European Strategy for Particle Physics

Cracovia

10-12 Settembre 2012

Clara Troncon

European Stategy for Particle Physics

Geneva, 15 December 2011.

CERN Council today announced an Open Symposium to be held on 10-13 September 2012 at Cracow, Poland for the purpose of updating the European Strategy for Particle Physics. Council adopted Europe's current strategy for the field in July 2006 with an understanding that it be brought up to date at appropriate intervals of typically five years.

"Particle physics has always been a long-term, internationally coordinated endeavour, that requires long-term vision,"* said Chair of the strategy group, Tatsuya Nakada, a Professor at the Swiss institute, EPFL in Lausanne. *"With the increasing size and complexity of our experimental facilities, this is more true now than ever, and a clear European strategy, integrated into the broader global picture, is essential."

The Open Symposium is part of a process designed to get the maximum input from the particle physics community and other stakeholders from both inside and outside Europe, since Europe's strategy forms part of a global whole. Opinion will be solicited from the individual scientists who carry out the research, communities that stand to benefit and the research ministries that foot the bill. It will be organized by a preparatory group appointed by Council and will provide an opportunity for the worldwide particle physics community to express its views on the scientific objectives of the strategy. Submissions of written statements from individual physicists, groups of scientists representing specific interests, such as an experiment or a topic of theoretical research, will be solicited, along with contributions from institutions and organizations such as funding agencies and science ministries. After discussion in the Open Symposium, these will be made available to the European Strategy Group tasked by Council with drafting the updated strategy document under the chair of the Scientific Secretary.

Council will discuss the updated European strategy in March 2013 and will hold a special session in Brussels in early Summer 2013 to adopt the strategy. It is also expected that the update of the strategy will become an agenda item for the EU Council of Ministers meeting to be held at the same time.

European Strategy for Particle Physics

The symposium marks the first update of a strategy initially put in place in 2006 with a view to coordinating particle physics research in Europe, as well as Europe's participation in projects hosted in other regions. A CERN Council nominated strategy group will distil input from the symposium into a draft strategy update to be discussed by the CERN Council in March 2013. The final version will then be presented to the Council in Brussels in May 2013, at a meeting timed to coincide with a ministerial-level meeting of the European Competitiveness Council.

Topics under discussion at Krakow ranged from

- **considerations of potential facilities to succeed the Large Hadron Collider, which is scheduled to run well beyond 2020,**
- **to the complementarity between accelerator-based research and cosmic ray studies,**
- **and future facilities for neutrino science.**

Although the LHC is at the beginning of its research programme, the long lead-times for the development of high-energy frontier research facilities, as well for some precision experiments, requires preliminary work to begin early in order to maintain continuity.

"The European strategy for particle physics is a sign of the global nature of particle physics," **said CERN Director General Rolf Heuer.** *"It ensures that Europe's resources are deployed in an optimal and responsible way, and integrated into a global vision for our field."*

A regular exchange of information among the three regions, the Americas, Asia and Europe takes place through the global body ICFA, the International Committee for Future Accelerators. ICFA recently produced a document describing global opportunities for particle physics, Beacons of Discovery. The updated European strategy to be presented in Brussels in May 2013 will embody Europe's contribution to this global approach to the exploration of the fundamental nature of matter.

European Strategy for Particle Physics Symposium

Circa 500 fisici presenti

~ 170 documenti inviati (da collaborazioni, Istituzioni, singoli)

Momento particolarmente interessante per questo campo: seguiva di poco l'annuncio dato il 4 luglio al CERN da ATLAS e CMS della scoperta di una nuova particella consistente con il tanto atteso bosone di Higgs.

I risultati di LHC hanno dominato le riflessioni e discussioni, (oltre che molte presentazioni …)

La scoperta di una particella consistente con il bosone di Higgs a 125 GeV cambia molte cose:

- **E' un grande passo avanti per questo campo**
- **Diventa PRIORITA' misurare le sue proprieta', capire la sua natura e il suo ruolo nel meccanismo di rottura dell' asimmetria elettrodebole**
- **Tutte le opzioni possibili in quest'area vanno rivalutate o raffinate**

Una scoperta che indirizza il futuro della ricerca in Fisica delle particelle.

European Strategy for Particle Physics Symposium - Agenda

High Energy Frontier Physics (Dissertori, T. Wyatt)
Flavour Physics (Isidori,Teubert, Grojean)
Strong Interaction Physics
Astroparticle Physics, Gravitation and Cosmology
Neutrino Physics

Accelerator Physics and Technology (C.Biscari)
Instrumentation, Computing and General Infrastructure
Theory

Status of other regions

High Energy Frontier

Executive Summary

- the **SM** (in terms of its QCD and EWK parts) **works perfectly well**, up to the % level, at the highest energies probed so far (7 and 8 TeV).
- We have **very advanced theory tools** at hand
- there is **a new boson** of mass ~125 GeV, with properties consistent with the SM Higgs, within the current uncertainties.
  More data needed to ascertain the nature of this object.
- **so far, no indications of BSM** physics from direct searches at the HEF:
  - colored SUSY particles (first generations) ruled out up to O(1 TeV), for a light LSP;
  - “natural” SUSY probed at level of a few hundred GeV of 3rd generation spartners;
  - exotica: heavy objects probed up to masses of 2-3 TeV;
  - a lot of room still to be explored, **14 TeV will be essential**!
- **very few anomalies** in the world-wide HEF data, no strongly smoking gun
- most important: at the LHC, we are **JUST AT THE BEGINNING** of the HEF exploration!

The super-exploitation of the CERN complex:
Injectors, LEP/LHC tunnel, infrastructures

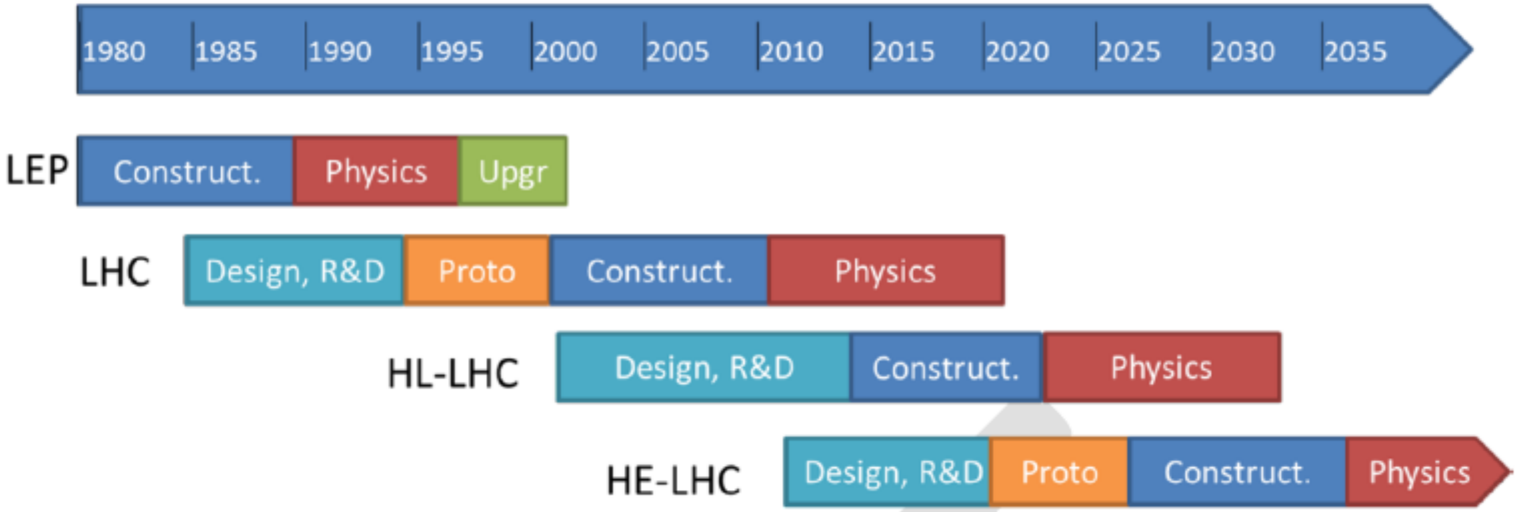


Figure 10. The possible timeline of LHC and its upgrades.

Proton-proton colliders

Facility	**Years**	**Ecm [TeV]**	**Luminosity [10^{34} $cm^{-2}s^{-2}$]**	**int Luminosity [fb^{-1}]**	**Comments**
nominal LHC	2014-2021	14	1	300	
HL-LHC	2023-2030	14	5	3000	luminosity levelling
HE-LHC	>2035	26-33	>2	100-300 / yr	dipole fields 16-20 T
V-LHC		42-100			new 80 km tunnel

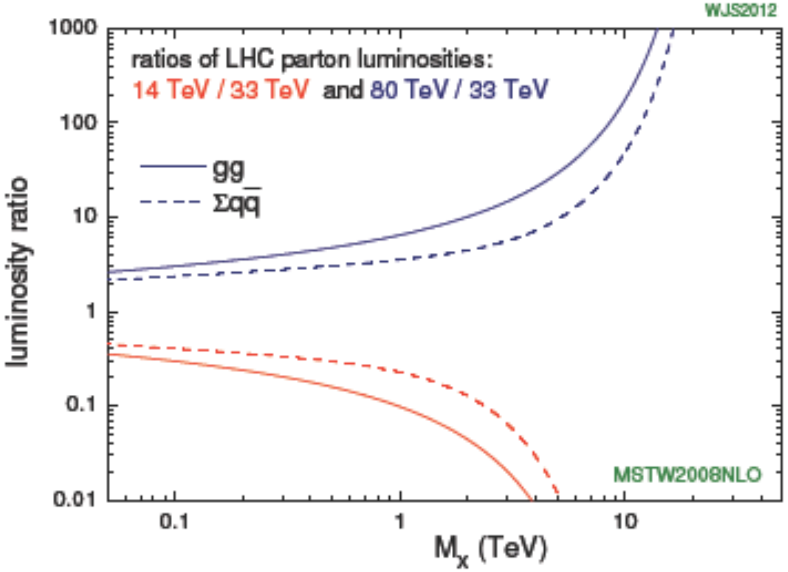
c.f. previous steps in √s at hadron colliders

Sp$\bar{p}$S → Tevatron → LHC
0.64 → 2 → 14 TeV

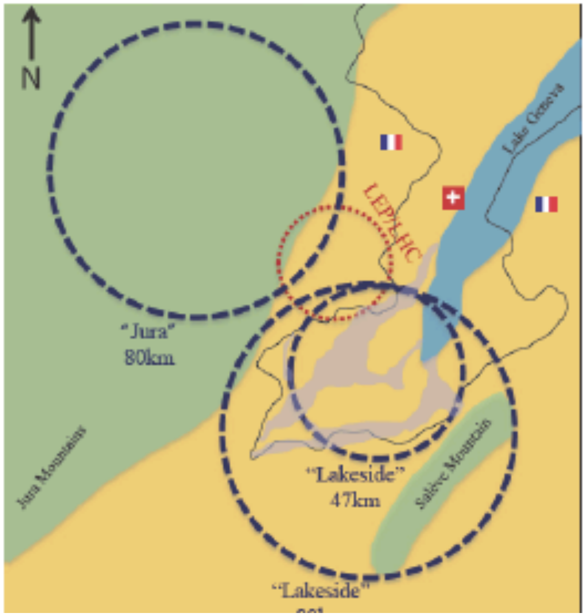
N.B. Very significant challenges to operate trigger/detector and do physics at very high luminosity/high pile-up at HL-LHC and beyond

Possible future high energy proton-proton collider

- Gain a factor of >100 in luminosity for parton-parton collisions of mass
  - at 4-5 TeV for 33 TeV relative to 14 TeV
  - at 10-15 TeV for 80 TeV relative to 33 TeV
    - Plot: thanks to James Stirling (private communication)



- First geological feasibility studies for 80 km ring at CERN carried out
- High field dual beam dipoles are very large
  - Ideal tunnel diameter needs to be larger than for LHC
  - Reinvestigate proton-antiproton!?
    - Single beam pipe
    - but could enough antiprotons ever be produced?



Beyond HE-LHC : new tunnels in Geneve area

47 km – 80 km

1) 42 TeV c.o.m. with 8.3 T (present LHC dipoles)

2) 80 TeV c.o.m. with 16 T (high field based on Nb3Sn)

3) 100 TeV c.o.m with 20 T (very high field based on HTS)

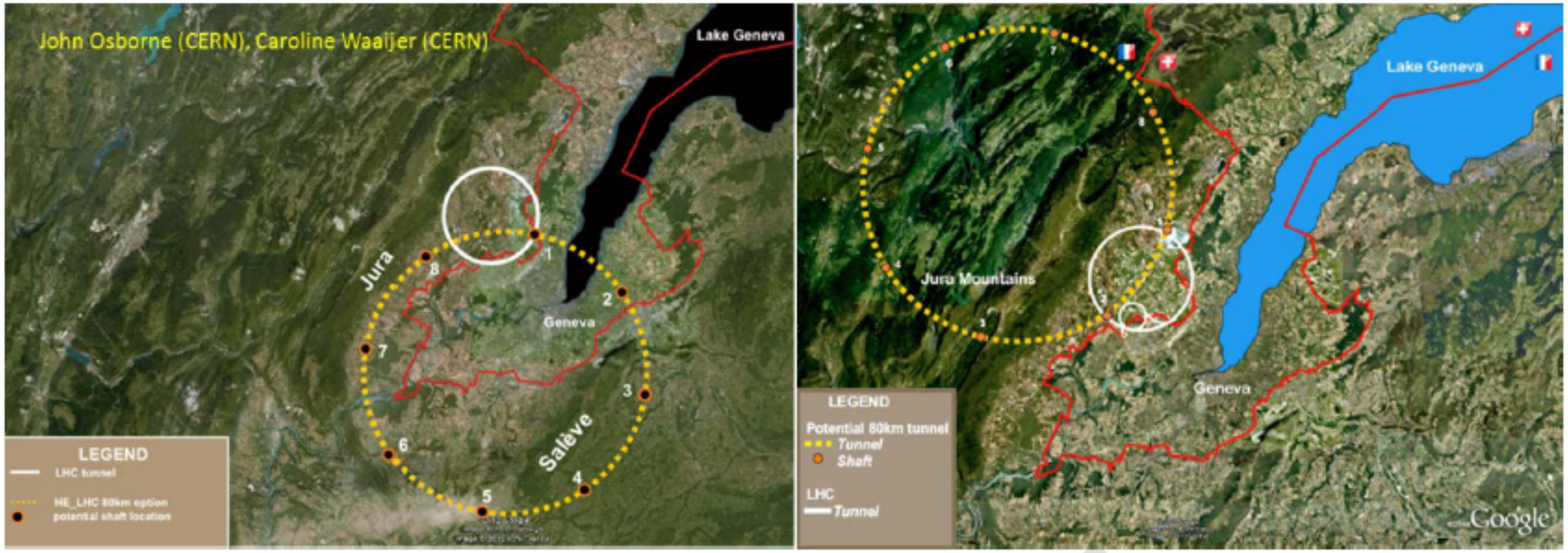
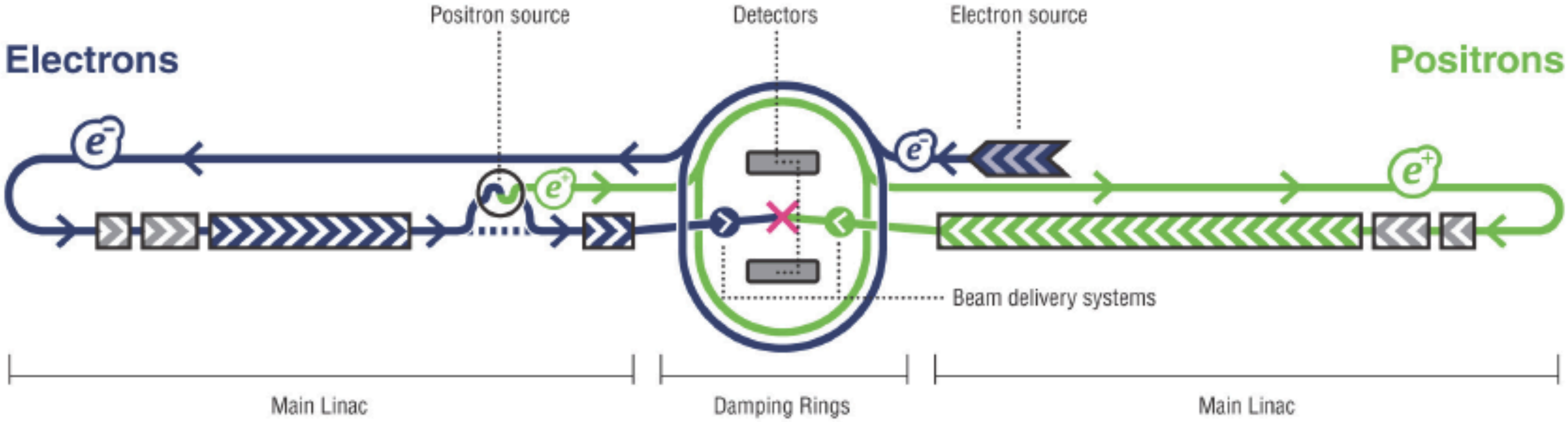

