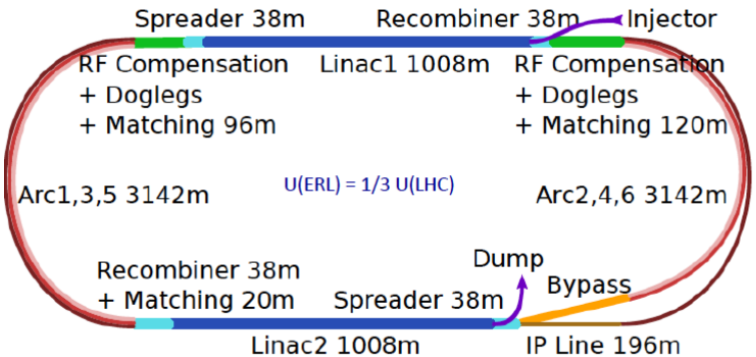
LHeC: Status and Prospects

Overview
The LHeC at High Luminosity
PERLE
European Strategy and CERN

cf many talks at this workshop:
N Armesto, D Britzger, C Gwenlan, O Fischer, W Kaabi, P Newman, B Mellado, A Stasto

For FCCeh see FCC books 1 (physics) and 2 (FCC-hh with eh integrated)
See also the CDR presentation in March 2019: https://indico.cern.ch/event/789349/
With talks on FCC-eh machine (OB), Higgs in eh (UK) and QCD (MK)

Max Klein
For the LHeC Collaboration
DIS Workshop, Torino, 10.4.2019



Three Raisons d'etre of the LHeC

Sustainability and Cost

LHC:
- see: SM, Higgs and no BSM
- use: Investment of O(5) BSF
- run: HL LHC until ~2040

LHeC [1206.2913]
- 1.2 TeV ep/A for O(1)BSF

→ Establish novel ep+pp Twin Collider Facility at CERN: sustains HL LHC and bridges to CERN's long term future
For installation during LS4 (2030+) and long term use (HE LHC, FCCeh)

Physics

- **Microscope**: World's Cleanest High Resolution
- **Empowerment** of the LHC Physics Programme
- **Creation** of a high precision, novel Higgs facility
- **Discovery** Beyond the Standard Model
- **Revolution** of Nuclear Particle Physics

Technology

Accelerator: Novel SRF ERL, green power facility
Detector: Novel high tech (CMOS..) apparatus

→ Keep accelerator and detector base uptodate while preparing for colliders that cost O(10)BSF

CERN-ACC-NOTE-2018-0084
December 18, 2018

Exploring the Energy Frontier with Deep Inelastic Scattering at the LHC

A Contribution to the Update of the European Strategy on Particle Physics

LHeC and PERLE Collaboration

LHeC also described in the ES paper by A.Caldwell, A.Levy, R.Ent, P.Newman and F.Olness

CERN-ACC-NOTE-2018-0086 December 18, 2018

PERLE : A High Power Energy Recovery Facility for Europe

A Contribution to the Update of the European Strategy on Particle Physics

Cockcroft Institute, AsTEC Daresbury, TU Darmstadt, BINP Novosibirsk, CERN, Liverpool University, IPN and LAL Orsay, Jefferson Laboratory, CEA Saclay

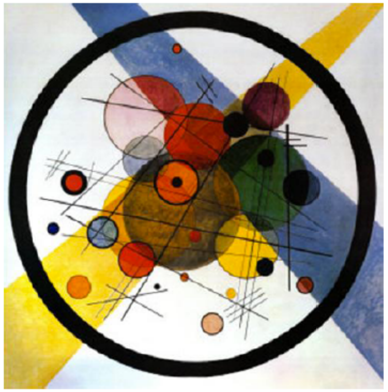
CERN-OPEN-2019-nnn
Geneva, April 10, 2019

CERN

LHeC

The Large Hadron Electron Collider at High Luminosity

Update on the 2012 LHeC Report
on the Physics and Design Concepts for Machine and Detector



Submitted to J.Phys. G

HEP and LHC

Physics

Detector and IR

ERL at CERN

Appendix

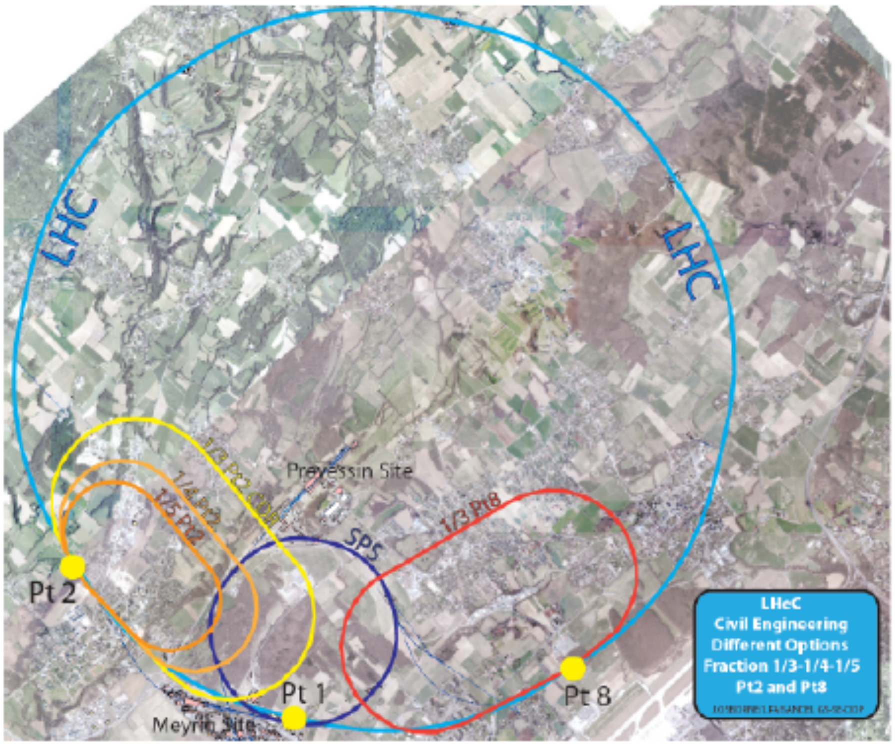
Timeline+Cost

PERLE

Workshop 24/25.10.2019 (tbc) near to CERN

Goal: conclusion of report and clarity about next steps

LHC (HL+HE) Footprint of ERL FCC



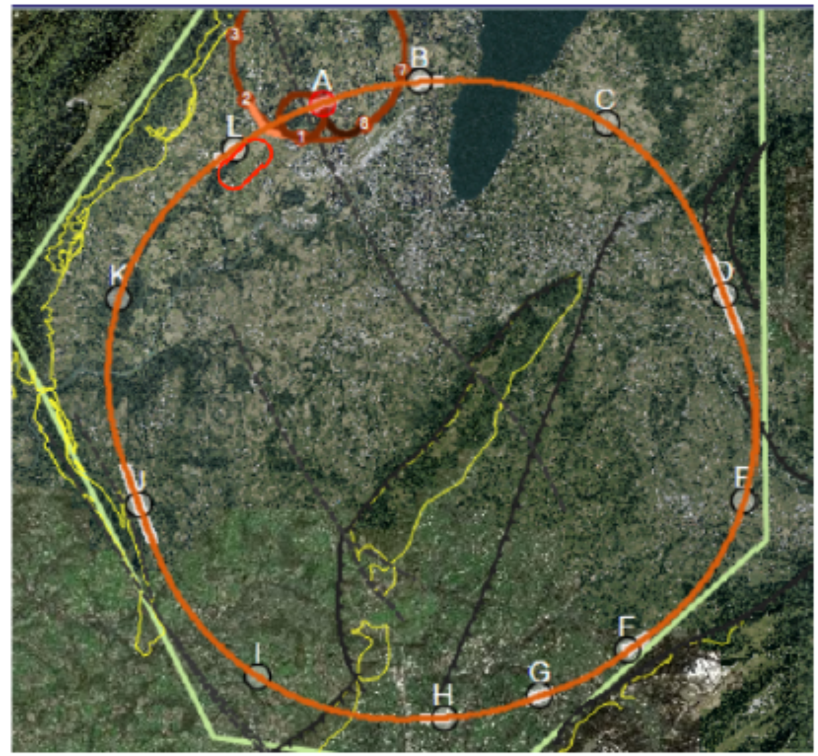


Figure 2: Possible locations of the ERL racetrack electron accelerator for the LHeC (left) and the FCC-he (right). The LHeC is shown to be tangential to Point 2 and Point 8. For Point 2 three sizes are drawn corresponding to a fraction of the LHC circumference of 1/3 (outer, default with $E_e = 60\,\text{GeV}$), 1/4 (the size of the SPS, $E_e = 56\,\text{GeV}$) and 1/5 (most inner track, $E_e = 52\,\text{GeV}$). To the right one sees that the 8.9 km default racetrack configuration appears to be rather small as compared to the 100 km ring of the FCC. Present considerations suggest that Point L may be preferred as the position of the ERL, while two GPDs would be located at A and G.

