FUTURE HIGH INTENSITY PROTON BEAMS AT CERN

- Outcome of the HIP working group
- Outcome of the SPSC meeting in Villars (Sept. 2004)
- Next steps
- Final word

OUTCOME OF THE HIP WORKING GROUP

The HIP Working Group

- MEMBERS

M. Benedikt	PSB	Secretary
K. Cornelis	SPS	
R. Garoby		Chairman
E. Metral	PS	
F. Ruggiero	LHC	
M. Vretenar	Linac(s)	

- MANDATE
  - Define a list of specifications for beam performance based on perceived future physics needs.
  - Investigate possible changes to the CERN complex of proton accelerators.
  - Publish a summary of various alternatives and compare them in terms of performance, flexibility and approximate cost. A preferred scheme should be indicated with the possible option of a staged realisation.
  - Present recommendations to the A&B management by the end of 2003.
- REPORT : May 2004, CERN-AB-2004-022 OP/RF

Recorded requests

USER	CERN COMMITMENT*	USERS' WISHES	
	Short term	**Medium term** *[~ asap !]*	**Long term** *[2014 and beyond]*
LHC	**Planned beams**	**Ultimate luminosity**	Luminosity upgrades
FT (COMPASS)	**7.2×10^5 spills/y ?**	**7.2×10^5 spills/y**	
CNGS	**4.5×10^{19} p/year**	Upgrade ~ $\times2$	
ISOLDE	**1.92 μA ****	Upgrade ~ $\times5$	
Future ν beams			> 2 GeV / 4 MW
EURISOL			1-2 GeV / 5 MW

* Reference value for analysis

** 1350 pulses/h – 3.2×10^{13} ppp

Main upgrades considered

Category	Description	Main beneficiary
Short term	Reduced basic period (0.9 & 0.6 s)	ISOLDE
Medium term	“Loss-less” PS multi-turn ejection	CNGS
Medium term	Double PSB batch for CNGS	CNGS
Medium term	Energy upgrade of linac 2	ISOLDE, CNGS
Medium term	Linac 4 (=> single PSB batch for LHC)	LHC, ISOLDE
Long term	Low energy RCS (PSB replacement)	LHC, ν
Long term	SPL	LHC, EURISOL, ν
Long term	30 GeV RCS	LHC, ν
Long term	New 30 GeV PS (~ “PS XXI”)	LHC
Long term	1 TeV LHC injector (“Super-SPS”)	LHC

Evaluation procedure

Operational assumptions

- Schedules

		2006		2007 - 2010			
		PSB/PS complex	SPS complex	PSB/PS complex	SPS complex		LHC
					2007*	2008-10	
Total running time with beam	[h]	6000	5500	6000	5500	5500	5000
Setup and dedicated MD	[h]	1500	1500	600	1000	800	-
Physics operation	[h]	4500	4000	5400	4500	4700	-
Effective physics hours	[h]	4050	3200	4860	3600	3760	-

- Operation modes: LHC filling, LHC set-up, CNGS-FT
- Distribution of SPS operation modes

SPS operation mode		2006	2007	2010
Physics operation	[h]	4000	4500	4700
LHC filling mode	[%]	0	15	5
LHC setup mode	[%]	0	35	10
CNGS – FT mode	[%]	100	50	85

Performance without upgrades

Findings: shortage of protons & difficulty to reach the ultimate beam for LHC

	2006	2007	2010	Basic user's request
CNGS flux [$\times 10^{19}$ pot/year]	4.4*	4.2*	4.9*	4.5
FT spills [$\times 10^{5}$ /year]	3.3	1.8	3.3	7.2
East Hall spills [$\times 10^{6}$ /year]	1.3	2.3	2.3	2.3
NTOF flux [$\times 10^{19}$ pot/year]	1.4	1.6	1.6	1.5
ISOLDE flux [μA] [nb. of pulses/hour]	1.84 1296	1.65 1160	1.74 1220	1.92 1350
72 bunch train for LHC at PS exit [$\times 10^{11}$ ppb]	1.5	1.5	1.5	1.3 (2**)

* with important irradiation of PS equipment
** ultimate beam in LHC

Summary of recommendations

- In the short term, to define in 2004 and start in 2005 the 3 following projects:
  - **New multi-turn ejection for the PS**
  - **Increased intensity in the SPS for CNGS (implications in all machines).**
  - **0.9 s PSB repetition time.**
- In the medium term, to work on the design of **Linac 4** and prepare for a decision of construction at the end of 2006.
- In the long term, to prepare for a decision concerning the optimum future accelerator(s) by pursuing the **study of a Superconducting Proton Linac** and by exploring **alternative scenarios for the LHC upgrade**.

