Guardando nella Sfera di Cristallo

IFAE 2018 – XVII edizione degli Incontri di Fisica delle Alte Energie

Milano, 4-6 Aprile 2018
Edificio U4, Aula 08
Piazza della Scienza 4

Frontiera Energia
Frontiera Intensità
Cosmologia e Astroparticelle
Nuove Tecnologie

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Sito web: http://ifae2018.mib.infn.it

Sergio Bertolucci
Università di Bologna e INFN

After LHC initial phase :

- We have consolidated the Standard Model (a wealth of measurements at 7-8 TeV, including the rare, and very sensitive to New Physics, $B_s \to \mu\mu$ decay)

- We have completed the Standard Model: discovery of the messenger of the BEH-field, the Higgs boson discovery

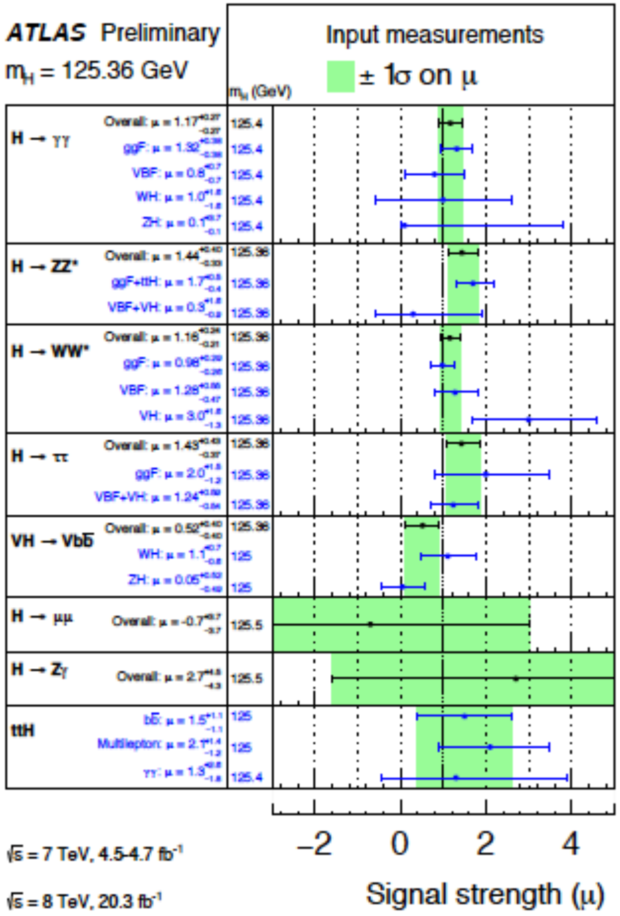
- **We have NO evidence of New Physics, although hints are coming (and going)**

Higgs production, rates, couplings

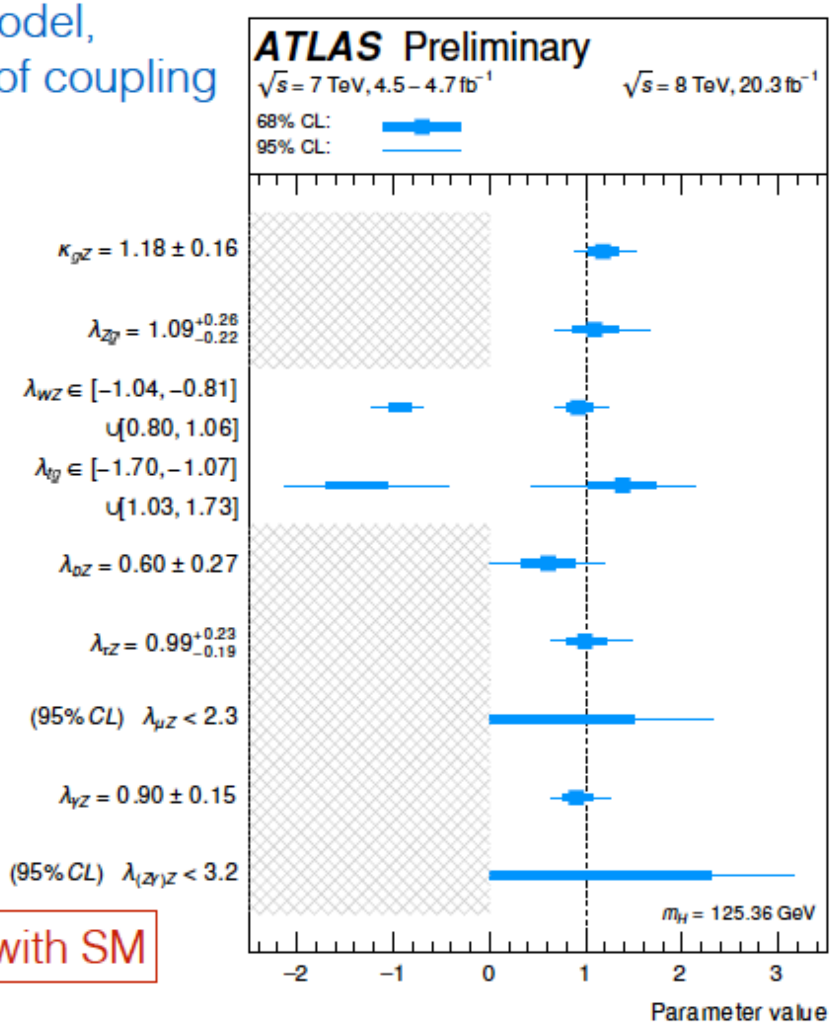
ATLAS-CONF-2015-007

Measurement of coupling strengths in a variety of models, with varying levels of model dependence (assumptions)

Combination of most channels



Most generic model, measure ratios of coupling strengths



→ consistency with SM

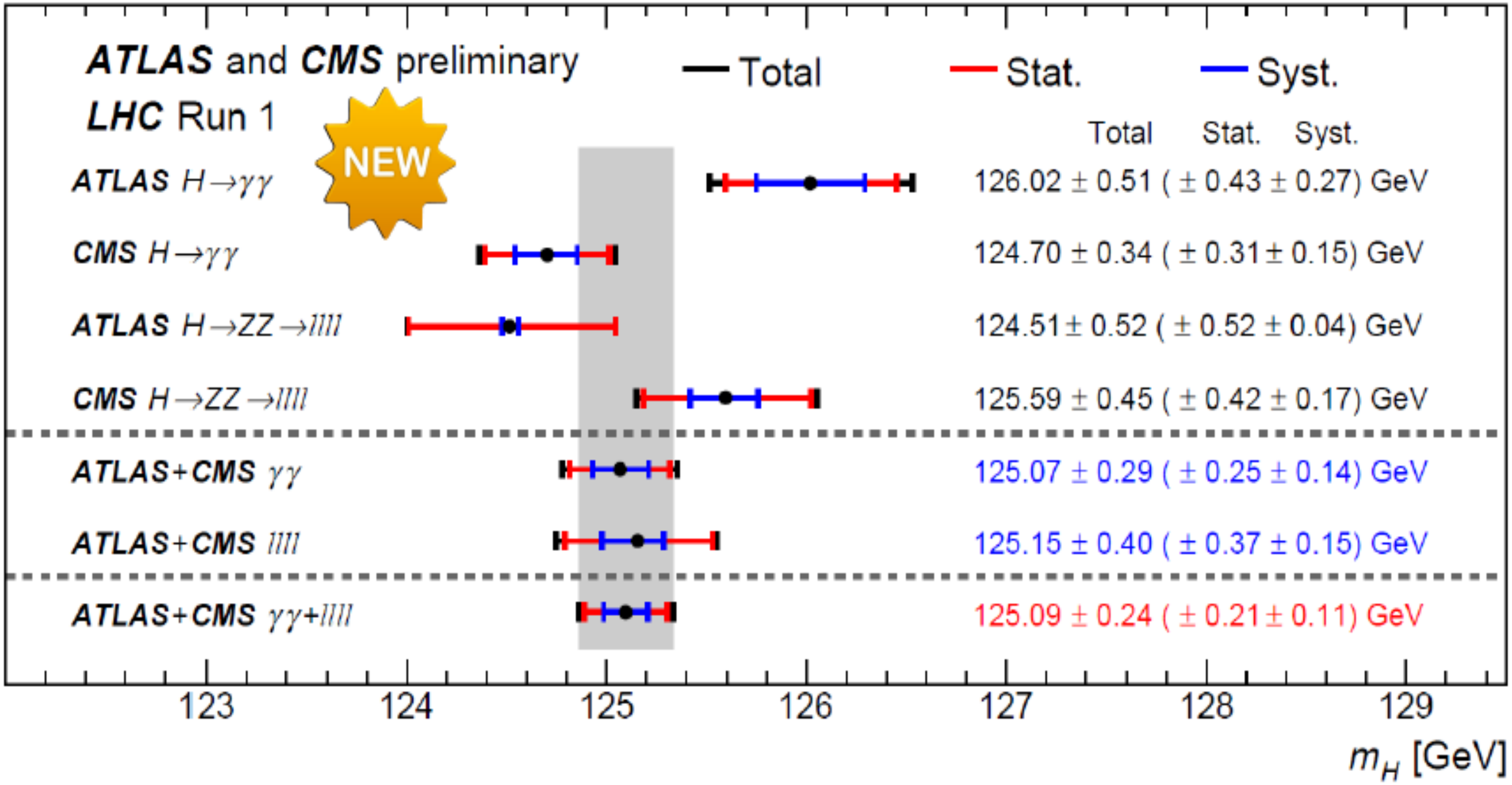
VBF invisible Higgs search (ATLAS-CONF-2015-004):
BR(H→invis.) < 29% (obs.) and < 35% (exp.) at 95% CL.

ATLAS+CMS Higgs mass combination

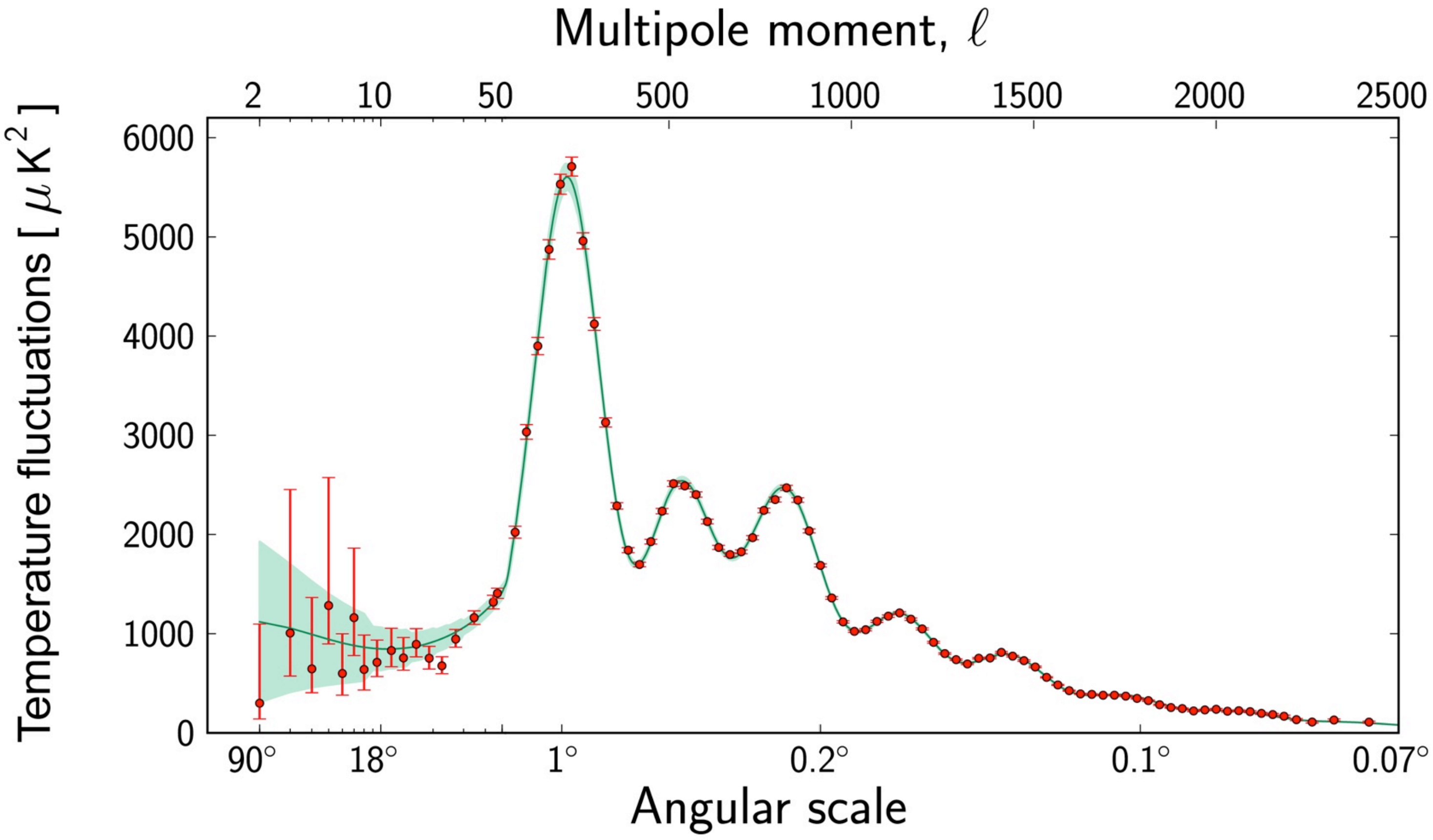
… and the ATLAS+CMS combined Higgs boson mass is:

$$m_H = 125.09 \pm 0.24 \text{ GeV}$$ **(0.19% precision!)**

$$= 125.09 \pm 0.21(\text{stat.}) \pm 0.11(\text{syst.}) \text{ GeV}$$



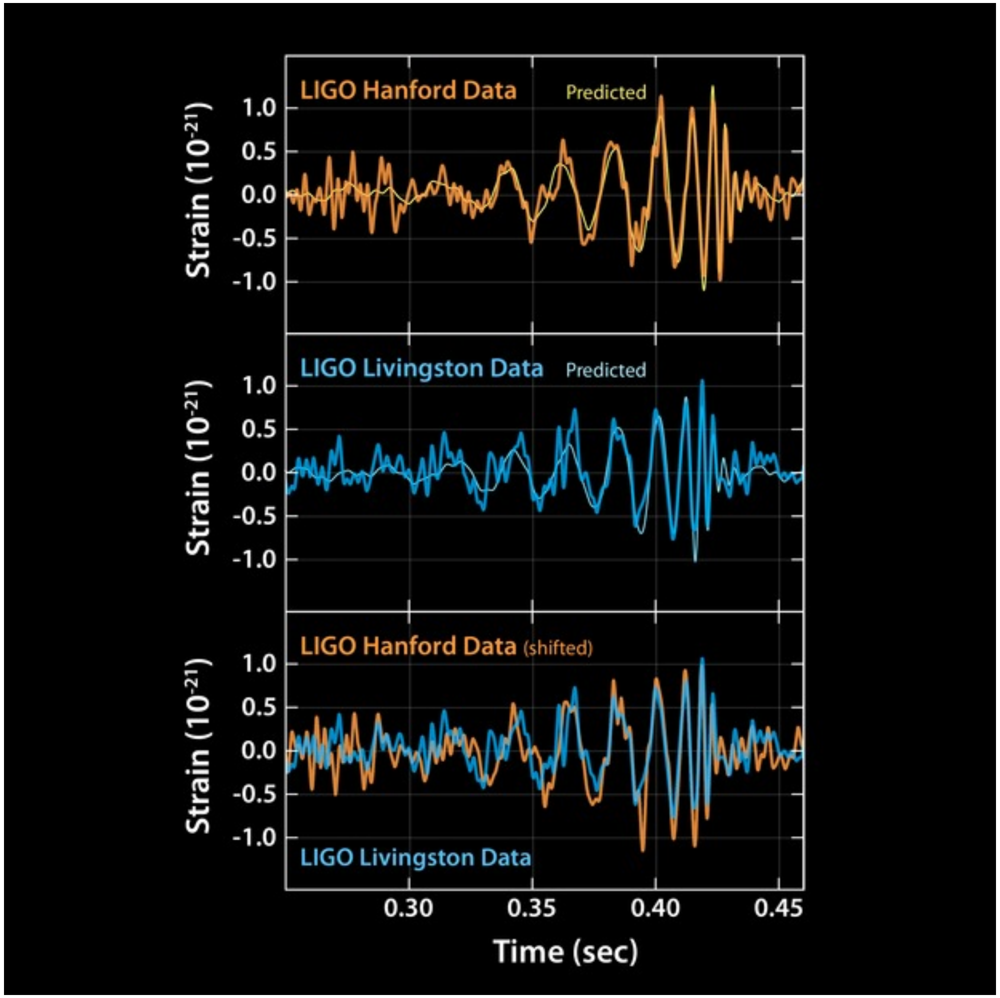
The Cosmologic Standard Model: λCDM



…and gravitational waves!