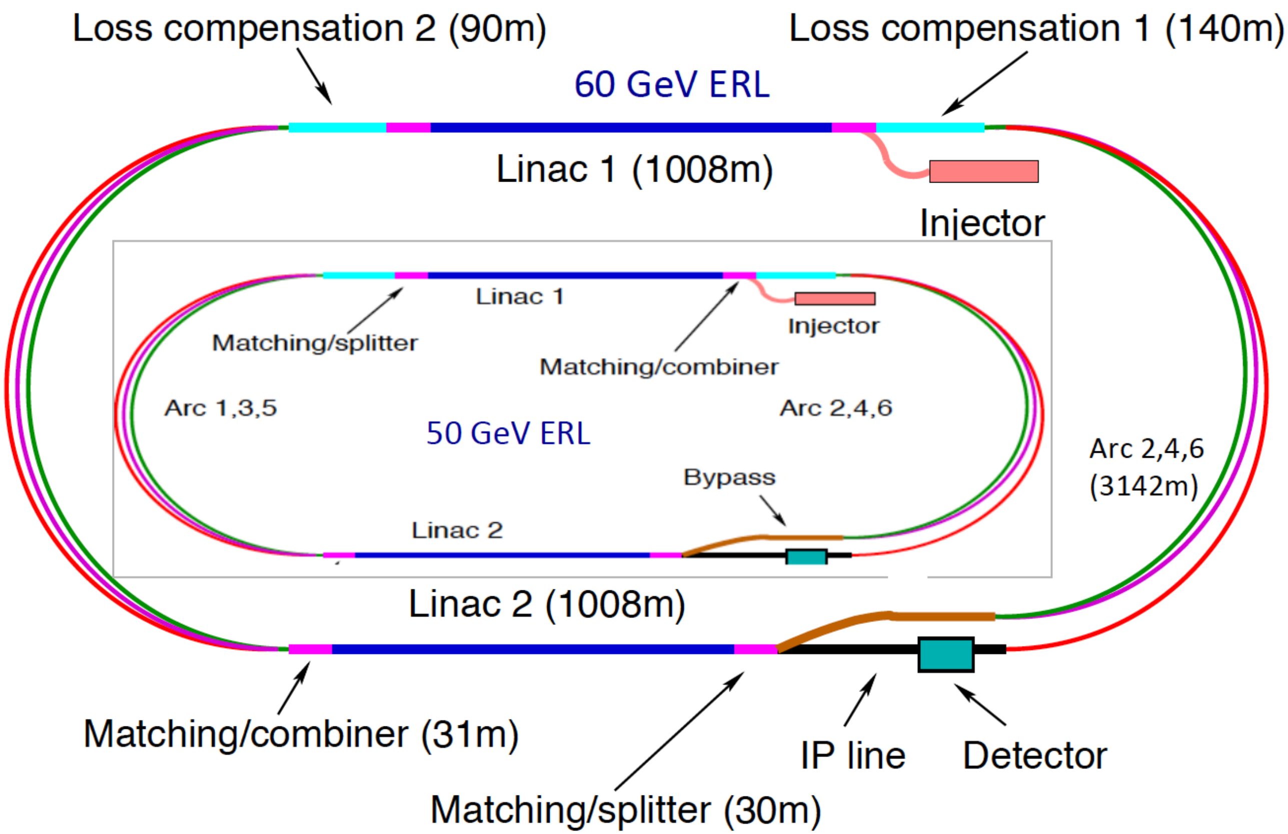


Figure 6: Schematic view of the three-turn LHeC configuration with two oppositely positioned electron linacs and three arcs housed in the same tunnel. Two configurations are shown: Outer: Default $E_e = 60\,\text{GeV}$ with linacs of about 1 km length and 1 km arc radius leading to an ERL circumference of about 9 km, or 1/3 of the LHC length. Inner: Sketch for $E_e = 50\,\text{GeV}$ with linacs of about 0.8 km length and 0.7 km arc radius leading to an ERL circumference of the SPS size, i.e. 6.7 km or 1/4 of the LHC length. An energy larger than 50 GeV is crucial for searches, precision Higgs and low x physics. The 1/4 circumference configuration permits upgrading to about 55 GeV.

From LHeC strategy paper CERN-ACC-NOTE-2018-0084

For cost and effort reasons, the LHeC very likely will use 50..55 GeV., instead of 60.
Full cost estimate made for strategy: O Bruening: CERN-ACC_2018-061: 1.3 BCH (50 GeV)

Very encouraging cavity results

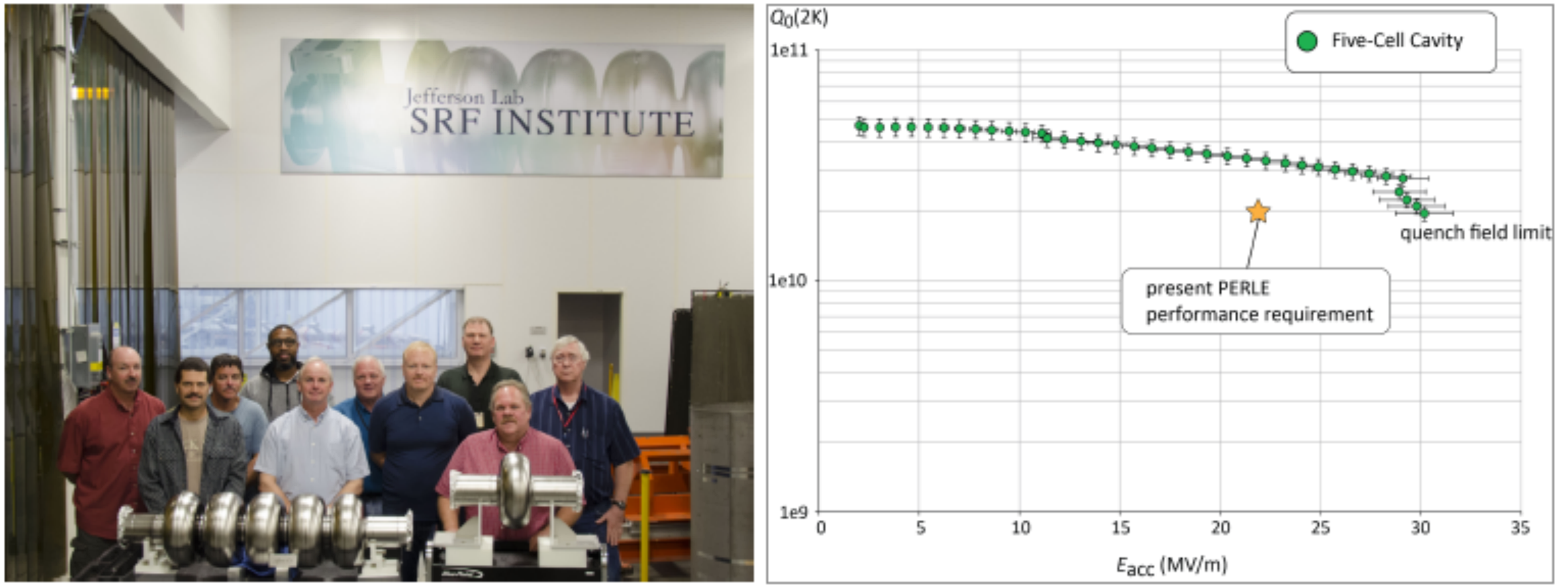


Figure 2: Left: Jlab team behind the 5-cell and a single cell Niobium cavity; Right: Vertical test result of the five-cell 802 MHz Niobium cavity. The yellow star indicates the edge of the performance considered for operation of PERLE with a typical CW gradient optimum around 20 MV/m.

From PERLE strategy paper CERN-ACC-NOTE-2018-0086

Room for somewhat larger gradient, base for high ERL performance and PERLE

Luminosity vs Physics

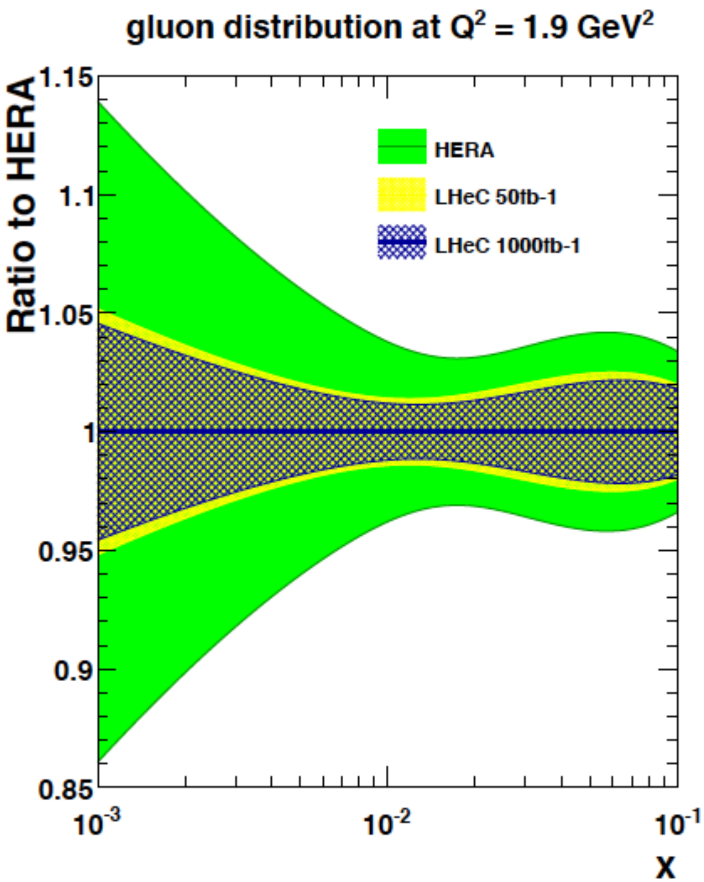


Figure 6: Uncertainty on the determination of the gluon distribution in the x range relevant for Higgs measurements at the LHC, based on the combined HERA data (outer band, green) and for the LHeC with the full data set (inner band, blue) and from the first running period (yellow, around the inner band. The LHeC uncertainties comprise full correlated systematic error estimates besides the statistics.

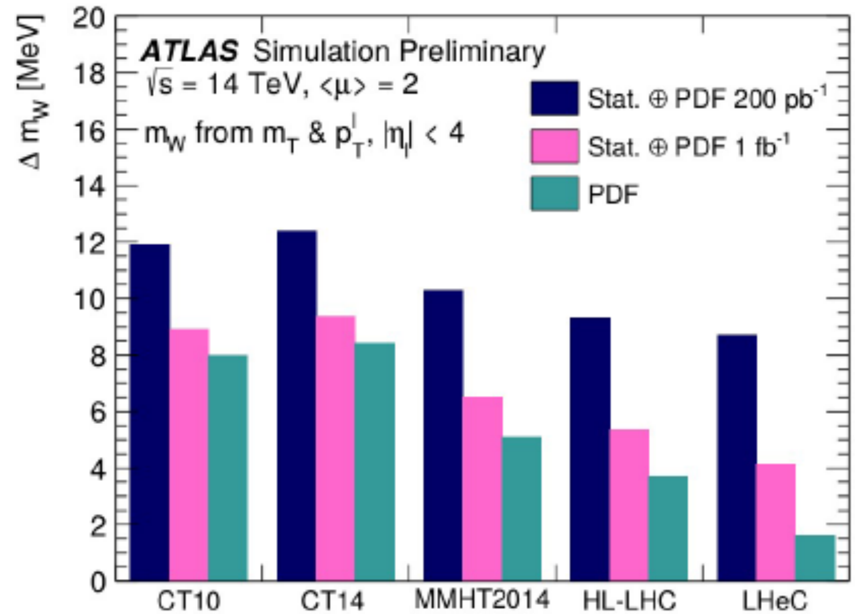
For LHC to have an impact on the search and precision physics program at HL-LHC it is crucial that PDF and QCD information is available early, see C Gwenlan at this workshop.

