Introductory remarks - to second day

Hard exclusive processes with a future *ep* /eA collider

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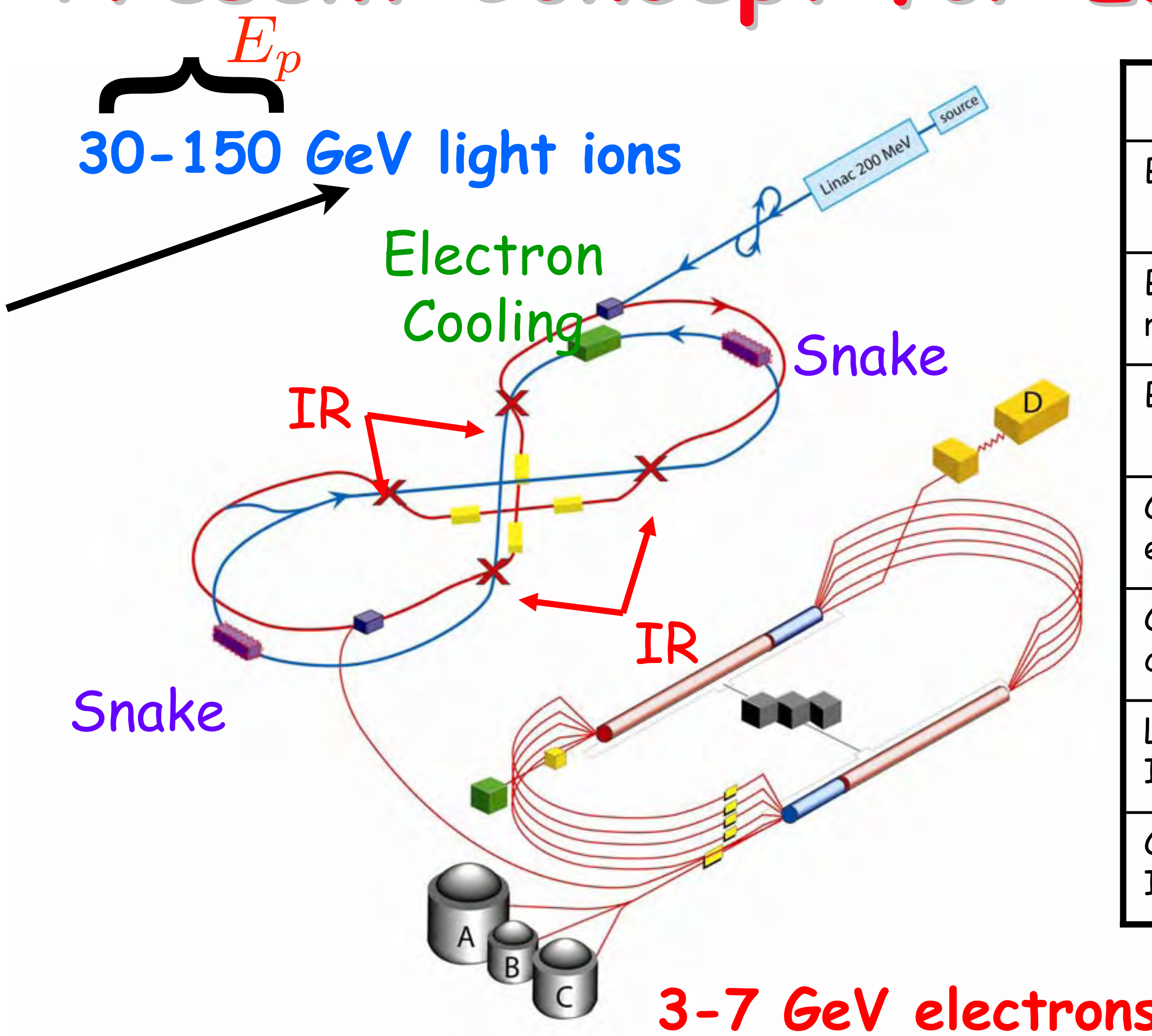
Joint INT/JLab/BNL Workshop

