Particle identification in the HARP large angle detector

A. Bolshakova, I. Boiko, F. Dydak, Yu. Nefedov

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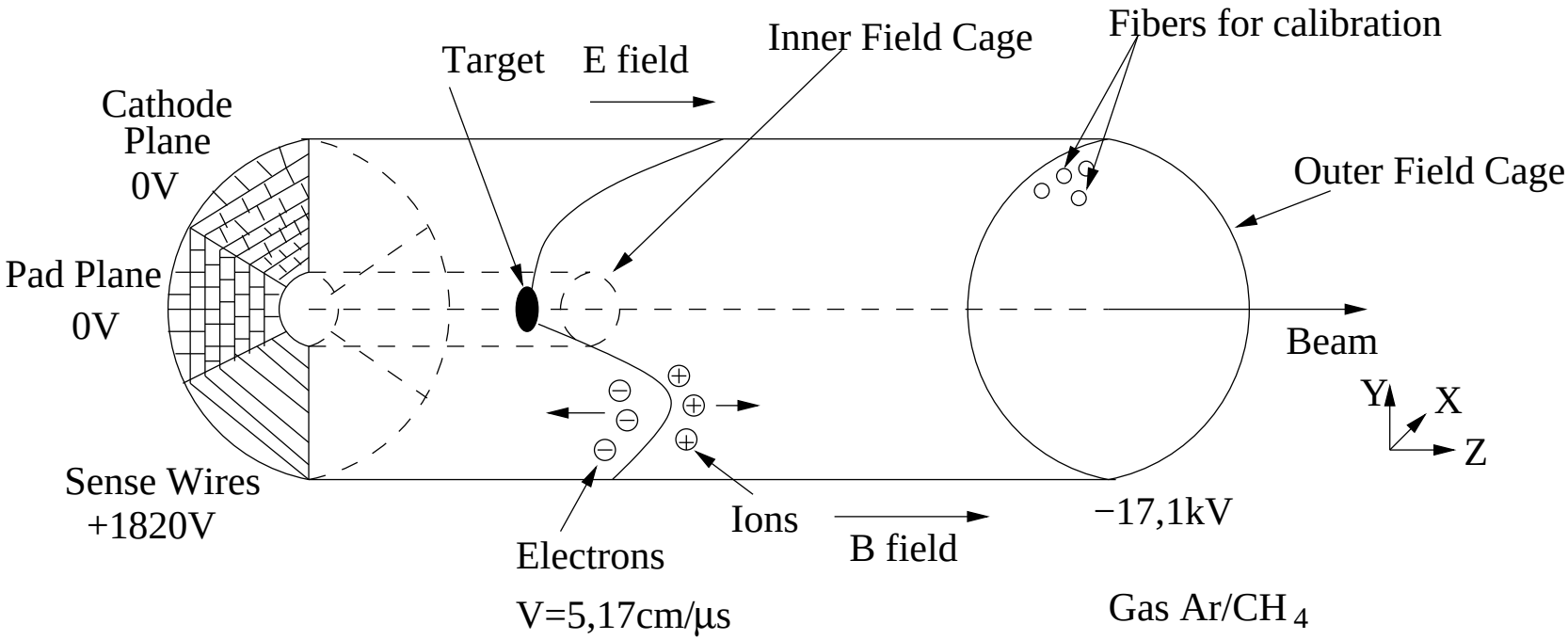
The workshop "Neutrino physics at accelerators"

Outline

- The comparison and correction of Monte Carlo by Data;
- The results of particle identification program.

- Monte Carlo: Be 8GeV, Ta 3GeV, H_2O
- Data: Be +8,9 GeV

Target setting

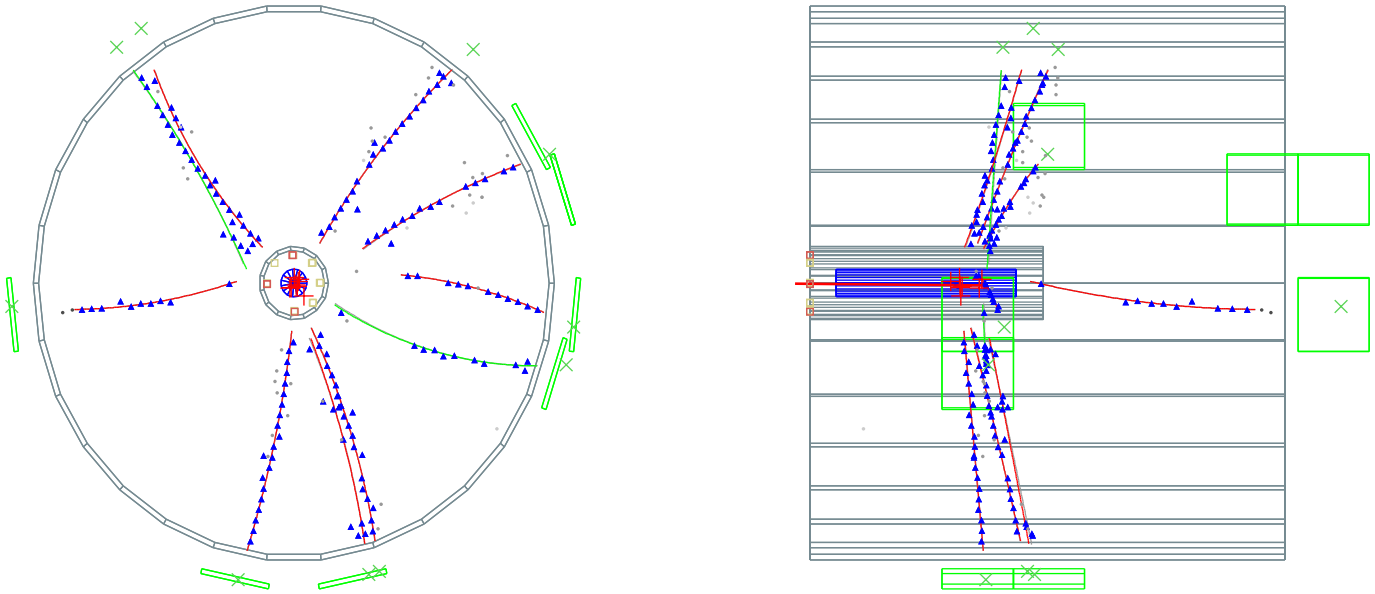


- The Ar(91%) CH_4 (9%) gas mix was used in TPC.
- Active length of TPC is 1557mm.

The problem is to determine type of particle using the variables β and dE/dx and kinematic variables: P and θ (to calculate the probability of particle to be proton, electron or π).

Run# 14363 Event# 41

Right Side



- RPC - mesuring of time $\rightarrow \beta$;
- TPC - mesuring of signal amplitude $\rightarrow$ dE/dx;
- TPC - track curvature $\rightarrow$ P;
- TPC - kinematics $\rightarrow$ angle θ ;

The calculation of probabilities of particles

The probabilities of particles are computed by formula (i = p, π, e):

$$P(i|\beta, dE/dx, p_T, \theta) = \frac{P((\beta, dE/dx)|i, p_T, \theta) \cdot N_i(p_T, \theta)}{\sum_{i=1}^{3} P((\beta, dE/dx)|i, p_T, \theta) \cdot N_i(p_T, \theta)}$$

where $P((\beta, dE/dx)|i, p_T, \theta)$ is probability density function which is normalized to unity. It represent the data in the bin (p_T, θ).

$N_i(p_T, \theta)$ - is relative number of each type of particles.

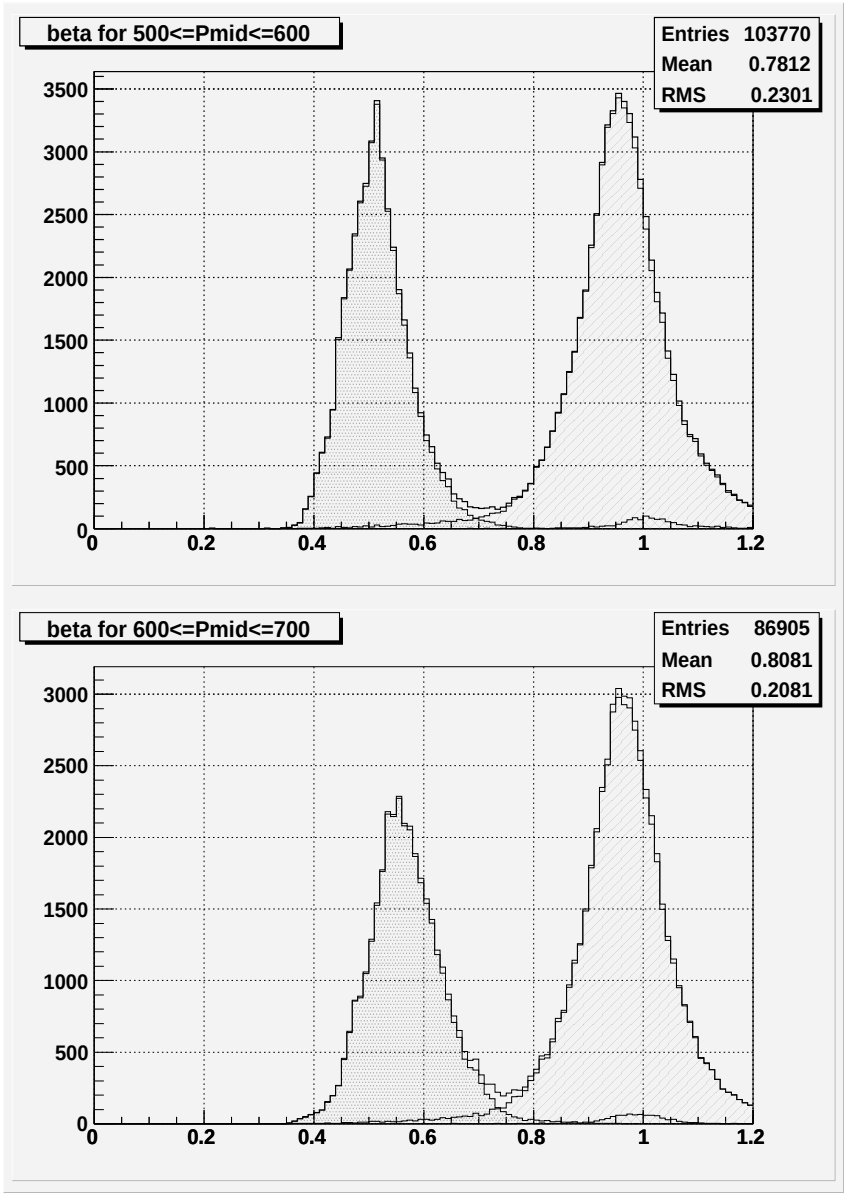
$\sum_{i=1}^{3} P((\beta, dE/dx)|i, p_T, \theta)$ is normalized to unity too.

