sLHC

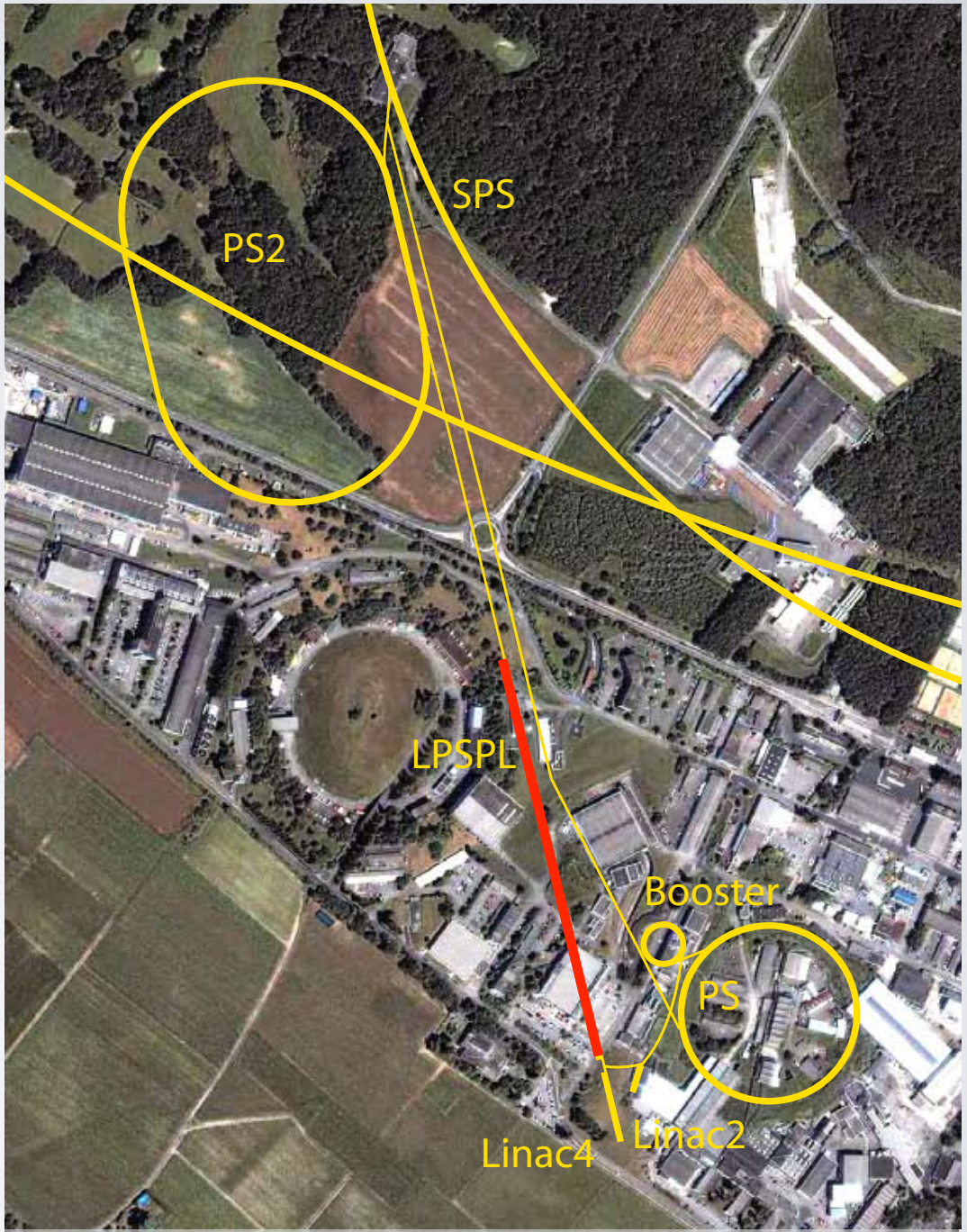
SPL MACHINE ARCHITECTURE

F. Gerigk

SPL cryo-segmentation workshop

9-10 Nov. 2009

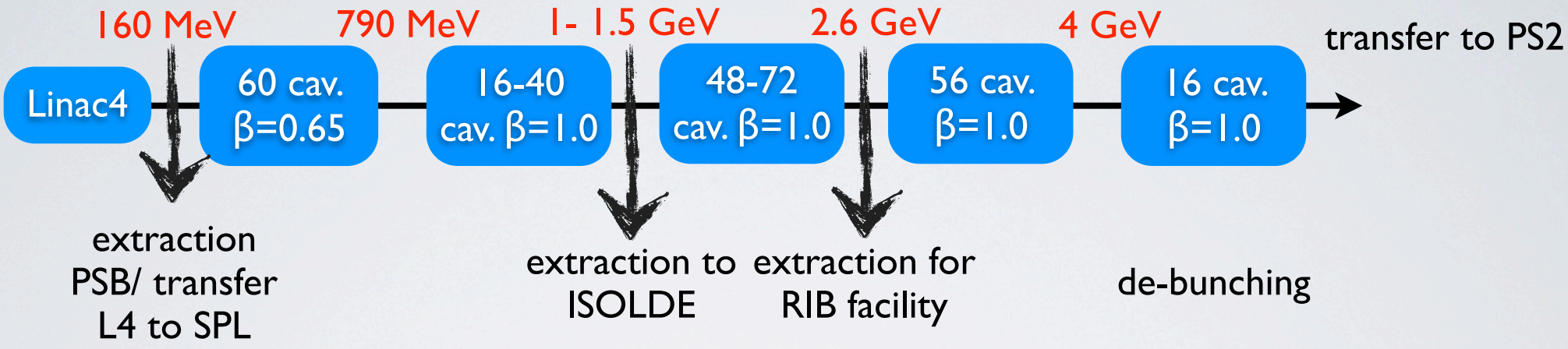
http://www.cern.ch/project-spl



OUTLINE

- overview and main parameters,
