IDEA Tracker Resolution Studies

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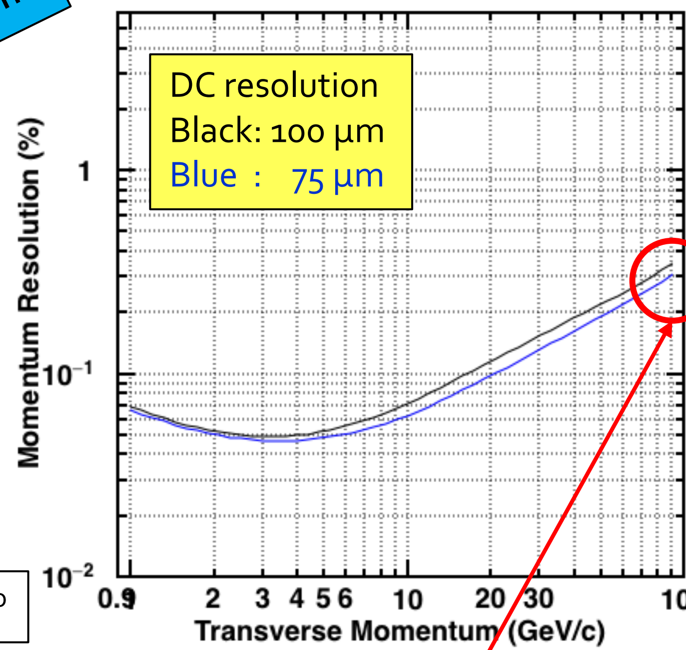
Mogens Dam
Niels Bohr Institute
Copenhagen, Denmark

IDEA Tracking System Performance – First Results

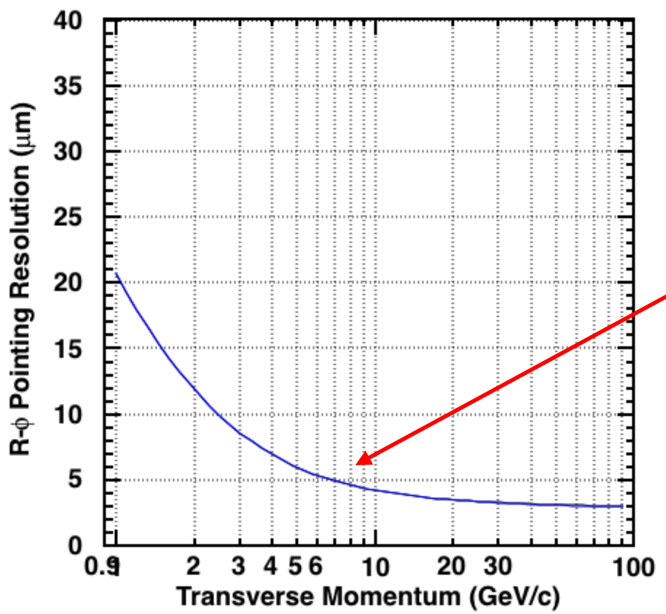
- Beam pipe: r = 1.56 cm; 0.48% of X_0
- Five VTX layers (5 µm resolution)
  - r = 1.7, 2.3, 3.1 cm; 0.3% of X_0 per layer
  - r = 15, 25 cm; 1% of X_0 per layer
- Drift chamber (112 layers of 100 (75) µm resolution)
  - r = 35-200 cm (1.47 cm drift cells)
- One precise Si strip measurement (10 µm resolution)
  - r = 201 cm
- Very light: Total of ~5% of X_0 before pre-shower

