UNIVERSITY OF BIRMINGHAM

Status of tracker development

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EIC UK meeting

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For more details please refer to eRD25 report, March 2021, https://wiki.bnl.gov/conferences/images/3/36/ERD25-Mar20-final.pdf

Vertex and tracking at EIC

- All proposed EIC detector concepts are equipped with a vertex and tracking detector as their innermost element

- A well integrated, large acceptance vertex and tracking detector designed with high granularity and low material budget is needed to enable high precision measurements that are key to the EIC science programme

- The tracking and vertexing systems under consideration are based on semiconductor detector technologies and gaseous tracking detector technologies, with concept combining both technologies

Tracking requirements from physics

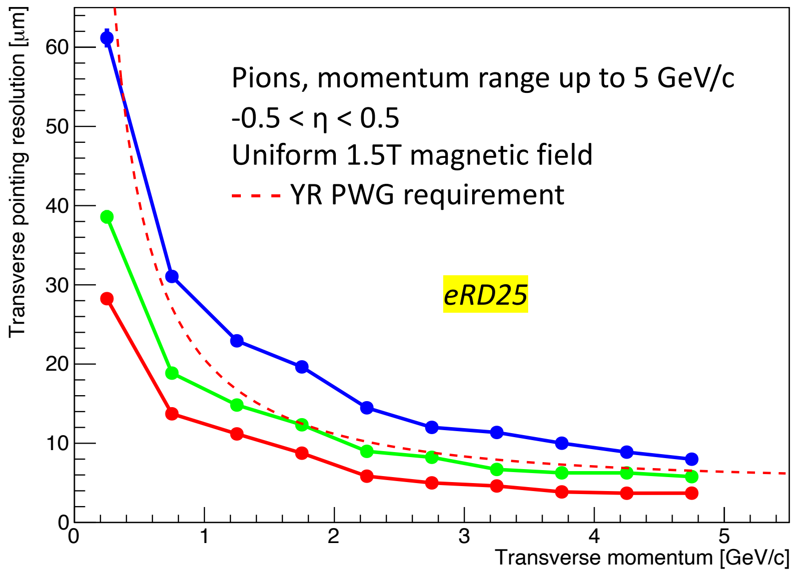
Tracking requirements from PWGs						
			Momentum res.	Material budget	Minimum pT	Transverse pointing res.
η						
-3.5 to -3.0	Central Detector	Backward Detector	σp/p ~ 0.1%×p ⊕ 0.5%	~5% X0 or less	100-150 MeV/c	
-3.0 to -2.5					100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 40 µm
-2.5 to -2.0			σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 20 µm
-2.0 to -1.5					100-150 MeV/c	
-1.5 to -1.0					100-150 MeV/c	
-1.0 to -0.5		Barrel	σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 20/pT µm ⊕ 5 µm
-0.5 to 0						
0 to 0.5						
0.5 to 1.0						
1.0 to 1.5		Forward Detector	σp/p ~ 0.05%×p ⊕ 1%		100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 20 µm
1.5 to 2.0					100-150 MeV/c	
2.0 to 2.5					100-150 MeV/c	
2.5 to 3.0			σp/p ~ 0.1%×p ⊕ 2%		100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 40 µm
3.0 to 3.5					100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 60 µm

From YR 11.2.2 at arXiv:2103.05419

- Silicon requirements:
  - Spatial resolution: ~5 µm in tracking layers and disks (~20 µm pixel pitch), ~3 µm in the vertex layers (~10 µm pixel pitch)
  - Material budget: <0.8/0.3% X/X0 per layer/disk, < 0.1% X/X0 per vertex layer
  - Power consumption 20 - 40 mW/cm^2
  - Integration time ~2 µs

