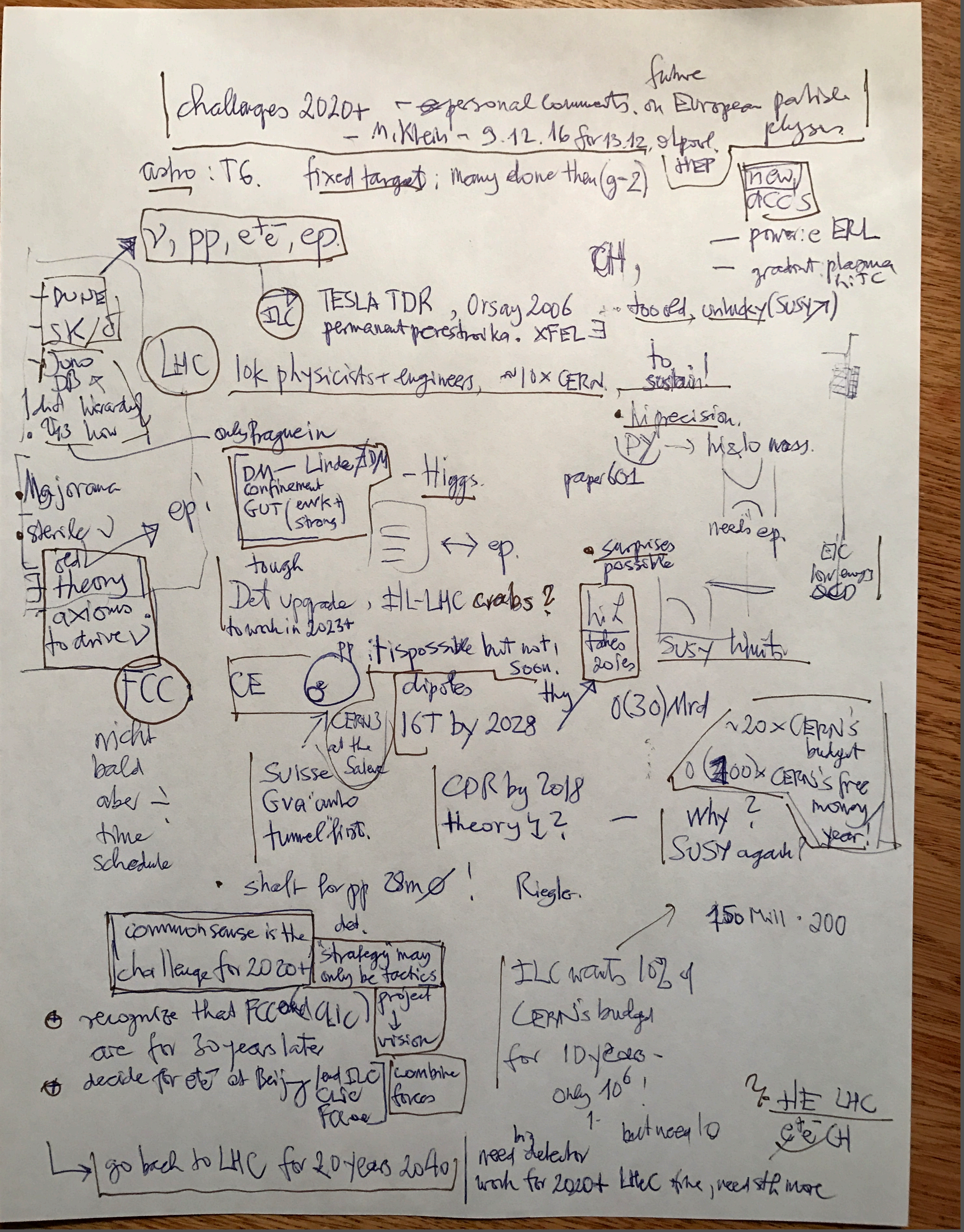


challenges 2020+ – ~~e~~ personal comments. on future European particle physics

– M. Klein – 9.12.16 for 13.12, Lpool, HEP

astro : T6. fixed target ; many done then (g-2)

new accs

– power: e ERL

– gradient: plasma hi JC

ν, pp, e⁺e⁻, ep.

CH,

DUNE

SK / δ

Juno

DB

1 hit hierarchy

θ13 low

ILC TESLA TDR, Orsay 2006 ~~too old~~, unlucky (SUSY ↗)

permanent perestroika. XFEL ∃

LHC 10k physicists + engineers, ~10 × CERN. to sustain!

only Prague in

• hi precision.

PY → hi & lo mass.

• Majorana

• sterile ν

ep

∃ old theory

axions

to drive ν

DM – Linde / ADM

confinement

GUT (ewk + strong)

– Higgs.

paper 601

↔ ep.

needs ep.

• surprises possible

EIC low energy QCD

tough

Det upgrade, HL-LHC crabs?

to work in 2023+

hi L takes 20 yrs

SUSY limits

FCC

nicht bald aber time schedule

CE pp

it is possible but not, soon.

dipoles 16T by 2028

thy

CERN 3 at the Saleve

O(30) Mrd

~20 × CERN's budget

O(~~1~~100) × CERN's free money / year!

Suisse Gva canton tunnel first.

CDR by 2018

theory ↓?

– Why? SUSY again?

• shaft for pp 28m Ø ! Riegler.

det.

~~1~~50 Mill · 200

common sense is the challenge for 2020+

strategy may only be tactics

project ↓ vision

⊕ recognize that FCC ~~and~~ (ILC) are for 30 years later

⊕ decide for e⁺e⁻ at Beijing (and ILC CLIC FCCee)

combine forces

ILC wants 10% of CERN's budget for 10 years – only 10⁶ !

1 but need 10

% HE LHC

e⁺e⁻ CH

↳ go back to LHC for 20 years 2040

need detector (lumi) work for 2020+ LHC time, need sth more

Challenges 2020+

Remarks on the Future of (European) Particle Physics

What may be recommended in 2020?

Max Klein

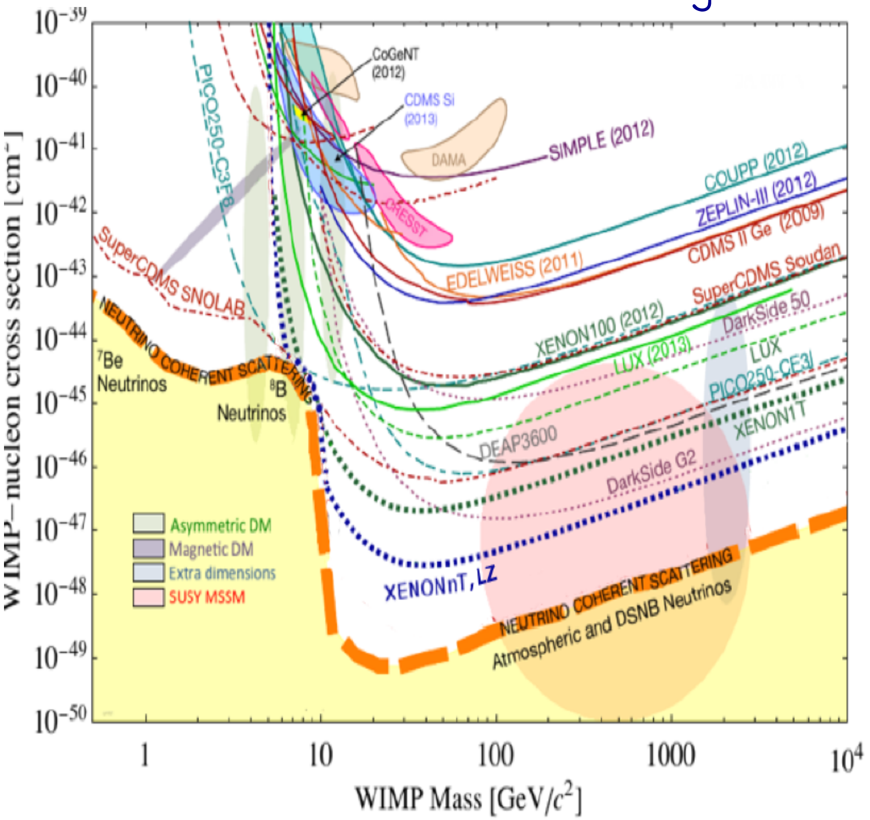
HEP Liverpool, 13.12.2016

Dark Matter

limits by 2022

In this image, dark matter (blue) has become separated from luminous matter (red) in the bullet cluster. (Image courtesy: Chandra)

http://www.interactions.org/cms/?pid=1034004



Direct search experiments

ANAIS, ArDM, ADMX, COUP, CEDEX, PANDA-X, TEXONO, CoGeNT, CDMS, CRESST, DAMA/LIBRA, DARWIN DEAP, DARKSIDE, EDELWEISS, EURECA, FUNK, KIMS, LHC, LZ, PICASSO, SIMPLE, XENON100, XMASS

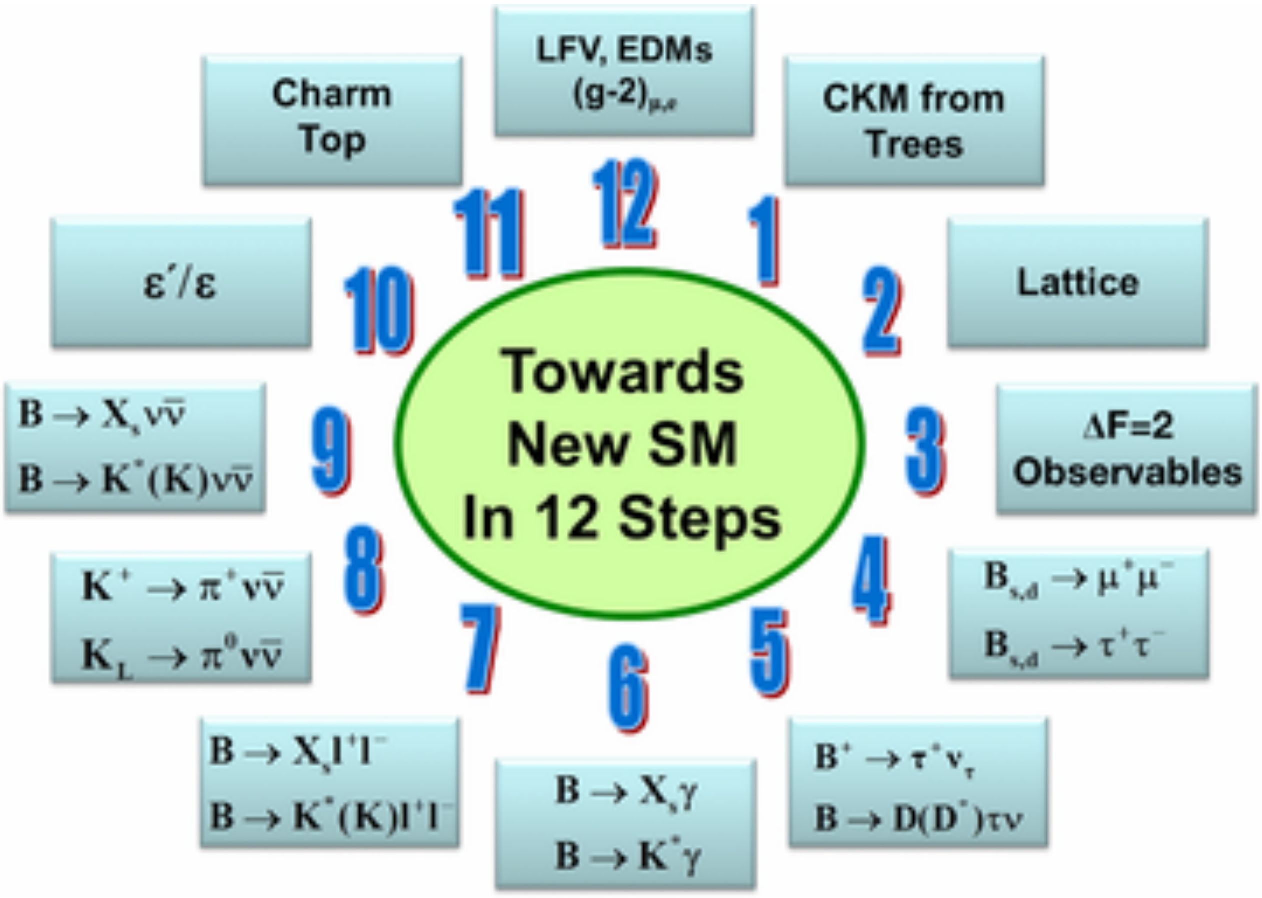
Indirect search experiments

AMS, ALPS, ANTARES, BAIKAL, CTA, FGST-LAT, GAPS, HPS, HESS, ICECUBE, IMAX, MAGIC, PAMELA, SK VERITAS

Ann. Phys. (Berlin) **528**, No. 1–2, 96–101 (2016) / DOI 10.1002/andp.201500103

Flavour physics: Status and perspectives

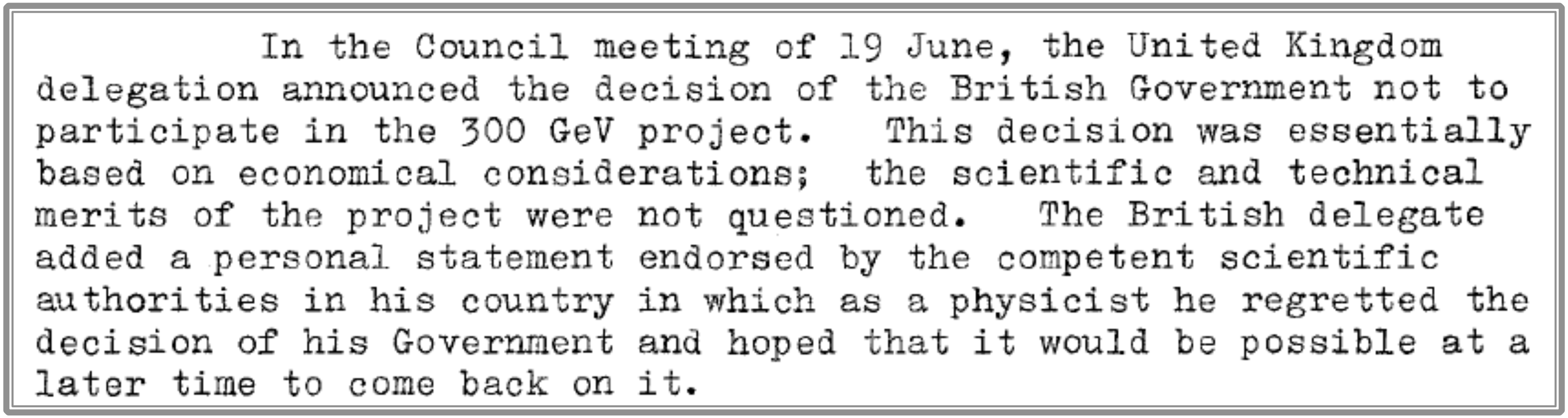
*Andrzej J. Buras**



1st session of CERN Council, 15.2.1952 - Niels Bohr watching us.. → HEP = Grand Challenges

Funding HEP

E.Amaldi to ECFA, 10.7.1968

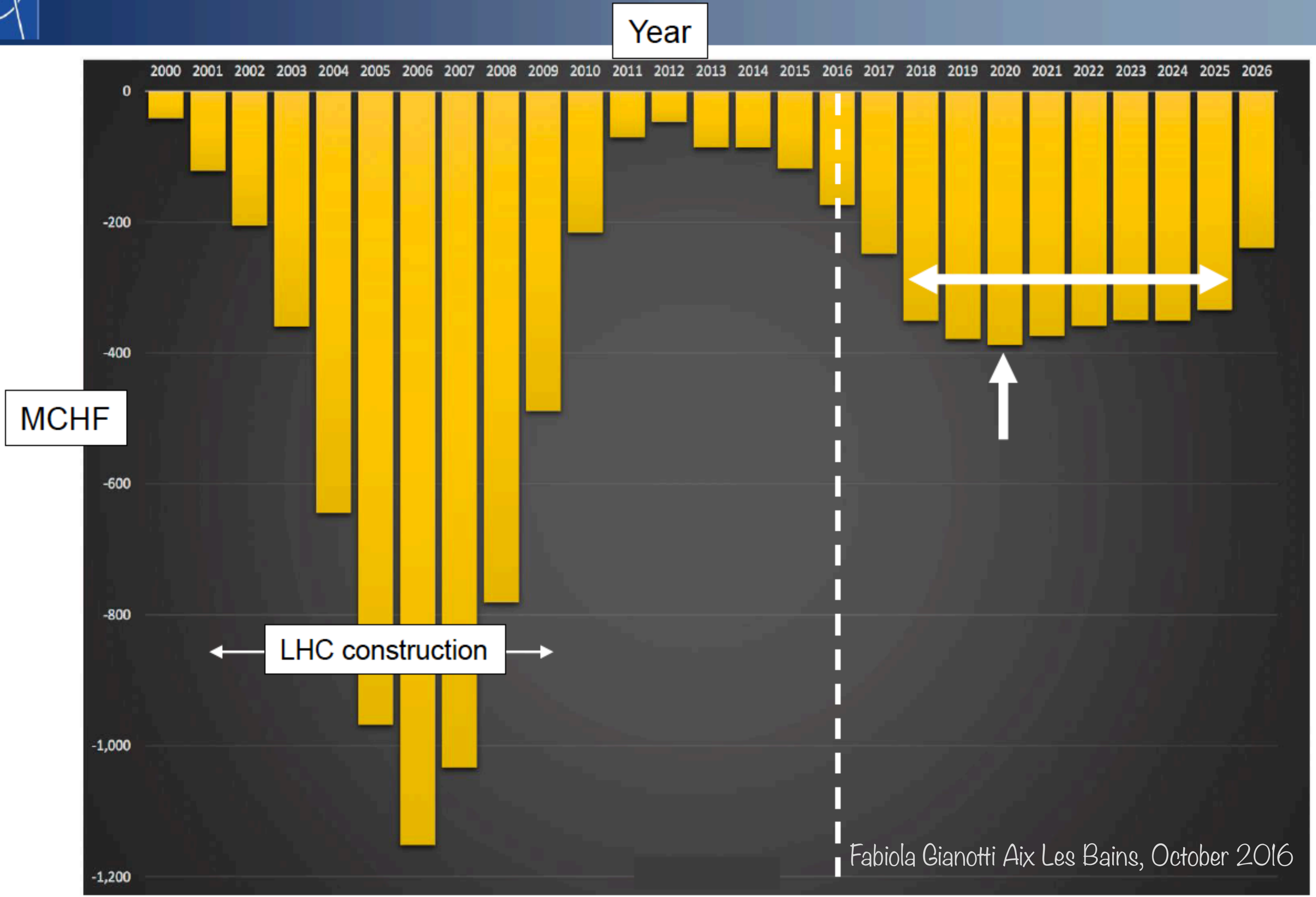


In the Council meeting of 19 June, the United Kingdom delegation announced the decision of the British Government not to participate in the 300 GeV project. This decision was essentially based on economical considerations; the scientific and technical merits of the project were not questioned. The British delegate added a personal statement endorsed by the competent scientific authorities in his country in which as a physicist he regretted the decision of his Government and hoped that it would be possible at a later time to come back on it.

