

# Development of an event generator for antihyperon-hyperon pair production in antiproton-proton collisions

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A 10hp Project Presentation at Group Meeting

1<sup>st</sup> March 2022



UPPSALA  
UNIVERSITET

Uppsala University

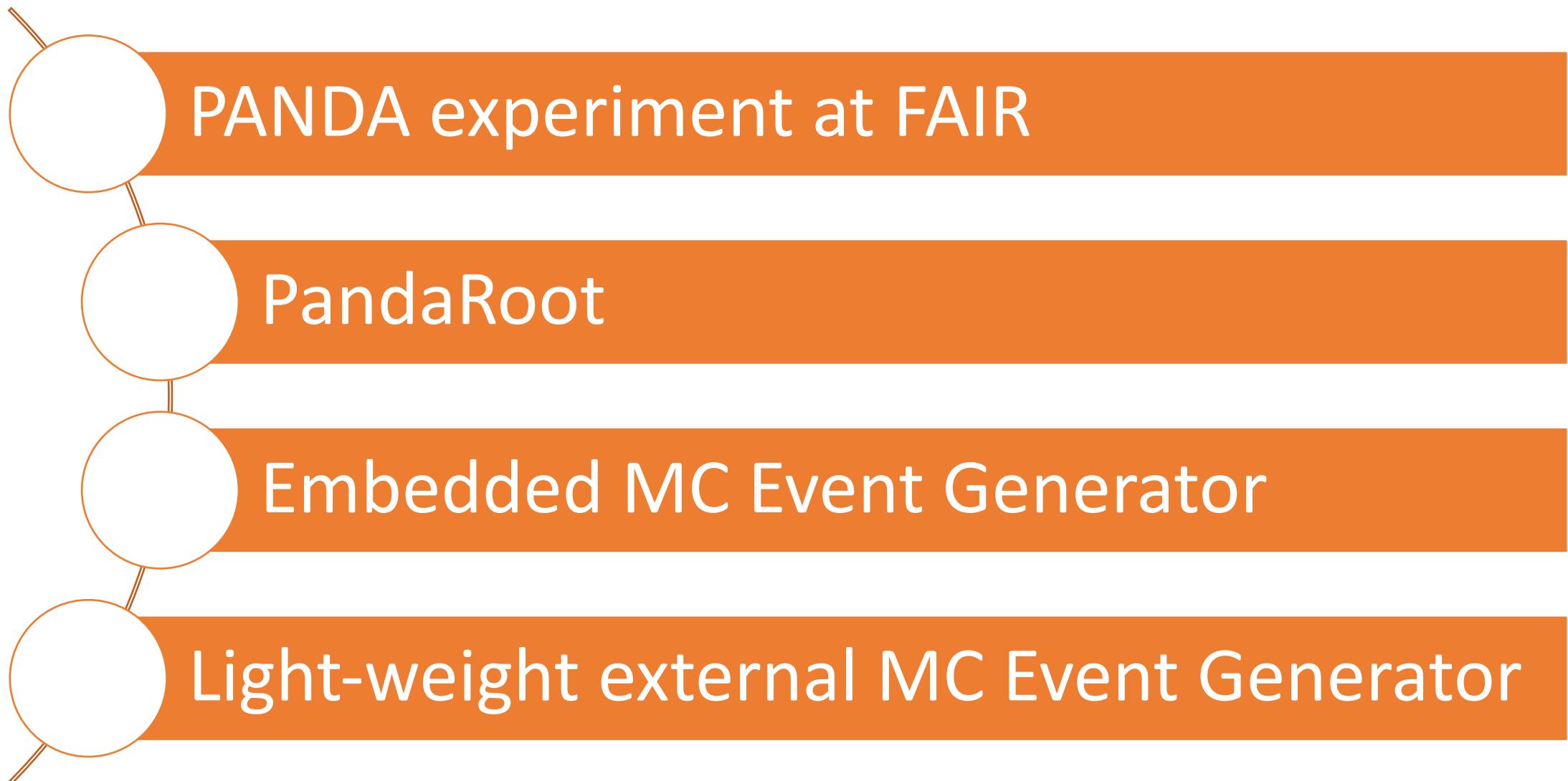
Presenter: Vitor José Shen

Supervisor: Michael Papenbrock

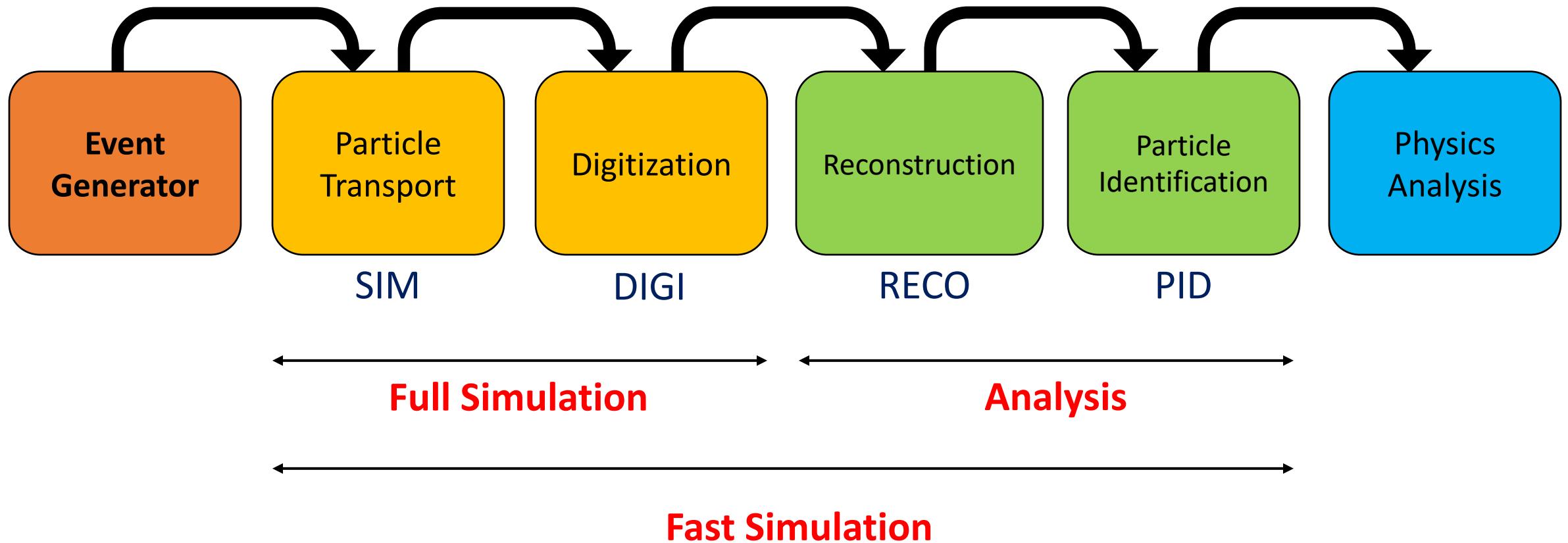
# Outline

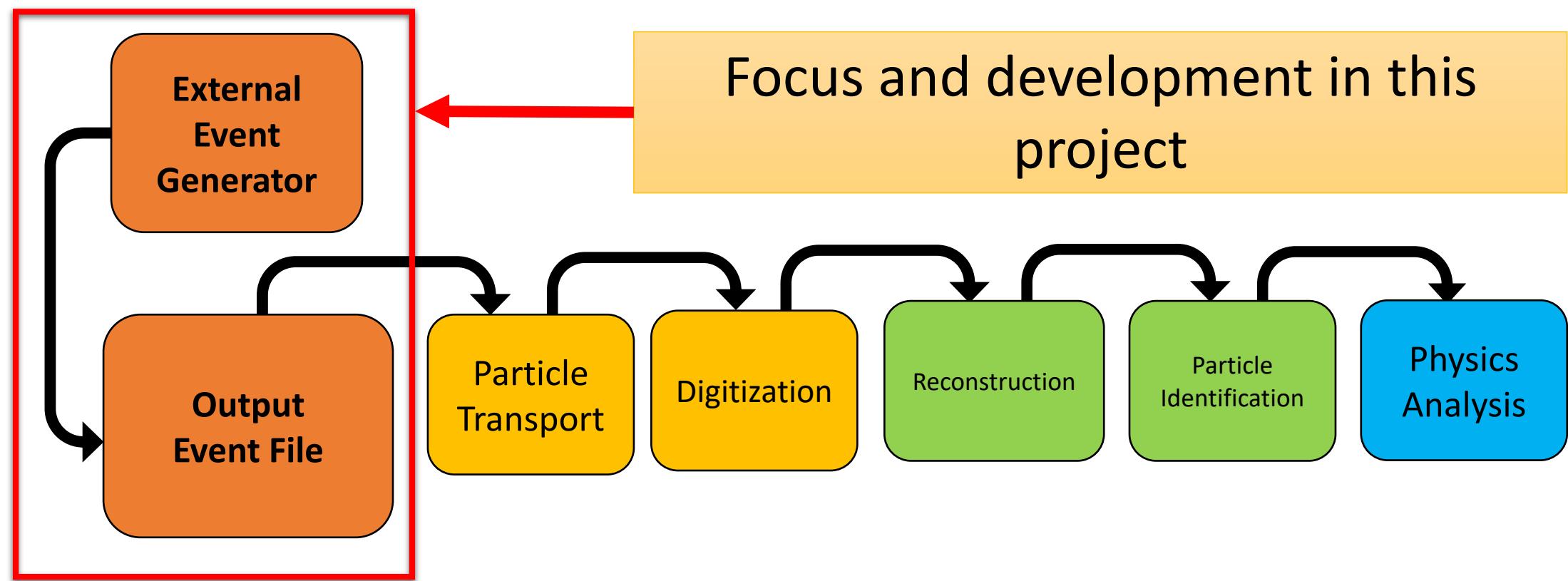
- Introduction p.2
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# Introduction

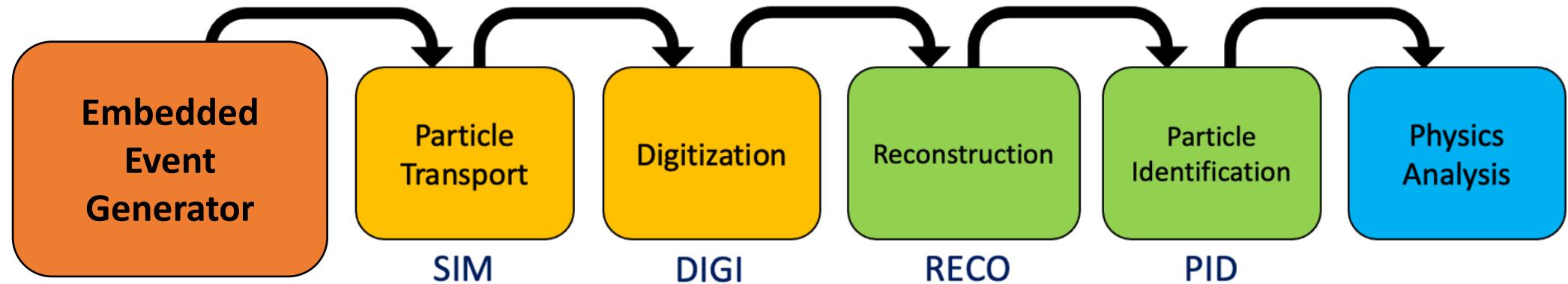


# Main Framework of PandaRoot



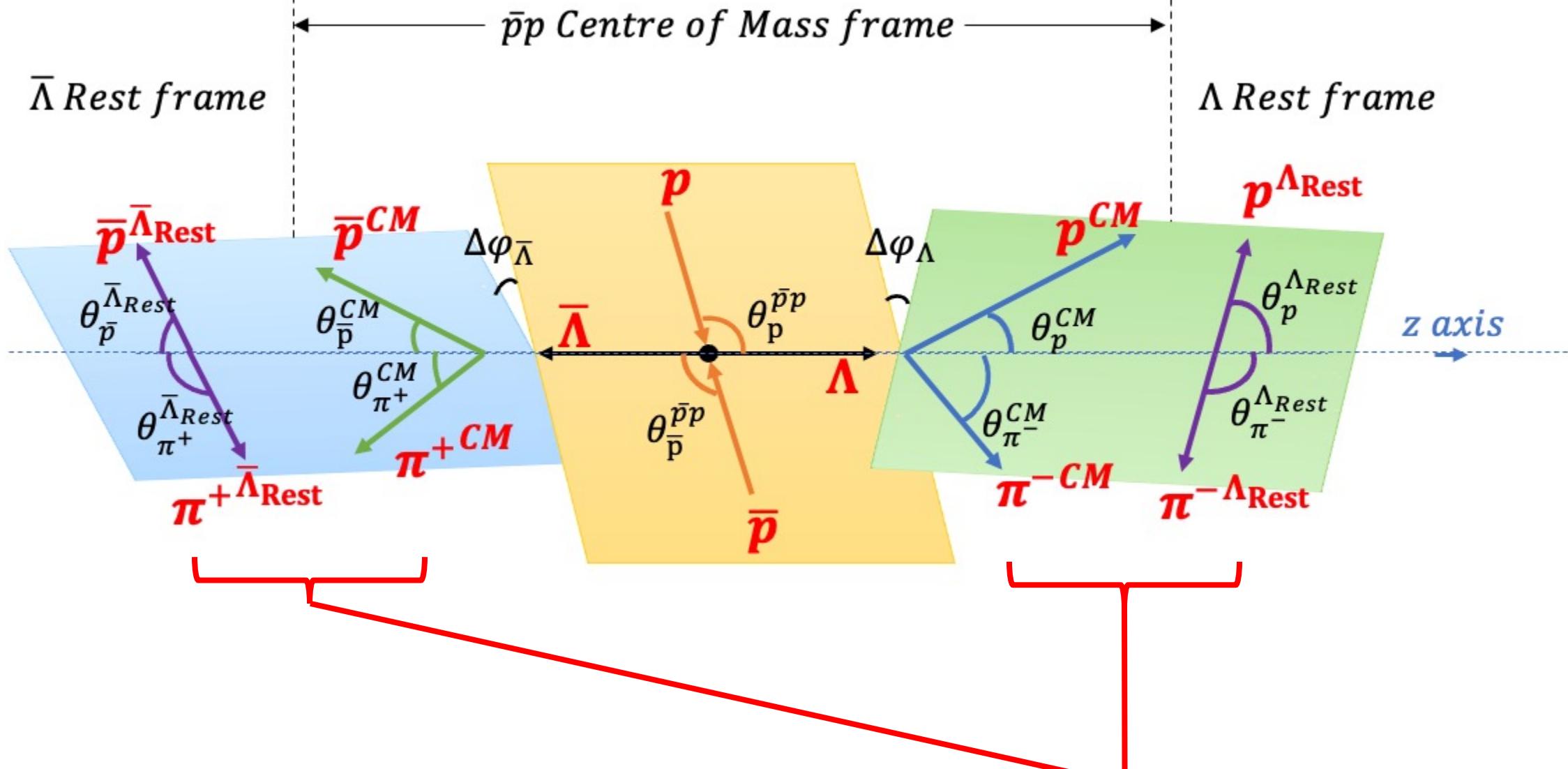


VS.



