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

- 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)

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
“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) + VNIIIEF (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) + VNIIIEF (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)

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☹ 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

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<th>PHASE 1 (PSB)</th>
<th>PHASE 2 (SPL)</th>
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<tr>
<td>Beam energy</td>
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<td>Maximum repetition rate</td>
<td>2 Hz</td>
<td>50 Hz</td>
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<td>Source current</td>
<td>50 mA</td>
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<td>RFQ current</td>
<td>40 mA</td>
<td>50 mA</td>
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<tr>
<td>Chopper beam-on factor</td>
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<td>Current after chopper</td>
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<td>Maximum pulse length</td>
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<td>Average current</td>
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<td>3000 µA</td>
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<td>Maximum beam duty cycle</td>
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<td>0.33 π mm mrad</td>
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<td>Longitudinal emittance</td>
<td>0.24 π deg MeV</td>
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Linac 4 layout (1)

**95keV**
- H-
- RFQ

**3MeV**
- MEBT
- chopping line
- 3.6 m

**30 mA, 0.1% duty**

**30 mA, 0.1% duty**

**40MeV**
- Drift Tube Linac
- 352 MHz
- 16.7 m
- 3 tanks
- 5 klystrons

**90MeV**
- Cell-Coupled Drift Tube L.
- 352 MHz
- 30.1 m
- 33 tanks
- 6 klystrons

**SCL**
- Side Coupled Linac
- 704 MHz
- 28.1 m
- 20 tanks
- 5 klystrons

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

**Total Linac4: 86.5 m, 17 klystrons**
Linac 4 layout (2)

3 MeV Test Place
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
- Beam Shape and Halo Monitor
- HV pulsed power supplies for the LEP klystrons
- HV switch unit
- Pulser
- Computer
- Water cooler x2 channels
- X-axis translator

R.G. 13 16/11/2004
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)

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

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
OUTCOME OF THE “HIGH INTENSITY PROTONS” WORKING GROUP
Identified users’ requests

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<tr>
<th>USER</th>
<th>CERN COMMITMENT</th>
<th>USERS’ WISHES</th>
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<td>Short term</td>
<td>Medium term</td>
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<td>[~ asap !]</td>
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<tr>
<td>LHC</td>
<td>Planned beams</td>
<td>Ultimate luminosity</td>
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<tr>
<td>FT (COMPASS)</td>
<td>$4.3\times10^5$ spills/y</td>
<td>$7.2\times10^5$ spills/y</td>
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<tr>
<td>CNGS</td>
<td>$4.5\times10^{19}$ p/year</td>
<td>Upgrade $\sim \times 2$</td>
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<tr>
<td>ISOLDE</td>
<td>$1.92\ \mu$A *</td>
<td>Upgrade $\sim \times 5$</td>
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<td>Future $\nu$ beams</td>
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<td>EURISOL</td>
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* 1350 pulses/h – $3.2\times10^{13}$ 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.]
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) $7 \times 10^{13}$ ppp in the SPS and (iii) Linac4 injecting in the PSB

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<th>(i)</th>
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<th>(i)+(ii)+(iii)</th>
<th>Basic user’s request</th>
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<td>CNOS flux [$\times 10^{19}$ pot/year]</td>
<td>4.7 (4.5)</td>
<td>7.0 (4.5)</td>
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<td>FT spills [$\times 10^5$ /year]</td>
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<td>3.0 (5.1)</td>
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<td>ISOLDE flux [$\mu$A] [nb. of pulses/hour]</td>
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<td>72 bunch train for LHC at PS exit [$\times 10^{11}$ ppb]</td>
<td>1.5</td>
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<td>1.3 (2*)</td>
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* ultimate
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<th>Present accelerator</th>
<th>Replacement accelerator</th>
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<td>LHC upgrade</td>
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<tr>
<td>Linac2</td>
<td>Linac4</td>
<td>50 → 160 MeV H⁺ → H⁻</td>
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<td>PSB</td>
<td>2.2 GeV RCS* for HEP</td>
<td>1.4 → 2.2 GeV 10 → 250 kW</td>
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<td>2.2 GeV/mMW RCS*</td>
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<td>2.2 GeV/50 Hz SPL*</td>
<td>1.4 → 2.2 GeV 0.01 → 4 MW</td>
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<td>PS</td>
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<td>5 Hz RCS*/**</td>
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<td>0.45 → 1 TeV Intensity x 2</td>
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* with brightness x2  ** need new injector(s)
Possible planning

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- RF test place ready
- 3 MeV test place ready
- Linac4 approval
- SPL approval
- LHC upgrade

R.G. 20 16/11/2004
SPSC ("VILLARS")
RECOMMENDATIONS FOR
THE FUTURE OF FIXED
TARGET PHYSICS
Report on the SPSC Villars Meeting
September 22-28 2004
John Dainton
University of Liverpool, GB
(on behalf of the SPSC)
SPSC Recommendations (p.21)
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 @ 4.5x10^{19}pot/yr)
- CNGS + COMPASS ? multi-turn xtraction longer running period
- no compelling case for extending CNGS beyond 2011 @ realisable pot/yr (< ~ 3x 4.5x10^{19}pot/yr)
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
    - dynamics: low energy, resonance
    - \( \nu \) physics: evaluation & R&D @ CERN
      - \( p \)-driver ↔ superbeam ↔ detector
    - global context → NF
  - All but HI benefit from/require high intensity
    - RCPSB  RCPS  …

synergies with other science?  SPL?
CONSEQUENCES FOR RADIO-ACTIVE ION BEAMS
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).
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 ($4.5 \times 10^{19}$ 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

- 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.