STATUS, UPGRADES AND PERSPECTIVES OF THE HEAVY ION ACCELERATOR COMPLEX AT INFN-LNL

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INFN-LNL

ECOS meeting 16-05-2013

SUMMARY

1. Heavy Ion Accelerator Complex (Tandem, ALPI, PIAVE) and operation numbers
2. Facts 2012 for each accelerator
3. Planned upgrades in the SPES scenario

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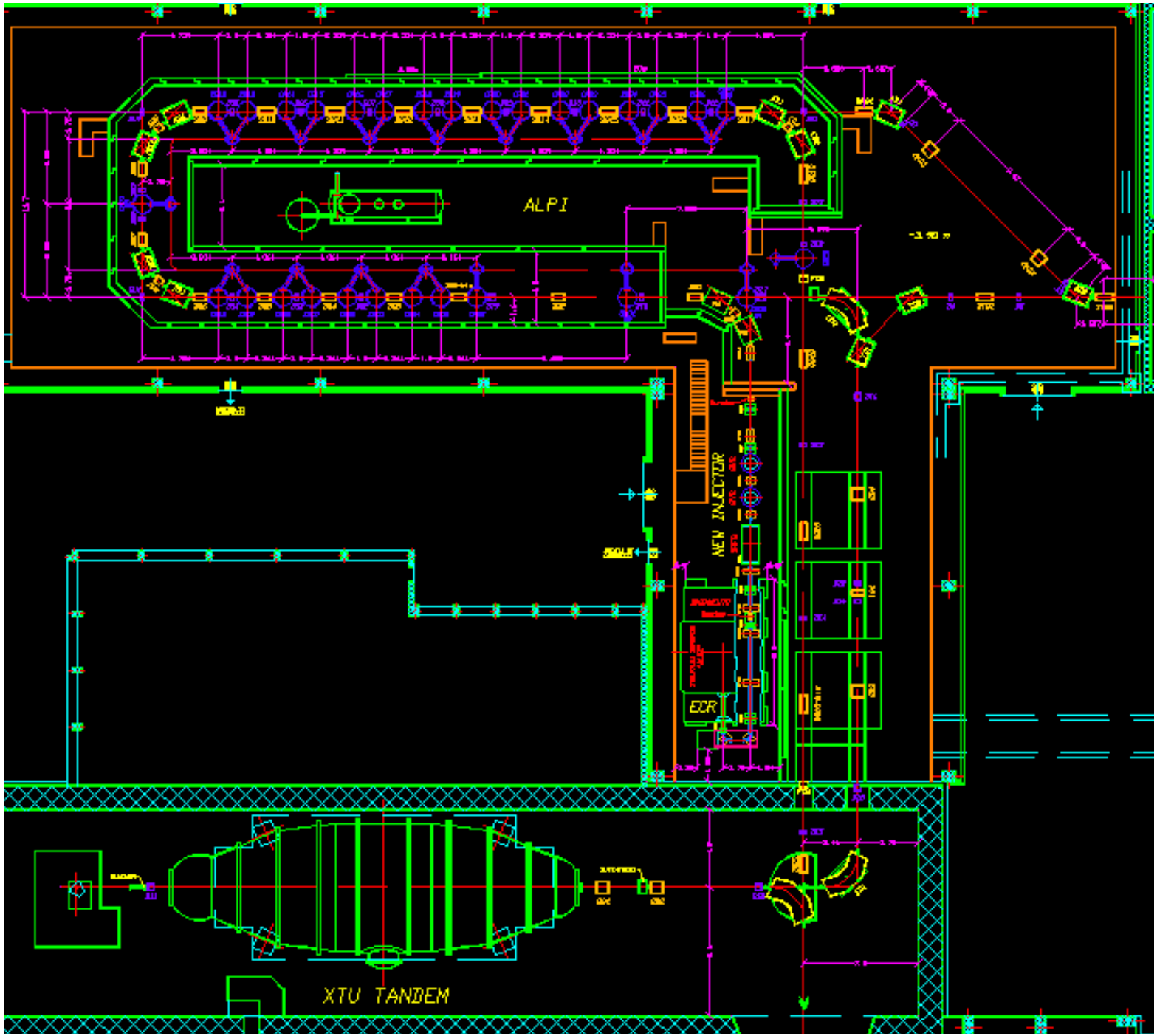
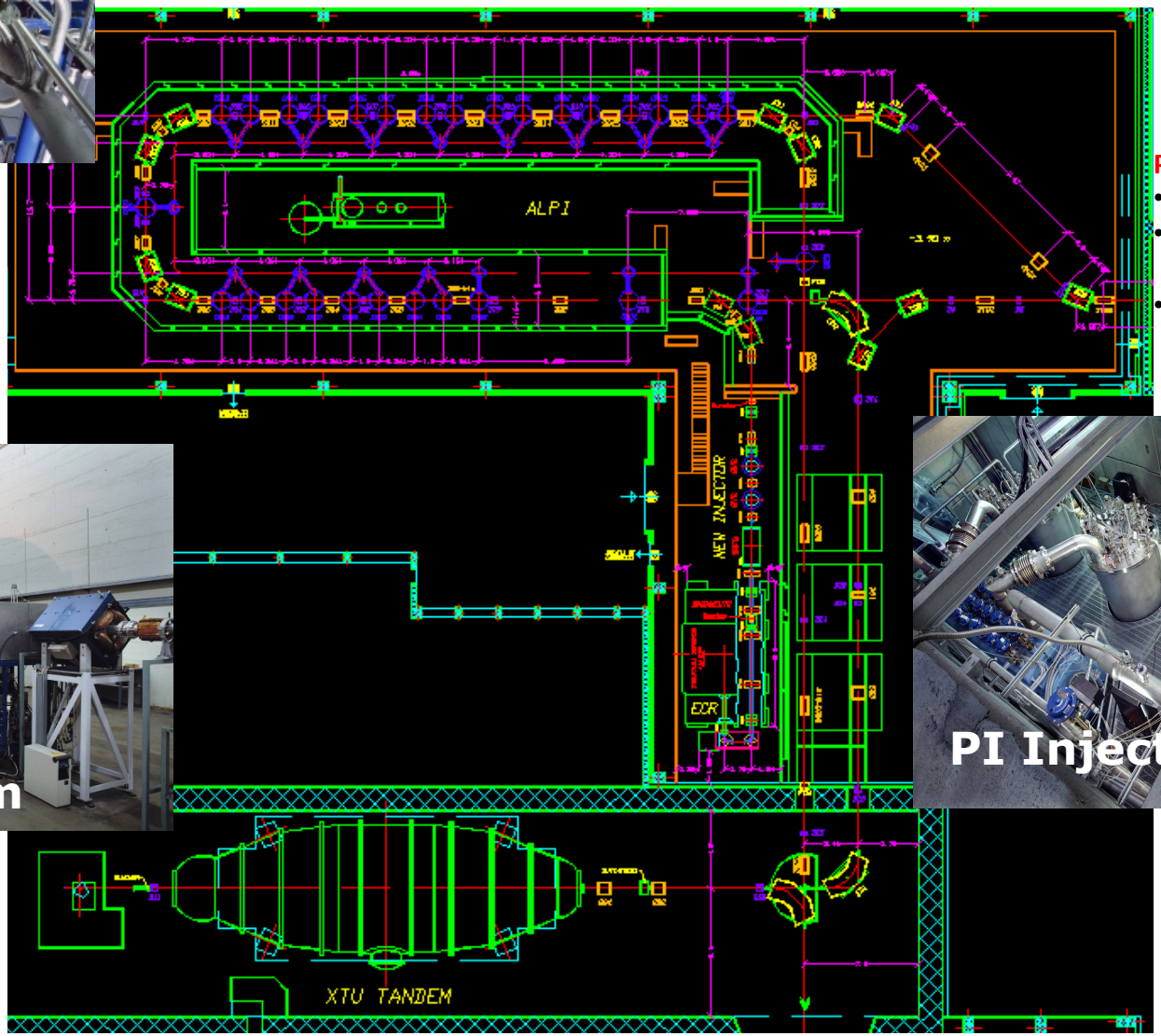
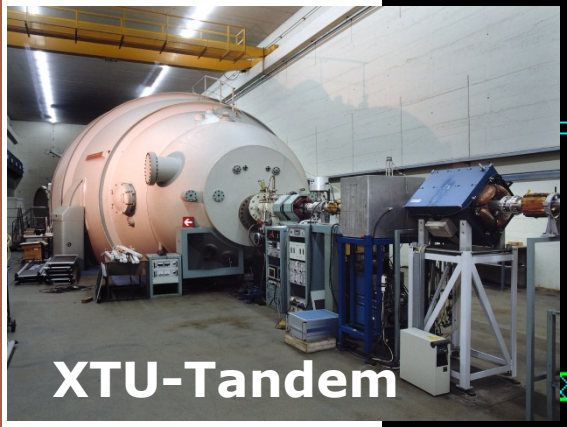
Padova
Exp Hall
Techn. Plants
2 MeV VdG
7 MV VdG
SC PIAVE
Exp Halls
SC Linac ALPI
Tandem
Adriatic Sea

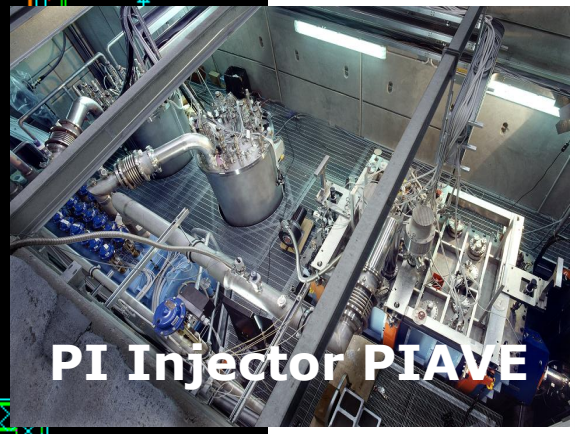

ALPI
NEW INJECTOR
ECR
XTU TANDEM

ALPI:
- 4(β=0.047)+12(β=0.055) QWRs 80 MHz (full Nb)
- 44(β=0.11)+8(β=0.13) QWRs 160 MHz (Cu/Nb)



