R.-D. Heuer, CERN

Vancouver, June 4, 2012

Past few decades

"Discovery" of Standard Model

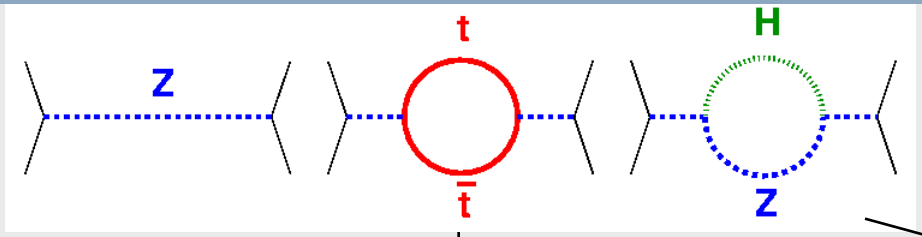
At the energy frontier through synergy of

hadron - hadron colliders (e.g. Tevatron)

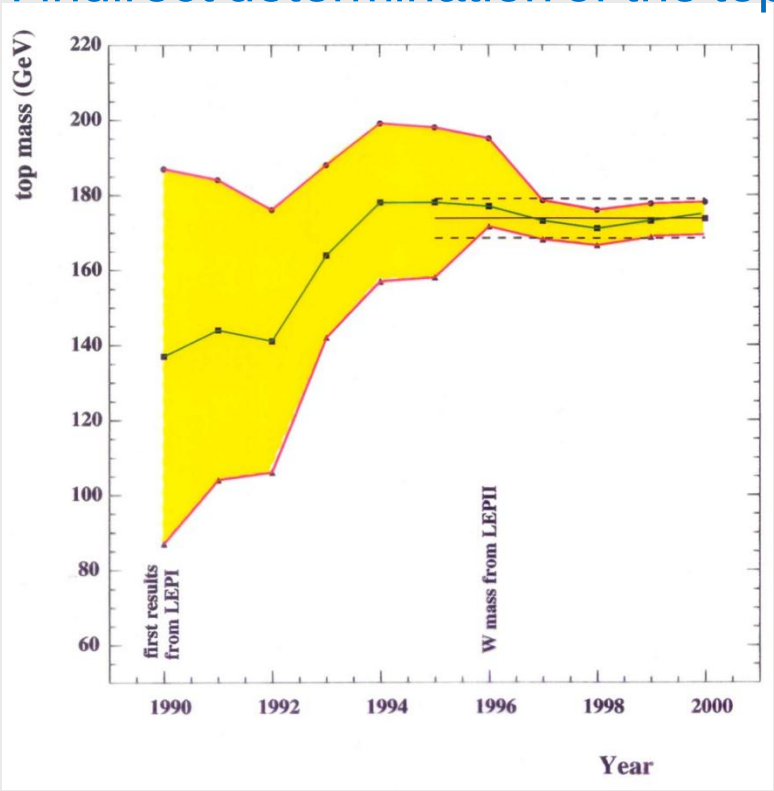
lepton - hadron colliders (HERA)

lepton - lepton colliders (e.g. LEP, SLC)

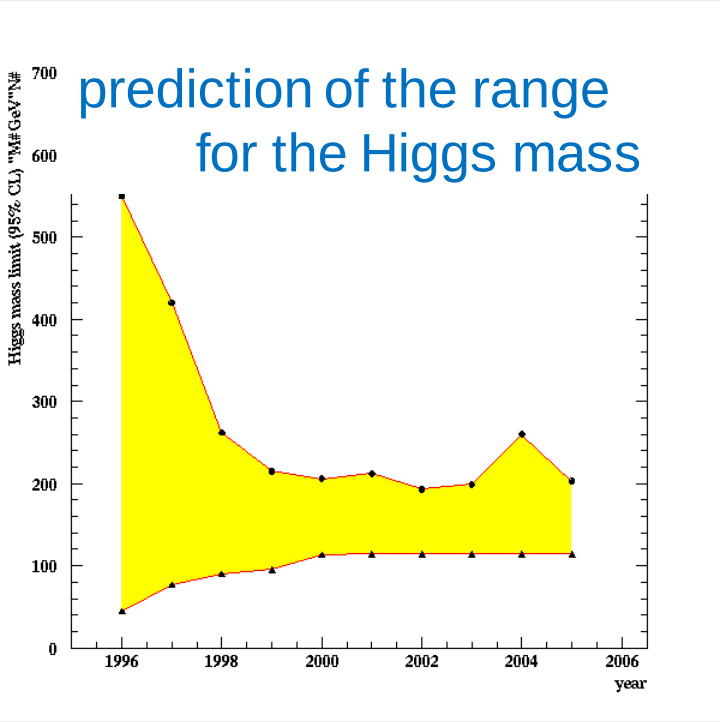
Test of the SM at the Level of Quantum Fluctuations



LEP: indirect determination of the top mass



prediction of the range for the Higgs mass



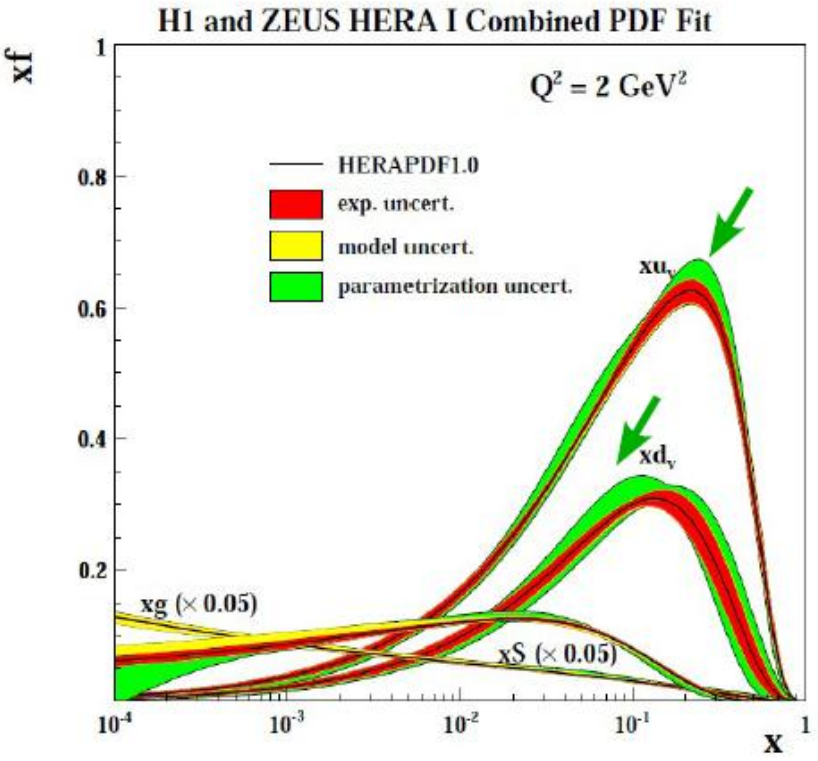
possible due to
- precision measurements
- known higher order electroweak corrections

