The Low-Power SPL (LPSPL)

Frank Gerigk

Beam'07, 1-5 October 2007

Outline

- requirements & basic parameters,
- linac layout,
- RF system & cryo-modules,
- civil engineering,
- outlook.

Motivation

upgrade of the LHC proton injector chain:

- remove reliability concerns in the chain,
- provide a beam suitable for all foreseen LHC upgrade scenarios,

provide an injector that can be upgraded to supply protons for:

- neutrino physics,
- Eurisol/ISOLDE upgrades,
- performance improvement for SPS fixed target physics,

➡ see R. Garoby (Tuesday, 9:00 this workshop)

Baseline parameters

low-power operation (LPSPL): injection into PS2

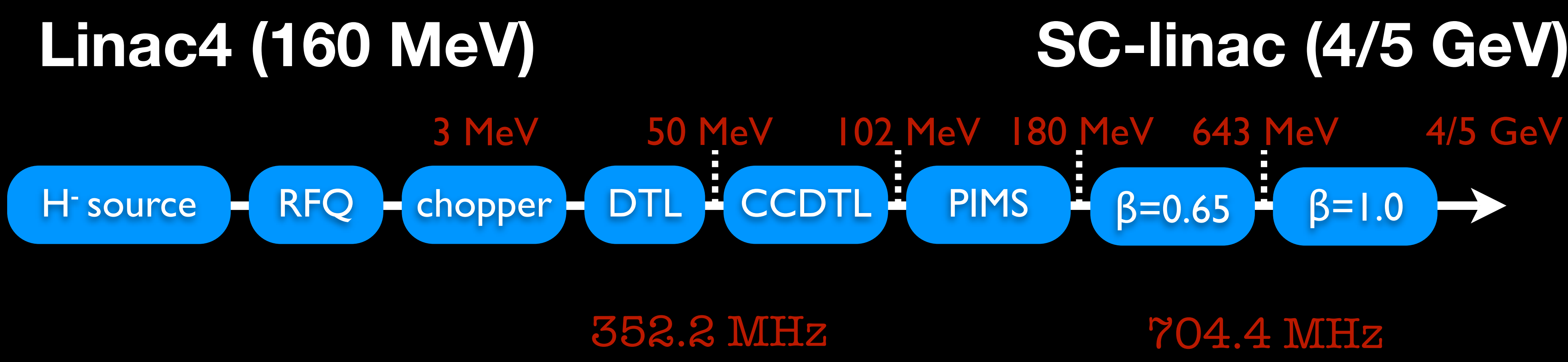
- 1.5 x 10^{14} particles per pulse (H^-), 1 Hz (design for 2 Hz),
- 4 GeV, 0.2 MW
- 1.2 ms pulse length for 20 mA average pulse current.

high-power operation (SPL): PS2 plus high-power

- > 1.0 x 10^{14} particles per pulse (H^-), 50 Hz,
- 5 GeV, 4 MW,
- 0.4 ms pulse length for 40 mA average current.

SPL machine layout

- Linac4 will inject at 160 MeV into the PSB,
- during construction and commissioning of the LPSPL, Linac4 will continue as PSB injector and provide beam to commission SPL/PS2,
- when PS2 is running, the “switching” area will be replaced with a 160-180 MeV normal conducting linac.



