CLIC Luminosity Overview

R. Corsini

Or, rather:

What integrated luminosity could we expect from CLIC?

CLIC Luminosity Overview

A warning:

I will not answer such question!

Which is indeed a very complex one, hiding behind it a number of other questions:

- How long will it take to reach the nominal peak luminosity?
- What will be the evolution of the peak luminosity during commissioning (and after)?
- How much machine-time will be taken for tuning to peak performance?
- How stable would be the machine, once tuned?
- What will be the overall machine reliability?
- How many, and how long, will be the shut-down periods?
- What will be the physics run scenarios (variable energy, specific running conditions...)?

... And – I fear – I don‘t know the answer to a single one among them.

However, I will attempt to give some hints, by using examples from the past, highlighting similarities and differences between CLIC and other past/existing/planned projects and, overall, trying to stimulate further reflections & studies.

The ILC model (I)

From Barry’s talk:

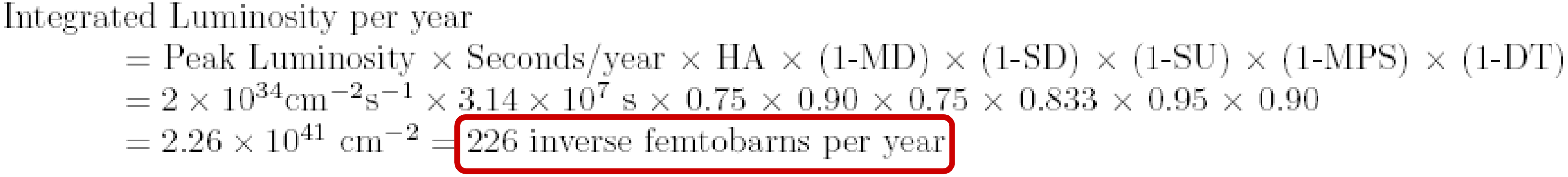
- Luminosity → $\int L dt = 500\ \mathrm{fb}^{-1}$ in 4 years

- Integrated luminosity was (rightly) considered a design requirement for ILC

- Let‘s see how this is linked to peak luminosity, and to commissioning ramp-up

The ILC model (II)

During “mature” operation period



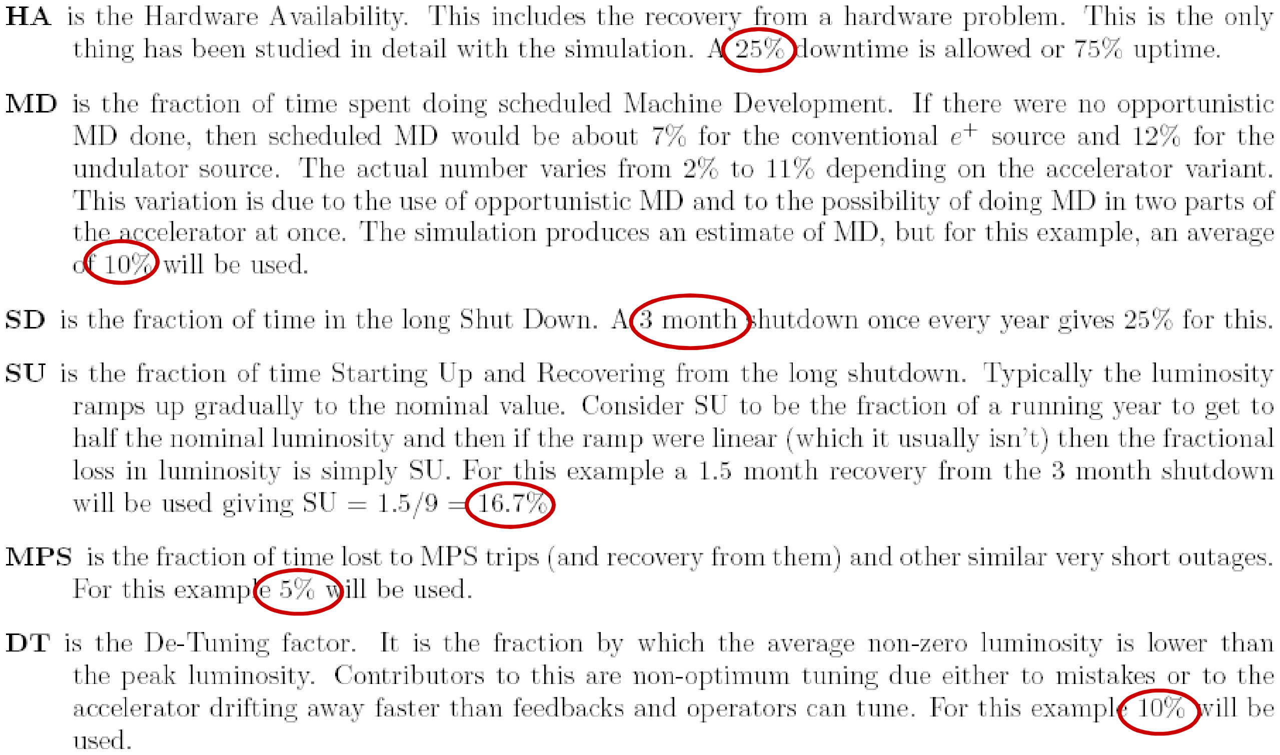
Integrated Luminosity per year

$$= \text{Peak Luminosity} \times \text{Seconds/year} \times \text{HA} \times (1\text{-MD}) \times (1\text{-SD}) \times (1\text{-SU}) \times (1\text{-MPS}) \times (1\text{-DT})$$

$$= 2 \times 10^{34}\text{cm}^{-2}\text{s}^{-1} \times 3.14 \times 10^{7}\ \text{s} \times 0.75 \times 0.90 \times 0.75 \times 0.833 \times 0.95 \times 0.90$$

$$= 2.26 \times 10^{41}\ \text{cm}^{-2} = \boxed{226 \text{ inverse femtobarns per year}}$$

$\int Ldt \rightarrow L_{peak} \times 1.1\ 10^{7}$ sec /year



HA is the Hardware Availability. This includes the recovery from a hardware problem. This is the only thing has been studied in detail with the simulation. A 25% downtime is allowed or 75% uptime.

