NICA-MPD Physics Seminar

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The first tests of MC data obtained using vHLLE model

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Abstract

The first tests of Monte Carlo production (generator+GEANT+reconstruction) of Au+Au collisions at $\sqrt{s_{NN}}$=11.5 GeV within the vHLLE model are presented. The results of particle identification using ionization energy loss (dE/dx) in the TPC and the time-of-flight information (β) from TOF in the MPD experimental setup are shown. The technical issues of generating a response (energy loss) of the TPC is discussed.

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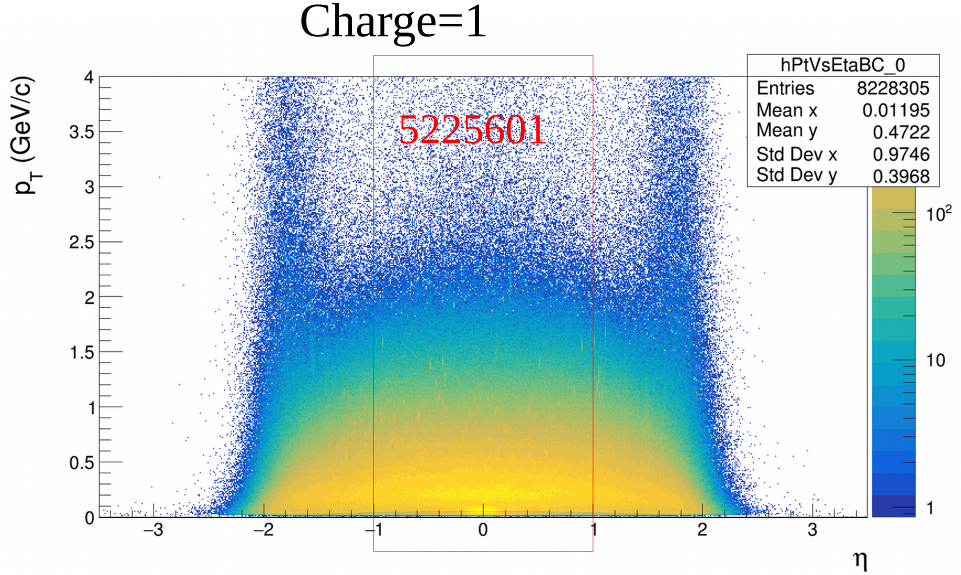
Outline

- MC production (vHLLE+GEANT+reconstruction) Au+Au
  - Statistics: ~7e5 $\sqrt{s_{NN}}$=11.5 GeV 0-5%
  - $|Z_{vert}|$<50 cm, $|\eta| < 1$, number of TPC hits > 20, $p_T > 0.1$ GeV/c
- PID using dE/dx in TPC
- PID using TOF
- Bayesian PID
- Conclusions

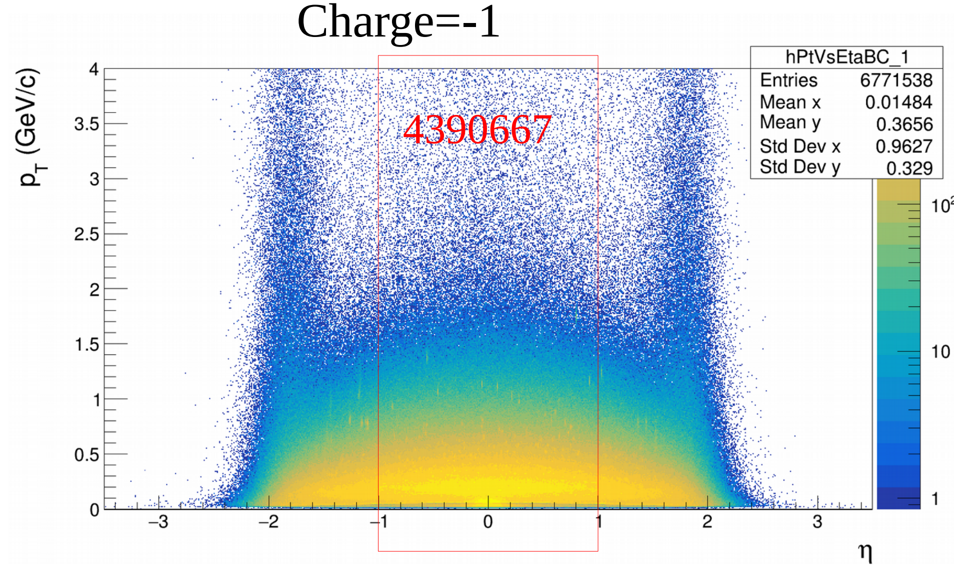
Acceptance: AuAu $\sqrt{s_{NN}}$=11.5 GeV 0-5% (vHLLE+GEANT+Rec)

Before any cuts

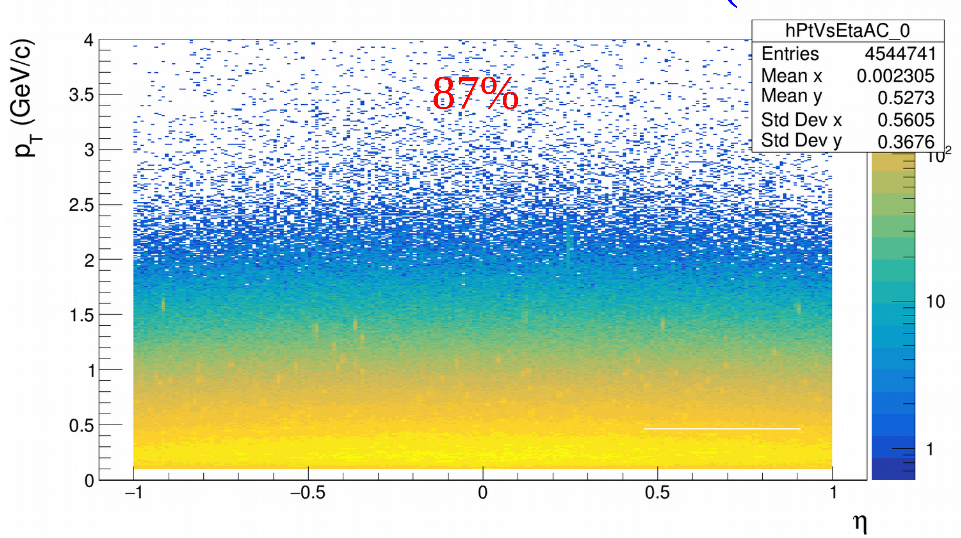
Charge=1

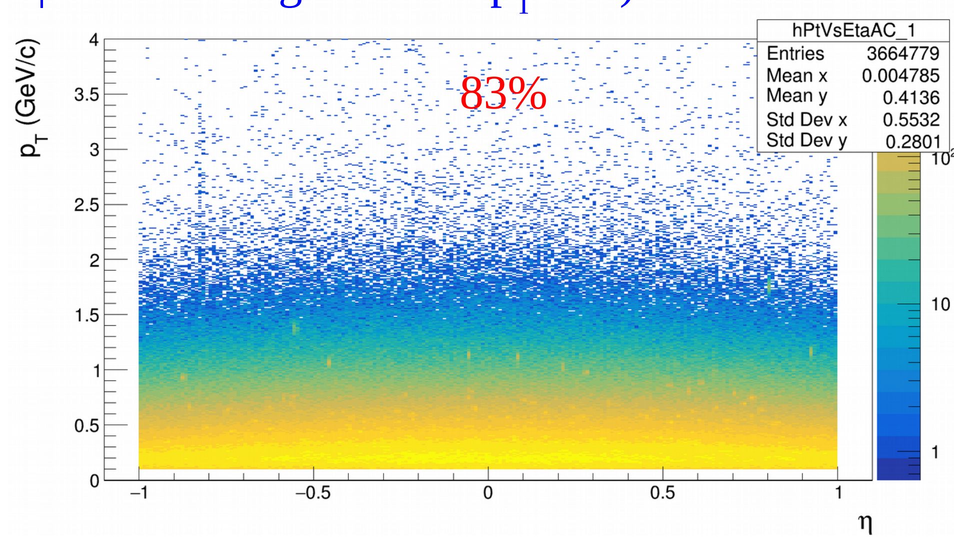


Charge=-1



After cuts(nHits>20 && |eta|<1 && charge!=0 && p_T>0.1)

