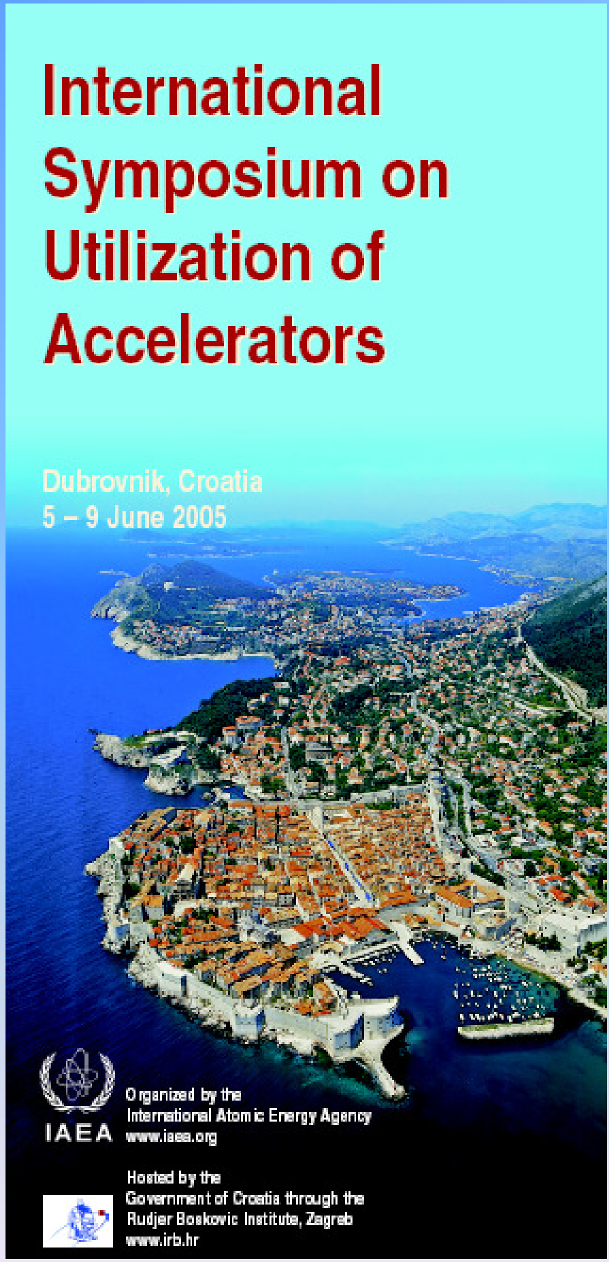

Optimisation of Accelerator Reliability for ADS: Example of SC Cavities and the Associated RF Power Couplers

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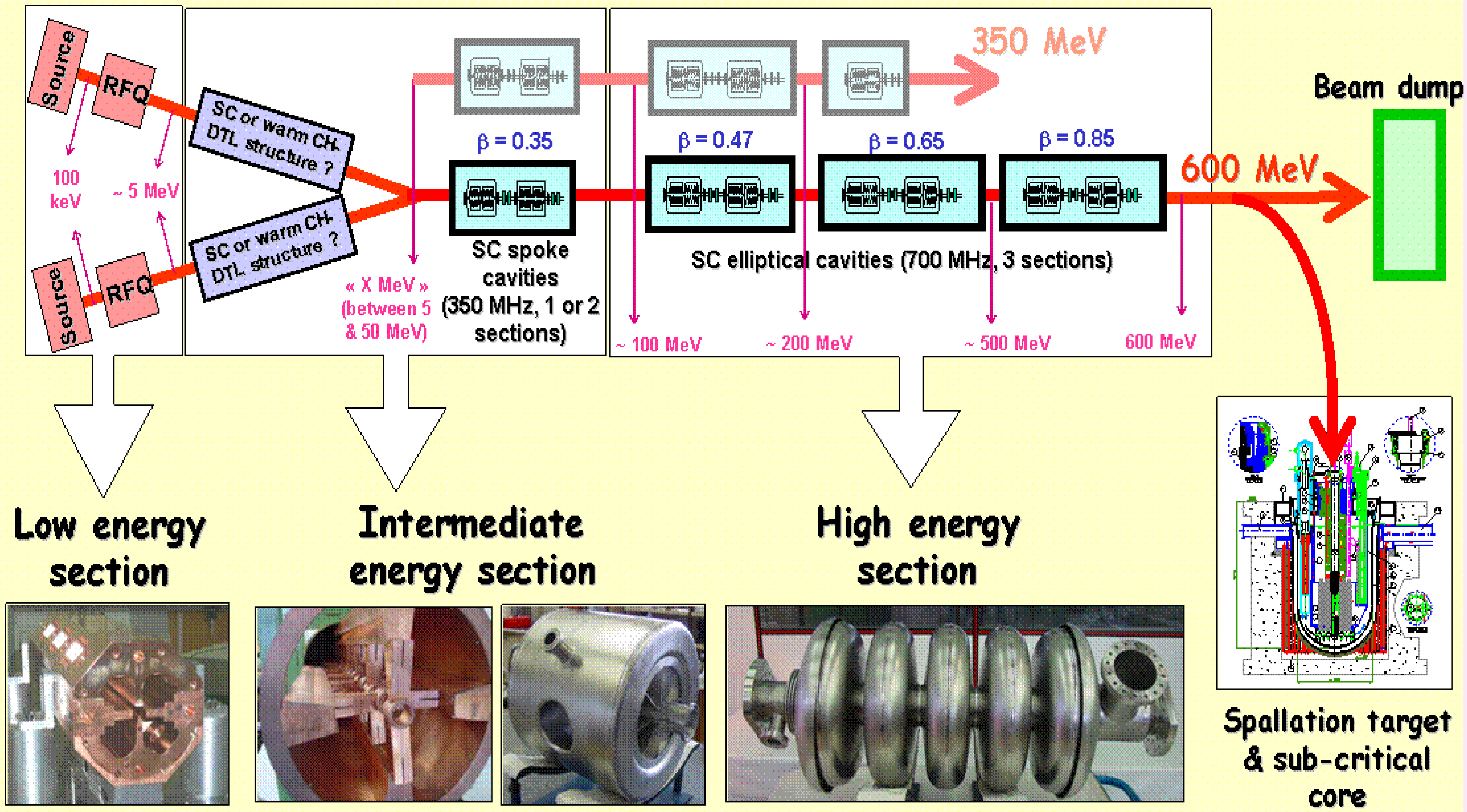
Optimisation of Accelerator Reliability for ADS

