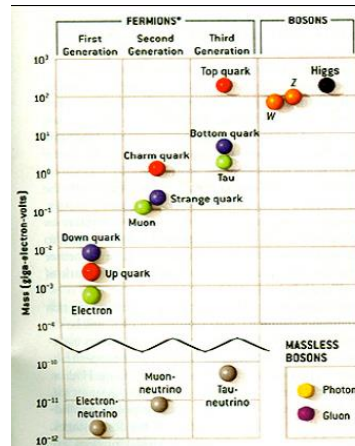
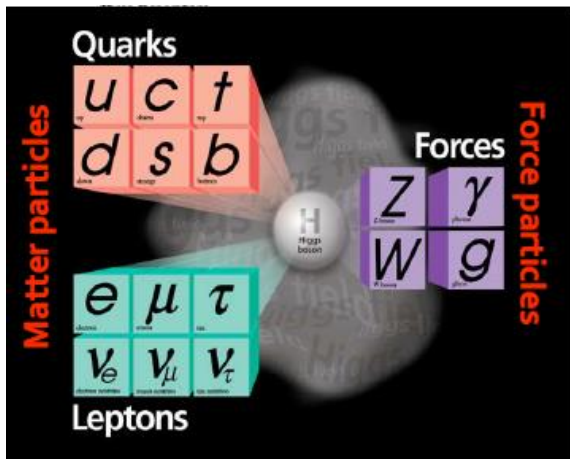


Prospectives en Physique des Particules auprès des accélérateurs

Roy Aleksan, Marc Besançon,
Laurent Chevalier, Paul Colas,
Claude Guyot, Laurent Schoeffel,
Philippe Schwemling, Maxim Titov

Etat actuel du Modèle Standard



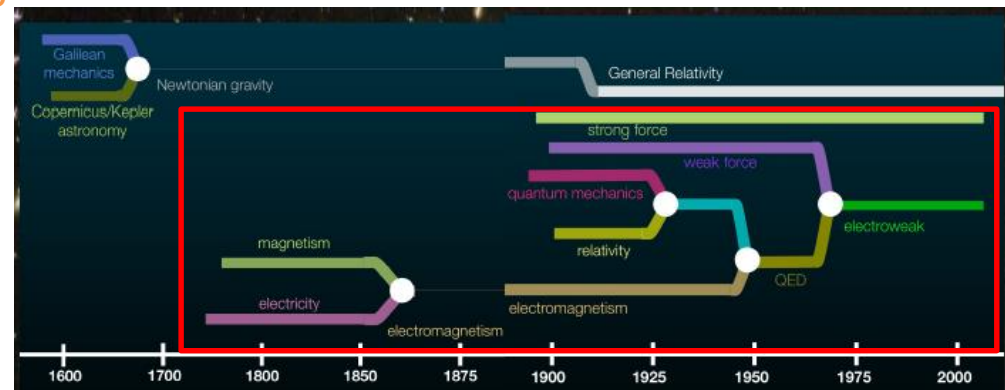
Classe les particules élémentaires et unifie leurs interactions

- Trois familles de particules de matière: **quarks** et **leptons**
- particules vecteurs de force : **bosons de jauge**
- le **boson de Higgs**

Si la particule découverte en 2012 au LHC est bien le Higgs, le Modèle Standard est « complet »

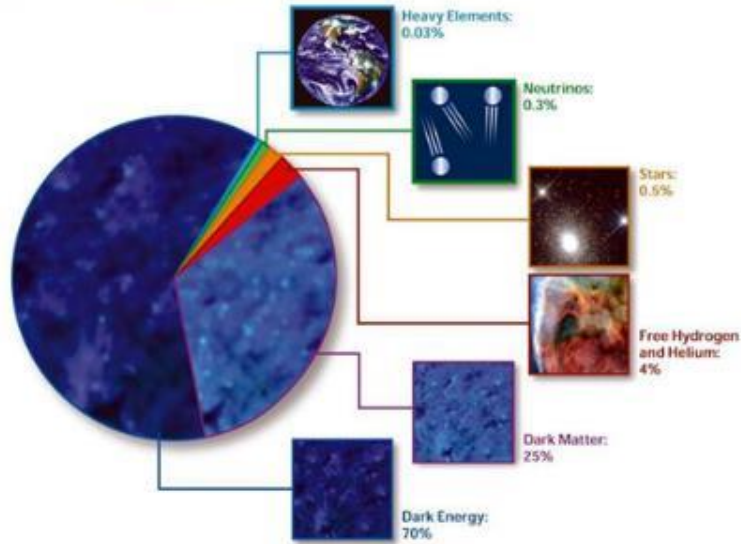
De multiples questions restent ouvertes

- Nature des neutrinos : Dirac ou Majorana ?
- Masse des neutrinos étonnamment faible
- Echelle de masse des particules
- Pourquoi trois générations ?
- Origine du potentiel de Higgs ?
- « Naturalité » de l'échelle électrofaible
- Problème CP fort
- Unification des interactions
- Physique à l'échelle de la gravité quantique



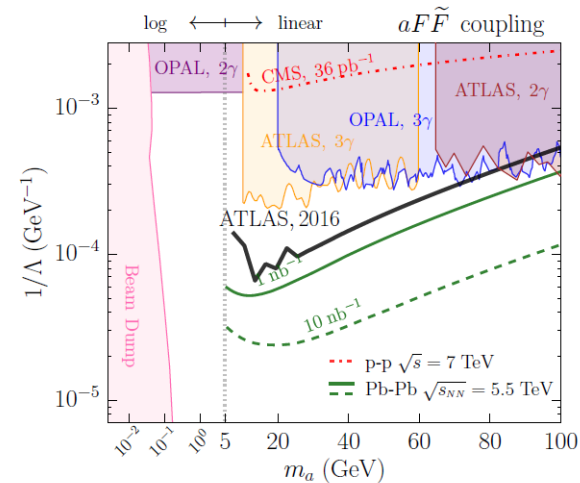
physique des particules et cosmologie

COMPOSITION OF THE COSMOS



Un exemple d'application: $\gamma\gamma \rightarrow a \rightarrow \gamma\gamma$

Pour un couplage de l'axion (a , m_a) au champ EM de la forme $\frac{1}{\Lambda} a F \tilde{F}$ (arXiv:1709.07110).



L. Schoeffel

18

Certaines questions ouvertes en cosmologie ont leur contrepartie en physique des particules

- Asymétrie baryonique de l'univers (matière/antimatière)
- Matière noire : 25% de la densité de l'Univers est de la matière non baryonique
- Energie noire : 70% de la densité de l'Univers est de nature inconnue
- Origine de l'inflation primordiale ?

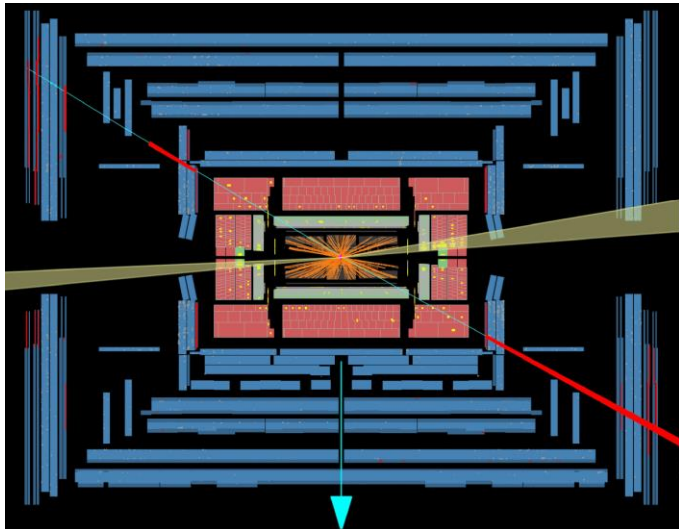
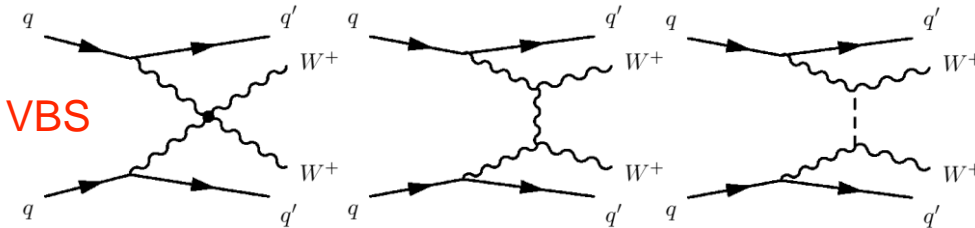
DIFFUSION DE BOSONS VECTEURS

Pour sonder le secteur de brisure de la symétrie électrofaible, il faut :

1. mesurer les **couplages du boson de Higgs** avec précision
2. étudier les **interactions entre bosons vecteurs** à haute énergie (VBS)
 - comment faire ?

Exemple : rechercher la production de paires de bosons W

- de même signe (*pour combattre le bruit de fond WW*)
- accompagnés de deux jets « vers l'avant et l'arrière »

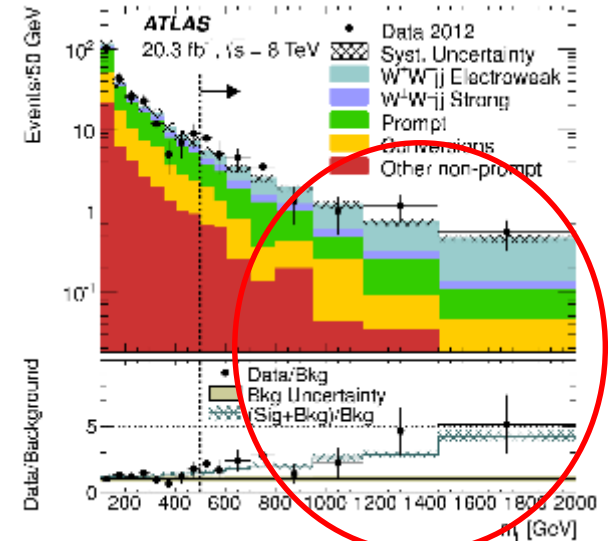


Signature expérimentale :

- deux leptons (e, μ) de même signe
- deux « jets » à bas angle

En haut à droite : distribution de la « masse invariante » des deux jets (= l'énergie de l'interaction)

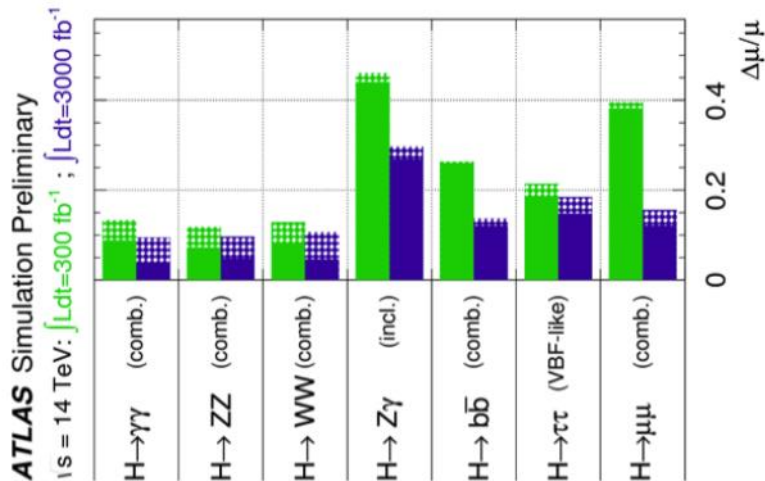
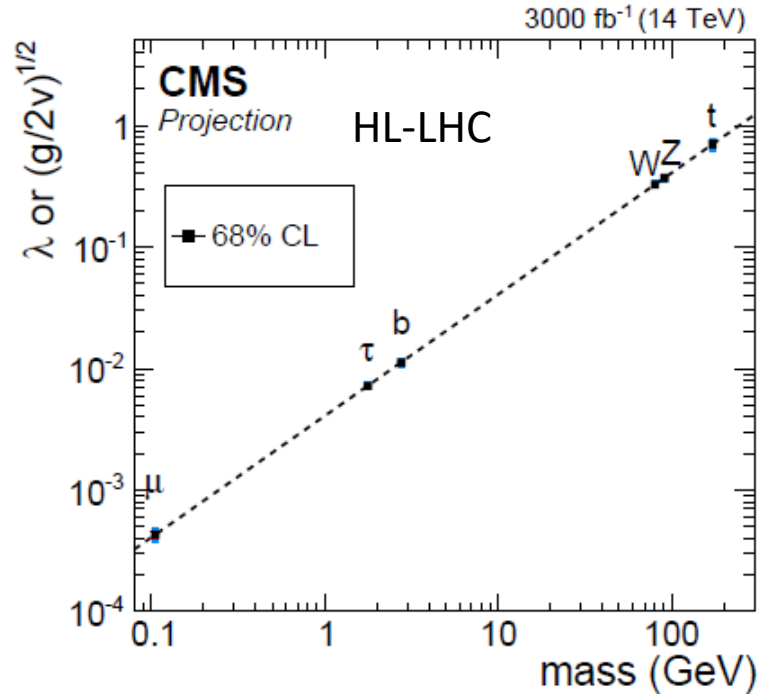
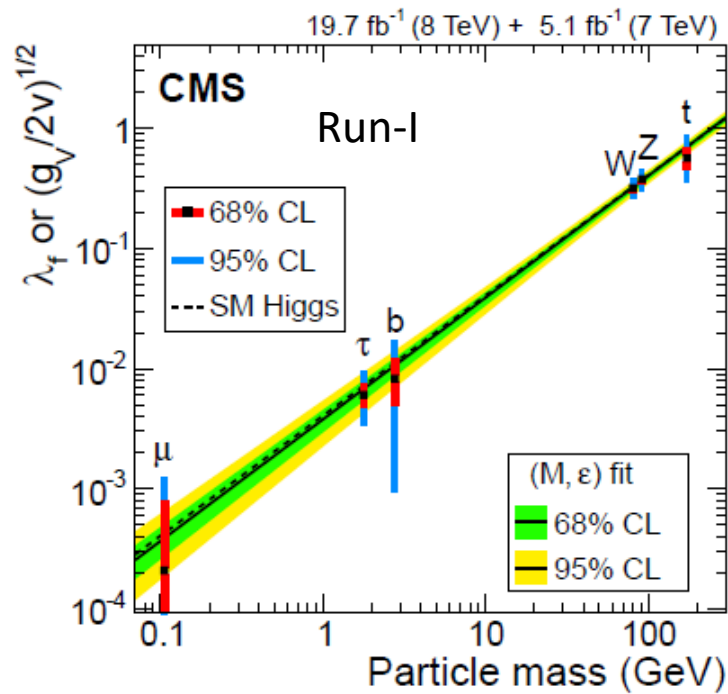
PRL 113 (2014) 141803



Atlas et CMS commencent à explorer les interaction de bosons W et Z à haute énergie

L'étude précise du secteur de brisure de la symétrie électrofaible nécessite une quantité de données que seul permet le HL-LHC

Couplages du boson de Higgs (HL-LHC)



H:

Snowmass 2013 CMS extrapolation

L (fb ⁻¹)	κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	BR _{inv}
300	[5, 7]	[4, 6]	[4, 6]	[6, 8]	[10, 13]	[14, 15]	[6, 8]	[41, 41]	[14, 18]
3000	[2, 5]	[2, 5]	[2, 4]	[3, 5]	[4, 7]	[7, 10]	[2, 5]	[10, 12]	[7, 11]

Model	κ_V	κ_b	κ_γ
Singlet Mixing	~ 6%	~ 6%	~ 6%
2HDM	~ 1%	~ 10%	~ 1%
Decoupling MSSM	~ -0.0013%	~ 1.6%	~ -0.4%
Composite	~ -3%	~ -(3-9)%	~ -9%
Top Partner	~ -2%	~ -2%	~ +1%

Gupta, Rzehak & Wells;
 Dawson et al.

