EICUG

Electron-Ion Collider User Group Meeting

2019 JULY 22-26 PARIS

École Nationale Supérieure de Chimie

The world's most powerful microscope for studying the "glue" that binds the building blocks of visible matter

3D STRUCTURE OF PROTON AND NUCLEI

GLUON SATURATION AND THE COLOR GLASS CONDENSATE

SOLVING THE MYSTERY OF THE PROTON SPIN

MENT

International Advisory Committee

Daniël BOER: Groningen
Silvia DALLA TORRE: INFN/Trieste
Abhay DESHPANDE: BNL/Stony Brook
Rolf ENT: JLAB
Yuji GOTO: RIKEN
Tanja HORN: CUA
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Marco RADICI: INF
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Andrei SERYI: JLA
Ernst SICHTERMANN: LBNL
Bernd SURROW: Temple
Thomas ULLRICH: BNL
Ferdinand WILLEKE: BNL
Rikutaro YOSHIDA: JLAB

Summary of European Particle Physics Strategy Update

(from the EIC point of view)

Marco Radici
INFN - Pavia

Local Organizing Committee

Francesco BOSSU: CEA-Saclay
Valérie FROIS: CNRS/IN2P3, Sec
Carlos MUÑOZ CAMACHO: CNR
Franck SABATIÉ: CEA-Saclay

https://indico.in2p3.fr/event/EICUG2019

Scan me

INFN Istituto Nazionale di Fisica Nucleare

What's the EPPS Update ?

*".. The **European Particle Physics Strategy** is the cornerstone of Europe's decision making process for the long-term future of the field.."*

B. Erazmus, e-EPS bulletin July 2019

Update of **EPPS** is under way

previous update on 2013:

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

The EIC User Group is naturally interested in this update

In particular, the European Community of the EIC UG

Motivation

Many synergies between CERN and US-based EIC:

Physics: - Heavy-Ion program (ALICE)
- Hadron program (COMPASS)
- eP collider plans (LHeC, FCCeh, VHEeP, PePIC,..)
....

Accelerator R&D: Crab Cavities, Energy Recovery Linac, SRF,..

Detector R&D

synergy / complementarity between LHC and EIC already addressed in other previous talks

How does the **EPPS** Update work?

The EPPS Update

Preparatory steps

managed by CERN Council:

- nominating various Committees
- venues and dates of meetings
- call for scientific input, etc..

Community input

from individuals, research groups, institutions..
Deadline: **18 Dec. 2018**

Open Symposium

Community discussion on inputs
13-16 May 2019,
Granada (Spain)

Briefing Book

Critical summary on input from Community
Due by **end of Sept. 2019**

Updated Strategy

Final document
Drafting **Jan. 2020**
Submission **Mar. 2020**
CERN Council final decision **May 2020**

The Main Players in EPPS Update

start → **Strategy Secretariat** → end

supervises and coordinates all steps of Update
chaired by Halina Abramowicz

2018/19

Physics Preparatory Group

- collects all inputs
- organizes the Granada Symposium
- writes the Briefing Book

2019/20

European Strategy Group

- builds consensus
- drafts final document on

Updated Strategy

see Backup slides for more details

The EIC UG in the EPPS Update

* The EIC Steering Committee **invited H. Abramowicz** at previous EIC UG meeting (C.U.A., Washington DC, July 2018)

* Oct. 2nd, 2018: informal **meeting** between R. Yoshida, R. Ent, A. Deshpande, and **Eckhard Elsen** (CERN Director of Research and Computing):

  - aware of large European interest / involvement in EIC
  - aware of many synergies of EIC with physics program at CERN
  - encourage **submission of EIC documents** on physics, accelerator, detector, during the EPPS Community input step
  - encourage participation of **EIC UG delegation** in the Granada Open Symposium to give input to the discussion

The EIC UG documents for EPPS input

10-page "whitepaper" on synergies between EIC and EPPS science cases

December 18, 2018

Synergies between a U.S.-based Electron-Ion Collider and the European research in Particle Physics

Contact Persons: Daniël Boer[1], Marco Radici[2]

On behalf of the Electron-Ion Collider (EIC) User Group[3]

Abstract

This document is submitted as input to the European Strategy for Particle Physics Update (ESPPU). The U.S.-based Electron-Ion Collider (EIC) project recently received strong endorsement by the U.S. National Academies of Sciences, Engineering, and Medicine, bringing its realization another step closer. A large group of European scientists is already involved in the EIC project. Currently, more than a quarter of the EIC User Group (consisting of over 800 scientists) is based in Europe. This European involvement is not only an important driver of the EIC, but can also be beneficial for a number of related ongoing and planned particle physics experiments at CERN. In this document, the connections between the scientific questions addressed at CERN and at the EIC are outlined, as well as the shared interest regarding detector R&D. The aim is to highlight how the synergies between the European Particle Physics research and the EIC project offer ample opportunities to foster progress at the forefront of collider physics.

