Operational Experience in PIAVI-ALPI Complex

E. Fagotti INFN-LNL

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Machine History

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Machine History

Machine Upgrade Status

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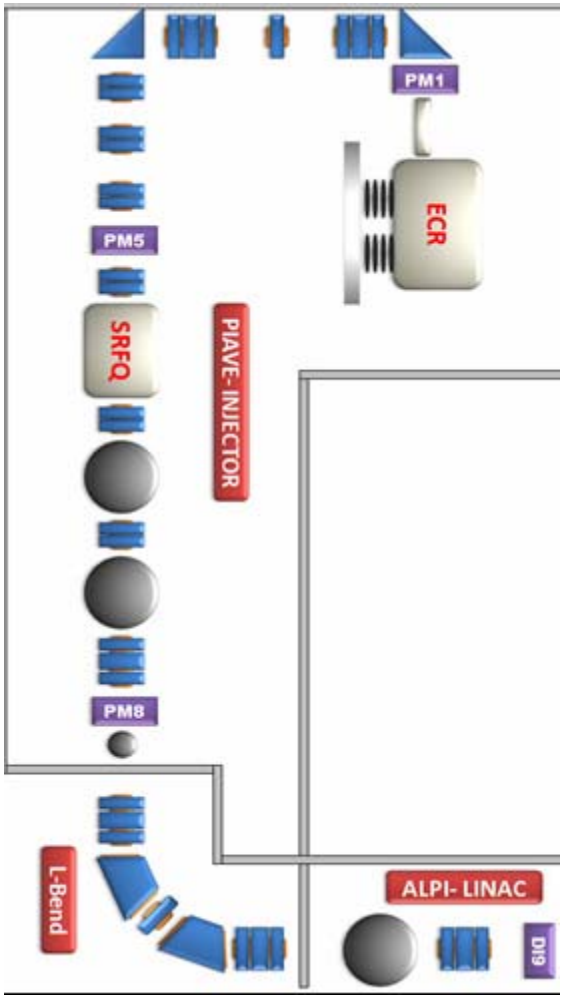
Machine History

Future Perspective

Machine Upgrade Status

Machine History

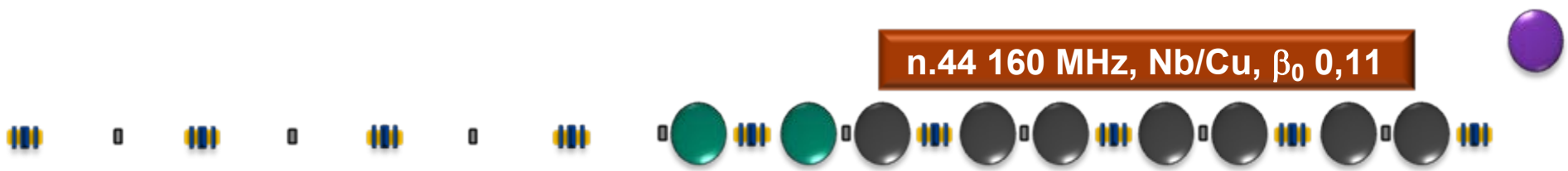
INFN Legnaro National Laboratory



PIAVE-ALPI COMPLEX

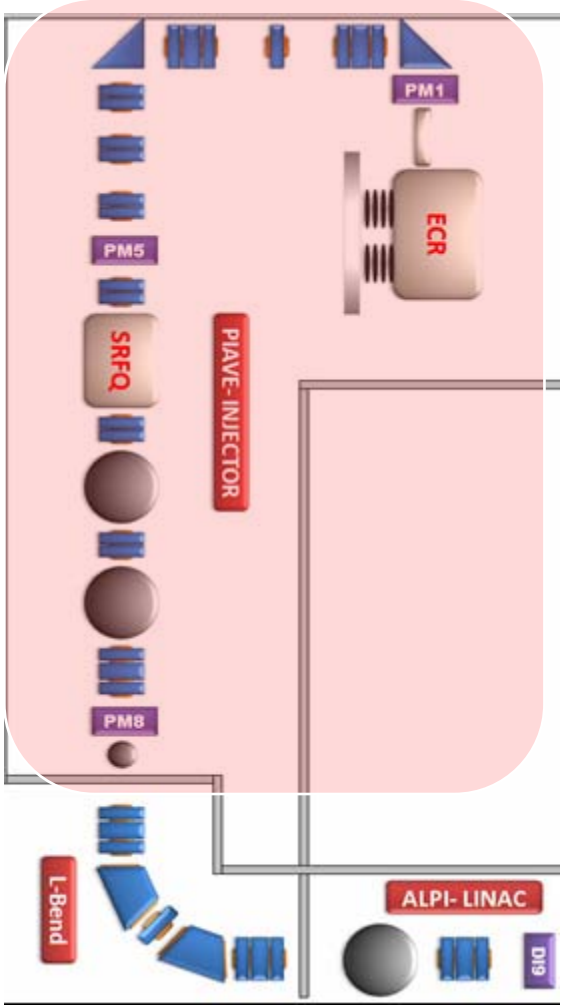
n.12 80 MHz,
full Nb, β_0 0,055

n.44 160 MHz, Nb/Cu, β_0 0,11



n.8 160 MHz,
Nb/Cu, β_0 0,13

PIAVE-ALPI COMPLEX



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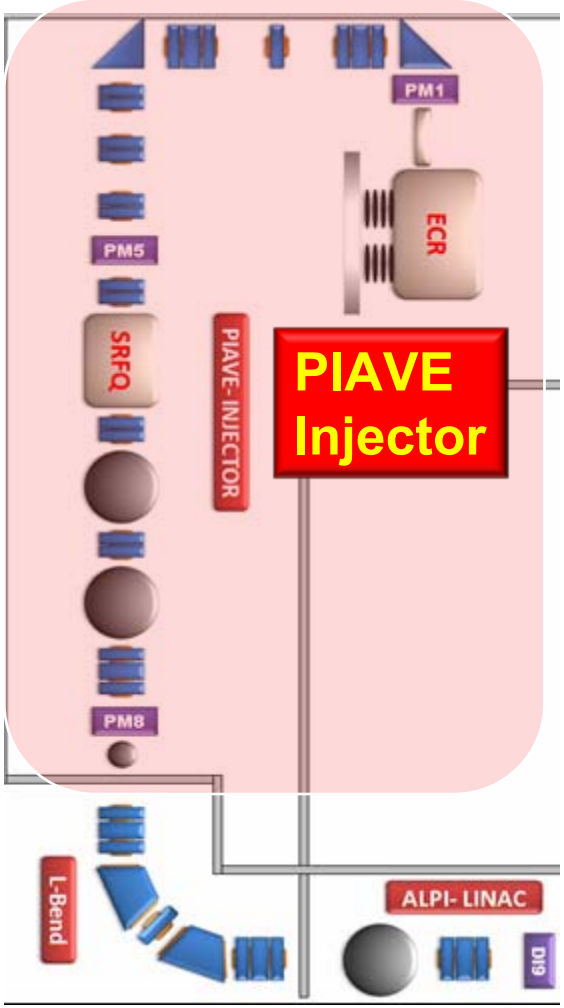

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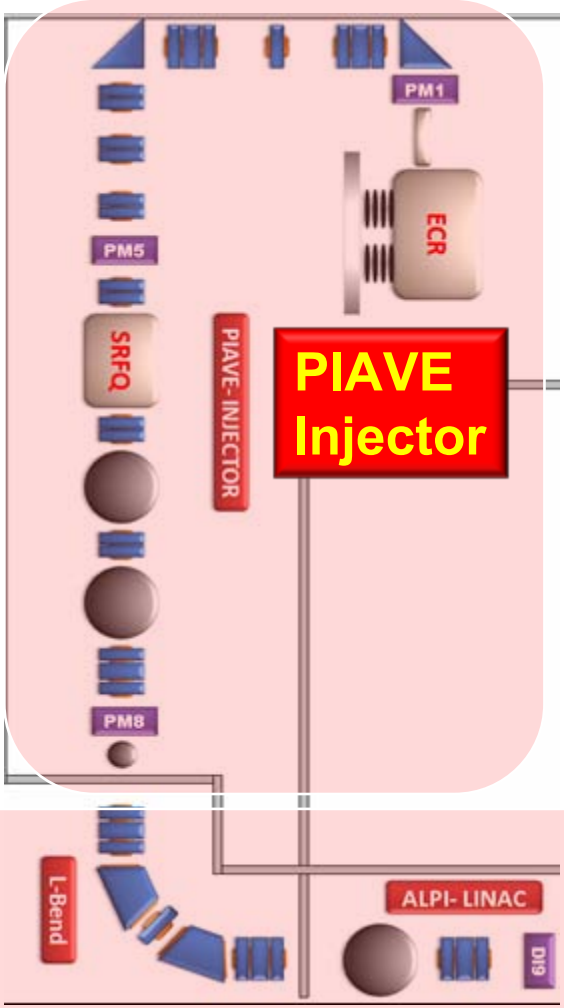
PIAVE-ALPI COMPLEX



