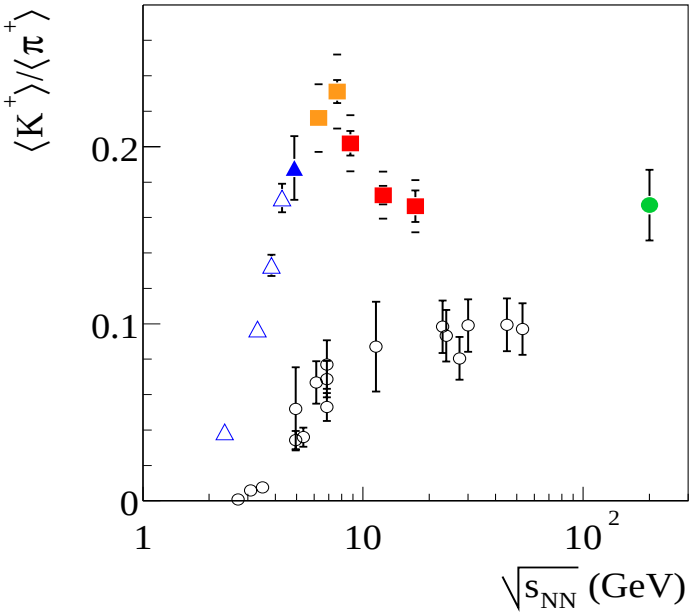
Event-by-Event Fluctuations of Particle Ratios

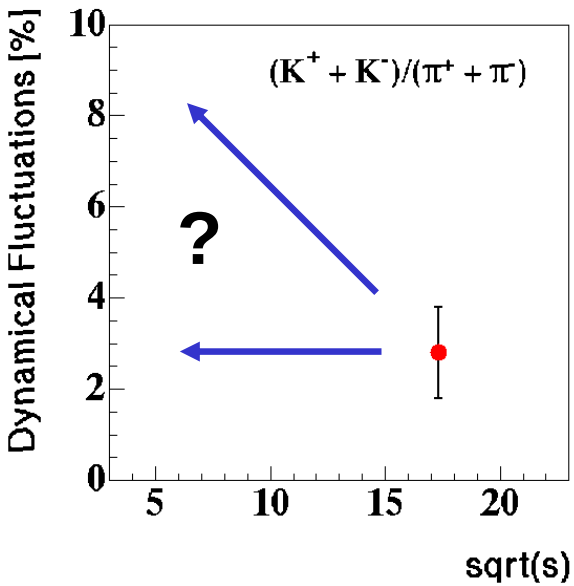
Christof Roland / MIT
For the NA49 Collaboration

Quark Matter 2004
Oakland,CA

Motivation

Energy dependence of the $\langle K^+ \rangle / \langle \pi^+ \rangle$ ratio



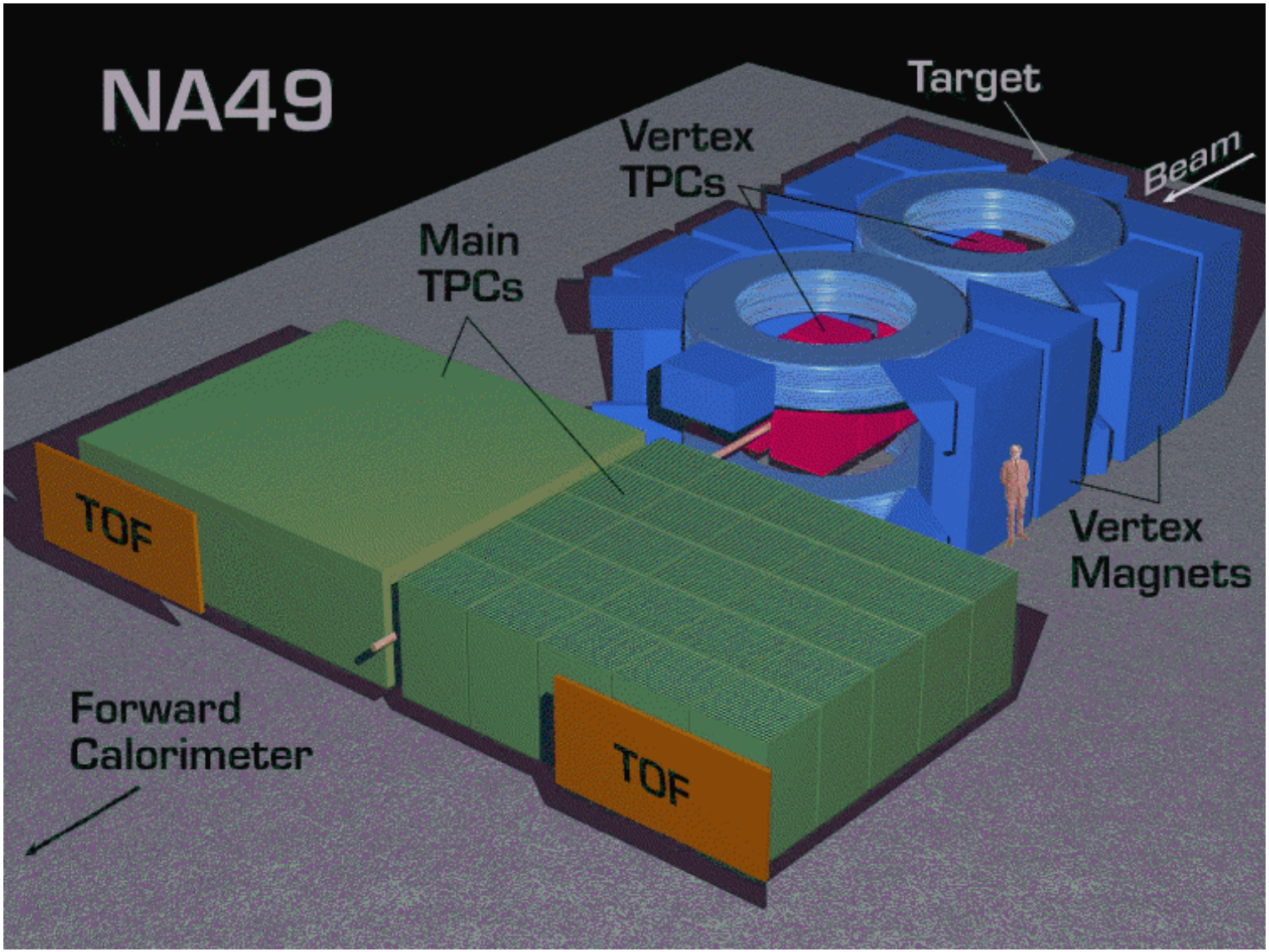


Event-by-event fluctuations of the $(K^+ + K^-)/(\pi^+ + \pi^-)$ ratio at 160 GeV

