Complementary Detectors at EIC

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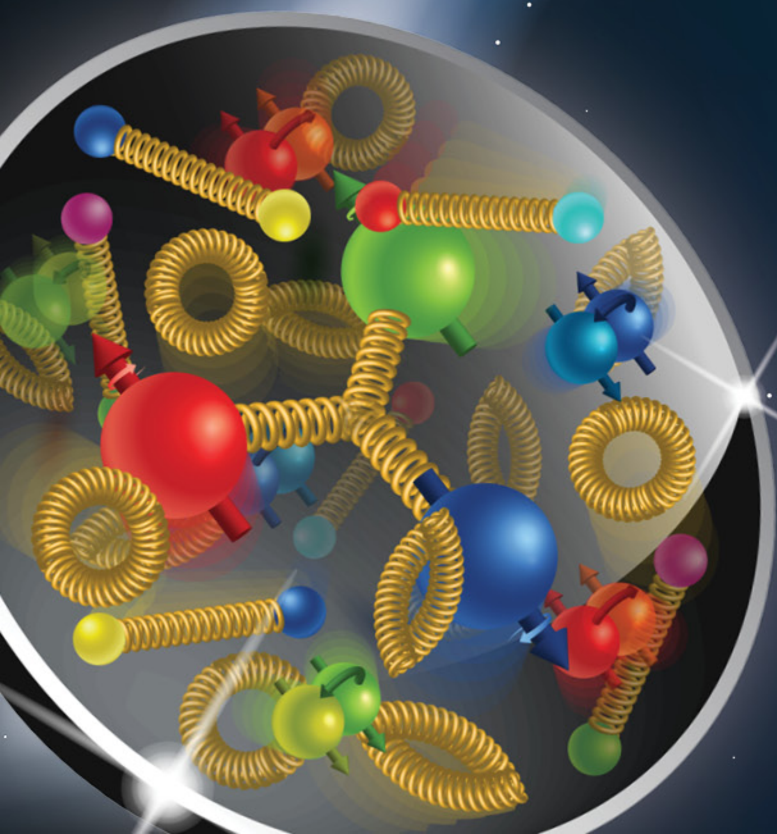

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We want it all

high Luminosity
at full acceptance

But there are some boundary conditions
→ accelerator
→ experiment

Boundary Conditions

Interaction Region:

Table B.1: Summary of 2nd IR design requirements and their comparison to the 1st IR.

#	Parameter	EIC IR #1	EIC IR #2	Impact
1	Energy range electrons [GeV] protons [GeV]	 $5-18$ $41, 100-275$	 $5-18$ $41, 100-275$	Facility operation
2	CM energy range of optimum luminosity [GeV]	$80-120$	$45-80$	Physics priorities
3	Crossing angle [mrad]	25	$25-50$	p_T resolution, acceptance, geometry
4	Detector space symmetry [m]	$-4.5/+4.5$	$-(3.5-4.5)/+(5.5-4.5)$	Forward/rear acceptance balance
5	Forward angular acceptance [mrad]	20	$20-30$	Spectrometer dipole aperture
6	Far-forward angular acceptance [mrad]	4.5	$5-10$	Neutron cone, p_T^{max}
7	Minimum $\Delta(B\rho)/(B\rho)$ allowing for detection of $p_T=0$ fragments	0.1	$0.003-0.01$	Beam focus with dispersion, reach in x_L and p_T resolution, reach in x_B for exclusive processes
8	Angular beam divergence at IP, h/v, rms [mrad]	$0.1/0.2$	< 0.2	p_T^{min}, p_T resolution
9	Low Q^2 electron acceptance	< 0.1	< 0.1	Not a hard requirement

- All beams transport over full energy range
- Magnet aperture-edge fields < 4.6 T
  - Detune low-beta or do not run for E_p>~180 GeV
- Sufficient DA and momentum aperture

- Total beam-beam < 0.03 (p), 0.1 (e)
- Beam aperture >10σ (p); >15σ_x/20σ_x H/V (e)
  - Electron aperture accommodates non-Gaussian tails
- Dispersion and dispersion' constraints at crab cavities

Luminosity vs. Detector Space

Luminosity: $$L = \frac{h \cdot f_{rev} \cdot n \cdot n_b \cdot N_e/n \cdot N_p/n}{4\pi \cdot \frac{\sigma_x \sigma_y}{n}}$$

