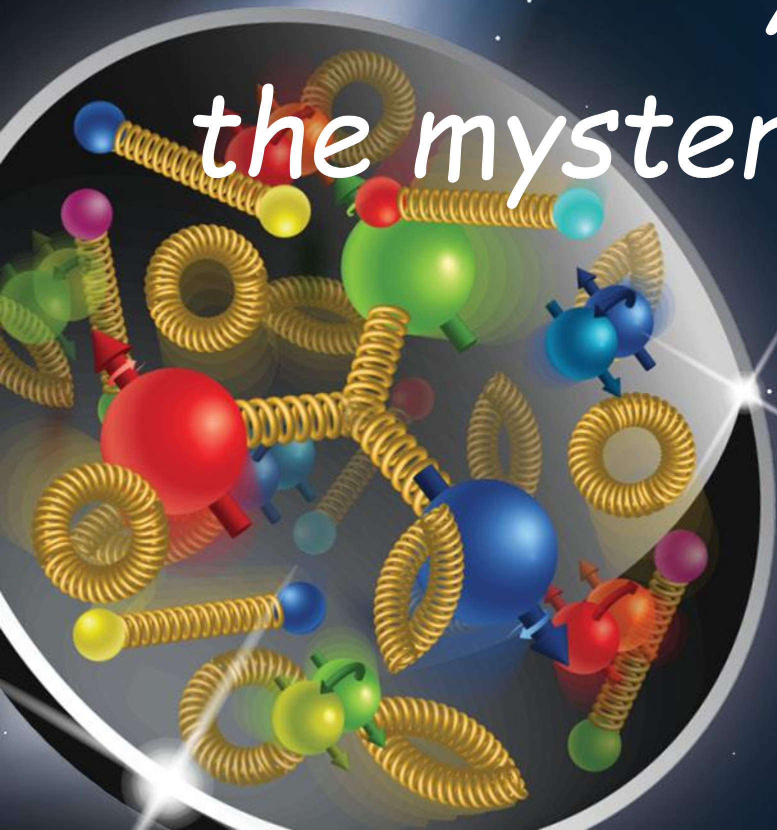
The electron-ion collider: A collider to unravel the mysteries of visible matter



E.C. Aschenauer (BNL)

Electron Ion Collider

Brookhaven National Laboratory Jefferson Lab U.S. DEPARTMENT OF ENERGY Office of Science

The EIC Facility

What is the EIC:

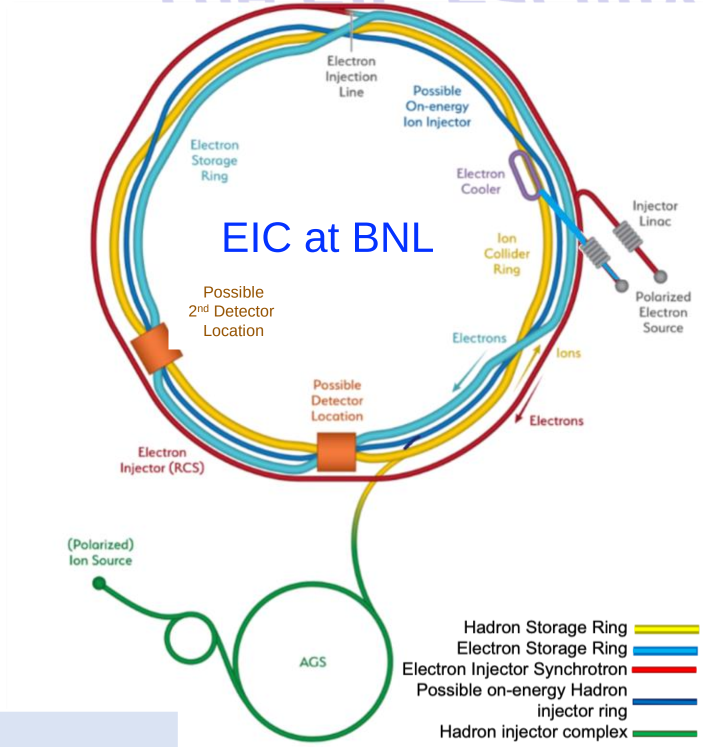
A high luminosity (10^{33} – 10^{34} $cm^{-2}s^{-1}$) polarized electron proton / ion collider with $\sqrt{s_{ep}}$ = 28 – 140 GeV

What is included in the EIC Project:

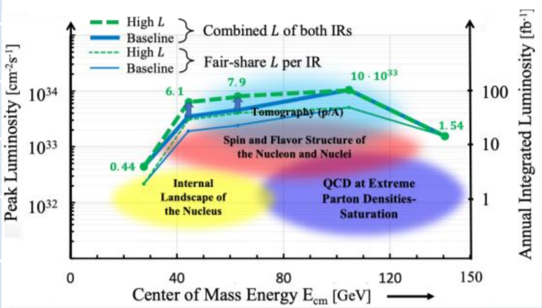
the collider & one interaction region and one general purpose detector

What can the EIC Facility support:

at minimum > 2 decades increase in kinematic coverage in x and Q^2

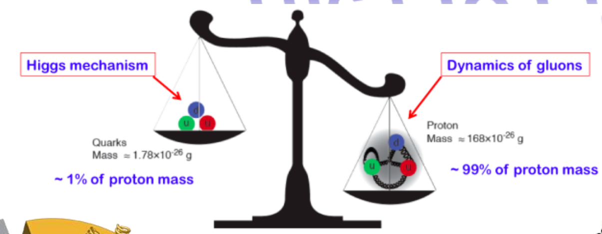


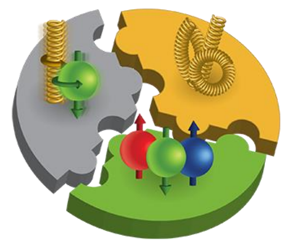
Double Ring Design Based on Existing RHIC Facilities	
Hadron Storage Ring: 40, 100 - 275 GeV	**Electron Storage Ring: 5 - 18 GeV**
RHIC Ring and Injector Complex: p to Pb	9 MW Synchrotron Radiation
1A Beam Current	Large Beam Current - 2.5 A
1160 bunches → 9 ns bunch spacing	
Light ion beams (p, d, ^{3}He) polarized (L,T)	Polarized electron beams
Nuclear beams: d to U	**Electron Rapid Cycling Synchrotron**
Requires Strong Cooling: new concept →CEC	Spin Transparent Due to High Periodicity
High Luminosity Interaction Region – one on project – 2nd one possible	
25 mrad Crossing Angle with Crab Cavities	

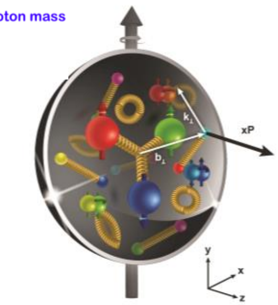


The EIC Physics

How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?
How do the nucleon properties emerge from them and their interactions?

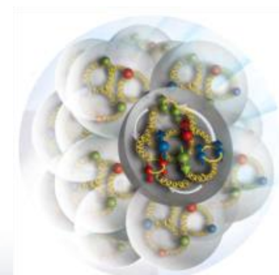




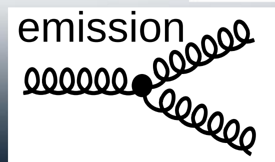


How do color-charged quarks and gluons, and colorless jets, interact with a nuclear medium?
How do the confined hadronic states emerge from these quarks and gluons?
How do the quark-gluon interactions create nuclear binding?

How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?
What happens to the gluon density in nuclei? Does it saturate at high energy, giving rise to a gluonic matter with universal properties in all nuclei, even the proton?

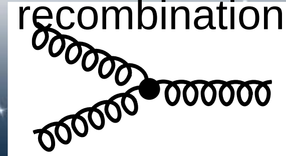


gluon emission



?=

gluon recombination

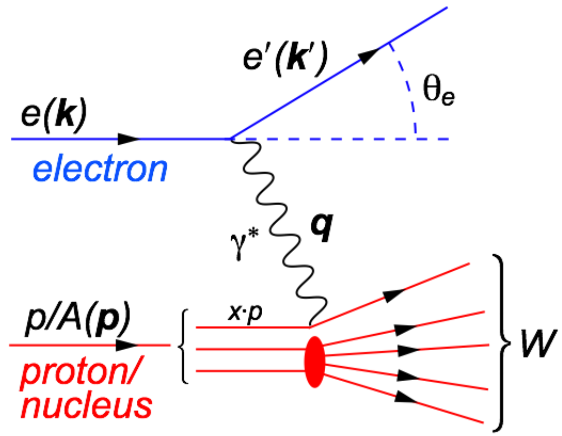


What is needed to address the EIC Physics

The Golden Process:

Deep Inelastic Scattering (DIS):

- As a probe, electron beams provide unmatched precision of the electromagnetic interaction
- Direct, model independent determination of parton kinematics of physics processes



$$Q^2 = s \cdot x \cdot y$$

s: center-of-mass energy squared

Q^2: resolution power

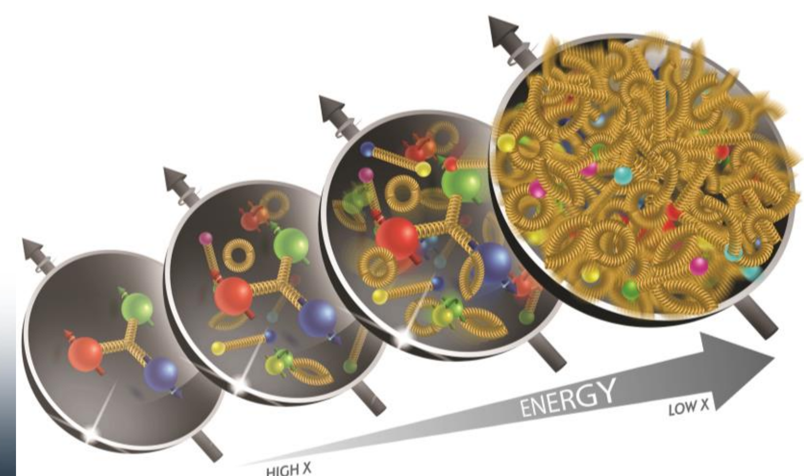
x: the fraction of the nucleon's momentum carried by the struck quark (0<x<1)

y: inelasticity

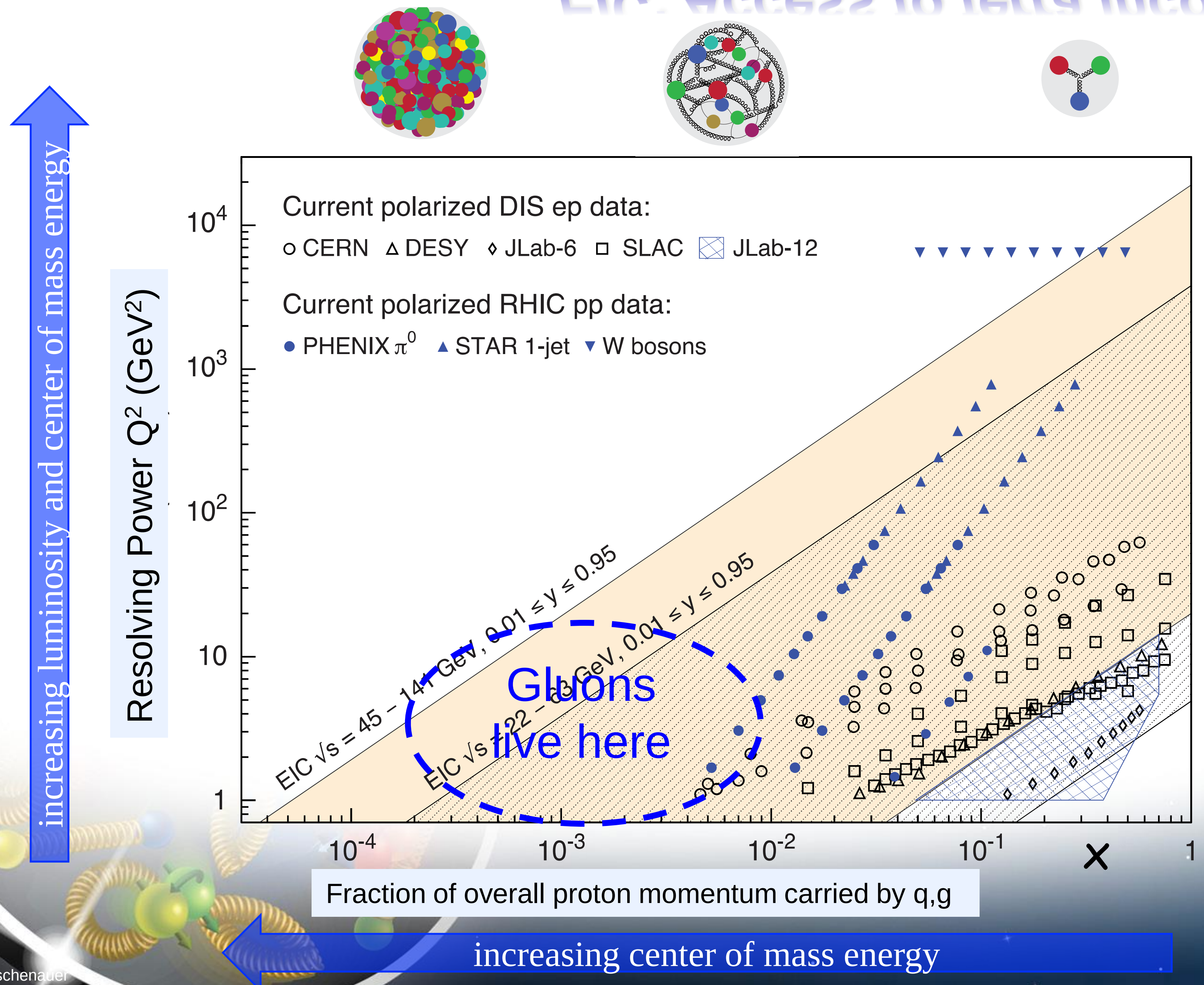
large kinematic coverage:

→ center-of-mass energy $\sqrt{s}$: 20 – 140 GeV

→ access to x and Q^2 over a wide range



EIC: Access to terra incognita



What do we know: Mass of the Proton

Visible world: *mainly made of light quarks – its mass emerges from quark-gluon interactions.*

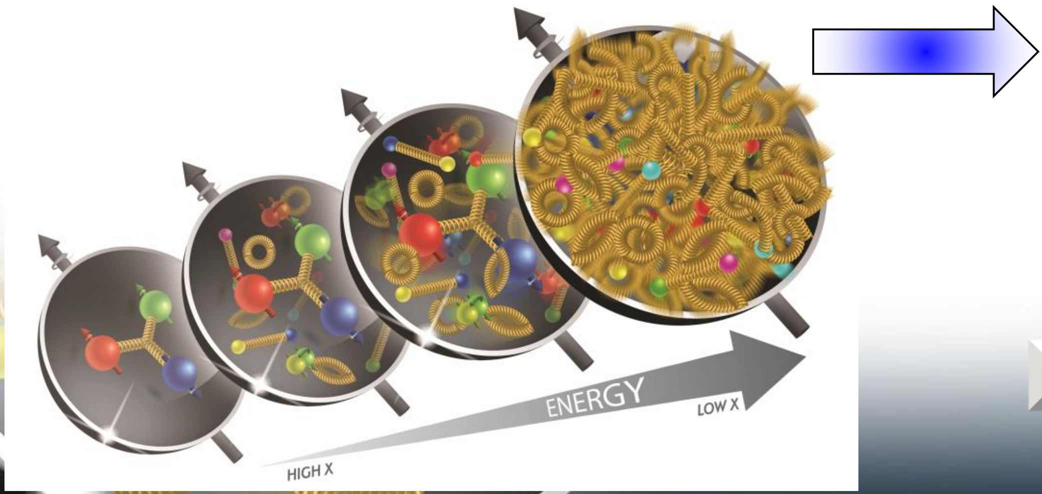
Proton

Quark structure: uud
Mass ~ 940 MeV (~1 GeV)
Proton Mass: 1.8×10^{-27} kg
The Sum of all Quark masses accounts for 1% of the proton mass

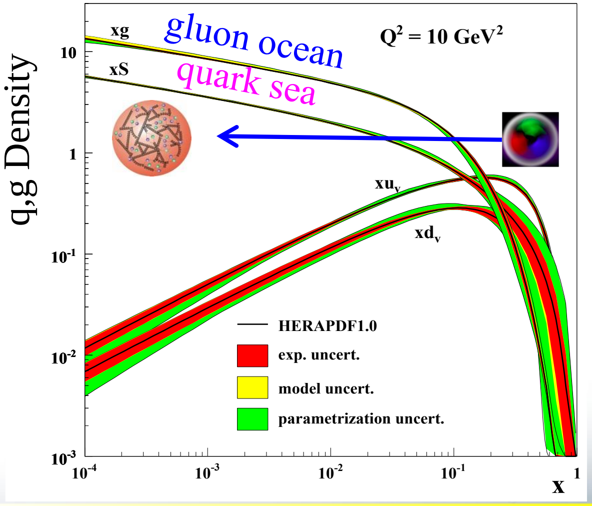
Where does the rest of the mass hide ?

