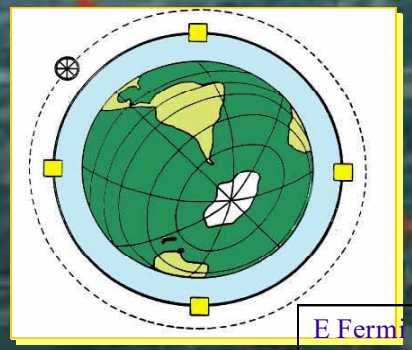
Views for the Future of CERN

GRID TECHNOLOGY WORKSHOP
Islamabad, October 20, 2003

Luciano MAIANI, CERN



Introduction

- CERN today is fully engaged in the LHC, the first multi-billion, high tech project in Particle Physics;
- The recent difficulties have shown the determination of the CERN personnel to keep the LHC on the road and to remain the spearhead of particle physics in Europe;
- The large user community (about 6000 people) makes it impossible to discuss the future of CERN in isolation from the future of particle physics in Europe and world-wide.

- Acknowledgement:
  - Discussions on the future of CERN after the LHC have taken place at several times, starting from 2001, and I have learned a lot from them :
    - Faculty EP-TH meeting, Jan. 2001
    - ECFA Study Group, approved in summer 2001
    - SPC study, presented to Council in Dec. 2001
    - Committee of Council, March and June 2003
    - ECFA & ICFA meetings
    - Faculty EP-TH meeting, July 2003
- A personal view !

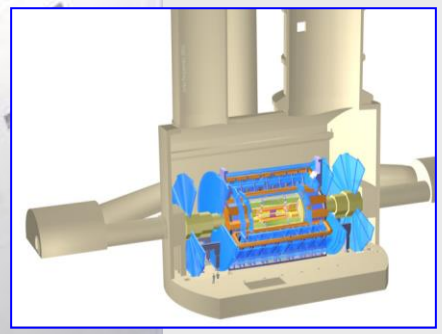
1. Views on CERN future

- In a way, it is a trivial question…CERN's future is the LHC:
  - Commissioning 2007;
  - Physics: 2007- 2022 (at least);
  - Consolidation programme
  - Luminosity upgrade can prolong LHC lifetime and extend its discovery potential by 15-30% in mass;
  - Energy upgrading rather costly and further in the future, as it requires the development of new high field magnets (Nb3Sn?15 Tesla ?).

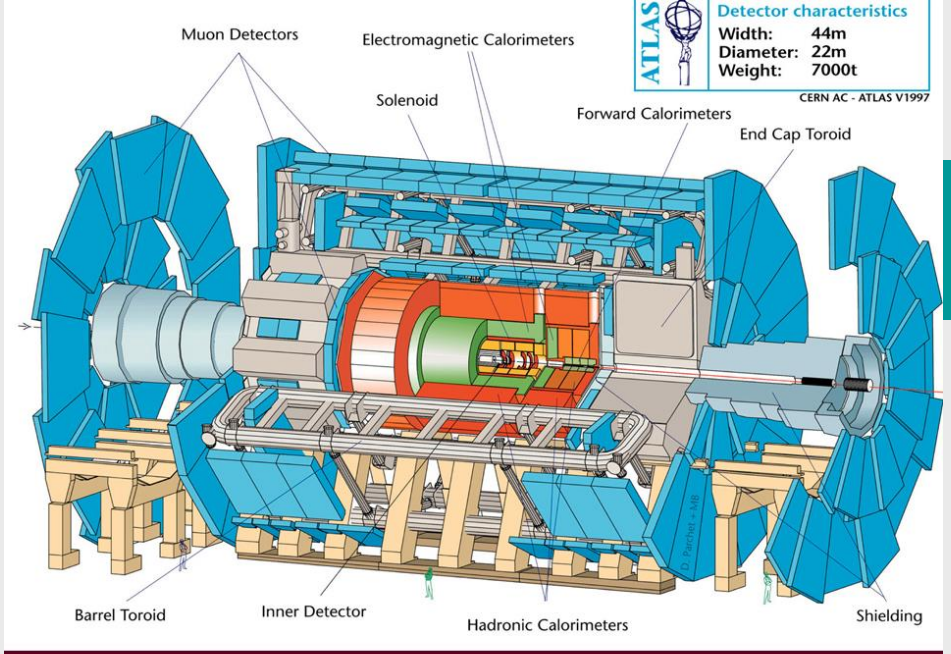
} Some resources available in CERN plan.

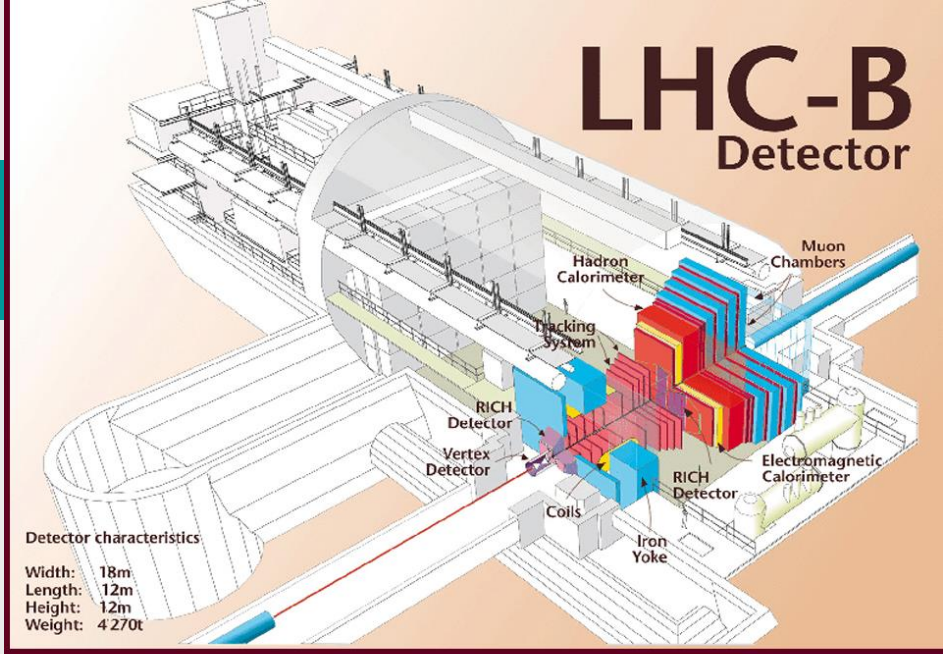
- However:
  - Important HEP physics problems and corresponding scientific communities are not addressed by the LHC;
  - Diversification is needed;
  - e+ e - Linear Collider (subTeV): TESLA/NLC/JLC ?
  - Discussion must start now