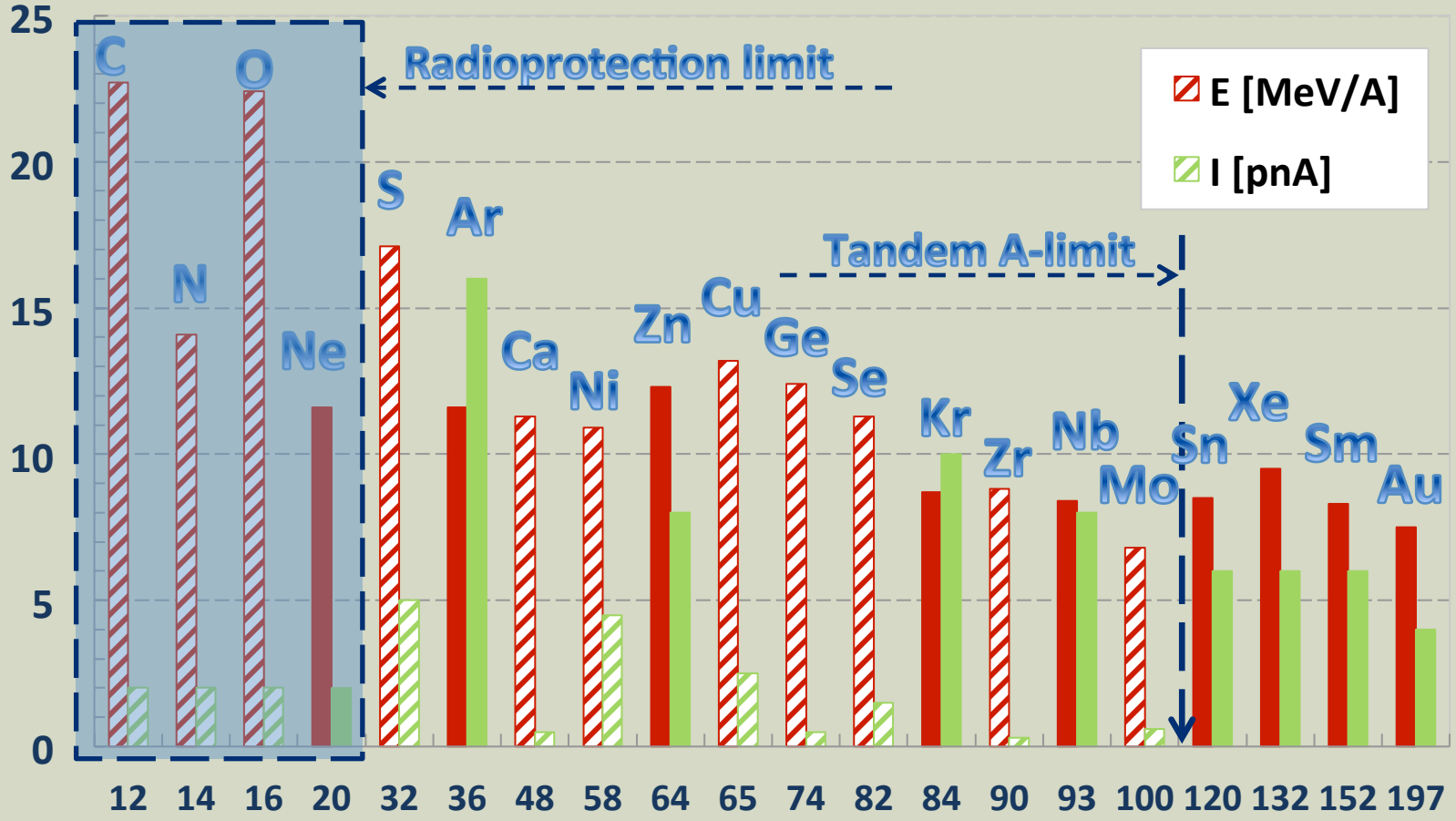
PIAVE:
- ECR source
- 2 s.c. RFQs 80 MHz (Nb bulk)
- 8(β=0.047) QWRs 80 MHz (full Nb)



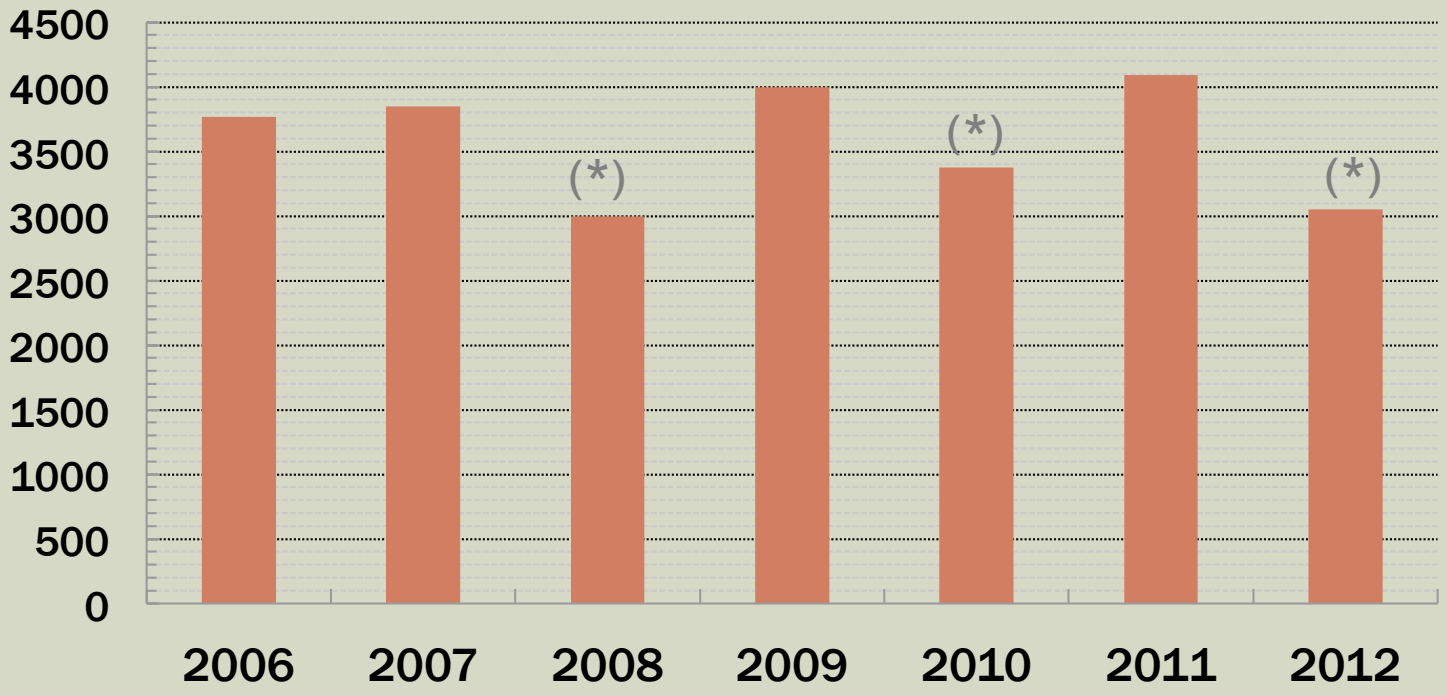


TANDEM:
- 14.5 MV (15.34 MV)
- from 1H to 197Au
- excluded noble gas

TANDEM-ALPI , PIAVE-ALPI: REPRESENTATIVE BEAMS

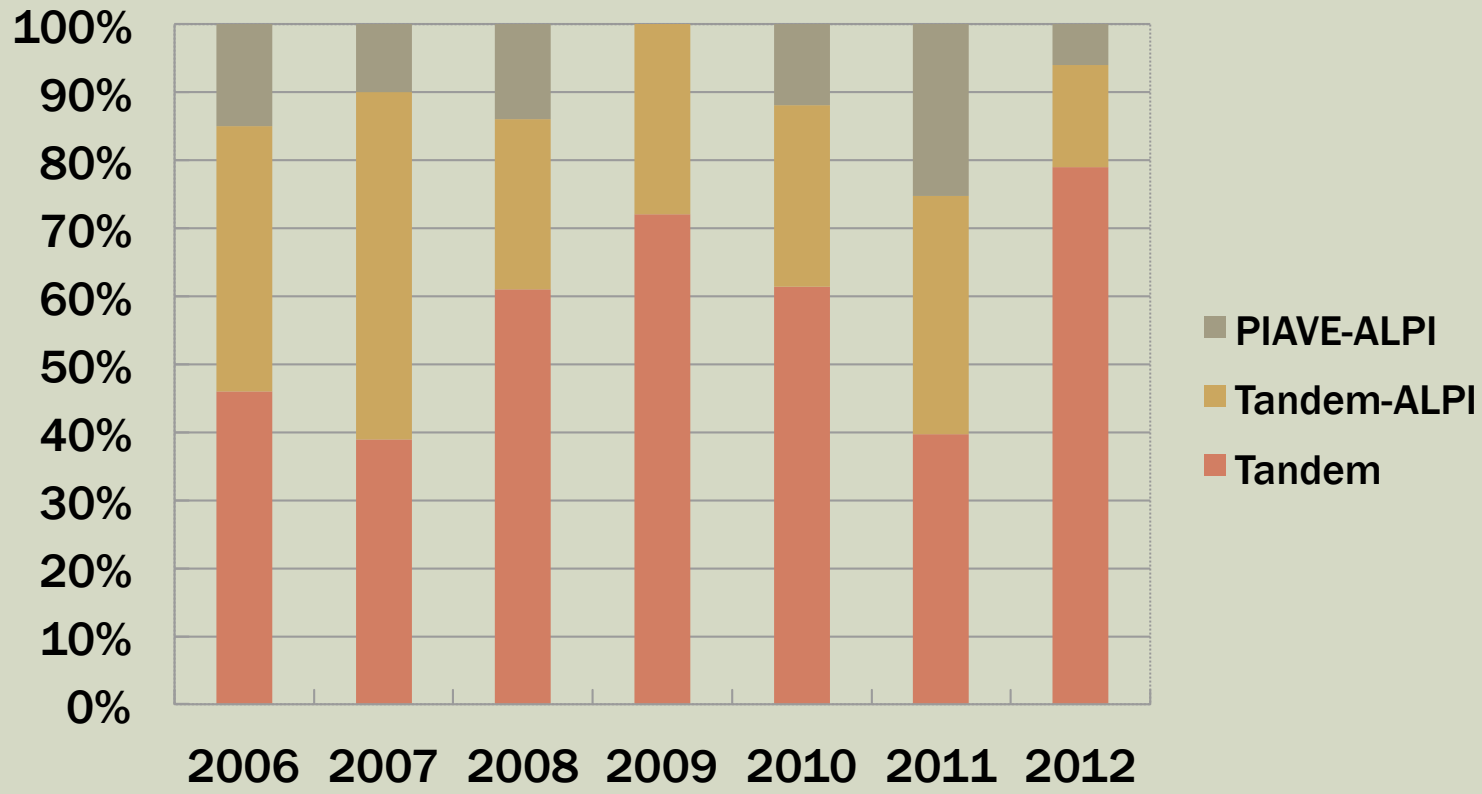


BEAM FOR USERS AND ACCELERATOR TESTS 2006-2012



(*) 2008: Special T maintenance (2,5 months);
2010: Replacement of SF6 heat exchangers, water leakage (T)
2012: Replacement of Exp-Channel Switcher (2 months); longer vacation and SNEAP12 at LNL in October (3 wks)