Most of mass generated by dynamics

Gluon rise discovered by HERA e-p



Density of quarks or gluons inside the proton

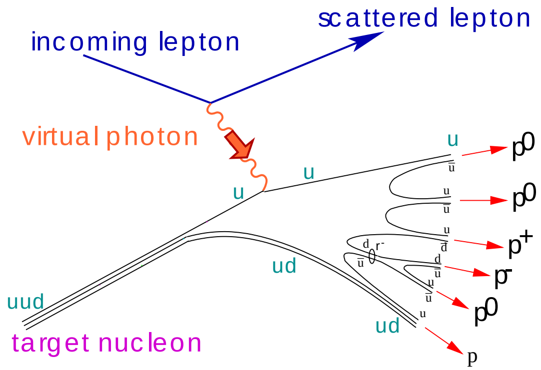


The proton is dominated by gluons

EIC can access gluons in different ways to study their contribution to the nucleon

HOW TO ACCESS PARTONS IN DIS

SIDIS:



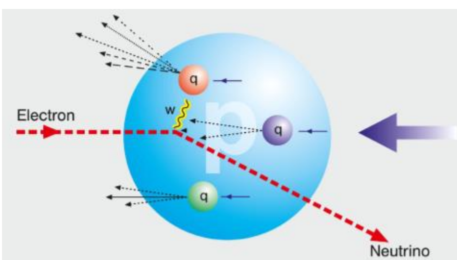
Detect scattered lepton (DIS) in coincidence with identified hadrons (SIDIS)

→ one can measure the correlation between different hadrons as fct. of p_t, z, η

→ needs fragmentation functions to correlate hadron type with parton

→ Detector: PID over a wide range of η and p

Charge Current:

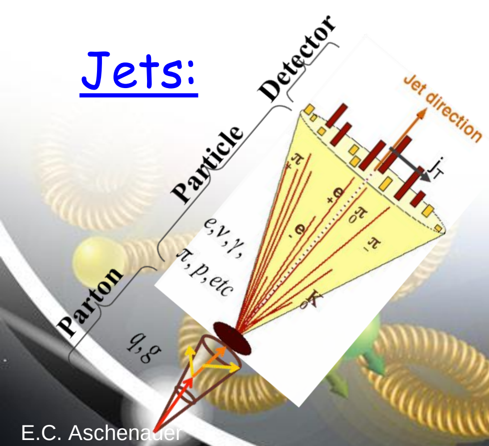


W-exchange: direct access to the quark flavor

no FF – complementary to SIDIS

→ Detector: large rapidity coverage and large $\sqrt{s}$

Jets:



best observable to access parton kinematics tag partons through the sub-processes and jet substructure

→ di-jets: relative p_t → correlated to k_t

→ tag on PGF

→ Detector: large rapidity coverage and PID

How to access Gluons in DIS

Gluons manifest themselves through

1. the behavior of the cross section as function of x and Q^2

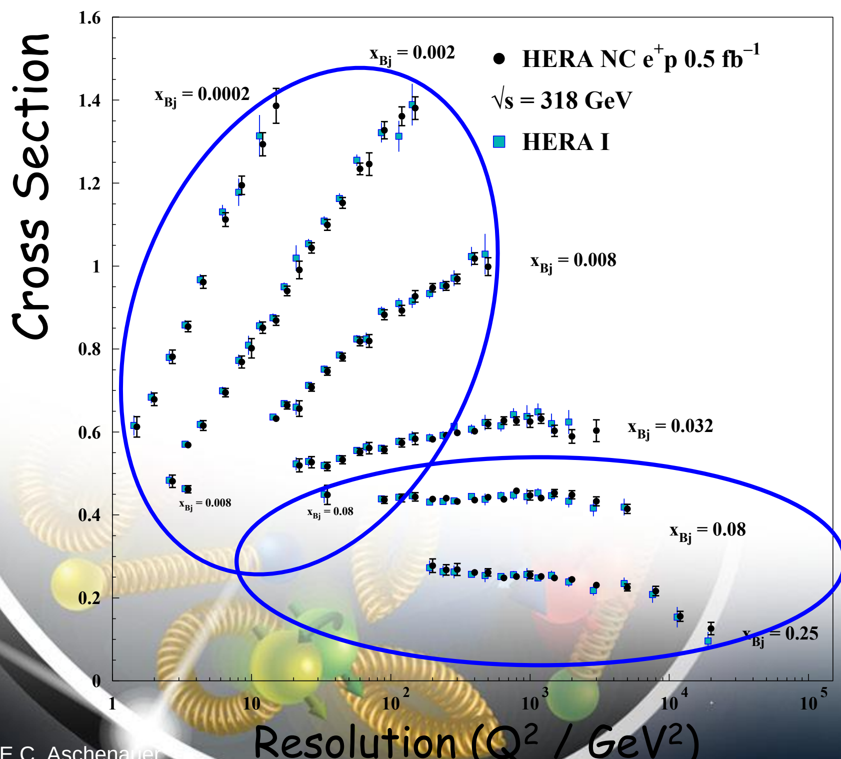
$$\frac{d^2\sigma^{ep\to eX}}{dxdQ^2} = \frac{4\pi\alpha^2_{e.m.}}{xQ^4}\left[\left(1-y+\frac{y^2}{2}\right)F_2(x,Q^2) - \frac{y^2}{2}F_L(x,Q^2)\right]$$

quark+anti-quark momentum distributions (F_2)

gluon momentum distribution (F_L)

without gluons the cross section depends only on x, no dependence on Q^2 → $F_2(x)$

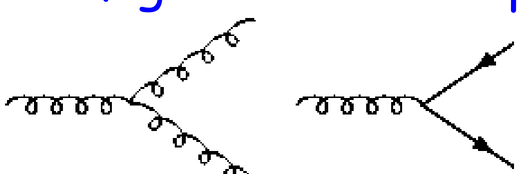
Bjorken scaling



BUT:

Observe strong rise of cross section with both x and Q^2

Because of gluon initiated processes



Scaling violation

→ Gluon Distribution: $d\sigma(x,Q^2)/d\ln Q^2$

How to access Gluons in DIS

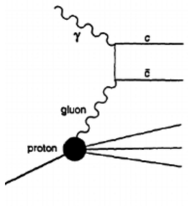
1. Gluons manifest themselves through
   the scaling violation of the cross section as function of x and Q^2
   $dF_2(x,Q^2)/d\ln Q^2 \rightarrow G(x,Q^2)$

$$\frac{d^2\sigma^{ep\to eX}}{dx\,dQ^2} = \frac{4\pi\alpha^2_{e.m.}}{xQ^4}\left[\left(1-y+\frac{y^2}{2}\right)F_2(x,Q^2) - \frac{y^2}{2}F_L(x,Q^2)\right]$$

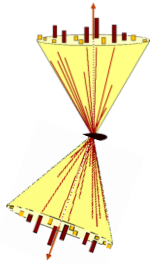
quark+anti-quark momentum distributions (F_2)

gluon momentum distribution (F_L)

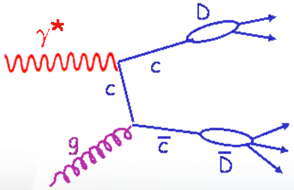
2. Directly through the measurement of F_L
3. Through tagging of the photon gluon fusion process



   1. Di-jets

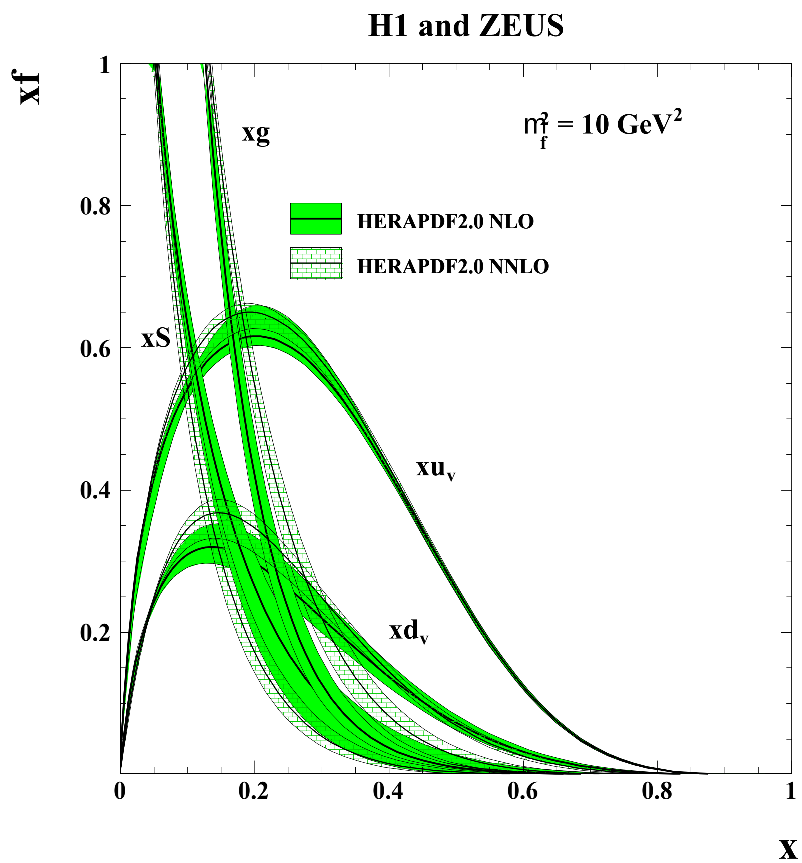


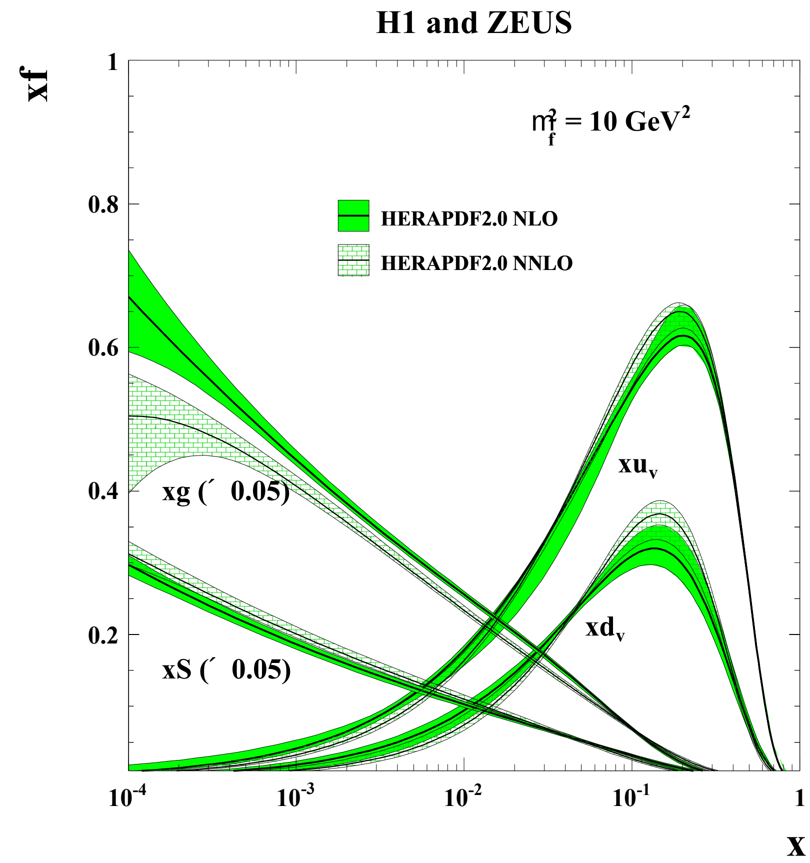
   2. charm production



All these process need a wide coverage in x and Q^2

The unpolarized Proton PDFs





At x of 0.3 the proton is dominated by gluons and sea quarks they should drive the inner structure of the proton

The Spin of the Proton

SPIN is one of the fundamental properties of matter

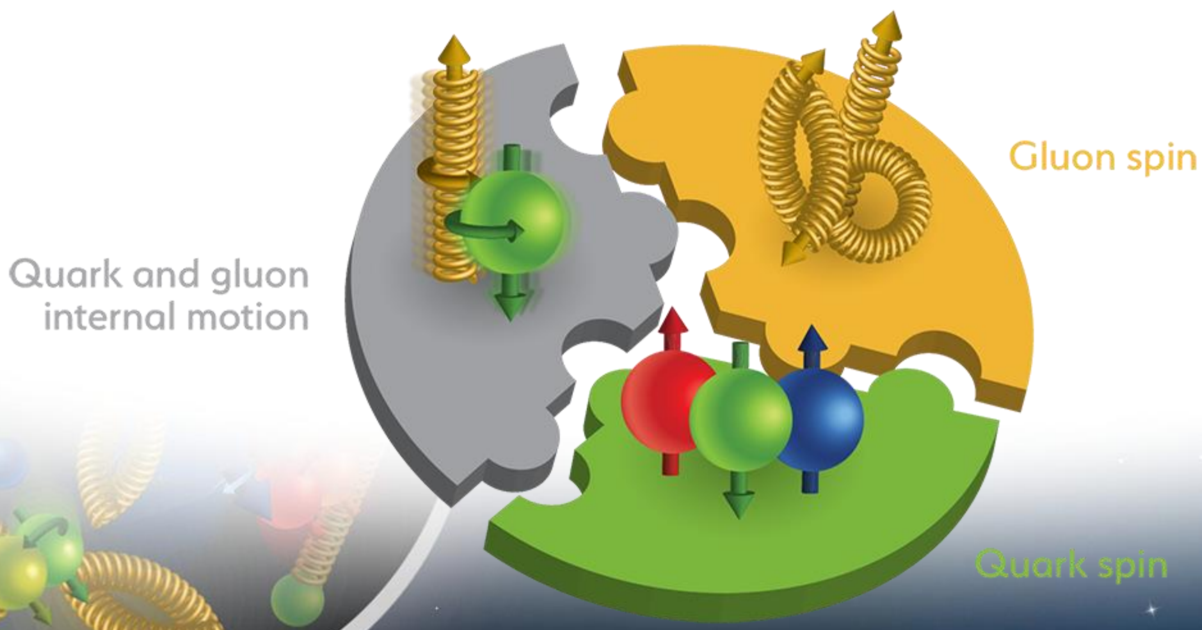
all elementary particles, but the Higgs carry spin

Spin cannot be explained by a static picture of the proton

It is more than the number ½ ! It is the interplay between the intrinsic properties and interactions of quarks and gluons

What do we know:

$$\frac{1}{2}\hbar = \left\langle P,\frac{1}{2} | J^z_{QCD} | P,\frac{1}{2} \right\rangle = \underbrace{\frac{1}{2}\int_0^1 dx \Delta\Sigma(x,Q^2)}_{\text{total quark spin}} + \underbrace{\int_0^1 dx \Delta G(x,Q^2)}_{\text{gluon spin}} + \underbrace{\int_0^1 dx (\sum_q L_q^z + L_g^z)}_{\text{angular momentum}}$$



How to decompose the Spin of the Proton

To determine the contribution of quarks and gluons to the spin of the proton, one needs to measure the cross-section difference g_1 as function of x and Q^2

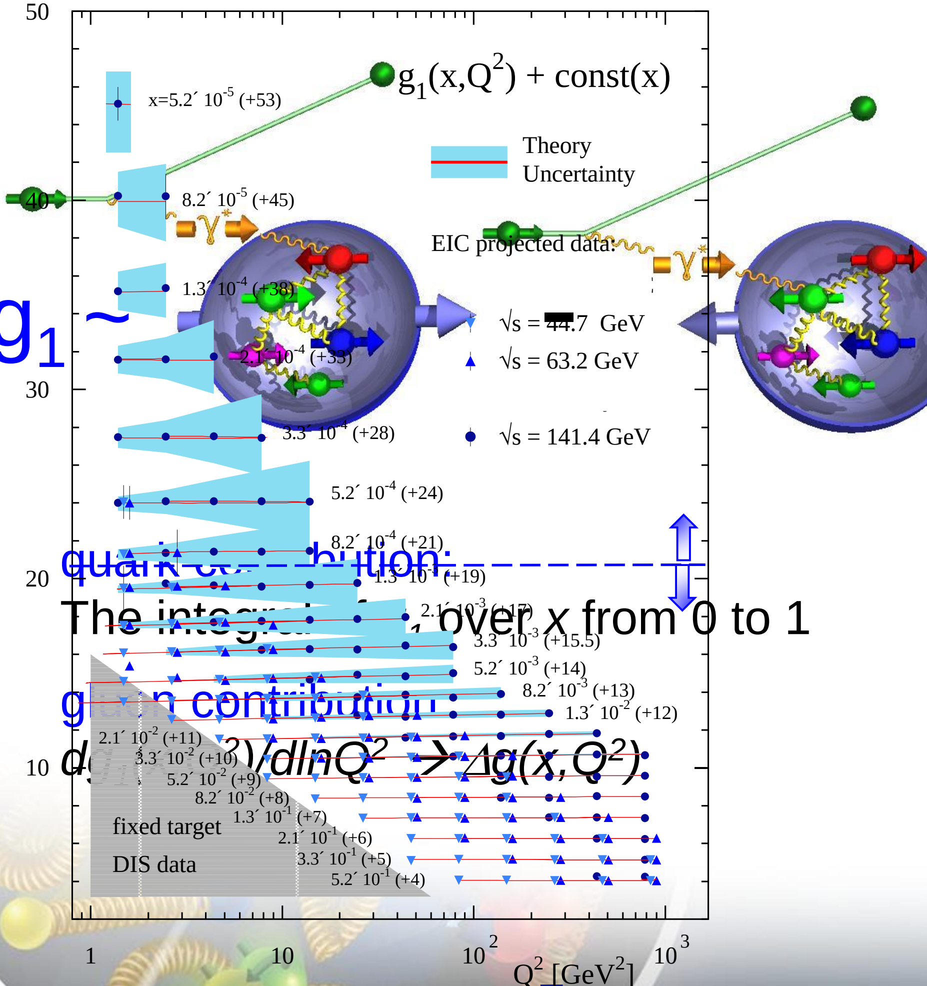
$g_1 \sim$

quark contribution:

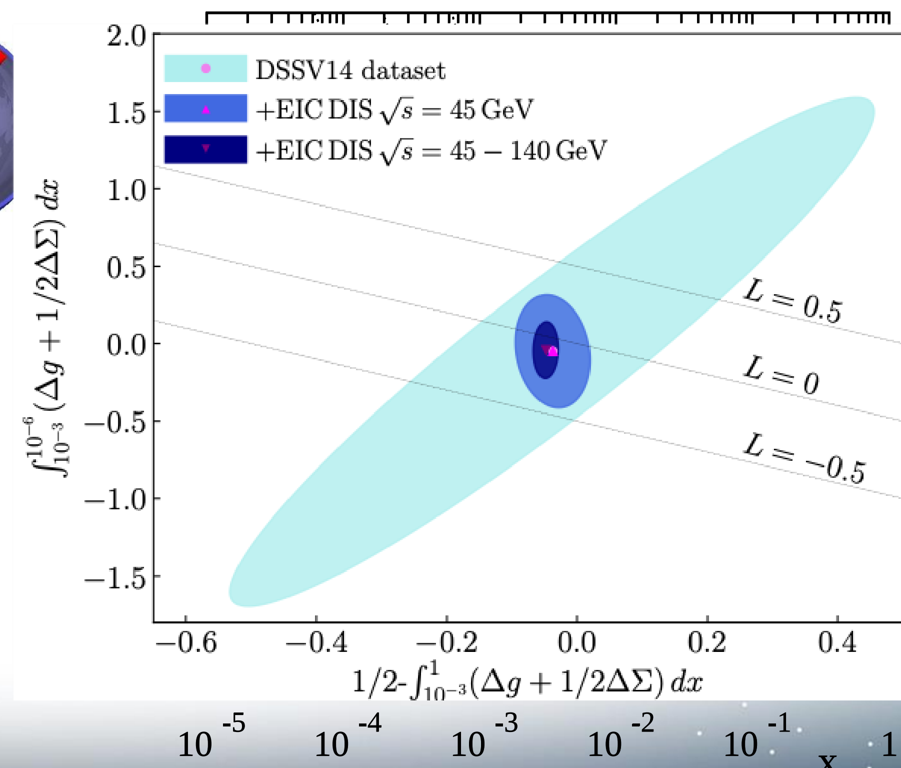
The integral of g_1 over x from 0 to 1

gluon contribution:

$dg_1(x,Q^2)/d\ln Q^2 \rightarrow \Delta g(x,Q^2)$



The current knowledge about g_1 as function of x at Q^2=10 GeV^2



R. Sassot et al. arXiv:2007:083000 & 1509.06489 & 1206.6014

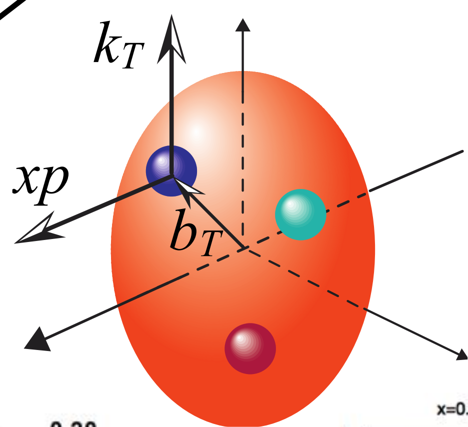
2+1 dimensional Imaging of Quarks & Gluons