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

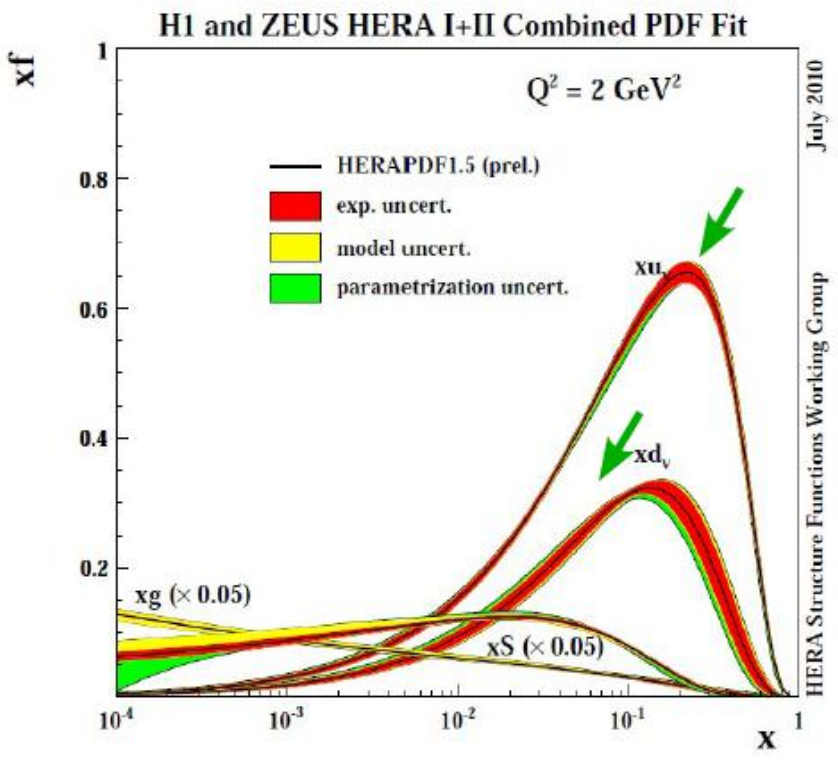
HERA: Impact on PDF

Fits to new combined HERA data: HERAPDF1.5

HERAPDF1.0



HERAPDF1.5



Completion of an era: Tevatron

Accelerator Innovations

- First major SC synchrotron
- Industrial production of SC cable (MRI)
- Electron cooling
- New RF manipulation techniques

Detector innovations

- Silicon vertex detectors in hadron environment
- LAr-U238 hadron calorimetry
- Advanced triggering

Analysis Innovations

- Data mining from Petabytes of data
- Use of neural networks, boosted decision trees
- Major impact on LHC planning and developing
- GRID pioneers

Major discoveries

- Top quark
- B_s mixing
- Precision W and Top mass → Higgs mass prediction
- Direct Higgs searches
- Ruled out many exotica

The next generation

- Fantastic training ground for next generation
- More than 500 Ph.D.s
- Produced critical personnel for the next steps, especially LHC

Key Questions of Particle Physics

origin of mass/matter or
origin of electroweak symmetry breaking

unification of forces

fundamental symmetry of forces a
matter

where is antima

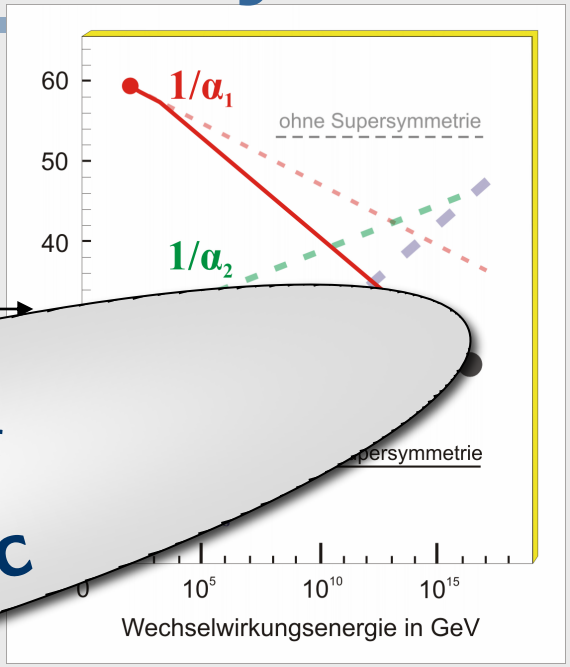
unificatio
genera

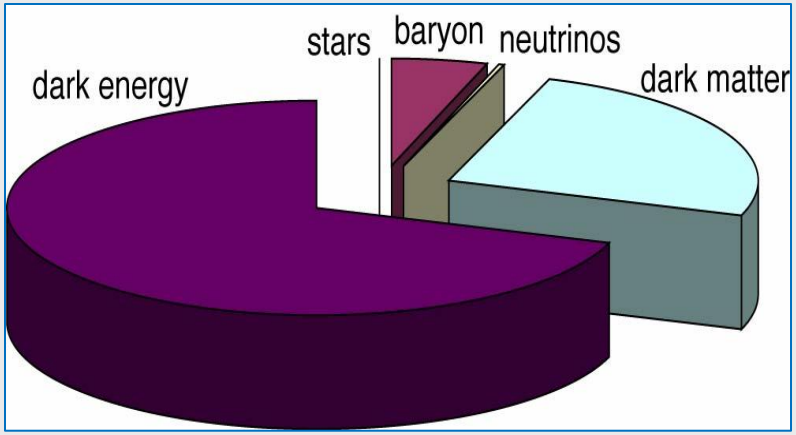
number of space/time dimensions

what is dark matter

what is dark energy

For most questions:
new particles should appear
at **TeV** scale or below
→ **territory of the LHC**





‘Today’

Exciting Times

At the energy frontier, the LHC brings us into unexplored territory:

Excellent progress

Accelerator – Experiments – Grid Comp.

