Europejska strategia w fizyce cząstek - pierwsze uaktualnienie 2013

Jan Królikowski

Links

Strategy statement 2006: http://council.web.cern.ch/council/en/EuropeanStrategy/ESStatement.pdf

Discussion document 2006: http://council.web.cern.ch/council/en/EuropeanStrategy/ESDiscussion.pdf

2012/13: http://europeanstrategygroup.web.cern.ch/europeanstrategygroup/

Geneza

<u>Czerwiec 2006</u>- Rada CERN przyjęła dokument „European Strategy for Particle Physics" (ESPP 2006)

W tym dokumencie przewidziano uaktualnienie w 2011.

Rada CERNu postanowiła przesunąć termin uaktualnienia o 2 lata. Prace rozpoczęły się w 2011 od powołania **European Strategy Group** (ESG , A. Zalewska/ J. Królikowski) i **ES Preparatory Group** (ESPG, A.F. Żarnecki z Polski).

- Szereg zebrań roboczych,
- CERN Council Open Symposium on European Strategy for Particle Physics, Kraków, wrzesień 2012 (seminaria A. F. Żarneckiego i E. Rondio, październik 2012),
- Physics Briefing Book to ESG,
- Warsztaty w Erice , styczeń 2013
- CERN Council European Strategy session March 2013

Cele, które stawia sobie dokument...

Recall the Council Document

- The Strategy Update shall in particular aim at:
  - enhancing the visibility of existing European particle physics programmes;
  - increasing collaboration among Europe's particle physics laboratories, institutes and universities;
  - promoting a coordinated European participation in global projects and in regional projects outside Europe;
  - encouraging knowledge transfer to other disciplines, industry, and society.
- The proposal shall include a review of the implementation of the 2006 Strategy, as well as of the structures and procedures currently in place with regard to the Strategy.

Erice:ESG recommendation for the High Energy Frontier colliders

- **Europe+ World**: LHC and its upgrades
- **US+ World: LBNE**
- **Japan + World**: ILC 250--->500--->1000 GeV

Obecnie nie ma co liczyć na fundusze na nowe projekty! Może będzie lepiej po 2020?

Strategia europejska udziału w projektach globalnych

Na rynku:

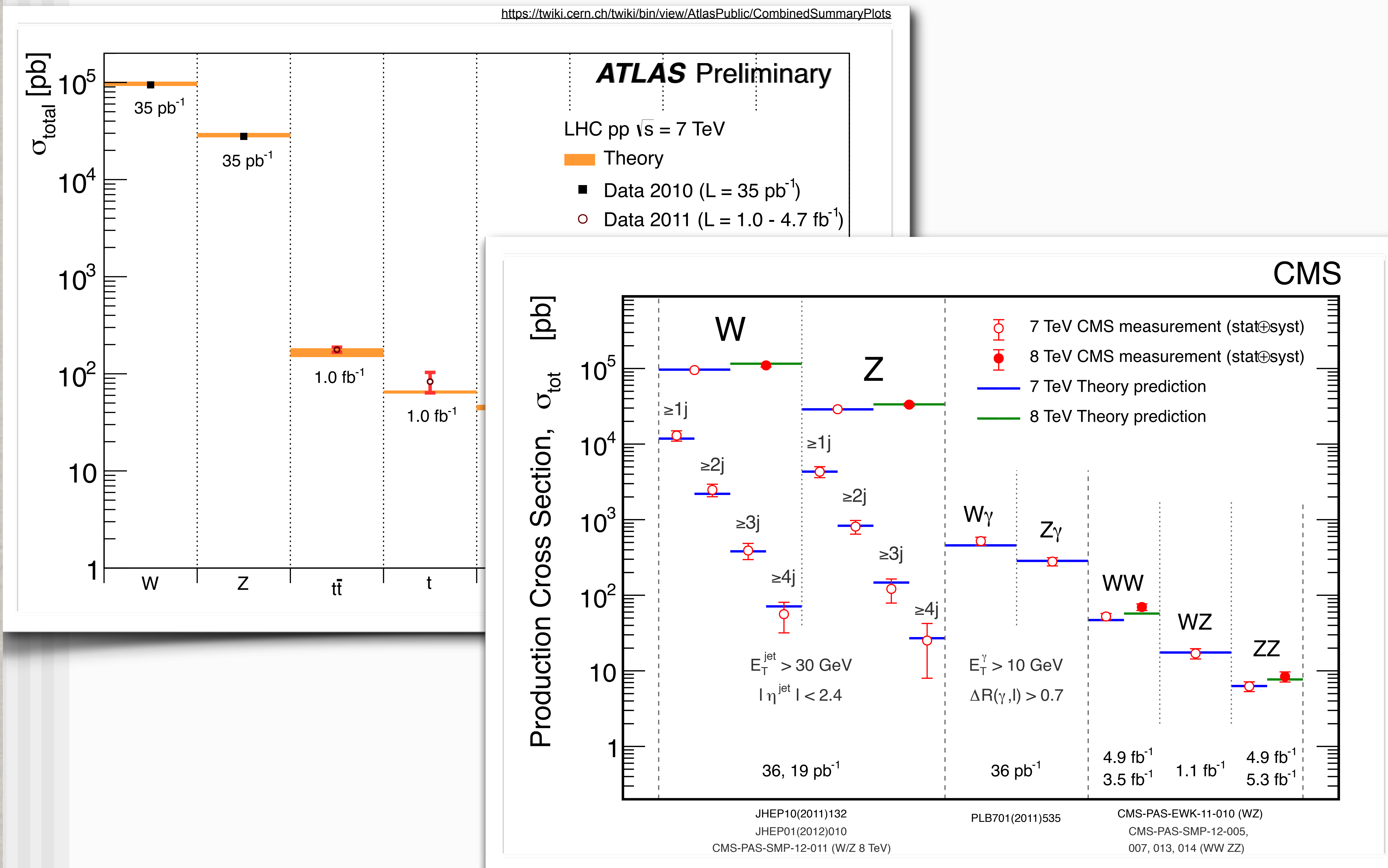
- **pp**: LHC, HL-LHC (14 TeV, $5.10^{34}/cm^2.s$), HE-LHC (26-33 TeV)
- **Higgs factories e^+e^-** (liniowe i kołowe), SAPHIRE ($\gamma\gamma$), Zderzacz Mionowy
- **Nowe źródła neutrin**
- **Zderzacz Mionowy**

Wielkie projekty globalne o różnej skali trudności i kosztów.

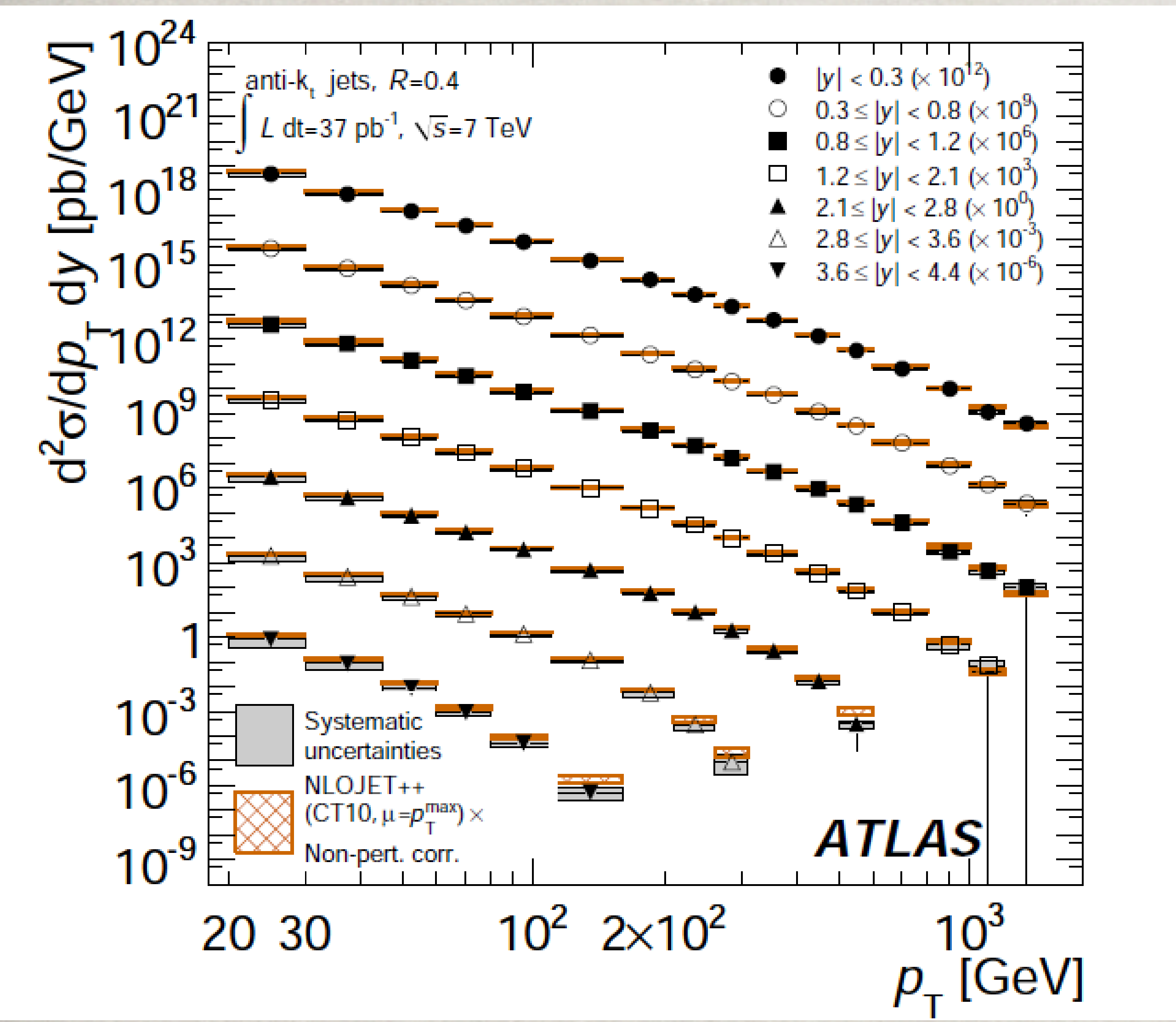
M. in. będą zapewne wymagały daleko idących zmian w prawie krajów- gospodarzy.