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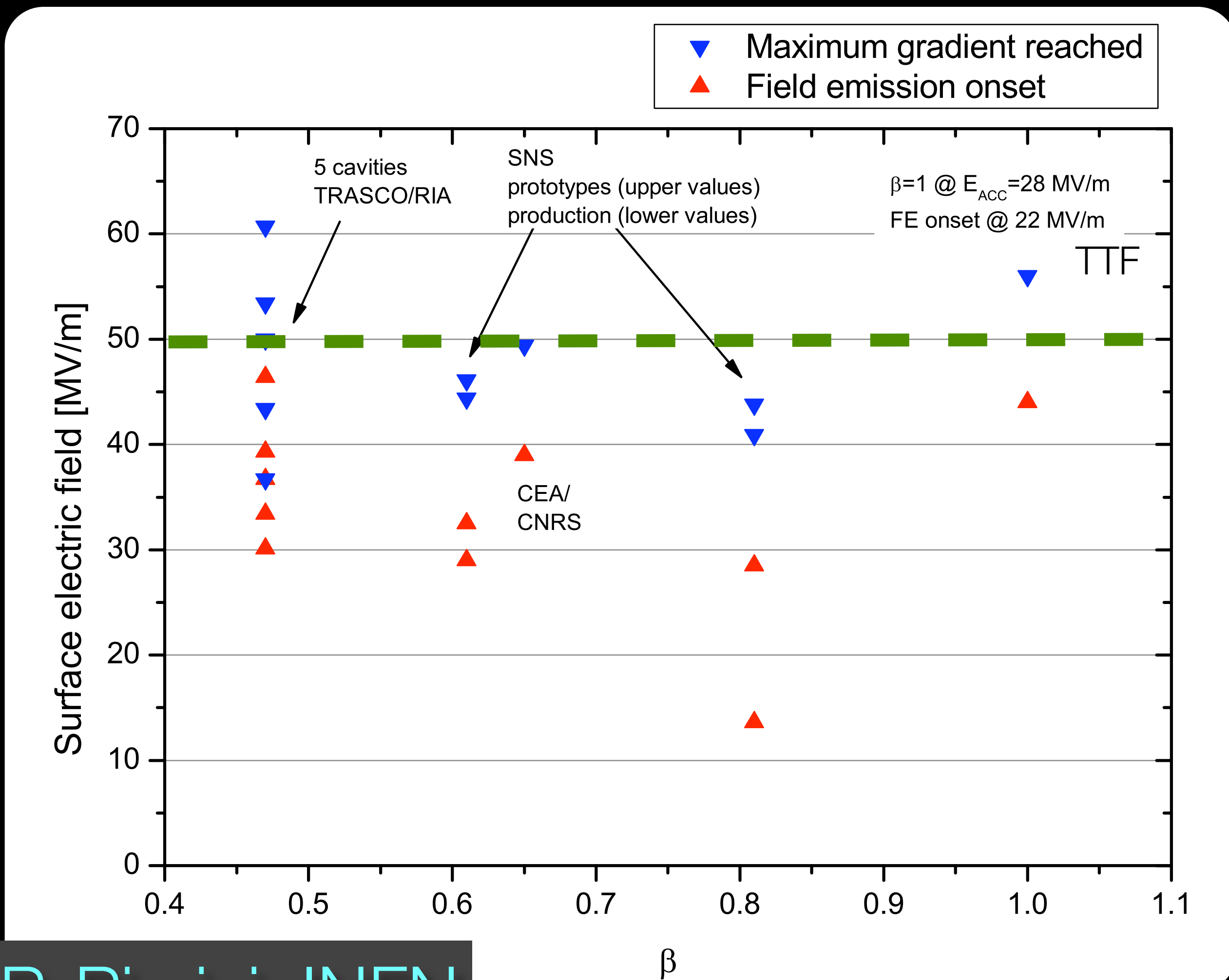
main parameters

SPL type	full-power	low-power
E [GeV]	5.0	4.0
P_{beam} [MW]	>4	0.192
f_{rep} [Hz]	50	2
$I_{average}$ [mA]	40	20
t_{pulse} [ms]	0.4	1.2
$n_{protons/pulse}$ [10^{14}]	1.0	1.5
Max. filling time PS2 [ms]	0.6	1.2
$n_{klystron}$ (Linac4 + SPL)	19+53	19+24
$n_{SC\ cavities}$	234	194
inst. $P_{RF(peak)}$ [MW]	220	100
$P_{facility}$ [MW]	38.5	4.5
$P_{cryo,\ electric}$ [MW]	4.5	1.5
T_{cryo} [K]	2	2
length [m]	534	459

SC cavities

peak surface fields (electric)

