

Estimation of the space - time particle production volume in particle collisions

N.G. Fadeev (JINR)

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 - particle time-energy relation or particle time-energy quantum rule
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Particle time – energy relation or particle time-energy quantum rule

$$E_T = \sqrt{m^2 + P_T^2}$$

$$E = \sqrt{E_T^2 + P_z^2}$$

$$E_T / E = \sqrt{1 - \beta_z^2} \equiv c \cdot \Delta T / c \cdot \Delta T \quad \beta_z = \Delta Z / c \cdot \Delta T - \text{longitudinal component}$$

$$c \Delta T = c \Delta T \sqrt{1 - \beta_z^2}$$

$\Delta T, \Delta T$ - proper time and corresponding time in the rest frame (c.m.s. at LHC)

$$E_T \cdot \Delta T = E \cdot \Delta T \approx n \cdot h$$

Planck's postulate:

$$E_{\text{photon}} = h \nu = h / \Delta T$$

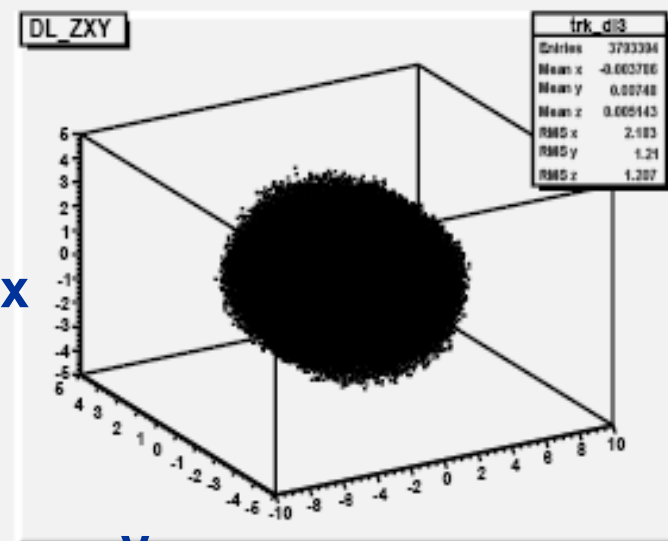
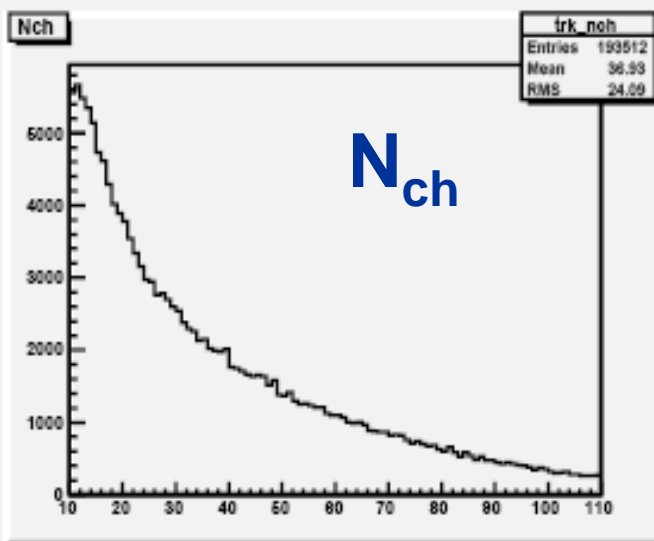
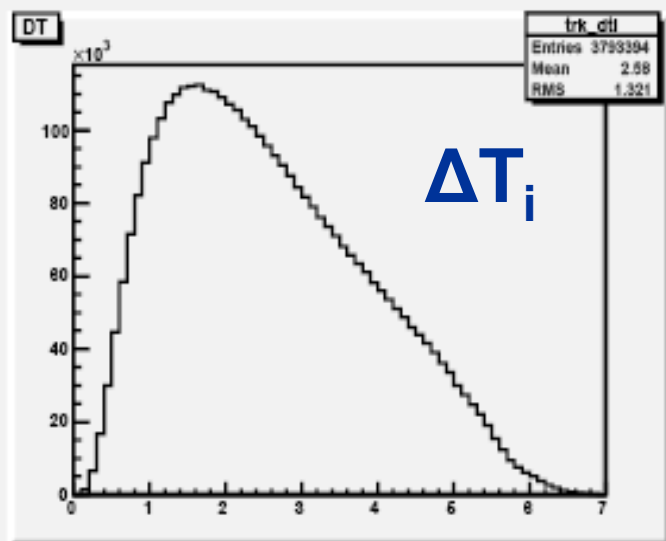
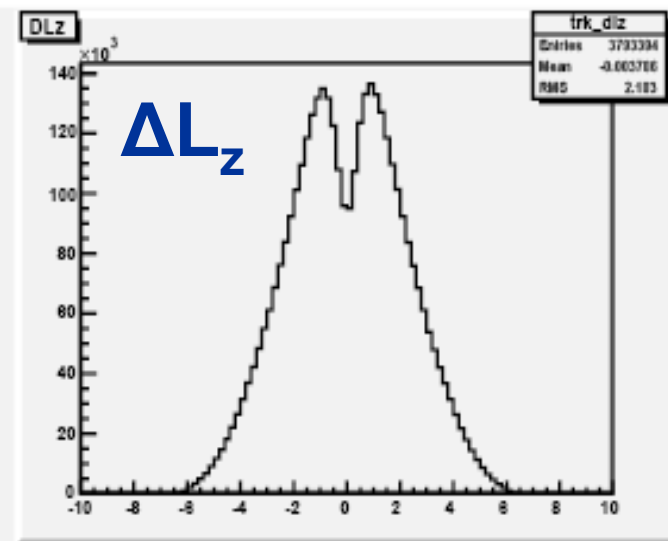
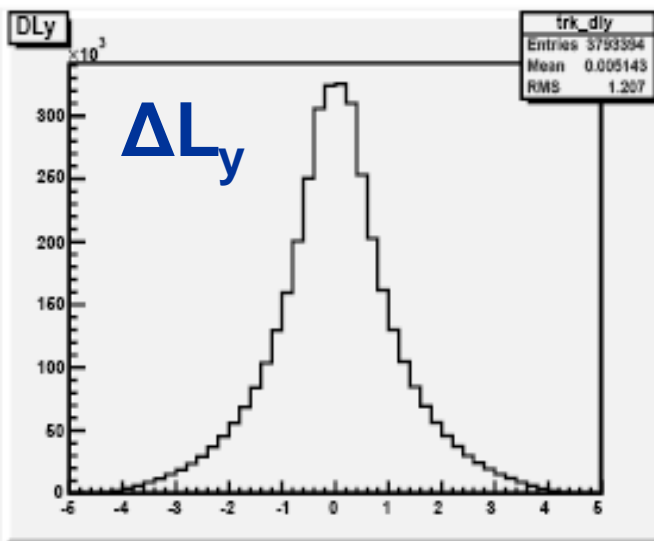
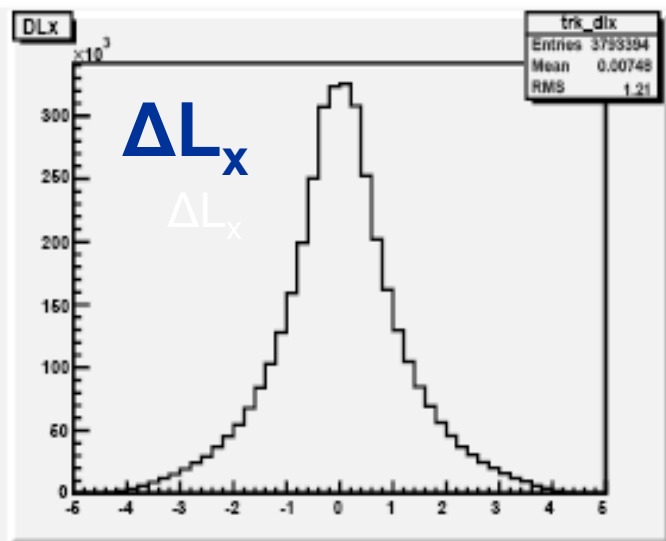
$$\Delta T \approx h / E_T, \quad (n = 1)$$