← PDF study with 50 vs 1000 fb^{-1}

From Higgs in ep paper, imminent.

LHC and LHeC

ATLAS: Impact studies were done on M_W + weak mixing angle, with LHeC prospects



Workshop on
Ultimate Precision at Hadron Colliders

Institut Pascal, Paris-Saclay

Nov. 25 – Dec. 6, 2019

Fabrice Balli, Louis Fayard, Marumi Kado, Zhiqing Zhang, Maarten Boonekamp

Further study on how the exploitation of the LHC can be maximised with LHeC, will also look at EIC potential.

Publications of main results

most recent [cf LHeC web page: http://lhec.web.cern.ch]

Inclusive diffraction at the LHeC and FCC-eh

Néstor Armesto[1], Paul R. Newman[2], Wojciech Słomiński[3], and Anna M. Staśto[4]

[1] *Instituto Galego de Física de Altas Enerxías IGFAE, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Galicia-Spain*
[2] *School of Physics and Astronomy, University of Birmingham, UK*
[3] *Institute of Physics, Jagiellonian University, Krakow, Poland*
[4] *Department of Physics, Penn State University, University Park, PA 16802, USA*

January 29, 2019

Abstract

We analyse the possibilities for the study of inclusive diffraction offered by future electron–proton/nucleus colliders in the TeV regime, the Large Hadron-electron Collider as an upgrade of the HL-LHC and the Future Circular Collider in electron-hadron mode. Compared to *ep* collisions at HERA, we find an extension of the available kinematic range in x by a factor of order 20 and of the maximum Q^2 by a factor of order 100 for LHeC, while the FCC version would extend the coverage by a further order of magnitude both in x and Q^2. This translates into a range of available momentum fraction of the diffractive exchange with respect to the hadron (ξ), down to $10^{-4} - 10^{-5}$ for a wide range of the momentum fraction of the parton with respect to the diffractive exchange (β). Using the same framework and methodology employed in previous studies at HERA and under very conservative assumptions for the luminosities and systematic errors, we find an improvement in the extraction of diffractive parton densities from fits to reduced cross sections for inclusive coherent diffraction in *ep* by about an order of magnitude. We analyse the sensitivity to kinematic cuts and variations of the fit framework. We also note sensitivity to the shape of the gluon distribution, and to physics beyond linear twist-2 DGLAP evolution at moderate Q^2. For eA, we find that an extraction of the currently unmeasured nuclear diffractive parton densities is possible with similar accuracy to that in *ep*.

arXiv:1901.09076

DRAFT 9.4.19

Precision Higgs Physics at High-Energy Electron-Proton Colliders

LHeC Higgs Study Group

G. Azuelos, S. Behera, J. De Blas, D. Hampson, R. Islam, S. Kawaguchi, E. Kay, U. Klein, M. Klein, P. Kostka, M. Kumar, M. Kuze, B. Mellado, M. O'Keefe, R. Li, C. Gwenlan, R. Ruan, T. Sekine, A. Senol, H. Sun, M. Tanaka, K. Wang, C. Zhang

Tentative authorlist - TO BE UPDATED

Abstract. The Higgs boson and its physics have become a central topic of modern particle physics and a key parameter in the evaluation of future high energy collider projects. This paper provides a summary and overview on the potential of future luminous, energy frontier electron-proton colliders, especially the LHeC, the HE-LHC and the FCC-eh, for precision Standard Model measurements of the properties of the Higgs boson in deep inelastic scattering. Detailed analyses are presented on the prospects for accurate measurements of the Higgs boson decays into pairs of bottom and charm quarks. An extended study is performed for estimating the precision on the Higgs couplings in the most abundant decay channels, based on measurements in the charged and weak neutral current DIS reactions. The addition of *ep* information to the expected HL-LHC Higgs coupling measurements is demonstrated to lead to major improvements on the Higgs results one can expect to come from the LHC facility at large.

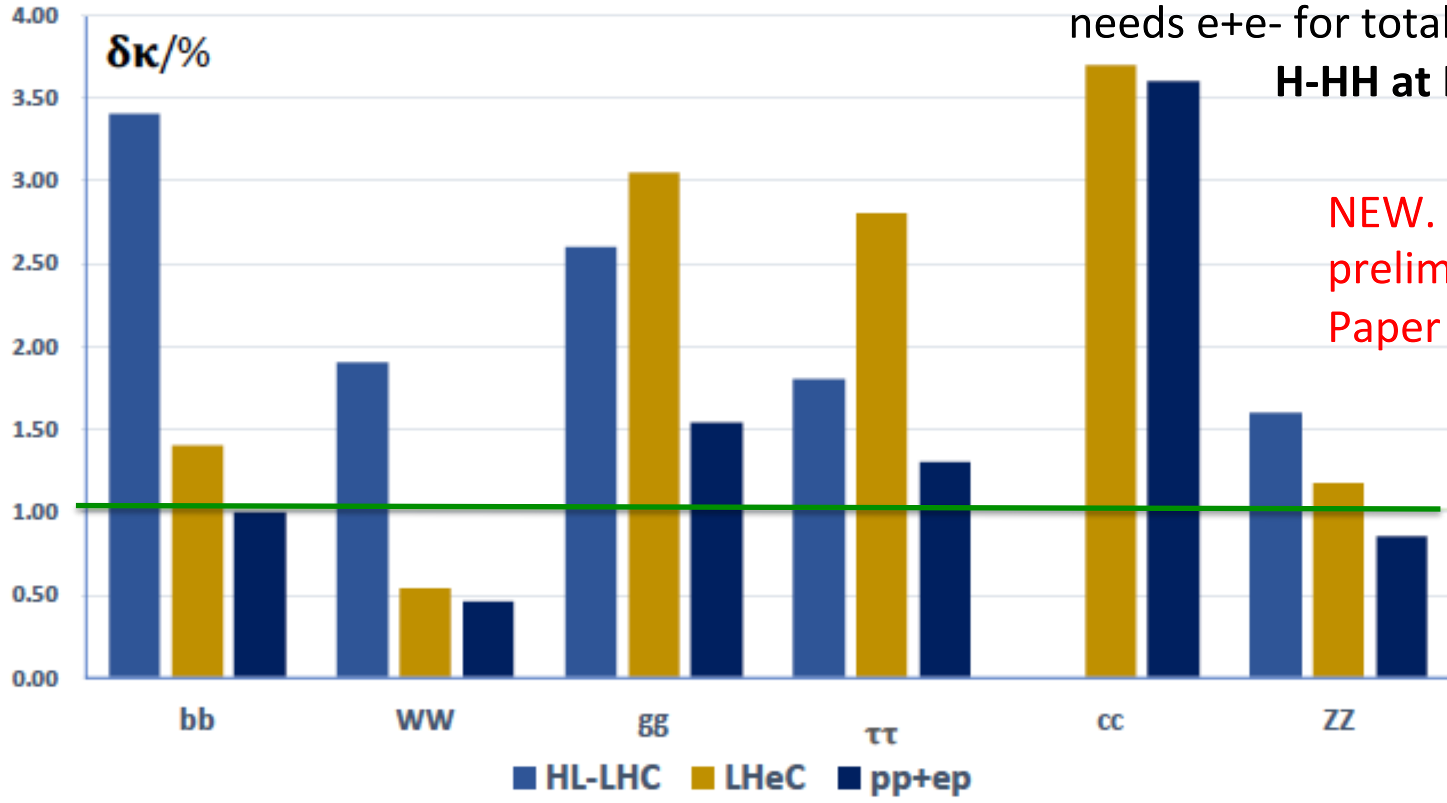
Before Granada, end of April, intended

Talk in Higgs session tomorrow: B Mellado

4.2. Determination of Higgs Couplings in pp and ep

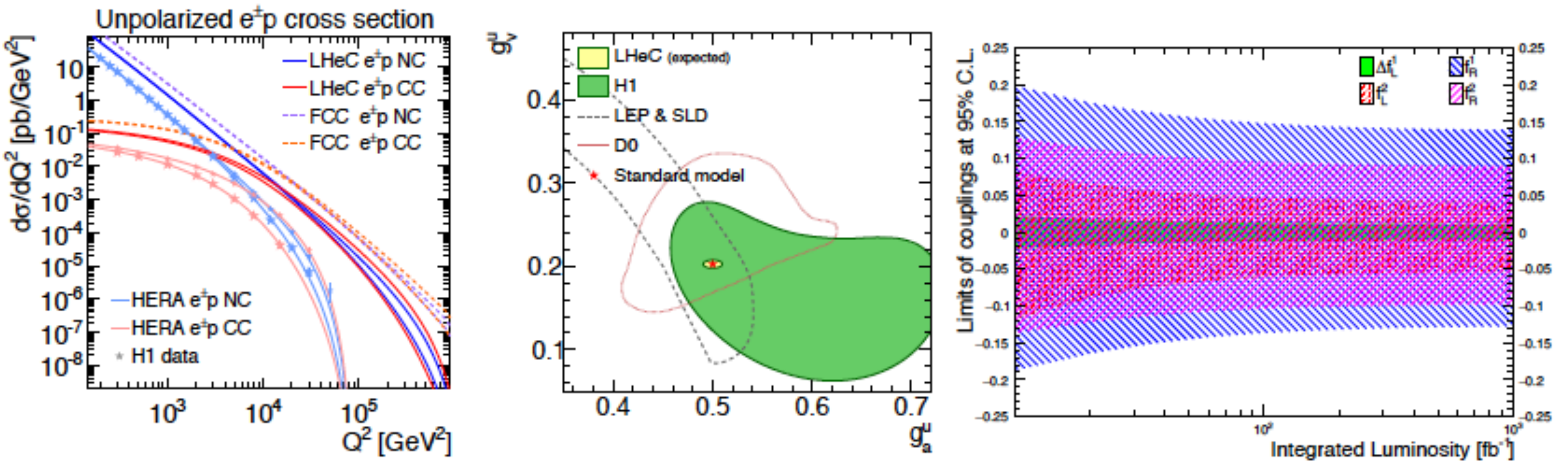
HL-LH(e)C ensures centre of Higgs physics stays at CERN in the thirties. High precision needs e+e- for total width.

H-HH at HL-LHC!