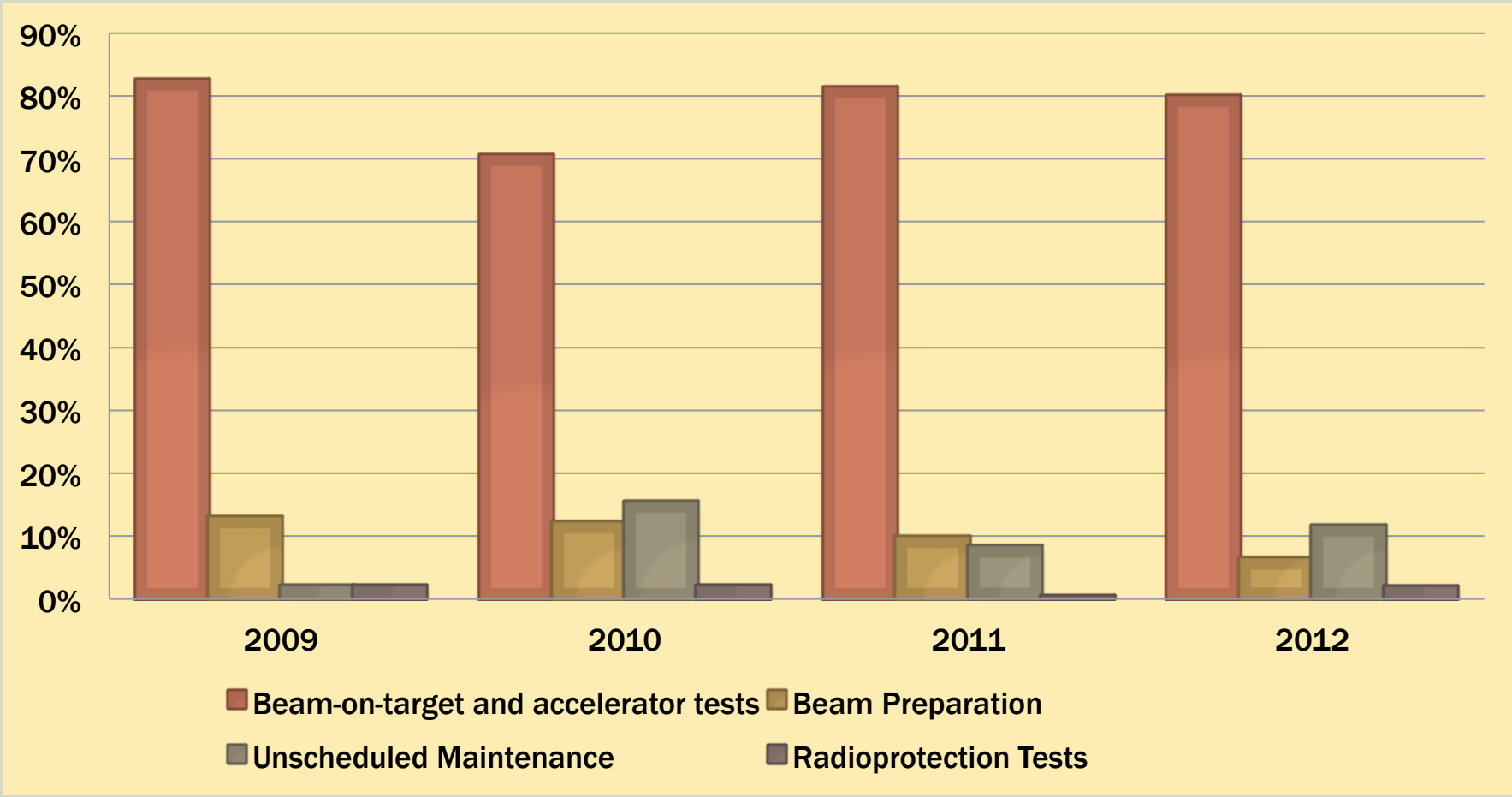
SHARING BETWEEN T, T-A AND P-A



2008-2009: ECRIS Replacement

2010 (Fall): faults of Cold-Box internal purifier and CB control system

AVAILABLE BEAM (FOR USERS AND ACCELERATOR TESTS) VS (…)



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MAINTENANCE ON TANDEM EXPERIMENTAL CHANNEL SWITCHER

Function

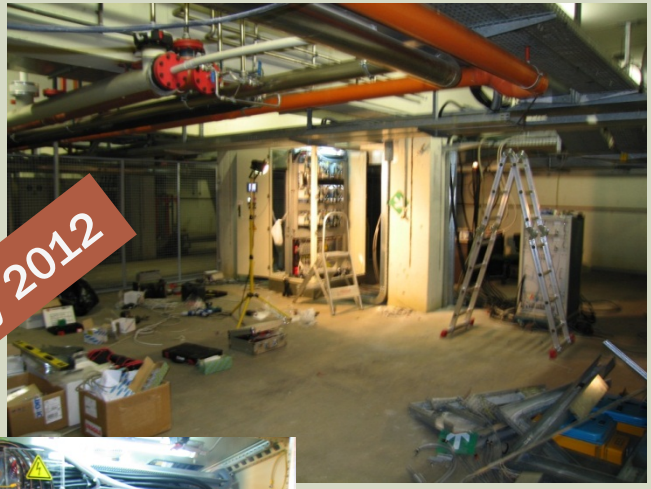
It switches:

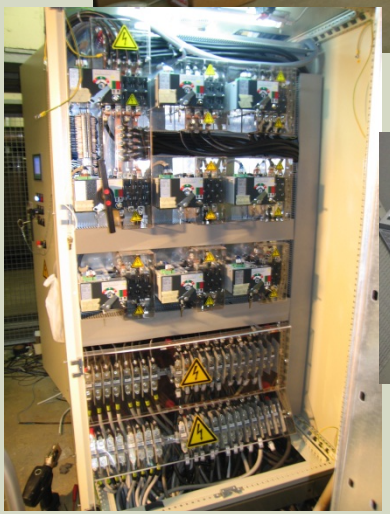
- Control P.S. Lens A, B, SW, H.E.
- Vacuum control interface (valve 1 for each line)
- Management of safety interlocks

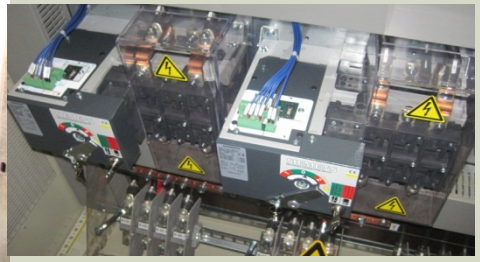
Through:

- Remotely controlled bistable switches (via real time Ethernet, PROFIBUS & PROFINET (PI))

Completed in May 2012







Tandem up to V_T ~ 14,5 MV

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ECR ION SOURCE

- **Source group**: 1 physicist (ECR), 2 technicians
- Priority in Fall 2012: Preparatory work on the ECR Charge Breeder for SPES
- Mo and Au beams in March and April
- List of **ECR beams** planned for experimental tests:
  - Within 2013: Ca and Pb

  [Pb, to be checked if $^{208}Pb^{30+}$ is feasible]
  - Later: Dy, Pd

  [Pd – $T(P_{vap} = 1\ Pa) = 1448°C$, while $T_{max,oven} \sim 1400°C$;
  … Au - $T(P_{vap} = 1\ Pa) = 1373°C$ and Au was ok)

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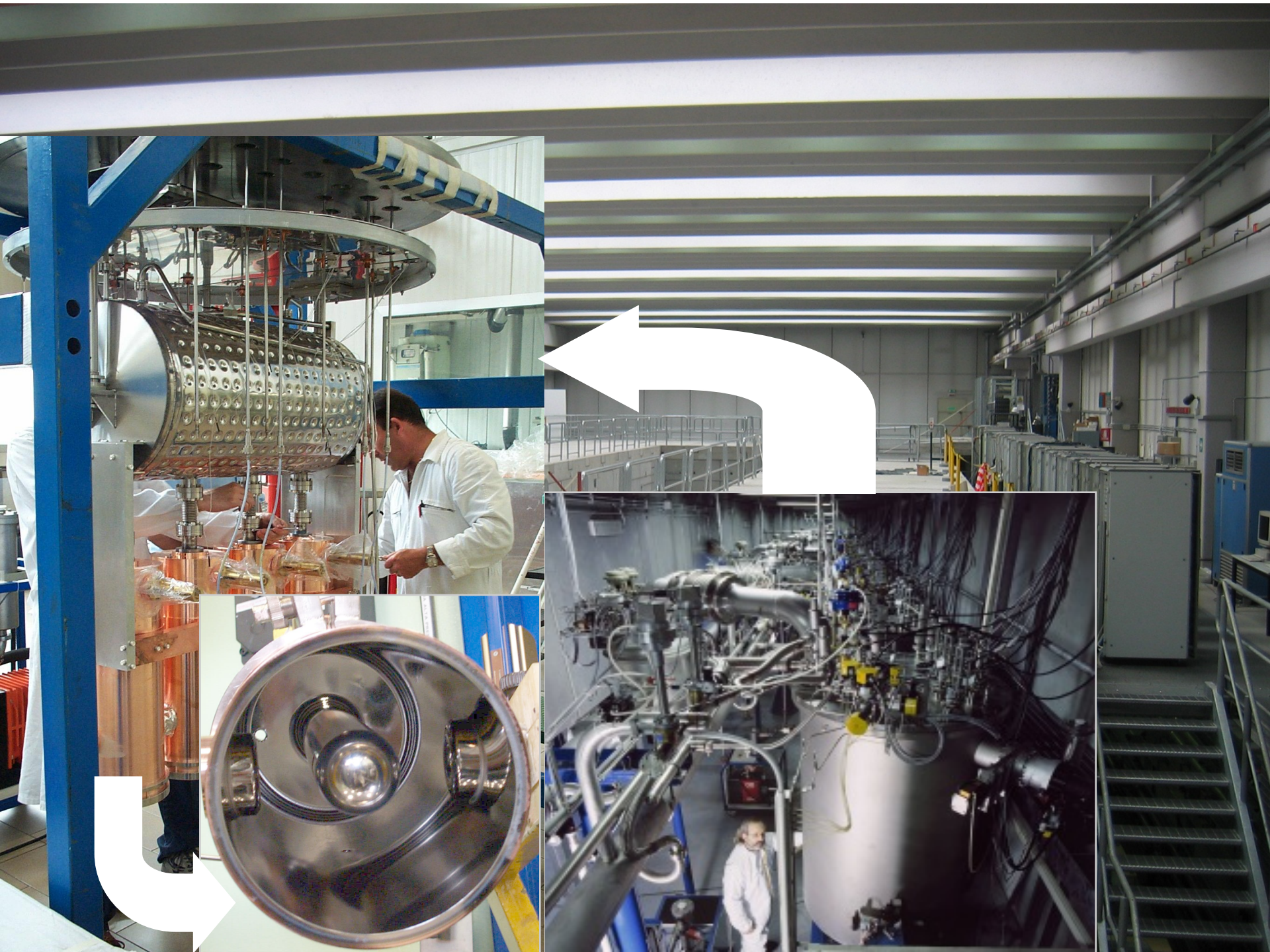
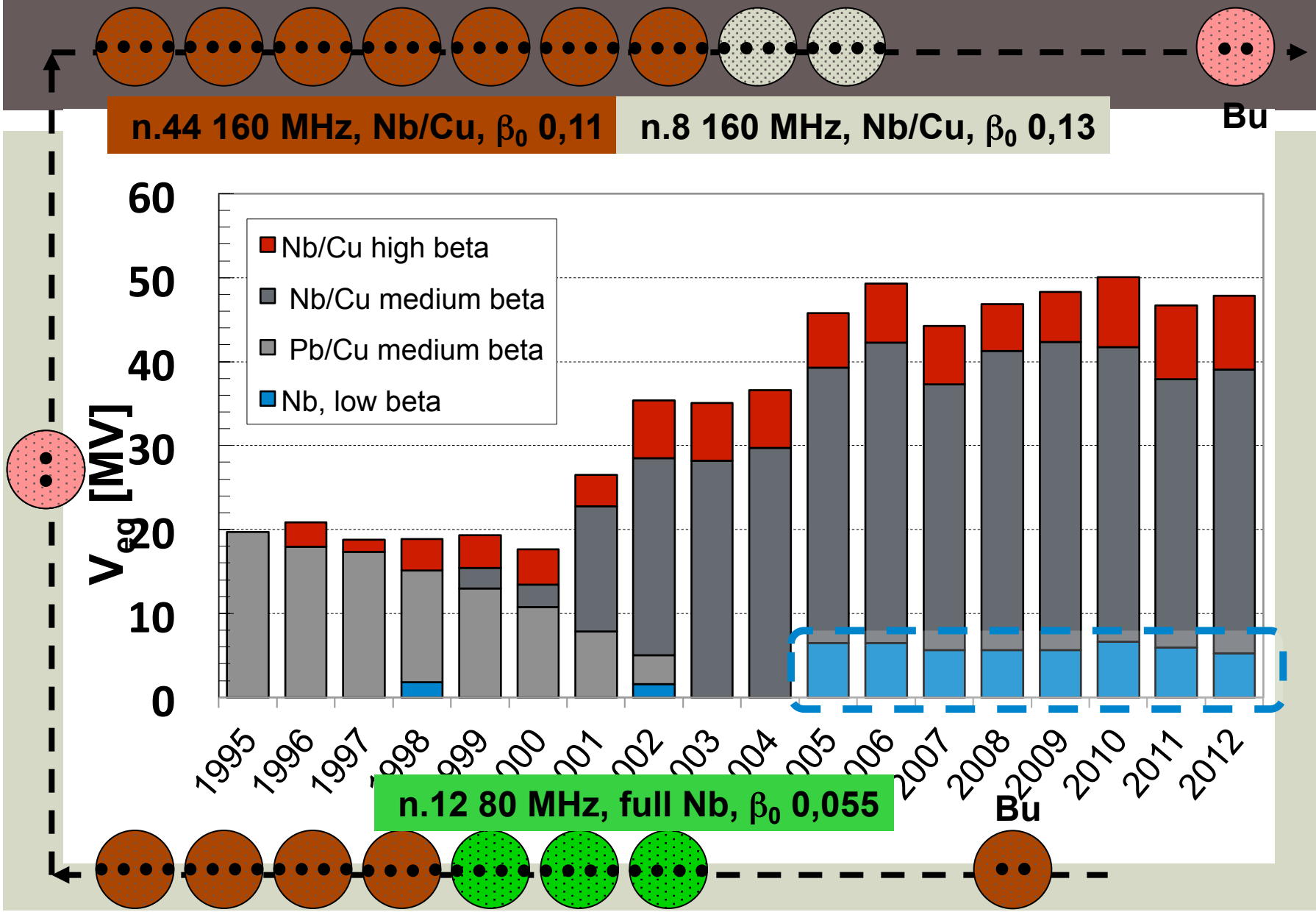
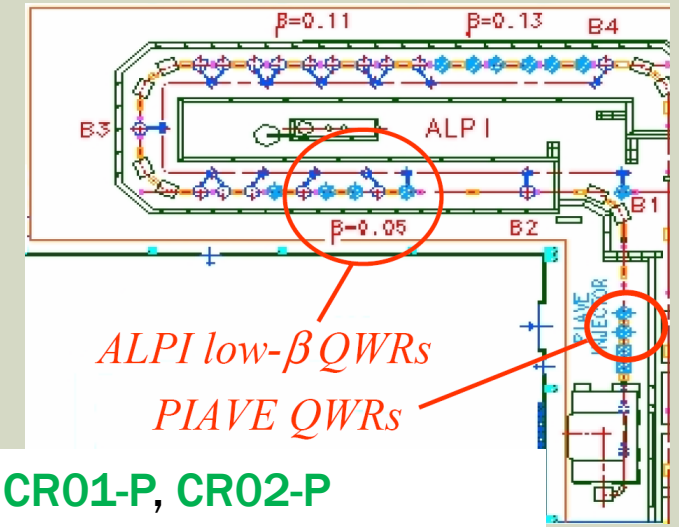