MD is the fraction of time spent doing scheduled Machine Development. If there were no opportunistic MD done, then scheduled MD would be about 7% for the conventional e^{+} source and 12% for the undulator source. The actual number varies from 2% to 11% depending on the accelerator variant. This variation is due to the use of opportunistic MD and to the possibility of doing MD in two parts of the accelerator at once. The simulation produces an estimate of MD, but for this example, an average of 10% will be used.

SD is the fraction of time in the long Shut Down. A 3 month shutdown once every year gives 25% for this.

SU is the fraction of time Starting Up and Recovering from the long shutdown. Typically the luminosity ramps up gradually to the nominal value. Consider SU to be the fraction of a running year to get to half the nominal luminosity and then if the ramp were linear (which it usually isn't) then the fractional loss in luminosity is simply SU. For this example a 1.5 month recovery from the 3 month shutdown will be used giving SU = 1.5/9 = 16.7%

MPS is the fraction of time lost to MPS trips (and recovery from them) and other similar very short outages. For this example 5% will be used.

DT is the De-Tuning factor. It is the fraction by which the average non-zero luminosity is lower than the peak luminosity. Contributors to this are non-optimum tuning due either to mistakes or to the accelerator drifting away faster than feedbacks and operators can tune. For this example 10% will be used.

The ILC model (III)

- 1 year commissioning (not accounted for)
- 4 years of ramp up in performance (25%, 50%, 75% and 100% of the peak)
- Integrated luminosity during this period ≈ 500 fb^{-1}

- Is it a reasonable model?

- Can it be applied to CLIC?

The LEP lesson (I)

Commissioning, ramp-up and nominal peak luminosity

The LEP collider at CERN was commissioned in 1989 and operated until the end of the year 2000. It performed many years above design expectations. In particular it was possible to push the instantaneous luminosity a factor of 4 above its design value, at higher beam energies than foreseen in the design.

The instantaneous luminosity already reached 70% of its design value in the second year of LEP operation. This illustrates the sound design strategy for LEP1, the great care in the accelerator construction, and the good knowledge of the relevant accelerator physics for LEP1. To surpass the design luminosity at LEP1 required four years and an increased number of bunches, originally not foreseen in the design.

The accelerator physics in the LEP2 regime of ultra-strong radiation damping was not well known. As a result the design estimate of the luminosity turned out to be too pessimistic. Taking profit of a much higher beam-beam limit, strong focusing optics, and manipulations of the damping partition numbers the design luminosity was immediately surpassed.

As it is true for all colliders, the final luminosity performance was only possible due to many ideas and concepts that were not foreseen in the original design.

Proceedings of the Second Asian Particle Accelerator Conference, Beijing, China, 2001

LEP LUMINOSITY REVISITED: DESIGN AND REALITY

Ralph W. Assmann for the LEP team, CERN, Geneva, Switzerland

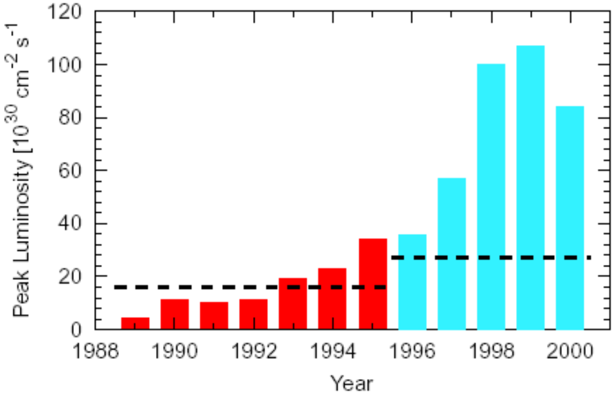


Figure 1: Peak luminosity for each year of LEP operation. The dashed lines indicate the design luminosities for LEP1 (red bars) and LEP2 (blue bars).