John Osborne (CERN), Caroline Waaijer (CERN)

Figure 9. Two possible location, upon geological study, of the 80 km ring for a Super HE-LHC (option at left is strongly preferred)

ILC

Two single-beam linacs with superconducting RF accelerating cavities ~40 MV/m



Schematic layout of the ILC complex

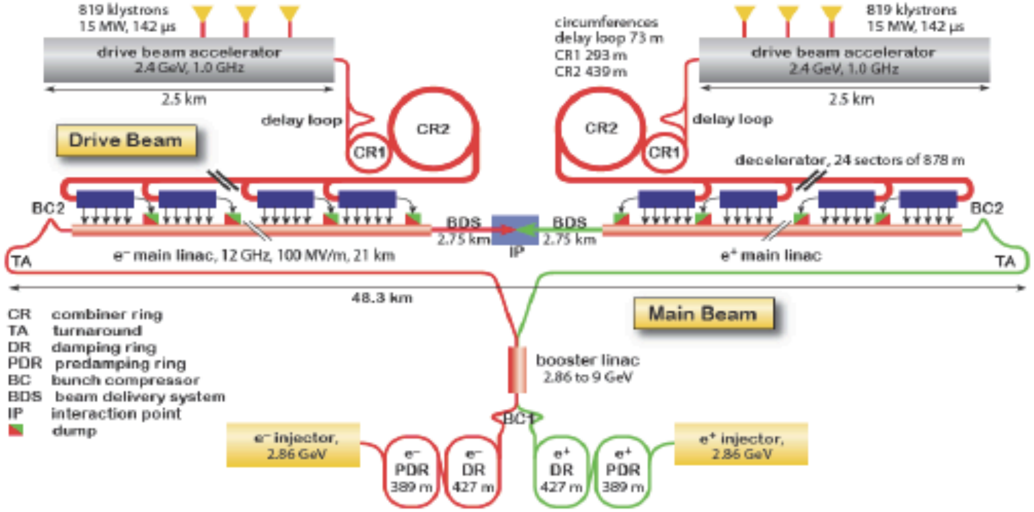
- For √s = 500 GeV total length of facility ~30 km
- Established technology
  - Industrial production of high field superconducting cavities now well established

CLIC

Two double-beam linacs

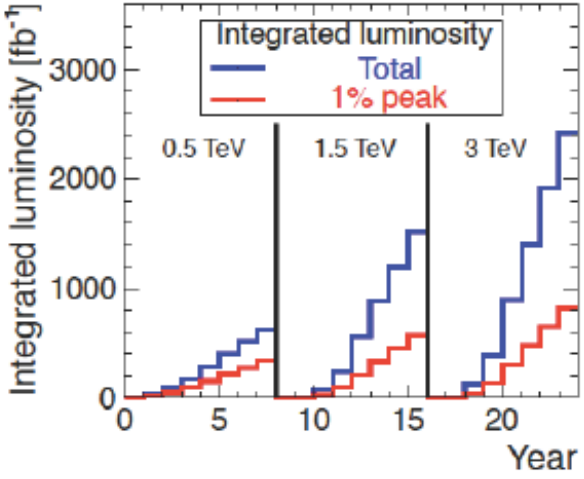
- Low energy, high current drive beam powers ~100 MV/m RF cavities in main linac

Overview of the CLIC layout at √s = 3 TeV



- Two scenarios considered for staged construction of machine
- Scenario A employs higher aperture cavities for 500 GeV running:
  - allows higher beam current and factor 2 increase in luminosity above 99% of √s
  - but these cavities must be replaced for 3 TeV running
- Scenario B employs nominal aperture cavities throughout the programme to minimize overall cost

Projected integrated luminosity for CLIC "scenario B"



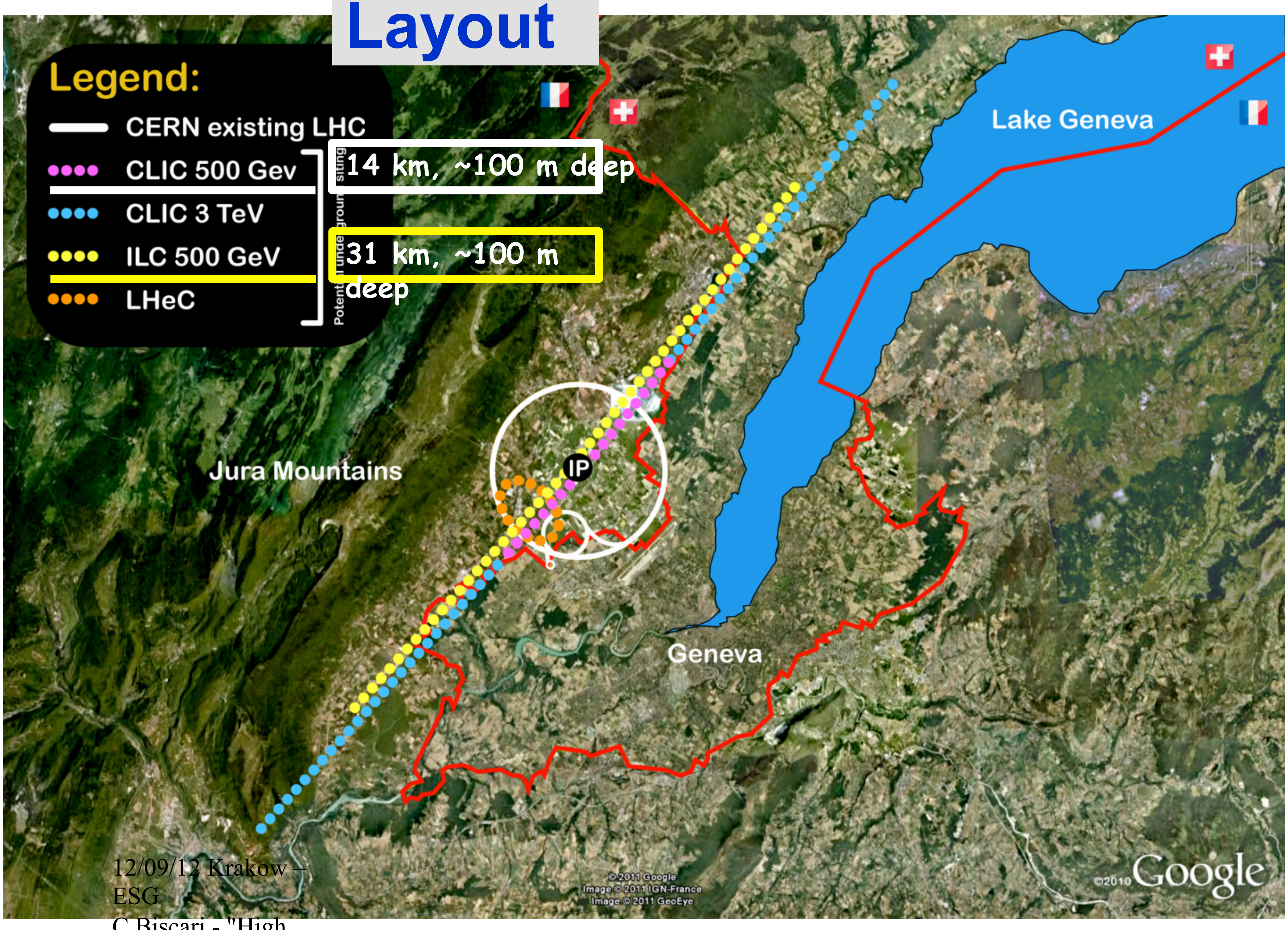
CLIC

- Dual beam acceleration technology
- R&D at CERN ~ 25 y
- Normal conducting cavities
- 12 GHz, 100 MV/m
- Maximum energy 3 TeV cm – Phase I at 0.5 TeV
- International collaboration around CTF3

ILC

- Well extablished SC rf technology (TESLA, FLASH, XFEL…)
- Decision in 2004
- Rf cavities ~ TESLA like
- 1.3 GHz, 31.5 MV/m
- Maximum energy 1 TeV cm - Phase I at 0.5 TeV
- GDE (Global Design Effort) - International collaboration
- Site independent

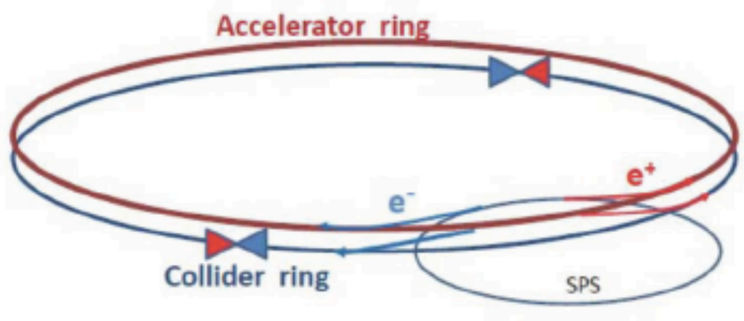
Layout



14 km, ~100 m deep

31 km, ~100 m deep

Circular e^+e^- colliders



E.g., LEP3:

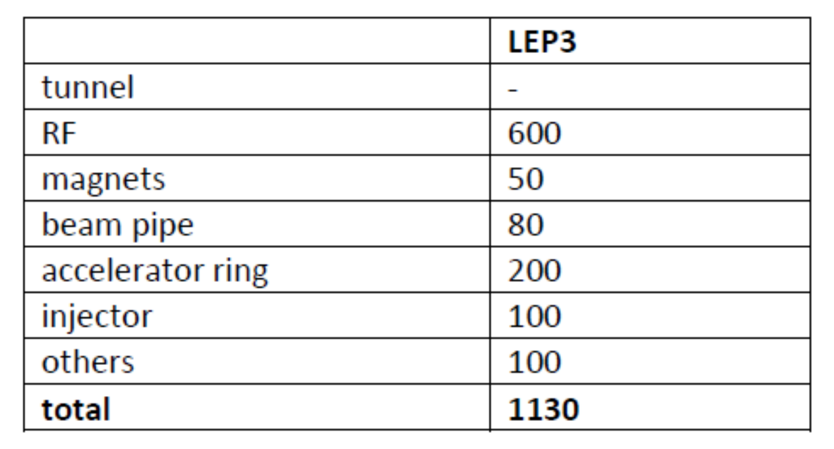
- √s = 240 GeV in the LHC tunnel to produce $e^+e^- \rightarrow ZH$ events
- Short beam lifetime (~16 mins) requires two ring scheme
  - Top up injection from 240 GeV "accelerator ring"
  - "Collider ring" supplying 2-4 interaction points $L = 10^{34}\ cm^{-2}s^{-1}$ per IP
    - Re-use ATLAS and CMS and/or install two dedicated LC-type detectors
- Current design uses arc optics from LHeC ring
  - Dipole fill factor 0.75 (smaller than for LEP)
  - increased synchrotron energy loss (7 GeV per turn)
  - redesign possible?
- $e^\pm$ polarization probably not possible at √s = 240 GeV
- In principle space is available to install compact e^+e^- facility on top of LHC ring
  - Is this really feasible?
  - Alternatively wait until completion of LHC physics programme and removal of LHC ring?
- SuperTRISTAN is a proposal for a similar machine in Japan

E.g., TLEP:

- √s = 350 GeV in 80 km LHC tunnel to reach thresholds for top pair and $e^+e^- \rightarrow \nu\nu WW \rightarrow \nu\nu H$

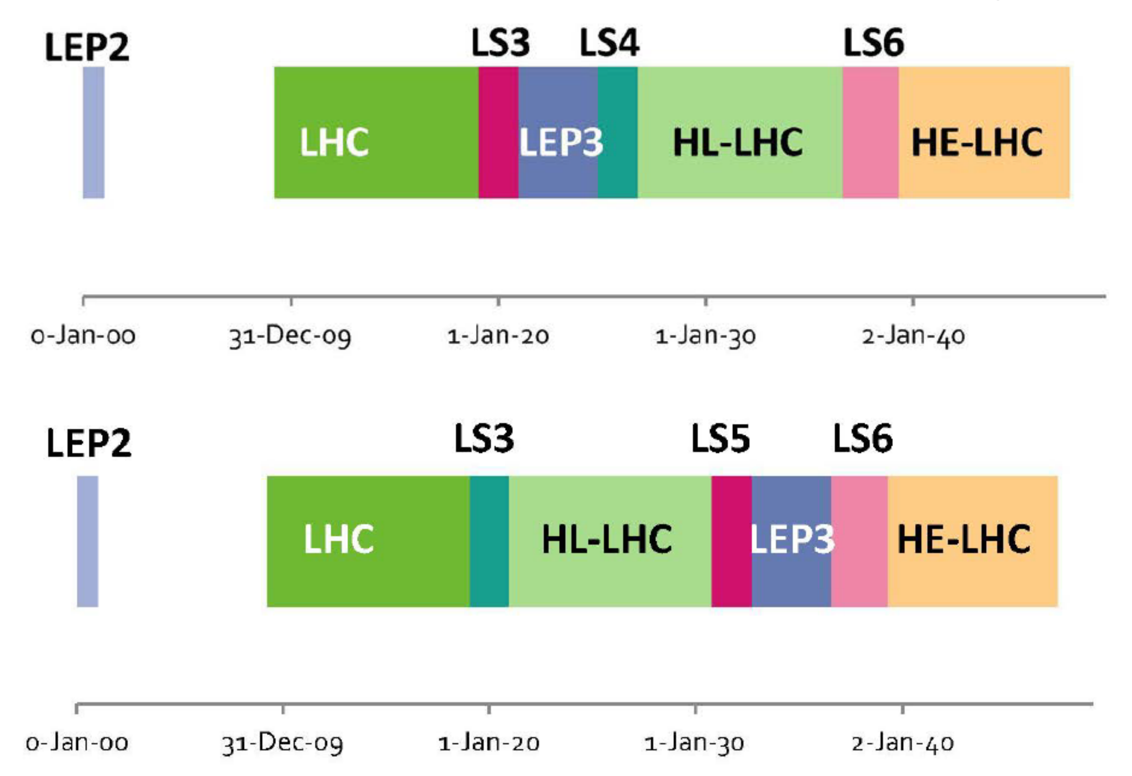
LEP3

Rough cost estimate



	LEP3
tunnel	-
RF	600
magnets	50
beam pipe	80
accelerator ring	200
injector	100
others	100
total	**1130**

Possible schedules



CIRCULAR e+e- COLLIDERS

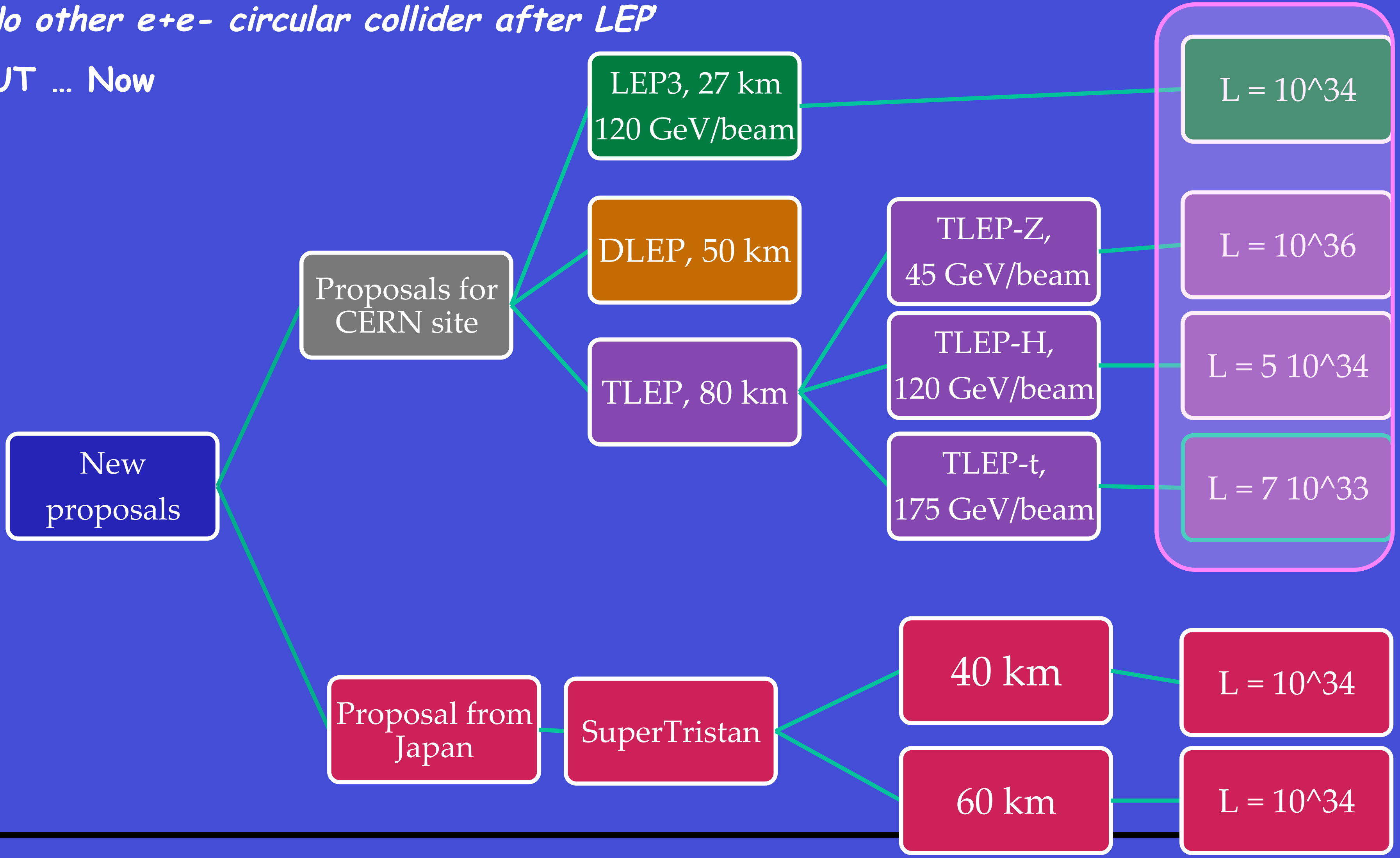
Constant SR Power/beam

50 MW

Heard in the last decades:

'No other e+e- circular collider after LEP'

BUT … Now



New proposals

Proposals for CERN site

LEP3, 27 km 120 GeV/beam

DLEP, 50 km

TLEP, 80 km

TLEP-Z, 45 GeV/beam

TLEP-H, 120 GeV/beam

TLEP-t, 175 GeV/beam

L = 10^34

L = 10^36

L = 5 10^34

L = 7 10^33

Proposal from Japan

SuperTristan

40 km

60 km

L = 10^34

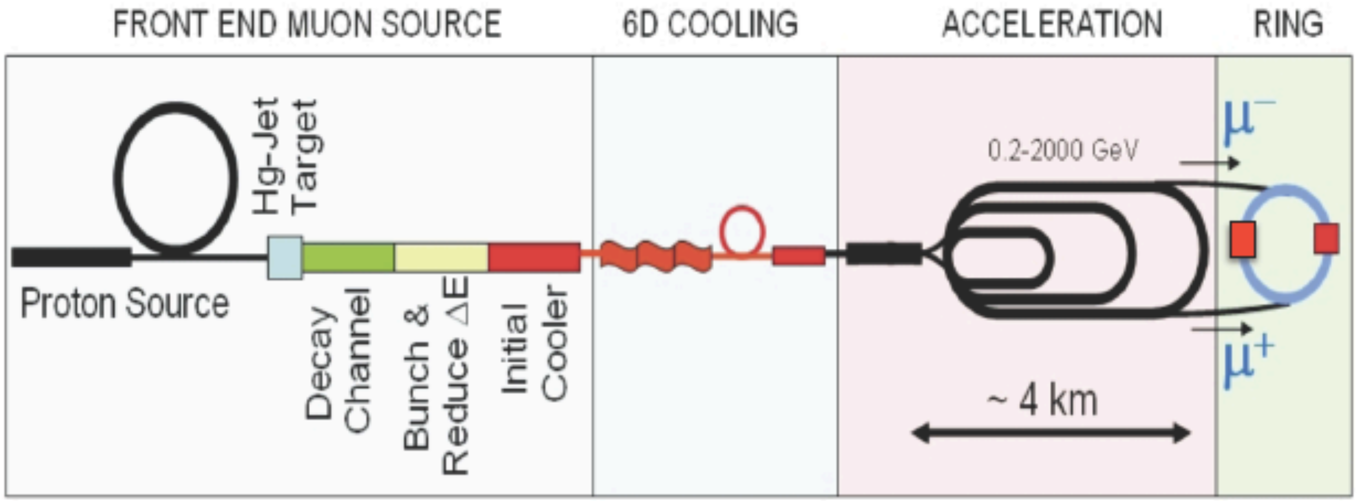
L = 10^34

e^+e^- collider summary

	ILC	ILC	ILC	CLIC	CLIC	CLIC	LEP3
$\sqrt{s}$ [GeV]	250	500	1000	500	1500	3000	240
Luminosity [10^{34} cm^{-1}s^{-1}]	0.75	1.8	4.9	1.3	3.7	5.9	1 per IP
>0.99 $\sqrt{s}$ fraction	87%	58%	45%	54%	38%	34%	100%
polarization e^-	80%	80%	80%	80%	80%	80%	-
polarization e^+	30%	30%	20%	>50%?	>50%?	>50%?	-
beam size σ_x [nm]	729	474	335	100	60	40	71000
beam size σ_y [nm]	7.7	5.9	2.7	2.6	1.5	1	320
Power [MW]	128	162	300	235	364	589	200

- Both ILC and circular e^+e^- machines offer the option of "GigaZ"
  - Collect 10^9 (ILC) to 10^{11} (LEP3, with 80% $e^\pm$ polarization) Z events in one year at E_{cm} = 91 GeV
  - Improve by an order of magnitude or more on the precision of the LEP/SLC measurements of Z couplings
- Also running at WW threshold to improve m_W

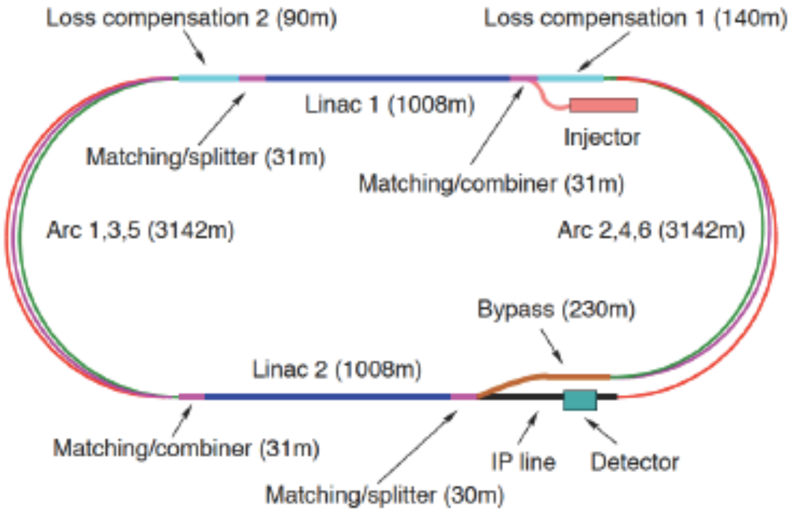
Muon collider



- Potential advantages wrt. e^+e^-
- Smaller facility size
  - Synchrotron radiation losses ~ E^4/m^4r
- Smaller energy spread
  - Beamsstrahlung ~ E^4/m^4
- s-channel Higgs production ~m^2

- Target L = 10^{34} $cm^{-2}s^{-1}$ per IP
- Many technical challenges to be faced
  - Intense proton source
  - Muon cooling
  - Can detectors survive muon decay rate and still do the physics?
- Could be a follow-on from (or precursor to) a ν-factory

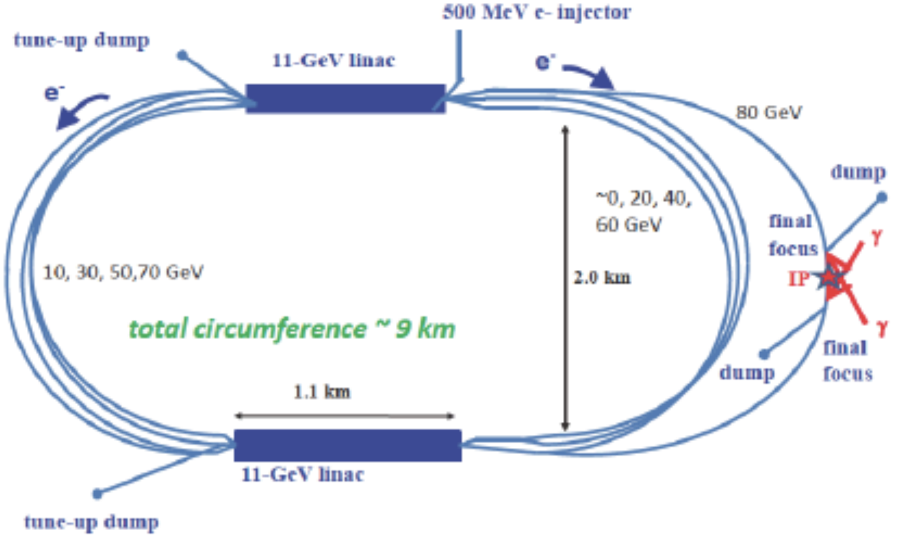
electron-proton collider (LHeC)



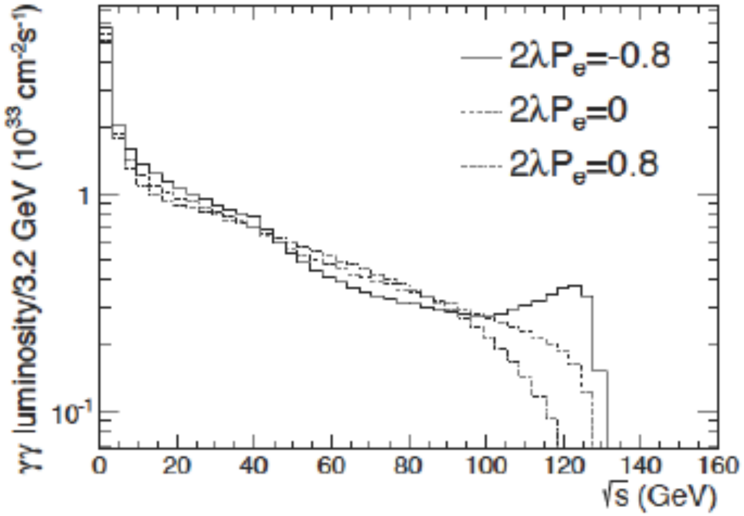
- Double ("race-track") linear accelerator option now preferred
- 10 x 2 x 3=60 GeV $e^{\pm}$ beam
- Unused beam returned from IP to recover energy

- Q^2_{max} ~ 1 TeV
- Luminosity 10^{33} $cm^{-2}s^{-1}$ (e^-p), 10^{32} $cm^{-2}s^{-1}$ (e^+p)
- Integrated luminosity aim ~100 fb^{-1}
- e^- polarization ~ 90%
  - Q^2_{max} and luminosity are factors of around 30 and 100, respectively, higher than at HERA
- N.B. precise QCD (PDFs, α_s, MC, etc) is very important for HEF programme at LHC!
  - In addition, some particular HEF reach
  - e^-N collisions also possible

Photon-photon colliders



γ γ luminosity as function of √s for different polarization of laser photons (λ) and electrons (P_e)



- Photon-photon collisions at √s = 125 GeV for γ γ → H (s-channel)
- E.g., SAPPHiRE:
- Pair of recirculating linacs similar in design to those proposed for the LHeC
  - E_{beam} = 80 GeV
- Laser back-scatter system peak power 6 x 10^{21} Wm^{-2}
  - Needs R&D!
- γ γ Luminosity ~0.3 x 10^{34} cm^{-2}s^{-1} for √s ≈ 125 GeV
- Some advantages over e^+e^- for Higgs
  - Lower beam energy
  - Do not need positron source

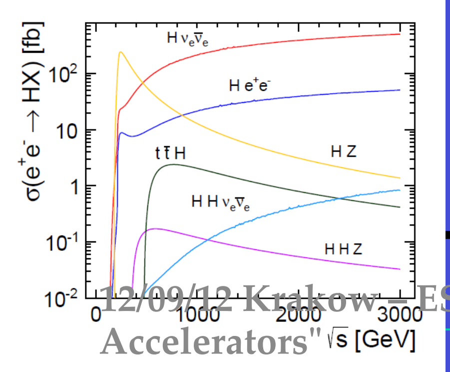
Comparison of possible HIGGS factories at the lowest energy

250 GeV for e+e-, 160 GeV for g-g

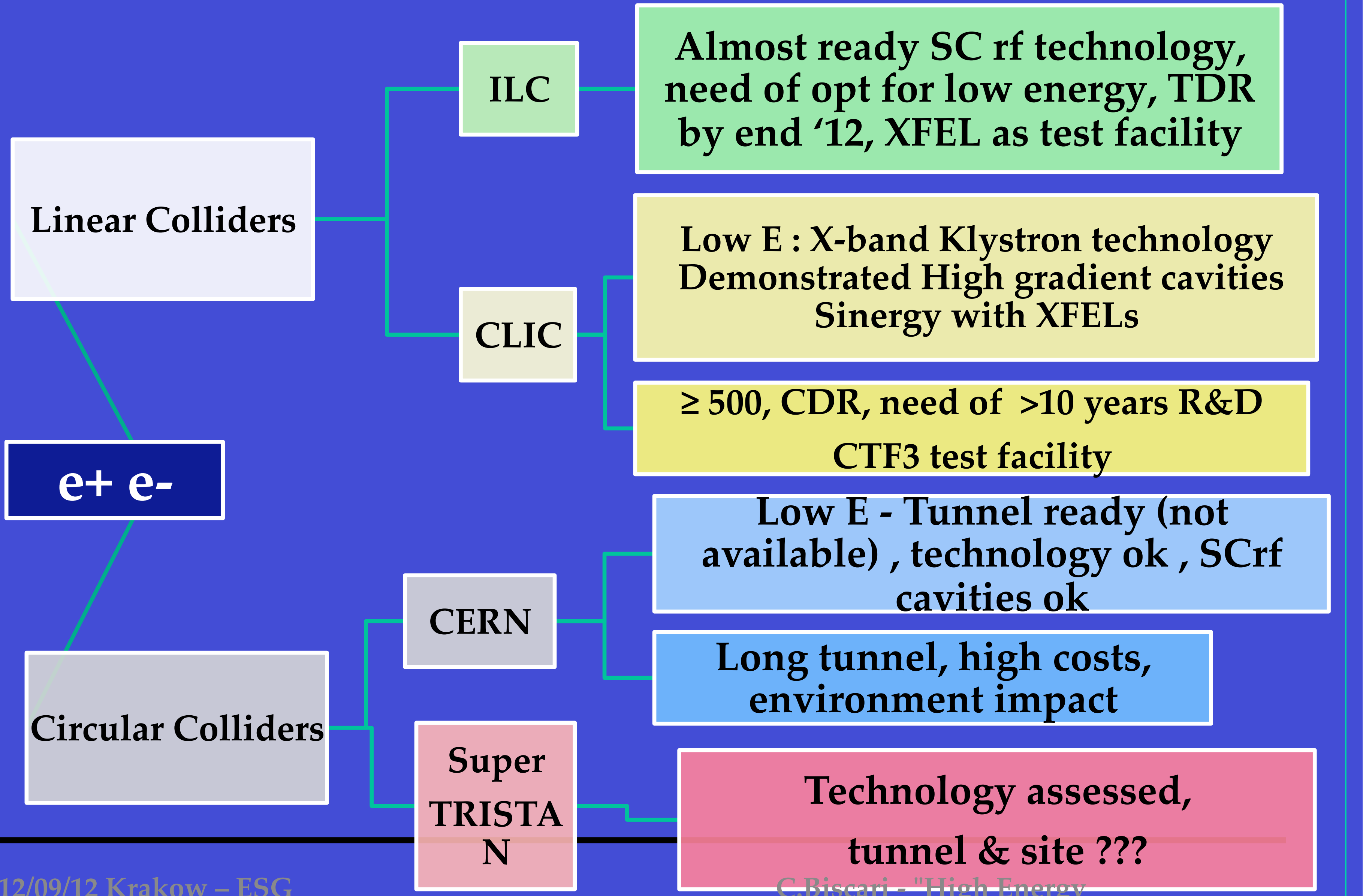
	Reliable Technol - TESTS	SITE Ready	Need of R&D	First HIGGS Boson (today T0)	COST Within 50% conf. level	FUTURE energy UPGRADE
ILC	2012	Japan?	X	2020	5	1 TeV
CLIC - klystrons	2014	GREEN	XX	2022	5	3 TeV
LEP3	2012	➢ 2020	X	2024	2	250 GeV
SuperTRISTAN	2012	GREEN	X	2022	3	500 GeV
SAPPHIRE	2016	➢ 2016	XXX	2022	?	160 GeV
New g–g	2016	GREEN	XXX	>2022	?	160 GeV
Muon collider	2020	GREEN	XXXX	➢ 2025	?	3 TeV

HIGGS FACTORIES e+e-

- **e+ e-**
  - Linear Colliders
    - ILC
      - 250 GeV
      - 500 GeV
    - CLIC
      - 250 GeV + Klystron based
      - 500 GeV
      - > 500 GeV
  - Circular Colliders
    - CERN
      - LEP3 at LHC tunnel
      - DLEP – New tunnel, 53 km
      - TLEP – New tunnel, 80 km
    - Super TRISTAN
      - 250 GeV– 40, 60 km tunnel
      - 400
      - 500