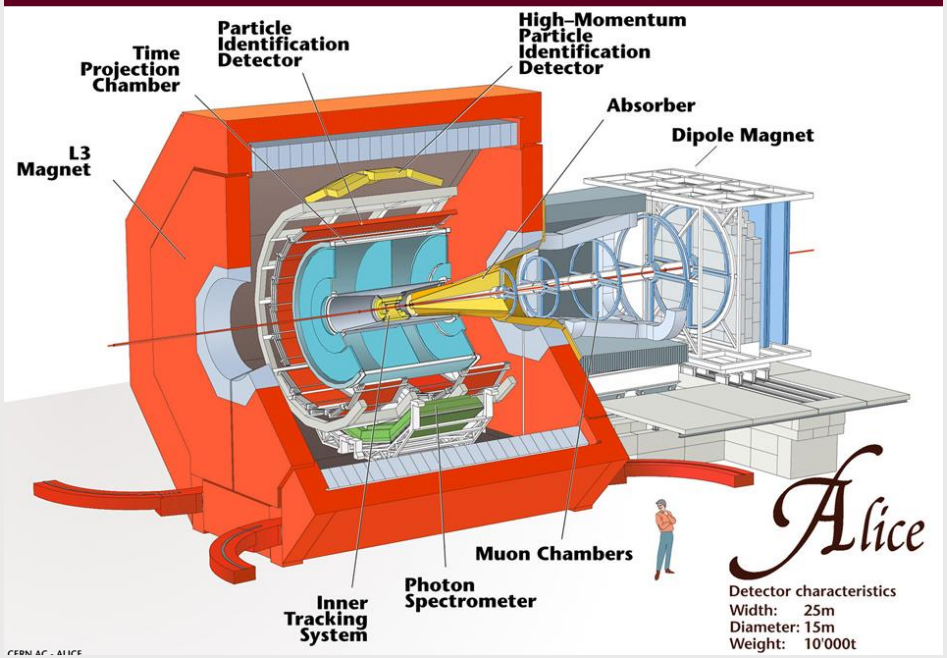
ATLAS Cavern: July 2003

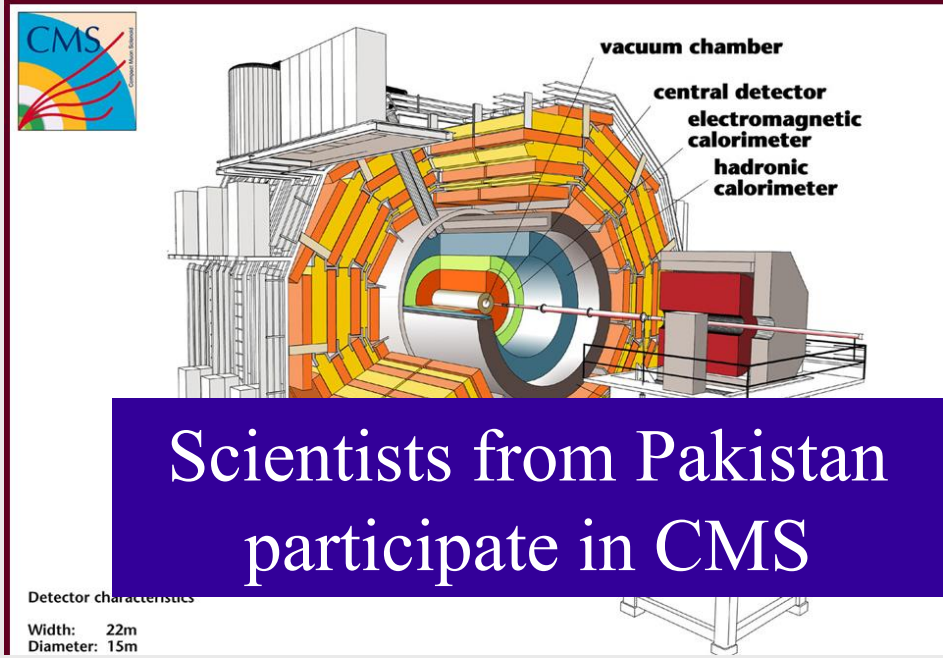


Large Hadron Collider: Cryogenic Dipoles on store at CERN

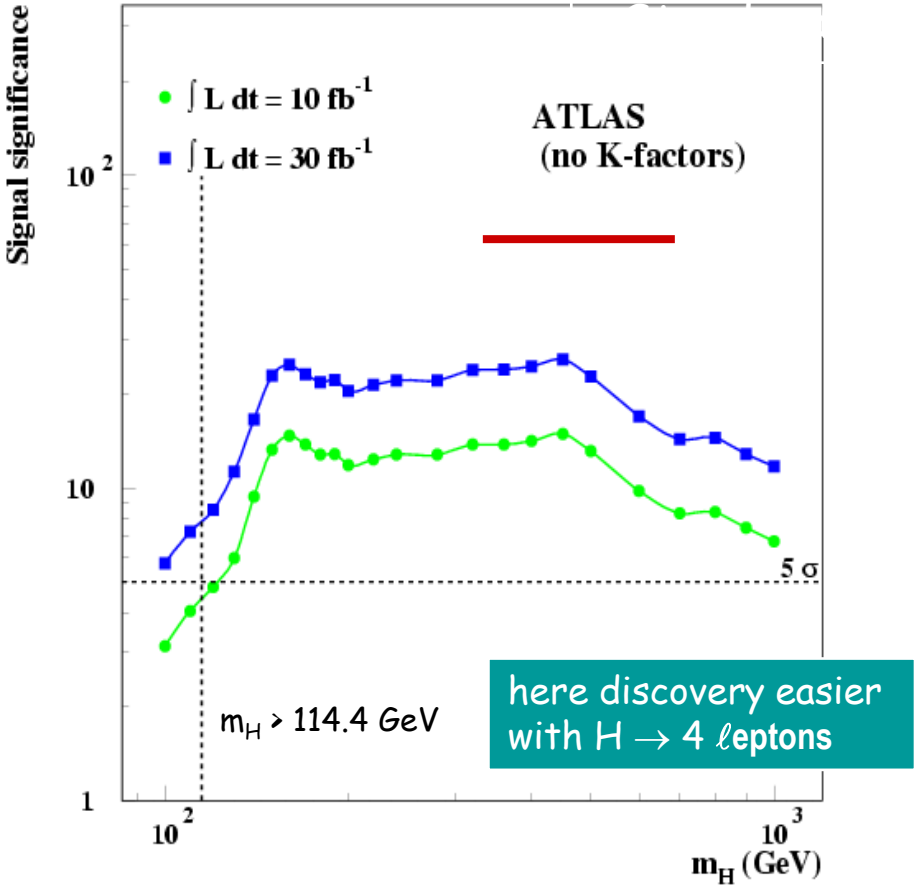




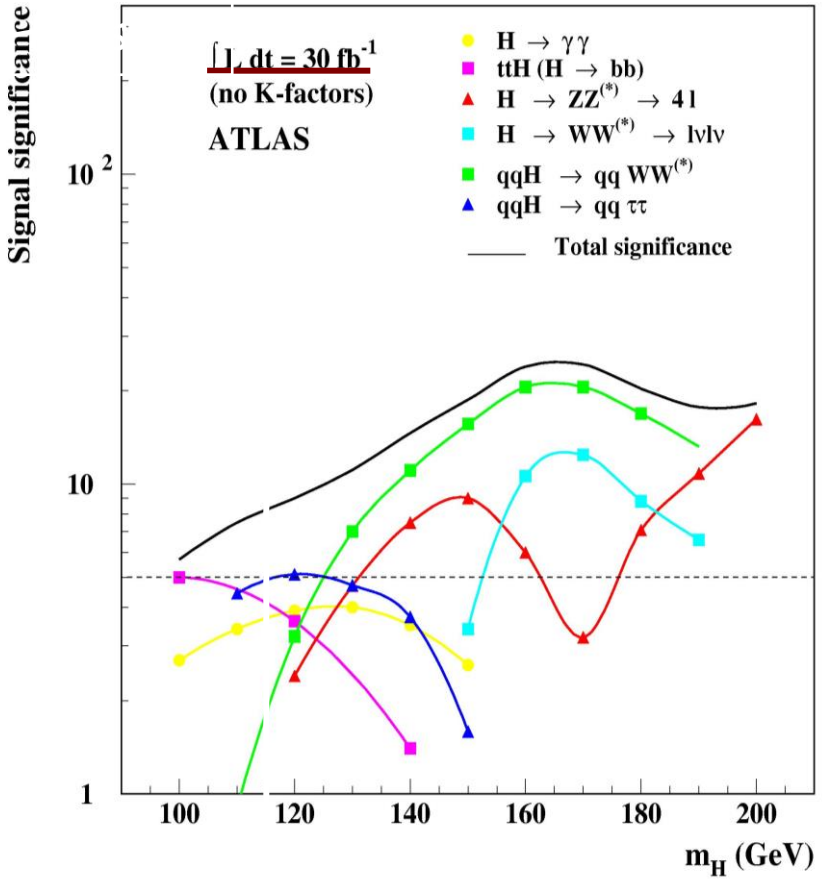




Scientists from Pakistan participate in CMS

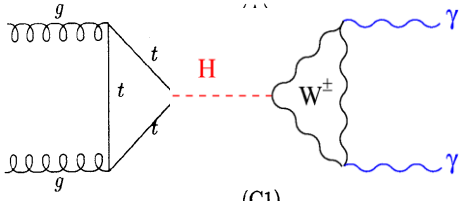


here discovery easier with H → 4 ℓeptons

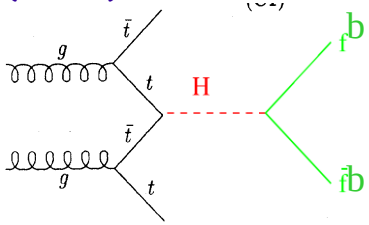


For m_H ~ 115 GeV and 10 fb^{-1}, 3 complementary channels accessible:

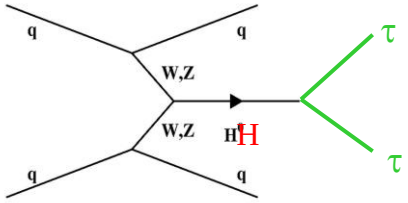
H → γγ (2 σ)



ttH → tt bb → bℓν bjj bb (2.2 σ)



