LBNL

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UC Riverside - January 16, 2020

A few assorted comments, really

LBNL EIC past involvement:

LBNL/my closing slide from our September 2019 meeting

1. Make and establish EIC science case (Feng, Ernst),
2. Forward/backward tracking (Barbara, Ernst, Yue Shi, students),
3. One LBNL supported LDRD (Spencer et al.),
   - STAR-light evolved to eSTAR-light,
   - some effort related to Si-based tracking, jet-studies,
4. eRD16 (Barbara, Ernst, Yue Shi)
5. EIC User Group roles (Barbara, Ernst)

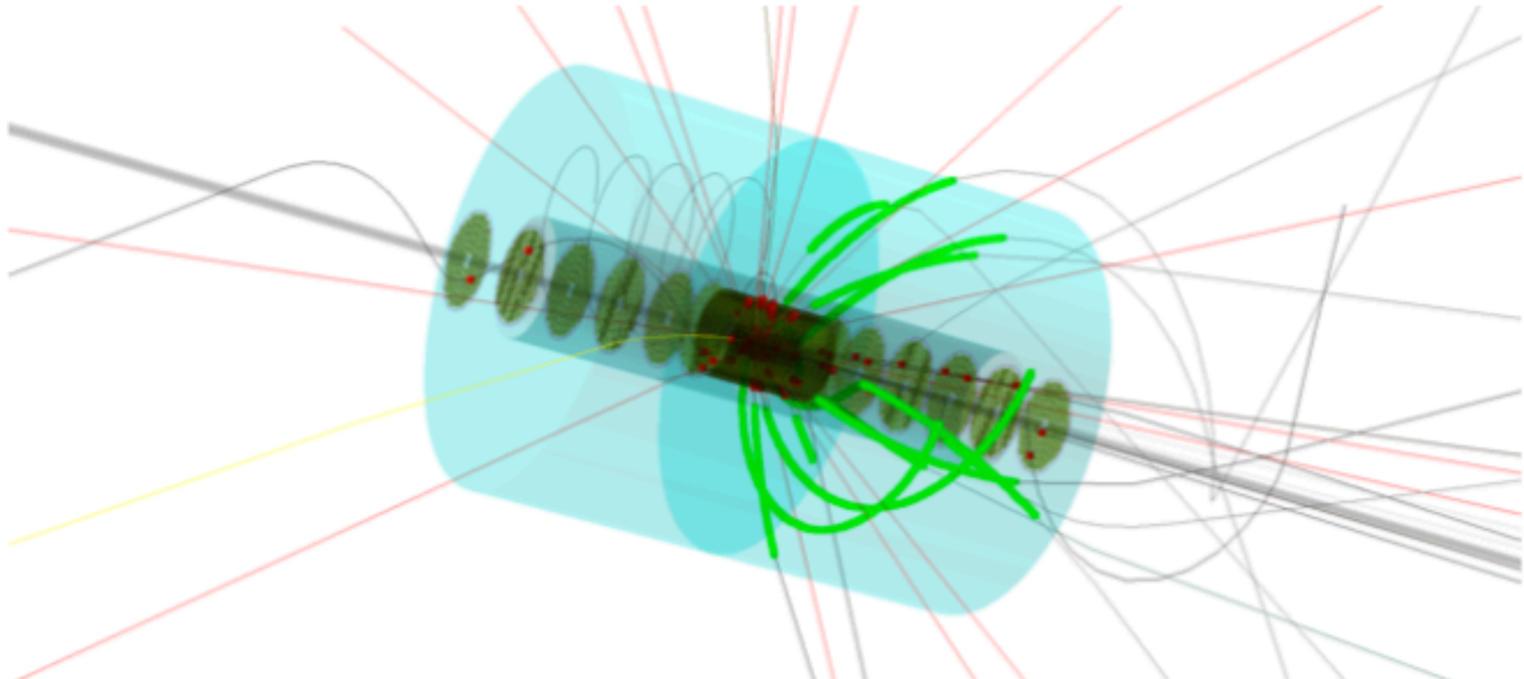
My take on current status:

1. Some EIC timelines will be much sooner than many have internalized,
2. Real opportunity to “think big” in terms of tracking,

Near-term plans:

1. eRD16 effort will simulate all-Si tracker performance,
   - (some) overlap with SIDIS and jet studies, displaced vertices,
2. eSTAR-light and related effort will continue,
3. Stated interest in fast-sensor development,
4. Real need (and strengths) for integration,
5. Future EICUG roles to be seen.

