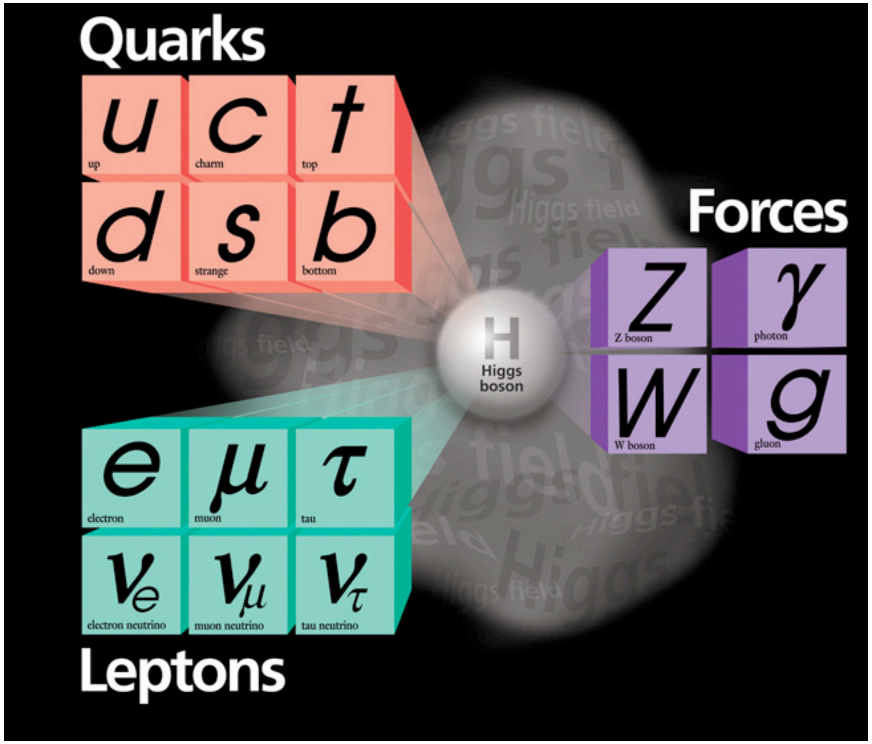
Where Are We Going in the Field of High Energy Accelerators ?

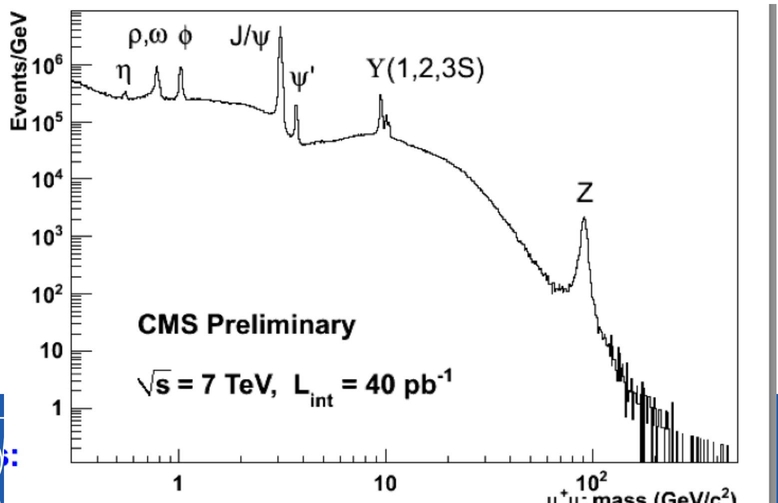
Outline:

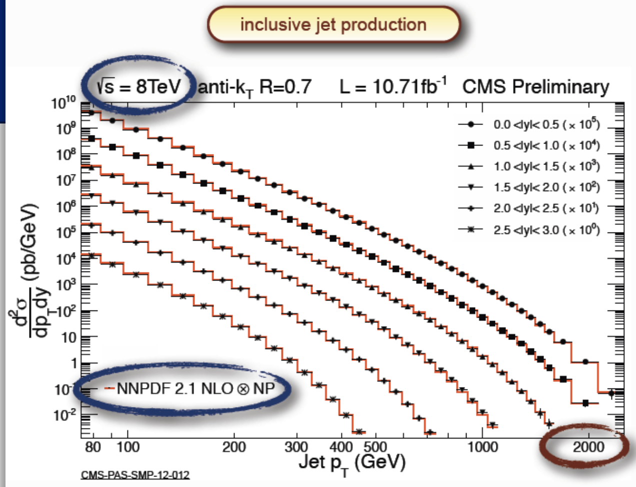
- Particle Physics and prospects
- Accelerator Projects
- Strategies and realities
- Beam Instrumentation and Summary

Slides from numerous sources, have tried to leave names on them acknowledging the source

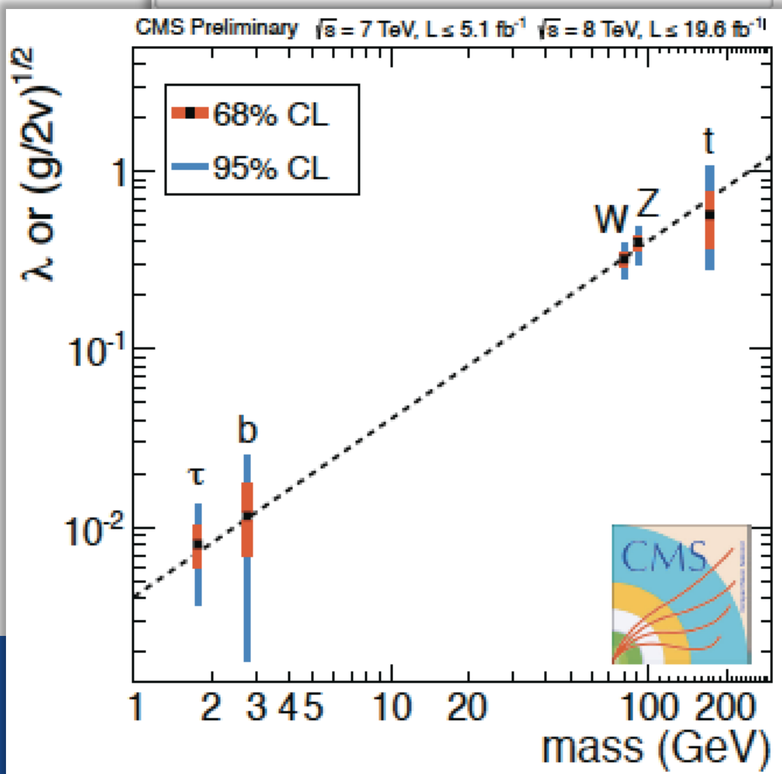
The Standard Model





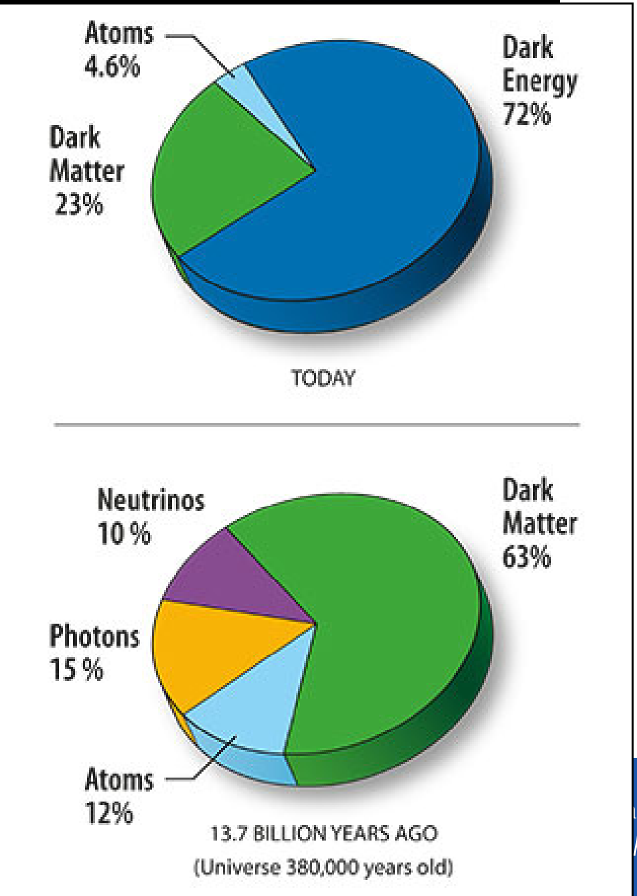


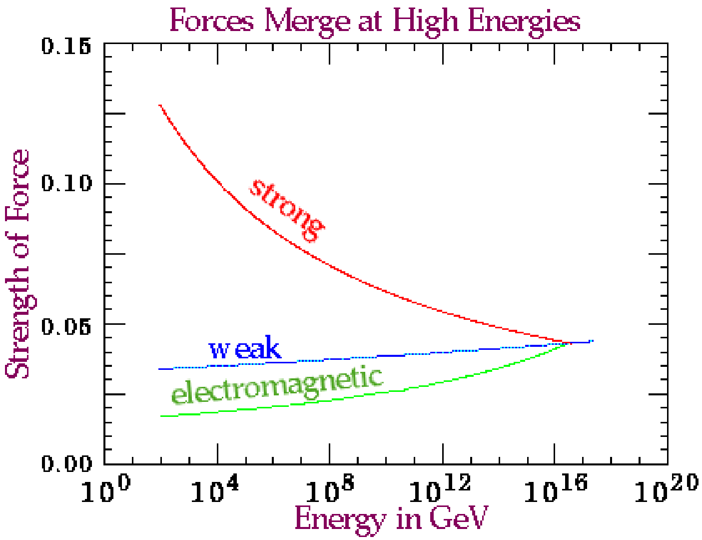
- NLO QCD describes data over ~10 orders of magnitude!
- excellent exp. progress: jet energy scale uncertainties at the **1-2%** level
- for central rapidities: similar exp. and theo. uncertainties, **5 - 10%**
- inclusive jet data : start to be important tool for constraining PDFs

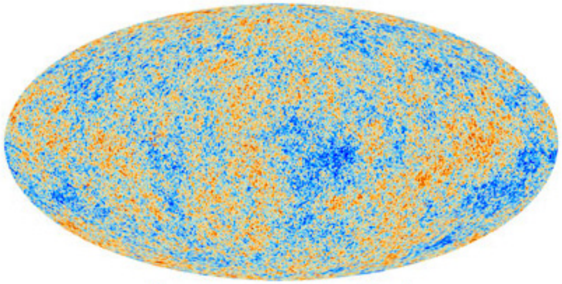


CERN

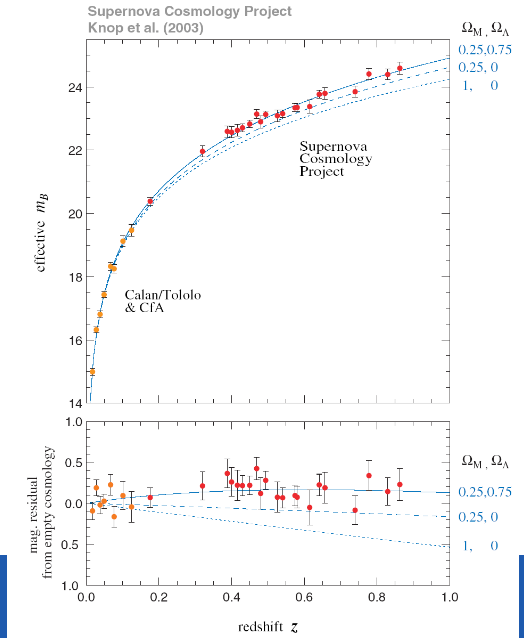
Beyond the Standard Model







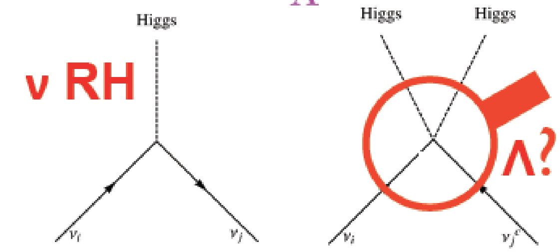
The universe as seen by Planck



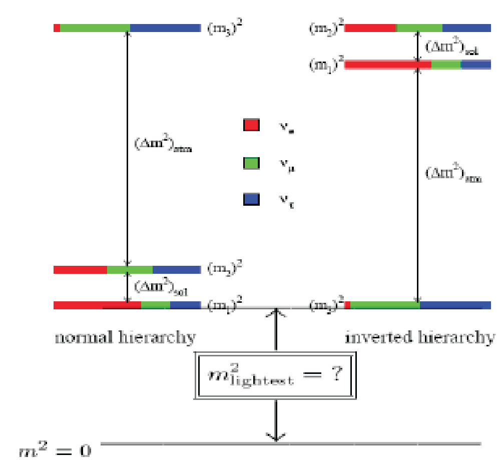
Neutrinos

- **Neutrinos play a fundamental and special role in particle physics, astrophysics and cosmology**
- **Neutrino masses** → presently the only evidence of new physics beyond the SM – additional d.o.f. must exist: either **ν RH** and/or **new scale Λ** (>> TeV ?)
- **A window to questions related to a deeper description of physics and to the evolution of the Universe:**
  - Why are neutrino masses so small ?
  - Why is the mixing matrix so different than the one of quarks? What does this picture suggest ?
  - **How is the hierarchy of the ν mass eigenstates ?**
  - Which is the absolute mass of the lightest state ?
  - Are neutrinos Majorana particles ?
  - **P, CP, CPT are fundamental symmetries. "P is maximally violated by neutrinos but CP is saved" (W. Pauli). Is CP violated by neutrinos as well or is it a special feature of quarks ?**
  - Are there sterile states and is there mixing … ?

$$\underbrace{Y^{ij}\Psi_L^i\Psi_R^j\phi}_{-\mathcal{L}_{\rm Dirac}} + \underbrace{\frac{g^{ij}}{\Lambda}\Psi_L^i\Psi_L^{T,j}\phi\phi^T}_{-\mathcal{L}_{\rm Majorana}}$$



$$V_{MNS} \sim \begin{pmatrix} 0.8 & 0.5 & 0.2 \\ 0.4 & 0.6 & 0.7 \\ 0.4 & 0.6 & 0.7 \end{pmatrix} \qquad V_{CKM} \sim \begin{pmatrix} 1 & 0.2 & 0.001 \\ 0.2 & 1 & 0.01 \\ 0.001 & 0.01 & 1 \end{pmatrix}$$



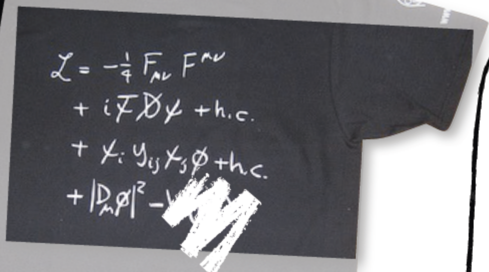
SM & New Physics

$\Lambda_{\rm UV}^4 \sqrt{g}$ cosmological constant D=0

$+\Lambda_{\rm UV}^2 |H|^2$ Higgs mass D=2

$+\theta_{\rm QCD}\, G_{\mu\nu}\tilde{G}^{\mu\nu}$ strong CP problem D=4

3 problems
imposed to us by data:
whatever the scale of NP is,
some special structure is
needed to avoid these pbs



D=4 Lagrangian
describes perfectly the data
but... it is not enough

$+\frac{b_{ij}}{\Lambda_{UV}} L_i L_j H^2$

D=5 operators are needed
to generate neutrino masses $\Lambda_{\rm UV} \sim 10^{14\div 18}$ GeV?

$+\frac{c_{ijkl}}{\Lambda_{\rm UV}^2} \bar{F}_i F_j \bar{F}_k F_l \cdot$

$+ \ldots$ (59 independent structures)

D=6 operators
capture the leading effects of
New Physics

SM & New Physics

$\Lambda_{\rm UV}^4 \sqrt{g}$ cosmological constant D=0

$+\Lambda_{\rm UV}^2 |H|^2$ Higgs mass D=2

$+\theta_{\rm QCD}\, G_{\mu\nu}\tilde{G}^{\mu\nu}$ strong CP problem D=4

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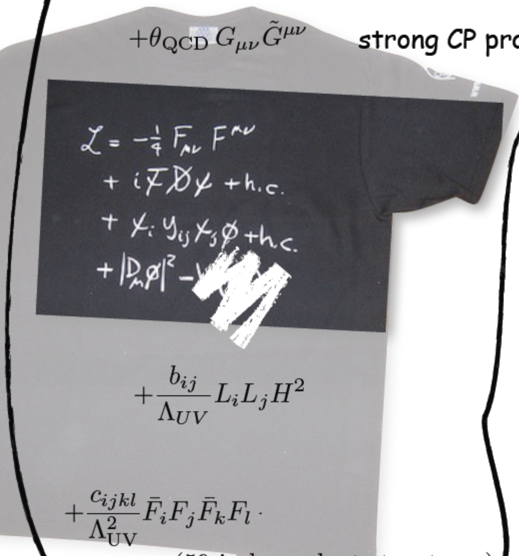

D=4 Lagrangian
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D=5 operator
to generate ne

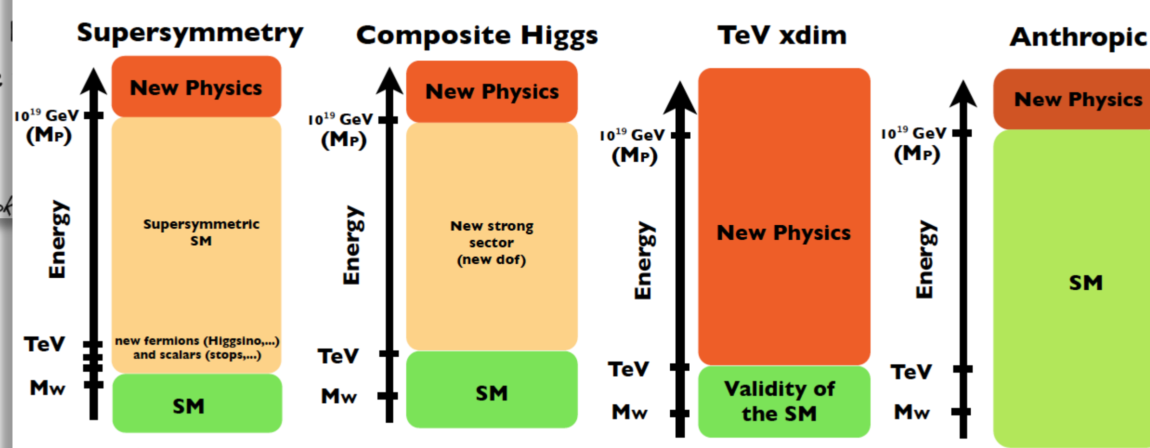
$$+\frac{c_{ijkl}}{\Lambda_{\rm UV}^2} \bar{F}_i F_j \bar{F}_k F_l \cdot$$

$+ \ldots$ (59 independent structures)

capture

Which New Physics?

A. Pomarol, lecture @ CERN, '13



natural — unnatural

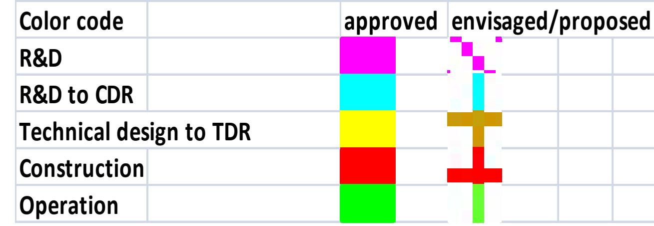
still plausible
but may be not in their
minimal/simplest incarnations

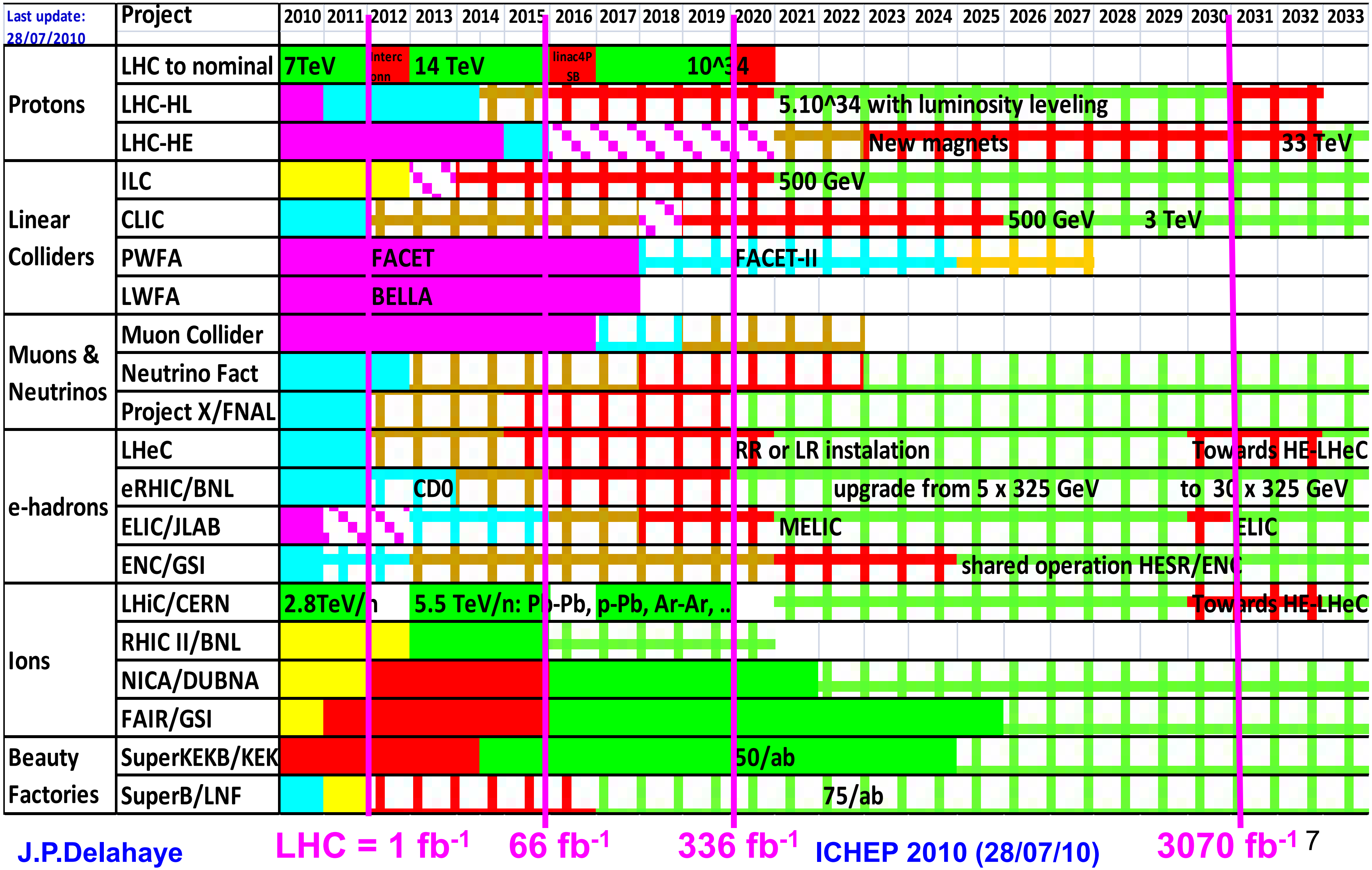
unlikely

Will we
ever
know?

(can the Nature be unnatural?)