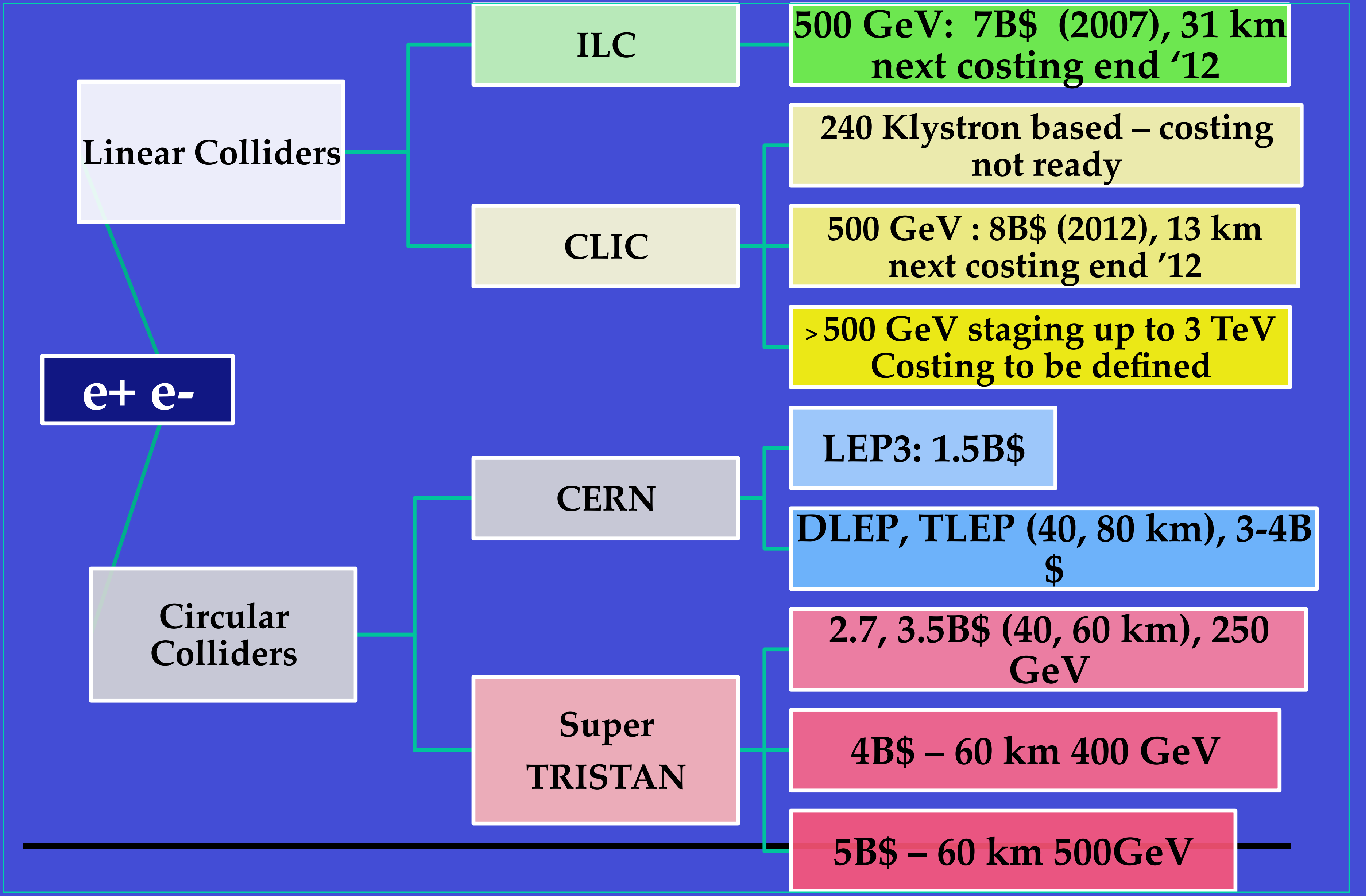
HIGGS FACTORIES e+e- R&D & main is



e+ e-

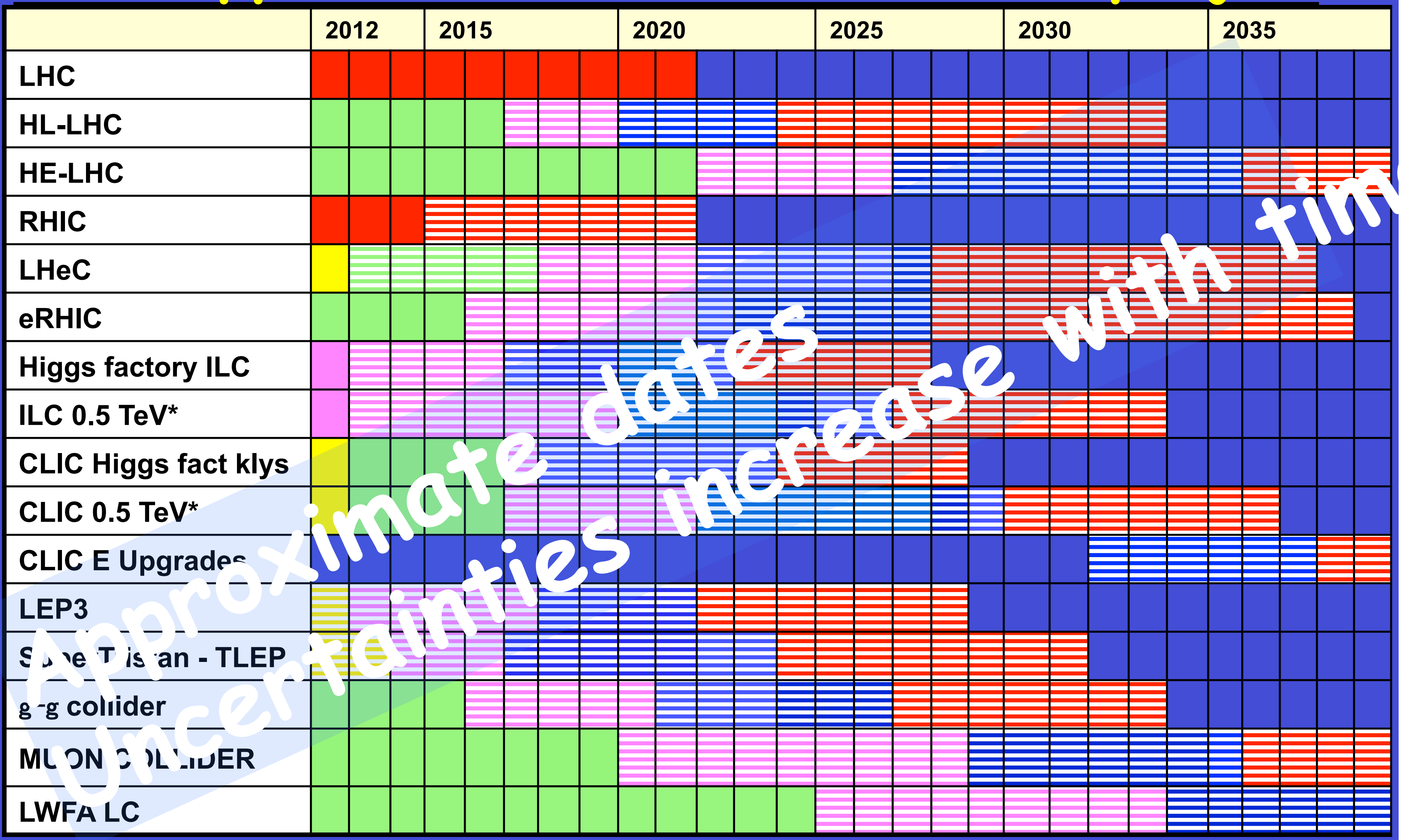
- **Linear Colliders**
  - **ILC**
    - Almost ready SC rf technology, need of opt for low energy, TDR by end ‘12, XFEL as test facility
  - **CLIC**
    - Low E : X-band Klystron technology Demonstrated High gradient cavities Sinergy with XFELs
    - ≥ 500, CDR, need of >10 years R&D CTF3 test facility
- **Circular Colliders**
  - **CERN**
    - Low E - Tunnel ready (not available) , technology ok , SCrf cavities ok
    - Long tunnel, high costs, environment impact
  - **Super TRISTAN**
    - Technology assessed, tunnel & site ???

HIGGS FACTORIES e+e- rough costs estimations (B$)



- e+ e-
  - Linear Colliders
    - ILC
      - 500 GeV: 7B$ (2007), 31 km next costing end ‘12
    - CLIC
      - 240 Klystron based – costing not ready
      - 500 GeV : 8B$ (2012), 13 km next costing end ’12
      - > 500 GeV staging up to 3 TeV Costing to be defined
  - Circular Colliders
    - CERN
      - LEP3: 1.5B$
      - DLEP, TLEP (40, 80 km), 3-4B $
    - Super TRISTAN
      - 2.7, 3.5B$ (40, 60 km), 250 GeV
      - 4B$ – 60 km 400 GeV
      - 5B$ – 60 km 500GeV

Approximate Timelines of HE projects



RDR (CDR) R&D TDR/Preparation Construction Operation

APPROVED

Not Approved

* In the hypothesis of a first stage at 250GeV

Physics reach of future high energy frontier facilities

Define "benchmark" set of energy frontier physics questions/measurements:

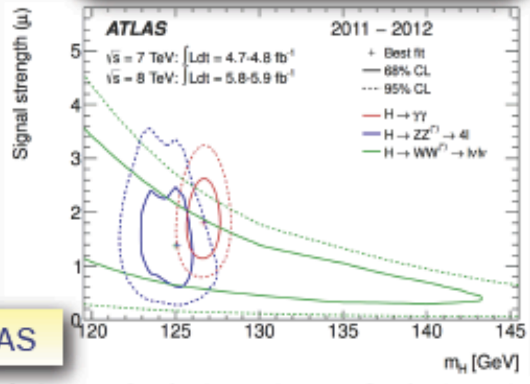
- Measurement of Higgs-like particle properties
  - mass, spin, couplings
- Measurement of gauge boson pair scattering at high energies
- Other precise EW measurements
  - W mass, $\sin^2\theta_W$, etc.
    - Give access to new physics through quantum effects
- Measurement of top quark properties
  - mass, couplings, spin correlations, W helicity, tt resonance search, etc.
- Generic cases of sensitivity of searches for massive particles/new interactions

Properties of this boson

the shopping list

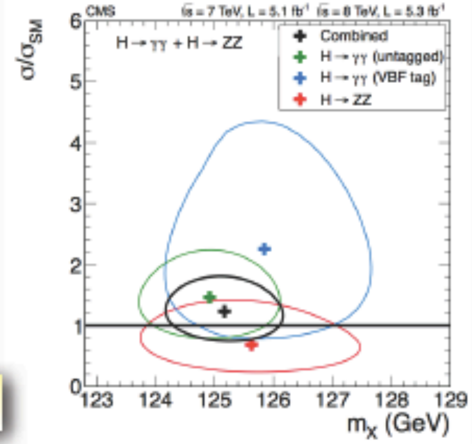
- mass
- spin and parity (J^P)
- CP (even, odd, or admixture?)
- couplings to vector bosons: is this boson related to EWSB, and how much does it contribute to restoring unitarity in $W_L W_L$ scattering
- couplings to fermions
  - is Yukawa interaction at work?
  - contribution to restoring unitarity?
- couplings proportional to mass ?
- is there only one such state, or more?
- elementary or composite?
- self-interaction

Mass vs signal strength:



ATLAS

$$126.0 \pm 0.4\,(\text{stat}) \pm 0.4\,(\text{sys})\ \text{GeV}$$



CMS

$$125.3 \pm 0.4\,(\text{stat.}) \pm 0.5\,(\text{syst.})\ \text{GeV}$$

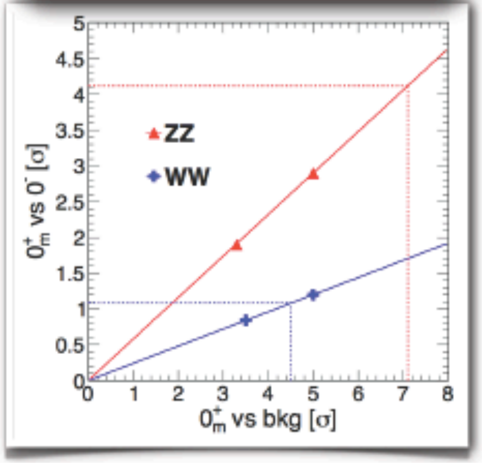
- expected precision at the LHC: ~100 MeV
- expected precision at a linear collider: ≲ 40-50 MeV

J^P and CP

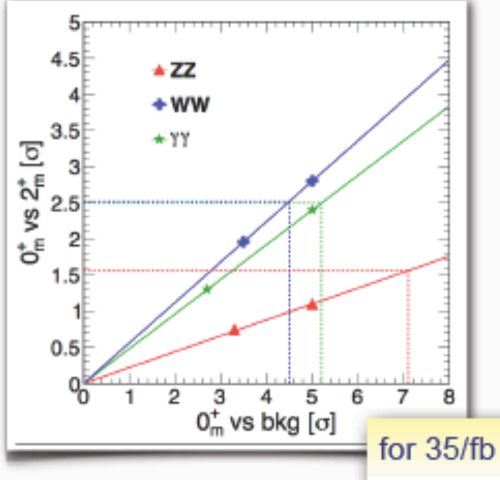
Status and questions

- decay to two photons: cannot be spin 1 (Landau-Yang theorem)
- **J^P**: currently tested at the LHC, using angular correlations in ZZ*, WW* and γγ
- **J^P**: by end of 8 TeV run, assuming a total of 35/fb per exp: **~4 σ separation of 0^+ vs 0^- and 0^+ vs 2^+**
- **CP**: somewhat more tricky, basic question of possible mixture of CP-even and CP-odd
- If focus at LHC stays on WW*, ZZ* and VBF: limited sensitivity to distinguish pure CP-even state from admixture of CP-even and CP-odd components
- Linear collider: threshold behaviour of $e^+e^- \to ttH$ gives precision measurement of CP mixing.

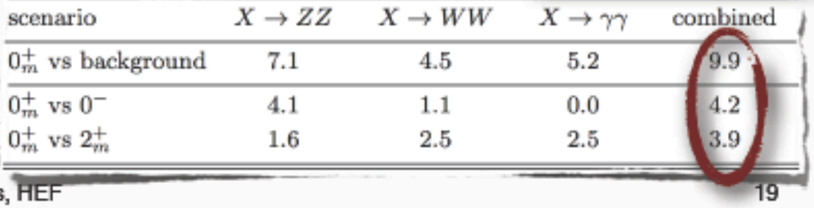
J^P: LHC 2012 prospects



Expected hypotheses separation significance versus signal observation significance
arXiv:1208.4018v1 [hep-ph], Bolognesi et al.



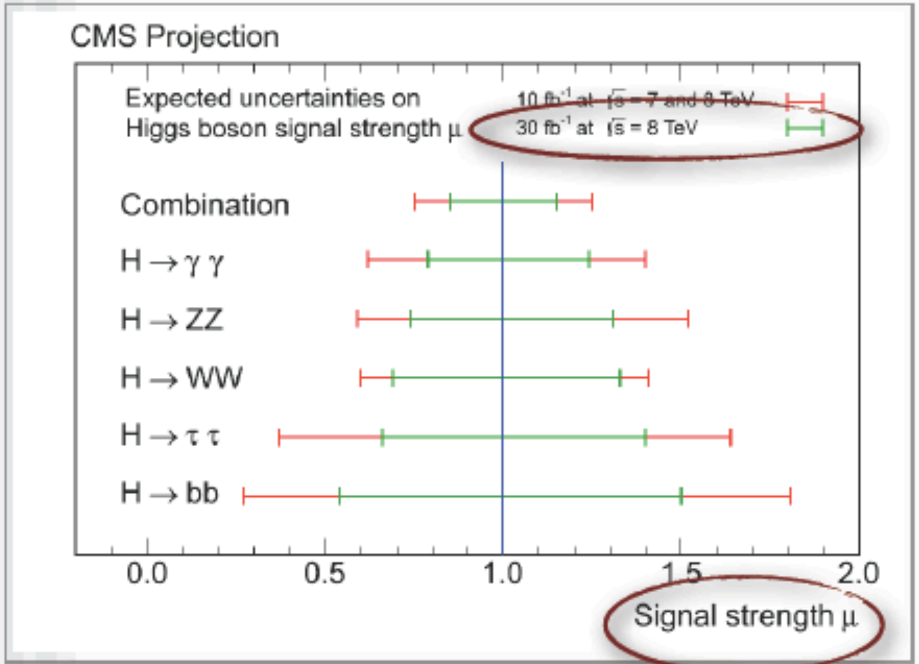
for 35/fb per exp.



