Detector Complementarity: Current Thinking

EIC Detector Advisory Committee
Review Meeting
29 September 2020

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Background

DOE Statement:

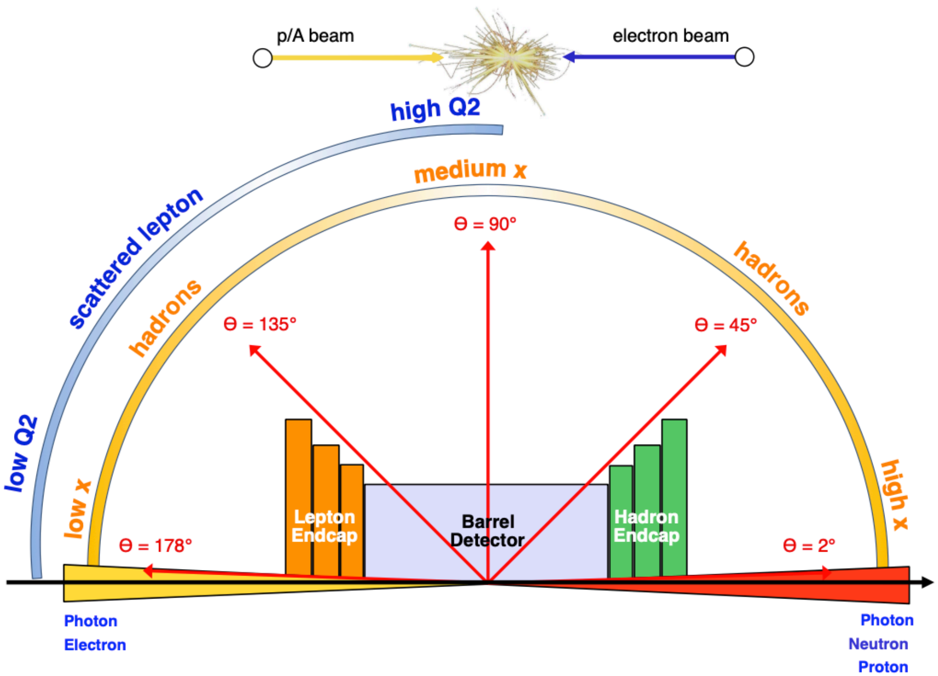
EIC scope includes the machine upgrades to RHIC asset and two interactions regions with one of the interaction regions outfitted with a major detector.
Scientific instrumentation for the second interaction region not included in the scope.

- High energy colliders usually have (at least) two detectors
- We have a pretty good idea how one basic detector layout might look (details and technologies still being discussed)
- Second detector is more of a blank page - opportunity to refine and enhance EIC physics program

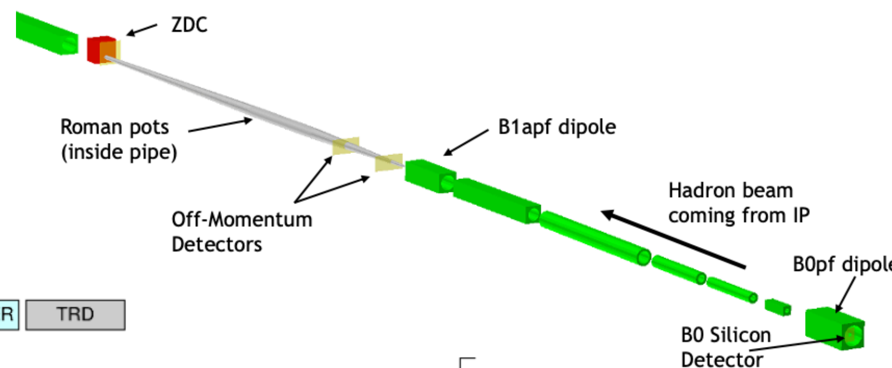
Important from the outset to assess 'complementarity' possibilities in terms of physics motivation and detector options