Tentative schedule new projects

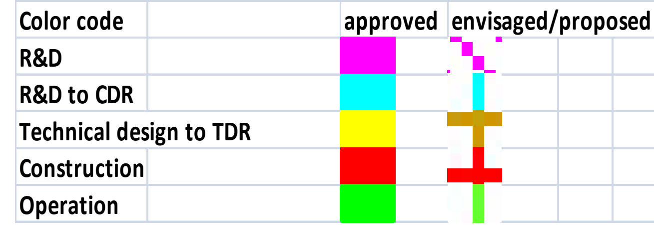


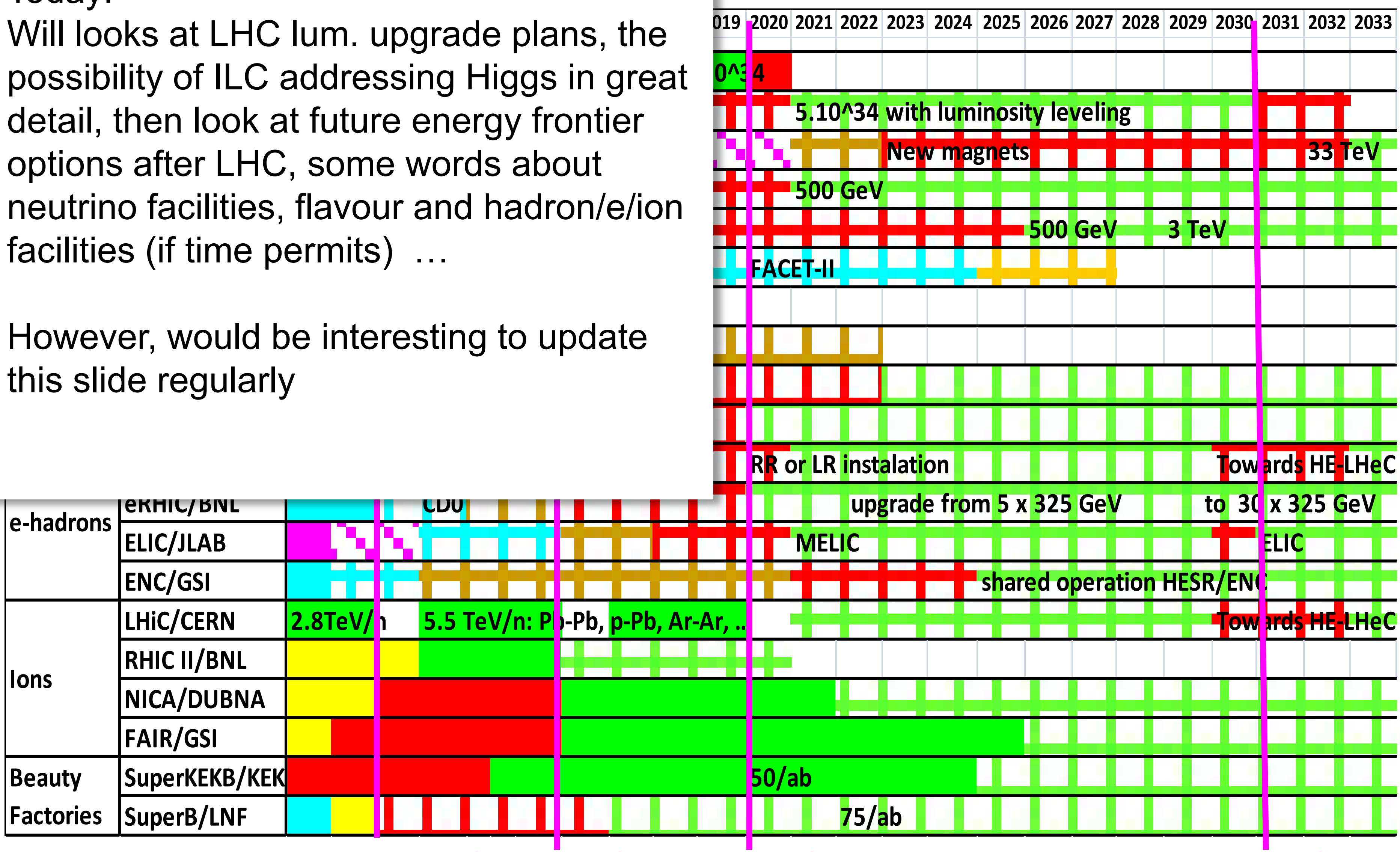


Tentative schedule new projects

Today:
Will looks at LHC lum. upgrade plans, the possibility of ILC addressing Higgs in great detail, then look at future energy frontier options after LHC, some words about neutrino facilities, flavour and hadron/e/ion facilities (if time permits) …

However, would be interesting to update this slide regularly





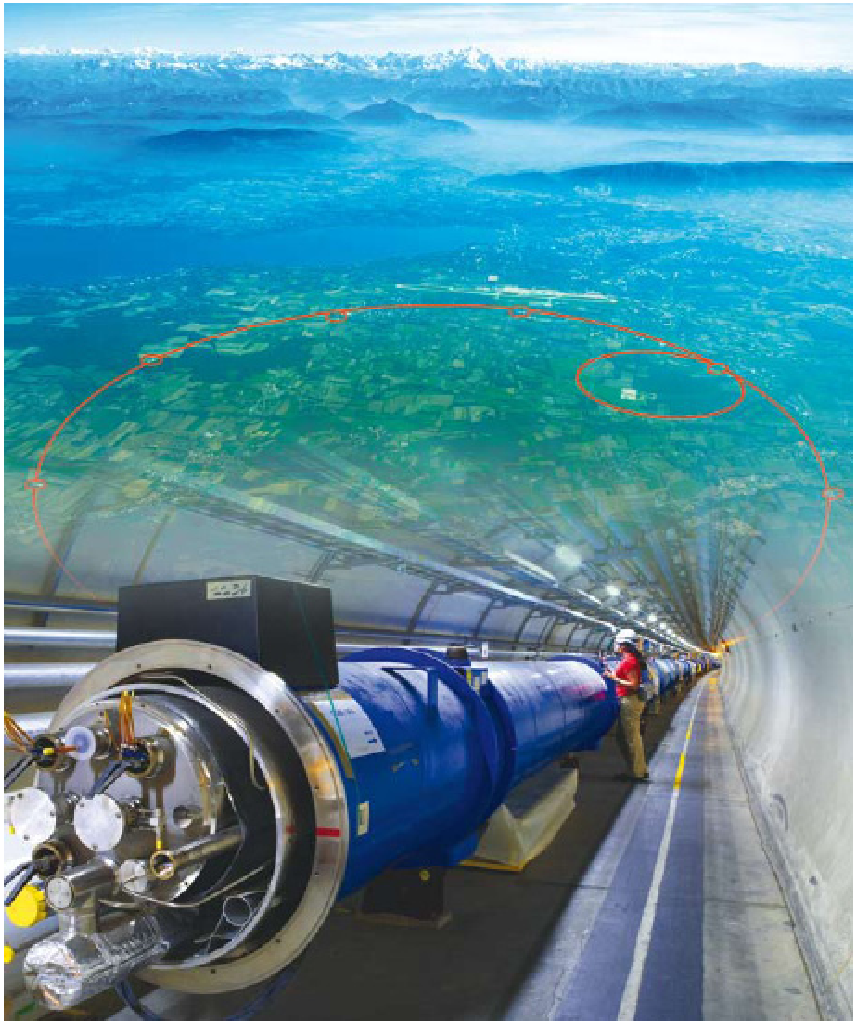
J.P.Delahaye ICHEP 2010 (28/07/10)

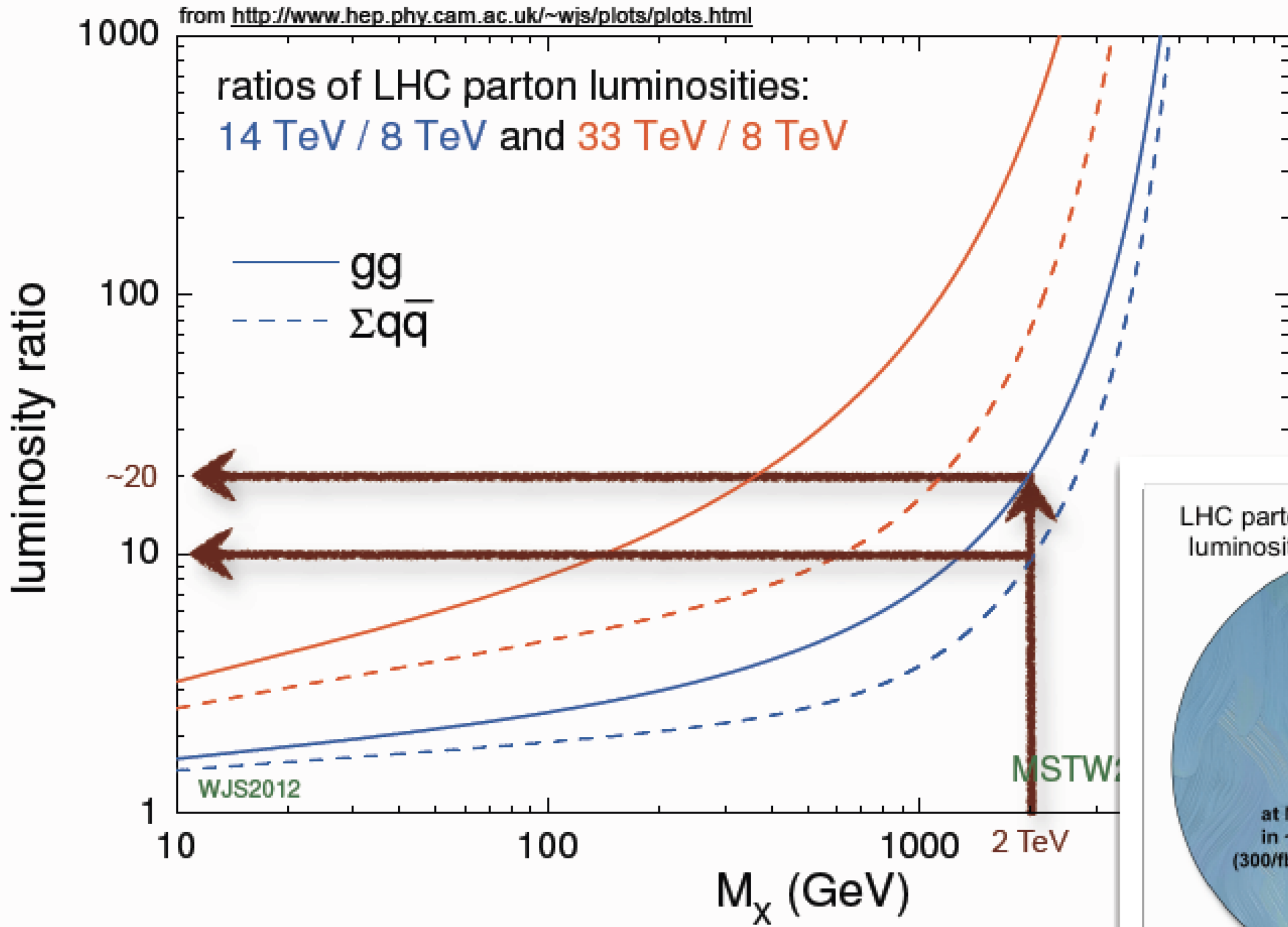
LHC (Large Hadron Collider)

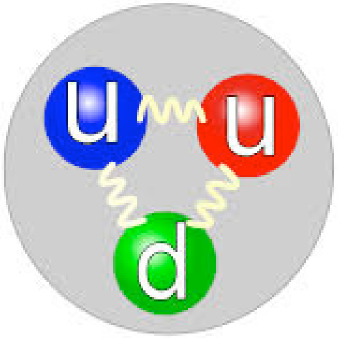
14 TeV proton-proton accelerator-collider built in the LEP tunnel

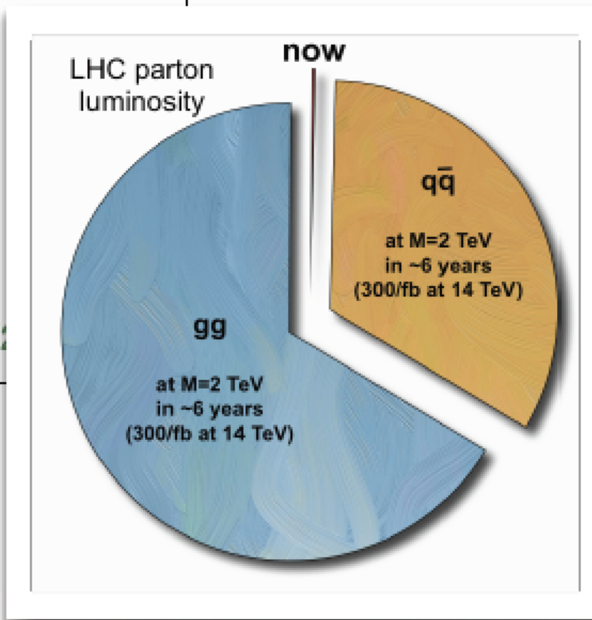
Lead-Lead (Lead-proton) collisions

1983 : First studies for the LHC project
1988 : First magnet model (feasibility)
1989 : Approval of the LHC by the CERN Council
1996-1999 : Series production industrialisation
1998 : Declaration of Public Utility & Start of civil engineering
1998-2000 : Placement of the main production contracts
2004 : Start of the LHC installation
2005-2007 : Magnets Installation in the tunnel
2006-2008 : Hardware commissioning
2008-2009 : Beam commissioning and repair
2009-2030 : Physics exploitation



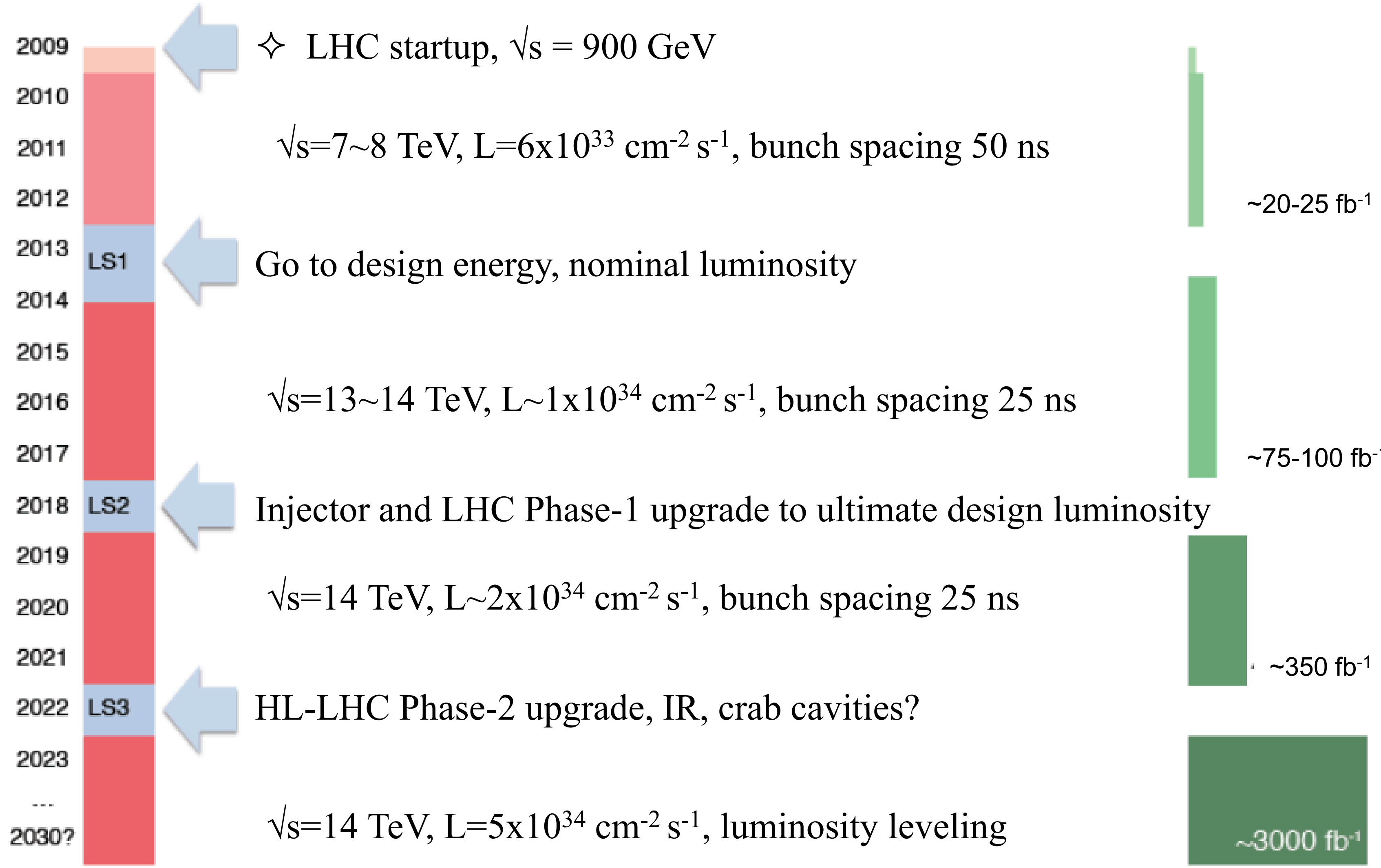




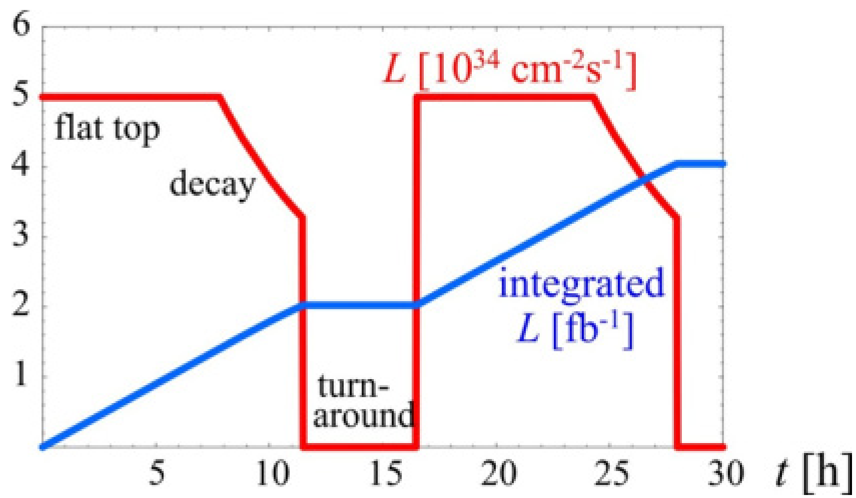


for a fixed mass scale

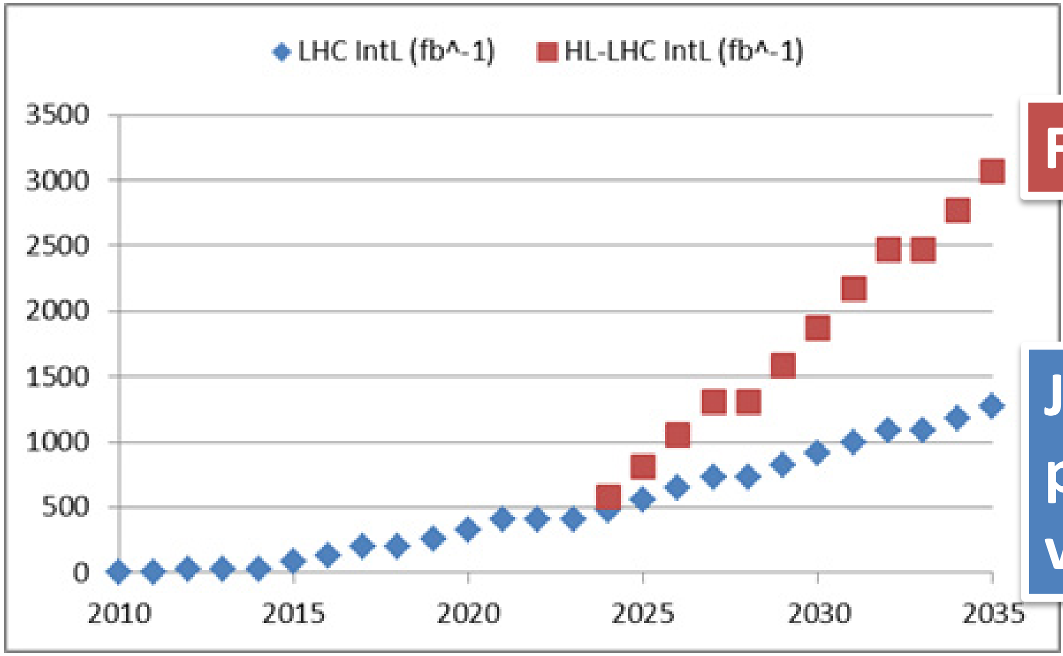
“Exploitation of the full potential of the LHC"



Final goal : 3000 fb^{-1} by 2030's…



5 10^{34} levelled lumi
(25 10^{34} virtual peak lumi)
140 pile up (average)
3 fb-1 per day
60% of efficiency
250 fb-1 /year
300 fb-1/year as «ultimate»



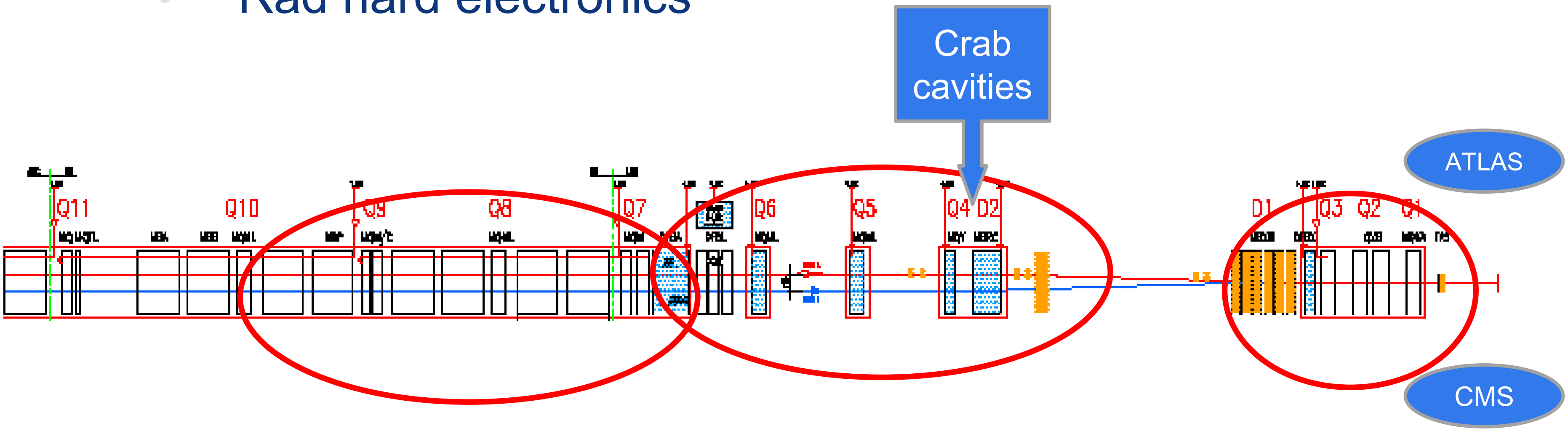
Full project

Just continue improving performance through vigorous consolidation

Steve Myers

Hardware for the Upgrade

- New high field insertion quadrupoles
- Upgraded cryogenic system for IP1 and IP5
- Upgrade of the intensity in the Injector Chain
- Crab Cavities to take advantage of the small beta*
- Single Event Upsets
  - SC links to allow power converters to be moved to surface
  - Rad hard electronics



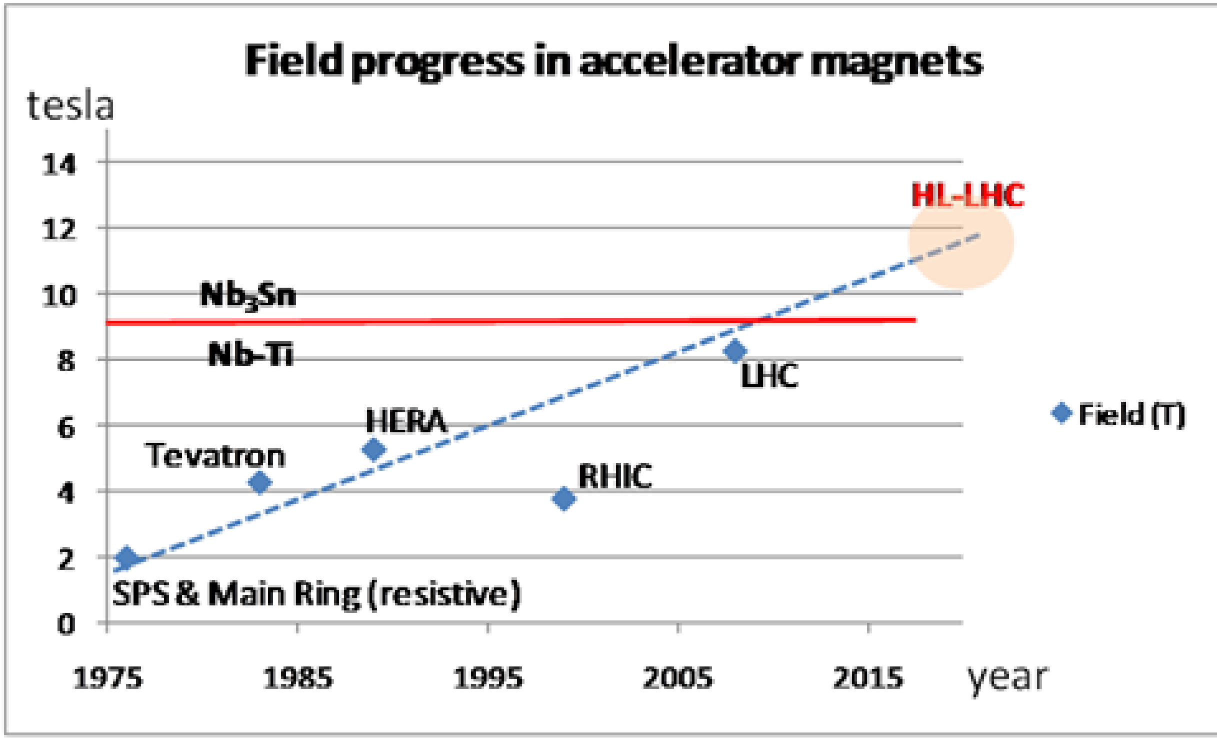
Squeezing the beams: High Field SC Magnets

13 T, 140 mm aperture Quads for the inner triplet

LHC: 8 T, 70 mm.

