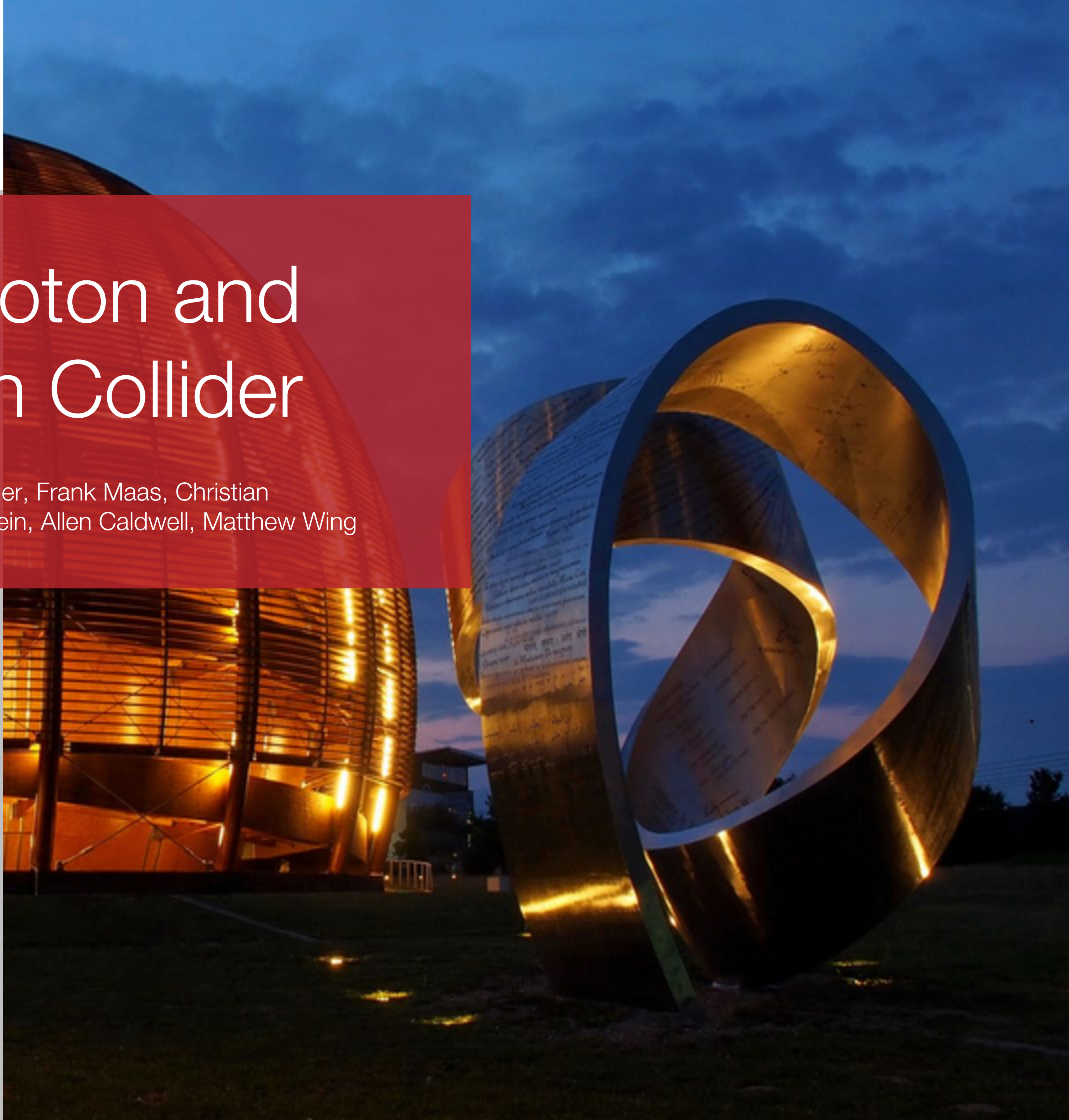
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

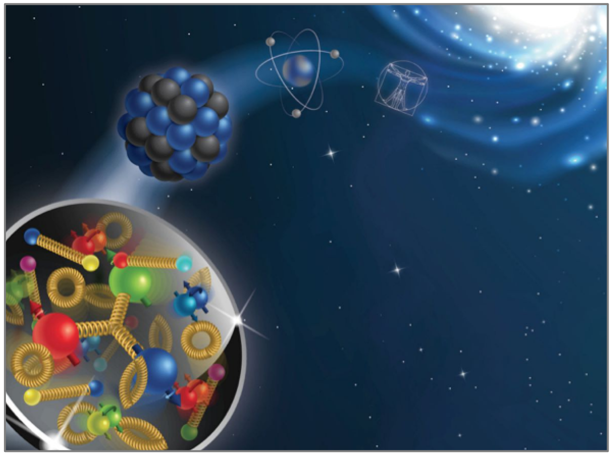
Electron-Proton and Electron-Ion Collider

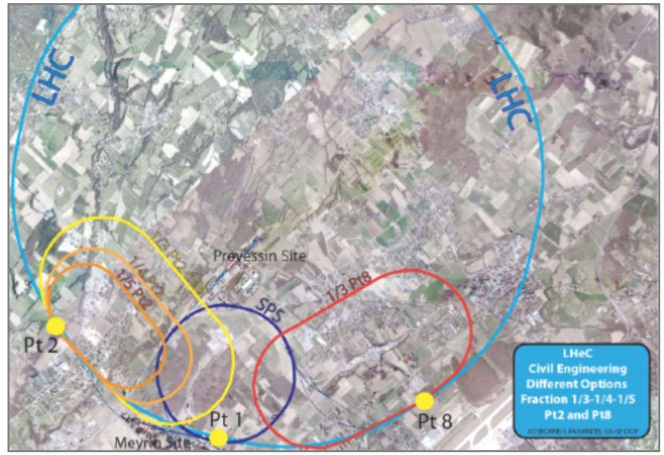
Matthias Schott

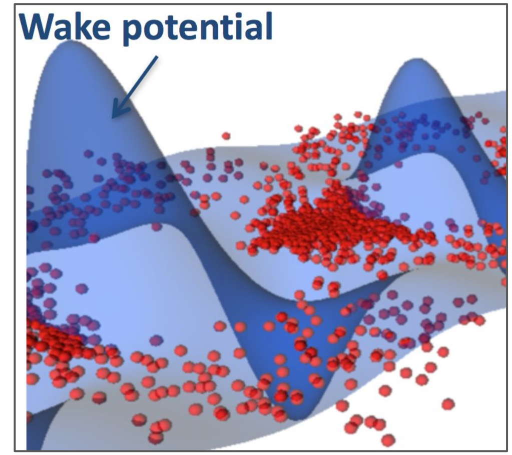
with help of Elke-Caroline Aschenauer, Frank Maas, Christian Schwanenberger, Max Klein, Uta Klein, Allen Caldwell, Matthew Wing



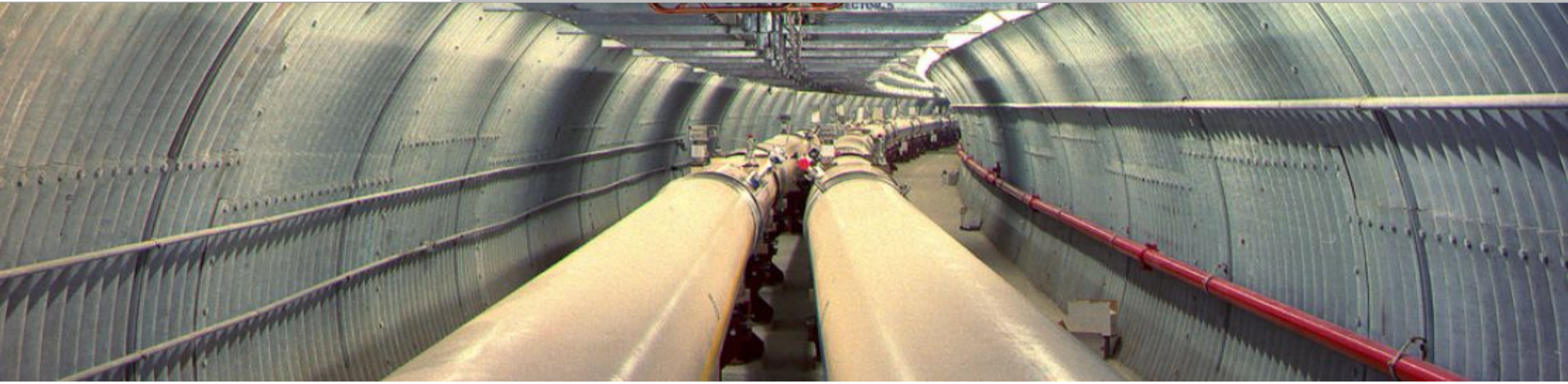
Overview







- Disclaimer: I am not an expert on any of the following projects and topics
  - but experts are in the room
- Three projects covered
  - EIC in the US
  - LHeC
  - VHEeP (and PEPIC): very high energy eP and eA colliders
- Each project will be summarized in a few slides based on the previous workshop, followed by updates and points for discussion
  - Status studies in Europe (LHeC, FCC-ep) by M. Klein
  - Status of studies in the US (EIC) by E.-C. Aschenauer

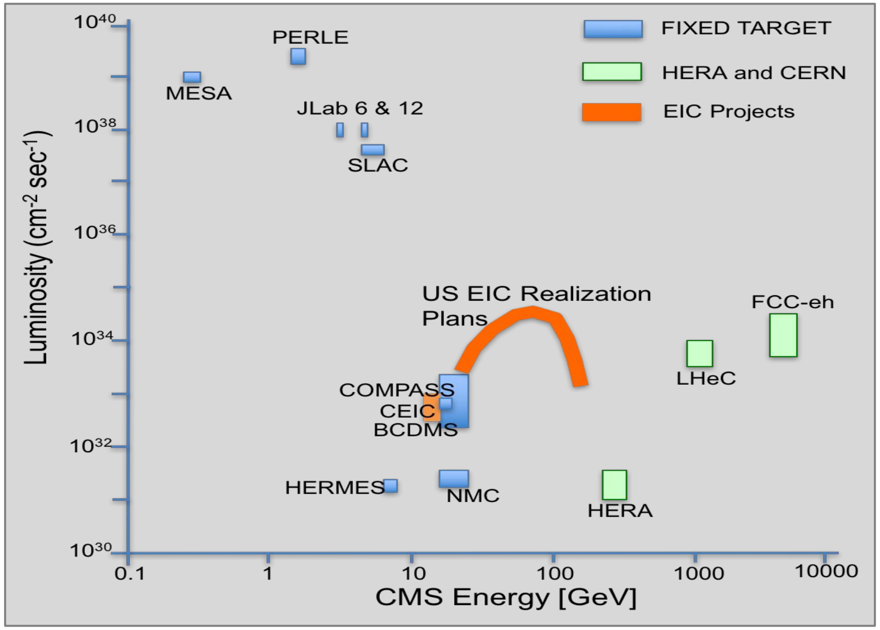


Electron Ion Collider in the US

Some basic facts on EIC in the US

- eRHIC: Electron-Ion Collider at BNL
  - arXiv:1409.1633 for linac-ring option
  - 5-18 GeV polarized electrons
  - 275 GeV polarized protons / 110 GeV/u heavy ion beams
  - also polarized p, deuterium and He-3

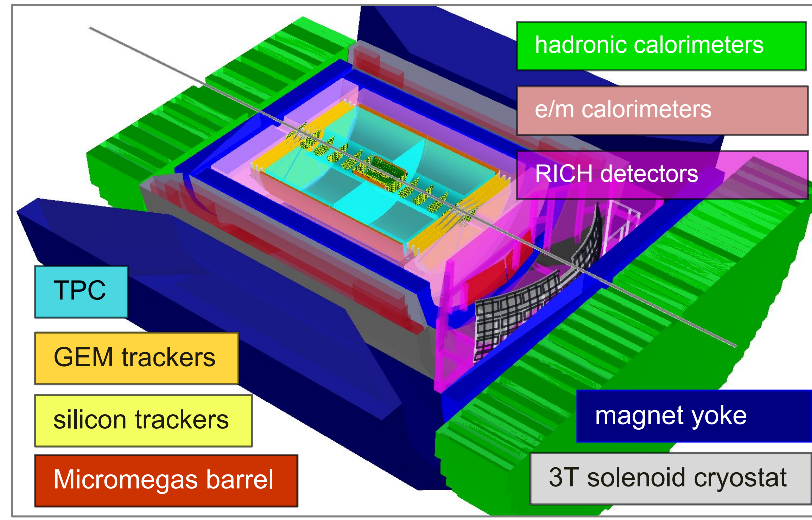
- JLEIC: Jefferson Lab's electron-ion collider, MEIC
  - arXiv:1504.07961
  - 3 to 10 GeV for electrons
  - 20 to 100 GeV for protons (up to 40 GeV per nucleon for ions)
  - polarized protons, deuterons, he-3
  - Heavy ions up to lead need not to be polarized