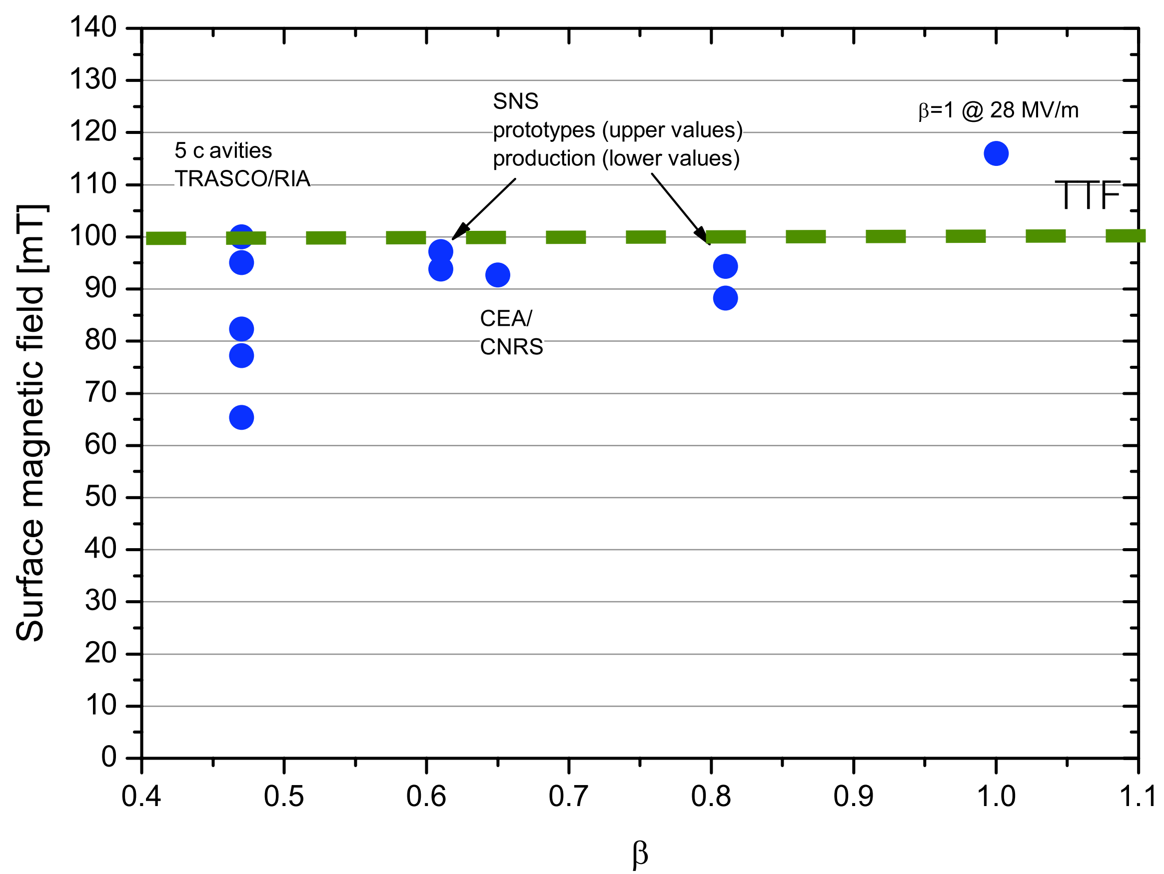


P. Pierini, INFN

- max. surface fields are based on measured cavity performance,
- surface fields: 50 MV/m and 100 mT are challenging but seem realistic for pulsed operation,
- **chosen gradients: 19/25 MV/m** for β=0.65/1

SC cavities

peak surface fields (magnetic)



