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!

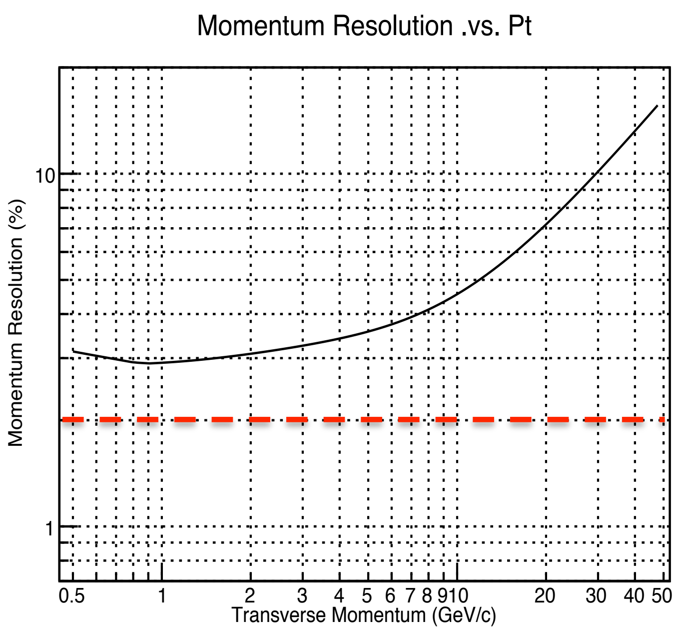
- **Fast smearing and/or full GEANT using EICRoot (to date)**
  Transition to G4E/eJana and/or Fun4all underway