Slide from Berlin



Reaching 0.3% at 100 GeV

Performance at θ = 65°



Impact parameter resolution

$$\sigma_{d_0} = a \oplus \frac{b}{p \sin^{3/2}\theta}$$

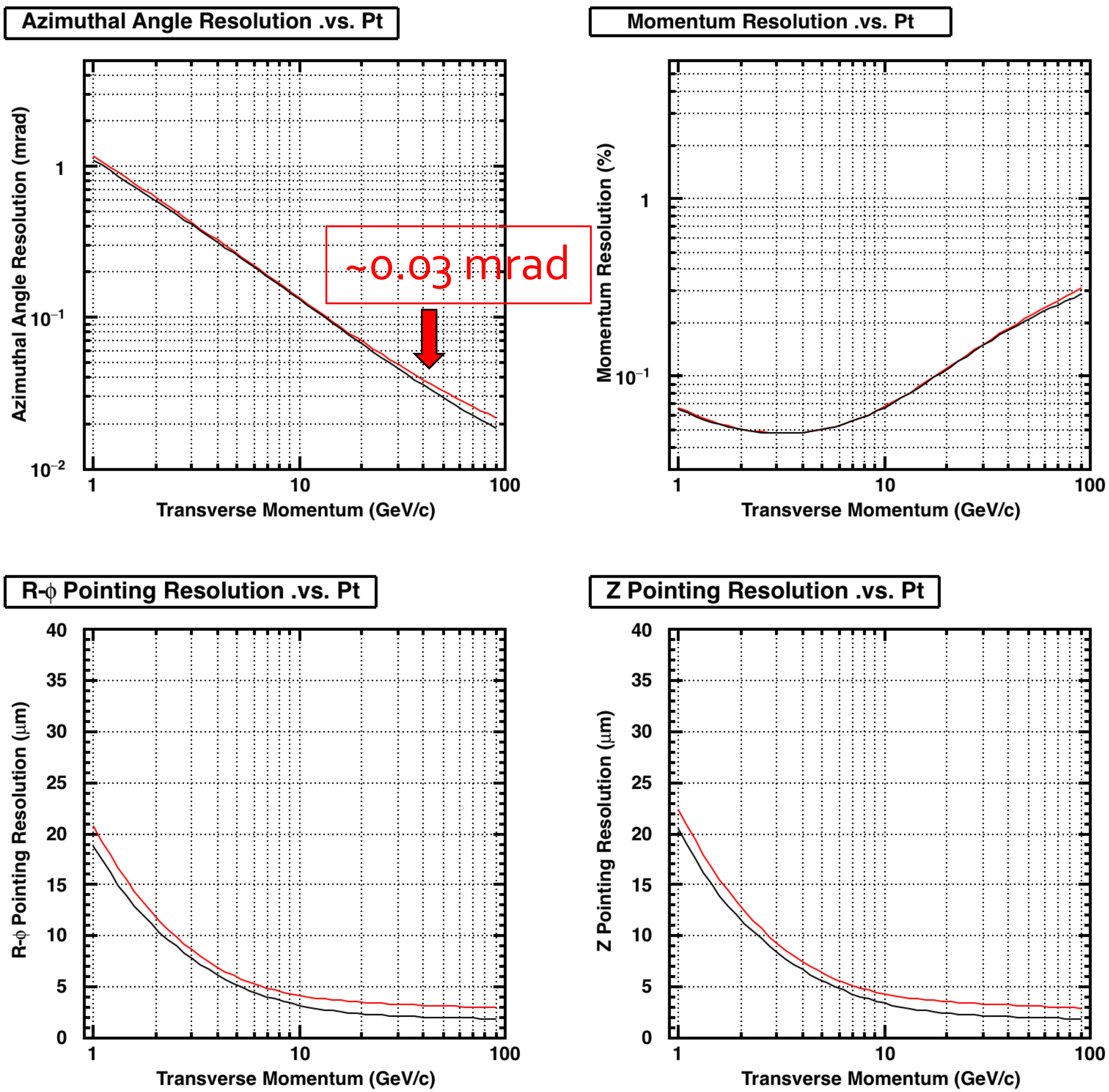
$a \simeq$ 3 µm $b \simeq$ 18 µm GeV

Results by ALICE tracking system optimization tool kindly provided by R. Shahoyan

Very fresh results.
Optimization to be done!

More realistic(?) resolutions

- Red: Berlin
- Black: New
  - Inspired by ILD/SiD/CLIC:
    - VTX: 5 -> 3 μm
    - Outer Si: 10 -> 7 μm
  - Franco Grancagnolo:
    - DC: $\sigma_{R\phi}$ = 75 -> 80 μm
- Changes basically only affects vertex resolution
  - Except at highest p_T
- Use black curve as new reference



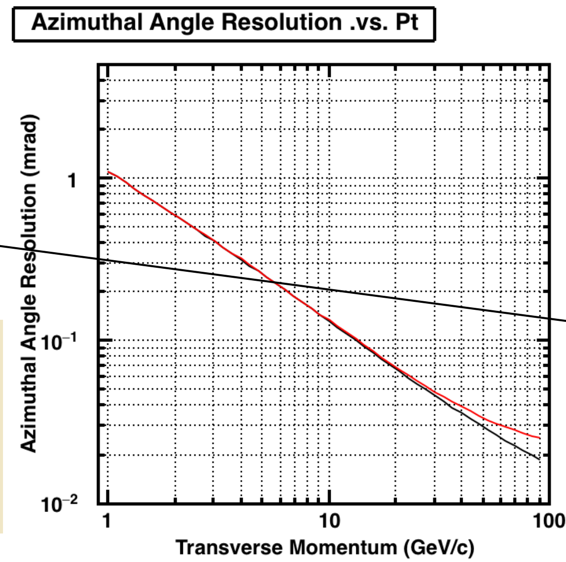
Drop VTX layers 4-7

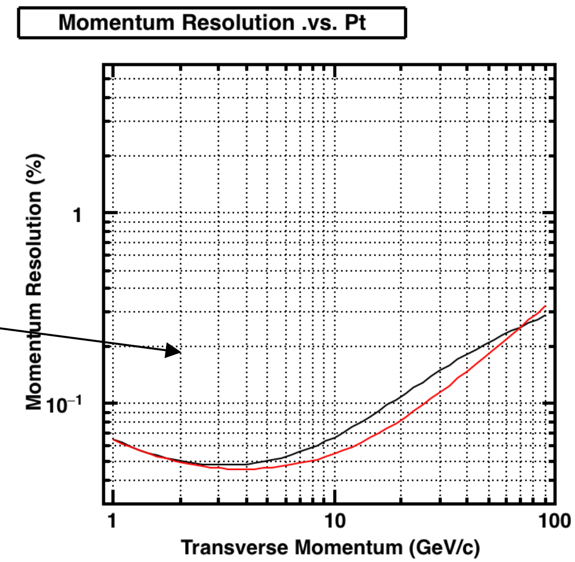
- Black: Reference
- Black: Drop the 4 outermost VTX layers
  - Generally better momentum resolution!

