Momentum resolution of straw detector in sextant geometry

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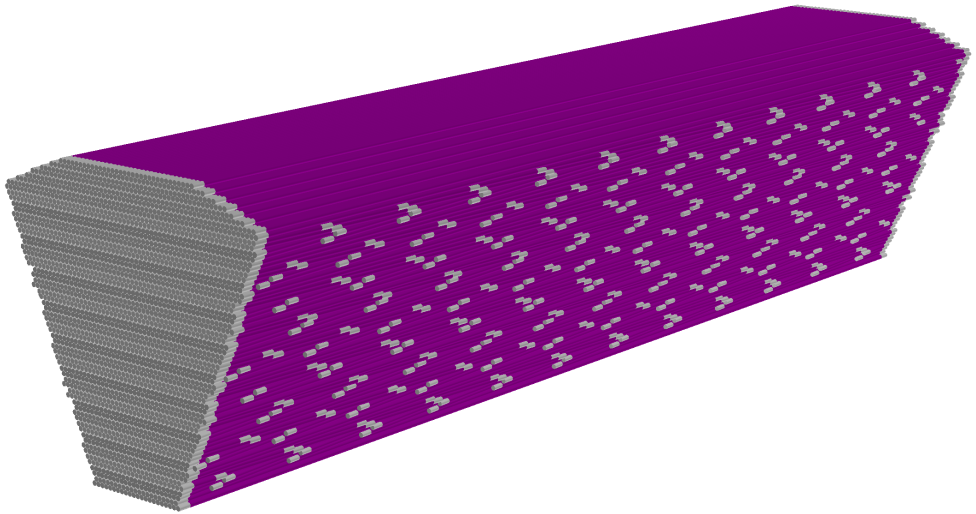
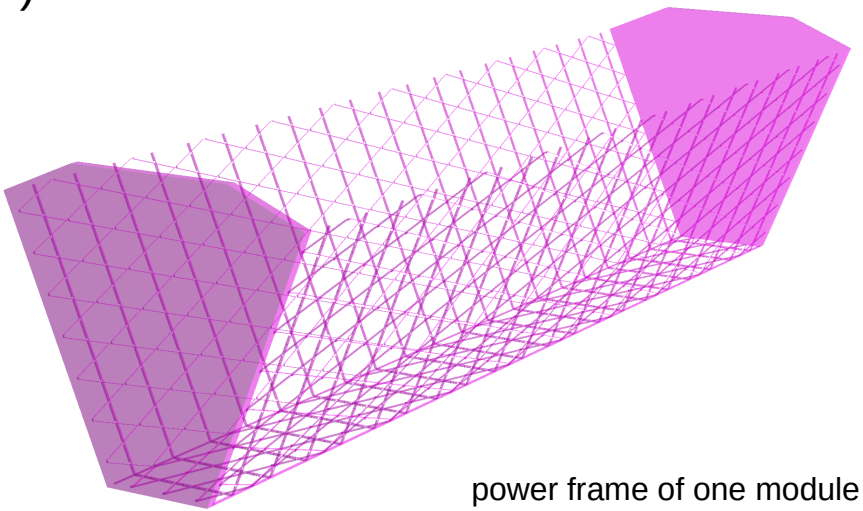
Current description of the straw tracker geometry in SpdRoot (development branch): octant version

8 modules (octants); each module consists from 31 double layer of straw tubes, with alternating tilt angles Z (0°) — U (+3°) — V (-3°)





power frame of one module

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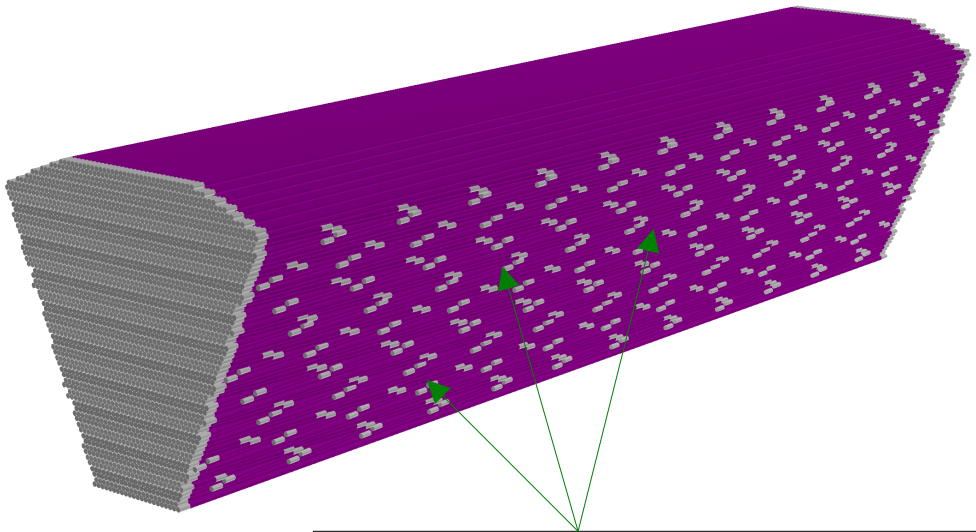
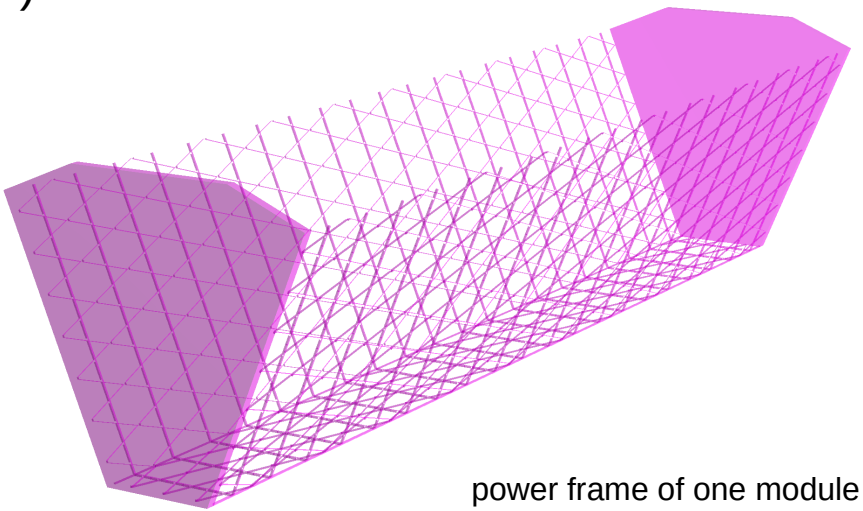
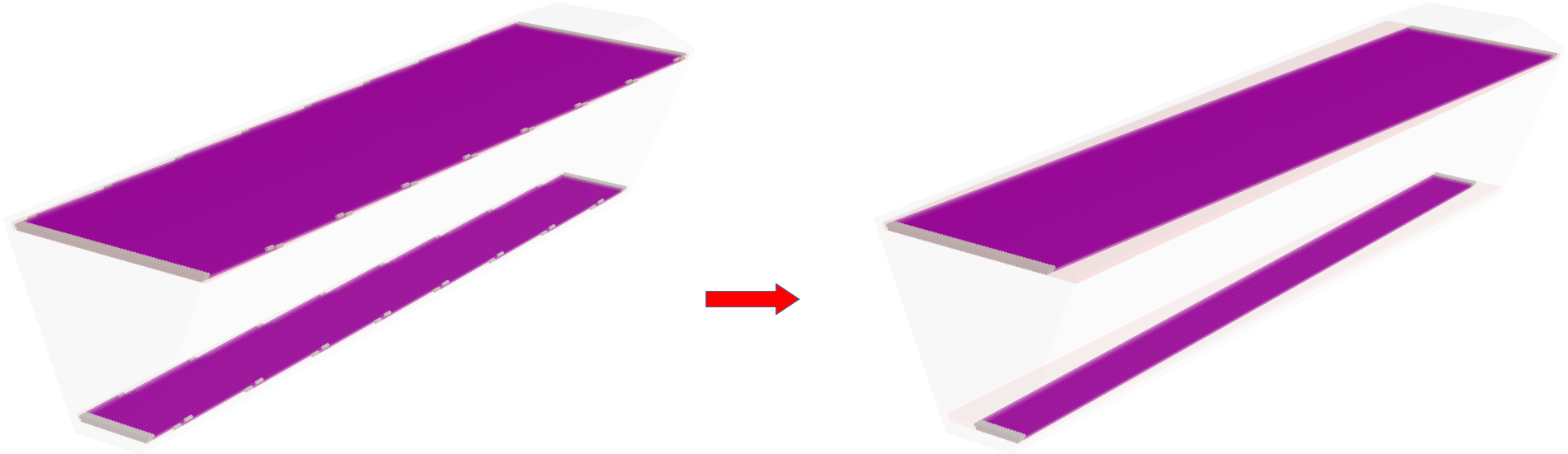




power frame of one module

The tubes, one end of which comes out on the side of the module, have to be **removed** in this geometry, because no solution was found how to connect them to the gas system.

Octant geometry without short tubes

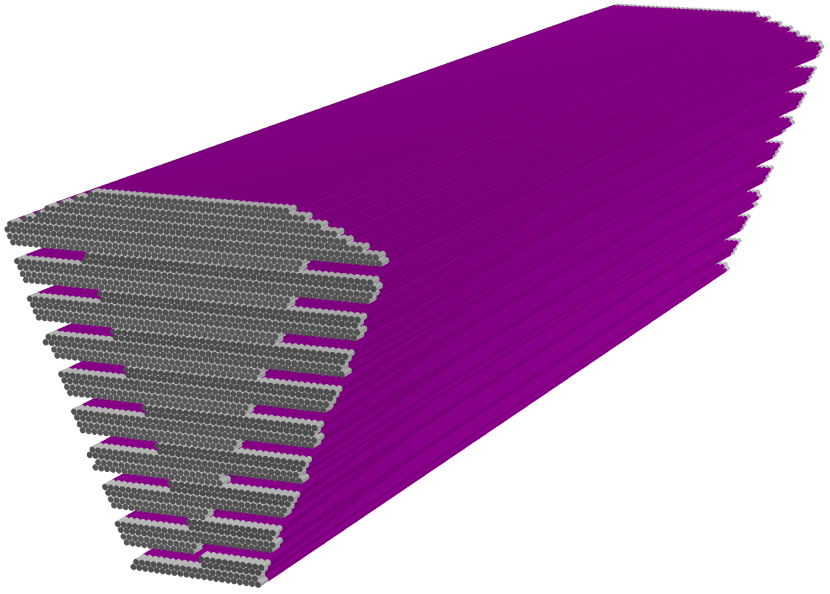


For tilt angle α = 3° from 20% to 55% of sensitive area of U/V layers is lost.

For tilt angle α = 2° from 13% to 37% of sensitive area of U/V layers is lost *(shown above)*.

Dead zones in the central part.

Octant geometry without short tubes

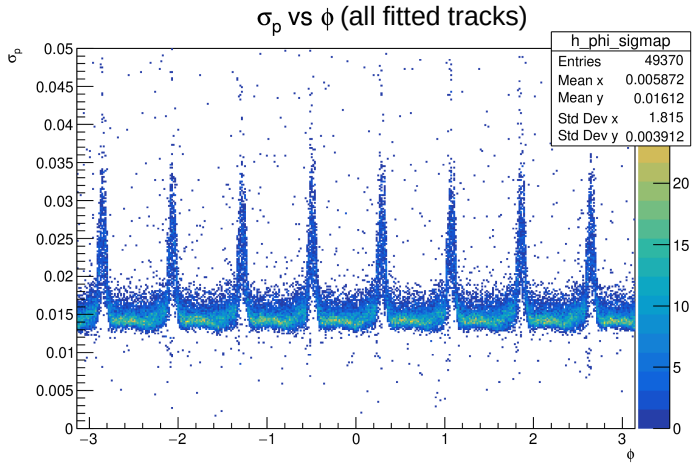


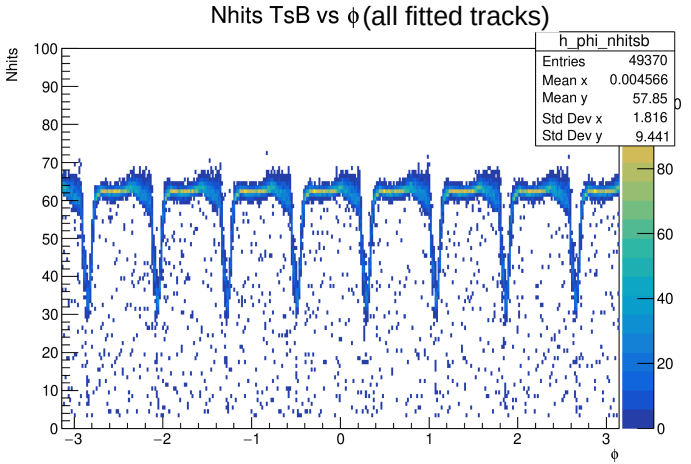
```
SpdTsTBGeoMapper *tsb_mapper = SpdTsTBGeoMapper::Instance();

tsb_mapper->MakeShortStraws(false);
```

Comparison of octant geometries with / without short tubes

Octant geometry, α = 3°, with short straws

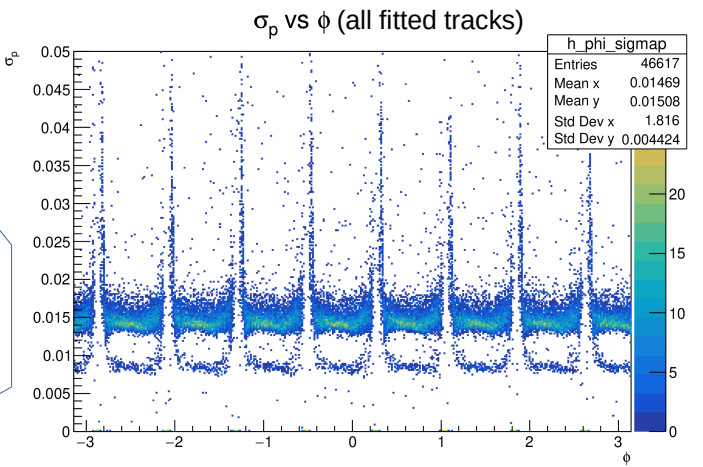
Tracks with fit pars exist	99,9%
Tracks with fit converged	97,8%

