High Intensity Proton Sources

(Superconducting Linacs for High Intensity Proton Beams)

A. Facco

INFN-LNL

Introduction

We will call **High Intensity Proton Sources** (HIPS, extended definition!) accelerators providing proton beams of ~ **1÷100 mA**, at energy from ~**50 MeV** to ~ **2 GeV**

Special issues :

- **high beam power**
- Low beam **losses**
- rf structures for nearly **every** β
- Non relativistic beams with **space charge** and possible **halo**
- High **reliability** and, for ADS, **no beam interruption >1s**

Only linacs are competitive in the all range; this talk will be focused on the large majority of the future HIPS: the ones including a **superconducting linac**

HIPS applications

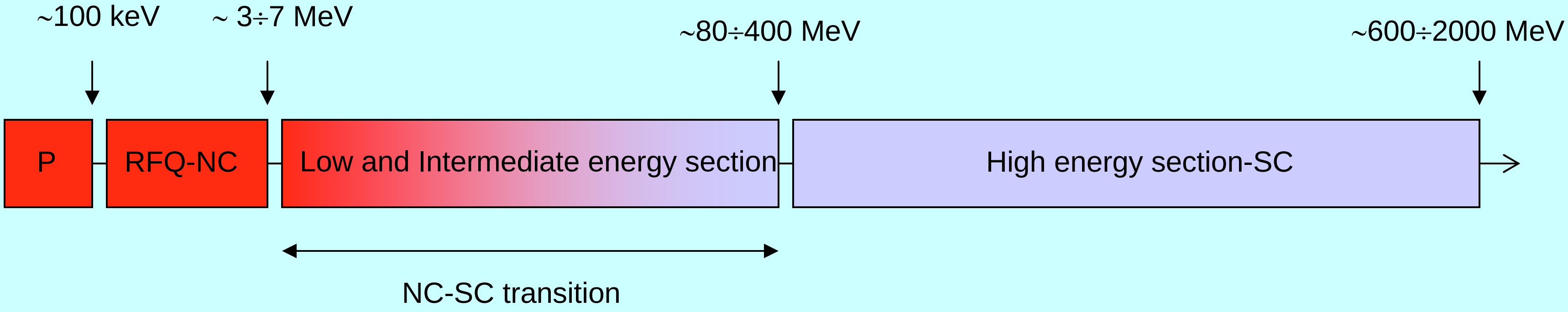
Many applications, both as standalone machines or as injectors:

– Spallation neutrons sources	(pulsed power)
– Sub-critical nuclear reactor powering	(avg power, reliability)
– Nuclear waste transmutation	(“)
– Production of tritium (military applications)	(avg power)
– Radioactive ion beams production	(“)
– Neutrino factories	(“)
– Production of radioisotopes for medical use	(“)
– …	

Possible significant impact in research but also in everyday life: increasing interest in large communities

High Intensity Superconducting Proton Linacs

(**HISPL** from now on)



~100 keV

~ 3÷7 MeV

~80÷400 MeV

~600÷2000 MeV

P

RFQ-NC

Low and Intermediate energy section

High energy section-SC

NC-SC transition

The consolidated scheme of modern HIPS includes

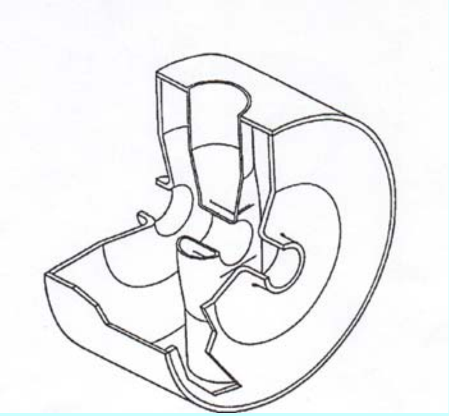
- a proton (H^+,H^-) injector and a normal conducting RFQ
- a SC high energy linac with multicell, elliptical cavities
- A low and intermediate energy linac, either NC (DTL, CCL), SC (low-β elliptical, spoke, half wave coaxial, reentrant…) or both

Although one is under construction and activity in the field is growing fast,

no HISPL exists yet!

Historical highlights

•**superconducting low-β proton linacs** made of reentrant cavities have been proposed at Stanford in the ’70



•superconducting low-β accelerators for **high brightness proton beams** have been studied at ANL in the late ’80; this led to Spoke geometries

Why Superconducting at high-β?

- **SNS** studies assessed that**,** at least **above 200 MeV** the SC solution is preferable even for pulsed beam:
  - Flexibility, modularity
  - High gradient
  - Power efficiency
  - Better vacuum
  - Large aperture

    → **cost, performance and reliability**
- This is even more true for cw machines and for lower current

Why Superconducting at low beta?

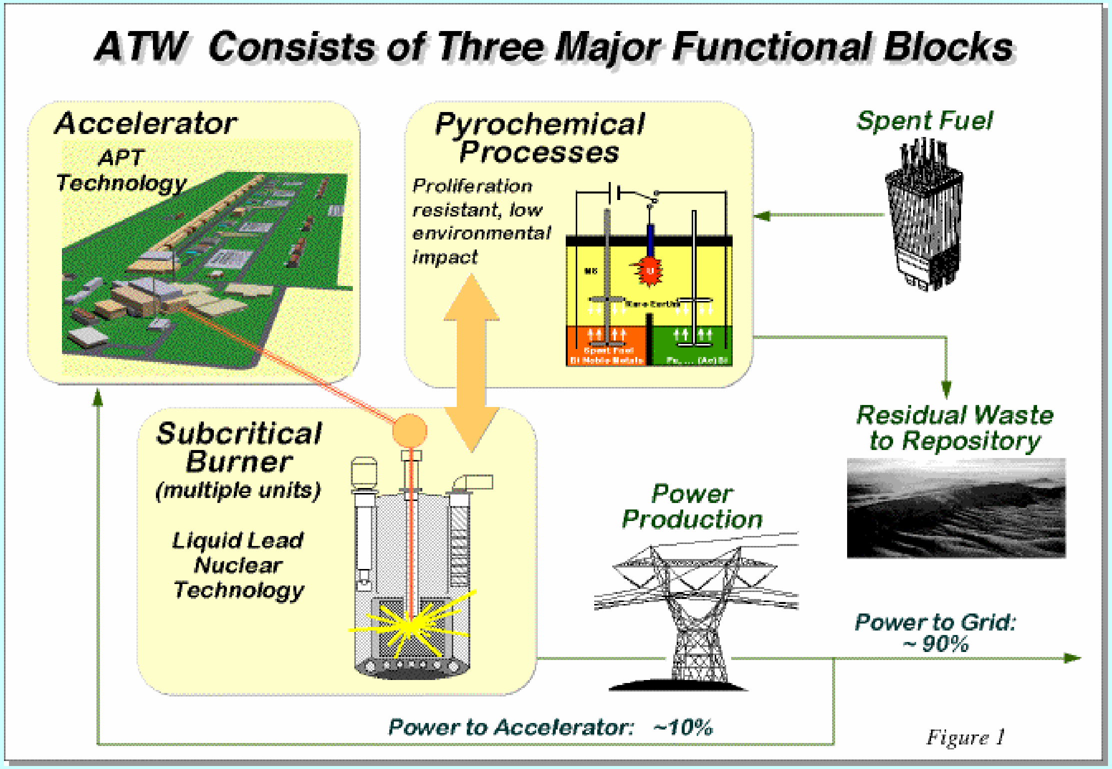
- The previous arguments substantially still hold

- Short, independently phased cavities:
  - Variable beam velocity profile
  - Fault tolerance
  - Spare cavities on line

- Problems:
  - The gradient could be limited by beam dynamics (especially below 20 MeV)

- Optimum NC-SC transition energy: it depends on beam current, time structure and linac requirements

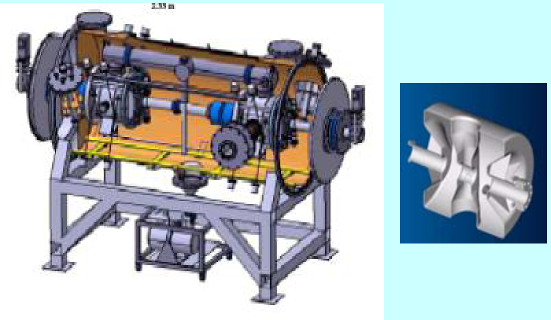
ADS systems



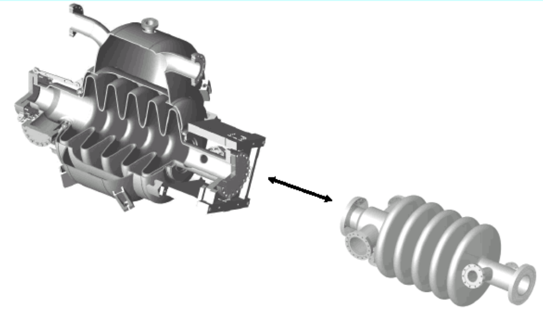
Reliability – no beam interruption longer than 1 s

HISPL cavities highlights

Schematic of the XADS cryomodule and 2-gap spoke cavity (IPNO)



Schematic of the ADTF cavity (LANL)



type	Low-β (~0.1÷0.5)	High-β (~0.5÷0.9)
# cells	1÷19 (typ. 2)	4÷9
Frequency MHz	160 ÷352	352 ÷ 972
Operating T	4.2 K	2.2 K
Coupler	Up to 200 kW	Up to 2 MW pulsed, 500 kW cw
Aperture	30 ÷ 60 mm	80 ÷ 100 mm
Design gradient	5÷8 MV/m	6÷13 MV/m

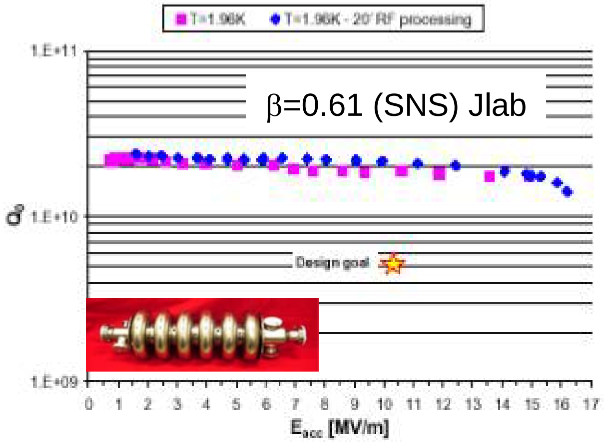
Proton and heavy ion linacs

- Significant overlap between the two fields, and common evolution (RIA, SPIRAL 2…)

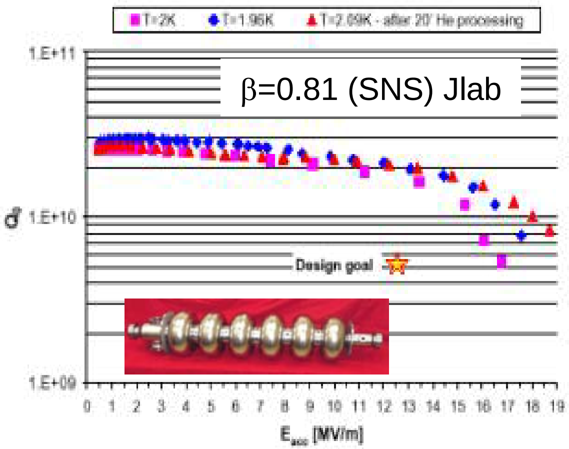
- The main differences are at low-β :
  - larger rf power couplers, rf ports and beam aperture
  - Larger Q_{ext} ⇒ easier rf control
  - Higher frequency at low beta (from RFQ)
  - Shorter cavities for fault tolerance at low beta

Example: β=0.1
10 mA protons ⇒ 350 MHz reentrant cavity
10 μA heavy ions ⇒ 100 MHz QWR

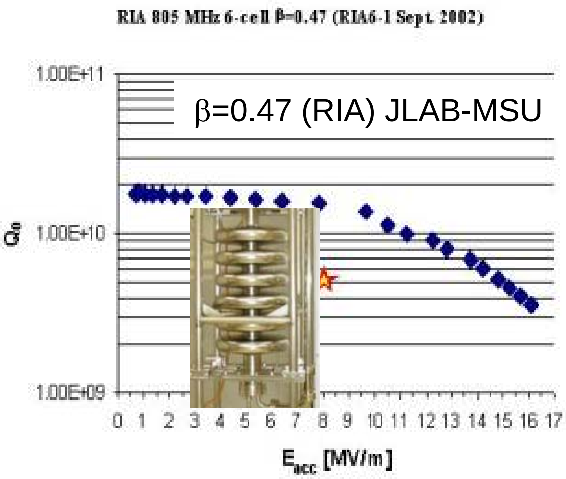
High-β cavities examples



β=0.61 (SNS) Jlab

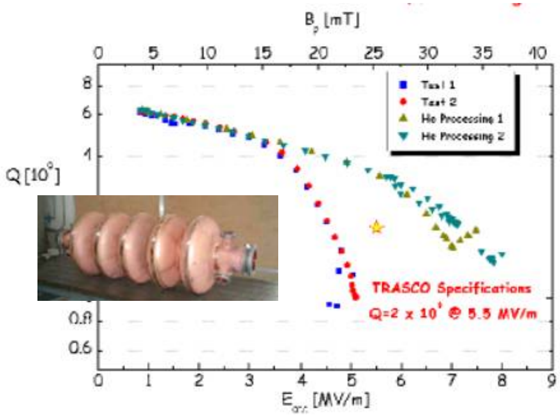


β=0.81 (SNS) Jlab



β=0.47 (RIA) JLAB-MSU

- Prototypes successfully developed by JLAB, KEK, JAERI, LANL, CEA Saclay, IPN Orsay, INFN Milano, CERN



β=0.85 (TRASCO) CERN
352 MHz Nb-Cu - 4.2 K

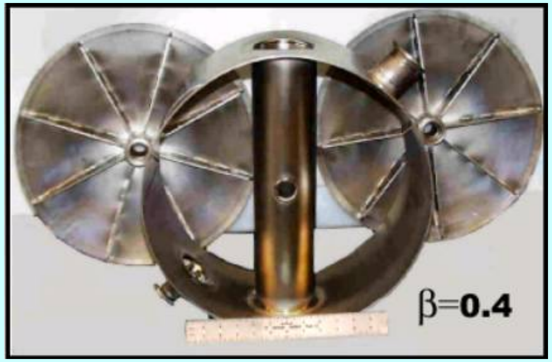
Low-β cavities

1 gap reentrant- LNL
352 MHz, β>0.1

2 gap spoke- LANL
352 MHz, β=0.2

2 gap spoke- IPN Orsay
352 MHz, β=0.36

2 gap spoke- 345 MHz β=0.4
ANL for RIA



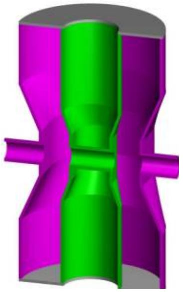
- short cavities, wide β acceptance
- 1-2-3 gap cavity prototypes successfully developed by ANL, INFN Legnaro, LANL, IPN Orsay
- High power rf couplers not fully developed yet, as well as tuners

