Maintenance activities at Laboratori Nazionali di Legnaro

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LNL - INFN - Identity Card

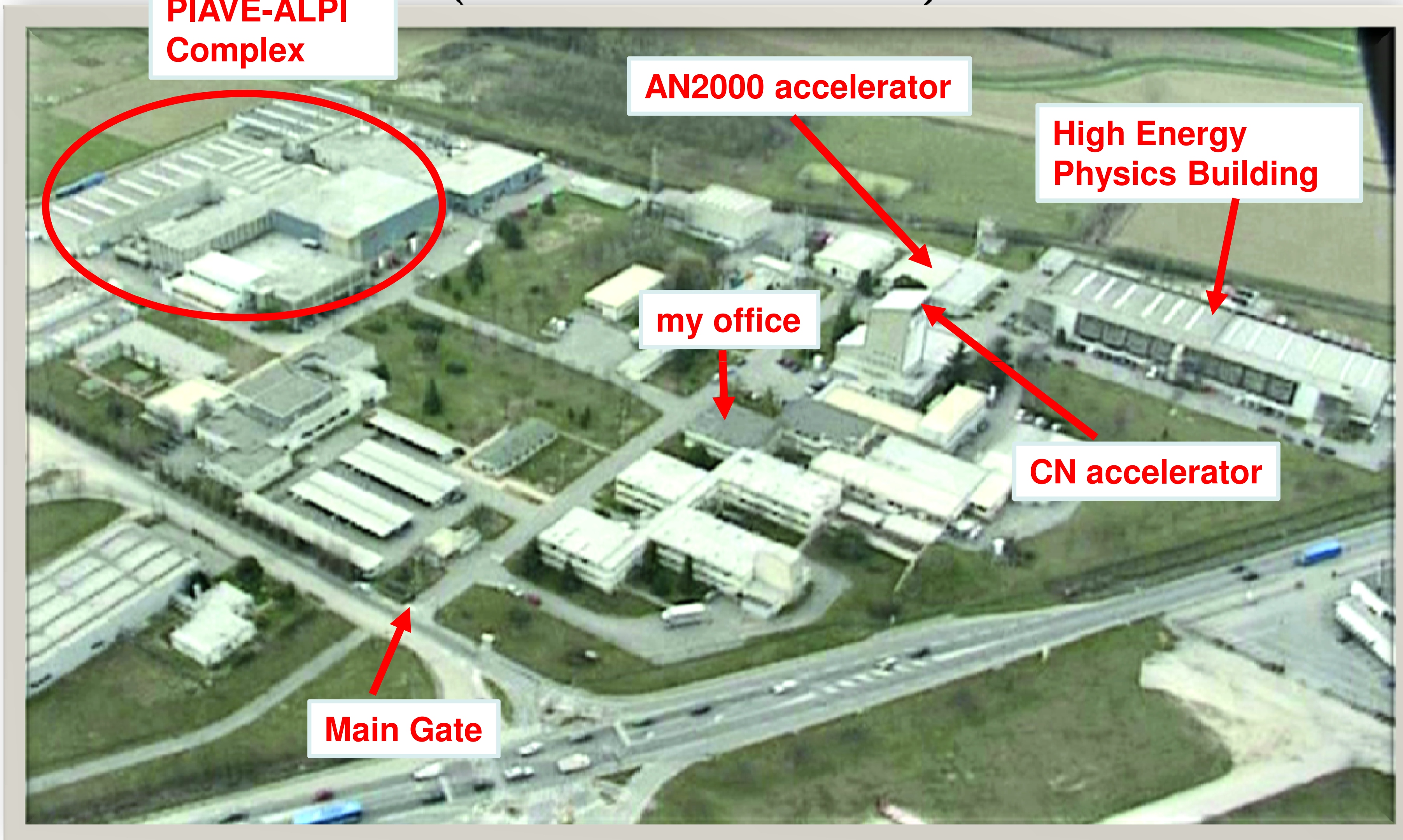
MULTI TASK
MULTI DISCIPLINARY
But mainly
Nuclear Physics Based
User Oriented
Laboratories

CORE RESEARCH ACTIVITIES

1. Nuclear Structure and Dynamics

2. Applications and Interdisciplinary use of ion beams and nuclear techniques and methods

Laboratori Nazionali di Legnaro (founded in 1960)

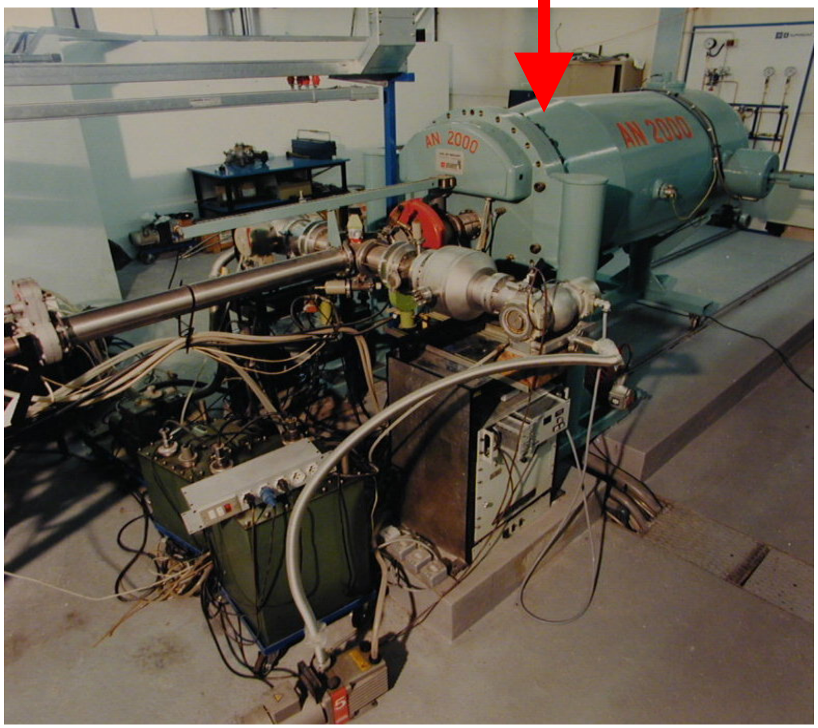


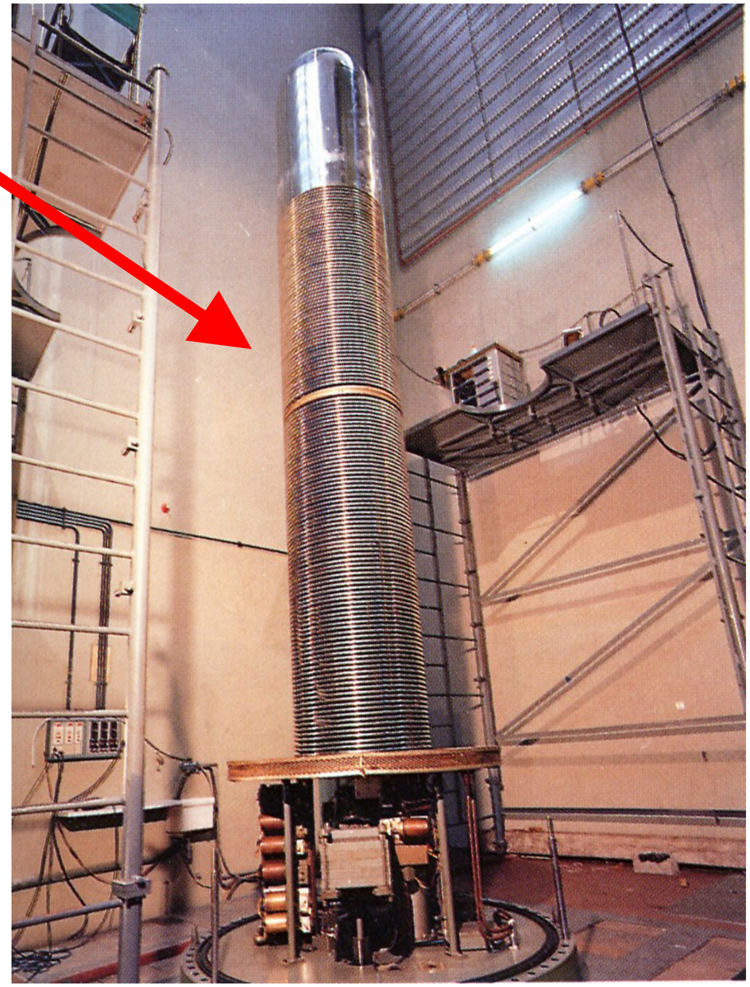
Low energy electrostatic accelerators

7-MV - CN - Van de Graaff (1961)

