RLIUP (summary)

Review of LHC and Injector Upgrade Plans

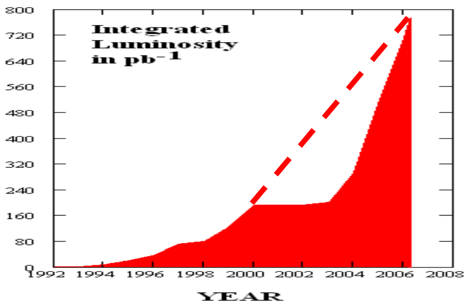
History

- Present “10 year” schedule was
  - proposed and developed at a time when we had much less information than now
  - and was not developed in a self-consistent (iterative) way.

Comment on Machine Performance

- In the early years of operation, spectacular performance increase can be attained by pushing accelerator physics limitations (intensity, beta*, emittance …)
- After some years of operation, these possibilities become exhausted
- Slower performance increases then comes by upgrades and small (%) improvements on a multitude of fronts including machine availability etc
- LHC is entering this new phase (upgrades and small improvements on many fronts)
  - Both need careful planning

Maximise LHC Performance (Useful integrated luminosity)



- Peak Luminosity
  - Pile-Up in the detectors
  - Accelerators performance
- Useful Integrated Luminosity (4 detectors)
  - Time available for physics (iterative with shutdowns)
    - Play-off between upgrades and time lost for physics
  - Timing of Upgrades (sooner the better)
- Beam Energy??
  - During discussion with CMAC possibility of energy increase came up.

Shutdowns (when and how long?)

- Factors for planning the timing (start) of the shutdowns are
  - Technical lead-time needed (experiments + machine)
  - Funding profiles (mostly experiments)
  - Radiation damage effects (integrated luminosity), expts + machine,..defines date limit
  - Need for regular preventative maintenance (mostly machine)
- Driving factors for the duration of the shutdowns
  - Amount of Work to be done (machine and the experiments)
  - $\Rightarrow$ Manpower resources needed (and co-habitation)
  - Environment (Induced radiation); manpower limitation?
  - Efficiency of ability to carry out work (access time...)

Structure of the Review

- 5 different scenarios for comparison of performance and cost
- Each scenario encompasses all accelerators in the LHC chain
- For each scenario
  - Identify the technical requirements (work needed and shutdowns)
  - evaluate the peak and integrated yearly luminosities (time available for physics)

Note: In the preparation for the review, these scenarios were meant for comparison. Later, it became apparent that they could be better used for the evaluation of the evolution of the performance with time over the long time scale examined

Objectives of RLIUP

- Review the critical criteria for the evaluation of the long term performance of LHC
  - Radiation limits for the detectors (fb-1)⇒start of LS3
  - Radiation limit for the inner triplets etc ⇒ LS3
  - Peak luminosity… PU, 25ns, brightness from injectors, UFOs, beam heating, instabilities
  - Machine availability

The Matrix From Mike Lamont

Input on Runs and Shutdowns

	Run 2	EYETS	LS2	Run 3	LS3
ALICE		Contingency	18 mo. Shift into 2018		
ATLAS	3 years	No	14 mo. Start 2018		27 (35) mo. Start 2022
CMS	EYETS plus N months	5 months	14 – 18 mo. Not before summer		30 – 35 mo. Start 2023
LHCb		Contingency	18 mo. End 2018		
Cryo	4 years max.	Selective maintenance			
Maintenance		Selective maintenance	16 mo.		20 mo.
LIU		9.5 months for L4 connect/or cable prep.	20.5 mo. beam to pilot		
LHC	3 years max contiguous	Opens way for year 4	18 mo.	3 years	2 years

Answers (from RLIUP) to Important Questions

- Radiation Limit for detectors and machine
  - 300 – 500 fb-1 (machine possibly more critical)
- LS2 needs ~18-24 months
- LS3 needs ~ 24-36 months
- Run2 should last for 3 years

Luminosity

- The overriding limitation to integrated luminosity is due to event pile-up. The presently proposed upgrade to the detectors foresees an increase to 140 PU (average) with a possible extension to around 200.
  - Several new schemes have been proposed on the machine side in order to alleviate the PU problem by reducing the “pile-up density”. These schemes will be further investigated and tested as soon as possible.
  - Together we should continue to explore new possibilities to allow even higher PU than the 140 (200) presently foreseen.