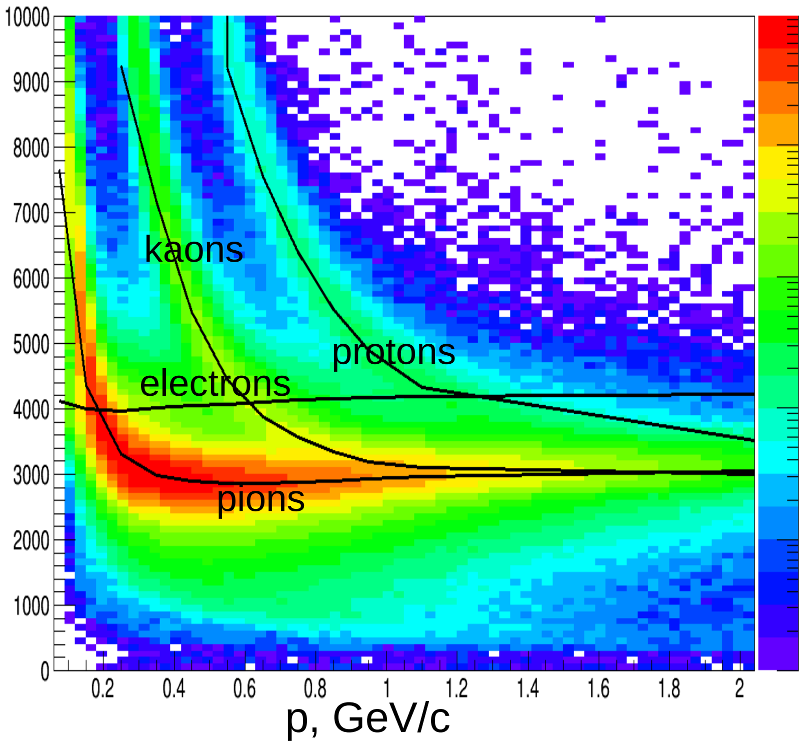




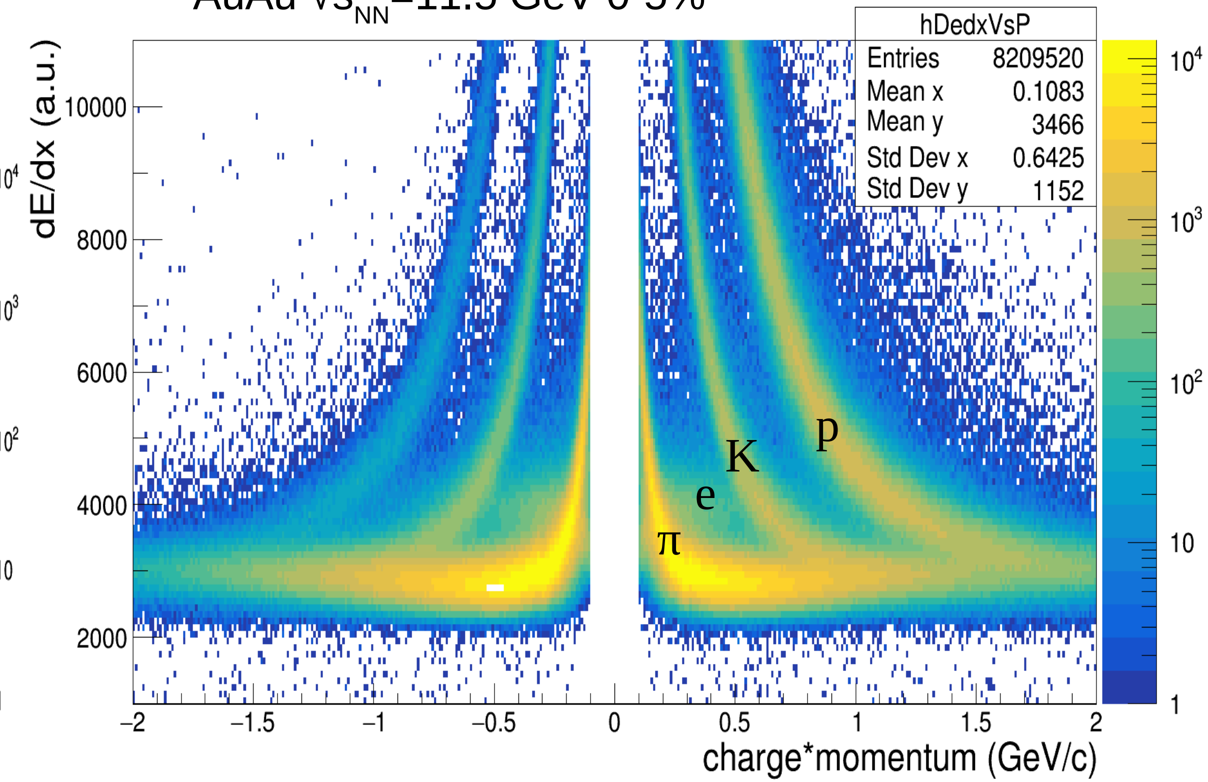
- About 15% of tracks got lost after cuts

TPC ionization energy loss

AuAu $\sqrt{s_{NN}}$=7.7 GeV 0-5%

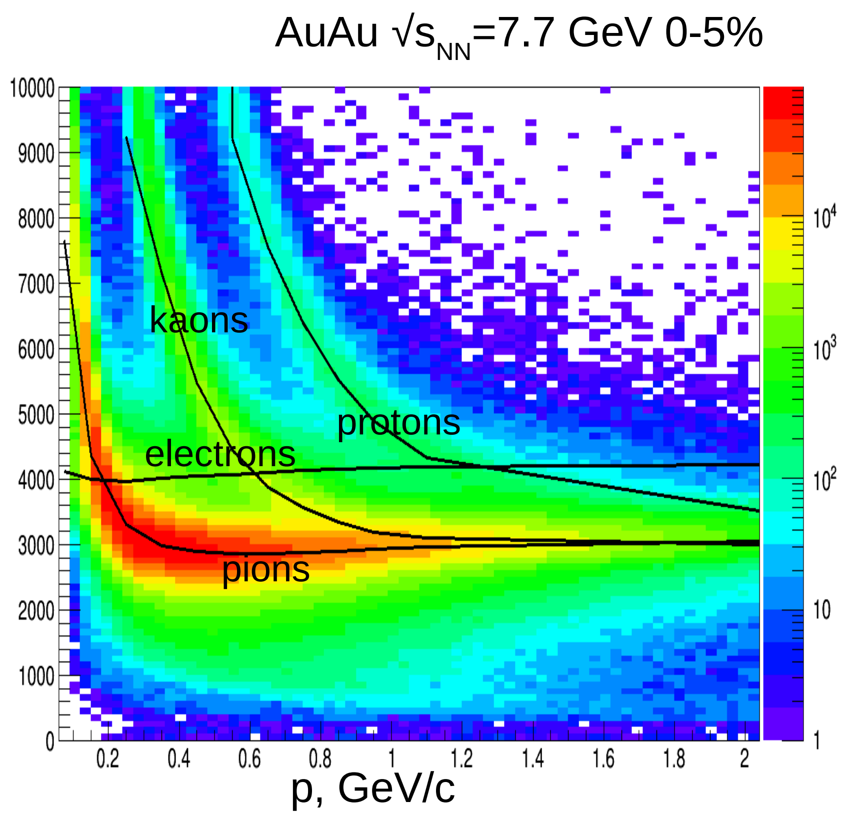


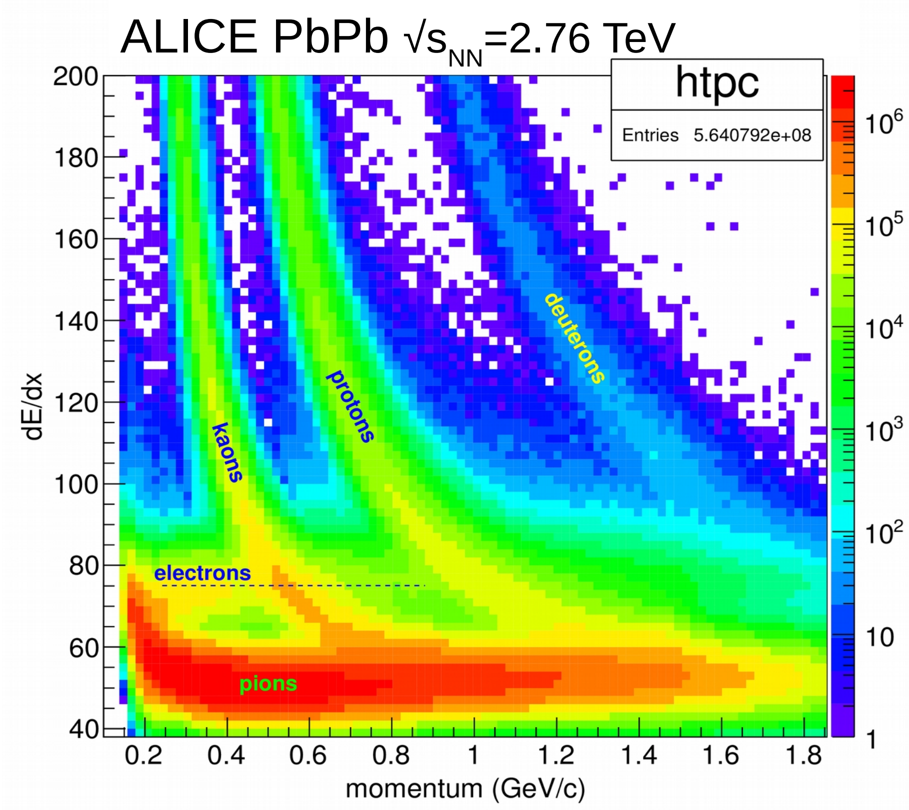
AuAu $\sqrt{s_{NN}}$=11.5 GeV 0-5%



- Previous (left) and new (right) results looks similar
- It is possible that new results show less background ?

