Complementarity of EIC Detectors: Introduction to the Working Group

2nd (Virtual / Pavia) EIC
Yellow Report Workshop
22 May 2020

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Background - Why a dedicated Complementary Detectors Group?

- Baseline DoE EIC funding only covers one Interaction Region and Detector

- Second IR funding may come from other (non-DOE) sources … multi-$100M investment (see also detectors EoI call)

- Baseline accelerator design includes two IRs as a boundary condition (IR6, IR8) → non-trivial impact (see Ferdi Willeke)

- **Requires very solid physics justification →**

Complementary Detectors Group Goal:

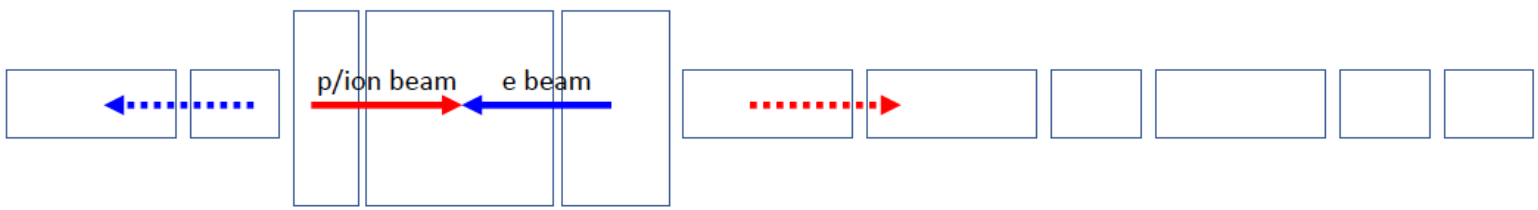
"Collect crisp and clear arguments why two detectors will enhance the physics output of the EIC"

[complementarity includes the IR design, keeping consistency with accelerator design in mind]

What is in place already? - Schematically

Cartoon/Model of the Extended Detector and IR

- ❑ EIC physics covers the entire region (backward, central, forward)
- ❑ Many EIC science processes rely on excellent and fully integrated forward detection scheme



far-backward e detection	e final-focus quads	"Central detector", includes e endcap, central, and p/ion endcap detectors	Ion final-focus quads	far-forward h detection	forward dipole	far-forward h detection	forward dipole	far-forward h detection
Low-Q^2 spectroscopy		Inclusive Structure Functions, TMDs, heavy flavors and jets, electrons for GPDs		Baryon decay π/K structure evaporated n		GPDs/DVCS, tagging, diffraction		lowest-t, diffraction
GEMs Diamond detectors?		Vertex and Tracking detectors, particle identification detectors, calorimetry detectors, muon detectors, etc.		GEMs ZDCs e/γ calorim.		GEMs Roman pots e/γ calorim.		Roman pots GEMs?

physics examples

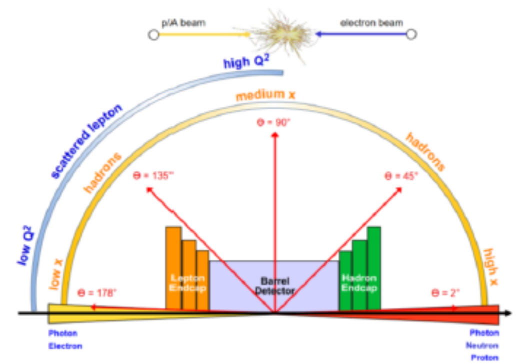
detector examples

[Tanja Horn, Wed 20 May]

What is in place already? - Schematically

The Interactive Detector Matrix

https://physdiv.jlab.org/DetectorMatrix/



- ➢ Supersedes the EIC Detector Handbook
- ➢ Collects physics requirements "real time", lists all technologies for a given region, and links to studies that established the numbers
- ➢ **Is the official EIC set of physics requirements and technology parameters**

