The High Energy Frontier

Past

Present

Future

Courtesy Peter Reid

Past few decades

“Discovery” of Standard Model

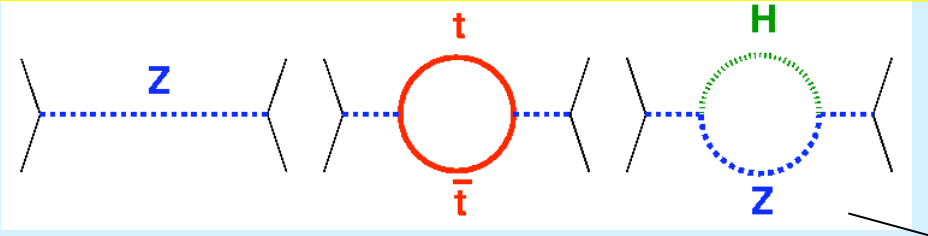
through synergy of

hadron - hadron colliders (e.g. Tevatron)

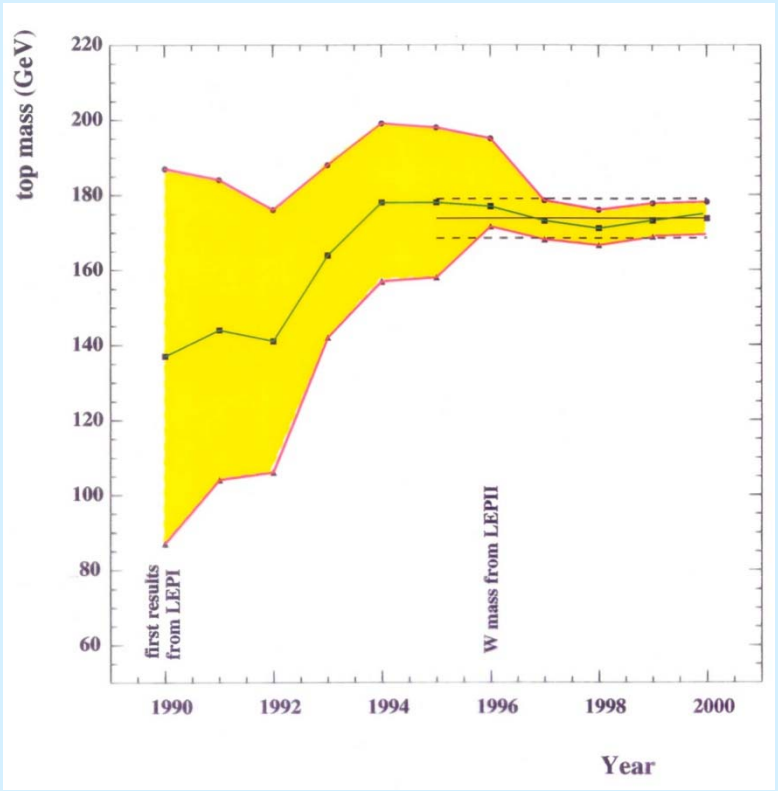
lepton - hadron colliders (HERA)

lepton - lepton colliders (e.g. LEP)

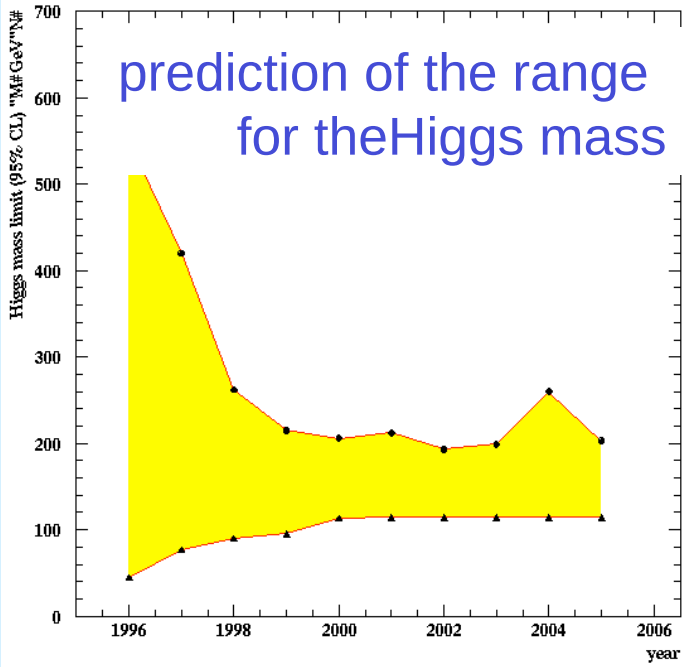
Test of the SM at the Level of Quantum Fluctuations



indirect determination of the top mass



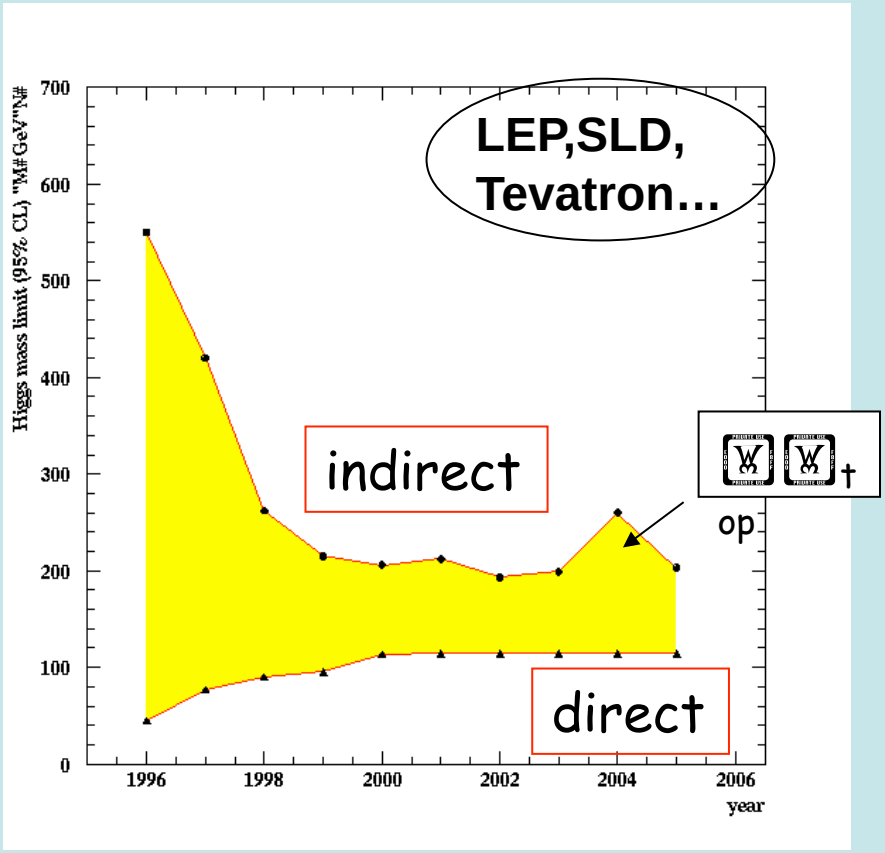
prediction of the range for theHiggs mass



possible due to
- precision measurements
- known higher order electroweak corrections

$$\propto \left(\frac{M_t}{M_W}\right)^2, \ln\left(\frac{M_h}{M_W}\right)$$

Time evolution of experimental limits on the Higgs boson mass



M_H between 114 and ~200 GeV

Synergy of colliders

Today's knowledge:

only through combination of results from different accelerator types

in particular:
Lepton and Hadron Collider

together with highly developed **theoretical calculations**

Key Questions of Particle Physics today

origin of mass/matter or
origin of electroweak symmetry b g

unification of forces

fundamental symmet and matter

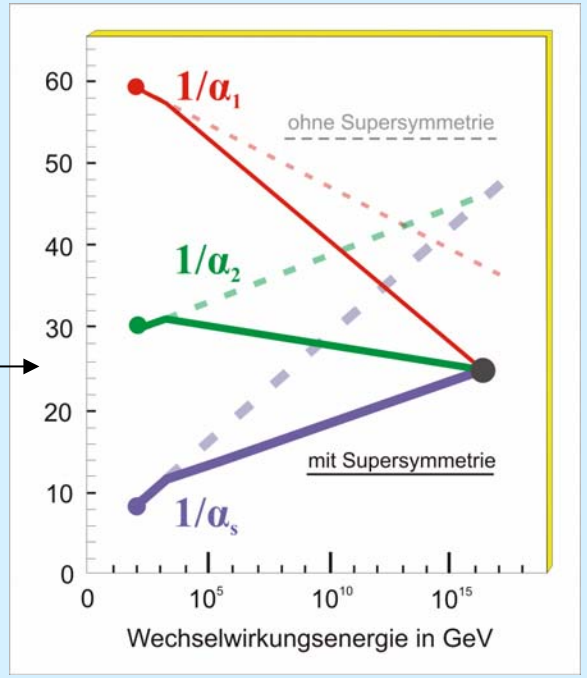
unification physics and gener

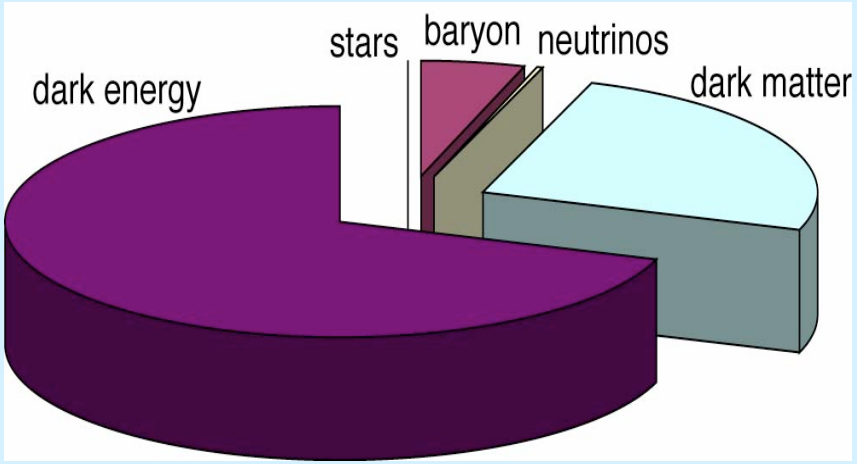
p pace/time dimensions

w dark matter

what is dark energy

addressable at the energy frontier
first step: LHC

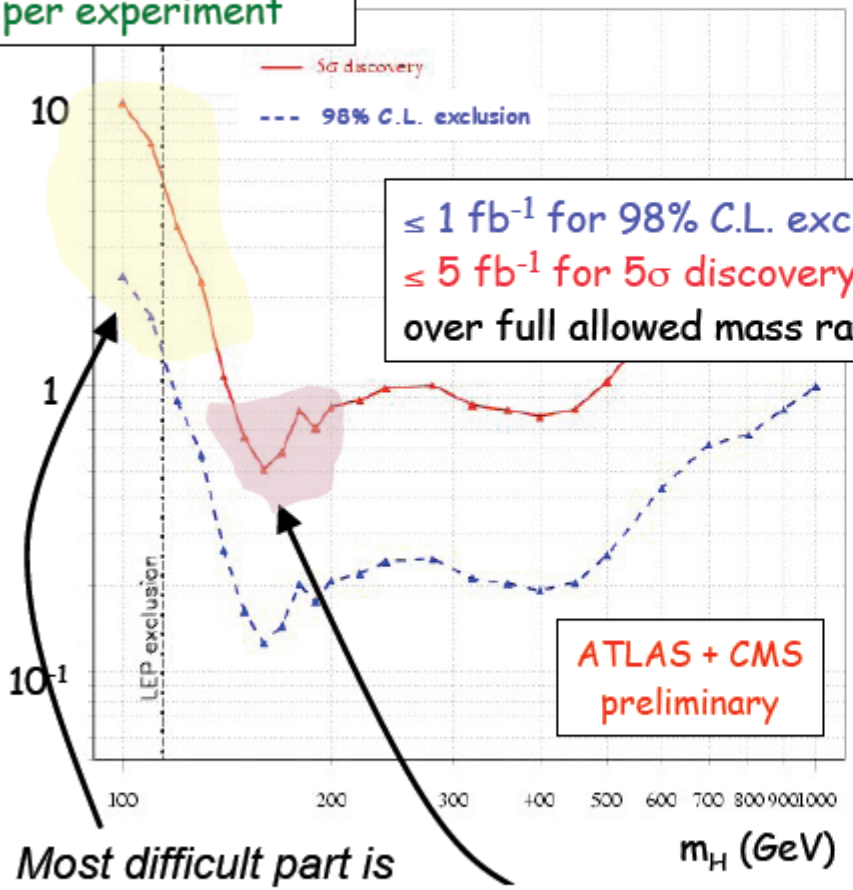




SM Higgs Reach

LHC

Needed ∫Ldt (fb^{-1}) per experiment

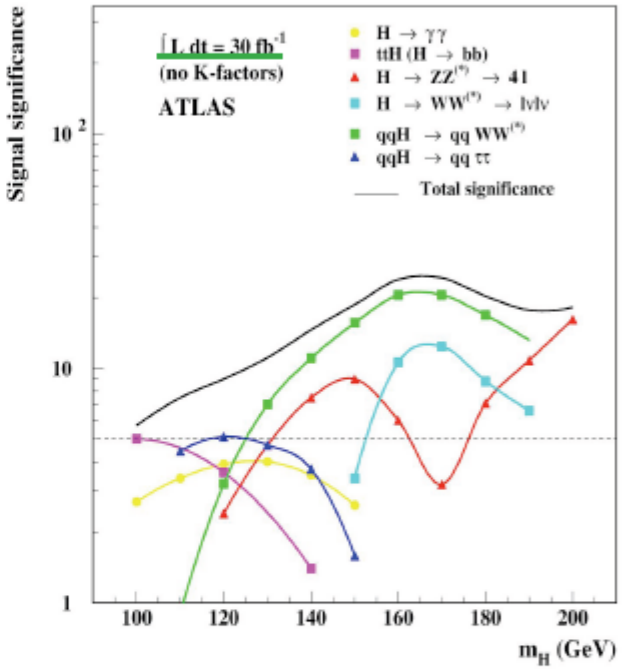


≤ 1 fb^{-1} for 98% C.L. exclusion
≤ 5 fb^{-1} for 5σ discovery
over full allowed mass range

ATLAS + CMS preliminary

Most difficult part is M_h~115 GeV

Early discovery already Possible with 1fb^{-1} H→WW$^{(*)}$→2l



With 1fb^{-1} of understood data:

- *potential to exclude almost all m_h values*
- *potential to discover higgs with m_h~165 GeV*

LHC will give us an answer!

but it will take time. . .

Commissioning: A Real Challenge

The commissioning of LHC machine
of unprecedented complexity and performance
will be one of the challenges in the next year!
Only commissioned experiments we will be able
to open the door to the new physics world!

Restart of the LHC: November this year

1. Is there a Higgs?
2. What is the Higgs mass?
3. Is the Higgs a SM-like weak doub
4. Is the Higgs elementa
5. Is the stabili symmetry or dyn
6. ective at the weak scale?
7. cover DM at the LHC?
8. Are there extra dimensions? Are there new strong forces?
9. Are there totally unexpected phenomena?
10. What is the mechanism of EW breaking?

Initial phase of LHC will tell which way nature wants us to go

Standard

Nearly Standard

Not at all Standard

The next decades

Initial Phase of LHC will tell the way to go

Possible ways beyond LHC

hadron - hadron collider (sLHC / DLHC)

lepton - lepton collider (ILC / CLIC)

lepton - hadron collider (LHeC)

The European Strategy for particle physics

one possible way : luminosity upgrade

3. The LHC will be the energy frontier machine for the foreseeable future, maintaining European leadership in the field; *the highest priority is to fully exploit the physics potential of the LHC, resources for completion of the initial programme have to be secured such that machine and experiments can operate optimally at their design performance.* A subsequent major luminosity upgrade (SLHC), motivated by physics results and operation experience, will be enabled by focussed R&D; *to this end, R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015.*

sLHC

$L \sim 10^{35}$

Two Phase Luminosity Upgrade:

gradually increase performance of LHC,

i.e. towards luminosity upgrade ($L \sim 10^{35}$) sLHC:

- New inner triplet -> towards $L \sim 2*10^{34}$
- New Linac (Linac4) -> towards $L \sim 4*10^{34}$

  construction started → earliest implementation~ 2013/14

- New PS (PS2 with double circumference)
- Superconducting Proton Linac (SPL)

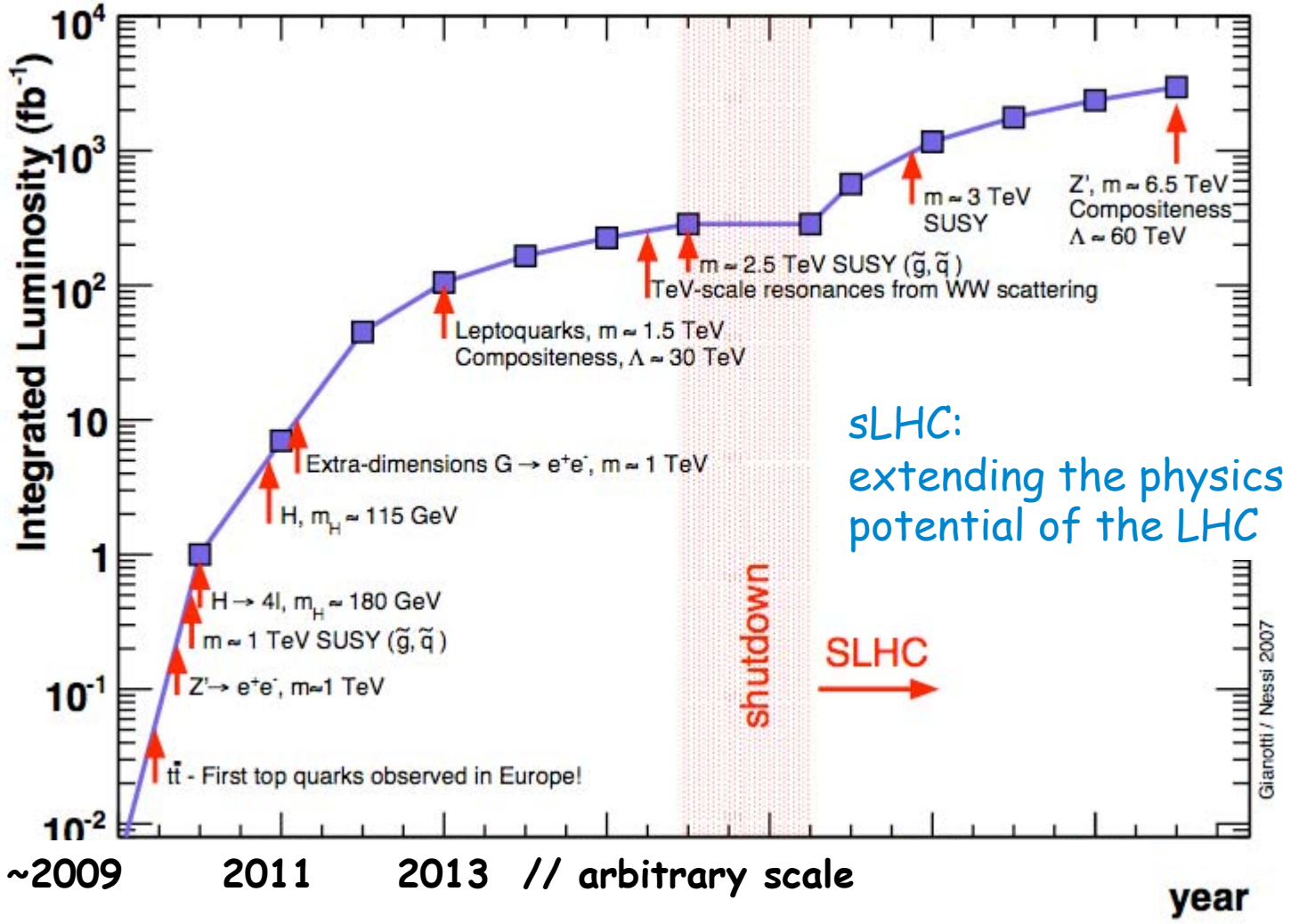
  start ***design*** now, ready for decision ~ 2012

  aimed for $L \sim 10^{35}$ if physics requires

sLHC

- Detector R&D

Important: international collaboration

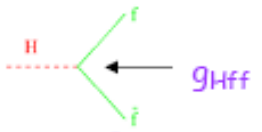


sLHC:
extending the physics
potential of the LHC

Higgs Couplings

Higgs couplings!