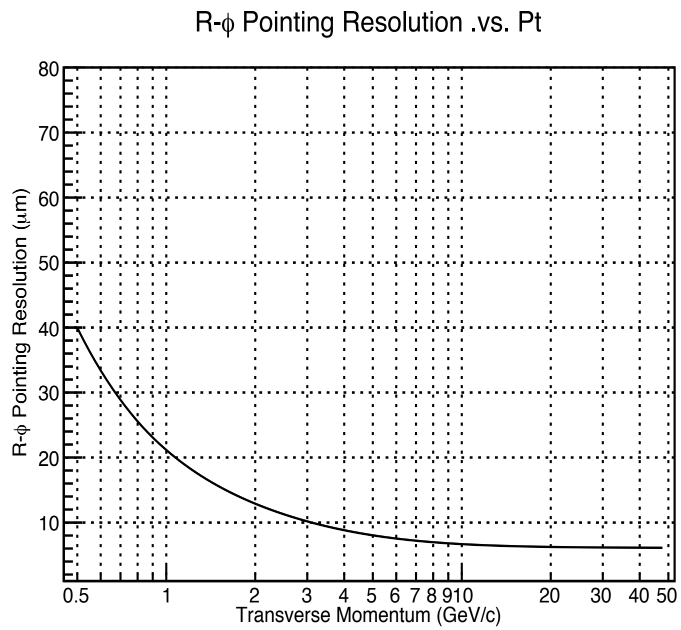
INFN Bari tracking simulation studies

	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

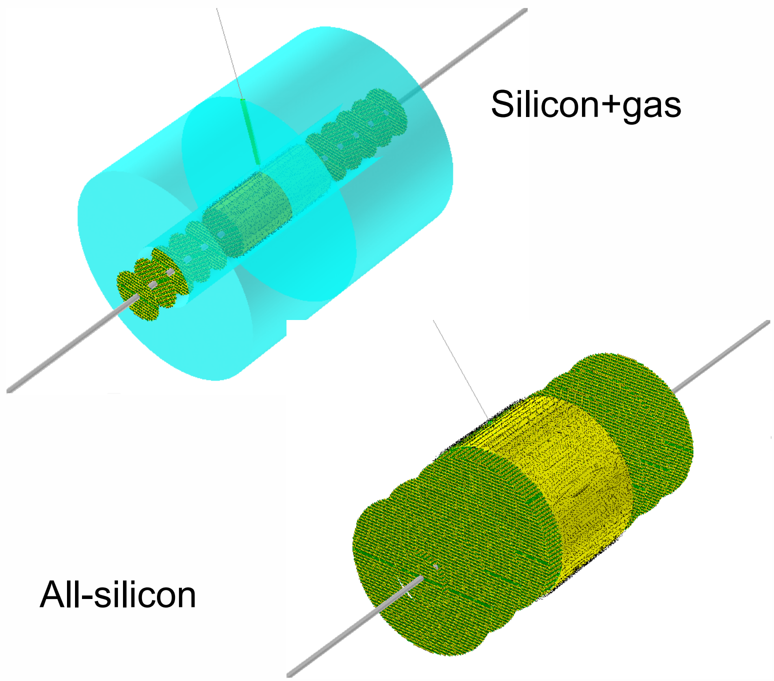




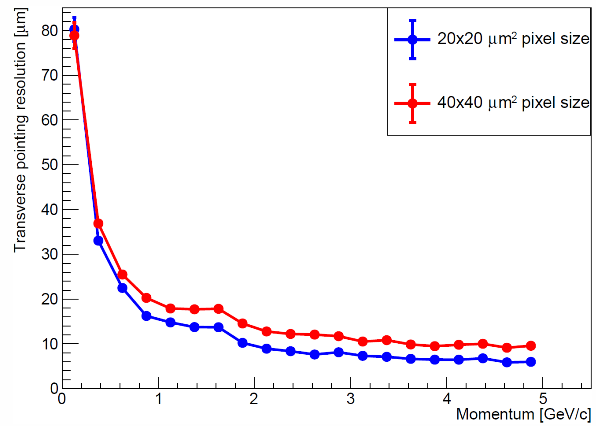
D. Elia, A. Mastroserio

Simulation examples

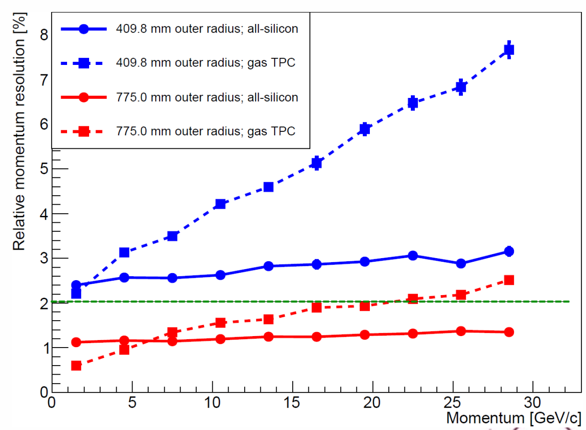
Birmingham Simulations:
1.5T field, R_{out}=77.5cm, 10 layers



Transverse pointing resolution, different silicon pixel sizes.



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



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

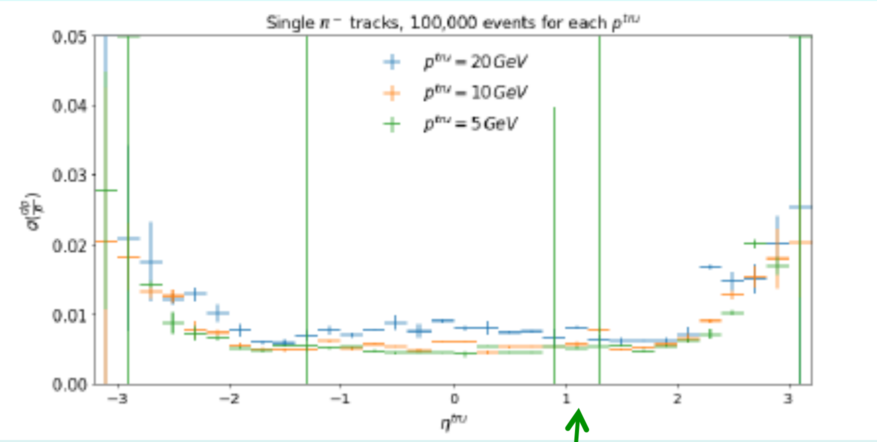
Conclusions:

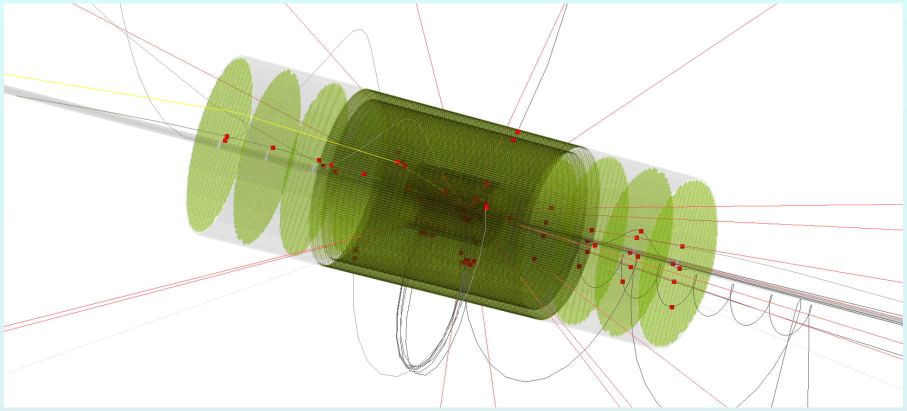
- **Smaller pixel size improves resolution (currently 20x20 μm² or smaller considered optimal)**
- **Two layers close to the beampipe are beneficial**
- **All-silicon prefered if more compact tracker desired**

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

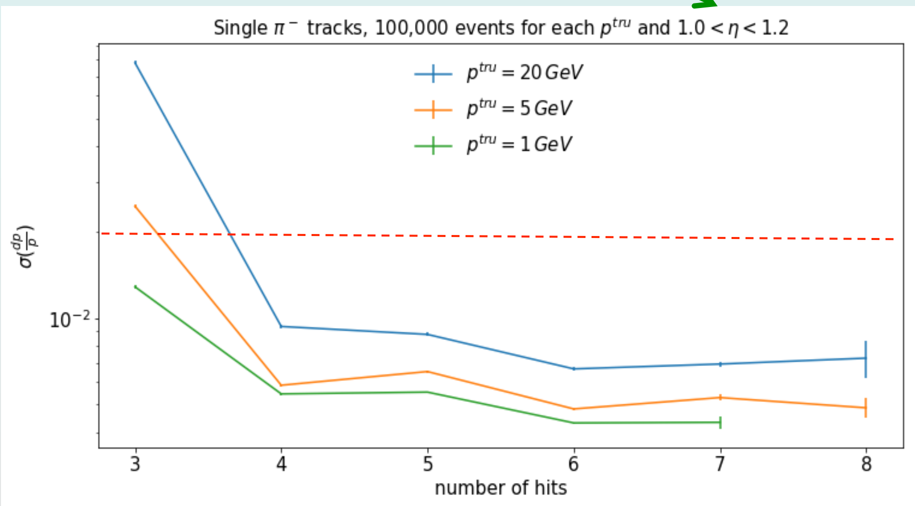
Berkeley: 6 layers @ 2.3,4.7,14, 16, 34, 43 cm *3T field*