Accelerator specifications



Optimisation of Accelerator Reliability for ADS

Critical area: the RF system

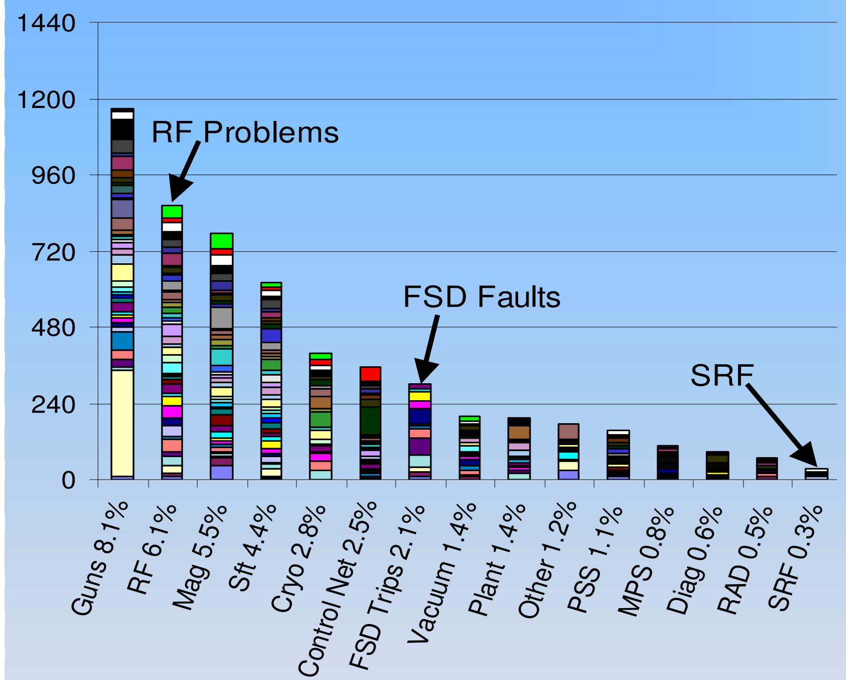
Component SNS	Number	MTBF, khr	Failures year	MTTR, hr	Down Time/ year, hr
Klystron	81	50	9.72	4.5	43.7
Wave Guide	81	150	3.24	3.0	9.72
Load	81	75	6.48	3.0	19.4
Circulator	81	50	9.72	3.0	29.2
Converter/ Modulator	7	22.6	1.86	4.0	7.43
Transmitter	14	5.6	15	3.0	45.0
Window	81	100	4.68	24.0	116.6
LLRF	81	100	4.68	2.0	9.73
Totals			55.7		280.8

Table 4. Down time allocation for the 805 MHz, Super Conducting (SRF) RF System.

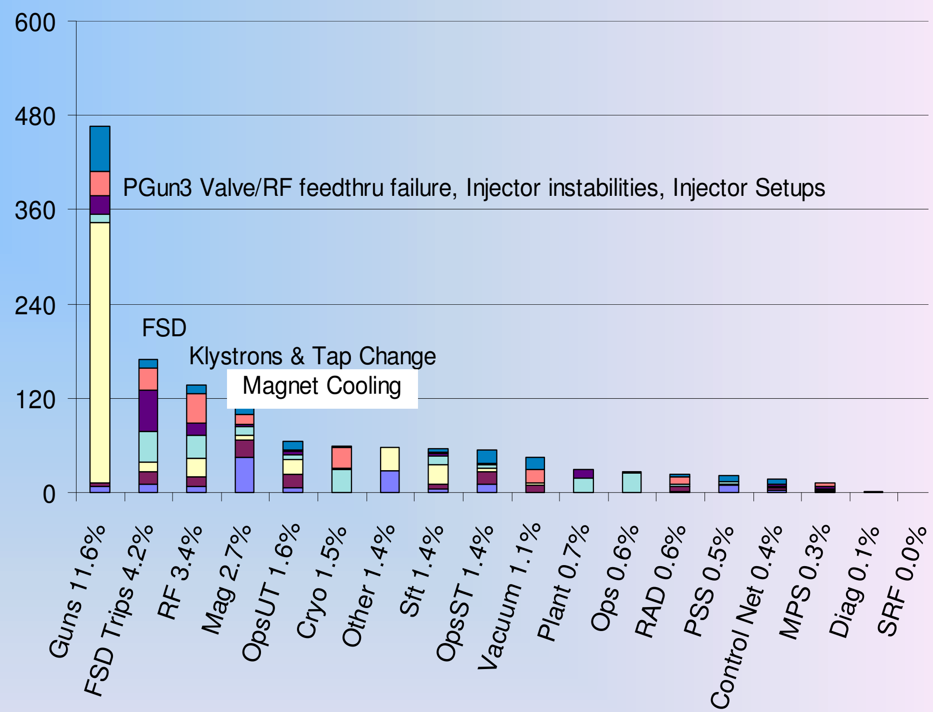
Optimisation of Accelerator Reliability for ADS