View Matrix   View Model   View Help   Login to Edit

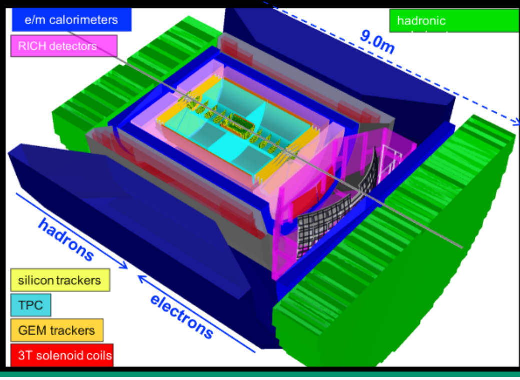
η	Nomenclature			Tracking			Electrons		π/K/p		HCAL	Muons
				Resolution	Allowed X/X0	Si-Vertex	Resolution σE/E	PID	p-Range (GeV/c)	Separation	Resolution σE/E	
-6.9 to -5.8	↓ p/A	Auxiliary Detectors	low-Q2 tagger	σθ/θ < 1.5%; 10-6 < Q2 < 10-2 GeV2								
...												
-4.5 to -4.0			Instrumentation to separate charged particles from photons				2%/√E					
-4.0 to -3.5												
-3.5 to -3.0		Central Detector	Backward Detector	σp/p ~ 0.1%⊕0.5%	~5% or less X	TBD		π suppression up to 1:10^4	≤ 7 GeV/c	≥ 3 σ	~50%/√E	
-3.0 to -2.5												
-2.5 to -2.0				σp/p 0.1%⊕0.5%			2%/√E					
-2.0 to -1.5				σp/p 0.05%⊕0.5%			7%/√E					
-1.5 to -1.0							7%/√E					
-1.0 to -0.5			Barrel	σp/p ~0.05%×p+0.5%		σxyz ~ 20 μm, d0(z) ~d0(rΦ) ~ 20/pT GeV μm + 5 μm	(10-12)%/√E		≤ 5 GeV/c			TBD
-0.5 to 0.0												
0.0 to 0.5												
0.5 to 1.0												
1.0 to 1.5			Forward Detectors	σp/p ~0.05%×p+1.0%		TBD			≤ 8 GeV/c		~50%/√E	
1.5 to 2.0												
2.0 to 2.5									≤ 20 GeV/c			
2.5 to 3.0				σp/p ~ 0.1%×p+2.0%								
3.0 to 3.5									≤ 45 GeV/c			
3.5 to 4.0	↑ e	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 to 4.5												
...			Neutron Detection									
> 6.2			Proton Spectrometer	σintrinsic(|t|)/|t| < 1%; Acceptance: 0.2 < pT < 1.2 GeV/c								

Thanks to: Walt Akers, Elke Aschenauer, Rolf Ent, Thomas Ullrich 11

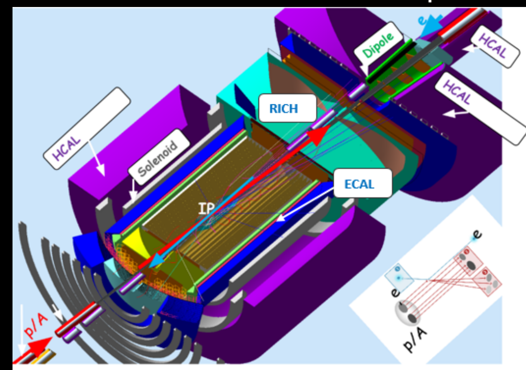
[Tanja Horn, Wed 20 May]

