Open MIC Session

Goal:

Collect crisp and clear arguments why two detectors will enhance the physics output of the EIC complementarity includes the IR design, but keeping consistency with accelerator design in mind

Questions to address :

- Have you / your WG group identified requirements which conflict with the current baseline detector and IR design
- Do you have suggestion how to most effectively reach the goal

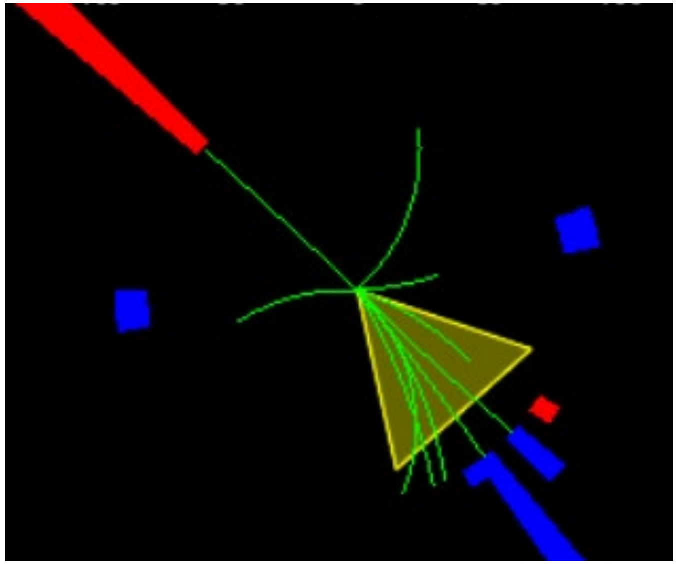
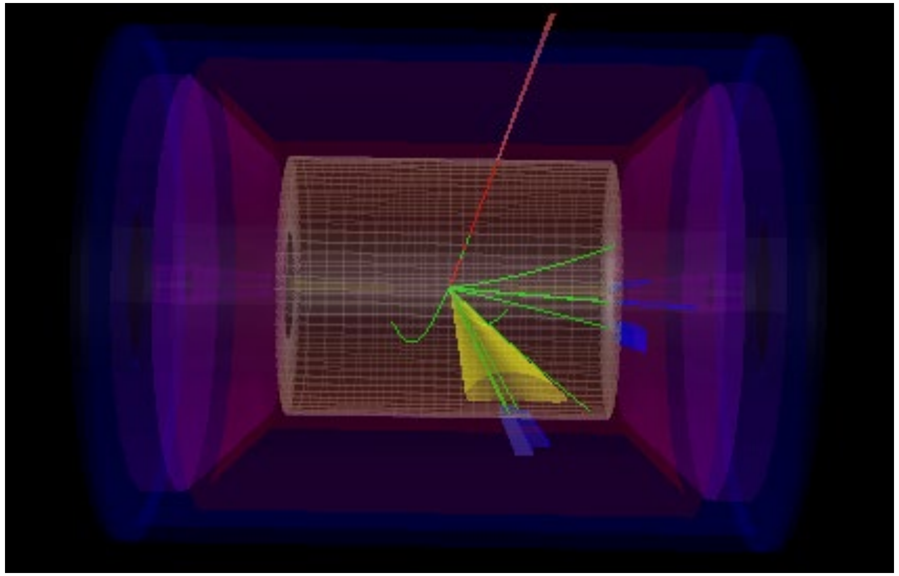
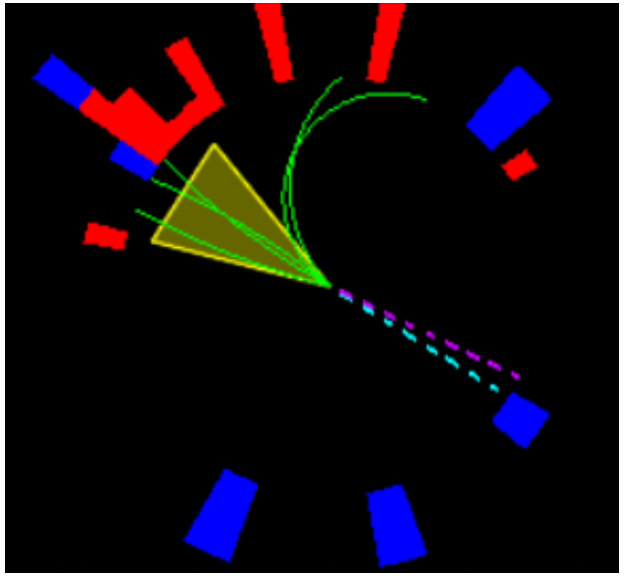
→ not more than 3 slides

Contributions from:

- Miguel Arratia
- Ernst Sichtermann and colleagues
- Domenico, Kondo and Leo
- Vasiliy Morozov

Complementarity of SIDIS and jets for 3D imaging

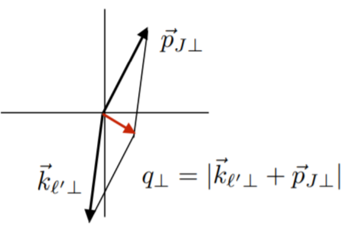
EIC, a jet factory, will make the first jets in polarized DIS

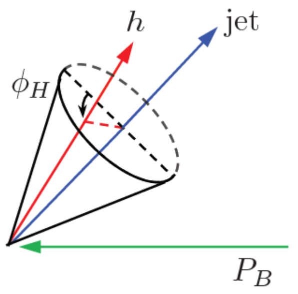




- DIS jets: a new tool for 3D imaging.
- Potential for unique jet program, unlike any previous collider or fixed-target experiment

A new and complementary way to reach EIC goals
Ideally, one should pursue this physics with both SIDIS and jets

