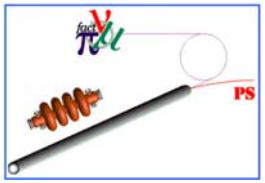
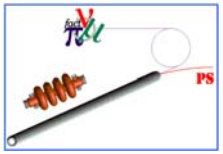


Status of CERN Injectors Upgrades

- Introduction
- Status of linac developments
- Outcome of the HIP working group
- SPSC recommendations
- Consequences for Radio-active Ion Beams
- Final word



INTRODUCTION

Context & References

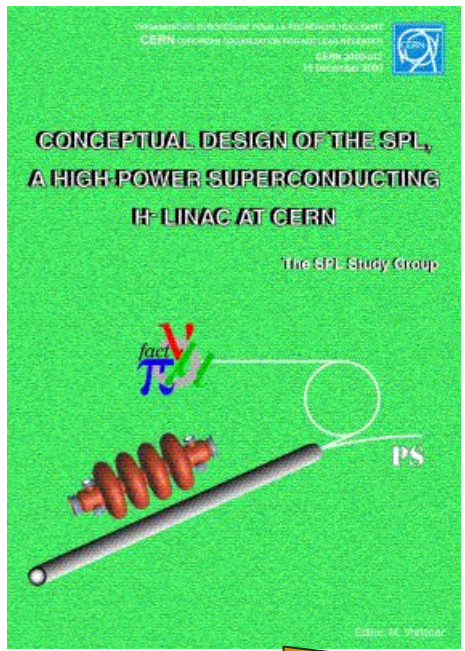
- **SPL Study**

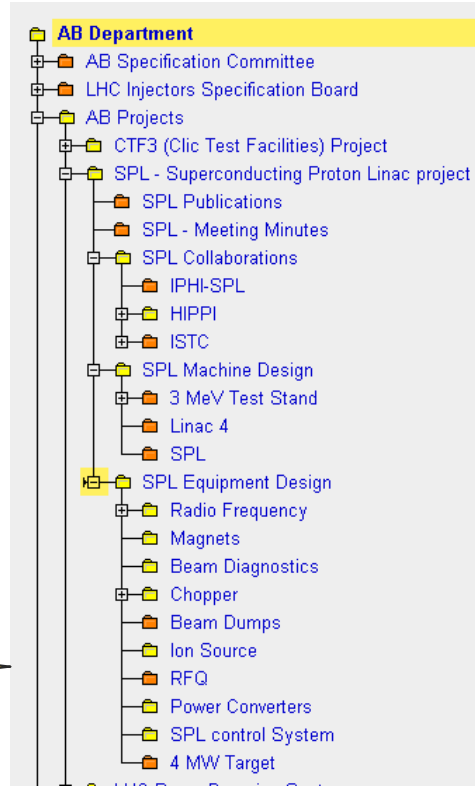
  B. Autin, E. Benedico Mora, A. Blondel, K. Bongardt (**KFZ Juelich**), O. Brunner, L. Bruno, F. Caspers, E. Cennini, E. Chiaveri, S. Claudet, H. Frischholz, R. Garoby, F. Gerigk (**RAL**), K. Hanke, H. Haseroth, C. Hill, I. Hoffman (**GSI**), J. Inigo-Golfin, M. Jimenez, M. Hori (**Tokyo Univ**.), D. Kuchler, M. Lindroos, A. Lombardi, R. Losito, R. Nunes, M. Magistris, A. Millich, T. Otto, M. Paoluzzi, J. Pedersen, M. Poehler, H. Ravn, A. Rohlev, C. Rossi, R.D. Ryne (**LANL**), M. Sanmarti, E. Sargsyan, H. Schönauer, M. Silari, T. Steiner, J. Tuckmantel, D. Valuch, H. Vinckle, A. Vital, M. Vretenar

- **HIP working group**

  M. Benedikt, K. Cornelis, R. Garoby, E. Metral, F. Ruggiero, M. Vretenar

- **Present characteristics (Conceptual Design Report 1):**
  - are “optimized” for a neutrino factory
  - assume the use of LEP cavities & klystrons up to the highest energy
- **Update is planned (CDR 2):**
  - based on updated physics’ requests
  - using 704 MHz RF and bulk Niobium cavities
  - in collaboration with CEA-Saclay & INFN-Milano
  - to be published in mid-2005
- **Up-to-date information is available:**
  - on the CERN EDMS
  - on the SPL site: **http://ps-div.web.cern.ch/ps-div/SPL_SG/**





Collaborations (1/3)

RFQ (IPHI)

"Injecteur de Protons de Haute Intensité" (in French)

IPHI - CERN collaboration

Collaboration between CEA-Saclay / IN2P3 / CERN

Goal: Build a **3 MeV RFQ** to be tested in CW with 100 mA beam current **at Saclay** in 2006 and **delivered at CERN in 2007** for the 3 MeV test place (pre-injector of the future linac 4 & SPL)

First 1 m section

"High Intensity Protons Pulsed Injectors"

Collaborations (2/3)