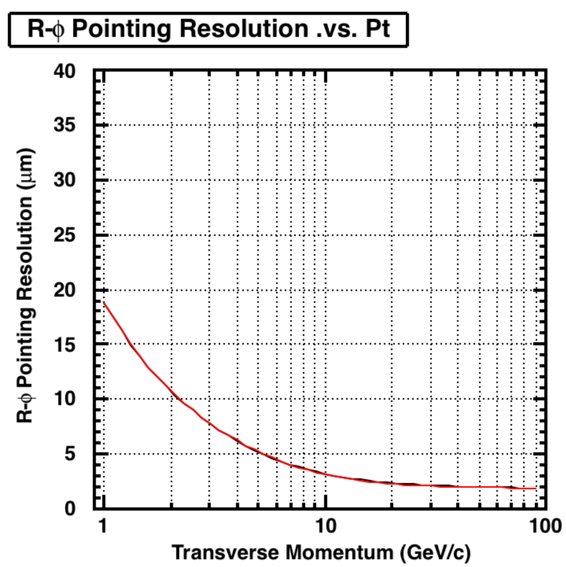
Name	r [cm]	X0	phi & z res [um]		layerEff
0. vertex	0.00	0.0000	-	-	-
1. bpipe	1.56	0.0048	-	-	-
2. ALICE_vtx1	1.70	0.0030	3	3	1.00
3. ALICE_vtx2	2.30	0.0030	3	3	1.00
4. ALICE_vtx3	3.10	0.0030	3	3	1.00
5. ALICE_vtx4	18.00	0.0100	3	3	1.00
6. ALICE_vtx5	20.00	0.0100	3	3	1.00
7. ALICE_vtx6	33.00	0.0100	3	3	1.00
8. ALICE_vtx7	35.00	0.0100	3	3	1.00

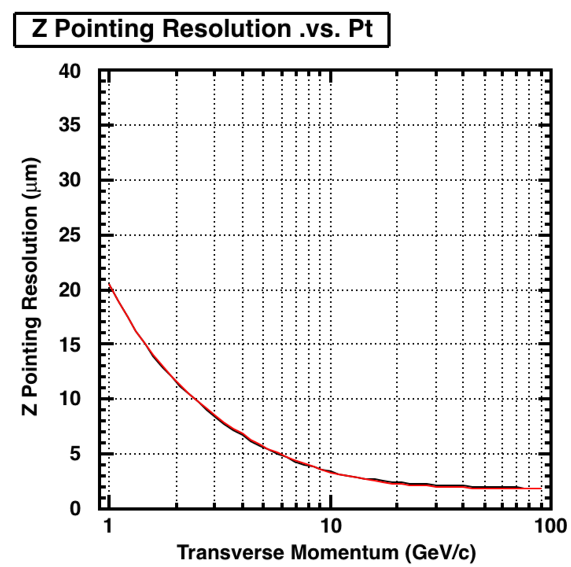
Dropping the "heavy" 1% Xo layers

Lesson:
Multiple scattering is important.
Mimimize material









Compare "ALICE VTX" to CLIC VTX

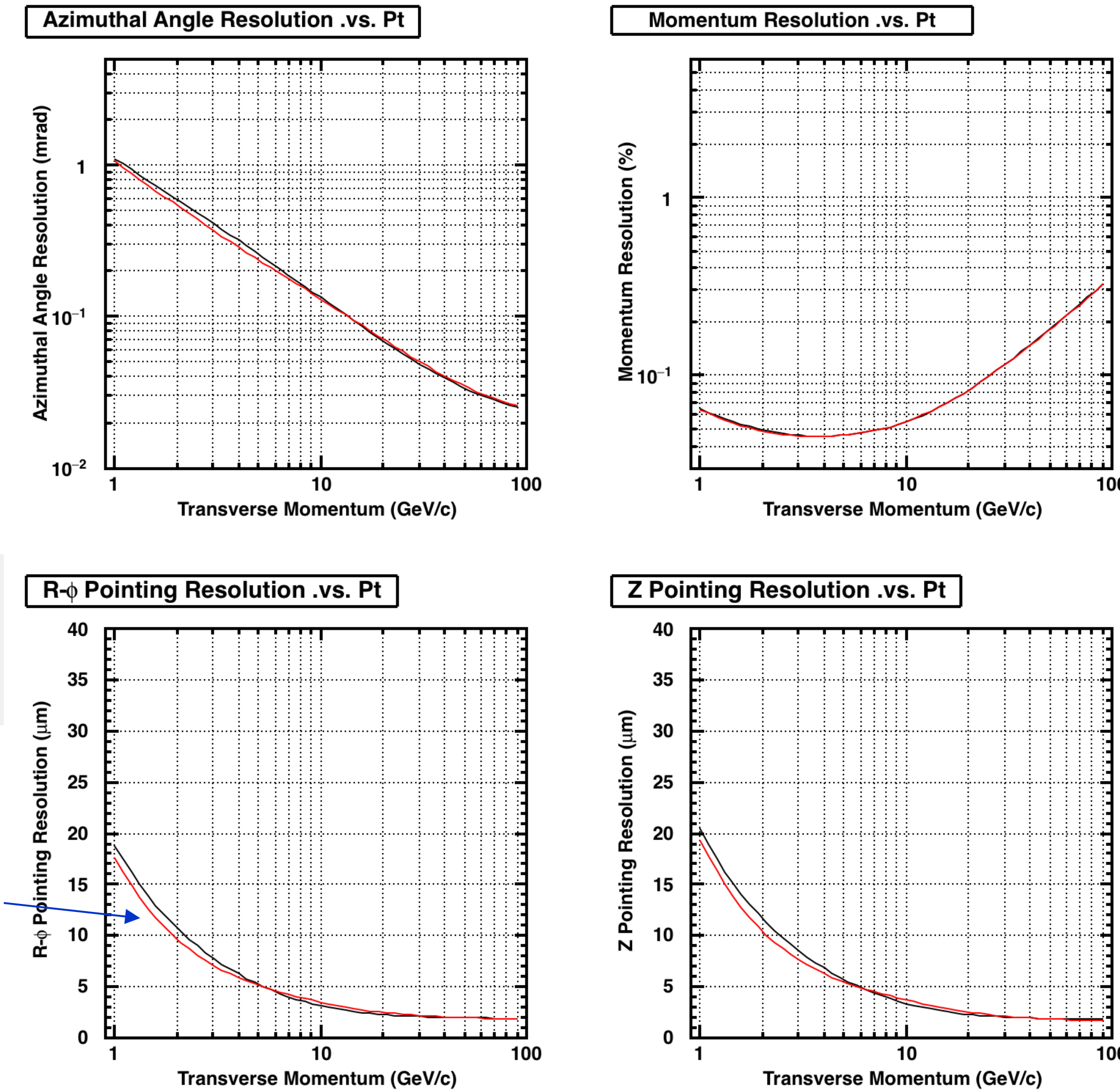
- ALICE: 3 single layers
  - 0.3% Xo
  - 3 µm resolution

