Impact Parameter Resolution Studies

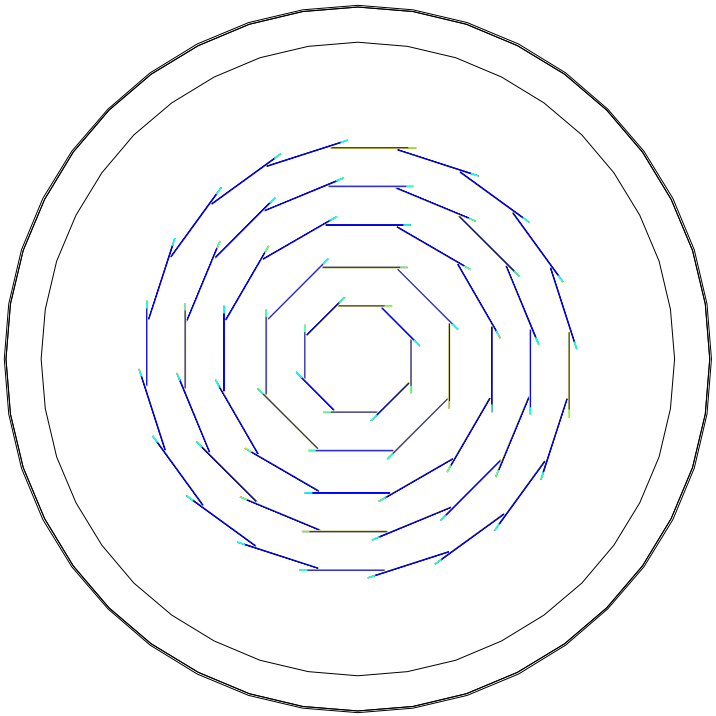
D.Grandjean, G.Gaycken

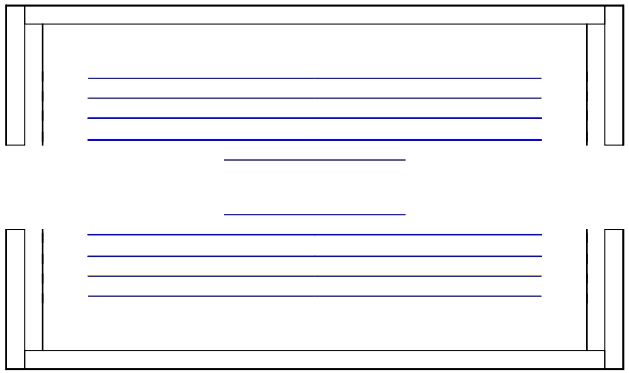
Institut de Recherche Subatomiques
Strasbourg

ECFA Workshop Durham September 2004

Outline

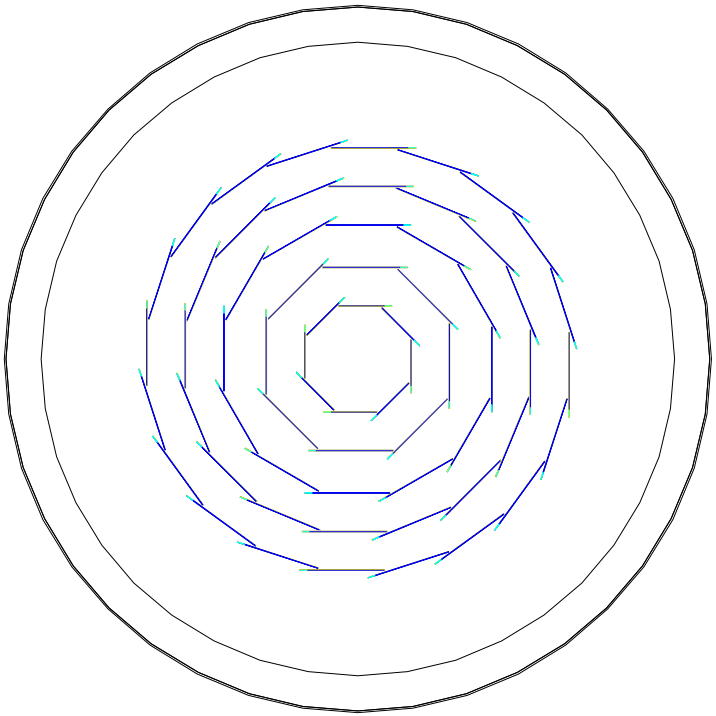
Vertex Detector Geometry



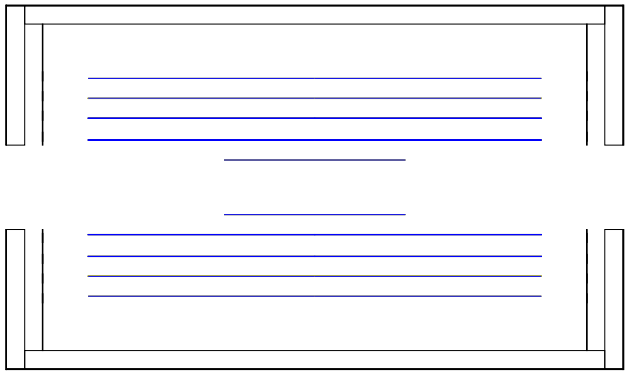


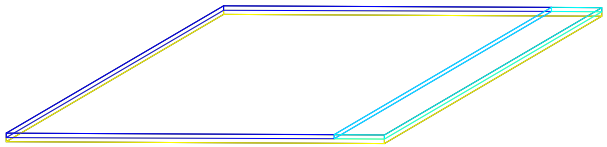
shares beam pipe and cryostat geometry
with CCD option

Vertex Detector Geometry



shares beam pipe and cryostat geometry with CCD option





- carbon support
- sensitive silicon layer on top
- insensitive edge for electronics

Impact Parameter Resolution - Simple Calculation

Impact parameter resolution limited by:

1. finite single point resolution
2. multiple scattering

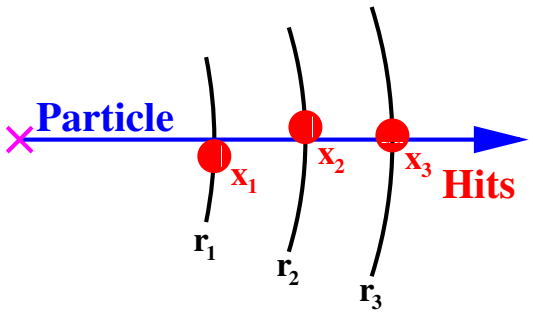
Impact Parameter Resolution - Simple Calculation

Impact parameter resolution limited by:

1. finite single point resolution
2. multiple scattering

Impact Parameter Resolution - Simple Calculation

1. Finite single point resolution:

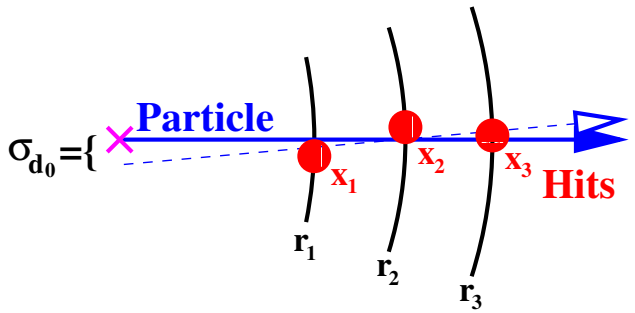


- Linear fit: $f(r) = r \cdot s + t$ (rz-plane or neglecting B)
- Error on the offset $t \longrightarrow$ impact parameter resolution:

$$\sigma_{d_0} = \frac{\sqrt{\sum \left(\sum r_i^2 - r_i \sum r_k\right)^2}}{n \sum r_i^2 - \sum r_l \sum r_k} \sigma_{\mathrm{SP}} = a$$

