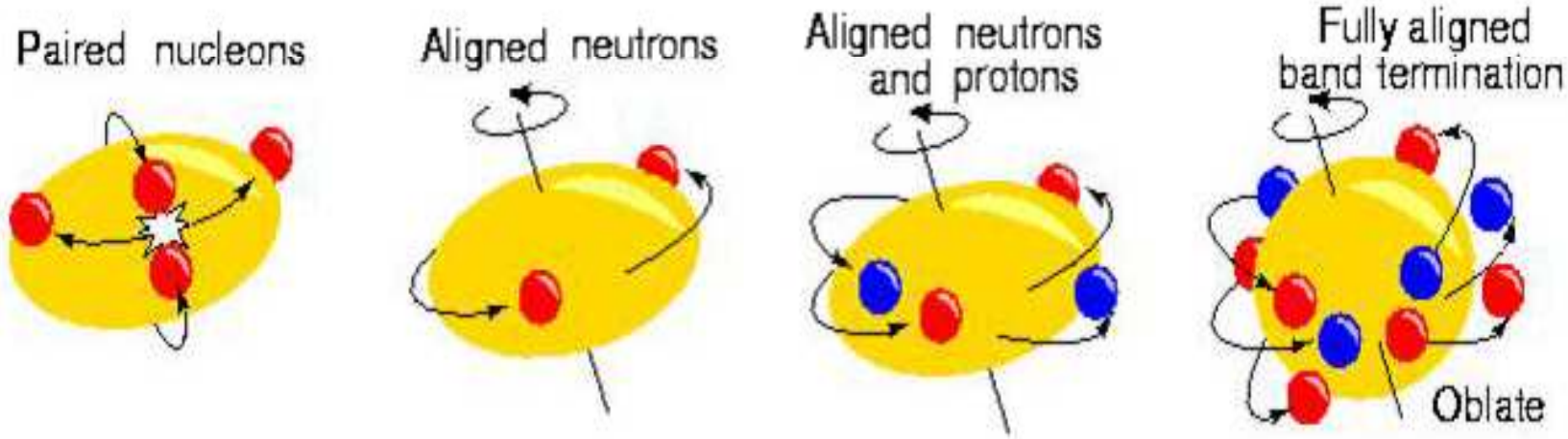
- Low Energy Nuclear Physics
  - Heavy Ion Linacs
- Medium Energy Nuclear Physics
  - Electron linacs, recirculating
- High Energy Particle Physics
  - Electron (positron) storage rings
- Light Sources
  - Electron storage rings
  - Linac based Free Electron Lasers (FEL)



Low Energy Nuclear Physics,

What's it good for?

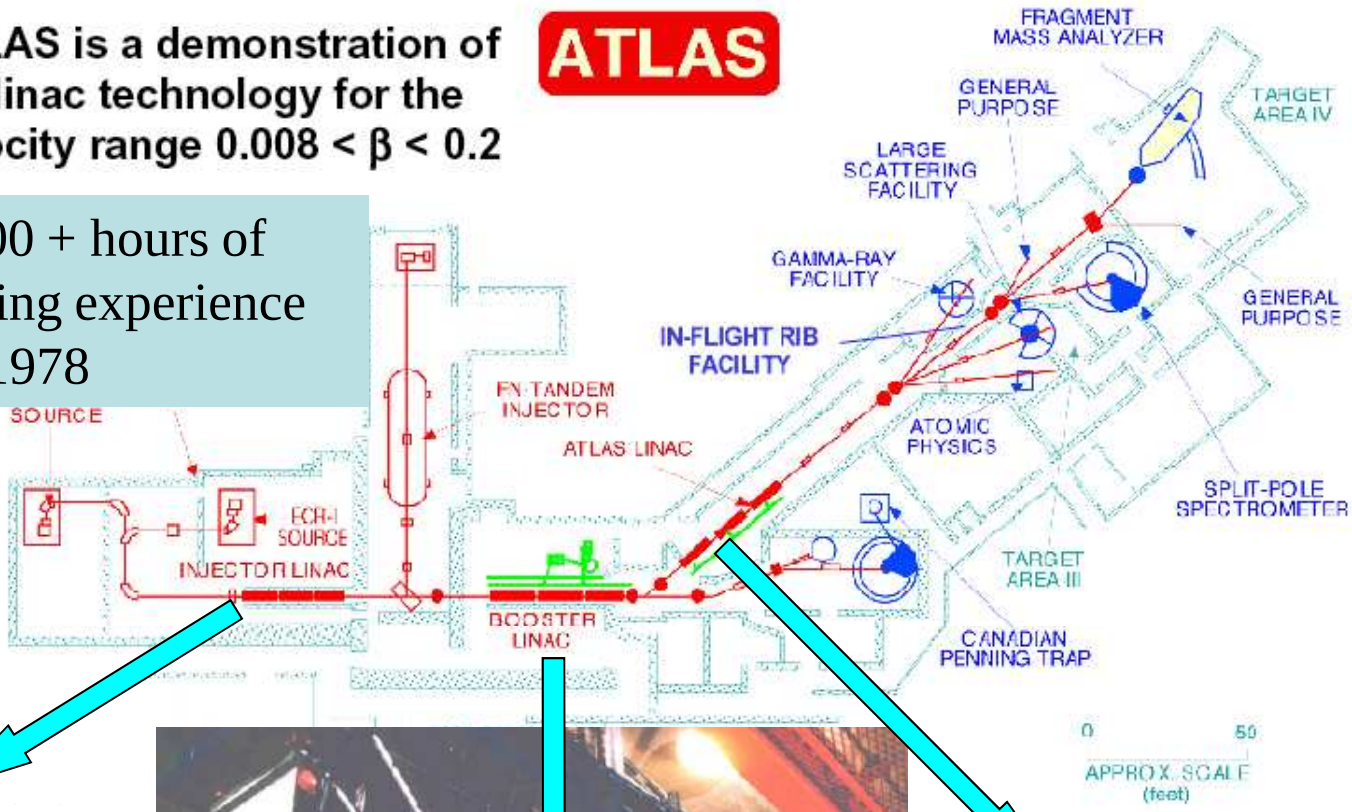
Understanding nuclear structure, nuclear shape, spin, vibration, rotation

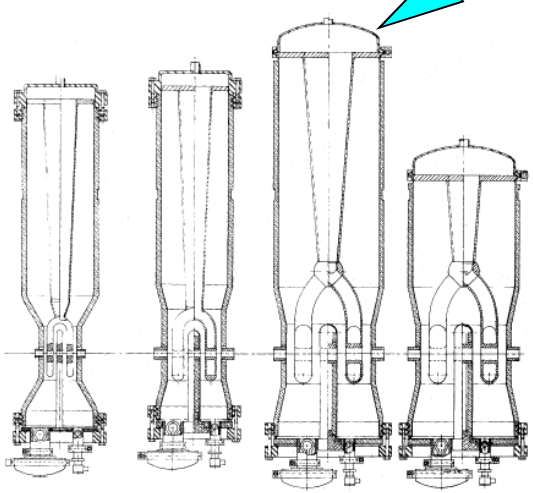


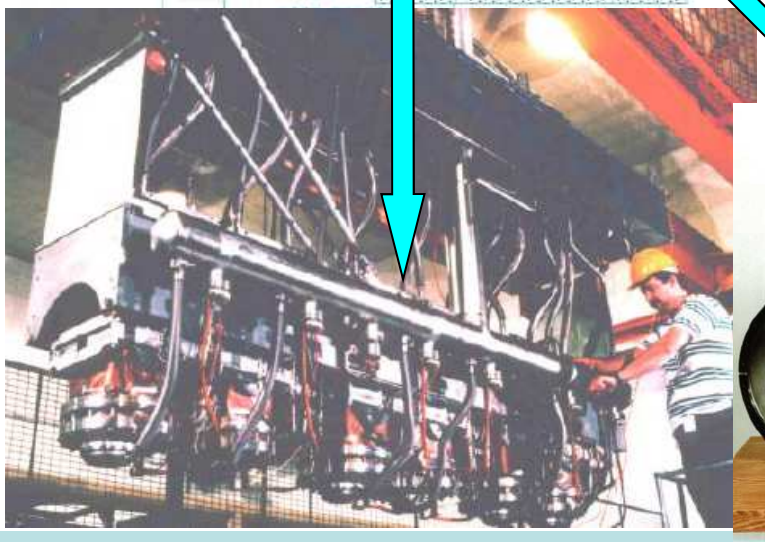
ATLAS is a demonstration of SC linac technology for the velocity range 0.008 < β < 0.2

ATLAS

100,000 + hours of operating experience since 1978







Superconducting Accelerating Structures

10 Heavy Ion Linacs Installed

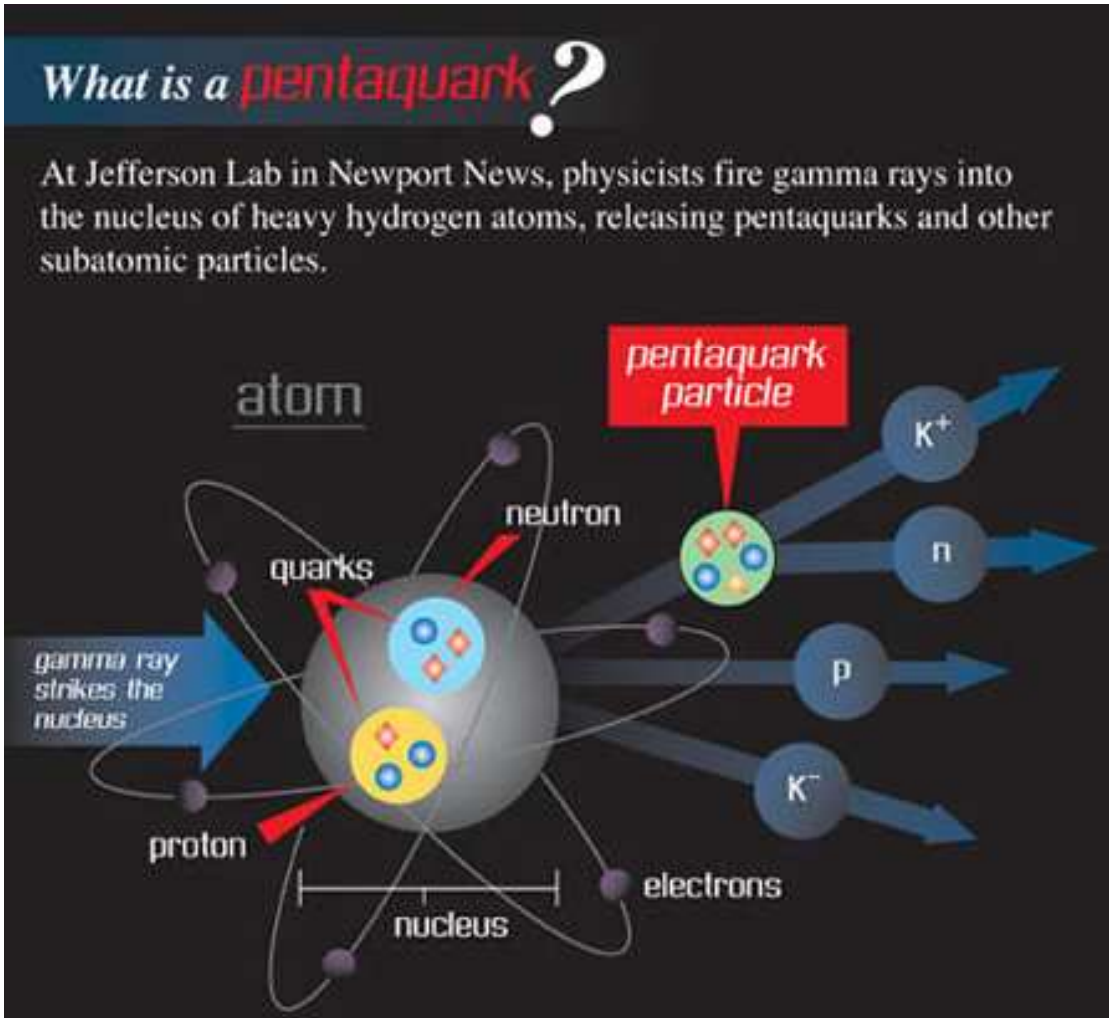
- ATLAS (Argonne) US
- Stony Brook
- U. of Washington
- Florida State U
- Kansas State U
- Delhi U
- JAERI (Japan)
- ALPI (Italy)
- ANU (Australia)
- ISAC-II (TRIUMF-Canada)
- 3-5 MV/m

- > 270 SC structures

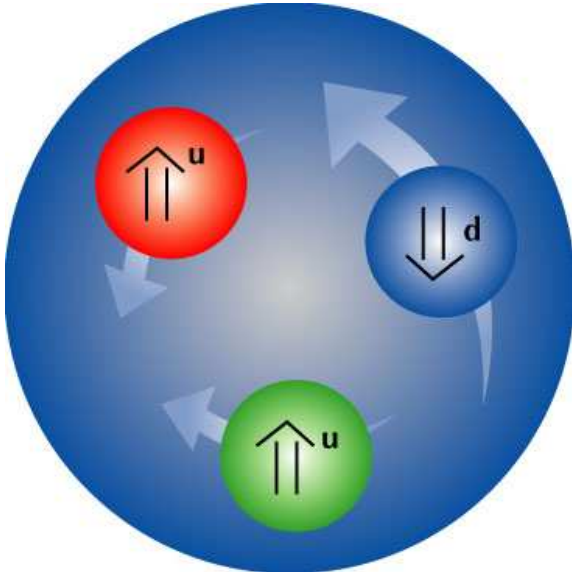
Medium Energy Nuclear Physics

Understanding the quark-gluon structure of nucleus

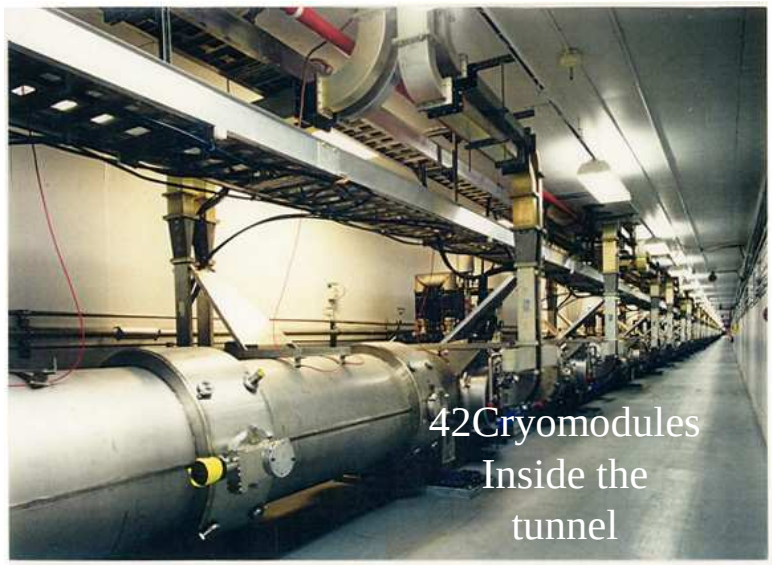
Exotic combinations - penta-quark



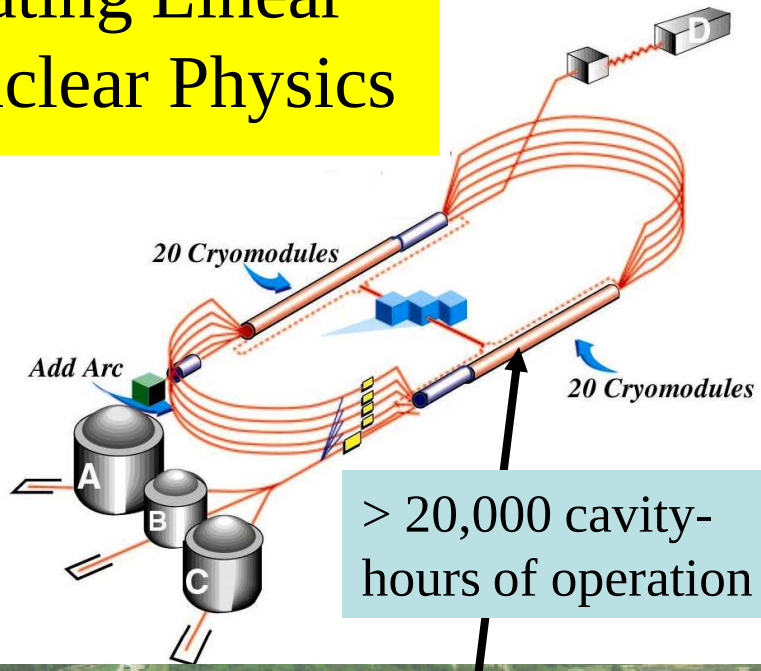
Distribution of nuclear spin



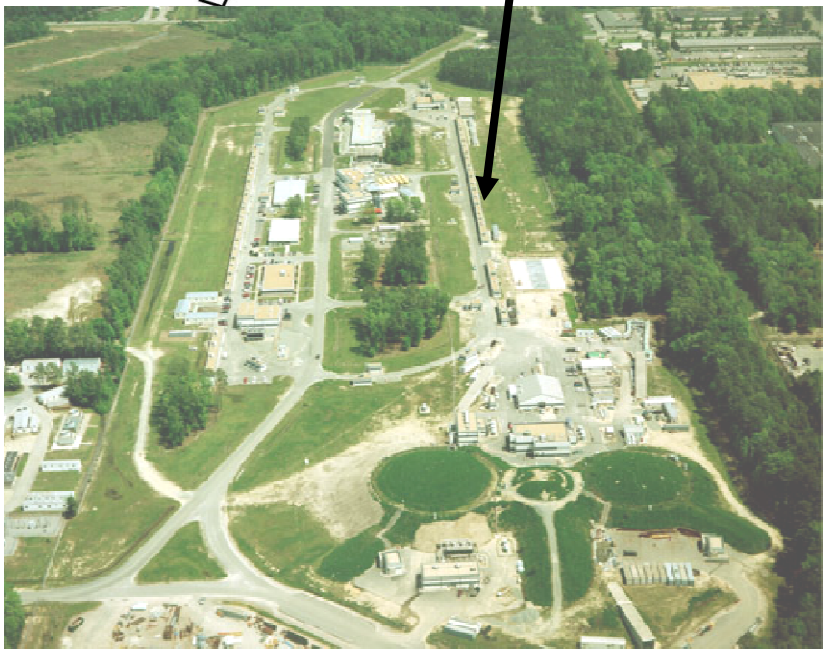
6 GeV Re-circulating Linear Accelerator for Nuclear Physics