$$\Delta T \approx h / E \approx h / P$$

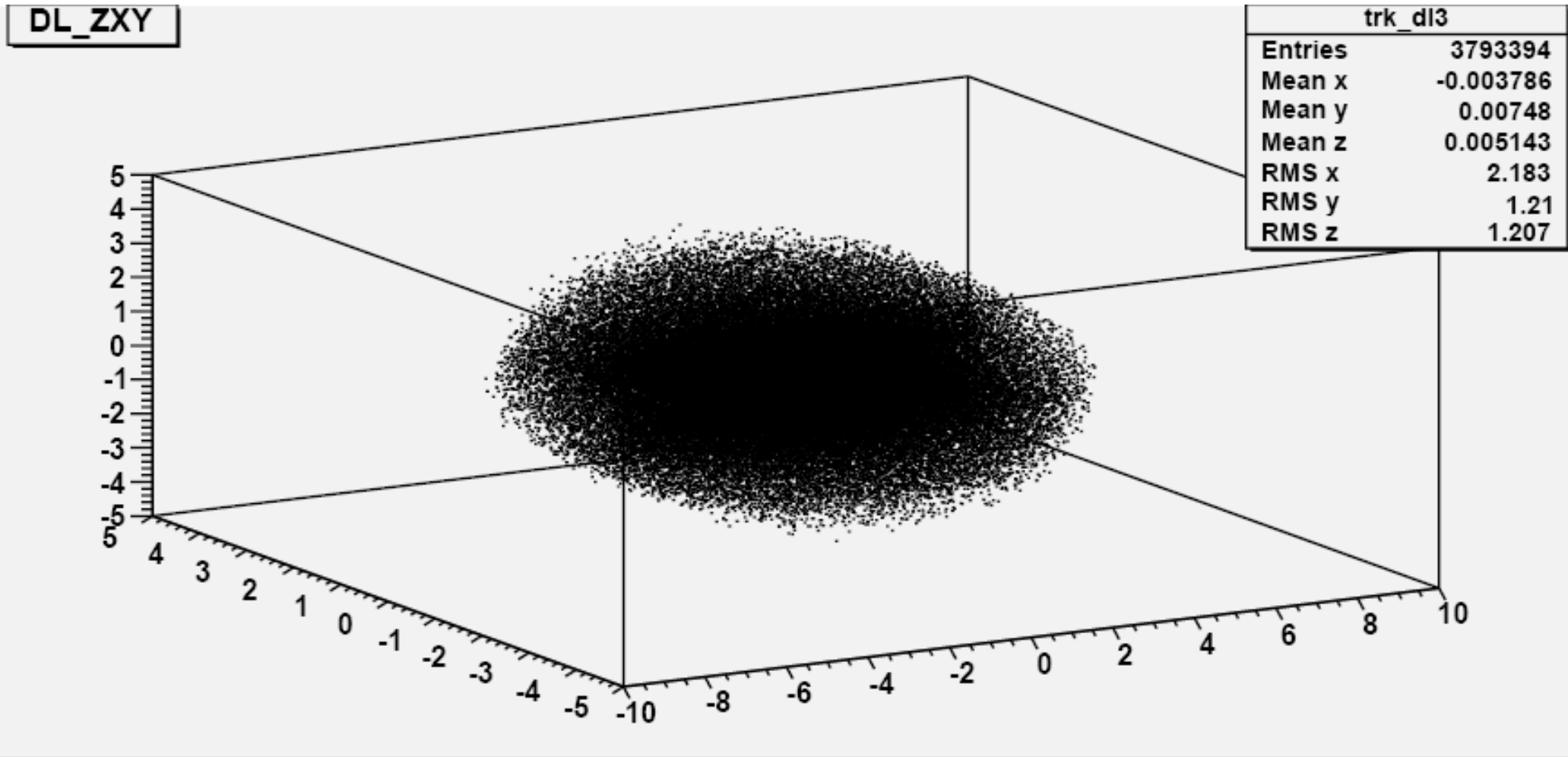
$$\Delta L_z \approx \beta_z \Delta T, \quad \Delta L_x \approx \beta_x \Delta T, \quad \Delta L_y \approx \beta_y \Delta T$$