Machine availability and turn round

- The limitation is the peak luminosity,
- $\Rightarrow$ Optimise the time available for physics
  - Minimise down time due to faults
    - More in-depth analysis of down-time and “amplification factor”
    - Prioritized (by risk analysis) mitigation of most critical faults by consolidation
  - Faster turn round “physics to physics”.
    - Technical upgrades to the LHC equipment (e.g. modification of power supplies to allow faster ramp down of magnets)
    - More streamlined operational procedures (e.g. combined ramp and squeeze)

To do

- Resources:
  - Global (machine, detectors and services) resources loaded schedule is need as soon as possible
  - This schedule can be used to identify and correct weaknesses in areas of expertise (e.g. cabling…)
- ALARA:
  - radiation must be optimized by design (minimum access time needed for exchanges and the use of the right materials) (actiwys)
- Electron cloud
  - In case of problems with 25ns, short term mitigation (new scrubbing scheme) and long term solutions must be sought (this is so critical that even very costly new technical schemes should not be excluded)
    - Partial or full coating of chambers, clearing electrodes, …

Important Comments

- *(A. B.1st Talk), ESB: Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting* ***ten times more data than in the initial design, by around 2030.***
- *(F.G. 2nd Talk)*
  - *The STRONG physics case for the HL-LHC with 3000 fb-1 comes from the imperative necessity of exploring this scale as much as we can with the highest-E facility we have today (note: no other planned machine, except a 100 TeV pp collider, has a similar direct discovery potential). ……..*
  - *We have NO evidence of new physics. implies that,* if New Physics exists at the TeV scale and is discovered at √s ~ 14 TeV in 2015++, its spectrum is quite heavy it will require a lot of luminosity (HL-LHC 3000 fb-1*)* **and energy** *to study it in detail ..implications for future machines (e.g.* most likely not accessible at a 0.5 TeV LC)
  - **HL-LHC is a Higgs Factory.** It can measure the Higgs coupling with an accuracy of a few %

Strategy

- LHC has been constructed, operated and will continue to be operated on a CONSTANT BUDGET
- We have a beautiful scientific facility, unique in the world.
- The community has invested (and are investing) a huge amount of their resources in this unique facility both for construction and for operation.
- **The FULL operational costs integrated over the future operating years exceeds the proposed upgrade costs. Hence we should operate this unique facility in the most efficient way possible.**

This means

- Both Upgrades, LIU and HL-LHC, should aim for the maximum useful integrated luminosity possible
- LS3 should come as soon as possible in order to maximize the integrated luminosity (every delay by one year of LS3 “costs” 200fb-1)
- LS2 should not delay LS3.

The goal of 3000fb-1 by ~2035 is challenging but attainable

Comparisons of Shutdown Scenarios

Scenario 1 (S1)