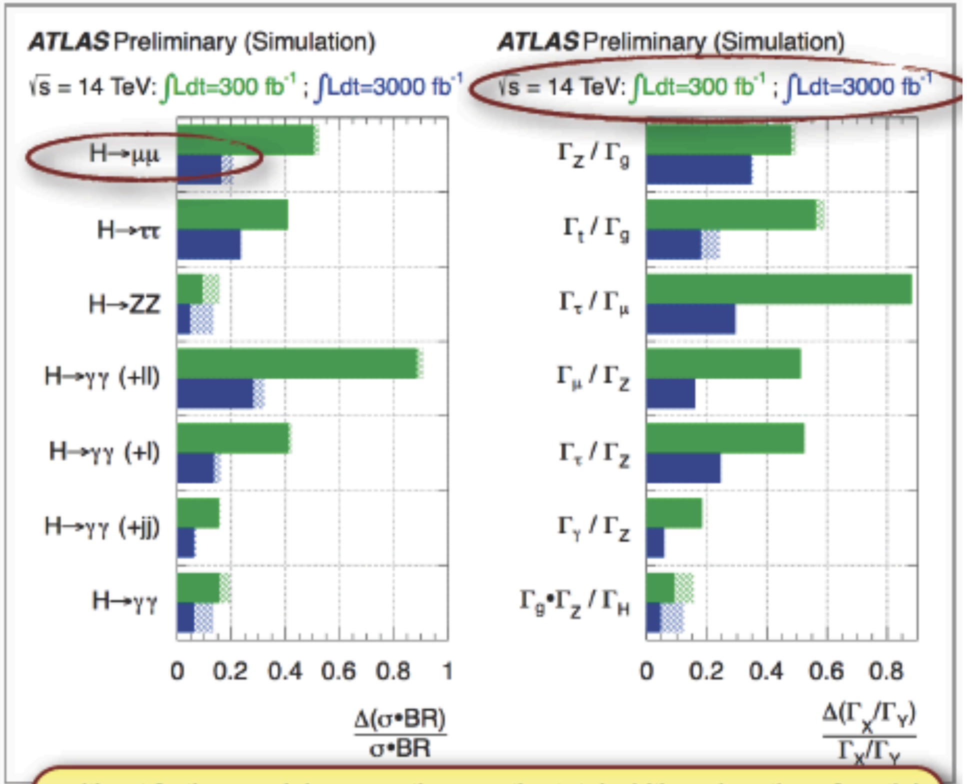
scenario	$X \to ZZ$	$X \to WW$	$X \to \gamma\gamma$	combined
0^+_m vs background	7.1	4.5	5.2	9.9
0^+_m vs 0^-	4.1	1.1	0.0	4.2
0^+_m vs 2^+_m	1.6	2.5	2.5	3.9

Projections : VERY PRELIMINARY

from the ATLAS/CMS input documents to the strategy process



- ~15 % precision on total signal strength achievable **with 30/fb at 8 TeV**
- **5σ each** in γγ and ZZ channels, **~3σ each** in WW, bb, tautau in reach



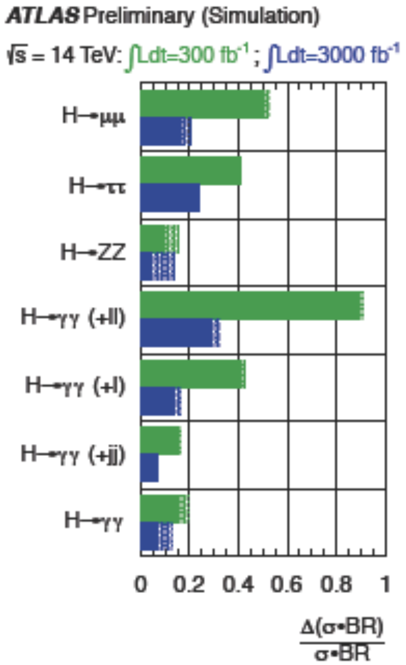
without further model assumptions on the total width: only ratios of partial widths accessible

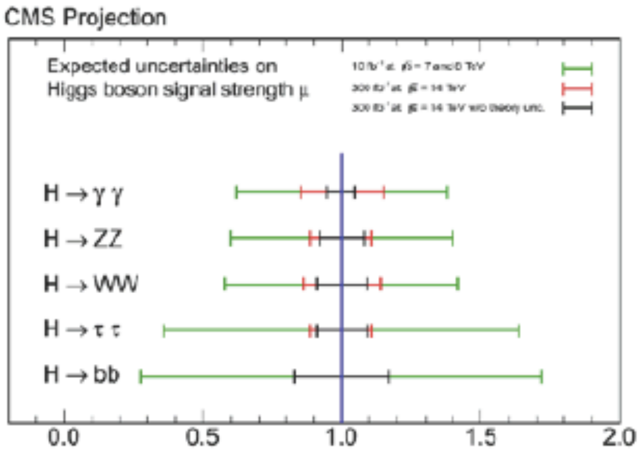
- coupling scale factors: 5-10% precision achievable with 300/fb at 14 TeV
- ratios of partial widths: in the 5-30% range, for luminosities up to 3/ab
- very rare channels such as H→μμ accessible at the 20% level, with a HL-LHC
- Higgs self-coupling (double-Higgs production): most promising channels, such as bbγγ, currently under study. 3σ/exp possible at HL-LHC, and **30% prec. on λ_{HHH}** possible if more channels added and exps. combined
- **NOTE**: This is not the final word from the LHC experiments, in terms of projections
- lepton colliders: absolute coupling measurements at the % level, see more in talks by Ch. Grojean and T. Wyatt

Higgs couplings measurements

$LHC_{300/fb}$, HL-LHC, ILC, CLIC

will measure Higgs couplings with good/excellent precision





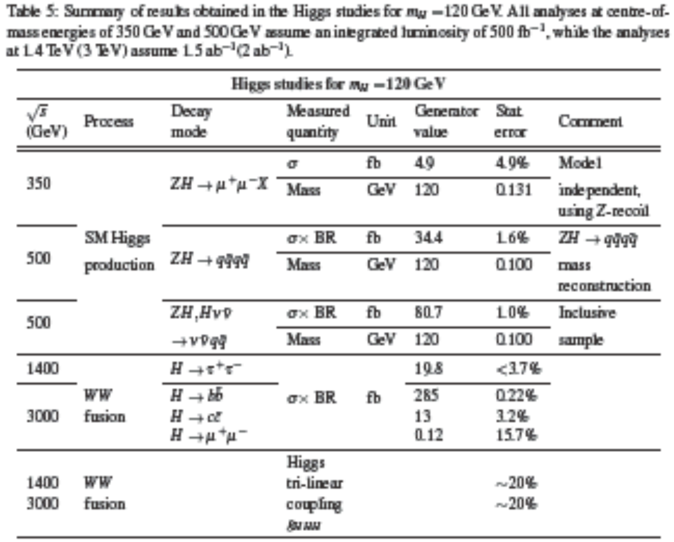


Table 5: Summary of results obtained in the Higgs studies for $m_H = 120$ GeV. All analyses at centre-of-mass energies of 350 GeV and 500 GeV assume an integrated luminosity of 500 fb^{-1}, while the analyses at 1.4 TeV (3 TeV) assume 1.5 ab^{-1}(2 ab^{-1}).

Higgs studies for $m_H = 120$ GeV							
$\sqrt{s}$ (GeV)	Process	Decay mode	Measured quantity	Unit	Generator value	Stat error	Comment
350	SM Higgs production	$ZH \to \mu^+\mu^- X$	σ	fb	4.9	4.9%	Model independent, using Z-recoil
			Mass	GeV	120	0.131	
500		$ZH \to q\bar{q}q\bar{q}$	$\sigma\times$ BR	fb	34.4	1.6%	$ZH \to q\bar{q}q\bar{q}$ mass reconstruction
			Mass	GeV	120	0.100	
500		$ZH, H\nu\bar{\nu} \to \nu\bar{\nu}q\bar{q}$	$\sigma\times$ BR	fb	80.7	1.0%	Inclusive sample
			Mass	GeV	120	0.100	
1400	WW fusion	$H \to \tau^+\tau^-$	$\sigma\times$ BR	fb	19.8	<3.7%	
3000		$H \to b\bar{b}$			285	0.22%	
		$H \to c\bar{c}$			13	3.2%	
		$H \to \mu^+\mu^-$			0.12	15.7%	
1400	WW fusion		Higgs tri-linear coupling g_{HHH}			~20%	
3000						~20%	

5-10% @ $LHC^{14TeV}_{300/fb}$

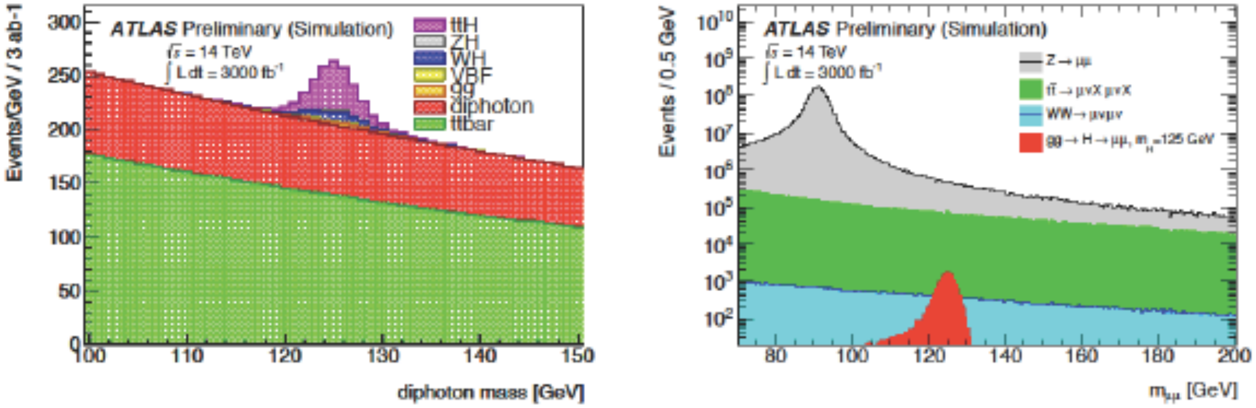
1-5% @ ILC/CLIC

direct acces to Γ_{inv}

Higgs at the LHC

- In pp many possible H decays are for practical purposes "invisible"
- Can measure only ratios of couplings

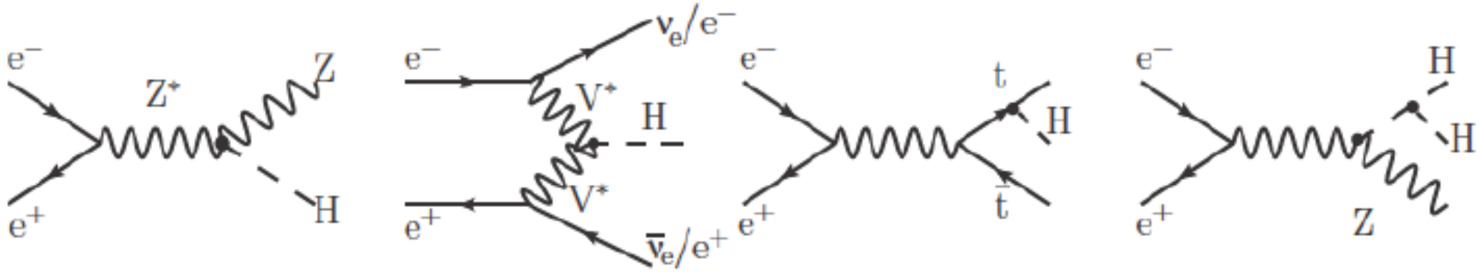
$\sigma_i \cdot \mathrm{BR}_j$ is assumed to be proportional to $\Gamma_i \cdot \Gamma_j / \Gamma_H$ with $i = g, W, Z, t$ and $j = W, Z, \gamma, \mu, \tau$.



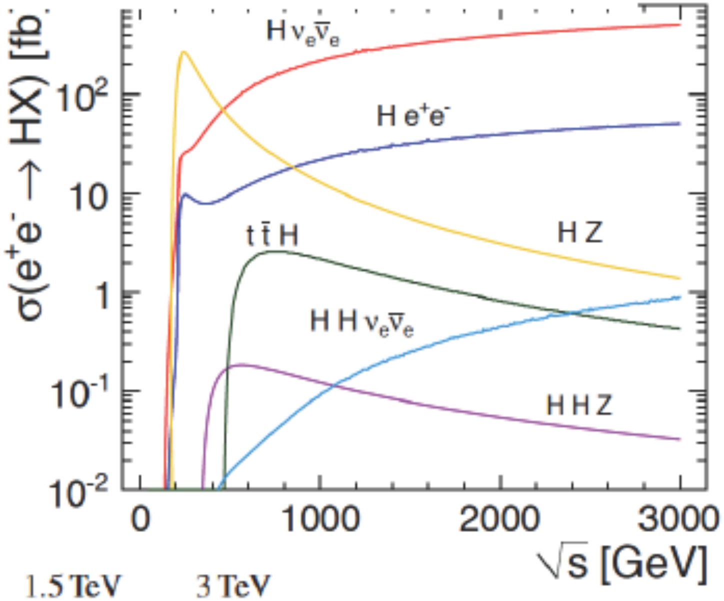
(a) (b)

Figure 1: Expected invariant mass distribution for (a) $t\bar{t}H, H \to \gamma\gamma$ in the 1-lepton selection and (b) the inclusive $H \to \mu\mu$ channel, for an assumed integrated luminosity of 3000 fb^{-1}

Higgs in e^+e^-



Many studies performed using full Geant-based MC

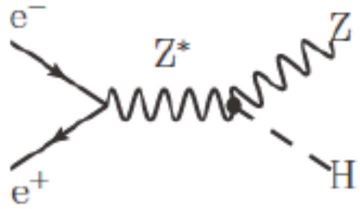


Integrated luminosity and numbers of events expected for initial 5 years running at each value of E_{cm}

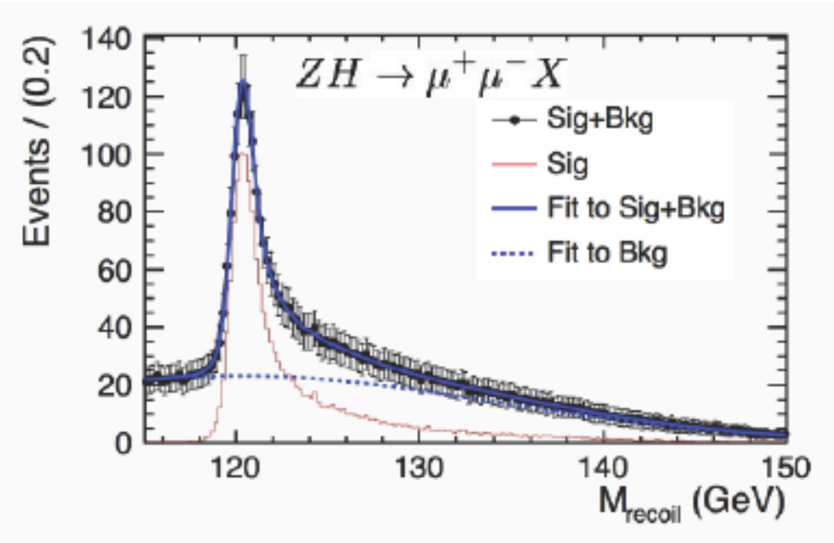
	250 GeV	350 GeV	500 GeV	1 TeV	1.5 TeV	3 TeV
$\sigma(e^+e^- \to ZH)$	240 fb	129 fb	57 fb	13 fb	6 fb	1 fb
$\sigma(e^+e^- \to H\nu_e\bar{\nu}_e)$	8 fb	30 fb	75 fb	210 fb	309 fb	484 fb
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}	500 fb^{-1}	1000 fb^{-1}	1500 fb^{-1}	2000 fb^{-1}
# ZH events	60,000	45,500	28,500	13,000	7,500	2,000
# $H\nu_e\bar{\nu}_e$ events	2,000	10,500	37,500	210,000	460,000	970,000

$\sqrt{s}$ ~ 250 GeV ZH

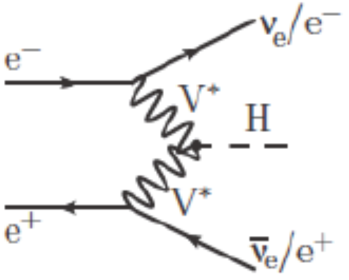
- Recoil mass in l^+l^-X events
  - very powerful
  - σ_{ZH} independent of decay mode
    - including invisible decays



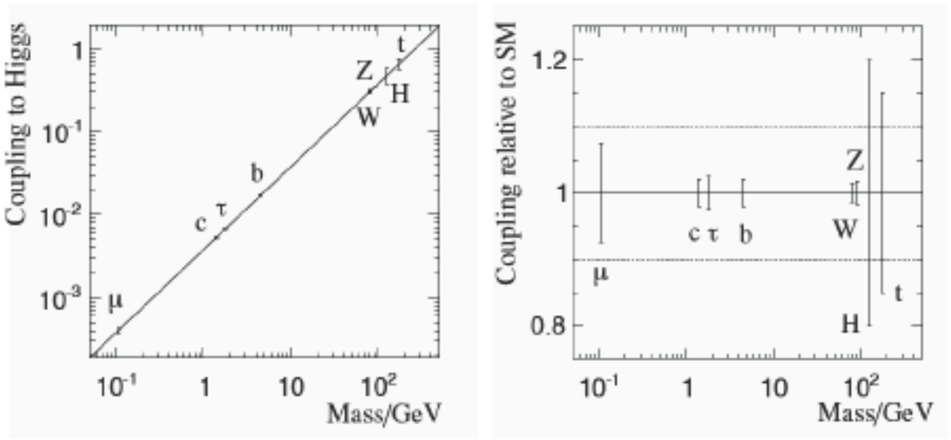
$\sqrt{s}$	250 GeV	350 GeV
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}
$\Delta(\sigma)/\sigma$	3 %	4 %
$\Delta(g_{HZZ})/g_{HZZ}$	1.5 %	2 %