Phys. Rev. Lett 86 1965 (2001)

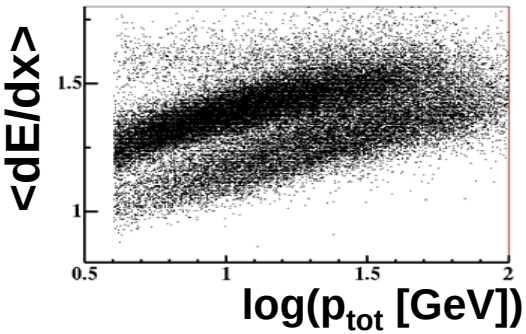
What is the energy dependence of the fluctuation signal?

The NA49 Detector

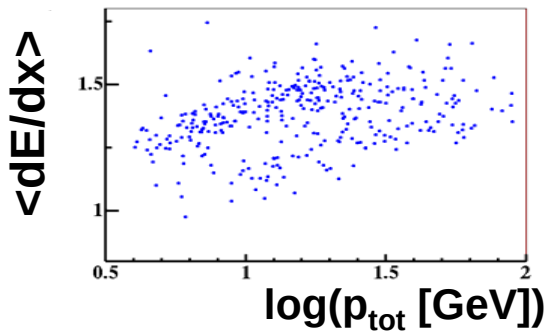


Event-by-Event estimation of the particle ratios

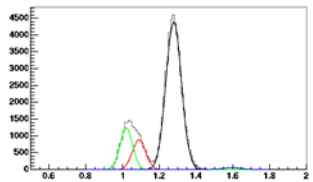
Event Ensemble:



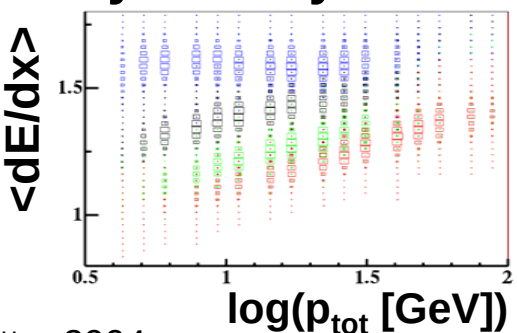
One Event:



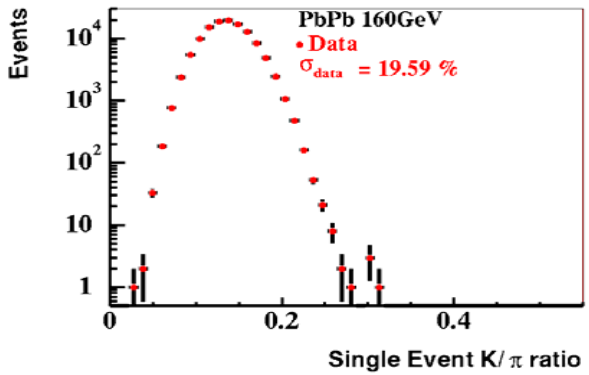
Fit dE/dx spectra in 4D binning



Probability density function:



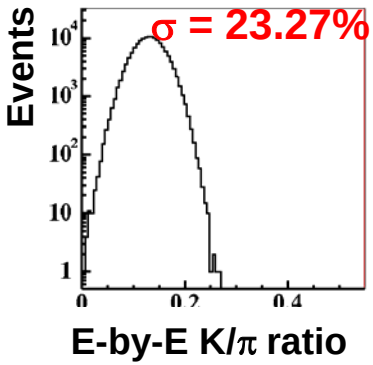
- **Vary relative normalization of the particle species (K/π,p/π) in the PDF**
- **Extract ratios with maximum likelihood fit**



Extracting the Fluctuation Signal

Process the relative widths of the distributions: σ = RMS/Mean * 100 [%]

"Data" Events



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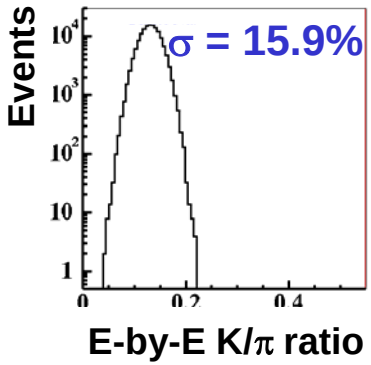
Finite Number Statistics



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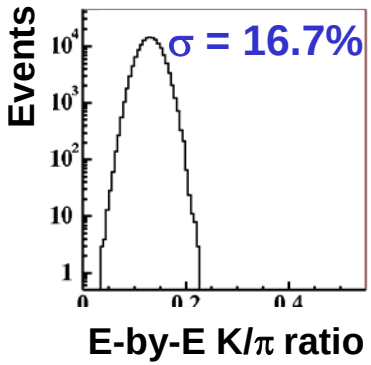
Experimental Resolution



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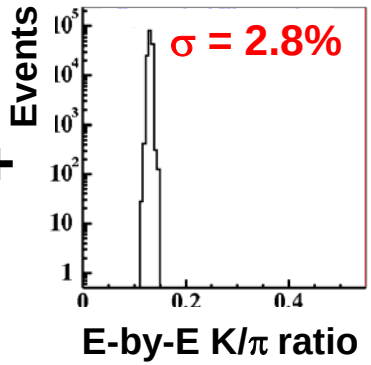
Dynamical Fluctuations