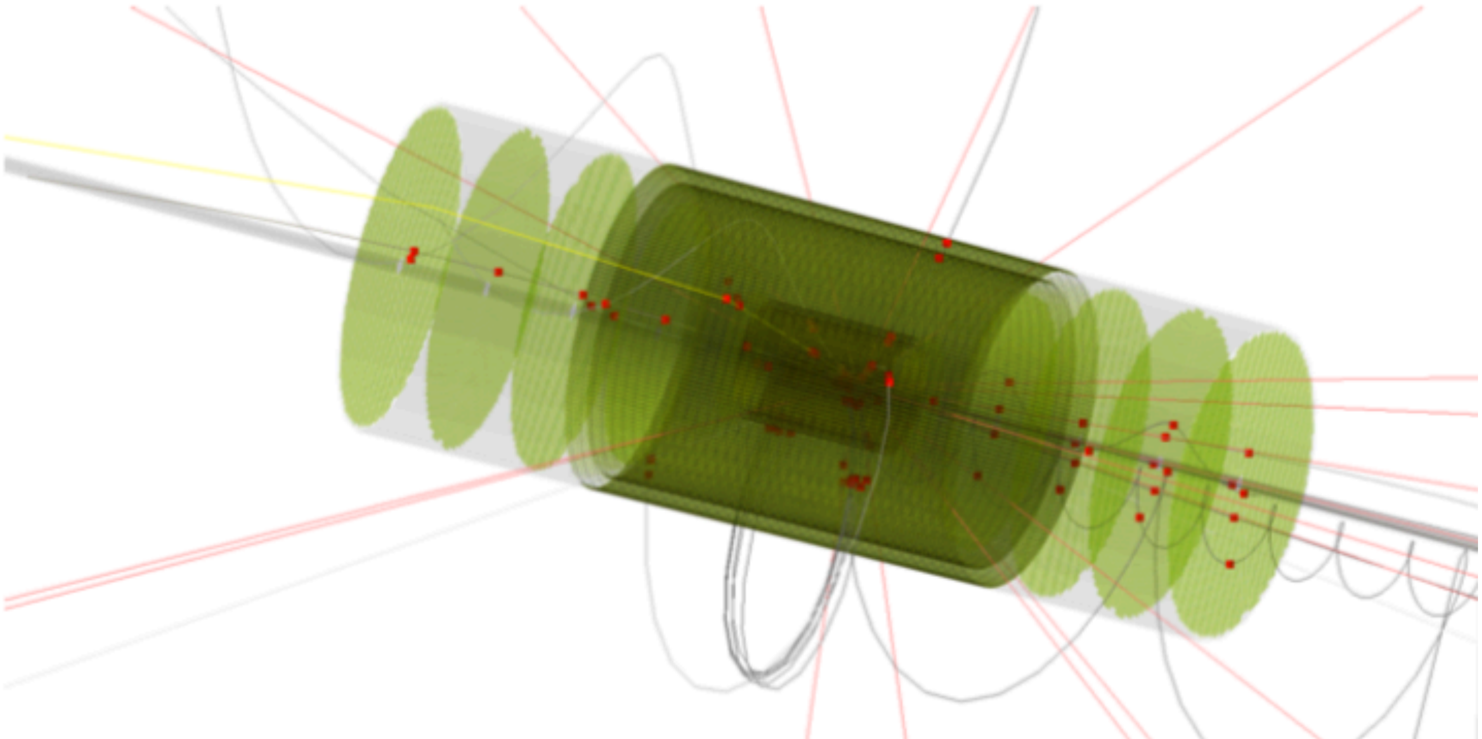
1. eRD16 simulation effort - work shown here by Yue Shi



- eRHIC green-field detector design concept
- 80 cm radius TPC
- Vertexing and forward disks with MAPS (ALPIDE chip)
- Barrel layers: 2.3, 4.7, 14, 16 cm
- Only MAPS + TPC simulated here

challenge: go beyond single-track observables.

