Summary of tracking simulations

- Silicon vertex detector + TPC
- All-silicon tracker
- Neither

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First, a few caveats

- **There are mistakes, misunderstanding & ignorance**
  Those are all mine!

- **Many thanks to everyone for proving slides**
  I've tried to synthesize from those where we stand
  I've omitted some things due to time limitations
  I've combined with some summary of conclusions

- **Summary material is to inform discussions**
  Next steps
  How to split up the work among us
  How best to collaborate toward optimized tracking

Gas tracker simulations

- **eRD6**
- **Micromegas tracker**

I will come back to these

All- silicon tracker studies

- **Bari, Birmingham (eRD18), LBNL + UC Berkeley (eRD16)**
  - **All-silicon trackers: barrel & endcaps**
  - **Alpide-type MAPS sensors, several pixel sizes**
  - **1.5T or 3T solenoidal field**
  - **5, 10, 6 barrel layers, respectively**
  - **Outer radii = 18cm, 80cm, 43cm, respectively**
  - **Layer thicknesses vary from 0.2% – 0.8% radiation length**

- **Physics**
  - **Groups have simulated: charmed mesons (barrel), heavy flavor (~1< η< 2), heavy flavor jets (~0.5< η< 2), DIS jets (~0< η< -2)**
  - ***TRACKER MUST ENABLE ALL EIC PHYSICS GOALS!***

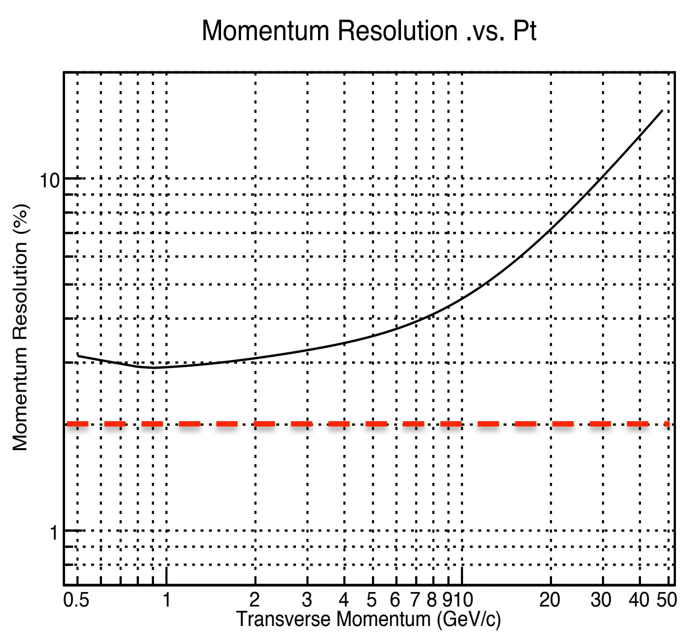
- **Fast smearing and/or full GEANT using EICRoot (to date)**
  - **Transition to G4E/eJana and/or Fun4all underway**

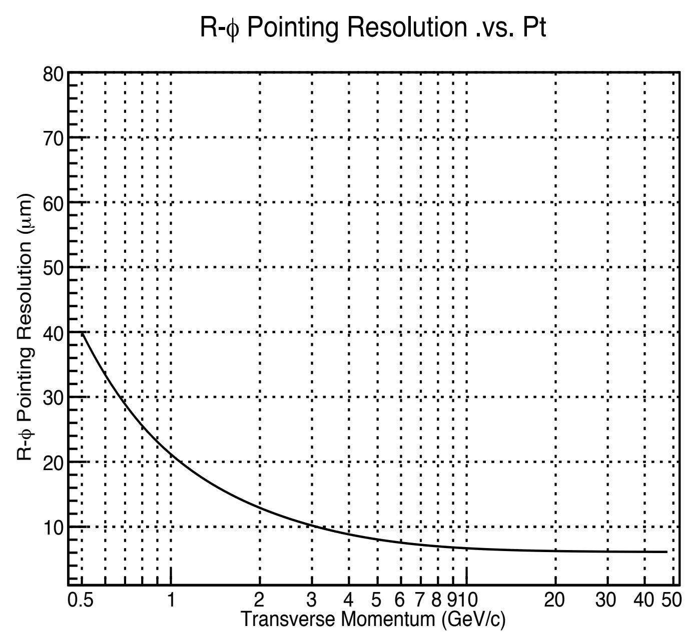
INFN Bari tracking simulation studies

	R (cm)	X/X0 (%)	Cell size (um²)
Beam pipe	1.80	0.2	
SPL #1	2.34	0.3	20 x 20
SPL #2	4.68	0.3	20 x 20
SPL #3	8.76	0.8	20 x 20
SPL #4	13.38	0.8	20 x 20
SPL #5	18.00	0.8	20 x 20

NB: uses ALICE ITS design simulation code; 1.5T field

conclusion – need barrel pixel layers or gas tracker at larger radius for resolution goal