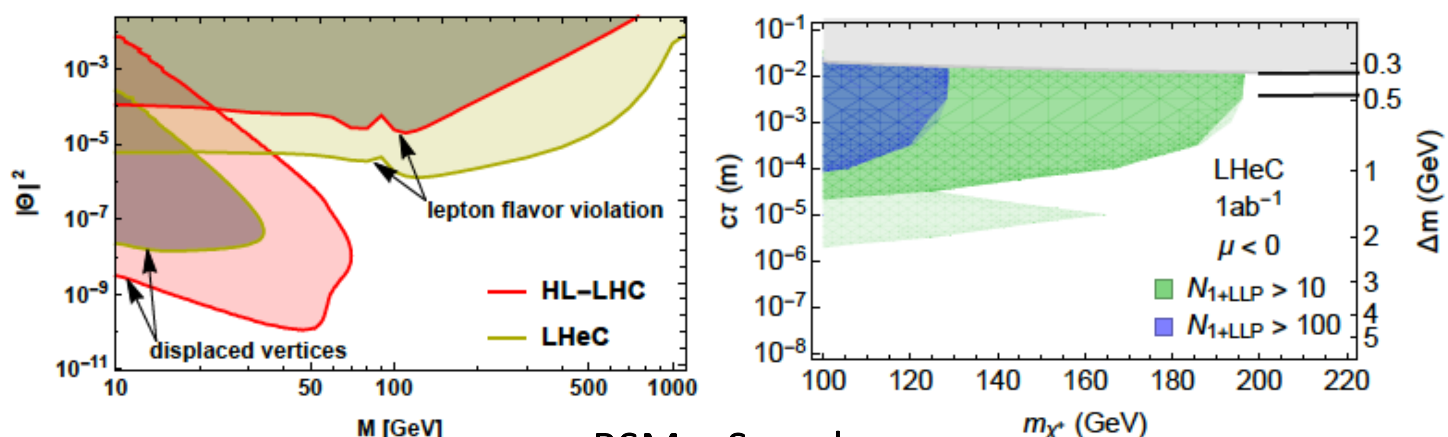
NEW.
preliminary
Paper soon

Figure 4: PRELIMINARY Uncertainties of coupling constant determinations using the kappa framework at the LHC in the six most frequent decay channels from the combination of ATLAS and CMS prospects at HL-LHC (blue, $3\,\mathrm{ab}^{-1}$), the LHeC (gold, $1\,\mathrm{ab}^{-1}$) and the combination of *pp* and *ee* (dark blue).



Electroweak+Top Physics

Figure 1: Left: Unpolarised inclusive NC and CC DIS cross sections as a function of Q^2 at the LHeC, in comparison to HERA (H1 [17]) and FCC-eh expectations; Middle: Determination of the up-quark weak neutral current vector and axial-vector couplings with LHeC (yellow) compared with current determinations; Right: Expected sensitivities as a function of the integrated luminosity on the SM and anomalous W_{tb} couplings [18].



BSM + Searches

Figure 4: Left: Prospects for direct right-handed neutrino searches at the LHeC, first estimates for HL-LHC prospects for comparison, based on [34]. Right: Reach for long-lived Higgsinos in the mass (m_χ) - lifetime ($c\tau$) plane, compared to disappearing tracks at the HL-LHC [35], shown by the black lines. Light shading indicates the uncertainty in the predicted number of events due to different hadronization and LLP reconstruction assumptions. For details, see [36].

From LHeC strategy paper CERN-ACC-NOTE-2018-0084

Energy and Luminosity ePb Prospects

Table 3: Baseline parameters of future electron-ion collider configurations based on the electron ERL, in concurrent eA and AA operation mode.

parameter [unit]	LHeC (HL-LHC)	eA at HE-LHC	FCC-he
$E_{\rm Pb}$ [PeV]	0.574	1.03	4.1
E_e [GeV]	60	60	60
$\sqrt{s_{eN}}$ electron-nucleon [TeV]	0.8	1.1	2.2
bunch spacing [ns]	50	50	100
no. of bunches	1200	1200	2072
ions per bunch [10^8]	1.8	1.8	1.8
$\gamma\epsilon_A$ [μm]	1.5	1.0	0.9
electrons per bunch [10^9]	4.67	6.2	12.5
electron current [mA]	15	20	20
IP beta function β_A^* [cm]	7	10	15
hourglass factor H_{geom}	0.9	0.9	0.9
pinch factor H_{b-b}	1.3	1.3	1.3
bunch filling H_{coll}	0.8	0.8	0.8
luminosity [10^{32}cm^{-2}s^{-1}]	7	18	54

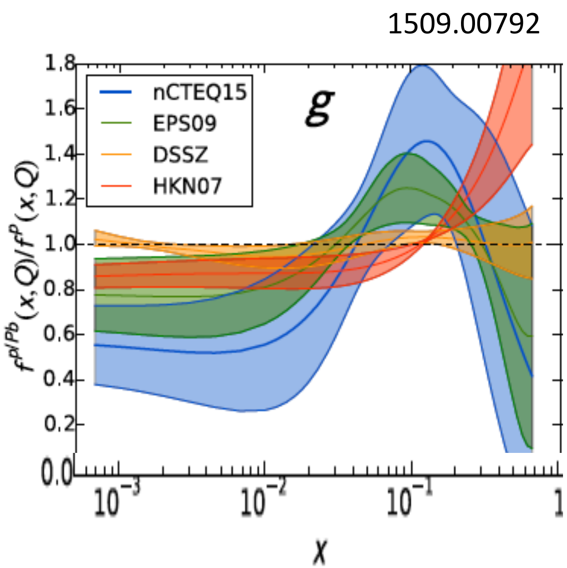
Oliver Brüning[1], John Jowett[1], Max Klein[2],
Dario Pellegrini[1], Daniel Schulte[1], Frank Zimmermann[1]

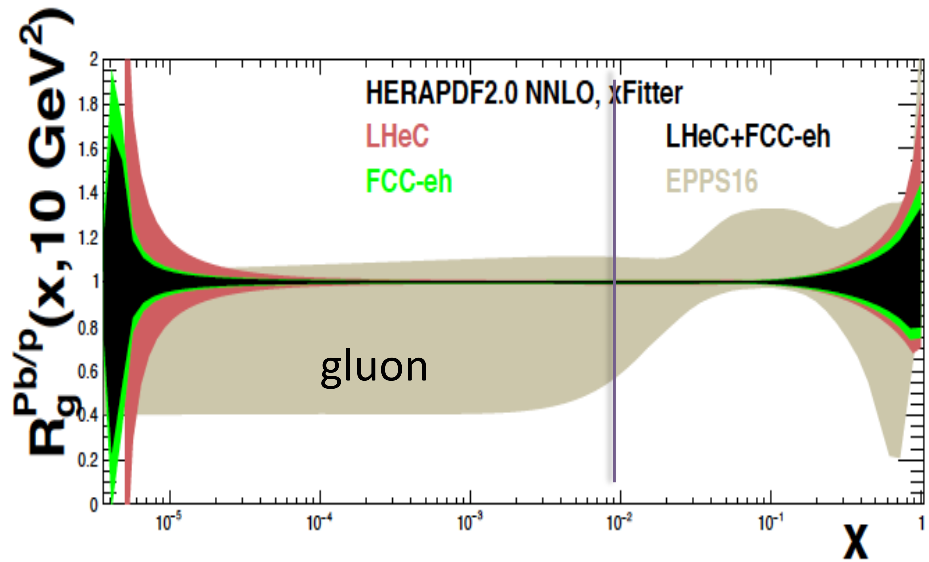
EDMS 17979910 | FCC-ACC-RPT-0012

2017

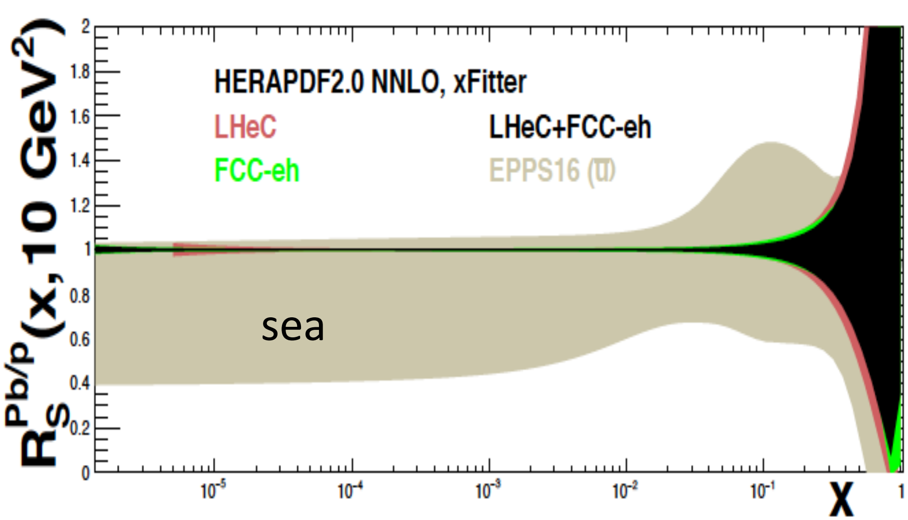
Determination of p and A PDFs at LHeC/FCCeh