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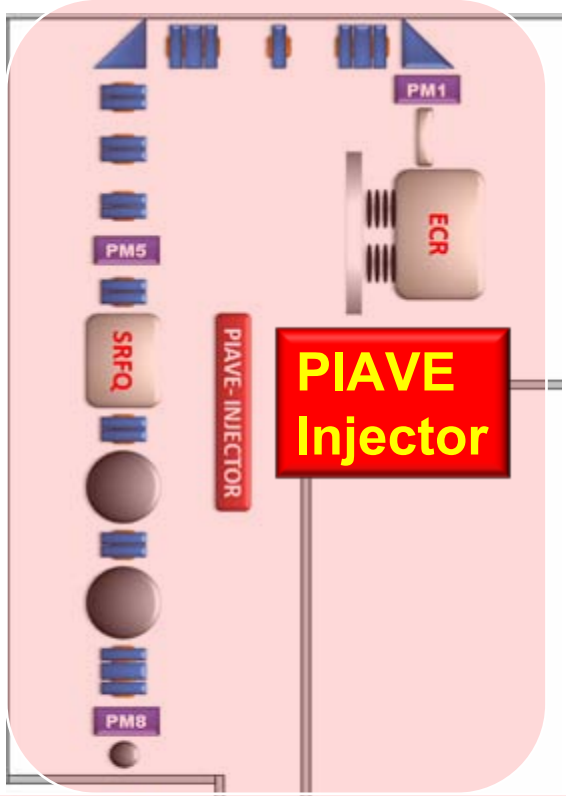
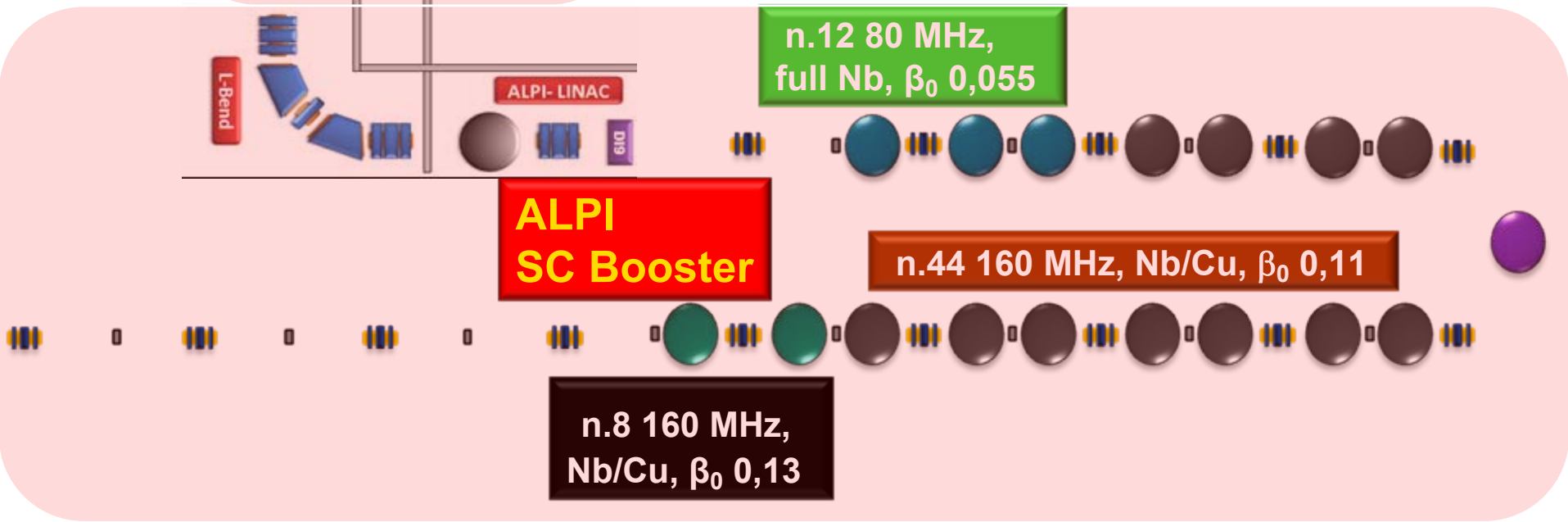
PIAVE-ALPI COMPLEX

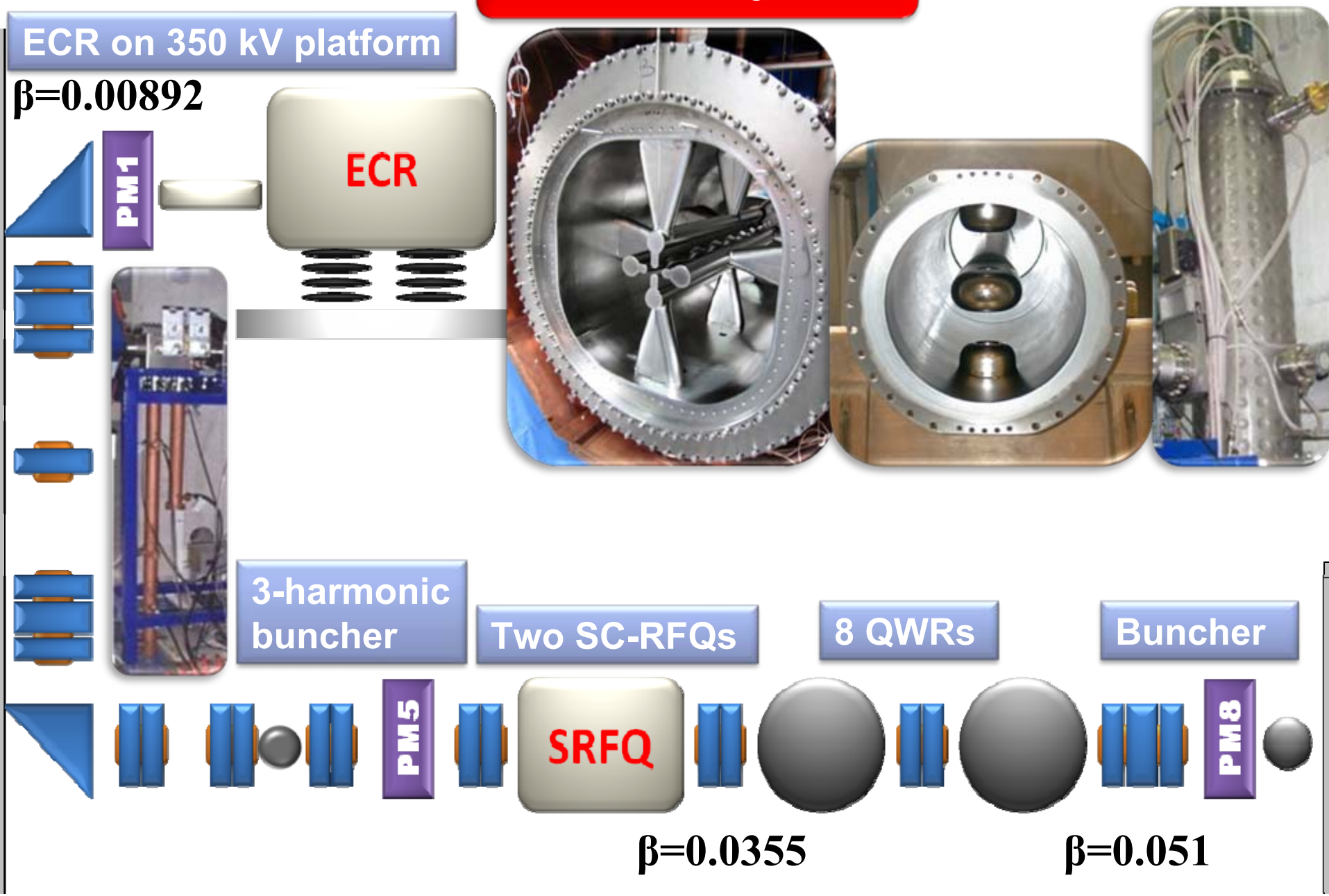




PIAVE Injector

ECR on 350 kV platform

β=0.00892



Upgraded ALICE source

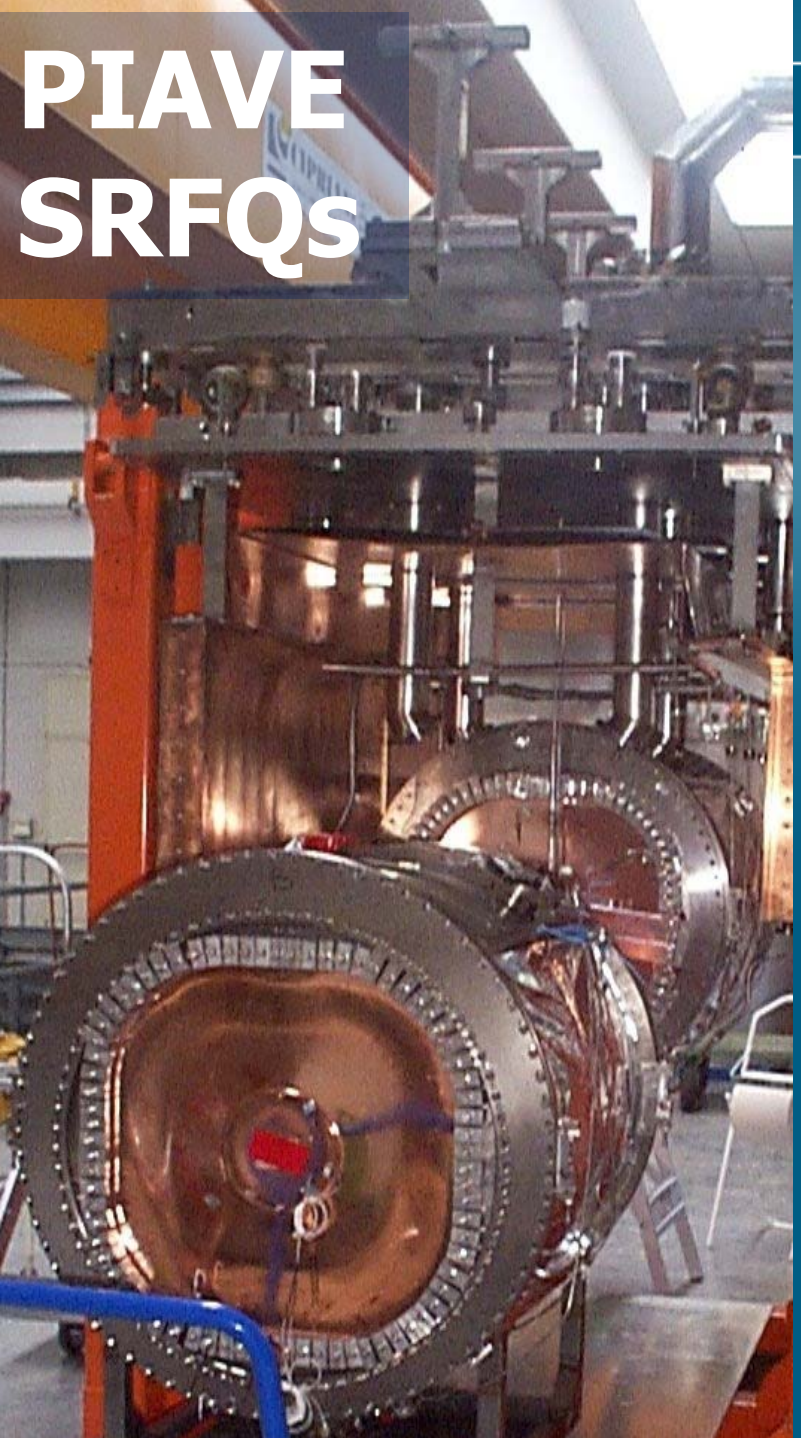
Water cooled plasma chamber

- RF power increase
- Shift to high value of charge state
- Ex. 0.4 μA $^{136}Xe^{23+}$ or 0.2 μA $^{136}Xe^{24+}$

Frequency tuning

Xe ion	I_{ext} @14.363 GHz [na]	I_{ext} @14.400 GHz [na]	I Ratio
11+	900	1760	0.51
12+	1160	2210	0.52
13+	1462	2750	0.53
14+	1875	3220	0.58
15+	2475	3710	0.67
16+	2900	4000	0.73
19+	4800	3410	1.41
20+	4000	2440	1.64
21+	3000	1420	2.11
22+	2000	790	2.53
23+	1200	370	3.24
24+	740	187	3.96
I_{Total} Xe	26512	26267	

