Bunching system for SPES project

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Work Package B9 (RNB Accelerator), Work Unit B.4 (Bunchers)

Existing bunching systems for TANDEM, PIAVE and ALPI

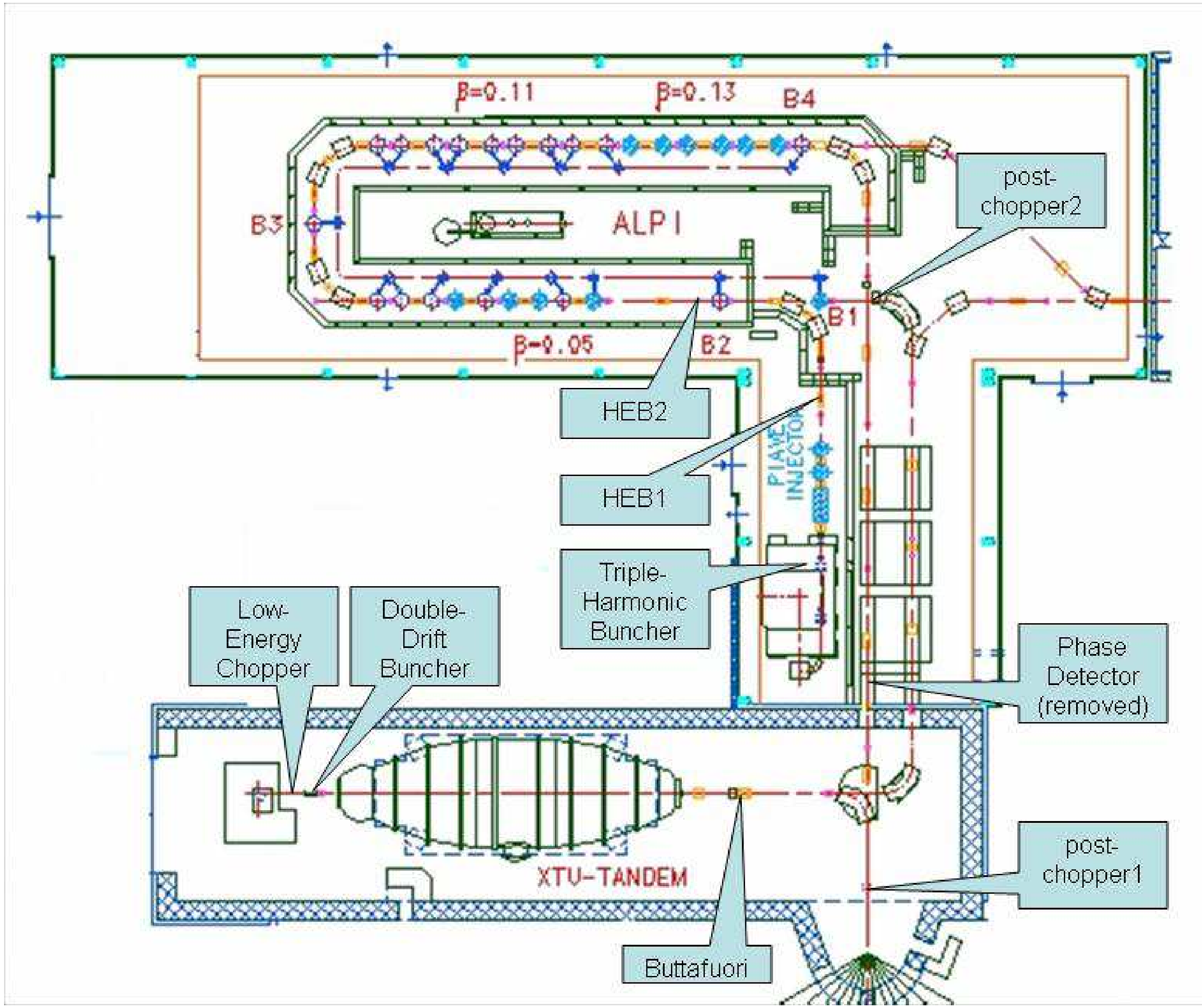


Fig.1. View of the existing accelerator facility

-Tandem-ALPI
Double Drift Buncher
5 MHz (5/2^n MHz
with low energy
chopper)