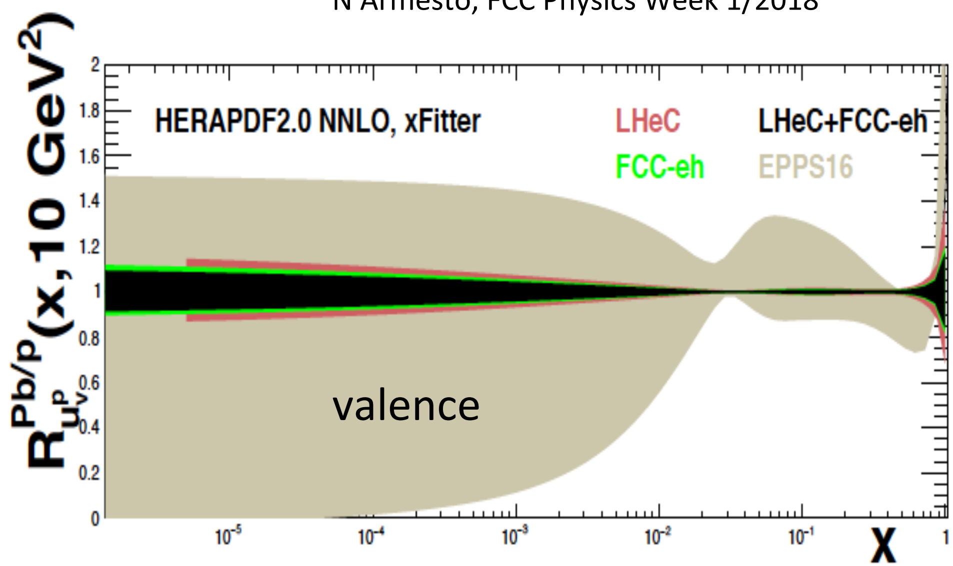
present status → on xg Pb/p





N Armesto, FCC Physics Week 1/2018





LHeC: Full error, $\Delta\chi^2 = 1$. EPPS $\Delta\chi^2 = 52$

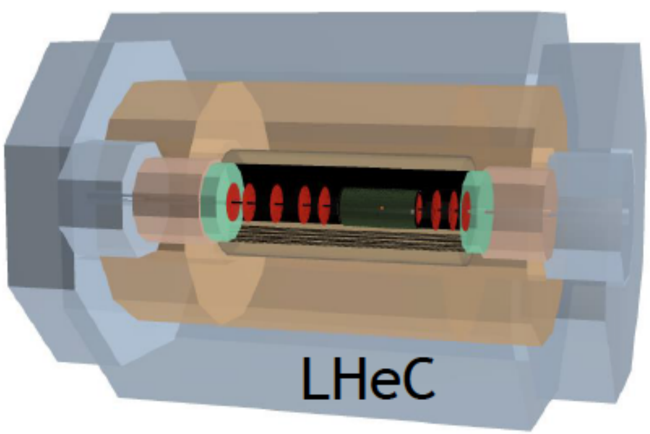
- CDR 2012

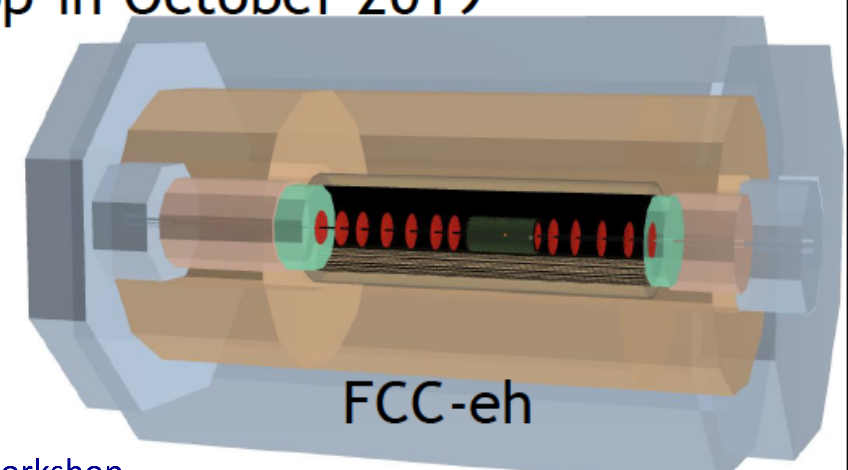
Summary

- Since then
  1) Possibility of 10^{34} cm^{-2} s^{-1} → new environment
  2) LHC Higgs discovery → new physics focus
  3) Longer term perspective of HE-LHeC / FCC-eh

- Current ongoing work: optimize w.r.t. precision physics, H, t ... re-evaluation of tracking & calorimetry, interaction region

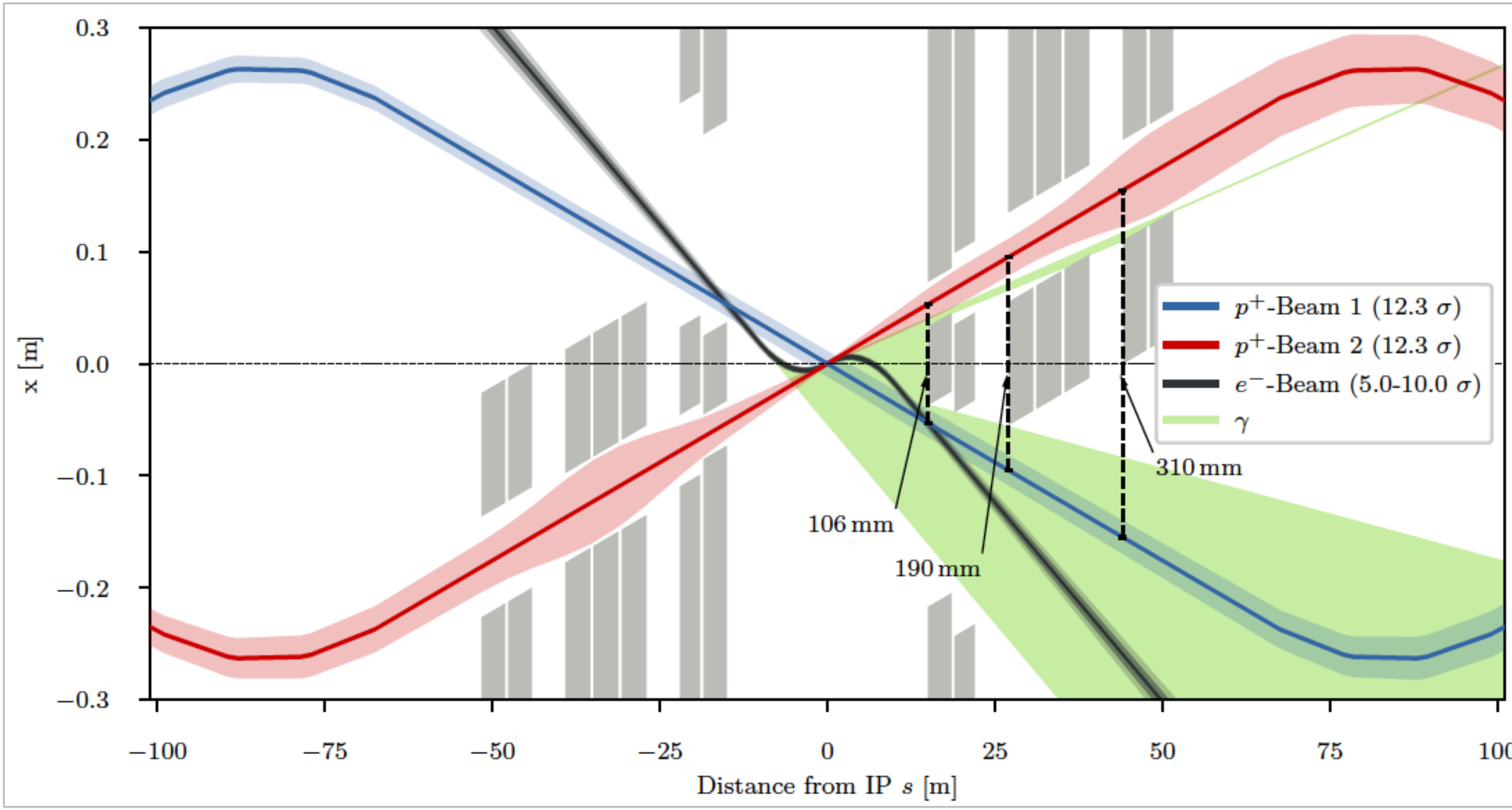
- Next goal ...
  1) Update CDR (physics, technical) → "The LHeC at High Luminosity" converging at workshop in October 2019





P Newman, this workshop

Interaction Region



Roman Martin

Study for LHeC and FCC-eh; reduction of synchrotron load with magnet alterations and 50 GeV
K Andre, E Cruz, B Holzer, R Martin, R Tomas, with B Parker, S Russenschuck. Work in progress

PERLE

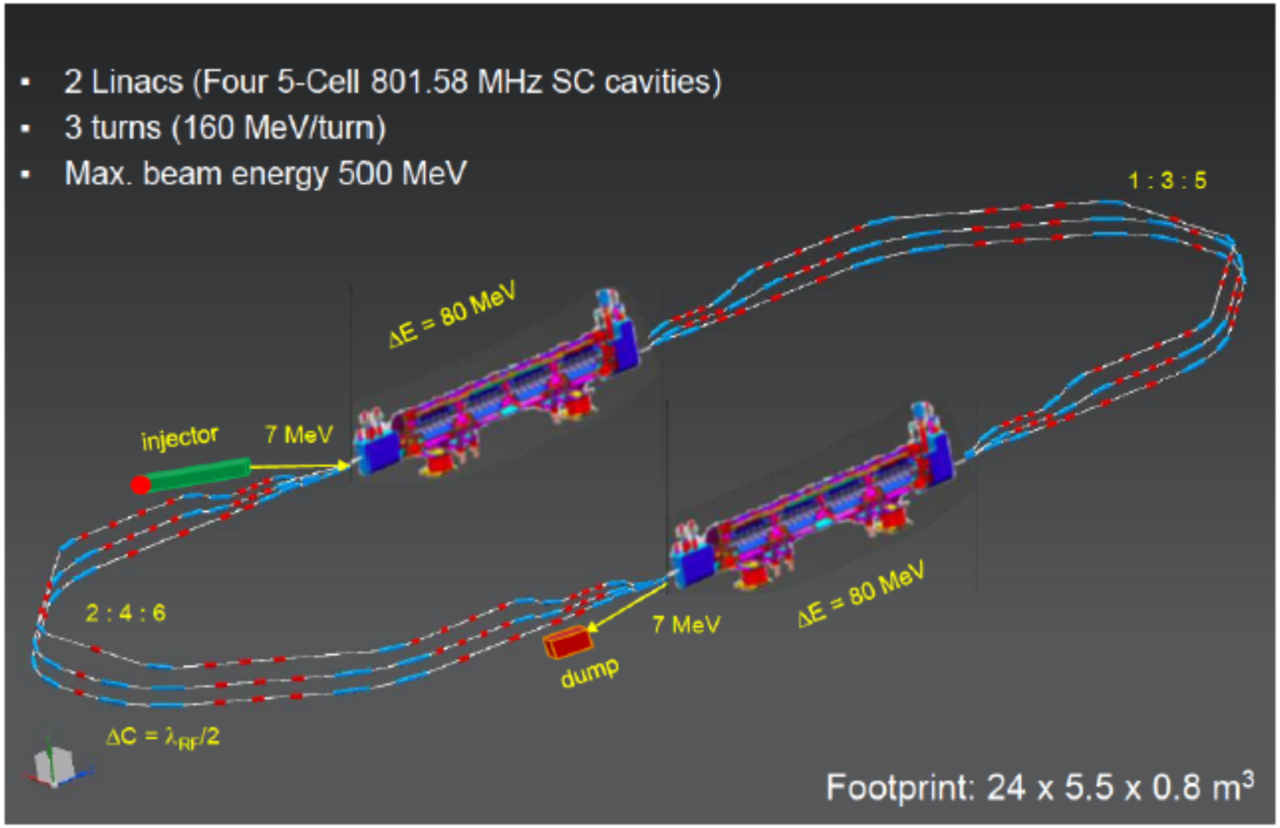


Figure 1: PERLE layout featuring two parallel linacs each hosting a cryomodule housing four 5-cell SC cavities, achieving 500 MeV in three passes.