convincing us and the academic and public society – necessary, but not always sufficient

here Brexit could be avoided… (note that CERN is NOT an EU Laboratory)

Cumulative Budget Deficit (CBD) vs time

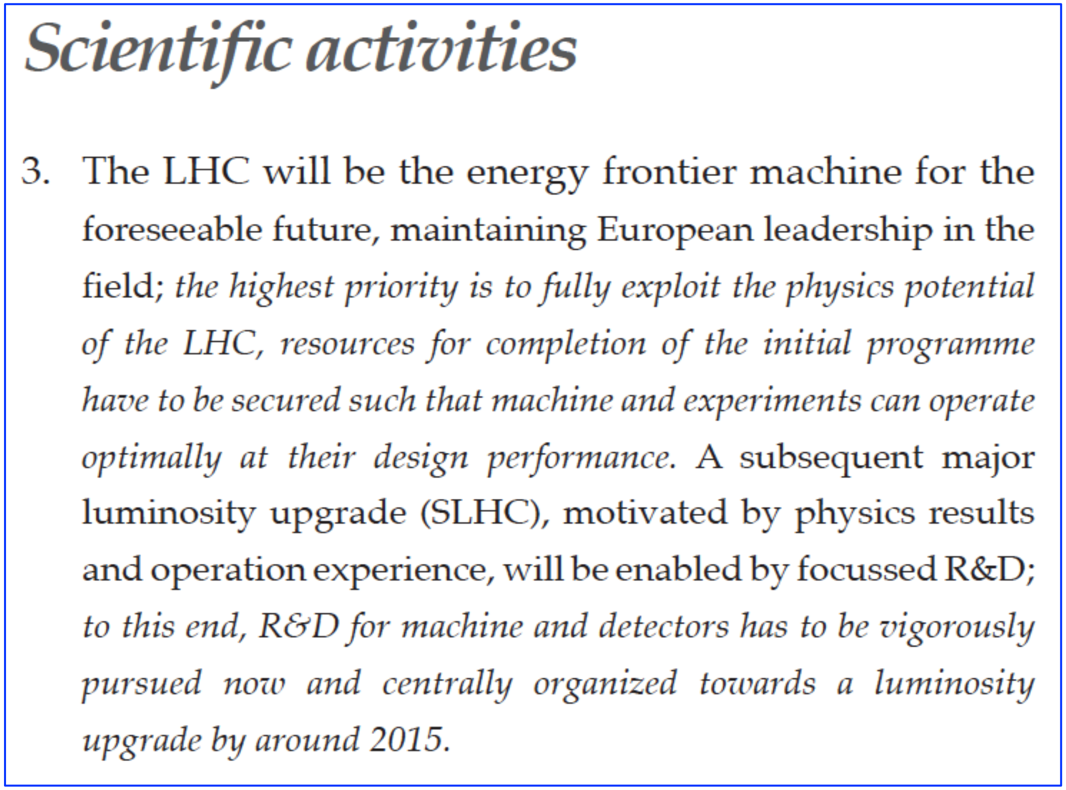


Fabiola Gianotti Aix Les Bains, October 2016

CERN's free annual money is O(100) Million SF – it is constrained by HL LHC A 10 Billion investment needs 100 years to be financed out of that budget. ILC dreams about 10% of the CERN budget for construction, CLIC and FCC O(10-20) Billion SF

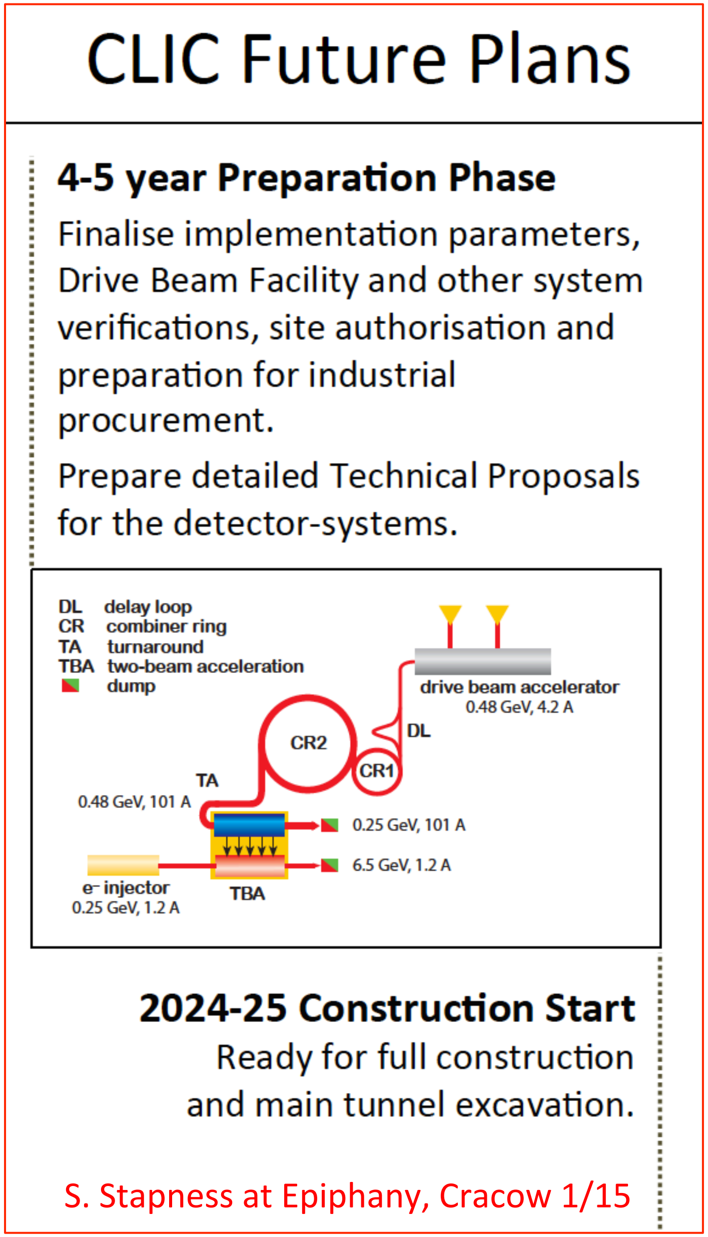
Time Projections...

The Orsay/Zeuthen 2006/7 HEP strategy predicted the HL LHC Upgrade to happen in 2015, it was wrong by ten years, ten years before the expected event!



Scientific activities

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.*



CLIC Future Plans

4-5 year Preparation Phase

Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

Prepare detailed Technical Proposals for the detector-systems.

2024-25 Construction Start

Ready for full construction and main tunnel excavation.

S. Stapness at Epiphany, Cracow 1/15

A challenge for the 2020 strategy: become realistic, may stay optimistic, but don't be wrong another time

Next decades

Rolf Heuer at
Aix Les Bains
1. 10. 2013

Road beyond Standard Model

LHC results vital to guide the way at the energy frontier

At the energy frontier through synergy of

hadron - hadron colliders (LHC, (V)HE-LHC?)

lepton - hadron colliders (LHeC ??)

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

The Particle Physics Potential

- Higgs Physics
  - Higgs Boson Phenomenology
  - Study of the Higgs Boson Profile
  - Study of SUSY Higgs Bosons
  - Non SUSY Extensions of the SM

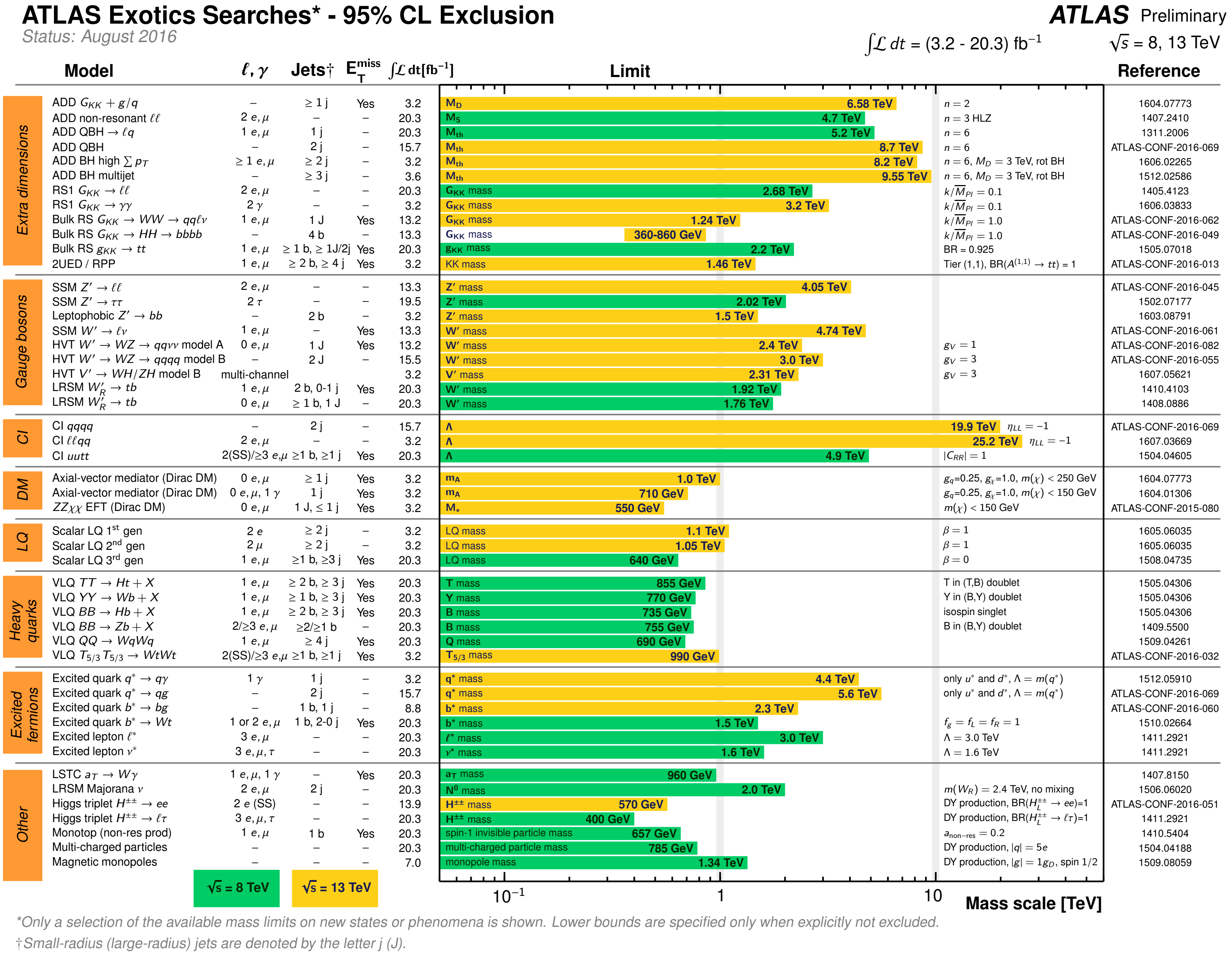
- Supersymmetry
  - MSSM
  - Sleptons
  - Charginos and Neutralinos
  - Stop Particles
  - The Minimal Supergravity Model mSUGRA
  - Gauge Mediated SUSY Breaking
  - Anomaly Mediated SUSY Breaking
  - SUSY with R-Parity Violation

- Alternative Theories
  - Extra Dimensions
  - Strong Electroweak Symmetry Breaking
  - Compositness

- Precision Measurements
  - Electroweak Gauge Bosons
  - Extended Gauge Theories
  - Top Quark Physics
  - QCD

of the ILC as seen in 2001

Albrecht Wagner, ECFA Plenary, July 2001



ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 20.3)\ \text{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt[\text{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	🟨 M_D 6.58 TeV	$n = 2$	1604.07773
	ADD non-resonant $\ell\ell$	2 e, μ	–	–	20.3	🟩 M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\rightarrow \ell q$	1 e, μ	1 j	–	20.3	🟩 M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	15.7	🟨 M_{th} 8.7 TeV	$n = 6$	ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	🟨 M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	🟨 M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \rightarrow \ell\ell$	2 e, μ	–	–	20.3	🟩 G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2 γ	–	–	3.2	🟨 G_{KK} mass 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$	1606.03833
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	1 e, μ	1 J	Yes	13.2	🟨 G_{KK} mass 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbb$	–	4 b	–	13.3	🟨 G_{KK} mass 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-049
	Bulk RS $g_{KK} \rightarrow tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	🟩 g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 4 j	Yes	3.2	🟨 KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \rightarrow tt$) = 1	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e, μ	–	–	13.3	🟨 Z' mass 4.05 TeV		ATLAS-CONF-2016-045
	SSM $Z' \rightarrow \tau\tau$	2 τ	–	–	19.5	🟩 Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \rightarrow bb$	–	2 b	–	3.2	🟨 Z' mass 1.5 TeV		1603.08791
	SSM $W' \rightarrow \ell\nu$	1 e, μ	–	Yes	13.3	🟨 W' mass 4.74 TeV		ATLAS-CONF-2016-061
	HVT $W' \rightarrow WZ \rightarrow qq\nu\nu$ model A	0 e, μ	1 J	Yes	13.2	🟨 W' mass 2.4 TeV	$g_V = 1$	ATLAS-CONF-2016-082
	HVT $W' \rightarrow WZ \rightarrow qqqq$ model B	–	2 J	–	15.5	🟨 W' mass 3.0 TeV	$g_V = 3$	ATLAS-CONF-2016-055
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel			3.2	🟨 V' mass 2.31 TeV	$g_V = 3$	1607.05621
	LRSM $W'_R \rightarrow tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	🟩 W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \rightarrow tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	🟩 W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	15.7	🟨 Λ 19.9 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	2 e, μ	–	–	3.2	🟨 Λ 25.2 TeV	$\eta_{LL} = -1$	1607.03669
	CI $uutt$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	20.3	🟩 Λ 4.9 TeV	$\lvert C_{RR}\rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	≥ 1 j	Yes	3.2	🟨 m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 250$ GeV	1604.07773
	Axial-vector mediator (Dirac DM)	0 e, μ, 1 γ	1 j	Yes	3.2	🟨 m_A 710 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 150$ GeV	1604.01306
	$ZZ\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	🟨 M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	🟨 LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	🟨 LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥1 b, ≥3 j	Yes	20.3	🟩 LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \rightarrow Ht + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \rightarrow Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	🟩 Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \rightarrow Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \rightarrow Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	🟩 B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \rightarrow WqWq$	1 e, μ	≥ 4 j	Yes	20.3	🟩 Q mass 690 GeV		1509.04261
	VLQ $T_{5/3} T_{5/3} \rightarrow WtWt$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	3.2	🟨 $T_{5/3}$ mass 990 GeV		ATLAS-CONF-2016-032
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1 γ	1 j	–	3.2	🟨 q^* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \rightarrow qg$	–	2 j	–	15.7	🟨 q^* mass 5.6 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2016-069
	Excited quark $b^* \rightarrow bg$	–	1 b, 1 j	–	8.8	🟨 b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \rightarrow Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	🟩 b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	🟩 ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	🟩 ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	🟩 a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	🟩 N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow ee$	2 e (SS)	–	–	13.9	🟨 $H^{\pm\pm}$ mass 570 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow ee$)=1	ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	3 e, μ, τ	–	–	20.3	🟩 $H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	🟩 spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	🟩 multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	🟩 monopole mass 1.34 TeV	DY production, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

🟩 $\sqrt{s}$ = 8 TeV

🟨 $\sqrt{s}$ = 13 TeV

*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

†Small-radius (large-radius) jets are denoted by the letter j (J).