LS2 (2018) lasts for 1.5 years, LS3 (2022) for 2 years

S2 = S1 delayed by 1 year

S3 = S2 delayed by 1 year

= S1 delayed by 2 years

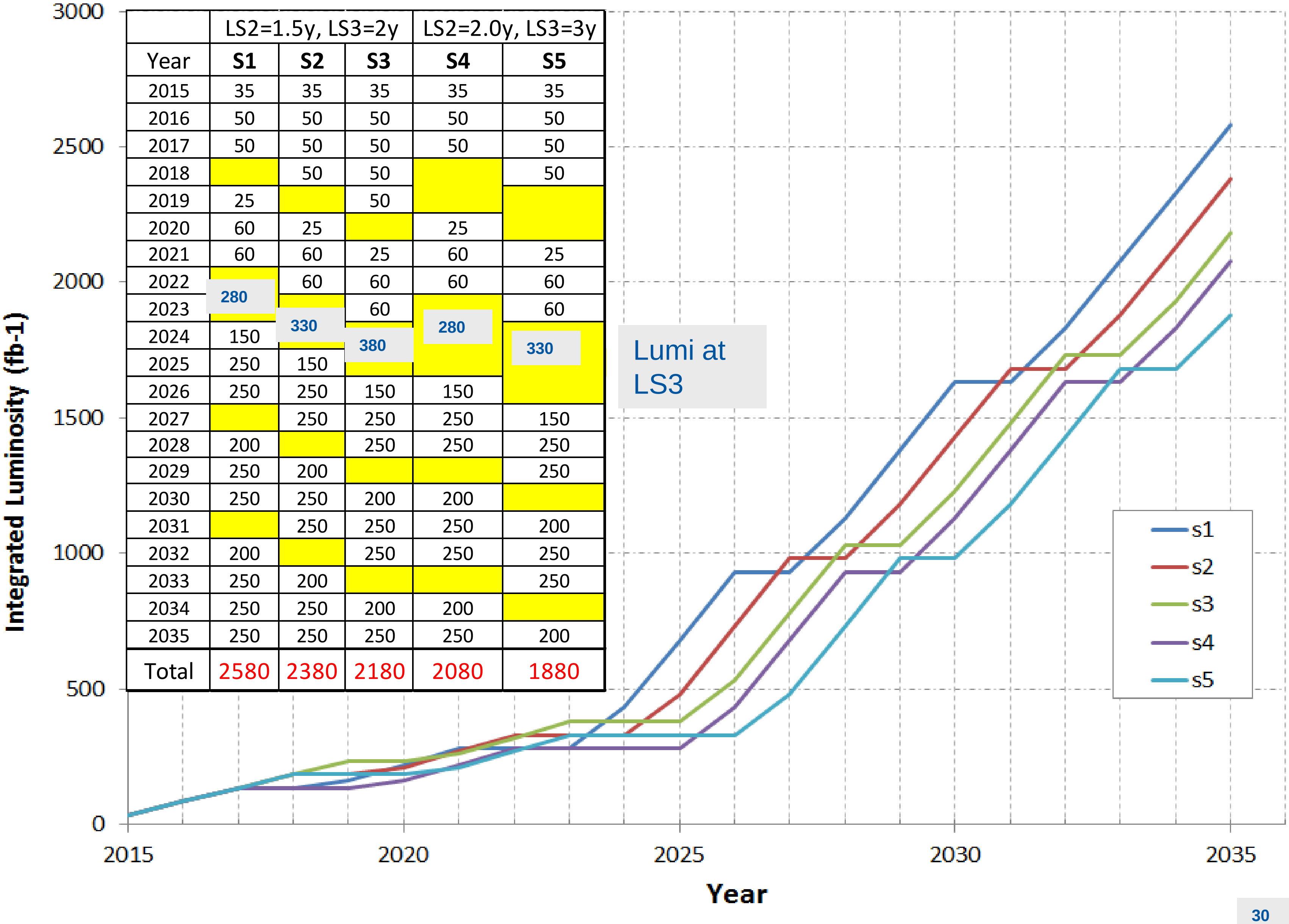
Scenario 4 (S4)

LS2 (2018) lasts for 2 years, LS3 for 3 years

S5 = S4 delayed by 1 year

	LS2=1.5y, LS3=2y			LS2=2.0y, LS3=3y	
Year	**S1**	**S2**	**S3**	**S4**	**S5**
2015	35	35	35	35	35
2016	50	50	50	50	50
2017	50	50	50	50	50
2018		50	50		50
2019	25		50		
2020	60	25		25	
2021	60	60	25	60	25
2022		60	60	60	60
2023			60		60
2024	150				
2025	250	150			
2026	250	250	150	150	
2027		250	250	250	150
2028	200		250	250	250
2029	250	200			250
2030	250	250	200	200	
2031		250	250	250	200
2032	200		250	250	250
2033	250	200			250
2034	250	250	200	200	
2035	250	250	250	250	200
Total	2580	2380	2180	2080	1880

	LS2=1.5y, LS3=2y			LS2=2.0y, LS3=3y	
Year	**S1**	**S2**	**S3**	**S4**	**S5**
2015	35	35	35	35	35
2016	50	50	50	50	50
2017	50	50	50	50	50
2018		50	50		50
2019	25		50		
2020	60	25		25	
2021	60	60	25	60	25
2022		60	60	60	60
2023			60		60
2024	150				
2025	250	150			
2026	250	250	150	150	
2027		250	250	250	150
2028	200		250	250	250
2029	250	200			250
2030	250	250	200	200	
2031		250	250	250	200
2032	200		250	250	250
2033	250	200			250
2034	250	250	200	200	
2035	250	250	250	250	200
Total	2580	2380	2180	2080	1880



What needs to be done with some urgency

- Decide on the shutdown scenario
  (Management of CERN and detectors)
- Implementation of new plan
  - A global resources loaded schedule for accelerators and experiments
    - Limitations imposed on personnel by radiation
    - Improve access to tunnel
- Start now with requests, to identify and strengthen weak areas of expertise

Summary of Summary of Summaries (list)

- Performance
  - Pile-up and pile-up density (detectors and machine)
  - 25ns: e-cloud, scrubbing, short term mitigation, long term solution
  - Machine availability: minimise down time, speed up turn around
- Shutdowns
  - Plan well in advance: global resource loaded schedule, identify and rectify weaknesses in expertise areas
  - Design for ALARA; minimum intervention time and use of correct materials (actiwys)
- Beam Energy
  - Investigate increase of maximum beam energy in the medium term (?? Use of 11T magnets for collimation??)

END