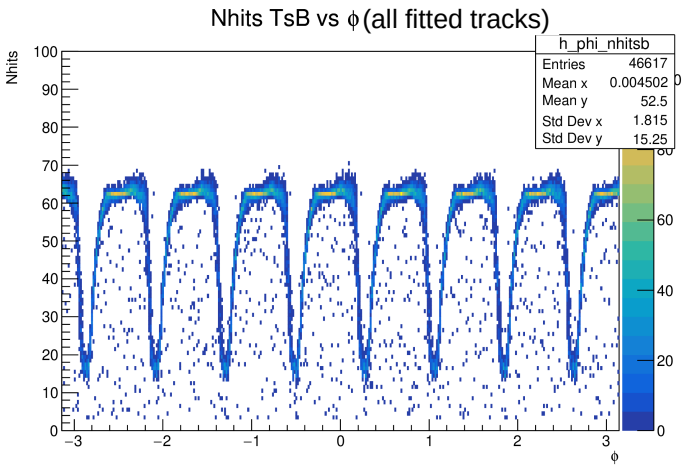


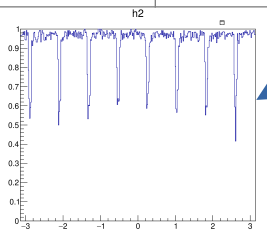


Octant geometry, α = 2°, no short straws

Tracks with fit pars exist	94,3%
Tracks with fit converged	83,6%

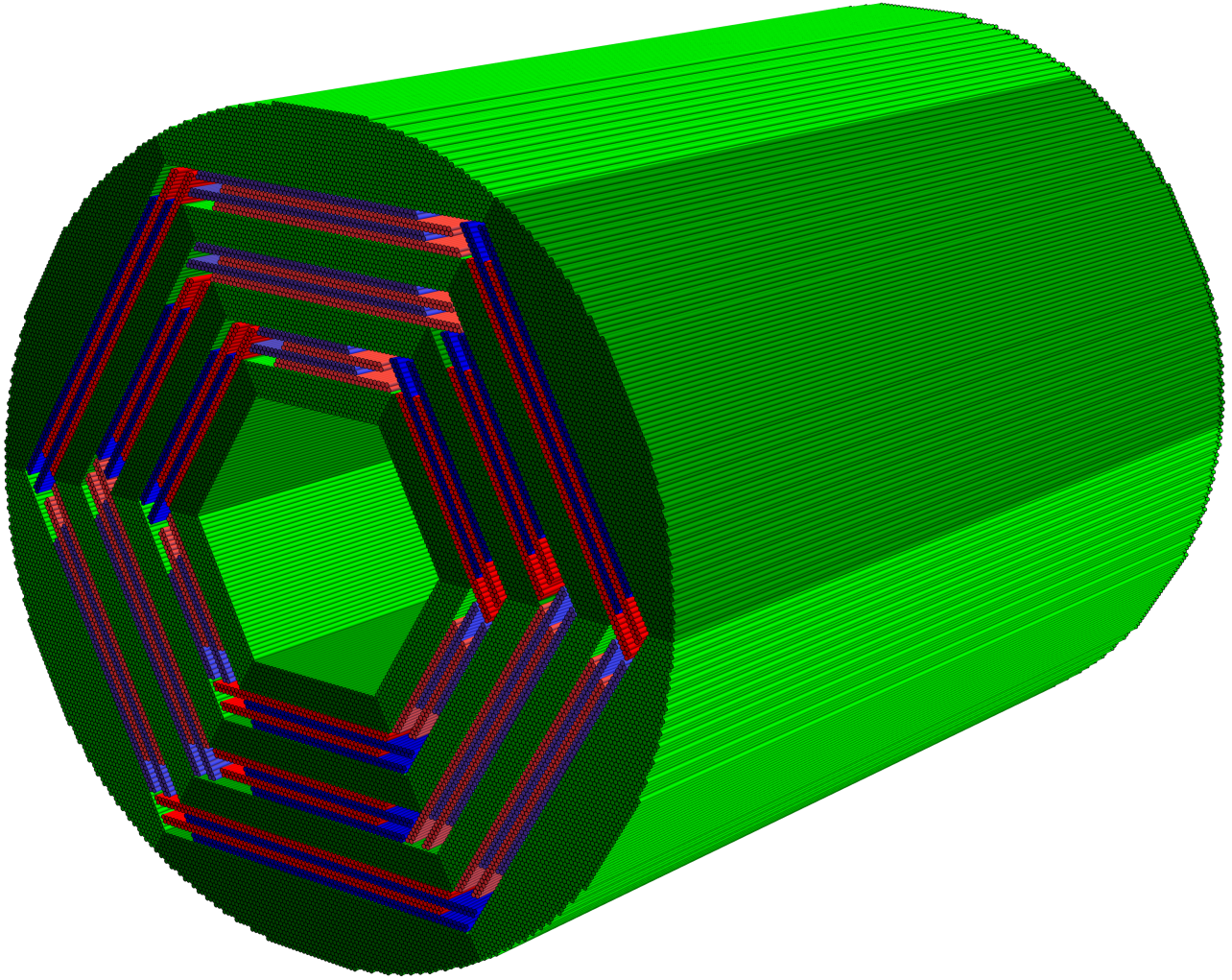






Used sample: P = 1 GeV/c; θ = π/2; Z_0 ~ Gaus(0, 30 cm); only straw tracker.

Sextant geometry: general view



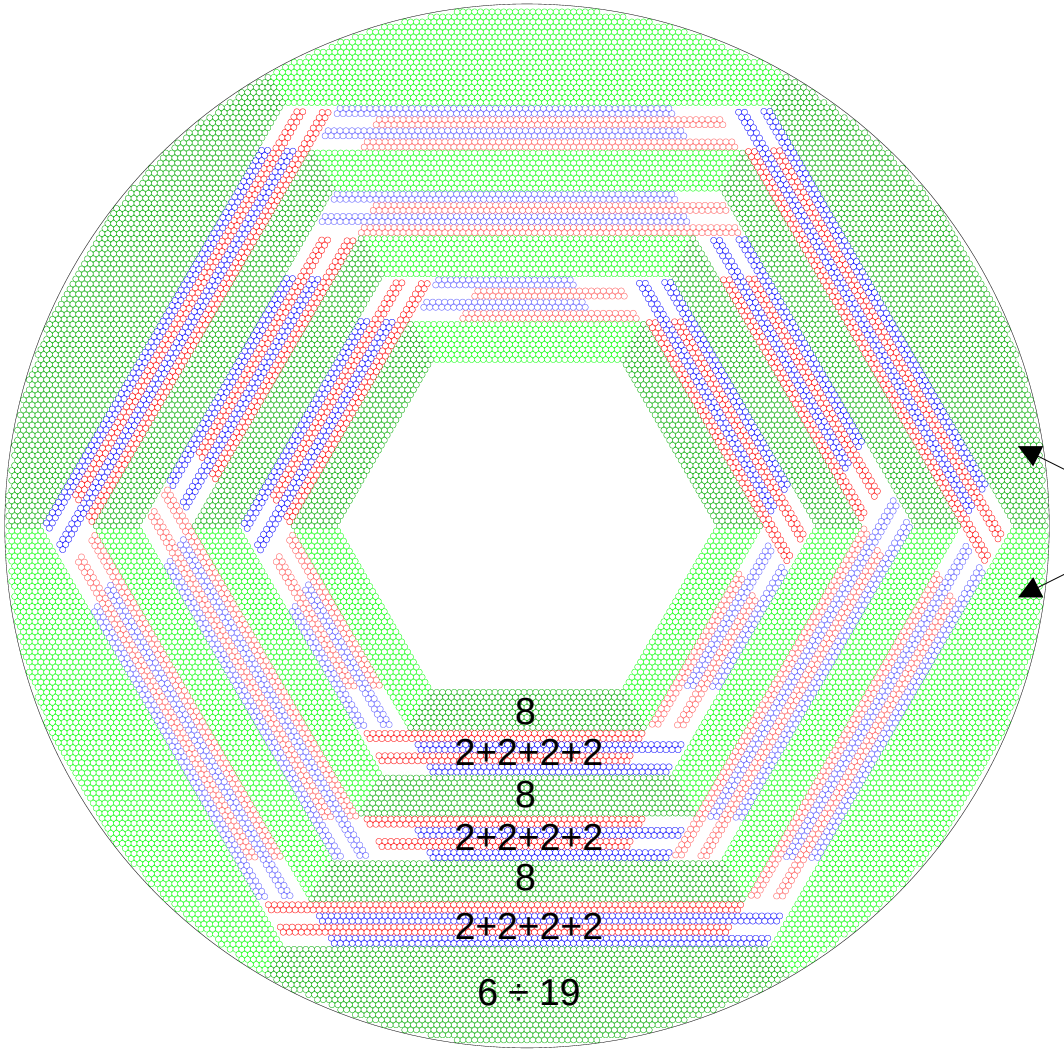
Sextant geometry: cross section at $z = L/2$

z tubes form dense (honeycomb-like) packing everywhere, that enhances rigidity of the structure.

Between the z layers, u/v layers are inserted in a non-trivial way.

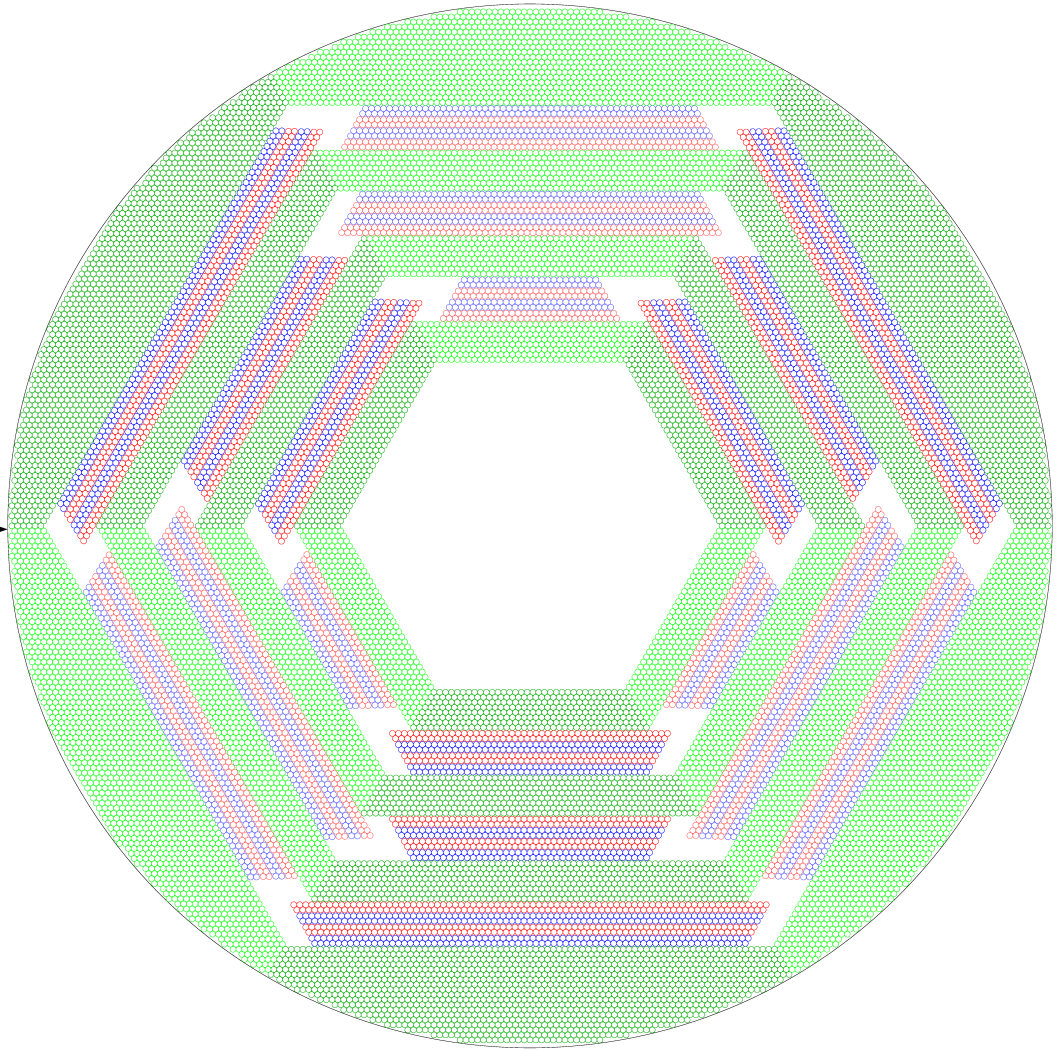
1) The radius of the oblique tubes is selected so as not to disturb the position of the z layers;

2) Widths of u/v layers are alternately extended or reduced in order to avoid dead zones at the joints of modules.