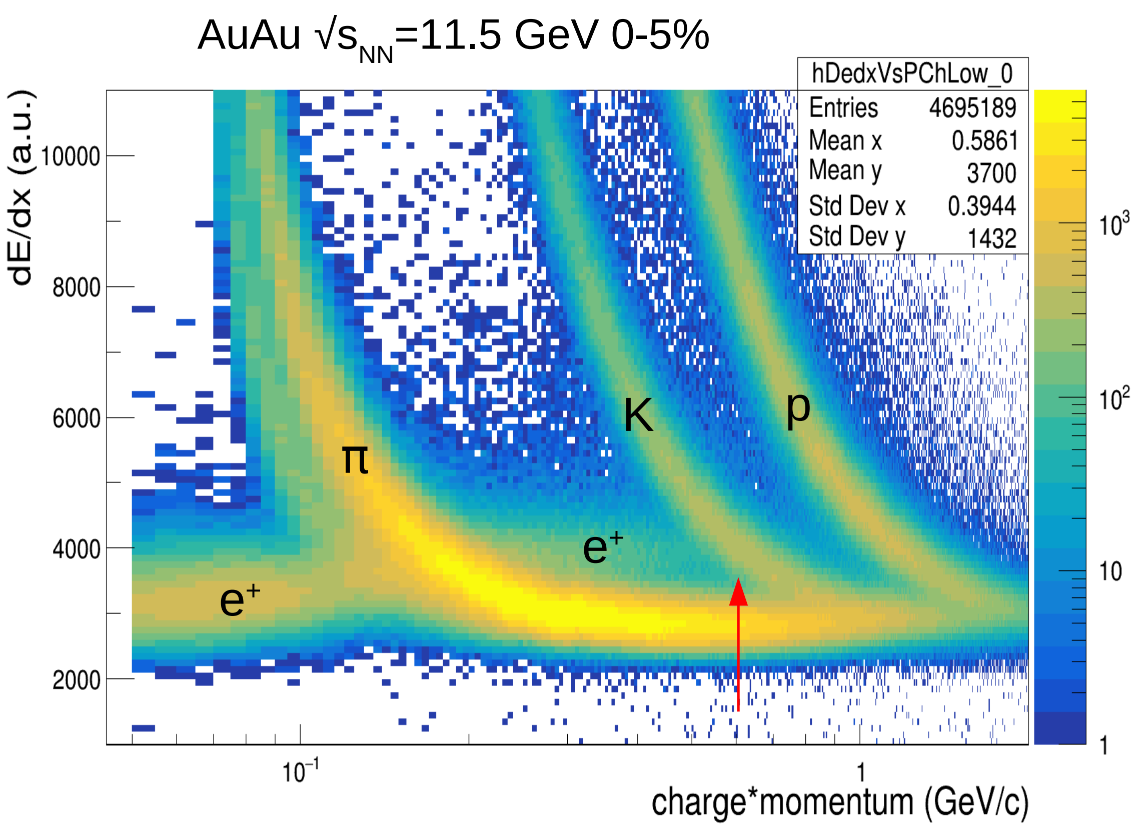
TPC energy loss MPD and ALICE

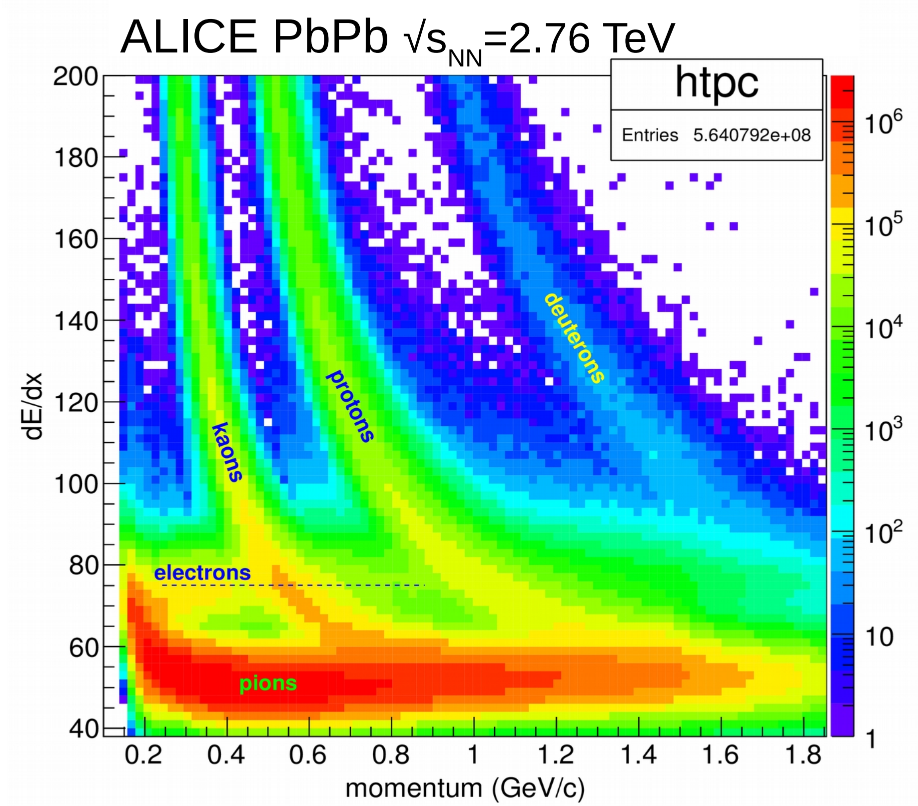




- MPD MC(left) and ALICE data(right) TPC dE/dx – qualitatively similar
- But the intersection of e and K curves are in different places
- MPD MC: at p~0.6 GeV/c, ALICE data: at p~0.45 GeV/c

TPC energy loss MPD and ALICE





- MPD MC(left) and ALICE data(right) TPC dE/dx – qualitatively similar
- But the intersection of e and K curves are in different places
- MPD MC: at p~0.6 GeV/c, ALICE data: at p~0.45 GeV/c

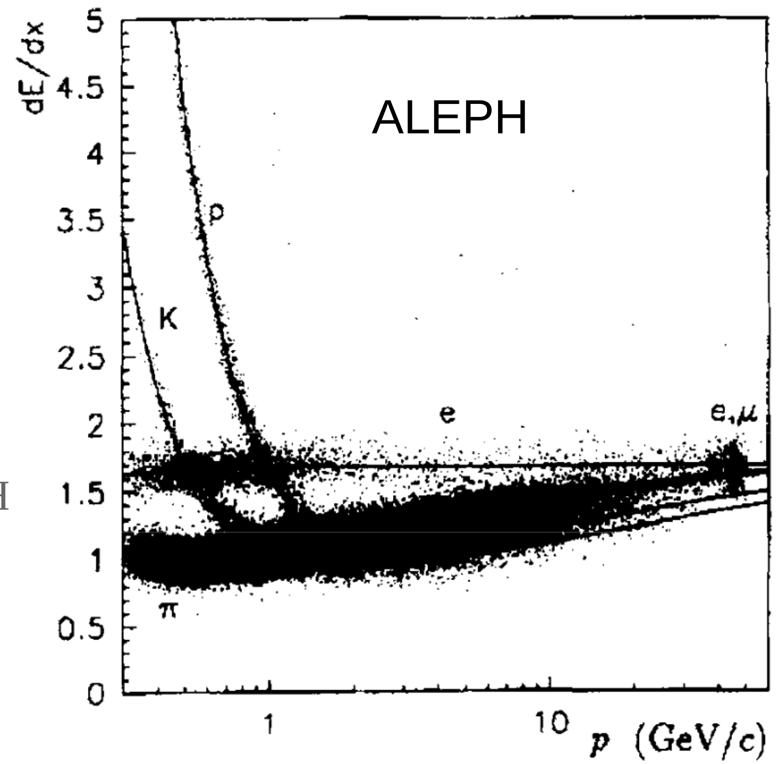
Nsigma PID procedure

- The value of mean and σ is obtained from the projection TPC dE/dx for each given momentum
  - Truncation procedure is used:

    Initially dE/dx is Landau distributed; but long tail influences particle separation
  - Data were truncated:
    - the fit was done in the region +/- RMS of the maximum position of energy loss distribution
    - data distribution became Gaussian-like
- The procedure is done separately for each particle.
- The data obtained are fit using the Bethe-Bloch energy loss formula in ALEPH parametrization:

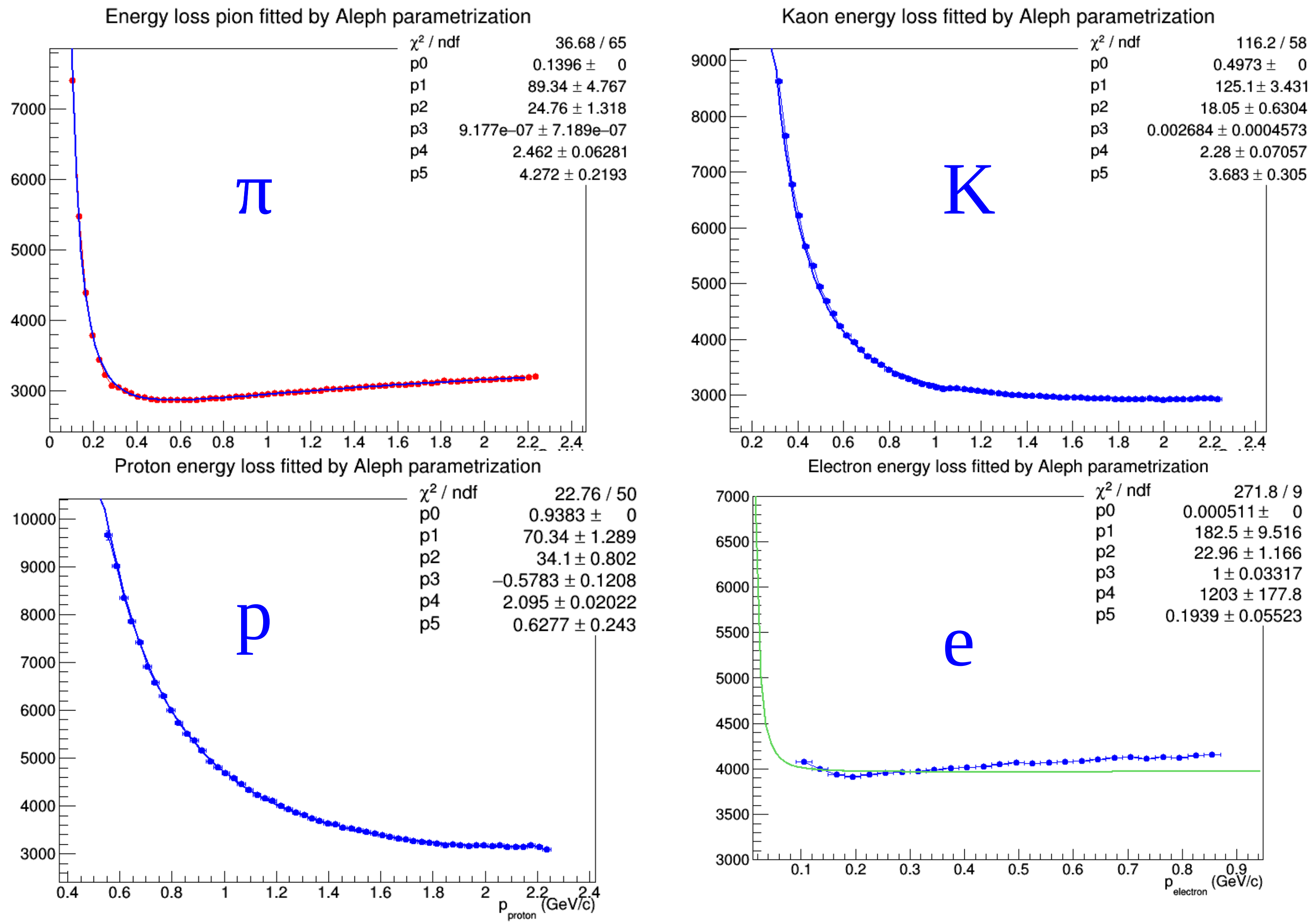
$$f(\beta\gamma) = \frac{P_1}{\beta^{P_4}} \cdot \left\{ P_2 - \beta^{P_4} - \ln\left[P_3 + \frac{1}{(\beta\gamma)^{P_5}} \right] \right\}$$

[ALEPH Collaboration, D. Buskulic et al., "Performance of the ALEPH detector at LEP," Nucl. Instrum. Meth. A360 (1995) 481–506.]