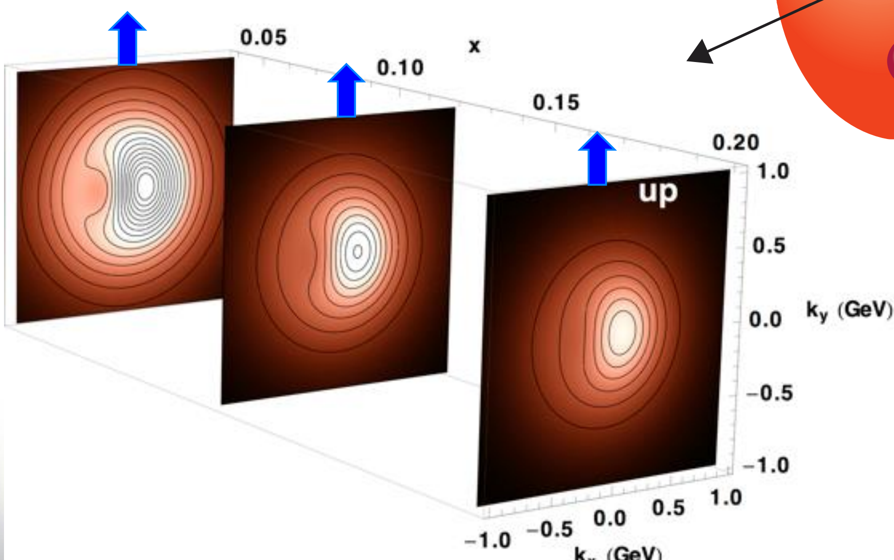
Wigner function → QCD genetic map

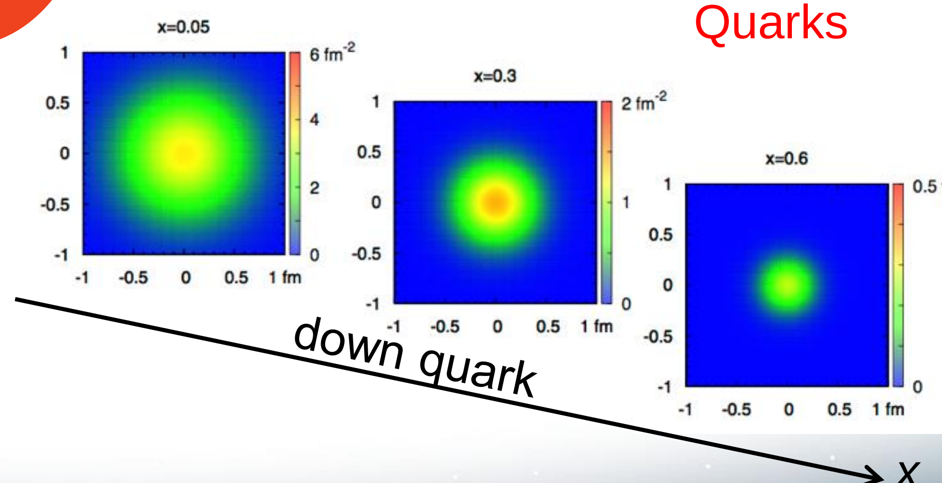
$W(x,b_T,k_T)$

Momentum space $\int d^2b_T$ → $f(x,k_T)$

$\int d^2k_T$ → $f(x,b_T)$ *Coordinate space*







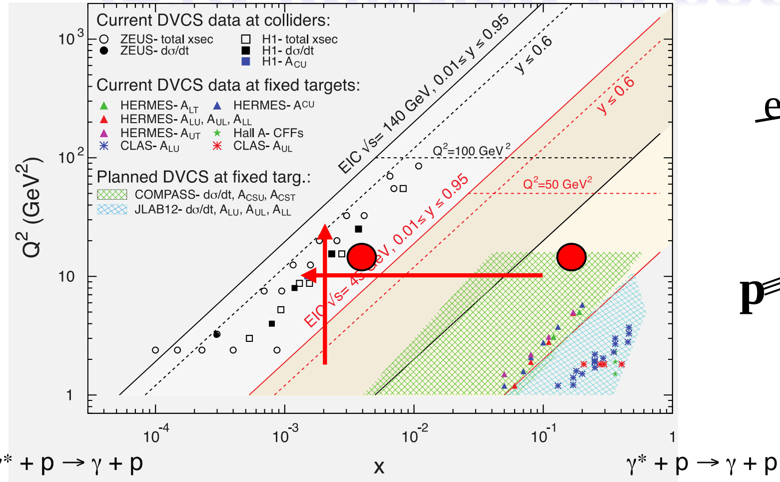
Spin-dependent 3D momentum space images from semi-inclusive scattering

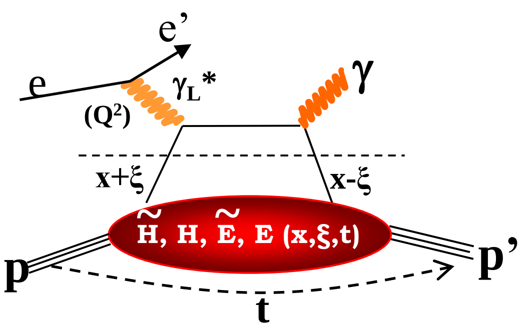
Spin-dependent 2+1D coordinate space images from exclusive scattering

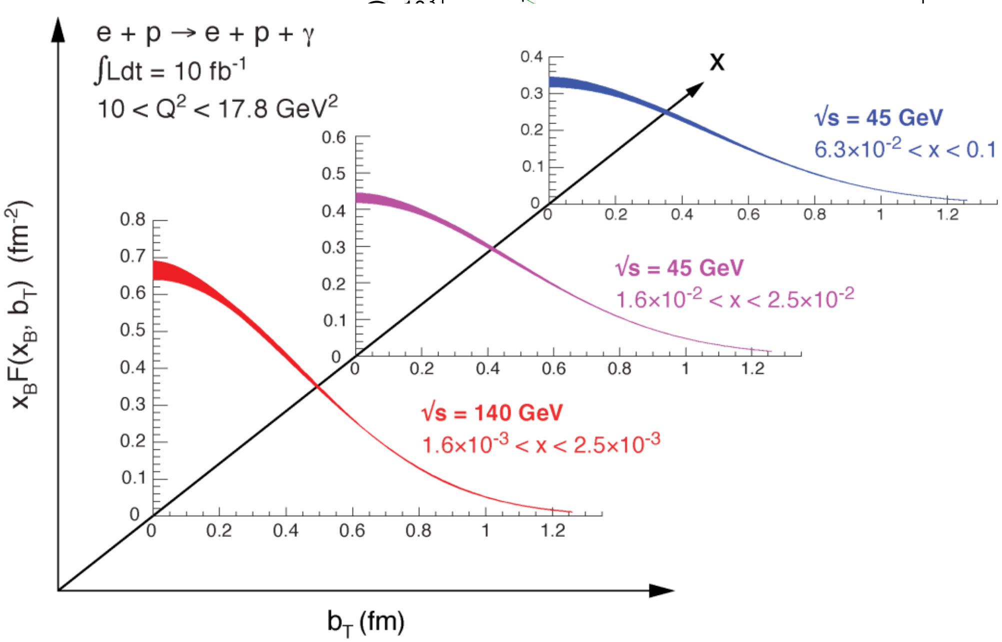
2+1d-Imaging in coordinate space

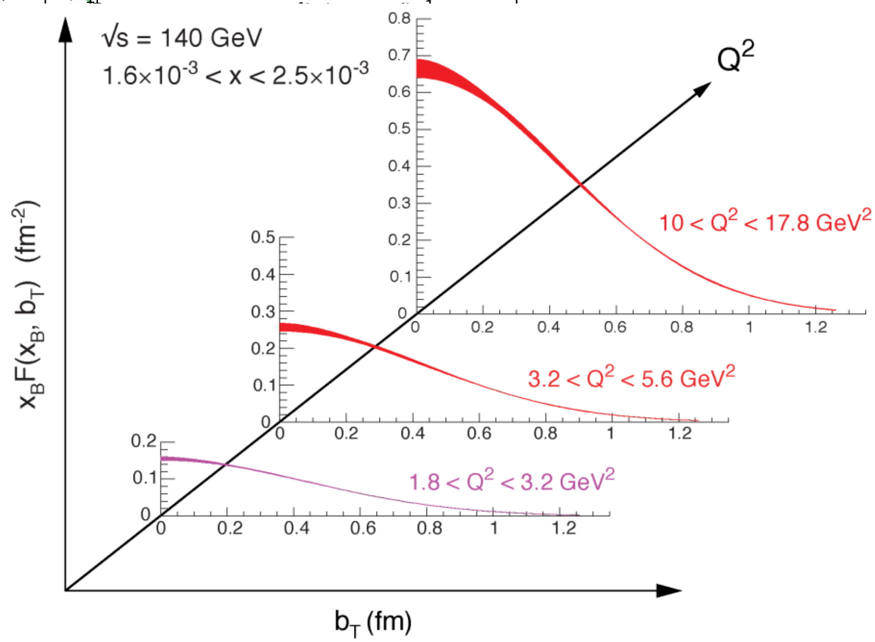
High precision imaging at EIC at low and high x

Golden channel: DVCS



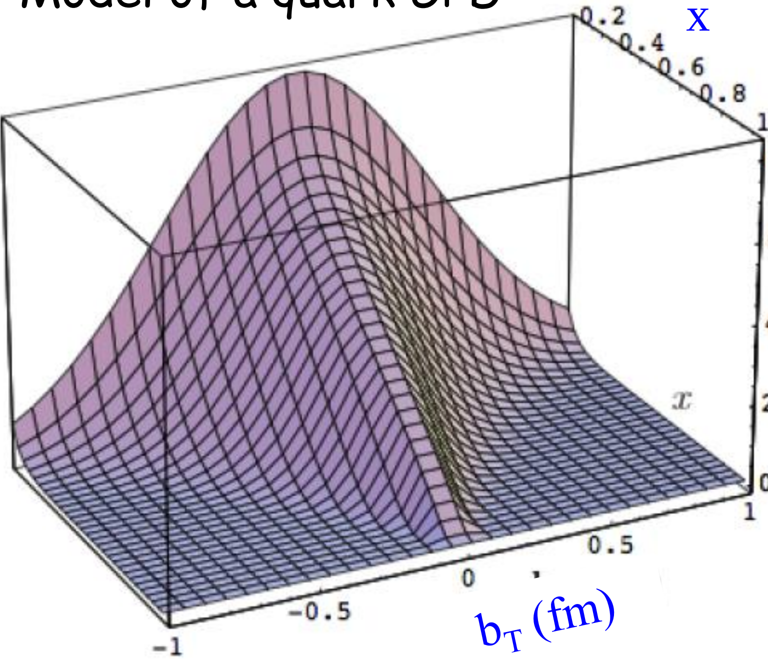




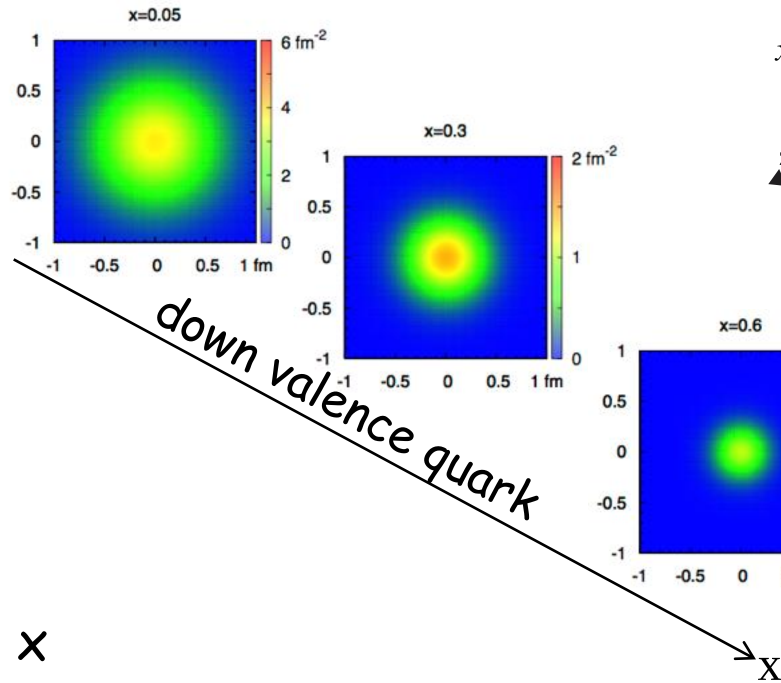


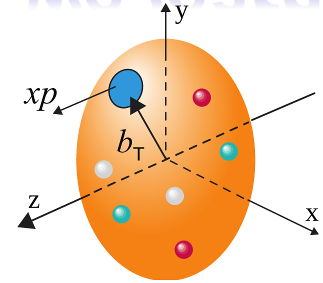
What can we learn

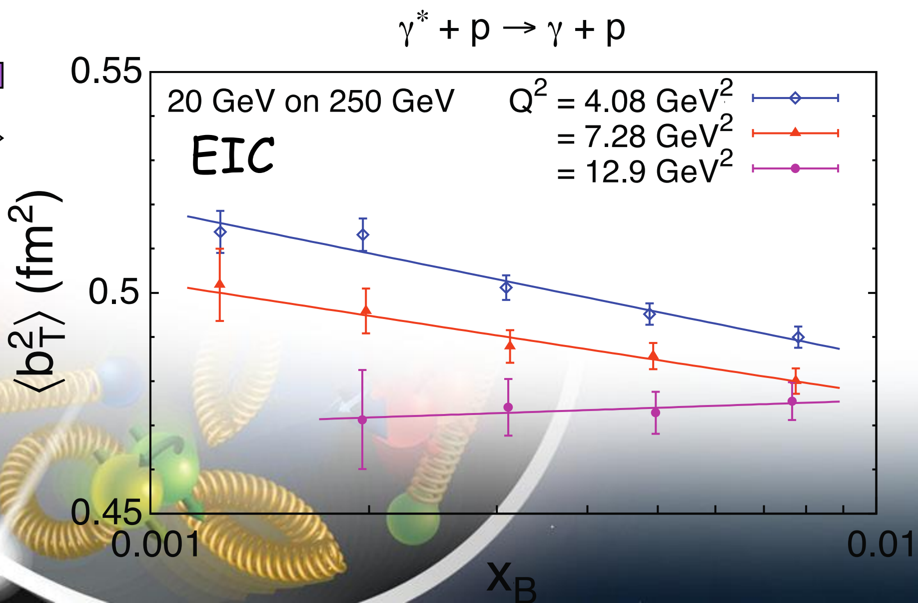
Model of a quark GPD



b_T decreasing as a function of x







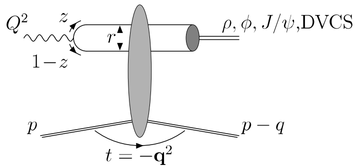
Valence (high x) quarks at the **center** → small b_T

Sea (small x) quarks at the périphérie → high b_T ?

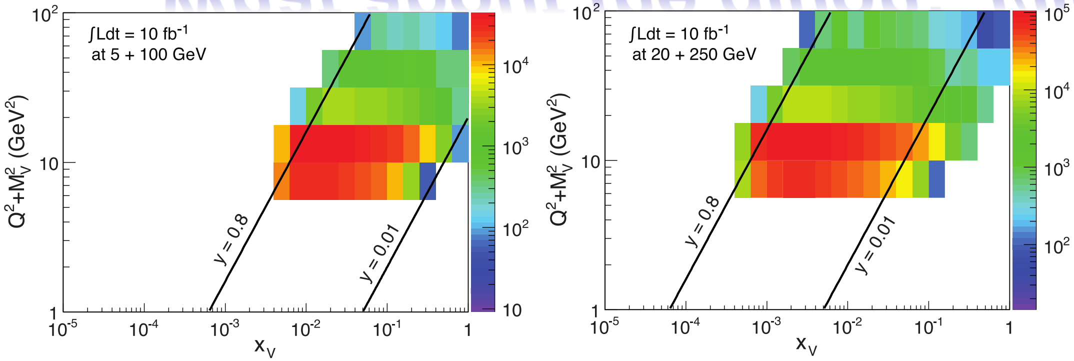
GLUONS ???

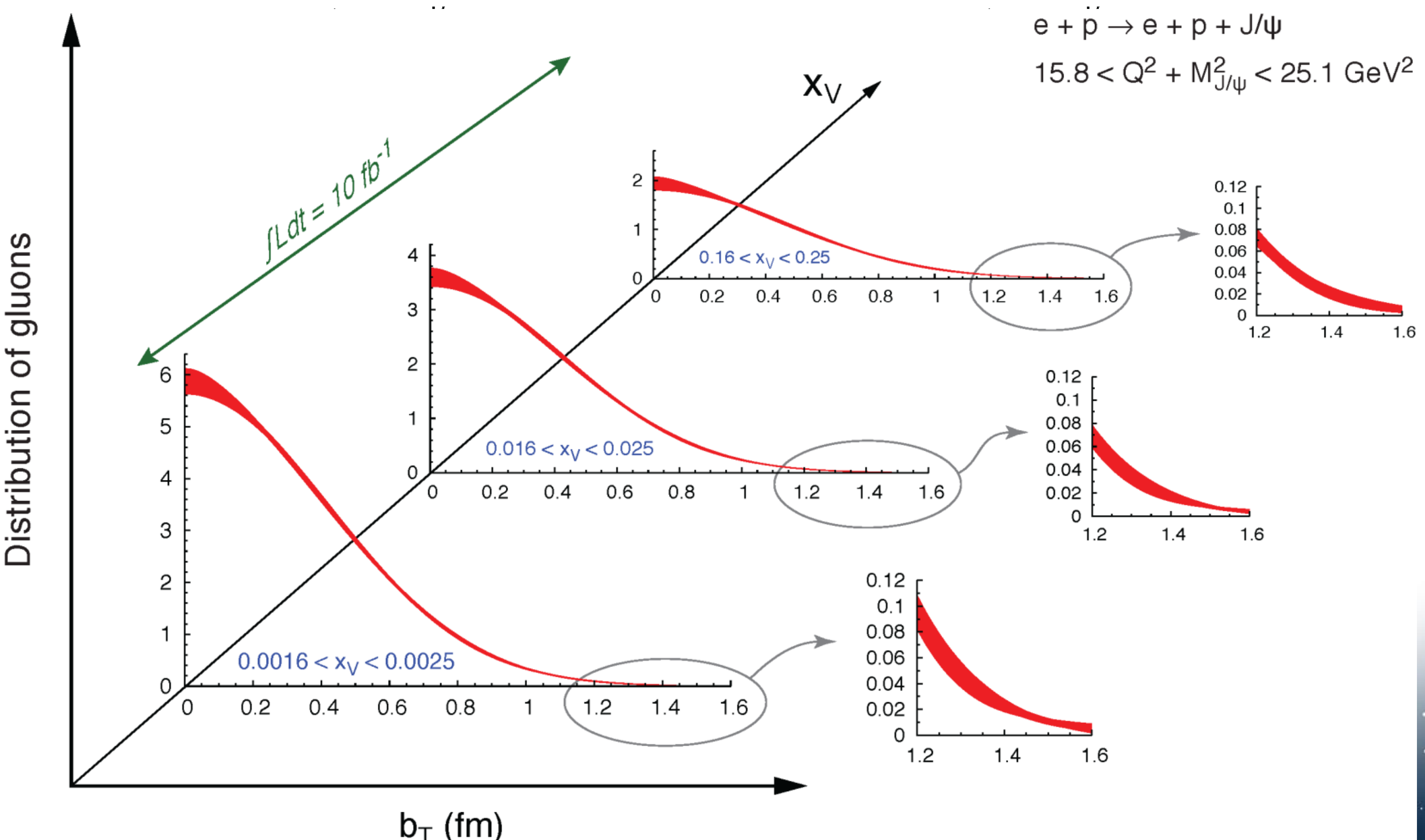
What about the gluon: J/ψ

To improve imaging on gluons add J/ψ observables



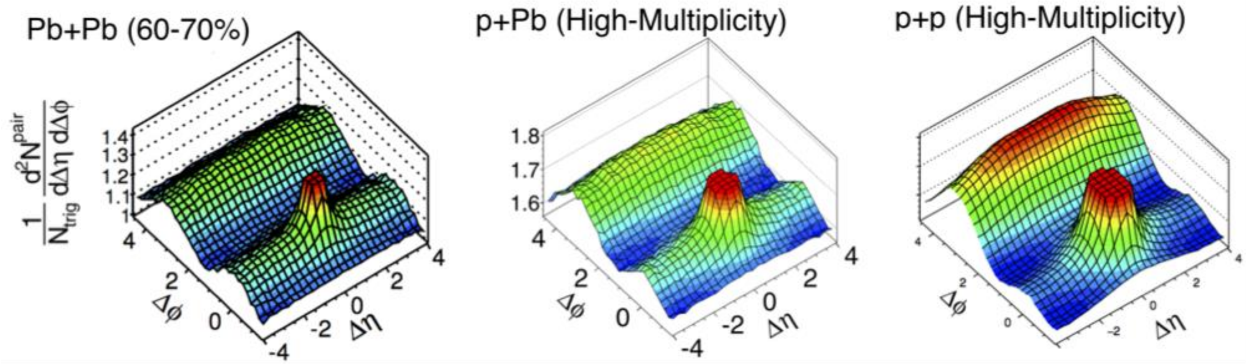
- cross section
- A_{UT}
- …..





