Food for Thought and to Trigger Discussions

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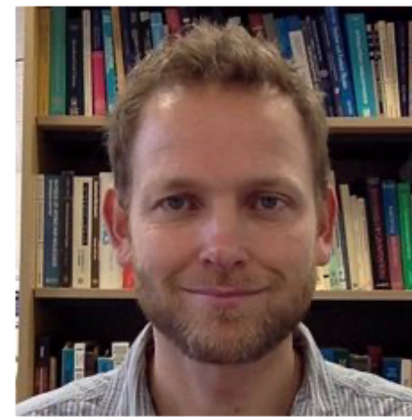
Electron Ion Collider

BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science



Paul Newman as co-convener

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Questions to be answered

- Physics:
  - what physics processes have contradictory requirements not able to consolidate in one detector
  - what physics processes need a dedicated detector / cannot be fulfilled by a general-purpose detector
  - which physics processes need modifications to the EIC IR design
  - what is driving the systematic uncertainties of the measurements you are studying

- Subdetectors:
  - document performance of different subdetector technologies
    - resolution
    - material budget
    - radiation hardness
    - cost and time to construct the subdetector
    - how much longer till the technology is ready for mass production or is it shovel ready
    - what drives the systematics of a subdetector using a specific technology
    - any rate limitations
  - any limitations in the performance for very small bunch spacing =< 2ns
  - is +/- 4.5 m enough to fit the detector

Questions to be answered

- Detector and Physics:
  - What Magnetic field is optimal
  - what inner radius of the magnet is needed
  - any problems if the focusing quadrupoles would be inside the detector volume

  - Simulation tools:
    - Is a fast smearing generator enough to answer the complementarity questions to Physics WGs
    - Do the Detector WGs have all simulation tool in hand to answer the questions
    - Is there any chance to have a complete detector simulation available in the YR time frame

- Provocative Question
  - What is the advantage to have one detector ? IR design which can only do part of the physics program

Funding Requirements

What is included in the Project:

Nomenclature:

experimental equipment includes main and forward detector

interaction region: all accelerator equipment between the crab-cavities including polarimeters and Luminosity monitor and spin rotators

Remember:

US costing includes overhead (location dependent), contingency (35%) and labor costs

to avoid confusion I quote only direct costs for subdetectors and equipment in general

See also Rolf's US Costing 101 slide EICUG_1st_YR_Meeting_Temple_Timeline_v4.pdf

Let's go to numbers:

Interaction Region:

Total: $106 M

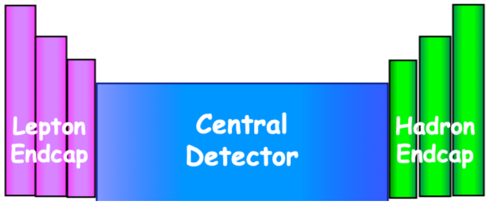
- with IR Magnets + Spin Rotator: $68 M
- Crab cavities: $21 M

Experimental Equipment:

Total: $150M for labor and M&S → more details to come

Funding Requirements

	Cost End 2019	Assumtions
Central Detector		
Magnet	$25,000,000.00	
ECal	$6,142,559.00	reuse large fraction of an ECal, need new readout
HCal	$150,000.00	reuse HCAL preferably integrated to Magent, need new readout
TPC or MM-Barrel	$3,220,000.00	
μ-Vertex	$5,798,263.00	
RICH / DIRC	$10,602,500.00	
Total	**$50,913,322.00**	
Hadron Endcap		
RICH	$10,200,000.00	
ECal	$665,411.00	use existig ECal-towers, need new readout
HCal	$7,316,000.00	
Tracking	$470,000.00	
Tracking behind RICH	$1,206,300.00	
Low-rapidity tracking	$5,239,429.00	
Total	**$25,097,140.00**	
Lepton Endcap		
RICH	$4,241,000.00	
ECal	$5,073,524.00	
HCal	$7,316,000.00	
Tracking	$470,000.00	
Low-rapidity tracking	$5,239,429.00	
Total	**$22,339,953.00**	
Electronics		
DAQ / Trigger	$6,000,000.00	
Infrastructure		
Integration	$12,768,743.44	
Auxilliary Detectors		
ZDC	$650,000.00	
Roman Pots & B0-Detectors	$1,500,000.00	
Low Q_2-Tagger	$500,000.00	
Total	**$2,650,000.00**	
Complete Total:	**$119,769,158.44**	
Cost to Project:	**$59,246,800.44**	



