A Cost-Effective Energy Upgrade of the ALPI Linac at INFN-Legnaro

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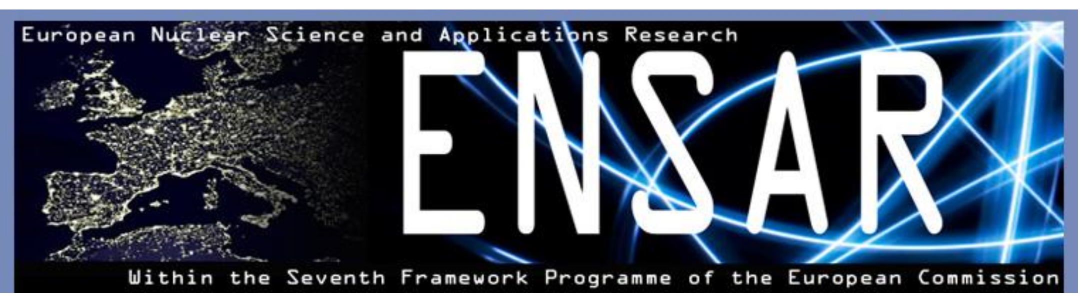
Talk Content

1. Bird’s eye view: present status of INFN-LNL accelerating facilities
2. Next goal on the stable beam front (with very limited resources…) – *RIBs being the priority*
3. Recent progress on: ECR, cryogenic plant, cavities
4. Proposal for a cost-effective energy upgrade for very heavy ion bems

A User-oriented Lab, in a EU framework



2010-2014

Funded by the European Commission within its Seventh Framework Programme (FP7) under the specific programme 'Capacities'. It provides coordinated access to the EU NP Facilities: GANIL (F), GSI (D), joint LNL-LNS (I), JYFL (FI), KVI (NL), CERN-ISOLDE (CH) and ALTO (F).

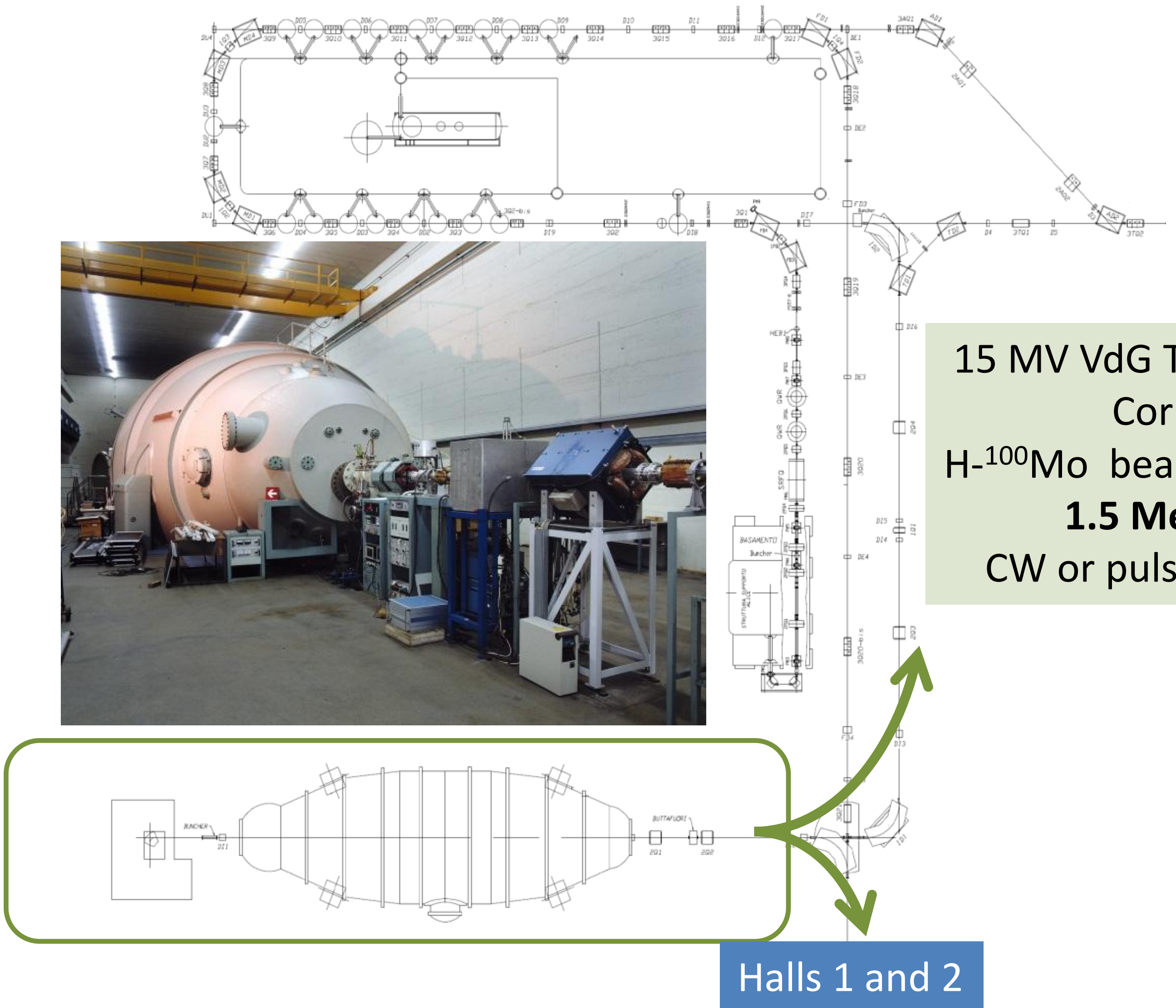
INFN offers LNL and LNS infrastructures jointly