Statistical fluctuations

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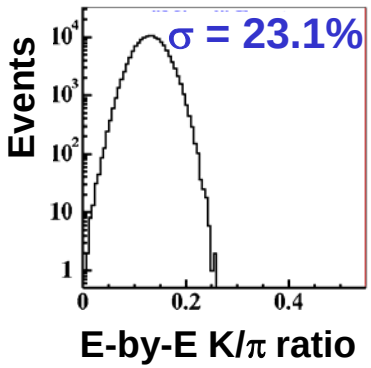
"mixed" Events

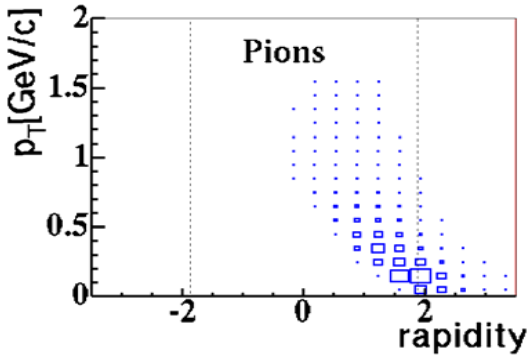


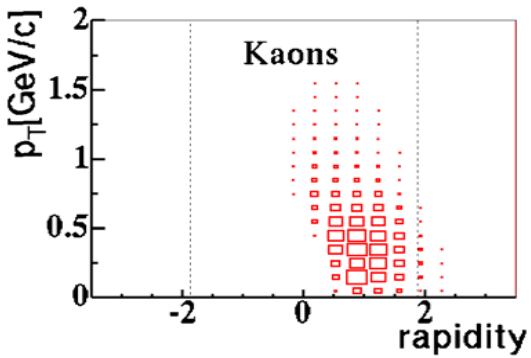
Compare data to mixed events:

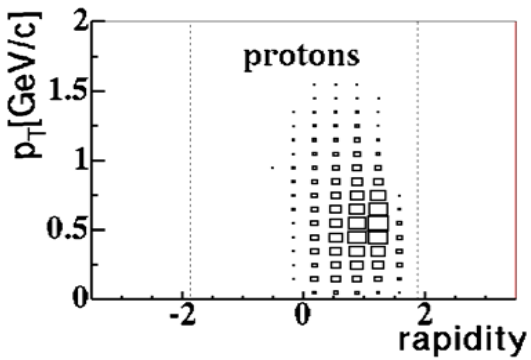
$$\sigma^2_{data} - \sigma^2_{mix} = \sigma^2_{dynamic}$$

Acceptance

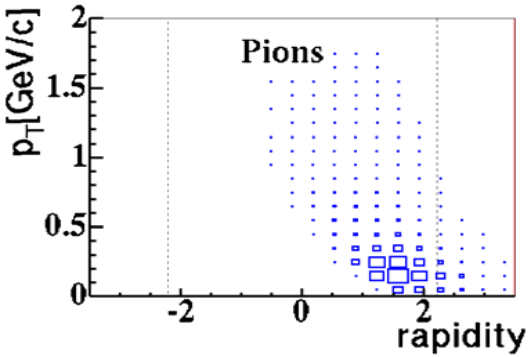
20 GeV:

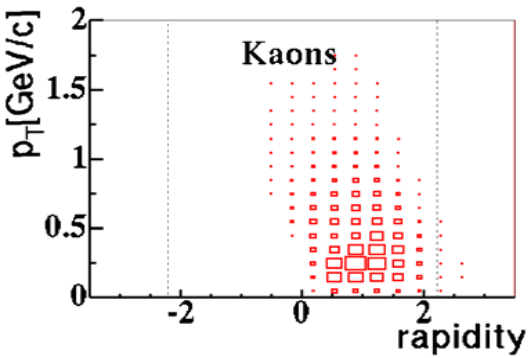


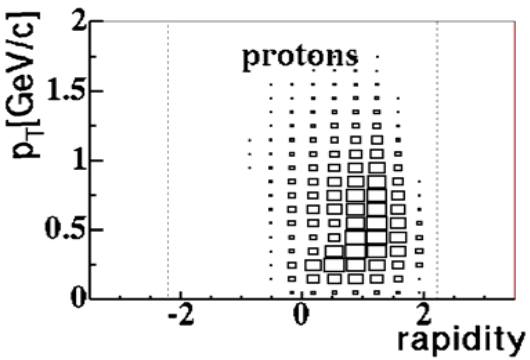




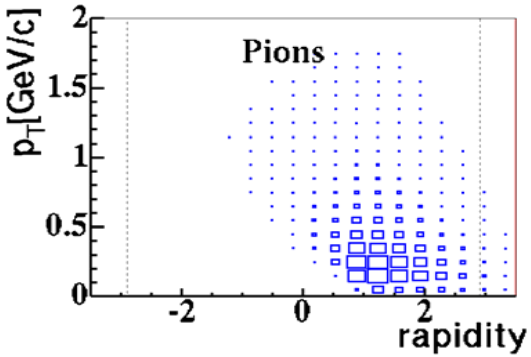
40 GeV:

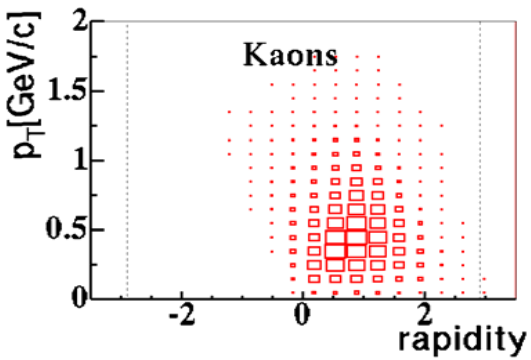


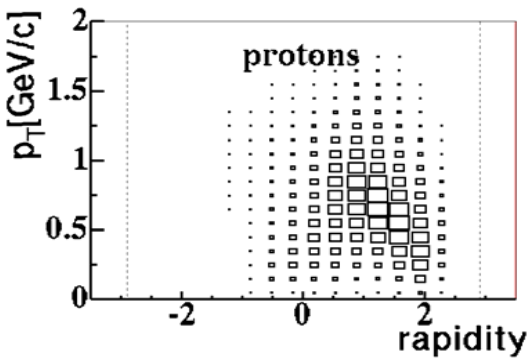




160 GeV:







Event Selection

- Select 3% most central events at all energies
  - **Selection based on energy of projectile spectators**
  - **Tight selection to prevent remaining centrality dependence of K/π within the event sample**