or 160 MHz with B2
only

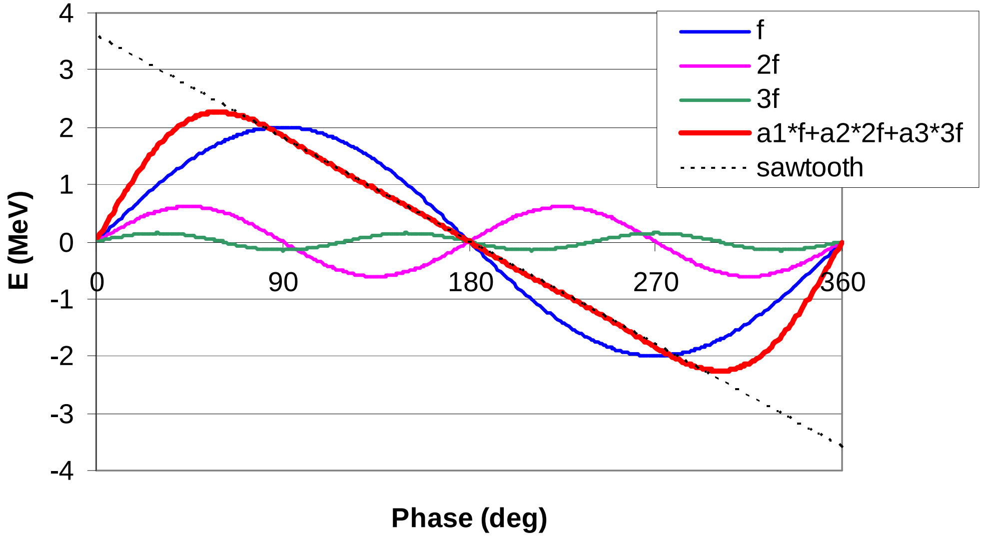
-PIAVE-ALPI
-3-harmonic buncher
40 MHz

-Double Drift and 3
harmonic bunchers
can provide 70%
efficiency with good
emittance

-Choppers remove
peak tails and
background between
main peaks

PIAVE triple-harmonic buncher

- **2 QWRs, 3 harmonics**
- **40, 80 and 120 MHz**
- **air-cooled**
- **in PIAVE upstreams SRFQs**
- **β=0.009**



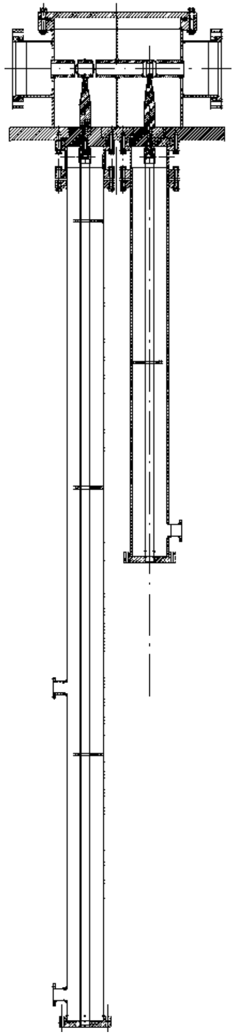


Fig. 2. PIAVE triple harmonic buncher

Delivering the beams from PIAVE and SPES production facility to ALPI according to beam dynamics simulations will be provided by two beam lines, which contain totally 5 High Energy 80 MHz room temperature bunchers (HEB) and one 5 MHz Low Energy Buncher (LEB). Two of the HEB for optimal β = 0.052 have been already built and are in operation since 2002 (HEB1 and HEB2) and three new ones (HEB3, HEB4, HEB5) for optimal β = 0.04 have to be built in framework of SPES project . Maximum gap voltage for double gap HEB will be equal 70 kV (total voltage is 140 kV). 5 MHz Low Energy Buncher, which will be installed upstream RFQ has optimal β = 0.003515 and total voltage V= 1 kV.

