CERN : present status and possible perspectives

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Reference: Presentation of CERN – in the Briefing Book Volume 1 – Section X , Chapt 2.4

- **CERN enables Europe to be a world leader in experimental EPP and a centre of excellence in EP theoritical physics;**
- **Success in european and international collaborations with small and large countries;**
- **Strong technical record in computing , designing, constructing, operating accelerators → strong engineering, stable and substantial resources**

CERN should not be considered as another EPP Laboratory in competition with all other European Laboratories

but the place where european experimental programmes and related R&D, agreed by the european EP community and political authorities, are implemented through laboratory collaborations

Summary of Personnel Statistics (2005)

	Staff		Fellows/Paid Associates
	Limited duration	Indefinite	Unpaid users
Research Physicists	31	42	197 MS 4308 NMS 2025
Scientific & Engineering Work	330	627	395
Technical work	371	527	42
Manual Work	113	120	--
Administration	204	270	9
	1049	1586	643
Total		2635	F 246 PMS 272 PNMS 125

Summary of annual budget expenditures for 2008-2010 (in 2005 prices)

		MCHF
LHC		
	Personnel	165
	Material	100
non-LHC	Personnel	240
	Material	180
(including infrastructure, accelerators, energy)		
Debt interest		40
	Total	725
Debt reimbursement		280
	Total	**1005**

CERN – mission and role

for the benefit of European High Energy physics

- **Research**
  - **develop, build, run unique ‘frontier’ facilities**

- **Provide an environment for training physicists and engineers**

- **Facilitate and actively pursue Technology Transfer**

- **Foster international collaboration**

CERN – mission and role

Illustrations of role wider than 'just' own program (for which it has the responsibility) :

It is natural that CERN is requested:

- **To participate in various EU programs:**

  CARE / EUROTEV – more later
  ENLIGHT – hadron therapy network

- **To be a host for 'Recognized Experiments' → list on next slide**

- **To facilitate and support various 'non main stream' but top notch**
- **projects: ISOLDE, n-TOF, rare K decay, hadron spectroscopy...**