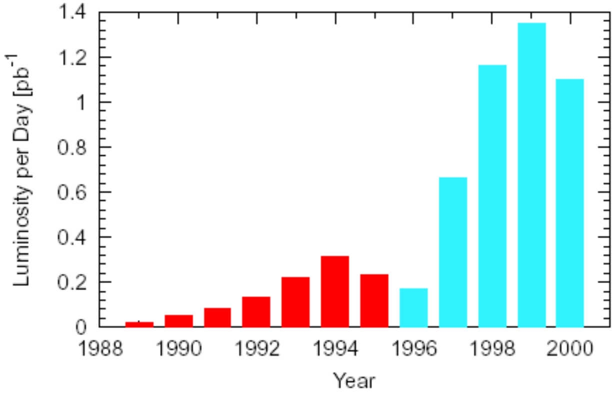
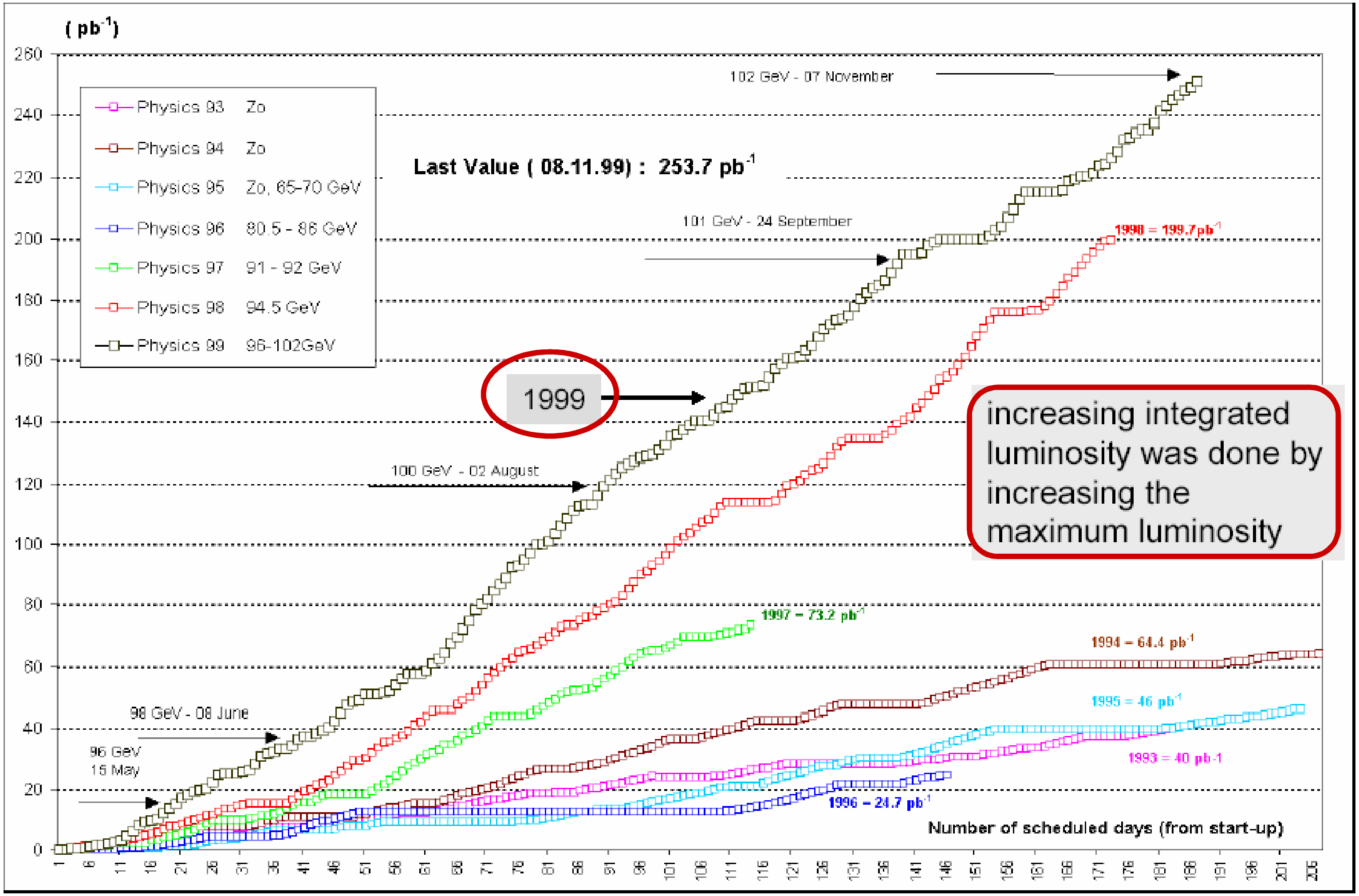


Figure 2: Average luminosity delivered per scheduled day of physics for each year of LEP operation. The red bars indicate LEP1 running, the blue bars LEP2 running.

The LEP lesson (II)

Commissioning, ramp-up and nominal peak luminosity



increasing integrated luminosity was done by increasing the maximum luminosity

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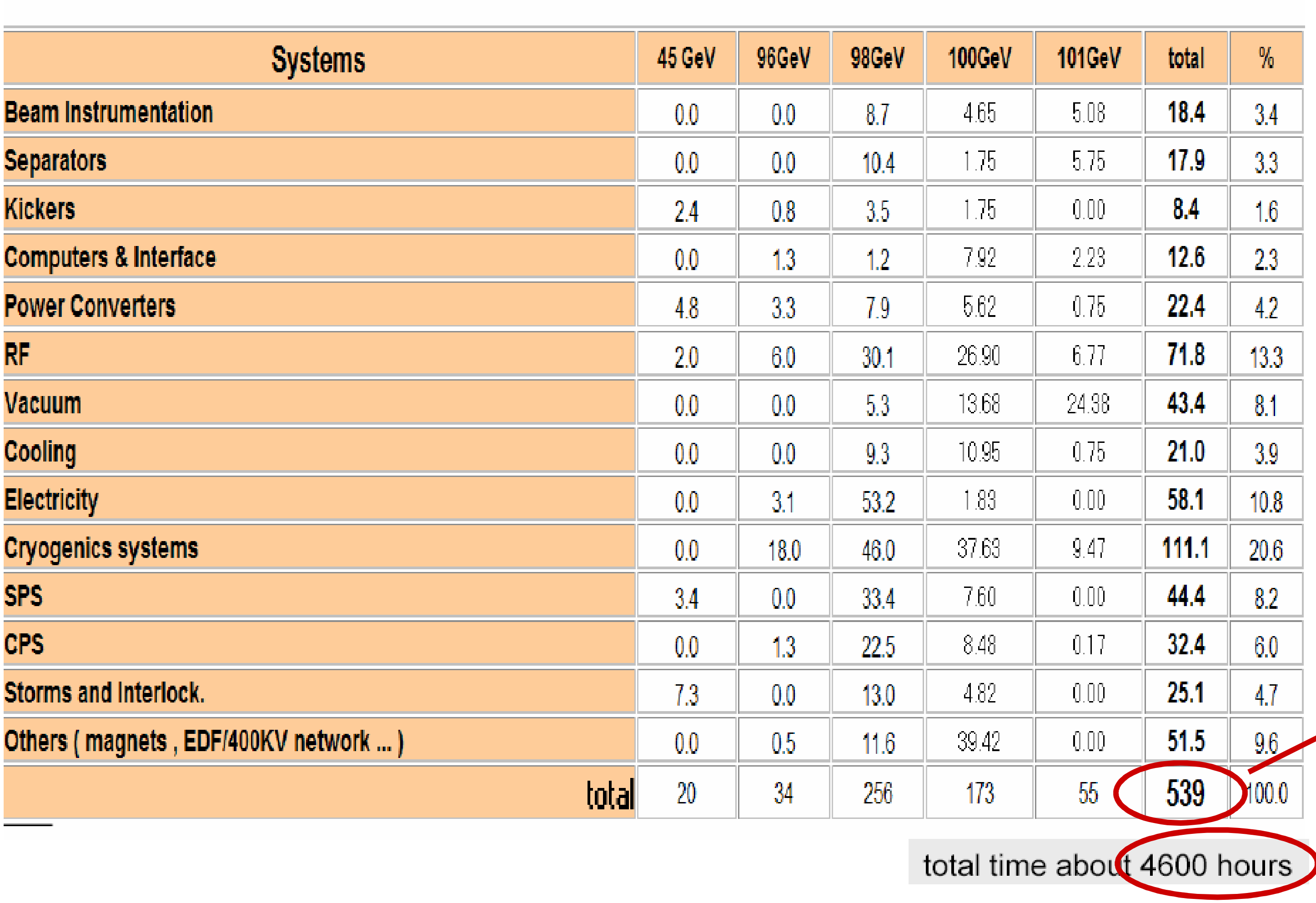
The LEP lesson (III)