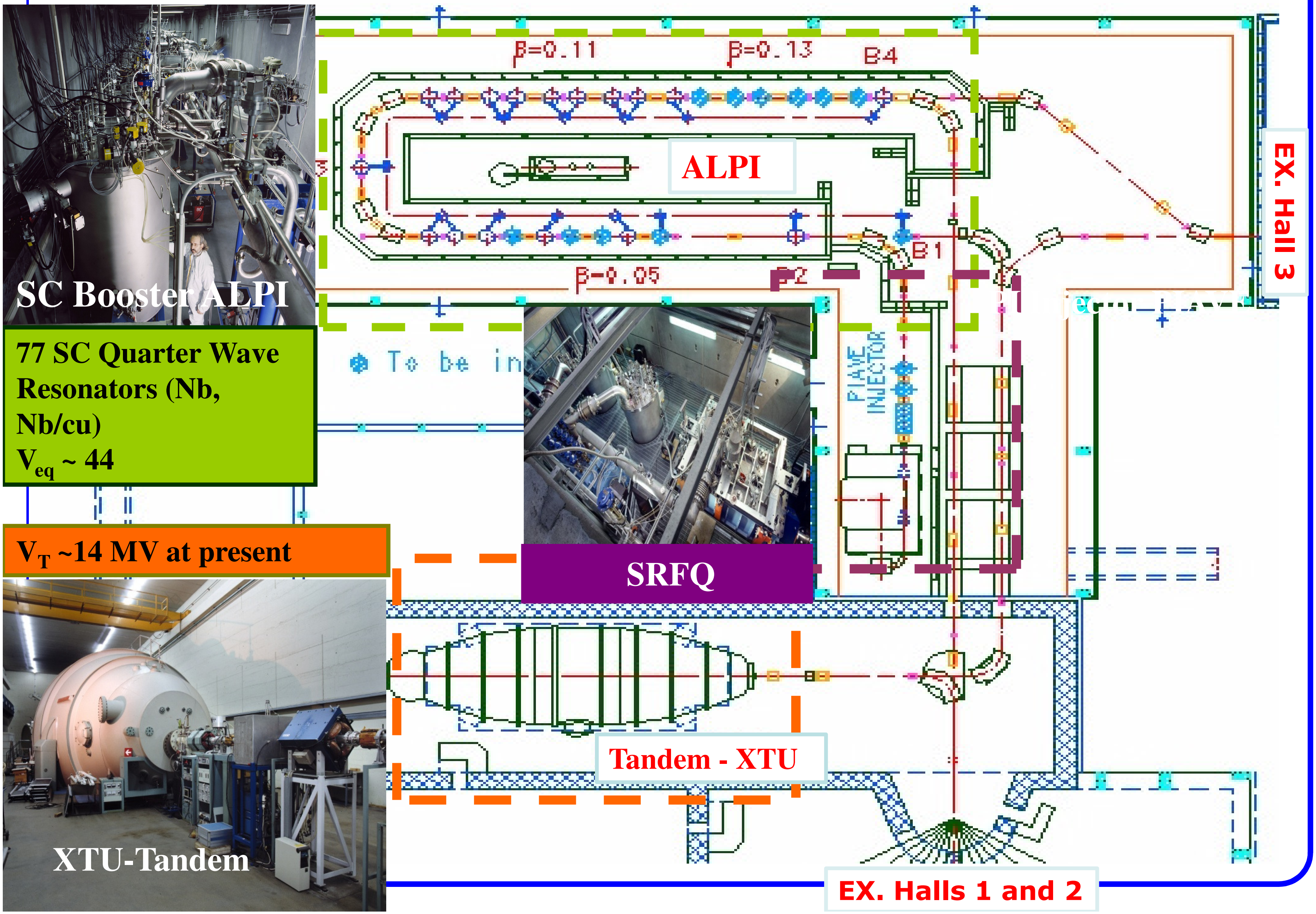
2-MV - AN2000

Van de Graaff (1971)

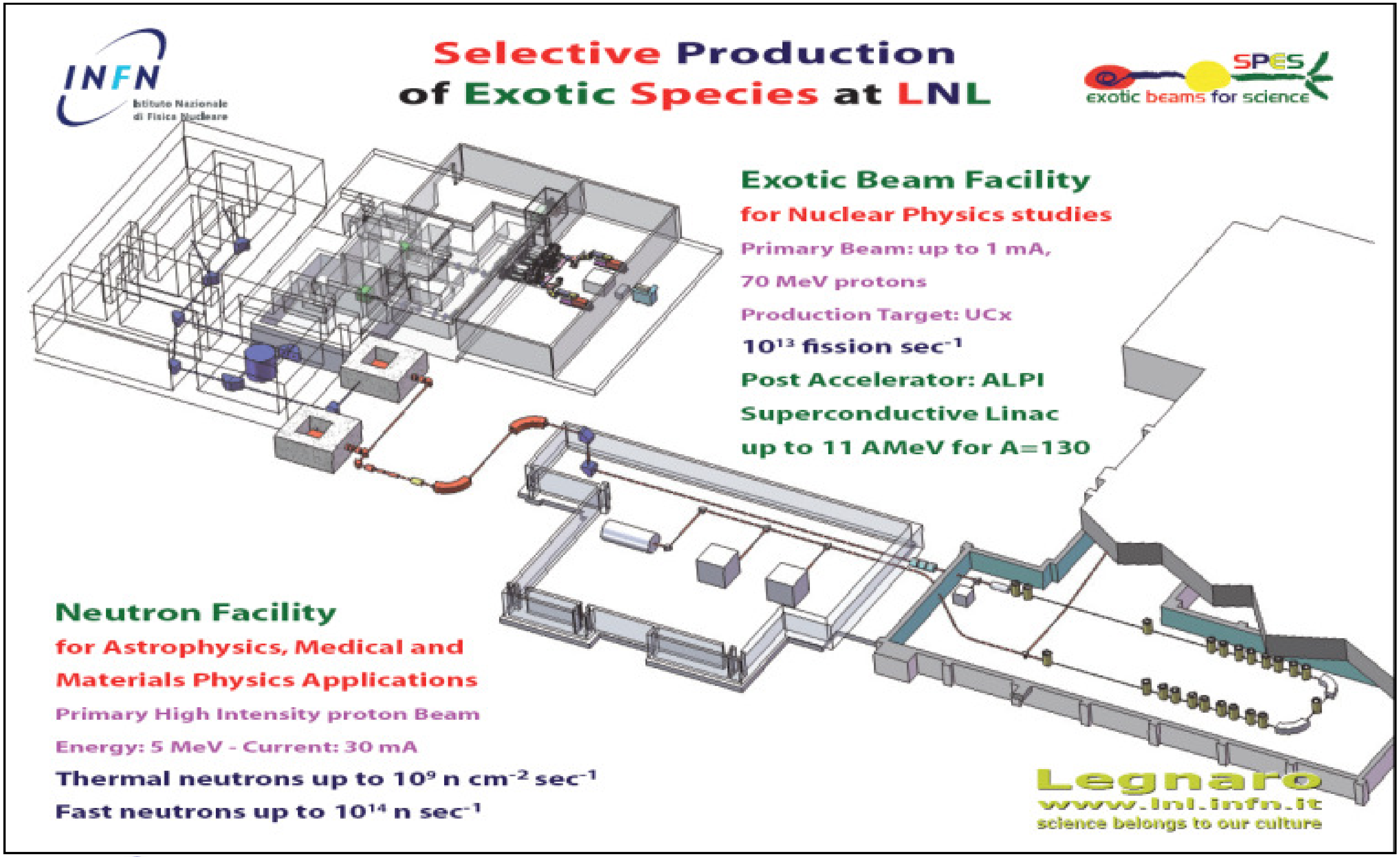




LNL –PIAVE-Tandem-ALPI- COMPLEX



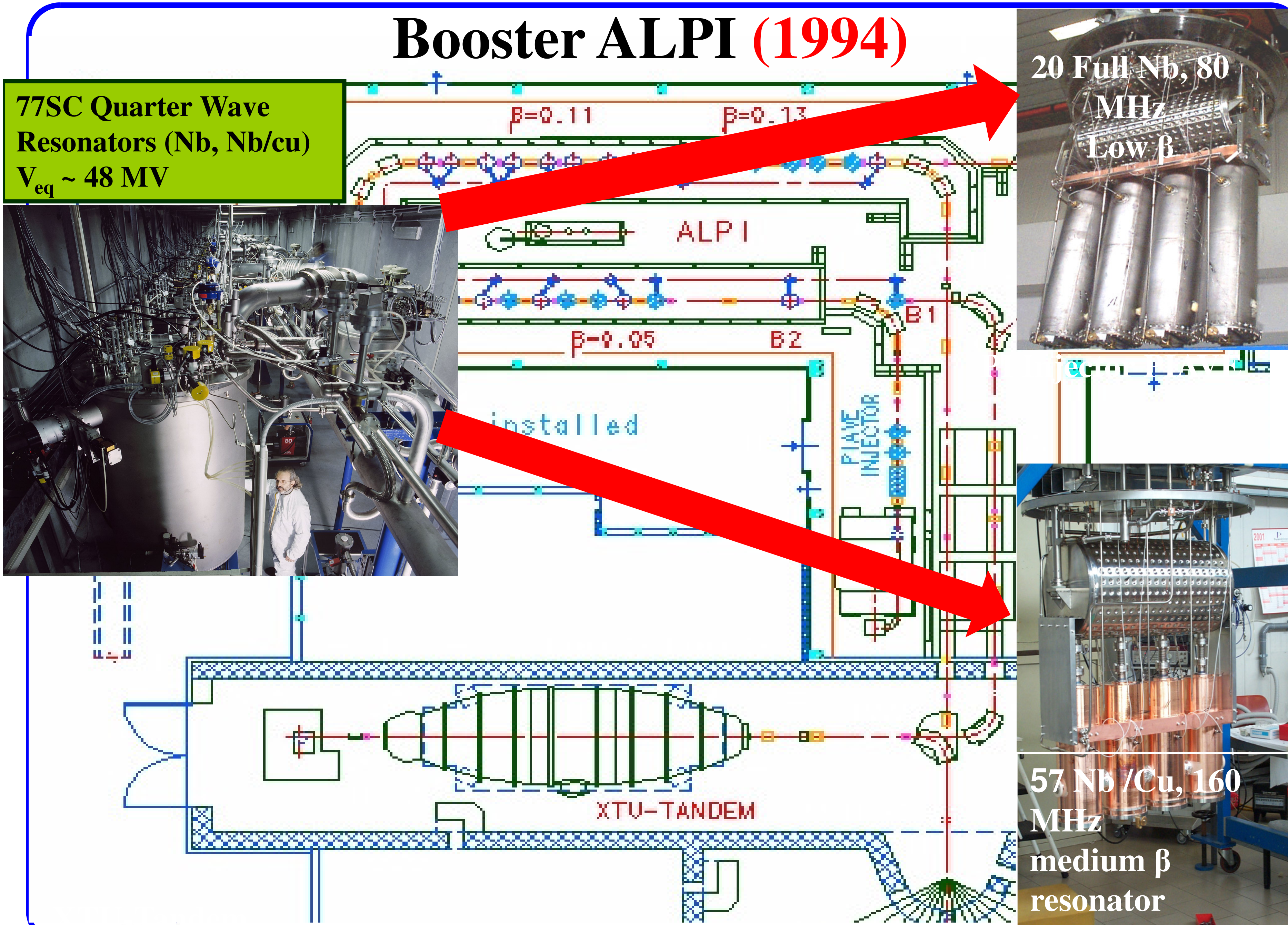
Further PIAVE-ALPI upgrade included in the SPES project framework (2016)