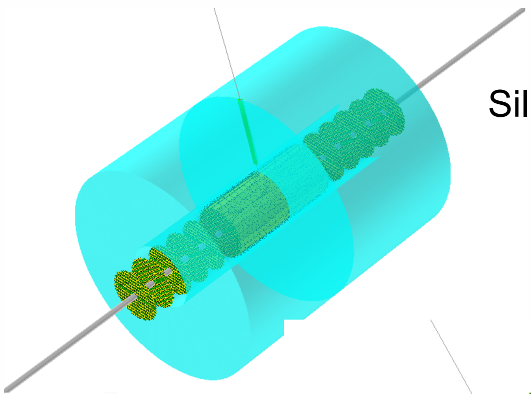




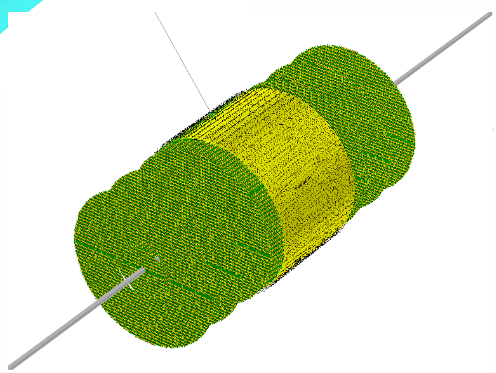
D. Elia, A. Mastroserio

Birmingham Simulations:
1.5T field, R_{out}=77.5cm, 10 layers

Simulation examples

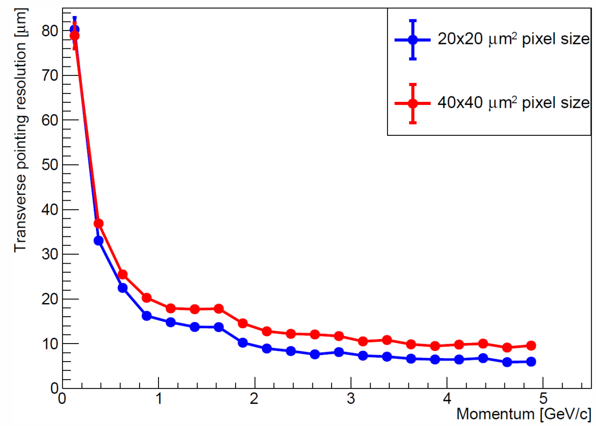


Silicon+gas



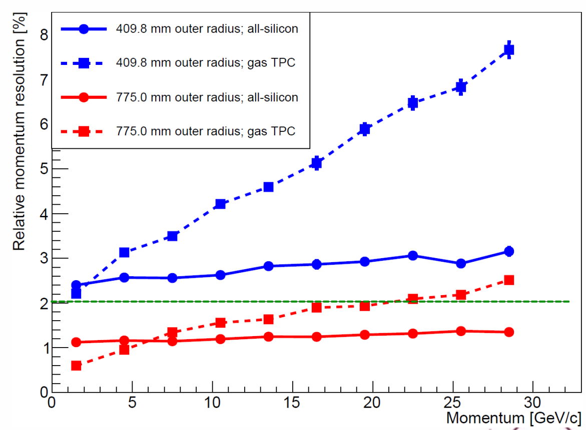
All-silicon

Transverse pointing resolution, different silicon pixel sizes.



Details and full list of simulations can be found in report: https://indico.bnl.gov/event/7689/contributions/35412/attachments/26828/40846/Simulation_report_Feb2020.pdf

Relative momentum resolution, different outer radii, comparing all-silicon with Si+gas.



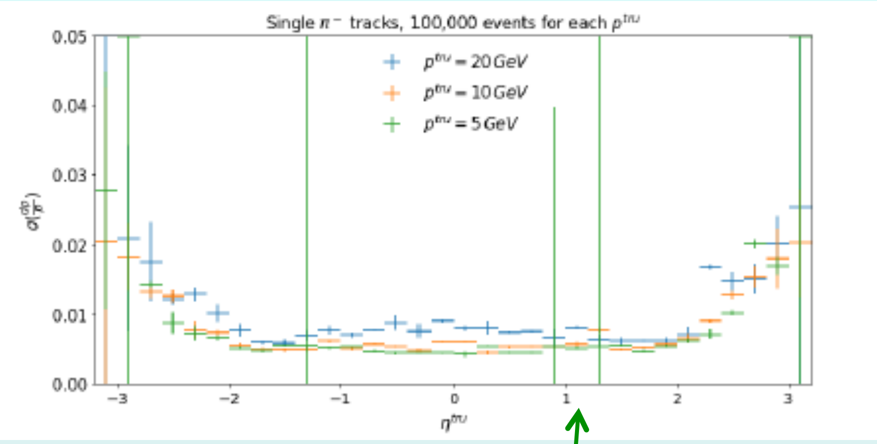
Conclusions:

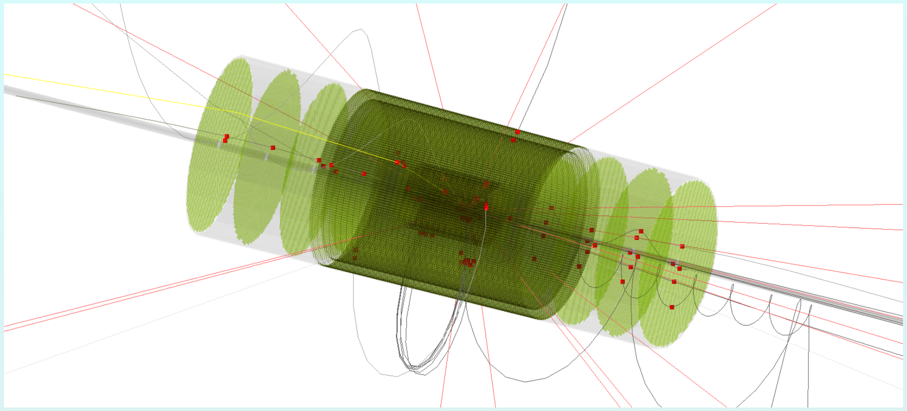
- **Smaller pixel size improves resolution (currently 20x20 μm² or smaller considered optimal)**
- **Two layers close to the beampipe are beneficial**
- **All-silicon prefered if more compact tracker desired**

BVJ: all-Si outperforms TPC for p>6 GeV/c

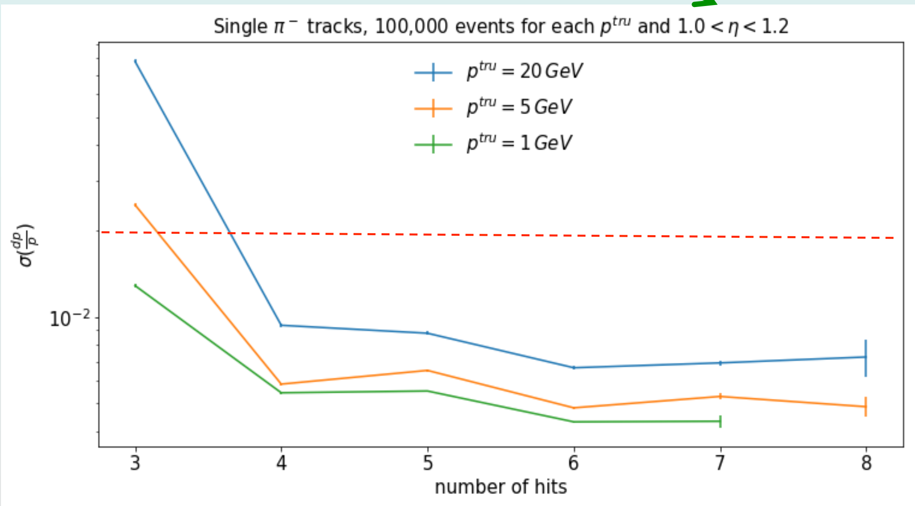
Berkeley: 6 layers @ 2.3,4.7,14, 16, 34, 43 cm *3T field*

Study transition region between barrel & 6 layer endcaps





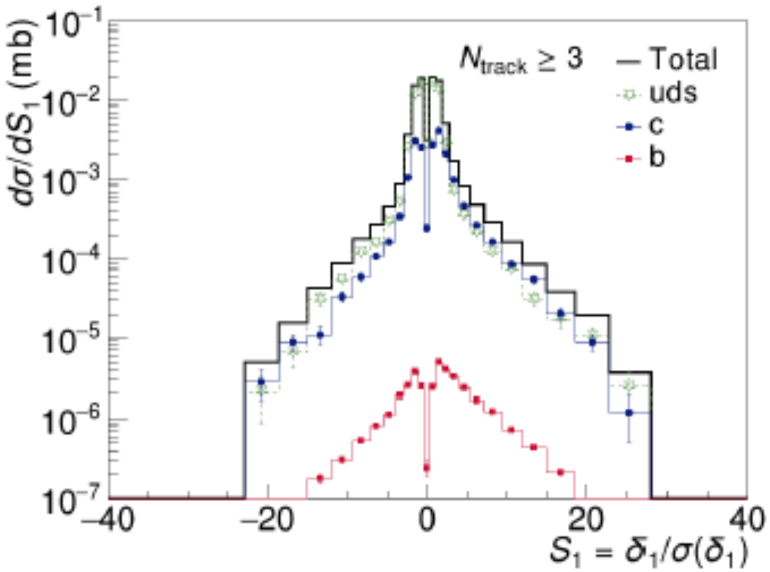
support cone, services modeled as 5mm Al