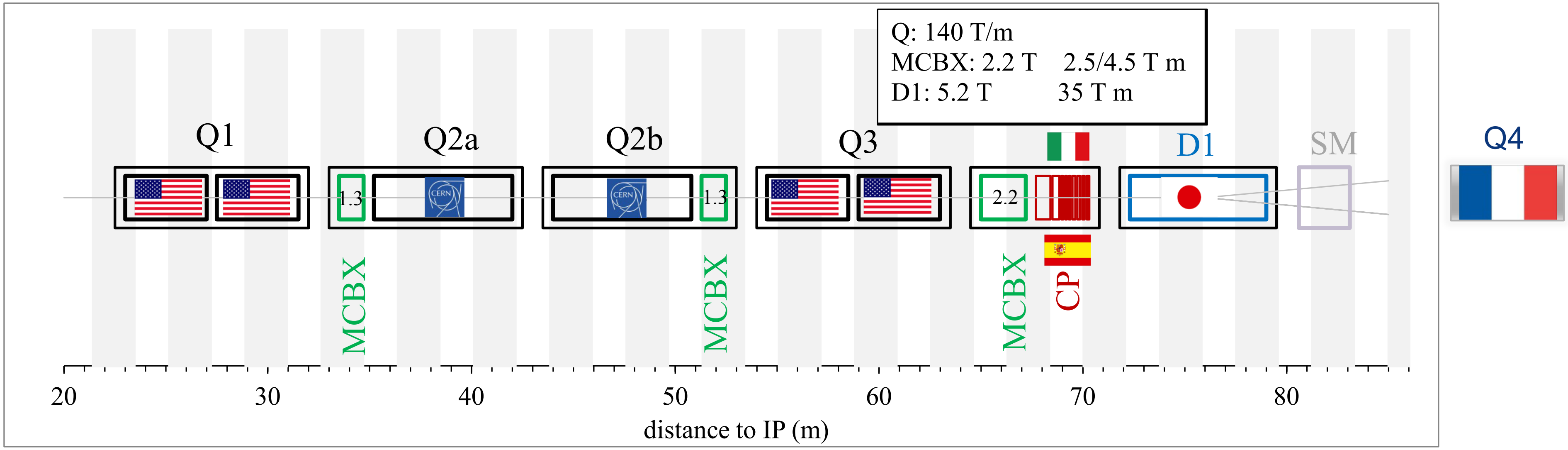
More focus strength, β^* as low as 15 cm (55 cm in LHC).
In some scheme even β^* down to 7.5 cm are considered

Dipoles for beam recombination/separation capable of 6-8 T with 150-180 mm aperture
(LHC: 1.8 T, 70 mm)



Setting up International collaboration

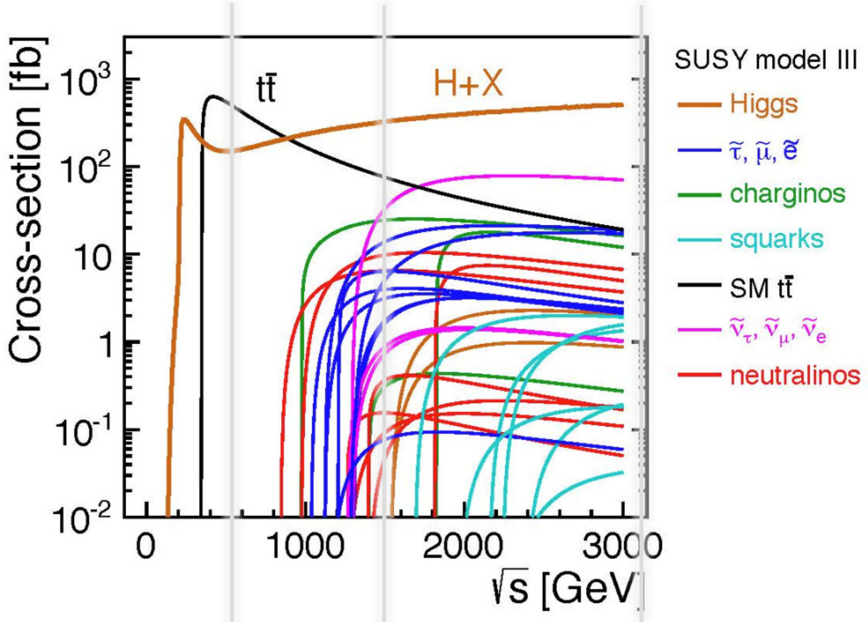
with national laboratories but also involving industrial firms



Baseline layout of HL-LHC IR region

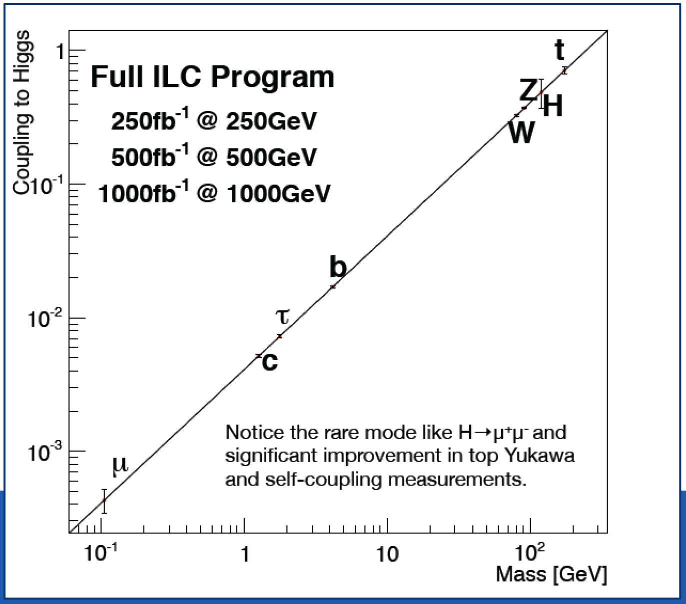
Physics at Linear Colliders

- **Physics case for the Linear Collider:**
  - **Higgs physics (SM and non-SM)**
  - **Top**
  - SUSY
  - Higgs strong interactions
  - New Z' sector
  - Contact interactions
  - Extra dimensions
  - ....

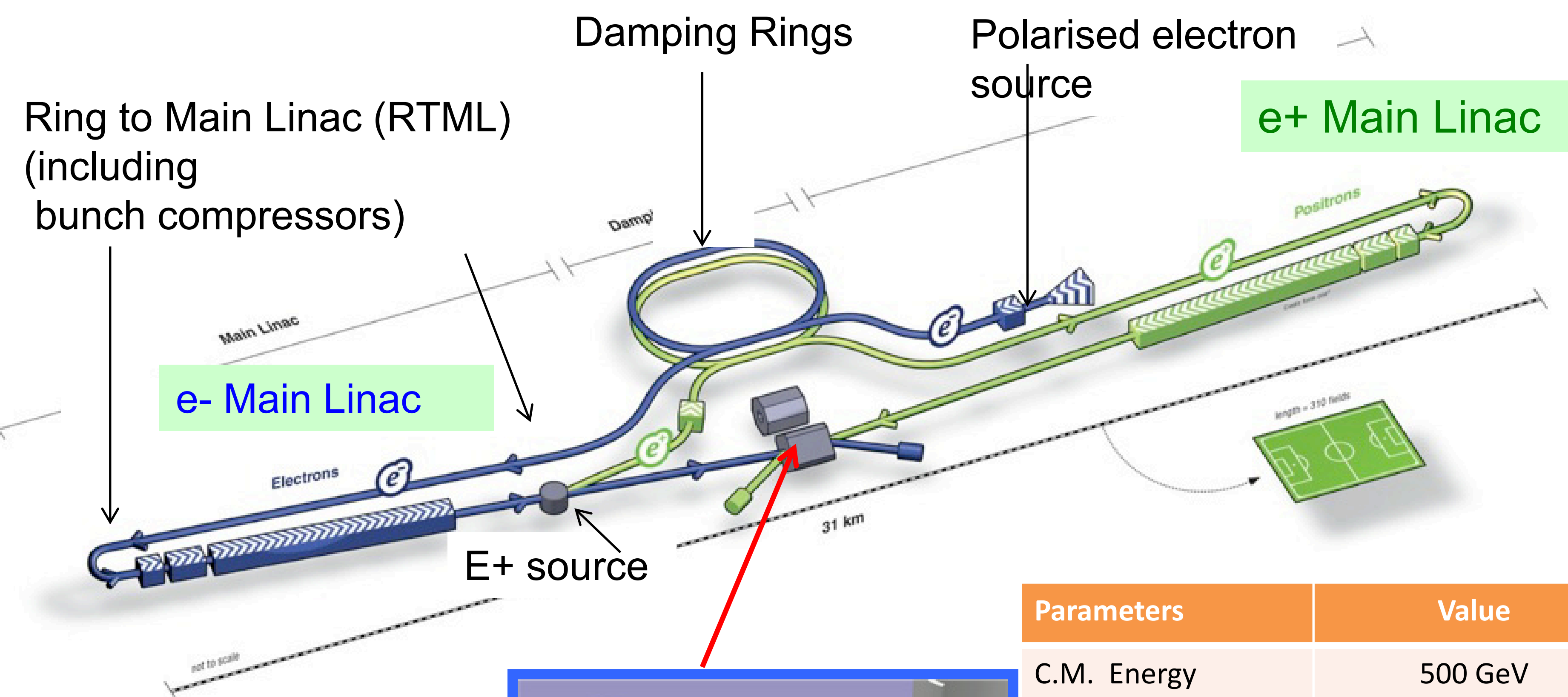


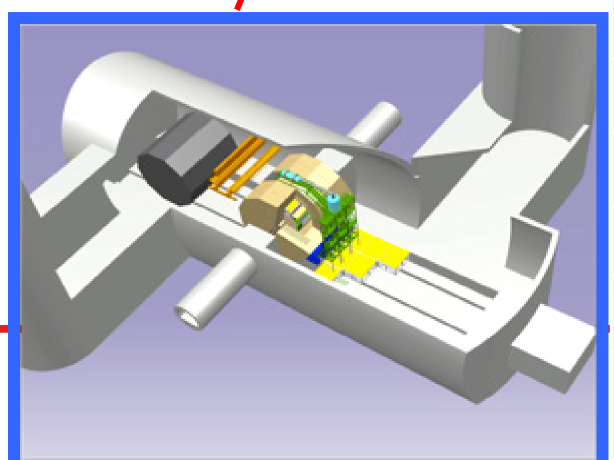
ILC ⇒ CLIC

- Higgs discovery also establishes a strong case for an e+e- collider (at least in the 350 GeV range – above 500 GeV useful)
- … will come back later to CLIC aiming for the highest possible energies



ILC TDR Layout

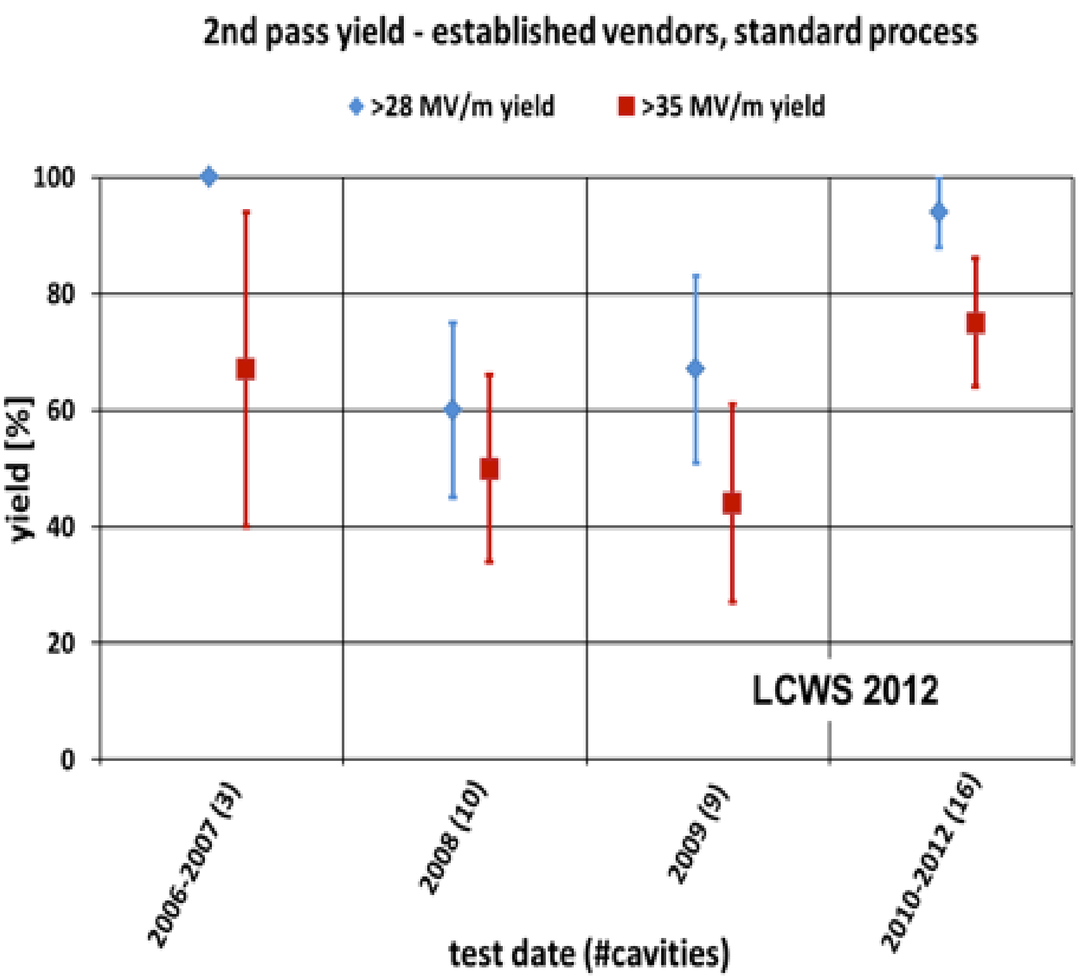


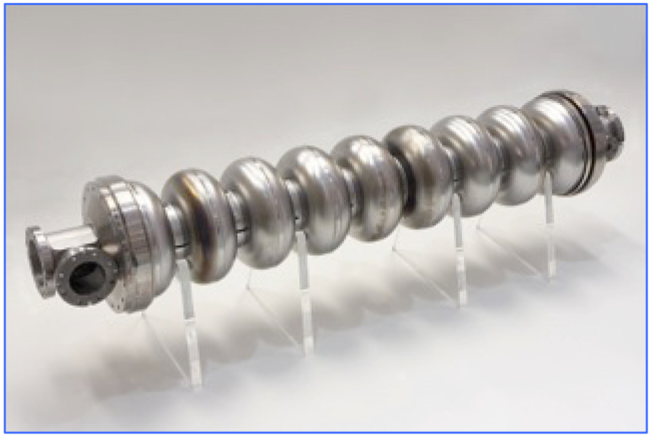


Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8×10^{34} cm^{-2}s^{-1}
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
E gradient in SCRF acc. cavity	31.5 MV/m +/-20% Q_0 = 1E10

ILC Scheme | © www.form-one.de

Progress in SCRF Cavity Gradient





Production yield:
94 % at > 28 MV/m,

Average gradient:
37.1 MV/m

reached (2012)

Accelerator System Tests

2009 ~

FLASH (DESY)

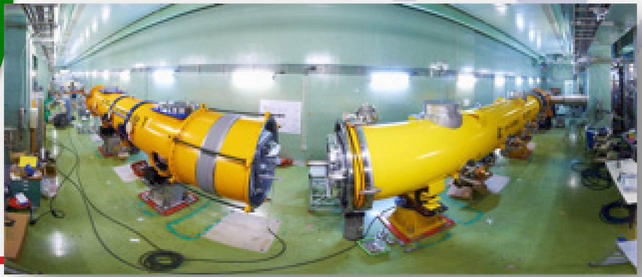
- TDP focus
- 7 CM → 1.2 GeV beam
- photon user facility

NML (FNAL)

- Under construction
- Up to 6 cryomodules
- Operation: end 2012
  - (3 CM)

STF (KEK)

- "Quantum Beam" experiment 2011
- 1 CM with beam 2013
- (2 CM 2015)



Full systems integration testing

ILC-TDR evaluation (2013-2)

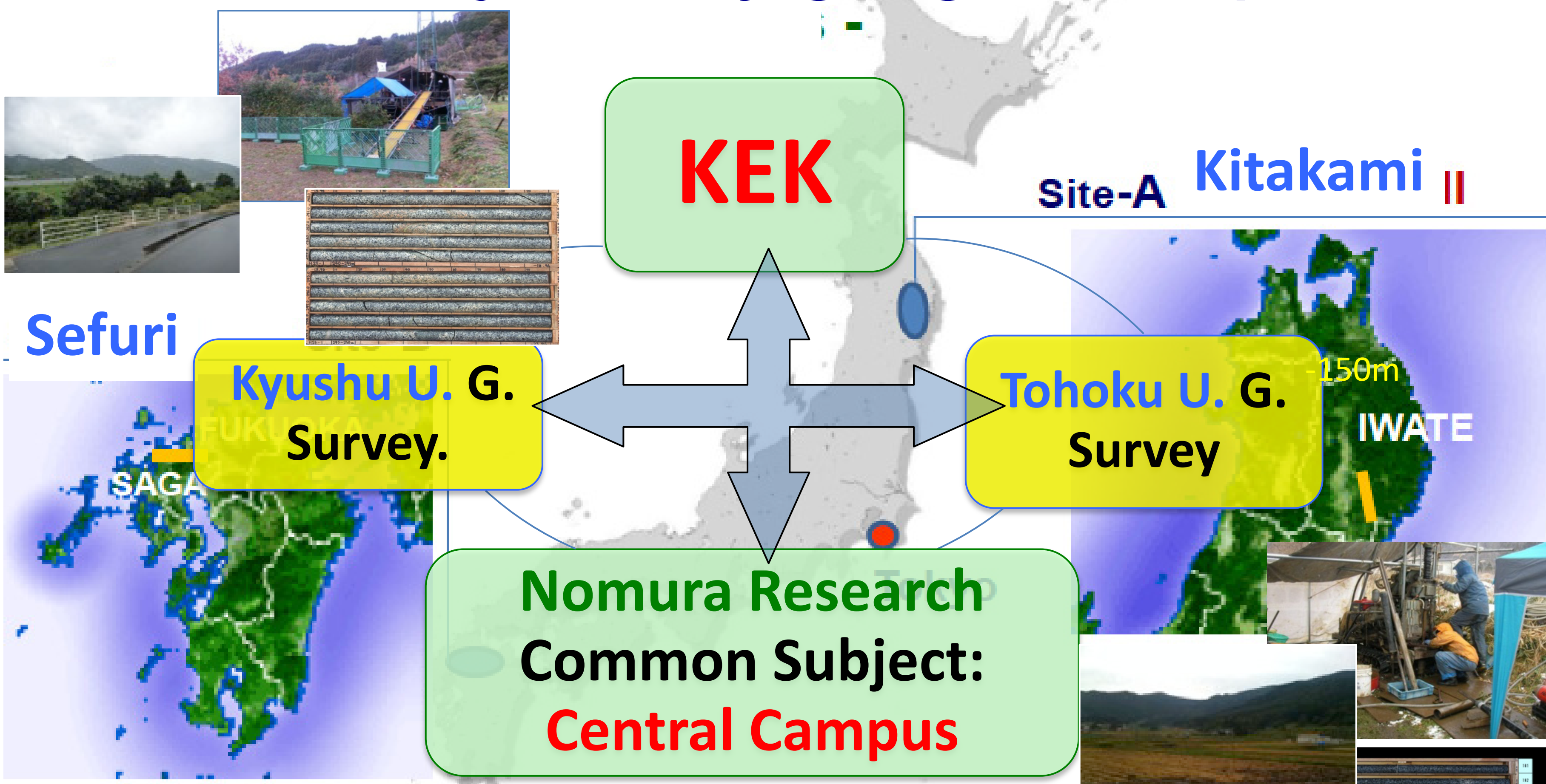
	M&S Value (Ratio)	M&S Value (GILCU)	M&S Value converted (GJY)	M&S Prem.:	Labor (M person-hr)	Labor Prem.:
RDR-2007	1	6.31 [1)]	---		24.4	
RDR-2012 (15% inflation)	1.15	7.27 [1)]	---		24.4	
TDR-2012 average for 3 region	1.23	7.78 [1)]	---		22.6	
TDR- (Asia) mountain site	1.26	7.98 [1)]	830 [2)]	26 %	22.9	24 %

1) Estimated by using PPP (purchasing power parity) methodology established by OECD
2) Conversion to Japanese Yen: using currency exchange rates
- assuming a model with 100JYen/USD, 115 Jyen/Ero

* Budget not incluced, above :
- Project preparation, Operation (0.39GILCU, 850 FTE) 、Detectors (~ 2 x 0.4 GILCU