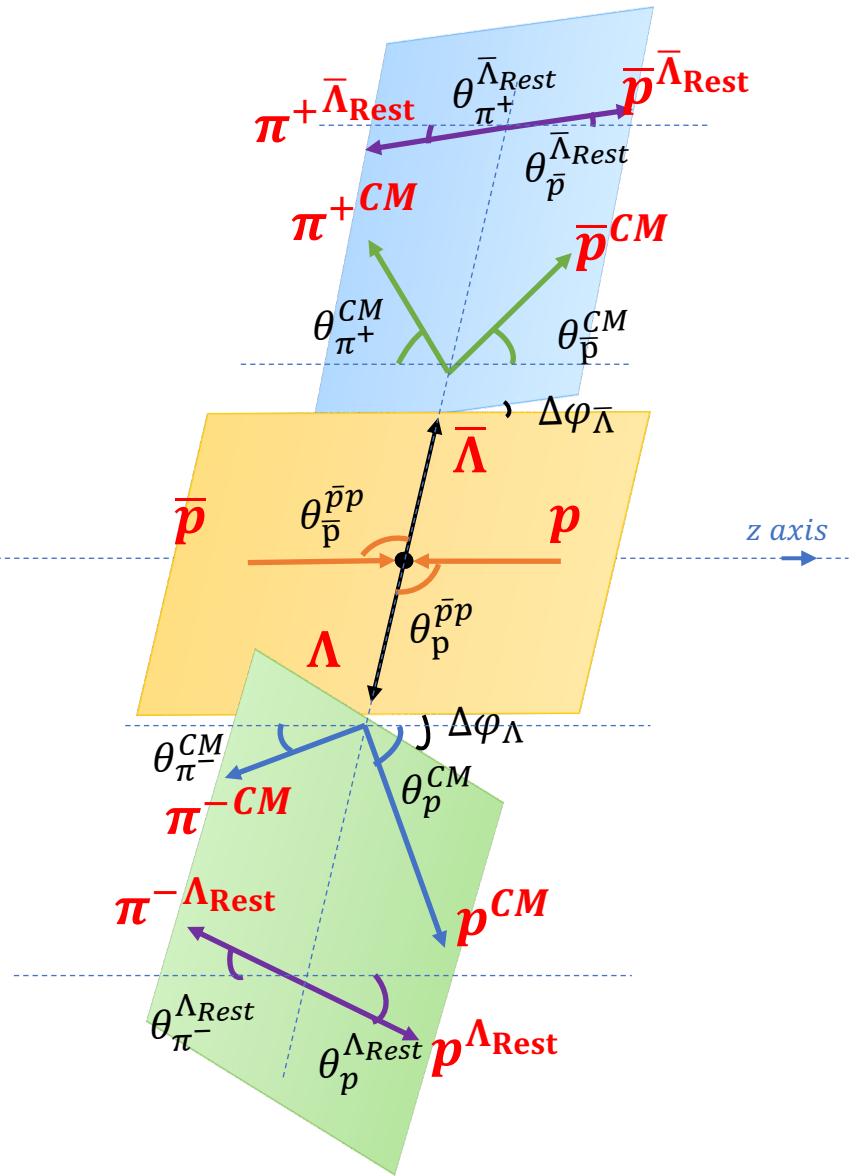
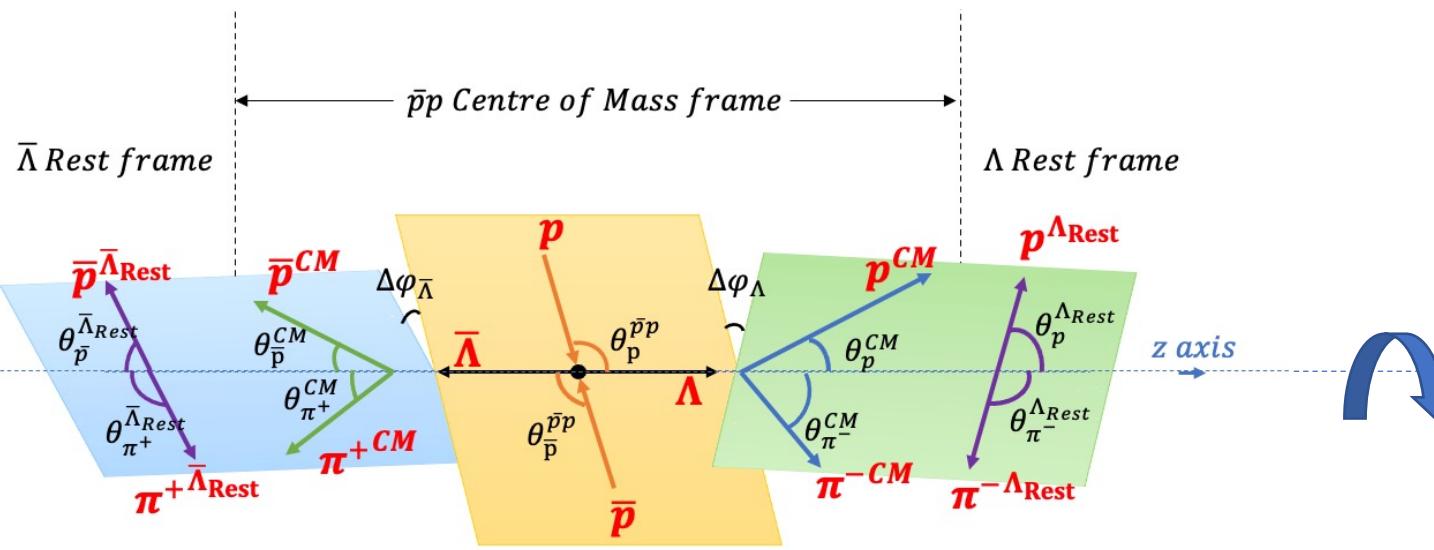
# Kinematics

Methedology



Different reference frames and Boost

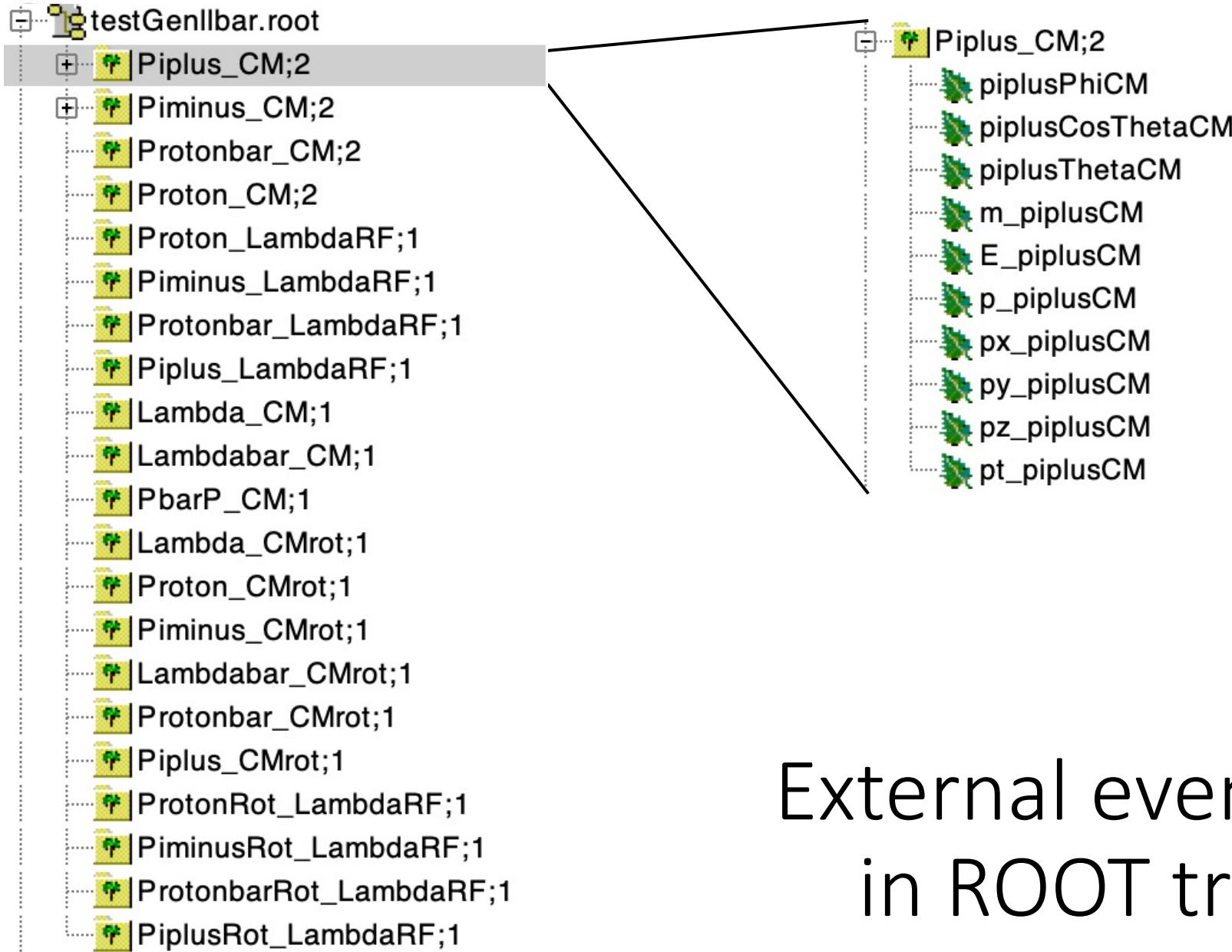
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# Rotation

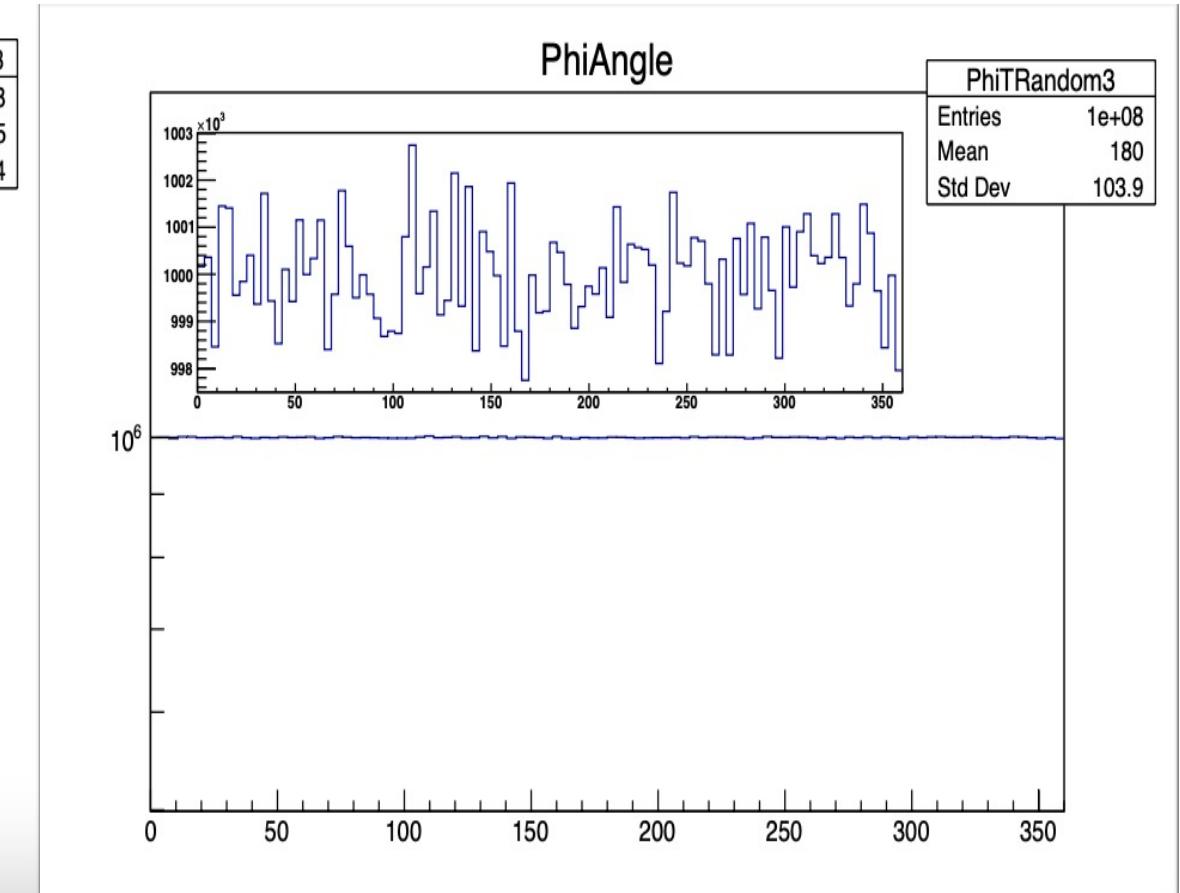
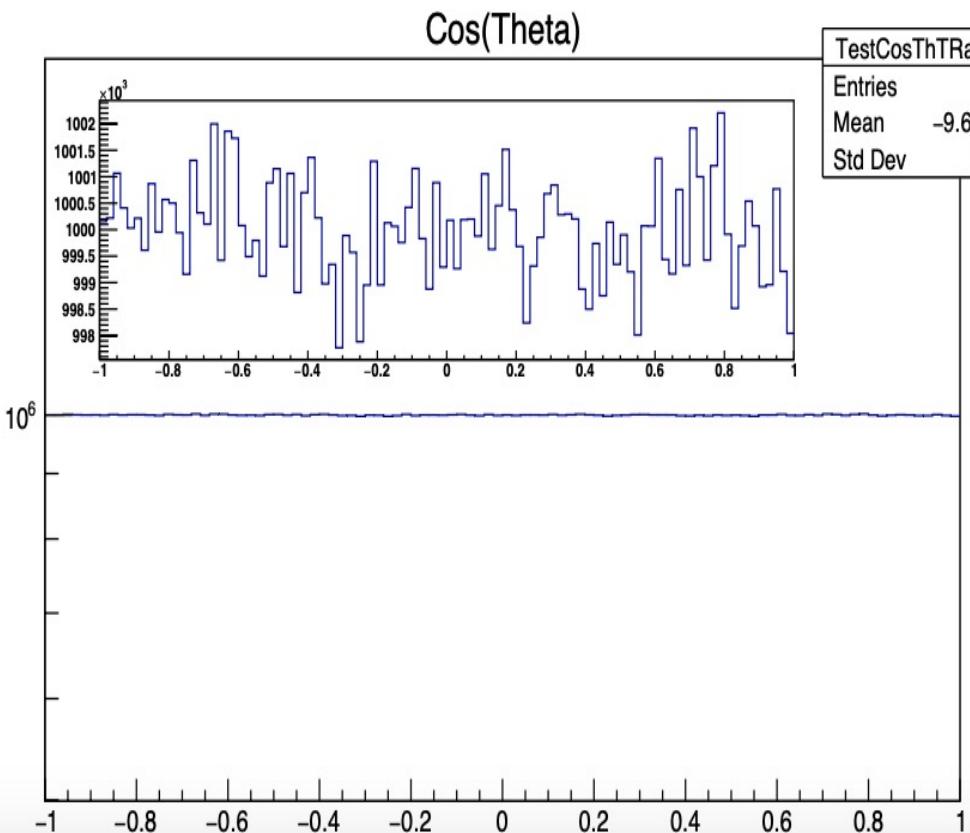
# The developing of an external Event Generator