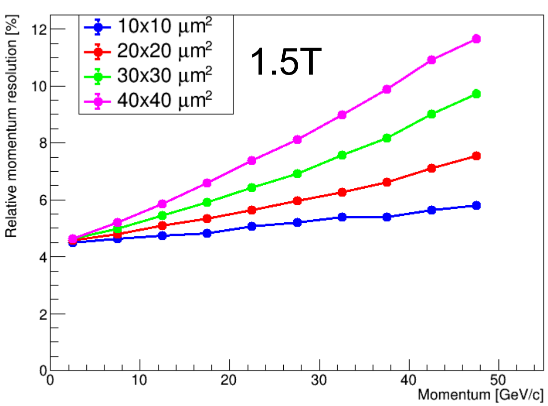
Simulation driven technology choice

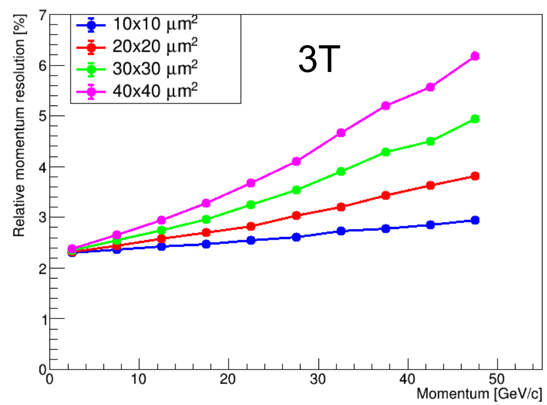
- Pre-YR simulations showed the need for high granularity and low material budget



	Green	Blue	Red (ITS3 derived EIC SVT)
Beam pipe radius [mm]	18	**31**	**31**
x/X0 vertex	0.3%	0.3%	**0.05%**
x/X0 tracking layers	0.8%	0.8%	0.8%
Pixel pitch [um]	20	20	**10**

A beam pipe radius of 18 mm and a pixel pitch of 20 um were used in pre-CD0 simulations.





Forward region studied; η = 3
Single electrons fired from centre
Magnetic field: uniform 1.5 T and 3 T
Vertex layers and disks: 0.3% x/X0
Tracking layers: 0.8% x/X0
Beam pipe radius: 18 mm
See H. Wennlöf at http://cern.ch/go/xKk6

ITS3-derived EIC SVT

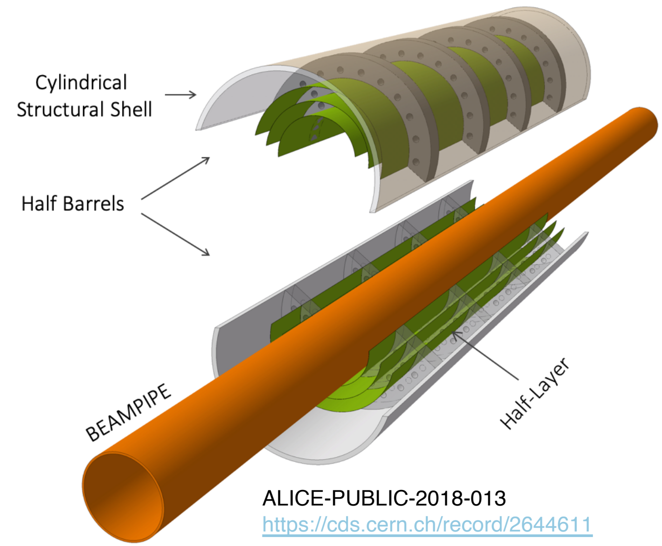
- 65 nm MAPS sensor, 10 µm pixel pitch, <20mW/cm^2
- ITS3 concept for the vertexing layers
  - Wafer scale sensor, thin and bent around beam pipe
  - <0.1% X/X0
- EIC variant for the staves and discs
  - Sensor size vs yield optimisation (stitched but not wafer scale), conventional stave and disc structures, work on cooling, structure and services to meet X/X0