Event Statistics

Beam Energy	Events	Tracks/Event	
		Data Set 1	Data Set 2
20 GeV	140 k	58	65
30 GeV	170 k	100	115
40 GeV	160 k	141	163
80 GeV	140 k	269	321
160 GeV	120 k	450	560

Error Estimate

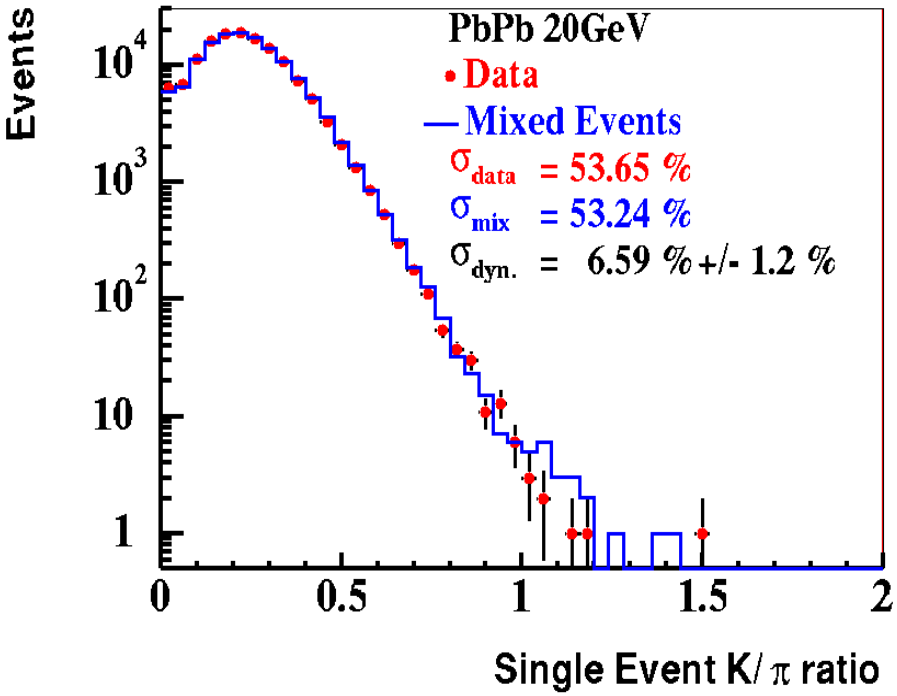
- Systematic checks
  - **dE/dx stability**
  - **Linearity of the e-by-e estimators**
  - **Various σ_{dyn} extraction methods**
  - **All methods tested successfully on MC events**

- Systematic errors from processing two data sets
  - **Vary track selection and multiplicity per event**
  - **Data points from arithmetic mean**
  - **Systematic error from the difference in the data points**