Padova
Adriatic Sea

INFN

Istituto Nazionale di Fisica Nucleare

INFN-LNL Heavy Ion Accelerator Complex – XTU Tandem

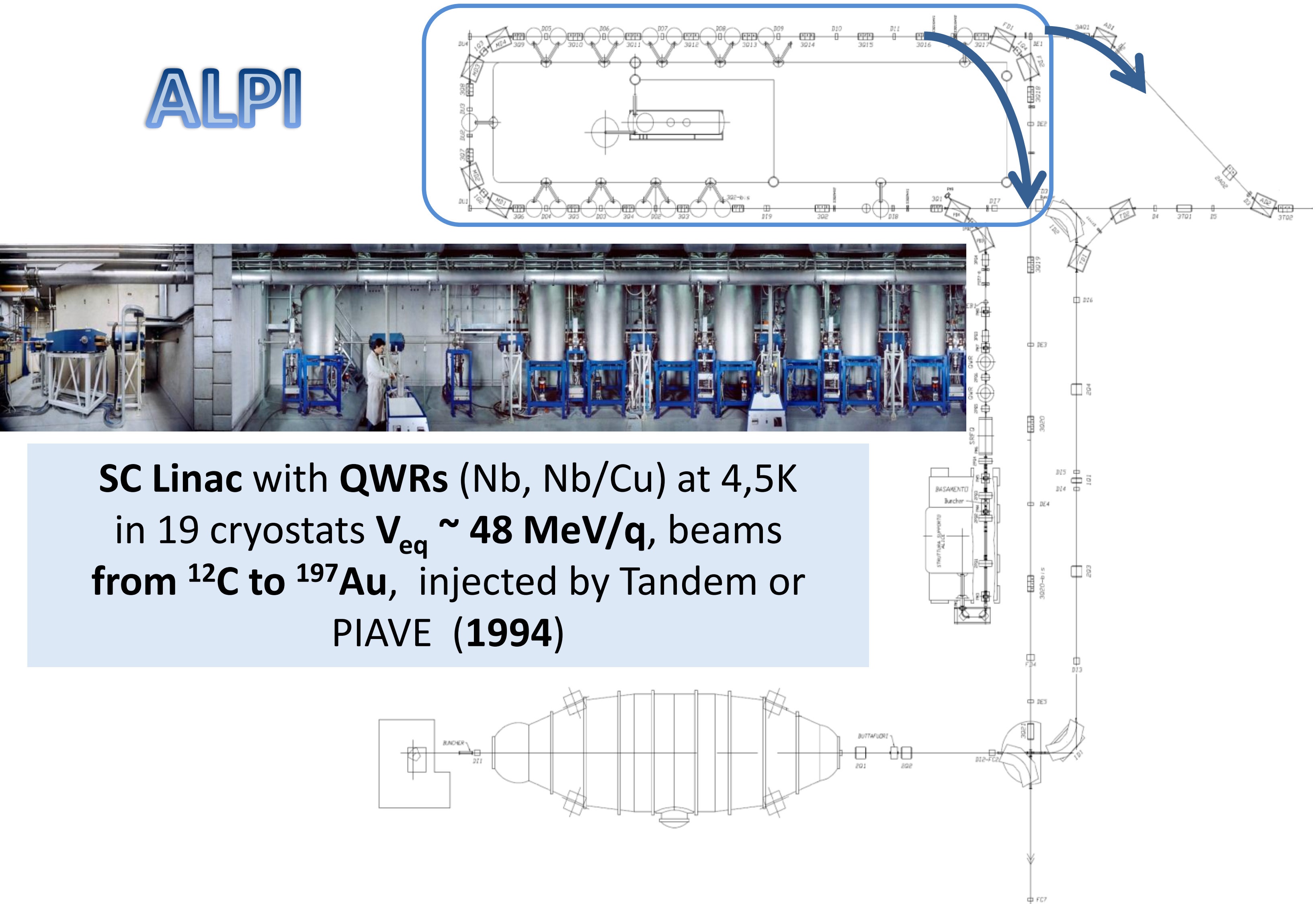


Moby Dick

15 MV VdG Tandem (HV Corp),
H-^{100}Mo beams, E = **30 ÷ 1.5 MeV/A**,
CW or pulsed (**1984**)

INFN-LNL Heavy Ion Accelerator Complex – SC Linac

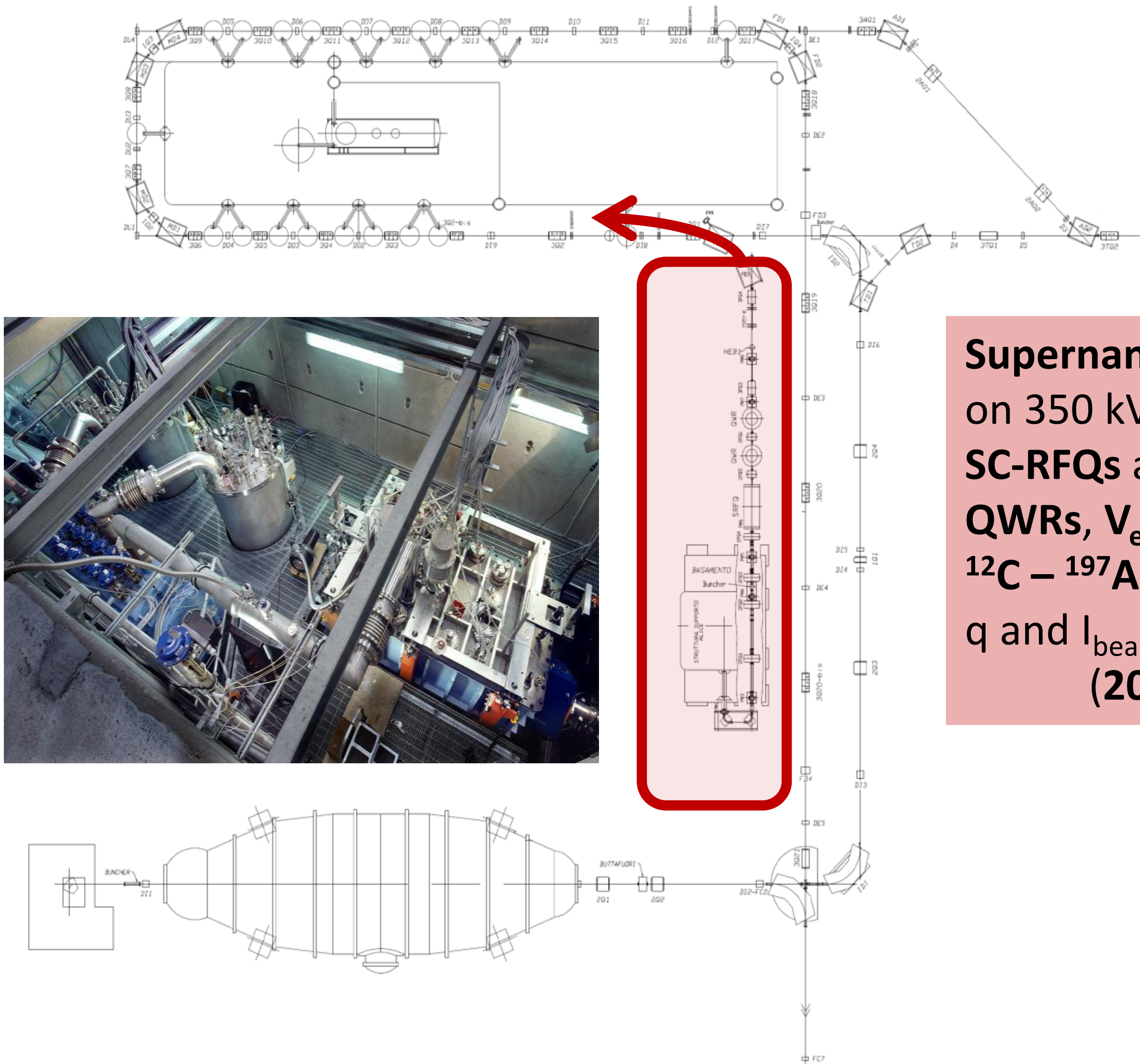
ALPI



SC Linac with **QWRs** (Nb, Nb/Cu) at 4,5K in 19 cryostats **V_{eq} ~ 48 MeV/q**, beams **from ^{12}C to ^{197}Au**, injected by Tandem or PIAVE (**1994**)

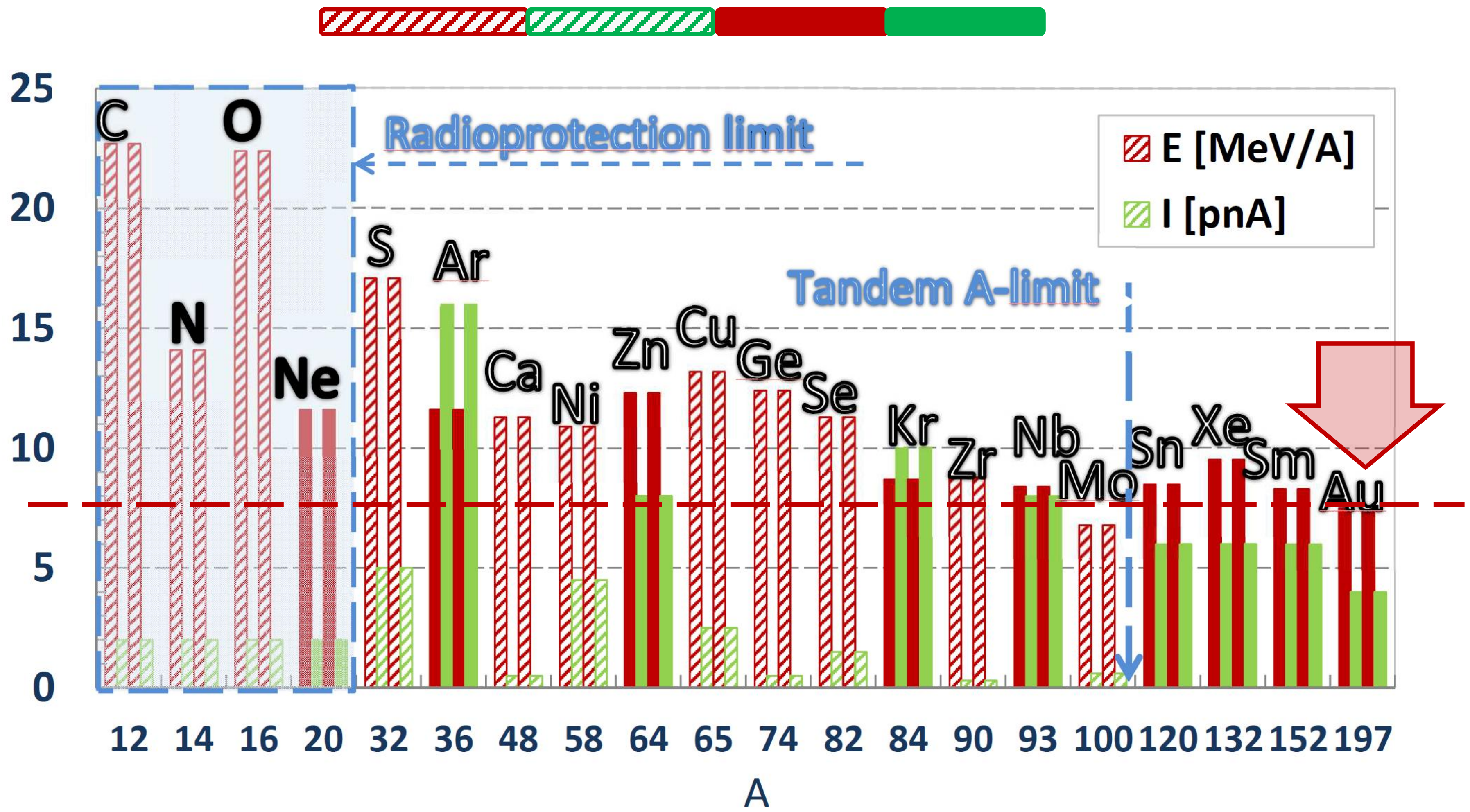
INFN-LNL Heavy Ion Accelerator Complex – SC Linac Injector

PIAVE

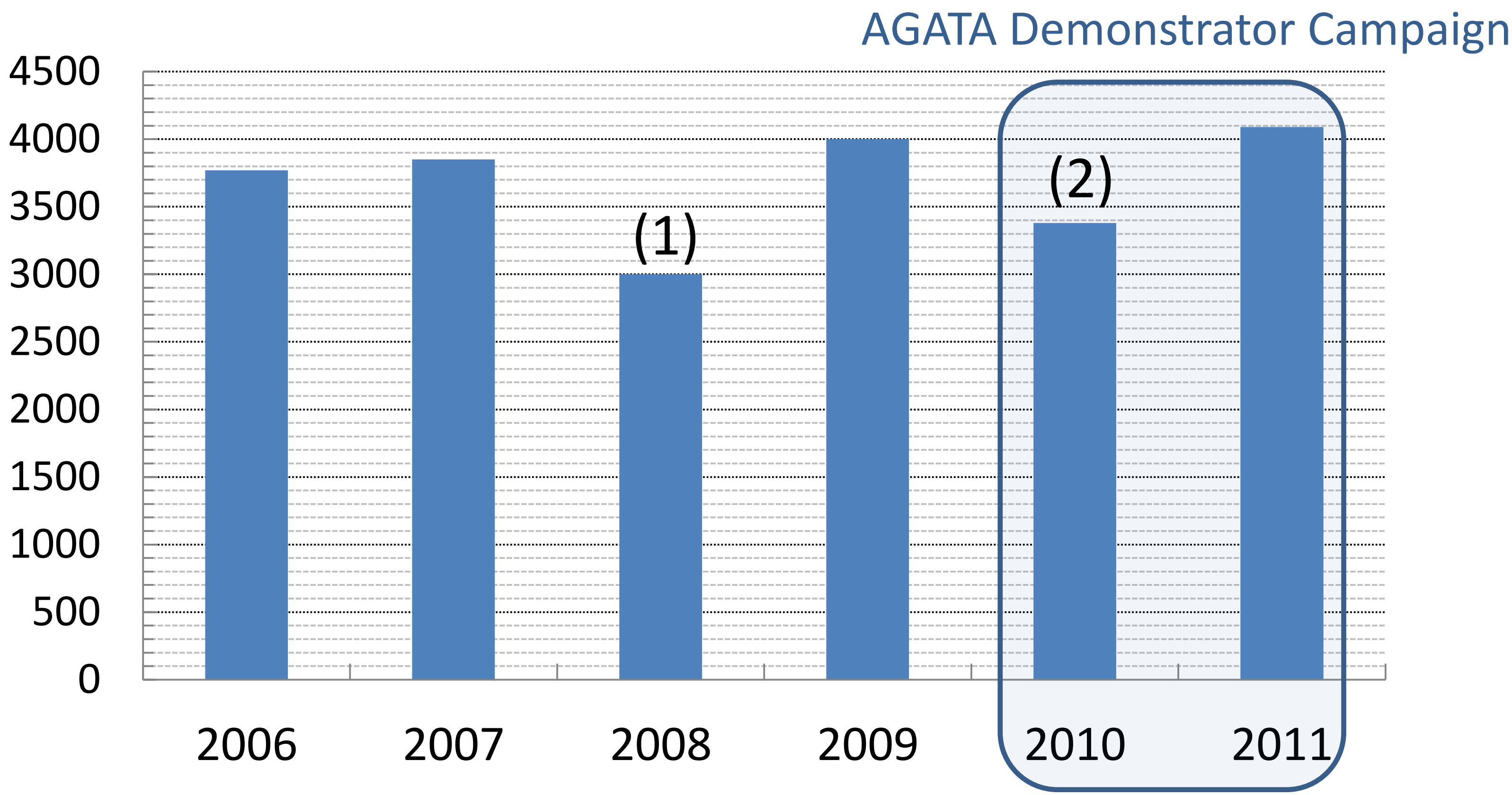


Supernanogan ECR on 350 kV platform
SC-RFQs and
QWRs, V_{eq} ~ 8 MV
^{12}C – ^{197}Au (higher q and I_{beam})
(2006)

T-A and P-A Typical Beams



Beam Hours Available for Experiments

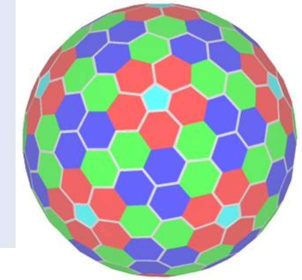


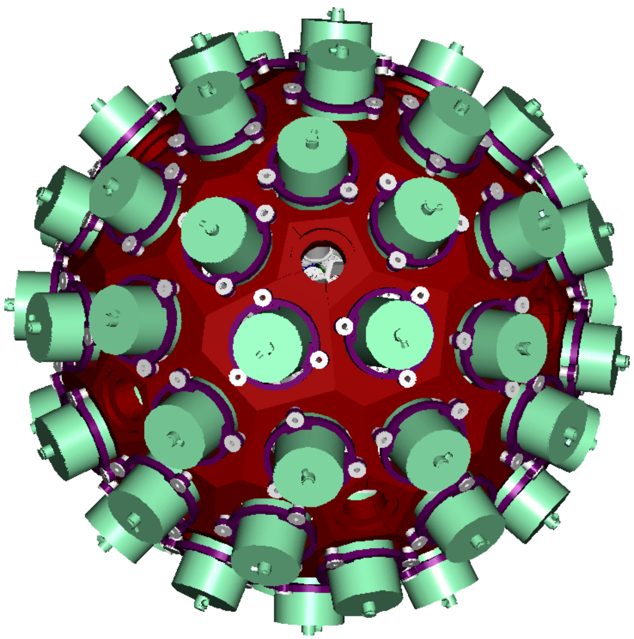
(1) Supernanogan ECRIS installation and Special XTU Maintenance