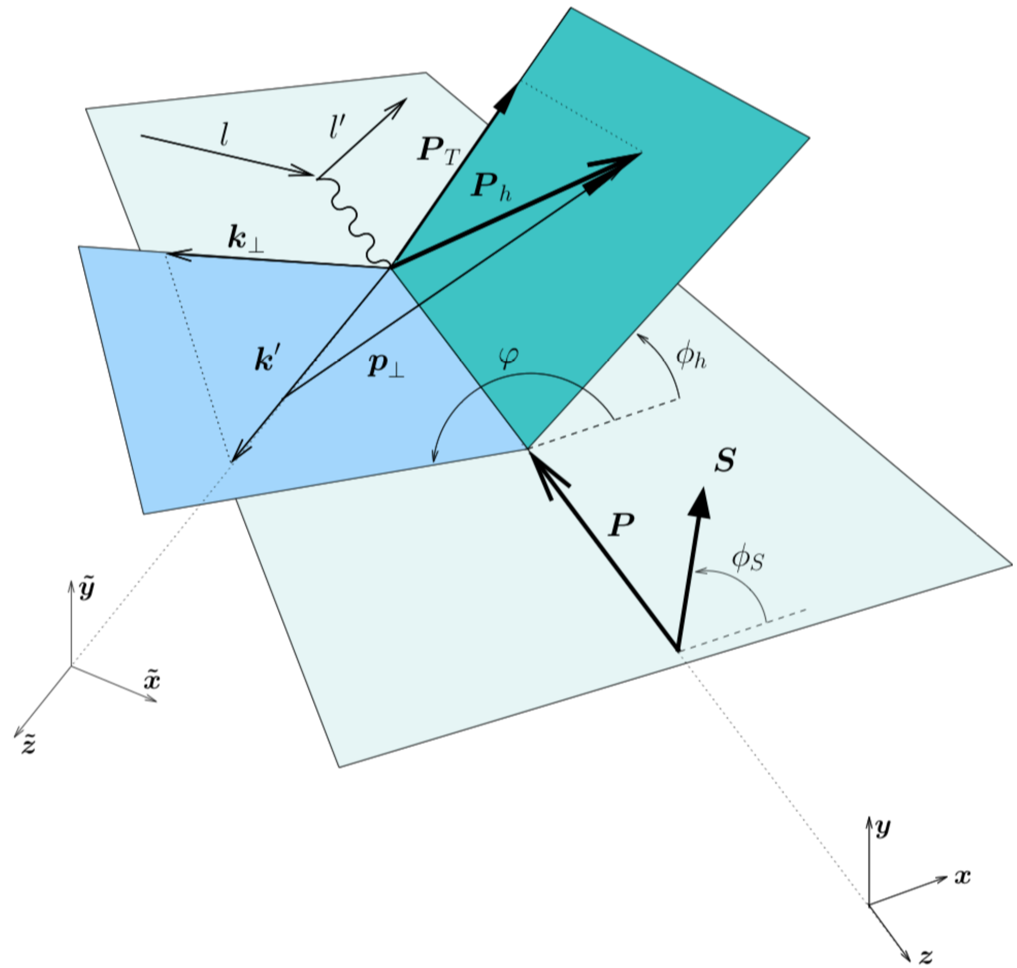
1, 4. eRD16 simulation effort - work shown here by Yue Shi



- Developed by LBNL's eRD16 generic EIC detector R&D project
- Additional barrel layers:
  - 5th layer at 39 cm ≈ upgraded ALICE ITS layer 6 (pixel)
  - 6th layer at 43 cm ≈ old ALICE ITS layer 6 (strip)

challenge: investigate an all-silicon tracking concept,
explore infrastructure impact on physics.

1, 4. eRD16 simulation effort



challenge: go beyond single-track observables,
directly relevance to resolutions for spin physics,
and synergistic with other studies (charm, jets).

