Yellow Report – Detector Working Group

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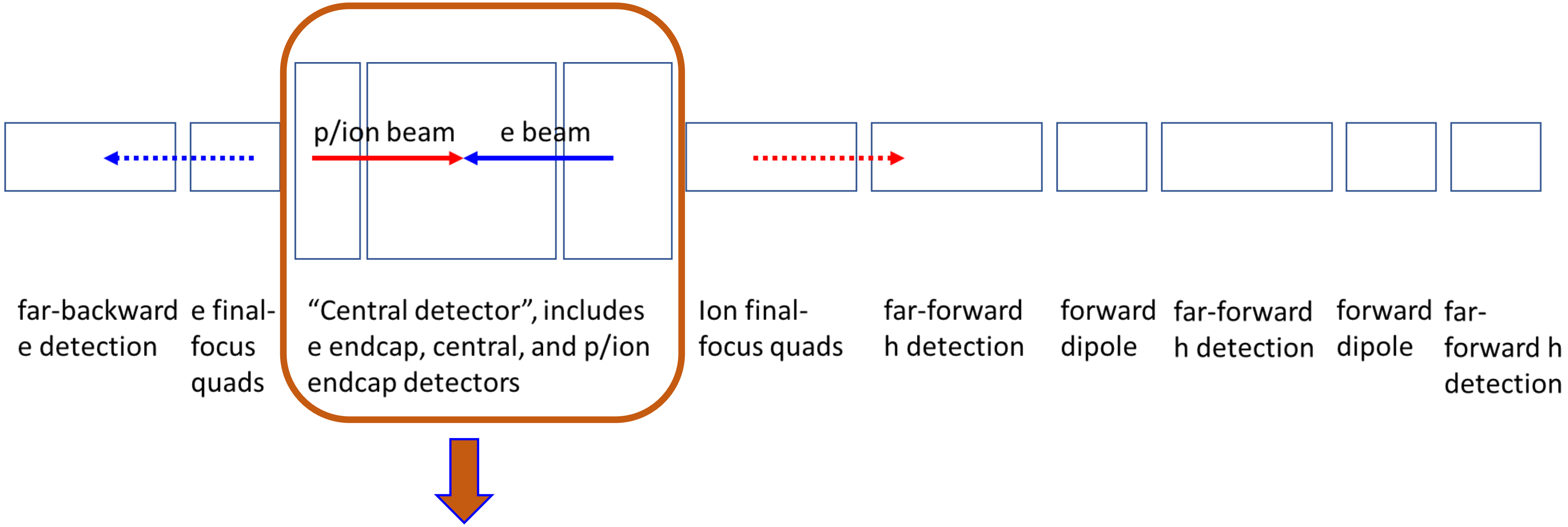
- ❑ Path Towards Integrated Detector Simulations
- ❑ Detector Matrix Review and Moving the Needle Forward

Path towards Integrated Detector Simulations

Cartoon/Model of the Extended Detector and IR



For this discussion focus on the example of the Central Detector

- **Status of simulations for Tracking, Particle ID, and Calorimetry**

Tracking simulation activity summary

Overview:

- working on the main deliverables:
  - ✓ evaluate all-silicon vs hybrid (silicon & gaseous) trackers
  - ✓ compare realistic alternatives (TPC, MPGD options) for gaseous detectors, barrel and forward
- baseline performance studies (mainly EicRoot-based) available at Pavia:
  - ✓ central region Si-vertex + TPC + Fast MPGD Layers
  - ✓ endcap region GEM (MPGD) trackers
  - ✓ all-silicon (barrel) tracker + forward/backward silicon disks
  - ✓ comparisons all-silicon vs BeAST (Si-vertex + TPC + MPGDs) concepts
- recent (increasing) effort within Fun4All simulation framework:
  - ✓ implementation of all-silicon tracker
  - ✓ moving all-silicon layout studies from EicRoot to Fun4All
  - ✓ replacing TPC with MPGD layers
  - ✓ first implementation of Forward Silicon Tracker (FST)

