Development of super-conducting spoke cavities for an ADS linac

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Table of contents

Table of contents

Why do we need special reliability ?

Definition of reliability engineering

Facing each component failures of a complex system, such as a driver accelerator, i.e anticipating and monitoring the probability of these failures to achieve the nominal and required behavior of the system.

Consequences of beam failures

Frequently beam interruptions can seriously damage :

- the reactor structures
- the target
- the fuel elements

and also decrease

- the plant availability

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Special reliability for the proton beam

Maximum beam intensity	$4mA$ CW on target
Proton energy	$600MeV$
Beam entry	Vertically
Beam trip number	$<$ 5 per 3 month operation cycle (exceeding 1 second)
Beam stability	Energy $\pm 1\%$ Intensity : $\pm 2\%$ Size $\pm 10\%$

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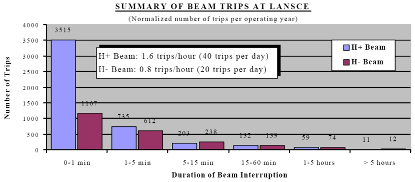
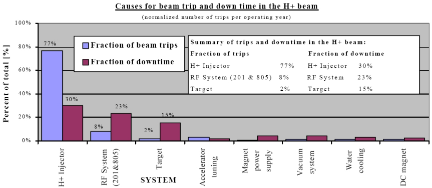
LANSCE

Beam failure statistics of the accelerator facility



Systems responsible for trips and downtime in the H^+ beam



- Injector : 77% of the trips and 30% of the downtime
- RF system : 8% of the trips but accountable for 23% of the downtime

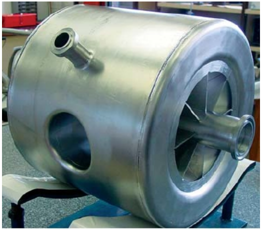
Table of contents

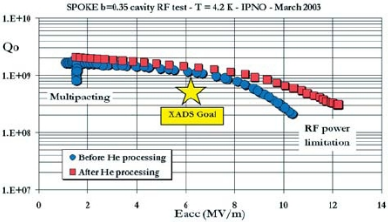
Component overdesign

Overdesign

Any components of the linac must operate well below their technological upper limit.

For the SC spoke $\beta = 0.35$, the maximum accelerating field is twice as much as the working one : $E_{acc,max} = 2E_{acc,nominal}$





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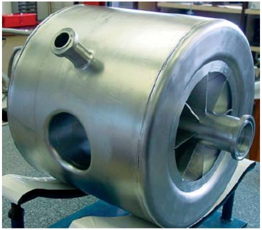

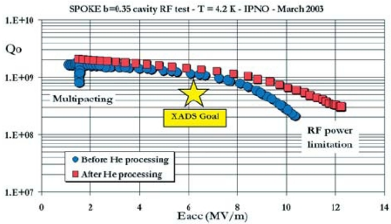

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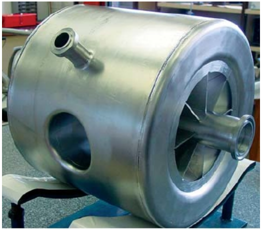
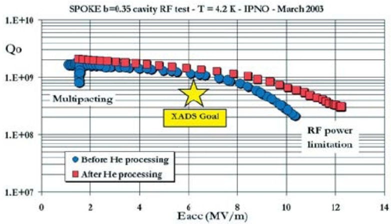


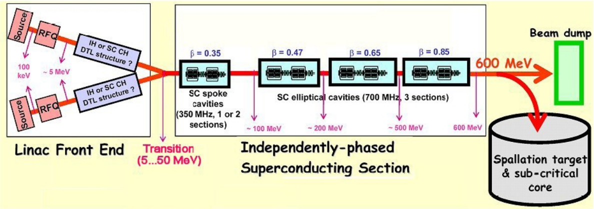


High degree of redundancy

Redundancy

Several components achieve the same function. In case of failure of one, the other component could be turn on to ensure the well running of the function.