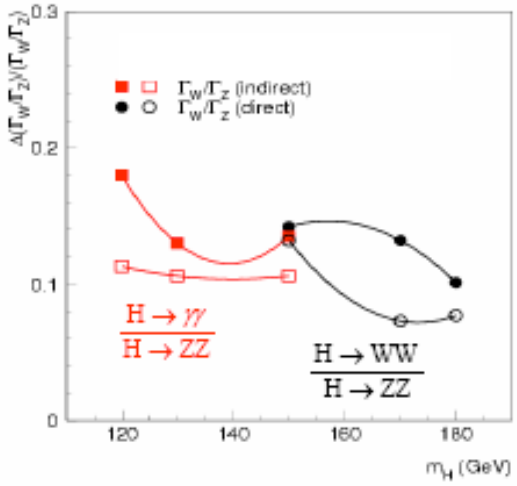
Couplings obtained from measured rate in a given production channel:



$$R_{ff} = \int L\,dt \bullet \sigma(e^+e^-, pp \to H + X) \bullet BR(H \to ff) \qquad BR(H \to ff) = \frac{\Gamma_f}{\Gamma_{tot}}$$

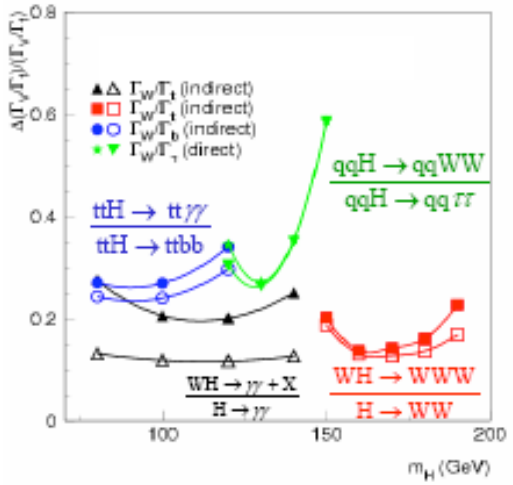
→ deduce $\Gamma_f \sim g^2_{Hff}$

- Hadron Colliders: Γ_{tot} and $\sigma(pp \to H+X)$ from theory → without theory inputs measure ratios of rates in various channels (Γ_{tot} and σ cancel) → $\Gamma_f/\Gamma_{f'}$



Closed symbols:
LHC 600 fb^{-1}

Open symbols:
SLHC 6000 fb^{-1}

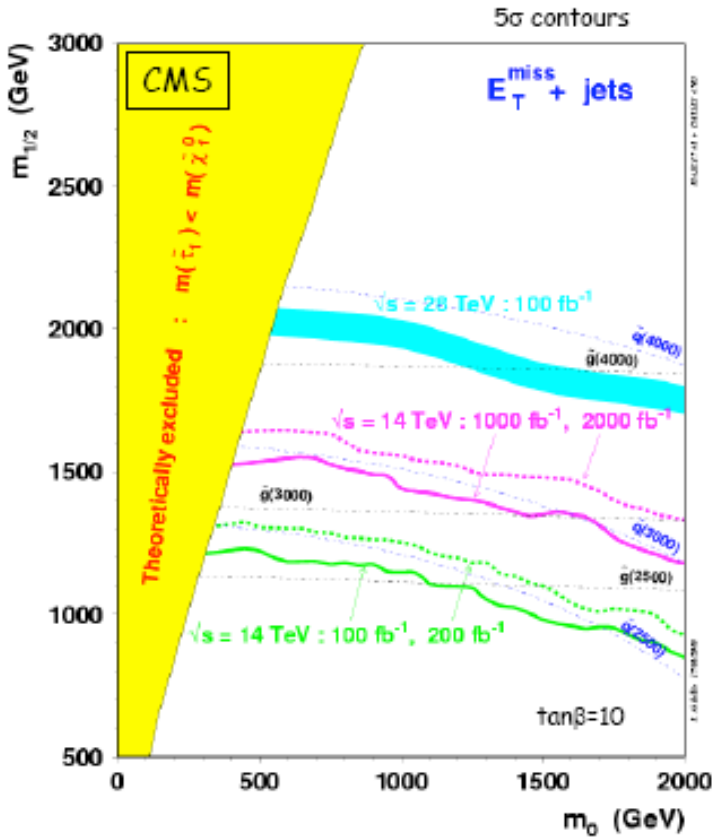


SLHC could improve LHC precision by up to ~ 2

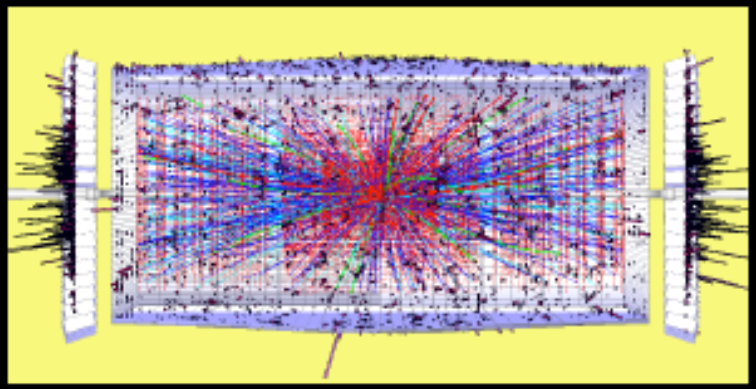
Supersymmetry

Impact of the SLHC
Extending the discovery region
by roughly 0.5 TeV i.e. from
~2.5 TeV → 3 TeV

This extension involved high
E_T jets/leptons and missing E_T
⇒ Not compromised by increased
pile-up at SLHC

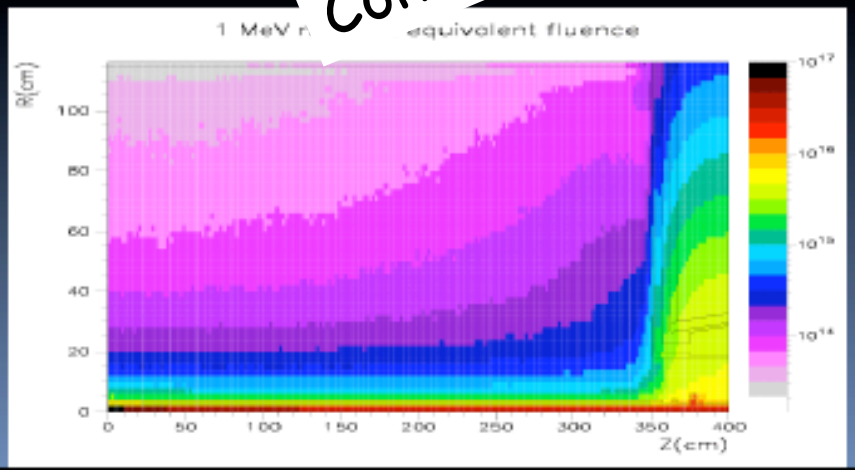


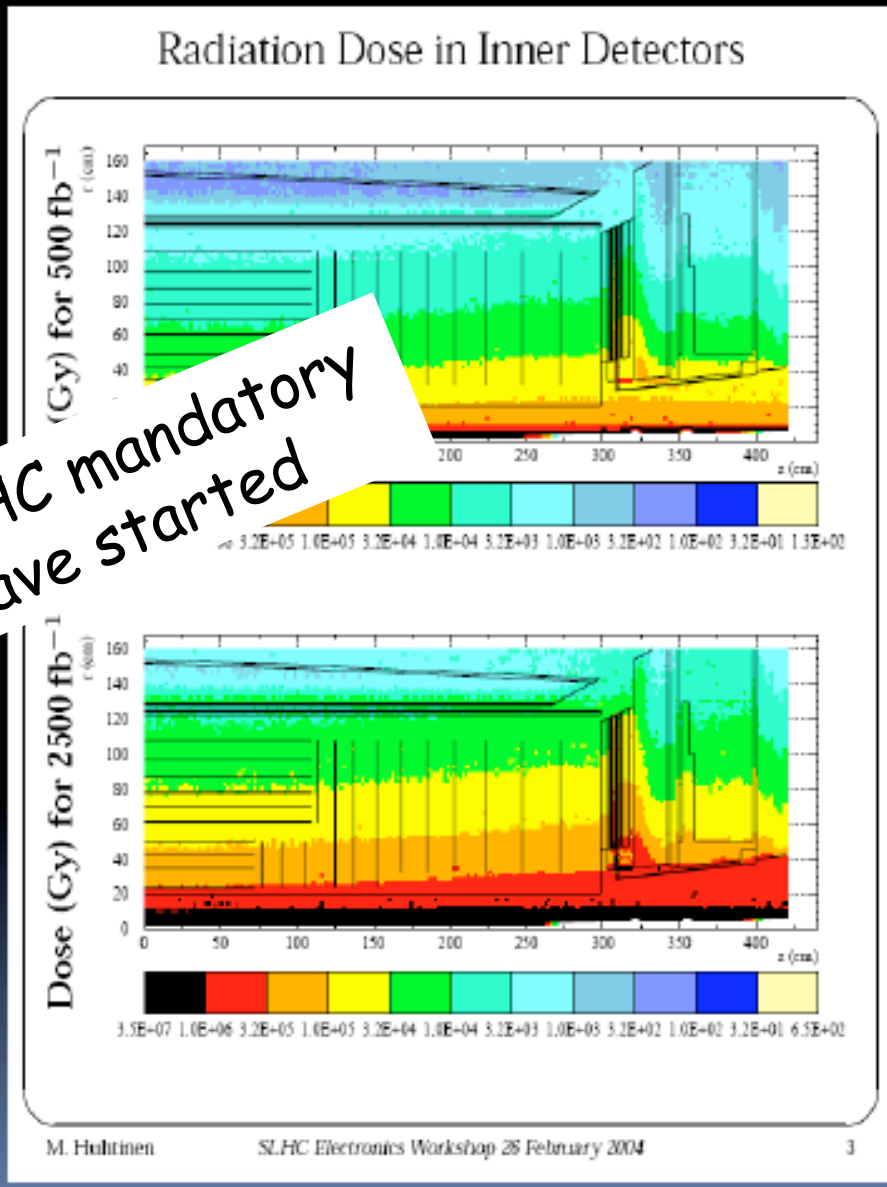
What are the conditions at SLHC?