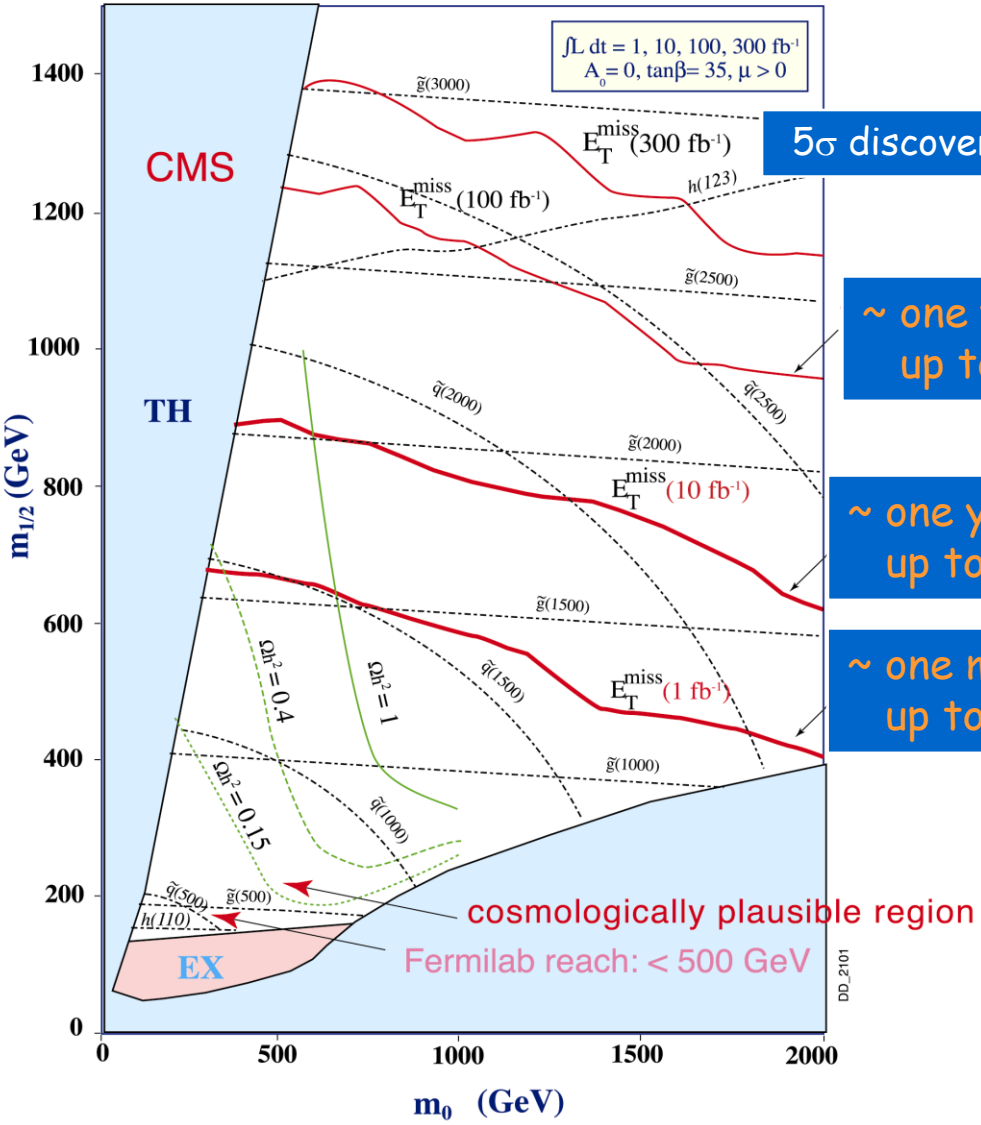
qqH → qqττ (2.7 σ)



SUPERSYMMETRY

Large $\tilde{q}\tilde{q}, \tilde{q}\tilde{g}, \tilde{g}\tilde{g}$ cross-section → ≈ 100 events/day at 10^{33} for:

$m(\tilde{q}, \tilde{g}) \sim 1$ TeV



5σ discovery curves

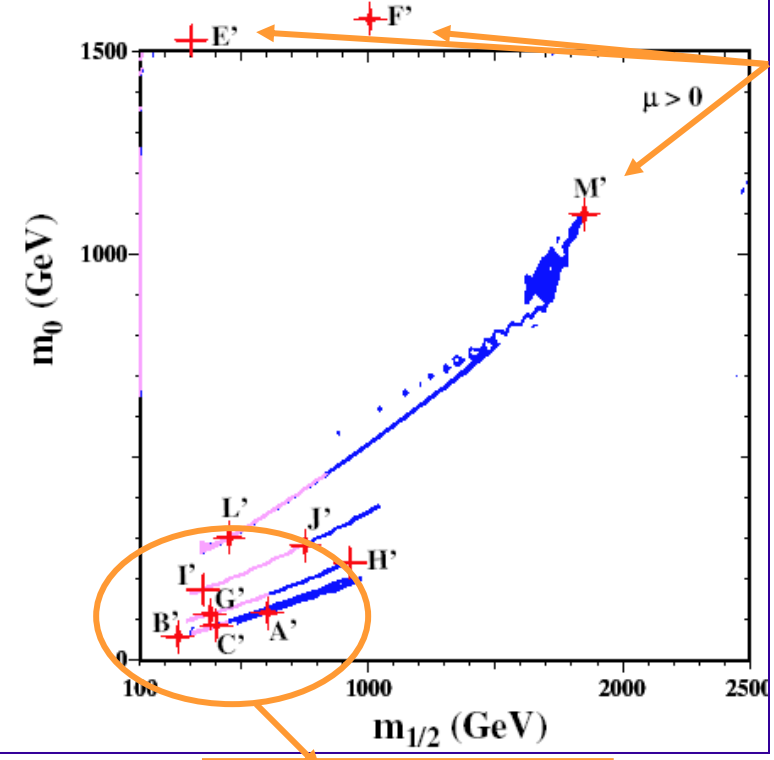
Reach of Multijet + E_T^{miss} searches (most powerful and model-independent signature if R-parity conserved)

