NEu2012

Plans for proton accelerators at CERN

R. Garoby – 13/04/2010

OUTLINE

- Scenario 1: new LHC injectors
- Scenario 2:
  - Linac4
  - Consolidation & upgrade of the other injectors
  - R & D for high power SPL
- Comments

Scenario 1*:
New LHC injectors

* Detailed during Workshop on
"European Strategy for Future Neutrino Physics"
CERN, 1-3 October 2009

Motivation

Scenario 1 : New LHC injectors

1. Reliability ↑

The present accelerators are getting old (PS is 50 years old…) and they operate far beyond their initial design parameters

⇒ Interest of new accelerators tailored to the LHC and its future needs

2. Performance ↑

- Luminosity depends directly upon beam brightness N/ε^*

$$L \propto \frac{N_b}{\varepsilon_{X,Y}} \cdot N_b \cdot k_b$$

with N_b : number of protons/bunch

$\varepsilon_{X,Y}$: normalized transverse emittances

k_b : number of bunches per ring

- Brightness is limited by space charge at low energy in the injectors

$$\Delta Q_{SC} \propto \frac{N_b}{\varepsilon_{X,Y}} \cdot \frac{R}{\beta\gamma^2}$$

with N_b : number of protons/bunch

$\varepsilon_{X,Y}$: normalized transverse emittances

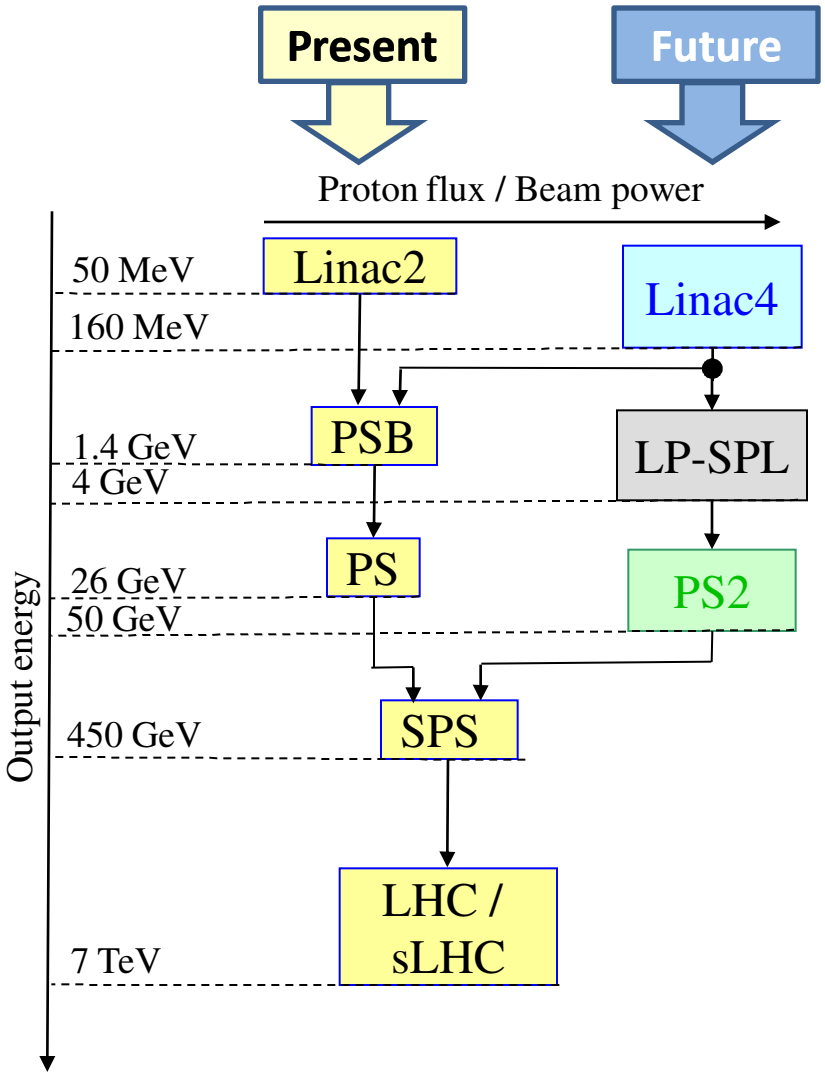
R : mean radius of the accelerator

$\beta\gamma$: classical relativistic parameters

⇒ Need to increase the injection energy in the synchrotrons

Description

Scenario 1 : New LHC injectors



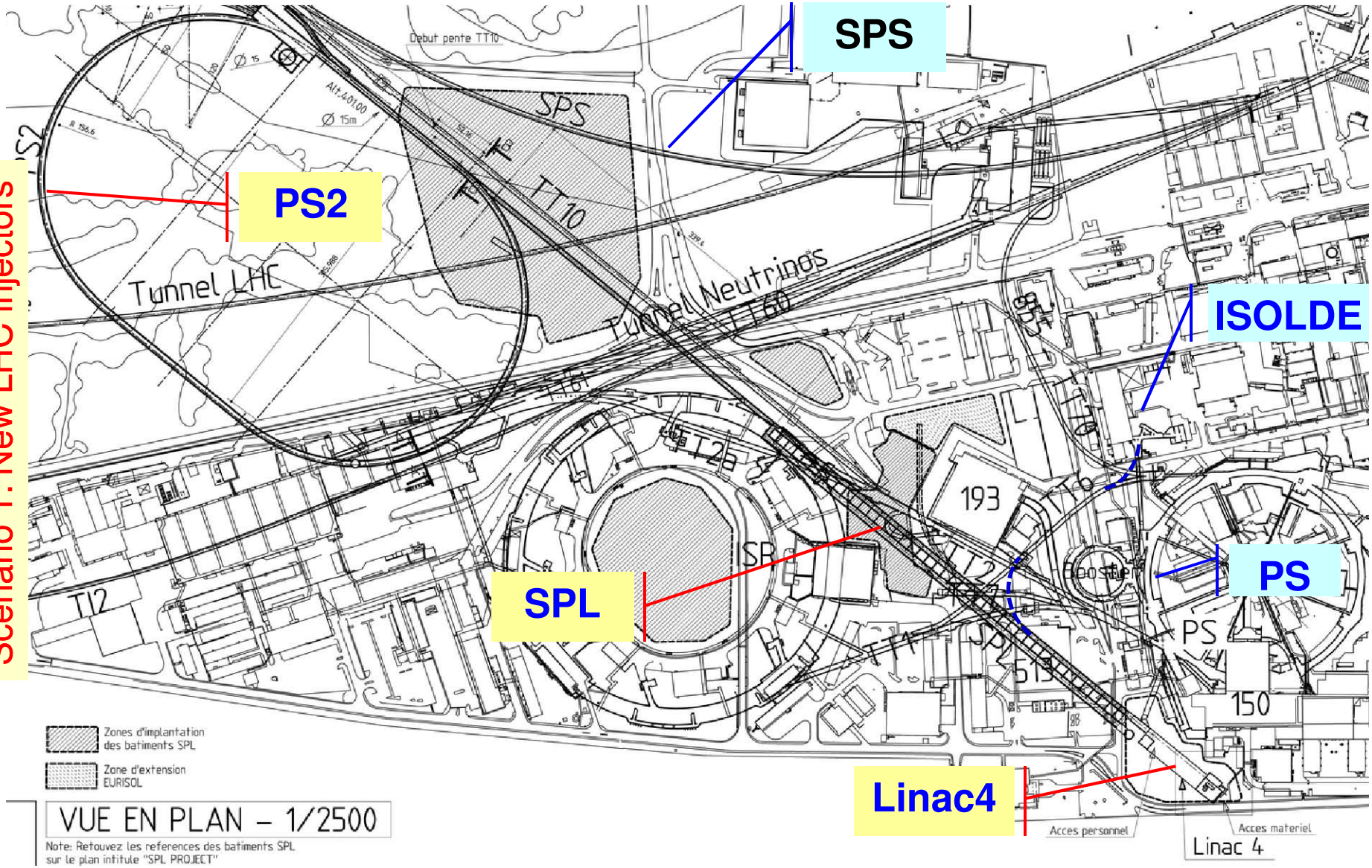
LP-SPL:
Low Power-Superconducting Proton Linac (4 GeV)