- 300 – 400 pile-up events at start of spill (unless luminosity leveling)
- Want to survive at least 3000 fb^{-1} dat
- B-layer at 37 mm:
  - ~30 tracks per
  - >10^{16} 1
  - Few 10

Detector R&D for sLHC mandatory
Concerted efforts have started



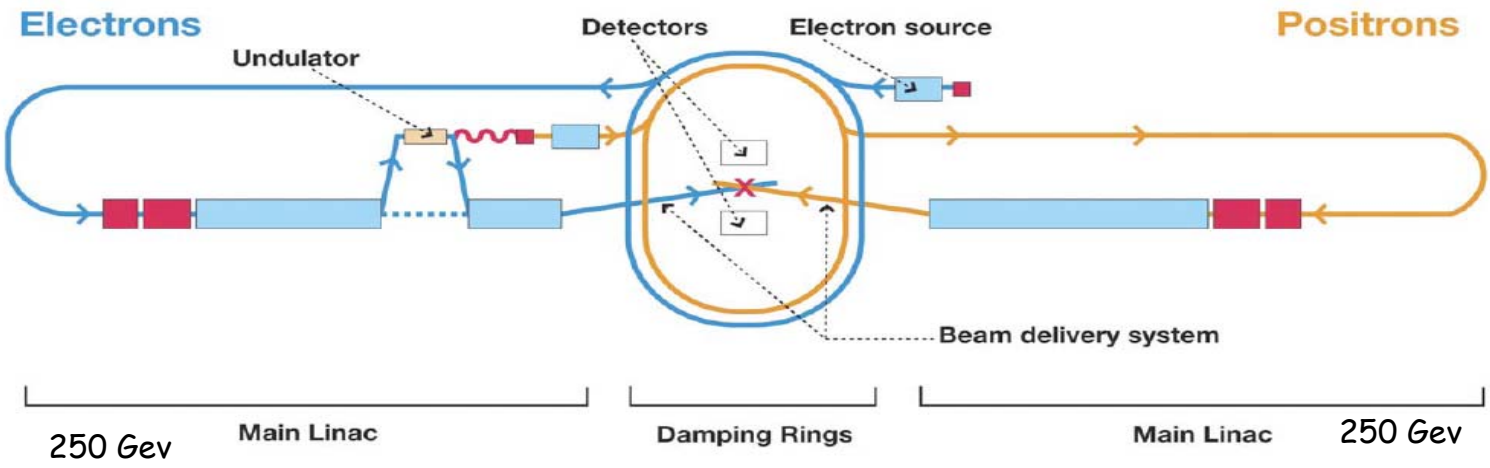


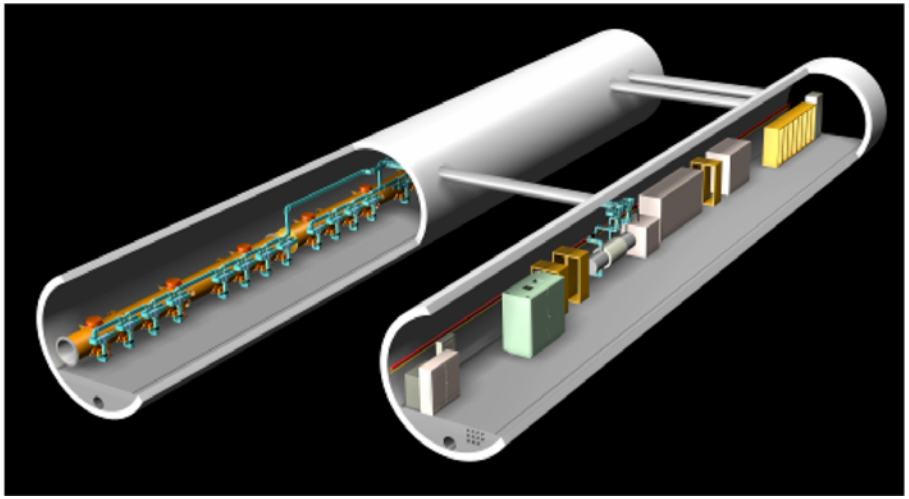
The European Strategy for particle physics

4. In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme; *a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.*

5. It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier; *there should be a strong well-coordinated European activity, including CERN, through the Global Design Effort, for its design and technical preparation towards the construction decision, to be ready for a new assessment by Council around 2010.*

ILC Baseline Design





e+ e- Linear Collider

Energy	250 Gev x 250 GeV
# of RF units	560
# of cryomodules	1680
# of 9-cell cavities	14560

2 Detectors push-pull

2 10^{34} peak luminosity

5 Hz rep rate, 1000 -> 6000 bunches

IP : s_x 350 – 620 nm; s_y 3.5 – 9.0 nm

Total power ~230 MW

Toward Industrialization

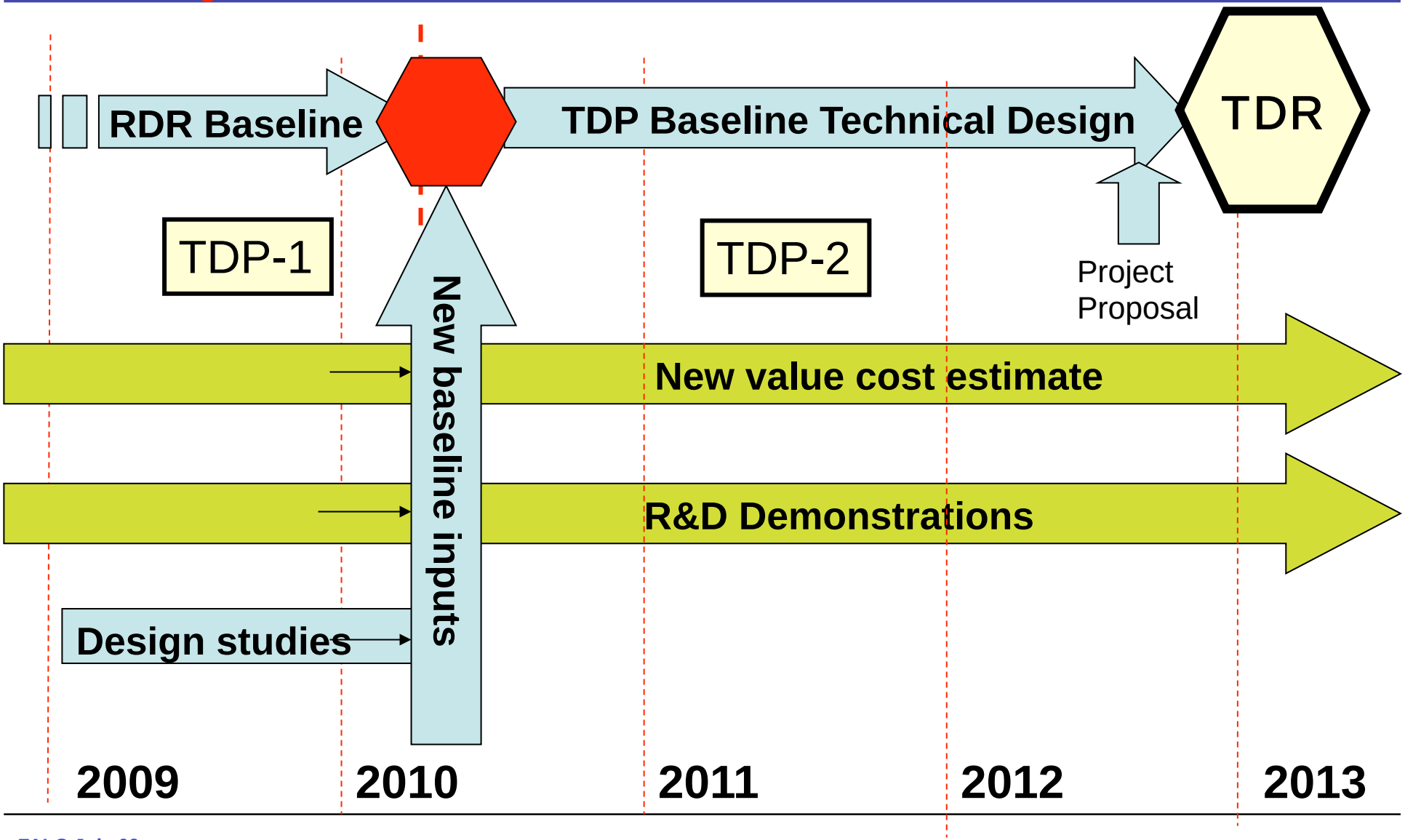
- **Global status of Industries**
  - Research Instruments and Zanon in Europe
  - AES, Niowave, PAVAC in Americas
  - MHI in Asia

Project Scope			
Euro XFEL	~800	2 years	~1 cavity / da
Project X	~400	3 years	~2 cavities/ week
ILC	~15,500	4 years	~20 cavities / day
(3 regions			~7 cavities / day)

Call for ender out

- **Industrial Capacity: status and scope**
  - No company currently has required ILC capacity
  - Understand what is needed (and cost) by 2012