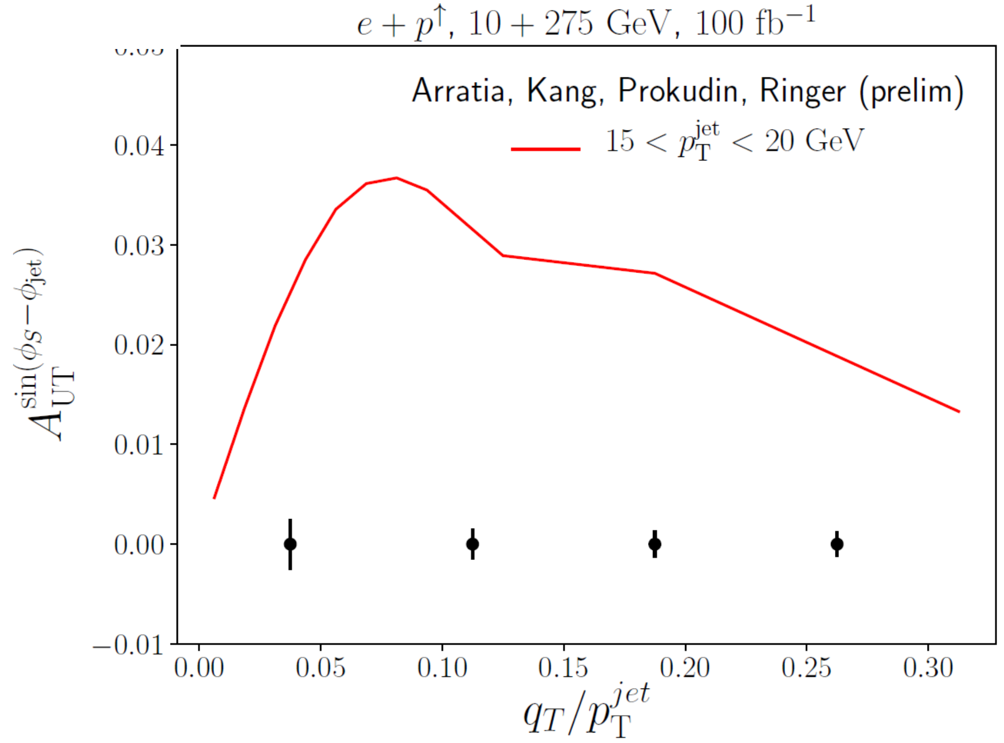
Transverse plane





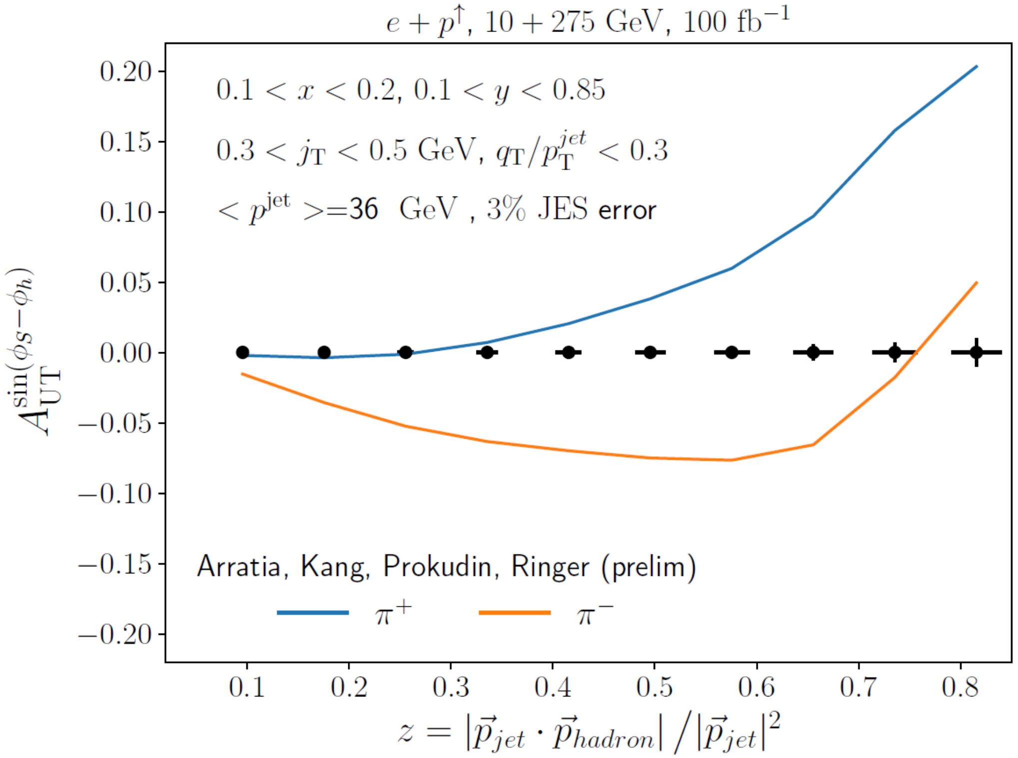
Quark Sivers

(lepton-jet azimuthal correlation)



Quark Transversity

(hadron-in-jet measurement)



$$\frac{d\sigma}{dy_e\, d^2\vec{p}_T^{\,e}\, d^2\vec{q}_T} = \sigma_0\, H_q(Q,\mu) \sum_q e_q^2\, J_q(p_T^{\rm jet} R,$$

$$\times \int \frac{d^2\vec{b}_T}{(2\pi)^2}\, e^{i\vec{q}_T\cdot\vec{b}_T}\, f_q(x,\vec{b}_T,\mu)\, S_q(\vec{b}_T, y_{\rm jet}, R, \mu)\,.$$

$$\frac{d\sigma}{dy_e\, d^2\vec{p}_T^{\,e}\, d^2\vec{q}_T\, dz_h\, d^2\vec{j}_T^{\,h}} = \times\, \sigma_0\, H_q(Q,\mu) \sum_q e_q^2\, \mathcal{G}_q(z_h, \vec{j}_T, p_T^{\rm jet} R, \mu)$$

$$\times \int \frac{d^2\vec{b}_T}{(2\pi)^2}\, e^{i\vec{q}_T\cdot\vec{b}_T}\, f_q(x,\vec{b}_T,\mu)\, S_q(\vec{b}_T, y_{\rm jet}, R$$

Similar formalism than, PRL 122 192003 (2019), Phys.Lett.B 774 (2017) 635-642, and arXiv:1812.07549

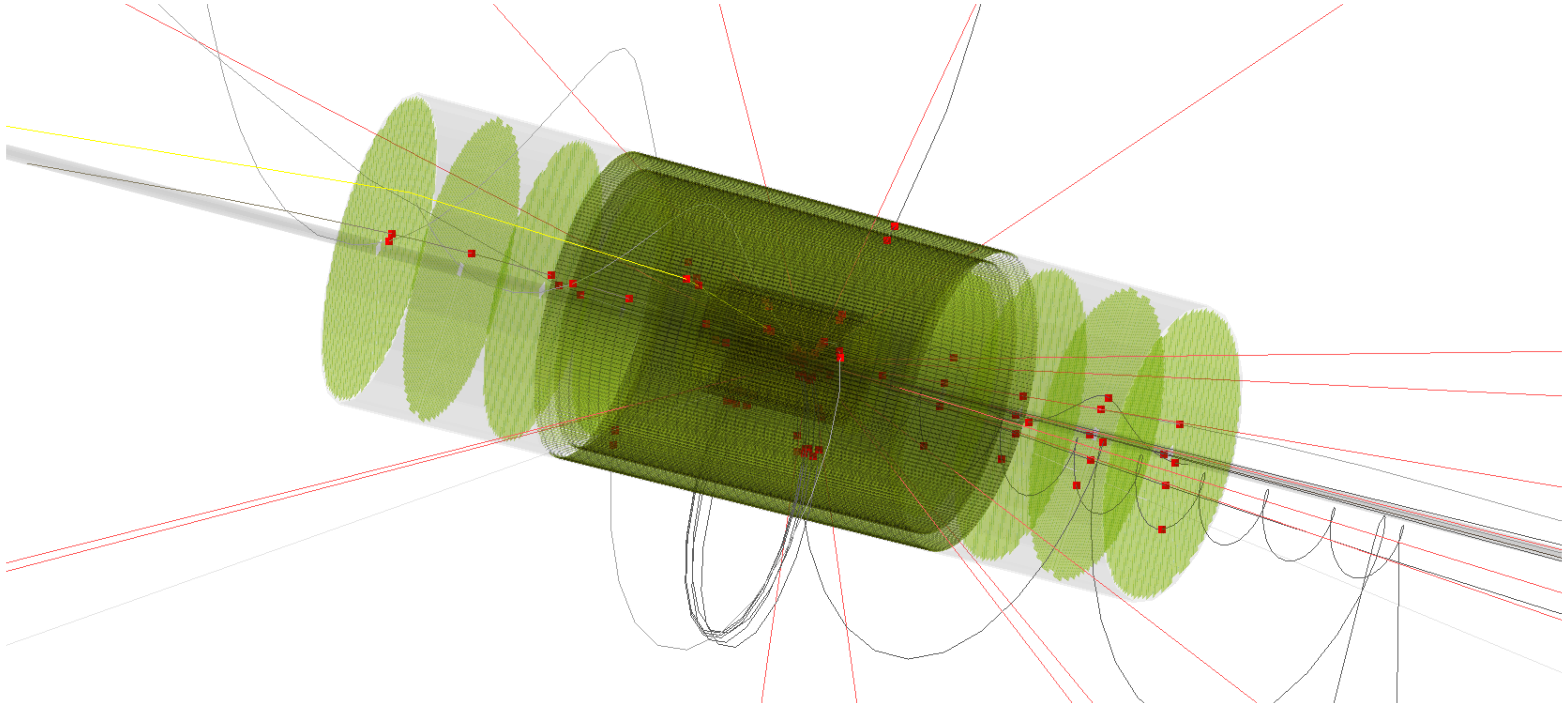
Jet-based measurements have different requirements than SIDIS
-> complementarity of both physics and detector requirements!
For jets, full hermiticity is more important. Energy resolution drives angular resolution