ALPI V_{EQ} INCREASE



LOWER BETA RESONATOR UPGRADE

Upgrade consists in refrigerating input RF power coupler with liquid nitrogen, so as to increase the input RF power and be able to keep QWR locked up to 5 MV/m (vs. present 3 MV/m) – thin wall Nb cavities are less stable mechanically



PIAVE: CR01-P, CR02-P
ALPI: CR03, CR04, CR05, CR06

Status: CR03 completed and tested (2010), CR02-P (2011) and CR05 (2012) completed and mounted, CR01-P completed in Fall 2012, CR04 and CR06 in 2013

A. Facco

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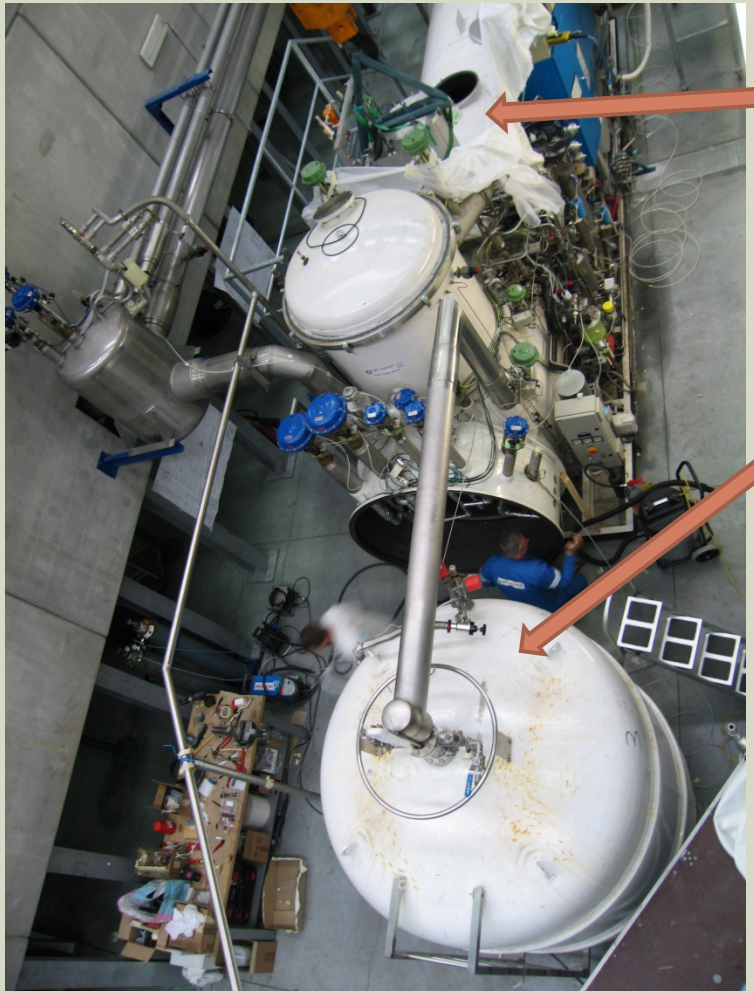
ALPI CRYOGENIC SYSTEM UPGRADE



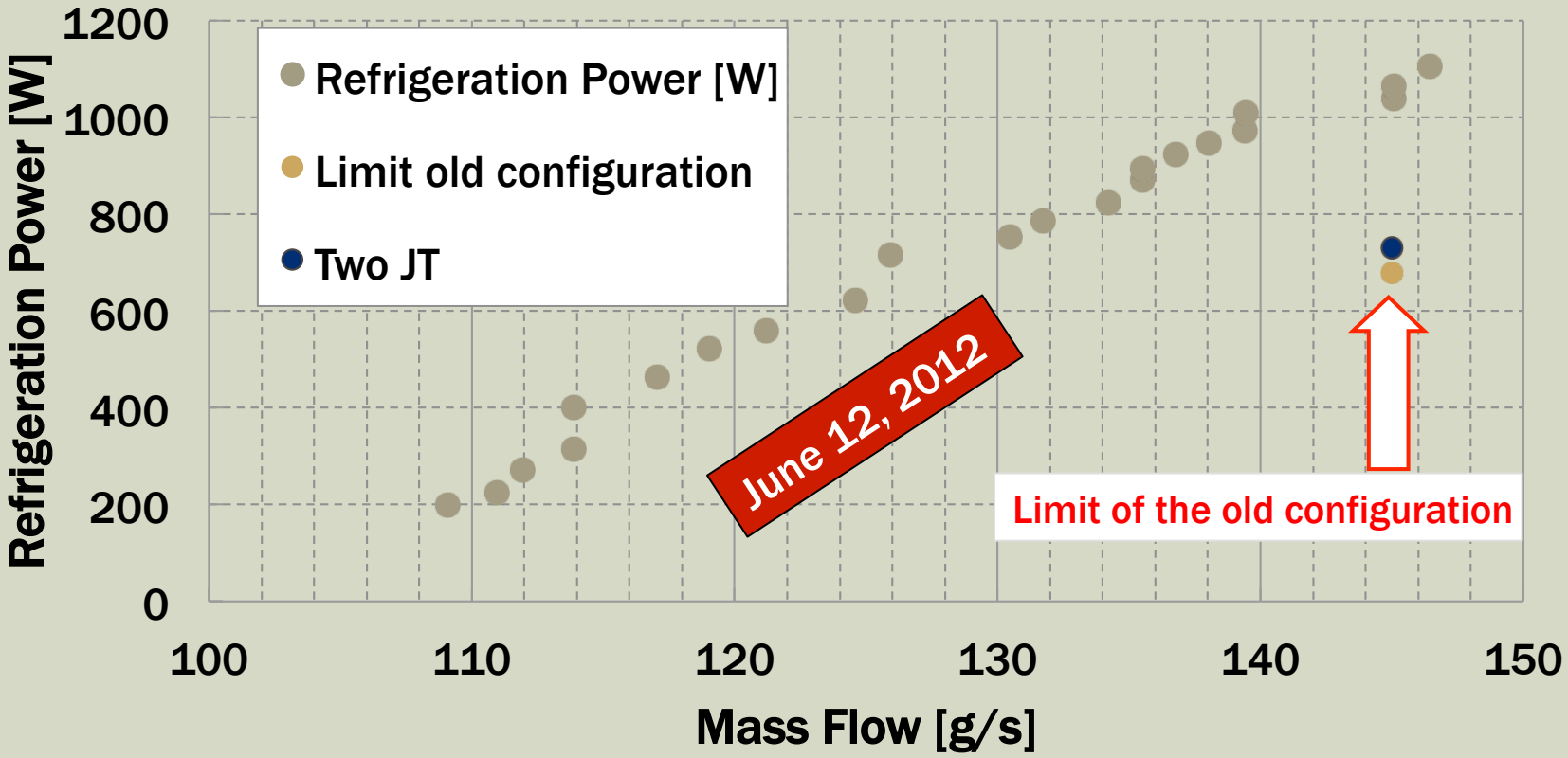
1. Implememtation of a 3° turbine, in place of the «wet expander», increase of 30% of cryogenic power expected
2. Replacement of the machine

m

Completed in May 2012

R. Pengo, P. Modanese et al.

HE REFRIGERATOR UPGRADE



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

R. Pengo, P. Modanese et al.

HE REFRIGERATOR UPGRADE

- **One issue is still open** and prevents from using the 3rd turbine efficiently:
  - **inlet regulation valve of the added turbine** dose not allow its automatic pre-cooling;
  - it was done manually for the above demonstration test, but it cannot be accepted
  - valve plug was changed, with no success
  - a **new valve** with smaller flux coefficient (Kv) must be installed

- Originally planned for April 2013, moved to **early September 2013** since Air Liquide was not available (2 weeks delay in restart in Fall 2013)

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LASER TRACKER (FARO LTD.) AND ACCESSORIES

System Specifications

Dimensions
Head size: 311(W) x 556(H) mm
Head weight: 17.7kg (19.5kg w/IFM option)
Controller size: 282(L) x 158(D) x 214(H) mm
Controller weight: 5.2kg

Range
Horizontal envelope: +/- 270°
Vertical envelope: +72.5° to -52.5°
Minimum working range: 0 meters
Maximum working range: 55m with select targets
40m with standard 1.5" & 7/8" SMRs
30m with standard 1/2" SMR

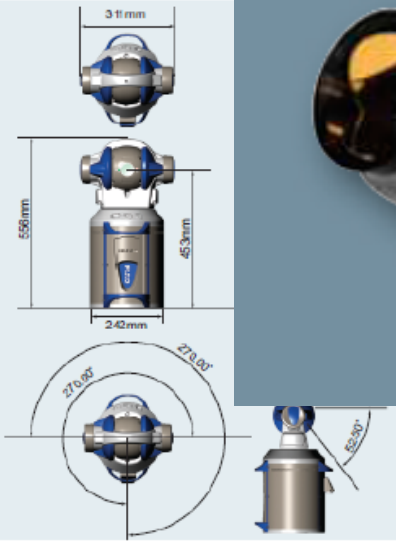
Environmental
Altitude: -700 to 2,450 meters
Humidity: 0 to 95% non-condensing
Operating Temperature: -15°C to 50°C

