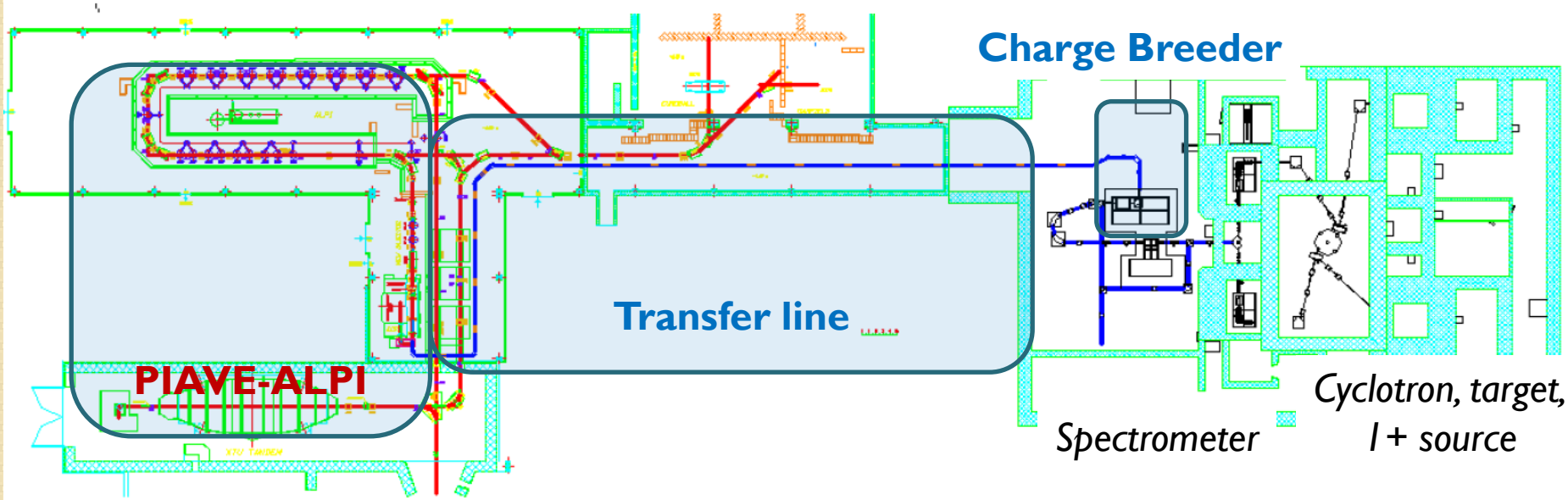
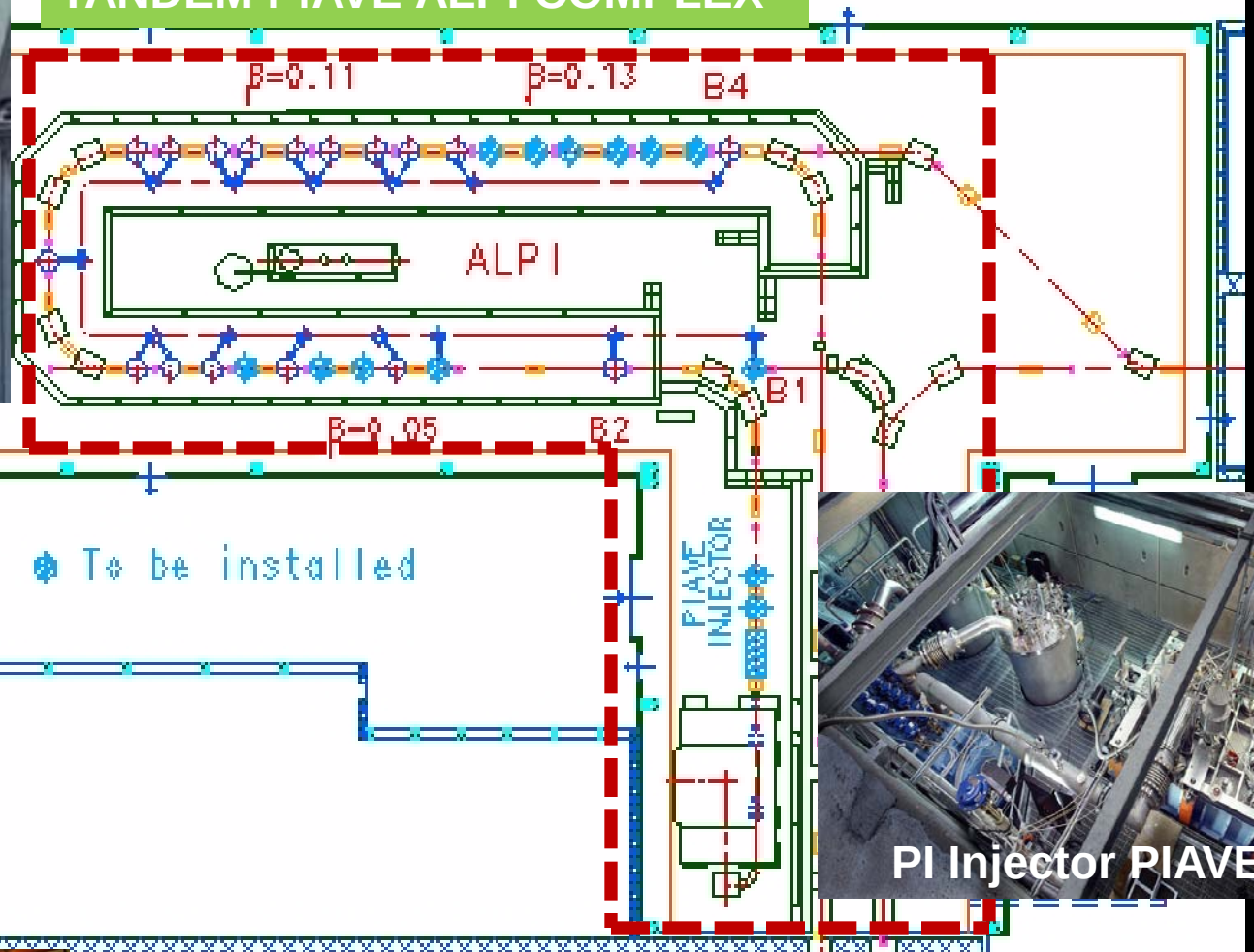
Post-acceleration and ALPI Upgrade

G. Bisoffi, for the RNB Accelerator Group



0.	Present situation with stable beams	2.	From the Charge Breeder to PIAVE
1.	PIAVE-ALPI Upgrade for RNBs and stable beams	3.	SPES-specific issues on the RNB Accelerator

TANDEM PIAVE ALPI COMPLEX

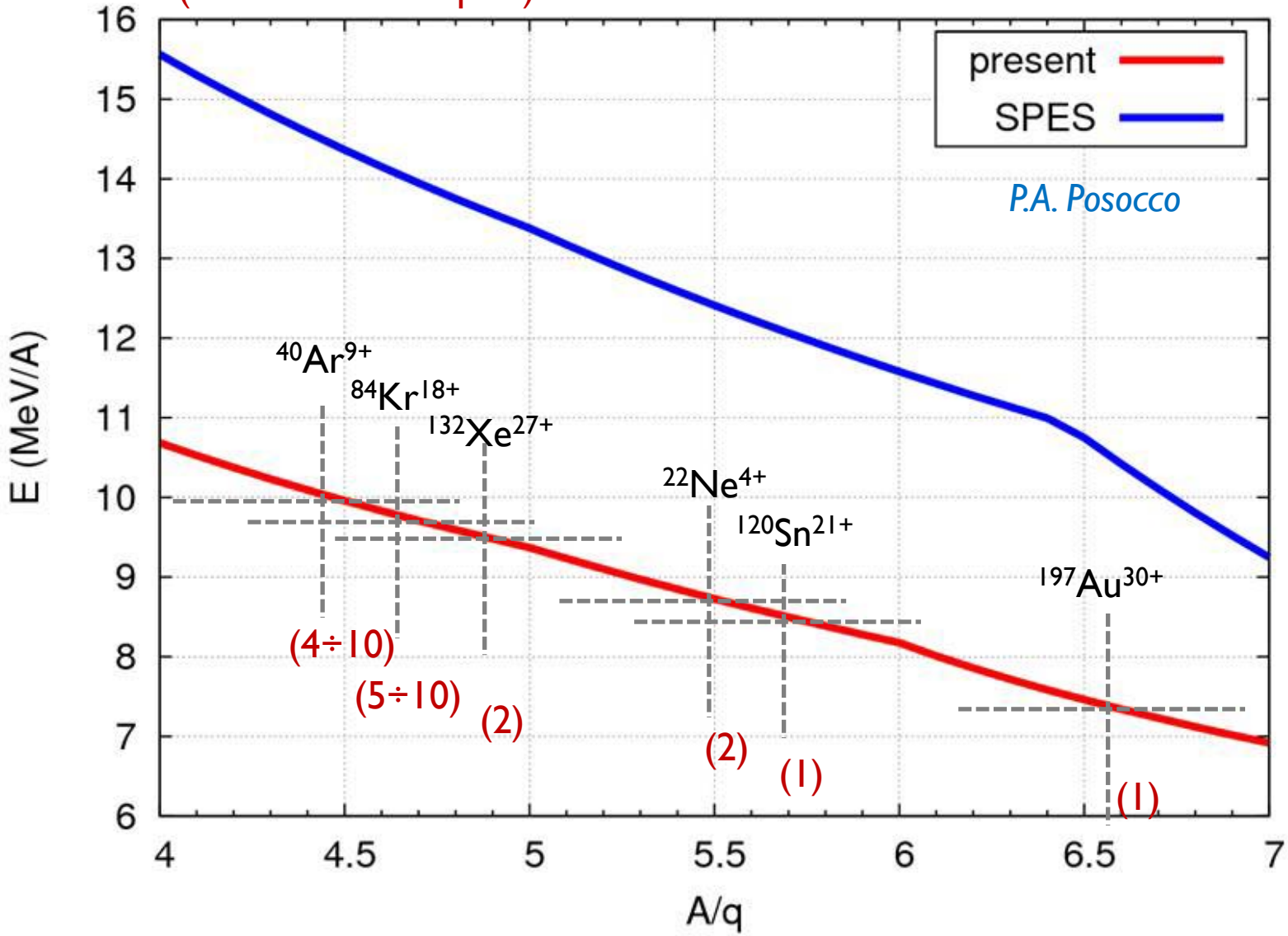


Recent and on-going Upgrades

- New ECR ion source (Supernanogan)
  - →Higher charge state for a given current
  - →Higher current for a given charge state
  - →Tests on several beam species (no test bench)
- Stripping foil station in ALPI
  - →Increased charge state and higher final energies
  - →Lower final current (20%)
- Increased capability of lower energy section (Low Beta Upgrade = <u>higher accelerating field</u> on first ALPI cryostats)
  - →Higher final energy
  - →Better beam dynamics in the linac → better overall transmission, higher current at the experiment
  - →Being carried out (→ end of 2011)

Present Performance (stable beams)

(beam current in pnA)