Boson de Higgs : feuille de route

Run-1

Découverte du boson de Higgs à 125 GeV

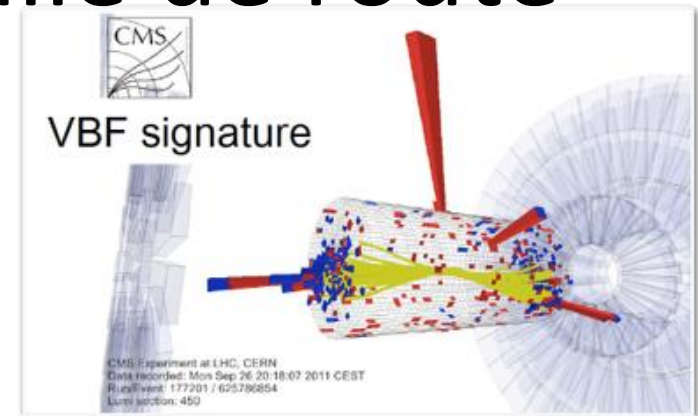
- en accord avec la théorie, avec des incertitudes qui restent importantes

Run-2

Boson de Higgs pour tester la théorie électrofaible

- observer les productions VBF et VH
- observer les canaux de désintégration $\pi\pi$ et $b\bar{b}$
- contraindre la largeur totale (études hors couche de masse)
- observer la production $t\bar{t}H$, couplage direct au top
- observer les désintégrations super rares $\mu\mu$ et $Z\gamma$, \rightarrow couplage à la deuxième famille de fermions et diagrammes à boucles (observation potentielle NP)
- mesurer *avec précision* les couplages du boson de Higgs (<5%)
- observer la production double de bosons de Higgs et l'auto-couplage du boson de Higgs

HL-LHC



Boson de Higgs comme sonde de Nouvelle Physique

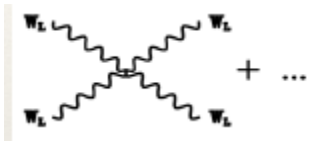
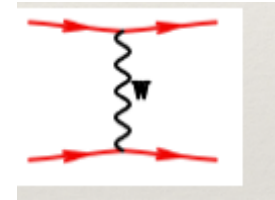
- rechercher des désintégrations interdites, par exemple « violant » la saveur leptonique
- rechercher d'autres particules partenaires dans le secteur scalaire, neutres ou chargées
- sonder l'hypothèse que le boson de Higgs soit un portail vers un « secteur caché » lié à la matière noire (largeur « invisible »)

A QUELLE ÉCHELLE REGARDER ?

Par le passé, il y a souvent eu des indications de l'échelle d'énergie suivante à laquelle « quelque chose » devait se passer :



Diagramme divergent
(Fermi 1933)
Régularisé par l'échange d'un W (découvert
en 1983 au CERN)



Processus divergent
Doit être régularisé par l'échange d'un Higgs
(A vérifier expérimentalement !) ou autre chose

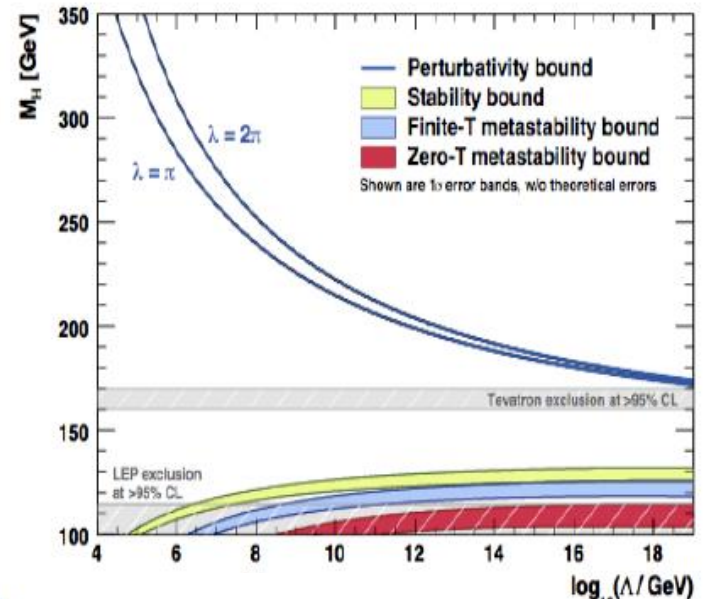


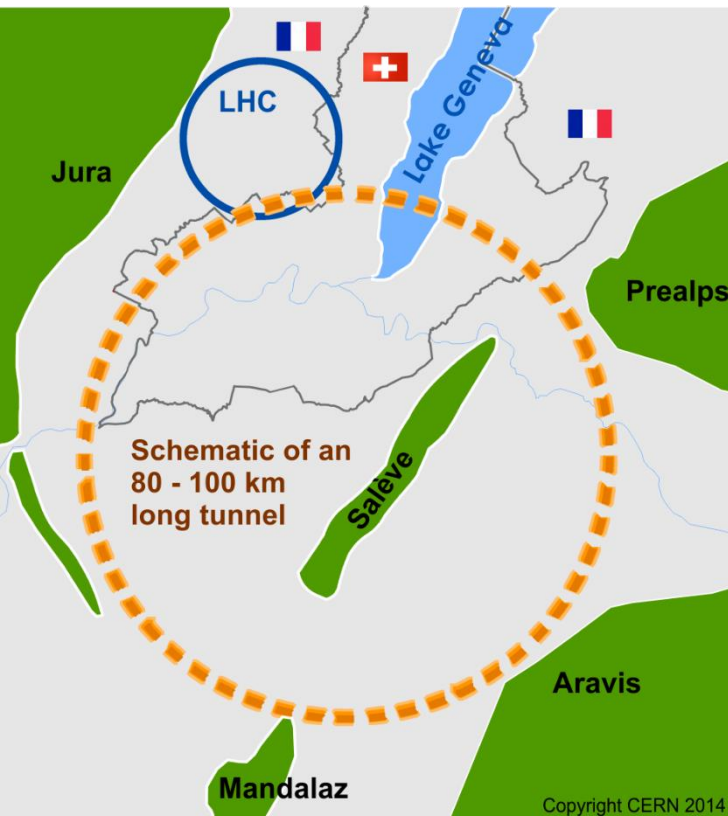
Il n'y a plus de telles indications
à exploiter à l'heure actuelle

Le Modèle Standard est-il valable
jusqu'à l'échelle de Planck ?

Il faut regarder aux échelles d'énergie
les plus élevées accessibles

FCC-hh, HE-LHC
FCC-ee, ILC (mesures de précision)





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

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

$\sim 16 \text{ T} \Rightarrow 100 \text{ TeV } pp \text{ in } 100 \text{ km}$

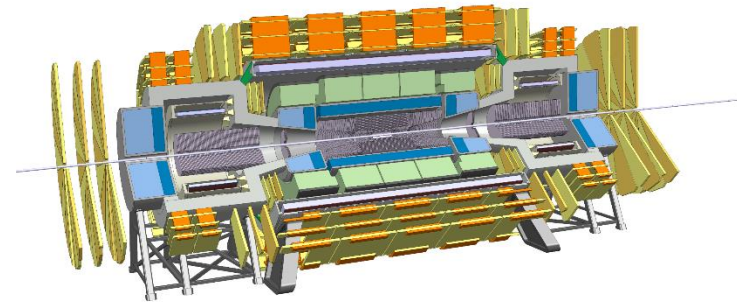
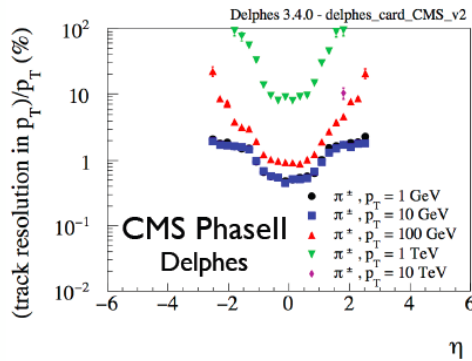
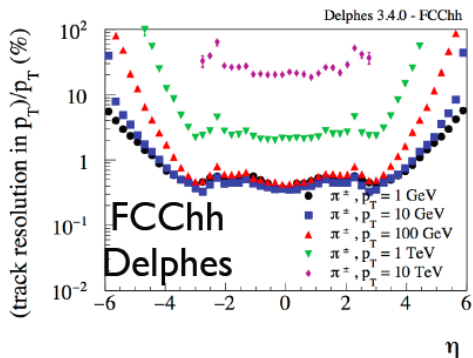
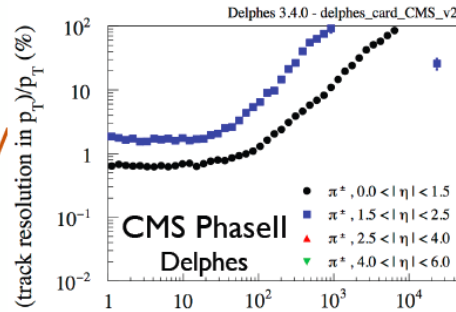
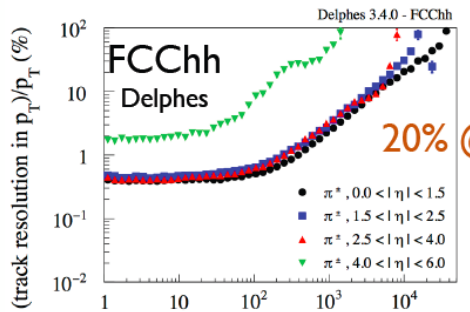
- **$\sim 100 \text{ km}$ tunnel infrastructure** in Geneva area, site specific
- **e^+e^- collider (*FCC-ee*)**, as potential first step
- **$p-e$ (*FCC-he*) option**, integration one IP, e from ERL
- **HE-LHC** with *FCC-hh* technology
- **CDR for end 2018**

Cost : 5G\$ (tunnel), 15-20 G\$ (total)

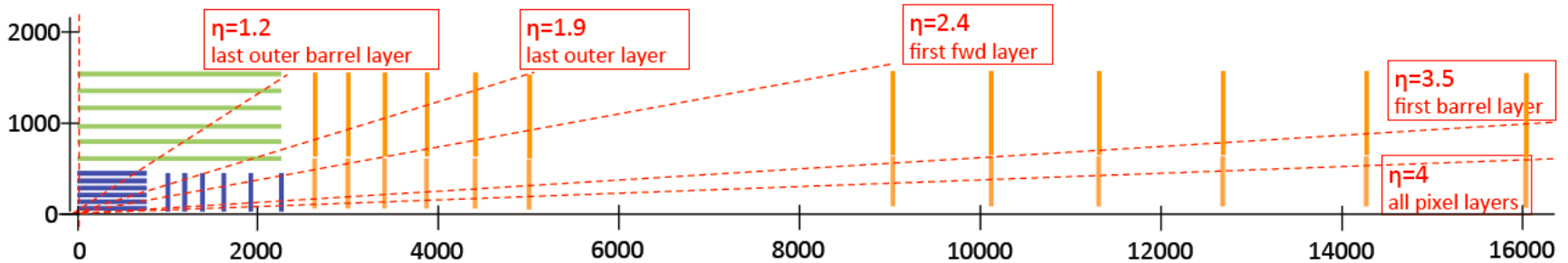
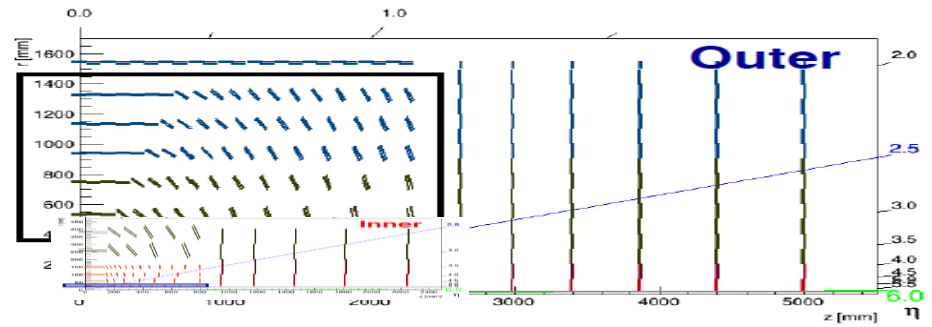
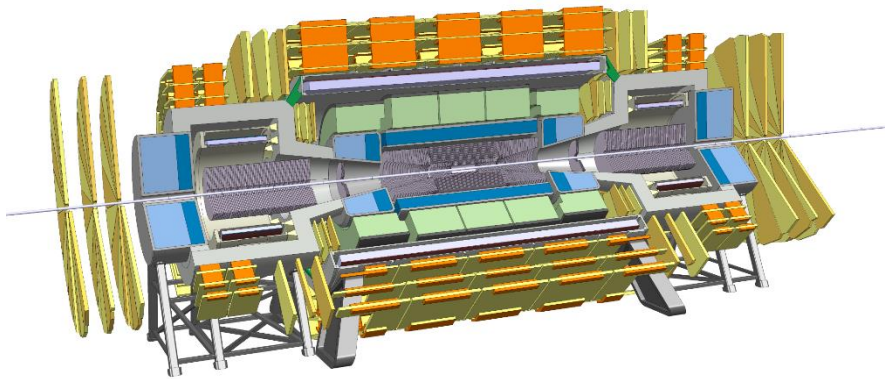
Benchmark processes, detector requirements from physics