From PERLE strategy paper CERN-ACC-NOTE-2018-0086

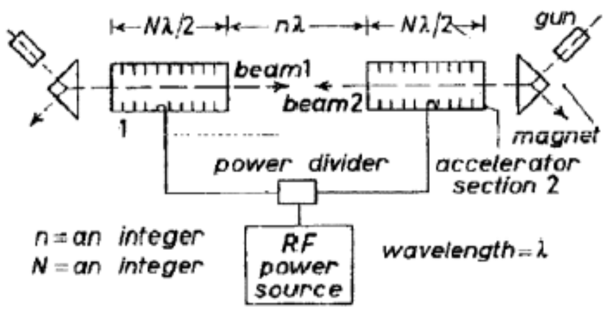
cf Walid Kaabi, this workshop 9.4. for more information

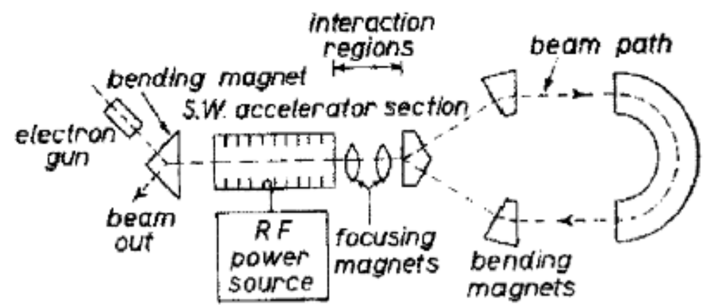
Energy Recovery

Motivation: Accelerator Technology Development

- **Energy Recovery Linac concept:** First proposal 50 years ago

  M. Tigner: "A Possible Apparatus for Electron Clashing-Beam Experiments",
  Il Nuovo Cimento Series 10, Vol. 37, issue 3, pp 1228-1231,1 Giugno 1965





- **First Tests:** Done at SCA @ Stanford in 1986

  Interesting concept for FELs and Compton photon light sources,
  and high current electron cooler concepts and **colliders → SRF!!!**

Revolutionary concept – viable today owing to SCRF quality. Power reduction ~ tenfold

PERLE

From PERLE strategy paper CERN-ACC-NOTE-2018-0086

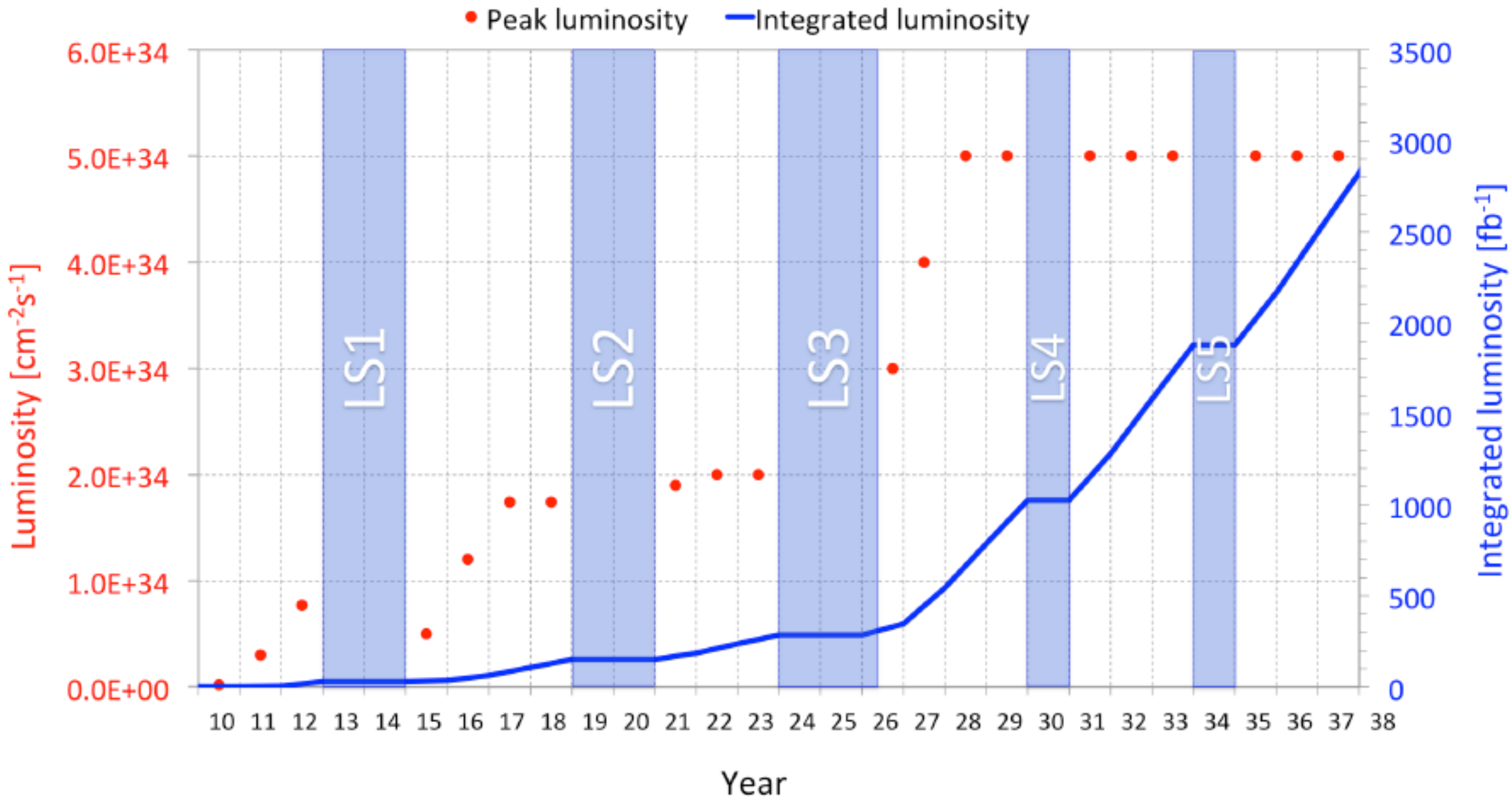
Target Date	Milestone
May 2019	Dressed cavity design completion (HOM coupler, He tank)
Sept 2019	Adapted SPL cryomodule design completion
End 2019	Injection line (booster) design completion
Early 2020	Technical Design Report
Mid 2021	SPL cryomodule assembly
2022	Sequential installation at Orsay
2023	Phase 1 operation
2024	Second cryomodule completion
2025	Phase 2 operation

Table 2: Milestones, tentative, for PERLE at Orsay.

Radiation safety: no nuclear requirements – long process, nearly done: Orsay suited!
Gun from Daresbury (ALICE) being sent to Orsay. Work on next milestones..

cBeta to demonstrate multi-turn ERL (1.3GHz, FFAG, lower currents).
BERLIN-PRO single turn, 1.3GHz, 100mA technical ERL Collaboration

Time Line for Nominal HL-LHC Performance



HL-LHC: Major effort to upgrade the LHC luminosity (~2 BCHF: Linac4,HL-LHC,ATLAS+CMS)
Rare channels, new particles, high precision, extended search range and H-HH (5σ in sight)
LS3 is an almost 3 years shutdown which may start in 2024 → 8 years away from HL data

Particle Physics at O(1) TeV ~2010-2050

Four Decades

The goal of current developments is to maximally exploit the LHC and to complement It with ep (LHeC) and ee (ILC, CepC..??) colliders to explore the TeV scale and find new directions of HEP as theory is less prescriptive

Electrons may be brought to the LHC and a new 1 TeV energy eh collider can be built, with its own fundamental physics, at a cost O(1/10) that of the ee machines in sight.

pp

LHC(b)

Rare Higgs Decays, H-HH?
Precision W,Z,top,
QCD, Flavour
No SUSY, BSM - yet

ep

LHeC

Maximise LHC Physics:
Precision QCD, α_s , el.weak
Precision Higgs
BSM?