[1]: *Van Swinderen Institute for Particle Physics and Gravity, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands*
email: d.boer@rug.nl

[2]: *INFN Sezione di Pavia, via Bassi 6, I-27100 Pavia, Italy*
email: marco.radici@pv.infn.it

[3]: with contributions from E. Aschenauer, S. Dalla Torre, M. Diehl, T. Lappi, T. Ullrich, and Yuxiang Zhao; and with useful comments and remarks from F. Bossu, A. Bressan, A. Deshpande, C. Hyde, K. Kumar, H. Montgomery, H. Moutarde, F. Sabatié, G. Schnell, E. Sichtermann, M. Winn, and R. Yoshida.

https://indico.cern.ch/event/765096/contributions/
input #99

- **EIC** will hopefully start running in ~ 2030's concurrently with **HL-LHC**

- neutral/charged **e-weak DIS** constrains **high-x PDFs** with independent BSM-insensitive data

- **SIDIS data** → better Fragm.Functs. → better **strange PDF** (also **polarized**)
  → test universality/factorization/evolution of **TMDs and transition to collinear** regime by comparing e-p and p-p collision

- **DVCS / DVMP data** → **spatial distrib.** of partons in GPDs → info on **Multi-Part. Interactions**
  → access to **OAM, charge, pressure,..** distributions

- **e-A collision** → **nuclear** (gluon) **PDFs** (at large x)
  → **saturation** (with excl.+diffr. productions)
  → **initial state** conditions (ridge, elliptic flow)

- low-energy **BSM tests** ($\sin\theta_W$, M_W, g_T)

The EIC UG documents for EPPS input

10-page "whitepaper" on Accelerator R&D

https://indico.cern.ch/event/765096/contributions/
input #74

Electron Ion Collider Accelerator Science and Technology – Designs, R&D and Synergies with European research in Accelerator – submission to European Strategy Update on particle physics

Contact persons: Ferdinand Willeke*and Andrei Seryi†,
On behalf of Electron Ion Collider accelerator design team‡

December 9, 2018

Abstract

A U.S.-based Electron-Ion Collider (EIC) has recently been endorsed by the U.S. National Academies of Sciences, Engineering, and Medicine (NAS). This brings the realization of such a collider another step closer, after its earlier recommendation in the 2015 Long-Range Plan for U.S. nuclear science of the Nuclear Science Advisory Committee "as the highest priority for new facility construction following the completion of FRIB". The connections between the scientific questions addressed at CERN and at the EIC as well as the shared interest regarding detector R&D are addressed in a separate submitted document "Synergies between a U.S.-based Electron-Ion Collider and the European research in Particle Physics". There are, also, a large number of accelerator R&D topics that are associated with the US EIC that could be undertaken in collaboration that would be of enormous mutual benefit for European research centers and the US EIC.

An EIC will be an unprecedented collider that will need to maintain high luminosity (10^{33-34}cm^{-2}s^{-1}) over a very wide range of Center-of- Mass energies (20 GeV to ∼100 GeV, upgradable to ∼140 GeV), while accommodating highly polarized beams and many different ion species. Addressing the challenges of this machine requires R&D in areas such as crab cavities, energy-recovery linacs (for ion beam cooling), and high field magnets for the interaction points – areas in which U.S. and European centers are already investing in R&D, in many cases jointly.

A multi-laboratory collaboration is presently working on two site-specific EIC designs – eRHIC led by Brookhaven National Laboratory and JLEIC led by Jefferson Lab. While the designs are different, there are many common R&D issues on which eRHIC and JLEIC efforts are cooperating closely. The purpose of the present paper is to outline the status of the EIC accelerator designs and to discuss the most significant R&D subjects that have strong connection with developments in Europe, with the purpose of enlarging EIC collaboration both in physics and accelerator, to strengthen synergies with European accelerator projects, and – more generally – to maximize positive impact of fundamental science on society worldwide.