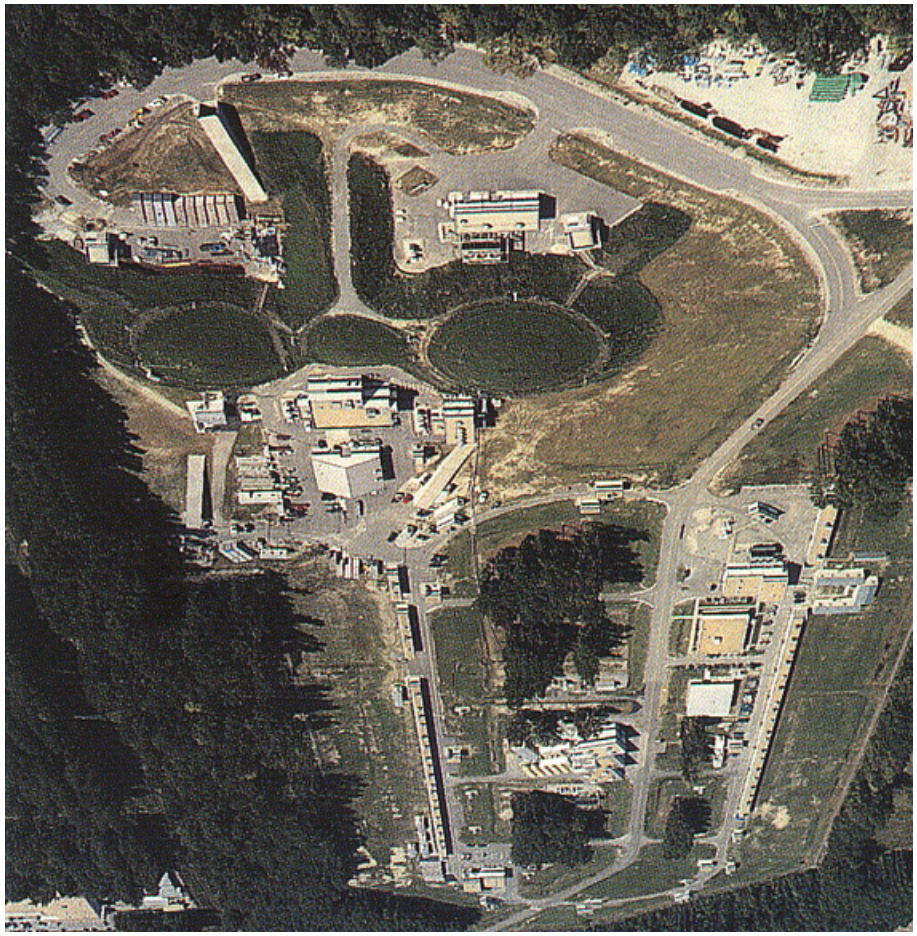
SOUTH LINAC CRYOMODULES

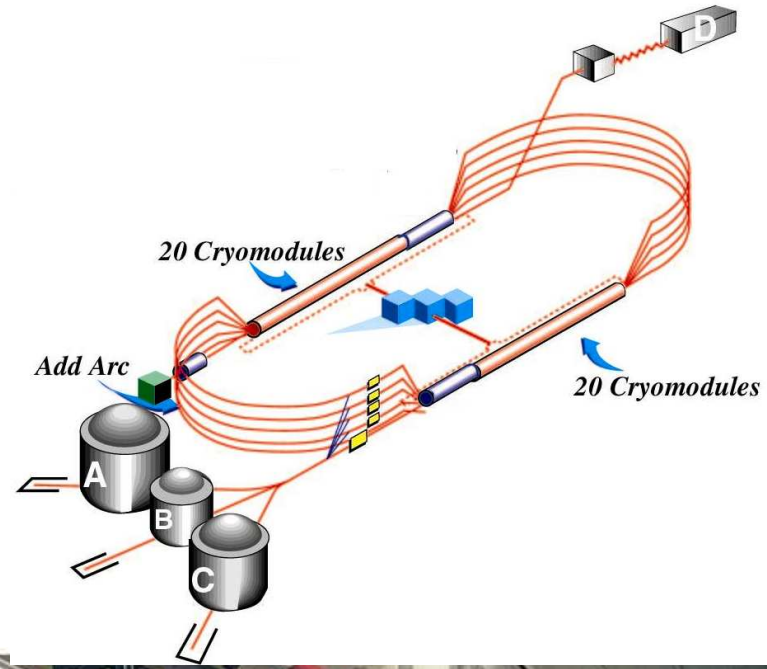


> 20,000 cavity-hours of operation



Nuclear Physics
Jlab - CEBAF



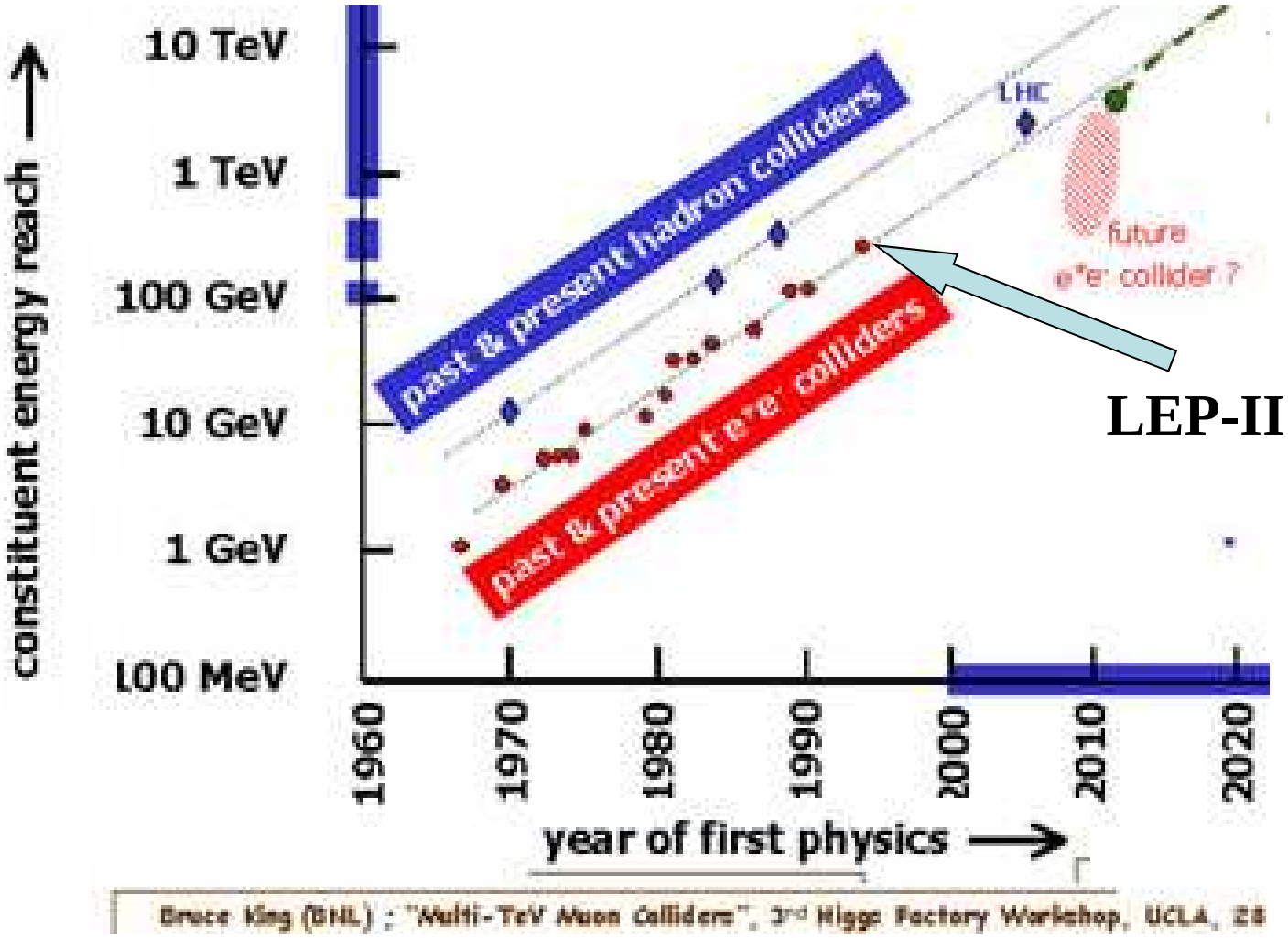


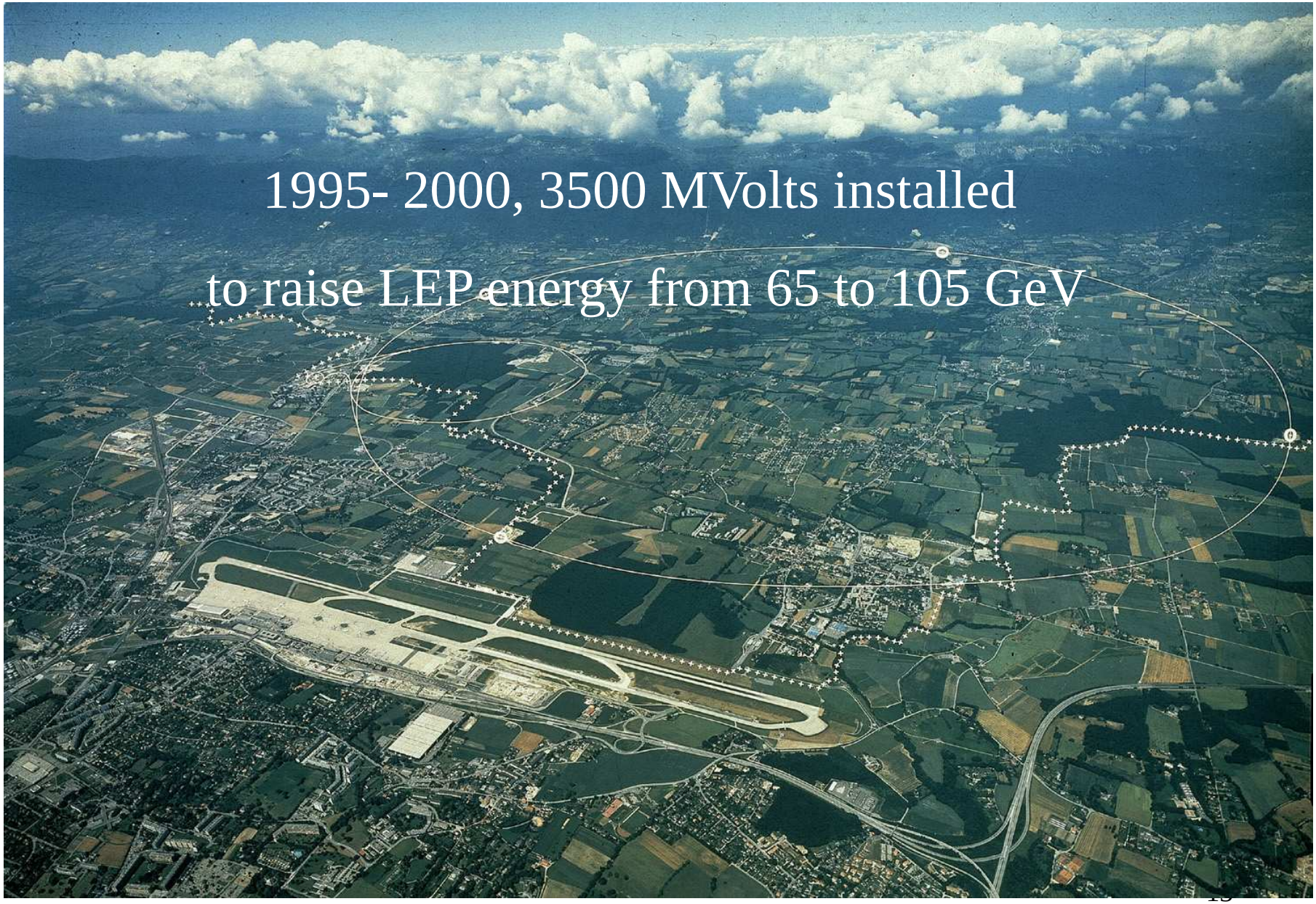
SOUTH LINAC CRYOMODULES

High Energy Physics,

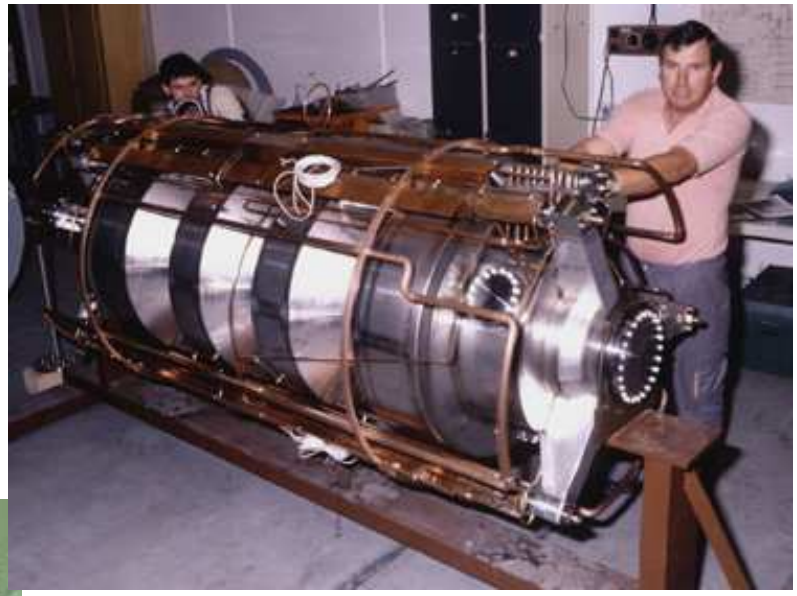
What's it good for?

High Energy Physics




1995- 2000, 3500 MVolts installed
to raise LEP energy from 65 to 105 GeV

350 MHz Nb-Cu Cavities for LEP-II



LEP-200 GeV

LEP

Acceleration system in straight sections at 4 points

Copper - and Superconducting cavities

56 288 cavities

Circumference 26.7 km, 4 experiments

Counter rotating e^+ and e^-, 4 bunches in each beam

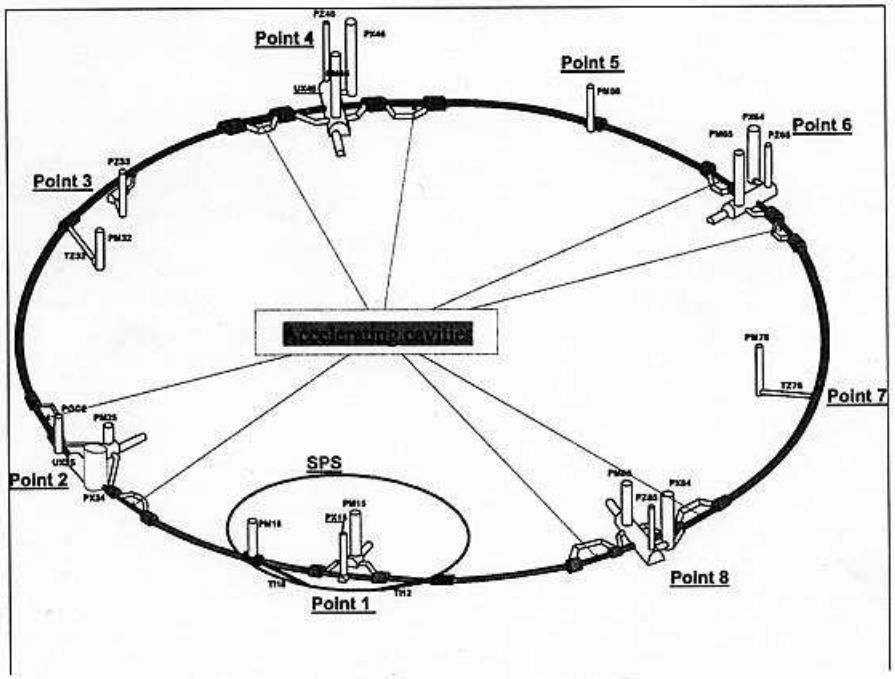
Total current 6 mA, 66 nC / bunch, σ_s = 5-10 mm

Maximum energy 104.5 GeV per beam

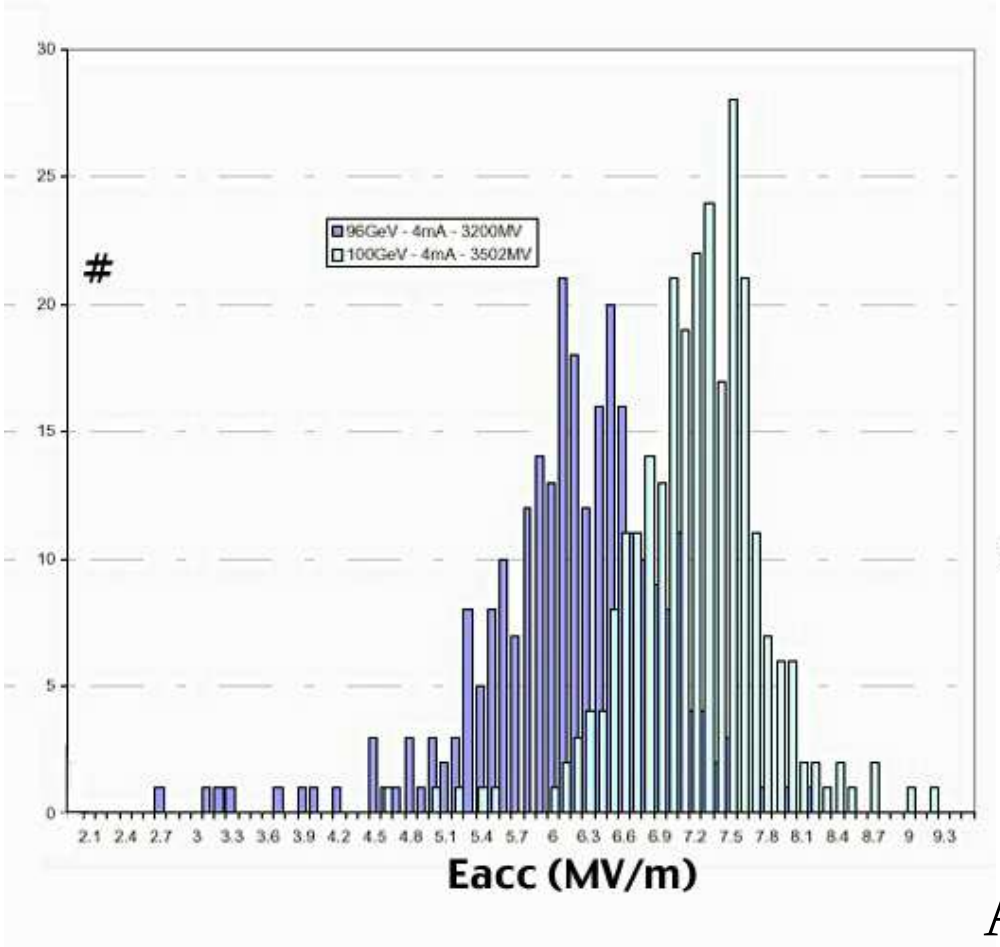
Synchrotron radiation: 3355 MeV/turn at 103.5 MeV