Name	r [cm]	X0	phi & z res [um]		layerEff
2. ALICE_vtx1	1.70	0.0030	3	3	1.00
3. ALICE_vtx2	2.30	0.0030	3	3	1.00
4. ALICE_vtx3	3.10	0.0030	3	3	1.00

- CLIC: 3 double layers
  - 3 * 2* 0.2% Xo
  - 3 µm, 6 µm, 4 µm resolutions

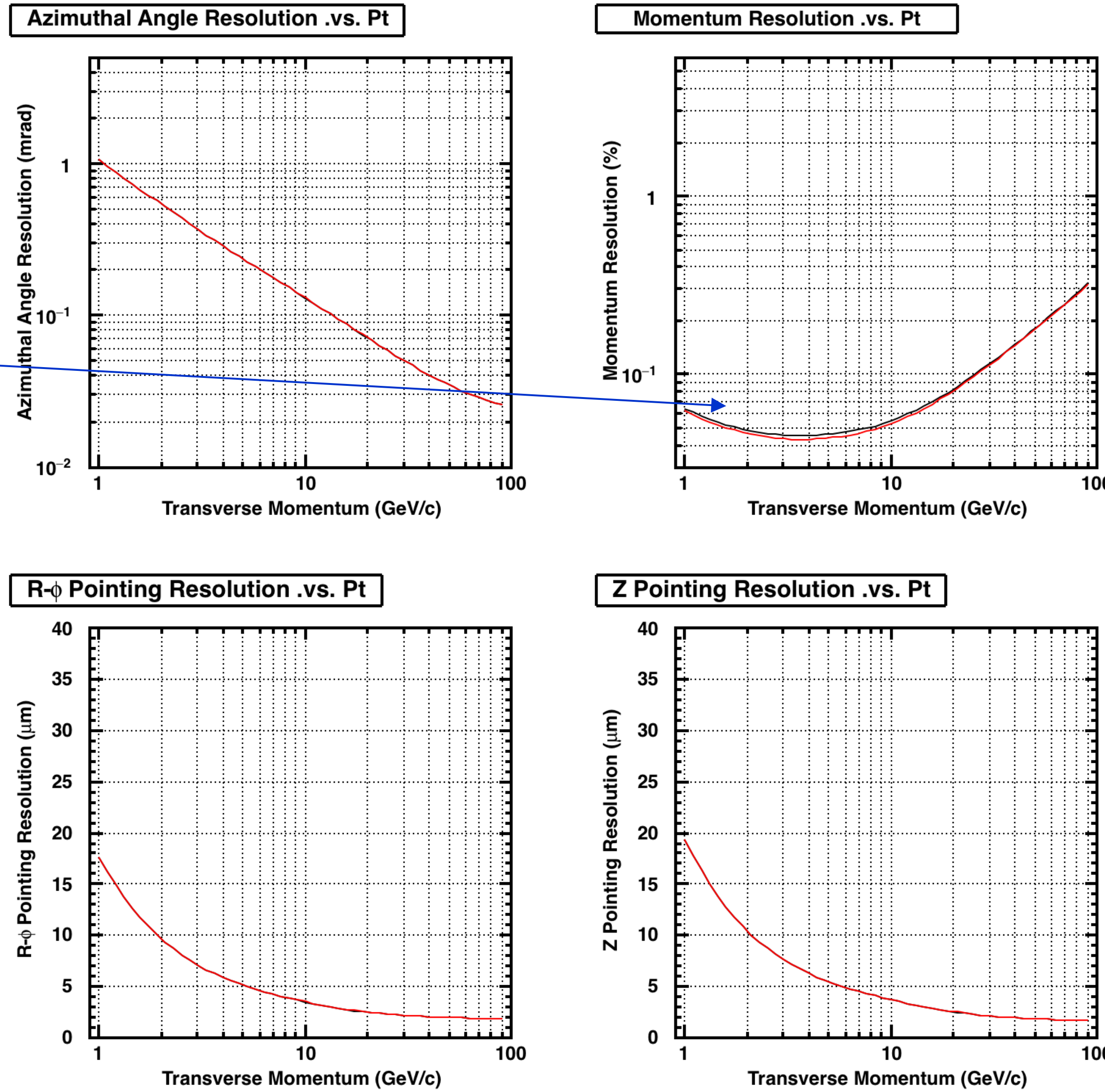
Name	r [cm]	X0	phi & z res [um]		layerEff
2. CLIC_vtx11	1.70	0.0020	3	3	1.00
3. CLIC_vtx12	1.90	0.0020	6	6	1.00
4. CLIC_vtx21	3.70	0.0020	4	4	1.00
5. CLIC_vtx22	3.90	0.0020	4	4	1.00
6. CLIC_vtx31	5.70	0.0020	4	4	1.00
7. CLIC_vtx32	5.90	0.0020	4	4	1.00