FCC-hh

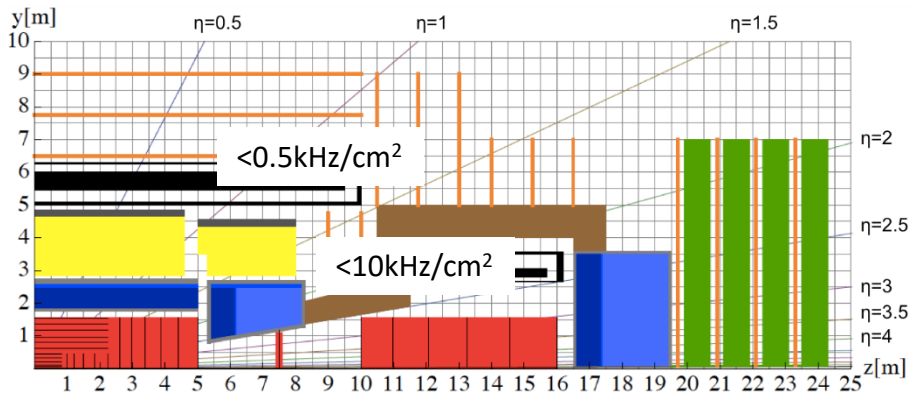
- Higgs physics
 - Higgs self-coupling (bbyy, bbTT, bb+leptons)
 - Top-Yukawa: - ttH, $H \rightarrow \gamma\gamma$ (threshold), $H \rightarrow bb$ (boosted)
 - Rare Higgs decays ($H \rightarrow cc$, $H \rightarrow \mu\mu$, $H \rightarrow ZZ$)
 - “Big Five”: Higgs decays ($H \rightarrow 4l$, WW , $\gamma\gamma$, TT , bb)
 - VBF (VBS)
 - BSM Higgs ($H^{+/-} \rightarrow tb$)
- Top physics
 - $tt\gamma/Z$
 - ttH/ttZ ratio?
 - tWb (single top s-channel)
 - - $g\bar{t}t$
 - FCNCs, rare decays
- Strong SUSY
 - gluinos, squarks: jets + MET, s.s dileptons + jets + MET
 - stops: 0/1 leptons + jets + MET
- Weak SUSY
 - EW-ino: 3/4 leptons + MET
 - Higgsino (disappearing tracks)
 - Dark Matter
- Heavy Resonances
 - $Z' \rightarrow tt, jj, ee/\mu\mu$:
 - $M_{Z'} = 5, 30 \text{ TeV}$
 - $m(q^*) = 50 \text{ TeV}$



Tracker



Muon system

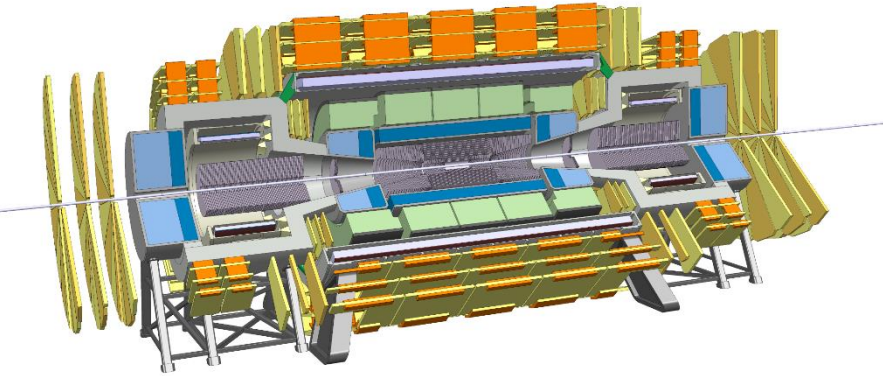


ATLAS muon system HL-LHC rates (kHz/cm²):

MDTs barrel:	0.28	
MDTs endcap:	0.42	
RPCs:		0.35
TGCs:		2
Micromegas and sTGCs:	9-10	

HL-LHC muon system gas detector technology will work for most of the FCC detector area

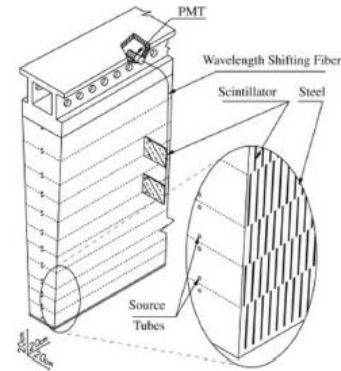
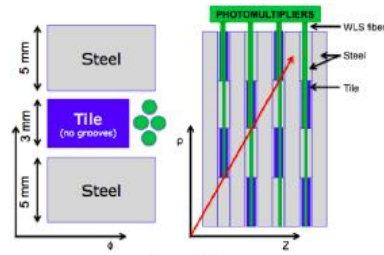
Calorimetry



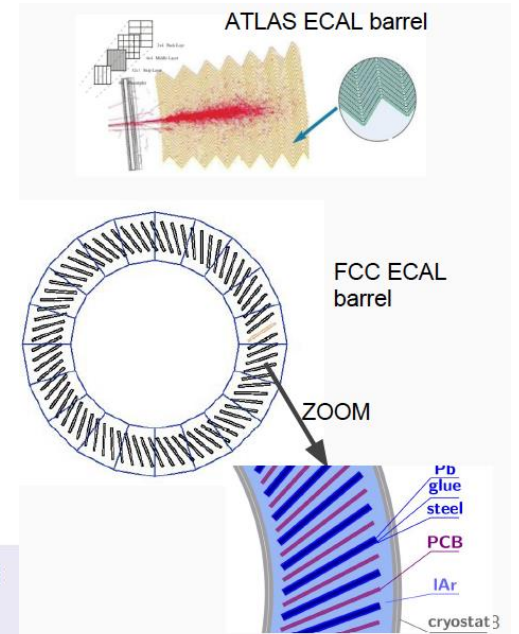
Barrel HCAL in Fe/Sci similar to ATLAS Tilecal

Barrel ECAL, Endcap ECAL/HCAL, Forward ECAL/HCAL are in LAr technology, which is intrinsically radiation hard.

Silicon ECAL and ideas for digital ECAL with MAPS are being discussed.



~ 11 λ FCC-hh HCAL, pion resolution:
 $\sigma E/E = 43\% / \sqrt{E} \oplus 2.7\%$

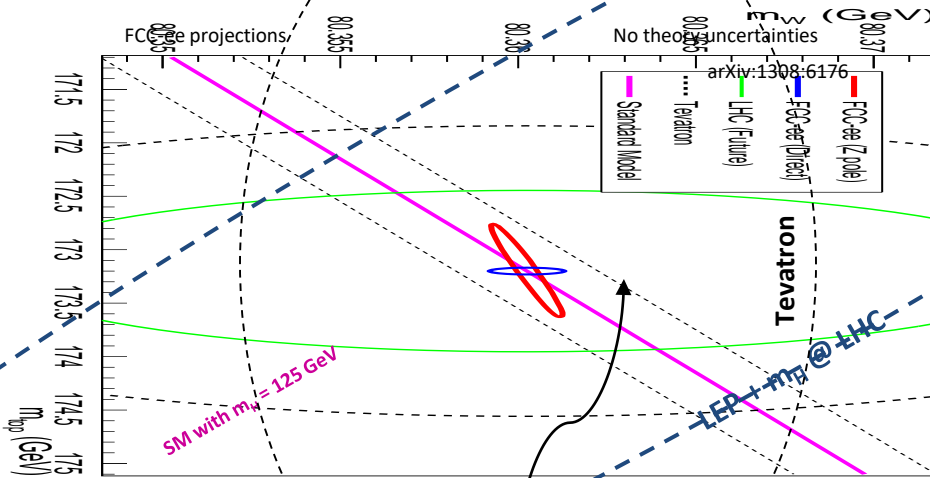


Goal energy resolution of 10% / sqrt(E) \oplus 1%

Global Fit and sensitivity to new physics

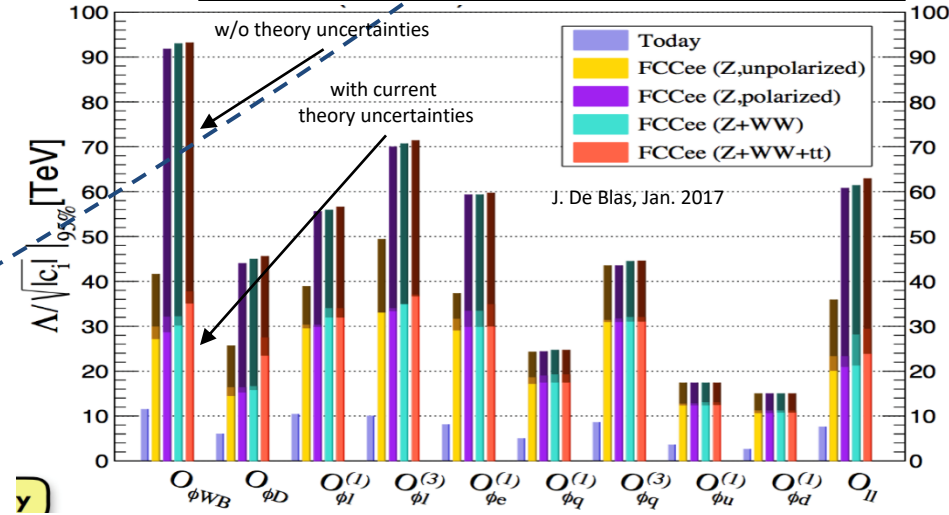
FCC-ee

- Combining all EW measurements
 - In the context of the SM ... and beyond



Without $m_Z(\alpha_{\text{QED}})$ @FCC-ee, the SM line would have a 2.6 (1.8) MeV width
 FCC-ee sensitivity severely drops without **POLARIZATION + STATISTICS**
 (and improved theory calculations)

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i}{\Lambda^2} \mathcal{O}_i$$



Today: $\Lambda > 5-10$ TeV

After FCC-ee: $\Lambda > 50-100$ TeV ?

Synergetic with FCC-hh

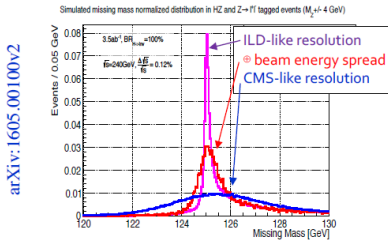
FCC-ee Detector Requirements

Momentum resolution

$$\sigma_{1/p} = 3 \times 10^{-5} \text{ GeV}^{-1}$$

[Matching beam energy spread: $1-2 \times 10^{-3}$]

Mass reconstruction from lepton pairs



Endpoint of lepton momentum spectrum

- Probe to 10^{-9} level lepton flavour violation $Z \rightarrow \tau e, Z \rightarrow \tau \mu$

□ ...

Jet Energy

$$\delta E/E \approx 30\% / \sqrt{E} \text{ (GeV)}$$

- Mass reconstruction from jet pairs. Resolution important for control of (combinatorial) backgrounds in multi-jet final states

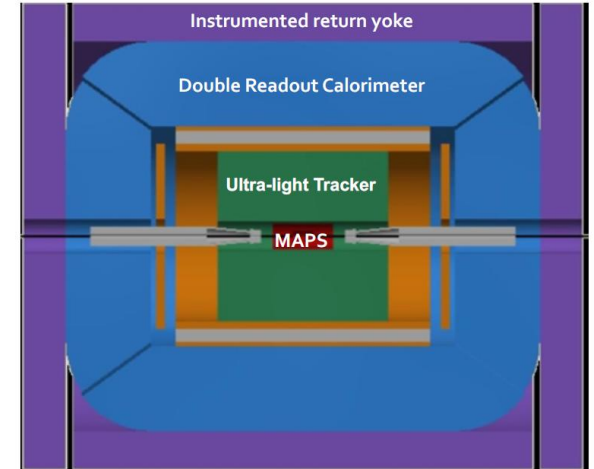
- $HZ \rightarrow 4 \text{ jets}, t\bar{t}_{\text{bar}}$ events etc.
- At $\delta E/E \approx 30\% / \sqrt{E} \text{ (GeV)}$, detector resolution is comparable to natural widths of W and Z bosons

FCC-ee Detector Concept – IDEA

IDEA detector concept based on present state-of-the-art technologies:

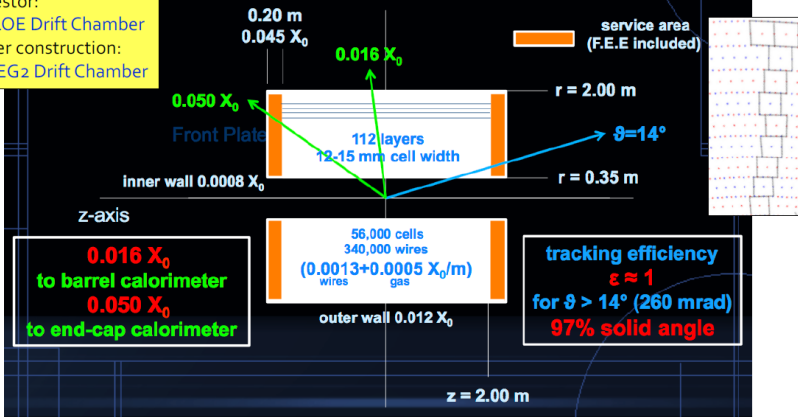
- Vertex detector, MAPS
- Ultra-light drift chamber with PID
- Pre-shower counter
- Double read-out calorimetry
- 2 T solenoidal magnetic field
- Possibly instrumented return yoke
- Or possibly surrounded by large tracking volume ($R \approx 8\text{m}$) for very weakly coupled (long-lived) particles