Up-time, availability

Uptime:
4059 hours = 1.47 10^7 sec / year

Compared to 1.1 10^7 sec /year (ILC)
Additional factor 26% → 1.4 10^7 sec / year

LEP Operation 1999



Systems	45 GeV	96GeV	98GeV	100GeV	101GeV	total	%
Beam Instrumentation	0.0	0.0	8.7	4.65	5.08	**18.4**	3.4
Separators	0.0	0.0	10.4	1.75	5.75	**17.9**	3.3
Kickers	2.4	0.8	3.5	1.75	0.00	**8.4**	1.6
Computers & Interface	0.0	1.3	1.2	7.92	2.23	**12.6**	2.3
Power Converters	4.8	3.3	7.9	5.62	0.75	**22.4**	4.2
RF	2.0	6.0	30.1	26.90	6.77	**71.8**	13.3
Vacuum	0.0	0.0	5.3	13.68	24.38	**43.4**	8.1
Cooling	0.0	0.0	9.3	10.95	0.75	**21.0**	3.9
Electricity	0.0	3.1	53.2	1.83	0.00	**58.1**	10.8
Cryogenics systems	0.0	18.0	46.0	37.63	9.47	**111.1**	20.6
SPS	3.4	0.0	33.4	7.60	0.00	**44.4**	8.2
CPS	0.0	1.3	22.5	8.48	0.17	**32.4**	6.0
Storms and Interlock.	7.3	0.0	13.0	4.82	0.00	**25.1**	4.7
Others (magnets , EDF/400KV network ...)	0.0	0.5	11.6	39.42	0.00	**51.5**	9.6
total	20	34	256	173	55	539	100.0

total time about 4600 hours

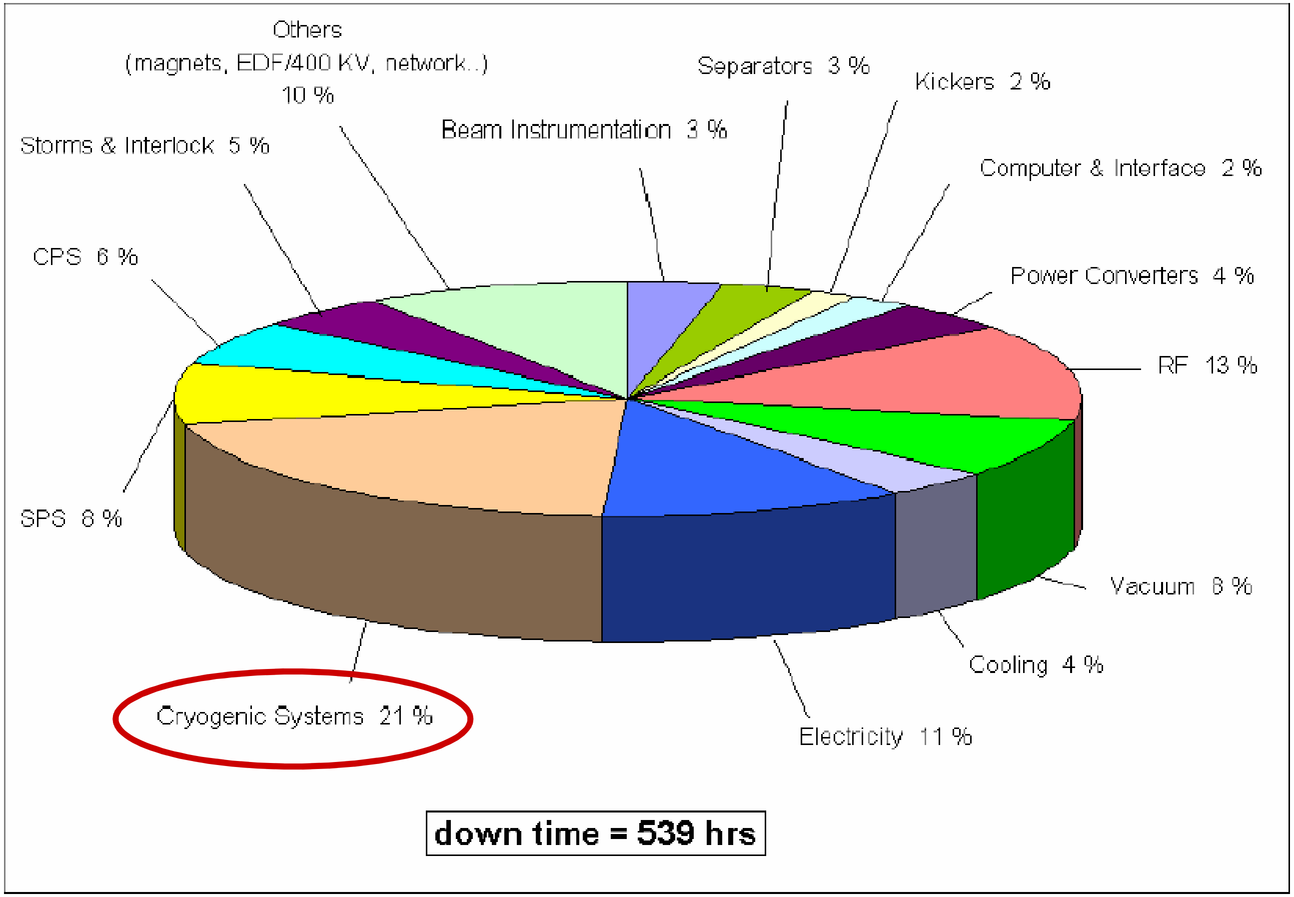
22 days
(12%)