Proton structure important for QGP in small systems

Collective phenomena seen in pA collisions, i.e. ATLAS 1409.792

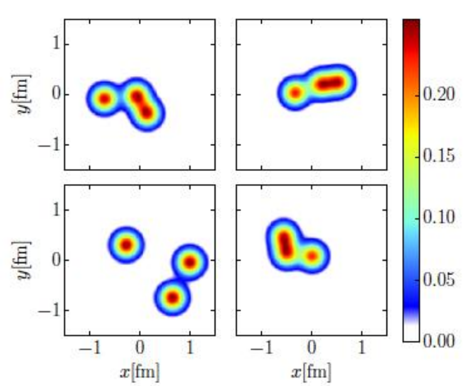


H. Mäntysaari & B. Schenke
arXiv:1607.01711

In a hydro-picture (used in AA) fluctuations in the proton are crucial to understand the seen pA@LHC behaviors

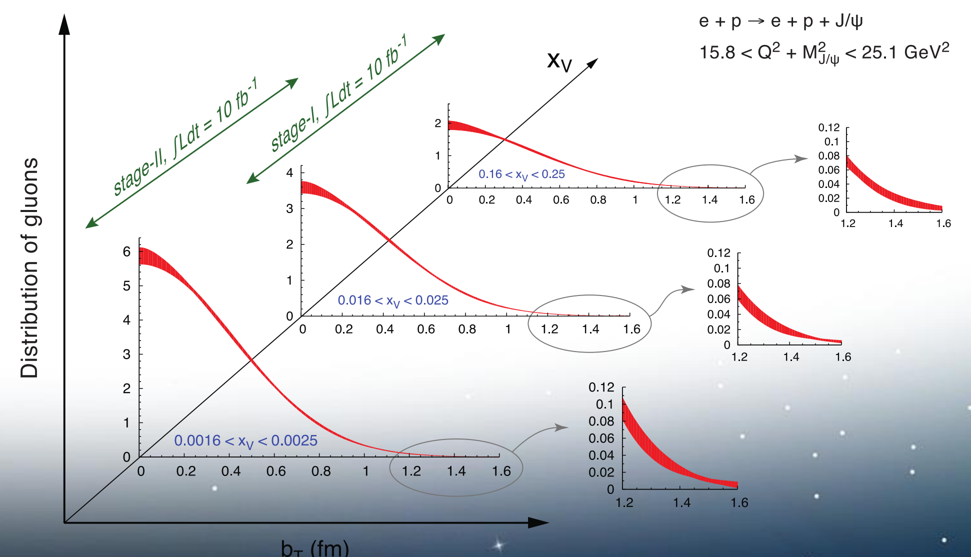
Only EIC can map out the spatial quark and gluon structure of the proton in x and Q^2

Examples of proton density profiles at $x \sim 10^{-3}$

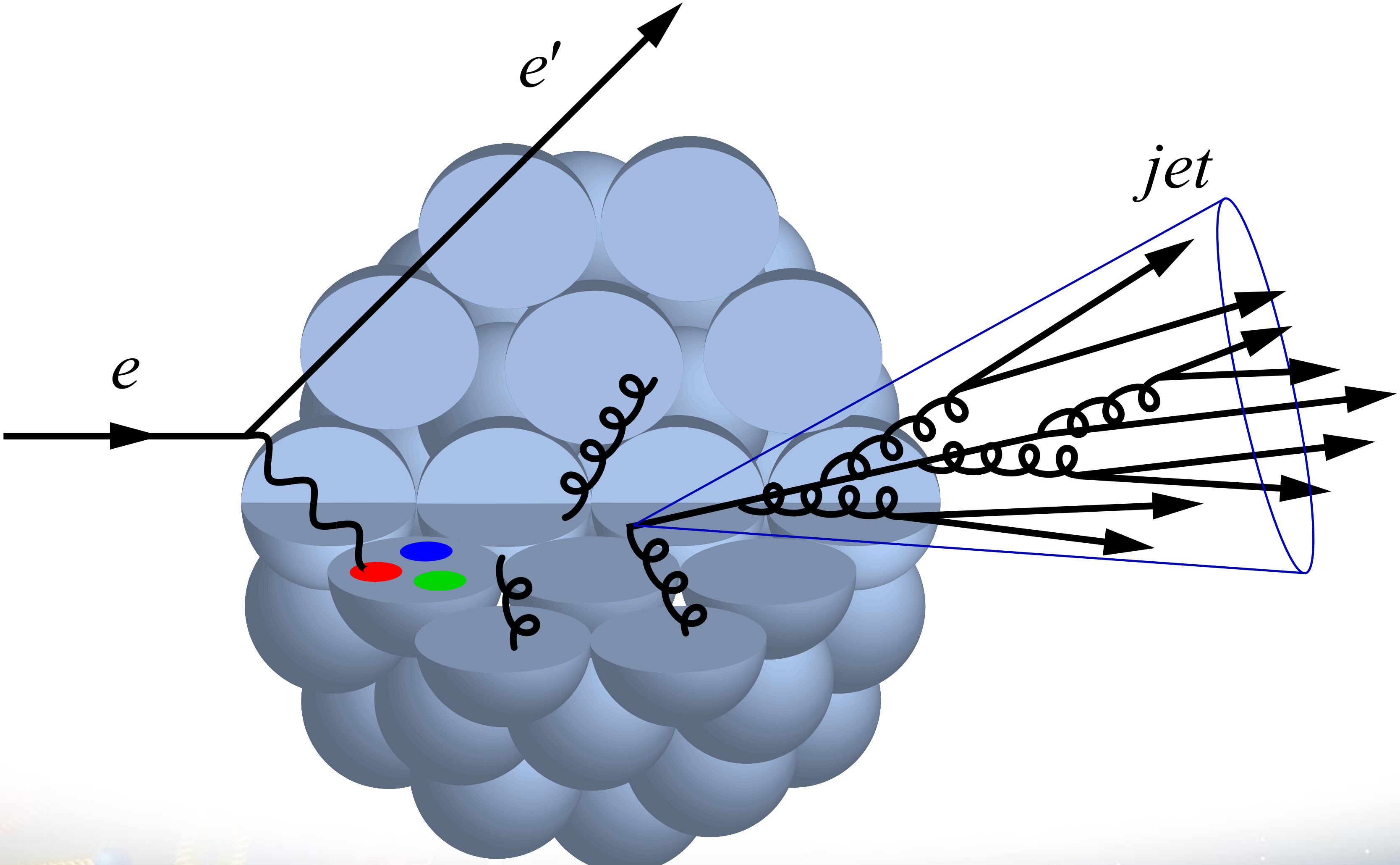


(a) $B_{qc} = 3.3\ \mathrm{GeV}^{-2}$, $B_q = 0.7\ \mathrm{GeV}^{-2}$

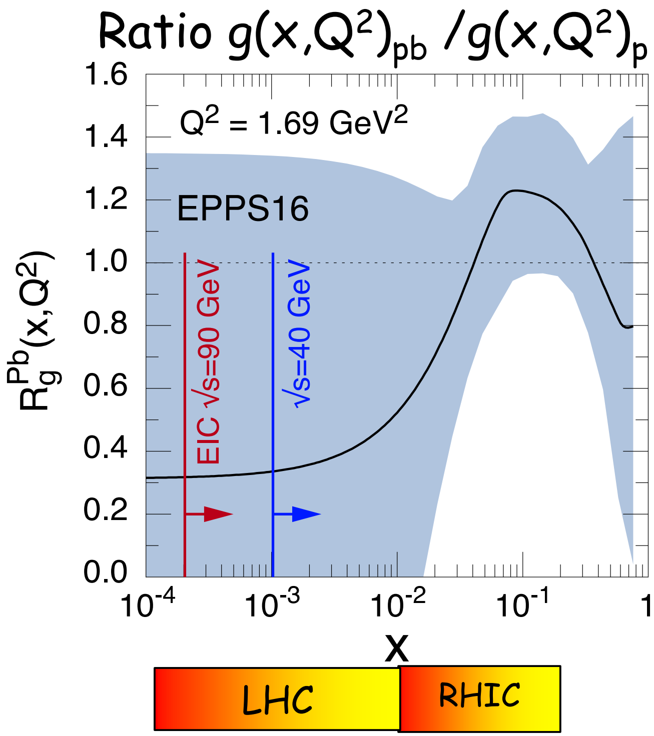
Study coherent and incoherent J/Ψ prod.



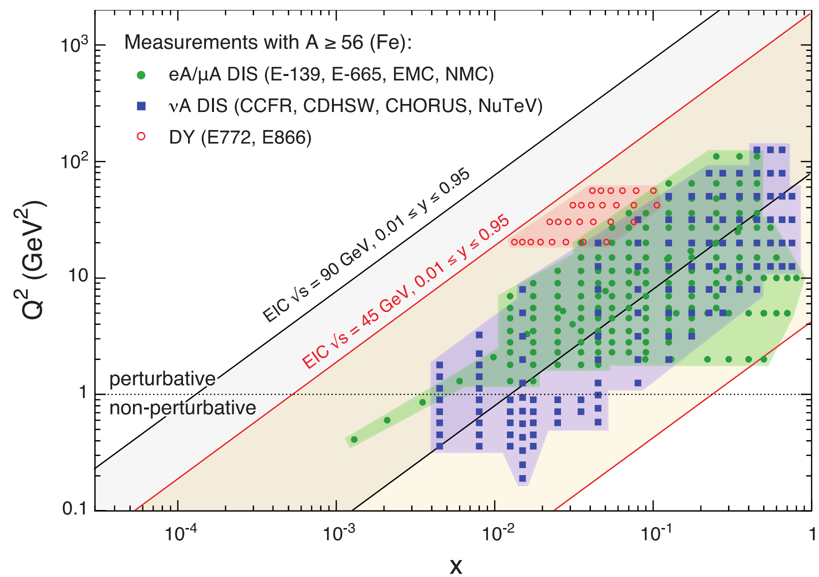
What about Nuclei?



nPDFs before and after EIC



DGLAP:
predicts Q^2 but not A-dependence and x-dependence
Saturation models:
predict A-dependence and x-dependence but not Q^2
→ Need: large Q^2 lever-arm for fixed x, A-scan



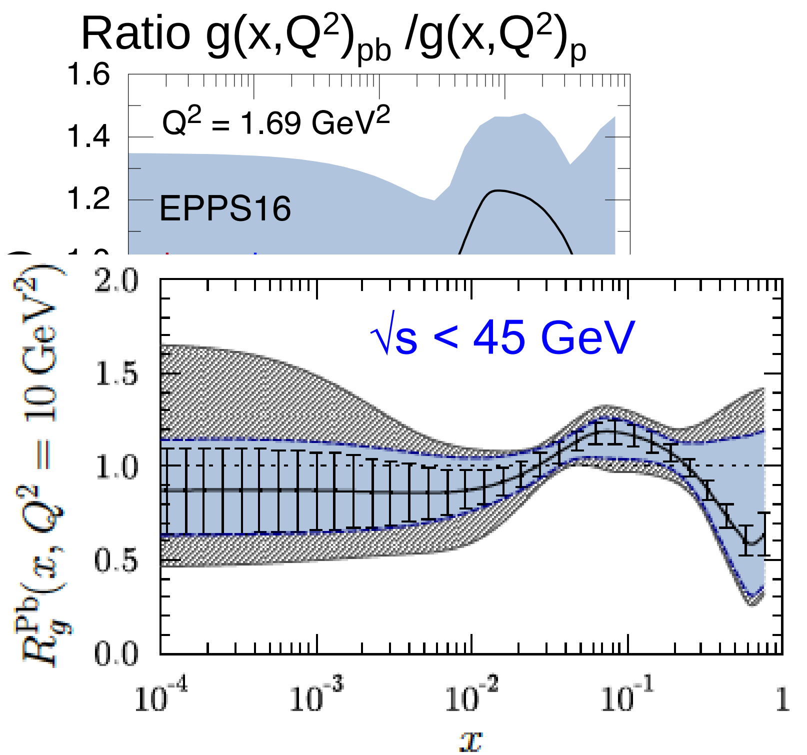
Measure different structure function in eA → constrain nPDF:

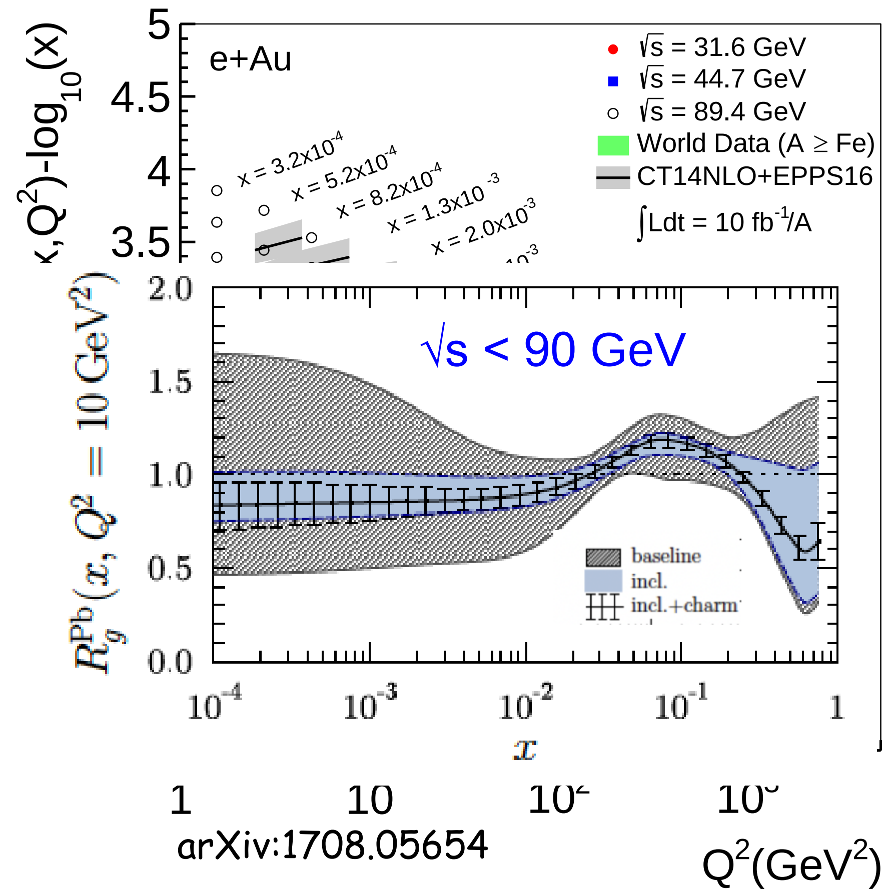
$$\frac{d^2\sigma^{ep\to eX}}{dx dQ^2} = \frac{4\pi\alpha^2_{e.m.}}{xQ^4}\left[\left(1-y+\frac{y^2}{2}\right)F_2(x,Q^2) - \frac{y^2}{2}F_L(x,Q^2)\right]$$

quark+anti-quark momentum distributions

gluon momentum distribution
or tag on charm → F_2^c

nPDFs before and after EIC





Measure different structure function in eA
→ constrain nPDF:

$$\frac{d^2\sigma^{ep\to eX}}{dxdQ^2} = \frac{4\pi\alpha_{e.m.}^2}{xQ^4}\left[\left(1 - y + \frac{y^2}{2}\right)F_2(x,Q^2) - \frac{y^2}{2}F_L(x,Q^2)\right]$$

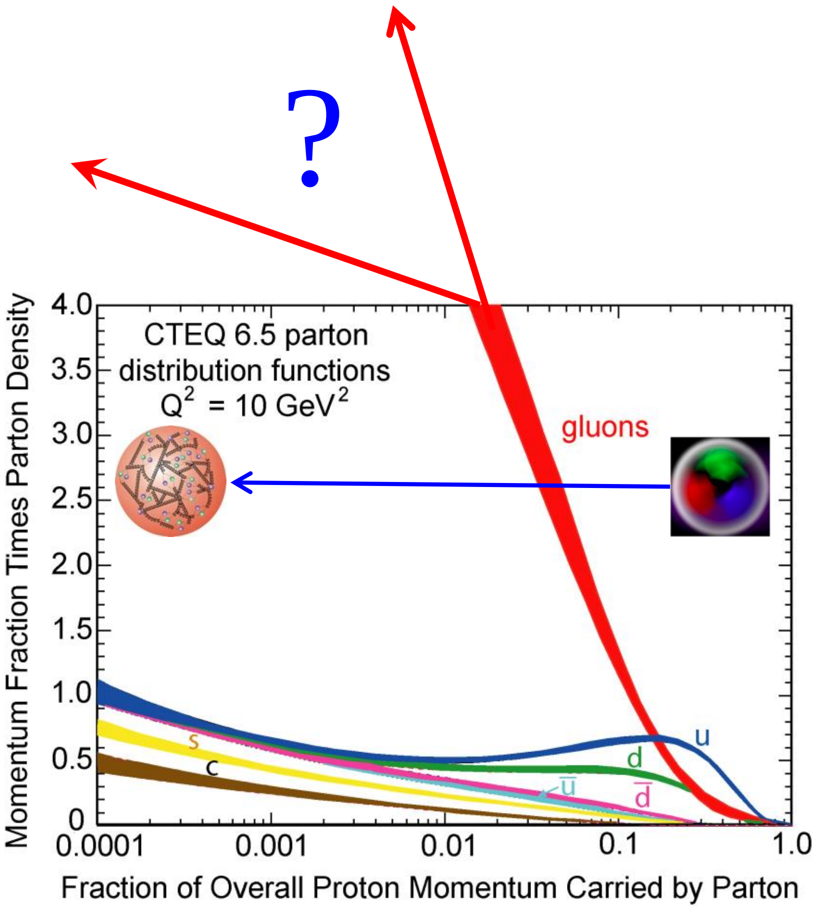
quark+anti-quark momentum distributions

gluon momentum distribution or tag on charm → F_2^C

Gluon distribution ~ $d\sigma(x,Q^2)/d\ln Q^2$

can EIC discover a new state of matter

Is the proton a runaway popcorn machine?