HIPPI inside CARE (6th Framework Program, Integrating Activities, CARE project, Coordinated Accelerator Research in Europe for Particle Physics)

"Joint Research Activity" supported by the European Union in the 6th Framework programme

- **Main Objectives**

  R&D of the technology for high intensity pulsed proton linear accelerators up to an energy of 200 MeV ⇒ Improvement of existing facilities (E.U. request) at GSI, RAL and CERN

- **Means**

  9 laboratories: RAL, CEA (Saclay), CERN, FZJ, GSI, Frankfurt University, INFN-Milano, IPN (Orsay), LPSC (Grenoble).
  11.1 MEuros + 3.6 MEuros (E.U.) over 5 years (2004 – 2008)

- **Organization ⇒ 5 Work Packages**
  - **WP1 : Management & Coordination (R. Garoby – CERN)**
  - **WP2 : Normal Conducting structures (J.M. Deconto – LPSC Grenoble)**
  - **WP3 : Superconducting structures (S. Chel – CEA Saclay)**
  - **WP4 : Beam chopper (A. Lombardi – CERN)**
  - **WP5 : Beam dynamics (I. Hoffmann – GSI)**

Collaborations (3/3)

ISTC projects for Linac 4 & SPL

Common features:
- One institute competent in accelerators + one nuclear city
- 2 years duration
- Design and construction of a prototype for high power tests at CERN

#2875 – BINP (Novossibirsk) + VNIITF (Snezinsk)

- Subject: Coupled Cavity Drift Tube Linac (CCDTL) structure (40-100 MeV) + cold model of SCL structure (100-200 MeV)
- Cost: k$ 550 (10805 man.days)
- Status: active since October 2003
- Prototype delivery: end 2005

#2888 – ITEP (Moscow) + VNIIEF (Sarov)

- Subject: Drift Tube Linac (DTL) structure with magnetic focusing (“Alvarez”) (3-40 MeV)
- Cost: k$ 498 (? Man.days)
- Status: active since April 2004
- Prototype delivery: summer 2006

#2889 - IHEP (Protvino)+ VNIIEF (Sarov)

- Subject: DTL structure with focusing by RF quadrupoles (DTL-RFQ) (3-40 MeV)
- Cost: k$ 500 (8399 man.days)
- Status: active since April 2004
- Prototype delivery: summer 2006

New Resources

1) From CERN:

DG's decision to allocate the resources missing for the completion of the E.U. supported activities. Result for HIPPI:

☺ **Staff (effective ~ mid-2005)**

	BDI	CO	PO	RF
Engineer				1
Technicians	1	1	1	2

😐 **Material (effective January 2005)**

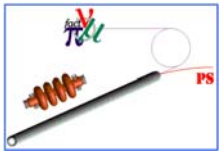
+ 50 kCHF/year
(=> 400 kCHF/year)

2) From outside (more collaborations…):

INDIA: 2 visiting scientists in 2004. Letters exchanged at the DG level.
Agreement in negotiation proposing Indian support for controls' software, operation of the 3 MeV test place and delivery of klystron power supply.

CHINA: Preliminary contacts at the highest level. Workshop in China next year to clearly establish the content of the agreement. Present proposal that China delivers the quadrupoles for the CCDTL section (40 to 90 MeV) of Linac4.

STATUS OF LINAC DEVELOPMENTS



Linac 4 parameters

	PHASE 1 (PSB)	PHASE 2 (SPL)	
Beam energy	**160**		MeV
Maximum repetition rate	**2**	**50**	Hz
Source current	**50**	**60**	mA
RFQ current	**40**	**50**	mA
Chopper beam-on factor	**75**	**62**	%
Current after chopper	**30**	**30**	mA
Maximum pulse length	**0.5**	**2**	ms
Average current	**15**	**3000**	μA
Maximum beam duty cycle	**0.1**	**10**	%
Transverse emittances (norm.)	**0.33**		π mm mrad
Longitudinal emittance	**0.24**		π deg MeV

