WHAT POINTS DO WE WANT TO MAKE

- ❑ Why do we need large $\sqrt{s}$
- ❑ Why doe we need high luminosity
- → show visually which physics is lost if one of the criteria is not fulfilled
- → we need a more intuitive plot showing the dependence of the physics on $\sqrt{s}$ and luminosity

Better “visualization” of saturation is needed

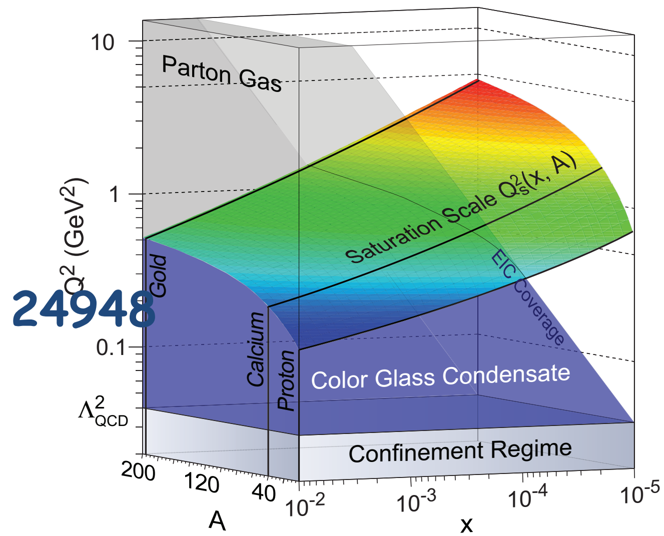
SATURATION

Requirements:

Need plots/animation that (i) visual saturation and (ii) motive high √s, i.e. low x reach

Critique focus on the iconic 3D plot:

People don't like it, say it is too complicated



SATURATION

Visualizing saturation

Depict how hadrons/nuclei grow and get denser with decreasing x and visualize effects of saturation on this trend. Visualize recombination as the damping effect.
Example: GPD like plot of proton or nucleus radius as function of x with and without saturation from x=1 to ~10^{-4}. Possibly better work out the connection of energy and “seeing” gluons (time dilation effects).
Show increase in size and density with increasing energy and how saturation tames explosive grow.

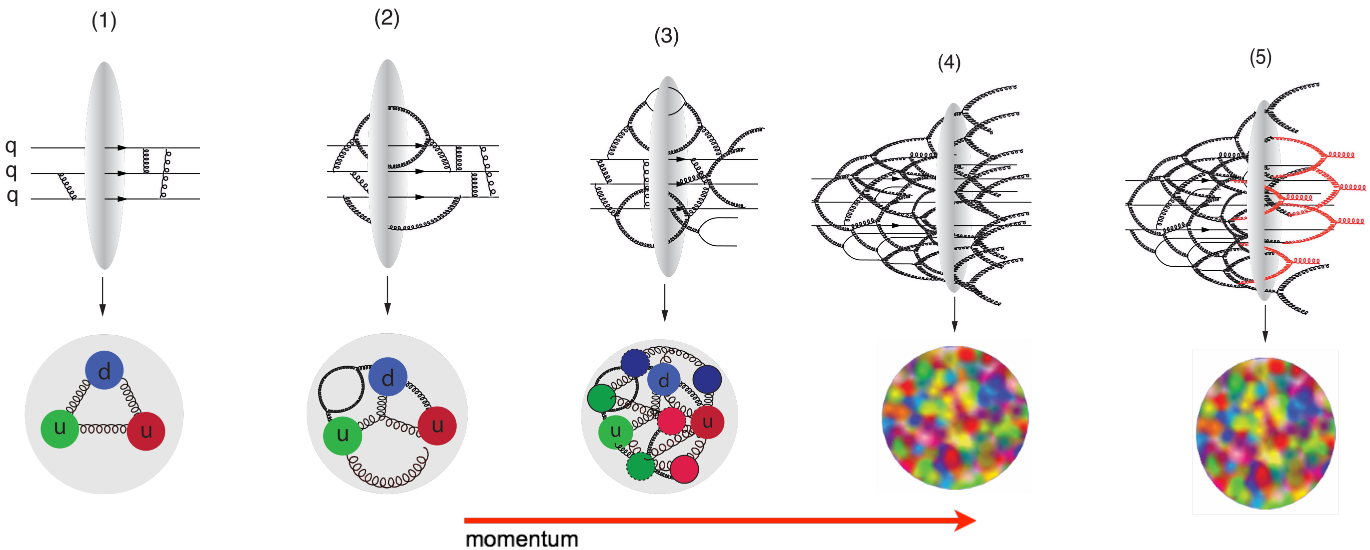
Have to bring in gluon density fluctuations (incoherent diff.)