What is in place already? - Detail

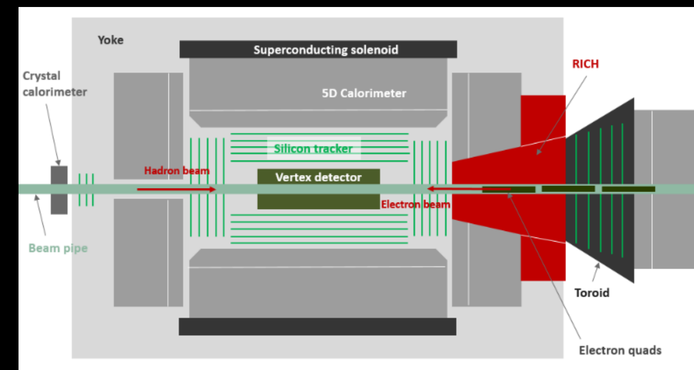
BEAST

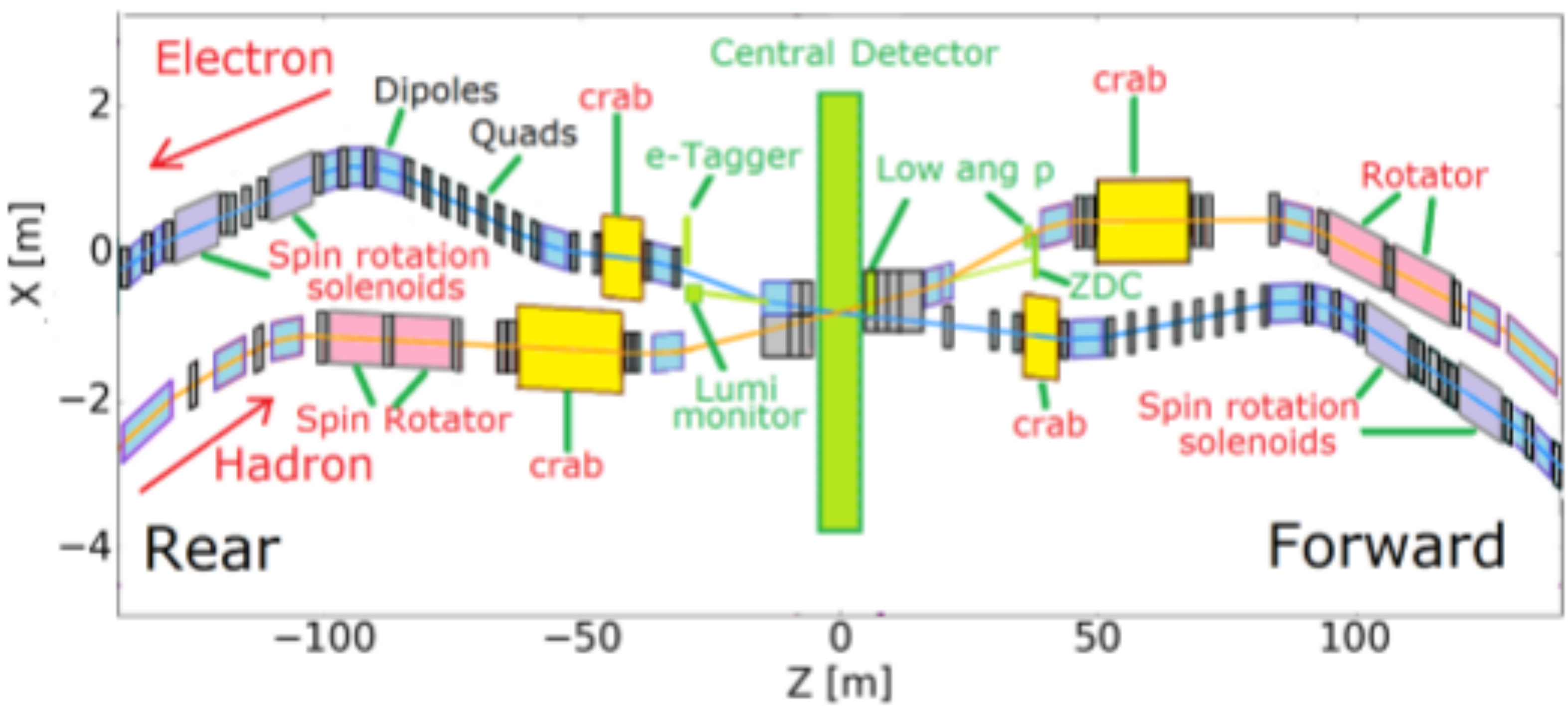


JLEIC Detector Concept



TOPSiDE





Starting Point for Working Group

- We have a pretty good idea how one basic detector design might look (technologies and details not set in stone)

- Second detector is a blank page → major opportunity to refine and enhance EIC physics program

→ can we base design on two complementarity detectors from the outset?

… different approach to energy frontier colliders, where solutions largely based on competition between multi-purpose detectors (H1-ZEUS, DO-CDF, ATLAS-CMS …)

… perhaps more familiar away from energy frontier? (fixed target experiments, RHIC experiments …)

Complementary Detector Motivations

1) Cross-checking important results (obvious!)