190 days
(54%)

The LEP lesson (IV)

Up-time, availability

LEP Downtime 1999



The SLC lesson

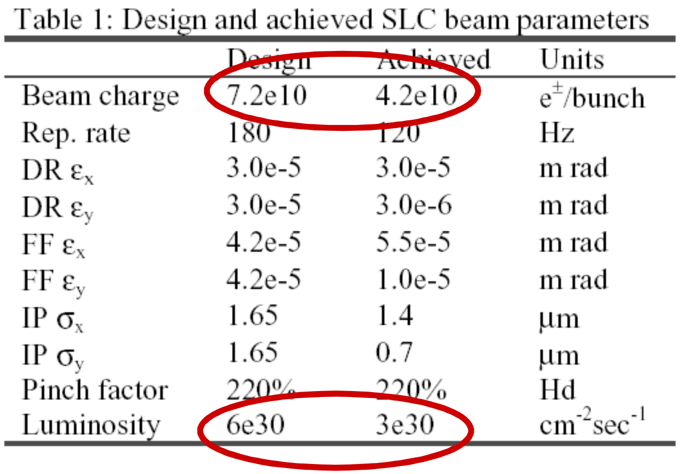
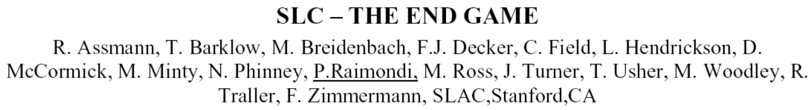


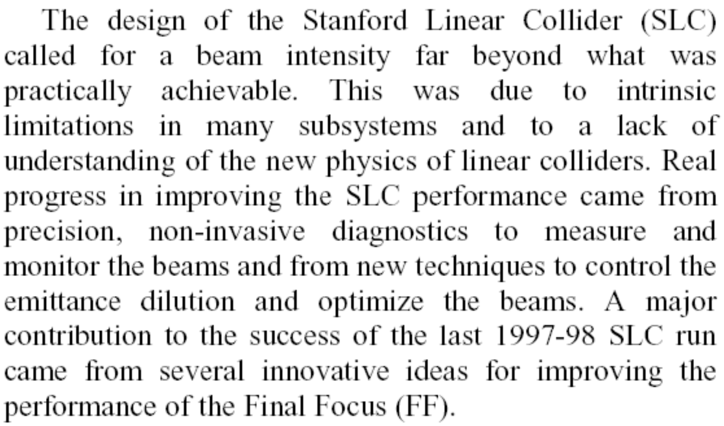
Table 1: Design and achieved SLC beam parameters

	Design	Achieved	Units
Beam charge	7.2e10	4.2e10	$e^{\pm}$/bunch
Rep. rate	180	120	Hz
DR ε_x	3.0e-5	3.0e-5	m rad
DR ε_y	3.0e-5	3.0e-6	m rad
FF ε_x	4.2e-5	5.5e-5	m rad
FF ε_y	4.2e-5	1.0e-5	m rad
IP σ_x	1.65	1.4	µm
IP σ_y	1.65	0.7	µm
Pinch factor	220%	220%	Hd
Luminosity	6e30	3e30	$cm^{-2}sec^{-1}$