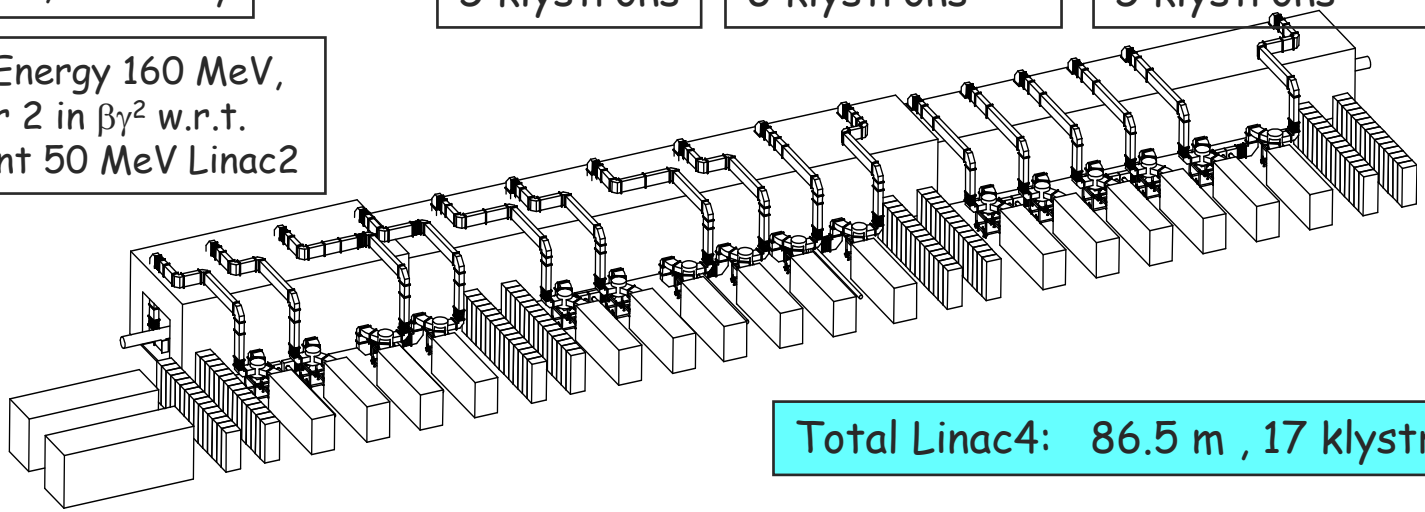
Linac 4 layout (1)

95keV | 3MeV | 40MeV | 90MeV | 160MeV

H-	RFQ	MEBT	DTL	CCDTL	SCL
	IPHI RFQ 6 m 1 klystron	chopping line 3.6 m	Drift Tube Linac 352 MHz 16.7 m 3 tanks 5 klystrons	Cell-Coupled Drift Tube L. 352 MHz 30.1 m 33 tanks 6 klystrons	Side Coupled Linac 704 MHz 28.1 m 20 tanks 5 klystrons