The brief introduction of the developing framework  
and the testing results of angular distribution

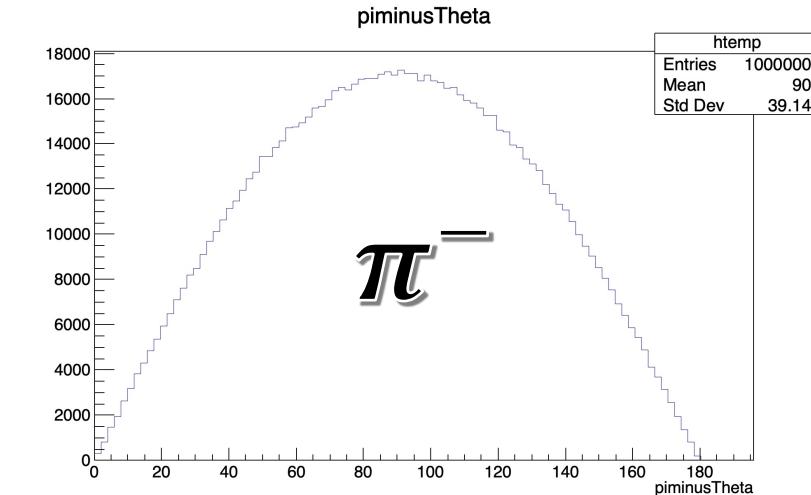
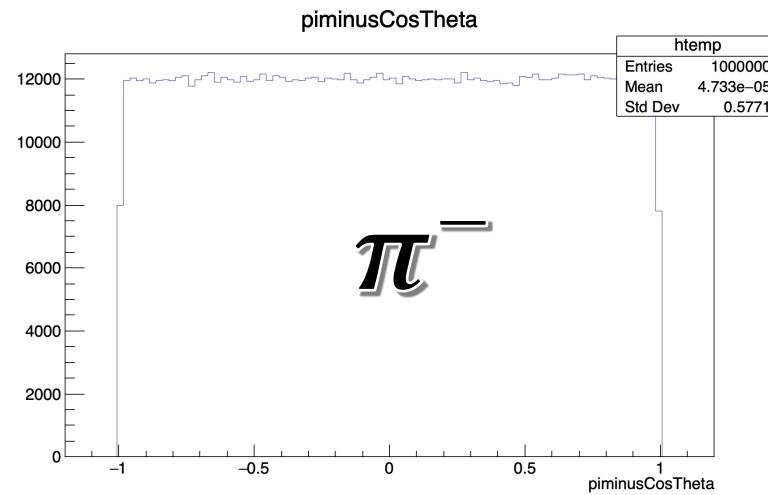
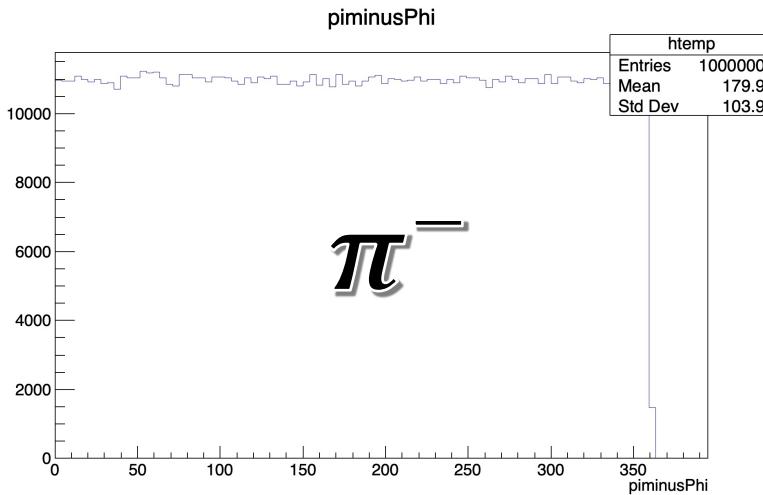
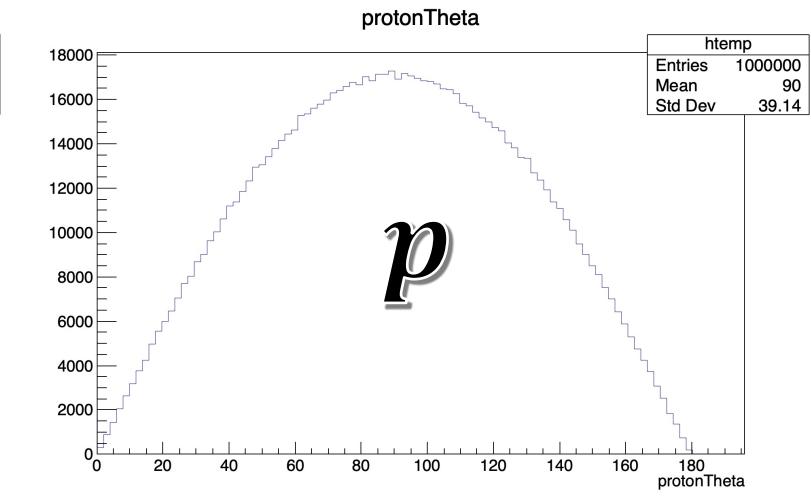
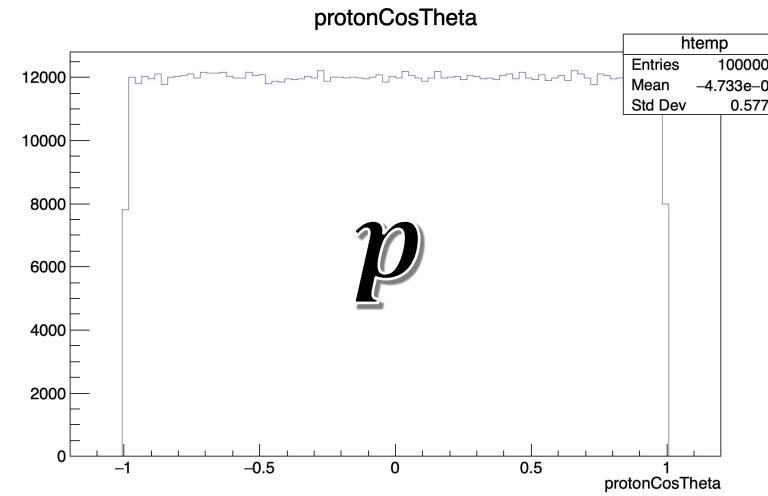
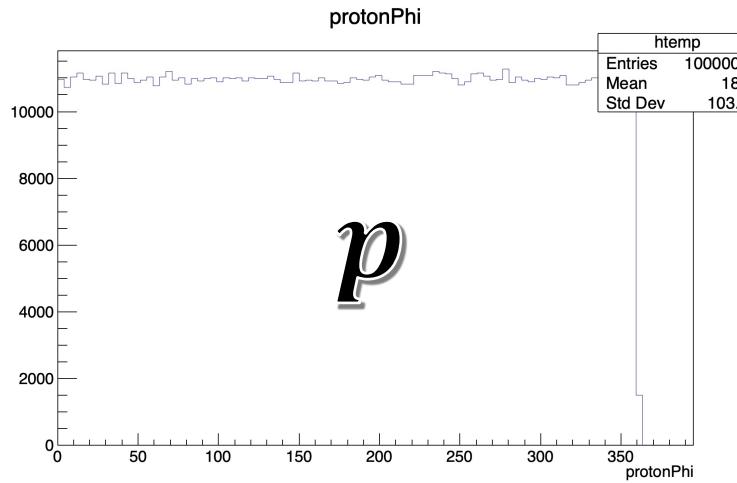