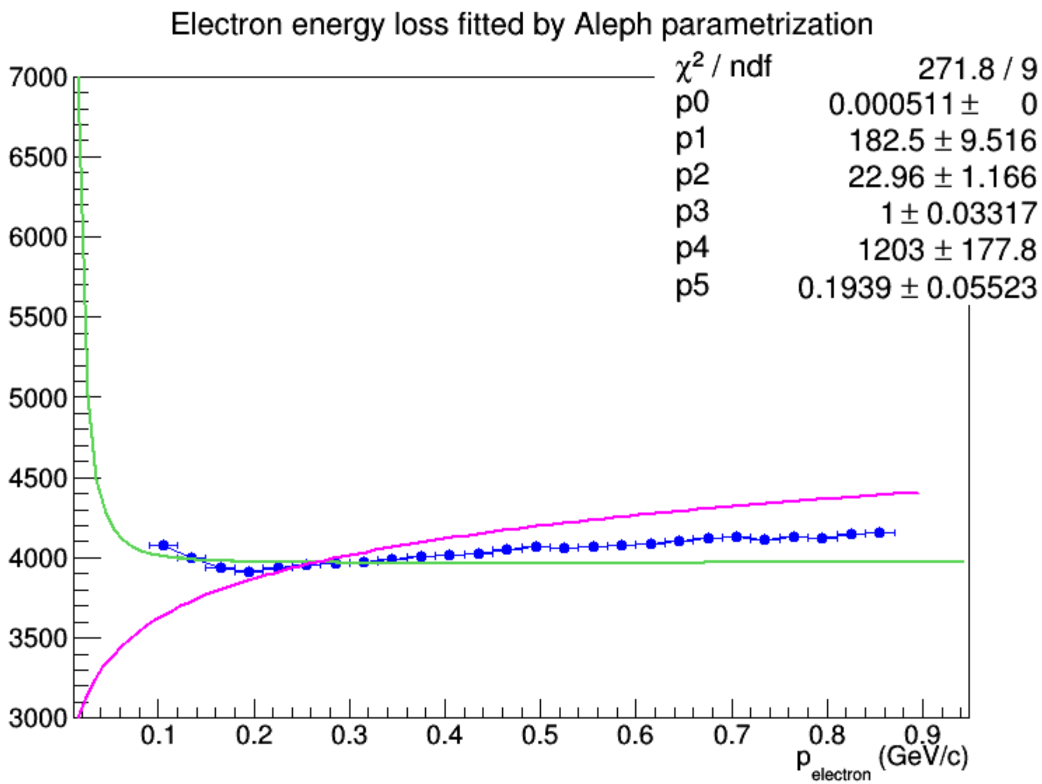
Example of MPD TPC energy loss parametization

AuAu $\sqrt{s_{NN}}$=7.7 GeV 0-5%



- ALEPH fit does very good job for π, K and p
- The problem is only for electrons

Fit problem for electrons



- MC dE/dx vs momentum for e
- Green – fit by Aleph parametirzation

$$f(\beta\gamma) = \frac{P_1}{\beta^{P_4}} \cdot \left\{ P_2 - \beta^{P_4} - \ln\left[P_3 + \frac{1}{(\beta\gamma)^{P_5}} \right] \right\},$$

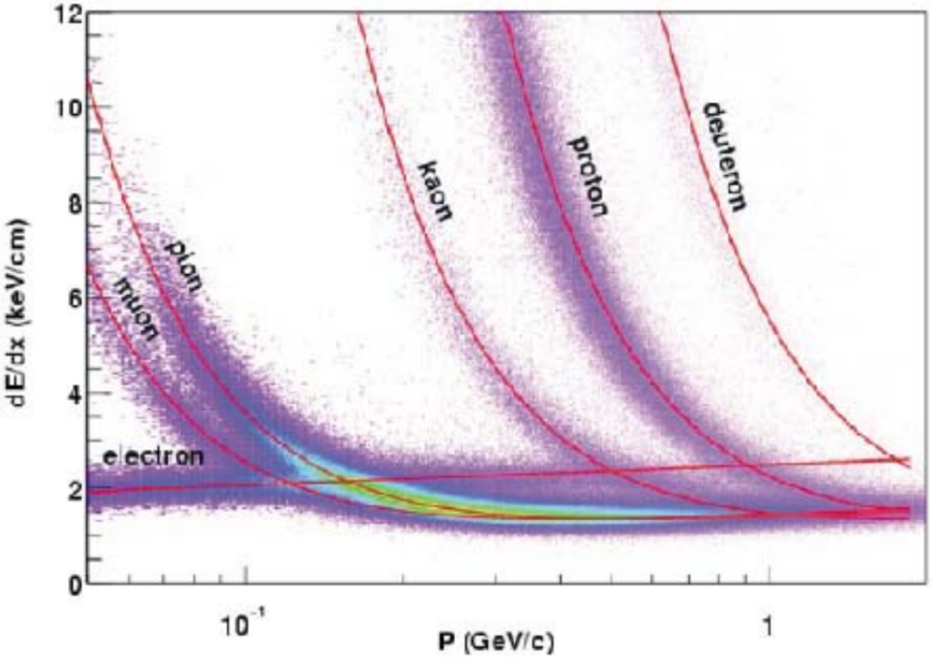
- The fit failed
- Bethe-Bloch calculation (magenta):

$$\left\langle -\frac{dE}{dx} \right\rangle = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 W_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

energy loss for electrons should go down with decreasing momentum at low momenta region

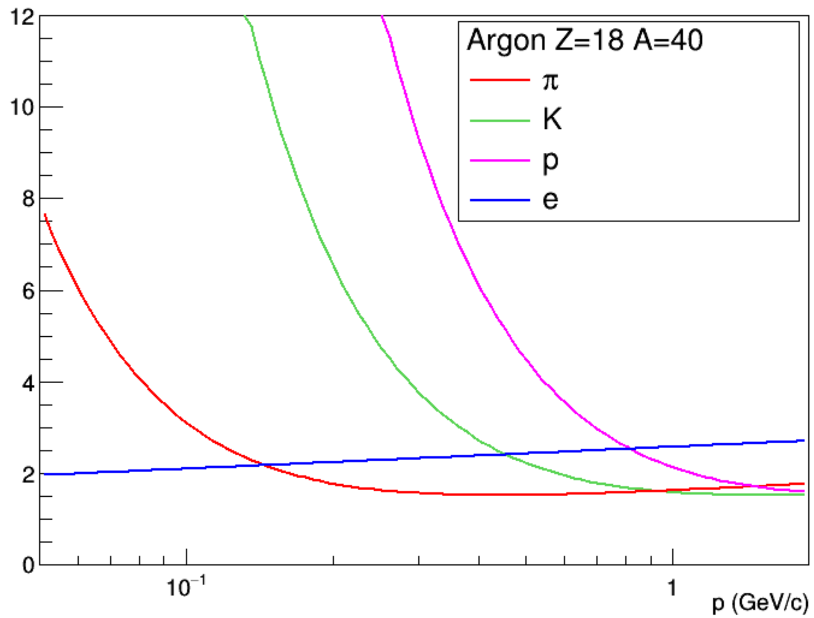
- MPD MC: ionization energy loss for electrons go up with decreasing momentum at low p

STAR and Bethe-Bloch

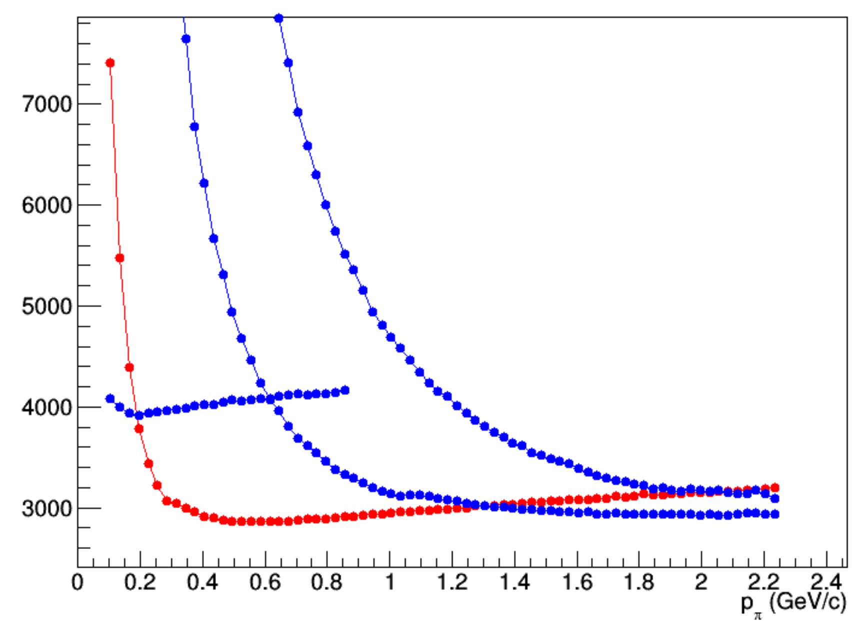


- dE/dx vs momentum in STAR TPC
- The intersection of e and K curves for STAR(and ALICE) and Bethe-Bloch calculations are at about 0.45 GeV/c
- The Bethe-Bloch formula for Ar gas shows same result (*STAR TCP: 90%Ar+10%CH_4*)
- ALICE&STAR: GEANT3 is not optimal for TPC dE/dx simultions
- MPD e and K at 0.6 GeV/c : GEANT3 (see A.Zinchenko talk)