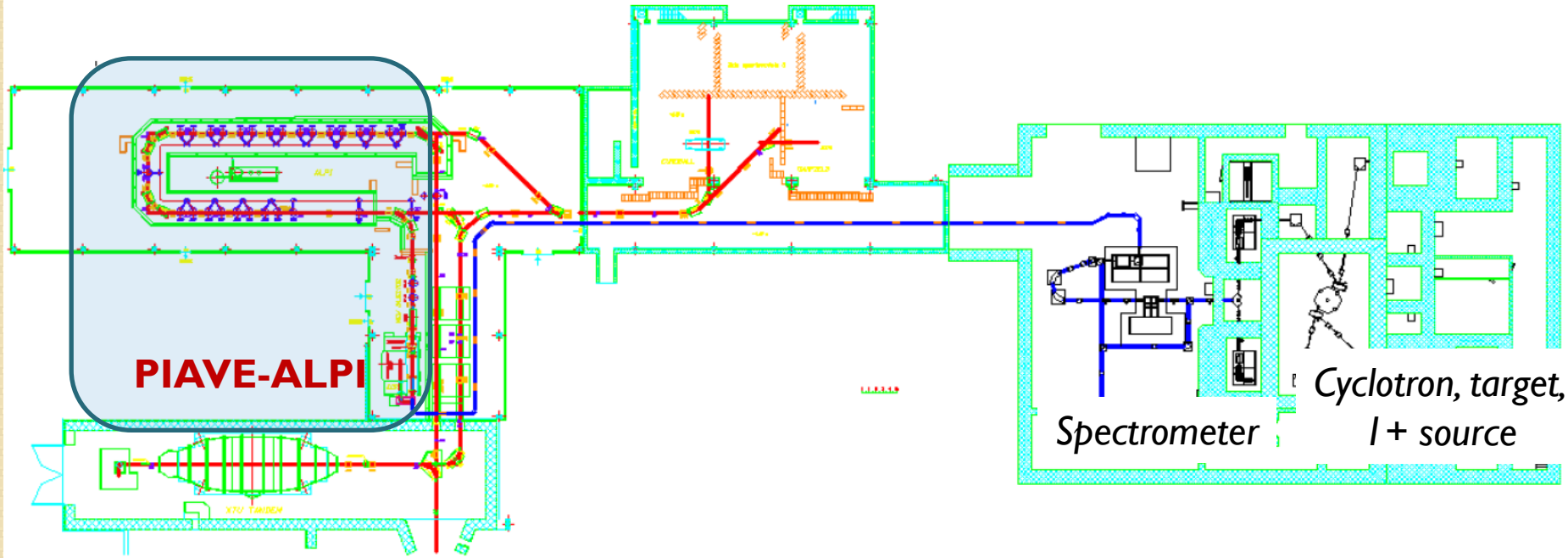
^{150,152,154}**Sm^{26+}** completed too and will be made available;

beams presently under test: **Nb, Zn, Mg, Dy, Mo**;

later on **Zr, Ca**

A. Galatà, INFN-LNL

SPES-RNB Accelerator



0. Present situation with stable beams
1. PIAVE-ALPI Upgrade for RNBs and stable beams
2. From the Charge Breeder to PIAVE
3. SPES-specific issues on the RNB Accelerator

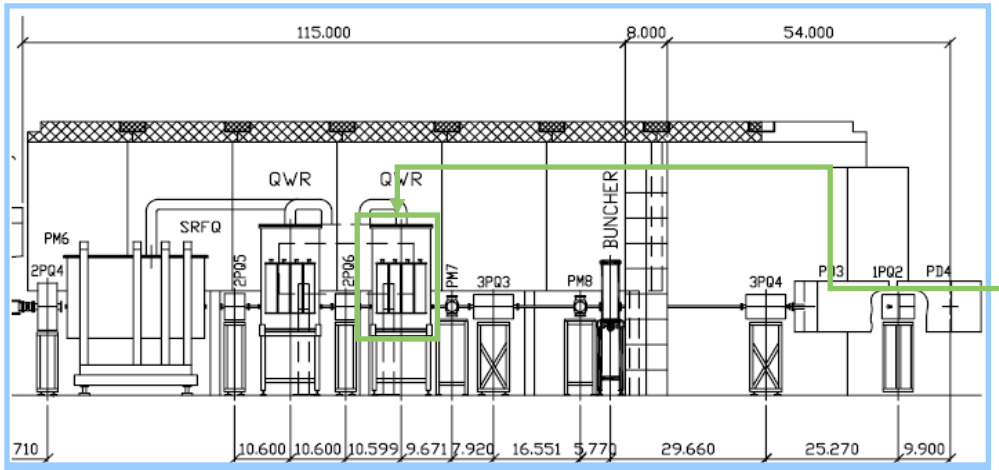
A more efficient machine lattice on PIAVE and ALPI

Motivation: achieve at least **10 MeV/A up to A/q=7** (most beam species, up to the heaviest) with a more efficient linac (better beam dynamics → higher beam transmission)

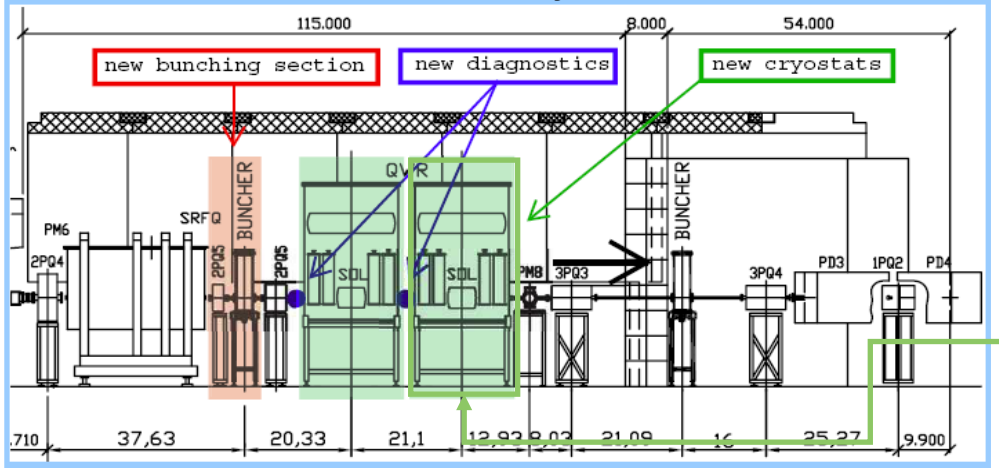
It applies to both RNB and stable beams

- PIAVE-Injector upgrade
  - → New cryostats with SC solenoids, new focusing elements
  - → Lower longitudinal emittance and losses, higher output energy from PIAVE injector
  - → Allows more efficient acceleration in ALPI
- ALPI-Booster Upgrade
  - → Higher accelerating field on first cryostats, two added; new buncher (focusing cavity); triplets replacement (20 T/m → 30 T/m)
  - → Better beam quality and higher energy

PIAVE upgrade

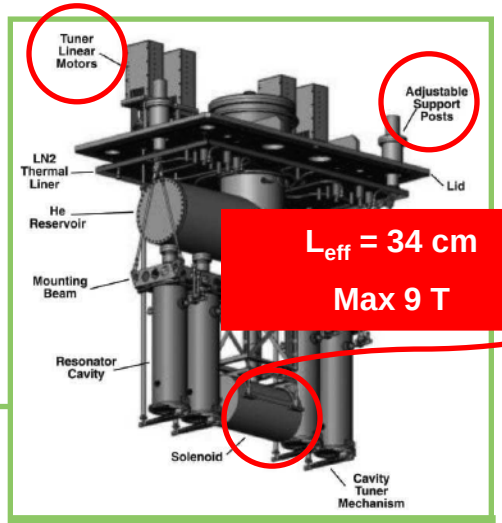


Present layout



New layout

PIAVE cryostat



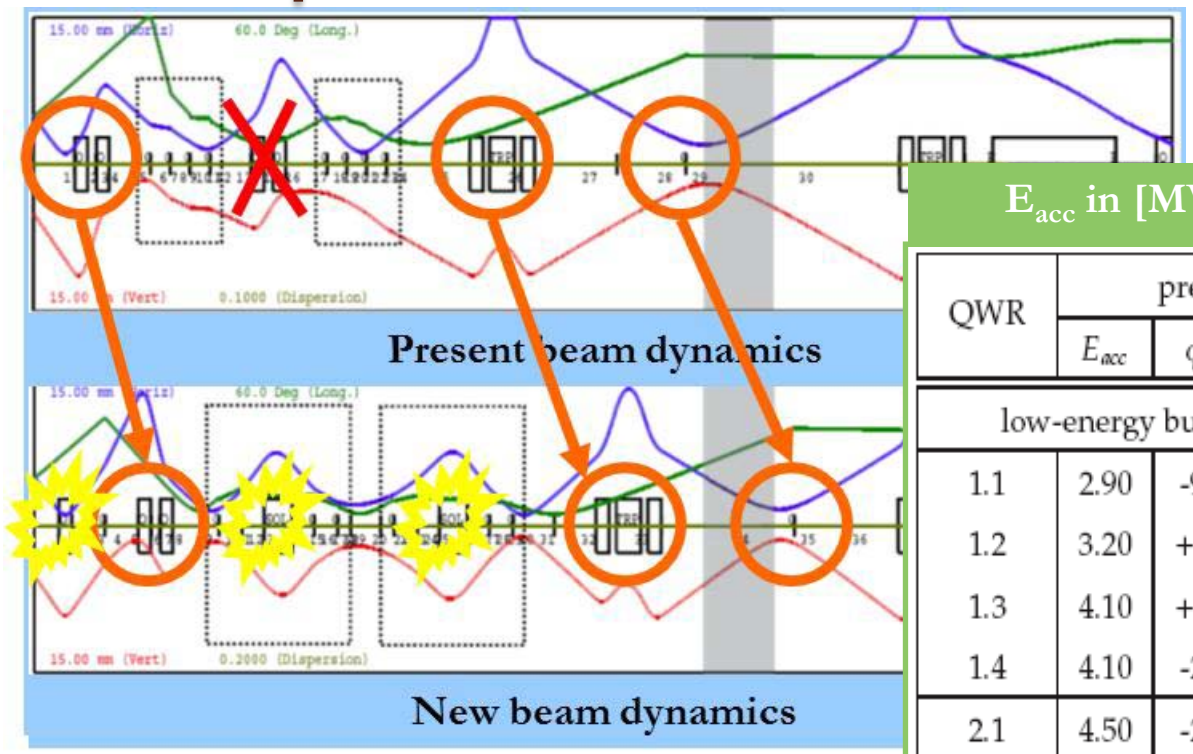
L_{eff} = 34 cm

Max 9 T

New cryostat

P.A. Posocco

PIAVE upgrade: beam dynamics comparison



E_{acc} in [MV/m], E in [MeV/A]

QWR	present			new		
	E_{acc}	ϕ_s	E	E_{acc}	ϕ_s	E
low-energy buncher				0.91	-90	0.588
1.1	2.90	-90	0.588	3.50	-30	0.656
1.2	3.20	+60	0.623	4.85	-30	0.756
1.3	4.10	+30	0.706	5.25	-30	0.869
1.4	4.10	-25	0.797	5.25	-30	0.984
2.1	4.50	-20	0.891	5.25	-30	1.101
2.2	4.50	-20	0.987	5.25	-30	1.218
2.3	4.50	-20	1.084	5.25	-30	1.334
2.4	4.50	+20	1.180	5.25	-30	1.449

Advantage of new cryostats:

1. Long. period is half of the transverse one

2. Symmetric tran. envelopes inside the QWRs

Simulated with PARMELA

P.A. Posocco

PIAVE upgrade: beam dynamics results

Comparison between PIAVE present and new layout

	SRFQ out	present PIAVE	new PIAVE	unit	*var.*
$\varepsilon_{x\ rms}$	0.100	0.102	0.105	mm mrad norm.	+3%
$\varepsilon_{y\ rms}$	0.100	0.138	0.105		-24%
$\varepsilon_{z\ rms}$	0.060	0.163	0.066		-60%
E	0.59	1.24	1.45	MeV/A	+17%