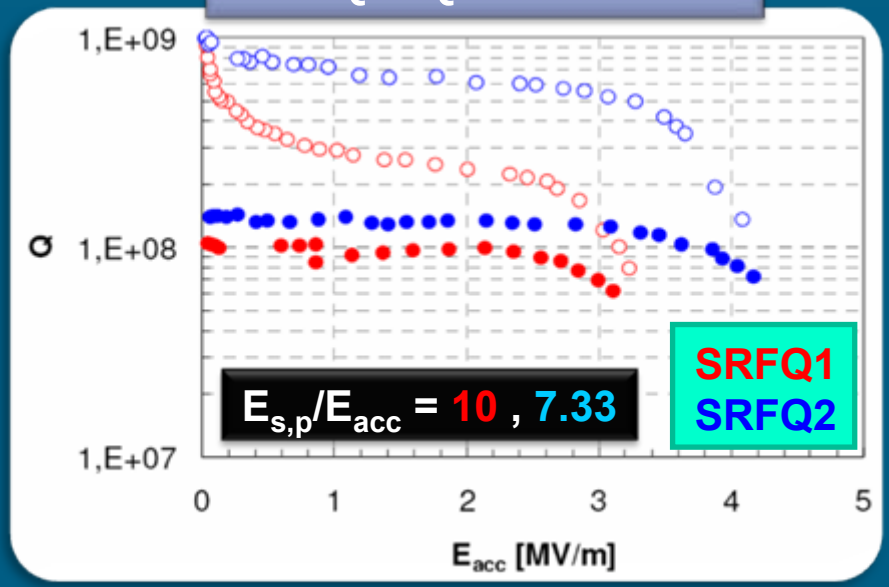
PIAVE SRFQs



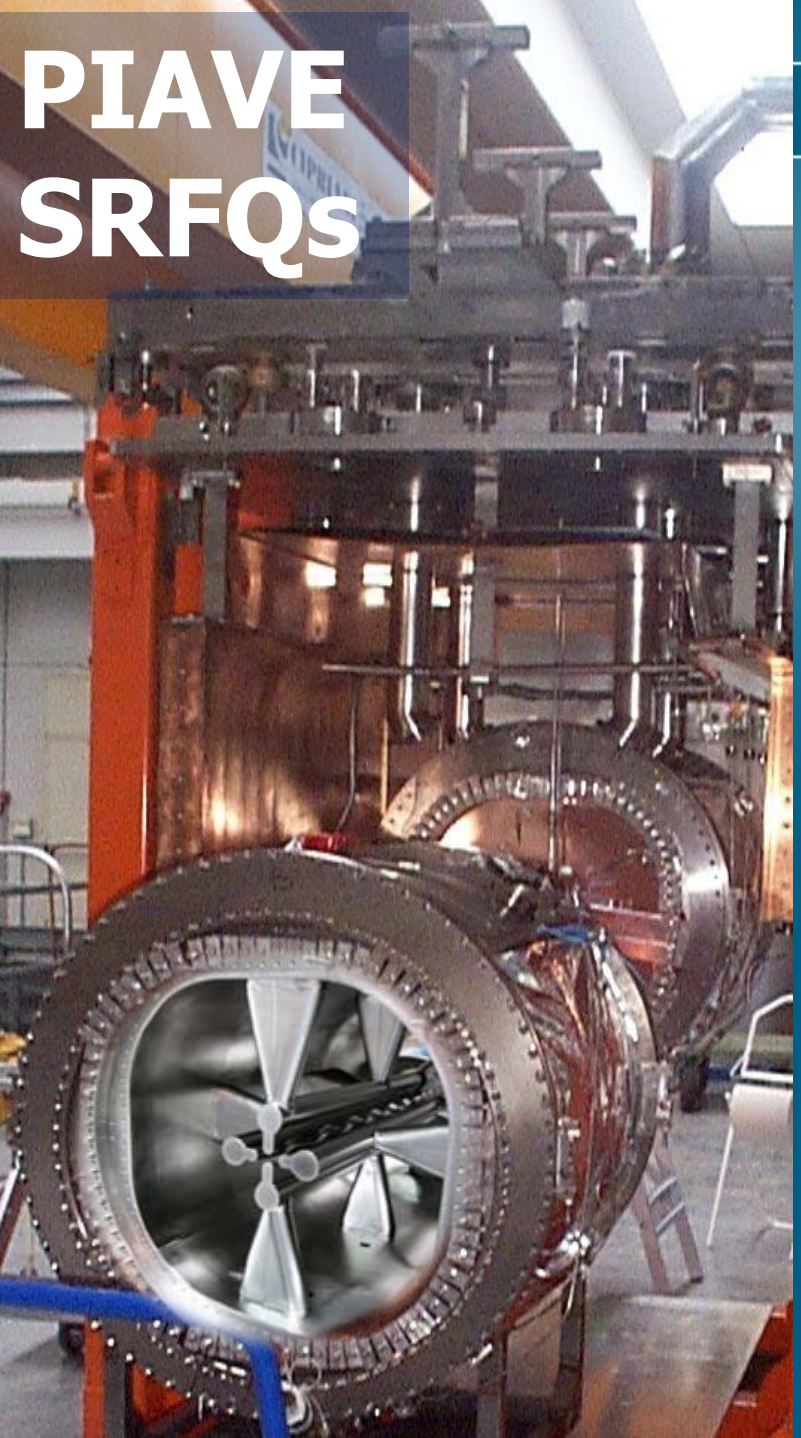
Main parameters

	SRFQ1	SRFQ2	
Frequency	80	80	MHz
Length	1.41	0.8	M
V	148	280	kV
$E_{s,p}$	25.5	25.5	MV/m
$E_{s,p}/E_a$	10	7.33	-
P_{dis}	10	10	W
Q	$1X10^8$	$2X10^8$	

SRFQs Q-curves



PIAVE SRFQs



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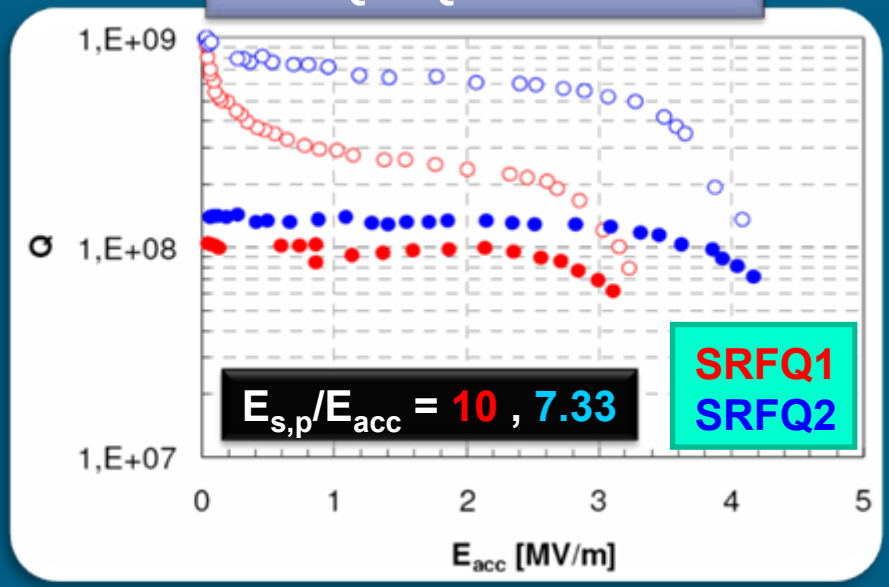
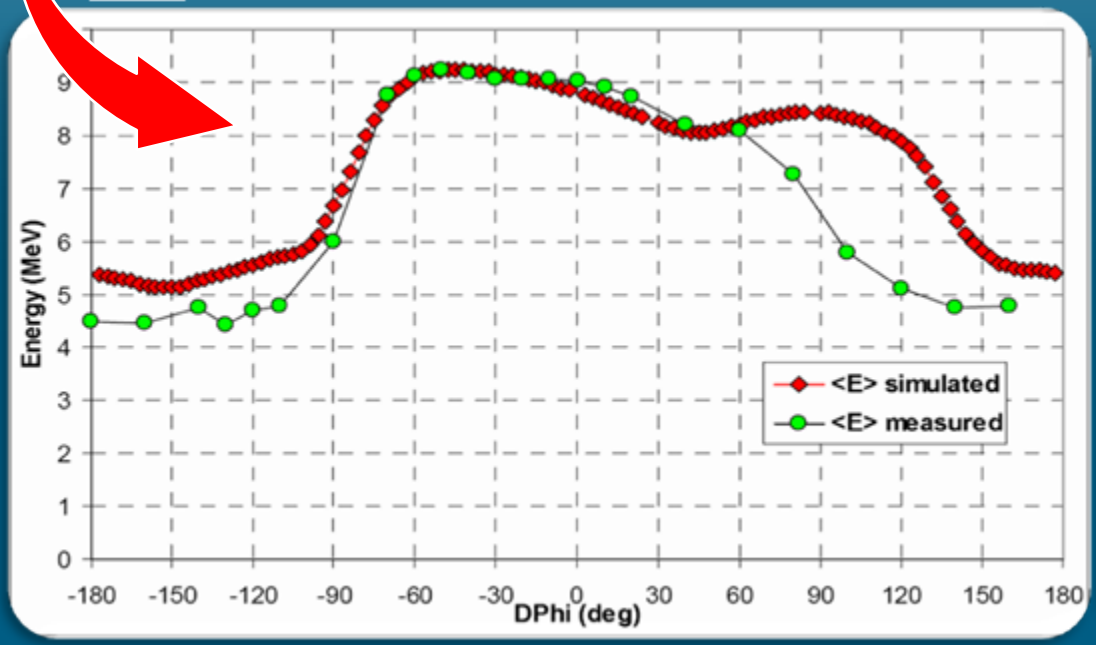
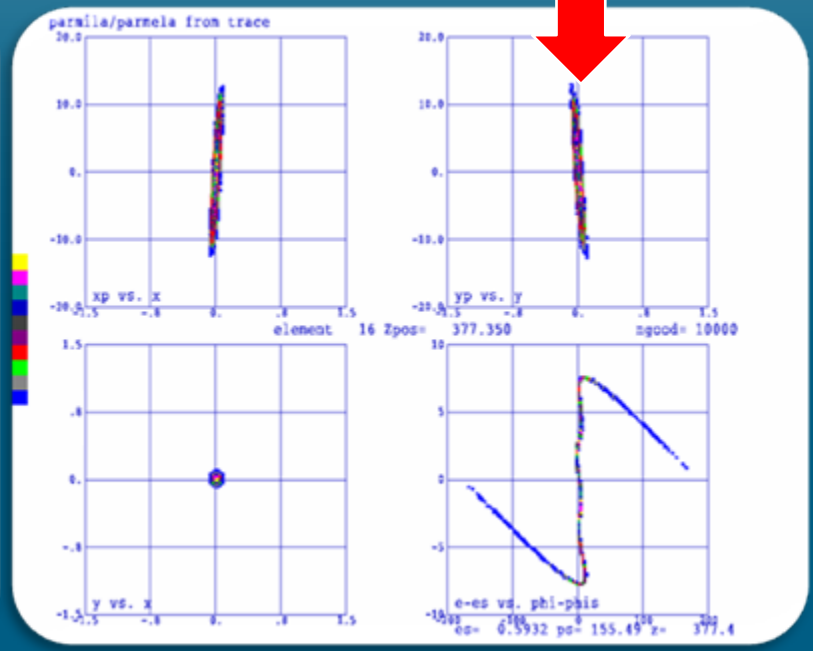
SRFQs Q-curves



