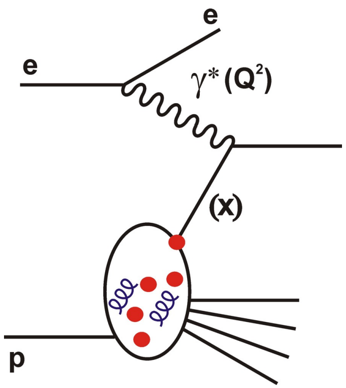
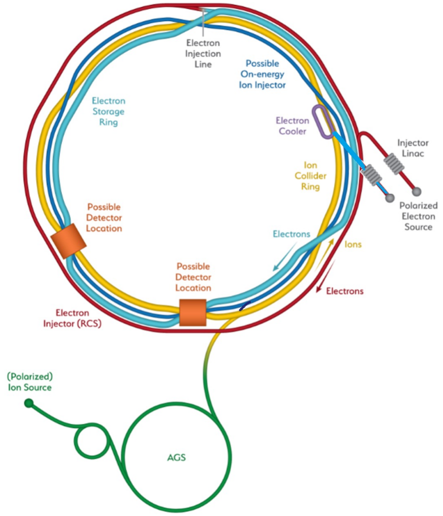
Lepton-Hadron Scattering and The Electron Ion Collider



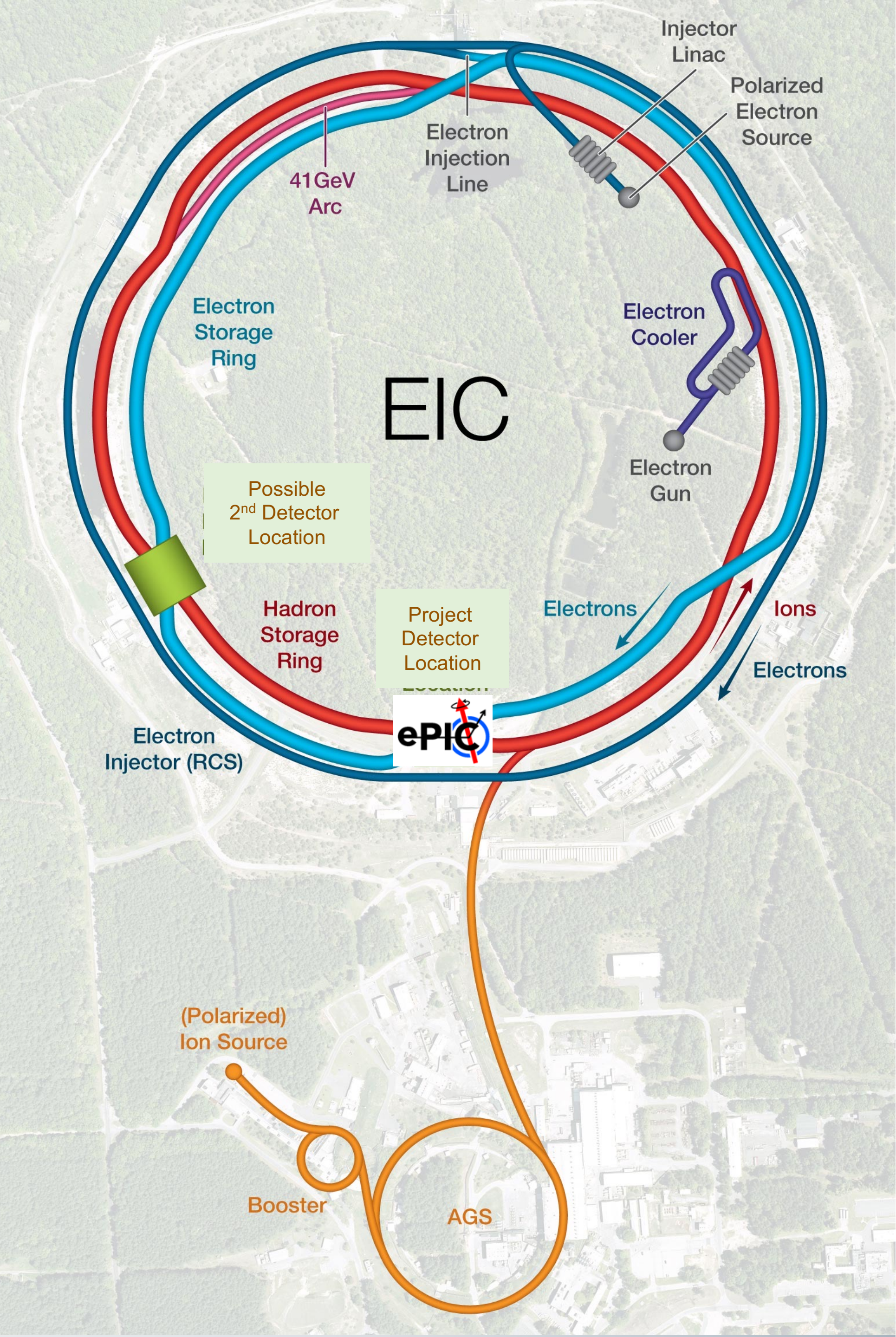
Paul Newman (Birmingham)

RAL Seminar
3 April 2024



1) DIS History and Context
2) Overview and Machine
3) The ePIC detector
4) Physics motivations
5) Timeline
6) UK involvement

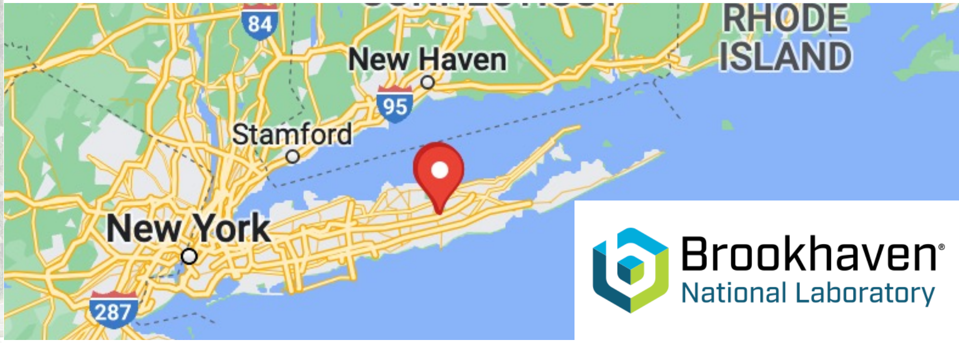
The Electron Ion Collider



New electron storage ring at BNL accelerator complex, to collide with existing RHIC proton / ion beams

On target to be the world's next high energy* collider, starting from the early 2030s

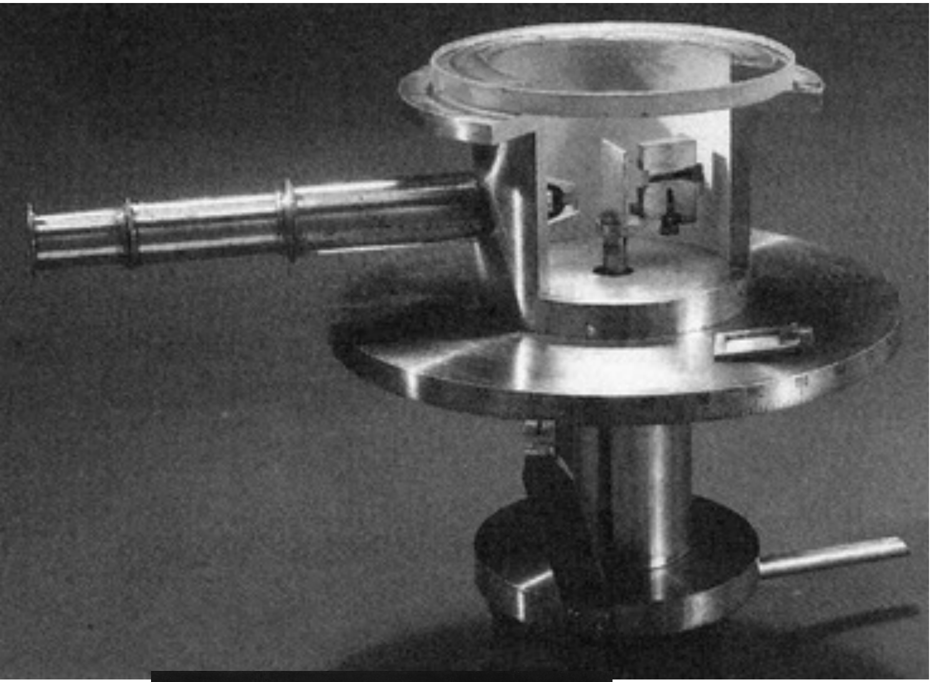
Scientific remit: exploration of strongly interacting matter using Deep Inelastic Scattering

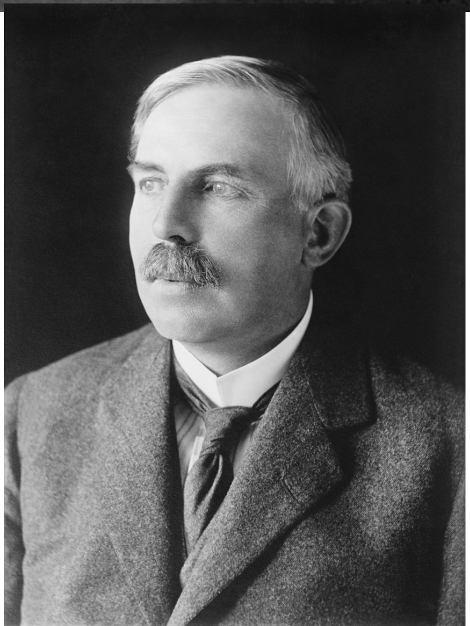


Brookhaven National Laboratory

* High energy ≠ energy frontier

Rutherford (1927, as President of Royal Society)



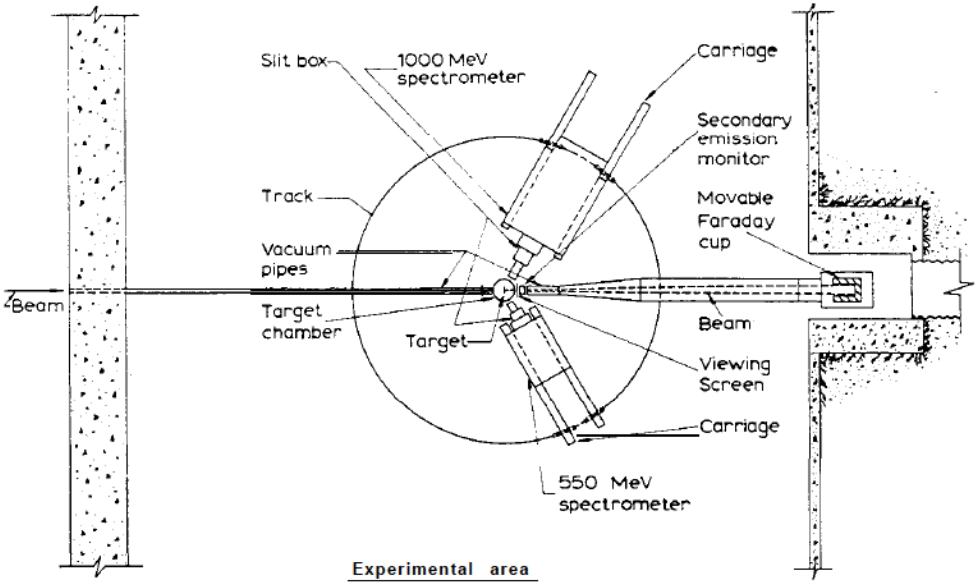


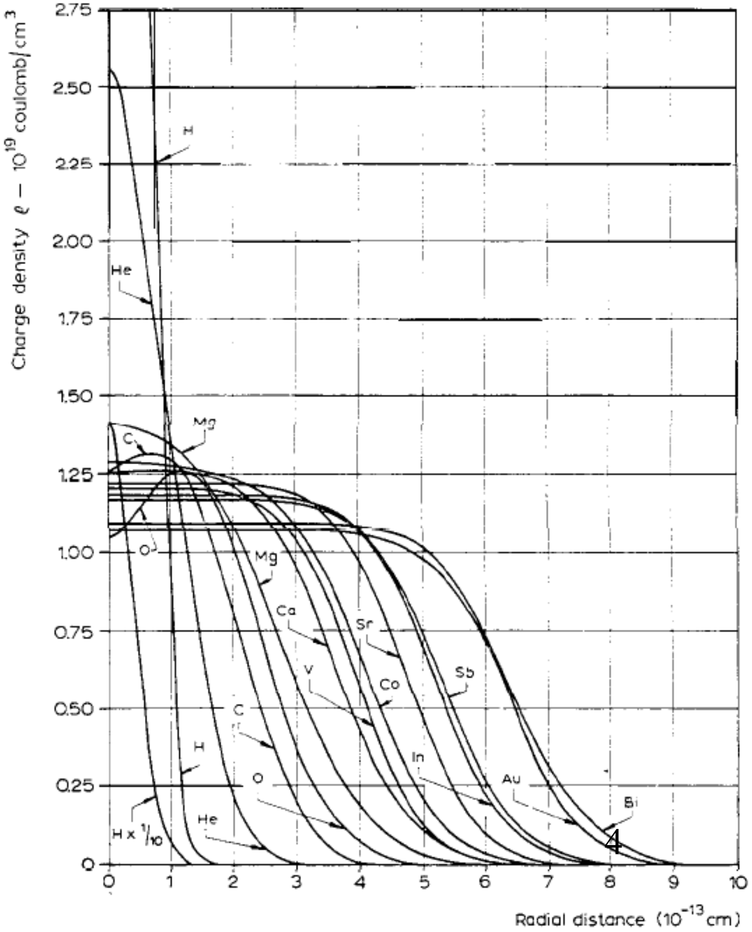
Following from the original scattering experiments (α particles on gold foil target) …

"It would be of great scientific interest if it were possible to have a supply of electrons … of which the individual energy of motion is greater even than that of the alpha particle."

Hofstadter (Nobel Prize 1961)

200 MeV Electrons on a fixed target …





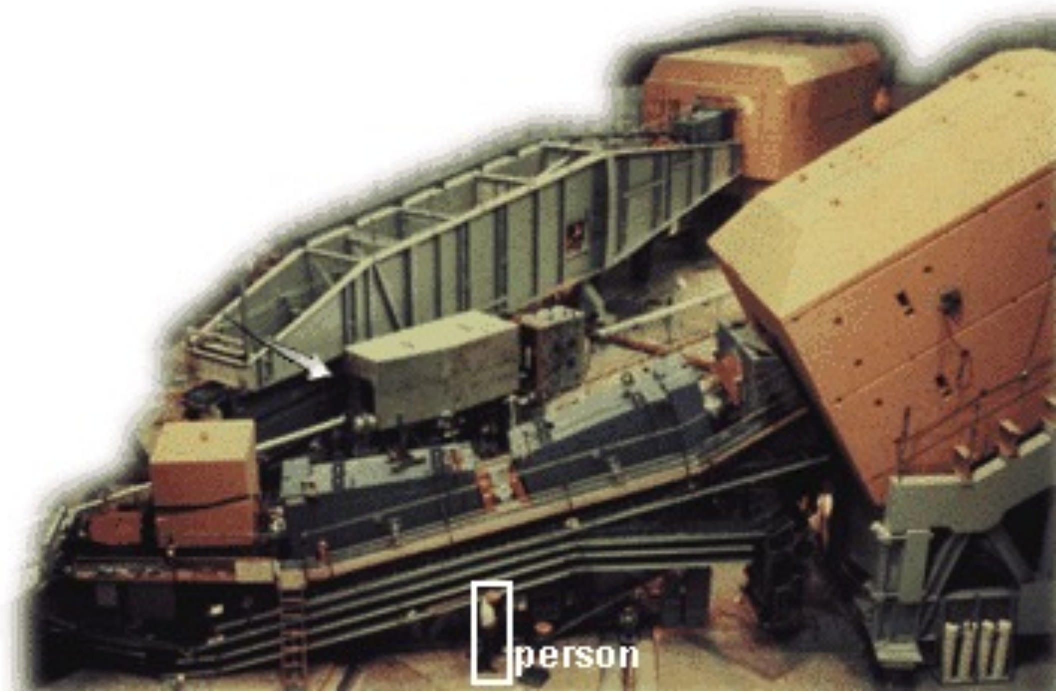
- Electron scattering reveals nuclear form factors (i.e. sizes)

… even a hydrogen nucleus (proton)
has finite size

… electric charge uniformly spread?

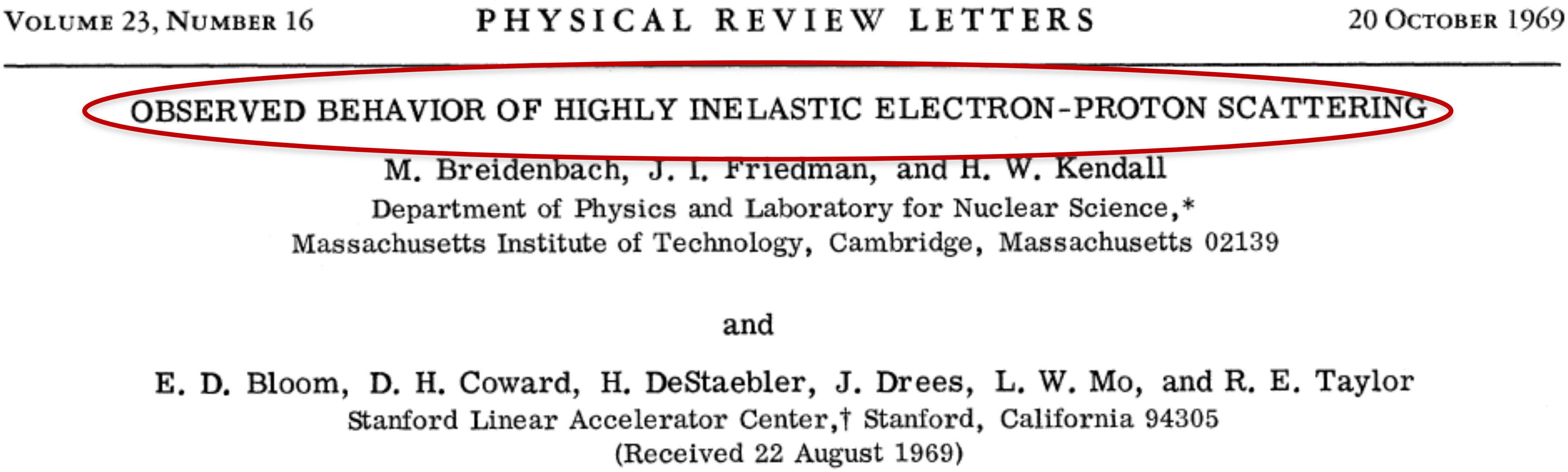
… “soft spheres” …

SLAC 1969: 20 GeV electrons on protons



… observed significant scattering through wide angles (like Rutherford’s alphas), implying ‘point-like’ scattering centres