PS2:
High Energy PS (~ 5 to 50 GeV – 0.3 Hz)

sLHC:
"Super-luminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)

Site layout

Scenario 1: New LHC injectors



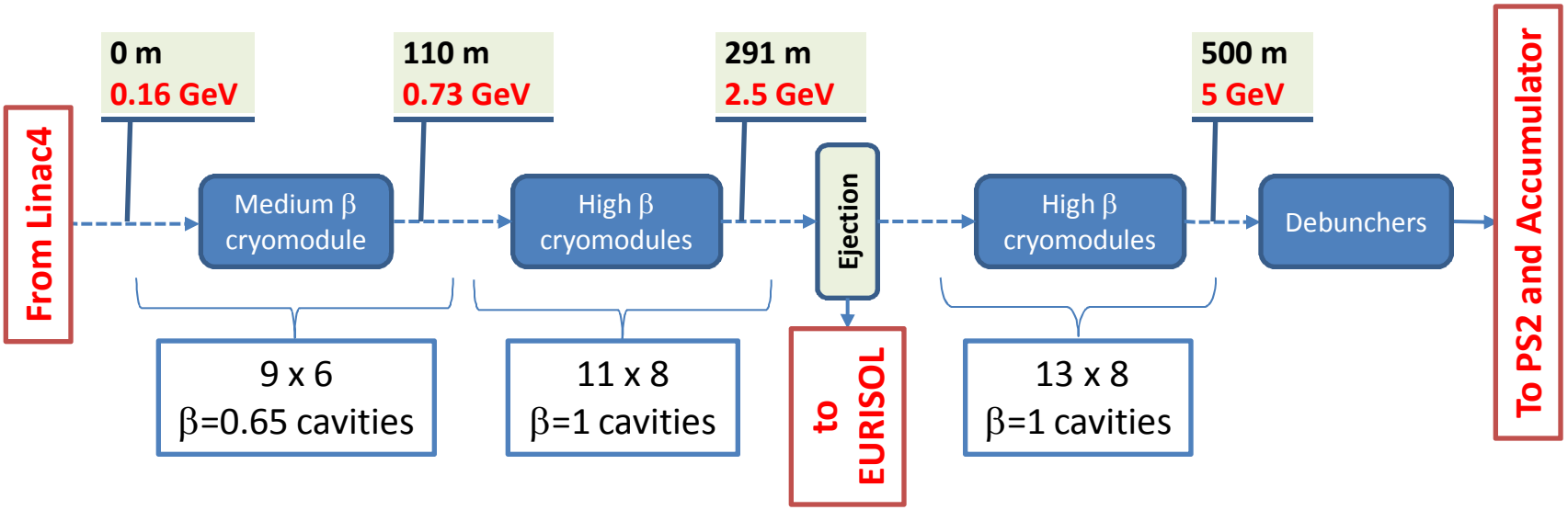
Potential SPL upgrade to High Power

(1/2)

- Upgrade of infrastructure (cooling water, electricity, cryogenics etc.)
- Replacement of klystron power supplies,
- Addition of 5 high β cryomodules to accelerate up to 5 GeV

Scenario 1 : New LHC injectors

SC-linac [160 MeV → 5 GeV] with ejection at intermediate energy



Length: ~500 m

Potential SPL upgrade to High Power

(2/2)