~ one year at 10^{34}: up to 2.8 TeV

~ one year at 10^{33} : up to 2.3 TeV

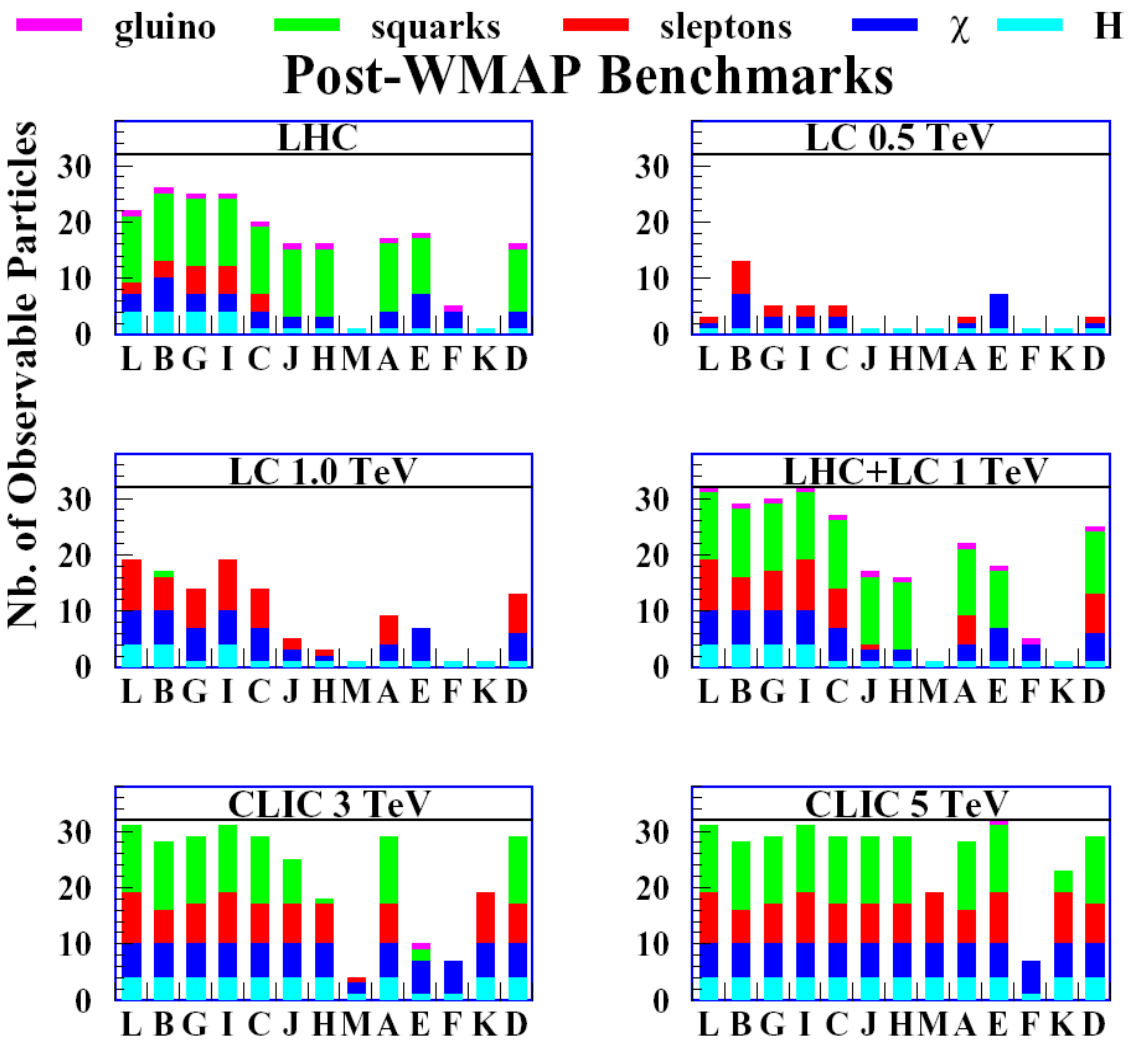
~ one month at 10^{33} : up to 2 TeV

→ **SUSY could be found quickly**



Fine-tuned

Typical (A, B, C..)



Benchmarking MSSMs restricted by Cosmological & Particle physics data

M. Battaglia et al., June 2003
hep-ph/0306219

1. Upgrading the LHC

Two options presently discussed/studied

- Higher luminosity $\sim 10^{35} cm^{-2} s^{-1}$ (SLHC)
  - Needs changes in machine and particularly in the detectors
  - Start change to SLHC mode some time 2012-2014
  - Collect ~3000 fb^{-1}/experiment in 3-4 years data taking.
- Higher energy (LHCx2)?
  - LHC can reach $\sqrt{s}$ = 15 TeV with present magnets (9T field)
  - $\sqrt{s}$ of 28 (25) TeV needs ~17 (15) T magnets $\Rightarrow$ R&D needed!
- One can envisage THREE PHASES:

Phase 0 – maximum performance, no hardware changes: $L = 2.3 \bullet 10^{34}$ $cm^{-2} s^{-1}$

Phase 1 – maximum performance while keeping LHC arcs unchanged
Luminosity upgrade ($\beta^* = 0.25$m, # bunches,...) $\rightarrow L = 5\text{-}10 \bullet 10^{34}$ $cm^{-2} s^{-1}$

Phase 2 – maximum performance with major hardware changes to the LHC
Energy (luminosity) upgrade $\rightarrow E_{beam} = 12.5$ TeV

Upgrading the LHC

Large Hadron Collider Project

LHC Project Report 626

Talks by F. Gianotti, D. Green and F. Ruggiero at the ICFA Seminar (Oct 2002)

MACHINE

LHC Luminosity and Energy Upgrade: A Feasibility Study

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CERN-TH/2002-078
hep-ph/0204087
April 1, 2002

DETECTORS

PHYSICS POTENTIAL AND EXPERIMENTAL CHALLENGES OF THE LHC LUMINOSITY UPGRADE

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Contributors: S. Abdullin [4], G. Azuelos [5], A. Ball [1], D. Barberis [6], A. Belyaev [7], P. Bloch [1], M. Bosman [8], L. Casagrande [1], D. Cavalli [9], P. Chumney [10], S. Cittolin [1], S.Dasu [10], A. De Roeck [1], N. Ellis [1], P. Farthouat [1], D. Fournier [11], J.-B. Hansen [1], I. Hinchliffe [12], M. Hohlfeld [13], M. Huhtinen [1], K. Jakobs [13], C. Joram [1], F. Mazzucato [14], G.Mikenberg [15], A. Miagkov[16], M. Moretti[17], S. Moretti [2,18], T. Niinikoski [1], A. Nikitenko[3,†], A. Nisati [19], F. Paige[20], S. Palestini [1], C.G. Papadopoulos[21], F. Piccinini[2,‡], R. Pittau[22], G. Polesello [23], E. Richter-Was[24], P. Sharp [1], S.R. Slabospitsky[16], W.H. Smith [10], S. Stapnes [25], G. Tonelli [26], E. Tsesmelis [1], Z. Usubov[27,28], L. Vacavant [12], J. van der Bij[29], A. Watson [30], M. Wielers [31]