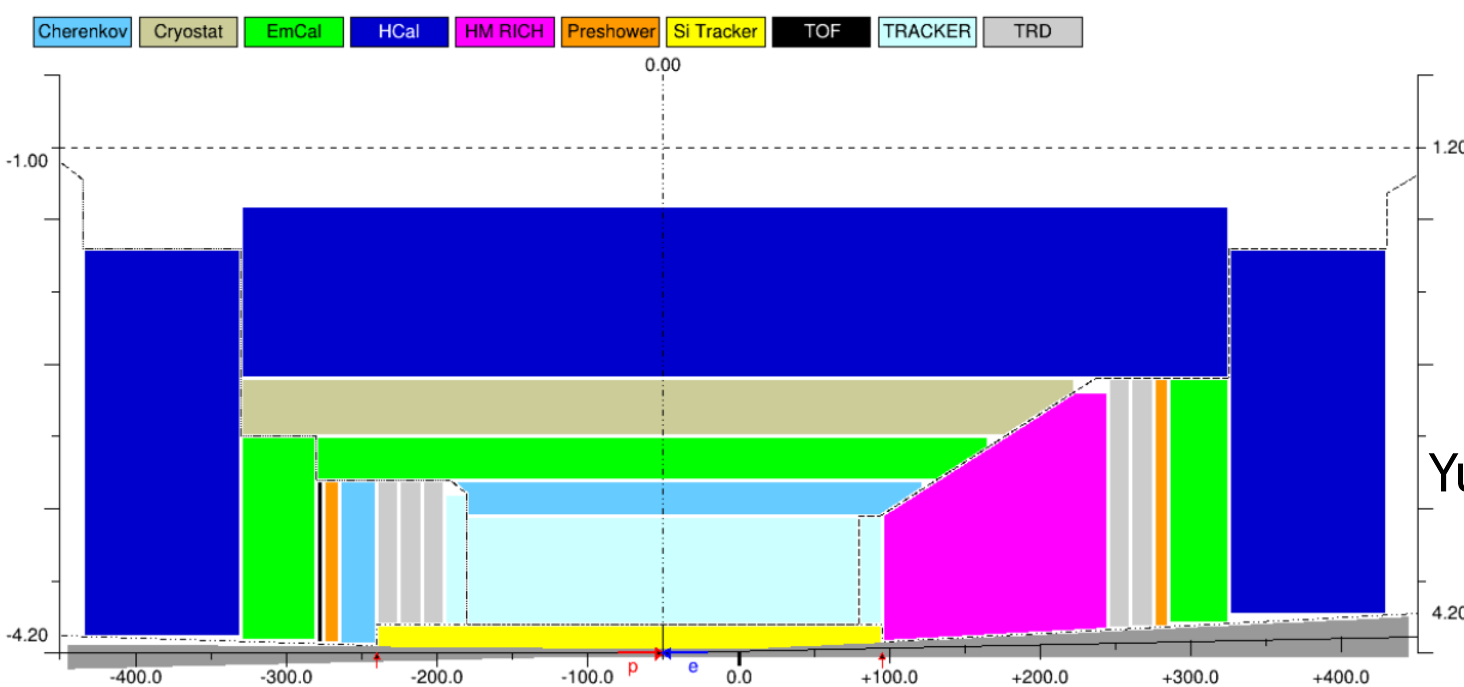
Yellow Report Complementarity group charged with collecting arguments why two detectors will enhance the physics output of the EIC

First Detector



Well developed reference concept for first detector and interaction region





[See talks by Silvia / Tanja and by Yuliya / Alexander]

What do we want from ‘Complementary’

1) Cross-checking important results (obvious!)