The LHC has not seen any sign of fundamentally new physics in the TeV region, besides the Higgs (yet)

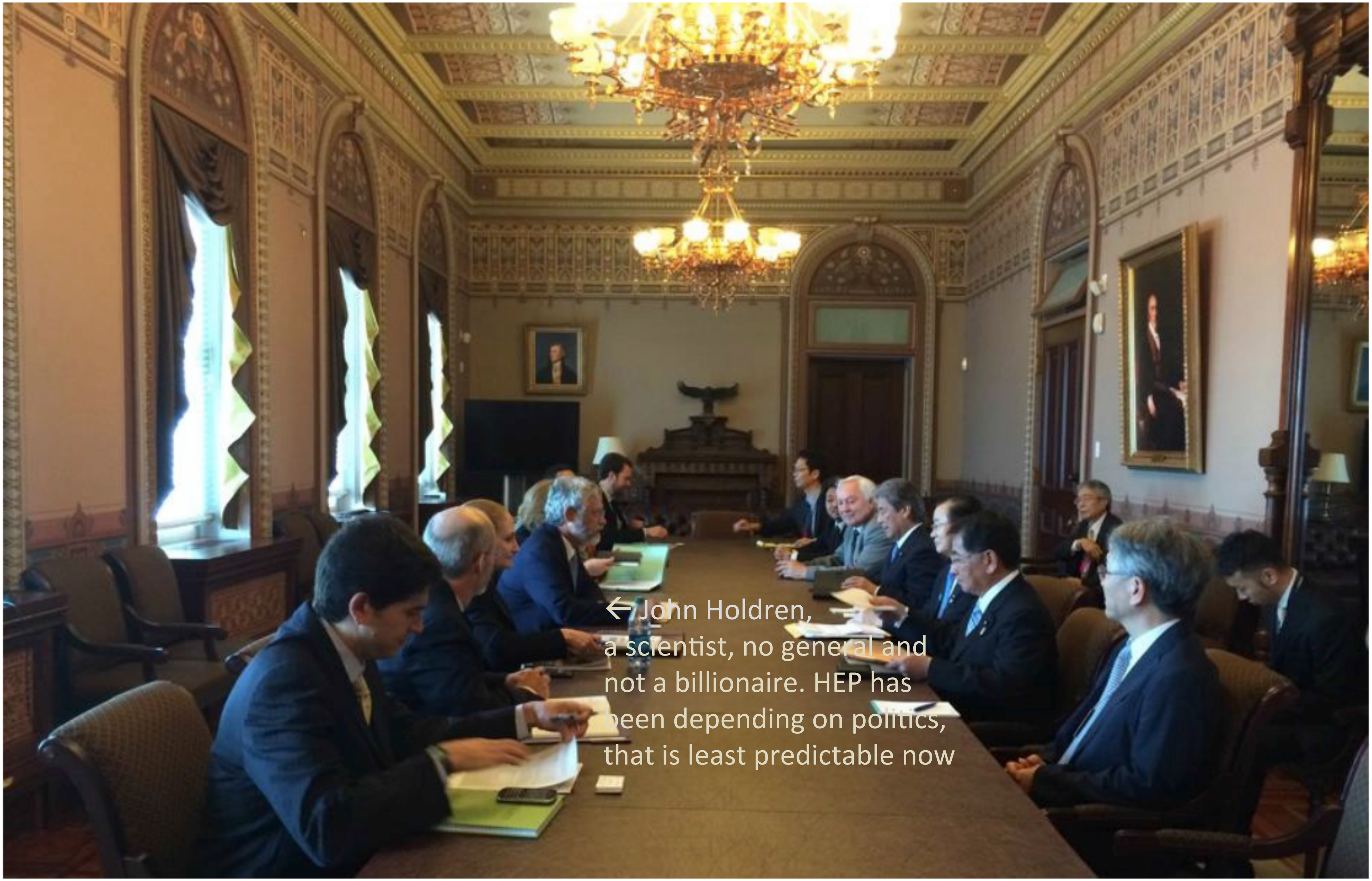
The Particle Physics Potential

- Higgs Physics
  - Higgs Boson Phenomenology
  - Study of the Higgs Boson Profile

- Precision Measurements
  - Electroweak Gauge Bosons
  - Extended Gauge Theories
  - Top Quark Physics
  - QCD

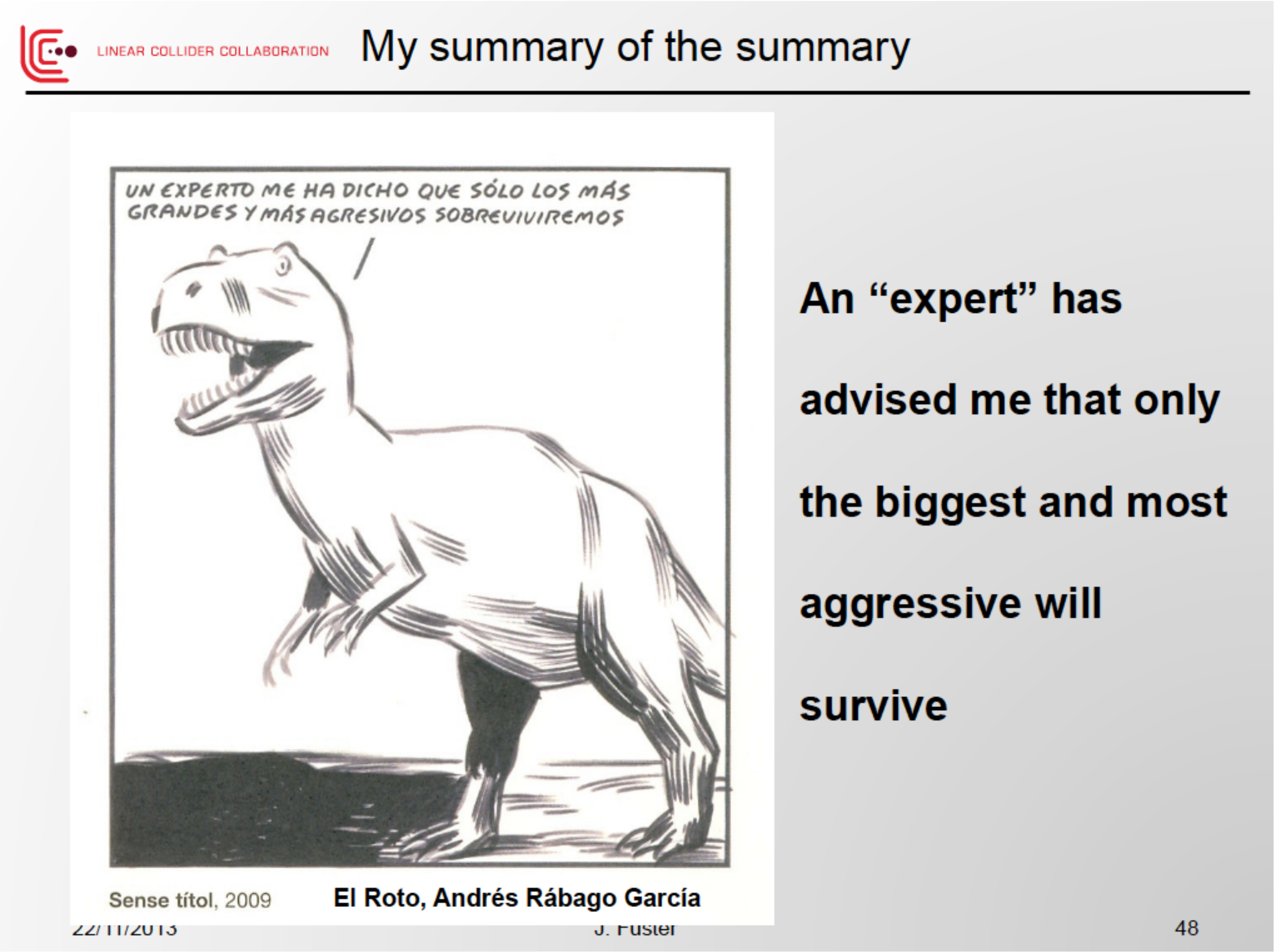
of the ILC as seen in 2016

July 23, 2014, White House, Eisenhower Executive Office Building



← John Holdren, a scientist, no general and not a billionaire. HEP has been depending on politics, that is least predictable now

Visit of Japanese Diet member+ science delegation in April 2015 to DC, recent visit to DoE, ..



LINEAR COLLIDER COLLABORATION

My summary of the summary

Sense títol, 2009 **El Roto, Andrés Rábago García**

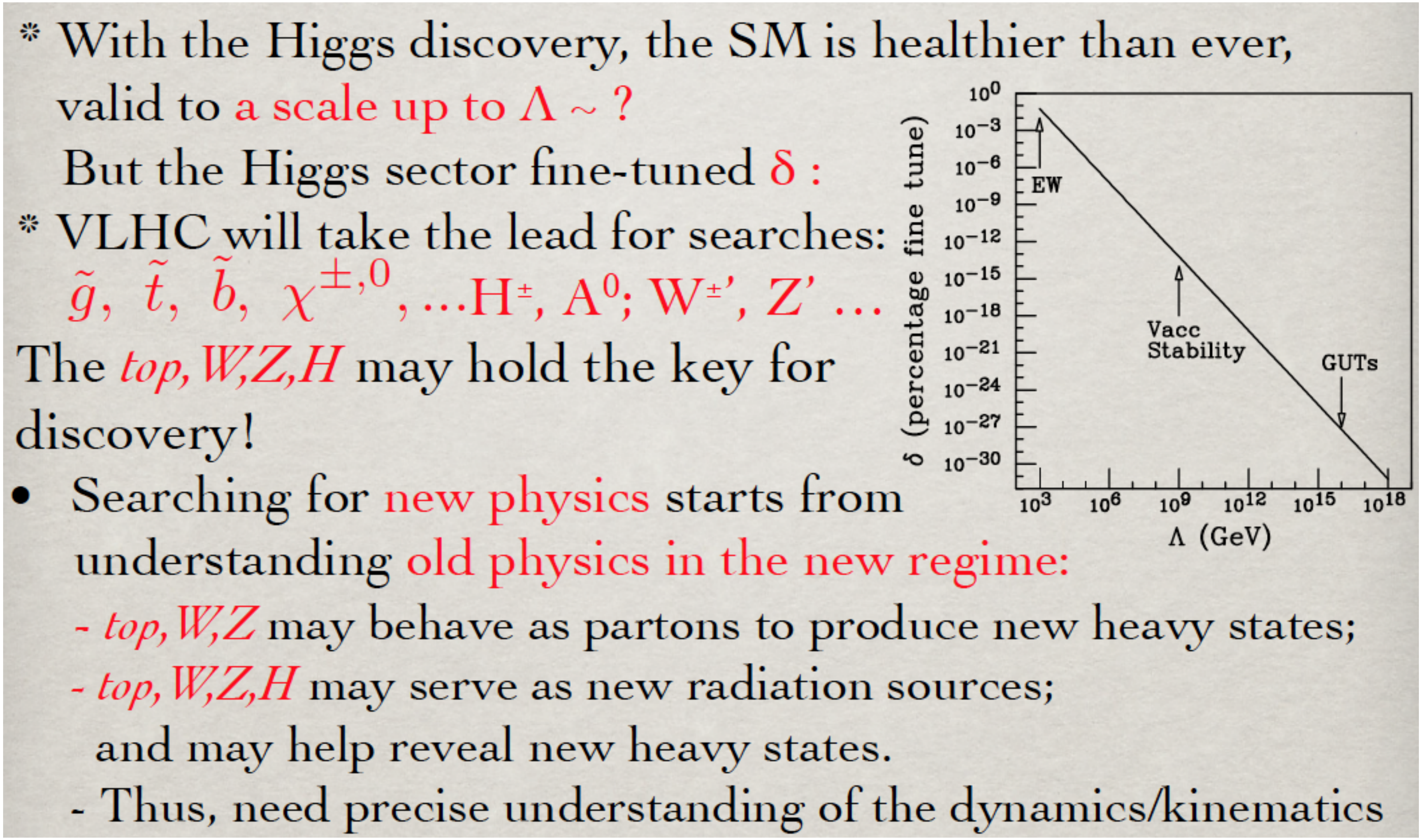
An "expert" has advised me that only the biggest and most aggressive will survive

22/11/2013 J. Fuster 48

Plenary ECFA talk by Juan Fuster, November 2013 at CERN, on the Linear Collider

JF: ECFA 11/2016: Recommendations to MEXT not before 2018 ...

Future HEP on one page



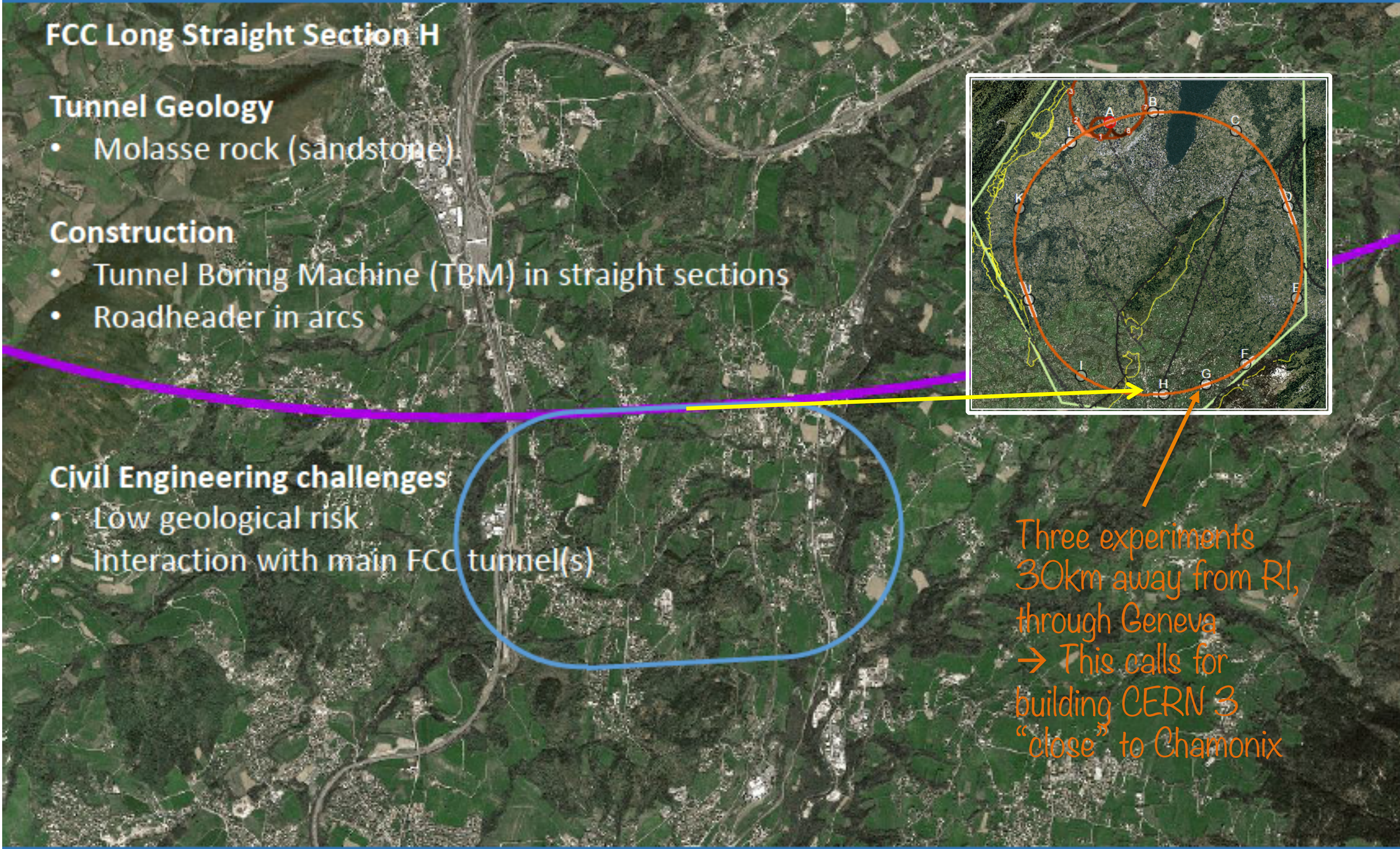
- With the Higgs discovery, the SM is healthier than ever, valid to a scale up to $\Lambda \sim$?
  But the Higgs sector fine-tuned δ :
- VLHC will take the lead for searches:
  $\tilde{g},\ \tilde{t},\ \tilde{b},\ \chi^{\pm,0}$, …$H^{\pm}$, A^0; $W^{\pm}$', Z' …

The *top, W,Z,H* may hold the key for discovery!