- parameters for cryogenics,
- major choices for cryo-segmentation,
- extraction areas,
- open questions

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

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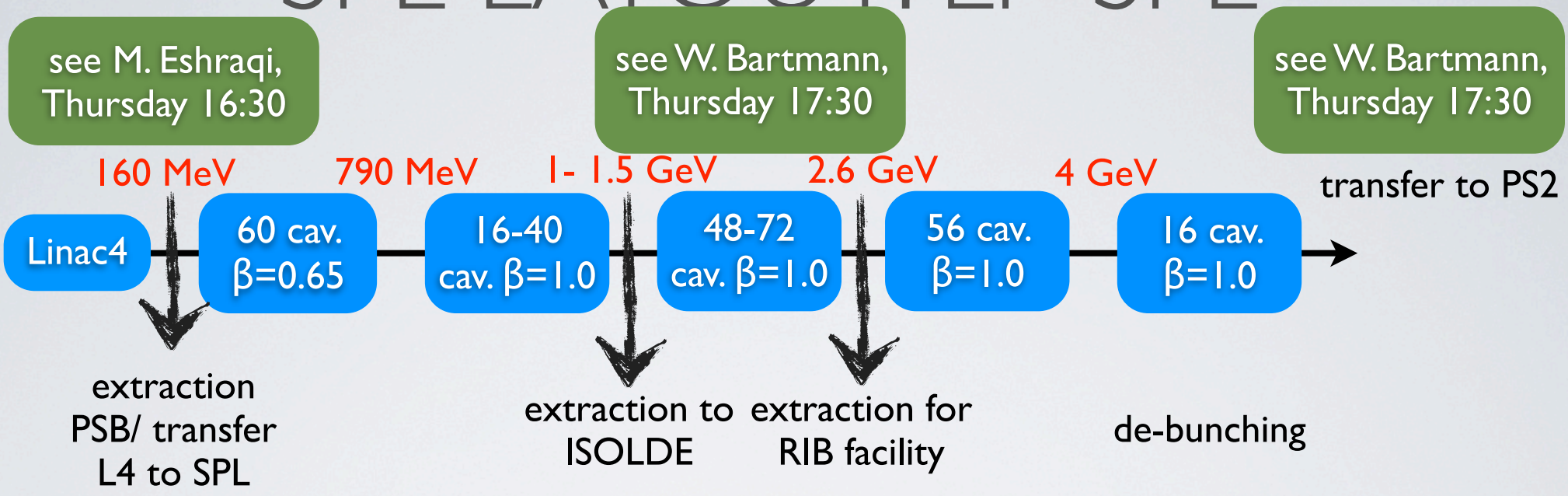
SPL LAYOUT: LP-SPL