Historic observation announced on February 2016 by the LIGO/VIRGO collaboration

It opens new ways to look at the Universe



Where we stand

- We have exhausted the number of “known unknown” within the current paradigm.

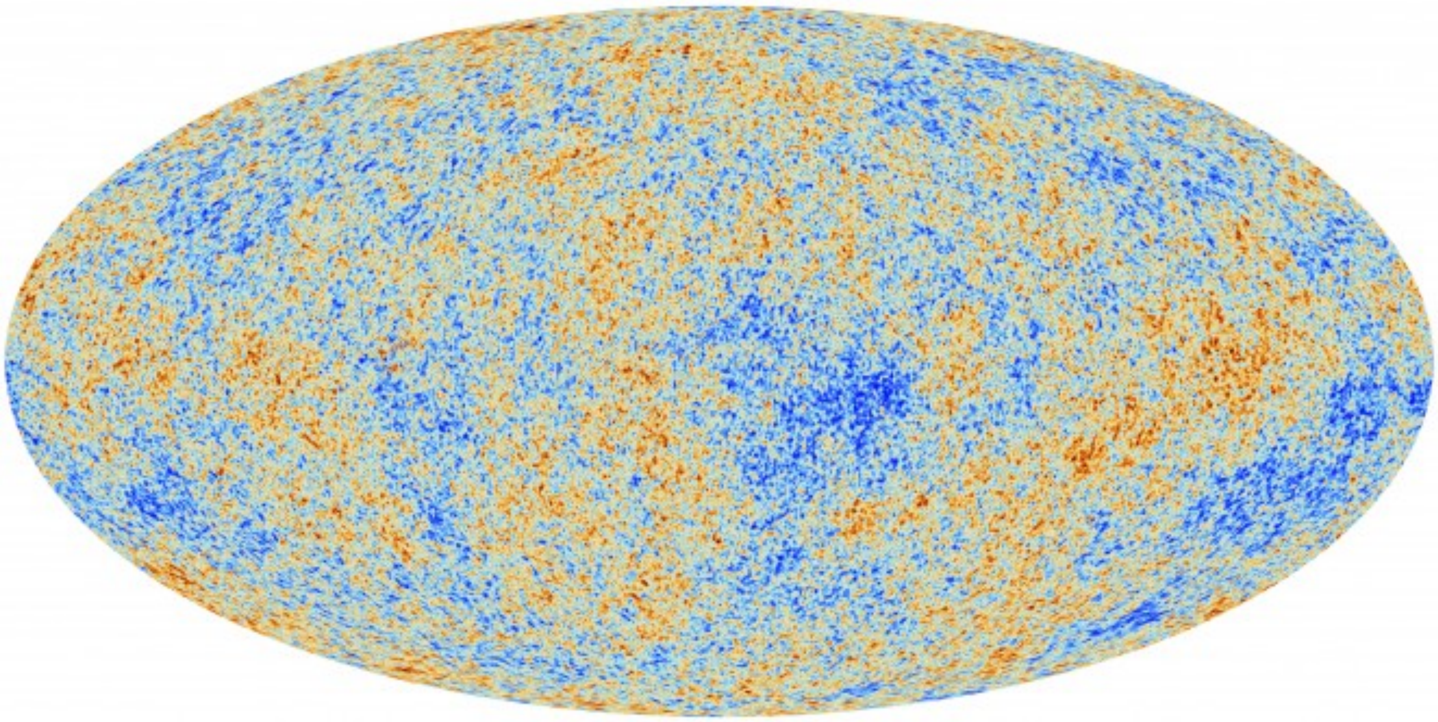
- Although the Standard Models of PP and Cosmology enjoy an enviable state of health, we know they are incomplete, because they cannot explain several outstanding questions, supported in many cases by solid experimental observations.

Because, despite its success….

…. we know that the Standard Model is not complete because:

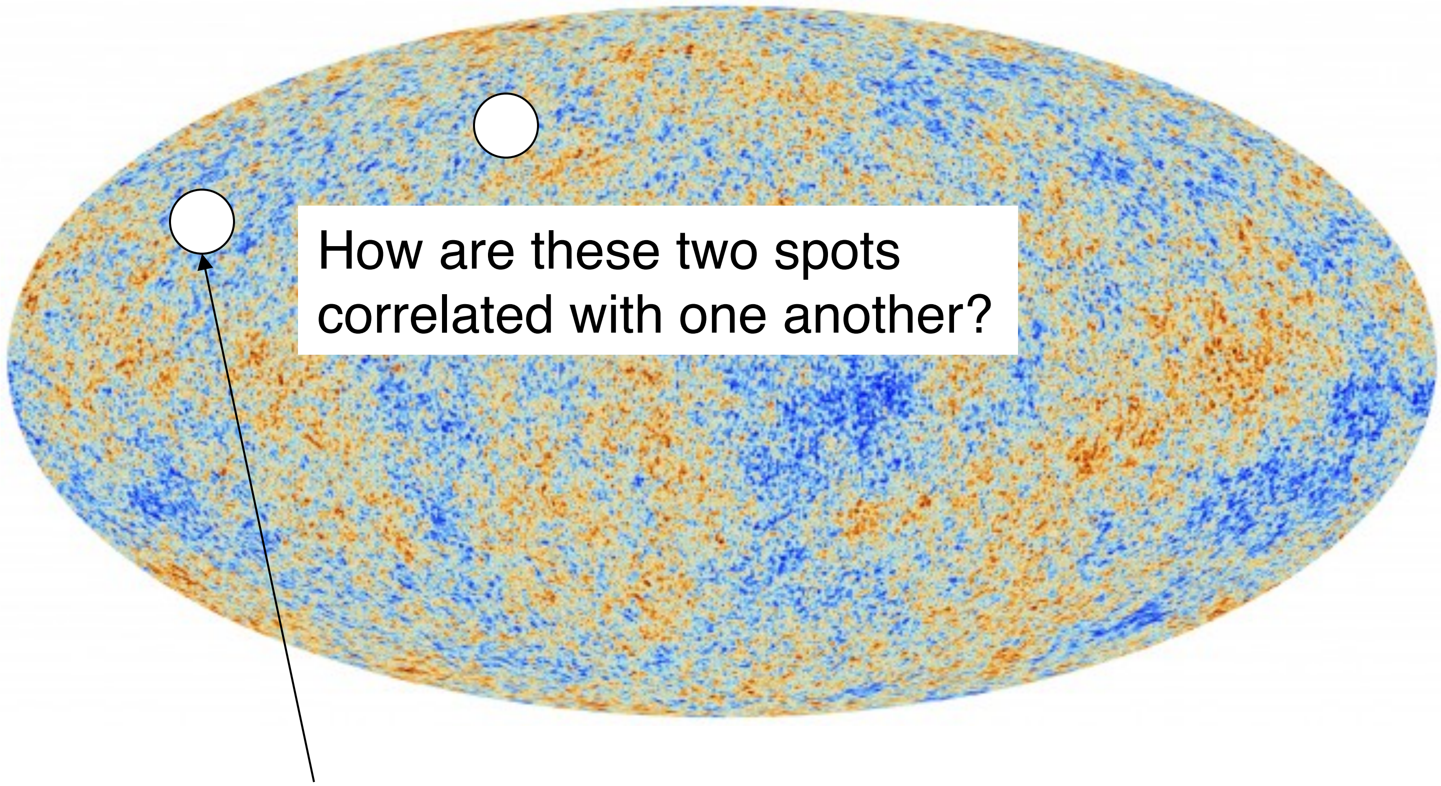
- It doesn’t solve the hierarchy problem
- It has no explanation for dark matter/dark energy
- Its mechanisms of CPV are too small to explain matter/antimatter imbalance
- It cannot provide a QFT of gravitation
- ….etc

e.g: fundamental questions in λCDM



Who/what planted the seeds of structure?

Was it even possible?



How are these two spots correlated with one another?

Hubble Radius (Distance light travels as the Universe doubles in size) at *t=400,000* years

Where is New Physics?

The question

- **Is the mass scale beyond our reach ?**
- **Is the mass scale within our reach, but final states are elusive ?**

We should be prepared to exploit both scenarios, through:

- **Precision**
- **Sensitivity (to elusive signatures)**
- **Extended energy/mass reach**

Looking for “unknown unknowns”

Needs a synergic use of:

- High-Energy colliders
- neutrino experiments (solar, short/long baseline, reactors, $0\nu\beta\beta$ decays),
- cosmic surveys (CMB, Supernovae, BAO)
- dark matter direct and indirect detection
- New generation of gravitational waves experiments
- precision measurements of rare decays and phenomena
- dedicated searches (WIMPS, axions, da particles)
- …..

From the Update of the European Strategy for Particle Physics

The success of the LHC is proof of the effectiveness of the European organizational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN.

Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.

The scale of the facilities required by particle physics is **resulting in the globalization of the field**. The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.

From the P5 report

Particle physics is global.

The United States and major players in other regions can together address the full breadth of the field's most urgent scientific questions **if each hosts a unique world-class facility at home and partners in high-priority facilities hosted elsewhere**.

Strong foundations of international cooperation exist, with the Large Hadron Collider (LHC) at CERN serving as an example of a successful large international science project.

Reliable partnerships are essential for the success of international projects. Building further international cooperation is an important theme of this report, and this perspective is finding worldwide resonance in an intensely competitive field.

From Japan HEP Community

The committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

Should a new particle such as a Higgs boson with a mass below approximately 1 TeV be confirmed at LHC, **Japan should take the leadership role in an early realization of an e+e- linear collider**. In particular, if the particle is light, experiments at low collision energy should be started at the earliest possible time. In parallel, continuous studies on new physics should be pursued for both LHC and the upgraded LHC version. Should the energy scale of new particles/physics be higher, accelerator R&D should be strengthened in order to realize the necessary collision energy.

Should the neutrino mixing angle $\boldsymbol{\theta}_{13}$ be confirmed as large, **Japan should aim to realize a large-scale neutrino detector through international cooperation**, accompanied by the necessary reinforcement of accelerator intensity, so allowing studies on CP symmetry through neutrino oscillations.
This new large-scale neutrino detector should have sufficient sensitivity to allow the search for proton decays, which would be direct evidence of Grand Unified Theories.

Where is New Physics?

The question

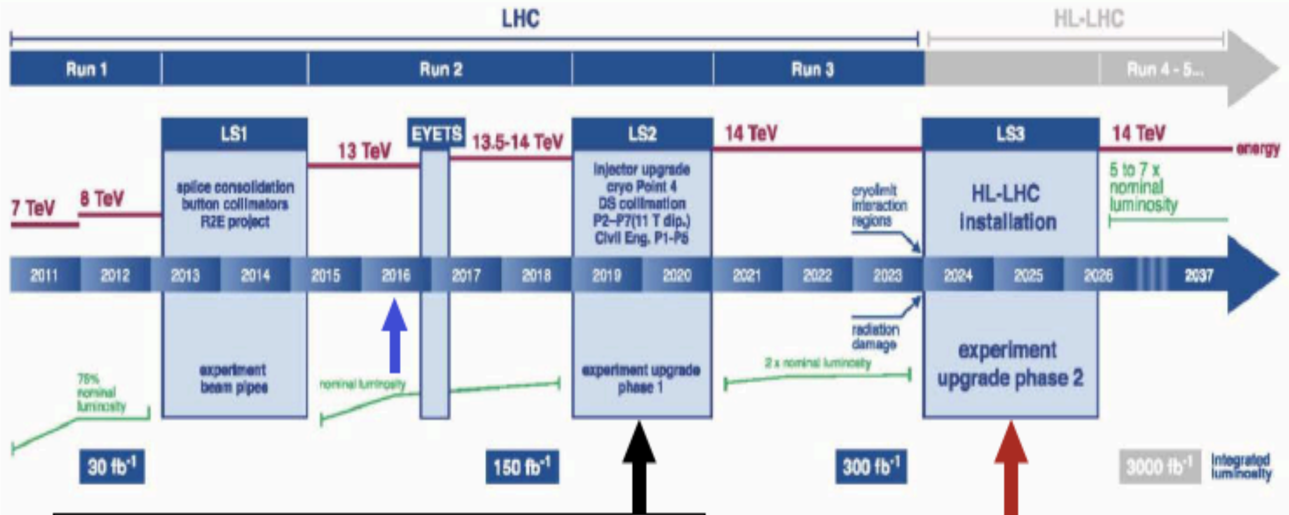
- **Is the mass scale beyond the LHC reach ?**
- **Is the mass scale within LHC's reach, but final states are elusive ?**

We should be prepared to exploit both scenarios, through:

- **Precision**
- **Sensitivity (to elusive signatures)**
- **Extended energy/mass reach**

The LHC timeline

- LHC
    - 300 fb^{-1} by 2023
        - 30 fb^{-1} Run 1
        - >100 fb^{-1} so far
        - …
- HL-LHC
    - ~3000 fb^{-1} by ~2035
    - levelled luminosity



LS2 (2019-2020):

- ☐ LHC Injectors Upgrade (LIU)
- ☐ Civil engineering for HL-LHC equipment @ P1,P5
- ☐ First 11 T dipoles P7; cryogenics in P4
- ☐ Phase-1 upgrade of LHC experiments

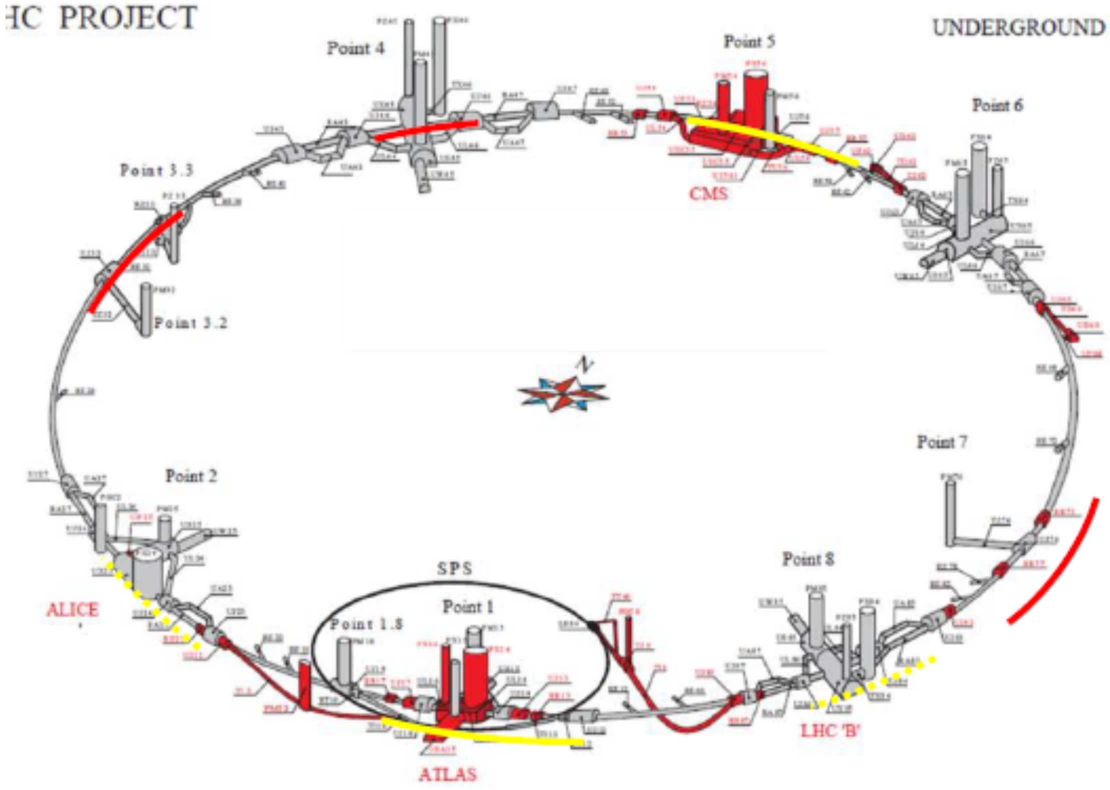
LS3 (2024-2026):