Request in preparation with support of AB management

Study approved with focus on beam loss

Work programme 2005 approved

Actively pursued

Partly supported in the frame of CARE

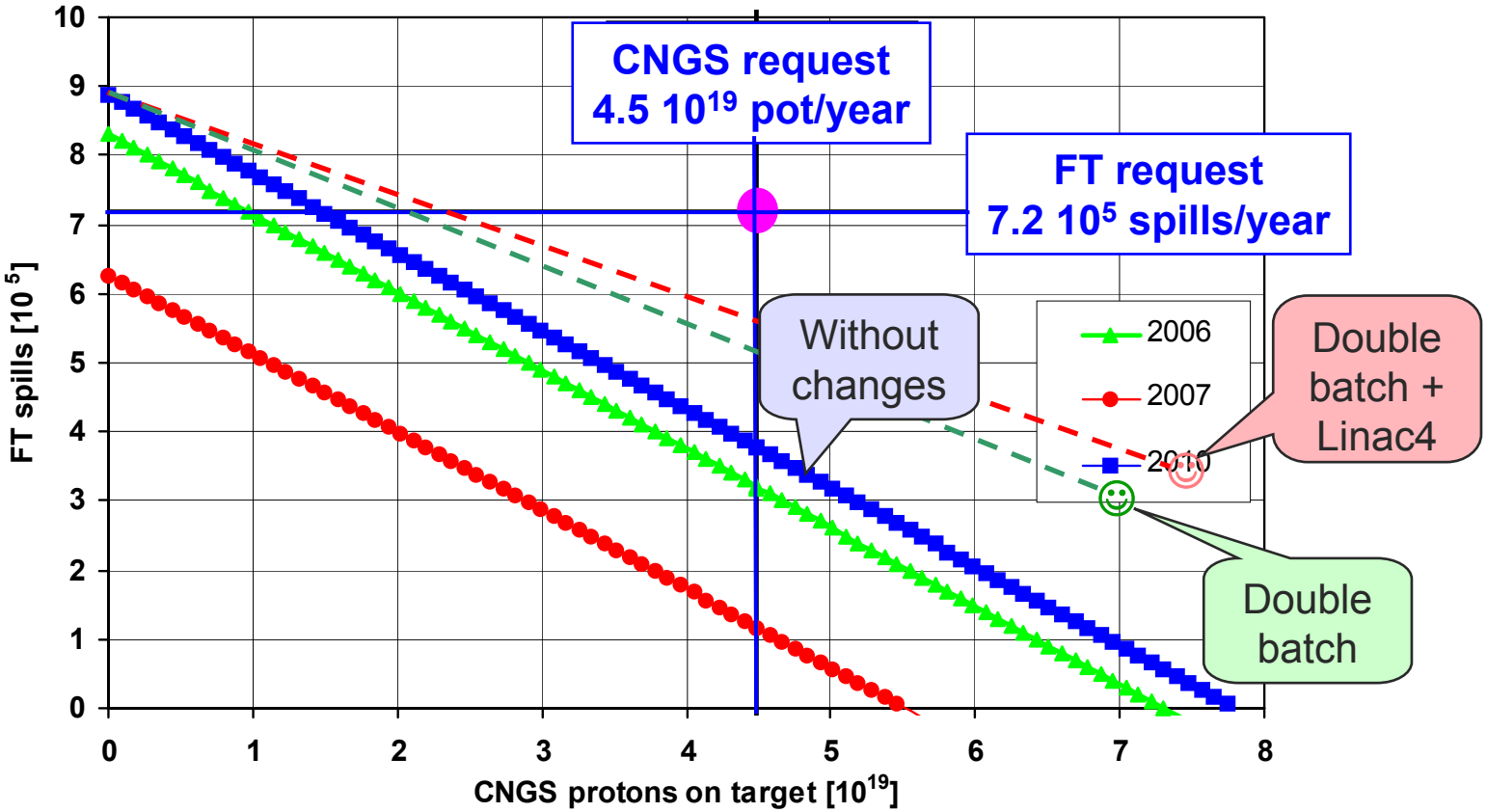
Medium term performance with upgrades

Performance in 2010 with (i) a PSB repetition period of 0.9 s, (ii) 7 10^{13} ppp in the SPS and (iii) Linac4 injecting in the PSB

		(i)	(i)+(ii)	(i)+(ii)+(iii)
	Standard operation	CNGS double batch	Linac 4	Basic user's request
CNGS flux [$\times 10^{19}$ pot/year]	4.7 (4.5)	7.0 (4.5)	7.5 (4.5)	4.5
FT spills [$\times 10^{5}$ /year]	3.2 (3.4)	3.0 (5.1)	3.2 (5.6)	7.2
East Hall spills [$\times 10^{6}$ /year]	2.3	2.3	2.3	2.3
NTOF flux [$\times 10^{19}$ pot/year]	1.7	1.6	1.7	1.5
ISOLDE flux [μA] [nb. of pulses/hour]	3.0 2126	2.45 1722	6.2 2160	1.9 1350
72 bunch train for LHC at PS exit [$\times 10^{11}$ ppb]	1.5	1.5	2	1.3 (2*)

* ultimate

Medium term proton “crisis”



CNGS and FT (COMPASS) share the available SPS cycles:

⇒ they cannot be satisfied simultaneously.

