The next 20 years: New machines for High Energy Physics

Europhysics Conference on High Energy Physics

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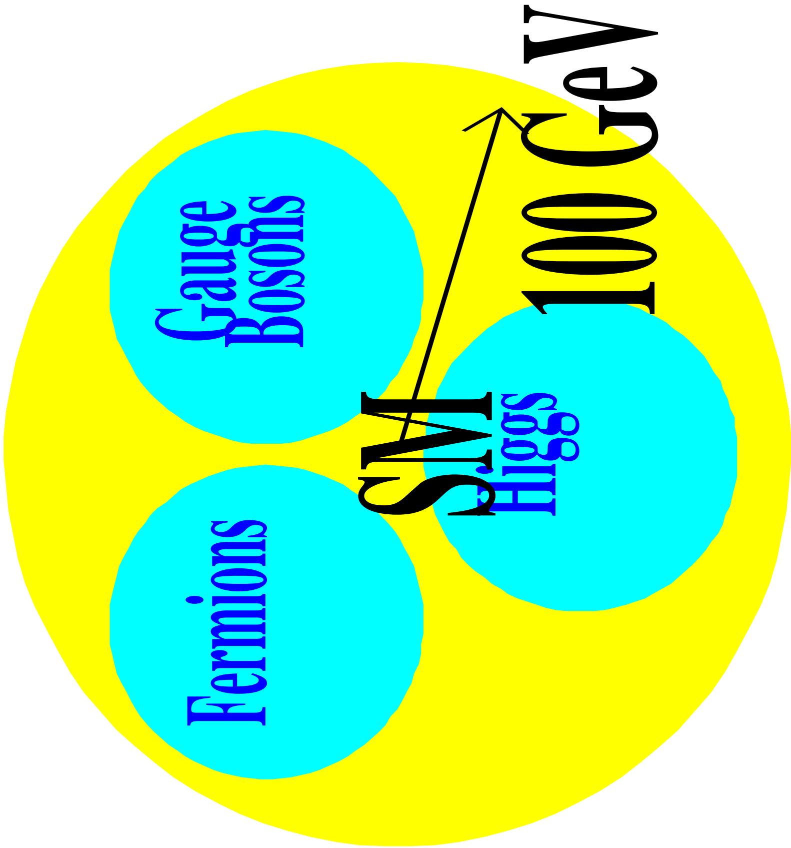
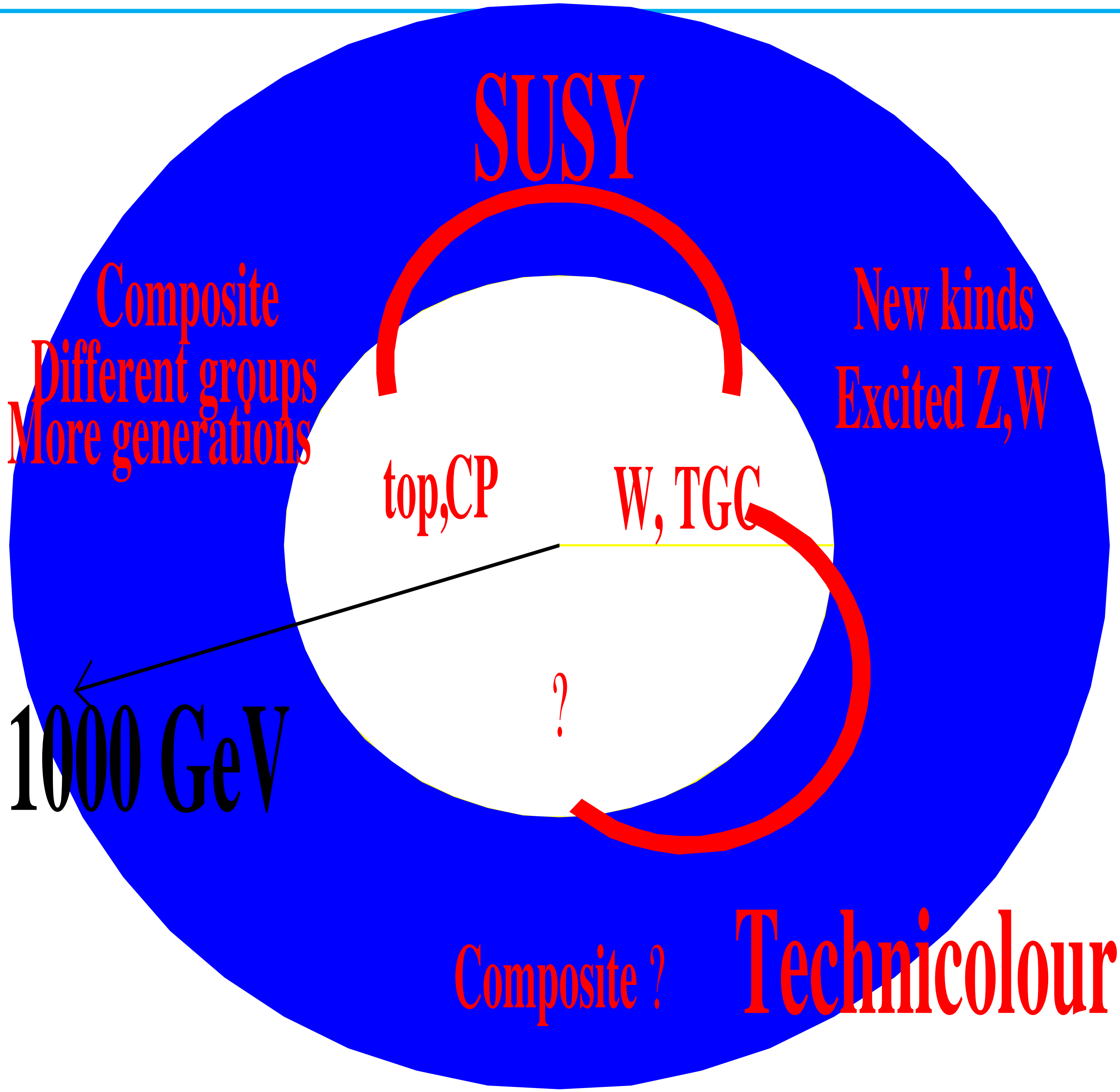
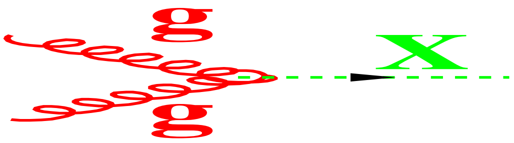
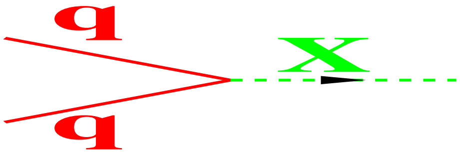