eA

Higgs + New Physics?
High Precision & Searches

e^+e^-

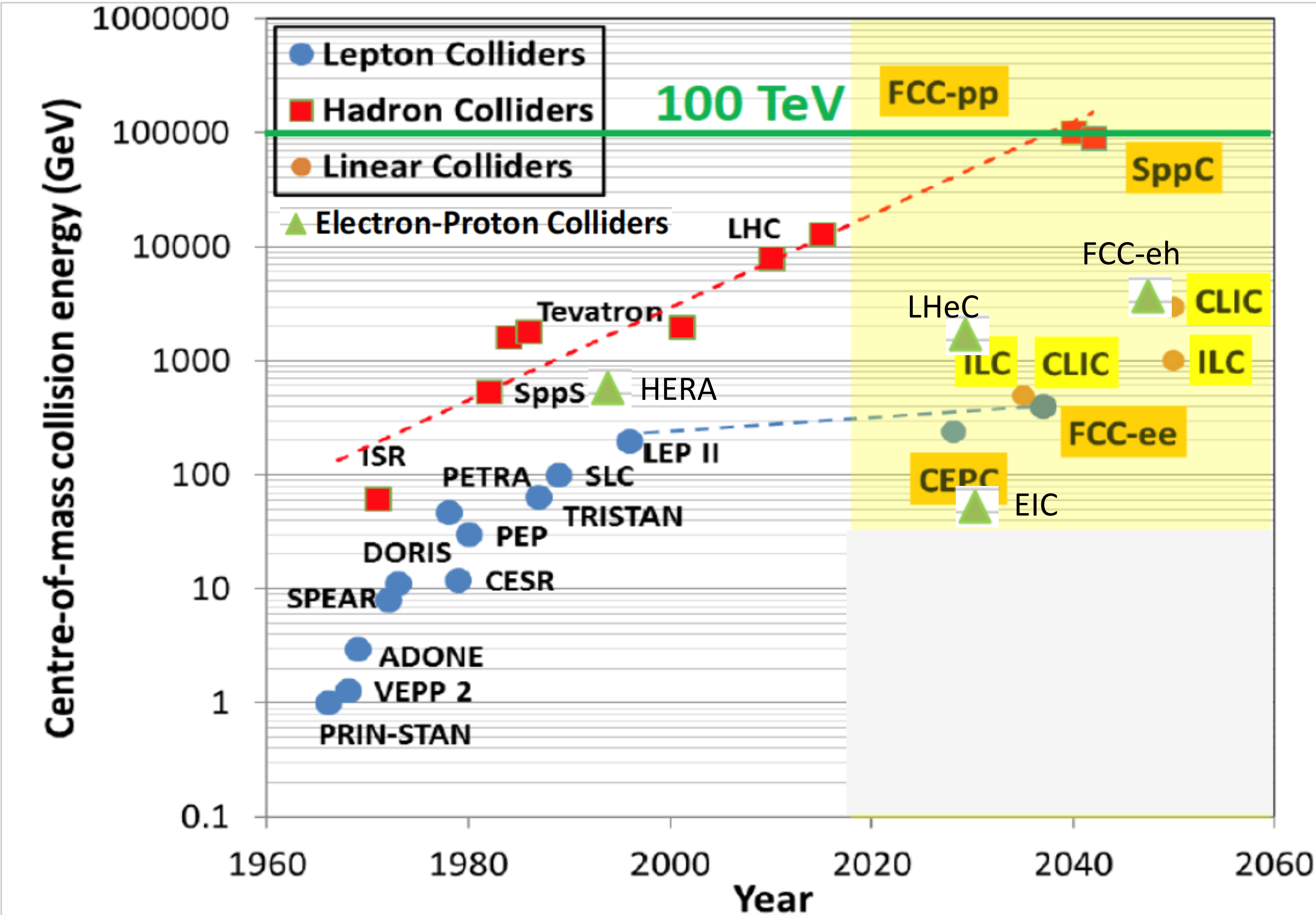
ILC, CepC, CLIC

Precision Higgs
Precision el.weak
α_s
BSM?

SuperB

Neutrino Physics
Hierarchy, CP, .. factory

MK June 2018



Adapted from M Benedikt (3/19)

Strategy of Energy Frontier HEP

- Physics, regions, continents, technology, energy, power, sociology, politics, science..
- Theory, unlike before is of little use, back to 1969 (quark discovery → SM)
- HEP was not successful with machines more expensive than LHC: SSC and ILC
- What is then the right strategy?
- The sequential model: all at CERN: HL-LHC − FCC-ee − FCC-hh/eh (2070ish)
  [the earth is the centre of the world, but where is the sun]
- The parallel model: e+e- in Asia, CERN: HL-LHC → FCC-hh/eh
  [global coordination]
- It is possible that HEP in Europe does not have the means to go beyond the LHC infrastructure in the foreseeable future
- We have to value the HL-LHC as high as possible, adding ep sustains it
- For the next 5 years to a decade, it is crucial that technology gets pushed (dipoles, RF)

Three Messages from the 2m LiNAC

-- **you do NOT need to promise to discover dark matter or know what new to expect when you increase the energy range** (a comment for Sabine H., we yet may have to readjust our perception about nature, its richness and our ability to predict it. 'we like to see the field to be driven by experiment' – Burt Richter 2009)

-- **you can build a 2 mile electron linac in 3 years time, if you really want it**
of course we could build LHeC as a bridge project, if only we decided to do so!

-- **electron-proton scattering is the best means to explore the substructure of matter**
a necessary complement to the LHC/FCC and moreover, now a unique Higgs facility

50 years since the discovery of quarks by the SLAC-MIT ep scattering experiment

---

W.K.H. PANOFSKY Vienna 8/1968 SLAC-PUB-502

Therefore theoretical speculations are focused on the possibility that these data might give evidence on the behaviour of point-like, charged structures within the nucleon.

Large Hadron Electron Collider on one page

E_e = 10-60 GeV, E_p =1-7 TeV: √s = 200 − 1300 GeV. **Kinematics**: $0 < Q^2 < s$, $1 > x \geq 10^{-6}$ (DIS)
ePolarisation P=±80%. Positrons: significantly lower intensity, unpolarised
Luminosity: O(10^{34}) $cm^{-2} s^{-1}$. integrated O(1) ab^{-1} for HL LHC and 2 ab^{-1} for HE LHC/FCCeh
e-ions 6 10^{32} $cm^{-2} s^{-1}$ O(10)fb^{-1} in ePb . O(1)fb^{-1} for ep F_L measurements

LHeC

Physics: QCD: develop+break? The world's best microscope. BSM (H, top, ν, SUSY..)
Transformations: Searches at LHC, LHC as Higgs Precision Facility, QCD of Nuclear Dynamics
LHeC has a deep, unique QCD p/A, H and BSM precision and discovery physics programme.

1802.04317

Time: Determined by the Large Hadron Collider (HL LHC needs till ~2040 for 3 ab^{-1})
LHeC: Detector Installation in 2 years, earliest in LS4 (2030/31).
HE LHC: re-use ERL. In between HL-HE, 10 years time of ERL Physics (laser, γγ..)
Very long term: FCC-eh

http://lhec.web.cern.ch

Challenges: Demonstration of ERL Technology (high electron current, multi-turn)
Design 3-beam IR for concurrent ep+pp operation, New Detector with Taggers - in 10 years.

The LHeC is a great opportunity to sustain deep inelastic physics within future HEP.
The cost of an ep Higgs event is O(1/10) of that at any of the 4 e^+e^- machines under consideration
It can be done: the LINAC is shorter than 2 miles and the time we have longer than HERA had.

CERN and world HEP: Vital to make the High Luminosity LHC programme a success.

Thanks

To the many colleagues who expressed an interest in ep/A and have been working

To the International Advisory Committee chaired by H.Schopper

To the FCC Advisory Committee chaired by Guenter Dissertori

To the convenors and members of the coordination group

To CERNs directorate for their interest even when that isn't unlimited − yet

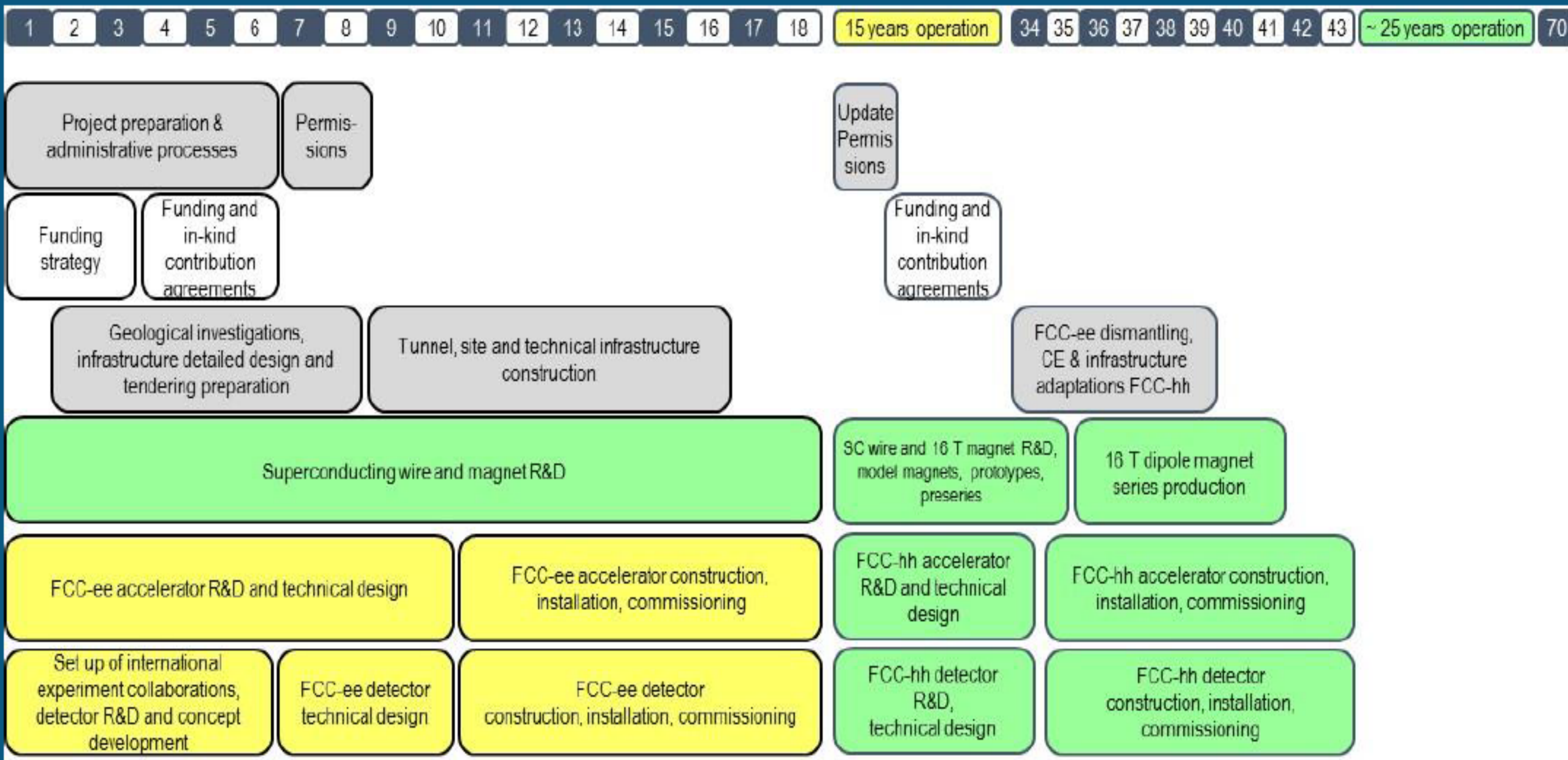
To leaders and colleagues from CNRS/Orsay, BINP Novosibirsk, CERN, Daresbury, Liverpool, Jlab and other institutions for their engagement to launch PERLE

For your attention and cooperation

backup

M Benedikt at Liverpool 22.3.19

FCC integrated project – technical timeline



A coherent HEP program throughout the 21st century

Is this what we want, does that sustain our field, when would be year 1?, what about: non EU, ep?