3 gap SPOKE, β=0.4
345 MHz
ANL for RIA

Low-β Coaxial Half–Wave

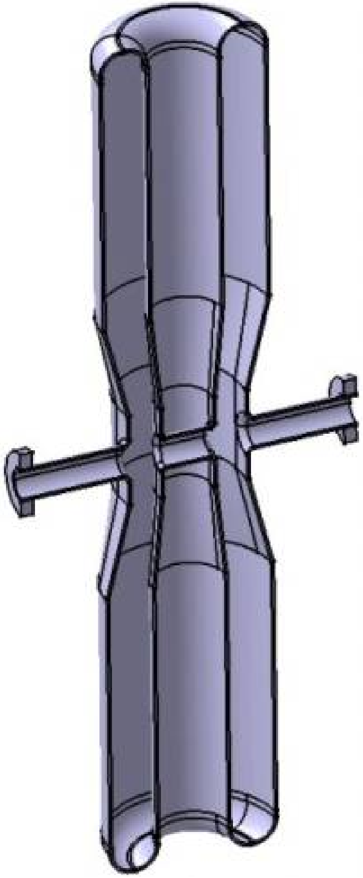
350 MHz, β=0.12
ANL

322 MHz,
β=0.28 HWR
MSU for RIA



352 MHz, β=0.31
HWR - LNL

160 MHz, β=0.12 HWR
For the COSY injector



- Developed first for heavy ion linacs
- Short real estate length, steering-free
- Alternative to QWRs and Spoke especially for ~150<f<350 MHz

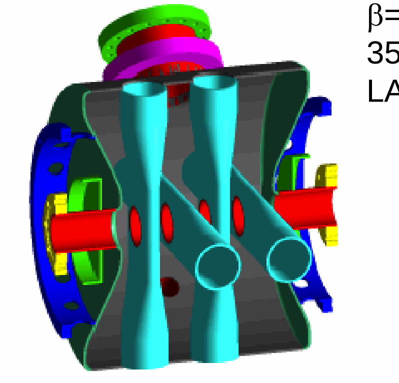
•Dedicated prototypes for HIPS under development at INFN Legnaro, IKF Juelich, Accel

4-gap SC cavities development
The Low-β zoo is still growing

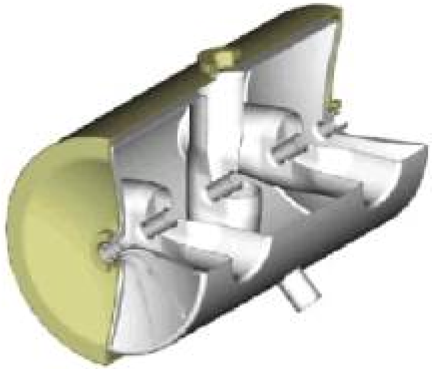
4 gap ladder,
352 MHz, β=0.12
INFN-LNL

β=0.2
784 MHz
IKF Juelich

β=0.12
352 MHz
LANL



- 4-gap cavities under development at ANL, INFN-Legnaro, LANL, IKF-Juelich
- Higher energy gain, lower velocity acceptance
- The 4-gap spoke was proposed in place of the the β=0.5 multicell

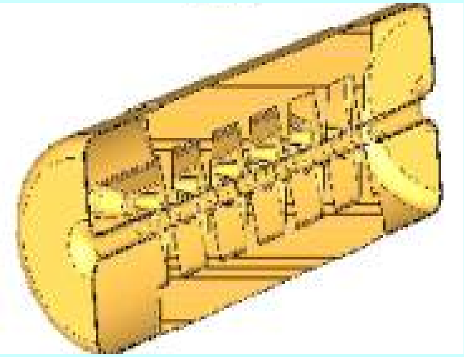


4 gap SPOKE, β=0.5
345 MHz - ANL for RIA

Multi-gap SC cavities development the ultimate limit?

19 gap CH, β=0.1
352 MHz

16 gap CH, β=0.1
174 MHz



- Multi-gap cavities under development Frankfurt Univ. and GSI

- Very large energy gain
- rather low acceptance in β
- KONUS beam dynamics required

Open questions:

- Multipacting
- Higher order modes
- Mechanical stability
- High power coupling

HISPL projects worldwide:High-β

Linac	E_{in}/ E_{out} MeV	I_{peak} mA	duty cycle, %	Rep. rate, Hz	N.cav. (types)	rf freq. MHz	Notes	Status
SNS USA	187 / 1000	26	6.25	60	81 (2)	805	H-	Construct. started operation 2006
ESS Europe	200 / 1330	114	6	50	137 (2)	704	H-, p	Proposal
Concert Europe	200 / 1330	114	6	50	137 (2)	704	H-,p	Project Study (closed)
J-PARK Japan	400 / 600	30	1.25	25	22 (1)	972	H-	Construction started R&D
APT USA	211 / 1030	100	100	CW	242 (2)	700	p	Project Study, R&D (closed)
ADTF H.E. USA	109 / 600	13	100	CW	133 (2)	700	p	Proposal R&D
XADS H.E. Europe	95 / 600	10	100	CW	88 (3)	700	p	Preliminary design Study, R&D
TRASCO H.E. Italy	100 / 1000	30	100	CW	124 (3)	704	p	Project Study R&D
EURISOL H.E. Europe	85 / 1000	5	100	CW	134 (3)	700	p	Project Study R&D
SPL CERN	120 / 2200	22	14	50	202 (3)	352	H-	Project Study R&D
KOMAC Korea	100 / 1000	20	100	CW	90 (3)	700	p	Proposal R&D
FNAL 8 GeV USA	87 / 8000	25	1	10	384 (4)	805/ 1207.5	H-, p	Proposal
AGS upgrade USA	200/ 1200	28	0.18	2.5	92 (3)	805/ 1610	p	Proposal

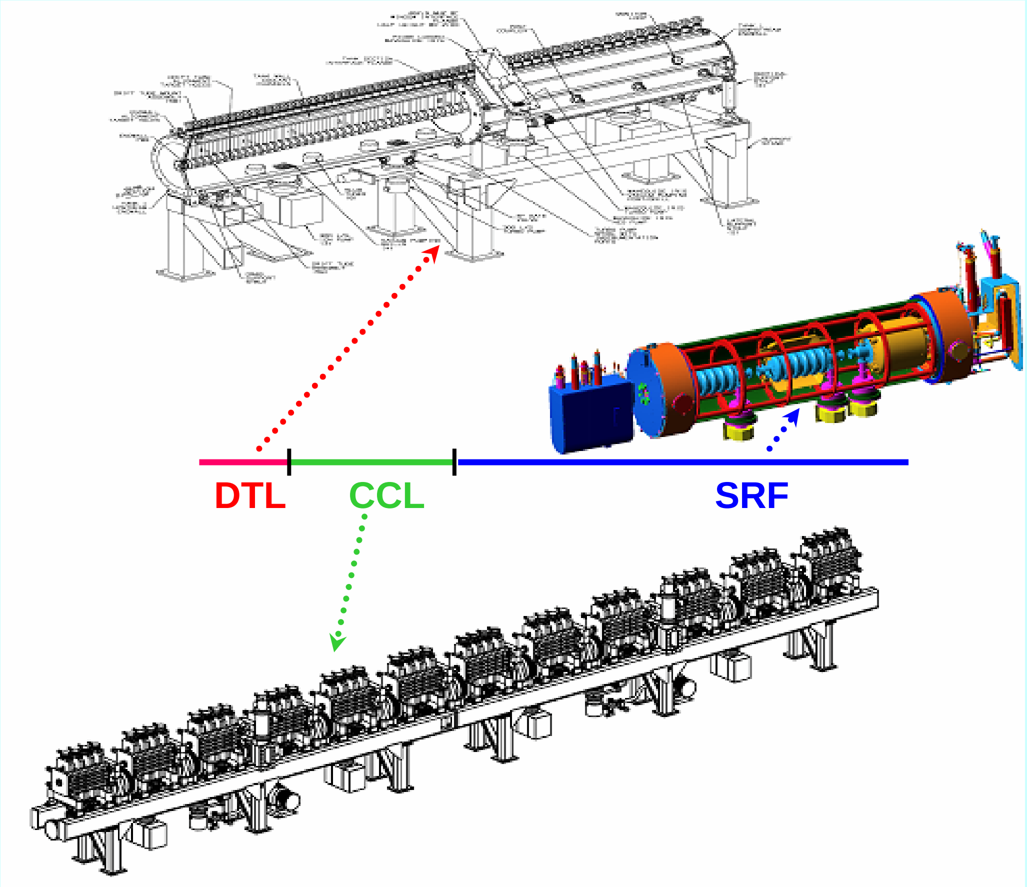
HISPL projects worldwide:
Low-β

Linac	E_{in}/ E_{out} MeV	I_{peak} mA	duty cycle, %	Rep. rate, Hz	Cavities N. (types)	rf freq. MHz	Notes	Status
ADTF L.E. USA	6.4 / 109	13	100	CW	128 (3)	350	p	Proposal R&D
XADS L.E. France	5 / 95	10	100	CW	96 (2)	350	p	Prelim. design study, R&D
TRASCO L.E. Italy	5 / 100	30	100	CW	230 (1)	352	p	Prelim. design study, R&D
SPES Italy	5 / 100	3	100	CW	113 (3)	352	p (d, A/q=3)	Proposal R&D
COSY INJ Germany	2.5 / 52	2	0.1	2	44 (2)	160/320	p, d	Proposal R&D
SARAF Israel	1.5 / 40	2	100	CW	48 (2)	176	p, d	Under constr. operation 2008

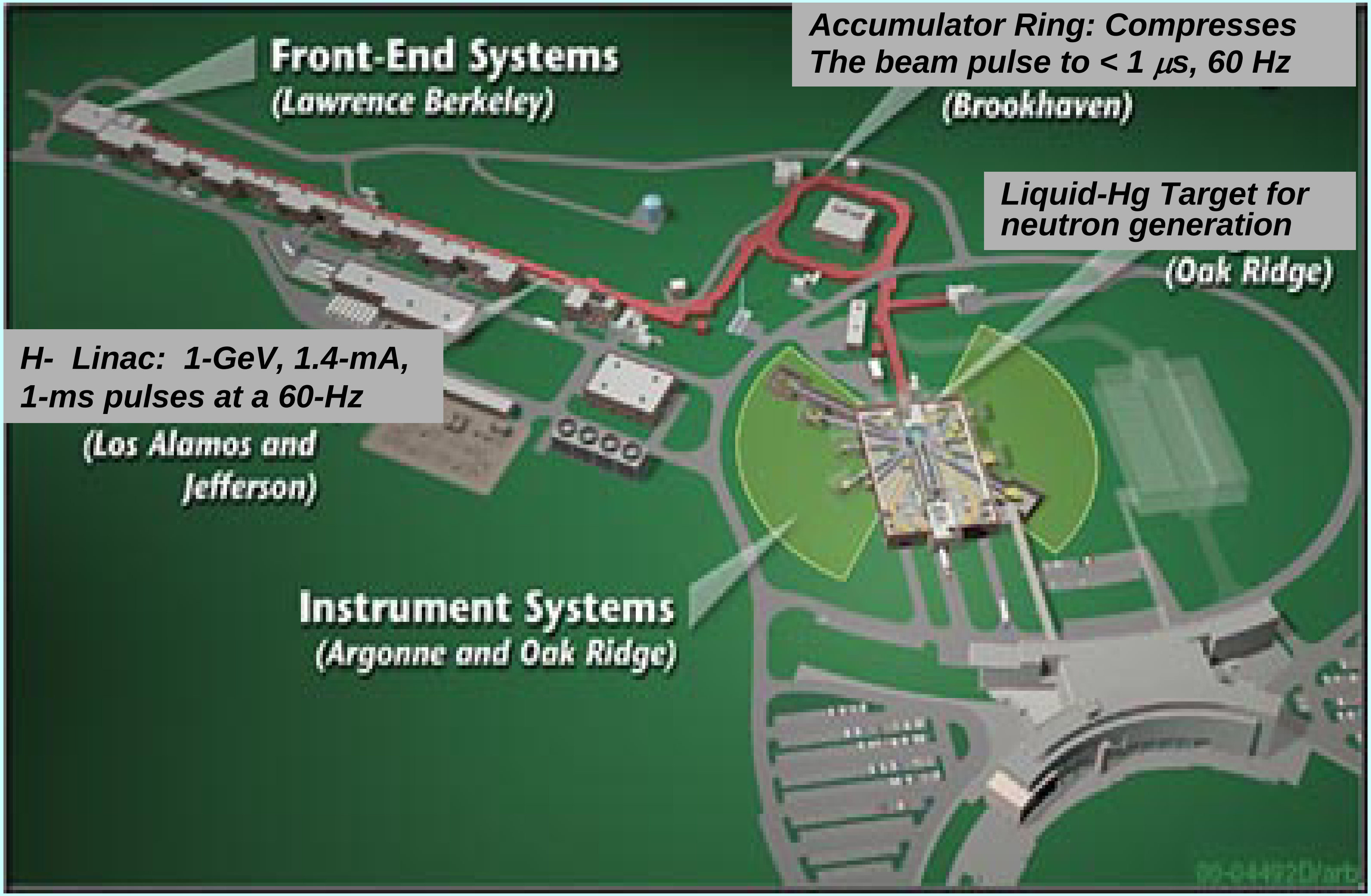
HISPL in USA

The first HISPL: SNS

- **SNS is a DOE-BES multi-lab construction project to create the world’s leading neutron-scattering science facility at ORNL**
- **SNS is Constructed by Six US-DOE-Laboratories: ANL, BNL, JLAB, LBNL, LANL and ORNL**
- **Cost: 1.4 B$**
- **SNS will be the first High Intensity Superconducting Proton Linac in operation from 2006**



Spallation Neutron Source

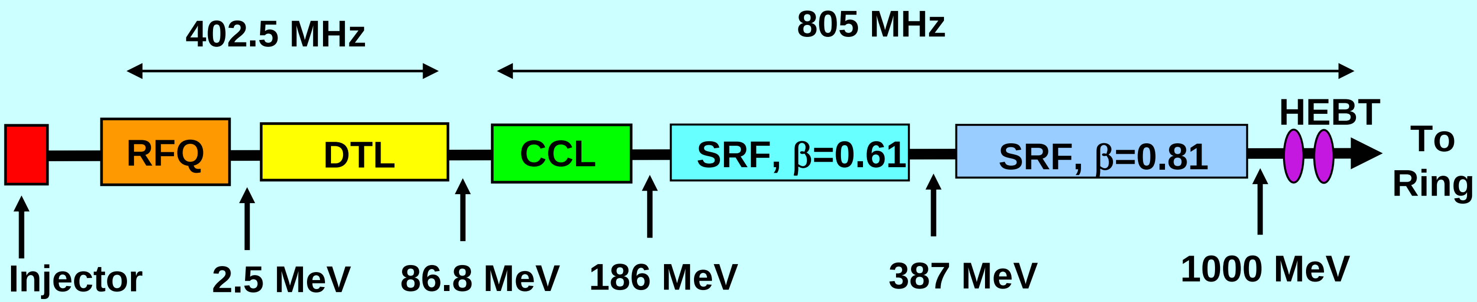


Accumulator Ring: Compresses The beam pulse to < 1 μs, 60 Hz

Liquid-Hg Target for neutron generation

H- Linac: 1-GeV, 1.4-mA, 1-ms pulses at a 60-Hz

Linear Accelerator



1 RFQ
6 DTL Tanks
4 CCL Modules

11 Medium-β Cryomodules - 3 Nb cavities each
12 High-β Cryomodules - 4 Nb cavities each

SRF Cavities	6-cell elliptical “Tesla type” tuner with fast piezo control Coaxial Rf couplers 50 kW av., 550 kW peak 1 klystron/cavity

Klystrons

➔ 94 total klystrons, three different kinds

402.5 MHz, 2.5 MW peak	7 (1 for RFQ, 6 for DTL)
805 MHz, 5 MW peak	6 (4 for CCL, 2 for HEBT)
805 MHz, 0.55 MW peak, SRF	81 (33 medium-β, 48 high-β)