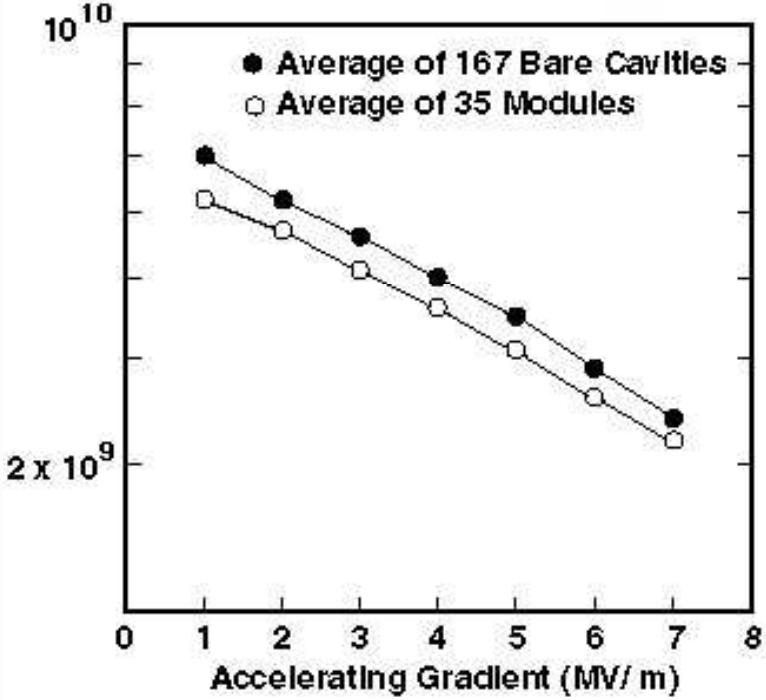
Available RF voltage 3660 MV

Power delivered to beam: 18.4 MW



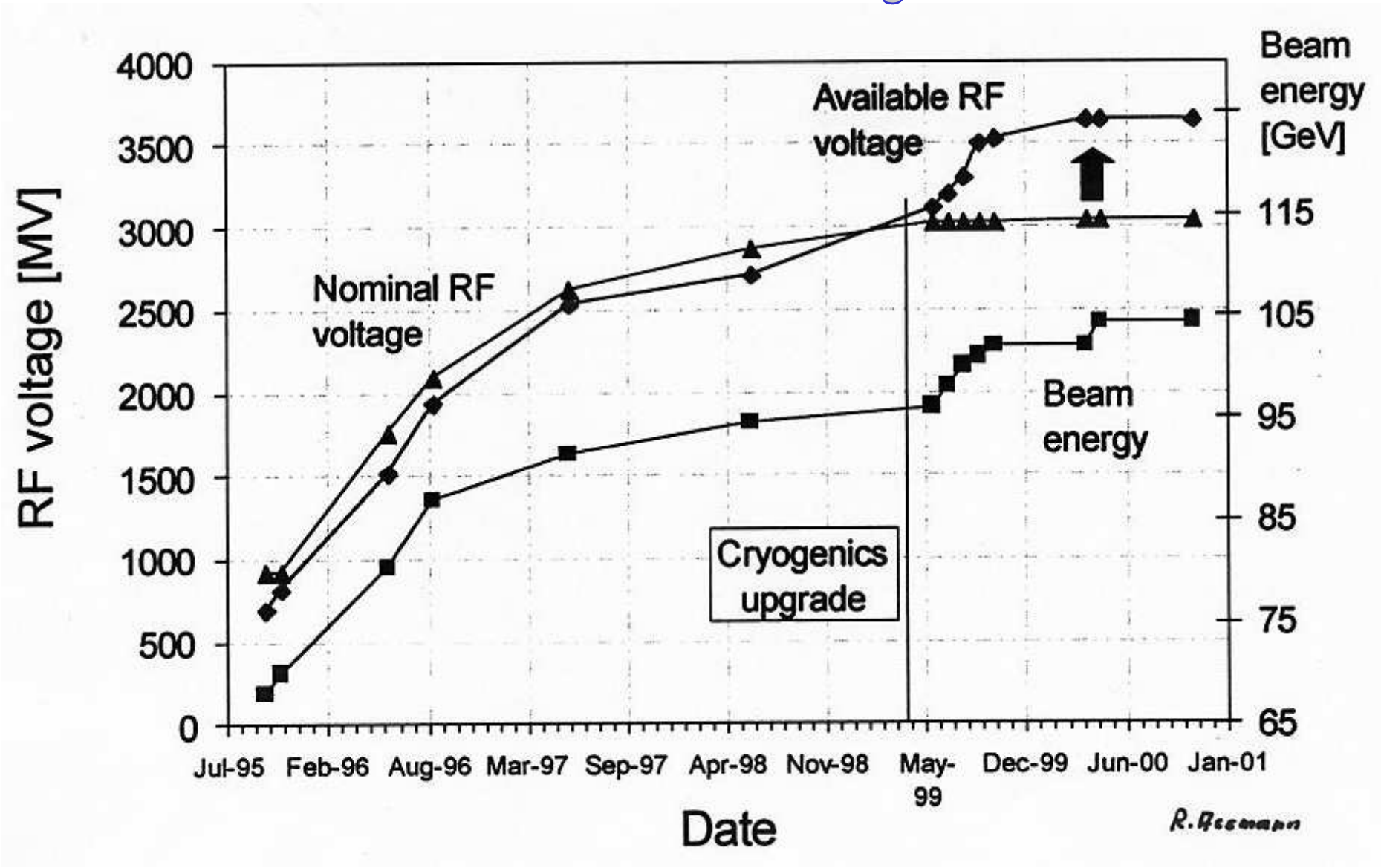
Performance of LEP Cavities





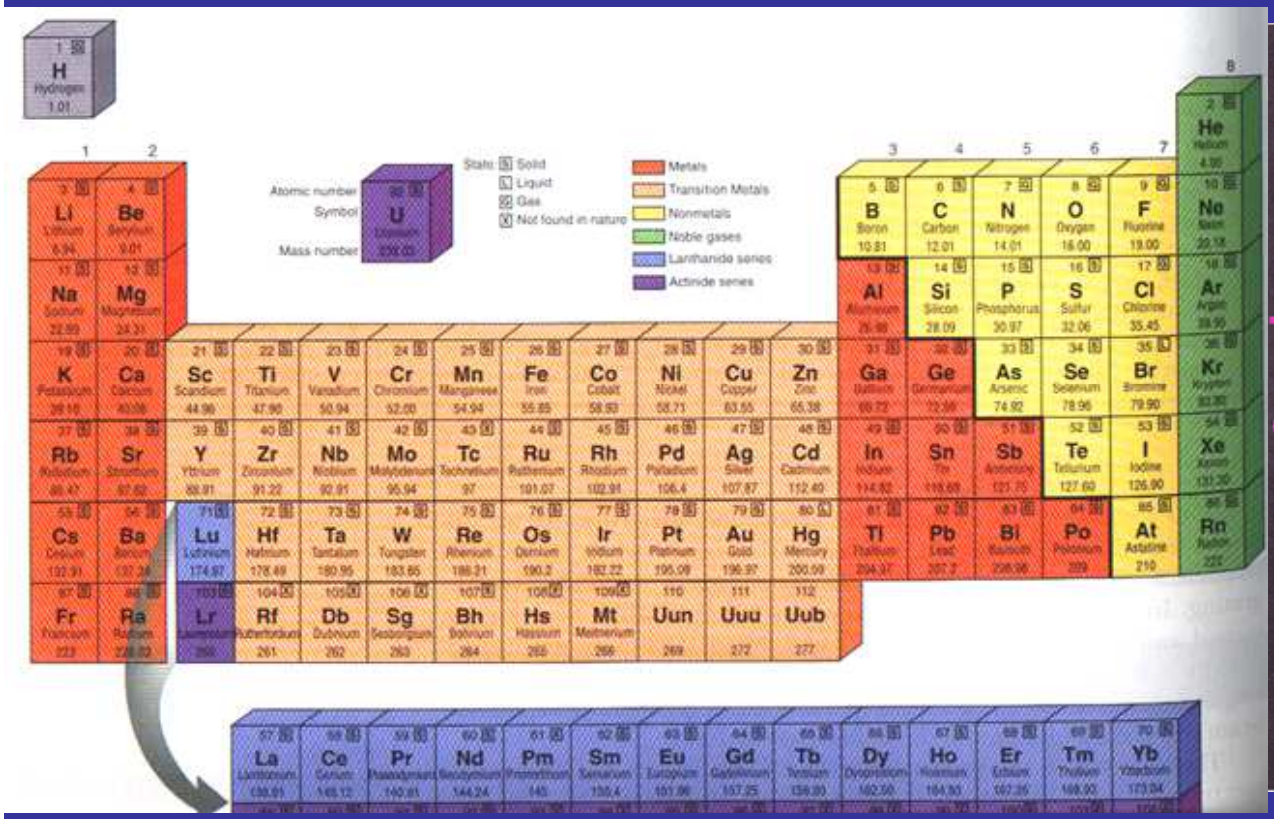
Alternate Materials
Afternoon Session

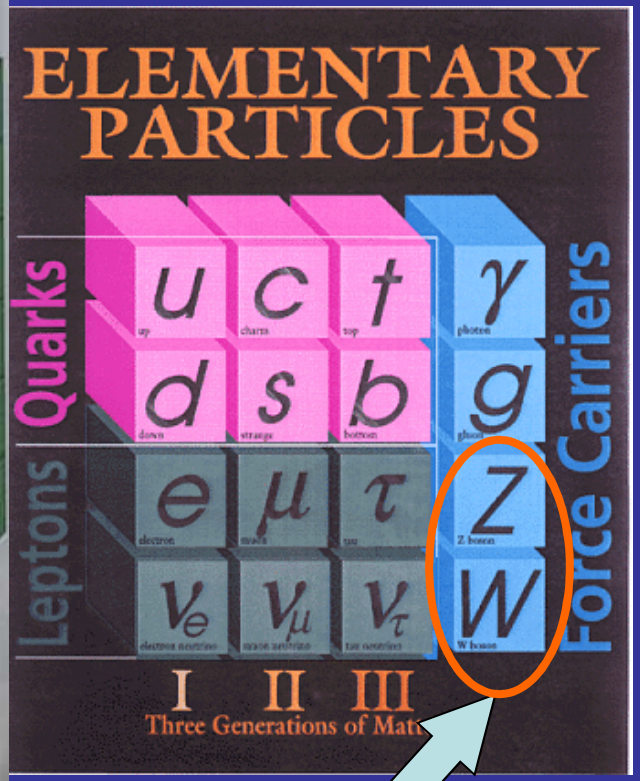
LEP Installed Voltage



LEP Cavities in Storage

Old and New
Periodic Tables of “Elements”





Major LEP-II studies & discoveries

Predicted from Unification of Weak and em forces

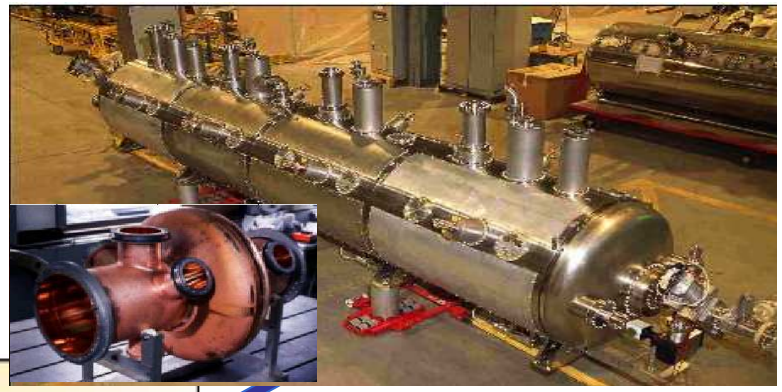
SRF Installed in Electron - Positron Storage Rings

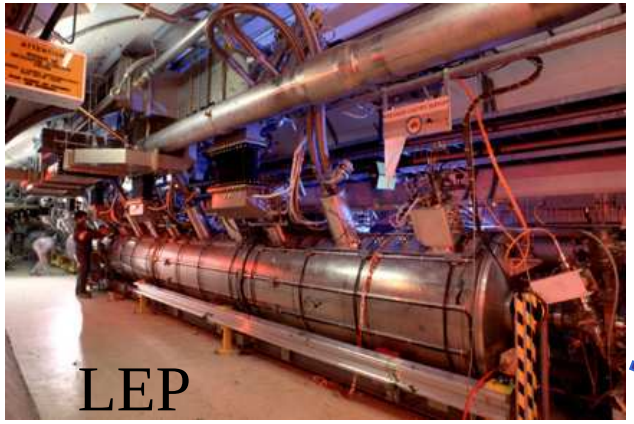
- TRISTAN - Japan
- HERA - Germany
- LEP-II - CERN (Europe)
- CESR-III - USA
- KEK-B Japan
- 5 - 8 MV/m