Study transition region between barrel & 6 layer endcaps



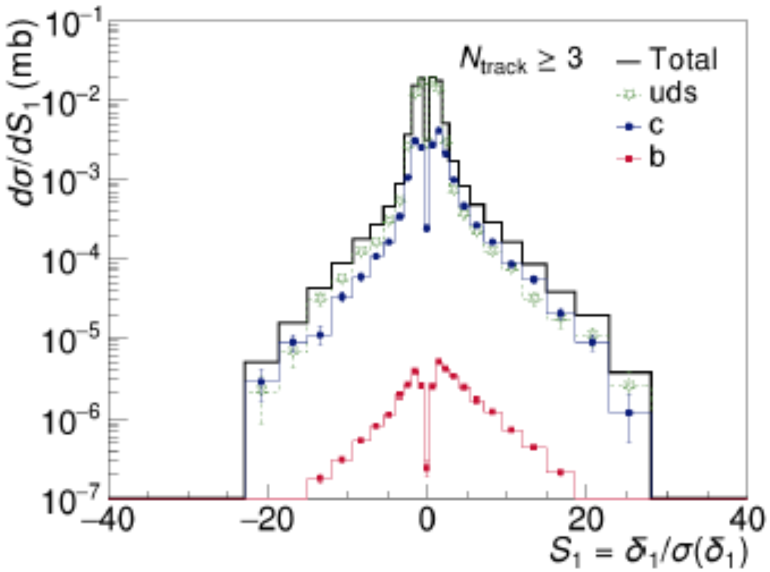


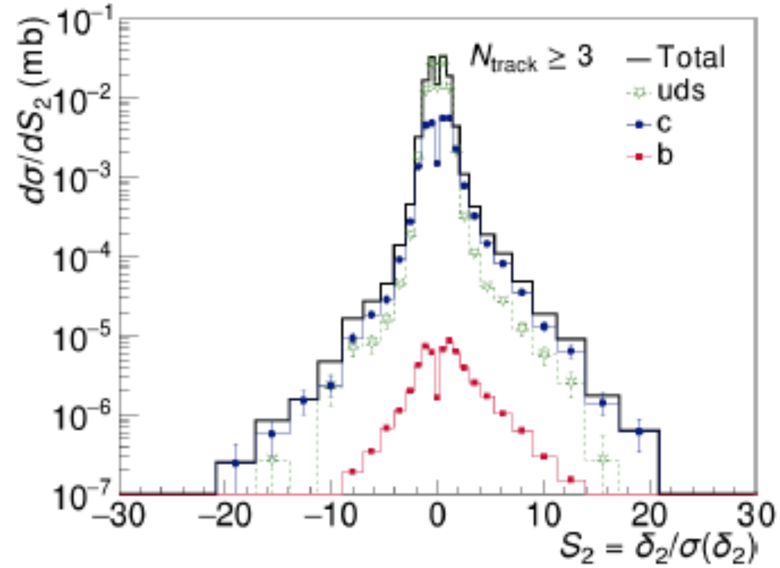
support cone, services modeled as 5mm Al

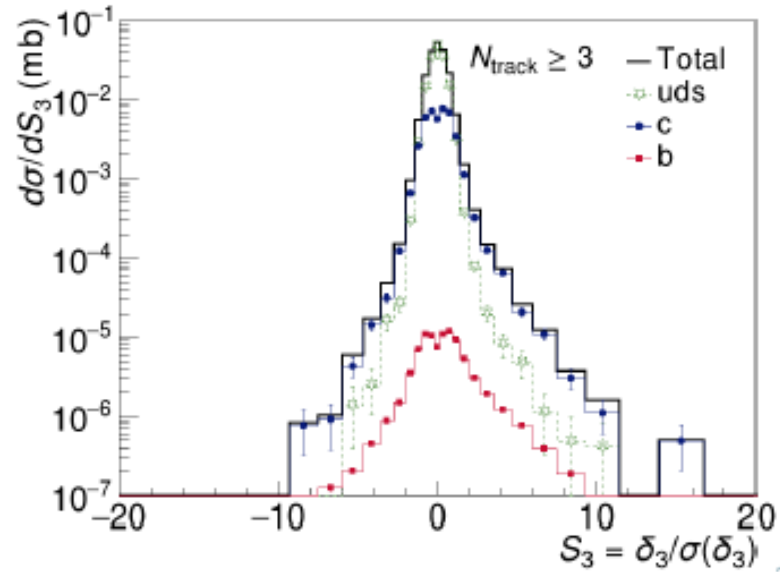


- ***Fewer hits per track in transition region***
- ***Need >3 hits for resolution & reconstruction efficiency (~18% efficiency loss – OK?)***
- ***Resolution degrades at large η due to insufficient Bdl***
- ***Barrel z-extent is paramount for forward and backward dp/p***