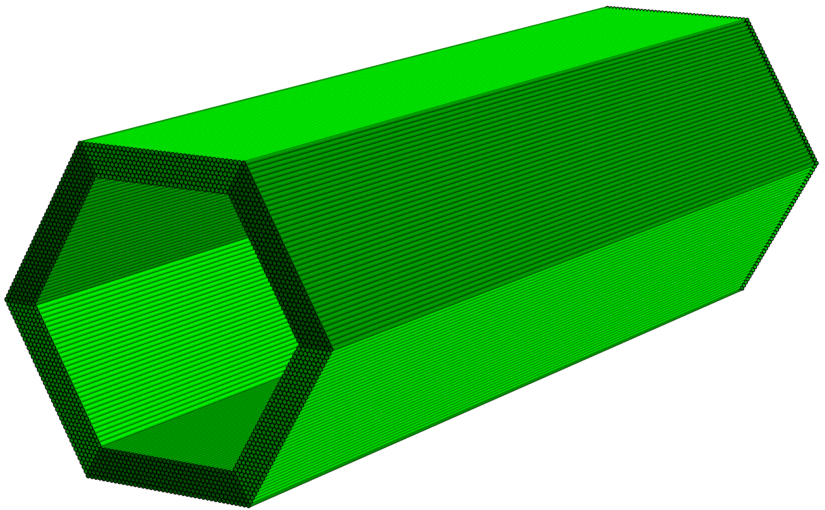


Sextant geometry: cross section at *z = 0*

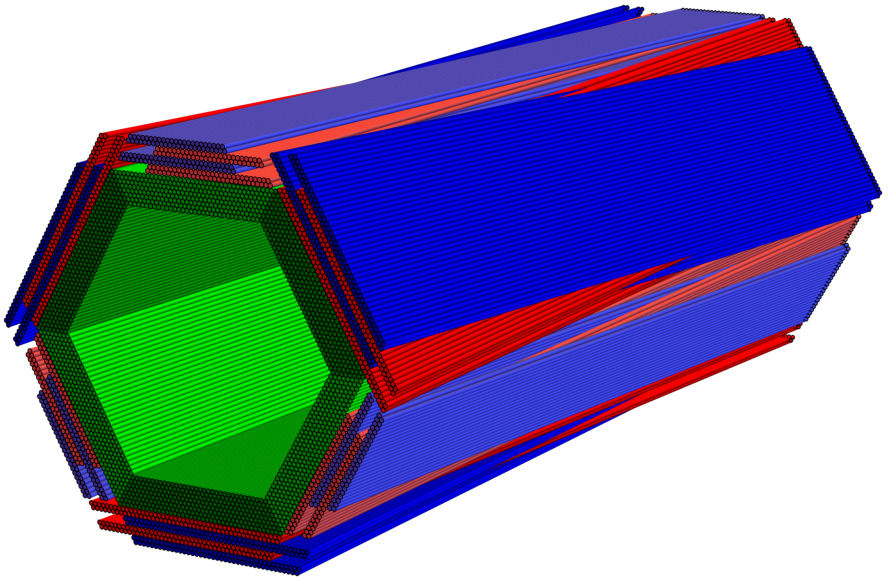
No dead zones at the joints of the modules