100 GeV
Gauge Bosons
SM
Higgs
Fermions


SUSY
Composite
Different groups
More generations
New kinds
Excited Z,W
top,CP
W, TGC
?
1000 GeV
Composite ?
Technicolour

The tools

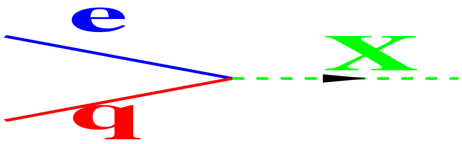
pp / $p\bar{p}$ collisions





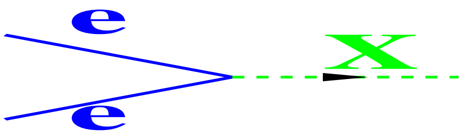
$M_X \;\propto\; s^{0.6}\mathcal{L}^{0.2}$: 10fold $\mathcal{L} \sim$ 1.6 in mass

ep collisions



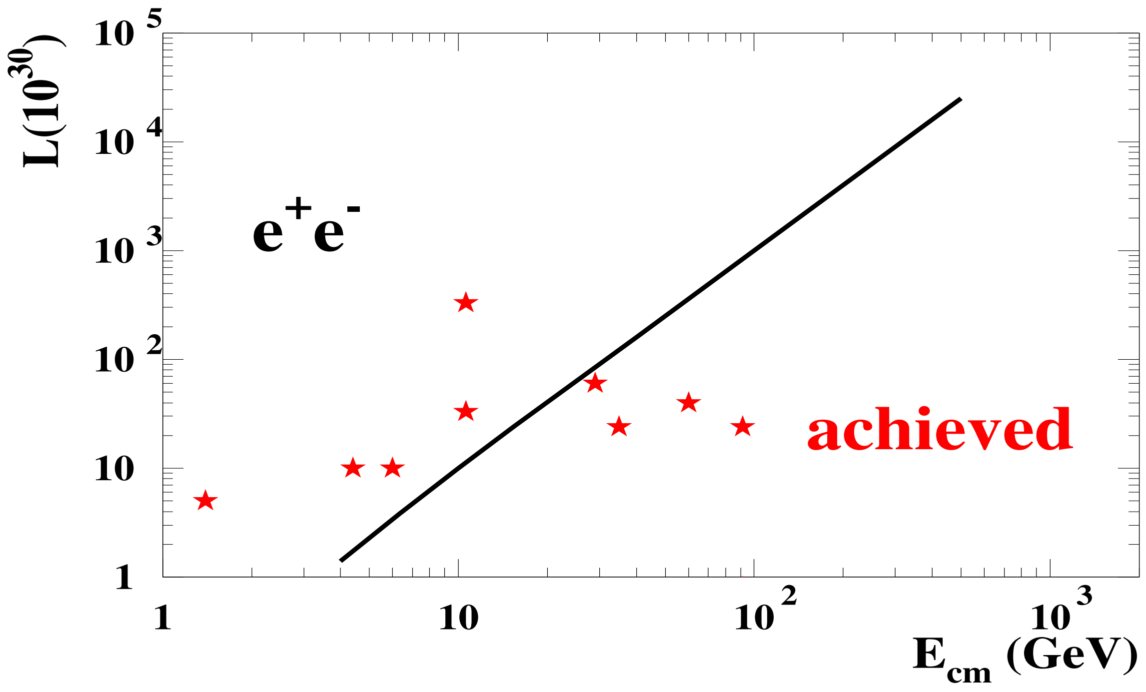
$M_X \;\propto\; s^{0.8}\mathcal{L}^{0.25}$: 10fold $\mathcal{L} \sim$ 1.8 in mass