Key message

LHC and the Standard Model

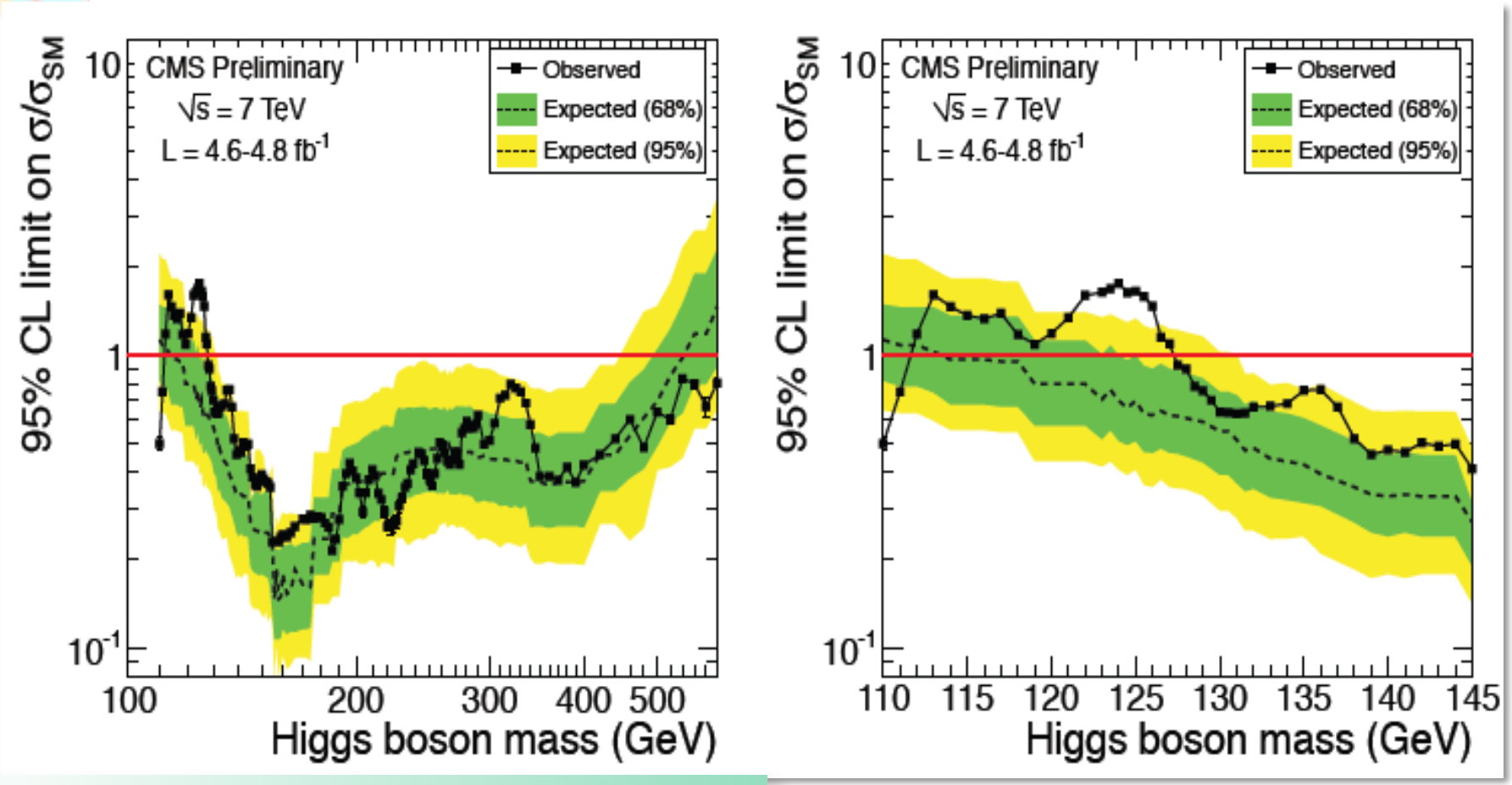
Finding the Higgs: **Discovery**

Excluding the SM-Higgs: **Discovery**

Reminder:

LHC is poised to clarify the mechanism by which elementary particles acquire mass