*Brookhaven National Laboratory, willeke@bnl.gov
†Jefferson Lab, seryi@jlab.org
‡U.S. R&D efforts on EIC are supported by the Department Of Energy Office of Nuclear Physics.

- incl./ semi-incl./ excl. processes; collisions at variable energies; different ion beams; high beam polarization → **very complex apparatus**

- very precise determination of **scattered electron** → constrain detector features

- excellent **hadron identification** over a wide phase space → diversified tools for particle identification

- detectors incorporated into the interaction region; **complete hemeticity** of the setup

- highly accurate **polarimetry** of e⁻, p, light ions

- diversified experience and leadership of **US** and **EU**

- **EU groups** from UK, GSI, INFN (Ge, Fe, Roma, Ts), IPN-Orsay, **collaborate** with **US** on R&D projects

- **INFN** project **EIC_NET** (45 FTE from 11 sections)

EIC in other documents of EPPS input

https://indico.cern.ch/event/765096/contributions/

- input #103 *The "DIS and Related Subjects" Strategy Document: Fundamental Science from Lepton-Hadron Scattering*
A. Caldwell, R. Ent, A. Levy, P. Newman, F. Olness

- input #163 *Quantum Chromodynamics: Theory - Input for the European Particle Physics Strategy Update*
N. Armesto, G. Bali, V. Braun, S. Collins, M. Diehl, E. Ferreiro, F. Hautmann, S. Moch, P. Mulders, J. Qiu

- National roadmaps: input #26 - INFN; input #115 - German Hadron; input #21 - INFN Hadron; input #148 - NuPECC; input #56 - Italian HI; input #88 - Czech Part. Phys.; …

- Other related documents:

input #159 - LHeC; input #140 - FCCeh; input #58 - AWAKE++; input #35 - VHEep	**colliders**
input #110 - ALICE; input #48 - HI Town Meet.; input #47 - fixed-target ALICE;…	**HI**
input #143 - COMPASSII; input #111 - LHCspin; input #67 - AFTER; input #39 - EPIC	**Hadron**
input #17 - PERLE	**Accel**
input #68 - ECFA Detector Panel; input #114 - MC event generators	**R&D**

EIC and the Granada Open Symposium

https://cafpe.ugr.es/eppsu2019/

8 discussion sessions, conveners from the Physics Preparatory Group

Accelerator Science and Technology
Caterina Biscari
Lenny Rivkin

Instrumentation and Computing
Xinchou Lou
Brigitte Vachon

Electroweak Physics
Keith Ellis
Beate Heinemann

Strong interactions
Jorgen D'Hondt
Krzysztof Redlich

Neutrino Physics
Stan Bentvelsen
Marco Zito

BSM at colliders
Gian Giudice
Paris Sphicas

Dark Matter and Dark Sector
Shoji Asai
Marcela Carena

Flavour Physics and CP violation
Belen Gavela
Antonio Zoccoli

EIC and the Granada Open Symposium

https://cafpe.ugr.es/eppsu2019/

Strong interactions

Jorgen D'Hondt
Krzysztof Redlich

- What are the experimental and theoretical pre-requisites to reach an adequate precision of perturbative and non-perturbative QCD predictions at the highest energies ?
- What can be learned from beams-on-target experiments at current and potential future (pre-)accelerators to test strong interactions ?
- How to probe the QGP equation of state and to establish whether there is a 1st order phase transition at high baryon density ?
- What is known about the make-up of the proton (mass, radius, spin, etc..) and how to extract it ?
- What is the role of strong interactions at very low and very high (up to astrophysical) energies ?

2 half days with 14 talks, grouped in 4 parallel sessions “topic-oriented" :
#1 “QCD”, #2 “Target”, #3 "Heavy Ions”, #4 “Topical”