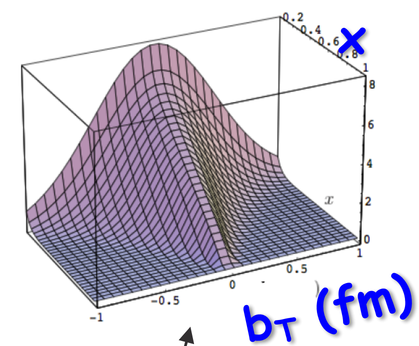
SATURATION

Visualizing saturation

Some ideas

Saturation = Recombination kicks in



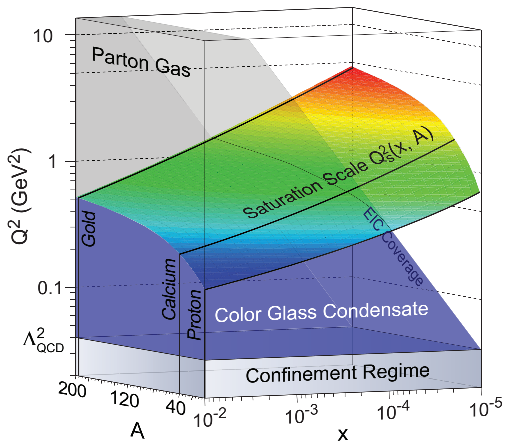


- This needs work
- Depict better (how?) that boost (= collider energy) brings time dilation which allows to see the glue and sea. A proton at rest all one sees are valence quarks
- Lower row (xy view) needs to show the **grow of the proton**
- May be accompanying this with an extended version (to $x=10^{-4}$) of this plot
- Also CGC impression needs to get improved
- And all of course animated

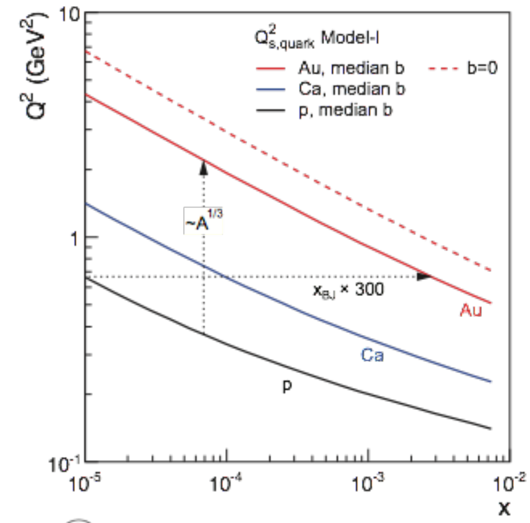
SATURATION

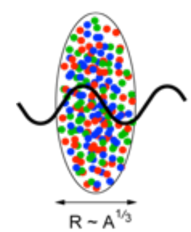
Visualizing saturation

Some ideas on the Oomph



3D -> 2D





$$(Q_s^A)^2 \approx cQ_0^2\left(\frac{A}{x}\right)^{1/3}$$

- Saturation scale and advantage of heavy nuclei. Right plot is good start but could be animated with showing the oomph and amplification effect better.
- Leaving the details of median b versus b=0 out (too detailed)

SATURATION

Motivate low-x reach

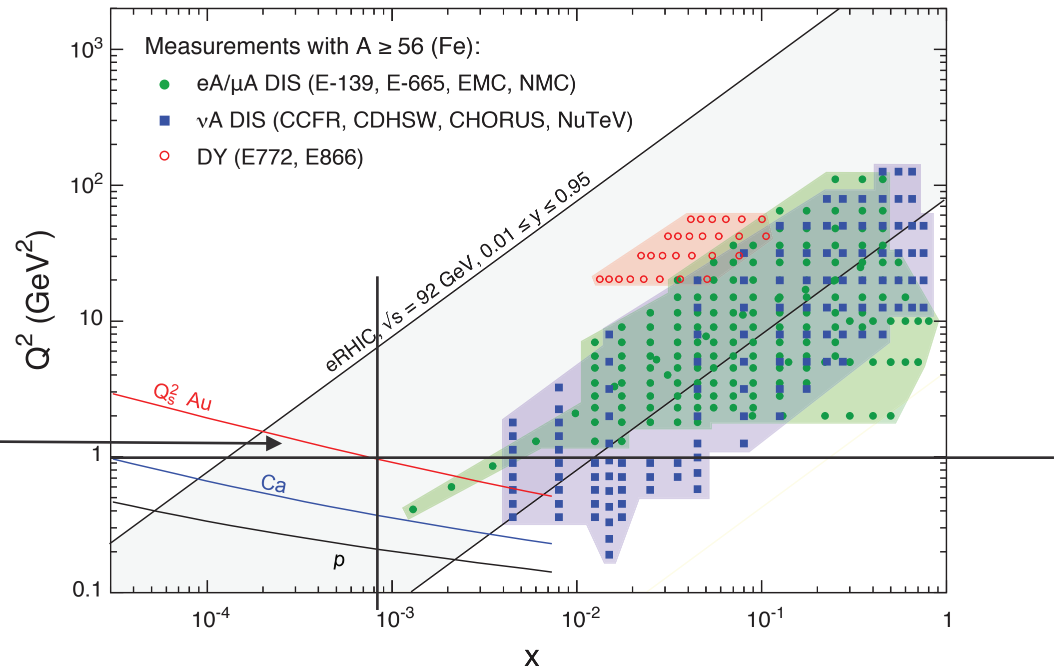
Reach into saturation reach at $Q^2 > 1$ GeV^2 to allow for comparisons with perturbative calculations. Mention Q lever arm but do not exaggerate due to LHeC.