1. Equal trans. emittances
2. Lower long. Emittance
3. Higher final energy

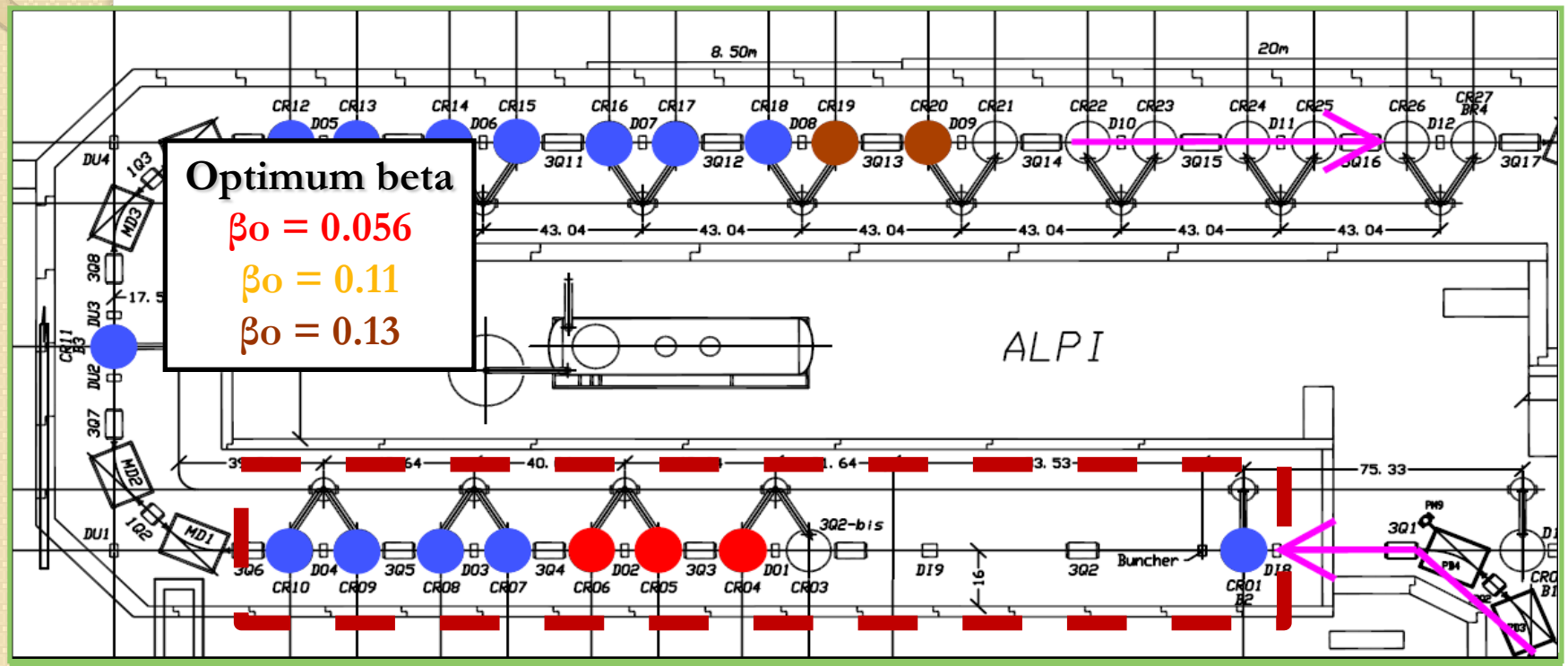
Single cavity failure

	all	1.1 off	1.2 off	1.3 off	1.4 off	2.1 off	2.2 off	2.3 off	2.4 off	unit
$\varepsilon_{x\ rms}$	*0.105*	0.105	0.105	0.100	0.104	0.101	0.100	0.103	0.103	mm mrad n.
$\varepsilon_{y\ rms}$	*0.105*	0.108	0.105	0.102	0.103	0.103	0.102	0.104	0.105	
$\varepsilon_{z\ rms}$	*0.066*	0.065	0.070	0.062	0.063	0.063	0.063	0.064	0.065	
E	*1.45*	1.37	1.31	1.35	1.36	1.34	1.34	1.33	1.31	MeV/A

The injector can be operated even if one cavity is off

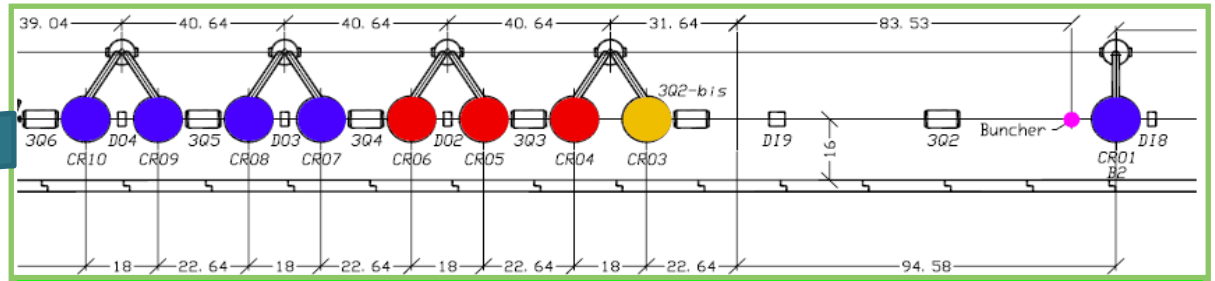
P.A. Posocco

ALPI Upgrade



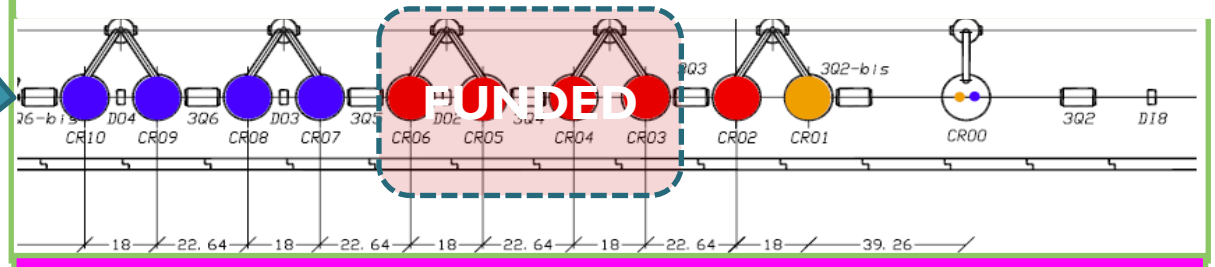
ALPI layout

ALPI: upgrade of low-energy cryostats



PRESENT SITUATION

1. **Upgrade lower-β cryostats (from 3 to 5,5 MV/m)**
2. **First cryostat with "funnel"-shaped beam dynamics**
3. **Two additional cryostats recovered from PIAVE Upgrade**
4. **New small cryostat for SC 80-160 MHz bunching cavities**



SPES

ALPI – Lower Beta Cavity Upgrade

- **Starting situation: 20 QWRs in 5 cryostats**

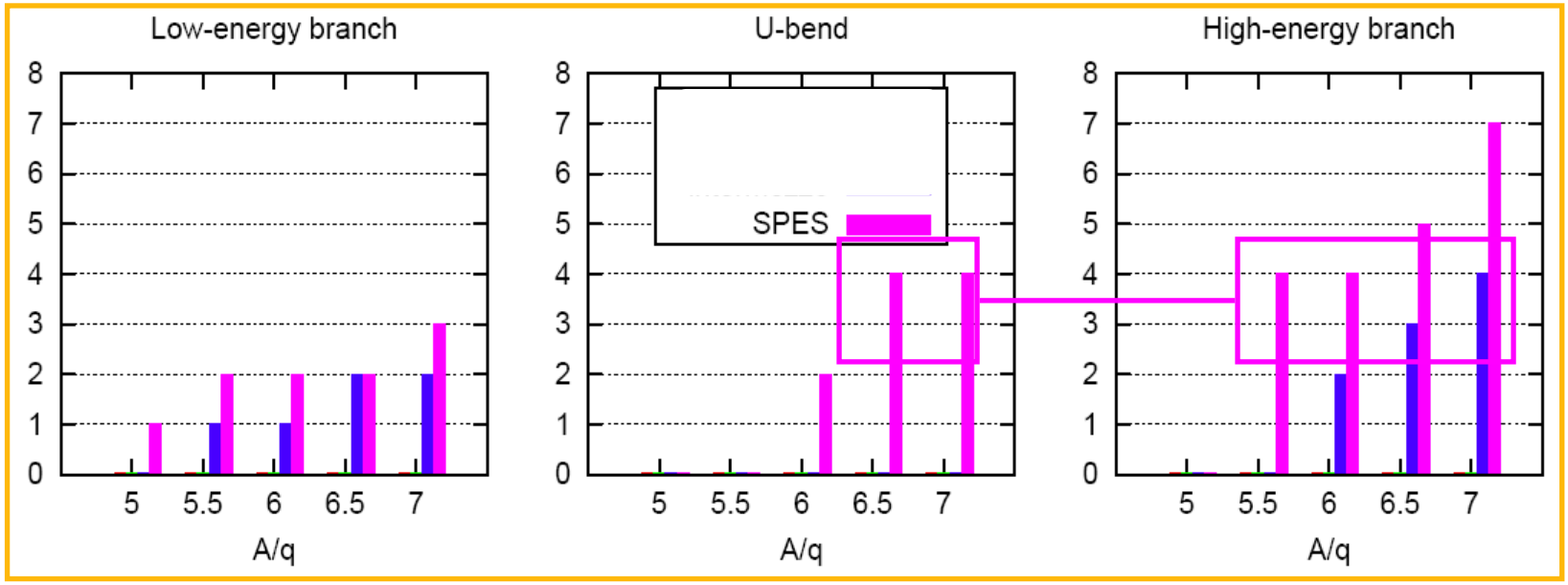
  E_a~ 3 MV/m (limited by rf system) - total accelerating voltage ~ 11 MV