- CLIC-like design:
  - Slightly better vertex resolution
  - Probably due to larger r-spacing
    - Trivial modification



Decrease Drift Chamber inner radius: 35 -> 20 cm

- Keep cell size the same:
  - 112 -> 122 cells
- Multiply all DC material by factor 180./165.
- Very minor improvement in momentum resolution
- Here and on following slides, use CLIC-like VTX

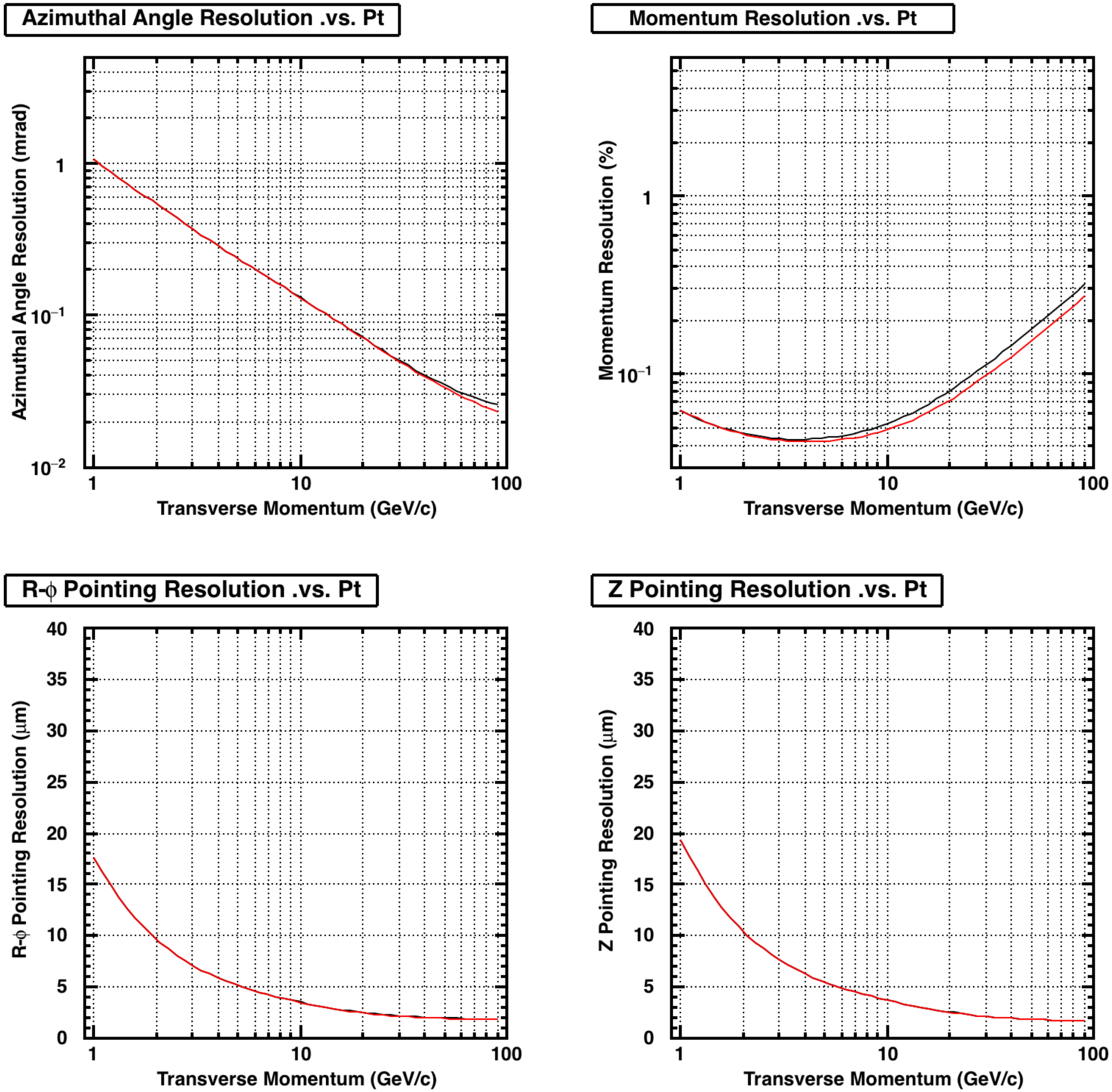


Reduce Drift Chamber Cell Size: 1.47 -> 1.0 cm

- Keep the same resolution of $\sigma_{r\phi}$ = 80 μm per point