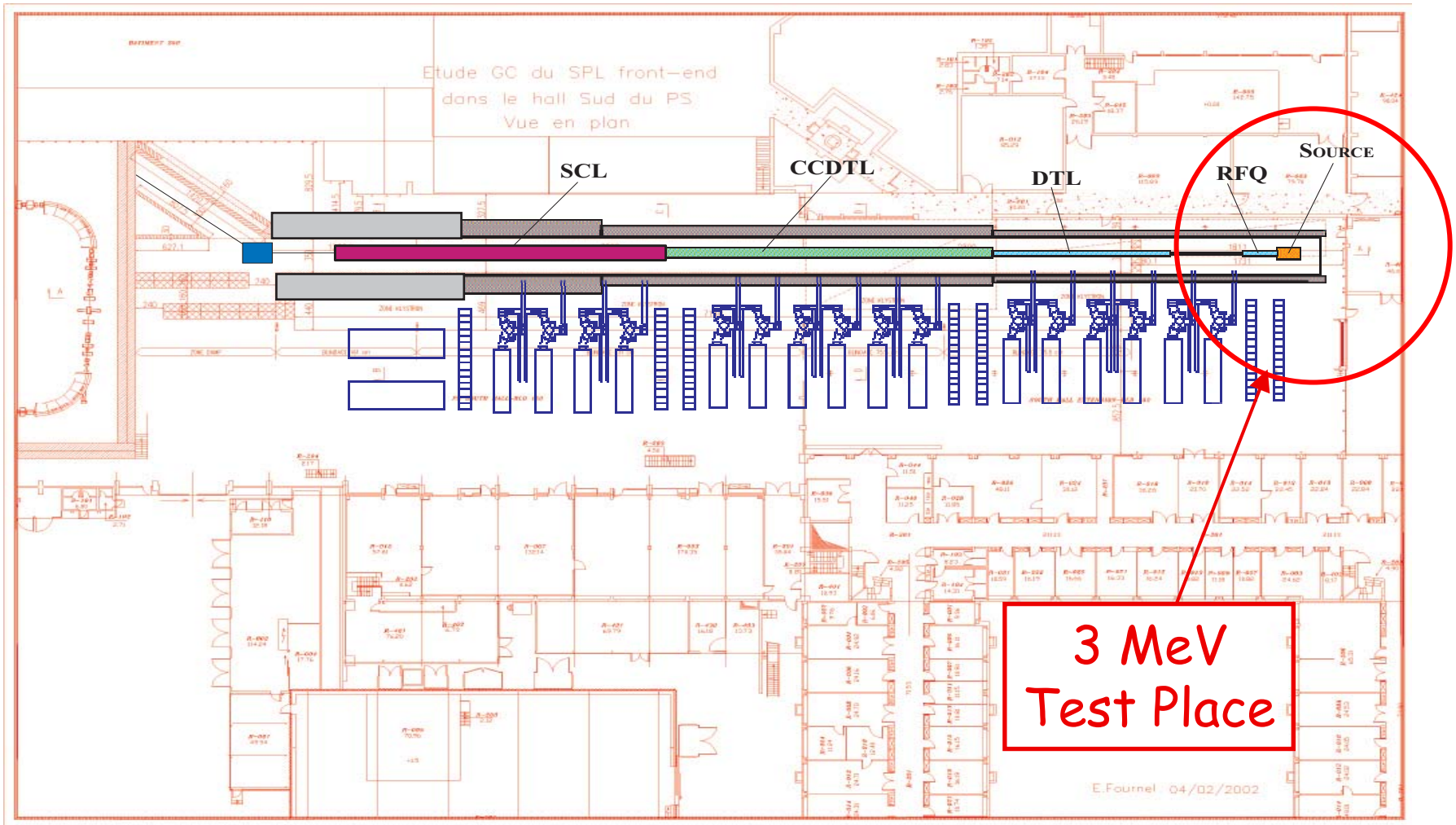
30 mA, 0.1% duty

Final Energy 160 MeV, factor 2 in $\beta\gamma^2$ w.r.t. present 50 MeV Linac2



Total Linac4: 86.5 m , 17 klystrons

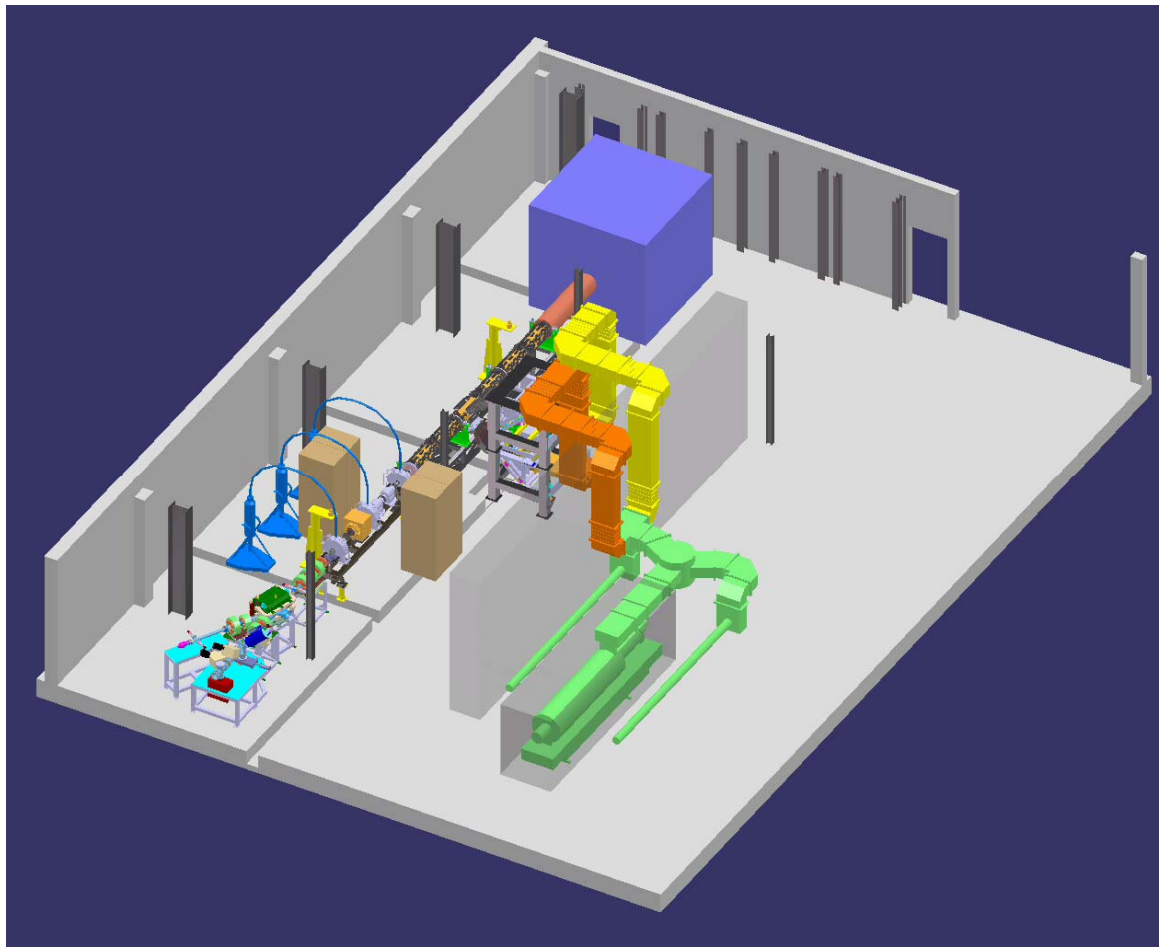
Linac 4 layout (2)



Progress towards Linac4 (1/3)

3 MeV Test Place: objectives

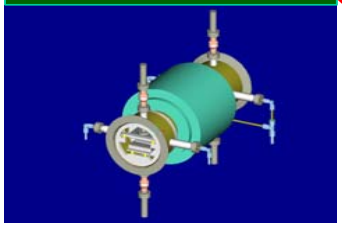
- Operation with beam : end 2007
- Beam dynamics studies at low energy.
- Demonstration of the chopper line capability to:
  - generate the required time structure of the beam
  - clean the beam from halo
  - match the beam to the subsequent RF structures.