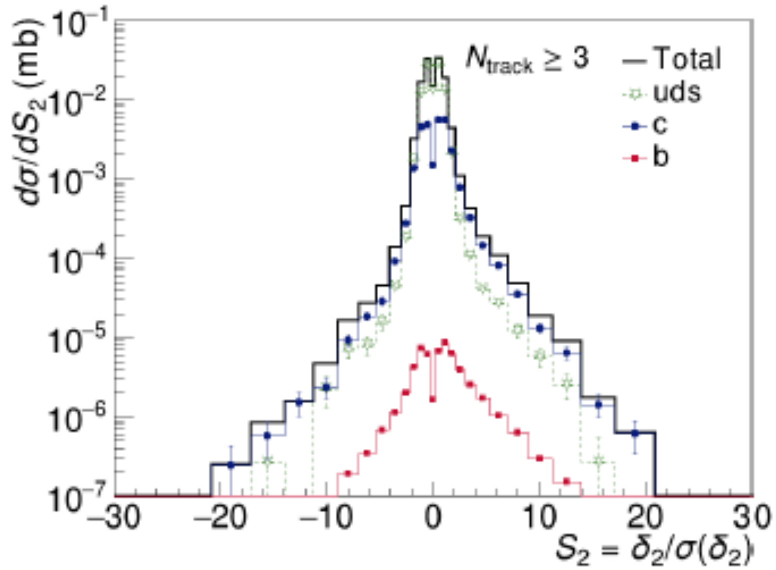


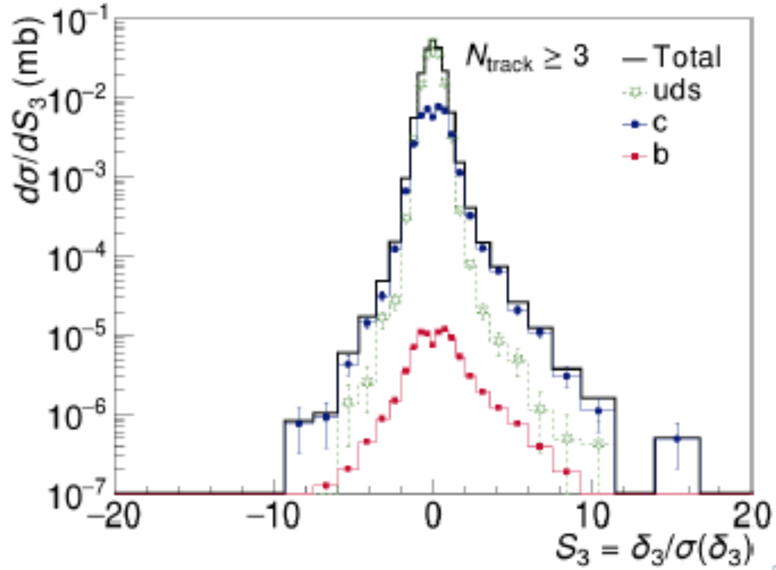
- ***Fewer hits per track in transition region***
- ***Need >3 hits for resolution & reconstruction efficiency***
  (~18% efficiency loss – OK?)
- ***Resolution degrades at large η due to insufficient Bdl***
- ***Barrel z-extent is paramount for forward and backward dp/p***

Tagging with 20 µm vertex/beamspot

Reconstructed di-jets
~ 0.5 < η < 2.0







- $20 \times 20\ \mu m^2$ MAPS
- Once the primary vertex/beamspot is well-reconstructed, the displaced vertex is not very sensitive to the pixel size