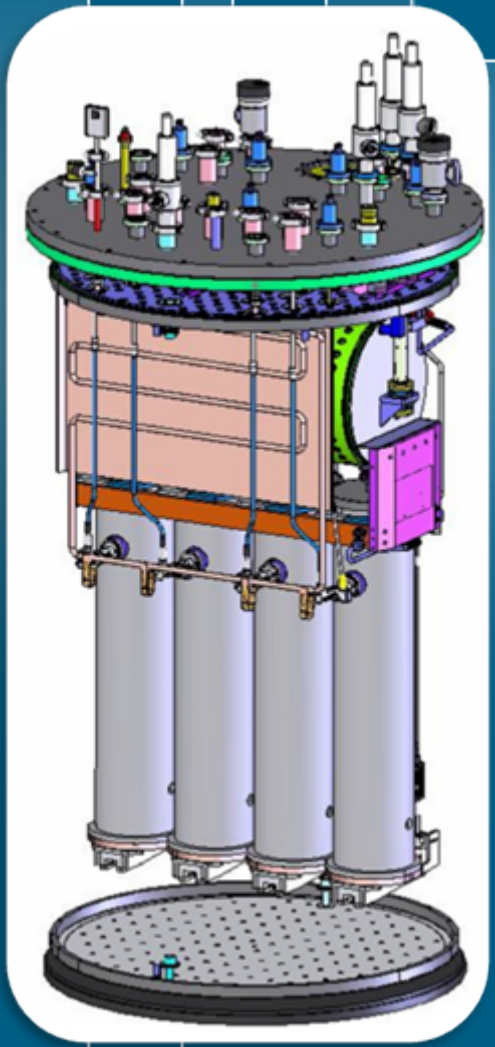
1. Field amplitude of the SRFQs and of the 3-h buncher set according to the computed values
2. Phase between SRFQ1 and SRFQ2 from simulations comparison (3-h buncher OFF)
3. 3-h buncher ON, phase setting for best transmission



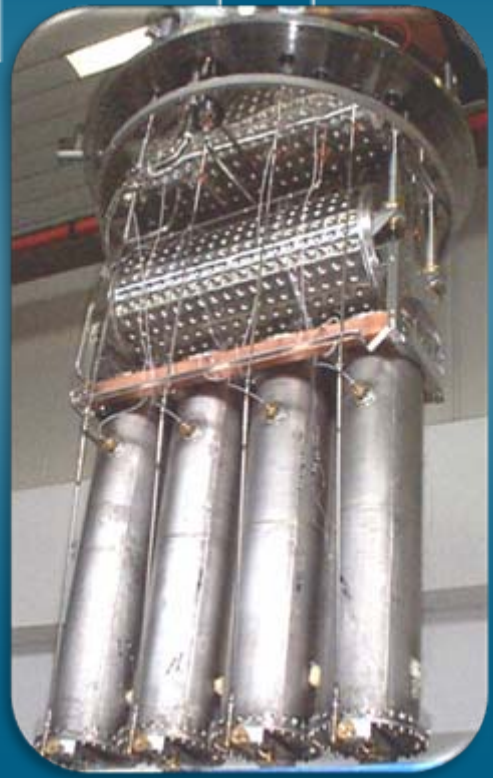


Simulated nominal transmission (bunching efficiency): 68%
Measured transmission: 68%

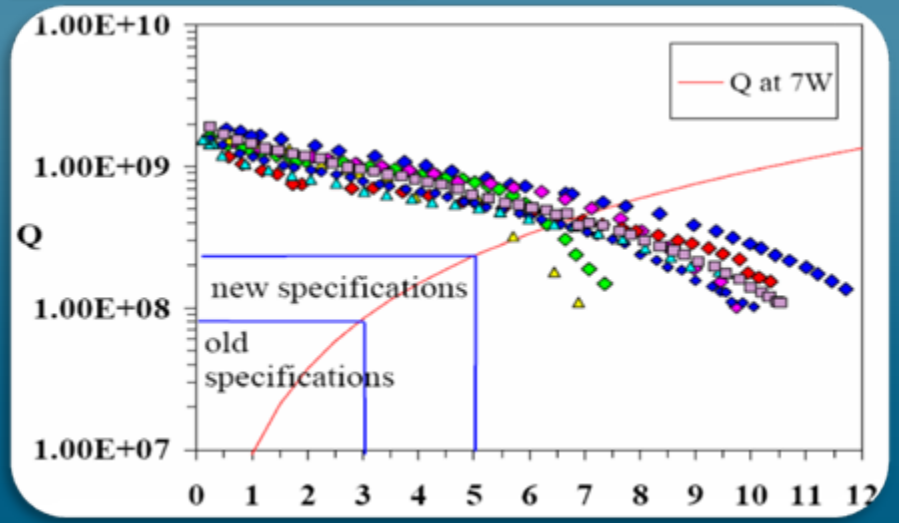
PIAVE QWRs



8 full Nb, 80 MHz
$\beta_{opt} = 0.047$

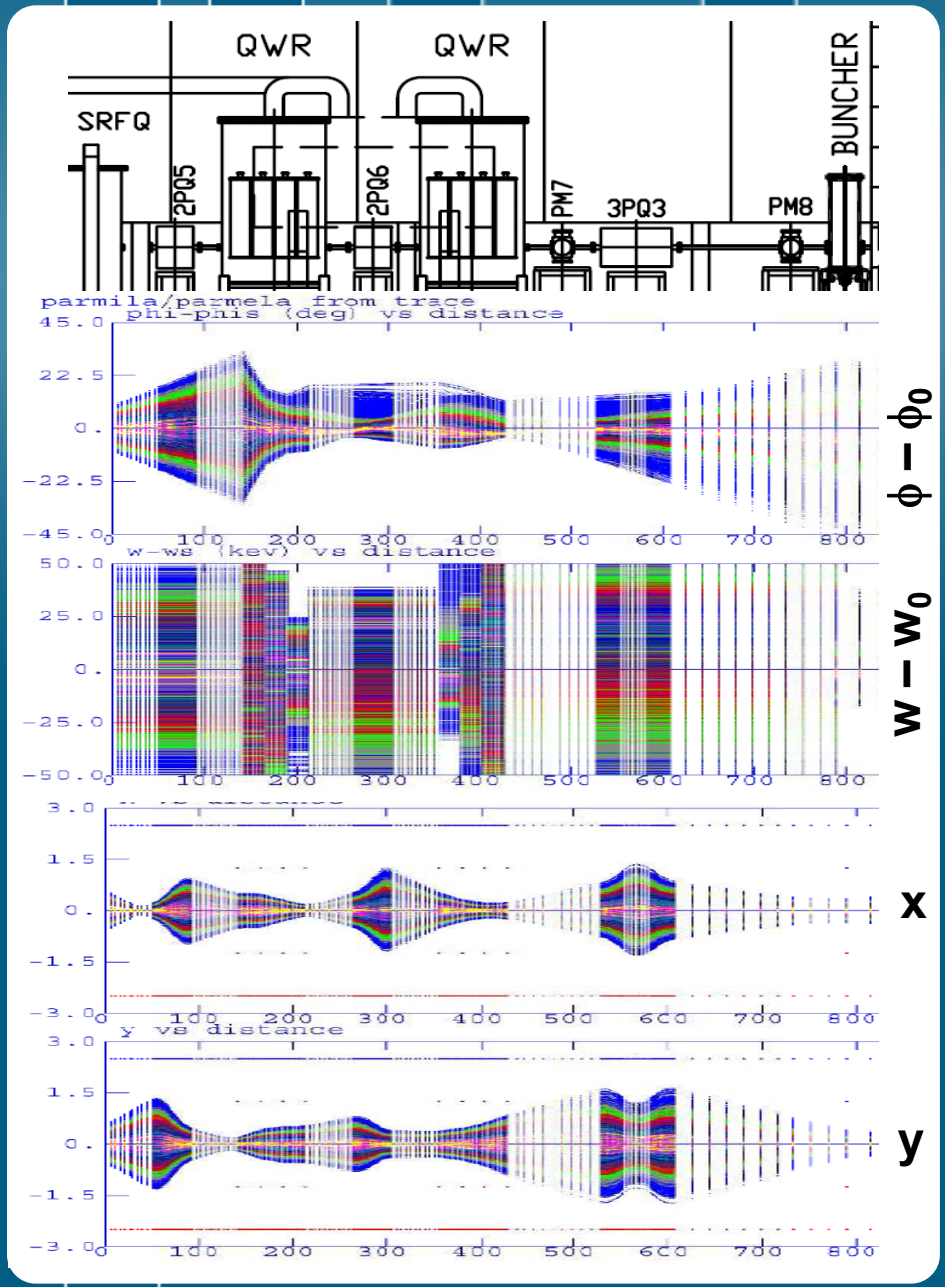


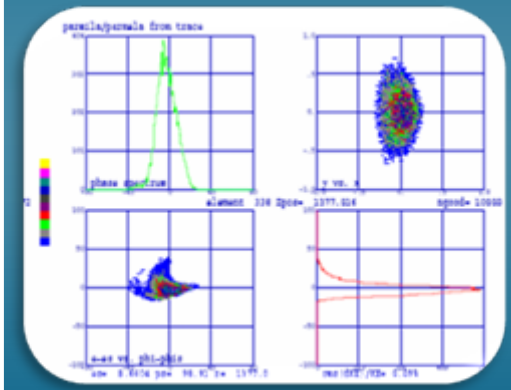
Off-line Q-curves



Maximum accelerating field in operation: 4.3 MV/m

Transport in the QWRs section





Longitudinal phase space at the end of injector

- Very compact layout
- Period:1 doublet / 4 cavities
- Lack of longitudinal matching
- First cavity used as buncher to limit longitudinal emittance increase
- Strong Bessel components on the fields inside the cavities
- Use of multi-particle codes for transport simulation

