SUMMARY TALK: OPENING SESSION

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Abstract

This paper provides a summary of Session 1 of the workshop. The session laid the basis for the subsequent detailed presentations and discussions on options for increasing the luminosity of the LHC. In particular, the session summarised the physics motivation, introduced critical items regarding the machine-detector interface, outlined options for upgrading the LHC insertion regions, and sketched the challenges for the fast-pulsed high energy injectors.

PHYSICS MOTIVATION

The full exploitation of the LHC is mandatory. Whatever new physics is observed at the LHC, it will require higher statistics and higher energies to further the understanding and the LHC is unique, as no other facility in the world can achieve these required higher statistics and energies in the foreseeable future. An upgrade to the LHC luminosity will provide an extension to the LHC physics discovery reach and improve precision measurements of parameters.

Observing the Higgs Boson at the LHC is required to complete the Standard Model. However, there are several valid theoretical and experimental arguments suggesting that the Standard Model is incomplete or that additional structures are required. Issues for the understanding of Dark Matter, Baryon Asymmetry of the Universe, particle mass spectra and mixing patterns, remain open and require further study.

The case for an increase in the LHC luminosity is shown in Figure 1. At low particle masses, the energy dependence of the production cross-section is relatively weak and a factor of ten increase in luminosity is better than a factor of two gain in beam energy. However, at high particle masses, an upgrade to the beam energy will eventually be needed.

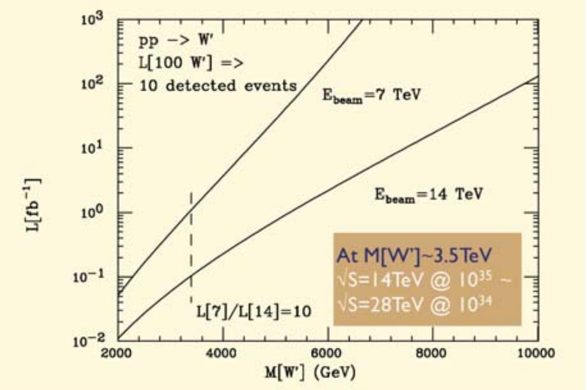


Figure 1: Reach in particle mass as a function of integrated luminosity for two beam energies.

Figure 2 shows the improved reach for Higgs Bosons within the Minimal Supersymmetric Standard Model (MSSM). Should a (light) Higgs not be observed at the LHC, an upgraded LHC could be used to study a new strong interaction regime in V_LV_L scattering.

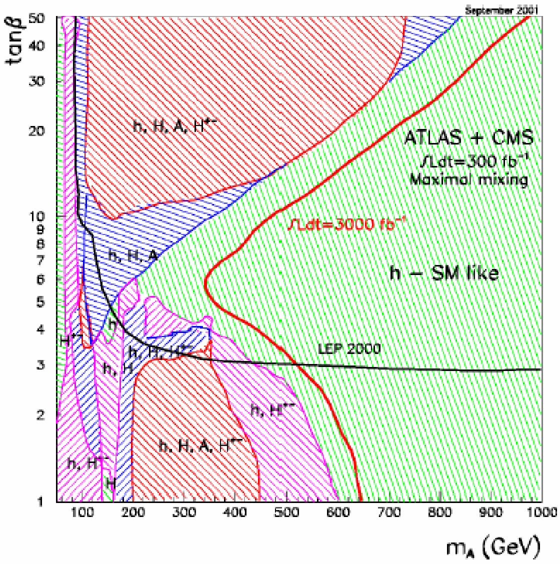


Figure 2: MSSM parameter space regions for a >5σ Higgs boson discovery. The extended reach for the case of an upgraded LHC luminosity, combining the data sets of ATLAS and CMS, is indicated.

A higher integrated luminosity also brings an increase in the supersymmetric (SUSY) particle discovery potential. Increasing the integrated luminosity from 300 fb^{-1} (LHC) to 3000 fb^{-1} (LHC upgrade) will increase the squark and gluino mass reach by ~500 GeV to 3 TeV.