Total AC power for RF Less than 20 MW

Major SNS Facility Parameters

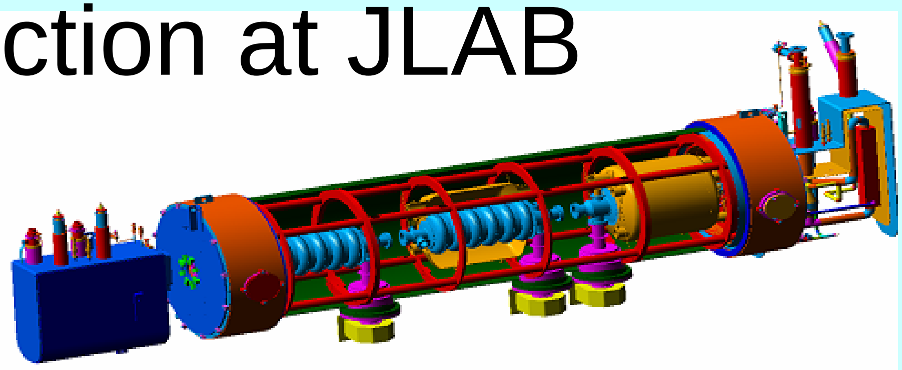
Proton beam energy on target	**1.0**	**GeV**
Proton beam current on target	1.4	mA
Power on target	**1.4**	**MW**
Pulse repetition rate	**60**	**Hz**
Beam macropulse duty factor	6.0	%
Ave. current in macro-pulse	26	mA
H^- peak current front end	> 38	mA
Chopper beam-on duty factor	68	%
RFQ output energy	2.5	MeV
FE + Linac length	335	m
DTL output energy	87	MeV
CCL output energy	185	MeV

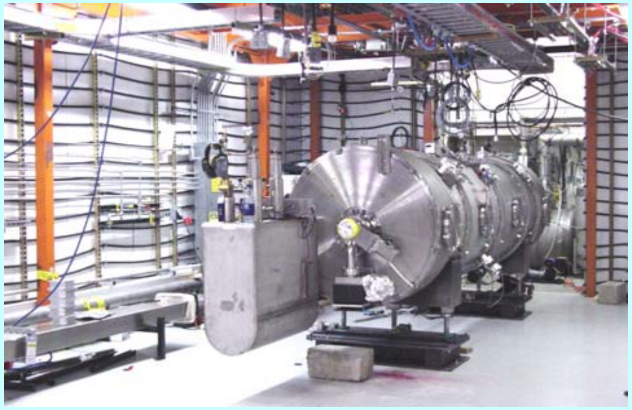
SC linac output energy	1.0	GeV
HEBT length	170	m
Accumulator ring circ.	248	m
Ring fill time	1.0	ms
Ring beam extraction gap	250	ns
RTBT length	150	m
Protons per pulse on tgt	1.5×10^{14}	
Proton pulse width on tgt	695	ns
Target material	**Liquid Hg**	
Weight of 1m³ Hg	**18 tons**	
Energy per Pulse	>17	kJ *
Maximum # Instruments	24	

- **> 5000 hours per year of user operations with**
- **high reliability (> 95% is the ultimate goal)**

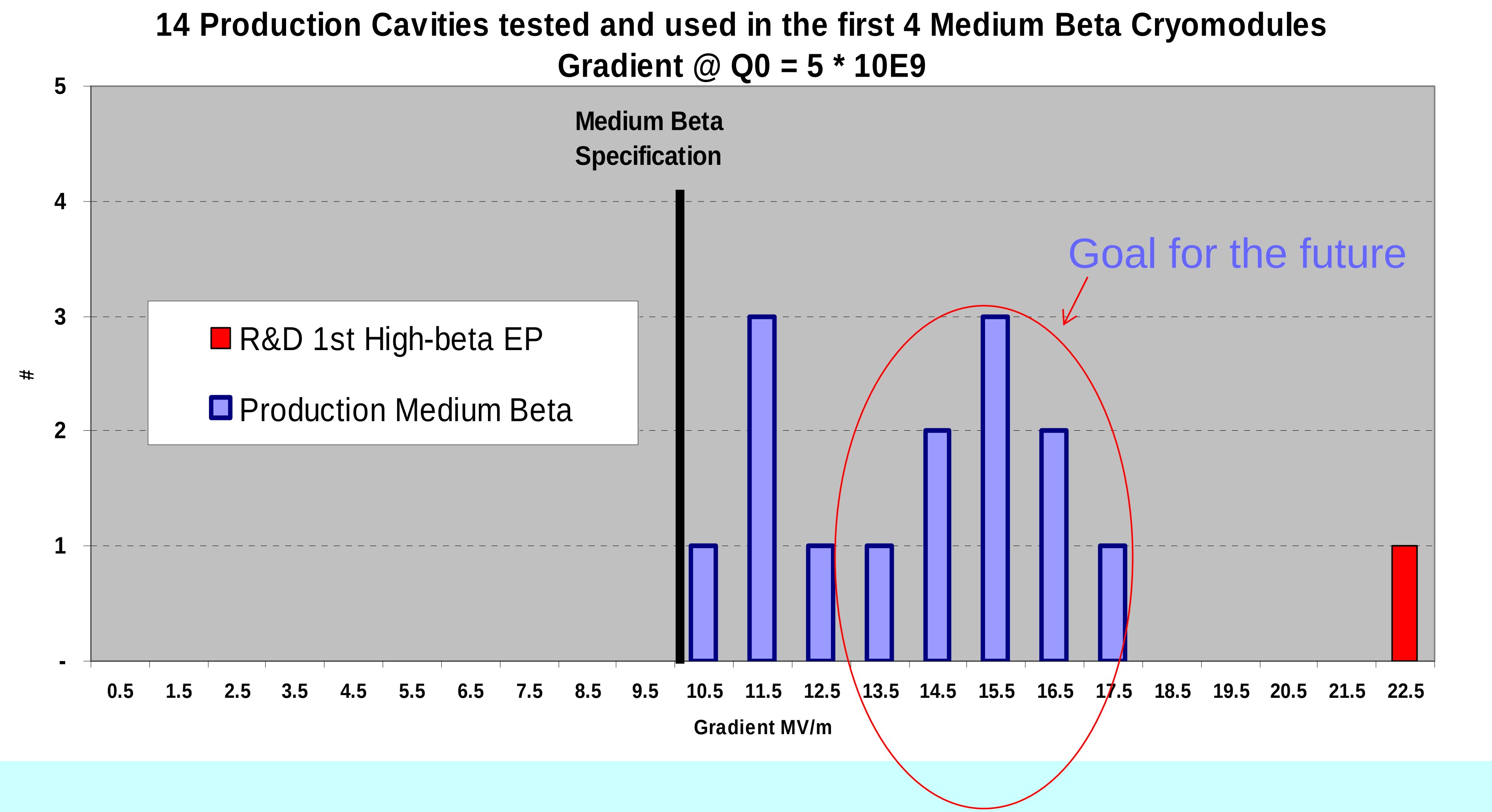
* Equivalent to the energy of Lance Armstrong at top speed

Cryomodule Production at JLAB





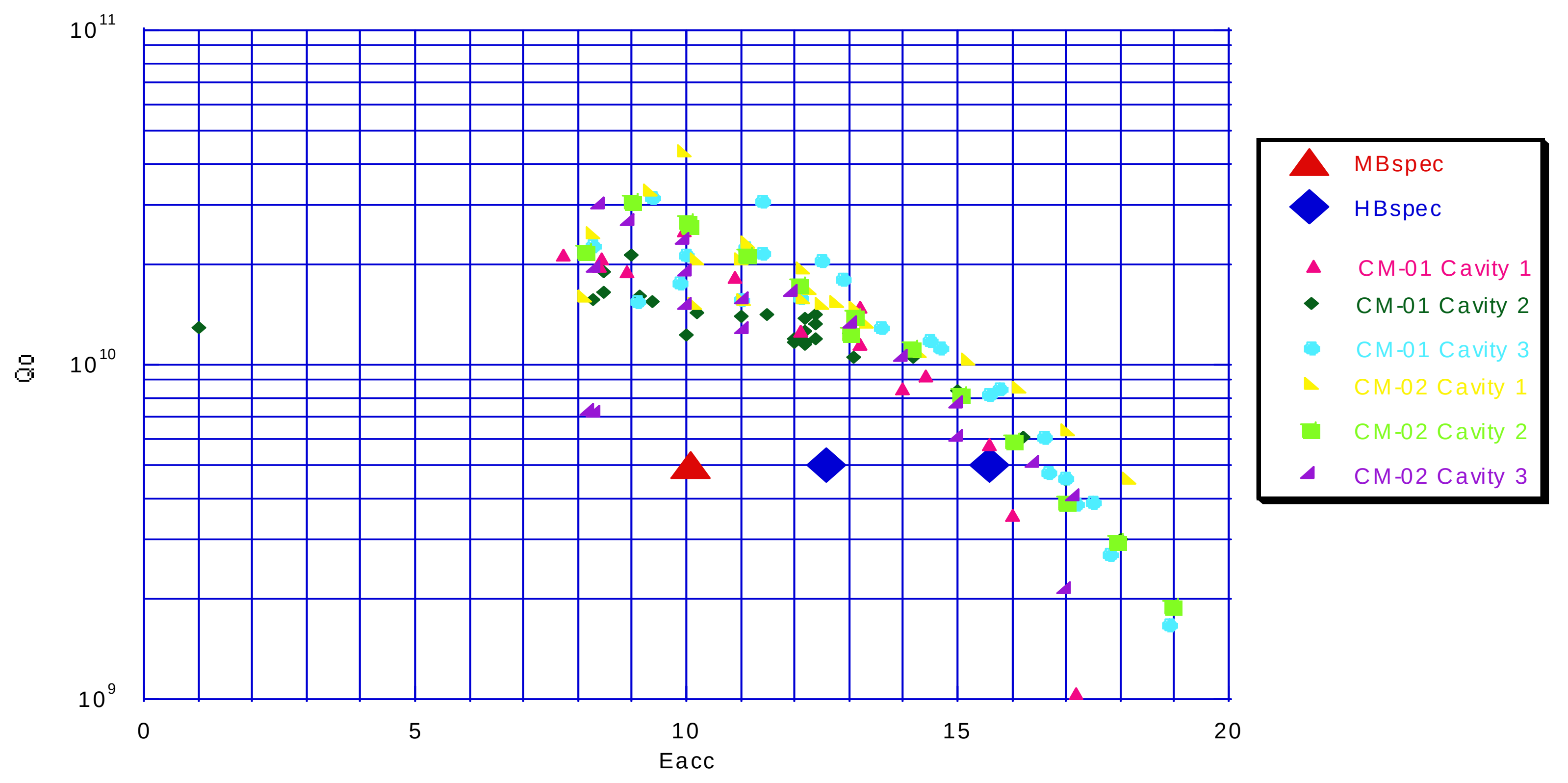
SNS Cavity Performance JLAB



Medium-β CM 1 and 2 Results

2 of 11 medium-β cryomodules

JLAB



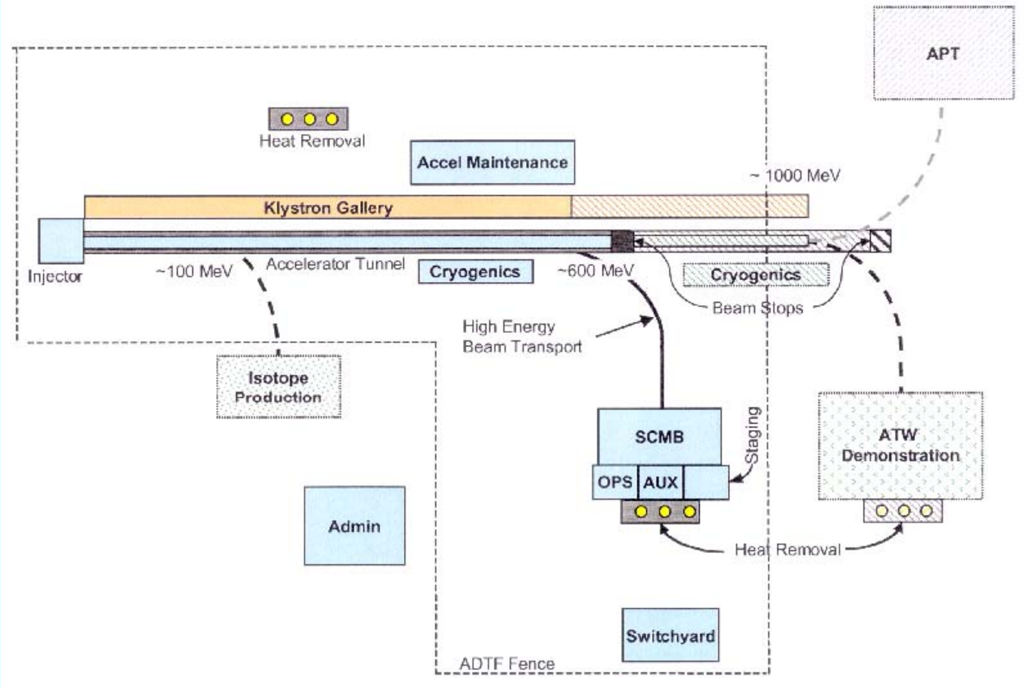
First Cryomodule in the SNS Tunnel 6/03

April 2003

Operation 2006

ADTF

Acceleration Demonstration Test Facility - LANL



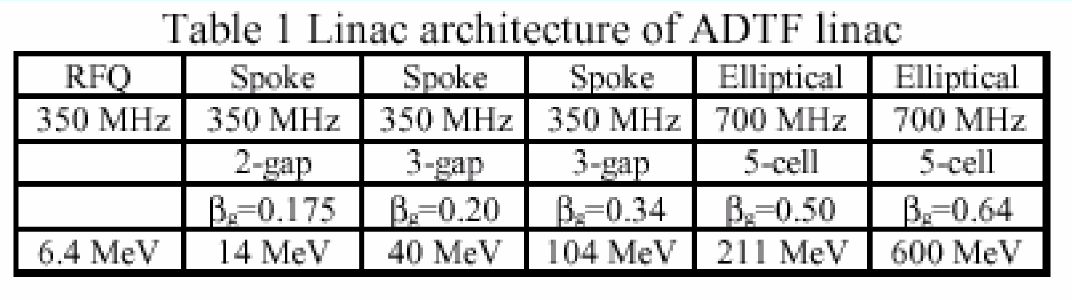
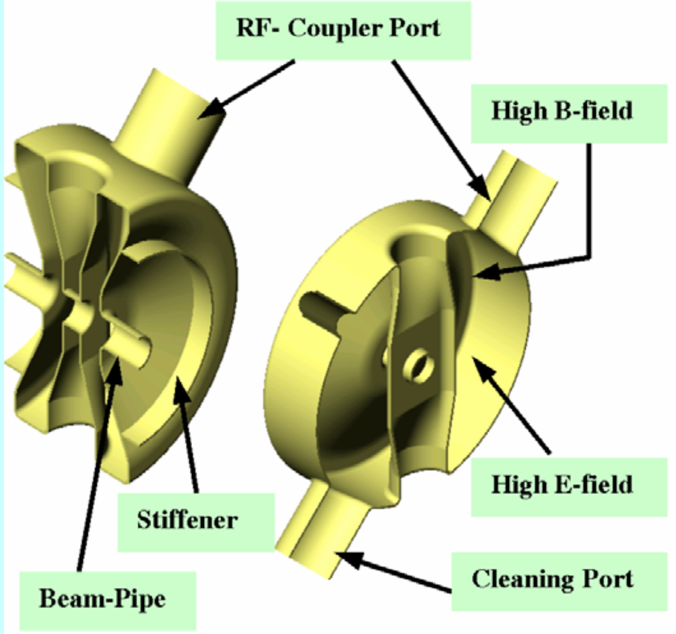