Estimated 315 FTEs over a period of 9 years amounts to $88 M using BNL labor bands

Assumptions:

reuse existing equipment

- ECal towers in Hadron Arm
- HCal towers in Central Det.
- ECal towers in Central Det.
- Reuse an existing Solenoid

- In-kind contributions: in the order of $35M

Funding Requirements

- What is needed for the 2nd detector and IR
  - everything which was discussed on the slide before
  - Detector system: Main and forward detectors \$120 M + the cost for the assumed reused equipment ~\$ 25 M
    - Labor is normally assumed 1:1 to the hardware cost: \$145 M
      - ✓ this number depends strongly on the methodologies used in different countries for costing
  - Interaction Region: \$ 106 M this cost might increase if IR design changes significantly

Total: \$251 M for M&S and equivalent of \$145 M for labor

We can also for 2nd Detector offset M&S cost for experimental equipment reusing existing equipment:

- an other Detector Solenoid
- Jlab has enough $PGWO_4$ towers for a lepton endcap ECal
- BABAR DIRC bars for Central Detector PID
- …… everything else which fulfills the requirements as determined by YR studies

Meeting organization

- Please everybody sign up to eicug-yr-detector-complementarity@eicug.org

- Frequency: every 2 weeks

- want to mix meetings with all Detector and Physics WG conveners only and the EIC-UG as a whole
  - first meetings to establish what work has already been done in the working groups to address the complementarity of two EIC detectors
    - conveners' best people to summarize as they have the overview
  - to make the input from the entire user group constructive will organize a meeting with
    - initial presentation the current status
    - an open mic session people can articulate their ideas and concerns

BACK UP

IR Requirements from Physics

	Hadron	Lepton
Machine element free region	High Luminosity → beam elements need to be very close to IP eRHIC: +/- 4.5 m JLEIC: +/- 3.5 m for main detector	
Beam pipe	Low mass material i.e. Beryllium	
Low Q^2 tagger		Acceptance: $Q^2 < \sim 0.1$ GeV
Zero Degree Calorimeter	60cm x 60cm x 2m @ ~30 m	
scattered proton/neutron acc. all energies for ep	Proton: 0.2 GeV < p_t < 1.3 GeV Neutron: p_t < 1.3 GeV	
scattered proton/neutron acc. all energies for eA	Proton and Neutron: Θ < 6 mrad ($\sqrt{s}$=50 GeV) Θ < 4 mrad ($\sqrt{s}$=100 GeV)	
Integration of detectors	Local polarimeter	
Luminosity	Relative Luminosity: $R = L^{++/--}/L^{+-/-+} < 10^{-4}$	
		γ acceptance: +/- 1 mrad → $\delta L/L < 1\%$

Requirements for EIC Detectors

Requirement	Detector
Vertexing Event vertex, secondary vertices, track impact parameter	Vertex detector Central tracker and solenoid
Electron identification and measurement $-4 < \eta < +4$	Central tracker and solenoid Calorimeter
Jet measurement Excellent energy resolution, kinematic reconstruction $-4 < \eta < +4$	Central tracker and solenoid Calorimeter
Pion/kaon/proton separation Barrel PID needed for p < 10 GeV/c In forward direction needed for p < 50 GeV/c In backward direction needed for p < 10 GeV/c	Central tracker and solenoid Forward dipole/toroid TOF or Čerenkov
Forward proton/ion detection and measurement Large acceptance for momenta up to almost the beam energy	Roman pots with timing
Forward neutron detection and measurement Excellent energy and angle measurement	0^0 calorimeter

Popular choices for the Major Subsystems

Vertex detector → Identify event vertex, secondary vertices, track impact parameters Silicon pixels, e.g. MAPS

Central tracker → Measure charged track momenta
Drift chamber, TPC + outer tracker or Silicon strips