Present Concept for ELIC

(Derbenev, Yunn, Bogacz, Krafft, Merminga, Zhang)

$$E_A = \frac{Z}{A} E_p$$

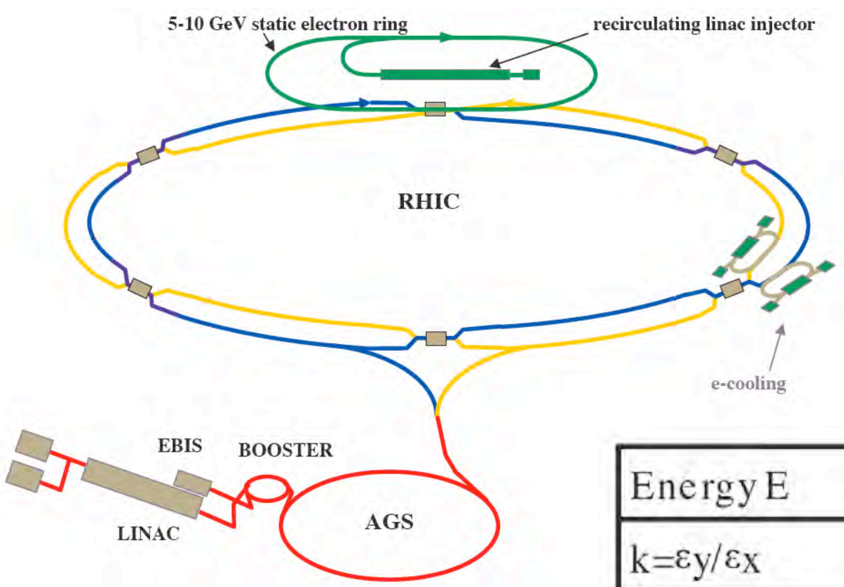


Parameter	Unit	Ring-Ring Design		
Beam energy	GeV	150/7	100/5	30/3
Bunch collision rate	GHz	1.5	1.5	1.5
Beam current	A	1/2.4	1/2.7	.3/4.1
Cooling beam energy	MeV	75	50	15
Cooling beam current	A	2	2	.6
Luminosity per IP, 10^{34}	$cm^{-2}s^{-1}$	7.7	5.6	.8
Core&luminosity IBS lifetime	h	24	24	>24

Now a Ring-Ring Design, using Polarized Electron Injection and "Stacking" in a Storage Ring (as presented at QCDFP/EIC2006 Workshop at BNL, July 2006)

Lower Energy option = LE

eRHIC Ring-Ring Design



Existing RHIC ring for polarized p and un-polarized A

Luminosity assumes at least 2 A-A experiments on (limiting the luminosity)

Electrons and positrons easily possible

One IR, can be built in short time scale

Energy E	[GeV]	10	250	10	100
k=εy/εx		0.18	1	0.18	1
Kσ=σy/σx		0.43	0.43	0.43	0.43
ε_n (ion)	[πmm mrad]		15.0		6.0
Emittancs εx	[nm.rad]	54.0	9.4	54.0	9.4
Emittancs εy	[nm.rad]	9.7	9.4	9.7	9.4
βx*	[m]	0.19	1.08	0.19	1.08
βy*	[m]	0.19	0.2	0.19	0.2
ξx		0.042	0.0095	0.033	0.0095
ξy		0.1	0.0041	0.08	0.0041
Particles/Bunch		1.40E+11	1.41E+11	1.38E+11	1.43E+09
Luminosity £	[$cm^{-2}s^{-1}$]		1.0E+33		1.0E+31

Table 2.4.2- 2 Parameters for higher luminosity--high electron beam energy.

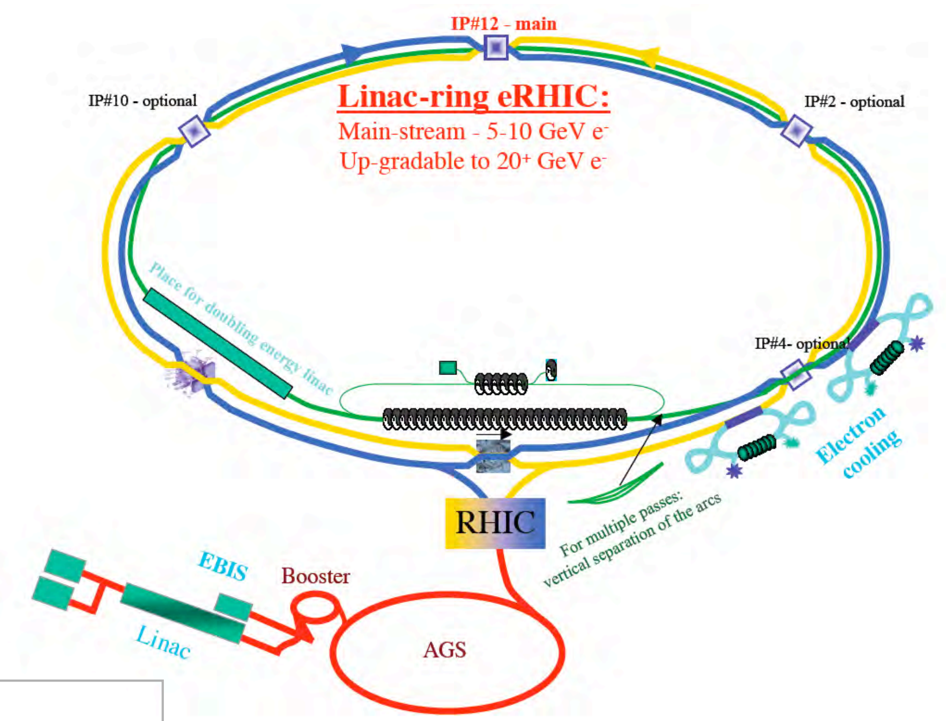
Source: eRHIC Zeroth Design Report
http://www.bnl.gov/eic