ALICE

Specifications

Parameter	ALPIDE (existing)	Wafer-scale sensor (this proposal)
Technology node	180 nm	65 nm
Silicon thickness	50 µm	20-40 µm
Pixel size	27 x 29 µm	O(10 x 10 µm)
Chip dimensions	1.5 x 3.0 cm	scalable up to 28 x 10 cm
Front-end pulse duration	~ 5 µs	~ 200 ns
Time resolution	~ 1 µs	< 100 ns (option: <10ns)
Max particle fluence	100 MHz/cm^2	100 MHz/cm^2
Max particle readout rate	10 MHz/cm^2	100 MHz/cm^2
Power Consumption	40 mW/cm^2	< 20 mW/cm^2 (pixel matrix)
Detection efficiency	> 99%	> 99%
Fake hit rate	< 10^{-7} event/pixel	< 10^{-7} event/pixel
NIEL radiation tolerance	~3 x 10^{13} 1 MeV n_{eq}/cm^2	10^{14} 1 MeV n_{eq}/cm^2
TID radiation tolerance	3 MRad	10 MRad

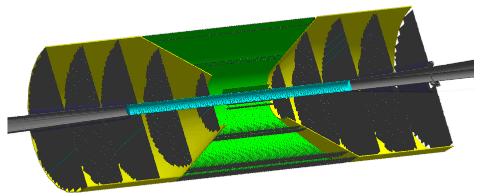
M. Mager | ITS3 kickoff | 04.12.2019 |

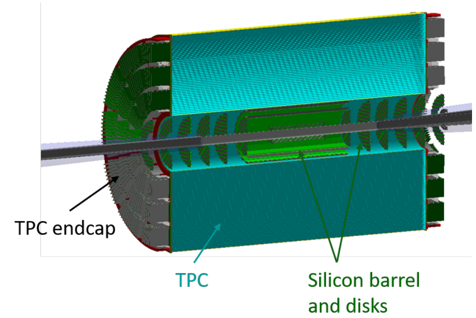


ALICE-PUBLIC-2018-013
https://cds.cern.ch/record/2644611

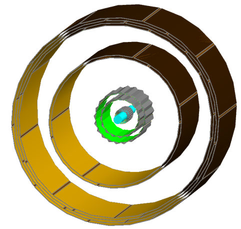
YR concepts

- Baseline concepts: all-silicon and hybrid (MAPS + TPC)

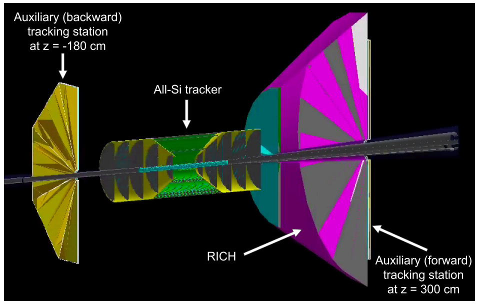


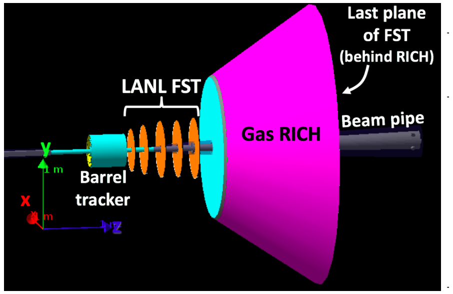


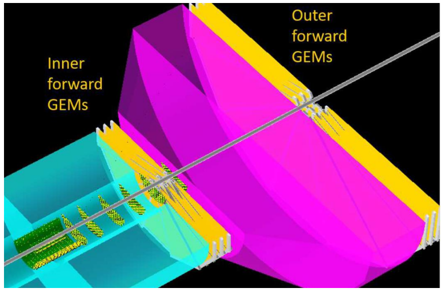
- MAPS + MPGD-based barrel



- Alternative tracking options exist in the backward and forward tracking regions





