# Parallel session

# Calorimeter & Particle ID & Tracking

# Tracking summary

**D. Elia, K. Gnanvo, L. Greiner**

for the Tracking WG

# Ongoing activities and available results

**Ongoing activities:**

- Working on the following main deliverables:
  - Evaluate all-silicon vs hybrid (silicon & gaseous) trackers
  - Compare realistic alternatives (TPC, MPGD options) for gaseous detectors, barrel and forward
- Preliminary performance studies (mainly EicRoot-based simulations):
  - Central region Si-vertex + TPC + Fast MPGD Layers **advanced**
  - Cylindrical Micromegas (MPGDs) **just started**
  - Endcap region GEM (MPGDs) trackers **just started**
  - All-silicon (barrel) tracker + forward/backward silicon disks **advanced**
  - Comparisons all-silicon vs BeAST (Si-vertex + TPC + MPGDs) concepts **ongoing**
- Effort on Fun4All and ESCalate frameworks:
  - first implementations of all-silicon tracker in Fun4All and G4E **ongoing**
  - plan to implement realistic material and services for all the tracking detectors **just started**

**Available results:**

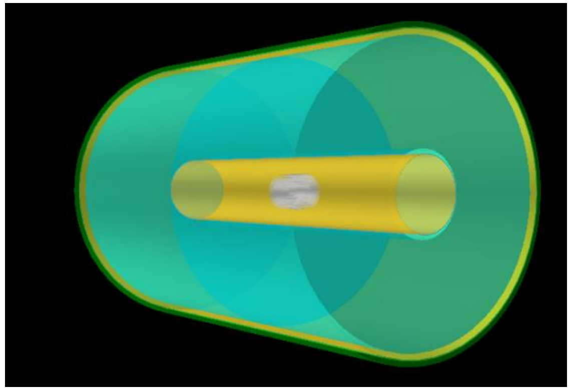
- Relative momentum and pointing resolutions (in different configurations and options)
- Angular resolutions at DIRC (Si-vertex + TPC + Fast MPGDs different options)

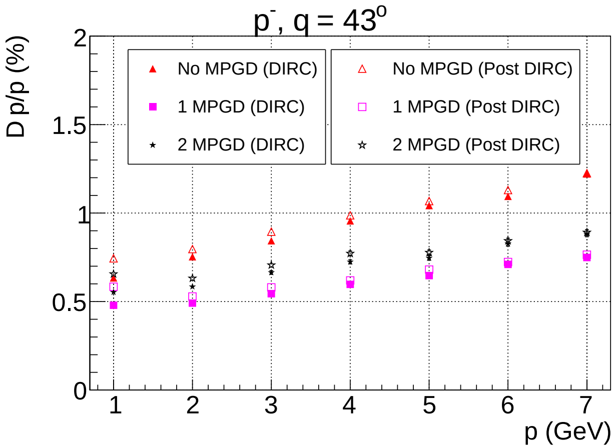
# Si vertex + Gaseous Tracking

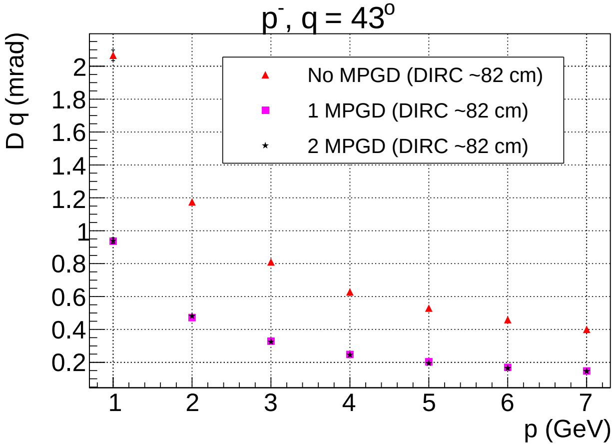
Matt Posik, for eRD6

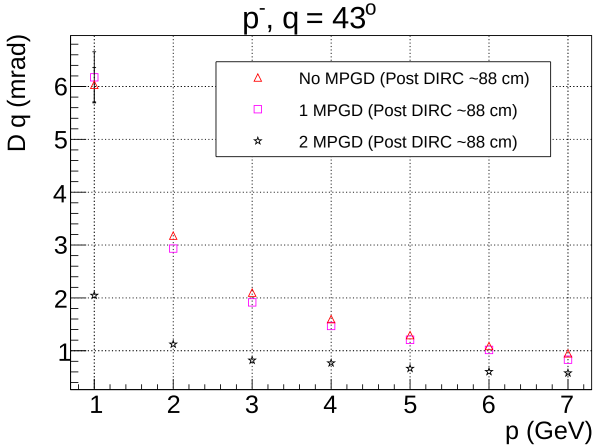
## Si-vertex + TPC + Fast MPGD layers

- ❑ Si-vertex tracker: 4 layers of 20 $\mu m \times 20\ \mu m$
- ❑ TPC: No distortion corrections, field cage and end cap materials included
- ❑ 3 configurations investigated
  - ○ No MPGDs
  - ○ One (or two) outer MPGD layers in front (or “sandwiching”) of DIRC
  - ○ One Inner MPGD layers: fast and calibration for TPC detector