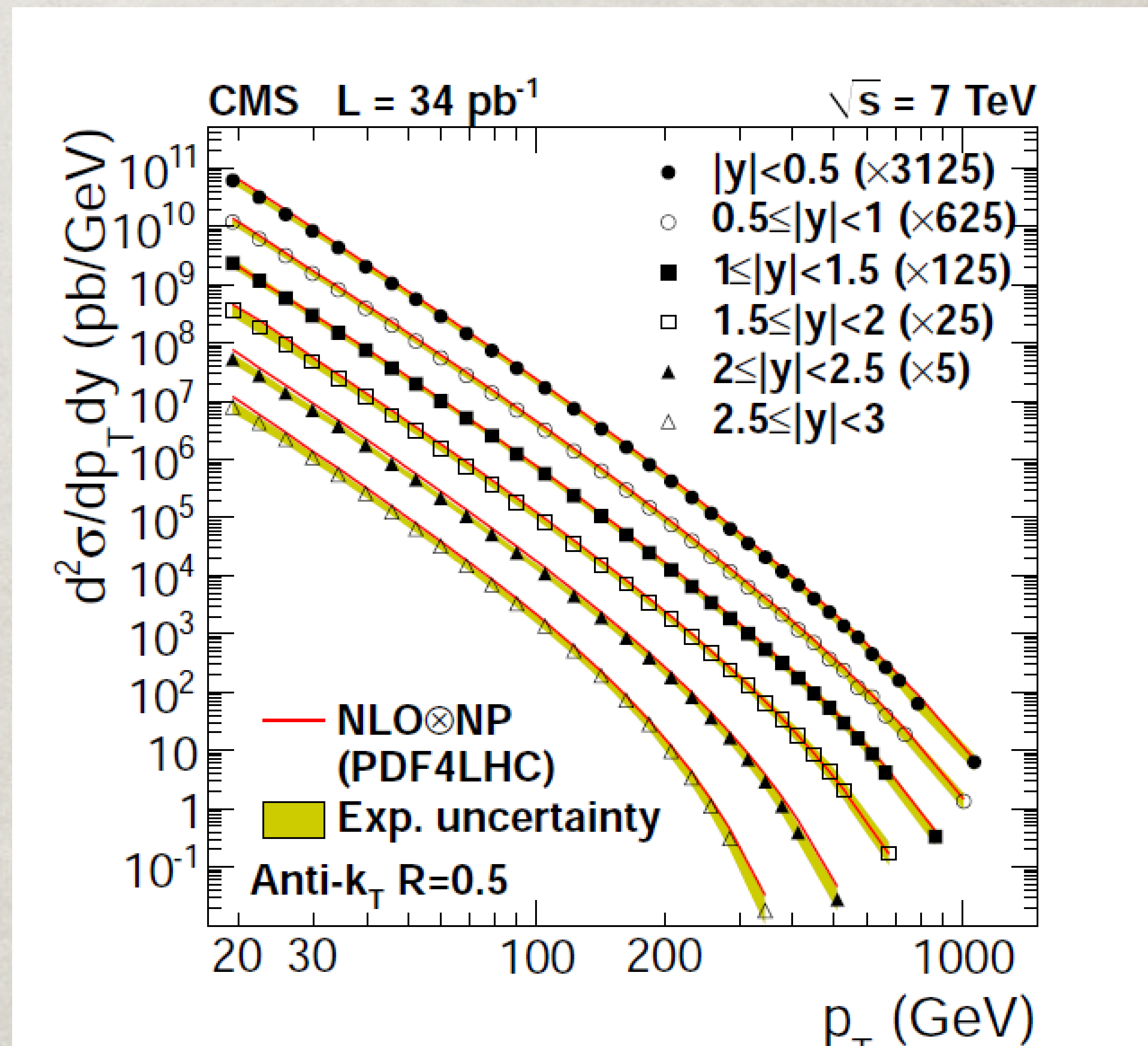
Potrzeba ustalenia ram udziału Europy w projektach globalnych:

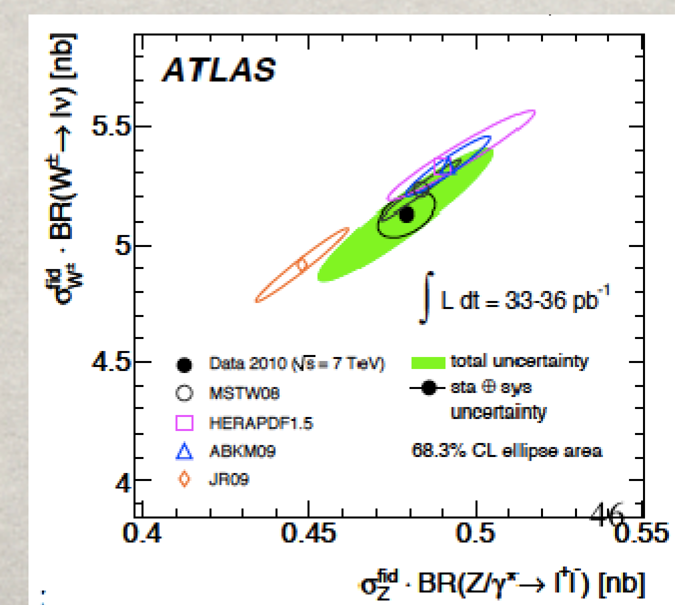
Standard Model Physics at the LHC



QCD rules at the LHC

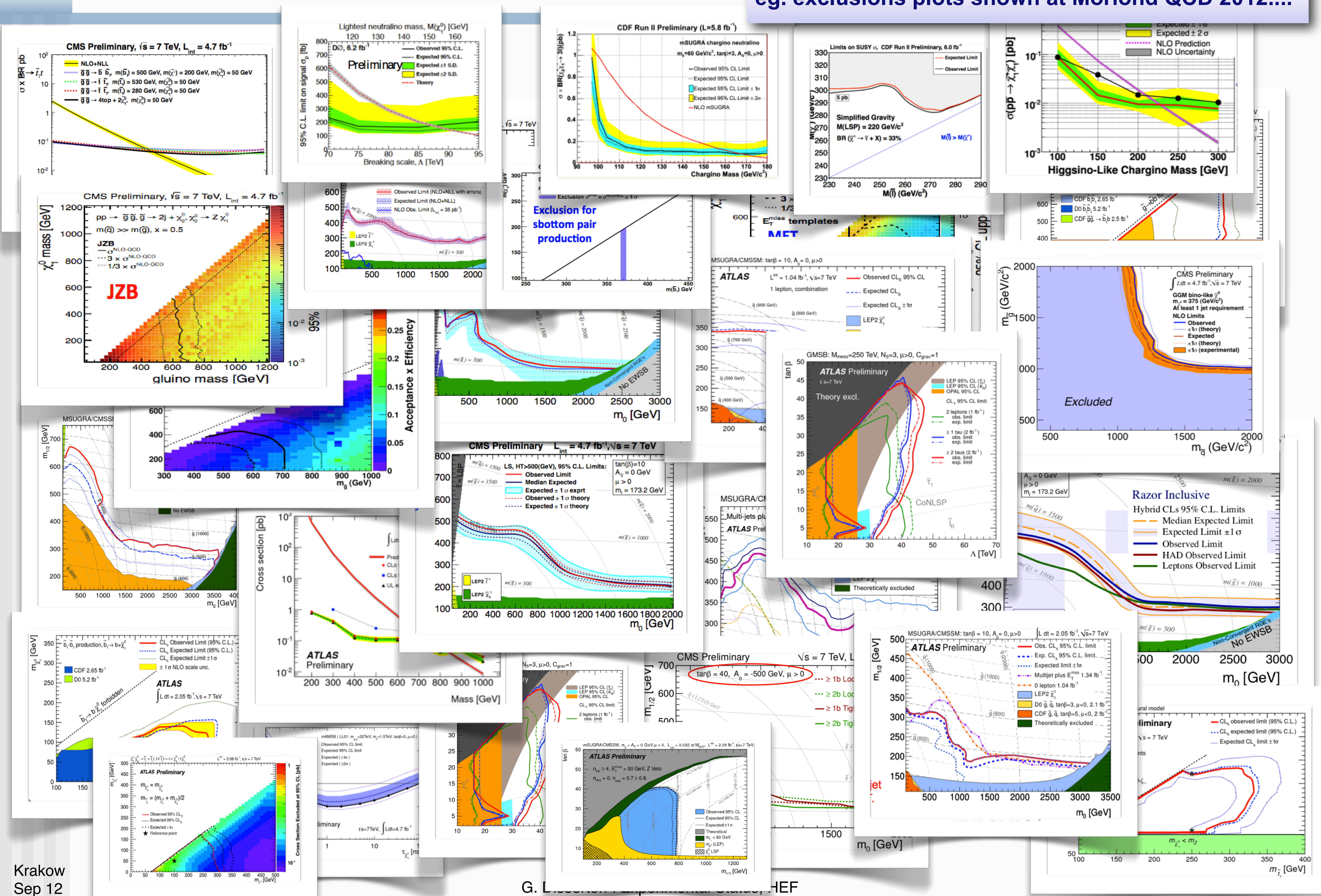






We have searched....

eg. exclusions plots shown at Moriond QCD 2012....



Yoshi Kuno, posumowanie Flavour Physics w Erice

Summary

- There has been substantial recent progress in flavour physics since 2006.
  - B factories (both Belle and BaBar), high PT physics (CDF, D0, ATLAS and CMS) and LHCb
  - NA62 for kaons, and MEG for muon CLFV.
- The success of the SM in flavour physics excludes new physics sources in ther flavour breaking sector at the TeV energy scale.
- With high intensity/luminosity facilities, future experiments would find deviations from the SM, and hints for new physics.
  - The key approach is to push forward the precision in the cleanest observables.
- Flavour physics is complementary to high-energy/high-PT physics, and also complementary amongst themselves.
- Flavour physics is required to understand new physics beyond the SM.

JKr: Krótkie prywatne podsumowanie

- Brak sygnałów Nowej Fizyki (BSM) jest deprymujący. Może potrzebujemy trochę więcej danych (**10**× **?, 100**×**, do 2021?, do 2030?**)
- Jeżeli do 2021 nie odkryjemy sygnałów NF pozostaje „tylko” **fizyka precyzyjnych pomiarów Higgsa, macierzy PMNS, macierzy CKM i fizyka zapachu, oraz badanie QCD** (w tym HI).
- Jest to fizyka trudna ale **pewna** (uda nam się zwiększyć dokładność), pod warunkiem dostępności **następnej** generacji akceleratorów. Czy zdobędziemy na to finansowanie?
- Obecnie dyskutowane strategie opierają się właśnie na jej realizacji.

Zderzacze pp-LHC

- Fabryki Higgsa

$$V(\Phi) = -\mu^2\Phi^\dagger\Phi + \lambda(\Phi^\dagger\Phi)^2 + Y^{ij}\Psi_L^i\Psi_R^j\Phi + \frac{g_{ij}}{\Lambda}\Psi_L^i\Psi_L^{jT}\Phi\Phi^T;$$

- Laboratorium Spontanicznego Łamania Symetrii poprzez fizykę zapachu

pp Collider- Time scale

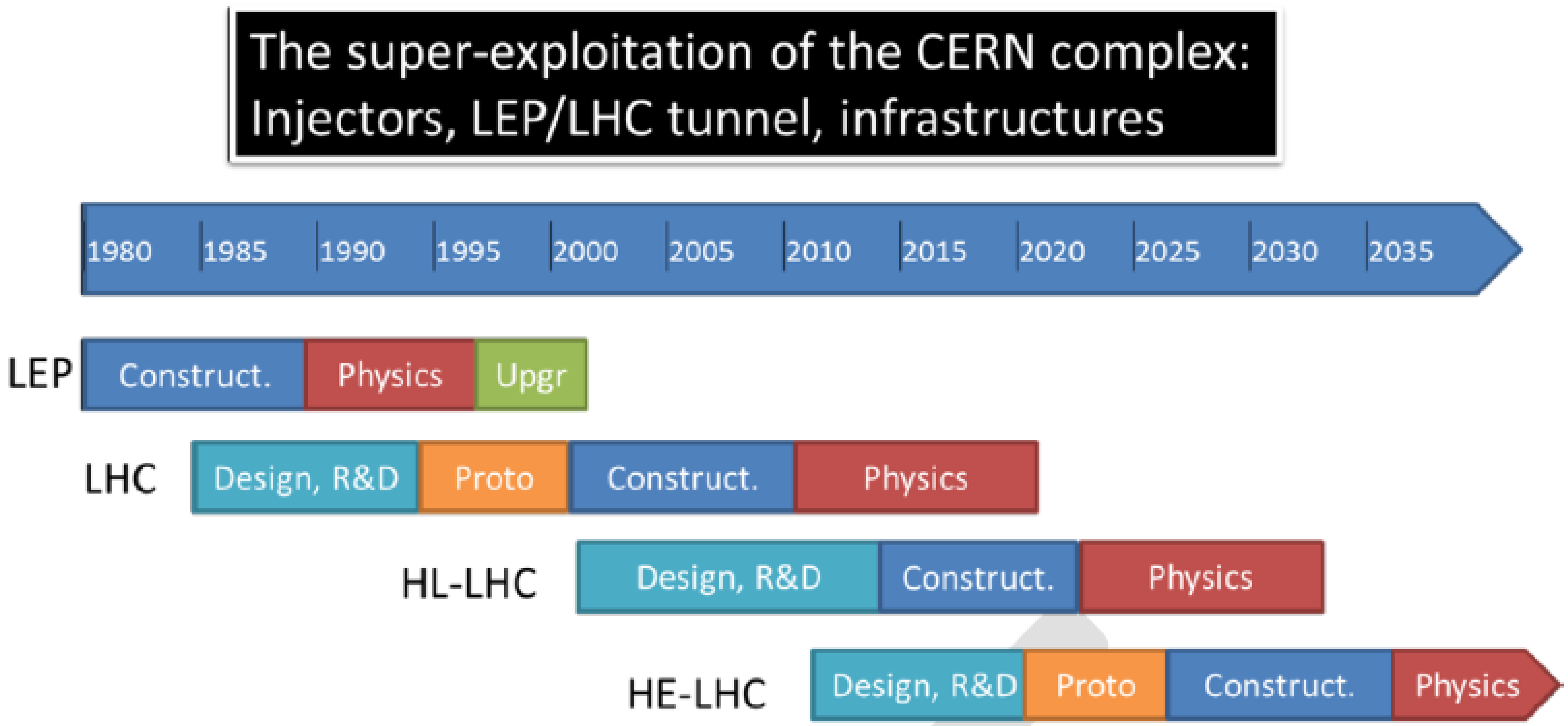


Figure 10. The possible timeline of LHC and its upgrades.