EIC and the Granada Open Symposium

CERN Council Open Symposium on the Update of
European Strategy for Particle Physics
13-16 May 2019 - Granada, Spain

https://cafpe.ugr.es/eppsu2019/

Strong interactions

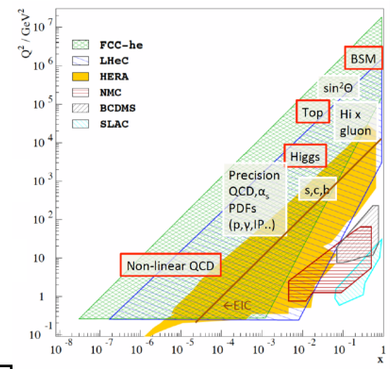
Jorgen D'Hondt
Krzysztof Redlich

several talks mentioned / discussed EIC physics

T. Gerhmann *Scientific Aspirations* (Sess. #1)

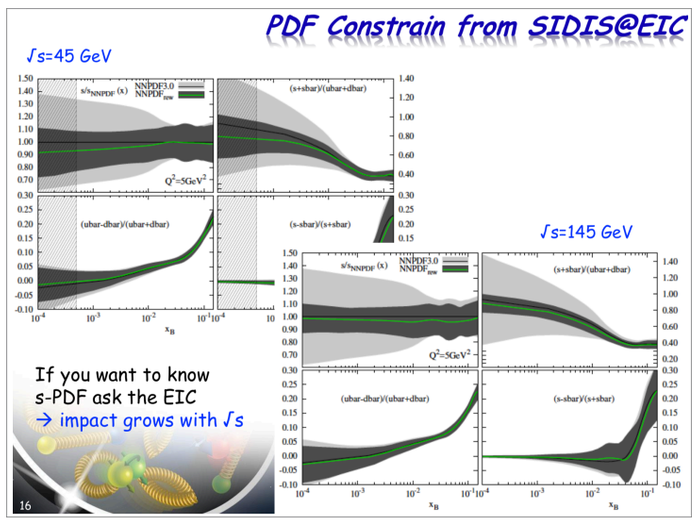
QCD at future facilities

- Lepton-hadron collisions from low to high energies
  (D. Boer, U.Klein)
  - Elastic, inelastic and deeply inelastic scattering on fixed targets at PBC@CERN (COMPASS++/AMBER): nucleon interactions and structure
  - Medium energy range US-based EIC project: 3D nucleon structure
  - High-energy frontier LHeC, FCC-eh: ultimate precision on PDF and QCD studies



D. Boer *What Strong Interaction Physics can one do with the LHC after the HL-LHC?* (Sess. #4)

Projections for unpolarized PDFs from EIC



Slide by Elke Aschenauer, INT program INT-18-3, 2018

Multi-dimensional parton distributions

TMDs: transverse momentum dependent PDFs

GPDs: off-forward PDFs

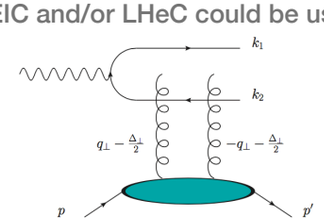
GTMD = off-forward TMD = Fourier transform of a Wigner distribution

$$G(x, \boldsymbol{k}_T, \boldsymbol{\Delta}_T) \overset{FT}{\longleftrightarrow} W(x, \boldsymbol{k}_T, \boldsymbol{b}_T)$$

Meißner, Metz, Schlegel, 2009 Ji, 2003; Belitsky, Ji & Yuan, 2004

Diffraction dijet production in eA at EIC and/or LHeC could be used to probe GTMDs for the first time

Altinoluk, Armesto, Beuf, Rezaeian, 2016;
Hatta, Xiao, Yuan, 2016



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Strong interactions

Jorgen D'Hondt
Krzysztof Redlich

several talks mentioned / discussed EIC physics

U. Klein *QCD at ep colliders* (Sess. #4)

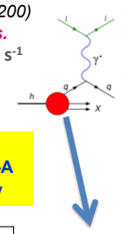
Future eh Colliders: EIC *and* LHeC Most advanced proposals

EIC:
$E_{c.m.s.}$ ~ 0.020- 0.14 TeV
White Paper: arXiv:1212.17010; **#99**

- *Polarised* electrons with E_e ~3–20 GeV
- ***Polarised*** *(70%)* ***proton*** beams and unpolarised heavy ion beams (A≤200)
- *High luminosity for* ***spin physics.***
- ep peak lumi $10^{33} – 10^{34}$ cm s^{-2} s^{-1}

LHeC:
$E_{c.m.s.}$ 0.2 - 1.3 TeV
CDR J. Phys. G 39, 075001 (2012)**; #159**

- ***Polarised*** *electrons with* E_e ~30-60 GeV to probe unpolarised *LHC proton and ion beams*
- *High luminosity for high* Q^2
- *Lower c.m.s. reached by lowering e and p beam energies to 10 GeV and 1 TeV resp.*
- ep peak lumi 10^{34} cm s^{-2} s^{-1}