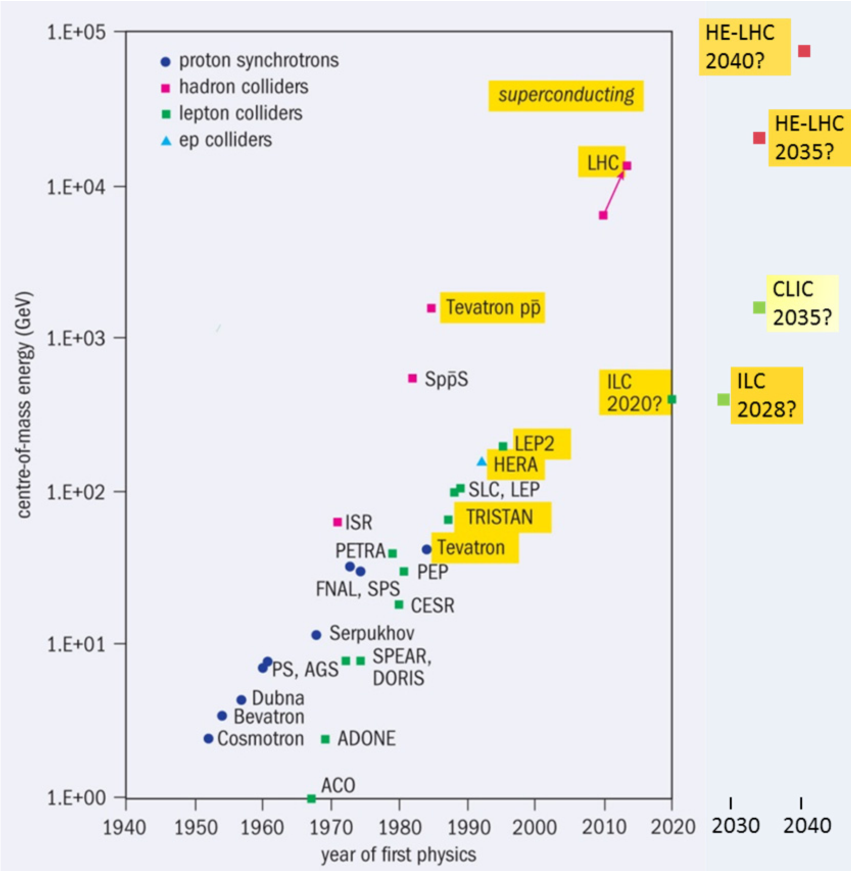
Geological Survey and Common-Subject Study, going on, in Japan

Geological Survey and Common-Subject Study, going on, in Japan

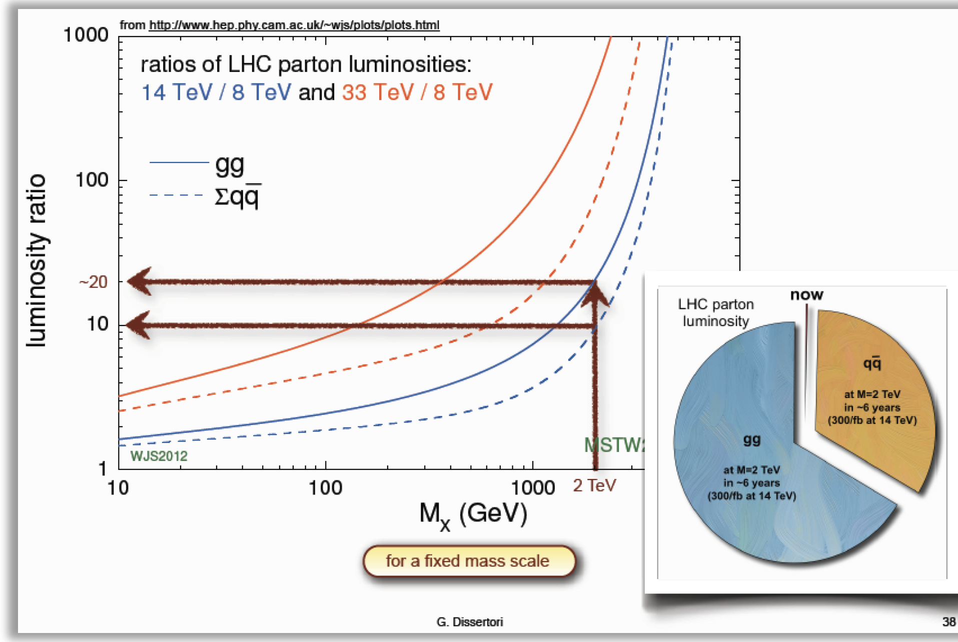


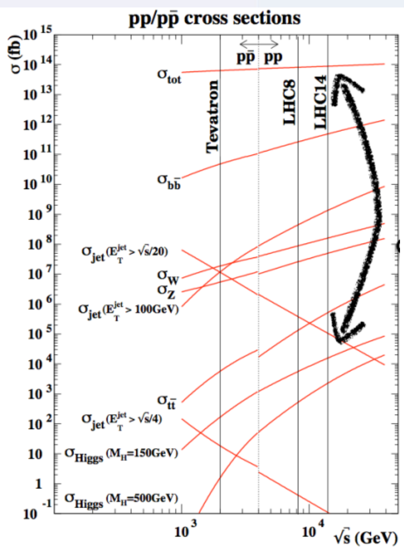
Report now available favouring northern site
Important report from Science Council underway

Energy frontier machines (hadrons or leptons)



L.Rossi

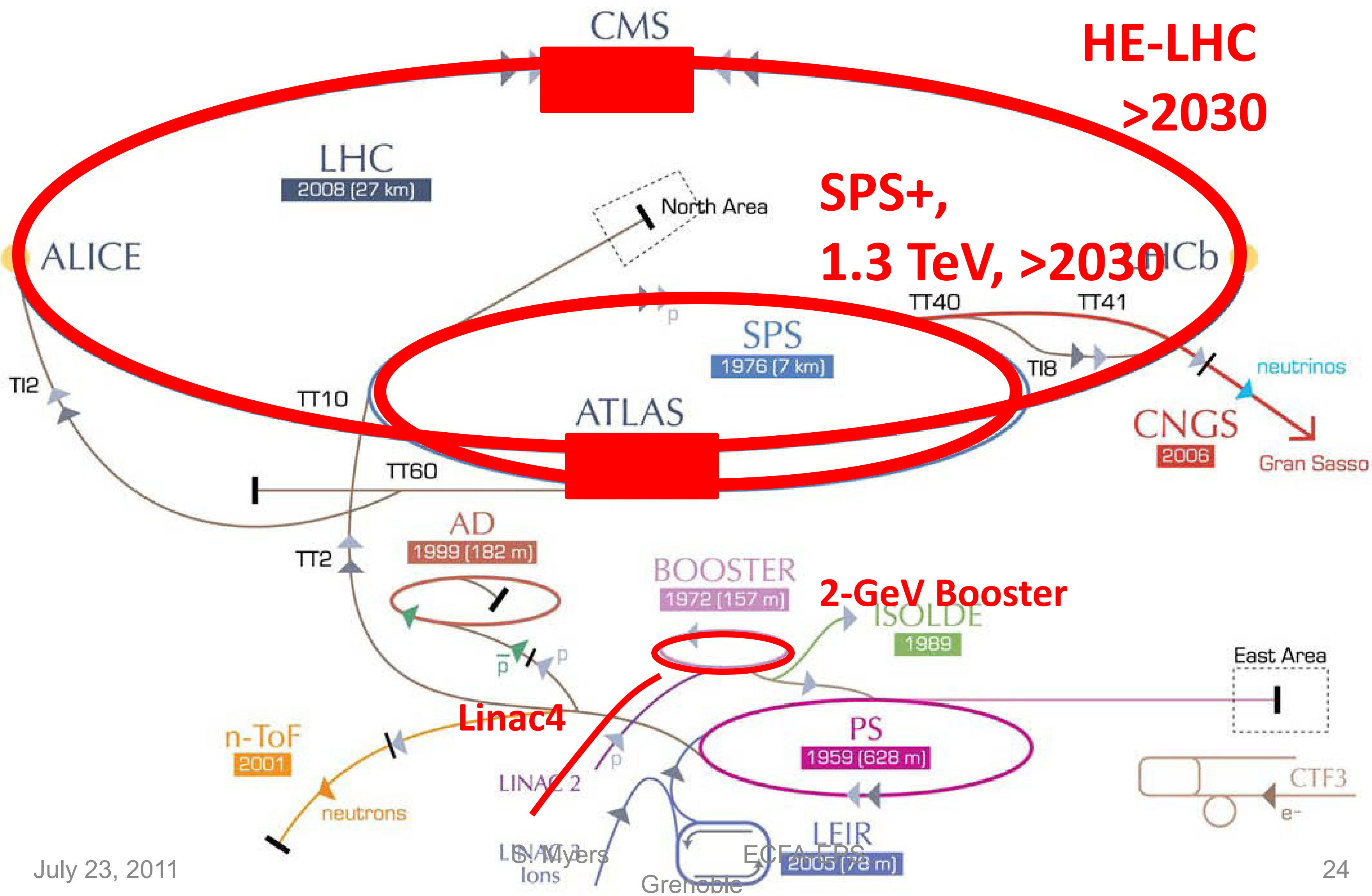




Process	VLHC 200 TeV	CLIC 3 TeV	CLIC 5 TeV
squarks	15	1.5	2.5
sleptons		1.5	2.5
Z'	30	20	30
q^*	70	3	5
l^*		3	5
Extra two dimensions	65	20 – 33	30 – 55
$W_L W_L$	30σ	70σ	90σ
TGC (95%)	0.0003	0.00013	0.00008
Λ compos.	130	300	400

Need to look at physics models (hopefully guided by new LHC data), reach (E,Lum), costs, schedules – to determine the way forward

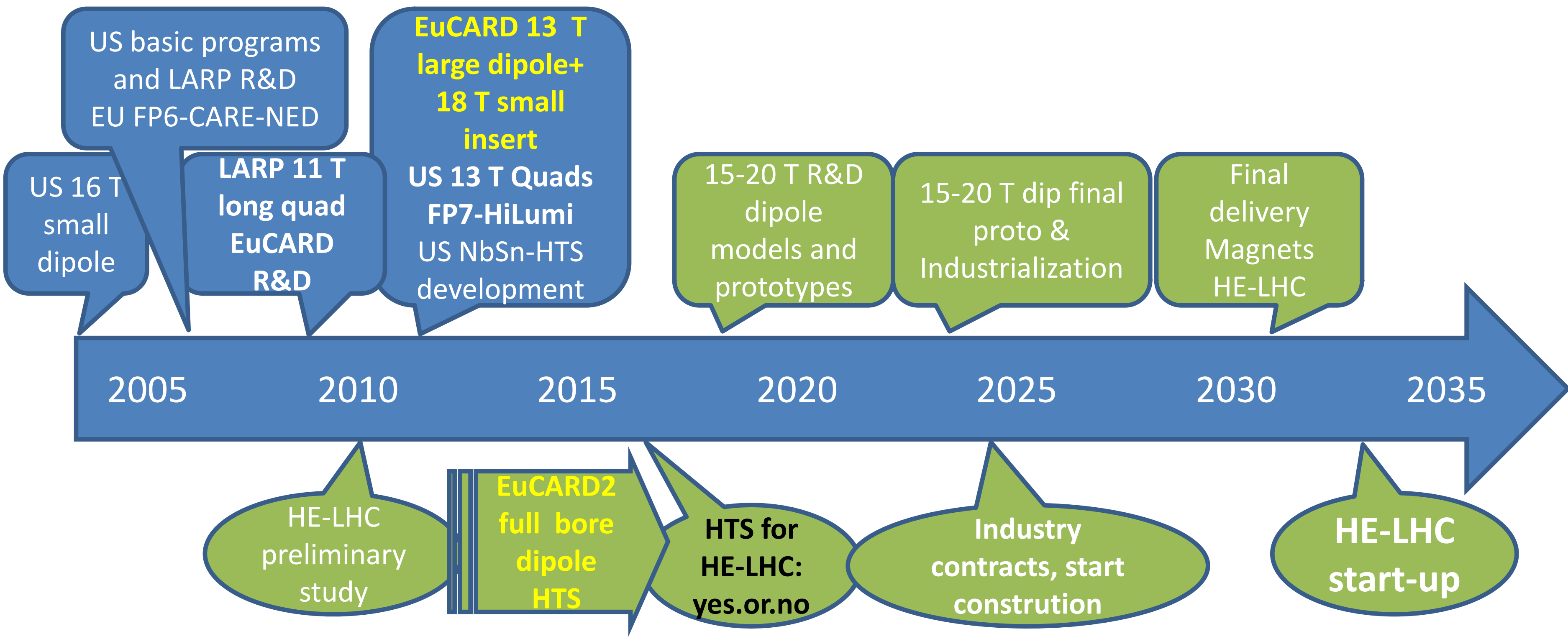
HE-LHC – LHC modifications



HE-LHC – main issues and R&D

- 20 Tesla dipole magnets based on Nb_3Sn, and HTS
- high-gradient quadrupole magnets for arc and IR
- ?? fast cycling SC magnets for 1-TeV injector ???
- emittance control in regime of strong SR damping and IBS
- cryogenic handling of SR heat load (first analysis; looks manageable)
- dynamic vacuum

An intense R&D programme is required to continue rigorously now if HE-LHC should become a real option for following the HL-LHC in the 2030s

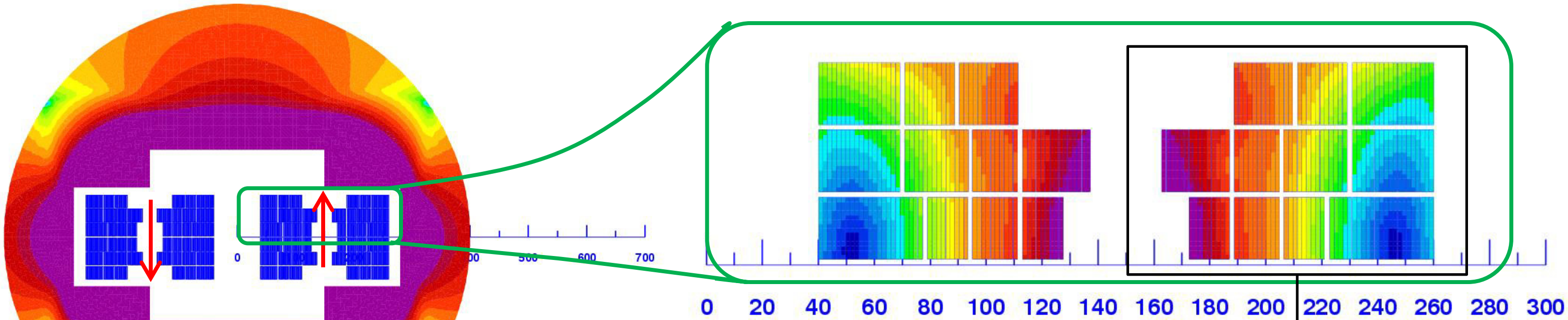


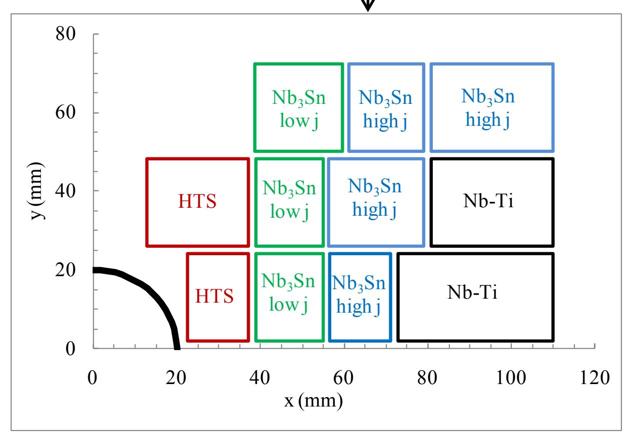
HL-LHC work as a test bed

From L. Rossi, CERN

First conceptual layout of a 20 Tesla magnet that would fit into the LHC tunnel

L. Rossi and E. Todesco





Material	N. turns	Coil fraction	Peak field	$J_{overall}$ (A/mm^2)
Nb-Ti	41	27%	8	380
Nb3Sn (high Jc)	55	37%	13	380
Nb3Sn (Low Jc)	30	20%	15	190
HTS	24	16%	20.5	380

Magnet design: 40 mm bore (depends on injection energy: > 1 Tev)
Very challenging but feasable: 300 mm inter-beam; anticoils to reduce flux
Approximately 2.5 times more SC than LHC: 3000 tonnes!
Multiple powering in the same magnet for FQ (and more sectioning for energy)
Certainly only a first attempt: cosϑ and other shapes will be also investigated

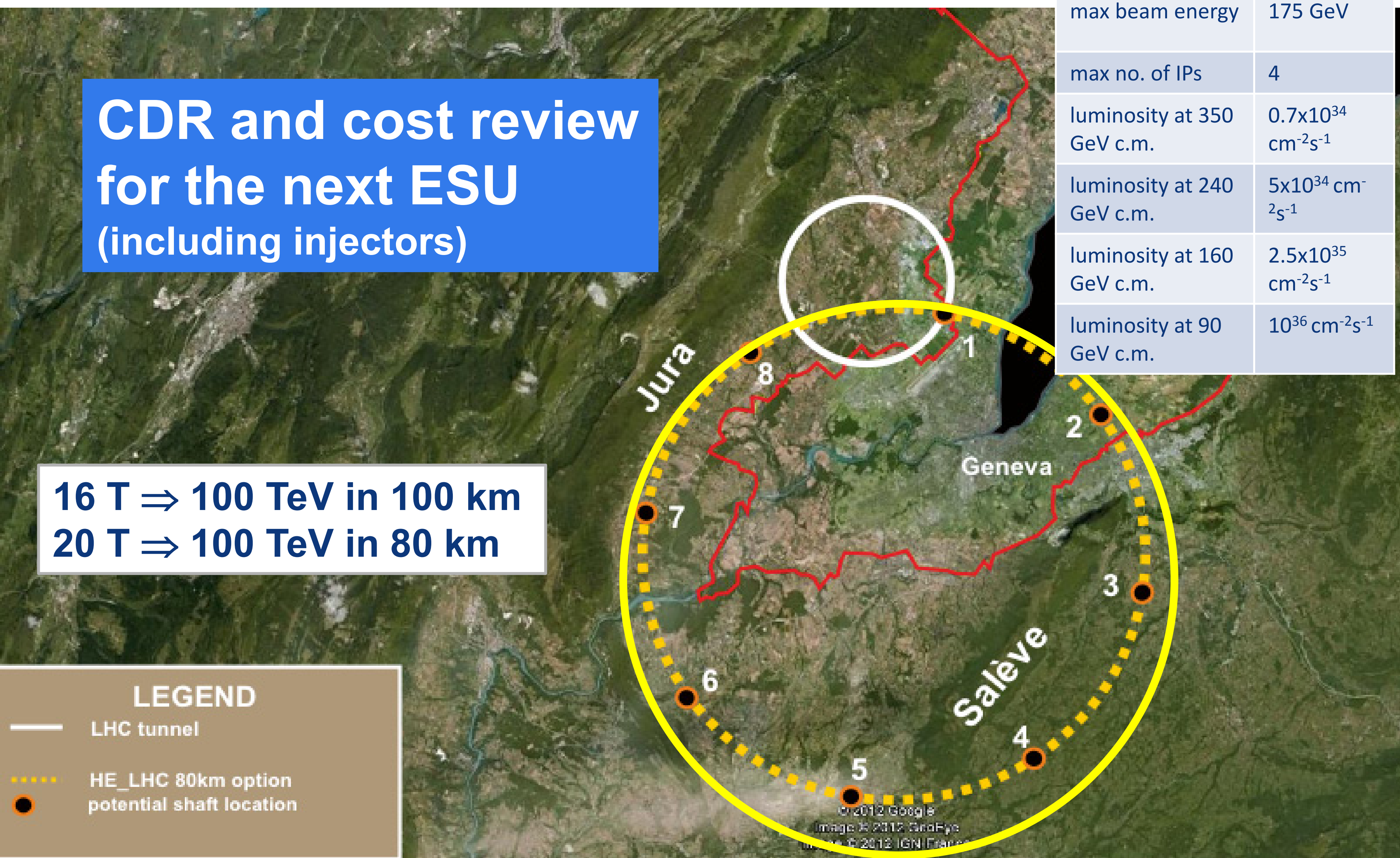
80-100 km tunnel in Geneva area – VHE-LHC

with possibility of e+-e- (TLEP) and p-e (VLHeC)

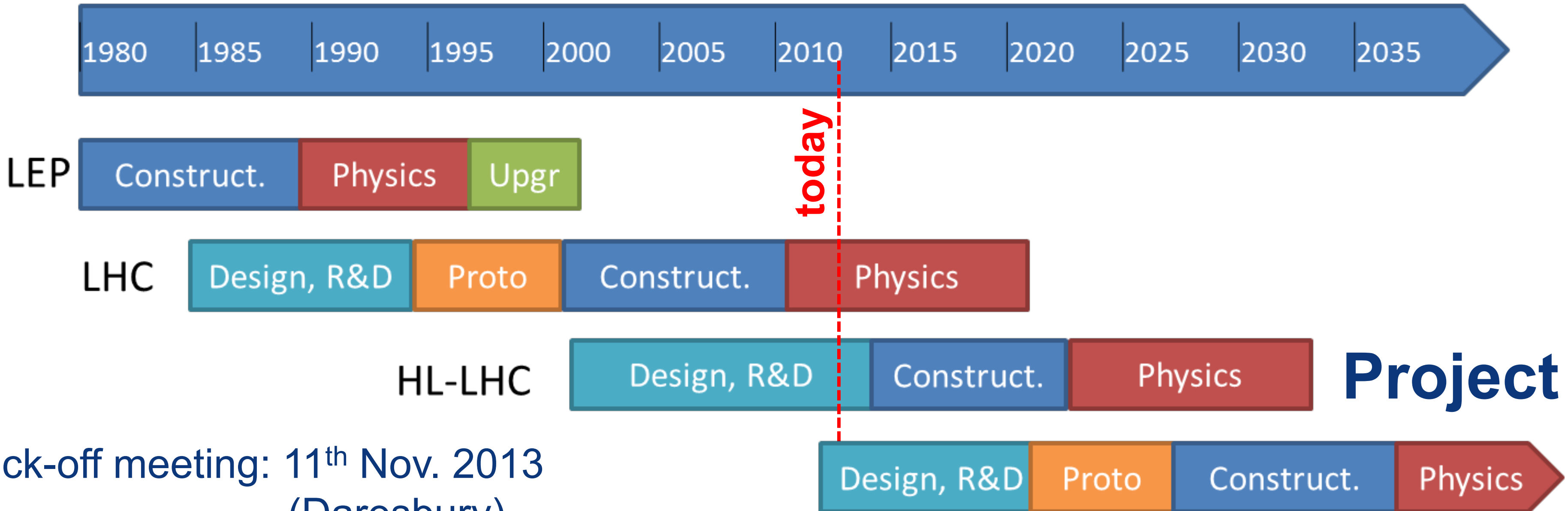
	TLEP
circumference	80 km
max beam energy	175 GeV
max no. of IPs	4
luminosity at 350 GeV c.m.	0.7×10^{34} $cm^{-2}s^{-1}$
luminosity at 240 GeV c.m.	5×10^{34} $cm^{-2}s^{-1}$
luminosity at 160 GeV c.m.	2.5×10^{35} $cm^{-2}s^{-1}$
luminosity at 90 GeV c.m.	10^{36} $cm^{-2}s^{-1}$

CDR and cost review for the next ESU
(including injectors)

16 T $\Rightarrow$ 100 TeV in 100 km
20 T $\Rightarrow$ 100 TeV in 80 km



"CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines."