- ☐ **HL-LHC installation**
- ☐ Phase-2 upgrade of ATLAS and CMS

Extending the reach…

- Weak boson scattering
- Higgs properties
- Supersymmetry searches and measurements
- Exotics
- t properties
- Rare decays
- CPV
- ..etc

The HL-LHC Project



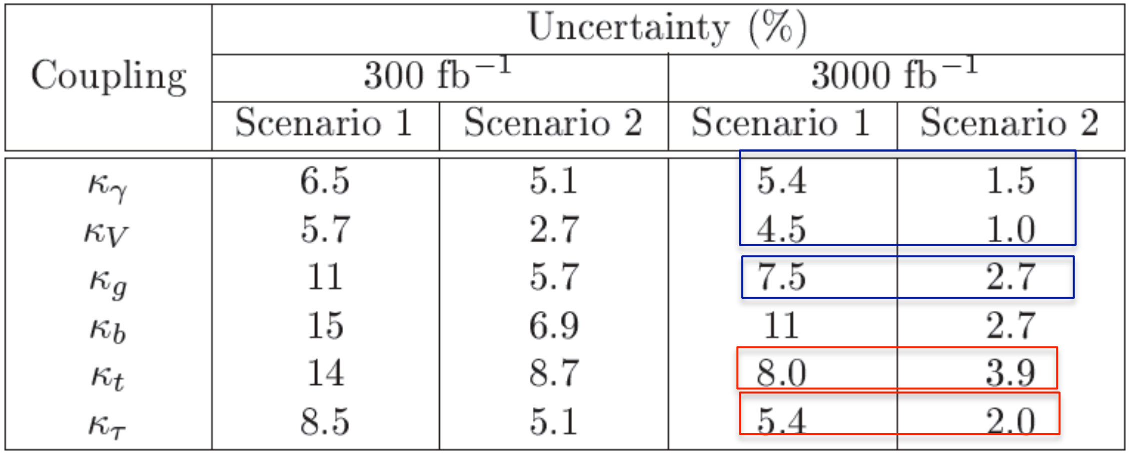
- New IR-quads Nb_3Sn (inner triplets)
- New 11 T Nb_3Sn (short) dipoles
- Collimation upgrade
- Cryogenics upgrade
- Crab Cavities
- Cold powering
- Machine protection
- …

Major intervention on more than 1.2 km of the LHC

Project leadership: L. Rossi and O. Brüning

Higgs couplings fit at HL-LHC

CMS



Coupling	Uncertainty (%)			
	300 fb^{-1}		3000 fb^{-1}	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
κ_γ	6.5	5.1	5.4	1.5
κ_V	5.7	2.7	4.5	1.0
κ_g	11	5.7	7.5	2.7
κ_b	15	6.9	11	2.7
κ_t	14	8.7	8.0	3.9
κ_τ	8.5	5.1	5.4	2.0

CMS Projection

Assumption NO invisible/undetectable contribution to Γ_H:

- Scenario 1: system./Theory err. unchanged w.r.t. current analysis
- Scenario 2: systematics scaled by 1/sqrt(L), theory errors scaled by ½

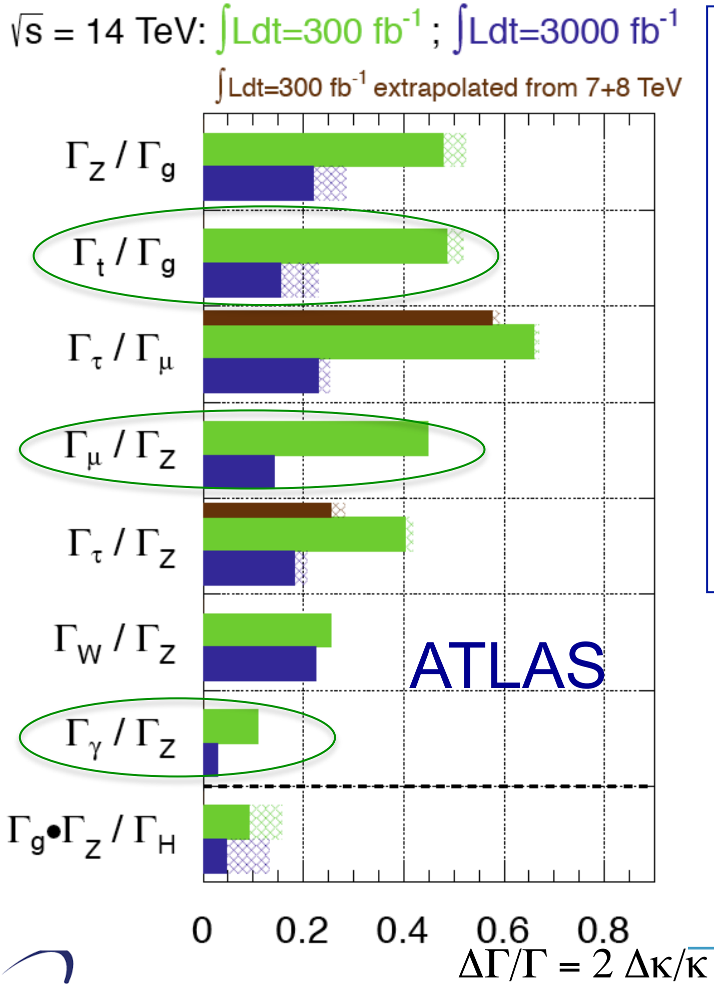
✓ γγ loop at 2-5% level

✓ down-type fermion couplings at 2-10% level

✓ direct top coupling at 4-8% level

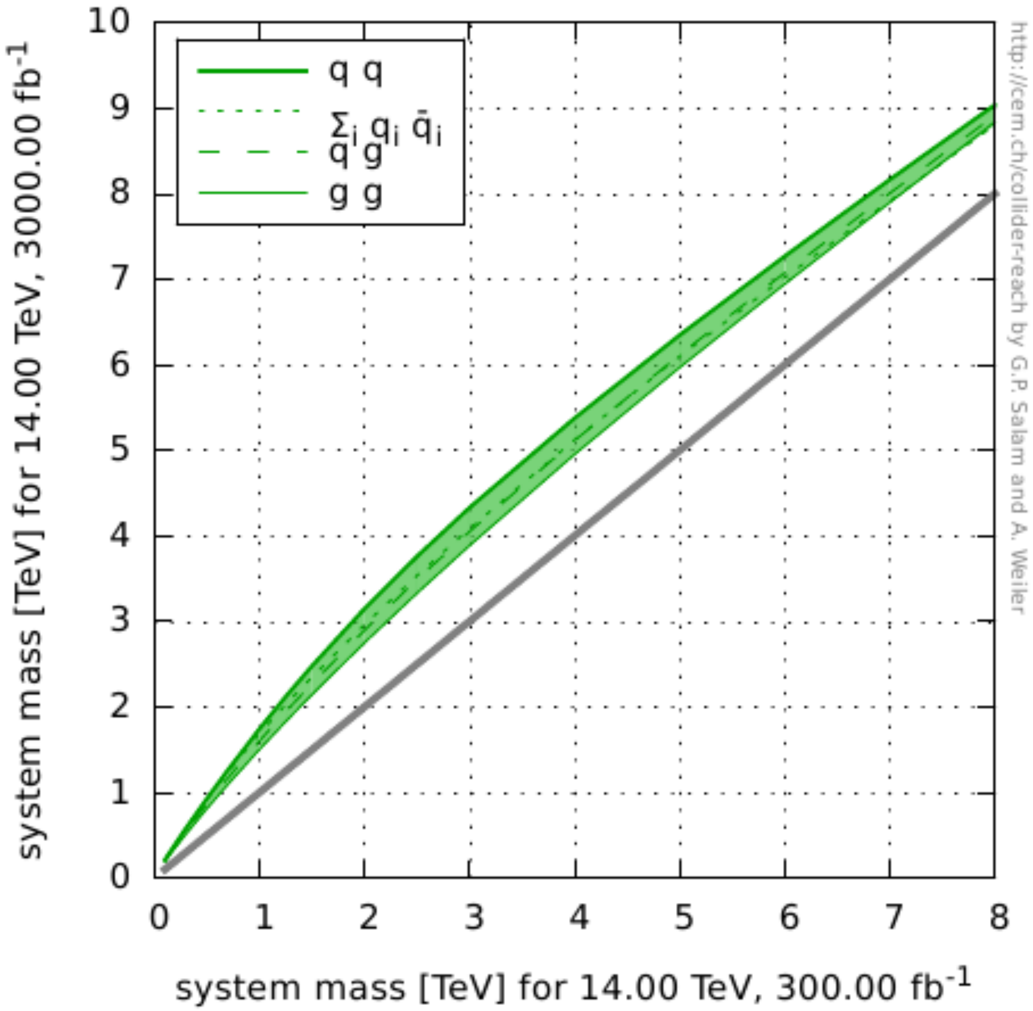
✓ gg loop at 3-8% level

Coupling Ratios Fit at HL-LHC



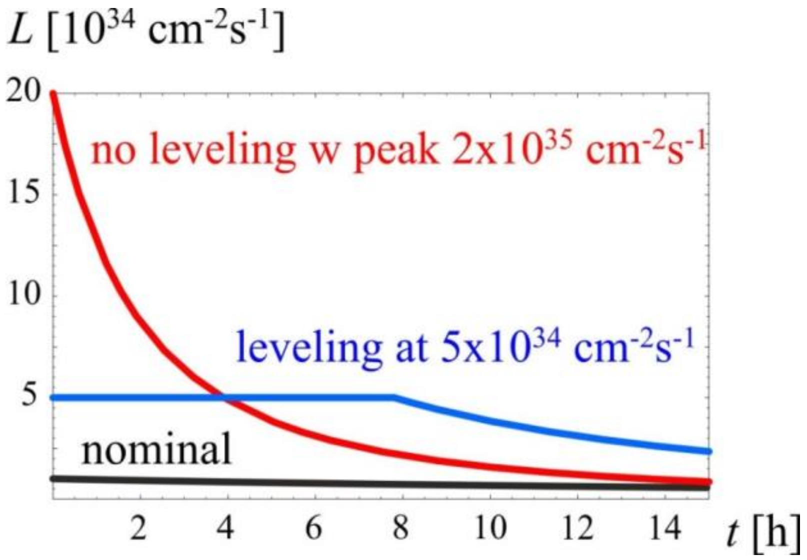
- Fit to coupling ratios:
  - No assumption BSM contributions to Γ_H
  - Some theory systematics cancels in the ratios
- Loop-induced Couplings $\gamma\gamma$ and gg treated as independent parameter
  - κ_γ/κ_Z tested at 2%
  - gg loop (BSM) κ_t/κ_g at 7-12%
  - 2nd generation ferm. κ_μ/κ_Z at 8%

Extending the reach….

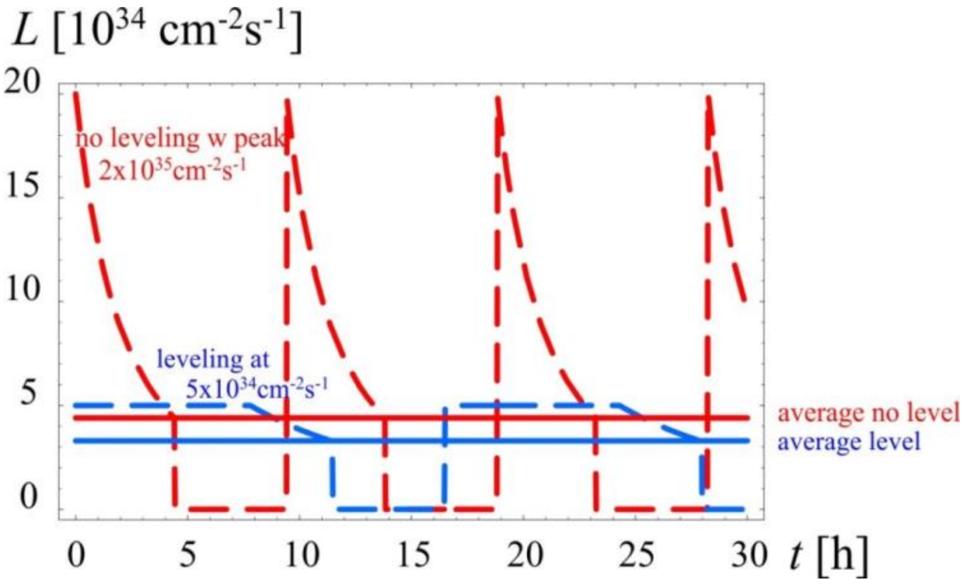


http://cern.ch/collider-reach by G.P. Salam and A. Weiler

Luminosity Levelling, a key to success



- High peak luminosity
- Minimize pile-up in experiments and provide "constant" luminosity



- Obtain about 3 - 4 fb^{-1}/day (40% stable beams)
- About 250 to 300 fb^{-1}/year

Baseline parameters of HL for reaching 250 -300 fb^{-1}/year

25 ns is the option

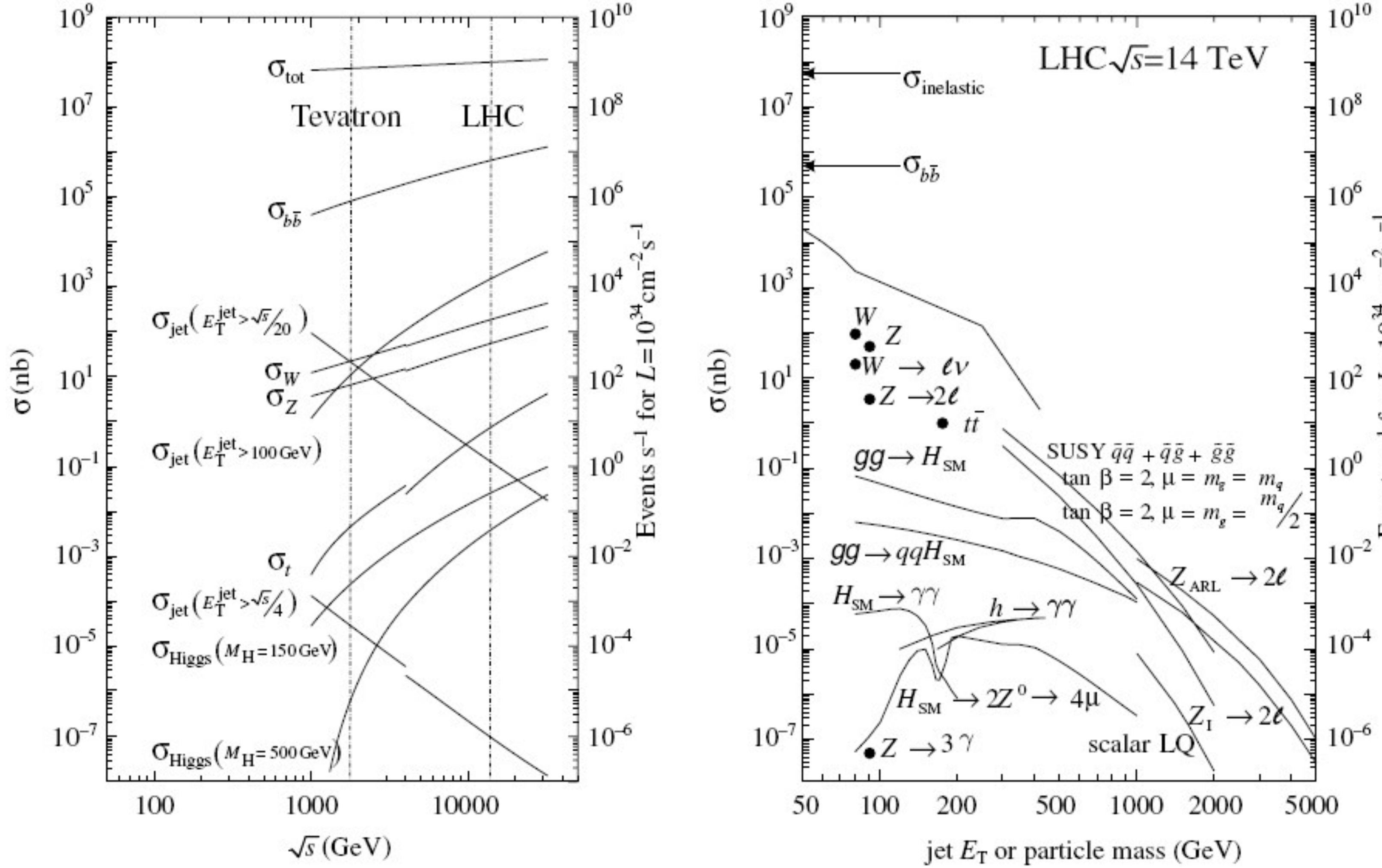
However:

50 ns should be kept as alive and possible because we DO NOT have enough experience on the actual limit *(e-clouds, I_{beam})*

	25 ns	**50 ns**
# Bunches	2808	1404
p/bunch [10^{11}]	**2.0 (1.01 A)**	**3.3 (0.83 A)**
ε_L [eV.s]	2.5	2.5
σ_z [cm]	7.5	7.5
$\sigma_{\delta p/p}$ [10^{-3}]	0.1	0.1
$\gamma\varepsilon_{x,y}$ [μm]	**2.5**	**3.0**
β^* [cm] (baseline)	15	15
X-angle [μrad]	**590 (12.5 σ)**	**590 (11.4 σ)**
Loss factor	0.30	0.33
Peak lumi [10^{34}]	6.0	7.4
Virtual lumi [10^{34}]	20.0	22.7
$T_{leveling}$ [h] @ 5E34	**7.8**	**6.8**
#Pile up @5E34	123	247

Continuous global optimisation with LIU

The detectors challenge



7 – 11 orders of magnitude between inelastic and “interesting” - “discovery” physics event rate

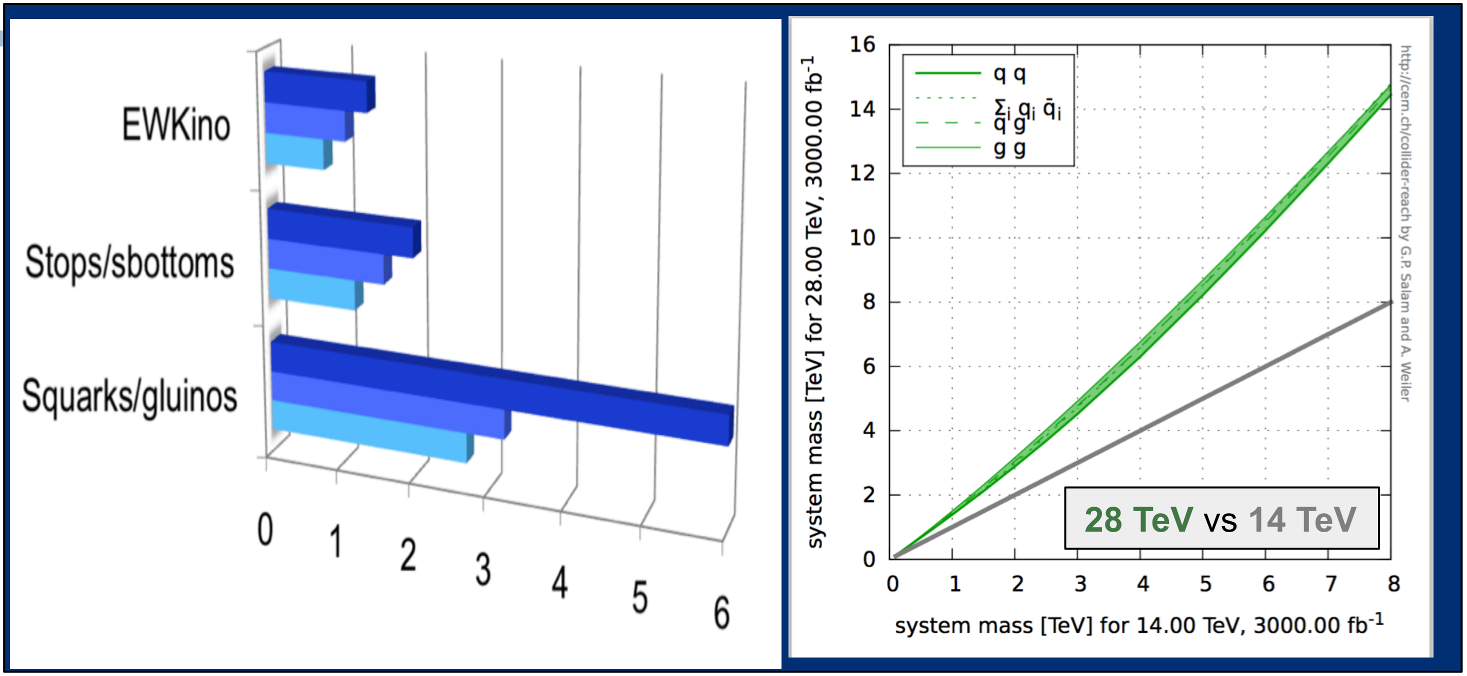
The detectors challenge

In order to exploit the LHC potential, experiments have to maintain full sensitivity for discovery, while keeping their capabilities to perform precision measurements at low p_T, in the presence of:

- Pileup
  - <PU> ≈ 50 events per crossing by LS2
  - <PU> ≈ 60 events per crossing by LS3
  - <PU> ≈ 140 events per crossing by HL-LHC
- Radiation damage
  - Requires work to maintain calibration
  - Limits performance-lifetime of the detectors
    - Light loss (calorimeters)
    - Increased leakage current (silicon detectors)

High Energy LHC (m.f.o)

Fabiola Gianotti,
FCC Week 2016

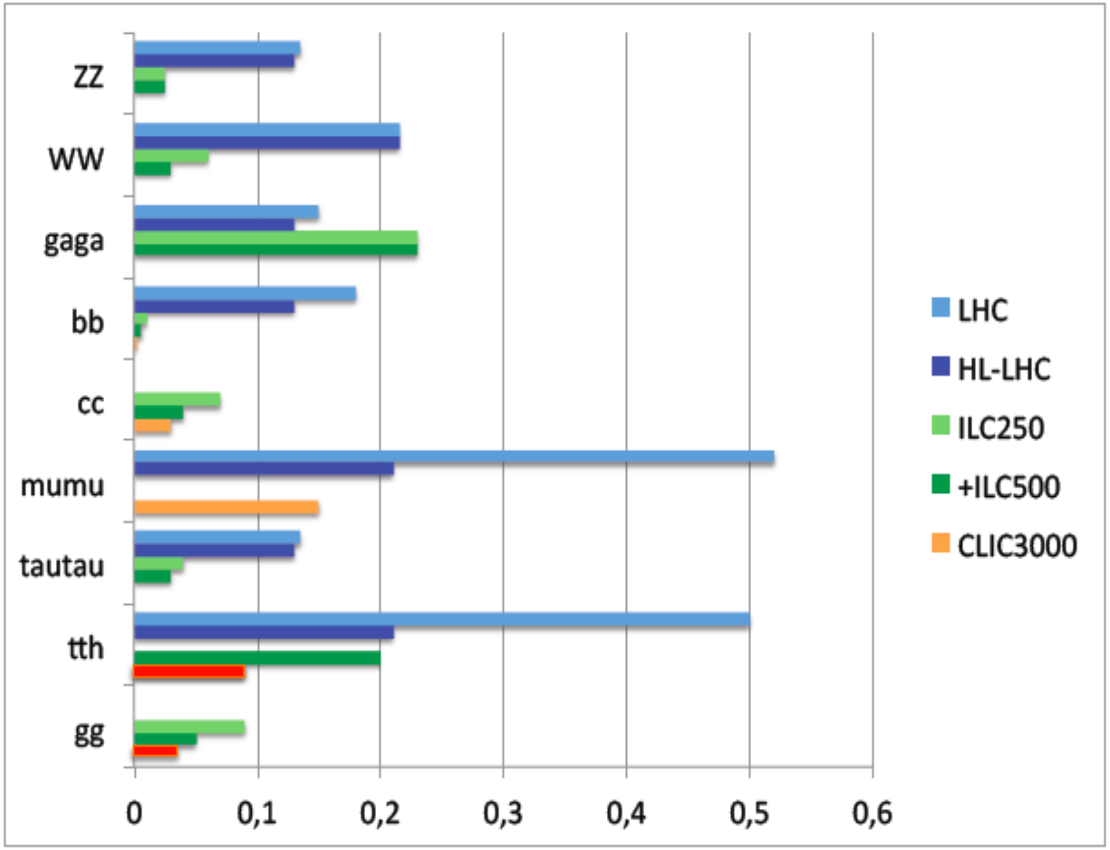


Various options, with increasing amount of HW changes, technical challenges, cost, and physics reach

WG set up to explore technical feasibility of pushing LHC energy to:
1) design value: 14 TeV
2) ultimate value: 15 TeV (corresponding to max dipole field of 9 T)
3) beyond (e.g. by replacing 1/3 of dipoles with 11 T Nb$_3$Sn magnets)
→ Identify open risks, needed tests and technical developments, trade-off between energy and machine efficiency/availability
→ Report on 1) end 2016, 2) end 2017, 3) end 2018 (in time for ES)

HE-LHC (part of FCC study): ~16 T magnets in LHC tunnel (→ $\sqrt{s}$~ 30 TeV)
- ☐ uses existing tunnel and infrastructure; can be built at fixed budget
- ☐ strong physics case if new physics from LHC/HL-LHC
- ☐ powerful demonstration of the FCC-hh magnet technology

LHC vs LC: „signal strength“



KD attempt to compile available experimental studies.
(best estimates)

HANDLE WITH CARE

fineprint:

ATLAS/CMS from Krakow notes
(= preliminary!)

LHC = (ATLAS+CMS)/2 (300 fb^{-1})
HL-LHC = ATLAS (3000 fb^{-1})
ILC250 = 250 fb^{-1} at 250 GeV
+ILC500 = 500 fb^{-1} at 500 GeV +
250 fb^{-1} at 250 GeV
ILC1000 + CLIC3000
are only examples

1) prec. on σ_{HZ}(total)
2) prec. on $\sigma_{WW\text{-}Fusion}$(total)

LHC – mostly syst. limited
LC – mostly stat. limited

ILC1000/CLIC1400 further improves precision

A lepton collider: an important asset…

..if

- Can be decided/built soon
- It might start at 250 Gev, but it should be upgradable at 500 GeV, with a possible extension to 1 TeV c.m.

Best candidate: the International Linear Collider:

- Mature design
- TDR delivered
- Japanese community has submitted to the government a request to host it.

ILC: not only a precision machine

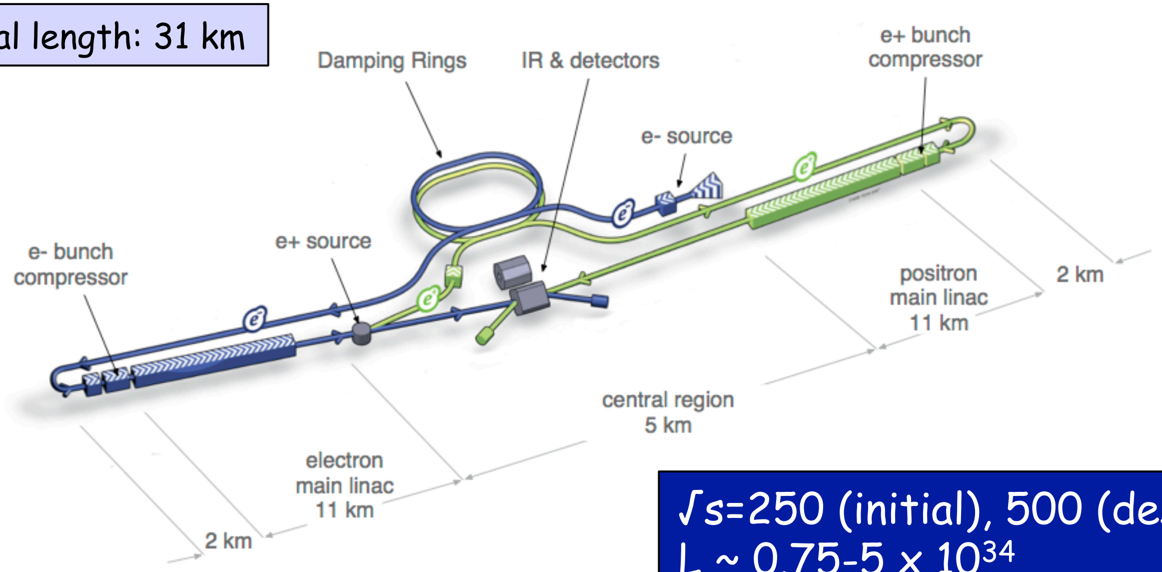
- Great impact in exploring the EWK part of Supersimmetry, in a region which might be not accessible at the LHC, because the unfavorable S/B.
- A fundamental contribution in the precision studies of the W and Z bosons and the top quark.