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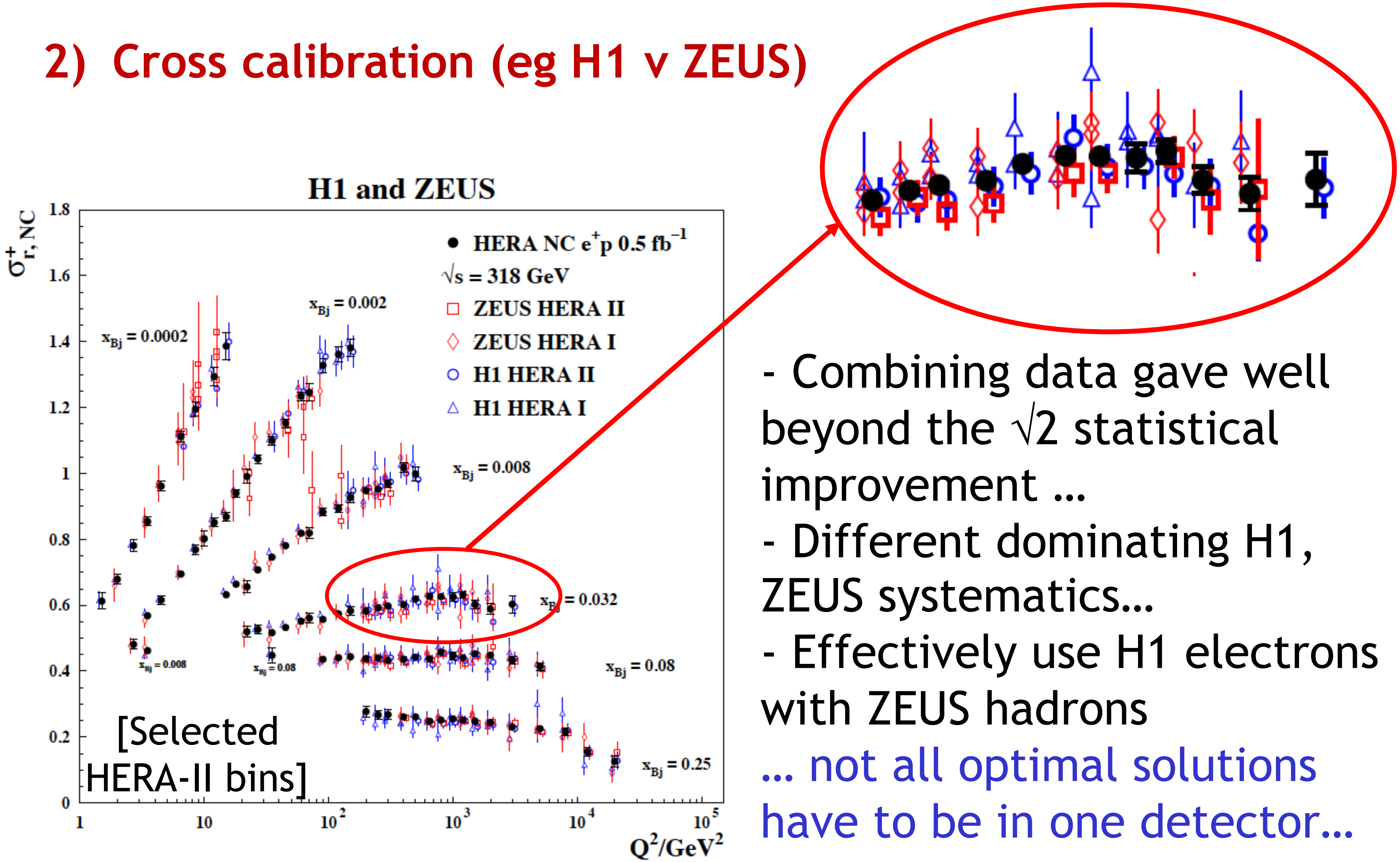