ALPI Booster

28 medium beta QWRs

8 high beta QWRs

2 bunchers

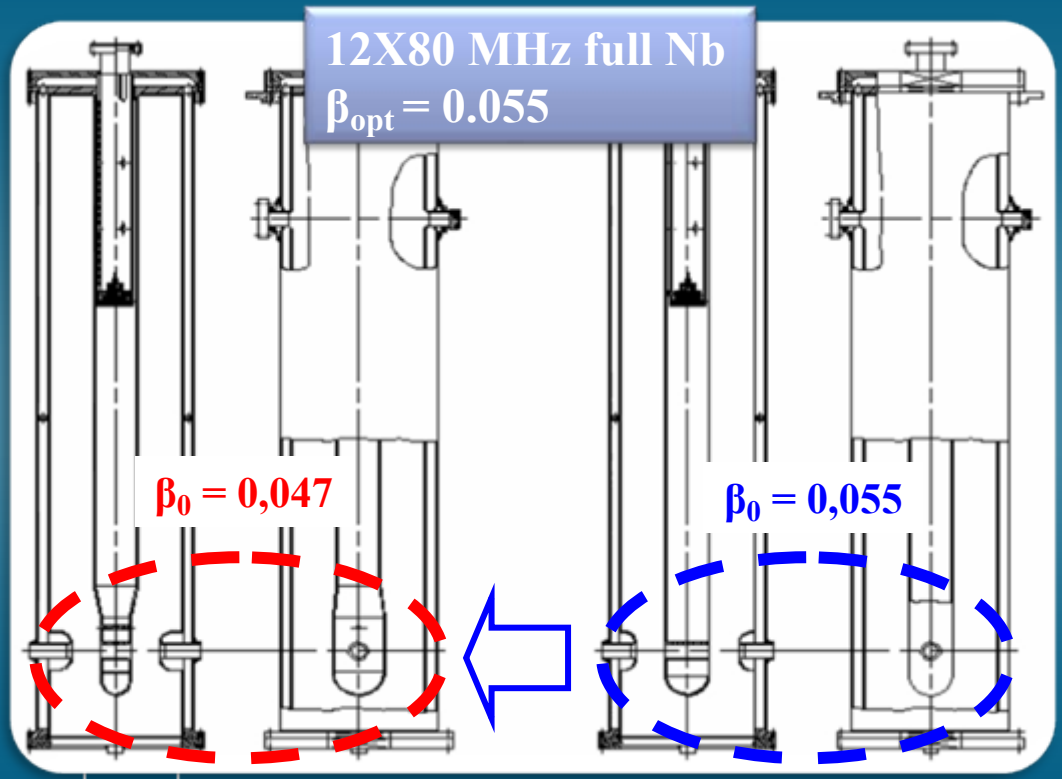
2 bunchers

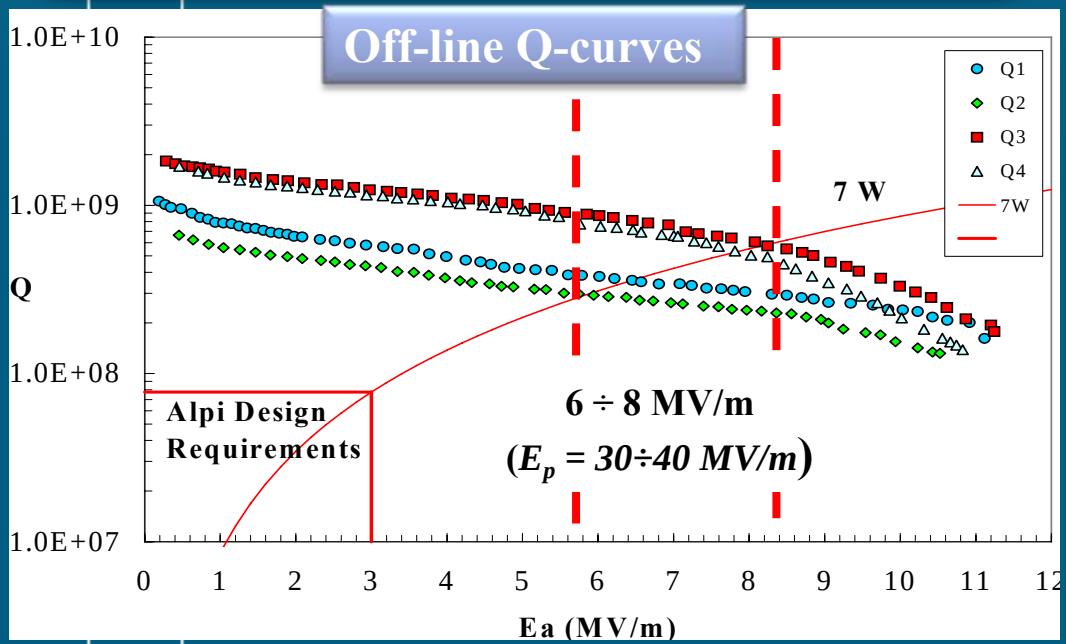
16medium beta QWRs

12 low beta QWRs

Buncher

ALPI Low β





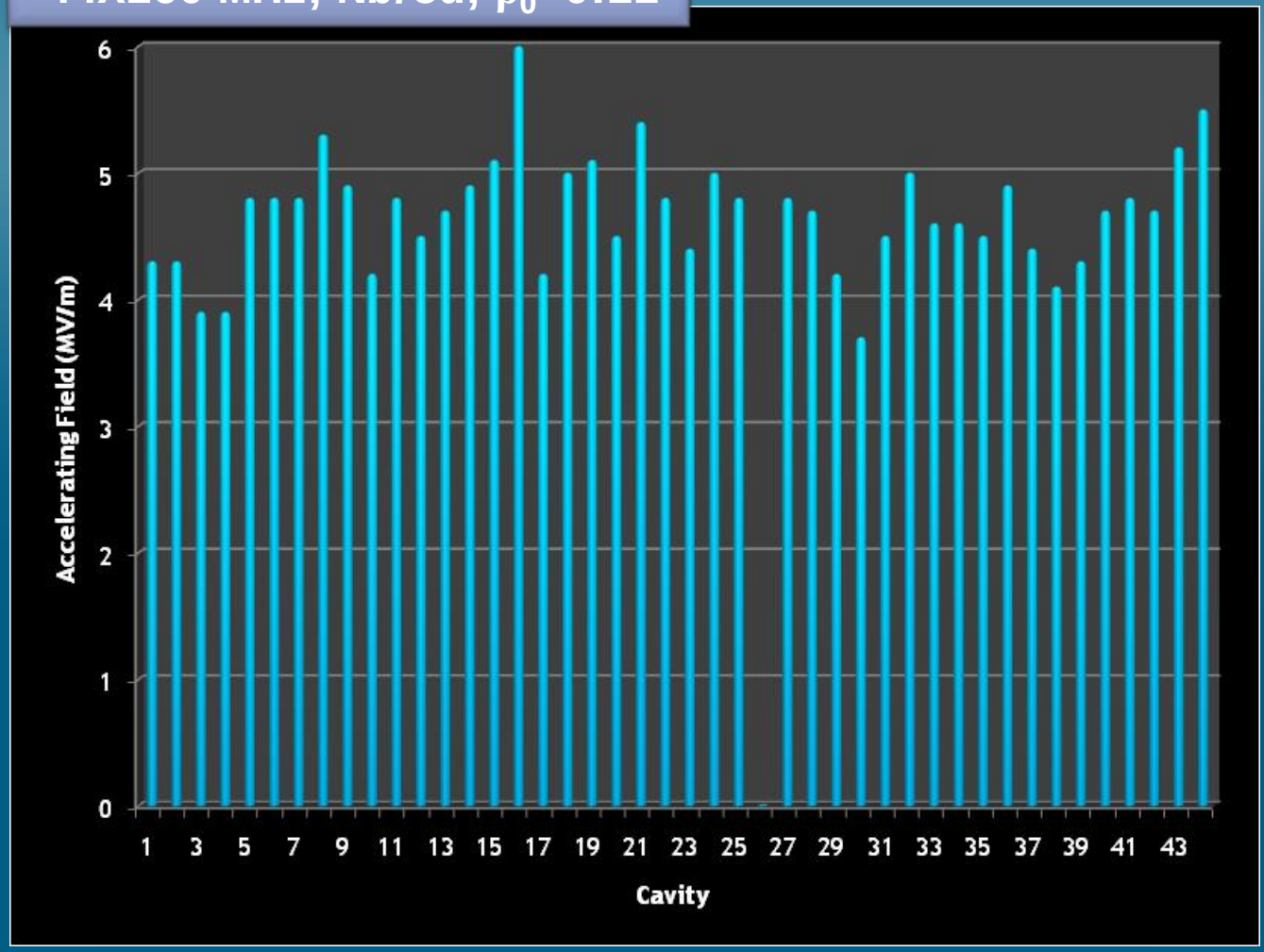
Frequency sensitivity to pressure changes :1 Hz/mbar
P_{He} occasionally fluctuates in ALPI at a rate of up to 100 mbar/min or more.

Thanks to work on cryogenic lines, mechanical damper, slow tuner, QWRS operate at 3-3.5 MV/m, still limited by RF system

Energy gain in this section is critical for the frequency jump.

ALPI Medium β

44X160 MHz, Nb/Cu, β_0=0.11



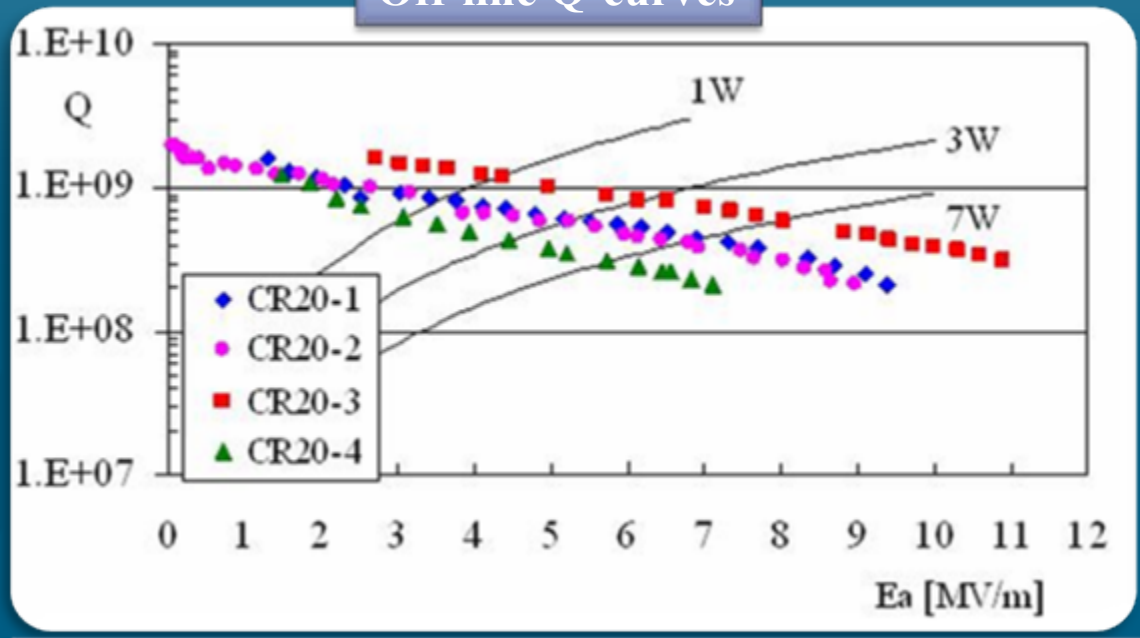
Phase stability is not an issue: Δf/ ΔP ~ 0,01 Hz/mbar

ALPI High β

- Retracted beam ports (β_0=0.13)
- Rounded shorting plate
- Capacitive coupler (no hole in high j region)
- Material: 99,95% OFHC Cu, no brazed joints on cavity, collar nor supports
- Ea ~ 6÷8 MV/m (Q_0 ~ 6÷7x10^8)

