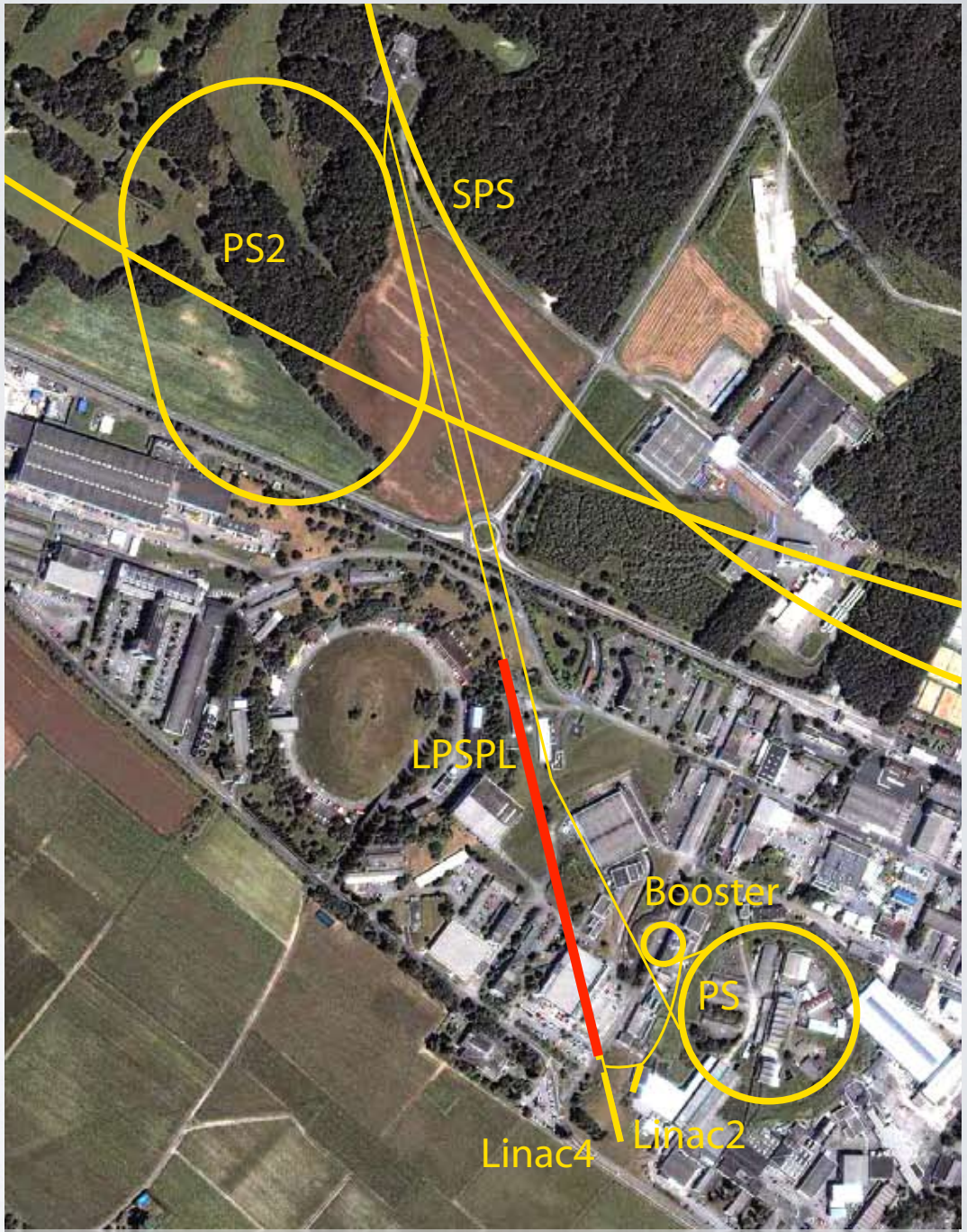
sLHC

SPL STATUS OF ARCHITECTURE & OPEN QUESTIONS

F. Gerigk

3d SPL collaboration meeting

11-13 Nov. 2009

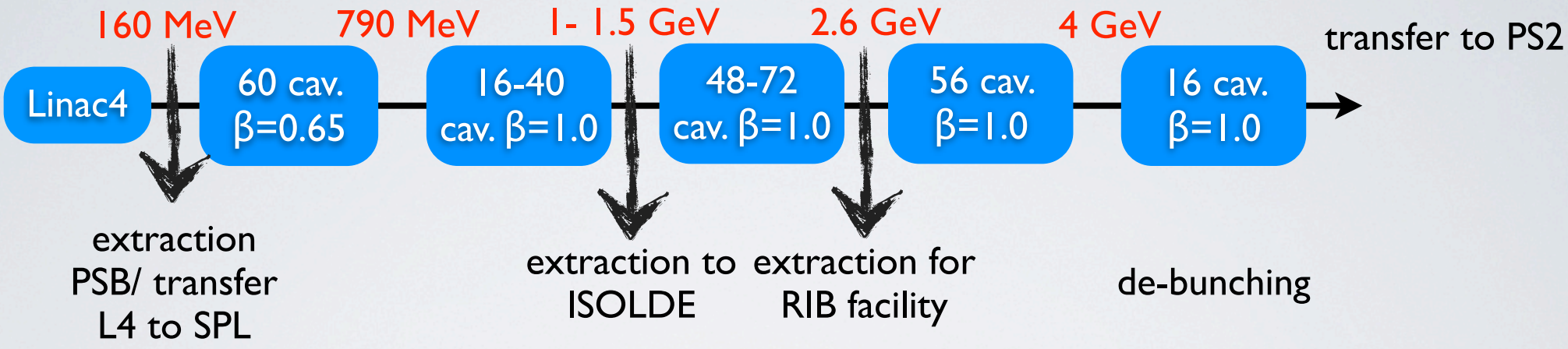


http://www.cern.ch/project-spl

OUTLINE

- **overview of the accelerator,**
- **main parameters,**
- **open questions to:**
  - cryogenics,
  - beam dynamics
  - RF,
  - laser stripping.