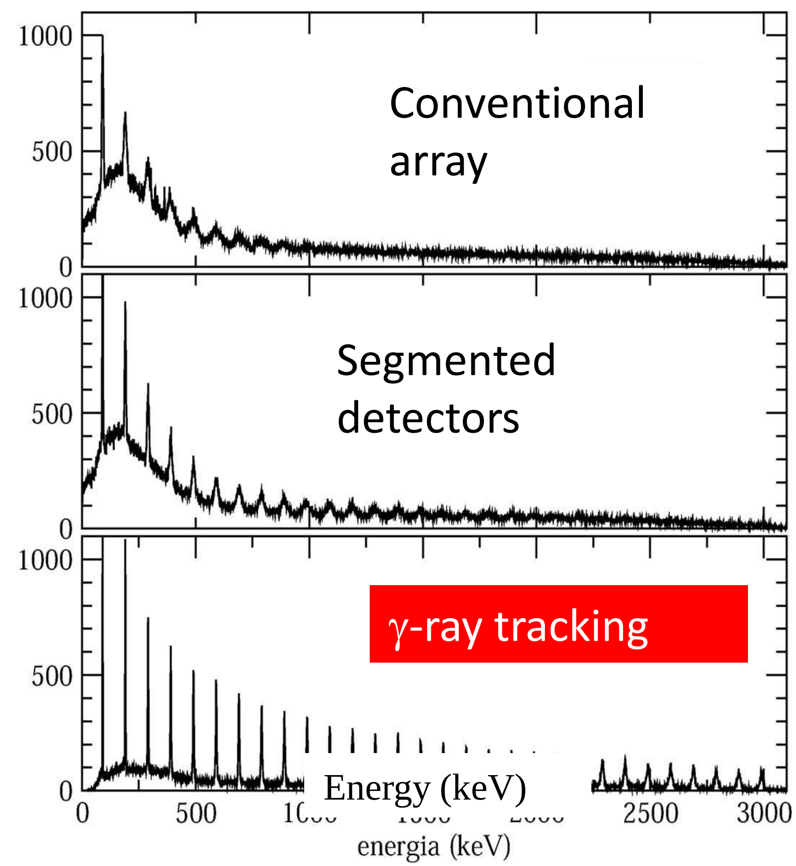
(2) Special Maintenance on the Cryogenic Plant

AGATA

(Advanced GAmma Tracking Array)







The innovative use of detectors in position-sensitive mode (combining digital DAQ, pulse shape analysis, γ-ray tracking) will result in high efficiency (~40%) and excellent energy resolution, making AGATA the ideal device for spectroscopic studies of weak channels.

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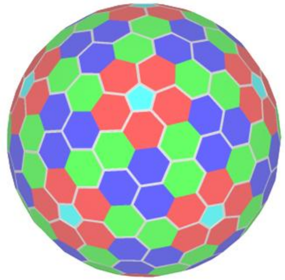

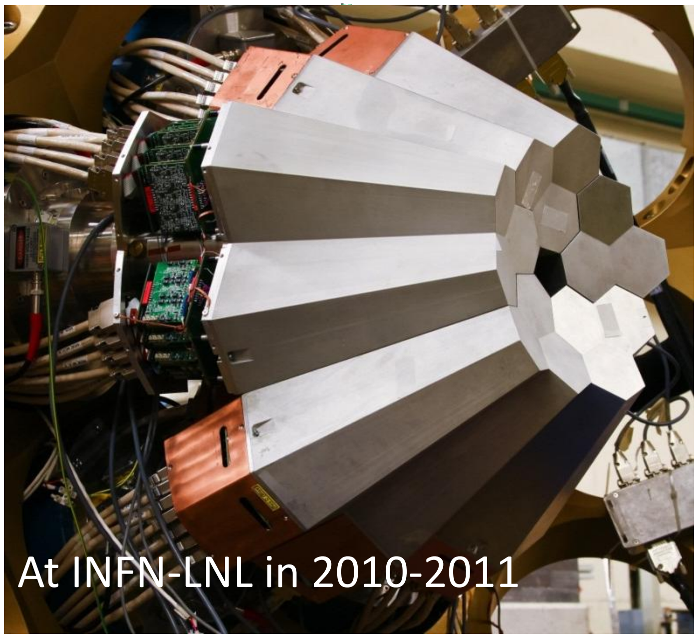

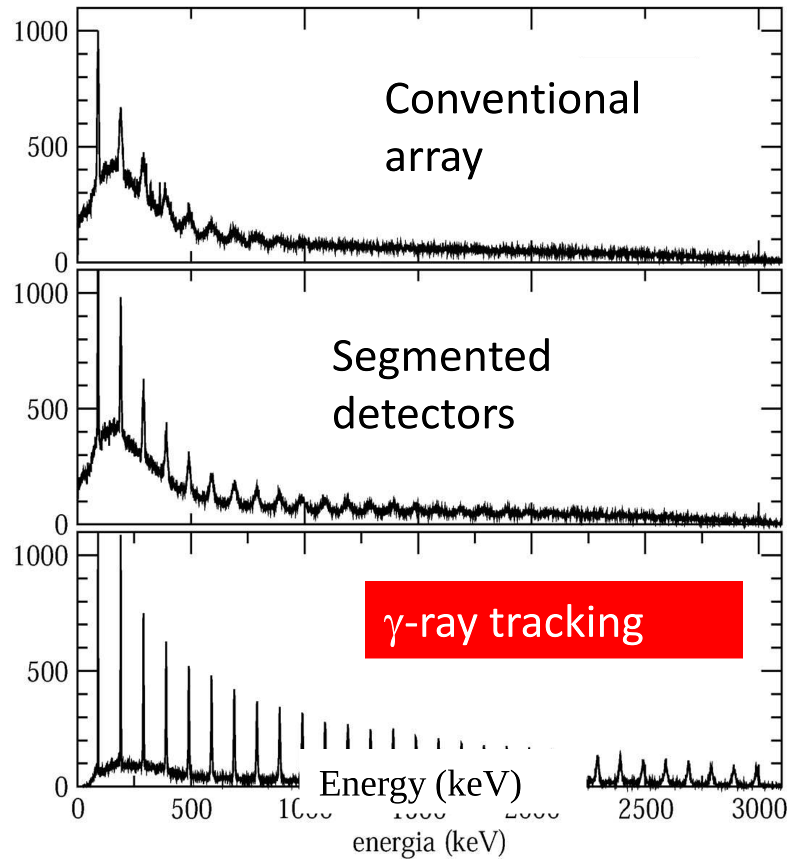

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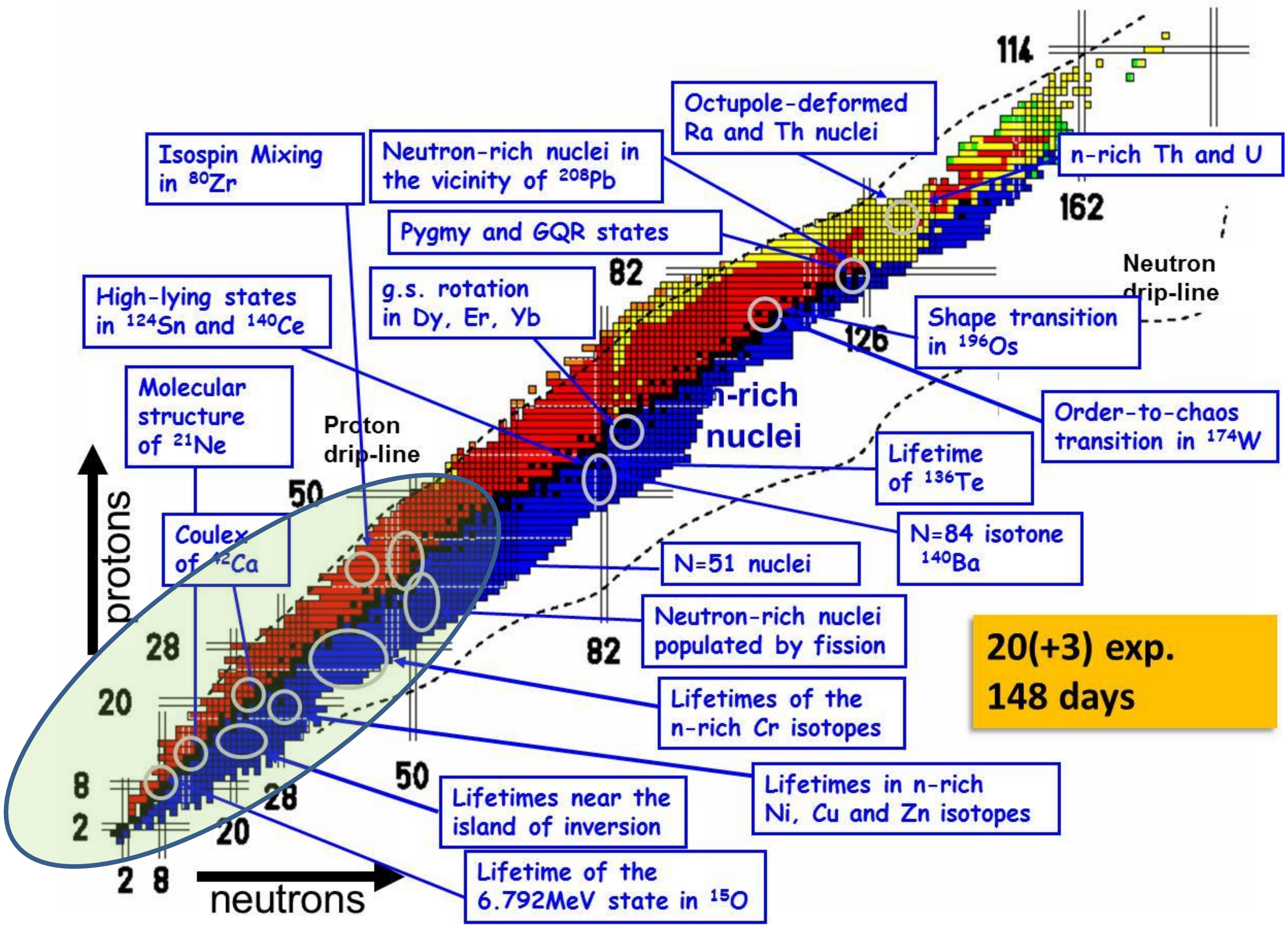
The Experimental Campaign at INFN-LNL (2010-2011)



20(+3) exp.
148 days

What are the next steps?