- but reduce emittances by factor n (note n_b is original number of bunches, new is $n \cdot n_b$), which requires much stronger cooling τ_{cool} ➔ τ_{cool} / 2,4, …
- The original luminosity is then recovered
- Luminosity can now be increased by squeezing the betas by a factor 2 which is possible since the envelope in the final focus quadrupoles has shrunk by a factor of √2 in x and y

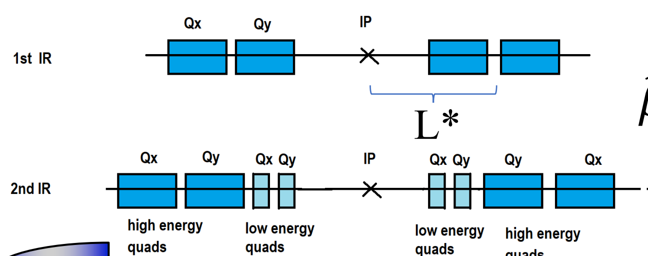
One is left to deal with the enhanced IR chromaticity which went up by a factor of 2 which reduces the dynamic aperture by a factor ~2

How to reduce IR chromaticity?

- Increase crossing angle to get final focus quadrupoles closer to IP

  θ_{cross} ➔ $\theta_{cross} \times 2$

  → **Impact on detector:** asymmetric material budget in outgoing hadron beam direction
  asymmetric and reduced acceptance for high η hadrons
- Electrons: final focus quadrupoles in the detector
- Hadrons:



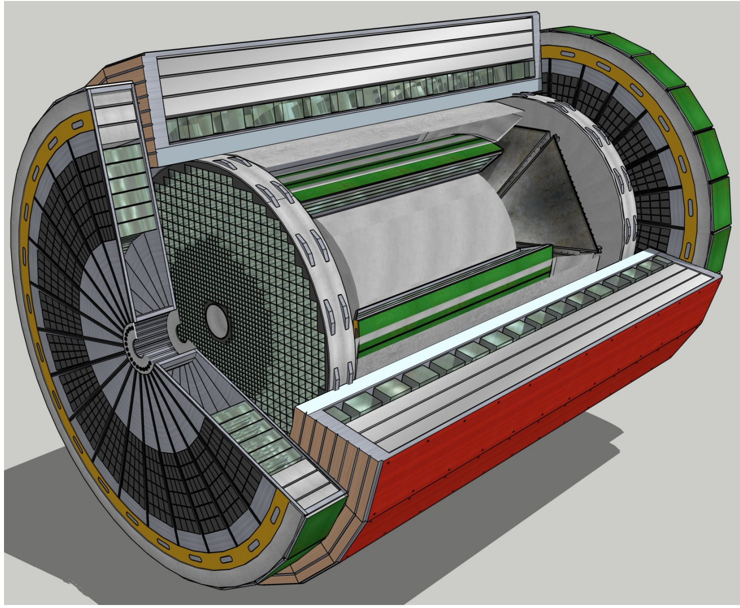
$$\hat{\beta} \propto L^{*2}/\beta^*$$

Detector Size directly coupled to Luminosity

General Purpose Detector

Overall detector requirements:

- Large rapidity ($-4 < \eta < 4$) coverage; and far beyond in especially far-forward detector regions
- High precision low mass tracking
  - small (μ-vertex) and large radius (gaseous-based) tracking
- Electromagnetic and Hadronic Calorimetry
  - equal coverage of tracking and EM-calorimetry
- High performance PID to separate π, K, p on track level
  - also need good e/p separation for electron-scattering
- Large acceptance for diffraction, tagging, neutrons from nuclear breakup: critical for physics program
  - Many ancillary detector integrated in the beam line: low-Q^2 tagger, Roman Pots, Zero-Degree Calorimeter, ….
- High control of systematics
  - luminosity monitors, electron & hadron Polarimetry