Some results for pp at $\sqrt{s}_{pp} = 7 \text{ TeV}$

(ATLAS minimum bias events dataset)

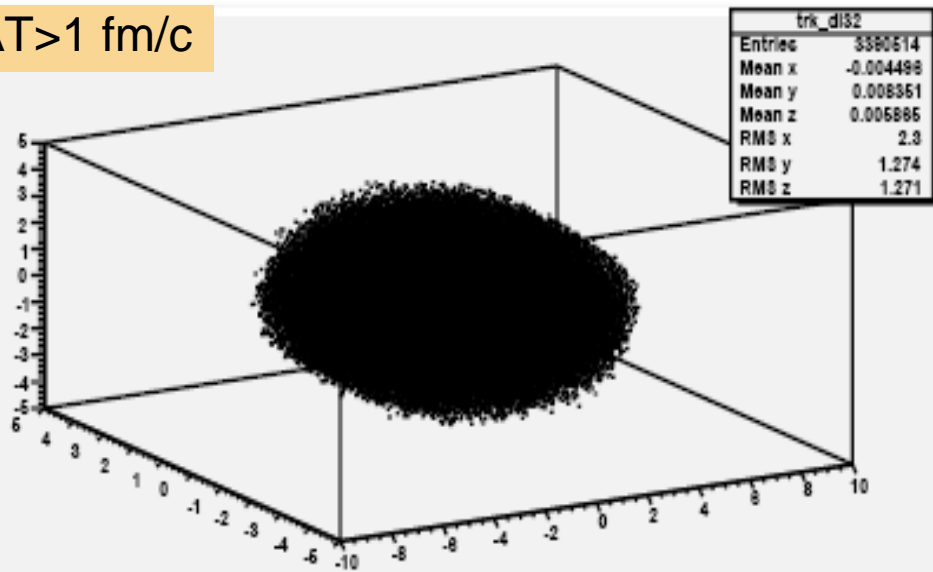


All events

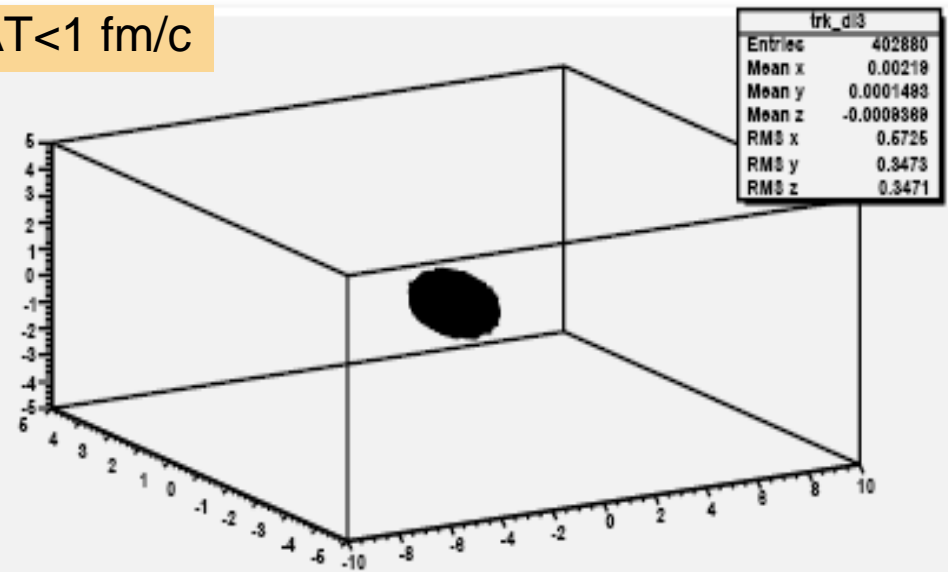


Different time slices (1)