The increased statistics of an upgraded LHC would also be used to improve precision measurements. Studies of Higgs couplings, triple gauge boson couplings and mass measurements of SUSY particles would all stand to benefit from an increased luminosity.

For all these physics studies, the total integrated luminosity, acquired in stable machine running conditions, remains a general aim.

MACHINE-DETECTOR INTERFACE

To be able to profit fully from an increased luminosity, the detector performance at an upgraded LHC should be as for the LHC. To maintain the same performance as the LHC, the Trackers need to be replaced by new detectors based on improved radiation-hard sensors and electronics. A proposal has been put forth for a three-level Pixel System, adapted to the particle fluence at various distances from the beamline, and will be tested in the coming years. Although for the most part the calorimeters and muon spectrometers do not need to be changed, the energy resolution of the former and the occupancy of the latter will be degraded due to the additional hits coming from pile-up events. Scintillators and certain end-cap electronics will, however, need to be exchanged in order to work in a high dose environment. It should also be noted that the repair of detectors in the end-cap regions would require more stringent planning, since the higher activation levels will limit the access time. The Level-1 trigger electronics and processors will need to be replaced in the case of a change in the accelerator bunch crossing frequency. A Tracker Trigger at Level-1 would be needed and is being developed to add to the rejection power provided by the Calorimeter and Muon Level-1 Triggers.

The experiments expressed a preference for a move from a 25 ns to a 12.5 ns bunch spacing. Changing from 25 ns to 10 ns or 15 ns would result in the need to re-build most of the detector front-end electronics. The detailed consequences concerning the impact on the experiment front-end electronics is currently being reviewed in the Collaborations.

Moreover, in order to fully profit from the increased luminosity, additional studies are being made on systems in the experimental areas. Changing the experimental beam pipe material from stainless steel to either aluminium or beryllium would significantly reduce the dose rate from activation. The background rate in the Muon System can be reduced by either incorporating a longer beryllium beam pipe section or by increasing the beam pipe diameter. The radiation shielding in the experimental area must be adapted to the higher luminosity.

Moving machine elements, such as the inner triplet quadrupoles, closer to the interaction point requires detailed studies by the experiments. In particular, the backsplash of particles from the absorber protecting the inner triplet and its impact on background rates in the experiment need to be evaluated. Increased activation levels will seriously affect the maintenance of the detector and remote-handling devices might become necessary.

LHC BEAM PARAMETERS AND INTERACTION REGION UPGRADE OPTIONS

As Figure 3 shows, due to the high radiation doses, the life expectancy of the LHC insertion region quadrupoles is estimated to be less than 10 years. Therefore, it is reasonable to plan for a machine luminosity upgrade based on new low-β insertion region magnets before about 2014.

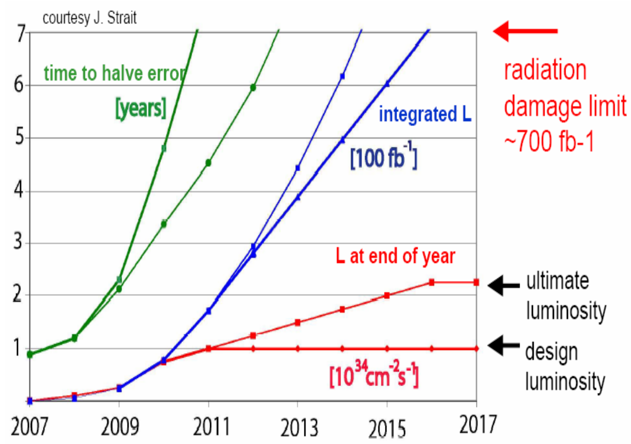

courtesy J. Strait

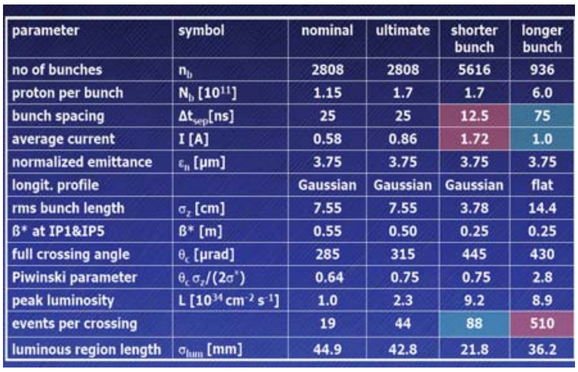
Figure 3: Projected time-scale for an LHC upgrade.