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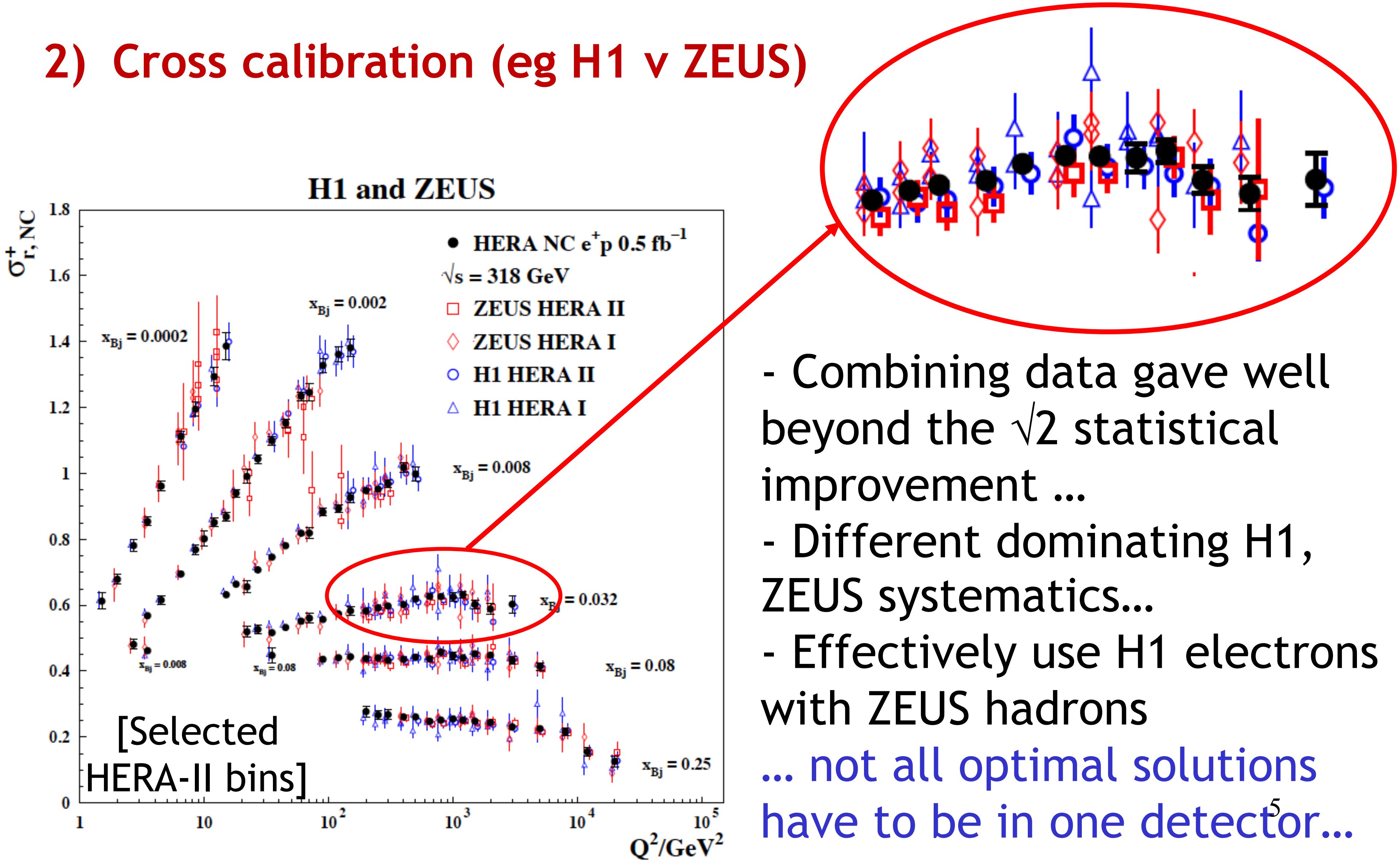
2) Cross calibration (eg H1 v ZEUS)