SPL LAYOUT: LP-SPL

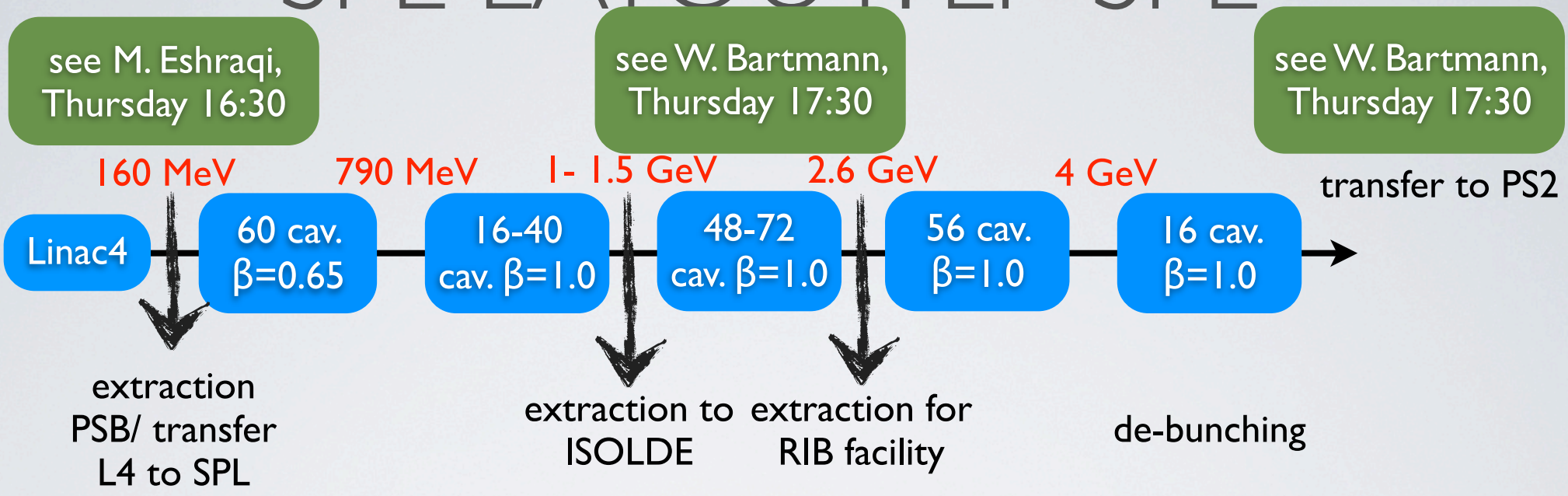


- construction of Low-Power SPL together with PS2,
- main users: PS2 (LHC), ISOLDE upgrade, EURISOL-0 (?),
- decision on construction expected for 2012.

kinetic energy	4 GeV
beam power (@ 4 GeV)	0.16 MW
repetition rate	0.6 - 2 Hz
beam pulse length	0.9 ms
average pulse current	20 mA
protons p. pulse	$1.1\ 10^{14}$
length (SC linac, nominal)	450 m

SPL machine architecture, F. Gerigk, cryo-segmentation workshop, Nov. 2009

SPL LAYOUT: LP-SPL



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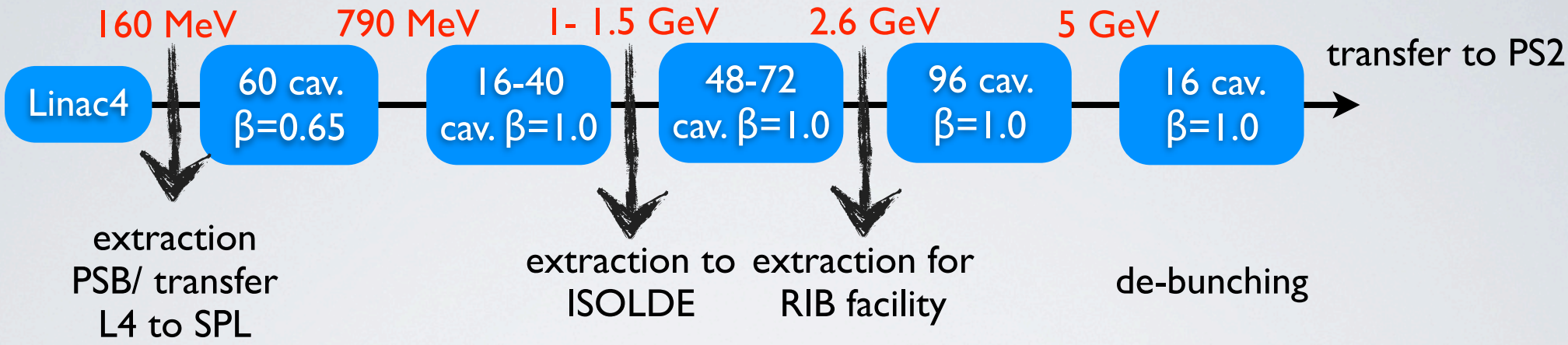
SPL LAYOUT: HP-SPL



- addition of klystrons,
- cavities from 4 to 5 GeV,
- replacement of all modulators,
- upgrade of electric/cryogenic infrastructure,
- possible high-power users: EURISOL, neutrinos, LHeC.

kinetic energy	5 GeV
beam power (@ 4 GeV)	3-8 MW
repetition rate	50 Hz
beam pulse length	0.4-1.2 ms
average pulse current	20/40 mA
protons p. pulse	1-3 10^{14}
length (SC linac, nominal)	525 m