External event generator  
in ROOT tree format

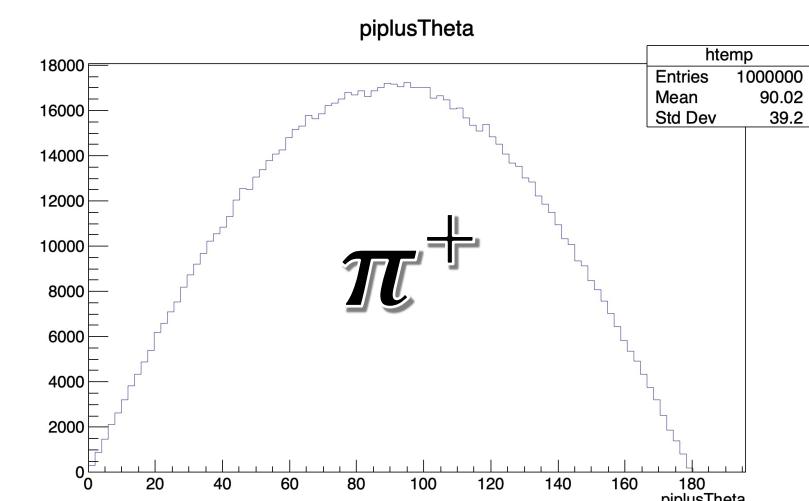
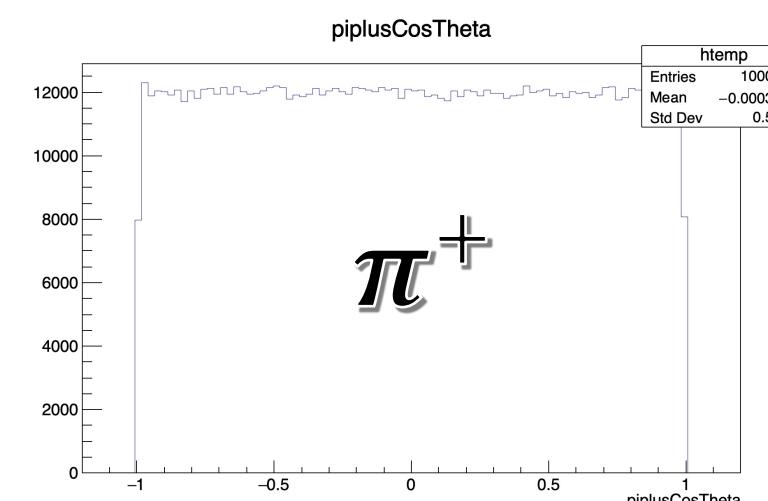
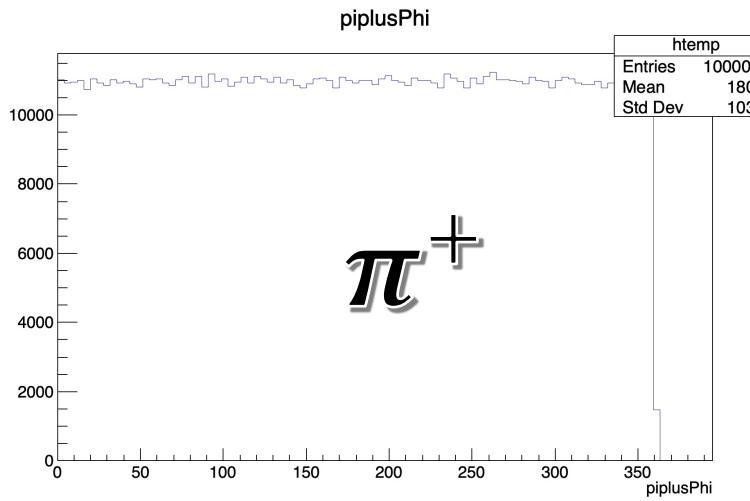
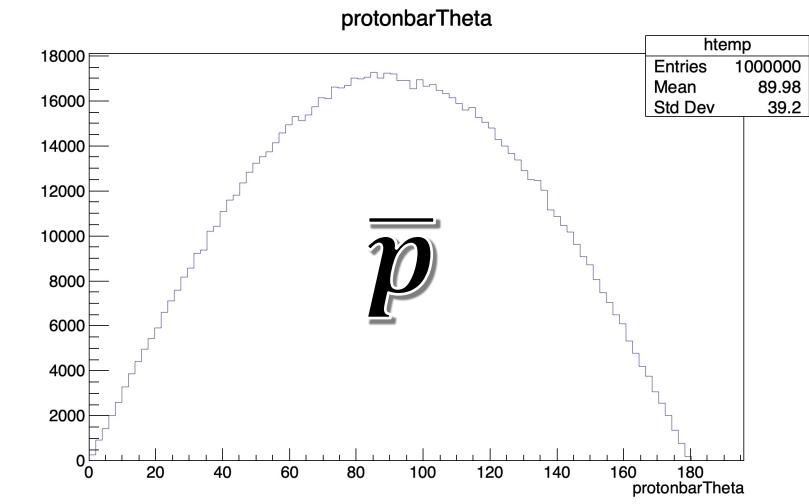
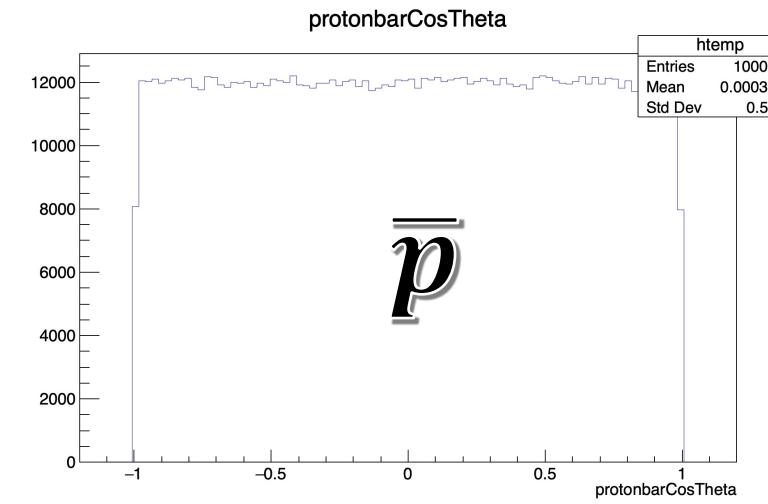
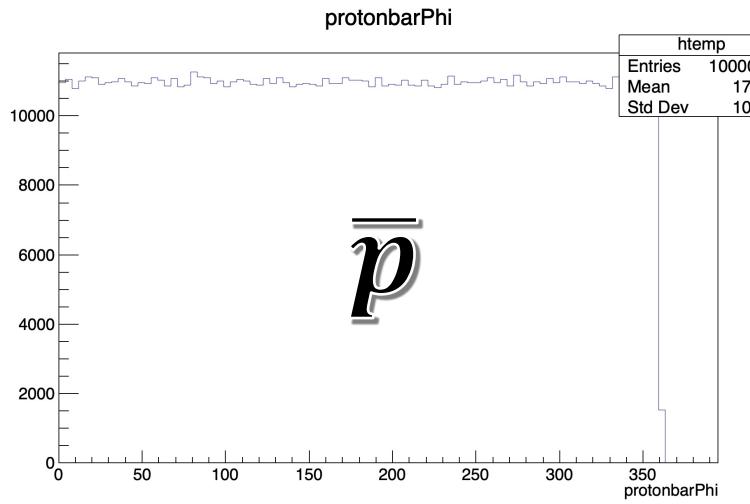
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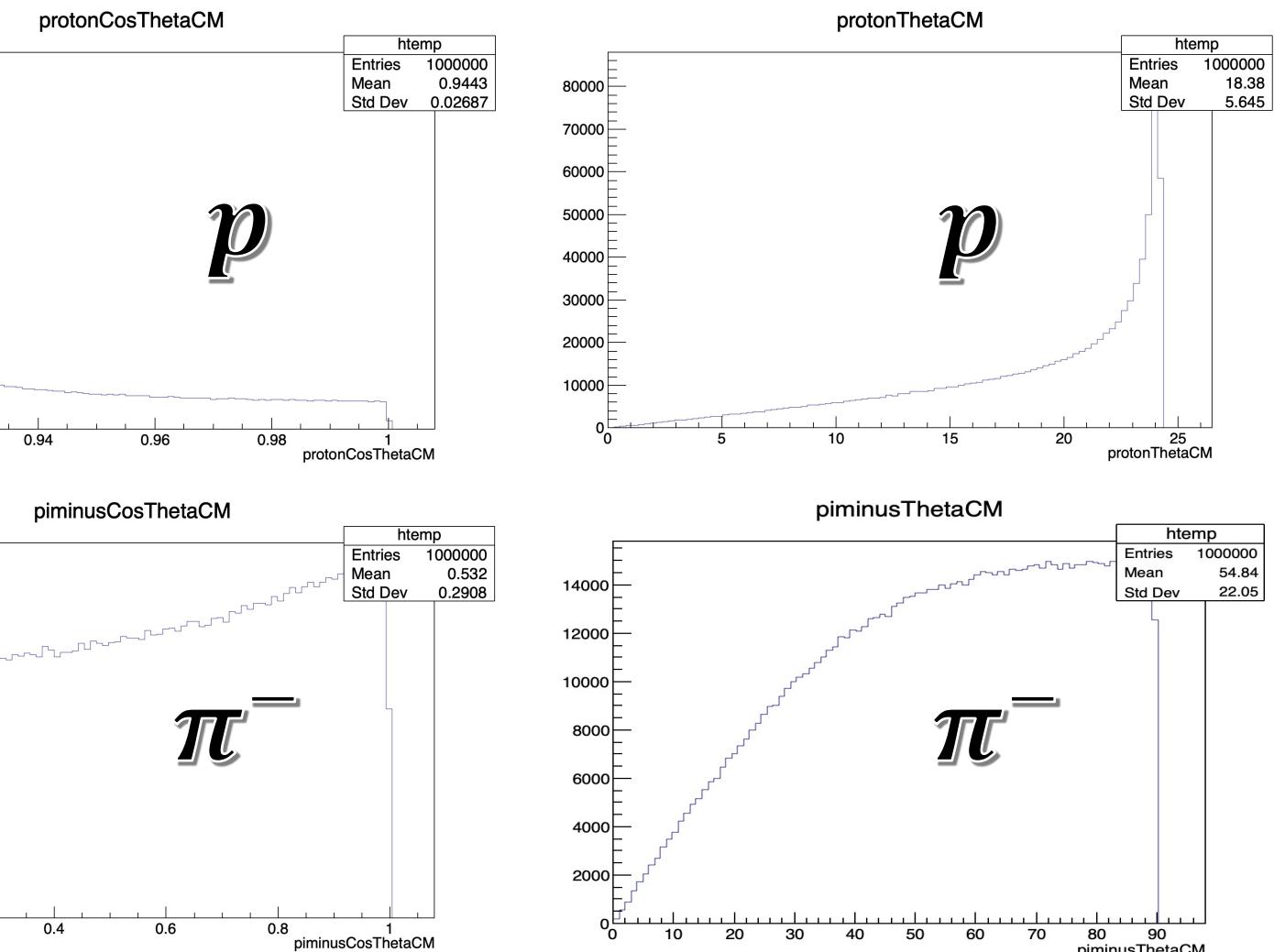
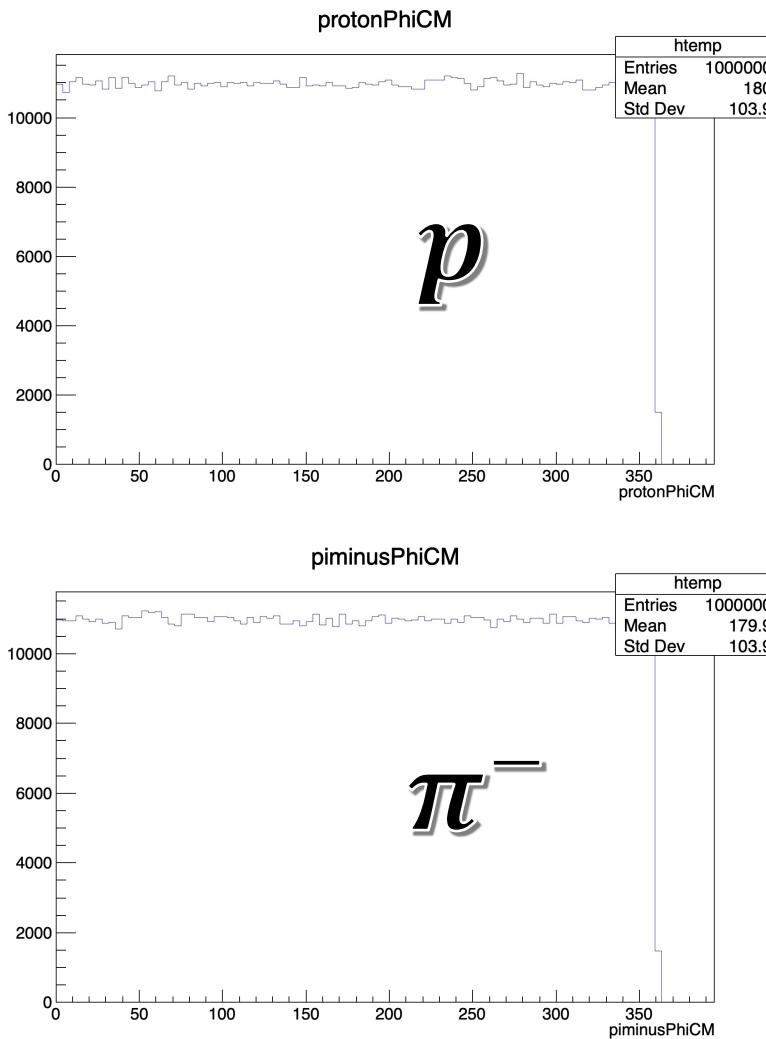
# $\Lambda$ rest frame



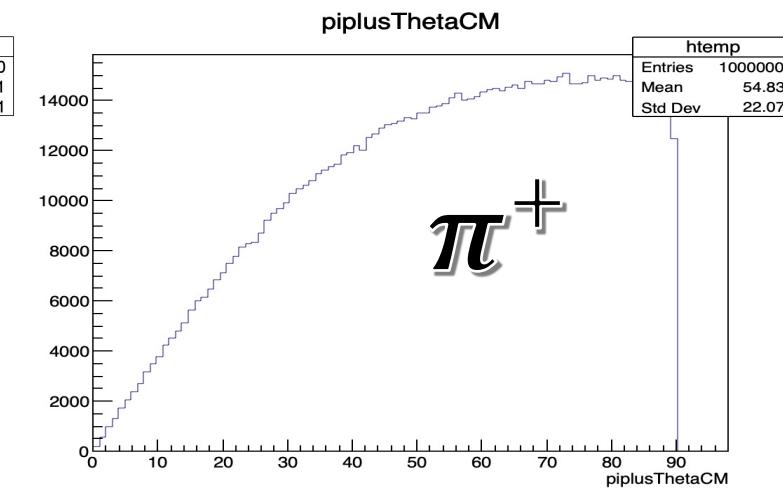
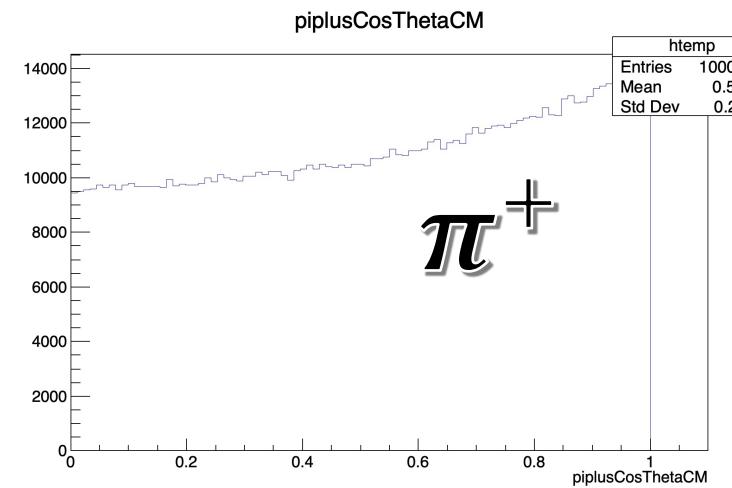
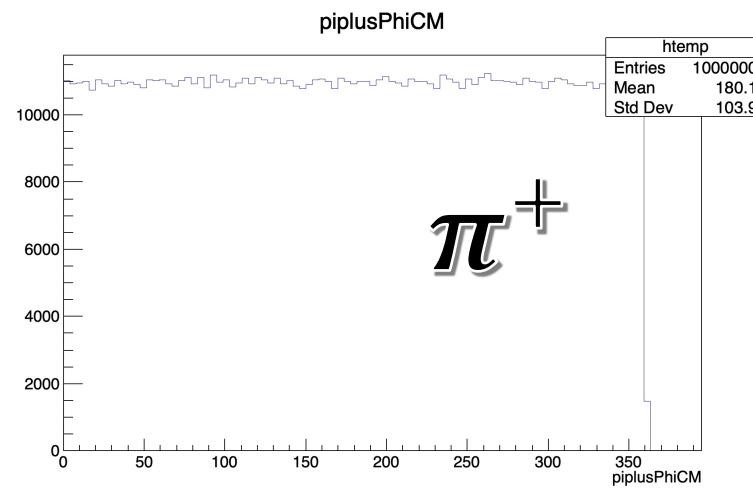
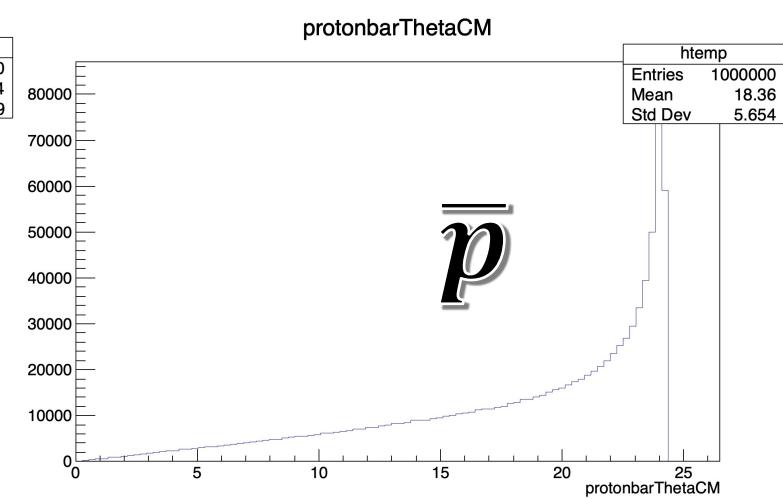
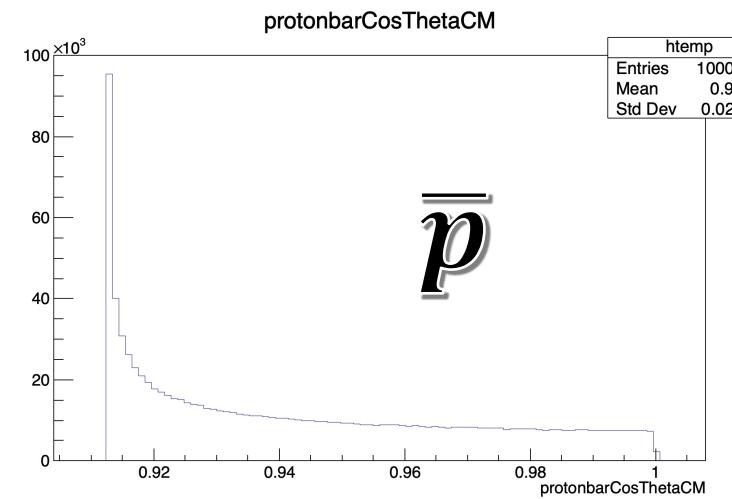
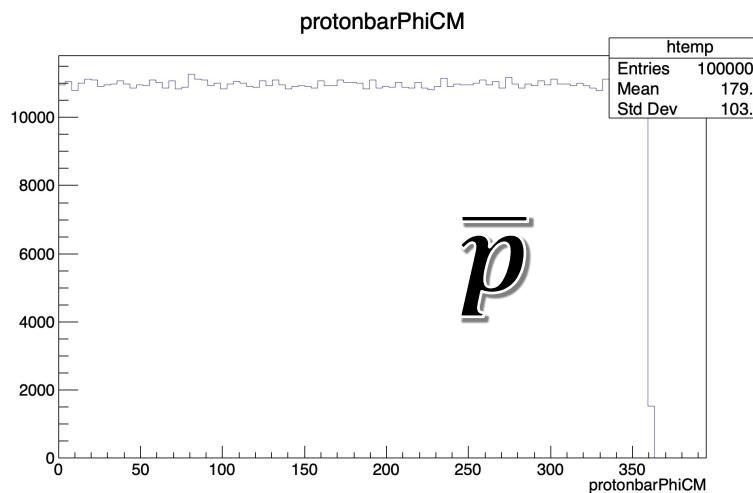
# $\bar{\Lambda}$ rest frame