  } new since Pavia
- main available results:
  - ✓ momentum/angular and pointing resolutions in different configurations/options

Tracking simulation activity summary

New since Pavia

Further details on the recent effort within Fun4All:

- ✓ implementation of all-silicon tracker:
  - detailed geometry study (eg material scan to understand features of X/X0 plot)
  - comparison of uniform to realistic B-field (performance compared with BeAST and sPHENIX maps)
  - first studies of jet reconstruction performance (ongoing)
- ✓ moving all-silicon layout studies from EicRoot to Fun4All:
  - managed to export geometries from EicRoot to Fun4All (via GDML)
  - all-silicon layout studies compared: no significant difference between the two frameworks
  - simulation of physics events to be propagated/reconstructed through different layouts (ongoing)
  - plan to check performance on benchmark signals (eg D0 invariant mass reconstruction)
- ✓ replacing TPC with MPGD layers:
  - improved tracker geometry with more realistic material (carbon fiber supports, PCB r/o boards etc)
  - new material budget scan performed (still within requirements)
  - performance (momentum/angular resolutions) re-checked, no significant degradation
  - preliminary simulation of uTPC mode (to be refined)
- ✓ first implementation of Forward Silicon Tracker (FST):
  - 6 FST planes (including 2 time-stamping planes) integrated with 3-layer Si barrel in the Babar magnet
  - preliminary performance at different pseudorapidity vs pixel cell size and sensor thickness
  - geometry and detector configuration to be optimized (ongoing)

Particle ID simulation activity summary

η	Nomenclature	Electrons		$\pi/K/p$		Technology
		Resolution	PID	p-Range	Separation	
-3.5 --> -1.0	Backward Detector	2-7% / √ E	rejection 10^4	≤ 7 GeV/c	> 3-sigma	HBD mRICH TRD LAPPD
-1.0 --> 1.0	Central Detector	10-12% / √ E	rejection 10^4	≤ 5 GeV/c	> 3-sigma	DIRC dE/dx LGAD
1.0 --> 2.0	Forward Detector-1	10-12% / √ E		≤ 8 GeV/c	> 3-sigma	dRICH mRICH LAPPD
2.0 --> 3.0	Forward Detector-1	10-12% / √ E		≤ 20 GeV/c	> 3-sigma	dRICH Gas RICH TRD
3.0 --> 3.5	Forward Detector-1	10-12% / √ E		≤ 45 GeV/c	> 3-sigma	dRICH Gas RICH TRD

Particle ID simulation activity summary

	p-Range @ Radiator L	Contributes to θ_c	Parameterized	Pro/con	External Constraints	Simulation
psec TOF **LGAD TOF**	Up to 10 GeV/c Depends on σ_t and L	N/A	YES	YES	YES	NO
dual RICH (dRICH) **(aerogel, gas)**	2-60 GeV/c @ 1.6 meter	YES • Chromaticity • Emission • Pixelation • Magnetic Field • Tracking	YES	YES	YES • Simulated with constant momentum	YES • GEMC/Geant4 • AI-driven Optimization
GEM RICH **(Gas Electron Multiplier)**	20 - 50 GeV/c @ 1 meter	YES • Chromaticity • (Emission) • Pixelation • Tracking	YES	YES	YES	YES (ePHENIX)
modular RICH (mRICH)	2-10 GeV/c @ 3.0 cm	YES • Chromaticity • Emission • Pixelation • Tracking	~YES	YES	YES (tracking)	YES • GEMC/Fun4All work in progress
Detection of Internally Reflected Cherenkov (DIRC)	0.8 - 6 GeV/c @ 1.7 cm	YES • Tracking • Multiple Scattering • Chromaticity • Emission • Pixelation	YES	YES	YES	YES • GEMC without B-field
$\frac{dE}{dx}$ **(TPC)**	0.5-3 GeV/c @ 60 cm $Ne : CF_4 50 : 50$	N/A	~YES (Parameterized Test Beam)	NO	N/A	YES • Fun4All sPHENIX
Transition Radiation Detector (TRD)	eID only p>1 GeV/c	N/A	NO	NO	N/A	YES • GEMC
Hadron Blind Detector (HBD)	eID only 0.1-4 GeV/c @ 50 cm	N/A	YES (Measured PHENIX HBD)	NO	N/A	YES • Fun4All PHENIX