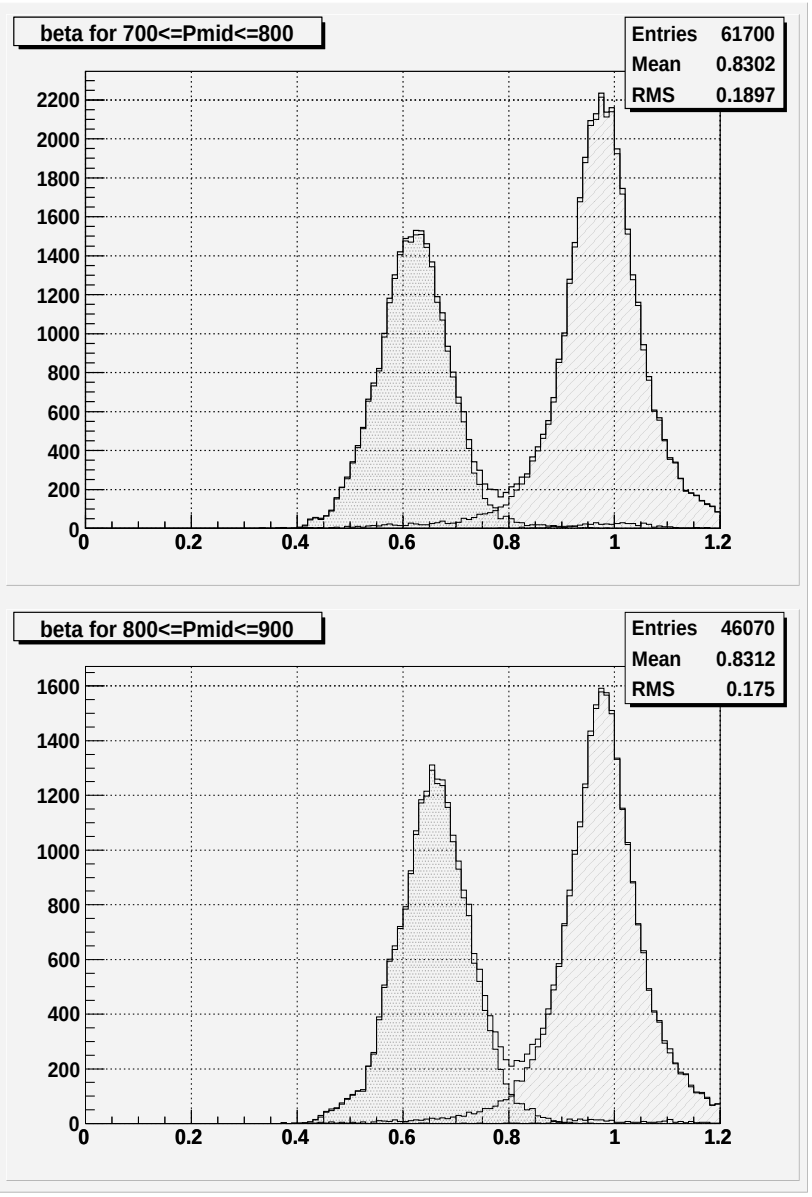
The comparison of MC Be 8 GeV with Data Be +8.9GeV:

The comparison was carry out for

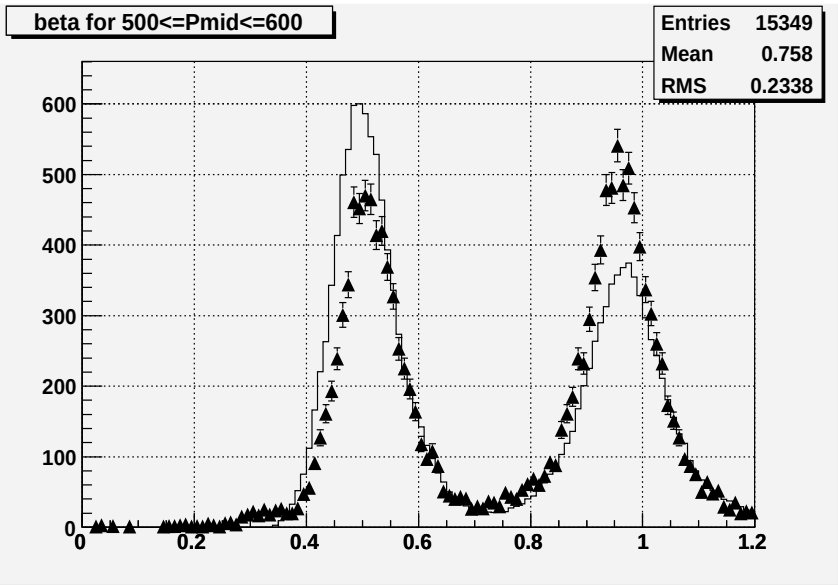
- **Variables:**
  - beta;
  - dE/dx.
- **Type of particles:**
  - negative particles;
  - positive particles;
  - all particles.
- **Momentum intervals:**
  1. 100 - 200 MeV;
  2. 200 - 300 MeV;
  3. 300 - 400 MeV;
  4. 400 - 500 MeV;
  5. 500 - 600 MeV;
  6. 600 - 700 MeV;
  7. 700 - 800 MeV;
  8. 800 - 900 MeV;
  9. 900 - 1000 MeV.

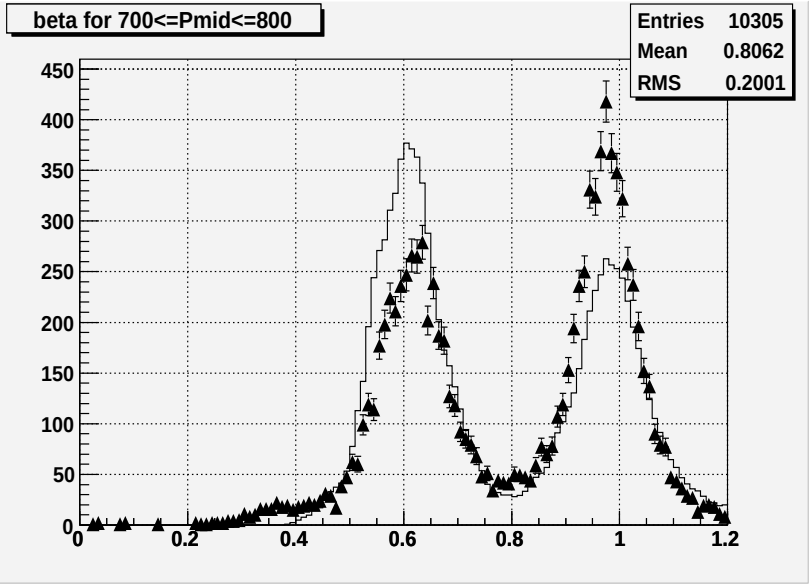
The MC β-variable for all particles:

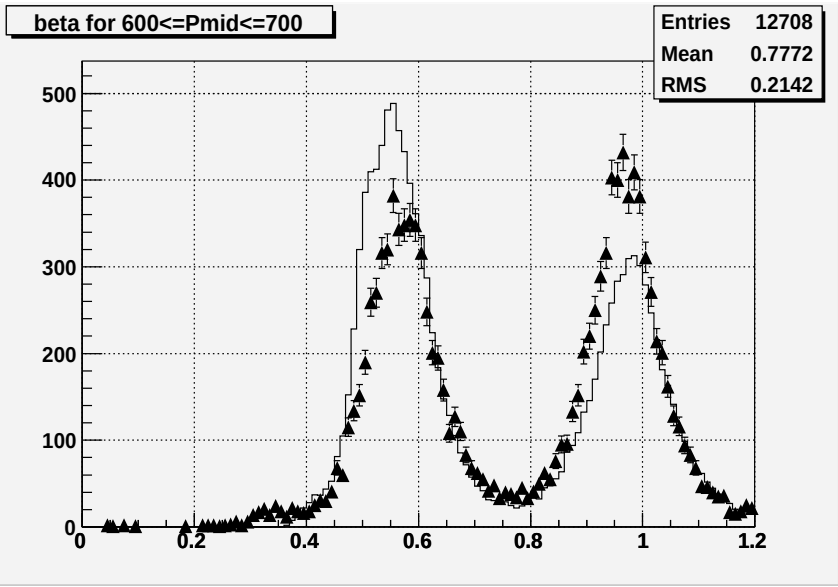


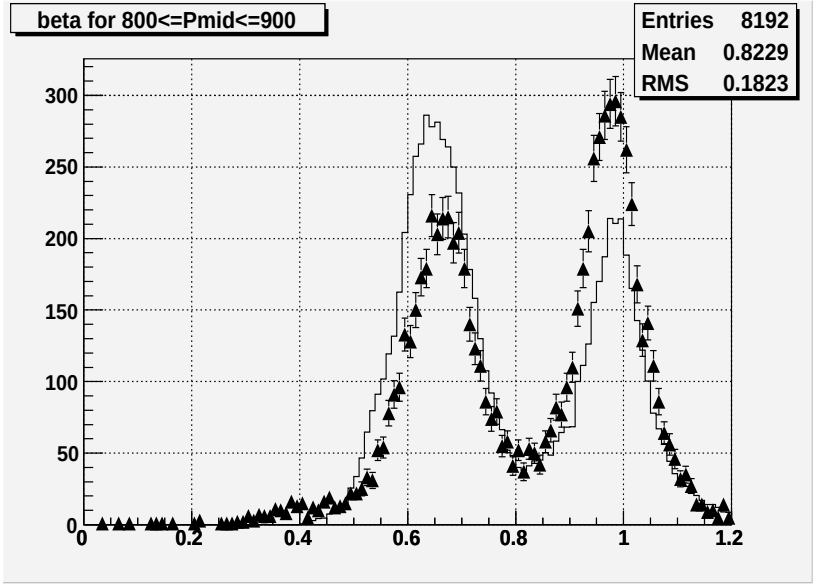


The β-variable for all particles before correction:

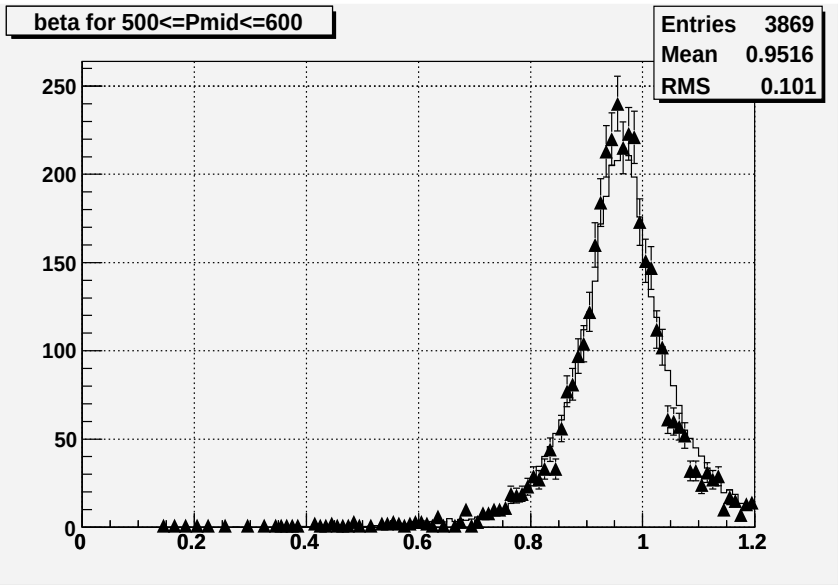


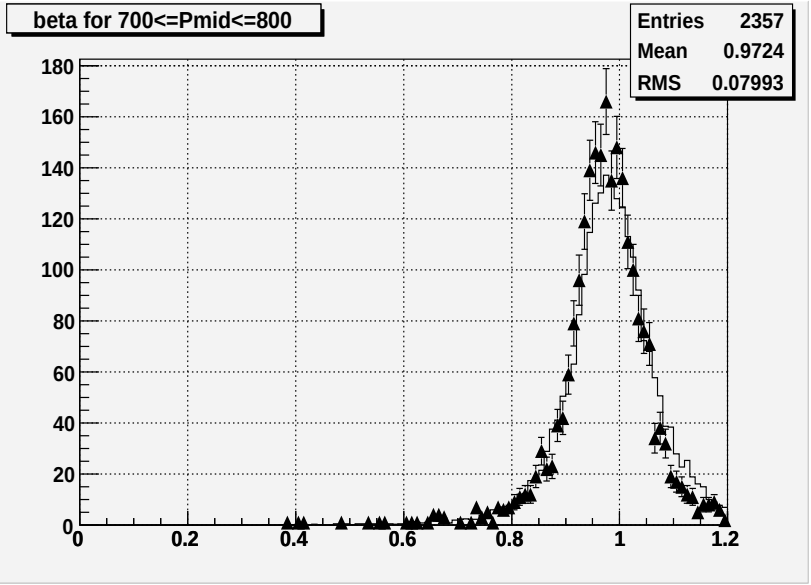


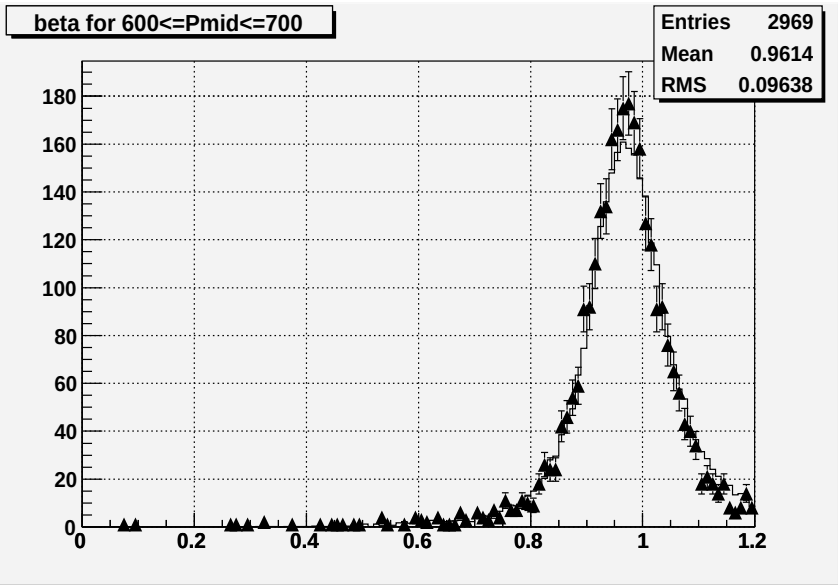


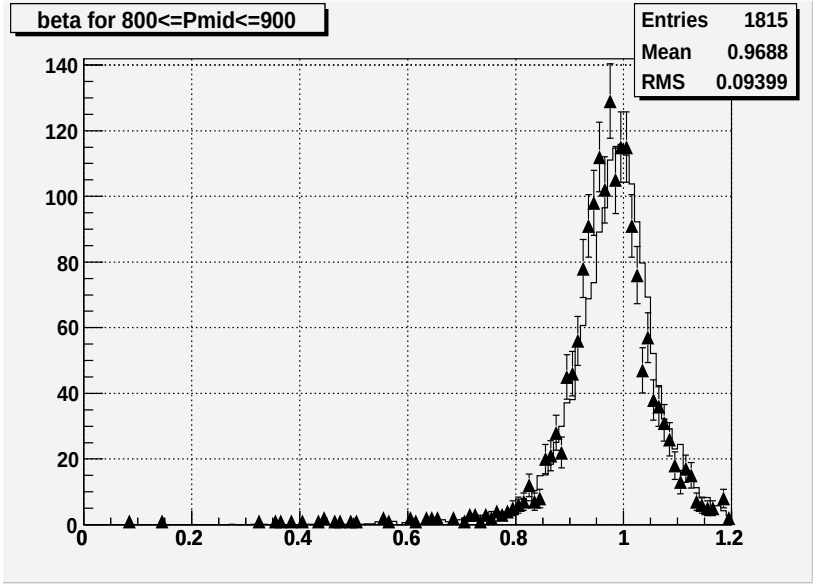


The β-variable for negative particles before correction:

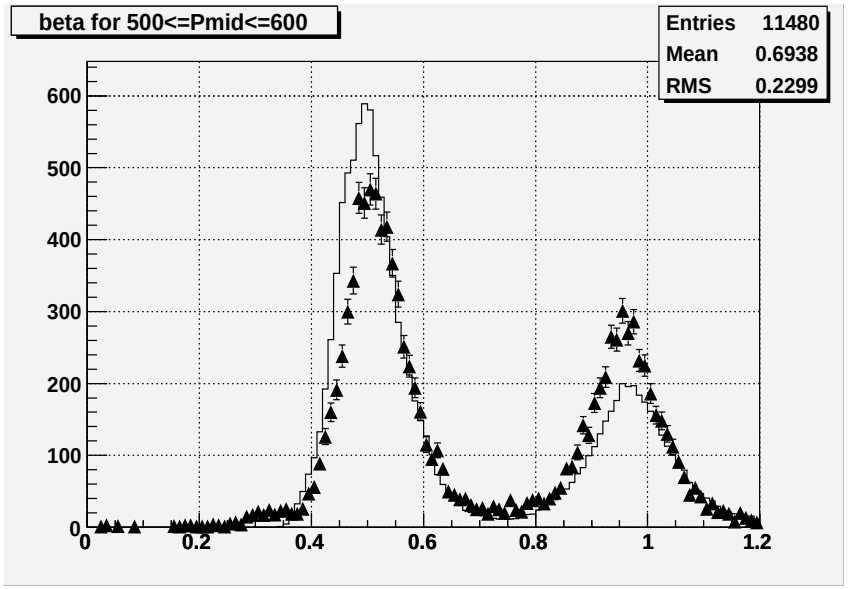


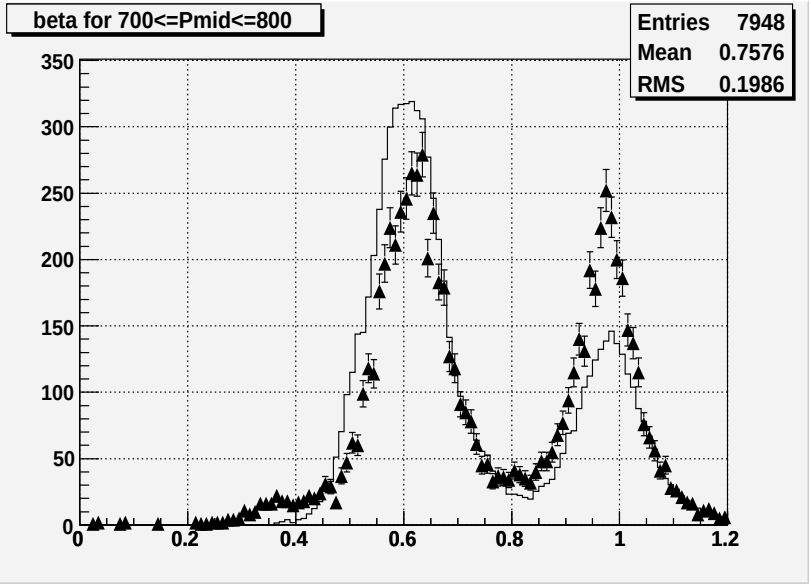


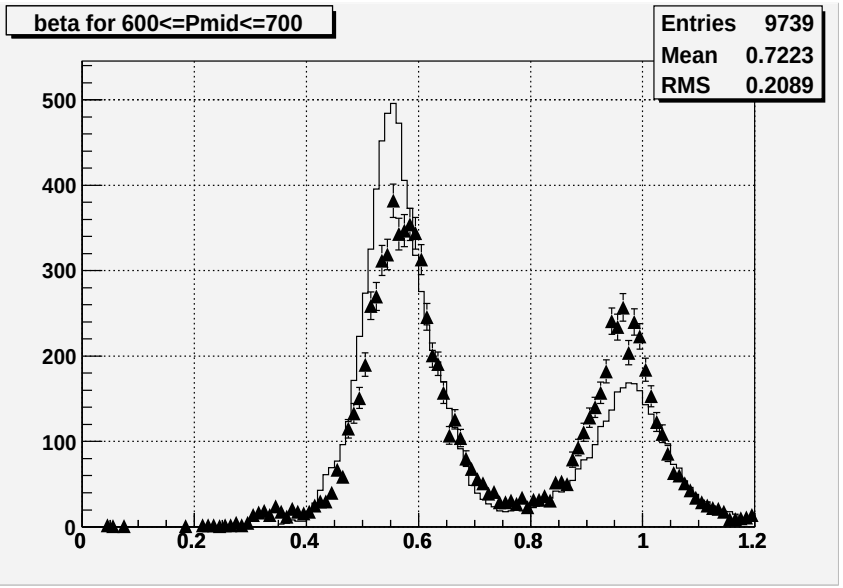


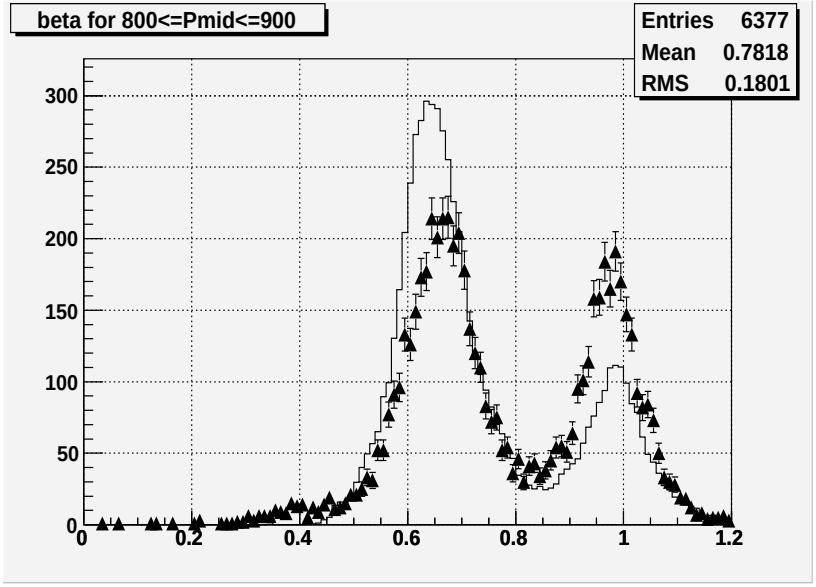


The β-variable for positive particles before correction:

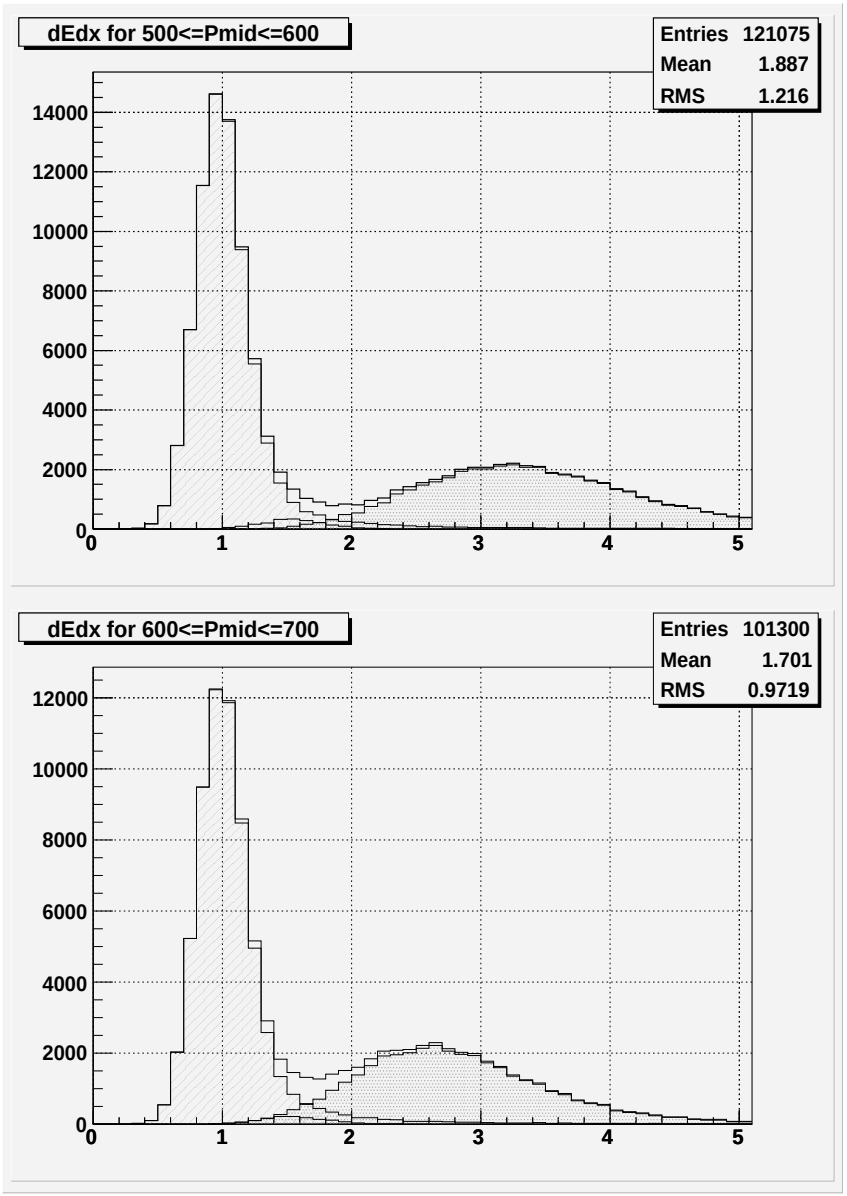


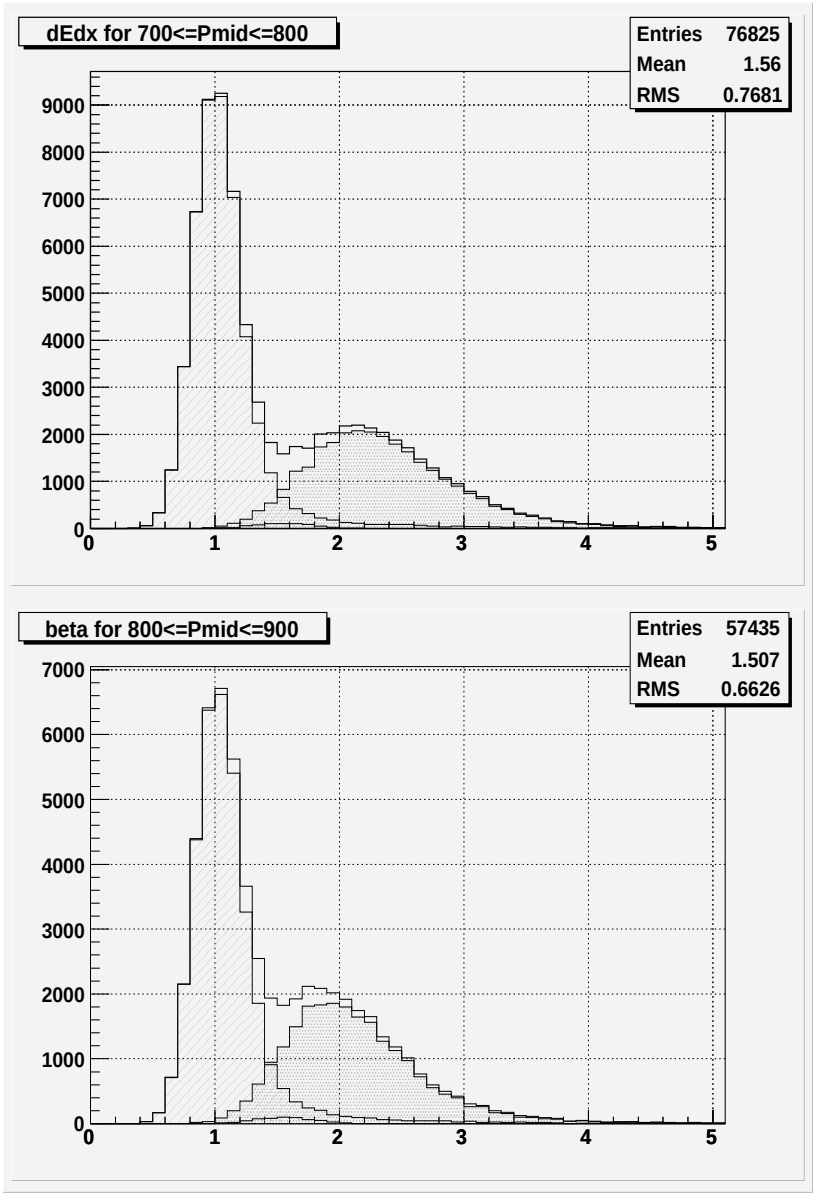




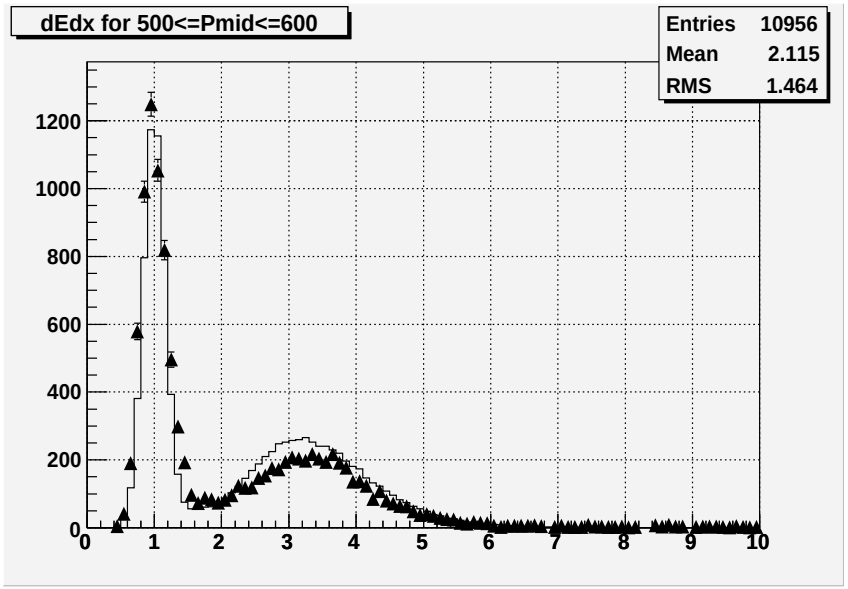


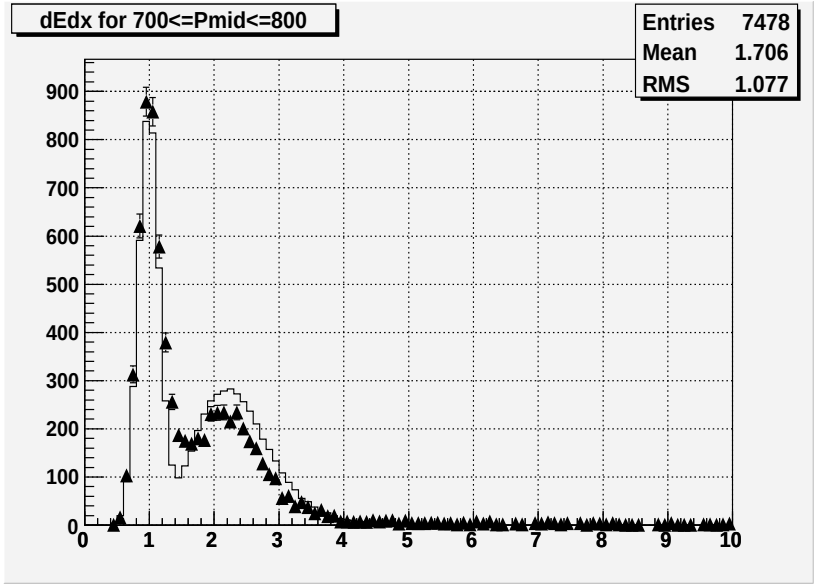
The MC dE/dx-variable for all particles:

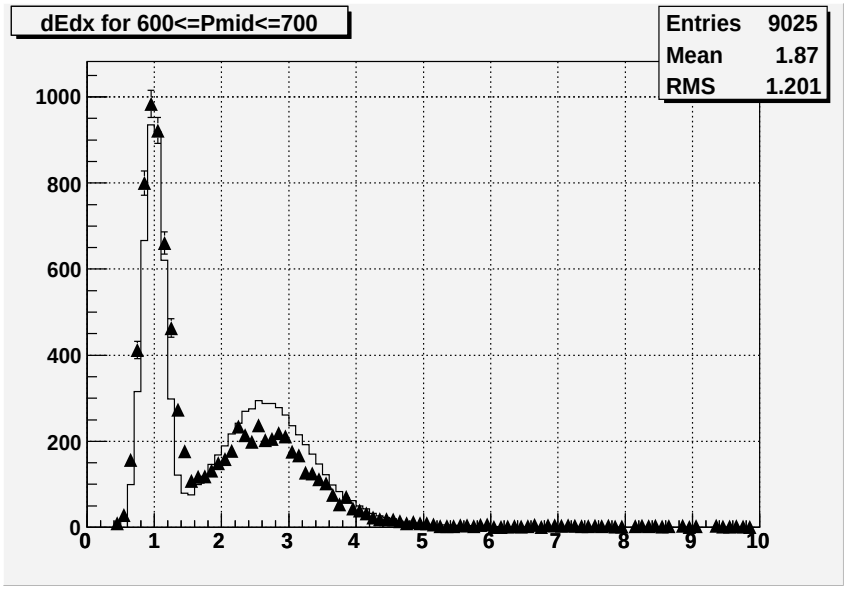


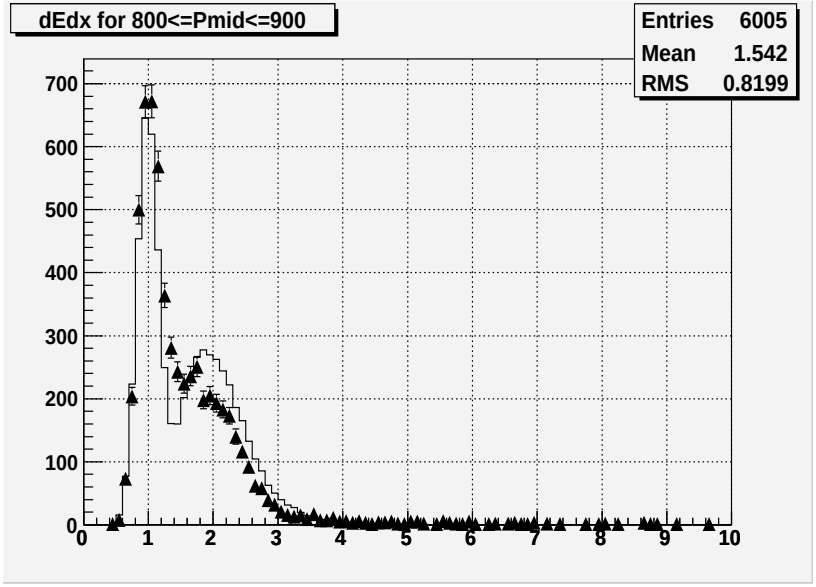


The dE/dx-variable for all particles before correction:

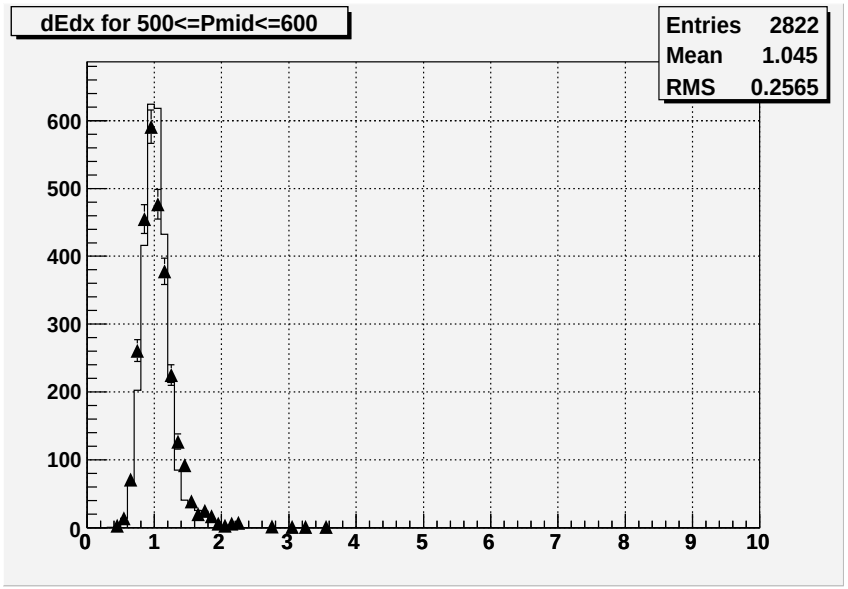


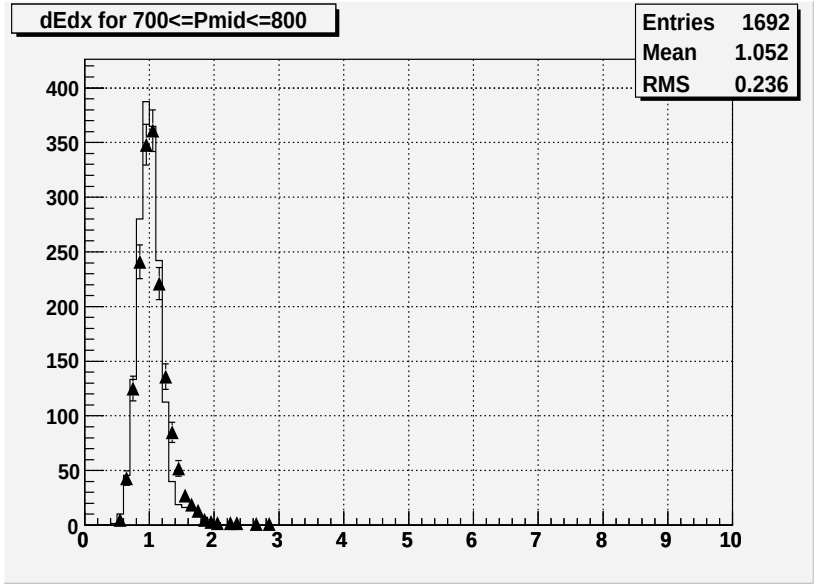


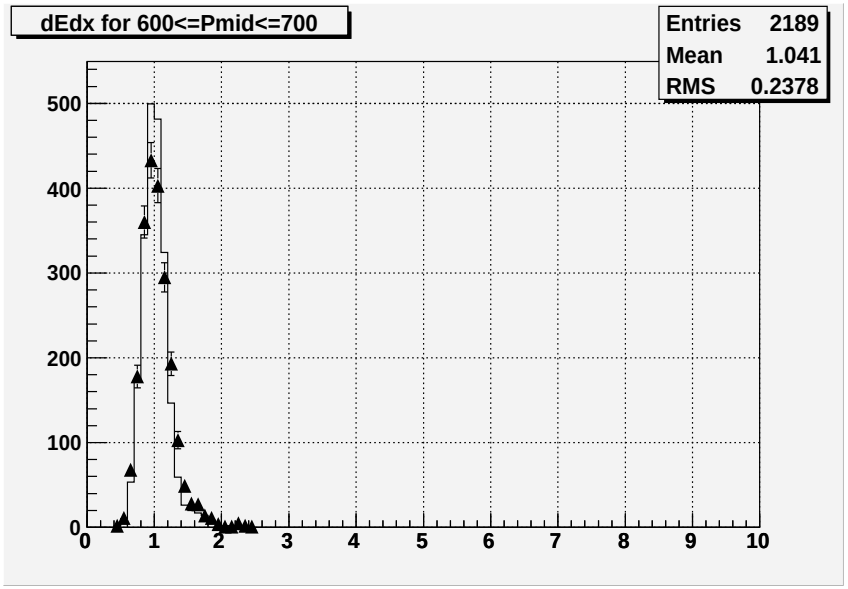


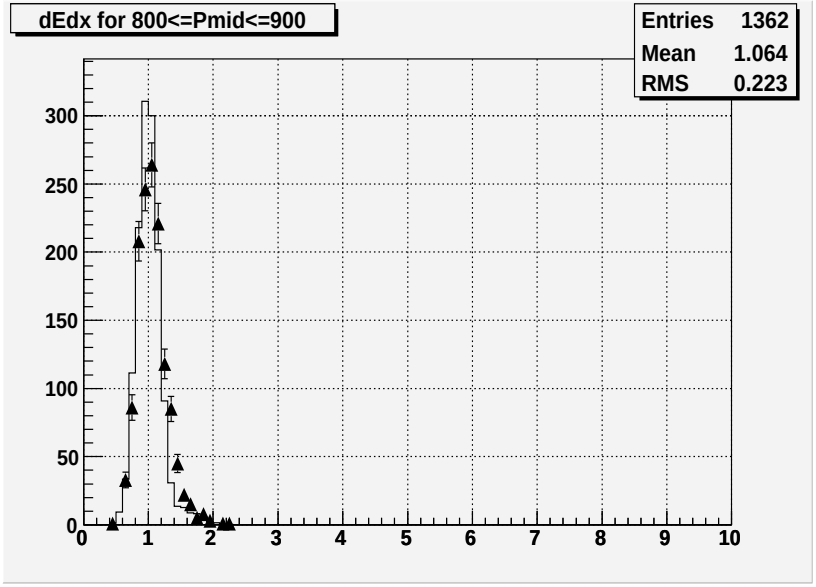


The dE/dx-variable for negative particles before correction:

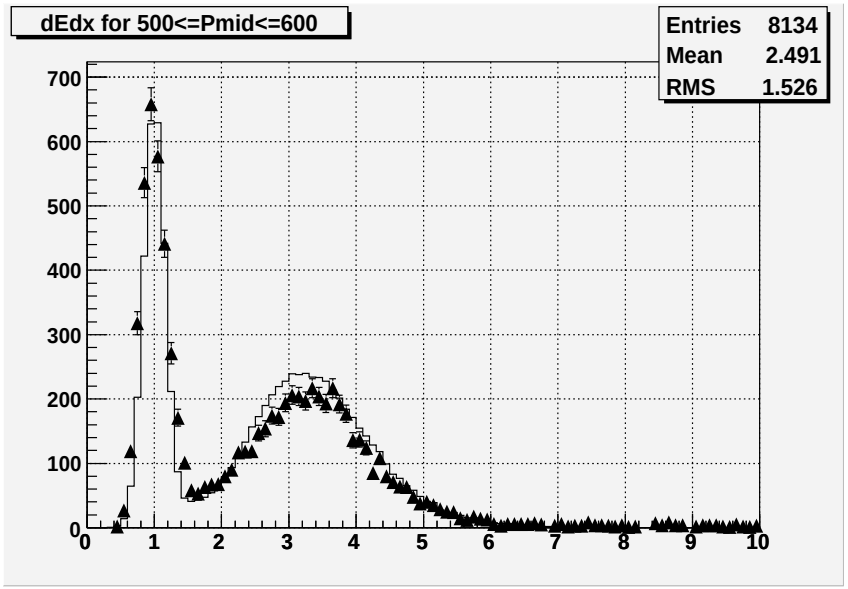


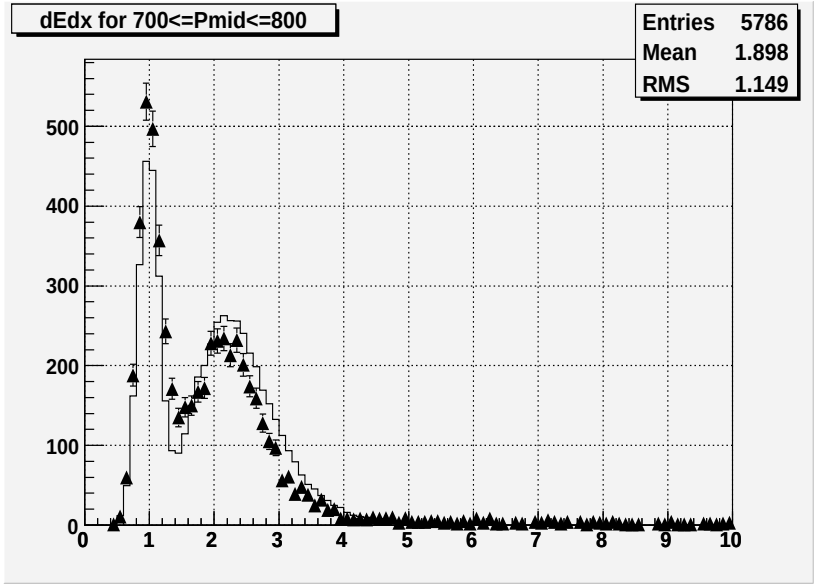


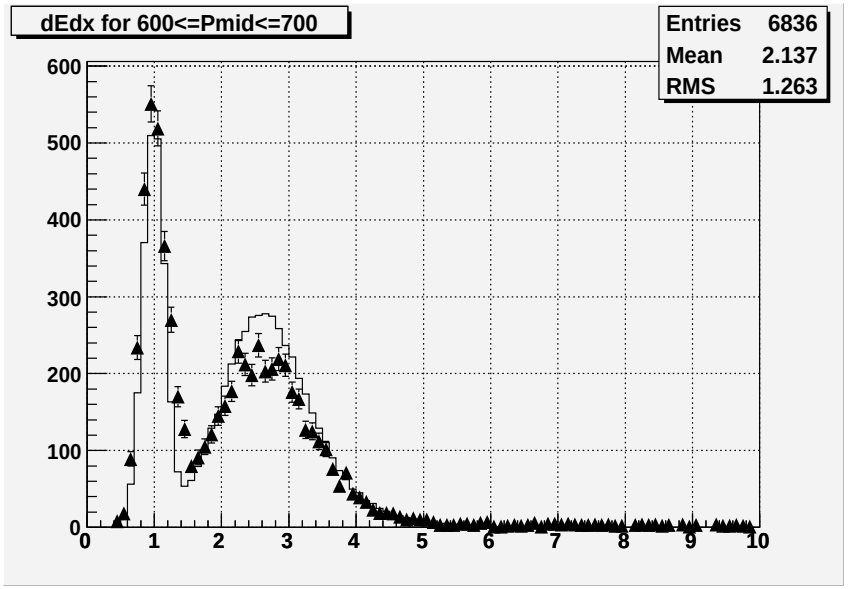


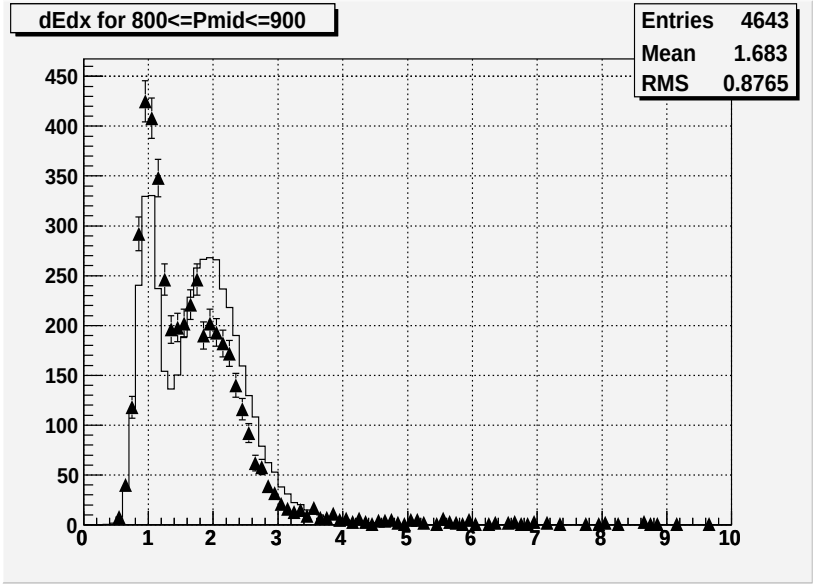


The dE/dx-variable for positive particles before correction:







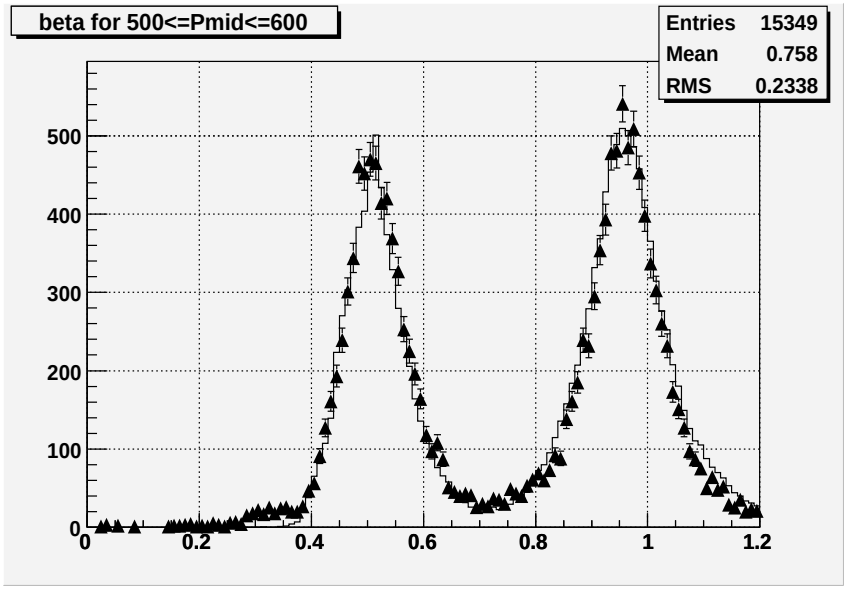


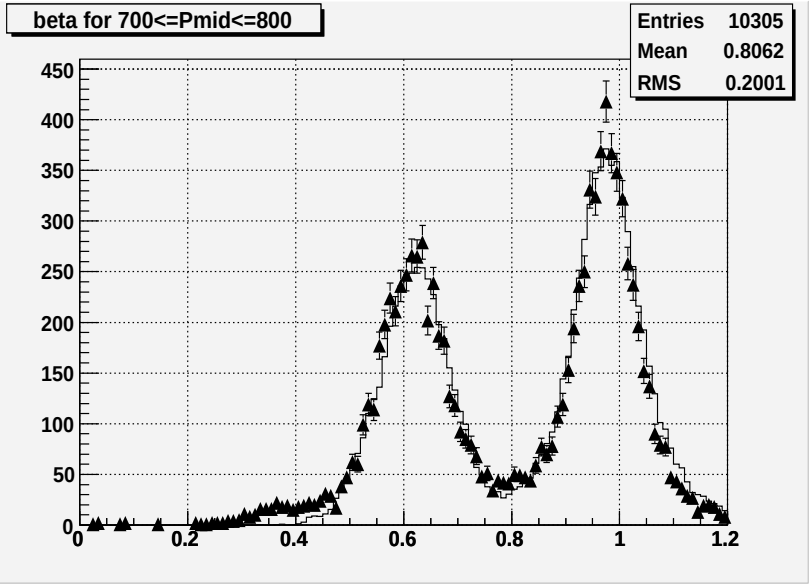
The corrections by Data Be +8,9GeV was:

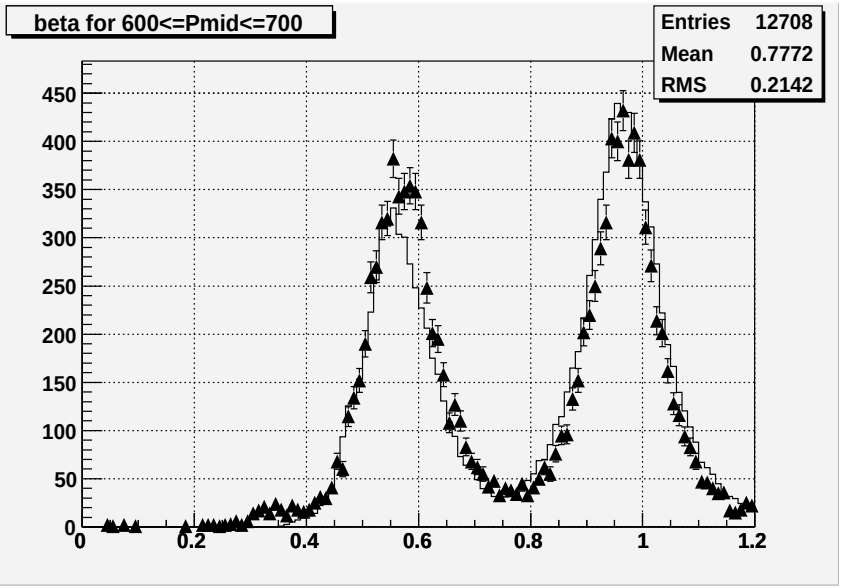
- **Track measurement:**
  - We take the "truth" track polar angle in the TPC gas and smear it by Gaussian with $\sigma = 0.01 * sin^2(\theta)$;
  - We take particle momentum in the TPC gas, and smear q/P_T by a Gaussian, with $\sigma = 0.30$ for pions and electrons and $\sigma = 0.40$ for protons;
  - We add a bias to q/P_T of protons, to reproduce the bias observed in the data. The bias is θ-dependent, +0.15 at $\theta = 90$, and -0.10 at $\theta = 30$, and extrapolated by line between them.
- **RPC timing:**
  - First of all we apply a smearing of "truth" RPC time by 110 ps, to take into account the resolution of beam TOF extrapolation;
  - We smear time by 45 ps, to take into account the "other sources of uncertainty";
  - Next, RPC time is smeared by a Gaussian with the σ equal to the intrinsic resolution. Resolution is a function of padring number, different for π and p. For e we assume the π resolution. We took σ from files provided for us by Igor Boiko;
  - For π and e (not for p) we take into account the timing bias due to backscattering. For certain fraction of tracks (about 10%) we add to the time certain positive delay according to exponential distribution. The fraction of such "delayed" hits and the slope of the exponent are both the functions of padring number;
  - For p we subtract from the time the value 45ps*log(dE/dx), where dE/dx is in units of MIP. This is to correct for steeper rise of avalanche from p.

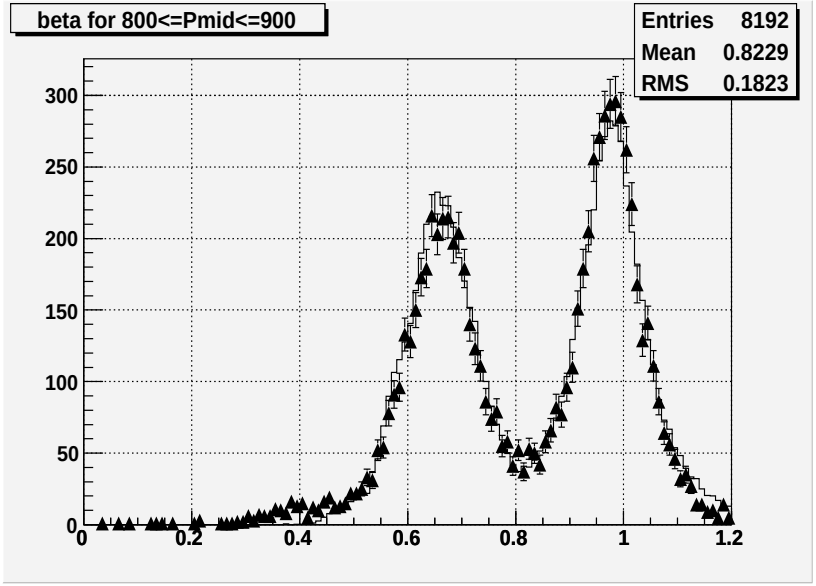
- **Number of particles:**
  - We use coefficient for number of protons 0.5;
  - We use coefficient for number of electrons and positrons 0.45;
  - The coefficient for pions is 1.
- **beta:**
  - We use left shifts for π:
    -0.007 for π^+ and -0.005 for π^-;
  - We use right shift for protons by formula:
    $\delta\beta = 0.005 + (\frac{350}{P})^2 * 0.012$;
    where P - is middle momentum smeared by Gaussian.
- **dE/dx:**
  - For electrons we assume that the expected dE/dx is always 1.55;
  - For pions and protons we calculate expected dE/dx from the Bethe-Bloch formula (using the "truth" momentum);
  - dE/dx was converted to units of MIP (divided by 0.39);
  - Next, we smear the "expected" value by a Gaussian with relative resolution 0.16;
  - For pions only we smear the dE/dx value by Landau with resolution 0.03 and use shift by formula:
    $\delta(dE/dx) = -0.18 + P * 0.0002$;
    where P - is middle momentum smeared by Gaussian.

The β-variable for all particles after correction:

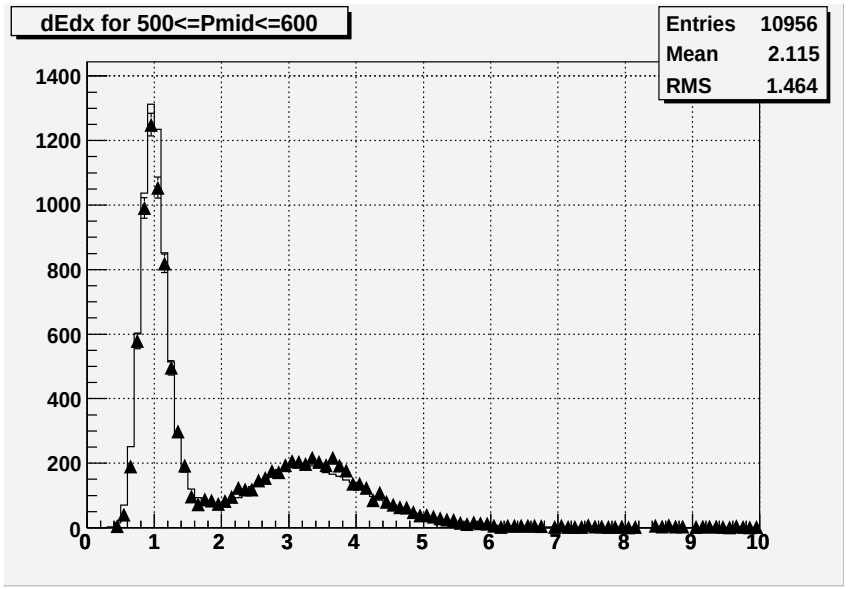


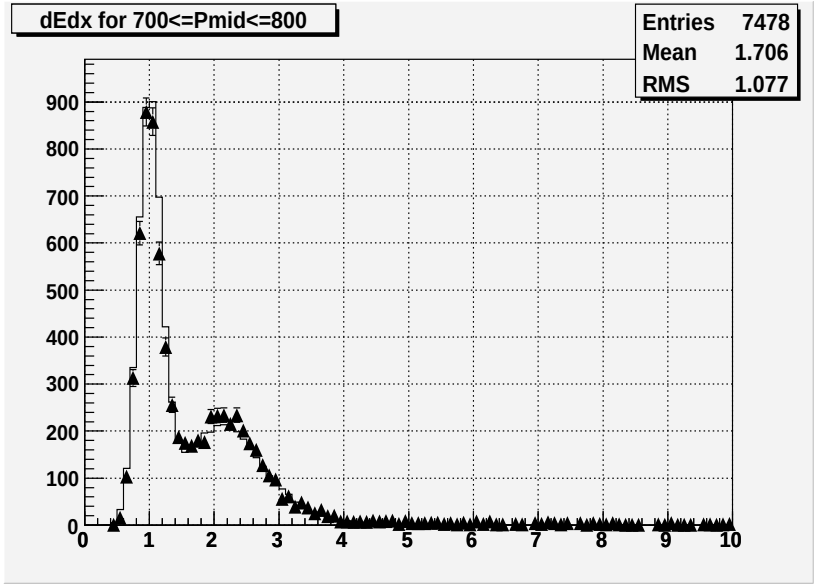


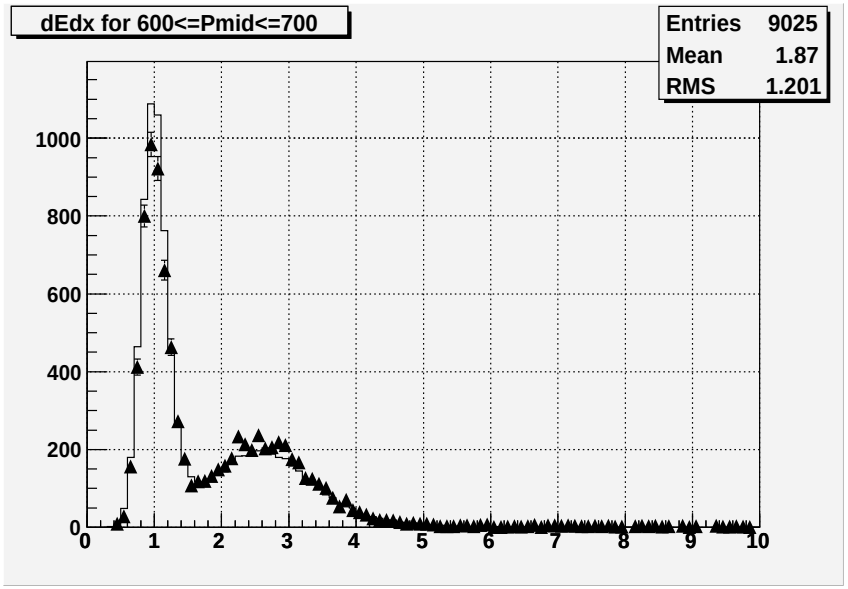


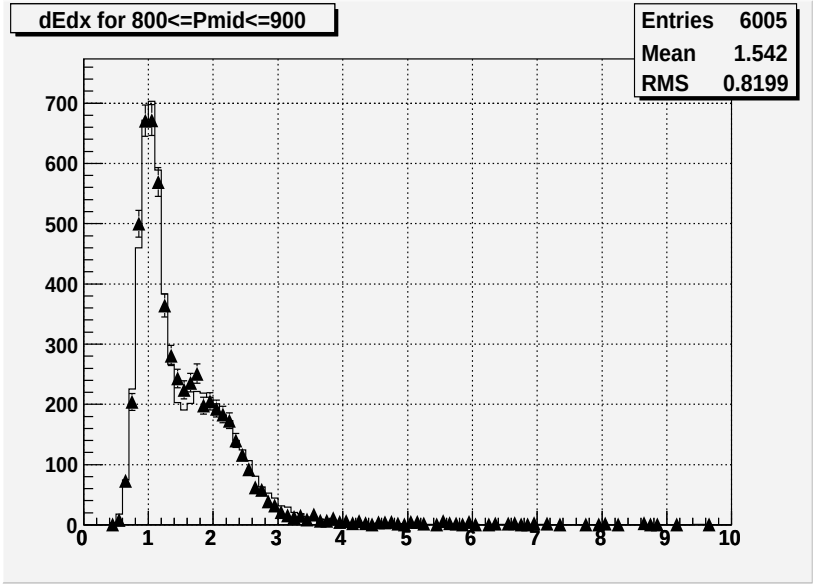


The dE/dx-variable for all particles after correction:









The algorithm of particle identification program

The probabilities of particles are computed by formula (i = p, π, e):

$$P(i|\beta, dE/dx, p_T, \theta) = \frac{P((\beta, dE/dx)|i, p_T, \theta) \cdot N_i(p_T, \theta)}{\sum_{i=1}^{3} P((\beta, dE/dx)|i, p_T, \theta) \cdot N_i(p_T, \theta)}$$

1. The program get particle with 4 variabls: Pt, θ, β, dE/dx ;
2. The program determine $P((\beta, dE/dx)|i, p_T, \theta)$ and $N_i(p_T, \theta)$ from MC tables;
3. The program calculate the Probability of particle.

In the case than:

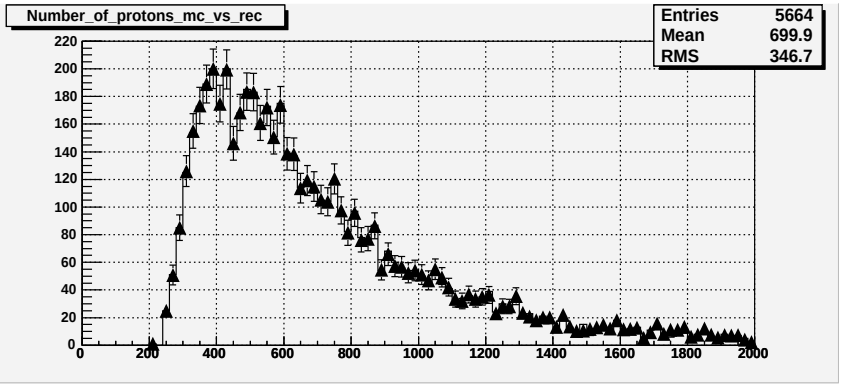
1. β and dE/dx are nonzero $\rightarrow$ Probability(β, dE/dx);
2. β is zero $\rightarrow$ Probability(dE/dx);
3. dE/dx is zero $\rightarrow$ Probability(β).

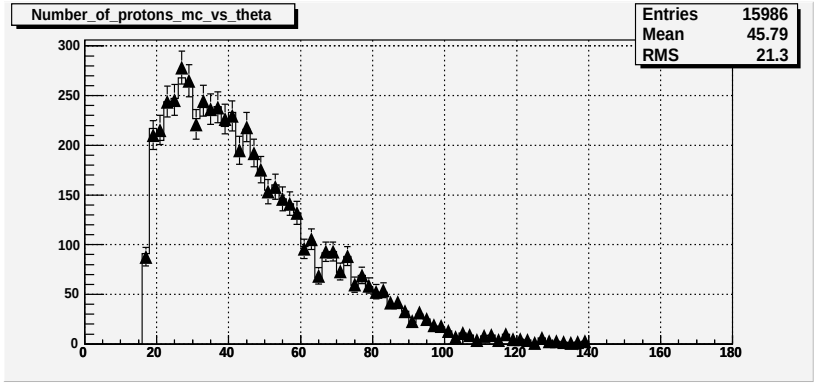
The results of particle identification program

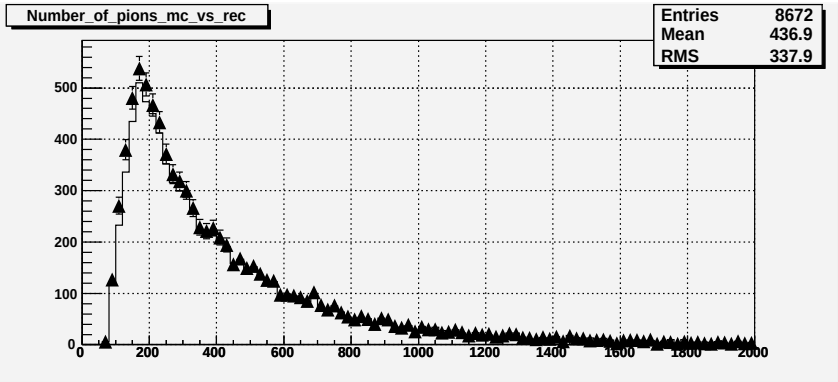
Prob \ mc	p	pi	e	efficiency(%)
p (5658)	5466	192	0	96.6
pi (8670)	271	8252	147	95.2
e (1650)	11	684	955	57.9
sum	5748	9128	1102	
purity (%)	95.1	90.4	86.7	

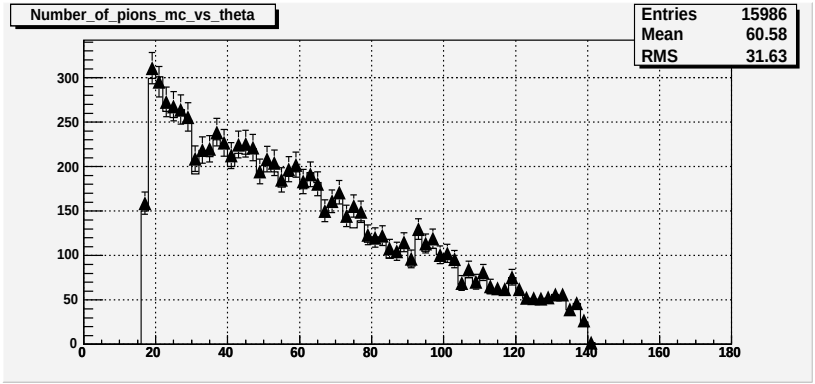
Table 1: *Be 8 GeV by Be 8 GeV.*

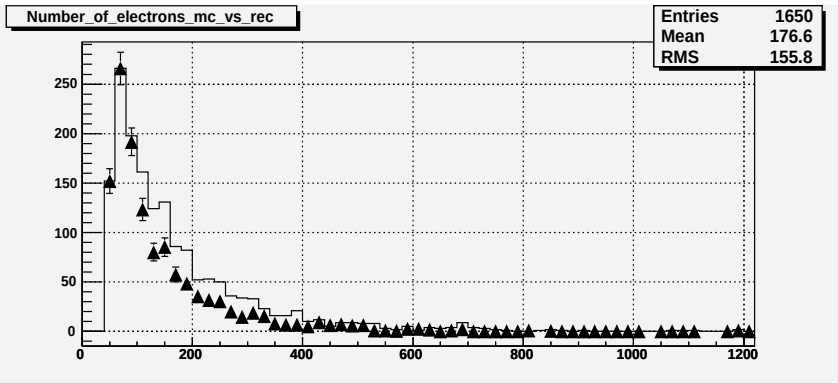
The comparison of MC and identificated particles

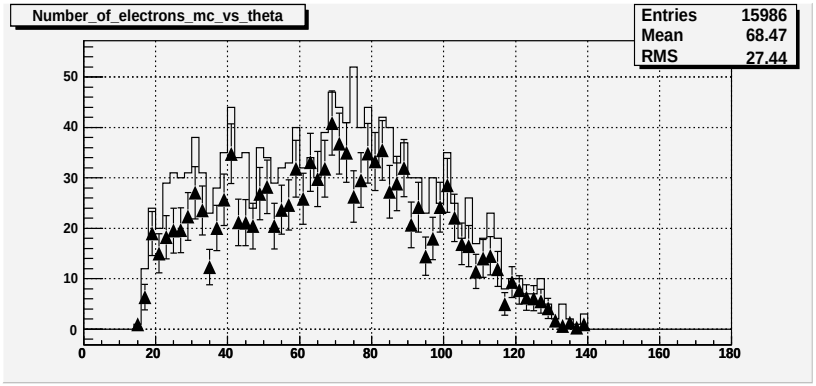












Conclusion

1. We have the particle identification program;

2. This program is checked on Monte Carlo;

3. Our future plans are:
   - to make this program better;
   - to add this program to reconstraction program.