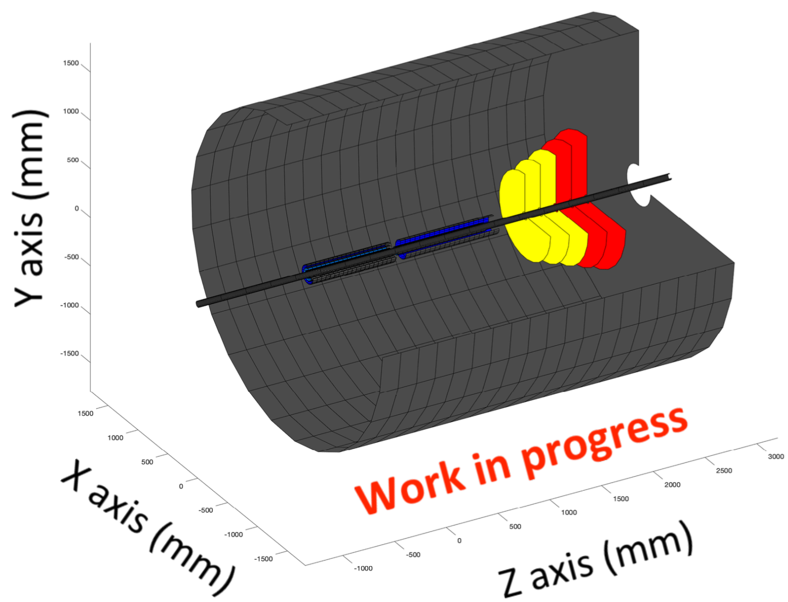
- ***Compact all-Si matches Si+TPC***

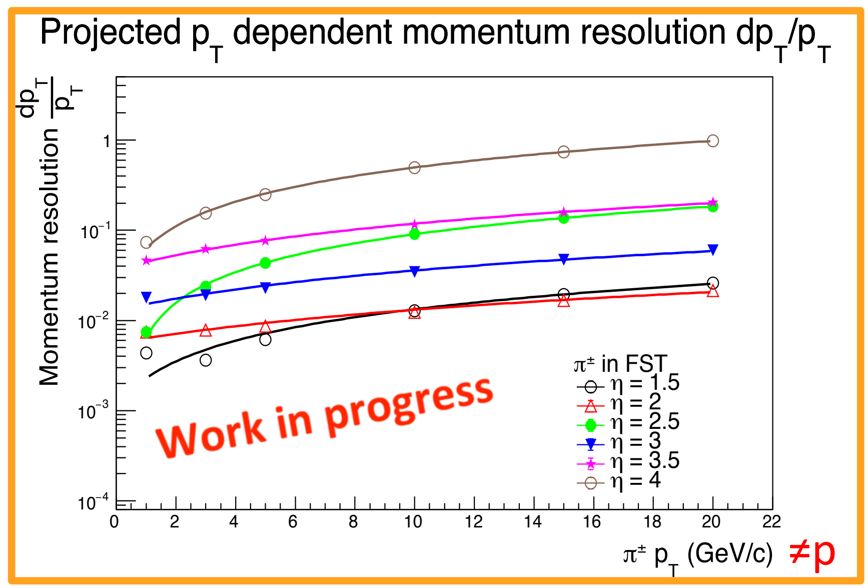
3T field

LANL EIC tracking simulation status

- Initial detector design in fast simulation (LDT package):
  - Mid-rapidity silicon vertex detector: 3-barrel layers of Monolithic Active Pixel Sensor (MAPS) type detector.
  - Forward-rapidity silicon tracking detector (FST): 2-barrel layers of MAPS + other silicon detector and 5 forward planes of MAPS + other silicon detector.

arXiv: 2002.05880





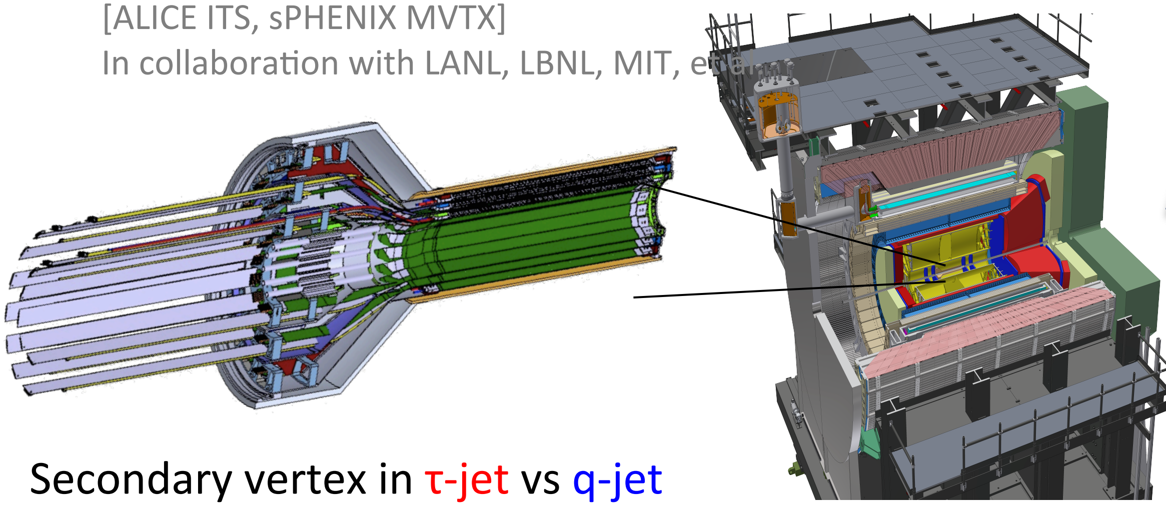
- Tracking performances are better than or consistent with the forward tracking requirements from the EIC detector handbook.

1.5T field
Hybrid tracker

Full chain simulation and reconstruction

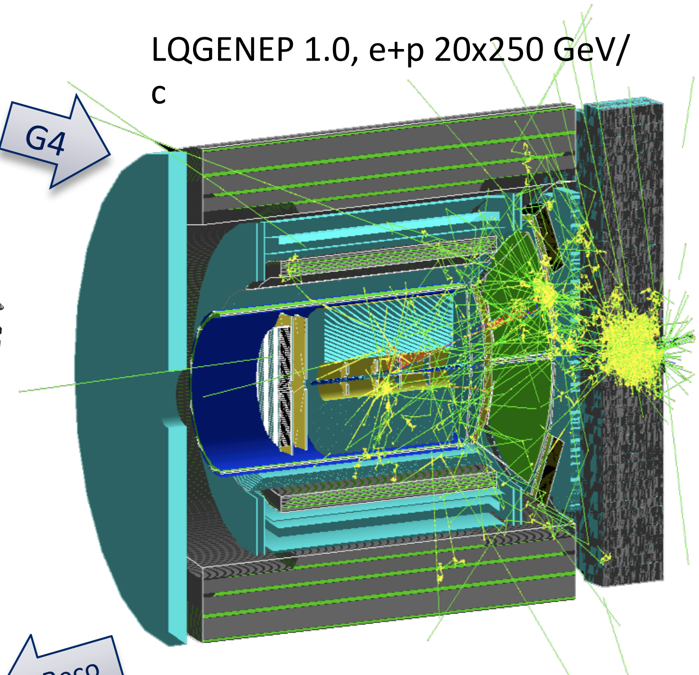
MAPS-based vertex tracker
[ALICE ITS, sPHENIX MVTX]
In collaboration with LANL, LBNL, MIT, etc.