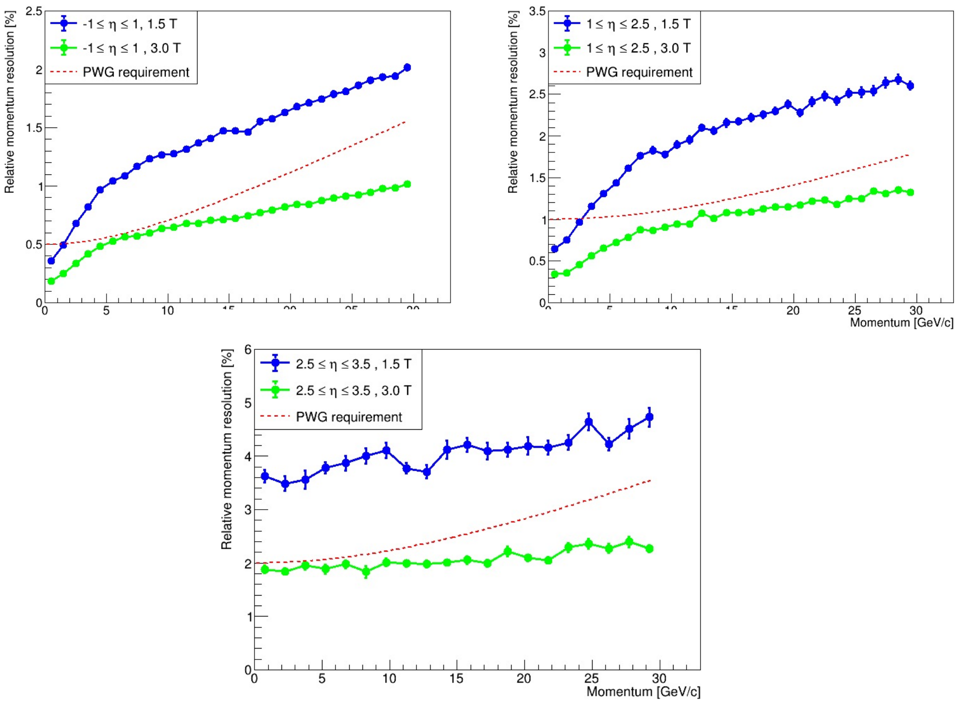


For more details see YR 11.2 at arXiv:2103.05419

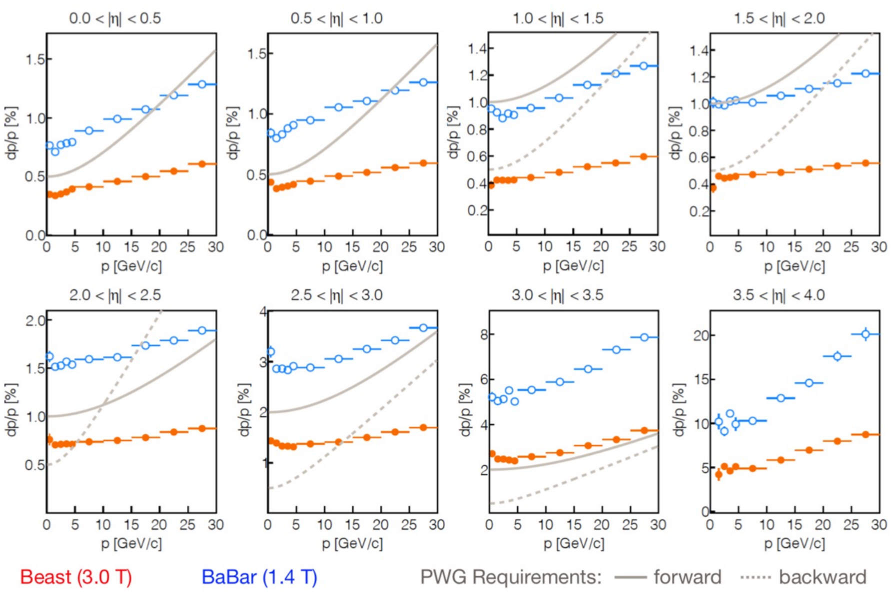
YR baseline concepts performance

- Transverse pointing resolution: requirements satisfied at both 1.5T and 3T at all pseudo-rapidity
- Relative momentum resolution: requirements better satisfied for the higher field value and in the central pseudo-rapidity region