- Searching for new physics starts from understanding old physics in the new regime:
  - *top, W,Z* may behave as partons to produce new heavy states;
  - *top, W,Z,H* may serve as new radiation sources; and may help reveal new heavy states.
  - Thus, need precise understanding of the dynamics/kinematics

FCC-he Civil Engineering

FCC-he Point H



FCC Long Straight Section H

Tunnel Geology

- Molasse rock (sandstone)

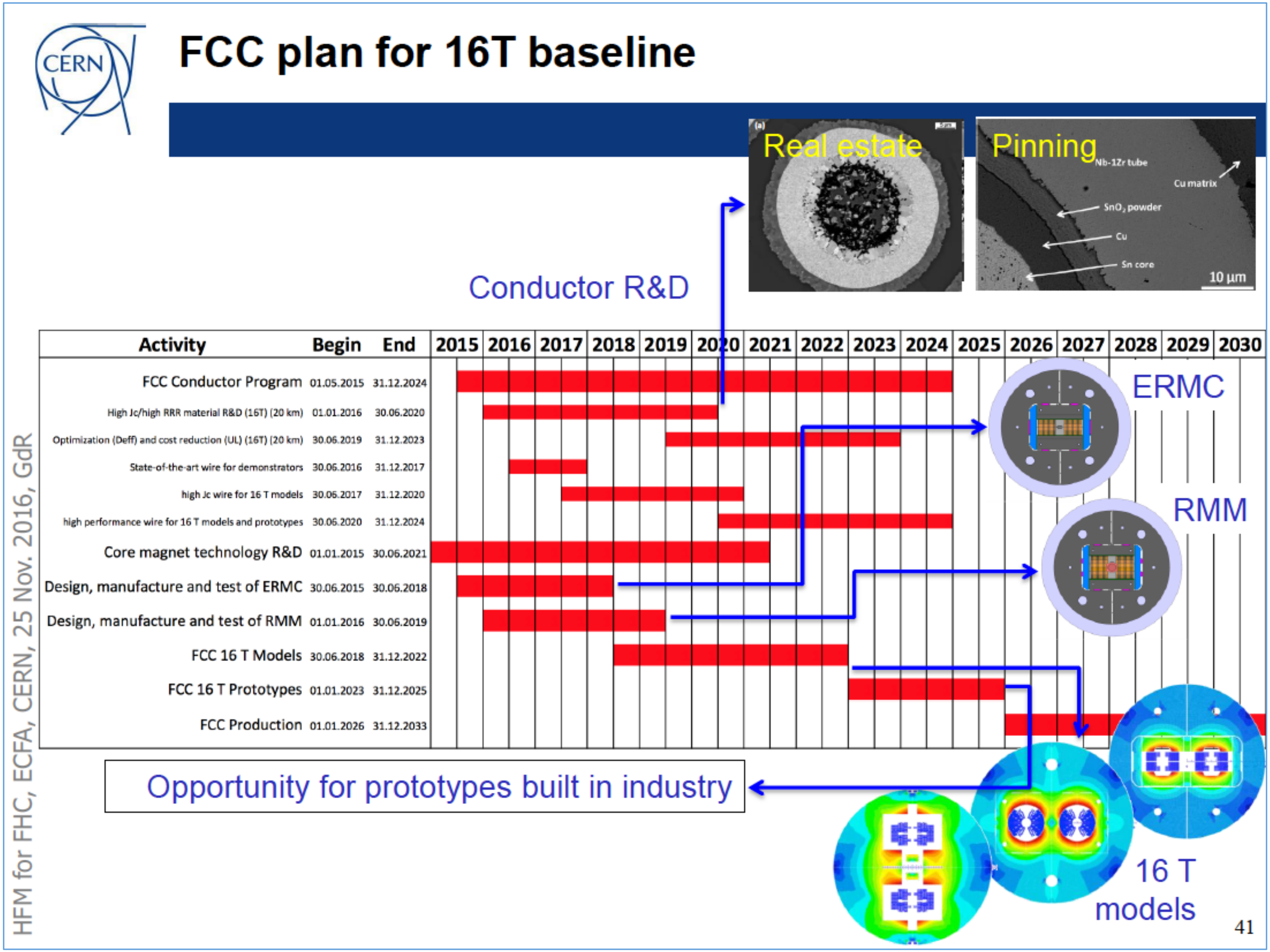
Construction

- Tunnel Boring Machine (TBM) in straight sections
- Roadheader in arcs

Civil Engineering challenges

- Low geological risk
- Interaction with main FCC tunnel(s)

Three experiments 30km away from RI, through Geneva
→ This calls for building CERN 3 "close" to Chamonix



FCC plan for 16T baseline

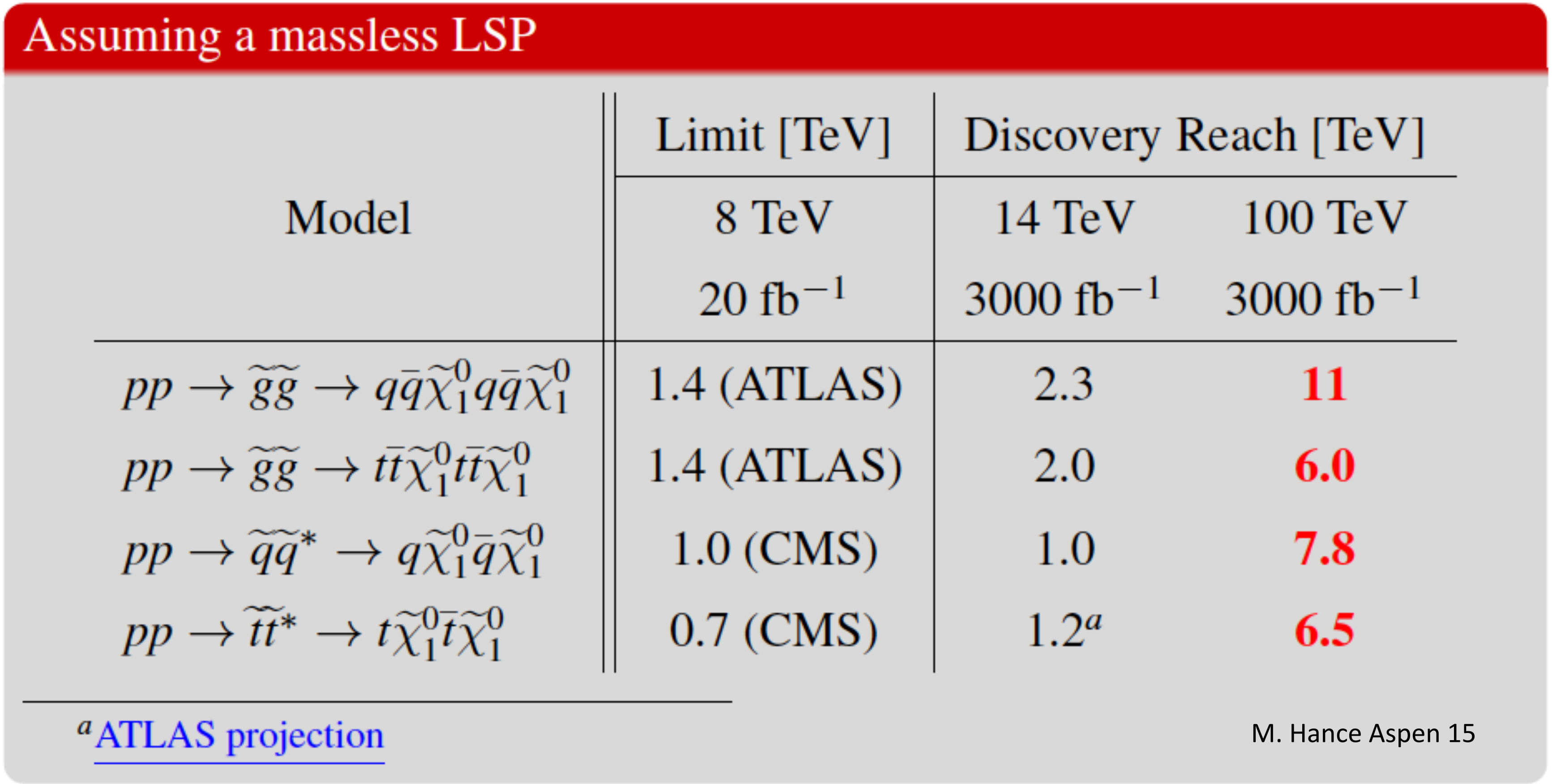
Conductor R&D

Activity	Begin	End
FCC Conductor Program	01.05.2015	31.12.2024
High Jc/high RRR material R&D (16T) (20 km)	01.01.2016	30.06.2020
Optimization (Deff) and cost reduction (UL) (16T) (20 km)	30.06.2019	31.12.2023
State-of-the-art wire for demonstrators	30.06.2016	31.12.2017
high Jc wire for 16 T models	30.06.2017	31.12.2020
high performance wire for 16 T models and prototypes	30.06.2020	31.12.2024
Core magnet technology R&D	01.01.2015	30.06.2021
Design, manufacture and test of ERMC	30.06.2015	30.06.2018
Design, manufacture and test of RMM	01.01.2016	30.06.2019
FCC 16 T Models	30.06.2018	31.12.2022
FCC 16 T Prototypes	01.01.2023	31.12.2025
FCC Production	01.01.2026	31.12.2033

Opportunity for prototypes built in industry

SC High Field Dipoles, 16 T NbSn$_3$ **(6k tons)** are envisaged to be available for industrial production 2028+

Future Searches for SUSY



Assuming a massless LSP

Model	Limit [TeV]	Discovery Reach [TeV]	
	8 TeV	14 TeV	100 TeV
	20 fb^{-1}	3000 fb^{-1}	3000 fb^{-1}
$pp \to \tilde{g}\tilde{g} \to q\bar{q}\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$	1.4 (ATLAS)	2.3	**11**
$pp \to \tilde{g}\tilde{g} \to t\bar{t}\tilde{\chi}_1^0 t\bar{t}\tilde{\chi}_1^0$	1.4 (ATLAS)	2.0	**6.0**
$pp \to \tilde{q}\tilde{q}^* \to q\tilde{\chi}_1^0 \bar{q}\tilde{\chi}_1^0$	1.0 (CMS)	1.0	**7.8**
$pp \to \tilde{t}\tilde{t}^* \to t\tilde{\chi}_1^0 \bar{t}\tilde{\chi}_1^0$	0.7 (CMS)	1.2[a]	**6.5**

---

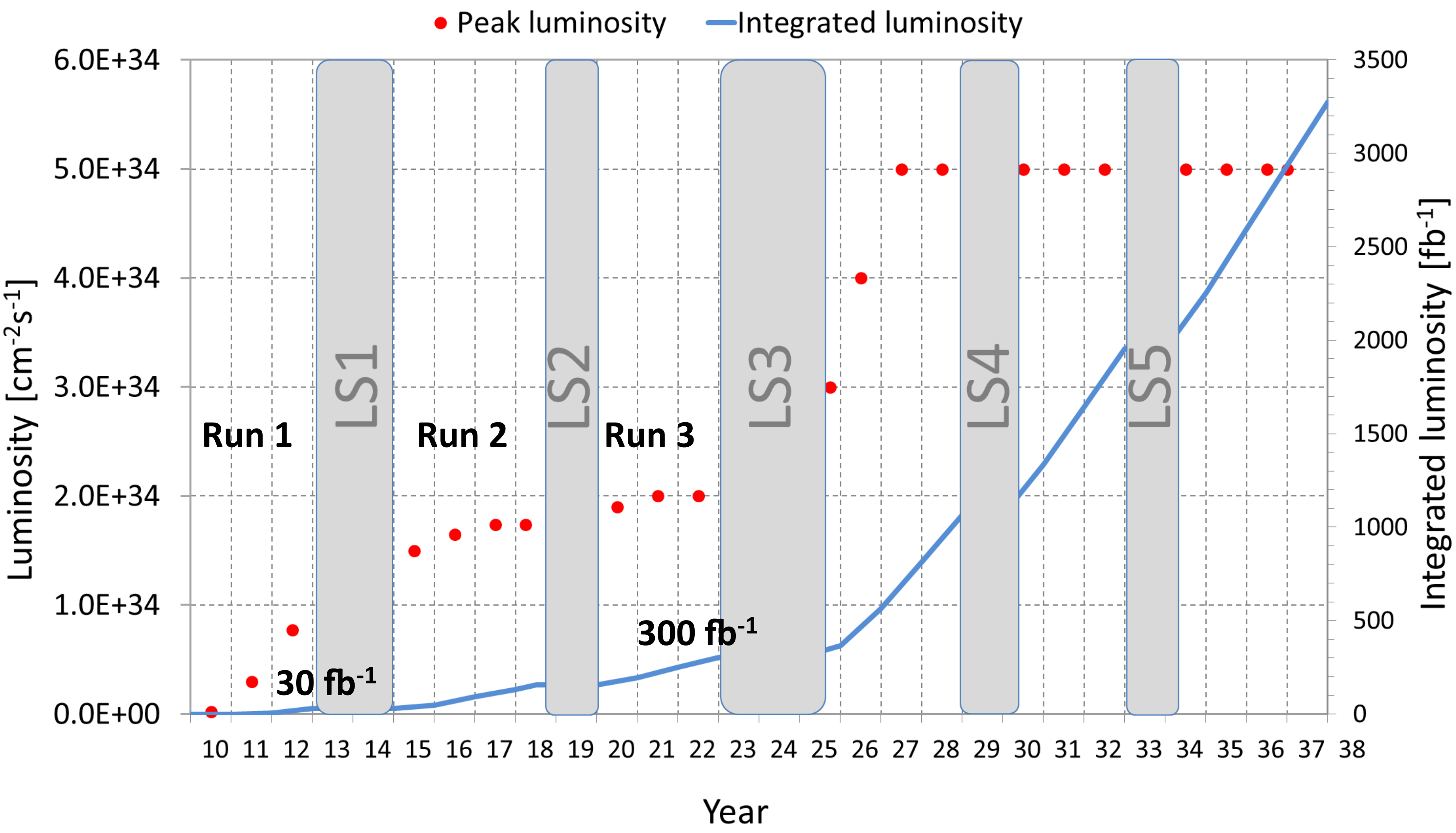
[a] ATLAS projection

M. Hance Aspen 15

WE look for new symmetries. SUSY is too beautiful to not exist but it is broken heavier and heavier

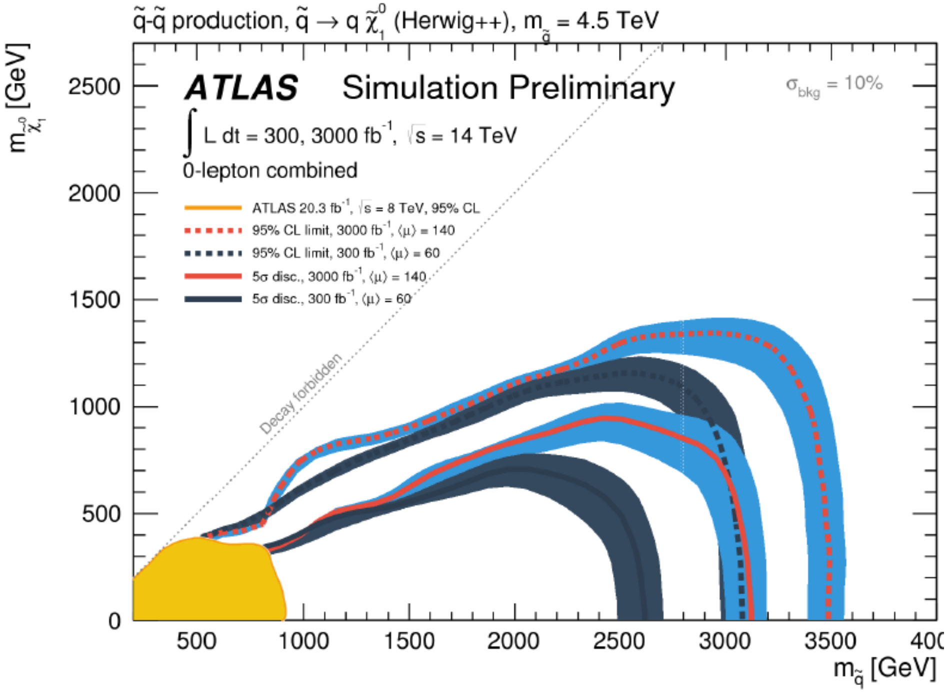
For the FCC to be built we need overriding reasons which the society can accept for the project to go ahead. Magnets and theory are the main challenges of the FCC, besides, at CERN, a tunnel below Lac Leman (Gotthard: 92-16), the funding and the future of the EU ...

Long Term Planning of the LHC Operation -2037+



F. Bordry at the FCC Workshop at Washington DC March 2015

Luminosity Upgrade – SUSY?