Indicative Physics Reach

Fabiola Gianotti: ICFA Seminar

Units are TeV (except $W_L W_L$ reach)

∫Ldt correspond to 1 year of running at nominal luminosity for 1 experiment

PROCESS	LHC 14 TeV 100 fb^{-1}	SLHC 14 TeV 1000 fb^{-1}	LHCx2 28 TeV 100 fb^{-1}	VLHC 40 TeV 100 fb^{-1}	VLHC 200 TeV 100 fb^{-1}	LC 0.8 TeV 500 fb^{-1}	LC 5 TeV 1000 fb^{-1}
Squarks	2.5	3	4	5	20	0.4	2.5
$W_L W_L$	2σ	4σ	4.5σ	7σ	18σ		90σ
Z'	5	6	8	11	35	8 *	30 *
Extra-dim (δ=2)	9	12	15	25	65	5-8.5 *	30-55 *
q*	6.5	7.5	9.5	13	75	0.8	5
Λ compositeness	30	40	40	50	100	100	400

* indirect reach (from precision measurements)

Approximate mass reach of pp machines:

$\sqrt{s}$ = 14 TeV, $L=10^{34}$ (LHC) : up to ≈ 6.5 TeV

$\sqrt{s}$ = 14 TeV, $L=10^{35}$ (SLHC) : up to ≈ 8 TeV

$\sqrt{s}$ = 28 TeV, $L=10^{34}$: up to ≈ 10 TeV

$\sqrt{s}$ = 40 TeV, $L=10^{34}$: up to ≈ 13 TeV

$\sqrt{s}$ = 200 TeV, $L=10^{34}$ (VLHC) : up to ≈ 75 TeV

2. CERN future: LC & other projects

- A sub-TeV e^+e^- collider is needed for precision Higgs boson physics
- Useful to distinguish SM from Minimal Supersymmetric SM;
- Multi TeV capability needed to really sort out Supersymmetry.... …

or any other Physics beyond the SM

- It is **not** in the interest of Europe to offer a site for a subTeV LC
  - LC is complementary to the LHC …and is in the same energy range;
  - HEP is a global enterprise: other regions sharing efforts and benefits is crucial for its vitality;
  - Doing the LHC, Europe **simply cannot afford** being a major shareholder also for the LC.
- Europe should **define soon** the extent of its participation in a subTeV Int. LC
  - a minority participation (10 %?)
  - **not all taken from CERN budget from 2011 onwards** (!!)...

CERN future: LC & other projects (cont'd)

- … so as to allow **intermediate scale projects to start**, using the infrastructures in allied Labs (EU, Russia, US) and at CERN, which have been instrumental to build the LHC (+ ISTC?):
  - **@ CERN**: Superconducting Proton Linac (νs, β-beams, nucl. phys.);
  - **@ DESY**: Free Electron Laser (Chem. and Biolog. applications) with TESLA technology.
- These projects will establish closer links between Accelerator Particle Physics and wide scientific communities:
  - BioChem (the dream of Björn Wiik)
  - and to Nucl. Phys. (as pioneered by Carlo Rubbia)…
  - In addition to Data GRID.
- CERN **has to participate** in AstroParticle Physics projects (choose one !):
  - Space physics (as European basis for detector integration), e.g. EUSO
  - Deep Underwater Neutrino telescopes (NESTOR/ANTARES…)
  - Auger in Northern Hemisphere
  - …??.

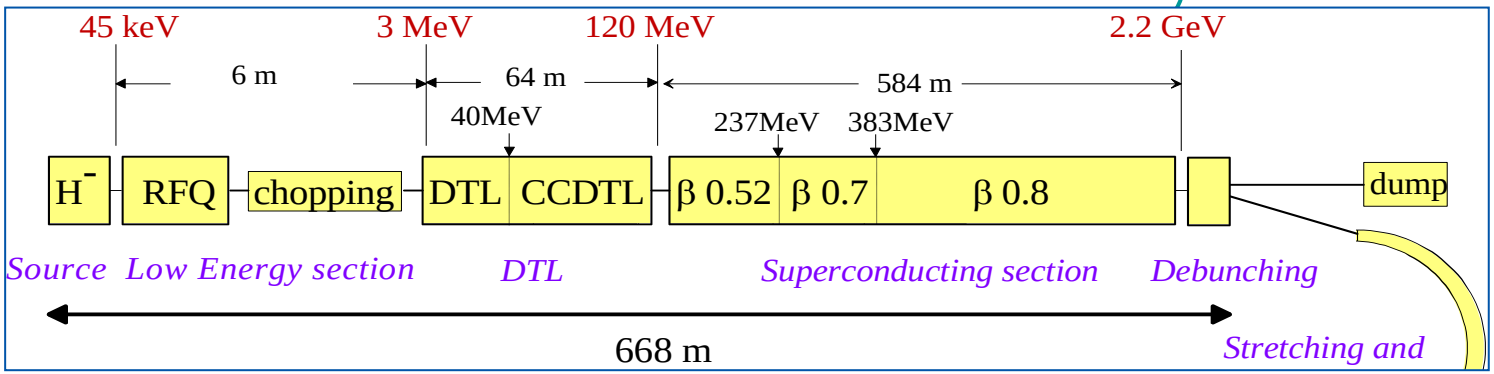
Superconducting Proton Linac
The SPL

- Performance upgrade of CERN Accelerator Complex
  - much higher beam brightness)
- Second Generation Radio-active Ion Beam Facility
  - 1000 times the present beam power)