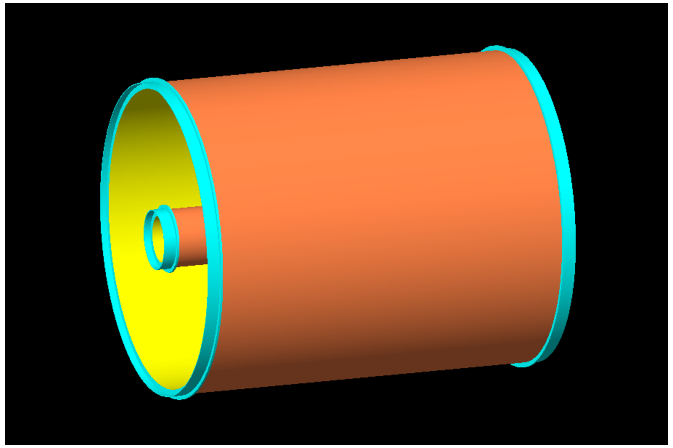




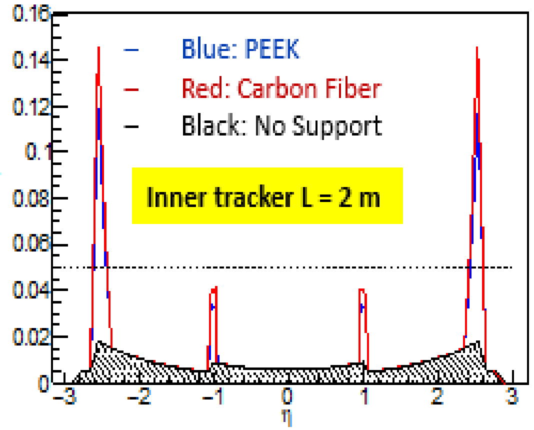



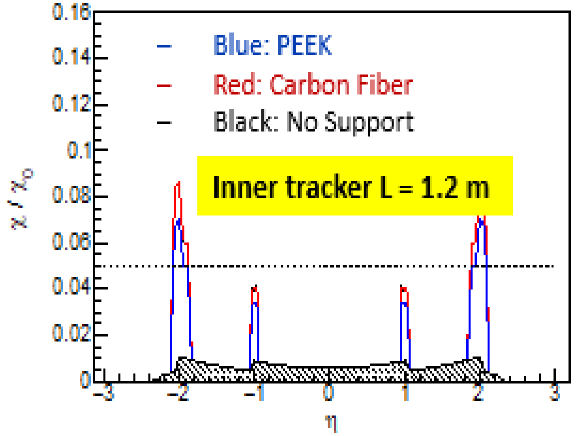

### Mock prototype (support ring)



### Material budget studies

- ❑ additional **inner µRWell:** Fast signal & calibration for TPC
- ❑ Detector configuration; Fast layers in barrel region
  - ○ Outer µRWell layers: L =2 m; radius = 80.0 cm
  - ○ Inner µRWell layer: L = 1.2 or 2 m; radius = 12.5 cm
  - ○ Impact of length & support structure on radiation length



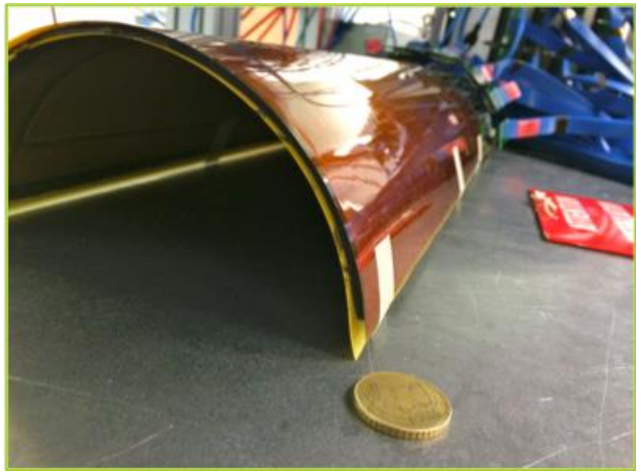



# Si vertex + Gaseous Tracking

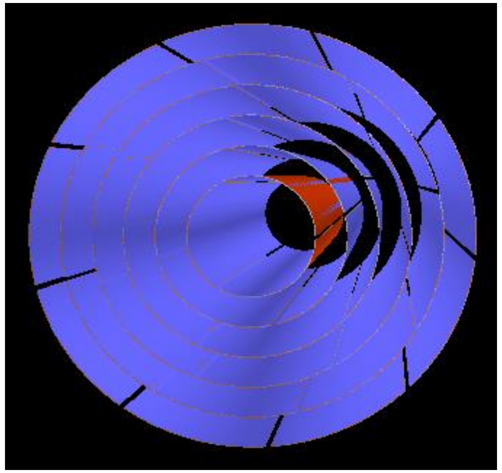
Qinhua Huang, CEA Saclay

## Si-vertex + Cylindrical MPGDs

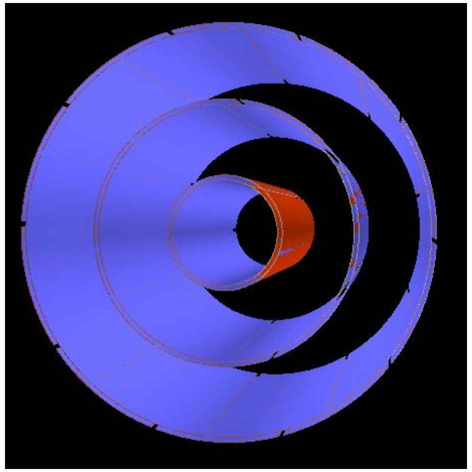
- Barrel MPGD tracker as TPC alternative:
  - Curved MPGD tiles with low material budget
  - Micromegas technology is being used in CLAS12
  - Possibly readout 2D coordinates on a single layer
- Simulation and performance study are under the ePhenix context
  - ePhenix TPC is replaced with the tracker
  - R is from 20 to 80cm, 2 configs are studied
- Compare material budget for TPC and 2D MPGD
  - Both TPC & 2D MPGD tracker compatible with X/X0<5% requirement for central tracker