The joint information coming from LHC and ILC might be a “conditio sine qua non” to enable the next particle accelerator at the energy frontier

International Linear Collider (ILC)

Technical Design Report released in June 2013

Total length: 31 km



√s=250 (initial), 500 (design), 1000 (upgrade) GeV
L ~ 0.75-5 x 10^{34}
(running at √s=90, 160, 350 GeV also envisaged)

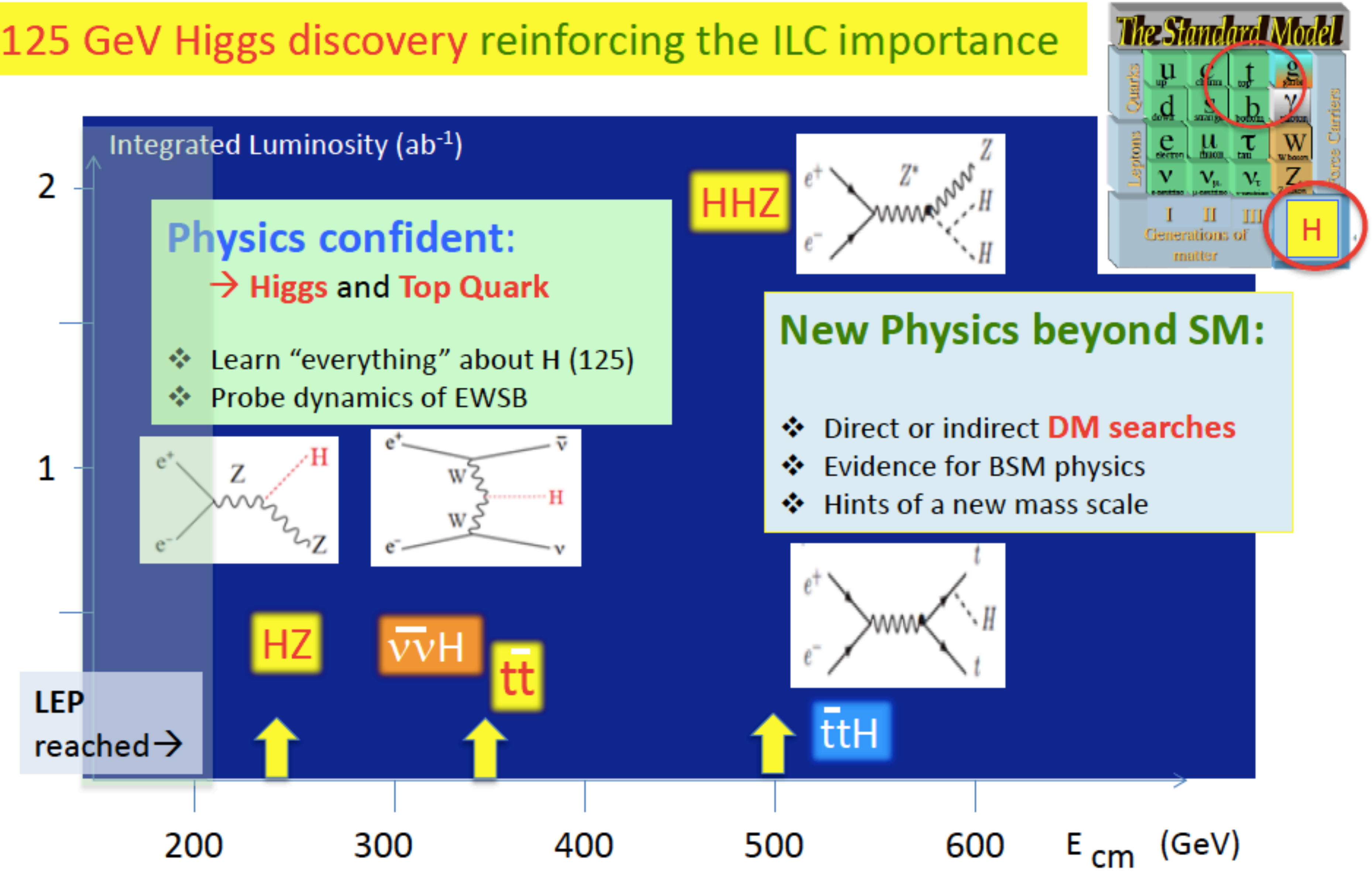
Main challenges:

- ❑ ~ 15000 SCRF cavities (1700 cryomodules), 31.5 MV/m gradient
- ❑ 1 TeV machine requires extension of main Linacs (50 km) and 45 MV/m
- ❑ Positron source; suppression of electron-cloud in positron damping ring
- ❑ Final focus: squeeze and collide nm-size beams

❑ Japan interested to host → decision ~2018 based also on ongoing international discussions
Mature technology: 20 years of R&D experience worldwide
(e.g. European xFEL at DESY is 5% of ILC, gradient 24 MV/m, some cavities achieved 29.6 MV/m)
→ Construction could technically start ~2019, duration ~10 years → physics could start ~2030

Important Energies in ILC

125 GeV Higgs discovery reinforcing the ILC importance



Physics confident:

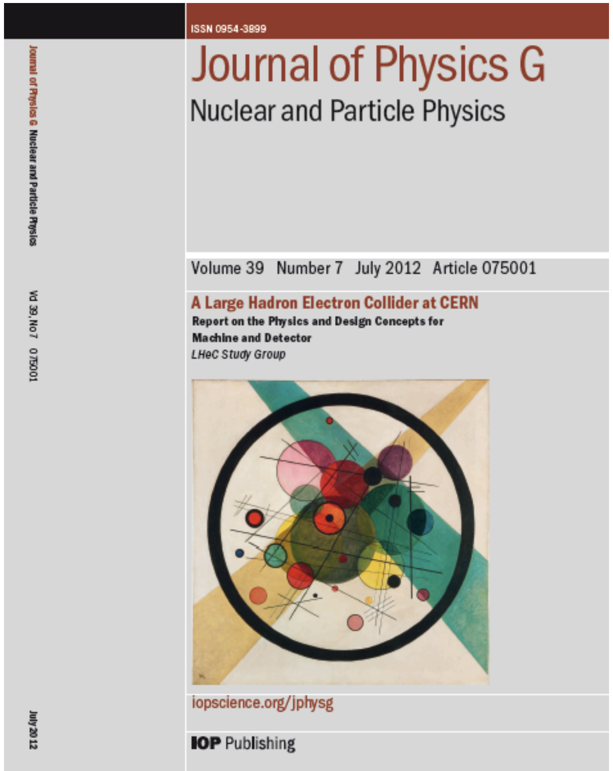
→ **Higgs** and **Top Quark**

- Learn “everything” about H (125)
- Probe dynamics of EWSB

New Physics beyond SM:

- Direct or indirect **DM searches**
- Evidence for BSM physics
- Hints of a new mass scale

LHeC, not only PDFs



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Nuclear and Particle Physics

Volume 39 Number 7 July 2012 Article 075001

A Large Hadron Electron Collider at CERN

Report on the Physics and Design Concepts for Machine and Detector

LHeC Study Group

iopscience.org/jphysg

IOP Publishing

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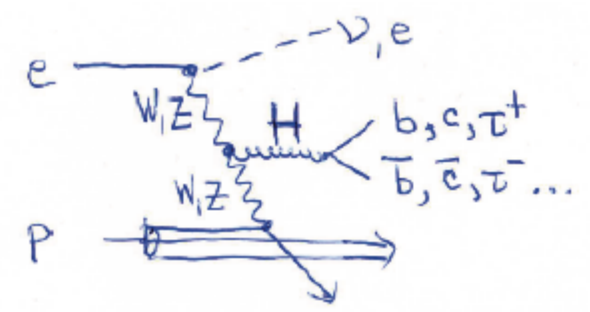
July 2012



Continuing activity on
Physics
Detector
ERL

Goal: L~10^{34} cm^{-2}s^{-1}

Five Major Themes of LHeC PHysics

The Cleanest High Resolution Microscope of the World

The Electron Beam Upgrade of the LHC

The First High Precision Higgs Facility

Discovery Beyond the Standard Model

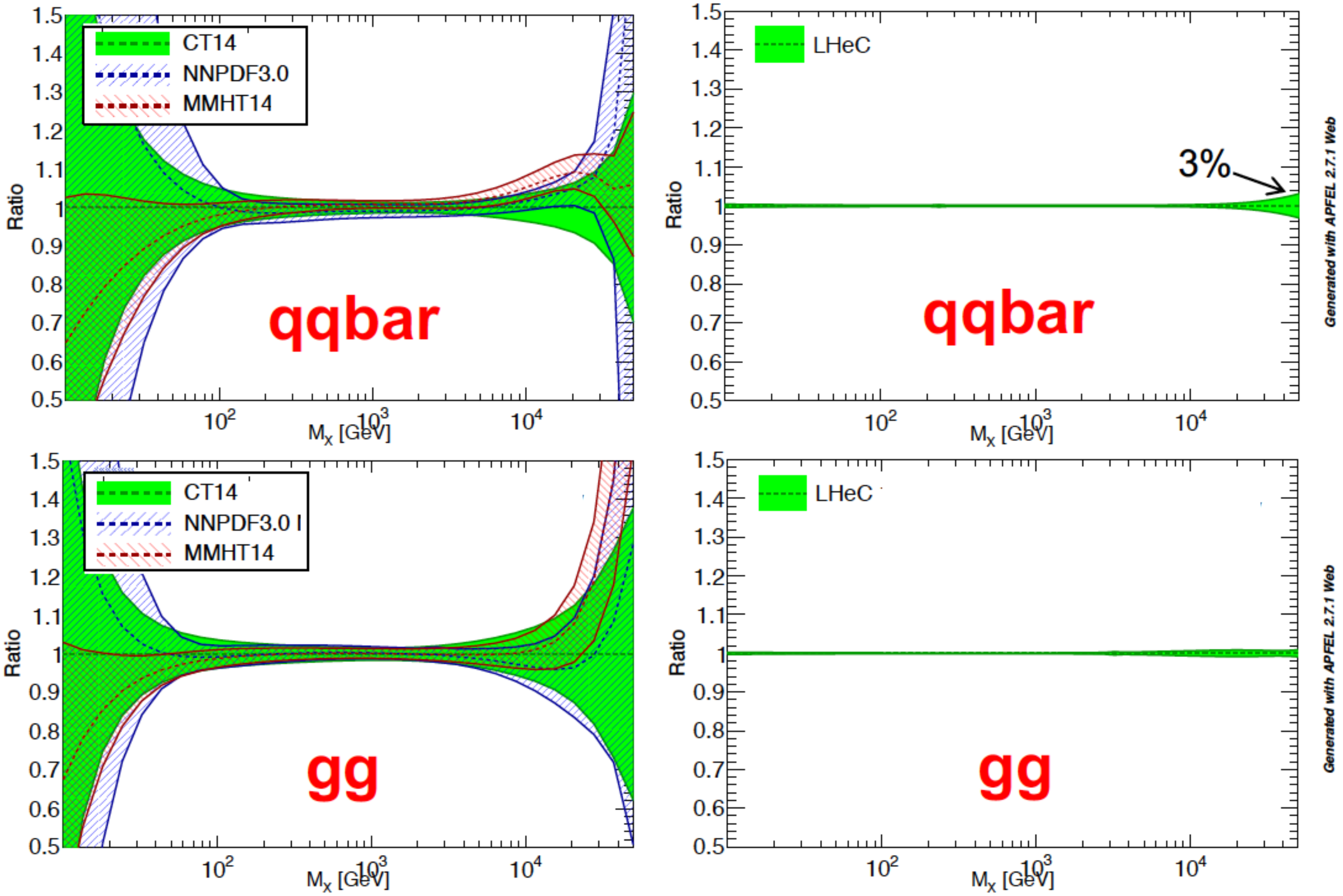
A Unique Nuclear Physics Facility

The LHeC PDF Programme

Resolve parton structure of the proton completely: u_v,d_v,s_v?,u,d,s,c,b,t and xg
Unprecedented range, sub% precision, free of parameterisation assumptions,
Resolve p structure, solve non linear and saturation issues, test QCD, N^3LO…

Strong Coupling in inclusive DIS at LHeC to 0.1%

Lattice??
Jets??
BCDMS??
GUTs?
Higgs in pp



Note that LHC is about to reach its own limits on PDFs. pp is NOT DIS, cf ATLAS W,Z to 0.5%

Top Physics

Top electric charge

EDM and MDM

Anomalous t-q-y and t-g-Z

V_{tb}

Top spin

W-t-b

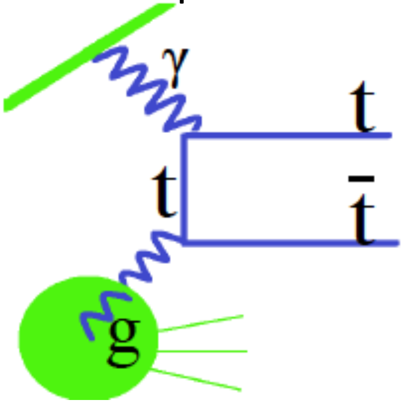
Top PDF

Top mass

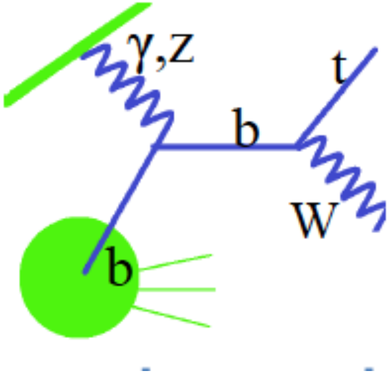
Top-Higgs (1602.04670)

CP nature of ttH (1702.03426)

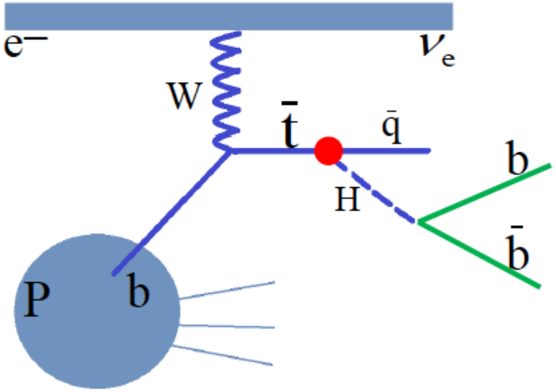
Pair production



Single production

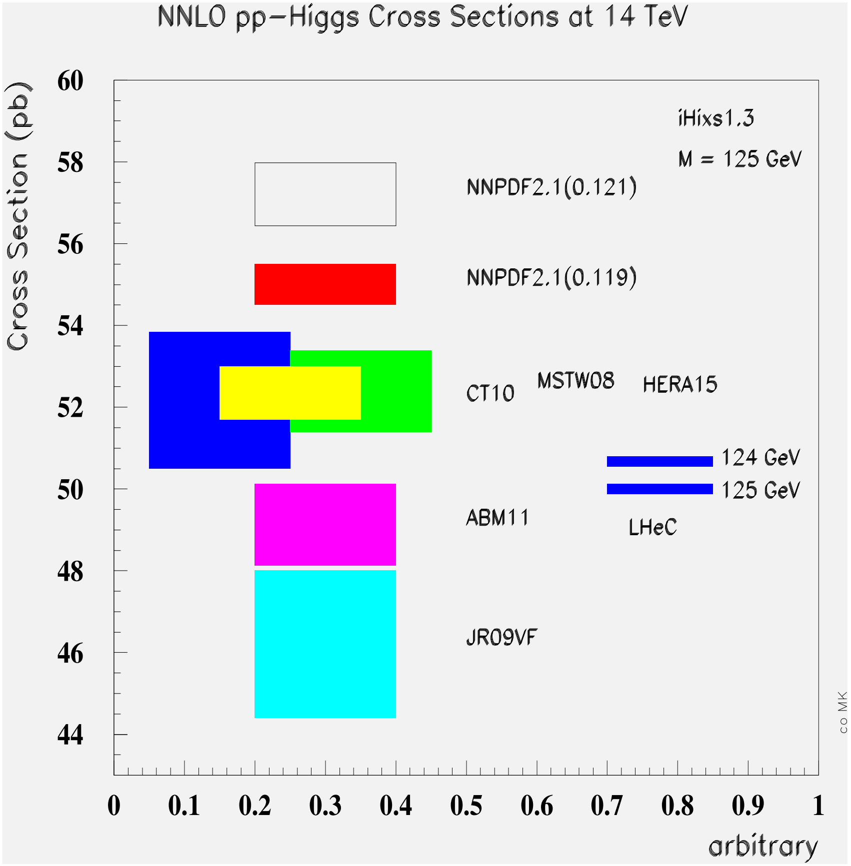


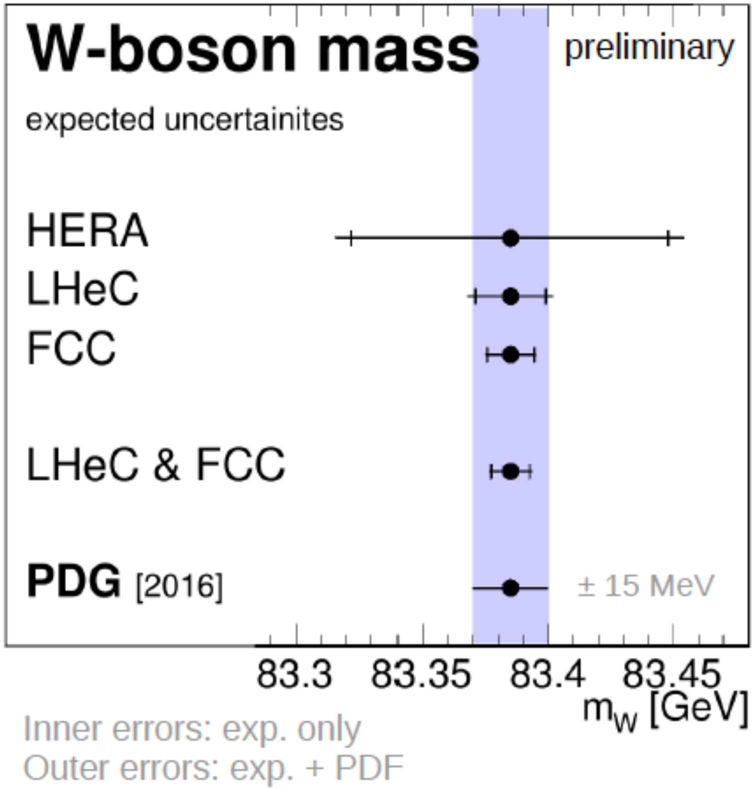
FCNC top Higgs CC interaction



Just started to fully see the huge potential of top physics in ep at high energies

High Precision for the LHC





Predict the Higg cross section in pp to 0.2% precision which matches the M_H measurement and removes the PDF error

Spacelike M_W to 10 MeV from ep
→ Electroweak thy test at 0.01% !