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

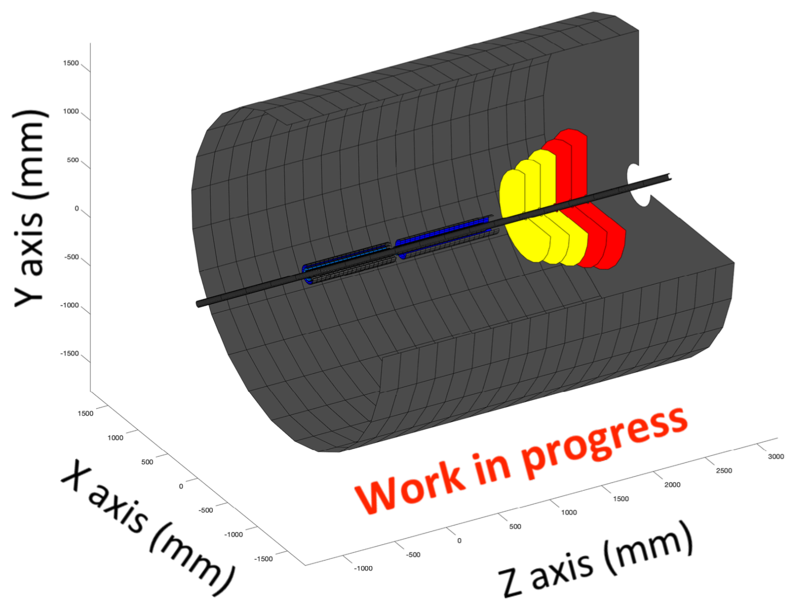
- ***Compact all-Si matches Si+TPC***

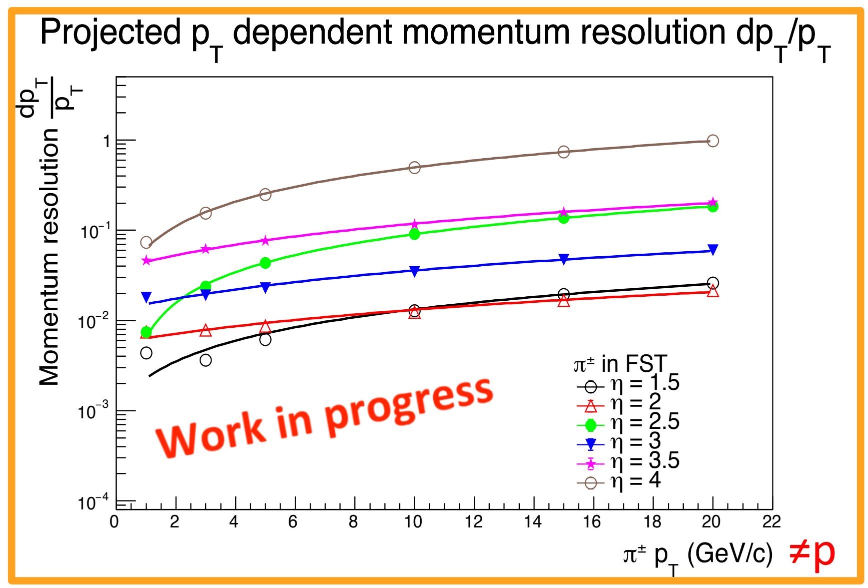
3T field

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.

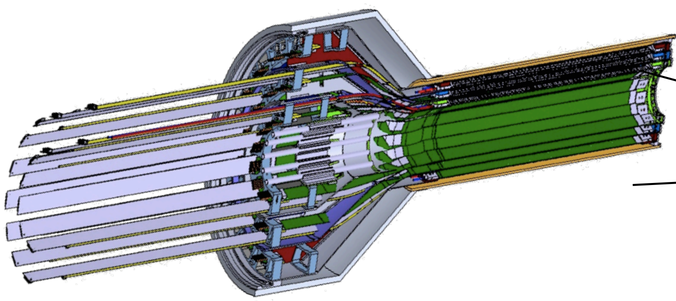
1.5T field
Hybrid tracker

Full chain simulation and reconstruction

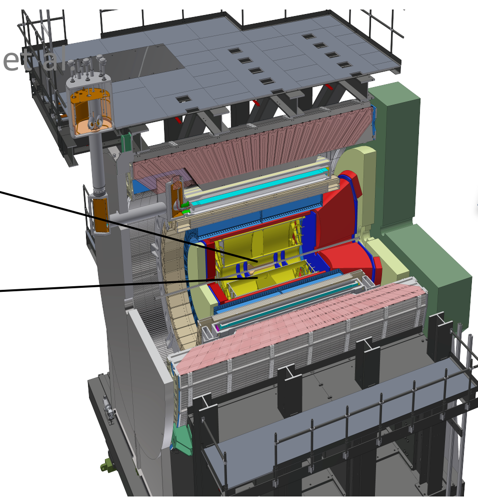
MAPS-based vertex tracker

[ALICE ITS, sPHENIX MVTX]

In collaboration with LANL, LBNL, MIT, etc.