Tandem-Accelerator
(1981)

- Negative ion source
- 14 MV terminal voltage
- SF6 insulating gas at 7 bars
- Single o double stripping stages

Booster ALPI (1994)



PIAVE- Positive Ion Injector (2005)

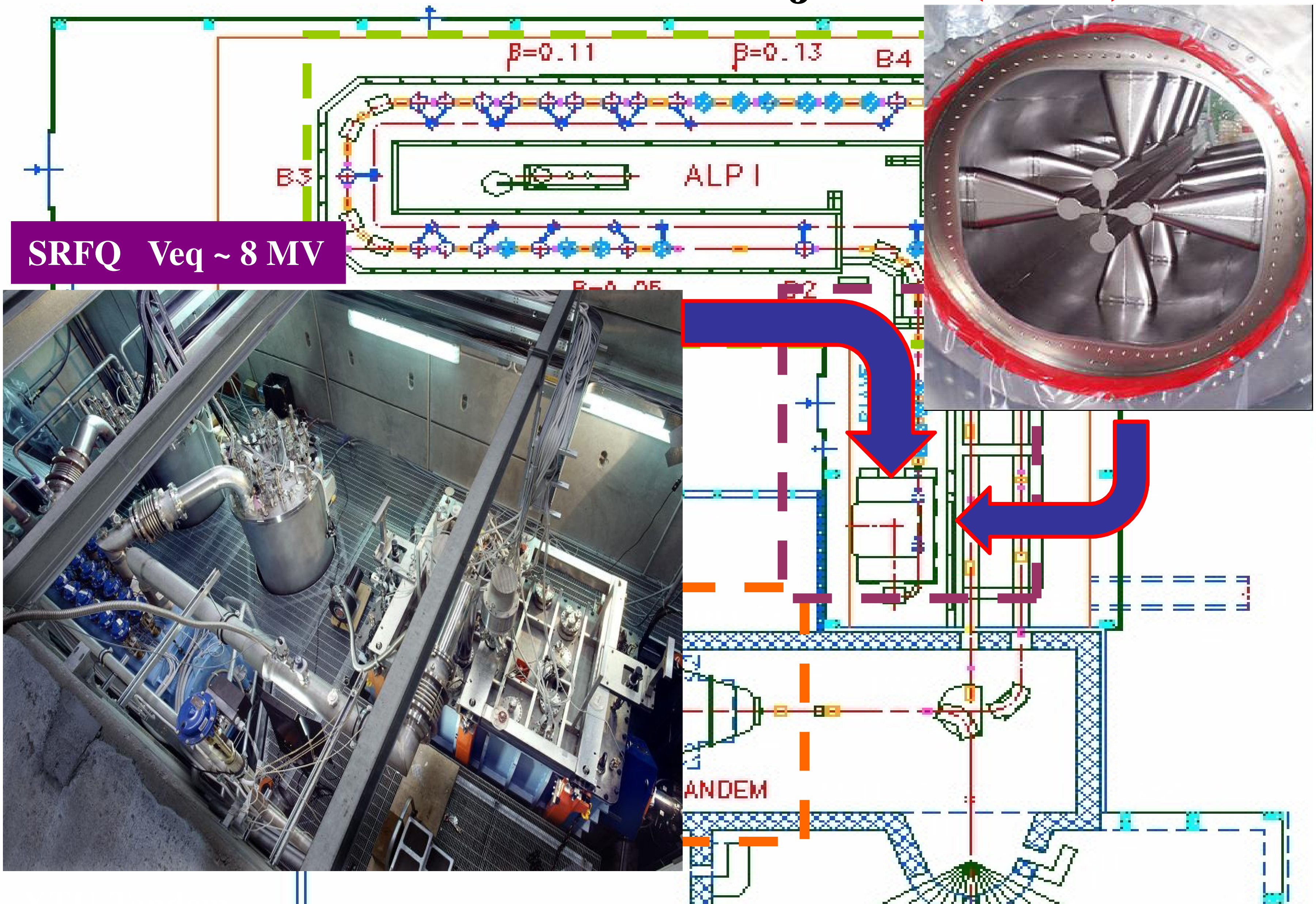


TABLE OF TANDEM-ALPI REPRESENTATIVE BEAMS

Beam	E [MeV]	E/A [MeV/A]	I target [pnA]
$^{12}C^{5+}$	240	20.0	2
$^{12}C^{6+}$	276	23.0	2
$^{16}O^{7+}$	328	20.5	2
$^{16}O^{8+}$	360	22.5	2
$^{32}S^{9+}$	448	14.0	20
$^{32}S^{10+}$	490	15.3	12
$^{32}S^{12+}$	565	17.7	5
$^{48}Ca^{9+}$	454	9.5	1.7

TABLE OF TANDEM-ALPI REPRESENTATIVE BEAMS

Beam	E [MeV]	E/A [MeV/A]	I target [pnA]
$^{48}Ca^{9+}$	454	9.5	1.7
$^{48}Ca^{10+}$	505	10.5	1.3
$^{48}Ca^{11+}$	550	11.5	0.5
$^{58}Ni^{11+}$	550	9.5	13
$^{58}Ni^{12+}$	602	10.4	10
$^{58}Ni^{13+}$	650	11.2	4.5
$^{58}Ni^{16+}$	770	13.3	3

TABLE OF TANDEM-ALPI REPRESENTATIVE BEAMS

Beam	E [MeV]	E/A [MeV/A]	I target [pnA]
$^{58}Ni^{16+}$	770	13.3	3
$^{65}Cu^{11+}$	545	8.4	12
$^{65}Cu^{12+}$	600	9.2	9
$^{65}Cu^{13+}$	650	10.0	3.5
$^{65}\underline{Cu}^{16+}$	<u>777</u>	<u>12.0</u>	<u>2.5</u>
$^{74}Ge^{11+}$	534	7.2	2.5
$^{74}Ge^{12+}$	592	8.0	2

TABLE OF TANDEM-ALPI REPRESENTATIVE BEAMS

Beam	E [MeV]	E/A [MeV/A]	I target [pnA]
$^{74}Ge^{13+}$	645	8.7	1
$^{74}Ge^{17+}$	826	11.2	0.3
$^{82}Se^{12+}$	582	7.1	7
$^{82}Se^{13+}$	639	7.8	4
$^{82}Se^{17+}$	820	10.0	1.5
$^{90}Zr^{12+}$	610	6.8	1
$^{90}Zr^{13+}$	630	7.0	0.6
$^{90}Zr^{14+}$	700	7.7	0.3
$^{100}Mo^{11+}$	545	5.4	0.7
$^{100}Mo^{12+}$	600	6.0	0.6

TABLE OF CURRENTLY AVAILABLE PIAVE-ALPI BEAMS

Beam	E [MeV]	E/A [MeV/A]	I target [pnA]
$^{22}Ne^{4+}$	243	11.0	2*
$^{40}Ar^{9+}$	390	9.8	4÷10
$^{84}Kr^{18+}$	800	9.5	5÷10
$^{120}Sn^{21+}$	850	7.1	1
$^{132}Xe^{27+}$	1200	9.1	2
$^{132}Xe^{26+}$	1050	8	1
$^{136}Xe^{34+}$	1240	9.1	0.3
$^{197}Au^{30+}$	1200	6.1	1

Maintenance should be Preventive and sometimes (<u>in the rare case</u>) Last minute, predictive

..., in the real life sometimes you can start with one strategie and during the work, you change the last strategy....or if the Maintenance is too big, the special maintenance is necessary (maybe you will do the special maintenance in more steps in order to not interfere too much with the accelerator operation)

<u>I think is very important to keep constant attention to every failure by statistic counter.</u>

How to decide the Maintenance aproach ?