Table 1: Channels listed are increasingly demanding. For every row consider all requirements above as well. The (x, Q^2) dependence of the observables is omitted for brevity. Date: May 21, 2020, Miguel Arratia

Channel	Observable	Goal	Physics-driven requirement	Category	numbers
e-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(\Delta\phi)$	k_T-dependence of quark Sivers	$\Delta\phi$ res. << intrinsic width $\sigma(\Delta\phi) < 0.02$ rad $R = 1.0 \rightarrow$ had. corr. $O(1)\%$ particle-flow reco	Jet res. Acceptance Granularity	ECAL&HCAL $dE/E < 60\%/\sqrt{E}$ 2π, $-1.0 < \eta < 3.5$ HCAL and ECAL endcap $\Delta\phi \times \Delta\eta \leq 0.025 \times 0.025$
h-in-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	q-transversity	dp/p at high $z <$ jet dE/E	Tracker PID	$dp/p < 3\%$ at 50 GeV, up to $\eta = 3.0$ up to $-1.0 < \eta < 3.5$ and 50 GeV
ν-jet (CC) 100 fb^{-1}	$d\sigma$, A_{UT}	u Sivers	$\Delta\phi$ << 0.3 rad Bkg. rej. to phot and NC >70% survival prob. for 5 bins per-decade in x, Q^2	E_T^{miss} res. Acceptance Jet/E_T^{miss} res.	$dE_T^{miss}/E_T^{miss} < 15\%$ 2π, $\|\eta\| < 3.5$ HCAL and ECAL E>100 MeV thres. ECAL E>400 MeV thres. HCAL $p_T > 100$ MeV tracker $dx/x < 20\%$, $dE_T^{miss}/E_T^{miss} < 15\%$
h-in-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	u-transversity	—	—	—
c-jet (CC) 100 fb^{-1}	$d\sigma$, A_{LL}	s PDF& helicity	charm-tagging	Tracker PID	c-jet tag at > 10% (<0.05%) $\sigma(DCA) = 20\ \mu$m, up to $\|\eta\| = 3$ $\approx 100\%$ eff. TBD
h-in-c-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	s-transversity	—	—	—
c-jet (e^+ CC) 100 fb^{-1}	$d\sigma$, A_{LL}	$s/\bar{s}$ asymmetry	positrons	—	—

Join the discussion at the first EIC jet workshop: https://www.bnl.gov/jetobs20/ ,
or the first workshop dedicated to jets for 3D imaging: https://indico.bnl.gov/event/8066/

A Compact All-Silicon Central Tracker Concept for EIC



Winston DeGraw, Rey Cruz Torres, Leo Greiner, Laura Gonella, Barbara Jacak, Peter Jones, Yue-Shi Lai, Ernst Sichtermann, Håkan Wennlöf, et al.

BERKELEY LAB

Berkeley
UNIVERSITY OF CALIFORNIA

UNIVERSITY OF BIRMINGHAM

EIC All-Silicon Tracker Concept

1. Space is at a premium at the EIC and the baseline general purpose detector(s) will need to be compact and tightly integrated,

2. EIC candidate baseline detector concepts feature graded charged-particle tracking resolution; track points are measured with better point resolution closer and closer to the IP,

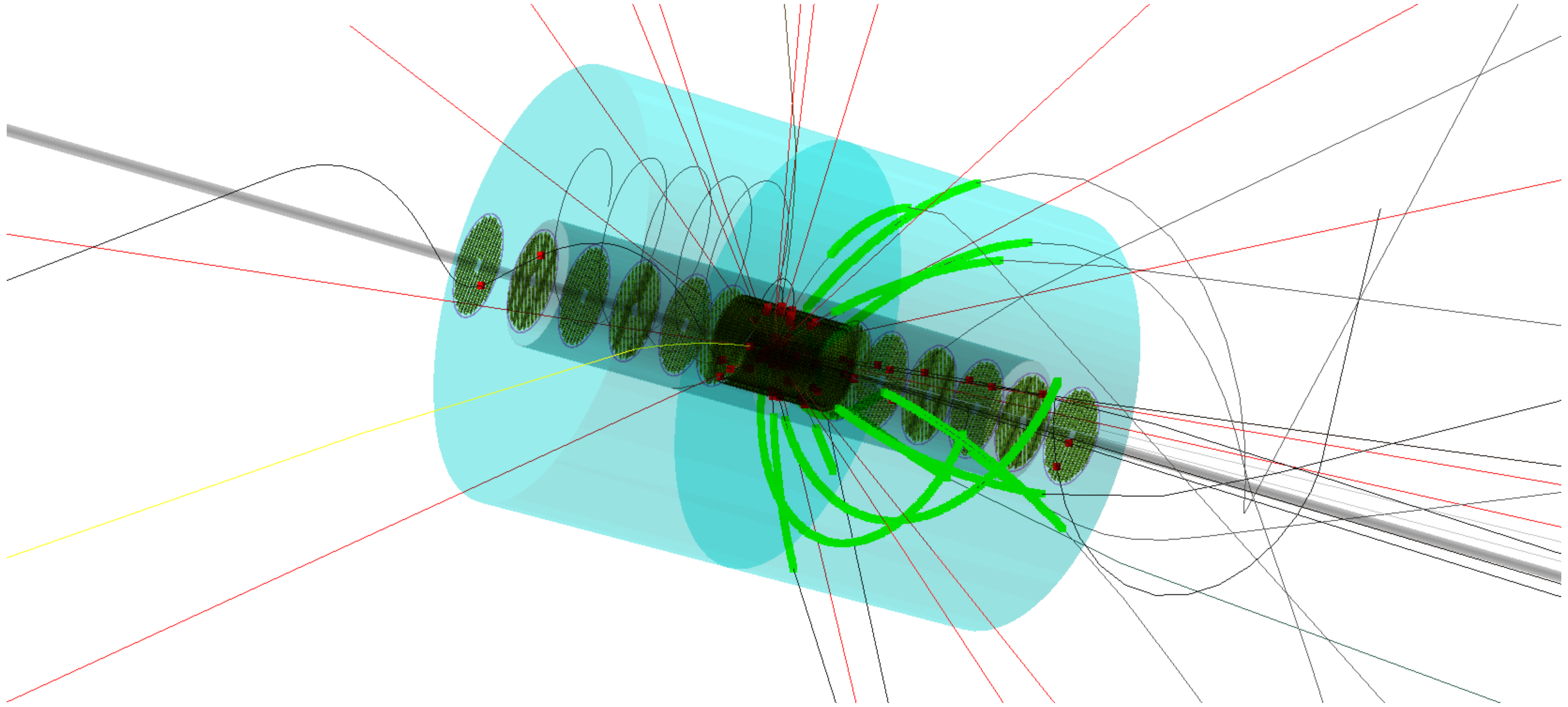
3. Closest to the IP one typically has barrel layers and disks with silicon-sensors; in BeAST, for example, these are monolithic-active pixel sensors (MAPS),