Long term alternatives

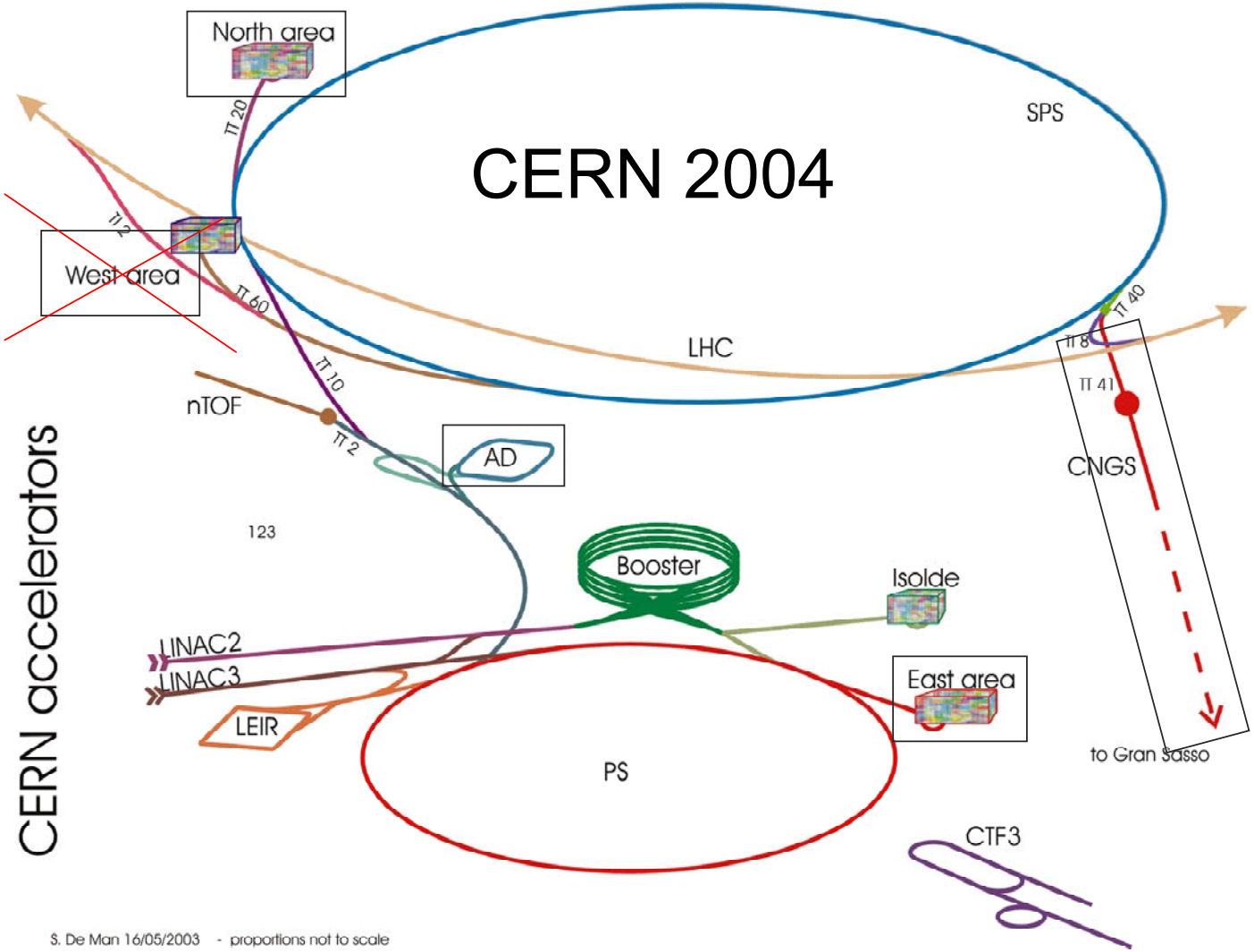
Present accelerator	Replacement accelerator	Improvement	INTEREST FOR			
			LHC upgrade	ν physics beyond CNGS	RIB beyond ISOLDE	Physics with k and μ
Linac2	Linac4	50 → 160 MeV $H^+ \rightarrow H^-$	+	0 (if alone)	0 (if alone)	0 (if alone)
PSB	2.2 GeV RCS* for HEP	1.4 → 2.2 GeV 10 → 250 kW	+	0 (if alone)	+	0 (if alone)
	2.2 GeV/mMW RCS*	1.4 → 2.2 GeV 0.01 → 4 MW	+	++ (super-beam, β-beam ?, ν factory)	+ (too short beam pulse)	0 (if alone)
	2.2 GeV/50 Hz SPL*	1.4 → 2.2 GeV 0.01 → 4 MW	+	+++ (super-beam, β-beam, ν factory)	+++	0 (if alone)
PS	SC PS*/** for HEP	26 → 50 GeV Intensity x 2	++	0 (if alone)	0	+
	5 Hz RCS*/**	26 → 50 GeV 0.1 → 4 MW	++	++ (ν factory)	0	+++
SPS	1 TeV SC SPS*/**	0.45 → 1 TeV Intensity x 2	+++	?	0	+++

* with brightness x2 ** need new injector(s)

OUTCOME OF THE SPSC VILLARS MEETING (Sept. 2004)

SPSC (Villars 2004)

SPSC Recommendations (p.21)



SPSC Recommendations (p.62)

- ν physics has noble history at CERN
- ν physics is in a new golden era
  - CERN beginning again pivotal global role
- CNGS commitment to ~ end of decade vital
  - 2006 important: COMPASS then CNGS @ end 06
  - CNGS crucial up to 2011 (window @ 4.5×10^{19} pot/yr)
  - CNGS + COMPASS ? multi-turn xtraction
    longer running period
  - no compelling case for extending CNGS beyond 2011 @ realisable pot/yr (< ~ 3x 4.5×10^{19} pot/yr)

SPSC Recommendations (p.63)

- Future neutrino facilities offer great promise for fundamental discoveries (such as CP violation) in neutrino physics, and a post-LHC construction window may exist for a facility to be sited at CERN.

- CERN should arrange a budget and personnel to enhance its participation in further developing the physics case and the technologies necessary for the realization of such facilities. This would allow CERN to play a significant role in such projects wherever they are sited.

- A high-power proton driver is a main building block of future projects, and is therefore required.

- A direct superbeam from a 2.2 GeV SPL does not appear to be the most attractive option for a future CERN neutrino experiment as it does not produce a significant advance on T2K.