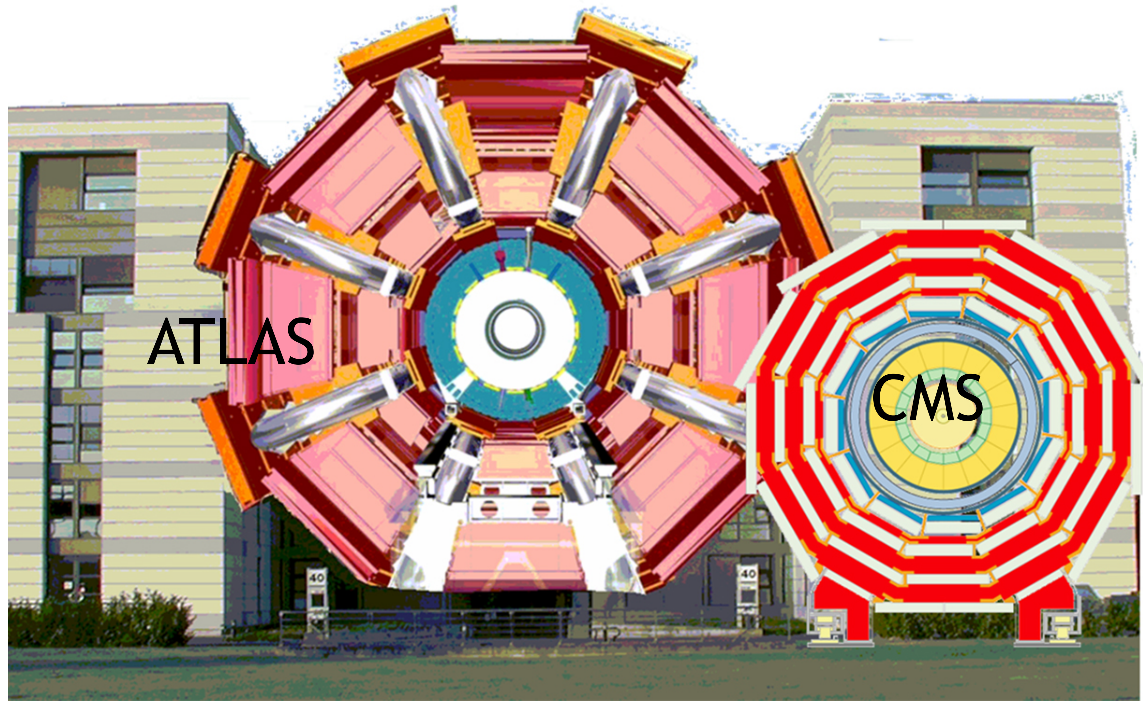
- Combining data gave well beyond the √2 statistical improvement …
- Different dominating H1, ZEUS systematics…
- Effectively use H1 electrons with ZEUS hadrons

… not all optimal solutions have to be in one detector…

What do we want from 'Complementary'

3) Redundancy versus unforeseen technology problems …

... by applying different detector technologies and philosophies to similar physics aims