We formed EIC generic detector R&D groups (eRD16 and eRD18, now eRD25) to study charged-particle tracking and MAPS silicon-sensor technology with the aim to address EIC low-mass vertexing and momentum-measurement needs,

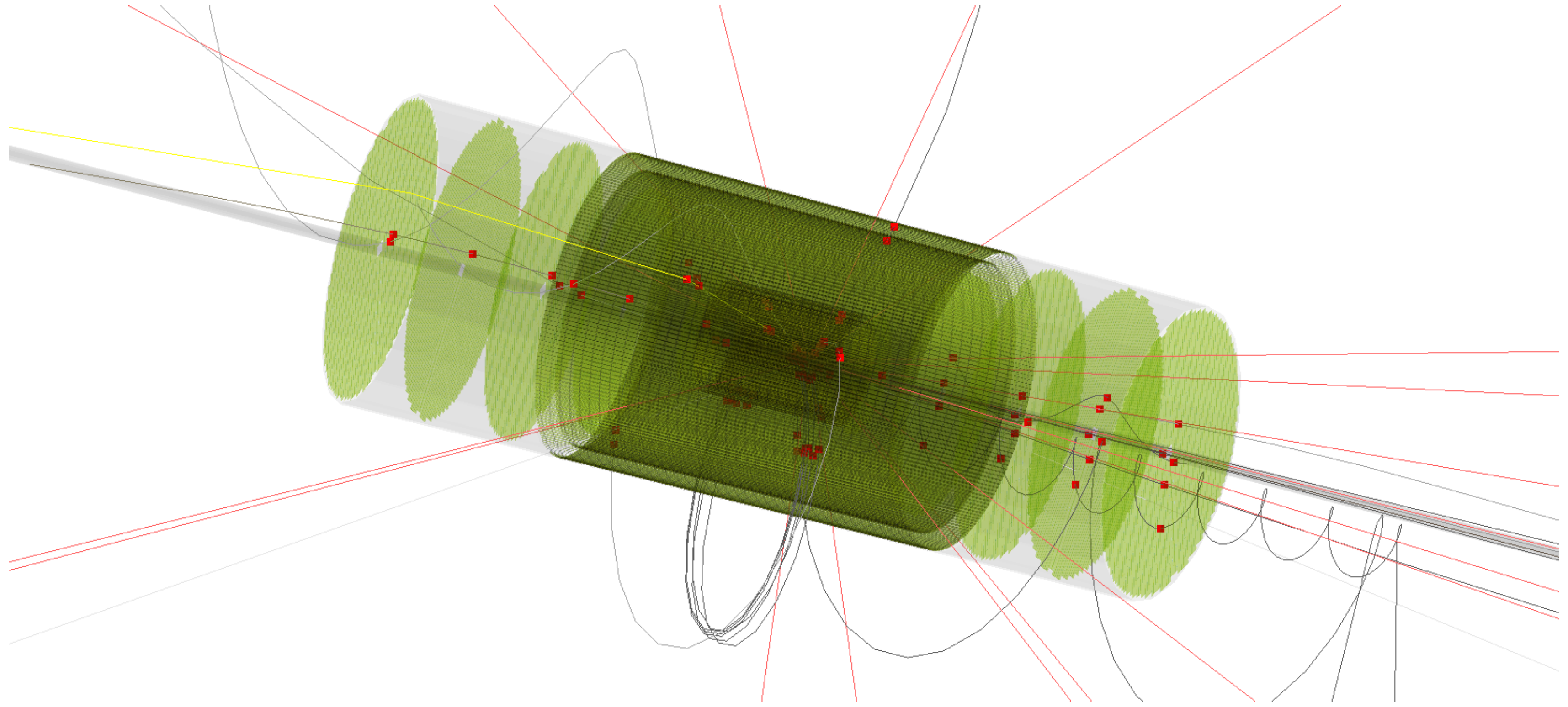
MAPS technology in HENP has come of age in recent years; the ALICE collaboration, for example, has construction a ~10m^2 MAPS-based upgrade, and is actively pursuing the next generation of technologies. Strong synergy with EIC, so we are teaming up.

➡ *What if EIC could benefit from superior position and pointing resolution along the full track trajectory?*