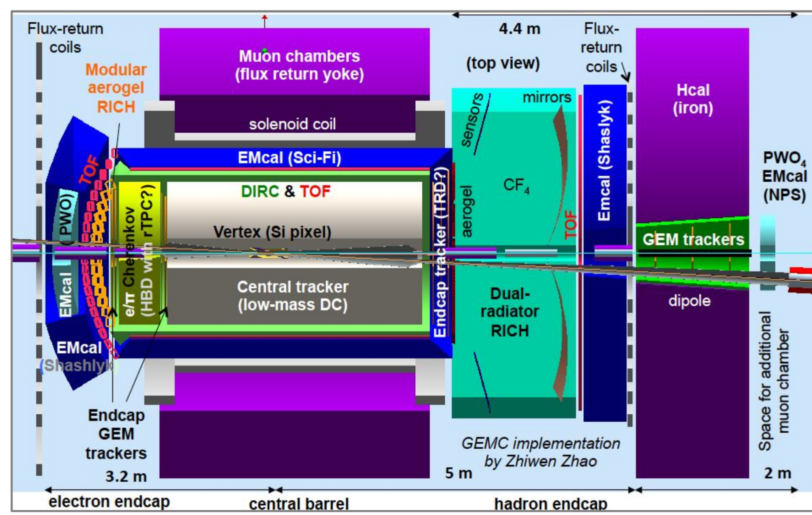


- High luminosity (10^{33} – 10^{34} $cm^{-2}s^{-1}$) polarized electron proton / ion collider
  - $\sqrt{s_{ep}}$ = 20 – 140 GeV
  - factor 100 to 1000 higher luminosity both electrons and protons / light nuclei polarized nuclear beams

EIC Detector Design(s)

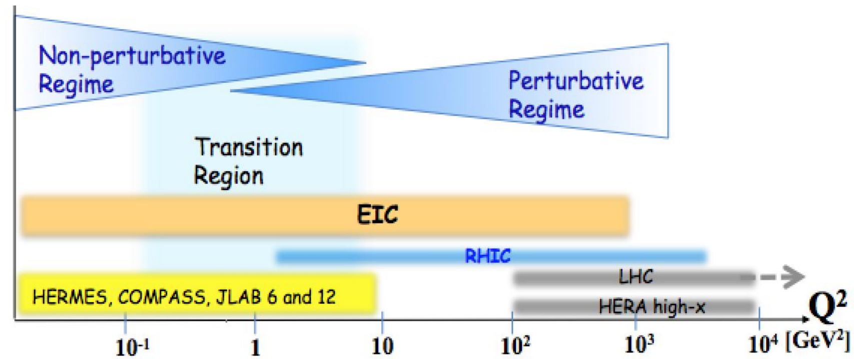
- Current emphasis on the design of a multipurpose detector
  - luminosity monitors
  - electron & hadron polarimetry
  - low Q^2-tagger
- Overall detector requirements
  - large acceptance: $-4.5 \lesssim \eta \lesssim 4.5$
  - high precision low mass tracking
  - equal coverage of tracking and EM-calorimetry
  - high performance PID to separate π, K, p on track level
  - high control on systematic effects
- EIC Detector technologies and requirements close to ILC detector



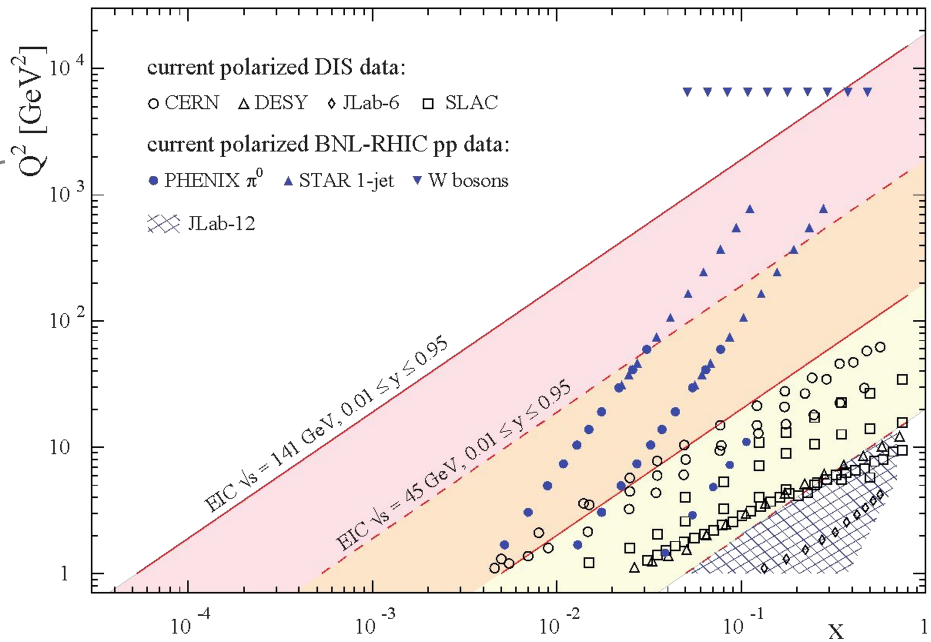


EIC's kinematic reach in x and Q^2

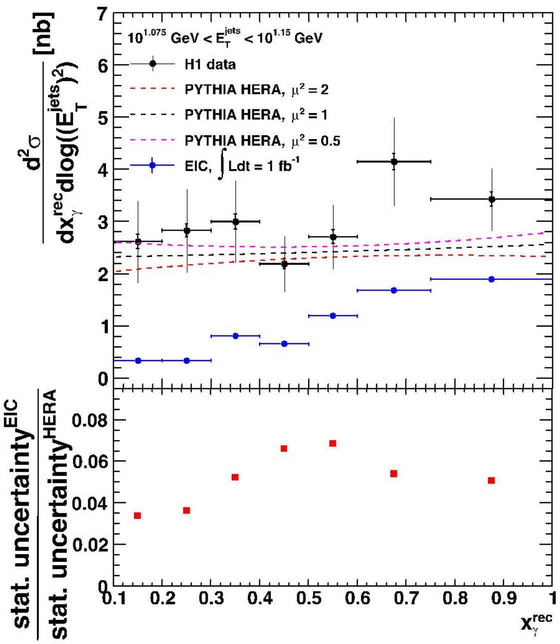
- EIC extends kinematic coverage for data with polarised beams and nuclei by 2 decades in x at a fixed Q^2 and by 2 decades in Q^2 at a fixed x
  - Map the transition from non-perturbative to perturbative regime



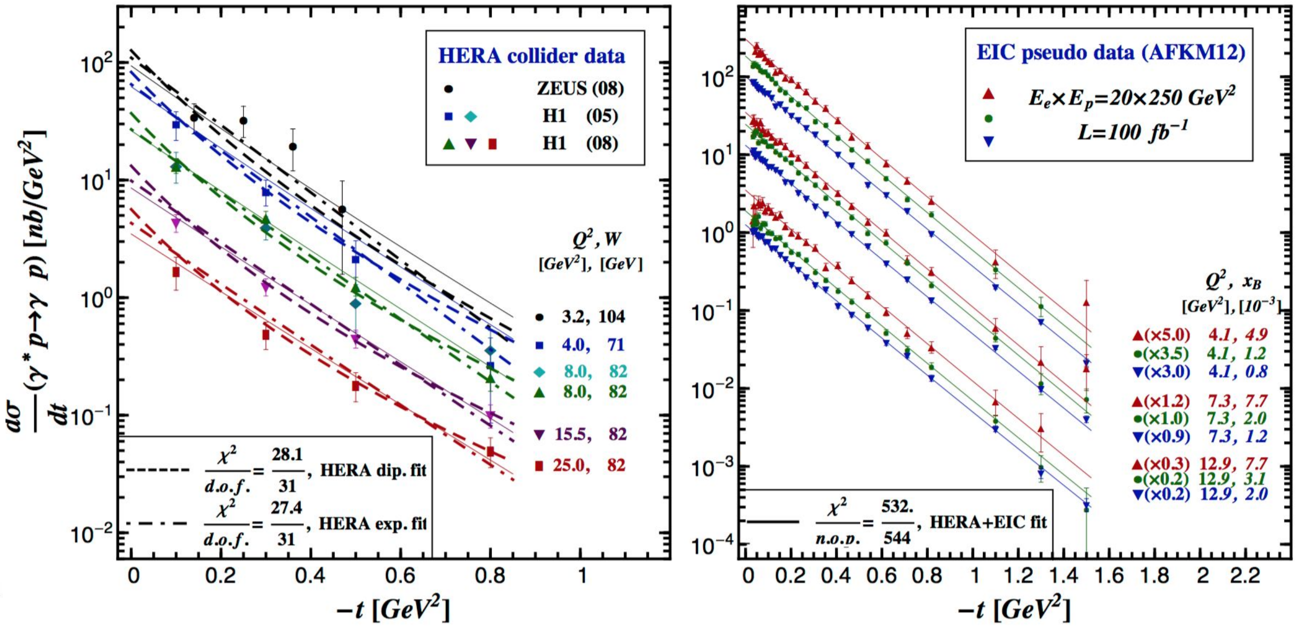
- In contrast to LHeC, the EIC in US are pure QCD machines
  - How are quarks and gluons, and their spins, distributed in nucleons?
  - How do the confined hadronic states emerge?
  - What happens to the gluon density in nuclei? Does it saturate?
  - What are the Proton PDFs at high x?
  - What do we know about nPDFs?
  - ... summarize only two aspects



Physics: Proton PDFs

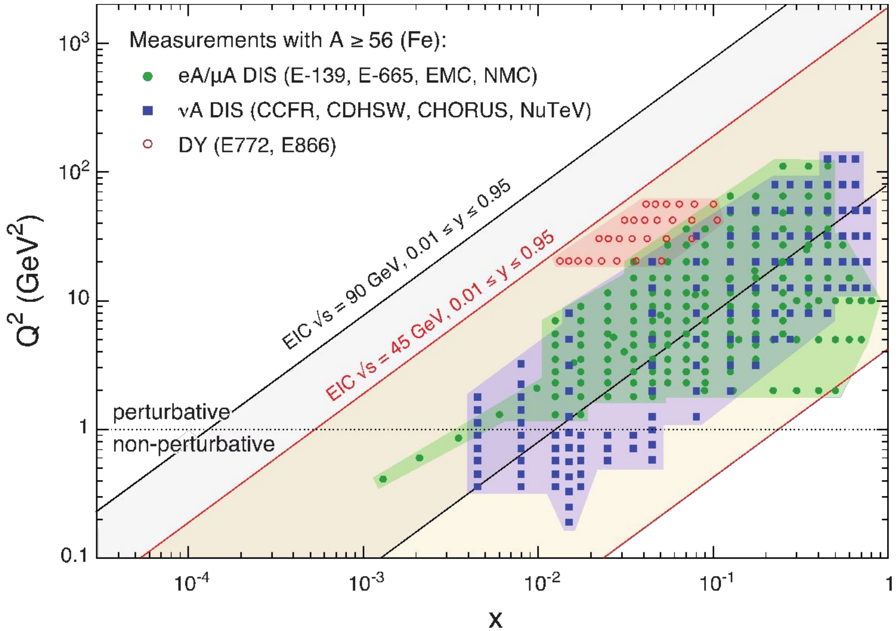


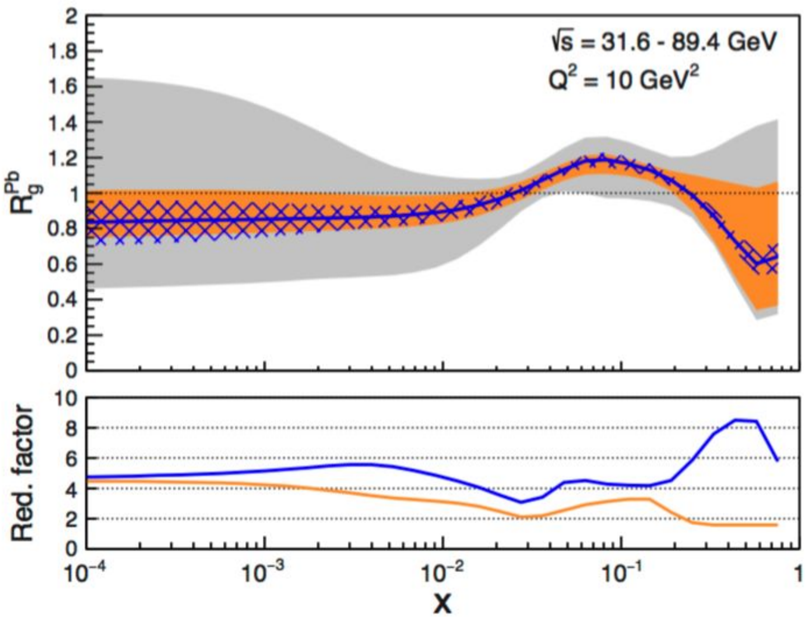
D. Mueller, K. Kumericki, S. Fazio, and E.C.Aschenauer arXiv:1304.0077



- Di-jets@EIC ideal probe to constrain (un)polarised Photon-PDFs
  - Direct/resolved contributions separat-ed reconstructing x_g
- Golden Channel: Deeply Virtual Compton scattering
  - Input for Generalized Parton Distributions; not collinear PDFs
  - Observable: cross sections (A_{UT}, A_{LU}, A_{UL}, A_C) as function of x, Q^2 and t
  - spatial distribution of quarks via Fourier transform of dσ/dt(x,Q^2)
  - Gluon distribution: through scaling violation of dσ/dt(x,Q^2) needs large lever in Q^2 at fixed x