New Combination

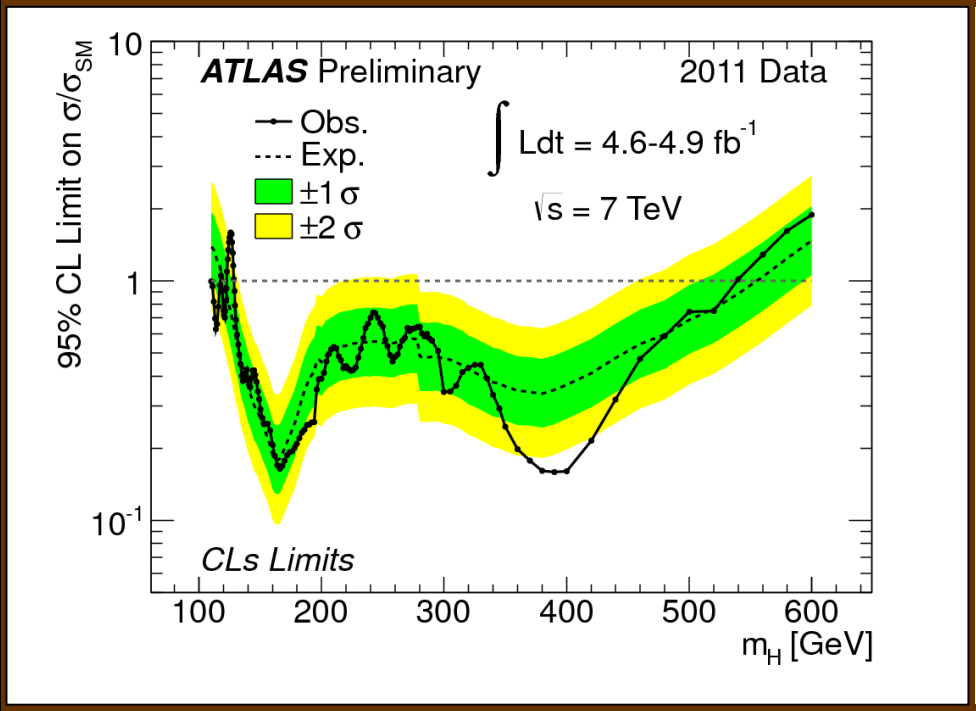


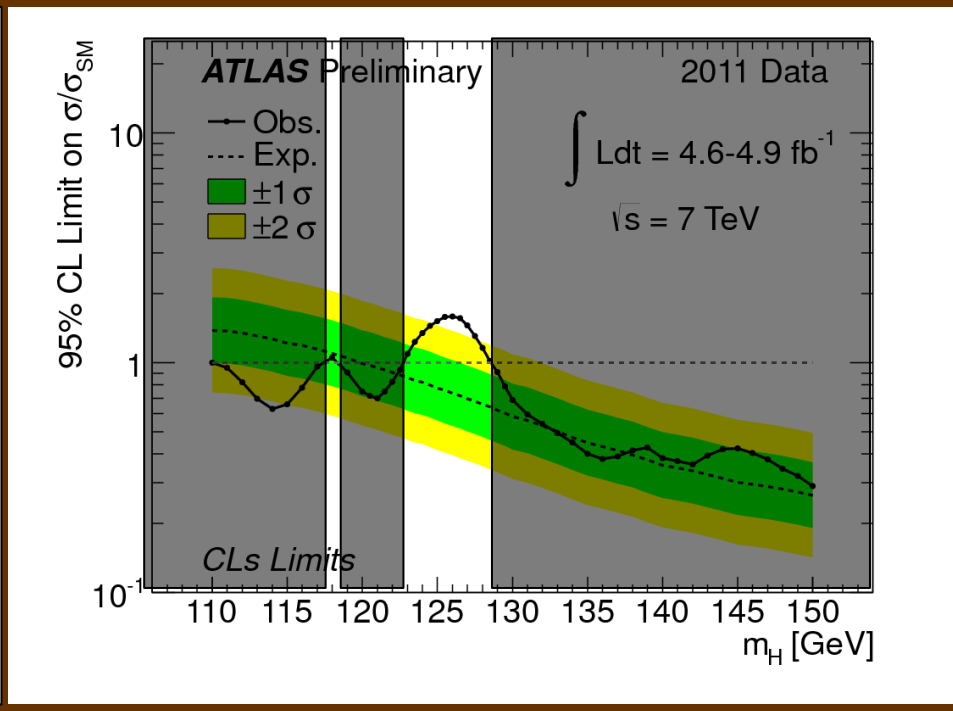
It took ~30 years to experimentally restrict the SM Higgs mass to be above 114 GeV CMS and ATLAS independently eliminated another ~475 GeV of the range in 2011

Expected exclusion 114.5 - 543 GeV
Observed exclusion 127.5 - 600 GeV

T

ATLAS: Combining all (12 !) channels together, full 2011 dataset





Excluded at 95% CL

110 < m_H < 122.5 GeV (except 117.5-118.5)
129 < m_H < 539 GeV

Expected if no signal

120-555 GeV

Excluded at 99% CL

130 <m_H< 486 GeV

Tevatron also sees enhancement in this mass region in the decay mode H→bb

NEW: full 2011 dataset

Higgs-Boson at 7 TeV

Status ~ today

SM Higgs boson excluded with 95% cl
up to a mass of 600 GeV
except for the window **122.5 to 127.5** GeV

“interesting fluctuations” around masses
of **124 to 126** GeV

Higgs-Boson at 7 and 8 TeV

Status ~ today

SM H… …% cl
up to …
excep… …**7.5** GeV

"intere… …asses
of **124 to 126** GeV

2012 run:
8 TeV, expect ~15/fb

SM-Higgs Boson up to a mass of some 600 GeV will either be discovered or ruled out until end 2012

What about Physics

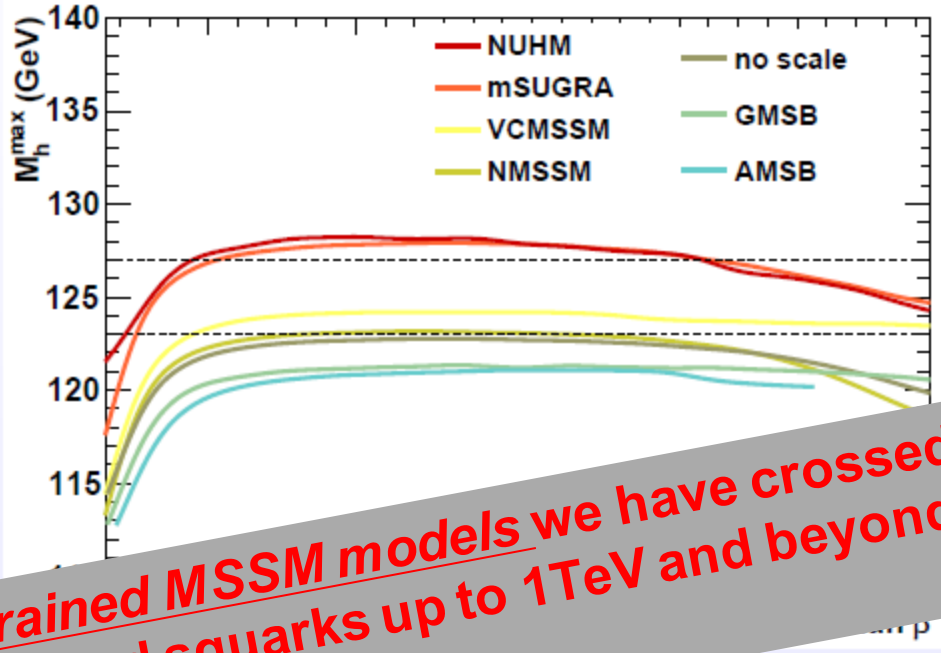
beyond the Standard Model ?