Radioactive Ion Beams

The Lab priority is the **SPES project**

1. **Driver**: 70 MeV, 700 uA proton cyclotron (purchased, in construction)
2. Multi-slice UC_x direct **target-ion-source station**, followed by HRMS, beam cooling systems
3. **RIB acceleration**: charge breeding, CW NC RFQ injection into ALPI

ALPI refurbishment: replace and modernize old components, accelerate ultra-low-I mid-A exotic beams beyond Coulomb barrier with typical U-targets (specific diagnostics)

M. Comunian (14.00 today!)

Stable Ion Beams

- Further **increase the final energy** for all ions (good for SPES too)
- Especially for **very heavy** ones
- **Increase** trasmission and $\mathbf{I_{exp}}$ AMARP

Target: ^{208}Pb at ~10 MeV/A and I ≥ 1 pnA

Three MUSTS:

(since this not the top priority):

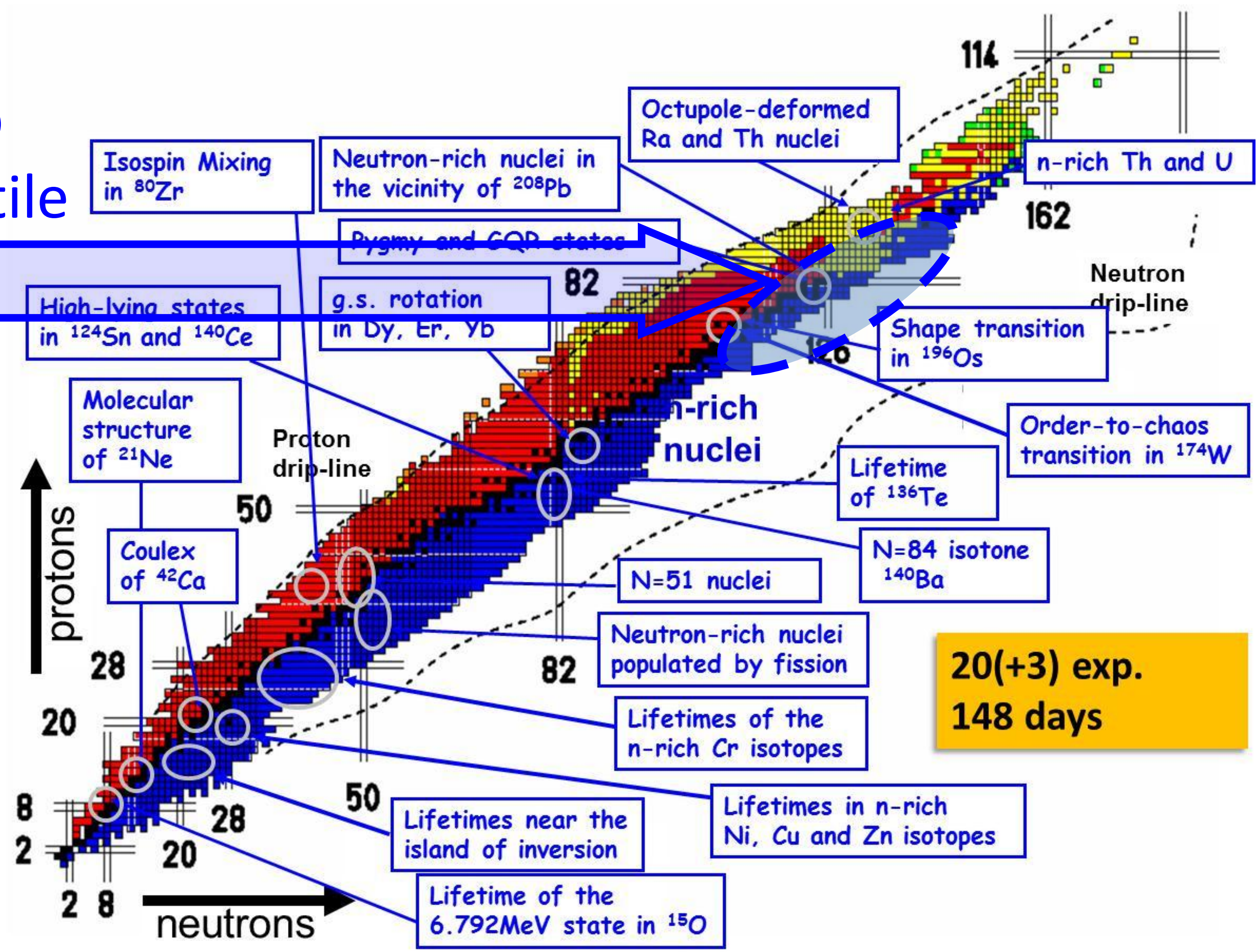
COST-EFFECTIVE

WORKLOAD-EFFECTIVE

(BEAM)TIME-EFFECTIVE

The very-heavy stable beam option

^{208}Pb projectile



20(+3) exp.
148 days

Ingredients for the ^{208}Pb 10 MeV/A – 1 pnA recipe

1. **ECRIS**: good (I,q) performance ($\underline{q \geq 30+}$)
2. **Ancillary Systems**: adequate performance (He refrigerator)
3. **ALPI:** Higher equivalent voltage (higher E_a? More resonators?)

   We can't violate the cost+workload effectiveness…

4. **Beam transmission:** overall improvement

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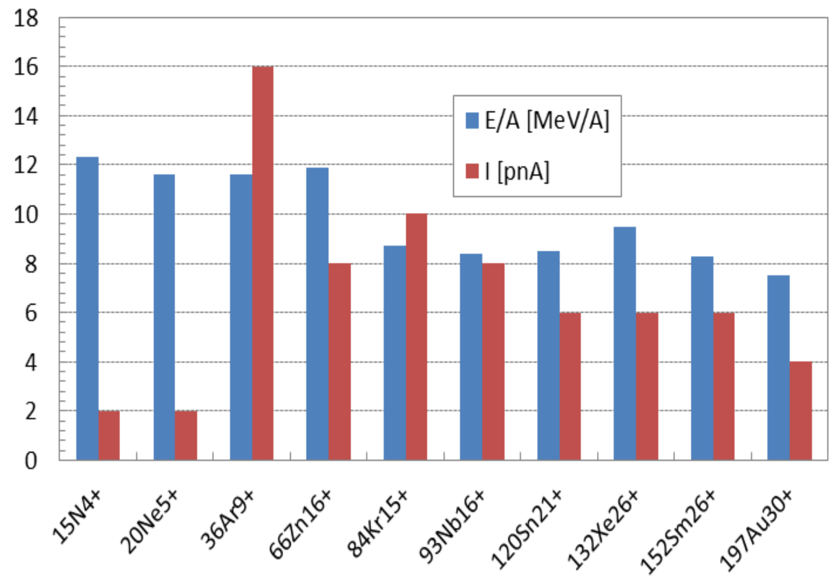
ECR Ion Source Status

A high V_{eq} linac is fully expoited with adequate ECRIS performance

- Since 2009: **LEGIS, an all-permanent-magnet Supernanogan source (Pantechnik)**
- Ar, Kr, Xe, Ag, Ta, Au readiliy available in the source acceptance tests
- **Metal beams** of specific interest to the EU nuclear physics community were **developed in the time left available by the official beam time schedule**
- Presently available beams: C, N, O, Mg, Ar, Zn, Kr, Nb, Sn, Sm, $^{197}Au^{30+}$
- Next planned developments: Mo, Ca, Pb, (Dy, Pd)



- **Spring 2012**: I_{max} through PIAVE 1→**2 euA** (tests with a $^{16}O^{3+}$ beam).
- OK → **5 euA** at least (from T- sensors on SC resonators and locking)
- **ALPI diagnostics** must be upgraded: 2 euA is present practical limit

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He Refrigerator Upgrade

Air Liquide- based on a **Claude cycle** processing up to 150 g/s He.

Liquid He production:

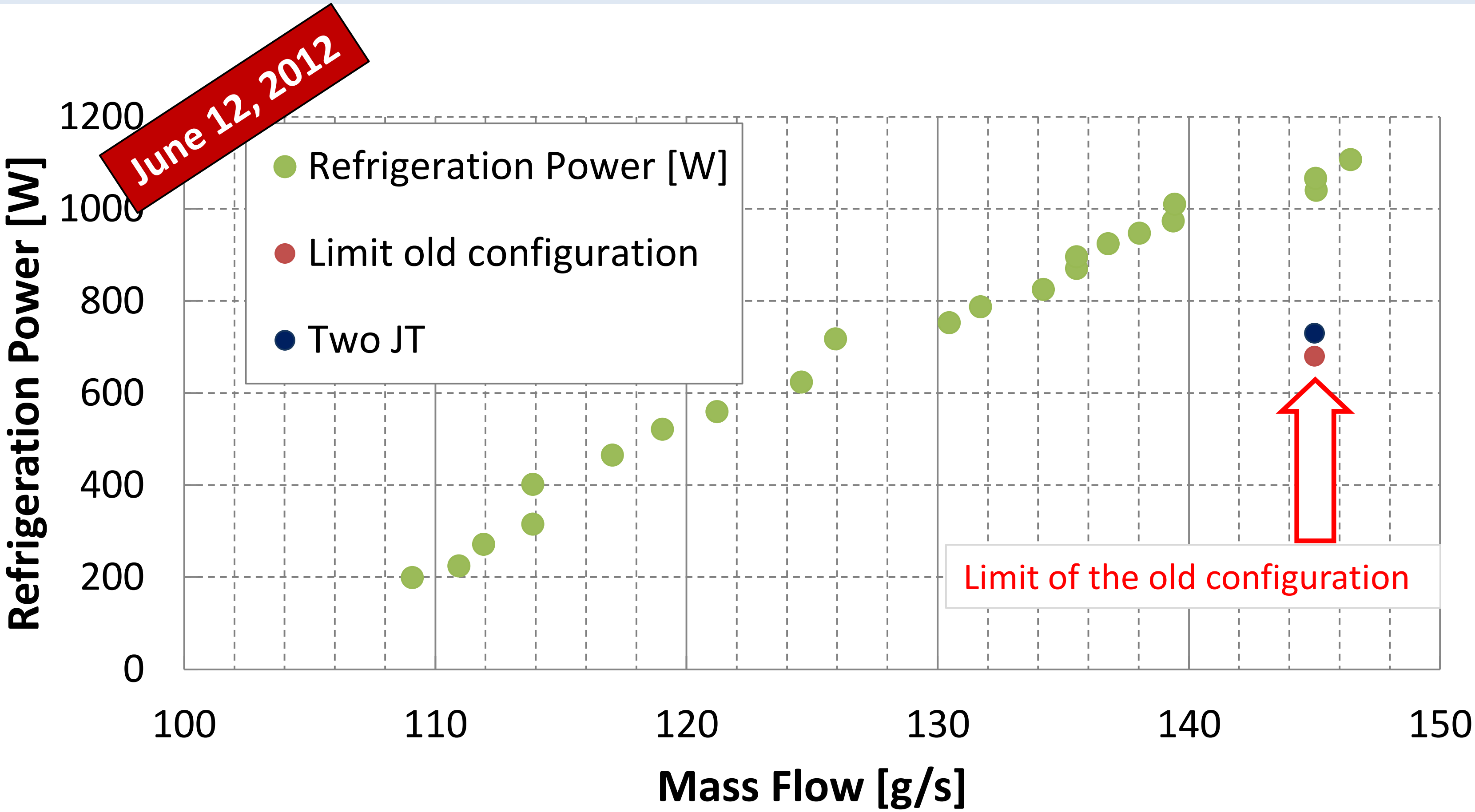
- **2 gas bearing turbines** (used for cooling cryostats shields too)
- **a JT expansion valve** (alternatively: a reciprocating wet expander -**WE**)

Commissioning result (with WE) -1991: 3900W (60K) + **1180W (4,5K)**

Noisy WE soon abandoned – **with JT**: **only ~ 700W @4,5K** - **NO redundancy**: barely enough for shield cooling and for cryostats and cavities installed – **cavities working at 6 W instead of 7 W** since 2010.