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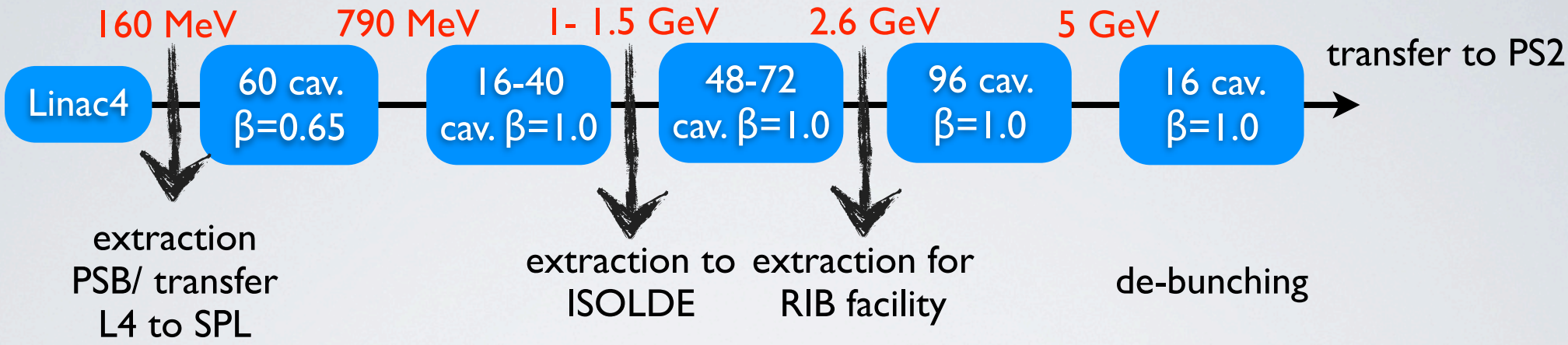
SPL LAYOUT: HP-SPL