Supersymmetry

Is SUSY in trouble ?

So far no excess in missing energy events,…,
go beyond CMSSM, consider pMSSM

SUSY requires a low mass Higgs Boson with severe constraints on the max. mass value



Mahmoudi

Within *the constrained MSSM models* we have crossed the border of excluding gluinos and squarks up to 1TeV and beyond. The air is getting thin for *constrained SUSY*. .....

A. Djouadi, F.M., J. Quevillon, Phys.Lett. B708 (2012) 162

	121.0	121.5	128.0	123.0	123.5	124.5	128.5

End

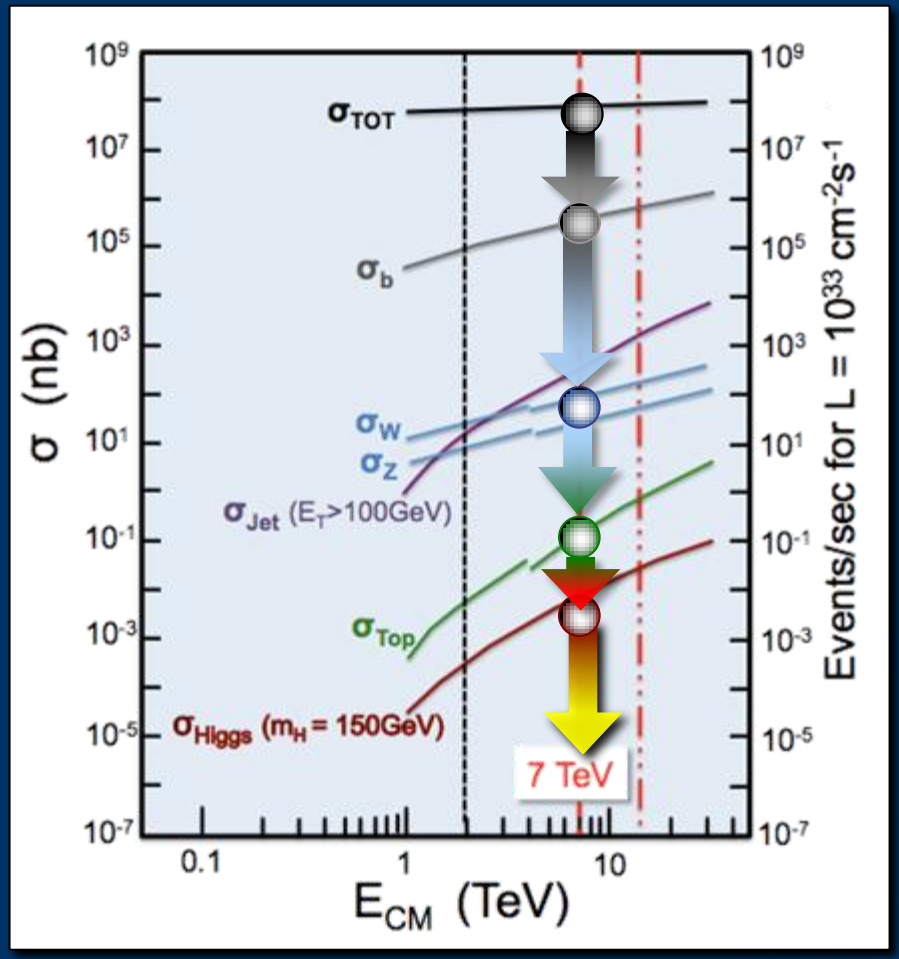
Higgs mass of

. . . but potential for discovery of SUSY sizeable at all LHC energies

Murayama, ICFA Seminar, 2011 CERN

LHC and Theory…

The 2011 and 2012 run …



Search for physics beyond SM

- Discovering new particles
- Making precise measurements of properties of known particles/forces: e.g. $B_s \rightarrow \mu^+\mu^-$

….in 2012 already over 4/fb delivered

→ will enter new territory !

The predictable future: LHC Time-line

2009 — Start of LHC

Run 1: 7 and 8 TeV centre of mass energy, luminosity ramping up to few 10^{33} cm^{-2} s^{-1}, few fb^{-1} delivered

2013/14 — LHC shut-down to prepare machine for design energy and nominal luminosity

Run 2: Ramp up luminosity to nominal (10[illegible] 00 fb^{-1}

2017/**18** — Injector and LHC Phase-I upgrad[illegible]

Run 3: Ramp up l[illegible] fb^{-1} / year accumul[illegible]

~2021/**22** — Phase-I[illegible] ng magnets and CRAB ca[illegible] with levelling

Run 4: Co[illegible] > 3000 fb^{-1}

2030

Study of the properties of the Higgs Boson
or
Other ew symmetry breaking mechanism
and
Physics beyond the Standard Model

Key message

There is a program at the energy frontier with the LHC for at least 20 years:

7 and 8 TeV
14 TeV design luminosity
14 TeV high luminosity (HL-LHC)


beyond LHC ?

Next decades

Road beyond Standard Model

At the energy frontier through synergy of

hadron - hadron (LHC, HE-LHC?)

lepton - hadron colliders (LHeC ??)

lepton - lepton colliders (LC (ILC or CLIC) ?)