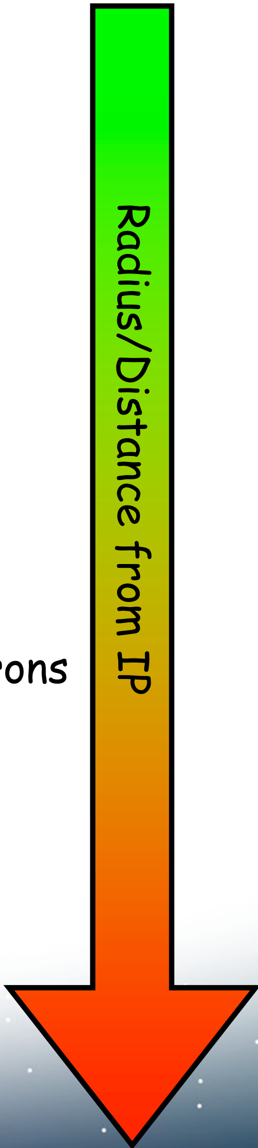
Forward tracker → Measure charged track momenta
GEMs, Micromegas, or Silicon strips, MAPS

Particle Identification → pion, kaon, proton separation
Time-of-Flight or RICH + dE/dx in tracker

Electromagnetic calorimeter → Measure photons (E, angle), identify electrons
Crystals (backward), Shashlik or Scintillator/Silicon-Tungsten

Hadron calorimeter → Measure charged hadrons , neutrons and K_L^0
Plastic scintillator or RPC + steel

+ Beam pipe, Solenoid, very forward and backward detectors



Impact of eRHIC Accelerator Design on Detector Design

high luminosity 10^{33-34} $cm^{-2}s^{-1}$:
- use detector technologies which can with stand high rates and radiation
- focusing magnets as close as possible to IP → confined space of detector

High collision frequency
- separation of signal to background becomes more challenging
  - bunch-by-bunch polarization measurement needs to be adapted

crossing angle
- need excellent vertex resolution to correct for the crossing angle in the measurement

asymmetric beam energies → boosted kinematics → high activity at high $|\eta|$
- a large acceptance detector is a must