Two Higher Energy options = HE

eRHIC Linac-Ring Design

If community support is wide

- A design that allows up to four IRs
- 10->20 GeV upgrade trivial
- Clear advantages for element free regions in Interaction regions



Parameters	ERL	ion ring	
		p	Au
C, m	1022 or 3833	3833	
E, GeV	5–10 2-20	250	100/u
n_b		360	
N_b	$1 \cdot 10^{11}$	$2 \cdot 10^{11}$	$2 \cdot 10^{9}$
I, A E_{rmsn} µm β^*, cm ξ	0.45 <50 ~100 ~1	0.45 3-9 20 0.024	
L, cm^{-2} s^{-1}		$1 \cdot 10^{34}$	$1 \cdot 10^{32}$

Use existing p and A beam ring

Add linac to the complex

Assumes 2 A-A experiments on, limiting the estimated luminosity (in reality this may not be true, and lumi can be increased)

Two direction - moderate $x > 0.05$ and pushing to as small x as possible

$$x_{min} \sim Q^2_{min}/W^2 = Q^2_{min}/4E_eE_p$$

$1/x_{min}$ linear in maximal E_e, E_p

Potential advantage of collider (<u>if collision region and detector are designed properly</u>) - detection of fast particles (nucleons, mesons, ...) in the nucleon/ nucleus fragmentation region.

Small x region - physics of large longitudinal distances

$$l_{coh}(x) = (1 \div 2)/m_N x \Longrightarrow l_{coh}(x = 10^{-2}) = 10 \div 20\, fm$$

probably beyond the range of lattice QCD in the next 15 years

Small x - in NLO interplay of quark and gluon GPDs

Need to measure both. Even more complicated that in DIS

Example: difference in the t-dependence of quark and gluon QPD

B_{DVCS} $(x=10^{-3}, Q^2=8\ GeV^2) \approx 6\ GeV^{-2}$

$B_{gluon\ gpd}$ $(x=10^{-3}, Q^2=3 \div 8\ GeV^2) \approx 3.5 \div 4.5\ GeV^{-2}$

from J/ψ electro/photo production

A.Freund and M.Mcdermott: σ_{DVCS} is difference of term due to quark and gluon gpd's with second term reducing σ_{DVCS} by nearly a factor of 2

$\Delta = B_{quark\ gpd} - B_{gluon\ gpd}$ → $B_{DVCS\ gpd} - B_{gluon\ gpd} = 2\ \Delta$

Crucial to have high precision measurements of t -dependence for a wide range of hard processes

Need to explore relative merits of different options from the angle of

- x, Q^2 range covered
- Acceptance in the forward region

accurate measurement of t -dependence for diagonal case

measurement of non-diagonal processes

$$\gamma^* + p \to \gamma(M) + \Delta^+(N^*)$$

$$\gamma^* + \vec{p} \to K^+ + \vec{\Lambda}$$

for small x I(N*)=1/2 - baryon spectroscopy; chiral dynamics for gpd's

- Particle ID in the current fragmentation region
- Tagged neutrons for neutron gpd's

At what x, Q^2 LE option with higher lumi wins over HE?

Optimizing energies of the runs - gains in the L/T separation

Nuclear gpds and exclusive processes

Nuclear pdf ≈ A x (nucleon pdf) for 0.4 > x > 0.02 with 10% accuracy

$\Downarrow$?