Impact Parameter Resolution - Simple Calculation

1. Finite single point resolution:

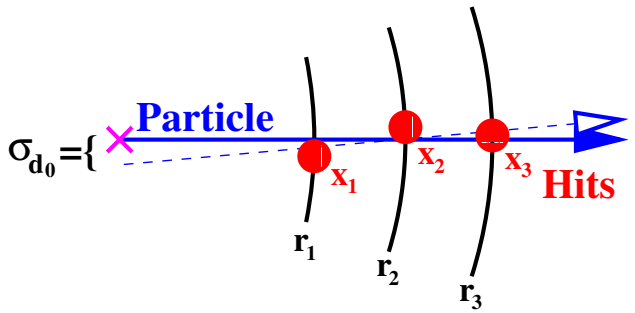


- Linear fit: $f(r) = r \cdot s + t$ (rz-plane or neglecting B)
- Error on the offset $t \rightarrow$ impact parameter resolution:

$$\sigma_{d_0} = \frac{\sqrt{\sum \left(\sum r_i^2 - r_i \sum r_k\right)^2}}{n \sum r_i^2 - \sum r_l \sum r_k} \sigma_{\mathrm{SP}} = a$$

Impact Parameter Resolution - Simple Calculation

1. Finite single point resolution:

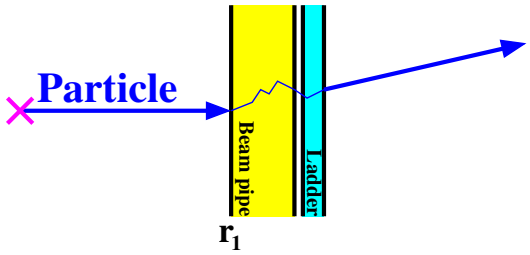


- Linear fit: $f(r) = r \cdot s + t$ (rz-plane or neglecting B)
- Error on the offset $t \longrightarrow$ impact parameter resolution:

$$\sigma_{d_0} = \frac{\sqrt{\sum \left(\sum r_l^2 - r_i \sum r_k\right)^2}}{n \sum r_i^2 - \sum r_l \sum r_k} \sigma_{\mathrm{SP}} = a$$

Impact Parameter Resolution - Simple Calculation

2. Multiple Scattering:



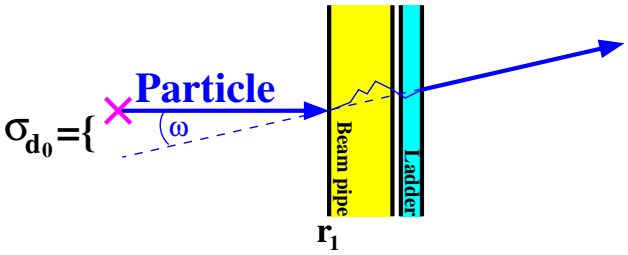
Scattering at thin layers:

$$\sigma_\theta = \frac{13.6\,\mathrm{MeV}}{\beta c p} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right) \right]$$

R.M. Barnett et al., PDG, Phys. Rev. D54 (1996) 1

Impact Parameter Resolution - Simple Calculation

2. Multiple Scattering:



Scattering at thin layers:

$$\sigma_\theta = \frac{13.6\,\mathrm{MeV}}{\beta cp} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right) \right]$$

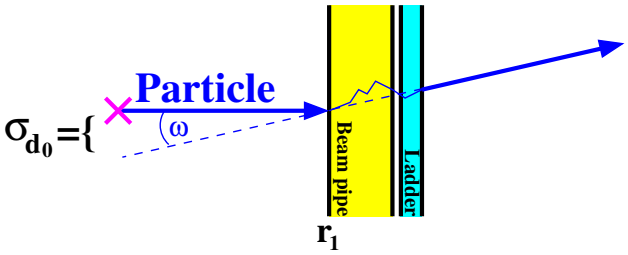
R.M. Barnett et al., PDG, Phys. Rev. D54 (1996) 1

Particles with $\theta = 90$

$r_1 \rightarrow \frac{r_1}{\sin\theta}$ and $x \rightarrow \frac{x}{\sin\theta}$

Impact Parameter Resolution - Simple Calculation

2. Multiple Scattering:



Scattering at thin layers:

$$\sigma_\theta = \frac{13.6\,\mathrm{MeV}}{\beta cp} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right) \right]$$

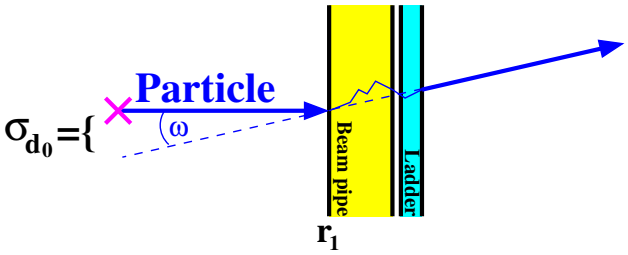
R.M. Barnett et al., PDG, Phys. Rev. D54 (1996) 1

Particles with $\theta \neq 90\,^\circ$

$r_1 \rightarrow \frac{r_1}{\sin\theta}$ and $x \rightarrow \frac{x}{\sin\theta}$

Impact Parameter Resolution - Simple Calculation

2. Multiple Scattering:



Scattering at thin layers:

$$\sigma_\theta = \frac{13.6\,\mathrm{MeV}}{\beta cp} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right)\right]$$

R.M. Barnett et al., PDG, Phys. Rev. D54 (1996) 1

Impact parameter resolution:

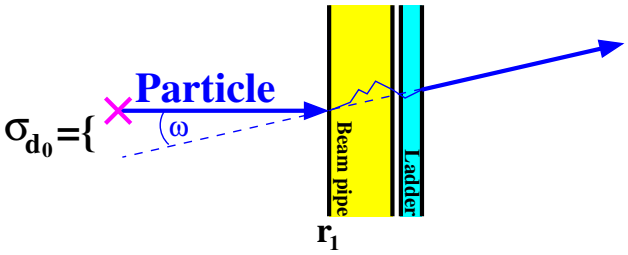
$$\begin{aligned} \sigma_{d0} &= r_1 \tan\omega \\ &\simeq \frac{r_1}{cp} 13.6\,\mathrm{MeV} \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right)\right] \end{aligned}$$

Particles with $\theta \neq 90°$

$r_1 \to \frac{r_1}{\sin\theta}$ and $x \to \frac{x}{\sin\theta}$

Impact Parameter Resolution - Simple Calculation

2. Multiple Scattering:



Scattering at thin layers:

$$\sigma_\theta = \frac{13.6\,\mathrm{MeV}}{\beta cp} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right)\right]$$

R.M. Barnett et al., PDG, Phys. Rev. D54 (1996) 1

Impact parameter resolution:

$$\begin{aligned} \sigma_{d0} &= \frac{r_1}{sin\theta} \tan\omega \\ &\simeq \frac{1}{cp \sin\theta \sqrt{\sin\theta}} \underbrace{r_1 13.6\,\mathrm{MeV} \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{\sin\theta\, X_0}\right)\right]}_{b} \end{aligned}$$

Particles with $\theta \neq 90°$

$r_1 \rightarrow \frac{r_1}{\sin\theta}$ and $x \rightarrow \frac{x}{\sin\theta}$

Impact Parameter Resolution - Examples

Impact parameter resolution:

	a	b
SLD	9	33
DELPHI	20	65
MIMOSA	4	10

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

Resolution Function

SLD

- 3 layers: 2.8, 3.8 and 4.83 cm
- material up to first layer:

beam pipe:	50 μm Titanium
	760 μm Beryllium
gas jacket:	500 μm Beryllium
support	
+CCD:	$0.4\% X_0$
$\rightarrow \sum x^i/X_0^i \simeq$	0.9%