2012: **3rd supercritical turbine** in place of WE, to increase refrigeration capacity at 4,5K **with the JT** expansion valve

He Refrigerator Upgrade



Measured **increase in the refrigeration capacity** 360 W (predicted 300W): **+ 51%**

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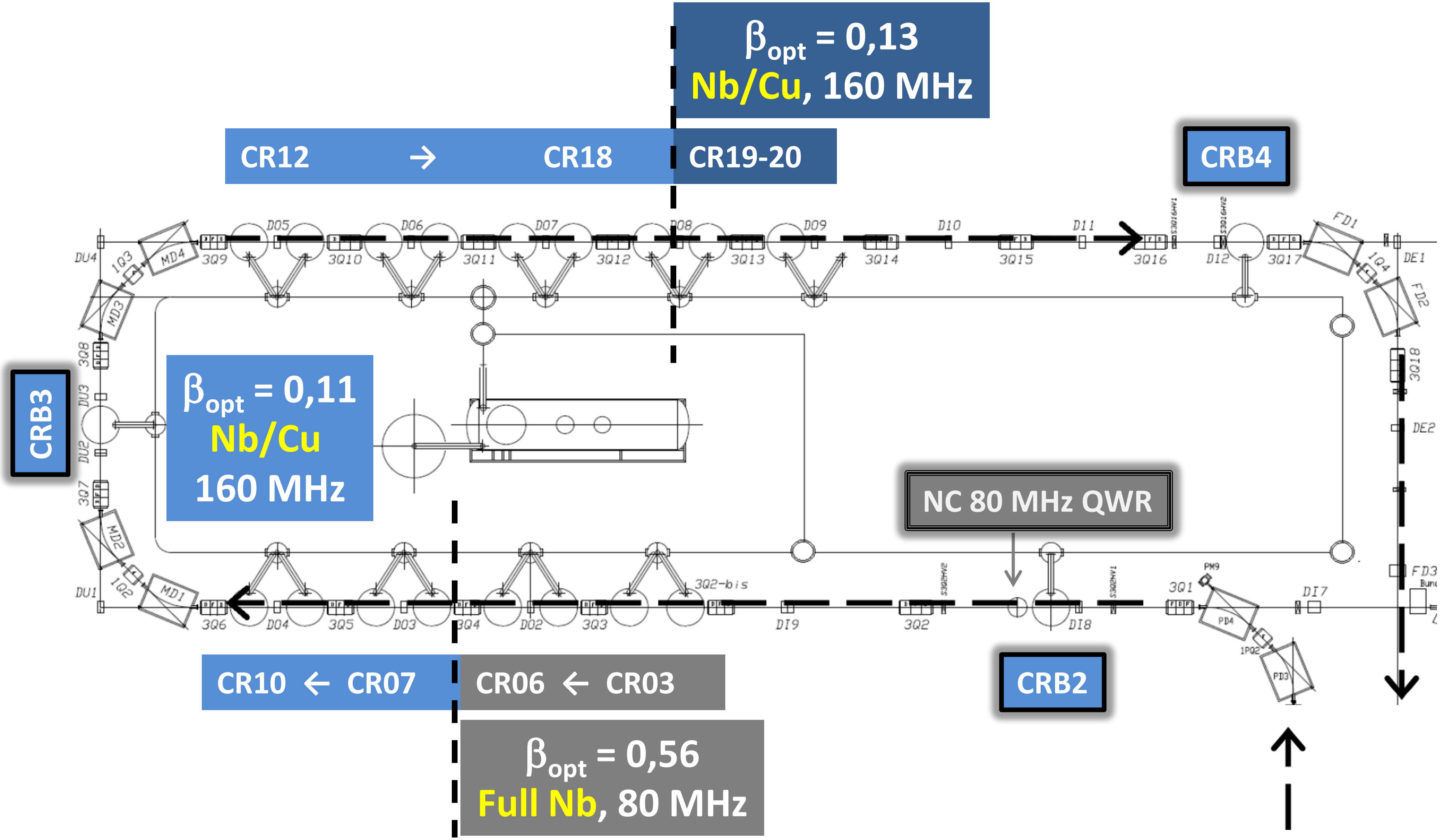
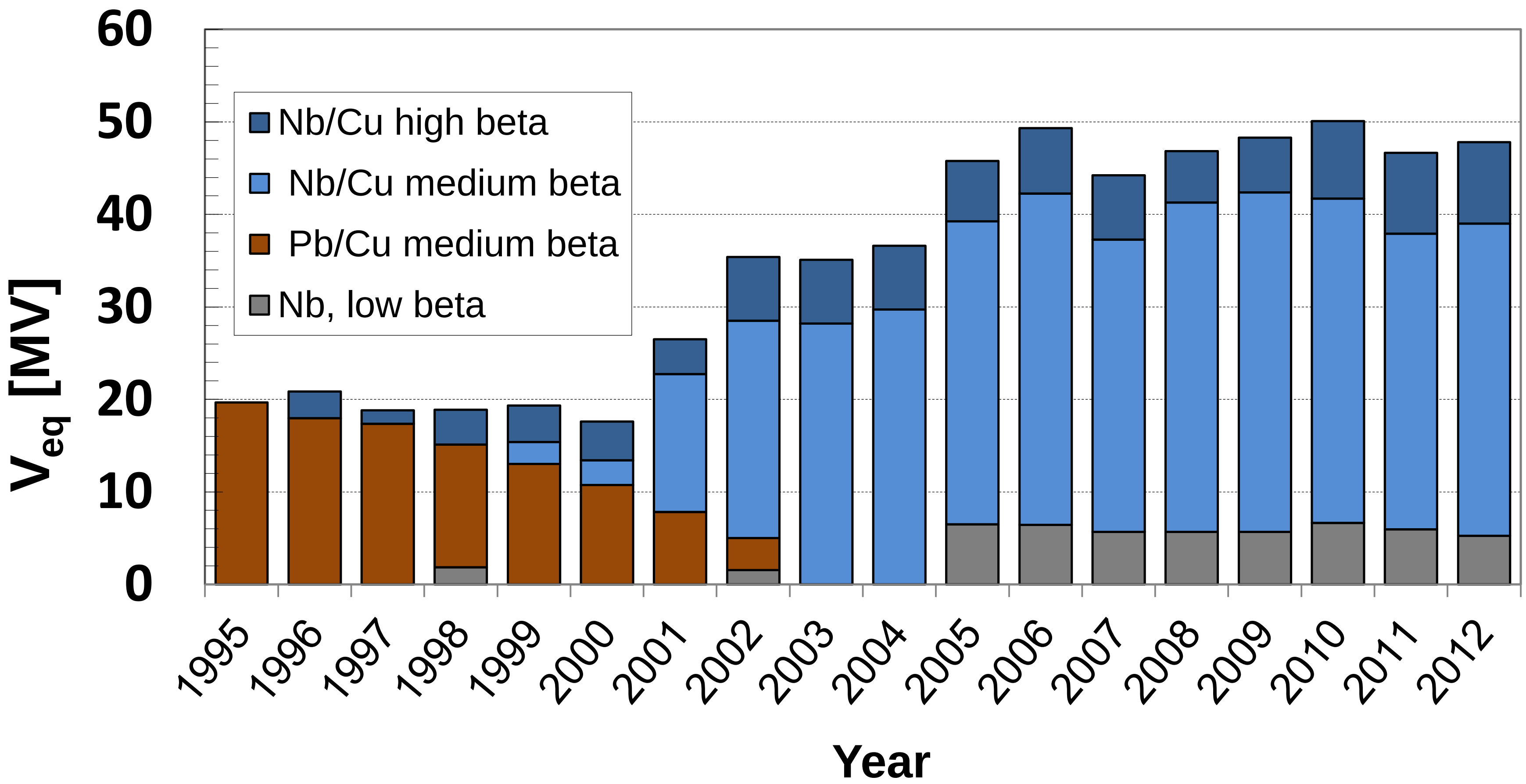
INFN Istituto Nazionale di Fisica Nucleare

QWR Families in ALPI



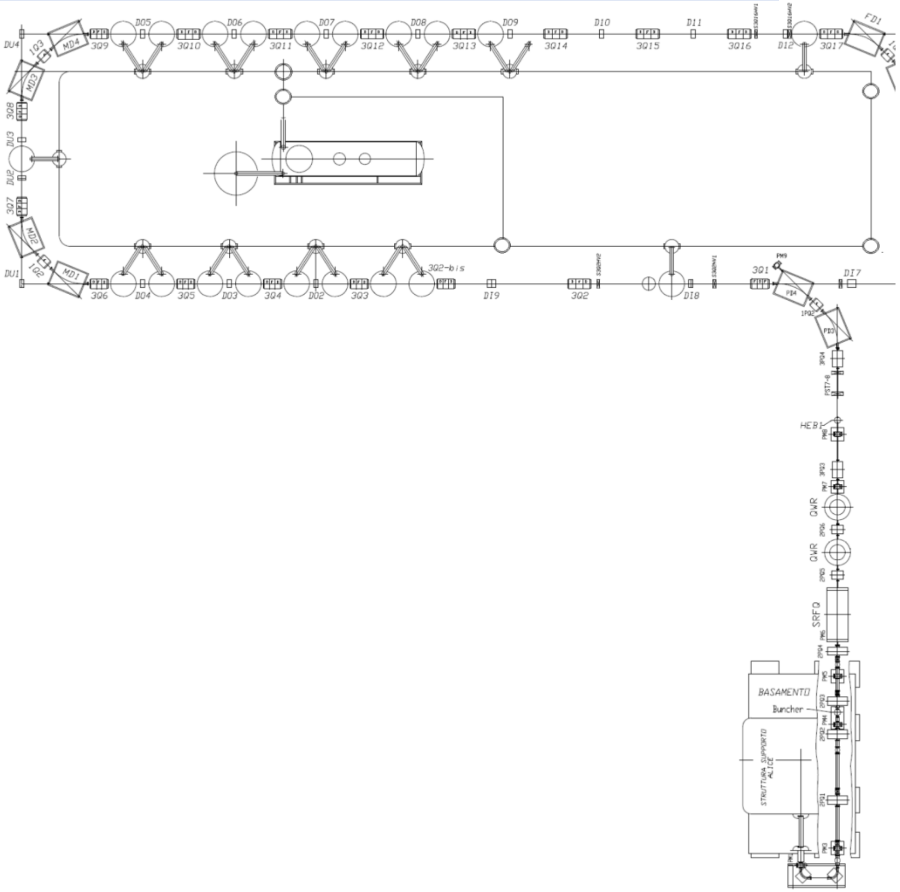
ALPI – An open workshop on QWR performance



… despite the flat top, the quest for higher E_{acc} continues…

Low-β Resonator Upgrade

Thin wall Nb cavities are less stable mechanically.
Upgrade: Liquid-N cooling of input RF power coupler, to increase $P_{RF,in}$ from 0,15 to 1 kW - QWR ϕ&A locking **from 3 to 5 MV/m** (or more)



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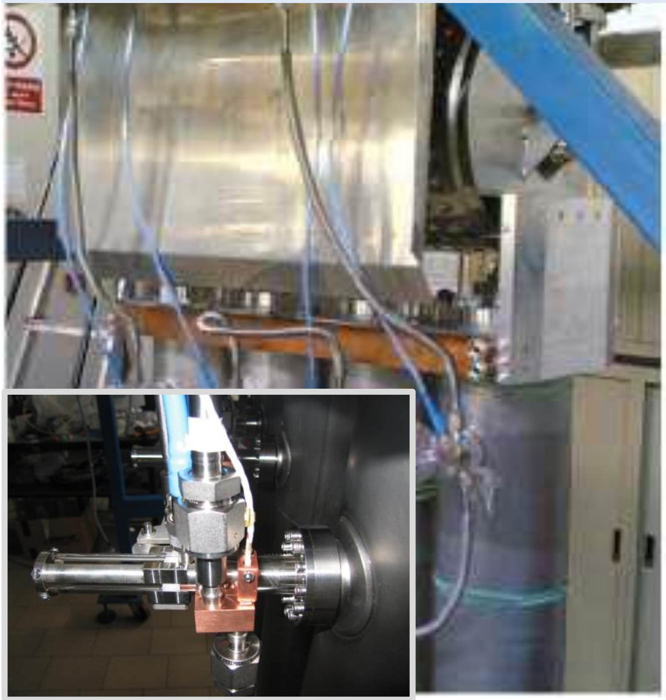
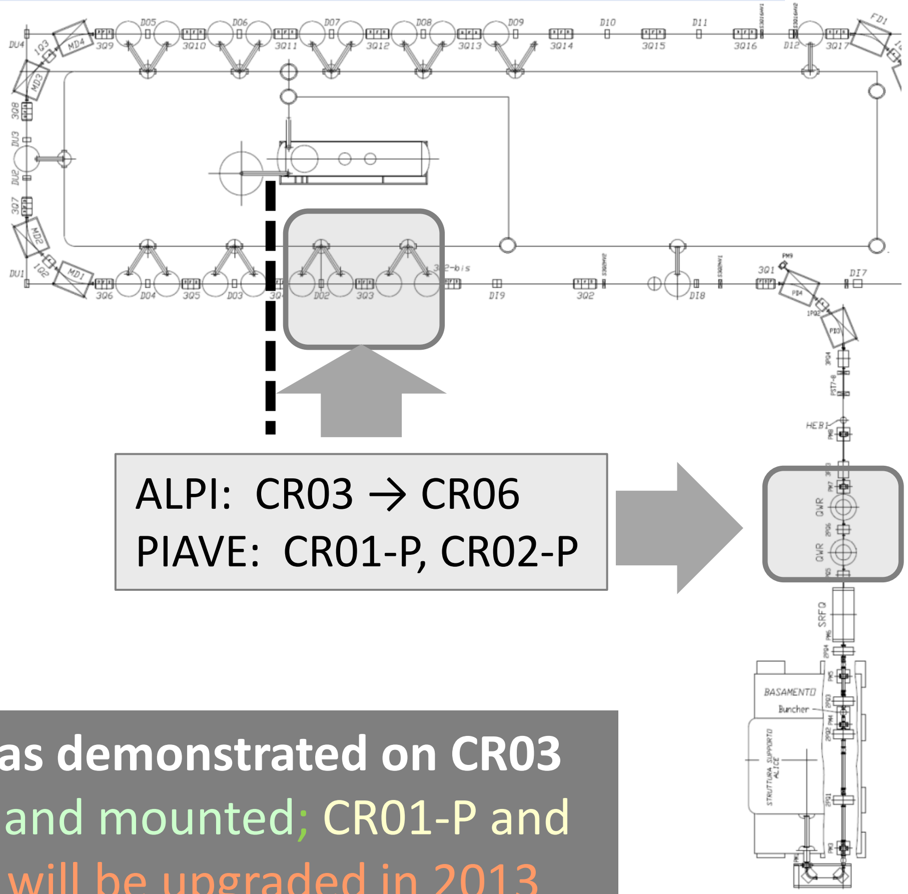
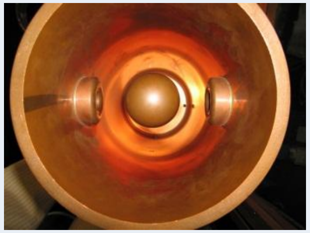