Critical area: the RF system

Lost Time Totals June'97-May'01



Lost Time Totals FY 2001



Reliability Example - CEBAF

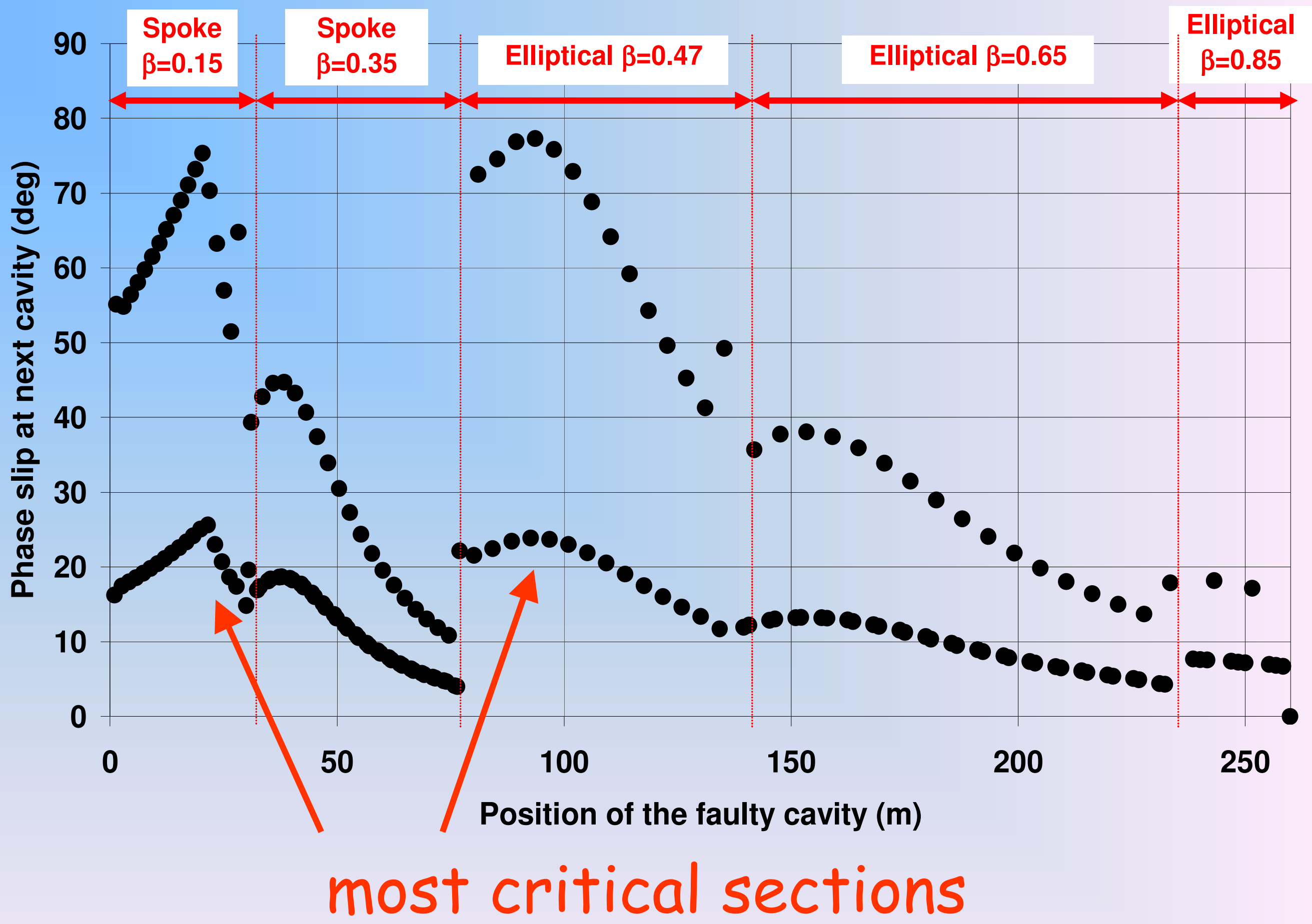
Consequences of cavity failure

We have a non-relativistic proton beam

Any energy loss will imply a phase slip along the linac increasing with the distance, beam can get out of stability region

$$\delta\varphi = 2\pi\left(\delta z / \lambda\right)\left(\delta\beta / \beta^2\right)$$

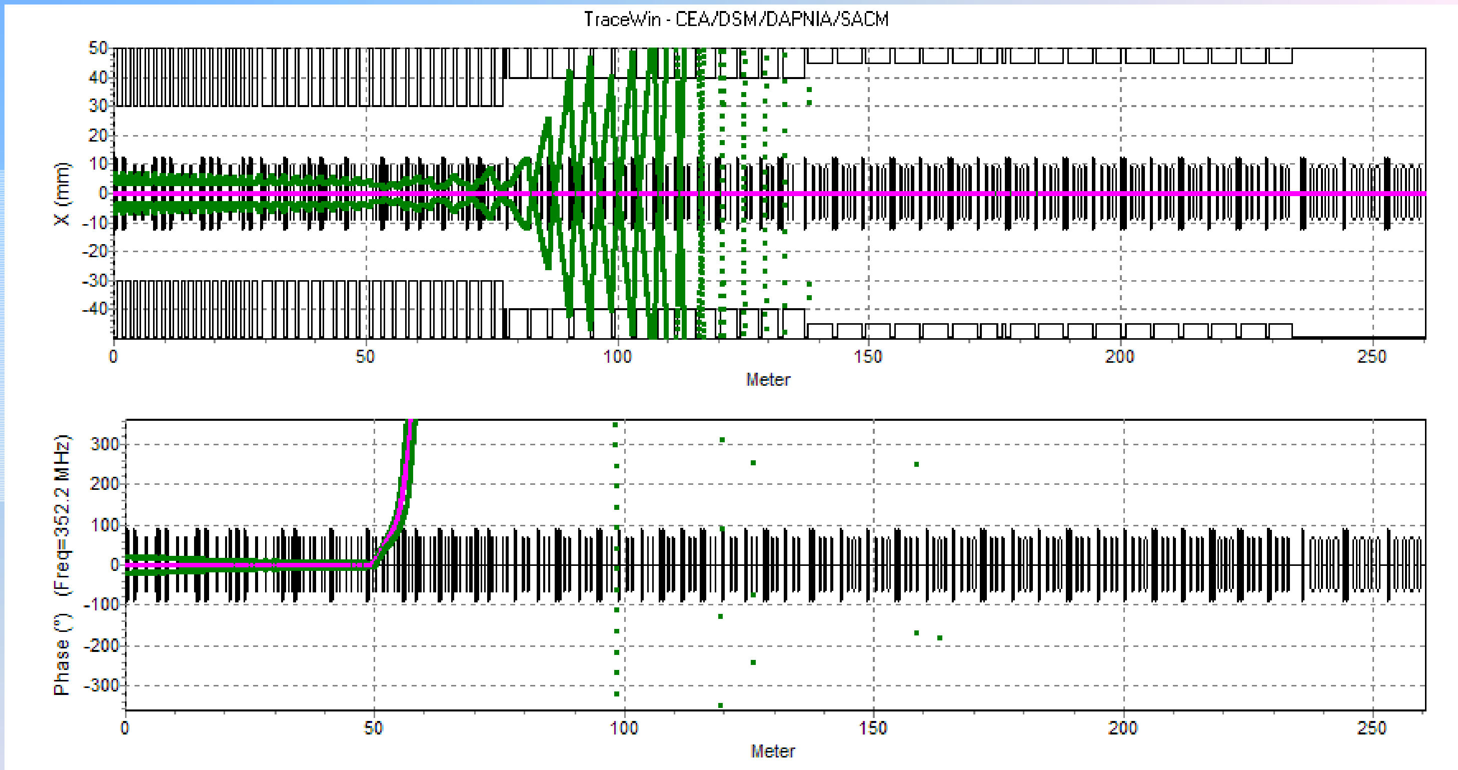
β is the beam velocity
λ the RF wavelength
δβ the velocity loss at δz