First Observation Of Proton Structure



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OBSERVED BEHAVIOR OF HIGHLY INELASTIC ELECTRON-PROTON SCATTERING

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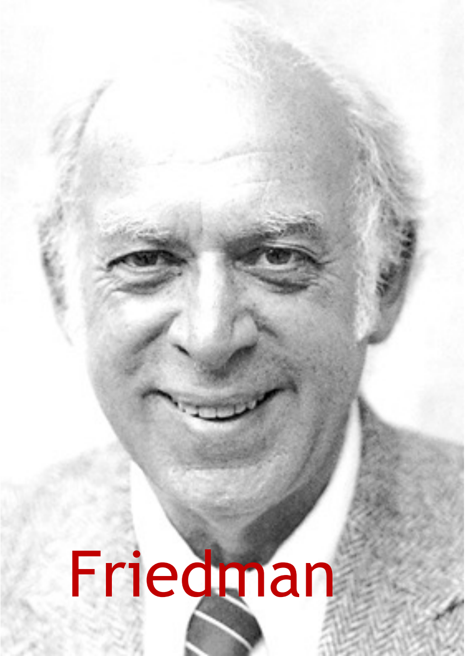
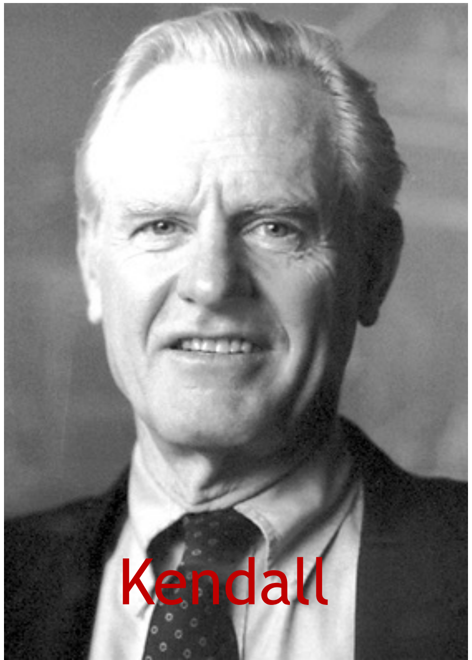
Department of Physics and Laboratory for Nuclear Science,*
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

and

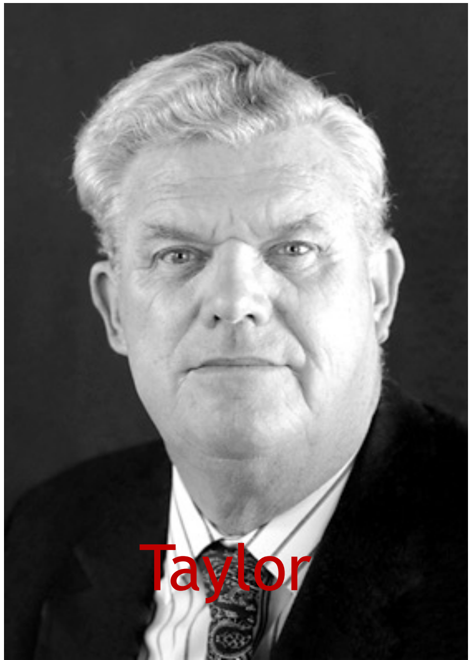
E. D. Bloom, D. H. Coward, H. DeStaebler, J. Drees, L. W. Mo, and R. E. Taylor
Stanford Linear Accelerator Center,† Stanford, California 94305
(Received 22 August 1969)



Friedman



Kendall



Taylor

Nobel
Prize
1990

HERA, DESY, Hamburg

$\sqrt{s_{ep}} \sim 300$ GeV

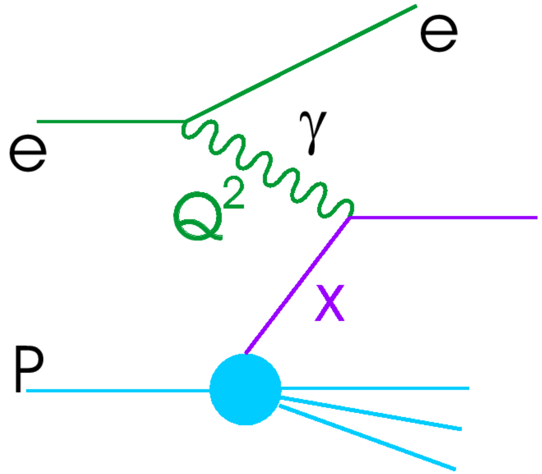
… equivalent to a 50 TeV beam on a fixed target proton

(1992-2007)

- So far still the only collider of electron and proton beams ever

→ Taught us much of what we know about proton structure
→ Only ~0.5 fb^{-1} per experiment
→ No deuteron or nuclear targets

Inclusive Neutral Current DIS: ep→ eX … a 2 Variable Problem



$$Q^2 = -q^2 \qquad x = \frac{-q^2}{2p\cdot q}$$

x = fraction of proton momentum carried by struck quark

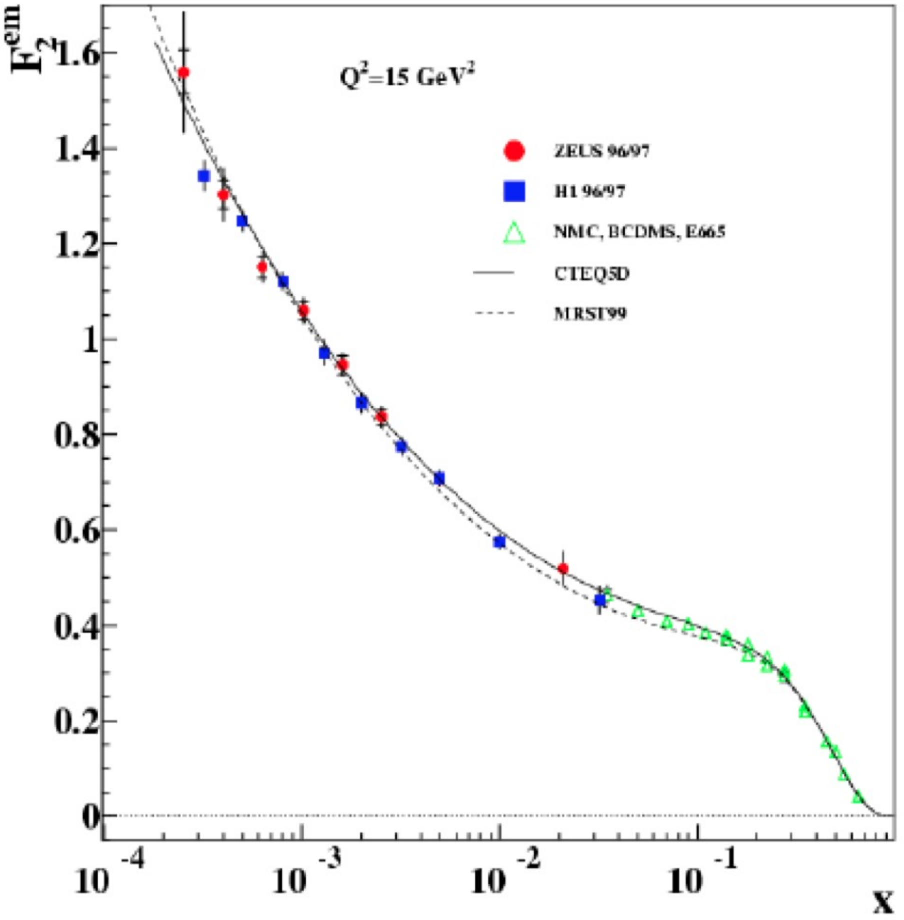
Q^2 = |4-momentum transfer squared| (photon virtuality)

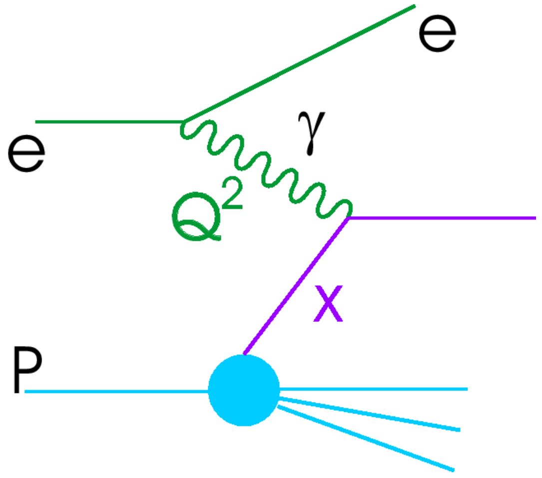
… measures the hardness /scale of collision

… inverse of (squared) resolved dimension

Note $x \geq \frac{Q^2}{s}$ … i.e. Maximum Q^2 and minimum x governed by CMS energy

Example Inclusive Neutral Current Data from Previous Experiments

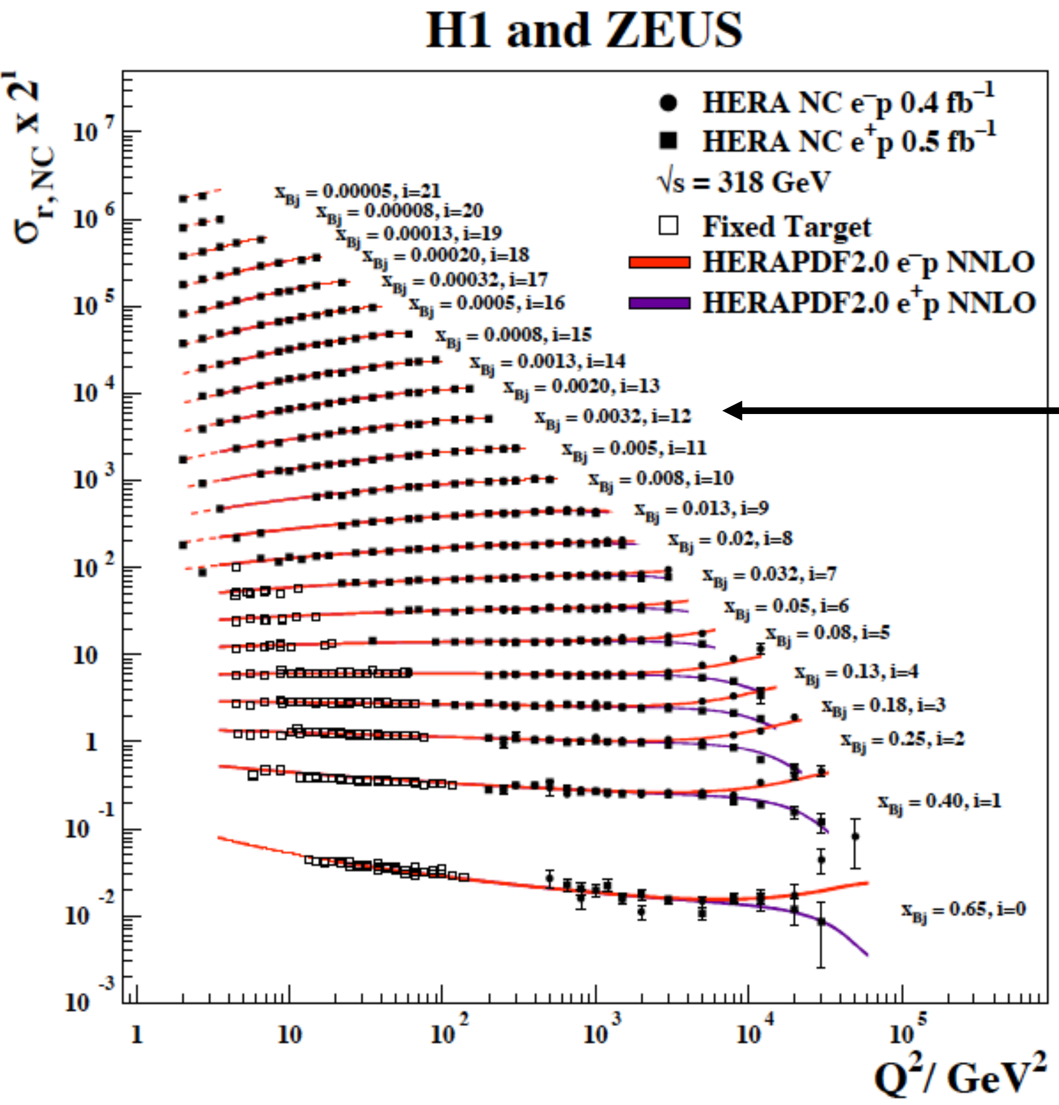




- Inclusive cross section measures (charge-squared weighted) sum of quark densities

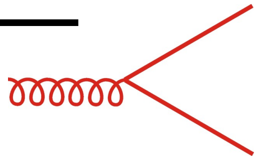
- Similar / better data at many other values of Q^2

QCD Evolution and the Gluon Density



- Q^2 dependence directly sensitive to the gluon density via splitting function …

$$g \rightarrow q\bar{q}$$

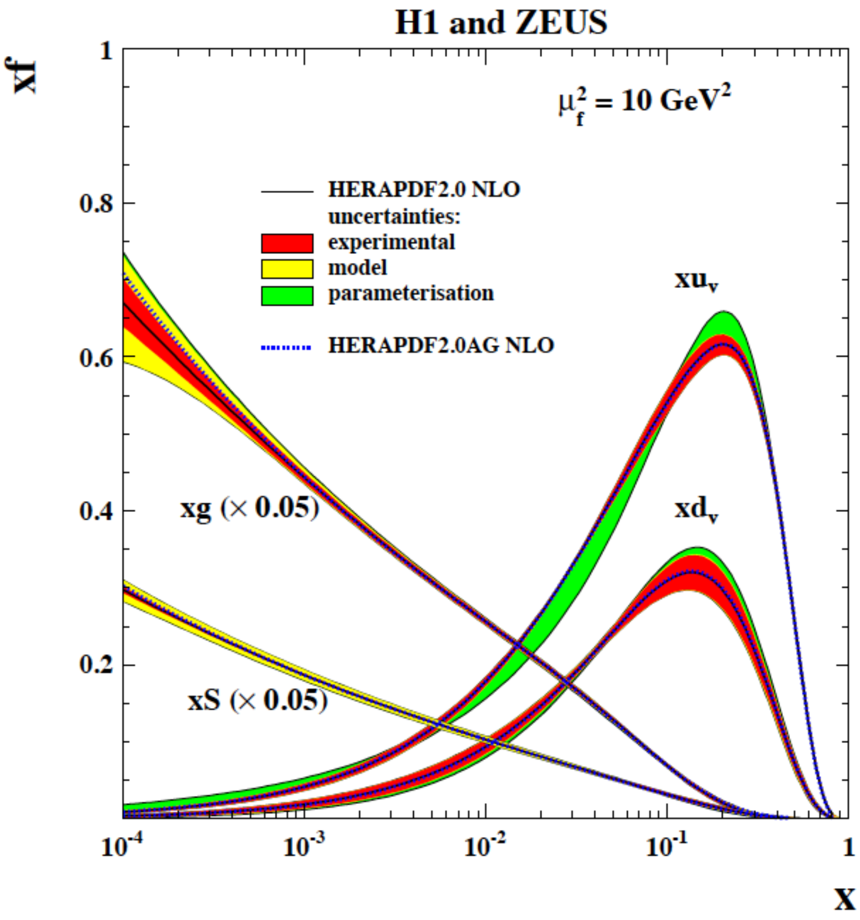


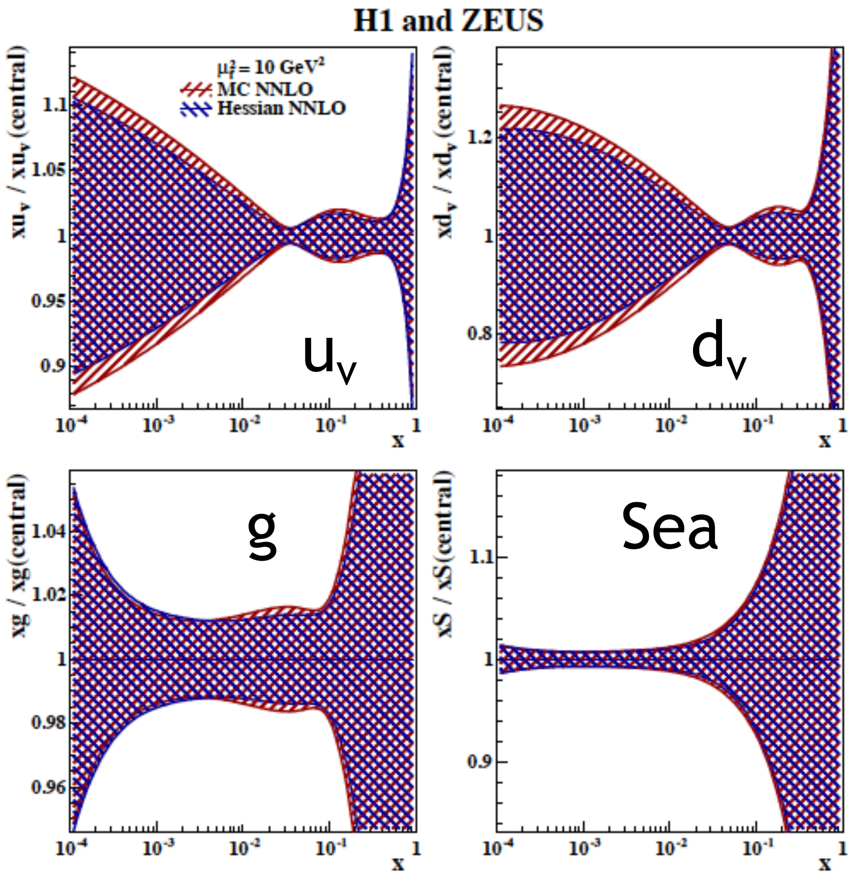
- DGLAP equations describe QCD evolution (to NNLO and approximate N^3LO accuracy)

- EW effects give different quark sensitivities (Z-exchange separates e^+p v e^-p, W-exchange gives charged current ($ep \rightarrow \nu X$)

→ Fits to data to extract proton parton densities

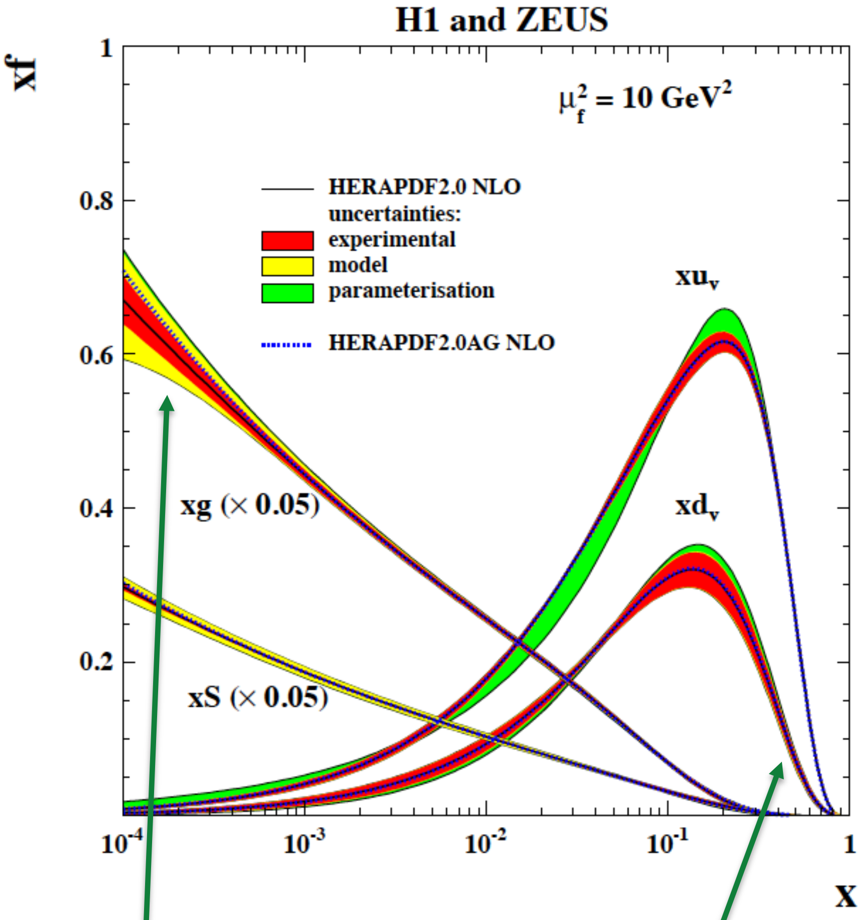
Proton PDFs from HERA only (HERAPDF2.0)

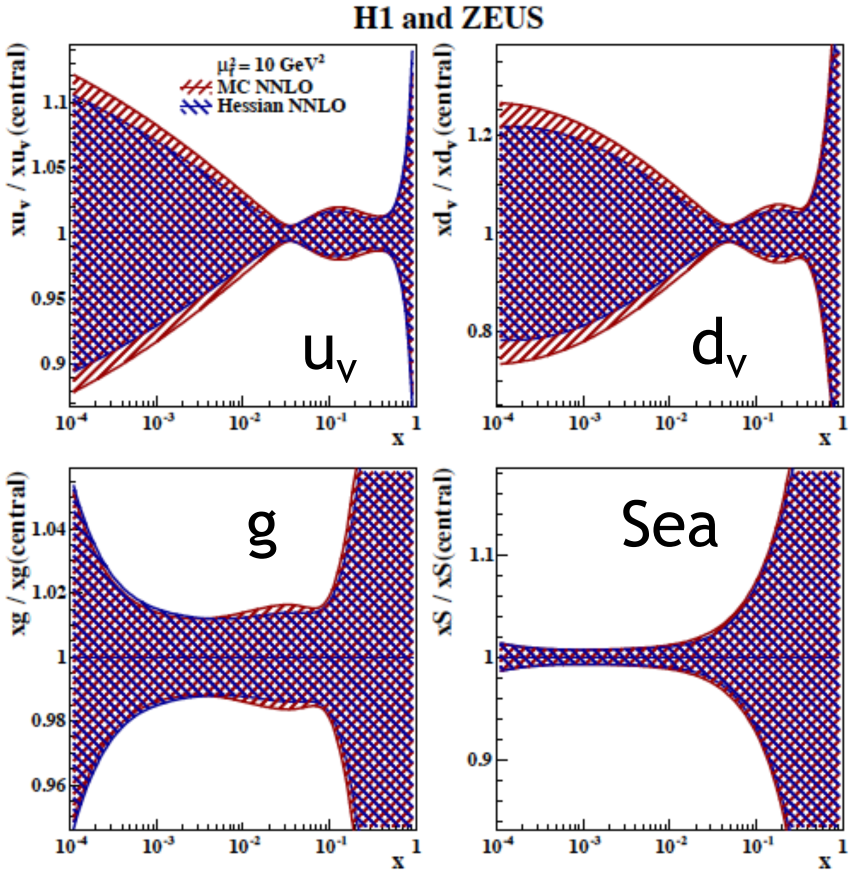




- At x ~ 10^{-2} : ~2% gluon, 1% quark precision
- Uncertainty explodes:
  - below $x=10^{-3}$ (kinematic limit)
  - above $x=10^{-1}$ (limited lumi)