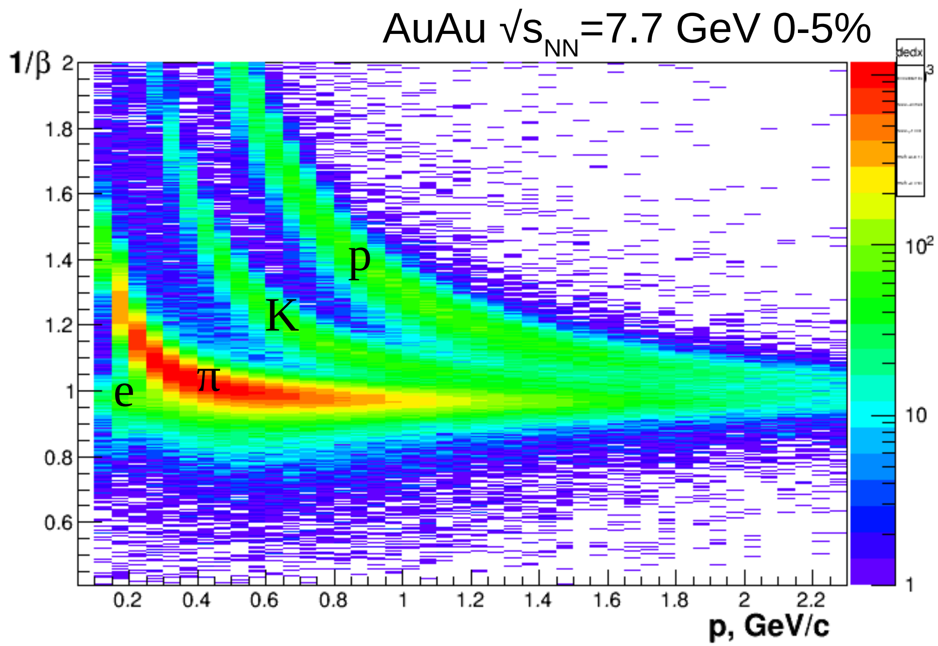
Energy loss by Bethe-Bloch equation

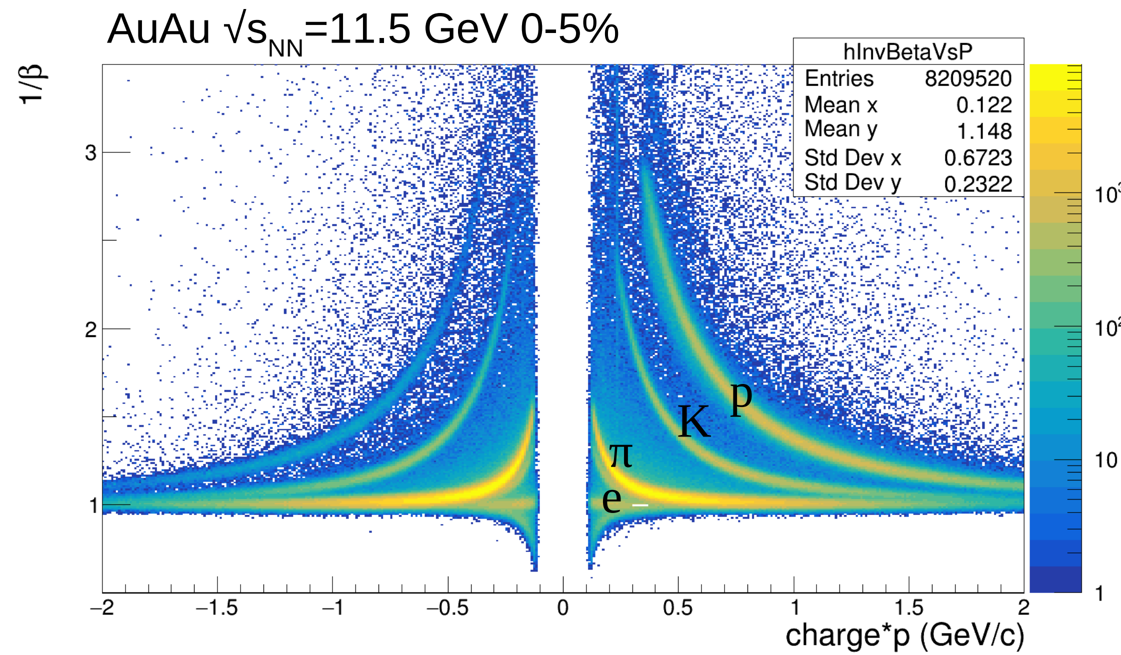


Energy loss pion fitted by Aleph parametrization



TOF response

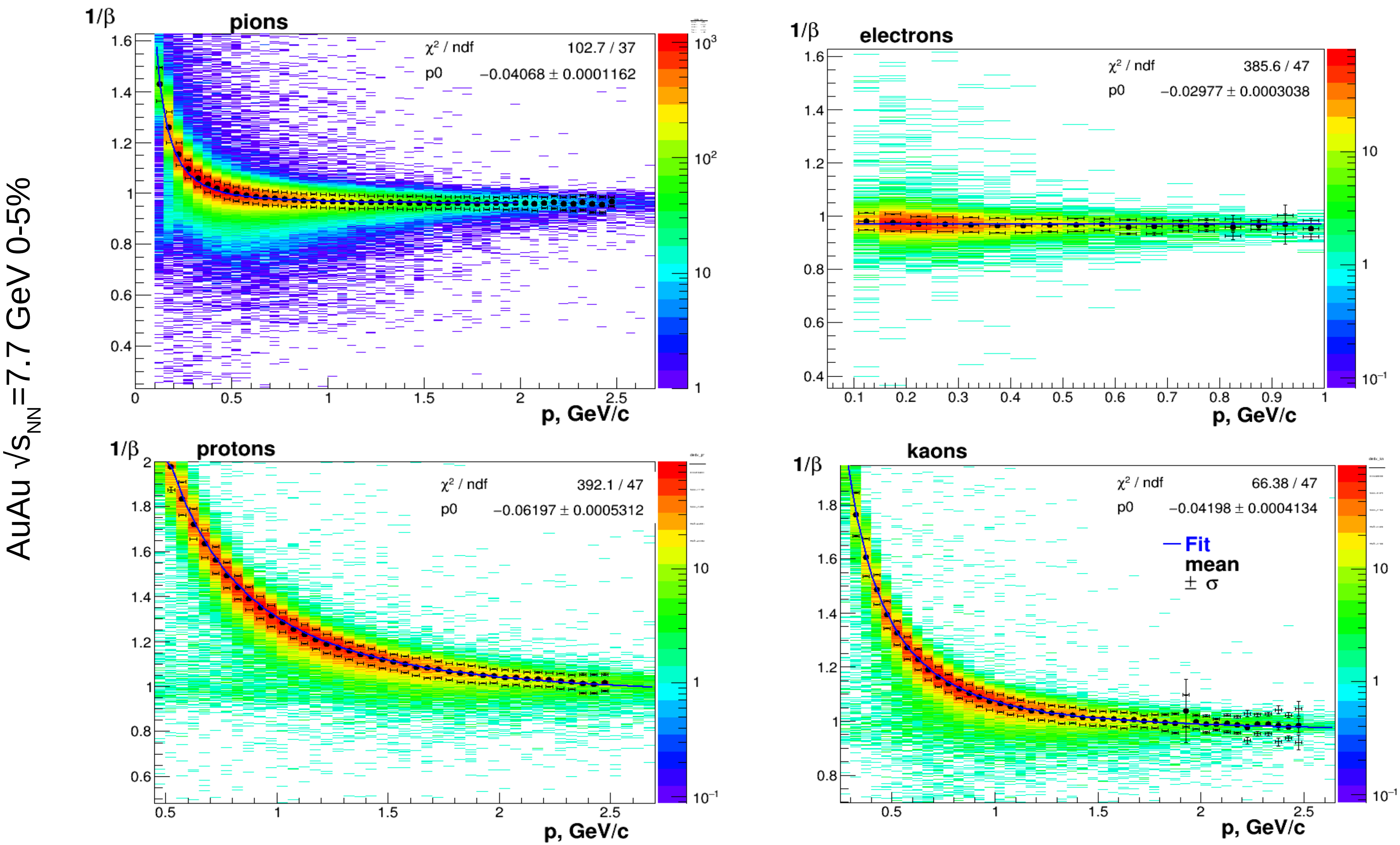




- Previous (left) and new (right) results looks similar
- It is possible that new results show less background ?