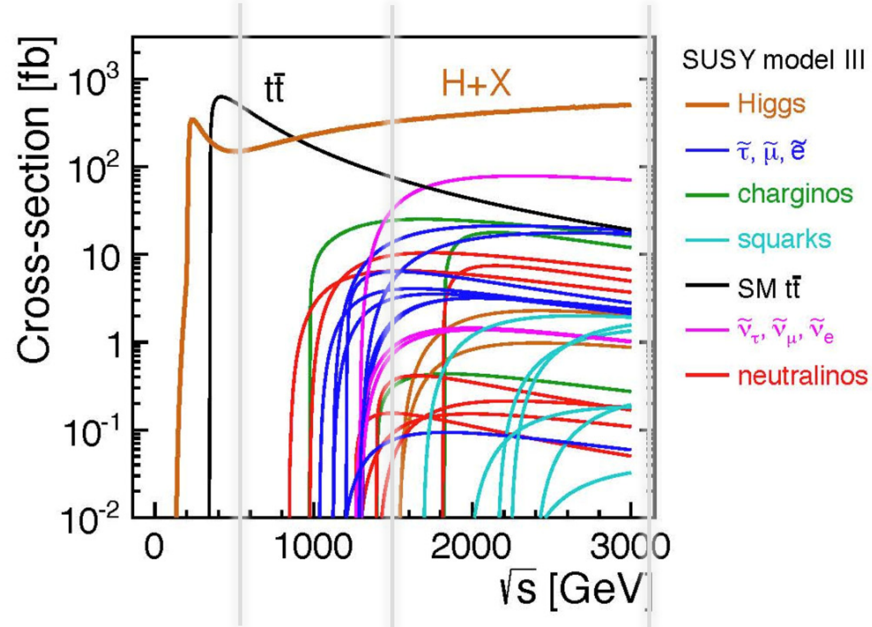
Kick-off meeting: 11th Nov. 2013
(Daresbury)

Study : VHE-LHC with TLEP

Kick-off meeting: February 2014
(CERN)

Physics at Linear Colliders from 250 GeV to 3000 GeV

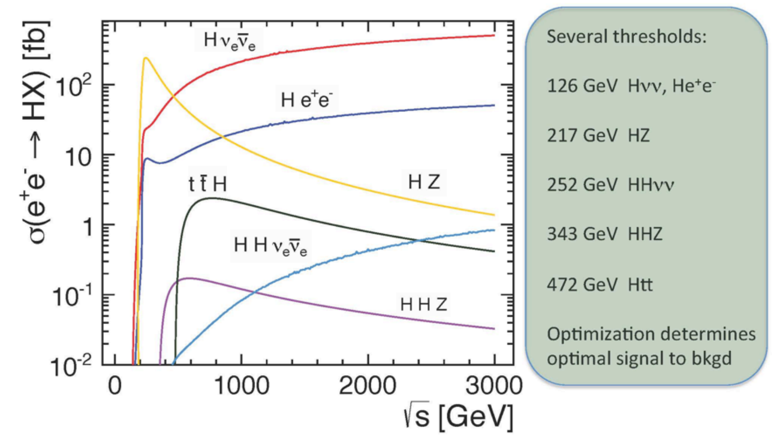
- **Physics case for the Linear Collider:**
  - **Higgs physics (SM and non-SM)**
  - **Top**
  - SUSY
  - Higgs strong interactions
  - New Z' sector
  - Contact interactions
  - Extra dimensions
  - ….



Recently: Further work on completing picture of Higgs prospects at ~350 GeV, ~1.4 TeV, ~3 TeV, example for CLIC:

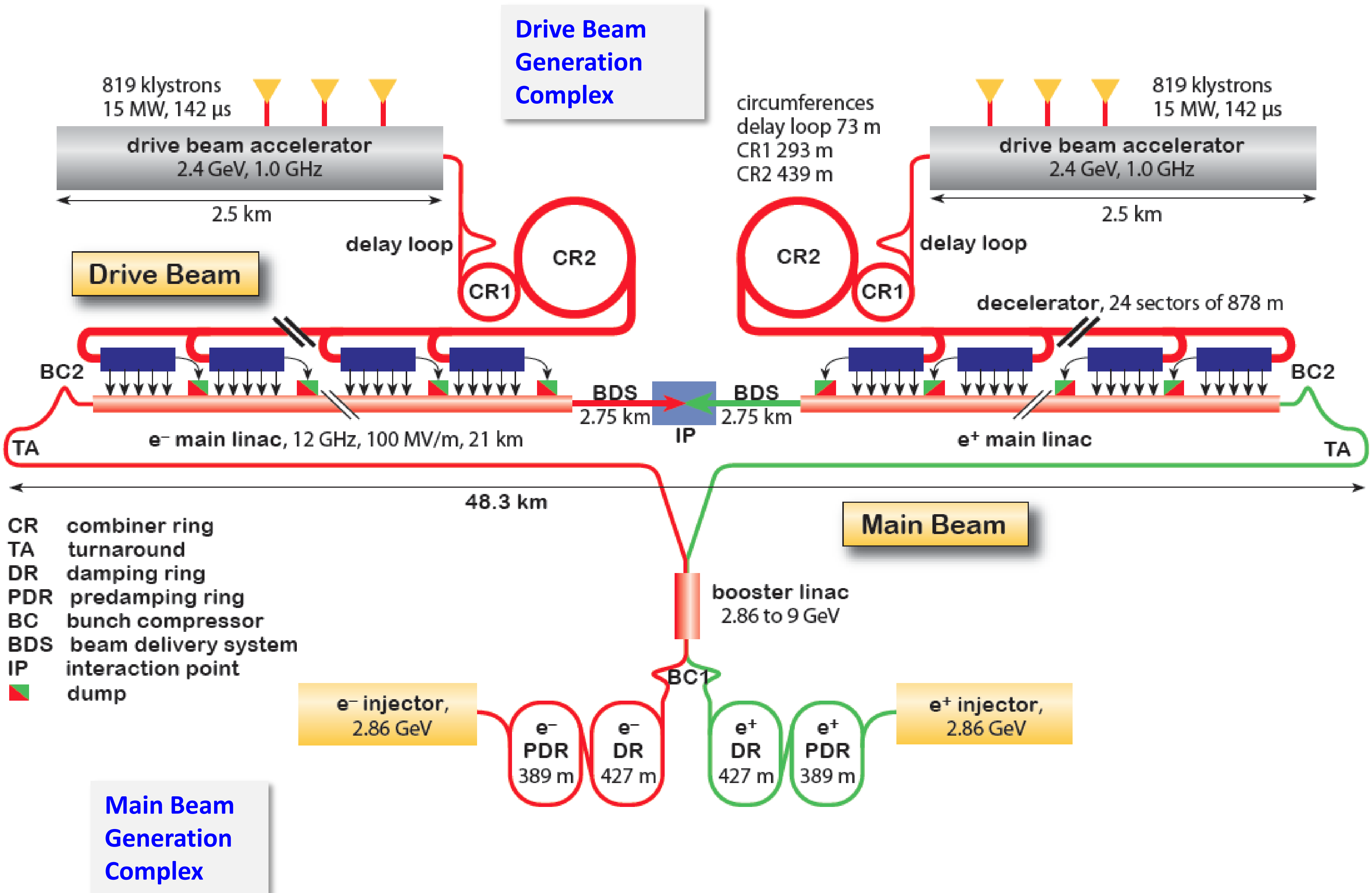
collision energy Polarization e⁻/e⁺	$\sqrt{s}$ = 1.4 TeV unpolarized	$\sqrt{s}$ = 1.4 TeV -80% / +30%	$\sqrt{s}$ = 3.0 TeV unpolarized	$\sqrt{s}$ = 3.0 TeV -80% / +30%
Δ σ(HHνν)	≈ 22%	≈ 18%	≈ 10%	≈ 7%
Δ λ_{HHH}	≈ 28%	≈ 22%	≈ 16%	≈ 11%
Numbers with polarized beams obtained by scaling signal and background cross sections, ignoring polarization-dependent changes to kinematic properties.				all cross section values: mH = 120 GeV

Higgs boson Production Cross-Sections

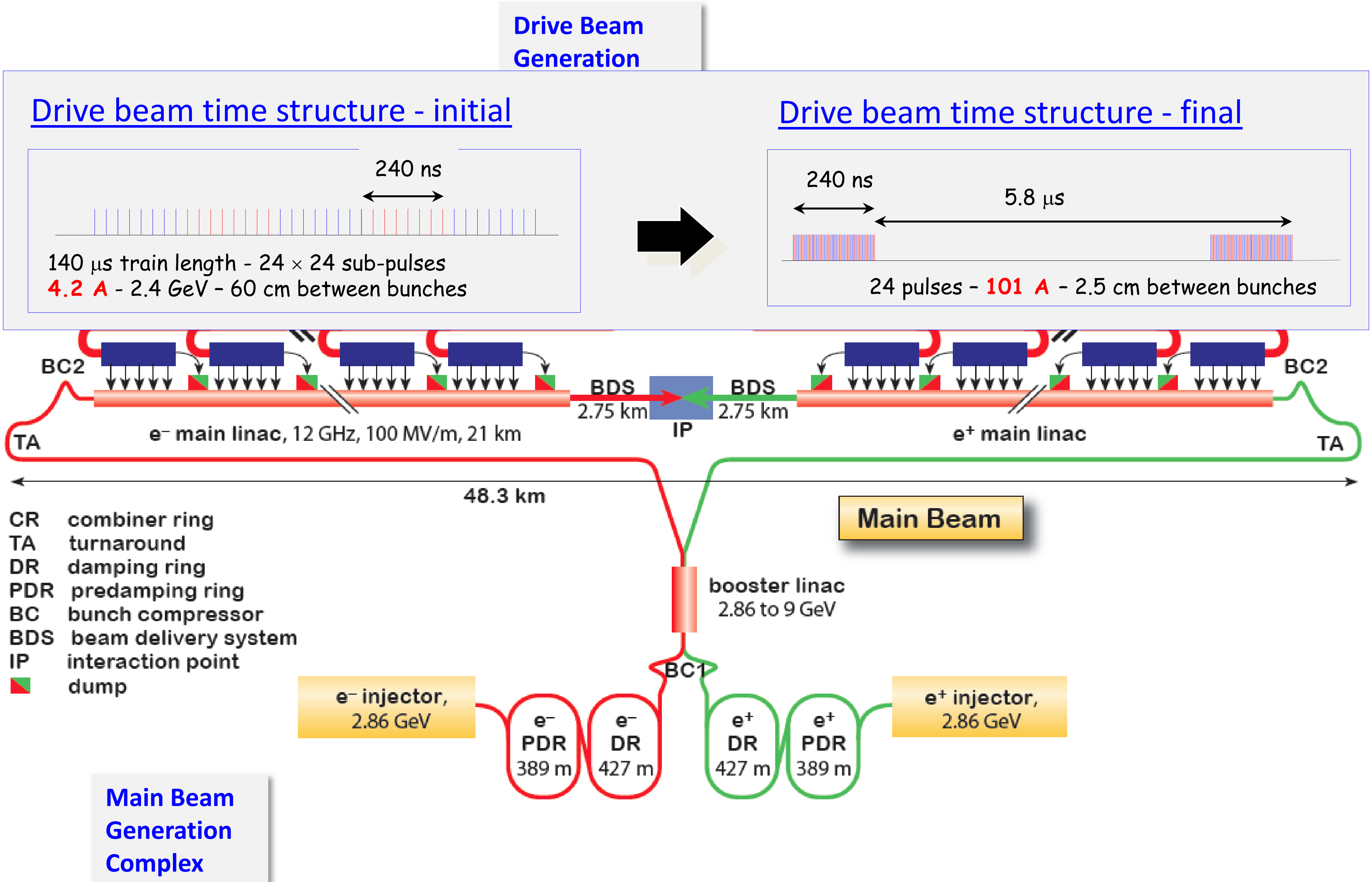


Lebrun et al., arXiv:1209.2543

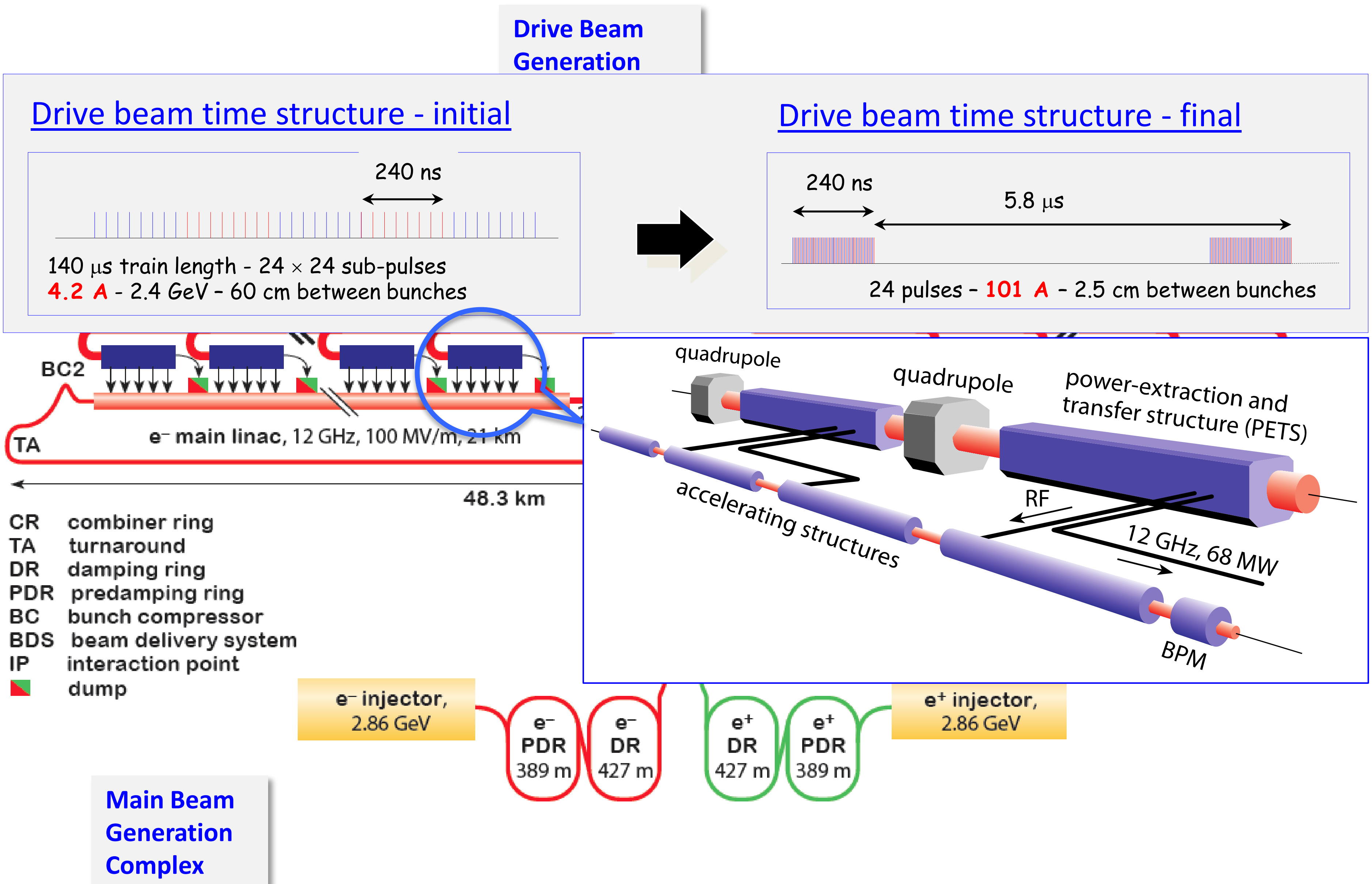
CLIC Layout at 3 TeV



CLIC Layout at 3 TeV



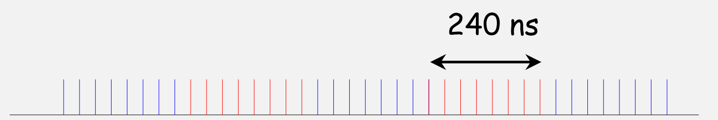
CLIC Layout at 3 TeV



CLIC Layout at 3 TeV

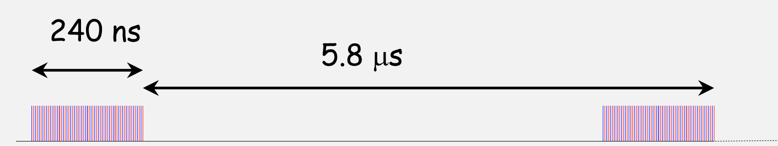
Drive Beam Generation

Drive beam time structure - initial

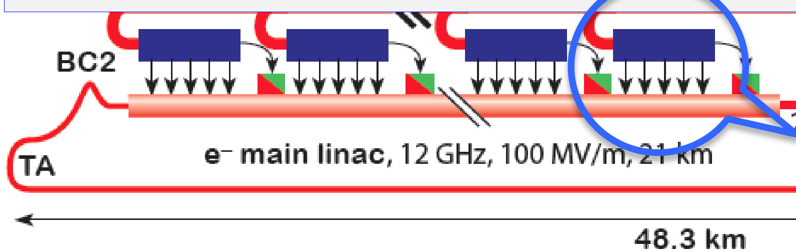


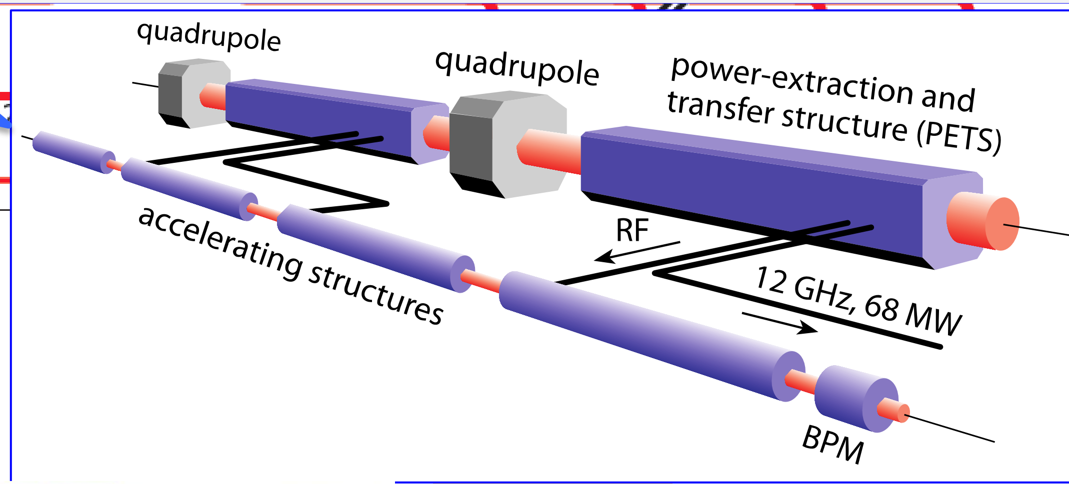
140 μs train length - 24 × 24 sub-pulses
4.2 A - 2.4 GeV – 60 cm between bunches

Drive beam time structure - final



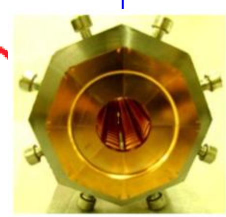
24 pulses – 101 A – 2.5 cm between bunches

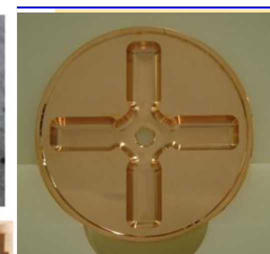
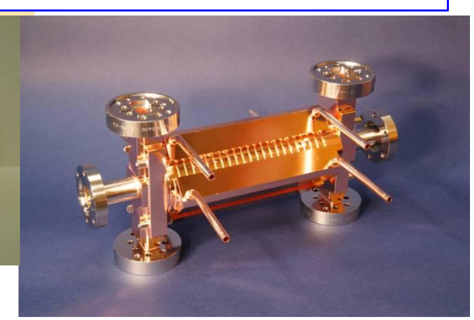




CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
dump

e⁻ injector,
2.86 GeV

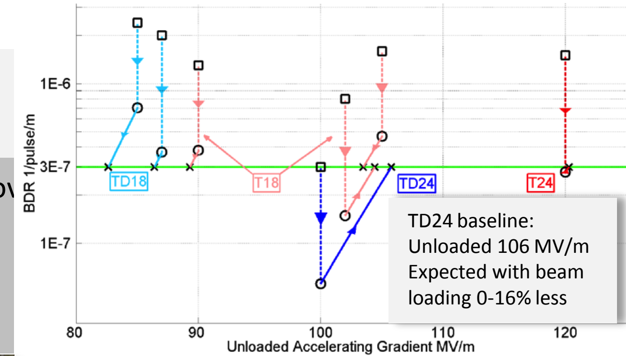


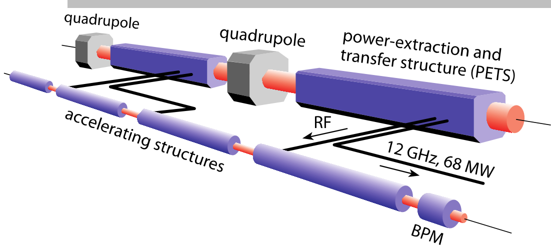
Main Beam Generation Complex

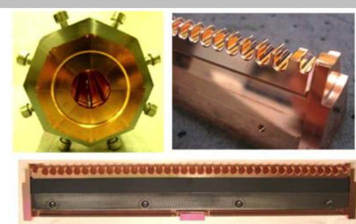
Conclusion of the accelerator CDR studies

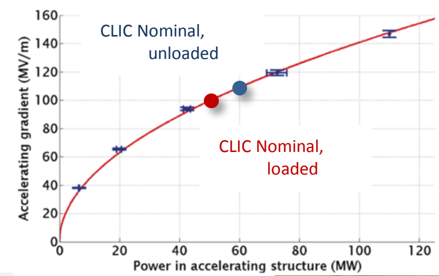
Main linac gradient
- Ongoing test close to or on target
- Uncertainty from beam loading being tested



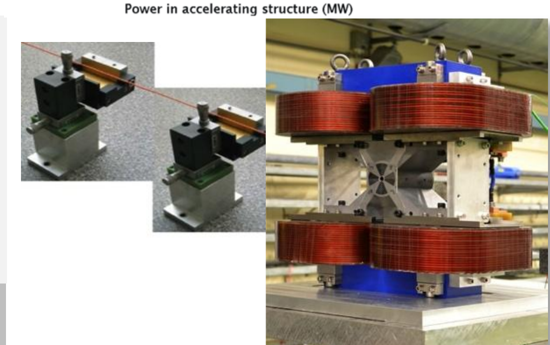
Drive beam scheme
- Generation tested, used to accelerate test beam abov specifications, deceleration as expected
- Improvements on operation, reliability, losses, more deceleration studies underway







Luminosity
- Damping ring like an ambitious light source, no show stopper
- Alignment system principle demonstrated
- Stabilisation system developed, benchmarked, better system in pipeline
- Simulations on or close to the target



Operation & Machine Protection
- Start-up sequence and low energy operation defined
- Most critical failure studied and first reliability studies

Implementation
- Consistent three stage implementation scenario defined
- Schedules, cost and power developed and presented
- Site and CE studies documented

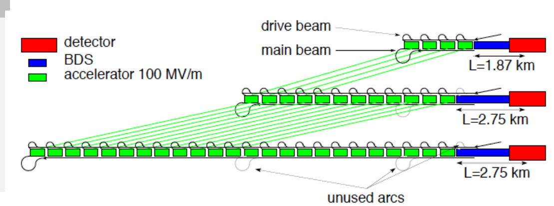


Fig. 3.6: Simplified upgrade scheme for CLIC staging scenario B.

Power/energy consumption

Considering 150 days per year of normal operation at nominal power and a luminosity ramp-up in the early years at each stage of collision energy, the development of yearly energy consumption can be sketched.