Physics: Nuclei PDFs

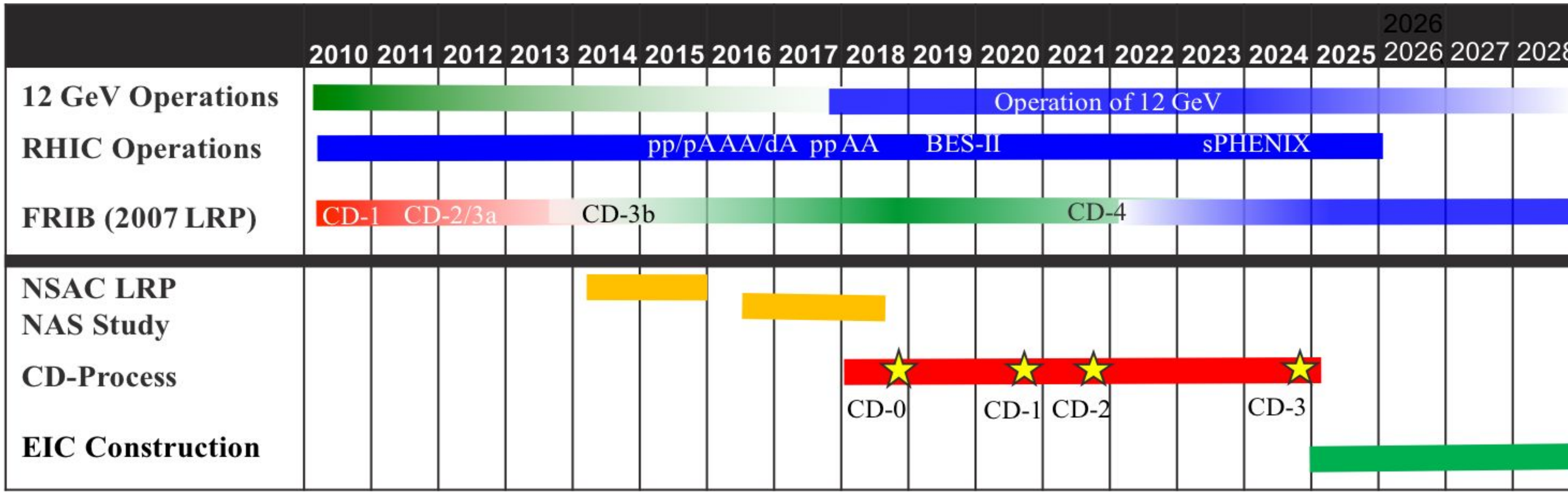




- Testing different models
  - **DGLAP**: predicts Q^2-, but no A- and x-dependence
  - **Saturation models**: predict A- and x-dependence but not Q^2 dependence
- Need: large Q^2 lever-arm for fixed x, A-scan

- Measure different structure function in eA constrain nPDF (arXiv:1708.05654)
  - Complementary to RHIC/LHC pA Provides information on initial state for heavy ion collisions.
  - Does the nucleus behave like a proton at low-x?

For Discussion: Project Related Issues



- What is the planning status in the US? When is a final approval expected?
  - NAS review completed in spring 2018
  - CD1: site selection
  - CD3 start of construction 2024
- Expected Project Costs?
  - Accelerator by U.S.
  - Detector shared by participants
- **Note:** sofar all the projects, which got a high recommendation in the Long Range Planning process in Nuclear Physics have been realized

For Discussion: Comparing EIC and LHeC?

- Does LHeC and EIC not cover the same physics?

  - EIC and LHeC target different physics
  - EIC can provide absolute critical information for the pA and AA program of LHC
  - Proton and nuclei PDFs are only a small part of the EIC physics program
    - First time possible to perform **3D hadron tomography** and study of hard exclusive reactions
      - only possible at the EIC and allows to test both, **perturbative QCD** and **lattice calculations**!
      - critical to understand long-range correlations seen in pA and pp collisions at the LHC
    - Large interest of the German HEP theory community

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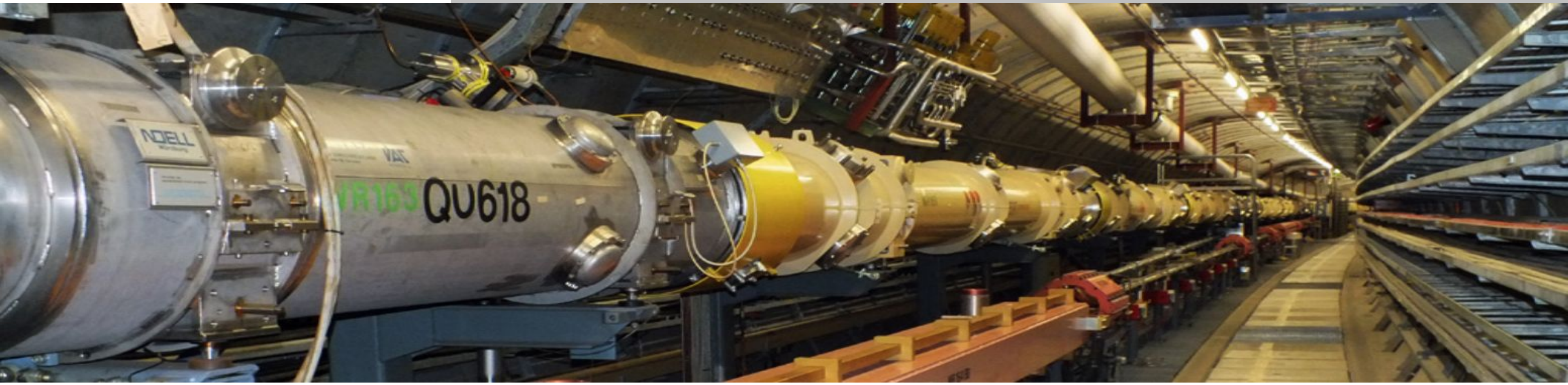
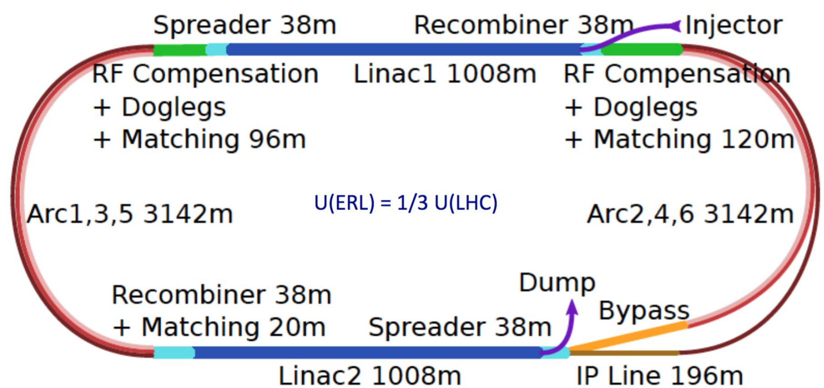
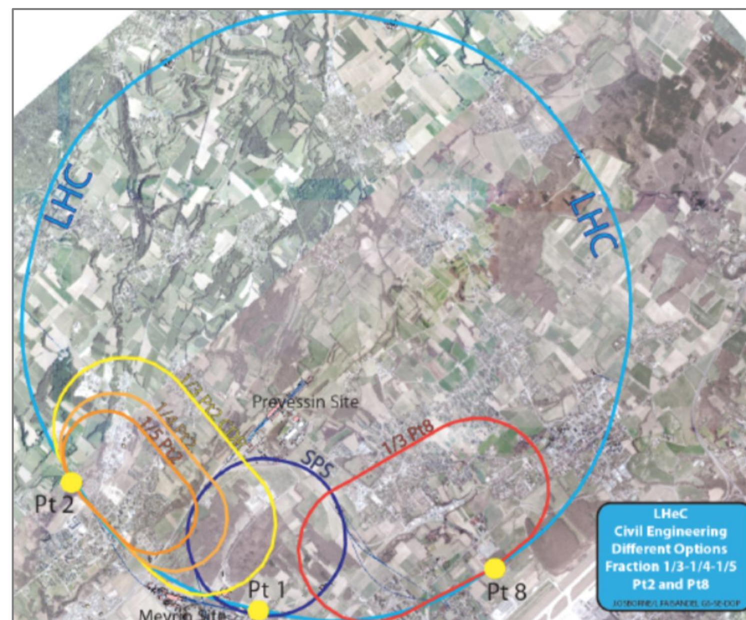


LHeC with energy recovery

Accelerator parameters and potential site

- Electron Energy Recovery Linac (ERL) added to LHC
  - E_e =10-60 GeV
  - E_p =1-7 TeV
    - 13.5 TeV HE-LHC, 50 TeV FCC
  - $\sqrt{s}$=200–1300 GeV
  - Kin.: $0<Q^2<10^6$ GeV^2,$1>x\geq10^{-6}$
    - Four orders of magnitude extension in deep inelastic lepton-nucleus (ion) scattering.
  - Electron Polarisation P=±80%.
  - Luminosity: O(10^{34}) cm^{-2}s^{-1}
  - integrated O(1) ab^{-1} for HL LHC
    - 1000 times HERA
    - O(10)fb^{-1} in ePb
  - operated simultaneously to LHC operation (not affected)

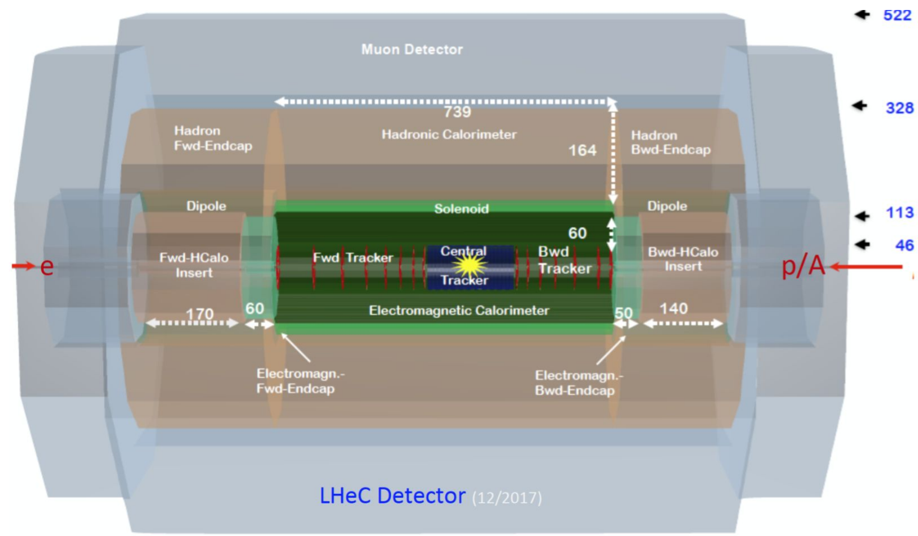




LHeC Detector and assumptions on physics reach

- Cross section with MadGraph5
  - tree-level Feynman diagrams using p_T of scattered quark as scale for ep processes
  - Fragmentation & hadronisation uses ep-customised Pythia.

- DELPHES Fast Detector Simulation
  - 'Standard' GPD LHC-detectors
    - Optimising vertex resolution a la ATLAS IBL of ~ 5 µm
    - ATLAS b-tagging efficiencies
    - Using state-of-the art hadronic and el.mag. Resolutions
  - Considering displaced vertices and impact parameter distributions

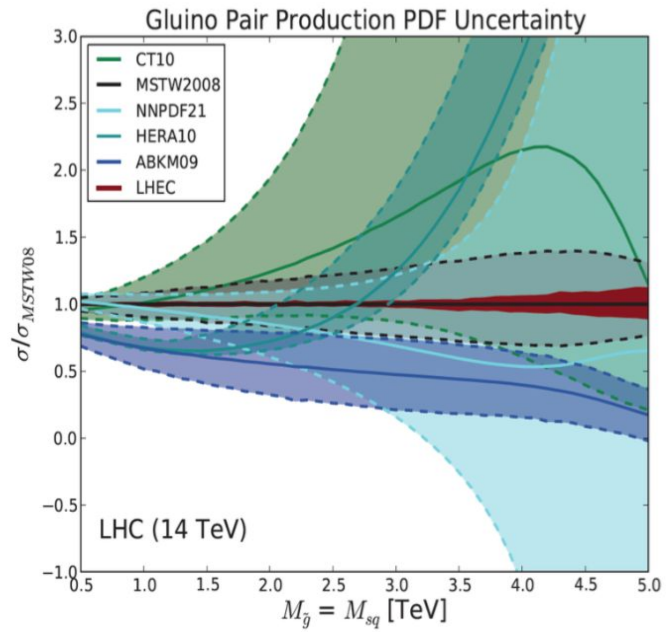


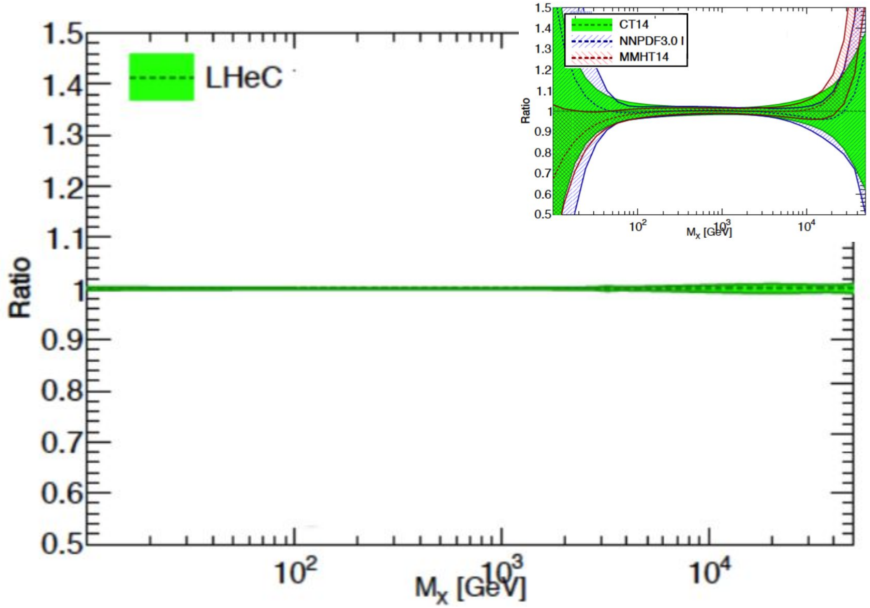
Length x Diameter: LHeC (13.3 x 9 m²) HE-LHC (15.6 x 10.4) FCCeh (19 x 12)

[arXiv:1802.04317]

Object	Acceptance
Electrons	|η|<4.7
Muons	|η|<4.7
Jets	|η|<5
b-tagging	|η|<3.5

Where would be those precise PDFs useful?