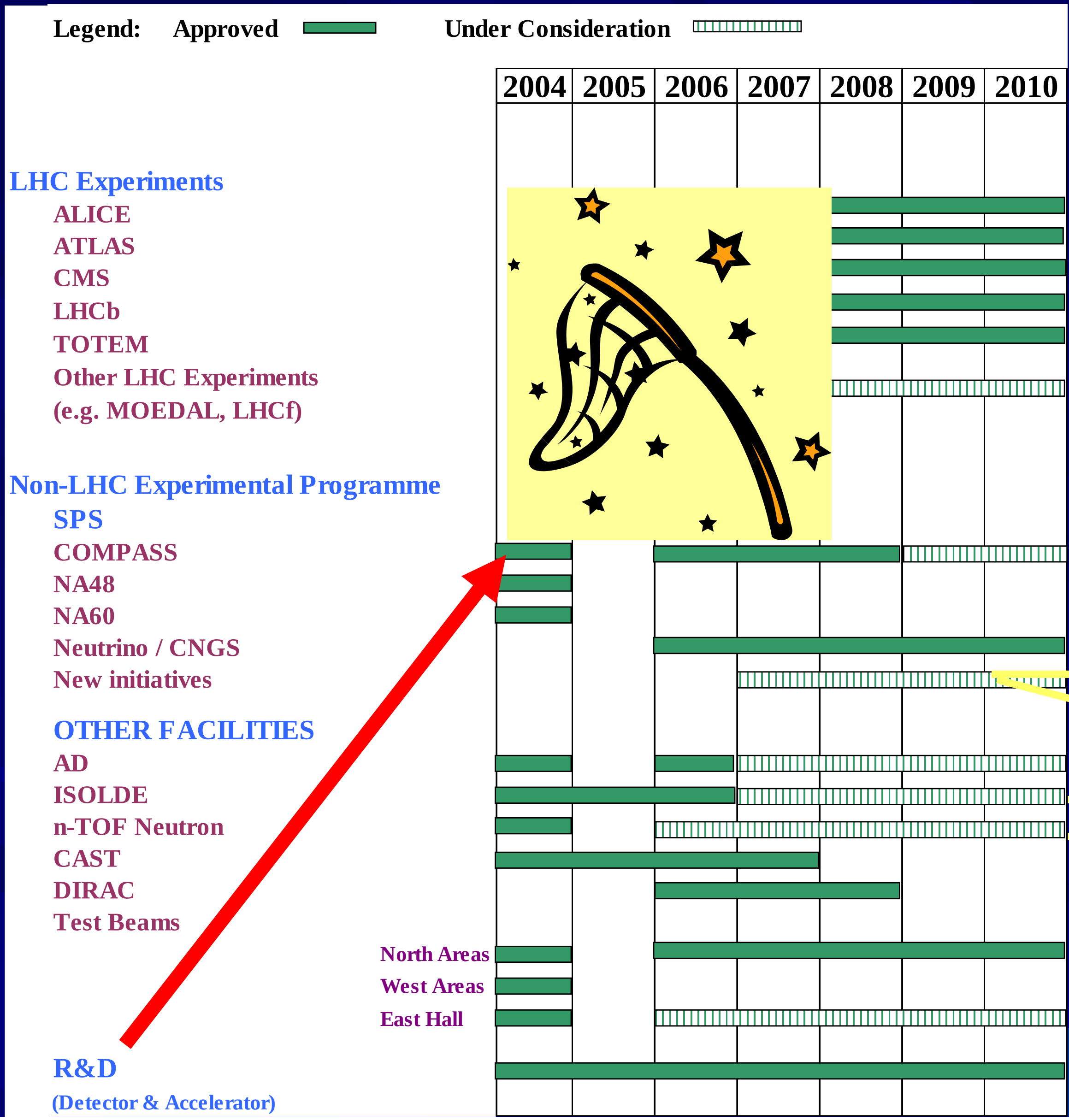
- **To lead the LCG/EGEE effort**

Recognized Experiments

RE

RE1	*(AMS)* Alpha Magnetic Spectrometer (AMS) for Extraterrestrial Study of Antimatter, Matter and Missing Matter on the International Space Station
RE3	*(AUGER PROJECT)* The Pierre Auger Observatory Project
RE5	*(EXPLORER)* The Gravitational Wave Detector EXPLORER
RE6	*(ANTARES)* ANTARES: An Undersea Neutrino telescope
RE7	*(GLAST)* GLAST
RE8	*(LISA)* LISA
RE9	*(NESTOR)* NESTOR-Neutrino Extended Submarine Telescope with Oceanographic Research
RE10	*(ICECUBE)* IceCube
RE11	*(MICE)* Muon Ionization Cooling Experiment
RE12	*(MEG)* MEG: search for the mu e decay at PSI
RE13	*(T2K)* Neutrino Oscillation Experiment at JHF
RE2A	*(CAPRICE)* Cosmic AntiParticle Ring Imaging Cerenkov Experiment
RE2B	*(PAMELA)* Search for Antimatter in Space

Planned Scientific Programme (MTP June 2005)



NA48/3 TP; R&D require

NA60 LoI for cont.

HIE ISOLDE

New tgt; add. beamlin

Rec. Expts.

ILC Expts.

The LHC programme

will start producing physics in 2007 with

- 'initial' detectors – remaining CtC, including staged items (mainly DAQ) to be provided until 2010/2011
- fully functional LCG Tier-0; CAF (full capacity requires additional funding)
- an LHC machine ramping up to 10^{33} cm^{-2} s^{-1} and then to 10^{34} cm^{-2} s^{-1}

We expect LHC results in 2010/2011 to provide a basis for deciding on future research at the energy frontier.

The LHC programme

These results are impossible to predict
(no Higgs (yet); a light Higgs; a heavy Higgs;
SUSY – Higgses, sleptons, squarks (light, heavy);
extra dimensions; ...)

but

the LHC is likely to reveal new fundamental mass scales in the region 0.114 - >~ 1 TeV

Its findings will highlight the next physics opportunities at the energy frontier

The LHC programme upgrade

1. Efficient running of the LHC complex requires consolidation of the injectors, in particular of the Proton Synchrotron (1959), but also of the SPS

2. A next step at the energy frontier could be a very high luminosity hadron collider at LHC energy (SLHC)
   - higher statistics
   - higher mass reach

   This requires major modifications of the injector complex and the LHC hardware and new R&D on detectors (higher irradiation on trackers)

Maximization of LHC Luminosity

(L1) - Minimize turn-around time by improving reliability / minimizing duration of stops