8X160 MHz, Nb/Cu, β_0=0.13

Off-line Q-curves



On line Ea: beyond 6 MV/m
Phase stability is not an issue ($\Delta f/\Delta P$ ~ 0,01 Hz/mbar)

- At present, low beta section gives not enough energy to prepare the beam for frequency jump

- Beam experiences strong non linear effects inside the first medium beta cavities (Bessel contribute)

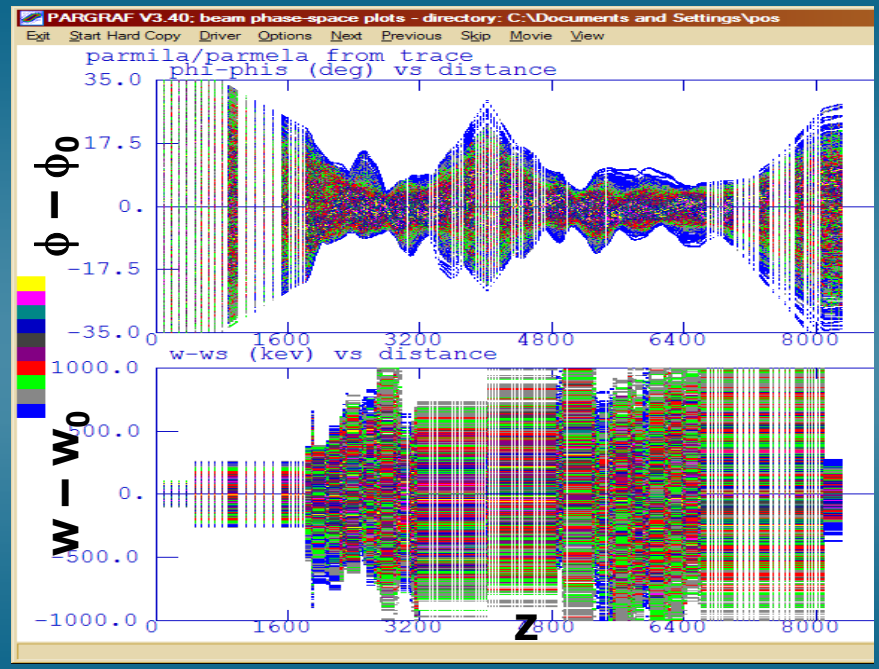
- It is extremely difficult to guarantee good transmission in the U-bend

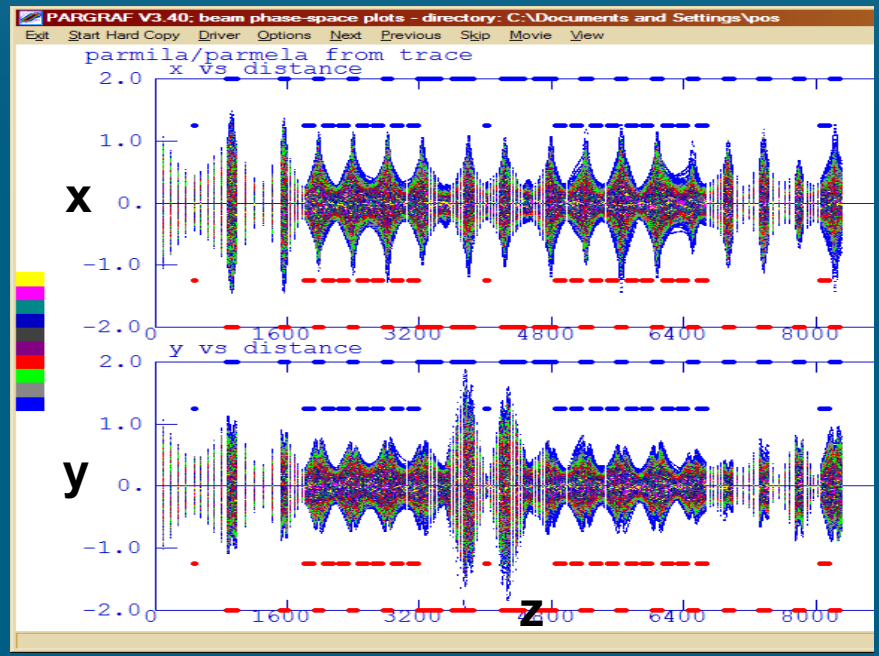
- Linear codes are simply unserviceable for ALPI beam dynamical studies

- PARMILA code (Bessel up to 5th order) results inaccurate for ALPI study

- PARMELA code works very well but optimization process is slow

- Alternate phase focusing is used to improve performance





Machine Upgrade Status

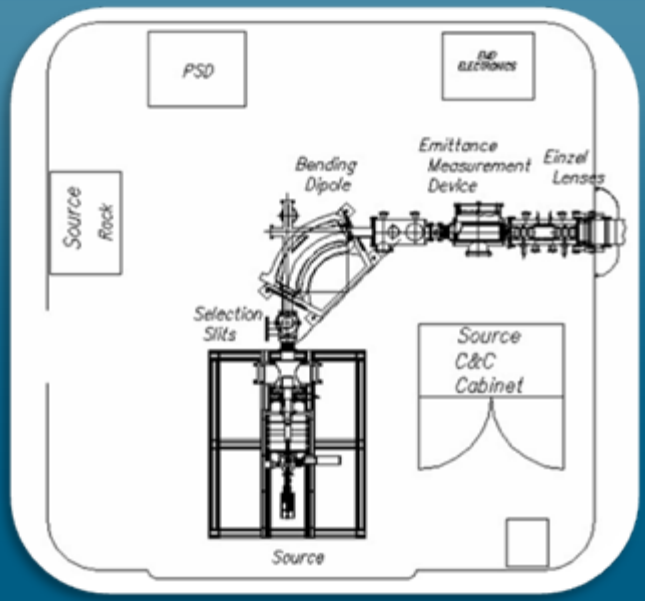
LEGIS Source

Pantechnik Supernanogan

New transport line up to accelerating tube

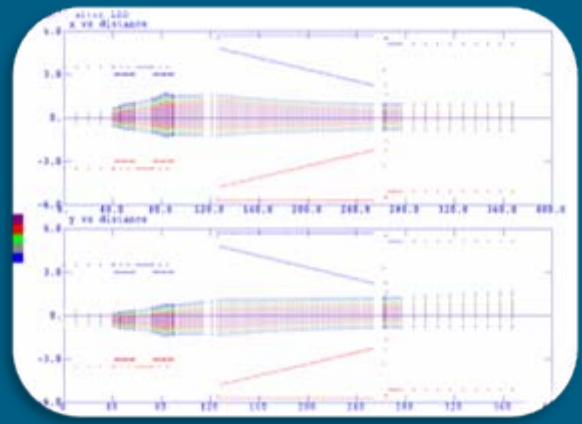
Measured emittances

	Ion	I(μA)
Gaseous Beams	O^{6+}	200
	Ar^{9+}	100
Matals with oven	Ag^{21+}	3
	Au^{26+}	10
	Au^{30+}	1
Metals with sputtering	Ta^{24+}	1



Ion	Ex.n.rms (mm-mrad)	Ey.n.rms (mm-mrad)
Ar^{9+}	0.059	0.048

PARMELA simulation with einzel and acc. tube “real” fields



Source misalignment problem discovered under commissioning

Solved using dipole multipolar corrector and a new steerer

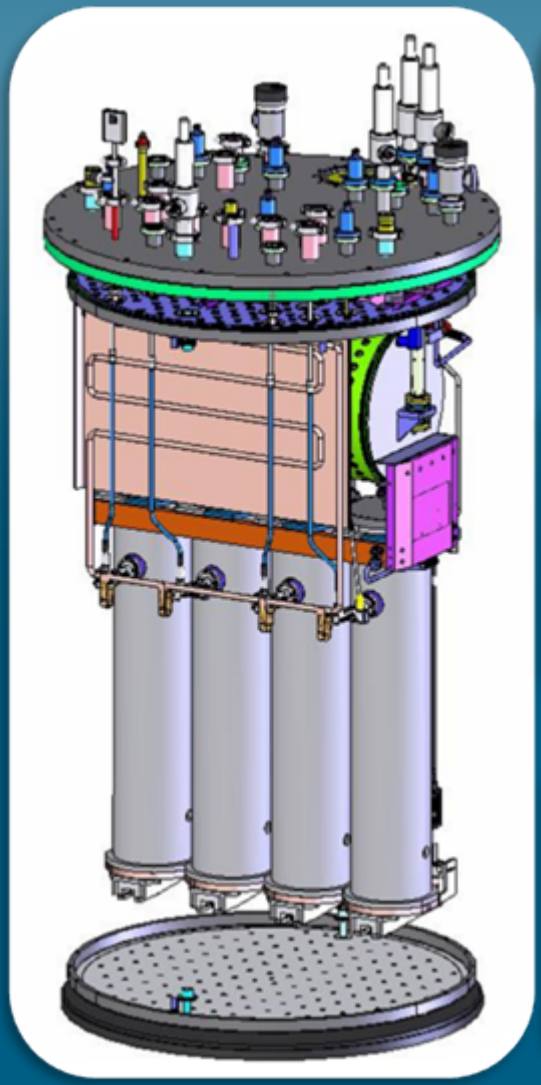
Present low β_0 QWR upgrade: RF system

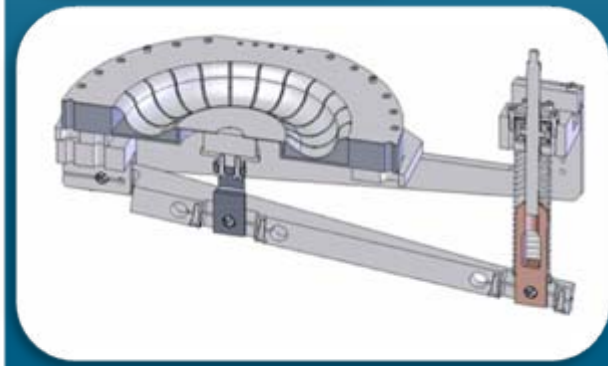
- One more low β_0 cryostat with 4 cavities
- $P_{ampl} = 150 \rightarrow 1000$ W
- Upgraded rf system

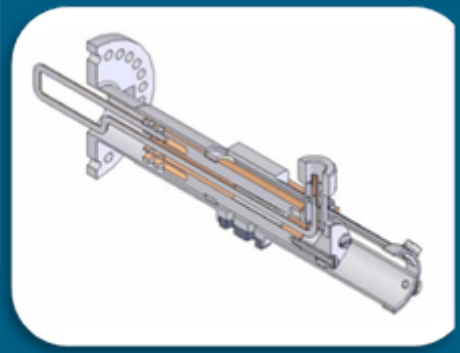
  -LN cooled couplers

  -LN cooled RF lines
- More efficient "slotted" slow tuner

Expected result:
$E_a = 3 \rightarrow 5$ MV/m







Upgrading of ALPI medium β QWRs

- Brazed joints
- Flat shorting plate
- Beam ports shape
- Inductive coupler (hole in high current region)