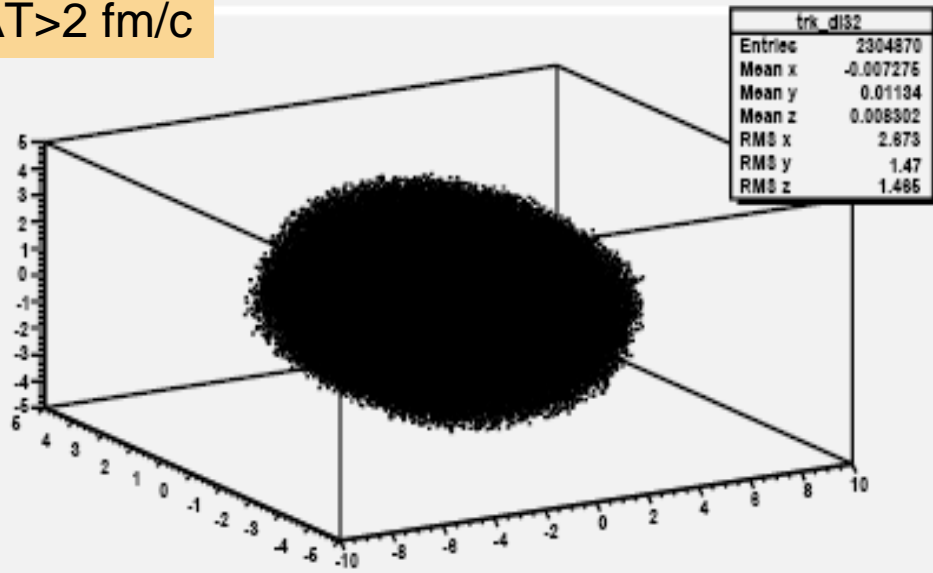
$\Delta T > 1$ fm/c



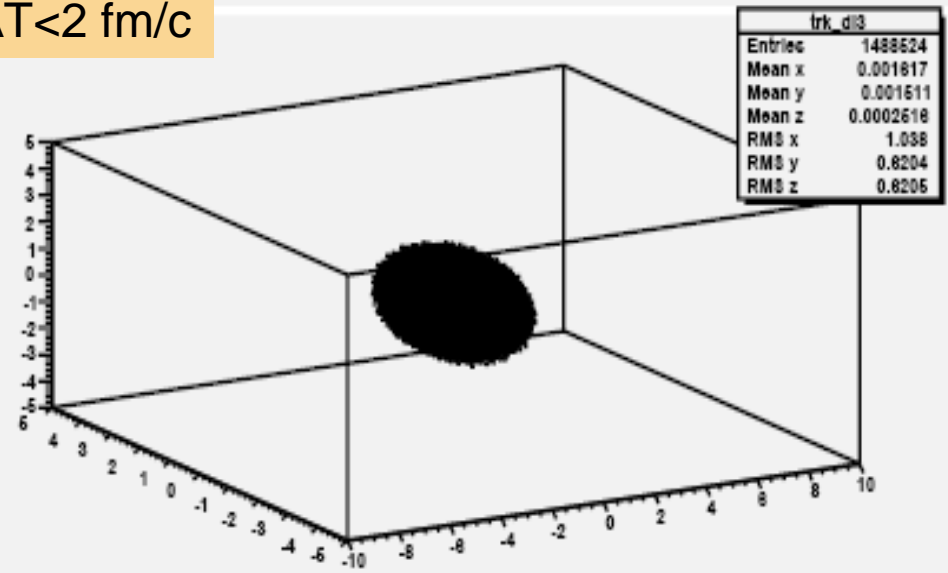
$\Delta T < 1$ fm/c



$\Delta T > 2$ fm/c

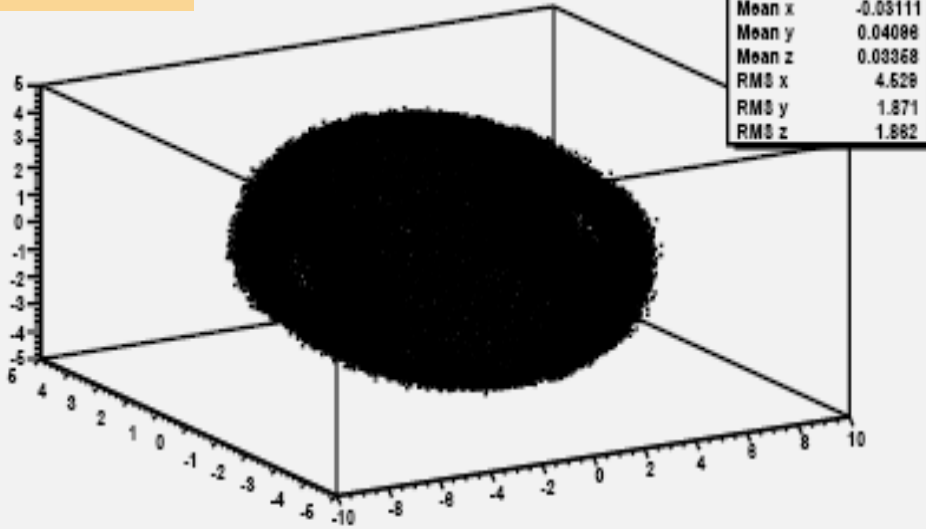


$\Delta T < 2$ fm/c

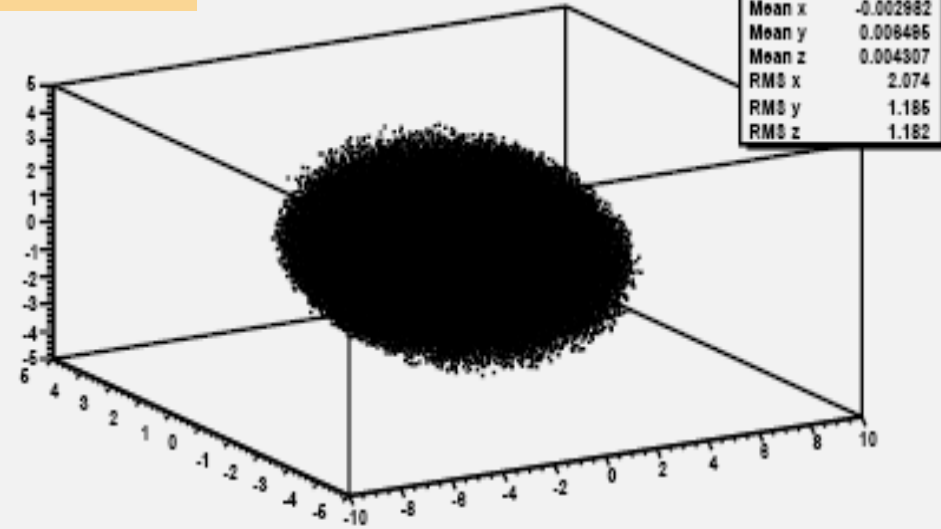


Different time slices (2)