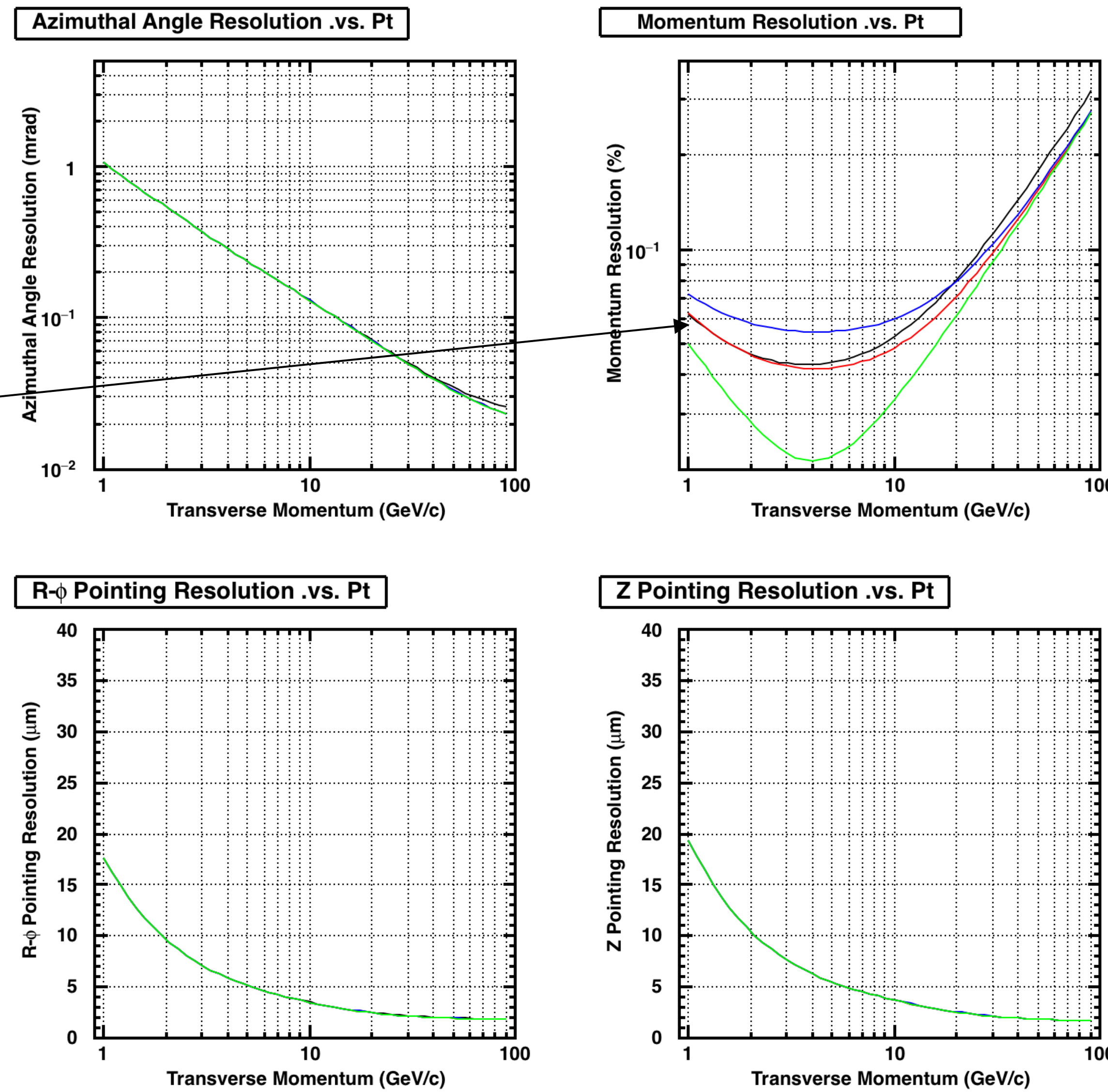
- Black: 1.47 cm cell size
- Red: 1.00 cm cell size

- Looks like a good idea, however, here no account is made of additional material from wires…
  - See next page



Reduce Drift Chamber Cell Size: Wire material

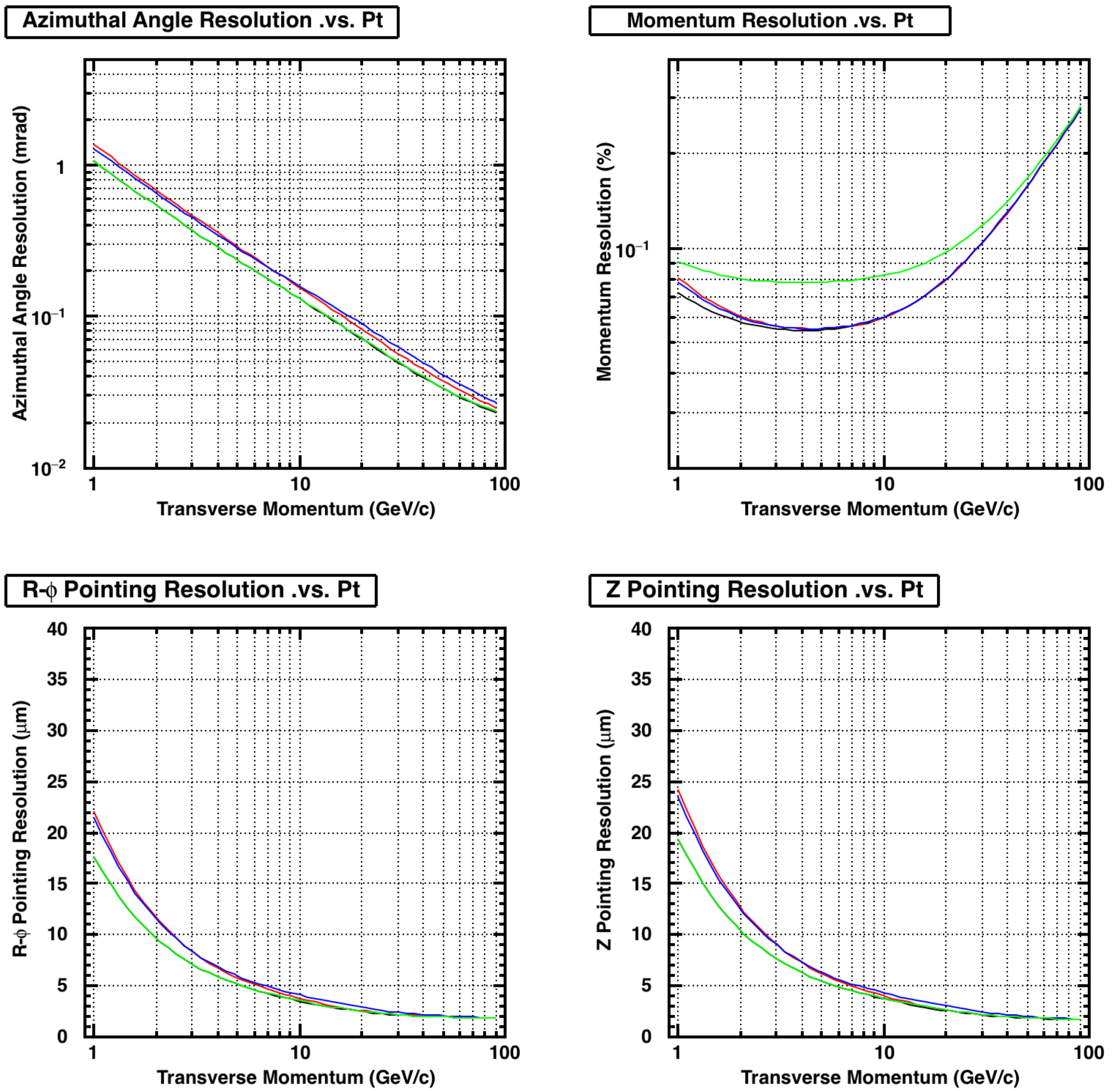
- Number of wires is inversely proportional to cell area
  - i.e. increase wire material by factor $1.47^2 = 2.18$
  - Looks modest:
    - 0.14% -> 0.31%
  - Surprising (to me): this has a large influence on momentum resolution at low momenta