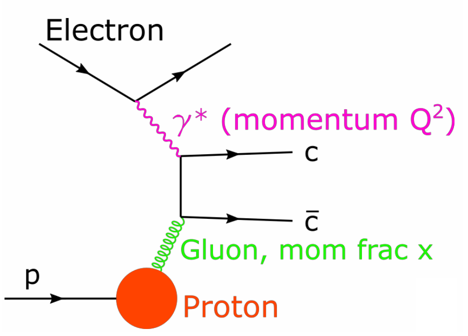
Hybrid – H. Wennlöf (Birmingham)



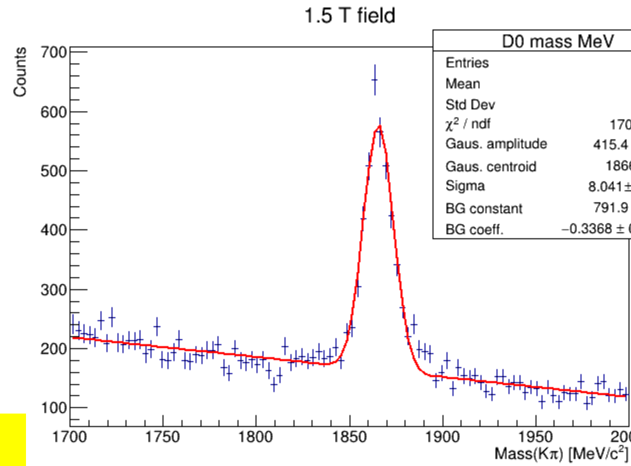
All-silicon, R. Cruz-Torres, LBNL

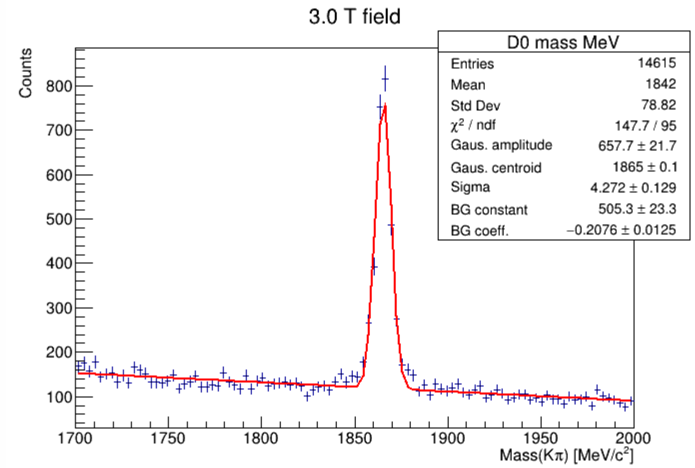


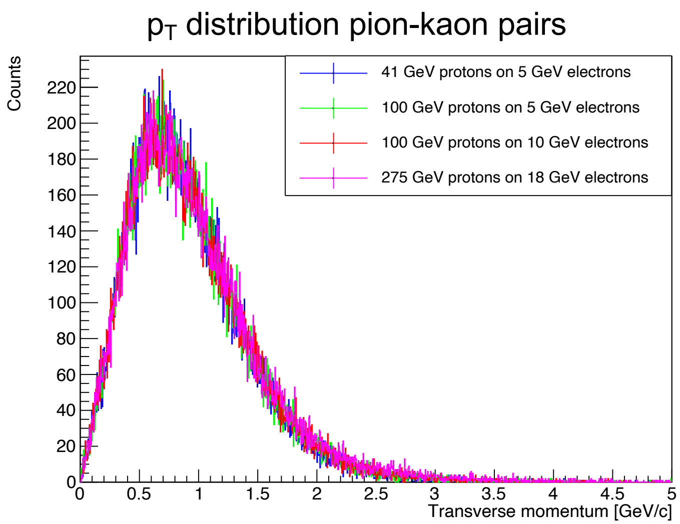
Hybrid Concept – Physics performance studies