Scenario 1 : New LHC injectors

Beam characteristics of the main options

	Option 1	Option 2
Energy (GeV)	2.5 or 5	2.5 and 5
Beam power (MW)	2.25 MW (2.5 GeV) or 4.5 MW (5 GeV)	5 MW (2.5 GeV) and 4 MW (5 GeV)
Rep. frequency (Hz)	50	50
Protons/pulse (x 10^{14})	1.1	2 (2.5 GeV) + 1 (5 GeV)
Av. Pulse current (mA)	20	40
Pulse duration (ms)	0.9	1 (2.5 GeV) + 0.4 (5 GeV)

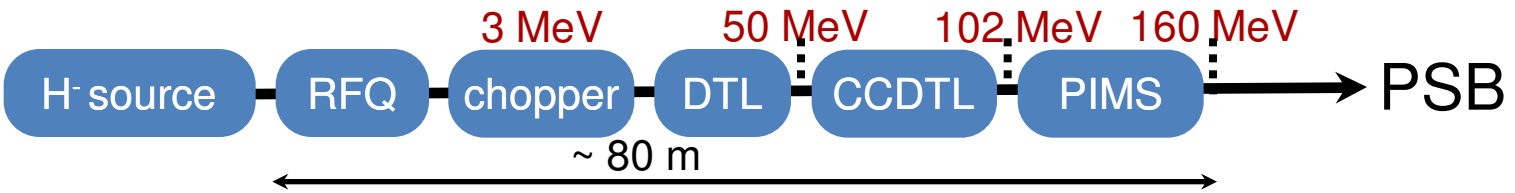
Faster rep. rate ⇒ new power supplies, more cooling etc.

2 × beam current ⇒ 2 × nb. of klystrons etc .

Scenario 2*:
Linac4 + consolidation & upgrade of existing injectors + SPL R & D

* From Chamonix 2010
"LHC Performance Workshop"
Chamonix, 25-29 January 2010

Linac4



Scenario 2

Ion species	H^-	
Output Energy	160	MeV
Bunch Frequency	352.2	MHz
Max. Rep. Rate	2	Hz
Max. Beam Pulse Length	1.2	ms
Max. Beam Duty Cycle	0.24	%
Chopper Beam-on Factor	65	%
Chopping scheme:		
222 transmitted /133 empty buckets		
Source current	80	mA
RFQ output current	70	mA
Linac pulse current	40	mA
N. particles per pulse	1.0	$\times 10^{14}$
Transverse emittance	0.4	π mm mrad

Max. rep. rate for accelerating structures: 50 Hz

H^- charge exchange injection in the PSB

160/50 MeV $\Rightarrow$ factor 2 in $\beta\gamma^2$) $\rightarrow$ doubled brightness in the PSB

Chopping at low energy to ease longitudinal capture and reduce beam loss in PSB.

- Structures and klystrons compatible with high power SPL
- Power supplies and electronics dimensioned for PSB and LP-SPL

Linac4 construction site – May 2009

from M. Vretenar

Linac4 tunnel ("cut and cover" excavation) seen from high-energy side.