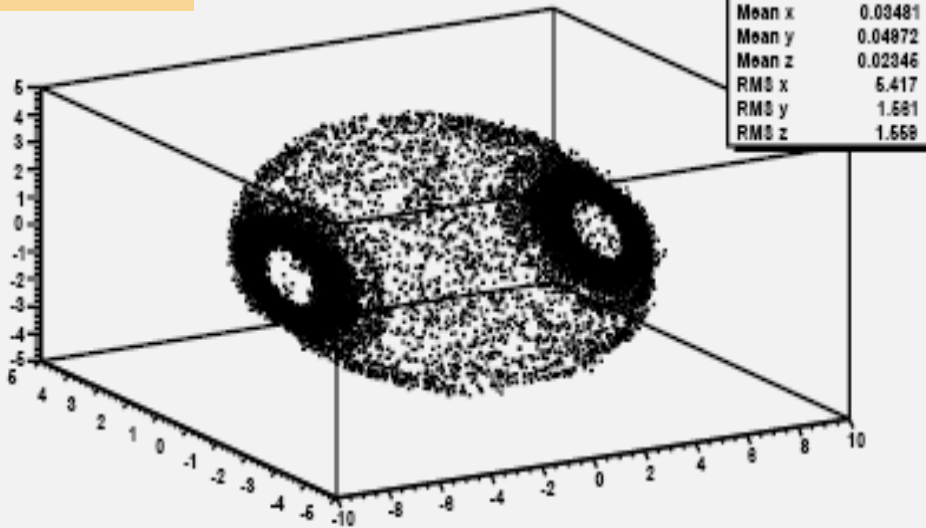
$\Delta T > 5$ fm/c



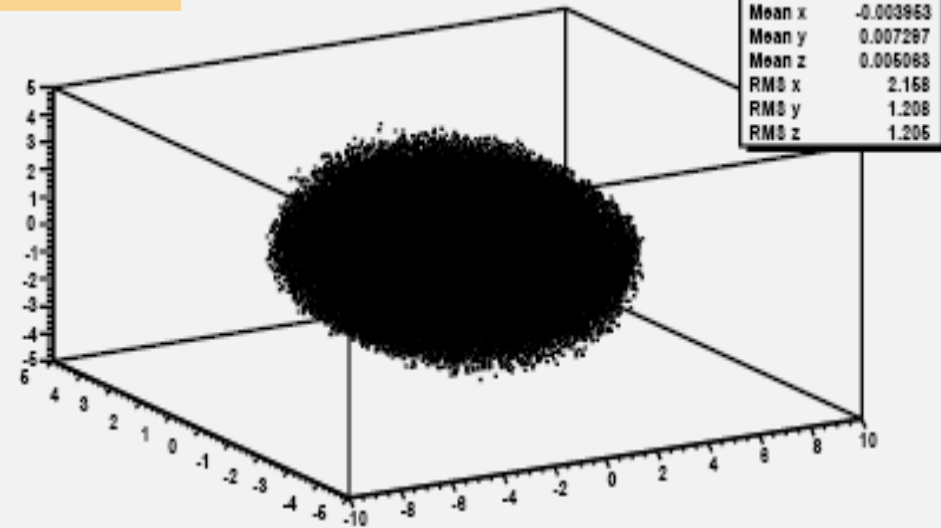
$\Delta T < 5$ fm/c



$\Delta T > 6$ fm/c



$\Delta T < 6$ fm/c



Conclusion

- Particle time - energy relation or particle time - energy quantum rule ($E_T \Delta T = E \Delta \tau = n h$) is found while studying minimum bias events
- The relation was applied for estimation of the particle production volume
- One may use the approach to estimate the nuclear matter density

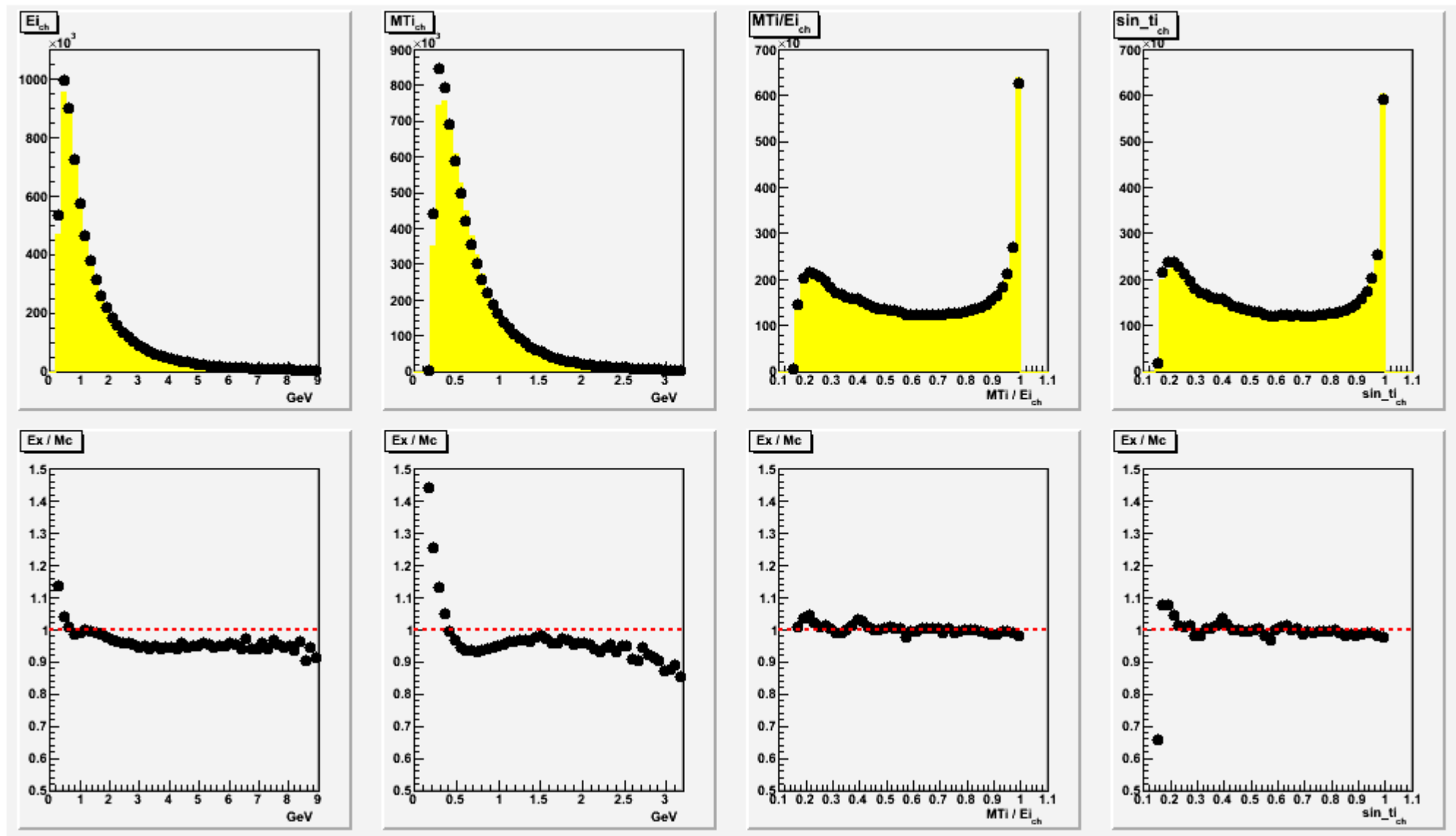
THANK YOU!