LHC results will guide the way at the energy frontier

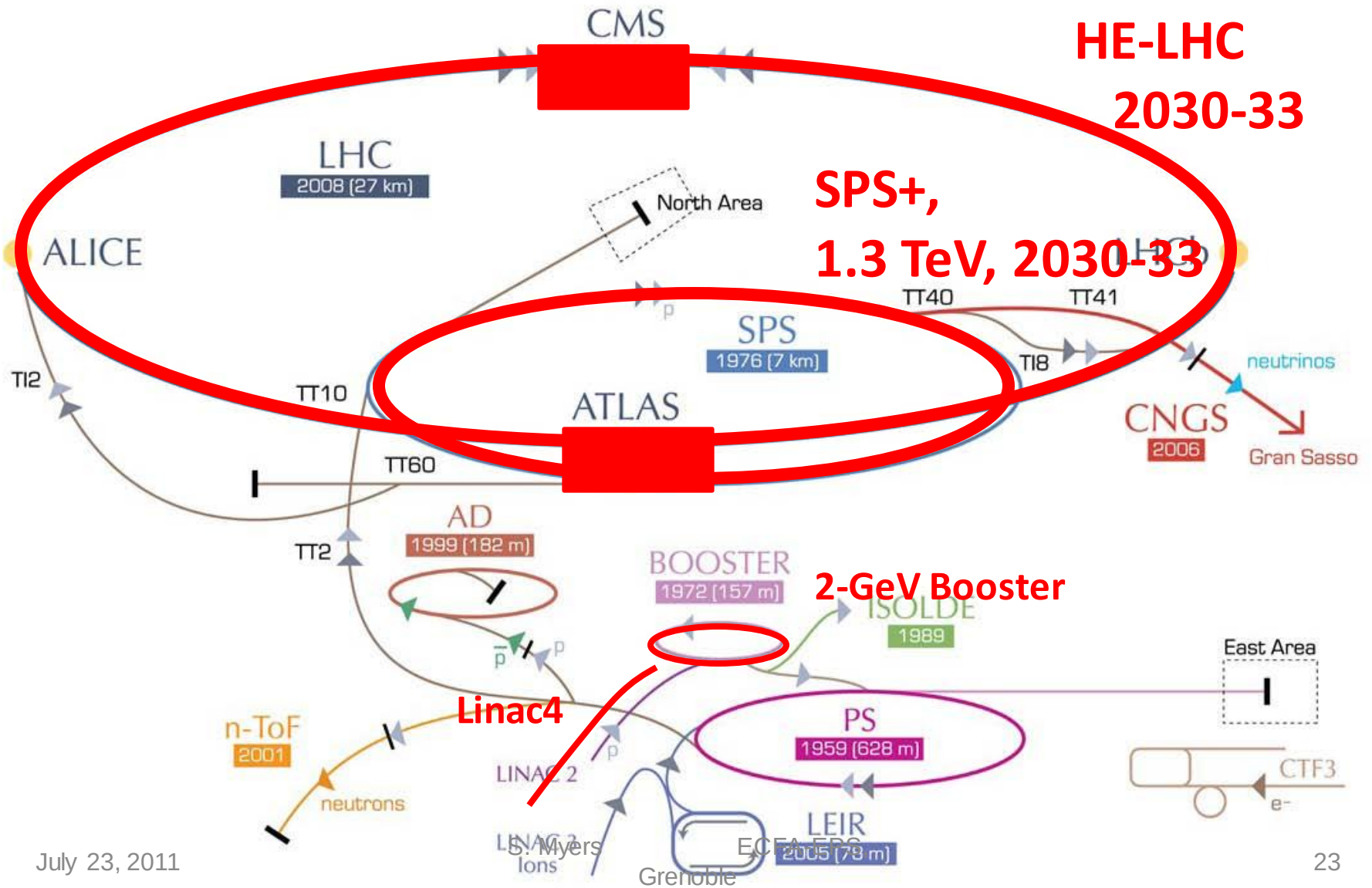
High Energy Hadron – Hadron Collider

HE - LHC

Study of New Physics Phenomena

main challenge: High-Field Magnets

HE-LHC – LHC modifications

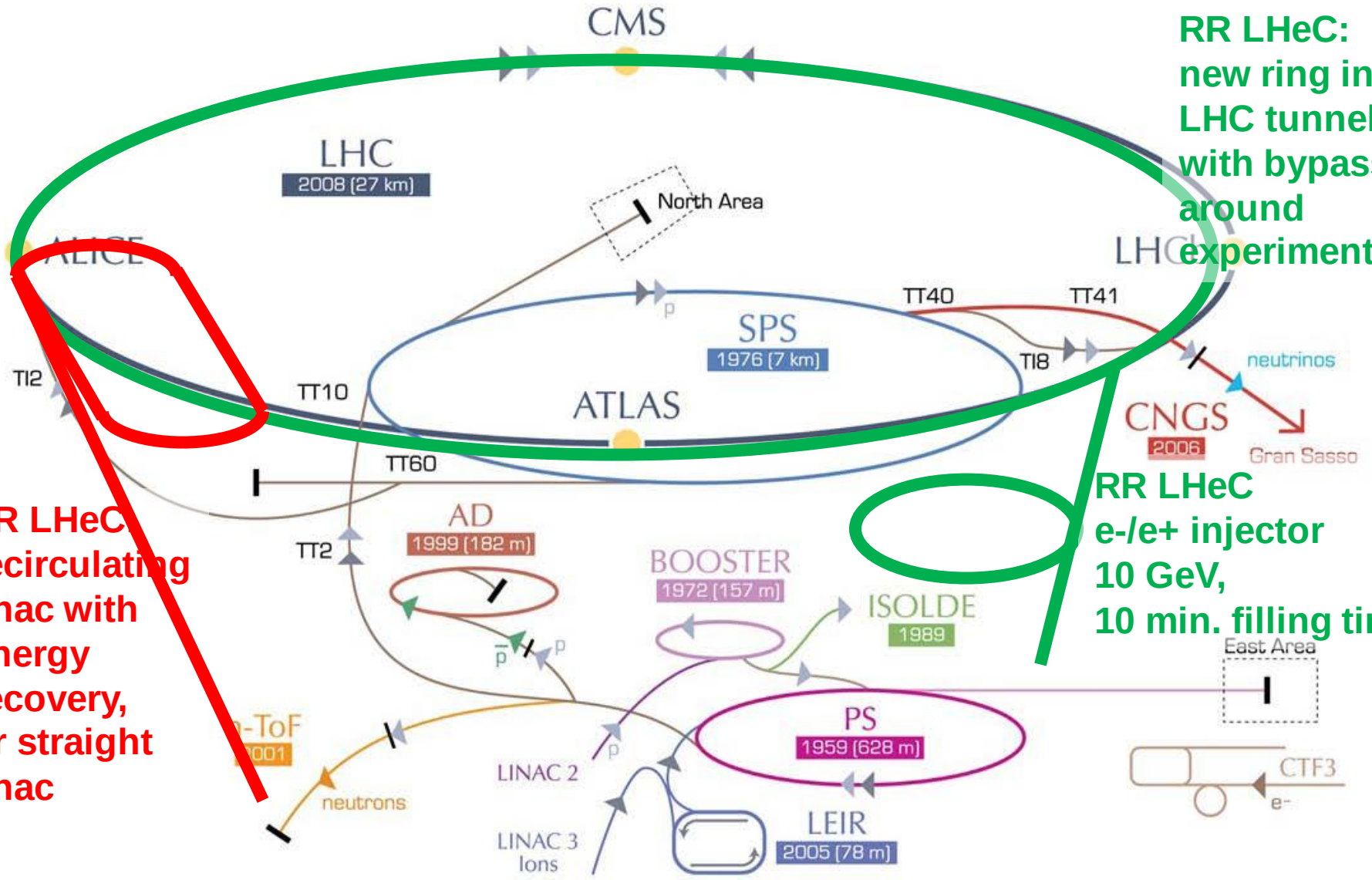


Lepton – Hadron Collider

LHeC

QCD, Leptoquarks?