- Black: 1.47 cm cell size
- Red: 1.00 cm cell size, same material
- Blue: Increase wire material
- Green: No material inside DC
  - X check

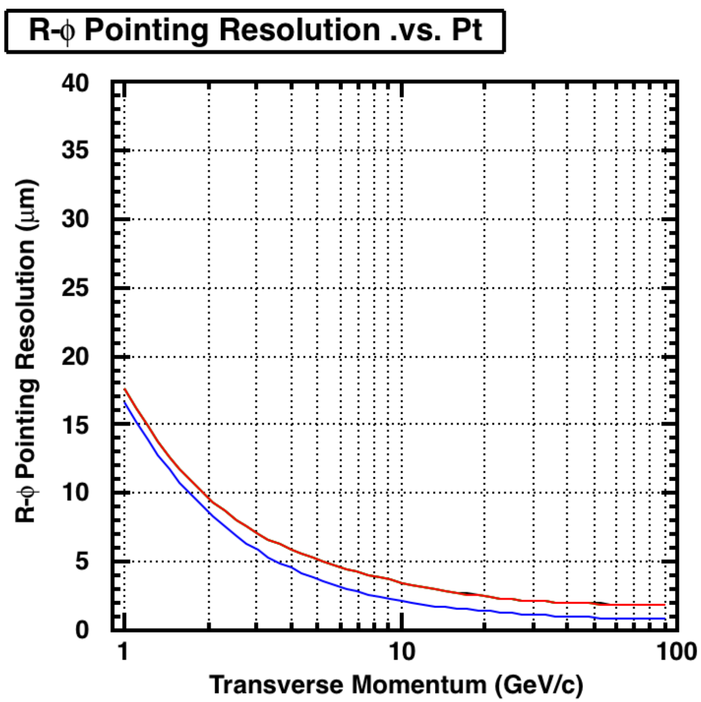
Material Study: Double Material

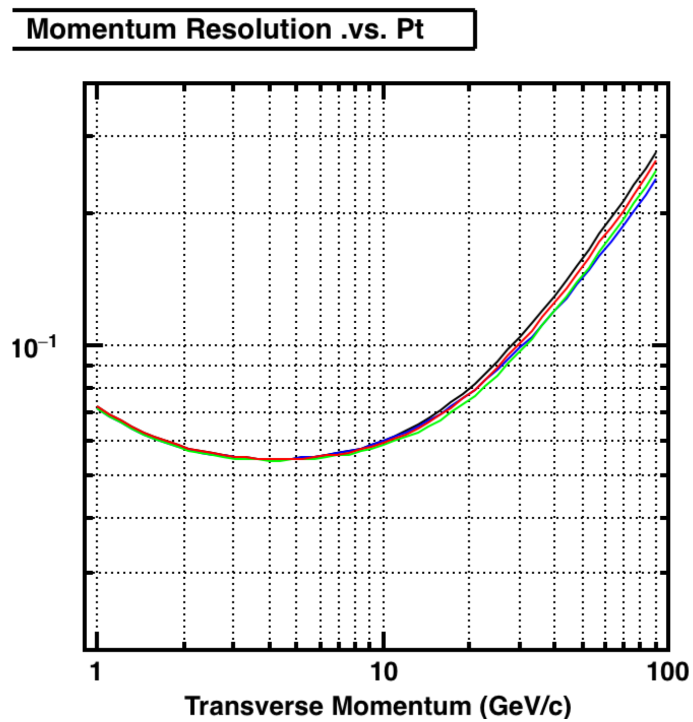
- Black: Reference
  - Beam pipe: 0.48% of Xo
  - VTX: CLIC-like
    - 6 * 0.2% of Xo
  - DC: 20-180cm; 1 cm cells
    - InWall: 0.08% of Xo
    - Wire+gas: 0.36% of Xo
    - OutWall: 1.3% of Xo
  - Outer Si: 201 cm, 7 μm
- Red: Double BP material
  - Minimal influence on σ_p
- Blue: Double VTX material
  - Minimal influence on σ_p
- Green: Double DC material
  - Minimal influence on impact parameter resolution