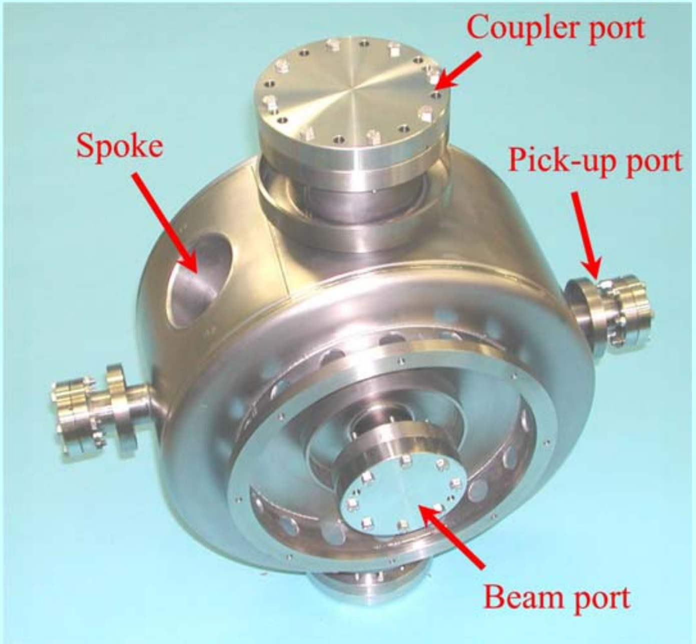
Table 1 Linac architecture of ADTF linac

RFQ	Spoke	Spoke	Spoke	Elliptical	Elliptical
350 MHz	350 MHz	350 MHz	350 MHz	700 MHz	700 MHz
	2-gap	3-gap	3-gap	5-cell	5-cell
	β_g=0.175	β_g=0.20	β_g=0.34	β_g=0.50	β_g=0.64
6.4 MeV	14 MeV	40 MeV	104 MeV	211 MeV	600 MeV

- Scope: Nuclear waste transmutation by means of a subcritical reactor
- Reliability: no uncontrolled beam interruptions >0.3 s
- 13 mA cw, 600 MeV linac, upgradable to APT needs
- All SC above 6.4 MeV
- LANL cavity technology
- Total project cost: 1.5 B$
- Construction time 10 y after approval

Two LANL/AAA β=0.175, 350-MHz, 2-gap spoke cavities were designed at LANL and fabricated in industry





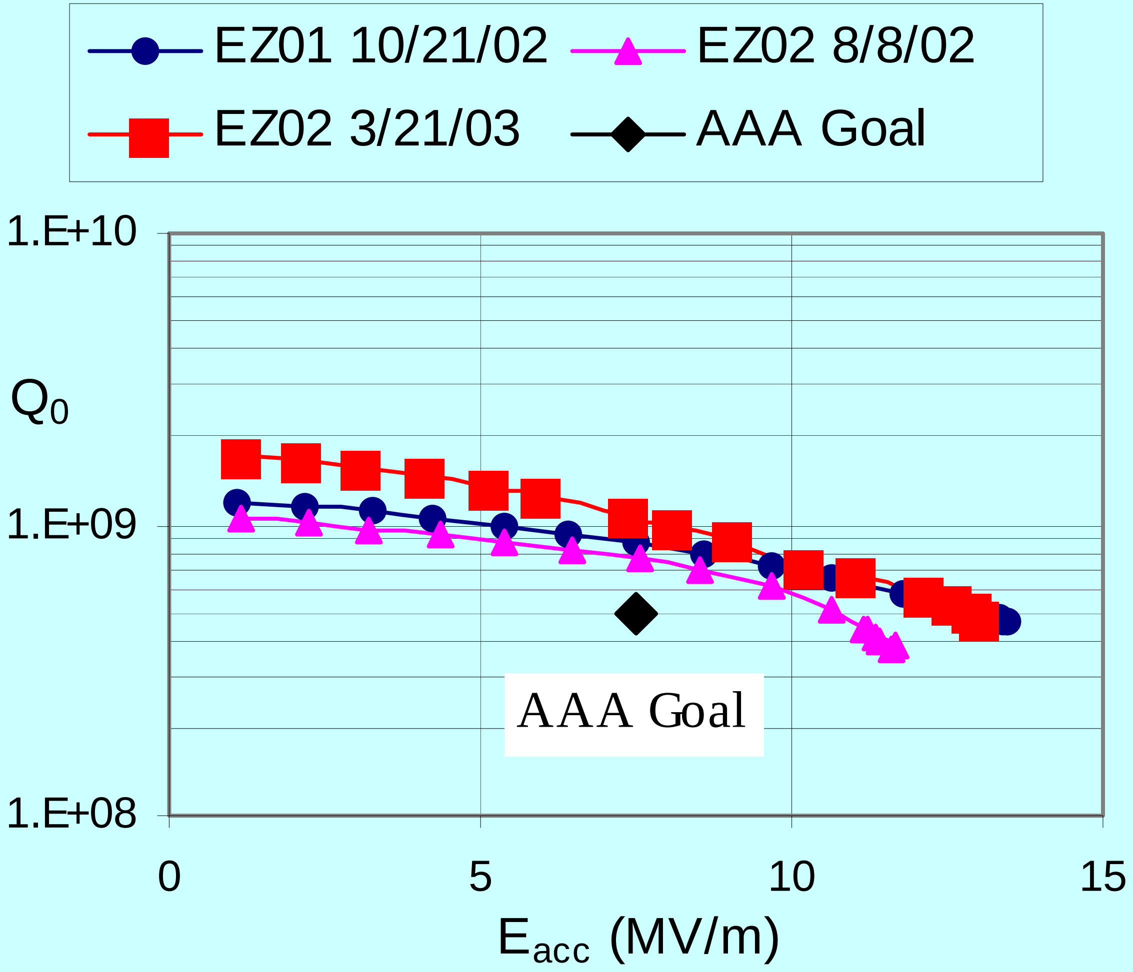
Cell diameter : 39.2 cm
Cavity length : 20 cm
Beam aperture : 5 cm

Manufactured by Zanon, Italy

E_{pk}/E_{acc} : 2.82
B_{pk}/E_{acc} : 7.4 mT/MV/m

These numbers are well optimized.

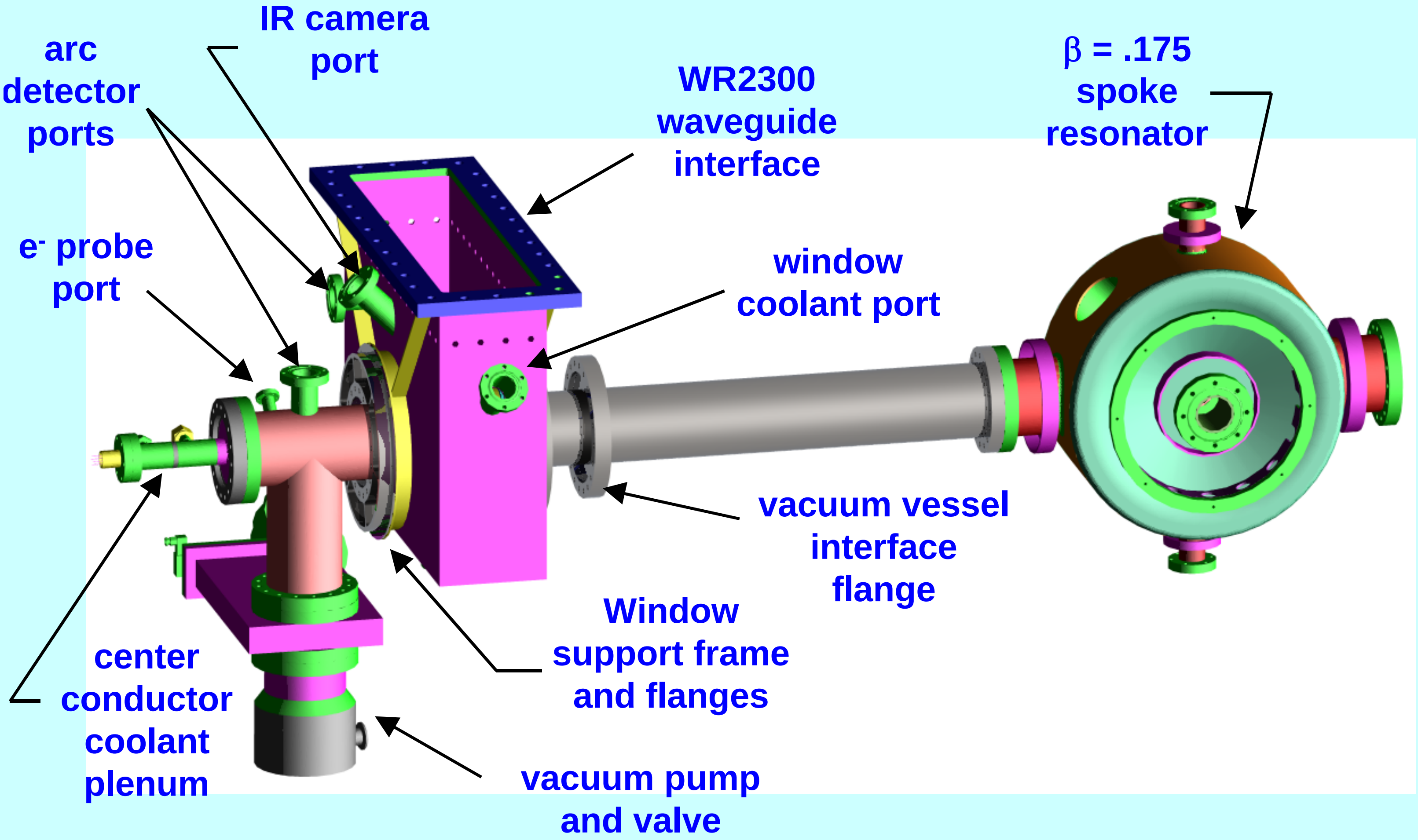
The two cavities EZ01 and EZ02 achieved E_{acc} = 13.5 MV/m and 13.0 MV/m, exceeding the AAA goal of 7.5 MV/m



Repeated cleaning of EZ02 improved the performance (red square).

Published in CERN COURIER Vol. 43 (1) p. 8 Jan/Feb 2003

A 103-mm (OD) power coupler has been designed for up to 100 mA beam (212 kW)



arc detector ports

IR camera port

WR2300 waveguide interface

β = .175 spoke resonator

e^- probe port

window coolant port

vacuum vessel interface flange

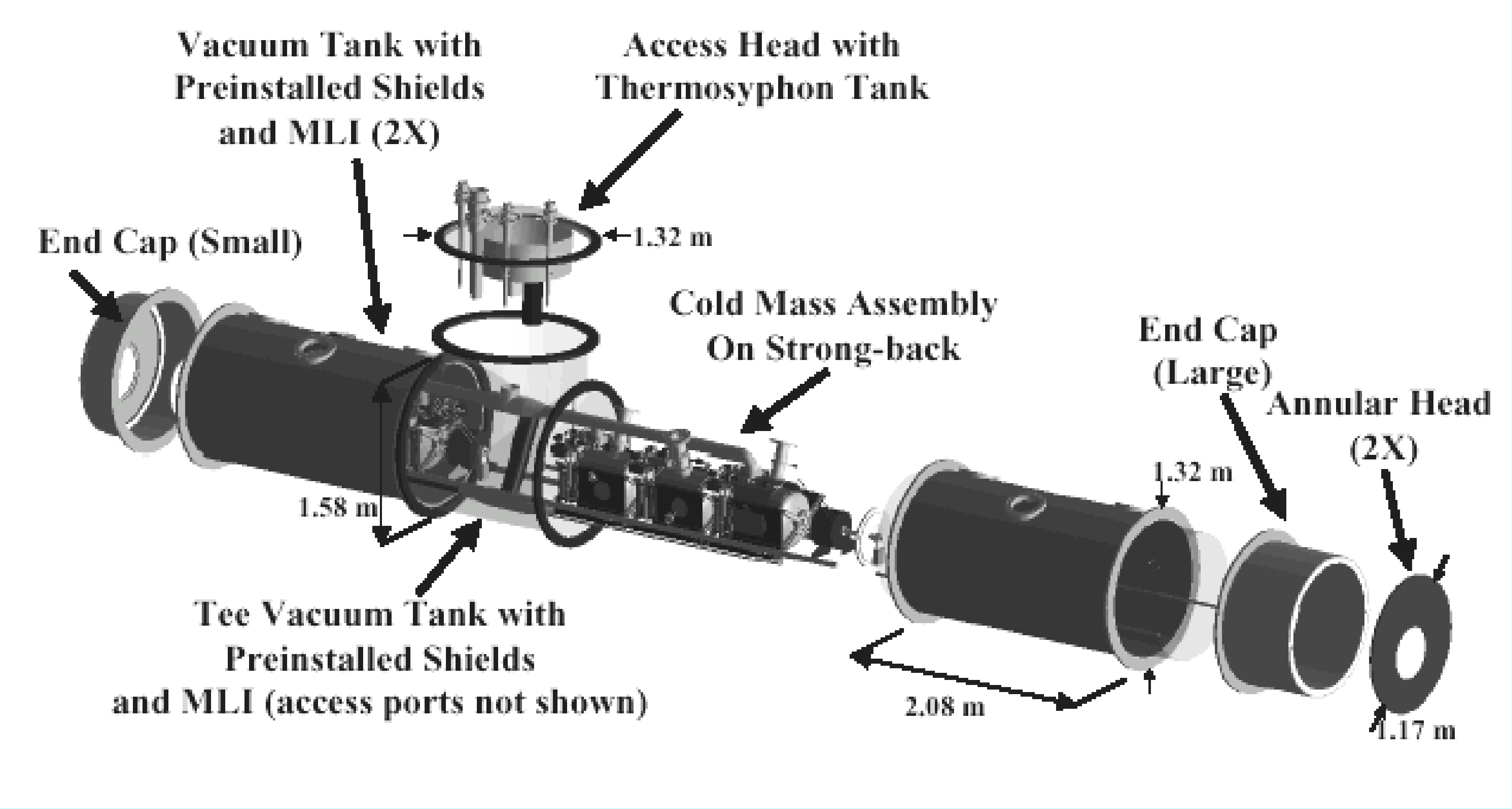
Window support frame and flanges

center conductor coolant plenum

vacuum pump and valve

A. Facco – SRF 2003

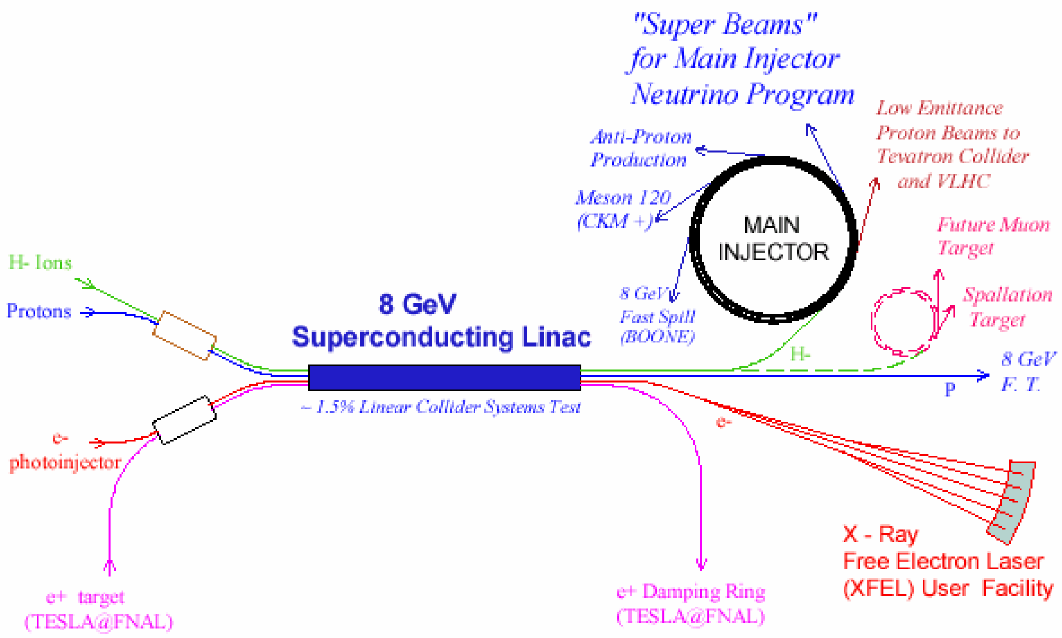
A cryomodule and a cryosystem have been designed