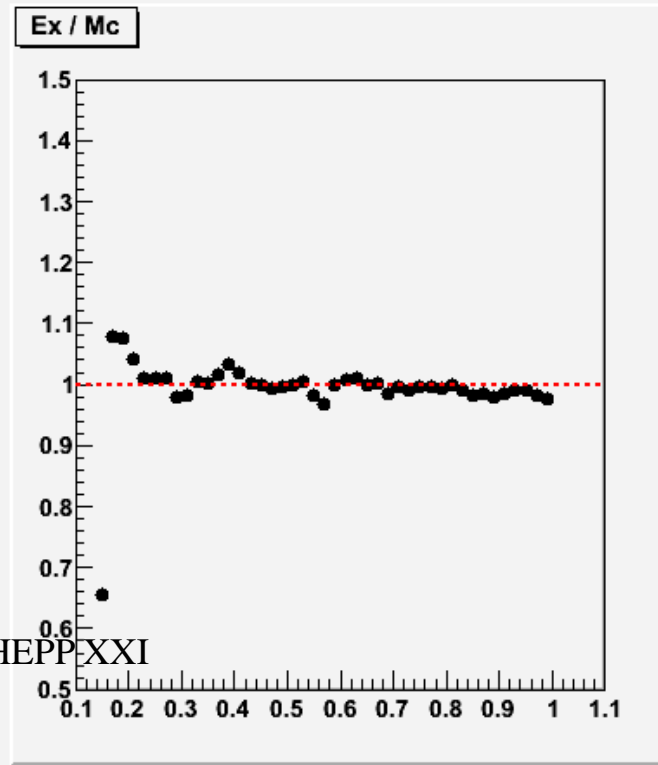
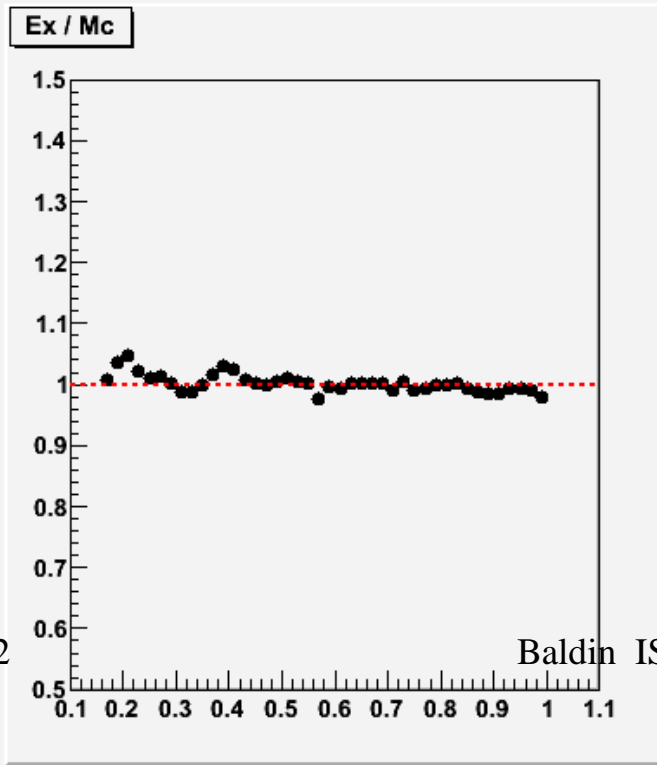
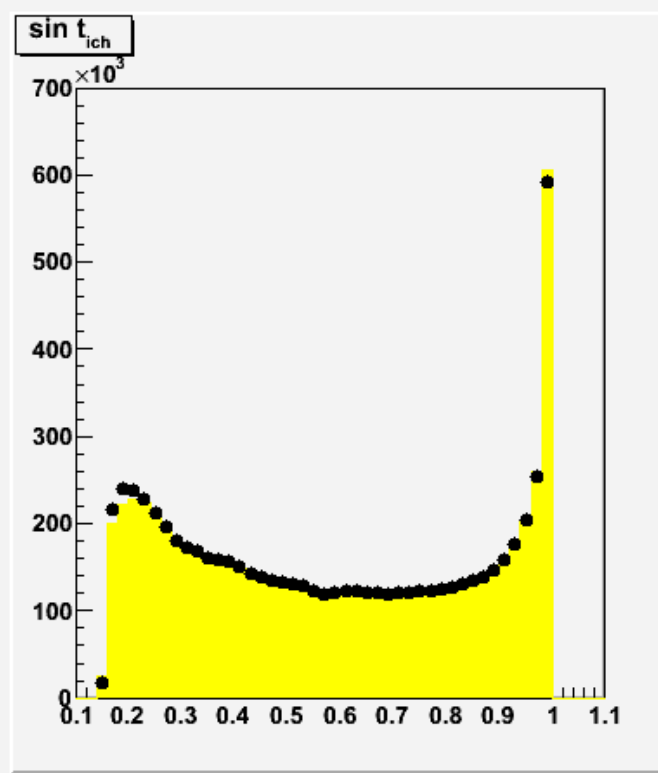
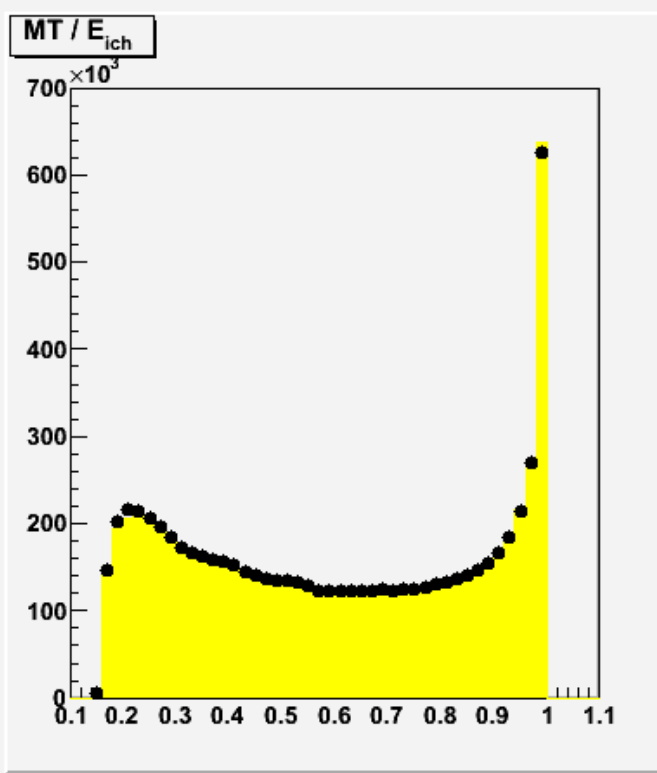
BACKUP SLIDES