5σ up to ~3TeV squarks

5σ up to ~1.2 TeV stops

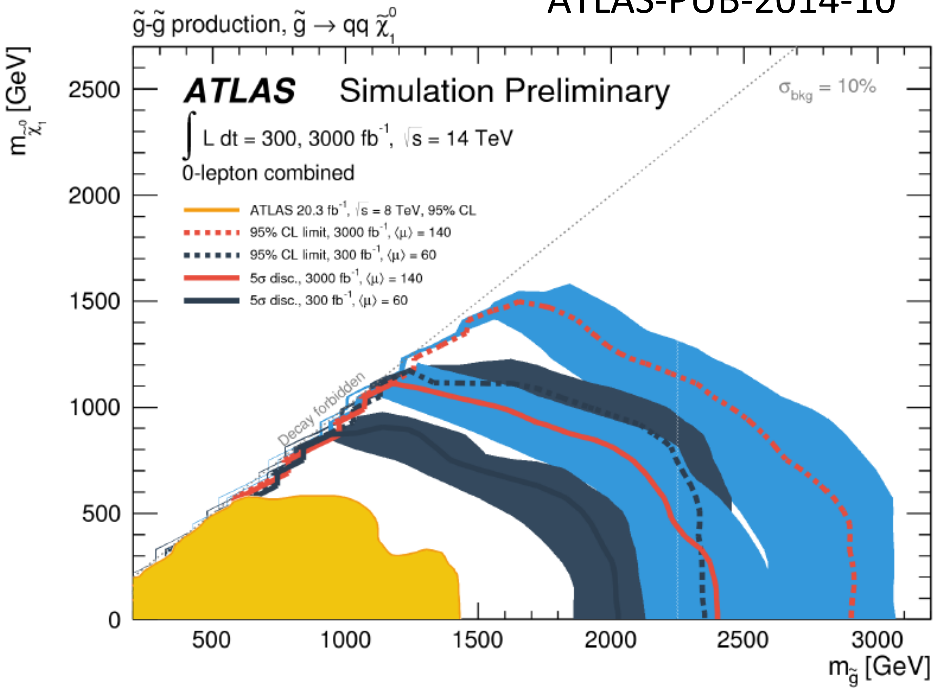
5σ up to ~1.3 TeV sbottoms

@ HL-LHC

5σ up to ~2.5TeV gluinos

@ HL-LHC

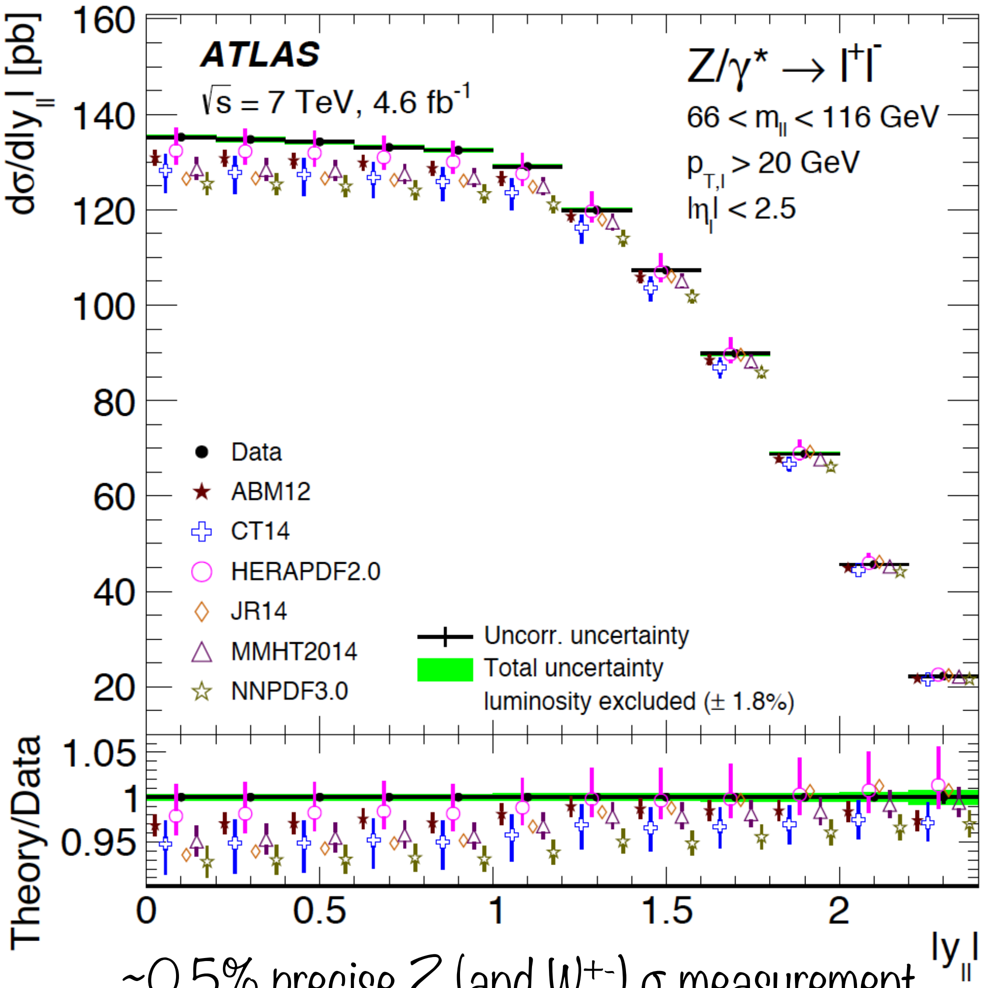
ATLAS-PUB-2014-10



cf Flera Rizatdinova at this workshop

Note that RUN 2 is for 100 fb^{-1} until LS2. Searches need **energy**, clarity and luminosity

High Precision on ATLAS



~0.5% precise Z (and W⁺⁻) σ measurement

Interpretation theory limited

arXiv:1612.03016 (yesterday, 12.12.16)

Our first
W mass
result, still
embargoed

cf Uta's talk

CERN Seminar, 13.12.2013

Hard to beat in HL-LHC Phase

QCD - Developments and Discoveries

AdS/CFT

Instantons

Odderons

Non pQCD

QGP

N^kLO

Resummation

Saturation and BFKL

Non-conventional PDFs …

Breaking of Factorisation

Free Quarks

Unconfined Color

New kind of coloured matter

Quark substructure

New symmetry embedding QCD

QCD may break .. (Quigg DIS13)

QCD is the richest part of the Standard Model Gauge Field Theory and will (have to) be developed much further, on its own and as background.

A New Era of Particle Physics

4.7.2012 greeting Melbourne from CERN

“The Higgs: So simple and yet so unnatural” G.Altarelli,arXiv:1308.0545

Future Higgs Physics – Key at HL- LHC

ATLAS LHC ATLAS HL-LHC LHeC

Mass

Width

Spin-Parity

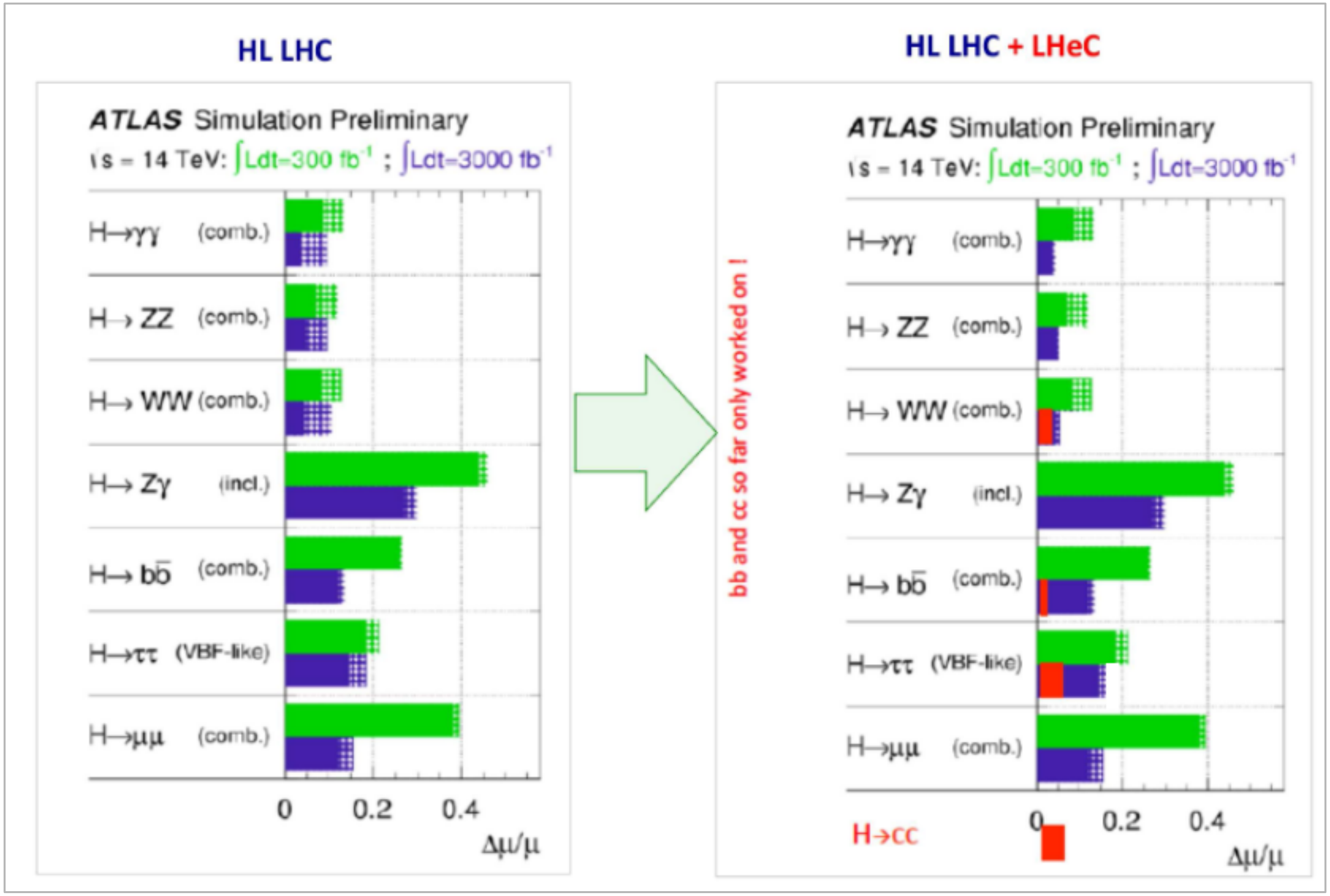
Couplings

Exotic Decays

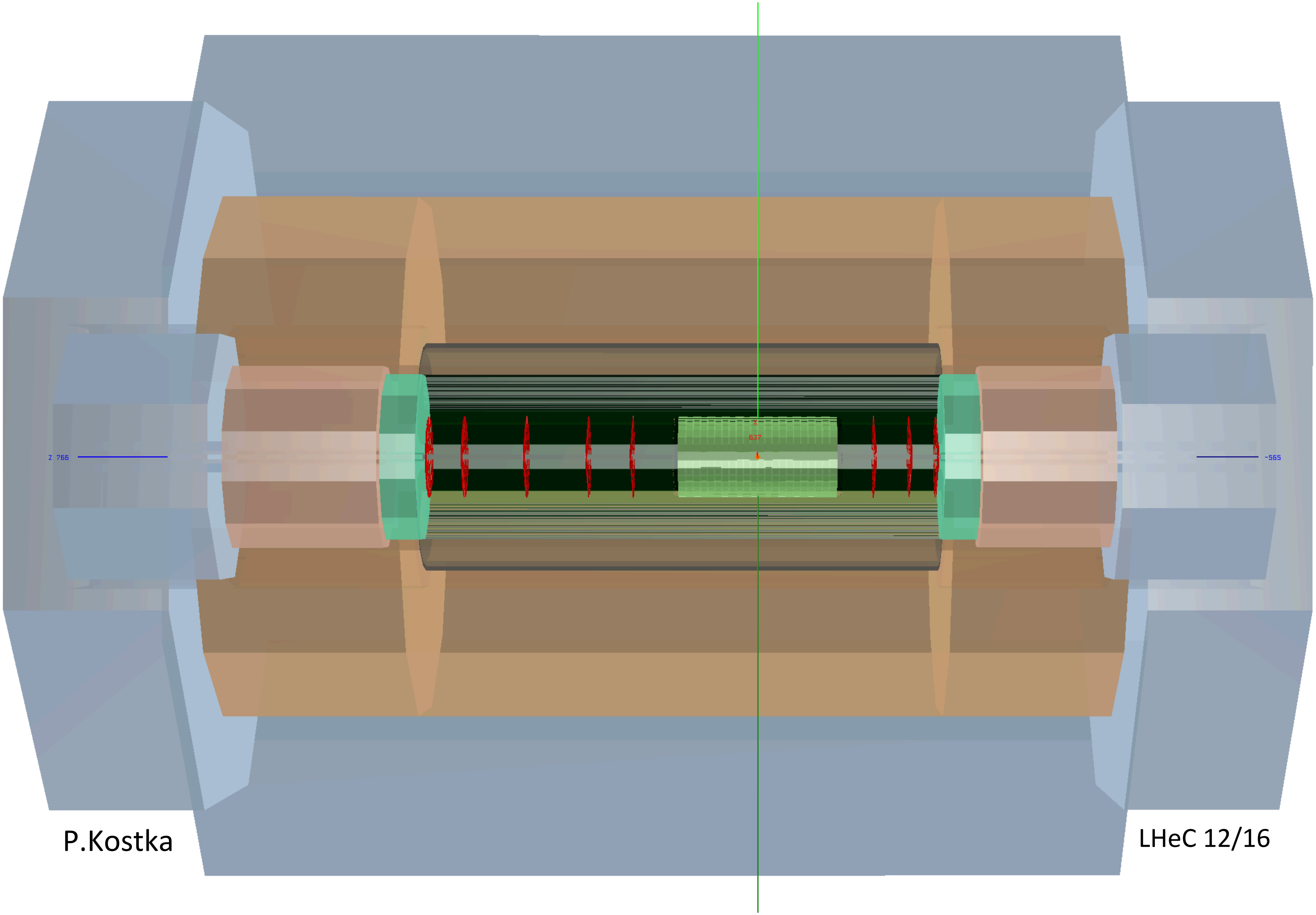
Structure

More Higgses ..

Major subject of HL LHC also when new physics may be discovered



ep and pp together make the LHC a real, high precision Higgs facility
→ We can make the HL LHC a sustainable, accepted endeavour.



P.Kostka

LHeC 12/16

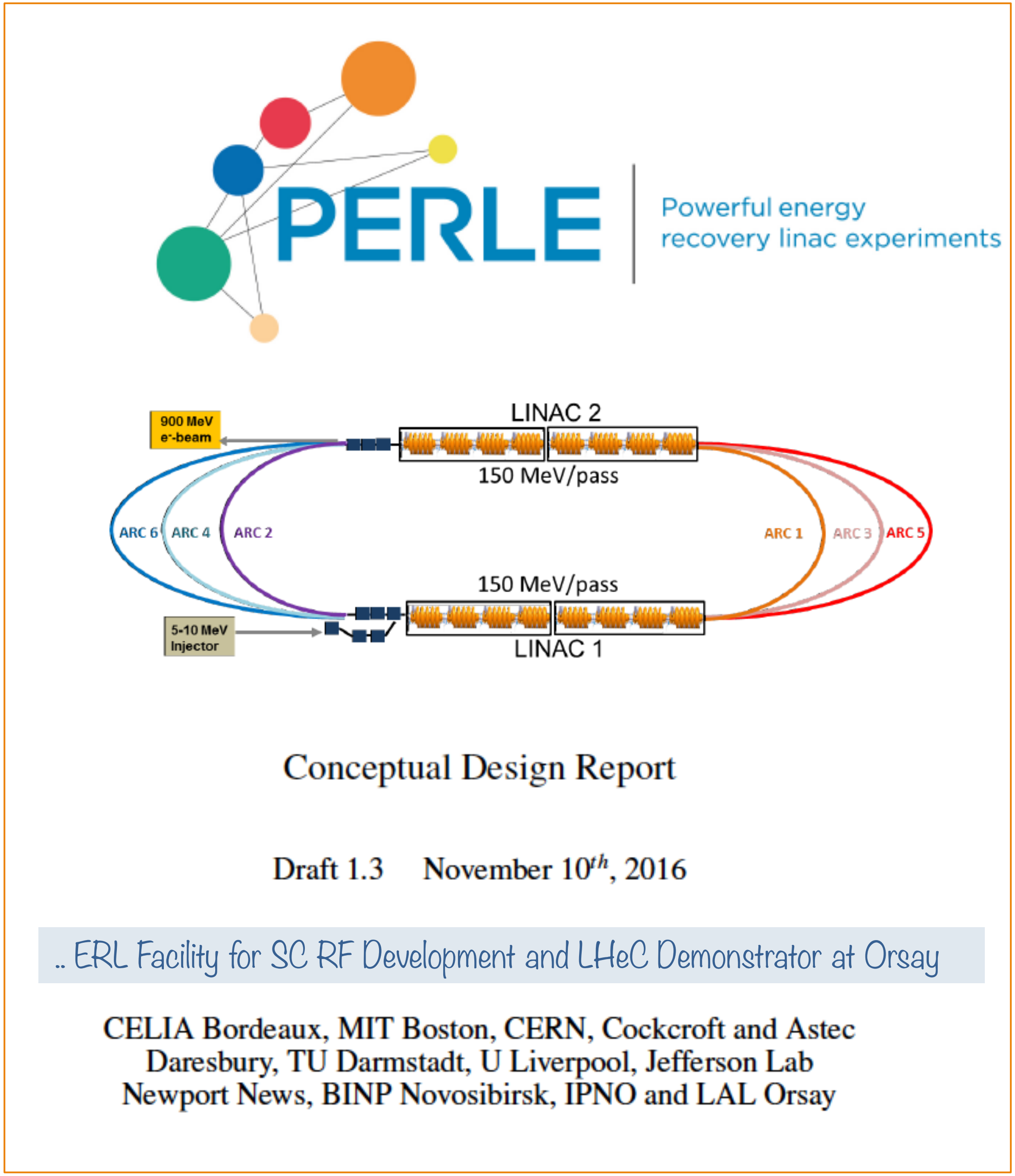
HEP needs new big detector projectS following the HL-LHC Upgrade, a challenge for 2020+

Many Accelerator Developments:

ERL (LHeC+ EIC)
Plasma
CTF3
HL LHC
XFEL...