To date no argument was presented why to go away from this overall concept

General Purpose Detector: Refined Requirements

View Matrix   View Model   View Help   Login to Edit

η	Nomenclature			Tracking: Resolution	Tracking: Allowed X/X_0	Tracking: Si-Vertex	Electrons: Resolution σ_E/E	Electrons: PID	π/K/p: p-Range (GeV/c)	π/K/p: Separation	HCAL: Resolution σ_E/E	Muons
-6.9 to -5.8			low-Q2 tagger	σθ/θ < 1.5%; 10-6 < Q2 < 10-2 GeV2								
...	↓ p/A	Auxiliary Detectors										
-4.5 to -4.0			Instrumentation to separate charged particles from photons									
-4.0 to -3.5							2%/√E					
-3.5 to -3.0				σ_p/p ~ 0.1%⊕0.5%								
-3.0 to -2.5												
-2.5 to -2.0			Backward Detector	σ_p/p 0.1%⊕0.5%		TBD	2%/√E		≤ 7 GeV/c		~50%/√E	
-2.0 to -1.5				σ_p/p 0.05%⊕0.5%			7%/√E					
-1.5 to -1.0							7%/√E	π suppression up to 1:10^4				
-1.0 to -0.5												
-0.5 to 0.0		Central Detector	Barrel	σ_p/p ~0.05%×p+0.5%	~5% or less X	σ_{xyz} ~ 20 µm, $d_0(z)$ ~$d_0(r\Phi)$ ~ 20/p_TGeV µm + 5 µm			≤ 5 GeV/c	≥ 3 σ		TBD
0.0 to 0.5												
0.5 to 1.0												
1.0 to 1.5									≤ 8 GeV/c			
1.5 to 2.0				σ_p/p ~0.05%×p+1.0%			(10-12)%/√E					
2.0 to 2.5			Forward Detectors			TBD			≤ 20 GeV/c		~50%/√E	
2.5 to 3.0				σ_p/p ~ 0.1%×p+2.0%								
3.0 to 3.5									≤ 45 GeV/c			
3.5 to 4.0			Instrumentation to separate charged particles from photons									
4.0 to 4.5												
...	↑ e	Auxiliary Detectors	Neutron Detection									
> 6.2			Proton Spectrometer	$\sigma_{intrinsic}(\|t\|)/\|t\|$ < 1%; Acceptance: 0.2 < p_t < 1.2 GeV/c								