LHeC options: RR and LR



RR LHeC: new ring in LHC tunnel, with bypasses around experiments

RR LHeC e-/e+ injector 10 GeV, 10 min. filling time

LR LHeC: recirculating linac with energy recovery, or straight linac

Frank Zimmermann, UPHUK4 Bodrum 2010

Lepton – Lepton Colliders

Linear Colliders: ILC / CLIC

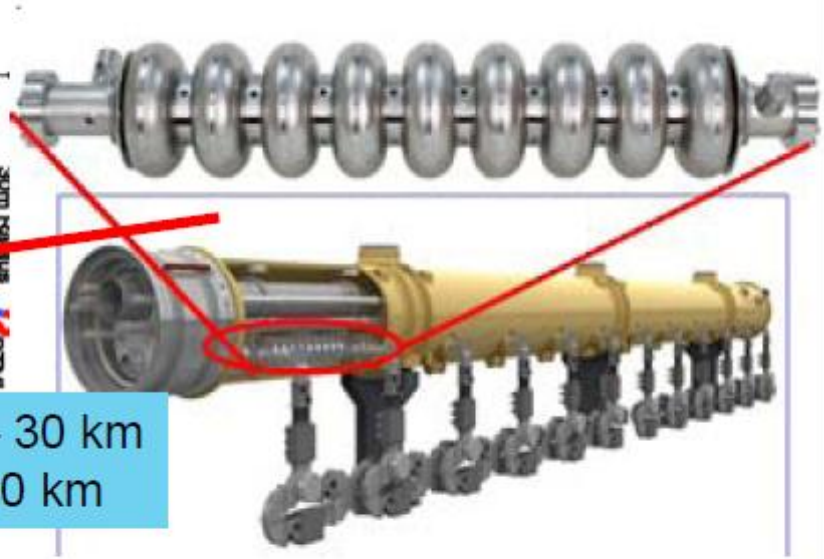
Both projects are global endeavours

Wide range of Physics Topics, e.g.