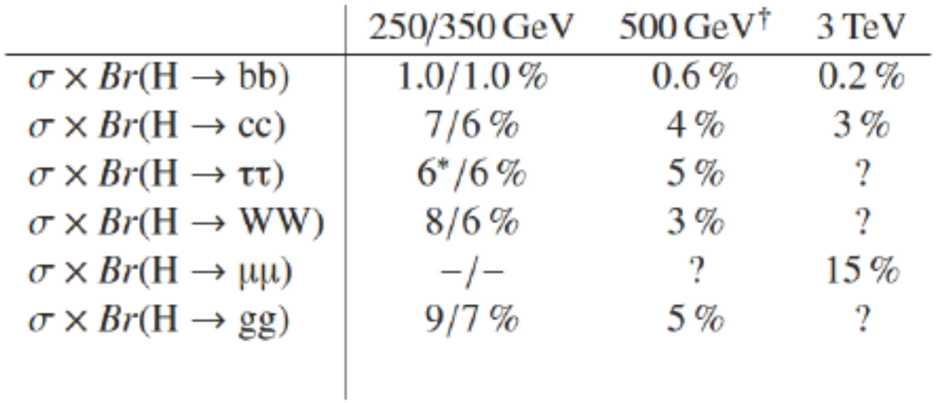
√s > 500 GeV WW and ZZ fusion



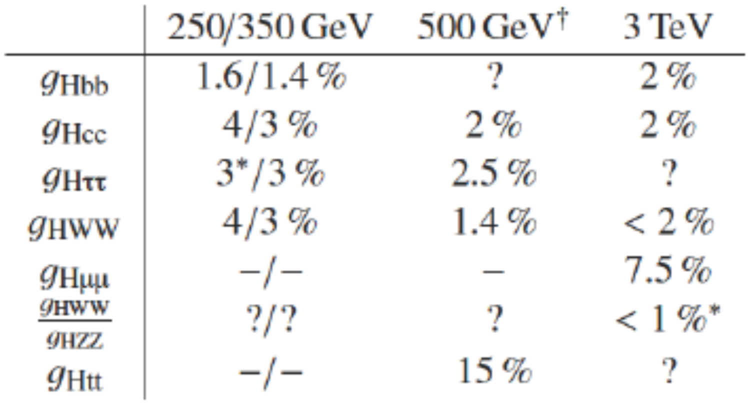
e⁺e⁻ precision on Higgs couplings assuming one operating point ~250 GeV and one ~500 GeV



I.e., typical e⁺e⁻ precisions on couplings ~few percent



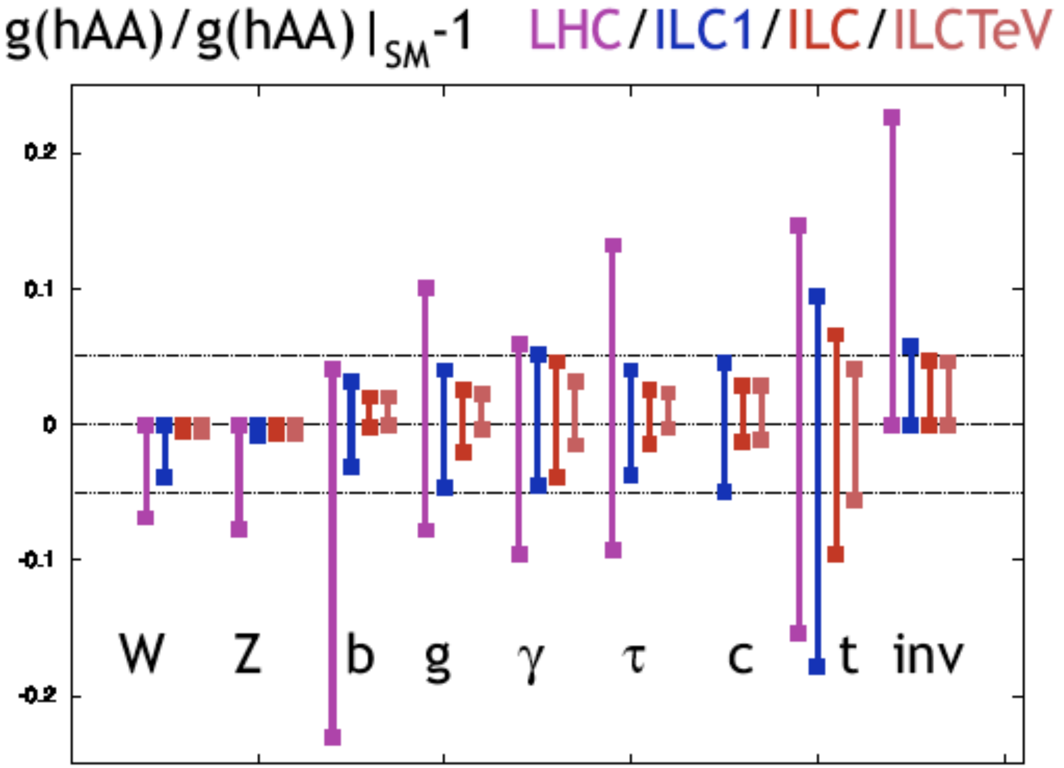
	250/350 GeV	500 GeV†	3 TeV
$\sigma \times Br(\mathrm{H} \to \mathrm{bb})$	1.0/1.0 %	0.6 %	0.2 %
$\sigma \times Br(\mathrm{H} \to \mathrm{cc})$	7/6 %	4 %	3 %
$\sigma \times Br(\mathrm{H} \to \tau\tau)$	6*/6 %	5 %	?
$\sigma \times Br(\mathrm{H} \to \mathrm{WW})$	8/6 %	3 %	?
$\sigma \times Br(\mathrm{H} \to \mu\mu)$	−/−	?	15 %
$\sigma \times Br(\mathrm{H} \to \mathrm{gg})$	9/7 %	5 %	?



	250/350 GeV	500 GeV†	3 TeV
g_{Hbb}	1.6/1.4 %	?	2 %
g_{Hcc}	4/3 %	2 %	2 %
$g_{\mathrm{H}\tau\tau}$	3*/3 %	2.5 %	?
g_{HWW}	4/3 %	1.4 %	< 2 %
$g_{\mathrm{H}\mu\mu}$	−/−	−	7.5 %
$\frac{g_{\mathrm{HWW}}}{g_{\mathrm{HZZ}}}$	?/?	?	< 1 %*
g_{Htt}	−/−	15 %	?

- N.B. Higgs production in WW and ZZ fusion can be studied also at LHeC
  - e.g., σ.Br (H->bb) precision ~4%

Higgs couplings measurements



Peskin'12

Figure 2: Comparison of the capabilities of LHC and ILC for model-independent measurements of Higgs boson couplings. The plot shows (from left to right in each set of error bars) 1 σ confidence intervals for LHC at 14 TeV with 300 fb^{-1}, for ILC at 250 GeV and 250 fb^{-1} ('ILC1'), for the full ILC program up to 500 GeV with 500 fb^{-1} ('ILC'), and for a program with 1000 fb^{-1} for an upgraded ILC at 1 TeV ('ILCTeV'). The marked horizontal band represents a 5% deviation from the Standard Model prediction for the coupling.

5-10% @ $\text{LHC}_{300/\text{fb}}^{14\text{TeV}}$

1-5% @ ILC/CLIC

Higgs mass and width

- Δm_H ~ 50 MeV
  - From recoil mass at √s = 250 GeV or direct reconstruction
- For m_H = 125 GeV, the total Higgs decay width in the SM is less than 5 MeV
  - Cannot be measured directly
  - Can be determined to ~5% using

$$\Gamma_H = \Gamma(\mathrm{H} \to \mathrm{WW}^*)/Br(\mathrm{H} \to \mathrm{WW}^*)$$

- Threshold behaviour of cross section gives information on CP

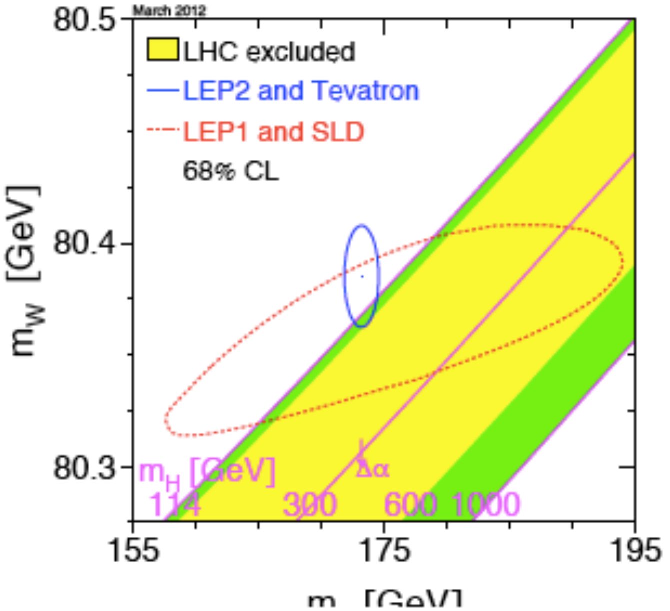
Higgs self-coupling

- Observing HH events: very difficult at the LHC
  - Destructive interference between diagrams involving HHH and gg → HH
    - σ_{HH} = 71, 34, 16 fb for $\lambda_{HHH}/\lambda_{HHH}^{SM}$ = 0,1,2
  - Most promising channels bbγγ, bbττ
  - Maybe ~3σ significance per expt in a few channels?
  - Maybe 30% measurement of λ_{HHH}?
  - At the moment estimates are very vague and based on a large degree of optimism
- This is not easy at LC either!
  - √s = 500 GeV ZHH
  - √s = 1000 GeV ννHH
  - Maybe 20% measurement of λ_{HHH}?

Other precise EW measurements

- W mass, $\sin^2\theta_W$, etc.
  - Measurements possible at LHC
    - Competitive with the LEP/Tevatron precision
      - but unlikely to make huge gains relative to LEP/Tevatron
- New e^+e^- machines running at $\sqrt{s} = M_Z$ and $\sqrt{s} = 2M_W$
  - could give order of magnitude or more improvements
    - e.g., $\Delta m_W \sim 0.5 - 1.0$ MeV?
    - e.g., $\sin^2\theta_W$ from polarization and forward-backward asymmetries

- $\sin^2\theta_W$ starts to look like the poor relation in this plot!
  - Significant theoretical progress would be required in the interpretation of more precise experimental measurements in this area!

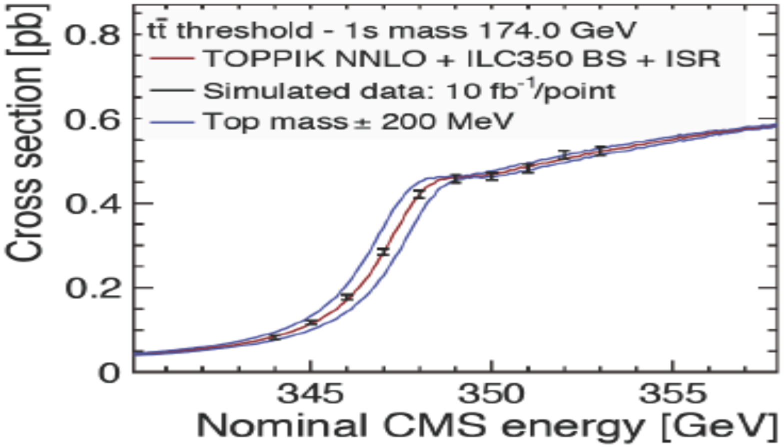


Top physics

- Huge numbers of events with 300 fb^{-1} at LHC
  - ~50M lepton+jet, 10M di-leptons, 15M single top
- Allows many interesting and precise measurements of top quark properties
  - mass, couplings, spin correlations, W helicity, A_{FB}, tt resonance search, etc.
- Δm_t ~ 1 GeV from Tevatron
- Hard to imagine a huge improvement at LHC, unless radically new ideas can be exploited?

Top physics at LC

- Threshold scan allows:
  - Δm_t ~ 20 MeV (expt)
    - with additional ~100 MeV ascribed to theoretical interpretation
  - $\Delta\Gamma_t$ ~ 30 MeV
- Use of polarized beams very powerful in making precise measurements of angular observables



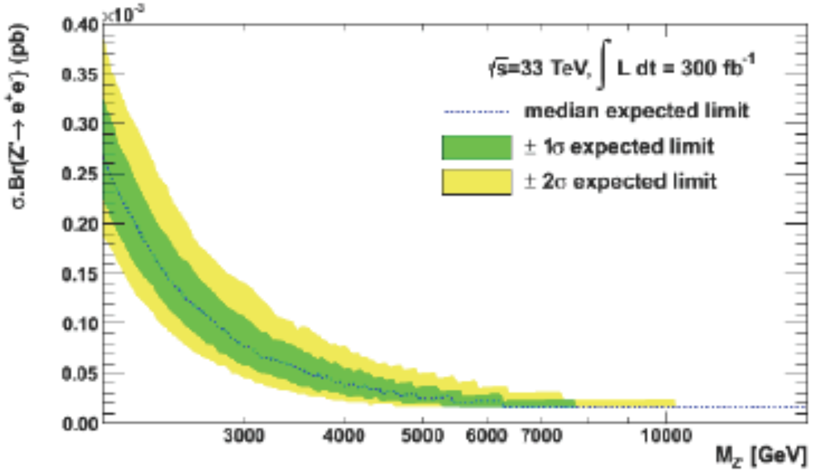
Resonance search in l^+l^- at LHC

- Challenge to maintain electron energy/muon momentum resolution in multi-TeV region
- Background dominated by SM Drell-Yan

model	$300\,\mathrm{fb}^{-1}$	$1000\,\mathrm{fb}^{-1}$	$3000\,\mathrm{fb}^{-1}$
$Z'_{SSM} \to ee$	6.5	7.2	7.8
$Z'_{SSM} \to \mu\mu$	6.4	7.1	7.6

(stat. uncertainties only)

- Example CMS projection for l^+l^- search at 33 TeV



Concluding remarks on high energy frontier

Can we think of any scenario in which it would make sense to stop running the LHC in ~2022 (once 300 fb^{-1} has been collected)?

- If we have found new particles
  - Presumably we shall want to study them and search for more at higher mass and/or lower σ.Br ?
- If we have found nothing new (other than SM higgs)
  - Would it make sense to switch off the LHC, when it might still represent the best chance of finding NP at higher mass/lower σ.Br ?
- In addition, there is an important programme of "bread and butter" physics at the LHC that will benefit from increasing the integrated luminosity beyond 300 fb^{-1}
    - Higgs couplings, top properties, vector boson pair scattering at high energies

- Large costs in consolidation of accelerators/detectors are required to enable the LHC to continue to run beyond 300 fb^{-1}
  - even without any upgrade to deliver HL-LHC
- Costs specific to HL-LHC upgrade represent small fraction (~10%?) of total running+consolidation cost of LHC programme for 2022-2030
- Expect HL-LHC upgrade to bring factor ~3 in integrated luminosity
  - 3000 fb^{-1} rather than 1000 fb^{-1} if continue to run until 2030 at ~100 fb^{-1}/year
    - Maybe hard to imagine sustaining a programme at constant luminosity over such a long period

Concluding remarks on high energy frontier

- LHC built to deliver 100s fb^{-1} at 14 TeV
- Currently we have ~20 fb^{-1} at 7-8 TeV
- It is too early to say what discoveries will be made at the LHC
  - In particular, at what mass the first BSM particles will be found
- We should welcome the wealth of possible future options as a strength of our field
  - Possible to imagine scenarios in which just about any of the above-mentioned large facilities might be the best next step
- Too early to decide what the next big machine will be?

- Whilst waiting for the discoveries (or absence thereof) that will shape the future of the field, can we agree on
  - the further studies that need to be made
    - accelerator and detector designs, physics cases
  - the R&D that needs to be made
- so that when we are in a position to take decisions about the next big HEF facility
  - (maybe by the next round of the European strategy process ;-)
- we can make rational, well-informed decisions?