(L2) - Remove bottle-necks towards ultimate luminosity

(SL) - Refine / select scenario for SLHC (start in ~ 2015)

LHC: “Maximize integrated luminosity” (2007- 2015)

(L1) - Minimize turn-around time by improving reliability / minimizing duration of physics interruptions

- Acute needs for consolidation. E.g.: magnets:
  - PS: “…degradation is the worst but taken care of…” [1]
    - 24 dipoles refurbished in 2005 (1rst part of “phase 1”)
    - rate for continuation: 8 additional dipoles / year

    Replacement of old PS is a requirement for long term reliability

  - SPS: “…seems to be a victim of accelerated degradation…” [1]
    - More measurements and proposal for extensive consolidation by the end of 2006

- Decrease of LHC filling time/operational simplifications
  - Single batch injection in the PS using Linac4 as PSB injector
  - 0.9 s cycling rate of the PSB and shorter acceleration cycle in the SPS

LHC: "Maximize integrated luminosity" (2007- 2015)

(L2) – Remove bottle-necks towards ultimate luminosity

– Increase injection energy in the PSB (→ Linac4) *[more R&D needed]*
  - Incoherent space charge tune spread at 50 MeV limits PSB performance. Even with 2 PSB batches, the ultimate beam for LHC cannot be obtained at the PS exit.
  - With Linac4 injecting at 160 MeV, a factor of 2 is gained.

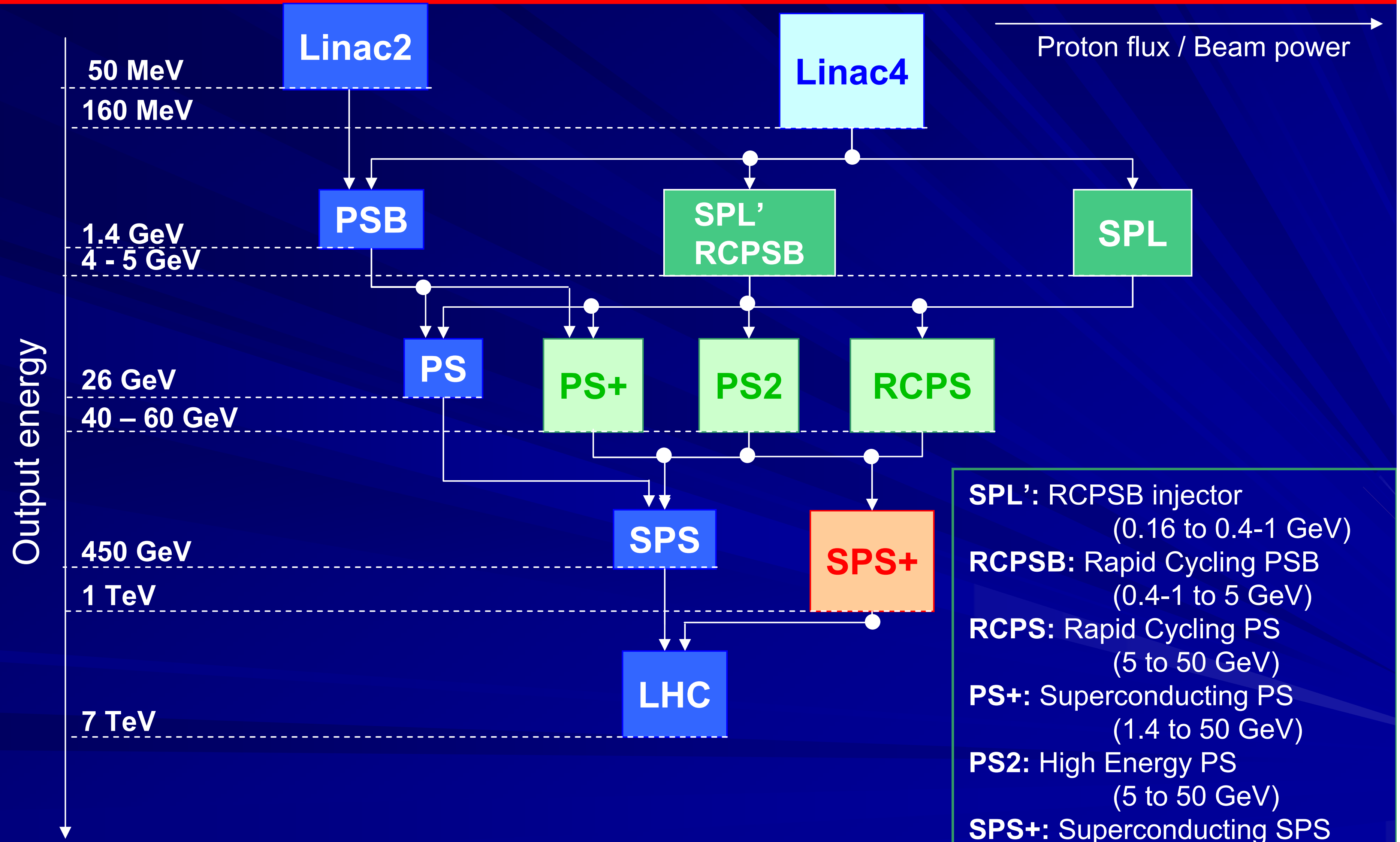
– Reduce the impedance of the SPS
  - Higher threshold for transverse and longitudinal instabilities