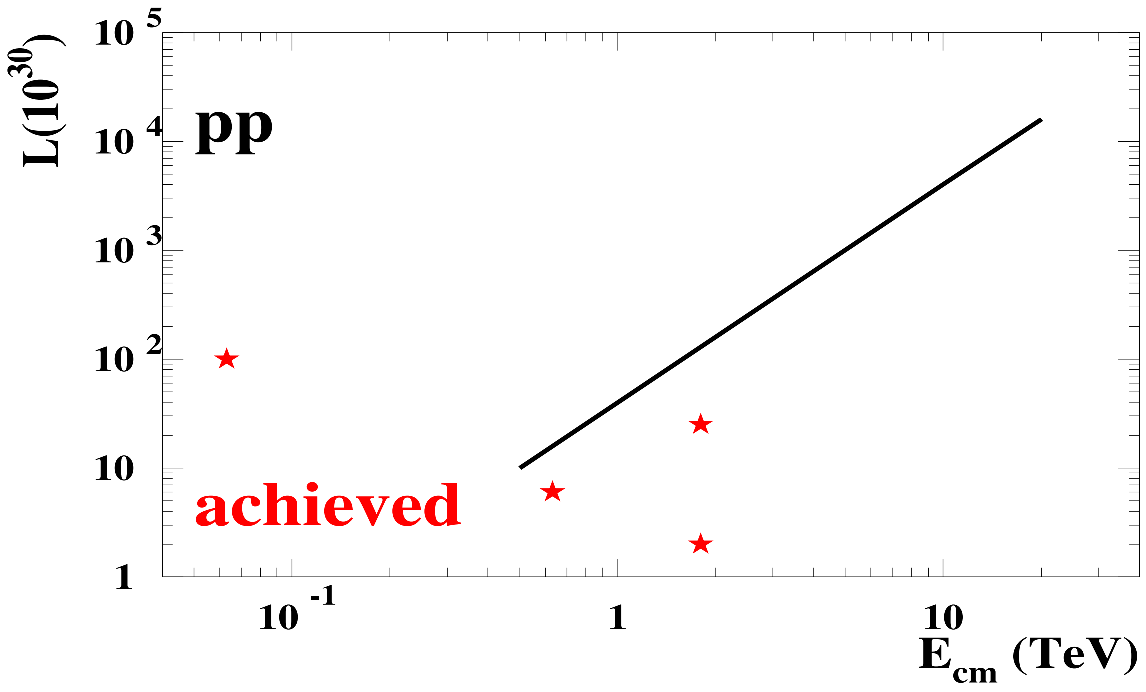
ee collisions



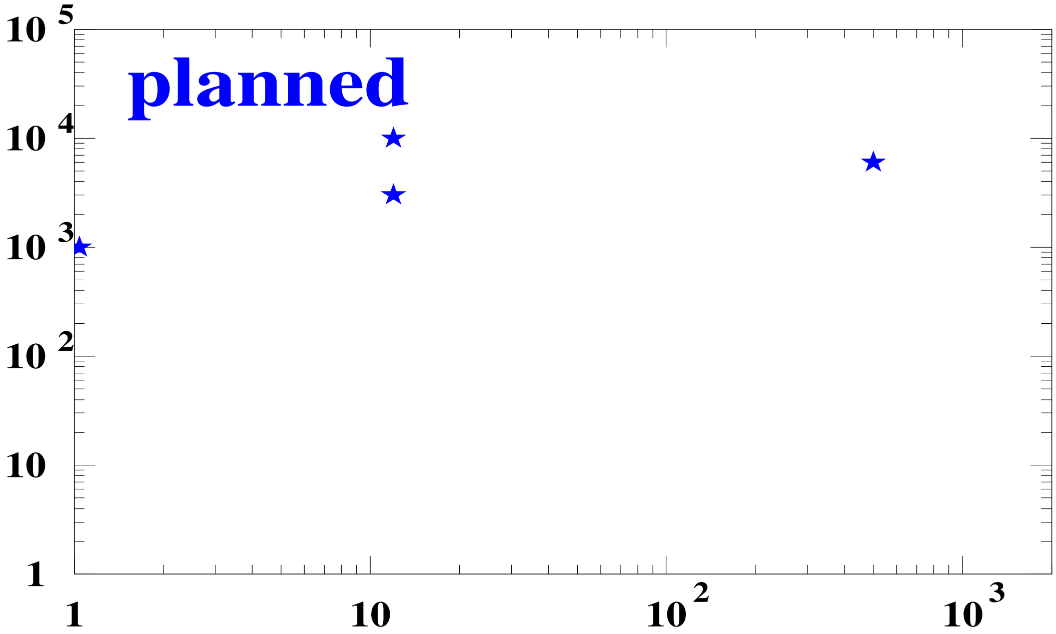
$M_X \;\propto\; s^{0.5}$

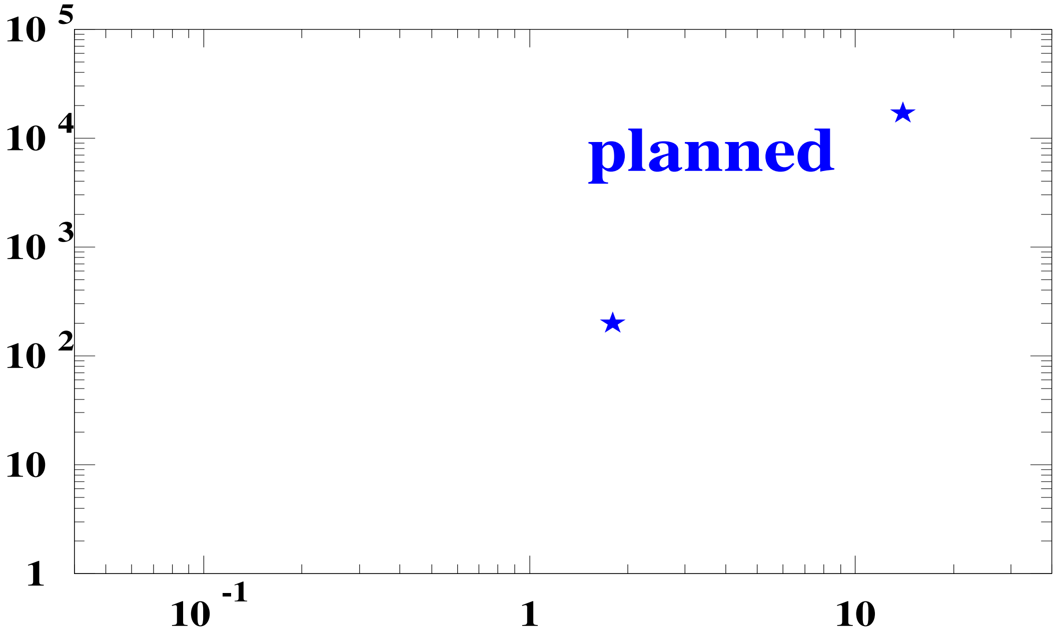
Luminosities vs energies





Luminosities vs energies





A Quantum jump in Luminosity!

pp Collider - present and near future

TEVATRON:

Data up to '96: $\mathcal{L} \sim 1.6 \cdot 10^{31} \Rightarrow \int \mathcal{L}$ ~120pb^{-1}

Upgrade: get more $\bar{p}$, increase $\sqrt{s}$ = 2 TeV

- Main Injector: higher currents
- Recycler: $\bar{p}$ accumulation

Run II ('99-'02) : $\mathcal{L} \sim 10^{32} \Rightarrow \int \mathcal{L}$ ~2 fb^{-1}

After 2002: continuous upgrade, e.g. more bunches

Requires detector upgrades

$\mathcal{L} \sim 2 \cdot 10^{33} \Rightarrow \int \mathcal{L}$ ~20 fb^{-1}

- Beauty mixing and $\not{C}P$
- SM: $\delta(m_t) \sim$ 3.5 (2) GeV, $\delta(m_W)$ ~0.04 (0.02) GeV
- New Physics mass ranges $\mathcal{O}$(300 GeV-700 GeV)

pp Collider - the future

LHC:

Approved in 1994, start - up 2005

initial $\mathcal{L} \sim 10^{33}$, more operational experience: $\mathcal{L} \sim 10^{34}$

- High field superconducting magnets
- 2385 bunches, high currents (stored E $\sim$ 75 kg TNT)