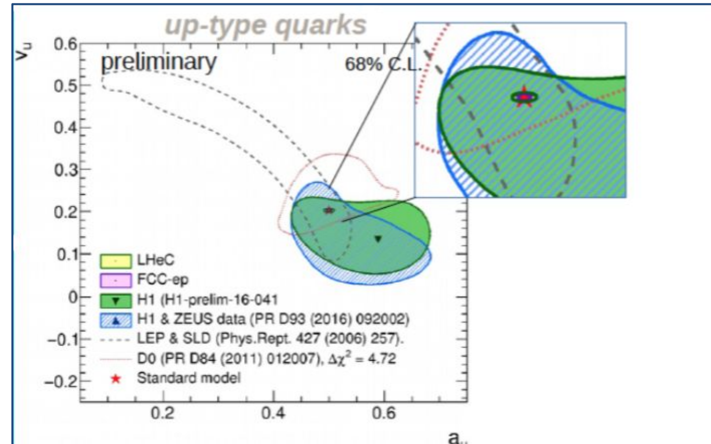
- Classic DIS Programme : Resolve parton structure of the proton completely
  - Large range, sub%-precision
  - No parameterisation assumptions
  - Resolve p structure
- PDF-Limitations at the LHC
  - SUSY, **Higgs (!)**, ….
  - LHeC would allow to reduce PDF uncertainties on sin2(Θ_W) to 0.000013,
    - improve LEP by factor of 3

Within and beyond the Standard Model

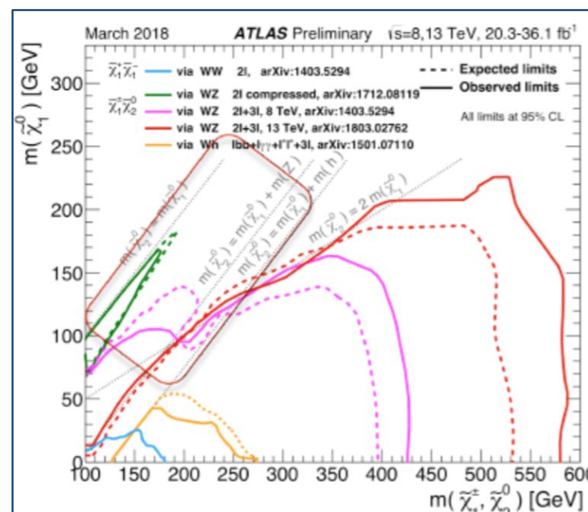
See: M. Klein (The Case for the LHeC@DIS2018)

- Full potential of BSM searches just starting to be explored
  - Higgs into Dark Matter, Neutralinos (RPV SUSY), Higgs into Scalars->4b
  - H±±, H± in Vector Boson Scattering
  - H+ in 2HDM
  - Triple Gauge Couplings
  - Contact Interactions
  - EWK SUSY: Close gaps in mass degeneracy, which we have at the LHC
  - Sterile Neutrinos
  - …

- LHeC much more than HERA: New Physics through
  - High Precision Higgs, Top and W's
  - CKM Element measurements
  - NC couplings
  - Quark Masses
  - …



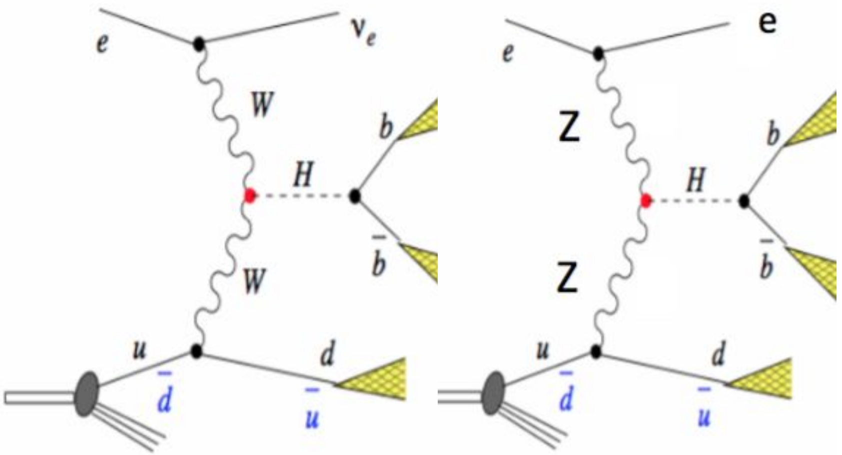
Britzger, MK, Spiessberger, Zhang – work still in progress



Higgs Portal (1/3)

See: U. Klein (Higgs physics at the LHeC and the FCC-he @DIS2018)

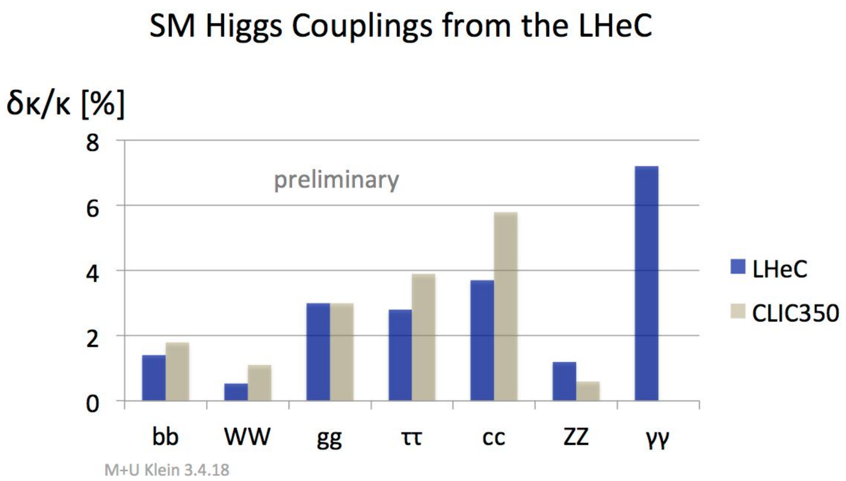
- Focus on Higgs potential of LHeC together with LHC
  - FCC studies will not be covered here
- Higgs production at LHeC via VBF
  - VBF: Small theory uncertainties!
  - Clean signatures (H_{bb} with S/B >1)
  - No pile-up (<0.1@LHeC), i.e. separation of ZZH and WWH
- Higgs rates @1000 fb^{-1} during HL LHC
  - Perfect opportunities to study bb final states
  - H_{cc} is suppressed by factor 20 compared to bb
  - Possible with dedicated charm-tagging: 400-600 H_{cc}

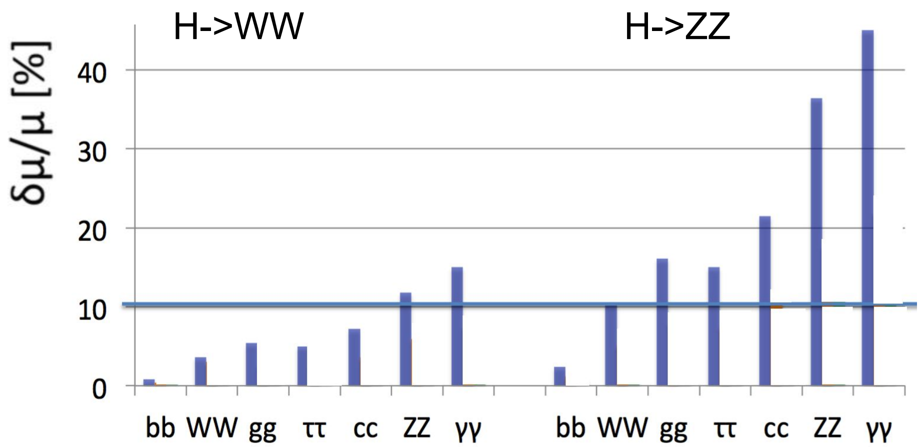


LHeC Higgs		CC (e^-p)	NC (e^-p)	CC (e^+p)
Polarisation		-0.8	-0.8	0
Luminosity [ab^{-1}]		1	1	0.1
Cross Section [fb]		196	25	58
Decay	BrFraction	N^H_{CC} e^-p	N^H_{NC} e^-p	N^H_{CC} e^+p
$H \to b\bar{b}$	0.577	113 100	13 900	3 350
$H \to c\bar{c}$	0.029	5 700	700	170
$H \to \tau^+\tau^-$	0.063	12 350	1 600	370
$H \to \mu\mu$	0.00022	50	5	–
$H \to 4l$	0.00013	30	3	–
$H \to 2l2\nu$	0.0106	2 080	250	60
$H \to gg$	0.086	16 850	2 050	500
$H \to WW$	0.215	42 100	5 150	1 250
$H \to ZZ$	0.0264	5 200	600	150

Higgs Portal (2/3)

See: U. Klein (Higgs physics at the LHeC and the FCC-he @DIS2018)





LHeC: 60 GeV x 7 TeV. **CLIC: 350 GeV** [arXiv:1608.07538, "model dependent fit"]

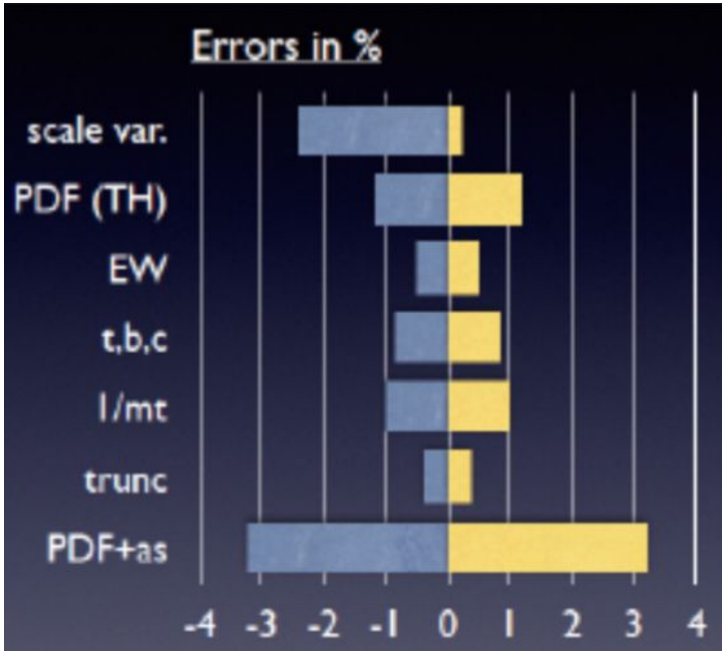
- NC and CC DIS together over-constrained Higgs couplings in a combined fit.
  - allows a model-dependent fit of coupling uncertainties, ala CLIC study
  - Assuming SM BR weighted by the measured κ values, and Γmd
- Couplings of the dominant Higgs decays could be measured to few percent precision at ep@HL-LHC
  - Complementarity of ee and ep to get model independent couplings, use absolute cross section from ee-collider.