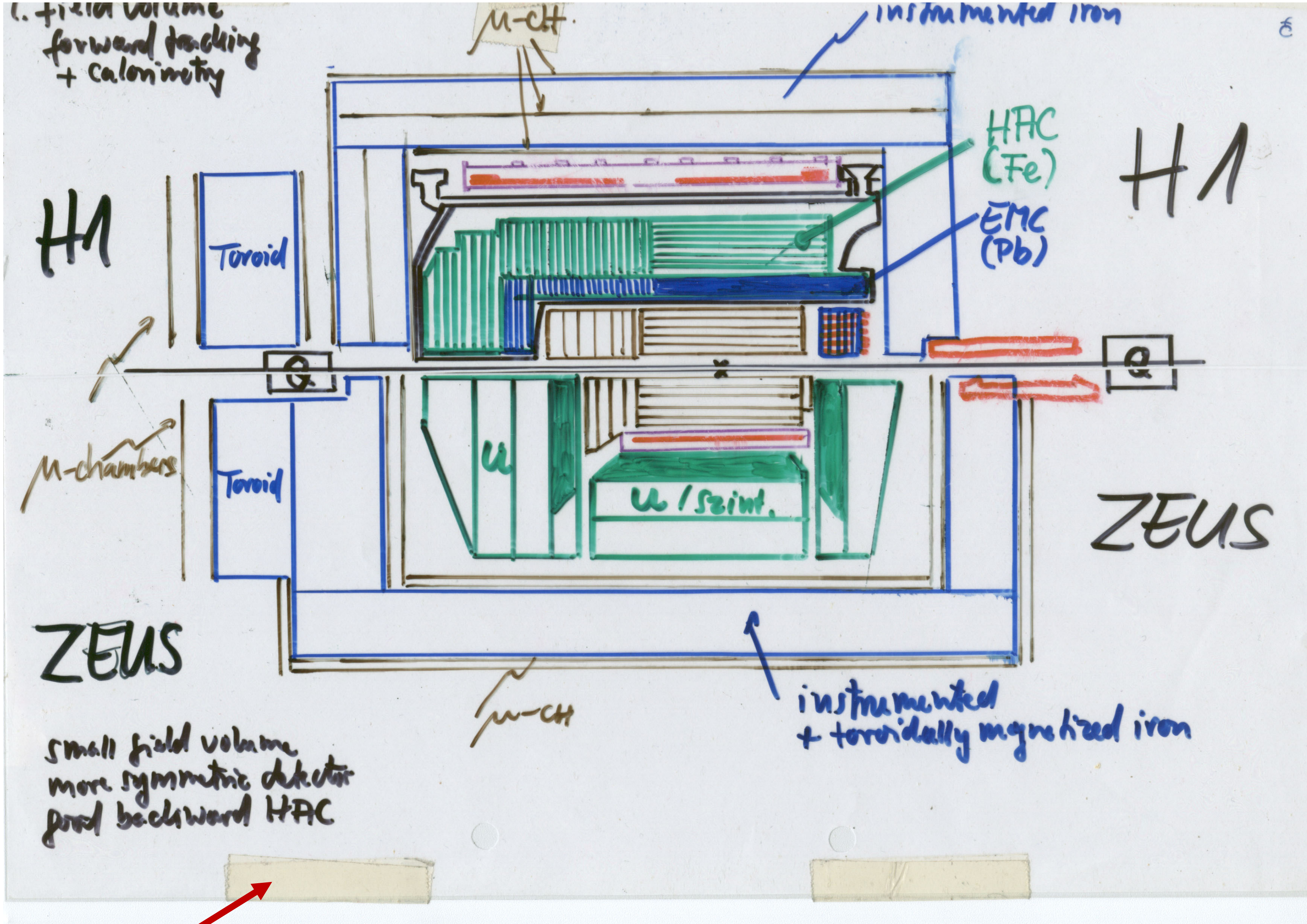
2) Cross calibration (eg H1 v ZEUS)