EIC All-Silicon Tracker Concept

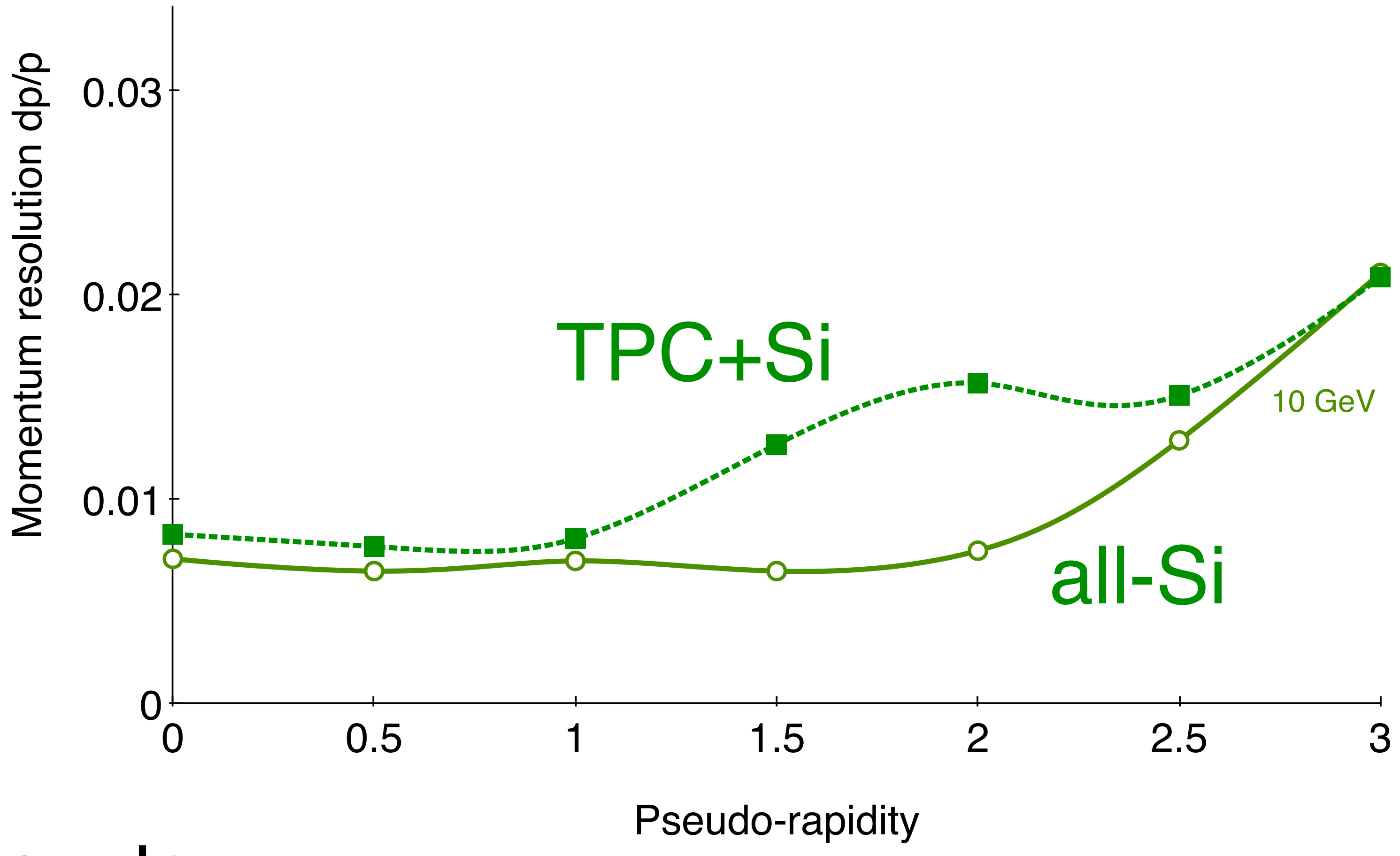


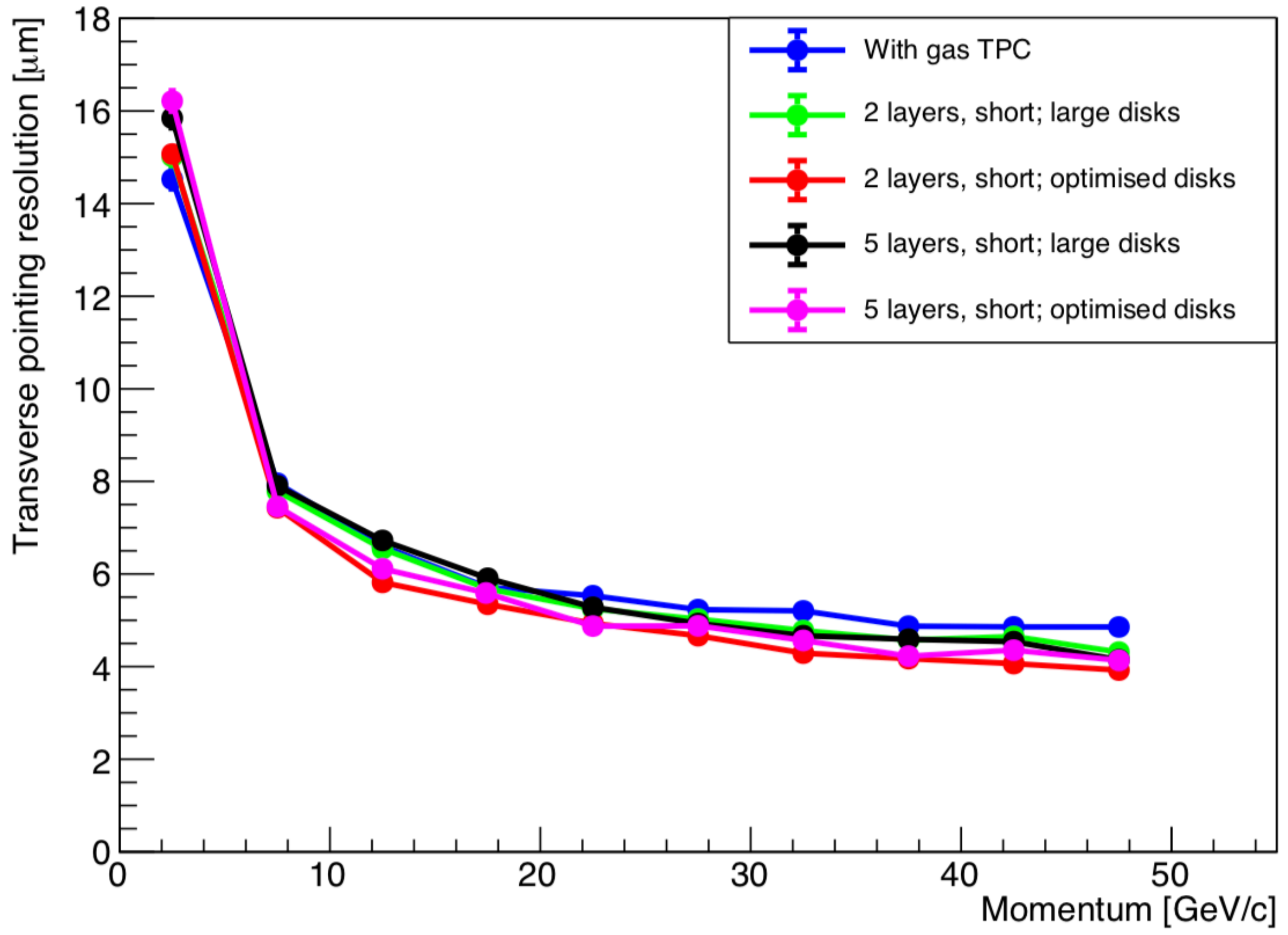
3T BeAST with ~80 cm outer radius TPC,
MAPS inner barrels & disks



~45 cm outer radius MAPS barrels and disks,
identical in length, $-1.2 < z < 1.2$ m
MAPS area ~15 m^2

- Similar or better momentum and angular performance, see also yesterday's tracking talks,
- Identical vertexing performance,
- Radially more compact, ~80 → ~45 cm,
- Thereby freeing ~35 cm that could be used for alternate purposes such as PID,
- Opportunities for complementary baseline detector concepts.





Slides from Domenico, Kondo and Leo

Tracking WG: technology input for complementarity

	TPC + Fast MPGD Layer	Cylindrical MPGD (Micromegas, µRWELL)	Drift Chambers / Straw Tubes	Planar MPGDs (GEM, Micromegas, µRWELL)	Small TGCs	MPGD-TRDs
Barrel region	Pros: - momentum res.; - additional dE/dx; - **cost** - **Low material in barrel** Cons: - **End cap material** - calibration space charge distortion	Pros: - Space point & angular res. - Time resolution (< 10 ns) - **Low material in End cap** - **Cost & robustness** Cons: - Momentum res. - Fabrication challenges - **Material budget in barrel**	Pros: - momentum res.; - additional dE/dx; - **cost** - **Low material in barrel** Cons: - **End cap material** - calibration - Stability issues	Pros: - Alternative to cylindrical MPGDs arrangement in polygons - **Easier fabrication** Cons: - Momentum res. - Detector space barrel - **Material budget in barrel**	N/A	N/A Radiator size
Hadron End Cap	N/A Only planar option		Pros: - momentum res.; - additional dE/dx; - **cost** Cons: - **Material budget** - calibration - Stability issues	Pros: - Momentum & angular res. - Low material (< 0.4% X/X0 per layer) - **Cost & robustness** Cons: - **?**	Pros: - Momentum & angular res. - **Cost & robustness** Cons: - **Material budget**	Pros: - Additional tracking - Angular res. for RICH - **Additional e/π PID** Cons: - Radiator size
Electron End Cap	N/A Only planar option		N/A	Pros: - Momentum & angular res. - Low material (<0.4%) - **Cost & robustness** Cons: - **?**	N/A Mainly because of material budget	Pros: - Additional tracking - **Complement main e PID in electron end cap** Cons: - Radiator size?