- Anticipated
- LHC- CERN

Accelerator Installations

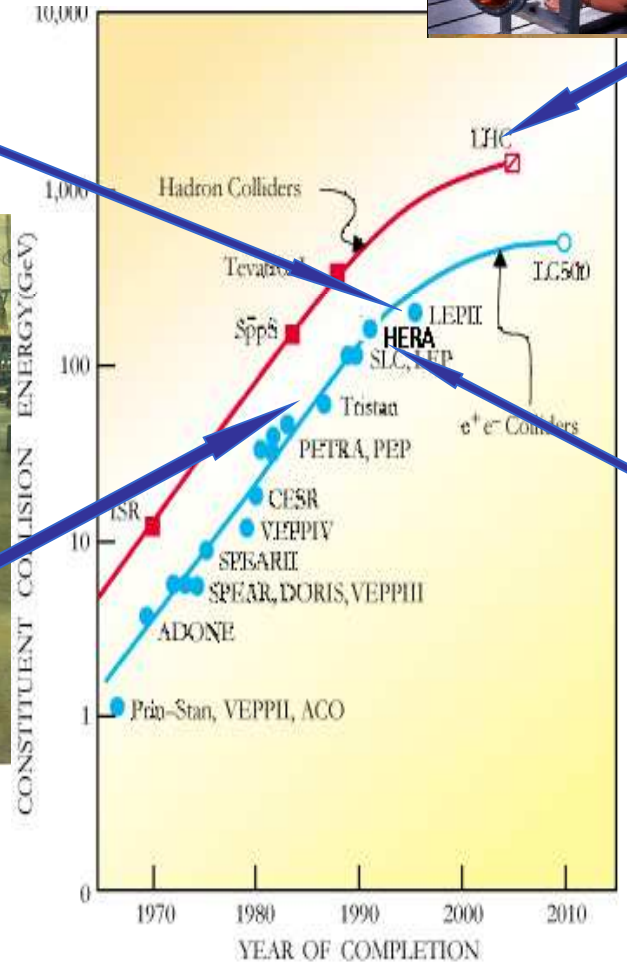
LHC

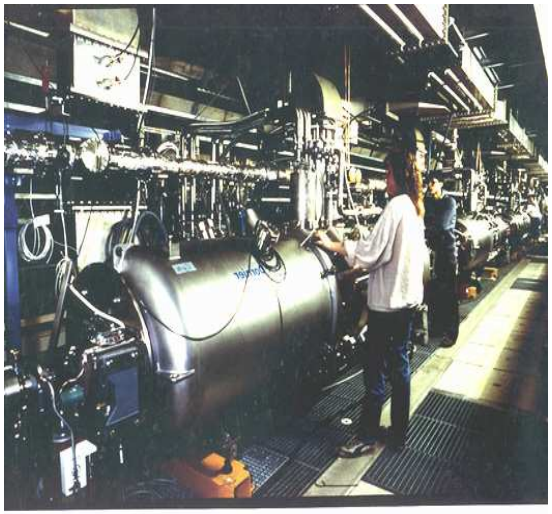




LEP

TRISTAN





HERA

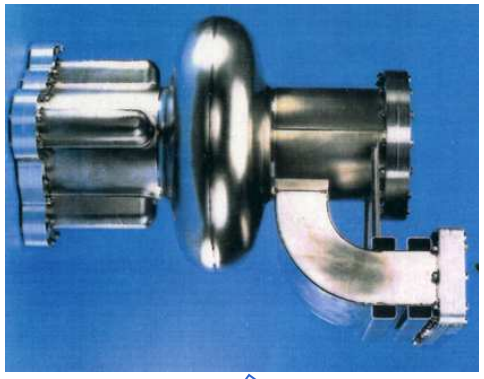
CORNELL UNIVERSITY

CESR at Cornell

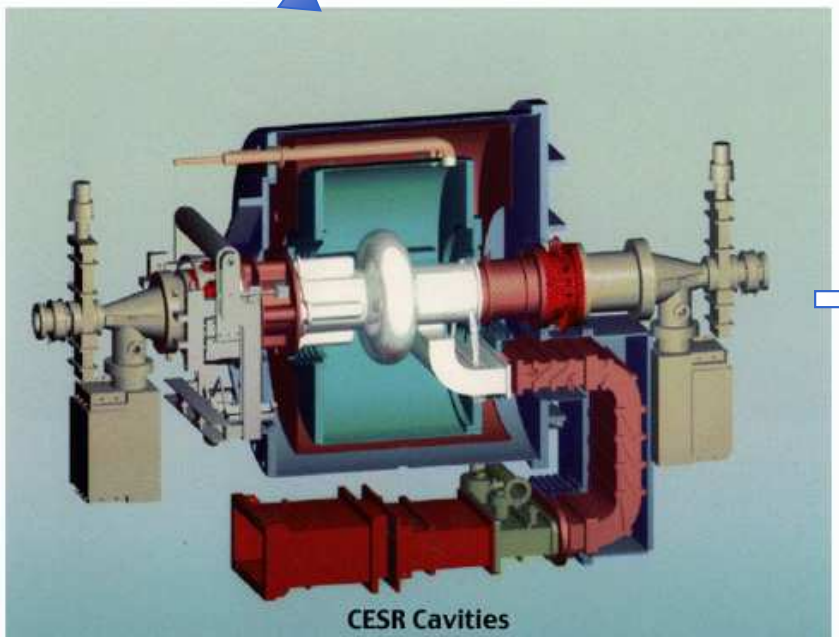
800 m
circumference

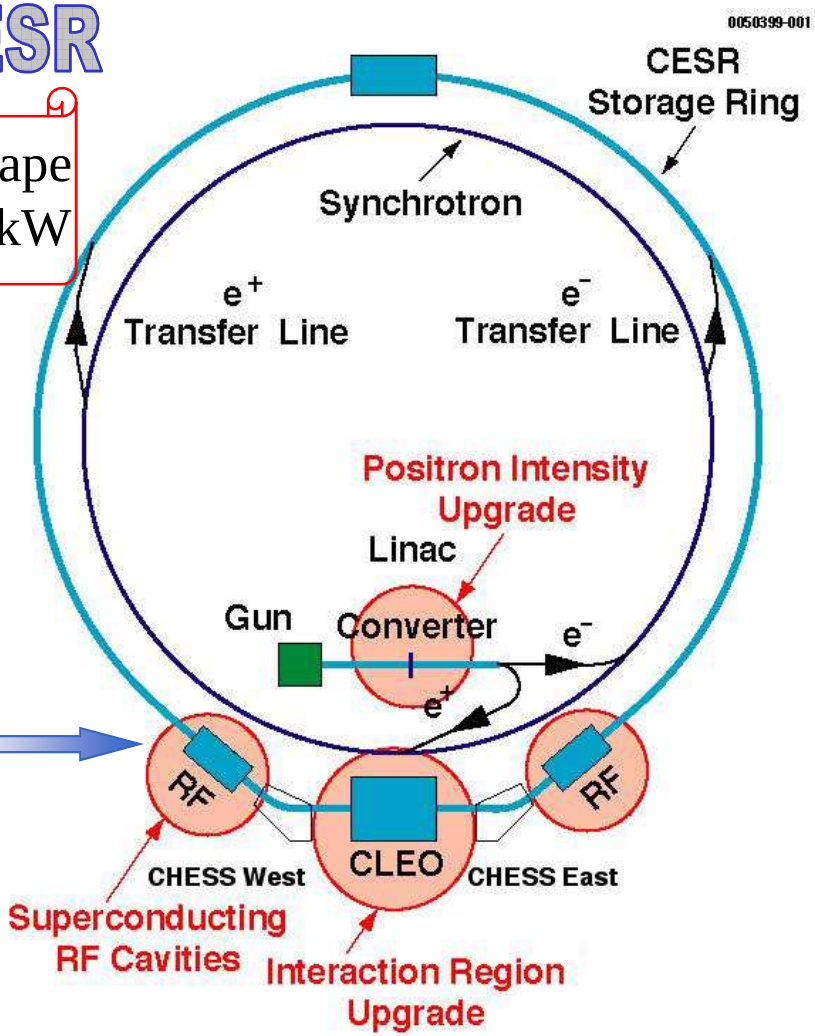
High Luminosity Rings

CESR



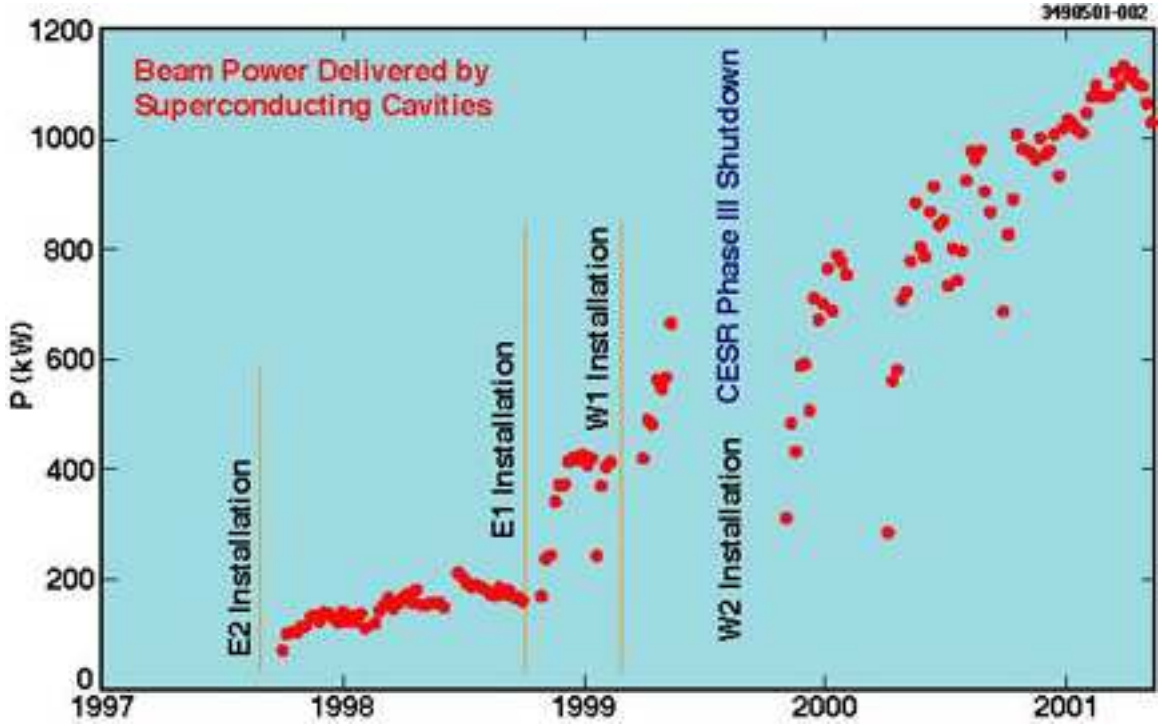
- Low Impedance Shape
- Beam Power > 290kW

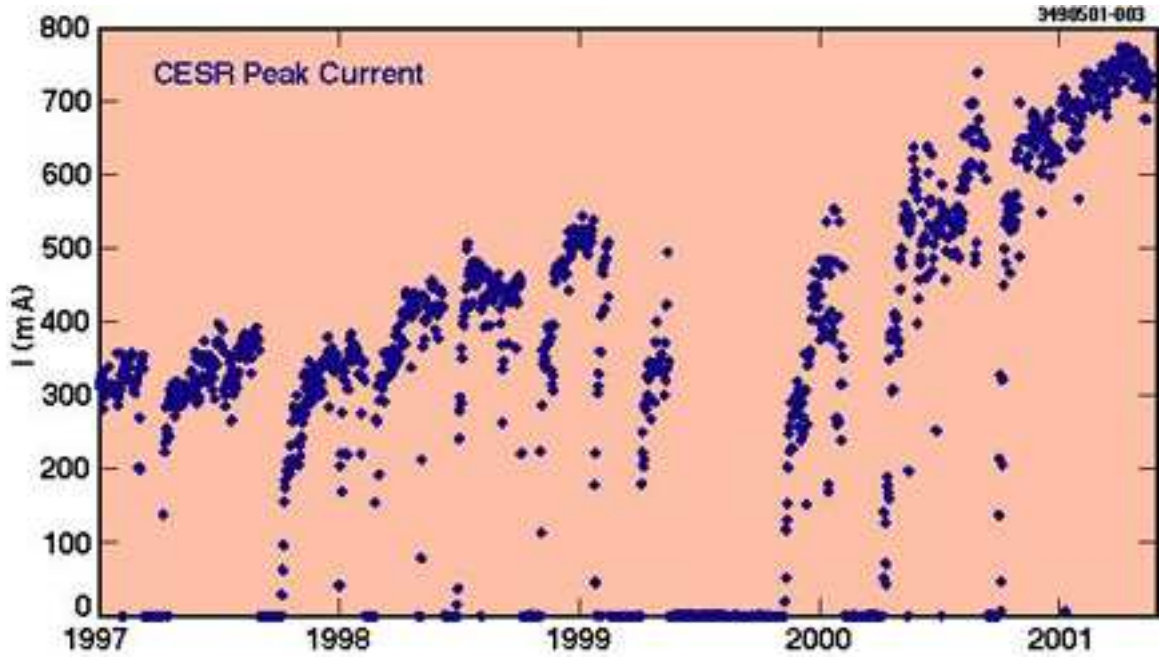




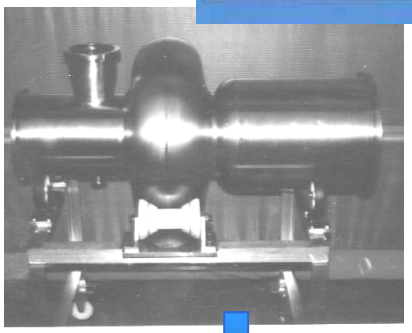
CORNELL UNIVERSITY

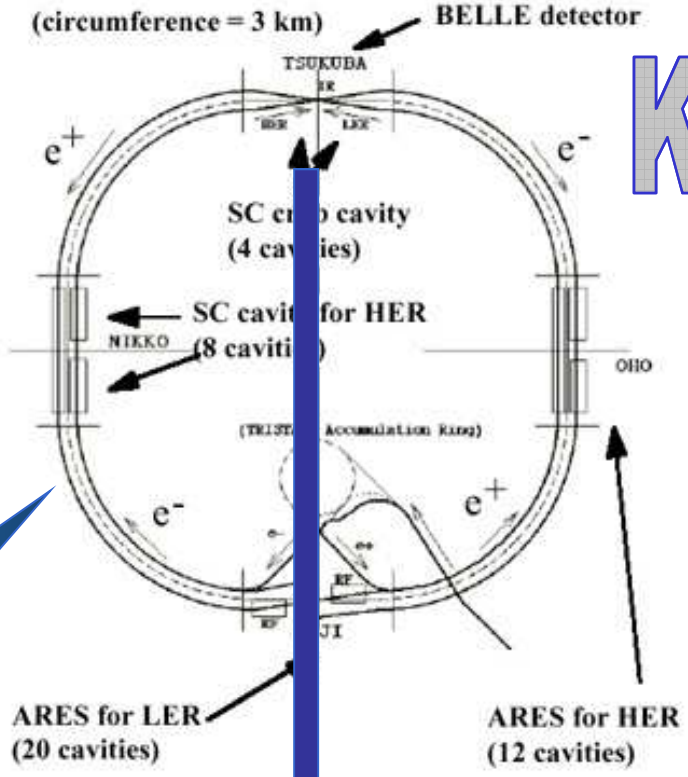
CESR

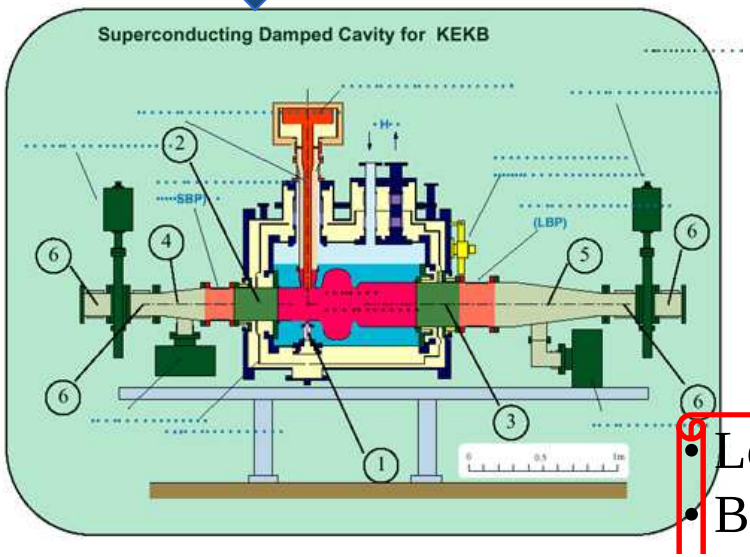

3490501-002
Beam Power Delivered by
Superconducting Cavities
P (kW)
1200
1000
800
600
400
200
0
1997
1998
1999
2000
2001
E2 Installation
E1 Installation
W1 Installation
W2 Installation
CESR Phase III Shutdown

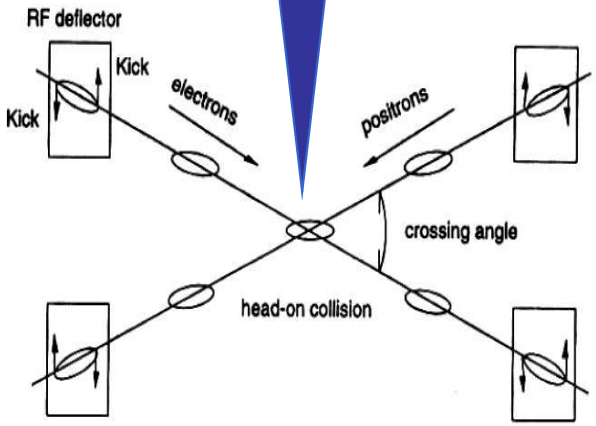

3490501-003
CESR Peak Current
I (mA)
800
700
600
500
400
300
200
100
0
1997
1998
1999
2000
2001

KEK-B







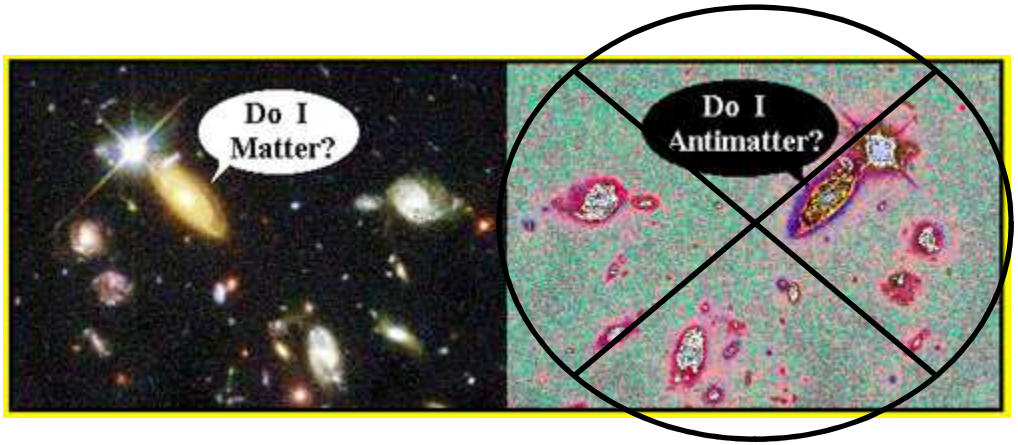


- Low Impedance Shape
- Beam Power 380 kW

Beauty's Soliloquy

by CERN's Nina Paley, *with apologies to William Shakespeare*

- To B or anti-B: that is the question
- Whether 'tis nobler in theory to suffer
- The violations of charge conjugation,
- Or to reflect against a sea of parity,
- And by opposing it, violate it? To C,to P,
- No more, and by CP to say we end
- The heartache and the thousand natural shocks?



Weak Interaction

Universe has left-right asymmetries manifest in the weak interaction

C is violated

P is violated

CP violation recognized as important ingredient in the evolution of the universe.

Why is the Universe Not Empty ?

The Universe was extremely hot just after it was born in the Big Bang:

There was lots of energy for making particles and antiparticles in pairs.

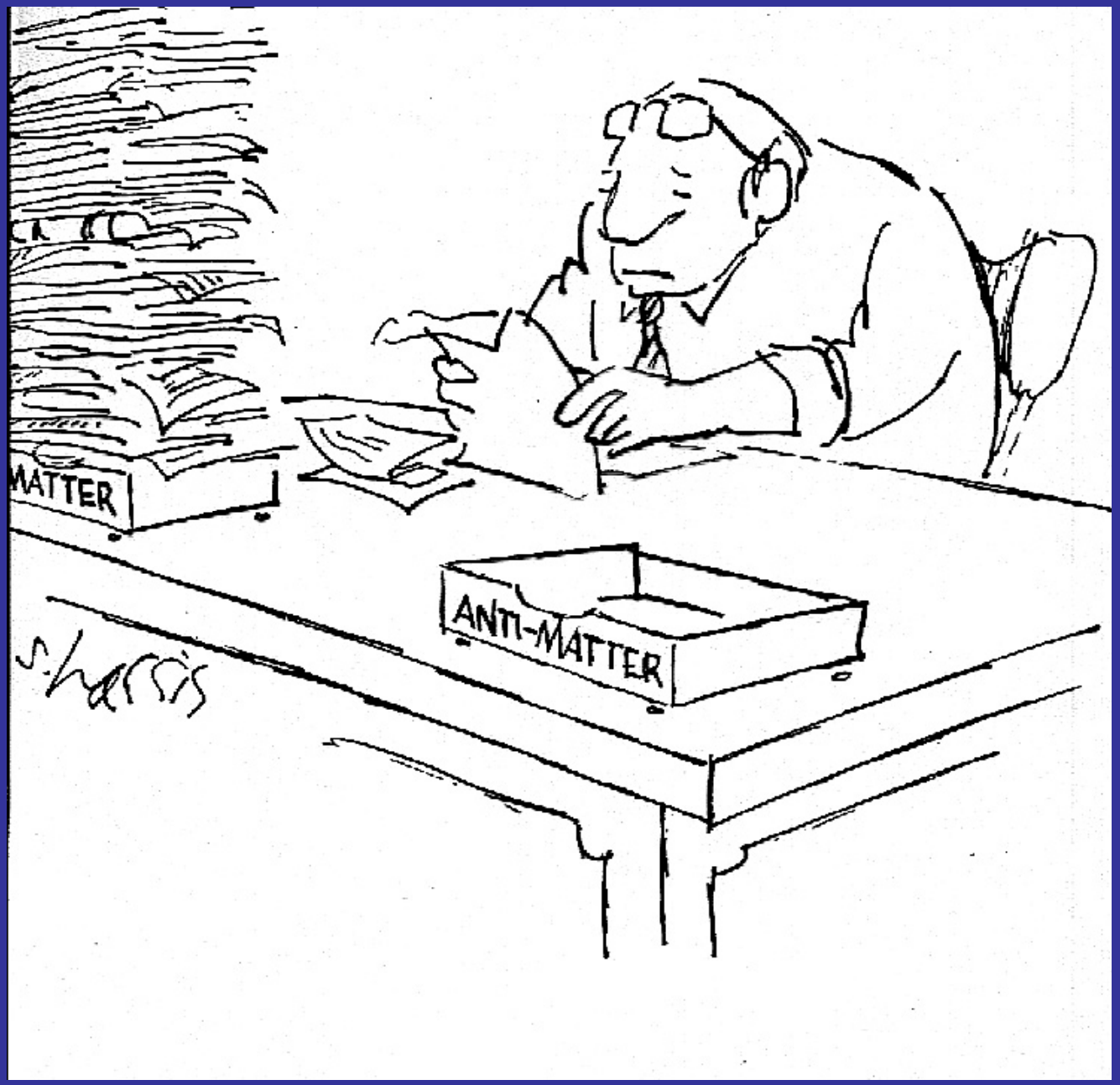
As the Universe cooled, these particles and antiparticles annihilated.

Had the amounts of matter and antimatter been equal, everything would have annihilated and the Universe would be empty.

Why is our Universe full of things like us and stars, and not empty?

⇒When the Universe was hot there must have been more matter than antimatter

After it cooled stars and humans were over.



Why the asymmetry ?