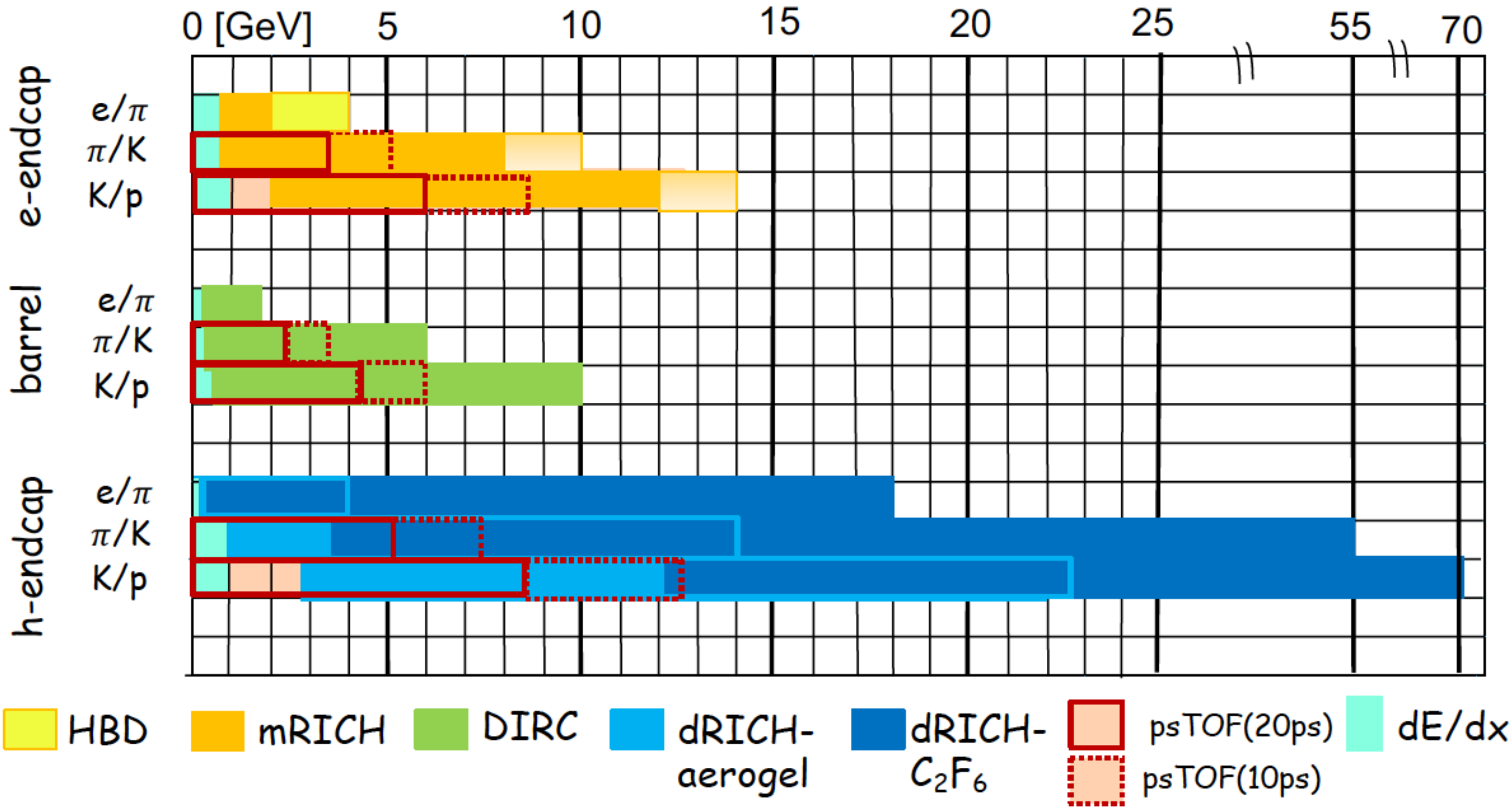
colliding different beam species: ep & eA has consequences for beam backgrounds
→ hadron beam backgrounds, i.e. beam gas events and synchrotron radiation
- detector and IR need protection systems designed in

nuclear beams: D to Pb
- high acceptance for nuclear breakup particles → p,n,γ

polarized electron and hadron (p,d,He-3) beams:
- high precision lepton and hadron polarimetery → bunch-by-bunch
- high precision luminosity measurement → spin sorted