A new insertion region lay-out is considered to be one straightforward way to raise the LHC luminosity. A new lay-out should allow for a lower β* and a reduction in long-range beam collisions. Various options for a new insertion region are being considered:

- Relatively simple designs include the LHC baseline insertion region with larger bore quadrupoles. This is referred to as the Quadrupole First variant. Moreover, the Dipole First option has the separation dipoles between the interaction point and 100 mm large-aperture quadrupole magnets. This option yields fewer long-range collisions but a larger β_{max}. These two designs have the potential of reducing β* by between a factor of 2 to 3.
- Alternative designs include incorporating the low-β quadrupoles between separation magnets and lay-outs with large crossing angles. Such designs might reduce β* by between a factor of 2.5 to 5.

Re-designing the insertion regions offers the possibility of moving elements of the accelerator, such as the low-β quadrupoles, separation dipoles and absorbers, closer to the interaction point to gain even more in luminosity. Integration with the experiments and their shielding should be studied.

Since an upgrade to the insertion region cannot alone achieve a factor 10 increase in the luminosity, additional ways must be developed to maximise the luminosity. Table 1 summarises example parameter sets whereby luminosities approaching 10^{35} cm^{-2} s^{-1} are reachable.



parameter	symbol	nominal	ultimate	shorter bunch	longer bunch
no of bunches	n_b	2808	2808	5616	936
proton per bunch	N_b [10^{11}]	1.15	1.7	1.7	6.0
bunch spacing	Δt_{sep}[ns]	25	25	12.5	75
average current	I [A]	0.58	0.86	1.72	1.0
normalized emittance	ε_n [µm]	3.75	3.75	3.75	3.75
longit. profile		Gaussian	Gaussian	Gaussian	flat
rms bunch length	σ_z [cm]	7.55	7.55	3.78	14.4
ß* at IP1&IP5	ß* [m]	0.55	0.50	0.25	0.25
full crossing angle	θ_c [µrad]	285	315	445	430
Piwinski parameter	$\theta_c \sigma_z/(2\sigma^*)$	0.64	0.75	0.75	2.8
peak luminosity	L [10^{34} cm^{-2} s^{-1}]	1.0	2.3	9.2	8.9
events per crossing		19	44	88	510
luminous region length	σ_{lum} [mm]	44.9	42.8	21.8	36.2

Table 1: Summary of example parameter sets whereby luminosities approaching 10^{35} cm^{-2} s^{-1} are reachable.

FAST-PULSED HIGH ENERGY INJECTORS

Additional gains may be obtained by upgrading the LHC injection chain in order to increase the beam intensity and brilliance beyond their present ultimate values. Upgrading the proton LINAC from 50 MeV to 160 MeV would reduce space-charge effects at the PS Booster injection, facilitating delivery of the highest LHC intensities. A new superconducting ring, coined the `super-PS', has also been proposed to be installed in the ex-ISR tunnel in order to accelerate the PS beams to 100 GeV, thus reducing the energy swing in to the SPS. Equipping the SPS with superconducting magnets and upgrading the transfer lines to allow injection in to the LHC at 1 TeV would increase the peak LHC luminosity by nearly a factor of 2 and would be the first step needed in view of an LHC energy upgrade. Finally, the Superconducting Proton Linac (SPL) and rapid-cycling synchrotrons could be included in the LHC injector chain.

CONCLUSIONS

An upgrade to the LHC luminosity will provide a significant extension to the LHC physics reach. The challenge for both the accelerator complex and experiments to reach a luminosity of 10^{35} cm^{-2} s^{-1} is, however, considerable. In view of this, it is recommended that the following points are taken under consideration:

- Several alternative ways to achieve the high luminosity goal must be considered.
- The R&D directions must be chosen judiciously.
- The R&D effort must start now.
- As resources are limited, convergence among the various options is a prerequisite.

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