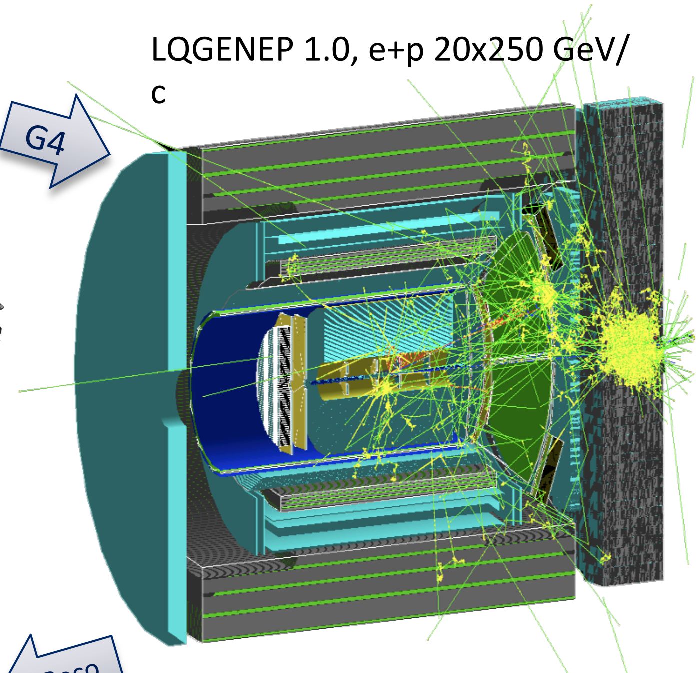


Early EIC detector concept [arXiv:1402.1209]



G4

LQGENEP 1.0, e+p 20x250 GeV/c



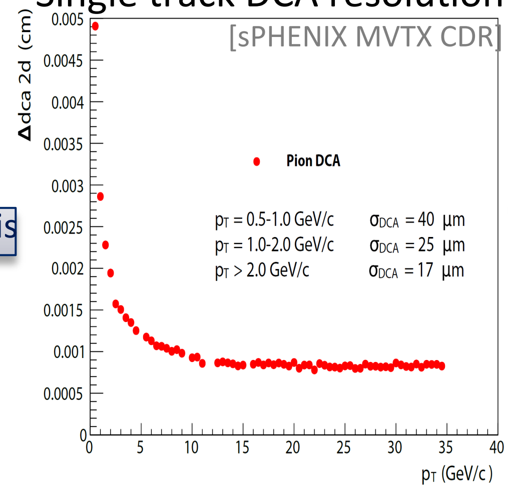
Reco

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

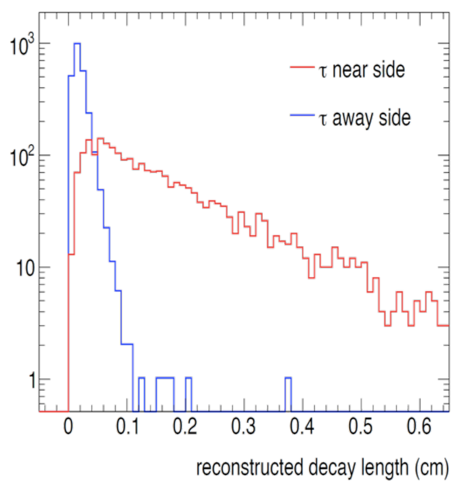
[sPHENIX MVTX CDR]