- single point resolution 4 μm

$$a = 11\,\mu\mathrm{m}$$
$$b = 29\,\mu\mathrm{m\,GeV}$$

Impact Parameter Resolution - Examples

Impact parameter resolution:

	a	b
SLD	9	33
DELPHI	20	65
MIMOSA	4	10

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

Resolution Function

Impact Parameter Resolution - Examples

Impact parameter resolution:

	a	b
SLD	9	33
DELPHI	20	65
MIMOSA	4	10

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

Resolution Function

MIMOSA

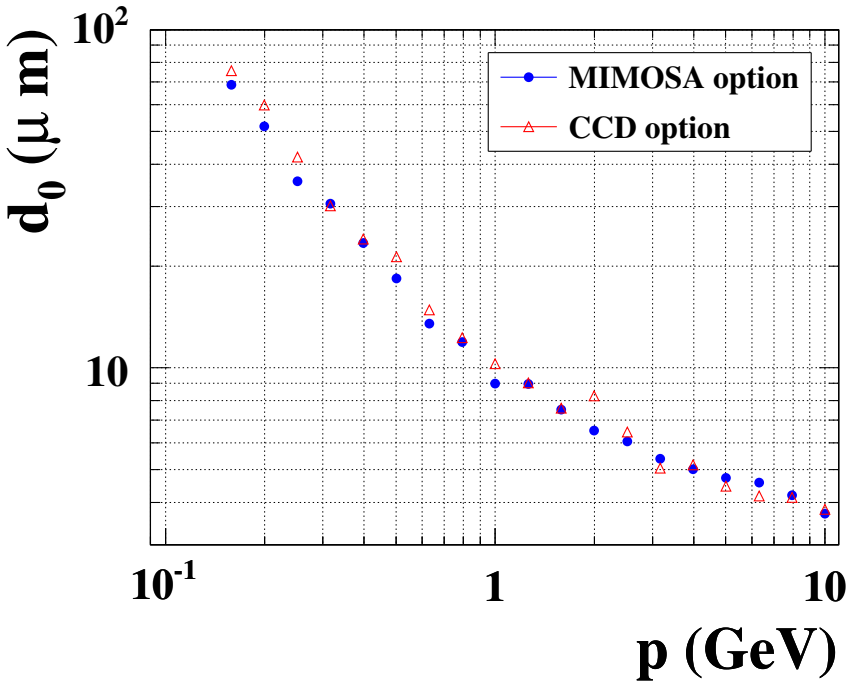
- 5 layers: 1.5, 2.6, 3.8, 4.9, 6 cm
- material up to first layer:

beam pipe:	500 μm Beryllium
support:	50 μm Carbon
MIMOSA:	50 μm Silicon
$\rightarrow \sum x^i/X_0^i \simeq$	0.2%

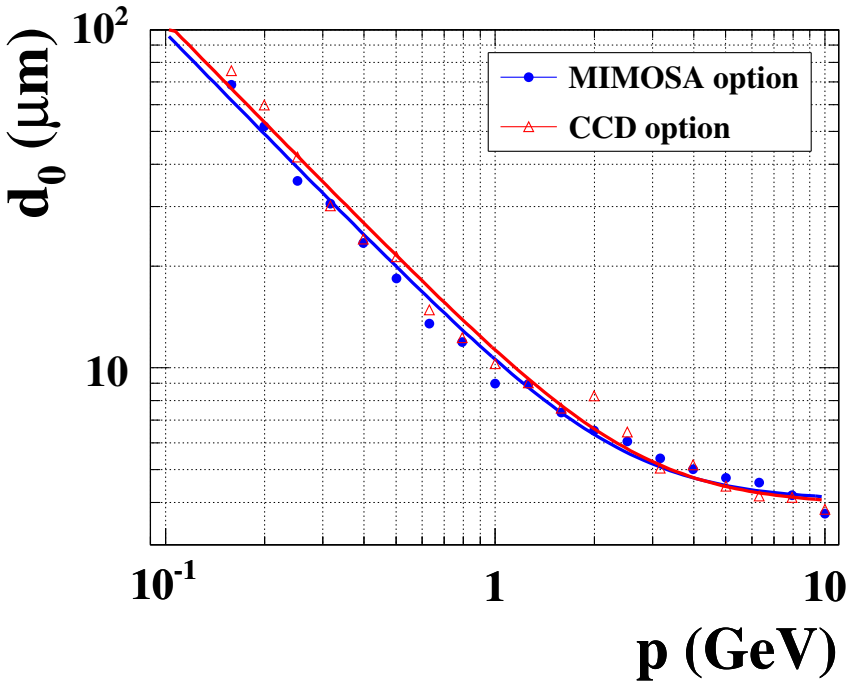
- single point resolution 3.5 μm

$$a = 4\,\mu\mathrm{m}$$
$$b = 7\,\mu\mathrm{m\,GeV}$$

Impact Parameter Resolution - MIMOSA vs CCD option



Impact Parameter Resolution - MIMOSA vs CCD option



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

Resolution Function

Cylindrical geometry
(CCD option):

$$a = 3.9 \pm 0.08$$
$$b = 10.6 \pm 0.15$$

Ladder based geometry
(MIMOSA option):

$$a = 4.0 \pm 0.08$$
$$b = 9.8 \pm 0.11$$

Low Momentum Particles

Reconstruction fails often for tracks with momenta < 0.7GeV
Reasons:

- Curling tracks produce many track segments in one detector. (Vertex detector + SIT)
- track segments often not merged.
- Incorrect error propagation along a curling track after reentering inner layers ?
  (Not proven!)

Dirty workaround for these studies

- hits are ignored after particles reenter inner detector layers
- generator information is used (BRAHMS options):
  - for the pattern matching
  - to merge segments from different detectors

Low Momentum Particles

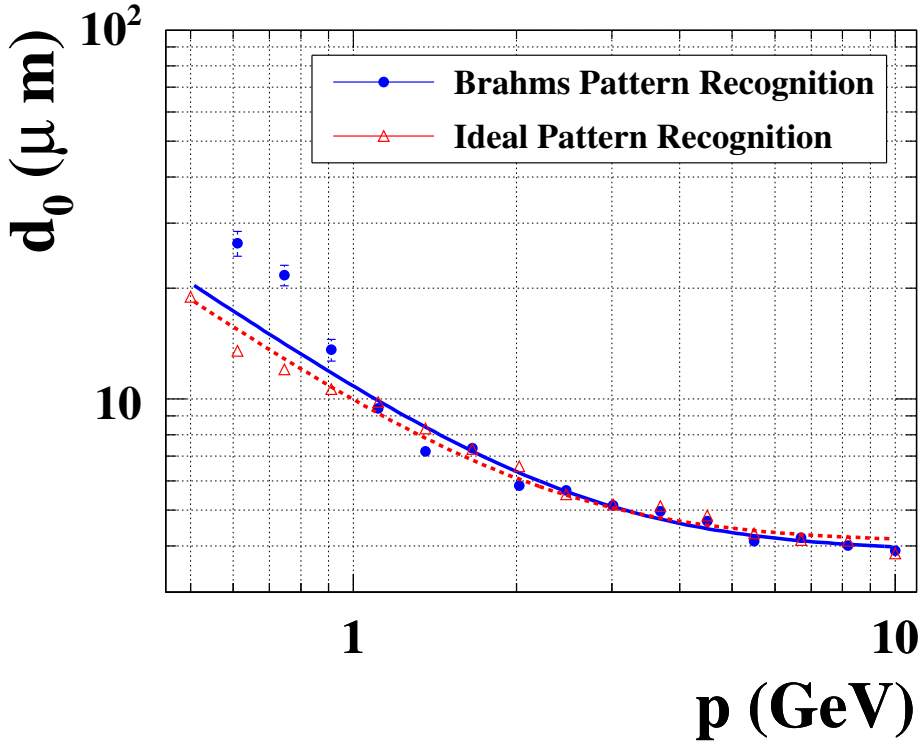
Reconstruction fails often for tracks with momenta < 0.7GeV
Reasons:

- Curling tracks produce many track segments in one detector. (Vertex detector + SIT)
- track segments often not merged.
- Incorrect error propagation along a curling track after reentering inner layers ?
  (Not proven!)