The first $\sim 20 MeV$ structure is duplicated



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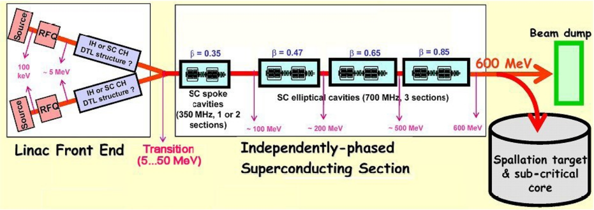

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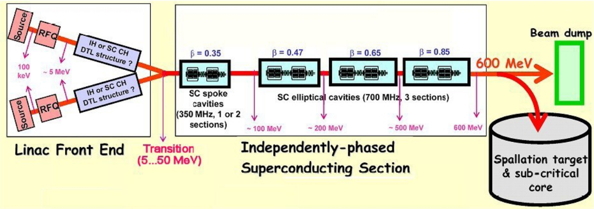
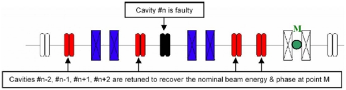


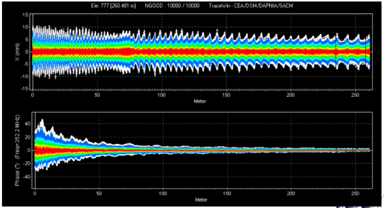
Fault tolerance capabilities

Fault tolerance

Monitoring the system in such a way that component failures do not lead to system failure.

The local compensation method





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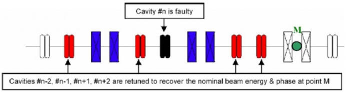

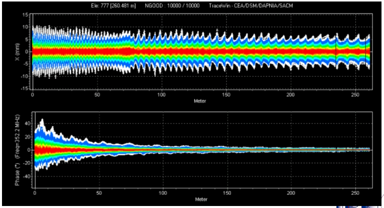

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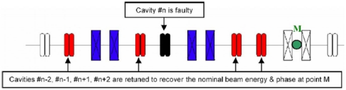


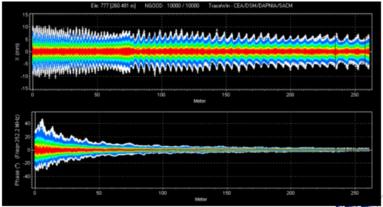
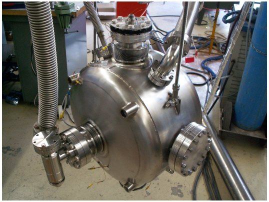


Table of contents

2 spoke prototypes $\beta = 0.35$ and $\beta = 0.15$



- 2-gap-structure
- super-conducting cavity
- large beam aperture : $50mm$ to $60mm$

Labs	Spoke-type	Geometrical /Optimal betas	Eacc max* [MV/m]	Epk [MV/m]	Bpk [mT]	Voltage gain [MV]	Limitation
IPN Orsay	Single	0.15/0.20	4.77	32	69	0.81	Quench
	Single	0.35/0.36	8.15	38	104	2.49	Power
ANL	Single	0.29/0.29	8.46	40	106	2.21	Quench
	Single	0.40/0.40	7.57	46	123	2.63	Quench
	Double	0.40/0.40	8.60	40	79	4.40	Quench
	Triple	0.50/0.50	7.65	28	88	6.65	Quench
	Triple	0.63/0.63	8.61	34	104	9.40	Quench
LANL	Single	0.175/0.21	7.50	38	99	1.34	Quench

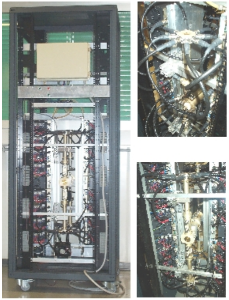
Mean values :