Calorimetry simulation activity summary

Calorimetry for EIC

η	ECAL							BCAL				
	total depth, cm	**Energy resolution σE/E, %**	**Spacial resolution σX, mm**	**Granularity, mm^2**	**Min. photon energy, MeV**	**PID e/π, π suppression**	**Technology examples***	**total depth, cm**	**Energy resolution σE/E, %**	**Spacial resolution σX, mm**	**Granularity, mm^2**	**Technology examples**
-3.5:-2.0	38	2.2/√E⊕1.0	3/√E⊕1	20×20	20	100	$PbWO_4$ crystals	105	50/√E⊕10	50/√E⊕30	100×100	Fe/Sc
-2.0:-1.0	38 50 50	8.0/√E⊕1.5 7.0/√E⊕1.5 5.0/√E⊕1.5	3/√E⊕1 6/√E⊕1 6/√E⊕1	25×25 40×40 40×40	50 50 30	100	W/Sc Shashlyk Pb/Sc Shashlyk DSB:Ce glass	105	50/√E⊕10	50/√E⊕30	100×100	Fe/Sc
-1.0:1.0	30	12/√E⊕2 14/√E⊕3	3/√E⊕1	25×25	100	100	W/Sc Shashlyk W powder/ScFi	110	100/√E⊕10	50/√E⊕30	100×100	Fe/Sc
1.0:3.5	38 38 50 50	12/√E⊕2 14/√E⊕3 10.0/√E⊕1.5 5.0/√E⊕1.5	3/√E⊕1 3/√E⊕1 6/√E⊕1 6/√E⊕1	25×25 25×25 40×40 40×40	100 100 100 30	100	W/Sc Shashlyk W powder/ScFi Pb/Sc Shashlyk DSB:Ce glass	105	50/√E⊕10	50/√E⊕30	100×100	Fe/Sc

* Additional technologies are under consideration

Calorimetry simulation activity summary

Calorimeter	Region	Simulation type	Status
$PbWO_4$	Backward	Escalade + GEMC	Active
glass TF1	Backward		
DSB:Ce scintillating glass	Backward	Escalade + GEMC	Active
Fe/Sc HCAL	Backward	Geant4	Active
Shashlik	Backward	Geant4 standalone Fun4All	Active
W/SciFi	Barrel	Fun4All	Active
Scintillating glass	Barrel	Escalade	Active
Fe/Sc HCAL	Barrel	Geant4 standalone	Active
W/SciFi	Forward	Fun4All	Active
Shashlik	Forward	Geant4 Standalone Fun4All	Active
DSB:Ce Scintillating glass	Forward	Escalade+GEMC	Active
Glass TF1	Forward		
Fe/Sc HCAL	Forward	Geant4 Standalone	Active

Path towards Integrated Simulations

- Simulations including Geant4 available for all regions of the central detector
  - Simulations also available for forward/backward detectors

- Next step towards integrated simulations is to merge the individual detector simulations into one of the existing tools
  - Make your simulation code available on the GitHub organization of the EIC: https://github.com/eic
  - Instructions on how to integrate standalone simulations into the existing EIC framework can be found on the SWG GitHub: https://eic.github.io/
  - Additional information on the existing tools:

    ESCalate: https://www.youtube.com/watch?v=-wAI9kWoLCs

    Fun4All: https://www.youtube.com/watch?v=fONXYf7IsP0

    EicToyModel: https://github.com/eic/EicToyModel