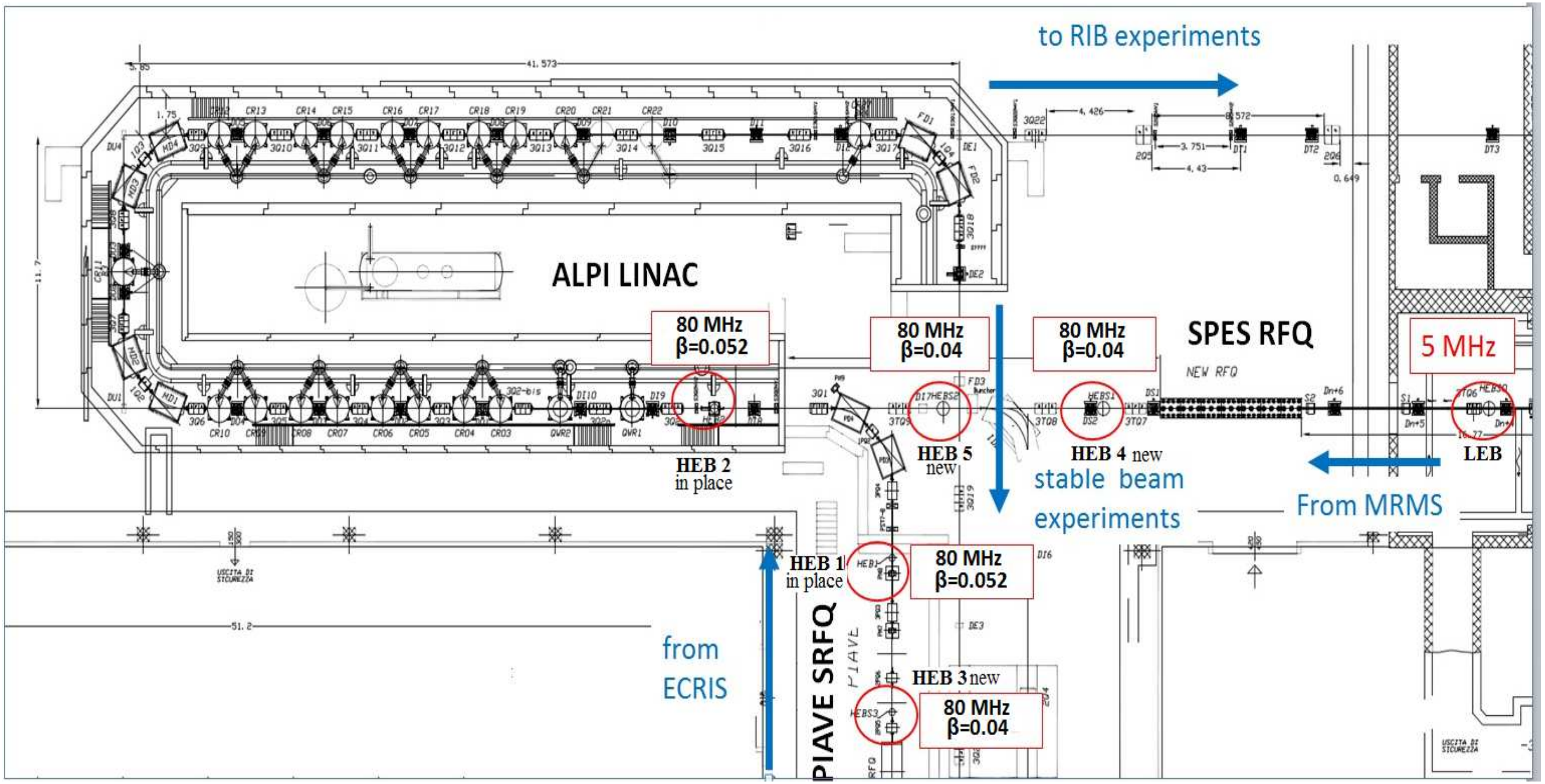


Fig. 3 Map of the SPES facility

Design of HEBS (high energy bunchers)

Design status of the High Energy Buncher for β=0.04 (HEB04)

The drawings of the existing buncher resonators (see Fig. 4) have been modified for β_opt = 0.04, changing only distance between centers of the gaps (Fig. 5) and can presently be used for fabrication. Unfortunately there is a problem associated with the manufacturer.

13 years ago outer conductors of the QWR were manufactured outside the LNL by ICOSS company. Double wall technology was used to provide water cooling the outer conductor of the resonator. Now ICOSS company does not exist and all attempts to find a new manufacturer, having such technology are till unsuccessful. However, the reduced power requirements for the HEB-04 allow us to reduce the water cooling capabilities and simplify the cavity design, with possible reduction of cost and construction time.

Fig. 4 . Photo of existing 80 MHz PIAVE buncher

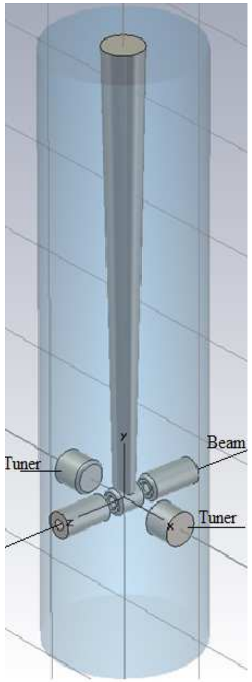


Fig .5. Code model view of the modified buncher

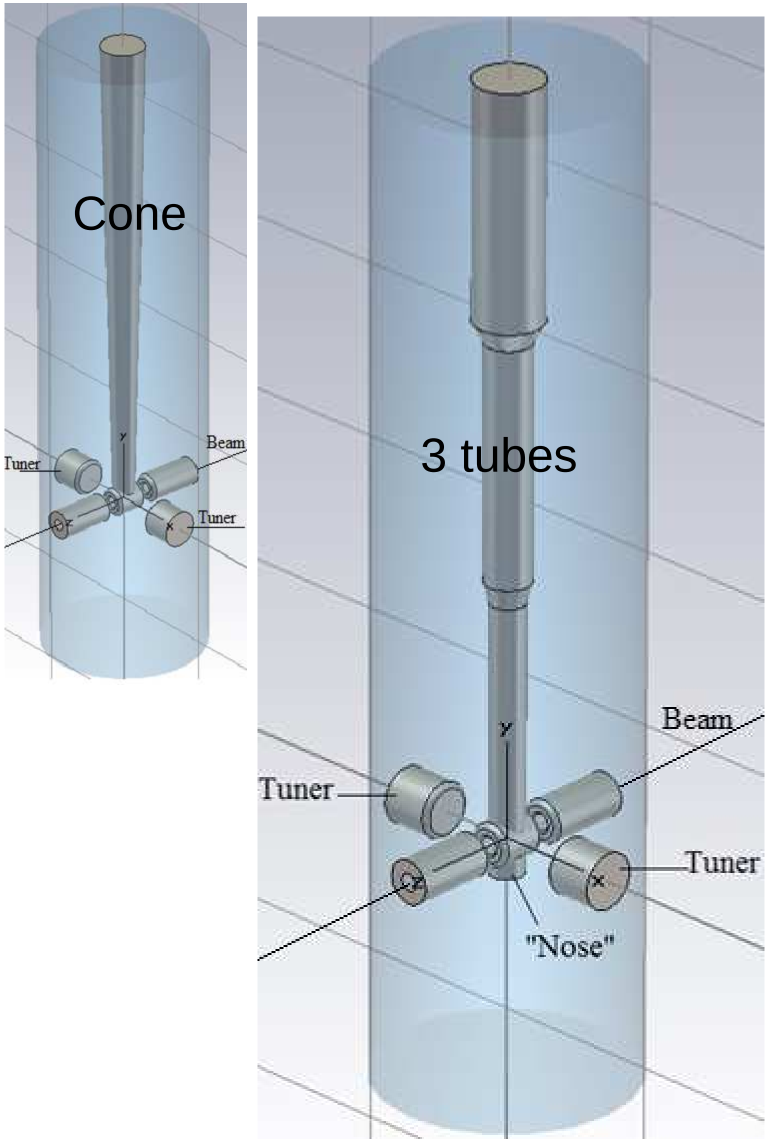


Fig. 6. Code model view of new version of the HEB

The new version of the bunchers (Fig. 6), since their rf power losses are about 1/3 of the PIAVE bunchers ones, will use:

- **air cooling on the outer conductor**, which will be made with 6 mm thick, commercially available copper tube with SS flanges brazed on it; the LNL furnace is perfectly fit for it;
- **Simplified** design (from the mechanical construction point of view) of the **inner conductor**, which will be made of 3 cylindrical sections of commercially available Cu tubes brazed together and supported by an internal SS tube with water transport functions;
- A **removable/machinable prolongation**, or “nose” of the inner conductor as the only one knob for central frequency adjustment at the very end of the cavity construction. This will allow “built-to-print” order to the vendor with no need of intermediate frequency tests, with cost and construction time saving.
- The design with **removable outer conductor** and rf contact worked very well in the PIAVE bunchers, and **will be preserved**.

Table 1. Parameters of the new SPES resonators (two versions)

Cavity inner conductor	Inner cavity diameter mm	Gap length mm	Outer drift tube rounding radius mm	Max. surface E - field MV/m	Total Power losses kW	Outer conductor power losses W	Quality factor Q
Cone	300	20	6	6.5	1.7	390	11297
3 cylindrical tubes	295	20	6	6.5	1.73	390	10.934

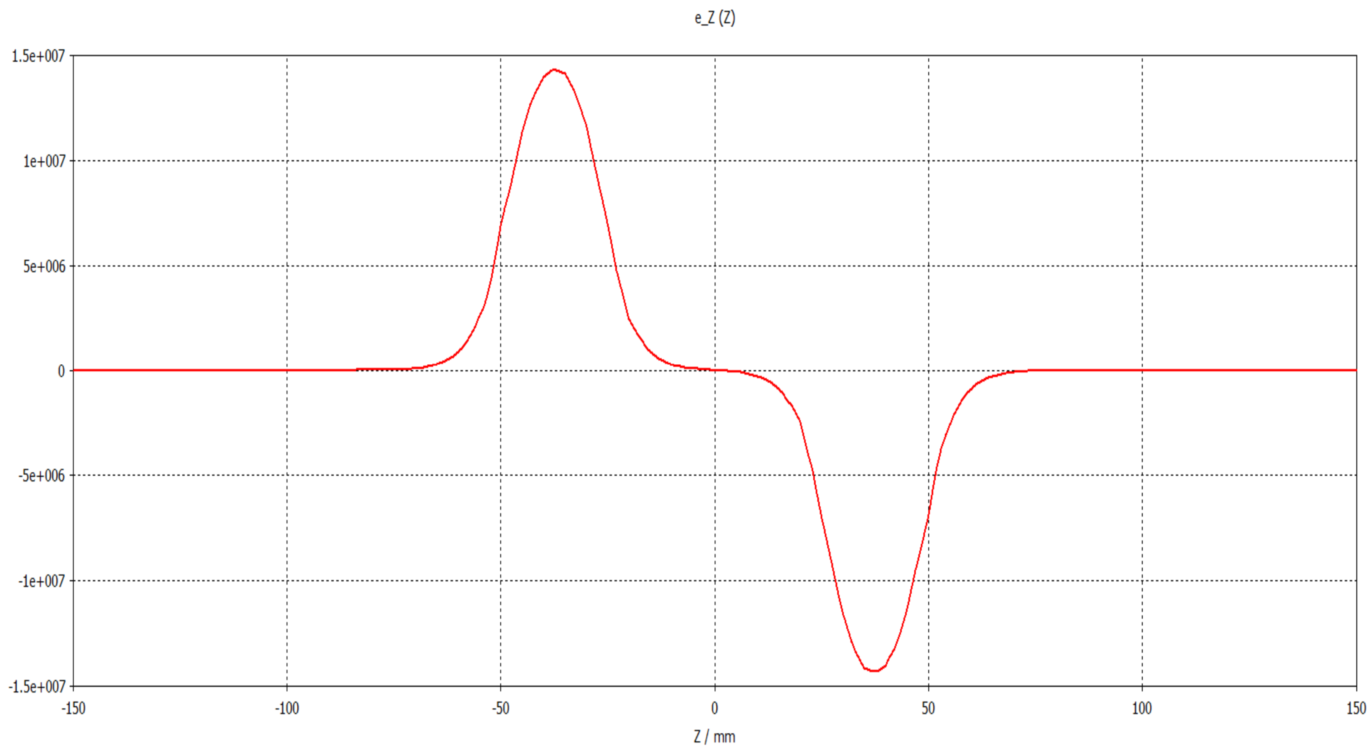
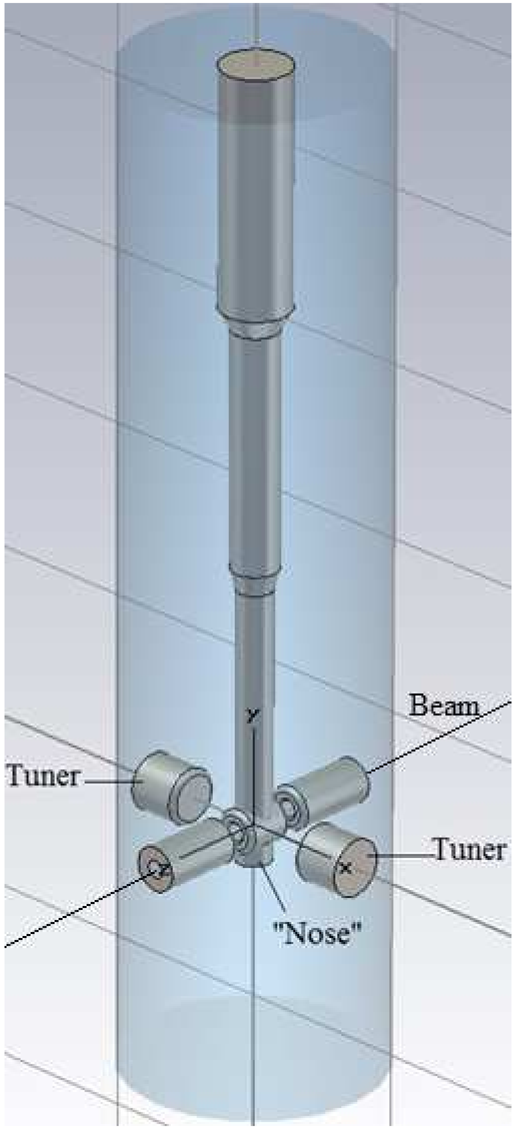