Proton PDFs from HERA only (HERAPDF2.0)



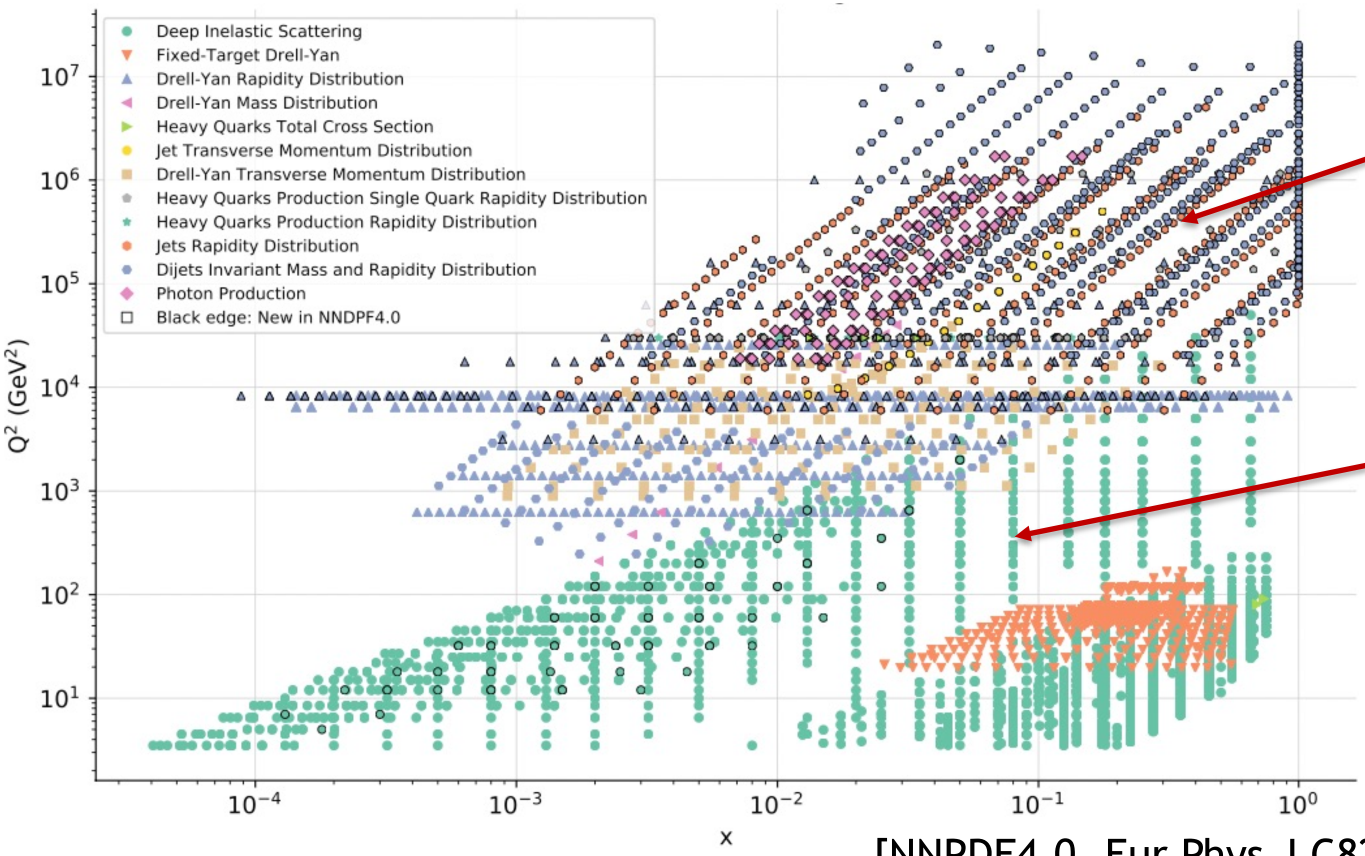


Strong interaction dragons?

Input to energy frontier discovery?

- At x ~ 10^{-2} : ~2% gluon, 1% quark precision
- Uncertainty explodes:
  - below x=10^{-3} (kinematic limit)
  - above x=10^{-1} (limited lumi)

Adding more data: Global PDF fits



Lots of PDF-sensitive observables at LHC

HERA limited at low x by kinematic range and high x by luminosity

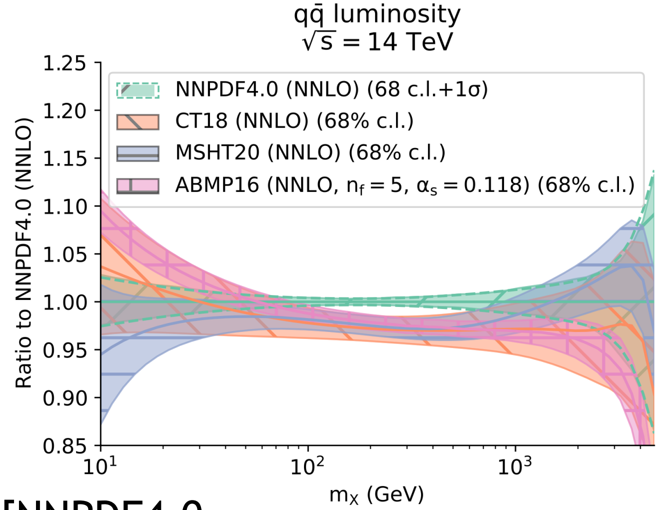
[NNPDF4.0, Eur Phys J C82 (2022) 428]

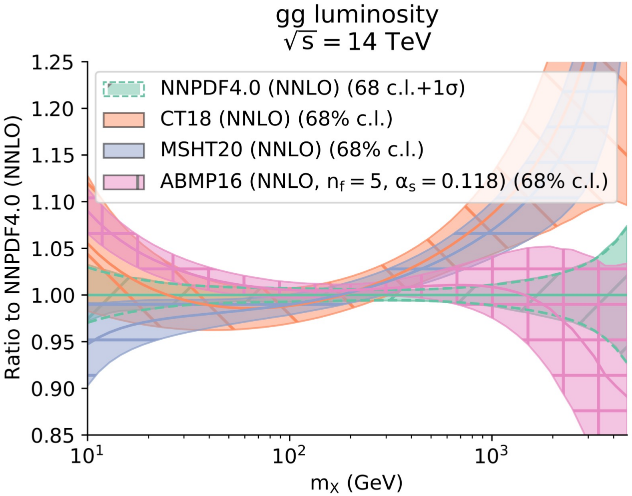
Including LHC data brings:
Advantages: improve precision at mid-high x, exploit all available inputs

Caveats: use of data that may contain BSM effects, theoretical complexity (eg non-perturbative input), some incompatibilities between data sets

Global Fits and LHC Parton Luminosities

e.g. Comparisons between current global fits on LHC $q\bar{q}$ and gg luminosities





[NNPDF4.0 ,
Eur Phys J C82 (2022) 428]

Global Fits and LHC Parton Luminosities

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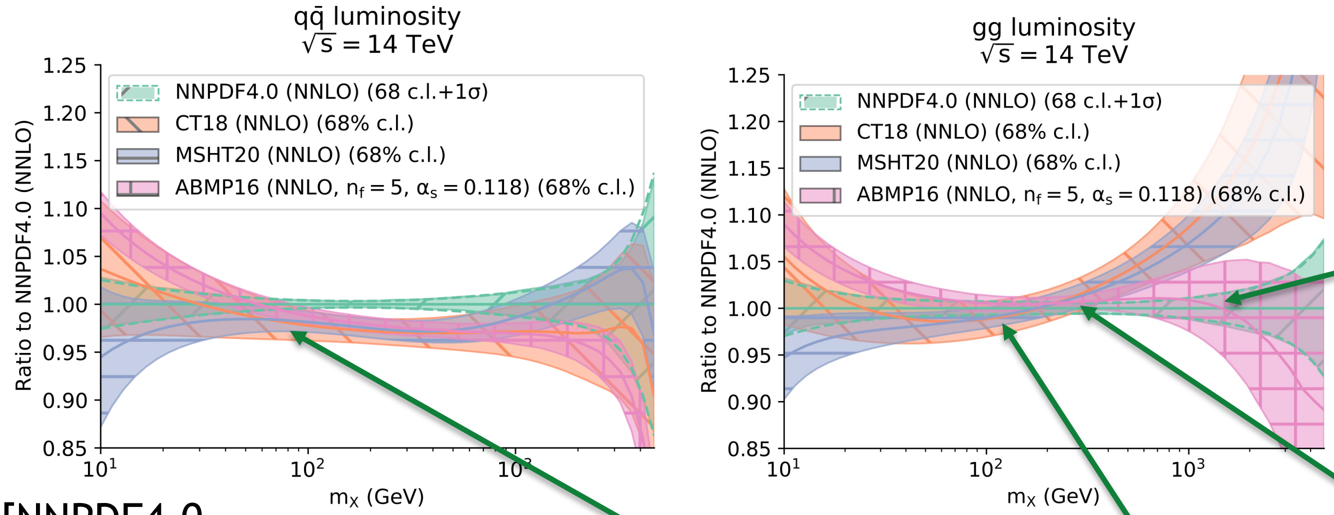
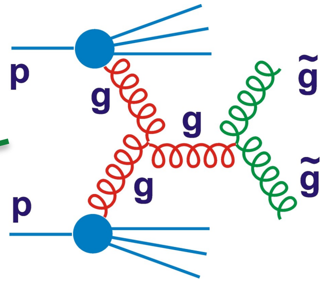
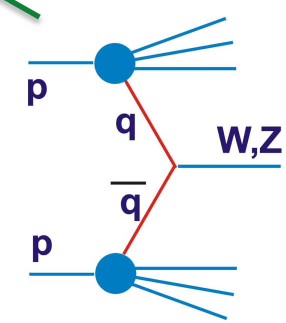
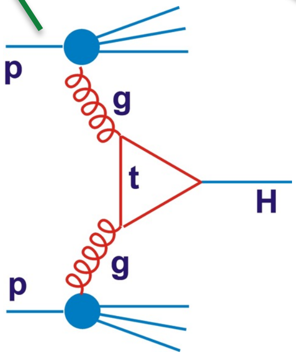
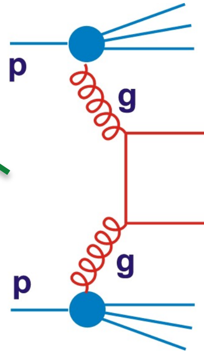


[NNPDF4.0 ,
Eur Phys J C82 (2022) 428]









- Knowing initial state often limits LHC precision measurements & searches

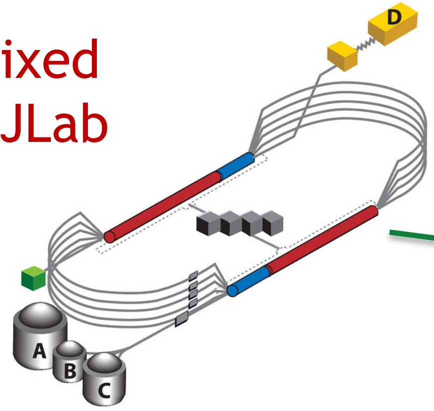
- Immense recent progress, but still large uncertainties and some tensions

Many more reasons to improve PDF precision:

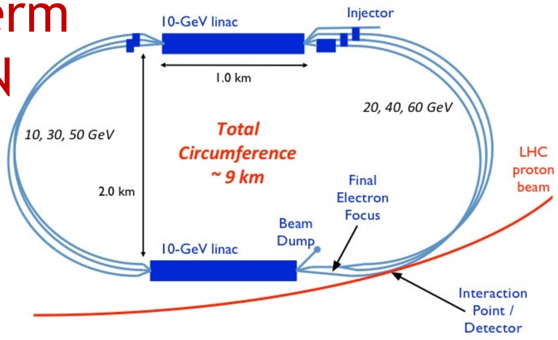
… Cosmic ray air showers, ν matter interactions, strong int’n dynamics …

Current and Future ep Colliders

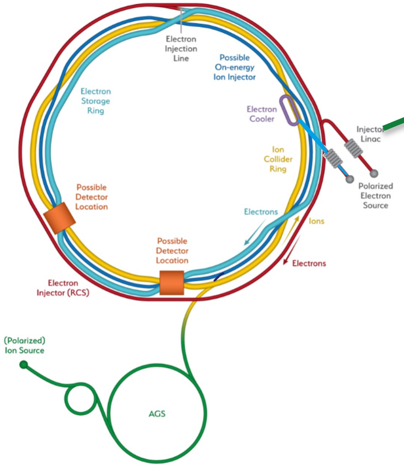
Ongoing fixed target @ JLab

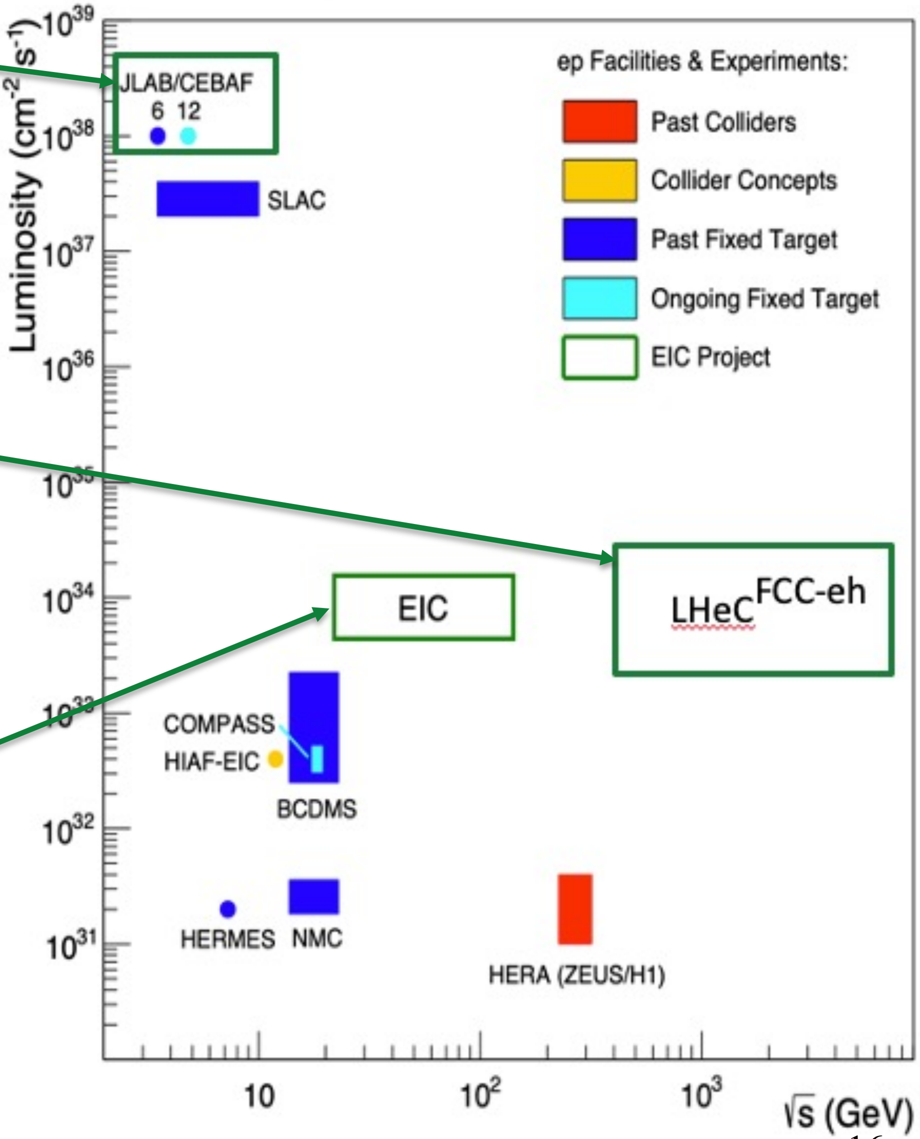


Longer-term @ CERN



On-target for early 2030s @ BNL

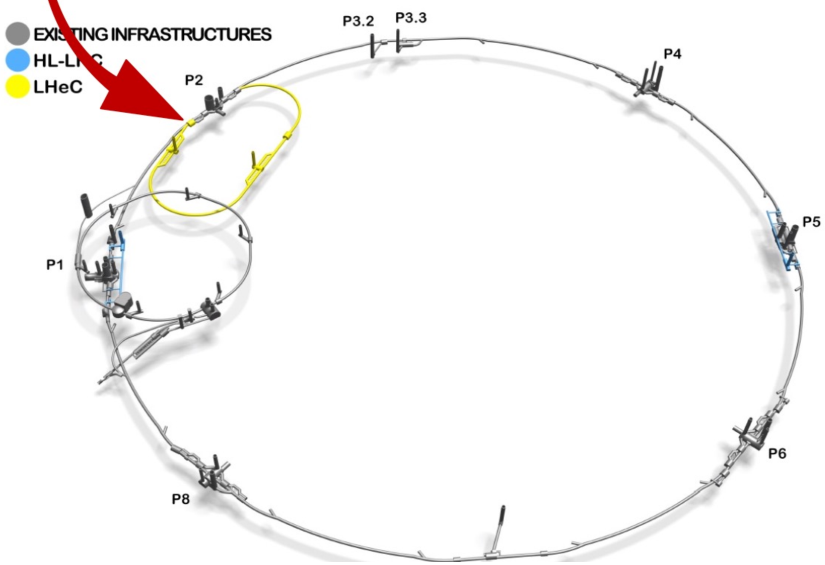




Future ep and eA Options at CERN

Renewed mandate, structure and coordination (J d'Hondt)
See https://indico.cern.ch/event/1335332/
https://indico.cern.ch/event/1367865/

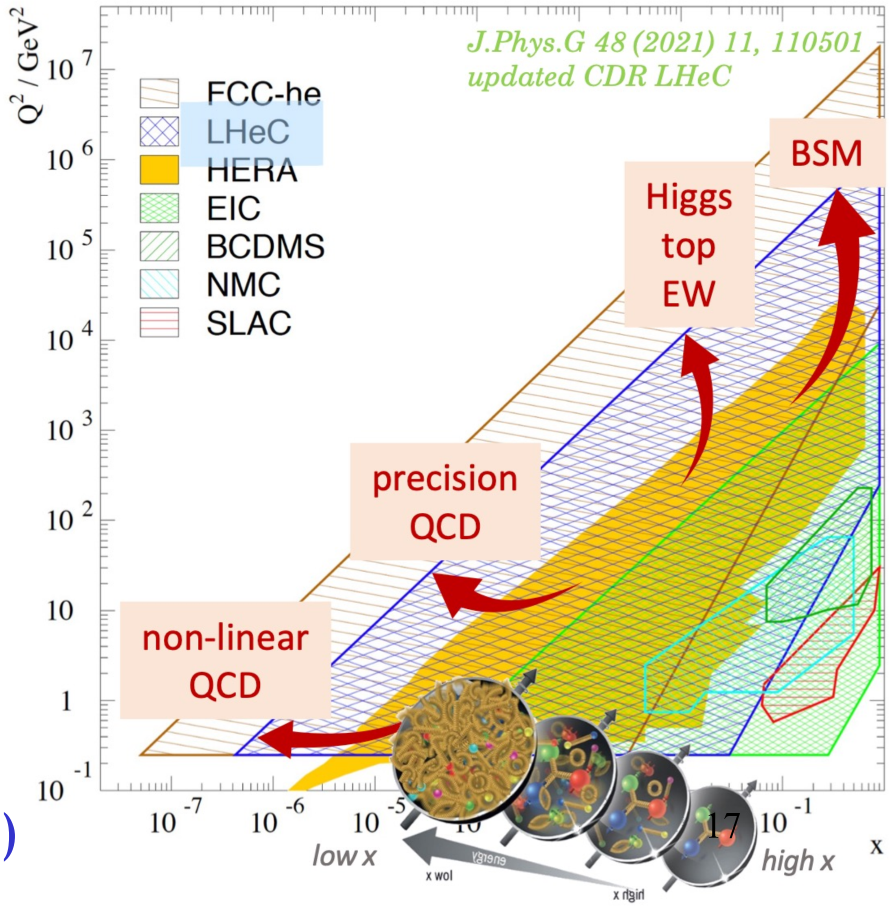
LHeC (>50 GeV electron beams)
E_{cms} = 0.2 – 1.3 TeV, (Q^2,x) range far beyond HERA
run ep/pp together with the HL-LHC ($\gtrsim$ Run5)