Optimisation of Accelerator Reliability for ADS

Consequences of cavity failure

If the synchronous phase or/and the accelerating field is too high, the beam is TOO LATE & leaves the stability region: the beam is lost



Beam dynamics simulation with TraceWin

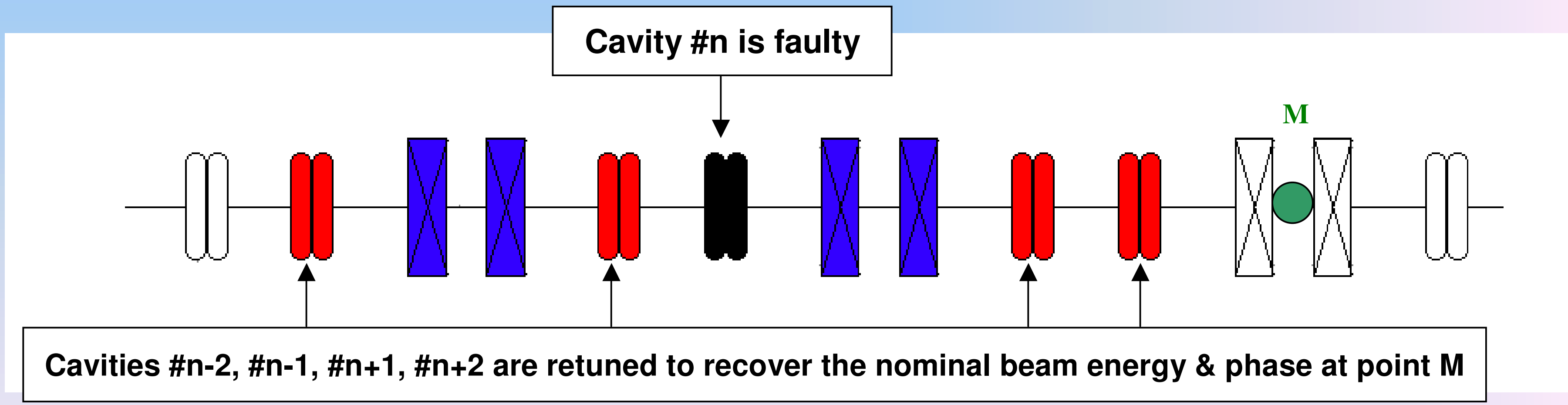
Optimisation of Accelerator Reliability for ADS

Need to have linac design that can handle the loss of one or several cavities

The modularity of our LINAC makes this possible because we have INDEPENDENTLY PHASED structures

We need to find procedure that use the neighbouring cavities to compensate phase/energy beam offset

These procedures should then be integrated in RF control system

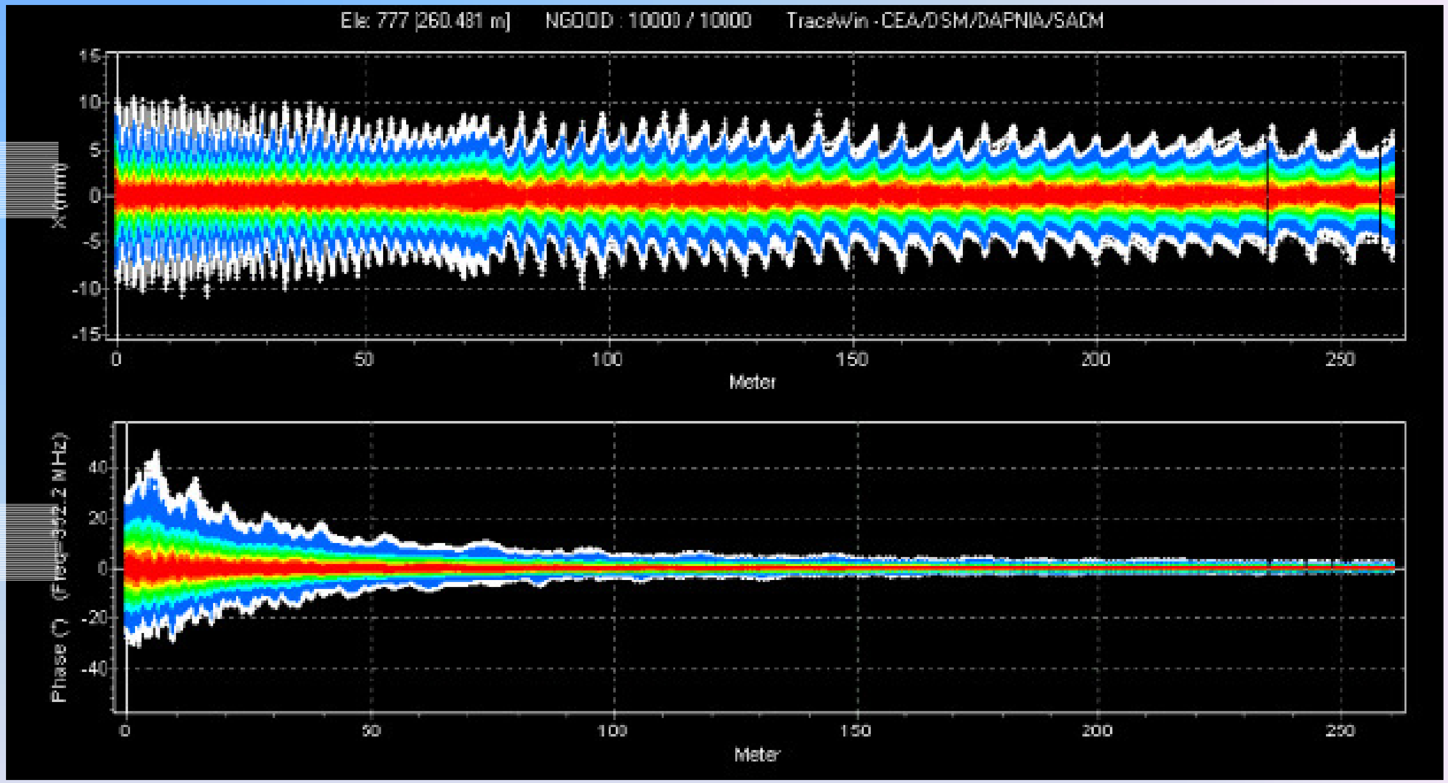


Optimisation of Accelerator Reliability for ADS

After retuning correct number of neighboring cavities

Amplitude

Phase



Optimisation of Accelerator Reliability for ADS

Study has been applied to **most representative cavities in all sections** (beginning, half and end of each section)