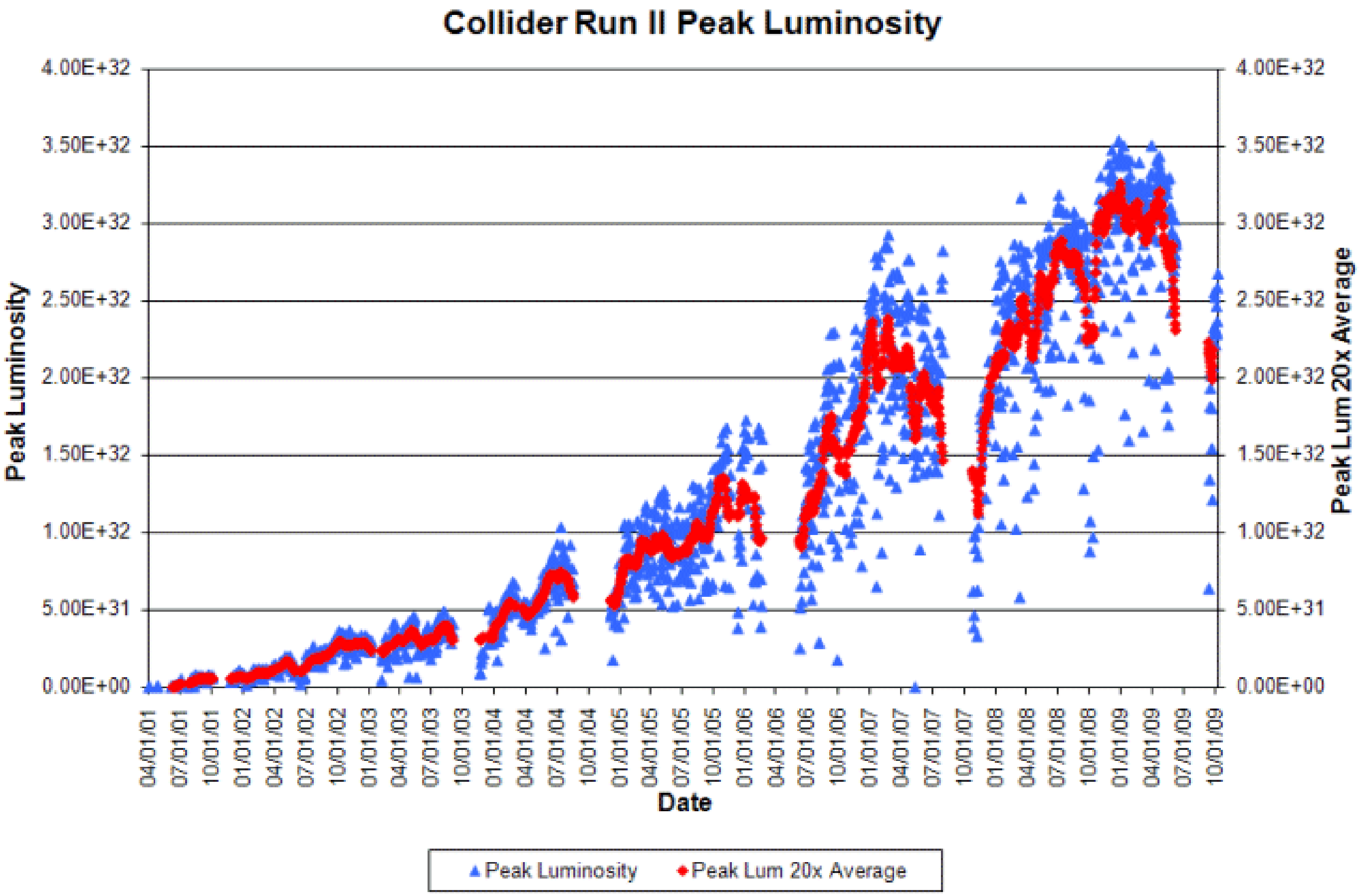
SLC – THE END GAME

R. Assmann, T. Barklow, M. Breidenbach, F.J. Decker, C. Field, L. Hendrickson, D. McCormick, M. Minty, N. Phinney, P.Raimondi, M. Ross, J. Turner, T. Usher, M. Woodley, R. Traller, F. Zimmermann, SLAC,Stanford,CA



The design of the Stanford Linear Collider (SLC) called for a beam intensity far beyond what was practically achievable. This was due to intrinsic limitations in many subsystems and to a lack of understanding of the new physics of linear colliders. Real progress in improving the SLC performance came from precision, non-invasive diagnostics to measure and monitor the beams and from new techniques to control the emittance dilution and optimize the beams. A major contribution to the success of the last 1997-98 SLC run came from several innovative ideas for improving the performance of the Final Focus (FF).