ALPI: CR03 → CR06
PIAVE: CR01-P, CR02-P

Reliable locking at 5 MV/m for days was demonstrated on CR03
Status: CR03, CR02-P, CR05 completed and mounted; CR01-P and CR06 presently in maintenance; CR04 will be upgraded in 2013

Medium-β Resonator Improvements

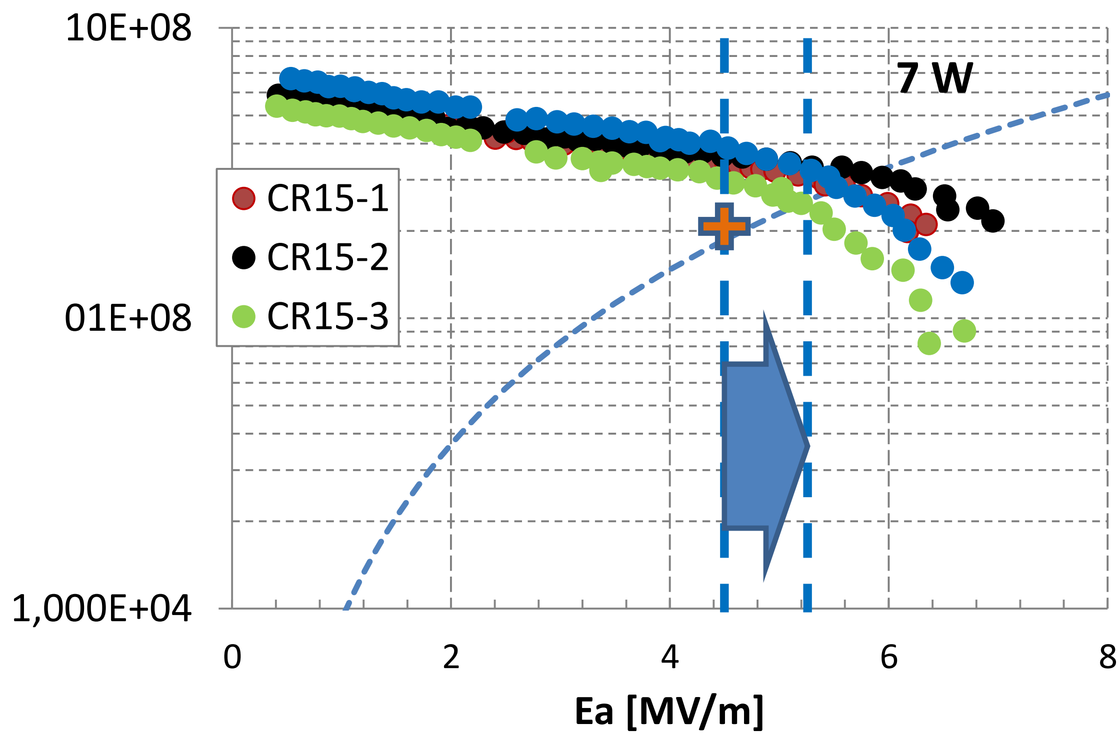


Cu base for presently installed Nb/Cu QWRs
E_a ~ 4,8 MV/m

PROTOTYPE CRYOSTAT CR15

Rounded-off shorting plate & beam ports, **E_a~5,5 MV/m**

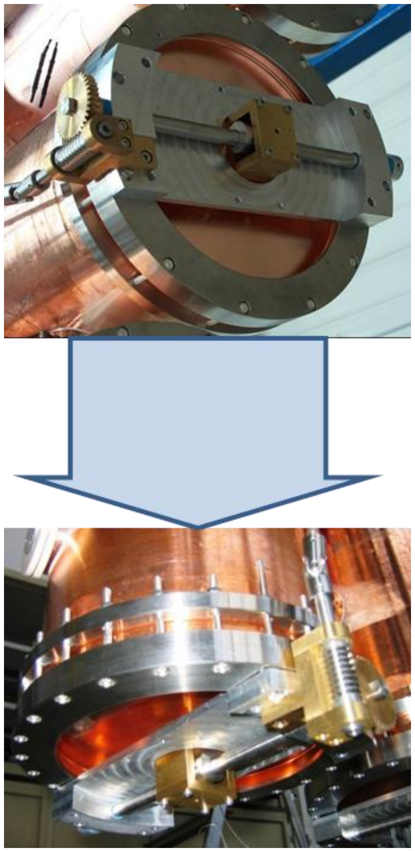
Measured in 02/2012

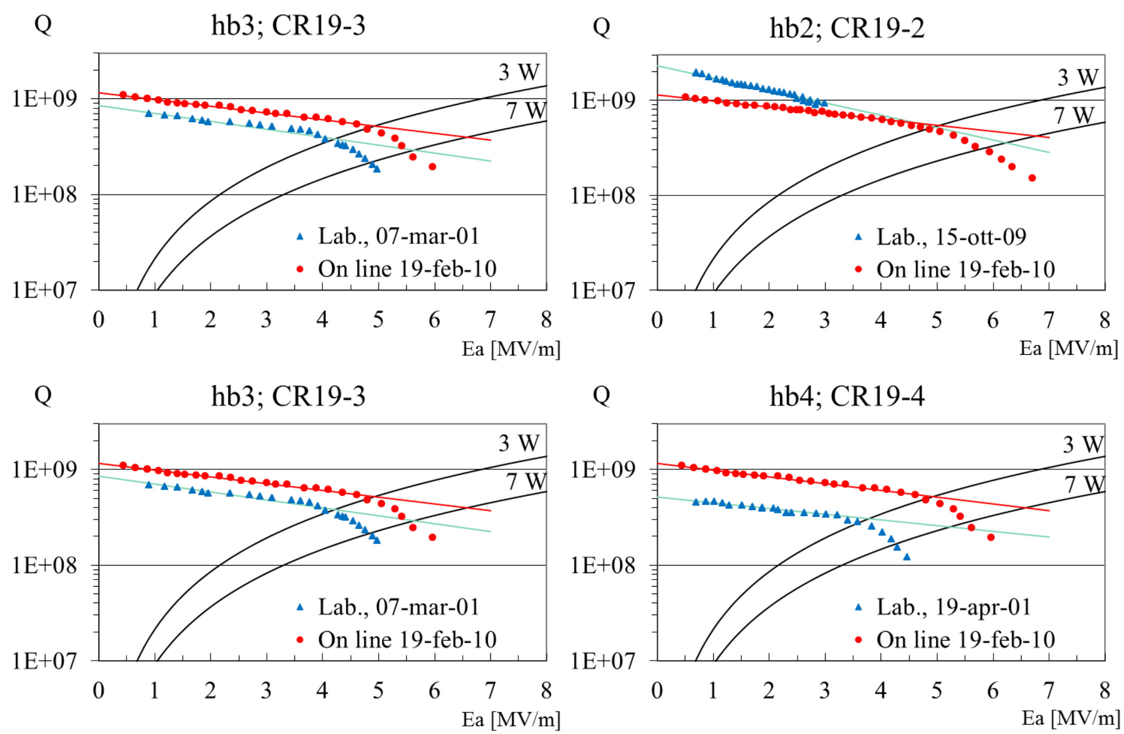


Further margins of improvement are possible …

A.M. Porcellato et al., Poster PO10

High-β Resonator Improvements





Removal of the In gasket, replaced by a **high pressure gasket-less joint** is beneficial to the Q, removing a source of dissipation.

Q improves, Q-slope does not change, **ΔE_a= + 1 MV/m**

Ingredients for the ^{208}Pb 10 MeV/A – 1 pnA recipe

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   We can't violate the cost+workload effectiveness…
4. **Beam transmission:** overall improvement

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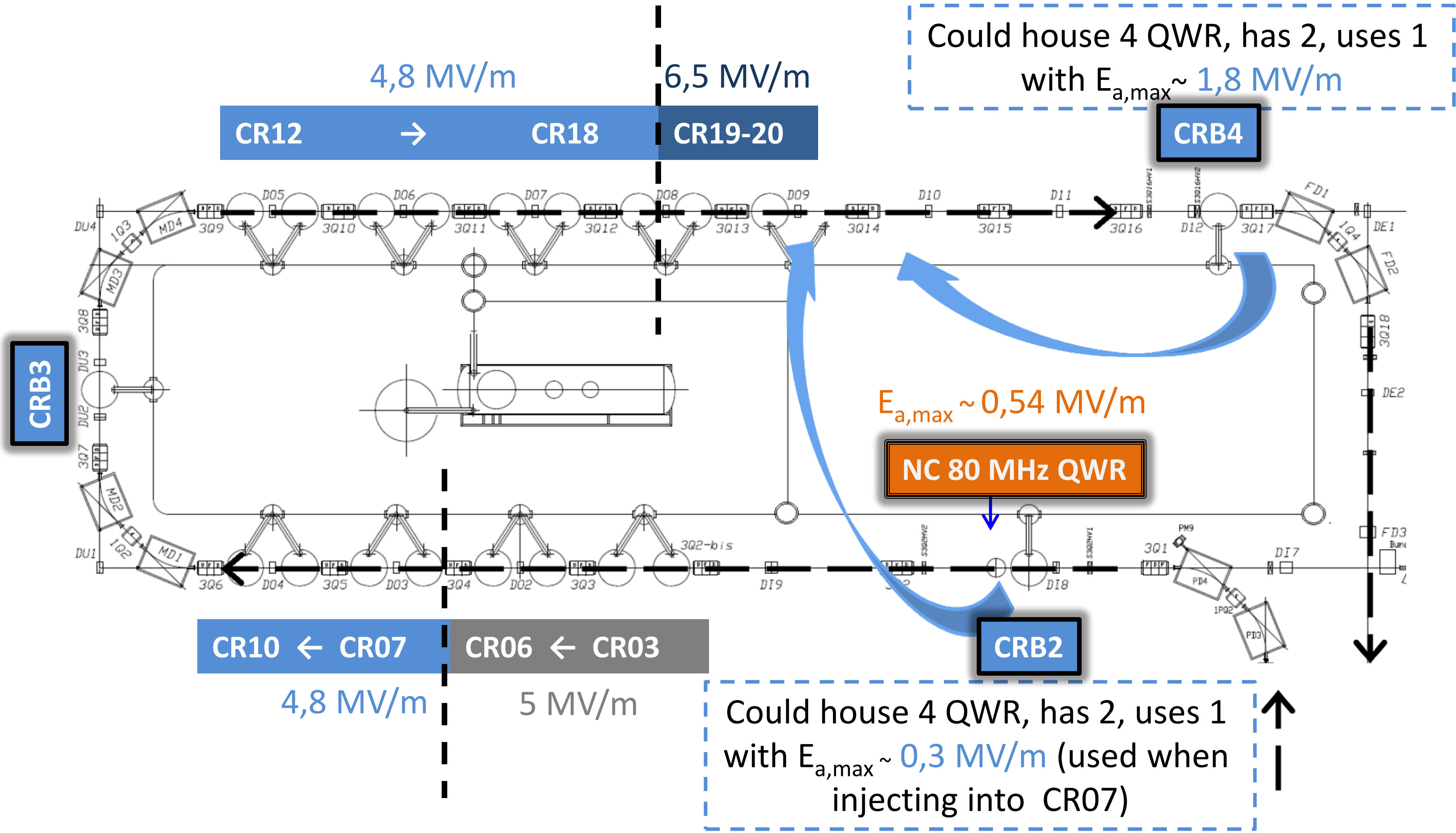
Full refurbishment of low and medium β_{opt} resonators can provide the required energy increase for beams such as $^{208}Pb^{30+}$
Or: addition of two more cryostats on the high energy side