World's first polarised e-p collider and medium energy e-A collider below HERA c.m.s. energy

High-energy frontier e-p and e-A collider running simultaneously with HL-LHC, expanding hugely HERA kinematics → exploring QCD+EW sector (e.g. top, Higgs, BSM…) above HERA c.m.s. energy

x_{min} ~ 1 x 10^{-4}
Q^2_{max} ~ 10^3 -10^4 GeV^2

Unravel non-perturbative proton structure with new measurements

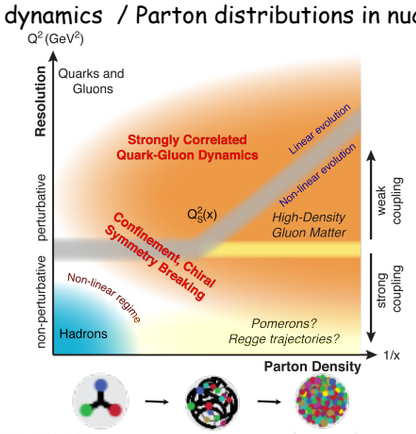
x_{min} ~ 6 x 10^{-7}
Q^2_{max} ~ 10^5 -10^6 GeV^2

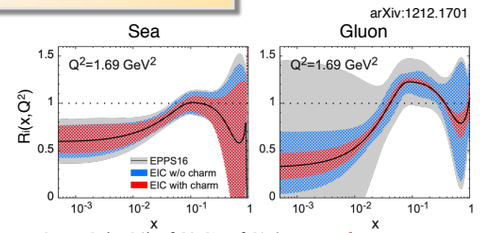
N. Armesto *QCD at eA colliders* (Sess. #3)

Physics cases:

The EIC Physics Pillars

QCD dynamics / Parton distributions in nuclei

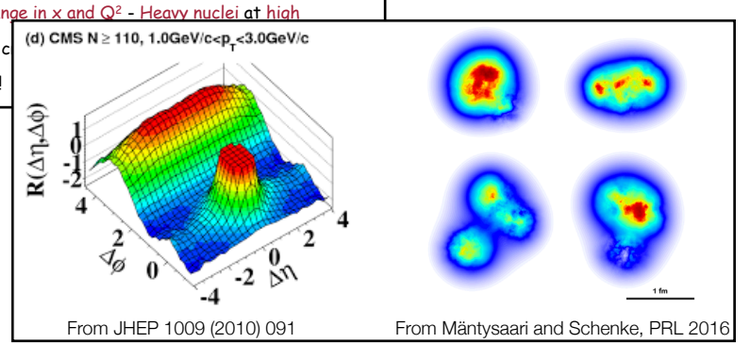




- Ratio $R_i(x,Q^2)$ of PDF's of Pb/p - Significant reduction of uncertainties of nuclear sea quarks / gluons with EIC
- Explore QCD landscape in various aspects over a wide range in x and Q^2 - Heavy nuclei at high energy c
matter!

European Strategy for Particle Physics
Granada, Spain, May 13-16, 2019

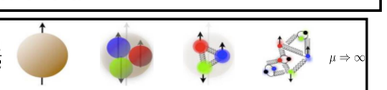
nPDF, initial state (ridge,..)
eA => access to low-x



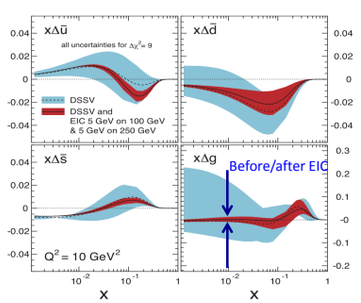
From JHEP 1009 (2010) 091

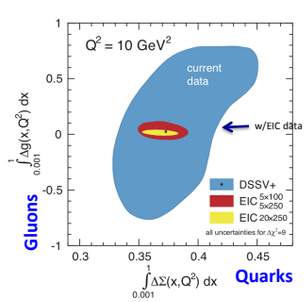
From Mäntysaari and Schenke, PRL 2016

Proton Spin @ EIC



Requires longitudinally polarised hadron and electron beams → unique for EIC !





