EIC: overview on tracking R&D

Francesco Bossù

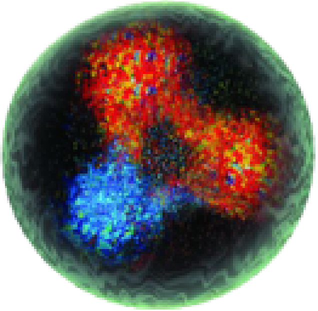
CEA-Saclay Irfu/DPhN

QDR QCD
LPT, 25/11/2019

The nucleon

- Most visible matter in the universe is made of nucleons
- Nucleons are composite objects in non-perturbative QCD regime
- Do we understand them?

- Open questions:
  - Mass of the nucleons not explained by the Higgs mechanisms
  - Internal structure
  - Spin puzzle
  - Confinement
  - How nucleons differ when in nuclei



Electromagnetic probe

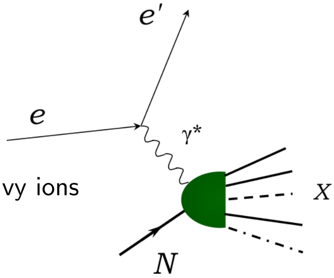
- Electron (or photon or muon) beam: clean probe, it couples electromagnetically

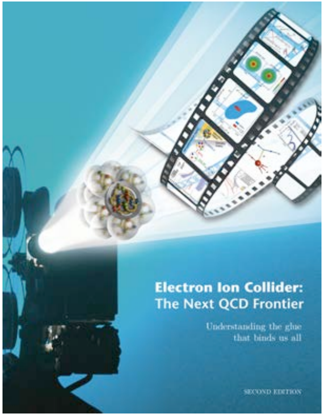
Measurements:

- Inclusive: detect only the scattered electron
- Semi-inclusive: detect the electron and parts of the debris
- Exclusive: detect all the final state particles

e-p experiment advantages:

- High luminosity
- Polarized electron beam
- Possibility to polarize also the target
- The target can vary: from hydrogen up to heavy ions



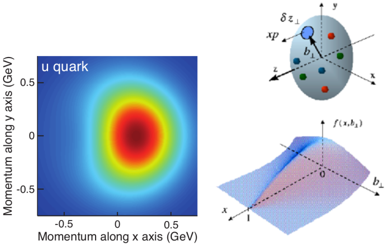


arXiv:1212.1701

Three main questions in the EIC white paper:

EIC: Study structure and dynamics of matter at high luminosity, high energy with polarized beams and wide range of nuclei

The future for e-p/A physics: Electron Ion Collider



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- How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleus?

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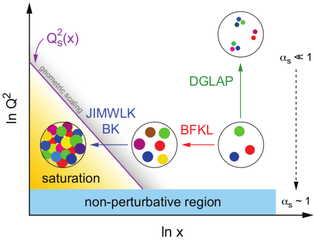

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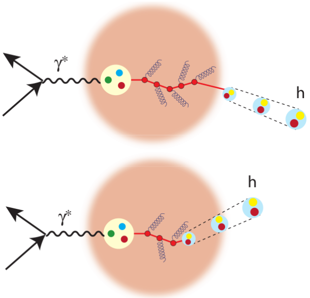

Three main questions in the EIC white paper:

- How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleus?
- Where does the saturation of gluon densities set in?
- How does the nuclear environment affect the distribution of quarks and gluons and their interactions in nuclei?