Analysis

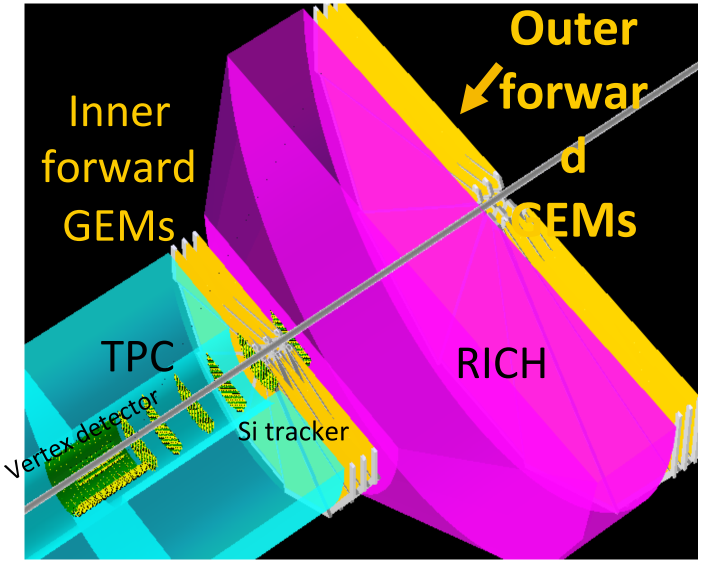
Secondary vertex in τ-jet vs q-jet

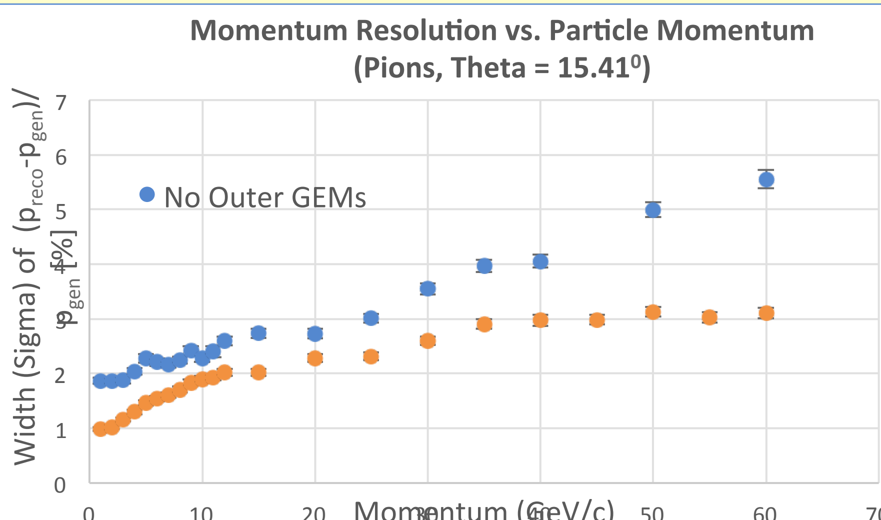
In collaboration with SBU, UMass

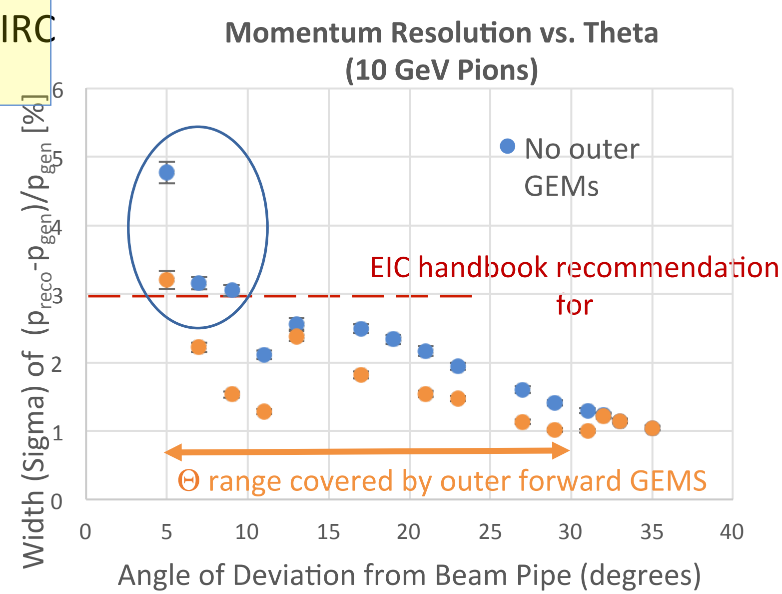


Gas Tracking Simulation Results (eRD6)

- 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.