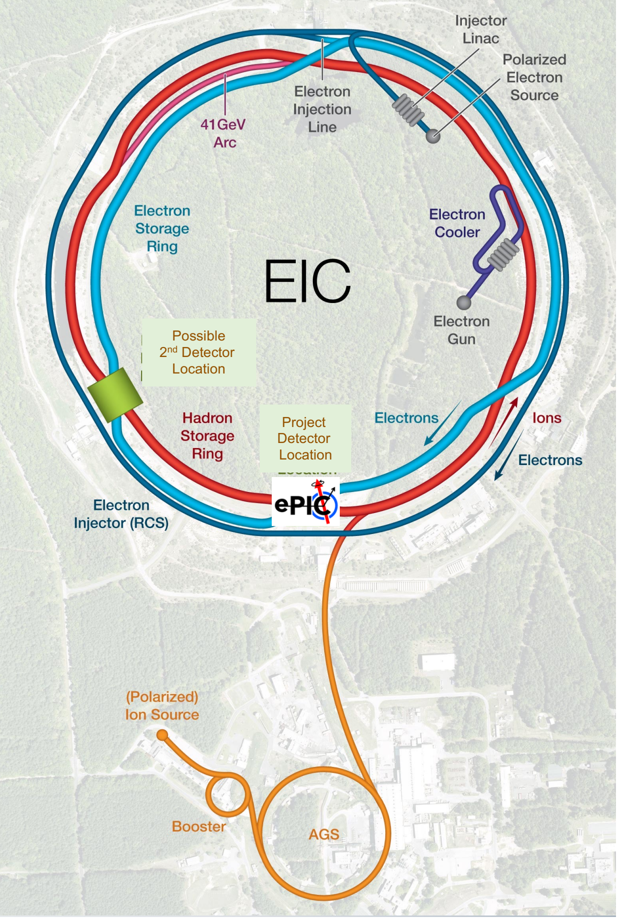
FCC-eh (60 GeV electron beams)
E_{cms} = 3.5 TeV, described in CDR of the FCC
run ep/pp together: FCC-hh + FCC-eh

- Extending lepton-proton energy frontier by up to 2 orders of magnitude

- Crucial technical step: Energy recorvery linac (prototype PERLE @ Orsay)



The Electron-Ion Collider (BNL)



New electron ring, to collide with RHIC p, A

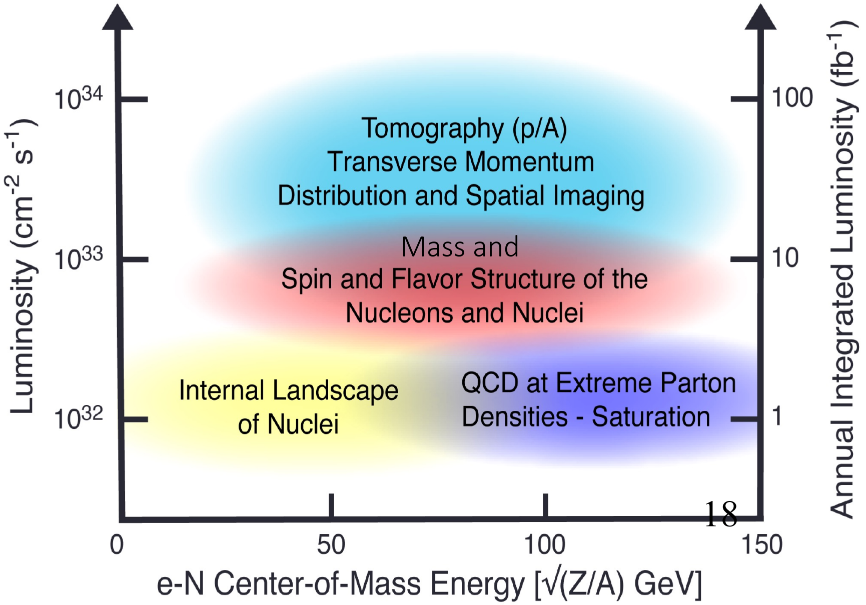
- Energy range **28 < $\sqrt{s}$ < 140 GeV**, accessing moderate / large x values compared with HERA

World's first …

- High lumi ep Collider **(~ 10^{34} cm^{-2} s^{-1})**
- Double-polarised DIS collider **(~70% for leptons and light hadrons)**
- eA collider **(Ions ranging from H to U)**

Specifications driven by science goals:

- 3D proton structure
- Proton mass
- Proton spin
- Dense partonic systems in nuclei



EIC Machine Design Parameters

Double Ring Design Based on Existing RHIC Facilities	
Hadron Storage Ring: 40, 100 - 275 GeV	**Electron Storage Ring: 5 - 18 GeV**
RHIC Ring and Injector Complex: p to Pb	9 MW Synchrotron Radiation
1A Beam Current	Large Beam Current - 2.5 A
10 ns bunch spacing and 1160 bunches	
Light ion beams (p, d, ^{3}He) polarized (L,T) > 70%	Polarized electron beam > 70%
Nuclear beams: d to U	**Electron Rapid Cycling Synchrotron**
Requires Strong Cooling: new concept →CEC	Spin Transparent Due to High Periodicity
One High Luminosity Interaction Region(s)	
25 mrad Crossing Angle with Crab Cavities	

Challenges from high lumi requirement include short bunch spacing and high beam currents …

→ Synchrotron load management
→ Significant crossing angle

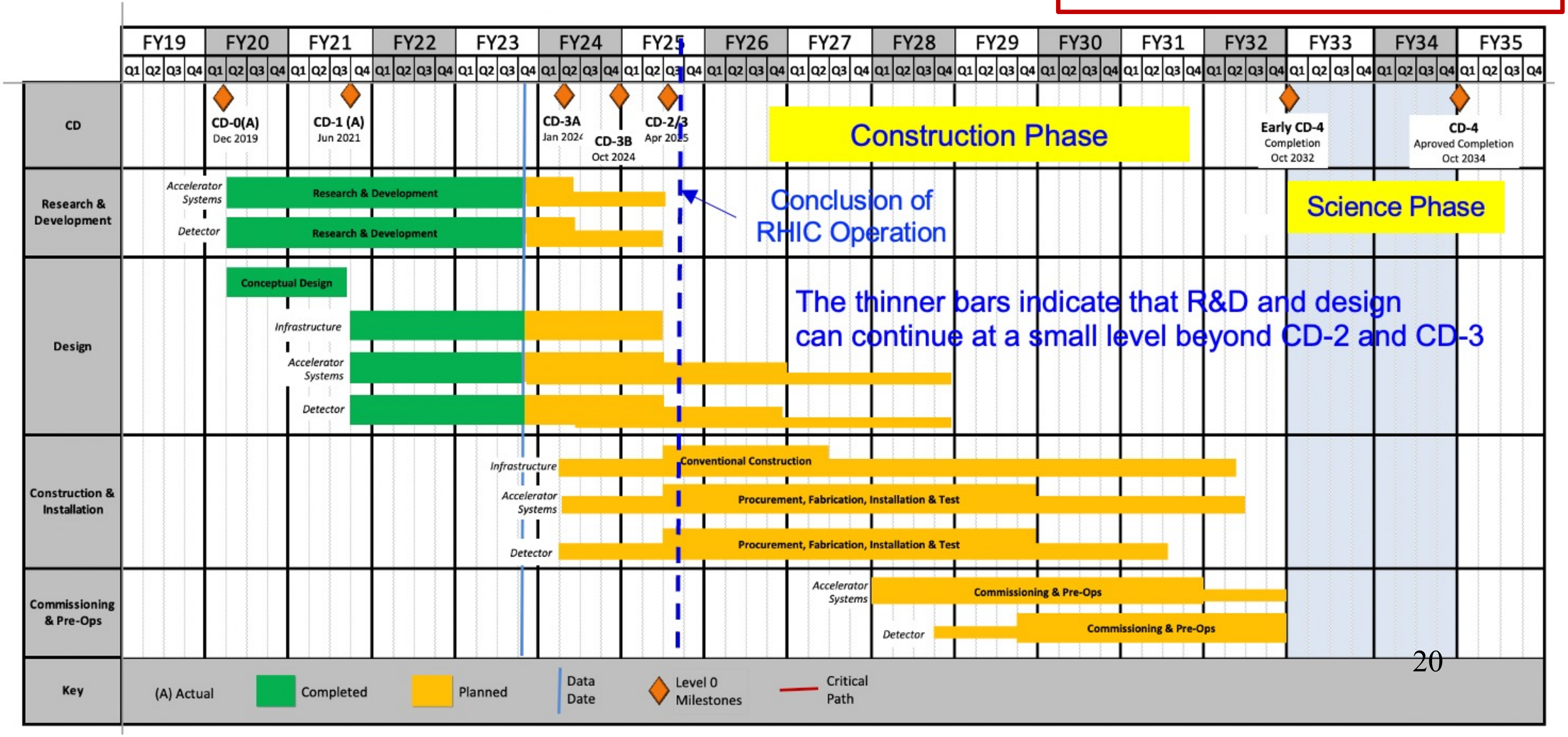
EIC Timeline

- Still several steps to go, but on target towards operation early/mid 2030s

- Total cost ~$2Bn (US project funds accelerator and one detector)

Critical Decision (CD) Milestones
CD-0 Approve Mission Need
CD-1 Approve Cost Range
CD-2 Approve Baseline Performance
CD-3 Approve Start Construction
CD-4A Approve Start of Operations
CD–4 Approve Project Completion

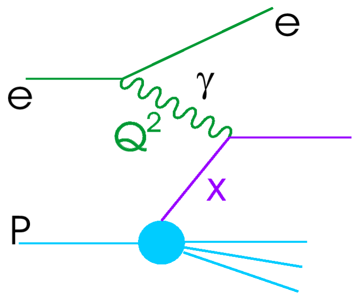
Upcoming Project Milestones
TDR – Q4 2024
CD2/3 review – Q1 2025
CD2/3 approval – Q2 2025 (April)



The thinner bars indicate that R&D and design can continue at a small level beyond CD-2 and CD-3

Observables / Detector Implications

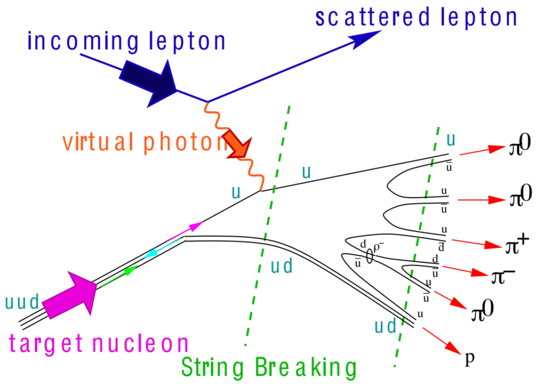
Inclusive



- Traditional DIS, following on from fixed target experiments and HERA → Longitudinal structure

… high acceptance, high performance electron identification and reconstruction

Semi-Inclusive



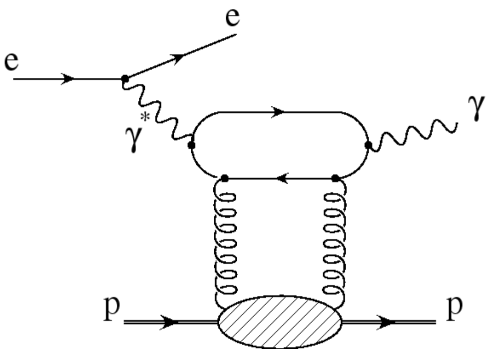
- Single particle, heavy flavour & jet spectra
  → p_T introduces transverse degrees of freedom
- Quark-flavour-identified DIS
  → Separation of u,d,s,c,b and antiquarks

… tracking and hadronic calorimetry

… heavy flavours identification from vertexing

… light flavours from dedicated PID detectors

Exclusive / Diffractive



- Processes with final state 'intact' protons
  → Correlations in space or momentum between pairs of partons

… efficient proton tagging over wide acceptance range

… high luminosity

A Detector for the EIC

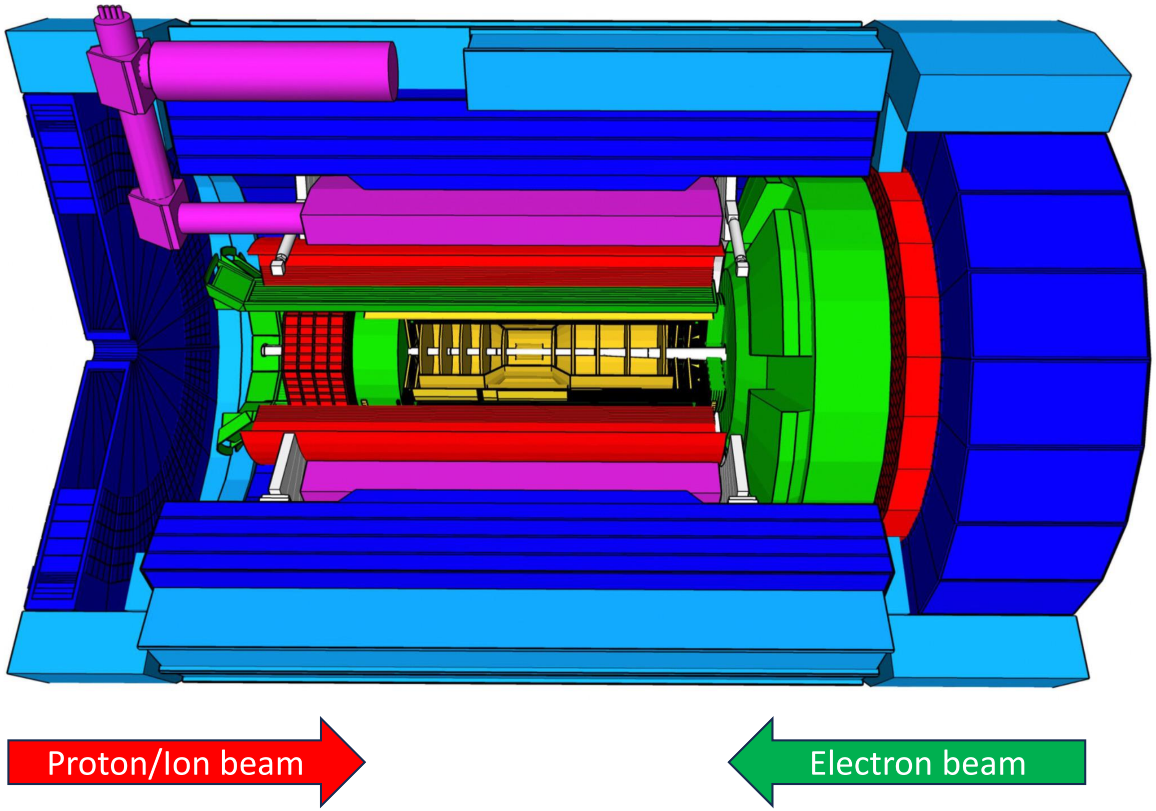
Magnet
- New 1.7 T SC solenoid, 2.8 m bore diameter

Tracking
- Si Vertex Tracker MAPS wafer-level stitched sensors (ALICE ITS3)
- Si Tracker MAPS barrel and disks
- Gaseous tracker: MPGDs (μRWELL, MMG) cylindrical and planar

PID
- high performance DIRC (hpDIRC)
- dual RICH (aerogel + gas) (forward)
- proximity focussing RICH (backward)
- ToF using AC-LGAD (barrel+forward)

EM Calorimetry
- imaging EMCal (barrel)
- W-powder/SciFi (forward)
- $PbWO_4$ crystals (backward)

Hadron calorimetry
- FeSc (barrel, re-used from sPHENIX)
- Steel/Scint – W/Scint (backward/forward)



- 9m long x 5m wide
- Extensive beamline instrumentation not shown (see later)
- Continuous streaming readout with emphasis on FEB zero-suppression
- Much lower radiation fluxes than LHC widens technology options

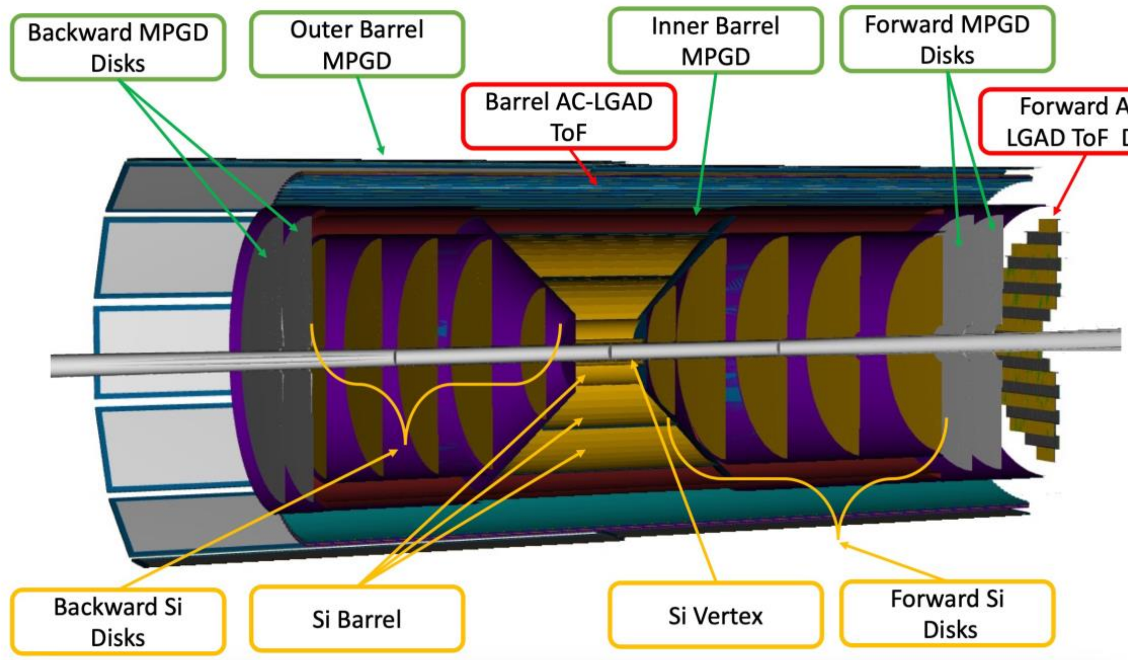
[ongoing work towards a second, complementary detector]

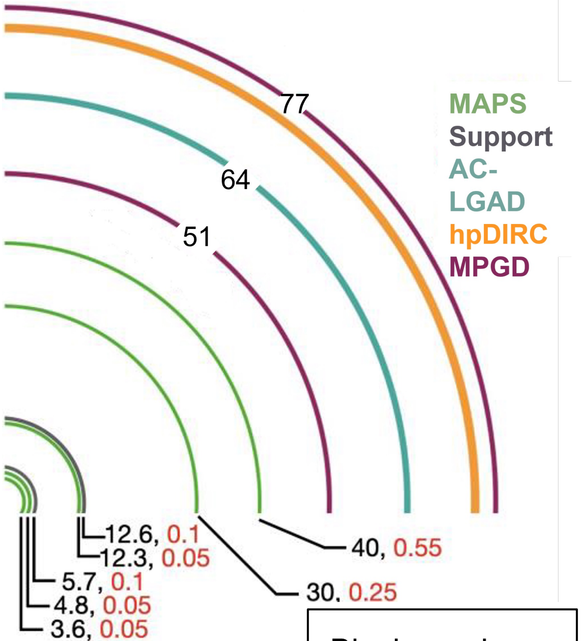
Tracking Detectors

Primarily based on MAPS silicon detectors (65nm technology)