In 2005 we had the possibility to build 4 new substrates having:

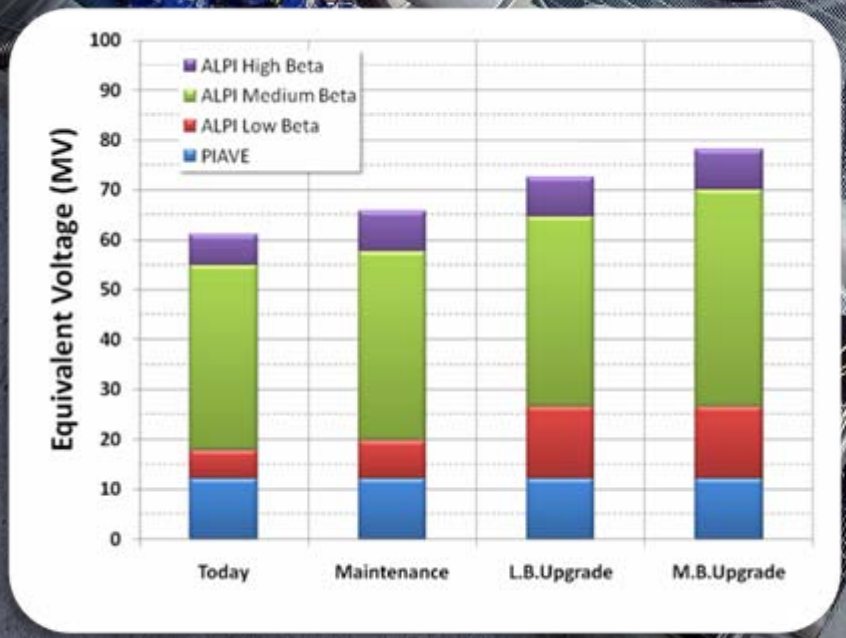
- New beam port design
- A rounded shorting plate
- A capacitive coupler
- No holes in high current regions
- No brazing in the outer resonator body

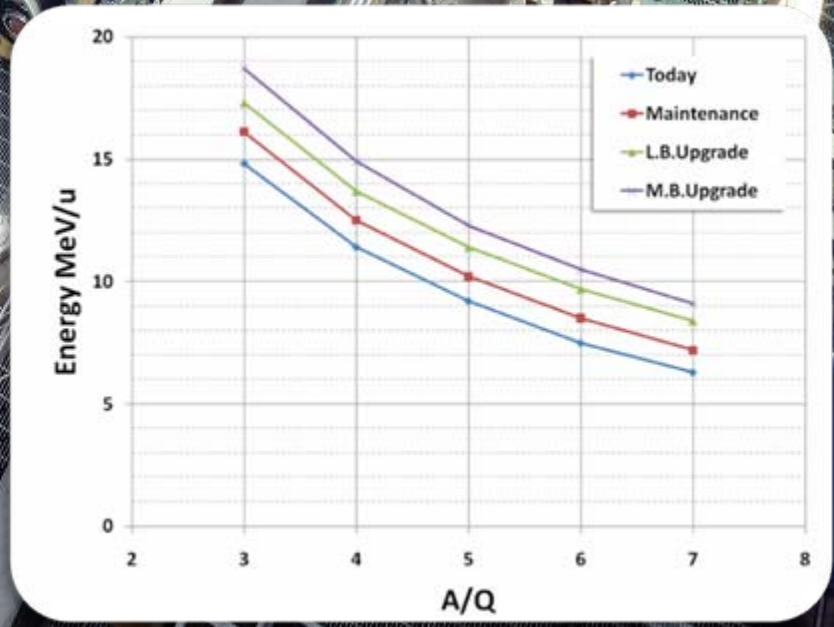
Limited the reached performance to 4.7MV/m @7W, a factor 2 higher than when Pb plated, but lower than the high β resonators performance

They are now ready to be installed;
5.5 MV/m expected on line

TABLE OF CURRENTLY AVAILABLE PIAVE-ALPI BEAMS

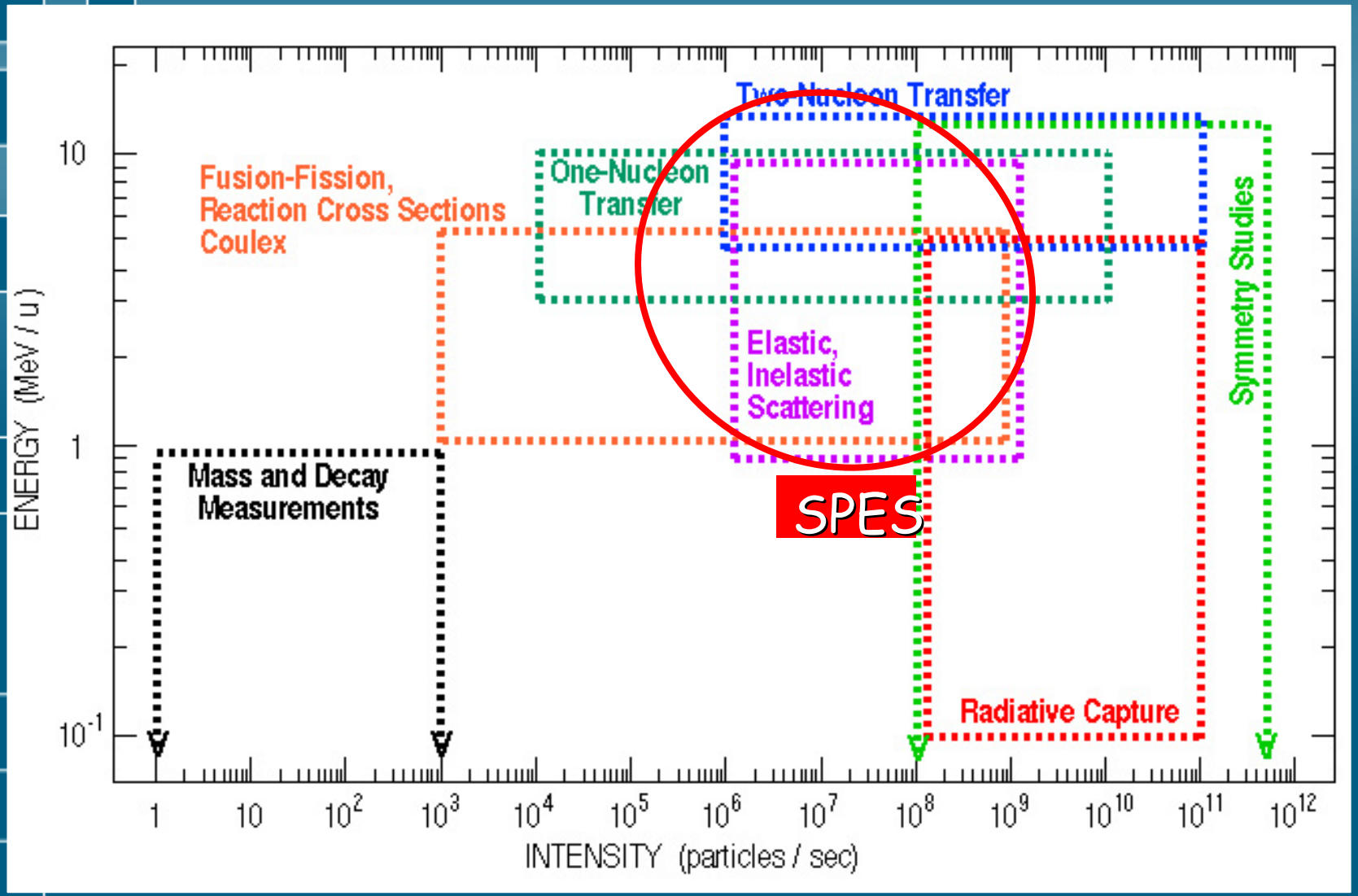
Beam	E [MeV]	E [MeV/u]	Beam Current [pnA]
$^{22}Ne^{4+}$	150	6.80	10
$^{40}Ar^{9+}$	350	8.75	4÷10
$^{84}Kr^{15+}$	600	7.14	5÷10
$^{132}Xe^{18+}$	720	5.45	5÷10
$^{132}Xe^{22+}$	950	7.20	3÷5