J. P. Kelley et al., CEC/ICMC 2001

FNAL 8 GeV linac

Multi-Mission 8 GeV Injector Linac



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8 GeV LINAC

Energy	GeV	8	
Particle Type	H- Ions, ~~Protons~~, or Electrons		
Rep. Rate	Hz	10	
Active Length	m	671	
Beam Current	mA	25	
Pulse Length	msec	1	
Beam Intensity	P / pulse	1.5E+14	(can be H-, P, or e-)
	P/hour	5.4E+18	
Linac Beam Power	MW avg.	2	
	MW peak	200	

"Copy" SNS 402.5 MHz RFQ & DTL up to 87MeV

805 MHz Superconducting Linac up to 1.2 GeV

- Three sections: Beta = 0.47, 0.61, 0.81
- Use cavity designs developed for SNS & RIA
- TESLA-style cryomodules for higher packing factor

1.2 GHz "TESLA" cryomodules from 1.2-8 GeV

- This section can accelerate electrons as well
- RF from one Klystron fanned out to 12 cavites

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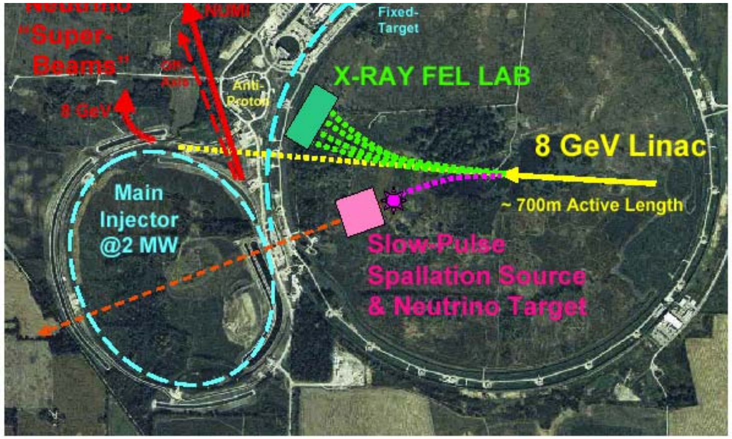
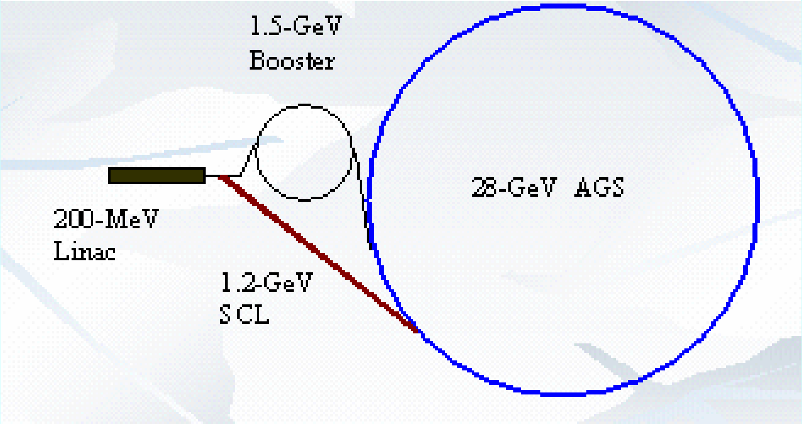
Estimated cost: 369 M$



The 1.2-GeV SCL for the 1-MW AGS Upgrade

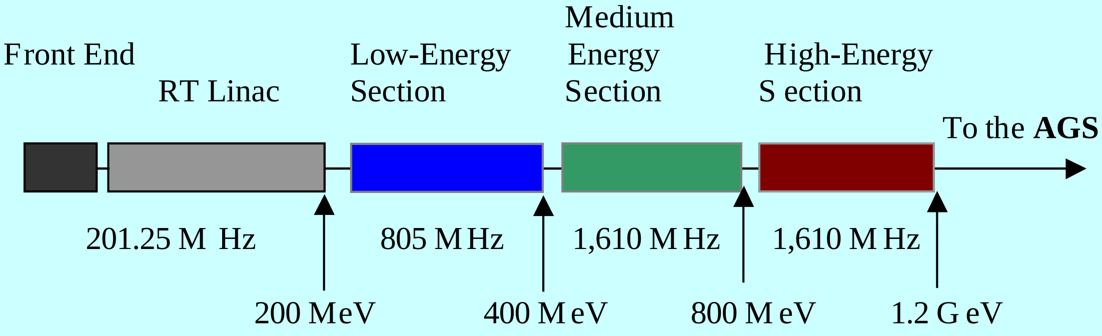
	AGS Present	AGS Upgrade	SNS
Kinetic Energy, GeV	28.0	28.0	1.0
Protons / Cycle, x 10^{14}	0.67	0.89	1.56
Repetition Rate, Hz	1/3	2.5	60
Ave. Power, MW	0.10	1.0	1.4
Linac Pulse Length, ms	--	0.72	1.0
Linac Duty Factor, %	--	0.18	6.0
Linac Peak Current, mA	--	28.0	38.0



Scope: increase ×10 the AGS beam power to produce intense neutrino beams

SNS cavity technology at twice the SNS frequency

Estimated cost: 100 M$



Front End

RT Linac

Low-Energy Section

Medium Energy Section

High-Energy Section

To the **AGS**

201.25 MHz

805 MHz

1,610 MHz

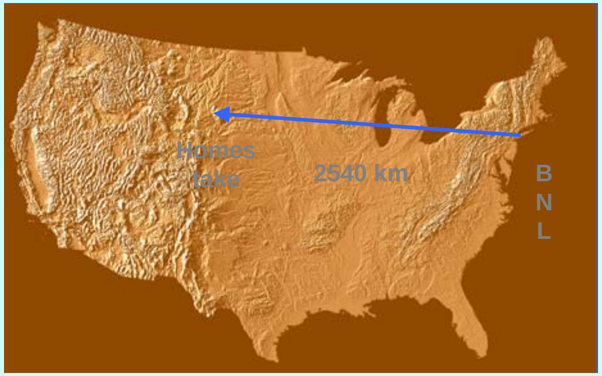
1,610 MHz

200 MeV

400 MeV

800 MeV

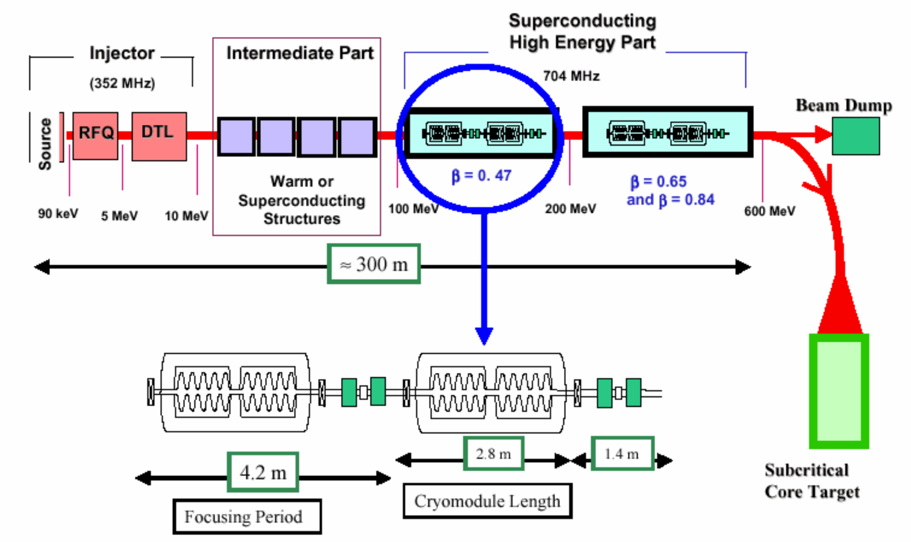
1.2 GeV

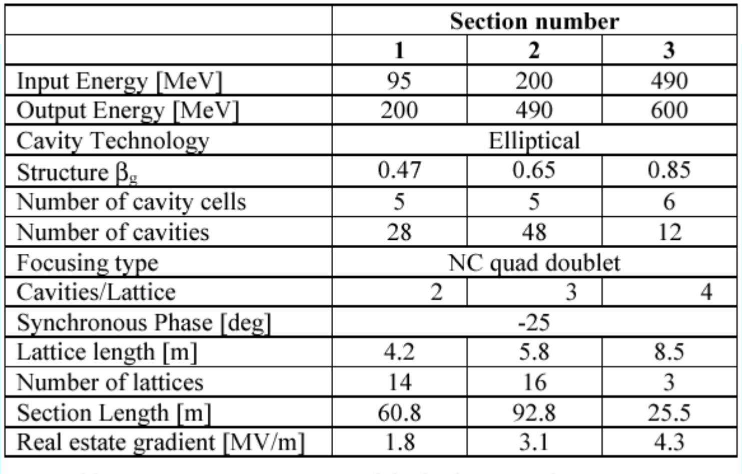


HISPL in EUROPE

XADS

Experimental Accelerator Driven System





	Section number		
	1	2	3
Input Energy [MeV]	95	200	490
Output Energy [MeV]	200	490	600
Cavity Technology	Elliptical		
Structure β_g	0.47	0.65	0.85
Number of cavity cells	5	5	6
Number of cavities	28	48	12
Focusing type	NC quad doublet		
Cavities/Lattice	2	3	4
Synchronous Phase [deg]	-25		
Lattice length [m]	4.2	5.8	8.5
Number of lattices	14	16	3
Section Length [m]	60.8	92.8	25.5
Real estate gradient [MV/m]	1.8	3.1	4.3

Table VIII - Main parameters of the high-energy linac sections.

- Scope: Nuclear waste transmutation by means of a AD subcritical reactor
- 25 partners, 12 M€ program 50% funded by the European Community
- Linac: High reliability, fault tolerance, stability!
- 10 mA cw
- 600 MeV (tunable)
- SC above ~10÷100 MeV
- French-Italian-German SC cavity technology developed in earlier national projects (ASH, IPHI, TRASCO, ESS, CONCERT,…)

EURISOL Driver

European Radioactive Ion Beam Facility Proton Driver

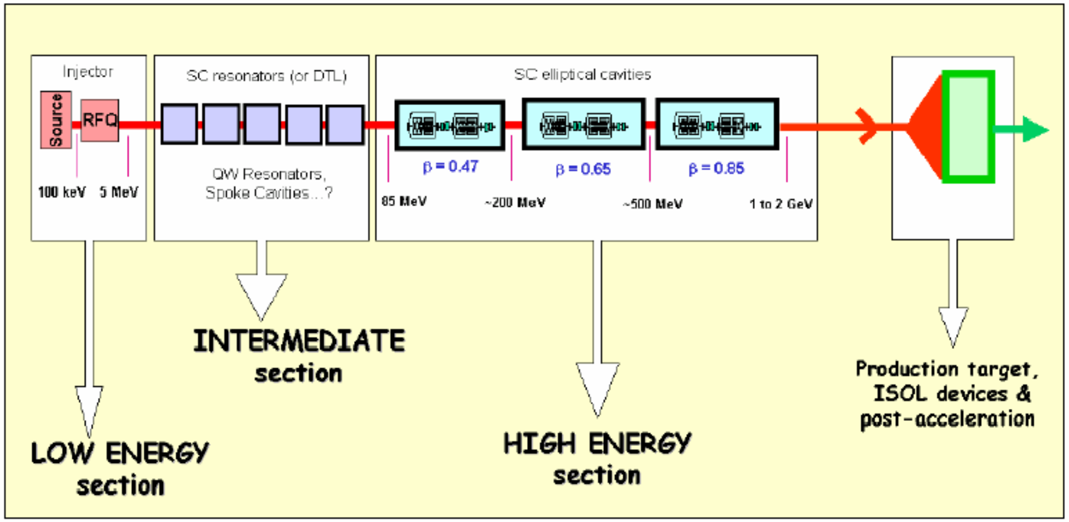


Fig. 3.1: General layout of the EURISOL proton driver accelerator.

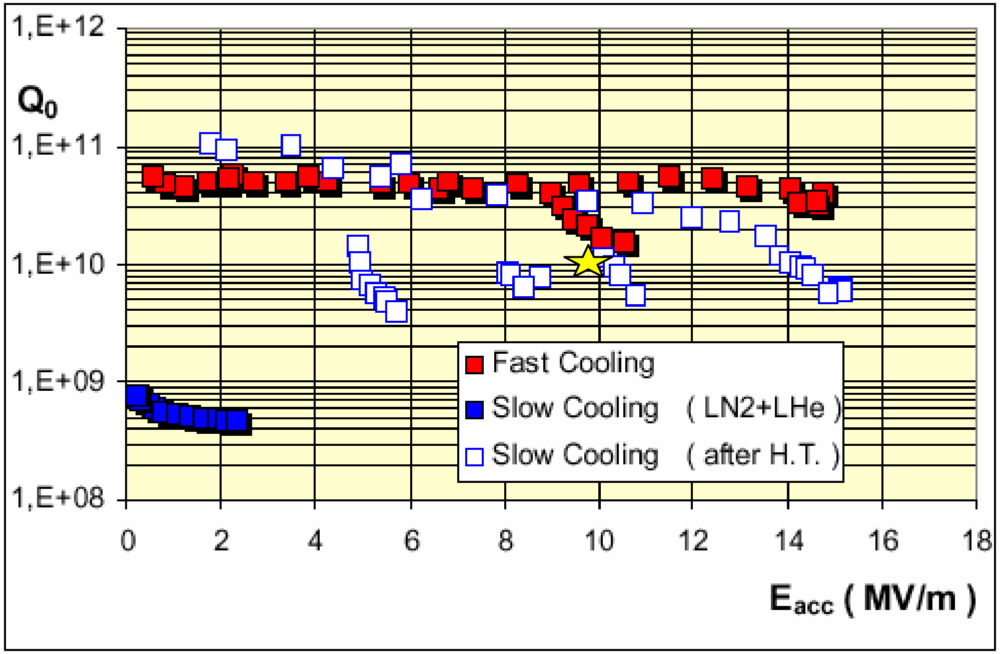
	β=0.47 section	β=0.65 section	β=0.85 section
Input energy (MeV)	85	192	481
No. of cavities per module	2	3	4
Lattice length (m)	4.1	5.65	8.1
No. of modules	15	16	14
No. of cavities	30	48	56
Section length (m)	61.5	90.4	113.4
E_{acc} (MV/m)	4.6 to 9.1	5.7 to 10.7	8.8 to 12.6

- Large international collaboration supported by the European Community
- French-Italian-German SC cavity technology
- 5 mA cw
- 1 GeV
- $P_{rf} \leq 50$ kW/cavity
- SC above 5÷85 MeV
- below 85 MeV few possible options

5-cell cavities β=0.65

5 cells 700 MHz β=0.65

Superconducting Cavity (CEA-CNRS)

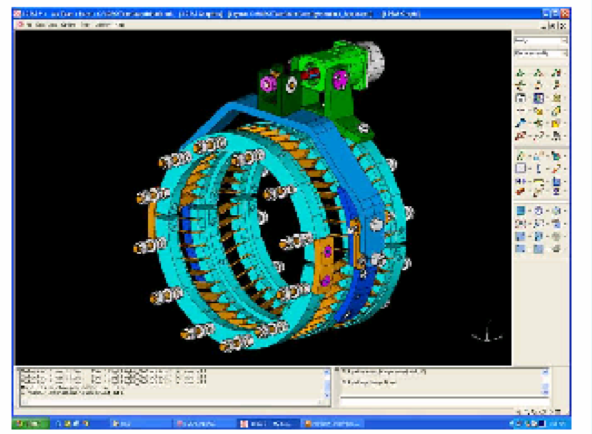


☆ (XADS goal : 1.10^{10} - 10 MV/m)