Dirty workaround for these studies

- hits are ignored after particles reenter inner detector layers
- generator information is used (BRAHMS options):
  - for the pattern matching
  - to merge segments from different detectors

Impact Parameter Resolution - Ideal vs Real Reconstruction



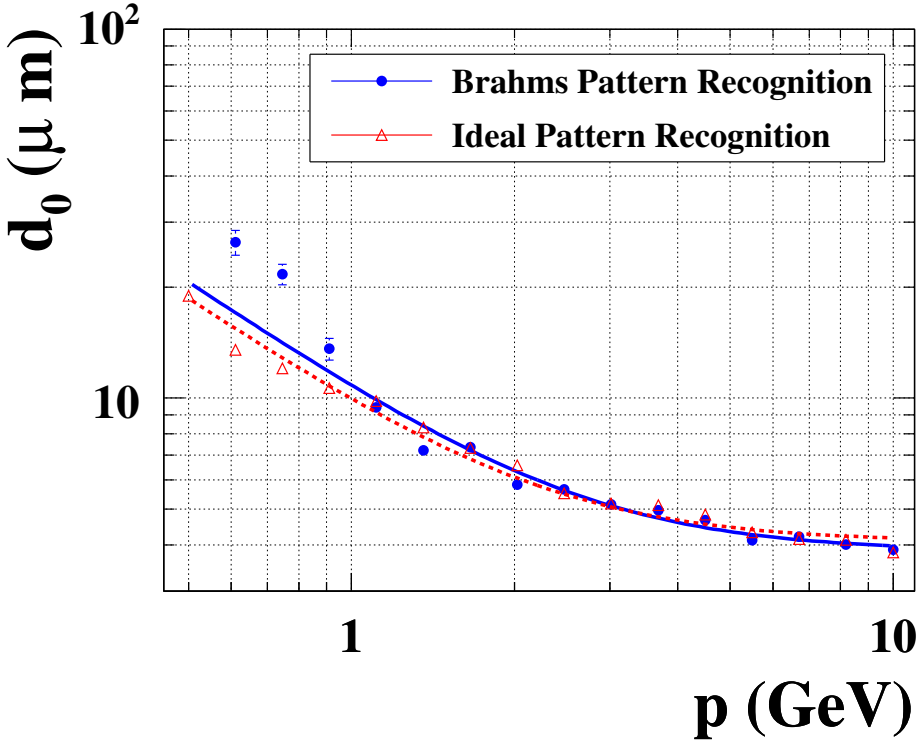
Real:

- pattern matching (BRAHMS)
- track segment merging (BRAHMS)

Ideal:

- generator information for:
  - pattern matching
  - track segment merging
- Hits are ignored after particles reentering inner detector layers.

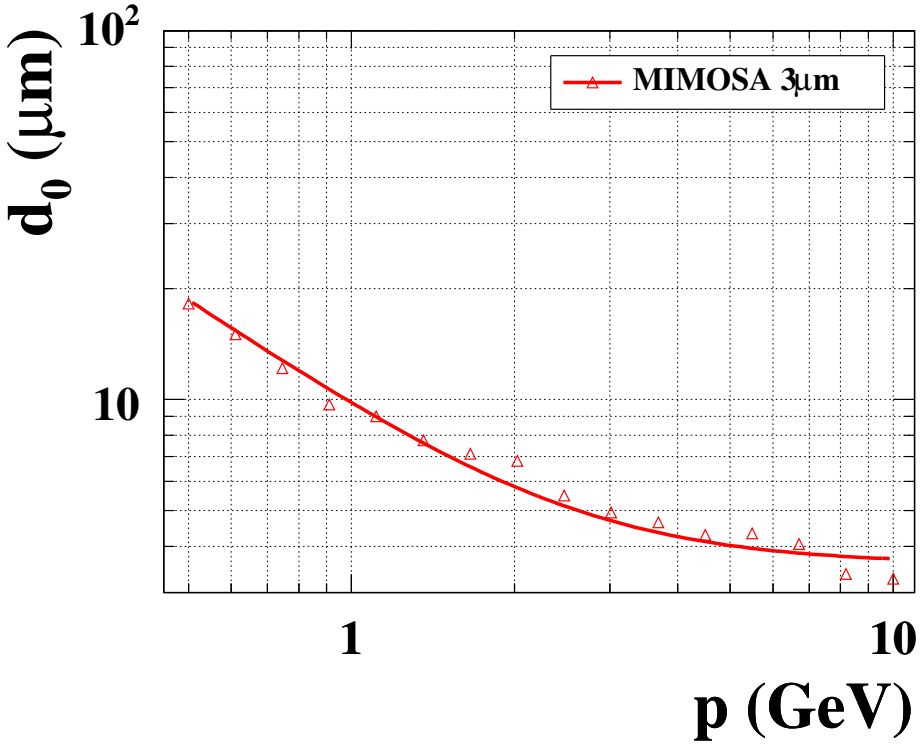
Impact Parameter Resolution - Ideal vs Real Reconstruction



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

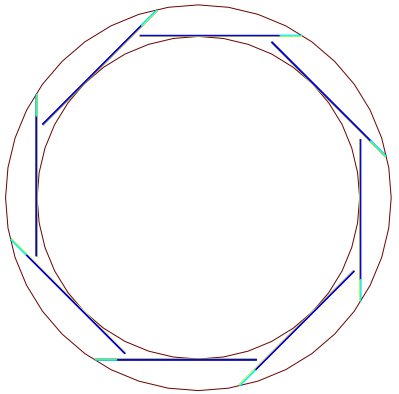
	a	b
Real	3.8 ± 0.07	10.1 ± 0.2
Ideal	4.1 ± 0.06	9.1 ± 0.9

Impact Parameter Resolution - Options for First Layer



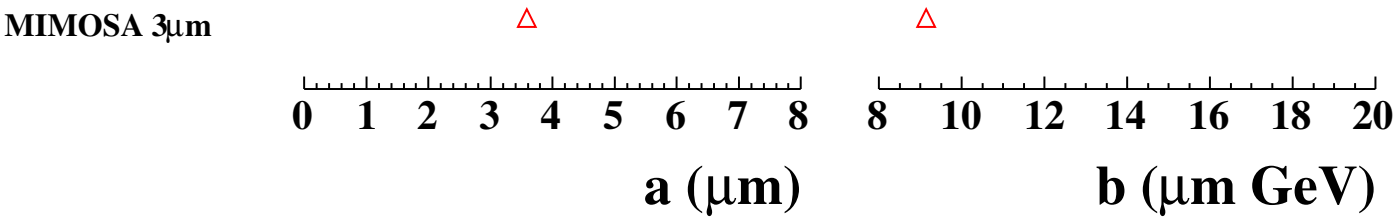
First layer equipped with:

MIMOSA

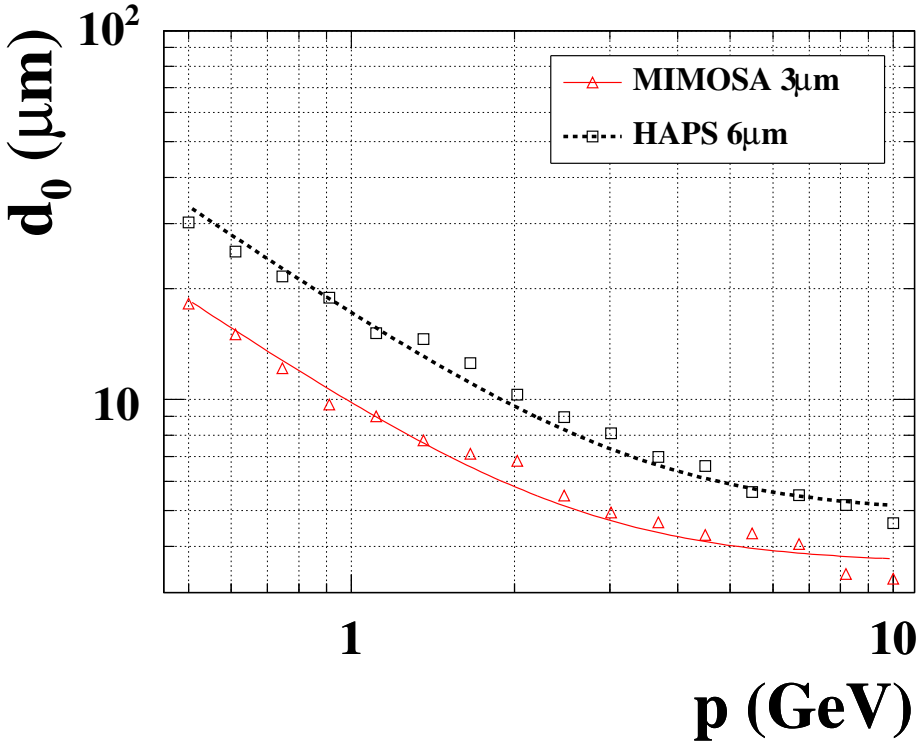


Single point resolution:

- 3 μm at layers 1 and 2
- 4 μm at layers 3 to 5

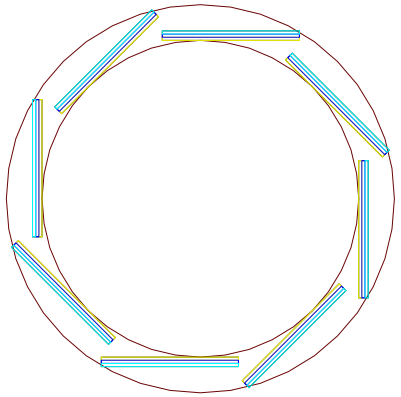


Impact Parameter Resolution - Options for First Layer

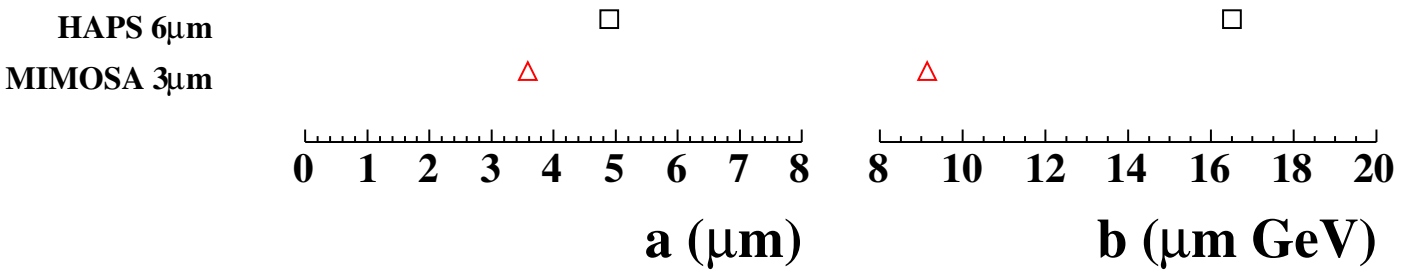


First layer equipped with:

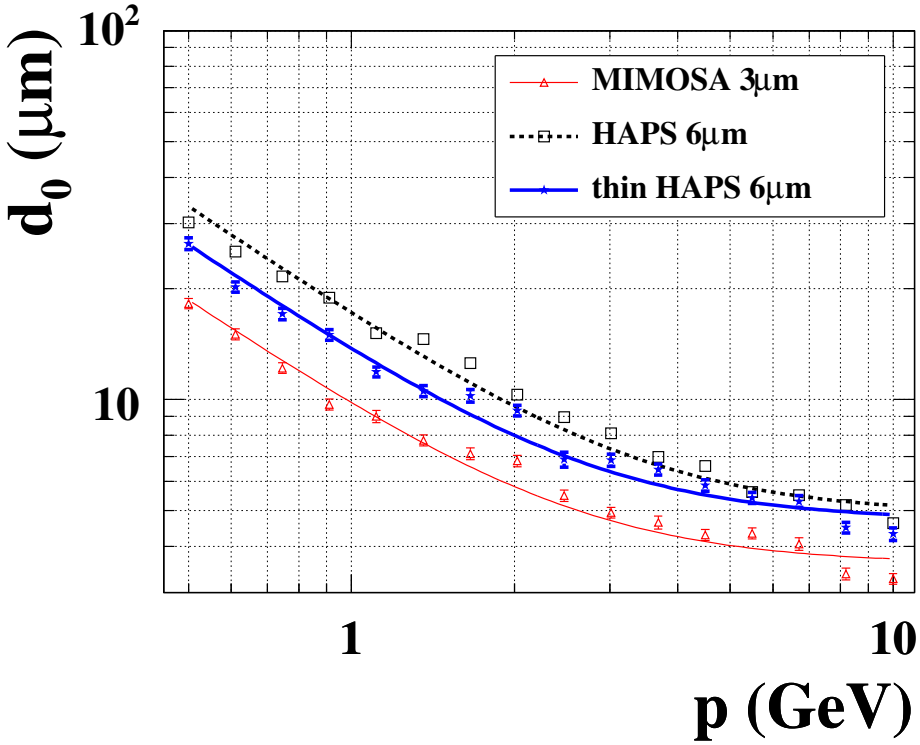
HAPS



- Low resolution (6 μm),
- but fast
- thickness $\simeq$ 600 μm

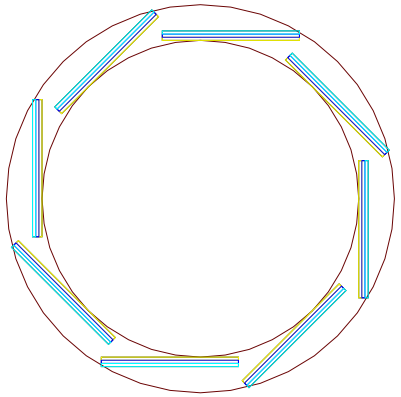


Impact Parameter Resolution - Options for First Layer

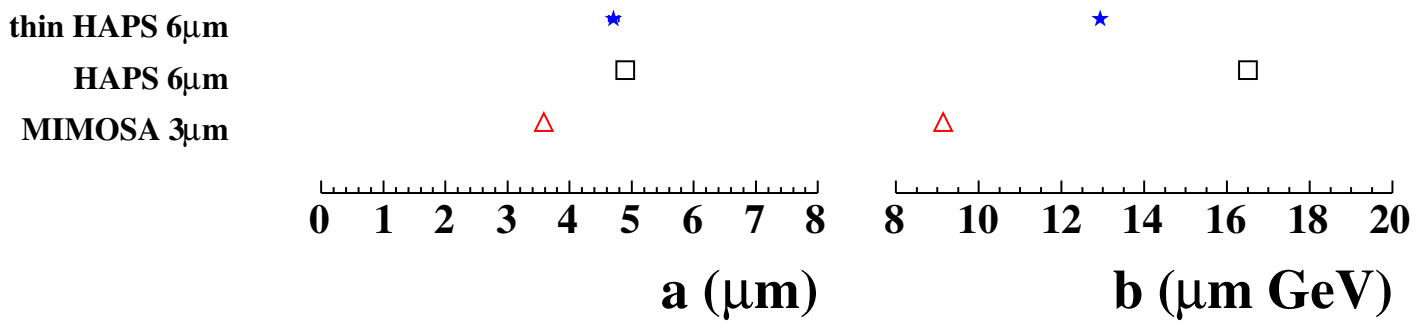


First layer equipped with:

Thin HAPS

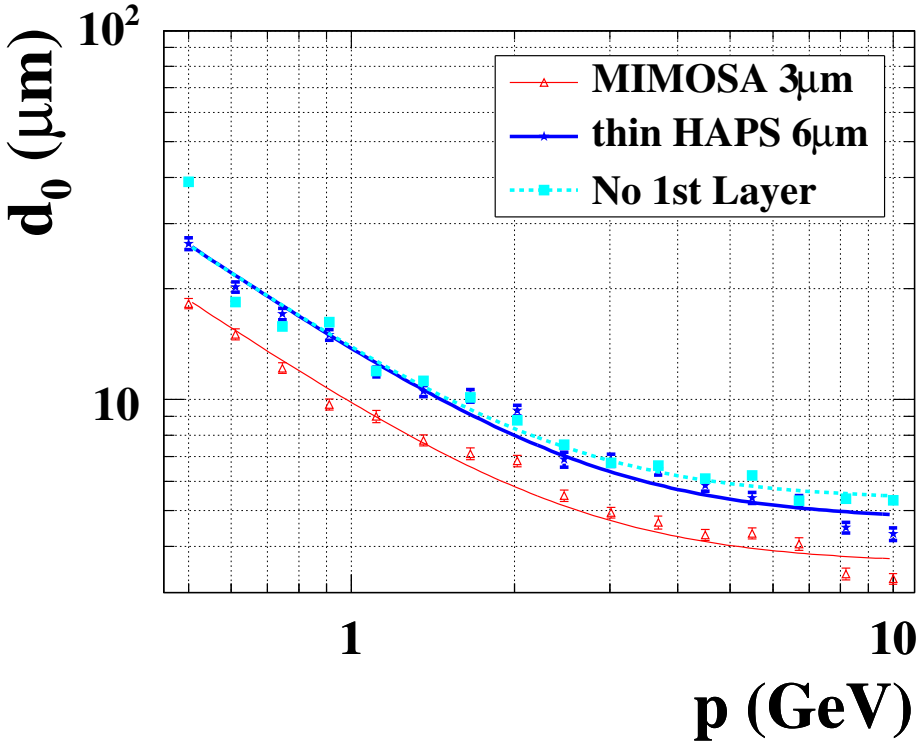


- Low resolution (6 μm),
- thickness $\simeq 3 \times 50\,\mu$m



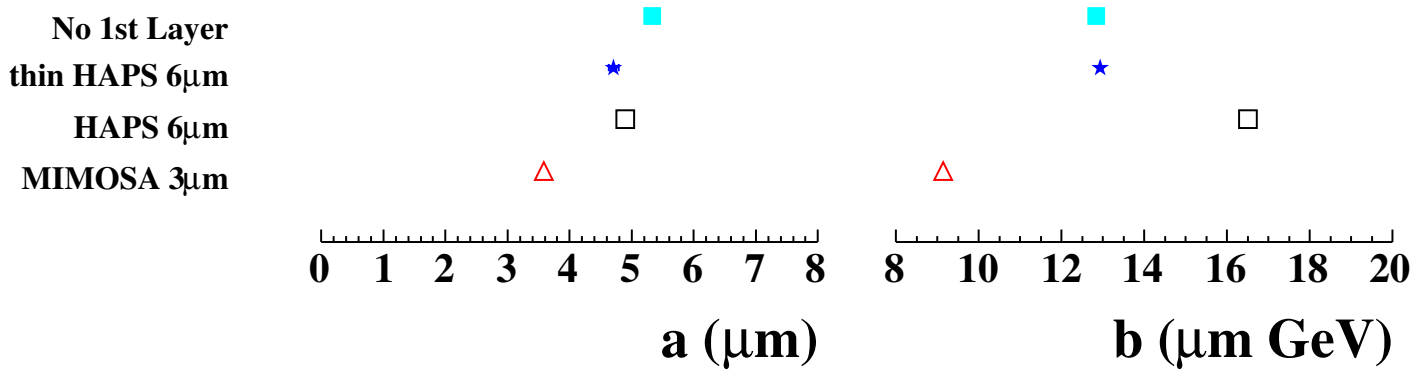
Impact Parameter Resolution - Options for First Layer

First layer equipped with:

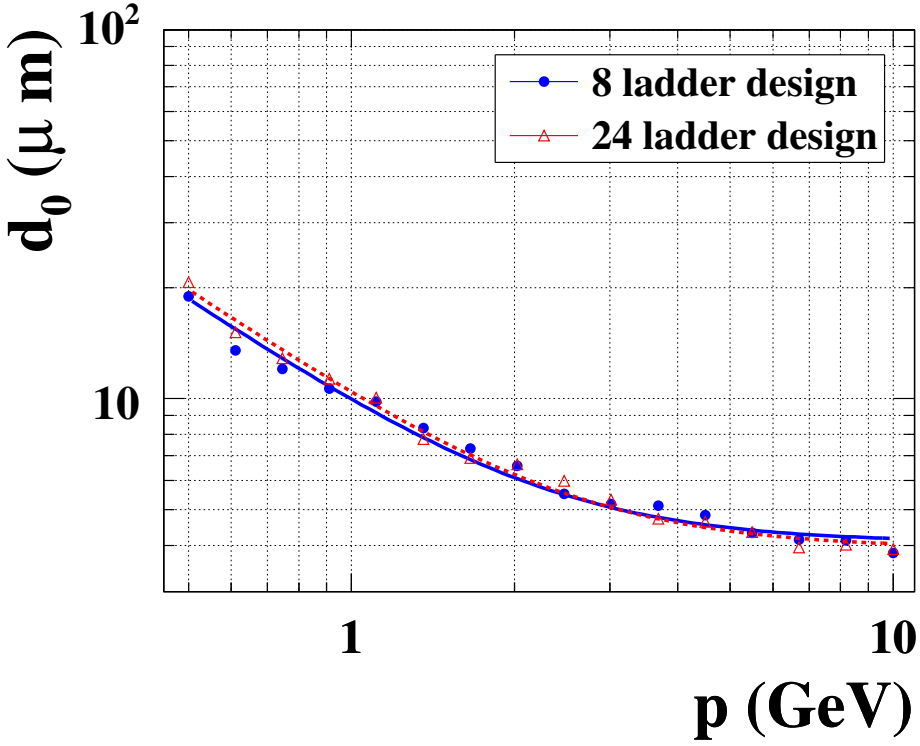


No First Layer

- Only four layers
- First layer at $r = 2.6cm$

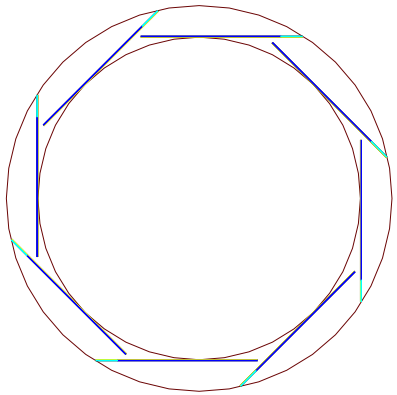


Impact Parameter Resolution - Wide vs Narrow Ladders

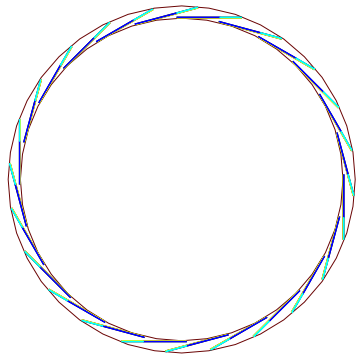


First layer equipped with:

8 Ladders



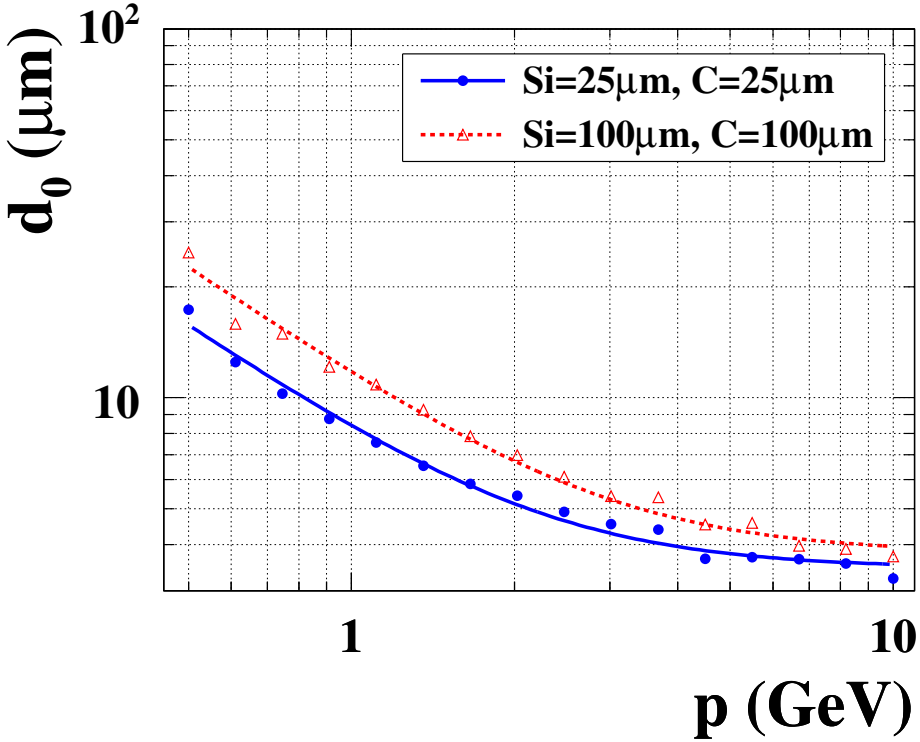
24 Ladders



Resolution function parameters:

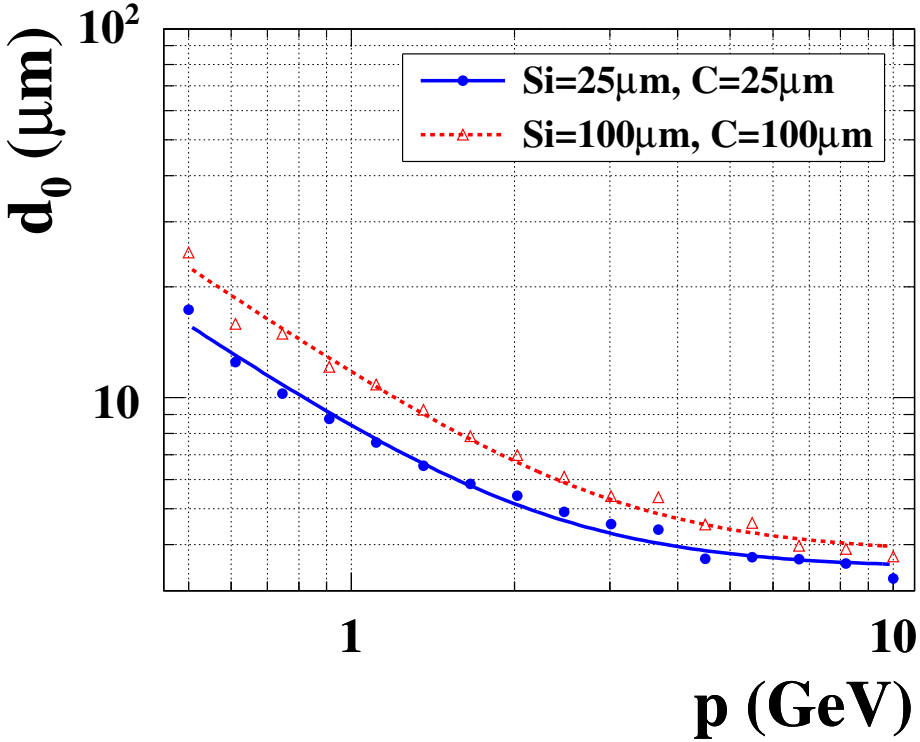
4.1 ± 0.06	3.9 ± 0.06	$= a$
9.1 ± 0.1	9.7 ± 0.1	$= b$

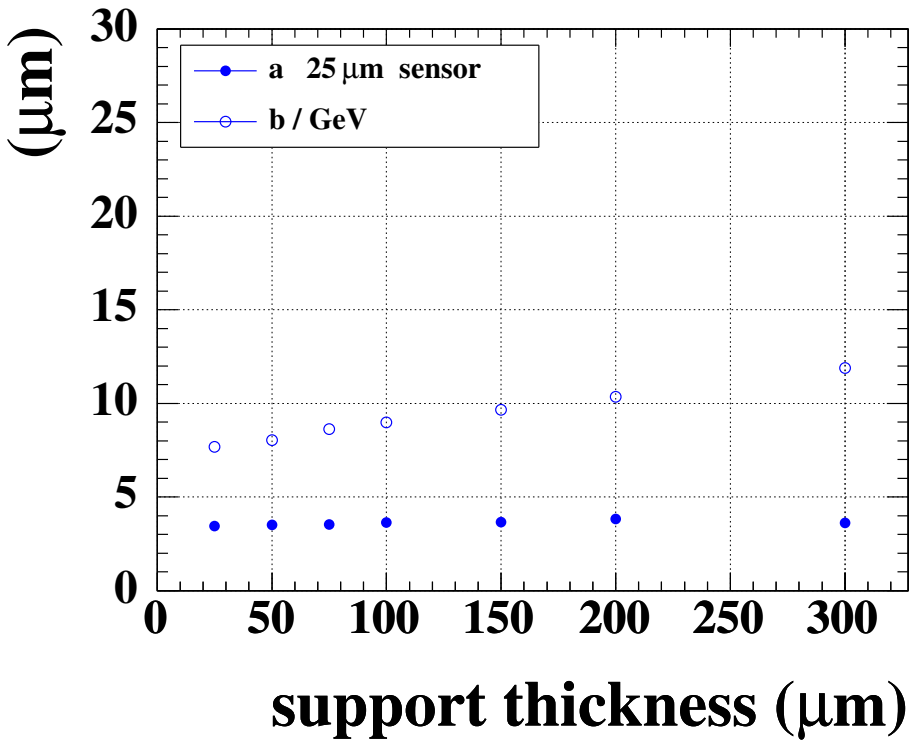
Impact Parameter Resolution - Thickness



(single point resolution 3 μm)