Two Options: Coil inside or outside calorimetry



Ultra-light drift chamber

Ancestor:
- KLOE Drift Chamber
Under construction:
- MEG2 Drift Chamber



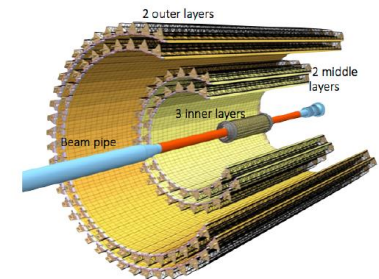
Courtesy of F. Grancagnolo

- 12-15 mm wide square drift cells
- 112 co-axial layers
- Alternating sign stereo angles
- GAS: 90% He – 10% iC_4H_{10}
- Point resolution
 - $\sigma_{xy} = 100 \mu\text{m}$ [potentially 75 μm]
 - $\sigma_z = 750 \mu\text{m}$

Vertex detector

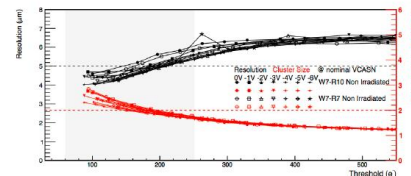
Inspired by new ALICE ITS based on MAPS technology

- Pixels $30 \times 30 \mu\text{m}^2$
- Light
 - Inner layers: 0.3% of X_0 / layer
 - Outer layers: 1% of X_0 / layer
- Performance:
 - Point resolution of 5 μm (or better)
 - Efficiency of $\sim 100\%$
 - Extremely low fake rate hit rate

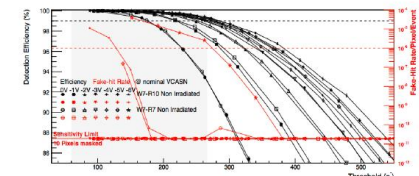


Courtesy J.W. van Hoorne

Position resolution and cluster size



Detection efficiency and fake-hit rate



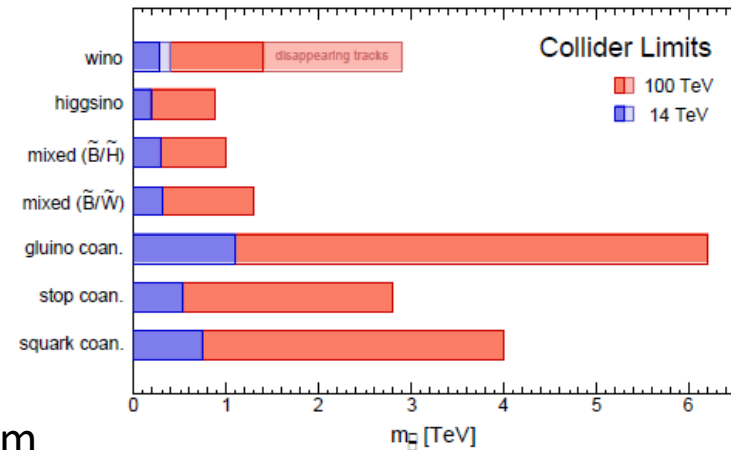
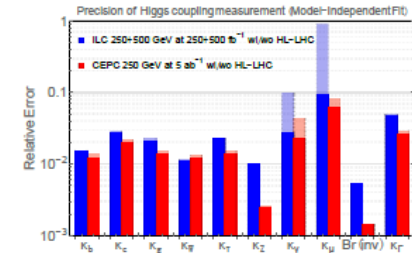
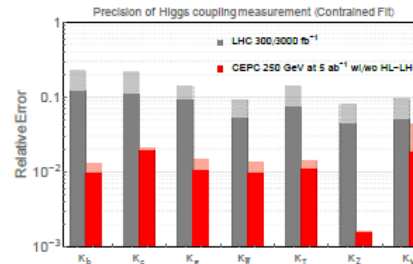
Circular Electron-Positron Collider CEPC

Table 1.2: Top Level Parameters for CEPC.

Parameter	Design Goal
Particles	e^+, e^-
Center of mass energy	240 GeV
Integrated luminosity (per IP per year)	250 fb^{-1}
No. of IPs	2

Table 1.3: Top Level Parameters for SPPC.

Parameter	Design Goal
Particles	p, p
Center of mass energy	70 TeV
Integrated luminosity (per IP per year)	(TBD)
No. of IPs	2



China's National Development and Reform Commission allocated some \$5 million for preliminary study (\$120 million requested).

Data taking could start around 2030

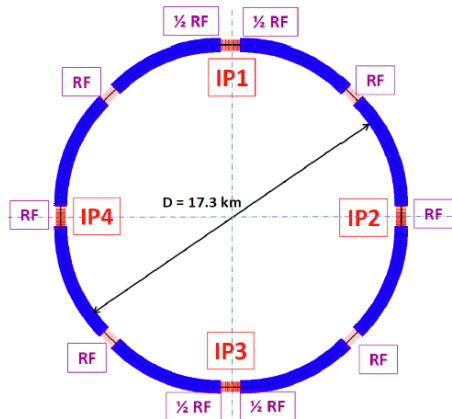


Figure 3.3: Illustration of the CEPC-SPPC ring sited in Qinghuangdao. The small circle is 50 km, and the big one 100 km. Which one will be chosen depends on the funding scenario.

Résumé de la situation ILC

ILC: Décision prise à LCWS 2016 (Morioka, Japon) de ne demander dans un premier temps que la machine à 250 GeV. (350 GeV et 500 GeV pour plus tard)

Coût réduit à 5 GILCU (-40 % de 8 GILCU = environ 5 G\$). Temps de construction ~6 ans.

Mise sur pied d'un plan d'action KEK-ILC en mai 2015.

Discussions Japon-US au niveau des ministères MEXT-DOE (mai et octobre 2016)

-> mise sur pied d'un plan d'action européen au niveau du CERN.

2017-2018 phase de pré-préparation (déjà en cours)

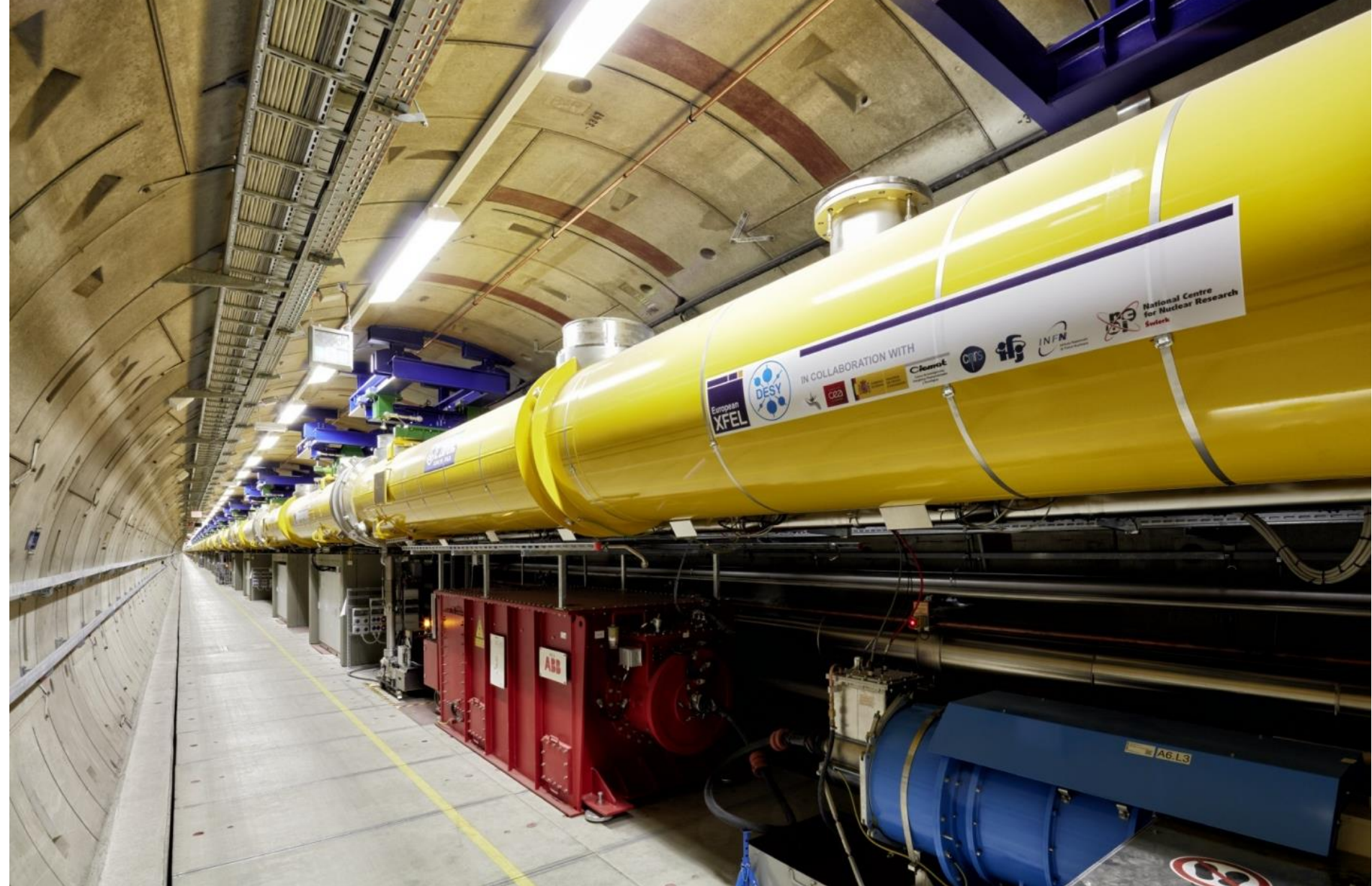
2019-2022 phase de préparation (initiée par une proposition officielle du gouvernement japonais suivi d'un update favorable de la stratégie européenne

2023 et au-delà : construction

Les expériences ILD, SiD ont leur gouvernance organisée et commencent à produire les études d'ingénierie.

LCWS2017 en France à Strasbourg la semaine prochaine!

(NB: la luminosité de l'ILC est limitée par la puissance consommée - 100 MW. On doit avoir ceci présent à l'esprit si on compare à d'autres schémas)



E-XFEL à Hambourg : proto de l'ILC, 20 GeV, fonctionne depuis janvier 2017

Higgs Couplings

Model-independent coupling fit, impossible at LHC

H20 Scenario

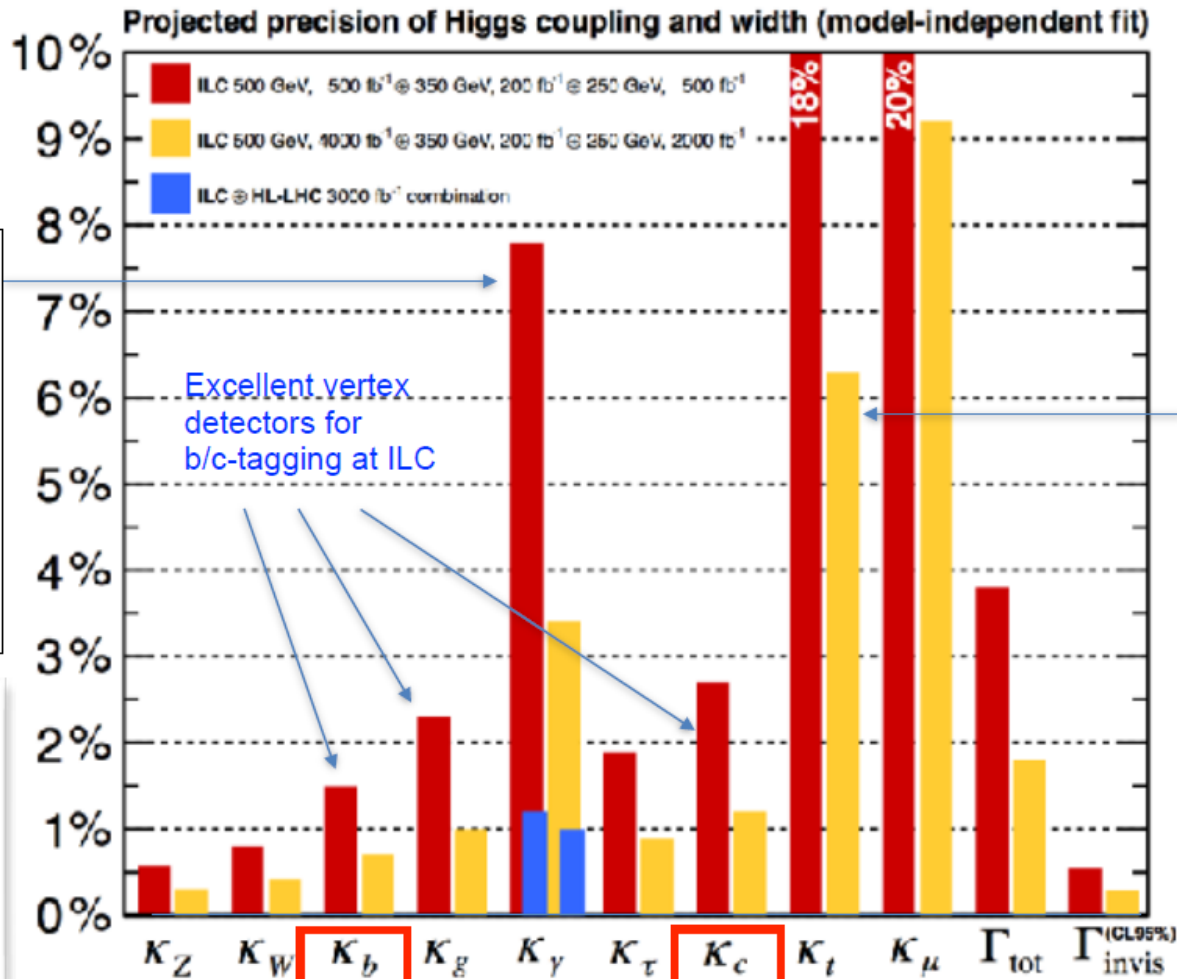
arXiv: 1506.05992
arXiv: 1506.07830

Better hyy with LHC/ILC synergy

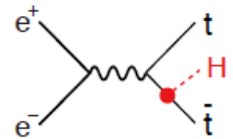
LHC can precisely measure
 $BR(h \rightarrow \gamma\gamma) / BR(h \rightarrow ZZ^*) = (K_\gamma / K_Z)^2$

ILC can precisely measure K_Z

All of major Higgs decay modes accessible at ILC with 250-500 GeV!