Re-optimize parts
- Reduced current density in normal-conducting magnets
- Reduction of heat loads to HVAC
- Re-optimization of accelerating gradient with different objective function

Efficiency
- Grid-to-RF power conversion
- Permanent or super-ferric superconducting magnets

Energy management
- Low-power configurations in case of beam interruption
- Modulation of scheduled operation to match electricity demand: Seasonal and Daily
- Power quality specifications

Waste heat recovery
- Possibilities of heat rejection at higher temperature
- Waste heat valorization by concomitant needs, e.g. residential heating, absorption cooling

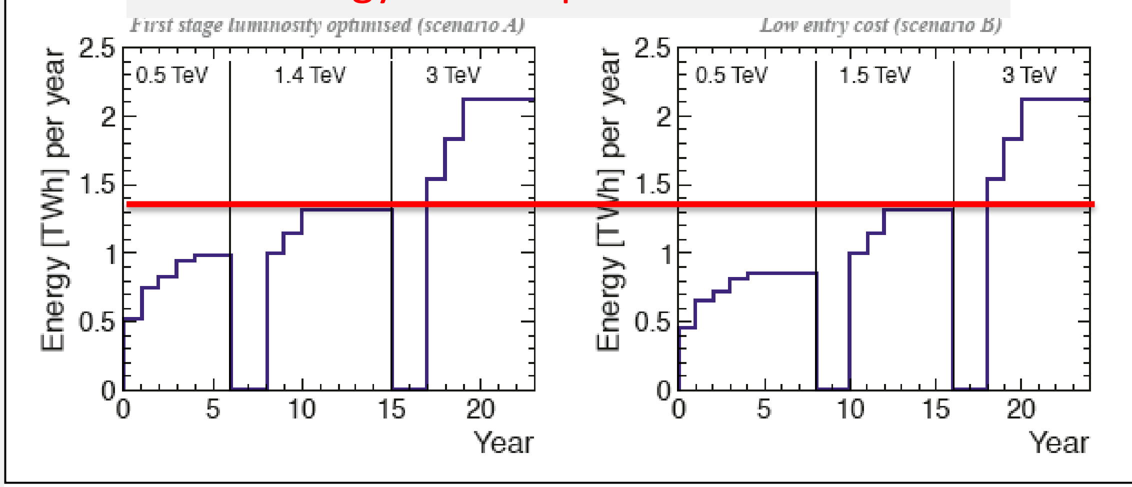
Beyond:
Scale with inst. luminosity – i.e. running at the very end of the project lifetime might be power limited and require more time.

Staging scenario	$\sqrt{s}$ (TeV)	$\mathscr{L}_{1\%}$ (cm^{-2}s^{-1})	$W_{main\ beam}$ (MW)	$P_{electric}$ (MW)
A	0.5	$1.4 \cdot 10^{34}$	9.6	272
	1.4	$1.3 \cdot 10^{34}$	12.9	364
	3.0	$2.0 \cdot 10^{34}$	27.7	589
B	0.5	$7.0 \cdot 10^{33}$	4.6	235
	1.5	$1.4 \cdot 10^{34}$	13.9	364
	3.0	$2.0 \cdot 10^{34}$	27.7	589

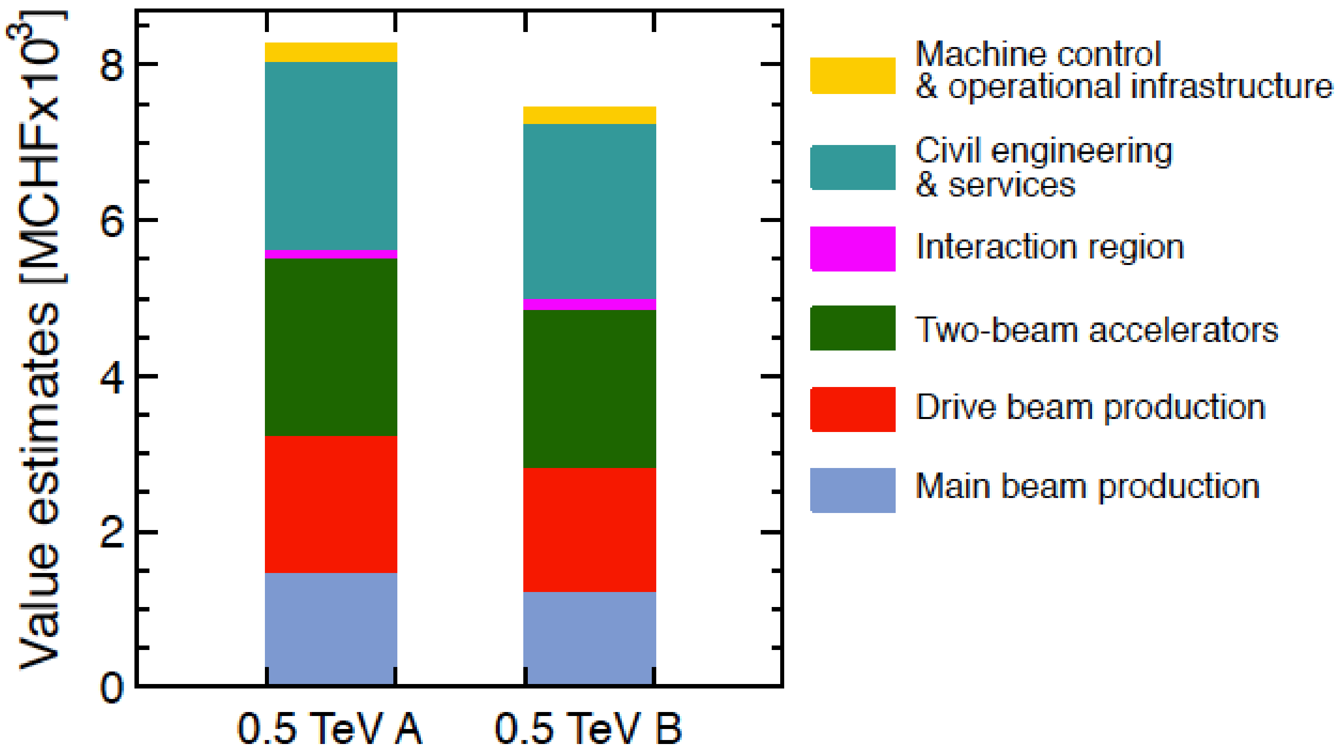
Table 5.2: Residual power without beams for staging scenarios A and B.

Staging scenario	$\sqrt{s}$ (TeV)	$P_{waiting\ for\ beam}$ (MW)	$P_{shutdown}$ (MW)
A	0.5	168	37
	1.4	190	42
	3.0	268	58
B	0.5	167	35
	1.5	190	42
	3.0	268	58

CERN energy consumption 2012: 1.35 TWh



Costs

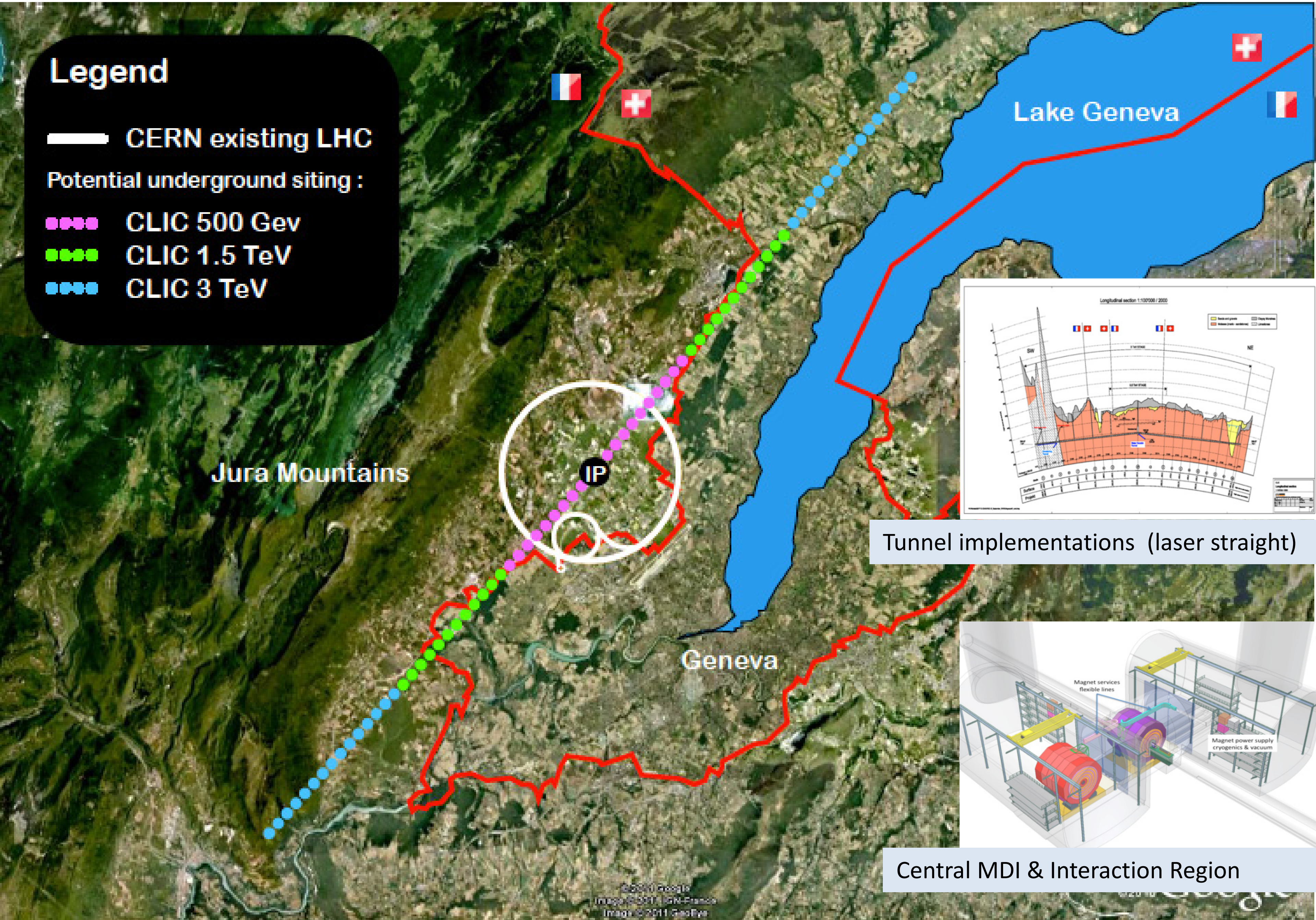


First to second stage: 4 MCHF/GeV (i.e. initial costs are very significant)

Caveats:

- Uncertainties 20-25%
- Possible savings around 10%
- However – first stage not optimised (work for next phase), parameters largely defined for 3 TeV final stage

CLIC near CERN

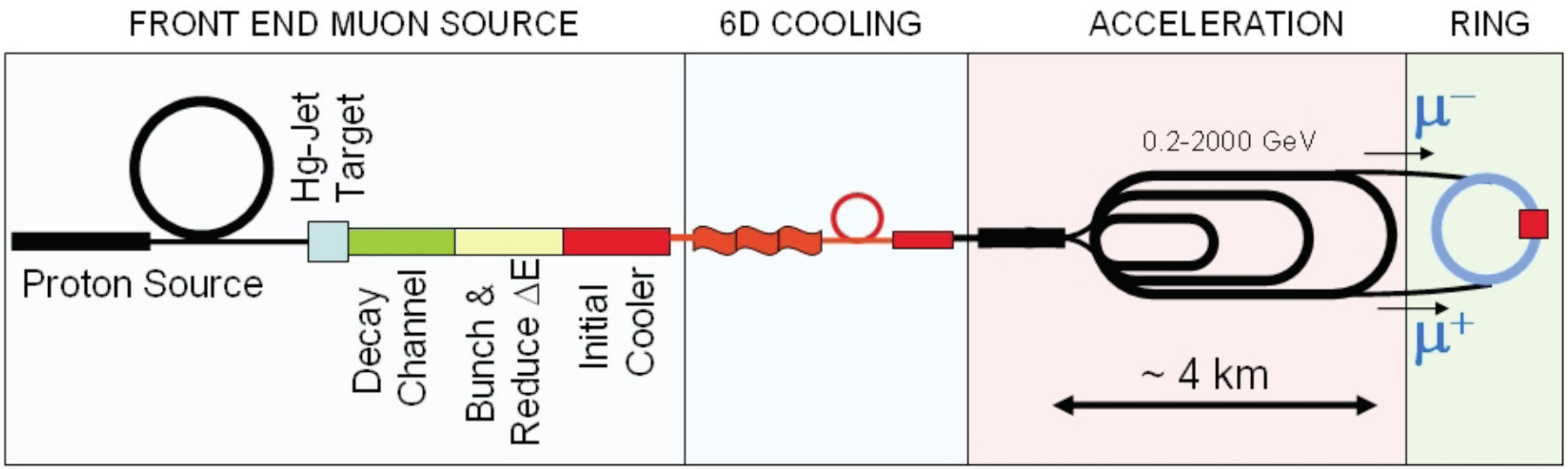


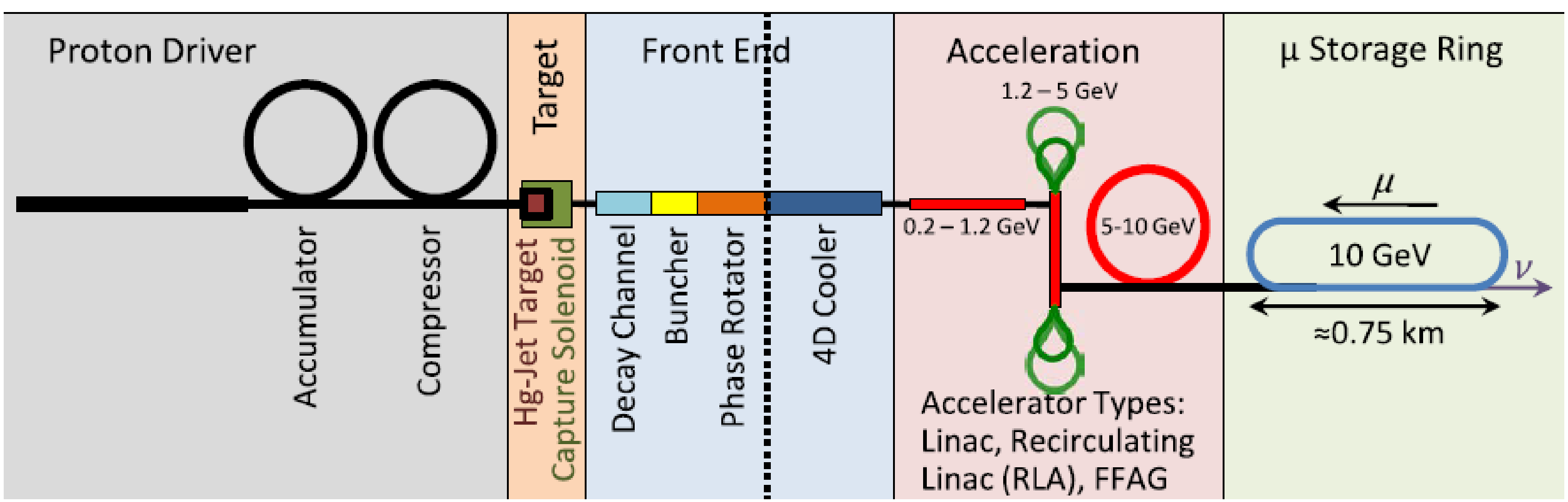
Tunnel implementations (laser straight)

Central MDI & Interaction Region

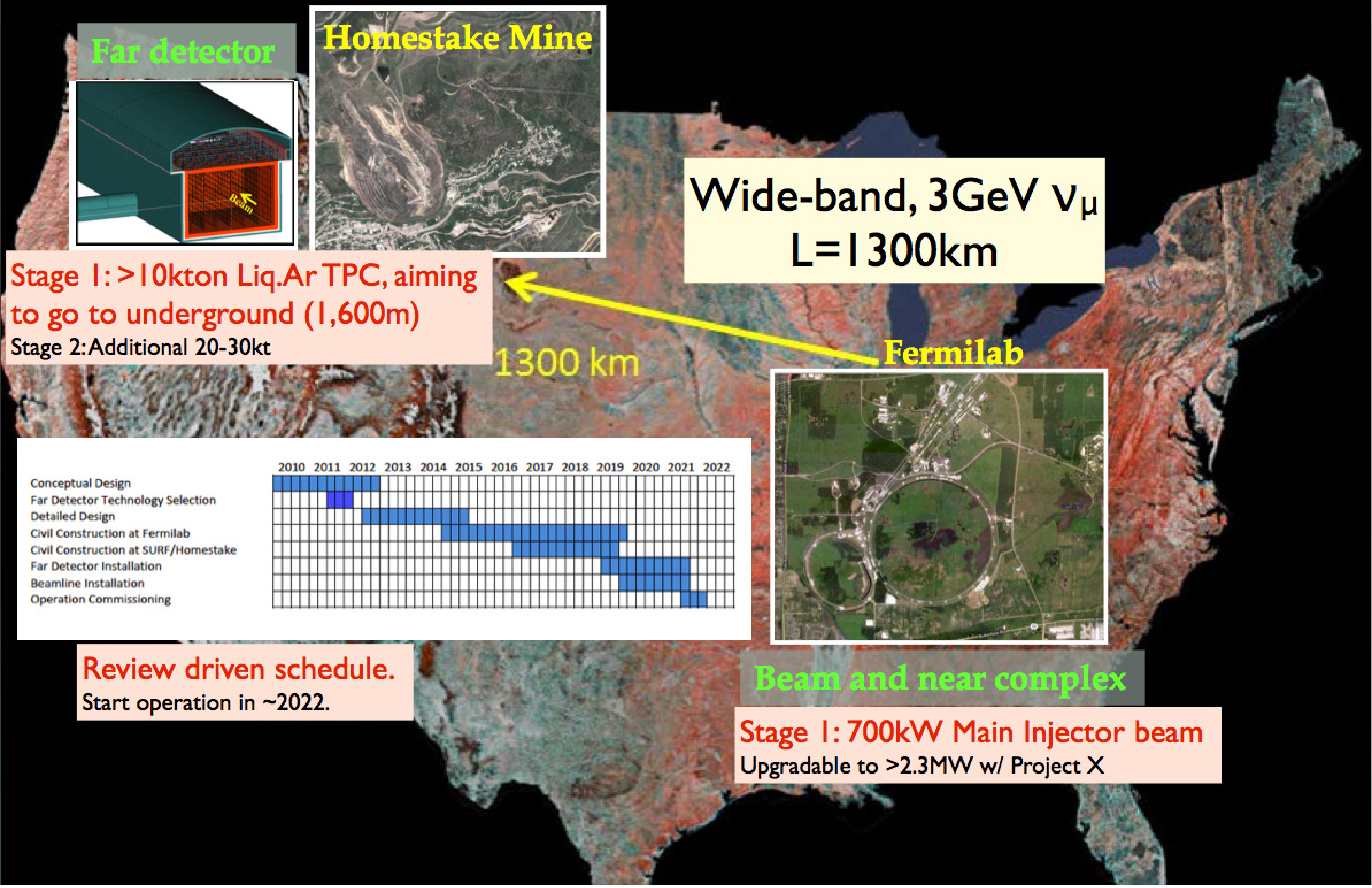
Muon Collider / Neutrino Factory

Many technical challenges, intensive R&D on target, cooling required

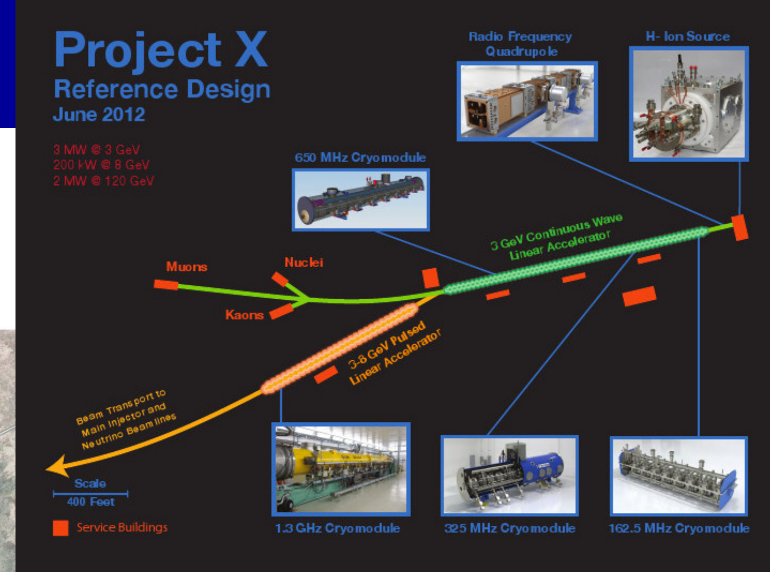




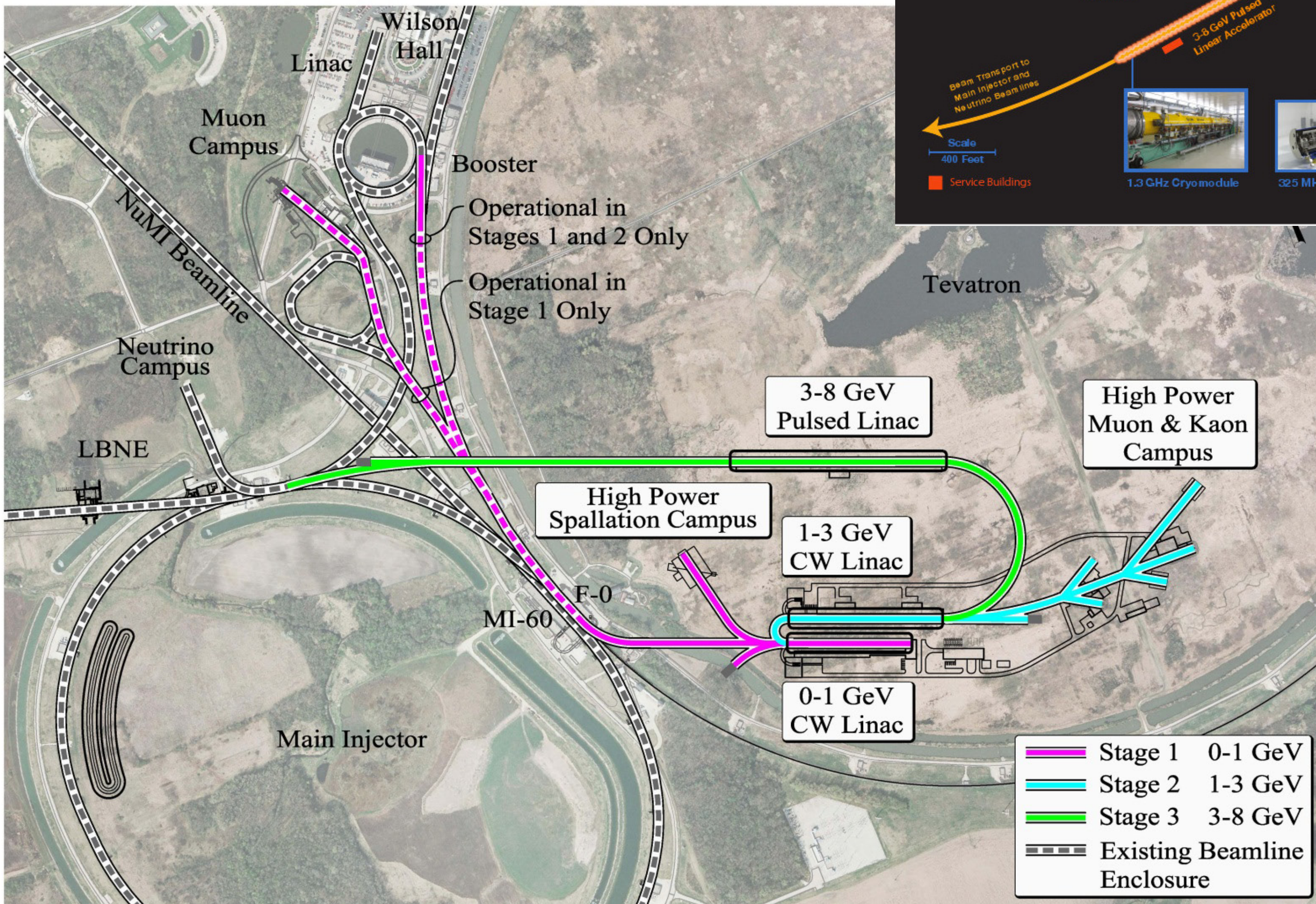
Long-Baseline Neutrino Experiment



Project-X



Project X
Reference Design
June 2012
3 MW @ 3 GeV
200 kW @ 8 GeV
2 MW @ 120 GeV
Radio Frequency Quadrupole
H- Ion Source
650 MHz Cryomodule
3 GeV Continuous Wave Linear Accelerator
Muons
Nuclei
Kaons
3-8 GeV Pulsed Linear Accelerator
Beam Transport to Main Injector and Neutrino Beam lines
Scale
400 Feet
Service Buildings
1.3 GHz Cryomodule
325 MHz Cryomodule
162.5 MHz Cryomodule