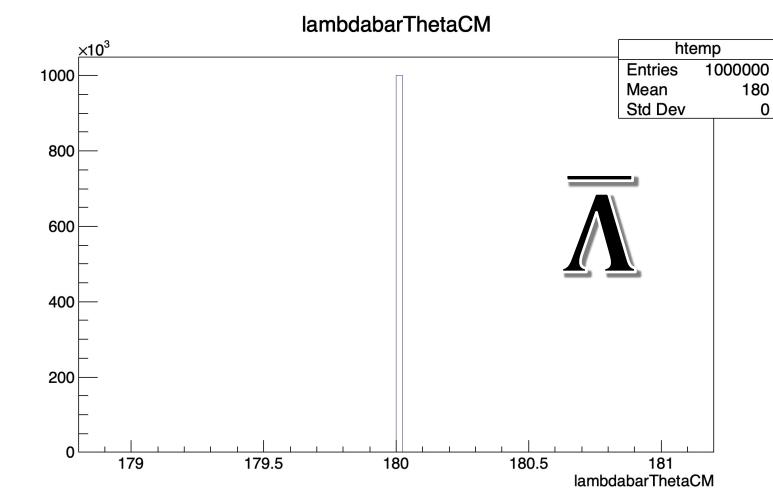
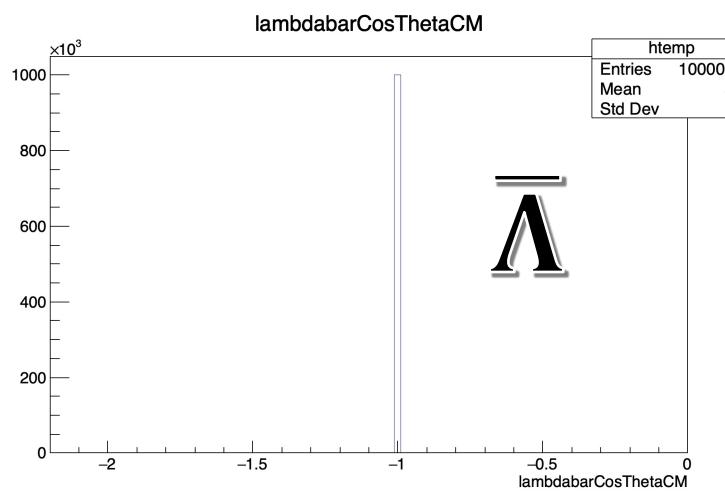
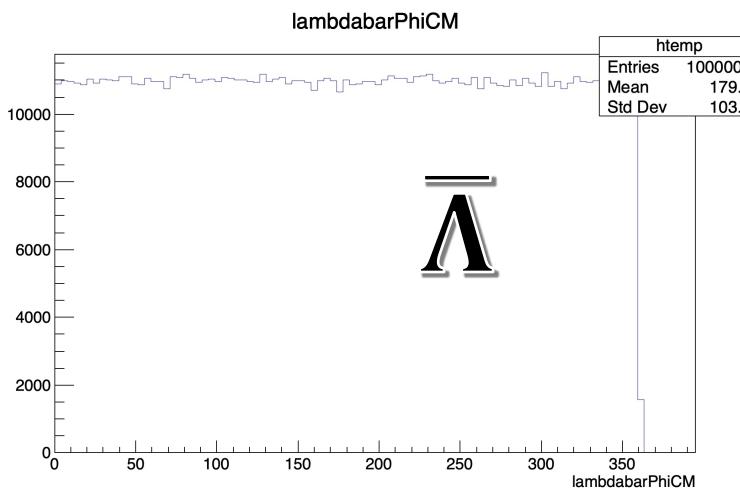
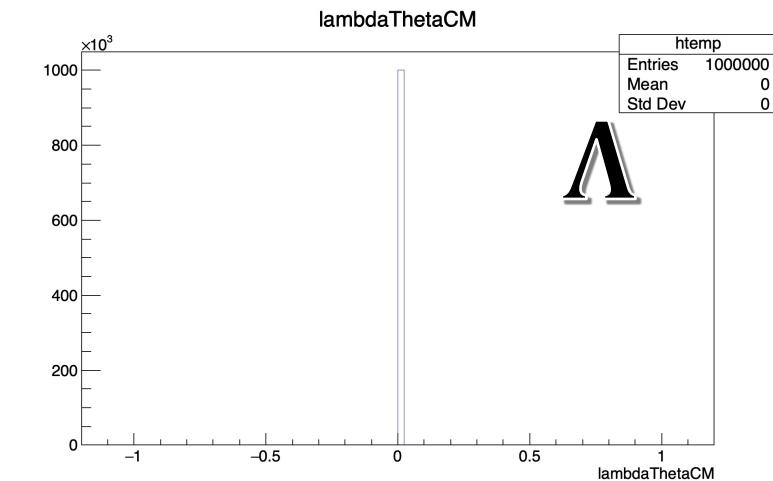
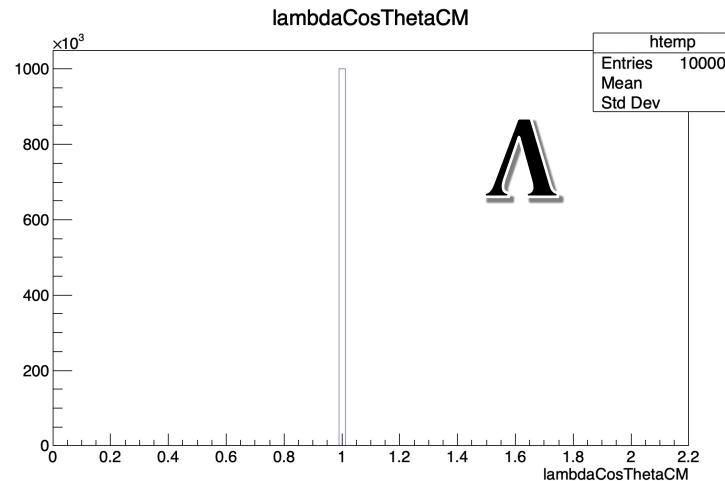
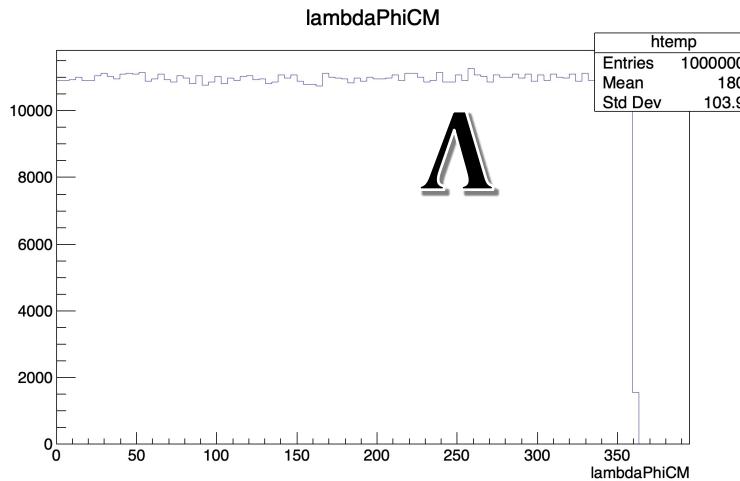
# $\bar{p}p$ CM frame



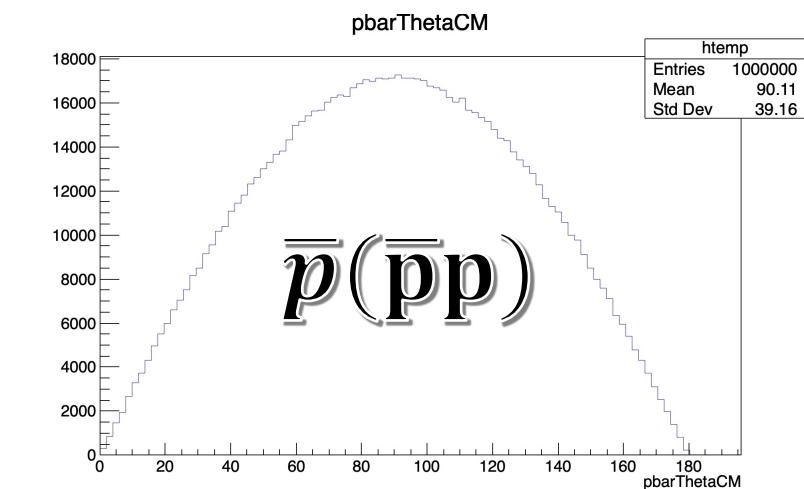
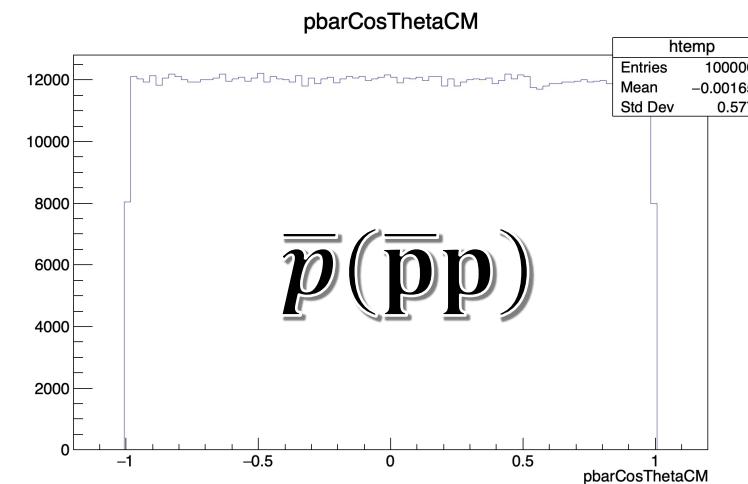
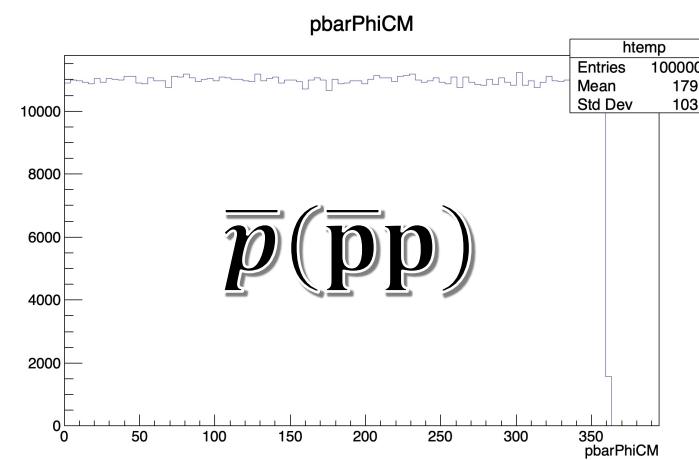
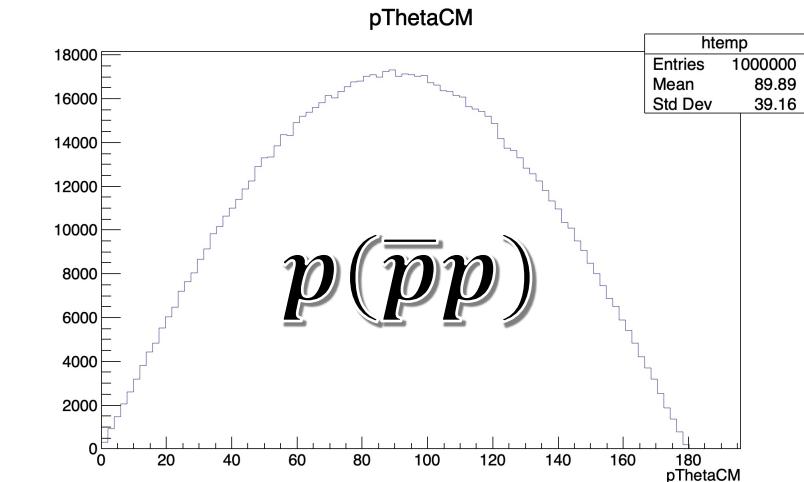
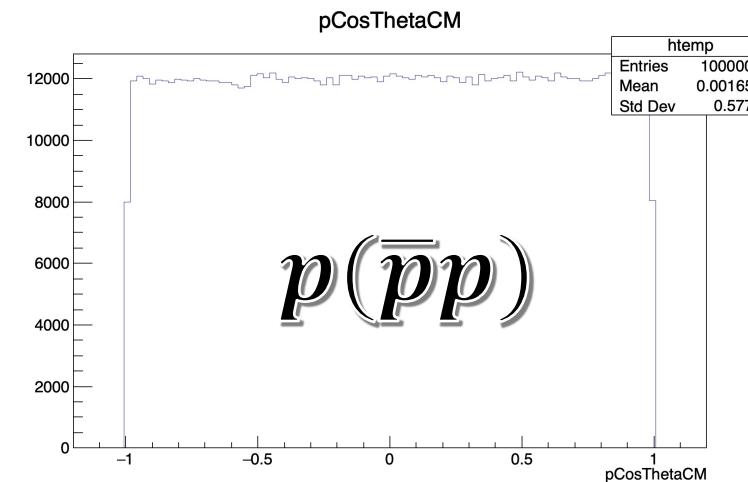
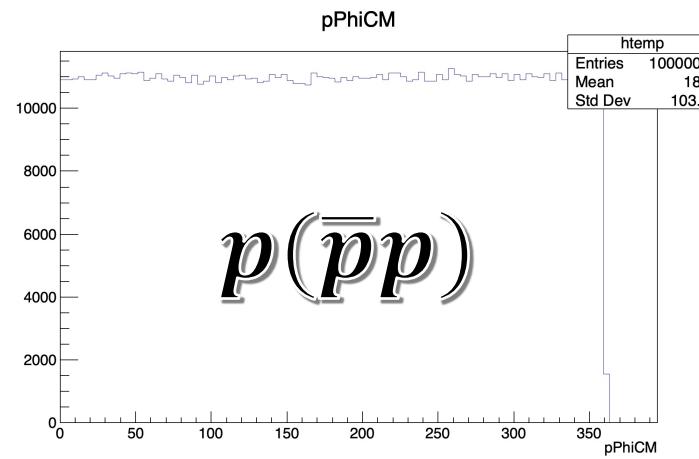
# $\bar{p}p$ CM frame