Tracking WG: technology input for complementarity

Tracking Si central detector (vertex + barrel + discs)

Technology: for the vertex, barrel and inner disc detectors, the only identified technology that meets the requirements are MAPS. No currently existing MAPS sensor appears to fully meet all of the EIC requirements (current simulations are based on ALPIDE sensors with a smaller pixel size 20 x 20 um^2). In order to produce a new sensor design that meets the EIC requirements a consortium of EIC groups are joining an ongoing sensor development effort at CERN. There are contingency plans for modification of existing sensor designs to meet EIC requirements should this CERN effort be unsuccessful.

There is general consensus that this is a promising path to pursue to deliver an EIC sensor in the given timeframe. Momentum and pointing resolution performance studies are in progress. EIC requirements seem satisfied.

ITS3 silicon design parameters

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

	Stave X/X0
ITS3 like vertexing	~0.1%
ITS3 like barrel (up to 1.5m length)	0.55 %
ITS3 like disc (up to 60 cm diameter)	0.24%

Si + gaseous detector vs. all silicon

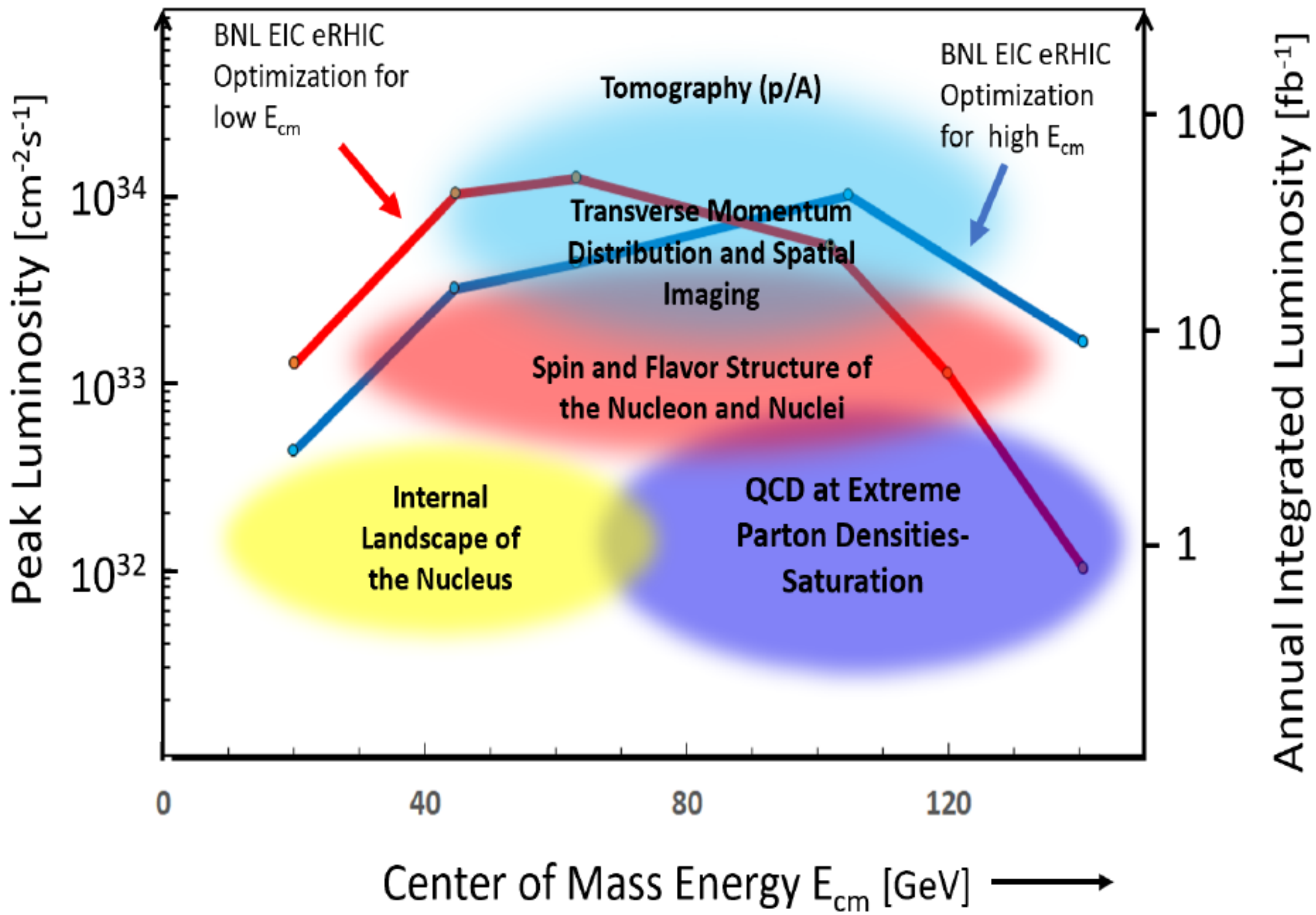
	Si + gaseous	All Si
Attributes for consideration	• dE/dx in gas for PID • Well understood technology - less R&D needed. • Costs less (likely) • Less material in tracking region • Worse single point resolution but more position samples	• Readout faster than TPC • Better momentum resolution than TPC at higher momentum (>~5GeV/c) • Can be made more compact • Less material in endcap regions • Fewer calibration/correction issues • Very high single point resolution

Slides by Vasiliy Morozov

EIC 2nd IR

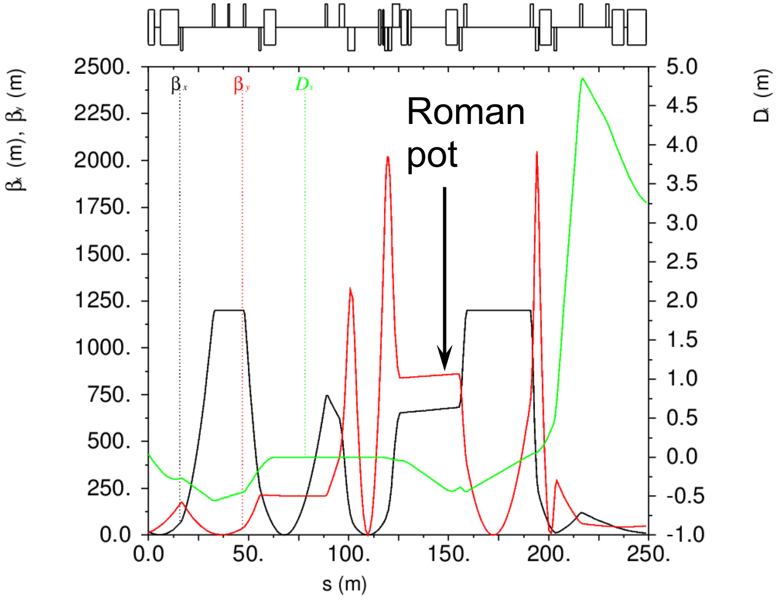
- High-level requirements
  - High luminosity at a low CM energy of ~60 GeV
  - Detector acceptance meeting physics requirements (what matters most for the machine design is the forward acceptance requirements)
  - If possible compatibility with running in parallel with the baseline detector