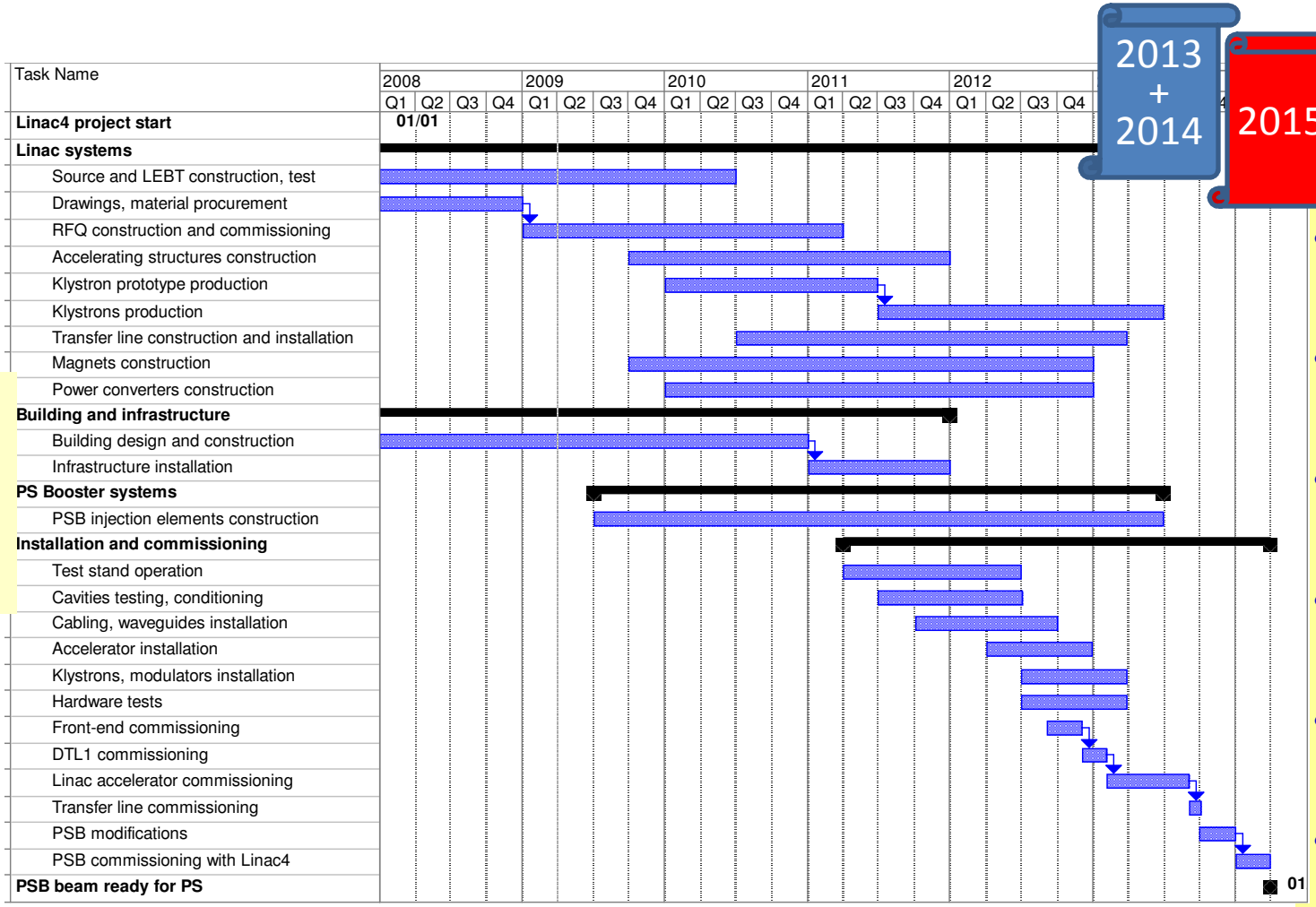
Final concrete works starting at low-energy side, excavation proceeding at high energy side.

Tunnel level -12 m, length 100 m.

Delivery of tunnel and surface equipment building end of 2010.

Scenario 2

LINAC4 planning



Scenario 2

project duration: ~ 7 years

Milestones

- End CE works: December 2010
- Infrastructure: 2011
- Installation: 2011-2012
- Commissioning: 2012 till 2014
- Modifications PSB: shut-down 2014/15
- **Operation: Spring 2015**

Consolidation & upgrade of the other injectors
(1/2)

Scenario 2

Motivation

- Consolidation is mandatory for reliable operation until ~2020 (earliest date of availability of new injectors)
- Cost of consolidation + new injectors is excessive
- Upgrades can be implemented while consolidating…

Description

Upgrade, replace or add equipment to:

- increase the maximum energy of the PSB up to ~ 2 GeV
- transfer and inject at 2 GeV in the PS
- make the PS and SPS capable to accelerate and manipulate beam with much higher brightness and longitudinal density...