Fig. 7. Distribution of electrical field longitudinal component E_Z on the beam axis

Two tuners and the «nose» will provide tuning resonant frequency of the buncher. They allow very large tuning range. One of the tuners will be movable and be used for fine tuning. Another one will be kept for field symmetry. Ranges of coarse tuning, which will be provided by the «nose» and tuners are shown on Fig.8 and Fig. 9 correspondingly.



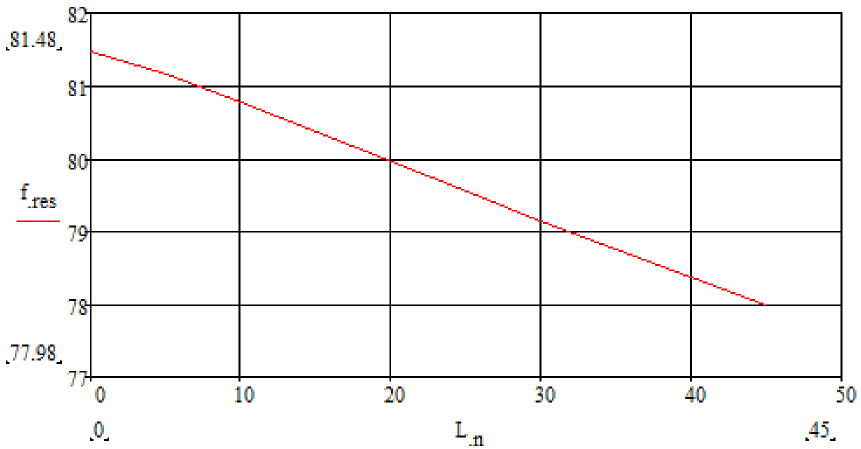


Fig. 8. Tuning range provided by the «nose»

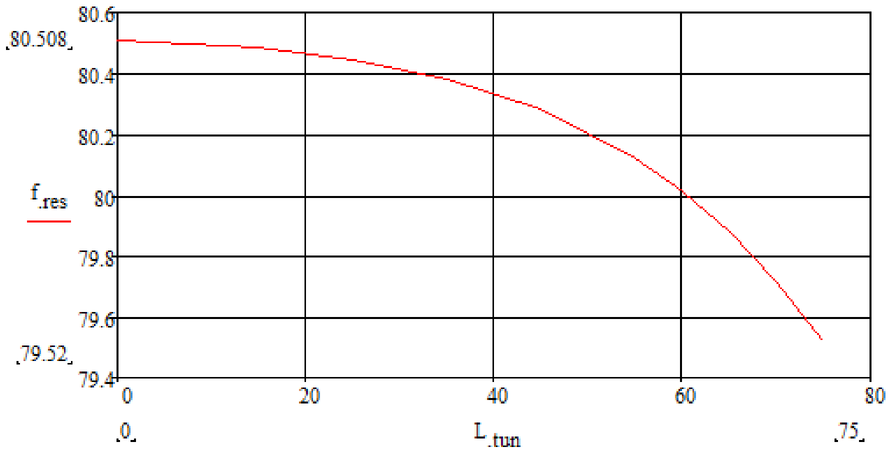
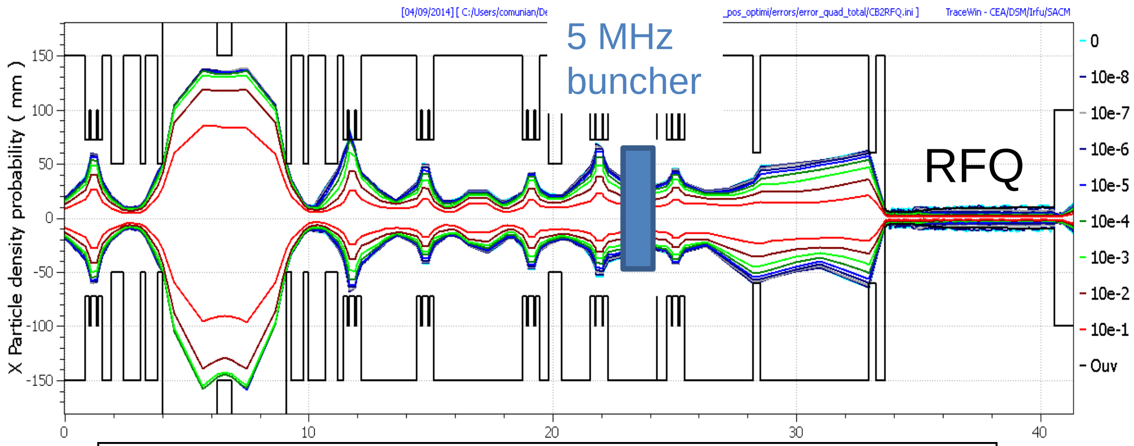