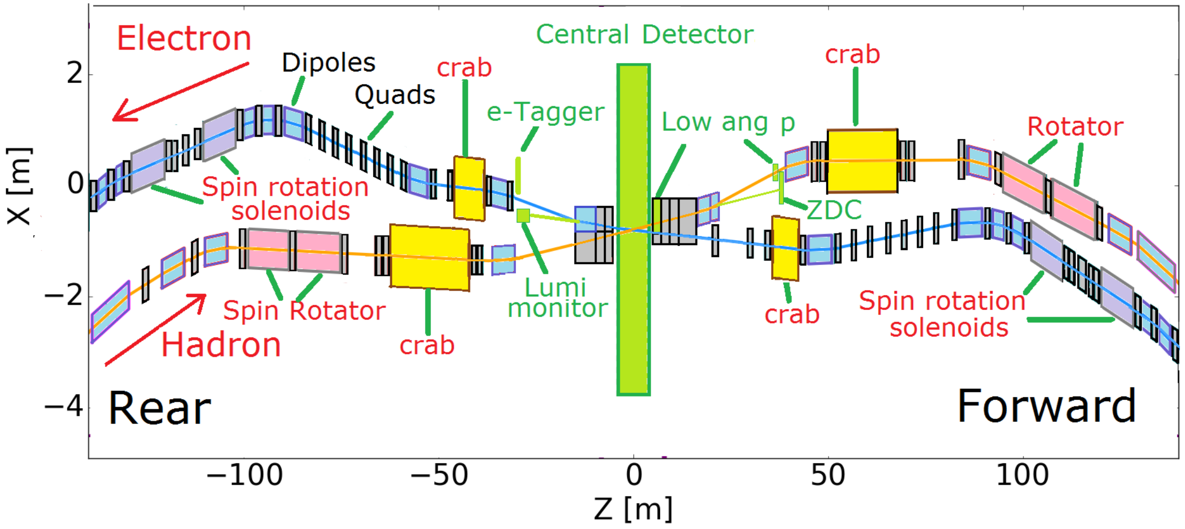
- Differences from the baseline IR that should result in a high luminosity at a low energy
  - Greater crossing angle of 50 mrad
  - Doubled collision rate
  - Closer placement of electron FFQs
  - Strong cooling
  - Stronger focusing at the IP
  - Shorter bunch length



2nd Detector Acceptance

- Acceptance parameters determining the IR design
  - Forward ion quadrupole aperture size determining the angular acceptance: divergence of the neutron cone and small-angle charged particles with $p_\perp$ up to 1.3 GeV
  - The necessity of the secondary focus: there is dispersion at the roman pot location in the baseline IR, it should allow detection of particles with $x_L < 0.9$ when $p_\perp = 0$
  - Shift of the IP from the center of the detector space to provide more room for sub-detectors in the forward direction. This is not a huge effect but affects the ion closed orbit correction.





Acceptance as Function of x_L and p_T

- p_T acceptance at $x_L = 0$

  $$p_T^{min} > 10\,p_0\,\theta_{IP} = 10\,p_0\sqrt{\varepsilon/\beta^*}$$

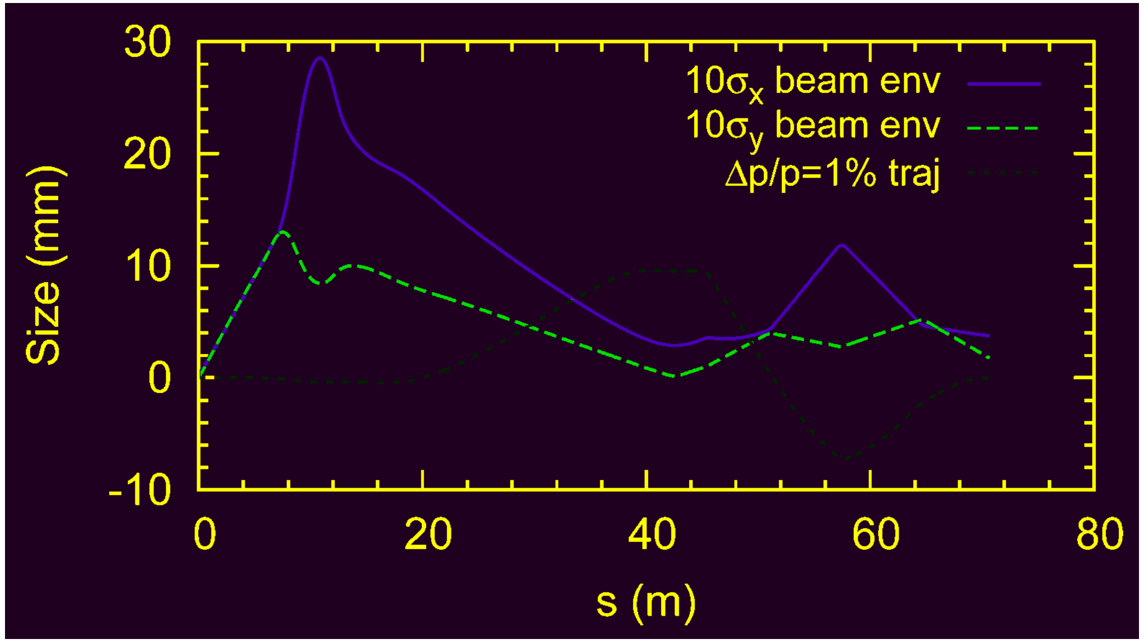
- x_L acceptance at $p_T = 0$
  - Requires dispersion D