Common set of track selection criteria

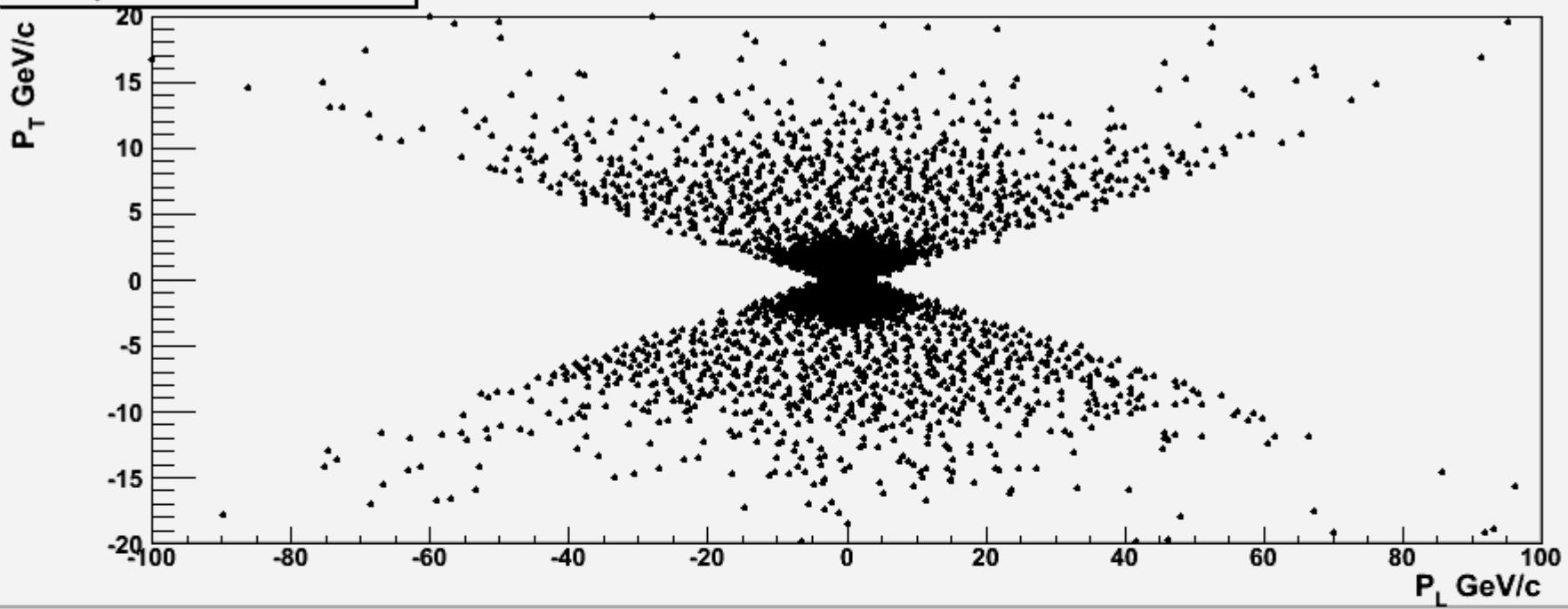
- $|\eta| \leq 2.5$
- $|d_0| \leq 1.5 \text{ mm}$
- $|z_0| \leq 200 \text{ mm}$
- $|(z_0 - z_v) \sin\theta| \leq 1.5 \text{ mm}$
- number of Pixel hits ≥ 1
- number of SCT clusters ≥ 1

- $|p_T| \geq 100 \text{ MeV}/c$; $n_{\text{ch}} \geq 2$





PTi($p_{iy} >, < 0$) vs PLi($p_{iz} >, < 0$)



P_{Ti} vs P_{Li}