Does this rise get tamed ?

Important to understand the initial condition for heavy ion collisons

till today only ambiguous hints

EIC: Spatial Gluon Distribution from dσ/dt

1950-60: Measurement of charge (proton) distribution in nuclei

Diffractive vector meson production: e + Au → e' + Au' + J/ψ

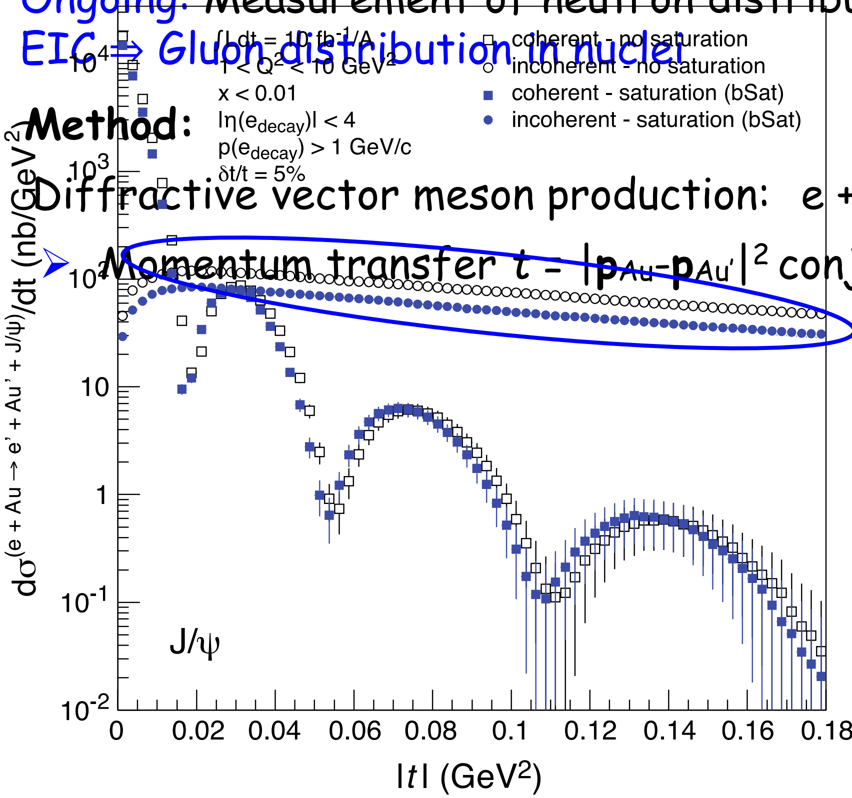
Ongoing: Measurement of neutron distribution in nuclei

EIC ⇒ Gluon distribution in nuclei

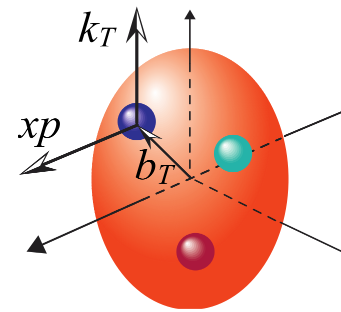
Method:

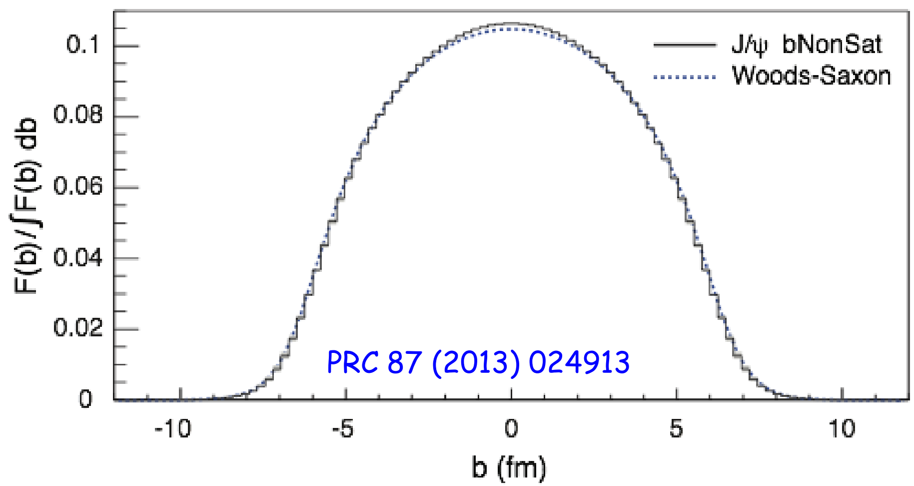
Diffractive vector meson production: e + Au → e' + Au' + J/ψ

➢ Momentum transfer $t = |p_{Au} - p_{Au'}|^2$ conjugate to b_T



Fourier Transform





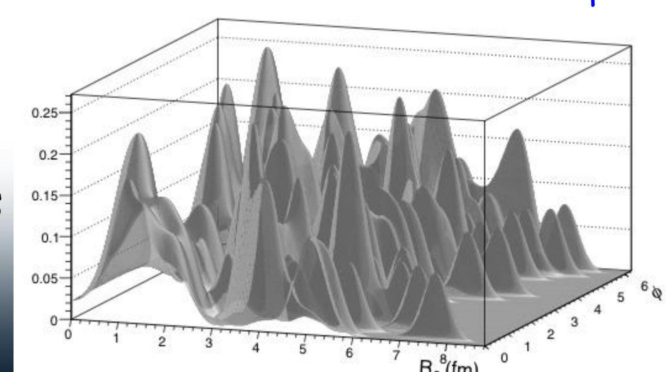
Hot topic:

- ➢ Lumpiness of source?
- ➢ Just Wood-Saxon+nucleon $g(b_T)$

❑ coherent part probes "shape of black disc"

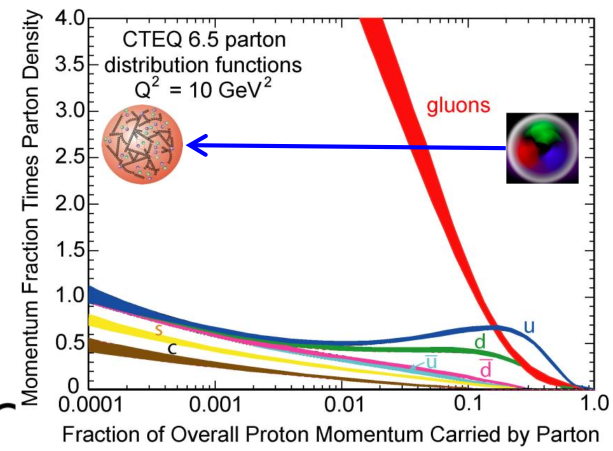
❑ incoherent part (large t) sensitive to "lumpiness of the source (= proton)
(fluctuations, hot spots, ...)

possible Source distribution with b_T^g = 2 GeV^{-2}



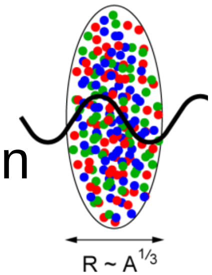
Studying non-linear effects

- Does the rise of $g(x,Q^2)$ get tamed ?
- Important to understand the initial condition for heavy ion collisions



Scattering of electrons off nuclei:

- Probes interact over distances $L \sim (2m_N x)^{-1}$
- For $L > 2 R_A \sim A^{1/3}$ probe cannot distinguish between nucleons in front or back of nucleon
- Probe interacts *coherently* with all nucleons



$$Q_s^2 \sim \frac{\alpha_s \, xG(x,Q_s^2)}{\pi R_A^2} \qquad \text{HERA}: \; xG \sim \frac{1}{x^{0.3}} \qquad \text{A dependence}: \; xG_A \sim A$$

Nuclear "Oomph" Factor
Pocket Formula:

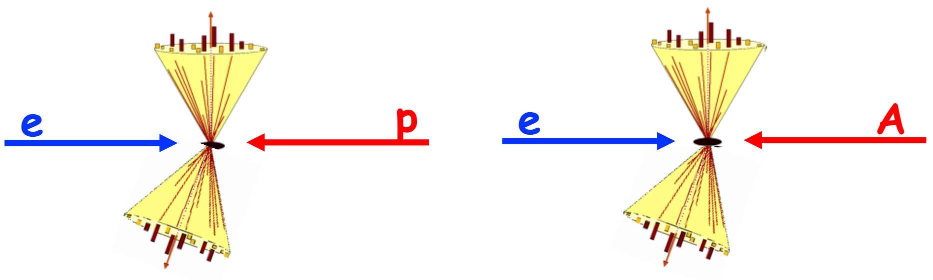
$$(Q_s^A)^2 \approx c Q_0^2 \left(\frac{A}{x}\right)^{1/3}$$

Enhancement of Q_S with A $\Rightarrow$ non-linear QCD regime reached at significantly lower energy in nuclei than in proton

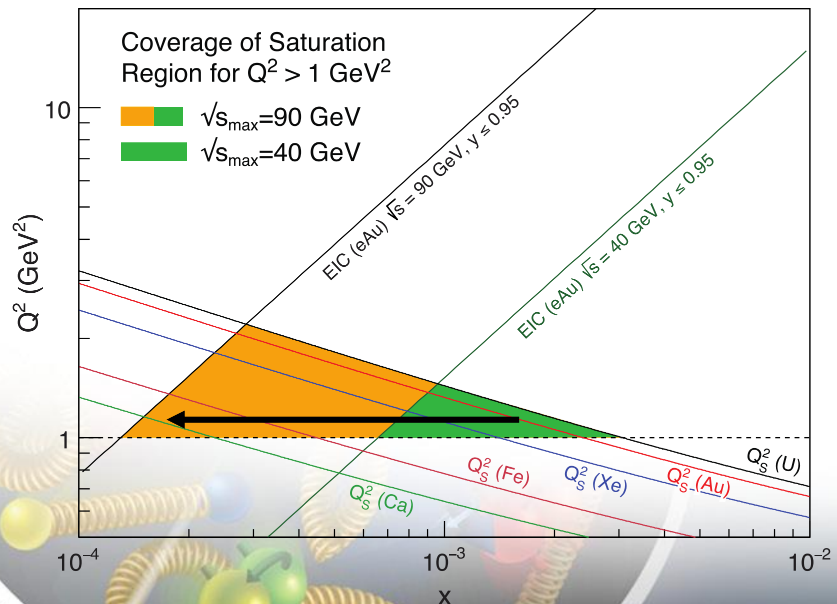
can EIC discover a new state of matter

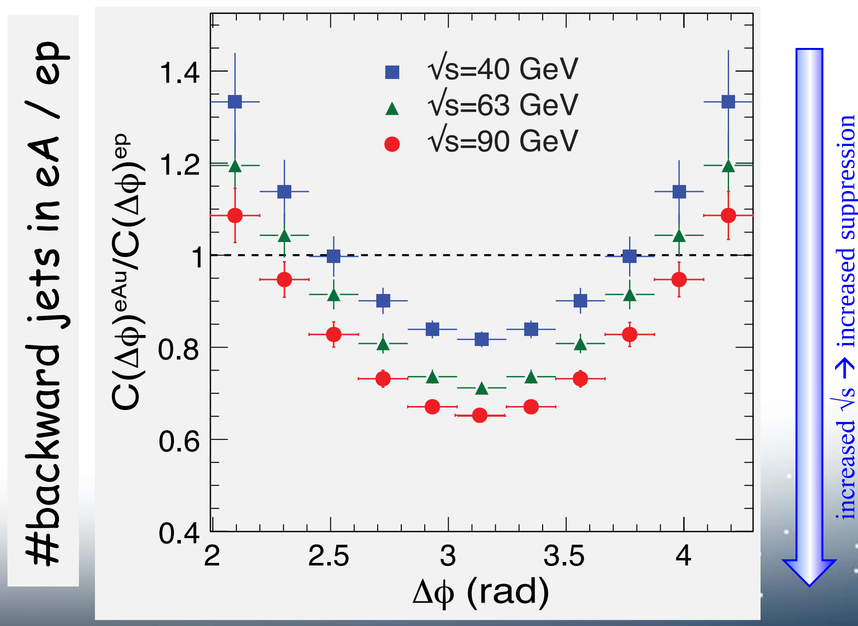
EIC provides an absolutely unique opportunity to have very high gluon densities
→ electron – lead collisions
combined with an unambiguous observable

counting experiment of Di-jets in ep and eA
Saturation:
Disappearance of backward jet in eA

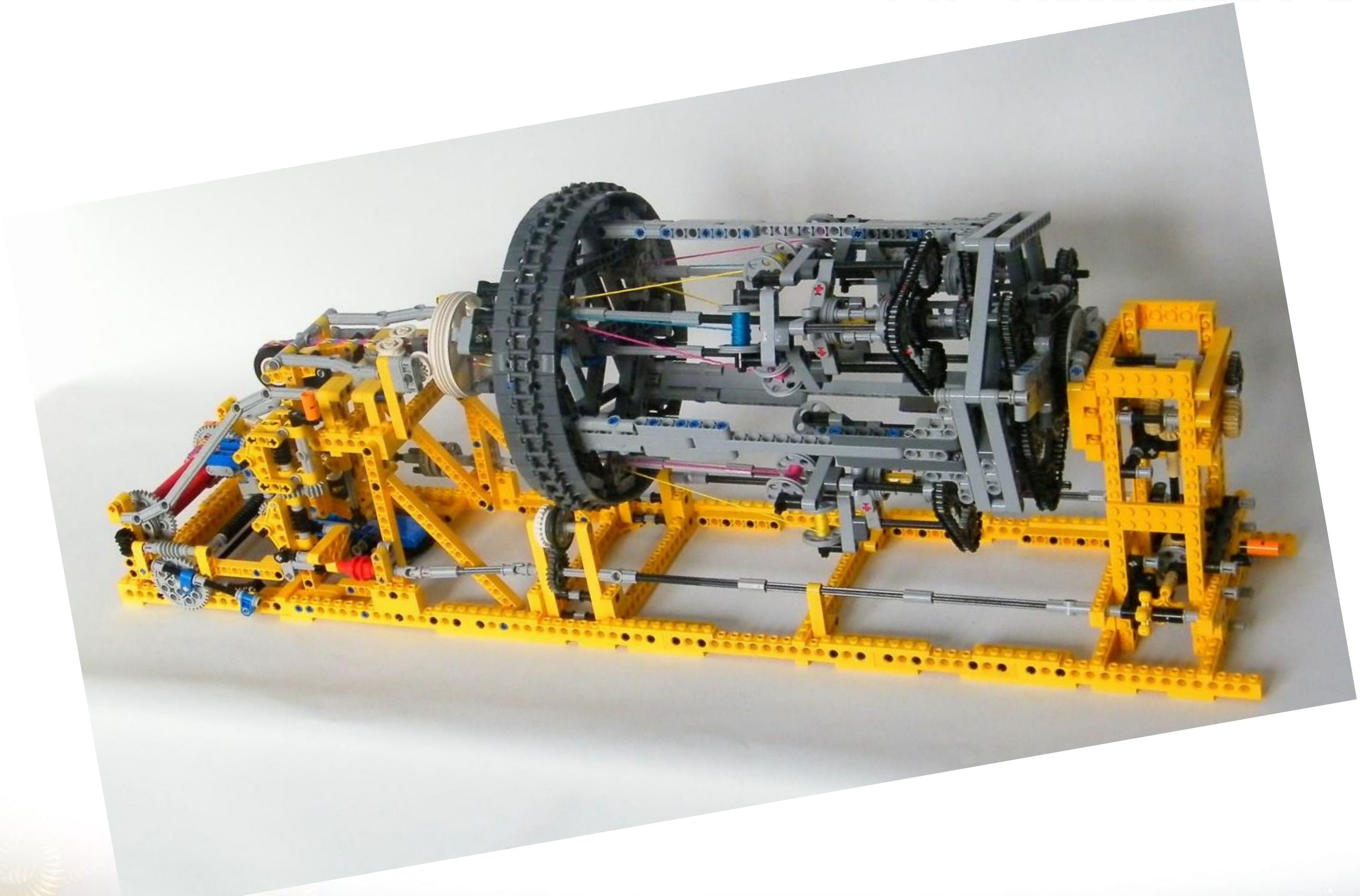


EIC will allow to unambiguously map the transition from a non-saturated to saturated regime





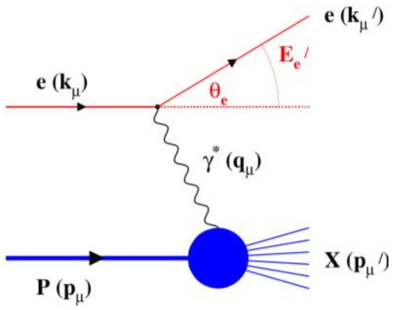
EIC Detector Concept

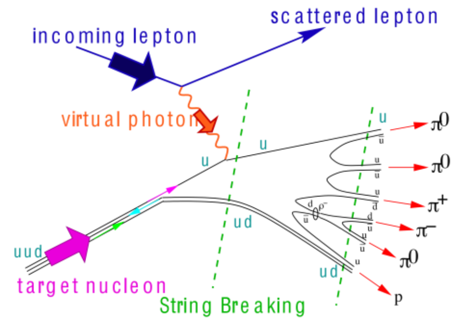


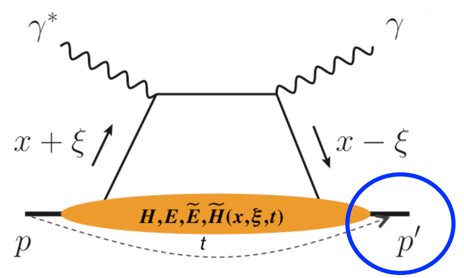
What is needed experimentally?

experimental measurements categories to address EIC physics:

Parton Distributions in nucleons and nuclei	Spin and Flavor structure of nucleons and nuclei	Tomography Transverse Momentum Dist.	QCD at Extreme Parton Densities - Saturation	Tomography Spatial Imaging







inclusive DIS

- measure scattered lepton
- multi-dimensional binning: x, Q^2
  → reach to lowest x, Q^2 impacts Interaction Region design

semi-inclusive DIS

- measure scattered lepton and hadrons in coincidence
- multi-dimensional binning: x, Q^2, z, p_T, Θ
  → particle identification over entire region is critical