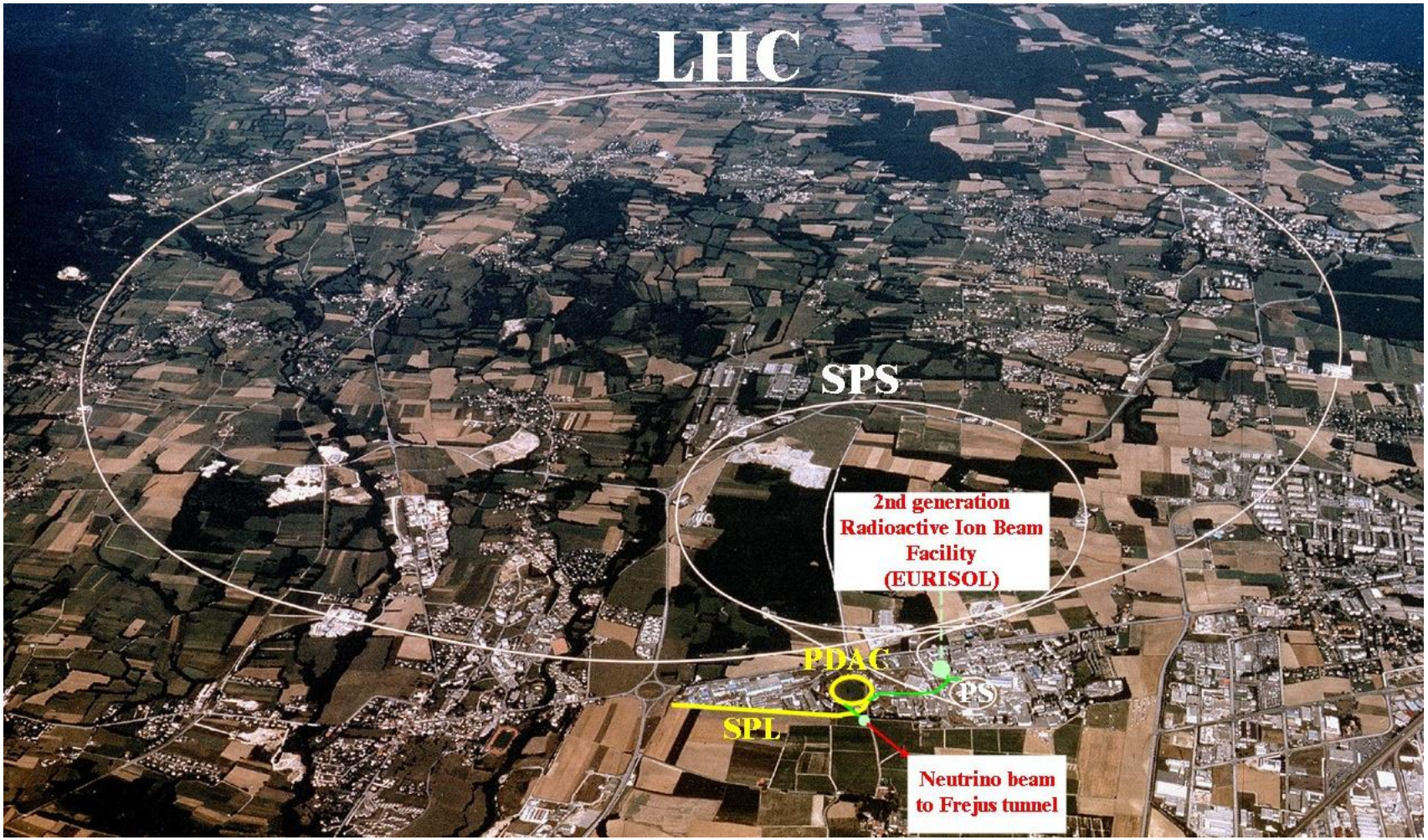
(Eurisol)

- Neutrino physics
  - 10 times the beam power of CNGS
  - Beta beams (ν beam from beta decay-in-flight of relativistic radioactive nuclei (^{6}He, ^{18} Ne)

The beam from a <u>single SPL</u> can be time-shared and satisfy quasi-simultaneously all these needs