Top Yukawa improves by going to 550 GeV



Near threshold → a factor of 4 enhancement of σ_{th} by going from 500 GeV to 550 GeV

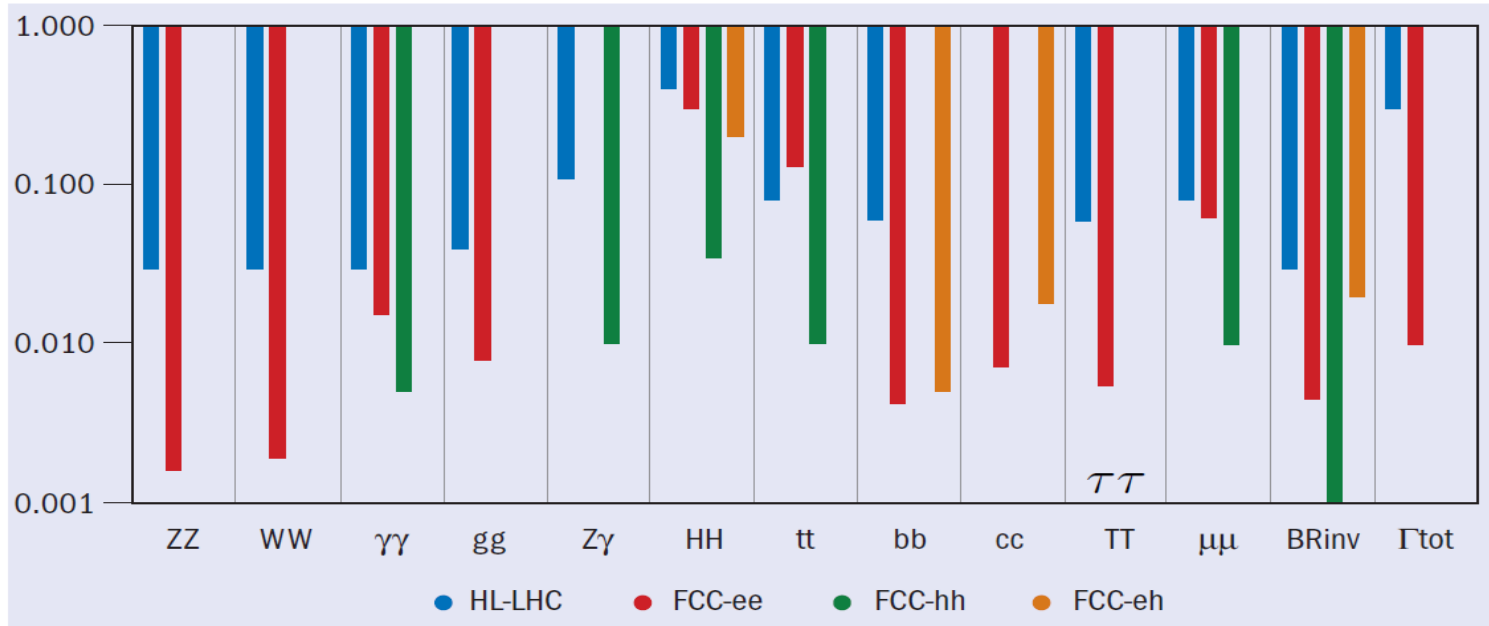
→ 3%

500 GeV already excellent except for K_t , K_μ , and K_γ

~1% or better for most couplings!

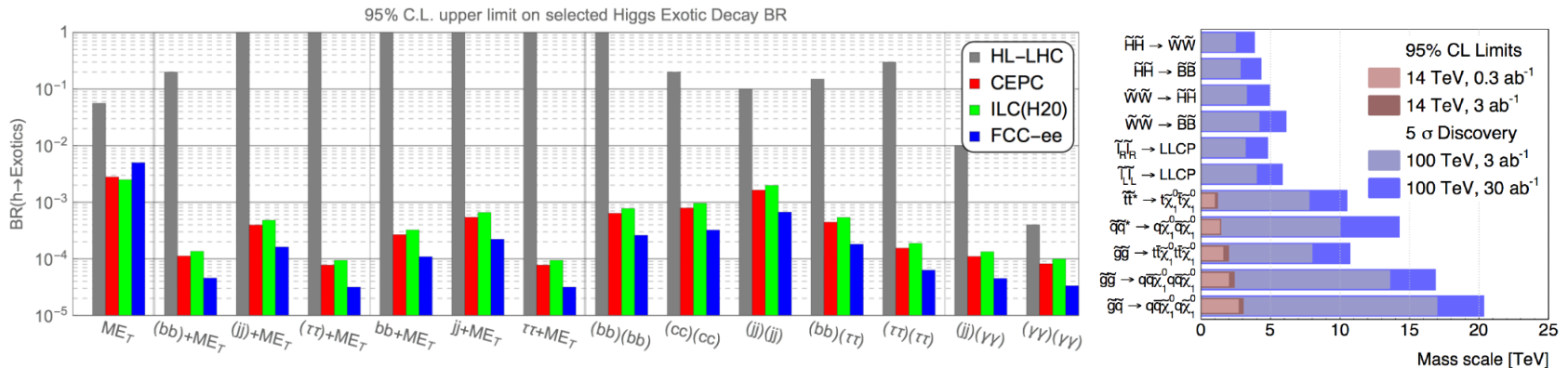
Higgs at FCC.

To summarise the Higgs programme...



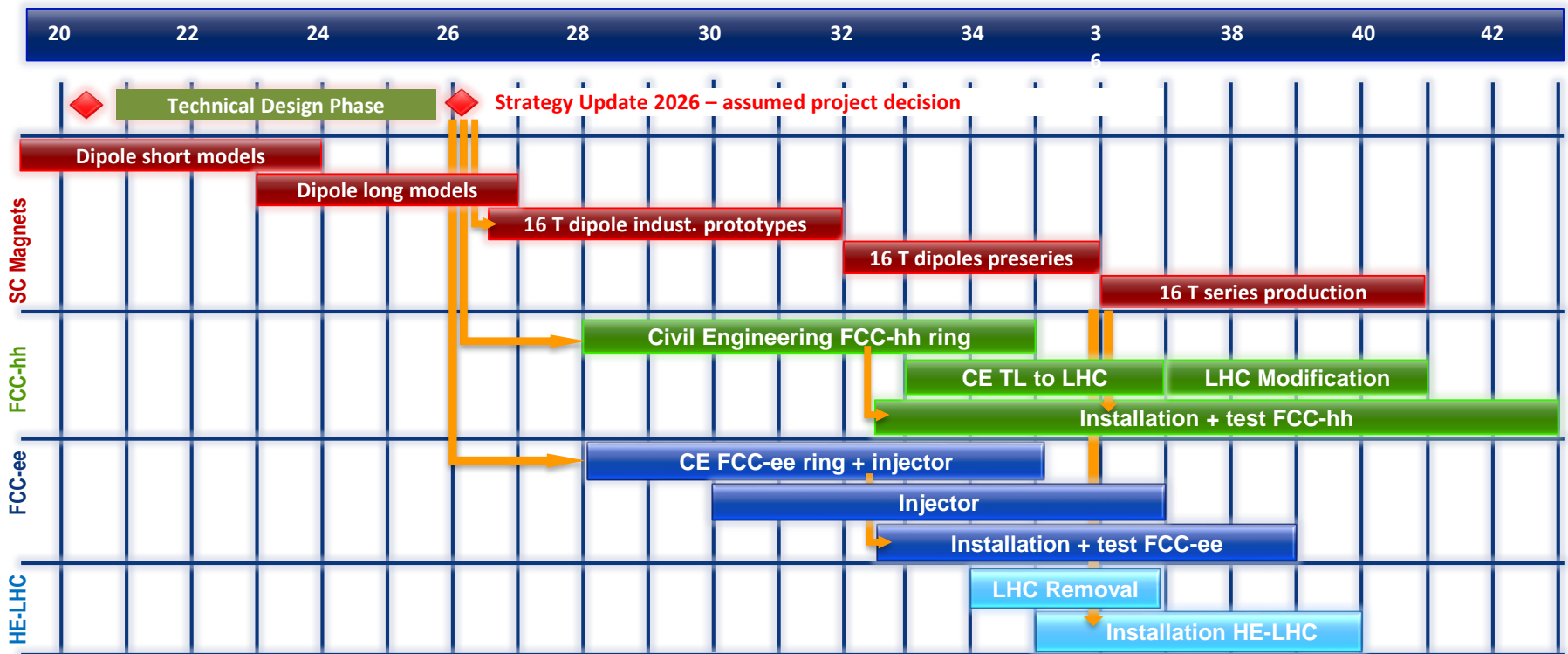
Note that y-axis is logarithmic!

Supersymmetry





Draft Schedule Considerations



ILC (250)
CEPC

ILC (350 ou 500)

EIC (Electron Ion Collider)

Espace des phases

(pour avoir un élément de comparaison):

$$x_{\min} \sim 10^{-4} \text{ et } Q^2_{\max} \sim 10^4 \text{ GeV}^2.$$

Il y a deux options:

- 1) eRHIC: qui nécessite un faisceau d'électrons
- 2) JLEIC: qui nécessite le faisceau de protons/ions.

Organisation:

Il y a 650 personnes, 142 instituts et 27 pays

Document de référence: arXiv: 1212.1701
(EIC the next QCD frontier)

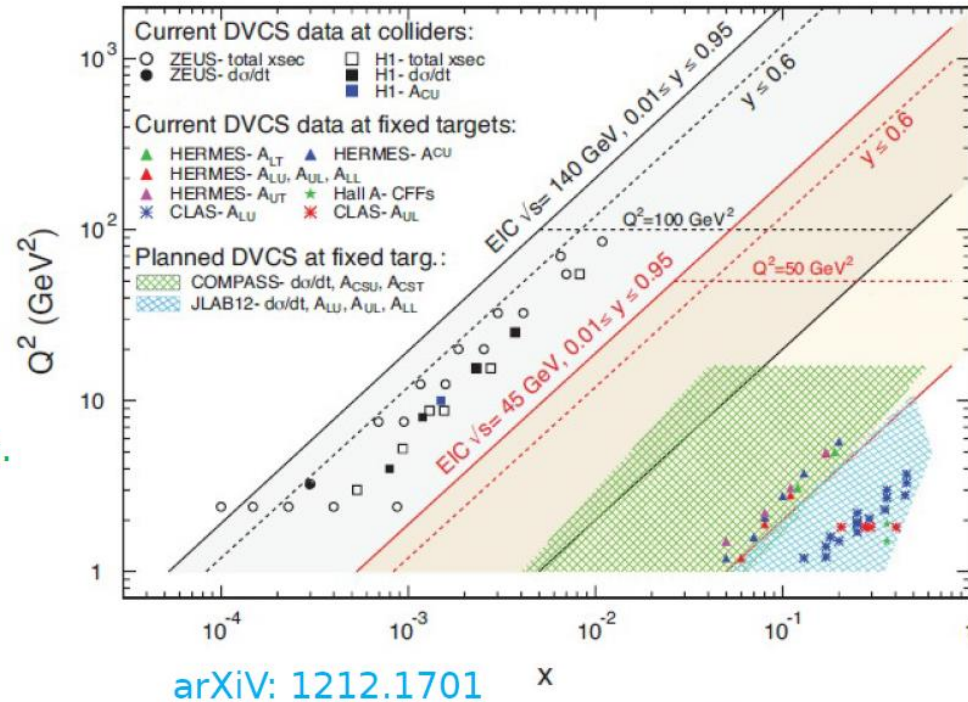
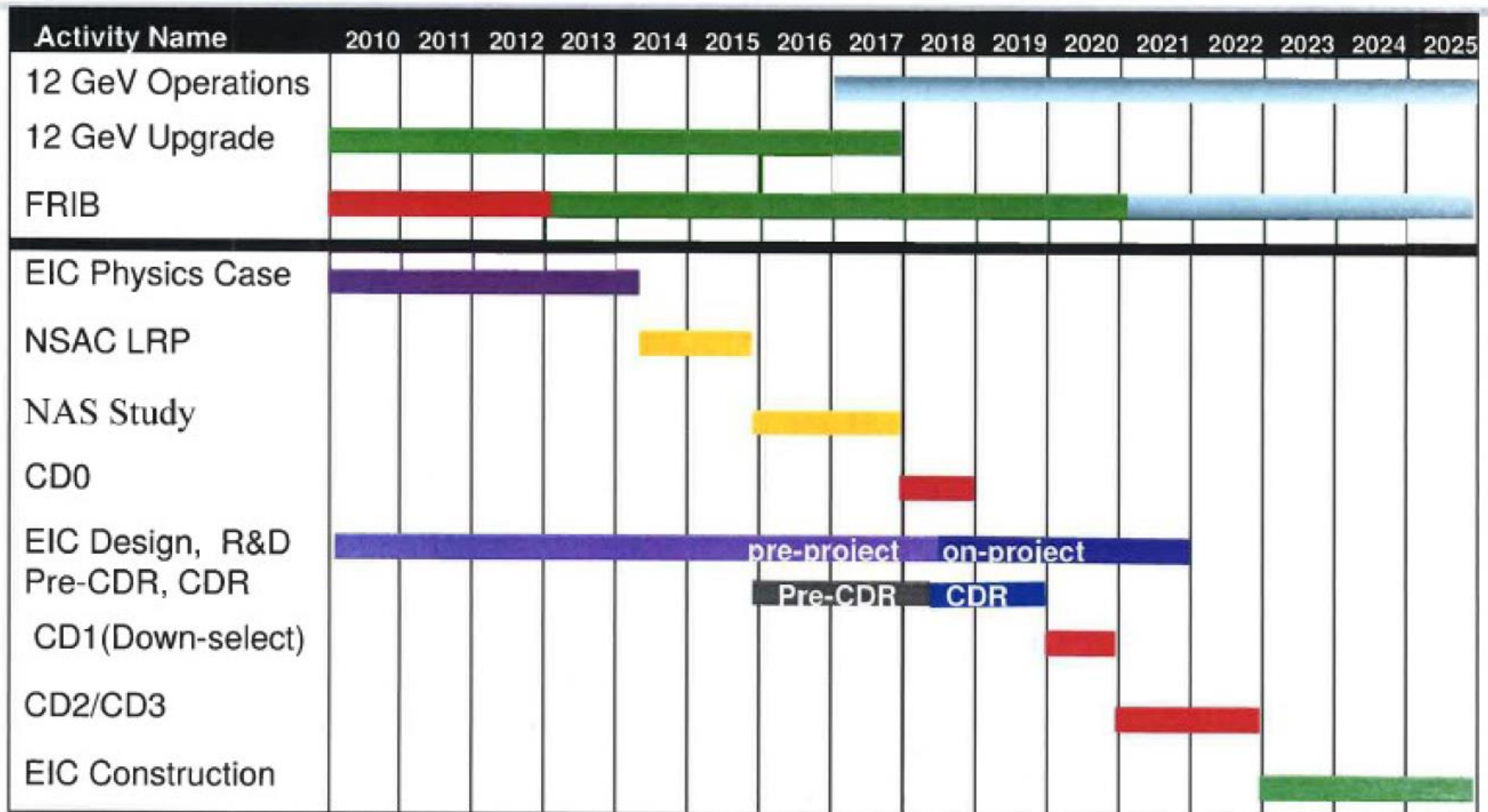


Figure 2.19: An overview of existing and planned measurements of DVCS in the x, Q^2 plane.