GDE Timeline

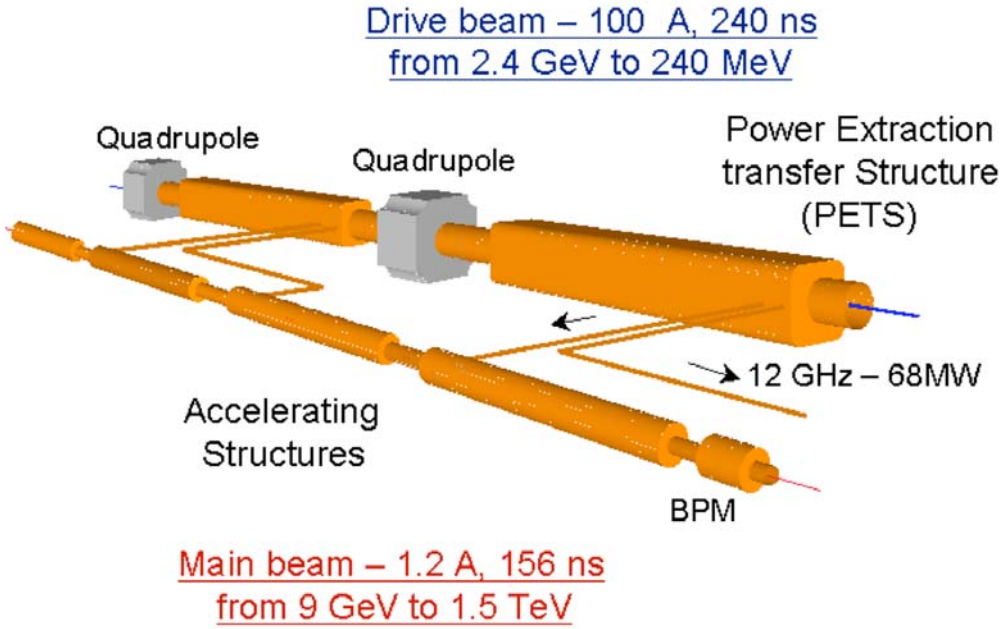


The CLIC Two Beam Scheme

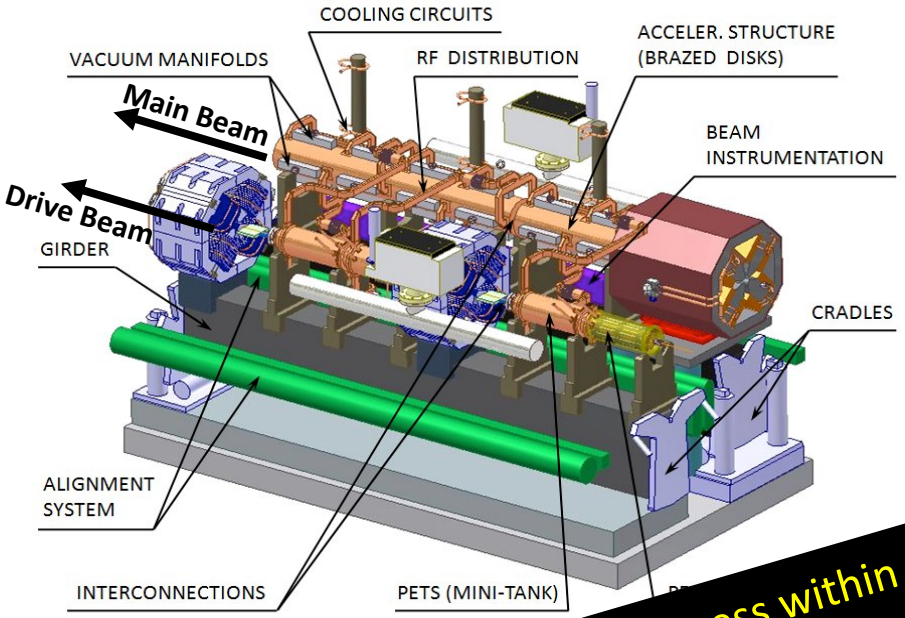
Two Beam Scheme:

Drive Beam supplies RF power

- 12 GHz bunch structure
- low energy (2.4 GeV - 240 MeV)
- high current (100A)

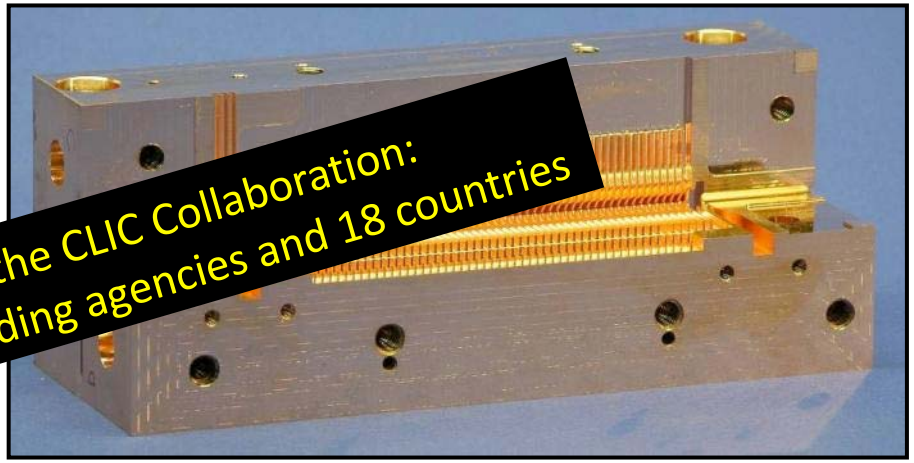


CLIC Accelerating Structures

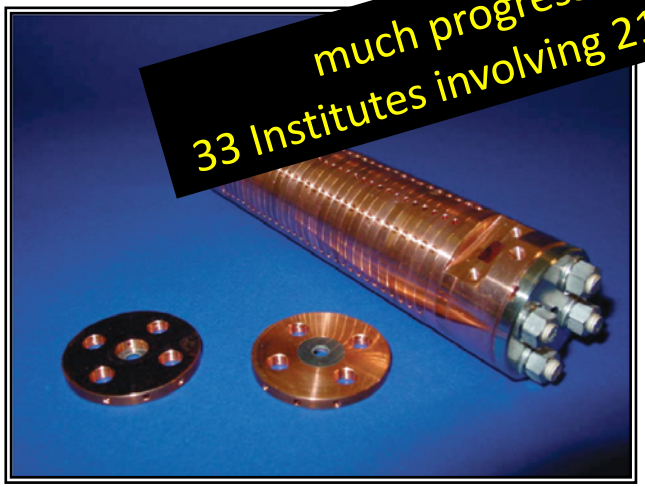


Objective:

- Withstand of 100 MV/m without damage
- breakdown rate < 10^{-7}
- Strong damping of HOMs



much progress within the CLIC Collaboration:
33 Institutes involving 21 funding agencies and 18 countries

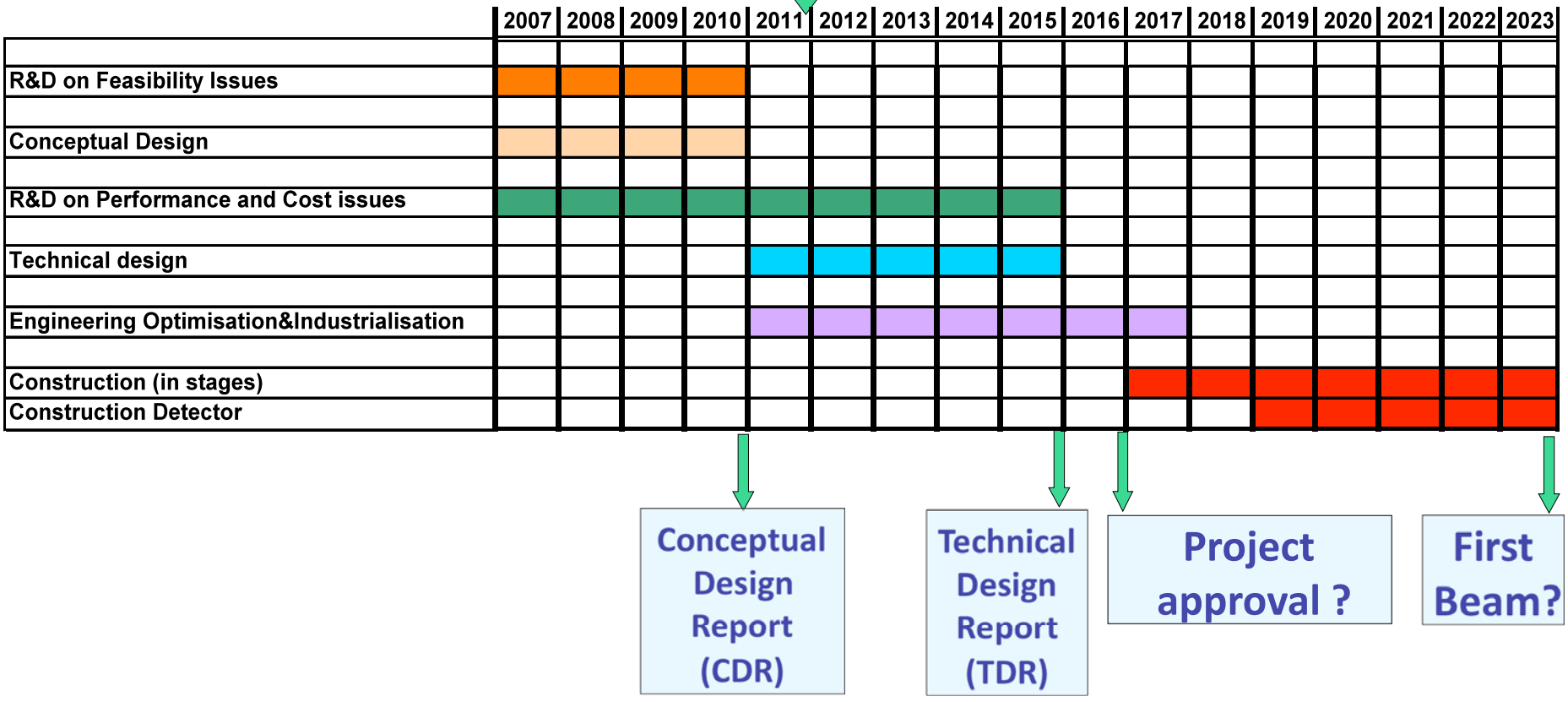


Technologies:

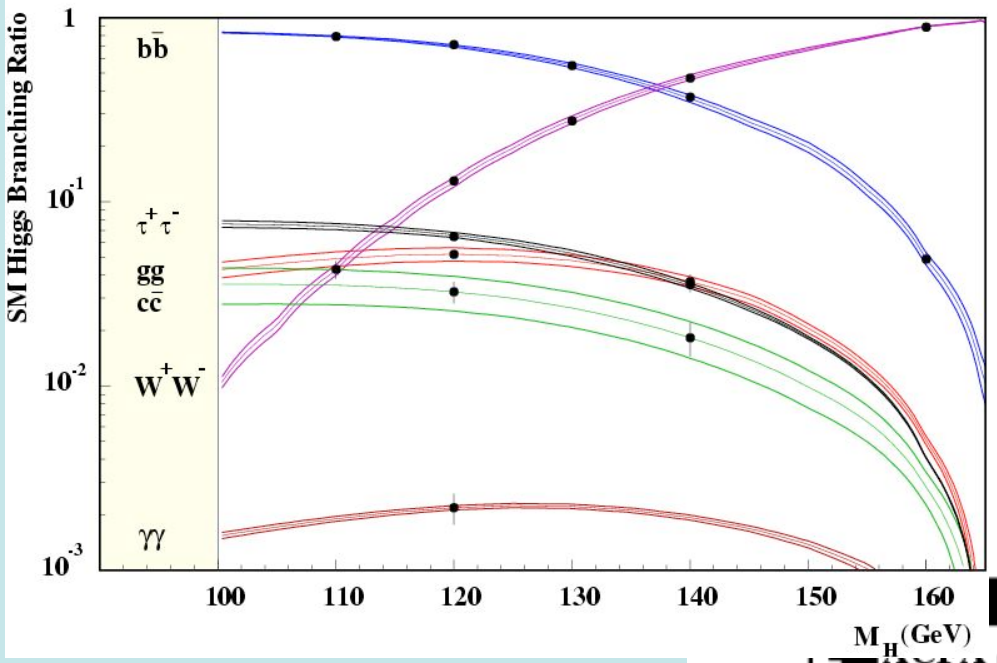
Brazed disks - milled quadrants

Tentative long-term CLIC scenario
Shortest, Success Oriented, Technically Limited Schedule

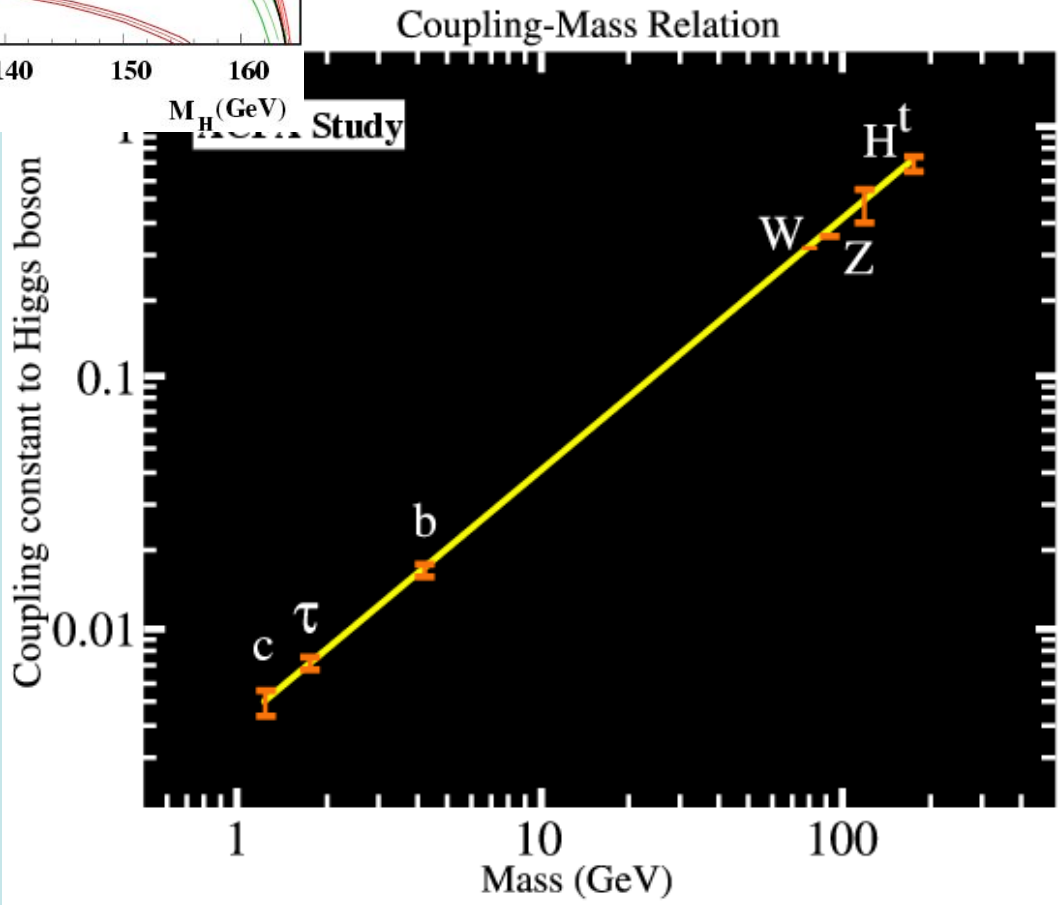
Technology evaluation and Physics assessment based on LHC results for a possible decision on Linear Collider with staged construction starting with the lowest energy required by Physics