- ***After upgrade: 24 QWRs (one more cryostat with 4 cavities)***

  E_a = 5 MV/m (upgraded rf system) - total accelerating voltage ~ 21 MV

Plan: CR04, CR05, CR06 replacement during operation, within 2011

Magnets upgrade from 21 to 30 T/m



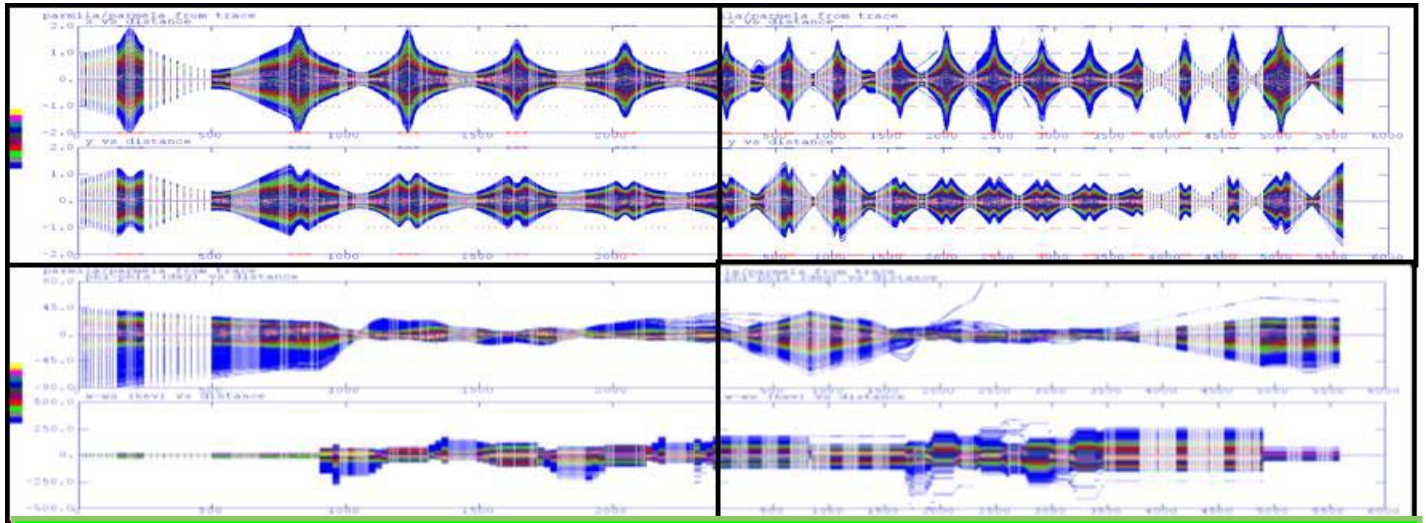
3Q3, 3Q4, 3Q5

3Q6, 3Q7, 3Q8, 3Q9

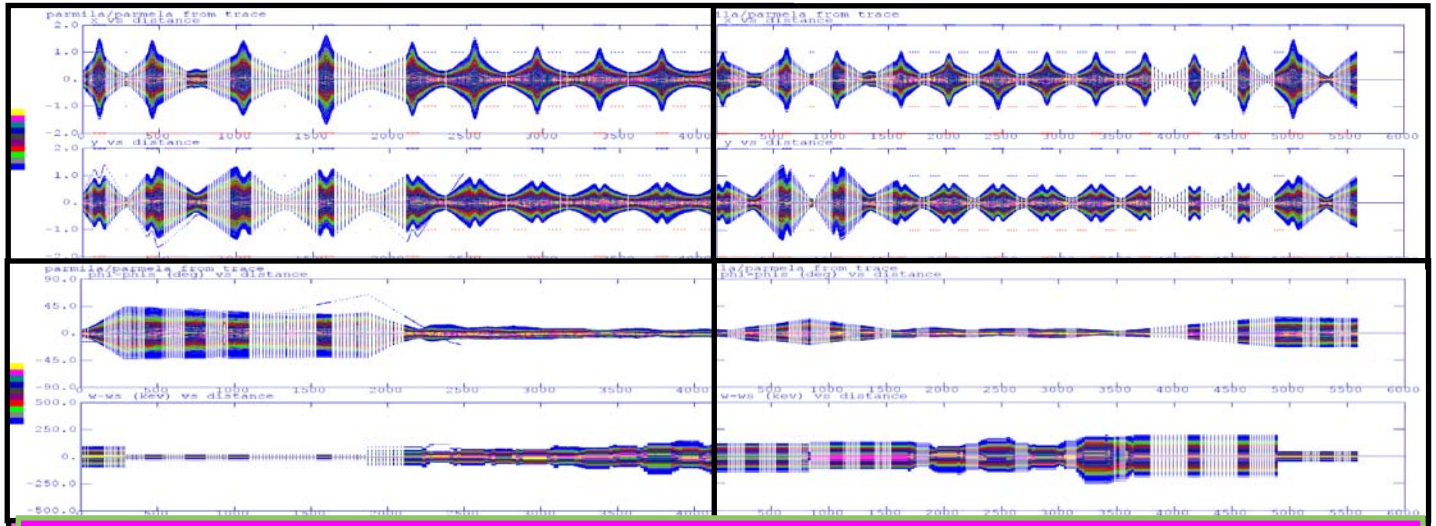
3Q10, 3Q11, 3Q12, 3Q13, 3Q14, 3Q15, 3Q16