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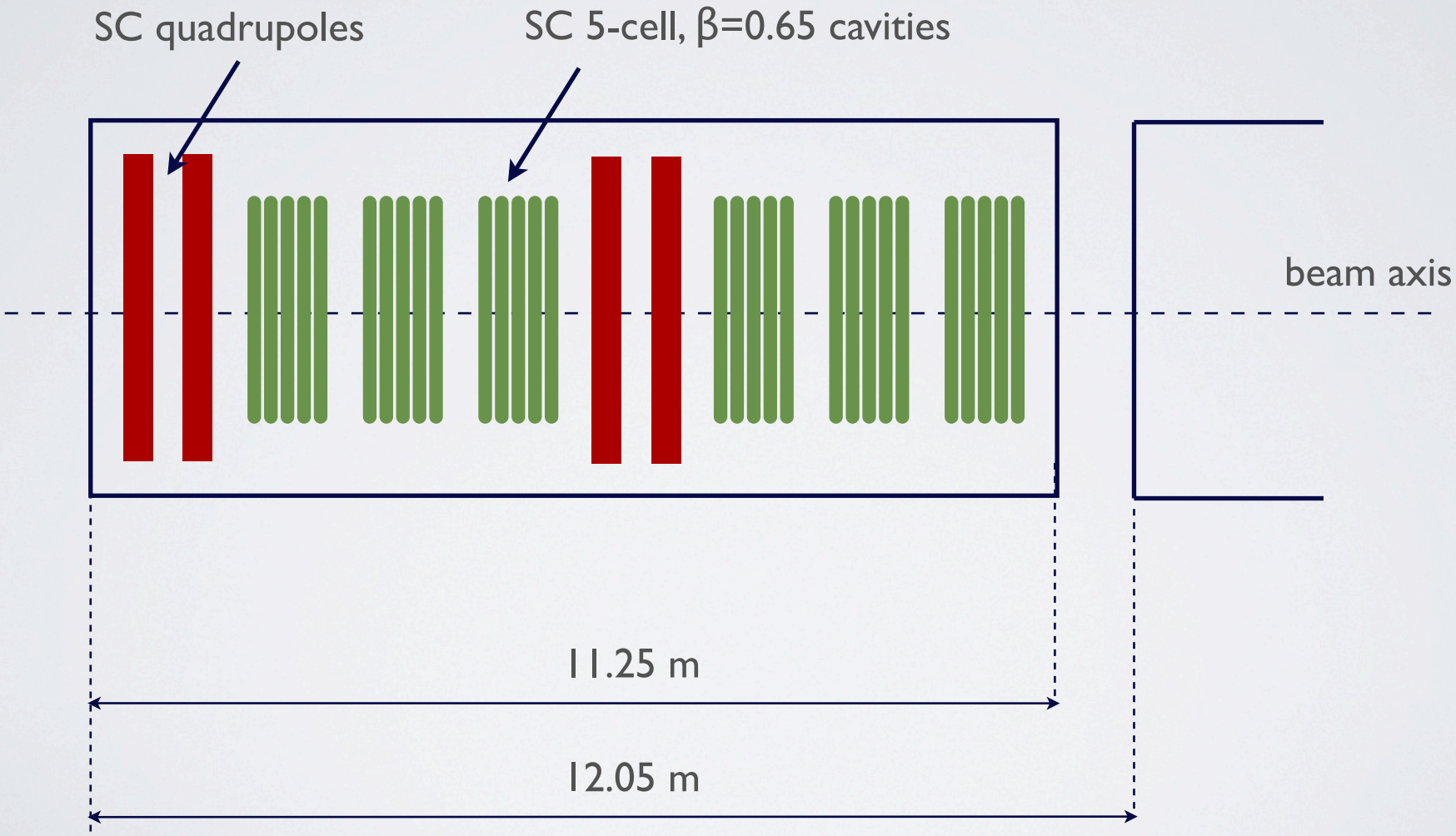
LOW-BETA CRYO-MODULE

baseline: doublet focusing, 6 cavities (704 MHz) per cryo-module



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HIGH-BETA CRYO-MODULE

baseline: doublet focusing, 8 cavities (704 MHz) per cryo-module

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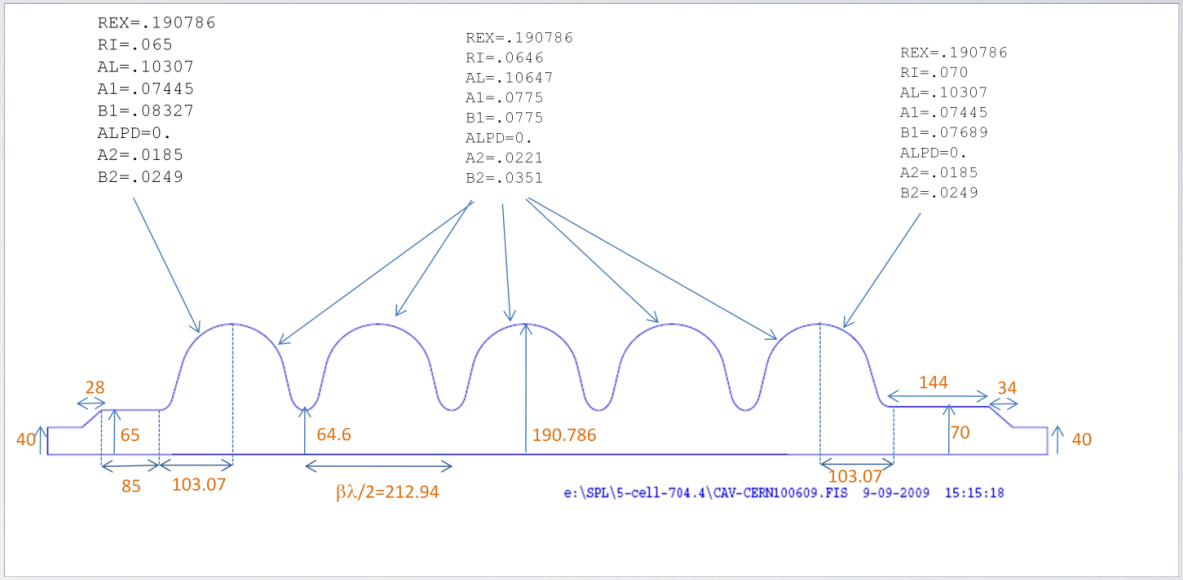
NOMINAL CAVITY DESIGN