– Increase injection energy in the SPS (→ PS+ / PS2 / RCPS) *[replacement of PS R&D needed]*
  - Reduced space charge tune spread
  - Smaller beam size => reduced loss at high intensity
  - Higher threshold of Transverse Mode Coupling Instability
  - Higher threshold of coupled bunch transverse instabilities in H-plane due to e-cloud
  - Shorter acceleration time (- 10 %)

LHC: "Maximize integrated luminosity" (2007- 2015)

– Phase 0: without hardware changes in the LHC
  - Improve injectors (⇒ actions L1 and L2) to increase brightness N_b/ε up to ultimate:
    $\rightarrow L_0 = 2.3 \times 10^{34}$ cm^{-2} s^{-1} & $\int Ldt \sim 1.5 \times$ nominal (= 100 fb^{-1} / year)
  - increase the dipole field from 8.33 to 9 T: ↑ E_{max} = 7.54 TeV
– Phase 1: with major hardware changes in the LHC (IR, RF, collimation, dump, …)
  - modify the insertion quadrupoles and/or layout: ↓ β^* = 0.25 m → more R&D needed in higher field magnets
  - increase crossing angle θ_c by $\sqrt{2}$: ↑ θ_c = 445 μrad
  - halve bunch length with new high harmonic RF system in the LHC:
    $\rightarrow L_0 = 4.6 \times 10^{34}$ cm^{-2}s^{-1} & $\int Ldt \sim 3 \times$ nominal (= 200 fb^{-1} / year)
  - double the number of bunches [⇒ new RF systems in the injectors (including SPS if 12.5 ns bunch spacing)] & increase θ_c:
    $\rightarrow L_0 = 9.2 \times 10^{34}$ cm^{-2}s^{-1} & $\int Ldt \sim 6 \times$ nominal (= 400 fb^{-1} / year)

Scenarios for proton injectors:
- possible combinations



SPL': RCPSB injector
(0.16 to 0.4-1 GeV)
RCPSB: Rapid Cycling PSB
(0.4-1 to 5 GeV)
RCPS: Rapid Cycling PS
(5 to 50 GeV)
PS+: Superconducting PS
(1.4 to 50 GeV)
PS2: High Energy PS
(5 to 50 GeV)
SPS+: Superconducting SPS
(50 to1000 GeV)

High Energy Frontier beyond LHC

3. A high energy, high luminosity electron-positron linear collider: Participation in Design Studies and R&D through EUROTEV and the CTF3 Collaboration

CERN in EUROTEV:

- **R&D activities linked to ILC and CLIC. Common issues independent of linac technology.**
- **CERN contributions on damping ring, beam delivery system, instrumentation and luminosity performance.**
- **Specific progress has been made at CERN on benchmarking of the e-cloud code, on the strategy to provide phase signal and on the setup of phase detector tests, benchmarking of CERN-used code for physics generator and beam-beam simulation, and analysis of tuning bumps based on emittance and luminosity measurements to optimize the performance.**

Summary of CERN participation and funding in Design Studies

EURONS-EURISOL: 2005-2008 (4 years)
DIRAC-EUROTEV: 2005-2007 (3 years)