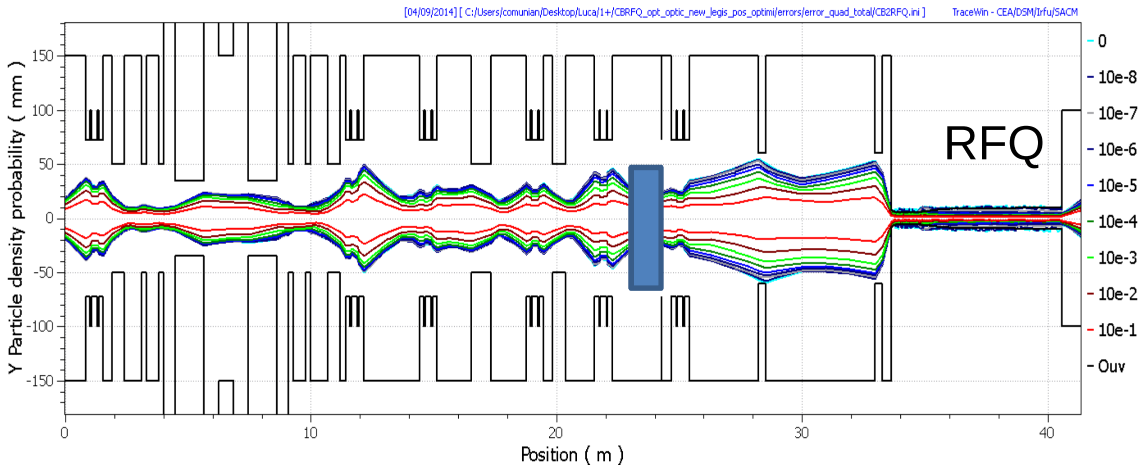
Fig. 9. Tuning range provided by two tuners

Design of low-f buncher

BD from CB to end of RFQ

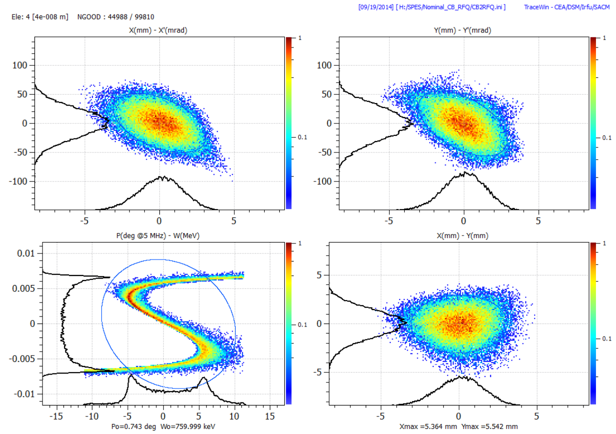


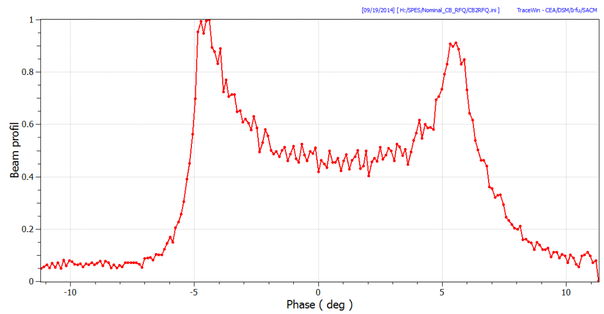
Total amount of space occupied by the beam due to quad errors