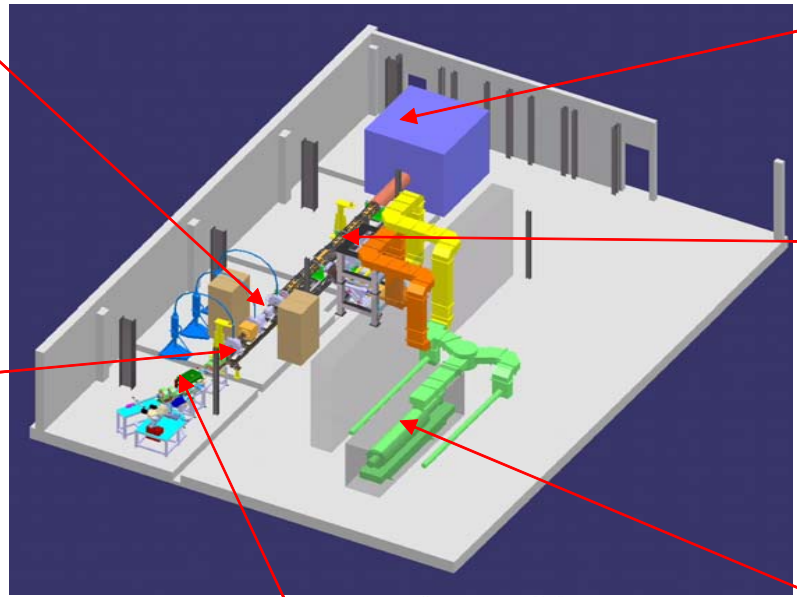
Progress towards Linac4 (2/3)

3 MeV Test Place: components

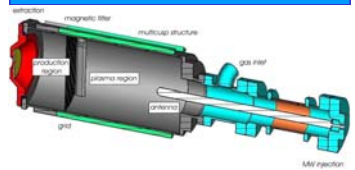
Chopper structure



Bunching cavities

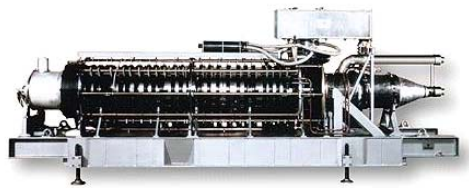


H⁻ ECR ion source

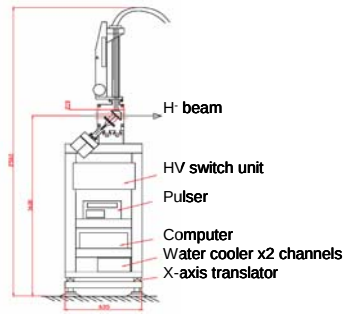


IPHI RFQ

HV pulsed power supplies for the LEP klystrons



Beam Shape and Halo Monitor

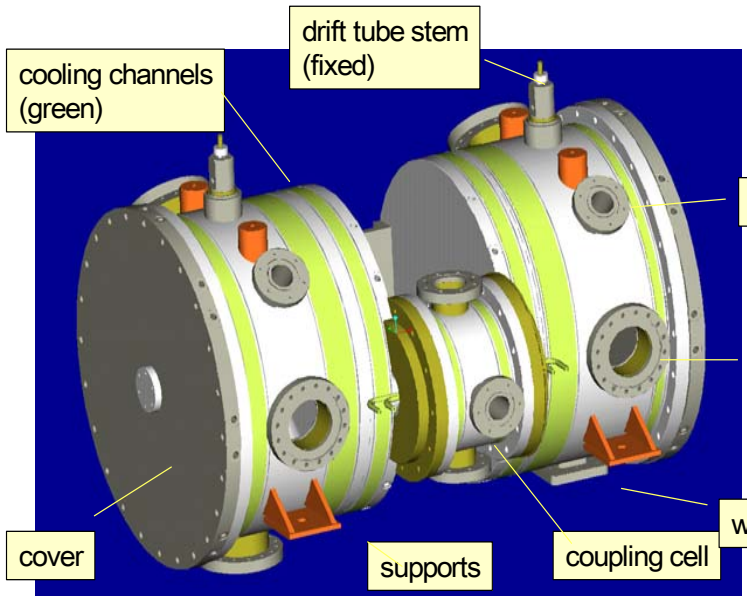


Progress towards Linac4 (3/3)

Development of Normal Conducting accelerating structures

3 – 40 MeV: **- DTL** (with CEA/IN2P3 and ITEP/VNIIEF): construction of a prototype Tank1 with dummy drift tubes + complete drift tube prototype (2006)
- or DTL-RFQ: high power prototype to be designed and built by IHEP/VNIIEF (2006)

40 – 90 MeV: **- CCDTL** full power one-cell prototype built at CERN (end 2003). Multi-cell prototype to be built at BINP/VNIITF (2006)