- Final word on Higgs (?), top, TGC
- New Physics mass ranges $\mathcal{O}$(800 GeV-3000 GeV)

Detectors - challenges: high rates, huge amount of data

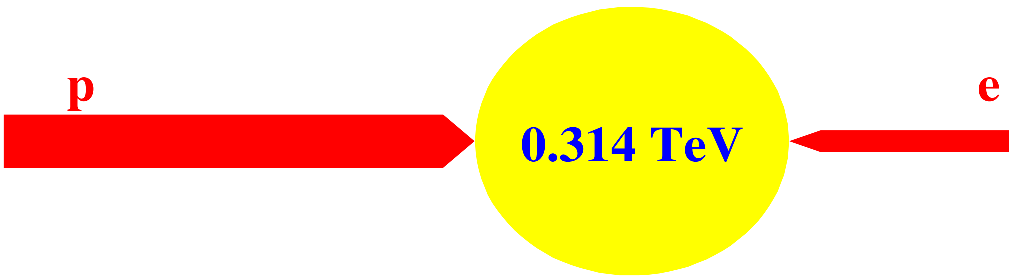
Multi - purpose: ATLAS, CMS

Dedicated B-physics: LHCB

Heavy Ion Physics: ALICE

ep Collider

HERA:



Since '91: $\mathcal{L} \sim 1.6 \cdot 10^{31} \Rightarrow \int \mathcal{L} \sim$40 pb^{-1}

Upgrade in '99/'00 shutdown

- New proton pre - accelerator
- Restructure intersection region: mini β

$\mathcal{L} \sim 8 \cdot 10^{31} \Rightarrow \int \mathcal{L} \sim$200 pb^{-1}/y

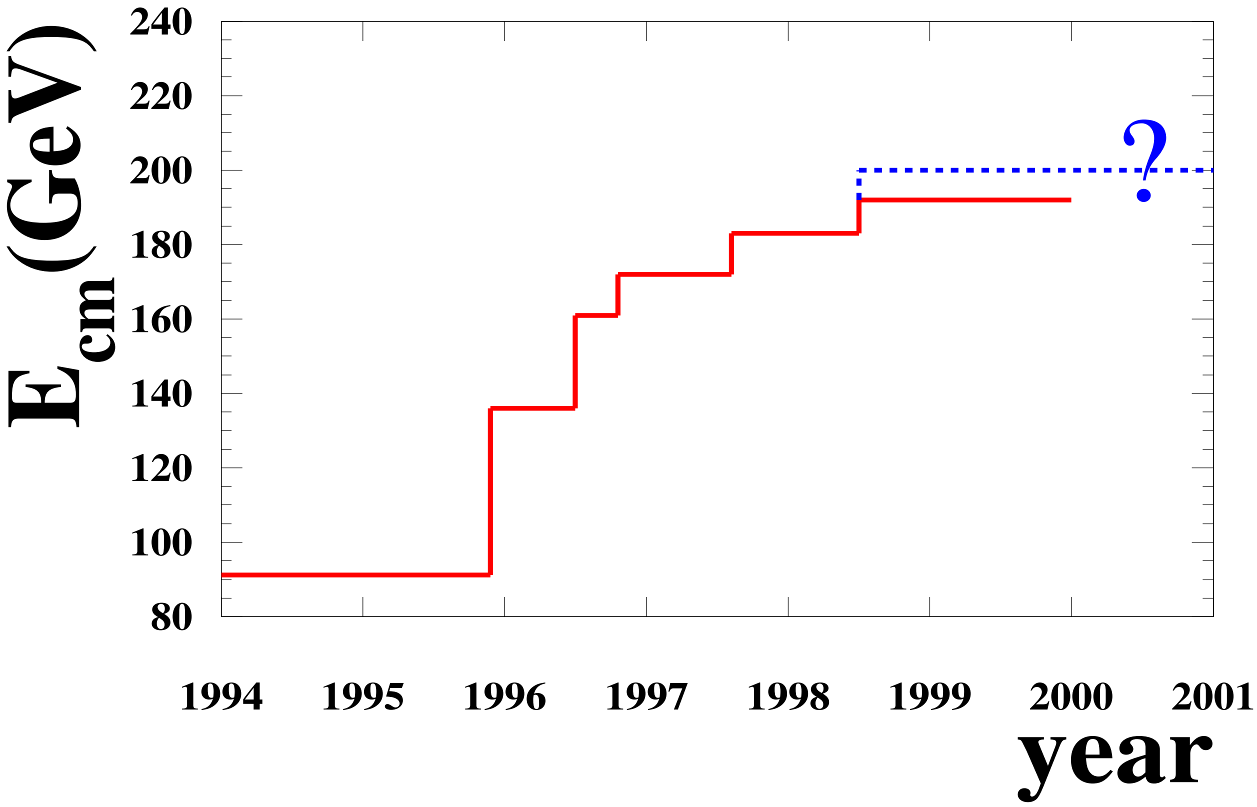
- Electroweak studies, particularly CC
- New Physics mass ranges $\mathcal{O}$(300 GeV)

