THE ARES PROJECT

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The ARES Design Study Group [0)]

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Summary

The Frascati (LNF) ARES Project,consisting of a Φ-Factory and of a SC Linac facility, approved by INFN on the 15th of June 1990, is presented.

A short History of the Project

The interest for a superconducting linear accelerator in Frascati dates back to the end of 1985. A SC Linac, a very versatile tool, has a number of features that were attractive for the HEP, NP, and Materials Science research groups operating in the Laboratory and in other INFN Sections and Universities, namely:

- continuous beams with very high intensity and energy resolution,
- possibility of testing the high charge, low emittance, high peak current, high repetition rate operation regime required by linear colliders.
- production of FEL radiation in the short wavelength region.

A first Workshop [1)] was held in Frascati in October 1986, on physics applications and on technical aspects of SC cavity design; it was decided to launch an R&D program on 500 MHz SC cavities.

A Discussion Meeting on "Physics Possibilities of a high Luminosity e^+e^- Facility of up to ≈12 GeV" was also held in Frascati in April 1987 [2)].

As a major part of the R&D program, a small pilot facility, LIS-A, was approved at the end of 1987 and is today near to completion [3)].

A feasibility study on a high luminosity 'Heavy-Quark and NP Facility based on a SC Linac' was completed during a third Workshop held in Courmayeur, in December 1987 [4)].

A number of critical points in the design were evidenced and a number of alternatives, among which that of a Φ-Factory, were put forward. It also appeared that the size of the project was not compatible with the foreseeable commitment of resources. Towards the end of 1988 the INFN Executive Committee therefore set up the ARES Design Study Group with the charge of producing a proposal for an accelerator complex of more moderate size that would include a Φ-Factory. Prototyping work on cavities was also started.

The Study Group report was published in January 1990 [5)].

A site-independent accelerator complex was presented that consisted of a 510 MeV Superconducting Linac and of a two-ring Φ-Factory collider.

The Linac would serve as an injector for the Φ-Factory and would therefore have to provide intense electron and positron beams. It would also serve as a test facility to develop techniques and components to be used for the future VHE Linear Colliders and as a high-quality FEL driver.

Further discussions with the INFN Management Board finally produced an optimised time- and cost-effective strategy, summarised in two Reports, that was approved by the INFN Board of Directors on June 15,1990. It consists of:

i) Construction of the proposed Φ-Factory on-site, in the existing ADONE buildings, using a conventional (existing or new) full energy injector,with the aim of starting Physics in 1995÷1996[6)]. ADONE, the presently operating 1.5 GeV collider also used for NP and SR, is to be de-commissioned in 1992÷1993.
ii) A revised on-site SC Linac test-facility, as proposed in Ref. 7), foreseeing the expansion of existing LISA buildings and facilities.

We briefly present here the approved, revised version of the original ARES design.

The ARES Φ-Factory

The two-ring Φ-Factory design criteria and lattice are described in an accompanying paper [8)]; we recall here its main specifications and design goals. The basic design luminosity of 10^{32} $cm^{-2}s^{-1}$ is achieved with head-on collisions. The storage rings are separated vertically and meet at a single interaction region; the opposite straight sections are dedicated to RF and injection. The rings are optimized at the Φ peak but can reach a top energy of ≥ .6 GeV. The full energy injector allows 'topping off' at the nominal energy, thereby improving the average integrated luminosity.

The specified value of the linear tune-shift parameter, ξ , is rather conservative; a fit of all existing data by J. Seeman and a model by M.Bassetti are used to estimate the dependence of ξ on energy and on the amount of radiated power (that determines the damping coefficients). The radiated energy is adjusted to the value required to achieve the desired value of ξ, at the Φ energy, by means of wigglers that are an integral part of the lattice. Additional (or higher field) wigglers, to further increase the amount of radiation and damping, could be inserted later if necessary.

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0) P. Amadei, A. Aragona, M. Barone, S. Bartalucci, M. Bassetti, M.E. Biagini, C. Biscari, R. Boni, M. Castellano, A. Cattoni , N. Cavallo, F. Cevenini, V. Chimenti, S. De Simone, D. Di Gioacchino, G. Di Pirro, S. Faini, G. Felici, M. Ferrario, L. Ferrucci, S. Gallo, U. Gambardella, A. Ghigo, S. Guiducci, S. Kulinski, M. R. Masullo, P. Michelato, C. Milardi, M. Minestrini, G. Modestino, C. Pagani, L. Palumbo, R. Parodi, P. Patteri, A. Peretti, M. Preger, G. Raffone, C. Sanelli, L. Serafini, M. Serio, F. Sgamma, B. Spataro, L. Trasatti, S. Tazzari, F. Tazzioli, C. Vaccarezza, M. Vescovi, G. Vignola.