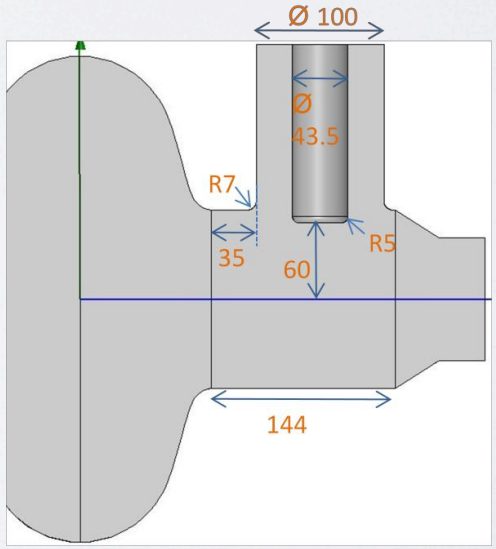
DIMENSIONS DE LA CAVITE SPL β = 1

DESIGN CEA-SACLAY



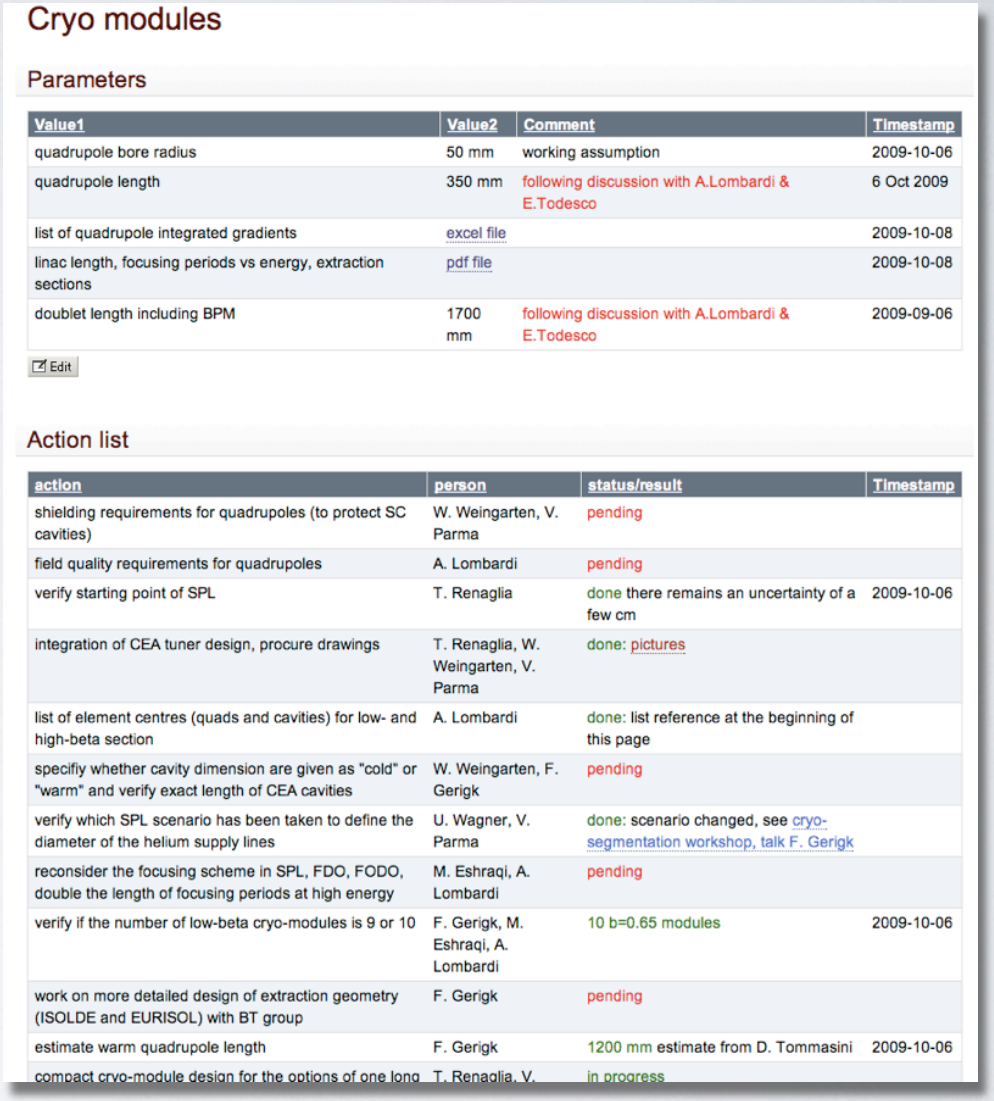
β=1, TWIKI site: https://twiki.cern.ch/twiki/bin/view/SPL/Cavitydesign

POSITION ET DIMENSIONS DU COUPLEUR DE PUISSANCE



REFERENCES FOR CRYO-MODULE DESIGN

https://twiki.cern.ch/twiki/bin/view/SPL/CryoModules



Cryo modules

Parameters

Value1	Value2	Comment	Timestamp
quadrupole bore radius	50 mm	working assumption	2009-10-06
quadrupole length	350 mm	following discussion with A.Lombardi & E.Todesco	6 Oct 2009
list of quadrupole integrated gradients	excel file		2009-10-08
linac length, focusing periods vs energy, extraction sections	pdf file		2009-10-08
doublet length including BPM	1700 mm	following discussion with A.Lombardi & E.Todesco	2009-09-06