Activity	Acronym	Requested EU Funds	EU to CERN resource allocation			CERN commitment		
		M€	Total M€	Material M€	Personnel (person-y)	Total MCHF	Material MCHF	Personnel (person-y)
Linear Collider	EUROTEV	9	1.6	0.25	6 (staff) 11 (fellows)	3	0.6	11.7 (staff) 4 (fellows)
Isolde and Beta-beams	EURISOL	9	1.5	0	11 (staff) 9.5 (fellows)	4	0	20.7 (staff) 12 (fellows)
PS orbit system and longitudinal damping	DIRAC	10	0.32	0.32	0	1.1	0.34	3 (staff) 2 (fellows)
Nuclear structures and beams	EURONS	9 (?)	1.3	0.64	3 (fellows)	2	0.2	6.5 (staff) 5 (fellows)

CLIC technology-related key issues (ILC-TRC 2003

CLIC

Covered by CTF3

R1: Feasibility

- R1.1: Test of damped accelerating structure at design gradient and pulse length
- R1.2: Validation of drive beam generation scheme with fully loaded linac operation
- R1.3: Design and test of damped ON/OFF power extraction structure

R2: Design finalisation

- R2.1: Developments of structures with hard-breaking materials (W, Mo…)
- R2.2: Validation of stability and losses of drive beam decelerator;
  Design of machine protection system
- R2.3: Test of relevant linac sub-unit with beam

Industrial development

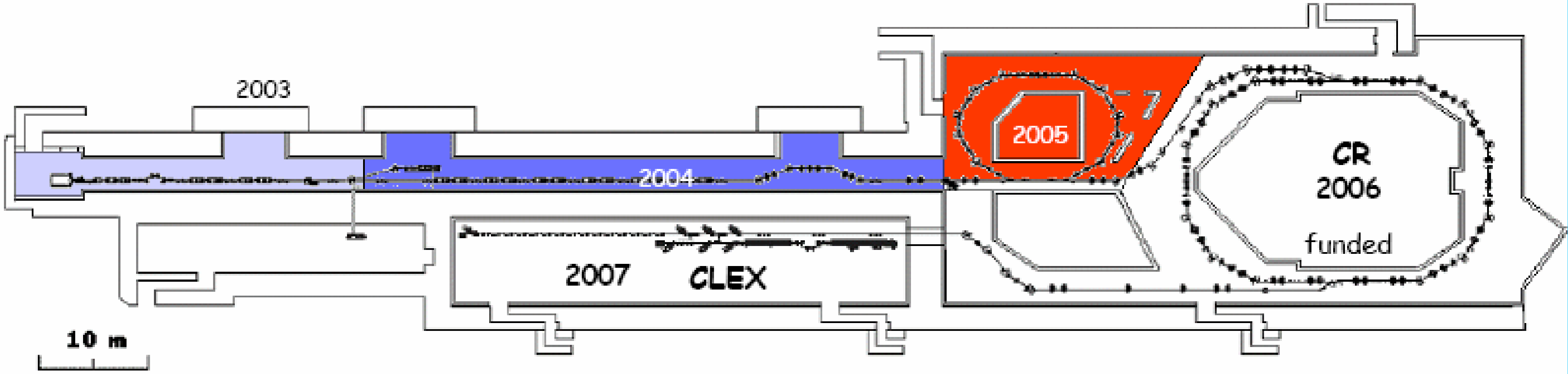
- R2.4: Validation of drive beam 40 MW, 937 MHz Multi-Beam Klystron with long RF pulse

- R2.5: Effects of coherent synchrotron radiation in bunch compressors
- R2.6: Design of an extraction line for 3 TeV c.m.

Covered by EUROTeV

CLIC

CTF3 project & schedule



SCHEDULE WITH EXTRA RESOURCES	2004	2005	2006	2007	2008	2009
Drive Beam Accelerator	■					
30 GHz power test stand in Drive Beam accelerator	■	■				
30 GHz power testing (4 months per year)		■	■	■	■	■
R1.1 feasibility test of CLIC structure				■		
Delay Loop	■	■				
Combiner Ring	■	■	■			
R1.2 feasibility test of Drive beam generation				■		
CLIC Experimental Area (CLEX)		■	■			
R1.3 feasibility test PETS				■		
Probe Beam			■	■		
R2.2 feasibility test representative CLIC linac section					■	
Test beam line		■	■	■	■	
R2.1 Beam stability bench mark tests					■	■

Other programme opportunities with new Proton Accelerators

4. Upgrade/modernization of CERN's accelerator complex will benefit the LHC programme (efficiency; luminosity), but also offers new opportunities, in particular for neutrino physics beyond OPERA; MINOS; T2K; ...