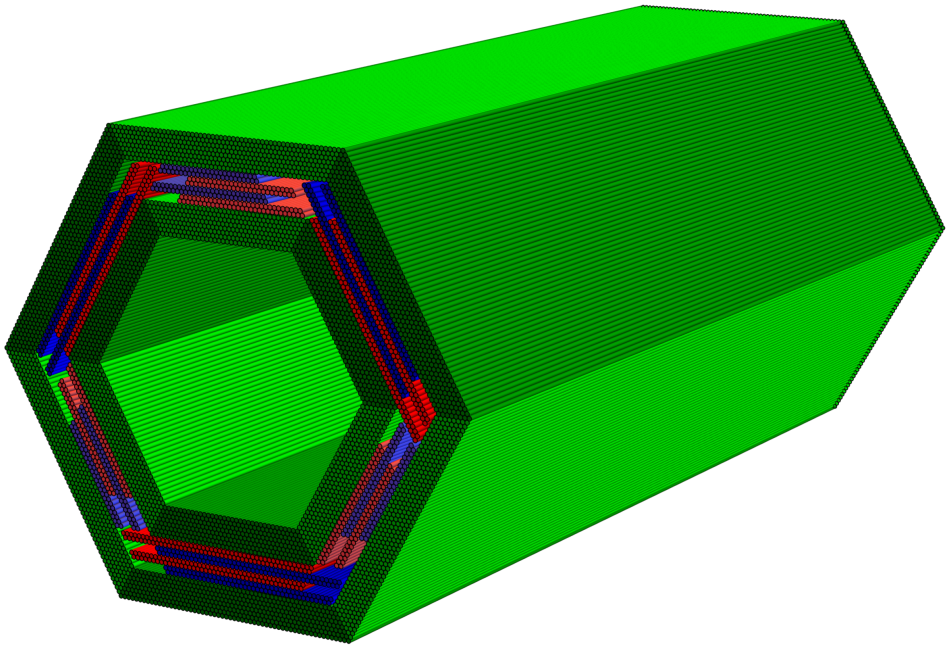
Sextant geometry



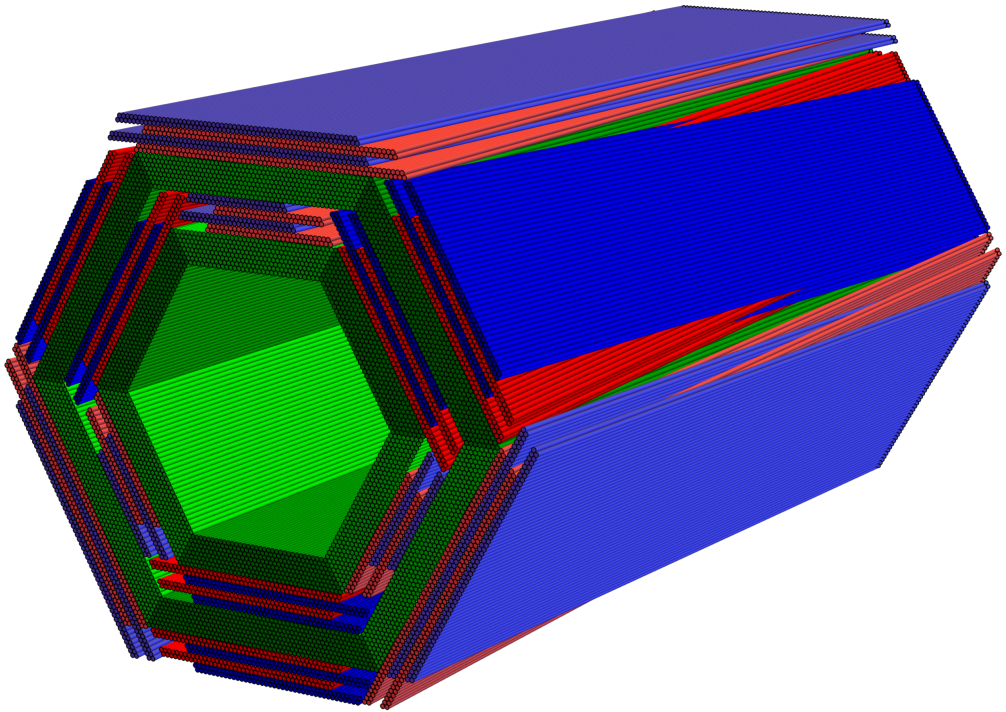
Sextant geometry



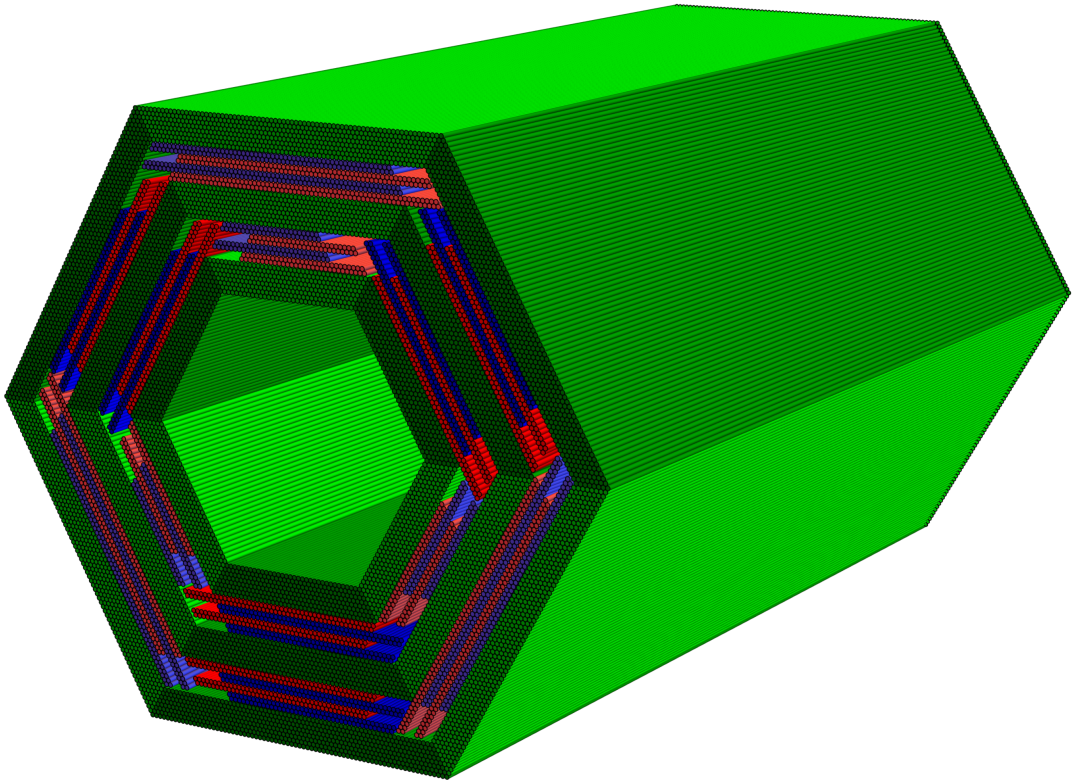
Sextant geometry



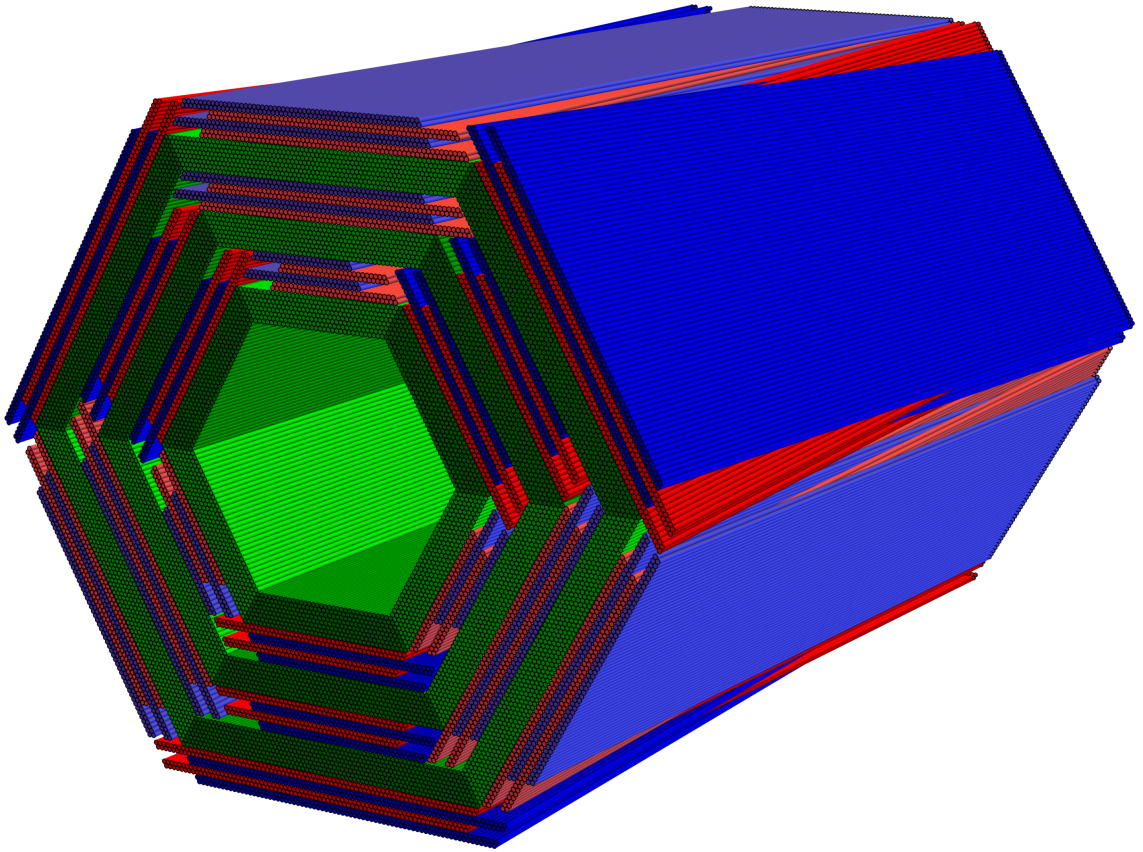
Sextant geometry



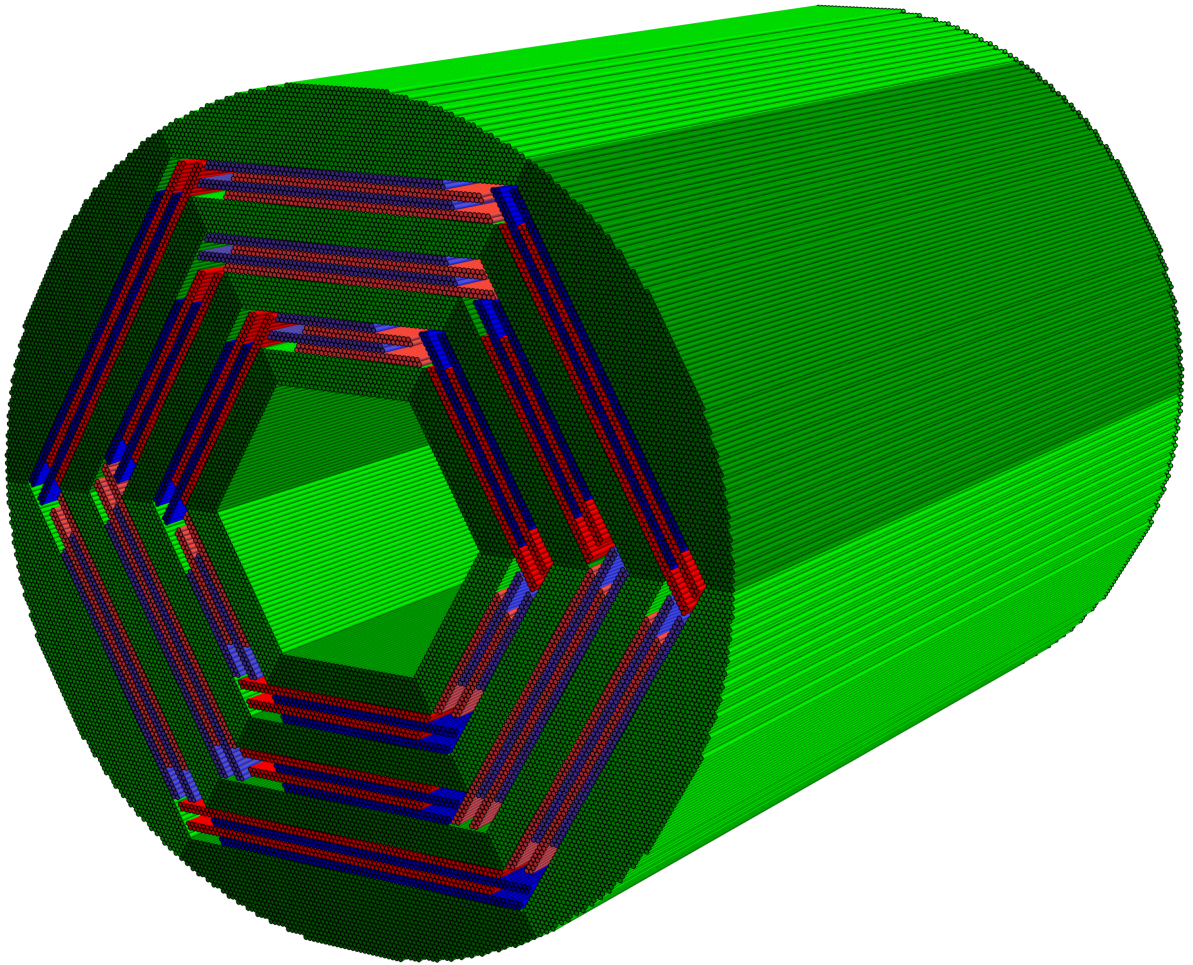
Sextant geometry



Sextant geometry



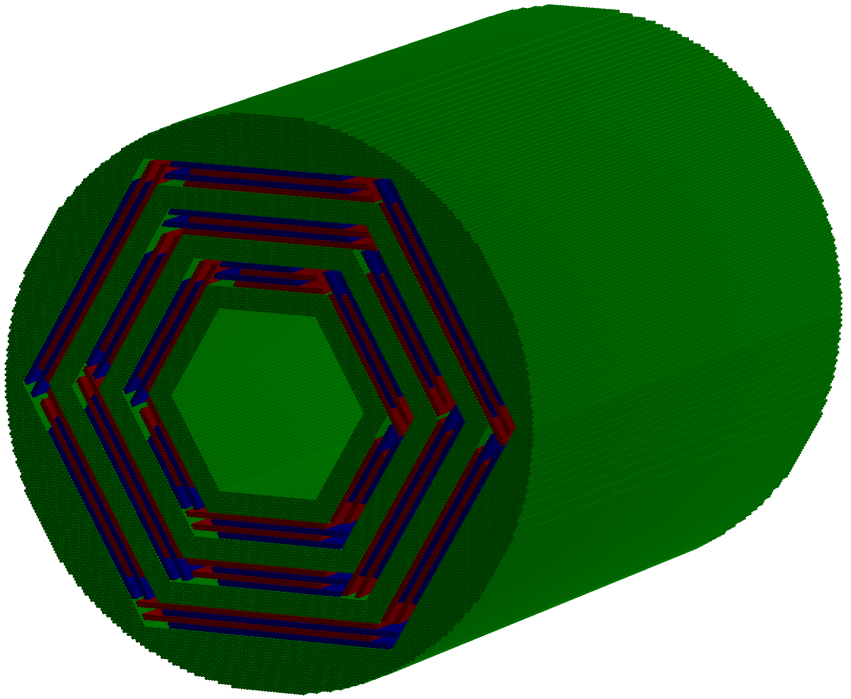
Sextant geometry



Sextant geometry in SpdRoot

Branch `straw-sextant-geometry`

New class **`SpdTsB`**



In simulation script:

```
SpdTsB *ts_barrel = new SpdTsB();

run->AddModule(ts_barrel);
```

The octant version is available as `SpdTsTB`, as before.

Details of sample / analysis

Sample:

- Artificial isotropic sample
- Primary vertex in (0,0,0)
- Tracker configuration: MM+STRAW (sextant version / octant version [with short tubes])
- Initial momentum: 1 GeV / 5 GeV

Analysis:

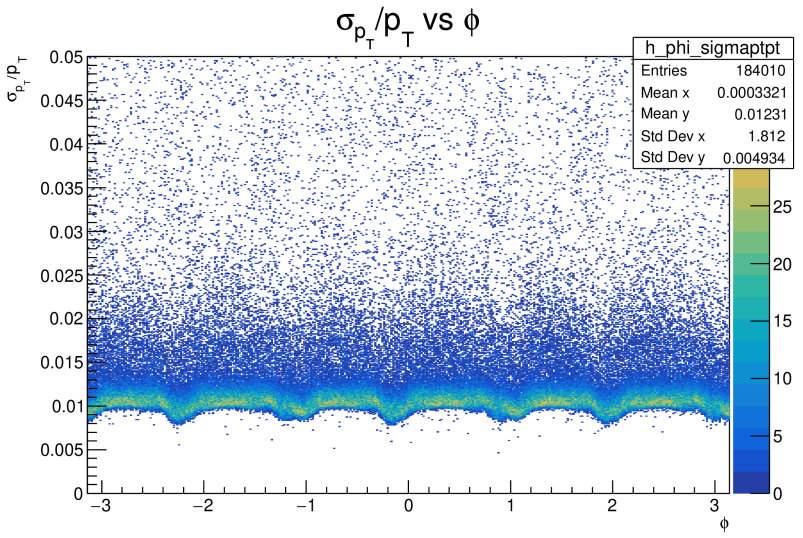
- Cut on track fit convergency was applied.
- θ, p_T, p_L are expressed as functions of p_x, p_y, p_z, and their resolution (σ) is calculated for each track using the covariance matrix provided by GenFit
- Distributions σ vs ϕ and σ vs θ are plotted.

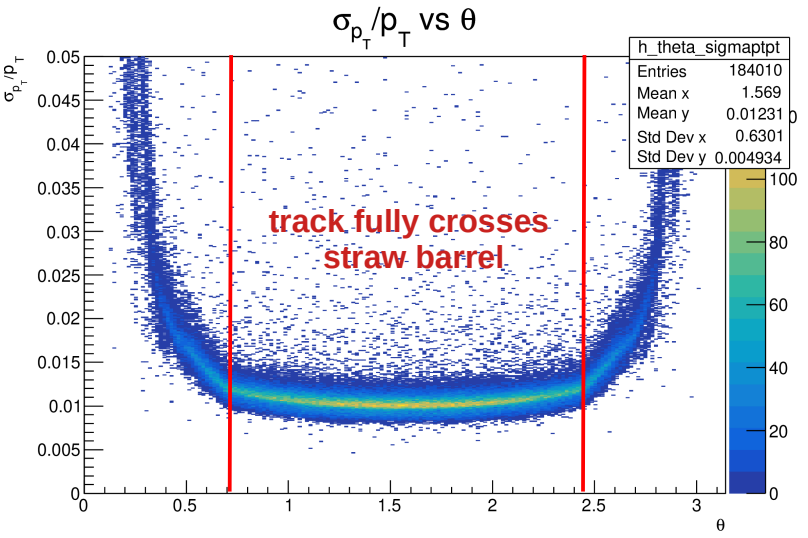
Transverse momentum resolution

MM+STRAW, p = 1 GeV/c: transverse momentum resolution

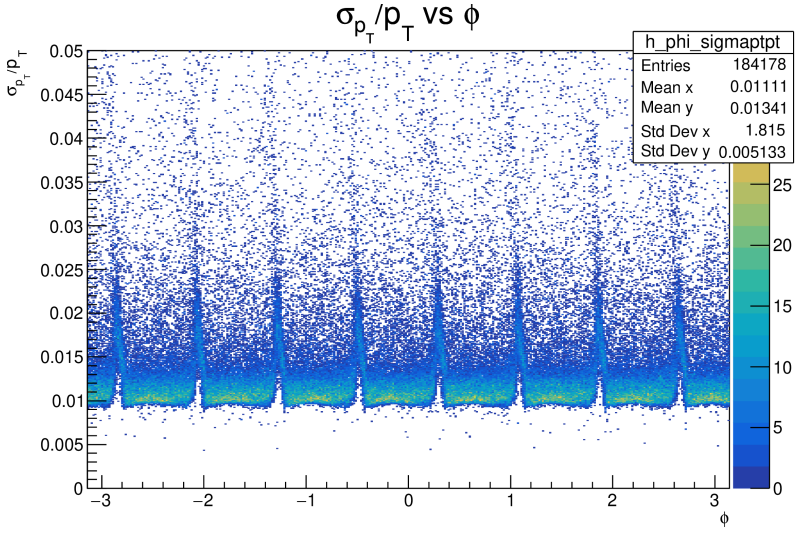
$\frac{\sigma_{p_T}}{p_T}$:

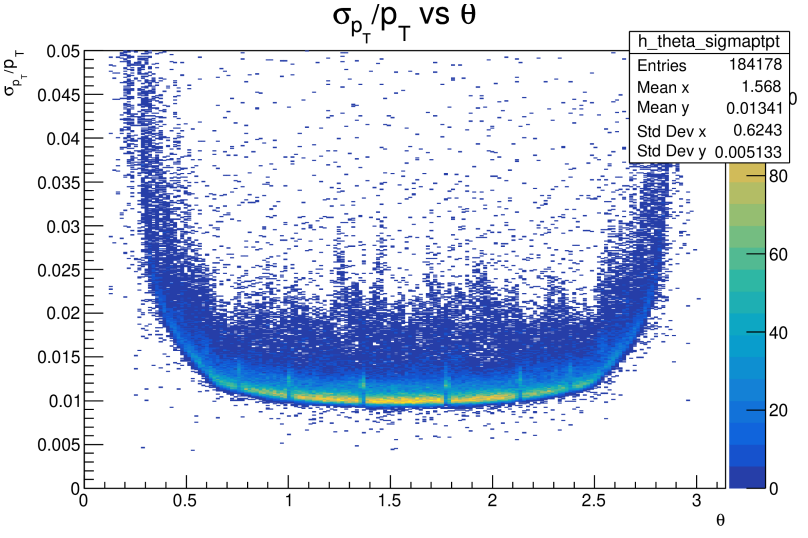
sextant version





octant version

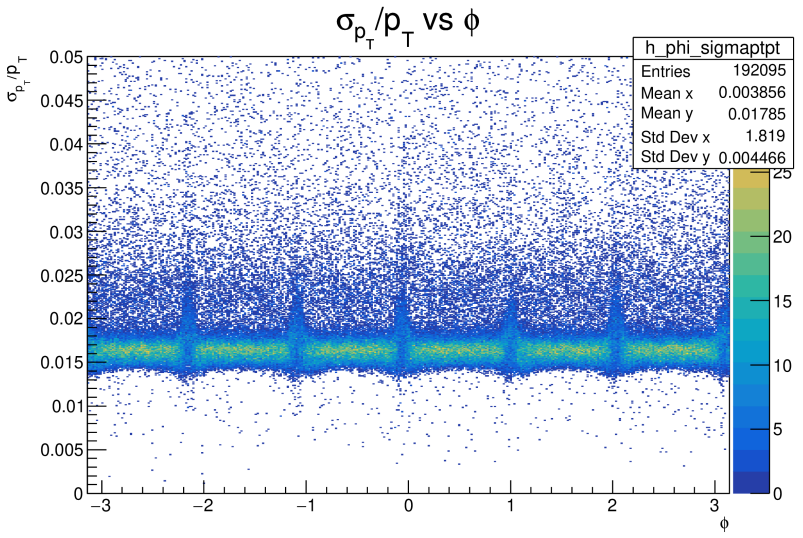


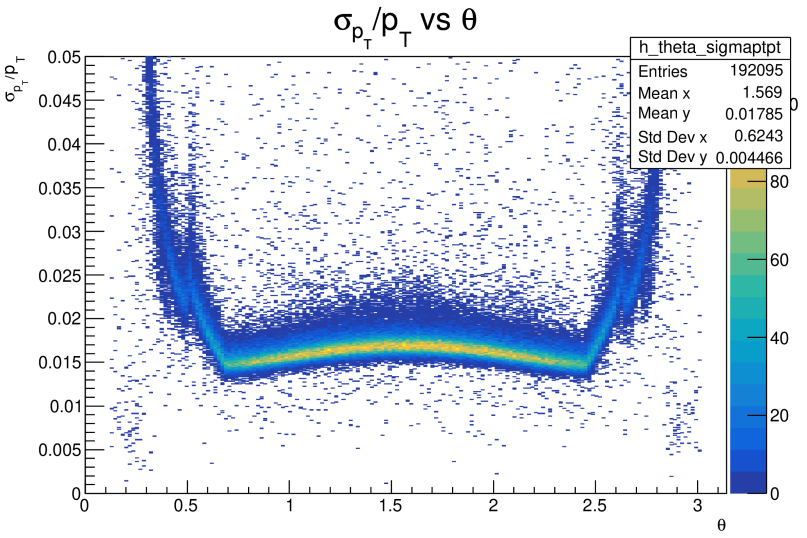


MM+STRAW, p = 5 GeV/c: transverse momentum resolution

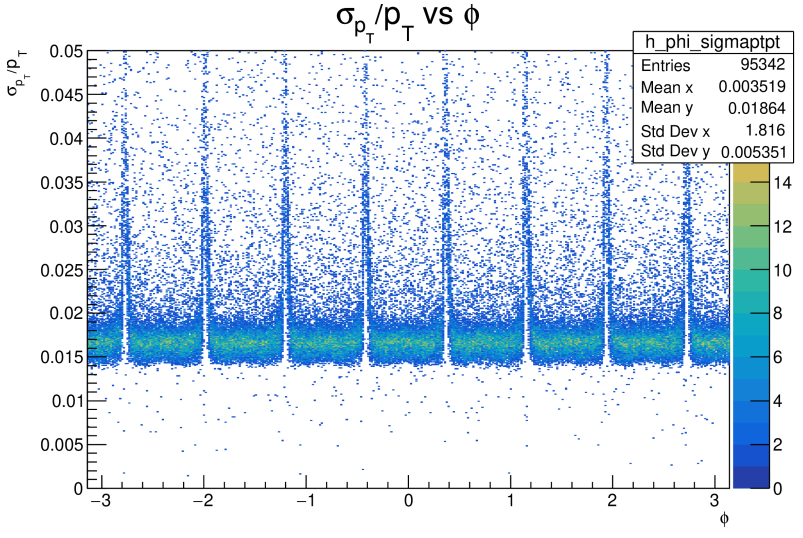
$\frac{\sigma_{p_T}}{p_T}$:

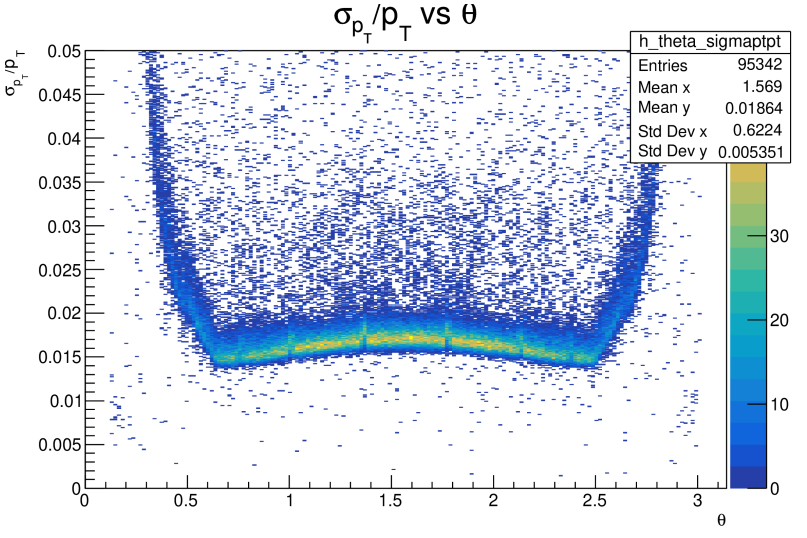
sextant version





octant version





Polar angle resolution

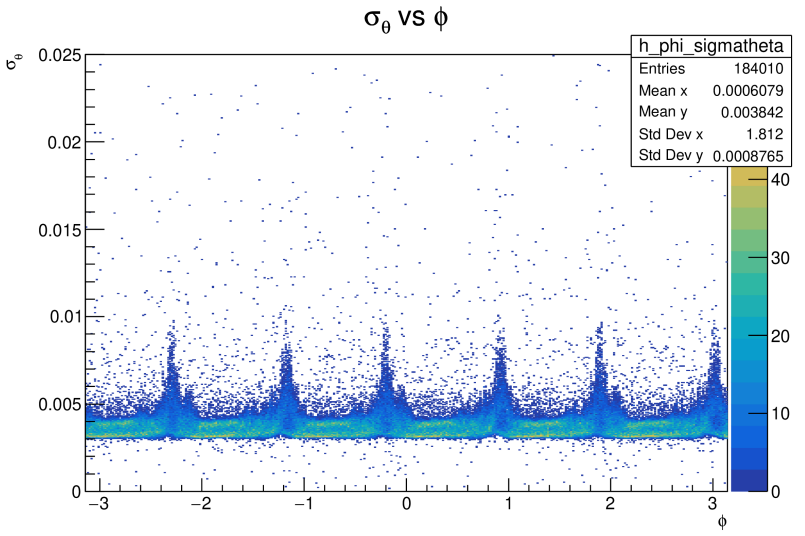
MM+STRAW, p = 1 GeV/c: polar angle resolution

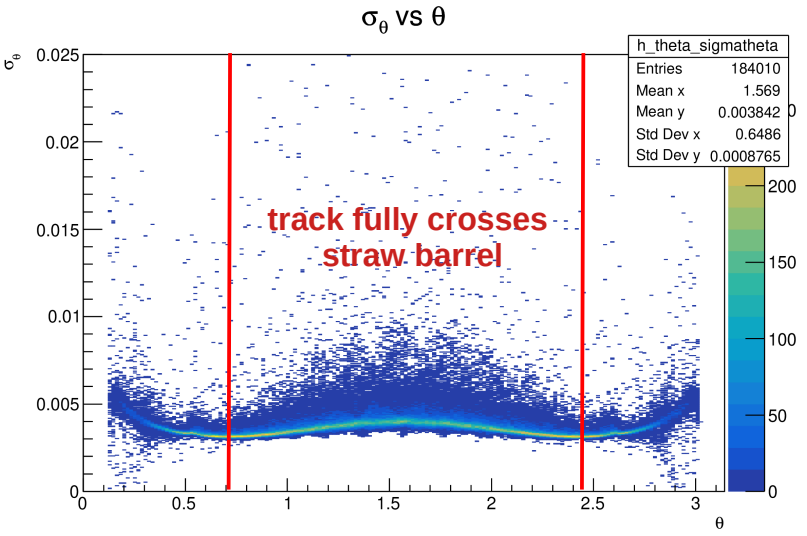
σ_θ:

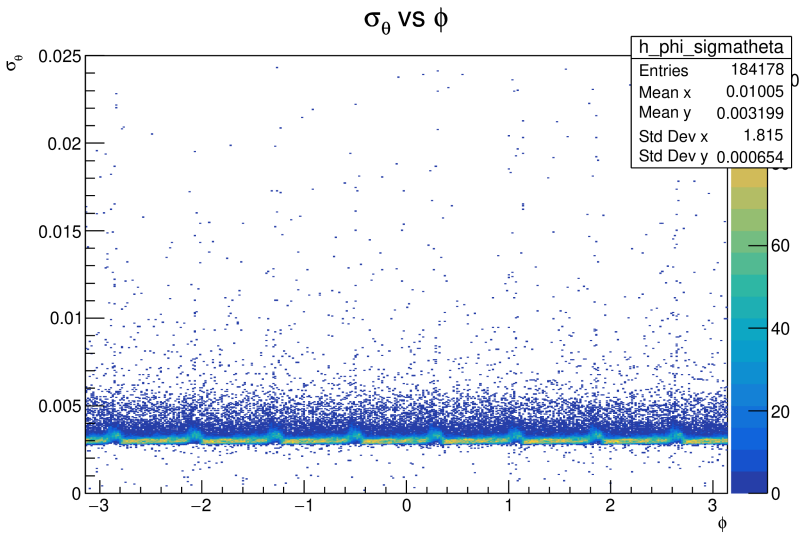
sextant version

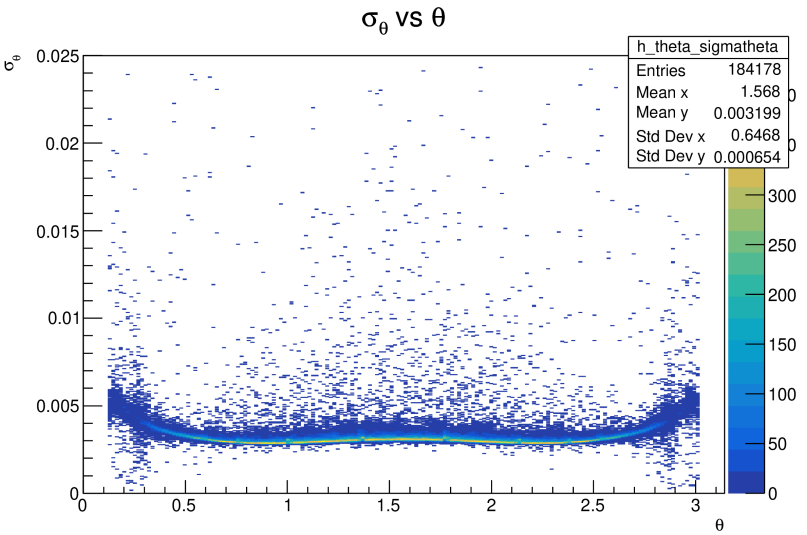
ratio ≈ 1.2

octant version









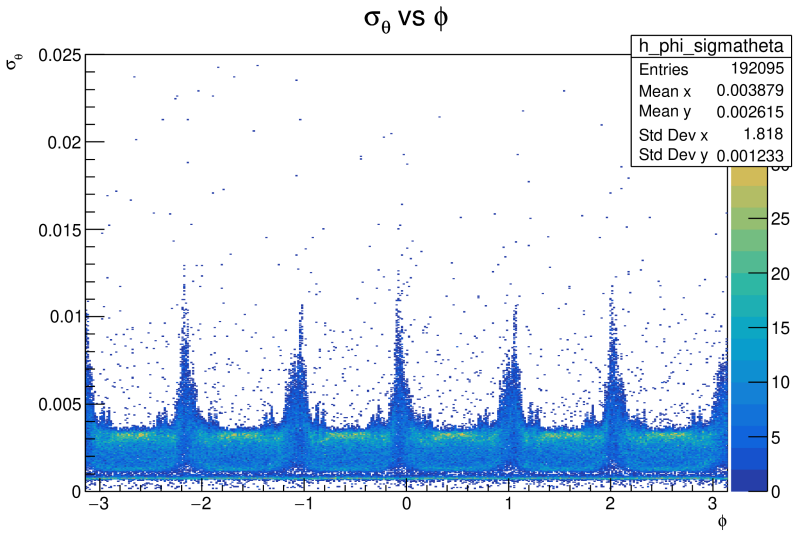
MM+STRAW, p = 5 GeV/c: polar angle resolution

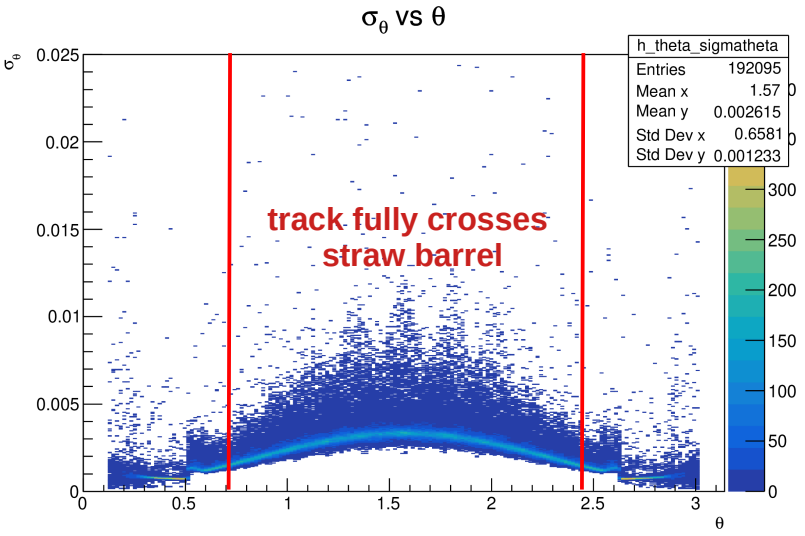
σ_θ:

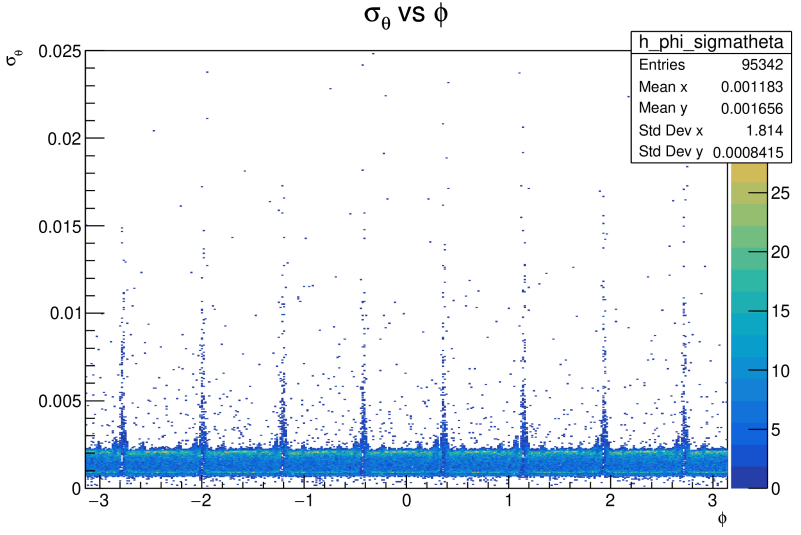
sextant version

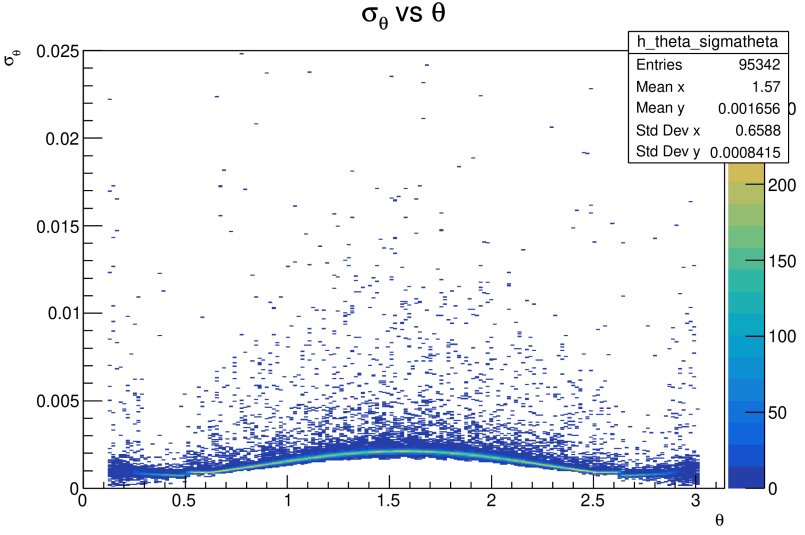
ratio ≈ 1.6

octant version



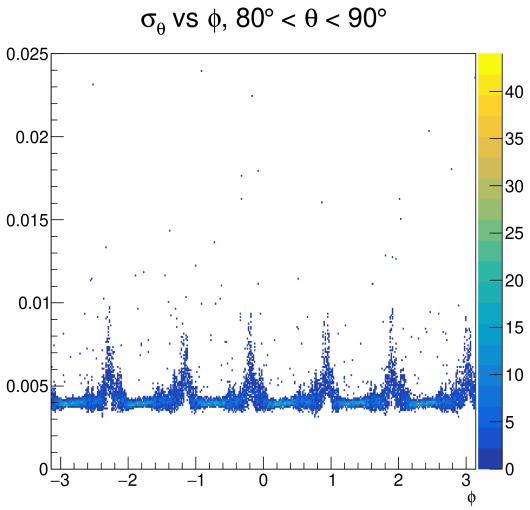




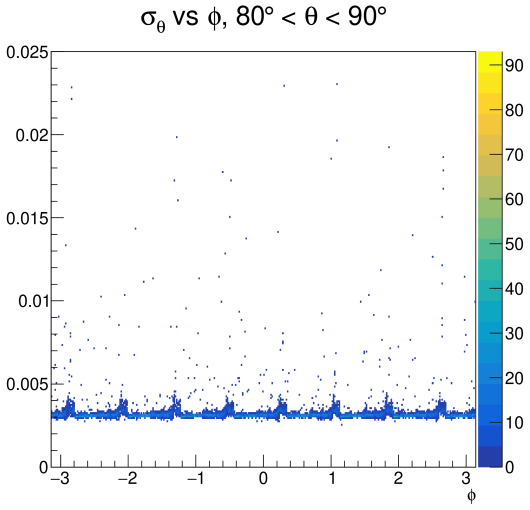


MM+STRAW, p = 1 GeV/c: polar angle resolution

sextant version



octant version

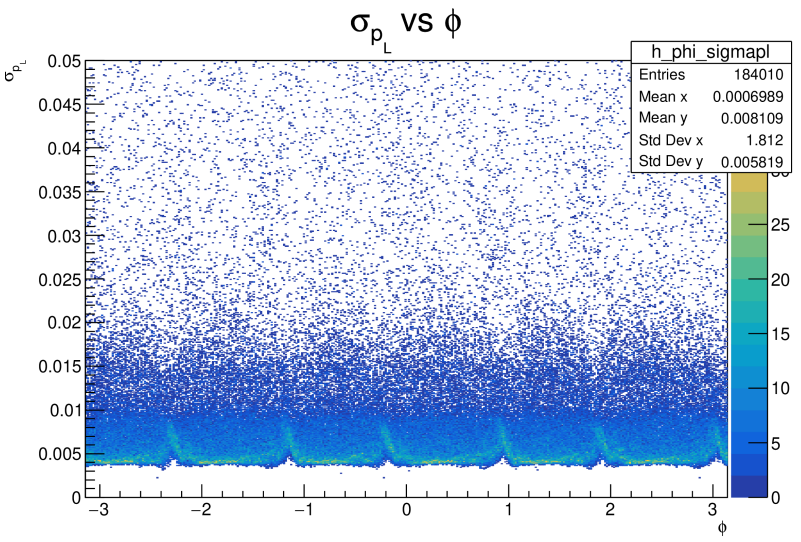


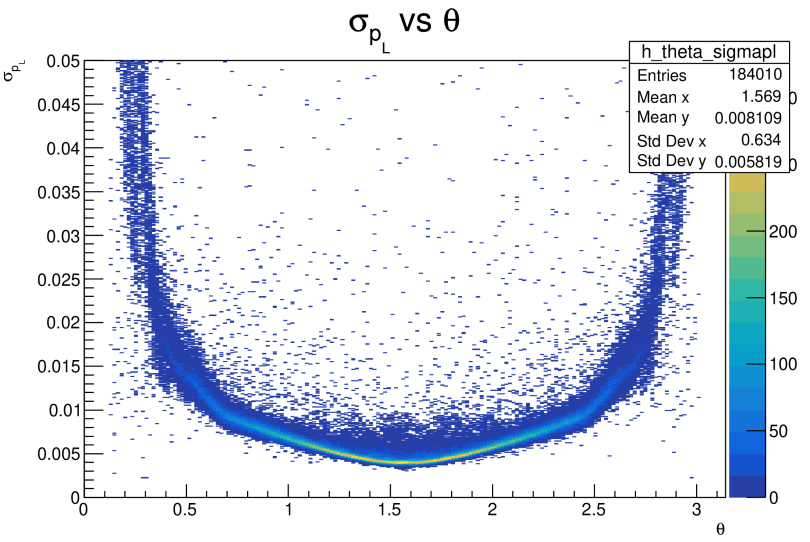
Longitudinal momentum resolution

MM+STRAW, p = 1 GeV/c: longitudinal momentum resolution

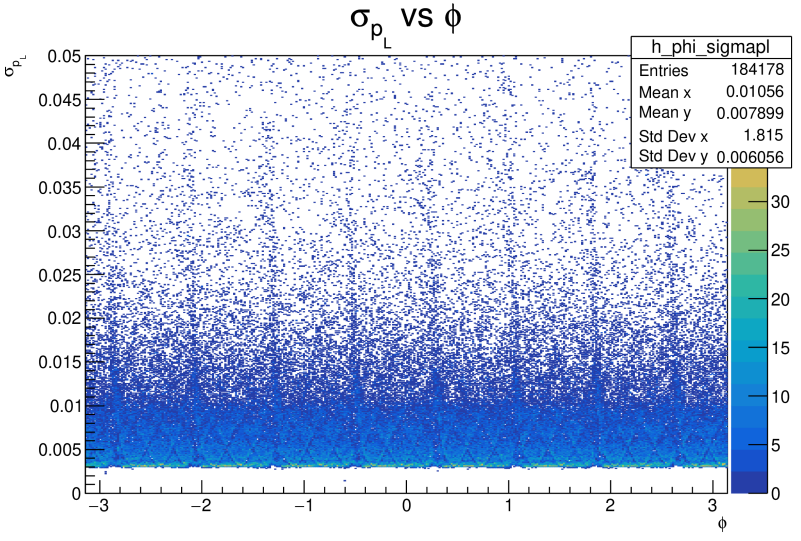
σ_{p_L}:

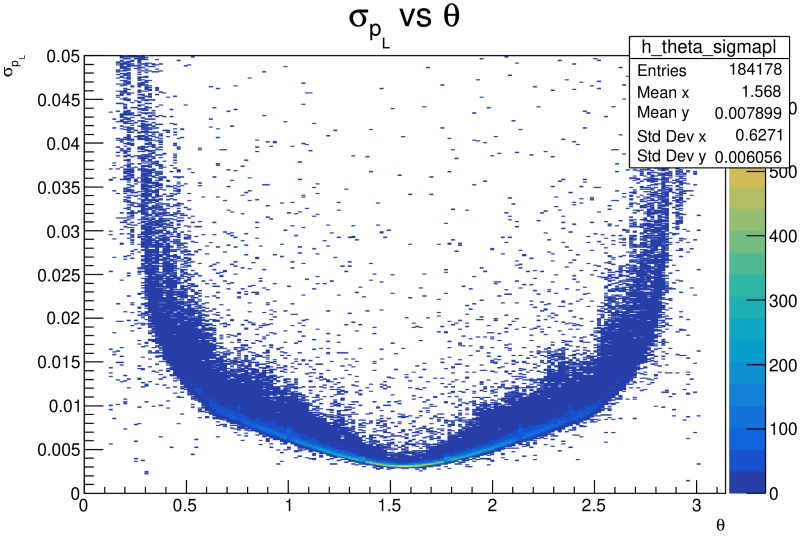
sextant version





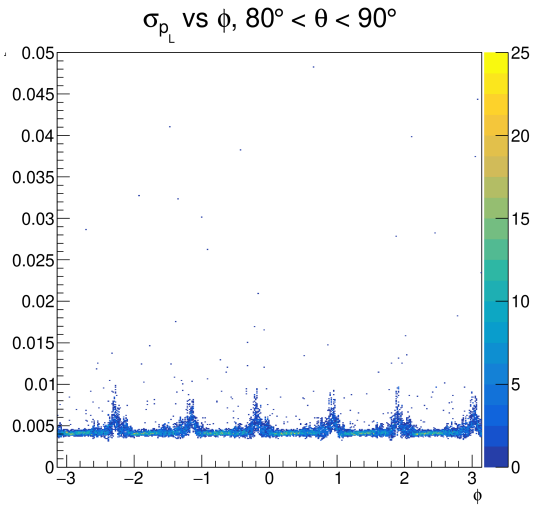
octant version

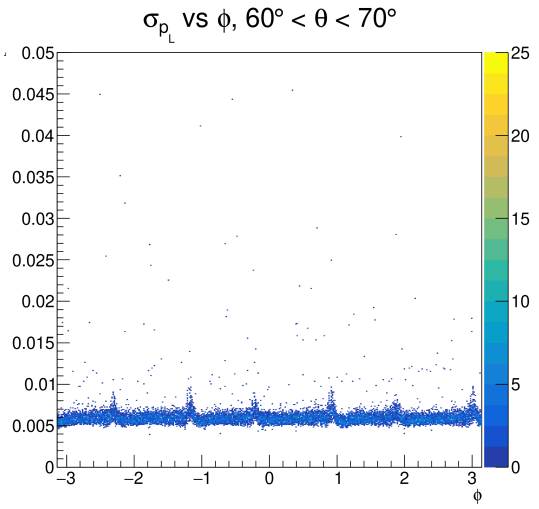


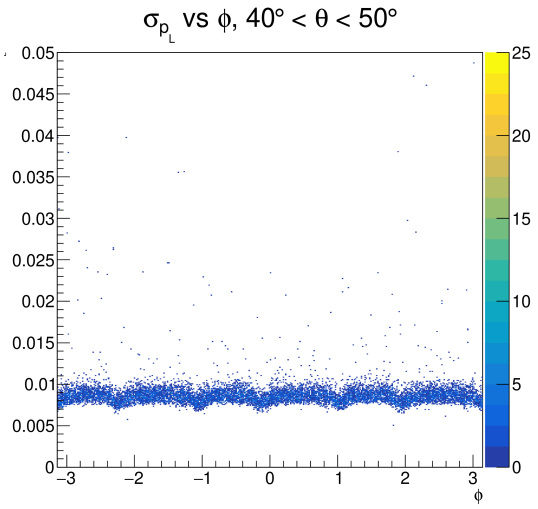


MM+STRAW, p = 1 GeV/c: longitudinal momentum resolution

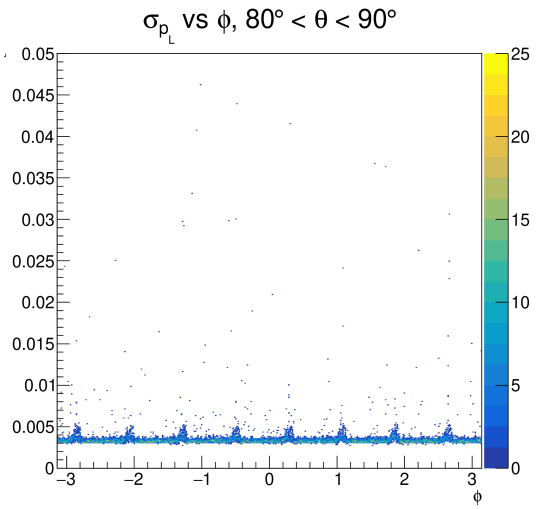
sextant version

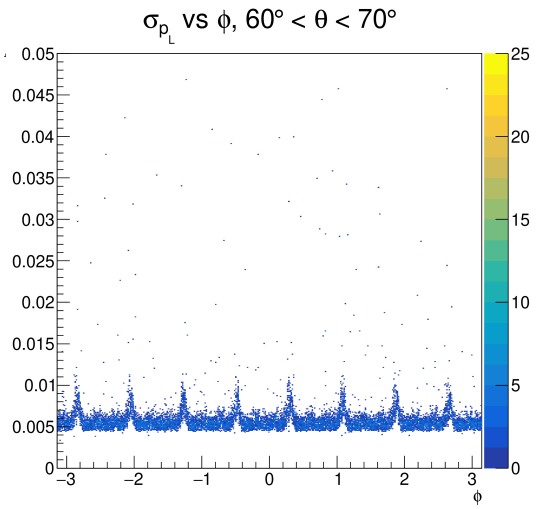


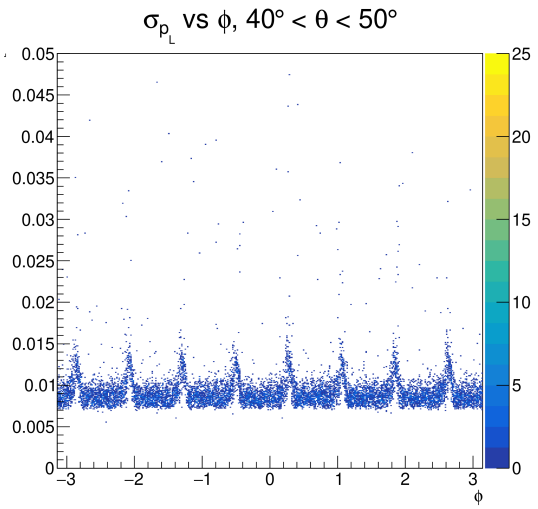




octant version

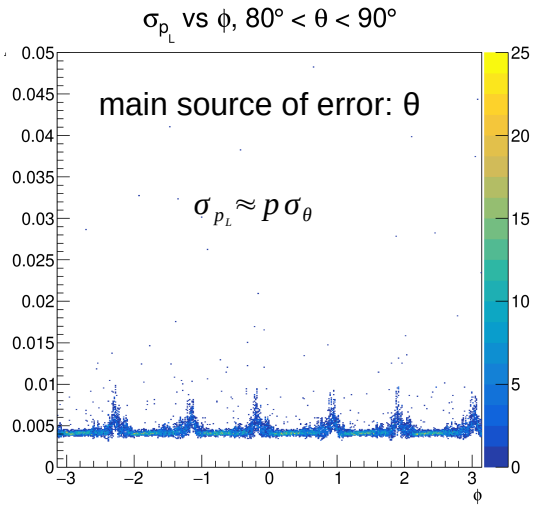


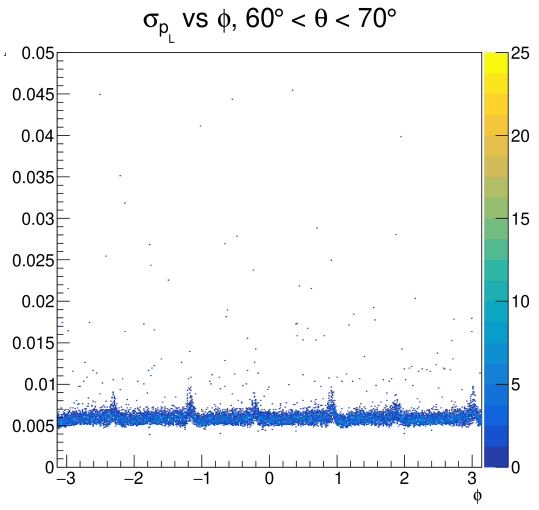


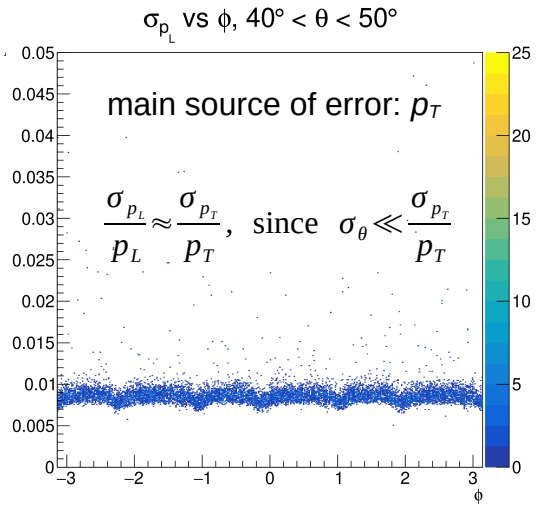


MM+STRAW, p = 1 GeV/c: longitudinal momentum resolution

sextant version







$p_L = p\cos\theta = p_T/\tan\theta$

Assuming independent errors of p_T and θ:

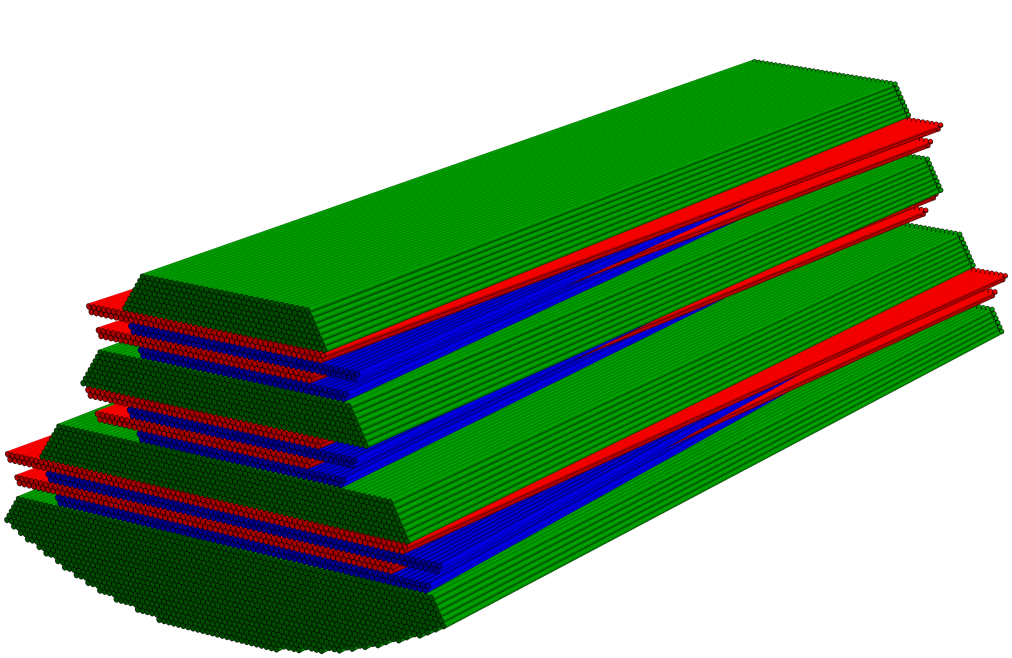
$$\sigma^2_{p_L} \approx p^2\left[\cos^2\theta\left(\frac{\sigma_{p_T}}{p_T}\right)^2 + \frac{1}{\sin^2\theta}\sigma^2_\theta\right], \qquad \left(\frac{\sigma_{p_L}}{p_L}\right)^2 \approx \left(\frac{\sigma_{p_T}}{p_T}\right)^2 + \frac{1}{\cos^2\theta\sin^2\theta}\sigma^2_\theta$$

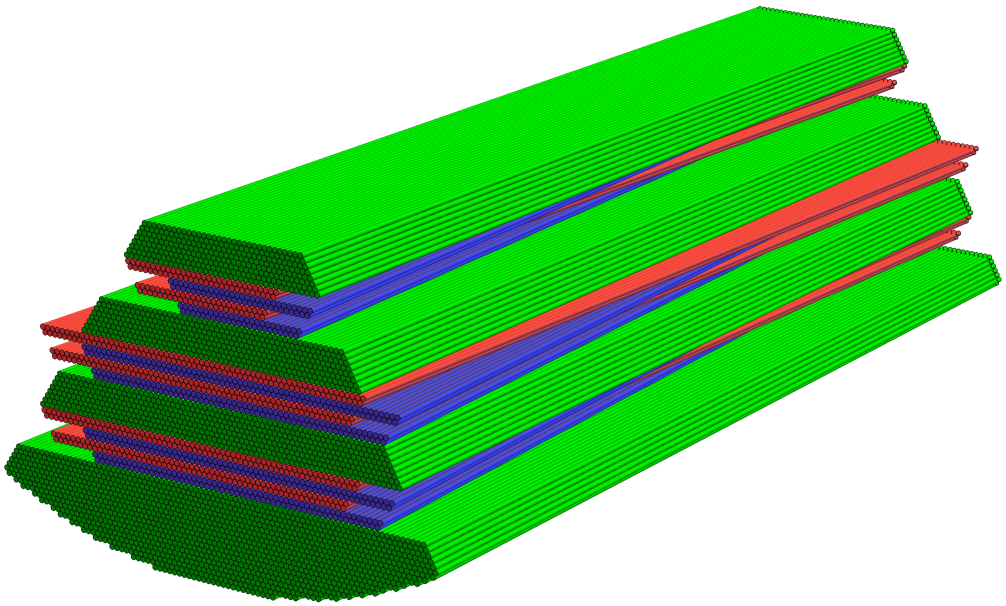
Summary

- A new sextant geometry of the straw tracker has been proposed recently in place of problematic octant geometry.
- Special arrangement of u/v layers in this geometry allows to avoid dead zones at the joints of the modules.
- No additional passive material between modules in sextant geometry.
- It was implemented in SpdRoot in a separate branch `straw-sextant-geometry`.
- Transverse momentum resolution values for sextant and current octant geometries are close.
- Polar angle resolution in sextant geometry is 1.2-1.6 times worser than in current version.

Backup slides

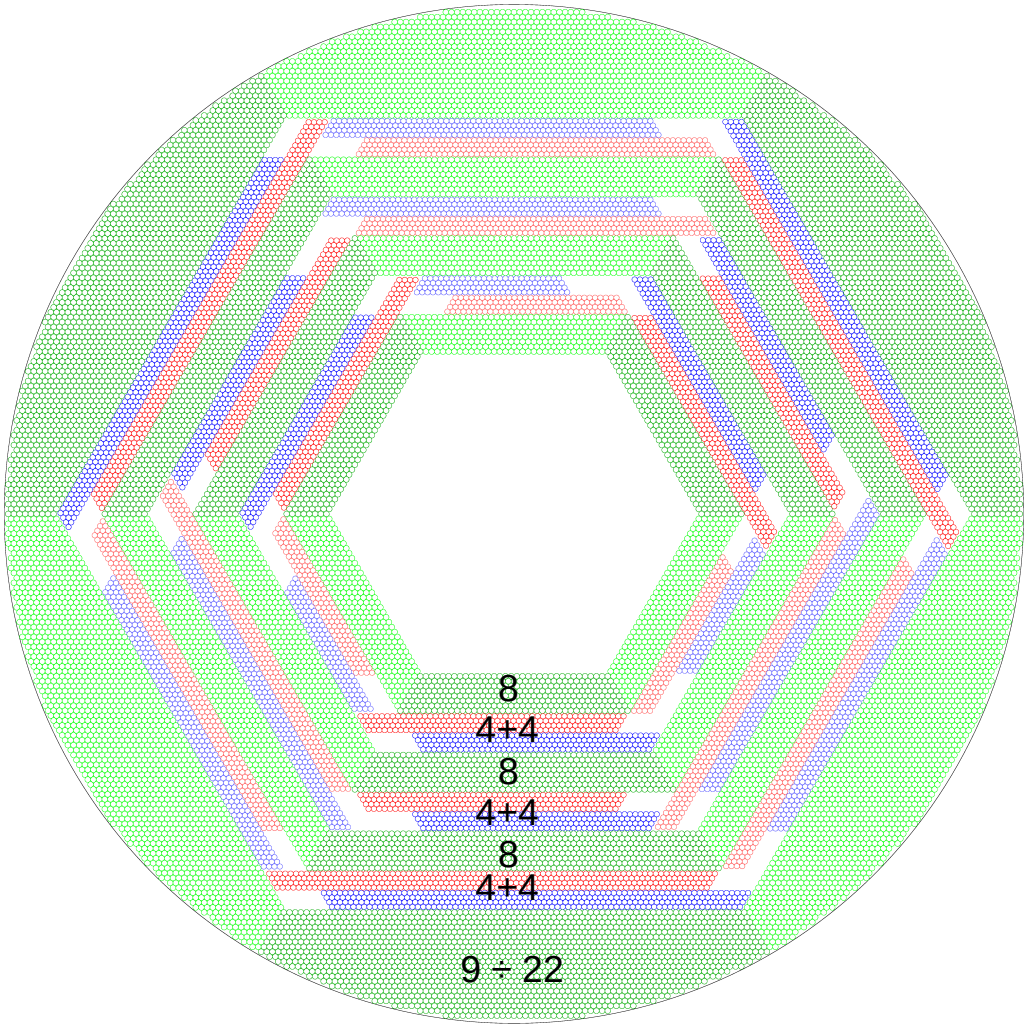
Sextant geometry





Two types of modules

Sextant geometry: modification



Formulas

$$p_T = \sqrt{p_x^2 + p_y^2}$$

$$\frac{\partial p_T}{\partial p_x} = \frac{p_x}{p_T}; \quad \frac{\partial p_T}{\partial p_y} = \frac{p_y}{p_T};$$

$$\sigma_{p_T}^2 = \left(\frac{\partial p_T}{\partial p_x}\right)^2 \sigma_{p_x}^2 + \left(\frac{\partial p_T}{\partial p_y}\right)^2 \sigma_{p_y}^2 + 2\frac{\partial p_T}{\partial p_x}\frac{\partial p_T}{\partial p_y} cov(p_x, p_y) = \left(\frac{p_x}{p_T}\right)^2 \sigma_{p_x}^2 + \left(\frac{p_y}{p_T}\right)^2 \sigma_{p_y}^2 + 2\frac{p_x p_y}{p_T^2} cov(p_x, p_y)$$

$$\theta = \arccos\frac{p_z}{p} = \arccos\left(\frac{p_z}{\sqrt{p_x^2 + p_y^2 + p_z^2}}\right)$$

$$\frac{\partial \theta}{\partial p_x} = \frac{p_x p_z}{p^2 p_T}; \quad \frac{\partial \theta}{\partial p_y} = \frac{p_y p_z}{p^2 p_T}; \quad \frac{\partial \theta}{\partial p_z} = -\frac{p_T}{p^2};$$

$$\sigma_\theta^2 = \frac{1}{p^4}\left[\frac{p_x^2 p_z^2}{p_T^2}\sigma_{p_x}^2 + \frac{p_y^2 p_z^2}{p_T^2}\sigma_{p_y}^2 + p_T^2\sigma_{p_z}^2 + 2\frac{p_x p_y p_z^2}{p_T^2} cov(p_x, p_y) - 2p_x p_z cov(p_x, p_z) - 2p_y p_z cov(p_y, p_z)\right]$$

$$\phi = \arctan\frac{p_y}{p_x}$$

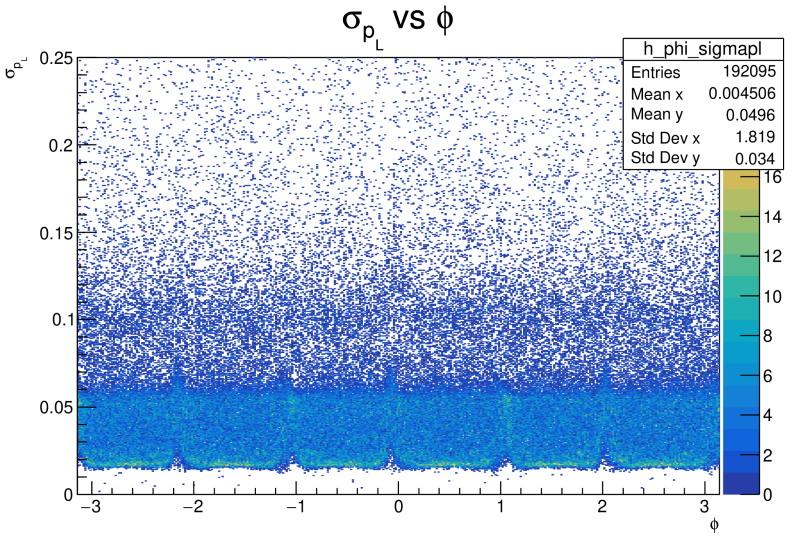
$$\frac{\partial \phi}{\partial p_x} = -\frac{p_y}{p_T^2}; \quad \frac{\partial \phi}{\partial p_y} = \frac{p_x}{p_T^2};$$

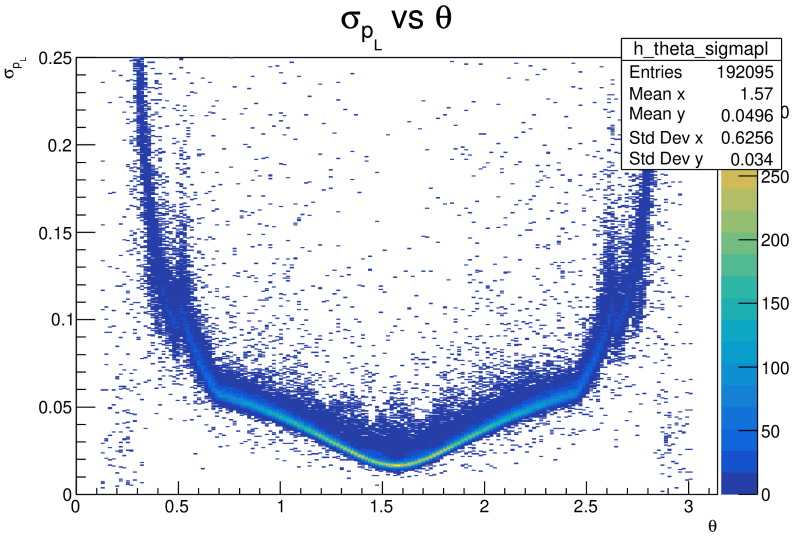
$$\sigma_\phi^2 = \frac{1}{p_T^4}\left[p_y^2\sigma_{p_x}^2 + p_x^2\sigma_{p_y}^2 - 2p_x p_y cov(p_x, p_y)\right]$$