Heavy-flavor in the EIC high-energy writeup, for example:

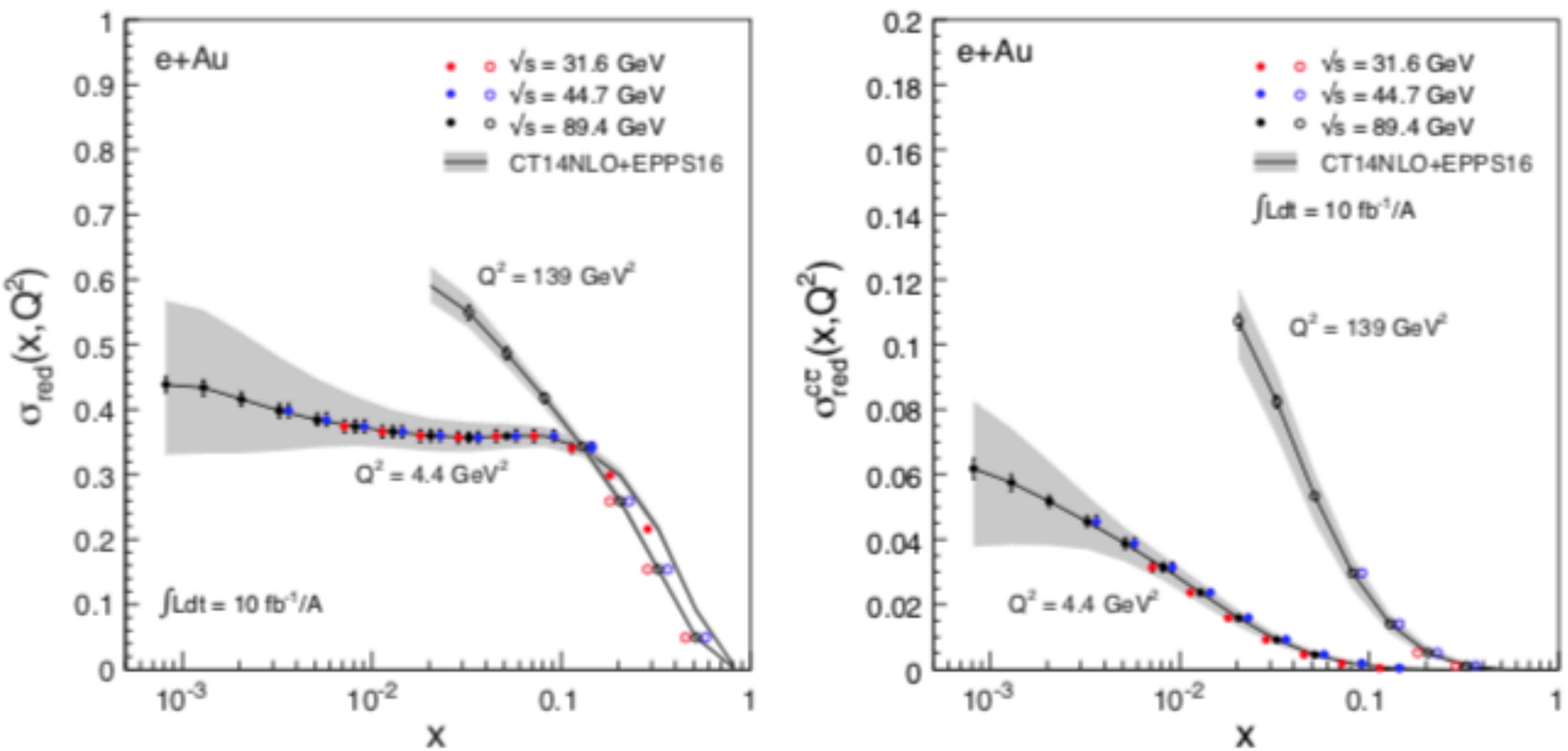
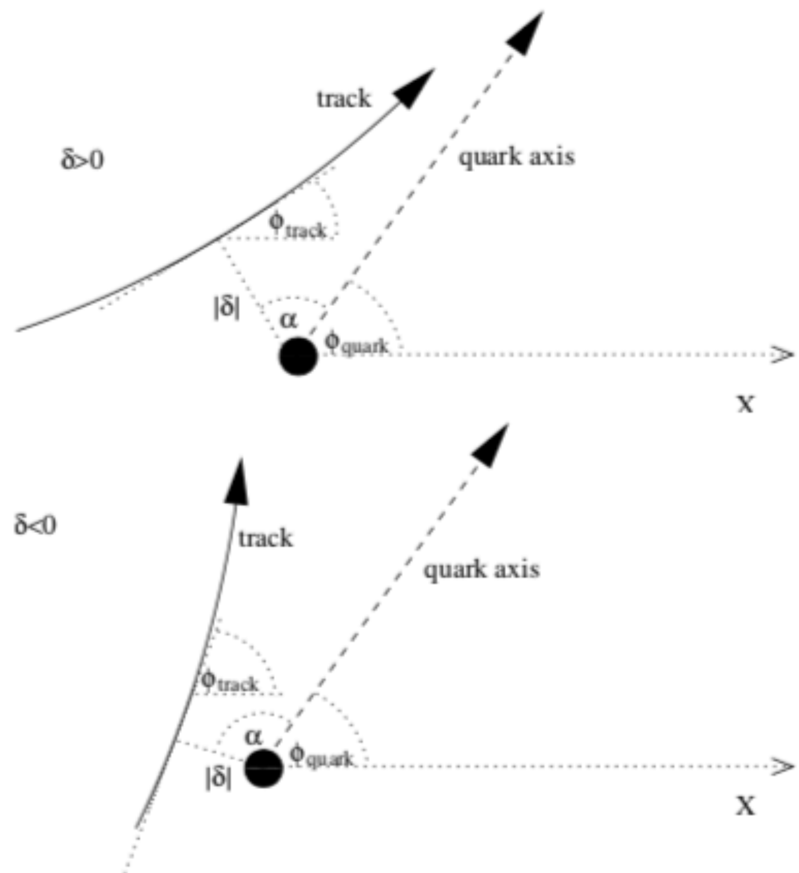