SATURATION

Motivate low-x reach

Some ideas

This little triangle is the area where LTS perturbative calculations and CGC can be compared

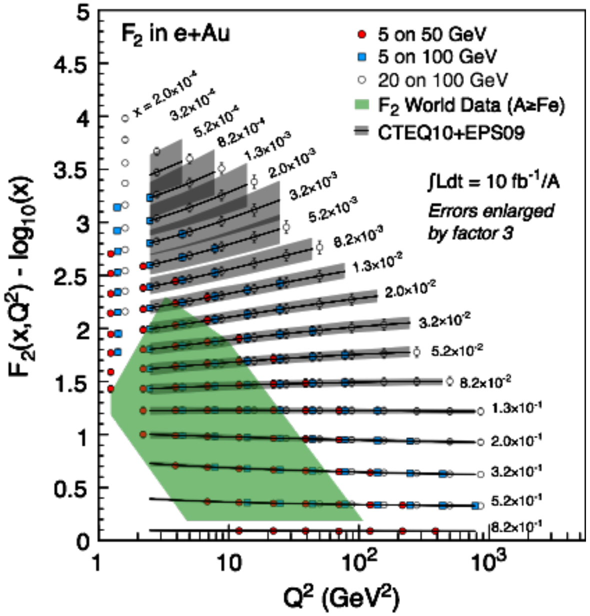


- Plot like this is the key
- Add lines of different energies and indicate perturbative regime (Q^2 > 1 GeV^2)
- For anything less than 20+100 the triangle shrinks even more
- At $\sqrt{s}$ = 35 GeV it is all gone for Au
- Triangle "only" important for perturbative LTS to CGC comparisons
- However Qs(x) is not sharp line …

SATURATION

Motivate low-x reach

Some ideas

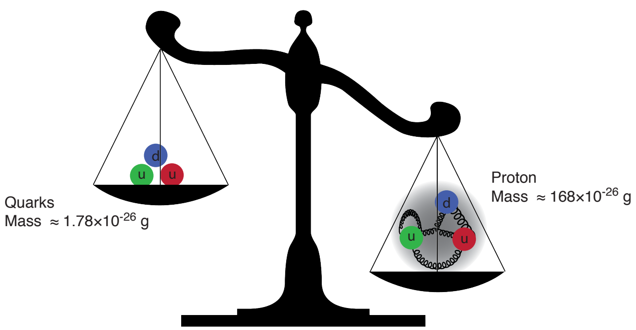


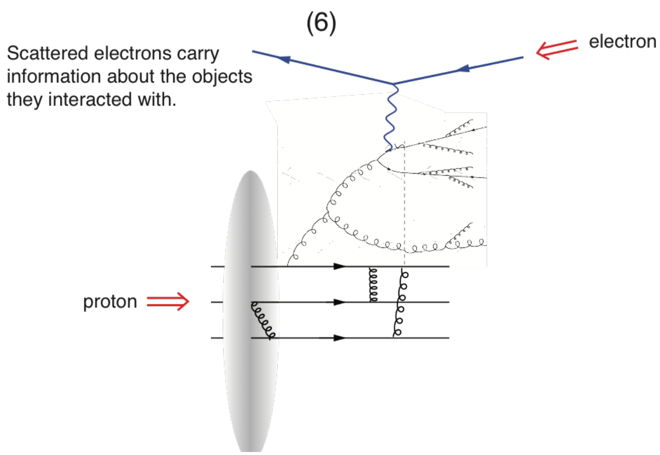
- Shows that we have Q2 lever arm (DGLAP at fix x along Q2)
- This needs to be pointed out better in plots like the above (how?)
- Possibly indicating the saturation regime here!!!
- Would complement the plot discussed on previous slide