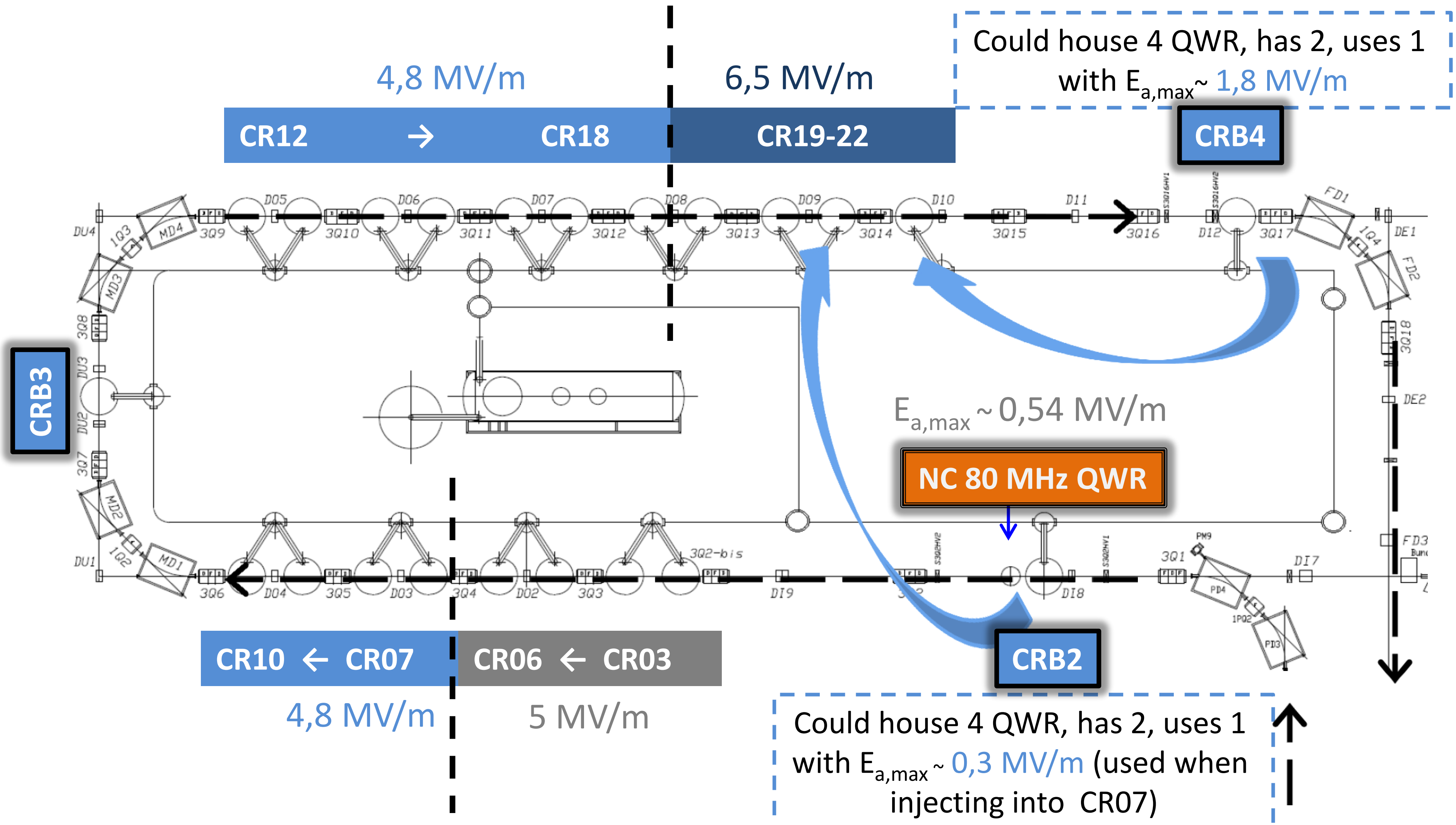
We can't violate the cost+workload effectiveness…