CDR of ERL demonstrator, and test facility with physics applications and technology goals, soon out

cf also ICFA beam Newsletter 68/2016



PERLE
Powerful energy recovery linac experiments

Conceptual Design Report

Draft 1.3 November 10th, 2016

.. ERL Facility for SC RF Development and LHeC Demonstrator at Orsay

CELIA Bordeaux, MIT Boston, CERN, Cockcroft and Astec
Daresbury, TU Darmstadt, U Liverpool, Jefferson Lab
Newport News, BINP Novosibirsk, IPNO and LAL Orsay

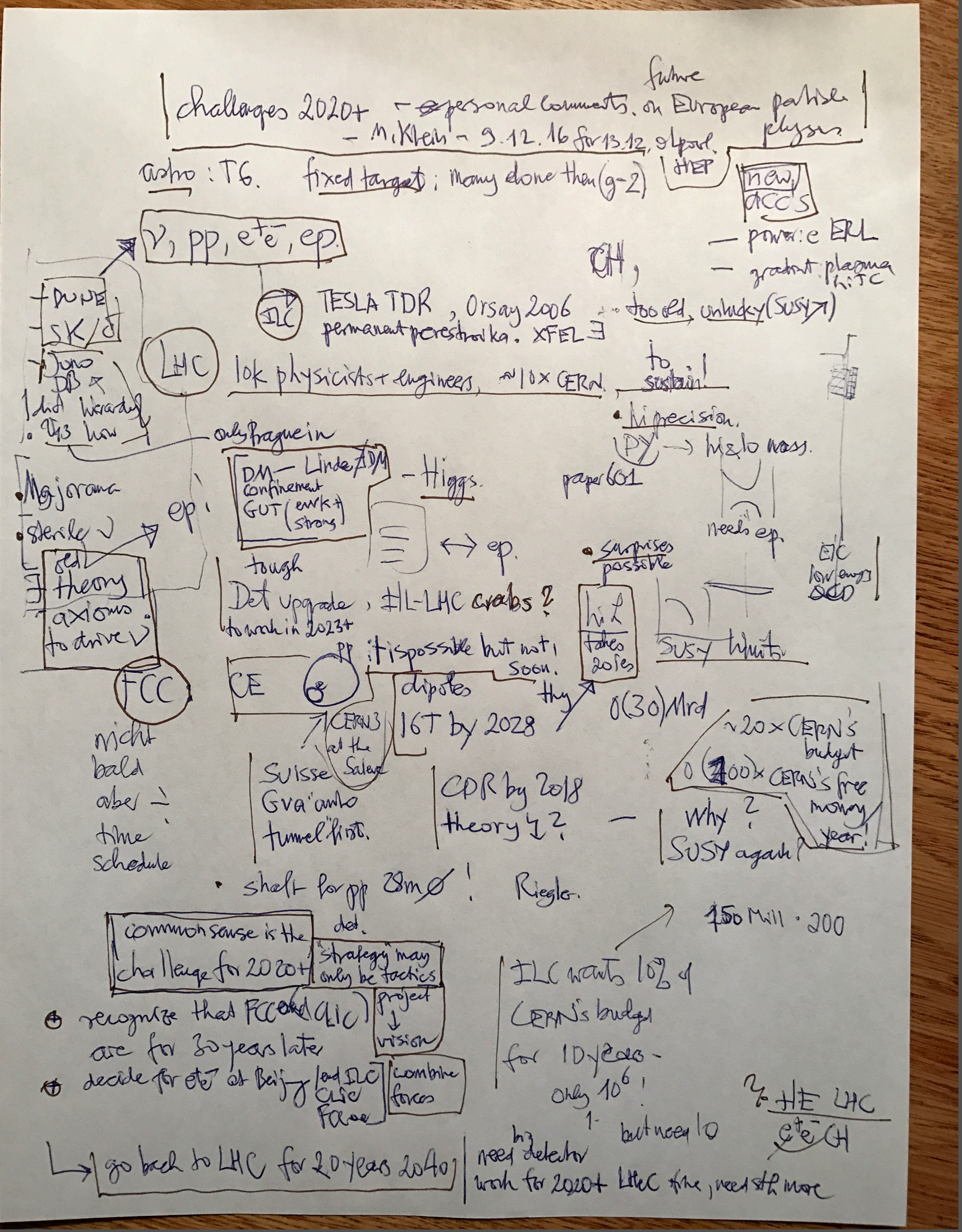
Physics

ep
$R(p)$, $\sin^2\theta$
Dark photons
γp
1000*L(ELI)
$E\gamma>30$keV
→ Unique photo-nuclear Physics

Technology

High Ie ~ 10mA
Multiturn ERL
SC RF
Cryomodules
Operation

Testfacility 1st
Userfacility 2nd



challanges 2020+ – ~~e~~ personal comments on European future particle physics
– M. Klein – 9.12.16 for 13.12, Liverpool, IHEP

astro : T6. fixed target ; many done then (g-2)

new accs
– power: e ERL
– gradient: plasma hiJC

ν, pp, e+e−, ep.

CH,

DUNE
SK/δ
Juno
DB
1 direct hierarchy
ν_{13} how

ILC TESLA TDR, Orsay 2006 .. too old, unlucky (SUSY↗)
permanent perestroika. XFEL ∃

LHC 10k physicists + engineers, ~10× CERN. to sustain!

• hi precision.
PY → hi & lo mass.

only Prague in

DM – Linde, ADM
confinement
GUT (ewk + strong)

– Higgs.

paper 601

needs ep.

• Majorana
• sterile ν

ep

old theory
∃ theory
axioms
to drive ν

↔ ep.

• surprises possible

EIC low energy QCD

tough
Det upgrade, HL-LHC crabs?
to work in 2023+

hi L takes 20 yrs

SUSY limits

FCC
nicht bald
aber –
time schedule

CE pp
CERN 3 at the Saleve
it is possible but not, soon.
dipoles 16T by 2028
thy

O(30) Mrd

~20 × CERN's budget
O(~~1~~ 400) × CERN's free money year!

Suisse
Gva canton
tunnel first.

CDR by 2018
theory ↓?

– Why? SUSY again?

• shaft for pp 28m ∅ !
Riegler.

det.

~~150~~ Mill · 200

common sense is the challenge for 2020+

strategy may only be tactics

project ↓ vision

ILC wants 10% of CERN's budget for 10 years – only 10^6! but need 10

⊕ recognize that FCC ~~and~~ (CLIC) are for 30 years later
⊕ decide for e+e− at Beijing (and ILC CLIC FCCee)

combine forces

% HE LHC
e^+e^- CH

↳ go back to LHC for 20 years 2040

hi L
need detector work for 2020+ LHC time, need sth more

1. Recognize that FCC is for 2050+ with only hh+eh at CERN

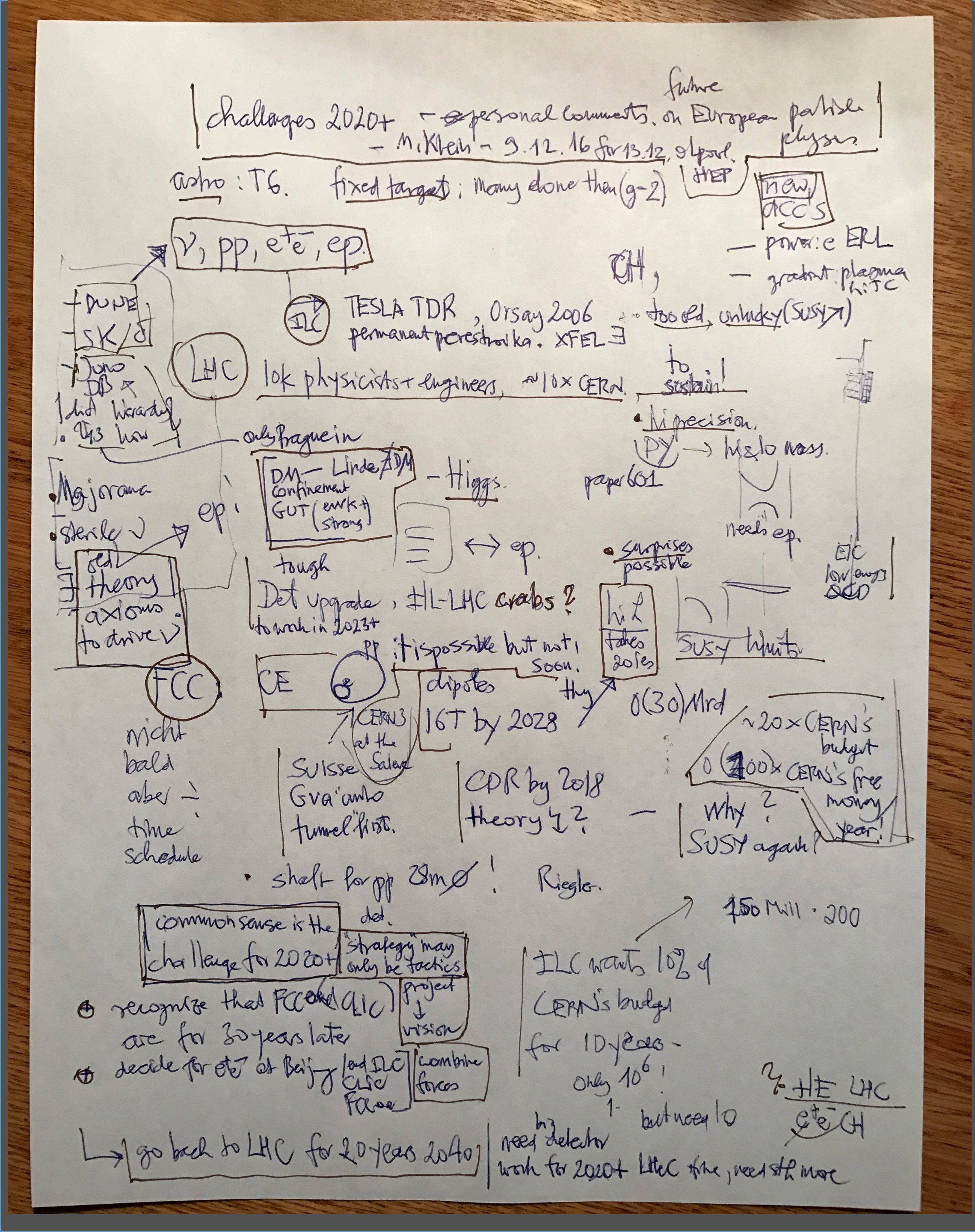
2. Decide to support ONE e+e- Collider, not impossible in China

3. Stress the exploitation of the LHC for +20 years (-2040) and consider how to sustain this

1-3:
a possible outcome of the 2020 European Strategy, perhaps..

Not impossible HE LHC stays unclear for longer than 2020 as that is still five years prior to HL LHC start-up.

Surprises can come any time
In experiment and theory too



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1. Recognize that FCC is for 2050+ with only hh+eh at CERN

2. Decide to support ONE e+e- Collider, not impossible in China

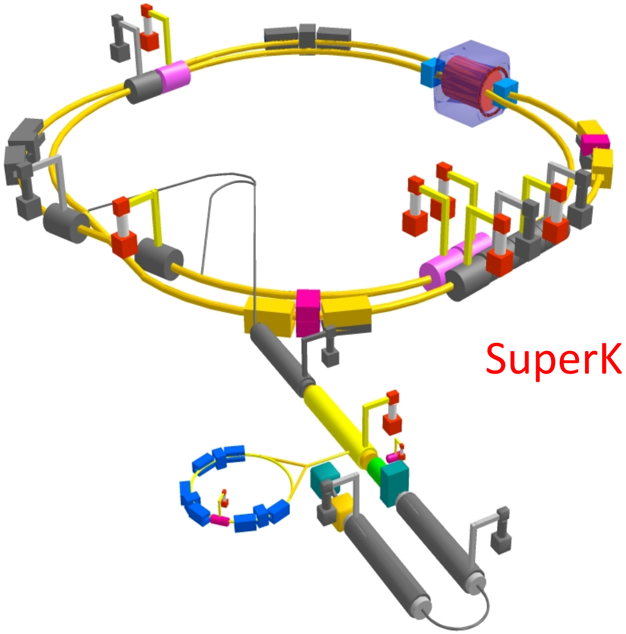
3. Move to the exploitation of the LHC for 20 years (-2040)
+ consider how to sustain this

Don't trust what you hear,
Listen to what you see -
This is what will be… (BS)

titel

FCC - ee

parameter	FCC-ee	LEP2
energy/beam	45 – 175 GeV	105 GeV
bunches/beam	**50 – 60000**	4
beam current	**6.6 – 1450 mA**	3 mA
hor. emittance	**~2 nm**	~22 nm
emittance ratio $\varepsilon_y/\varepsilon_y$	**0.1%**	1%
vert. IP beta function β_y^*	**1 mm**	50 mm
luminosity/IP	**1.5-280** x 10^{34} $cm^{-2}s^{-1}$	0.0012 x 10^{34} $cm^{-2}s^{-1}$
energy loss/turn	0.03-7.55 GeV	3.34 GeV
synchrotron radiation power	**100 MW**	23 MW
RF voltage	.3 – **11 GV**	3.5 GV

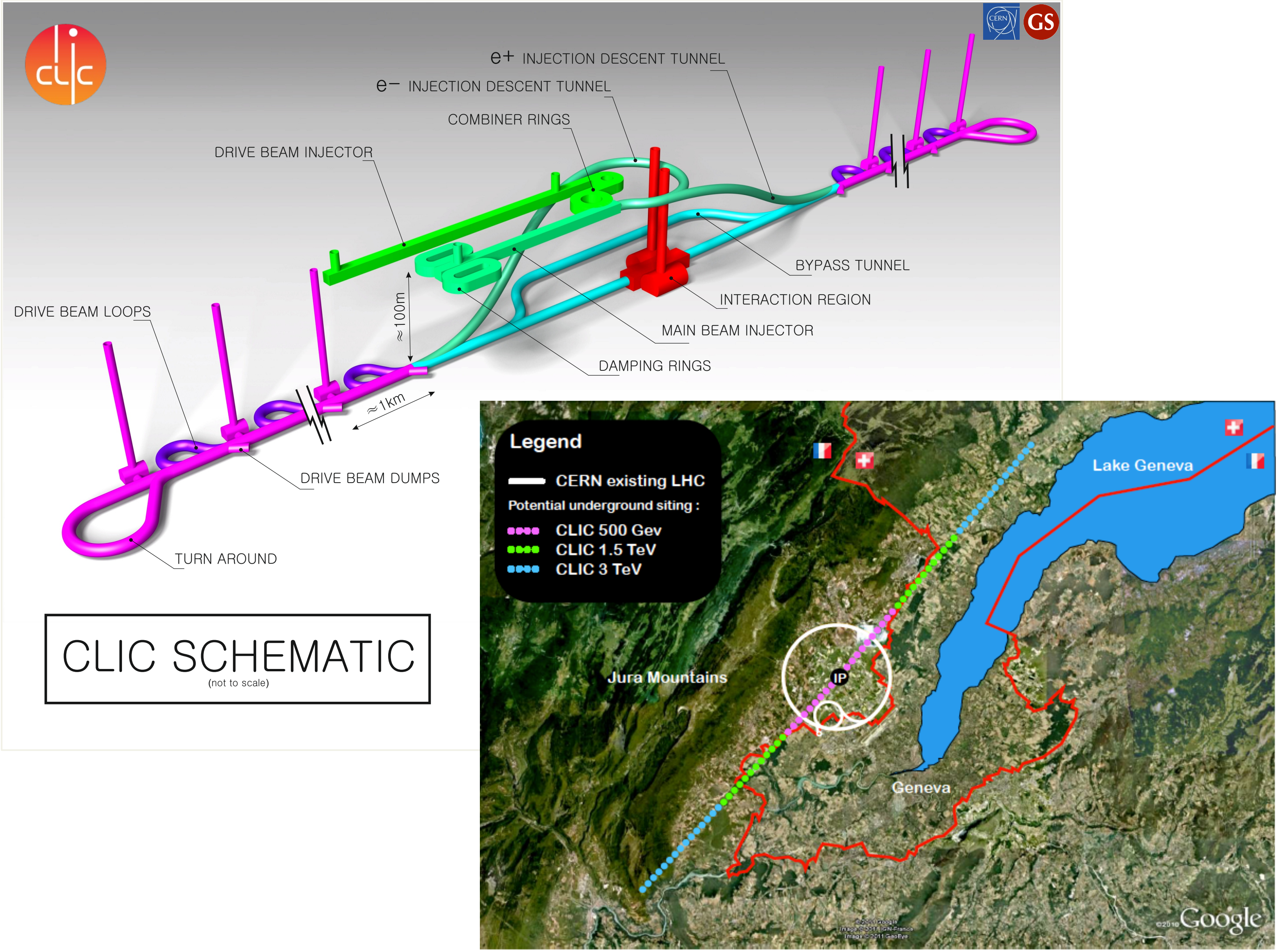


FCC- lifetime of O(10) min – 2 rings
with top up injection
SuperB: ~FCC-ee demonstrator