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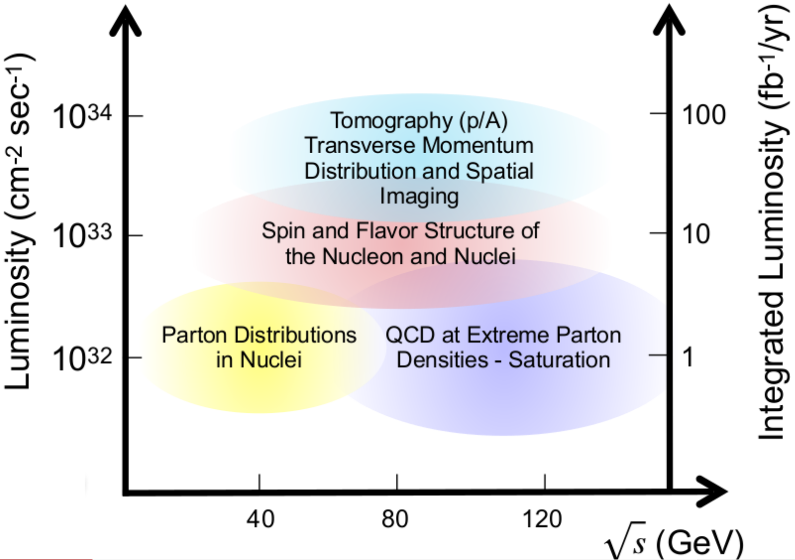
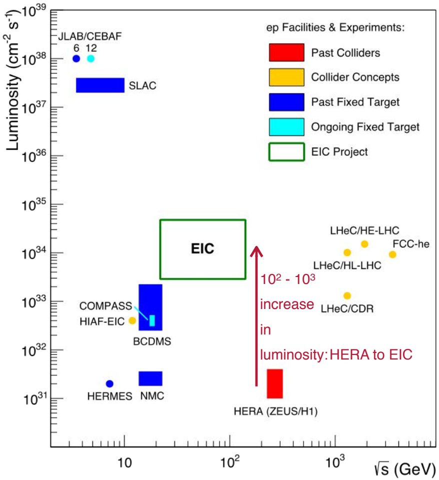
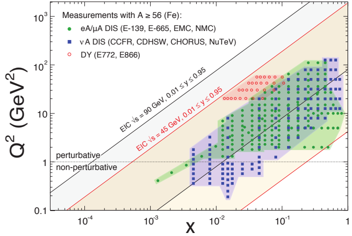


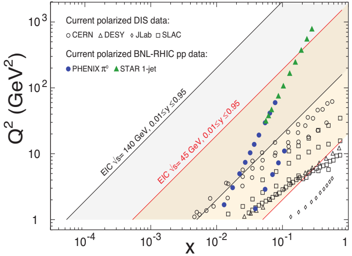
The EIC Facility Concepts

- Luminosity / $\sqrt{s}$ / Kinematic coverage





eA



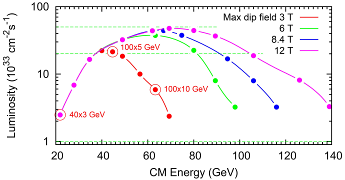
ep

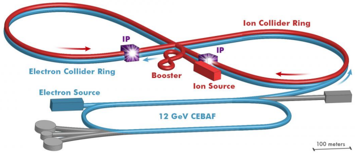
8th International Conference on Quarks and Nuclear Physics
Tsukuba, Japan, November 13 - 17, 2018

Bernd Surrow

JLEIC

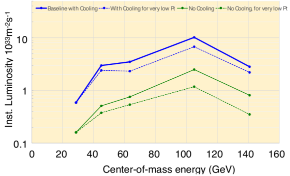
- Polarized electrons: 3 – 12GeV
- Polarized protons
- Up to $\sqrt{s}$ =100GeV
- Figure-8: p spin precession cancel

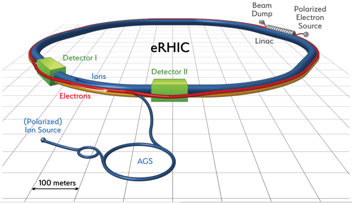




eRHIC

- Polarized electrons: 5 – 18GeV
- Polarized protons: up to 275 GeV
- Up to $\sqrt{s}$ = 140GeV





Key questions in the EIC white paper:

- How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleus?
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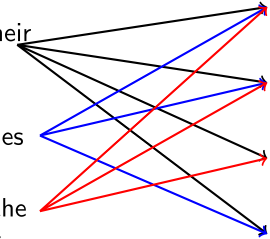