Early EIC detector concept [arXiv:1402.1209]



LQGENEP 1.0, e+p 20x250 GeV/c

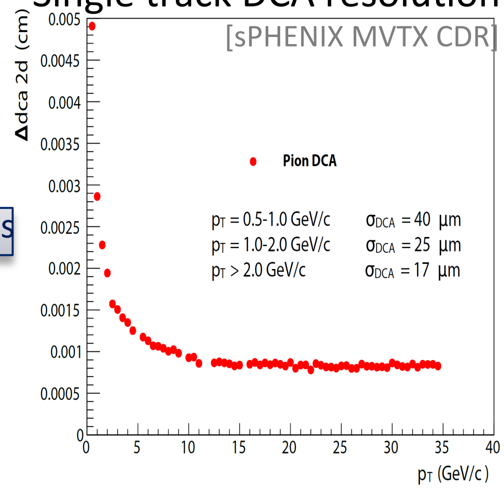
G4



Reco

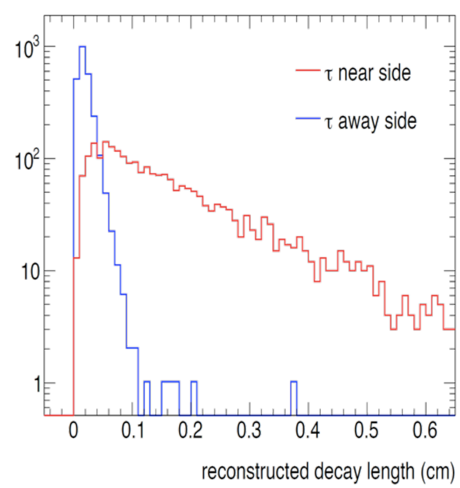
Geant4 simulation and reconstruction in Fun4All
- [Tutorial] https://eic-detector.github.io/
- [sPH-cQCD-2018-001] https://indico.bnl.gov/event/5283

Single track DCA resolution
[sPHENIX MVTX CDR]



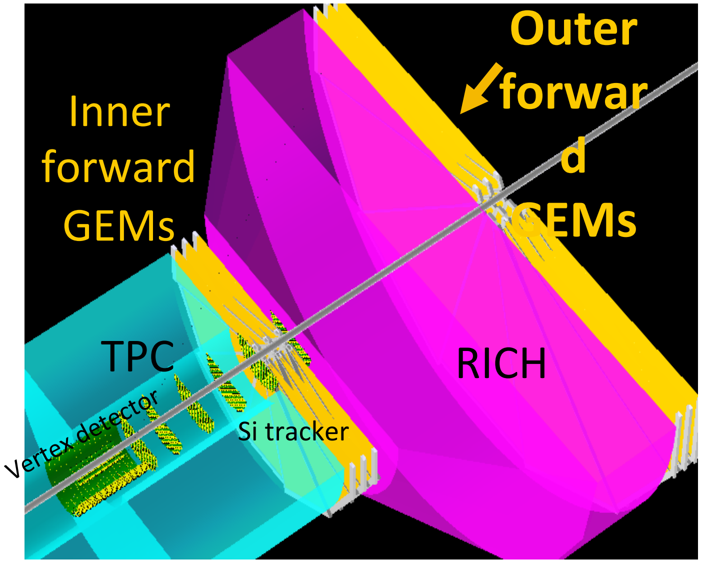
Analysis

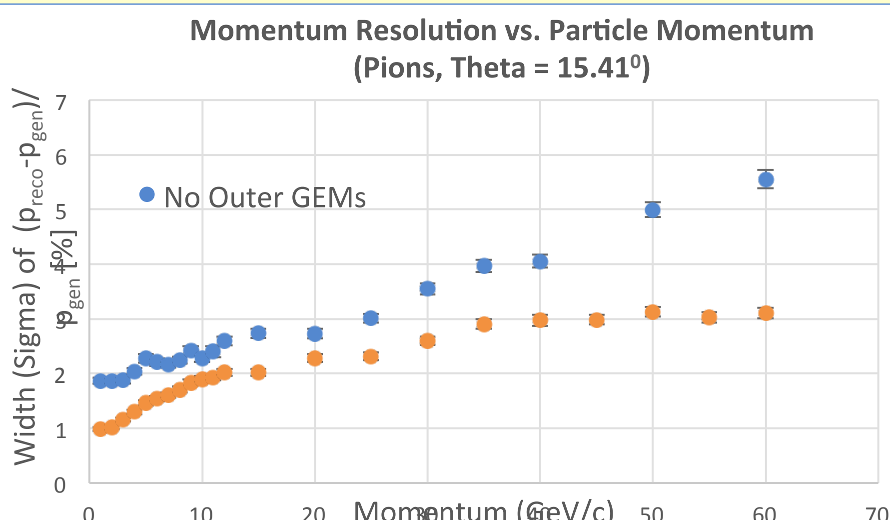
Secondary vertex in τ-jet vs q-jet
In collaboration with SBU, UMass