Proton-proton colliders

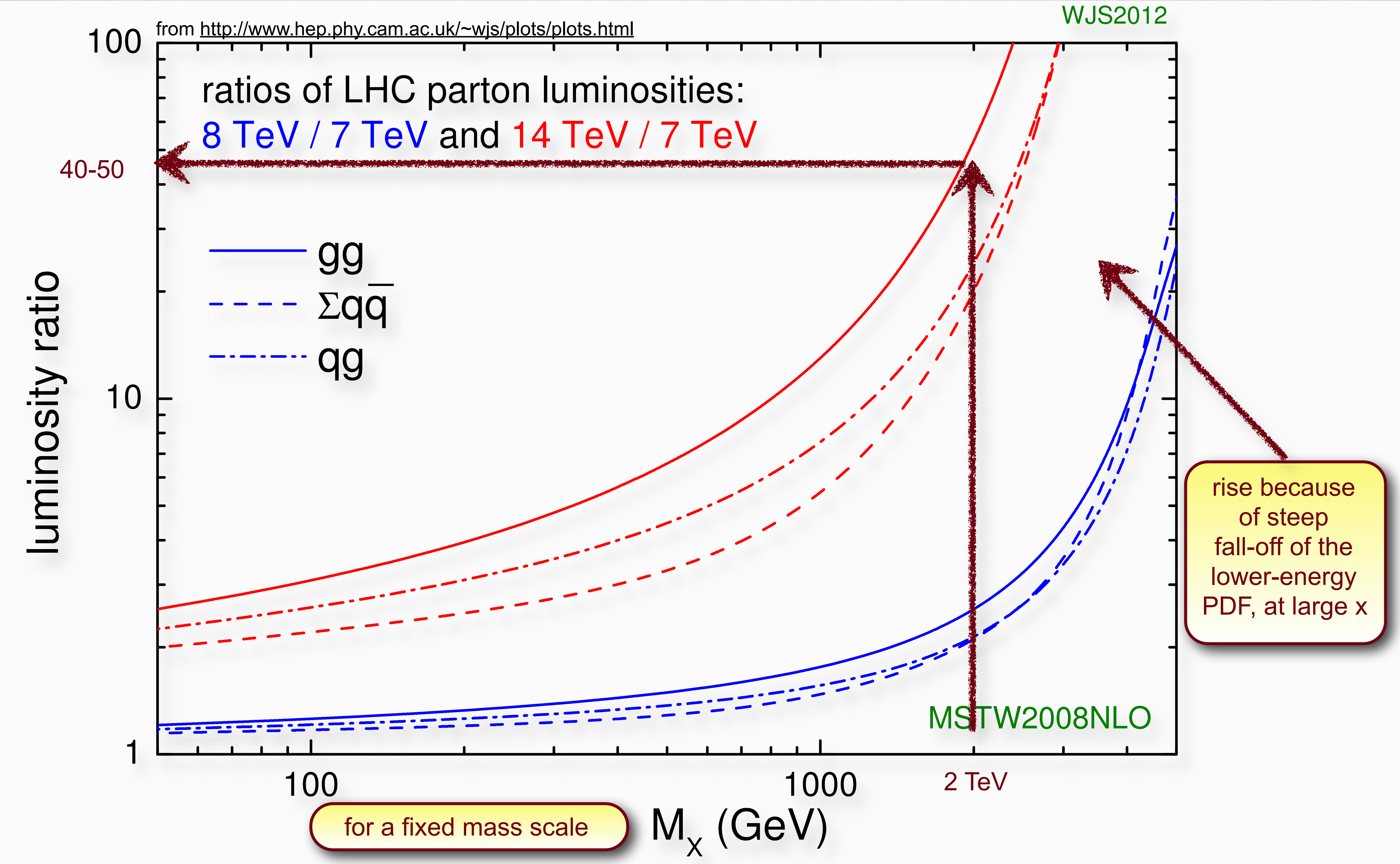
Facility	Years	Ecm [TeV]	Luminosity [10^{34} $cm^{-2}s^{-2}$]	int Luminosity [fb^{-1}]	Comments
nominal LHC	2014-2021	14	1-2	300	
HL-LHC	2023-2030	14	5	3000	luminosity levelling
HE-LHC	>2035	26-33	>2	100-300 / yr	dipole fields 16-20 T
V-LHC		42-100			new 80 km tunnel

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

$Sp\bar{p}S$ ➔ Tevatron ➔ LHC
0.63 ➔ 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

Parton luminosities 8/7 and 14/7 TeV



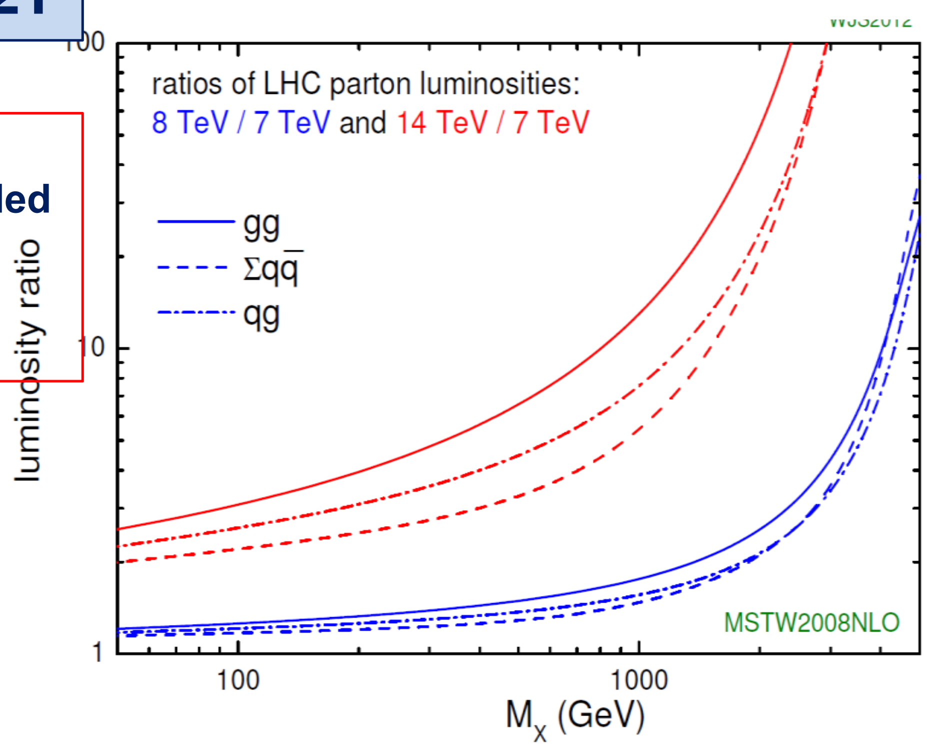
LHC do 2021?

Physics @ LHC: design performance

Design: $\sqrt{s}$ ~14 TeV, L=10^{34} $cm^{-2}s^{-1}$ and 300 fb^{-1} ~ 2021

CAVEAT: all the extrapolations (including HL-LHC) are based on:

- the present detector performance → substantial detector upgrade needed
- the current analyses methodology → might improve
- quoted results are per experiment
- ATLAS and CMS results are consistent



SUSY searches exclusion limits:

- generic squarks and gluinos up to 2.7 TeV
- direct stop/sbottom production up to 1.2 TeV.
- EWKinos up to about 800 GeV.