Diameter ~500 mm
Length ~ 800 mm

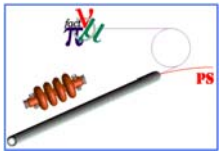
Material:
Cu-plated stainless steel

Assembling:
EB weldings, Helicoflex joints

machining and welding at CERN workshop finished (15.11.03)
to be tested with power in early summer 2004

90 – 160 MeV: **- SCL**:low power prototypes to be developed jointly by IN2P3 (Grenoble) and BINP/VNIITF

OUTCOME OF THE "HIGH INTENSITY PROTONS" WORKING GROUP

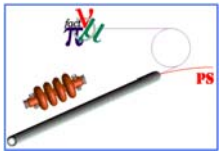


Identified users' requests[1]

USER	CERN COMMITMENT	USERS' WISHES	
	Short term	Medium term *[~ asap !]*	Long term *[beyond 2014]*
LHC	Planned beams	Ultimate luminosity	Luminosity upgrades
FT (COMPASS)	4.3×10^5 spills/y ?	7.2×10^5 spills/y	
CNGS	4.5×10^{19} p/year	Upgrade ~ × 2	
ISOLDE	1.92 µA *	Upgrade ~ × 5	
Future ν beams			> 2 GeV / 4 MW
EURISOL			1-2 GeV / 5 MW

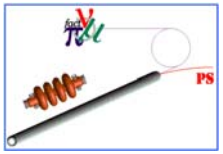
* 1350 pulses/h – 3.2×10^{13} ppp

[1]: assembled by the "High Intensity Protons" working group.
[CERN/AB working group mandated to (i) collect the present and foreseeable needs for high-intensity proton beams, (ii) analyze the capabilities of the CERN accelerator complex, (iii) compare possible improvements and (iv) recommend an upgrade path.]
"Report of the High Intensity Proton Working Group", CERN-AB-2004-022 OP/RF



HIP-WG 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, to 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 by pursuing the study of a Superconducting Proton Linac and by exploring alternative scenarios for the LHC upgrade.

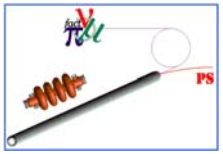


Medium term estimates

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) Standard operation	(i)+(ii) CNGS double batch	(i)+(ii)+(iii) 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)	3.3 (5.6)	7.2
East Hall spills [$\times 10^{6}$ /year]	1.5	1.4	1.5	1.3
NTOF flux [$\times 10^{19}$ pot/year]	1.6	1.5	1.6	1.5
ISOLDE flux [μA] [nb. of pulses/hour]	3.1 2200	2.6 1810	6.4 2240	1.9 1350
72 bunch train for LHC at PS exit [$\times 10^{11}$ ppb]	1.5	1.5	2	1.3 (2*)