The possible far future: LEP $\oplus$ LHC $\Rightarrow \sqrt{s}$ = 1.3 TeV

option left open, but little consideration, later than 2015 ?

e^+e^- Collider

LEP: start ’89, since ’96 stepwise energy upgrade



- Central issue: super conducting cavities

$\mathcal{L} \sim 4 \cdot 10^{31}$ achieved, hope for $\int \mathcal{L} \sim 500$ pb^{-1}

- SM: $m_W \sim$ 0.04 GeV, TGC ~0.1, Higgs $\rightarrow$ 100 GeV
- MSSM for $\tan\beta \leq$2, New Physics $\mathcal{O}$(100 GeV)

e^+e^-: the high energy frontier

Higher energy $\Rightarrow$ new principle: linear collider

Key question: which RF $\Rightarrow$ machine parameters

S,C,X -Band: 3,5.7,11.4 GHz	L - Band: 1.3 GHz
Conventional	SC cavities
strong wakefield	good stability
known technology	R & D

Vigorous international R & D

	NLC/JLC	SBLC	TESLA
Length (km)	14 - 28	35	32
I.P: $\sigma_{x,y}$ (nm)	3-6	15	19
P_{beam} **(MW)**	3-5	7	8

From idea to reality

'96/'97	Conceptual Design Reports
X $\geq$ '00?	Technical Design Report + Governmental approval
X + $\geq$6 y	First collisions

Which energy ?

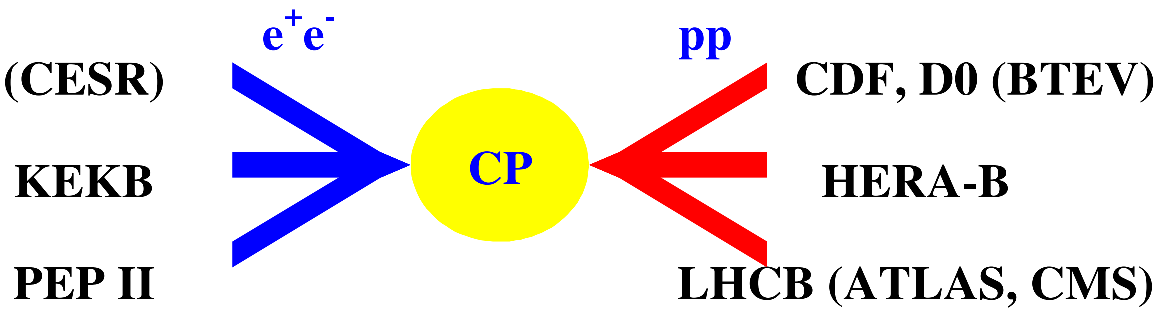
Concensus: in steps towards 'final' E_{cm}

Step I	250 GeV	**a light Higgs ?**
	380 GeV	**a top factory**
	500 GeV	**wide range**
Step II	1000 GeV	**the beyond SM range**
Step II	2000 GeV	**the unknown**

World Wide B's

Dedicated machines and detectors for $\not{C}\!P$ in Beauty

... and strange sector: CERN, Tevatron, DAϕNE



The gold plated process

Understanding $\not{C}\!P$: additional modes

$B^0 \rightarrow \pi\pi,\ \rho\pi, B_s \rightarrow K_s^0\rho^0,\ D_sK$ ......

A comprehensive picture

e^+e^-:

- Use resonance enhancement $\Upsilon(4S)$
- Asymmetric collisions (9 $\otimes$ 3.1 GeV)

  Buys a factor $\mathcal{O}(6)$ cpd to symmetric
- Dedicated machines !

  High lumi because two beam pipes

pp:

- Very high cross sectioni, but S/B$\sim$ 10^{-6}

  Trigger and data reduction essential
- Dedicated detectors

	e^+e^-			pp		
	CESR	PEPII	KEKB	HERA-B	CDF/D0	LHCB
Prod.	symm	asymm	asymm	fixed t.	coll.	coll
Start	ongoing	'99	'99	$>$'98	'00	'05
$\mathcal{L}$	$\geq 10^{33}$	$\geq 3 \cdot 10^{33}$	$\geq 10^{33}$	$\sim 10^{33}$	$\geq 10^{32}$	$\geq 10^{33}$

The race is on !