- 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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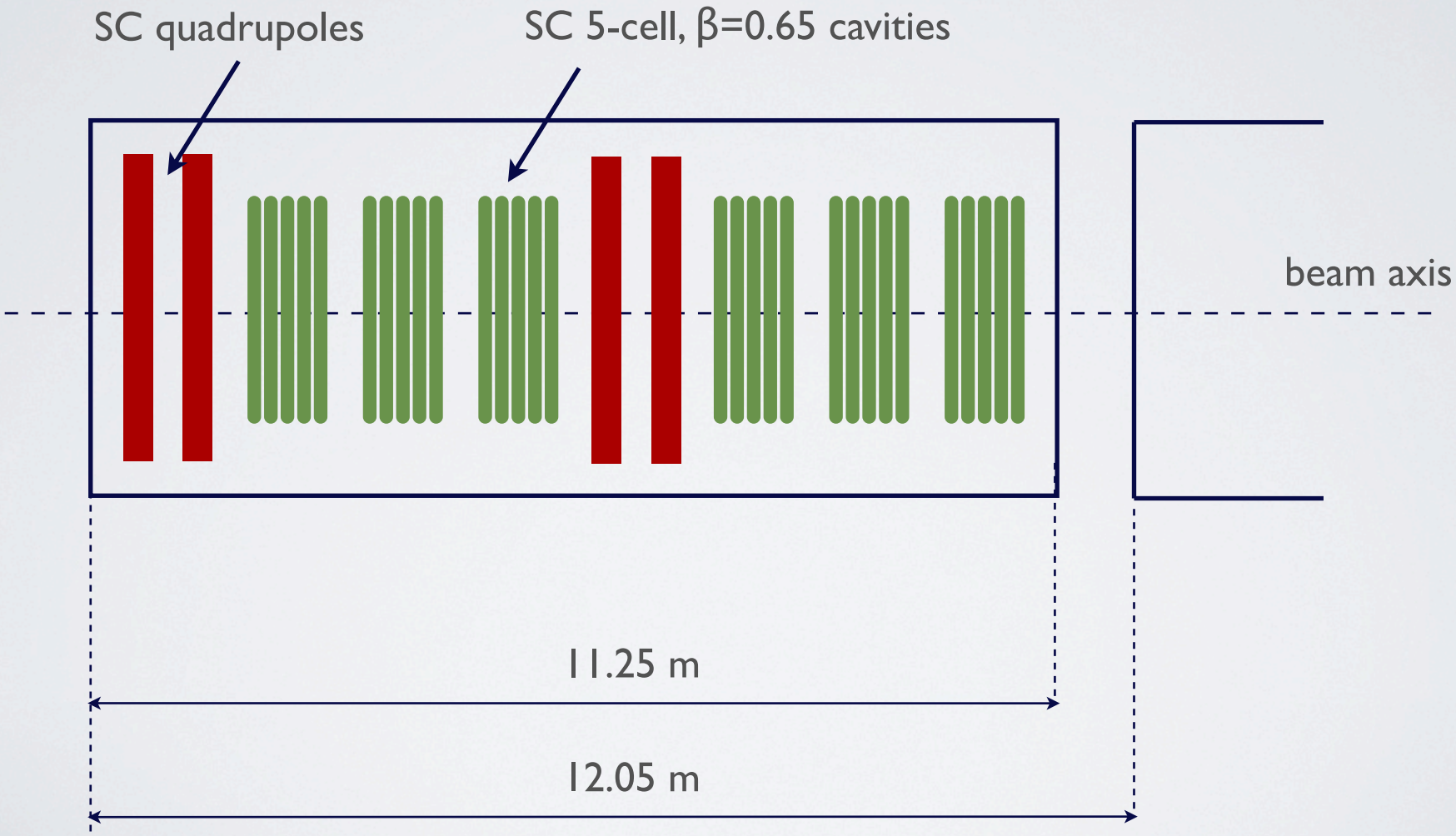
LOW-BETA CRYO-MODULE