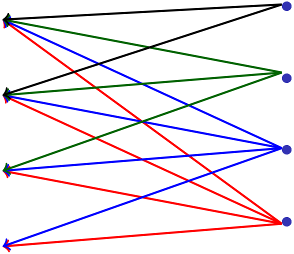
Key measurements:

- Inclusive DIS
- Semi-inclusive DIS
- Exclusive DIS
- Diffraction

The future for e-p/A physics: Electron Ion Collider

Key requirements:

- Electron identification - scattered lepton
- Momentum and angular resolution - x, Q^2
- $\pi^{\pm}, K^{\pm}, p, \bar{p}, \gamma$, identification
- Rapidity coverage, t resolution

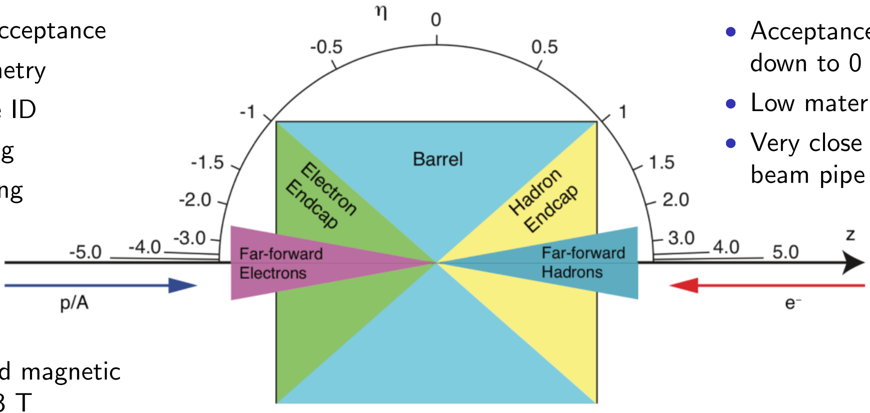


Key measurements:

- Inclusive DIS
- Semi-inclusive DIS
- Exclusive DIS
- Diffraction

EIC Detector concepts

- $\sim 4\pi$ acceptance
- Calorimetry
- Particle ID
- Tracking
- Vertexing

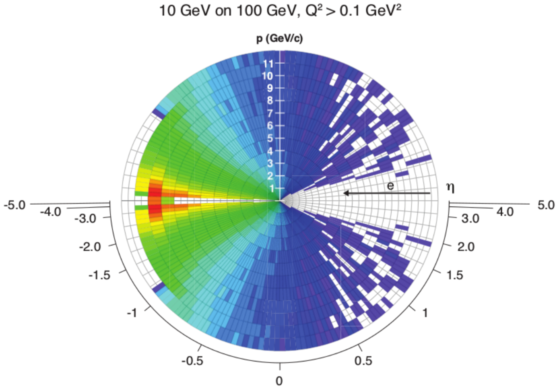


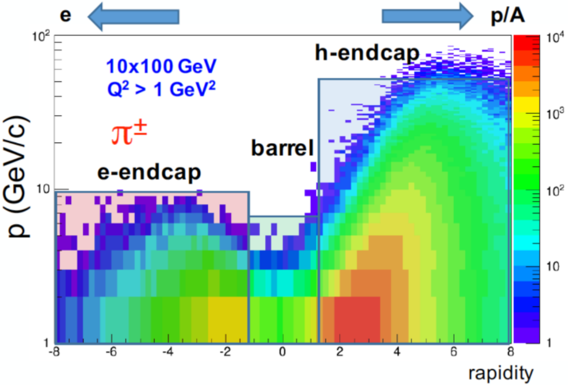
EIC detector Handbook, figure 2

- Acceptance even down to 0 deg
- Low material budget
- Very close to the beam pipe