Envisioned JLEIC Timeline



CD0 = DOE "Mission Need" statement; **CD1** = design choice and site selection (VA/NY)
CD2/CD3 = establish project baseline cost and schedule

Qui pour faire quoi à l'heure actuelle ?

- ILC, FCC-ee : ~4 personnes
- HE-LHC : 0
- FCC-hh : 3 personnes
- EIC : 1 personne

Conclusions

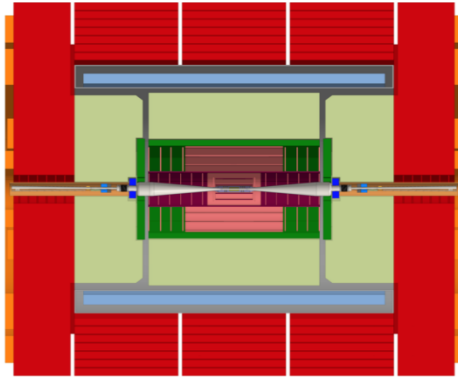
- La découverte du boson de Higgs ne complète pas notre compréhension du Modèle Standard
- Compréhension fine nécessaire du rôle et de la nature du boson de Higgs
 - Mesure à quelques % des couplages
 - Rôle dans la régularisation de la diffusion $W W$
 - Nombres quantiques, nature composite ou pas ?
- Utilisation du boson de Higgs comme une ouverture vers la Nouvelle Physique
 - Le boson de Higgs se couple-t-il avec la matière noire ou avec d'autres nouvelles particules ?
- Tests de précision du Modèle Standard et recherche indirecte de nouvelle physique
 - Désintégrations rares des mésons beaux
 - Désintégrations rares du quark top
- Recherche directe de nouvelle physique
 - Supersymétrie
 - Beaucoup d'autres modèles sur le marché...
- Beaucoup de projets à long terme
- Seul le LHC puis le HL-LHC permettront d'avancer au cours des 10-15 prochaines années
- Il faut préparer les expériences futures en parallèle
- Nécessaire insertion de l'Irfu dans les stratégies européennes et mondiale
- Nouvelles idées ? Techniques d'accélération ?

Backup

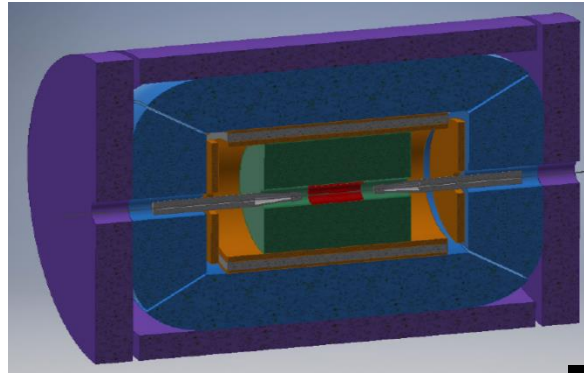
Detector designs

- Designs driven by the unprecedented precision of the measurements

- “CLIC-detector revisited”

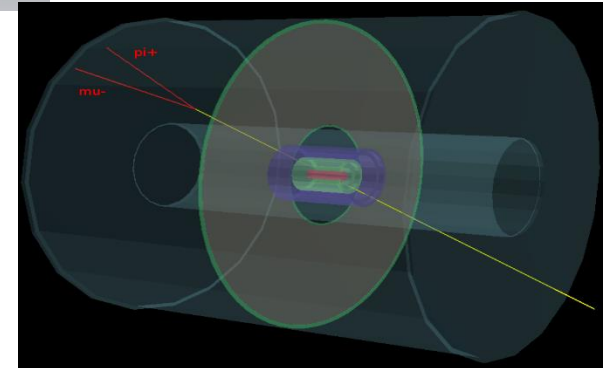


- “IDEA”



- Vertex detector: ALICE
- Tracking: MEG2
- Si Preshower
- Ultra-thin solenoid (2T)
- Calorimeter: DREAM
- Equipped return yoke

- Possibly surrounded by large tracking volume ($R = 8\text{m}$)
 - Very weakly coupled (long-lived) particles
 - E.g., RH neutrinos as DM candidates

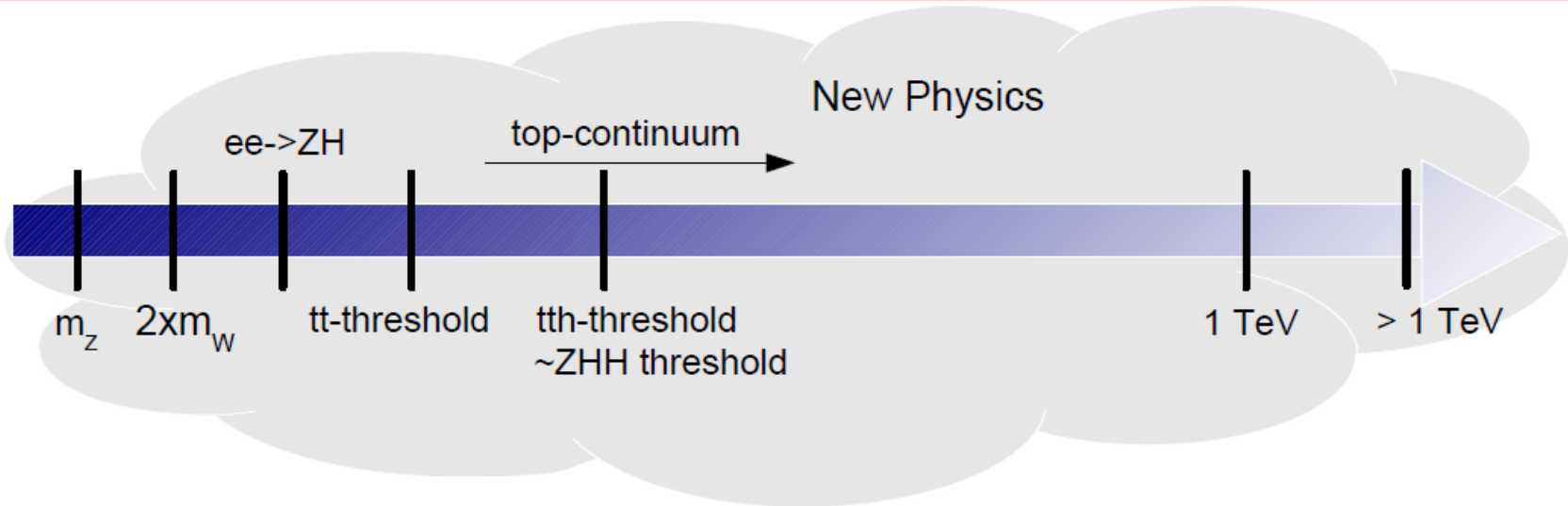


Operation model

M. Benedikt
May 2017

- Physics goals (see next slides)
 - $\sim 150 \text{ ab}^{-1}$ around the Z pole ($\sim 25 \text{ ab}^{-1}$ at 88 and 94 GeV, 100 ab^{-1} at 91 GeV)
 - $\sim 10 \text{ ab}^{-1}$ around the WW threshold (161 GeV with \pm few GeV scan)
 - $\sim 5 \text{ ab}^{-1}$ at the HZ cross section maximum ($\sim 240 \text{ GeV}$)
 - $\sim 1.5 \text{ ab}^{-1}$ at and above the top threshold (a fraction at $\sim 350 \text{ GeV}$, the rest at $\sim 370 \text{ GeV}$)
- Assumptions
 - 200 scheduled physics days per years
 - Hübner factor ~ 0.6 (lower than PEP-II, 0.63, and KEKB, 0.8)
 - Winter shutdowns used to change machine configuration between working points
- Run plan with 2 IP and the baseline optics

\sqrt{s} (GeV)	Z	WW	HZ	top
Lumi ($\text{ab}^{-1}/\text{year}$)	15, then 30	4	1	0.3
Events/year	1.5×10^{12}	1.5×10^7	2.0×10^5	2.0×10^5
Physics goal	150 ab^{-1}	10 ab^{-1}	5 ab^{-1}	1.5 ab^{-1}
Runtime (years)	6	2	5	5

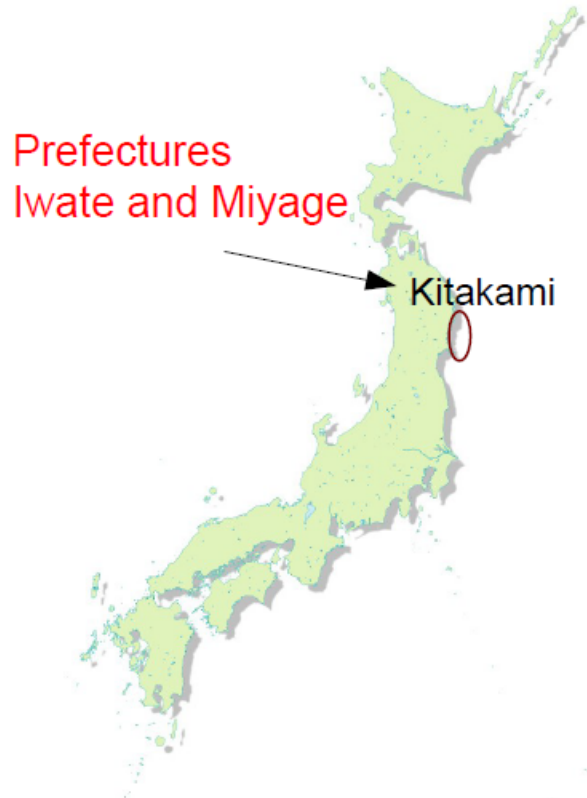


- All Standard Model particles within reach of e^+e^- linear colliders
 - High precision tests of Standard Model over wide range to detect onset of new physics
- Machine settings can be “tailored” for specific processes
 - Centre-of-Mass energy
 - Beam polarisation

$$\sigma_{P,P'} = \frac{1}{4} [(1 - PP')(\sigma_{LR} + \sigma_{RL}) + (P - P')(\sigma_{RL} - \sigma_{LR})]$$

- “Background free” searches for BSM through beam polarisation

Most probable host country: **Japan**



Most probable site:
Kitakami Mountains
50 km of solid rock

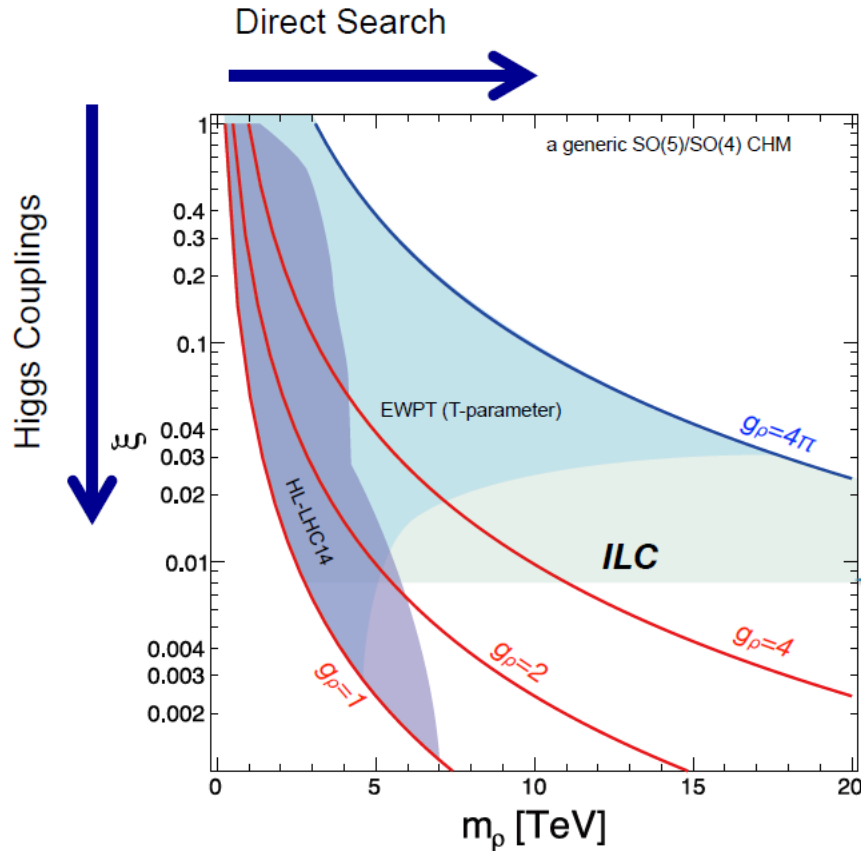
- ILC is evaluated by Japanese Ministry MEXT since 2014
 - e.g. 2 visits to LAL by Nomura consulting Company
- Recently Japanese Particle Physics Community expressed unanimous support for ILC that starts at 250 GeV “JAHEP” Statement
 - Debate at next LCWS in Strasbourg
 - Debate at ICFA Seminar in Ottawa
- Expect decision by Japanese Government on hosting the ILC by Summer 2018
 - ILC was recently discussed between Diet members and Japan's Prime Minister
 - More and more lights turn to green
- Input to next European Strategy