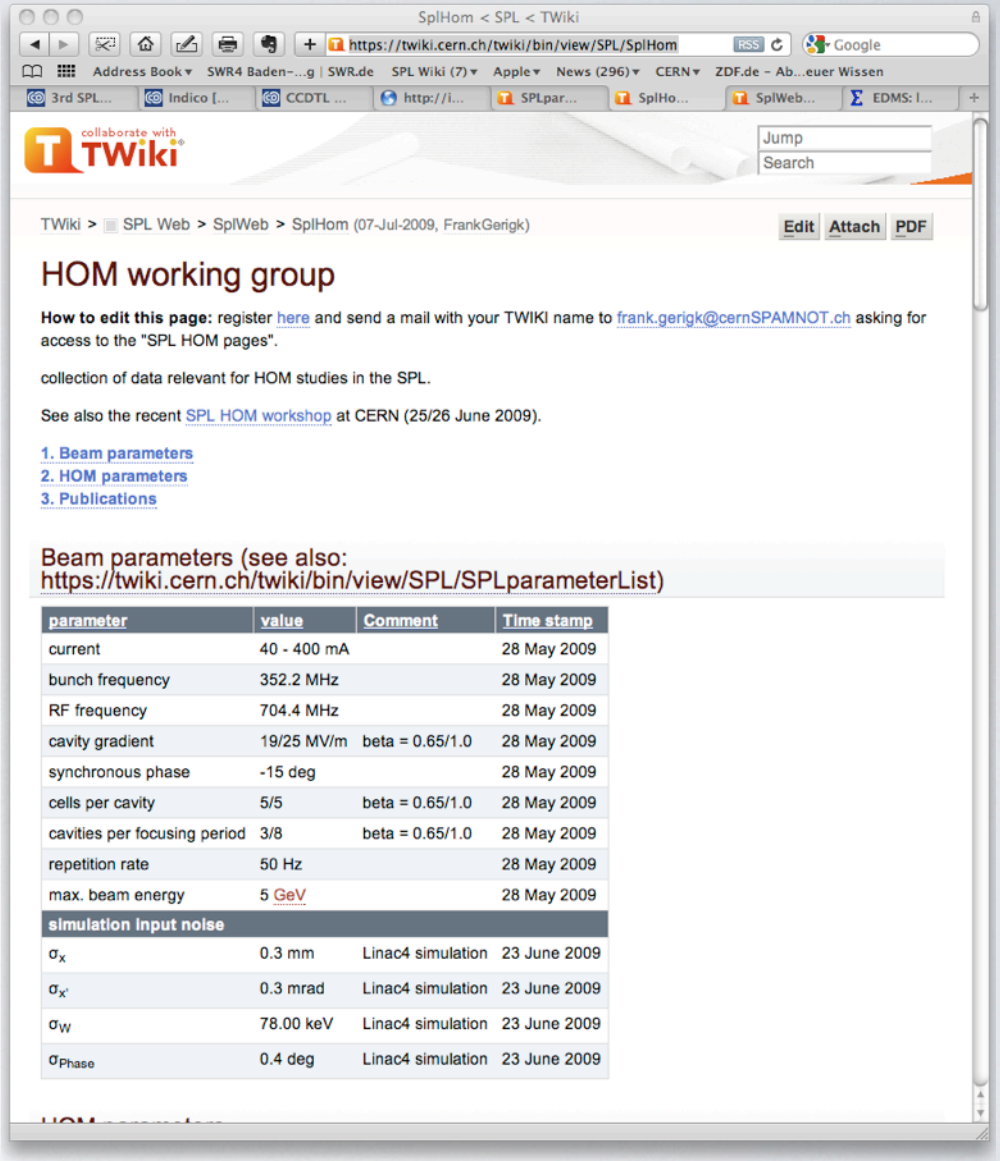
Edit

Action list

action	person	status/result	Timestamp
shielding requirements for quadrupoles (to protect SC cavities)	W. Weingarten, V. Parma	pending	
field quality requirements for quadrupoles	A. Lombardi	pending	
verify starting point of SPL	T. Renaglia	done there remains an uncertainty of a few cm	2009-10-06
integration of CEA tuner design, procure drawings	T. Renaglia, W. Weingarten, V. Parma	done: pictures	
list of element centres (quads and cavities) for low- and high-beta section	A. Lombardi	done: list reference at the beginning of this page	
specifiy whether cavity dimension are given as "cold" or "warm" and verify exact length of CEA cavities	W. Weingarten, F. Gerigk	pending	
verify which SPL scenario has been taken to define the diameter of the helium supply lines	U. Wagner, V. Parma	done: scenario changed, see cryo-segmentation workshop, talk F. Gerigk	
reconsider the focusing scheme in SPL, FDO, FODO, double the length of focusing periods at high energy	M. Eshraqi, A. Lombardi	pending	
verify if the number of low-beta cryo-modules is 9 or 10	F. Gerigk, M. Eshraqi, A. Lombardi	10 b=0.65 modules	2009-10-06
work on more detailed design of extraction geometry (ISOLDE and EURISOL) with BT group	F. Gerigk	pending	
estimate warm quadrupole length	F. Gerigk	1200 mm estimate from D. Tommasini	2009-10-06
compact cryo-module design for the options of one long	T. Renaglia, V.	in progress	

REFERENCES TO HOMS

https://twiki.cern.ch/twiki/bin/view/SPL/SplHom



parameter	value	Comment	Time stamp
current	40 - 400 mA		28 May 2009
bunch frequency	352.2 MHz		28 May 2009
RF frequency	704.4 MHz		28 May 2009
cavity gradient	19/25 MV/m	beta = 0.65/1.0	28 May 2009
synchronous phase	-15 deg		28 May 2009
cells per cavity	5/5	beta = 0.65/1.0	28 May 2009
cavities per focusing period	3/8	beta = 0.65/1.0	28 May 2009
repetition rate	50 Hz		28 May 2009
max. beam energy	5 GeV		28 May 2009
simulation input noise			
σ_x	0.3 mm	Linac4 simulation	23 June 2009
$\sigma_{x'}$	0.3 mrad	Linac4 simulation	23 June 2009
σ_W	78.00 keV	Linac4 simulation	23 June 2009
σ_{Phase}	0.4 deg	Linac4 simulation	23 June 2009

SPL parameters

operation type	low-power	high-power low-current	high-power high-current
E [GeV]	4	2.5 (**or** 5)	2.5 (**and** 5)
P_{beam} [MW]	0.192	3 (6)	4 (+4)
f_{rep} [Hz]	2	50	50
$I_{average}$ [mA]	0-20	0-20	0-40
t_{pulse} [ms]	≤0.9	≤1.2	≤0.8 (+0.4)
$n_{protons/pulse}$ [10^{14}]	≤1.1	≤1.5	≤2 (+1)
main user	PS2/ISOLDE	PS2/neutrinos/ EURISOL	PS2/neutrinos/ EURISOL
			+ LHeC (tbd)

each option has impact on the civil engineering and technical choices for the LP-SPL!