The value of the vertical betatron function, β_y at the crossing point is also conservative and could be gradually lowered; a complete solution for the interaction region lattice including beam separation has been worked out.

A short parameter list is given in Table I.

Higher luminosities could also be achieved by later implementing a crab-crossing scheme. A preliminary specification is given in Ref. 6).

The ARES SC Linac

The goals are to develop the technology of linear accelerators, SC RF cavities and electron colliders, by building a high-field, high current, low emittance SC linear accelerator to constitute a significant step towards collider-grade parameters. It must accelerate very low emittance beams without degradation and be capable of reaching a single-pass energy high enough to perform significant beam quality tests and FEL experiments.

The RF cavity and the status of the R&D work are described in references 7) and 9).

A FEL program to produce high power laser beams in the region of wavelengths below 100 nm, not accessible to ordinary lasers is also briefly outlined in Reference 7).

Table I - Φ-Factory Main Parameters

Luminosity	[cm^{-2} s^{-1}]	$\geq 10^{32}$
Emittance	[m rad]	10^{-6}
Total current (/ring)	[A]	1.0
Coupling coefficient, κ		.01
ξ_y		.04
ξ_x		.04
β_y	[cm]	4.5
Collision frequency	[MHz]	71.4
Number of bunches (/ring)		24
Bunch length	[cm]	3
N$^{\underline{er}}$ of particles per bunch		8.9 10^{10}

Figure 1 shows, schematically, the physical layout of the accelerator in its fully expanded configuration that includes the final RF gun, the bunch length compressor and the layout of a possible recirculation channel. The LISA injector, including the capture and preacceleration sections will be installed lateral to the RF one, for preliminary tests.

The accelerator consists of twenty 500 MHz, four-cell SC high performance RF cavities (nominal: E_{acc}=10 MV/m@Q=3 10^9); its nominal energy of 240 MeV, at nominal field value, is high enough that recirculation without too much deterioration of the beam quality can be envisaged as part of a later upgrade.

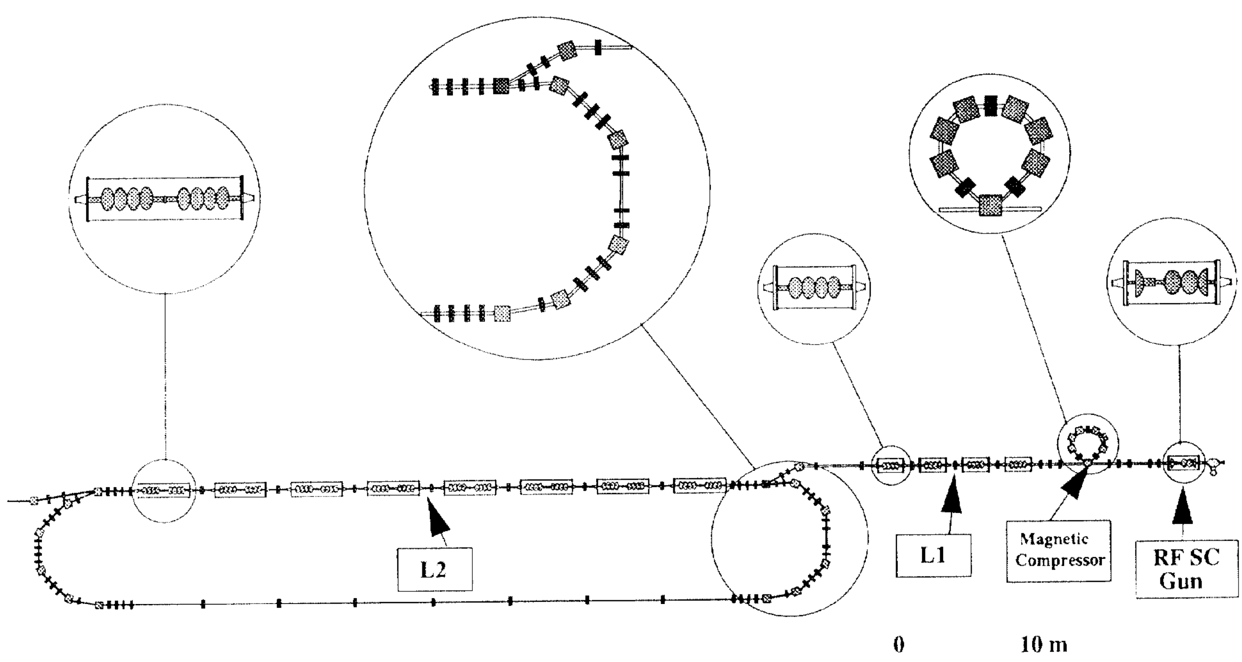

Fig. 1 - Schematic layout of the ARES SC LINAC.

The accelerator is housed in a tunnel extension of the existing LISA Hall; a second parallel tunnel is also foreseen to house service equipment and, when required, the recirculation hardware.