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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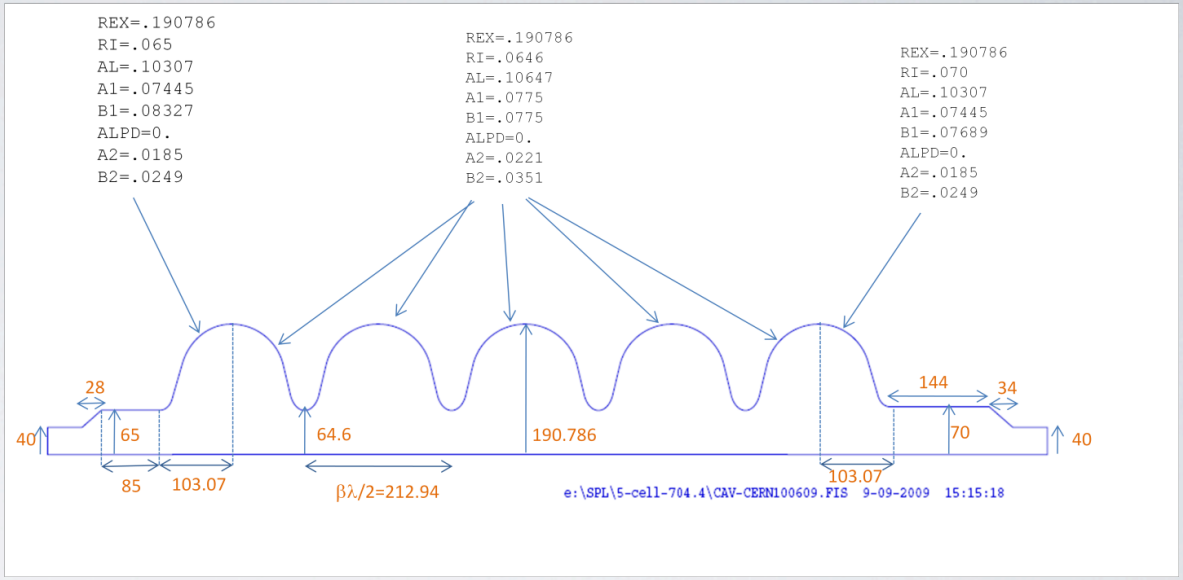
NOMINAL CAVITY DESIGN