- Leaning heavily on ALICE ITS3
- Stitched wafer-scale sensors, thinned and bent around beampipe

  → Very low material budget ($0.05X_0$ per layer for inner layers)
- 20x20μm pixels
- 5 barrel layers + 5 disks (total $8.5m^2$ silicon)





Black numbers are radii in cm

Red numbers are material in % X0

LGAD layers provide fast timing (~20ns)

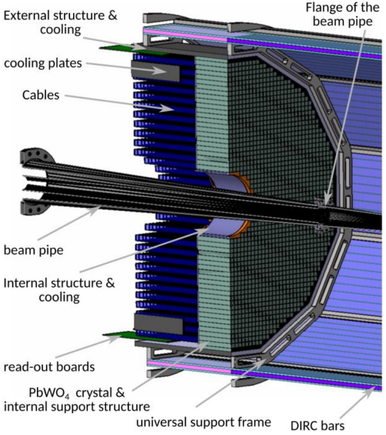
Outer gaseous detectors add additional hit points for track reconstruction

Calorimeter Overview

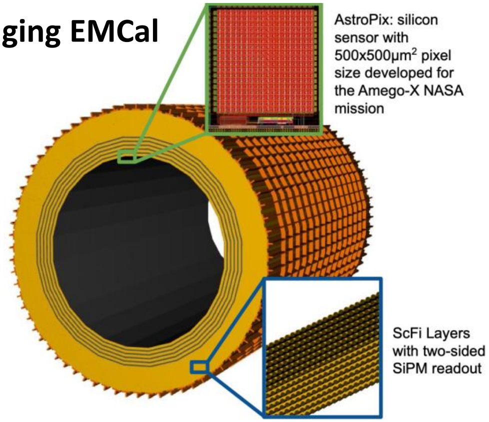
- Different technologies in barrel and end-caps, as required for varying performance targets
- New ECAL designs / technologies,
- HCAL partially recycles previous detectors
- All read out with Si PMs

Electron Endcap EMCal

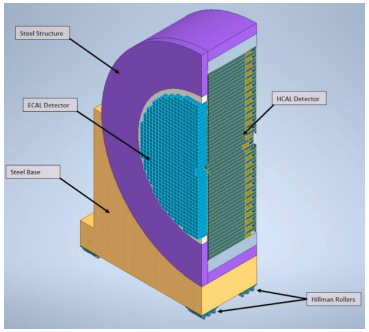
$PbWO_4$ crystals



Barrel Imaging EMCal

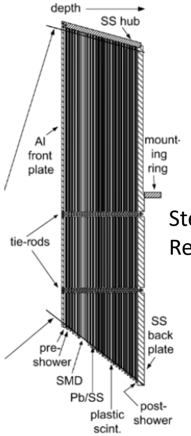


Hadron Endcap EMCal



High granularity W-powder/SciFi EMCal

Electron Endcap HCal



Steel/Scint Sandwich (10 layers)
Reuse of STAR scint. tiles

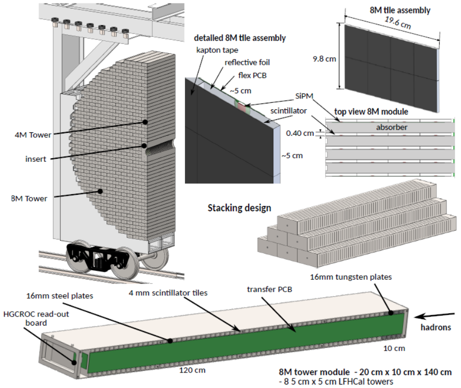
Barrel HCal

sPHENIX barrel calorimeter with new SiPMs

Hadron Endcap HCal

Longitudinally separated HCAL Steel/Sc & W/Sc sandwich

SiPM-on-tile readout

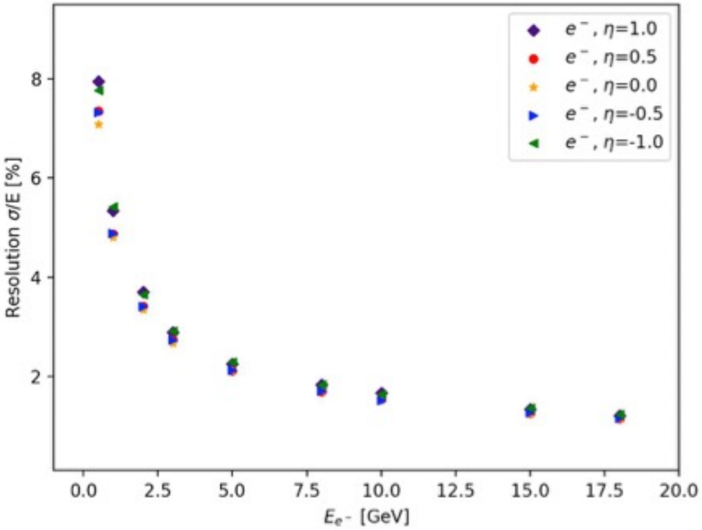


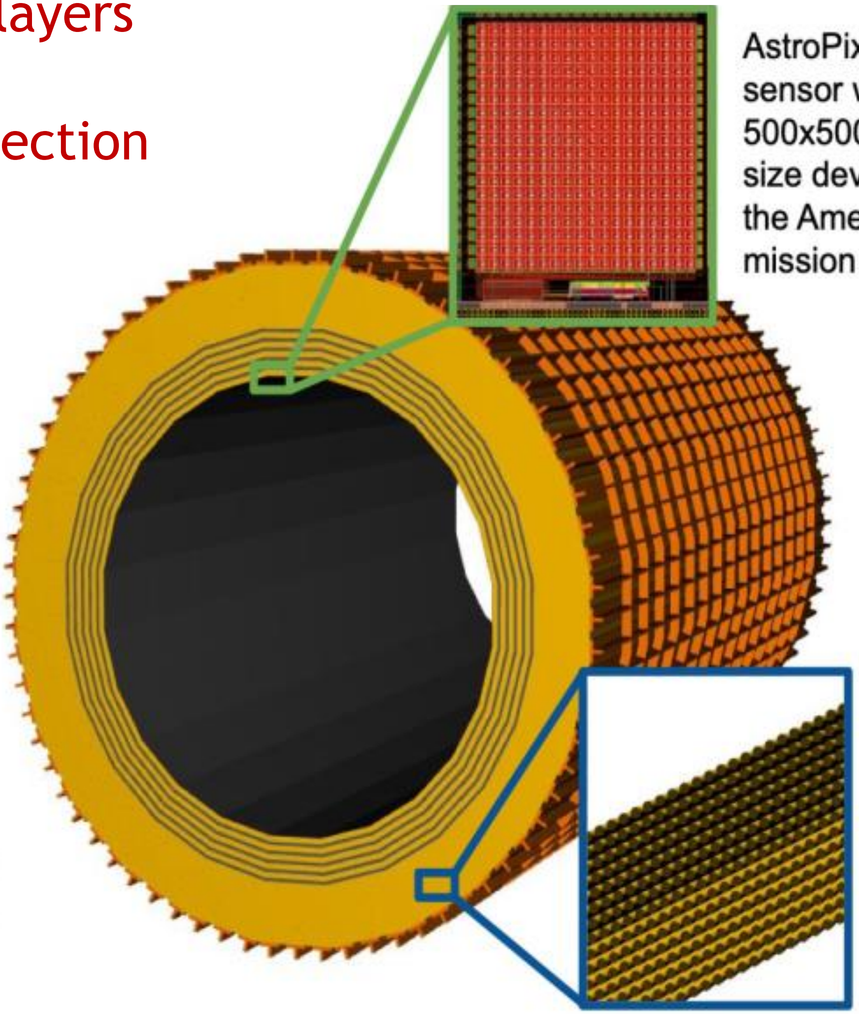
+ high granularity insert at largest η

Barrel ‘Imaging ECAL’

- 4 MAPS (Astropix) layers for position resolution.
- Interleaved with 5 Pb/SciFi layers for energy resolution
- Followed by large Pb/SciFi section

$$\boxed{\frac{\sigma}{E} \sim \frac{5\%}{\sqrt{E}} + 0.5\%}$$



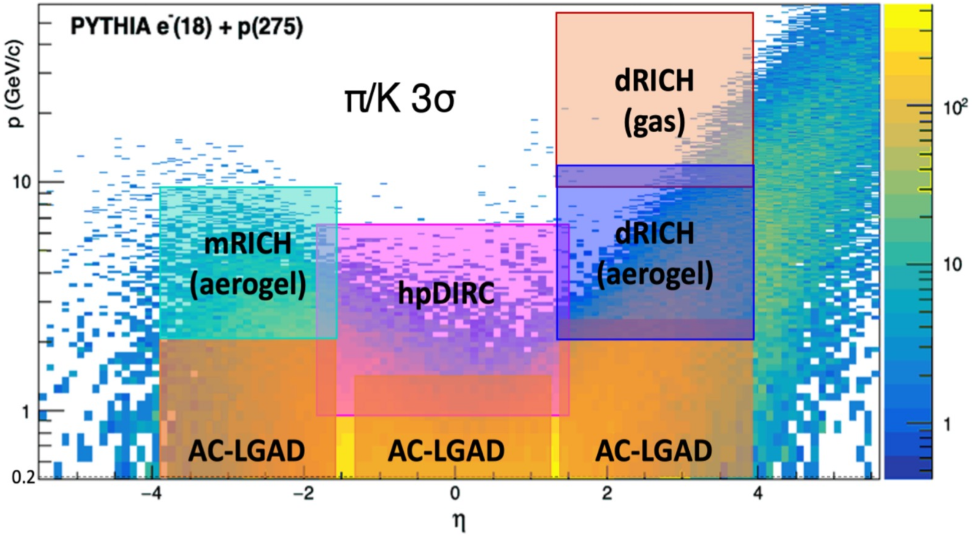


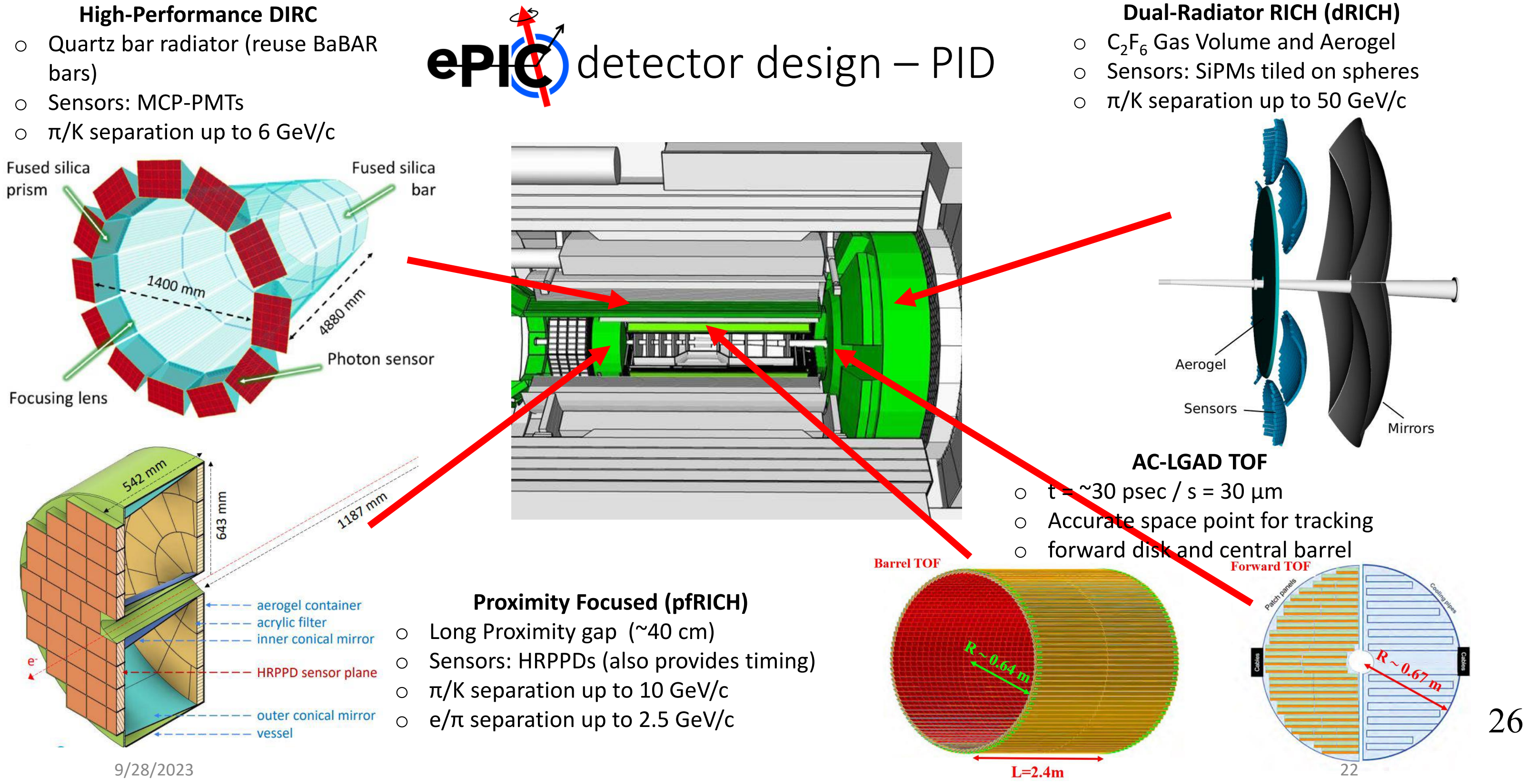
AstroPix: silicon sensor with 500x500μm^2 pixel size developed for the Amego-X NASA mission

ScFi Layers with two-sided SiPM readout

Particle Identification

- SIDIS programme relies on π / K / p (and other PID) separation …
- Cerenkov detectors at high momentum, augmented by AC-LGADs / ToF at low momentum





ePIC detector design – PID

High-Performance DIRC

- ○ Quartz bar radiator (reuse BaBAR bars)
- ○ Sensors: MCP-PMTs
- ○ π/K separation up to 6 GeV/c

Dual-Radiator RICH (dRICH)

- ○ C_2F_6 Gas Volume and Aerogel
- ○ Sensors: SiPMs tiled on spheres
- ○ π/K separation up to 50 GeV/c

AC-LGAD TOF

- ○ t = ~30 psec / s = 30 μm
- ○ Accurate space point for tracking
- ○ forward disk and central barrel

Proximity Focused (pfRICH)

- ○ Long Proximity gap (~40 cm)
- ○ Sensors: HRPPDs (also provides timing)
- ○ π/K separation up to 10 GeV/c
- ○ e/π separation up to 2.5 GeV/c

9/28/2023

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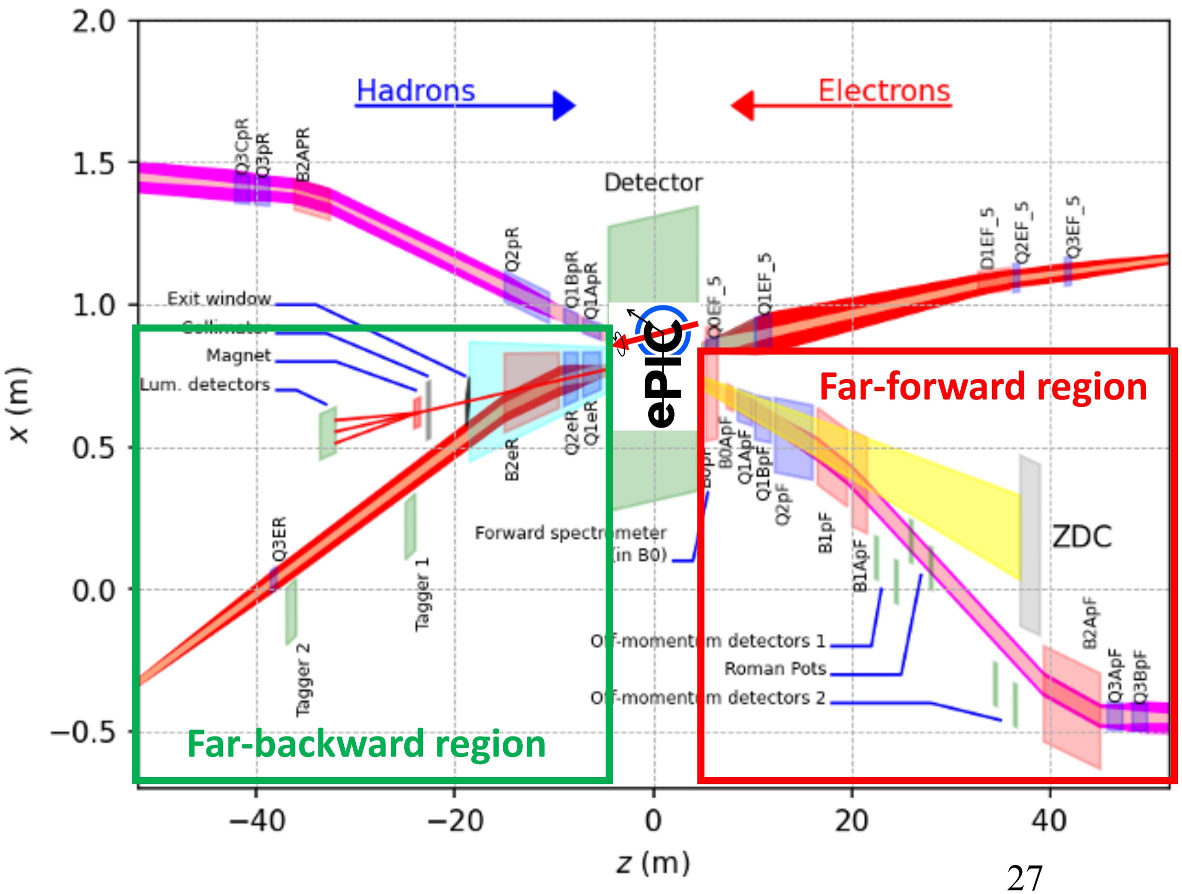
Interaction Region / Beamline Instrumentation

- Extensive beamline instrumentation integrated into IR design

- Tagging electrons and photons in backward direction for lowest Q^2 physics studies and lumi monitoring via ep→epγ