- We welcome the effort, partly funded by the EU, concerned with the conceptual design of a β-beam. At the same time CERN should support the European neutrino factory initiative in its conceptual design.

SPSC Recommendations (p.95)

- fixed target physics at CERN
  - > 2011: physics must be vibrant, important, leading

ion+ion ≥ 2009 (synergy with LHC)
rare flavour ≥ 2009 (synergy with LHC)
fundamental physics with $\bar{p}$ atoms
hadron structure: GPDs … if appropriate ?
dynamics: low energy, resonance
ν physics: evaluation & R&D @ CERN
p-driver ↔ superbeam ↔ detector
global context → NF

synergies with other science?
SPL?

All but HI benefit from/require high intensity
RCPSB RCPS …

NEXT STEPS

- Implications of SPSC Villars's recommendations for the AB department are being sent to the Research Board
- Special INTC meeting (Villars – Oct. 2005) ⇒ new set of recommendations
- Creation of an accelerator team to elaborate scenarios
- Accelerator studies in the frame of:
  - ***CARE*** [EU supported Integrated Activity: "Coordinated Accelerator Research in Europe" including networks (***BENE***: "Beams for European Neutrino Experiments", ***H3***: "High energy, High intensity, High brightness" accelerators) and the Joint Research Activity ***HIPPI***: "High Intensity Pulsed Proton Injectors"]
  - LHC upgrade studies
  - ***EURISOL*** Design Study [EU supported]

CERN DG's talk to the staff on 10/01/2005 (1)

The following strategic orientations are proposed for CERN activities in 2004-2010:

1. to keep the utmost priority for the completion of the LHC project, and strive for a start of operations in the summer of 2007;

2. to fulfil commitments previously made by CERN: CNGS, EGEE;

3. after an in-depth risk analysis review, to mitigate the consequences of failure of old equipment that is necessary for reliable LHC operation. i.e. Consolidation;

4. along the conclusions of SPSC Villars meeting, to prepare for 2006 and beyond a few new fixed target experiments, highly praised for their new physics potential outputs;

5. in line with the new policy by the European Commission for structuring the European Research Area, by promoting the coordination of laboratories in matters of R&D and new infrastructure (FP6 – CARE programme), to launch in the period 2004-2006 different studies in cooperation with other laboratories;

CERN DG's talk to the staff on 10/01/2005 (2)

- Their primary goal would be:
  - to develop detailed technical solutions for a future LHC luminosity upgrade to be commissioned around 2012-2015;
    - *Definition of the Linac4 (160 MeV-H-), in relation with the European Programme for a High Intensity Pulsed Proton Injector (HIPPI)*
    - *Definition of modifications to the magnets in the interaction regions at two crossing points of the LHC beams, linked with the European programme Next European Dipole (NED), aiming at 15 Tesla*
    - *Definition of new trackers for the upgrade of the ATLAS and CMS detectors, to withstand a factor 10 higher luminosity.*
  - to keep in touch with other design studies launched in Europe, of EURISOL and neutrino factories;

CERN DG's talk to the staff on 10/01/2005 (3)

Milestones …

7. in **2006-2007**, to decide on the ***implementation of the Linac 4 and any increased R&D programme***, depending on new funds made available and on a new HR policy;

8. in **2009-2010**, ***to review and redefine the strategy for CERN activities in the next decade 2011-2020 in the light of the first results from LHC and of progress and results from the previous actions.*** The possible choices are at present quite open. The future role of CERN will depend on these choices and their effective funding;

FINAL WORD

Personal comments

- In the short/medium term (~ 2010): shortage of proton beams for the approved users (worse if their expected upgrades are taken into account…) and risk with beam loss / hardware activation

  ⇒ **Need for:**
  - **implementing improvements as soon as possible**
  - **arbitration between users…**

- In the long term = Future of proton accelerators at CERN

  - LHC will operate until ~ 2020

  ⇒ **Consolidation + LHC upgrade**

  - LHC will always be a part-time user of the injector complex

  ⇒ **Other physics programmes can be covered if they are compatible with LHC needs. On top of value for science, synergy will be an important parameter.**