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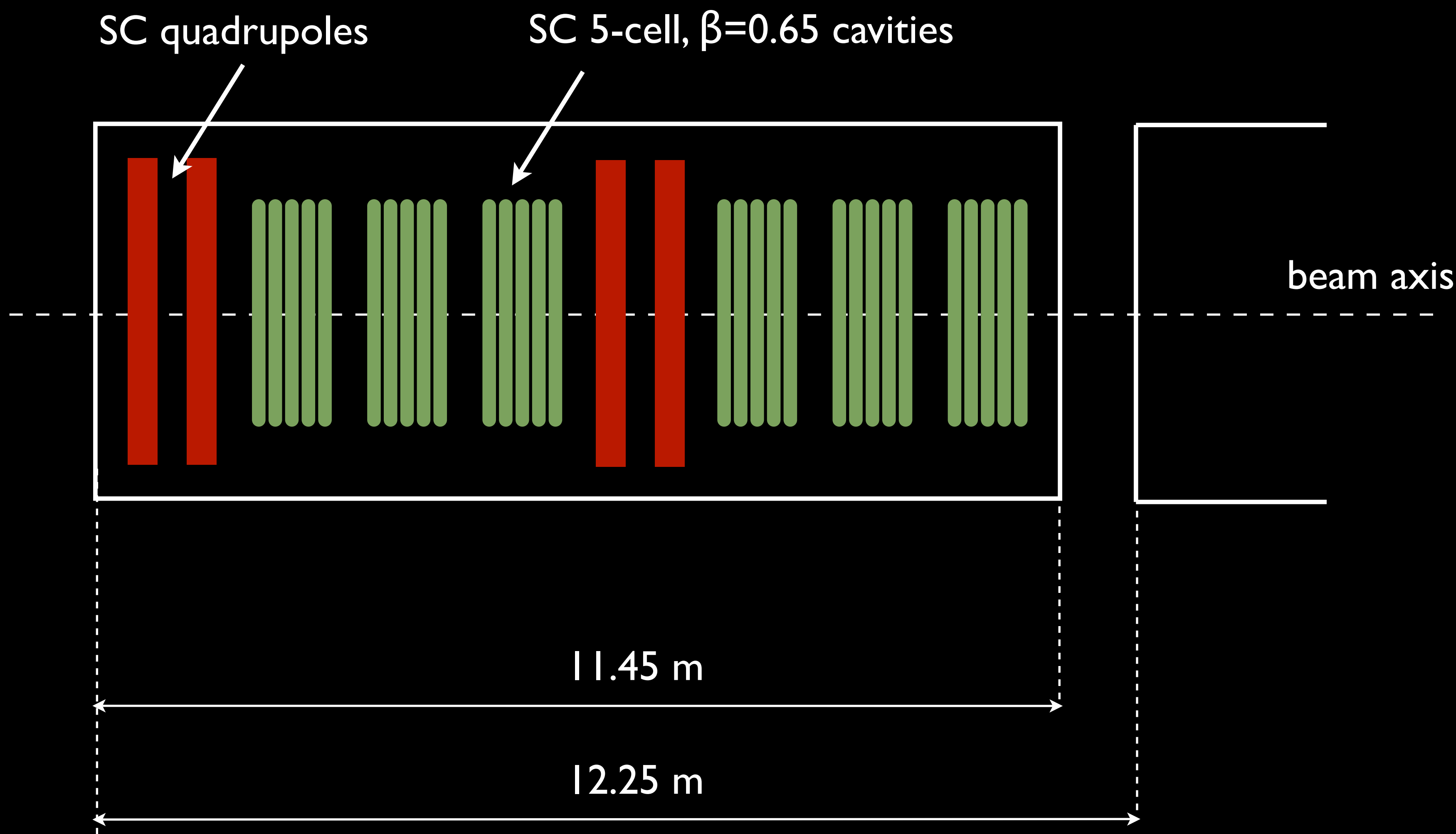
Basic β=0.65 cryo-module