Higgs Portal (3/3)

See: U. Klein (Higgs physics at the LHeC and the FCC-he @DIS2018)

- Branching for invisible Higgs
  - Use ZZH fusion process to estimate prospects of Higgs to invisible decay using standard cut/BDT analysis techniques
    - With $\sqrt{s}$=1.3 TeV, expect precision of 4-6%
- Measure CP Properties of Higgs
- Further precision tests
  - EW Precision
  - Compare 2nd and 3rd generation

$$\frac{\sigma_{WW\to H\to ii}}{\sigma_{ZZ\to H\to ii}} = \frac{\kappa_W^2}{\kappa_Z^2} \qquad \frac{\sigma_{WW\to H\to c\bar{c}}}{\sigma_{WW\to H\to b\bar{b}}} = \frac{\kappa_c^2}{\kappa_b^2}$$



G. Zanderighi, C.Anastasiou et al, 1602.00695

- Improve uncertainties on pp Higgs cross section via PDFs
- LHeC could reduce α_s and PDF uncertainties to below 0.5%

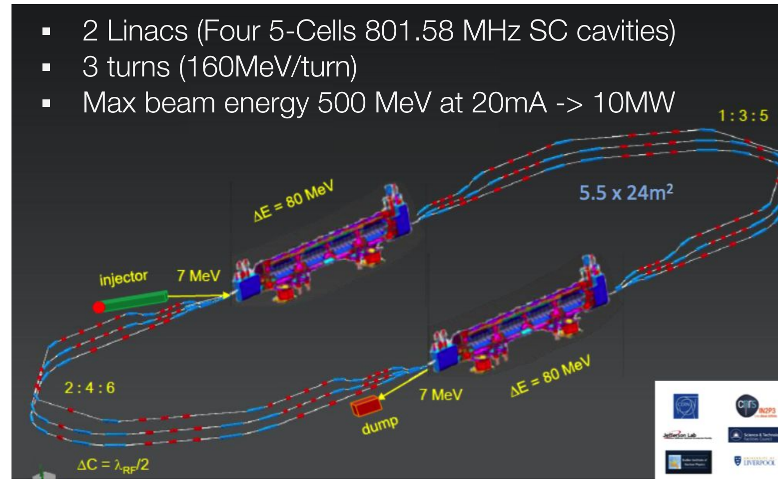
Discussion: Feasibility of an Energy Recovering Linac

(with input of F.Zimmermann)

- LHeC requires an ERL
  - three-pass ERL is proposed
  - Multi-bunch instabilities are a concern
  - Special low-impedance high-current cavities have been developed by JLAB for this purpose.
    - recent prototype achieved outstanding performance

- Small-scale ERLs have/will be(en) built
  - Mainz (MESA), Navy FEL at JLAB, CBETA at Cornell

- Dedicated prototype for LHeC planned in Orsay: Powerful ERL for Experiments (PERLE)



cf Walid Kaabi at Amsterdam FCC

First 802 MHz cavity successfully built (Jlab)

Discussion: Is an Energy Recovering Linac an Interesting Technology?

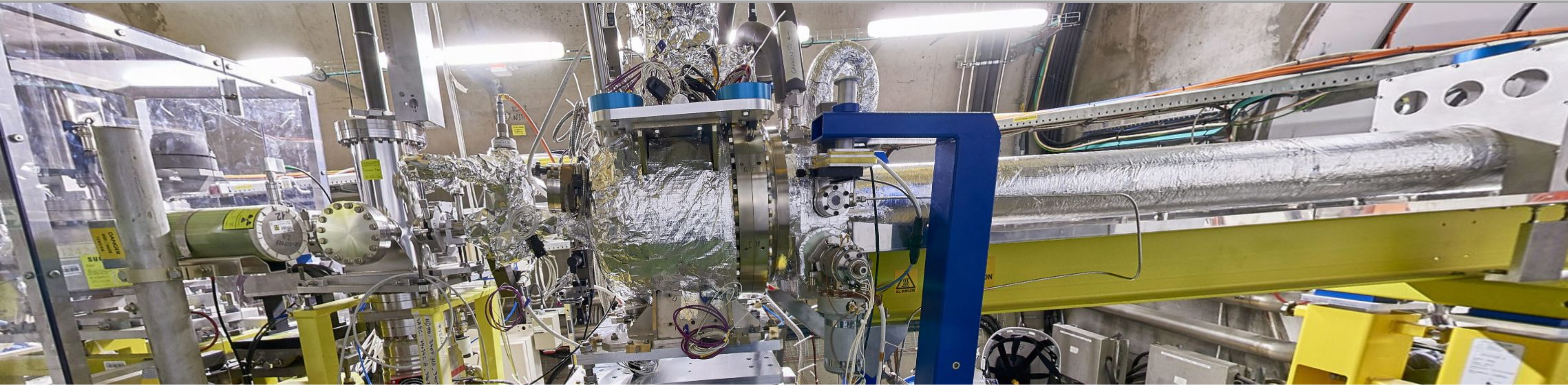
- The following remarks come from **Oliver Bruning (CERN)**
  - **In short: ERLs seems to be an interesting technology for many aspects**

- Many applications of ERLs
  - High flux XFEL photon sources
  - High energy Gamma ray sources with photon production via Compton back scattering using an electron beam and laser (even industrial applications)
  - cooling devices for hadron beams (EIC projects rely on very high electron beam currents for the hadron beam cooling that are only accessible through ERLs)
  - ERLs would allow for a large number of positrons in collisions due recuperation of the position beam after deceleration and use for new operation cycle

- Disadvantages of circular machines:
  - Circular machines is limited by the maximum acceptable beam-beam parameter: Achieving luminosities of 10^{34} $cm^{-2}s^{-1}$ are very challenging with a circular machine!
  - The ERL concept circumvents both of these limitations

Discussion: Are the projections solid?

- All studies conducted by two independent teams with different methods
- Assumptions on detector based on existing experience, (e.g. b-tagging)
  - b-tagging made enormous progress since HERA times
  - Very successful applied at ATLAS, CMS and LHCb in very high pile-up environment
- We certainly need more studies, new ideas and cross checks on
  - c-tagging
  - Invisible higgs
  - backgrounds
  - …
  - But so far, everything seems to be promising
    - Keep in mind: In reality, we have been always overachieving our projections (except @HERA)



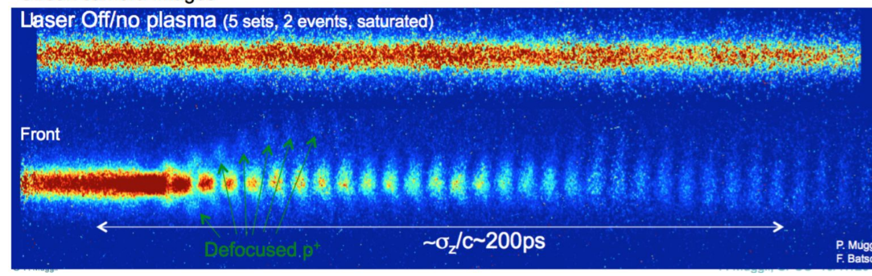
PEPIC and VHEeP

Plasma wake field acceleration and experimental results from AWAKE

- AWAKE Run 1
  - Understand the physics of self-modulation instability
    - Very promising results in 2017
  - 2018: demonstrate that electrons can be accelerated in the wake of a modulated proton bunch

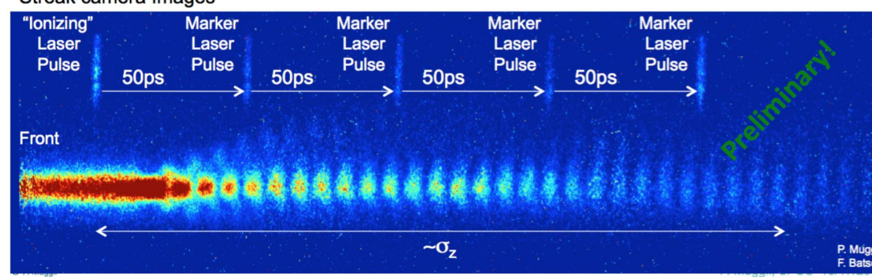
- AWAKE Run 2 (2021-2024)
  - Accelerate bunch of electrons, proof that the emmittance achieved would be sufficient to generate interesting luminosities
  - demonstrate that plasma cells with the right density and uniformity over tens of meters can be constructed
    - Proof scalable to hundreds of meters or more

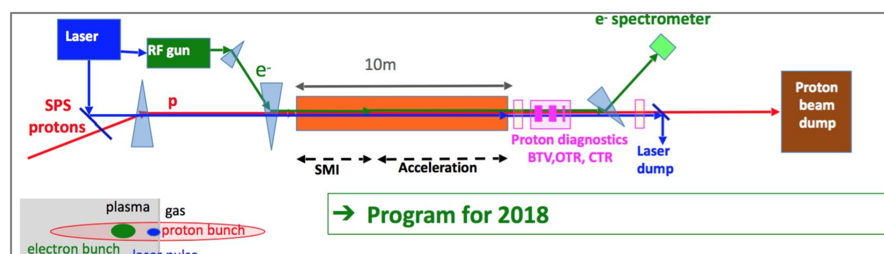
Streak camera Images



Streak camera Images

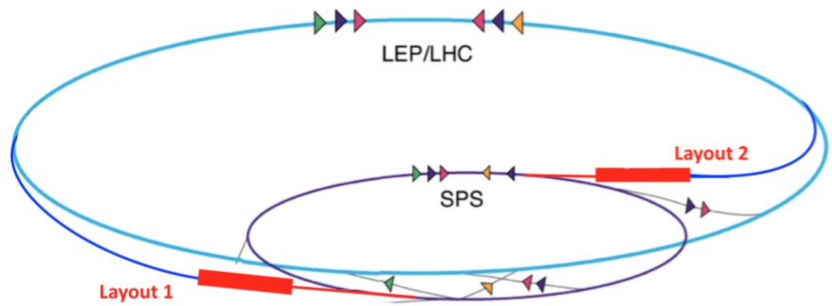
10 events each



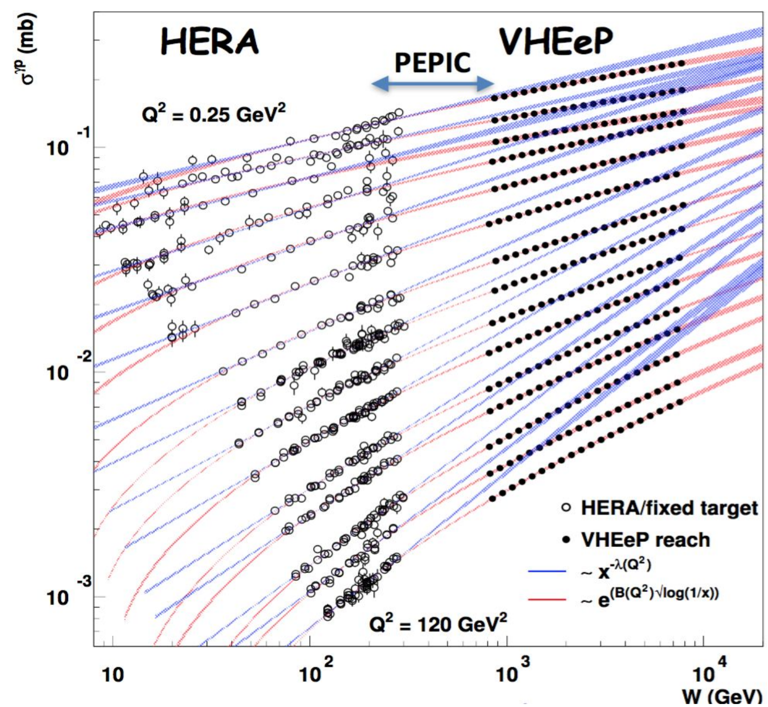


Physics Perspective (1/2)

- Physics with an electron-proton or electron-ion collider
  - Low luminosity version of LHeC
  - Very high energy electron-proton, electron-ion collider



- PEPIC (Plasma electron proton/ion collider)
  - O(100 GeV), colliding with LHC protons
  - exceeds HERA cm energy
  - Luminosity currently expected to be $<10^{30}\text{cm}^{-2}\,\text{s}^{-1}$. ($\int Ldt$=100-200$\text{pb}^{-1}$)

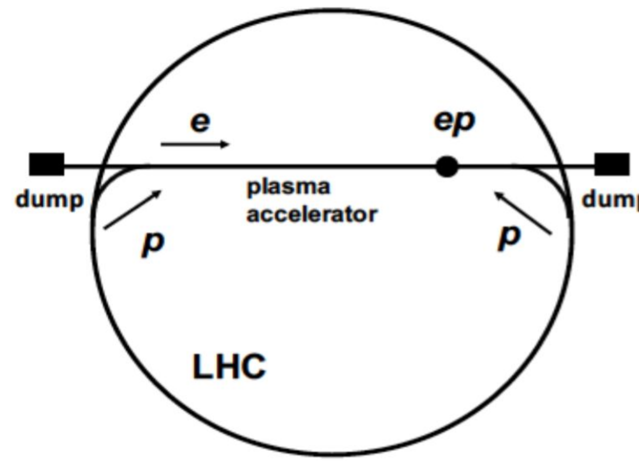


- PEPIC will e.g. distinguish different Q^2 scaling models for virtual γp-cross section
  - + beam dump (e.g.: dark photons)
  - + strong-field QED by colliding electron bunches with laser beam.