General Purpose Detector: Technology Possibilities

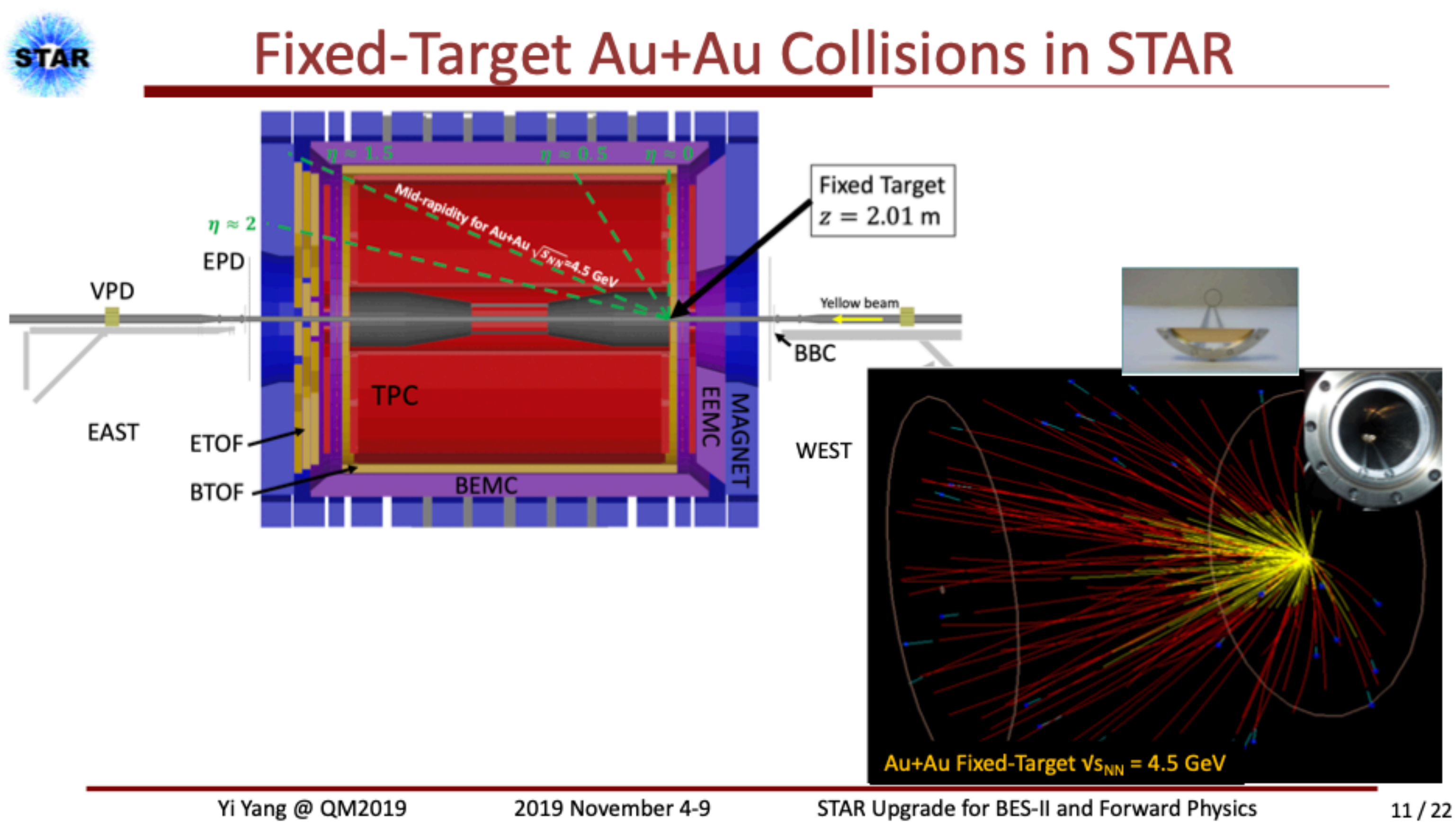
system	system components	reference detectors	detectors, alternative options considered by the community			
tracking	vertex	MAPS, 20 um pitch	MAPS, 10 um pitch			
	barrel	TPC	TPC surrounded by a micro-RWELL tracker	MAPS, 20 um pitch	set of coaxial cylindrical MICROMEGAS	
	forward & backward	MAPS, 20 um pitch	GEMs with Cr electrodes			
ECal	barrel	Pb/Sc Shashlyk	SciGlass	W powder/ScFi	W/Sc Shashlyk	
	forward	W powder/ScFi	SciGlass	Pb/Sc Shashlyk	W/Sc Shashlyk	
	backward, inner	$PbWO_4$	SciGlass			
	backward, outer	SciGlass	PbWO4	W powder/ScFi	W/Sc Shashlyk	Pb/Sc Shashlyk
h-PID	barrel	High performance DIRC & dE/dx (TPC)	reuse of BABAR DIRC bars	fine resolution TOF		
	forward, high p	fluorocarbon gaseous RICH	double RICH combining aerogel and fluorocarbon	high pressure Ar RICH		
	forward, medium p	aerogel				
	forward, low p	TOF	dE/dx			
	backward	modular RICH (aerogel)				
e/h separation at low p	forward	TOF & areogel & gaseous RICH	adding TRD			
	backward	modular RICH & TRD	Hadron Blind Detector			
HCal	barrel	Fe/Sc	RPC/DHCAL	Pb/Sc		
	forward	Fe/Sc	RPC/DHCAL	Pb/Sc		
	backward	Fe/Sc	RPC/DHCAL	Pb/Sc		

To get two detectors complementary in technology but with equal performance one needs to optimize the full detector and not only push individual subdetectors performances

Additional Science Opportunities

Integrate fixed target into collider:
→ done at LHC (ALICE and LHCb) and STAR@RHIC

for EIC on can do
→ ep/A fixed target --> access to high x
→ pp/A important to test universality for TMDs, GPDs, ……



Complementarity Matrix

Collect information neatly via a 'Physics Topic' v 'Detector Component' matrix

	Tracking	PID	Calorimetry	h-Beamline	e-Beamline	Magnet	Lumi	$\sqrt{s}$
Inclusive								
SIDIS		Click to add content						
Jets								
Heavy Flavours								
Exclusive								
Diffractive								

- Each element clickable to add content (could leads to a page with list of files / links)
  - → complementarity ideas (see list of questions asked to Working Groups)
  - → problems arising from baseline design
  - → …

- May need more rows, subdividing some of the PWGs (eg for SIDIS)

- ECA and PRN populate based on material from Complementarity meetings so far
- Invite others to add material before / during / after CUA meeting


BACK UP