- ***Precision measurement of ΔG and ΔΣ via extension to smaller x regime via pQCD scaling violations:*** *challenging measurements since spin asymmetries → 0 for small x*
- ***Orbital angular momentum L? Explore spin & quantum correlations observables***
  - → *(Spatial distance from origin) X (Transverse Momentum)*
  - → *needs a wealth of exp. data but link of observables to L remains theoretically challenging*

EIC and the Granada Open Symposium

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https://cafpe.ugr.es/eppsu2019/

Strong interactions

Jorgen D'Hondt
Krzysztof Redlich

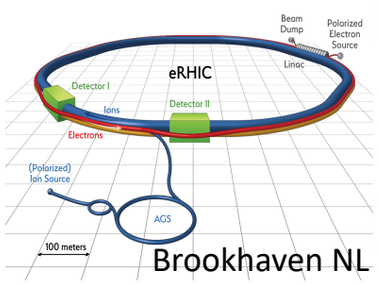
from his summary report in plenary session

The QCD case for eA collisions at high energies (EIC@US)

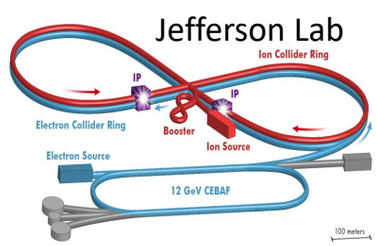
The US-based Electron-Ion Collider (EIC) can address three key questions.

- *How does the mass of the nucleon arise?*
- *How does the spin of the nucleon arise?*
- *What are the emergent properties of a dense system of gluons?*

Two realization concepts being developed.
First collisions from 2029-2030 onwards.

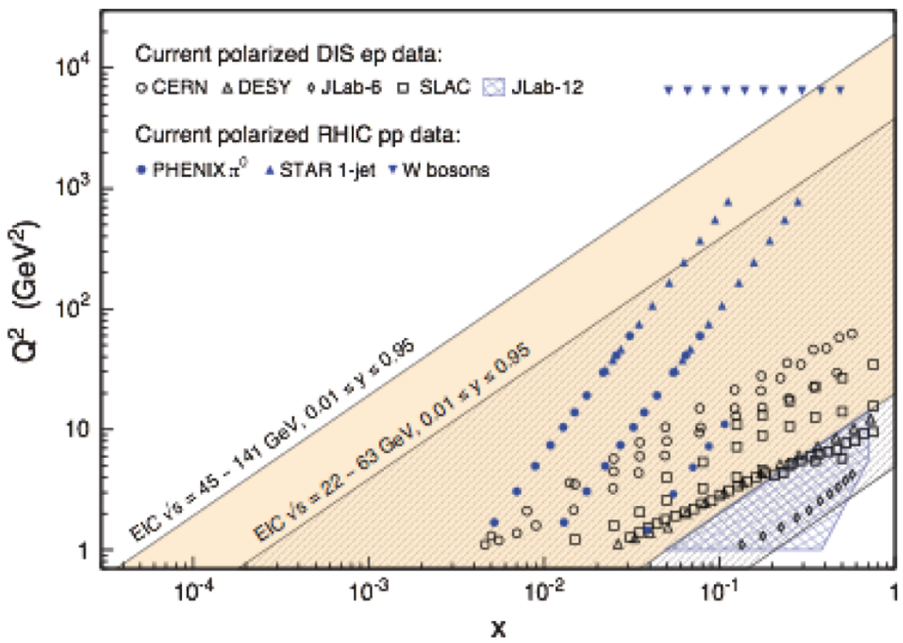


Brookhaven NL



Jefferson Lab

electron-proton DIS at EIC for *HL-LHC-like-x* PDFs
(towards 3D nucleon structures)



Research community at EIC is 1/3 European
Synergies with COMPASS, HL-LHC, LHC-FT, LHeC (ePb), FCC-eh (ePb) at CERN