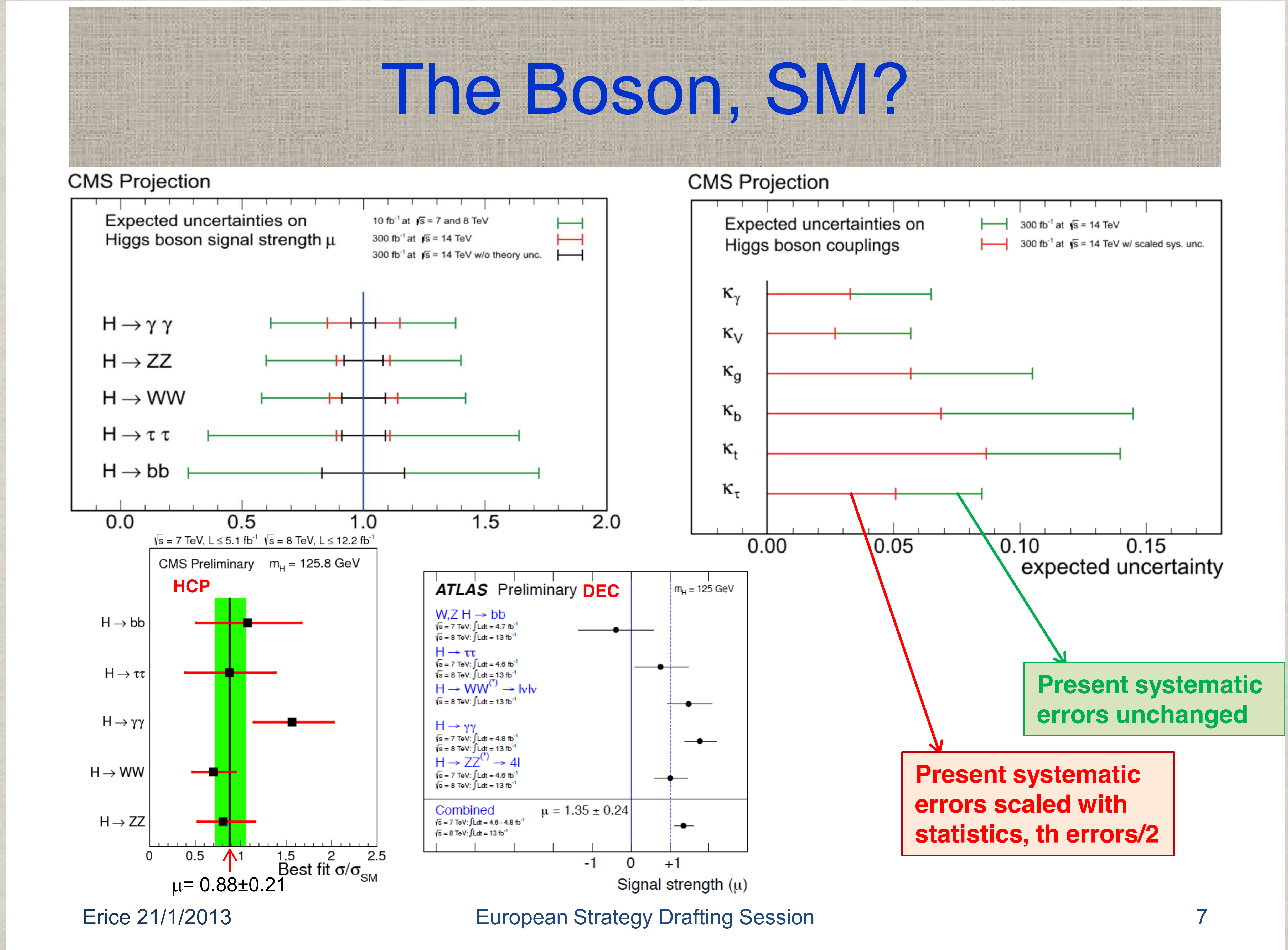
EXOTIC objects esclusion lmits:

- heavy narrow resonances Z' like will be probed to 6.5 TeV

The Higgs:

- Mass knowledge 100 MeV
- Quantum numbers determination @> 5σ
- CP nature clarified (5σ exclusion of CP-violating state)
- Signal strenght SM compatibility 5-10%
- Deviations from SM couplings 5-15%