It is related to CP violation

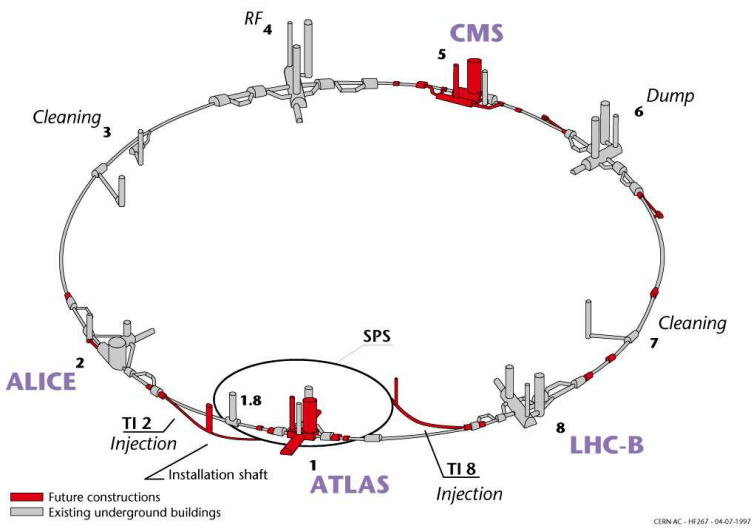
Understanding the origin of CP violation is one of the most basic and far-reaching problems in particle physics.

Mission of KEK-B And PEP-II

SRF is now ready for LHC

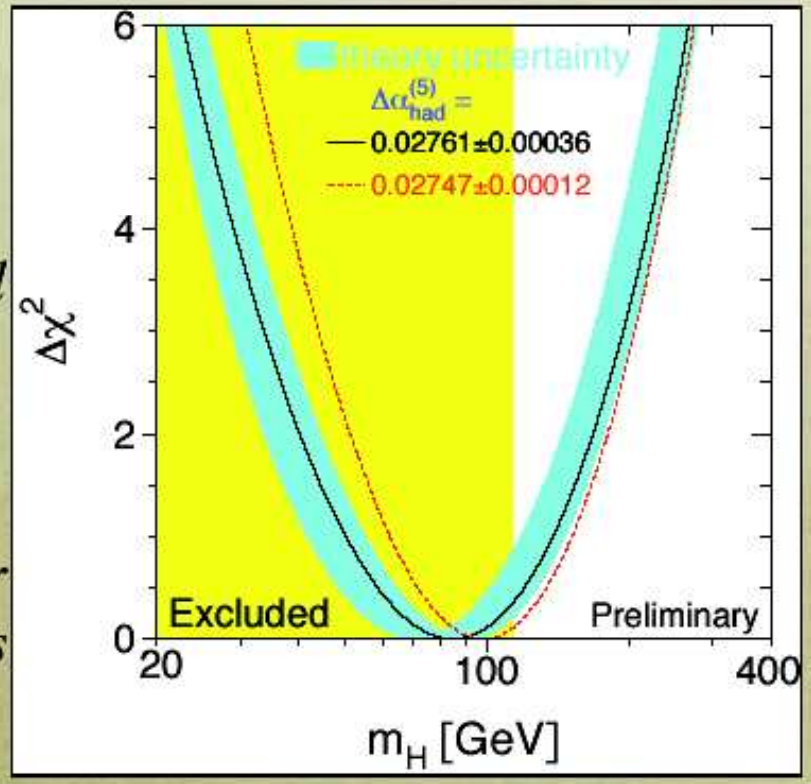
- 16 Nb-Cu Cavities
- 4 Cryomodules
- 16 MV per beam
- 10 MV/m

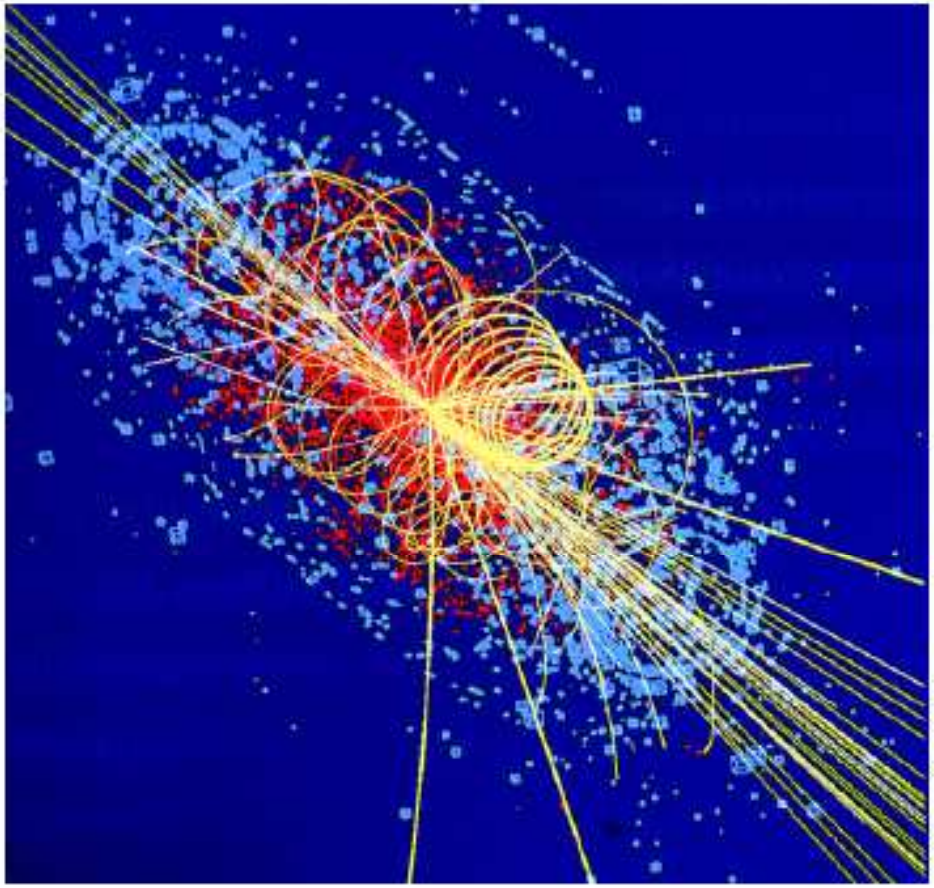
Layout of the LEP tunnel including future LHC infrastructures.



Higgs Boson is Most Likely "Just Around the Corner"

- *Higgs boson*
  = gap excitation
- *Current data combined with the Standard Model theory predict*
  m_H<196GeV (95%CL)
- *Tevatron at Fermilab has a chance to discover or exclude the SM Higgs boson by 2008*





Simulated decay of Higgs boson in the future CMS experiment at CERN. (Credit: CERN)

X-ACTLY SO !

The Roentgen Rays, the Roentgen Rays

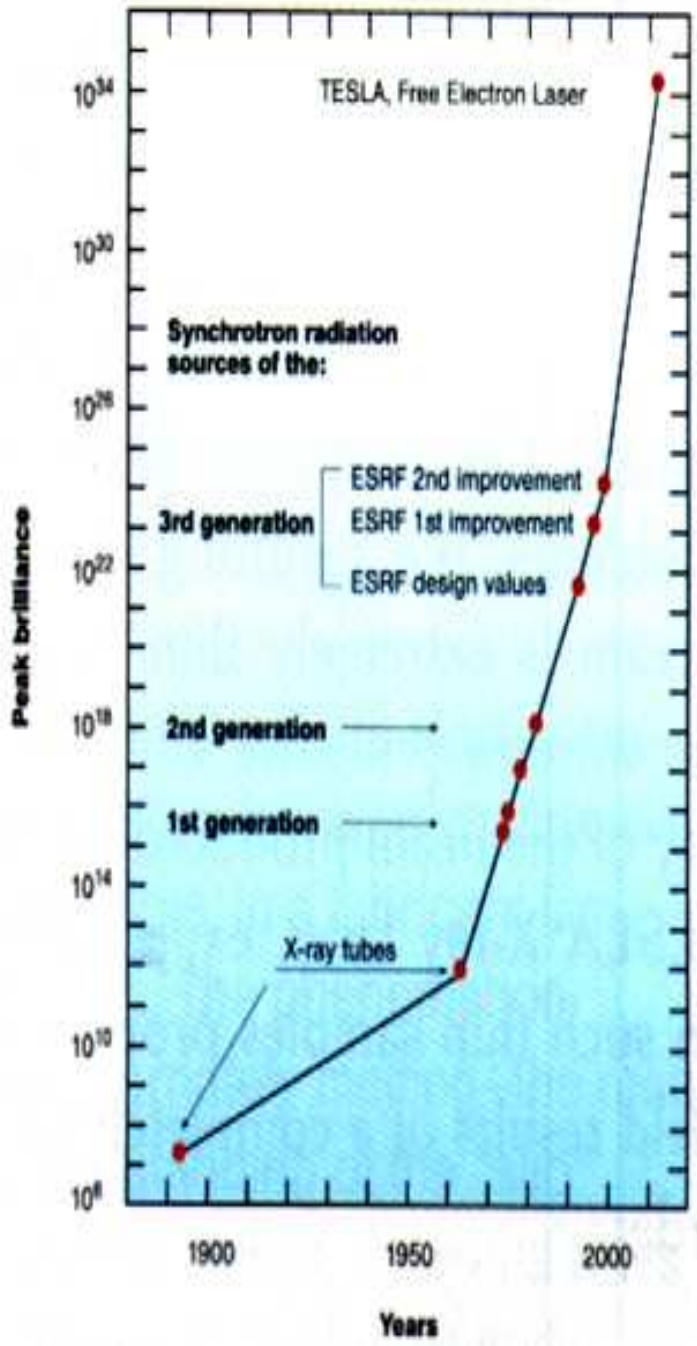
What is this craze?

The town's ablaze

With the new phase

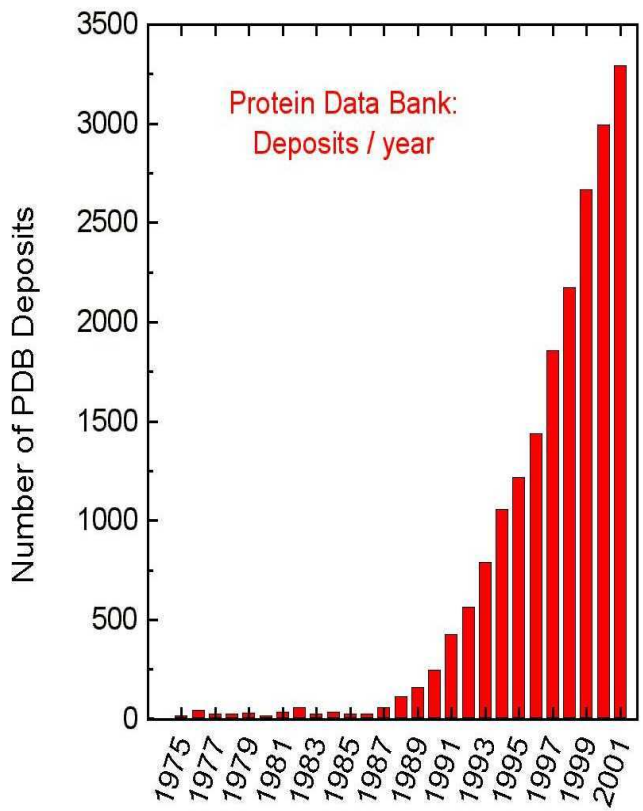
Of X-ray's ways

A Christmas present to civilization at the turn of the 20th century

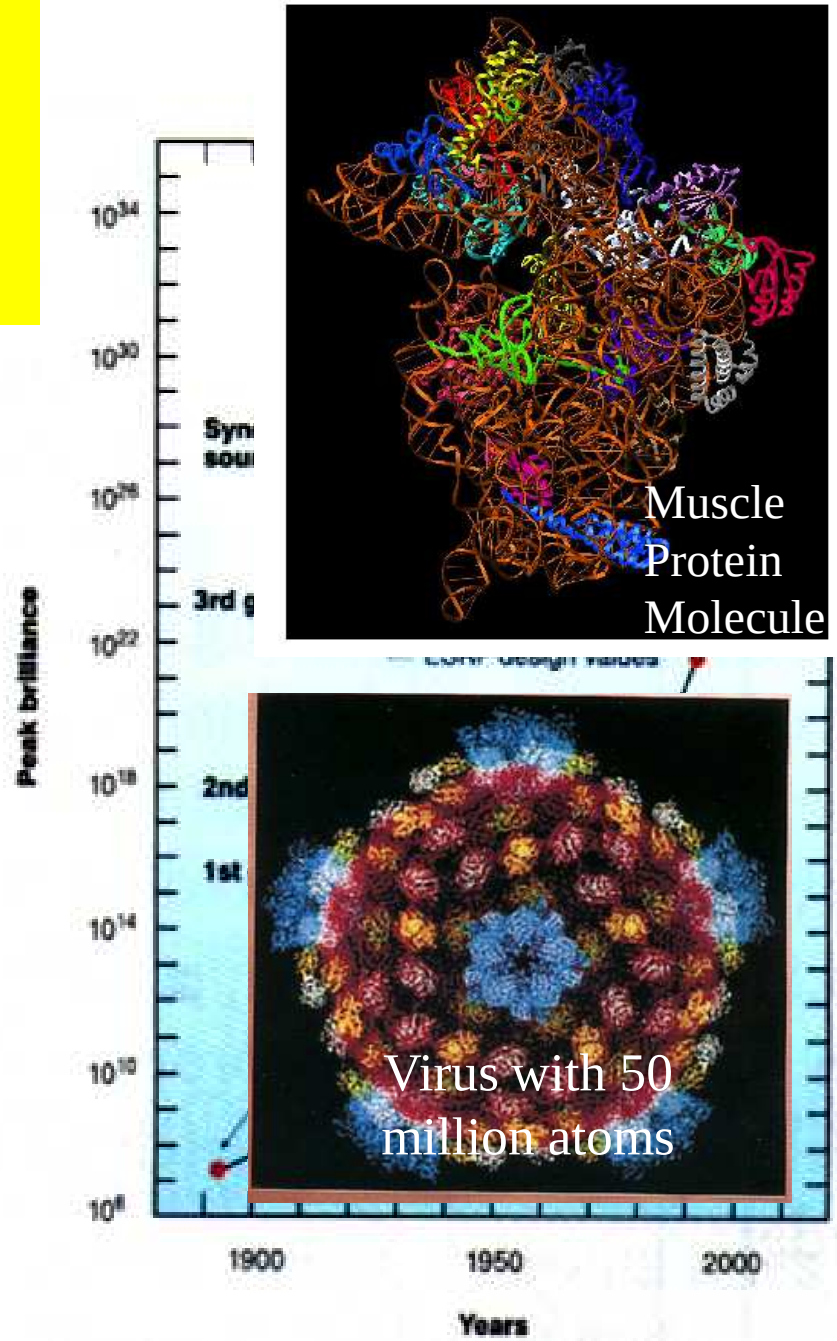

TESLA, Free Electron Laser
Synchrotron radiation sources of the:
3rd generation
ESRF 2nd improvement
ESRF 1st improvement
ESRF design values
2nd generation
1st generation
X-ray tubes
Peak brilliance
Years
1900
1950
2000

Synchrotron radiation (SR) is proving immensely important for the physical, biological, and engineering sciences.

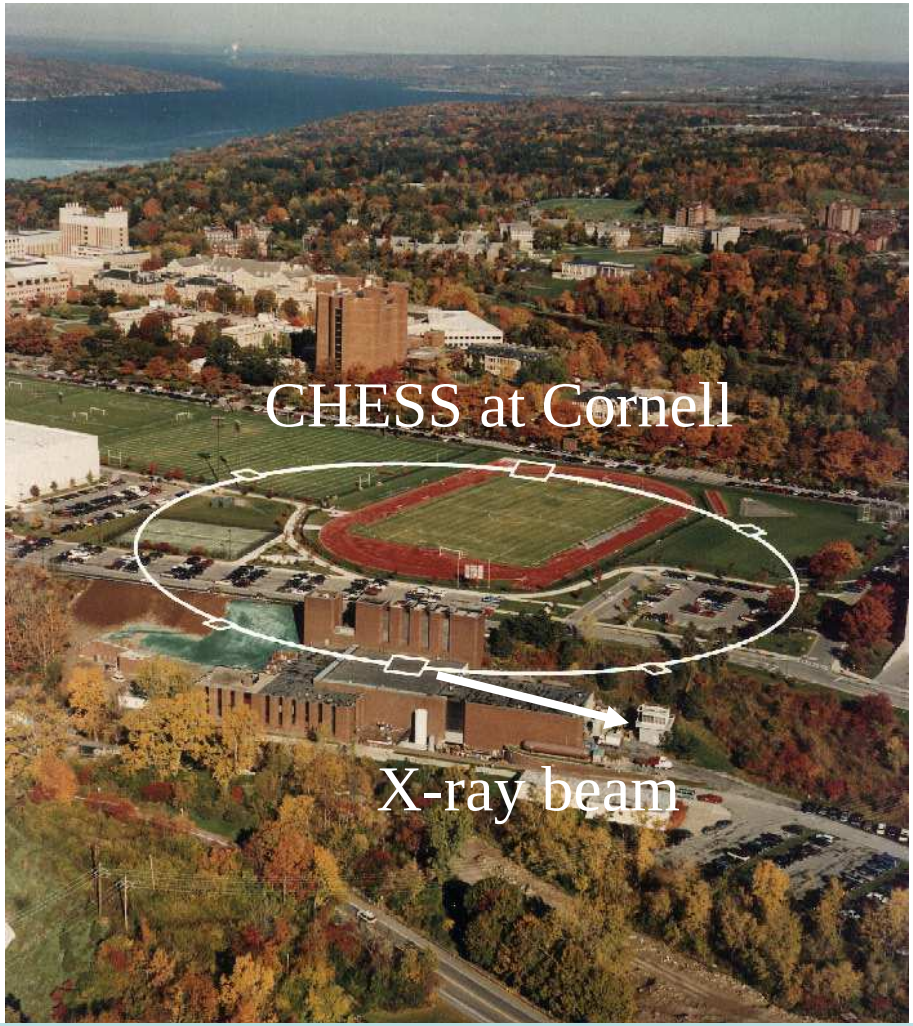
The demand continues to grow, with new uses opening all the time.