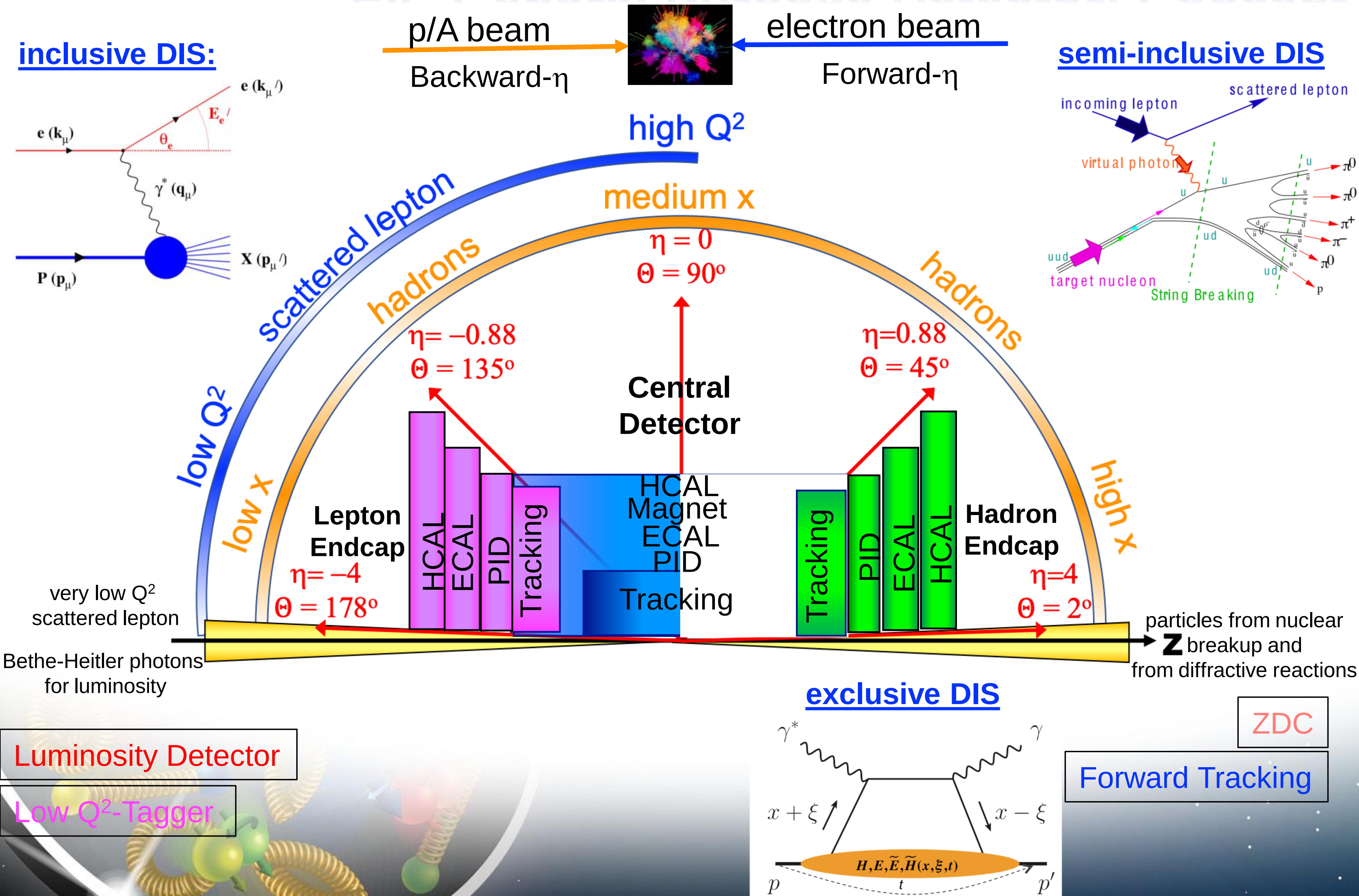
exclusive processes

- measure all particles in event
- multi-dimensional binning: x, Q^2, t, Θ
- proton p_t: 0.2 - 1.3 GeV
  → cannot be detected in main detector
  → strong impact on Interaction Region design

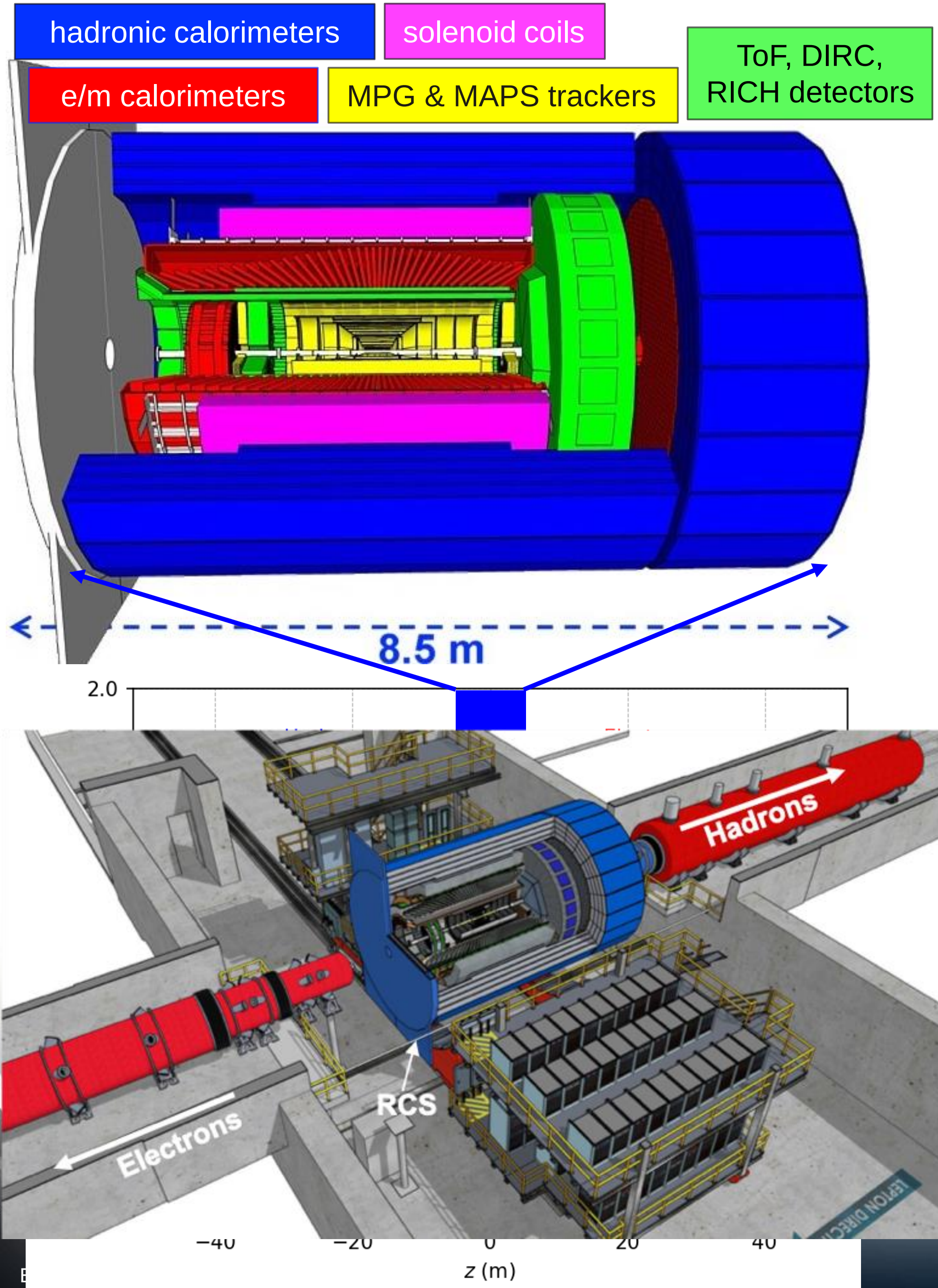
$\int$Ldt: 1 fb^{-1} | 10 fb^{-1} | 10 - 100 fb^{-1}

machine & detector requirements

EIC General Purpose Detector: Concept



Experimental Equipment



Overall detector requirements:

- Large rapidity (-4 < η < 4) coverage; and far beyond especially in far-forward detector regions
  - Large acceptance for diffraction, tagging, neutrons from nuclear breakup: critical for physics program Many ancillary detector along the beam lines: low-Q^2 tagger, Roman Pots, Zero-Degree Calorimeter, ….
- High precision low mass tracking
  - small (μ-vertex Silicon) and large radius (gaseous-based) tracking
- Electromagnetic and Hadronic Calorimetry
  - equal coverage of tracking and EM-calorimetry
- High performance PID to separate e, π, K, p on track level
  - good e/h separation critical for scattered electron identification
- Maximum scientific flexibility
  - Streaming DAQ → integrating AI/ML
- High control of systematics
  - luminosity monitor, electron & hadron Polarimetry
- Integration Integration Integration → critical
  - 50 cm between detector and first IR magnets

What is new/special for a EIC GPD

Vertex detector → Identify primary and secondary vertices,
Low material budget: 0.05% X/X_0 per layer;
High spatial resolution: 10 μm pitch CMOS Monolithic Active Pixel Sensor (MAPS)
→ synergy with Alice ITS3

Central tracker → Measure charged track momenta
MAPS – tracking layers in combination with micro pattern gas detectors

electron and hadron endcap tracker → Measure charged track momenta
MAPS – disks in combination with micro pattern gas detectors

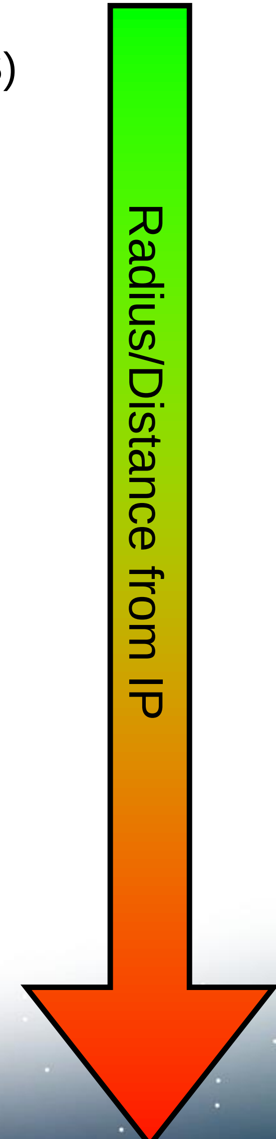
Particle Identification → pion, kaon, proton separation
RICH detectors & Time-of-Flight
high resolution timing detectors (, LAPPS, LGAD) 10 – 30 ps
novel photon sensors: MCP-PMT / LAPPD

Electromagnetic calorimeter → Measure photons (E, angle), identify electrons
Crystals (backward), W/SciFi Spacal (forward)
Barrel: Pb/SciFi+imaging part or Scintillating glass → cost effective

Hadron calorimeter → Measure charged hadrons, neutrons and K_L^0
challenge achieve ~50%/√E + 10% for low E hadrons (<E> ~ 20 GeV)
Fe/Sc sandwich with longitudinal segmentation

DAQ & Readout Electronics: trigger-less / streaming DAQ
Integrate AI into DAQ → cognizant Detector

+ Beam pipe and very forward and backward detectors



Take Away Message

Why EIC now?

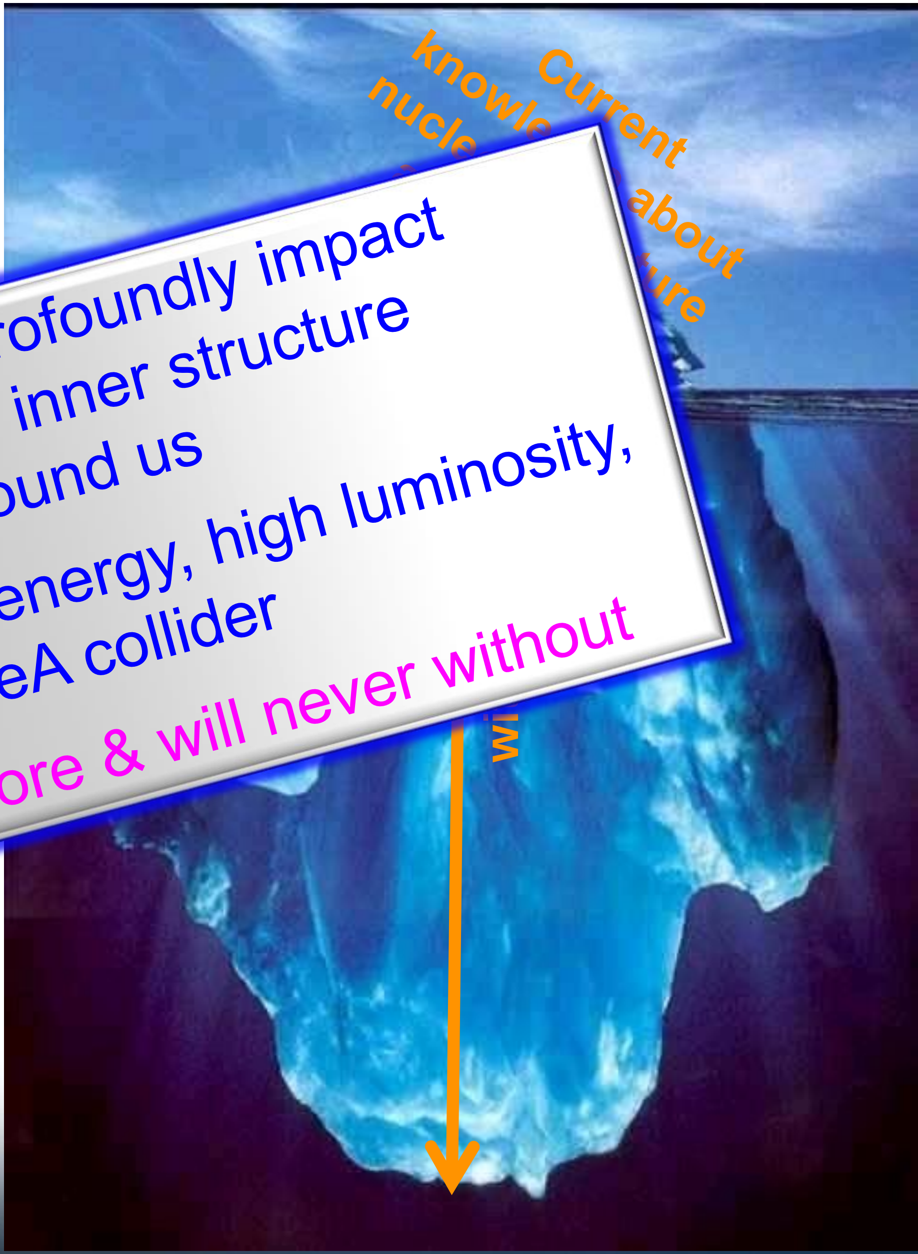
"all stars align":

- theory developments will allow to obtain the answers to the big questions discussed
- detector technologies allow f… detector with high … and parti…
- a… co…
  - …
  - …
  - a… …mass energies
  - h… …with highest A
  - de…ding acceptance requirements can be realized in IR design

EIC science program will profoundly impact our understanding of the inner structure of the world around us

uniquely tied to a future high energy, high luminosity, polarized ep / eA collider

never been measured before & will never without



Let's get to work and built the EIC

Please join us


BACK UP

The EIC: A Unique Collider

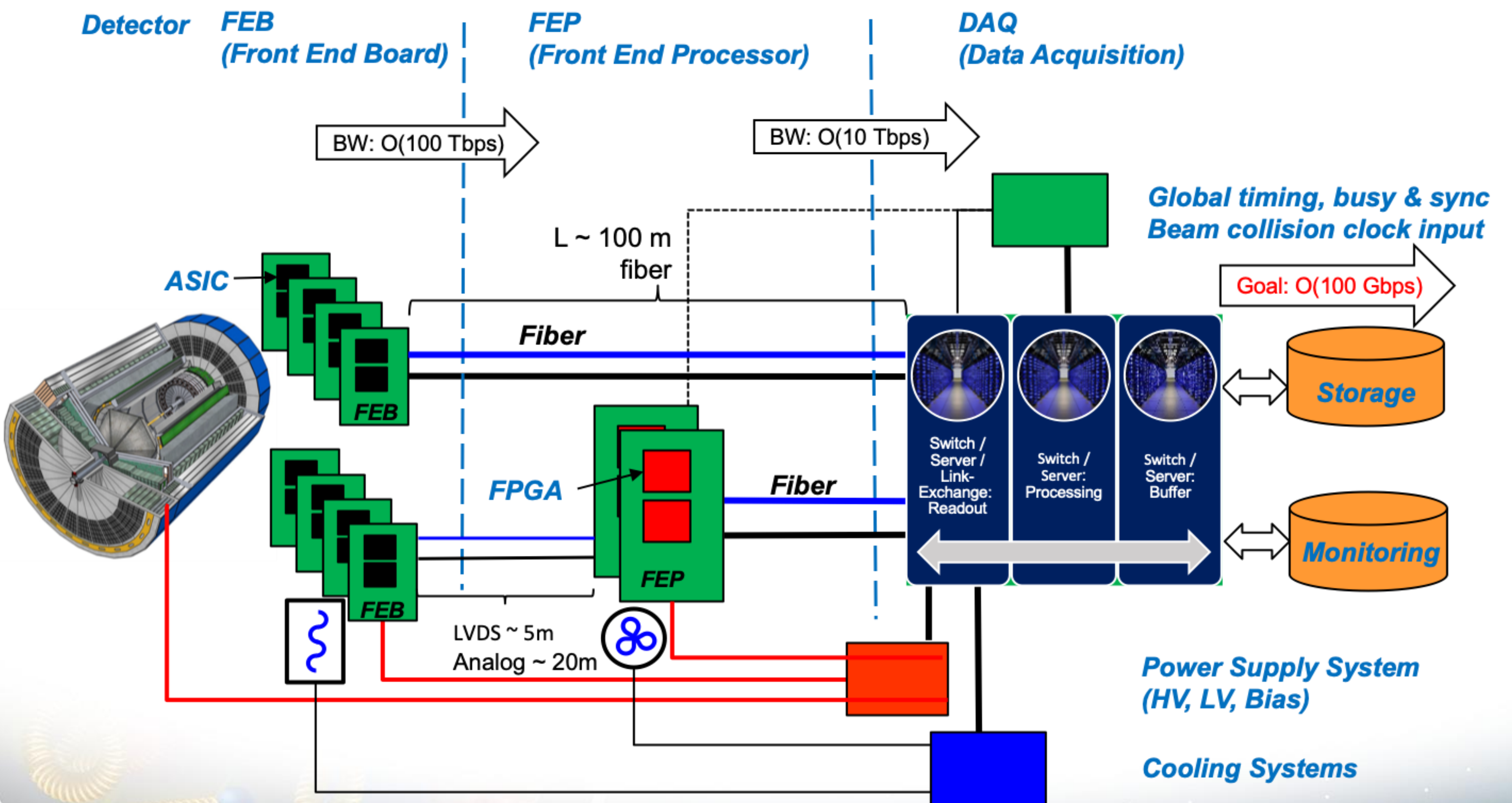
EIC	LHC
collide different beam species: ep & eA → consequences for beam backgrounds → hadron beam backgrounds, i.e. beam gas events → synchrotron radiation	collide the same beam species: pp, pA, AA → beam backgrounds → hadron beam backgrounds, i.e. beam gas events, high pile up
asymmetric beam energies → boosted kinematics → high activity at high $\lvert\eta\rvert$	symmetric beam energies → kinematics is not boosted → most activity at midrapidity
Small bunch spacing: >= 9ns	moderate bunch spacing: 25 ns
crossing angle: 25mrad	no significant crossing angle yet (150 μrad now)
wide range in center of mass energies → factor 6	LHC limited range in center of mass energies → factor 2
electron beam follows B-factory design parameters but polarized	
both beams are polarized → stat uncertainty: $\sim 1/(P_1 P_2 (\int L\, dt)^{1/2})$	no beam polarization → stat uncertainty: $\sim 1/(\int L\, dt)^{1/2}$