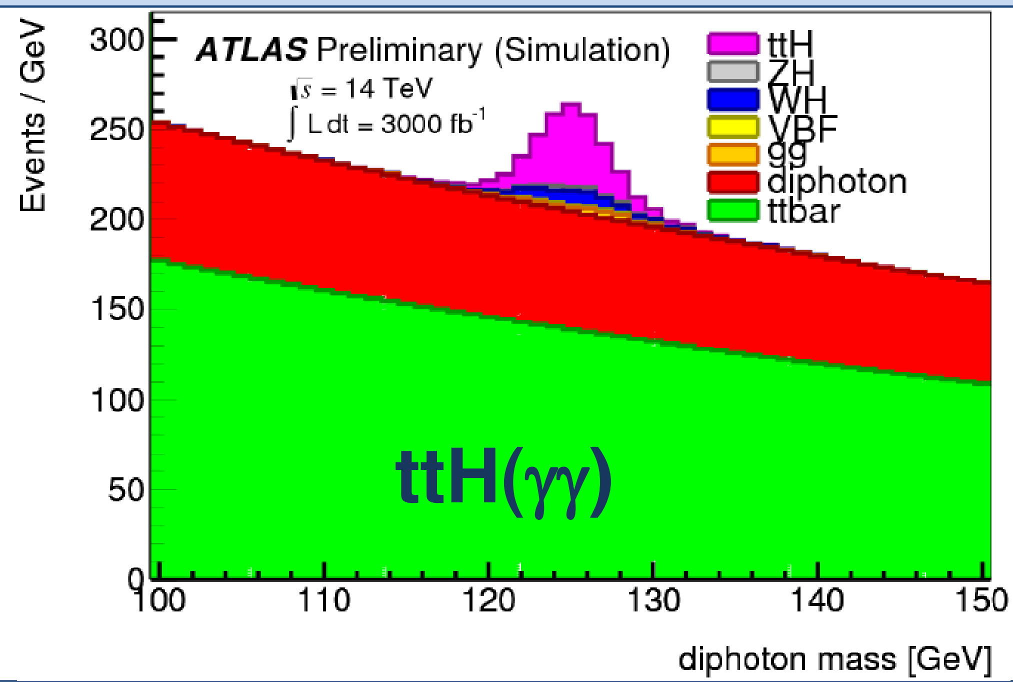
Higgs do 2021? symulacje CMS

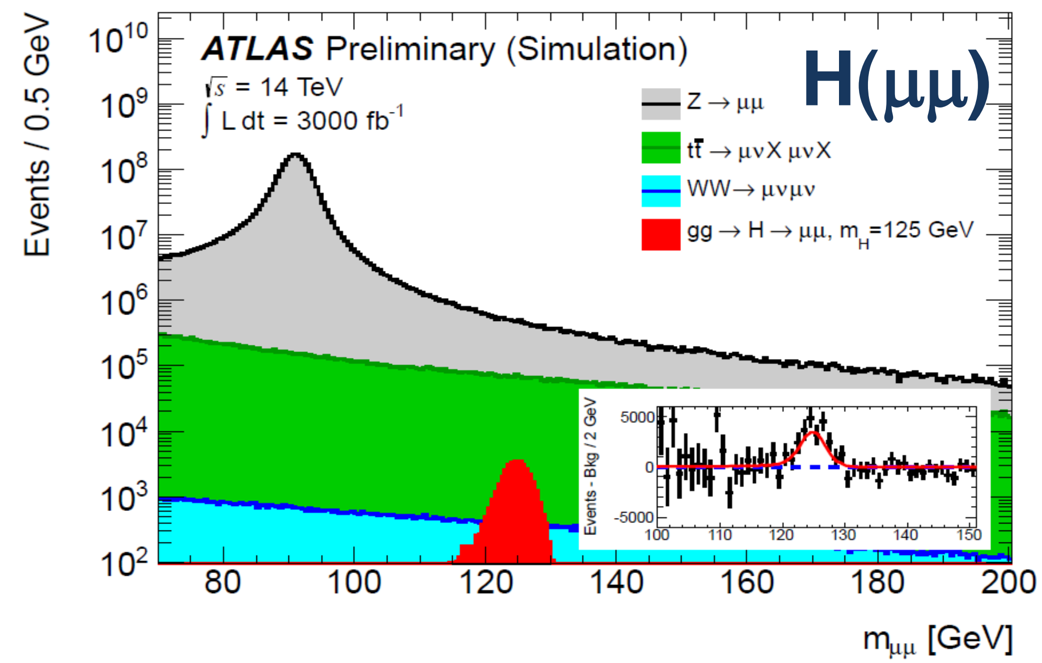


HE-LHC do 2031, symulacje ATLAS

Physics @ LHC: high luminosity

HL-LHC: √s ~14 TeV, L=5x10^{34} cm^{-2}s^{-1} and 3000 fb^{-1} ~ 2030



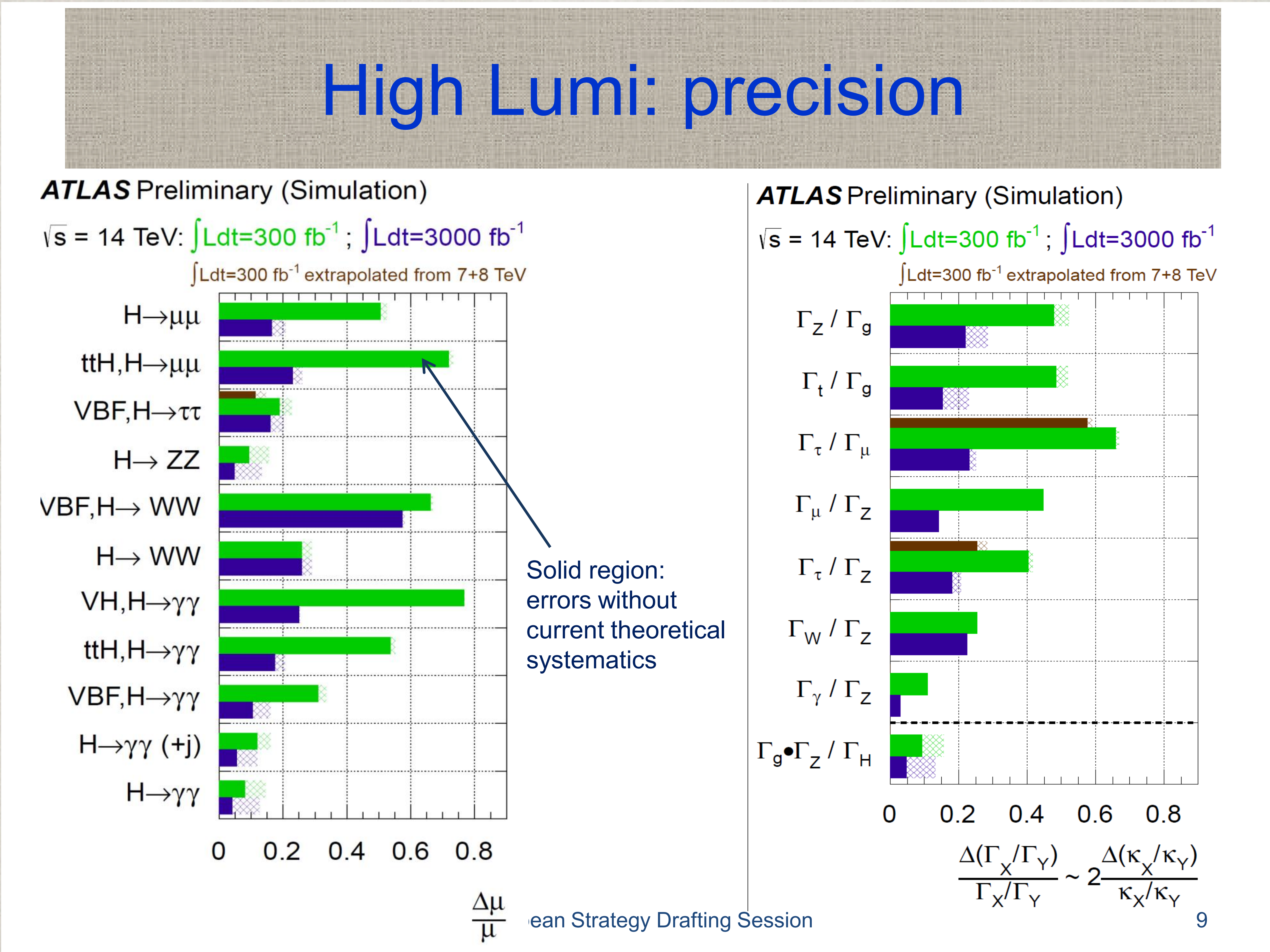


CMS ESTIMATE

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

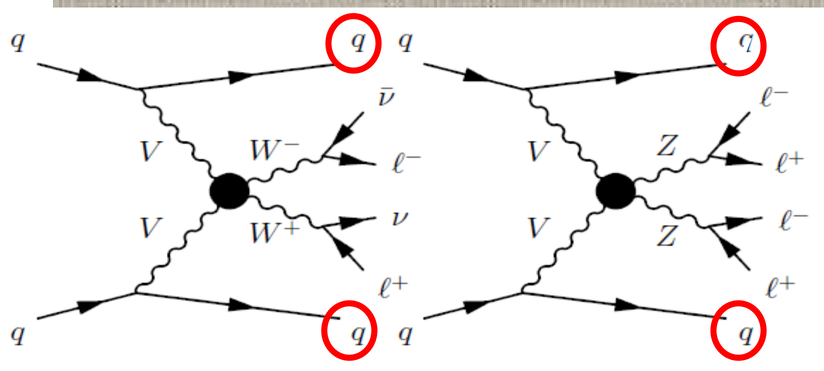
Profit from statistics:
- **rare H production channels**
- **rare H decay channels**
- **H couplings**
- **Higgs self coupling (HH detection)**
- **VBS: dynamics of EWSB (is it SM?)**
- **New physics with suppressed couplings**

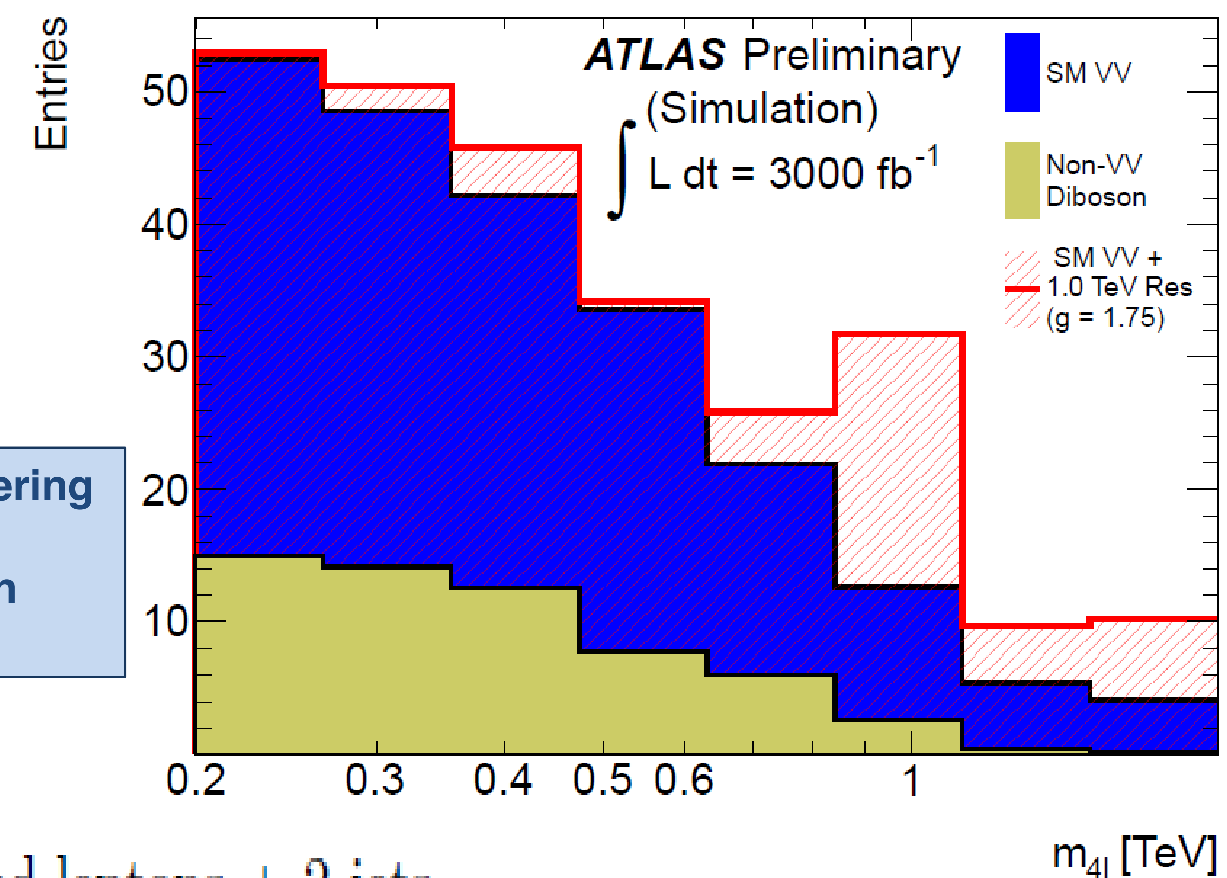
HE-LHC do 2030, symulacje ATLAS



HE-LHC do 2030, symulacje ATLAS

Vector Boson Scattering





Is unitarity in longitudinal Vector Boson Scattering restored as expected by a SM Higgs?
e. g. **In composite Higgs models resonances in M(VV) may appear...**

$$ZZ + 2\,\text{jets} \rightarrow 4\ \text{charged leptons} + 2\ \text{jets},$$

Model	$300\ \text{fb}^{-1}$	$3000\ \text{fb}^{-1}$
$m_{\text{resonance}} = 500\ \text{GeV},\ g = 1.0$	$2.4\ \sigma$	$7.5\ \sigma$
$m_{\text{resonance}} = 1\ \text{TeV},\ g = 1.75$	$1.7\ \sigma$	$5.5\ \sigma$
$m_{\text{resonance}} = 1\ \text{TeV},\ g = 2.5$	$3.0\ \sigma$	$9.4\ \sigma$

Improved sensitivity with 3000 fb^{-1} for 3 different models (ATLAS).