* ultimate

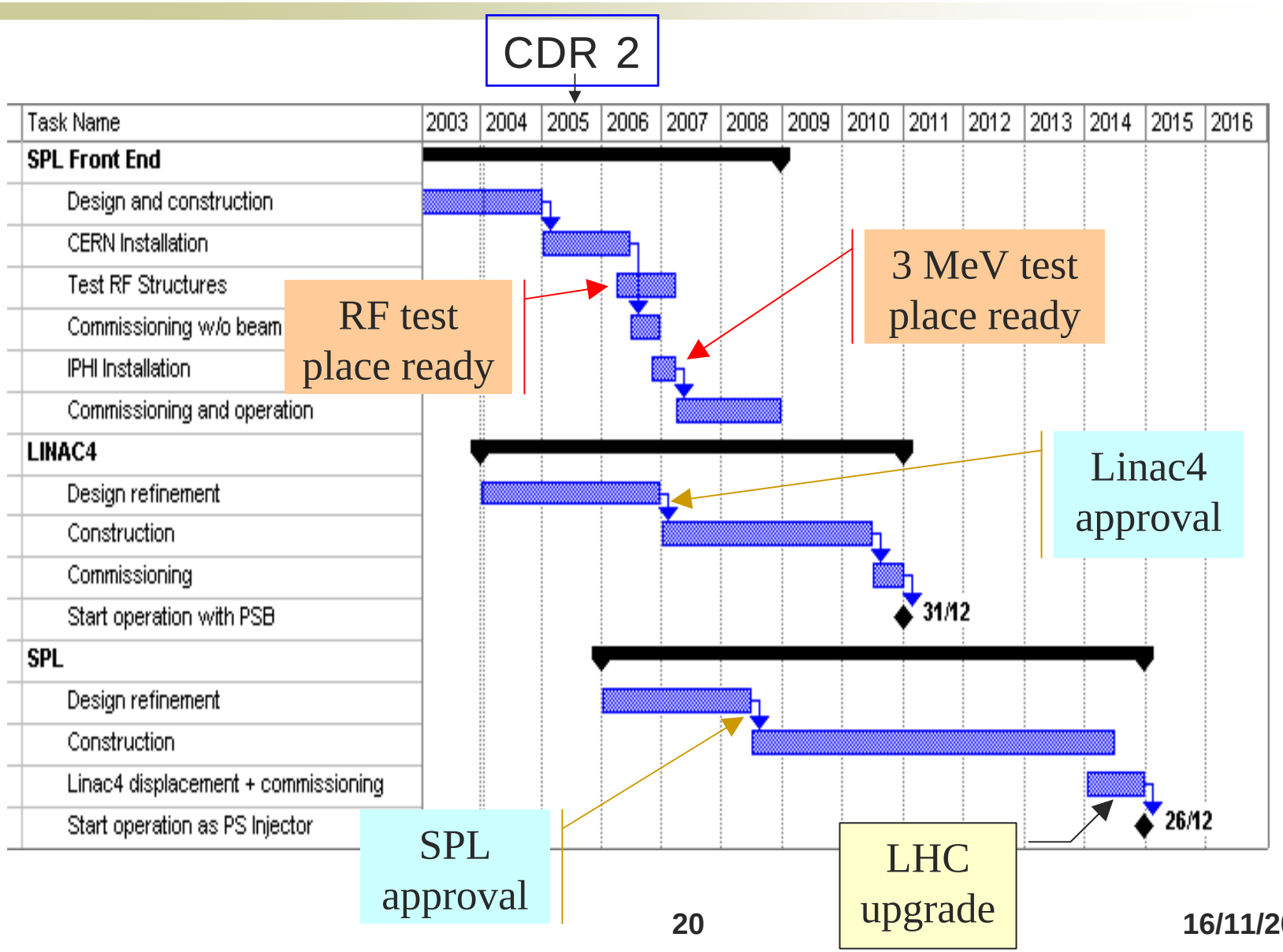


Comparison of drivers at CERN

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)

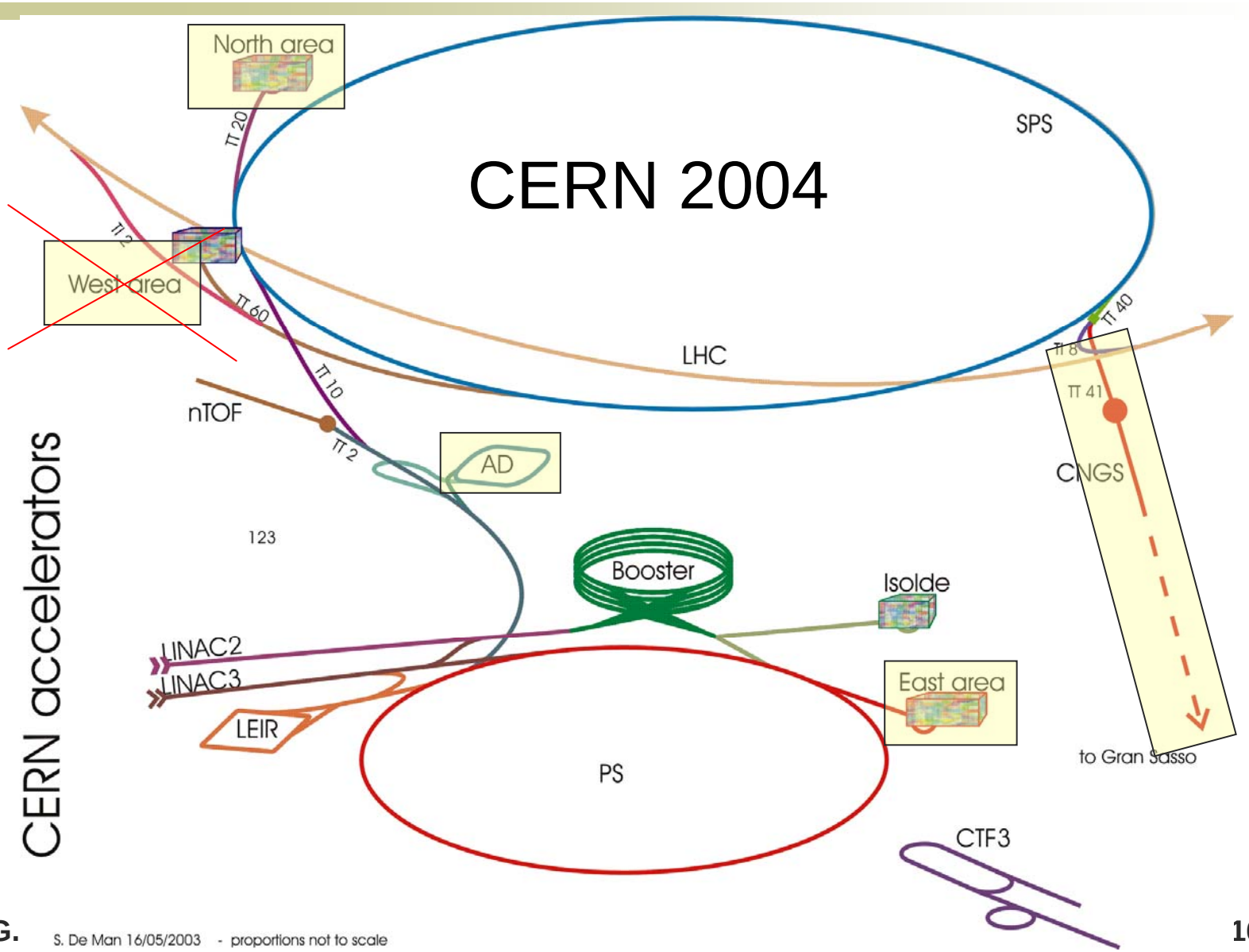
Possible planning



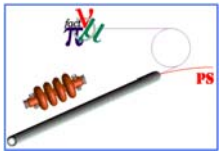
SPSC ("VILLARS") RECOMMENDATIONS FOR THE FUTURE OF FIXED TARGET PHYSICS

SPSC (Villars 2004)