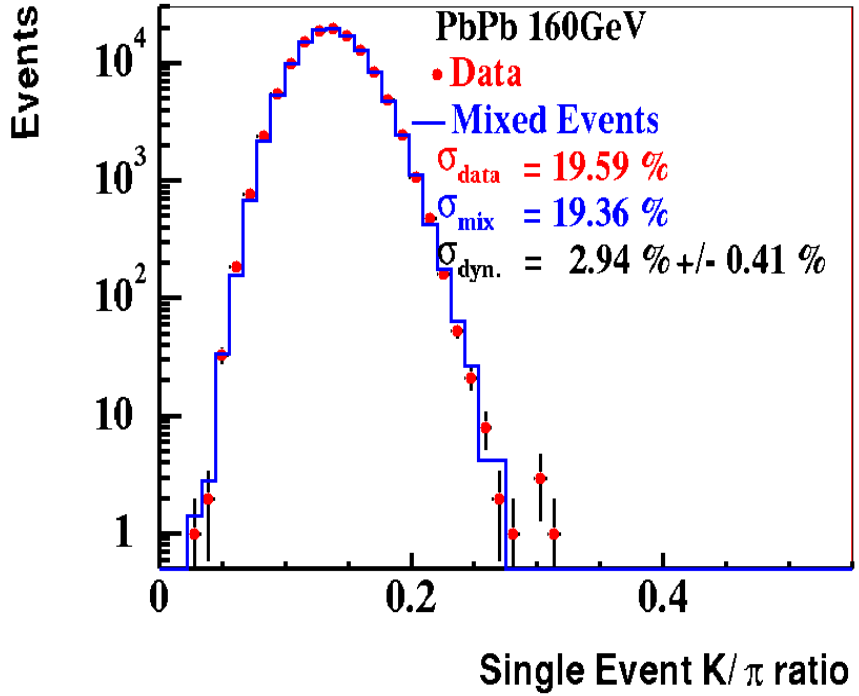
The E-by-E Kaon/Pion Ratio

Data Set 1

20 GeV



160 GeV



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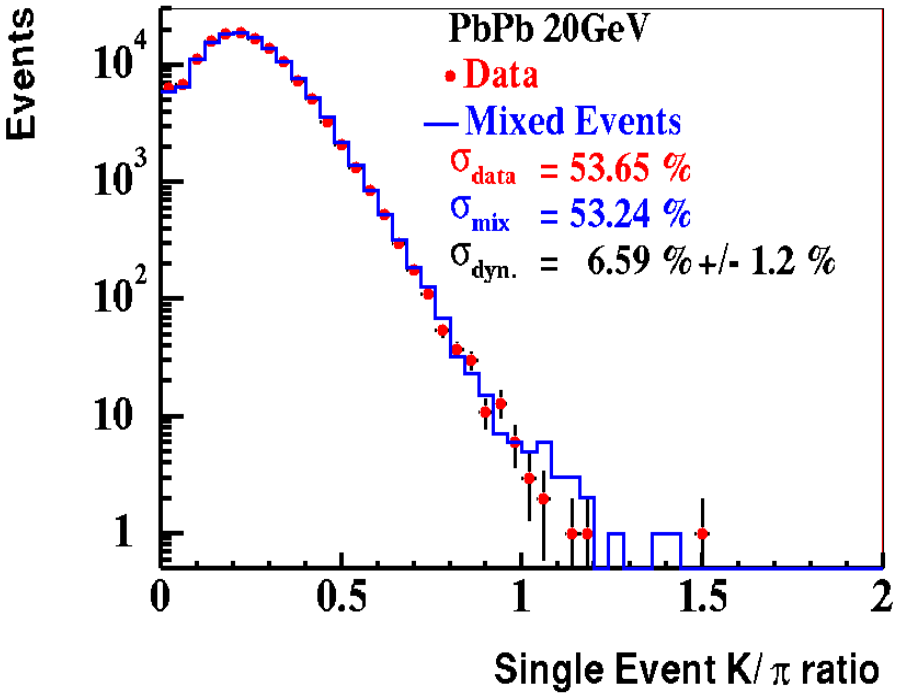
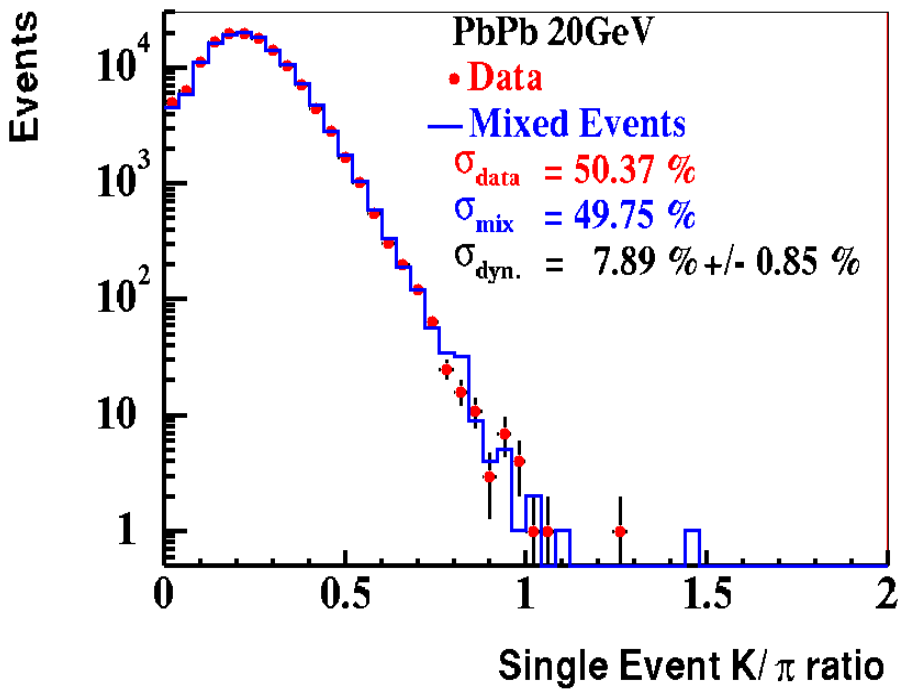
The E-by-E Kaon/Pion Ratio