A short description of the rationale of the layout is as follows.

Electrons are generated by the (≥ 4 MeV) gun, passed through a matching section and accelerated by the first Linac Section, L1, consisting of four SC cavities each providing a nominal voltage gain of 12 MV. At the output of L1 the nominal beam energy is ≈ 52 MeV or slightly higher, the exact value depending on the type of gun. A parameter list for the final SC gun arrangement [10] is given in Table II.

Table II - RF Injector Expected Performance

Bunch charge [nC]	.5	10
Output energy [MeV]	10	10
Energy spread Dg/g [%]	± .5	± 3
Transv. norm. emittance [m]	< 5 10^{-6}	< 4 10^{-5}
I peak; no compression [A]	20	200
I peak; with compression [A]	400	1000

Each four-cell SC cavity in section L1 has its own cryostat and forms a cryomodule. The distance between focusing elements is thus minimised in the low energy region where space-charge forces are important and that between adjacent cryostats is also kept to a minimum: focusing, diagnostics, control and vacuum components are integrated within 0.6 m, corresponding to one RF wavelength.

Section L2 consists of 16 four-cell cavities; the cryomodule now contains two cavities to increase the filling factor. The nominal voltage provided by Section L2 is 192 MV and the overall beam nominal energy at the output of L2 is therefore ≈ 240 MeV. First-pass transverse beam sizes along the Linac, for an invariant emittance of 10^{-6} m, are shown in Fig. 2. [11].

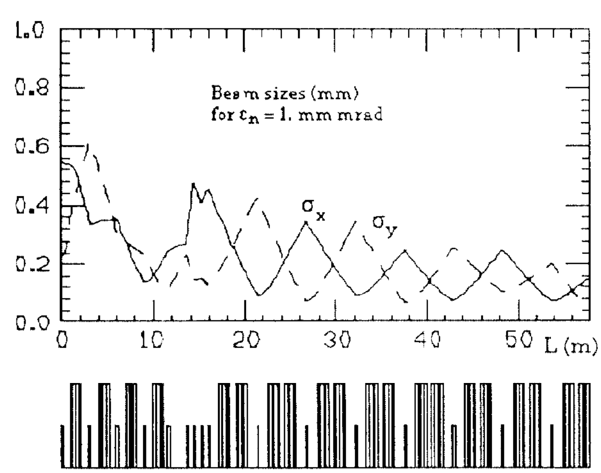

Fig. 2 - Transverse beam sizes along the linac.

Beam dynamics computations [7), 11)] show that for worst-case parameters (Q = 15 nC and σ_l = 1 cm) the emittance degradation is always less than 1% and is therefore negligible. The advantage of the low -frequency structure is here most evident. Parasitic energy losses and energy spread are also very small, as shown in Table III.

Table III - Overall parasitic energy loss and energy spread

Bunch Length, σ_l [mm]	3	5	10
Energy loss / cell [keV]	.44 (.41)	.38 (.29)	.29
Overall energy loss [keV]	35 (33)	30 (23)	23
Energy spread / cell [keV]	.22	.18	.13
Overall energy spread [keV]	18.	14.	10.

Values in parentheses are TBCI computations.

The electron beam is then brought to the main Linac Section, L2, through an isochronous achromatic channel that includes all splitter and combiner devices required to handle the primary and the recirculated electron beams.

RF installations, refrigeration plant, vacuum and control systems are described in detail in Reference 7). The overall required plug-power inventory adds up to less than 2 MW.

References

1) Proc. 'Discussion Meeting on SC Linear Accelerators'; Frascati, Oct. 1986

2) Proc. 'Discussion Meeting on Physics possibilities of a high luminosity e^+e^- facility of up to 12 GeV', Frascati, Apr. 1987.

3) A. Aragona et al., 'Status of the LISA SC Linac Project', This Conference.

4) Proc. Courmayeur, 14 - 18 December 1987, E. De Santis, M. Greco, M. Piccolo and S. Tazzari Eds., Italian Phys. Soc., Conf. Proc. 9, 1988.

5) 'ARES Design Study, The Machine', LNF-90/005 (R), Frascati, Jan 1990.

6) 'Proposal for a Φ-Factory', LNF-90/031(R), Frascati, April 1990.

7) 'The ARES SC Linac', LNF - 90/035(R), May 1990, and references.

8) S. Bartalucci et al., 'Design criteria and lattice of a Φ-Factory storage ring in Frascati', This Conference.

9) ARES Cavities Group, 'R&D on SC cavities for ARES', This Conference.

10) P. Michelato, C.Pagani, A.Peretti, L.Serafini, 'Design of the SC Laser-driven Injector for ARES', This Conference.

11) S. Bartalucci, C.Biscari, L.Palumbo, B.Spataro, 'Study of Beam Transport and dynamics in the ARES SC Linac', This Conference.