Composite Higgs: Reach

Complementary approaches to probe composite Higgs models

- Direct search for heavy resonances at the LHC
- Indirect search via Higgs couplings at the ILC

Comparison depends on the coupling strength (g_*)



Based on Contino, et al, JHEP 1402 (2014) 006
Torre, Thamm, Wulzer 2014
Grojean @ LCWS 2014

$$\xi = \frac{g_\rho^2}{m_\rho^2} v^2 = \frac{v^2}{f^2}$$

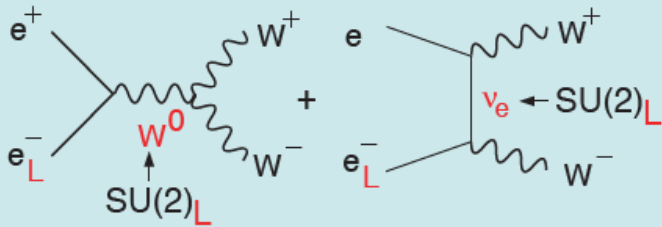
$$\frac{g_{hVV}}{g_{SMVV}} = \sqrt{1 - \xi}$$

ILC (250+500 LumiUP)

$$\Delta \frac{g_{hVV}}{g_{hVV}} = 0.4\%$$

Power of Beam Polarization

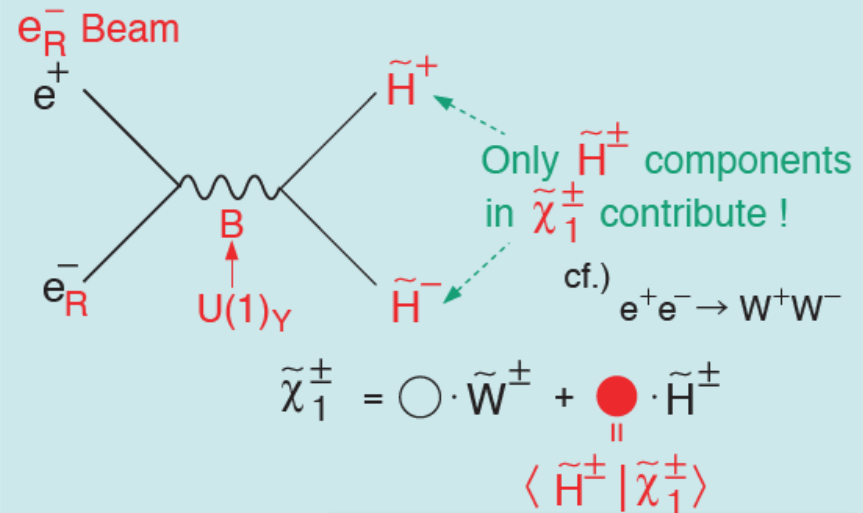
$W^+ W^-$ (Largest SM BG in SUSY searches)



In the symmetry limit, $\sigma_{WW} \rightarrow 0$ for e_R^- !

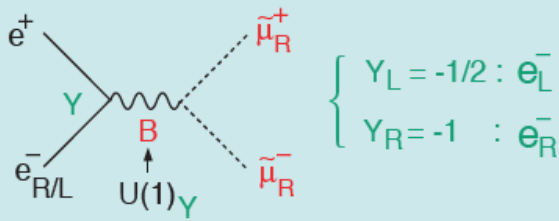
BG Suppression

Chargino Pair



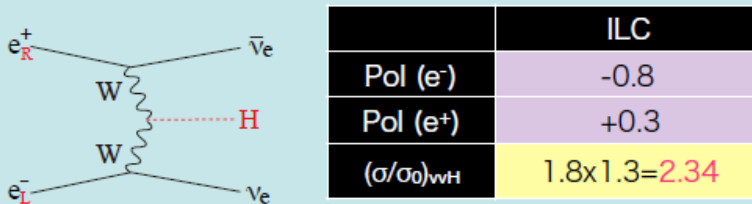
Decomposition

Slepton Pair



In the symmetry limit, $\sigma_R = 4 \sigma_L$!

WW-fusion Higgs Prod.



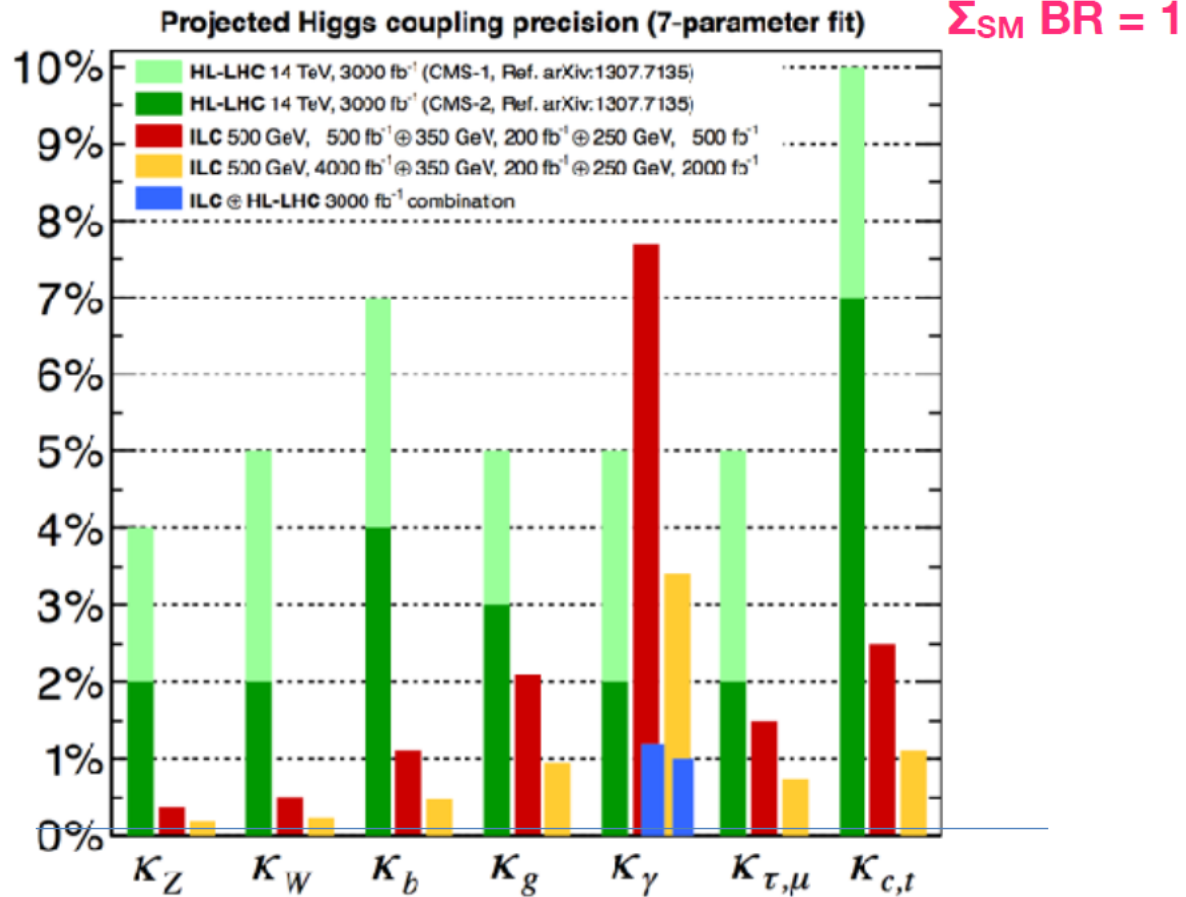
Signal Enhancement

Model-dependent coupling fit (LHC-style 7-parameter fit)

H20 Scenario

arXiv: 1506.05992

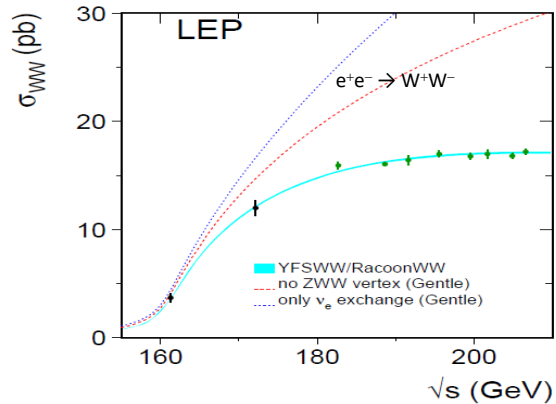
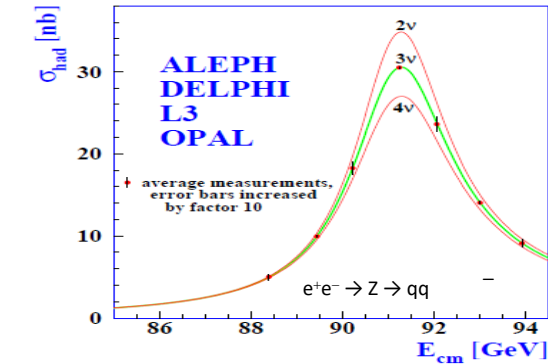
arXiv: 1506.07830



Possible to achieve precision far exceeding LHC!

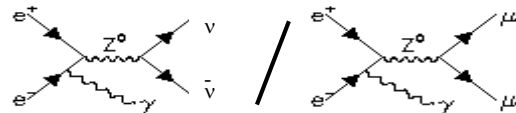
Physics at FCC-ee

- Precision EW measurements with a Z resonance scan :



- ◆ **Lineshape** (Current)
 - m_Z, Γ_Z to < 100 keV (2.2 MeV)
- ◆ **Asymmetries**
 - $\sin^2\theta_W$ to 6×10^{-6} (1.6×10^{-4})
 - $\alpha_{\text{QED}}(m_Z)$ to 3×10^{-5} (1.5×10^{-4})
- ◆ **Branching ratios, R_l, R_b**
 - $\alpha_s(m_Z)$ to **0.0002** (0.002)

- ◆ **Threshold scan** (Current)
 - m_W to < 500 keV (15 MeV)
- ◆ **Branching ratios R_l, R_{had}**
 - $\alpha_s(m_W)$ to **0.0002** (0.002)
- ◆ **Radiative returns $e^+e^- \rightarrow \gamma Z$**
 - N_γ to **0.0004** (0.008)



- And also :
- TGC / QCG
 - Rare W decays

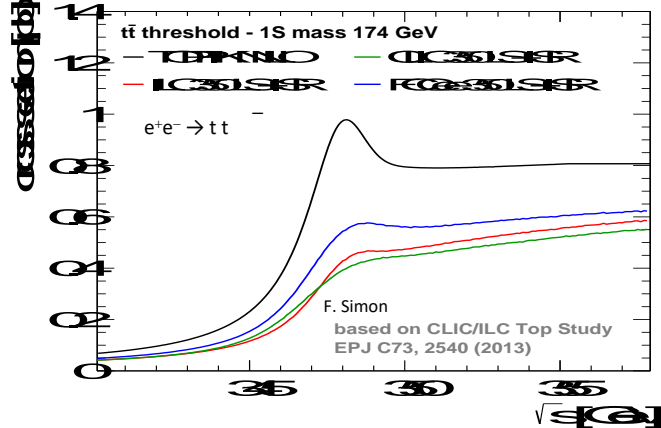
Prediction from
Z measurements
after the FCC-ee

$$\begin{aligned}
 m_W &= 80.3593 \pm 0.0001 (m_{\text{top}}) \pm 0.0001 (m_Z) \pm 0.0003 (a_{\text{QED}}) \\
 &\quad \pm 0.0002 (a_s) \pm 0.0000 (m_H) \pm 0.0004 (\text{theo.}) \\
 &= 80.3593 \pm 0.0005 \text{ GeV} \quad (\sim \text{precision of direct measurement})
 \end{aligned}$$

Physics goals at and above the top threshold

- Primary goal : precise m_{top} measurement at threshold

Review talk from P. Azzi

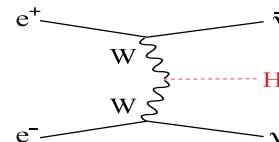


- ◆ Essential for full harnessing of Z & W precision data
 - 10 MeV precision (stat.) reached with 0.2 ab^{-1}
- ◆ Benefits from α_s measurement at lower \sqrt{s}
 - QCD higher orders : dominant syst. (30 MeV)
- ◆ Also from threshold scan:
 - Top decay width, top Yukawa coupling

- Many interesting opportunities slightly above threshold (370 GeV)

- Top EW couplings, $t\bar{t}\gamma$ and $t\bar{t}Z$, to 1%
 - Sensitive to new physics
 - Synergetic with FCC-hh for $t\bar{t}H$ Yukawa coupling measurement
- Anomalous top production and decay
- Higgs decay width to 1%
- ...