Erice 21/1/2013 European Strategy Drafting Session 10

Kluczowe dla zrozumienia m.in. samooddziaływania higgsów

Podsumowanie z Krakowa
High Energy Frontier

<u>High Energy Frontier</u>

- 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

Podsumowanie HE Frontier Erice

Table 2.1: Overview of proton-proton colliders.

pp colliders

Facility	Years	E_{cm} [TeV]	Luminosity [$10^{34}cm^{-2}s^{-1}$]	Int. luminosity [fb^{-1}]	Comments
Design LHC	2014–21	14	1–2	300	
HL-LHC	2024–30	14	5	3000	luminosity levelling
HE-LHC	>2035	26–33	2	100–300/yr	dipole fields 16–20 T
VHE-LHC	>2035	42–100			new 80 km tunnel

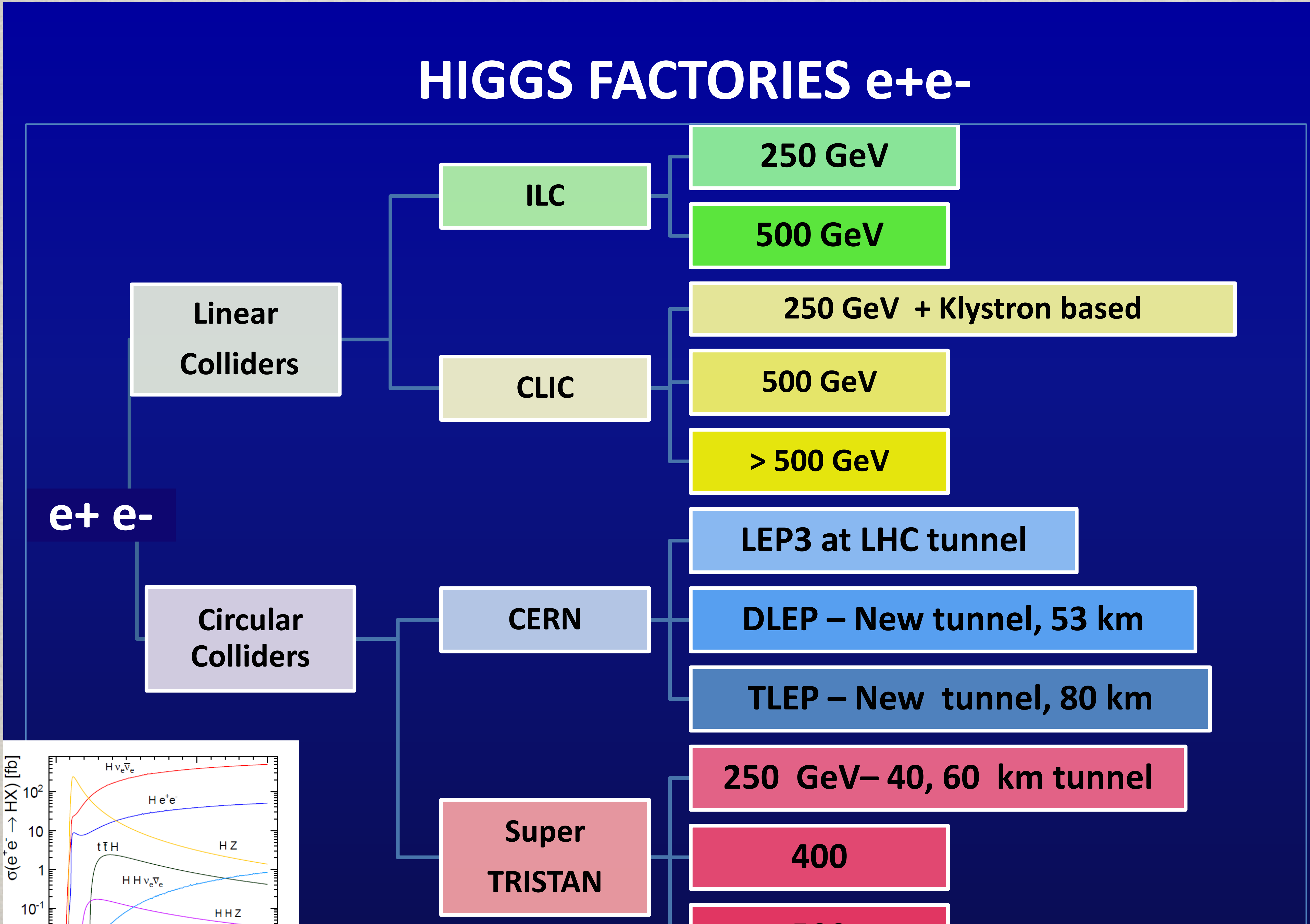
Table 2.2: Overview of electron-positron colliders (*different scenarios)

e+e- colliders

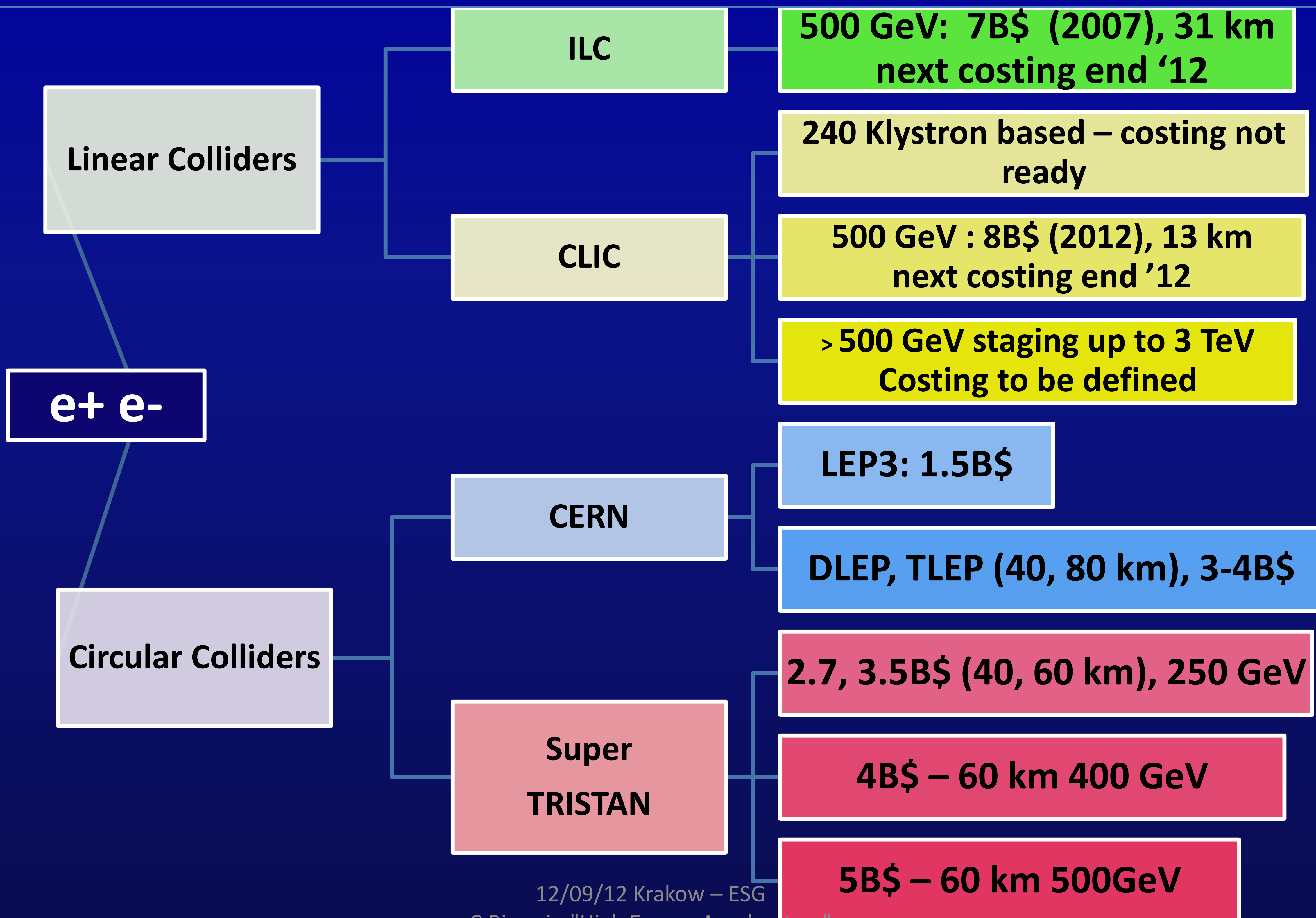
Facility	Year	E_{cm} [GeV]	Luminosity [$10^{34}cm^{-2}s^{-1}$]	Tunnel length [km]
ILC 250	<2030	250	0.75	
ILC 500		500	1.8	∼ 30
ILC 1000		1000		∼ 50
CLIC 500	>2030	500	2.3 (1.3)*	∼ 13
CLIC 1400		1400 (1500)*	3.2 (3.7)*	∼ 27
CLIC 3000		3000	5.9	∼ 48
LEP3	>2024	240	1	LEP/LHC
TLEP	>2030	240	5	80 (ring)
TLEP		350	0.65	80 (ring)