The new 3Q2-ter can be either 3Q4 or 3Q5

3Q7 and 3Q8 can be replaced with two high-energy triplets



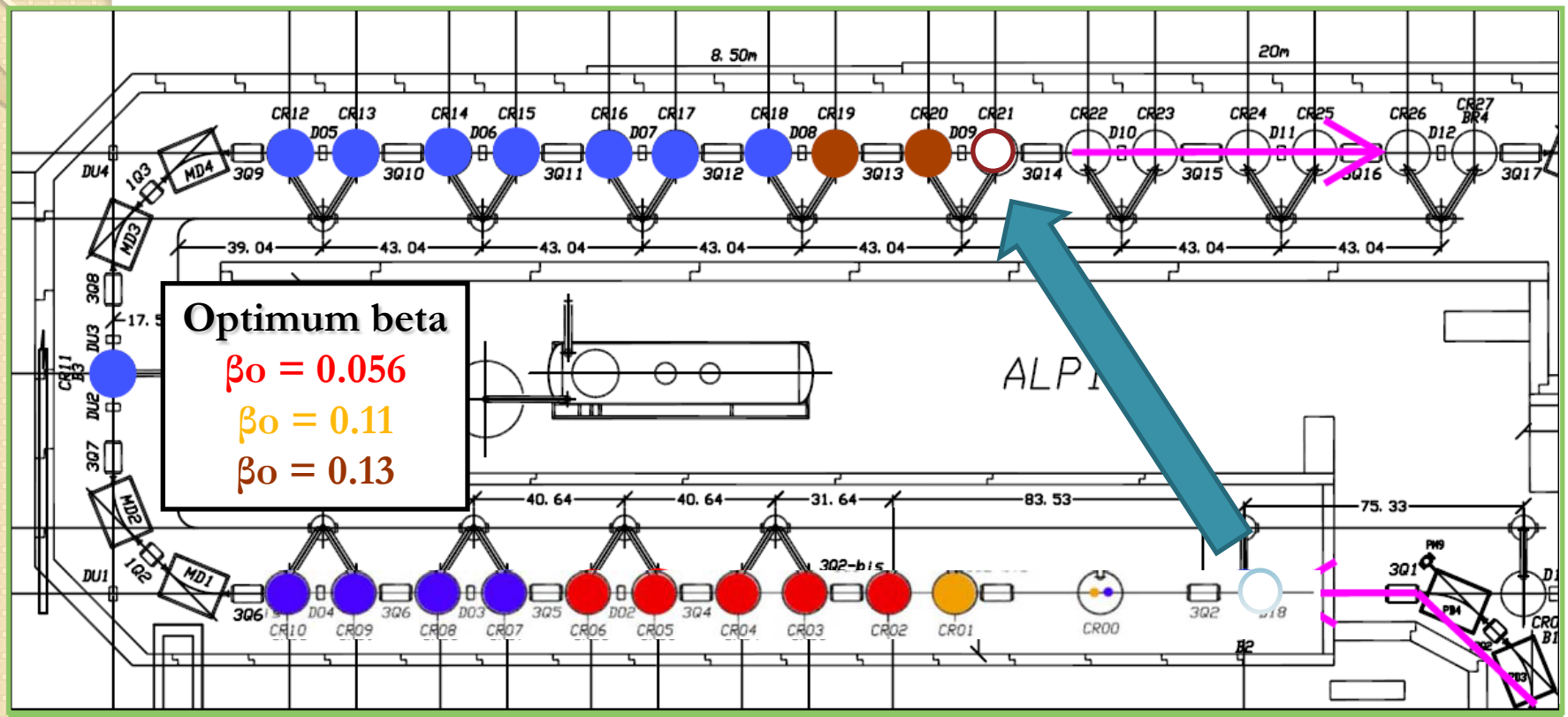
PRESENT SITUATION



SPES

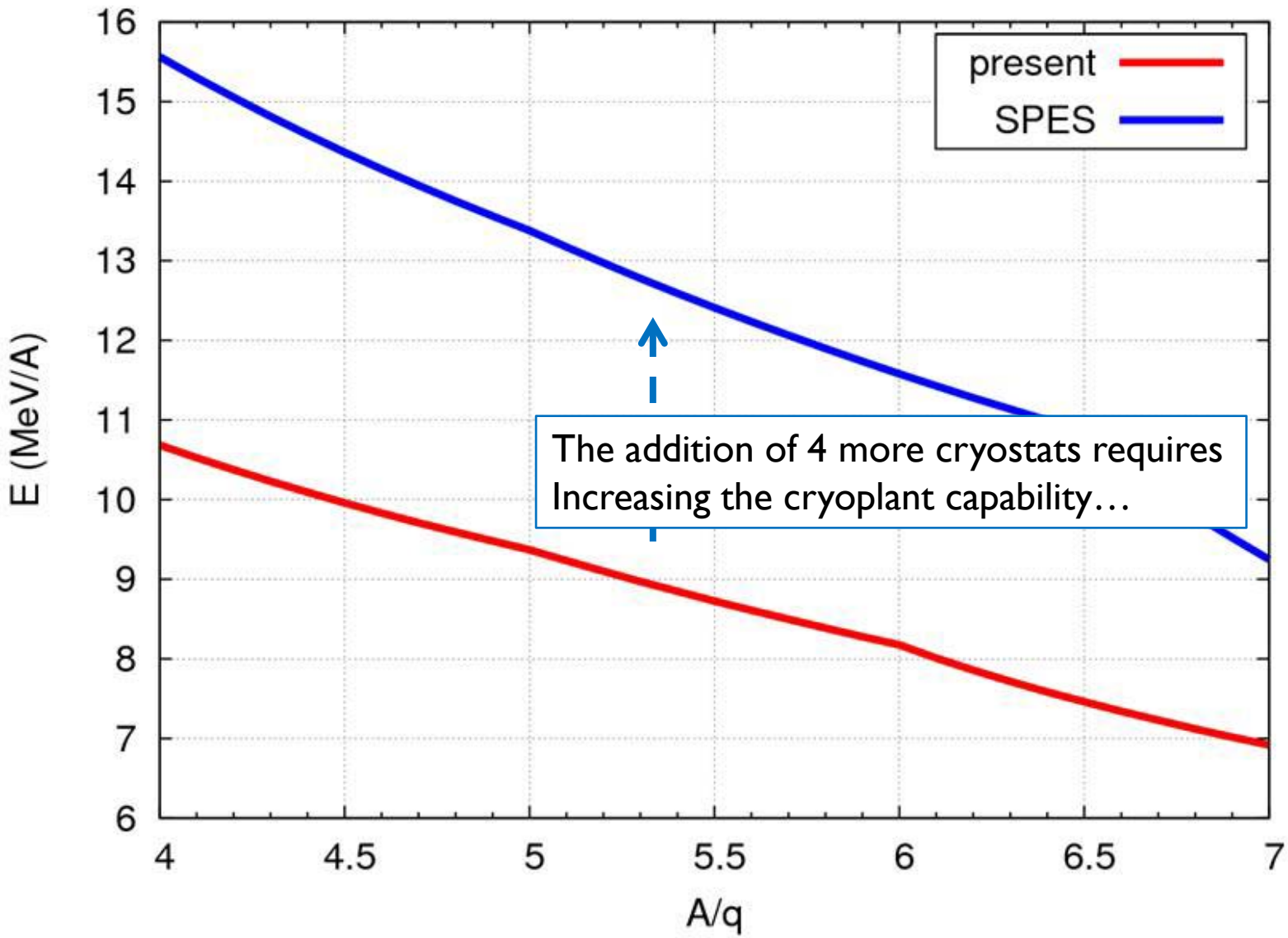
P.A. Posocco

ALPI upgrades



ALPI layout

Final result of PIAVE-ALPI Upgrade

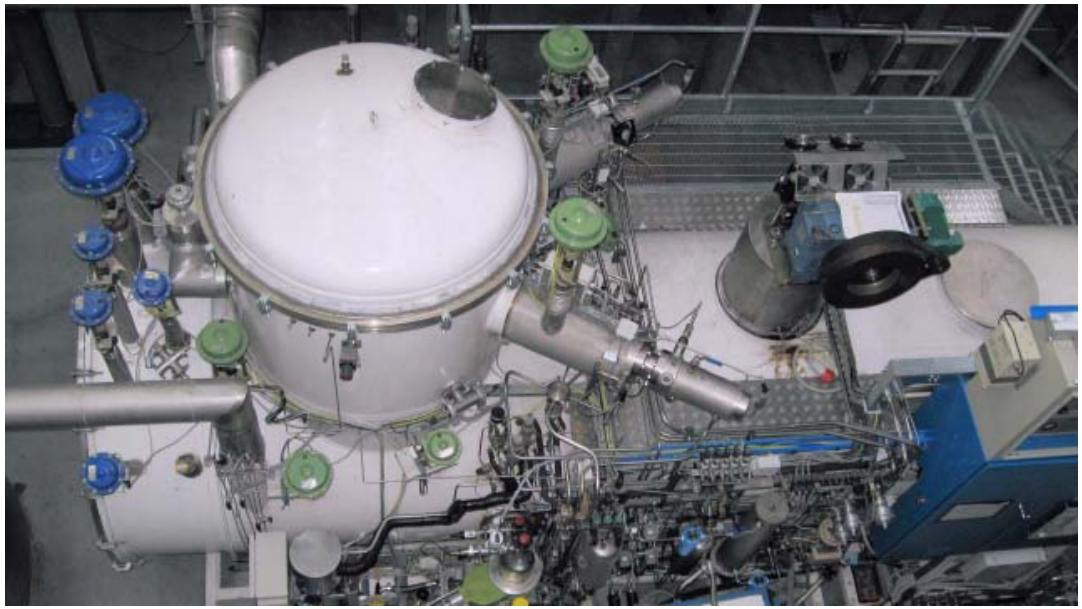


The addition of 4 more cryostats requires Increasing the cryoplant capability…

P.A. Posocco

PRESENT SITUATION

ALPI cryogenic system: upgrade of the refrigeration power



- Claude cycle, i.e. 2 expansion turbines and a JT valve
- 150 g/s, more than 3900 W at ~ 70 K, around **800 W at 4,2 K** (barely sufficient for the present linac configuration)

R. Pengo, INFN-LNL

SELECTED UPGRADED CONFIGURATION

The process of the cold box (and the consequent available power) has been calculated for the two cases:

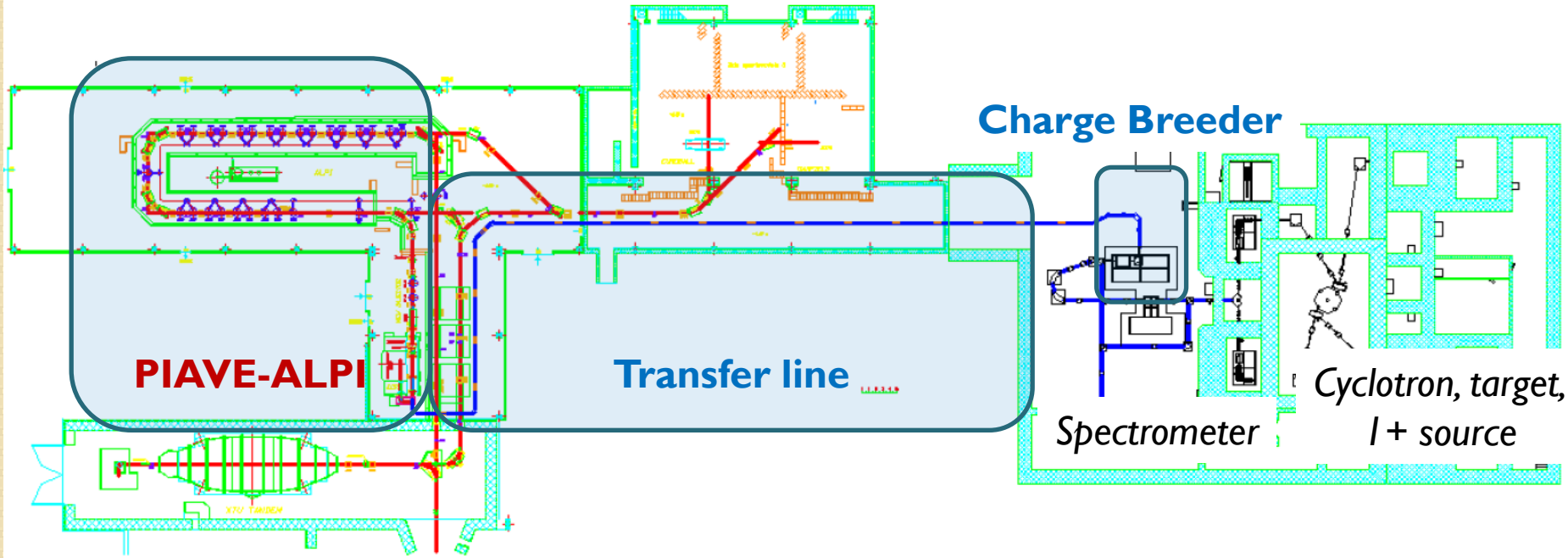
1. addition of a second JT valve in the process
2. addition of a third turbine in the process

Simulation case	HP pressure (bar abs)	LP pressure (bar abs)	Temperature at screen inlet (K)	Temperature at screen outlet (K)	Intermediate heat load (W)	Available power @4.4K (W)
CURRENT CONFIGURATION 2 cryogenic expansion turbines + 1 Joule-Thomson valve	16	1.05	60	80	3900	805
UPGRADE PROPOSITION FOR THE REFRIGERATOR						
Addition of a third turbine	16	1.05	60	80	3900	1195
Addition of a second Joule-Thomson valve	16	1.05	60	80	3900	845

Order has been placed: AL will be ready when INFN-LNL will propose a **2 months dedicated shutdown** for the upgrade implementation

R. Pengo, INFN-LNL

SPES-RNB Accelerator



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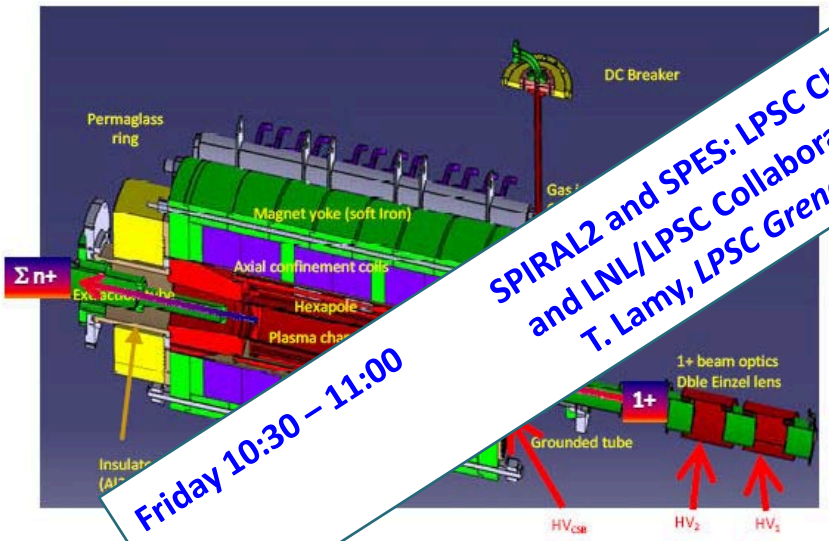
The Charge Breeder

Role: slows down the 1^+ beam, captures and further ionizes it, and then extracts it as highly charged beam for post-acceleration.

SPES adopts a PHOENIX type ECR ion (LPSC [illegible]le) similar to the one being developed for SPIRAL2.

SPIRAL2 and SPES: LPSC Charge Breeder Developments
and LNL/LPSC Collaboration
T. Lamy, *LPSC Grenoble*
Friday 10:30 – 11:00



[illegible]IRAL2

[illegible]teristics (comparable to [illegible]RIUMF) are *'for the moment'* [illegible]nsidered as satisfactory (it is a "nuclearized" CB)

For SPES

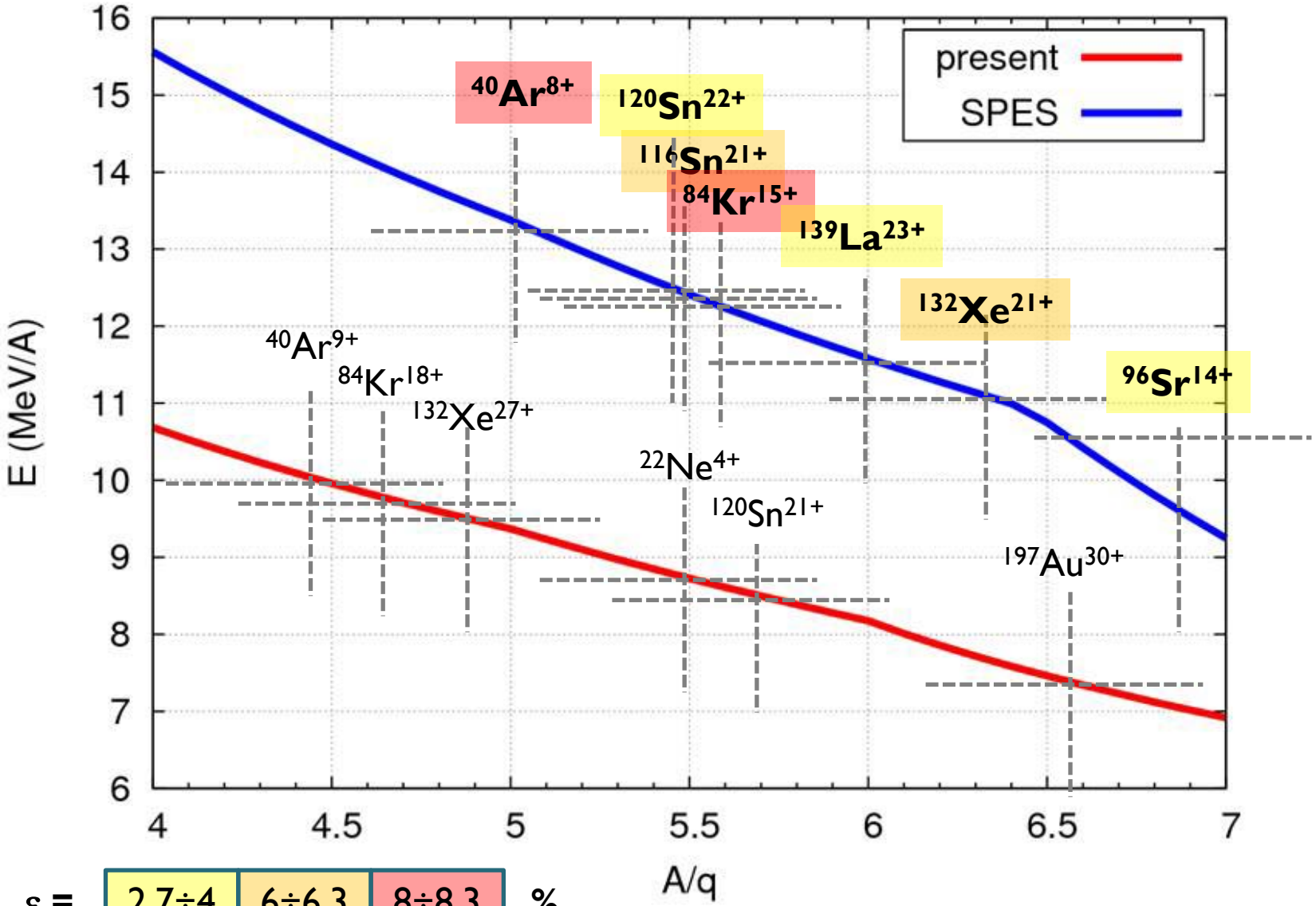
Higher efficiencies on high charge states expected