- Solenoid magnetic field: 3 T

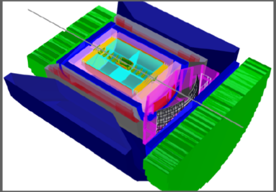
EIC Particle distributions



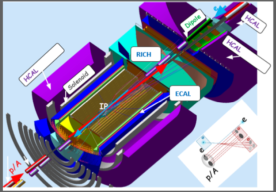


EIC Detector concepts

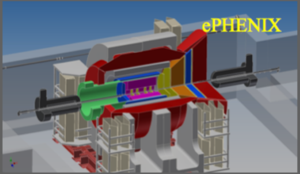
Brookhaven concept: BEAST



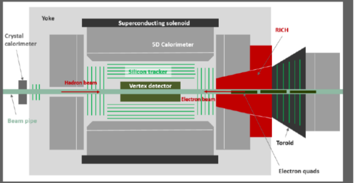
Jefferson lab concept: JLEIC



sPhenix → ePhenix



Argonne concept: TOPSiDE



EIC Detector requirements

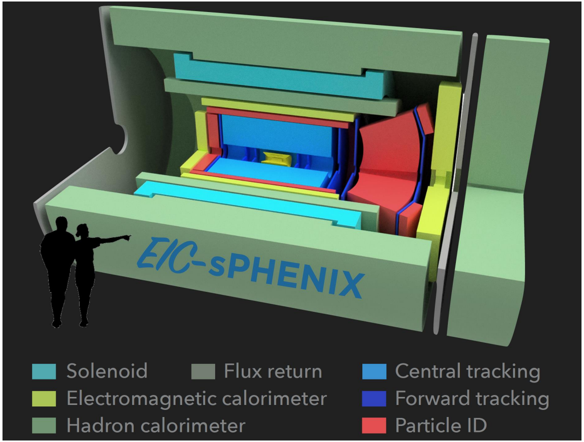
EIC Detector Requirements

η	Nomenclature			Tracking			Electrons		π/K/p PID		HCAL	Muons
				Resolution	Allowed X/X_0	Si-Vertex	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Resolution σ_E/E	
-6.9 — -5.8			low-Q² tagger	$\delta\theta/\theta < 1.5\%$; $10^{-6} < Q^2 < 10^{-2}$ GeV²								
…	↓ p/A	Auxiliary Detectors										
-4.5 — -4.0			Instrumentation to separate charged particles from photons									
-4.0 — -3.5												
-3.5 — -3.0				$\sigma_p/p \sim 0.1\% \times p + 2.0\%$			2%/√E					
-3.0 — -2.5												
-2.5 — -2.0			Backwards Detectors			TBD			≤ 7 GeV/c		~50%/√E	
-2.0 — -1.5				$\sigma_p/p \sim 0.05\% \times p + 1.0\%$								
-1.5 — -1.0							7%/√E	π suppression up to 1:10⁴				
-1.0 — -0.5												
-0.5 — 0.0		Central Detector	Barrel	$\sigma_p/p \sim 0.05\% \times p + 0.5\%$	~5% or less	$\sigma_{xyz} \sim 20$ µm, $d_0(z) \sim d_0(r\phi) \sim 20/p_T$ GeV µm + 5 µm			≤ 5 GeV/c	≥ 3σ	TBD	TBD
0.0 — 0.5												
0.5 — 1.0												
1.0 — 1.5												
1.5 — 2.0				$\sigma_p/p \sim 0.05\% \times p + 1.0\%$			(10-12)%/√E		≤ 8 GeV/c			
2.0 — 2.5			Forward Detectors			TBD					~50%/√E	
2.5 — 3.0									≤ 20 GeV/c			
3.0 — 3.5				$\sigma_p/p \sim 0.1\% \times p + 2.0\%$					≤ 45 GeV/c			
3.5 — 4.0			Instrumentation to separate charged particles from photons									
4.0 — 4.5												
…	↑e	Auxiliary Detectors										
> 6.2			Proton Spectrometer	$\sigma_{intrinsic}(\lvert t \rvert)/\lvert t \rvert < 1\%$; Acceptance: $0.2 < p_T < 1.2$ GeV/c								