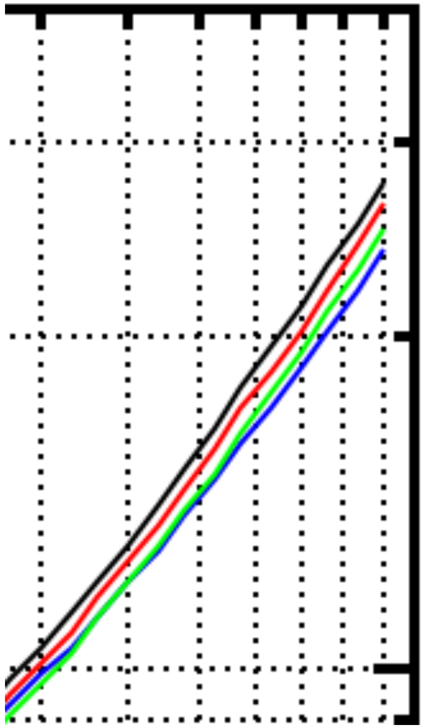


Point Resolution Study

- Black: Reference
- Blue: 1 μm point VTX resolution everywhere
- Green: 70 μm DC rϕ resolution (was 80 μm)
- Red: 5 μm Outer Si point resolution (was 7 μm)
  - E.g. From two layers

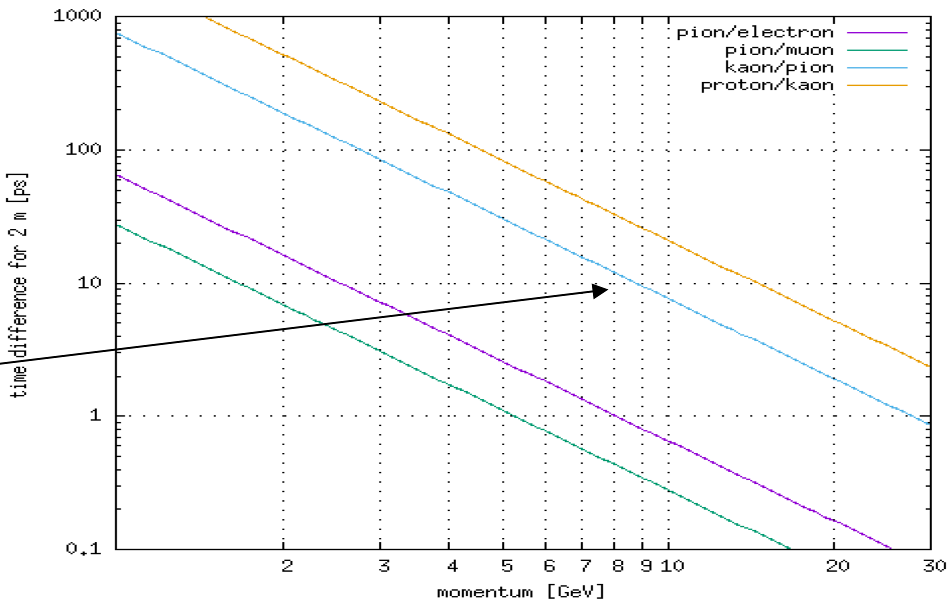


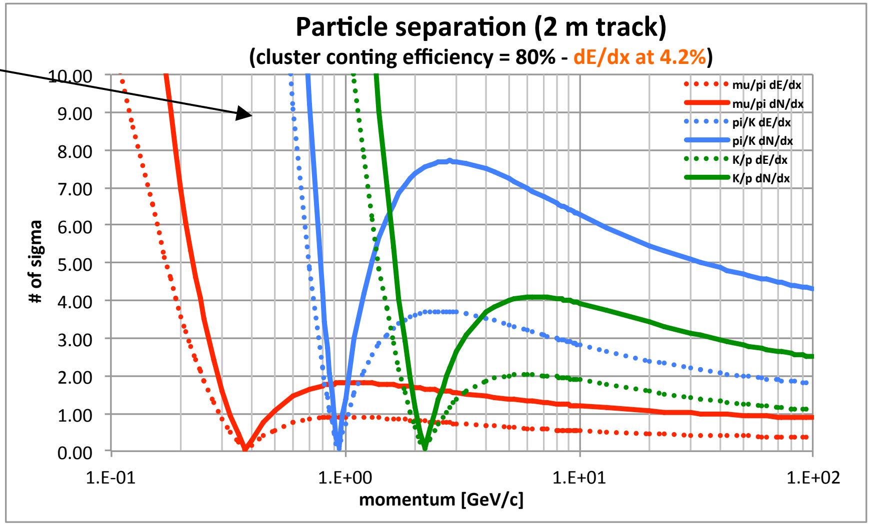




Something completely different: TOF

- Ultrafast silicon detectors are approaching 20 ps resolution, possibly going to 10 ps and below.
- Use outer layer of Si tracker for TOF measurement?
- 10 ps gives pion/kaon separation up to 7-8 GeV
- Worthwhile pursuing? Particularly for all-silicon detector which does not have dE/dx measurent like the Cluster Counting Drift Chamber





Summary

- First studies of IDEA tracker resolution presented
- Some conclusions:
  - Limit Si sensors only to dedicated vertex detector (r<60 mm)
    - Aim to have VTX very light to mimimise multiple scattering
      - However, cooling…
  - Beam pipe + VTX material plus VTX point resolution important for impact parameter resolution
  - Drift Chamber material important for momentum resolution for $p_T \lesssim 20$ GeV
    - Multiple scattering from wires inside DC
      - Probably not well described by my tool: 112 discrete layers vs. few wires hit
  - Point resolution of all detector elements important for higher momenta

- Si tracker based TOF measurement