- Technical aspects in chapter 8
- eh colliders in chapter 5
- $\mu^+\mu^-$ and $\gamma\gamma$ colliders similar physics program as e^+e^- colliders

Fabryki Higgsa

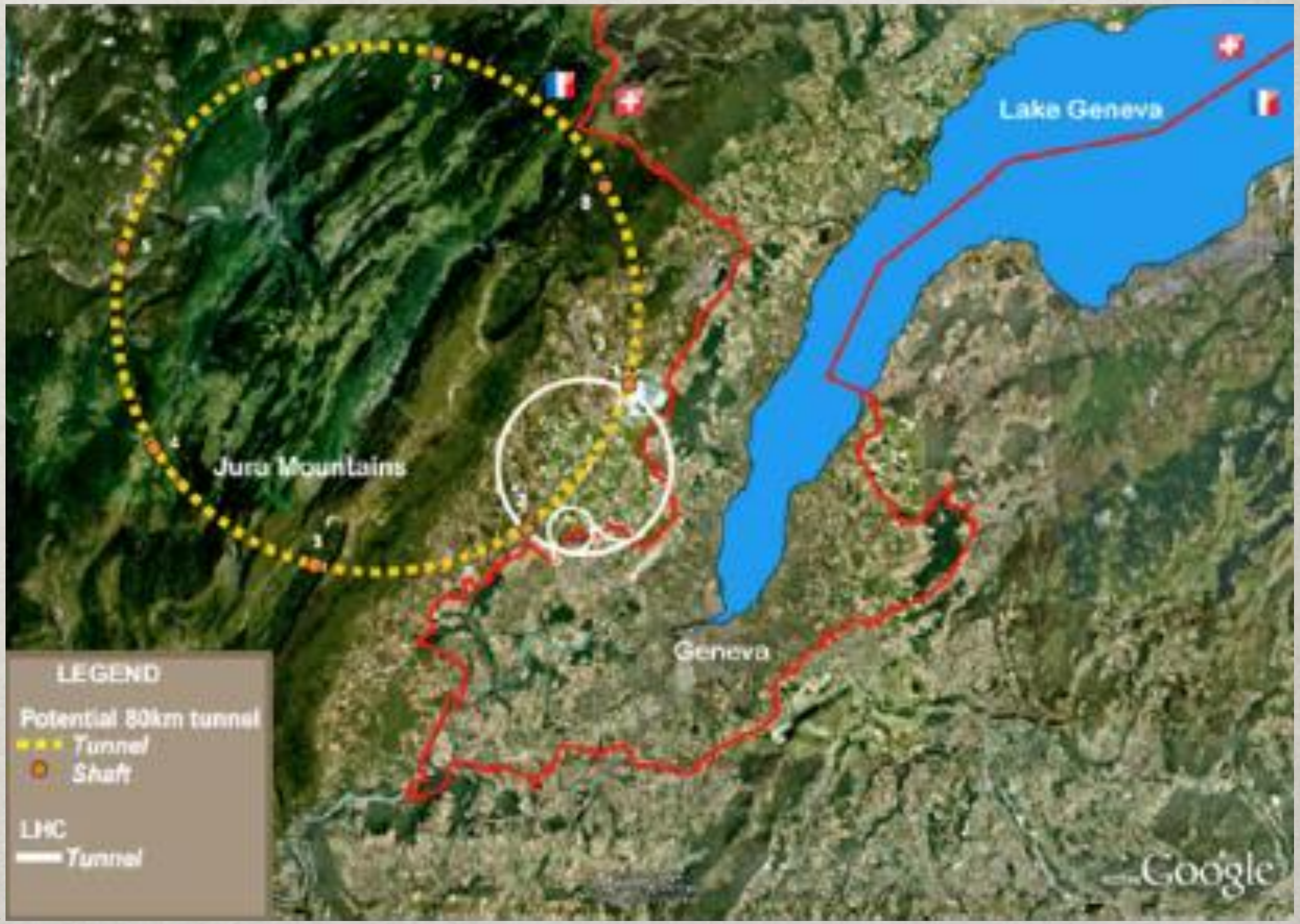

HIGGS FACTORIES e+e-
e+ e-
Linear Colliders
ILC
250 GeV
500 GeV
CLIC
250 GeV + Klystron based
500 GeV
> 500 GeV
Circular Colliders
CERN
LEP3 at LHC tunnel
DLEP – New tunnel, 53 km
TLEP – New tunnel, 80 km
Super TRISTAN
250 GeV– 40, 60 km tunnel
400
HZ
HHZ

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



Beyond HE-LHC

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)



„QCD” colliders

„QCD" accelerators, including LHeC

The following points could be considered in the discussion on the strategy update:

- For the upgrade of the LHC Pb beam programme after LS2, luminosities of order $6 \times 10^{27}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ are essential to reach the proposed physics goals.

- Some of the possible LHC measurements, which are crucial for understanding of strong interactions, require dedicated low-pileup running. The resulting loss in the total luminosity is expected to be small.

- Dedicated analysis, taking into account all relevant experimental and theoretical aspects, should be performed to give quantitative estimates of the PDF accuracy which can be ultimately reached with the LHC data. This is required for comparison with LHeC capabilities, against the background of the exact requirements of HL-LHC for PDF uncertainties, which should be established as well.

- The LHeC project offers, in addition to the PDF studies motivated by LHC needs, a very rich and diverse physics programme by itself. If the project is to be considered as one of the future collider options, dedicated effort towards the preparation of Technical Design Report is needed.

- The fixed-target programme at CERN gives a very valuable contribution to research in strong interaction physics. It offers unique measurement possibilities which can not be covered at other facilities.

Neutrino physics and the US program

No LB neutrino expt. in Europe

- Erice: Paula Errola for Finland:

  - Ministeries of Education and Culture, Employment and Economy, and Transport and Communication 21 Dec 2012: **"Finland cannot commit herself to host Laguna, mainly because of the very heavy costs involved and a limited national scientific community in the country in this area."**
  - **"We have identified the need to upgrade our scientific infrastructures as one of the most urgent science policy actions, and we are painfully aware that in the coming years we will hardly be able to finance even the most highly prioritized infrastructures due to stringent public budgets ahead of us."**
  - Decision based on an analysis made by the involved ministries, Academy of Finland, and Science and Innovation Agency TEKES. Input from the involved scientific communities.

Latest news from the US
Erice: Mel Shochet

Energy Frontier

- **LHC is the US focus**
  - **Involvement is planned in both detector & accelerator upgrades**
  - **To get the needed funding:**
    - **HL-LHC needs strong endorsement from ESG**
    - **It would help if there were words about the importance or need of US technology, e.g. NbSn magnets.**
- **ILC in Japan**
  - **DOE wants to be supportive.**
  - **Current schedule is difficult because of the overlap with HL-LHC and LBNE.**
  - **Will be considered by the next HEPAP P5 subpanel following this summer's community-wide Snowmass meeting.**

Cosmic Frontier

- **Dark matter, dark energy, and cosmic rays are integral parts of the US particle physics program.**
  - **dark matter technology down-select after next round of experiments**
  - **dark energy: DES, LSST**
  - **cosmic rays: Fermi, Veritas, HAWK**

US news contd.

Intensity Frontier

- US strategy is to have the world-leading program at the intensity frontier.
- Proton source
  - Beam power from the Main Injector has been doubled to 700 kW for NOνA
  - 8 GeV power is also being increased for the short-baseline ν and μ programs
  - In the longer term, Project X
    - another x3 from Main Injector to LBNE
    - another x10 at lower energy (for ν, μ, and K)

- LBNE is central to the US Intensity Frontier plan.
  - FNAL → Sanford Underground Research Facility (SURF) is a near optimal baseline (1300 km)
  - 700 kW → 2 MW
  - phased plan
  - Phase 1
    - 10 kt LAr detector at the surface
    - CD1 achieved in the past month
      - approves conceptual design
      - releases the funding to complete the design
    - beamline construction to start in 2015
    - full experimental facility completion early in the next decade
  - Significant opportunity for new collaborators to expand the scientific scope.

  "We welcome the opportunity to develop a full partnership on LBNE with our European colleagues."

Approximate costs in European accounting

(from Jim Strait, LBNE Project Manager)

- Putting the detector underground — 55 MEuros
- Doubling the detector mass to 20 kt — 55 MEuros