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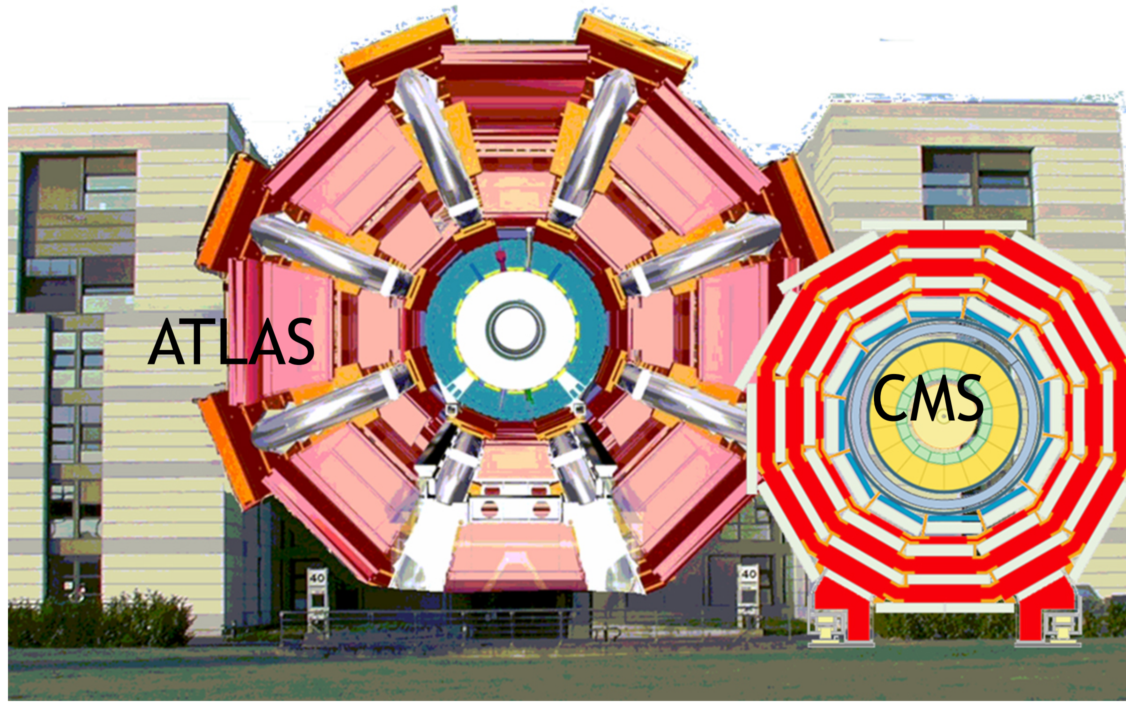
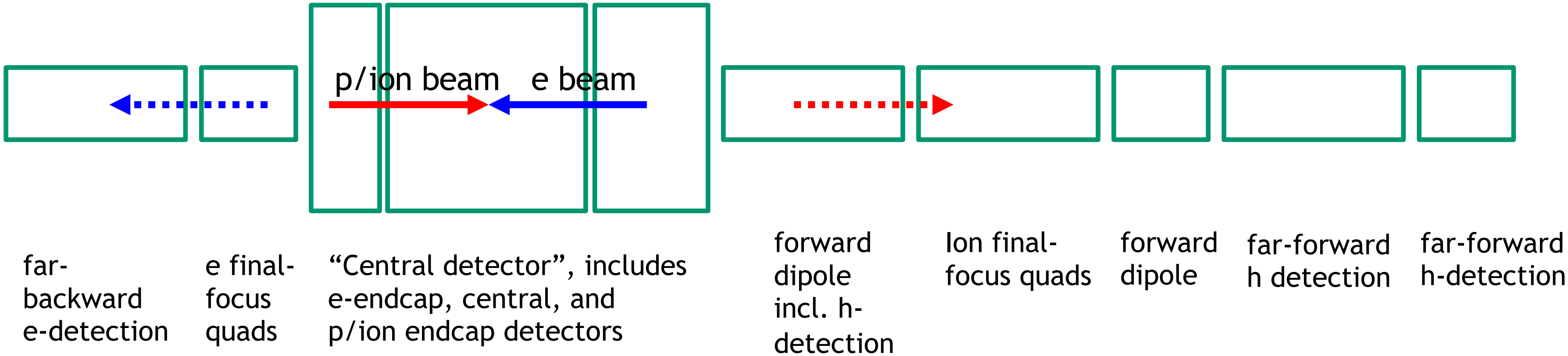


4) Different primary physics focuses …

…optimizing overall sensitivity to EIC physics programme?...

There are Boundary Conditions



- Beam elements / magnet structures limit central detector
  - → Main detector $\pm$ 4.5m (& IR-instrumentation $\pm$ 35m)
  - → Space requirement for dedicated muon detectors?
- Synchrotron fan, crossing angle determine angular acceptance for main detector and beam-line / IR instrumentation
  - → IR instrumentation angular range to ~ 1.5^o
  - → Main detector instrumentation to $|\eta|$ ~ 3.5 – 4.0

- Length of central detector has impact on luminosity (distance to first quadrupole).
  - → compromise between acceptance and luminosity

Complementarity Working Group Activities

1) Discuss detailed aims and needs with Physics Working Group conveners

"Have you identified key physics aims that conflict with the current baseline /schematic detector and IR design?"

2) Discuss with Detector Working Group conveners

"Assuming we have two detectors, how you could build in complementarity within the overall constraints imposed by the accelerator and associated considerations?"

[Many subsidiary questions]

… no compelling argument (yet) for a second detector with specialised / limited physics focus.