In every case, the beam can be transported up to high energy with 100% transmission, small emittance growths, nominal parameters

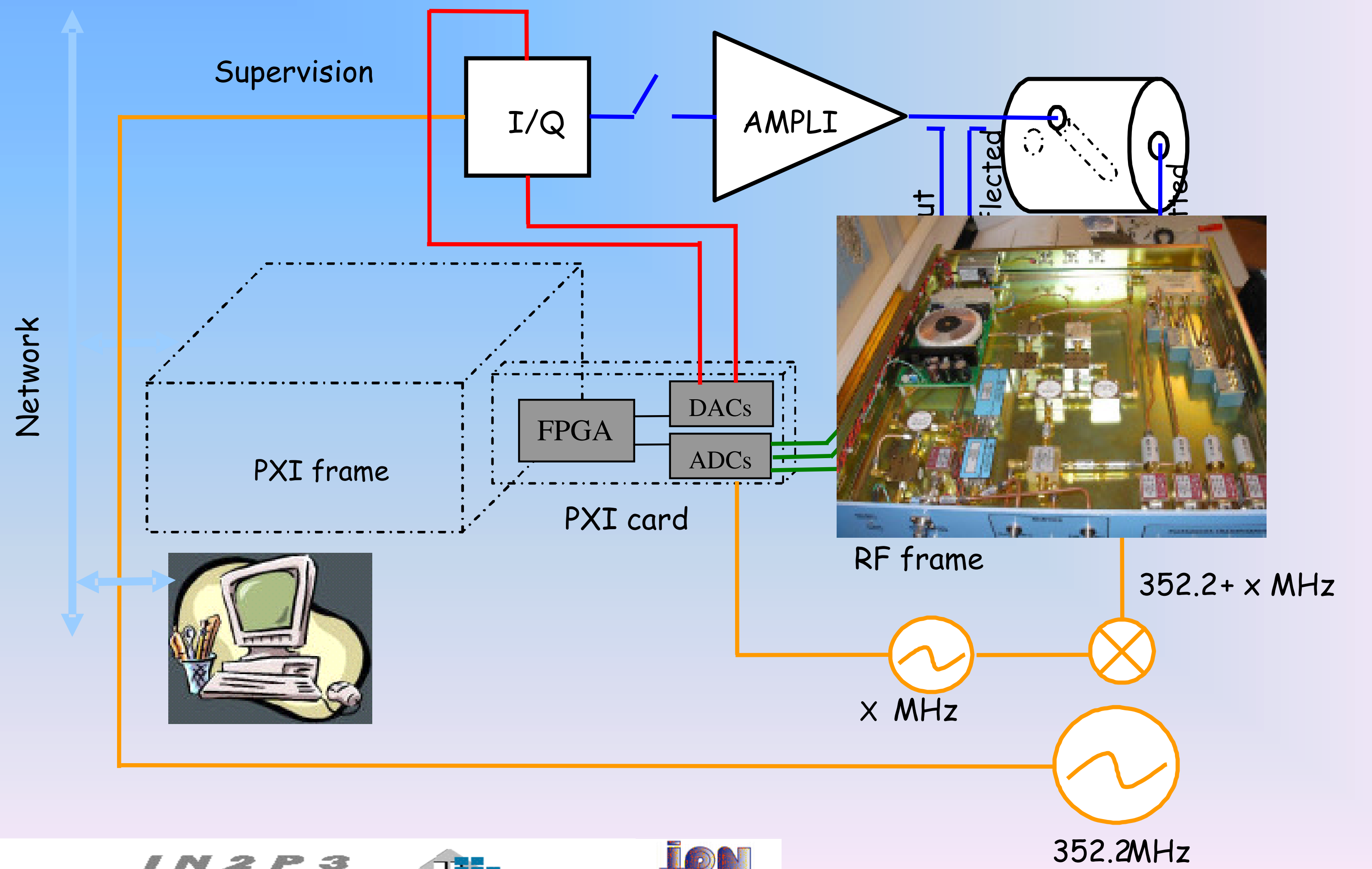
Only for E < 10 MeV increase above 30% is necessary