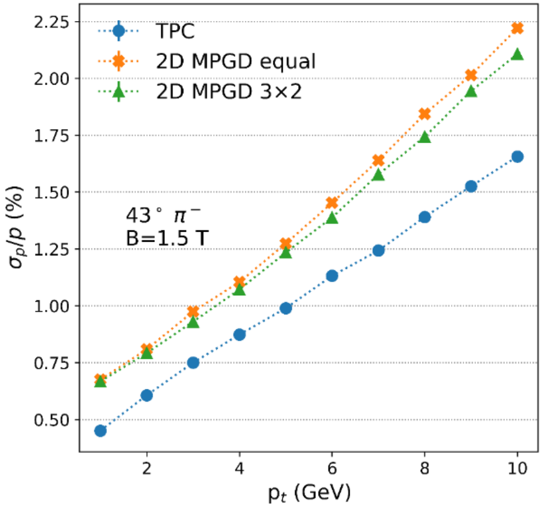
X/X0 ~ 0.3% per layer

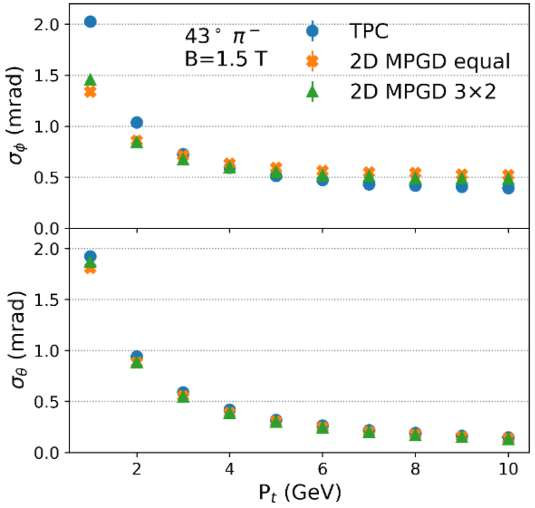


6 equidistant layers

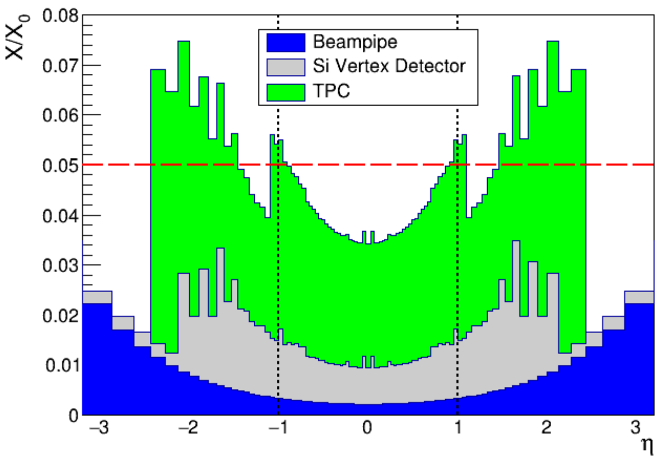


6 layers arranged as 3x2

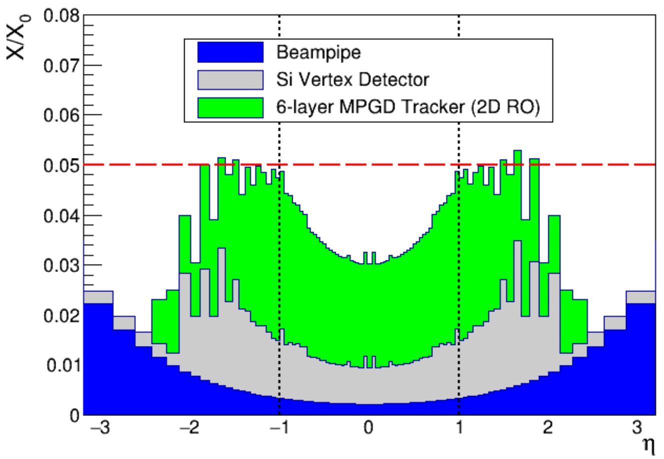



TPC




6-layer 2D RO MPGD tracker



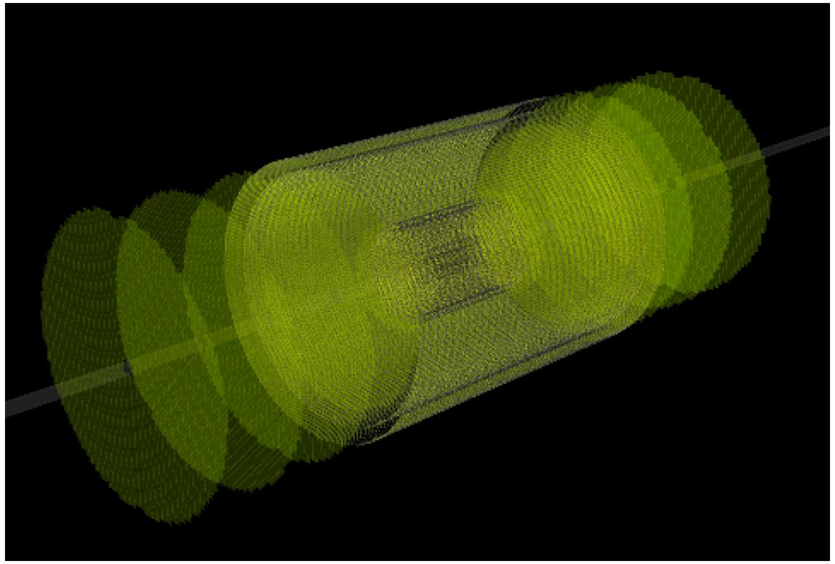
# Gaseous Detectors: technology input for complementarity