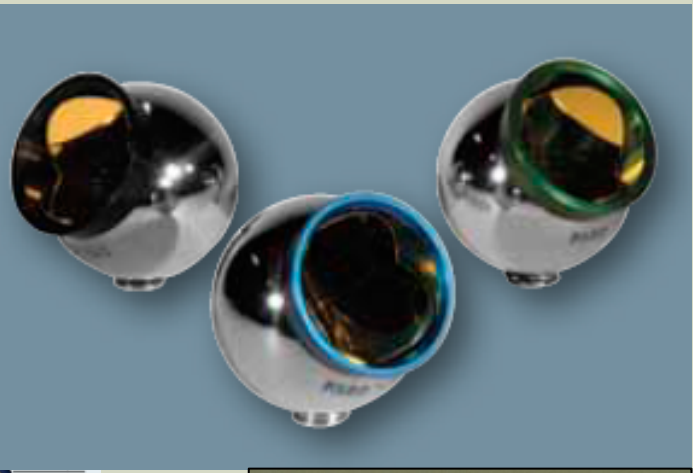
Laser Emission**
633-635 nm Laser, 1 milliwatt max/ew.
Class II Laser Product

Distance Measurement Performance

Agile ADM	Optional Interferometer
Resolution: 0.5µm	Resolution: 0.158µm
Sample rate: 10,000/sec	Accuracy (MPE): 4µm + 0.8µm/m
Accuracy (MPE): 16µm + 0.8µm/m	Maxim. radial velocity: 4m/sec
R0 parameter (MPE): 16µm	R0 parameter (MPE): 16µm

Angle Measurement Performance
Angular accuracy (MPE): 20 µm + 5 µm/m
Maximum angular velocity: 180°/sec
Precision Level Accuracy: +/- 2 arcseconds

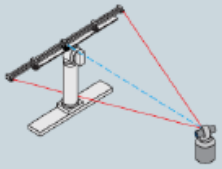




Point-to-Point Typical Accuracy***

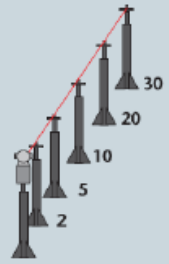
Horizontal Scale Bar Measurement (2.3 m)

Range (m)	ADM (mm)	IFM (mm)
2	0.022	0.021
5	0.032	0.032
10	0.049	0.049
20	0.085	0.085
30	0.120	0.120
40	0.156	0.156
50*	0.191	0.191
55*	0.209	0.209

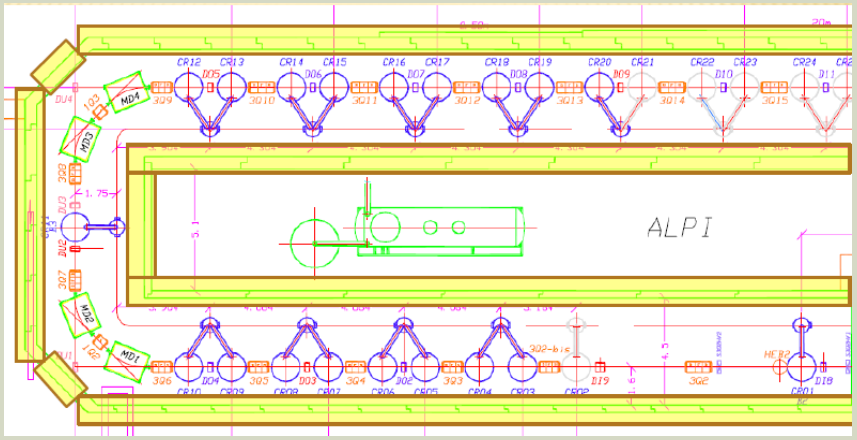


In-Line Distance Measurement

Length (m)	Distance (m)	ADM (mm)	IFM (mm)
2 - 5	3	0.009	0.003
2 - 10	8	0.011	0.005
2 - 20	18	0.015	0.009
2 - 30	28	0.019	0.013
2 - 40	38	0.023	0.017
2 - 50*	48	0.027	0.021
2 - 55*	53	0.029	0.023