Identify all the machine systems, the subsystem of each system......, and after that you can decide the right aproach

Preventive

1 subsistem
- **Charge system control every maintenance**
- **Laddertron change evry 14000 hours**

2 Subsitem
- **Alternatore belt change every 20000 hours**
- **Corona point change every 3 years**

3 Subsistem
- **Voltage divider control every maintenance**
- **Nylatron bar change every 40000 hours**

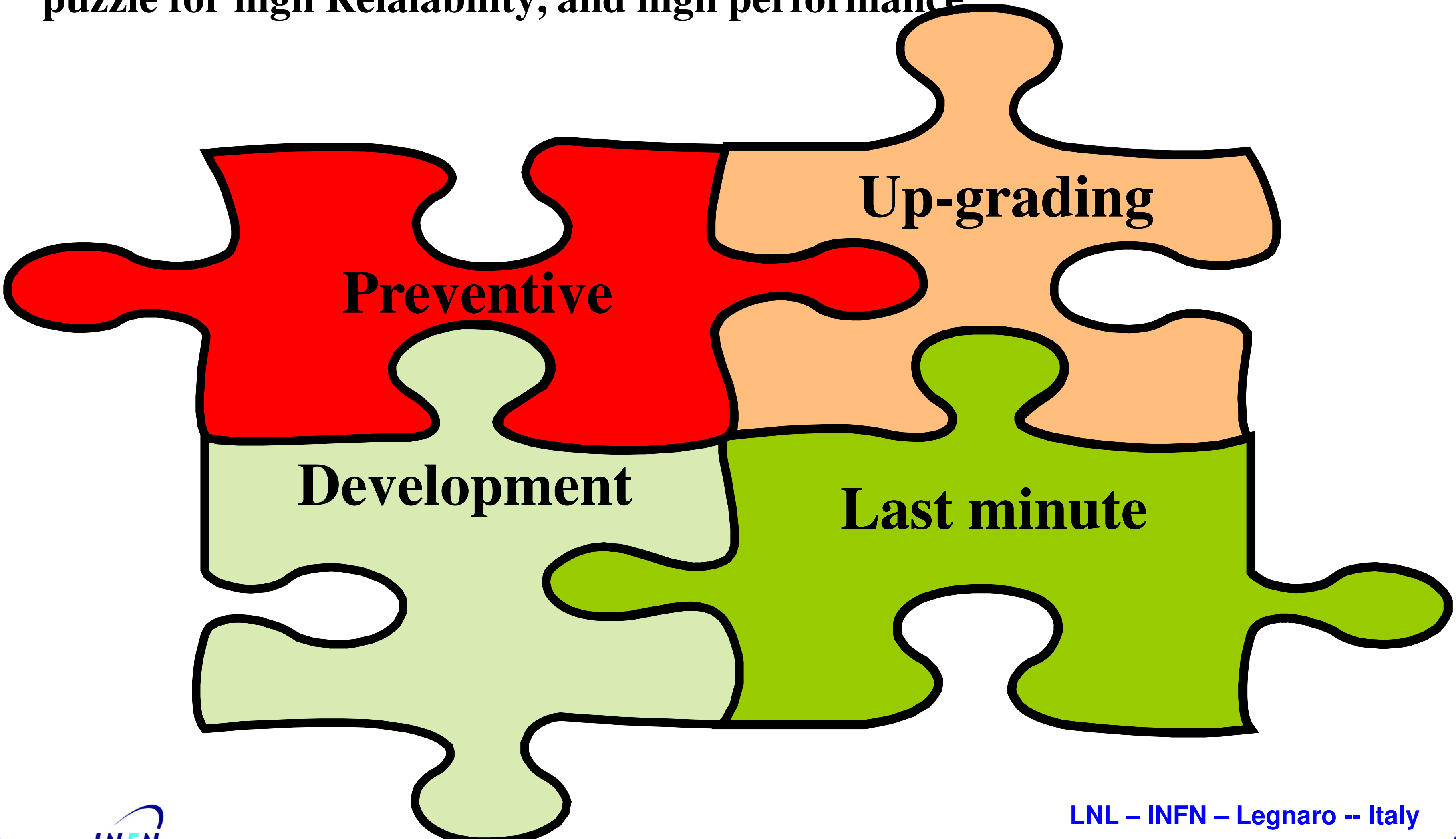
Last minute

- P.S. For the charge sistem in the terminal
- P.S. For vacuum pom p sistem in the terminal

If the number of Last minute maintenance events increases, change approach tos preventive maintenance, or development, or up-granding

Not Maintenance alone

In any case the maintenace, preventive, Last minute, predictive, Development and the Up-grading, they must complete the necessary puzzle for high Relaiability, and high performance.



Why maintenance ?

Safety reason

Cost

People cost

Electrical power

User cost

1 Day beam loss cost ~ 30 K euro

Exemple of Last minute Maintenance

- **July 2005**

problem with resistors, value changed from ~500MΩ to ~340 MΩ

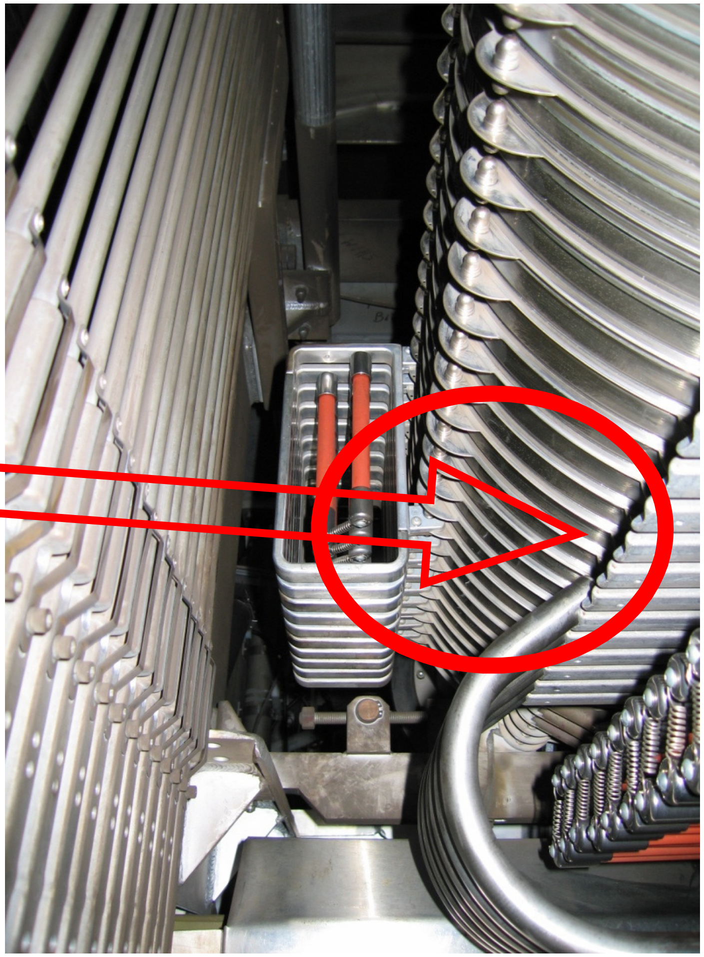
(particularly in sec.1 & sec.8).