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

# All Silicon Tracking concepts

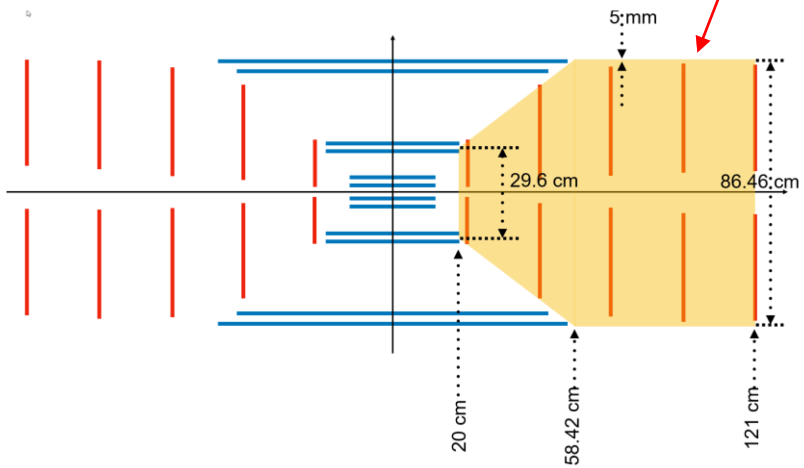
Ernst Sichtermann et al, eRD16

## All silicon inner detector design

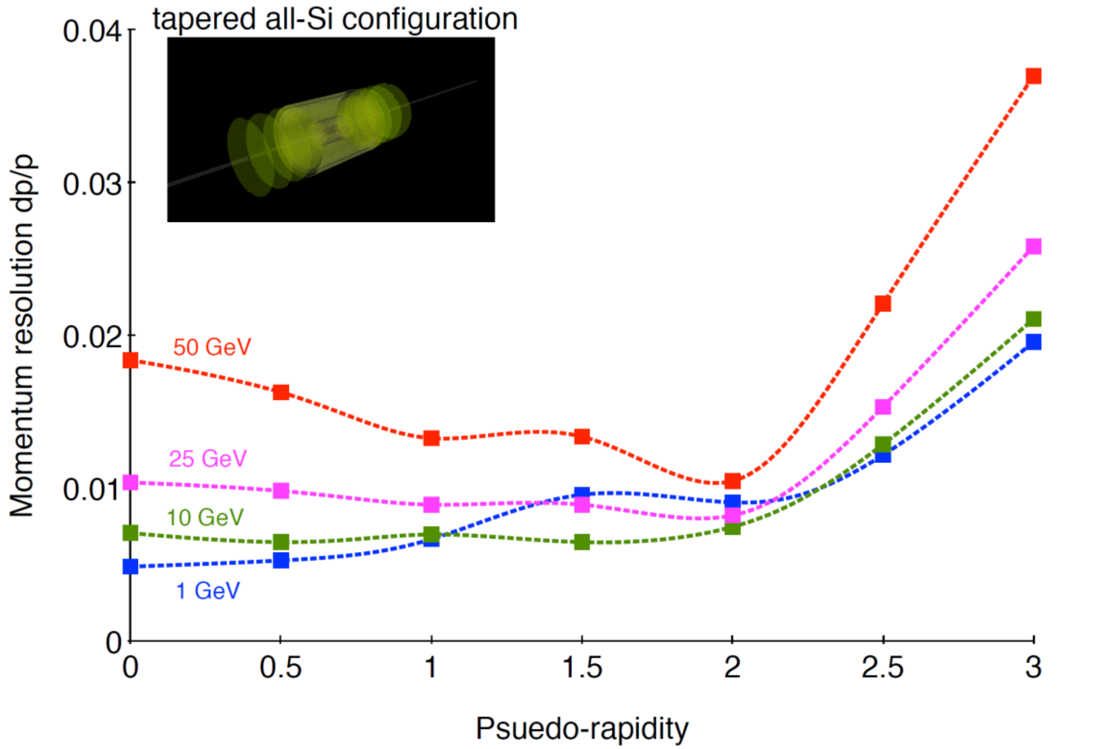


**EIC-root**

tapered all-Si configuration, r ~ 43cm




- Multiple configurations simulated, tapered all Si configuration shown.
- An all-silicon tracker, two eRD18 vertex layers, seven eRD16, “tapered”, equidistant disks in a BeAST configuration, and an ALICE-like outer barrel, in a 3T solenoidal field
- Identical barrel configurations, identical in length (*z*) to BeAST.
- Material cones/cylinders (5mm Al) surrounding the disks were implemented to make a start on the effects associated with support structures, read-out infrastructure, etc.; studies started/in progress.