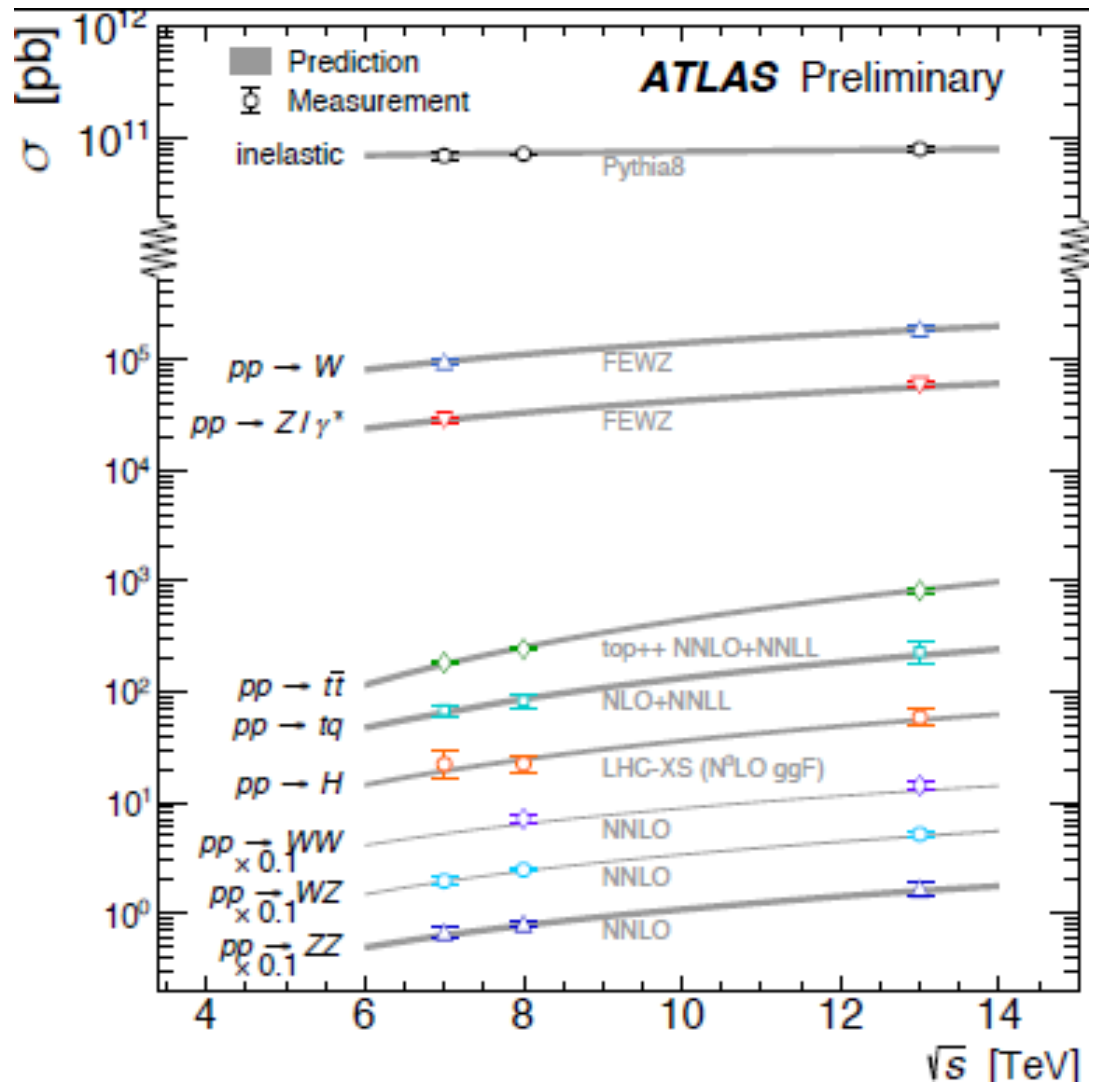
Review talk from C. Grojean



Review talk from M. Klute

Le Modèle Standard au Run-1 et au Run-2

- Processus bien décrits (quelques %) par la théorie sur plusieurs ordres de grandeur
- La machinerie du Modèle Standard fonctionne remarquablement bien



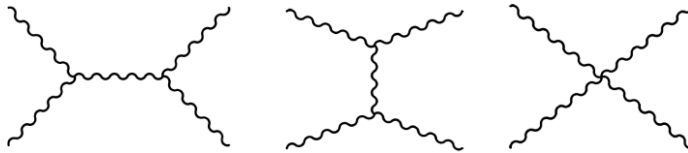
SECTEUR DE BRISURE DE LA SYMÉTRIE ÉLECTROFAIBLE

Le **boson de Higgs** joue deux rôles fondamentaux dans le Modèle Standard

- « Unitarisation » de la diffusion des bosons W et Z à haute énergie
 - Directement liée à la **génération de la masse des bosons W et Z**
 - Fixe les **couplages du boson de Higgs aux bosons W et Z**

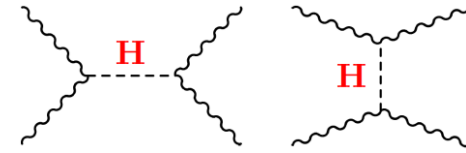
Contribution des bosons W et Z :

WW → WW



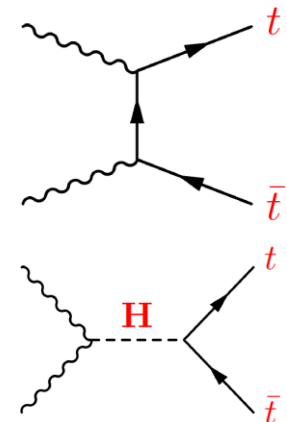
- croît comme E au carré
- conduit à une violation de l'unitarité à $E \sim 1 \text{ TeV}$
- en absence de boson de Higgs :
Nouvelle Physique nécessaire au TeV

Contribution du boson de Higgs :



- croît comme E au carré *mais avec signe opposé*
- restauration de l'unitarité si et seulement si :
 - ✓ $m_H < 800 \text{ GeV}$
 - ✓ couplages prédits par le Modèle Standard

- « Unitarisation » de la réaction WW ou ZZ → fermion-antifermion
 - Directement liée à la **génération de la masse des fermions**
 - Fixe les **couplages du boson de Higgs aux fermions**



Toute **dévi**ation des **couplages** du boson de Higgs avec les bosons et les fermions par rapport aux prédictions implique une **Nouvelle Physique**

EIC: objectifs de physique et implications

- 1) Construction du moment cinétique J dans les nucléons (spins des quarks, gluons, moments orbitaux)
- 2) La question 1) sous-tend la question 2): Tomographie des nucléons...
Je discute rapidement ces deux points plus loin...
- 3) Structure en partons des noyaux (ions lourds): effets de saturation etc.

Il y a une continuité: HERA -> Jlab / RHIC / Compass ->....

Ce sont des points de métrologie mais aussi de compréhension (non-triviale) de la structure de matière dans les nucléons/noyaux.

Conséquences pratiques

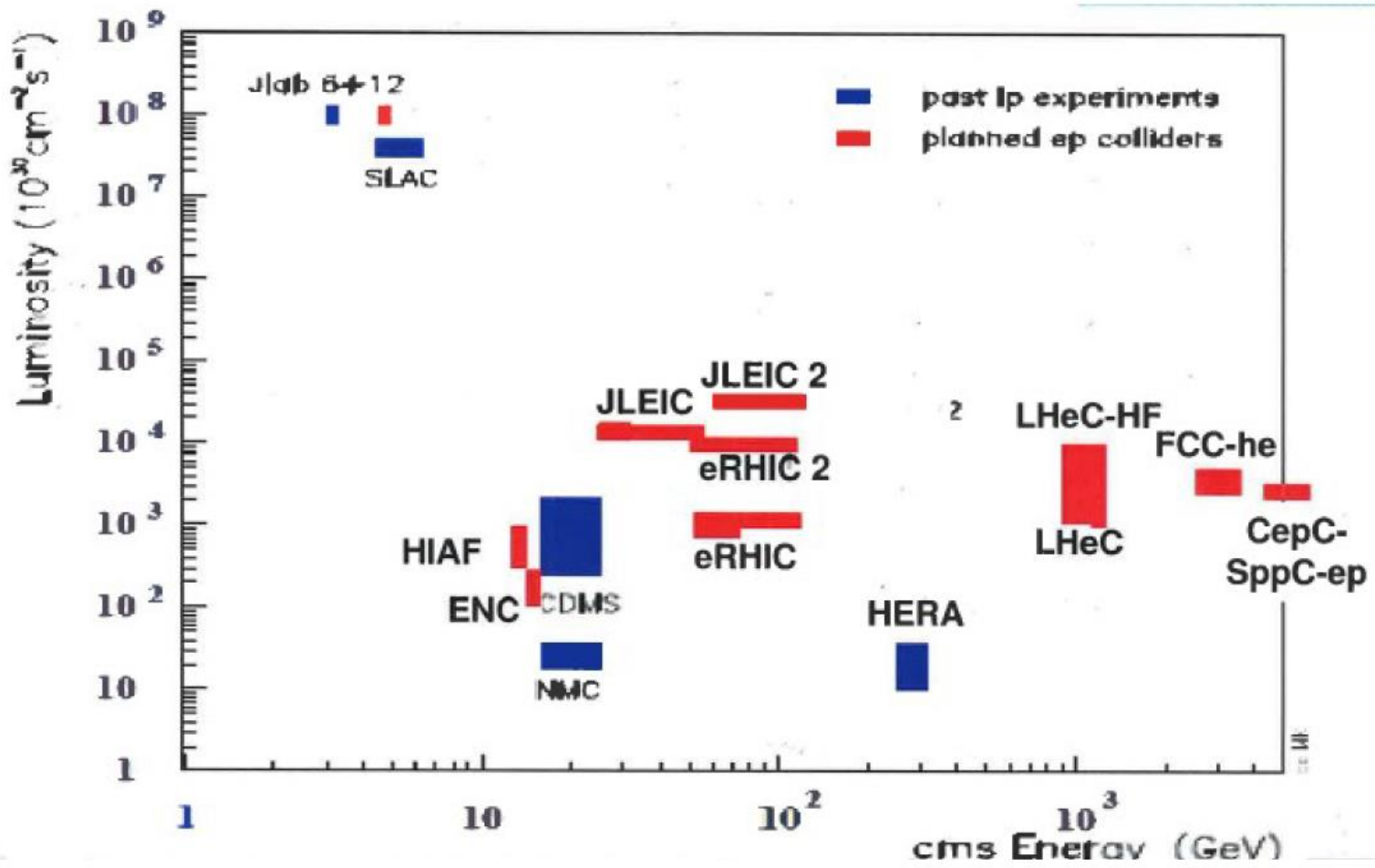
(rien d'irréaliste)

Faisceau de leptons qui va agir comme une sonde contre un faisceau de protons/ions, les deux peuvent être polarisés à plus de 70% : $E_e = 20-30 \text{ GeV}$, $E_p = 250-350 \text{ GeV}$, $E_{\text{ions}} = 100-150 \text{ GeV/A}$.

Ce qui implique: $s = 100 \text{ GeV}^2 - 1000 \text{ GeV}^2$

Une luminosité environ 100 à 1000 fois celle de HERA (soit environ $10^{34} / \text{cm}^2 / \text{s}$)

Beaucoup de noyaux possibles: Deutérium, Li jusqu'au Plomb.



CC BY

The 1st European Strategy for Particle Physics of July 2006

- 1.&2. Recognition of CERN's central role in the global effort
 3. Commission and exploit the **LHC**
 4. Do R&D for future energy and luminosity frontier: **CLIC**
 5. Consider **ILC** as fundamental to complement LHC results
 6. Coordinate Europe to prepare **neutrino physics** case for ~2012
 - 7.&9.&13. Work with ApPEC, NuPECC and EU/EC
 8. National & regional labs/collab's for flavour- and precision physics
 10. Support theoretical particle physics
 11. Establish European Strategy Secretariat with a Scientific Secretary
 12. Create framework for Europe to engage in global PP projects
 14. Involve non-Member States
 - 15.&16.&17. Communicate, Innovate & Connect to industry
- (bold emphasis added by the slides' author)

Present (May 2013) European Strategy: Preamble

- a) The success of the LHC is proof of the effectiveness of the European organisational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN. *Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.*

- a) *The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.*

for next update

=> Marching order

Present European Strategy:








High-priority large-scale scientific activities

- c) Europe's **top priority** should be the exploitation of **the full potential of the LHC**, including the high-luminosity upgrade of the machine and detectors with a view to collecting **ten times more data than in the initial design**, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma. □
- d) CERN should undertake **design studies for accelerator** projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to **a vigorous accelerator R&D programme**, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide. □
- e) There is a strong scientific case for an electron-positron collider, complementary to the LHC, ... The initiative from the Japanese particle physics community to host the **ILC in Japan** is most welcome, ... *Europe looks forward to a proposal from Japan to discuss a possible participation.*
- e) CERN should develop a **neutrino programme** to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan. □

YOU !

Present European Strategy:

Other essential scientific activities

- g) *Europe should support a diverse, vibrant **theoretical physics** programme, ranging from abstract to applied topics, in close collaboration with experiments and extending to neighbouring fields such as astroparticle physics and cosmology. Such support should extend also to high-performance computing and software development.* 
- h) ***Experiments in Europe with unique reach** should be supported, as well as participation in experiments in other regions of the world.* 
- i) ***Detector R&D** programmes should be supported strongly at CERN, national institutes, laboratories and universities. Infrastructure and engineering capabilities for the R&D programme and construction of large detectors, as well as infrastructures for data analysis, data preservation and distributed data-intensive computing should be maintained and further developed.* 
- j) *In the coming years, CERN should seek a **closer collaboration with ApPEC** on detector R&D with a view to maintaining the community's capability for unique projects in this field.* 
- k) *The CERN Laboratory should maintain its **capability to perform unique experiments**. CERN should continue to work with NuPECC on topics of mutual interest.* 
- l) ***CERN should be the framework within which to organise a global particle physics accelerator project in Europe, and should also be the leading European partner in global particle physics accelerator projects elsewhere.** Possible additional contributions to such projects from CERN's Member and Associate Member States in Europe should be coordinated with CERN.* 
- m) *CERN and the particle physics community should strengthen their relations with the European Commission in order to participate further in the development of the European Research Area.* 

Next Update of European Strategy: Set in motion in December 2016

Council decisions in December 2016:

1) Aim at adopting an updated strategy in May 2020

Arguments for time frame:

- 2013-2020 is 7 years between updates
- End of LHC run 2 at end of 2018
- FCC Conceptual Design Report by end 2018
- CLIC update (staged implementation plan, cost, etc.) by end 2018
- Report of Physics Beyond Colliders Study Group by end 2018
- Japanese decision on ILC should be known by end 2018
- Advances in Neutrino physics

2) Appoint a Strategy Secretary early, i.e. September 2017

- Input/work needed to organise the strategy discussion

Next Update of European Strategy: Approximate Timeline

September 2017

**Appointment of Strategy Secretary
and installation of Strategy**

Secretariat

(Call for nominations dead-

line 24 May,

1st discussion in 15 June

Council Closed Session)

September 2018

**Appointment of ESG and PPG by the Council
= Formal opening of the**

process

2019

Preparation of the briefing book, including

- 1 or 2 town meetings
- other consultations of the field

January 2020

Drafting of the proposed strategy by the ESG