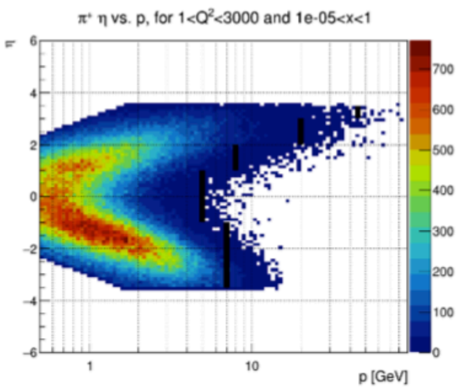
→ **Working assumption is two complementary GPDs**

Example Opportunity for Physics Complementarity

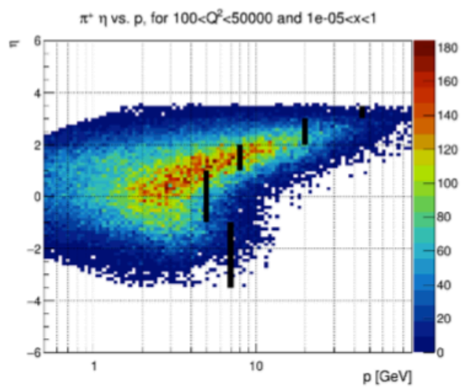
Magnetic Field Strength compromises for charged particles in central region

- Low field → low p_T acceptance : Semi-inclusive DIS for TMDs, FFs etc
  : Samples for Spectroscopy (HF etc)

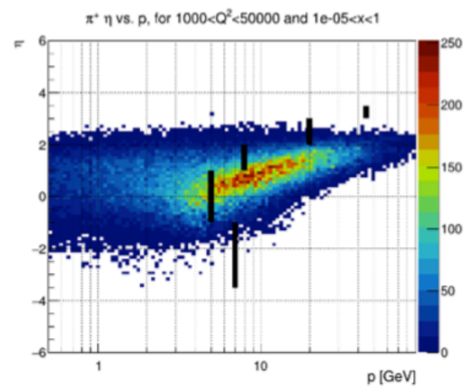
$Q^2 > 1$ GeV^2



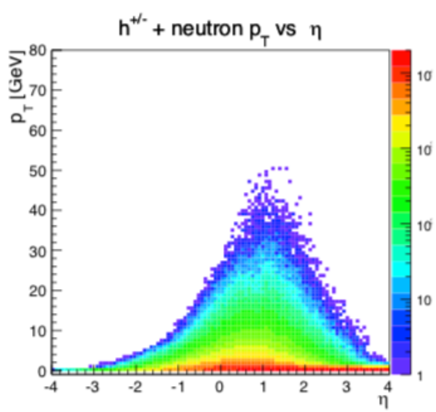
$Q^2 > 100$ GeV^2



$Q^2 > 1000$ GeV^2



- High field → high p_T precision : Scattered electron in inclusive NC DIS
  : Inclusive hadrons for inclusive CC DIS
  : \`Back-to-back' for gluon Sivers / satn
  : Mass precision in Spectroscopy (HF etc)



[Also opportunities to trade off space allocations for tracking v Particle ID]

Complementarity through Technology Choices

Multiple proposals / alternatives for each subdetector …

→ Different strengths and weaknesses

→ Optimised to different p_T / other kinematics

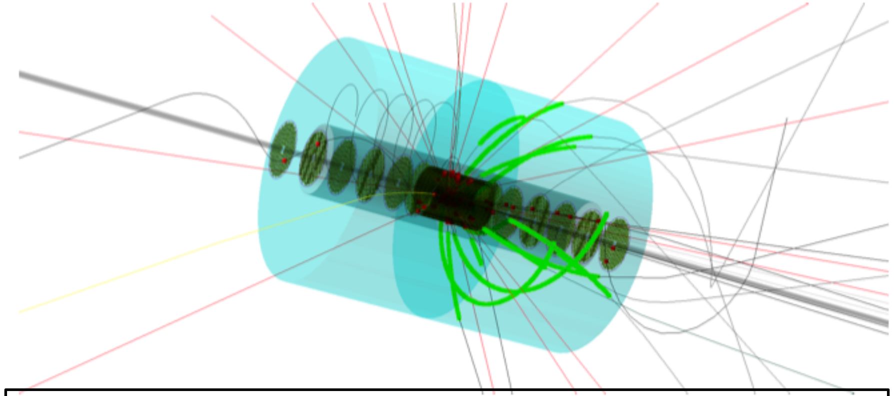
→ Different space requirements

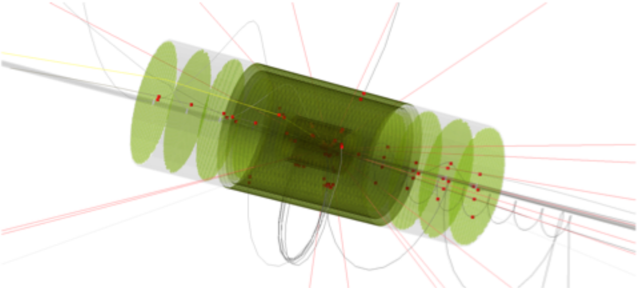
→ Different risks / technology-readiness