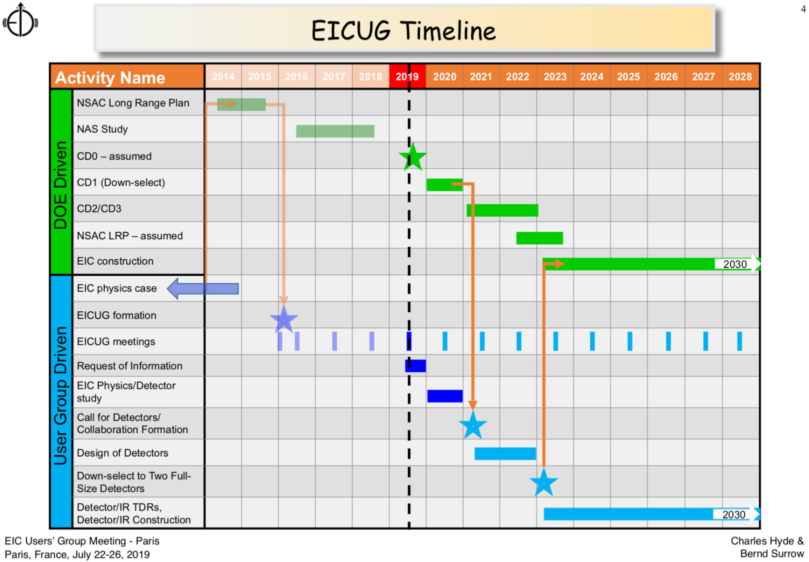
Table 2: Physics requirements for a an EIC detector

Requirements for tracking detectors:

- Large area
- Low material budget: $X/X_0 < 5\%$
- Very good momentum resolution: $\sigma_p/p \sim 0.05\% \cdot p$



EIC road map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EICUG Timeline
Activity Name
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
DOE Driven
NSAC Long Range Plan
NAS Study
CD0 – assumed
CD1 (Down-select)
CD2/CD3
NSAC LRP – assumed
EIC construction
2030
User Group Driven
EIC physics case
EICUG formation
EICUG meetings
Request of Information
EIC Physics/Detector study
Call for Detectors/ Collaboration Formation
Design of Detectors
Down-select to Two Full-Size Detectors
Detector/IR TDRs, Detector/IR Construction
2030
EIC Users' Group Meeting - Paris
Paris, France, July 22-26, 2019
Charles Hyde &
Bernd Surrow

Tracking detectors R&D for EIC at CEA

Two main areas:

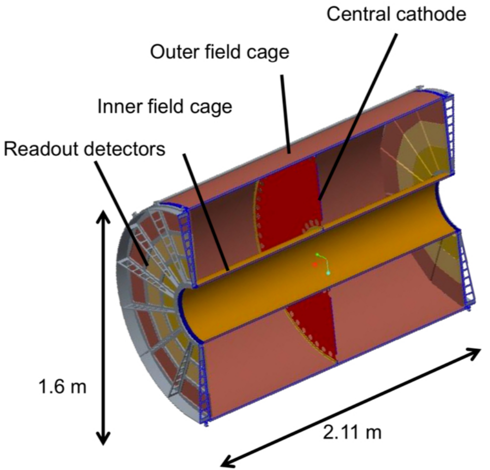
- Time Projection Chamber read-out detectors
- Large area tracking detectors

TPC read-out

Compact TPC:

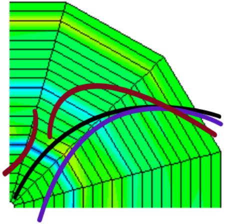
- Must work at large collision rates
- Continuous read-out: un-gated
- Very good tracking, very small material budget
- Possibly, good energy resolution (dE/dx) for particle identification
- Small pad size
- At high rates, possible distortions of the E field due to ion back flow

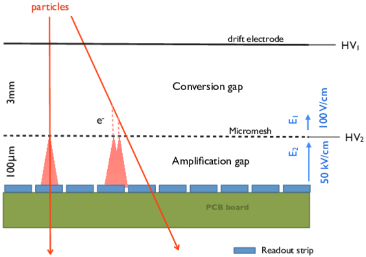
Micro-pattern gaseous detectors can be optimized to fulfill these requirements



TPC read-out - ongoing R&D

- Ion back flow: the fraction of ions from the avalanche that enters the TPC drift volume
- IBF causes distortions in the drift electric field
- Goal is to minimize the ion back-flow
- And possibly preserving a good energy resolution