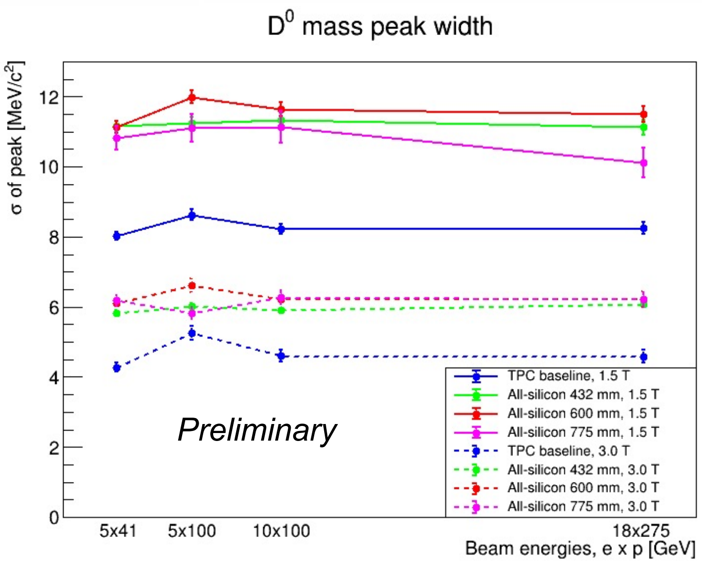


H. Wennlöf (Birmingham)









For more on all-silicon concept see arXiv:2102.08337

Current work in proto-collaborations

- Tracking working groups exist in both EIC@IP6 and ECCE

- Example: EIC@IP6 tracking WG
  - Identify no more than 2 technologies that will be costed and integrated into the full detector system
  - Choice of technology based on assessment of technical capabilities, available workforce, technology readiness on the available timescale, simulation output
  - Optimise previous YR layouts based on technology down select, updated B-field maps, beam crossing angle, etc.
  - Detailed estimation of services and support

EIC SC consortium

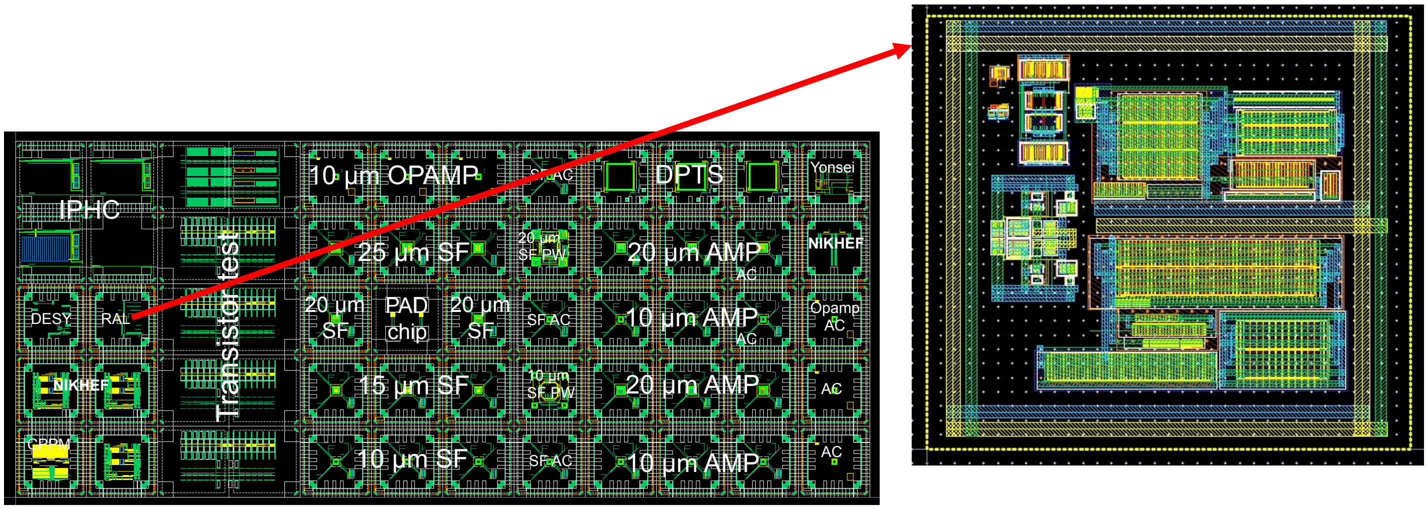
- The development of an ITS3 derived EIC vertex and tracking detector is carried out by the EIC Silicon Consortium
  - EOI: https://indico.bnl.gov/event/8552/contributions/43219/
  - LBNL, Uni Birmingham, RAL, BNL, INFN leadership
  - To join: https://lists.bnl.gov/mailman/listinfo/eic-rd-silicon-l
  - Indico: https://indico.bnl.gov/category/354/