- 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…

Complementary design of H1 and ZEUS?



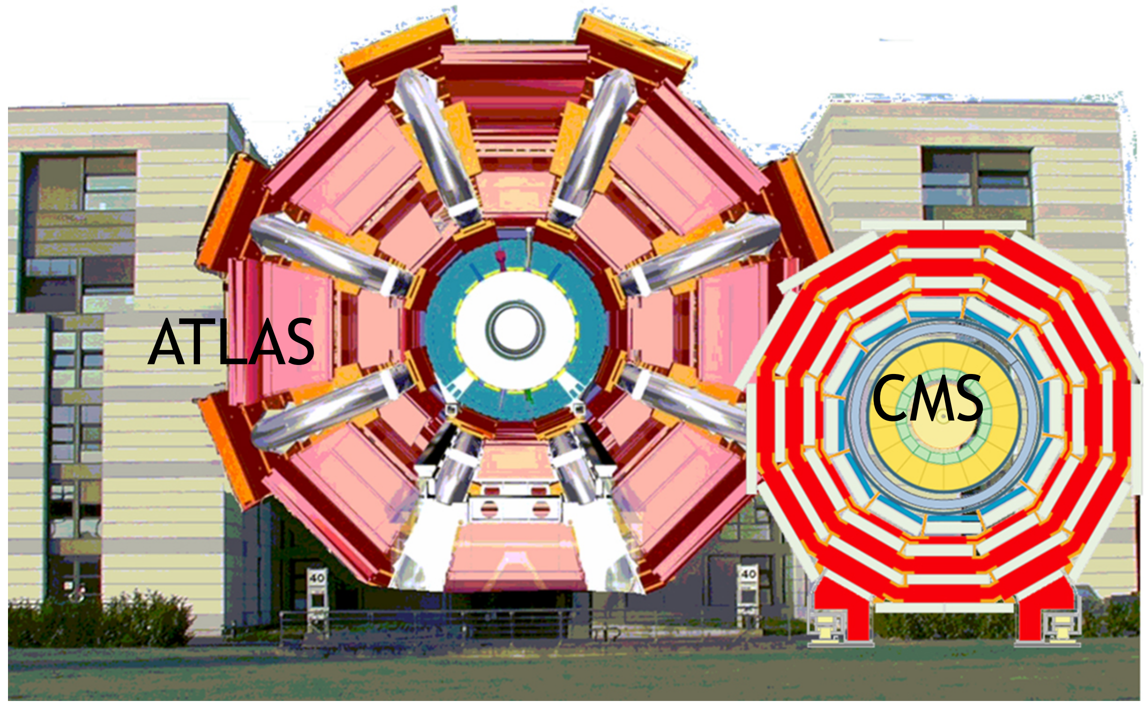
User defined animation

[Franz Eisele, ~ 1986]

Complementary Detector Motivations

3) Redundancy versus unforeseen technology problems …

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



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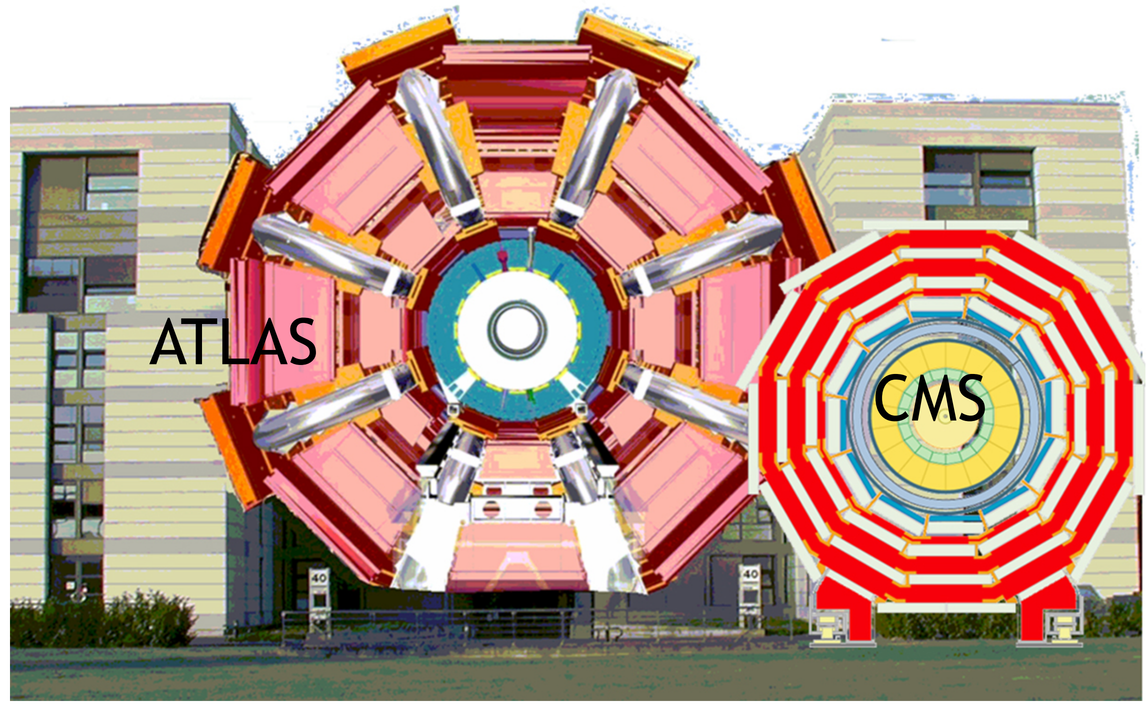