Figure 22: Inclusive (*left*) and charm (*right*) reduced cross-sections as a function of x at the Q^2 values of 4.4 GeV^2 (solid circles) and 139 GeV^2 (open circles) at three different center-of-mass energies. See text for details.

What did HERA do (technically)?

Prior HERA Work on Vertexing/Flavor Tagging in DIS

- H1 demonstrated heavy-quark tagging at HERA [Eur. Phys. J. C 65, 89–109 (2010), arXiv:0907.2643]
- Variable cuts on the *n*-th track with the highest displacement significance
- Tracks with $p_T > 300$ MeV
- $|\delta|$ is the track vertex distance to the beamspot/primary vertex
- $\sigma(\delta)$ is the uncertainty
- The sign of δ is positive if in the direction of the struck quark in the (x, y) plane, negative otherwise
- H1 reconstructs the struck quark ϕ_{quark} using jet reconstruction, with ϕ_e only as fallback



H1, Eur. Phys. J. C 65, 89–109 (2010)

What did HERA do (technically)?

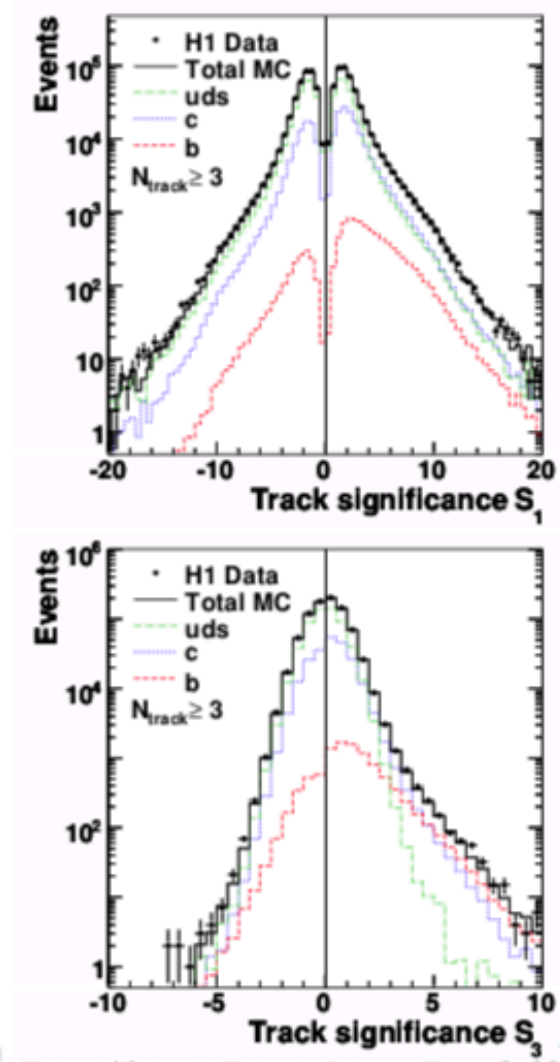
Prior HERA Work on Vertexing/Flavor Tagging in DIS