SATURATION

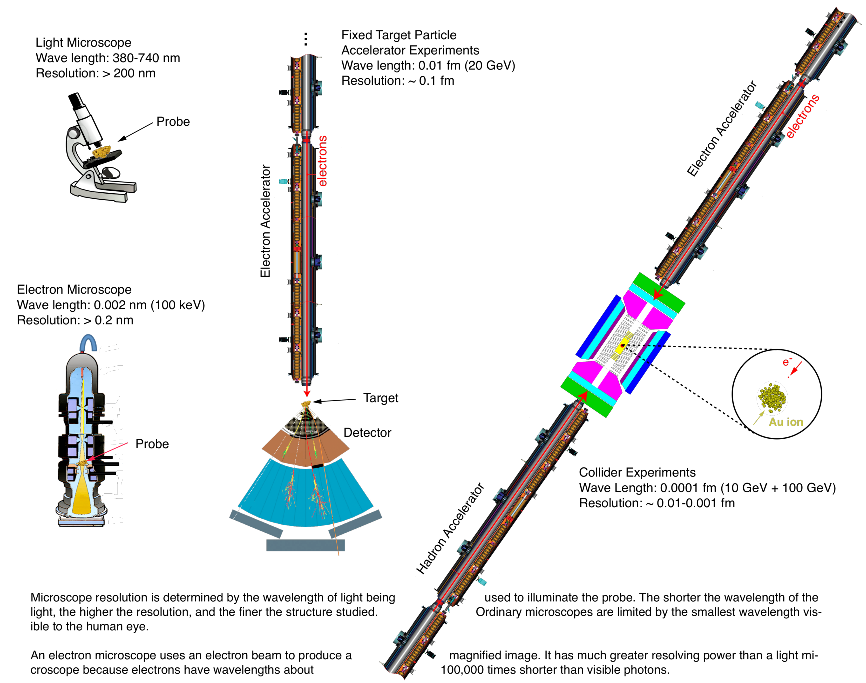
Other

Some ideas created in the process of preparing the Sci AM article





Studying the structure of Matter at less that 10^{-15} meter
with high resolution femto-scopes



Microscope resolution is determined by the wavelength of light being used to illuminate the probe. The shorter the wavelength of the light, the higher the resolution, and the finer the structure studied. Ordinary microscopes are limited by the smallest wavelength visible to the human eye.

An electron microscope uses an electron beam to produce a magnified image. It has much greater resolving power than a light microscope because electrons have wavelengths about 100,000 times shorter than visible photons.

Electron microscope resolutions are limited by their electron energy, roughly to energies corresponding to about 1/5 of the electron mass. Large and complex particle accelerators overcome this limit by producing electron beams with energies of up to about 10,000 times the electron mass.) The earliest experiments with such energetic electrons probed matter in a stationary target. Pioneering experiments at the Stanford Linear Collider (SLAC) achieved resolutions of order 0.1 Fermi (1 Fermi = 10^{-15} meters, roughly the size of the proton.) These experiments succeeded in discovering point-like, fractionally charged objects within protons and neutrons, interpreted as quarks.

Much higher resolutions in stationary target experiments require prohibitively large and expensive accelerators. The way out is to also accelerate the target, colliding electron and target together at high energies. A prominent example of this type of sub-Fermi probe, or "femto-scope", was the HERA collider at DESY, Germany. This machine was the first electron-proton collider and pointed to the unexpected prominent role gluons play deep inside the proton. A future electron-ion collider (EIC) machine will allow collisions of electrons with spin-polarized protons, as well as light and heavy atomic nuclei. Both such experiments will be firsts for collider experiments, with intensities a 1000 fold compared to HERA. The EIC will provide the resolution and intensity to map out in detail the three-dimensional structures in protons and atomic nuclei. This will resolve outstanding puzzles of the sub-atomic universe at distances well below a millionth of a billionth of a meter.

SATURATION

In the whitepaper we show that we can measure
The density profile of glue rho(bT).

Is there a plot that shows saturated rho(bT) versus
non-saturated (bT).
All this is of course model dependent but so be it.

HADRONIZATION

the process to study features of confinement
Advantages studying hadronization in ep / eA:

- can separate favoured and unfavoured fragmentation
- can separate initial from final state effects
- can study correlations between current and target region
  - separate higher QCD effects (radiation) from fragmentation effects

can we show the QGP in small systems is a hadronization effect,
→ cos phi in sidis events over a large rapidity range -4 to 4

- eA:

Better work out the nucleus as analyzer of hadronization. Hadronization as local deconfinement process that can be studied with nuclei. Have to go beyond simple multiplicity ration plots. Connect different location of hadronization to different observations.

The one plot we have in the White Paper is not the most thrilling one…