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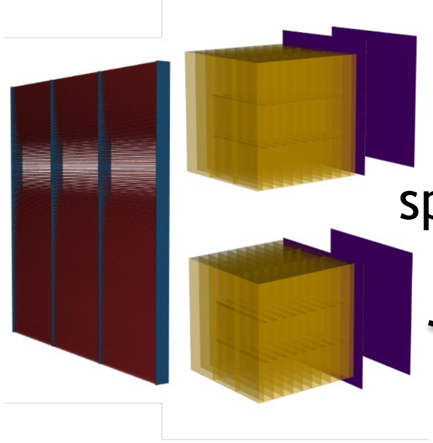
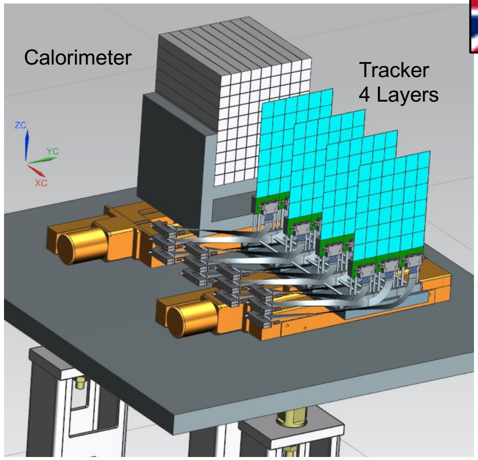
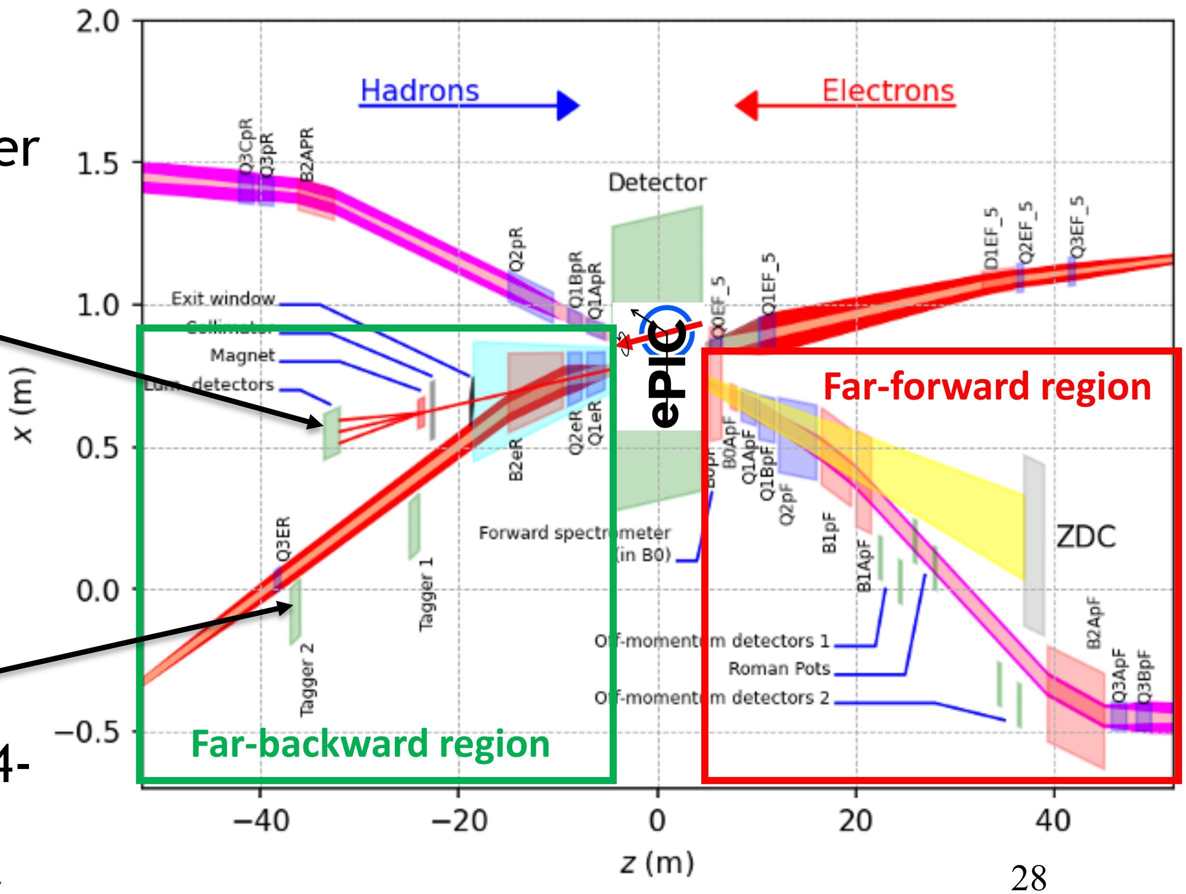


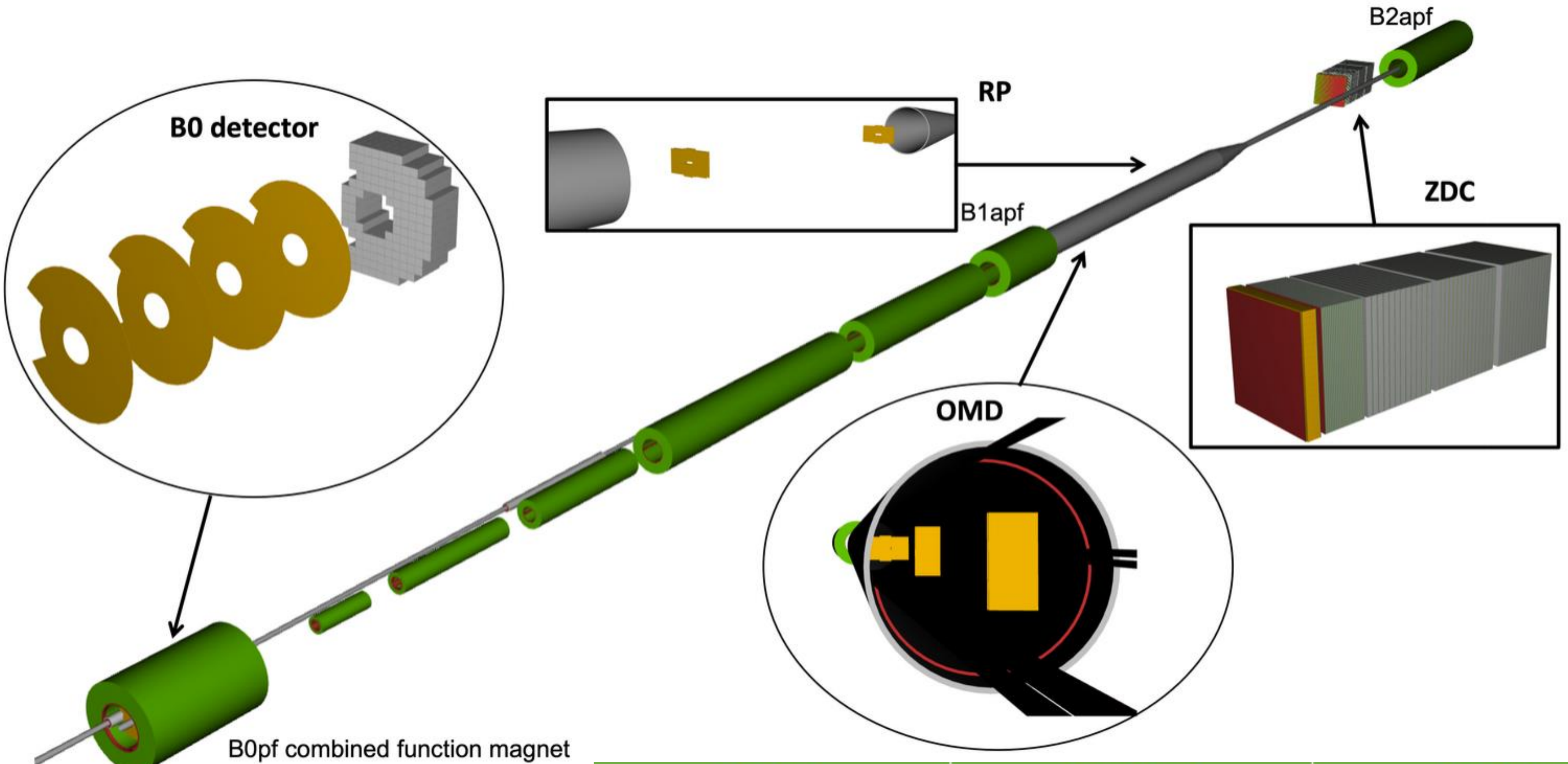
W-Sci-Fi
Lumi Pair
spectrometer



Timepix4-
based
tracker



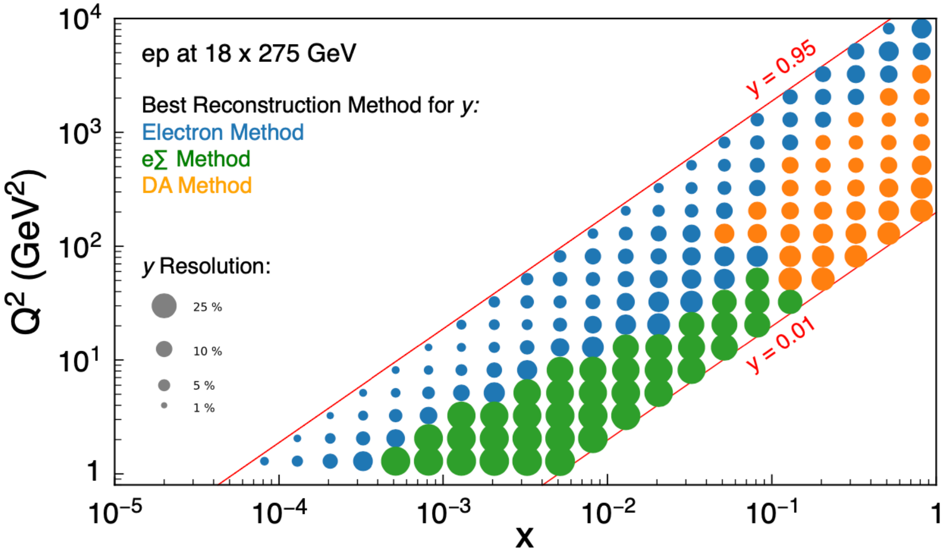
Far Forward Region



Detector	Acceptance	Particles
Zero-Degree Calorimeter (ZDC)	$\theta < 5.5\,mrad$	Neutrons, photons
Roman Pots (2 stations)	$0^* < \theta < 5.0\,mrad$ (*10σ beam cut)	Protons, light nuclei
Off-Momentum Detectors (2 stations)	$0 < \theta < 5.0\,mrad$	Charged particles
B0 Detector	$5.5 < \theta < 20\,mrad$	Charged particles, tagged photons

Hermetic forward coverage except for beampipe

Performance and Measurement Strategy



- Choose reconstruction methods exploiting the hadronic final state as well as the electron to optimise (x, Q^2) resolutions throughout phase-space

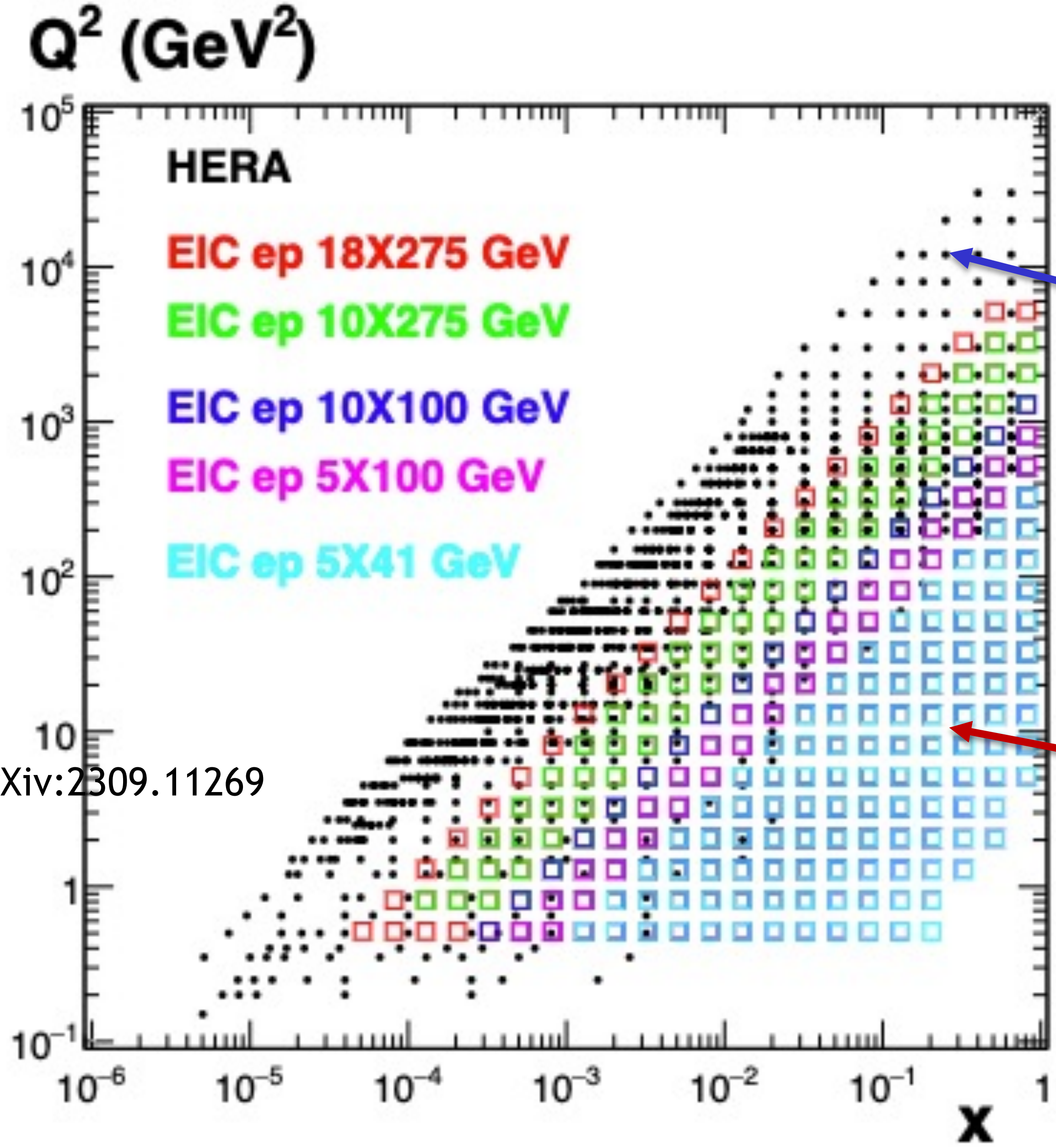
- Exploit overlaps between data at different $\sqrt{s}$ to avoid 'extreme' phase space regions

e-beam E	p-beam E	$\sqrt{s}$ (GeV)	inte. Lumi. (fb^{-1})
18	275	140	15.4
10	275	105	100.0
10	100	63	79.0
5	100	45	61.0
5	41	29	4.4

- Systematic precision estimated from experience at HERA, expected EIC detector performance, and guesswork

Simulations based on precision:
- 1.5-2.5% point-to-point uncorrelated
- 2.5% normalisation

Inclusive EIC Data Impact on Proton PDFs



arXiv:2309.11269

HERA data have limited high x sensitivity due to $1/Q^4$ factor in cross section and kinematic x / Q^2 correlation

EIC data fills in large x, modest Q^2 region with high precision

Impact of EIC on HERAPDF2.0

Fractional total uncertainties with / without simulated EIC data included with HERA

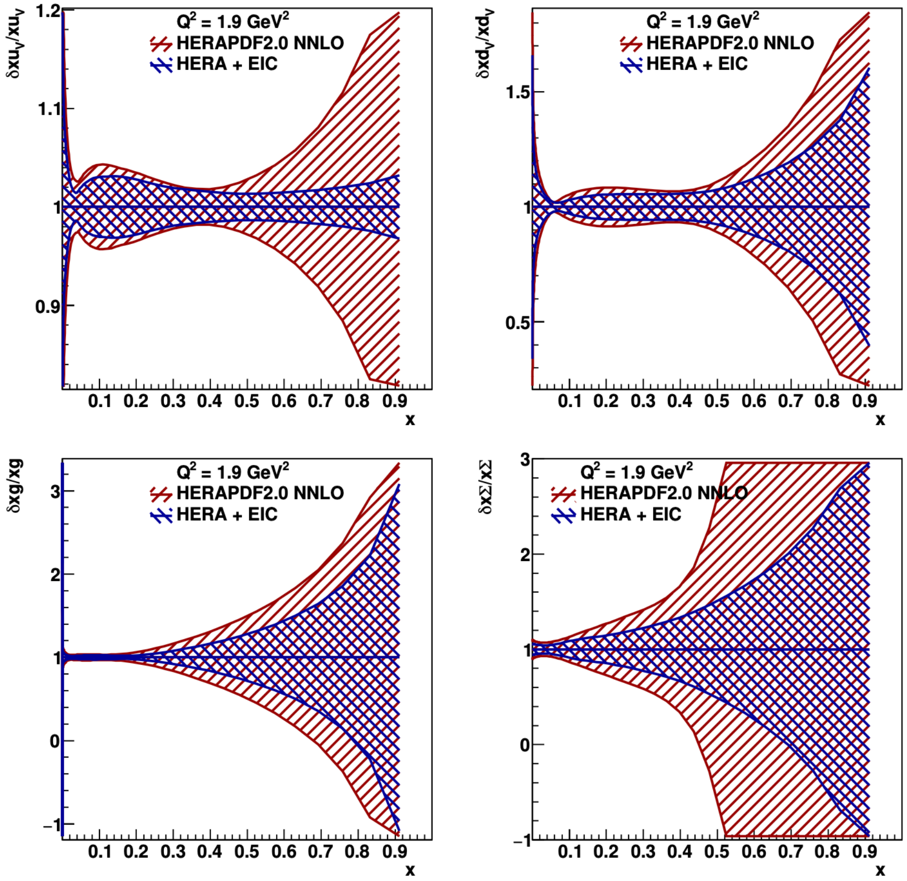
… EIC will bring significant reduction in uncertainties for all parton species at large x

… most notable improvements for up quarks (charge-squared weighting)

Precision high x EIC data ideally suited to the extraction of α_s

… simulated result is factor ~2 better than current world experimental average, and than lattice QCD average

… scale uncertainties remain to be understood (ongoing work)



[Eur Phys J C83 (2023), 1011]
[arXiv:2309.11269]

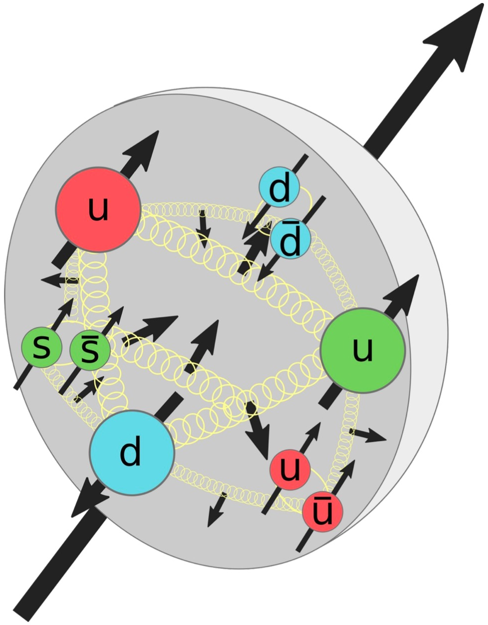
$$\alpha_s(M_Z^2) = 0.1159 \pm 0.0004 \text{ (exp)} \quad {}^{+0.0002}_{-0.0001} \text{ (model + parameterisation)}$$

Physics Motivation: Proton Spin

- Spin ½ is much more complicated than ↑↑↓ …

- EMC ‘spin crisis’ (1987) … quarks only carry about 10% of the nucleon spin

- Viewed at the parton level, complicated mixture of quark, gluon and relative orbital motion, evolving with Q^2, but always = ½



Jaffe-Manohar sum rule:

$$\boxed{\Delta\Sigma/2}+\boxed{\Delta G}+\boxed{\ell_q}+\boxed{\ell_g}=\hbar/2$$

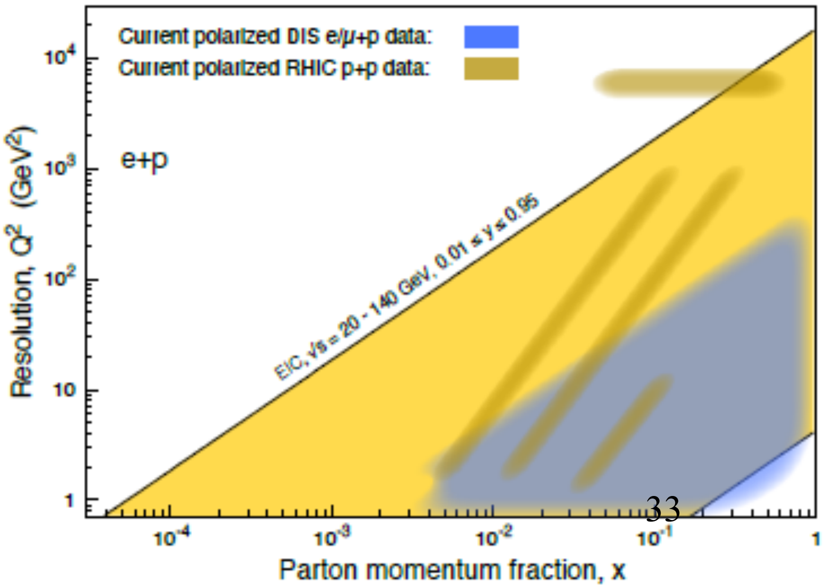
Quark helicity

Gluon helicity

Quark canonical orbital angular momentum

Gluon canonical orbital angular momentum

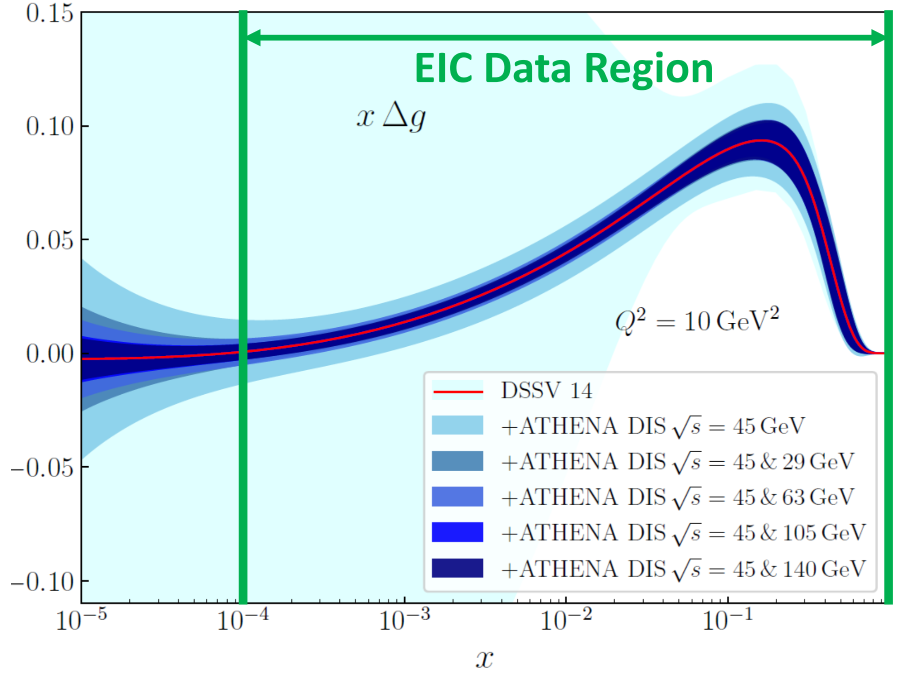
- Very little known about gluon helicity contribution or importance of low x region