Data Set 1

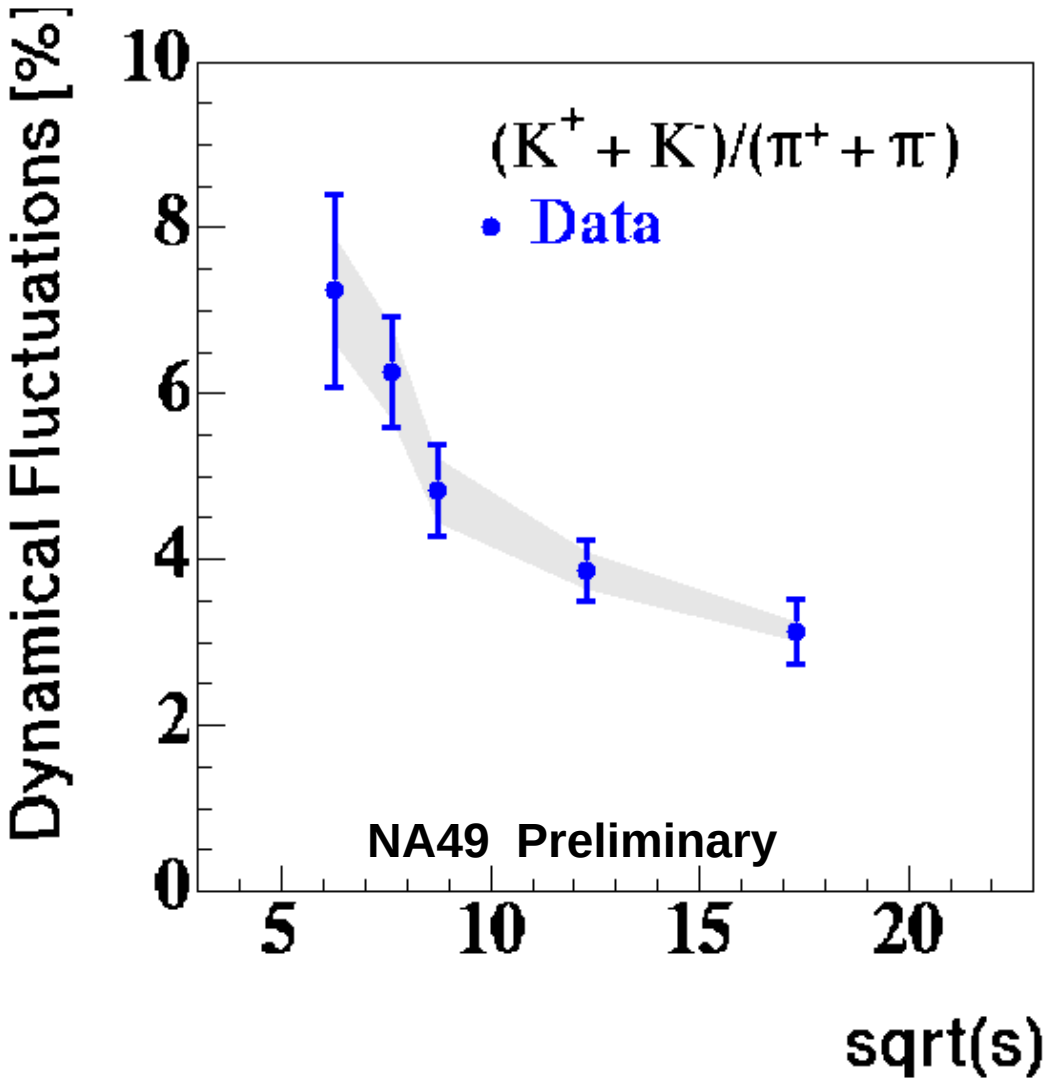


Data Set 2



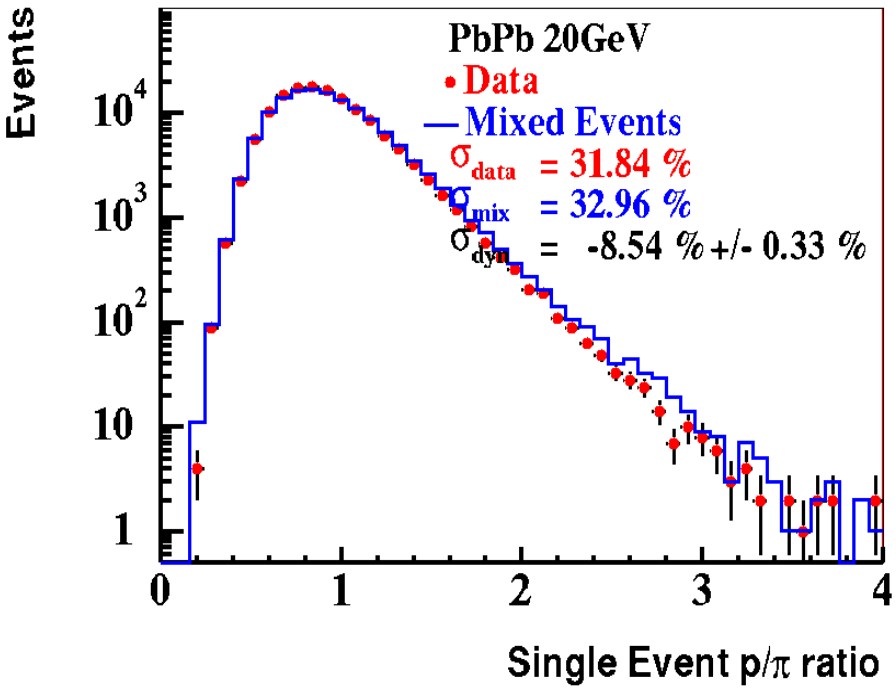
NA49 Preliminary

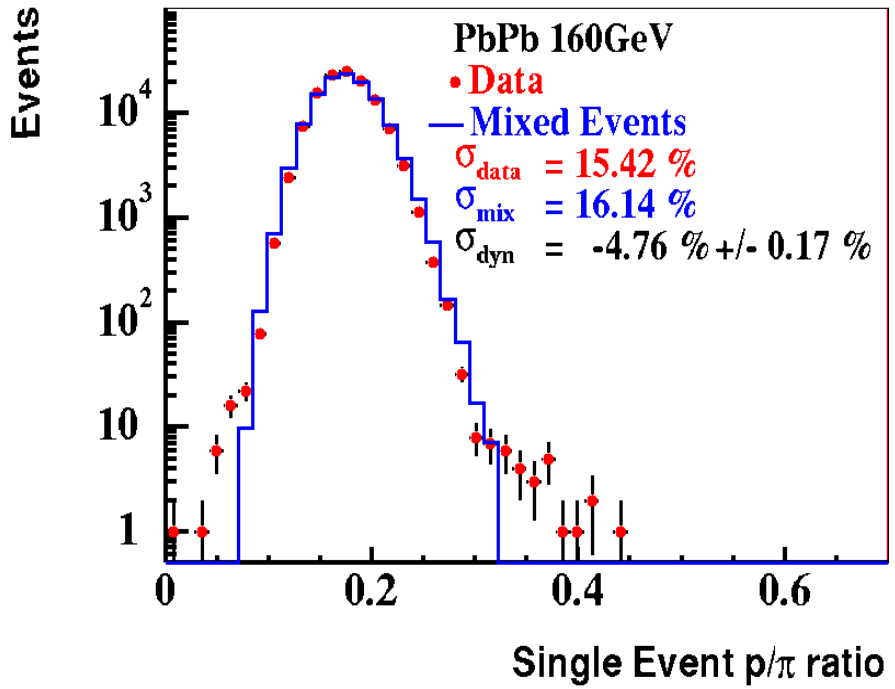
The E-by-E Kaon/Pion Ratio



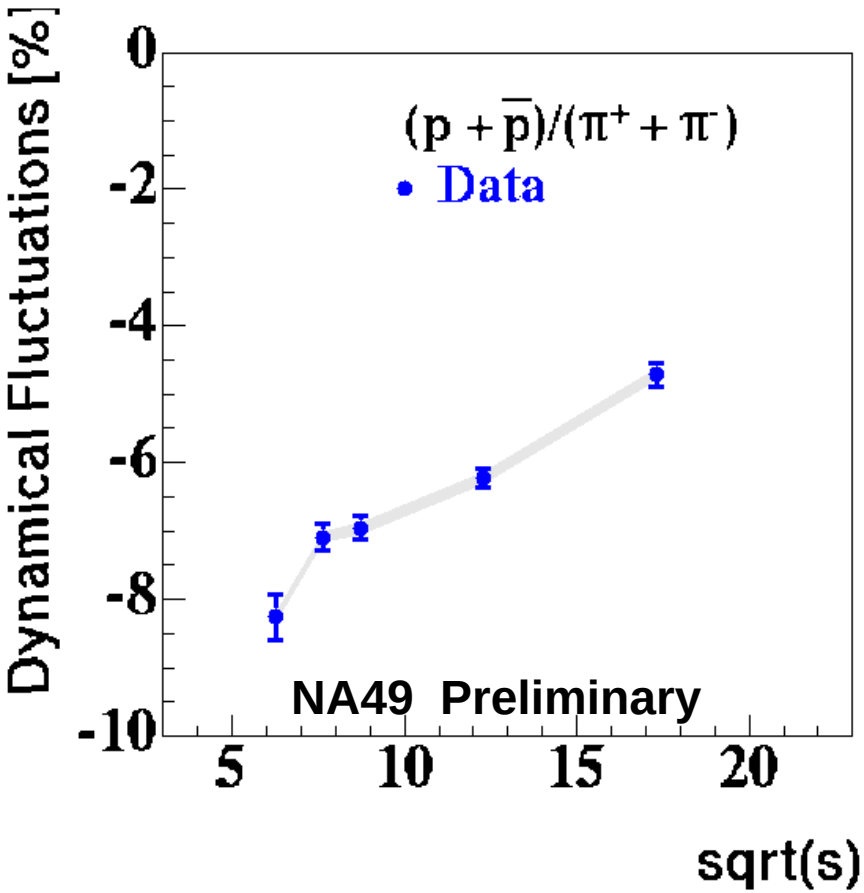
Increased fluctuation signal at lower beam energies