- The EIC SC is open to institutes from different emerging collaborations interested to work on the proposed sensor solution for their specific EIC detector implementation
  - Similar concept to the CERN RD groups (such as RD50, RD53)
  - This will maximise the successful delivery of the technology with the lowest cost to the project

- Work packaged defined; work ongoing with ITS3 on sensor design, and thinning and bending
- Silicon strategy document, estimate of R&D costs, timeline of development up to CD4 drafted and shared with to the EIC project detector systems coordinators

Sensor development

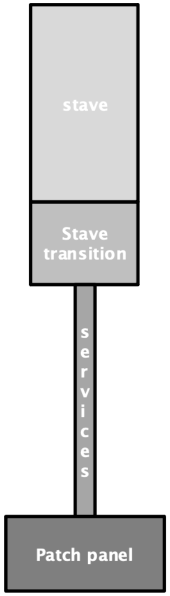
- RAL already involved in first 65 nm submission with ITS3 Work Package 2 (first EIC institute involved in EIC MAPS design at this stage!)
  - Funded via the EIC Generic Detector R&D programme, project eRD25 Silicon Tracking and Vertexing Consortium, Birmingham/LBNL/RAL



- ITS3 ER1 submission planning ongoing, including stitched matrix, submission later this year
- RAL+Brunel, LBNL and BNL defining contribution in discussion with ITS3 sensor design group (Walter Snoeys, Gianluca Aglieri Rinella)

Work on services and supports

- Material estimates for services and supports available (extrapolation based on ALICE ITS2 with ITS3 sensor power consumption)
  - Implemented already in EIC YR hybrid baseline concept



	Stave X/X0	Stave transition (per 100 cm^2 of Si surface)	Services (per 100 cm^2 of Si surface)	Patch panel (per 100 cm^2 of Si surface)
ITS3 like vertexing	~0.1%	6.66 cm^3 of material with X/X0 of 0.0684 per traversed cm	2.96 cm^2 cross section with X/X0 of 0.022 per traversed cm	4.32 cm x 1cm x 1 cm with 0.102 X/X0 per traversed cm
ITS3 like barrel (up to 1.5m length)	0.55 %	4.286 cm^3 of material with X/X0 of 0.0684 per traversed cm	1.905 cm^2 cross section with X/X0 of 0.022 per traversed cm	2.778cm x 1cm x 1 cm with 0.102 X/X0 per traversed cm
ITS3 like disc (up to 60 cm diameter)	0.24%	6.66 cm^3 of material with X/X0 of 0.0684 per traversed cm	2.96 cm^2 cross section with X/X0 of 0.022 per traversed cm	4.321 cm x 1cm x 1 cm with 0.102 X/X0 per traversed cm

https://indico.bnl.gov/event/8231/contributions/37955/
https://indico.bnl.gov/event/9080/contributions/40920/

- Detailed review of powering options including possible configurations with DC-DC converter or serial powering, estimate of material budget and timescale for development carried out and summarised in a document
  - https://www.eicug.org/web/sites/default/files/Powering-options-for-an-EIC-silicon-tracker.pdf

Conclusion

- Work on the development of a vertex and tracking system for the EIC is well underway

- Baseline concepts developed and validated for the YR exercise

- Technology choice driven by physics requirements: 65 nm MAPS, ITS3 derived EIC detector

- Tracking concepts further developed within proto-collaborations and EIC Si Consortium
  - Good time to join the effort with whatever resource available
  - Lots of work to do/possibilities to engage