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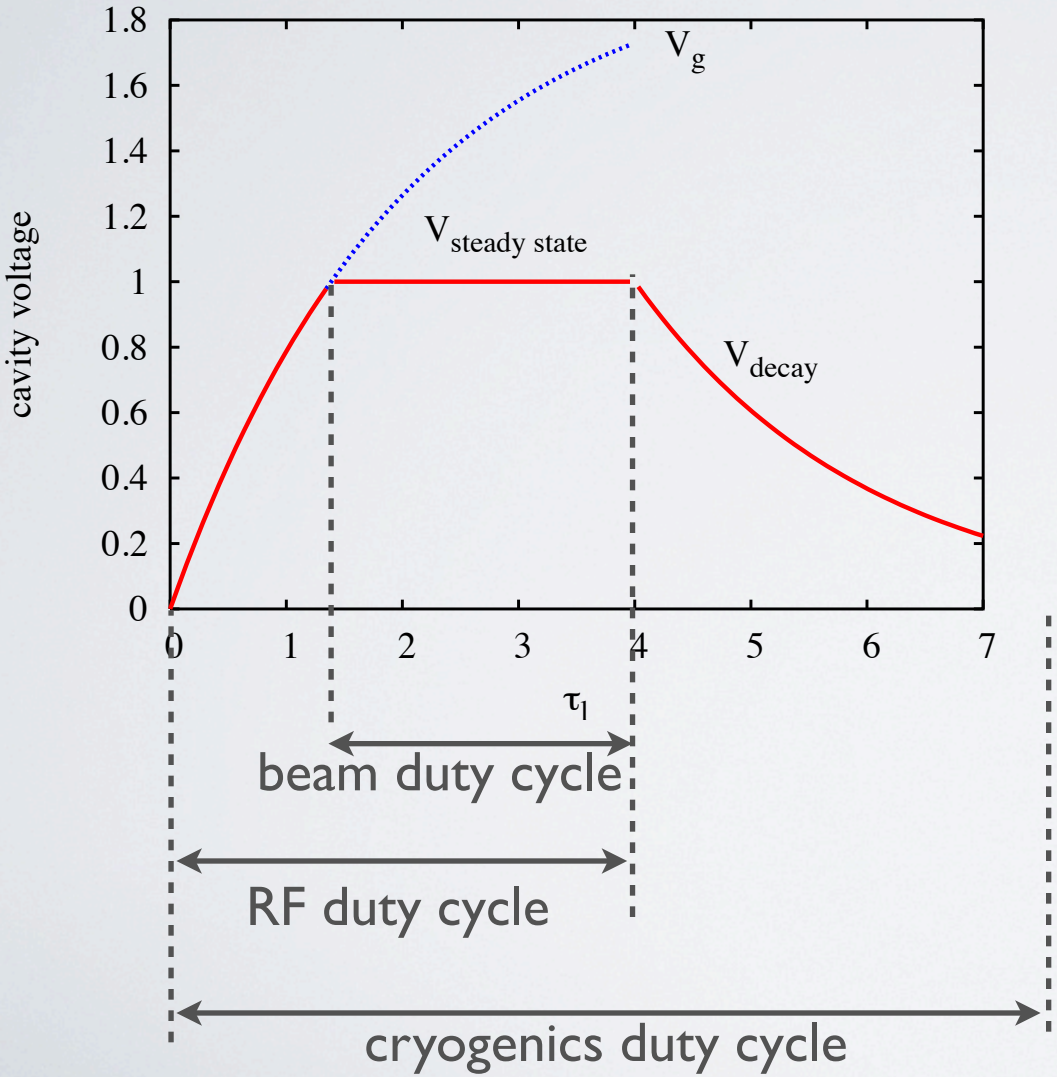
DIFFERENT DESIGN PARAMETERS FOR RF, CRYO, BEAM DYNAMICS



- **beam duty cycle:** for dumps, collimators, diagnostics, radiation protection, HOMs ➜ nom. design for high-current/high-power.
- **RF duty cycle:** modulators, klystrons, RF distribution, LLRF ➜ nom. design for low & high-current/high power.
- **cryo-duty cycle:** cryo-plant, cryo-modules, RF coupler, RF loads ➜ nom. design for low-current/high-power.

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DESIGN PARAMETERS FOR BEAM DYNAMICS

	LP-SPL	HP-SPL
particle species	H^-	H^-
max. gradient (β=0.65/β=1)	19.3/25 MV/m	19.3/25 MV/m
RF frequency	704 MHz	704 MHz
average pulse current	20 mA	40 mA
peak current	32 mA	64 mA
max. chopping ratio	5 (full) + 3 (empty)	5 (full) + 3 (empty)
max. repetition rate	2 Hz	50 Hz
beam pulse length	1.2 ms	0.4 ms
beam duty cycle	0.24%	2%

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NEW MAX. DESIGN PARAMETERS FOR CRYOGENICS (HP-SPL)

$P_{2K,\ HOM+coupler}$	0.43 x $P_{2K,\ diss}$
$P_{2K,\ static}$	0.3055 W/m
$P_{5\text{-}8K,\ static}$	1.31 W/m
$P_{50\text{-}75K,\ static}$	7.67 W/m
$P_{5\text{-}8K,\ HOM}$	6.1 W/module
$P_{50\text{-}75K,\ HOM}$	102 W/module
$P_{beam\ loss}$	1 W/m

	LP-SPL	HP-low c.
max. gradient (β=0.65/β=1)	19.3/25 MV/m	19.3/25 MV/m
RF frequency	704 MHz	704 MHz
Q_0 (β=0.65/β=1)	5.8/8.4 x 10^9	5.8/8.4 x 10^9
(R/Q) (β=0.65/β=1)	**320/525**	**320/525**
cells per cavity	5	5
beam current	20 mA	**20 mA**
repetition rate	2 Hz	50 Hz
beam pulse length	0.9 ms	**1.2 ms**
beam duty cycle	0.18%	**6%**
cryogenics duty cycle	0.36%	**10.6%**
$P_{average}$ /mod.* (β=0.65/β=1)	(14+3.5)/(22+4.4) W	**97/215 W**

*6/8 cavities w/o magnets

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DESIGN PARAMETERS FOR RF

	LP-SPL	HP-low-current	HP-high-current
max. gradient (β=0.65/β=1)	19.3/25 MV/m	19.3/25 MV/m	19.3/25 MV/m
RF frequency	704 MHz	704 MHz	704 MHz
average pulse current	20 mA	20 mA	40 mA
max. repetition rate	2 Hz	50 Hz	50 Hz
beam pulse length	≤0.9 ms	≤1.2 ms	≤ 0.8 (+0.4) ms
RF pulse length (filling time + beam pulse)	≤1.8 ms	≤2.1 ms	≤ 1.21 (+0.4) ms
RF duty cycle (coupler matching for 20 mA)	0.4%	10.1%	6.1 (+2)%
power per cavity (β=0.65/1)	80-275/250-500 kW	80-275/250-500 kW	160-550/500-1000 kW
power p. c. (incl. controls)	100-360/325-650 kW	100-360/325-650 kW	200-720/650-1300 kW

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COMPARISON WITH ESS (T.B.C)