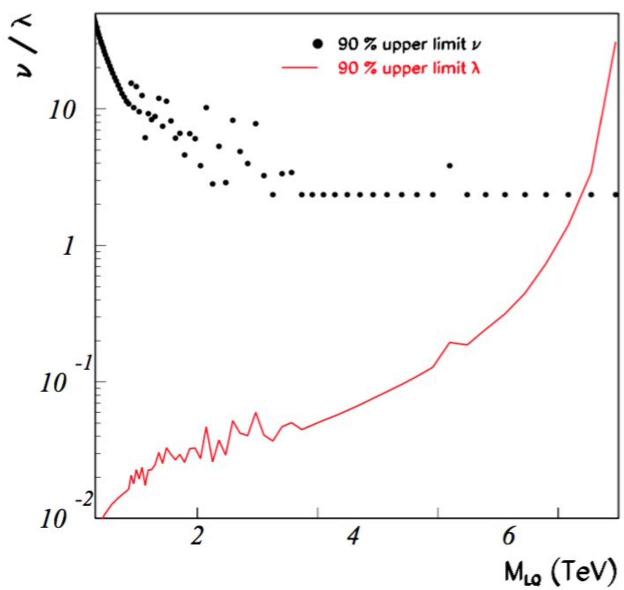
Physics Perspective (2/2)

Caldwell, Wing, EPJ C76 (2016) 463

- VHEeP: E_e = 3 TeV and E_p = 7 TeV
  - $\sqrt{s}$ = 9 TeV; 30x higher than HERA
  - Reach in (high) Q^2 and (low) Bjorken x extended by factor ~1000
  - Luminosity 10^{28}-10^{29} $cm^{-2}s^{-1}$



- Opens new physics perspectives
  - low-x physics and high-energy neutrino physics
  - AdS/CFT at very low-x physics
  - Leptoquarks
  - specific eA physics topics
  - …



Discussion and Critical Questions

- What is the potential physics program of PEPIC?
  - Similar luminosity as HERA
  - PEPIC offers to study „HERA“ physics (structure functions at small-x, diffractive cross sections, saturation scale) at significantly smaller x, i.e. a >10 larger level arm
  - Possibility to scatter on ions, i.e. probe high densities. Fully new ideas appear:
    - AdS/CFT correspondence: arXiv:hep-th/0603115v2
    - probing fundamental aspects of QCD as a quantum theory: arXiv:1702.03489v3
- How could PEPIC be funded? What about detectors for PEPIC?
  - PEPIC costs could go into the CERN budget; detector developments are a great opportunity for university groups after the LHC detector upgrades
- What kind of detector is needed to study the forward-regime of physics at VHEeP?
  - Indeed between fixed target and collider detector; dedicated studies required
- What could be a realistic timeline for PEPIC?
  - If AWAKE Run-2 is successful, PEPIC could come in O(10y) in parallel to LHC

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Some thoughts for discussion

Summary

- **PEPIC:** The AWAKE project aims to demonstrate in the coming years that bunches of electrons can be accelerated in a plasma in the wake of a proton bunch with high gradients and with good emittance preservation. In parallel, the community should develop concepts for the application of this technology to particle physics projects. A first colliding beam experiment, which would run concurrently with the LHC, would use the SPS to provide electron-proton and electron-ion collisions (PEPIC project), extending considerably the physics reach of HERA at moderate cost. A longer-term project is very high energy electron-proton and electron-ion collisions based on this technology (VHEeP) to reveal the fundamental structure of hadronic matter at centre-of-mass energies up to about 10 TeV.

- **LHeC:** The LHeC is designed to enable energy frontier lepton-hadron scattering experimentation at a luminosity a thousand times higher than HERA's. This provides the cleanest resolution to the substructure of matter, enables discovery in QCD as well as the top and electroweak sectors, through high precision, and it empowers the HL LHC programme, by synchronous ep and pp operation, to much further reaching Higgs SM and BSM physics. The LHeC can build a unique laboratory for nuclear particle physics that can not be built anywhere else but at CERN. The LHeC a viable and interesting option for developing CERN, and global HEP, as it establishes a next TeV energy scale collider, built on the LHC infrastructure at affordable cost. With the LHeC and a next e+e- collider, global HEP would achieve the goal of restoring the crucial unity of pp, ep and ee physics for exploring nature at the energy frontier of collider physics. Several groups are evaluating the LHeC potential with the possible outcome of supporting it.

- **EIC:** Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new electron ion collider (EIC), providing unprecedented precision and versatility. The timely realization of this instrument is enabled by recent advances in accelerator technology. The EIC will, for the first time, provide precise three-dimensional momentum and spatial images of partons in nucleons and nuclei. It will definitively reveal the origin of the nucleon spin and will explore a new quantum chromodynamics (QCD) frontier of ultra-dense gluon fields, with the potential to discover a new form of gluon matter predicted to be common to all nuclei. This science will be made possible by the EIC's unique capability of colliding polarized electrons with with polarized protons, polarized light ions, and heavy nuclei at high luminosity.

Further Reading

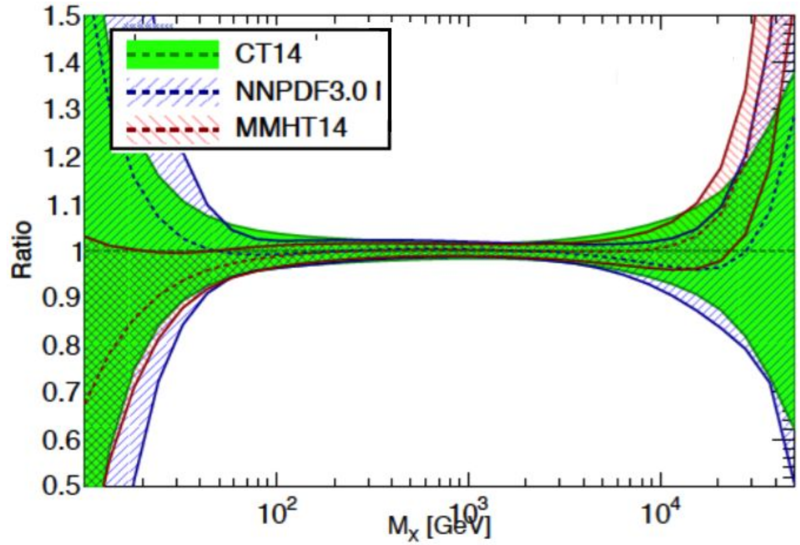
- LHeC CDR
  - arXiv:1206.2913
- Higgs physics at the LHeC and the FCC-he (U. Klein)
  - DIS2018 Kobe, Japan, April 16-20, 2018
- Very high energy eP and eA colliders (Allen Caldwell, Matthew Wing)
  - DIS2018 Kobe, Japan, April 16-20, 2018
- The Case for a US-based Electron-Ion Collider (EIC) facility (Bernd Surrow)
  - DIS2018 Kobe, Japan, April 16-20, 2018
- Physics case for ep and eA colliders (Néstor Armesto)
  - Workshop on Future Hadron Colliders at the Energy Frontier DESY, 15.12.2017

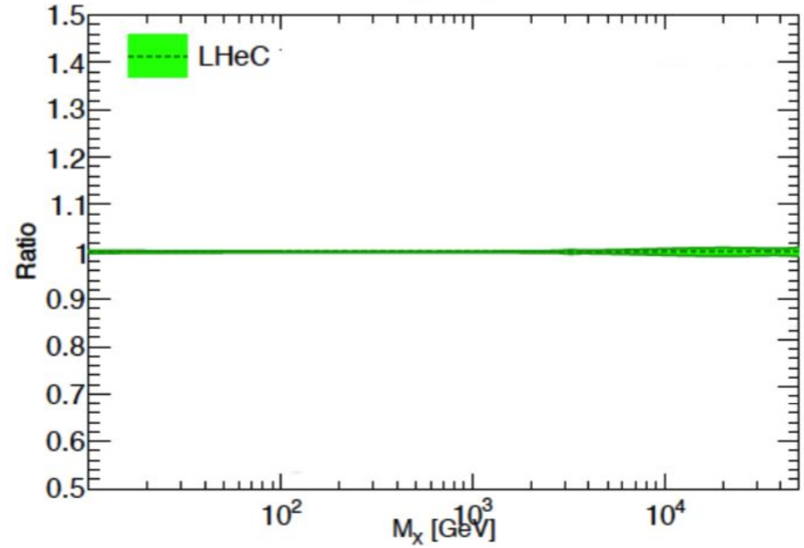
Discussion

New QCD/Electroweak Physics in Deep Inelastic Scattering

- Classic DIS Programme with the LHeC
  - Generalised Parton Distributions "proton in 3D – tomography"
  - Unintegrated Parton Distributions – DGLAP/BFKL?
  - Diffractive Parton Distributions: pomeron, confinement?
  - Photon Parton Distribution
  - Neutron Parton Distributions

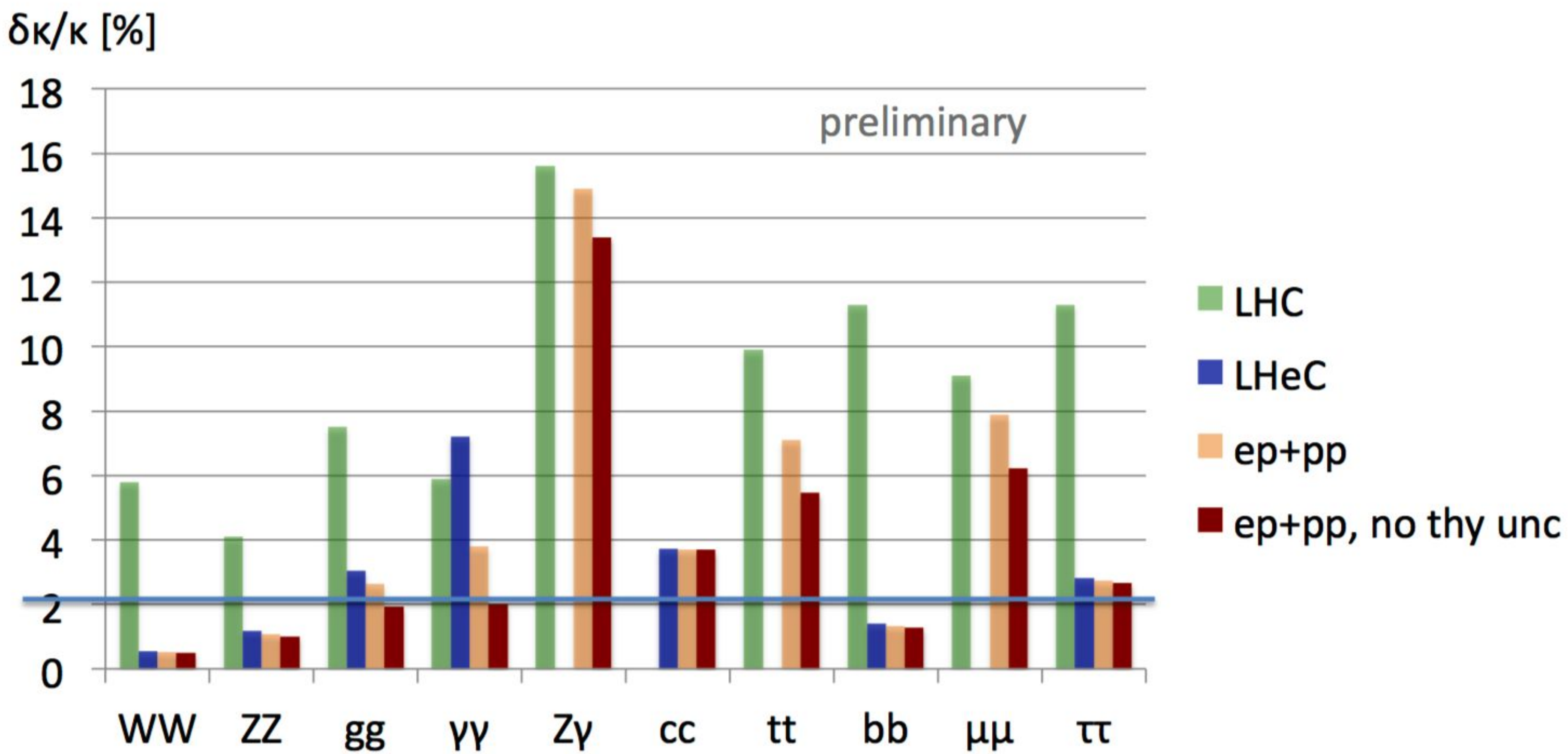
- Resolve parton structure of the proton completely
  - Large range, sub%-precision
  - No parameterisation assumptions
  - Resolve p structure
  - solve non linear and saturation issues
  - test QCD, N3LO...