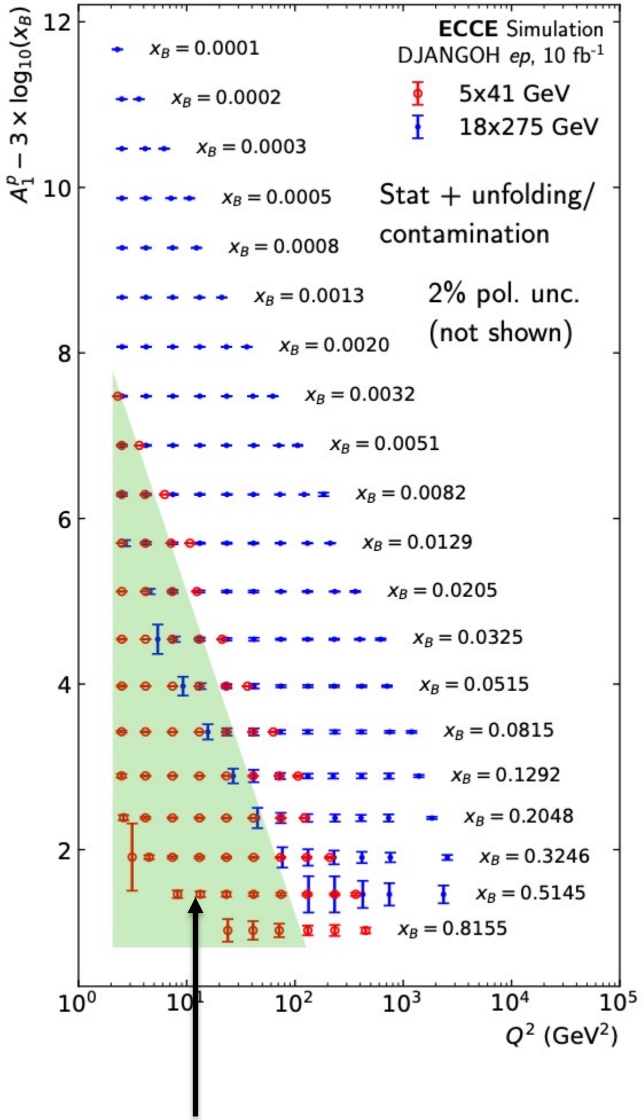


Proton Spin Simulation

Can be resolved in full with EIC inclusive, semi-inclusive and exclusive data

e.g. impact relative to recent global fit (DSSV14) of inclusive EIC data (double spin asymmetries 15fb^{-1} and 70% e,p polarization)





Previously measured region (green)

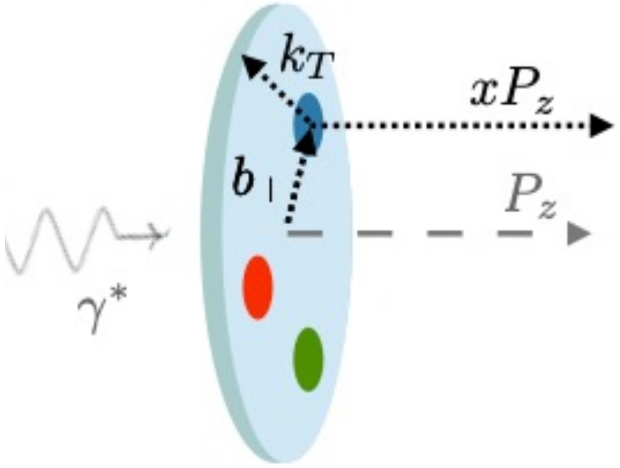
EIC measures down to x ~ 5 x 10^{-3} for 1 < Q^2 < 100 GeV^2

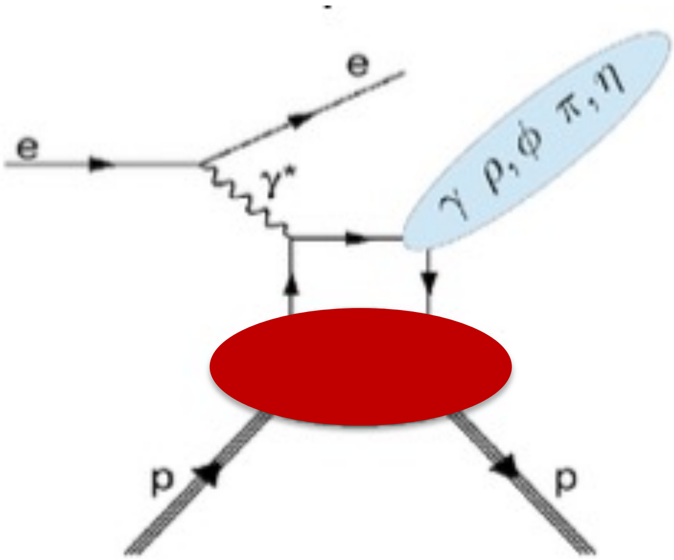
Physics Motivation: 3D Structure

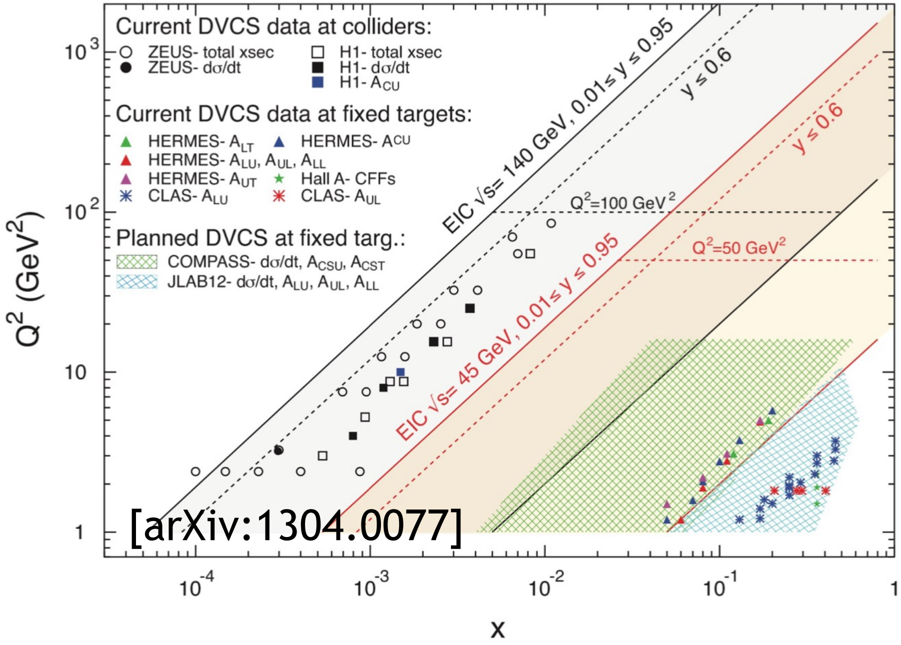
Exclusive processes, yielding intact protons, require (minimum) 2 partons exchanged

→ Sensitivity to correlations between partons in longitudinal / transverse momentum and spatial coordinates

→ access to 3D tomography



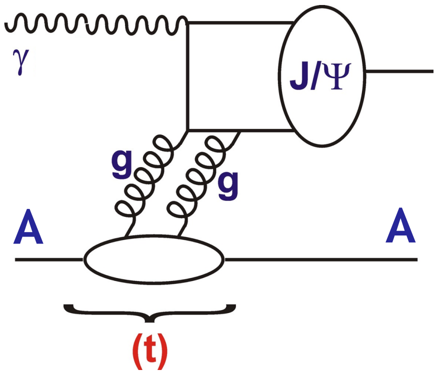


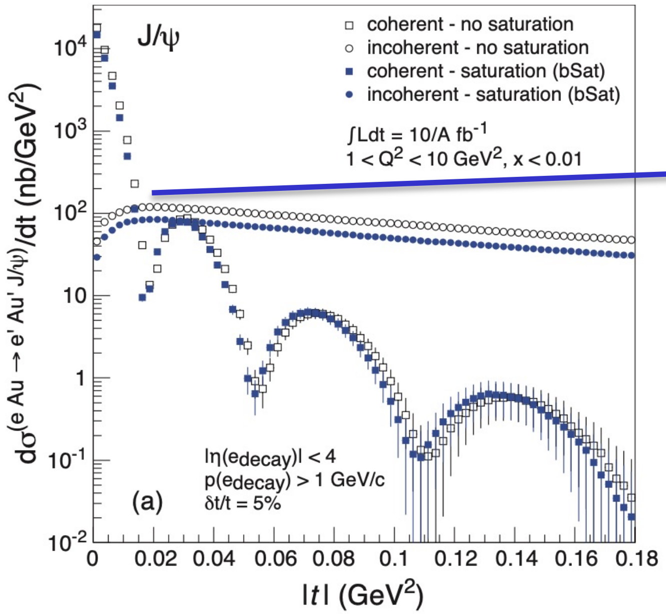


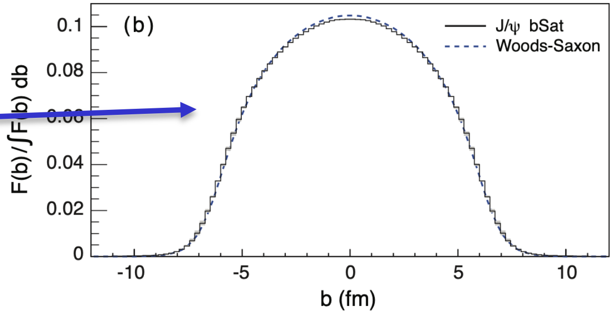
[arXiv:1304.0077]

e.g. Deeply Virtual Compton Scattering, ep → eγp:
EIC fills gap between (high stats) fixed target & (low stats) HERA data

Physics Motivation: Dense Gluonic Systems







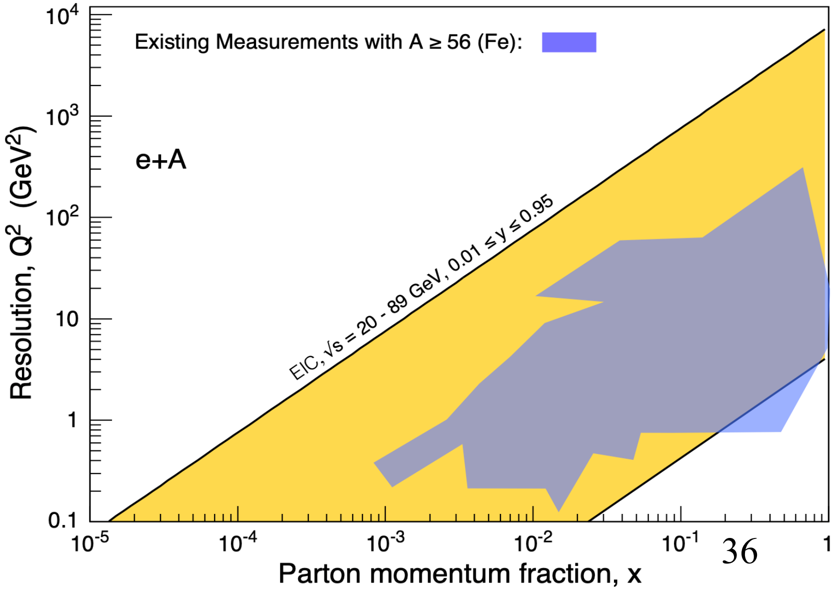
e.g. Coherent J/Ψ in eAu: dips sensitive to saturation

Mandelstam t in exclusive processes conjugate to transverse spatial distributions

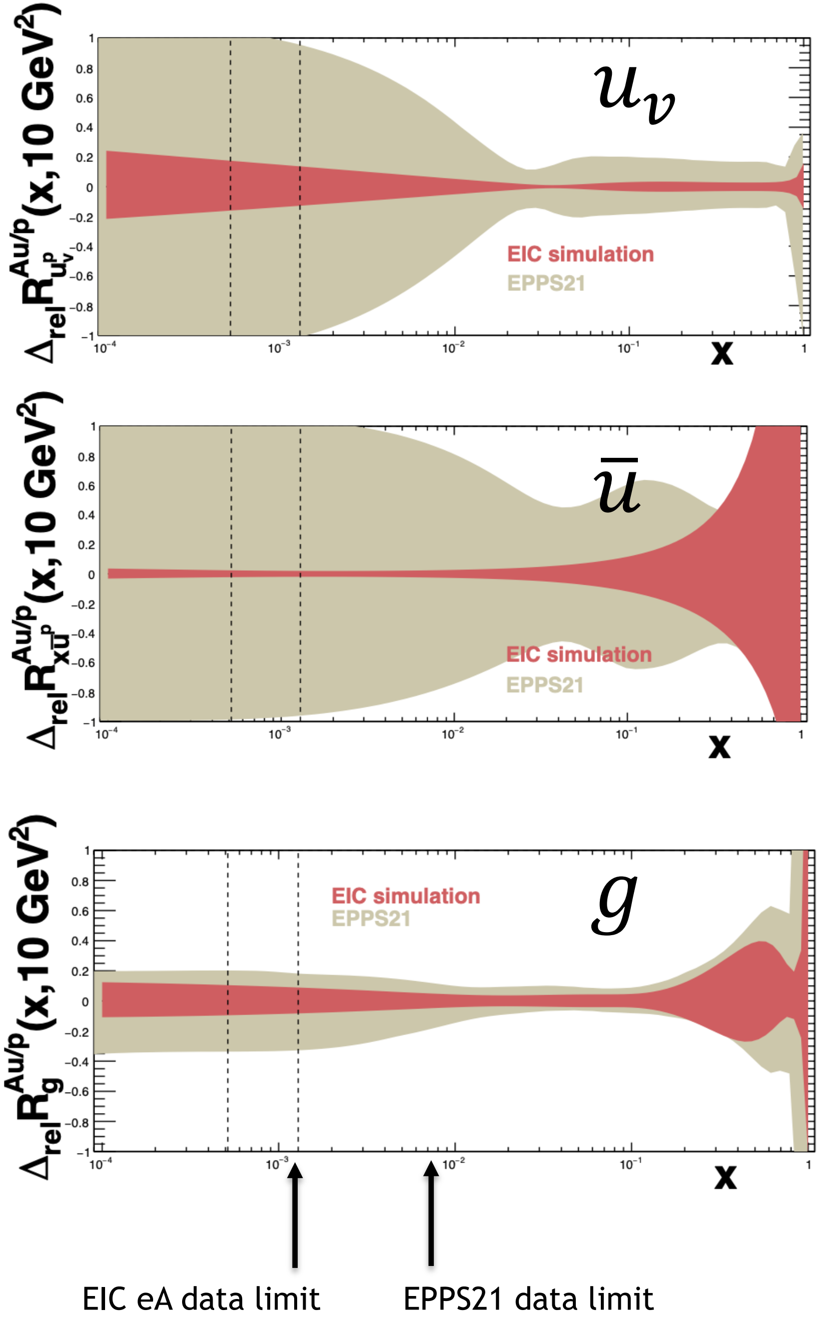
→ Fourier transform the target

Nuclei enhance density of partons (“ $A^{1/3}$ ” factor)

→ Very large impact on eA phase space, extending into expected region of density effects



Impact on Nuclear PDFs



EIC eA data limit

EPPS21 data limit

- Nuclear effects in PDFs still not fully understood.
- Important e.g. for initial State in QGP studies

Usually expressed in terms of nuclear modification ratio relative to scaled isospin-adjusted nucleons:

$$R = \frac{f_{i/A}}{A f_{i/p}} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$$

Sensitivity of EIC relative to EPPS21 recent nuclear PDFs (EIC-only fit)

→ Factor ~ 2 improvement at x~0.1

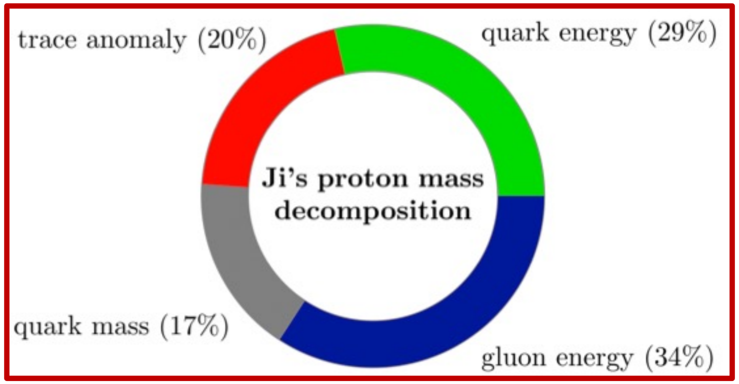
→ Very substantial improvement in newly accessed low x region

Physics Motivation: Proton Mass

- Constituent quark masses contribute ~1% of the proton mass

- Remainder is `emergent' → generated by (QCD) dynamics of multi-body strongly interacting system

- Decomposition along similar lines to spin:



$$m_p = m_m + m_q + m_g + m_a$$

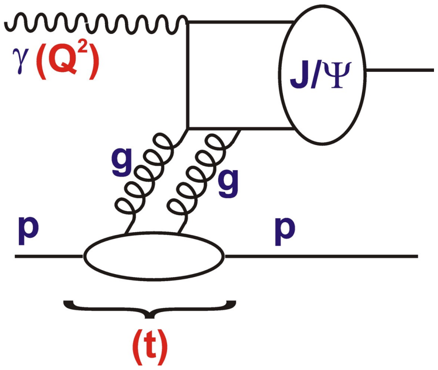
Valence and sea quark masses (including heavy quarks)

Quark and gluon ‘KE’ from confinement and relative motion

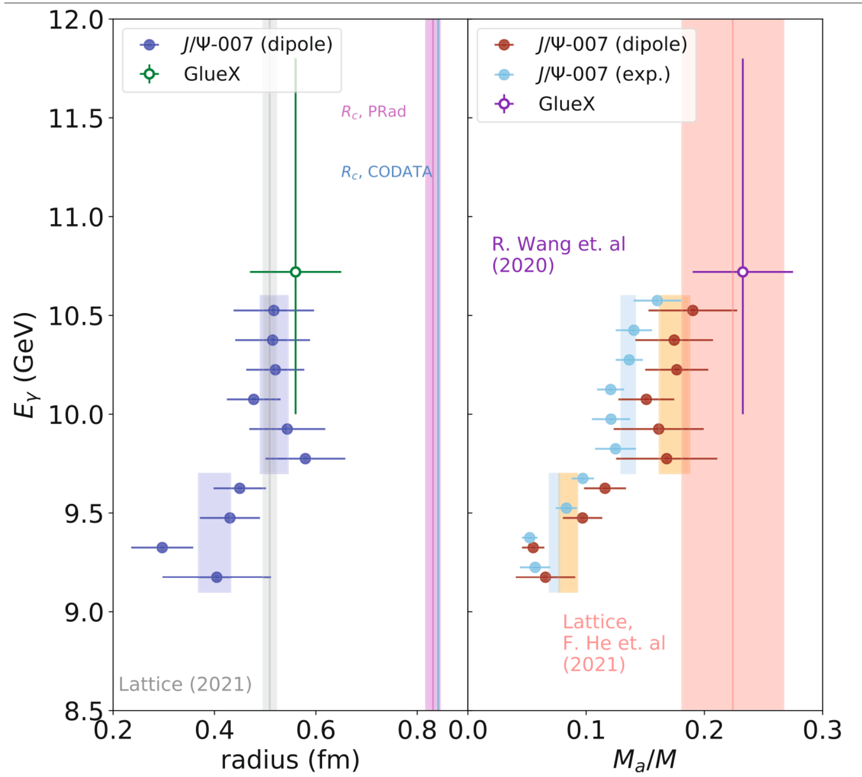
QCD trace anomaly (purely quantum effect - chiral condensates)