Another example: Tevatron



Another example: Tevatron

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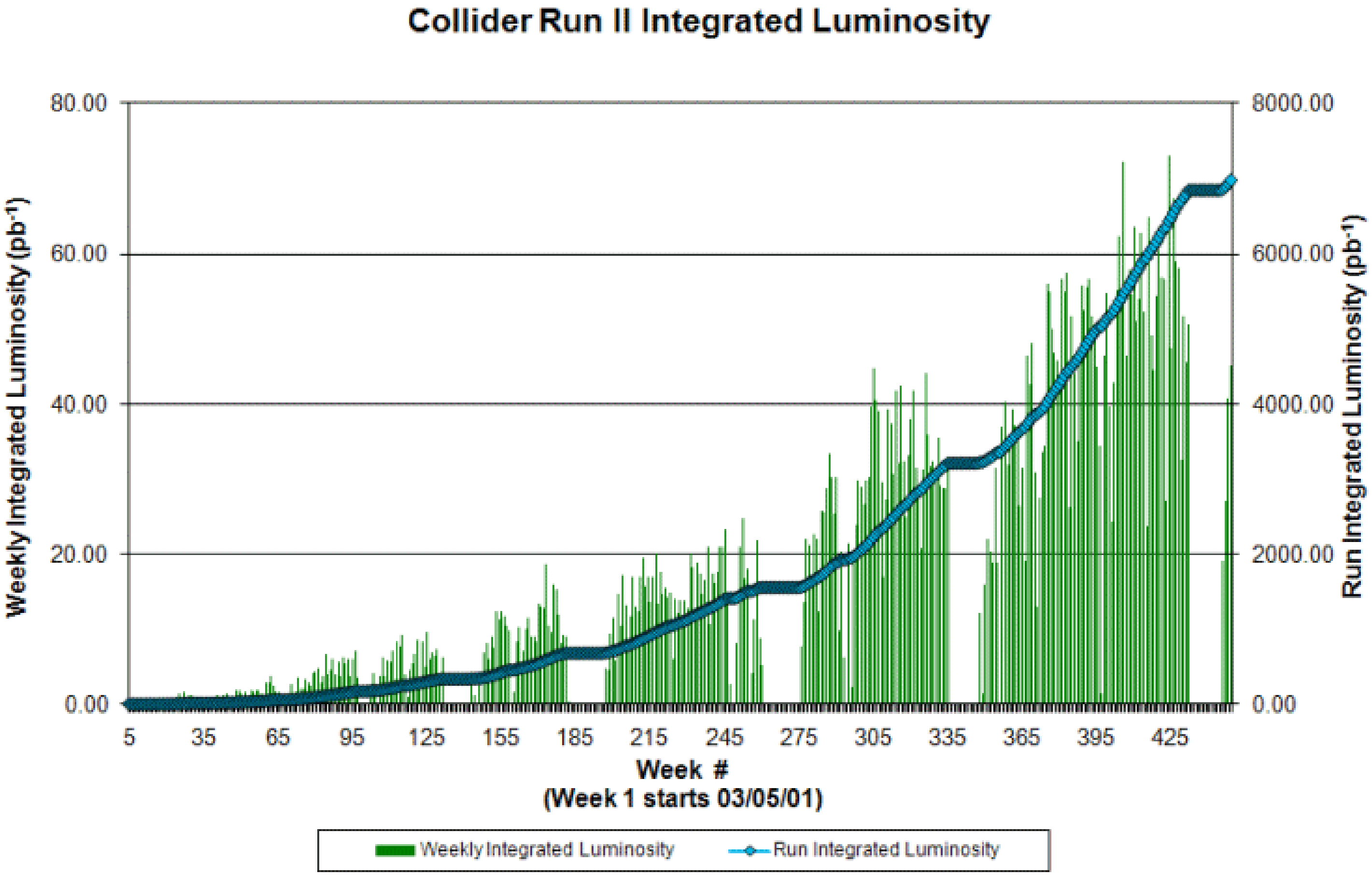
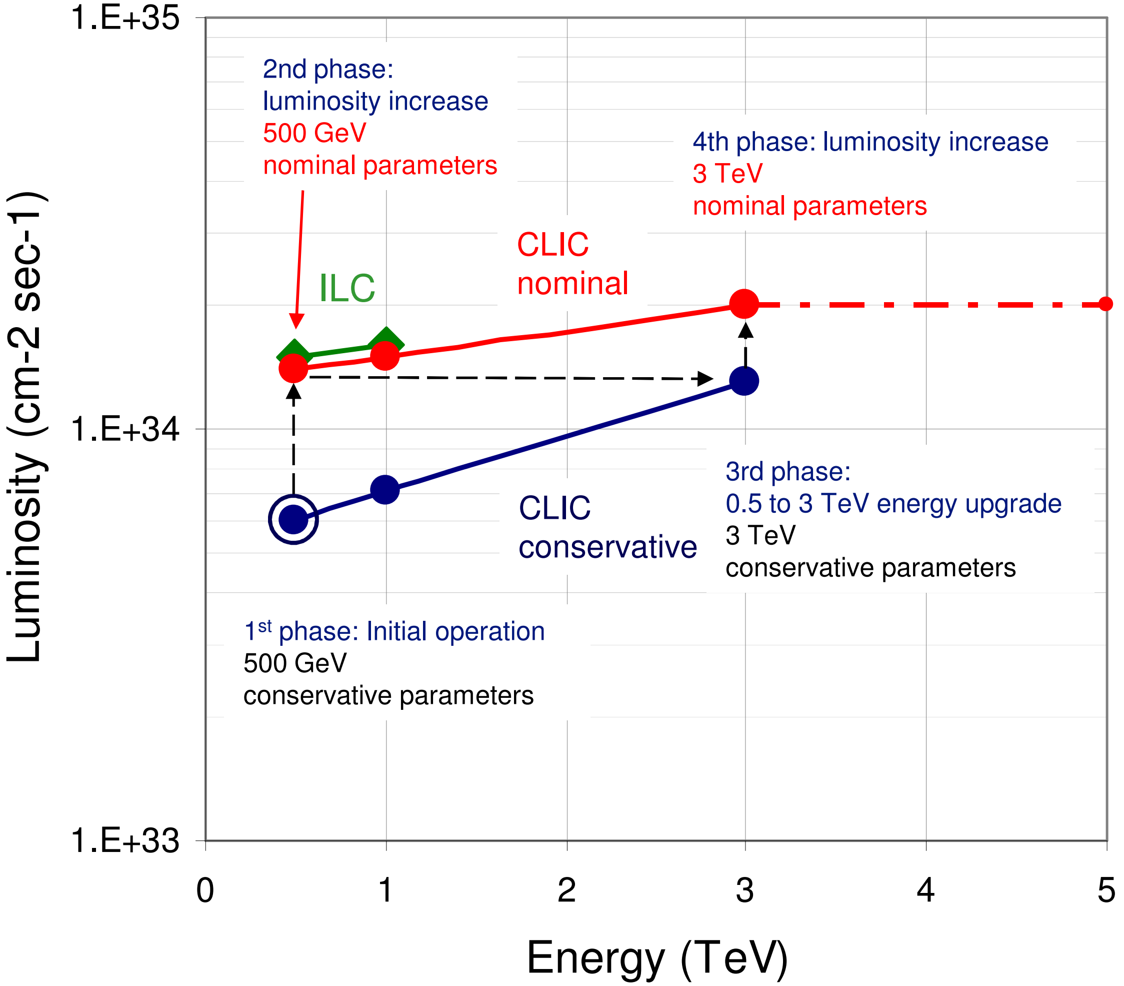