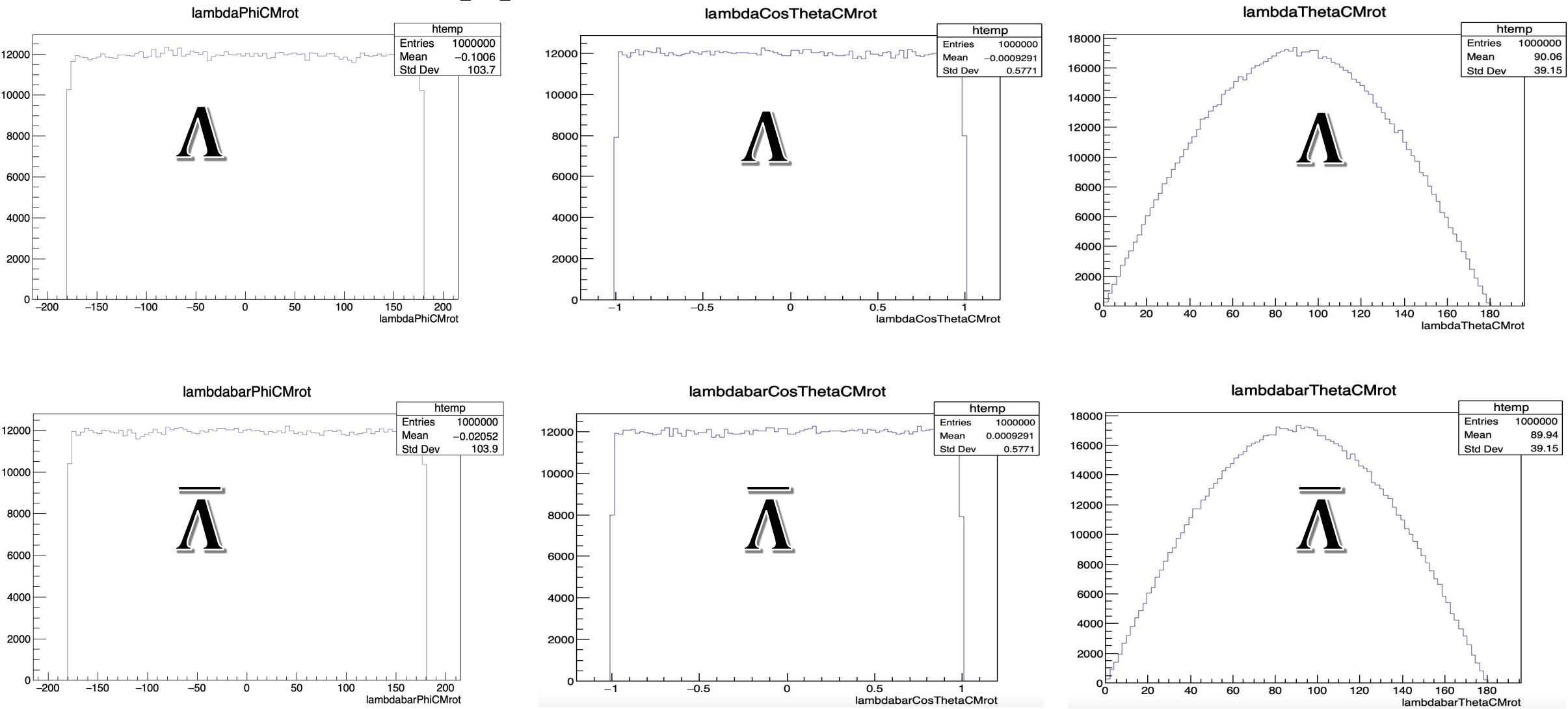
# $\bar{p}p$ CM frame



# $\bar{p}p$ CM frame

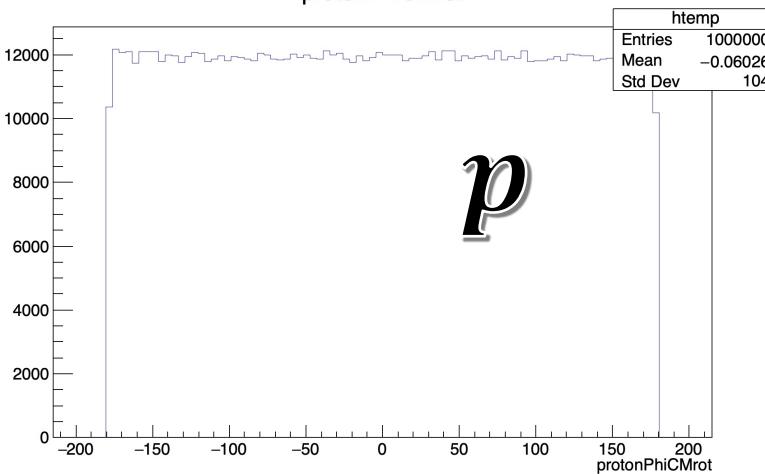


# $\bar{p}p$ CM frame (Rotation)

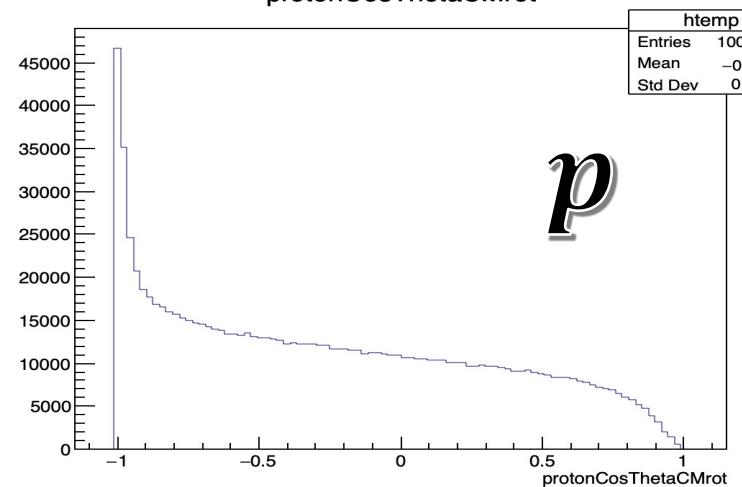


# $\bar{p}p$ CM frame (Rotation)

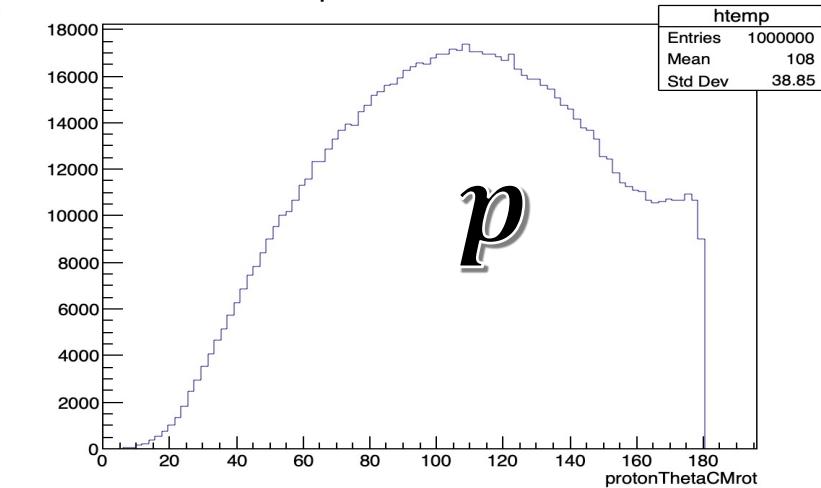
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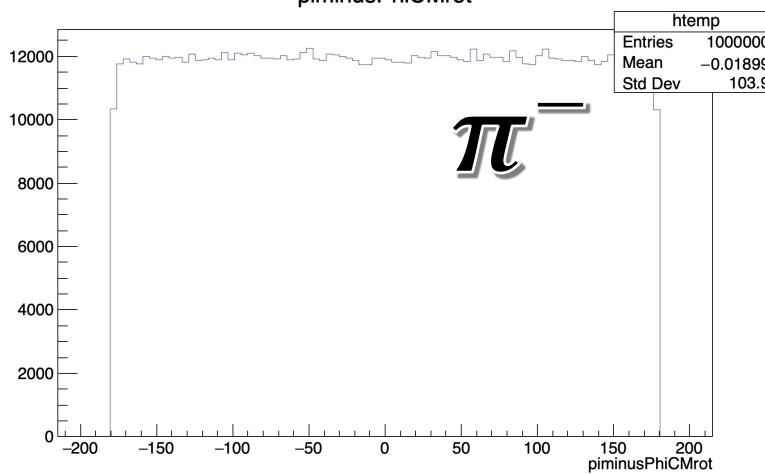
protonCosThetaCMrot



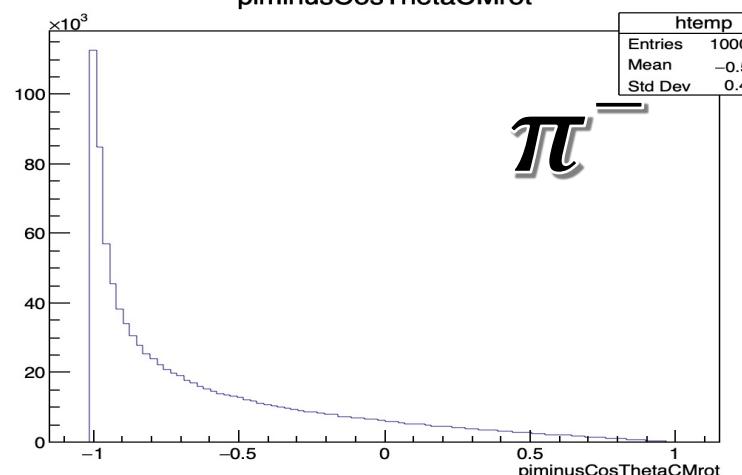
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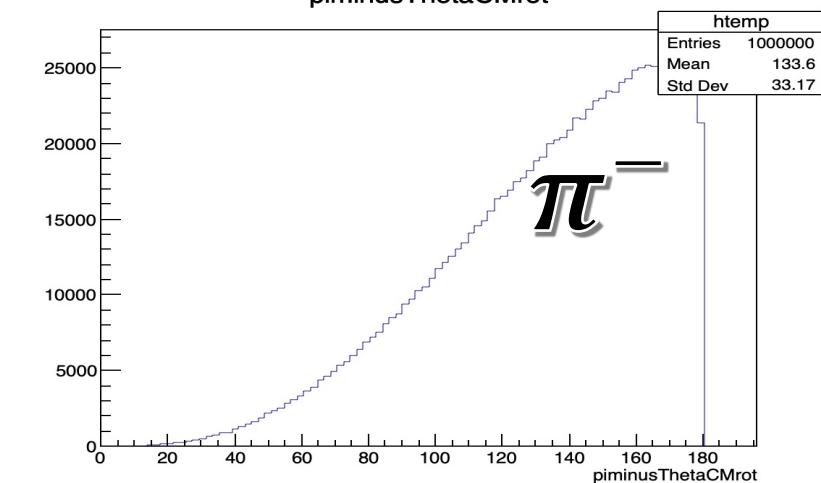
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piminusCosThetaCMrot