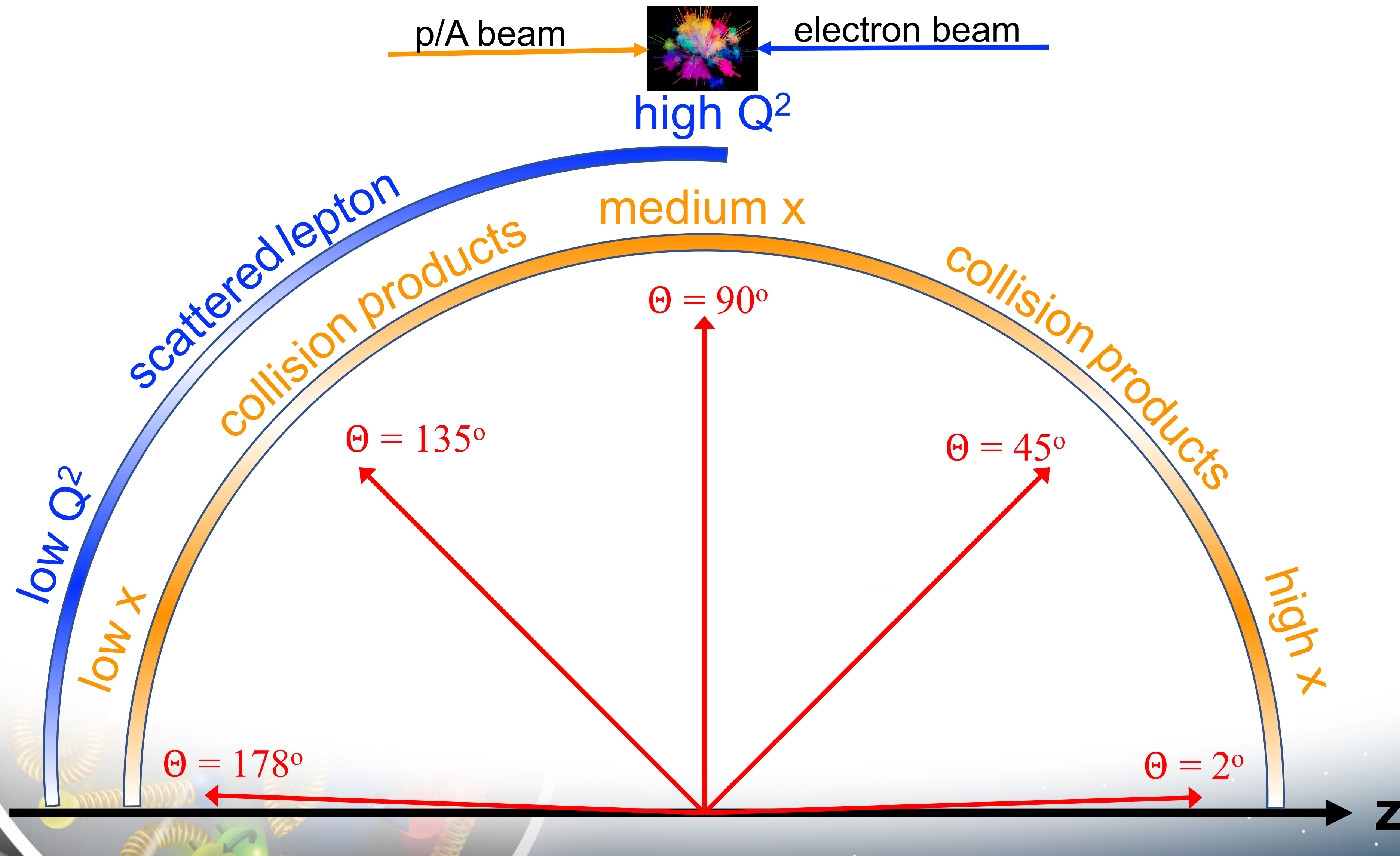
Hadron PID Requirements

Interplay between different technologies

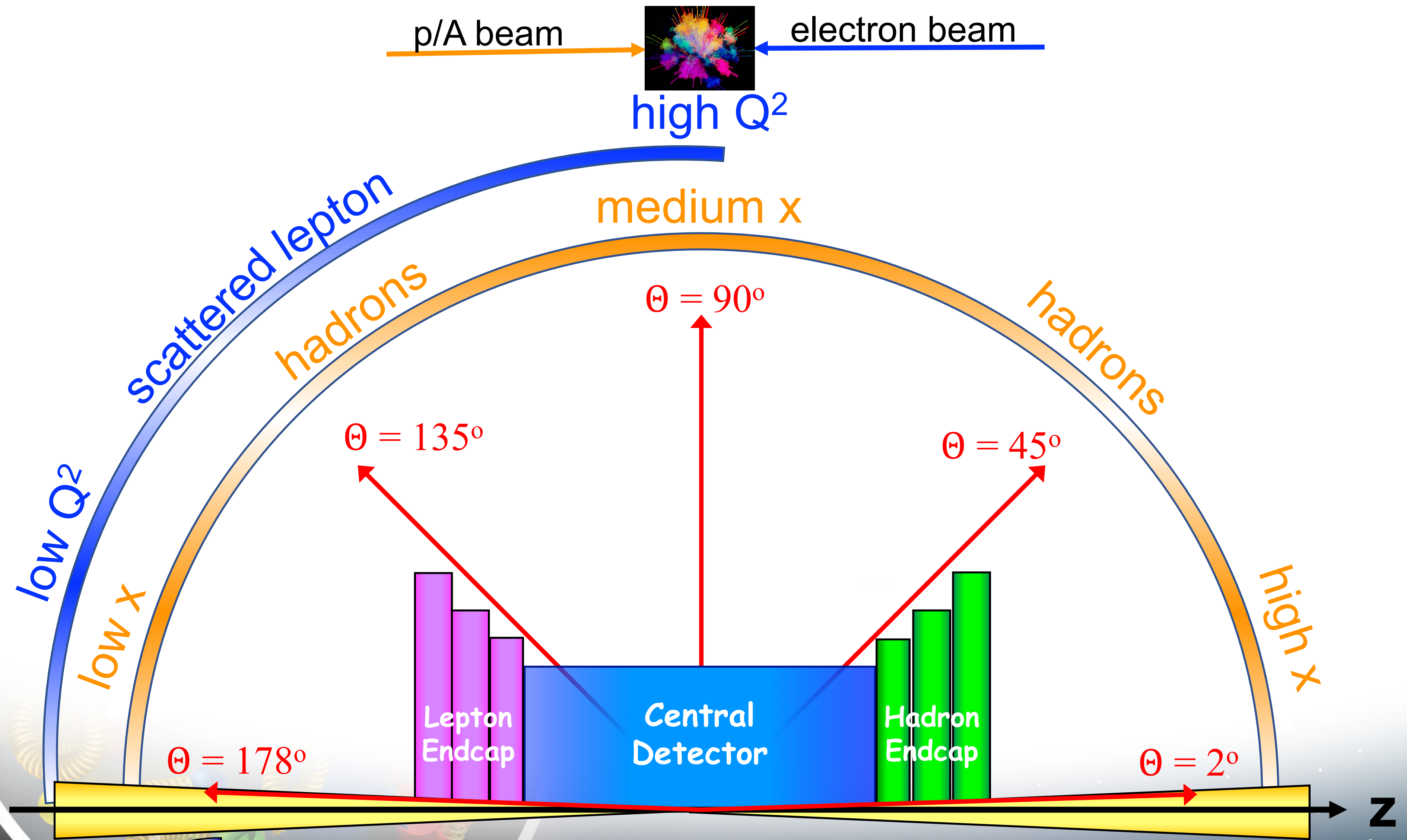


Here, electron/hadron separation shown only from Cherenkov detectors.
Main e/h rejection is done by calorimeters.