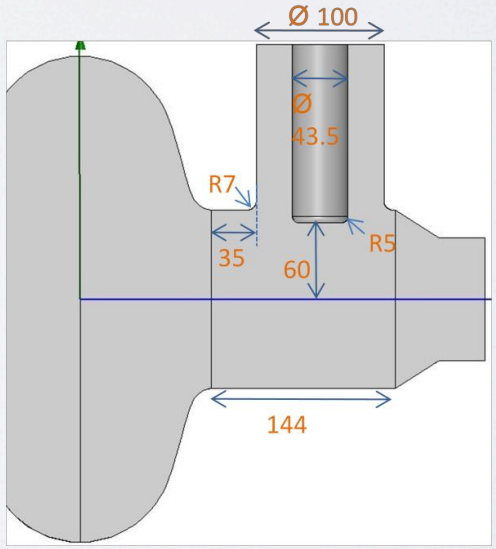
DIMENSIONS DE LA CAVITE SPL β = 1

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	

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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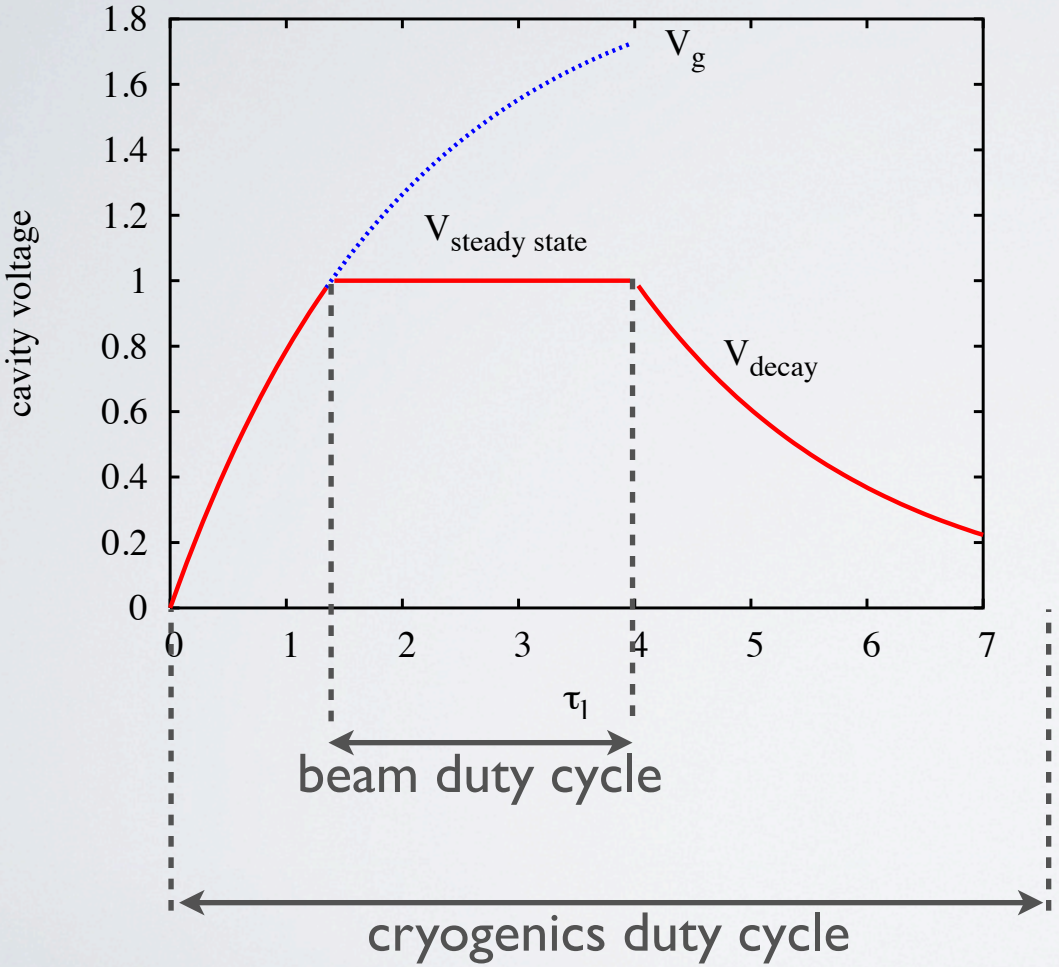
PRESENT DESIGN PARAMETERS FOR CRYOGENICS (HP-SPL)



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)	290/570
cells per cavity	5
beam current	40 mA
repetition rate	50 Hz
beam pulse length	0.4 ms
beam duty cycle	2%
cryogenics duty cycle	4.1%

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FURTHER ASSUMPTIONS (USING LONG STRINGS)

nominal estimate for HP-SPL (5 GeV, 4 MW, 40 mA, 50 Hz)

$P_{2K,\ HOM+coupler}$	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

~(50+3.5) W@2K/module (dynamic+static, 6 cavities, β=0.65, w/o doublets)

~(85+4.4) W@2K/module (dynamic+static, 8 cavities, β=1.0, w/o doublets)

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OPEN QUESTIONS ON PARAMETERS

- gradient of 25 MV/m @ β=1, 20 MV/m promises higher yield!

~reduction of 30% for dynamic load per module, but 25% increase in length

- 4 or 5 GeV as final energy, it seems that 4 GeV is sufficient for neutrinos!

most likely together with lower gradient

- so far low-current option was not considered for cryogenics, longer duty cycle, needed in any case for PS2 injection

higher cryo duty cycle more than doubles the cryogenic load!!

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NEW "WORST CASE" DESIGN PARAMETERS FOR CRYOGENICS

$P_{2K,\ HOM+coupler}$	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

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**
cells per cavity	5
beam current	**20 mA**
repetition rate	50 Hz
beam pulse length	**1.2 ms**
beam duty cycle	**6%**
cryogenics duty cycle	**10.6%**

~(93+3.5) W@2K/module (dynamic+static, 6 cavities, β=0.65, w/o doublets)

~(210+4.4) W@2K/module (dynamic+static, 8 cavities, β=1.0, w/o doublets)

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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%**
cryogenics duty cycle	**8.2%**

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 mA
repetition rate	50 Hz
beam pulse length	**1.2 ms**
beam duty cycle	**6%**
cryogenics duty cycle	**10.6%**