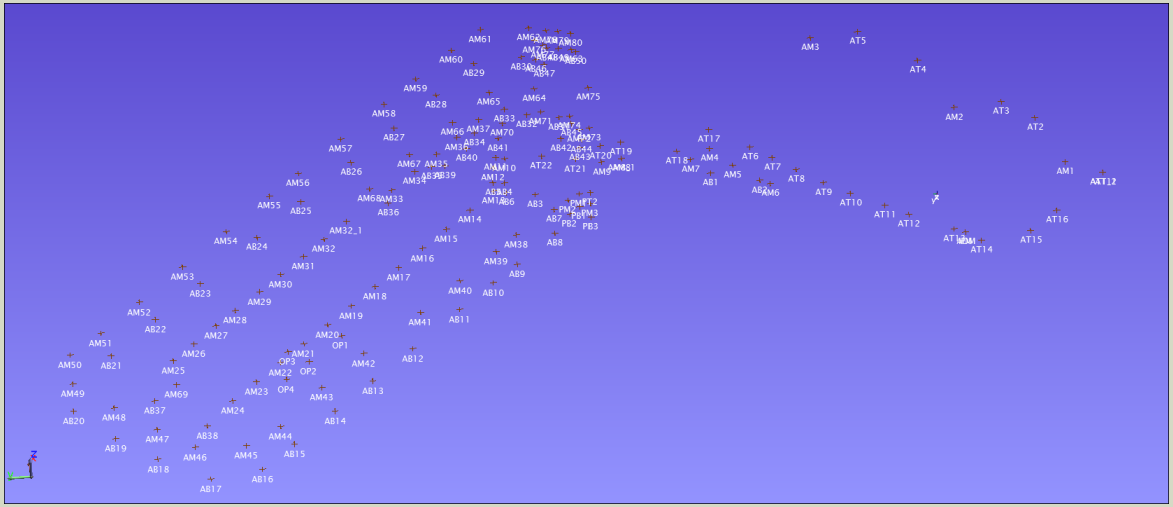


NETWORK QUALIFICATION

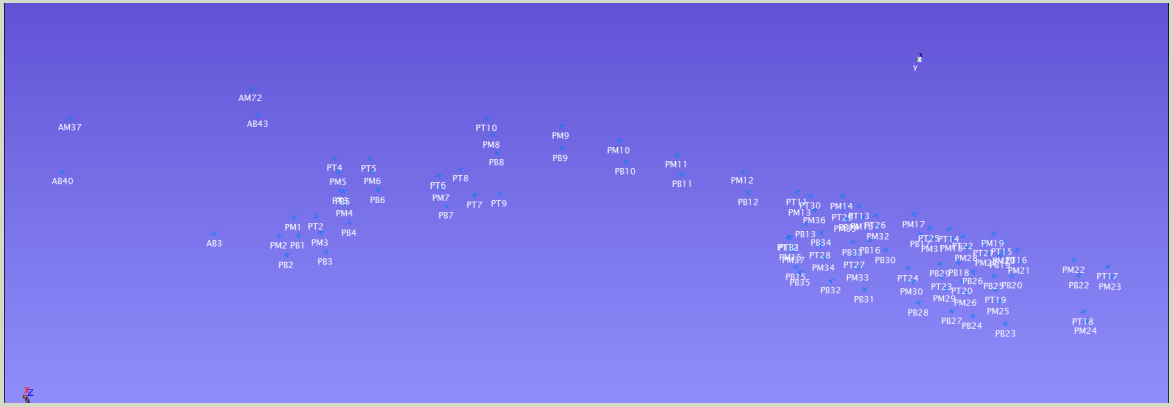


- 152 reference points in ALPI
- 104 reference points in PIAVE

NETWORK QUALIFICATION

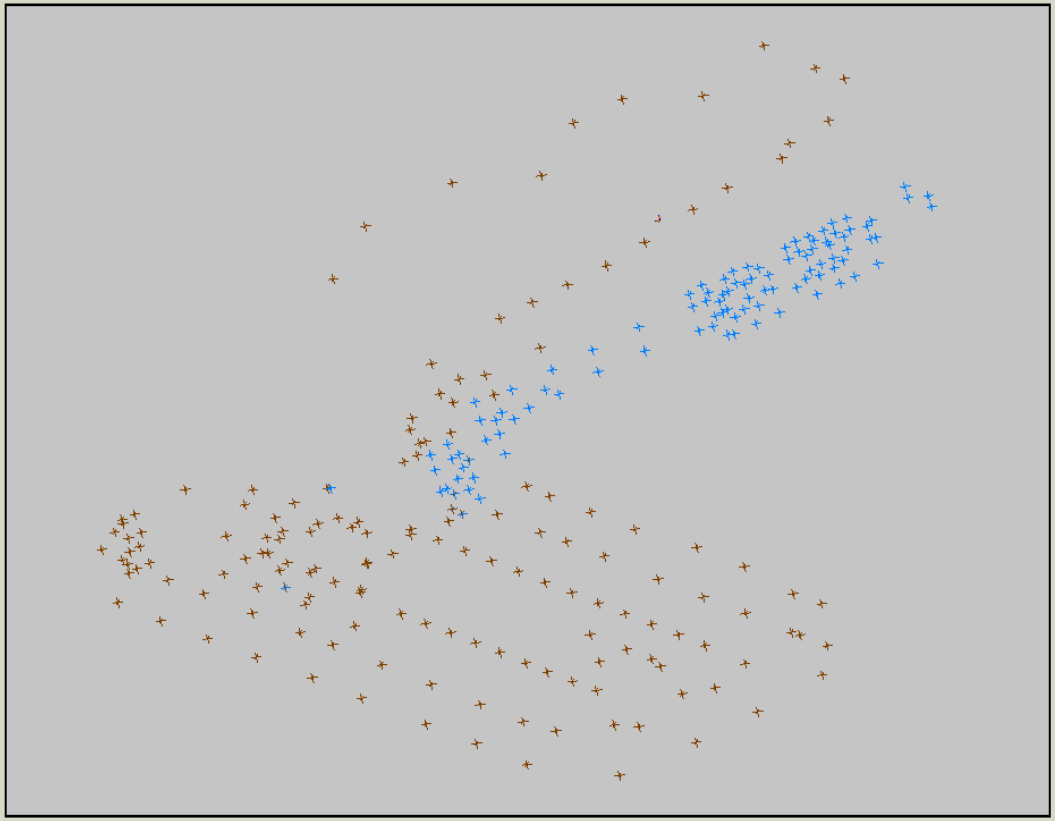


ALPI



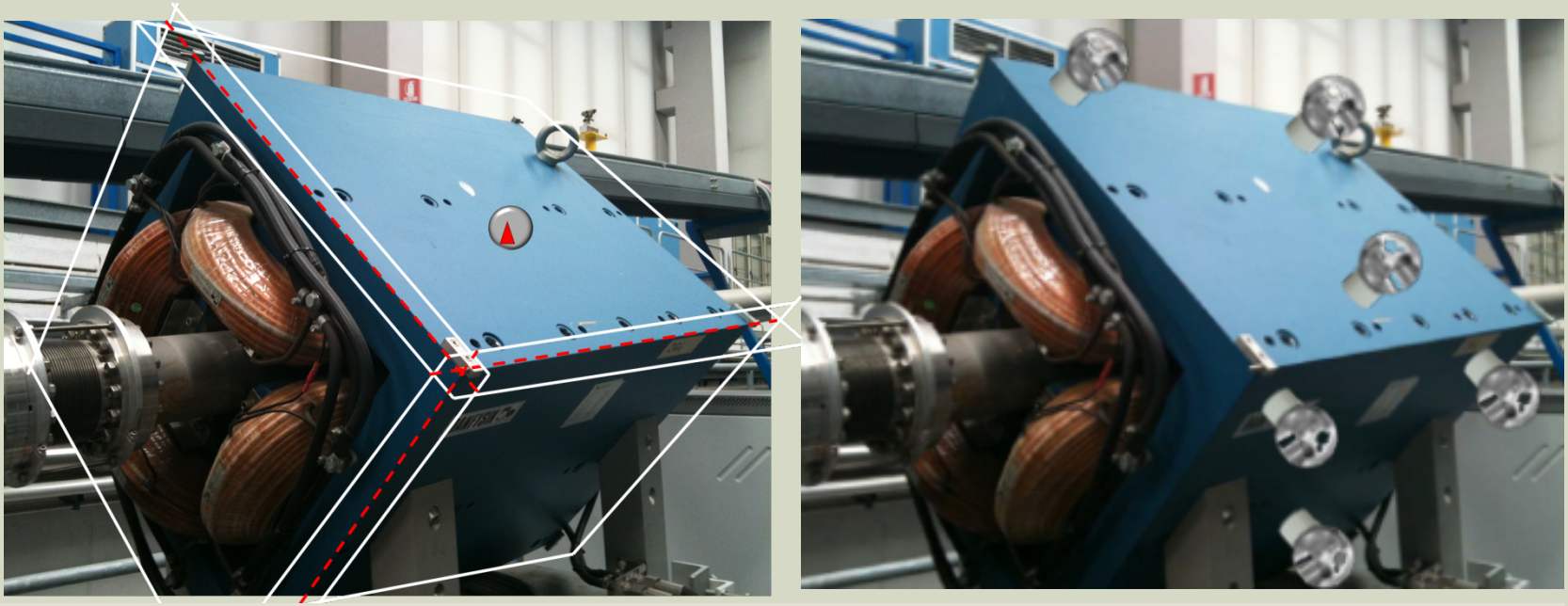
PIAVE

JOINT NETWORK VERIFIED



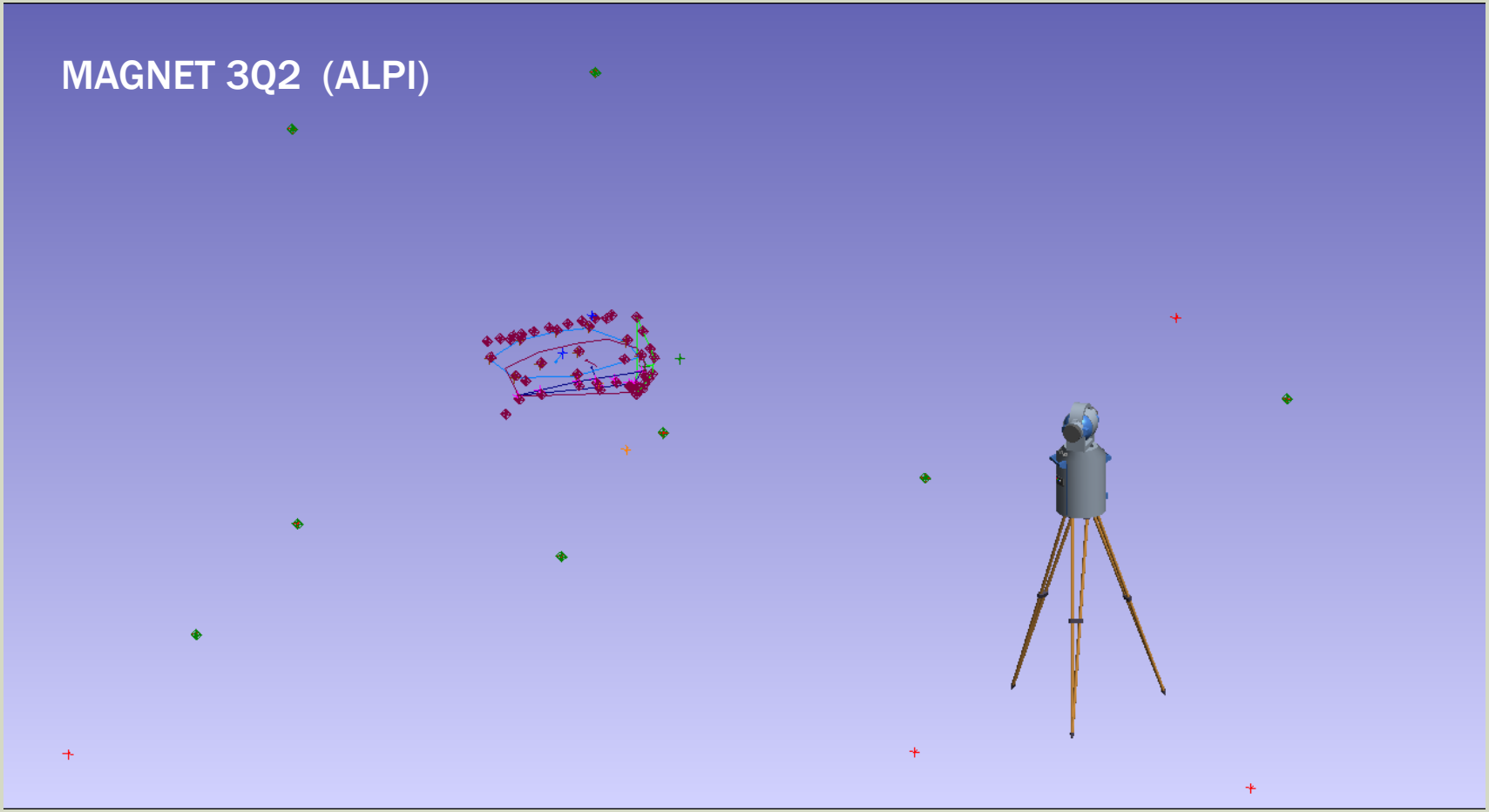
Maximum error detected after network test: 0.07 mm
RMS error: 0.05 mm

FIDUCIALIZATION OF MAGNETS, CRYOSTATS, DIAGNOSTICS BOXES



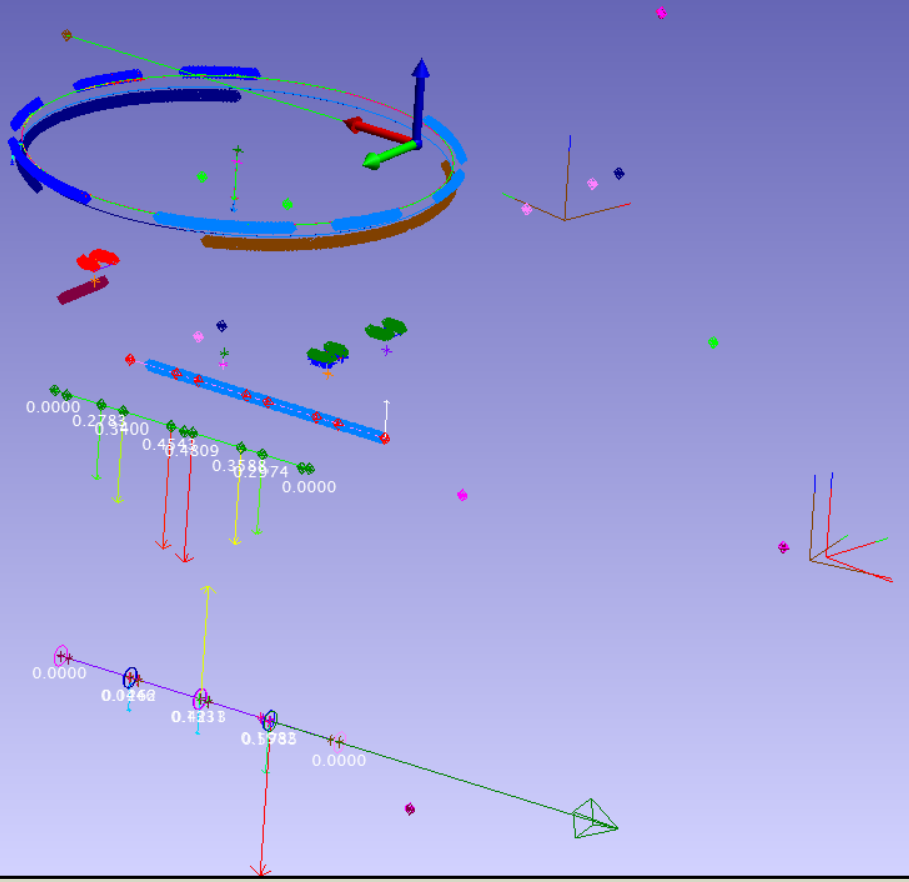
1. Two surfaces and upper edge are scanned to define geometrical axis of the quadrupole (within 0.05 mm maximum distance from magnetic one)
2. Positions of Corner Cube Rflectors are referred to such axis

MAGNET FIDUCIALIZATION

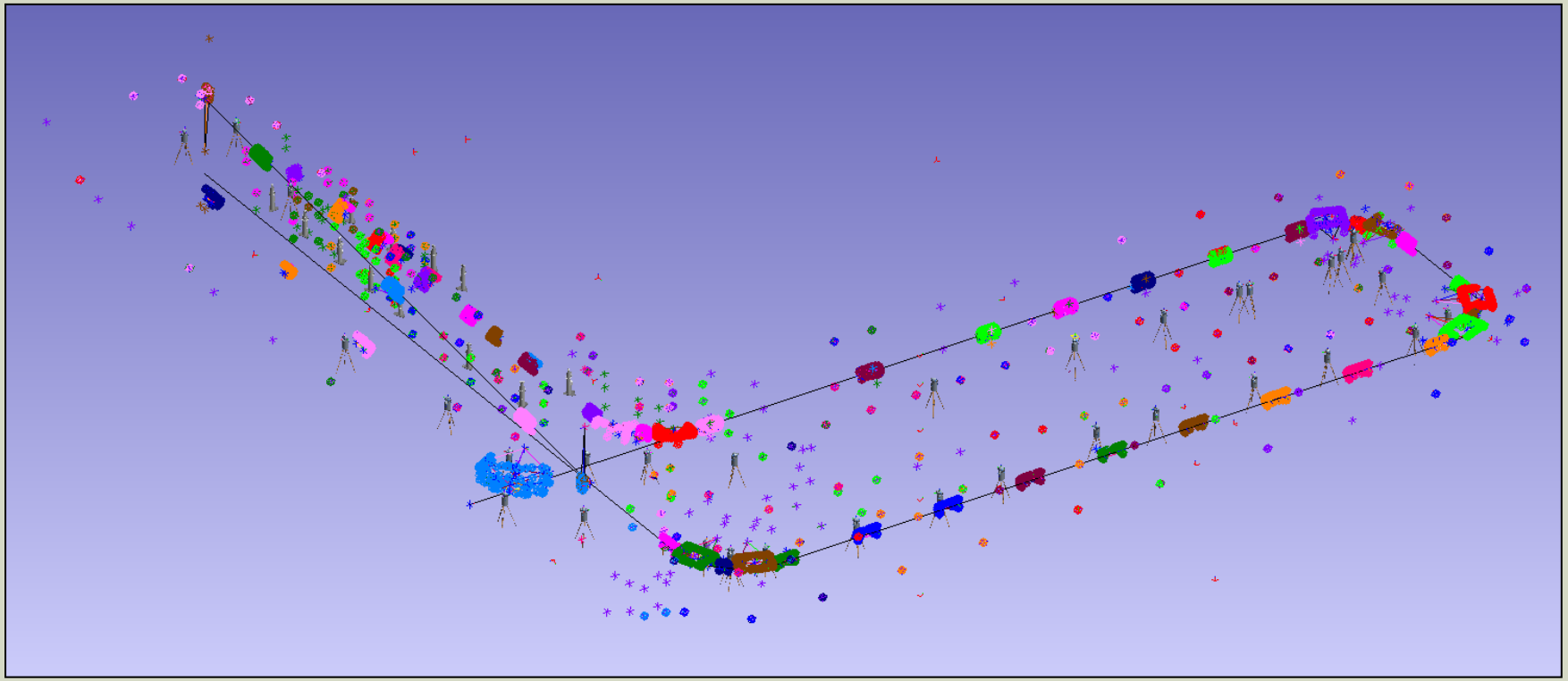


CRYOSTAT FIDUCIALIZATION

CRYOSTAT CR01-P (PIAVE)