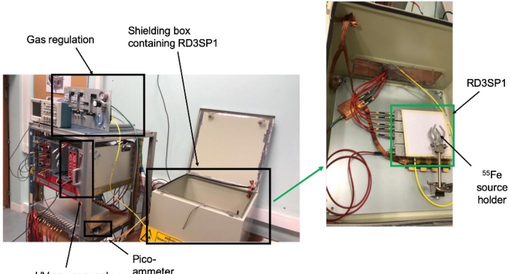


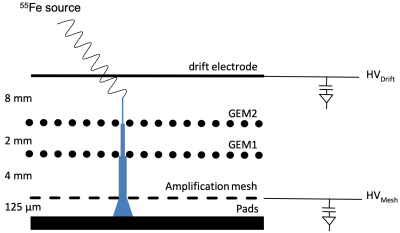
- The "standard" solution, driven by ALICE, is 4-GEMs
- DPhN and DEDIP focus on Micromegas based solutions

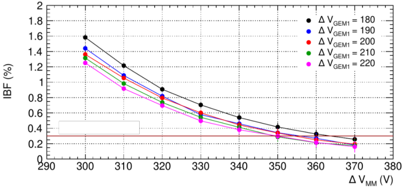
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

TPC read-out - ongoing R&D

- First setup studied: hybrid 2 GEMs and 1 MM
- Measurements with Fe^{55} performed at DEDIP by A.Glaenzer
- First results both with Ar-iC_4H_{10} and Ne-CF_4 show that very low IBF values can be reached with a gain of 2000
- Ongoing tests on 2 Micromesh prototypes







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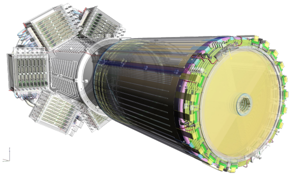
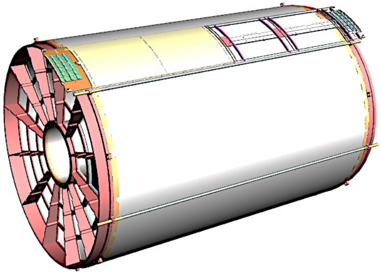
Micromegas tracker - ongoing R&D

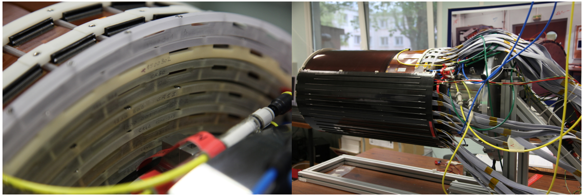
- Cylindrical MM detectors
- Low material budget
- Large areas
- Spatial resolution $\sim 100\mu$m
- High rate capabilities
- As outside tracker for helping TPCs
- Or as a multilayer tracker

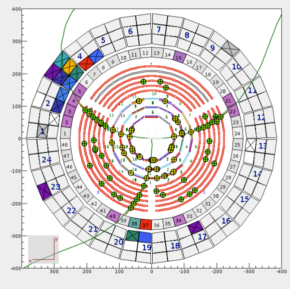


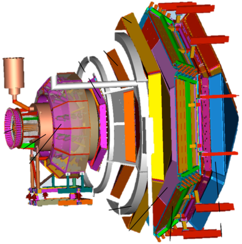


Micromegas tracker - ongoing R&D

- Technology already in use in CLAS12: Mircomegas Vertex Tracker
- $4m^2$ surface, limited space: 6 layers in 10 cm
- DREAM electronics for 20k channels
- $X/X_0 \sim 5\%$







Summary

- EIC is getting more and more a concrete idea
- The EICUG is starting the writing of a Yellow Report
- Irfu well placed in R&D of MPGDs for EIC
- also thanks to STRONG 2020 funding

Outlook:

- Next years will be crucial for the definition of detector features and needs
- It will be crucial to have estimates of background rates: dedicated campaigns of realistic simulations needed

Material information: M. Vandenbroucke, A. Glaenzer, B. Surrow, E. Sichtermann, EIC White paper, EIC Detector R&D handbook