SPL on the CERN site



Beta Beams

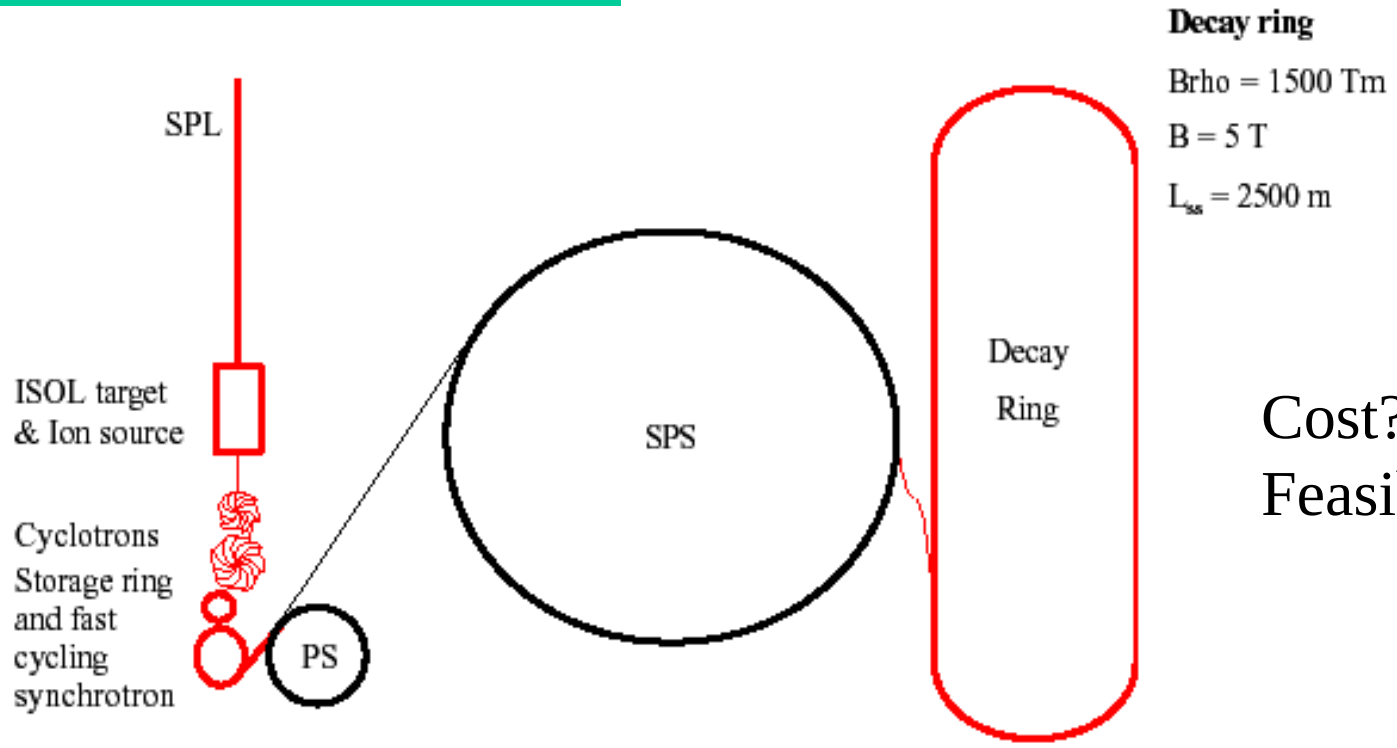


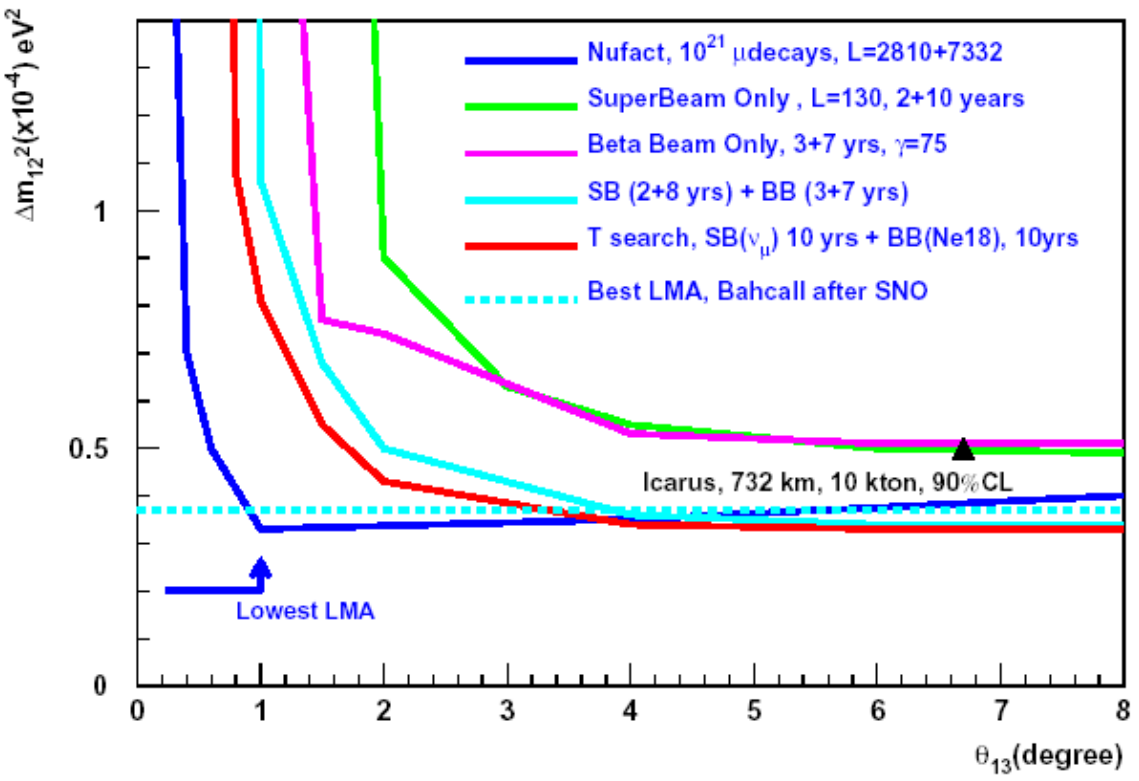
Figure 1: The CERN baseline scenario

Cost?
Feasibility?

	Isotope	A/Z	T ½ (s)	Q_β g.s to g.s (MeV)	Q_β eff (MeV)	E_β av (MeV)	E_ν av (MeV)	Ions/bunch	Decay rate (s^{-1})	rate / $E_{\nu\,av}$ (s^{-1})
best β^-	^{6}He	3.0	0.80	3.5	3.5	1.57	1.94	$5\cdot10^{12}$	$4\cdot10^{10}$	$2\cdot10^{10}$
best β^+	^{18}Ne	1.8	1.67	3.3	3.0	1.50	1.52	$1\cdot10^{12}$	$4\cdot10^{9}$	$3\cdot10^{9}$

CP sensitivity

Region in $\Delta m^2 - \theta_{13}$ plane where it is possible to distinguish $\delta = 90^0$ from $\delta = 0^0$



M. Mezzetto, *"Physics reach of Super + Beta Beams"*, NNN02, CERN, 16-18 January 2002

…in the longer term

- In 2009 (2007, if some extra resources are found) CTF3 will be able to tell if standing feasibility issues of CLIC can be solved (R1 issues);
- Around 2012 (2010), CERN should be able to launch a MultiTeV Global LC, based on CLIC technology;

- CLIC can be staged from lower energy (if no subTeV LC yet decided);
- The energy doubling of the LHC based on High Field Magnets may be a (alternative?) option to be seriously considered !

- Physics at the new facility could start around 2022-2027, i.e. about 15-20 years after the LHC commissioning

.. R&D has to start soon !!

3. Summarising

My very personal conclusions:

- Default:
  - LHC
  - Lab consolidation
  - LHC luminosity upgrade
- Active but restricted EU and CERN participation to subTeV LC;
- Intermediate projects (SPL, FEL) made in a coordinated way by a network of allied HEP Labs;
- CERN into AstroParticle (space? underwater?Auger2?...)

Prepare now for MultiTeV in the 2020's: CLIC - or LHCx2