doublet focusing, 2 periods per module



Beam dynamics incl. error studies and steering: R. Duperrier, D. Uriot, CEA

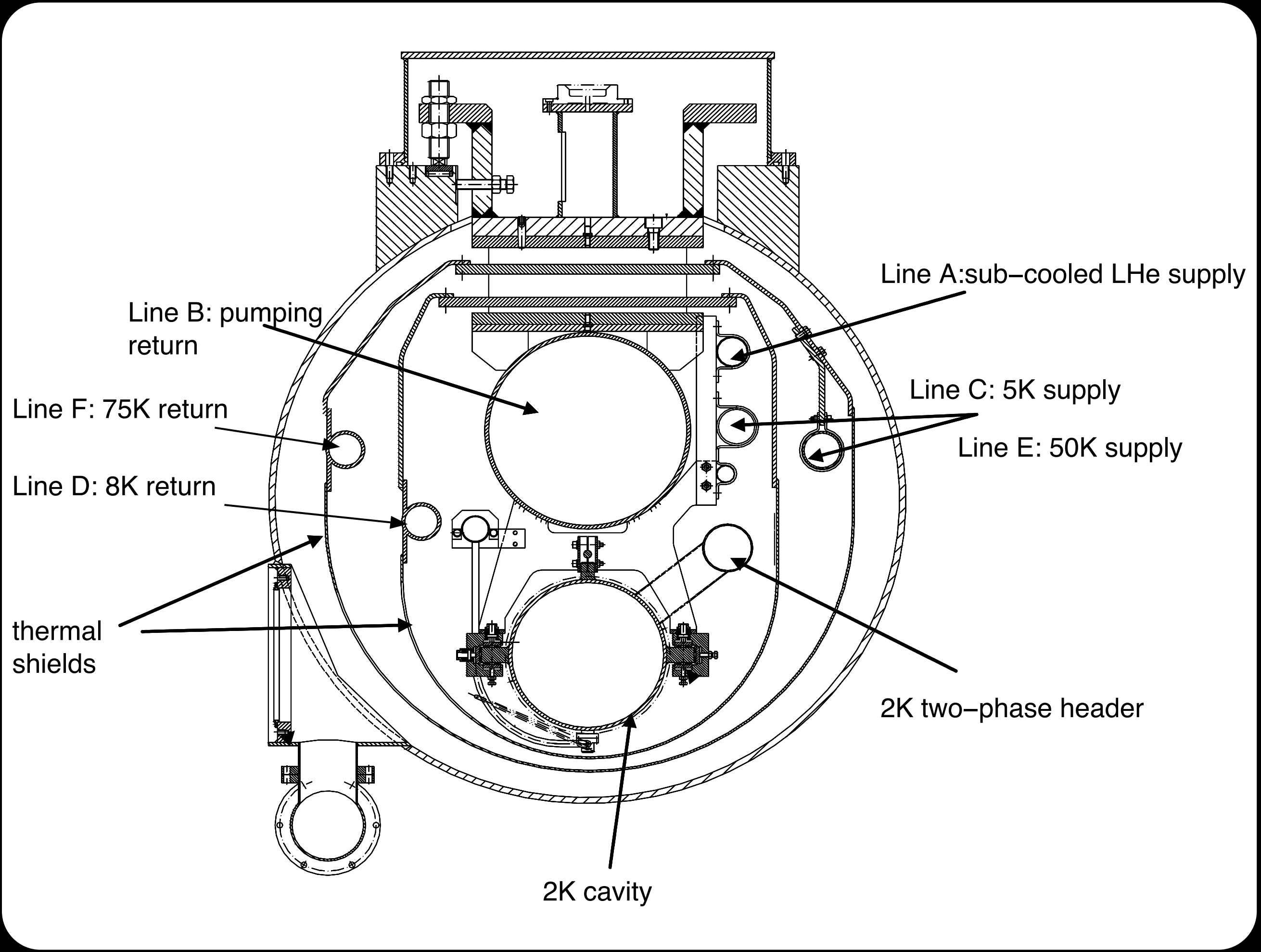
Basic β=1 cryo-module

doublet focusing, 1 period per module

Beam dynamics incl. error studies and steering: R. Duperrier, D. Uriot, CEA

SPL cryo-module

principle: start from the TESLA/ILC design...



- long modules with a low number of cold/ warm transitions and low static losses,
- cold quadrupoles,
- high packing factor,
- requires high reliability of all components and several years of R&D!

SPL cryo-module & RF system

in preparation for a viable design we need to:

- design and construct a full-scale cryo-module (adapting the TESLA/ ILC approach to 704 MHz),
- test cavities in the cryo-module at full power and full duty cycle (LPSPL & SPL),
- test the complete RF system (5 MW pulsed klystron @ 704 MHz, RF splitting: up to 16 cavities powered by one klystron!),
- test high-power phase shifters, control system, cavity tuning, etc.
- collaboration with DESY/INFN/CEA/IN2P3 mandatory!