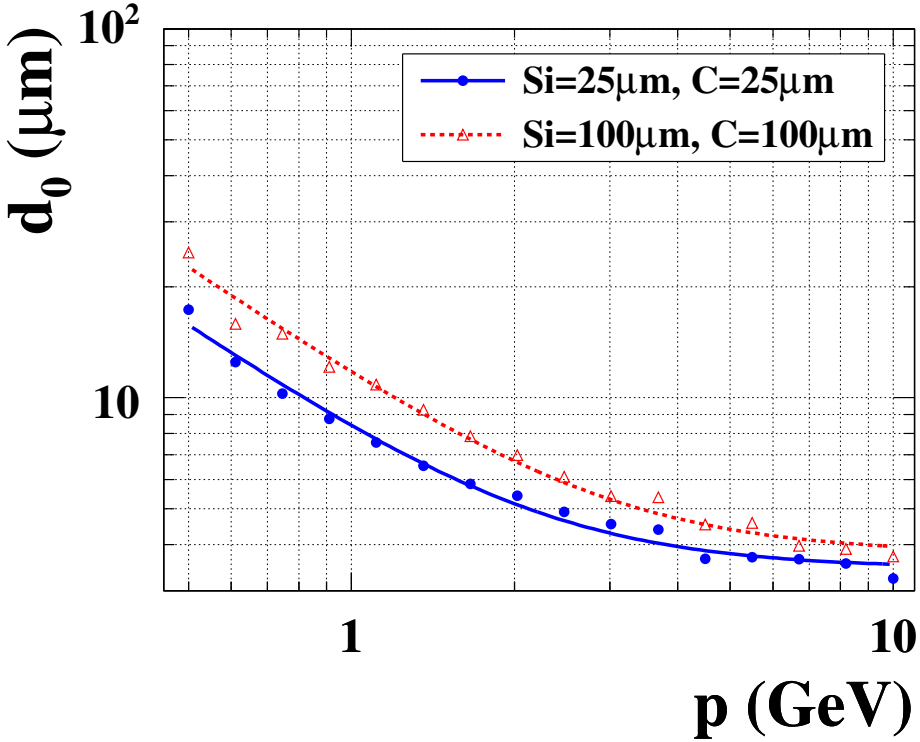
Impact Parameter Resolution - Thickness

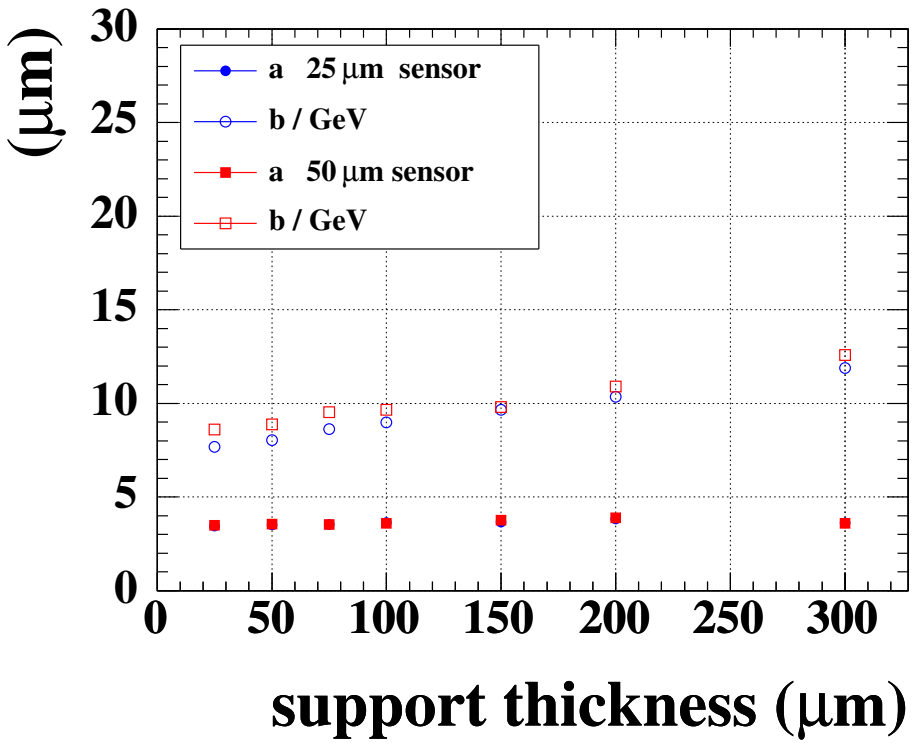




(single point resolution 3 μm)

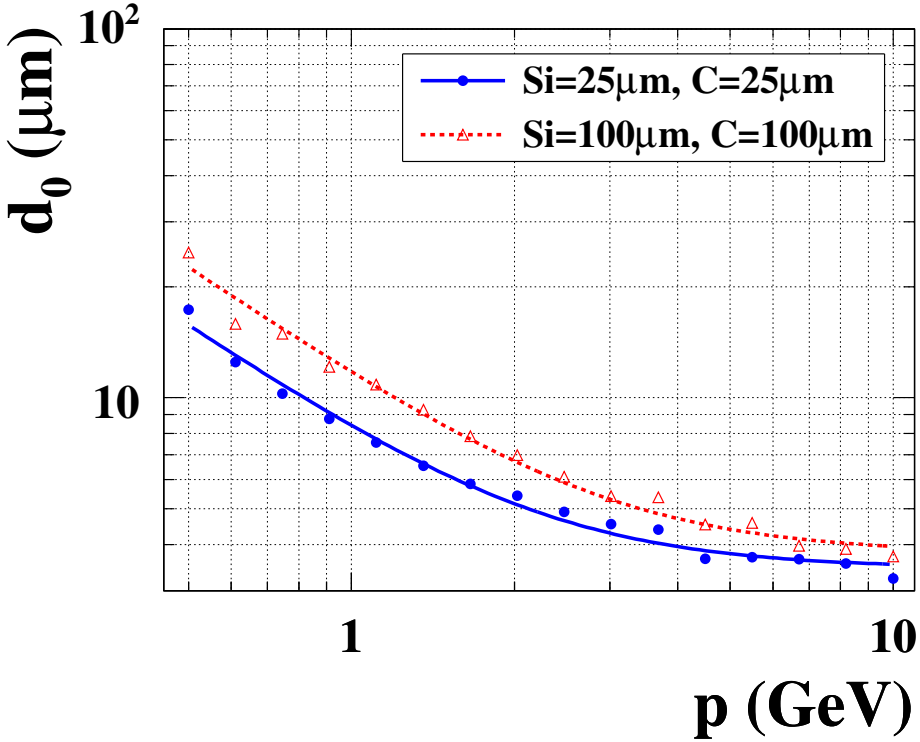
Impact Parameter Resolution - Thickness

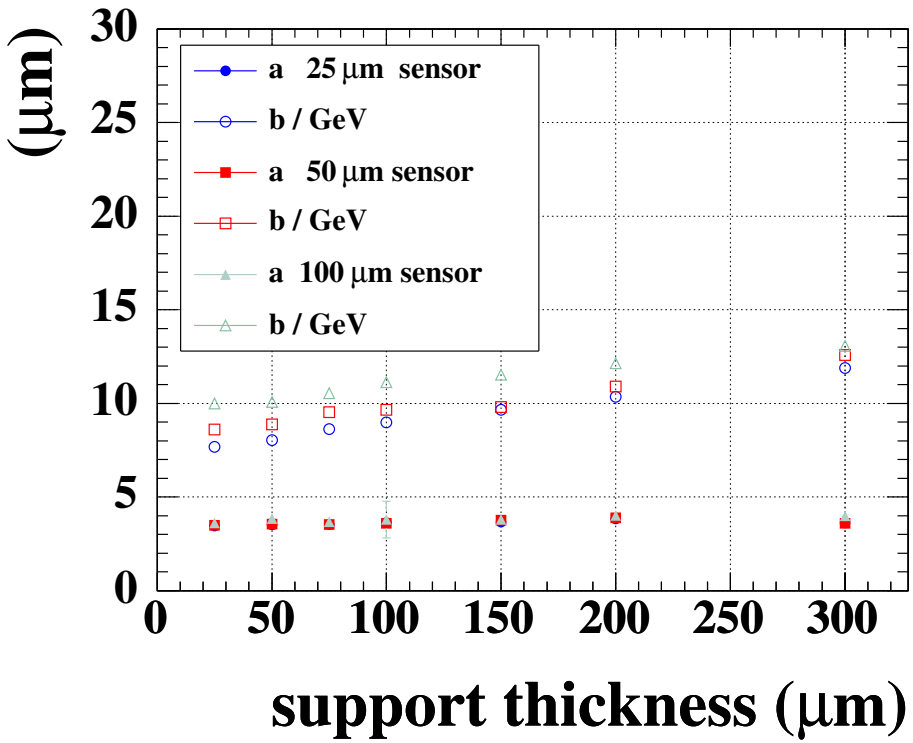




(single point resolution 3 μm)

Impact Parameter Resolution - Thickness





(single point resolution 3 μm)

Summary & Outlook

Summary:

- confidence in resolution estimate
- physics case studies to find:
  - necessary resolution
  - momentum range (lower boarder)

Outlook:

- Geometry available for Brahms
  - Patch-set available
  - Awaiting inclusion into Brahms main trunk
- Note in preparation (needs polishing)

Summary & Outlook

Summary:

- confidence in resolution estimate
- physics case studies to find:
  - necessary resolution
  - momentum range (lower boarder)

Outlook:

- Geometry available for Brahms
  - Patch-set available
  - Awaiting inclusion into Brahms main trunk
- Note in preparation (needs polishing)