Initially resistors support broke

➔ Bad trasmission

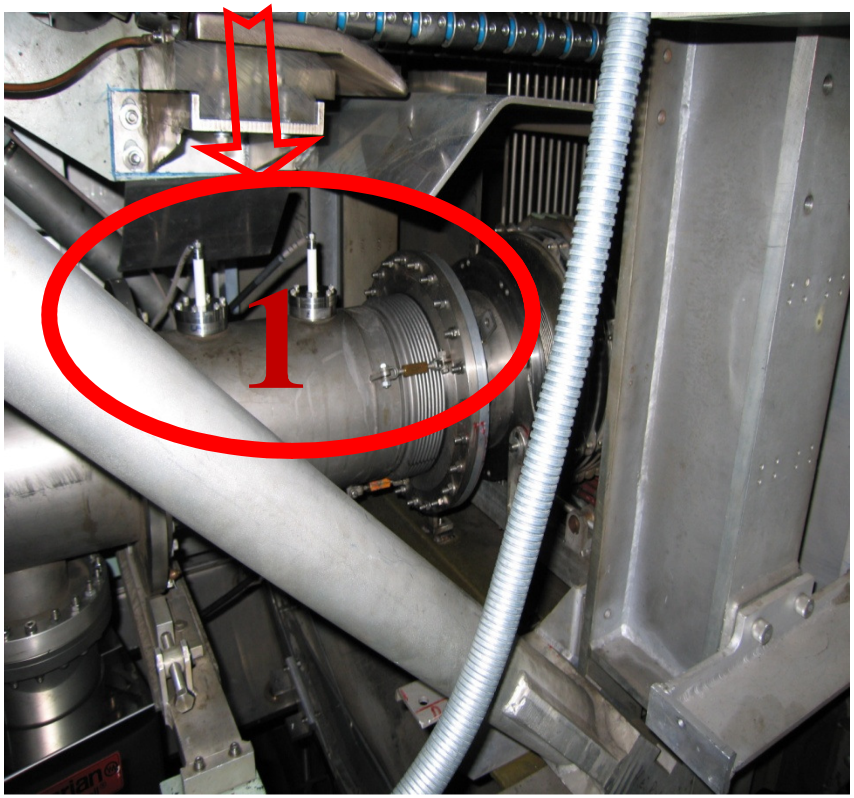
➔ Low T.V.(12-12.5)MV

Repleced **Resistor** **Support broken**

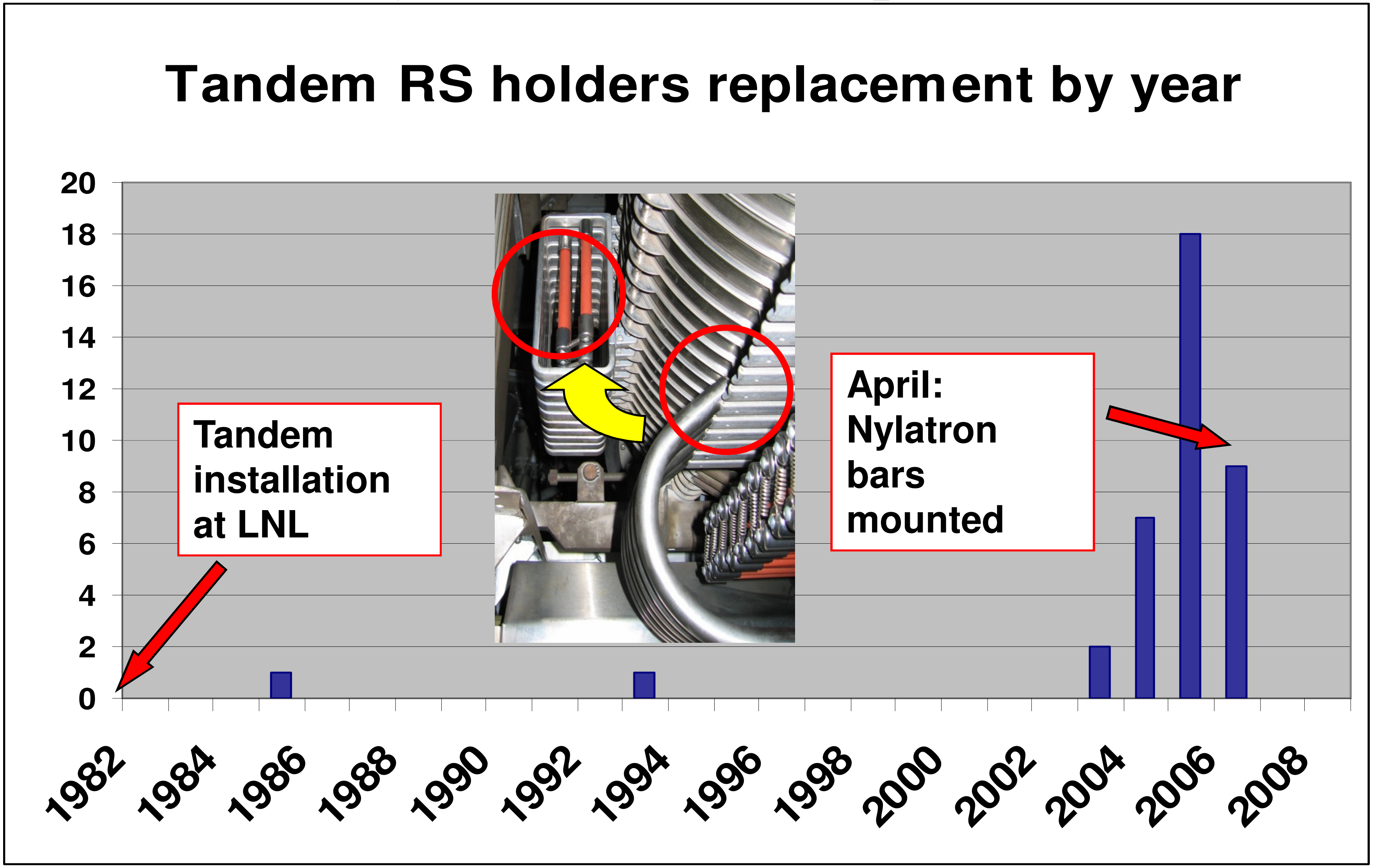


Repeated problems with the Tandem ,
the Last minute aproach increased the statistic

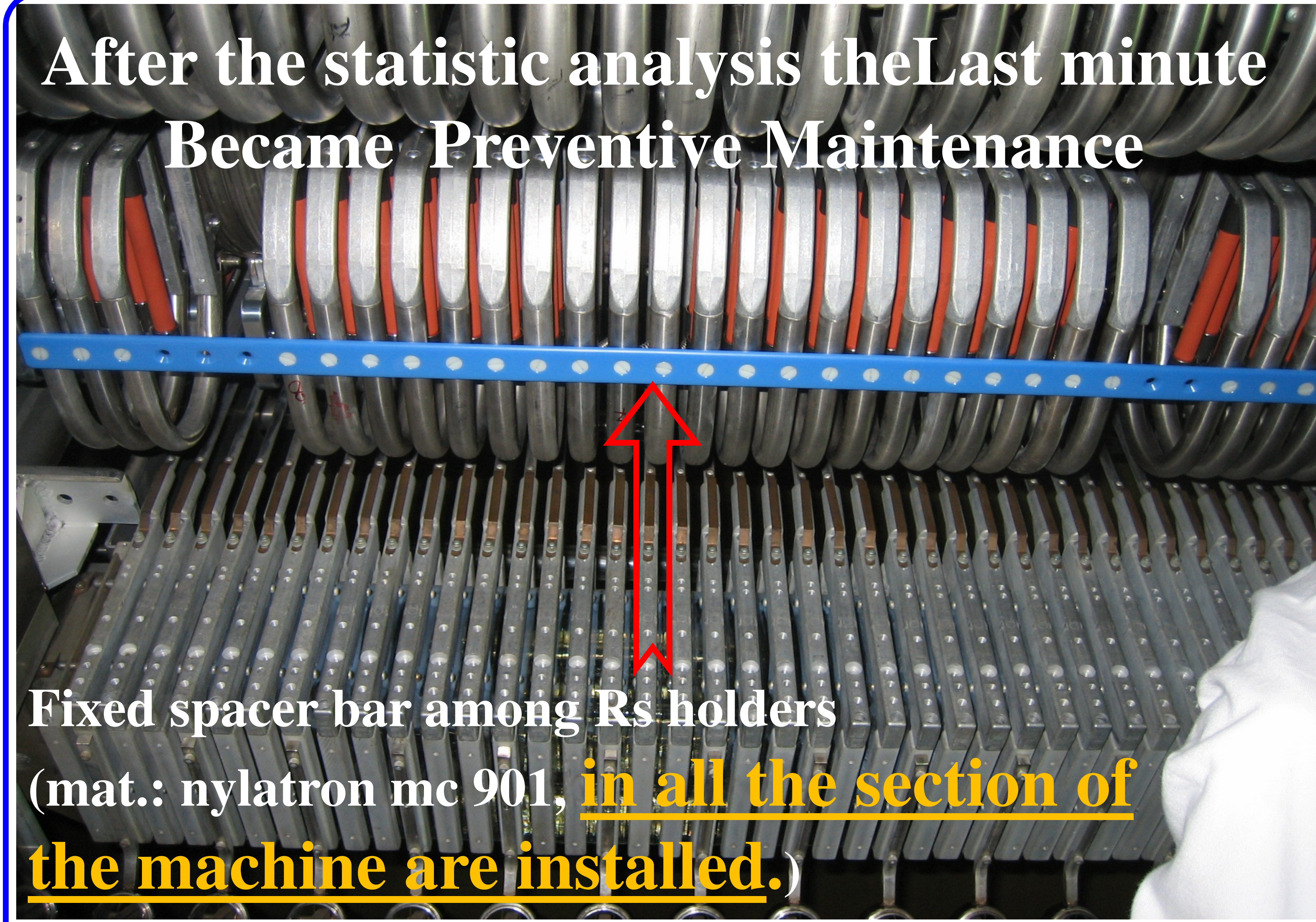
- **Ocober-December 2005**:
  10 unscheduled opening: 9 for broken resistor support and 1 for vacuum problem



Analysis of the statistic problems



After the statistic analysis theLast minute Became Preventive Maintenance



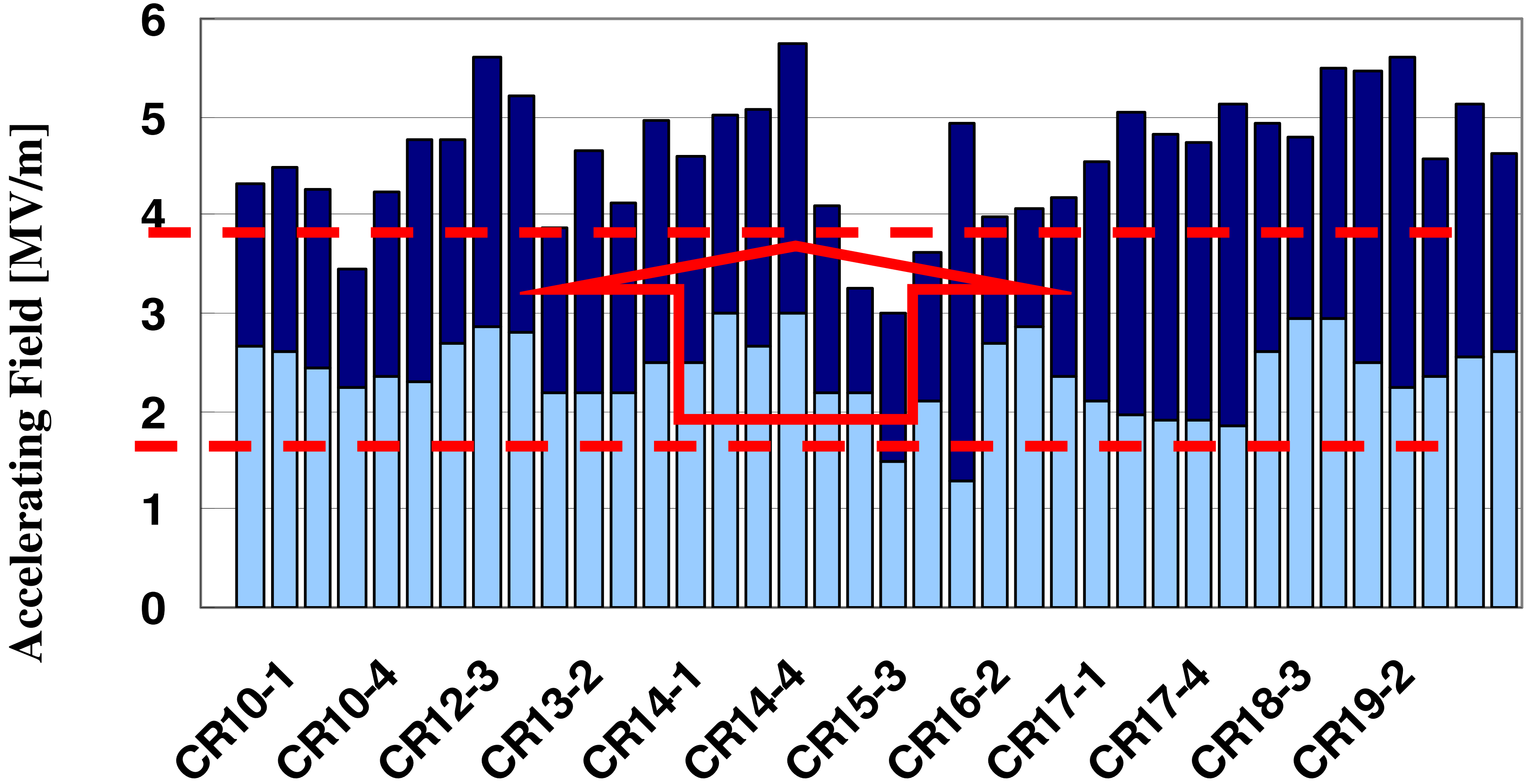
Fixed spacer bar among Rs holders (mat.: nylatron mc 901, **in all the section of the machine are installed.**)