The CLIC upgrades scenario

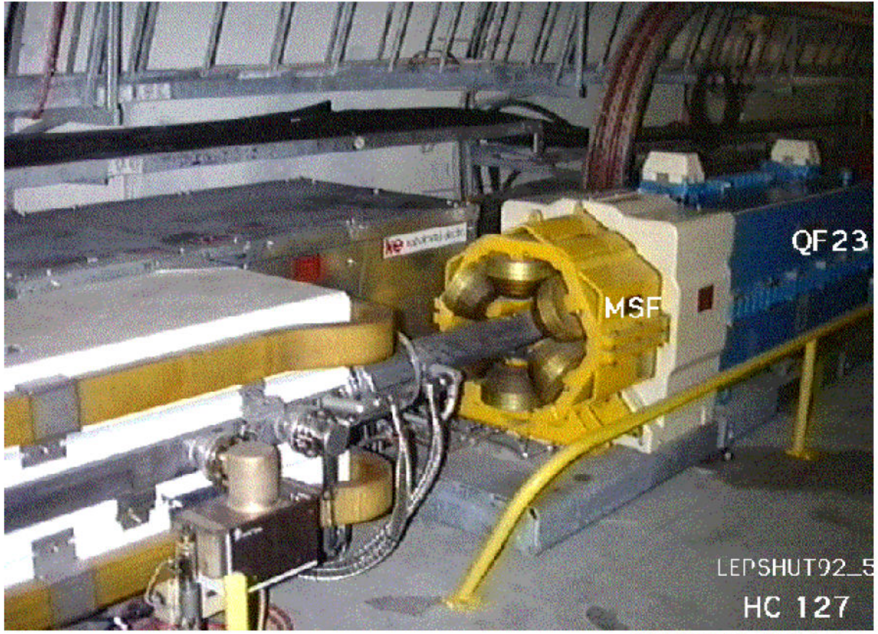


The CLIC upgrades scenario

Center-of-mass energy	CLIC 500 GeV		CLIC 3 TeV	
Beam parameters	Relaxed	Nominal	Relaxed	Nominal
Accelerating structure	502		G	
Total (Peak 1%) luminosity	$8.8(5.8)\cdot10^{33}$	$2.3(1.4)\cdot10^{34}$	$7.3(3.5)\cdot10^{33}$	$5.9(2.0)\cdot10^{34}$
Repetition rate (Hz)	50			
Loaded accel. gradient MV/m	80		100	
Main linac RF frequency GHz	12			
Bunch charge10^9	6.8		3.72	
Bunch separation (ns)	0.5			
Beam pulse duration (ns)	177		156	
Beam power/beam MWatts	4.9		14	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	7.5/40	4.8/25	7.5/40	0.66/20
Hor/Vert FF focusing (mm)	4/0.4	4 / 0.1	4/0.4	4 / 0.1
Hor./vert. IP beam size (nm)	248 / 5.7	202 / 2.3	101/3.3	40 / 1
Hadronic events/crossing at IP	0.07	0.19	0.28	2.7
Coherent pairs at IP	10	100	$2.5\ 10^{7}$	$3.8\ 10^{8}$
BDS length (km)	1.87		2.75	
Total site length km	13.0		48.3	
Wall plug to beam transfert eff	7.5%		6.8%	
Total power consumption MW	129.4		415	

The “LHC lesson”

Interconnection between magnets: LEP



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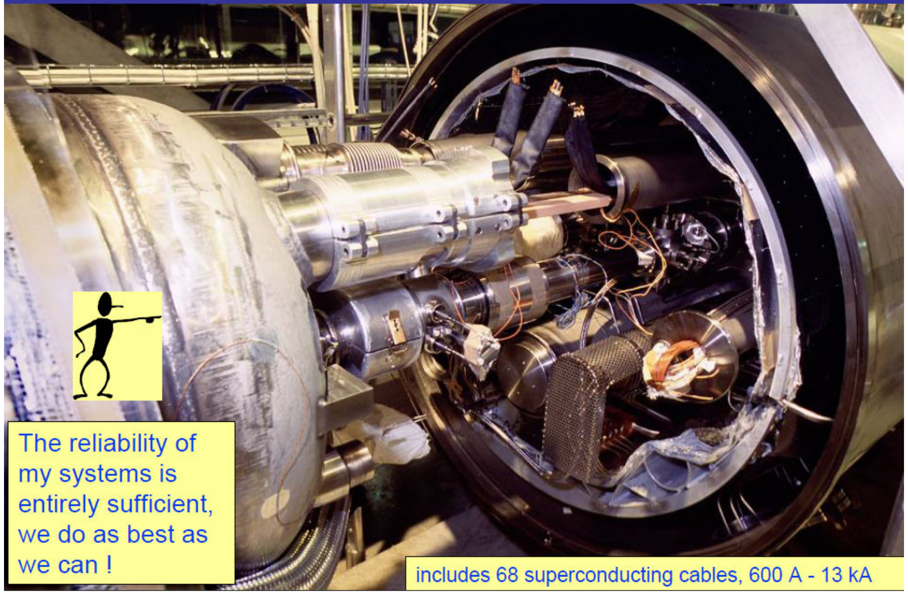
Interconnect between two superconducting magnets



The reliability of my systems is entirely sufficient, we do as best as we can !

includes 68 superconducting cables, 600 A - 13 kA

Conclusions

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