No need for LP-SPL nor PS2

Consolidation & upgrade of the other injectors
(2/2)

Preparation & implementation procedures

- Task forces on “PSB upgrade” and “SPS upgrade” reporting on April 14 to the CERN management (L.M.C. meeting)
- Integration in the “Medium Term Plan” (2011-2015) to be submitted to the SPC (May) and the CERN Council (June)
- Tentative planning: completion as soon as possible => before 2016 (beginning of second LHC operation period at nominal energy)

Scenario 2

R & D for a high power SPL
(1/3)

Scenario 2

Motivation

- Preserve potential for some alternative physics programmes (Neutrinos, RIB)
- Preserve possibility of new injectors at long term (e.g. DLHC option…)
- Update CERN competences in superconducting RF
- Synergy with other applications outside of CERN

Description

- Focused on high beam power
- R & D only (no work on integration / civil engineering / environmental impact)

R & D for a high power SPL
(2/3)

Proposed subjects until 2015
(in continuity with the work done for the LP-SPL)

Scenario 2

- R & D towards a high duty cycle H^- source
- Study of the optimum high power RF architecture for a high power SPL
- Design, construction and test of superconducting RF cavities (704 MHz – 5 cells – β=1)
- Development of high power RF coupler, HOM damper and adaptation of tuner
- Upgrade of the SM18 test place [2 K cooling + pulsed RF source at 704 MHz (1 MW @ 50 Hz)]
- Pulsed high power RF tests of contiguous cavities in a single cryostat
- Design, construction and test a high power klystron modulator
- Design, construction and test of a prototype cryomodule equipped with 8 β=1 cavities

R & D for a high power SPL
(3/3)

Preparation & implementation procedures

- Presentation of proposal on April 14 to the CERN management (L.M.C. meeting)
- Integration in the "Medium Term Plan" (2011-2015) to be submitted to the SPC (May) and the CERN Council (June)

Scenario 2

- Tentative planning:
  - First half of 2013: high power test of 4 sc cavities in a cryostat
  - 2015: high power test of 8 sc cavities in a prototype full size cryomodule
  - >2015 - Reminder: preparing a project proposal require work (> 2 years) on integration, safety, civil engineering design and the realization of an impact study

In-phase with ESS design update

Comments

Impact on neutrino physics at CERN

	Scenario 1	Scenario 2
PS ν experiment	~ OK	? To be studied
Conventional ν beam from SPS	Potential for ~3 x the CNGS flux	Potential for ~1.5 x the CNGS flux
Conventional ν beam from PS2	OK up to 400 kW of beam power	
Conventional ν super beam from SPL	Needs upgrade of LP-SPL + accumulator + target	Needs construction of SPL + accumulator + target
β beam	OK for production of ^{6}He Needs another driver for ^{18}Ne	Needs construction of driver(s) for production of ^{6}He and ^{18}Ne
ν factory	Needs upgrade of LP-SPL + accumulator / compressor + target + muon accelerator complex…	Needs construction of proton driver (e.g. SPL-based) + target + muon accelerator complex…

Comments

Decision process
- Status -

- Scenario 1 was favored until the end of 2009
- Scenario 2 arose during the Chamonix 2010 workshop, associated with an in-depth analysis of the short & medium term needs of LHC, and a major revision of the planning of increase of its performance

Comments

- Decision between scenarios is part of the overall scientific strategy of CERN presently under study
- A proposal will be submitted to the SPC (May 3) and to the CERN Council (June 17-18) for implementation within the MTP and LTP

THANK YOU
FOR YOUR ATTENTION!