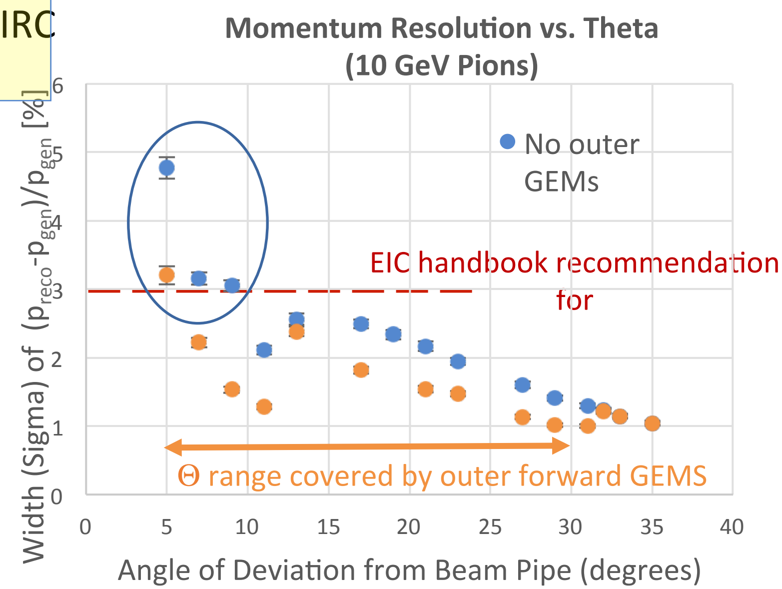


Gas Tracking Simulation Results (eRD6)

- Gas tracking simulations have so far been done in EicRoot framework with the Beast configuration.
- Investigate use of outer forward GEMs placed behind the RICH to improve tracking precision and provide impact points to help with seeding the RICH ring reconstruction.
    - Detectors simulated: vertex tracker, silicon trackers, GEM, TPC, RICH volume.
    - Magnetic field = 1.5 T
- Significant improvement in momentum resolution, particularly at smaller polar angle where TPC acceptance quickly drops.
- Fast tracking $\mu RWell$ operating in μTPC mode was implemented to study directional information to aid in DIRC performance.



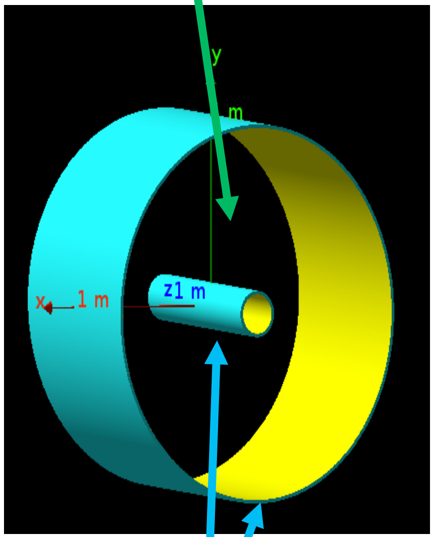




Gas Tracking Simulation Next Steps

- Transition gas detector simulation work to supported EIC simulation frameworks: Fun4All / g4e
  - **Our Requirements:** Help from software group to implement geometry/materials into an EIC detector
  - **Goal:** Fast simulation and later full simulation of tracking performance
  - **Deliverables:** Performance studies i.e. resolutions (momentum, space points) compared to EIC handbook requirements.
- Central Trackers
  - **TPC**: Full geometry and materials including end cap.
  - **Fast tracking -** Sandwiched around central tracker (e.g. TPC, Silicon barrel tracker …) and provides directional information for DIRC.
- Forward Tracking
  - **Forward GEM Tracker**: Full geometry implementation
  - **GEM TRD/T**: Located behind the RICH and would provide direction information for the RICH as well as additional PID (discrimination). discrimination.
- Study integrated gas tracking performance