Without buncher, output longitudinal emittance after the RFQ is 0.067 π mm mrad

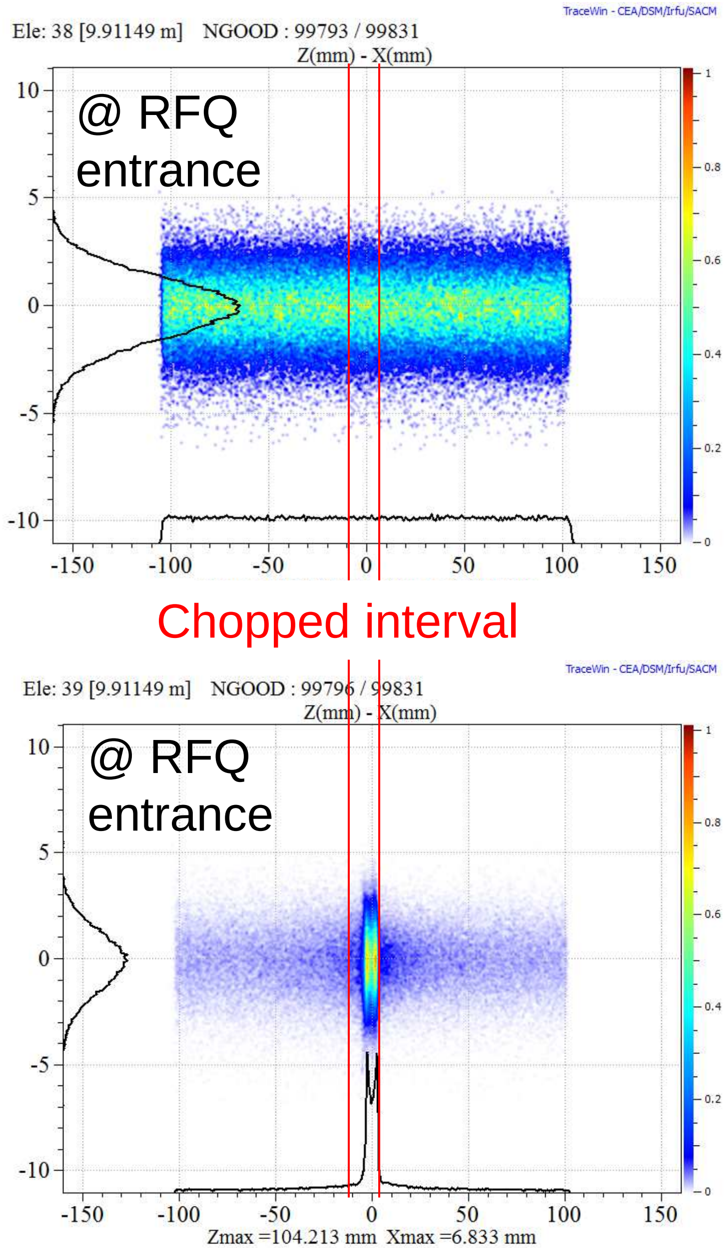
If 5 MHz buncher is on:





Transmission - 45 % (with chopping sutellite bunchers downstream RFQ). RFQ output longitudinal emittance - 0.0371 π mm mrad

without buncher
(only chopper)



- Transmission: 3 %

with
buncher

Transmission: 45 %

Design of 5 MHz Low Energy Buncher (LEB) for the SPES Project

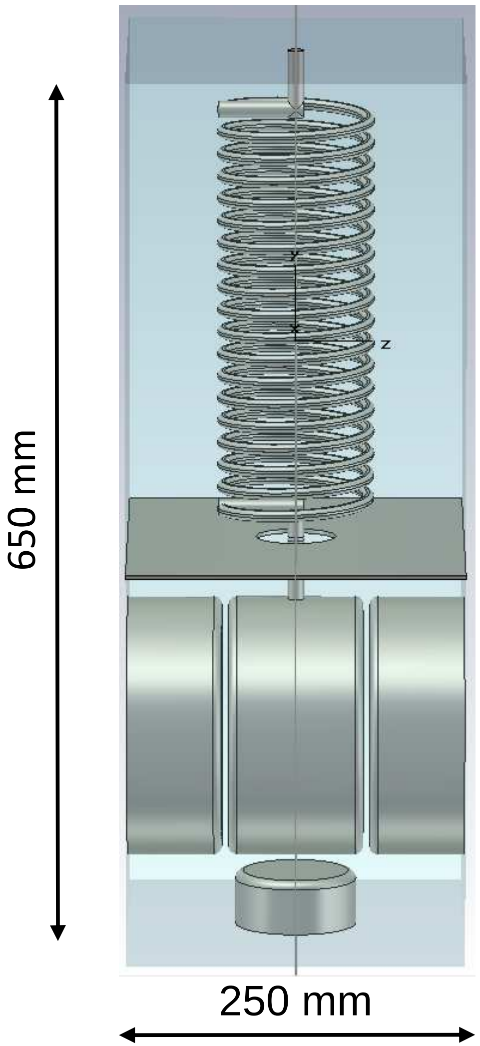


Fig.10. General view of the two gap LEB

For low frequency resonant systems it is more **convenient to use lumped circuit elements**, such as inductance and capacitance. In our case the capacitance is defined by geometrical dimensions of the drift tubes. Since βλ has been fixed and determined by RFQ, the double gap resonant system can be used (see Fig.10). Inner and outer drift tube diameter are 80 mm and 192 mm correspondingly. Distance between centers of the gaps = 105 mm.

Inductance is helical (spiral) coil consisting of 18 turns of 8 mm copper pipe. Coil length L= 300 mm, coil diameter D= 100 mm.Total gap voltage is equal 1000 V, i.e. 500 V for gap. Optimal β = 0.003515, βλ/2 = 105 mm Only drift tubes will be installed inside vacuum chamber. The coil will be placed on air. A tuner installed on the bottom of the the vacuum chamber allows frequency tuning in range of 10-100 kHz. Transit time factor of the LEB is equal 0.78.