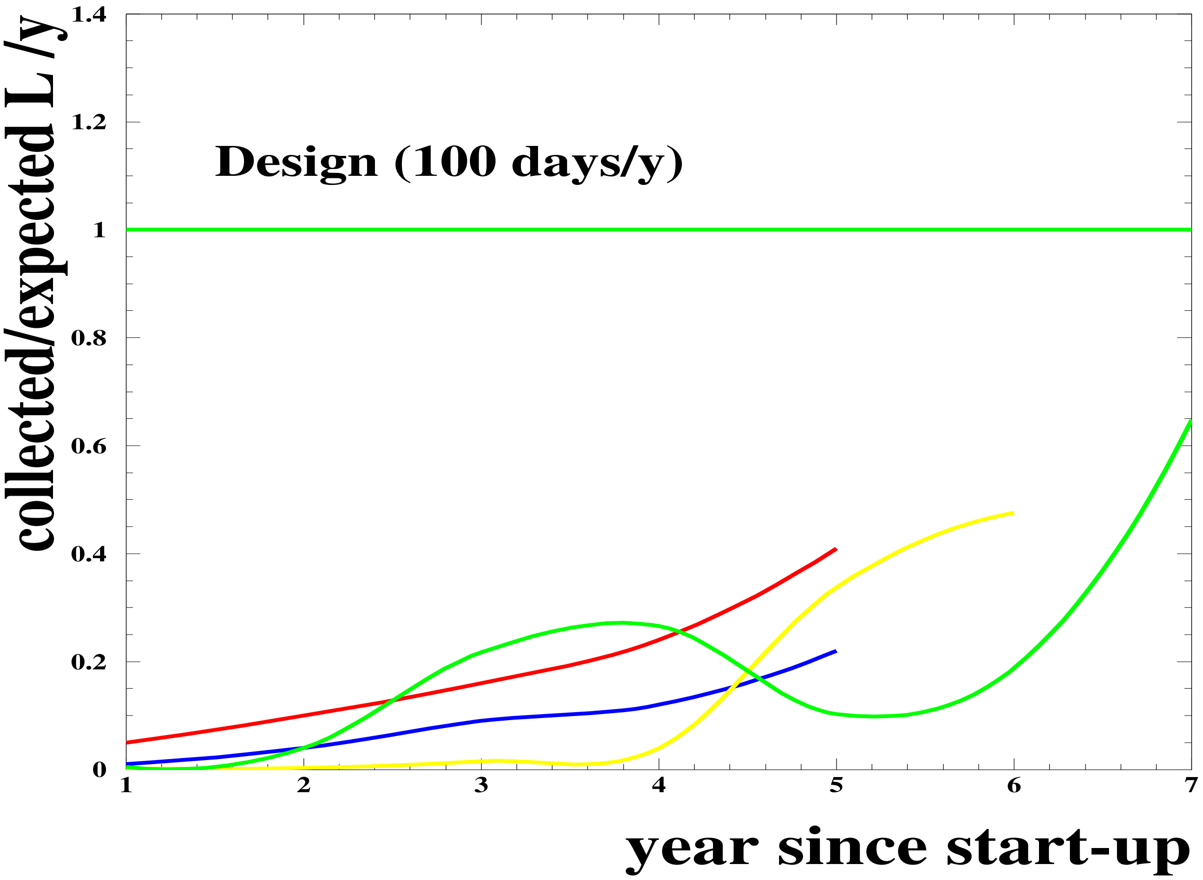
A word of warning ...

What is the design luminosity ?

Machine physicists: **Maximum** luminosity $\mathcal{L}_{max}$

Exptl. physicists: annual $\int \mathcal{L} = \mathcal{L}_{max}$·100 days

The experience: $R = (\int_{year}^{collected} \mathcal{L})/(\mathcal{L} \cdot 10^7)$



⇒ For first 4 y: annual $\int \mathcal{L} \sim \mathcal{L}_{max}$·10 days

⇒ For next 4 y: annual $\int \mathcal{L} \sim \mathcal{L}_{max}$·30 days

But then .....

Experiencing and exploring data helps!

Example LEP:

	Projected	**Achieved**
m_Z	**25**	**2.0 MeV**
Γ_Z	**50**	**2.7 MeV**
Higgs reach	**40 GeV**	**65 GeV**

Example Tevatron:

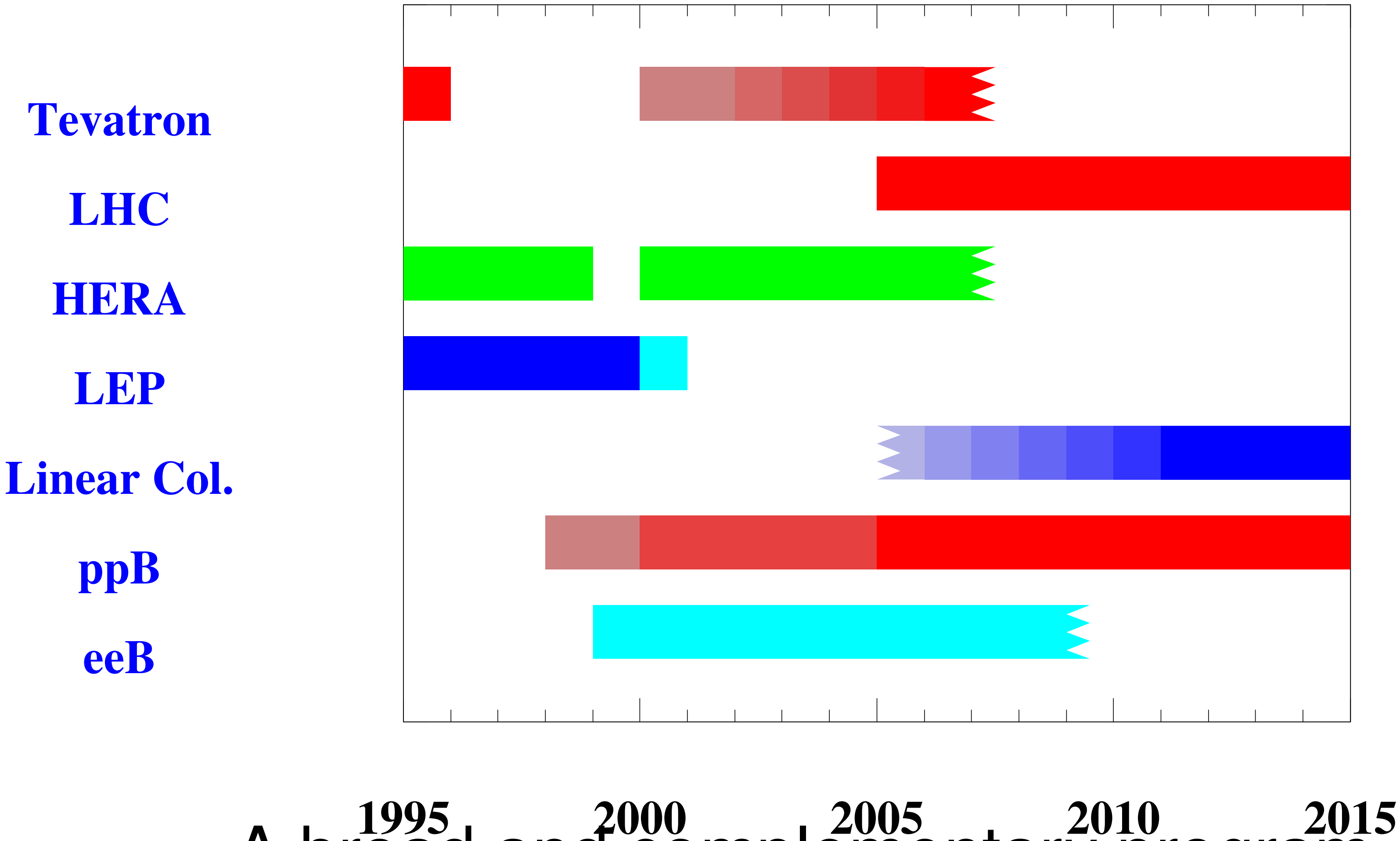
- **High precision M_Z, M_W measurement**
- **Excellent B - lifetime results**

Example HERA:

- **Low x physics**

As time goes by: new ideas, new methods .....

The next 20 years



A broad and complementary program

When we are close to retirement ....

	today	2000	2005	2015
δM_W (MeV)	100	40	25	15
δM_{top} (GeV)	6	6.	2.	0.2
TGC's	0.5	0.1	0.07	0.001
Higgs range (GeV)	75	100	130	1000
Contact Interaction (TeV)	3	10		50
$\not{C}P(\delta(\sin 2\beta)$		0.1	0.02	$<$0.01
MSSM range $(\tan\beta)$		< 2		complete
M_{χ^+} (GeV)	80	100	($<$250)	250
Leptoquarks (GeV)	$\sim$220		360	1500
Excited leptons (GeV)	$\sim$150	200		500
Z' (GeV)	$\sim$500		1300	$>$ 7000

..... OR COMPLETELY DIFFERENT???

Conclusions

- A broad and comprehensive program in HE physics from 1 GeV to 10 TeV
- Challenging machine and detector designs high currents, high power, high data flow
- Sensitivity to energy scales will be reached where SM should loose its validity!
- During the next 20 y, ground has to be laid for the next-to-next generation
  - $\Rightarrow$ Hadron Collider (VLHC) 100 TeV
  - $\Rightarrow$ $\mu^+\mu^-$ collider of $\sim$ 4 TeV
  - $\Rightarrow$ New methods of acceleration