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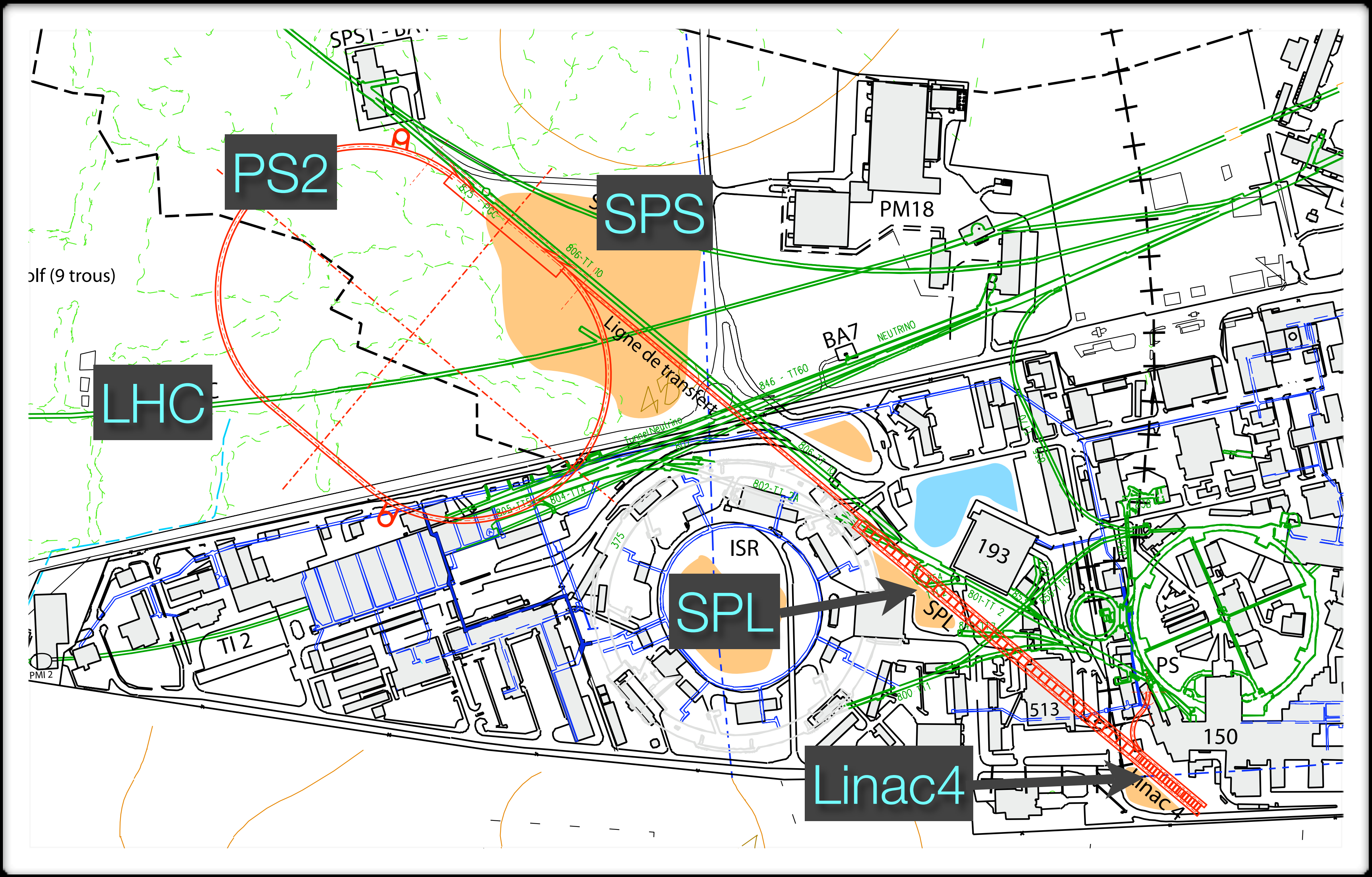
bids for funding of cryo-module development and RF test stand (FP7, etc) are in preparation.