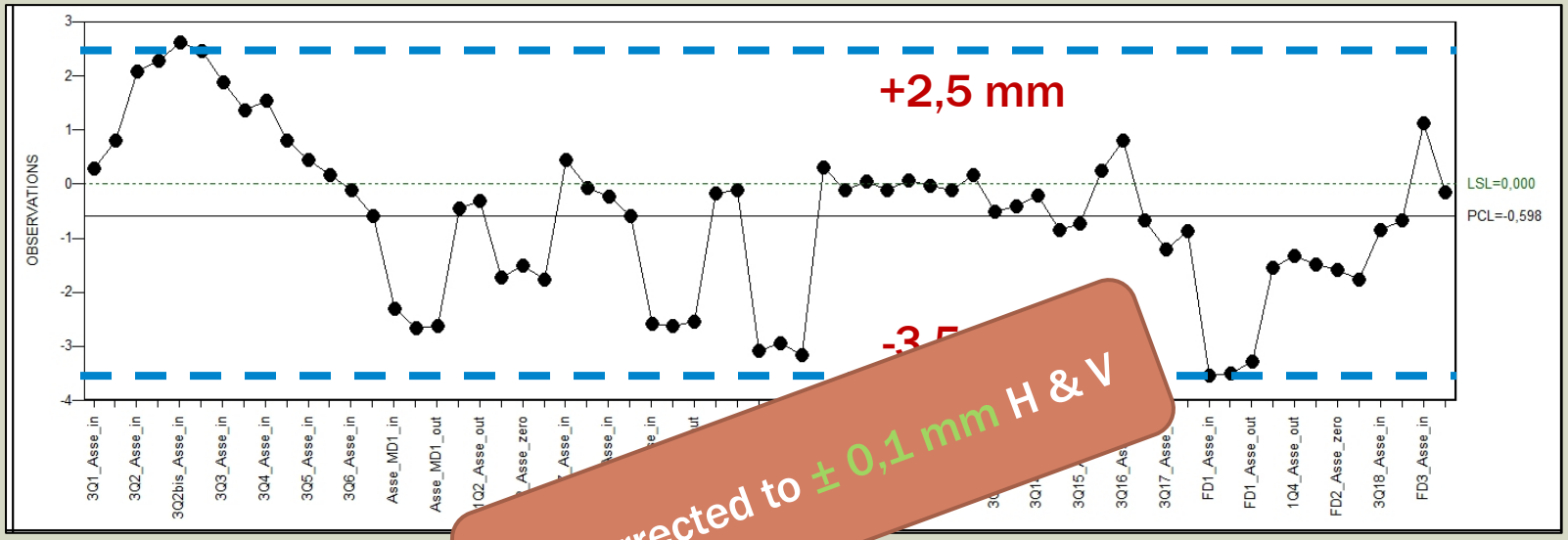


OUTPUT OF FIDUCIALIZATION OF ALL MAGNETS IN ALPI



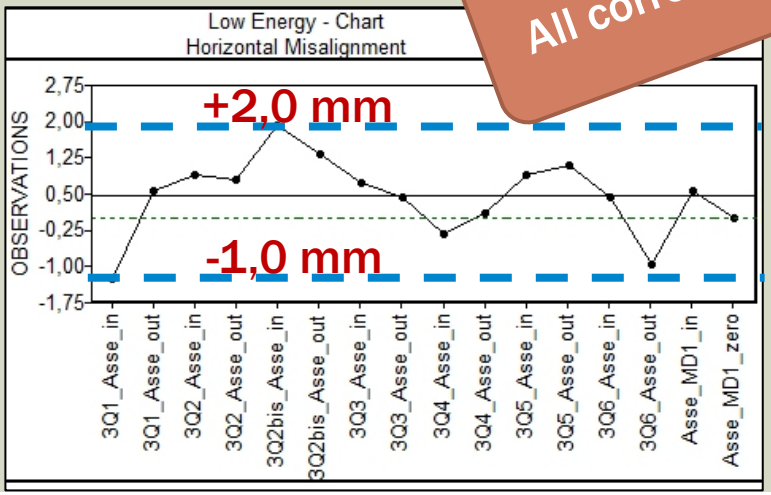
ALPI QUADRUPOLE MISALIGNMENT

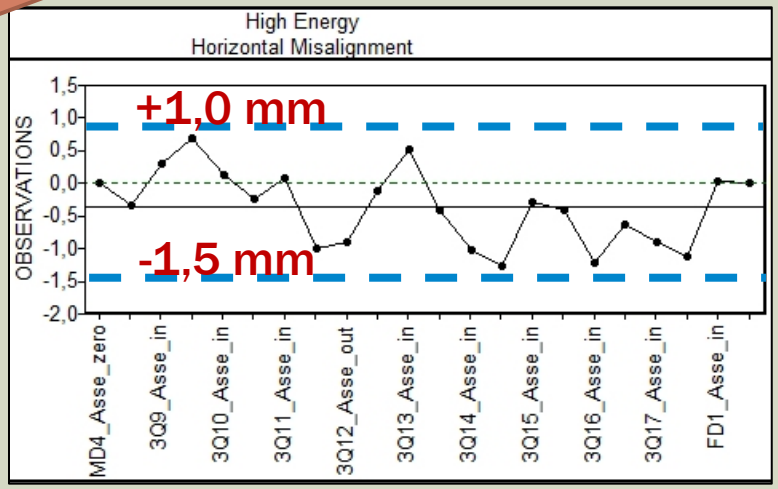
VER



All corrected to ± 0,1 mm H & V

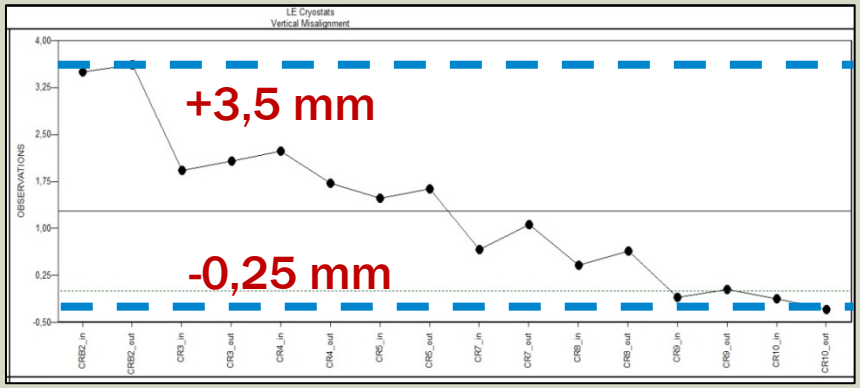
HOR

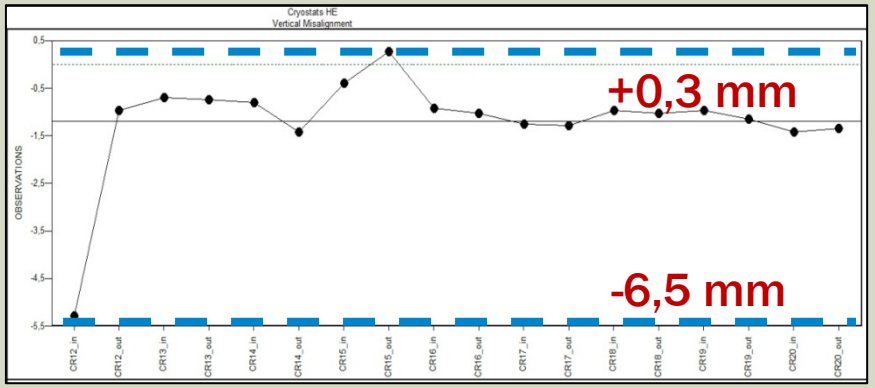




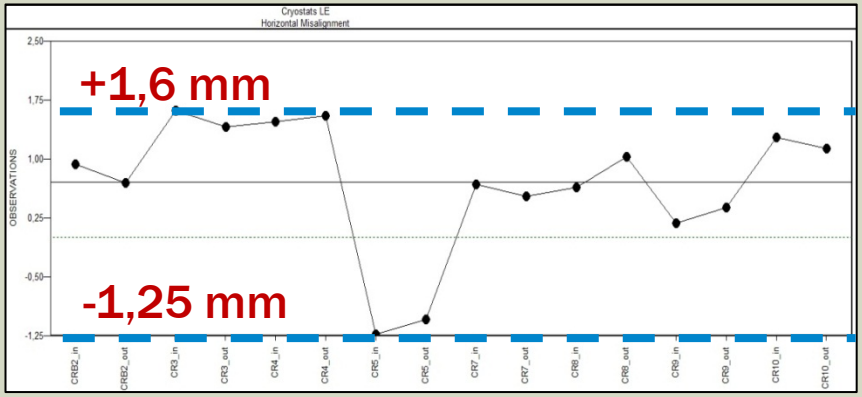
ALPI CRYOSTAT MISALIGNMENT

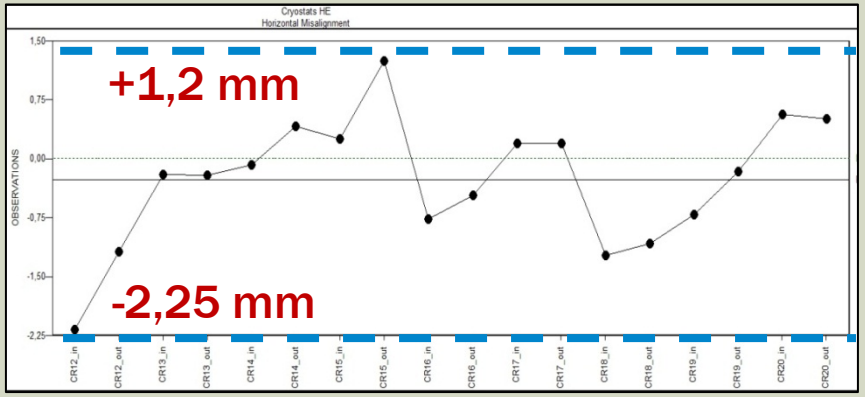
VER





HOR





Low Energy Branch

High Energy Branch

ALIGNMENT STATUS

- All ALPI quadrupoles: aligned to better than ± 0,1 mm
- ALPI cryostats (except a few on the HE branch due to lack of time): aligned to better than ± 0,1 mm
- High energy transfer line from ALPI to Tandem building wall: aligned to better than ± 0,1 mm
- Low energy transfer line from Tandem to ALPI: network qualified through the wall, Tandem area aligned to better than ± 0,1 mm
- To be done: ALPI low energy transfer line, PIAVE, beam lines in Halls 1 & 2, transfer line from ALPI to Hall 3

ALIGNMENT PRELIMINEARY RESULTS

- First transport of Br beam through Tandem-ALPI after alignment resulted in an operative ALPI transmission increase from 25% to 58%
- After steerers correction of ALPI injection misalignment (due to still misaligned low energy transport line), ALPI beam transportation and acceleration is less problematic respect to the old configuration. This imply a reduction of beam preparation time.