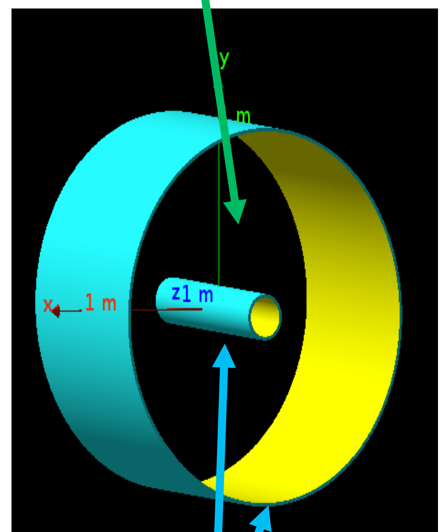


INFN Trieste, Temple University, Yale University, University of Virginia, Florida Tech, Stony Brook University, Brookhaven National Laboratory

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

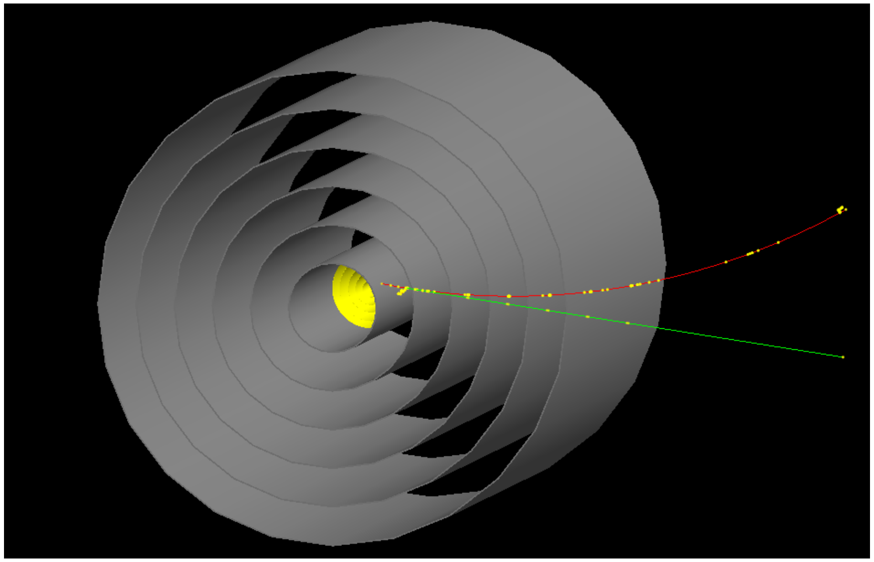
Favorite central tracking detector
TPC, Silicon, …

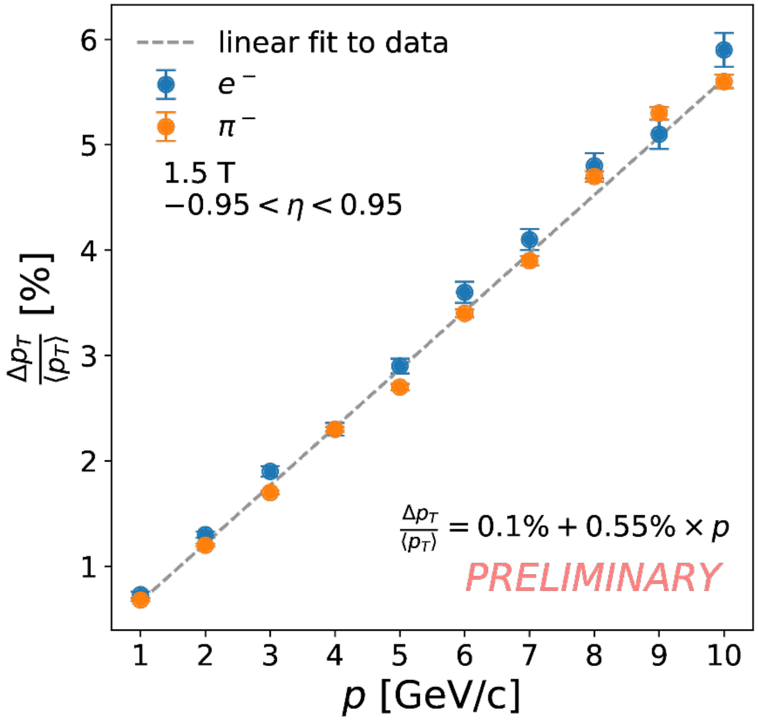


Fast
mini-drift trackers

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?*