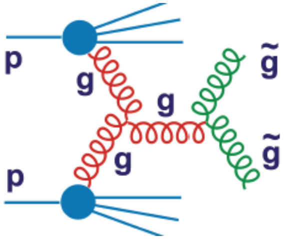
Predict M_W in pp to 2.8 MeV →
Remove PDF uncertainty on M_W LHC

Search Range Extension - worth the Lumi Upgrade

External, reliable input (PDFs, factorisation..) is crucial for range extension + CI interpretation

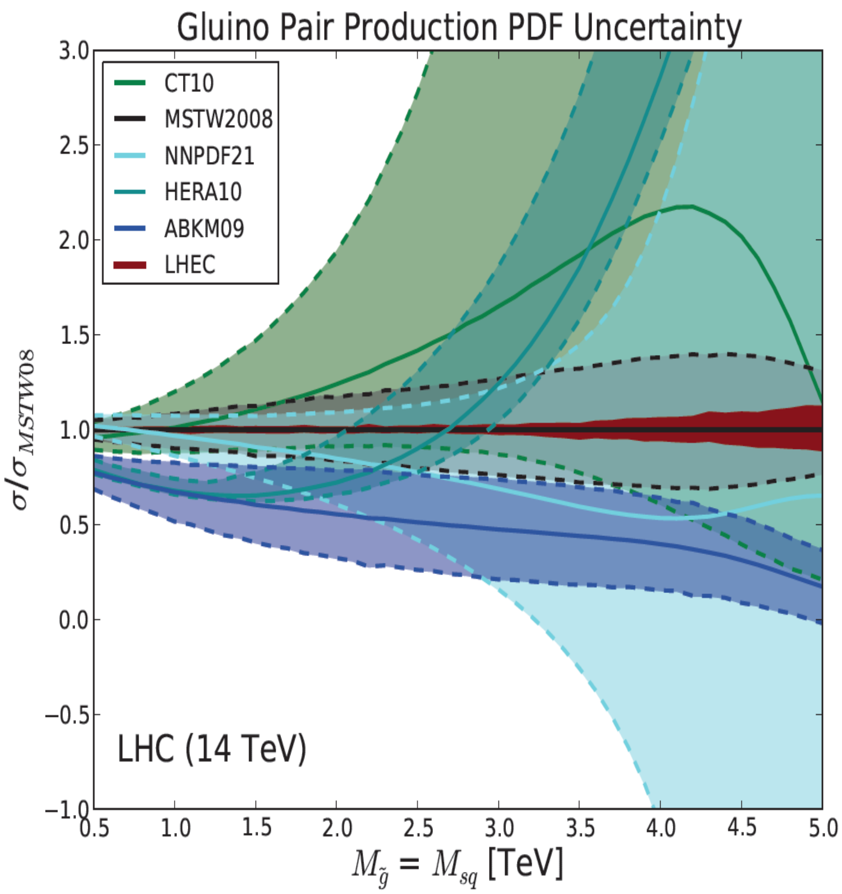
GLUON

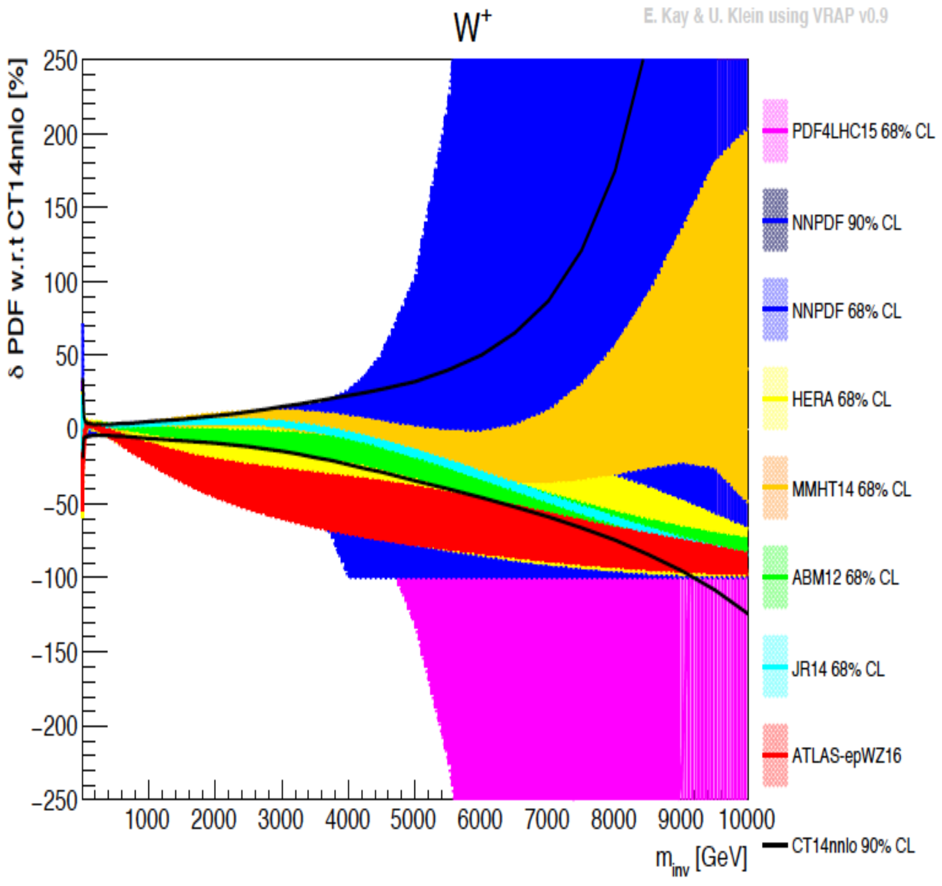
SUSY, RPC, RPV, LQS..

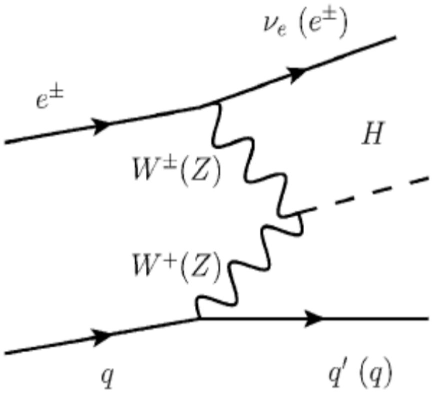


QUARKS

Exotic+ Extra boson searches at high mass







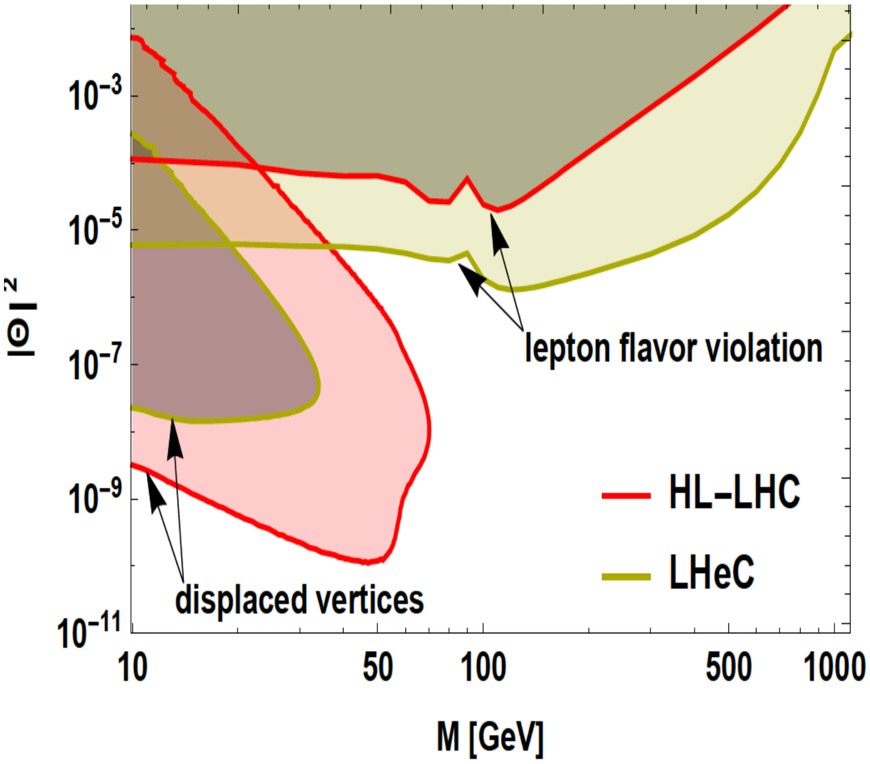
Higgs Physics with ep

κ in %	HL LHC	LHeC HL	LHeC HE	FCC-eh
H → bb	10	0.5	0.3	0.2
H → cc	50?	4	2.8	1.8

- Higgs is produced via an EW process in ep collisions
  - **No contamination from ggF and no pile-up**
  - **Precise theoretical control of the cross-section**
- Superior sensitivity of ep with respect to pp in various aspects:
  - **h → bb,cc,tautau couplings, unique access to WW-H-WW**
    - **Access to h → gg?**
  - **Structure of hVV and top Yukawa couplings**
- Access to hh and invisible decays (dark matter) in ep collisions
- Removal of QCD uncertainties to gg → H calculation for LHC
- **LHC can be transformed into a high precision Higgs facility.**

Possible Discoveries Beyond SM with LHeC

Search for Sterile Neutrinos (LHC **LHeC**)



QCD:

No saturation

BFKL

Instantons

Higher symmetry embedding QCD

Electroweak:

EFTs

Exotic Higgs Decays

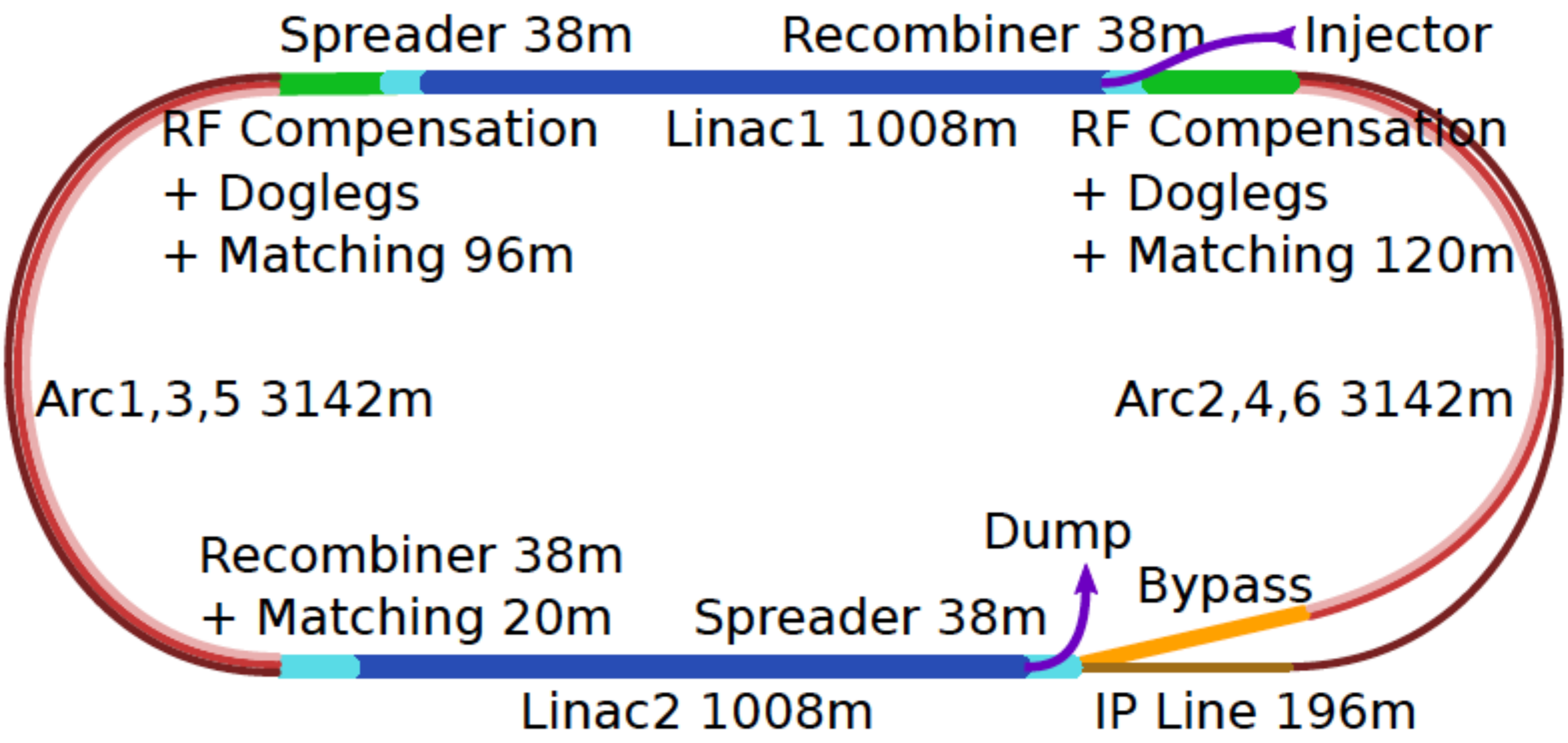
Extension of Higgs Sector

Sterile Neutrinos …

It is a wasted p that does NOT collide with an e beam
(Oliver Fischer - 2017)

It would be a waste not to exploit the 7 TeV beams for ep and eA physics at some stage during the LHC time (Guido Altarelli – 2008)