High Energy Frontier

- Discovery of Higgs-like state is a landmark for the field (and a triumph for the LHC)
- Plethora of SM measurements with increasing precision (QCD,t,W,Z,VV,...)
- Searches for NP leading to o(TeV) limits on new particles

- Excellent prospects (much increased NP reach!) for 14 TeV LHC (300 fb^{-1})
- Higgs measurements & WW unitarity require HL-LHC 3000 fb^{-1} upgrade (detectors + machine)

- Excellent physics case for the study of „Higgs" state (+top, EW) in depth with high precision and complementary to LHC in e^+e^- ($\gamma\gamma$?, ep??)
- Announcement from Japanese community to aim hosting ILC (250-500 GeV) as global project
- Assess which machine best suited for this program (linear vs. circular)
- Time matters – technical readiness also

- In absence of direct evidence for NP and strong theoretical guidance too early to decide on post-LHC facility for HEF (CLIC, HE-LHC(33), UHE-LHC(50+), μC, Plasma??, ...)
- Maintain critical R&D and feasibility studies

Future facilities in heavy flavour physics

- LHCb upgrade
  - In 2012 luminosity levelled at 4 x 10^{32} $cm^{-2}s^{-1}$
    - Mean number of collisions per crossing $\mu \sim 1.6$ (design 0.4)
  - By 2017 can expect to collect total of ~7 fb^{-1}
  - 2018 upgrade
    - Readout entire detector at 40 MHz + software trigger
    - Replace precision tracking detectors
  - 2019 onwards
    - Luminosity levelled at 1-2 x 10^{33} $cm^{-2}s^{-1}$ ($\mu \sim 2$-4)
    - Collect ~5 fb^{-1}/year to achieve total of ~50 fb^{-1}
- Next generation B factory
  - SuperKEKB and Super-B (Frascati)
  - Luminosity ~10^{36} $cm^{-2}s^{-1}$
    - approaching two orders of magnitude increase wrt. first generation B factories
  - Collect ~50 ab^{-1} or more on $\Upsilon(4s)$ and several ab^{-1} on $\Upsilon(5s)$
  - Substantially improved detectors wrt. first generation
- Many HF observables sensitive to contributions from potential BSM physics
  - e.g., $B_s^0 \rightarrow \mu\mu$, $b \rightarrow s\gamma$, $B^+ \rightarrow \tau^+\nu$ complement SUSY constraints from direct searches at ATLAS/CMS

Future prospects

"Minimalistic" list of the key (low-energy) quark flavor-violating observables:

γ from tree ($B \to DK$, ...)	S-LHCb
$\lvert V_{ub} \rvert$ from exclusive semi-leptonic B decays	S-Bfactory [SuperKEKB & SuperB]
$B_{s,d} \to l^+ l^-$	S-LHCb + ATLAS & CMS
CPV in B_s mix. [ϕ_s]	S-LHCb
$B \to K^{(*)} l^+ l^-, \nu\nu$	S-LHCb / S-Bfactory
$B \to \tau\nu, \mu\nu$ (+D)	S-Bfactory
$K \to \pi\nu\nu$	Kaon beams [NA62, KOTO, ORKA]
CPV in charm	S-LHCb / S-Bfactory

Summary by Belle II collaboration demonstrating complementarity of next generation B factory and LHCb

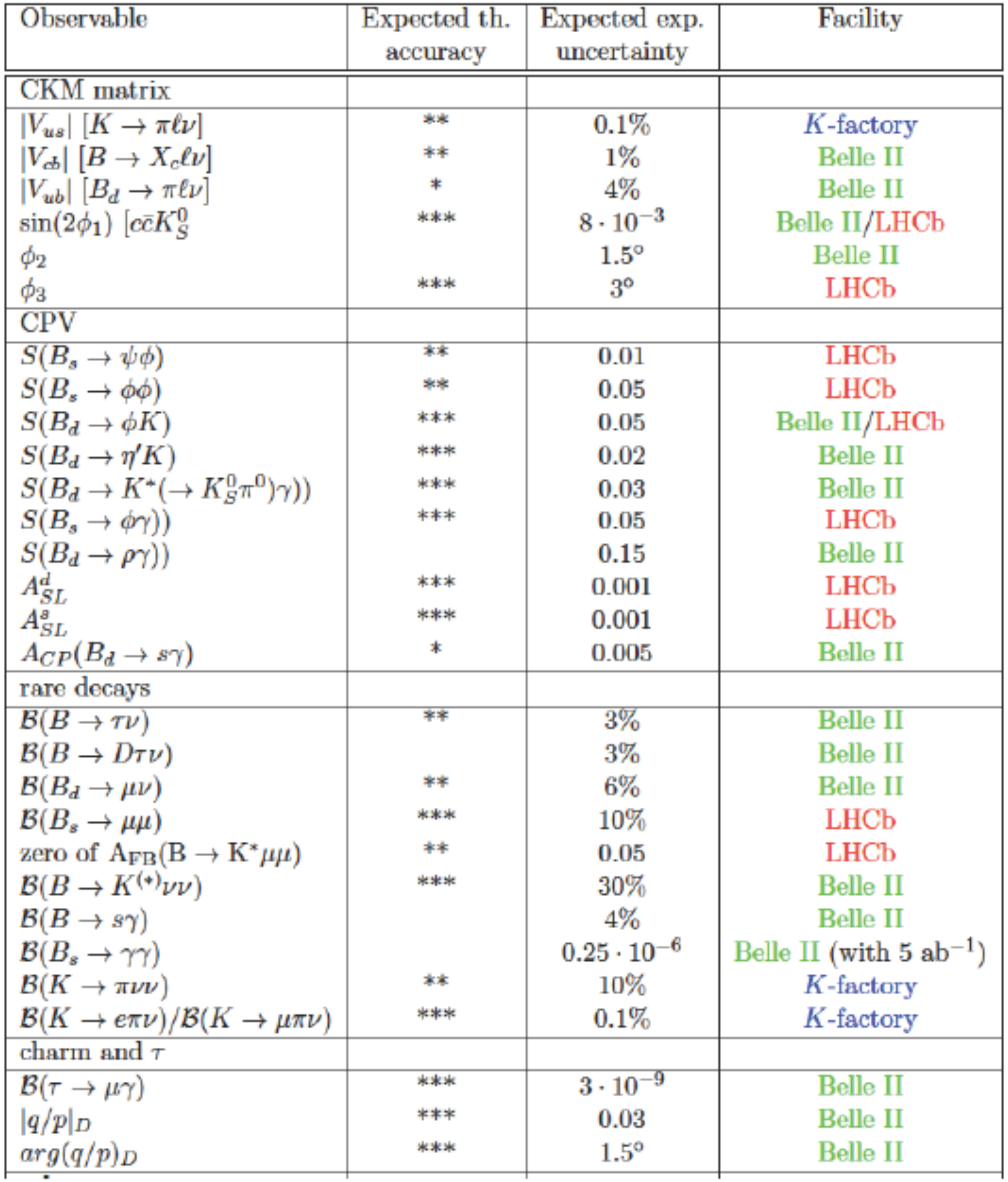
Assumed integrated luminosities:

Belle II: 50 ab^{-1}

LHCb: 10 fb^{-1}

Theoretical uncertainties and “gold-plated” tests of SM:

What is the quality of the gold-plating?



Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\|V_{us}\|$ $[K \to \pi\ell\nu]$	**	0.1%	K-factory
$\|V_{cb}\|$ $[B \to X_c\ell\nu]$	**	1%	Belle II
$\|V_{ub}\|$ $[B_d \to \pi\ell\nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K_S^0$	***	$8 \cdot 10^{-3}$	Belle II/LHCb
ϕ_2		1.5°	Belle II
ϕ_3	***	3°	LHCb
CPV			
$S(B_s \to \psi\phi)$	**	0.01	LHCb
$S(B_s \to \phi\phi)$	**	0.05	LHCb
$S(B_d \to \phi K)$	***	0.05	Belle II/LHCb
$S(B_d \to \eta' K)$	***	0.02	Belle II
$S(B_d \to K^*(\to K_S^0\pi^0)\gamma))$	***	0.03	Belle II
$S(B_s \to \phi\gamma))$	***	0.05	LHCb
$S(B_d \to \rho\gamma))$		0.15	Belle II
A_{SL}^d	***	0.001	LHCb
A_{SL}^s	***	0.001	LHCb
$A_{CP}(B_d \to s\gamma)$	*	0.005	Belle II
rare decays			
$\mathcal{B}(B \to \tau\nu)$	**	3%	Belle II
$\mathcal{B}(B \to D\tau\nu)$		3%	Belle II
$\mathcal{B}(B_d \to \mu\nu)$	**	6%	Belle II
$\mathcal{B}(B_s \to \mu\mu)$	***	10%	LHCb
zero of $A_{FB}(B \to K^*\mu\mu)$	**	0.05	LHCb
$\mathcal{B}(B \to K^{(*)}\nu\nu)$	***	30%	Belle II
$\mathcal{B}(B \to s\gamma)$		4%	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$		$0.25 \cdot 10^{-6}$	Belle II (with 5 ab^{-1})
$\mathcal{B}(K \to \pi\nu\nu)$	**	10%	K-factory
$\mathcal{B}(K \to e\pi\nu)/\mathcal{B}(K \to \mu\pi\nu)$	***	0.1%	K-factory
charm and τ			
$\mathcal{B}(\tau \to \mu\gamma)$	***	$3 \cdot 10^{-9}$	Belle II
$\|q/p\|_D$	***	0.03	Belle II
$arg(q/p)_D$	***	1.5°	Belle II

Concluding remarks on heavy flavour

- LHCb upgrade and next generation B factory physics programmes are largely complementary
  - LHCb dominates most measurements with B_s, b-baryons, decays to final states consisting entirely of charged particles
  - Next generation B factory dominates measurements in final states containing invisible or neutral particles
- Both are likely to make important contributions

- Physics programme of next generation B factories consists largely of refining measurements and searches for rare decays
  - No guarantee of BSM effects – maybe results will be "only" improved limits?
  - Motivation for two facilities (SuperKEKB and Super-B)?
    - C.f. when the first generation B factories were proposed
    - A major new observation was expected (CPV in B^0)
      - Natural to have two experiments to confirm discovery and cross check subsequent measurements

Summary of Flavour Physics and Symmetry Session

- Recent Progress
  - B Factories (Belle and Barbar) have completed data taking and continue to provide wide range of interesting results, including CP violation and rare decays.
  - LHCb has demonstrated that precision flavour physics is possible at hadron collider
  - High-p_T experiments (CDF, D0, ATLAS, CMS) also doing excellent flavour physics
  - Detailed study made of CP violation and rare decays in B system (now including B_s)
  - NA62 is completing its preparation for precision kaon physics
  - MEG at PSI is improving a search for $\mu \to e\gamma$ at $2.4\mathrm{x}10^{-12}$
- Open Issues
  - No clear sign of physics beyond the Standard Model in flavour sector, and possible key measurements (a la G. Isidori) are as follows.
    - Φ_s, $|V_{ub}|$, CP angle gamma, B rare decays such as $B_s \to \mu\mu$ and $B \to \tau\nu$
    - CP violation in charm
    - K rare decays such as $K \to \pi\nu\nu$
    - Charged lepton flavor violation (CLFV) eg. $\mu \to e\gamma$, $\mu N \to eN$, $\mu \to eee$, $\tau \to \mu\gamma$, etc.
    - Muon g-2 and EDM (neutron, electron, muon, atom)
- Towards a Strategic Plan
  - Essential to maintain a diverse programme (B, D, K, charged leptons)
  - Flavour experiments typically on smaller scale than Higgs/neutrino, but crucial for search for/understanding of New Physics
  - LHCb and its upgrade form an important part of the exploitation of the LHC
  - An upgraded B Factory will give complementary physics coverage
  - CLFV (μ and τ) and EDM could provide a clean demonstration of new physics

Summary slide, strong interaction session Open Symposium on European Strategy for Particle Physics, Cracow, Poland, Sep. 2012

2 talks: P. Newman, QCD at HE frontier H. Appelshaeuser, QGP

Summary QCD: new facility LHeC + ongoing projects (Compass, LHC expts,...)
Discussion: LHeC-- unprecedented kinematic range for DIS studies ep, eA
low x (saturation) physics, some capability for Higgs physics.
Improved pdf constrains as required for HL-LHC. important input for QGP?
Or is pp/pA sufficient? Time scale around 2025. Interference with HL LHC?
Proton spin physics: Compass, RHICpp, JLAB12, and future eRHIC/eLIC

Summary QGP: top priority: LHC ion running and ALICE upgrade, to 2025
also: interesting physics remains at high baryon density (5 < sqrt(s) < 40 GeV)
Discussion: important discovery potential with 50 kHz Pb-Pb running for ALICE, ATLAS, CMS
Ions in HE LHC?
LHC program complementary to RHIC

high baryon density: RHIC-BES, SPS, NICA, FAIR/CBM (SIS300?)
need of experiments at all 4 facilities? coordination needed, time scales?
special role of SPS

Astroparticle physics, gravitation and cosmology - session summary

- **Large variety of exciting experiments and physics topics** - APP community size has grown fast in recent 5 years: in Europe now ~ 2000 scientists
- **The following synergies were identified** :
  - LHC searches for new particles and direct/indirect searches for dark matter , axions
  - Specific models may relate $0\nu\beta\beta$ measurements (low E) and LHC results (high E)
  - Sterile neutrinos and dark matter
  - HE cosmic rays and LHC measurements, eg AUGER and LHC cross sections
  - Next LBL neutrino detector should have capabilities for astroparticle physics to justifty investment ; therefore it should go underground
- **On the role of CERN:**
  - There should be a closer collaboration between ApPEC and CERN, eg exchange of information
  - The CERN convention allows research in the field of cosmic rays
- **Organisation of APP projects:**
  - Present planning stops around 2020 (with exceptions): wait for results for next phases
  - Global planning is needed on worldwide scale
  - APP is in between astrophysics, cosmology and particle physics – which community decides on core business of given project?
  - CERN, national agencies and ApPEC should support R&D program on neutrino detectors & beam design studies

Summary of the ν session

- ν mass and mixings confirmed by many experiments and remain, with dark matter, the only present evidence of beyond the Standard Model physics.
- As the highest priority we should determine the unknown oscillation parameters and look for surprises. CP violation and the ν mass hierarchy could be keys to the matter/antimatter asymmetry of the Universe.
- A large and effective European community exists in this area.
- Long baselines are optimal for determining the mass hierarchy, real advantage of the CERN → Pyhäsalmi baseline and, to a lesser extent, LBNE.
- The CERN → Pyhäsalmi baseline is also near optimal for a Neutrino Factory.
- Shorter (~hundreds of kilometres) baselines with huge detectors would allow very high statistics measurements more helpful for CP violation, particularly if hierarchy is known. This is the case of T2HK (also European alternatives such as CERN → Frejus, CERN → Canfranc, or ESS-based ν beam)
- For best performance and synergy an experiment of each category is needed → Coherence with efforts in other regions. Coordination and cooperation with our international colleagues mandatory.
- Anomalies in a range of phenomena at lower energies perhaps point to sterile neutrinos, and a proposed experiment at CERN would be highly competitive.
- More sophisticated future projects, which EUROnu has concluded should be a Neutrino Factory, necessary to achieve the desired sensitivity to the CP phase and probe new physics.
- R&D including projects such as MICE and nuStorm (which may also offer a definitive test for sterile neutrinos) should be supported.
- Experiments in absolute neutrino mass, especially in neutrinoless double-beta decay, are also a top priority.
- Hadron production, neutrino cross-section, and other support measurements will be essential to reach the neutrino oscillation sensitivity goals.