MM+STRAW, p = 5 GeV/c: longitudinal momentum resolution

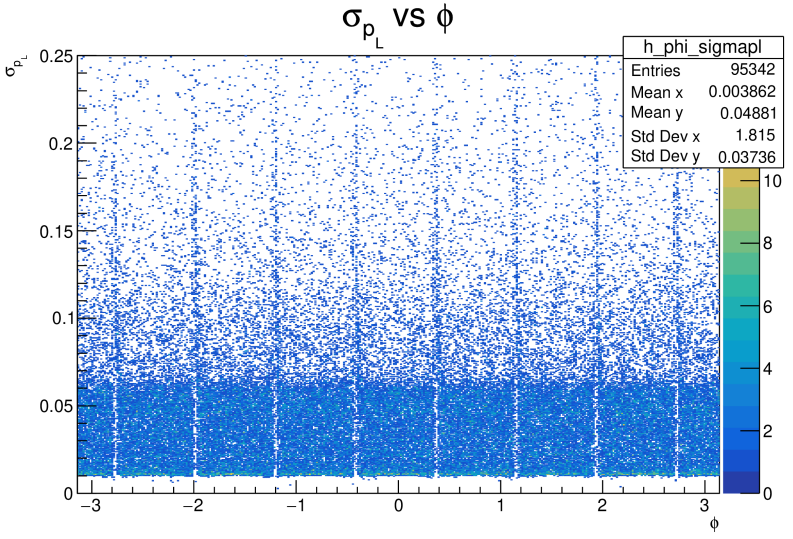
σ_{p_L}:

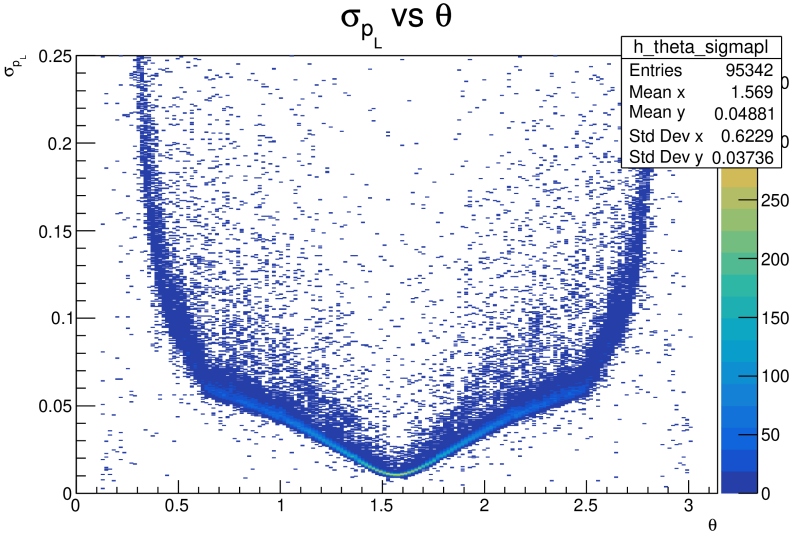
sextant version





octant version

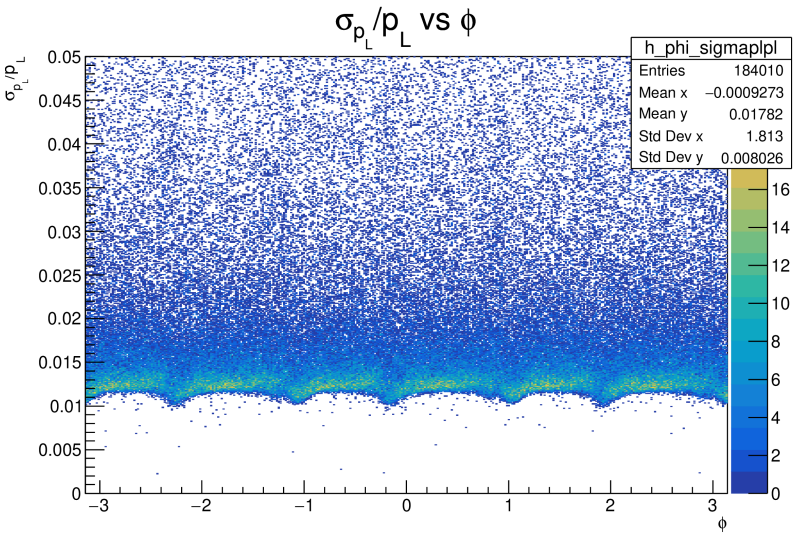


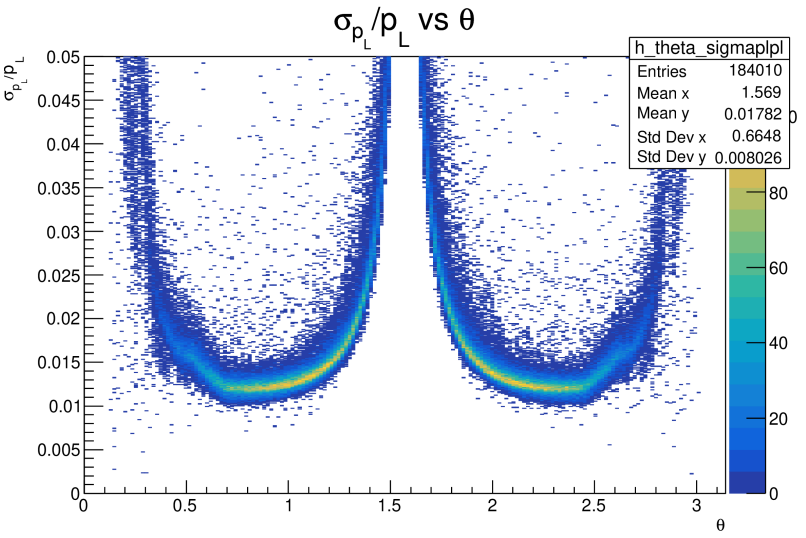


MM+STRAW, p = 1 GeV/c: longitudinal momentum resolution

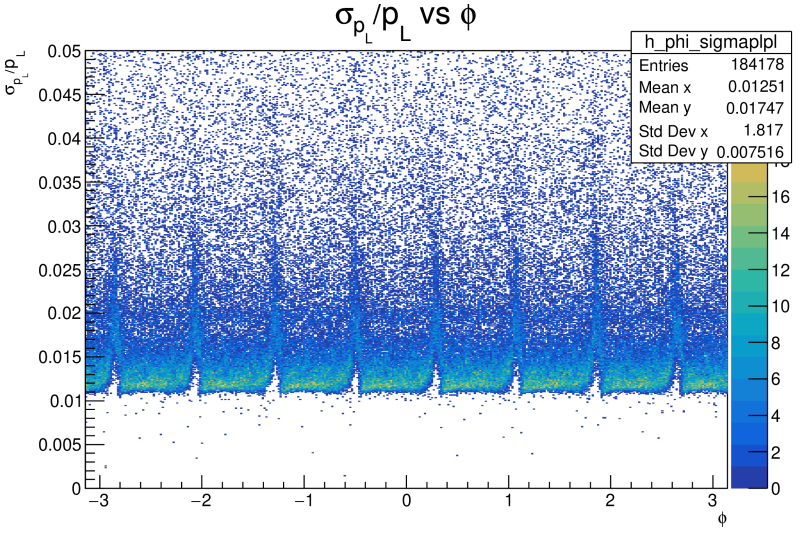
$$\frac{\sigma_{p_L}}{p_L}:$$

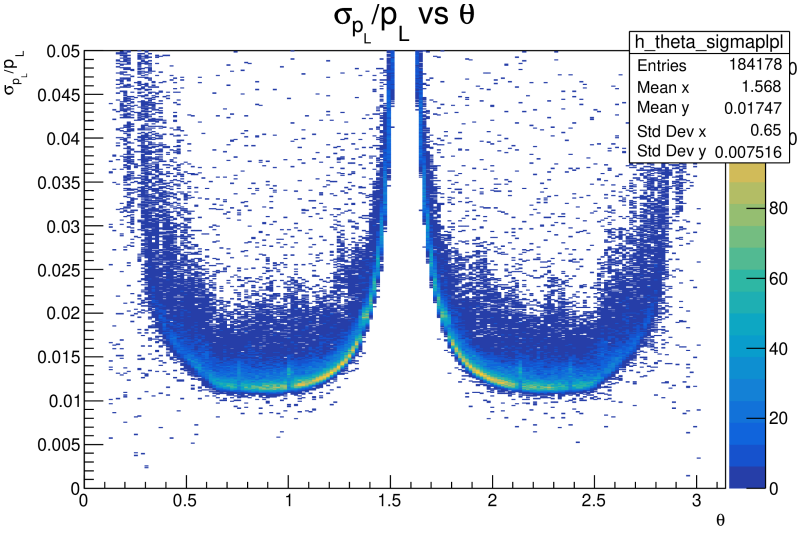
sextant version





octant version

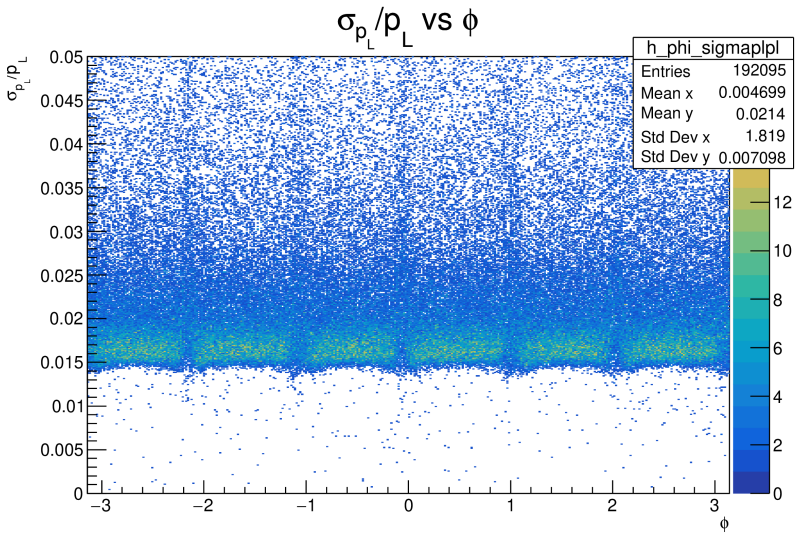


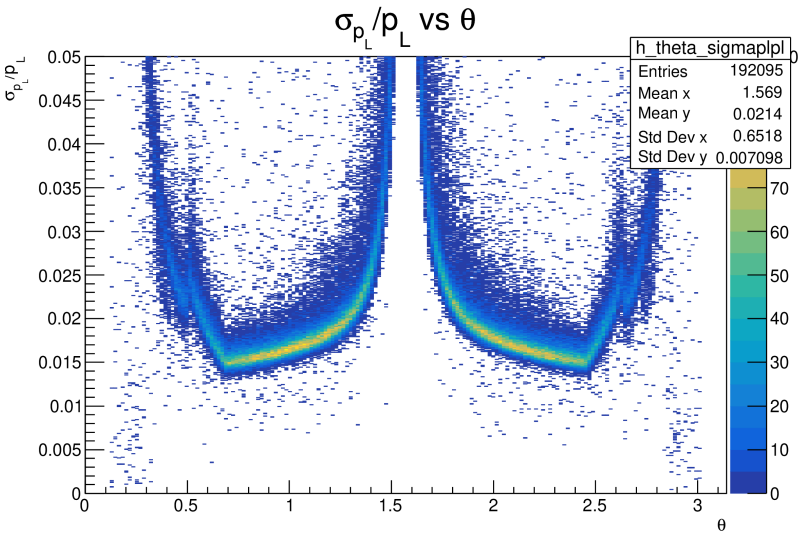


MM+STRAW, p = 5 GeV/c: longitudinal momentum resolution

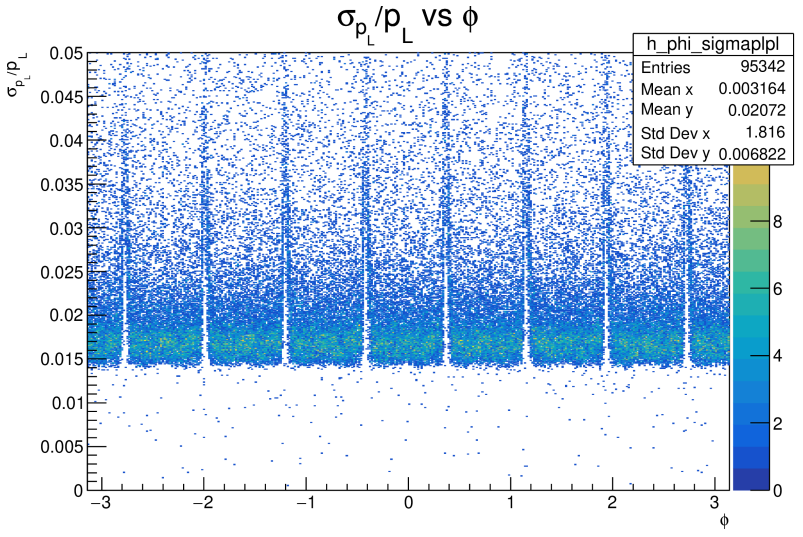
$\frac{\sigma_{p_L}}{p_L}$:

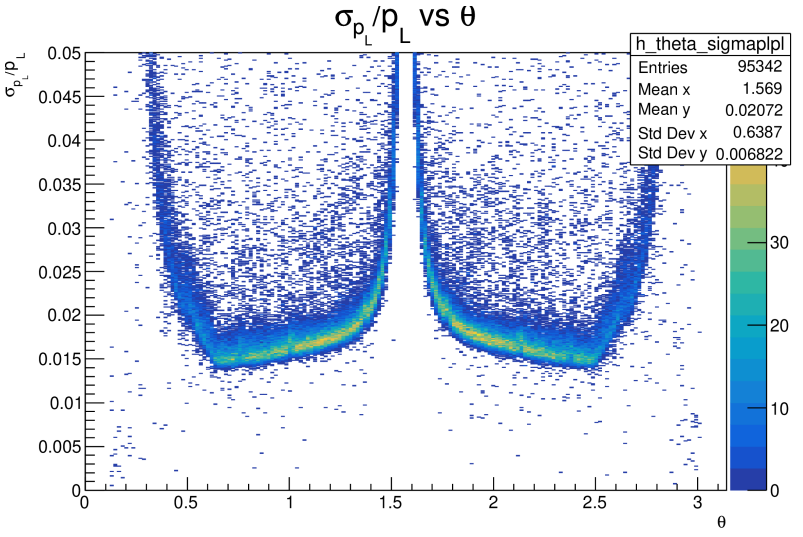
sextant version





octant version





Number of hits in U/V layers