- $S = \delta/\sigma(\delta)$ for each of the track
- S_n is the n-th highest S in a given event by magnitude, $|S_1| > |S_2| > \cdots$

Main remaining differences to H1:

- Primary vertex is reconstructed (no beamspot assumption)
- ϕ_{quark} is always $\pi - \phi_e$ (no reconstructed jets)
- I will used N_{track} for all tracks (with $p_T > 300$ MeV)
- N^q_{track} for struck quark direction tracks

H1, Eur. Phys. J. C 65, 89–109 (2010)



1, 4. eRD16 simulation effort - work shown here by Yue Shi

Simulation

- 10 vs. 100 GeV e–p, or $\sqrt{s} = 63.3$ GeV
- 20µm × 20µm × 8 cm beamspot
- MC event generator: PYTHIA-eRHIC (PYTHIA 6)
- GEANT/digitization: EicRoot by the BNL EIC task force
  - `https://git.racf.bnl.gov/gitea/EIC/EicRoot.git`
  - GEANT 3, GSI FairRoot-based
  - Includes an implementation of BeAST for eRHIC
- EicRoot heavily modified for this study:
  - (Tapered) all-Si detector concept from LBNL's eRD16 generic detector R&D project
  - Export of detector geometry and hit position/uncertainty, including previously missing coordinate transform
  - GENFIT/RAVE full event reconstruction and vertexing
- Limitations:
  - No pattern recognition, tracks seeded by GEANT hit–MC truth association
  - Digitization by Gaussian-$\sqrt{12}$ smearing, no pixel occupancy effect

challenge: path forward, EIC-root is end-of-life.