- $E_{acc} = 8MV/m$
- $E_{pk} = 38MV/m$
- $B_{pk} = 100mT$

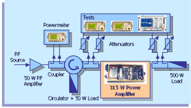
$10kW$ Solid-state amplifier

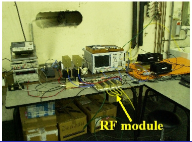
- several modules of $315W$ each
- one module failure does not affect significantly the amplifier behavior
- circulators can support the total reflected power

RF amplifier

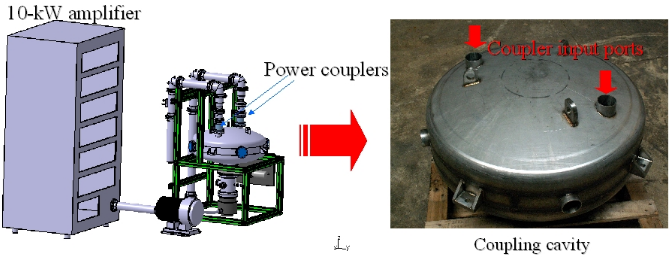


RF module test bench





High power RF test bench



- All components ordered (some already delivered as the coupling cavity, the vacuum pumping system, the supporting frame . . .)
- Final location and installation are almost finished
- June/July 2007 : first tests

A small scale horizontal cryostat

- Cryomodule for fully equipped Spoke cavities (with power coupler & tuning system)
- Cool down at 2K and 4.2 K
- Useful space : $L_{max} = 690mm$ & $diam_{max} = 490mm$

Cryostat operation close to an accelerator configuration (without beam !)

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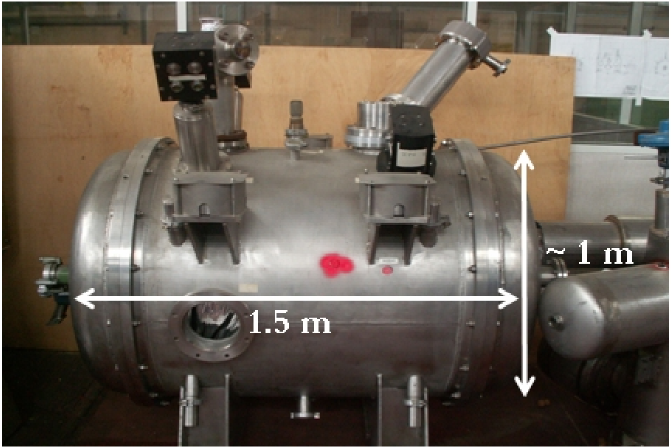
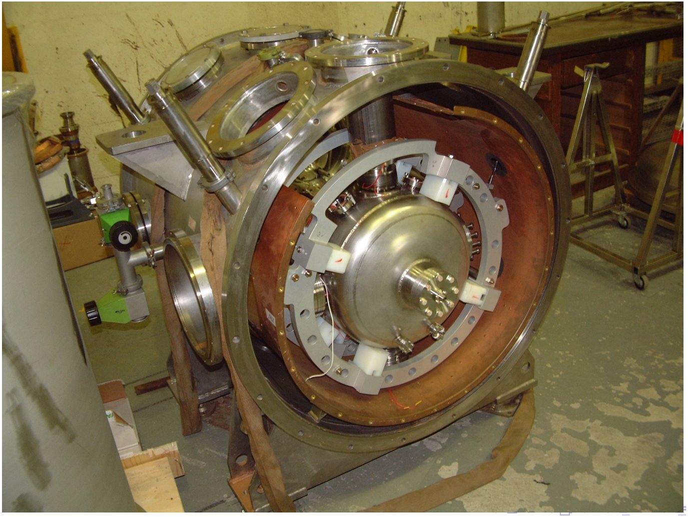
CMO cryostat