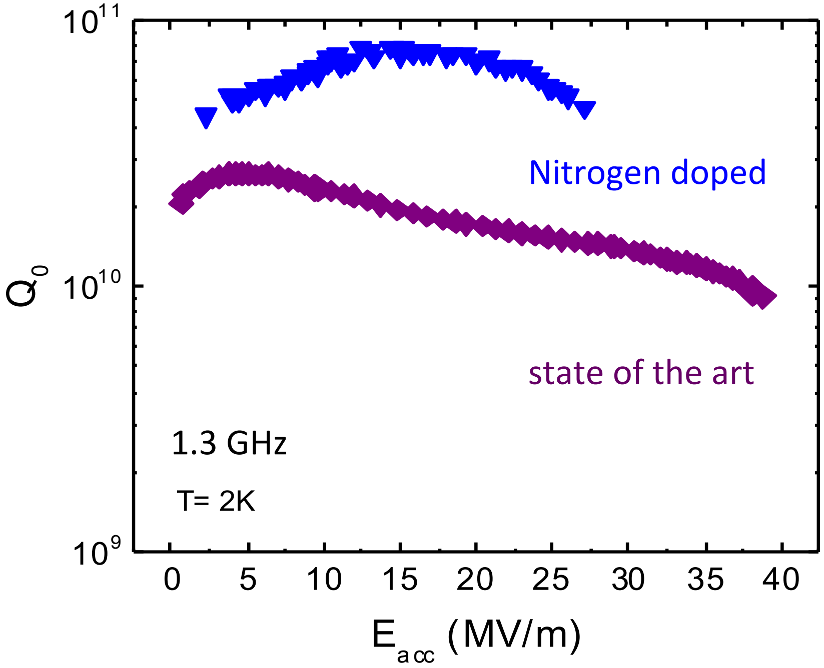
Z,W,H,t : two decades of operation

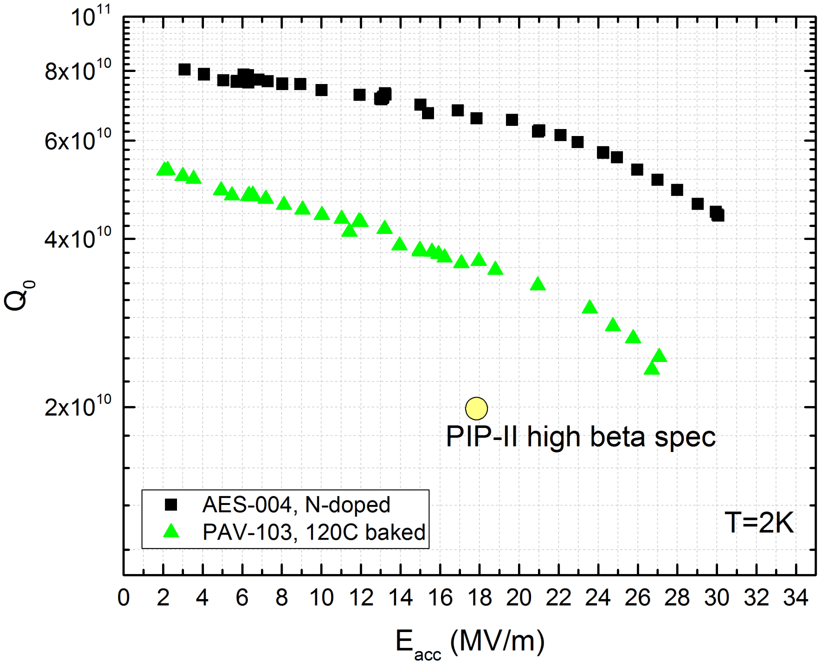
F.Zimmermann Washington March 2015

CLIC


clic
e+ INJECTION DESCENT TUNNEL
e− INJECTION DESCENT TUNNEL
COMBINER RINGS
DRIVE BEAM INJECTOR
BYPASS TUNNEL
INTERACTION REGION
MAIN BEAM INJECTOR
DAMPING RINGS
DRIVE BEAM LOOPS
DRIVE BEAM DUMPS
TURN AROUND
≈100m
≈1km
CLIC SCHEMATIC
(not to scale)
Legend
CERN existing LHC
Potential underground siting :
CLIC 500 Gev
CLIC 1.5 TeV
CLIC 3 TeV
Lake Geneva
Jura Mountains
IP
Geneva
©2010 Google

SC RF





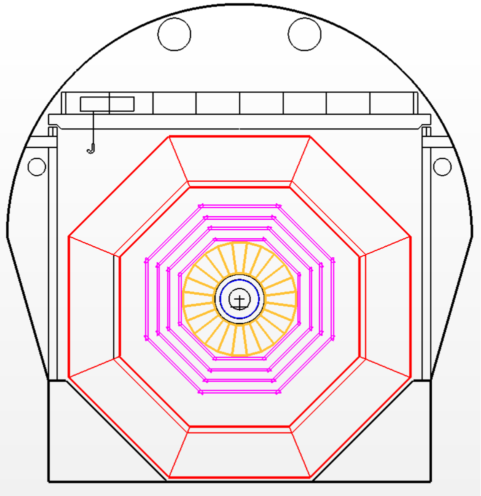
A.Grassellino et al,
2013 Supercond. Sci. Technol. **26** 102001
Rapid Communication – highlights of 2013

650 MHz Ni doped cavity

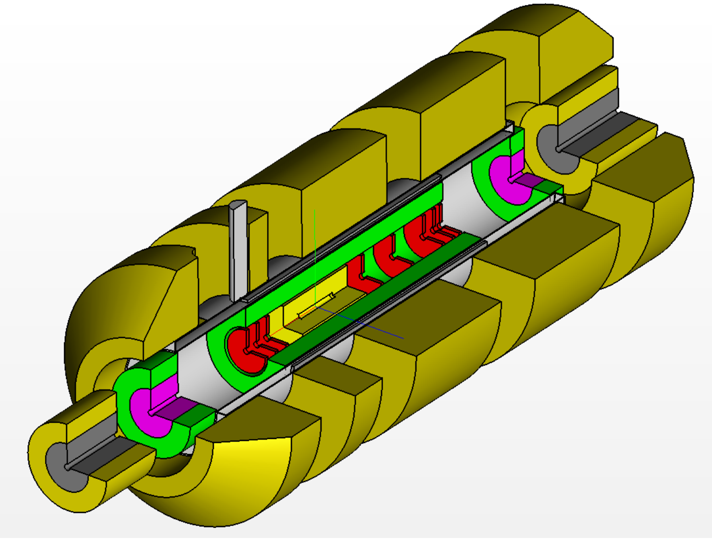
Strong development of SC Cavity technology (higher Q_0, gradient, lower cost)

cf. B Rimmer, E Jensen + at FCC-DC

Installation Study



Detector fits in L3 magnet support



Modular structure

LHeC INSTALLATION SCHEDULE

ACTIVITY	Q1			Q2			Q3			Q4			Q5			Q6			Q7			Q8		
DETECTOR CONTRUCTION ON SITE TO START BEFORE LHC LONG SHUT-DOWN																								
LHC LONG SHUTDOWN START (T0)																								
COIL COMMISSIONING ON SURFACE	■	■	■																					
ACTUAL DETECTOR DISMANTLING	■	■	■	■	■	■																		
PREPARATION FOR LOWERING				■	■	■																		
LOWERING TO CAVERN							■	■	■	■	■	■	■	■	■	■	■	■	■	■				
HCAL MODULES & CRYOSTAT								■	■	■	■	■	■											
CABLES & SERVICES											■	■	■	■	■	■	■	■	■	■				
BARREL MUON CHAMBERS												■	■	■										
ENDCAPS MUON CHAMBERS															■	■	■							
TRACKER & CALORIMETER PLUGS																		■	■	■				
BEAMPIPE & MACHINE																					■	■	■	
DETECTOR CHECK-OUT																								■
LHC LONG SHUTDOWN END (T0+24m)																								

ILC Statements

e) There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. ***Europe looks forward to a proposal from Japan to discuss a possible participation.***

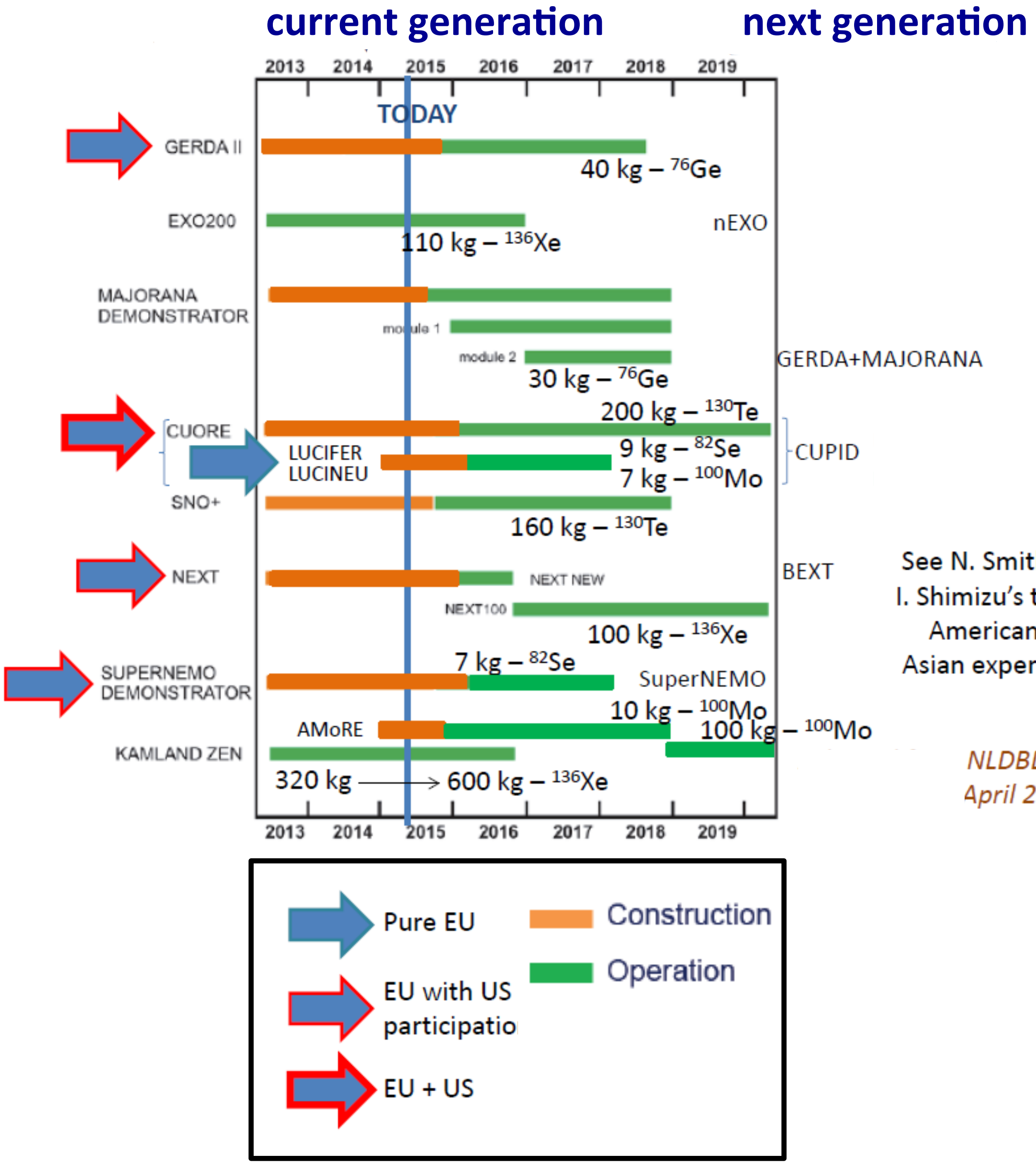
European Strategy Statement from 2013

Just waiting for positive sign from the Japanese government is not a recommended strategy, since Japanese government is waiting for the sign of ILC supports from the other countries/regions.

Sachio Komamiya, 21.4.2015 Chair of the Linear Collider Board

ECFA 11/16: MEXT statement expected in 2018 .. Last week: LCWS: Start with Higgs 250 GeV ?

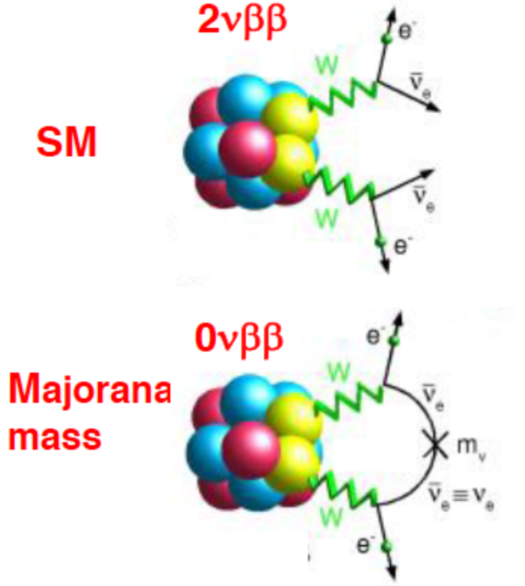
Neutrinos: ββ decay

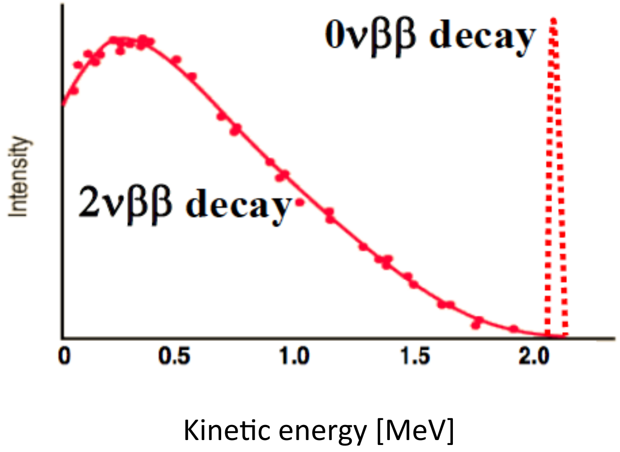


See N. Smith's and I. Shimizu's talks for American and Asian experiments

NLDBD-NSAC April 2014)