Site layout SPL



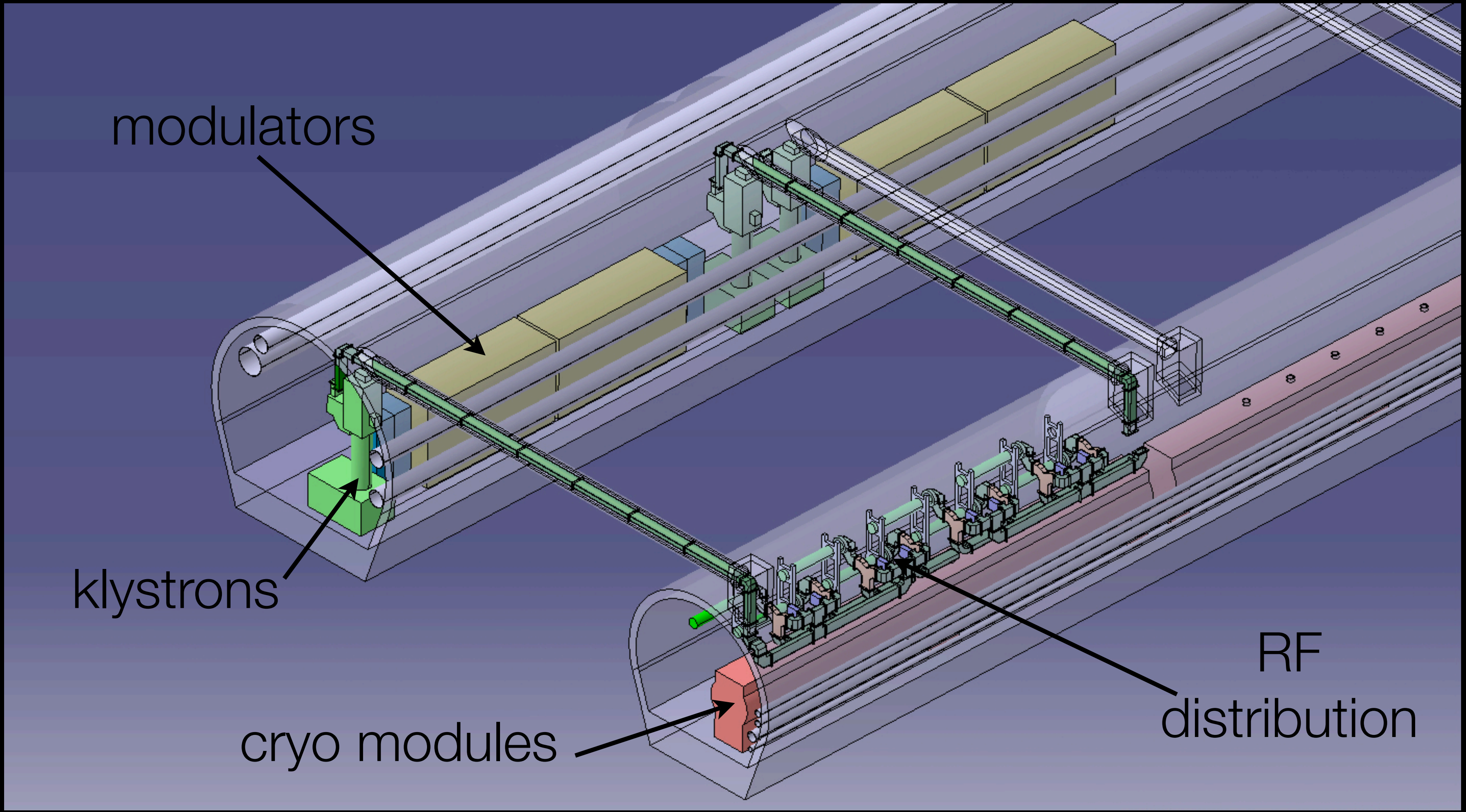
Installation LPSPL/SPL

- All underground installations like: tunnels, water pipes, cryogenic lines, cryostats, electricity supplies are designed for the multi-megawatt SPL,
- For the LPSPL ~half the number of klystrons/power supplies is installed, services (*cryo-plant, cooling towers, electrical substations*) and surface buildings are designed for low duty cycle & lower current, space foreseen for full-power SPL,

➡ e.g: for the LPSPL the complete power supplies fit into the klystron tunnel, for the full SPL half of the equipment is above ground,

- For the full SPL the installations and services need to be upgraded/replaced.