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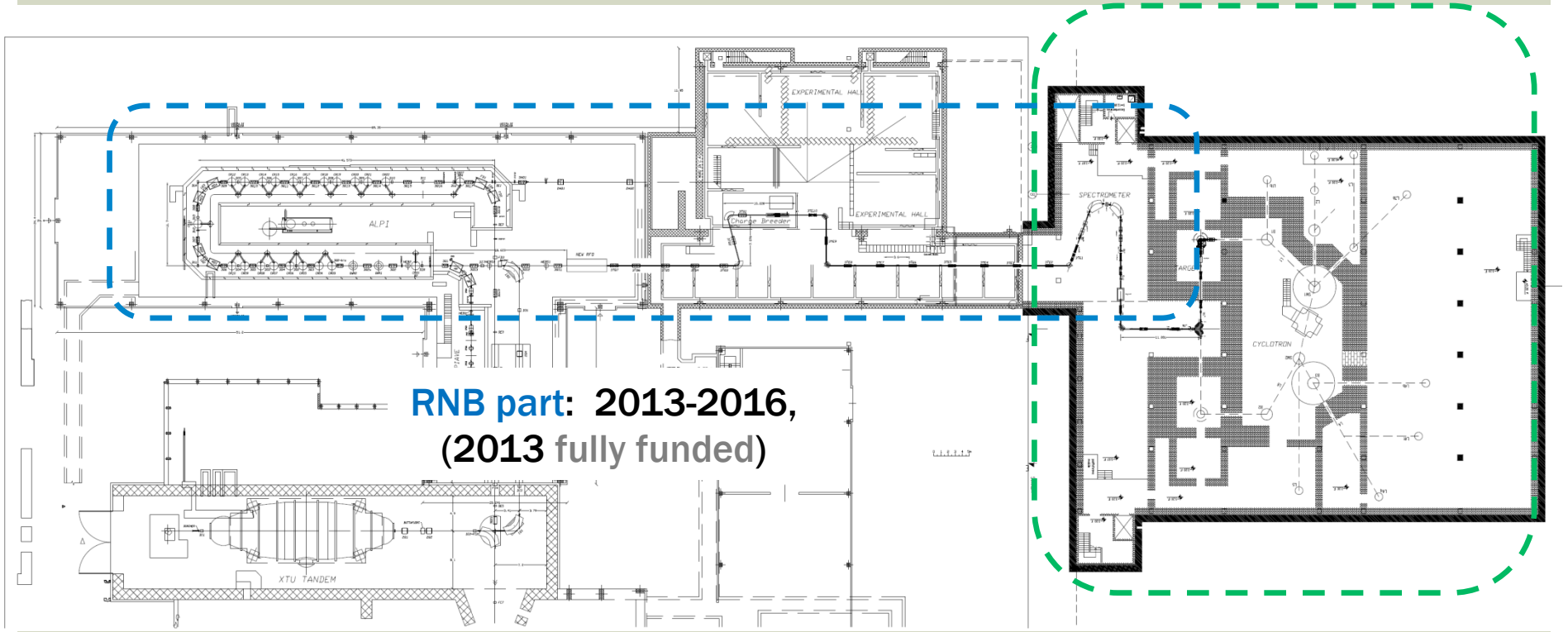
SPES LAYOUT



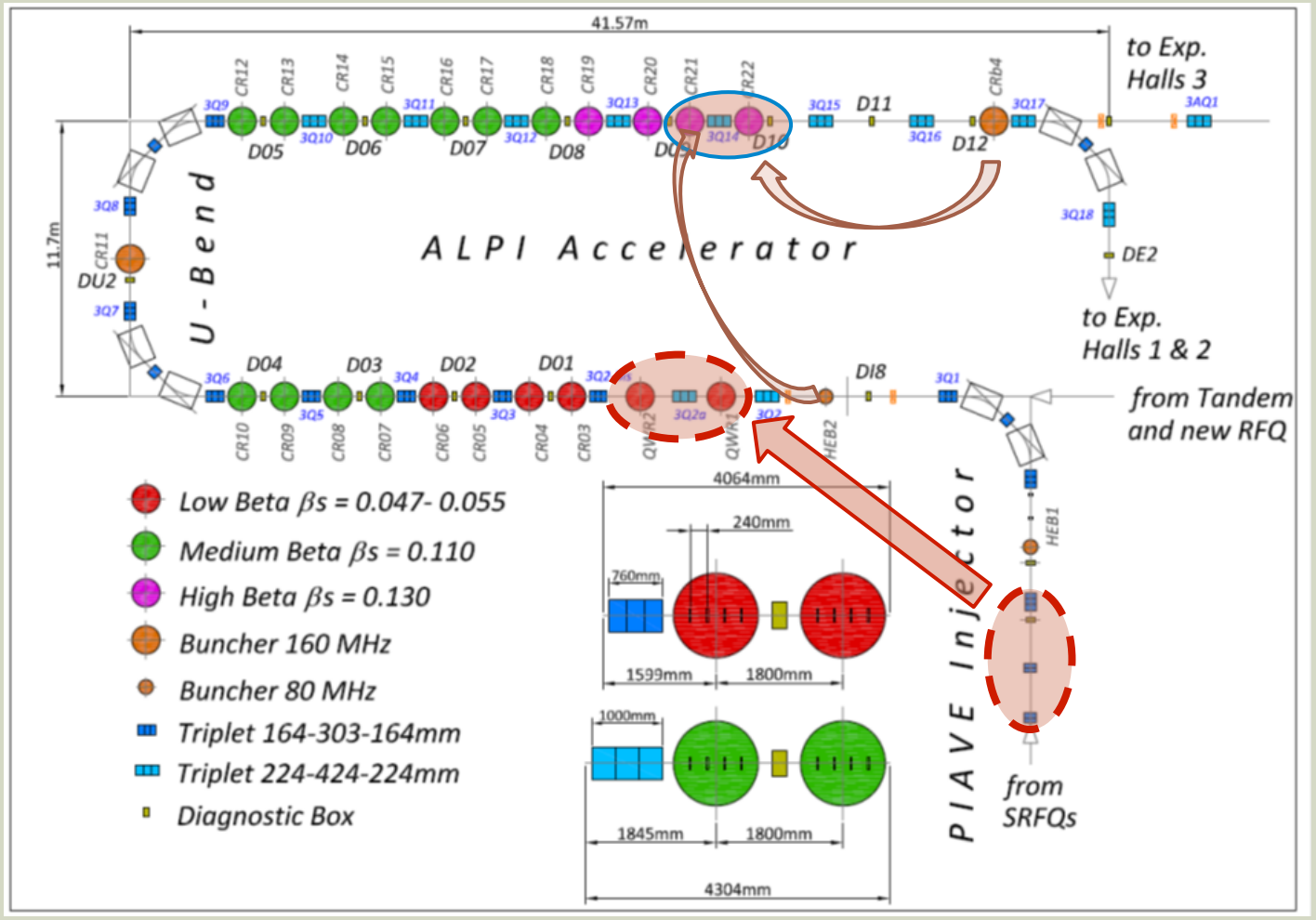
RNB part: 2013-2016,
(2013 fully funded)

Cyclotron & Building: funded,
Ground breaking in May 2013

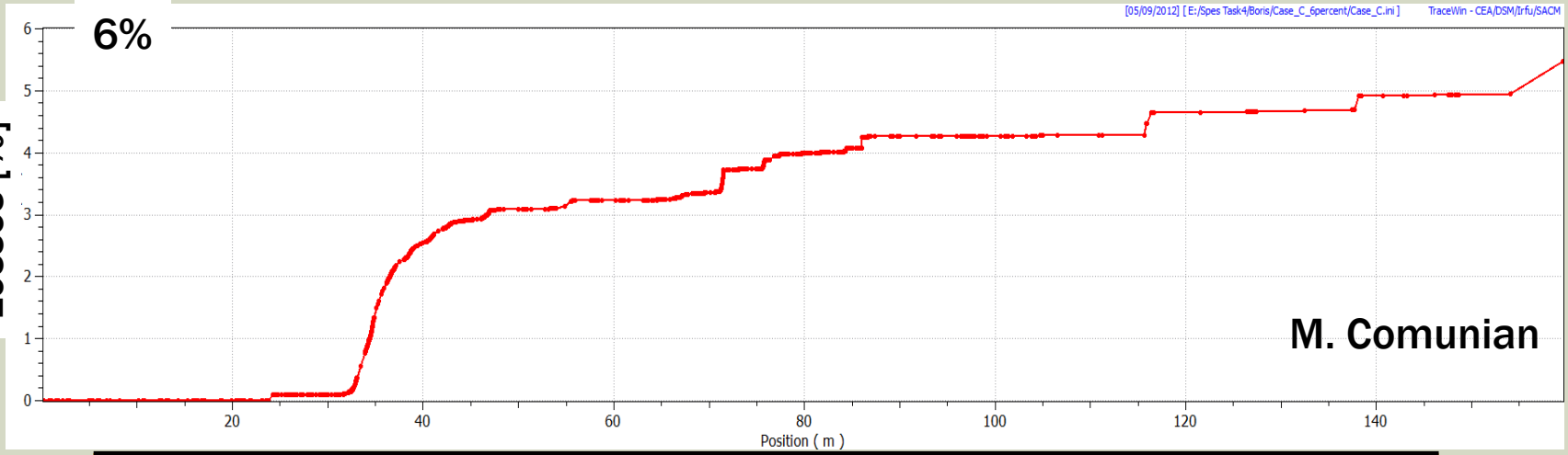
UPGRADES AND REFURBISHMENTS OF ALPI WITHIN SPES 1/2

- **Low-Beta Section Upgrade**: 16 resonators with $E_a \geq 5$ MV/m for better acceleration efficiency and transmission – nearly completed
- **New quadrupoles with a higher gradient** (30 vs 20 T/m) in the low-E branch to increase the overall beam transmission – being checked
- **Energy increase**: by adding two cryostats with Nb-sputtered cavities at the very end of the linac; these can be the result of a reshuffling in ALPI (next slide), being planned

RELOCATION OF PIAVE AND BUNCHER CRYOSTATS



ENERGY AND TRANSMISSION (SIMULATED)



Parameter [units]	PIAVE-ALPI	New RFQ-ALPI
A/q	7.0	7.0
Output Energy [MeV/u]	10.1	10.3
Output Emittance (rms, longitudinal) [deg-keV/u]	18	32
ALPI Transmission [%]	88	94
Total Transmission [%]	60	90

UPGRADES AND REFURBISHMENTS OF ALPI WITHIN SPES 2/2

- **Cryogenics** :

1. relocating PIAVE cryostats CR01-P and CR02-P to positions CR01 and CR02 in ALPI (adaptation of cryogenic lines);
2. increase of cryogenic power (almost done);
3. cryostats and the cryo-plant need a modernization of their control system;
4. cryo-module feedboxes to be stepwise replaced with new ones with external actuators;
5. compressor section of the cryogenic plant requires a number of important refurbishment steps.

- **Beam diagnostics for low-I beams** to be integrated with that for stable beams, in the space allocated for the diagnostics boxes available at present.
- **Control systems**: nearly all of them must be partly or completely upgraded (RF, diagnostics, magnets, access,…)
- **Vacuum system**: replacement of most pumps required by the ageing of ALPI ones; need of convoying all the exhaust residues into a common storage shall have to be evaluated versus radioprotection requirements

POSSIBLE OPERATION CALENDAR IN THE SPES FRAMEWORK

2013-2015

- **Tandem** available as usual on 2 semesters
- **ALPI** available 1 semester/year
    1. To involve more personnel on SPES;
    2. To save on electricity bill
- **PIAVE** available 1 semester/year in 2013 and 2015; unavailable in 2014 (ECR team involved in Charge Breeder assembly and tests)

2016-2017

- **For 1,5 year all machines unavailable** (operation team involved in overall SPES assembly)

CONCLUSIONS

- Completion of machine alignment: at least 200% increase of beam current at experiment
- Cryostat reshuffling and low beta upgrade: higher final energies (A/q≈7, 10 MeV/A)
- Cryo-plant upgrade: machine stability increase
- New room temperature RFQ: 150% increase of beam current at experiment