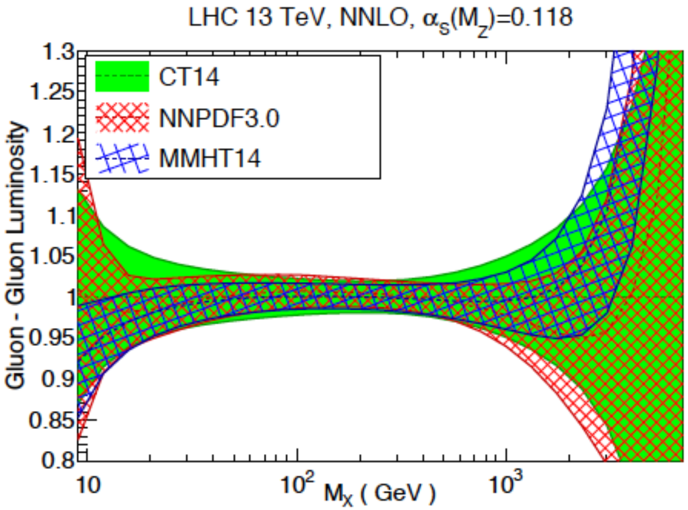
12

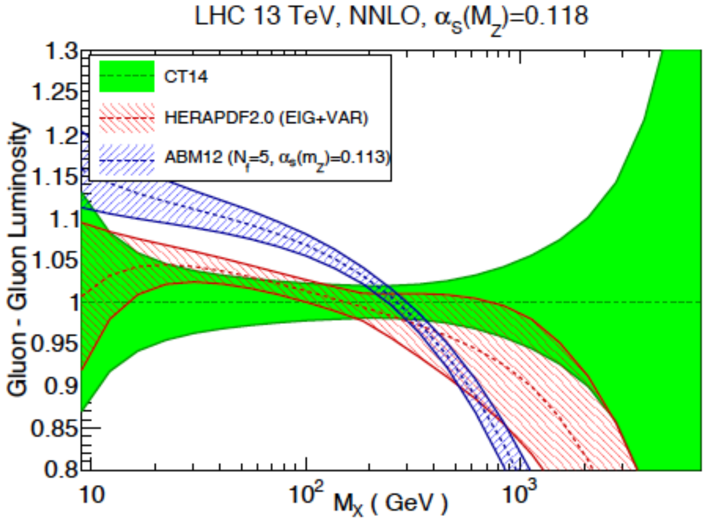




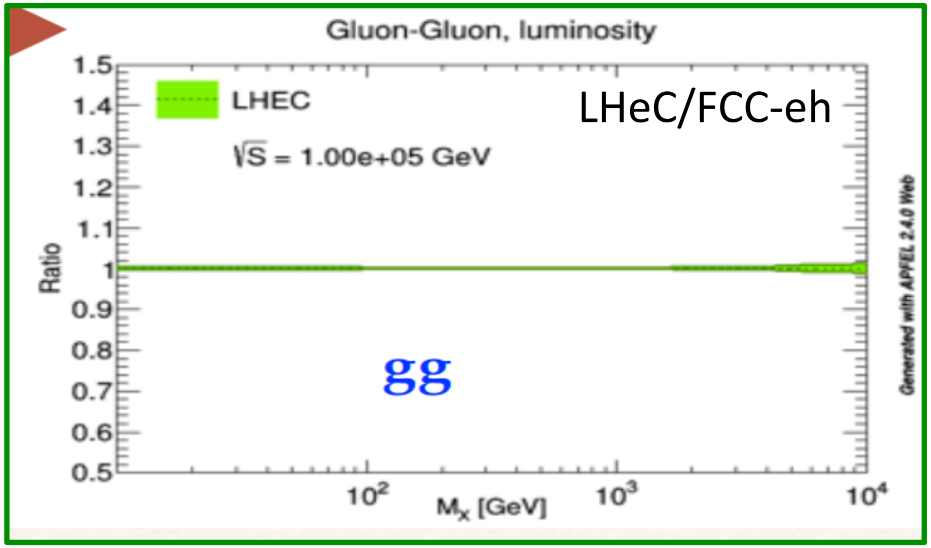
Gluon (gg) Luminosity

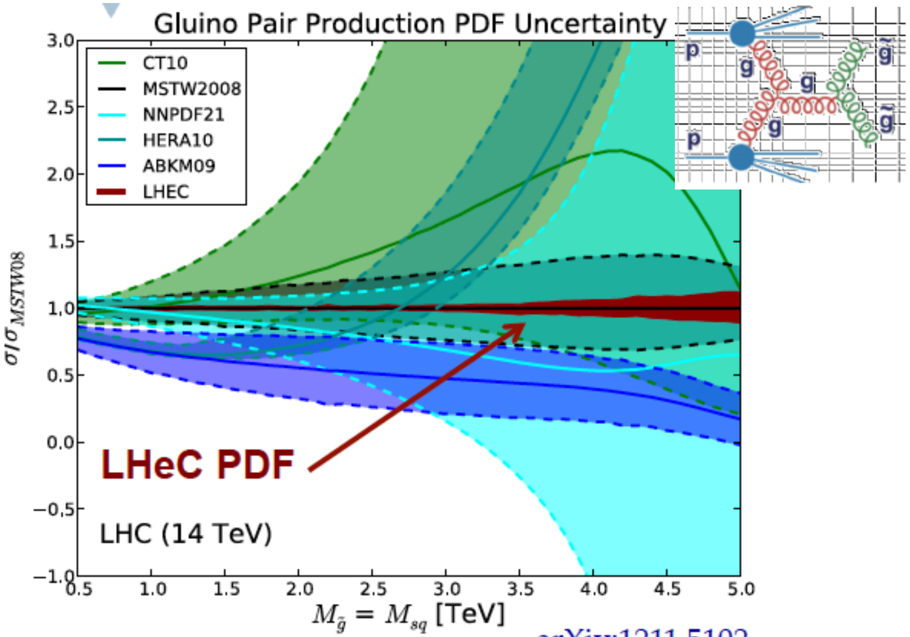
Present status





gg → H dominant process in pp
Crucial for SUSY searches/limits

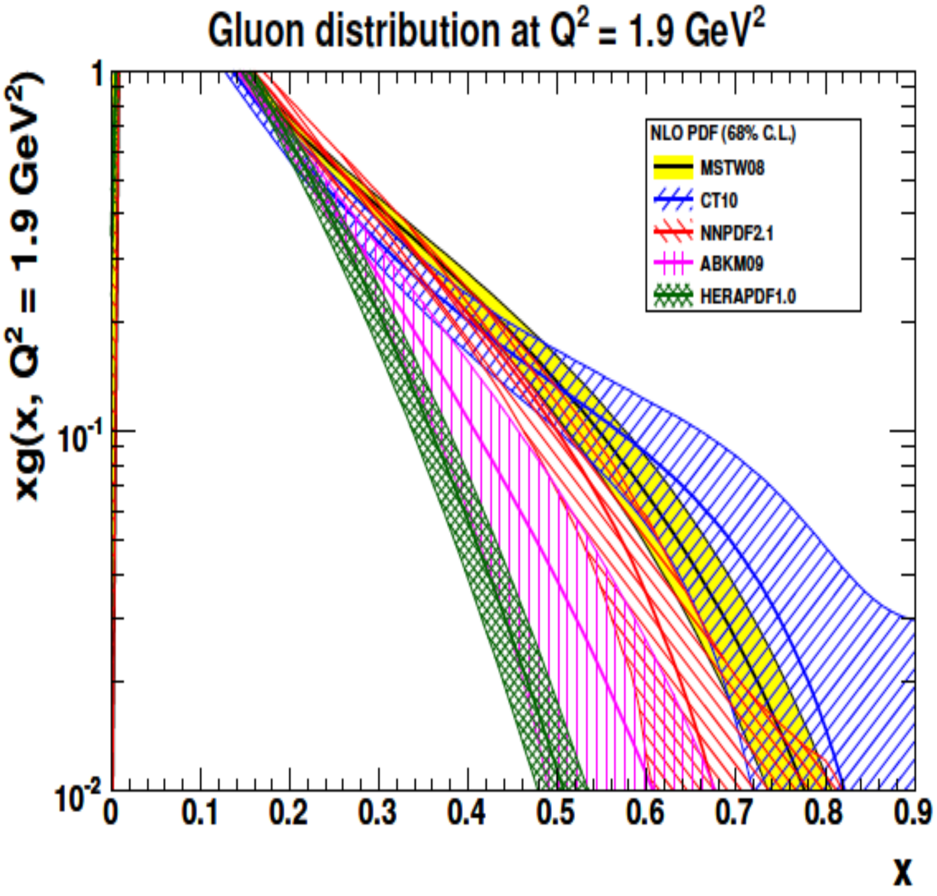




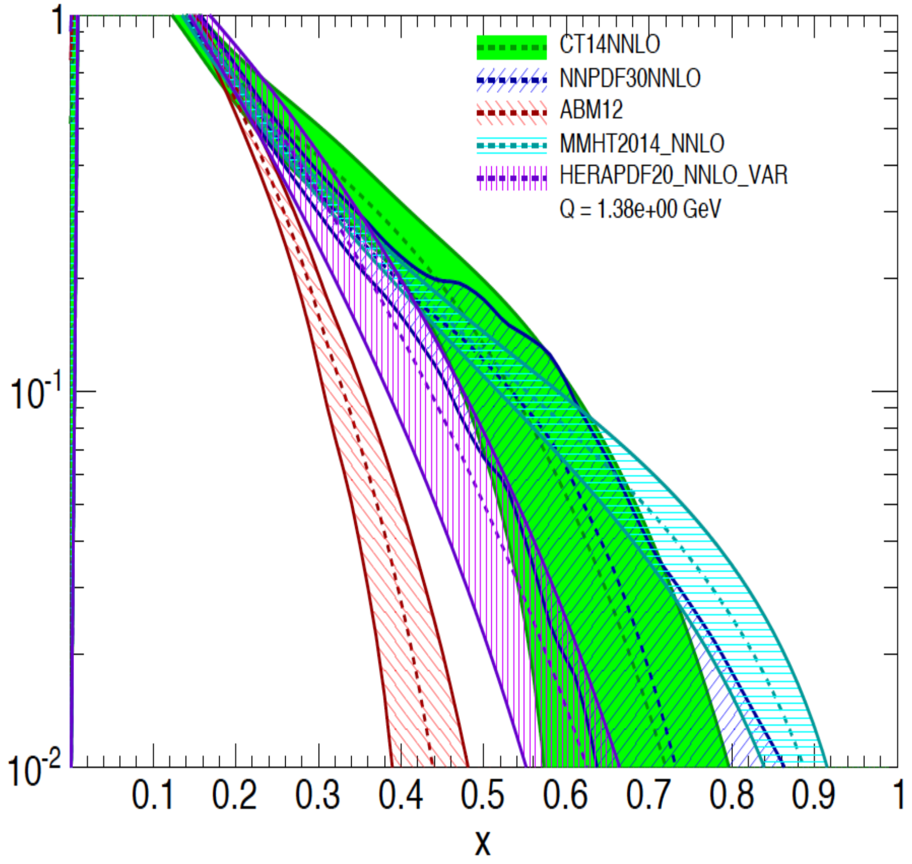
arXiv:1211.5102

Gluon Density

High x

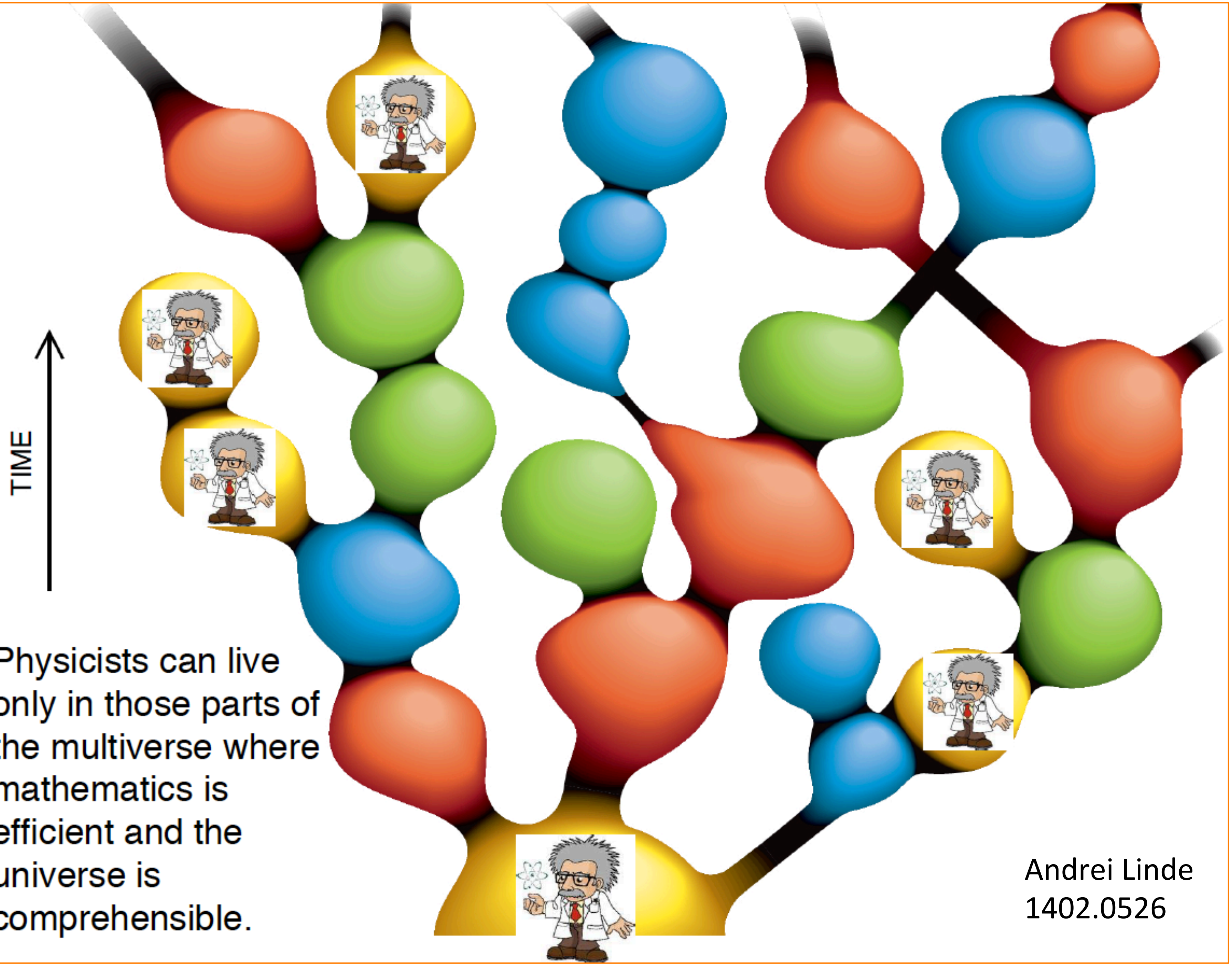


Gluon prior to LHC data (2011)



Gluon with (first) LHC data (2015)

used by CT14,NNPDF,MMHT



Physicists can live only in those parts of the multiverse where mathematics is efficient and the universe is comprehensible.

Andrei Linde
1402.0526

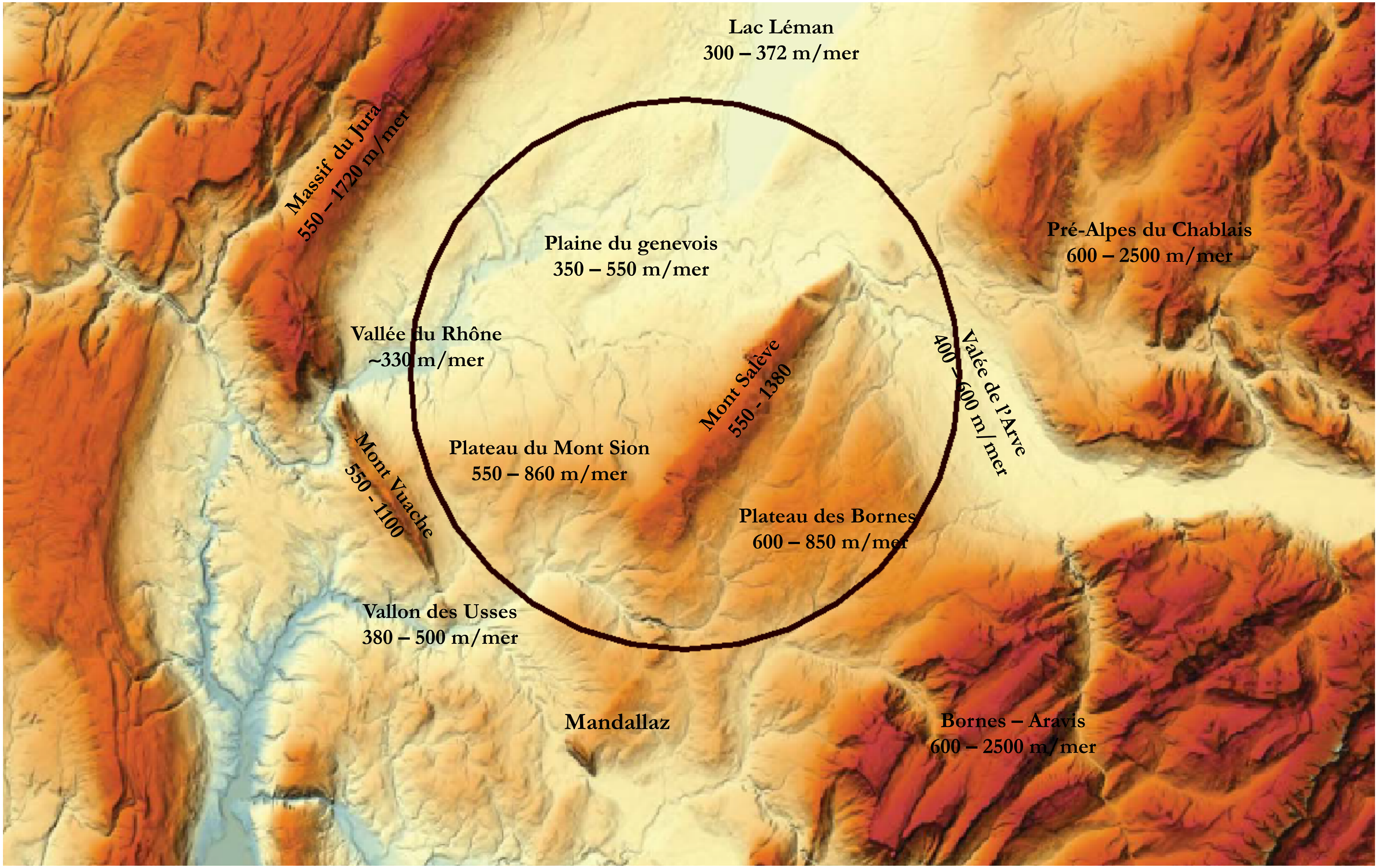
“The future belongs to those who believe in the beauty of their dreams.”

Anna Eleanor Roosevelt
(1884-1962)

Universal Declaration of Human Rights (1948)

cited by Frank Zimmermann at the FCC Meeting at Washington DC, March 2015

FCC


Lac Léman
300 – 372 m/mer
Massif du Jura
550 – 1720 m/mer
Plaine du genevois
350 – 550 m/mer
Pré-Alpes du Chablais
600 – 2500 m/mer
Vallée du Rhône
~330 m/mer
Mont Salève
550 - 1380
Valée de l'Arve
400 – 600 m/mer
Mont Vuache
550 - 1100
Plateau du Mont Sion
550 – 860 m/mer
Plateau des Bornes
600 – 850 m/mer
Vallon des Usses
380 – 500 m/mer
Mandallaz
Bornes – Aravis
600 – 2500 m/mer