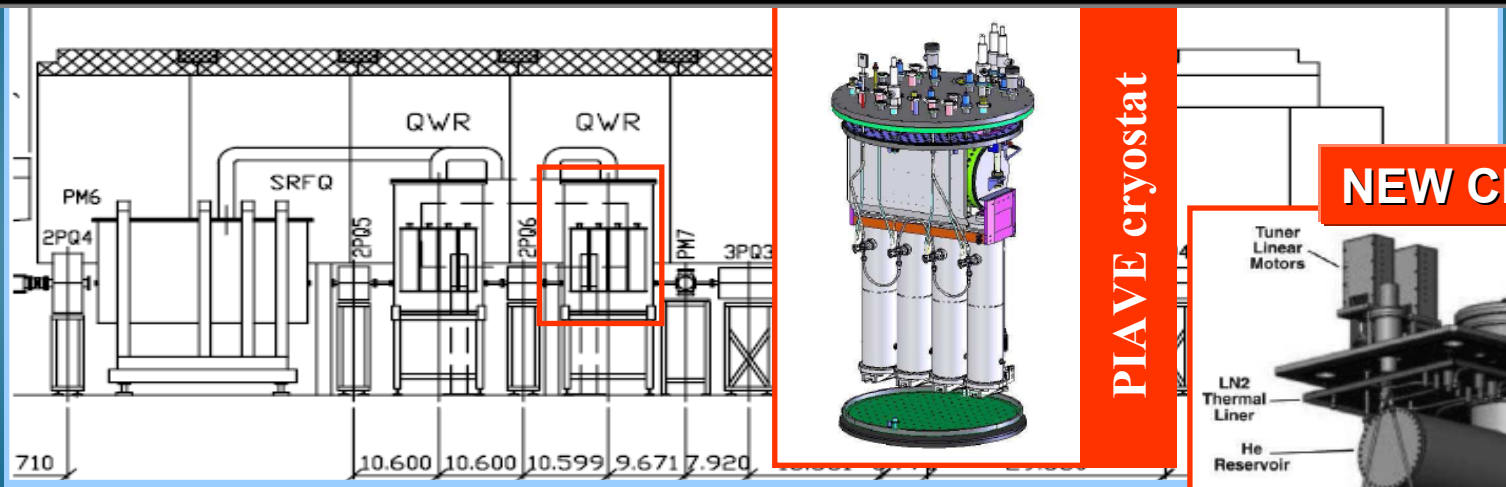


Future Perspective

Physics Domain with RIB

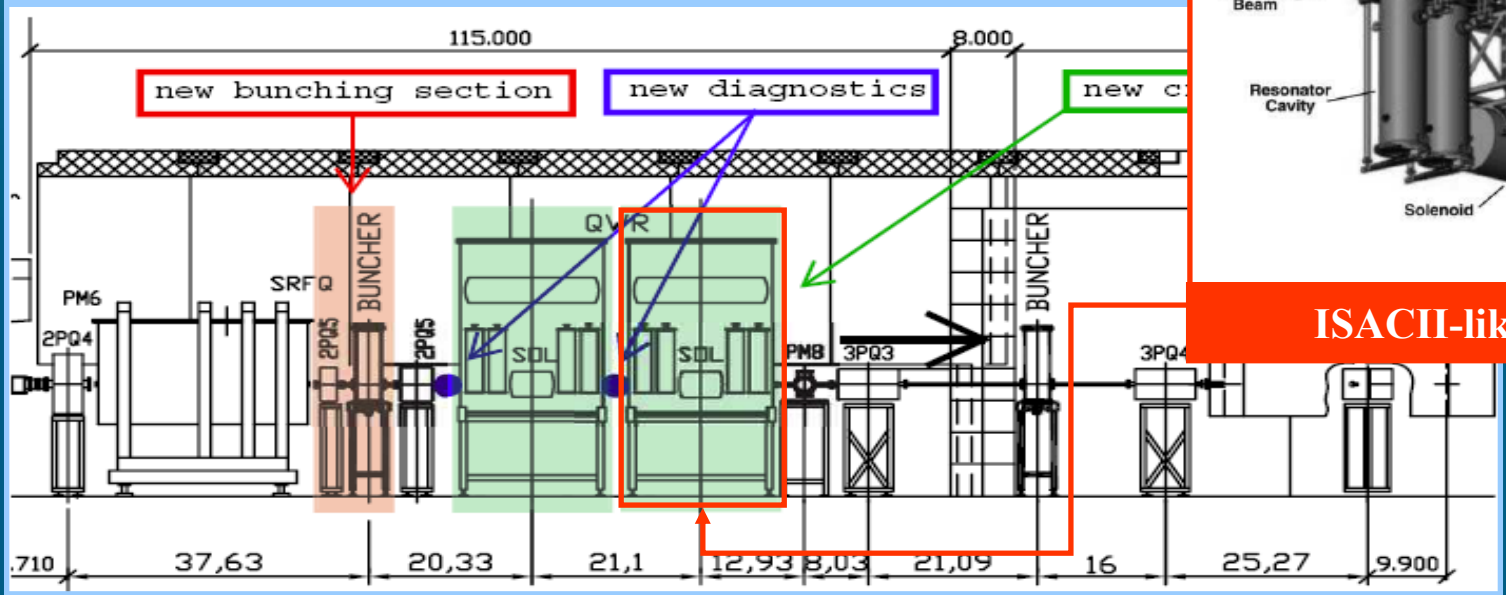


PIAVE-ALPI upgrade for AGATA & SPES



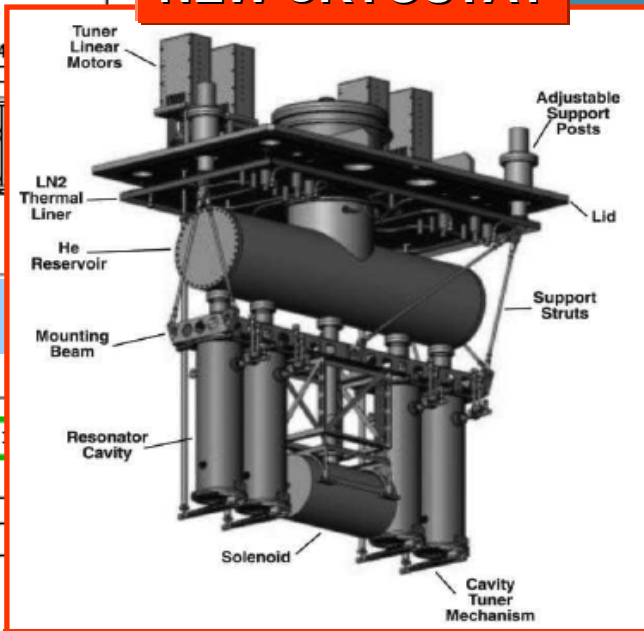
PIAVE cryostat

Present layout

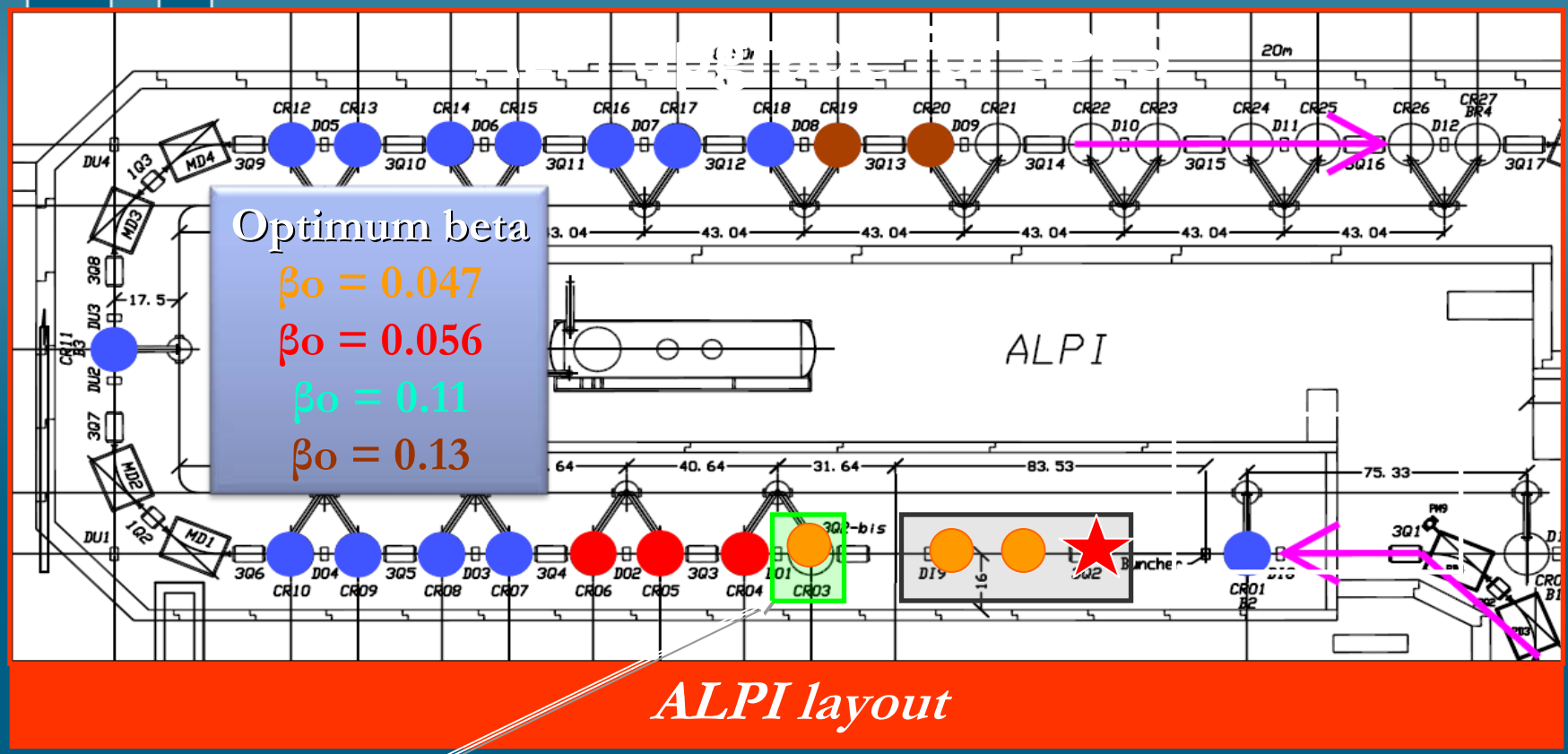


SPES layout

NEW CRYOSTAT



ISACII-like cryostats



ALPI layout

Funded upgrade Low Beta CR3

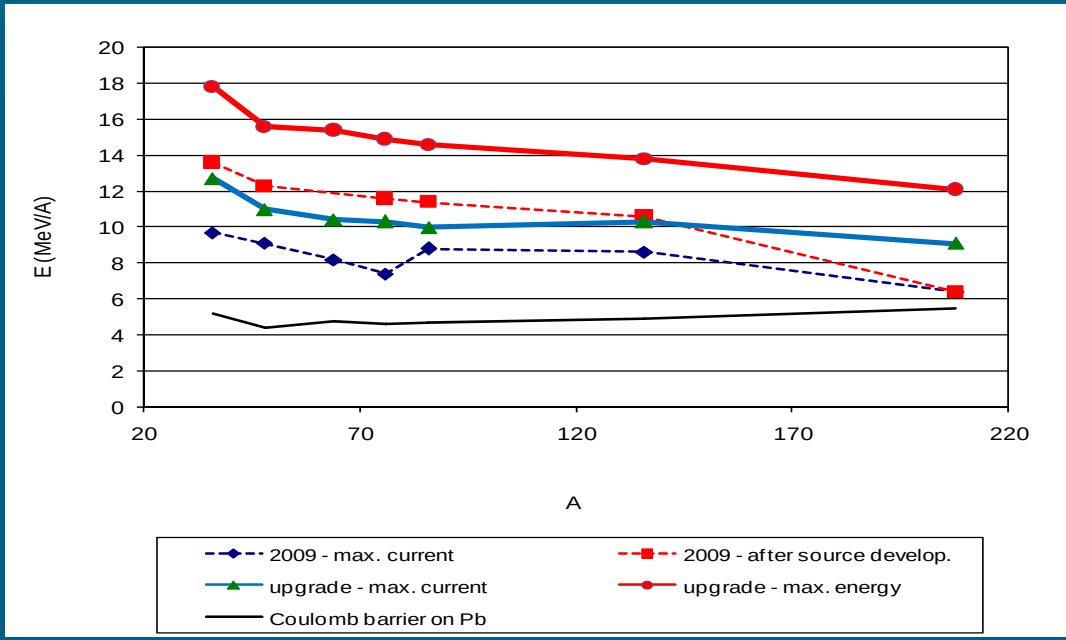
To be funded:

2 additional LowBeta Cryostats (CR1, CR2) a New buncher

New magnetic lenses (upgrade from 20 to 30 T/m)

PIAVE-ALPI resonators upgrade and their impact on beam final energy

		Present	Funded	Mid-β upgrade	SPES	
Resonator upgrade phases	CR01&CR02	0	0	0	5	Eacc (MV/m)
	CR03	0	5	5	5	
	CR04-CR06	3.5	5	5	5	
	CR07-CR18	4.8	4.8	5.5	5.5	
	CR19-CR20	5.5	5.5	5.5	5.5	



Conclusions

- PIAVE injector recommissioning with the new LEGIS source was completed
- The new injector demonstrated very good performance in terms of transmission and emittance
- Upgrade of the power supplies for the low beta section is completed
- New CR03 cryostat is ready for installation
- After CR03 installation, the same upgrades in the RF system will be applied to CR04-CR06
- The upgrading plan for SPES requirements is fully defined