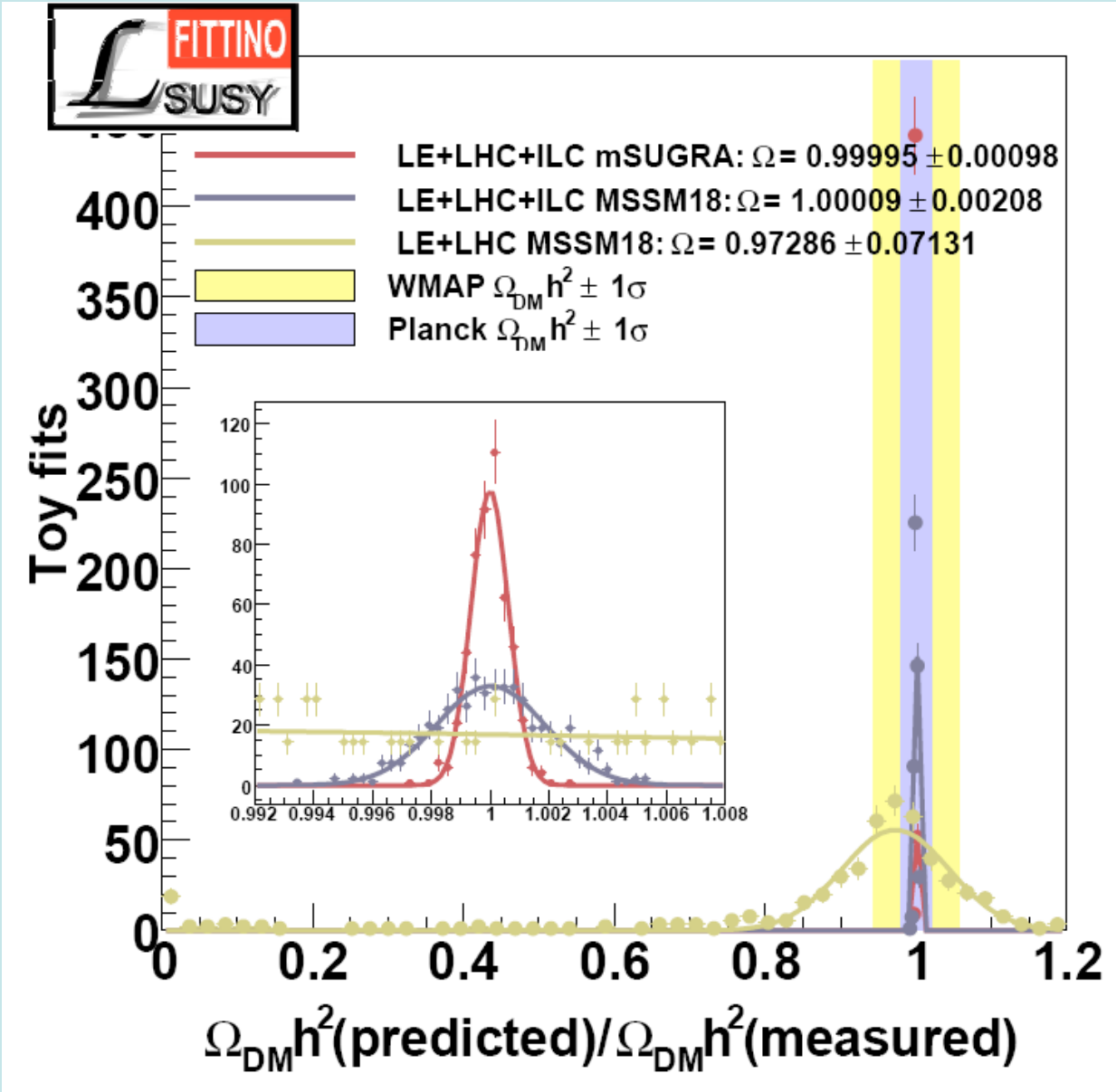
Precision Higgs physics LHC + LC

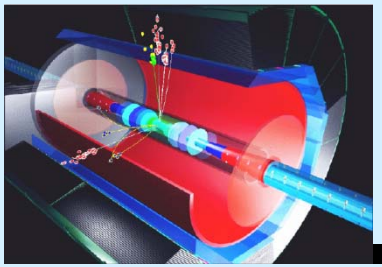


Determination of absolute coupling values with high precision



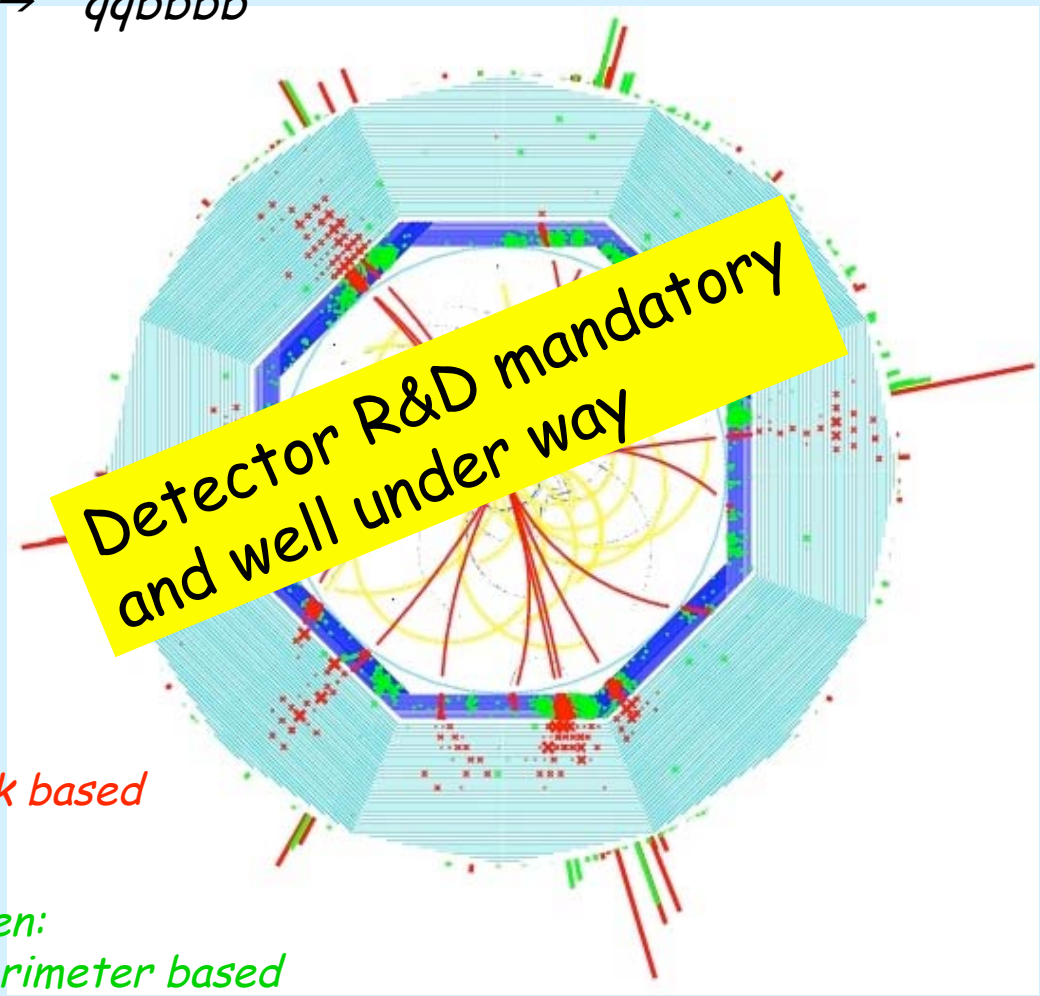
Dark Matter and SUSY





LC Detector challenges: calorimeter

ZHH → qqbbbb



Detector R&D mandatory and well under way

red: track based

green: calorimeter based

High precision measurements demand new approach to the reconstruction:

- particle flow (i.e. reconstruction of ALL individual particles)

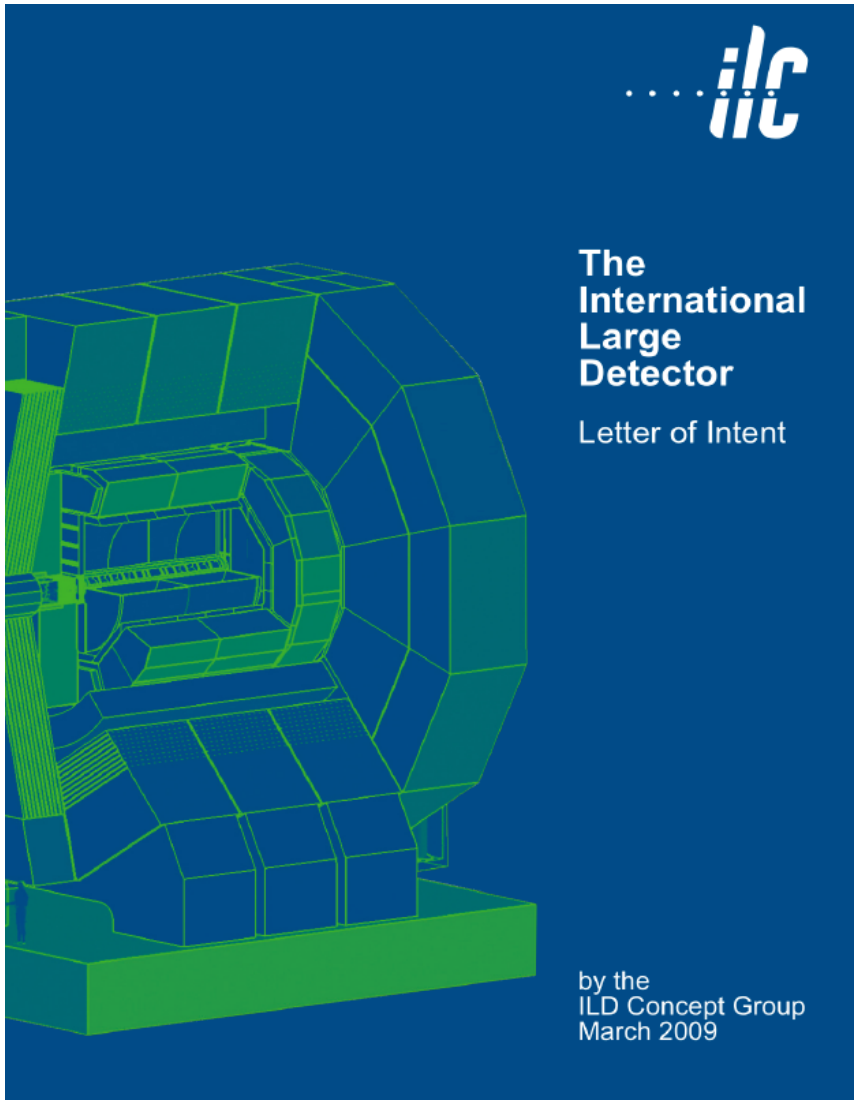
this requires

- unprecedented granularity

in three dimensions

R&D needed now for key components

An example of an LOI - The ILD group

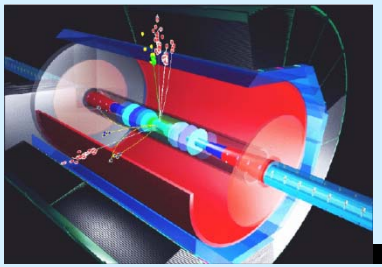


http://www.ilcild.org/documents/ild-letter-of-intent

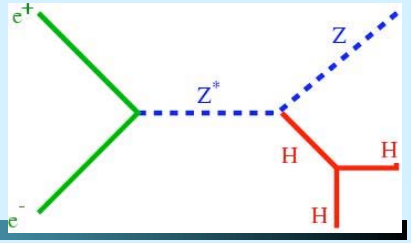
695 authors, 148 institutions

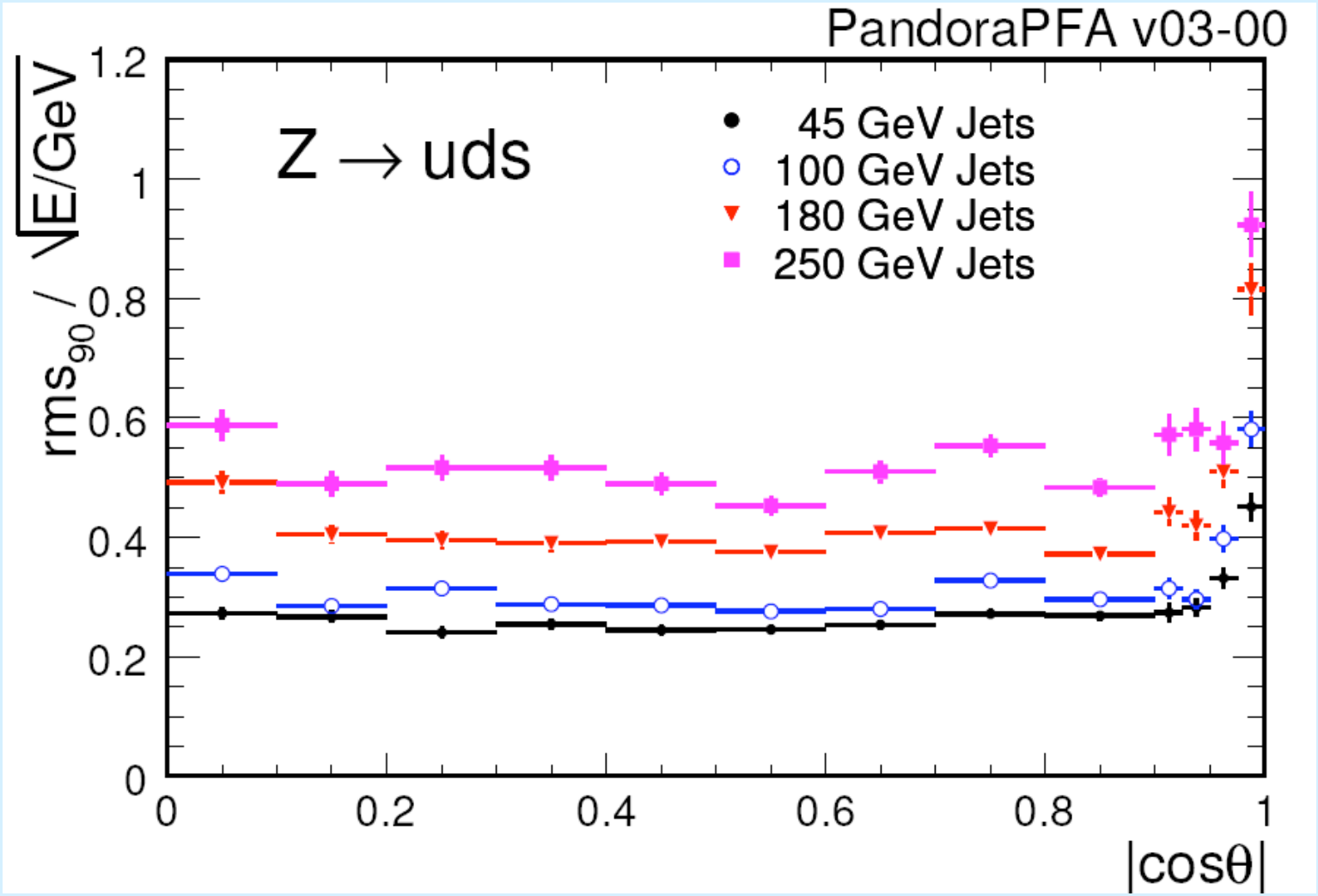
32 counties

Introduction
Detector Optimization
Physics performance
Sub-detector system
DAQ and computing
Detector integration and MDI
Costing
The group
R&D plan
Conclusion