4) Different primary physics focuses …

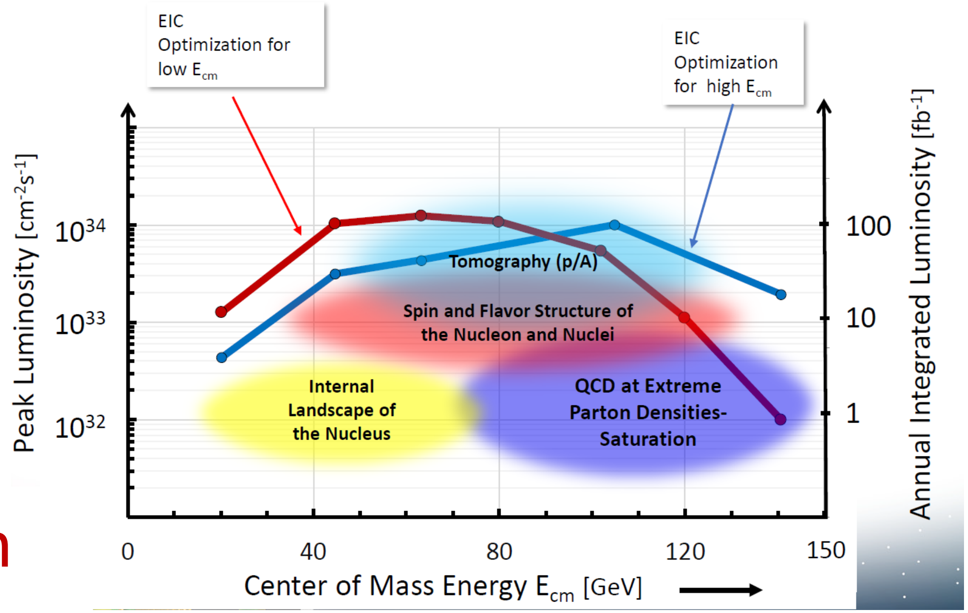
…optimizing overall sensitivity to EIC physics programme?...

→ **Main aim of the working group**

Scope of Different Primary Physics Focus

- Different CMS energies, luminosities can place emphasis on complementary kinematic regions (possible staging?) …

- Some topics (eg far forward) may require dedicated set-up of detector or interaction region



- Other possible key parameters:
  - Polarisation requirements
  - Positrons v electrons?
  - Material budgets
  - Solenoid / forward magnetic field strength
  - Bunch spacing (2ns is discussed …)
  - Space for detector (+/-4.5m longitudinally?)
  - Beamline instrumentation v IR design
  - Technology readiness

Initial Working Group Strategy

1) Discuss detailed aims and needs with Physics Working Group conveners – one or two groups per meeting

→ Basic underlying question (as also posed today): "Have you identified requirements which conflict with the current baseline /schematic detector and IR design?"

→ Detailed set of questions to guide discussion (see next 2 slides)

… and once that's completed …

2) Identify complementarities and conflicts and discuss with Detector Working Group conveners

3) Sketch a baseline plan with 2 detectors / IRs for wider discussion (including fully open meetings)

Questions posed to PWGs to steer discussion

- Can you briefly summarise your planned physics programme in terms of processes of interest and (where applicable) basic kinematic ranges in (x,Q^2) or other relevant variables.

- Which basic detector-level measurements (eg track p_T/η, scattered electron, forward neutron/proton observables, overall HFS, displaced vertices, dE/dx ...) are most essential to realise your physics aims? Can you already say what sort of measurement (acceptance) ranges and resolutions / performance you need?