# faulty cavity	section	Final energy	Emittance growth (%)		**# of retuned cavities (bef + aft)**	Max ΔEacc (%)	Max E_{pk} (SP) or B_{pk} (EL)	Max ΔPower (%)	# retuned quads (bef + aft)
			Transv.	Long.					
0	-	Nominal	+ 5 %	0 %	**-**	-	-	-	-
1	SP 0.15	Nominal	+ 7 %	+ 4 %	**0 + 4**	+ 67 %	19 MV/m	+ 67 %	0 + 4
2	SP 0.15	Nominal	+ 9 %	+ 12%	**1 + 3**	+ 90 %	19 MV/m	+ 68 %	0 + 4
3	SP 0.15	Nominal	+ 10%	+ 12%	**2 + 3**	+ 94 %	21 MV/m	+ 56 %	4 + 2
4	SP 0.15	Nominal	+ 9 %	+ 4 %	**3 + 3**	+ 46 %	15 MV/m	+ 35 %	2 + 4
19	SP 0.15	Nominal	+ 6 %	+ 6 %	**2 + 3**	+ 38 %	24 MV/m	+ 48 %	2 + 2
20	SP 0.15	Nominal	+ 9 %	+ 4 %	**3 + 2**	+ 37 %	26 MV/m	+ 58 %	2 + 2
35	SP 0.15	Nominal	+ 6 %	0 %	**2 + 3**	+ 20 %	32 MV/m	+ 27 %	2 + 2
36	SP 0.15	Nominal	+ 7 %	+ 4 %	**3 + 3**	+ 22 %	34 MV/m*	+ 32 %	2 + 2
37	SP 0.35	Nominal	+ 6 %	0 %	**3 + 2**	+ 22 %	35 MV/m*	+ 34 %	2 + 2
38	SP 0.35	Nominal	+ 7 %	+ 6 %	**3 + 4**	+ 29 %	31 MV/m	+ 26 %	2 + 2
39	SP 0.35	Nominal	+ 5 %	+ 5 %	**4 + 2**	+ 24 %	36 MV/m*	+ 35 %	4 + 2
61	SP 0.35	Nominal	+ 6 %	+ 2 %	**2 + 3**	+ 25 %	31 MV/m	+ 26 %	2 + 2
62	SP 0.35	Nominal	+ 6 %	0 %	**2 + 2**	+ 26 %	31 MV/m	+ 28 %	2 + 2
63	SP 0.35	Nominal	+ 5 %	+ 1 %	**3 + 2**	+ 25 %	31 MV/m	+ 27 %	2 + 2
94	SP 0.35	Nominal	+ 6 %	+ 2 %	**3 + 3**	+ 16 %	29 MV/m	+ 18 %	4 + 2
95	SP 0.35	Nominal	+ 7 %	- 1 %	**3 + 3**	+ 22 %	31 MV/m	+ 29 %	4 + 2
96	SP 0.35	Nominal	+ 5 %	+ 1 %	**4 + 2**	+ 21 %	30 MV/m	+ 25 %	4 + 2
97	EL 0.47	Nominal	+ 6 %	0 %	**3 + 3**	+ 18 %	59 mT	+27 %	4 + 2
98	EL 0.47	Nominal	+ 6 %	0 %	**3 + 2**	+ 23 %	62 mT	+ 31 %	4 + 2
109	EL 0.47	Nominal	+ 6 %	0 %	**3 + 3**	+ 20 %	60 mT	+ 28 %	4 + 2
110	EL 0.47	Nominal	+ 6 %	0 %	**3 + 2**	+ 20 %	60 mT	+ 29 %	2 + 2
123	EL 0.47	Nominal	+ 6 %	0 %	**2 + 4**	+ 20 %	60 mT	+ 26 %	4 + 2
124	EL 0.47	Nominal	+ 6 %	0 %	**3 + 3**	+ 19 %	60 mT	+ 28 %	4 + 2
125	EL 0.65	Nominal	+ 5 %	0 %	**2 + 3**	+ 18 %	59 mT	+ 27 %	4 + 2
126	EL 0.65	Nominal	+ 5 %	0 %	**3 + 4**	+ 21 %	61 mT	+ 20 %	4 + 2
127	EL 0.65	Nominal	+ 5 %	0 %	**3 + 3**	+ 21 %	61 mT	+ 25 %	4 + 2
146	EL 0.65	Nominal	+ 5 %	0 %	**3 + 3**	+ 18 %	59 mT	+ 22 %	4 + 2
147	EL 0.65	Nominal	+ 6 %	- 1 %	**3 + 4**	+ 19 %	60 mT	+ 22 %	4 + 2
148	EL 0.65	Nominal	+ 6 %	- 1 %	**3 + 3**	+ 20 %	60 mT	+ 22 %	4 + 2
173	EL 0.65	Nominal	+ 5 %	0 %	**3 + 4**	+ 17 %	59 mT	+ 19 %	4 + 2
174	EL 0.65	Nominal	+ 5 %	0 %	**3 + 3**	+ 18 %	59 mT	+ 22 %	4 + 2
175	EL 0.65	Nominal	+ 5 %	0 %	**4 + 4**	+ 17 %	59 mT	+ 18 %	4 + 2
176	EL 0.85	Nominal	+ 5 %	0 %	**3 + 5**	+ 18 %	59 mT	+ 22 %	4 + 2
177	EL 0.85	Nominal	+ 5 %	0 %	**4 + 4**	+ 18 %	59 mT	+ 20 %	4 + 2
178	EL 0.85	Nominal	+ 5 %	0 %	**5 + 4**	+ 18 %	59 mT	+ 19 %	4 + 2
179	EL 0.85	Nominal	+ 5 %	0 %	**6 + 4**	+ 17 %	59 mT	+ 16 %	4 + 2
184	EL 0.85	Nominal	+ 5 %	0 %	**4 + 3**	+ 17 %	59 mT	+ 29 %	2 + 2
185	EL 0.85	Nominal	+ 6 %	0 %	**5 + 2**	+ 19 %	60 mT	+ 30 %	2 + 2
186	EL 0.85	Nominal	+ 7 %	0 %	**6 + 1**	+ 21 %	61 mT	+ 33 %	2 + 2
187	EL 0.85	Nominal	+ 6 %	0 %	**7 + 0**	+ 25 %	63 mT	+ 37 %	2 + 2