Soke $\beta = 0.15$ cavity inside the cryostat

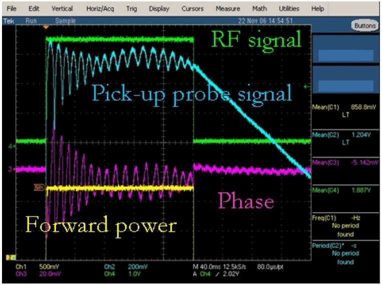


First results of the digital LLRF

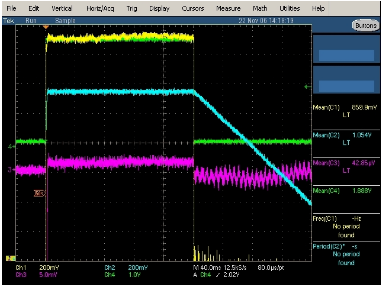
With the $\beta = 0.15$ Spoke cavity at $4.2K$ in a vertical cryostat

Amplitude : $0.1\% (< 0.1\%)$ and Phase : $0.6\% (< 0.5\%)$

Preliminary results



Without regulation



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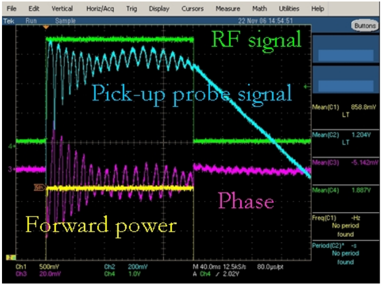

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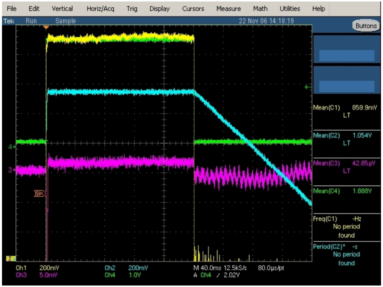
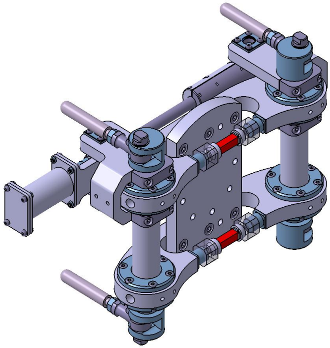


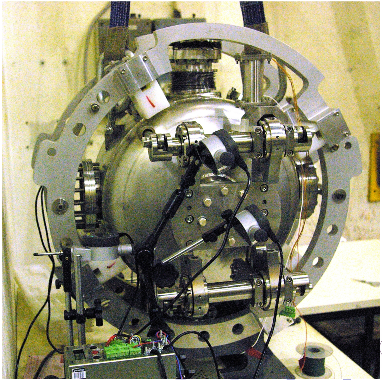
With regulation

Cold tuning system

Test at 300K

Average sensitivity : 0.887Hz per motor step





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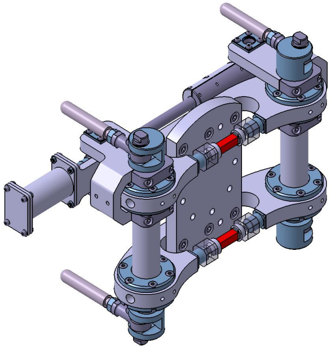

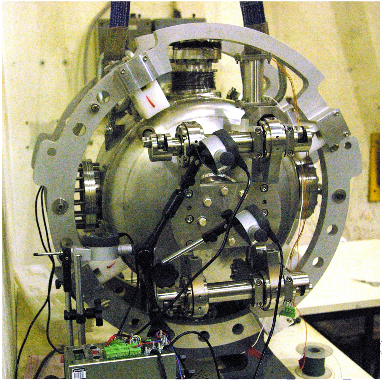

Outlooks with CM0

June/July 2007

CM0 is almost ready for the first cryogenic test including :

- an upgraded digital LLRF system
- the cold tuning system

October/November 2007

A long duration test will be run with a fully equipped Spoke $\beta = 0.15$ cavity :

- beam coupler supplied with the $10kW$ solid state amplifier
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- Spoke cavities performances
- Digital LLRF system in vertical cryostat
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