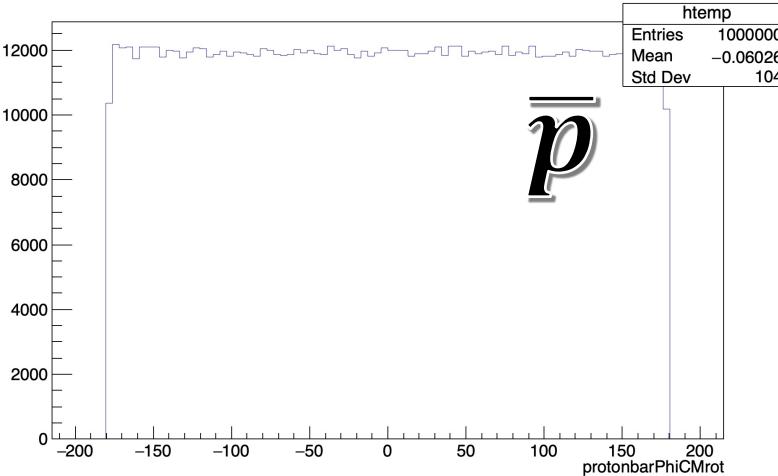


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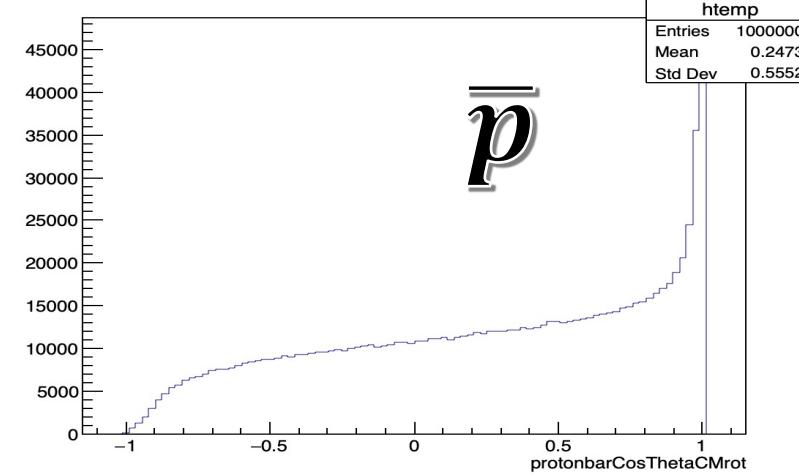


# $\bar{p}p$ CM frame (Rotation)

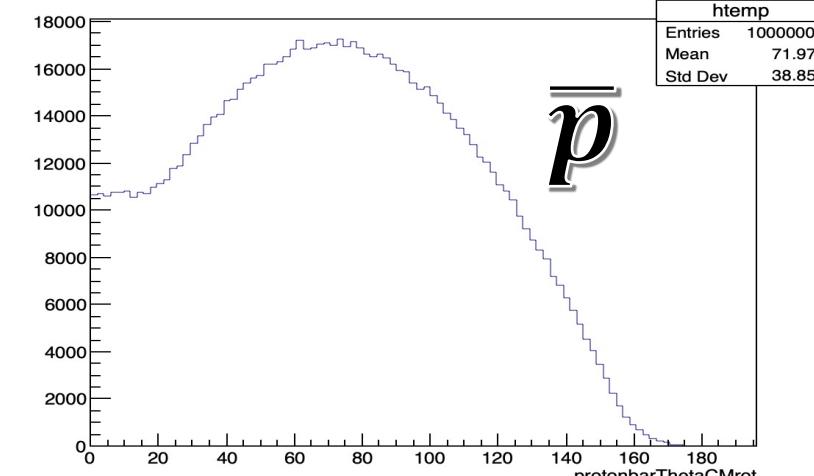
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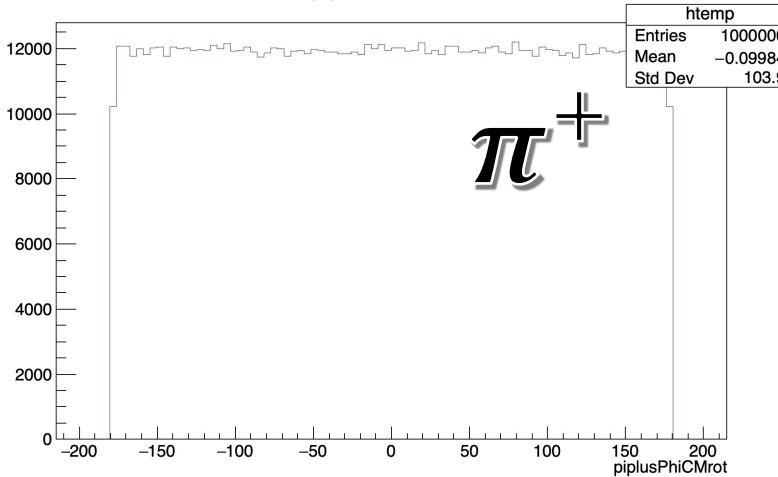
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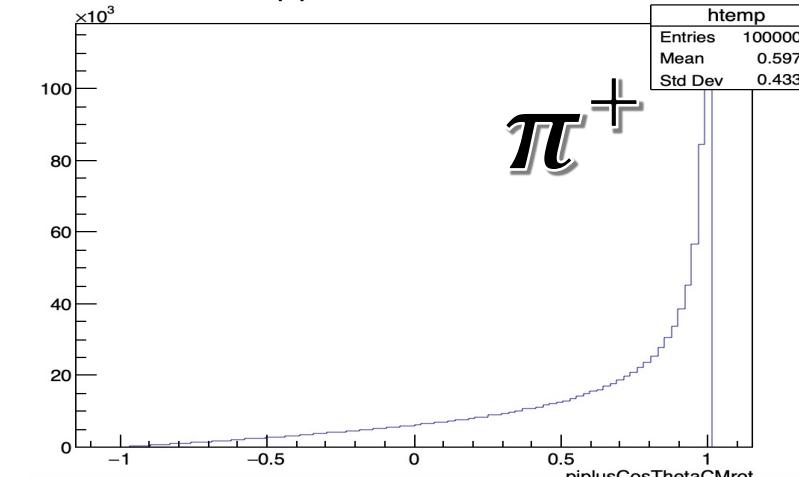
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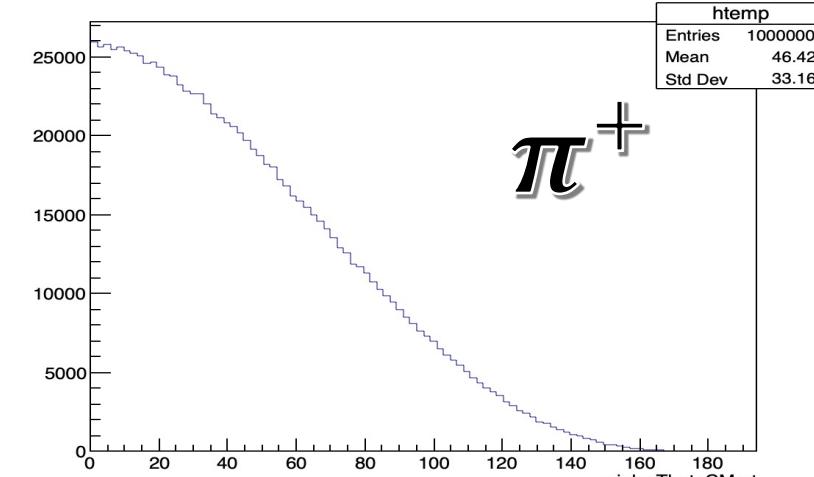
piplusPhiCMrot



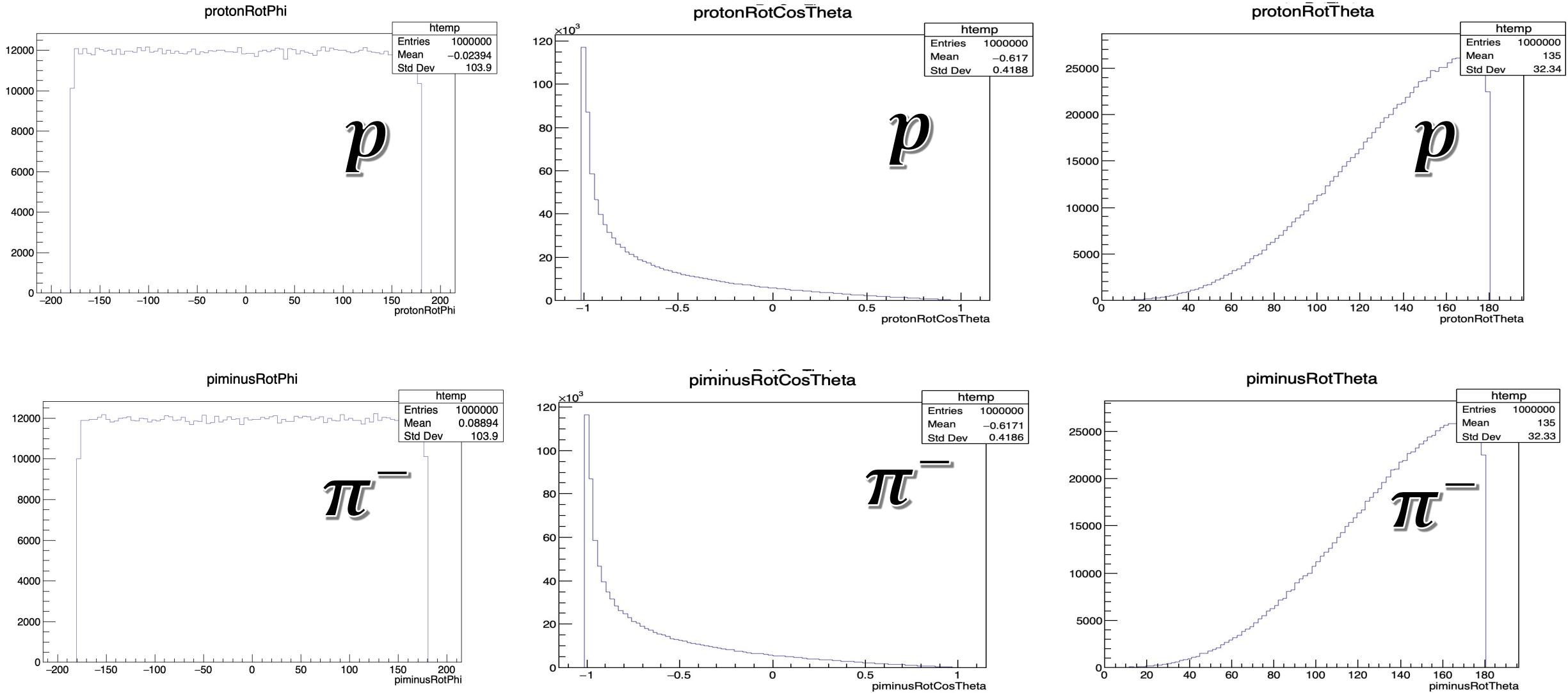
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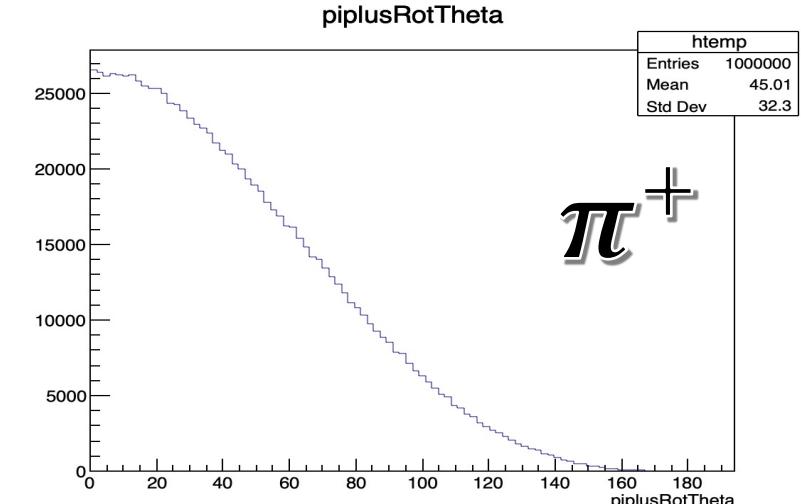
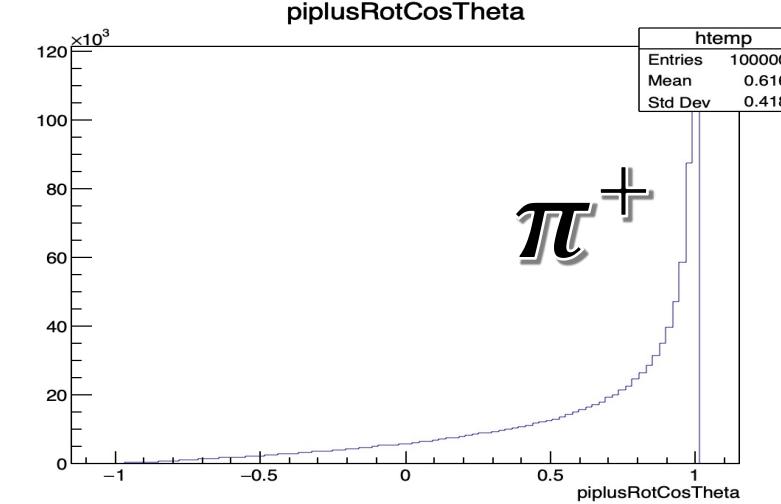
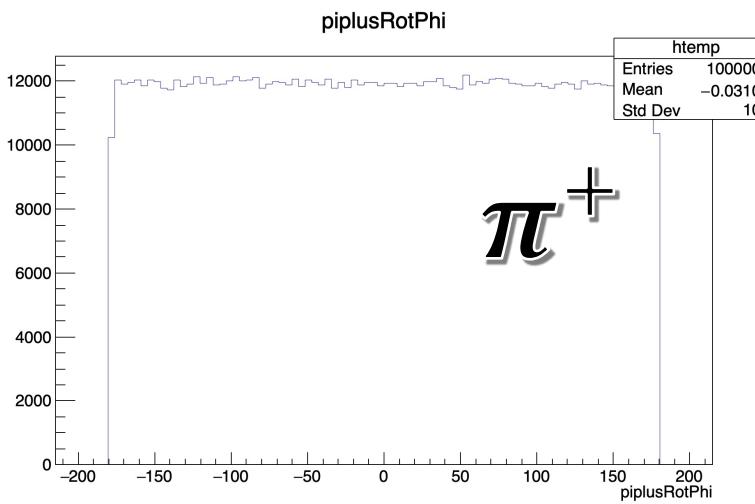
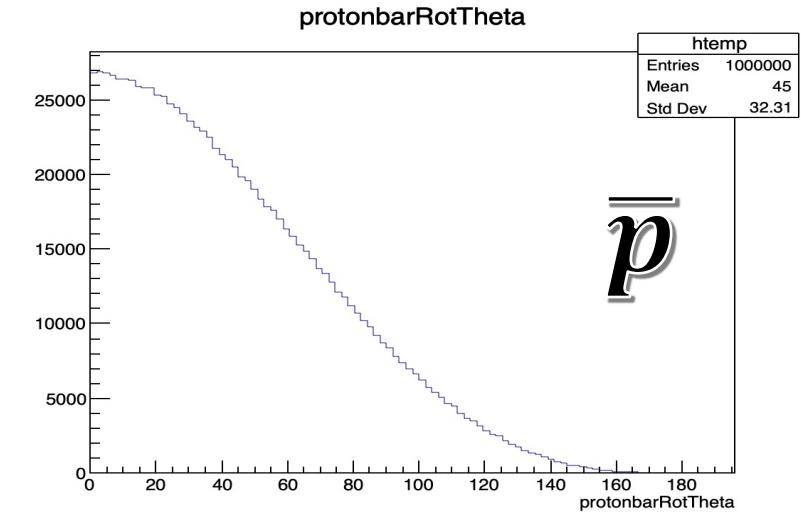
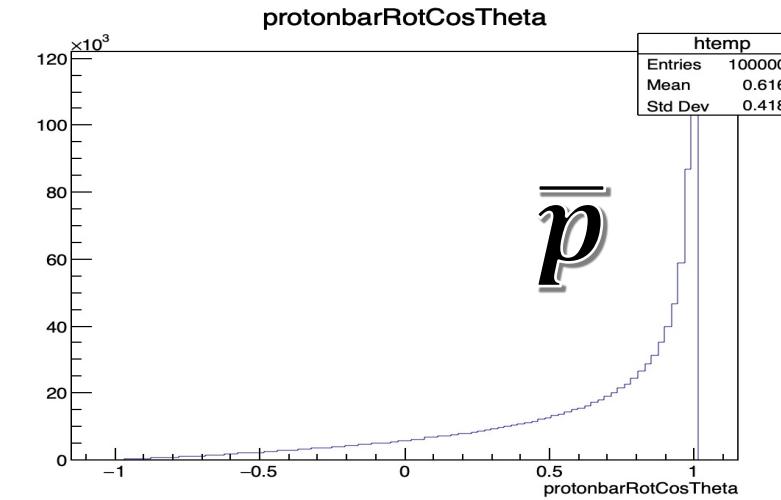
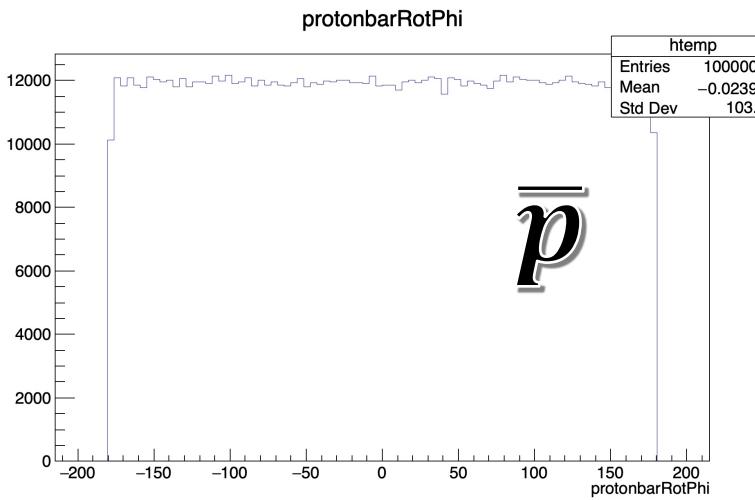
piplusThetaCMrot