Nσ for TOF signal

- TOF vs p is fit with hyperbolic function with additional parameter: $\frac{1}{\beta}=\sqrt{1+\left(\frac{m}{p}\right)^2}+p0$
- The value of sigma is obtained from the projection for each momentum
- TOF Nσ's are not in DST (TPC Nσ's are in DST, but they are junk)



Bayesian PID

- Bayesian probability:

$$P(i) = \frac{1}{\sqrt{2\pi}\sigma_{dE/dx}} \exp\left(-\frac{((dE/dx)_{meas} - (dE/dx)_{BB,i})^2}{2\sigma^2_{dE/dx}}\right)$$

- Weight:

$$w(i) = \frac{C(i)P(i)}{\sum_k P(k)w(k)}, \quad C(i) = \text{a'priori probabilities.}$$

for now: C(i) =1, w(i)>0.9

- Efficiency of the identification of type i:

$$\epsilon_i(p) = \frac{dN^{meas}_{ii}/dp}{dN_i/dp}$$

N_{ii}^{meas} – particles identified as type i

N_i – all generated particles type i

- Purity:

$$f_i(p) = \frac{dN^{true}_{ii}/dp}{dN^{meas}_{i}/dp}$$

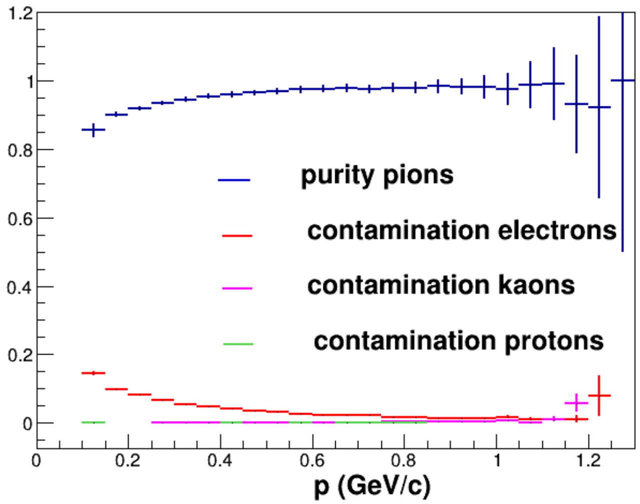
N_i^{meas} – all particles identified as type i

N_{ii}^{true} – all generated identified as particles type i

Bayesian PID performance: pions

– A. Mudrokh PID class was used –

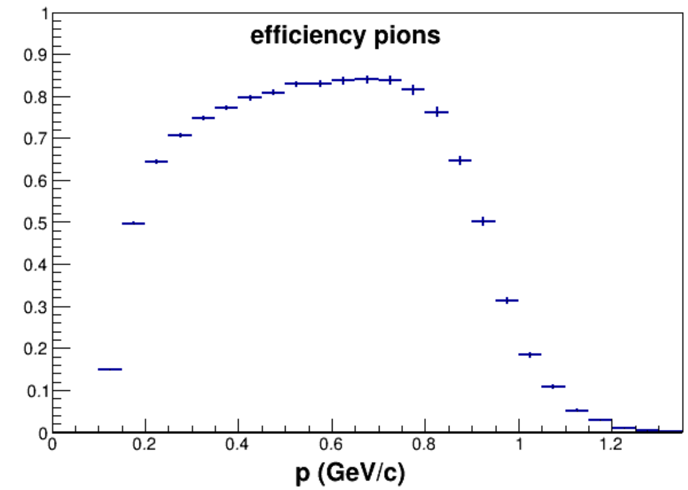
Purity and contamination



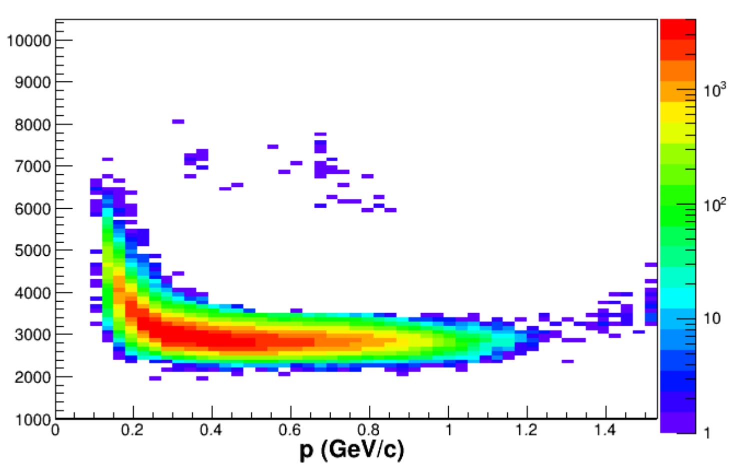
- Purity is about 0.95
- Purity decreases:
  at low momenta due to electron contamination;
  at p>1 GeV/c due to Kaon contamination.

- Efficiency significantly decreases at p<0.3 and p>0.8 GeV/c

Efficiency

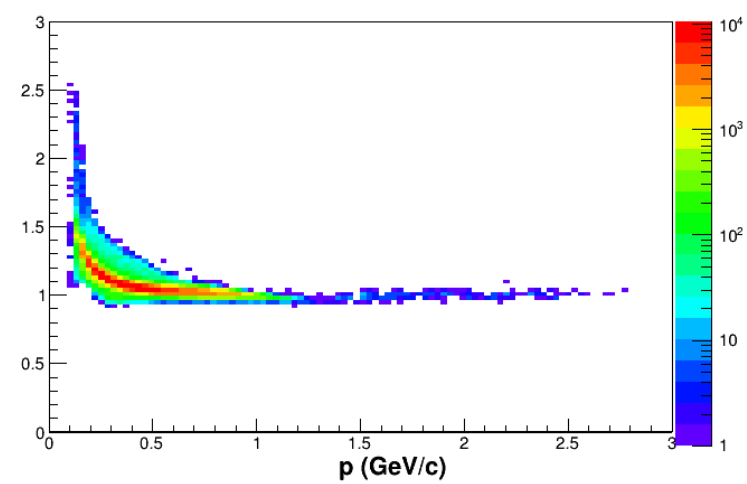


dE/dx of selected pions



- A little contamination can be seen at TPC plot
- TOF plot looks clean enough

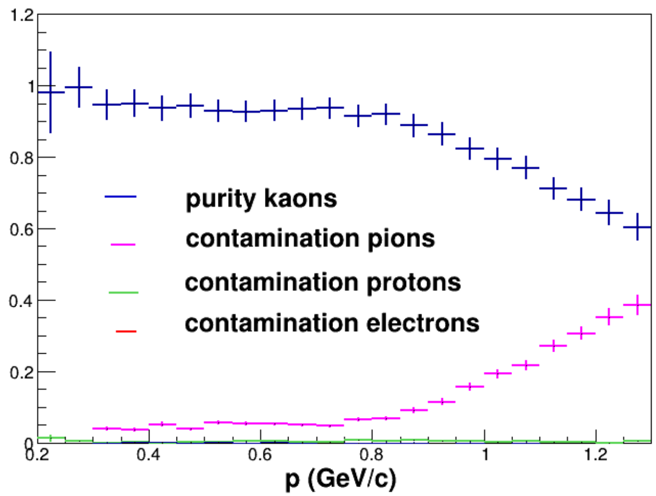
1/β of selected pions



Bayesian PID performance: kaons

– A. Mudrokh PID class was used –

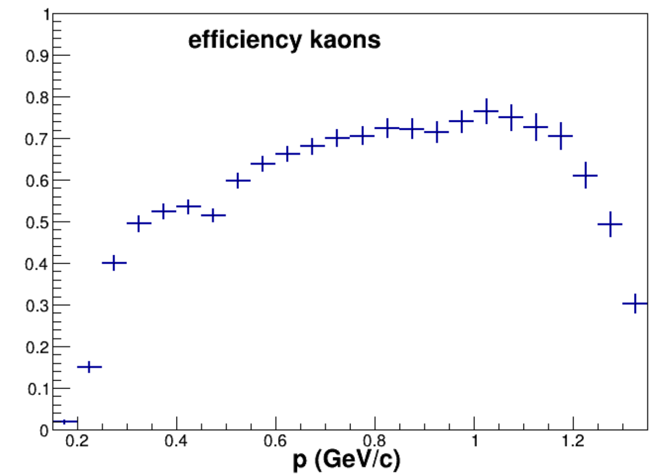
Purity and contamination



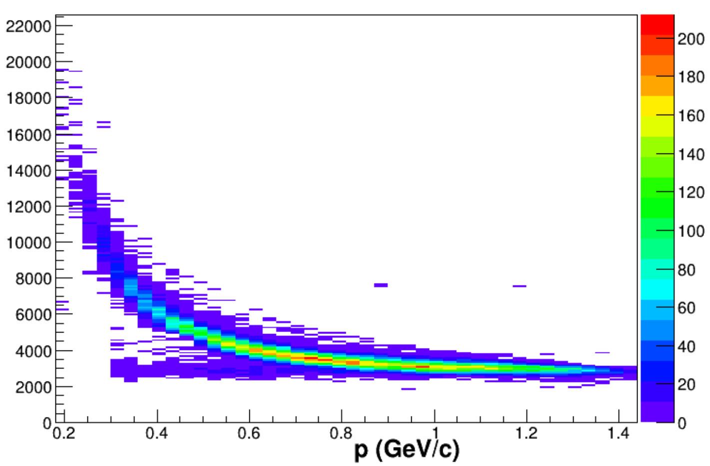
- Purity is about 0.95
- Purity decreases starting from p>0.8 GeV/c → due to pion contamination;
  electron contamination is negligible