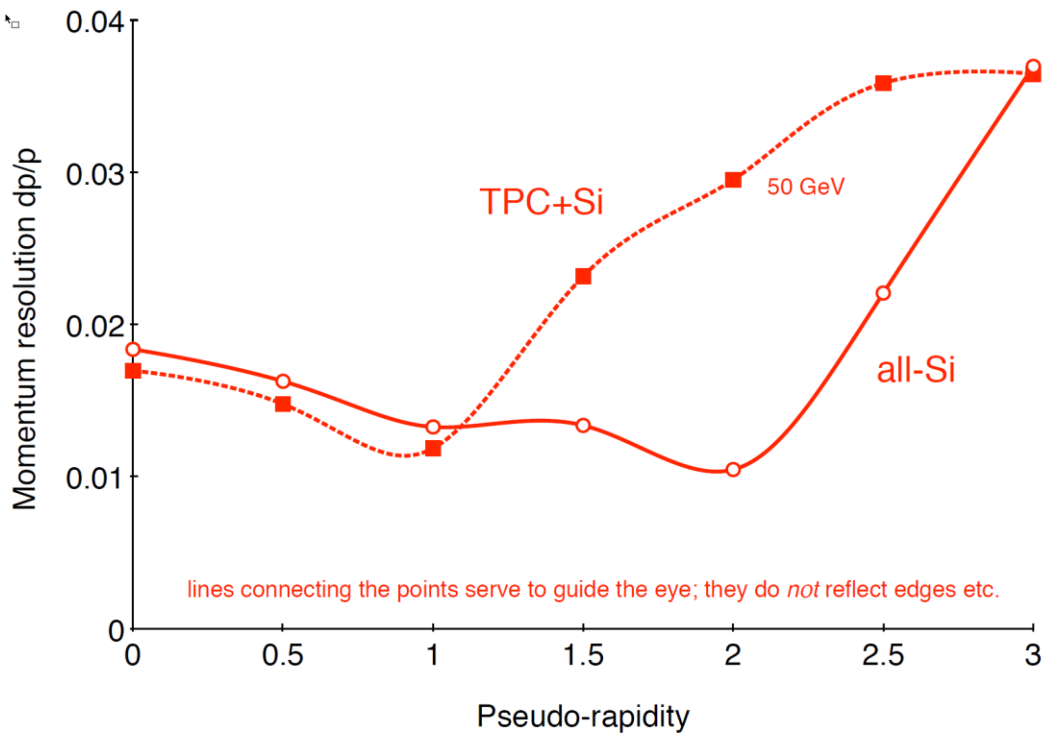


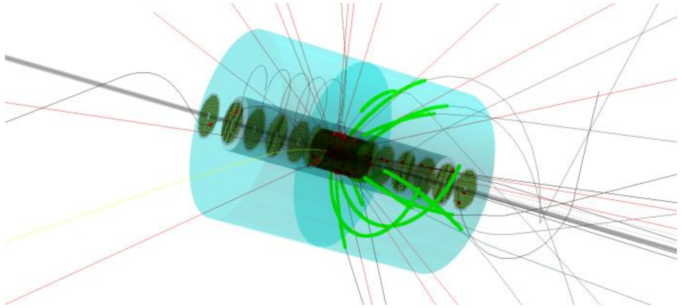
# All Silicon Tracking concepts

Ernst Sichtermann et al, eRD16

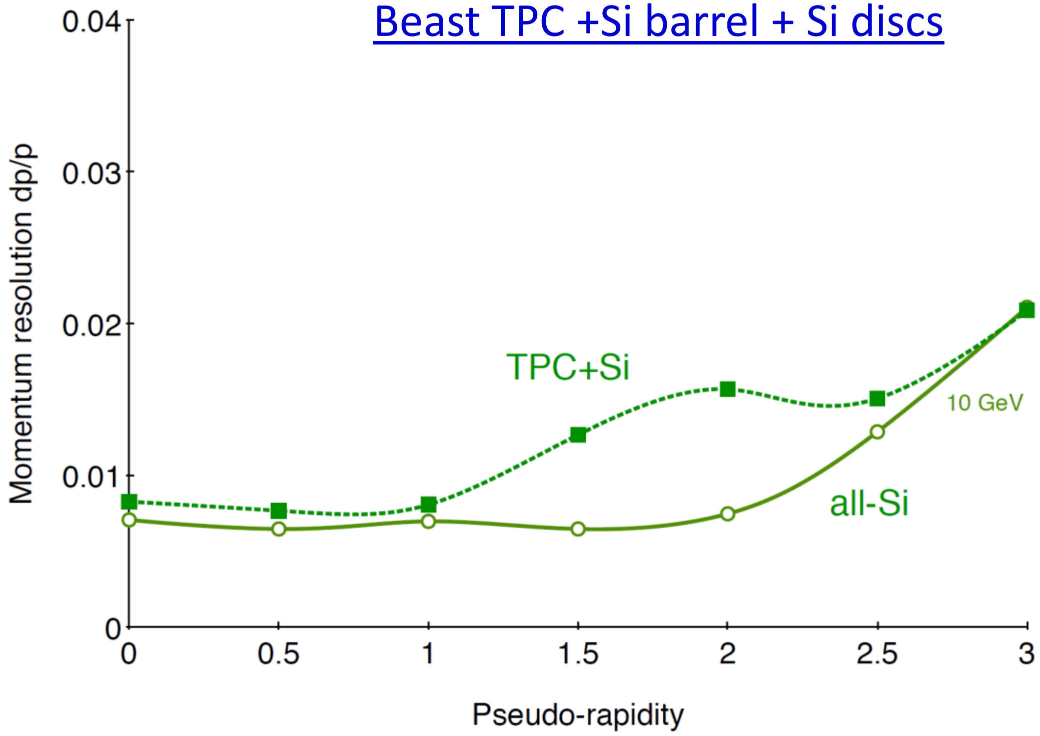
**Comparisons of (Beast TPC +Si barrel + Si discs) with all silicon design (TPC replaced with 5 Si barrel layers)**