# $\Lambda$ rest frame (Rotation)



# $\bar{\Lambda}$ rest frame (Rotation)



# Conclusion & Outlook

- **External Monte-Carlo Event Generator**

- $\bar{Y}Y$  pair production in  $\bar{p}p$  annihilation
- $\bar{p} + p \rightarrow \bar{\Lambda} + \Lambda \rightarrow p^-\pi^+ + p\pi^-$
- Kinematics relations of 4-vectors
- Angular distribution

- **Future development outlook**

- Implementation the testing of new models or formalisms about polarisation and spin-observables studies in the external MC event generator

# Appendix

# 4-vector

$$p_2^2 = (P - p_1)^2 = P^2 - 2P \cdot p_1 + p_1^2$$

and the mass

$$p_A^2 \equiv E_A^2 - \mathbf{p}_A^2 = m_A^2$$

$$m_2^2 = M^2 - 2ME_1 + m_1^2$$

The energy of the daughter particles can be solved

$$E_1 = \frac{M^2 + m_1^2 - m_2^2}{2M}$$

$$\begin{pmatrix} E_A \\ p_{Ax} \\ p_{Ay} \\ p_{Az} \end{pmatrix} + \begin{pmatrix} E_B \\ p_{Bx} \\ p_{By} \\ p_{Bz} \end{pmatrix} = \begin{pmatrix} E_C \\ p_{Cx} \\ p_{Cy} \\ p_{Cz} \end{pmatrix} + \begin{pmatrix} E_D \\ p_{Dx} \\ p_{Dy} \\ p_{Dz} \end{pmatrix}$$

and using the relation of  $E_2 = M - E_1$  in this case parent's rest frame

$$E_2 = \frac{M^2 + m_2^2 - m_1^2}{2M}$$

The momentum form  $|\mathbf{p}_1| = \sqrt{E_1^2 - m_1^2}$  and obtains

$$|\mathbf{p}_1| = \frac{\sqrt{(M^2 + m_1^2 - m_2^2)^2 - 4M^2m_1^2}}{2M} = \frac{\sqrt{(M^2 - m_1^2 - m_2^2)^2 - 4m_1^2m_2^2}}{2M}$$

$$\begin{cases} p_{p_x}^* = p_p^* \sin\theta^* \\ p_{p_z}^* = p_p^* \cos\theta^* \end{cases}$$

Considering

$$E_\Lambda = \sqrt{p_\Lambda^2 + m_\Lambda^2}$$

Similarly we have

$$\begin{cases} p_{\pi_x^-}^* = -p_{p_x}^* \\ p_{\pi_z^-}^* = -p_{p_z}^* \end{cases}$$

Also the  $\gamma$  factor and velocity

$$\begin{aligned} \gamma_\Lambda &= \frac{E_\Lambda}{m_\Lambda} \\ v_\Lambda &= \frac{p_\Lambda}{E_\Lambda} \end{aligned}$$

While the energy of them can also be found

$$\begin{cases} E_p^* = \frac{m_\Lambda^2 + m_p^2 - m_\pi^2}{2m_\Lambda} \\ E_\pi^* = m_\Lambda - E_p^* \end{cases}$$

Ultimately the Lorentz transformation (LT) can be done by multiply the factors above

$$\begin{cases} p_{p_x} = p_{p_x}^* \\ p_{p_z} = \gamma_\Lambda(p_{p_x}^* + v_\Lambda E_p^*) \\ \tan\theta_p = \frac{p_{p_x}}{p_{p_z}} \end{cases}$$

and similarly for the other daughter particle

$$\begin{cases} p_{p_{\pi^-}} = p_{p_{\pi^-}}^* \\ p_{p_{\pi^-}} = \gamma_\Lambda(p_{p_{\pi^-}}^* + v_\Lambda E_{\pi^-}^*) \\ \tan\theta_{\pi^-} = \frac{p_{p_{\pi^-}}}{p_{\pi_z^-}} \end{cases}$$

To perform the rotation, the relation of angles in spherical coordinates

$$\begin{cases} x = r \cos\varphi \sin\theta \\ y = r \sin\varphi \sin\theta \\ z = r \cos\theta \end{cases}$$

Also the rotation matrix can be considered to perform this operation.

$$R_x = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix}$$

$$R_y = \begin{pmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{pmatrix}$$

$$R_z = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

And in general

$$R = R_z(\alpha)R_y(\beta)R_x(\gamma)$$

A list of typical hyperons is summarised below.

Y	q	$c\tau$ (cm)	T (s)	M (GeV/c <sup>2</sup> )	Decay
$\Lambda$	uds	7.89	$2.632 \times 10^{-10}$	1.116	$p\pi^-$ (63.9%)
					$n\pi^0$ (35.8%)
$\Sigma^+$	uus	2.404	$8.018 \times 10^{-11}$	1.189	$p\pi^0$ (51.57%)
					$n\pi^+$ (48.31%)
$\Sigma^0$	uds	$2.22 \times 10^{-9}$	$7.4 \times 10^{-20}$	1.193	$\Lambda\gamma$ (100%)
$\Sigma^-$	dds	4.434	$1.479 \times 10^{-10}$	1.197	$n\pi^-$ (99.848%)
$\Xi^0$	uss	8.71	$2.0 \times 10^{-10}$	1.315	$\Lambda\pi^0$ (99.524%)
$\Xi^-$	dss	4.91	$1.639 \times 10^{-10}$	1.322	$\Lambda\pi^-$ (99.887%)
$\Omega^-$	sss	2.461	$8.21 \times 10^{-11}$	1.672	$\Lambda K^-$ (67.8%)
					$\Xi^0\pi^-$ (23.6%)
					$\Xi^-\pi^0$ (8.6%)

Table 1.1: Strange ground state hyperons. The name of hyperon, its quark content, mean decay length, mean lifetime, mass, and main decay with branching ration are shown, and they are denoted by Y, q,  $c\tau$ , T, M, and Deca [7].

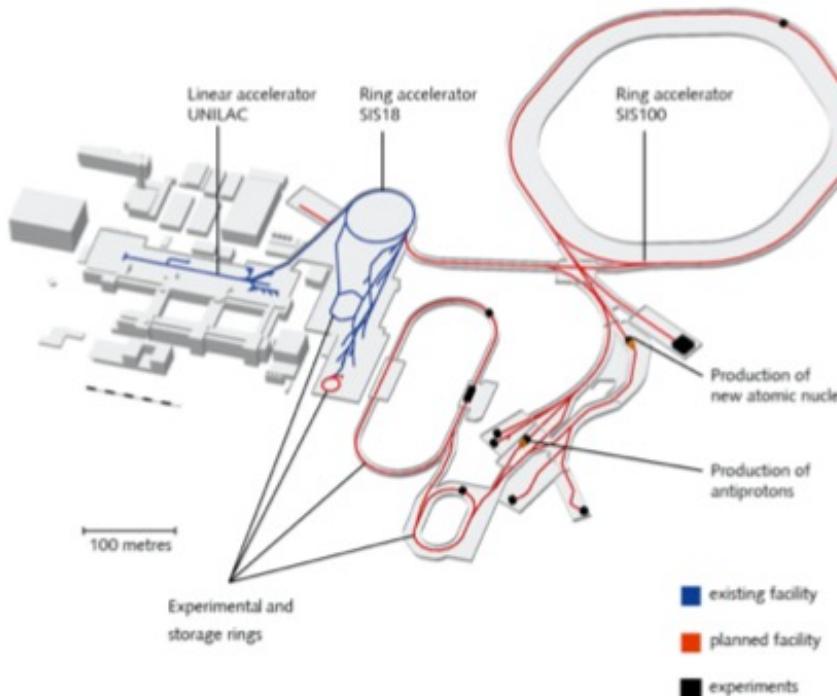


Figure 1.1: The Accelerator Facility of FAIR [2]

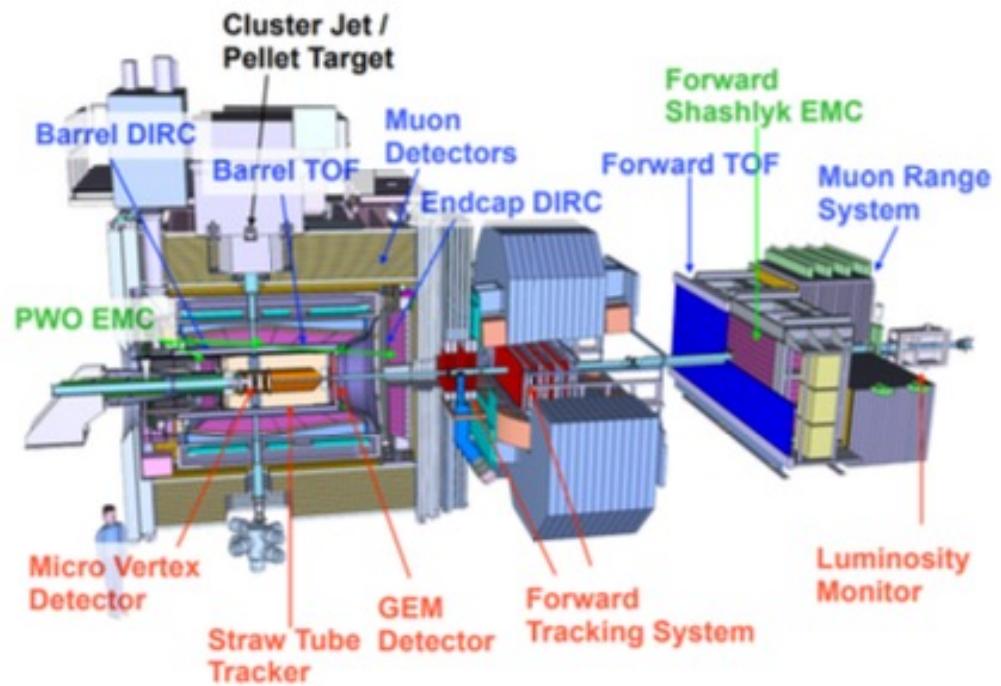


Figure 1.2: The Detector of PANDA [1]