- Efficiency is not flat
  Maximum value is ~0.75

Efficiency

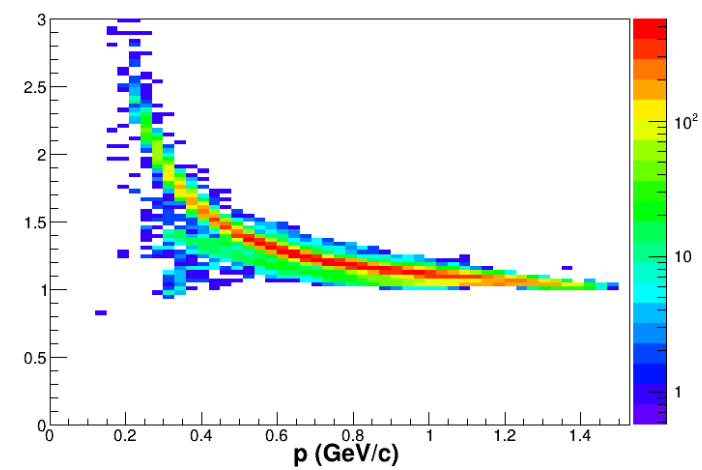


dE/dx of selected kaons



- π contamination
  is seen at both TPC
  and TOF plot

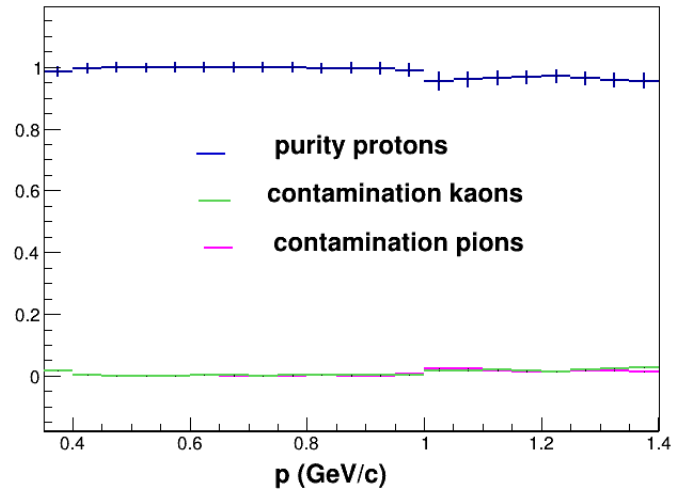
1/β of selected kaons



Bayesian PID performance: protons

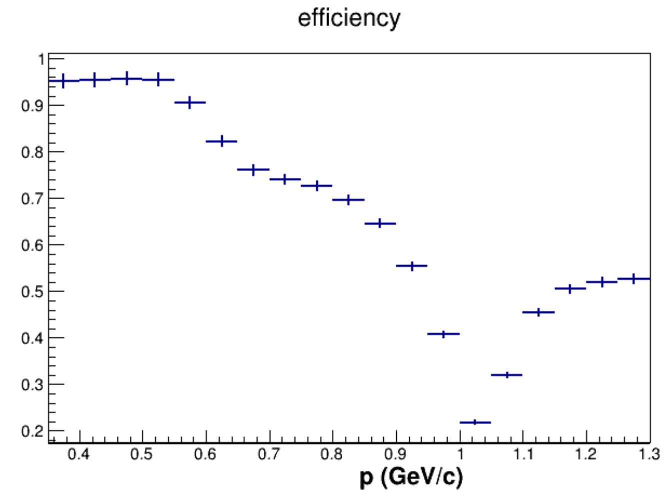
– A. Mudrokh PID class was used –

Purity and contamination

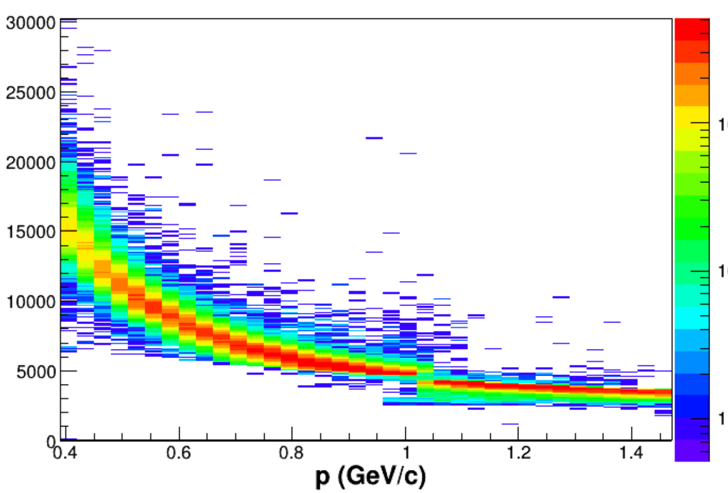


- Purity is rather stable ~1
- K,π contamination is at p>1 GeV/c
- Efficiency is not flat; 0.95 p<0.55 GeVc; minimum arount p=1GeV/c

Efficiency

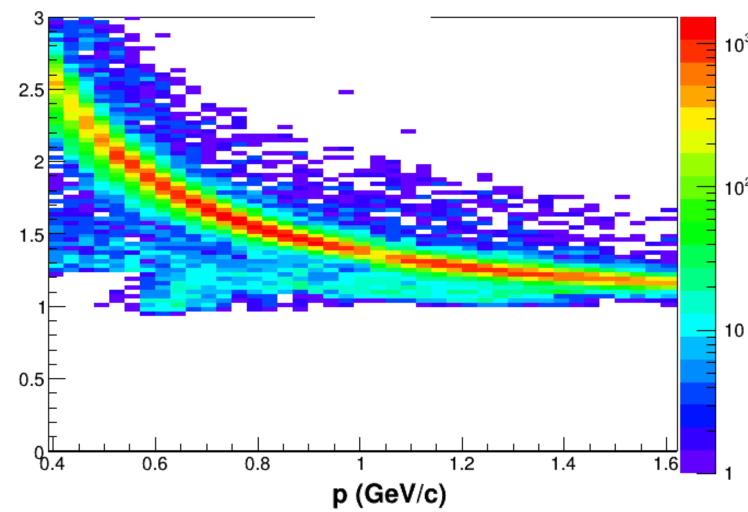


dE/dx of selected protons



- Some contamination is seen at TPC and TOF plot

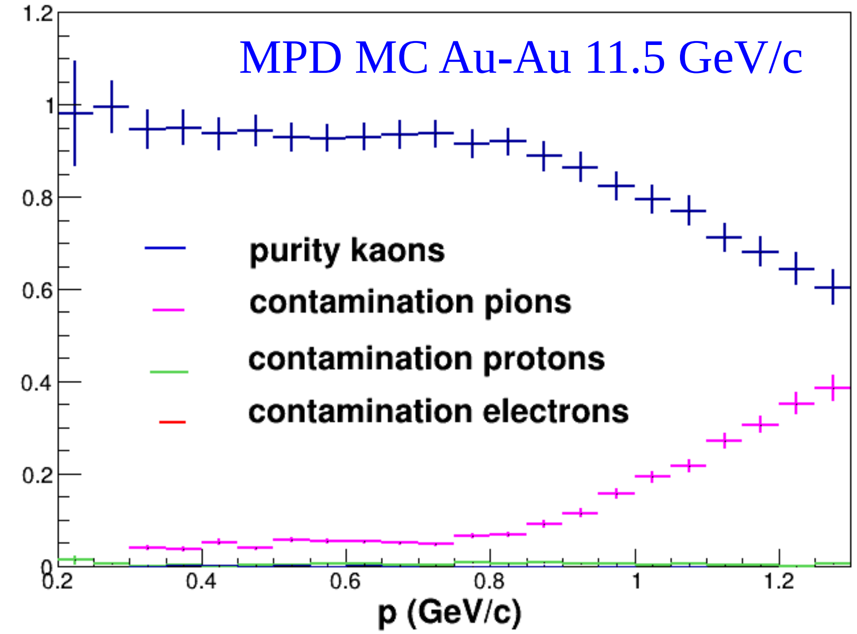
1/β of selected protons



Kaon purity and contamination

MPD MC (Bayesian PID)

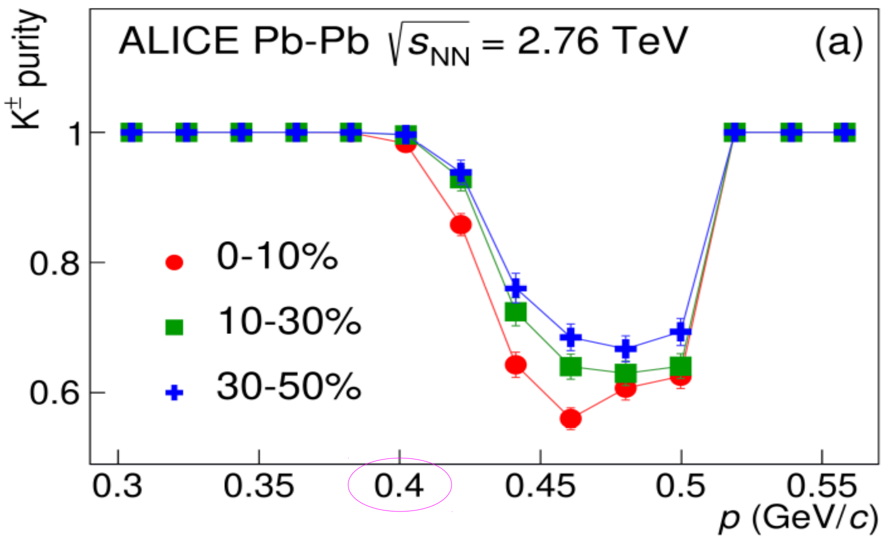
- Kaon purity ~ 0.95 at p<0.8 GeV/c
- Purity drops down starting from p~0.8 GeV/c
  and reaches value about 0.6 at p~1.3 GeV/c
- The main contamination is due to pions
- Electron contamination is negligible



ALICE (Nsigma PID)

- Purity is about 1 in wide momentum range
- The major contamination is due to electrons
- Purity drops down to 0.6 at 0.4<p<0.5 GeV/c

- Significant difference is found between purity and contamination in ALICA data and MPD MC



Conclusions

- The first tests of Monte Carlo production (generator+GEANT+reconstruction) of Au-Au collisions at $\sqrt{s_{NN}}$=11.5 GeV (and previous $\sqrt{s_{NN}}$=7.7 GeV) within the vHLLE model are presented.
- The results of particle identification using ionization energy loss (dE/dx) in the TPC is shown.
- The technical issues of generating a response (energy loss) of the TPC is discussed.
- The time-of-flight information (1/β) from TOF in the MPD experimental setup are shown.
- Bayesian PID performance was shown.
  Significant difference is found between kaon purity and contamination
  in ALICA data and MPD MC.