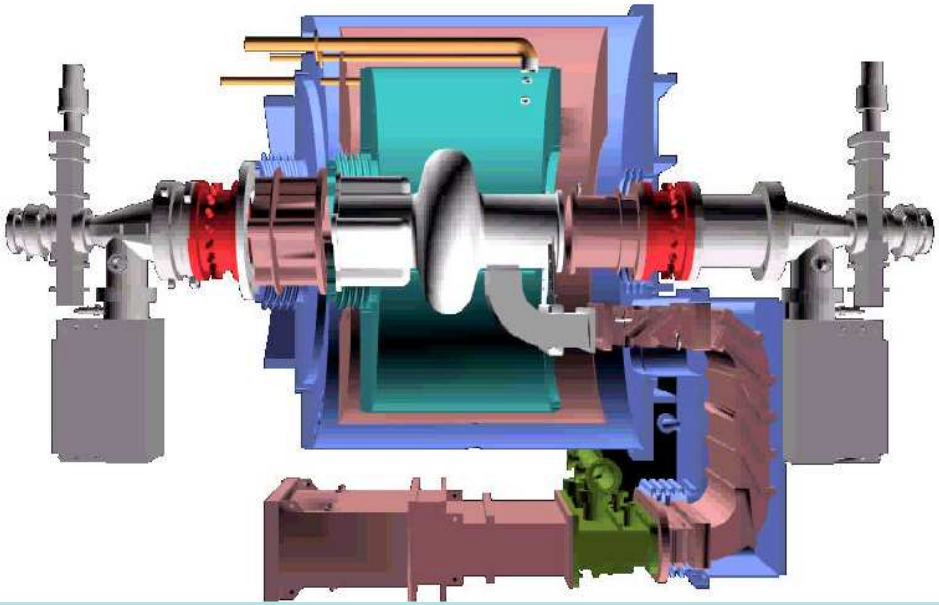


PDB depositions vs. year. Most due to SR.



Superconducting Cavities for the Cornell High Energy Synchrotron Radiation Source (CHESS)

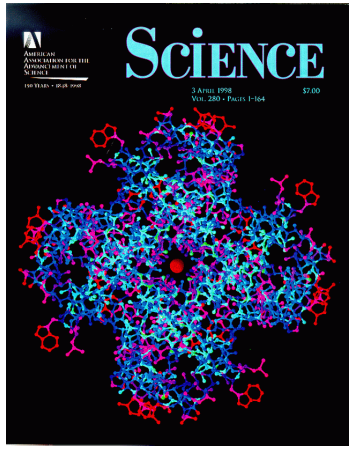




Similar superconducting technology to be used for new storage rings around the world: Canadian Light Source, DIAMOND light source (UK)…

Rod MacKinnon wins 2003 Chemistry Nobel

Dr. Rod MacKinnon of Rockefeller University is co-recipient of the 2003 Nobel Chemistry prize for determining the structure and function of membrane ion channels. Membrane channels allow selective passage of ions, such as Cl^-, or Na^+, across biological membrane. These ion currents are responsible for many cellular functions, such as nerve transduction.



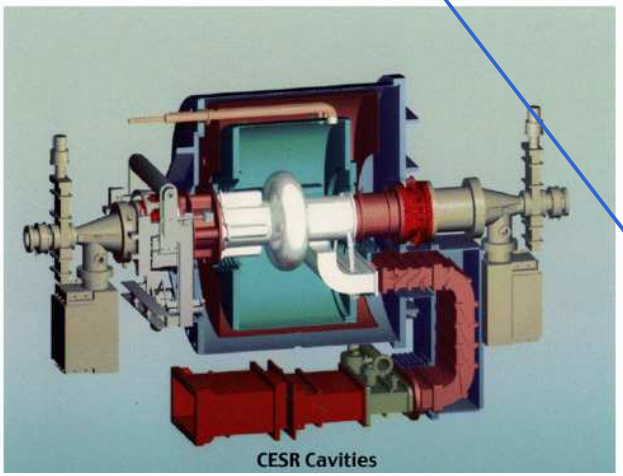
The break-through structure of a K^+ channel, using x-ray data acquired entirely at CHESS, electrified the world when it was published in *Science* in 1998. Subsequent work by Dr. MacKinnon revealed the structure of other channels, the mechanisms of rectification, selectivity, and gating. Most of the x-ray data for this body of work has been acquired at CHESS.

Storage Ring Light Sources

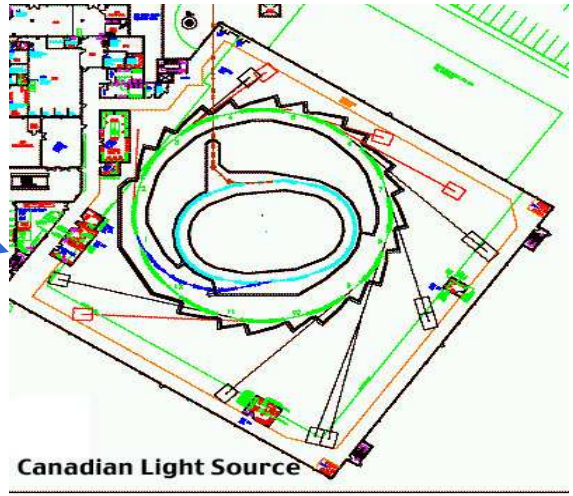
DIAMOND

Diamond Site

Taiwan Light Source



CESR Cavities

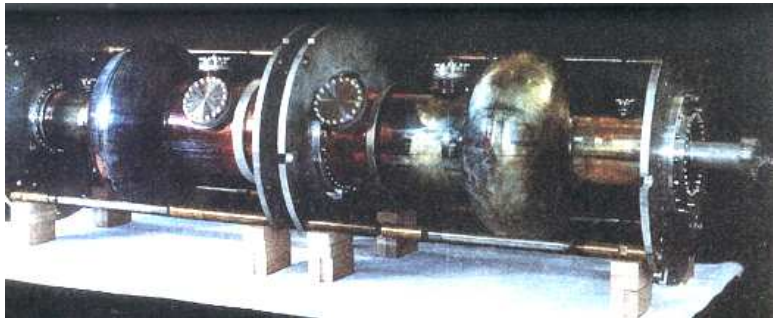


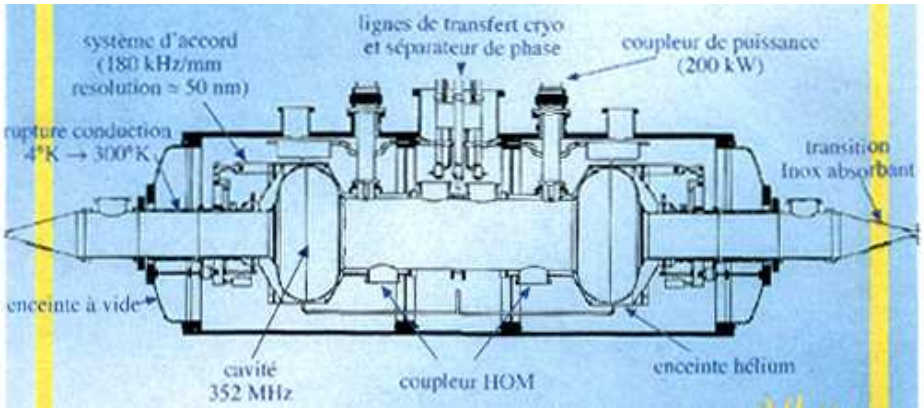
Canadian Light Source

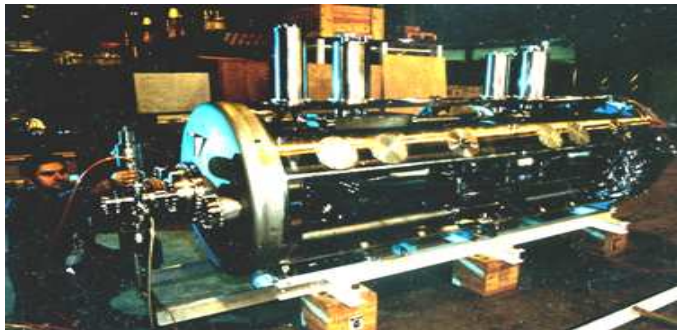
CANADIAN Light Source

CORNELL UNIVERSITY

SOLEIL







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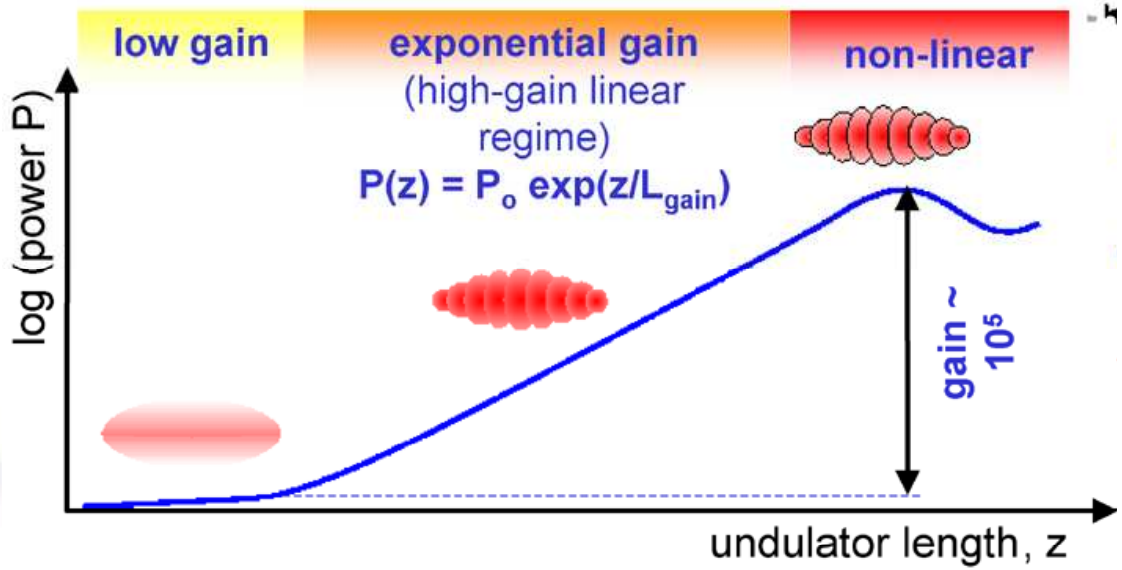
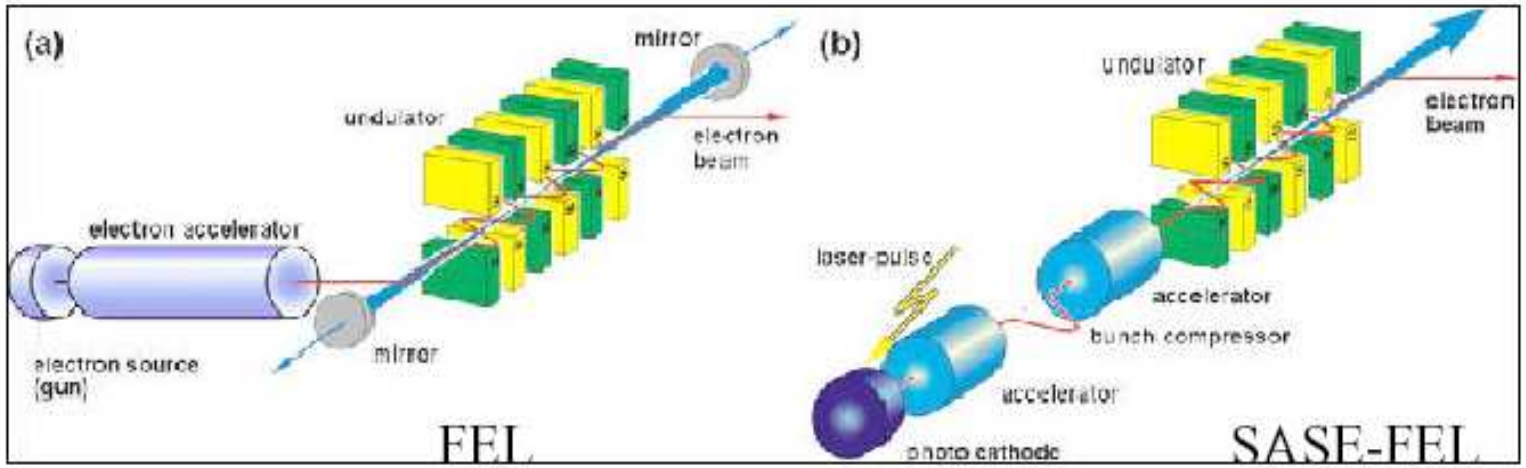
SRF in Electron Storage Rings

- Installed
- CESR/CHESS - USA
- Canadian Light Source
- ESRF (France)
- Swiss Light Source
  - For life time increase
- ELETTRA (Italy)
  - For life time increase
- Taiwan Light Source
- 6 - 8 MV/m

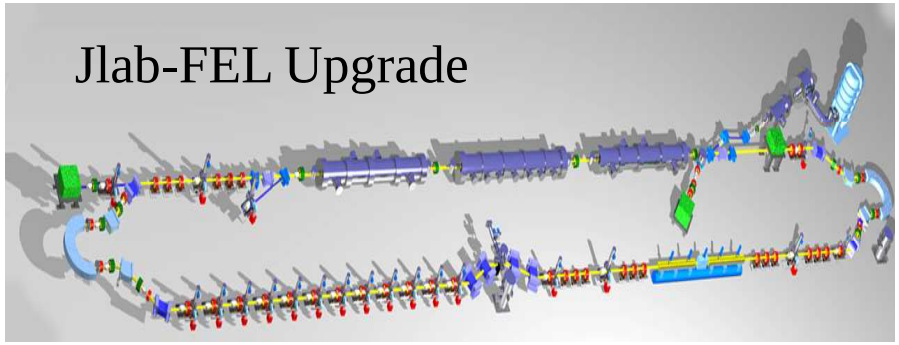
- Anticipated
- DIAMOND Light Source (UK)
- SOLEIL (France)
- SPAIN
- Beijing Tau-Charm Factory
- Shangai Light Source