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		

… final choices will require detailed simulations and simultaneous optimisation of the full detector, not just individual components

Example Complementarity through Detector Technology Choices: Tracking Region





1) Si + TPC - Based on BeAST

- 80cm outer radius TPC
- MAPS Si inner barrels and disks

2) All Silicon Concept

- 45cm outer radius
- MAPS barrels and disks (15m^2)

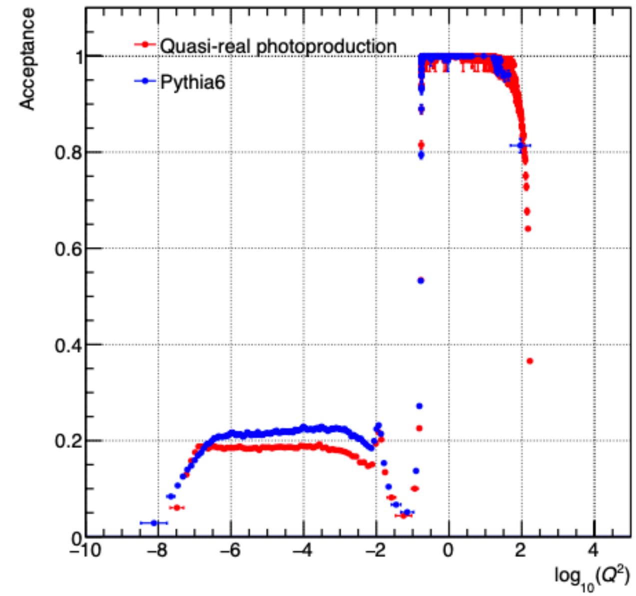
- Si version slightly improves momentum, vertexing performance and saves space to implement other (PID?) detectors

- TPC version provides PID from dE/dx & keeps low material budget

More Opportunities for Complementarity

- Gaps and Cracks

→ e.g. place gap in scattered electron acceptance between main detector and dipole/tagger in different places?
[Also Roman pot / B0 in hadron direction]



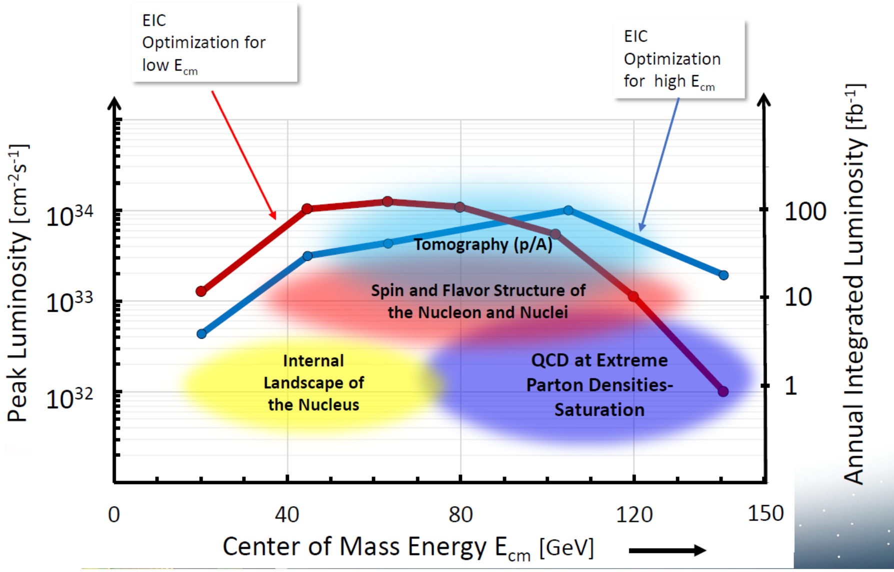
- Optimise to Performance at different $\sqrt{s}$