Main RF parameters of the resonant system and longitudinal electric field (E_Z) distribution along beam axis will be shown on next slide (Table 2 and Fig.11).

Double gap 5 MHz Low Energy Buncher (LEB)

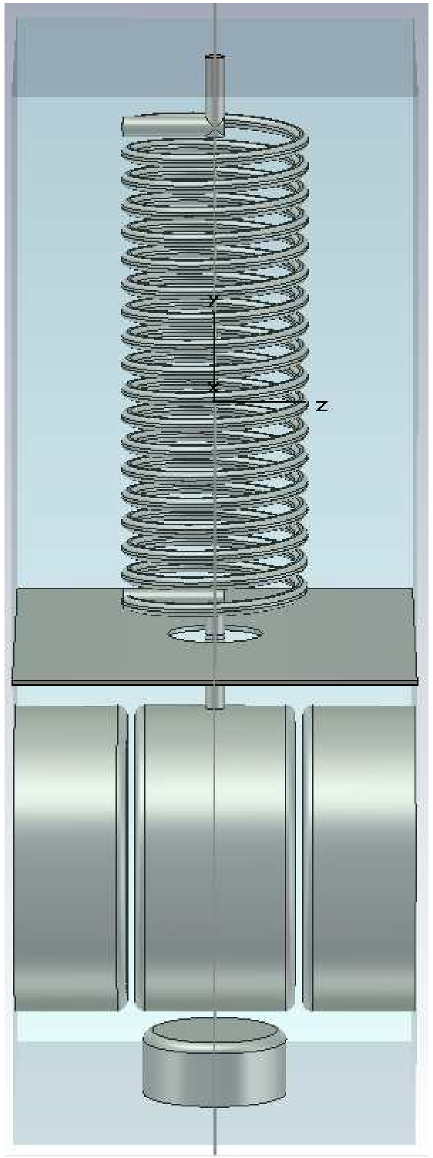


Table 2. Parameters of the two gap 5 MHz resonant system

Central tube length mm	Gap length mm	Tube outer rounding radius mm	β_opt	f_res MHz	Max. surface E - field MV/m	Power losses W	Q
100	5	6	0.003515	5	0.132	0.35	1462

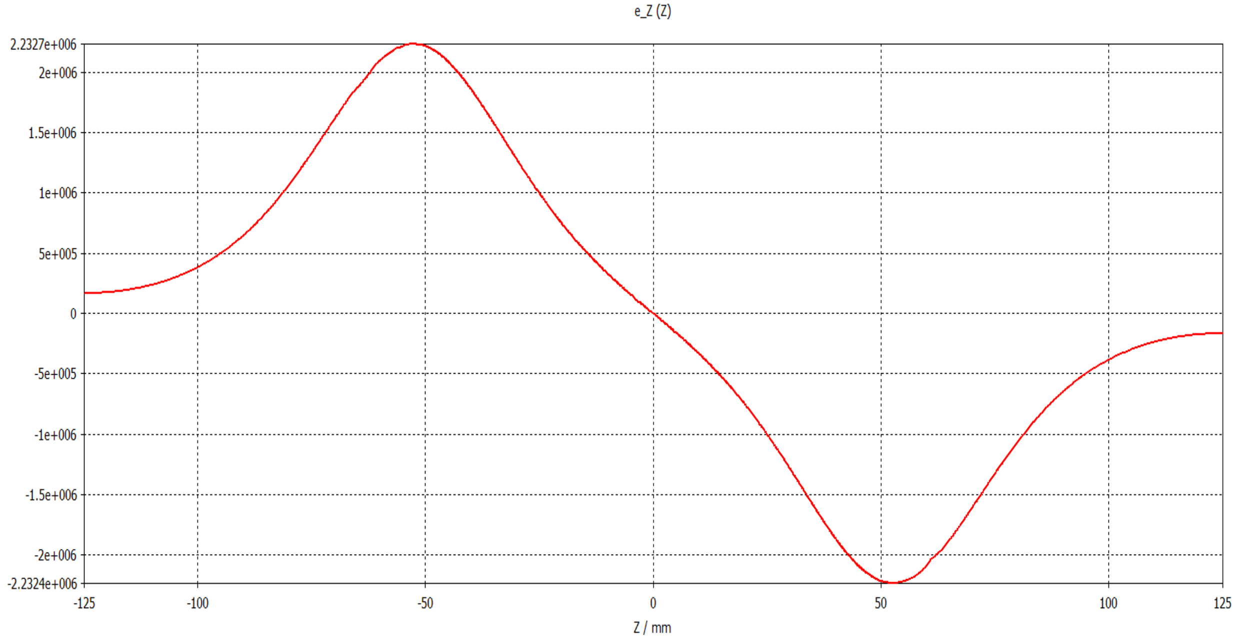


Fig. 11. Longitudinal electric field E_Z distribution on the beam axis

Conclusion

The following schedule for execution is being proposed:

High Energy Buncher:

- In a few weeks launching the mech design to be completed in the next 3 months, then 1 year for construction and then tests.

Low Energy Buncher:

- In the 3-6 months completing RF design of the LEB, plus 1 year mech design and construction, then tests.