LPSC, in **collaboration with SPES-LNL**, is conducting experiments on the LPSC test bench

f[GHZ]	P_max[W]	B_inj [T]	B_ext[T]	B_rad[T]	eff_max for gas [%]	eff_max for metals [%]	Charge breeding time
14.5	1000	1.5	1	1.35	8-10	3-5	From 3-4ms/q to 10-15ms/q

T. Lamy, LPSC-Grenoble

SPES Final Performance (Phoenix charge- bred beams)



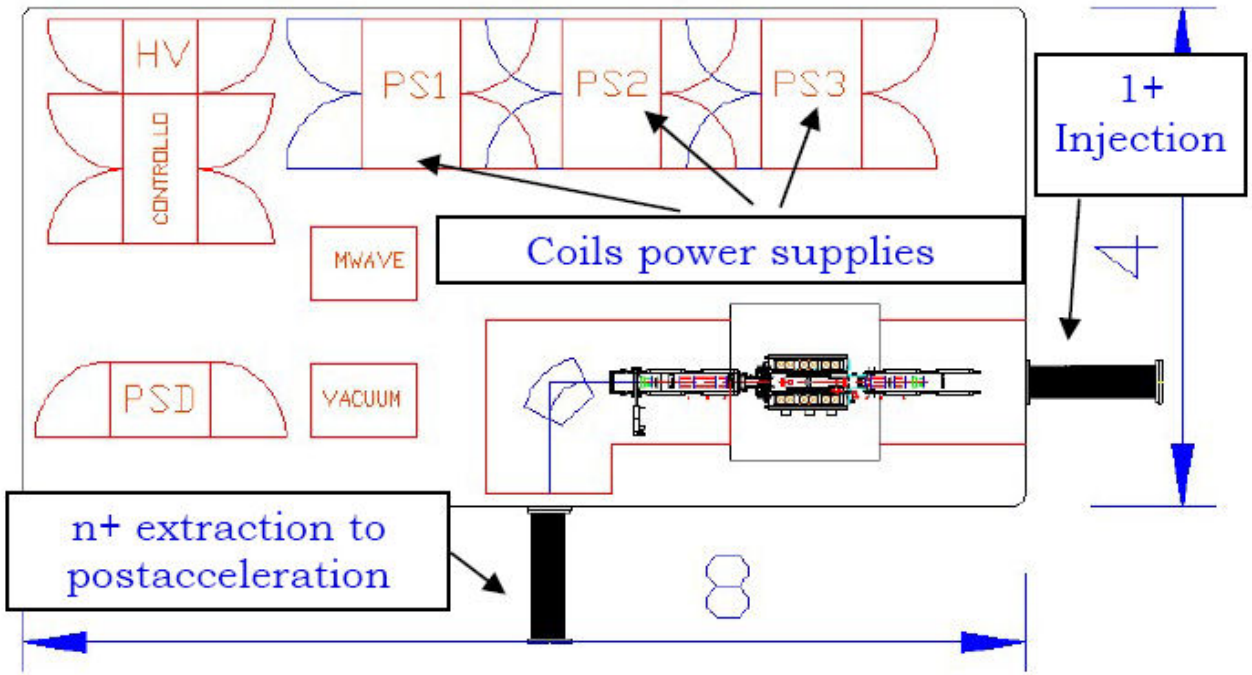
ε =

2,7÷4	6÷6,3	8÷8,3

%

The Charge Breeder Platform

Since the superconducting RFQ needs a fixed initial ion velocity, the CB will be housed in a 200 kV platform .

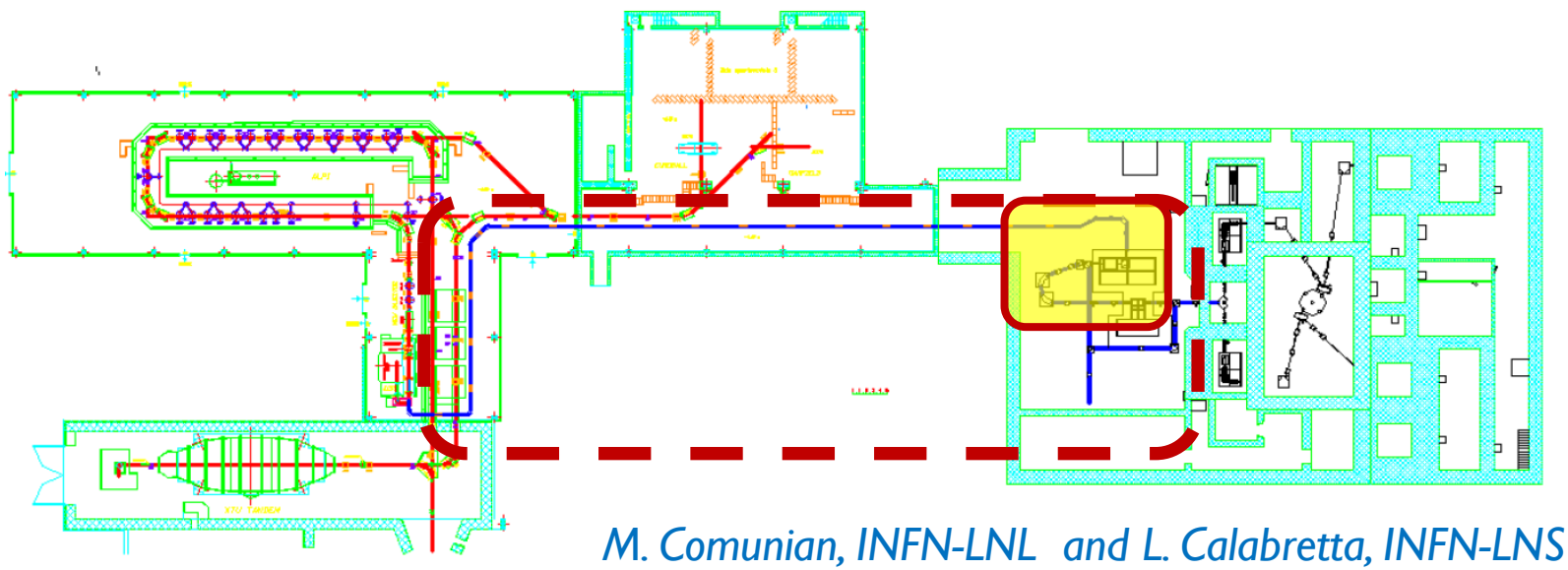


Size > 30m^2
Weight ~ 9T
P ~ 450kW
Φ_{H20}=12 m^3/h,
@ 6÷14 bar,

A. Galatà, INFN-LNL

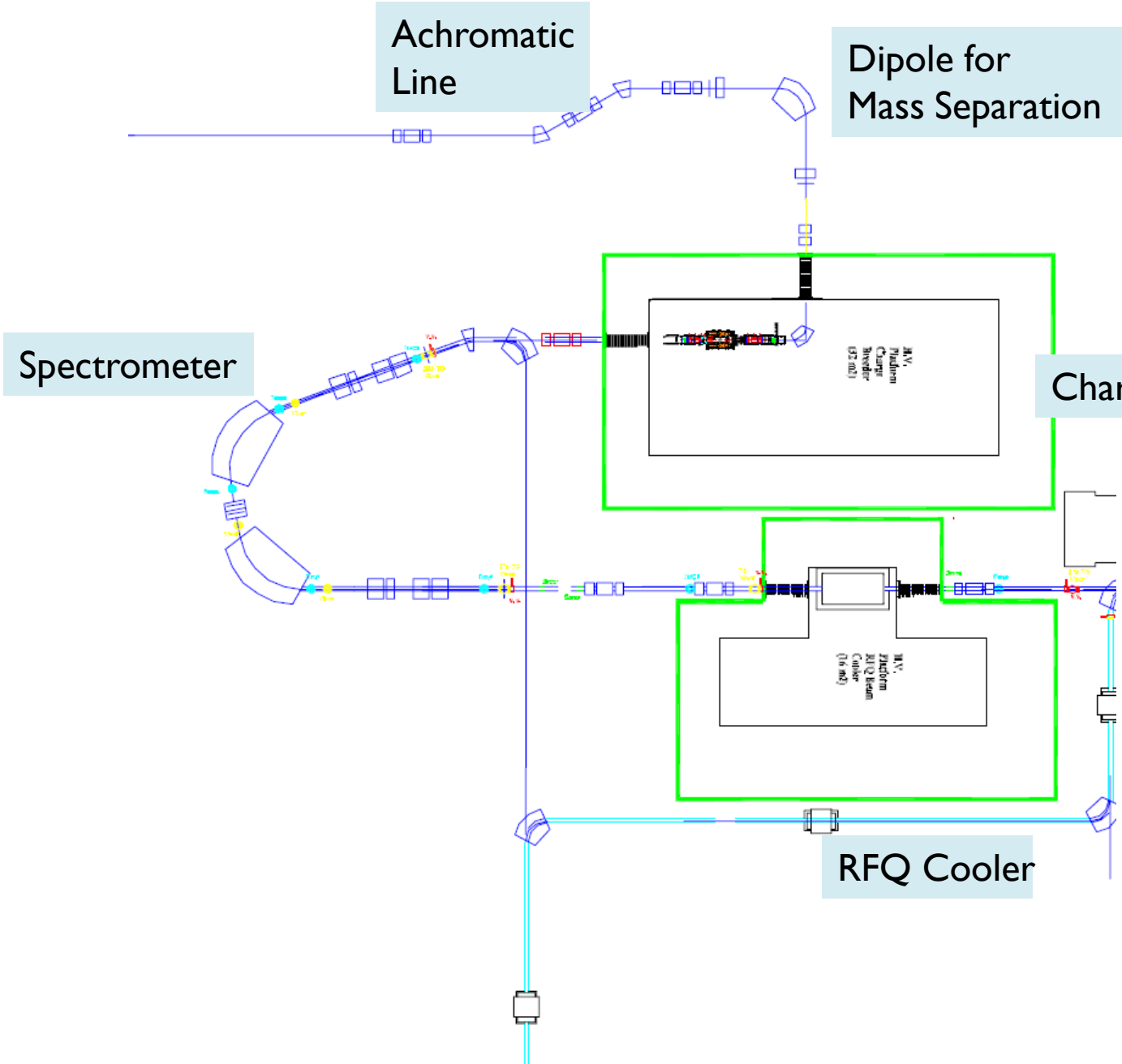
Transport Line from Charge Breeder to PIAVE