More on Higgs

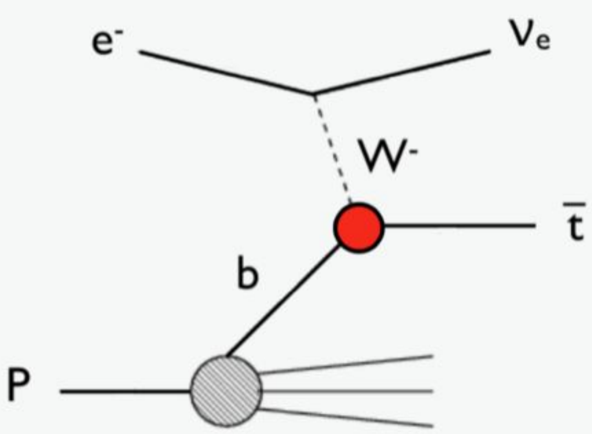
See: U. Klein (Higgs physics at the LHeC and the FCC-he @DIS2018)



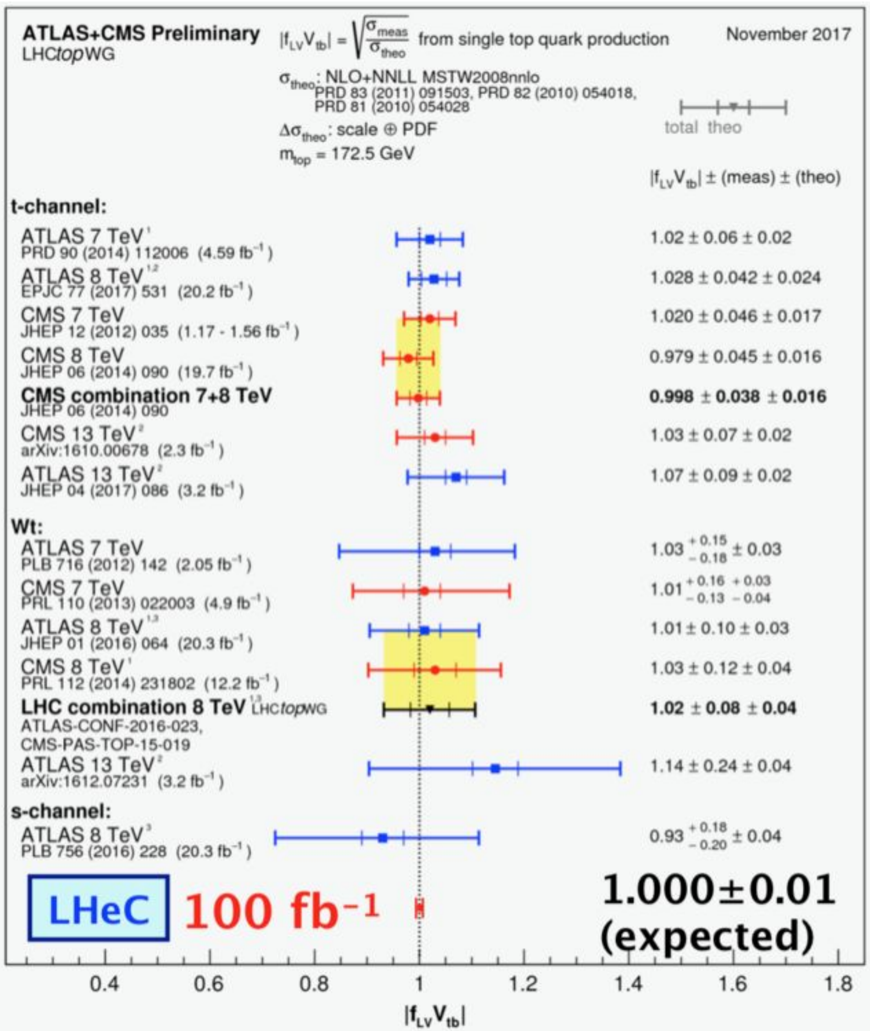
Further input to LHeC

C. Schwanenberger

1. including top-quark mass uncertainty
2. σ_{theo}: NLO PDF4LHC11 NPPS205 (2010) 10, CPC191 (2015) 74
3. including beam energy uncertainty

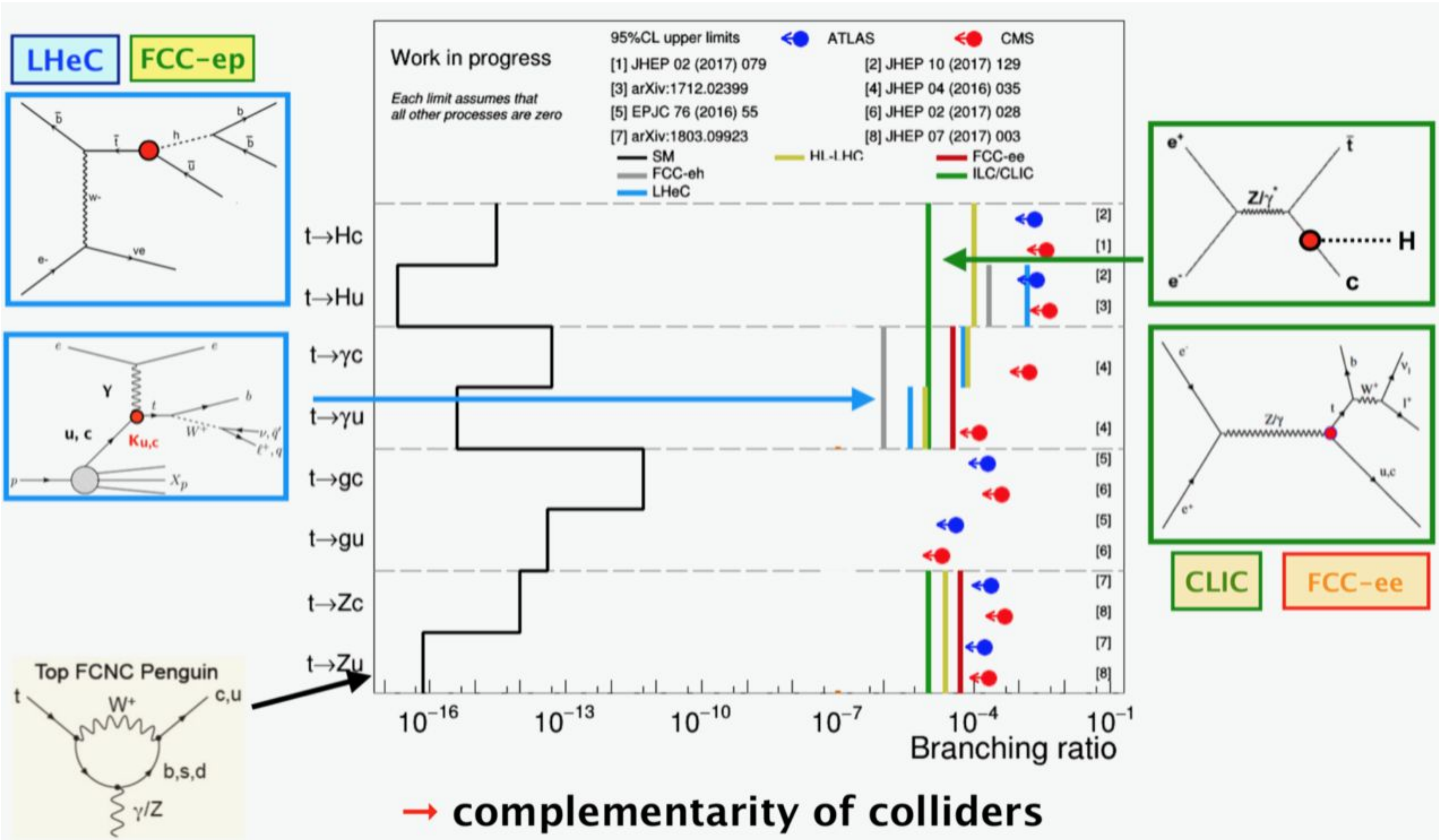


$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



Further input to LHeC

C. Schwanenberger

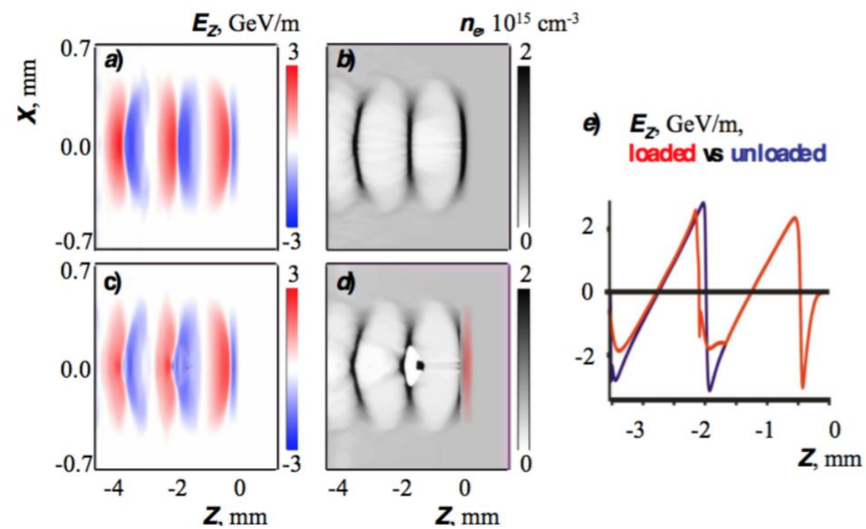


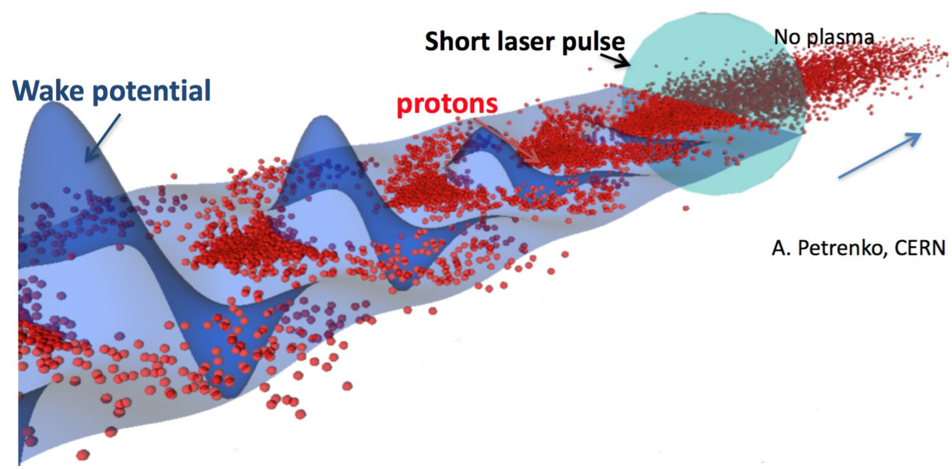
→ **complementarity of colliders**

Plasma wake field acceleration in a nutshell

- AWAKE and proton-driven wakefield acceleration: use existing infrastructure for the wakefield driver to accelerate electrons to high energy
  - SPS@CERN 20kJ/bunch
  - LHC@CERN 300 kJ/bunch

- Energy content of driver allows to consider single stage acceleration.
  - Need short drivers to create strong wakefields, but short high energy bunches do not exist.
    - Solution: self-modulation can be seeded by a sharp start of the beam (or beam-plasma interaction)
    - The ‘microbunches’ then drive strong wakes.





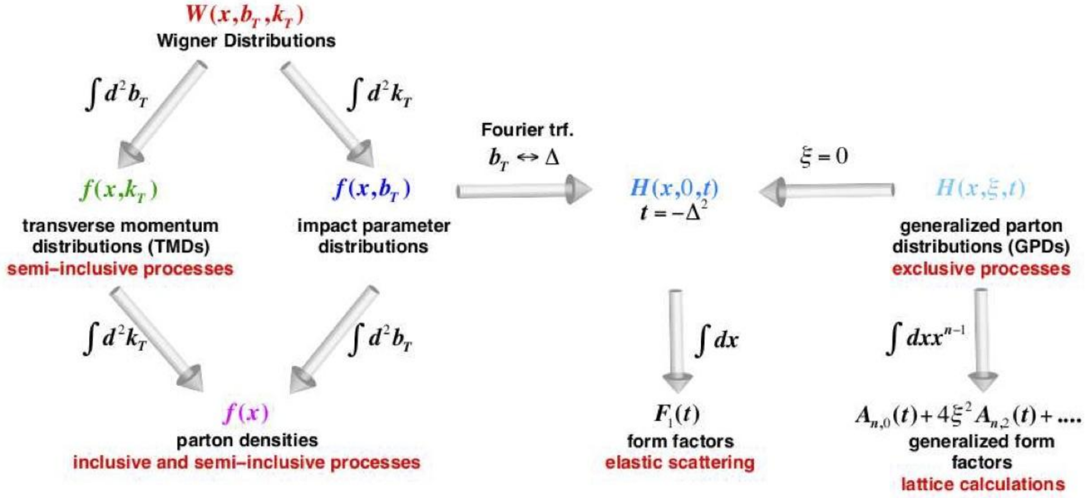
For Discussion: Can EIC contribute to PDFs relevant for LHC?

- Max. $Q^2=10^4$ GeV^2 at EIC, i.e. gluon-information only for $x > 2\text{-}3 * 10^{-3}$
  - significantly larger range at LHeC ($x_g > 2\text{-}3\ 10^{-5}$, also possible to address flavour separation, top PDF, strange PDFs)
  - Reply: EIC can do an excellent job on the flavor separation, we can measure charge current as well as tag the flavor through semi-inclusive DIS.
    - we can measure on protons and neutrons (through deuterium beams).