Thank you for you attention!!!

Backup slides

Bethe-Bloch Parameterization

Bethe Bloch Function (BBF): mean energy loss per unit path length

$$\left\langle \frac{dE}{dx} \right\rangle = Kz^2 \frac{Z}{A\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

$$\beta\gamma = \frac{\text{momentum}}{\text{mass}} \qquad \beta = \frac{\beta\gamma}{\sqrt{1 + (\beta\gamma)^2}}$$

Parametrization (Aleph Parametrization)

$$\left\langle \frac{dE}{dx} \right\rangle = \frac{p_0}{\beta^{p_3}} \left[p_1 - \beta^{p_3} - \ln \left(p_2 + \frac{1}{(\beta\gamma)^{p_4}} \right) \right]$$

It was find that parameterization used in MPDroot was different :

```
Float_t BetheBlochFunction(Float_t x, Float_t *p) {
  Float_t b = 1 / (x / TMath::Sqrt(1 + x * x));
  return p[0] / TMath::Power(b, p[3]) * (p[1] - TMath::Power(b, p[3]) -
TMath::Log(p[2] + TMath::Power(1 / x, p[4])));
}
```

The corrected Bethe-Bloch Function with Aleph parameterization

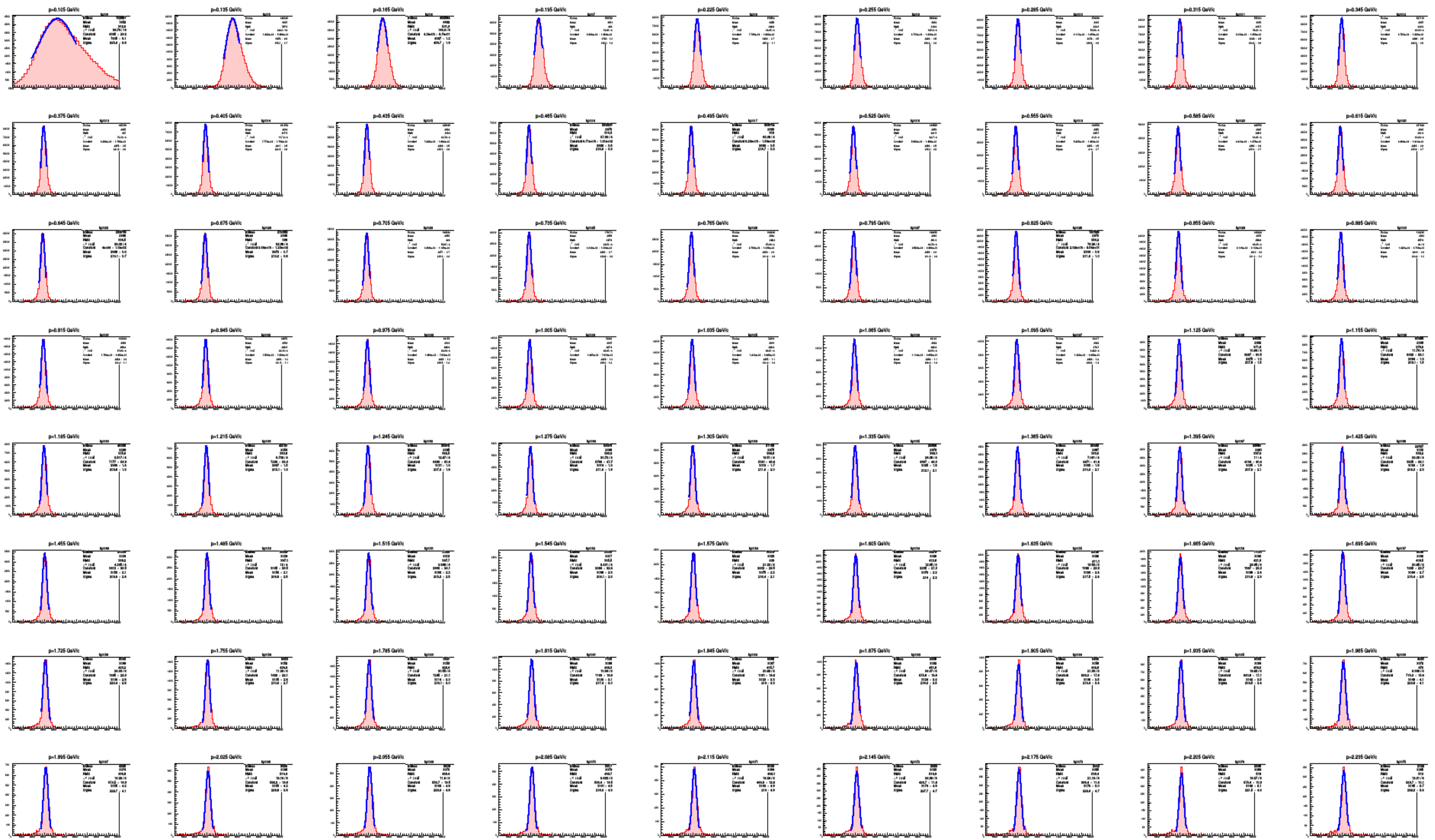
```
Double_t BetheBlochAlephFunc(Double_t *x, Double_t *par) {
  Double_t p=x[0];//kaon momentum
  Double_t mass=par[0];//Mass of particle 0.4937;//GeV/c2
  Double_t beta=p/TMath::Sqrt(p*p+mass*mass);

  //parameters from debugger
  Double_t kp1=par[1];
  Double_t kp2=par[2];
  Double_t kp3=par[3];
  Double_t kp4=par[4];
  Double_t kp5=par[5];

  Double_t aa = TMath::Power(beta,kp4);
  Double_t bb = TMath::Power(1./bg,kp5);

  bb=TMath::Log(kp3+bb);
  Double_t dMip=50.;//fMip in AliTPCPIDResponse.cxx. Correct?
  return (kp2-aa-bb)*kp1/aa;//*dMip;
}
```

dE/dx distributions for pions



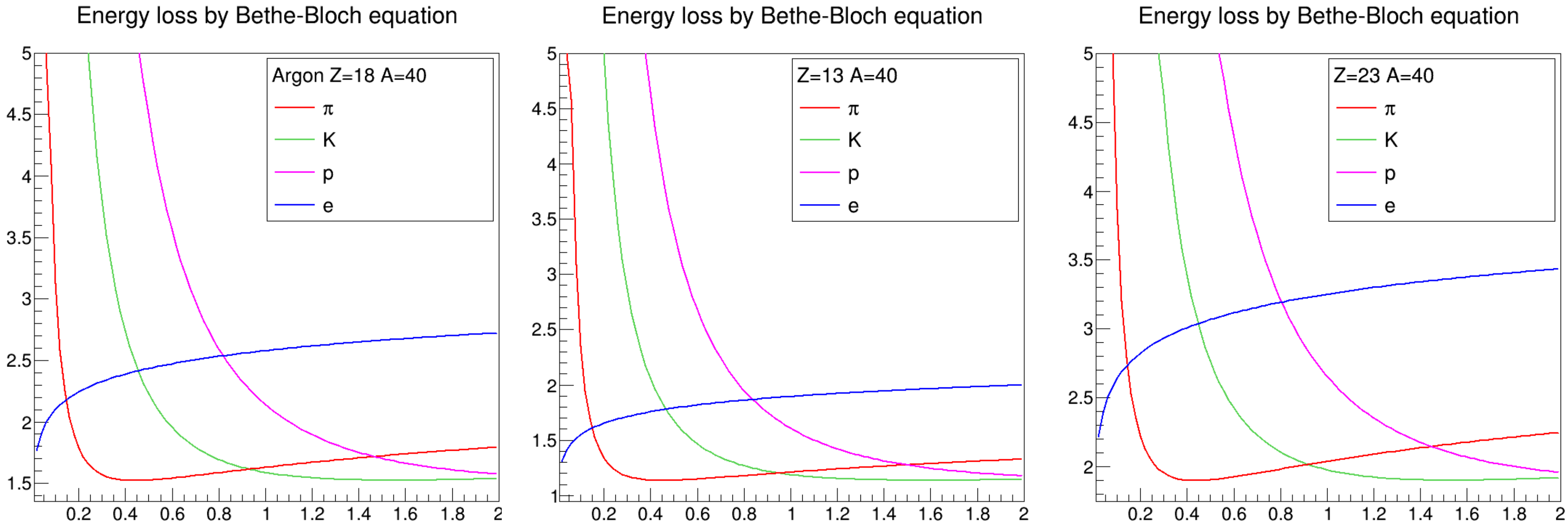
p (0.09, 2.25) GeV/c, 72 slices ; Blue color – Gaussian fit region : Maximum +/- RMS

Energy loss by Bethe-Bloch equation

$$\left\langle -\frac{dE}{dx} \right\rangle = K z^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2 m_e c^2 \beta^2 \gamma^2 W_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

To estimate <dE/dx> by BB equation Ar was used (STAR: 90%Ar+10%CH_4)

The intersection curves weakly dependent on the gas mixture (vary Z ± 5)



The intersection of K and electrons is about momentum 450 MeV/c

Bayesian PID: selected kaons in TPC