Higgs Prospects

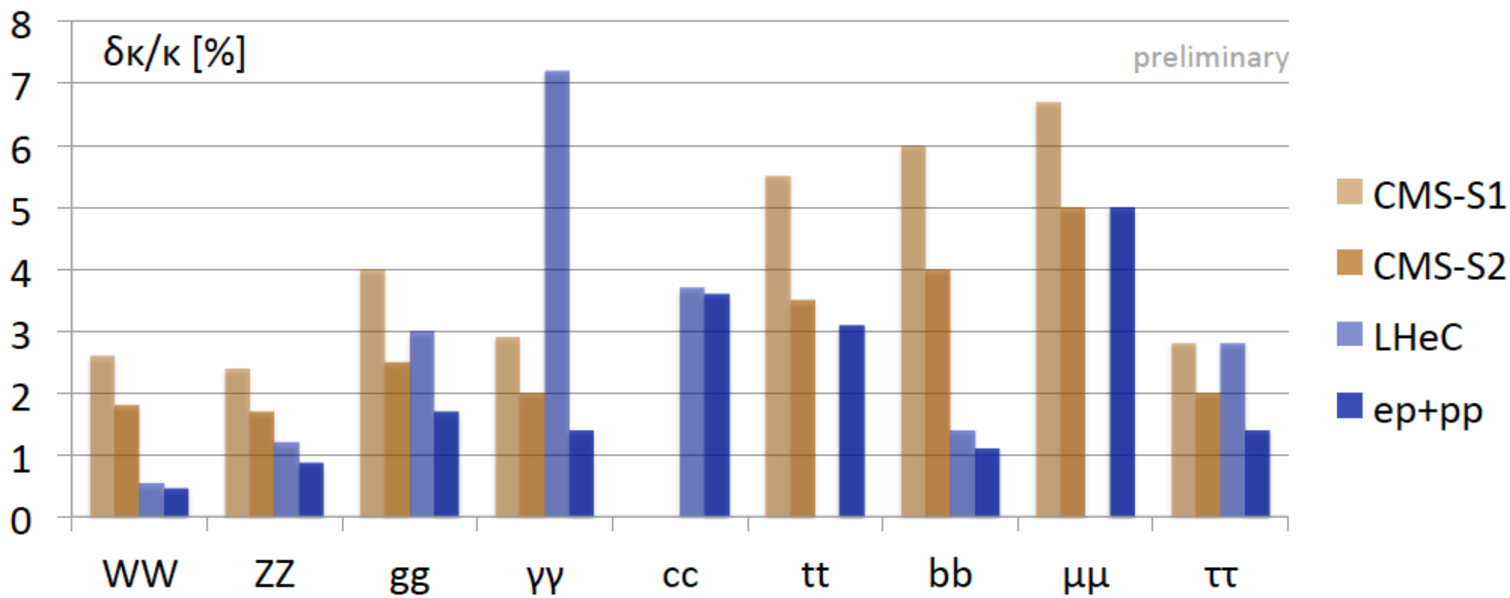


Figure 3: Determination of the κ scaling parameter uncertainties with SM width: Brown (light/dark): CMS with systematic error assumption S1/S2 [30]; Light Blue: LHeC; Dark Blue: Joint κ fit to CMS (S2) and LHeC H decay signal strengths. Note that LHC has no significant charm result, while LHeC has no precise results for very rare processes, as $H \to \mu\mu$.

From LHeC strategy paper CERN-ACC-NOTE-2018-0084

- Scenario S2 assumes that the theory uncertainty is halved, magically.
- CMS S2 prospects very close to CMS+ATLAS prospect from HL-LHC Workshop, for example: [bb: 4 → 3.4%, WW: 1.8 → 1.8% etc. note these are kappa values from joint fit, with cc=SM]

what Higgs precision do we need?

- If new particles with TeV mass, effects on Higgs couplings are small, need ILC precision to confirm and decipher them

  - Little Higgs models with TeV scale partners

$$\frac{g_{hgg}}{g_{h_{SM}gg}} = 1-(5\% \sim 9\%)$$
$$\frac{g_{h\gamma\gamma}}{g_{h_{SM}\gamma\gamma}} = 1-(5\% \sim 6\%)$$

  - Heavy Higgs effects

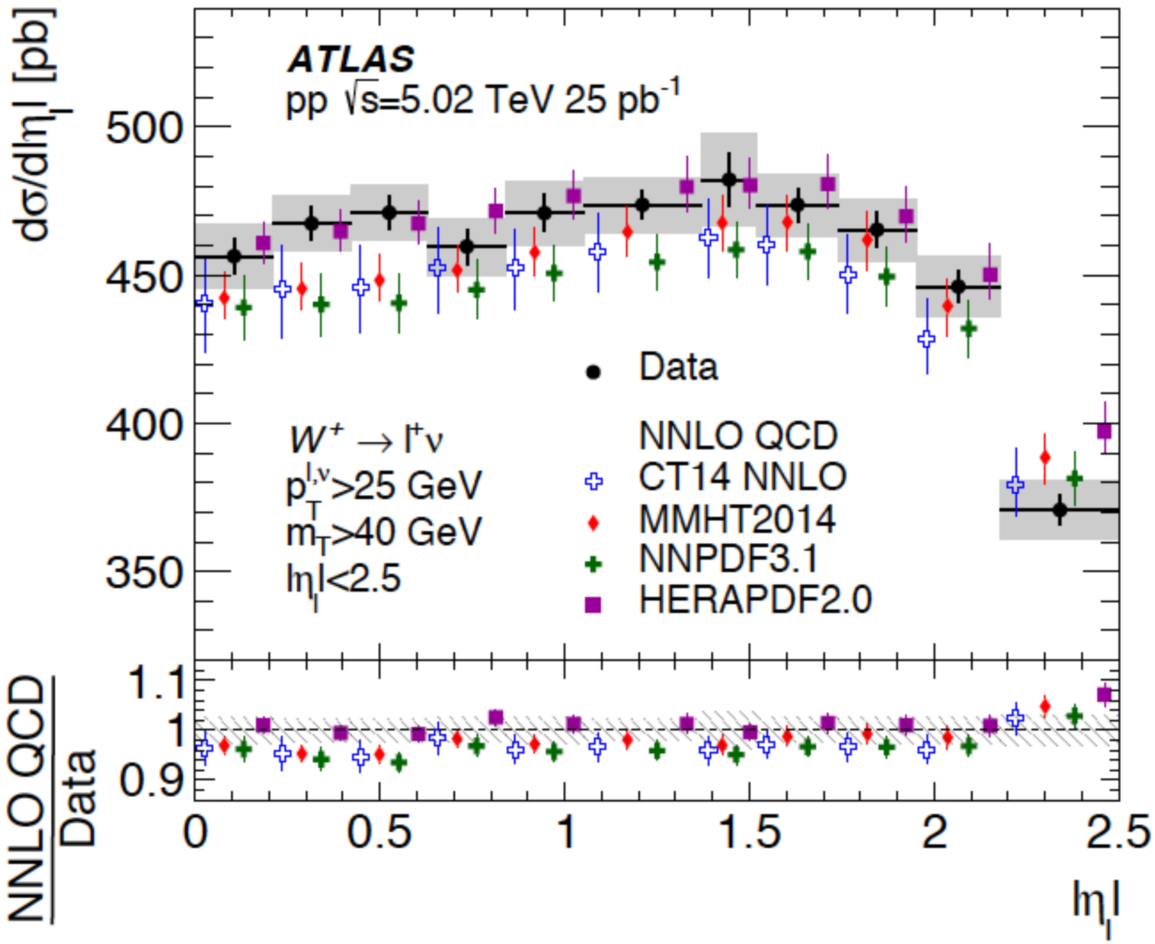
$$\frac{g_{hbb}}{g_{h_{SM}bb}} = \frac{g_{h\tau\tau}}{g_{h_{SM}\tau\tau}} \simeq 1+1.7\%\left(\frac{1\ \mathrm{TeV}}{m_A}\right)^2$$

  - Scalar top partner effects

$$\frac{g_{hgg}}{g_{h_{SM}gg}} \simeq 1+1.4\%\left(\frac{1\ \mathrm{TeV}}{m_T}\right)^2, \qquad \frac{g_{h\gamma\gamma}}{g_{h_{SM}\gamma\gamma}} \simeq 1-0.4\%\left(\frac{1\ \mathrm{TeV}}{m_T}\right)^2$$

ILC TDR Volume 2

W and Z



ATLAS
5 TeV W,Z data
1810.08424

HERAPDF2.0 is best and very good while CT14 is worst, as are others.
Ideal concept: import PDFs from ep and confront them with LHC data.
This tests QCD, avoids PDFs from pp and enables searches for BSM.

Jets

Rapidity ranges	P_{obs} CT14	MMHT2014	NNPDF3.0	HERAPDF2.0
Anti-k_t jets $R = 0.4$				
$\|y\| < 0.5$	44%	28%	25%	16%
$0.5 \leq \|y\| < 1.0$	43%	29%	18%	18%
$1.0 \leq \|y\| < 1.5$	44%	47%	46%	69%
$1.5 \leq \|y\| < 2.0$	3.7%	4.6%	7.7%	7.0%
$2.0 \leq \|y\| < 2.5$	92%	89%	89%	35%
$2.5 \leq \|y\| < 3.0$	4.5%	6.2%	16%	9.6%
Anti-k_t jets $R = 0.6$				
$\|y\| < 0.5$	6.7%	4.9%	4.6%	1.1%
$0.5 \leq \|y\| < 1.0$	1.3%	0.7%	0.4%	0.2%
$1.0 \leq \|y\| < 1.5$	30%	33%	47%	67%
$1.5 \leq \|y\| < 2.0$	12%	16%	15%	3.1%
$2.0 \leq \|y\| < 2.5$	94%	94%	91%	38%
$2.5 \leq \|y\| < 3.0$	13%	15%	20%	8.6%

Table 2: Observed P_{obs} values evaluated for the NLO QCD predictions corrected for non-perturbative and electroweak effects and the measured inclusive jet cross-section of anti-k_t jets with $R = 0.4$ and $R = 0.6$. Only measurements with $p_T > 100$ GeV are included. The predictions are evaluated for various PDF sets. The default scale choice $p_T^{jet,max}$ is used.

NNPDF 1706.00428

Impossible to achieve a good description of all rapidity bins with correlations included…

Used only central bin

ATLAS: 1706.03192 8 TeV jet data
"Tensions between the data and the theory predictions are observed"

CT14 best, but not good, and HERAPDF2.0 worst, as opposed to W paper

Very extensive studies on data correlations, including also 7 + 13 TeV

There is no simple pattern on how PDF sets describe LHC data. Using their projections as HL-LHC PDFs is indeed questionable.