- q/A=1/7 (example $^{132}Sn^{19+}$).
- β=0.00892 (SRFQ input) [V_{plat} = 233 kV].
- Input Emittance = 0.1 mmmrad RMS.
- Linear Design (not yet higher order modes, nor misalignments)
- Regular lattice (5 m spaced) of one family of ES quads

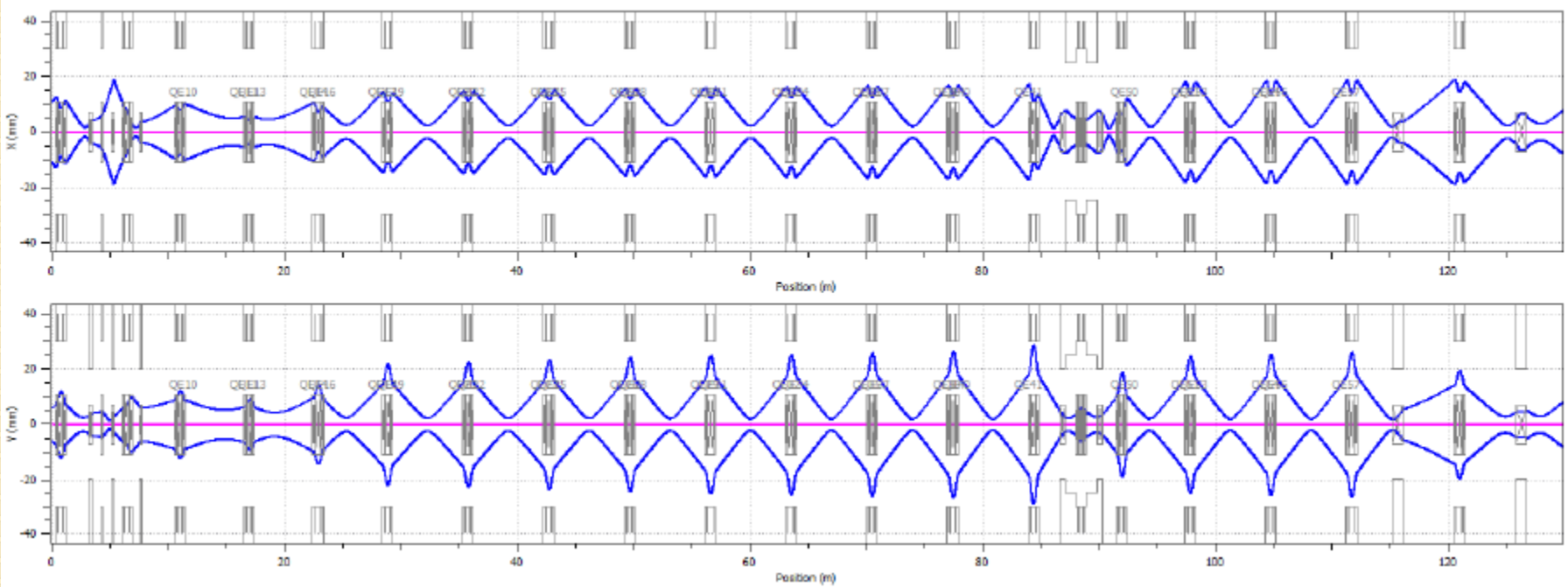


M. Comunian, INFN-LNL and L. Calabretta, INFN-LNS

Charge Breeder Layout

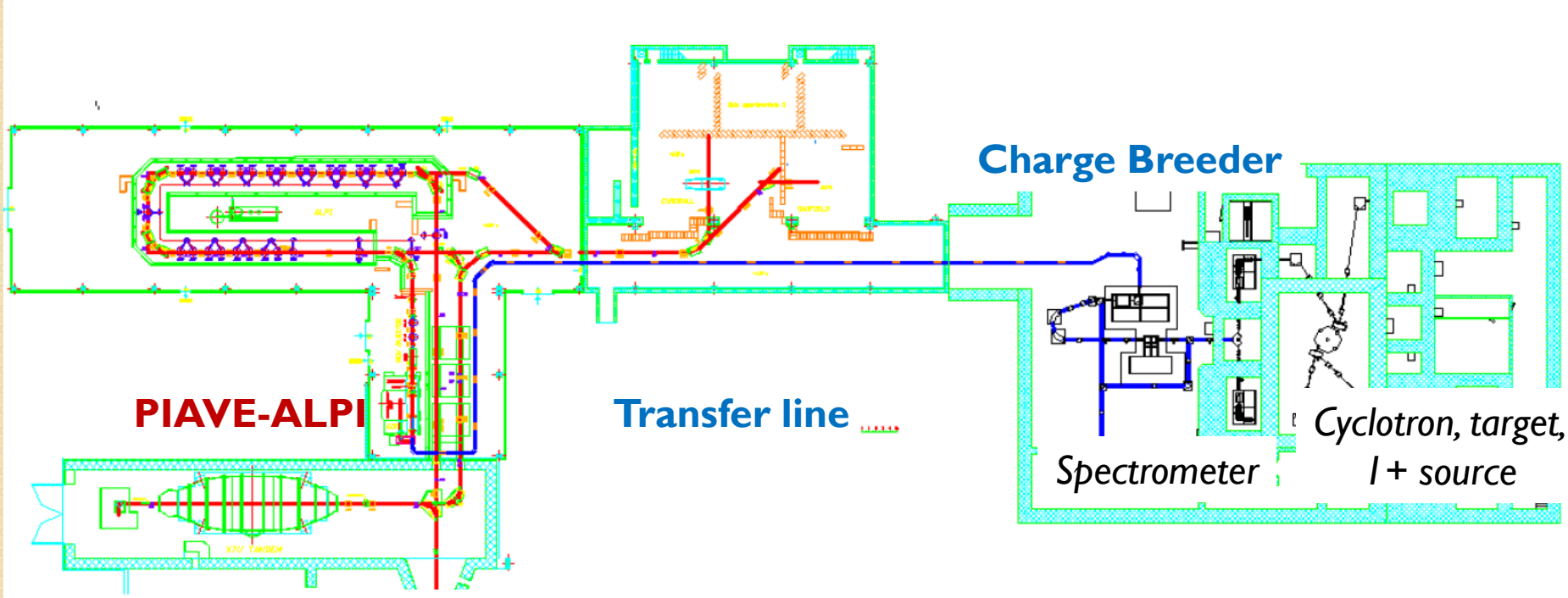


Tracewin simulation of the whole line – first order estimate



M. Comunian, INFN-LNL and L. Calabretta, INFN-LNS

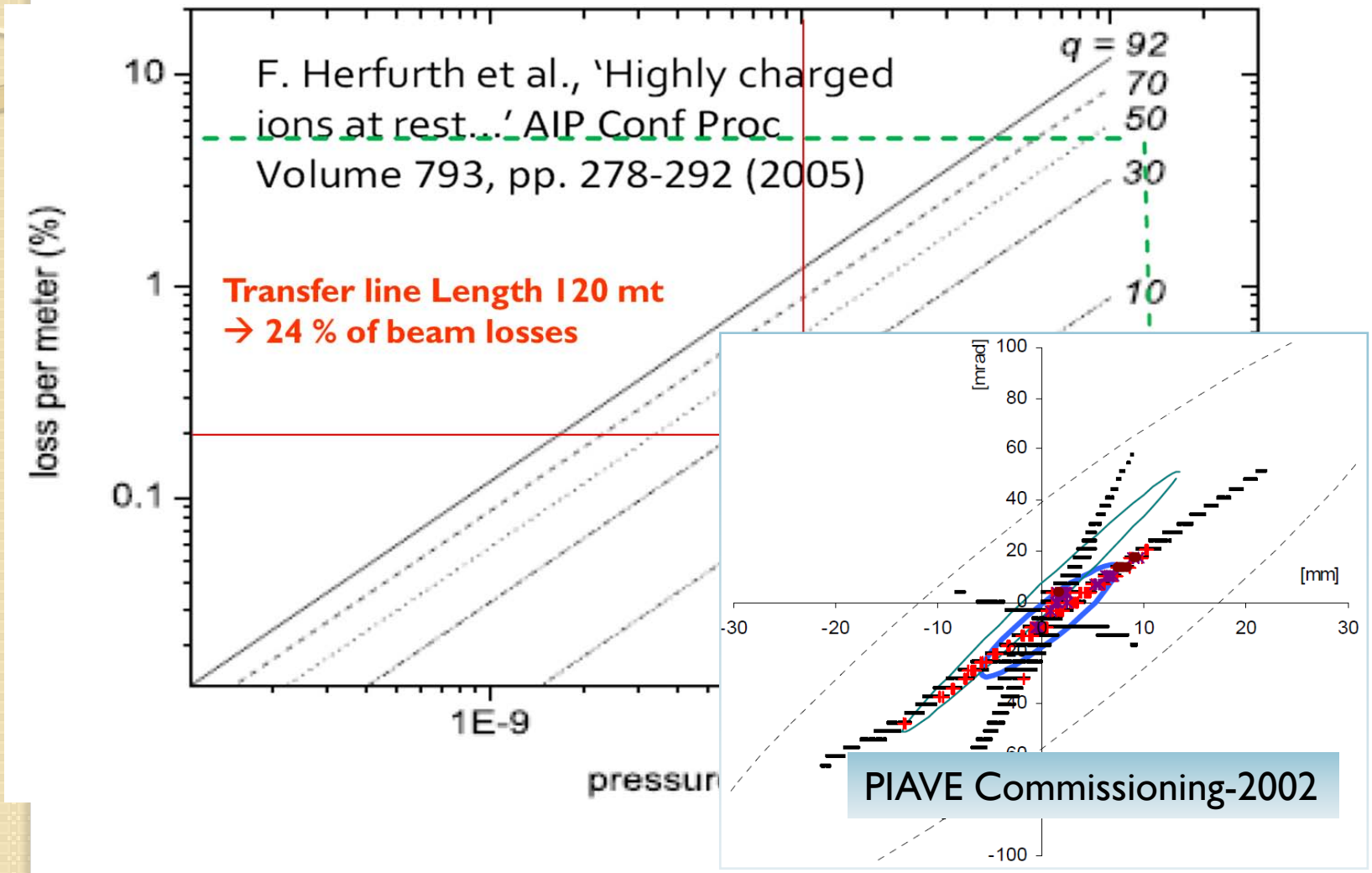
SPES-RNB Accelerator



<u>SPES-specific issues on the RNB Accelerator</u>:

1. **Vacuum** on the long low-energy transfer line;
2. Good **alignment** is mandatory;
3. **Beam diagnostics** for very low current beams