	ESS nom.	LP-SPL	ESS ult.	HP-high-current
P_{peak} p. cavity (MW)	1	0.5		1
RF pulse length (ms) (ESS: 15 MV/m, 75-50 mA)	2.3	1.8		1.2 (1.6)
Repetition rate (Hz)	20	2	40	50
Duty factor (%)	4.6	0.4	9.2	6.1 (8.1)
field stability (%/deg) after correction with LLRF	0.5	0.5	0.5	0.5
Pulse to pulse stability (%)	0.5	0.5	0.5	0.5
$P_{Klystron,peak}$ (MW), + distribution + LLRF	1.4-1.5	0.8		1.4-1.5
Klystron efficiency (%)	60%	65%		50-55%
Output power modulator (MW)	2.5	1.2		

compiled by K. Rathsman

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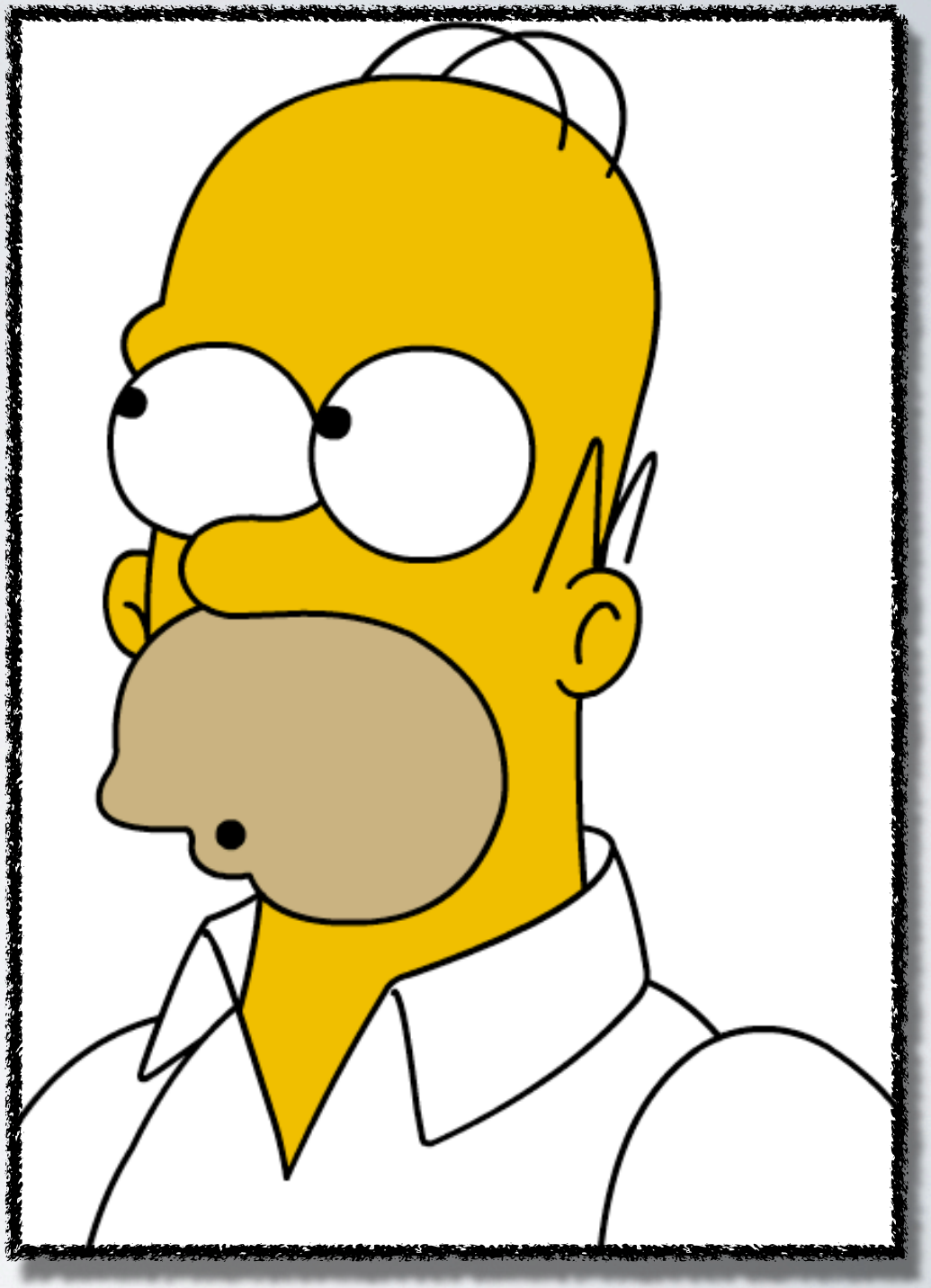
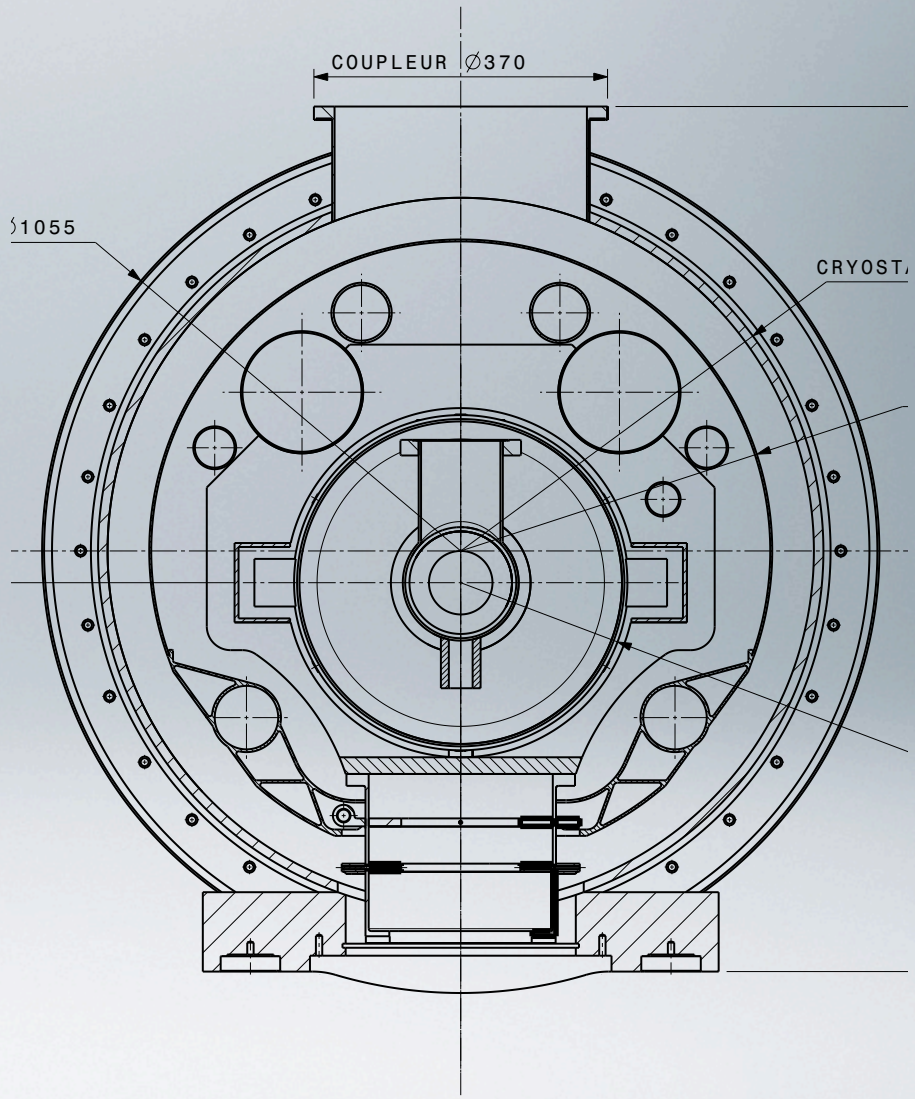
CONFUSED?