EIC General Purpose Detector: Concept



EIC General Purpose Detector: Concept

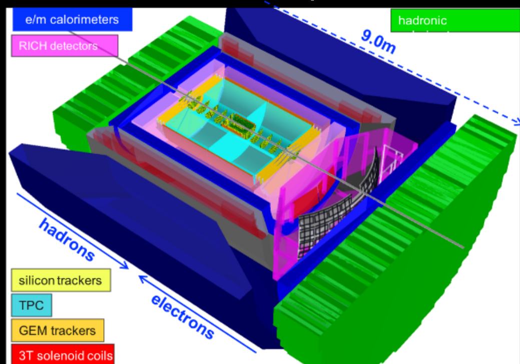


and all the detectors integrated in the IR along the beam line

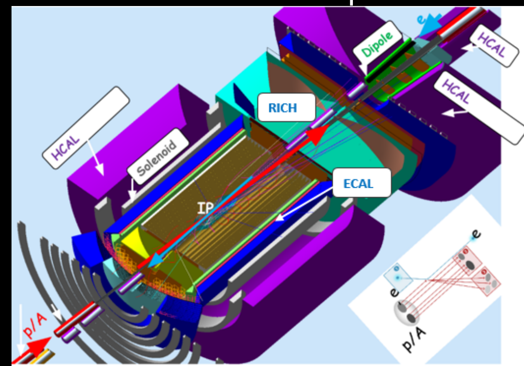
EIC General Purpose Detector Concepts

A general purpose EIC Detector system is complex

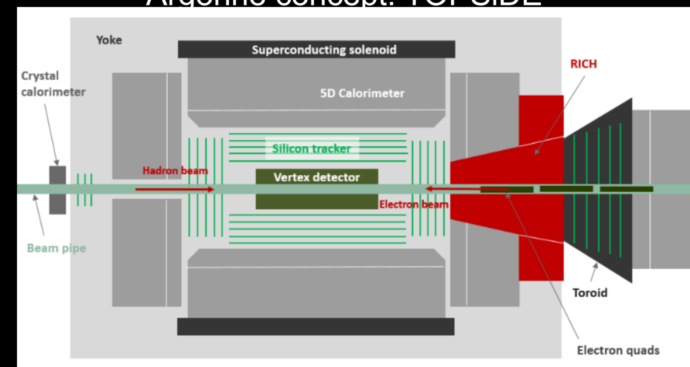
Brookhaven concept: BEAST



Jefferson lab concept: JLEIC



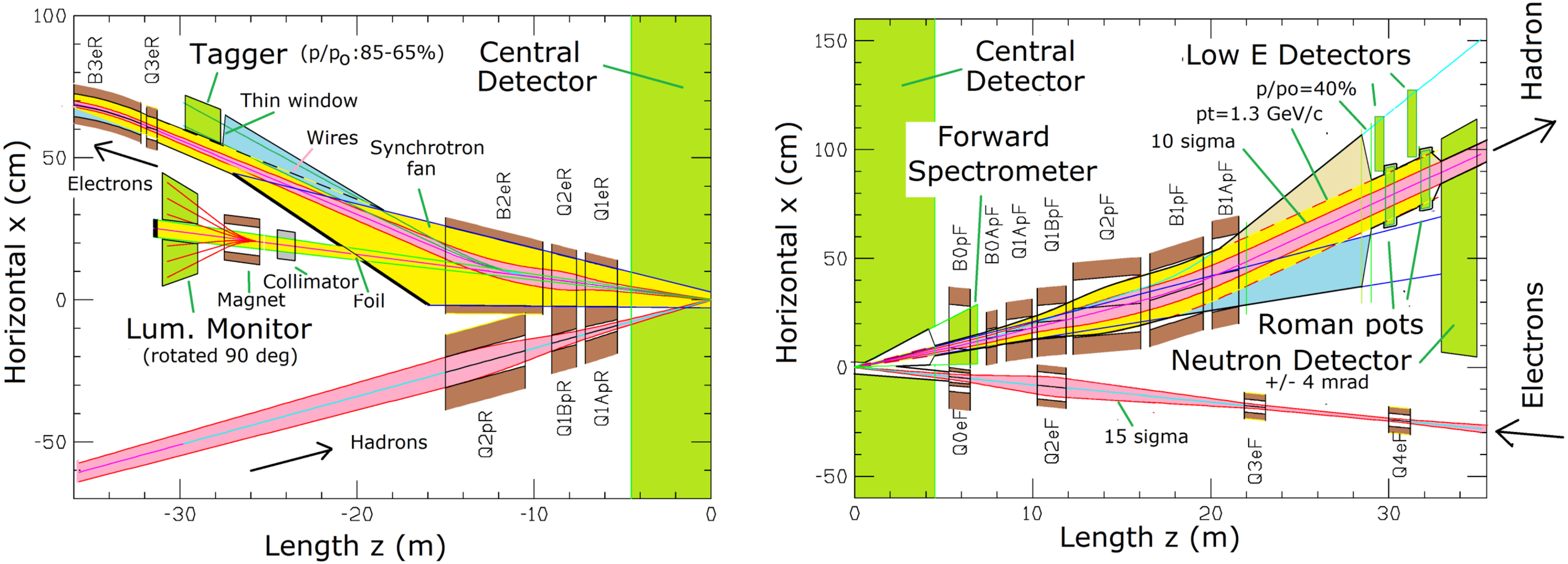
Argonne concept: TOPSiDE



- Large rapidity ($-4 < \eta < 4$) coverage
  - Electromagnetic and Hadronic Calorimetry
  - Particle ID detectors (positive π, K, p identification)
  - Tracking: small (μ-vertex) and large radius (i.e. TPC) Tracking
  - need all to be realized in +/- 4.5 m
- detector components extend along the beam line: Roman Pots, ZDC, …..
- Ancillary Detectors: electron & hadron Polarimetry, luminosity monitors

EIC IR Design

Rear Side **Detector Region** **Forward Side**



crossing angle to separate beams
and avoid synchrotron radiation from dipoles

Important detectors:
Hadron Beam: Si detectors in B0, Roman Pot, low-E Detectors, Zero Degree Calorimeter
Lepton Beam: LowQ^2 tagger
General: Luminosity Detector, electron and hadron polarimetry (different location)