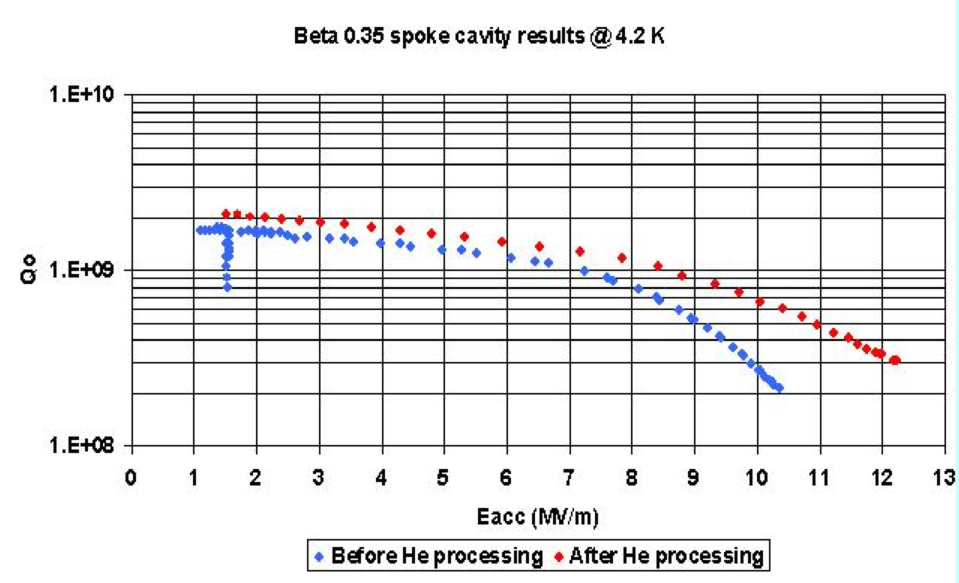
INFN Milano β=0.5 cavities

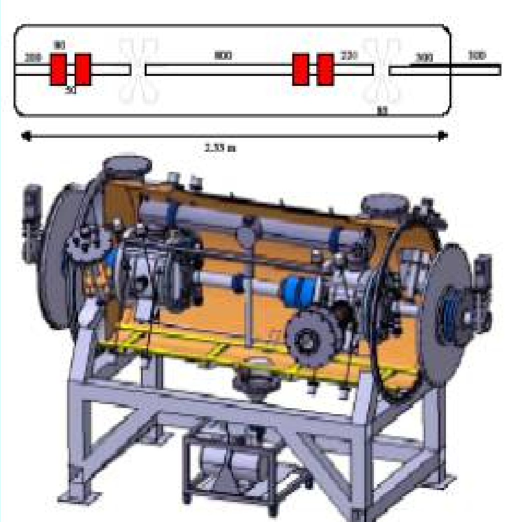
700 MHz, β=0.5 5-cells cavities

Tesla-type coaxial cold tuner for 700 MHz cavities



IPN Orsay β=0.35, 352 MHz Spoke resonator





Fault tolerant Spoke cavity Linac:

- 5÷ 80 MeV
- 84 cavities: 30 β=0.12 and 54 β=0.35
- Cavity aperture 60 mm
- Superconducting quadrupole doublets
- SC Linac length : 91 m
- Possible injector for XADS

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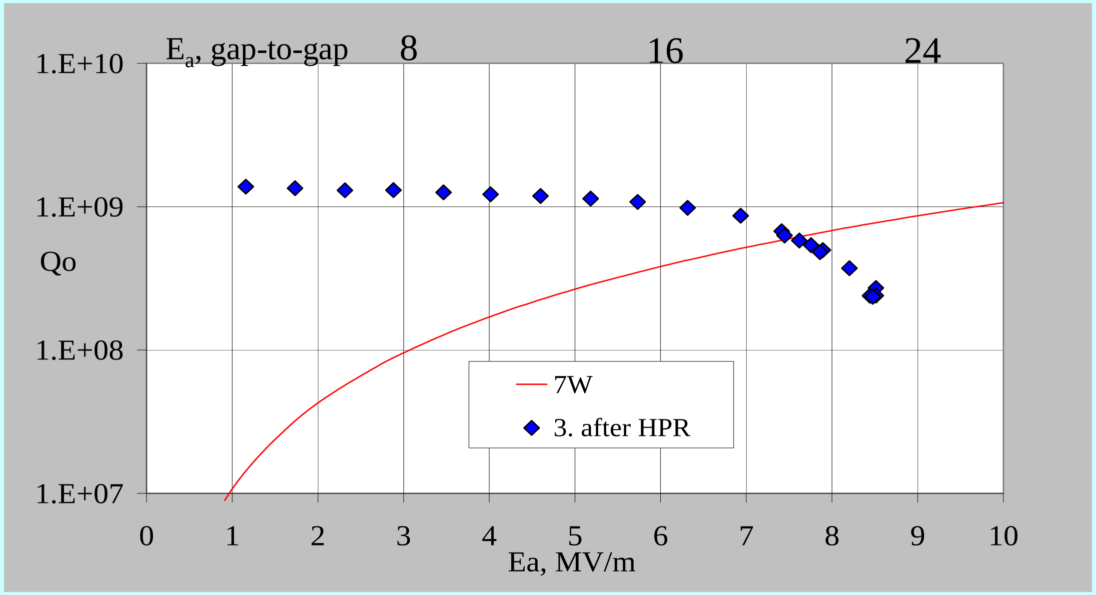
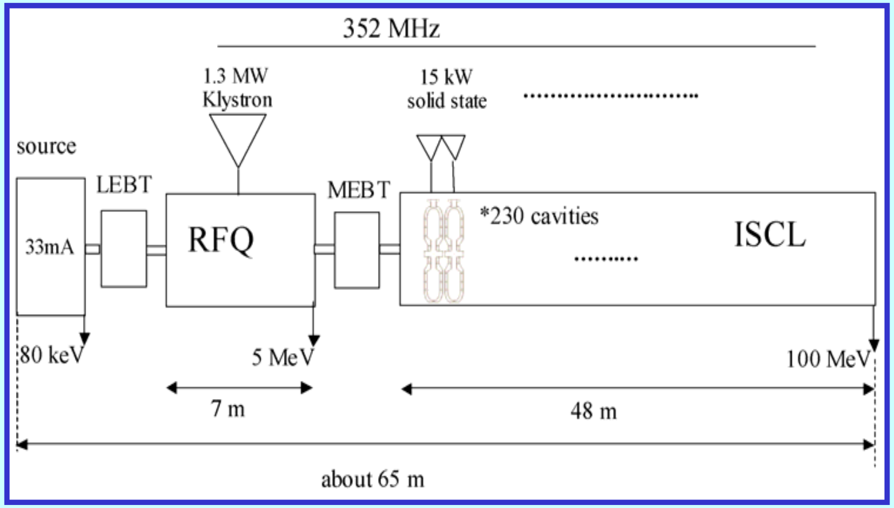
LNL β>0.1, 352 MHz Reentrant cavity





TRASCO 30 mA Fault tolerant Linac with Reentrant Cavities

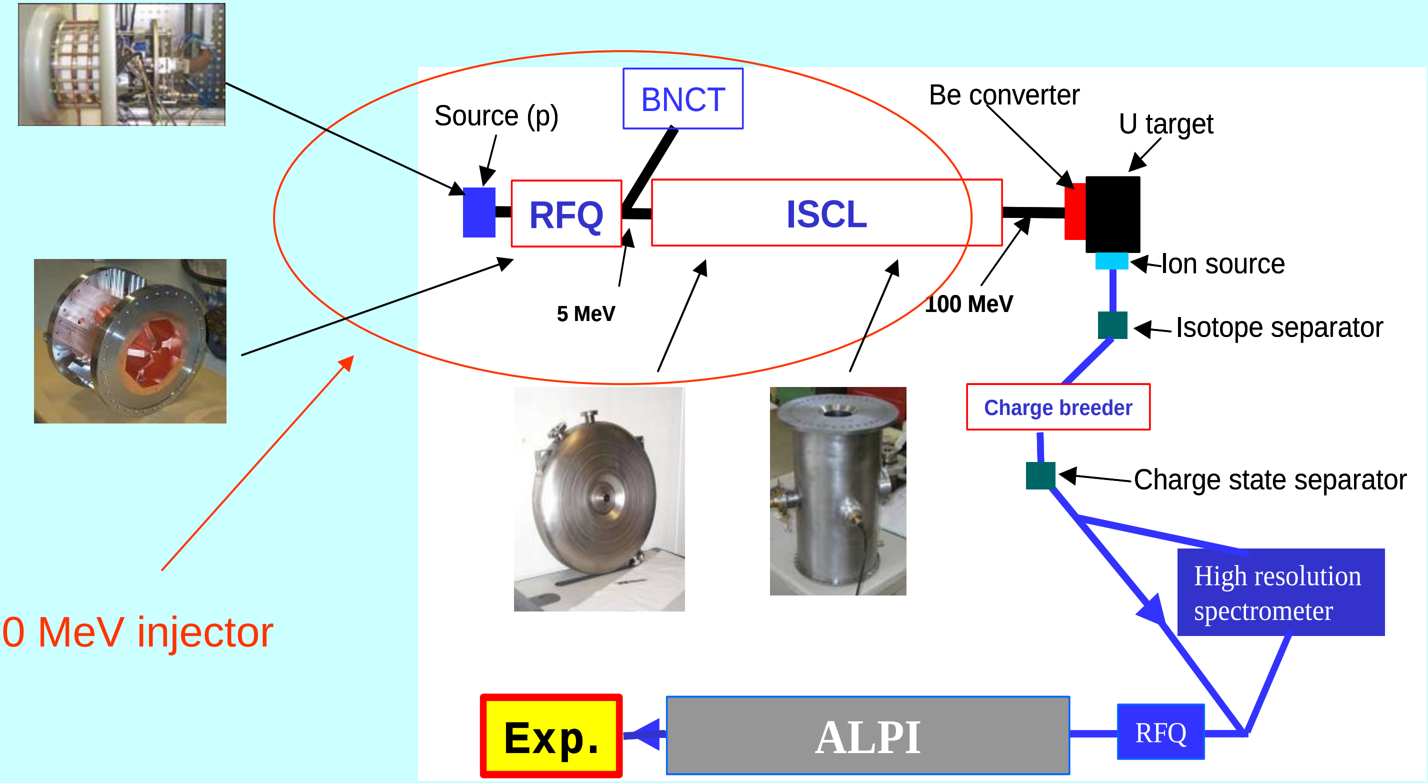
- 5÷ 100 MeV
- 230 cavities
- Cavity aperture 30 mm
- Superconducting quadrupole singlets in a FODO lattice

- SC Linac length : 48 m

SPES at LNL

Study and Production of Exotic Species

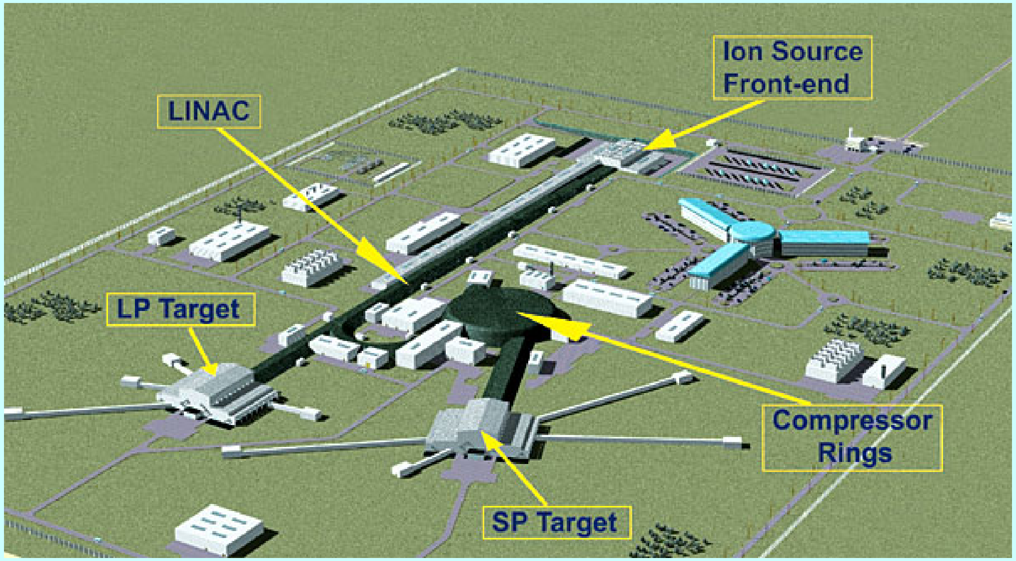
- Radioactive Ion Beam facility with a 100 MeV, 3 mA proton Driver
- RIB production with ISOL method
- RIB reacceleration in the existing LNL SC linac up to 15 MeV/u
- Neutron production at 5 MeV for BNCT skin melanoma treatment and neutron physics
- Critical decision for the construction of the 1st 20 MeV coming soon

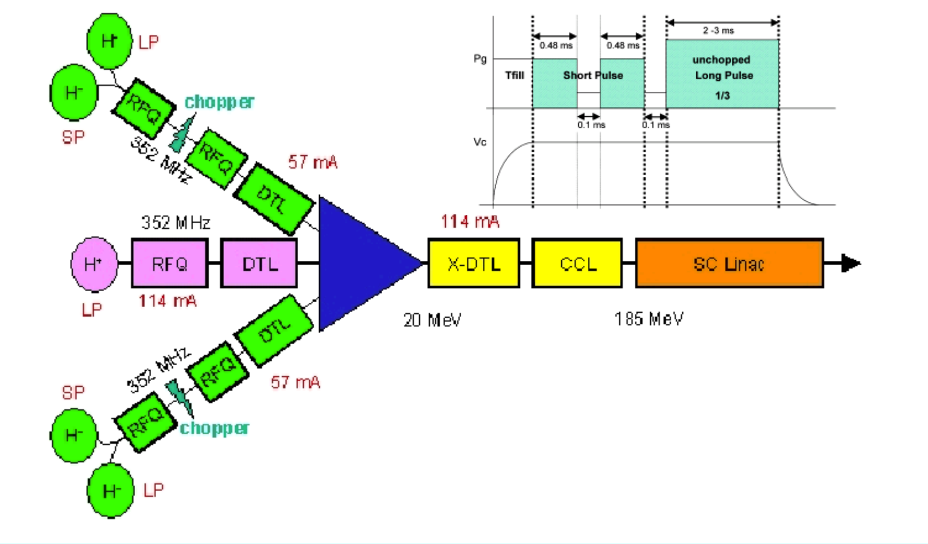


Possible 100 MeV injector for Eurisol

ESS - European Spallation Source

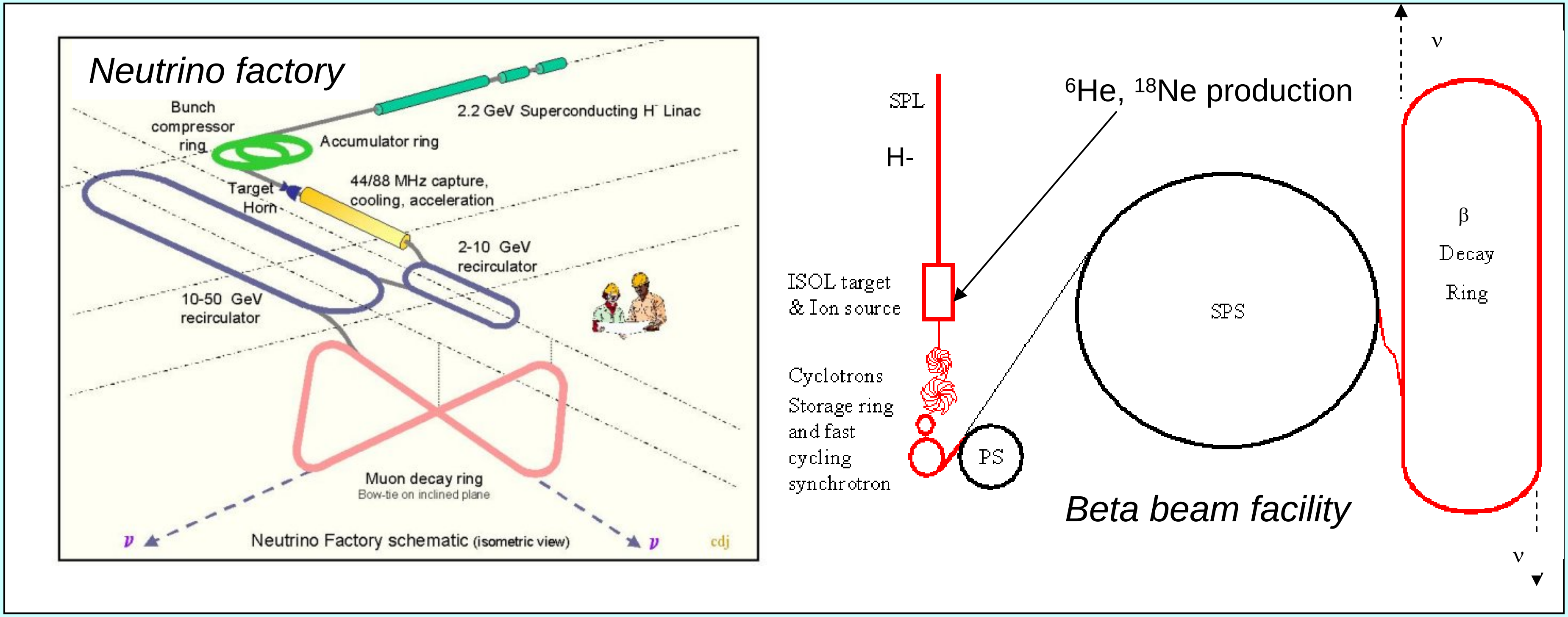
- 10 MW beam on 2 targets
- Proposal presented by 20 European institutions
- 10 y project; cost ~1.5 B€
- Weak support at present from most European governments
- Political decision hoped within 5 years