- Relations to experimental observables still being understood.
- Recent progress, eg with gravitational form factors of the proton

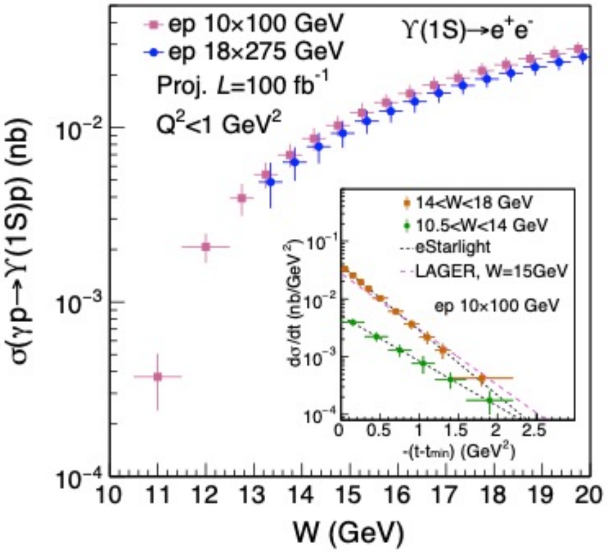
Proton Mass & Exclusive Vector Mesons

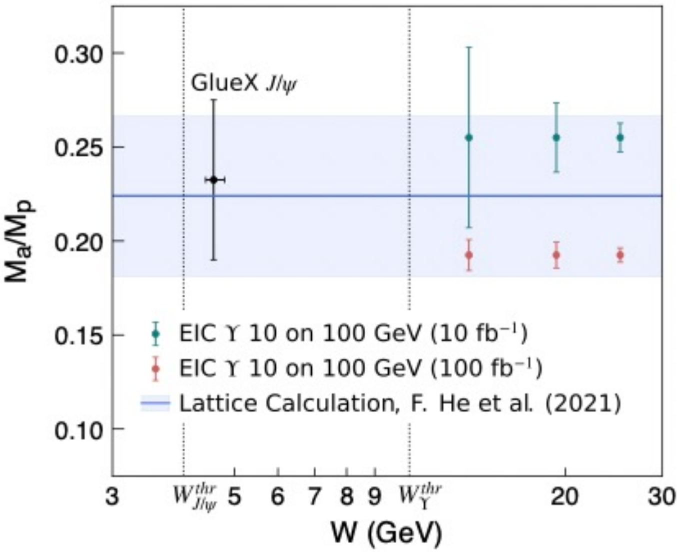


- Recent Jlab data on t dependences of J/Ψ production near threshold → Gravitational form factors



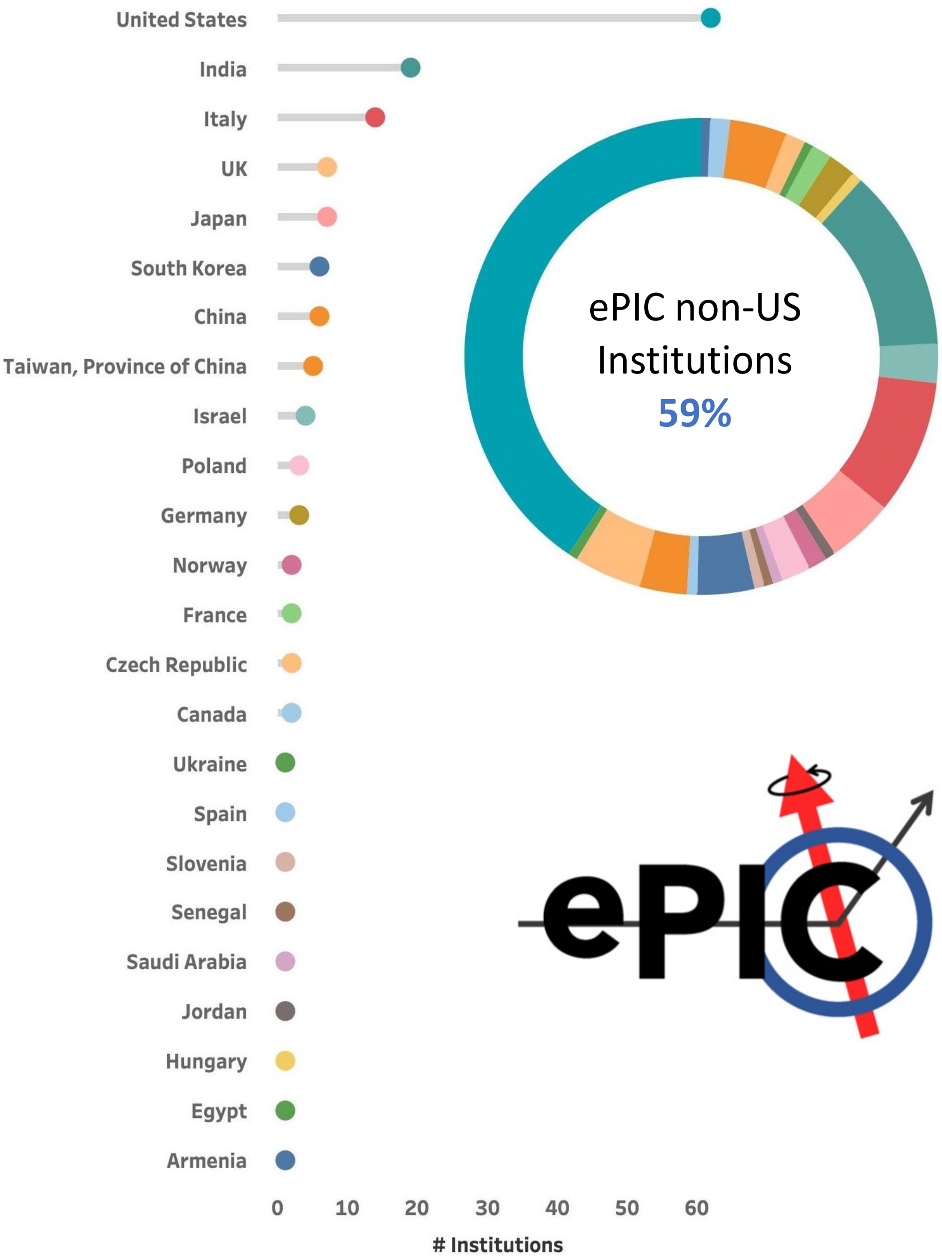
- Gluon radius smaller than charge radius
- Interpreted in terms of trace anomaly





Simulated EIC measurement extends the study to Υ with much improved precision

ePIC Collaboration Demographics



ePIC

Over 500 participants so far, from ~160 institutes in 24 countries

UK physicists deeply involved through initial motivation, collaboration formation and now ongoing roles.

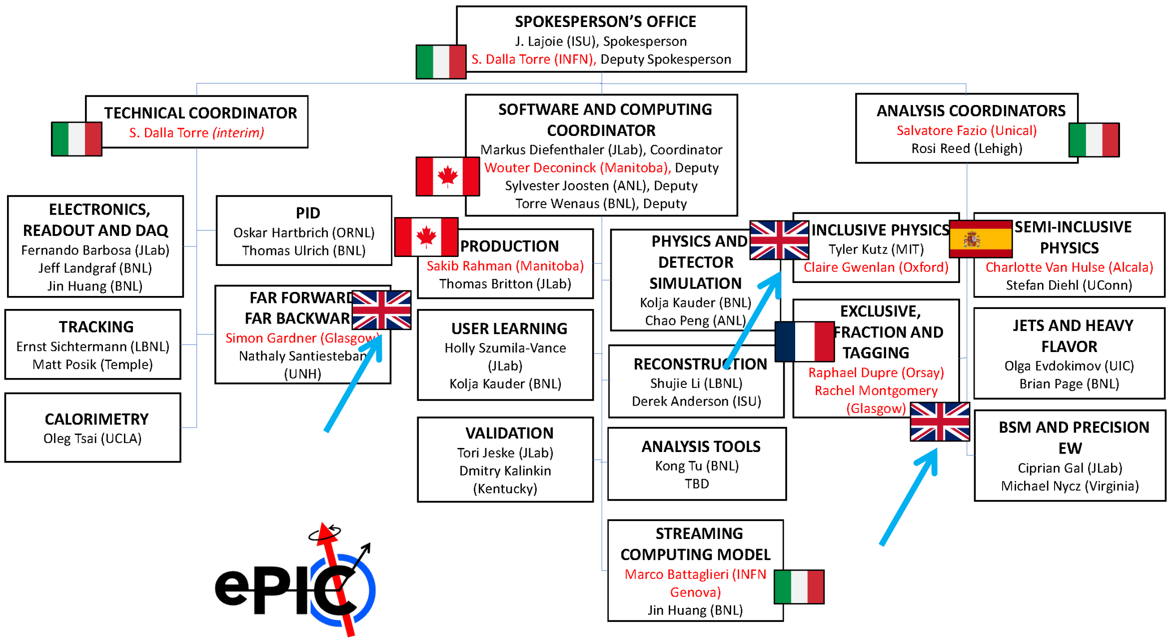
UK is the fourth largest contributor to ePIC

Part of a wider ‘EIC User Group’ organization with around 1400 members

ePIC structure and current UK Leadership

ePIC Collaboration

- International leadership



SPOKESPERSON'S OFFICE
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S. Dalla Torre (INFN), Deputy Spokesperson

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Wouter Deconinck (Manitoba), Deputy
Sylvester Joosten (ANL), Deputy
Torre Wenaus (BNL), Deputy

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Rosi Reed (Lehigh)

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Jeff Landgraf (BNL)
Jin Huang (BNL)

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Matt Posik (Temple)

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PID
Oskar Hartbrich (ORNL)
Thomas Ulrich (BNL)

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Nathaly Santiesteban (UNH)

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Kolja Kauder (BNL)

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Tori Jeske (JLab)
Dmitry Kalinkin (Kentucky)

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Chao Peng (ANL)

RECONSTRUCTION
Shujie Li (LBNL)
Derek Anderson (ISU)

ANALYSIS TOOLS
Kong Tu (BNL)
TBD

STREAMING COMPUTING MODEL
Marco Battaglieri (INFN Genova)
Jin Huang (BNL)

INCLUSIVE PHYSICS
Tyler Kutz (MIT)
Claire Gwenlan (Oxford)

EXCLUSIVE, DIFFRACTION AND TAGGING
Raphael Dupre (Orsay)
Rachel Montgomery (Glasgow)

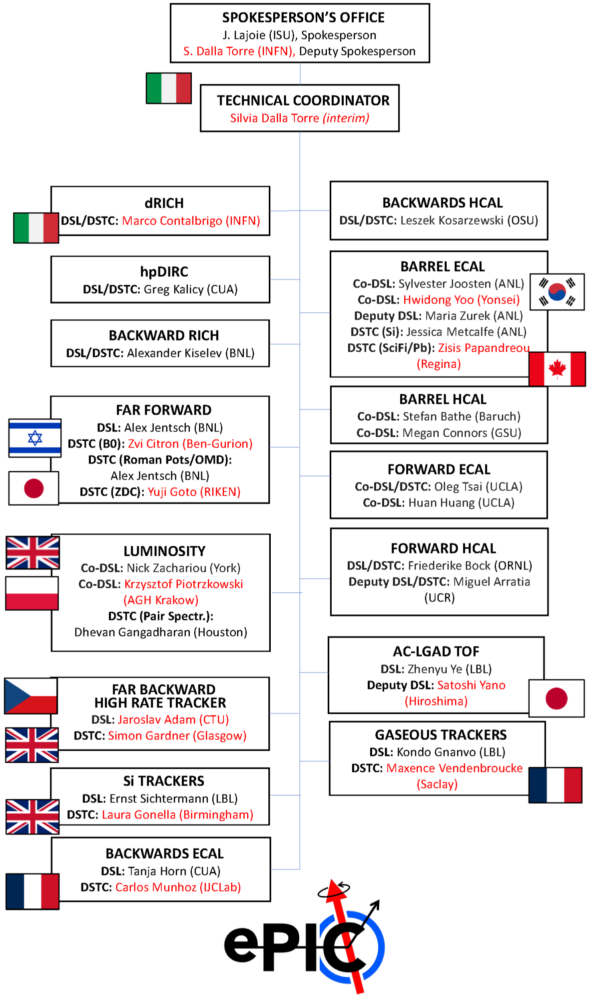
SEMI-INCLUSIVE PHYSICS
Charlotte Van Hulse (Alcala)
Stefan Diehl (UConn)

JETS AND HEAVY FLAVOR
Olga Evdokimov (UIC)
Brian Page (BNL)

BSM AND PRECISION EW
Ciprian Gal (JLab)
Michael Nycz (Virginia)

Working Groups

Paul Newman (Birmingham) – Executive Board
Nick Zachariou (York) – Conferences and Talks Committee



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hpDIRC
DSL/DSTC: Greg Kalicy (CUA)

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DSL/DSTC: Alexander Kiselev (BNL)

FAR FORWARD
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DSTC (B0): Zvi Citron (Ben-Gurion)
DSTC (Roman Pots/OMD): Alex Jentsch (BNL)
DSTC (ZDC): Yuji Goto (RIKEN)

LUMINOSITY
Co-DSL: Nick Zachariou (York)
Co-DSL: Krzysztof Piotrzkowski (AGH Krakow)
DSTC (Pair Spectr.): Dhevan Gangadharan (Houston)

FAR BACKWARD HIGH RATE TRACKER
DSL: Jaroslav Adam (CTU)
DSTC: Simon Gardner (Glasgow)

Si TRACKERS
DSL: Ernst Sichtermann (LBL)
DSTC: Laura Gonella (Birmingham)

BACKWARDS ECAL
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DSTC: Carlos Munhoz (IJCLab)

BACKWARDS HCAL
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Deputy DSL: Maria Zurek (ANL)
DSTC (Si): Jessica Metcalfe (ANL)
DSTC (SciFi/Pb): Zisis Papandreou (Regina)

BARREL HCAL
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FORWARD HCAL
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AC-LGAD TOF
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Deputy DSL: Satoshi Yano (Hiroshima)

GASEOUS TRACKERS
DSL: Kondo Gnanvo (LBL)
DSTC: Maxence Vendenbroucke (Saclay)

Detector Subsystem Collaborations

The UK Involvement Confirmed

27 March 2024

Recently announced major funding through UKRI infrastructure funding:

Home > News > Major research and innovation infrastructure investment announced

Major research and innovation infrastructure investment announced

UK-US collaboration

Another project will receive £58.8 million from UKRI in a partnership with the US Department of Energy (DOE), to develop new detector and accelerator infrastructure to address fundamental questions on the nature of matter.

The technology will be built by:

- two STFC national laboratories, Daresbury Laboratory in Cheshire and the Rutherford Appleton Laboratory in Oxfordshire
- the universities of Birmingham, Brunel, Glasgow, Lancaster, Liverpool, Oxford and York
- the Cockcroft Institute for Accelerator Science and Technology in Cheshire

It will be installed at the Electron-Ion Collider (EIC), a major new particle accelerator facility at the Brookhaven National Laboratory in New York in the US.

The UK Project in more detail

WP1: MAPS → 65nm CMOS (wafer scale) stitched sensors, developed from ALICE-ITS3, to be deployed in central tracker

→ Construction of 2 barrel layers, corresponding to around 1/3 of silicon tracker

WP2: Timepix → Application of pixel sensors for beamline electron tagger for luminosity and physics at $Q^2 \to 0$

WP3: Lumi Monitoring → Novel pair-spectrometer, beamline $\gamma \to ee$ counting

WP4: Accelerator → Primarily SRF systems for Energy Recovery cooler.

→ Also crab-cavity LLRF synchronisation, beam position monitoring, Energy Recovery modelling and design

University of Birmingham

Brunel University London

University of Glasgow

Lancaster University

Science & Technology Facilities Council
Daresbury Laboratory
Rutherford Appleton Laboratory
ASTeC

University of Liverpool

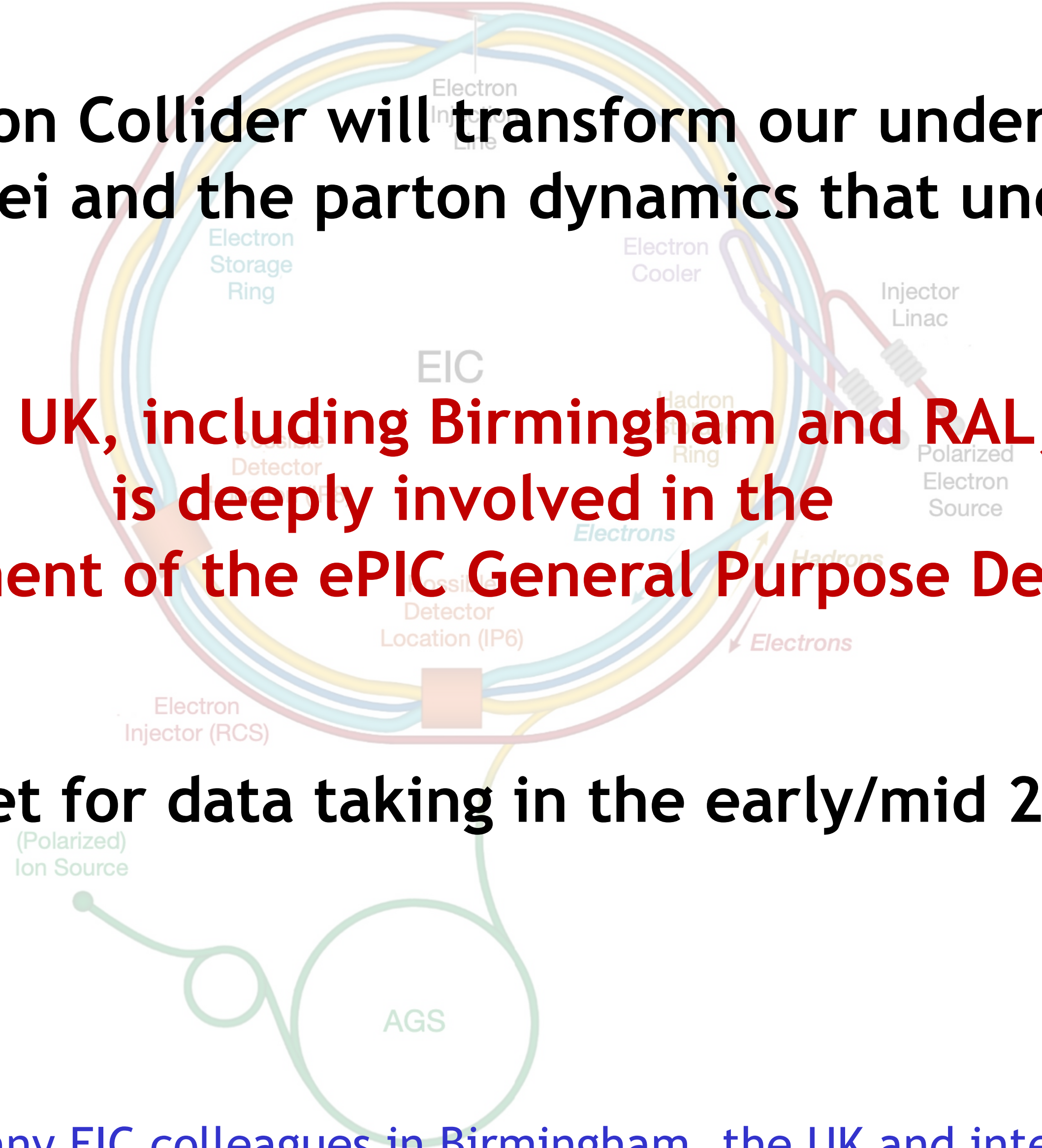
University of Oxford

University of York

The Cockcroft Institute of Accelerator Science and Technology

JAI John Adams Institute for Accelerator Science

Summary



The Electron Ion Collider will transform our understanding of nucleons, nuclei and the parton dynamics that underlie them

The UK, including Birmingham and RAL, is deeply involved in the development of the ePIC General Purpose Detector

On target for data taking in the early/mid 2030s

[with thanks to many EIC colleagues in Birmingham, the UK and internationally]