LHeC ERL Baseline Design



Spreader 38m

Recombiner 38m

Injector

RF Compensation
+ Doglegs
+ Matching 96m

Linac1 1008m

RF Compensation
+ Doglegs
+ Matching 120m

Arc1,3,5 3142m

Arc2,4,6 3142m

Recombiner 38m
+ Matching 20m

Spreader 38m

Dump

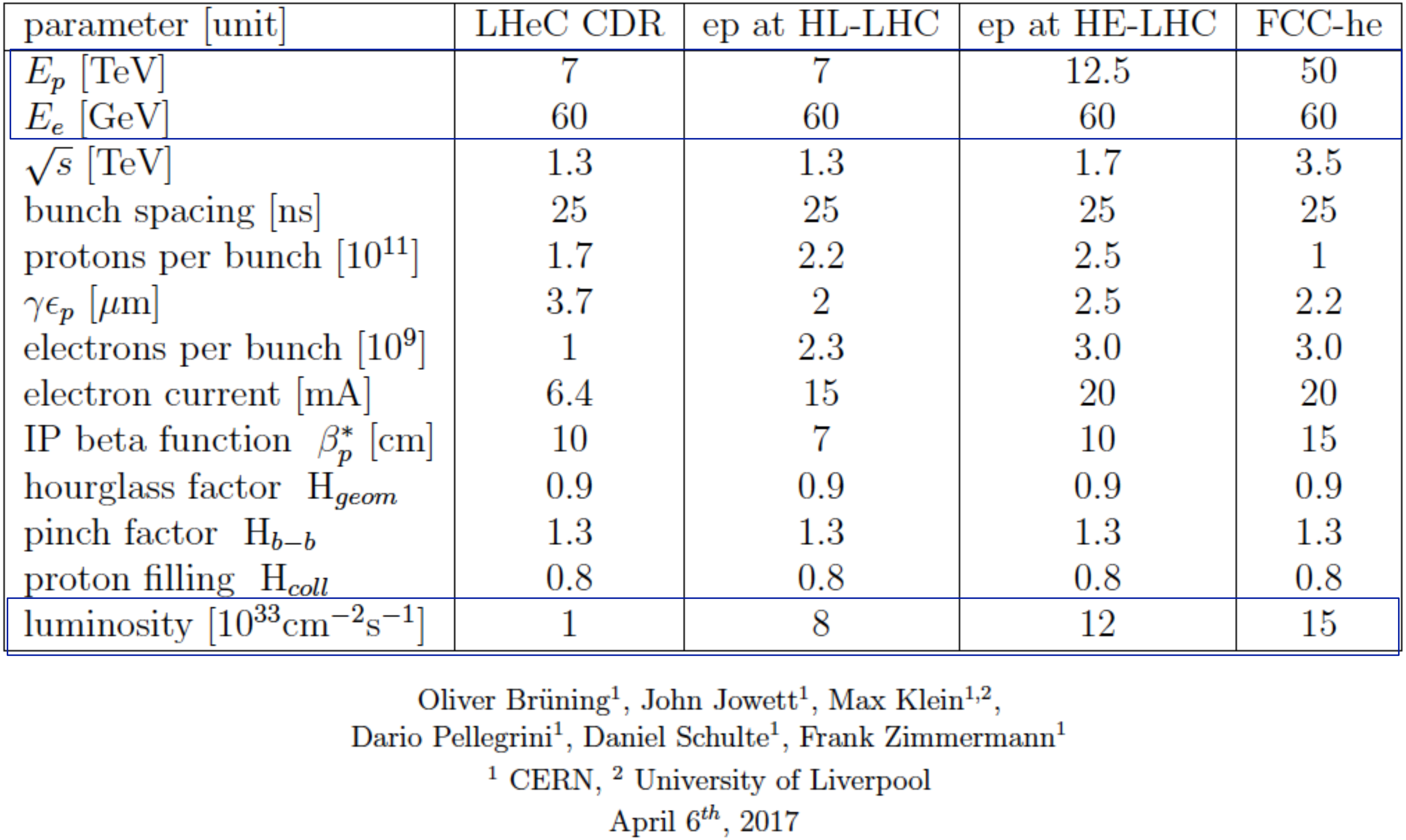
Bypass

Linac2 1008m

IP Line 196m

Concurrent operation to pp, LHC becomes a 3 beam faclity. P < 100 MW. CW

Luminosity for LHeC, HE-LHeC and FCC



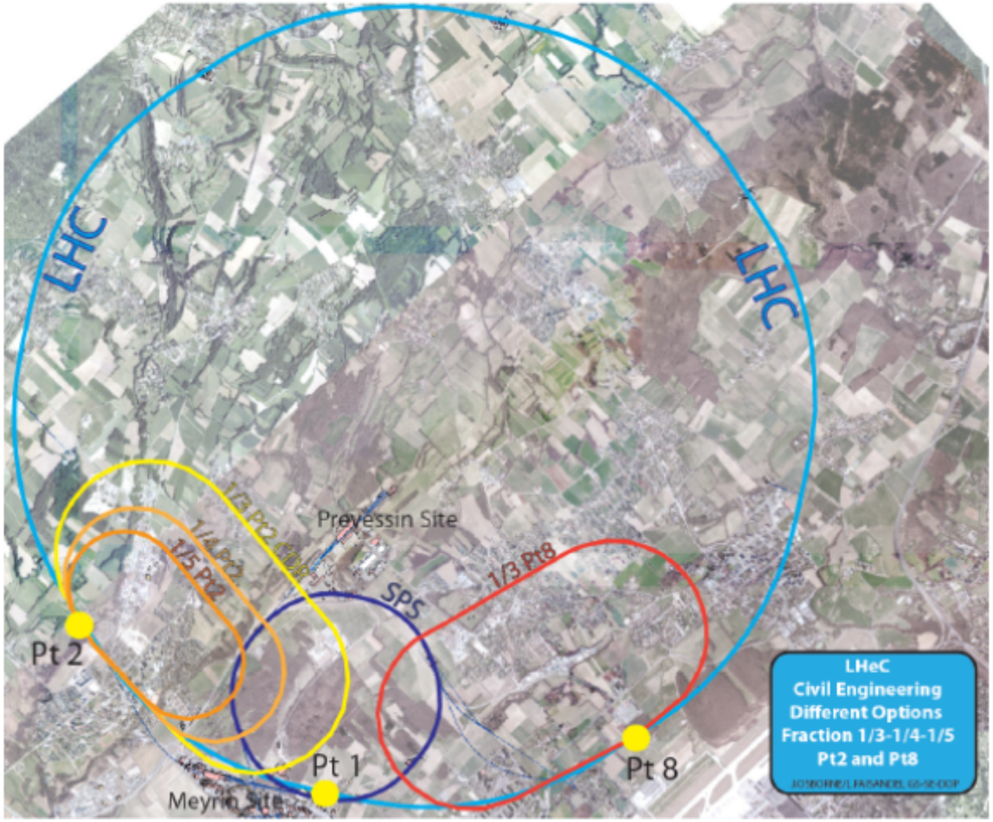
parameter [unit]	LHeC CDR	ep at HL-LHC	ep at HE-LHC	FCC-he
E_p [TeV]	7	7	12.5	50
E_e [GeV]	60	60	60	60
$\sqrt{s}$ [TeV]	1.3	1.3	1.7	3.5
bunch spacing [ns]	25	25	25	25
protons per bunch [10^{11}]	1.7	2.2	2.5	1
$\gamma\epsilon_p$ [μm]	3.7	2	2.5	2.2
electrons per bunch [10^9]	1	2.3	3.0	3.0
electron current [mA]	6.4	15	20	20
IP beta function β_p^* [cm]	10	7	10	15
hourglass factor H_{geom}	0.9	0.9	0.9	0.9
pinch factor H_{b-b}	1.3	1.3	1.3	1.3
proton filling H_{coll}	0.8	0.8	0.8	0.8
luminosity [$10^{33}\text{cm}^{-2}\text{s}^{-1}$]	1	8	12	15

Oliver Brüning[1], John Jowett[1], Max Klein[1,2],
Dario Pellegrini[1], Daniel Schulte[1], Frank Zimmermann[1]
[1] CERN, [2] University of Liverpool

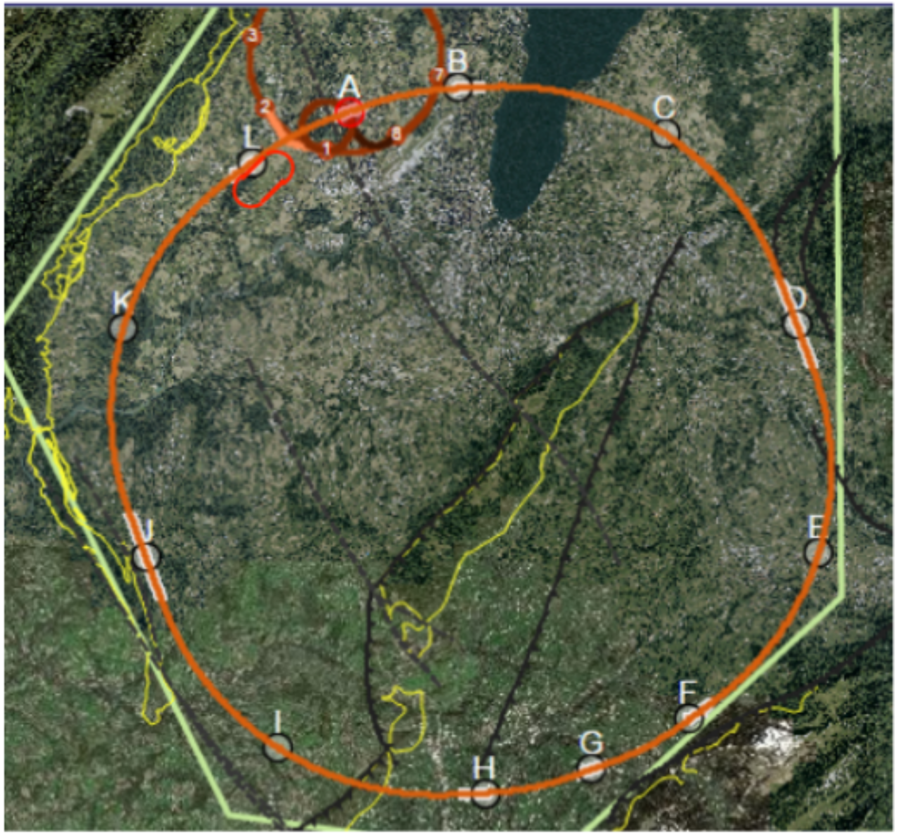
April 6th, 2017

Location + Footprint of the **electron ERL**

LHC



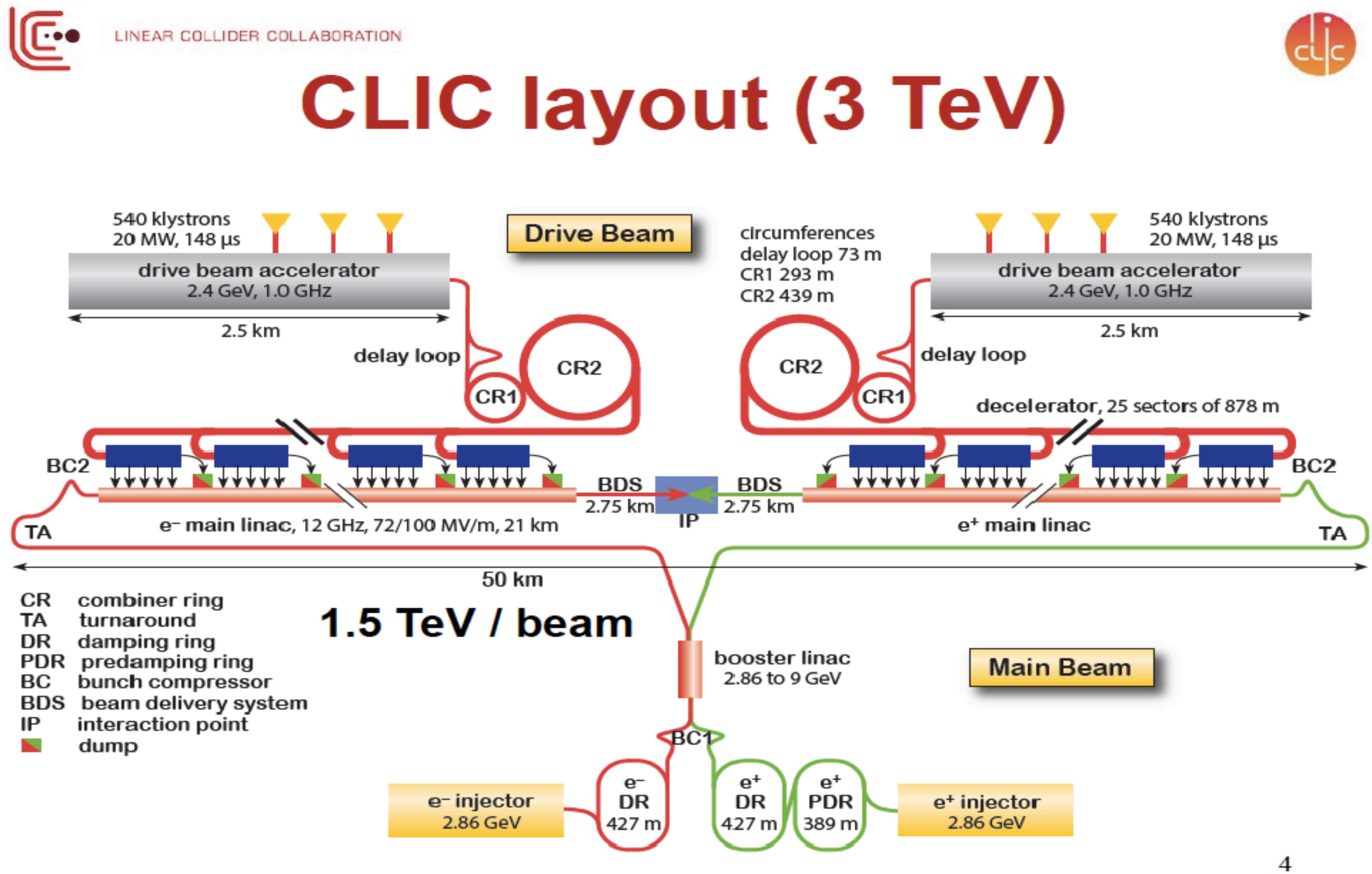
FCC



Energy – Cost – Physics – Footprint
are being reinvestigated

A 9km ERL is a small add-on for the FCC
Doubling the energy to 120 GeV hugely
Increases cost and effort.

More Linear Colliders...

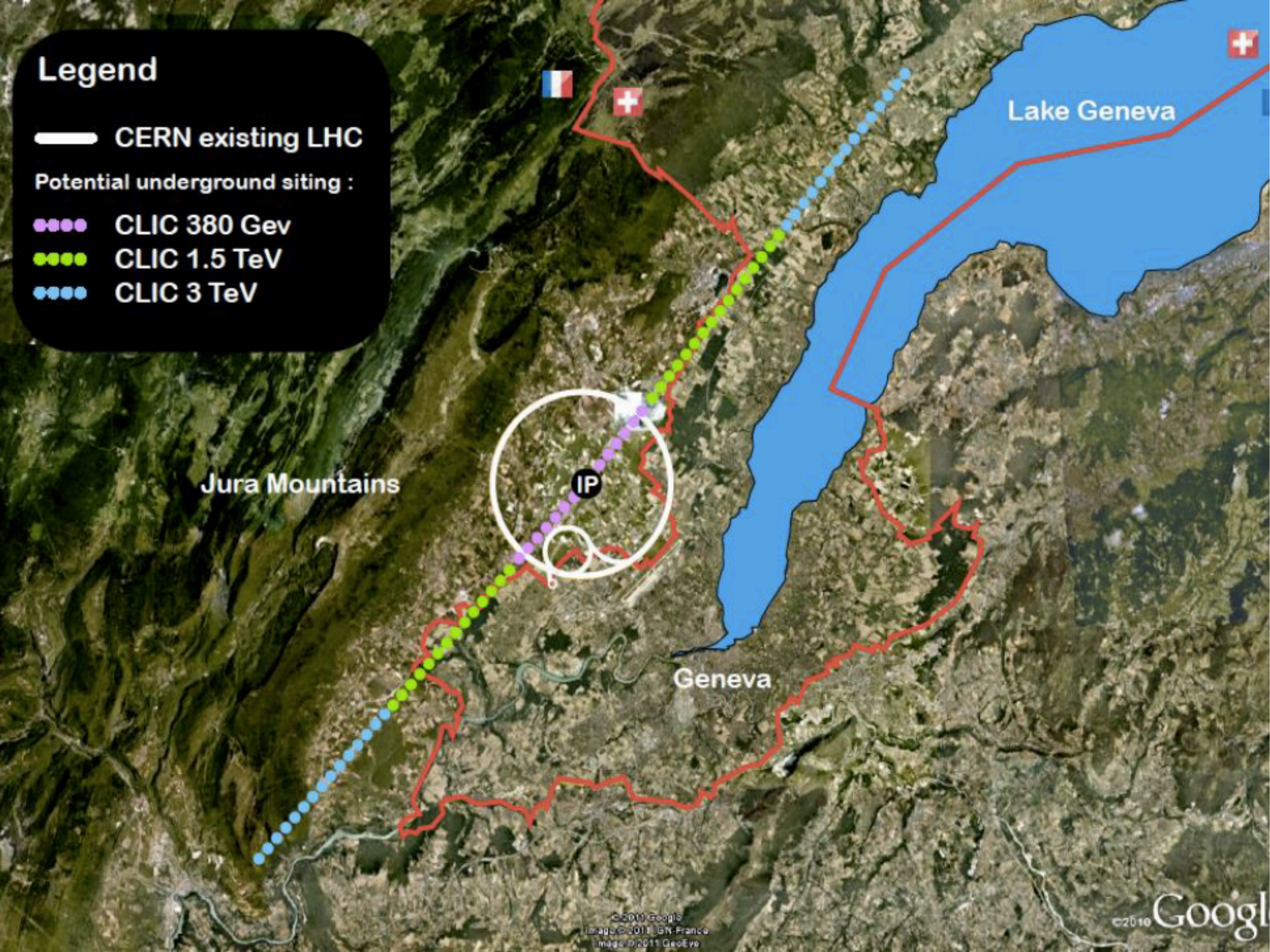


LINEAR COLLIDER COLLABORATION

CLIC layout (3 TeV)