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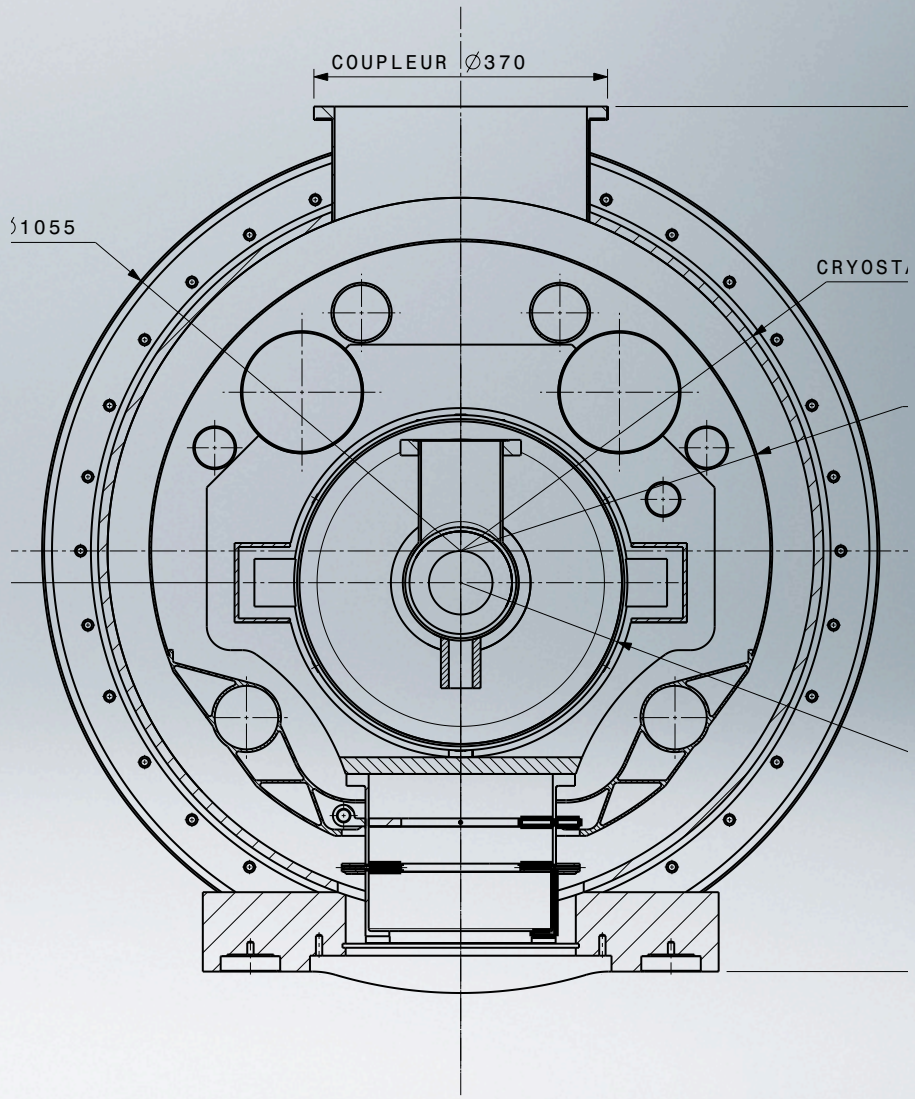
OPEN ISSUES

... which need urgent answers!



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?