- β=0.66 and β=0.85 5-cell cavities
- 10.5 and 12.5 MV/m (50 mT)
- 2 couplers/cavity, 1.6 MW peak
- 704 MHz, 185-1348 MeV SC linac
- 114 mA H- peak current
- 7.5% duty cycle
- 0.5 ms @50 Hz pulses on target 1
- 2 ms@16.6 Hz pulses on target 2

SPL at CERN



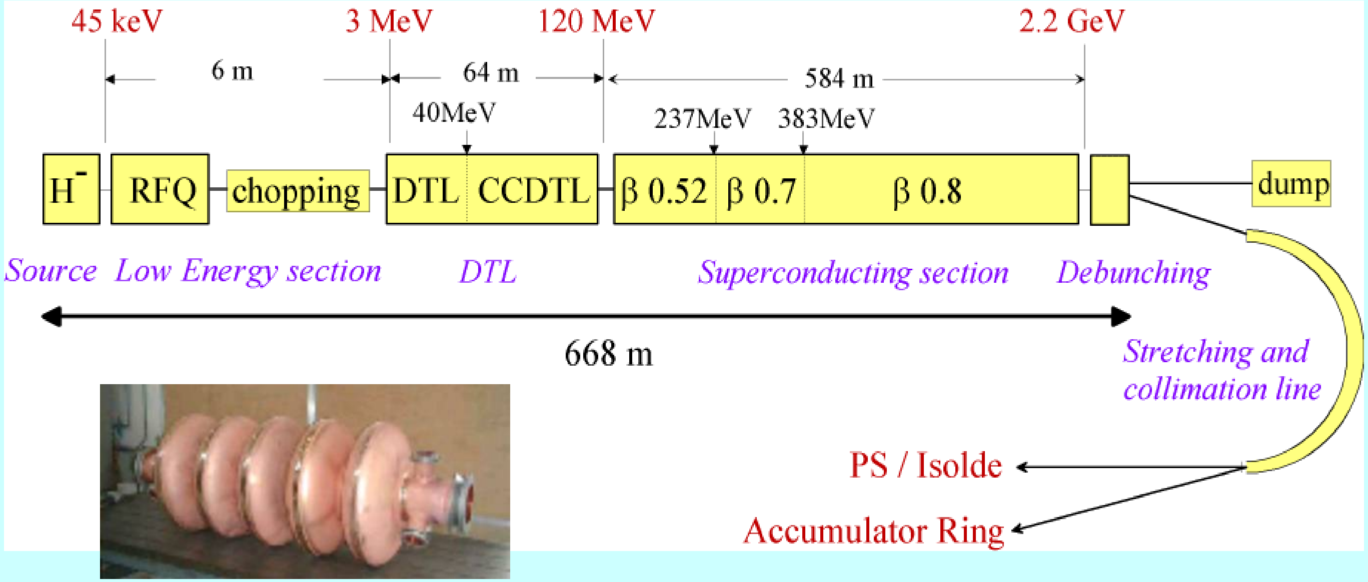
Scope:

To produce intense **neutrino beams** with good emittance (**Super beam, Beta beams**) to bombard underground detectors hundreds or thousands of Km apart

To **upgrade the injector chain for the LHC**

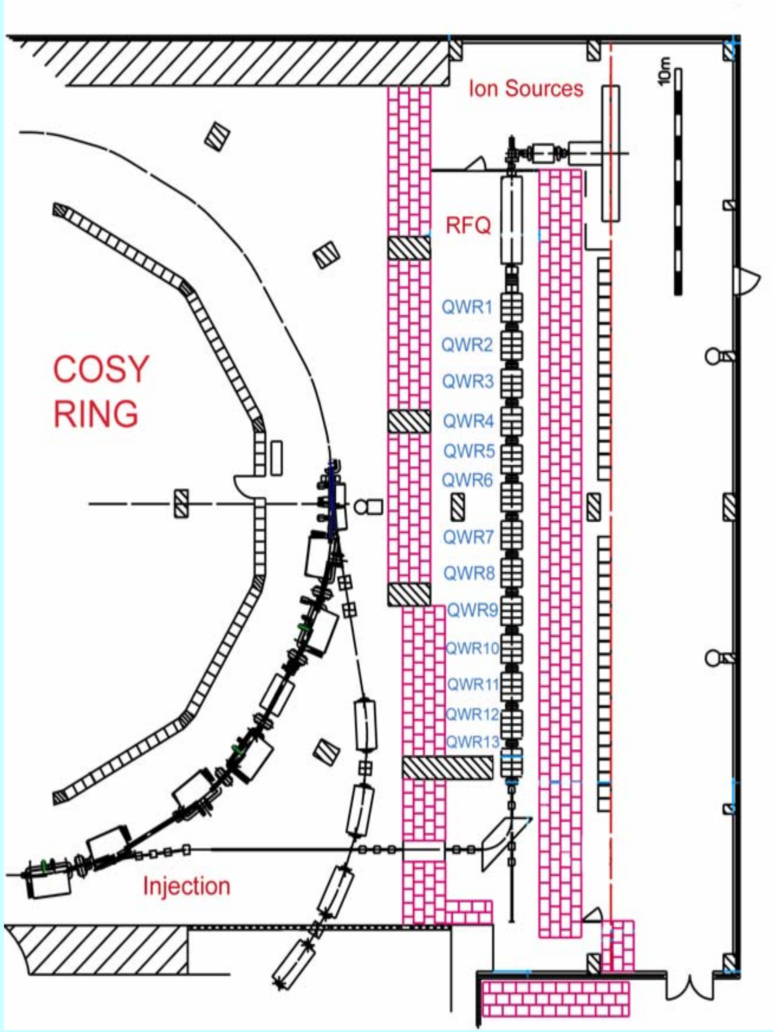
To produce heavy ion **radioactive beams** for nuclear physics (Isolde, Eurisol…)

Superconducting Proton Linac



- 13 mA, H^- beam at 2.2 GeV
- 2.8 ms pulses at 50 Hz (14% duty cycle)
- 4 MW beam power
- 352 MHz, 5 cell cavities made of Nb-Cu and Nb
- It could recuperate most of the RF equipment from the old LEP machine.

COSY-SCL at Juelich



Aim: injection of polarized H^-, D^- beams into the COSY Cooler Synchrotron ring to increase luminosity by 40

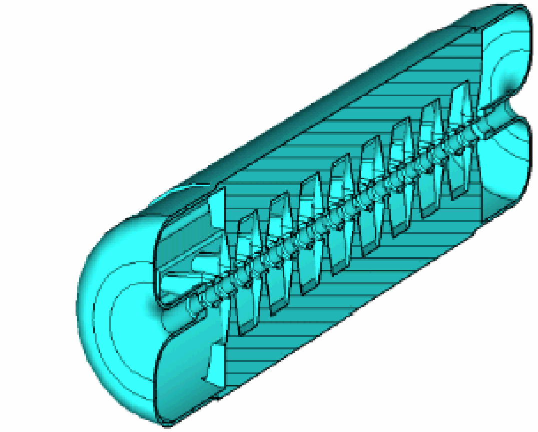
- 50 MeV with both beams
- 2 mA (COSY space charge limit)
- 0.5 ms pulses @ 2 Hz

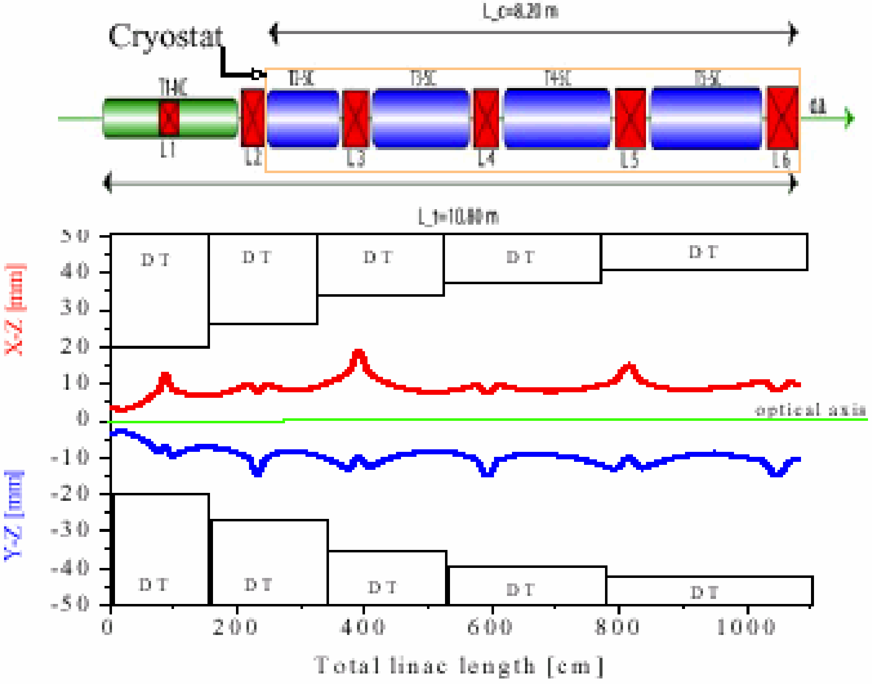
- 44 HWRs
- 8 MV/m
- 160-320 MHz
- β=0.11-0.2
- Prototypes under construction

Due to budget cuts the project was suspended for 2 years. The critical components R&D and the design work is continuing

IFMIF: 40 MeV SC linac for D^+

- International Fusion Material Irradiation Facility
- SC linac studied at IAP Frankfurt and GSI
- Deuteron beam on Li target for high neutron flux
- Main application: material testing

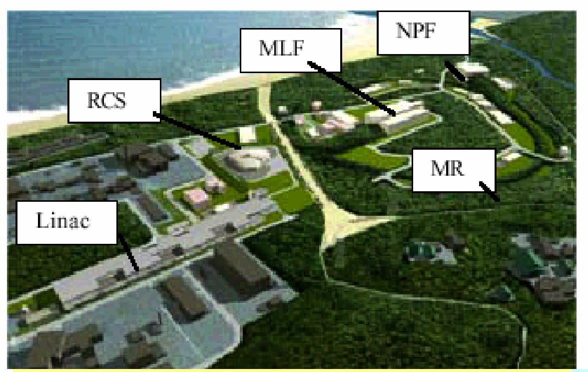


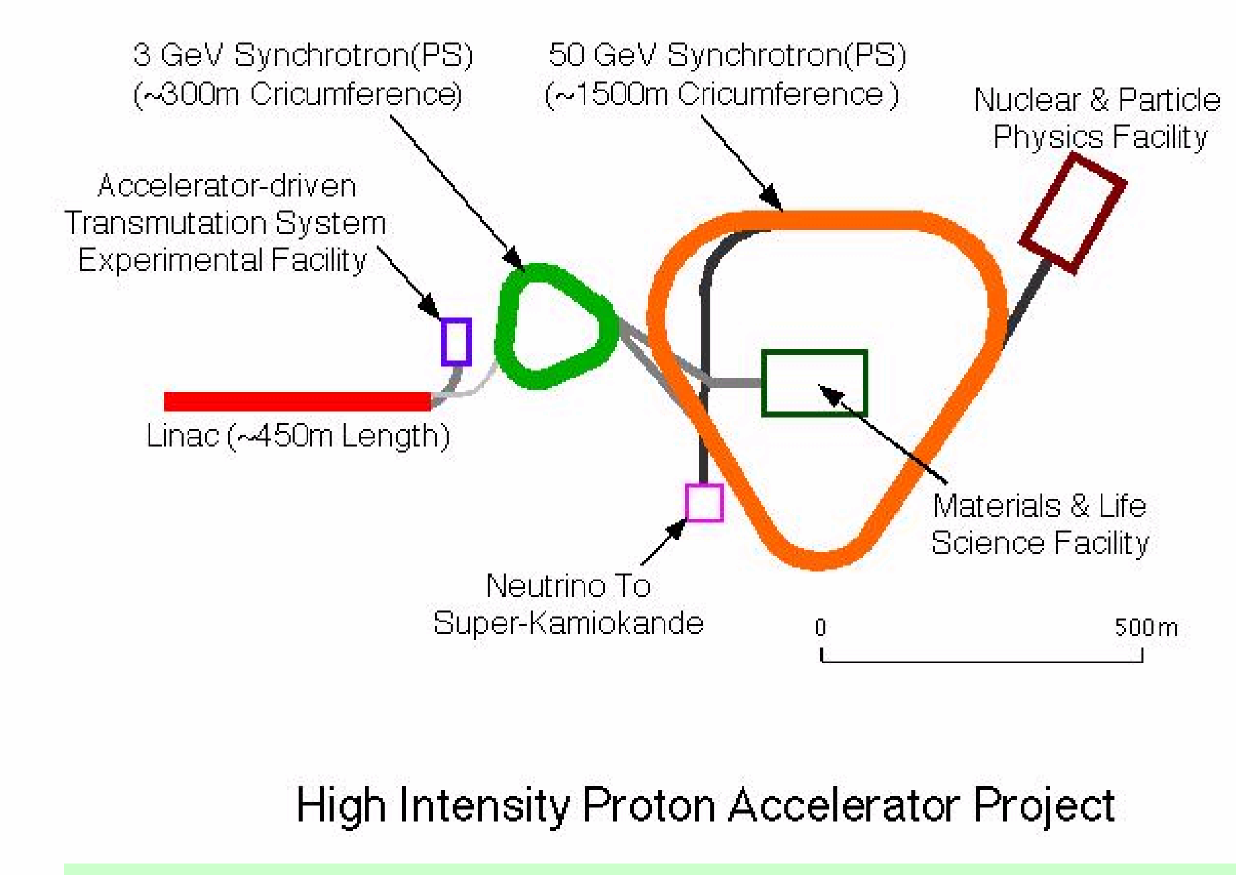


- E_{in}=5 MeV
- E_{out}40 MeV
- I= 125 mA CW
- 4 CH multi-gap 175 MHz SC cavities (+1 NC IH)
- 750 kW/cavity
- KONUS beam dynamics: extremely compact
- High efficiency