Beam losses along the transfer line due to interaction with residual gases

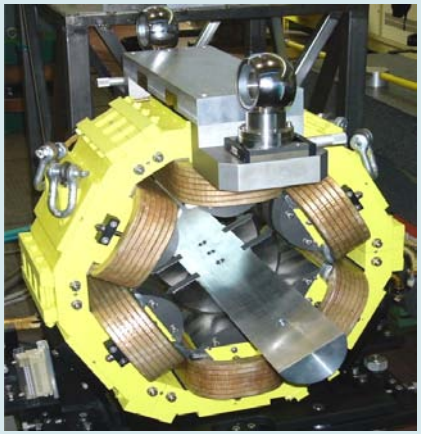


L. Calabretta, INFN-LNS and A. Pisent, INFN-LNL

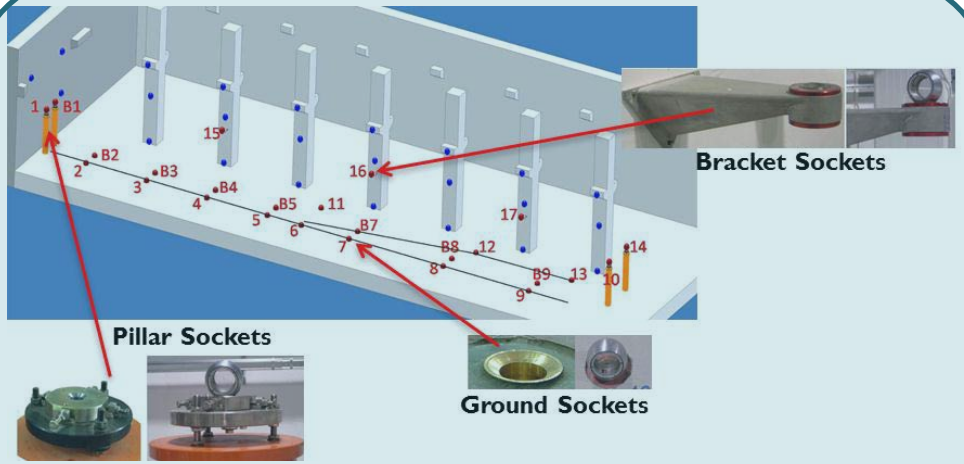
Precise and easy-to-verify alignment is mandatory for good T of fA RNBs

Optical alignment

Laser tracking



FIDUCIALIZATION OF COMPONENTS

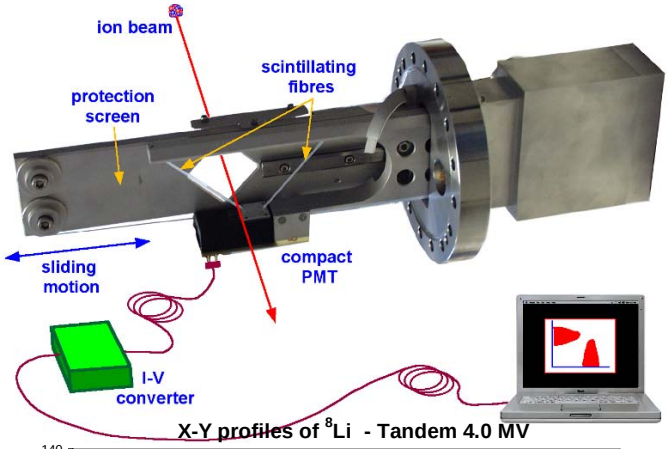


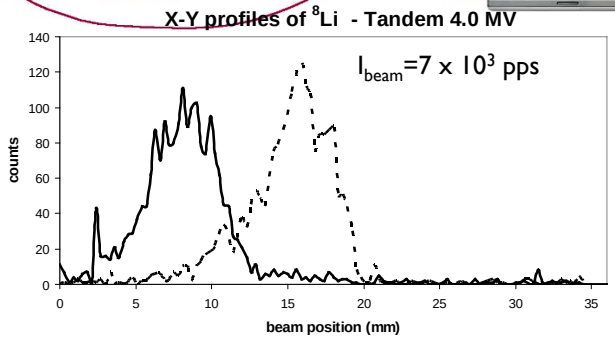
INSTALLATION AND QUALIFICATION OF REFERENCE NETWORKS

courtesy of F. Sgamma, INFN-LNF

Very low beam currents impose use of nuclear detection techniques

Pair of 300 500 μm scintillating fibres scanning the beam (INFN-LNS)

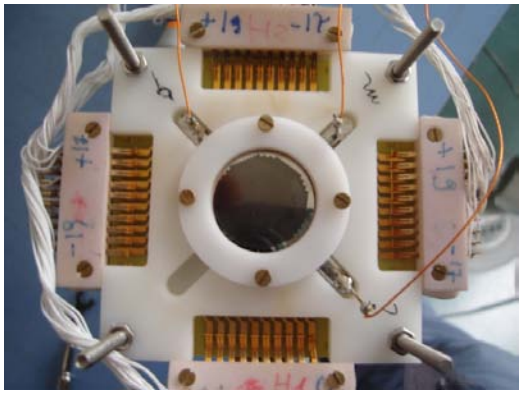


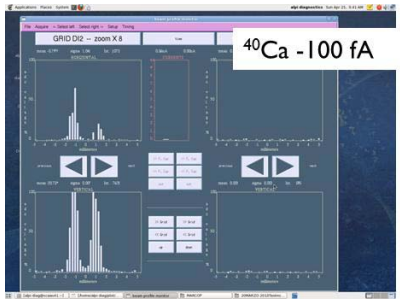


Glass (I ›10^6 pps) or plastic fibres (I ‹10^6 pps); Readout with a compact PMT.

L. Cosentino, INFN-LNS

MCP placed directly on the beam line, with a position sensitive anode (INFN-LNL)



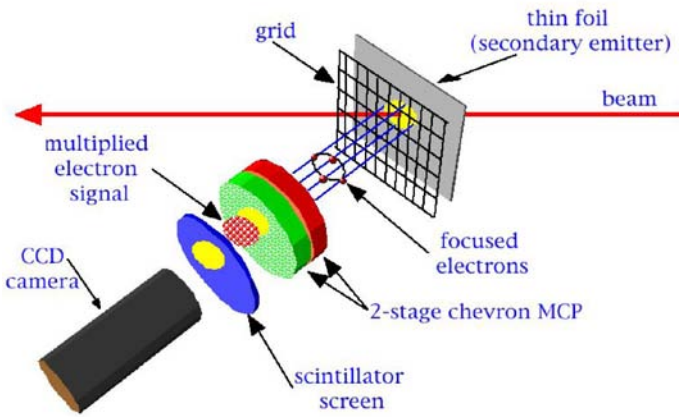


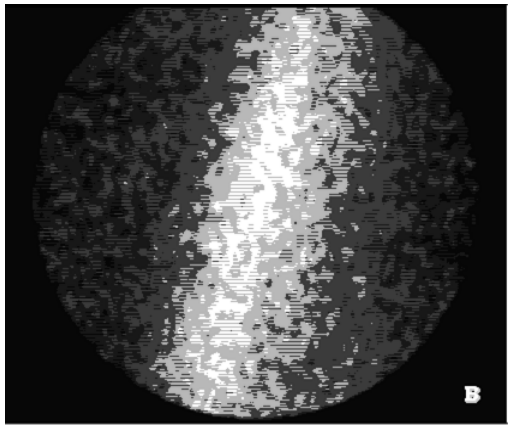
Wire step = 0.75 mm
10^5pps/cm^2 measured sensitivity.

M. Poggi, INFN-LNL

Position and profile monitor

MCP-based 2D BPM



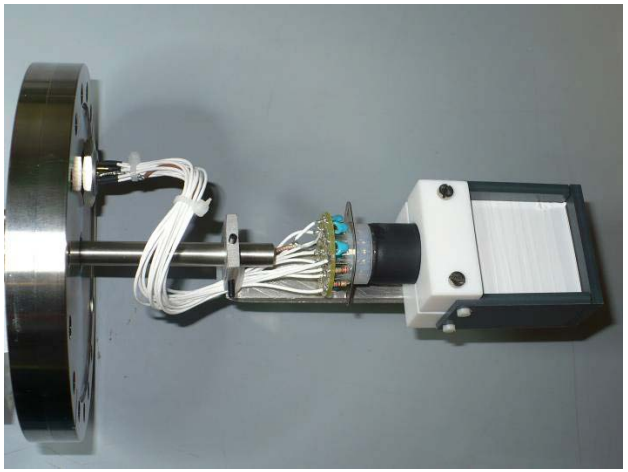


Sensitivity over 10^3 pps

Beam Current Monitor

Faraday Cup (I>100 fA)
- INFN-LNS
R&D on-going in INFN-LNL
(noise suppression)
Counting tecnique on Si Detector (on the beam, or elastically scattered by a foil)

Beam counter based on a plastic scintillator coupled to a PMT

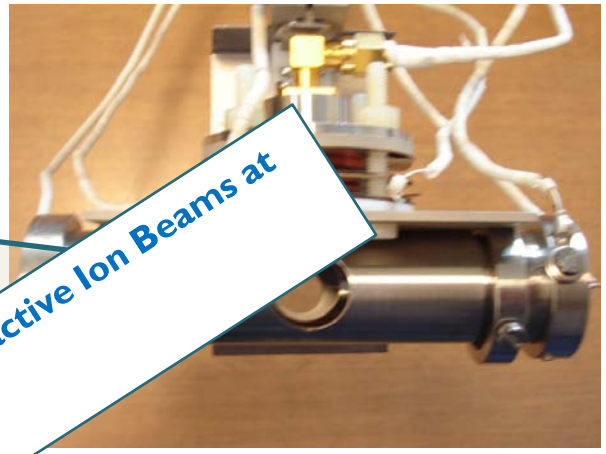


Intensities below 10^6pps

courtesy of L. Cosentino, INFN-LNS

Energy, timing, T&L emittances

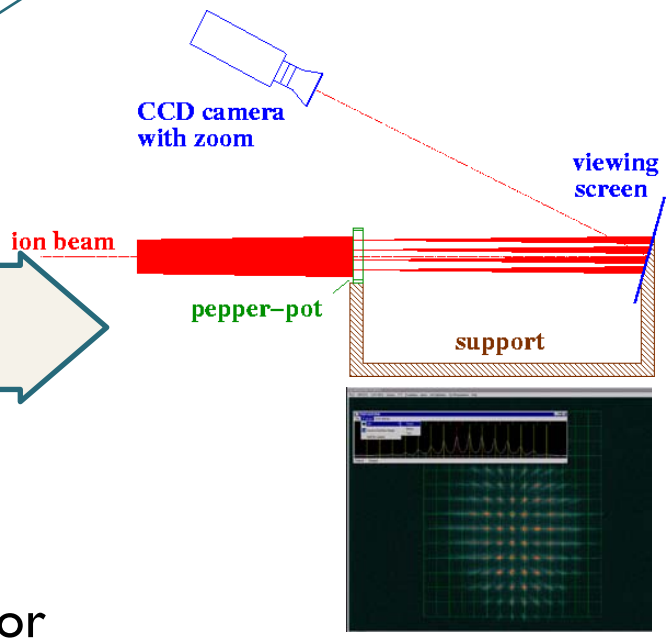
Energy: 1. bending magnet and a BPM (as usual)
2. TOF with 2 MCP as phase monitors (velocity)



Timing: silicon detector or MCP (electrons produced by a wire on the beam). Start-Stop by RF

Transverse emittance (

1. Slit-grid traditional ... e 'grid" is the intensi...
2. Pepper-p... slit" replaced by a sc... all holes (0.1mm); ... a scintillating screen.



Longit...dinal emittance ($\Delta\phi$, $\Delta E/E$):
Si detector (directly on collimated beam)
3-gradient method with bunch length monitor (with MCPs)

Courtesy of P. Forck, GSI

Wednesday 13:00 – 13:20 Diagnostic Devices for Radioactive Ion Beams at INFN LNS
L. Cosentino, INFN LNS

Outlook

- ALPI Upgrade has been triggered:
  - The accelerating field of the first cryostats is being improved
  - The refrigeration power of the cryo-plant will be improved (> 30% expected)
- Once funded, the upgrade can be completed with a renewed PIAVE-Injector, on ALPI with higher gradient magnetic quads and new bunchers
- Very low currents impose on the whole RNB Accel.:
  - Accurate and verifiable alignment (it is planned to introduce it on PIAVE-ALPI)
  - Dedicated beam diagnostics (R&D at INFN-LNS&LNL)