**EIC-root**



Beast TPC +Si barrel + Si discs

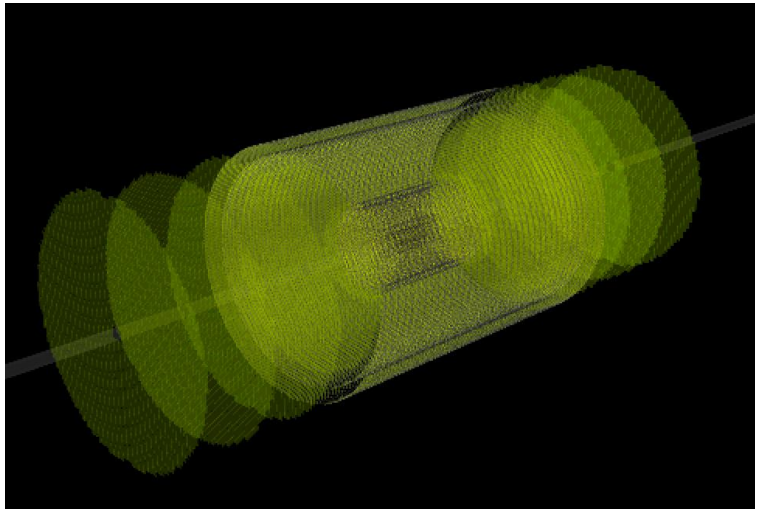


# All Silicon Tracking concepts

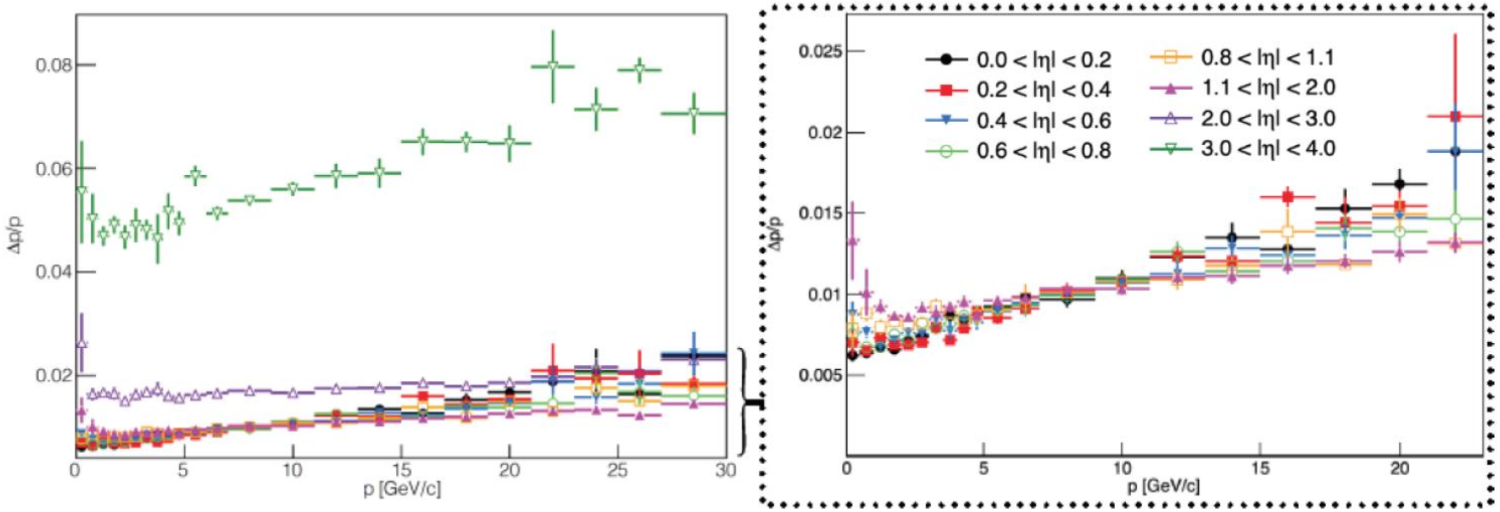
Rey Cruz-Torres, Winston DeGraw - UCB

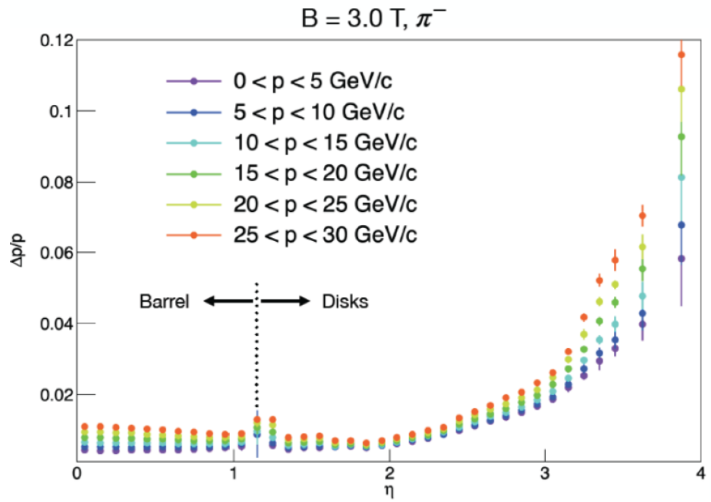
## All silicon inner detector design

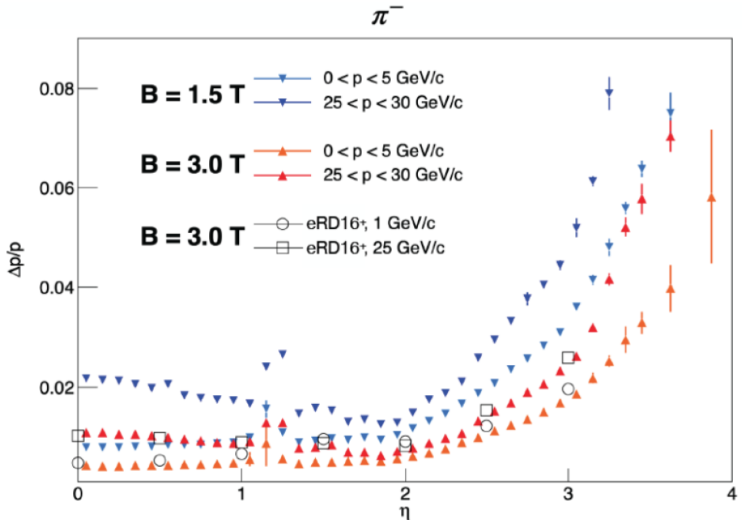
The “tapered all-Silicon” model from ERD16 implemented in Fun4All