EIC and the Granada Open Symposium

https://cafpe.ugr.es/eppsu2019/

Accelerator Science and Technology

Caterina Biscari

Lenny Rivkin

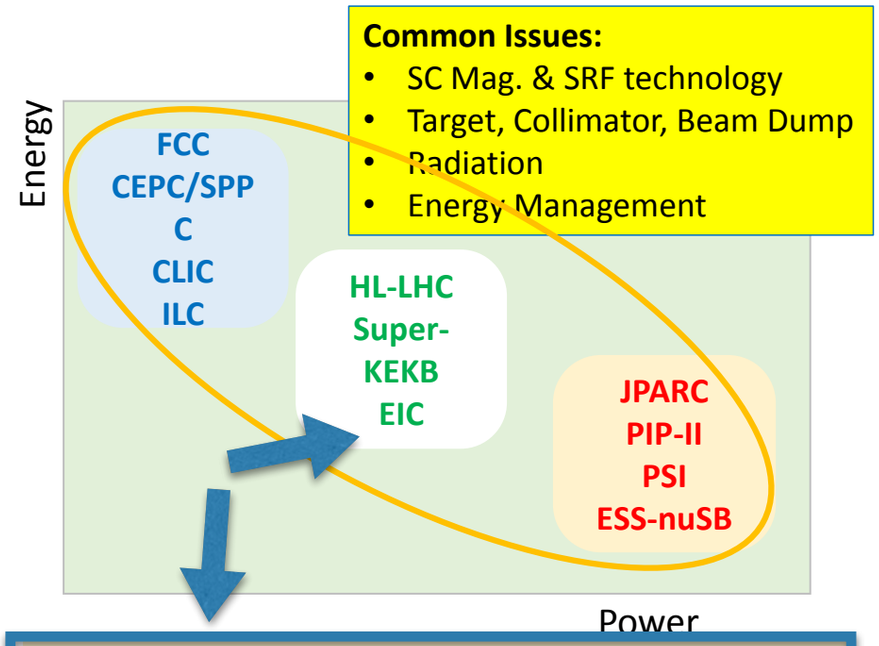
from her discussion report in plenary session

3.How to achieve proper complementarity for the high-intensity frontier vs. the high-energy frontier ?

Intensity frontier vs. Energy Frontier

Intensity – Acc.	Energy [GeV]	Power [MW]	Acc. Tech. Feature	SC Tech.
SPS*	450		Synchrotron	
Fnal M. Injector	120	0.7	Synchrotron	
J-PARC*	3 30	1 0,49 ~ 1.3	Linac/Synchr Ext. Beam	SCM
PIP-II	60 -120	.2	Linac (SRF) Synchrotron	SRF
PSI-HIPA*	0.59	1.4	Cycrotron	
FAIR (SIS100)	29	0.2	Synchrotron	SCM
(ESS) ESSnuSB *	2 2	2 ~ 5 (+5) 2 x 5	Linac	SRF
CEBAF	12	1	LINAC+Ring	SRF
Super-KEKB		---	Collider	
HL-LHC	2 x 7,000	---	Collider	SCM. SRF
EIC*		---	Collider	SCM, SRF

A. Yamamoto, 190512b



- Science is complementary, and
- Technology is based on common technology,
- Let us work together and maximize synergy !!

THANK YOU

for your

ATTENTION!

Backup Slides

Backup Slides

Strategy Secretariat

Composition :

- Halina Abramowicz — Chair
- Keith Ellis — Chair of CERN SPC
- Jorgen D'Hondt — Chair of ECFA
- Lenny Rivkin — Chair of EU LDG

Tasks : organize and coordinate the whole Strategy Update process

Backup Slides

Physics Preparatory Group

Composition :

- 4 members of Strategy Secretariat
- 4 members indicated by SPC: C. Biscari, B. Gavela, B. Heinemann, K. Redlich
- 4 members indicated by ECFA: S. Bentvelsen, P. Sphicas, M. Zito, A. Zoccoli
- 1 representative from CERN: G. Giudice
- 2 representatives from Americas and 2 from Asia (via ICFA): M. Carena (US), B. Vachon (Can), S. Asai (JP), X. Lou (Chi)

Tasks :

- collect input from Community and set up the physics cases
- organize the Open Symposium in Granada, 13-16 May, 2019
- draft the Briefing Book by end of September 2019

Backup Slides

European Strategy Group

Composition :
- 3 Chairs of Strategy Secretariat, SPC, and ECFA
- 22 one representative for each CERN Member State
- 10 one representative for each lab of the EU LDG
- 1 the CERN Director-General

+ invited :
- 1 the Chair of the CERN Council
- 7+3 one representative for each CERN associated/observer state
- 2 one representative from EU Commission and JINR
- 4 Chairs of ApPEC, NuPECC, FALC, ESFRI
- 17 members of Physics Preparatory Group

Tasks : build consensus and draft the Strategy Update final document

(Strategy Update Drafting Session: Bad Honnef, 20-24 Jan. 2020)