Nuclear gpd ≈ A x (nucleon gpd) for 0.4 > x > 0.02 with 10% accuracy

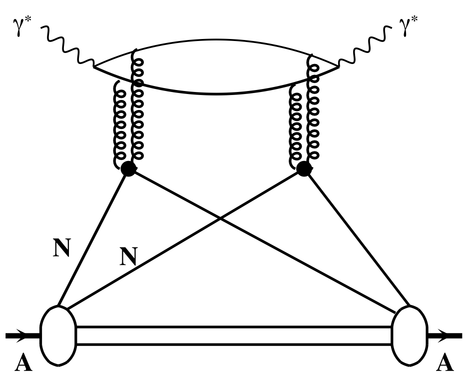
$\Downarrow$ ≡Color transparency

$$Amplitude(\gamma^* + A \to \gamma(V) + A) = Amplitude(\gamma^* + A \to \gamma(V) + A)F_A(t)$$

$$Amplitude(\gamma^* + A \to \gamma(V) + A'[nucleus\, breakup]) = 0_{|\, t=0}$$

≠ 0 due to EMC type effects

Deviations from CT due to HT effects - x~0.05 optimal as expansion effects are small



example of HT diagram leading to shadowing

For heavy nuclei can probe very small σ_{eff} ~ 5 mb

Another strategy - A -dependence of break up (good for all x)

$$\sigma(\gamma^* + A \to \gamma(V) + A'[nucleus\, breakup]) \propto A^n$$

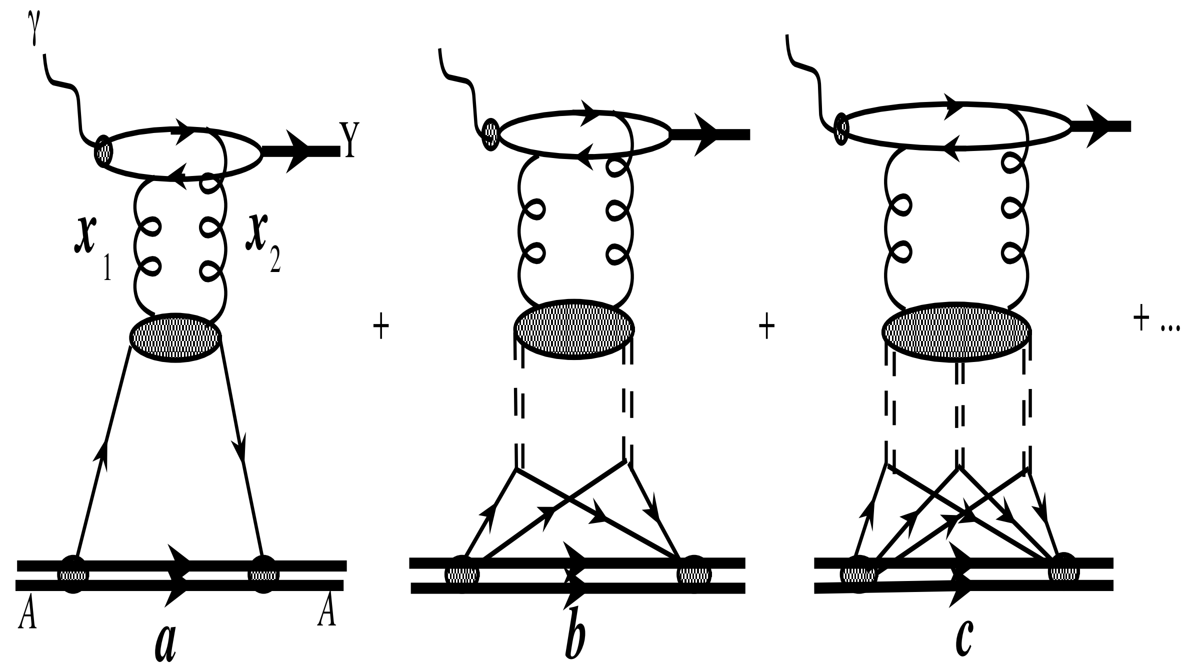
CT: n=1, large σ_{eff} n=1/3

The leading twist prediction is

$$\sigma_{\gamma A\to VA}(s) = \frac{d\sigma_{\gamma N\to VN}(s,t_{min})}{dt}\left[\frac{G_A(x_1,x_2,Q^2_{eff},t=0)}{AG_N(x_x,x_2,Q^2_{eff},t=0)}\right]^2$$

$$\cdot\int_{-\infty}^{t_{min}} dt\left|\int d^2b dz e^{i\vec{q}_t\cdot\vec{b}} e^{-q_l z}\rho(\vec{b},z)\right|^2,$$

where $x_1 - x_2 = \frac{m_V^2}{s} \equiv x.$



: High energy quarkonium photoproduction in the leading twist approxima

⇓

Factor of > 2 suppression of cross sections at x< 0.005 for large Q^2 for light mesons and for onium production for all Q. (Diagonal DVCS is very difficult for such x - Guzey talk)

Data with nuclei are crucial for determining the Q range which could be used to extract gpd's in scattering off nuleons