**Fun4All**



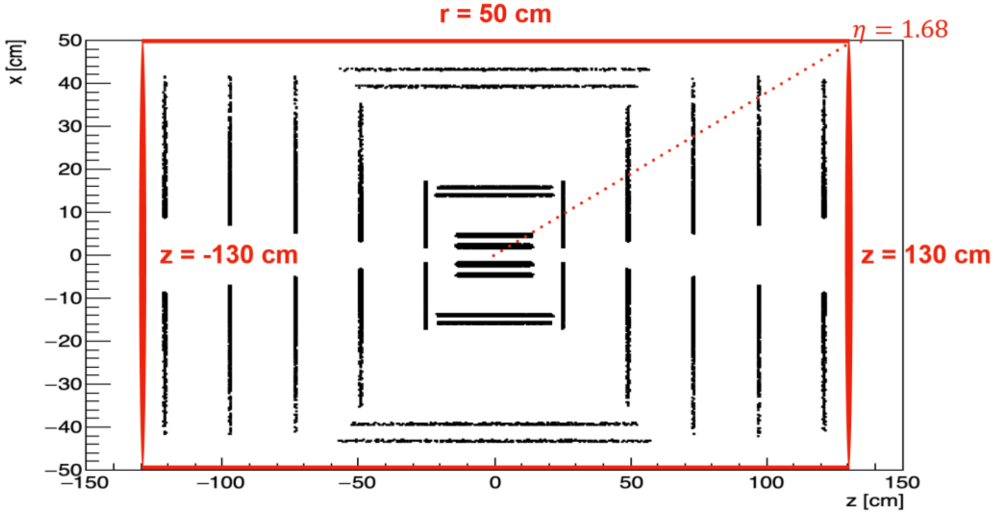

Performance very good and consistent with EICroot modeling

# All Silicon Tracking concepts

Rey Cruz-Torres, Winston DeGraw - UCB

## All silicon inner detector design – angular resolution at PID locations

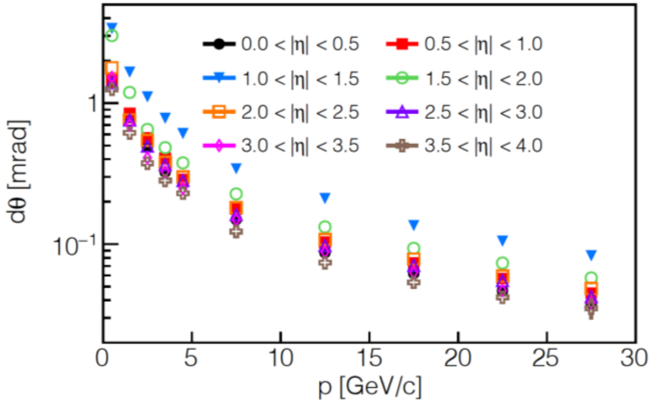
Again – using the "tapered all-silicon" model with Functionality added by Chris Pinkenburg to project momenta onto cylinders or planes

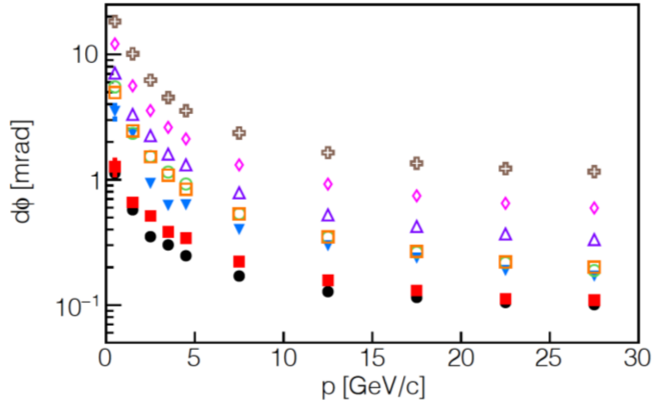


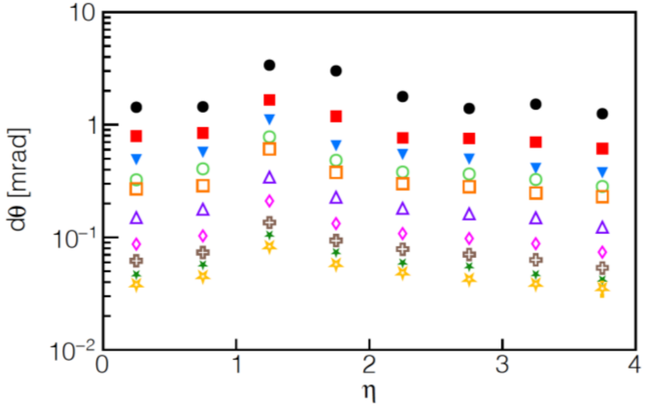

Fun4All

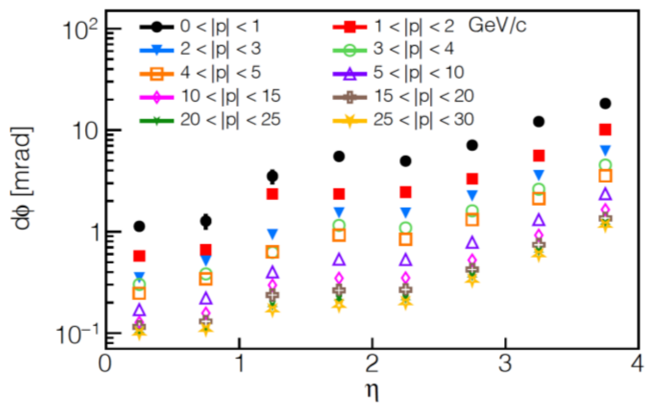
Initial results
Do not include PID detector material