Optimisation of Accelerator Reliability for ADS

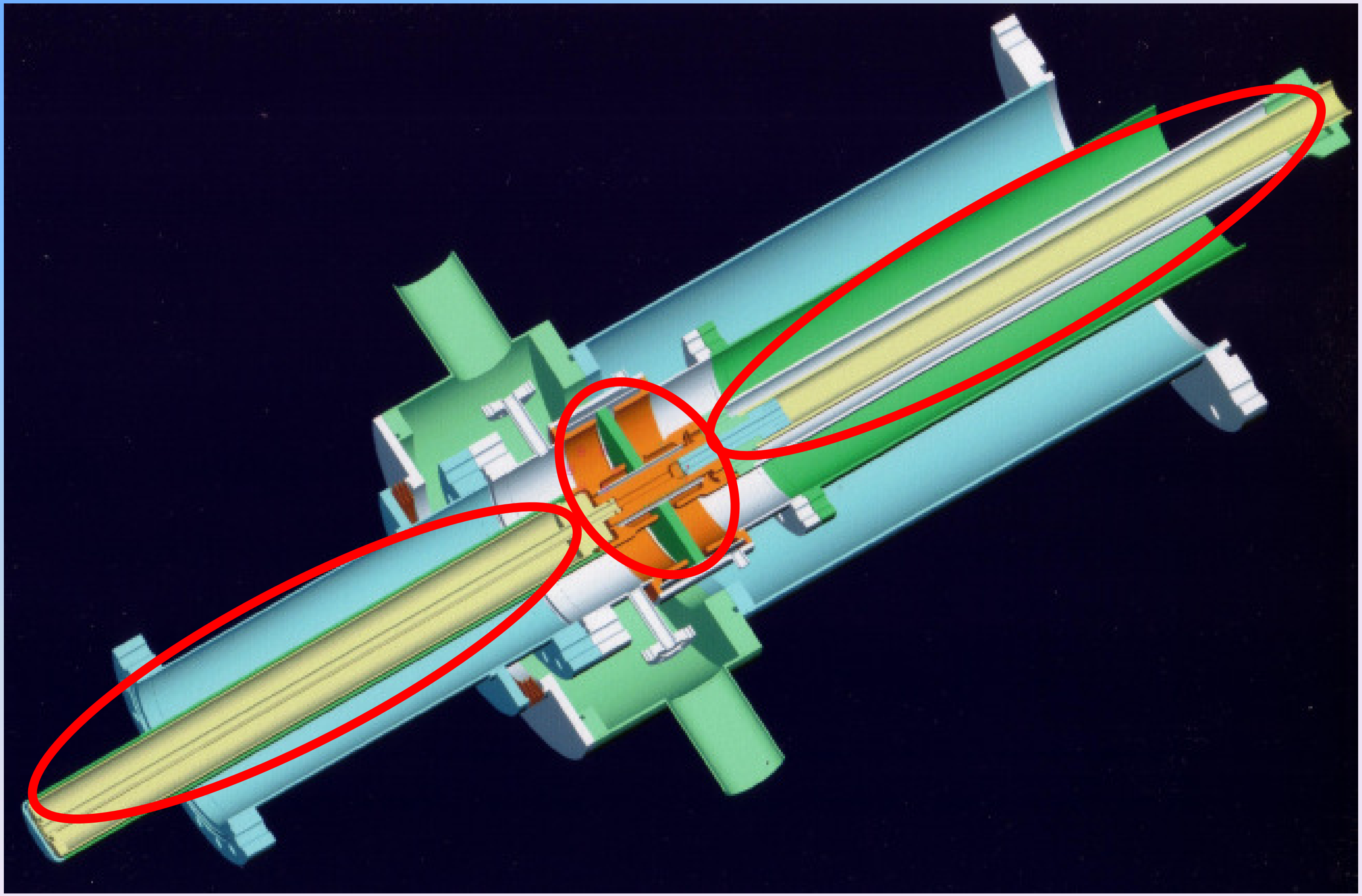
Low Level RF Fast Feedback System

Collaboration IPN Orsay and LPNHE Paris



Optimisation of Accelerator Reliability for ADS

Scheme of a RF Power Coupler



Different window geometries

Basic parameters

- 352.2 MHz
- Nominal power: 10 kW
- Capacitive coupler for CW operation

IPNO PhD dissertation by C. Mielot (2004)

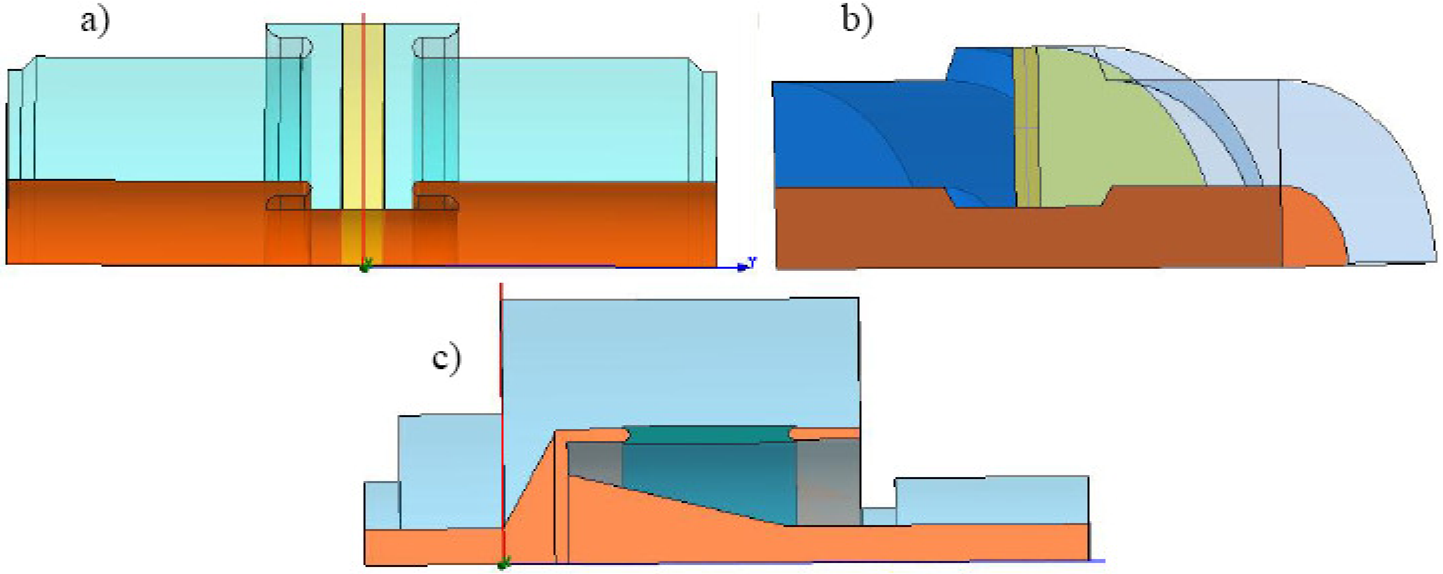
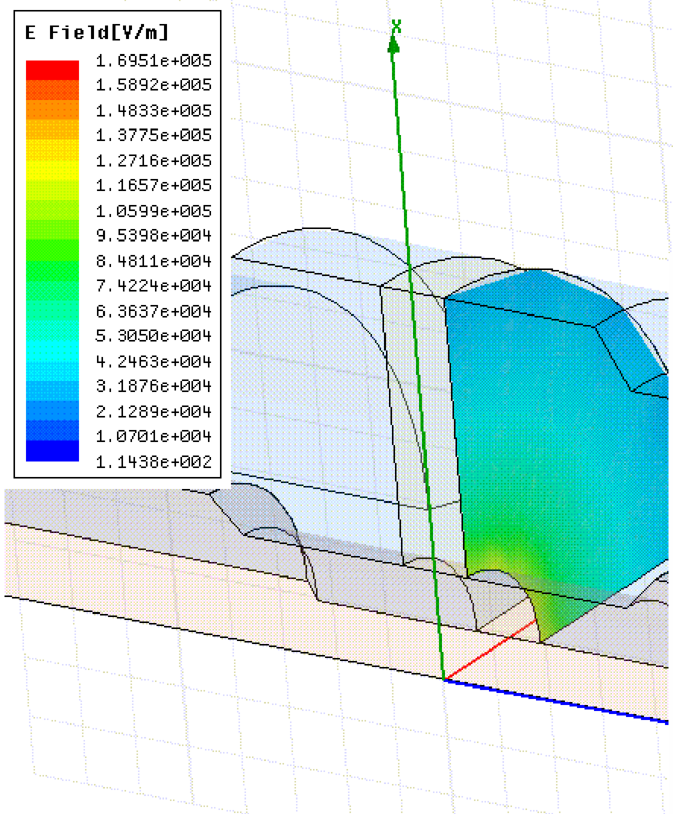
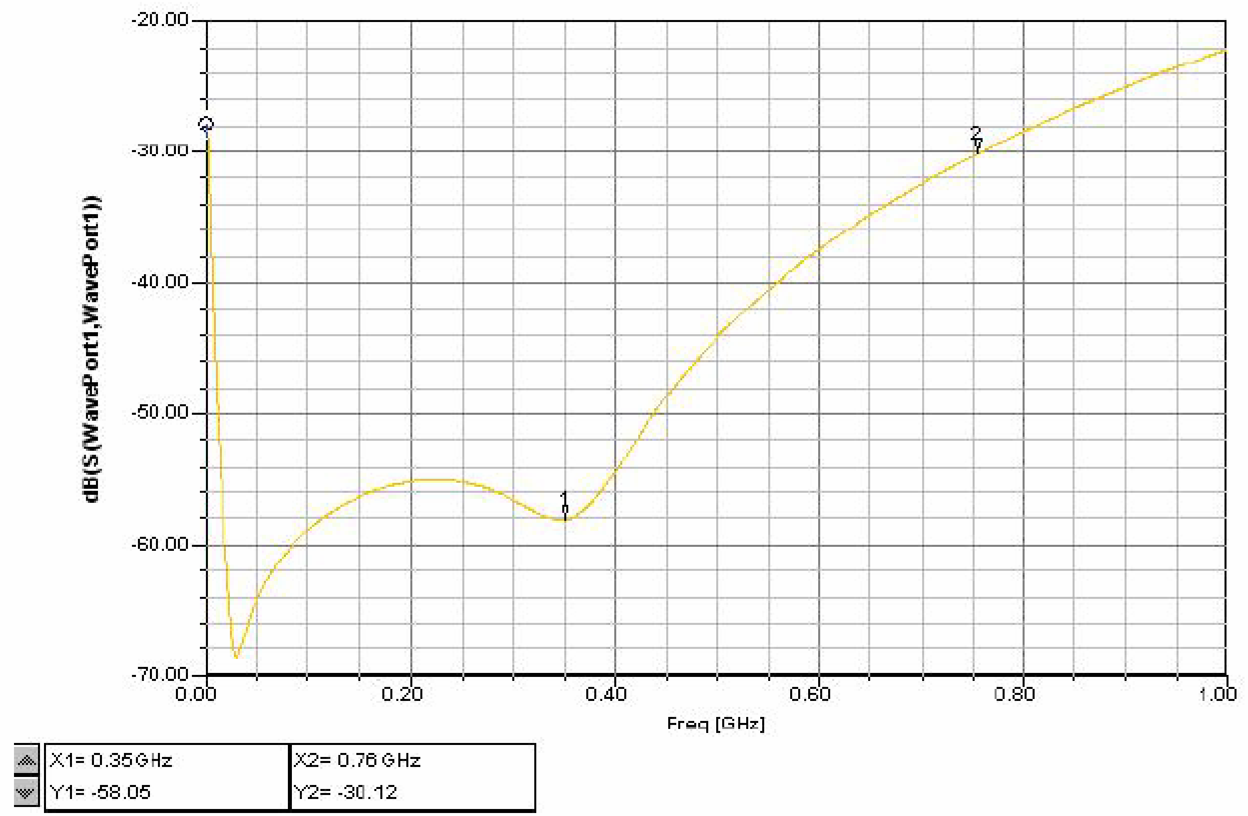