Differences impact detector design, acceptance and possible technologies

Streaming Readout Architecture

Possible at EIC as data rates manageable (500 kHz, O(100) Gbps)

Data
Configuration & Control
Power



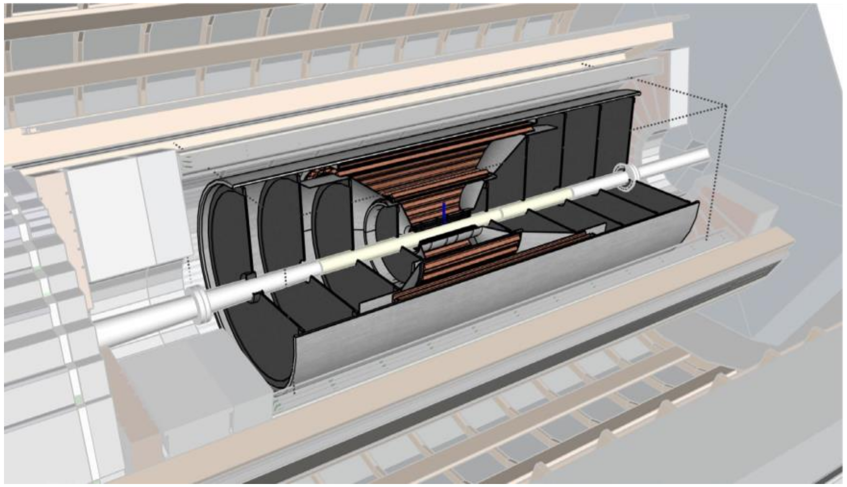
Integrate AI into DAQ → cognizant Detector

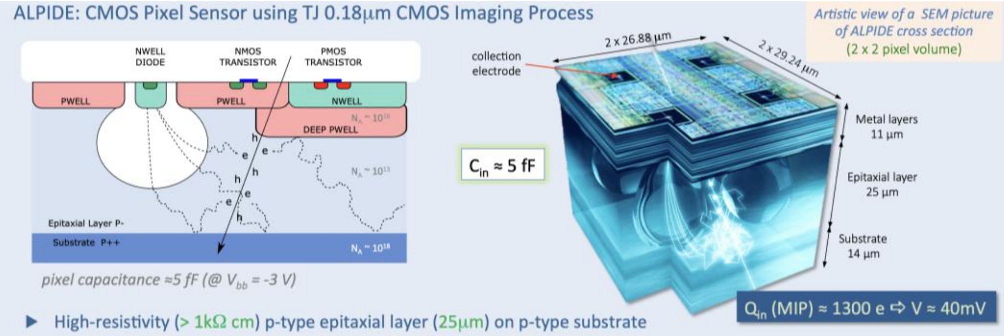
Sub-Detector Technologies

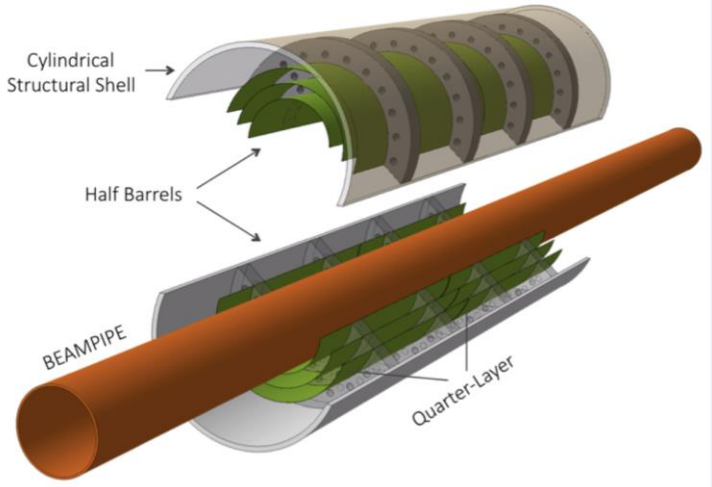
Tracking:

❑ Silicon – MAPS

- already ongoing R&D collaboration with CERN/ALICE ITS development (0.05% X/X_0 per layer & 10 μm pitch)
    - low mass EIC ITS-3 based forward disks new development



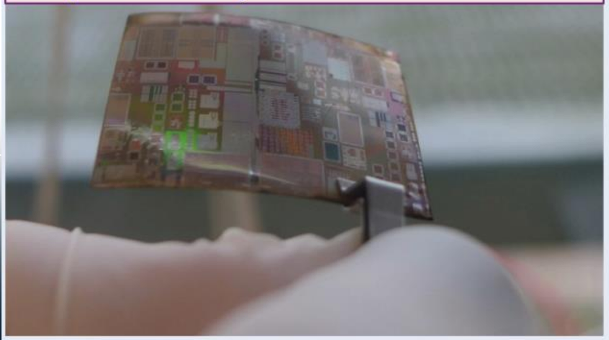




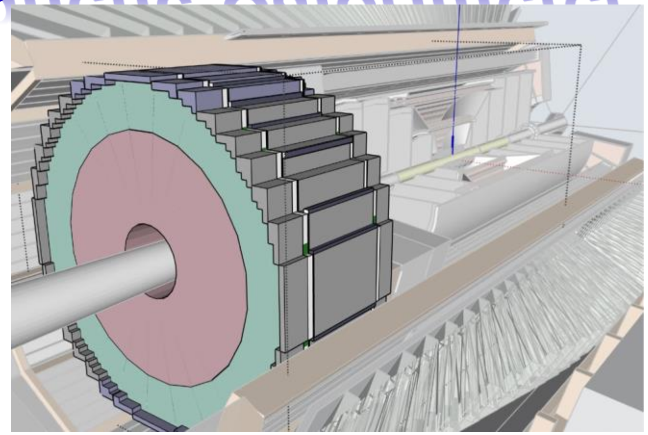
~900mm

Silicon Genesis: 20 micron thick wafer

Chipworks: 30µm-thick RF-SOI CMOS



Electro-Magnetic Calorimeter



Applications:

- Scattered electron kinematics measurement at large |η| in the e-endcap
- Photon detection and energy measurement
- e/h separation (via E/p & cluster topology)
- π^0/γ separation

Anticipated stochastic term in energy resolution & π suppression

η	[-4 .. -2]	[-2 .. -1]	[-1 .. 1]	[1 .. 4]
σ_E/E	~2%/√E	~(4-8)%/√E	~(12-14)%/√E	~(4*-12)%/√E
π suppression	Up to $1:10^{-4}$	Up to $1:10^{-3}$-10^{-2}	Up to $1:10^{-2}$	3σ e/π

Other considerations:

- Fast timing
- Compactness (small X_0 and R_M)
- Tower granularity
- Readout immune to the magnetic field

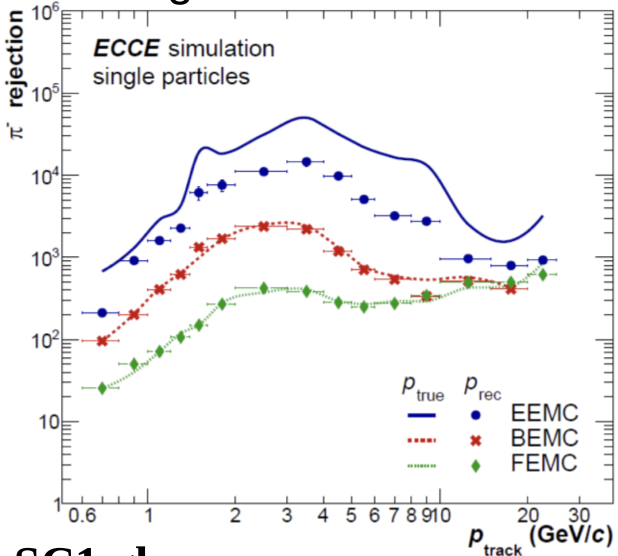
EIC Yellow Report

#	Type	sampling, mm	f_{samp}	X_0 mm	R_M mm	λ_I mm	cell mm^2	$\frac{X}{X_0}$	ΔZ cm	σ_E/E, % α	β
1	W/ScFi**	⌀0.47 ScFi W powd.	2%	7.0	19	200	25^2	20	30	2.5	13
2	$PbWO_4$***	-	-	8.9	19.6	203	20^2	22.5	35	1.0	2.5
3	Shashlyk***	0.75 W/Cu[a] 1.5 Sc	16%	12.4	26	250	25^2	20	40	1.6	8.3
4	W/ScFi** with PMT	0.59^2 ScFi W powd.|	12%	13	28	280	25^2	20	43	1.7	7.1
5	Shashlyk***	0.8 Pb 1.55 Sc	20%	16.4	35	520	40^2	20	48	1.5	6
6	TF1 Pb glass***	-	-	28	37	380	40^2	20	71	1.0	5-6
7	Sc. glass*[b]	-	-	26	35	400	40^2	20	67	1.0	3-4

Barrel ECal ala ECCE

Homogeneous, projective calorimeter based on SciGlass, cost-effective alternative to crystals

→ Design follows PANDA



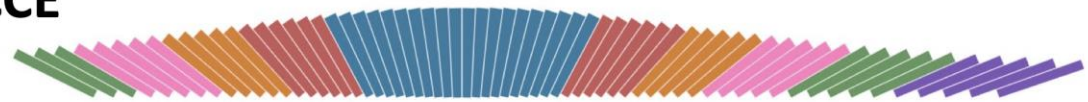
SC1 glass:

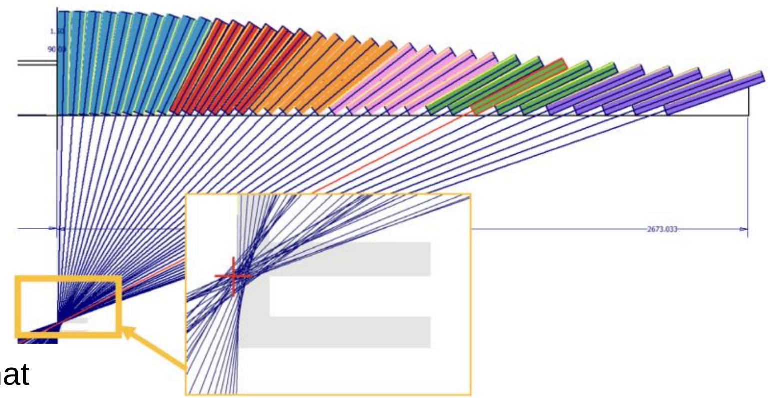
Feb 2020: 2cm x 2cm x 20cm (7 X0)

Dec 2020: 2cm x 2cm x 40cm (10-20 X0)

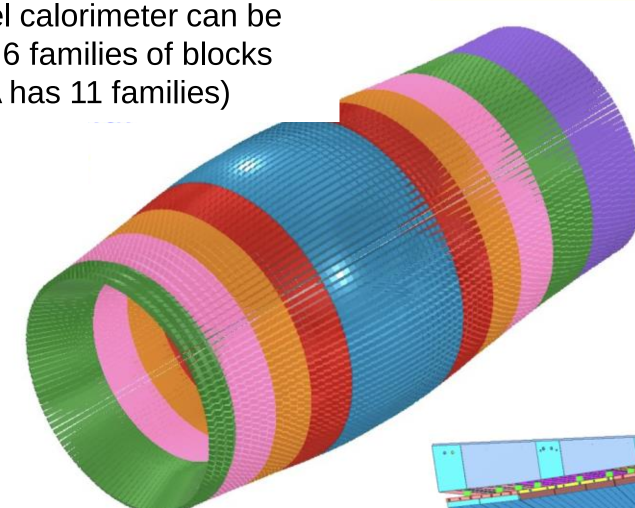
ECCE

Based on realistic CAD design (CUA)

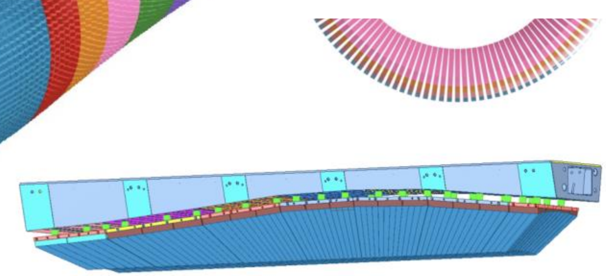




The geometry is optimized that ECCE barrel calorimeter can be made from 6 families of blocks (PANDA has 11 families)



With these families any gap is already reduced both angular and radially between glass blocks to <5mm

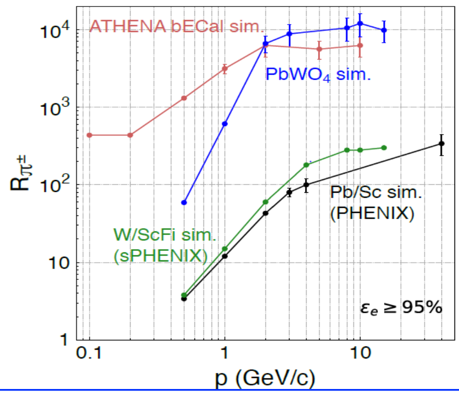


Barrel – ECal ala ATHENA

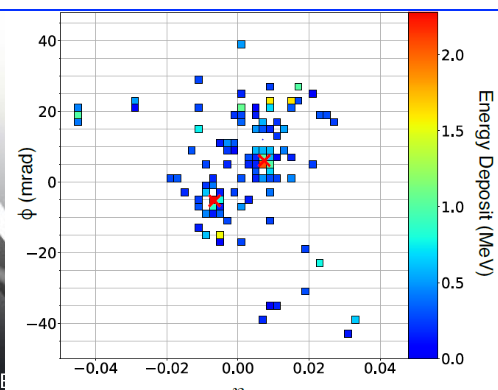
Hybrid concept:

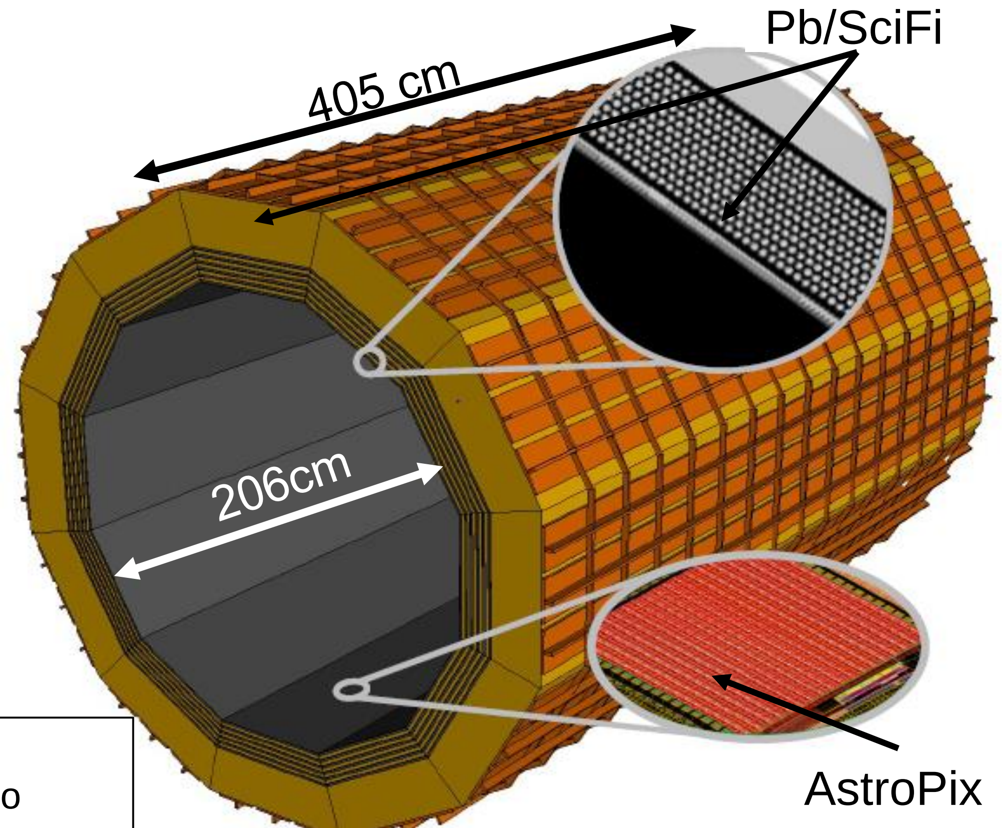
- 6 imaging layer: AstroPix and Pb/SciFi
    - AstroPix, monolithic Si sensor, dev
    - Pb/SciFi following KLOE, GlueX
- Reconstruct scattered and secondary electrons
- Separate e/π
- Identify and reconstruct g (also radiated from e)
- Identify π^0 also at high momenta

Separate e/π at low p



γ's from 15 GeV/c π^0 decay





also >1 λ_I contributing to bHCal

expected performance

Energy Resolution	$5.5\%/\sqrt{E} \oplus 1\%^a$
e/π separation	$>$ 99.8% pion rejection with 95% electron efficiency at $p \geq 0.1$ GeV/c^b.
E^{γ}_{min}	$<$ 100 MeV^c
Spatial Resolution	Cluster position resolution for 5 GeV photons at normal incident angle is below $\sigma = 2$ mm (at the surface of the stave $r = 103$ cm) or 0.12°. For comparison, the minimal opening angle of photons from $\pi^0 \rightarrow \gamma\gamma$ at 15 GeV is $\sim 1.05°$ (about 19 mm – 37 pixels – of separation at $r = 103$ cm).