1, 4. eRD16 early result(s) - work shown here by Yue Shi

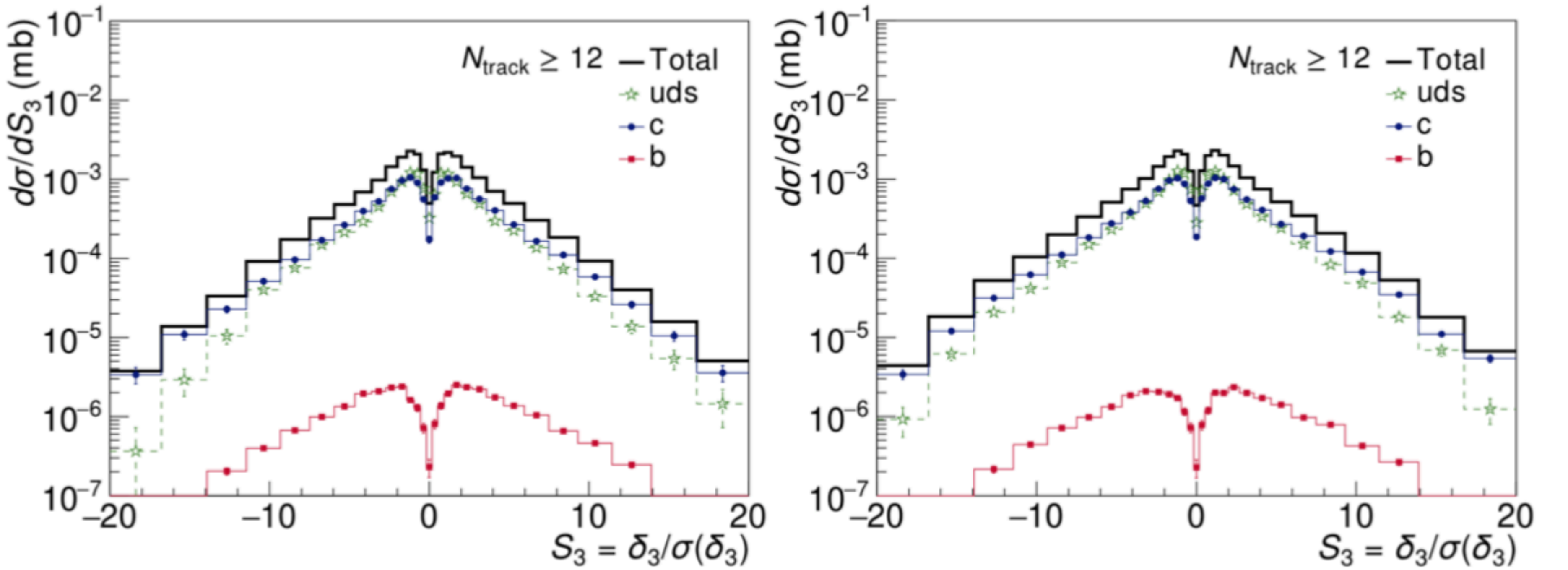


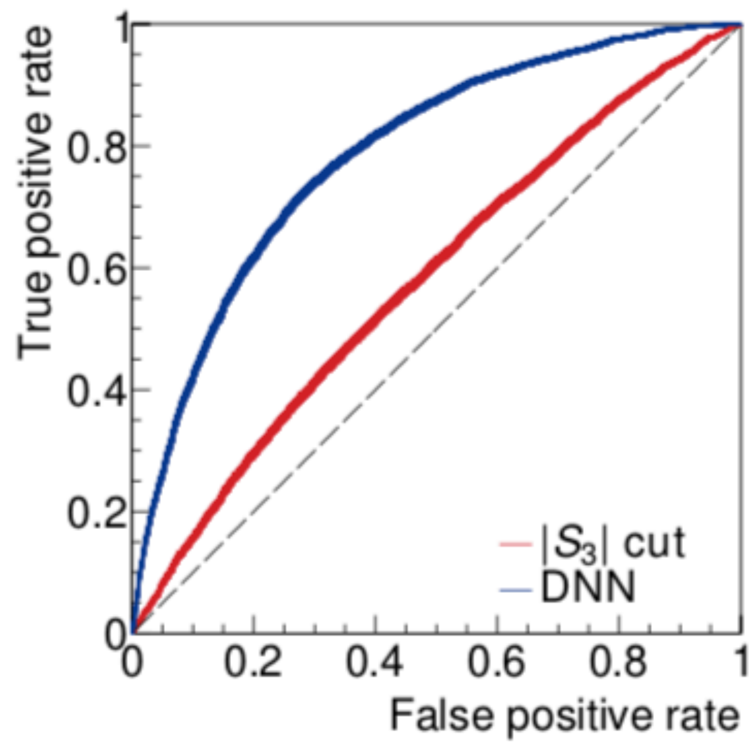
Figure 2: *The significance distribution for the tracks with the third-highest significance for (left) the BeAST and (right) the all-silicon tracking detector concepts shown in Figure 1 for selected total track multiplicities as indicated. The events were generated with PYTHIA-eRHIC, passed through EICroot detector response, and reconstructed using GENFIT/RAVE as described in the text.*

Confirms single-track studies that concluded that the inner-barrel is determining tagging-performance.

Yue Shi took it a step further for his DNP talk

All-Si with Deep Neural Network

- 6 hidden layer of 20 fully connected neurons
- Rectified linear unit (ReLU) activation
- 12 input (vs. 8 with H1): $\{S_1, S_2, S_3, N_{\text{track}}, N^q_{\text{track}}, \langle p_T \rangle, \max p_T, \langle S \rangle, \langle \delta \rangle, \max \delta, \langle \sigma(\delta) \rangle, \max \sigma(\delta)\}$
- 300k training samples, 100k validation
- Using TensorFlow 1.10
- Plotted for $N_{\text{track}} \geq 10$, "positive" = detect uds
- Drastic improvement over plain $|S_3|$-based cut



challenge: the work ahead ;-).