SPSC Recommendations (p.21)

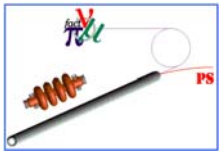


S. De Man 16/05/2003 - proportions not to scale



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)

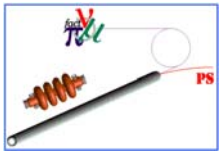
- Future neutrino facilities offer great promise for fundamental discoveries (such as CP violation) in neutrino physics, and a post-LHC construction window may exist for a facility to be sited at CERN.

- 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.



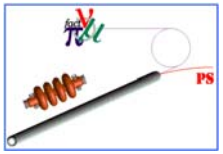
SPSC Recommendations (p.95)

- 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 …

CONSEQUENCES FOR RADIO-ACTIVE ION BEAMS



Medium / long term

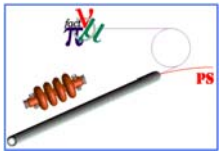
The driving forces for the definition of the future proton injectors at CERN are (in ~ order of influence):

- The LHC upgrade (H3 network inside CARE), which is likely to recommend a 1 TeV injector (+ probably Linac4).
- Neutrino physics (BENE network inside CARE), which is now encouraged to aim directly at a neutrino factory (compatible with a proton driver at 20-50 GeV)
- FT physics (SPSC – Villars), which favors a high power proton driver at CERN, with an energy ~ 20-50 GeV or even higher.

An adequate scenario has to be prepared (procedure under design…).

⇒ For the needs of the RIB community to be taken into account, a clear message must be communicated at the highest level of the organization.

Personal conviction: considering the ambitions, the proposal will be very costly, and arbitration will be unavoidable (~ 2008-2010).



Short / medium term

Before Linac4 is available, the only possibility to increase the proton flux to ISOLDE is by reducing the PSB repetition period (0.9 s has been defined by the HIP working group as a reasonable short term goal).

The AB management has soon to decide about it (meeting on December 6).

Approval will be more difficult than initially foreseen because:

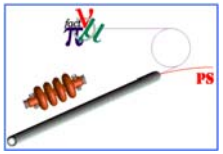
- Consequences for the equipments are extensive, and significant efforts are going to be necessary for debugging; Group Leaders are less and less favorable…
- The drawbacks for not doing it are mostly for ISOLDE, and less than originally thought, because of the SPSC preference for FT which is less demanding in terms of PSB cycles.

The SPSC clearly states that:

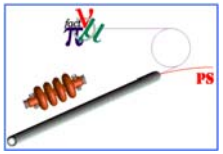
- CNGS should receive the foreseen flux (4.5 10^{19} pot/year),
- Efforts should be made to increase the SPS intensity and potential proton flux per year, **with the objective of reducing the number of cycles for CNGS in favor of COMPASS.**

The result would be no upgrade for ISOLDE in the short term, and even a reduction of the number of cycles with respect to today (~ -30 %)

⇒ For the needs of the RIB community to be taken into account, a clear message must be communicated at the highest level of the organization.



FINAL WORD



On the bright side …

The resources available for proton linac developments have remarkably increased during the past 2 years:

- clear support to the IPHI-CERN collaboration from all partners involved
- successful request for E.U. resources in favor of “Coordinated Accelerator Research in Europe” (CARE), including the HIPPI Joint Research Activity
- attribution of complementary resources by the CERN DG to help fulfill the work programme of the E.U. approved activities
- strong involvement of Russian laboratories with the help of the ISTC

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- many laboratories (in E.U. and in Russia) are jointly working in a coordinated way,
- a 3 MeV test place will be available at CERN in 2007,
- prototypes for linac4 accelerating structures will be available within 2 years

However, enthusiasm and support must be sustained, because…

- H- source development is lagging behind
- Too little is done on the superconducting linac part
- Information of the physics committee(s) has to be improved to strengthen conviction (need for deeper investigation of alternatives).

On the gloomy side …

- **For the short term, the reduction of the PSB repetition period to 0.9 s is not guaranteed to be approved.**
- **For the longer term, the recommendations from the Villars meeting:**
  - **do not take into account the needs of the physics community interested in Radio-active Ions,**
  - **have poorly rated the consensual proposal established between neutrino and RIB physicists, based on a large water Cherenkov detector in the Frejus tunnel + SPL + beta-beam.**