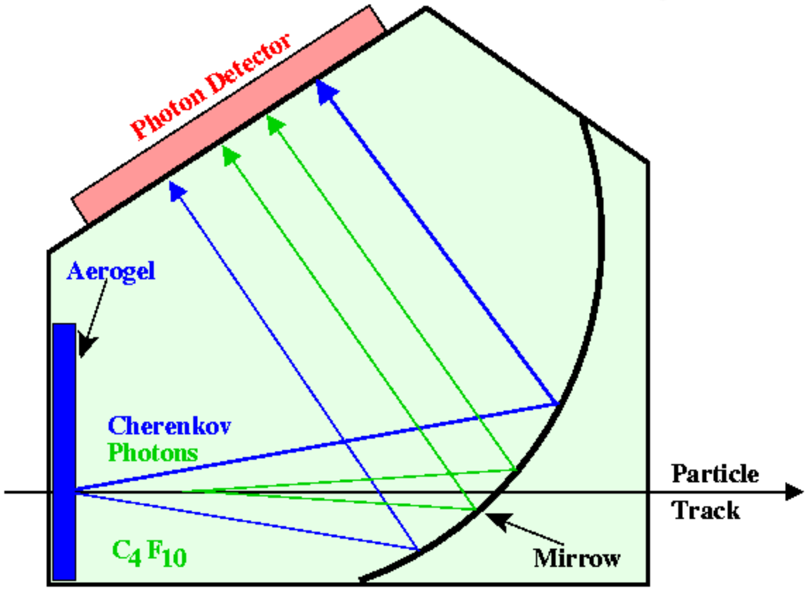
EIC PID
needs
are more demanding
then your
normal
collider detector

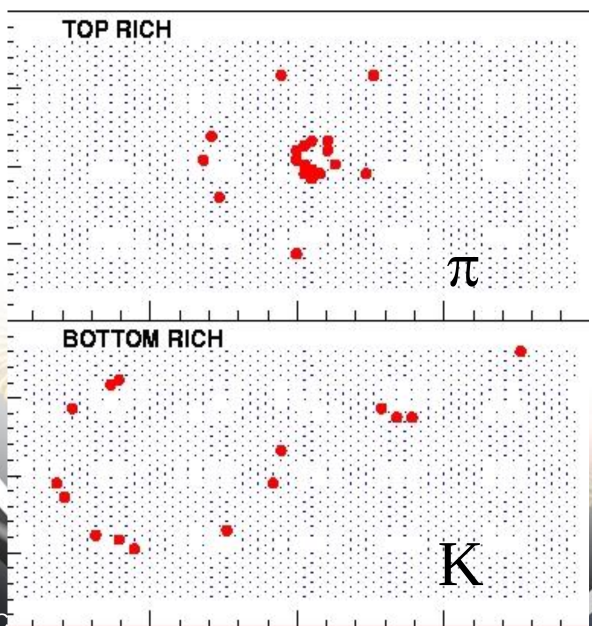
EIC
needs absolute
particle numbers at
high purity and low
contamination

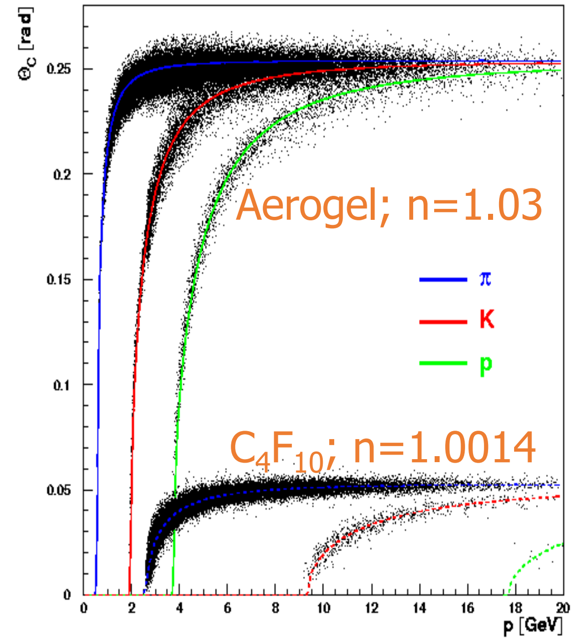
Cerenkov Based Detectors

hadron separation

Dual radiator RICH for π, K, p



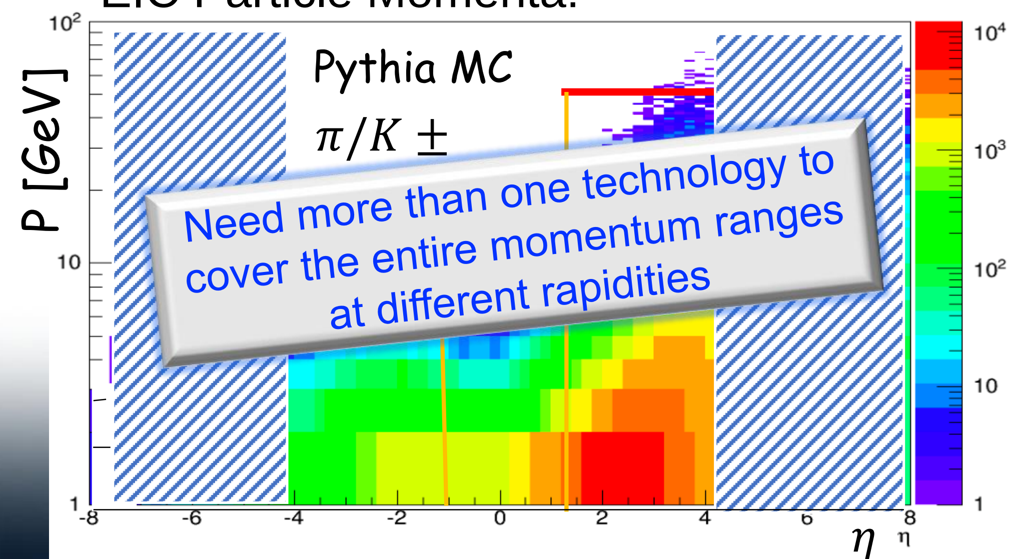




$$\cos\Theta_c = \frac{1}{\beta n}$$

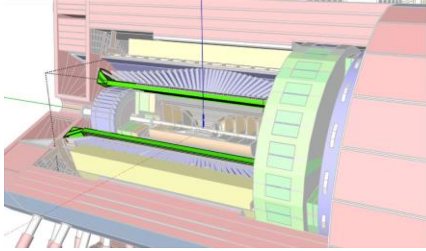
$$p = \frac{m\beta c}{\sqrt{1-\beta^2}}$$

EIC Particle Momenta:

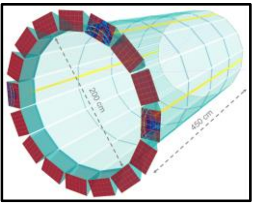


Need more than one technology to cover the entire momentum ranges at different rapidities

Hadron PID

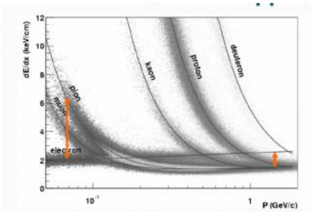


Barrel

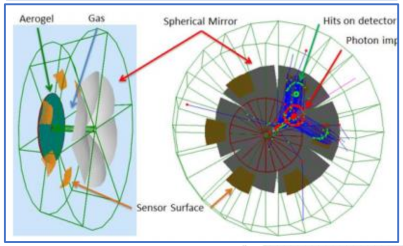


REFERENCE
hpDIRC (High Performance DIRC)
- Quartz bar radiator, light detection with MCP-PMTs
- Fully focused
- p/K 3s sep. at 6 GeV/c
- Reuse of BABAR DIRC as alternative
- Integration into a 4π detector can be challenging

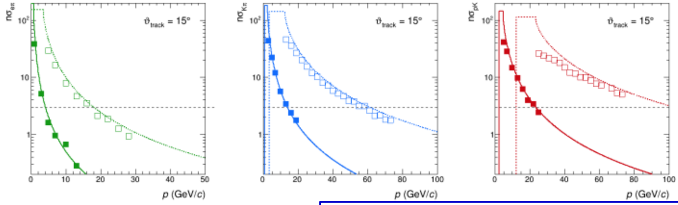
dE/dx from gaseous tracker, i.e. TPC complementary
STAR: ~ similar resolution expected



Forward Endcap

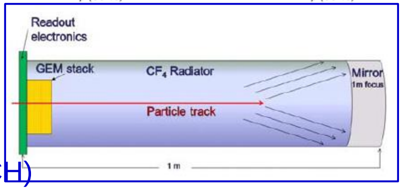


REFERENCE
dRICH (dual RICH)
- Aerogel and C-F gas radiators
- Full momentum range
- Sensor: Si PMs(TBC)
- p/K 3σ sep. at 50 GeV/c



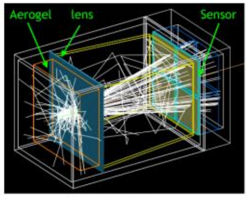
windowless RICH
- Gaseous sensors (MPGDs)
- CF_4 as radiator and sensor gas

Low p complements required:
- TOF ~ 2.5m lever arm / Aerogel (mRICH)



HP-RICH (high pressure RICH)
- Eco-friendly alternative for dRICH/windowless RICH
- Ar @ 3. 5 bar ↔ C_4F_{10} @ 1 bar
- Ar @ 2 bar ↔ CF_4 @ 1 bar

Backward Endcap



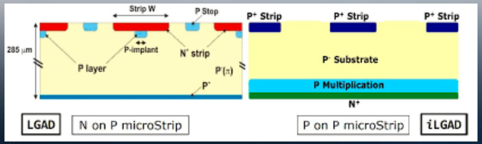
Geant4 Simulation
With realistic material optical properties

REFERENCE
mRICH (Modular RICH)
- Aerogel Cherenkov Det.
- Focused by Fresnel lens
- e, pi, K, p
- Sensor: SiPMs/ LAPPDs
- Adaptable to includeTOF
- π/K 3σ sep. at 10 GeV/c

Everywhere

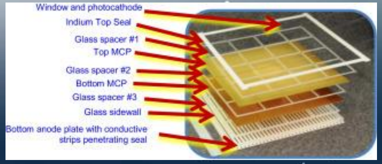
TOF with short lever arm

LGAD (Low Gain Avalanche Detector)
- Silicon Avalanche
- 20-35 psec
- Accurate space point for tracking
- Relevant also to central barrel
- R&D and PED by International consortium HEP & NP



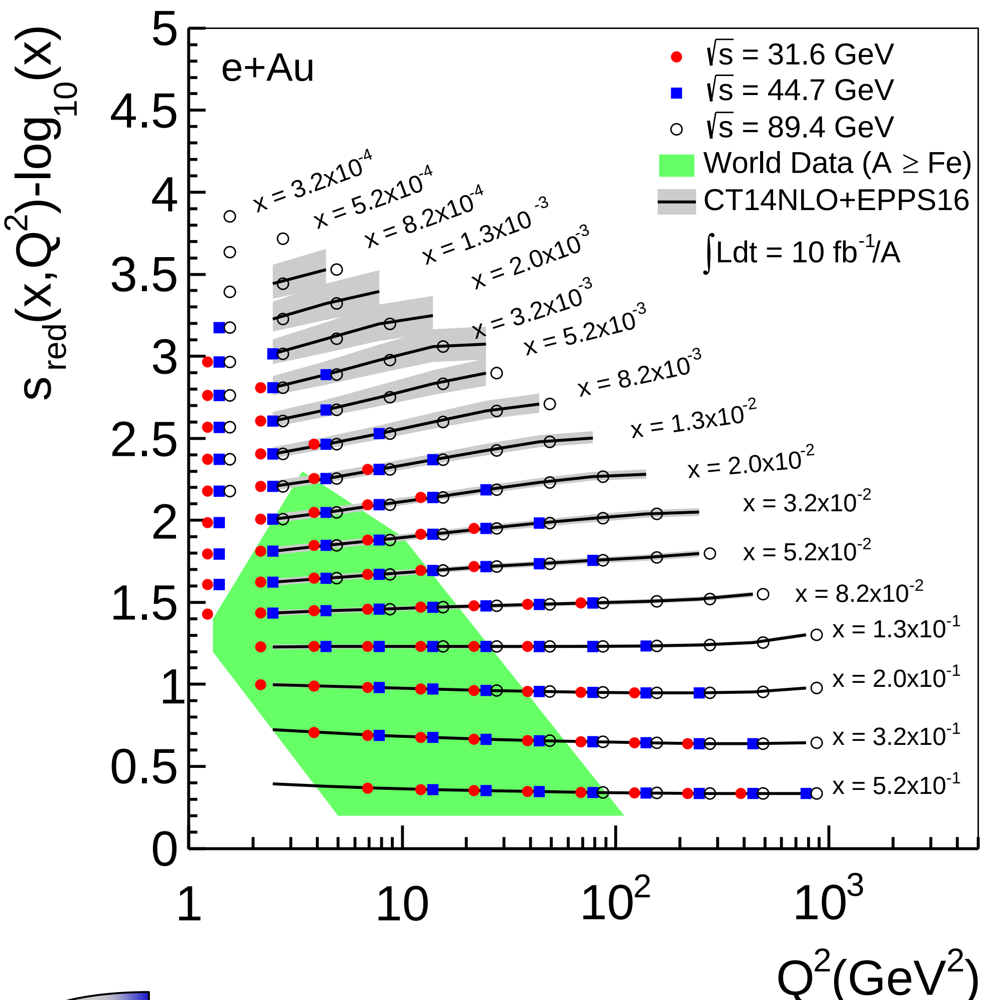
LAPPD (Large Area psec Photon Detector)
- MCP, Cherenkov in window
- 5-10 psec

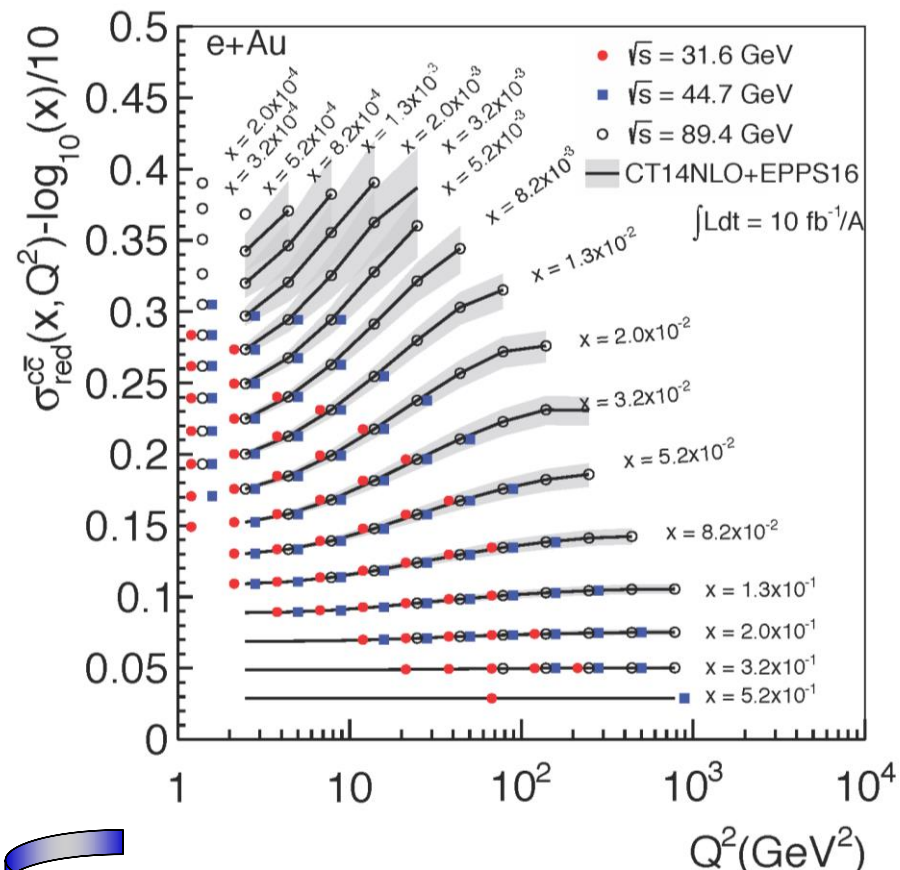
→ supported by DOE SBIR program



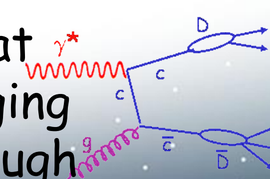
Inclusive Cross-Sections in eA

arXiv:1708.05654





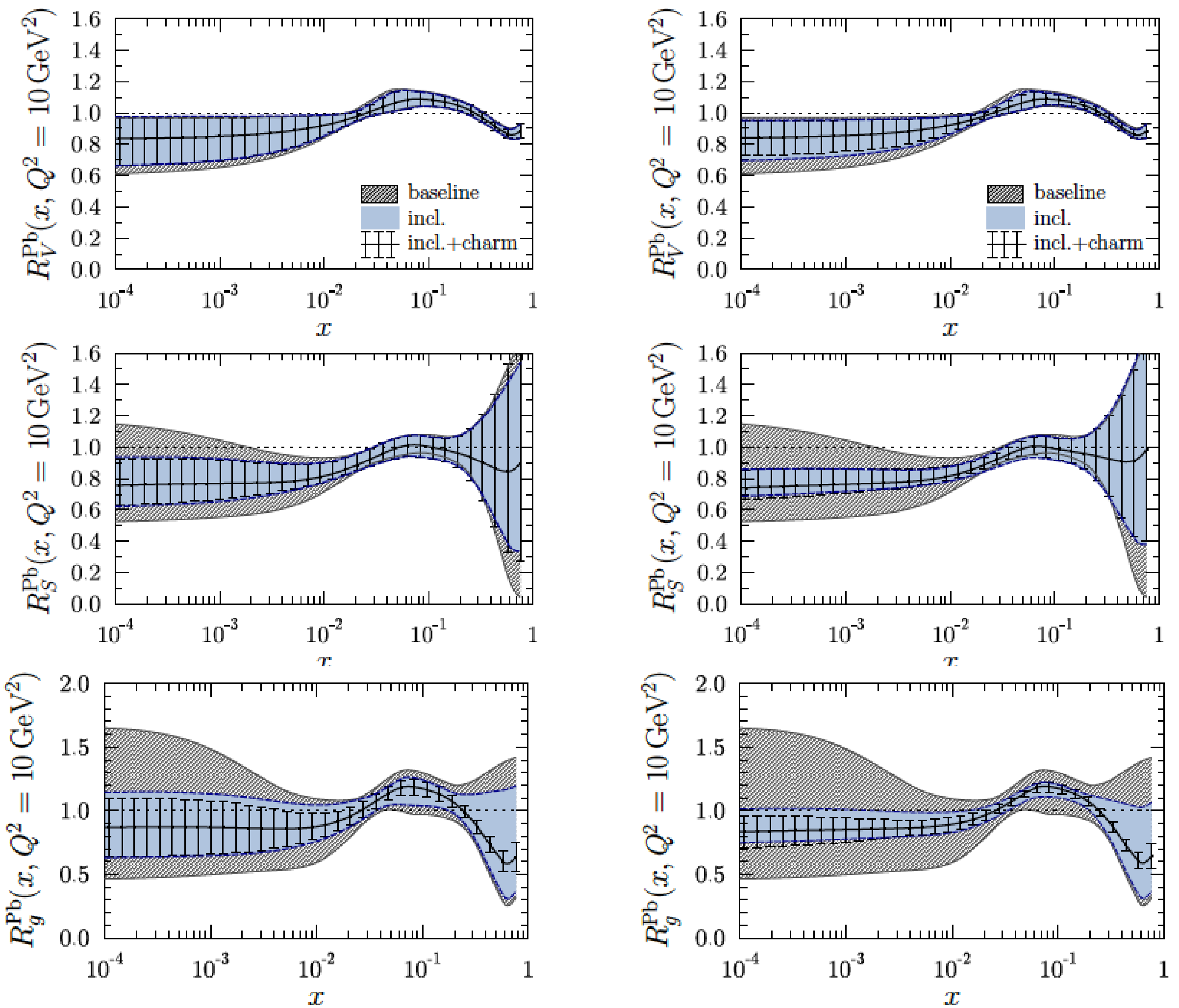
Direct Access to gluons at medium to high x by tagging photon-gluon fusion through charm events



Gluon distribution ~ $d\sigma(x,Q^2)/d\ln Q^2$

EIC: Impact on the Knowledge of 1D Nuclear PDFs

$\sqrt{s}$ < 45 GeV $\sqrt{s}$ < 90 GeV



Ratio of PDF of Pb over Proton

- Without EIC, large uncertainties
  → With EIC significantly reduced uncertainties
- Complementary to RHIC and LHC pA data. Provides information on initial state for heavy ion collisions.
- Does the nucleus behave like a proton at low-x?
  → relevant to very high-energy cosmic ray studies
  → critical input to AA
- arXiv:1708.05654