Could happen...Started as Development ended as Maintenance of all cryostats

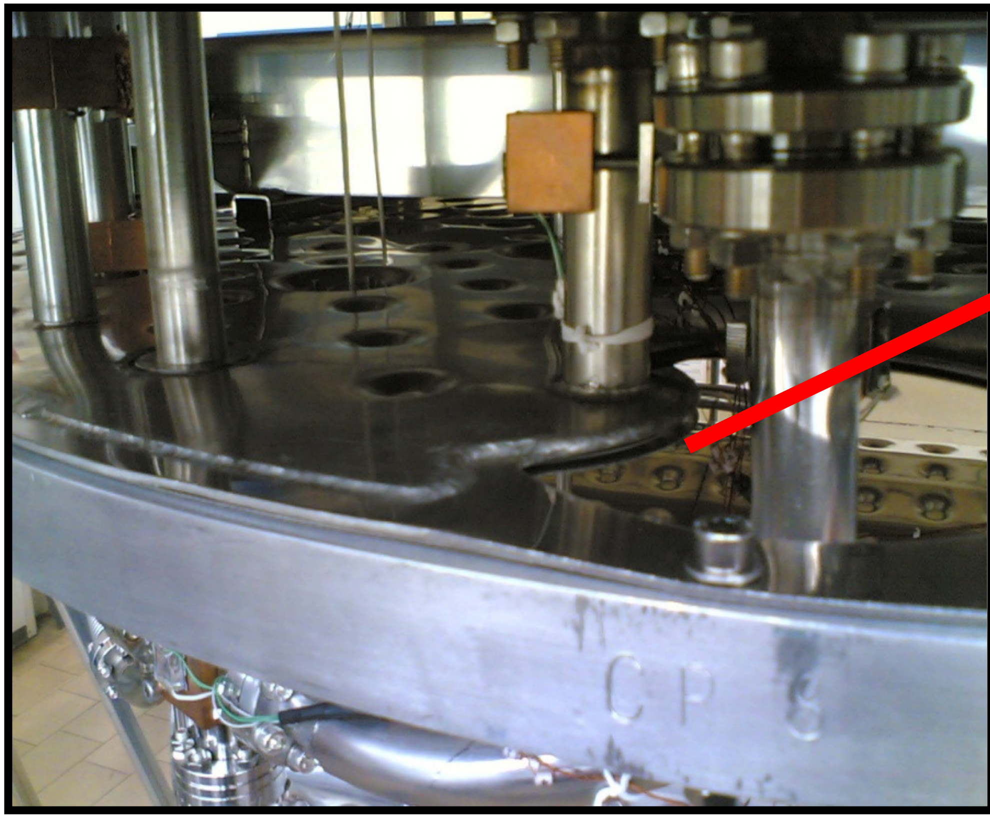
- LNL started to think about ALPI, a heavy ion SC linac equipped with QW, Pb on Cu resonators, less expensive and *easier* to build than Nb QWR.
- Since the beginning we investigated the possibility to substitute in the future Pb with Nb.
- A laboratory for Nb QWR sputtering was set up and a devoted research project was funded in 1987.

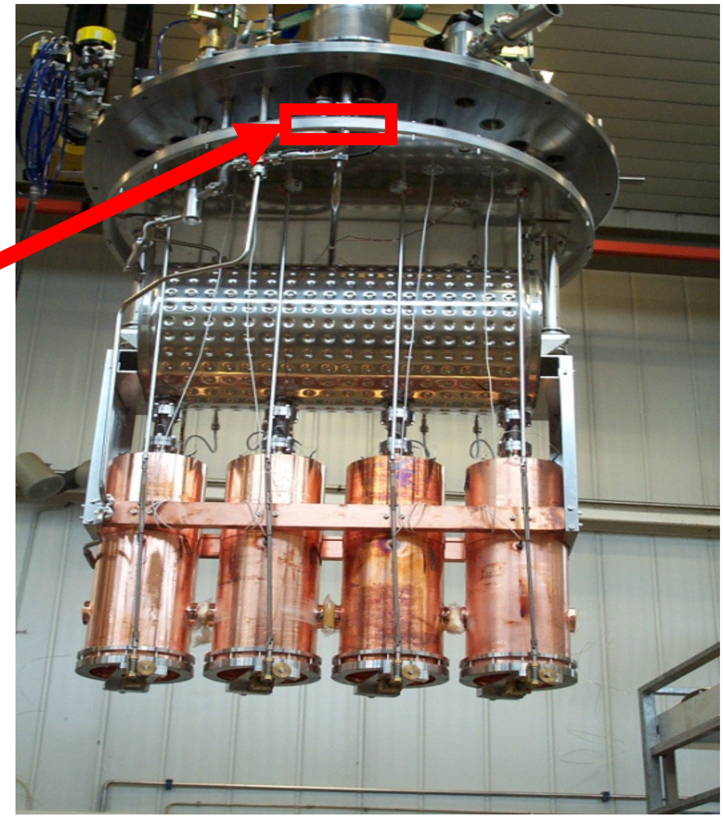
- 1987: Funding a Development on QWR Nb sputtering
- 1988-1999: DC biased sputtering choice and system set-up
- 1990: Obtaining good SC performance on samples
- 1991: Sputtering on a simplified prototype
- 1994: Design of a ALPI high b resonator suitable for sputtering production and compatible with existing cryostats
- 1995/1998 Production and installation of 4 high b cavities in ALPI
- 1998 Sputtering of a standard medium b ALPI resonator
- 2003 Upgrading of the medium b ALPI resonators

2003 Medium β ALPI cavities from Pb to Nb



Exemple of preventive maintenance 2009-10





Problem of mechanical fatigue, causing He gas leak from cryostat shields (VERY Dangerus).

➔ **Preventive Maintenance in all the** cryostats

Could happen... Started as maintenance Low-β tuning device ended as an upgrade

The main source of detuning, in these cavities, is the change of pressure of the helium bath. The standard ALPI mechanical tuner, although sufficient for slow corrections, is not well suited for frequency tracking in the presence of fast pressure fluctuations, due to large mechanical backlash and poor reproducibility.

ΔP in the Cold-box meaning Δf in the cavity

1. Resolution ~0.33 μm or better; this corresponds to frequency resolution below 1 Hz.
2. Very small and reproducible backlash in order to allow a fast tuner recovery .

We used the lever design of the TRIUMF QWR tuner with commercial backlash-free “C-FLEX” joints.
The system is linear and its theoretical resolution of on the tuning plate is 0.1 μm. This results in about 0.3 Hz tuning resolution for low-β quarter wave resonators; this value is well suited for our application.

1 mbar ~ 1 Hz

New tuner

The same problem (ΔP in the cold-box) trigger the start for an Upgrade of RF coupler for the Low β QWR

A new, liquid nitrogen cooled RF coupler, inspired by the ISAC_2 one, has been designed in order to maintain stable temperature with a forward power up to 500W, while limiting the thermal load to the liquid helium system within 1W. The main difference from the TRIUMF model is the 90 degrees corner near the connector, that allows keeping the overall length within 160 mm (the maximum available space in our cryostats) while leaving an effective strok of 80 mm; this results in a larger tuning range. The calculated heat load towards the liquid He circuit is around1 W.