Assuming EIC runs with varying (staged?) CMS energies …

→ Automatic complementary of kinematic regions corresponding to central acceptance

→ Ongoing work to design a second IR optimised for lumi at reduced $\sqrt{s}$

- Lower β^* with quads closer to the IP?
- Larger crossing angle?
- Reduced proton bunch length
- Increased number of bunches
- Secondary focus → far forward acceptance



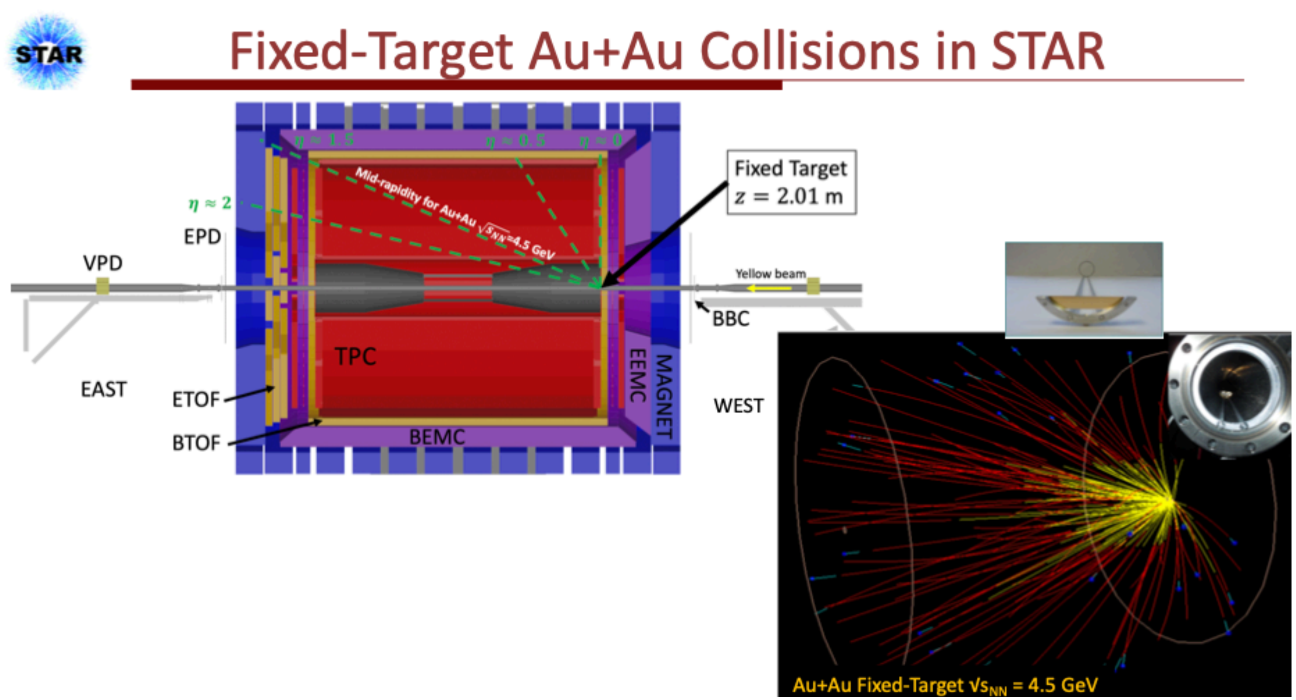
More In-built Complementarity

→ Integrate possibility of fixed target mode into detectors (based on either e- or p-beam) to emphasise new kinematic ranges that would normally be very forward or backward

→ High x physics in ep / eA

→ Novel regions for pp / pA

→ Successfully done previously at ALICE, LHCb, STAR



Summary / Interim Findings

- Essential to robustness of science programme to have two detectors

- To date no compelling arguments for a ‘specialised’ detector

  → working towards two GPDs with complementarity in details such as solenoid field and technology choices.

- Still investigating possibilities for novel IR designs

- Still sharpening up physics arguments

- Progress will ultimately require detailed simulations