- What is the advantage of an EIC project compared to LHeC?
  - Reply: all the studies on TMDs and GPDs in protons and nuclei, which will provide critical info to understand things like the long-range correlations in pp and pA. These measurements will be difficult to measure at LHeC. Also to obtain the full picture on these PDFs proton beam polarization is required.
  - LHeC and EIC are very complementary in their physics program and emphasis.
    - Current PDF Fits use quite old and imprecise DIS data (SLAC (`70), BCDMS (`80), NMC (`90)) in the kinematic regime of EIS

Further Input from Sven Olaf Moch to EIC

Hadron tomography



- Differential longitudinal-transverse parton structure (Wigner distributions)
- Connections to non-perturbative functions for QCD description of hard exclusive, semi-inclusive and inclusive reactions
  - parton distributions (PDFs)
  - transverse momentum dependent distributions (TMDs, fundamentally different from PDFs !!!)
  - generalized parton distributions (GPDs)

– p.1

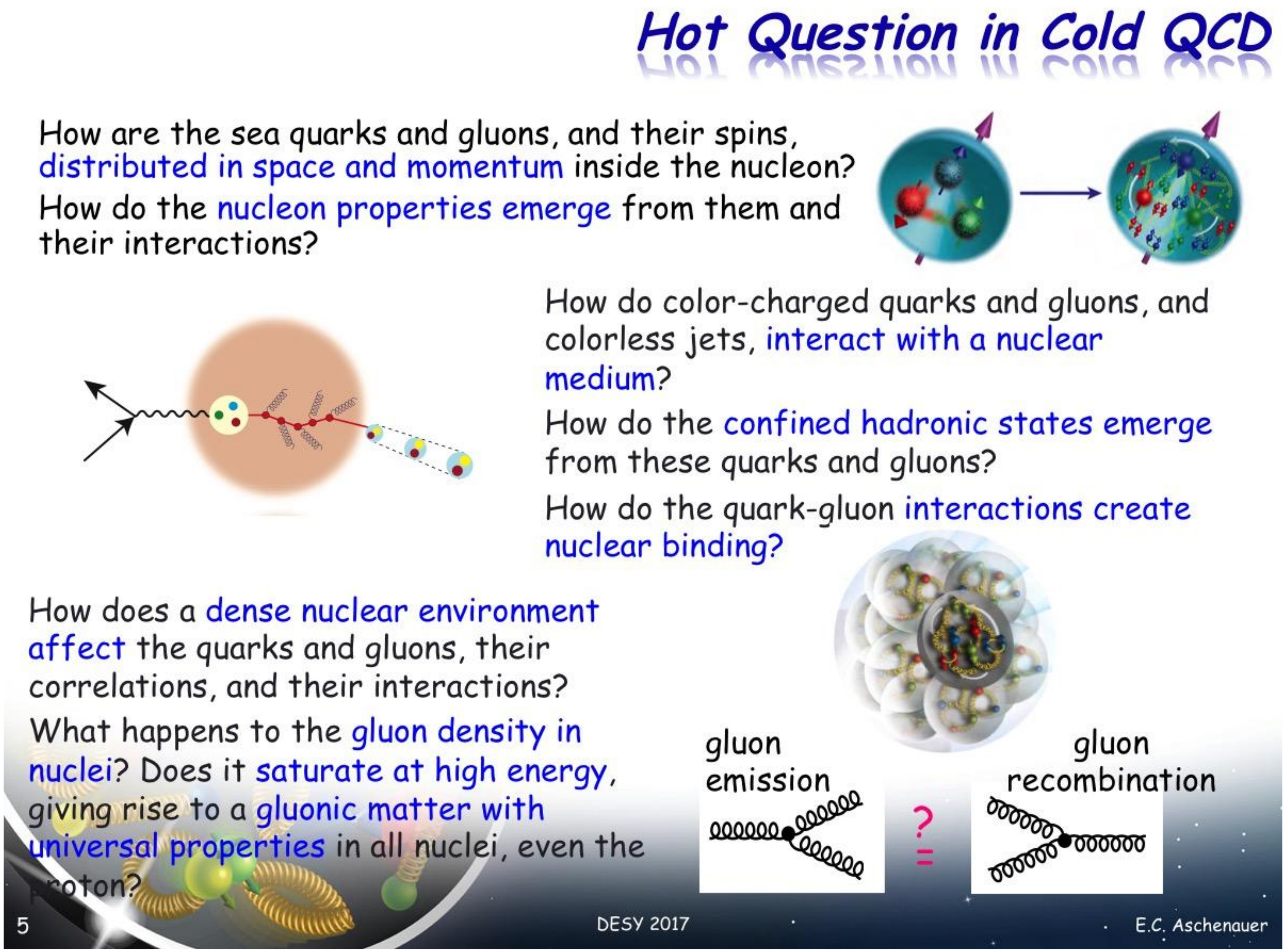
Further Input from Sven Olaf Moch to EIC

Electron-Ion Collider

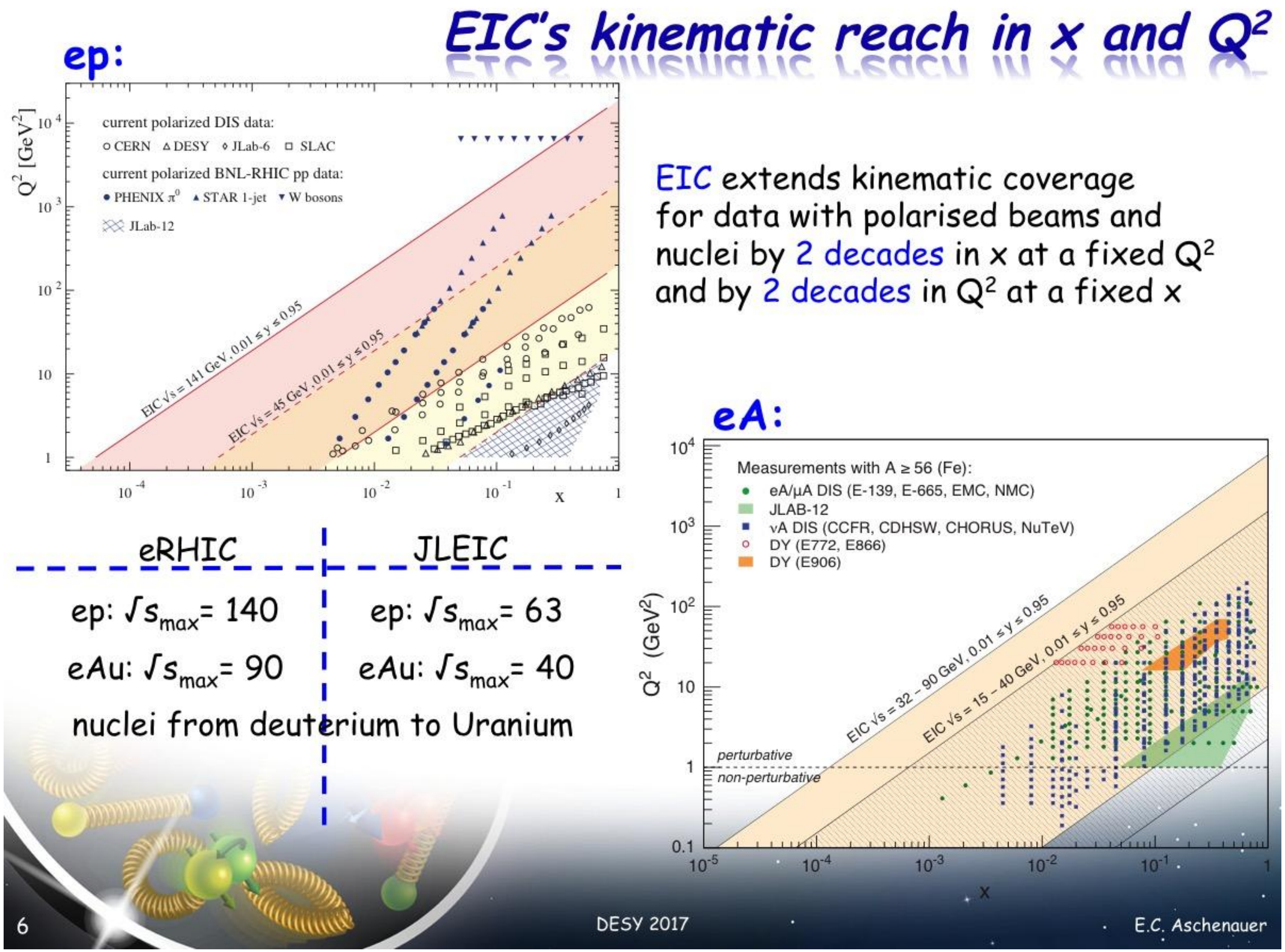
- EIC will provide a wealth of data on semi-inclusive reactions in deep-inelastic scattering (DIS)
  - unique window of parton kinematics (Bjorken $x \simeq 5 \cdot 10^4 \ldots 0.5$ and $Q^2 \simeq 1 \ldots 10^4$ GeV)
  - unprecedented studies with polarization
- Studies of
  - hard processes with nuclei
  - three-dimensional image of hadrons, both in coordinate (GPDs) and momentum (TMDs) space
  - light-flavor content of hadrons: strangeness distributions from semi-inclusive DIS with kaons and charged current DIS
- Impact of measurements on LHC program
  - improved structure functions for LHC predictions
- Active theory research at German universities (Bochum, Hamburg, Mainz, Regensburg, Tübingen) and at DESY
  - precision theory predictions for hard processes
  - strong lattice QCD (information on three-dimensional structure of hadrons, both in coordinate and momentum space)

– p.2

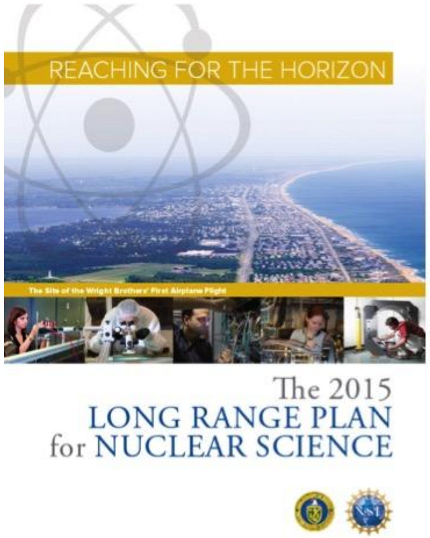
Further Input from Elke-Caroline Aschenauer to EIC



Further Input from Elke-Caroline Aschenauer to EIC



Further Input from Elke-Caroline Aschenauer to EIC



EIC Project Status

The EIC received in the 2015 Long Range Planning of the NSAC the following recommendation

"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB"

http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf

Note:
all projects which received recommendations in the past, i.e. FRIB, JLAB, have been realized

Path forward for the EIC:

- DOE sanctioned a science Review by National Academy of Science of EIC
  - → Expect report by June/July 2018
- Positive NAS review will trigger the DOE's CD process
  - → CD0 (acceptance of the critical need for science by DOE) likely FY19
  - → EIC-Proposal's Technical & Cost review → FY20 (site selection)
  - → Major Construction funds ("CD3") by 2022/23" (according to LRP2015)
    - ➤ Assuming 1.6% sustained increase over inflation of the next several years (Long Range Plan)
    - ➤ Consistent with the past 10 years of NP funding increases in the US
- First collisions sometime between 2028-2030
  - ➤ EIC will run in parallel to HL-LHC

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Further Input from Elke-Caroline Aschenauer to EIC

Critical Decision Process DOE

PROJECT ACQUISITION PROCESS AND CRITICAL DECISIONS					
Project Planning Phase		Project Execution Phase			Mission
Preconceptual Planning	Conceptual Design	Preliminary Design	Final Design	Construction	Operations

• CD-0	• CD-1	• CD-2	• CD-3	• CD-4
Approve Mission Need	Approve Preliminary Baseline Range	Approve Performance Baseline	Approve Start of Construction	Approve Start of Operations or Project Closeout

CD-0	CD-1	CD-2	CD-3	CD-4
Actions Authorized by Critical Decision Approval				
• Proceed with conceptual design using program funds • Request PED funding	• Allow expenditure of PED funds for design	• Establish baseline budget for construction • Continue design • Request construction funding	• Approve expenditure of funds for construction	• Allow start of operations or project closeout

PED: Project Engineering and Design

8 EIC Collaboration Meeting 2017 E.C. Aschenauer

Further Input from Elke-Caroline Aschenauer to EIC

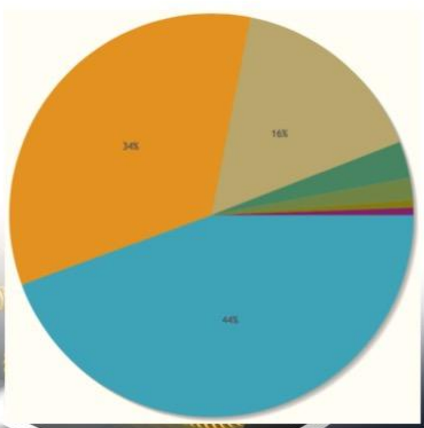
EIC User community

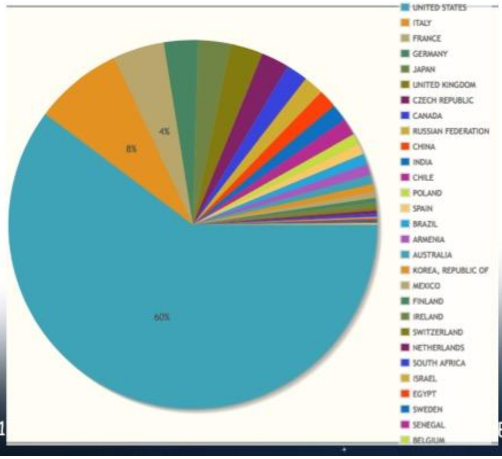
Currently ~737 members from 169 institutions from 29 countries from 7 world regions
US: 44% Europe: 34% Asia: 16%

→ continuously growing

→ Please sign up and join us
http://www.eicug.org

Distribution over the world:





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Further Input from Elke-Caroline Aschenauer to EIC

EIC User community

- Very active generic EIC detector R&D program:
  https://wiki.bnl.gov/conferences/index.php/EIC_R%25D
  37 groups collaborate in tracking, calorimeter, PID consortia and …….
  active participation from Europe;
  open to groups from everywhere around the globe
- EIC Conference series: POETIC (Physics Opportunities at an ElecTron-Ion Collider)
  19th – 22nd of March 2018: Regensburg Germany
  2019 Berkeley, USA
- Next EIC user group meeting:
  July 30 – August 3, 2018 at Catholic University Washington, DC
- INT-Program: Probing Nucleons and Nuclei in High-Energy Collisions (INT-18-3), October 1 – November 18, 2018.