4. **Beam transmission:** overall improvement

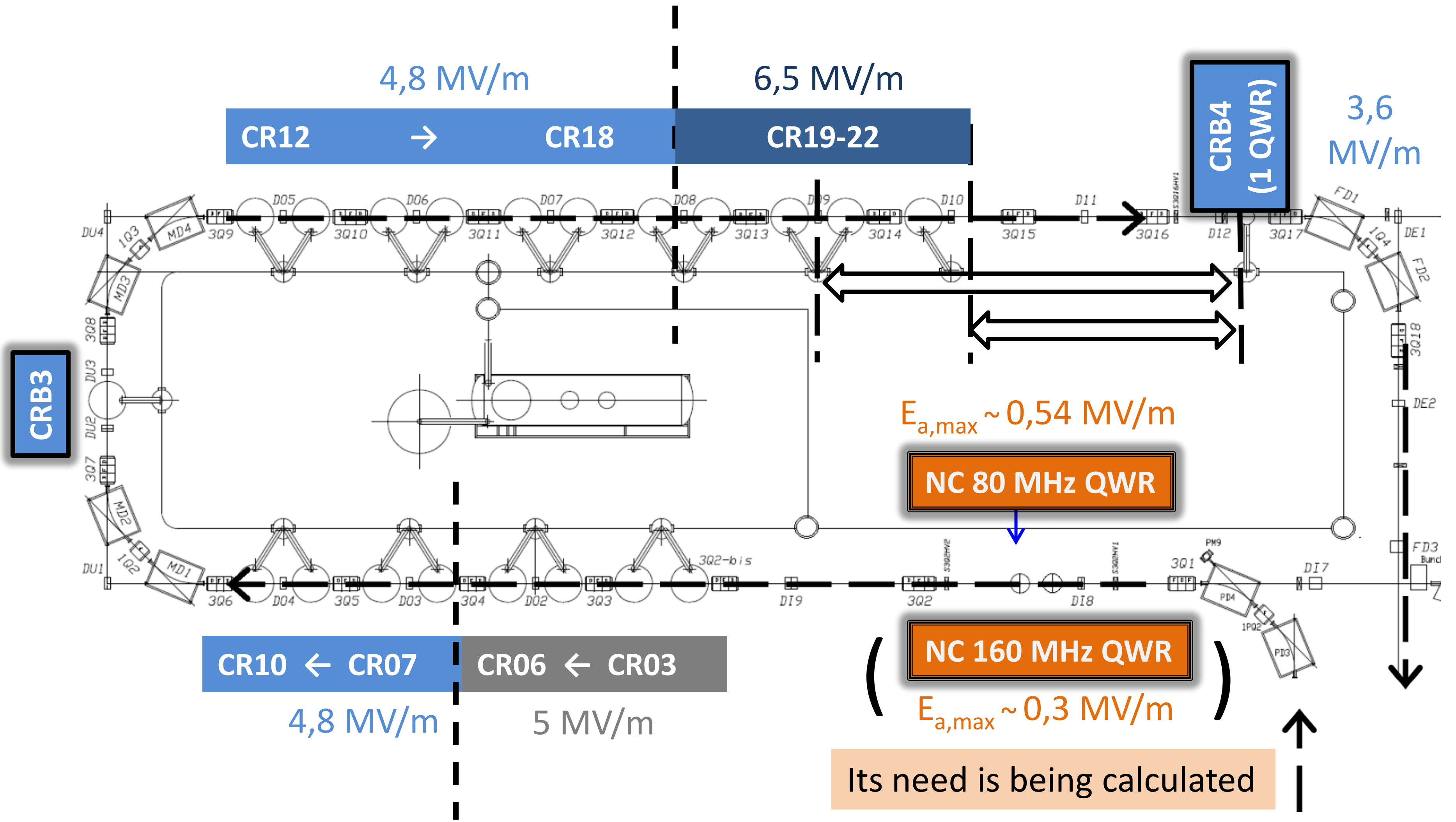
Reshuffling ALPI Cryostats



Reshuffling ALPI Cryostats

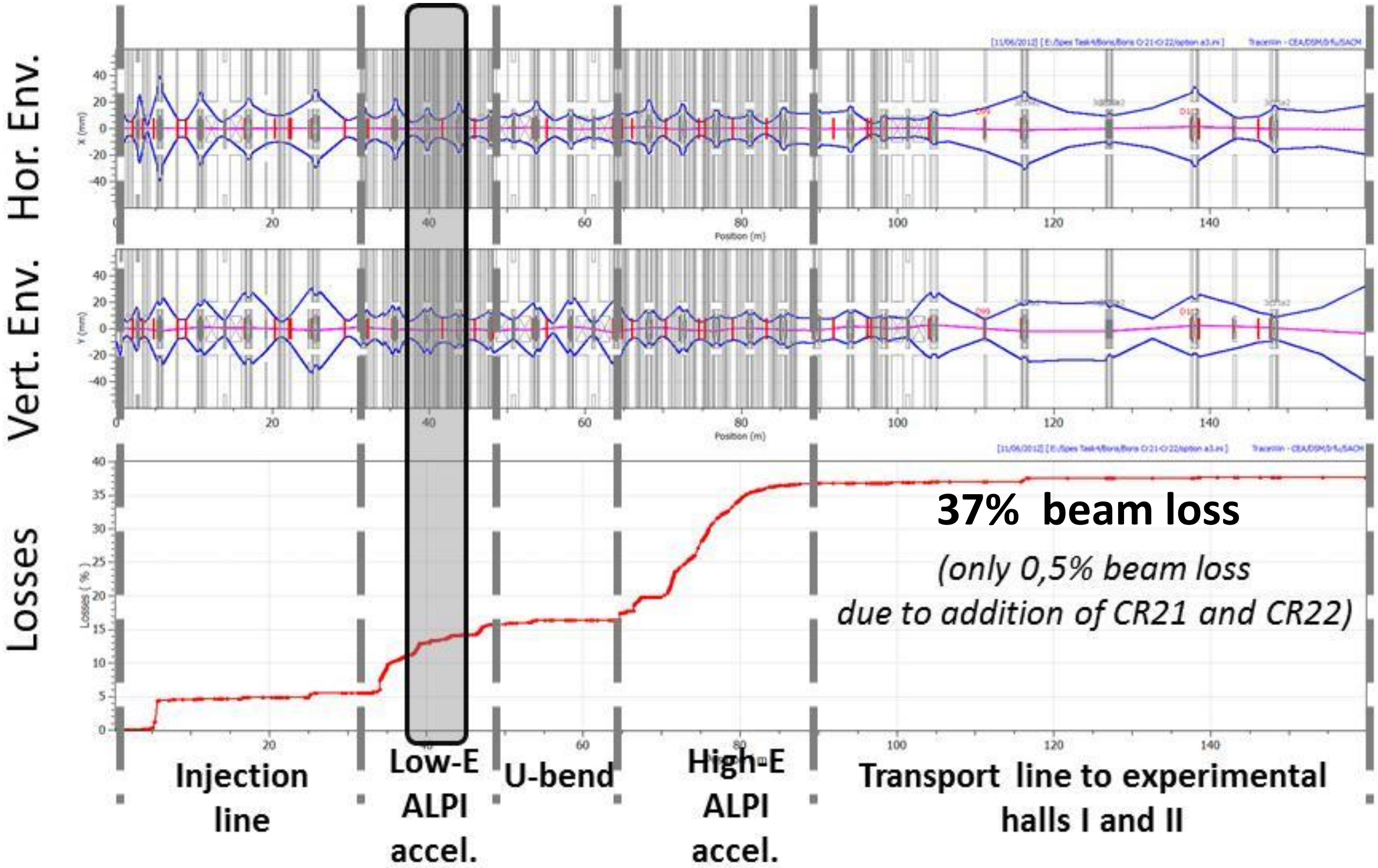


New bunchers



$^{208}Pb^{30+}$ (A/q~7) up to CR22

Assumptions: 4,5 MV/m from CR03 to CR18; 6,5 MV/m for CR19-CR22

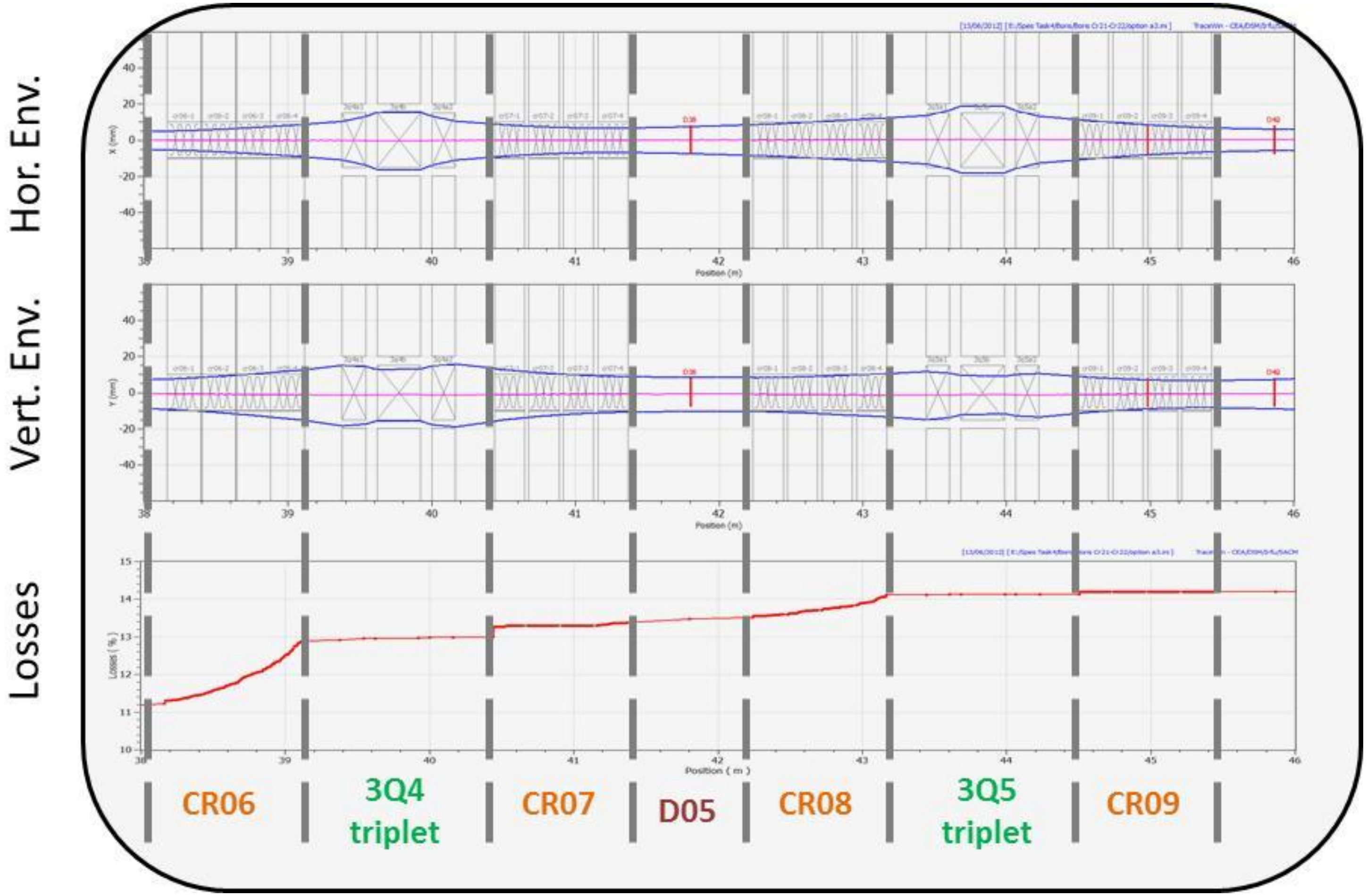


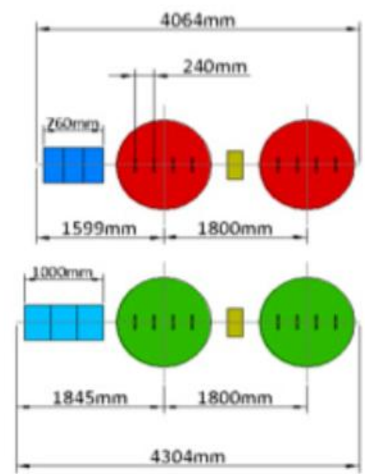
Final energy (CR20→CR22):

7,5 → **9,8 MeV/A**

TraceWin CEA, http://irfu.cea.fr/Sacm/logiciels/index.php

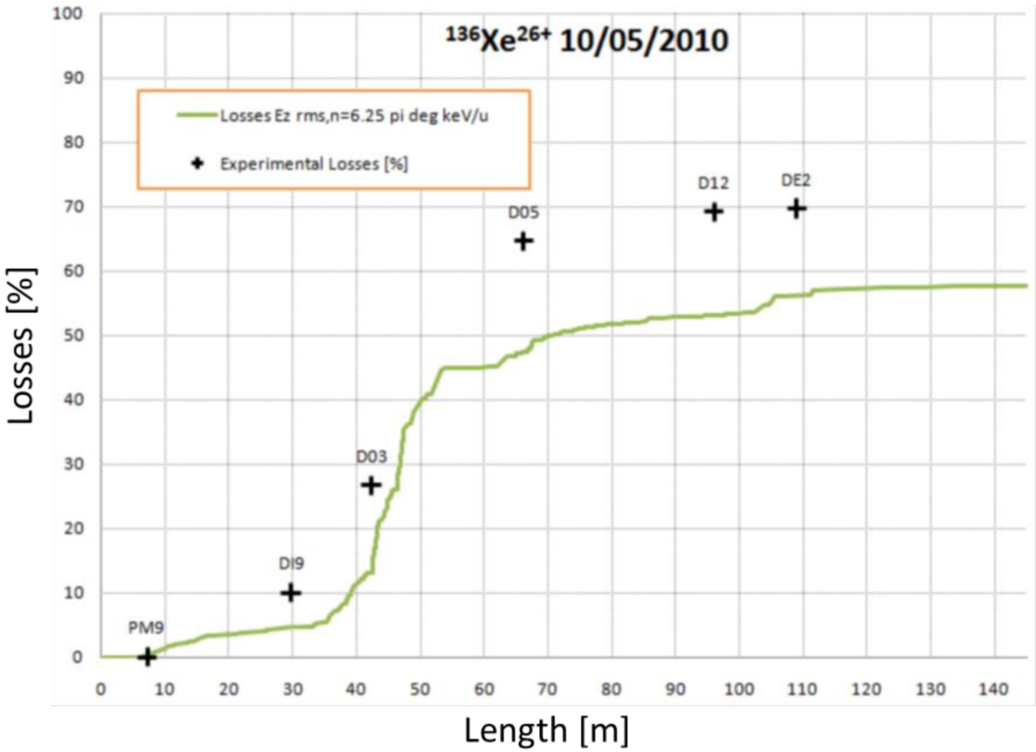
«Zooming in» shows loss location





Losses (37% in total) are located on the first and last cavities, in a row of 8 with no quads in between

Losses Budget

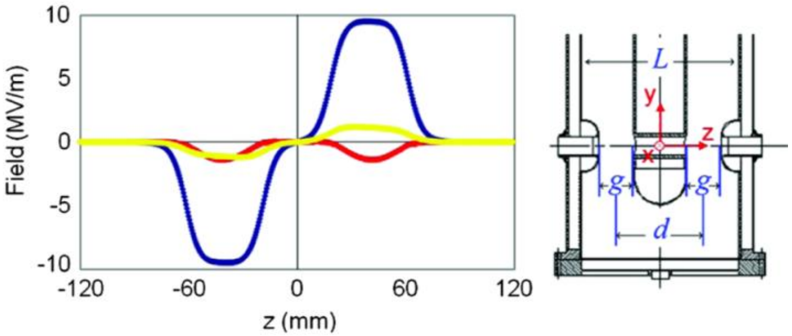


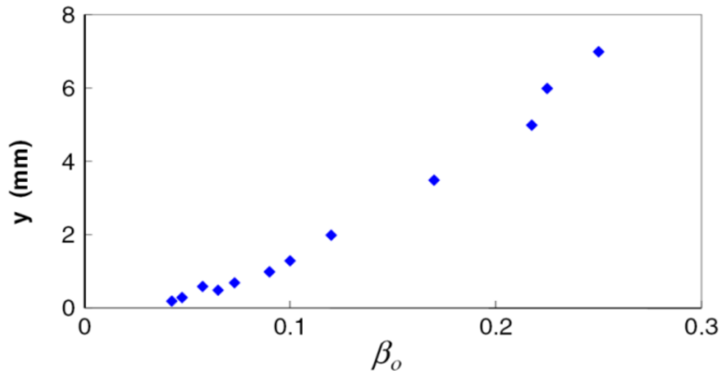
- ALPI has a «loose» lattice, justified $E_{a,\ des} \sim 3$ MV/m
- In the present conditions, losses are inevitable, unless a different layout is well enough motivated in the SPES project framework

M. Comunian, Physical Design of the SPES Facility, today at 2.00 pm

Moreover, **poor alignment in general** and a missing «on-purpose» **displacement between cavity axis and beam axis** increase loss budget by **another 20÷25%**

ALPI Alignment Campaign





- Correction of the QWR beam steering effect by offset beam axis

P.N. Ostroumov and K.W. Shepard, Phys. Rev. ST Accel. Beams 4, 110101 (2001)

A. Facco and V. Zviagintsev, Phys. Rev. ST Accel. Beams 14, 070101 (2011)

A laser tracking campaign just started, with the supervision of D. Bianculli (CNAO Foundation)

Outlook

- **Increase ALPI refrigeration capacity by 50%** (turbine T3) provides proper redundancy and leaves margin for more RF dissipation
- **Recent progress on medium-high β_{opt} QWR E_a** is promising, but applying it to the whole linac violates LABOUR-EFFECTIVENESS
- **Reshuffling of «bunching» cryostats** provides same energy increase, COST-EFFECTIVELY
- **Beam losses** budget is comparable to present one, will be improved by Laser Tracking alignment
- Provided that the **ECR** does its part, 10 MeV/A ^{208}Pb is within reach

TTF along ALPI