- Pursue development for {β-beam + super-beam} and ν factory Depending on physics and outcome of technical developments, elaborate a proposal for a ν facility at CERN 2010- 201x
- Other physics **[**physics with kaons, muons, heavy-ions (fixed-target), antiprotons and nuclear physics**]**
- Complement the accelerators resulting from the needs of priorities 1 & 2
- Adapt experiments to the capabilities of the accelerators

Scenarios for proton injectors:

- PS+ based (superconducting synchrotron 1.4 → ~ 50 GeV / 0.3 Hz)

		PS+ based		
	Linac4 PSB PS SPS	*Linac4* PSB *PS+* SPS	*Linac4* *SPL* *PS+* SPS	*Linac4* *SPL* *PS+* *SPS+*
L1, L2	Ultimate beam from PS	PS replaced Ultimate beam from SPS	PSB & PS replaced Ultimate beam from SPS	PSB, PS & SPS replaced
SLHC	+	++	++	+++
β beam	-	-	++ (γ >100)	++ (γ >200)
ν Factory	-	-	+++ (~5 GeV prod. beam)	+++ (~5 GeV prod. beam)
K, μ	-	x00 kW beam at 50 GeV	x00 kW beam at 50 GeV	x00 kW beam at 50 GeV
Nuclear Physics	-	-	+++	+++

Summary of CERN participation and funding over 5 years in the frame of ESGARD / CARE

Activity	Acronym	Allocated EU funds	EU to CERN allocation			CERN committment		
		(MEur.)	Total (MEur)	Mater. (MEur)	Person. (m-y)	Total (MCHF)	Mater. (MCHF)	Person. (m-y)
CARE NA1	ELAN	0.68	0.081	0.081	0	0.66	0.15	3 staff 0 fell
CARE NA2	BENE	0.45	0.058	0.058	0	0.47	0.11	1.8 staff 0.5 ds
CARE NA3	HHH	0.49	0.167	0.167	0	2.68	0.19	12.5 staff 3 fell
CARE JRA1	SRF	5.0	0	0	0	0	0	0
CARE JRA2	PHIN	3.54	1.178	1.103	1.5 fell	1.98	0.32	8 staff 2.5 fell
CARE JRA3	HIPPI	3.6	0.635	0.095	6 fell	8.73	2.0	29 staff 15 fell
CARE JRA4	NED	0.98	0.60	0.60	0	0.25	0.03	0.9 staff 0.6 fell
ESGARD&CARE Management		0	0	0	0	0.43	0.09	2 staff 0 fell
TOTAL		14.74	2.72	2.1	7.5 fell	15.21	2.9	57.2 staff 21.6 fell

Summary of R&D activities and needs

1. LHC luminosity upgrade:
   - Nb_3Sn wires and cables for inner triplet (NED $\in$ CARE)
   - High-field magnets (15T) NEW
   - Improved detector trackers for robustness against radiation

2. Proton accelerator complex upgrade:
   - Fast-ramping SC magnets NEW for PS+ (3.5T, 4T/s, 3.6s/cycle)
   - High intensity proton source (HIPPI $\in$ CARE) NEW (LINAC4, SPL)

3. Linear Collider: ILC and CLIC
   - EUROTEV and CTF3

4. Design Studies:
   - EUROTEV (generic LC aspects)
   - Participation in the GDE/ILC
   - Optimization of CLIC scheme
   - EURISOL – beta beam
   - Neutrino factory (not yet)

Conclusions

CERN is ready to make its contributions to the further development of high energy physics in the coming decades,

→first of all by providing the LHC, to be optimally exploited by the ATLAS, CMS, LHCb and ALICE collaborations;

→by endeavoring into a challenging R&D programme within large collaborations, in order to provide the community with results allowing timely choices around 2010 on:

- **CLIC technology and LC design;**
- **High field Nb_3Sn magnets (~15T)**
- **Pulse field NbTi magnets (3.5T, 4T/sec)**
- **Advanced proton accelerator design (SPL; fast cycling SC synchr.);**
- **neutrino factory design study**

→provided the community can convince the member states to adequately bridge the funding gap in CERN budgets from 2007 - 2011