Let us know and we will try to clarify the latest parameter sets!



OPEN ISSUES

... which need urgent answers!



QUESTIONS ON GRADIENT

- **gradient of 25 MV/m @ β=1**, 20 MV/m promises higher yield!
- **4 or 5 GeV as final energy**, it seems that 4 GeV is sufficient for neutrinos!

plan for 4 GeV assuming 20 MV/m, and consider 25 MV/m and 5 GeV as ultimate scenario?

topic #3 for joint session!
Thursday 15:00 - 15:30

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PROPOSAL FOR NOMINAL/ ULTIMATE PARAMETERS

nominal	
max. output energy	**4 GeV**
max. gradient (β=0.65/β=1)	**15.4/20 MV/m**
RF frequency	704 MHz
Q_0 (β=0.65/β=1)	**??**5.8/8.4 x 10^9**??**
(R/Q) (β=0.65/β=1)	320/525
beam current	20 mA
repetition rate	50 Hz
beam pulse length	**0.9 ms**
beam duty cycle	**4.5%**

ultimate	
max. output energy	**5 GeV**
max. gradient (β=0.65/β=1)	**19.3/25 MV/m**
RF frequency	704 MHz
Q_0 (β=0.65/β=1)	**??**5.8/8.4 x 10^9**??**
(R/Q) (β=0.65/β=1)	320/525
beam current	20/40 mA
repetition rate	50 Hz
beam pulse length	**≤1.2 ms**
beam duty cycle	**6%**

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QUESTIONS TO CRYOGENICS

- pros and cons of separated cryo-modules vs long strings:
  - how often do we need to exchange/access modules?
  - most common faults?
  - can we have access to the inside of the modules without taking them out of the linac?
  - warm/cold magnets ➜ D. Tommasini, Thursday 16:30
- length needed for cold/warm transitions (important for design of extraction areas to ISOLDE/EURISOL,
- how easy is it to double the cryogenic load?

today WG3, 16:30-18:00

QUESTIONS TO BEAM DYNAMICS

- Diagnostics and alignment needs ➜ P. Posocco, Thursday 10:30 D. Missiaen, Thursday 11:10
- Lattice structure (nominal: FDO, FODO?, FODO with longer focusing periods at higher energy?) ➜ M. Eshraqi, Thursday 9:00
- Linac4/SPL transfer line: need for de-bunching after the linac? injection parameters for PS2/accumulator ring ➜ see W. Bartmann, Thursday 17:30

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ISOLDE BEAM EXTRACTION

- H^- extraction and immediate stripping, between 1 and 1.5 GeV,
- need a dump location for stripped electrons,
- space requirements?
- assumed to be at low duty cycle (even for HP-SPL),
- can we use the transfer line to ISOLDE for emittance measurements (transverse & longitudinal)?

  ➡need to define a measurement line,

  ➡integration of measurement line,

see W. Bartmann, Thursday 17:30

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EURISOL BEAM EXTRACTION

- H- extraction & transport (!) at 2.5 GeV, partial stripping to be used for beam splitting, large radii (~75 m),
- extraction area needs to accommodate warm/cold transitions, diagnostics and should ideally not be longer than one "missing" cryo-module,

see W. Bartmann, Thursday 17:30

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LASER STRIPPING AT PS2/ ACCUMULATOR INJECTION

- laser stripping seems very attractive but requires a small energy spread in the beam (and ideally short pulse lengths),
- a small spread can be produced at the expense of larger phase width (and vice versa)... but larger phase width needs longer laser pulses (assuming the laser is synchronised with the bunches)..
- in case of failing cavities, or changing cavity performance we may easily walk out of the accepted energy window, therefore we need to define:
  - maximum energy acceptance,
  - can the energy level be changed if the spread remains constant?
  - are we willing to choose "conservative" gradients in order to make laser stripping work?

topic #2 for joint session!
Thursday 15:00 - 15:30

URGENT QUESTIONS TO RF

- Decision on power splitting scheme.

see E. Ciapala, Wednesday 16:30

- Type of power source for low-energy section (IOTs, klystrons, phase-locked magnetrons, solid-state)?

see A. Dexter, Wednesday 17:00

- Can we put the klystrons on the surface? Is a wave-guide length of up to 80 m acceptable for LLRF?

meeting of CERN experts <2010

topic #1 for joint session! Thursday 15:00 - 15:30

NEED MORE INFORMATION?

general SPL TWIKI pages:
https://twiki.cern.ch/twiki/bin/view/SPL/SplWeb

all SPL related meetings in INDICO:
http://indico.cern.ch/categoryDisplay.py?categId=1893

still doubts?
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