FIG. 4: Several window geometries: a) disk with chokes; b) disk without chokes; c) cylinder

Different window geometries





Different window geometries

TABLE 3: Comparison of main parameters for different window types

Window type	Disk with chokes	**Disk without chokes**	Cylinder	"Guide/coaxial"	"T"
S_{11} (dB)	-55,4	**-58**	-45,17	-60	-40,2
Band-width (MHz)	>1000	**760**	410	6	8
E_{surf} max (V/m)	$1{,}18.10^{5}$	$\mathbf{1{,}24.10^{5}}$	$1{,}50.10^{4}$	$1{,}24.10^{4}$	$2{,}30.10^{4}$
Losses (W)	60	**71,75**	68,2	147	33
% P_{losses}/ $P_{incident}$	0,30%	**0,36%**	0,34%	0,74%	0,17%
Window volume (mm^3)	$2{,}86.10^{4}$	[illegible]	[illegible]	[illegible]	[illegible]7.10^{5}
Voluminal losses (W/mm^3)	$2{,}10.10^{-3}$	[illegible]	[illegible]	[illegible]	1.10^{-4}

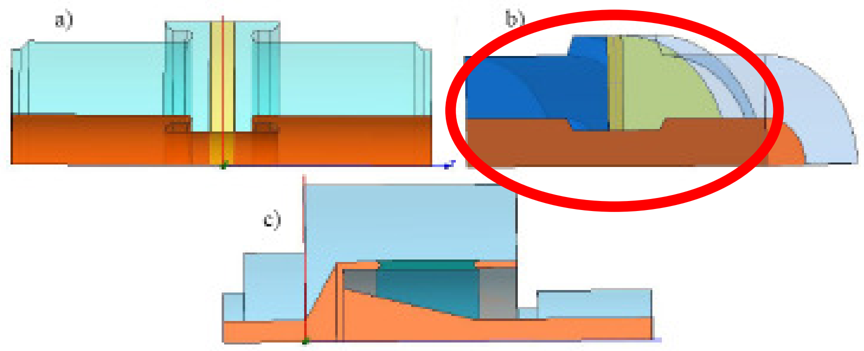


FIG. 4: Several window geometries: a) disk with chokes; b) disk without chokes; c) cylinder

Perspectives

Fault tolerance study as a part of the overall reliability study for ADS class accelerators has reached the stage of experimental validation.

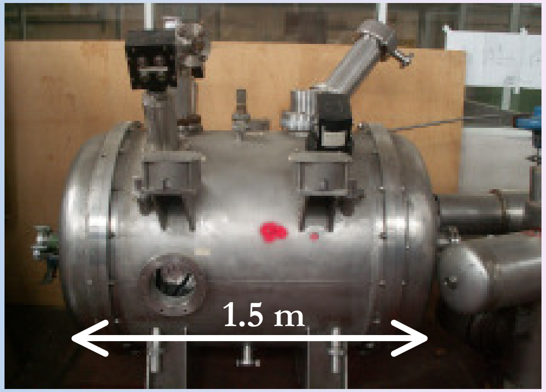
Low level RF system:

- currently under construction
- tests on SPOKE cavity foreseen for end 2005

RF power coupler

- thermo-mechanical study under way
- construction to start in fall 2005
- conditioning at room temperature foreseen for summer 2006

Perspectives



Tests of all components for a cryomodule :
LLRF digital system + RF power coupler + SPOKE cavity
in horizontal cryostat foreseen for 2007