Favorite central tracking detector
TPC, Silicon, …

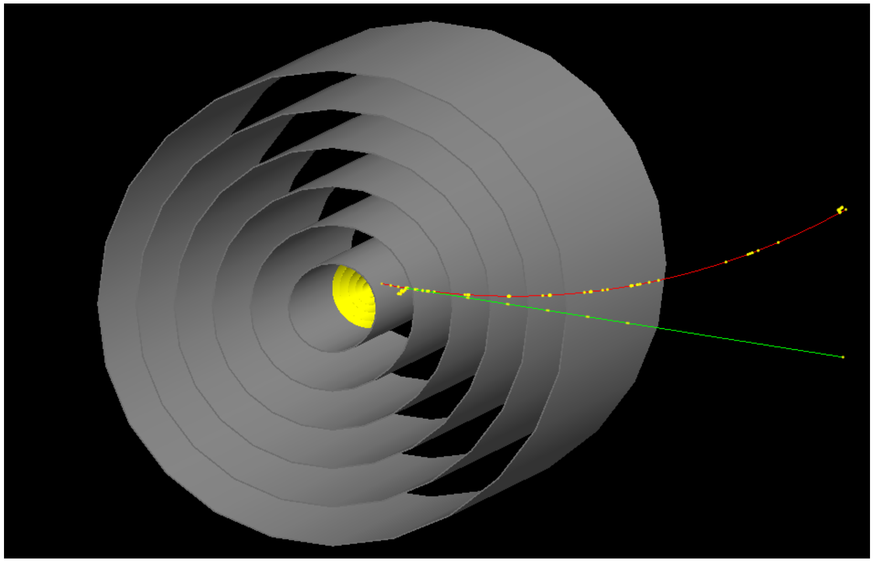


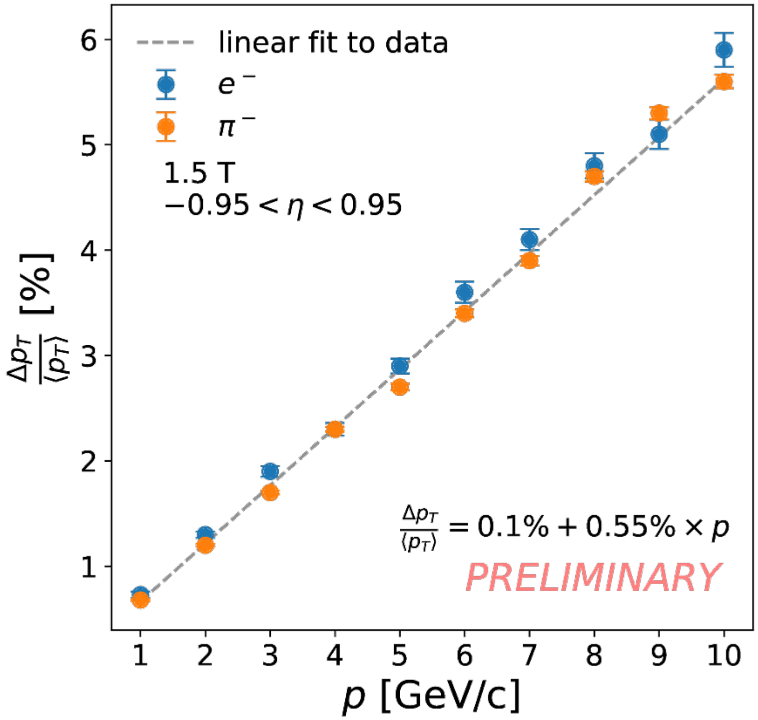
Fast
mini-drift trackers

INFN TRIESTE · TEMPLE UNIVERSITY · Yale University · University of Virginia · FLORIDA TECH · Stony Brook University · BROOKHAVEN NATIONAL LABORATORY

EIC tracking simulation at CEA-Saclay

- Current focus on the curved Micromegas (MM) tracker:
  - Curved tiles and low material budget
  - Technology is being used in CLAS12
- Current status of the simulation
  - A first demonstration with Fun4All has been set up
  - A preliminary estimation of the corresponding momentum resolution





We now know

- There are complementary ways to address general tracking
  - But we do need silicon for vertexing
- All-silicon tracker can match or exceed performance of hybrid silicon/gas tracking system
- Some fast tracking layers may be important to best utilize DIRCs
  - Needs some work to specify
- For silicon tracker
  - 20 micron x 20 micron pixels will do the job
  - All-silicon barrel must extend to R ≥ 45 cm, needs 5 or 6 layers
  - Endcaps need more optimization & hardware specification

Questions driving next steps

- Magnetic field? How to get sufficient forward Bdl?
- Optimum technology mix for tracking?
- Effect of thinner silicon (0.05% vs. 0.3% X/X_0)?
- What is the impact of more realistic mechanical infrastructure?
- Finish optimizing Si tracker layer placement (barrel & endcap both)
- Symmetric endcap trackers?
- How to optimize forward tracker?
  Higher Bdl vs higher spatial resolution?
  What will be affordable?
- Interaction between tracking and PID?
- What are the requirements for fast tracking layers?

Plans by groups (coming into the workshop)

- Everyone is switching to full simulations; benchmark fast-smear G4E/eJana and/or Fun4All (individual decision OK?!)
- Study gas tracker options (eRD6, Saclay)
- Implement more realistic material (Si⇩, services⇧) (Bari, Berkeley)
- Optimize Si barrel layout (Bari, Birmingham)
- Optimize Si endcap layout (LANL, Berkeley)
- Study jet efficiency & resolution, jet substructure (Berkeley, LANL, BNL)
- Move to non-ideal (from MC truth seeded) track finding (BNL, Berkeley)
- Tracker requirements driven by PID (BNL, eRD6)

To enable splitting up the work

- Can we agree on 1.5 or 3 T magnetic field?
- Can we agree on one master detector?
  - Majority use either BeAST or ePHENIX… ?
  - Simulating just one will allow sharing work to optimize layout and quantify tracker performance
  - *If other master chosen, then adapt our optimized solution to it*
- Could we pick a strawman Si vertex barrel tracker?
  - Uniform assumption to allow optimization of outer tracking
- Let's make a list of design parameters and agree on splitting up studies for them (do in the discussion session); e.g.
  - TPC – micromegas; how to drive technology choice?
  - Track pointing & speed requirements from PID detectors
  - Digitization code for each detector technology
  - Impact of realistic material thicknesses
  - Quantify improvements from thinner Si
  - Optimization of forward tracking w/ 1 or 2 Bdl assumptions
- Suggestion: make a list, split up the work, aim for ≤ 2 strawman trackers; then everyone can study their physics. *Next workshop?*