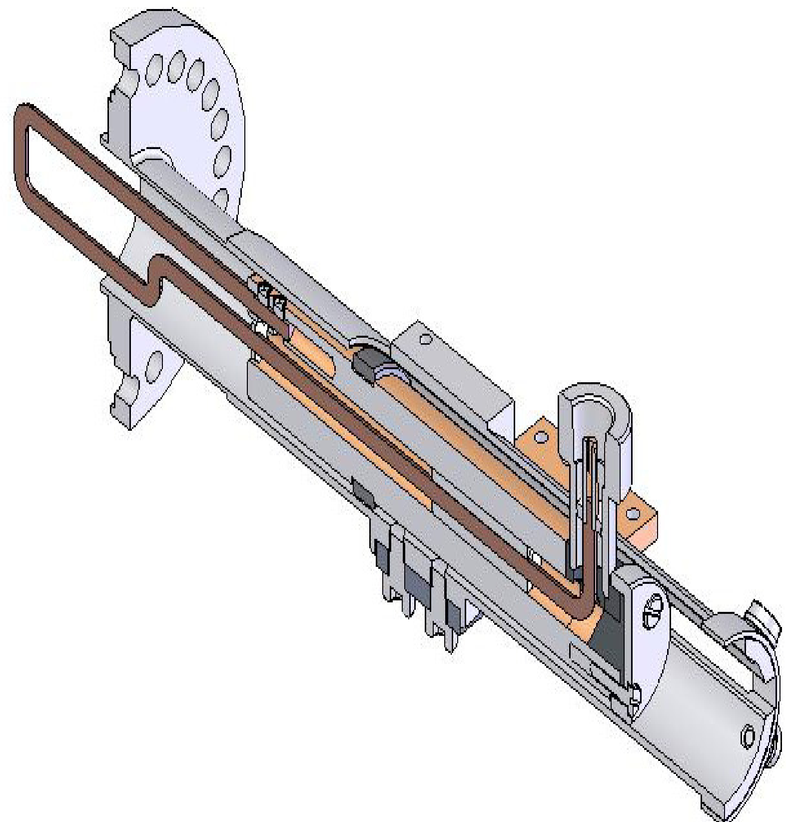
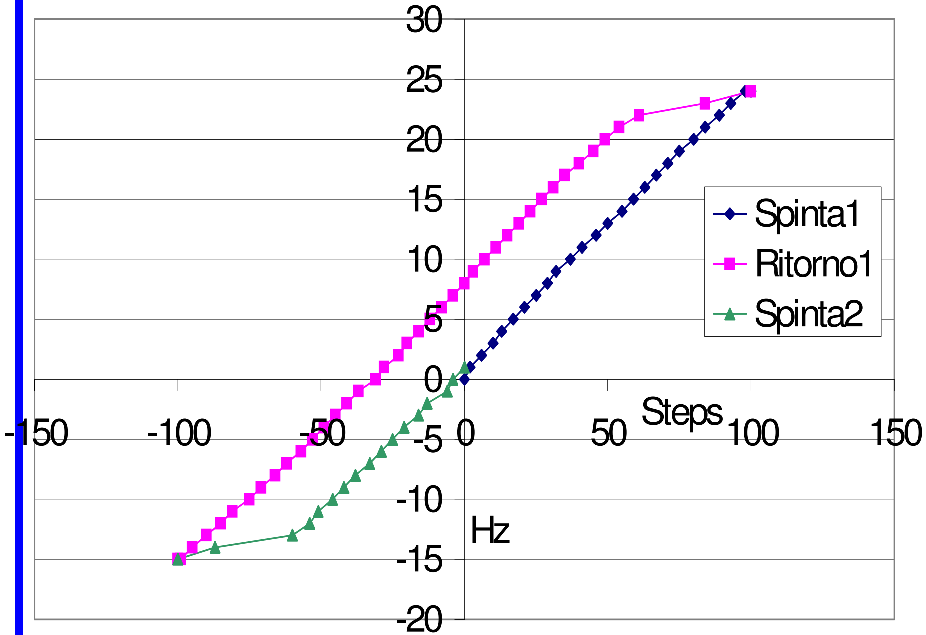
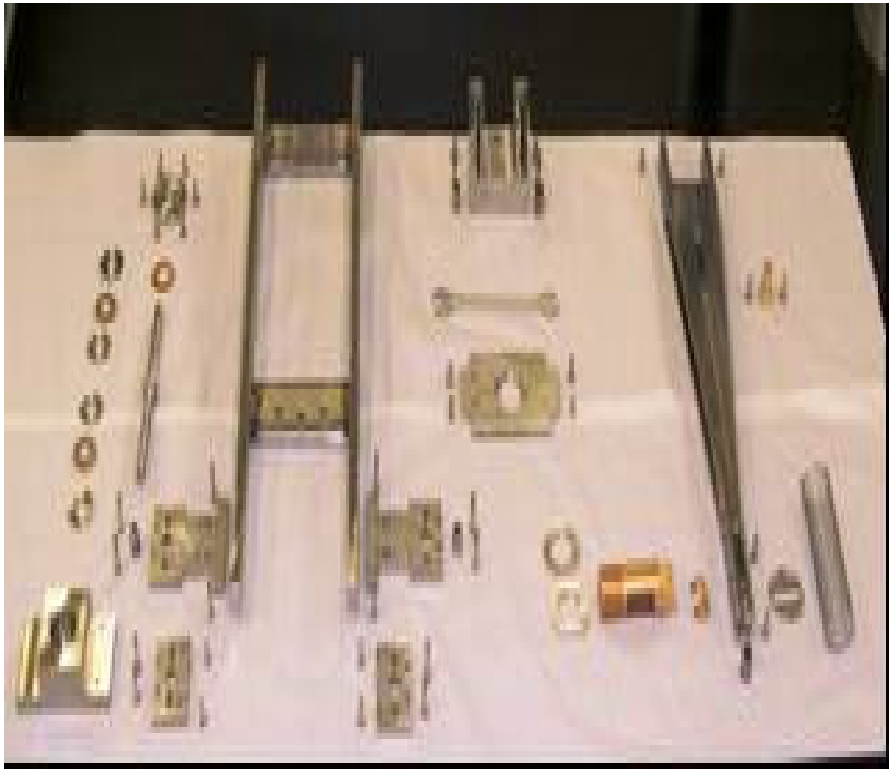


FIG 1: ***Cut view of the new cooled coupler prototype***

Low-β tuning device upgrading

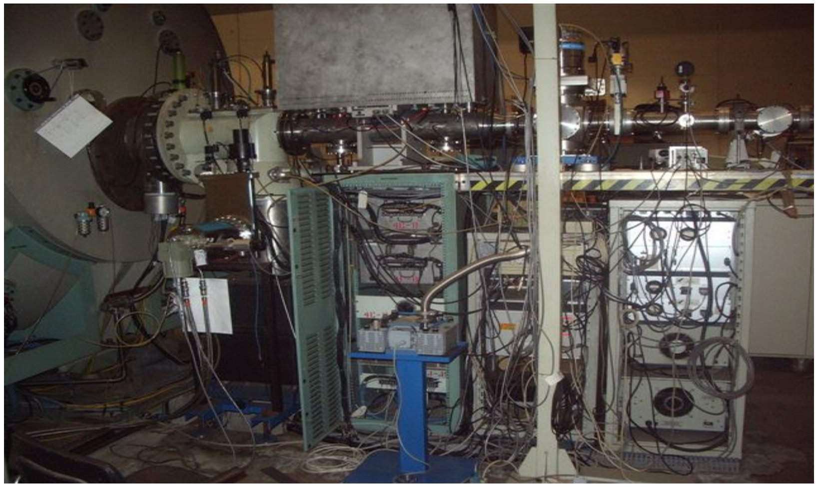




Resolution ~0.33 μm or better; this corresponds to frequency resolution below 1 Hz.

- **C-flex joints do not deteriorate the Q (> 10^9)of the QWR**
- **good linearity, resolution and reliability**
- **tuning range > 10 kHz**

Safety maintenaince of electrical wiring at Tandem XTU



Smooth transition from an all-on-paper to all-on DB E-Logbook

Microsoft Excel - PIAVE-ALPI_Controller.xls

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CAVITIES Controls

LNL ven-29 feb 2008 9.50

Mass (A)	136
Charge (Q)	23

MAGNETS

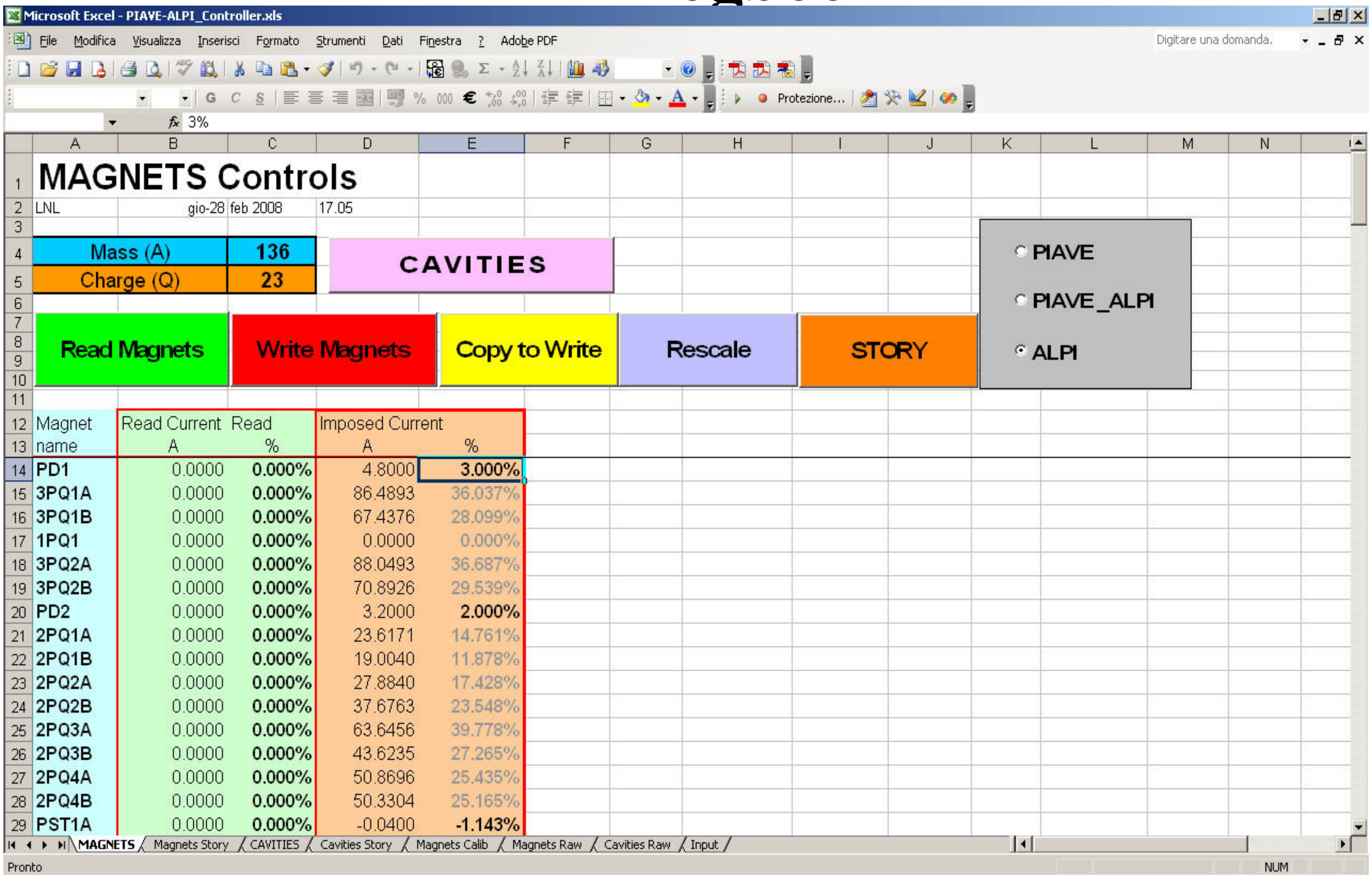
Read Cavities | Write Cavities | Copy to Write | Rescale | STORY