HISPL in ASIA

JPARK JAERI KEK





High Intensity Proton Accelerator Project

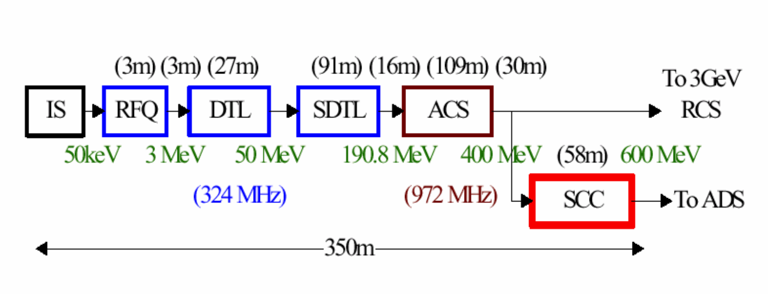
Under construction, to be completed in 2007

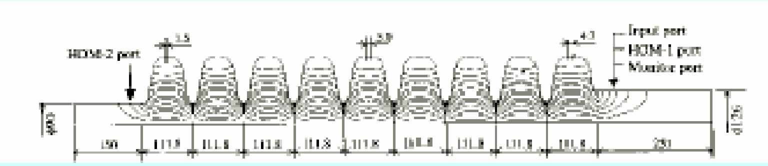
Aims: pursue frontier science in
- particle physics
- nuclear physics
- materials science
- life science
- nuclear technology

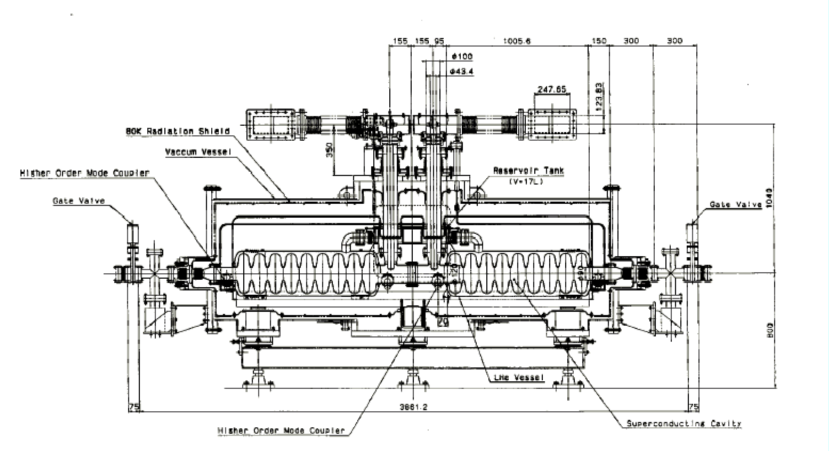
SC linac section not yet funded, still in R&D

The present new plan is proposed jointly by the High Energy Accelerator Research Organization (KEK) and the Japan Atomic Energy Research Institute (JAERI) and based on the past proposals of the Japan Hadron Facility (JHF) at KEK. and the Neutron Science Project(NSP) at JAERI.

JPARK SC Linac

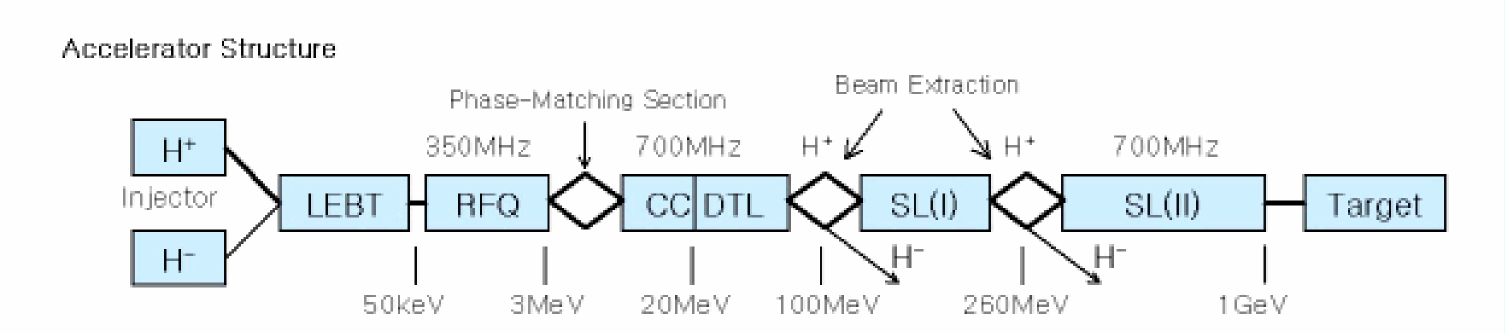


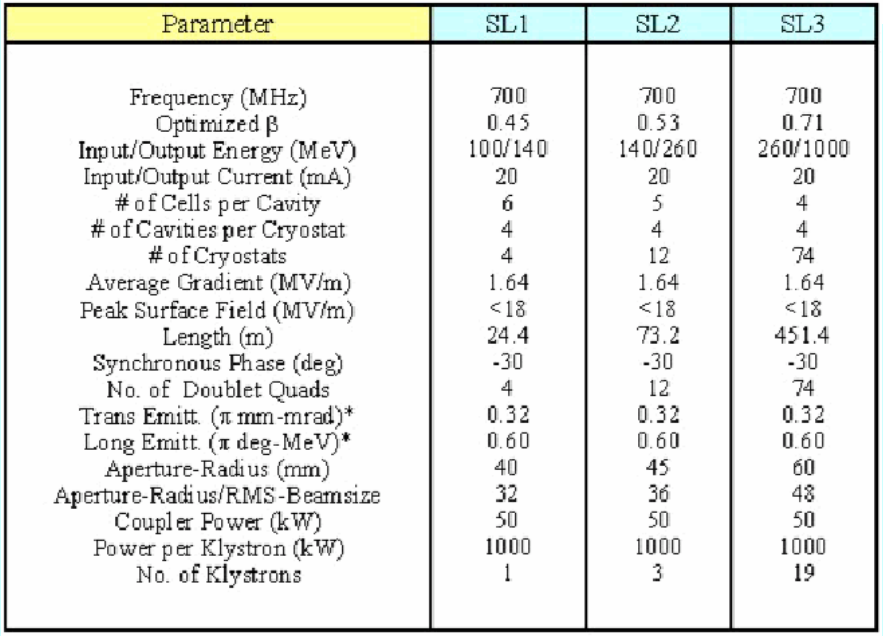




- Aim of the SC section: energy upgrade for ADS applications
  - 30 mA beam
  - 0.6 ms pulses @ 25 Hz (1.5 % duty cycle)
  - 11 cryomodules 2 cavities each
  - 9 cell, 972 MHz elliptical cavities with β=0.725 (no HOM expected)
  - Design gradient 10 MV/m
  - Cryomodule development in an advanced stage
  - Construction after 2006

KOMAC at KAERI
Korean Multi-purpose Accelerator Complex

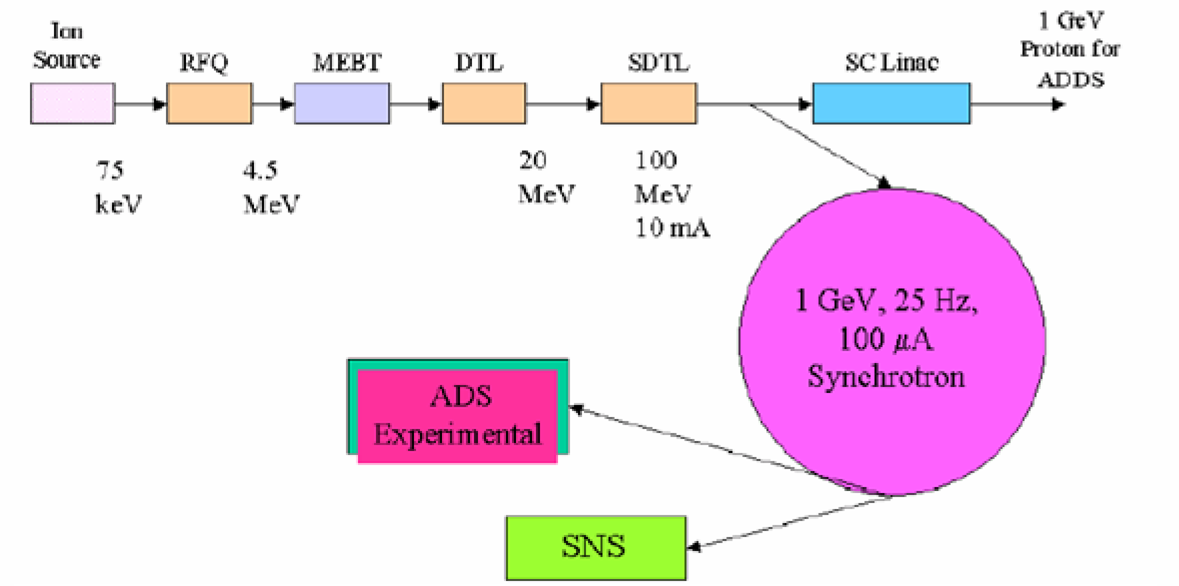




Parameter	SL1	SL2	SL3
Frequency (MHz)	700	700	700
Optimized β	0.45	0.53	0.71
Input/Output Energy (MeV)	100/140	140/260	260/1000
Input/Output Current (mA)	20	20	20
# of Cells per Cavity	6	5	4
# of Cavities per Cryostat	4	4	4
# of Cryostats	4	12	74
Average Gradient (MV/m)	1.64	1.64	1.64
Peak Surface Field (MV/m)	<18	<18	<18
Length (m)	24.4	73.2	451.4
Synchronous Phase (deg)	-30	-30	-30
No. of Doublet Quads	4	12	74
Trans Emitt. (π mm-mrad)*	0.32	0.32	0.32
Long Emitt. (π deg-MeV)*	0.60	0.60	0.60
Aperture-Radius (mm)	40	45	60
Aperture-Radius/RMS-Beamsize	32	36	48
Coupler Power (kW)	50	50	50
Power per Klystron (kW)	1000	1000	1000
No. of Klystrons	1	3	19

- Aim:
    - Basic research
    - Medical therapy
    - Waste transmutation
    - Industrial applications
- 20 mA, 1 GeV
- 20 MeV Linac R&D completed
- Project approved up to 100 MeV
- SL planned after 2008

Indian ADS program



Proposed linac and synchrotron under development at CAT, Indore

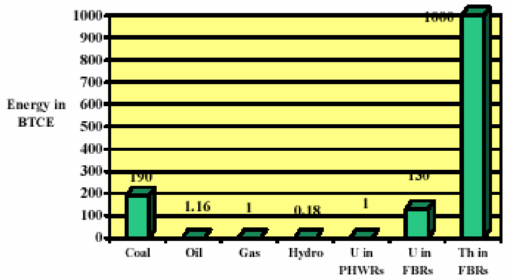


Figure 1. Energy resources in India

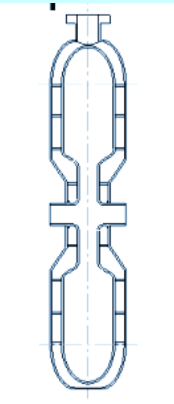
Scope of the program: Develop ADS for nuclear power production using Thorium fuel

•Aim at CAT: Build a multitask facility including ADS experiments and Spallation neutron source

•**Future development: 1GeV HISPL**

•In the next 5 years India will develop a 100 MeV, 10 mA NC linac (at CAT, Indore)

•**R&D on a SC 100 MeV linac with reentrant cavities**



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Accel 40 MeV P,D SC linac
The first low- β HISPL?

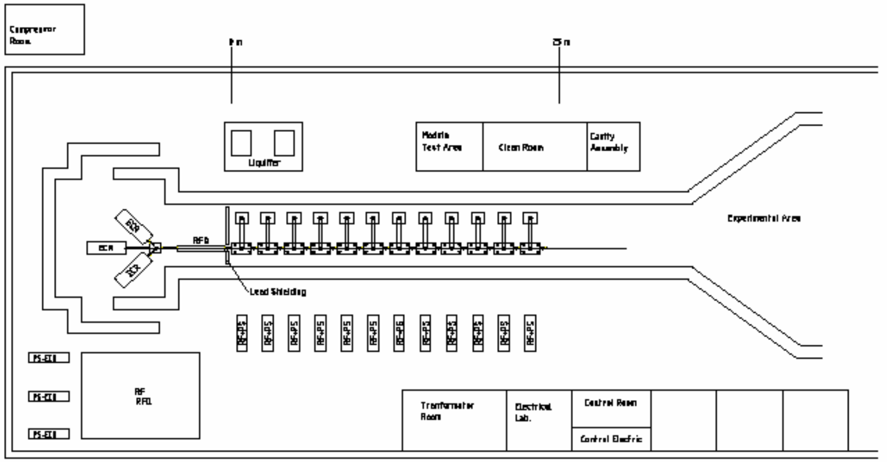
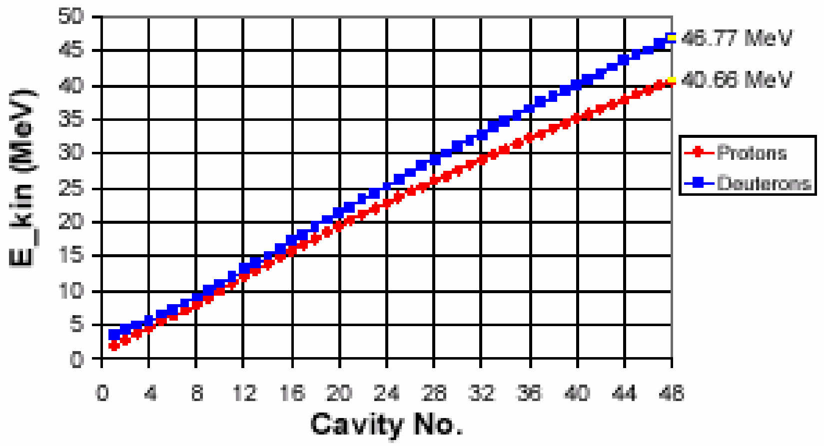
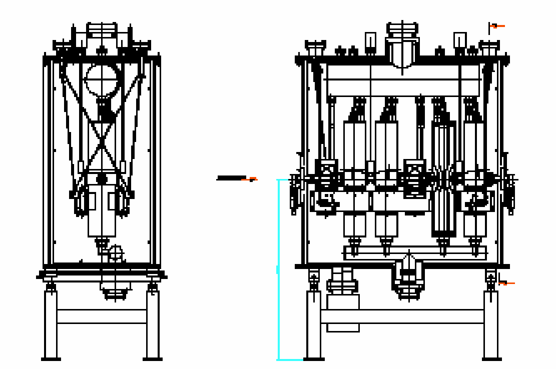


Figure 1: General layout

- “turn-key” wide-β linac for P,D alternative to cyclotrons
- To be built at SOREQ (Israel), SARAF project
- Main application: radioisotopes production for medical use
- <u>Project funded-Operation in 2008</u>

- **E_{in}=1.5 MeV**
- **E_{out}>40 MeV**
- **I= 4 mA CW**
- **48 HWRs - 176 MHz**





Conclusions

- The HISPL field is more active than ever with many laboratories involved
- SNS in an advanced stage of construction, other projects are starting and new proposals are coming for new applications
- high beta HISPL: the design is mature and all components developed
- low beta HISPL:
  - Different competing design schemes
  - Linac design and cavites are in continuous positive evolution
- New kinds of problems related to high power and reliability requirements must be faced: a lot to do and a promising future

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