LBNL hardware / R&D development(s) - Leo Greiner

Kickoff meeting held at CERN on December 4, 2019 for "ALICE ITS Upgrade in LS3"

https://indico.cern.ch/event/860914/

The most relevant efforts in this Letter of Intent (endorsed by the LHCC in September 2019) include:

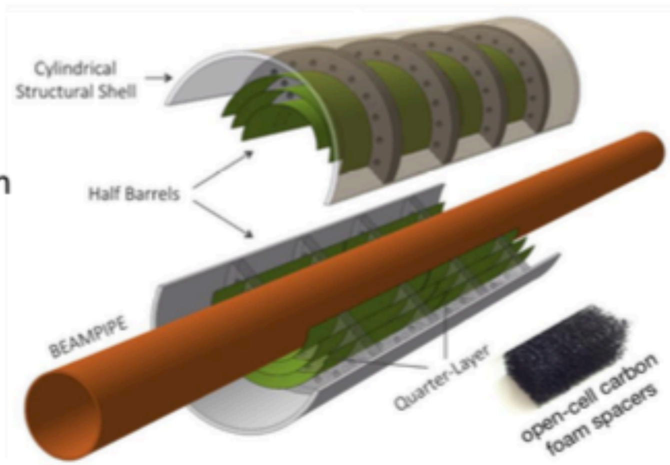
- Silicon R&D for next generation MAPS sensor (with significant improvements)

coupled with

- R&D into extremely low X/X0 cylindrical vertex detection with "bent" silicon

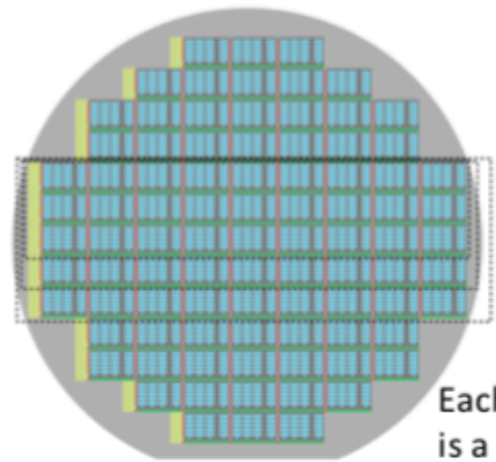
Much of this has already been presented by my colleague Vito Manzari at 2019 EIC User Group Meeting, 22-26 July 2019 Paris

"bent" silicon Detector concept



X/X0 ~ 0.05%

"stitched" silicon



Each layer half barrel is a single stitched sensor

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LBNL hardware / R&D development(s) - Leo Greiner

From Electron-Ion Collider Detector Requirements and R&D Handbook Version 1.1 p.30 4.1.1.2 Vertex/silicon tracker:

"With respect to ALPIDE, the EIC would certainly benefit in improvements in the integration time as well as in a further reduction of the energy consumption and material budget going towards 0.1-0.2% radiation length per layer. Timing-wise the ultimate goal of this technology would be to time stamp the bunch crossings where the primary interaction occurred."

Sensor 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

3

M. Mager | ITS3 kickoff | 04.12.2019 | 5

LBNL hardware / R&D development(s) - Leo Greiner

Comments

- This approved and supported research and development project contains many elements that can have application in an EIC detector set.
- The overlap between the sensor development goals and EIC requirements is significant.
- The timeframe (ALICE ITS 3 installation during CERN LS3) seems to be a reasonable match.
- CERN and collaborators will invest significant resources in this project => high likelihood of success.

- LBNL-RNC has joined this effort.
- In addition to the ALICE work package efforts that we are joining, we intend to also invest in the development of making stitched sensors into low X/X0 discs.
- We have spoken to others about these efforts (ITS3 silicon/detector and discs) and there is some interest in forming a group effort for applying these developments for EIC.

- Any questions or interest, please talk to me.

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challenge: integrate with eRD16, eRD18, and YR

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5. EIC User Group roles (Barbara, Ernst)

My take on current status:

1. Now is the time,
2. Opportunity to “think big” in terms of tracking continues to exist,

Near-term plans:

1. eRD16 effort is simulating all-Si tracker performance,
    - (some) overlap with SIDIS and jet studies, displaced vertices, YR
2. eRD16 and eRD18 intend to proceed as a consortium; inclusive.
3. Reasonably well-integrated in and aligned with Yellow-Report effort,
4. Anticipate EIC User Group roles going forward.