- For charged particles, how important is low p_T acceptance versus high p_T resolution (this informs the optimal choice of magnetic field)

- How important is integrated luminosity? For the anticipated integrated luminosities, will your observable be systematic or statistics-limited? If you expect to be systematically limited, which systematic source (or sources) are the most important?

Questions posed to PWGs to steer discussion

- How important is polarisation to your physics programme (quantify if possible, in terms of polarisation level and systematic precision requirements)? If applicable, discuss lepton and hadron polarization separately.

- What beam energies are ideal for your physics aims (quantify if possible)?

- How important is the Interaction Region design for your physics observable and do you have criteria that might impact the design? For example, would you be impacted by reduced forward acceptance for neutrons, protons, photons?

Answers to many of these questions known in some detail already (see eg Physics Working Group Summary on Wednesday)

→ May also evolve in time as YR work progresses

→ We will focus on collecting comprehensive information and optimizing response to limitations / conflicts …

Example slide from PWG summary

Summary of studied channels: kinematics

Note : Each kinematic map represents several physics channels

Measurement/ process	Main detector requirement	Expected YR plot	Physics goal/topic	Contact person	Comments
Neutral current e-p cross-sections and asymmetries	EMcal for e- energy, Tracker to reconstruct e- momentum and scattering angle, provide e/h discrimination (via E/p) and e+/e- separation	$A_{\|\|}$, $A_{\perp}$, A^{e}_{PV} $g_{1,2}$, $g^{\gamma Z}_{1,5}$ F_2, F_L, $F^{\gamma Z}_{2,3}$ Δg, g, Δs^{+}, s^{+} σ^{NC}_{red}, $\sin^2\theta_W$	Gluon and quark proton momentum & helicity PDFs. Non-linear QCD dynamics.	Barak Schmookler	✔ e-p 10-100 ▪ e-p 5-41 ▪ e-p 5-100 ▪ e-p 18-275 ? e+/pion maps? ? e-A?
Charged current e-p cross-sections and asymmetries	EMcal, HCal and tracker for E and p of hadronic recoil. Need low thresholds and as forward as possible.	A^{h}_{PV}, σ^{Cc}_{red}, $\Delta u/u$, $\Delta d/d$, high x sbar	Polarized and unpolarized sea quark asymmetries	Xiaoxuan Chu	✔ e-p 18-275

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[Olga Evdokimov, Wed 20 May]

First Detail Meeting Took Place

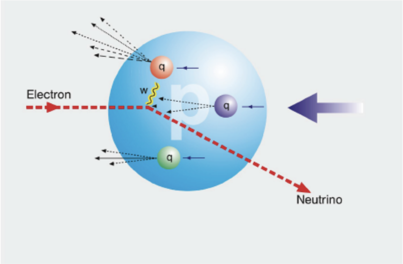
Critical Channels for Detector Development

- The inclusive group covers a large set of physics interests, ranging from gluon helicity to nuclear PDFs and non-linear dynamics.

- Parity violating (A_{PV}) and charged current (CC) channels were singled out, both for high scientific interest and stringent detector requirements.

  I. Inclusive A_{PV} - Small signal requires high precision measurement. Electron PID will be critical.

  II. σ^{CC}_{r} - Reduced cross-section requires reconstruction of Q^2, x from hadronic recoil. Pushing down thresholds for ECAL/HCAL will be critical.



- **Inclusive group** highlights electron PID and precision and thresholds for electron and hadronic recoil

- **SIDIS group**: different topics already lead to different optimal magnetic field choices

For charged particles, how important is low p_T acceptance versus high p_T resolution

- Competing requirements → run at different field strengths?
- Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
  - Need low p_T acceptance for low z and di-hadron partial waves and high p_T resolution for high z
- Gluon Sivers and Gluon Saturation
  - For back-to-back hadrons/dijets p_T resolution more important
- Spectroscopy
  - High p_T resolution (in particular forward) needed for mass resolution
- Lambda Production
  - p_T acceptance critical. High p_T resolution needed for mass resolution to constrain feed-down

- Other groups to follow in future meetings

- Thanks a lot to conveners for their engagement

Today's Open Mic: Questions Posed

- Have you / your WG group identified requirements which conflict with the current baseline detector and IR design

- Do you have suggestion how to most effectively reach the goal

→ Other comments and suggestions welcome
→ Not more than 3 slides each