$e^-$, B = 3.0 T



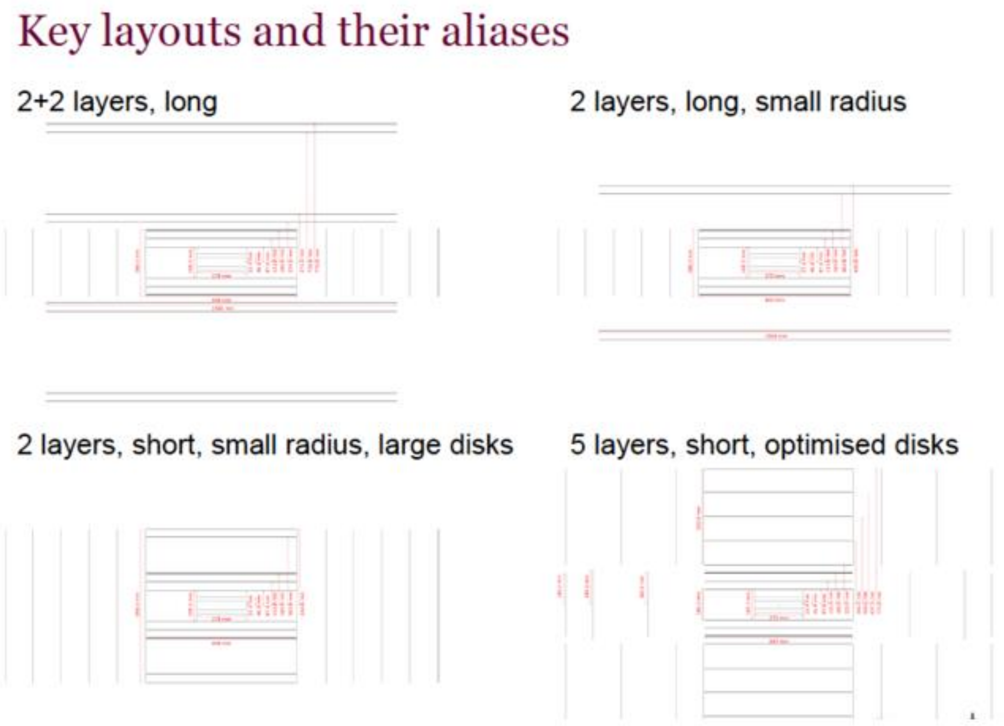



# All Silicon Tracking concepts

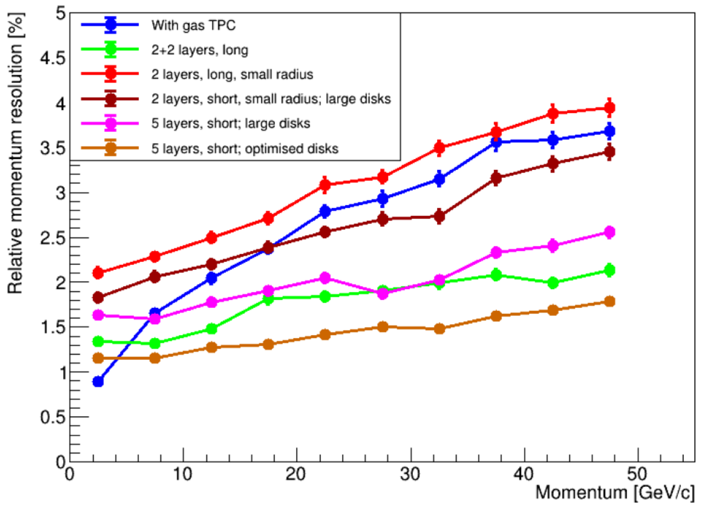
H. Wennlöf et al. ERD 18

**All silicon inner detector design and comparison with Beast TPC**

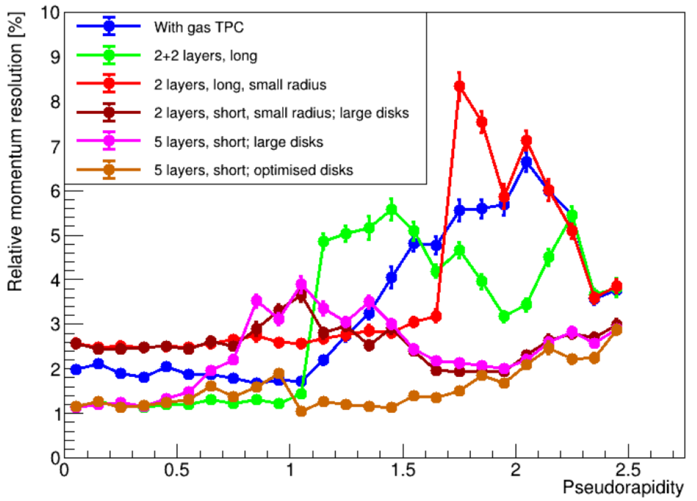
Many silicon geometries simulated – see tracking notes for full list




Relative momentum resolution vs p




Relative momentum resolution vs η




**EICroot**

- ❑ Large disk coverage is important to keep resolution at higher η
- ❑ All-silicon layout can outperform Si+TPCat p≥5 GeV/c
- ❑ Pointing resolutions do not change much between layouts, apart when layers are missed

# 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<br>• Well understood technology - less R&D needed.<br>• Costs less (likely)<br>• Less material in tracking region<br>• Worse single point resolution but more position samples | • Readout faster than TPC<br>• Better momentum resolution than TPC at higher momentum (>~5GeV/c)<br>• Can be made more compact<br>• Less material in endcap regions<br>• Fewer calibration/correction issues<br>• Very high single point resolution |