1) Long baseline projects in Europe and elsewhere: towards the discovery of Mass Hierarchy and CP Violation, test of the PMNS paradigm

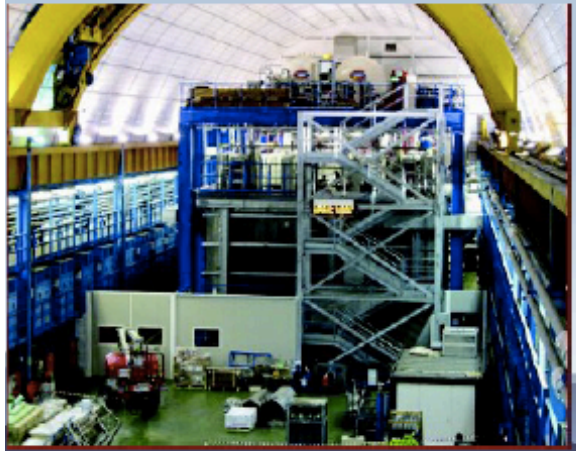
2) Short baseline projects : test the existence of new neutrino states

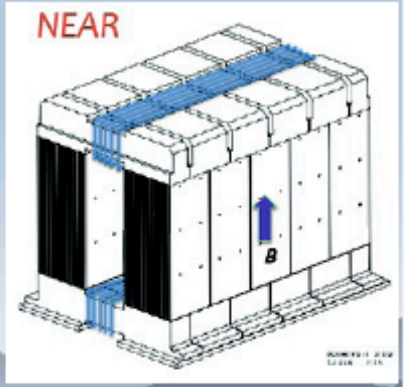
Long baseline projects

Project	Beam power MW	Fiducial Mass kt	Baseline km	MH	CPV 90%CL, (3σ)	Physics starts	Astrophysical program
LBNO	0.8	20- >100	2300	Excellent	71 (44)	2023	Yes
T2HK	0.75	500	295	No	86 (74)*	2023	Yes
LBNE	0.7	10	1300	OK	69 (43)	2022	No
Lund	5	440	365	Some	86 (70)	>2019	Yes
CERN-Canfranc	0.8-4	440	650	Some	80-88(80)	>2020	Yes

SPSC-P-347 (Icarus-Nessie)

- Proposal (SPSC-P-347, 150 authors) of a comprehensive search for new neutrino states around $\Delta m^2 \sim 1 eV^2$ using a SPS 110 GeV proton beam in the NA
- with two LAr detectors, at 1600 m (ICARUS T600 now at Gran Sasso) and 300m (T150), supplemented by two spectrometers
- Method : two identical detectors, with imaging properties and complete final state reconstruction





Accelerator Science & Technology Session

LHC & high-energy hadron collider

- LHC operating successfully (a huge technology success!)
- technology to go to 13-14 TeV and HL-LHC at hand with some development needed
- possibility to go to 26-33 TeV with 16-20 T magnets (HE-LHC), but substantial R&D needed ; higher energy requires a new tunnel (80 km → 80-100 TeV)

high-energy lepton collider

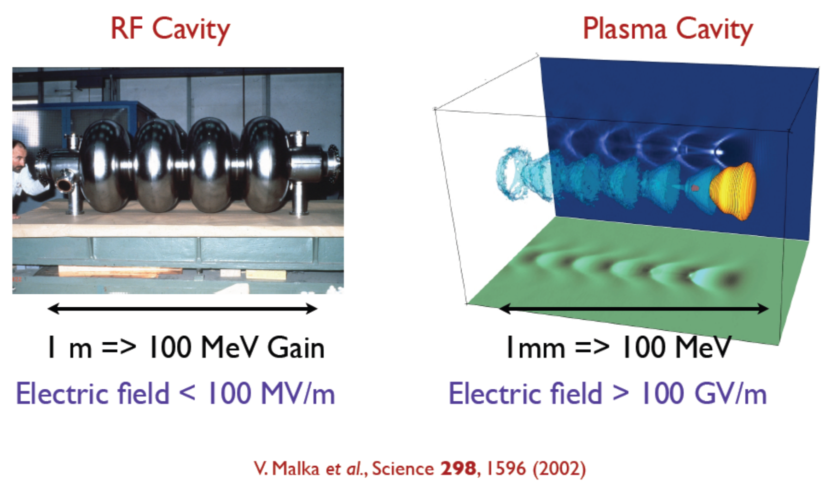
- great progress in SRF for ILC makes project possible ; very advanced proposal
- CLIC could be alternative, esp. if one wants to go to 3 TeV with still significant R&D
- new ideas for circular or $\gamma\gamma$ colliders; more studies needed on performance reach
- SRF ERL/RLA technology is attractive for many applications (LHeC, $\gamma\gamma$)
- to go to much higher energy using leptons requires muon collider, dielectric acceleration or plasma acceleration with increasing complexity and R&D needed

high intensity beams

- high power linacs being constructed (ESS, IFMIF, Project-X?); technology in hand
- improving neutrino beams with optimized existing infrastructures is possible
- high-intensity ν beam requires ν factory, with intense R&D
- technology for very-high luminosity flavor factories exists

many R&D topics common for various accelerators including other fields, ex. high-field magnets, RF structures & RF sources, particle sources, alignment & stabilization

collaboration with other fields should be promoted further



RF Cavity

Plasma Cavity

1 m => 100 MeV Gain

Electric field < 100 MV/m

1mm => 100 MeV

Electric field > 100 GV/m

V. Malka *et al.*, Science **298**, 1596 (2002)

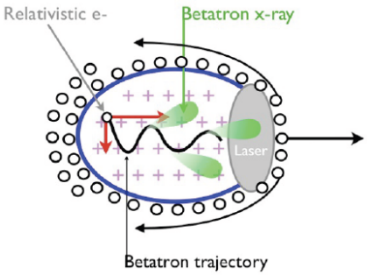
Plasma accelerators:

Transform transverse fields into longitudinal fields

- **Laser driven**
- **e- driven**
- **p driven**
- **Dielectric wakefields**

Demonstrated accelerating Gradients up to 3 orders of magnitudes beyond presently used RF technologies.

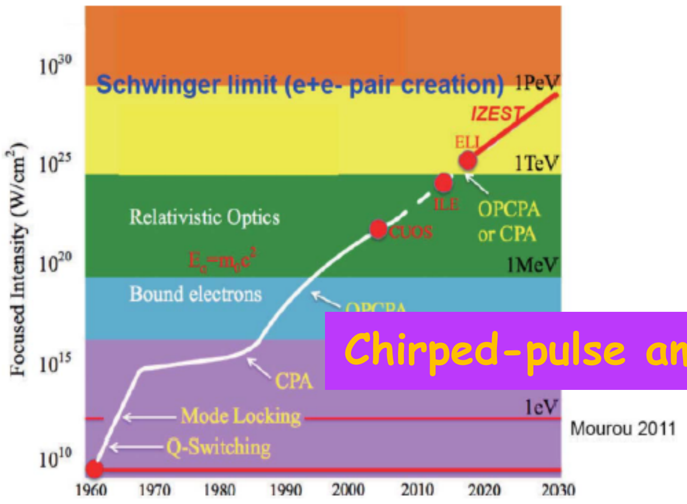
Laser driven PLASMA ACCELERATORS



Lasers as tools for fundamental physics

(ELI 10^{23-25} W/cm², ELI 4° Pillar, LIL, Russian Mega, Japanese Exawa IZEST)

K. Homma, D. Habs, G. Mourou, H. Ruhl and T. Tajima



Chirped-pulse amplification

. (color online) Updated progress in the leap of laser intensity as a function of years.[2)]

Decrease plasma density and increase laser power to reduce total power consumption

Computing tools & computing power (PIC codes) -> prediction of bubble regime for mono-energetic beams and short laser pulses

Laser-Plasma Accelerators:

- Accelerating field of few 100 GeV/m. **Over few cm**

- Quasi monoenergetic e-beam, from 100 MeV to 1 GeV, in mm to cm plasma.

- Relative energy spread of 1 %, femtosecond duration.

- Divergence of a few mrad, emittance of π.mm.mrad.

- Charge of about 10-100 pC.

loa **V. Malka** INFN, June 8 (2012)

Instrumentation, Computing and General Infrastructure

Detector R&D for Discovery Science:

-Many ongoing R&D efforts in Tracking (50%) / Calorimetry / PID / electronics

-New technologies: ~15 years R&D from conception to production → need to start early

-Step from R&D to realization requires industrialization / Technology transfer.

Discussion: More coherent / collaborative work among R&D communities.
More effort on education of and recognition for young physicists on detectors.
Is there a need to revive the DRDC committee?

Large scale projects / Infrastructures:

-LHC experiments pioneered an approach applicable to future large projects,

-Project management and strong host laboratory is pivotal to deliver large scale projects,

-Maintain local expertise at large laboratories to cope with production/commissioning.

Discussion: Training and education of young generation via specialized schools has to be supported / stronger role of Universities advisable.
Support of small size experiments as training platform for next generation.
How best to provide infrastructure/support for "greenfield" experiments?

Computing:

-Great success of LHC computing / WLCG, but needed ~15 years development

-Tier-structure lead to speedy delivery of results. Future funding uncertainties ? new computing model needed ?

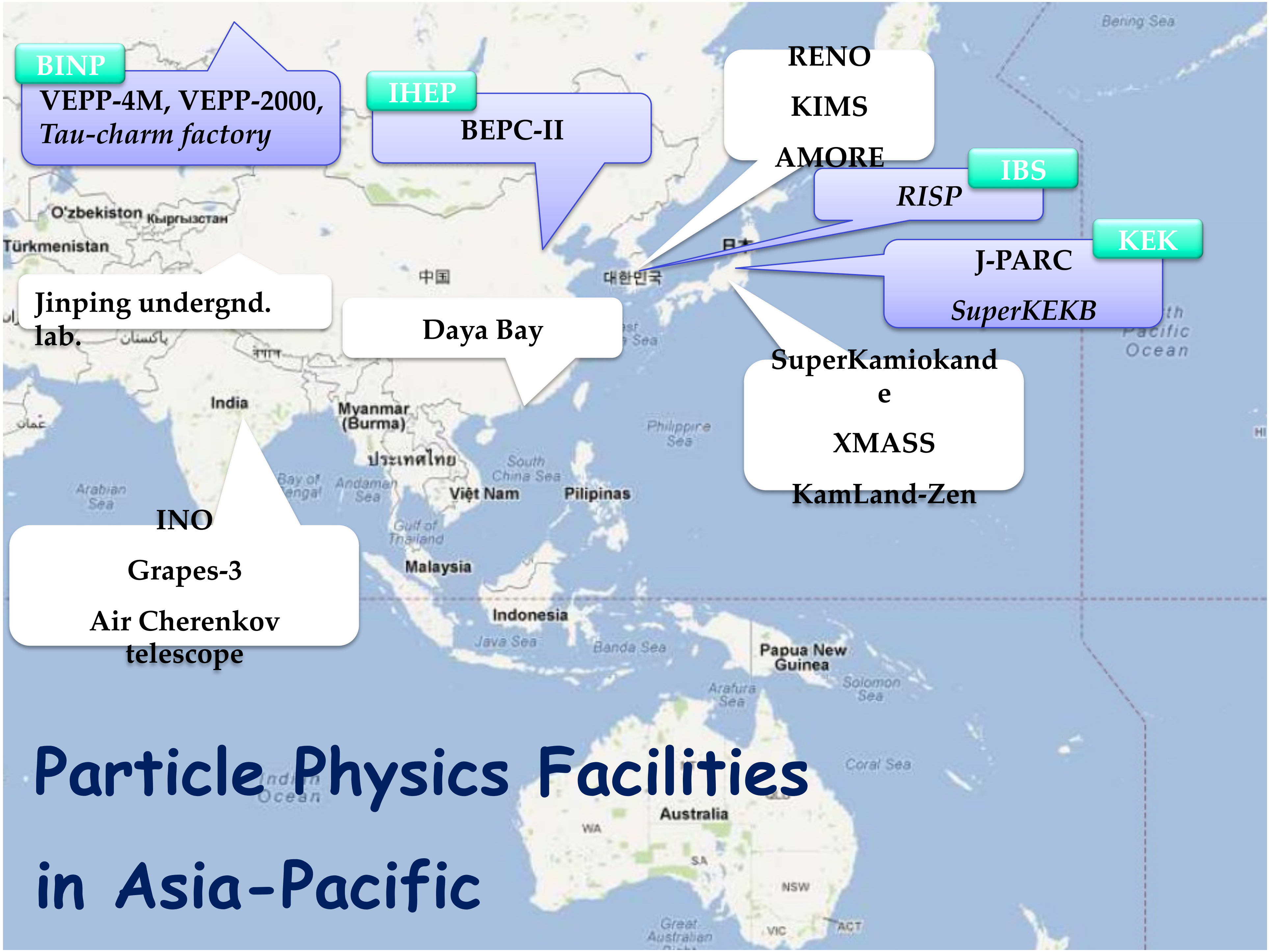
-Must handle multiple core processors in future → Experienced computing engineers needed

-GEANT4 very successful, but need further developments to cope with experiments and detector R&D of the future.

My general comments for discussion I

- Generally accepted (I hope):
  - Complementarity between Energy Frontier Experiments and Precision Measurements in search for physics beyond the Standard Model (i.e. direct- versus indirect-search).
  - For some cases, QCD effect introduces a sever limitation.
  - Complex hadronic system can generate new properties (e.g. QGP)
  - Neutrino physics possibly probing "very" high energy scale
- Exploitation of LHC covers almost every aspects
  → Energy Frontier, Precision, QCD and QGP
- For the next High Energy Frontier machine for New Physics search in Europe, we need to agree soon on a process to compare different options so that a community choice could be made at an appropriate moment (next Strategy Update?) with results from LHC13-14 data.

Particle Physics Facilities in Asia-Pacific



BINP
VEPP-4M, VEPP-2000,
Tau-charm factory

IHEP
BEPC-II

RENO
KIMS
AMORE

IBS
RISP

KEK
J-PARC
SuperKEKB

Jinping undergnd. lab.

Daya Bay

SuperKamiokande

XMASS

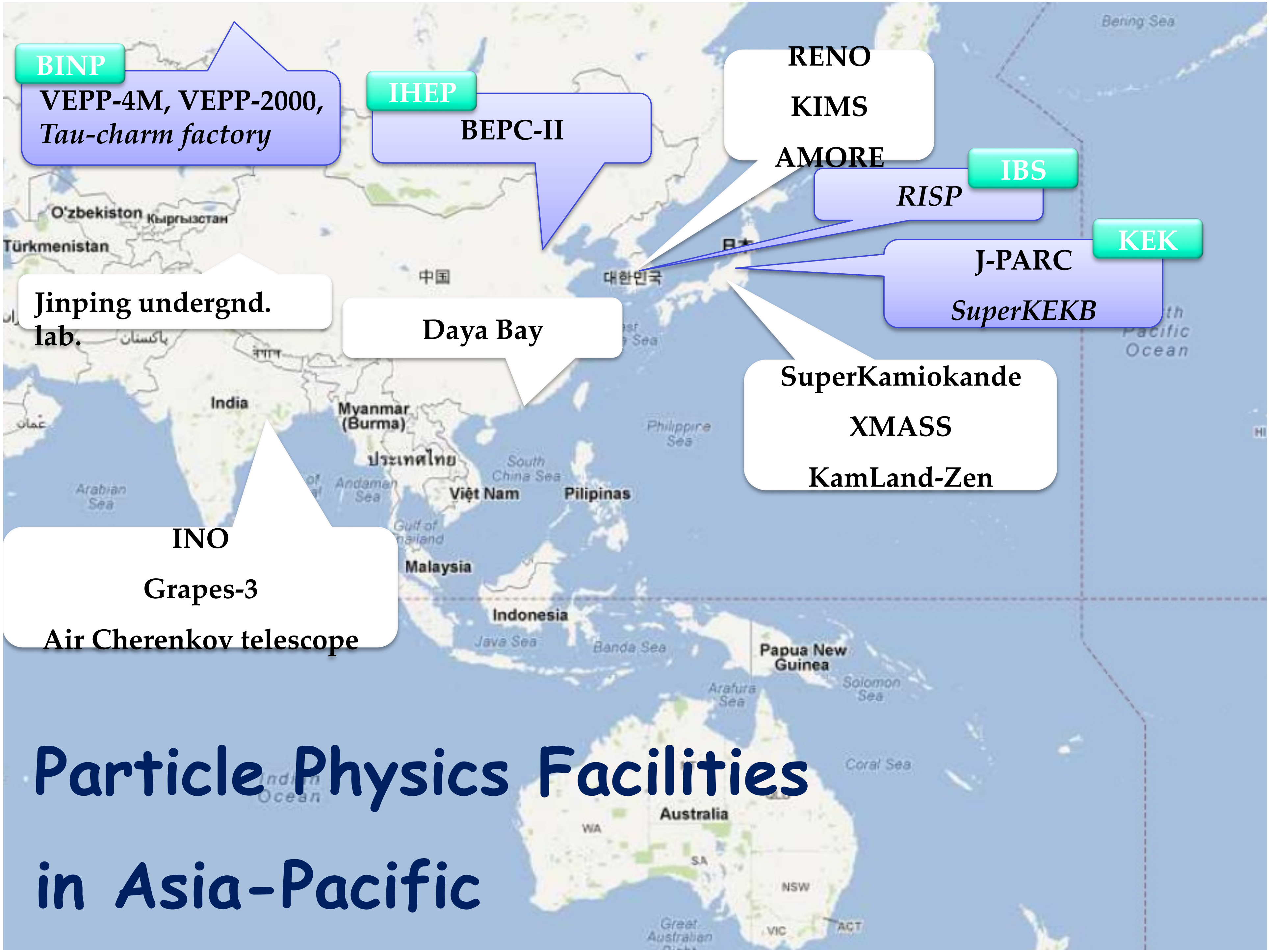
KamLand-Zen

INO

Grapes-3

Air Cherenkov telescope

Particle Physics Facilities in Asia-Pacific



BINP

VEPP-4M, VEPP-2000,
Tau-charm factory

IHEP

BEPC-II

RENO
KIMS
AMORE

IBS

RISP

KEK

J-PARC
SuperKEKB

Jinping undergnd. lab.

Daya Bay

SuperKamiokande
XMASS
KamLand-Zen

INO
Grapes-3
Air Cherenkov telescope

Summary –Physics landscape in Asia-Pacific in 2020's

- Future accelerators in Asia-Pacific
  - Super tau-charm factory at BINP
  - BEPCII continues to run at IHEP
  - SuperKEKB: high luminosity B factory at KEK
  - J-PARC: *K*, m and n program
  - RISP at IBS will join the particle physics research.
- Future non-accelerator facilities in Asia-Pacific
  - Daya Bay II and Jinping lab. in China
  - RENO-50 and Y2L in Korea
  - INO in India
  - SuperKamiokande and its upgrade, XMASS, KamLand-Zen, and many more in Japan
- Japanese HEP community strongly hopes to host ILC, and making all the possible efforts: intensive R&D on machine and detector, site investigation, organizational issues and actions to get understandings of general public and government.

(Prof. Masanori Yamahuchi - KEK)

Backup