Preliminary tunnel layout



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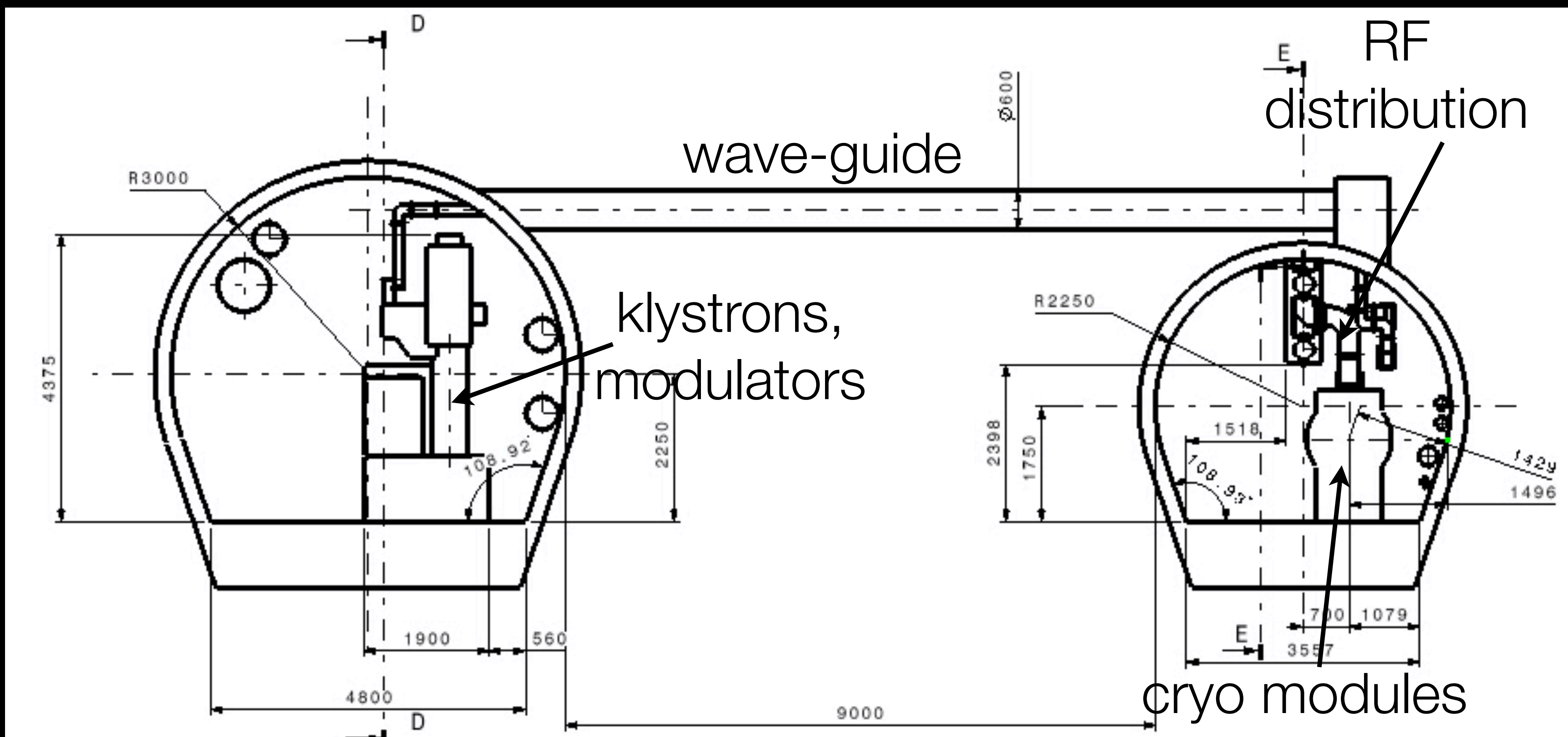

klystron tunnel
(diameter: 6 m)

accelerator tunnel
(diameter: 4.5 m)

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staged transition from LPSPL to SPL

phase 1: upgrade from 2 to 50 Hz

- 20 mA, 4 GeV, 1.6 MW,
- provide:
  - PS2: 1 Hz, 1.2 ms
  - high-power: 50 Hz, 0.4 ms,

➡ replace all klystron modulators and power supplies (including Linac4),

➡ new infrastructure for electricity, water, cryogenics,

  ➡ new surface buildings.

staged transition from LPSPL to SPL

phase 2: upgrade from 20 to 40 mA, 4 to 5 GeV

- 40 mA, 5 GeV, 50 Hz, 4 MW,
- provide:
  - PS2: 1 Hz, 1.2 ms,
  - high power: 50 Hz, 0.4 ms,

➡ install 8 additional cryo-modules,

➡ double the number of klystrons & power supplies in the SC part,

what we have done so far

- 2006 SPL conceptual design report remains valid (CERN-AB-2006-081, now different energy and a preliminary stage),
- Linac4 is approved,
- a cost & performance comparison of LPSPL and an RCS was published in May’07 (CERN-AB-2007-014-PAF),
- the LPSPL is now the baseline scenario for LHC proton injector upgrade,
- established a CERN working group for SPL high-power RF tests (cryogenics, RF, power, ...),
- first tunnel integration exercise is completed,
- consistent layout for a completely new proton injector chain is found (Linac4, SPL, PS2),

what comes next...

- finalise the siting exercise: feasibility study and civil engineering cost estimate for the end of 2007,
- FP7 bid for the construction of a full cryo-module with 2 cavities (+ 6 dummies?) in collaboration with CEA, INFN (?), DESY, IN2P3,
- FP7 bid for a high-power RF test stand at CERN, making use of the existing infrastructure in SM18 and equipping it for 704 MHz (5 MW klystron, RF distribution, modulator, etc),
- ... *and of course*: high-duty cycle H- source, SC quadrupoles, detailed beam dynamics, radiation protection, etc
- elaborate a technical design report including costs for a project decision in 2011/12.