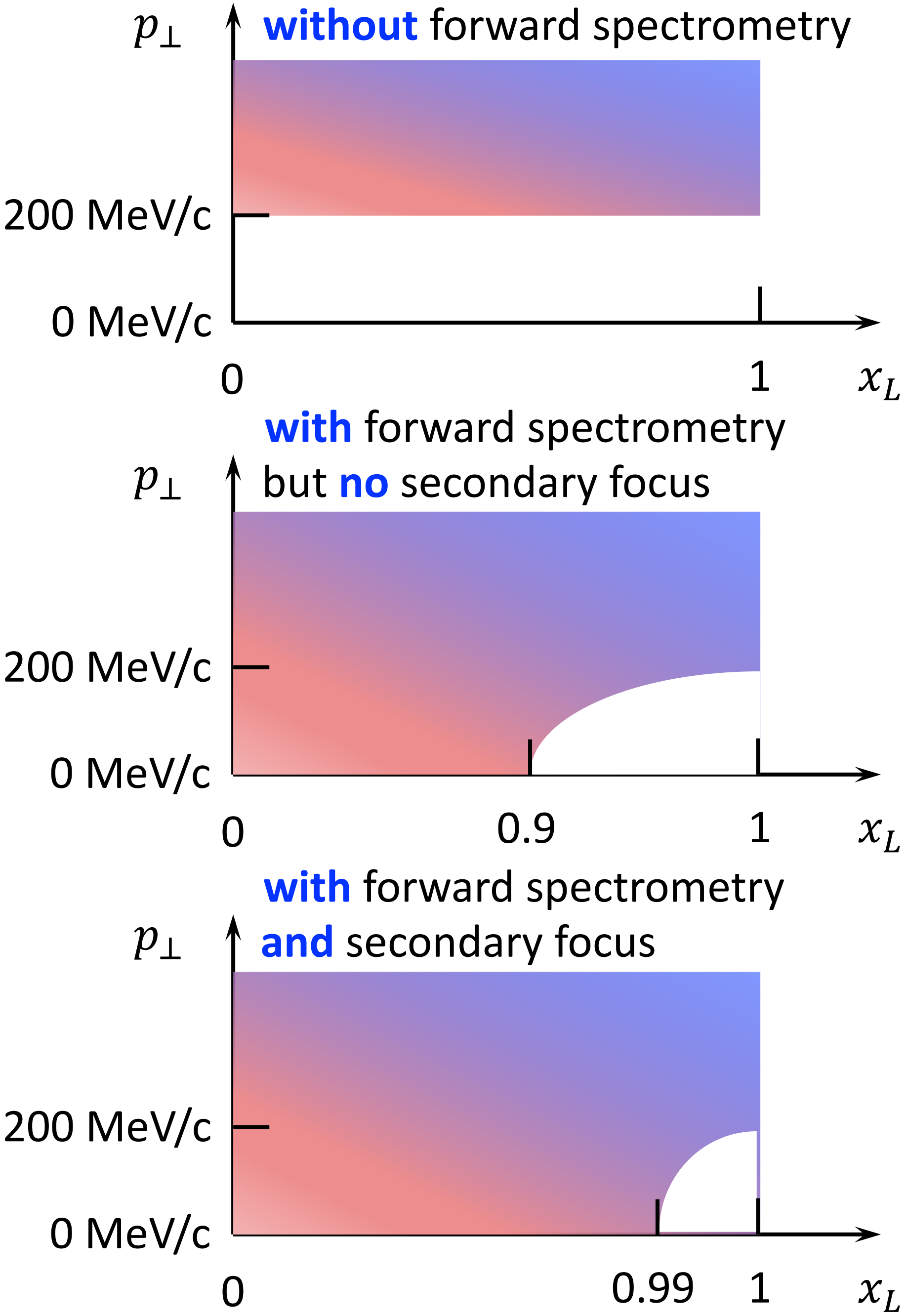
    $$1 - x_L > 10\frac{\sigma}{D} = 10\sqrt{\beta\varepsilon + D^2\sigma_\delta^2}/D$$

  - Secondary focus allows for

    $$|D\sigma_\delta| \gg \sqrt{\beta\varepsilon}$$

  - Therefore, one can approach the fundamental limit $x_L < 1 - 10\sigma_\delta$

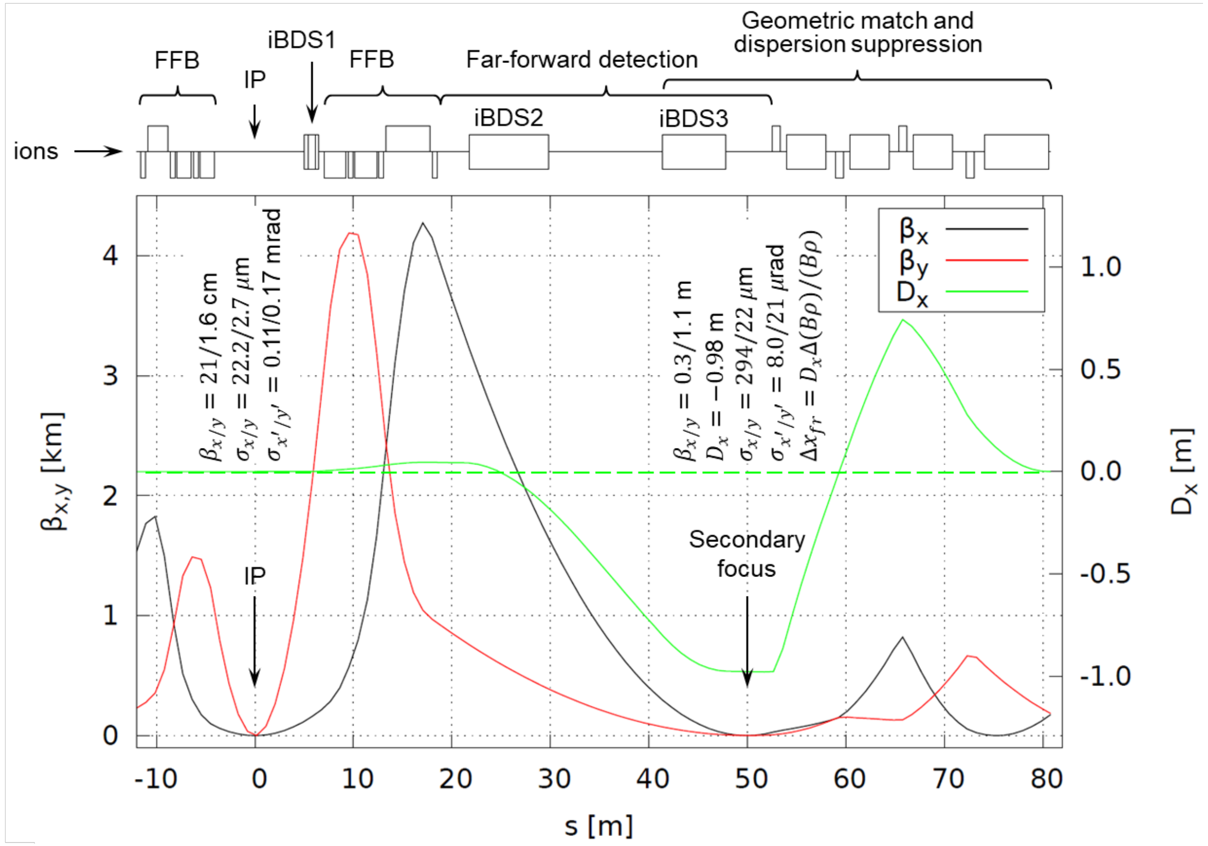




Backup

Why Secondary Focus?

- Illustration using JLEIC IR as an example
- It allows one to detect particles up to relatively high-x_L even with $p_\perp = 0$
- Needs physics motivation
- Assuming $\beta_x = 5$ m and $D_x = 0.5$ m at the secondary focus and $\varepsilon_x = 14$ nm and $\Delta p/p = 6.5 \cdot 10^{-4}$, particles detectable with $x_L < 0.99$ when $p_\perp = 0$.



- Illustration using JLEIC IR as an example
- It allows one to detect particles up to relatively high-x_L even with $p_\perp = 0$
- Needs physics motivation
- Assuming $\beta_x = 5$ m and $D_x = 0.5$ m at the secondary focus and $\varepsilon_x = 14$ nm and $\Delta p/p = 6.5 \cdot 10^{-4}$, particle detectable with $x_L < 0.99$ when $p_\perp = 0$.

Space Available for 2nd IR

- Assuming IP8 experimental hall dimensions
- The luminosity curve optimized for low energy adopted JLEIC IR parameters
- What if we simply drop the JLEIC 200 GeV IR into the lattice?
  - Clearly the geometry requires adjustment but it does not seem hopeless
  - There are additional constraints: crab cavity and spin rotator integration
  - Need to account for higher energy in case of parallel IR operation