CR	combiner ring
TA	turnaround
DR	damping ring
PDR	predamping ring
BC	bunch compressor
BDS	beam delivery system
IP	interaction point
🟥	dump

1.5 TeV / beam


Legend
CERN existing LHC
Potential underground siting :
CLIC 380 Gev
CLIC 1.5 TeV
CLIC 3 TeV
Lake Geneva
Jura Mountains
IP
Geneva
©2011 Google
Image ©2011 IGN-France
Image ©2011 GeoEye
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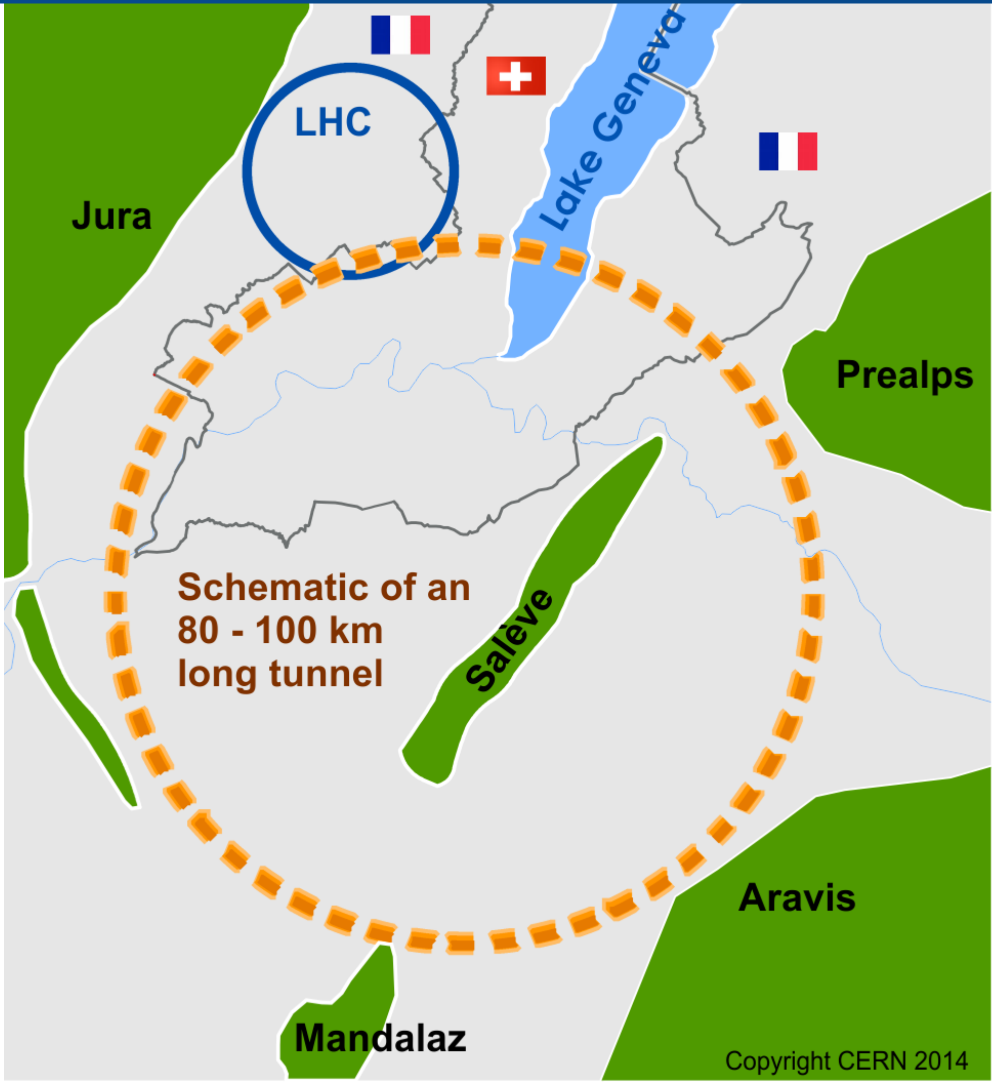
Future Circular Collider Study
Goal: CDR for European Strategy Update 2018/19

International FCC collaboration (CERN as host lab) to study:

- ***pp*-collider (*FCC-hh*)**
  → main emphasis, defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **80-100 km tunnel infrastructure** in Geneva area, site specific
- **e^+e^- collider (*FCC-ee*),** as potential first step
- ***p-e* (*FCC-he*) option,** integration one IP, FCC-hh & ERL
- **HE-LHC** with *FCC-hh* technology



Schematic of an 80 - 100 km long tunnel

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FCC: physics reach in a nutshell

FCC-hh: 100 TeV

- explore directly the 10-50 TeV E-scale
- provide conclusive exploration of EWSB dynamics
- study nature the Higgs potential and EW phase transition
- say final word about heavy WIMP dark matter
- etc.

FCC-ee: 90-350 GeV

- indirect sensitivity to E scales up to O(100 TeV) by measuring most Higgs couplings to O(0.1%), improving the precision of EW parameters measurements by ~20-200, $\Delta M_W < 1$ MeV, $\Delta m_{top} \sim 10$ MeV, etc.
- sensitivity to very-weakly coupled physics (e.g. light, weakly-coupled dark matter)
- etc.

FCC-ep: ~ 3.5 TeV

- unprecedented measurements of PDF and α_s
- new physics: leptoquarks, eeqq contact interactions, etc.
- Higgs couplings (e.g. Hbb to ~ 1%)
- etc.

Machines are complementary and synergetic, e.g. from measurement of ttH/ttZ ratio, and using ttZ coupling and H branching ratio from FCC-ee, FCC-hh can measure ttH to ~ 1%

The challenge is not only the machine…

Detectors R&D :

- Ultra-light, ultra-fast, ultra-granular, rad-hard, low-power Si trackers
- 10^8 channel imaging calorimeters (power consumption and cooling at high-rate machines,..)
- big-volume 5-6 T magnets (~2 x magnetic length and bore of ATLAS and CMS, ~50 GJ stored energy) to reach momentum resolutions of ~10% for p~20 TeV muons

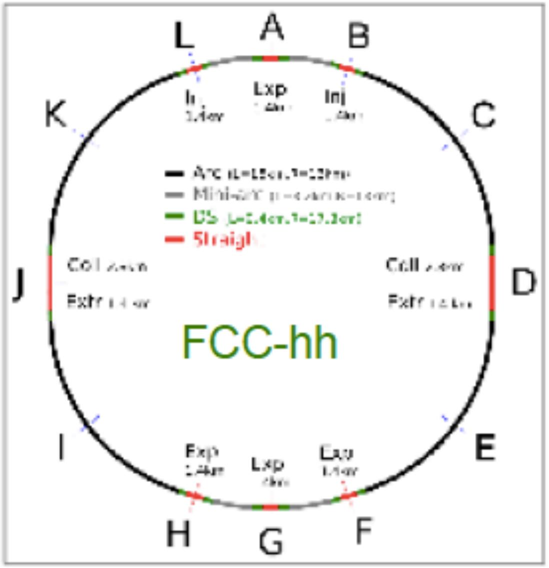
Theory:

- improved theoretical calculations (higher-order EW and QCD corrections) needed to match present and future experimental precision on EW observables, Higgs mass and branching ratios.
- Work together with experiments on model-independent analyses in the framework of Effective Field Theory

hadron collider parameters (*pp*)

parameter	FCC-hh		HE-LHC	(HL) LHC
collision energy cms [TeV]	100		25	14
dipole field [T]	16		16	8.3
circumference [km]	100		27	27
# IP	2 main & 2		2 & 2	2 & 2
beam current [A]	0.5		1.27	(1.12) 0.58
bunch intensity [10^{11}]	1 (0.2)	1 (0.2)	2.5	(2.2) 1.15
bunch spacing [ns]	25 (5)	25 (5)	25 (5)	25
IP $\beta^*_{x,y}$ [m]	1.1	0.3	0.25	(0.15) 0.55
luminosity/IP [10^{34} $cm^{-2}s^{-1}$]	5	30	34	(5) 1
peak #events/bunch crossing	170	1020 (204)	1070 (214)	(135) 27
stored energy/beam [GJ]	8.4		1.4	(0.7) 0.36
synchrotron rad. [W/m/beam]	30		4.1	(0.35) 0.18

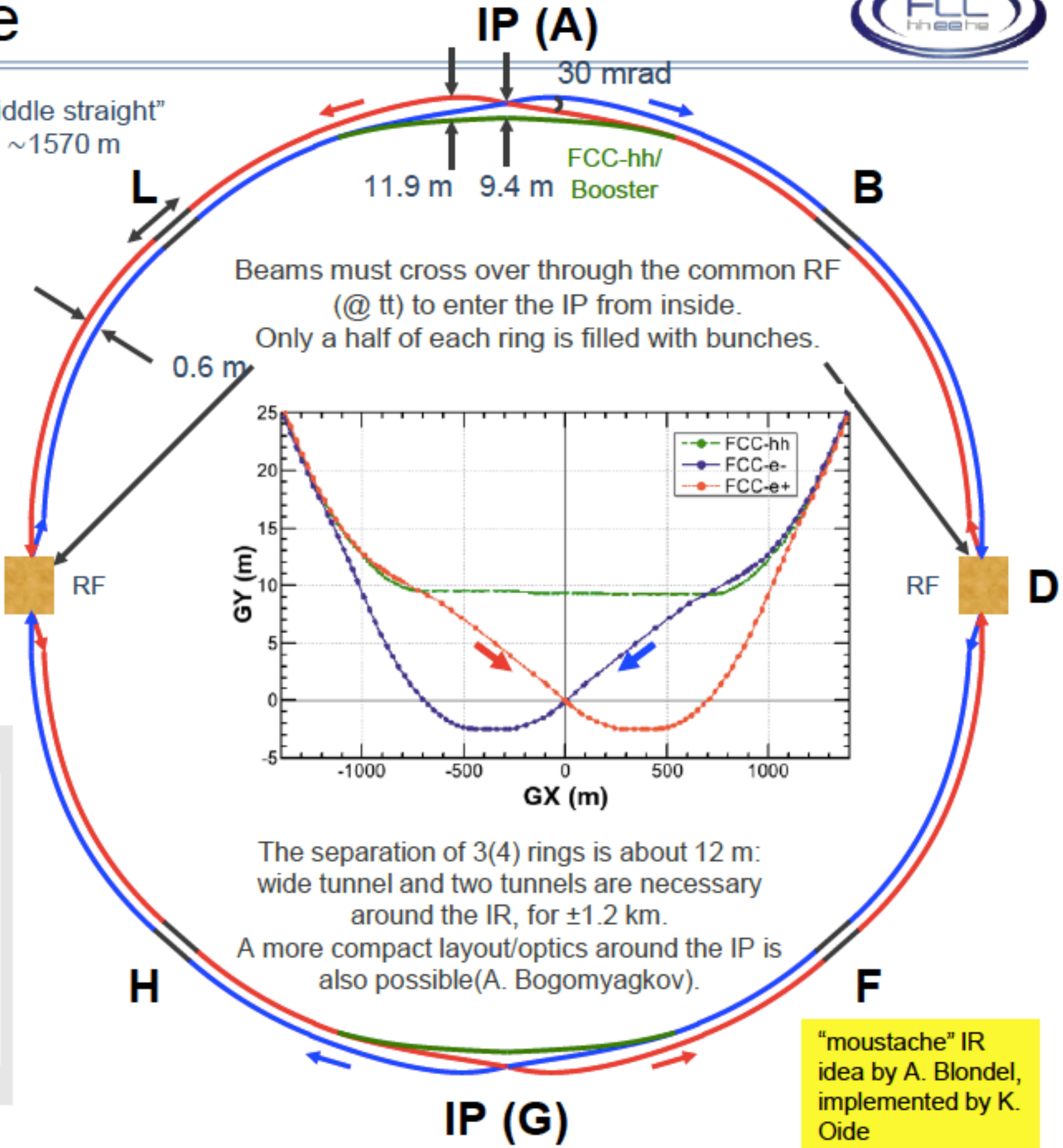
Layout of FCC-ee



“Middle straight”
~1570 m

“90/270 straight”
~4.7 km

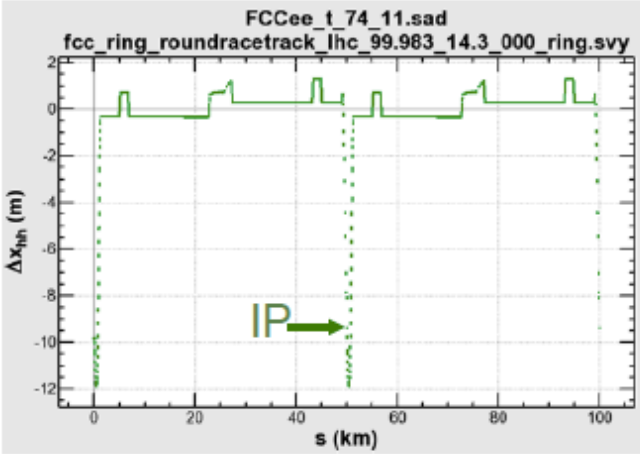
J



Beams must cross over through the common RF (@ tt) to enter the IP from inside.
Only a half of each ring is filled with bunches.

The separation of 3(4) rings is about 12 m: wide tunnel and two tunnels are necessary around the IR, for ±1.2 km.
A more compact layout/optics around the IP is also possible(A. Bogomyagkov).

“moustache” IR idea by A. Blondel, implemented by K. Oide



Relative distance to FCC-hh

In summary

An exciting period in front of us:

- We have finished the inventory of the “known unknown”…
- …but we have a vast space to explore (and a few tantalizing hints to probe)
- We have a solid physics program for the next 15 – 20 years
- In this time period we have to prepare for the next steps, setting directions, technologies and political frames.

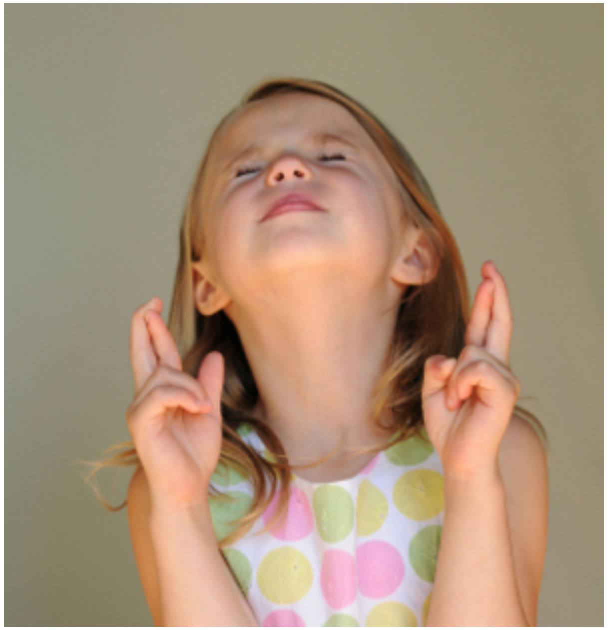
In summary

Experimental results will be dictating the agenda of the field.

We will need:

- Flexibility
- Preparedness
- Visionary global policies

- ...and a bit of luck!



Thank you!

THANK YOU