- Higgs (self) couplings
- Z, W, Top studies
- new physics phenomena

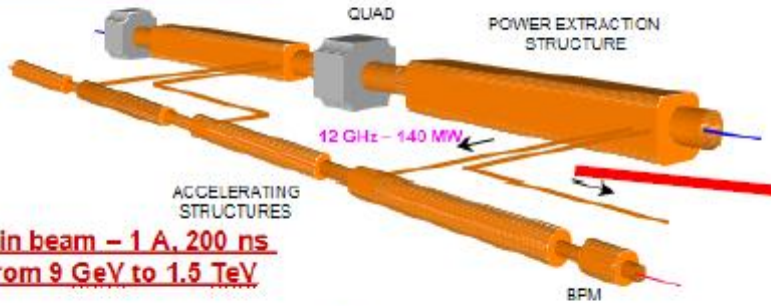
Linear Collider layouts

http://www.linearcollider.org/cms http://clic-study.web.cern.ch/CLIC-Study/

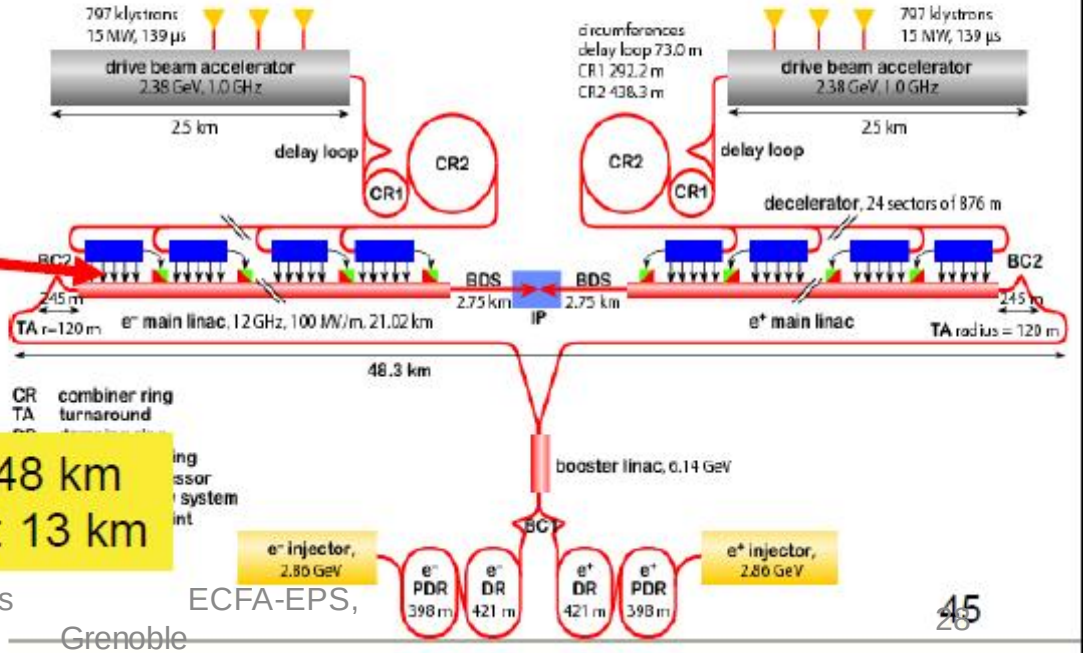


ILC 0.5 TeV – 30 km
ILC 1 TeV – 50 km

Drive beam - 95 A, 300 ns
from 2.4 GeV to 240 MeV



Main beam – 1 A, 200 ns
from 9 GeV to 1.5 TeV



CLIC 3 TeV: 48 km
CLIC 0.5 TeV: 13 km

Key message

High Priority Items for Linear Collider Projects

ILC and CLIC projects → LC project

Construction Cost

Power Consumption

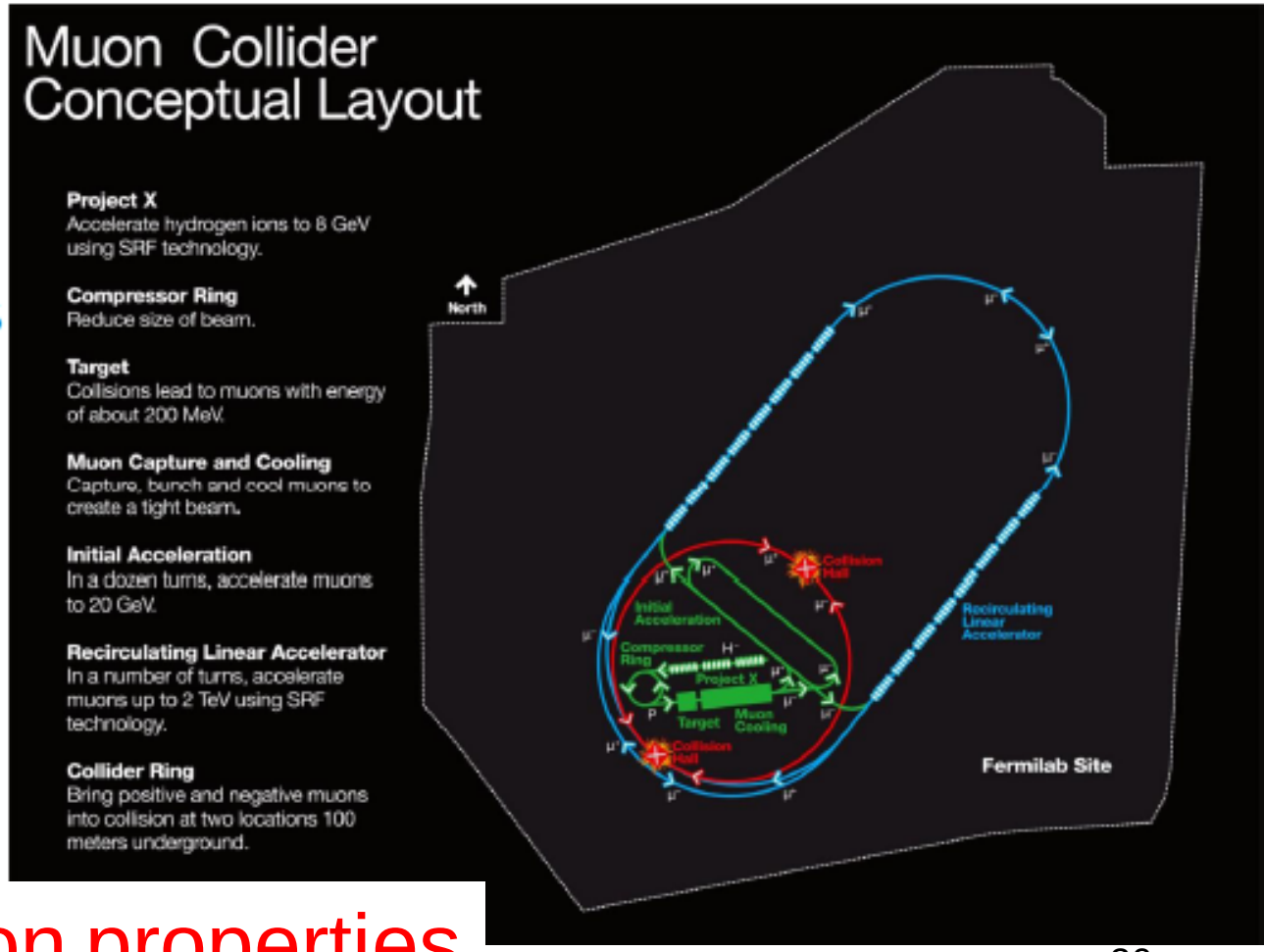
Value Engineering

Muon Collider

- Compact facility accelerating muons with recirculating linacs

Major Challenges

1. Muon generation
2. Cooling of muons
3. Cost-efficient acceleration
4. Collider ring and backgrounds from decays



- Higgs Boson properties

Key message

All projects need continuing accelerator and detector R&D;

All projects need continuing attention concerning a convincing physics case;
close collaboration exp-theo mandatory

so that the right decision can be made when the time comes to identify the next energy frontier accelerator (collider).
Today, we need to keep our choices open.

Choices ?

- Rich variety of projects under study
  at the energy frontier
  and the intensity frontier
- Global – Regional – National Projects

→ Need to present and discuss all these projects in an international context before making choices

→ Need to present physics case(s) always taking into account latest results at existing facilities

→ Need to present (additional) benefits to society from the very beginning of the project

from Choices ? *to* Choice !

- Update of the European Strategy for Particle Physics in 2012/13
  - Several Meetings with international participation
    → bottom-up process: community input requested
    1st open meeting September 2012, Cracow
  - Finalization: May/June 2013

- Started with the ICFA Seminar 3-6 October 2011 at CERN

  Use as 1st step to harmonize globally Particle Physics Strategy

CERN today….into the future

- CLIC conceptual design report by 2012
- Participation in all LC activiti
- LHeC conceptual ign report early 2012
- R&D high-field magnets (towards HE-LHC)
- Generic R&D (high-power SPL, Plasma Acc)
- Participation in Neutrino-Projects studied

Position CERN as Laboratory at the energy frontier

CERN: opening the door...

- **Membership for Non-European countries**
- **New Associate Membership defined**
- **Romania, Israel, Serbia** in accession to membership
- Negotiations concerning membership ongoing with **Cyprus, Slovenia,** and **Turkey**
- Several countries expressed interest in Associate Membership
- **CERN participation in global projects independent of location**

Today

Exciting Times

…. and I wish you

an exciting conference