Reading from Cavities				Writing to Cavities			
QWR NAME	AMP. MV/m	PHASE deg	STATUS	QWR NAME	AMP. MV/m	Ref PHASE deg	Reference deg
B3-40MHz	2.174	178	on	B3-40MHz	2.199	161	
B3-80MHz	0.725	157	on	B3-80MHz	0.768	141	
B3-120MHz	0.200	105	on	B3-120MHz	0.193	124	
SRFQ1	19.191	0	locked	SRFQ1	19.191	0	0
SRFQ2	18.907	164	locked	SRFQ2	18.907	164	139
PC1-QWR1	3.577	99	on	PC1-QWR1	2.446	99	-90
PC1-QWR2	3.972	246	on	PC1-QWR2	3.048	246	60
PC1-QWR3	3.874	155	on	PC1-QWR3	3.493	155	30
PC1-QWR4	3.782	68	on	PC1-QWR4	3.489	66	-25
PC2-QWR1	3.820	3	on	PC2-QWR1	3.820	3	-20
PC2-QWR2	4.306	165	on	PC2-QWR2	3.838	165	-20
PC2-QWR3	3.986	304	on	PC2-QWR3	3.850	304	-20
PC2-QWR4	3.848	6	on	PC2-QWR4	3.848	6	20
HEB1	357.312	42	on	HEB1	510.560	38	-90

MAGNETS / Magnets Story / CAVITIES / Cavities Story / Magnets Calib / Magnets Raw / Cavities Raw / Input

Pronto NUM

Smooth transition from an all-on-paper to all-on DB E-Logbook



Magnet name	Read Current A	Read %	Imposed Current A	%
PD1	0.0000	0.000%	4.8000	3.000%
3PQ1A	0.0000	0.000%	86.4893	36.037%
3PQ1B	0.0000	0.000%	67.4376	28.099%
1PQ1	0.0000	0.000%	0.0000	0.000%
3PQ2A	0.0000	0.000%	88.0493	36.687%
3PQ2B	0.0000	0.000%	70.8926	29.539%
PD2	0.0000	0.000%	3.2000	2.000%
2PQ1A	0.0000	0.000%	23.6171	14.761%
2PQ1B	0.0000	0.000%	19.0040	11.878%
2PQ2A	0.0000	0.000%	27.8840	17.428%
2PQ2B	0.0000	0.000%	37.6763	23.548%
2PQ3A	0.0000	0.000%	63.6456	39.778%
2PQ3B	0.0000	0.000%	43.6235	27.265%
2PQ4A	0.0000	0.000%	50.8696	25.435%
2PQ4B	0.0000	0.000%	50.3304	25.165%
PST1A	0.0000	0.000%	-0.0400	-1.143%

Smooth transition from an all-on-paper to all-on DB E-Logbook

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Arial 10 — 75% — Protezione...

K15

	A	HJ	HK	HL	HM	HN	HO	HP	HQ	HR	HS	HT	HU	HV	HW	HX	HY
1	COPY OK 246	29-feb-2008 23.02 136/ 23		29-feb-2008 23.33 136/ 23		03-mar-2008 08.14 136/ 23		03-mar-2008 08.44 136/ 23		03-mar-2008 09.14 136/ 23		03-mar-2008 09.45 136/ 23		03-mar-2008 10.15 136/ 23		03-mar-2008 10.45 136/ 23	
2	B3-40MHz	2.225	166	2.225	166	2.174	172	2.174	172	2.174	172	2.174	172	2.174	172	2.174	172
3	B3-80MHz	0.768	140	0.768	140	0.768	143	0.768	143	0.768	143	0.768	143	0.768	143	0.768	143
4	B3-120MHz	0.193	127	0.193	127	0.252	119	0.252	119	0.252	119	0.252	119	0.252	119	0.252	119
5	SRFQ1	19.19	0	19.19	0	19.41	0	19.41	0	19.41	0	19.41	0	19.41	0	19.41	0
6	SRFQ2	18.91	178	18.91	178	18.91	176	18.91	176	18.91	176	18.91	176	18.91	176	18.91	176
7	PC1-QWR1	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117
8	PC1-QWR2	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263
9	PC1-QWR3	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174
10	PC1-QWR4	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90
11	PC2-QWR1	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42
12	PC2-QWR2	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208
13	PC2-QWR3	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347
14	PC2-QWR4	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51
15	HEB1	498.9	88	498.9	88	465.6	88	465.6	88	465.6	88	465.6	88	465.6	88	465.6	88
16	HEB2	201	291	201	291	185.4	291	185.4	291	185.4	291	185.4	291	185.4	291	185.4	291
17																	
18																	
19	CRB2-Q1	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7
20	CRB2-Q2	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0
21	CRB1-Q1	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0
22	CR04-Q1	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215
23	CR04-Q2	1.1	0	1.1	0	0.503	0	0.503	0	0.503	0	0.503	0	0.503	0	0.503	0
24	CR04-Q3	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304
25	CR04-Q4	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356
26	CR05-Q1	3.608	193	3.608	193	3.734	193	3.734	193	3.734	193	3.734	193	3.734	193	3.734	193
27	CR05-Q2	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235
28	CR05-Q3	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253
29	CR05-Q4	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0
30	CR06-Q1	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125
31	CR06-Q2	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0
32	CR06-Q3	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117
33	CR06-Q4	3.349	134	3.349	134	2.785	132	2.785	132	2.785	132	2.785	132	2.785	132	2.785	132
34	CR07-Q1	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208
35	CR07-Q2	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148
36	CR07-Q3	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132
37	CR07-Q4	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98
38	CR08-Q1	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0
39	CR08-Q2	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1
40	CR08-Q3	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0
41	CR08-Q4	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0
42	CR09-Q1	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234

	A	HZ	IA	IB	IC	ID	IE	IF	IG	IH	II	IJ	IK	IL	IM
1	COPY OK 246	03-mar-2008 11.16 136/ 23		03-mar-2008 11.46 136/ 23		03-mar-2008 14.50 136/ 23		03-mar-2008 15.20 136/ 23		03-mar-2008 15.51 136/ 23		03-mar-2008 16.21 136/ 23		03-mar-2008 16.51 136/ 23	
2	B3-40MHz	2.174	172	2.174	172	2.174	172	2.174	172	2.174	172	2.174	172	2.174	172
3	B3-80MHz	0.768	143	0.768	143	0.768	143	0.768	143	0.768	143	0.768	143	0.768	143
4	B3-120MHz	0.252	119	0.252	119	0.252	119	0.252	119	0.252	119	0.252	119	0.252	119
5	SRFQ1	19.41	0	19.41	0	19.41	0	19.41	0	19.41	0	19.41	0	19.41	0
6	SRFQ2	18.91	176	18.91	176	18.91	176	18.91	176	18.91	176	18.91	176	18.91	176
7	PC1-QWR1	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117	2.446	117
8	PC1-QWR2	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263	3.048	263
9	PC1-QWR3	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174	3.493	174
10	PC1-QWR4	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90	3.489	90
11	PC2-QWR1	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42	3.82	42
12	PC2-QWR2	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208	3.838	208
13	PC2-QWR3	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347	3.85	347
14	PC2-QWR4	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51	3.848	51
15	HEB1	465.6	88	465.6	88	465.6	88	465.6	88	465.6	88	465.6	88	465.6	88
16	HEB2	185.4	291	185.4	291	185.4	291	185.4	291	185.4	291	185.4	291	185.4	291
17															
18															
19	CRB2-Q1	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7	0.217	7
20	CRB2-Q2	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0	3.801	0
21	CRB1-Q1	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0	13.91	0
22	CR04-Q1	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215	3.225	215
23	CR04-Q2	0.503	0	0.503	0	0.503	0	0.503	0	0.503	0	0.503	0	0.503	0
24	CR04-Q3	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304	4.225	304
25	CR04-Q4	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356	4.062	356
26	CR05-Q1	3.734	193	3.734	193	3.734	193	3.734	193	3.734	193	3.734	193	3.734	193
27	CR05-Q2	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235	4.132	235
28	CR05-Q3	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253	4.134	253
29	CR05-Q4	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0	0.745	0
30	CR06-Q1	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125	4.108	125
31	CR06-Q2	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0	0.366	0
32	CR06-Q3	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117	3.043	117
33	CR06-Q4	2.785	132	2.785	132	2.785	132	2.785	132	2.785	132	2.785	132	2.785	132
34	CR07-Q1	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208	4.331	208
35	CR07-Q2	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148	4.408	148
36	CR07-Q3	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132	3.627	132
37	CR07-Q4	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98	4.401	98
38	CR08-Q1	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0	0.336	0
39	CR08-Q2	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1	0.391	1
40	CR08-Q3	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0	0.351	0
41	CR08-Q4	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0	0.447	0
42	CR09-Q1	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234	4.029	234

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All the value of the magnets, and RF, are recorded every second

Maintenance Future?

My Big Job

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