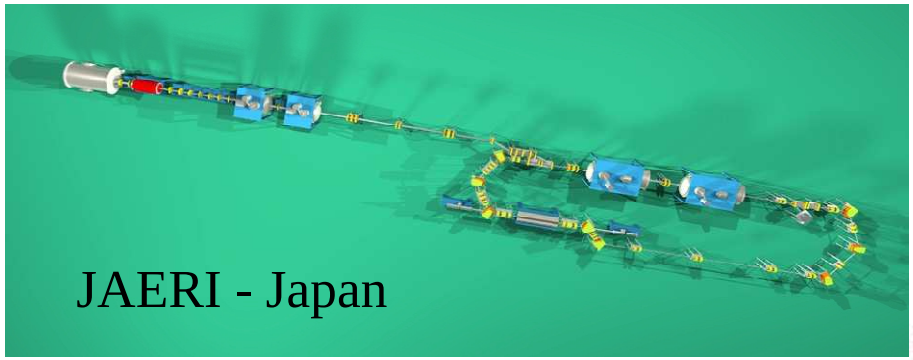
Lasers : Infra red, UV, X-ray

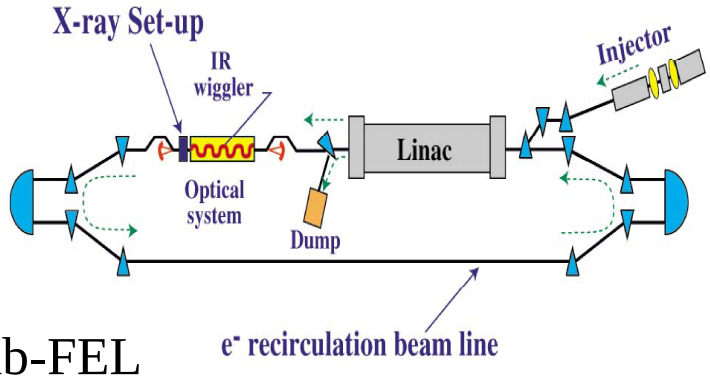




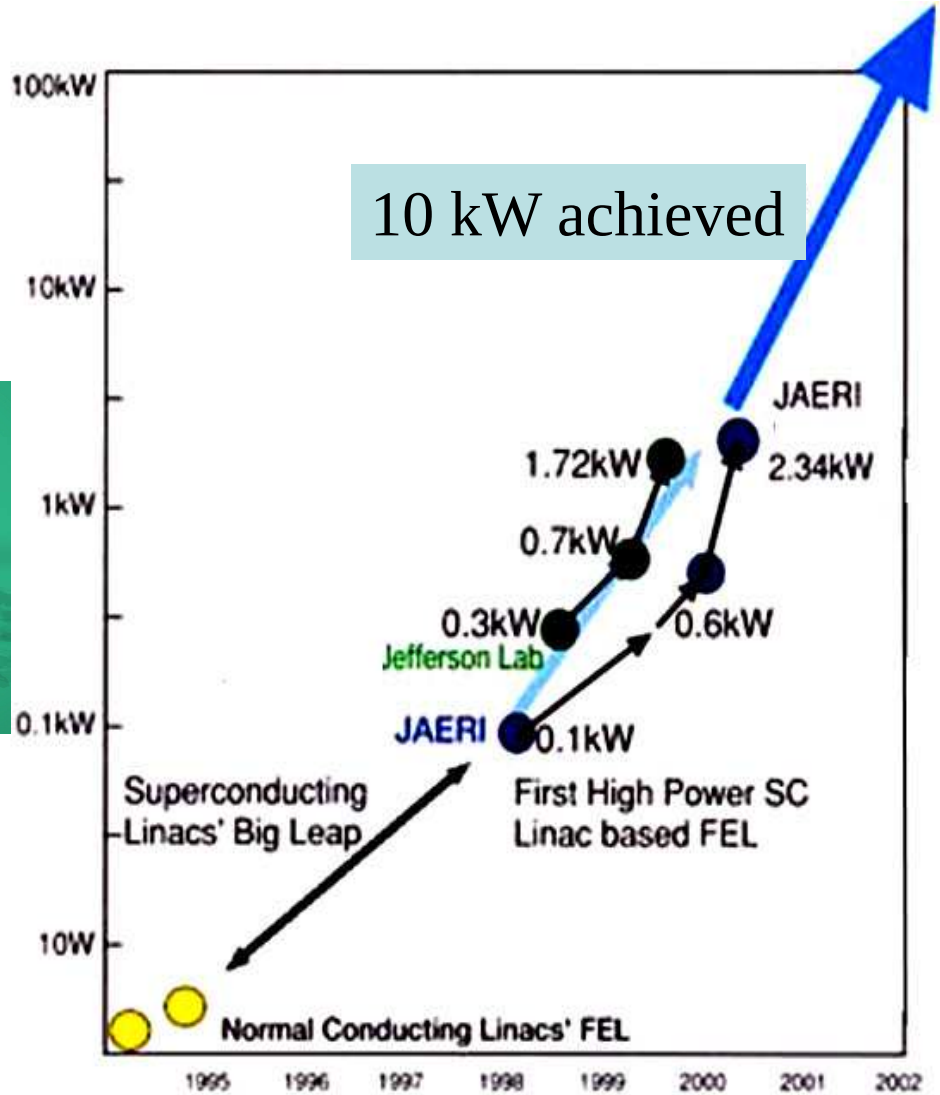
CW-FELs IR -> UV





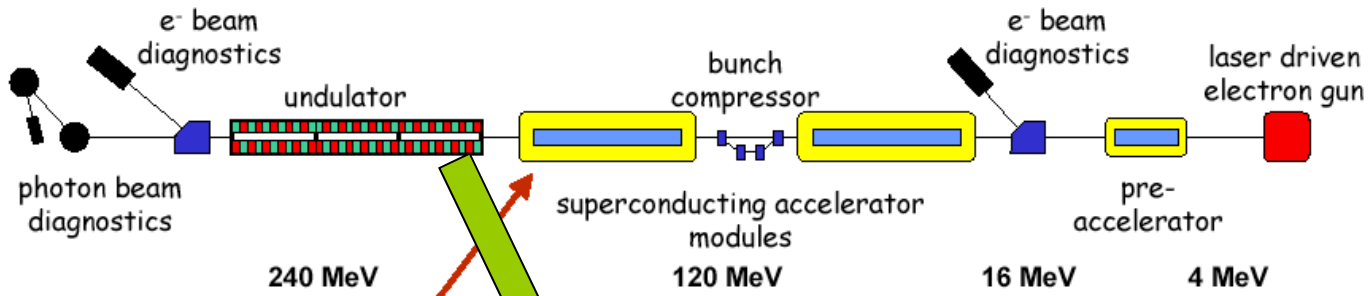


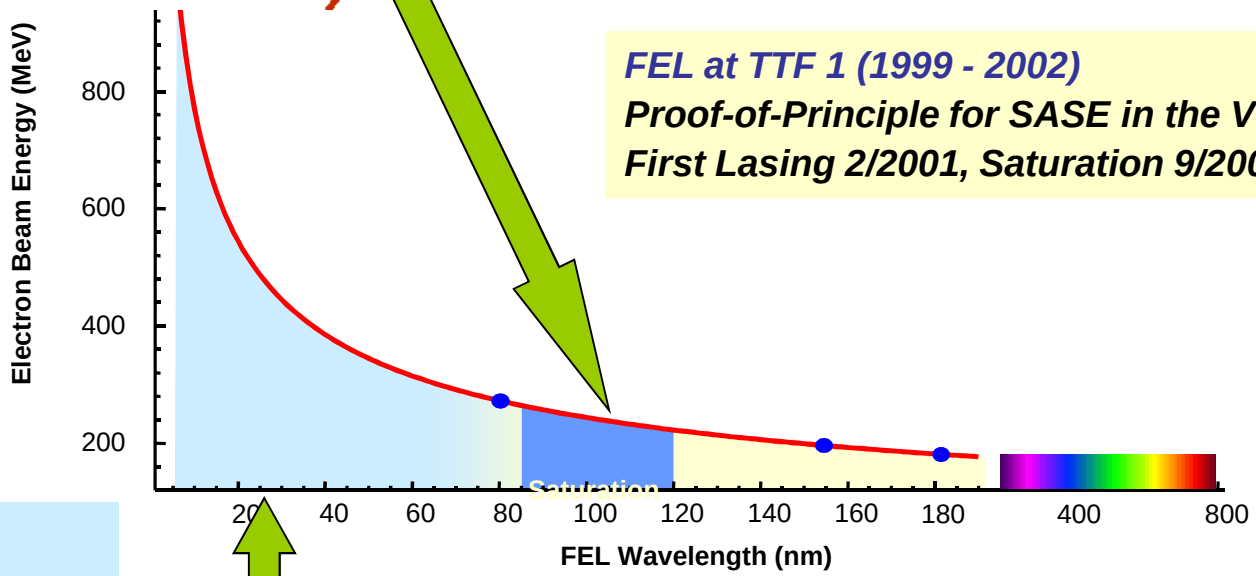
Jlab-FEL



1ST UPGRADE CAVITY STRING 9-4-02

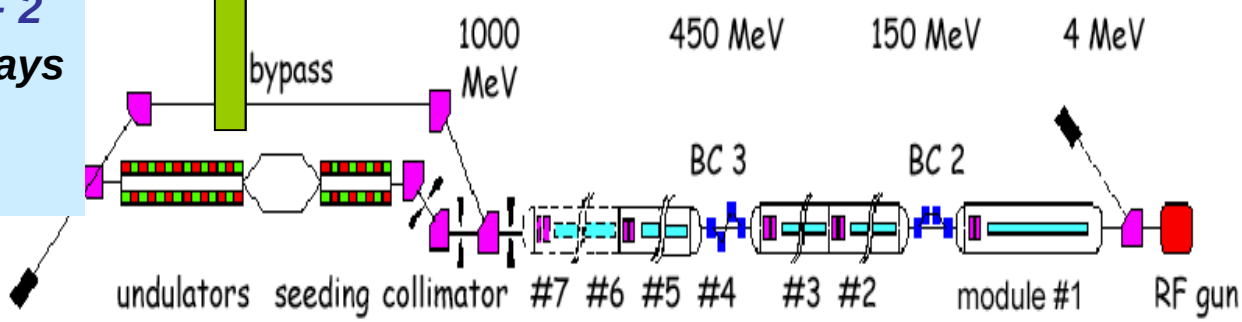
SASE-FELs VUV -> X-Rays





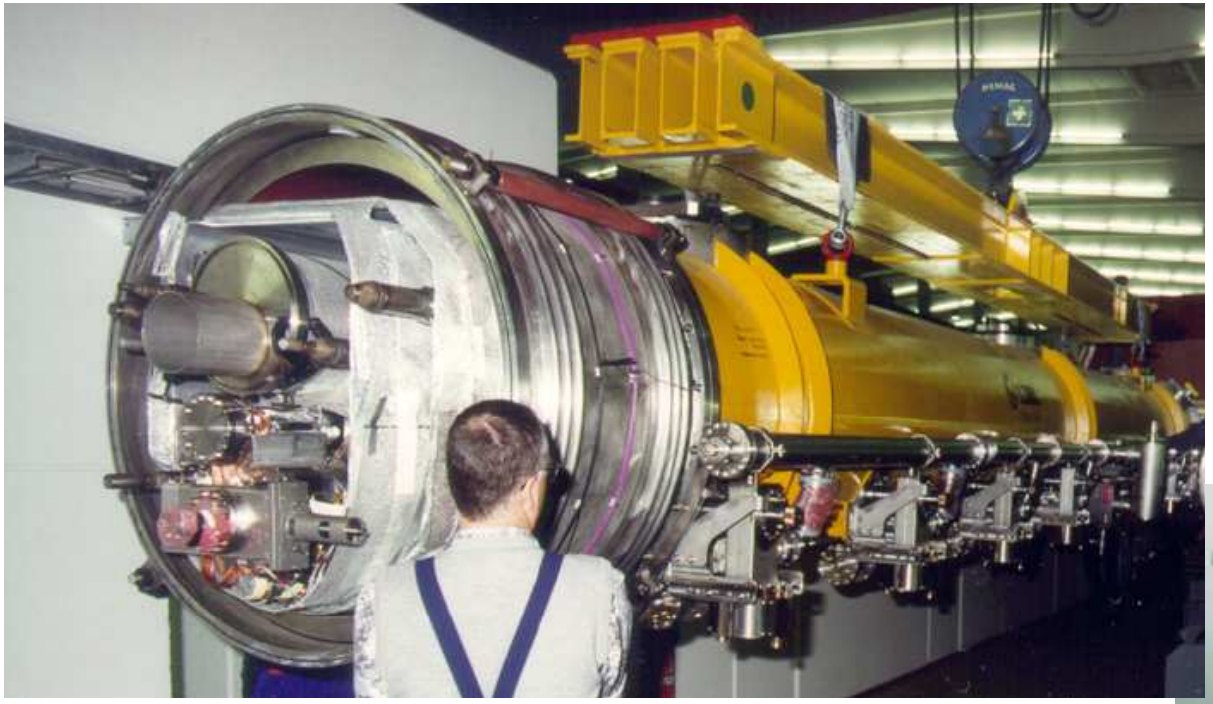
FEL at TTF 1 (1999 - 2002)
Proof-of-Principle for SASE in the VUV
First Lasing 2/2001, Saturation 9/2002

2004:
VUV FEL at TTF 2
VUV to Soft X-rays
: 100 - 6 nm
User facility

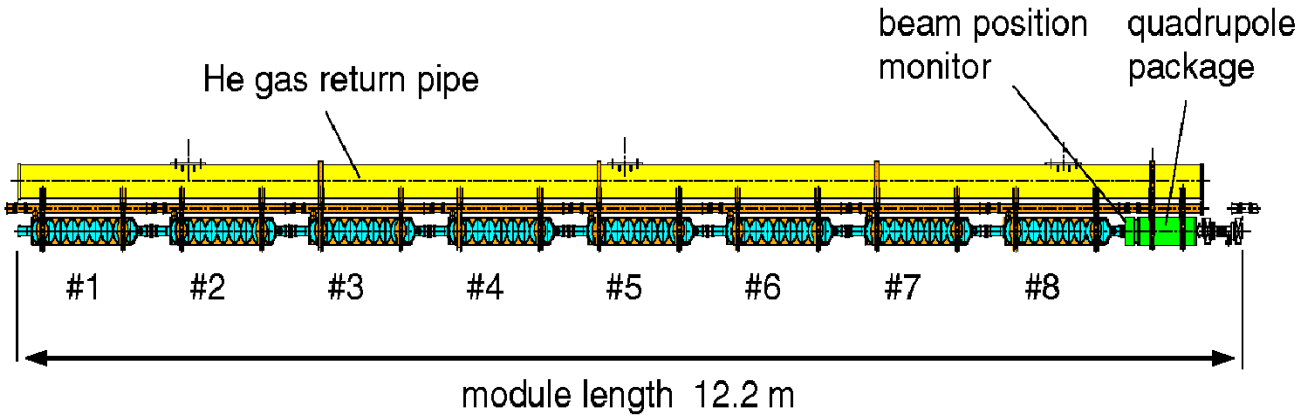


TTF-II

6 Modules Needed for 1 GeV Beam



8-Cavity Module

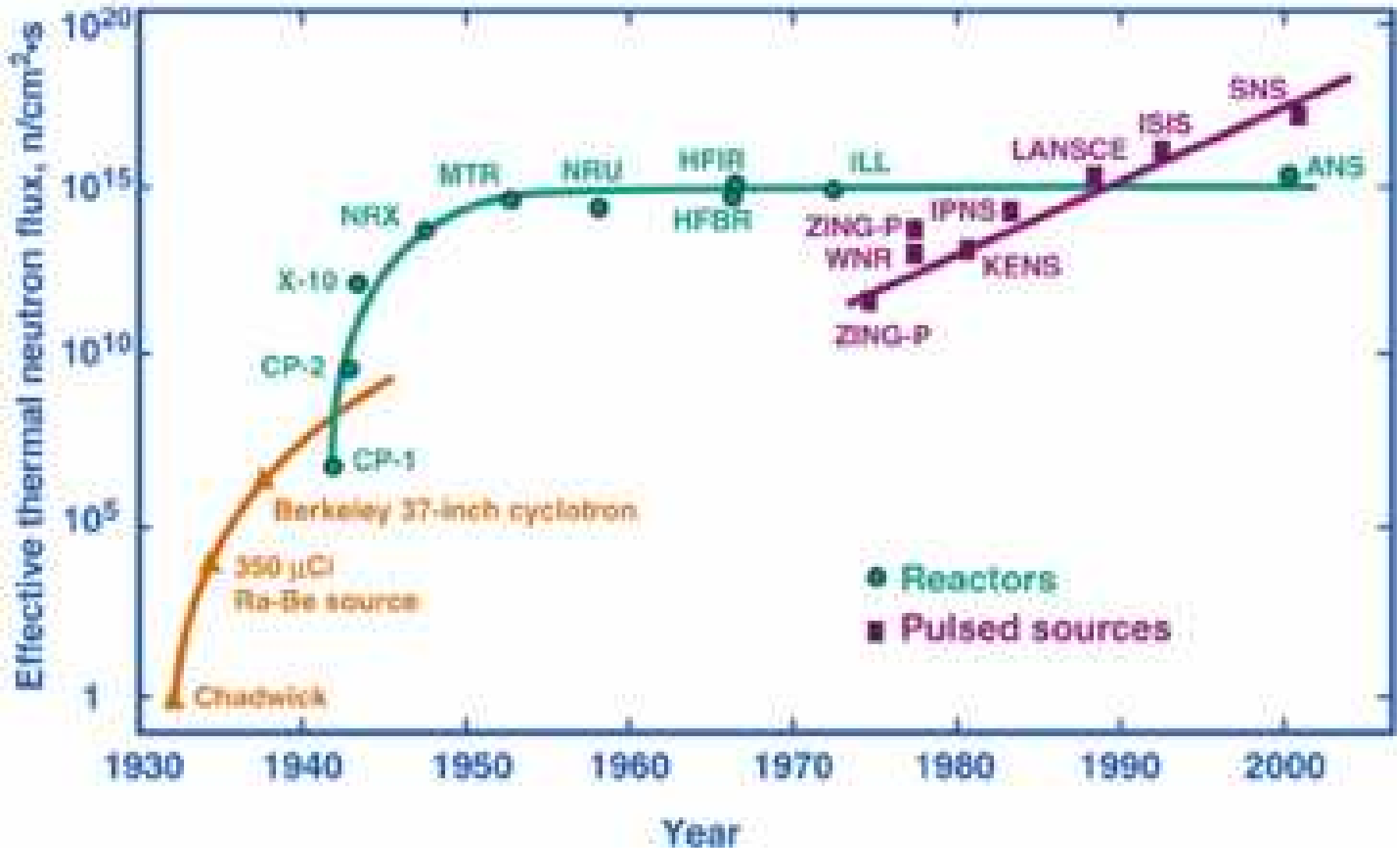


20 - 25 MV/m

Six Operating Light Sources

	E (MeV)	Wavelength (um)	
JAERI - Japan	16	20 - 30	ERL
ELBE Rossendorf-Germany	12 – 40	2 - 10	FEL
SCA- Stanford, USA	40 – 50	1 - 2	FEL,
DALINAC Darmstadt-Germany	40 – 50	2.5 - 7	FEL
JLAB- Va, USA	45 – 80	1 - 6	FEL, ERL
TTF-I – DESY, Germany	180 - 270	0.1 – 0.2	SASE-FEL

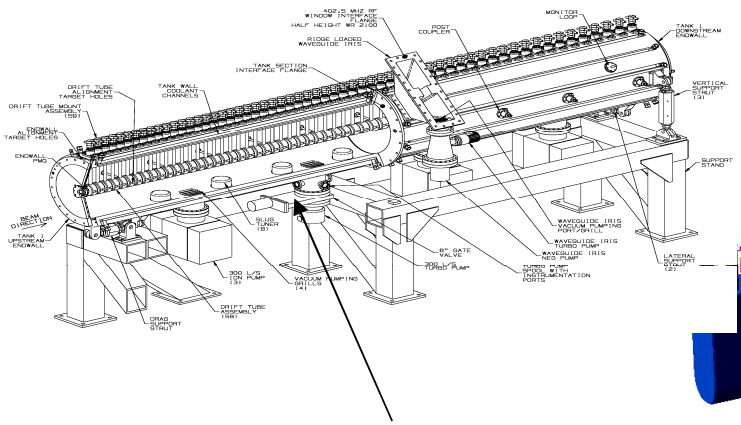
Neutron Sources

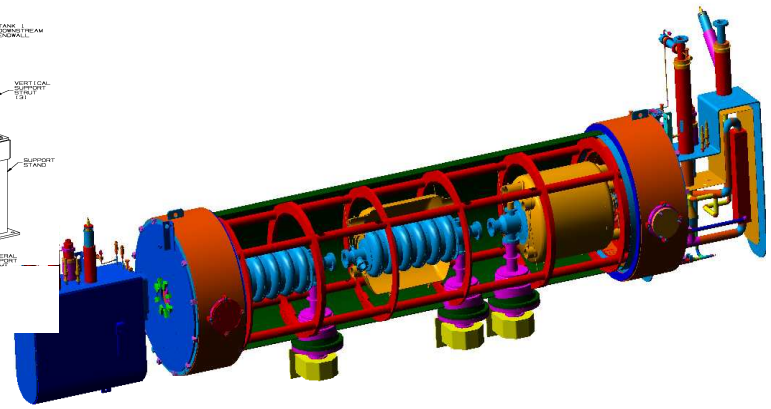


SNS Linac – 1000 feet long;

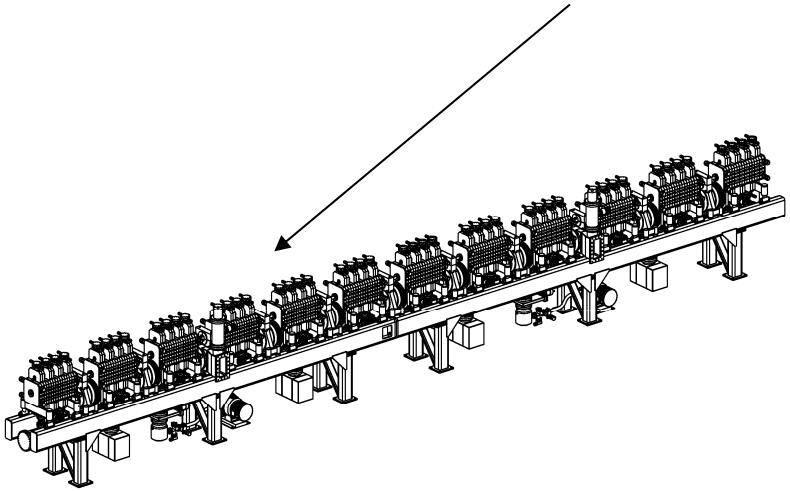
Normal conducting (copper) to 187 MeV; superconducting to 1000 MeV

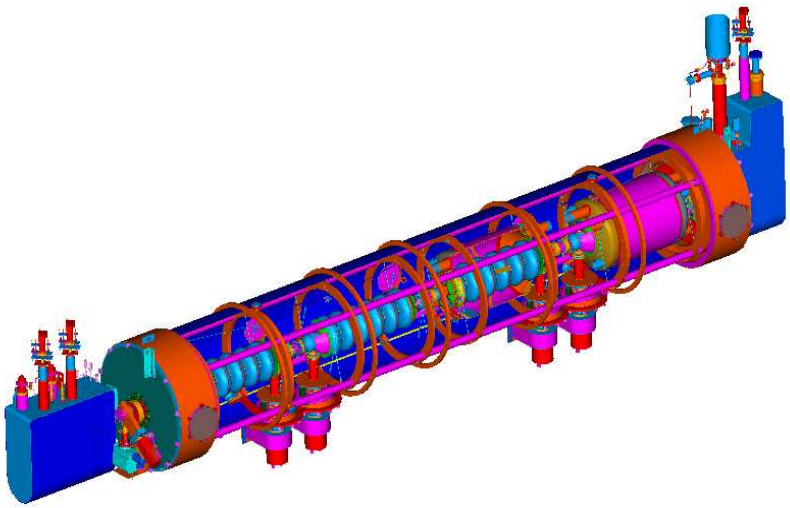
The SNS Linac consists of a drift-tube linac (DTL), a coupled-cavity linac (CCL), followed by a superconducting rf (SRF) linac