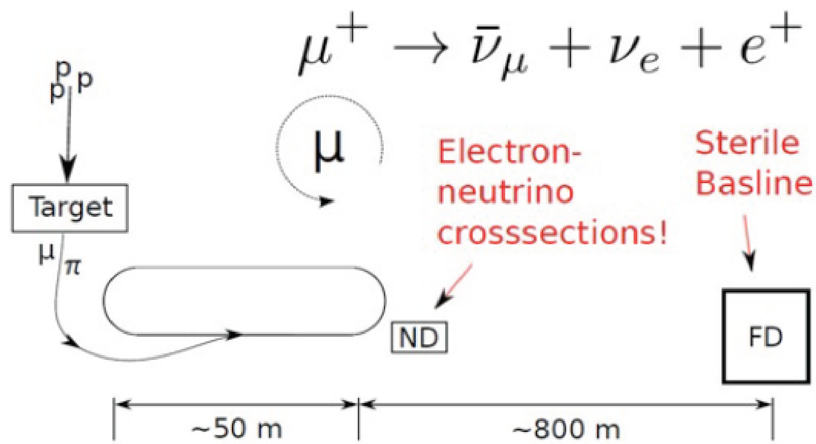


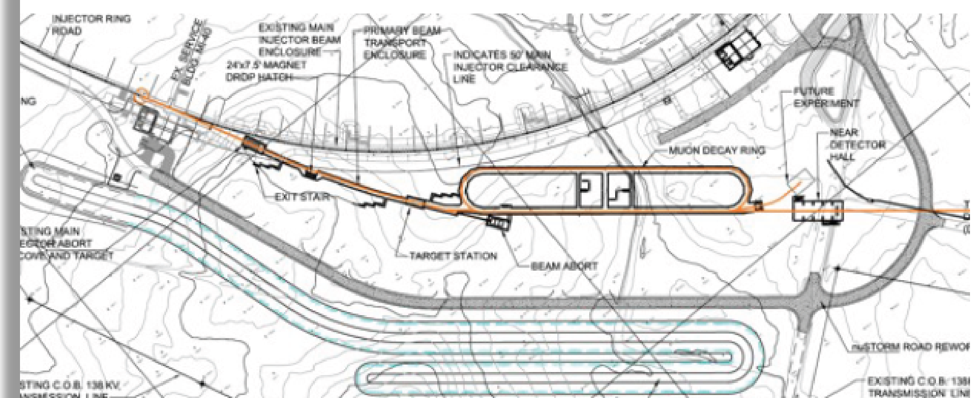
Wilson Hall
Linac
Muon Campus
Booster
Operational in Stages 1 and 2 Only
Operational in Stage 1 Only
NuMI Beamline
Neutrino Campus
Tevatron
LBNE
3-8 GeV Pulsed Linac
High Power Muon & Kaon Campus
High Power Spallation Campus
1-3 GeV CW Linac
F-0
MI-60
0-1 GeV CW Linac
Main Injector
Stage 1 0-1 GeV
Stage 2 1-3 GeV
Stage 3 3-8 GeV
Existing Beamline Enclosure

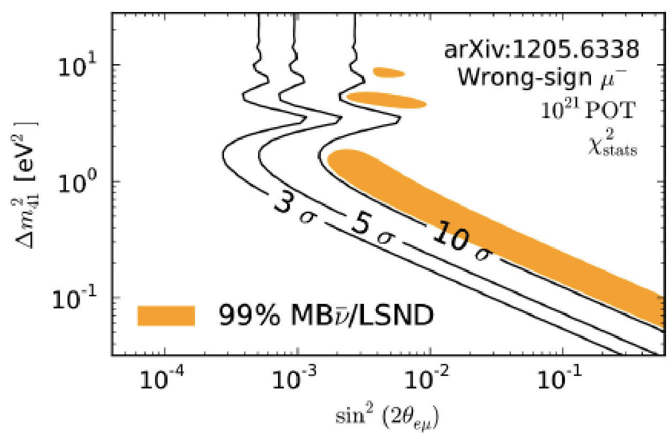
nu-STORM

- Neutrinos from Stored Muons (old idea but never realised!)
- Strongly revived interest in the combination of
  - a clear resolution of the short-baseline neutrino anomalies with >>5σ C.L.
  - the precise measurements of the electron neutrino cross-sections needed for LBL experiments,
  - and the synergy with neutrino-factory technology.
- **FNAL PAC stage-1 approval in June 2013. To be reviewed by US HEPAP P5 in the future (≈300M$ project).**
- **LOI submitted at CERN in June 2013, under review.**

Well-understood neutrino source:

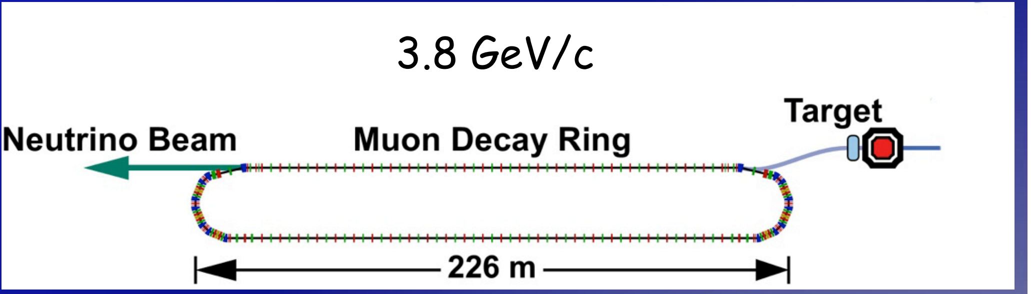




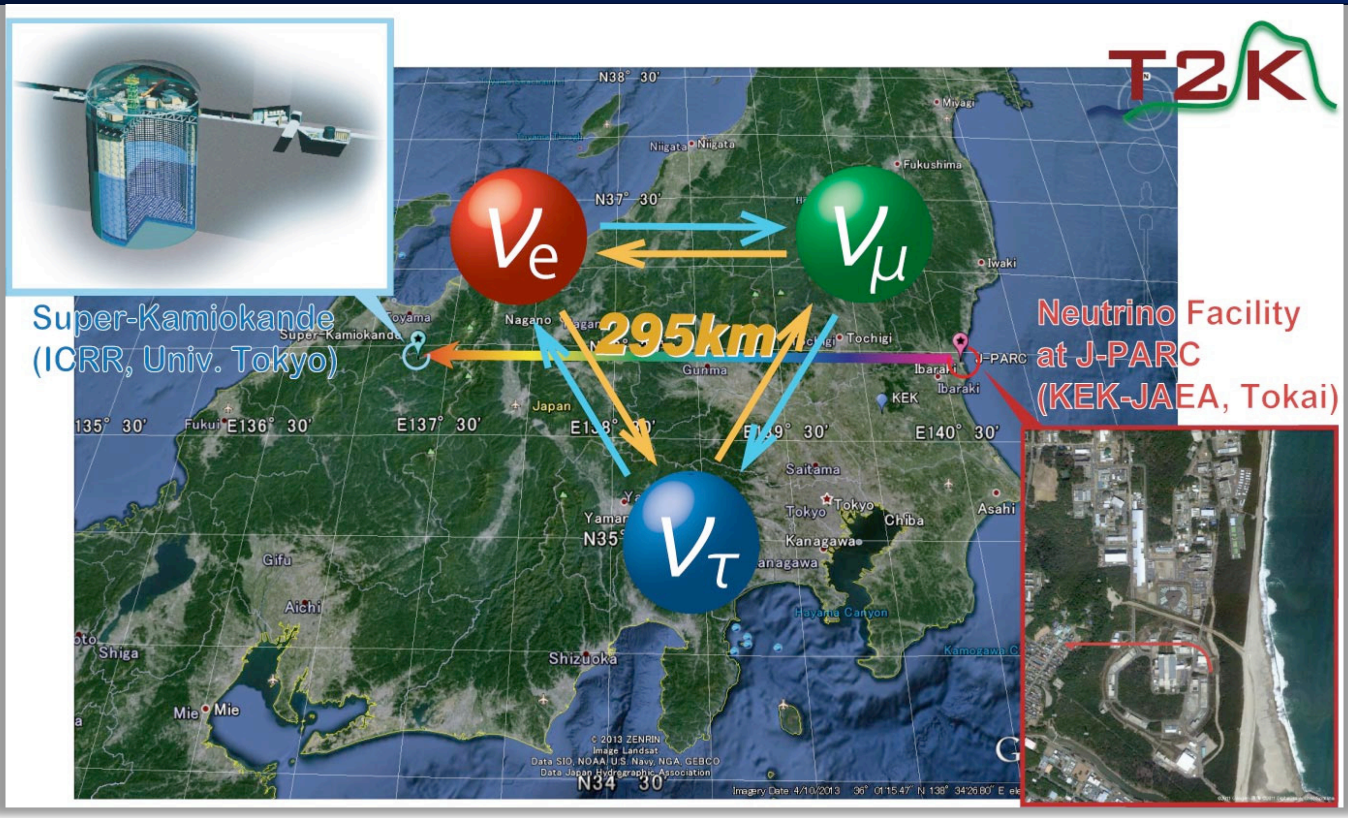


Baseline

- ~ 100 kW Target Station (designed for 400kW)
  - Assume 60-120 GeV proton
  - Carbon target
    - Inconel
  - Horn collection after target
- Collection/transport channel
  - Stochastic injection of π
- Decay ring
  - Large aperture FODO
    - Also considering RFFAG
  - Instrumentation
    - BCTs, mag-Spec in arc, polarimeter



J-PARC



At J-PARC, a proton beam is accelerated by a series of accelerators, which consists of

- A 400 MeV (currently operating at 180 MeV) linear accelerator (LINAC)
- A 3 GeV rapid cycling synchrotron (RCS)
- A 50 GeV (currently 30 GeV) main ring (MR)

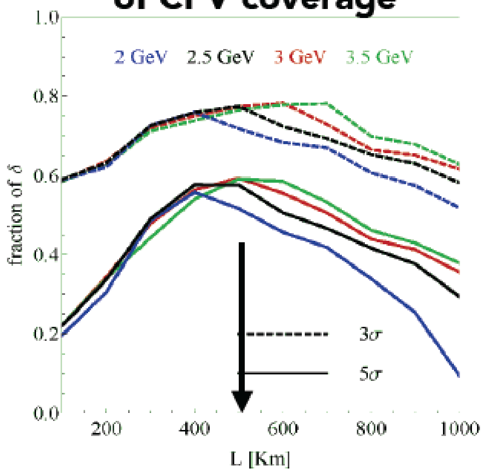
The applications of these beams include fundamental nuclear and particle physics, materials and life science, and nuclear technology.

Higher intensity plans exists, as well as detector upgrade plans …

The EUROSB concept

- The European Spallation Source (ESS), which is being built in Lund, will have a 5 MW 2.5 GeV superconducting linac
- First beams 2019, Full operation 2025
- **Idea: Double linac power to 10MW (+accumulator ring) to deliver in addition 5MW to a neutrino target to produce extremely intense beam with an average neutrino energy ≈300 MeV (Estimated additional cost for ν beam: 400M€)**
- A MEMPHYS 540kton Water Cerenkov detector at Garpenberg mine (L=540 km).

Preliminary estimate of CPV coverage

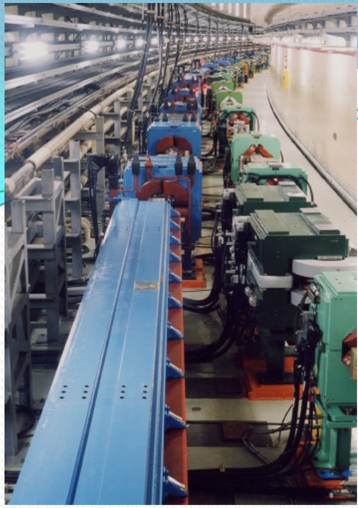


- Unique opportunity to develop MW-class very low-energy neutrino beam and understand operational issues (highly challenging!)
- Low energy beam poorly focused and cross-sections very low, so sensitivity limited by statistics (at present level of understanding of systematic errors)
- Synergy with LAGUNA/LBNO for the far site (CERN-Garpenberg≈1700km and Protvino-Garpenberg≈1300km) and detector

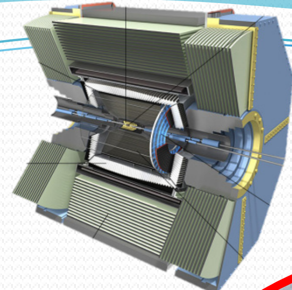
EPS-HEP 2013 A. Rubbia – Future neutrino programme 30

Flavour Factories

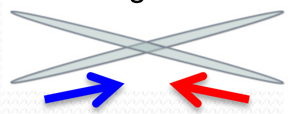
- Past:
  - PEP-II @ SLAC, USA
  - KEKB @ KEK, Japan
- Present:
  - DAΦNE @ INFN-LNF, Italy
  - Vepp2000 @ BINP, Russia
  - BEPCII @ IHEP, China
- Future:
  - SuperKEKB @ KEK
- Proposals:
  - Tau-Charm @ BINP, INFN, IHEP, TAC (Turkey)

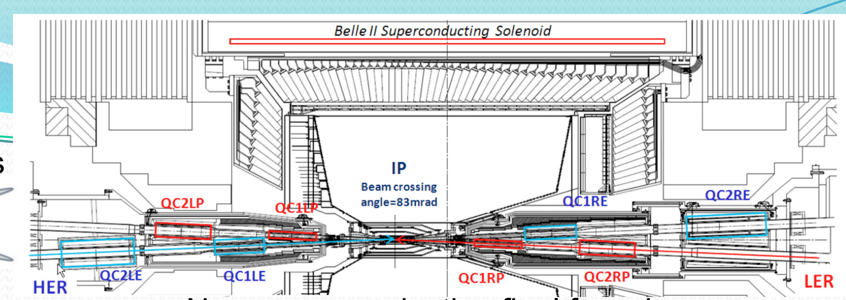


Upgrade to Belle II detector



Colliding bunches





New superconducting final focusing magnets near the IP

e^+ 3.6A

e^- 2.6A

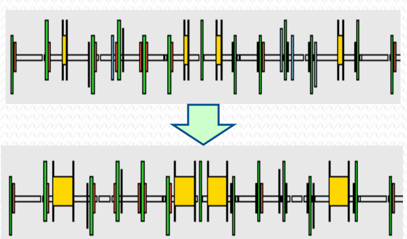
KEKB to SuperKEKB

- Nano-Beam scheme
  - extremely small β_y^*
  - low emittance
- Beam current double

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

40 times higher luminosity
2.1x10³⁴ --> 8x10³⁵ $cm^{-2}s^{-1}$

Redesign the lattice to squeeze the emittance (replace short dipoles with longer ones, increase wiggler cycles)



Replace beam pipes with TiN-coated beam pipes with antechambers

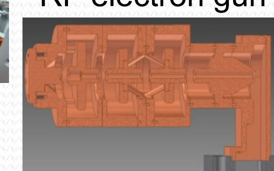
Reinforce RF systems for higher beam currents

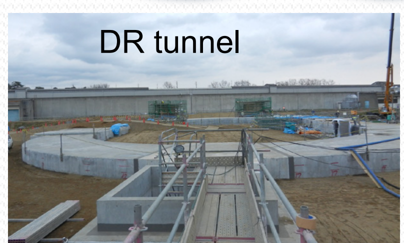
Improve monitors and control system

Injector Linac upgrade

Upgrade positron capture section

Low emittance RF electron gun





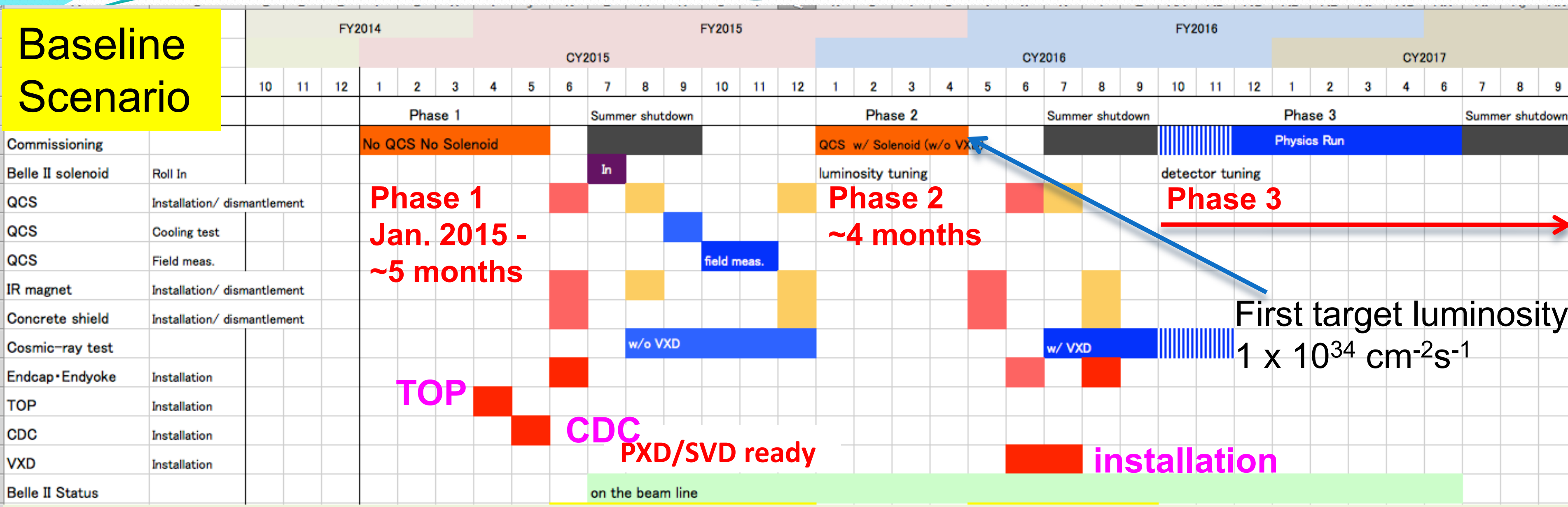
New e+ Damping Ring

Parameters of KEKB and SuperKEKB

parameters		KEKB(@record)		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7.007	GeV
Crossing angle (full)	φ	22		83		mrad
# of Bunches	N	1584		2500		
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.28	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Max. beam currents	I_b	2.0	1.4	3.6	2.6	A
Beam-beam param.	ξ_y	0.129	0.090	0.0881	0.0807	
Bunch Length	σ_z	6.0	6.0	6.0	5.0	mm
Horizontal Beam Size	σ_x^*	150	150	10	11	um
Vertical Beam Size	σ_y^*	0.94		0.048	0.062	um
Luminosity	**L**	**2.1×10^{34}**		**8×10^{35}**		**$cm^{-2}s^{-1}$**

Intra-beam scattering is included

Commissioning Scenario



[Phase 1] **No QCS, No Belle II**

- Basic machine tuning, Low emittance tuning
- Vacuum scrubbing (0.5 ~ 1.0 A, >1 month)
- DR commissioning start (~Apr. -)

[Phase 2] **With QCS, With Belle II (without Vertex Detector)**

- Small x-y coupling tuning, Collision tuning
- βy^* will be gradually squeezed
- Background study

[Phase 3] **With Full Belle II**

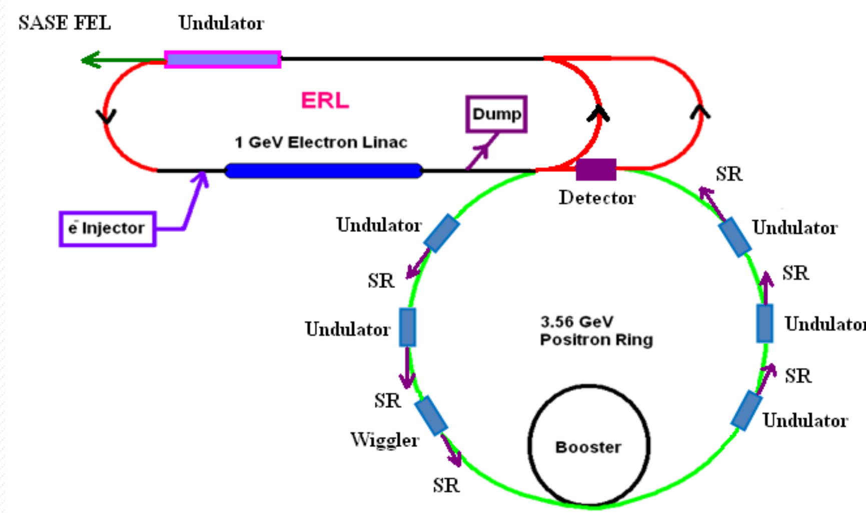
- Increase beam current with adding more RF
- Increase luminosity

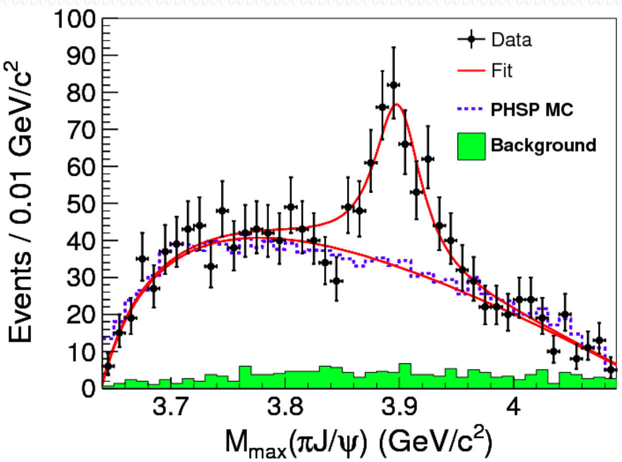
Super τ/charm proposals

	Italian Tau/Charm	BINP Tau/Charm	IHEP Tau/Charm	Turkish Charm
	2 rings	2 rings	2 rings	Linac+rin g
Luminosity ($cm^{-2}s^{-1}$)	1 x 10^{35}	1 x 10^{35}	1 x 10^{35}	1.4 x 10^{35}
Circumference (m)	340	360/800	990	250 (600?)
Beam energy (GeV)	1 →2.3	0.5 →2	3	1 + 3.56
Emittance H (nm)	5	3/10	10	16
Coupling (%)	0.25	0.5	0.5	0.3
IP β (x,y) (mm)	70, 0.6	200,0.6/20, 0.76	1000, 1	80, 5
bb V tune shift	0.64 → 0.08	0.095→0.17	0.06	0.12
Crab waist	YES	YES	YES	NO
Beam current (A)	1 → 1.7	1.8 → 1.7	2.7	0.48 + 4.8
N. of bunches	530	418	540	125