Particle Flow





LC design goal

$\alpha = 30\%$

Linear Collider Collaboration

- Prompted by the observation that there is significant synergy between the ILC & CLIC programs (electrons, positrons, high brightness beams, collision regions, beam dynamics ….) and a desire to effectively use existing resources several common working groups were set up in 2008.
  - Conventional facilities
  - Cost & schedule
  - Beam dynamics
  - Machine-Detector Interface & Beam delivery system
  - Physics & Detectors
- A recent management meeting at CERN reviewed collaborative status and looked at possible areas for additional co-operation.

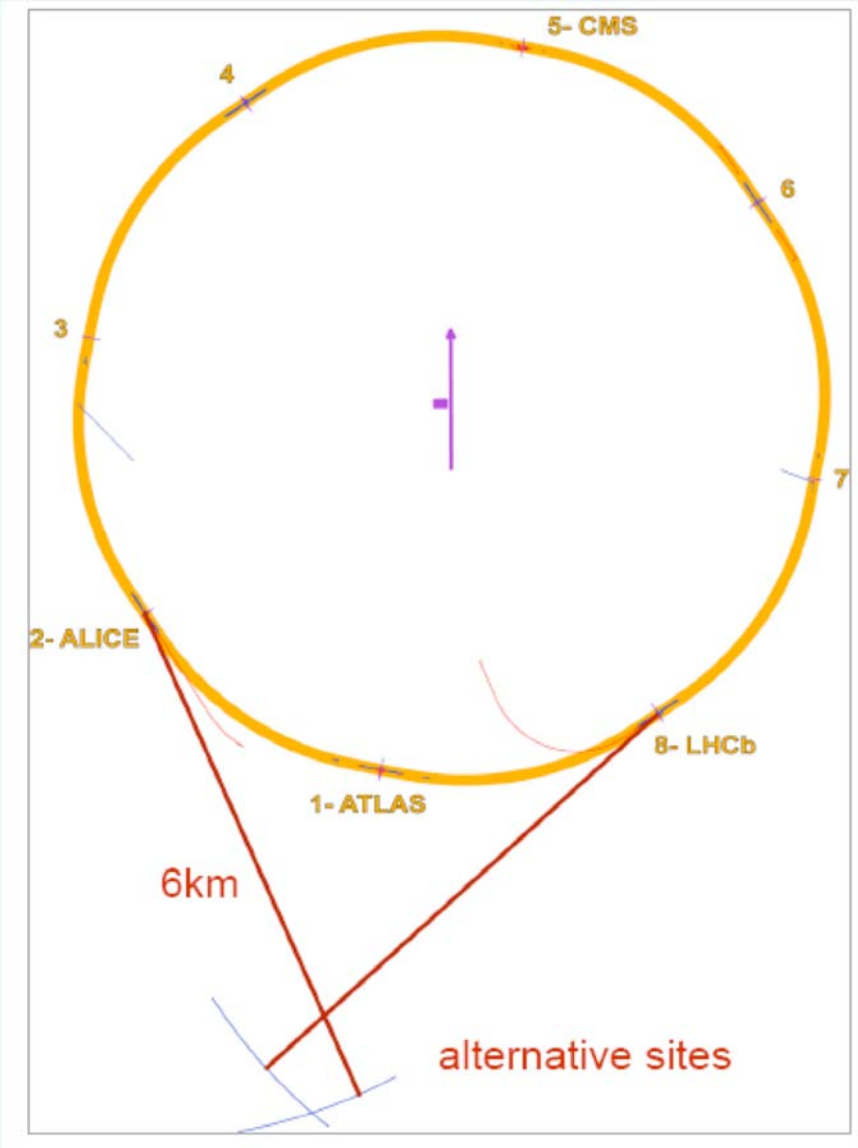
Linear Collider Collaboration

Conclusions from that meeting include:

- The existing working groups were deemed a success and we added two more (damping rings & positron production)
- Jean-Pierre Delahaye (CLIC Project Director) will join the GDE EC, and Brian Foster (European Regional Director) will join the CLIC steering committee.
- We will hold a joint annual meeting in 2010.

There were some discussion about the viability of creating a linear collider program strategy which would encompass both the ILC and CLIC programs. Such a strategy needs to be a win-win for both sides and also create something that is more than the sum of the parts. A joint statement is under consideration.

Large Hadron electron Collider: possible layouts



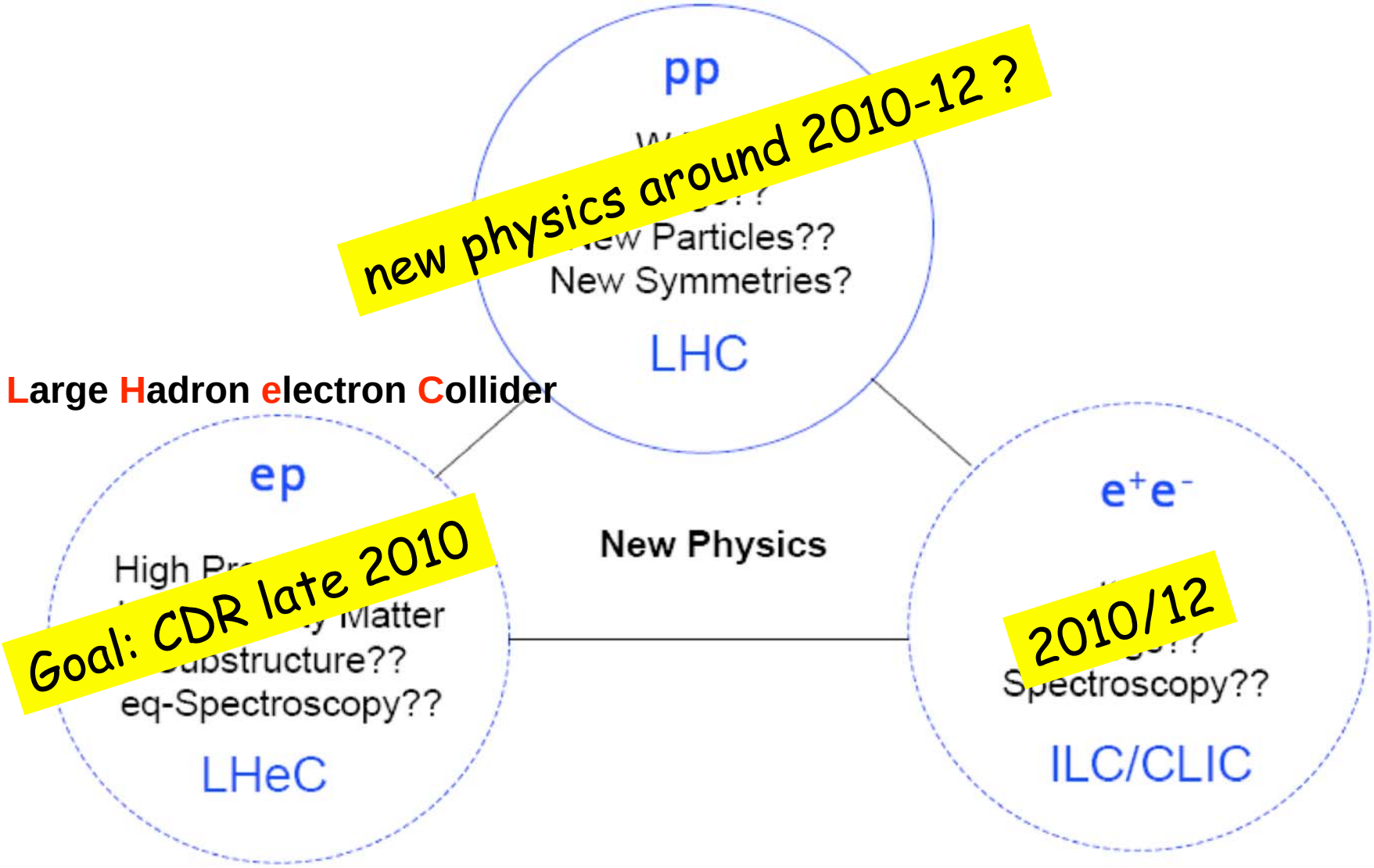
40 - 140 GeV
on
1 - 7 TeV

ring-ring solution:
$L \leq 10^{33}$

linac-ring solution:
L few 10^{31}

Would be the successor of HERA at higher cms

The TeV Scale [2008-2033..]



new physics around 2010-12 ?

Large Hadron electron Collider

Goal: CDR late 2010

2010/12

Key Messages

- Need to clear the cloud of TeV-scale physics to obtain clear views
- Synergy of colliders
- sLHC dual purpose

  luminosity increase and 'juvenation' of accelerator complex
- ILC could be constructed now
- CLIC more R&D needed
- Converge towards one LC project
- Detector R&D mandatory for all projects
- LHC results decisive

Great opportunities ahead at the TeV scale

Window of opportunity for decision on the way forward around 2012 (?)