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ANSWERS NEEDED FROM 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

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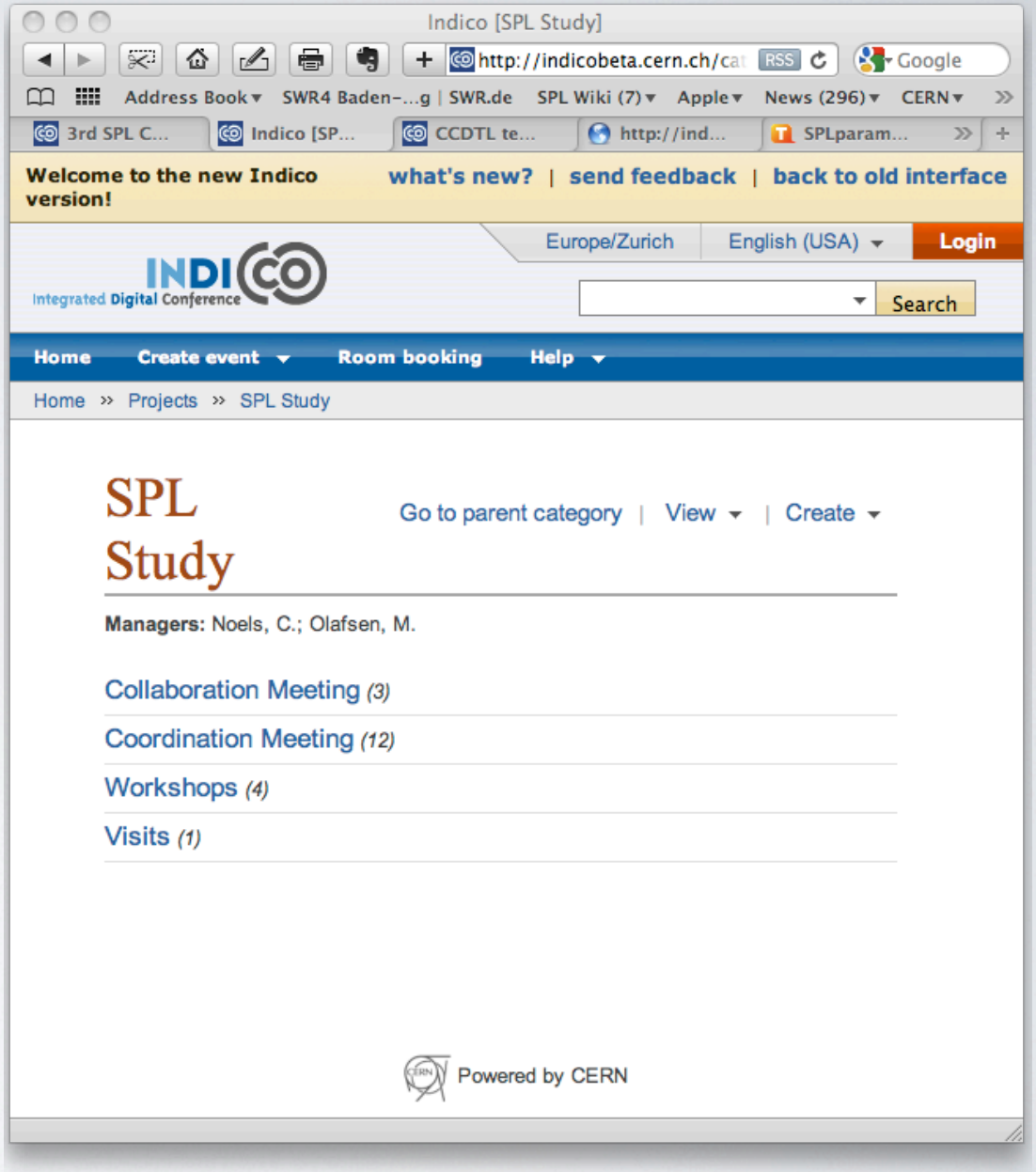
NEED MORE INFORMATION?

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?
Vittorio.Parma@cern.ch
Frank.Gerigk@cern.ch
Roland.Garoby@cern.ch



SPARE SLIDES

Q DEPENDANCE AT 25 MV/M

at 704 MHz: $Q_{2\,K} = 21 \times Q_{4.5\,K}$

at 1408 MHz: $Q_{2\,K} = 26 \times Q_{4.5\,K}$

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