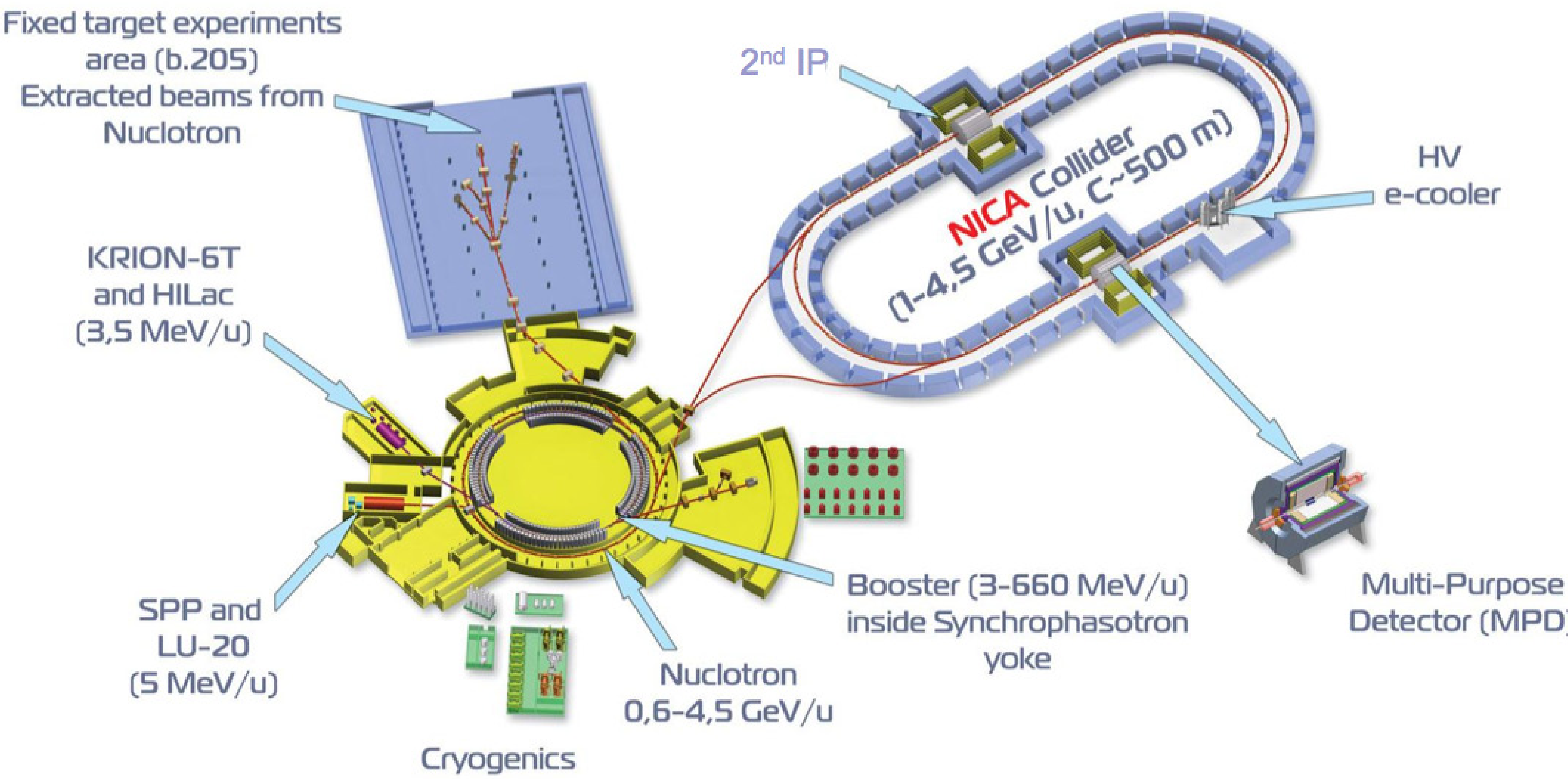
M. E. Biagini, INFN/LNF

Example of possible future…

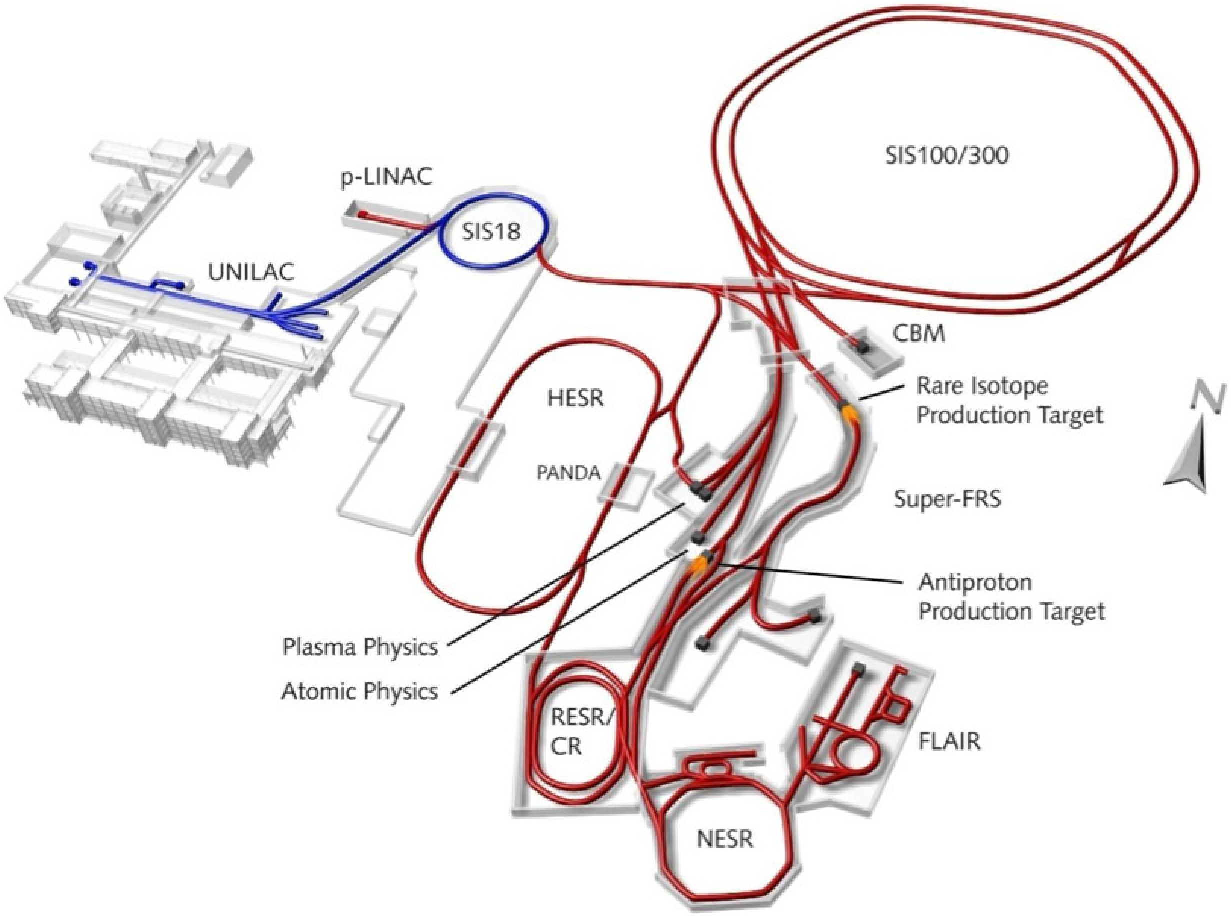




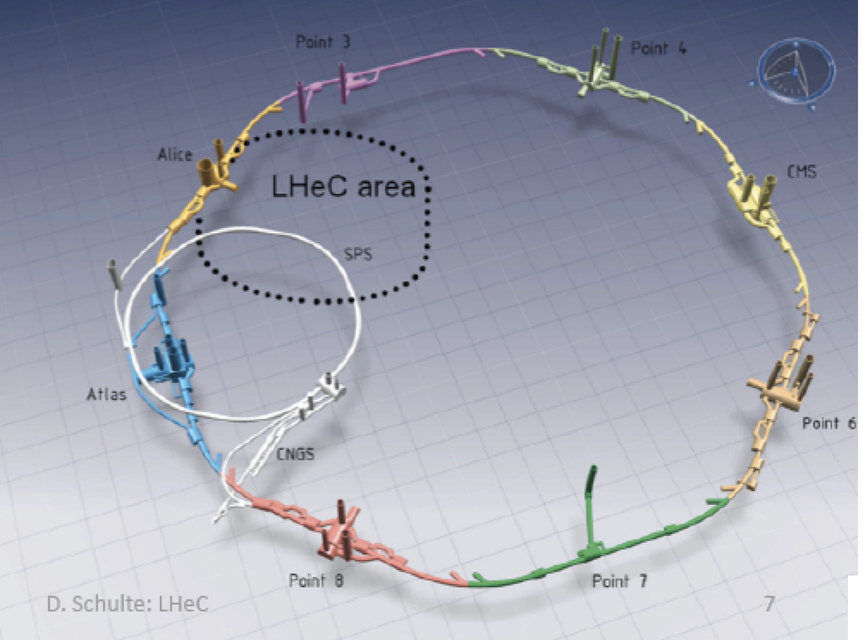
Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



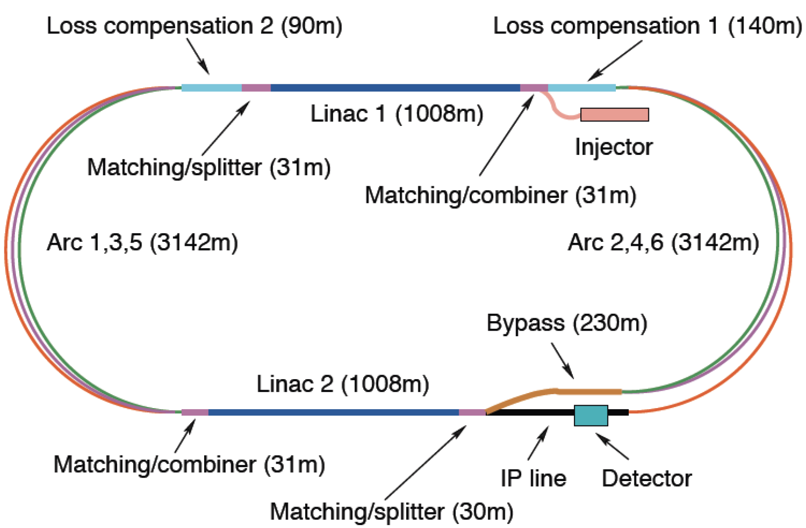
Facility for Antiproton and Ion Research - FAIR



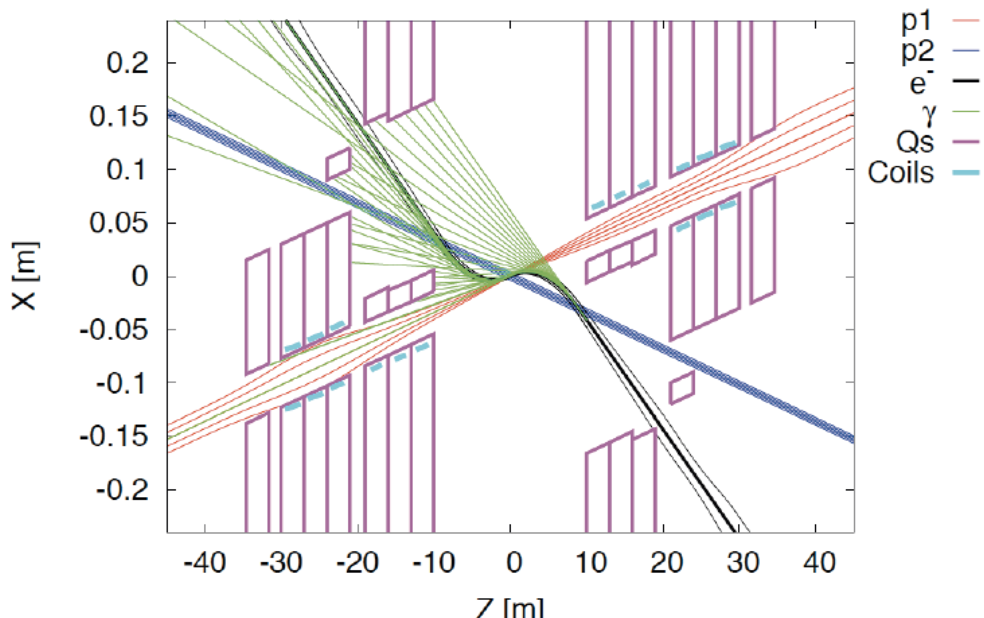
FAIR – HELMHOLTZ | ASSOCIATION GSI –



	protons	electrons
beam energy [GeV]	7000	60
Luminosity [$10^{33}cm^{-2}s^{-1}$]	1	
normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	3.75	50
IP beta function $\beta^*_{x,y}$ [m]	0.10	0.12
rms IP beam size $\sigma^*_{x,y}$ [μm]	7	7
rms IP divergence $\sigma'_{x,y}$ [μrad]	70	58
beam current [mA]	(860) 430	6.6
bunch spacing [ns]	(25) 50	(25) 50
bunch population	$1.7\text{x}10^{11}$	$(1\text{x}10^{9})$ $2\text{x}10^{9}$
Effective crossing angle	0.0	



Interaction Region



Goal: Identify compelling HEP science opportunities over an approximately 20-yr time frame

Not a prioritization, but can make scientific judgments

Deliverables:

"White papers"

Input to working group write-ups

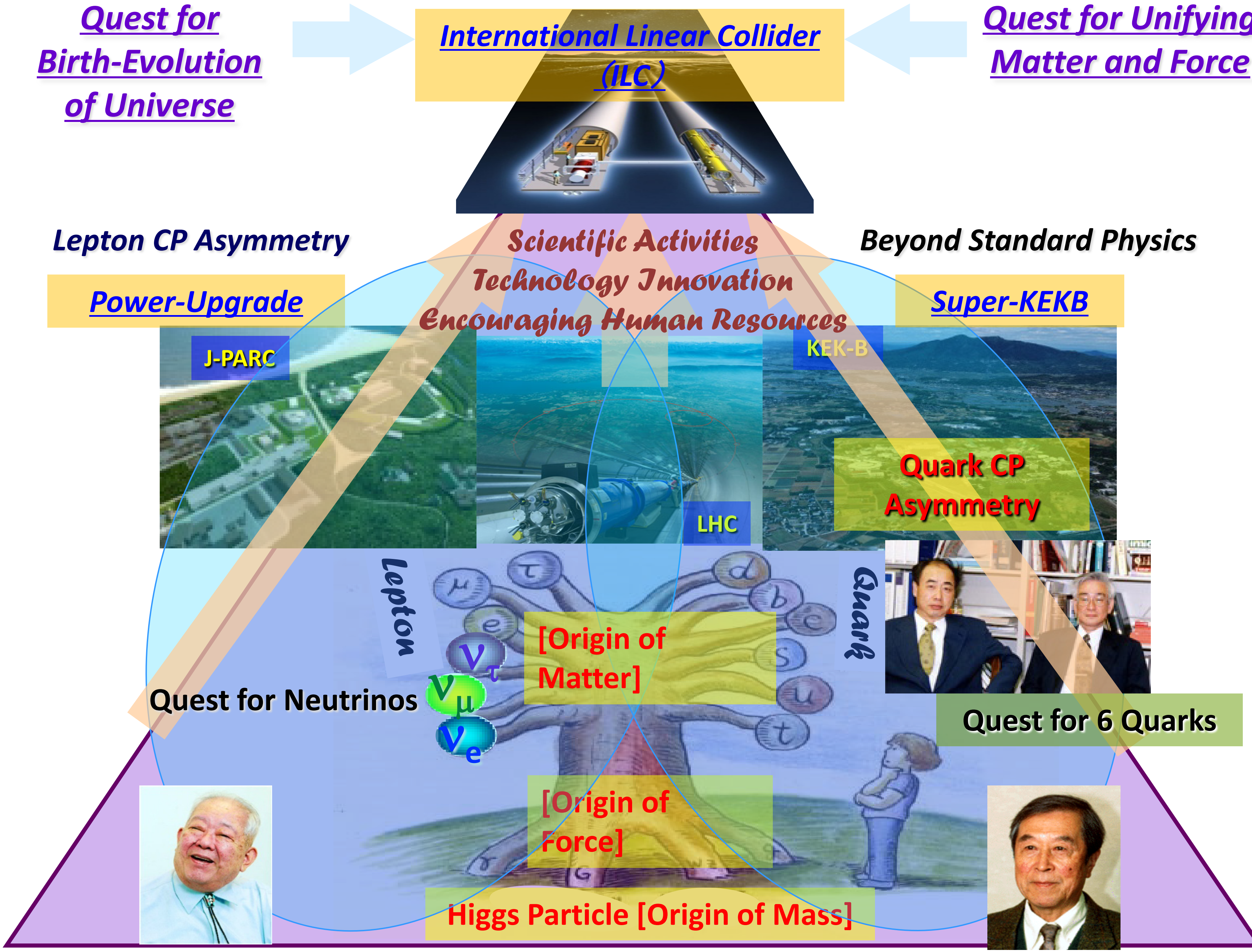
Report:

- *7x* 30-page group write-ups + theory report

  w/ executive summaries input to overview

- 30-page Overview

Analogous to Briefing Book of European Strategy Update


Quest for Birth-Evolution of Universe
International Linear Collider (ILC)
Quest for Unifying Matter and Force
Lepton CP Asymmetry
Scientific Activities
Technology Innovation
Encouraging Human Resources
Beyond Standard Physics
Power-Upgrade
Super-KEKB
J-PARC
KEK-B
LHC
Quark CP Asymmetry
Lepton
Quark
[Origin of Matter]
Quest for Neutrinos
ν_τ
ν_μ
ν_e
Quest for 6 Quarks
[Origin of Force]
Higgs Particle [Origin of Mass]

A Proposal for a Phased Execution of the International Linear Collider Project

The Japan Association of High Energy Physicists (JAHEP) endorsed the document on 18 October 2012

ILC shall be constructed in Japan as a global project based on agreement and participation by the international community.

Physics : Precision study of “Higgs Boson” , top quark, “dark matter” particles, and Higgs self-couplings,

Scenario : Start with a Higgs Boson Factory ~250 GeV. Upgraded in stages up to a center-of-mass energy of ~500 GeV, which is the baseline energy of the overall project. Technical extendability to a 1 TeV region shall be secured.

Japan covers 50% of the expenses (construction) of the overall project of a 500 GeV machine. The actual contributions, however, should be left to negotiations among the governments.

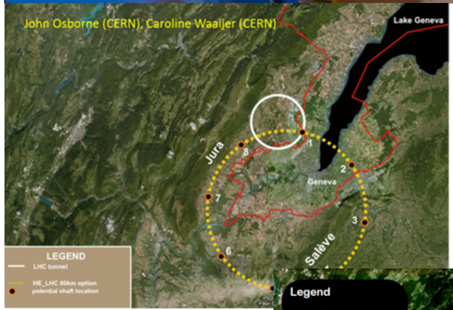
More recently: Site selection, political process, Science Council, international contacts …

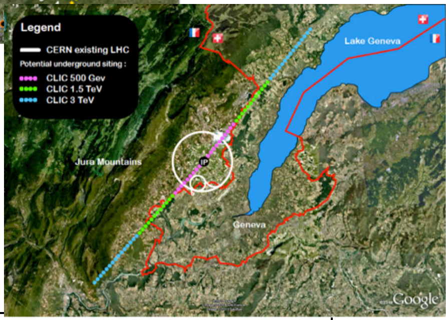
Also in Asia; China expressing interests in a 50km circular tunnel … will be interesting to follow

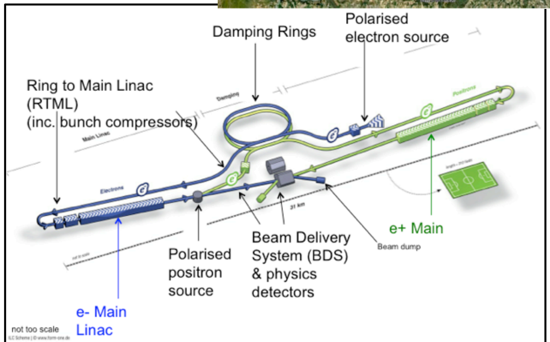
European Strategy Priorities

European Strategy priorities:

- LHC and LHC luminosity upgrades (until ~2030)
  - Higgs and Beyond the Standard Model physics in long term programme
- BSM – does it show up at LHC at 14 TeV, 2015 onwards ?
  - What are the best machines to access such physics directly post-LHC …. we don't know but we can prepare main options the next years towards next strategy update (~2018)
  - Two alternatives considered; higher energy hadrons (HE LHC or VHE LHC), or highest possible energy e+e- with CLIC
- ILC in Japan, a possibility for exploring the Higgs in detail, starting at 250 GeV
  - If implemented a comprehensive programme that can map out the Higgs sector in particular
- A European Neutrino programme in a global context, high lighting long baseline projects
- Several other points related to for example accelerator R&D …







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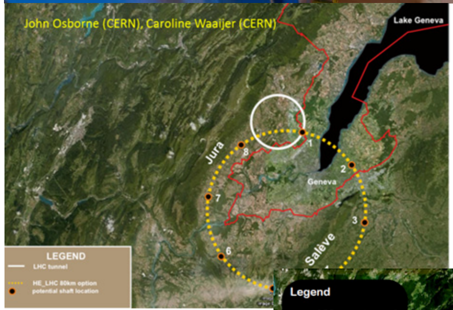

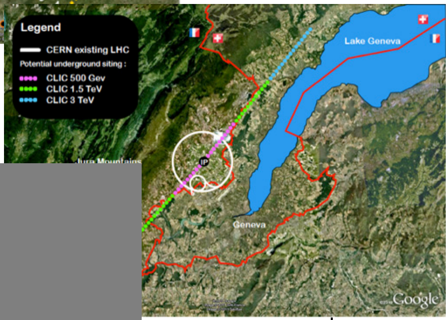

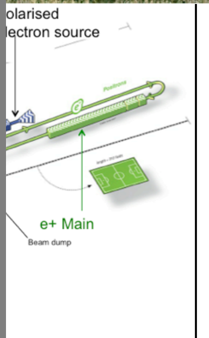

CERN MTP in June:

- Highest Priority:
  full exploitation of LHC physics potential (c)
- High Priority items:
  design studies and R&D at energy frontier (d)
  possible participation in the ILC Project (e)
  development of neutrino programme (f)
  unique fixed target physics programme (h)

Challenges for Beam Instrumentation

- **Unprecedented request for precision**
  - Positioning down to well below the micron level
- **Treatment of increasingly more data**
  - Bunch by bunch measurements for all parameters
- **Dealing with high beam powers**
  - Non-invasive measurement techniques
  - Robust and reliable machine protection systems
- **Dealing with the ultra-fast**
  - Measurements on the femto-second timescale
- **Dealing with the ultra-low**
  - Measurement of very small beam currents

Summary

LHC and LHC lum. upgrade remain backbone of future particle physics until 2030 at least

Energy frontier options are being developed, guidance for LHC at 14 TeV needed – decision points in 2016-19? Post LHC projects both challenging and interesting

ILC might turn into a construction project in the coming years

Neutrino programmes expected to become clearer – clear physics guidance exists, international discussion important.

Flavour physics alive a well with "new" facility at KEK coming up

Longer term other possibilities .. plasma for example

And don't forget light-sources, neutron facilities, medical accelerator and industrial accelerators – with strong technology links to the projects above. Would expects these links to strengthen, and important to work with in order to develop technology and industry capabilities