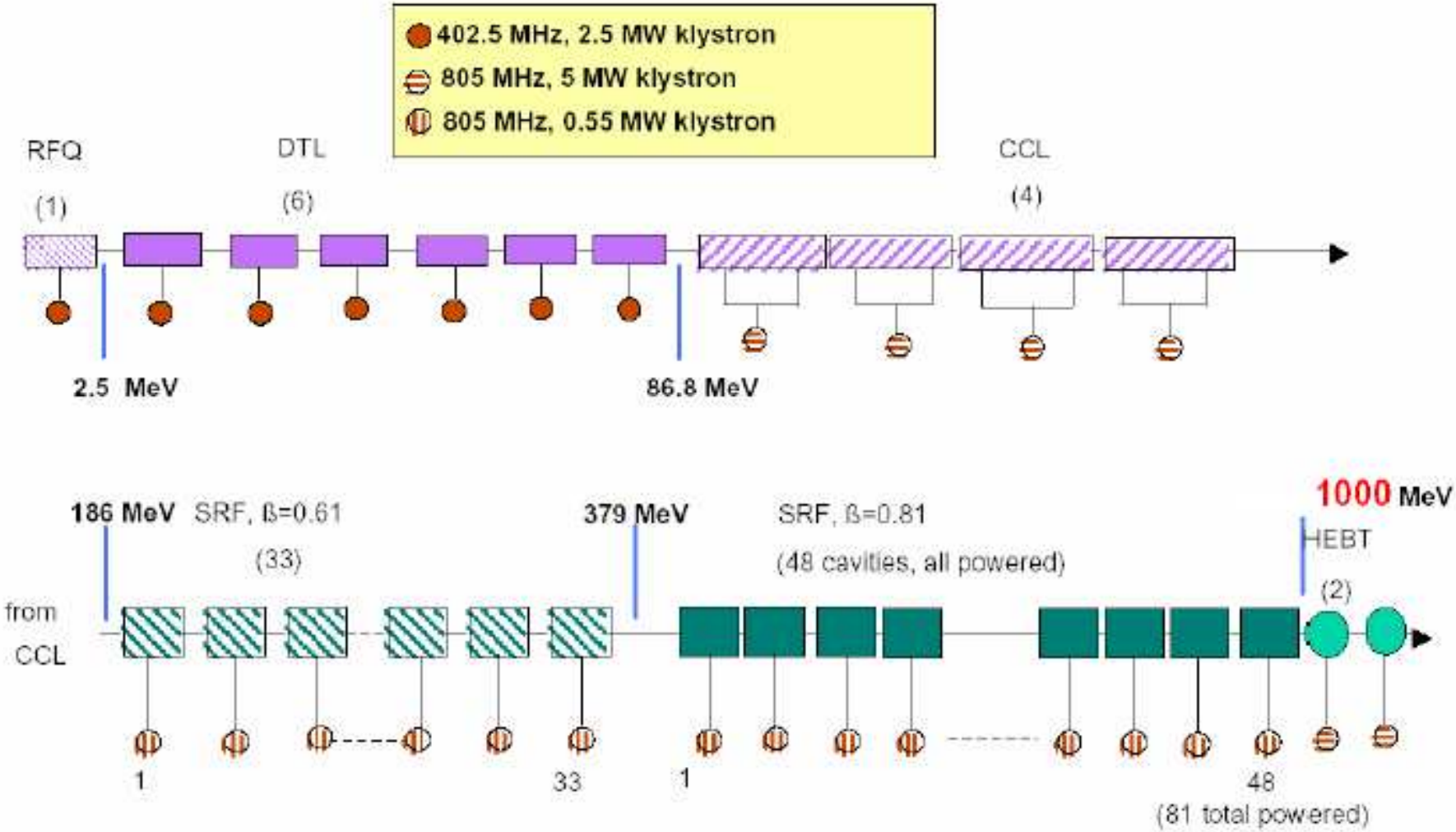


DTL **CCL** **SRF**

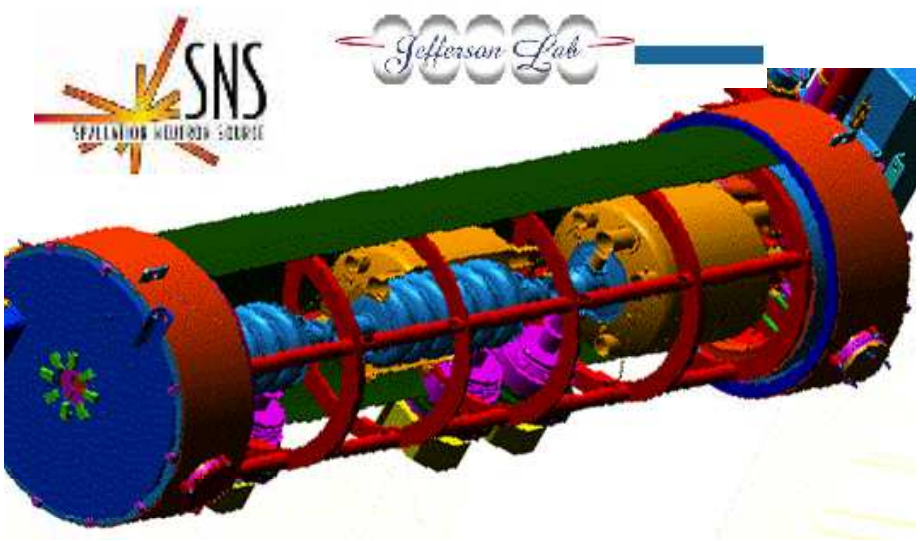




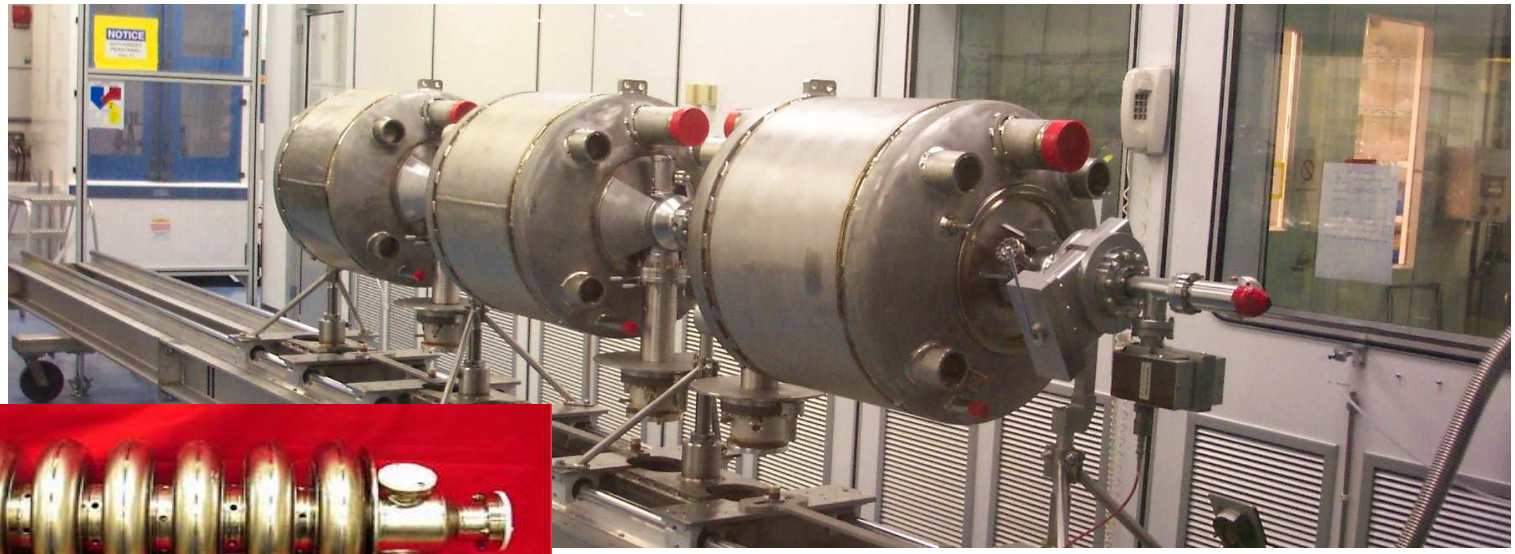
Important Developments for Fermilab Proton Driver

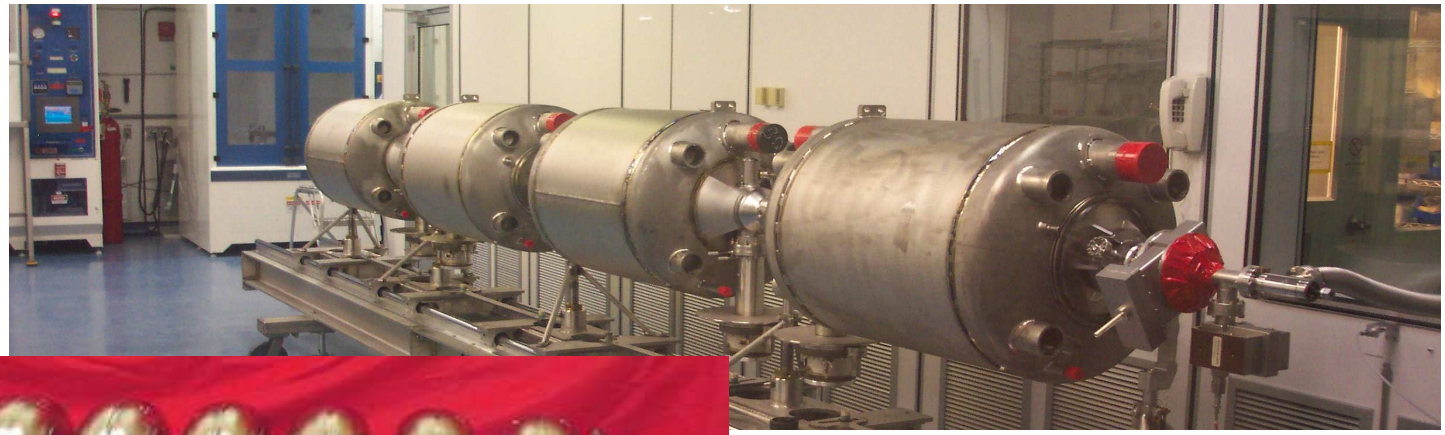


Spallation Neutron Source at Oak Ridge



Cavities

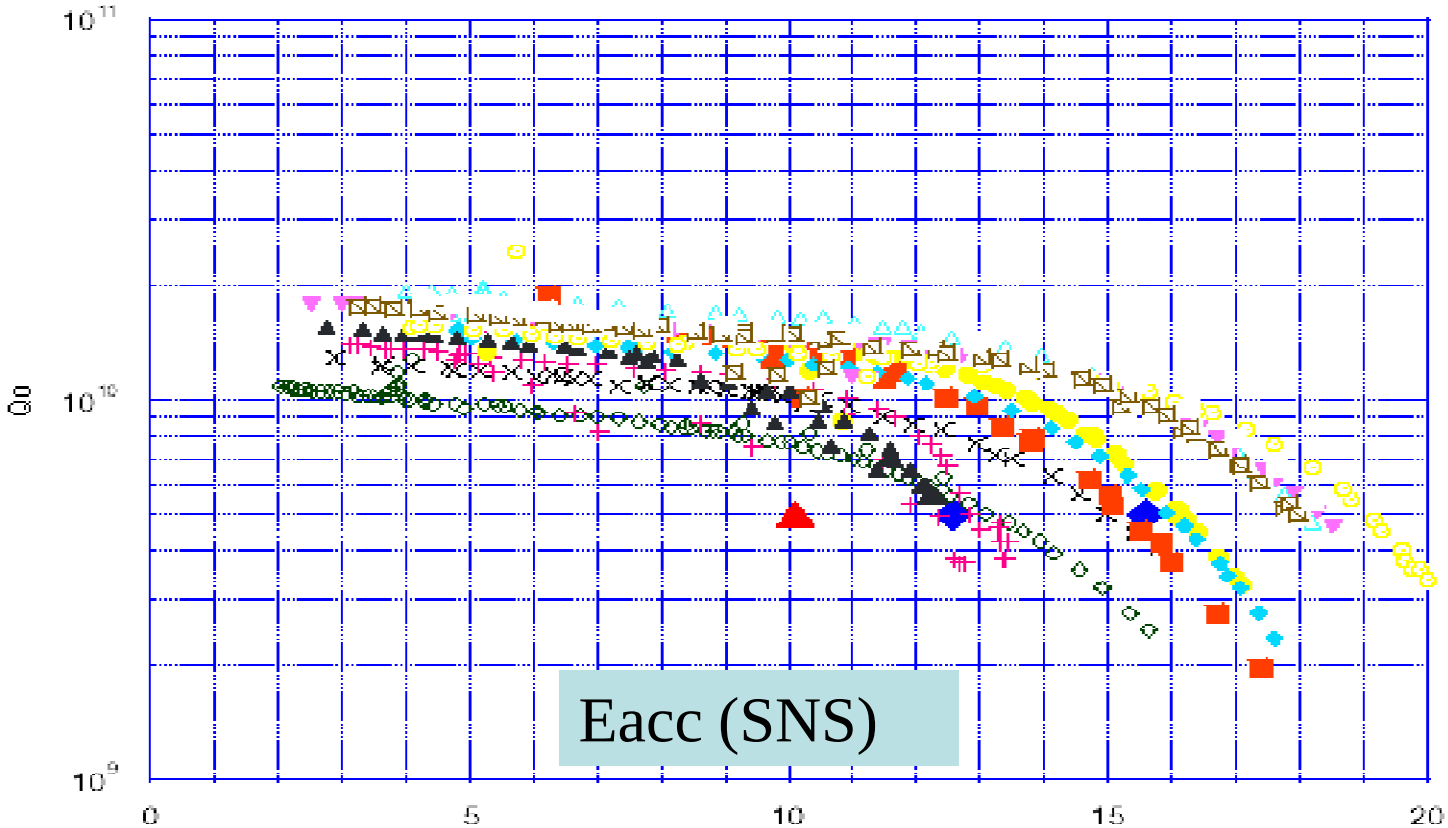




SNS Cryomodules at JLab

In the SNS Tunnel

Performance of SNS Structures, JLAB

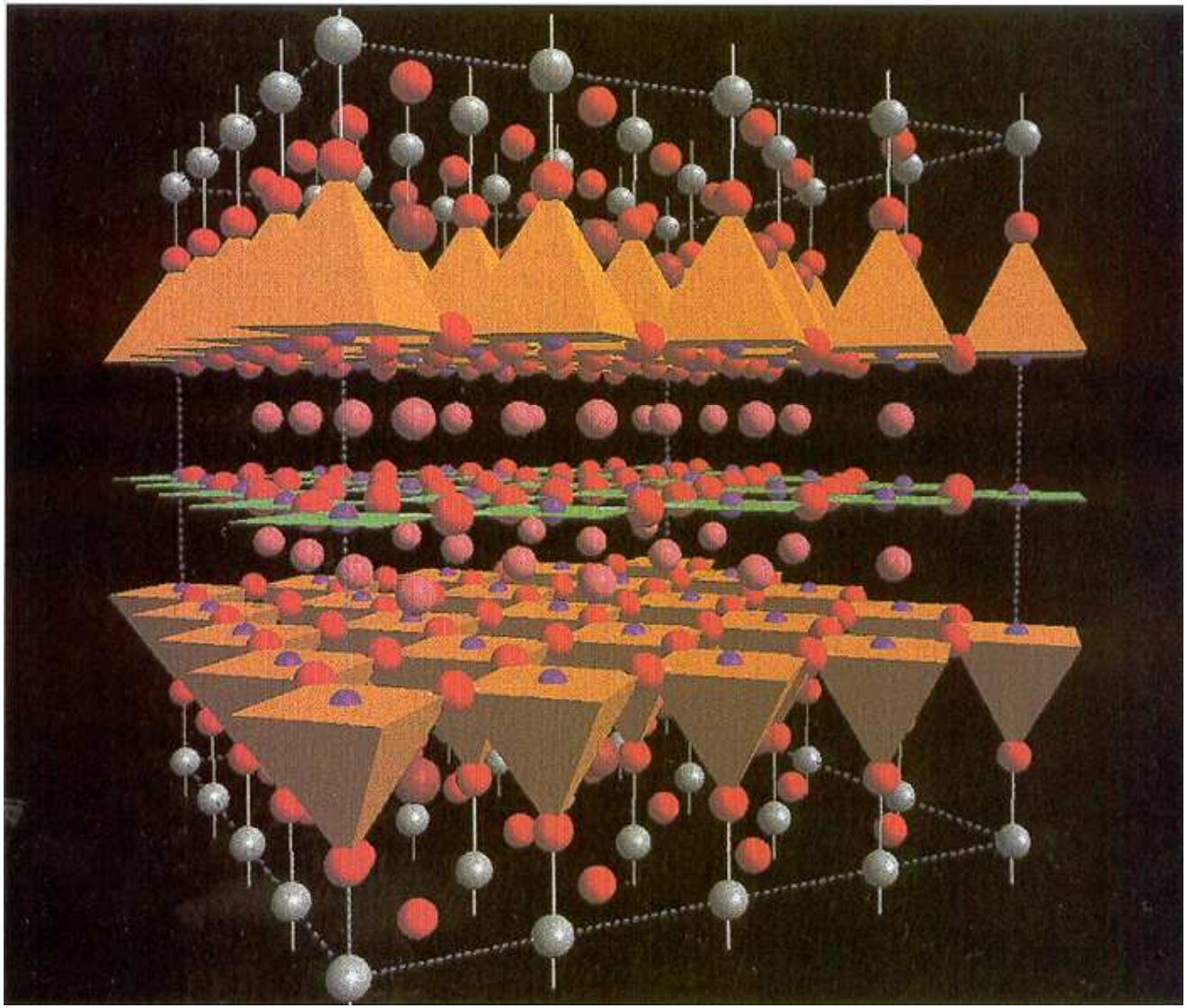


Eacc (TESLA equivalent)	20	25	30	35

β = 0.61, 805 MHz,

Epk/Eacc = 3.5

SNS Site at Oak Ridge

Neutron Science
Materials design
Drug discovery
Biotechnology
Advanced Engineering
Biology
Material Science
Soft Condensed Matter
Structural Chemistry
Templating of nanostructures
Magneto electronics
Solid State Physics
Fundamental Physics
Liquid and Glasses
Energy Resources
Particle physics cosmology astrophysics
Earth Science
Unveiling ancient technologies
Hydrogen Economy

Neutrons help elucidated crystal structure of YBCO