The E-by-E Proton/Pion Ratio





The E-by-E Proton/Pion Ratio



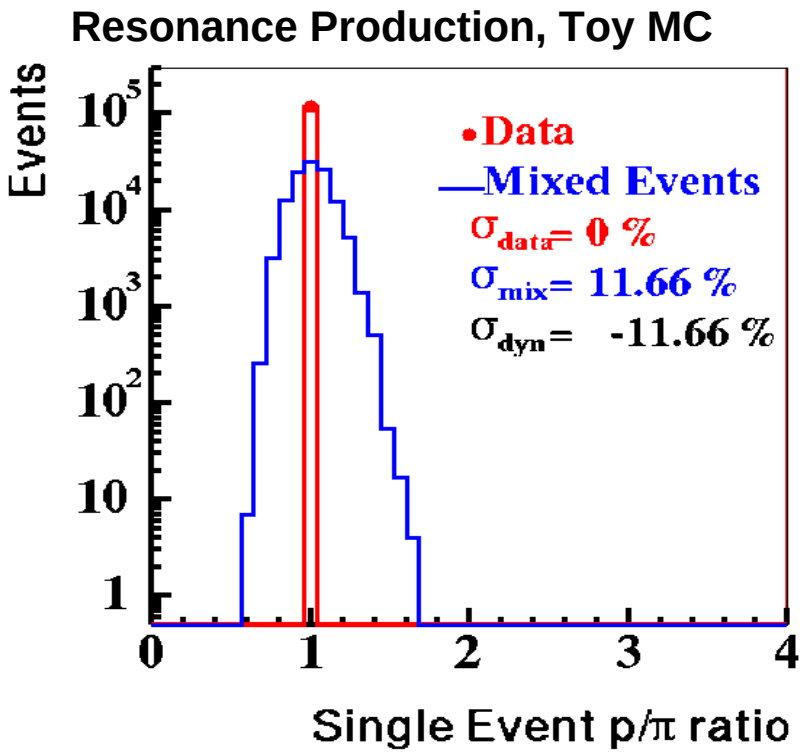
The e-by-e distribution of the proton/pion ratio is narrower for data than for mixed events

Effect is more pronounced at low beam energies

The E-by-E Proton/Pion Ratio

Gedanken Experiment:

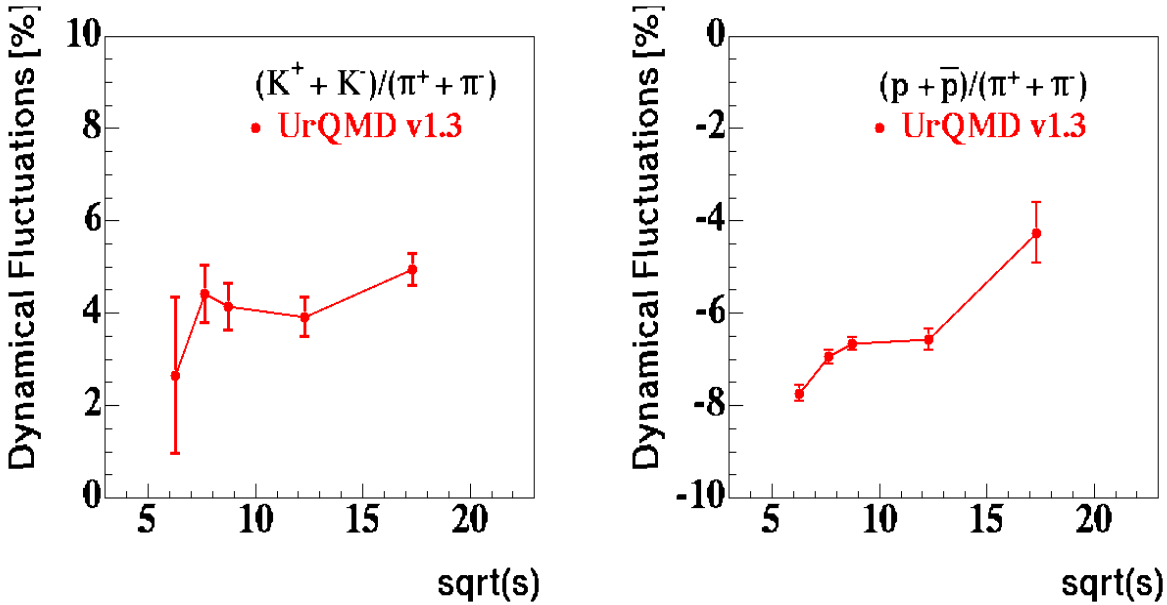
All protons and pions from resonances



Check influence of resonances in an Event Generator

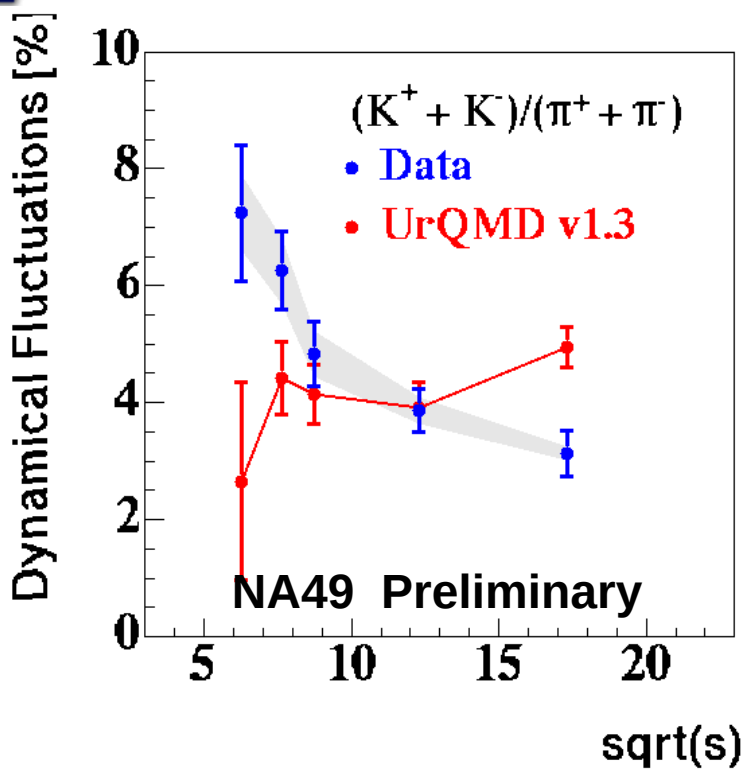
The UrQMD Event Generator

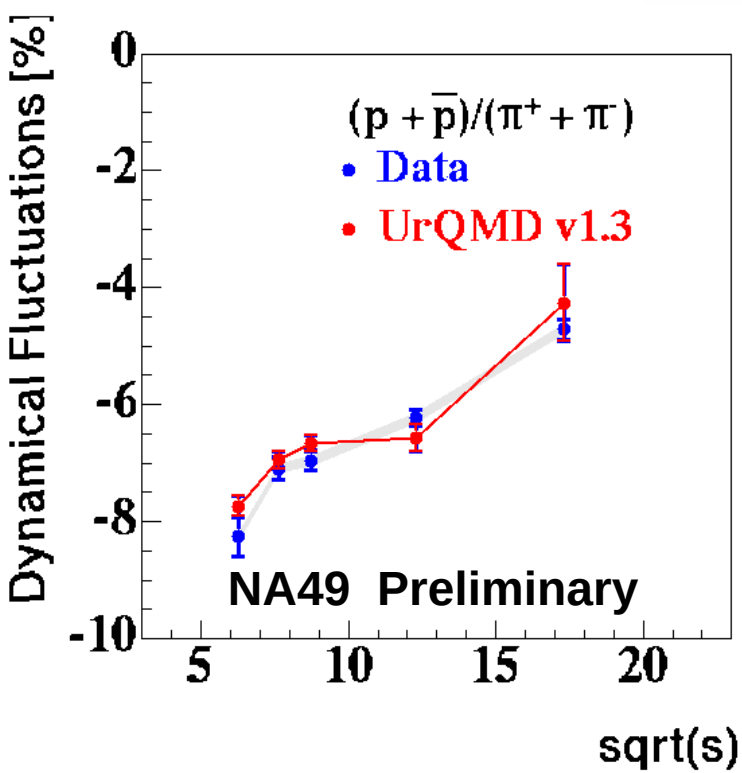
- Process UrQMD events like data
  - **Generate large samples, O(30k) events**



- Relative contribution of resonances changes with beam energy
- K/π fluctuation signal independent of beam energy
  - **Weak influence of resonances**
  - **Non zero value due to energy-, strangeness conservation**
- p/π fluctuation signal shows similar trend like data

Summary





- K/π fluctuations increase towards lower beam energy
  - **Significant enhancement over hadronic cascade model**
- p/π fluctuations are negative
  - **indicates a strong contribution from resonance decays**

END

Error Estimate

- Systematic checks
  - **dE/dx stability**
  - **Linearity of the e-by-e estimators**
  - **Various σ_{dyn} extraction methods**
  - **All methods tested successfully on MC events**

- Systematic errors from processing two data sets
  - **Vary track selection and multiplicity per event**
  - **Data points from arithmetic mean**
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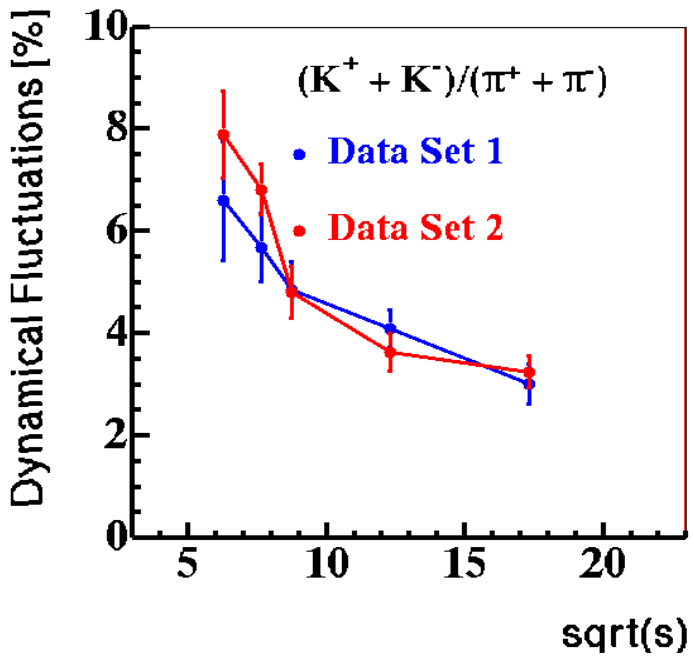
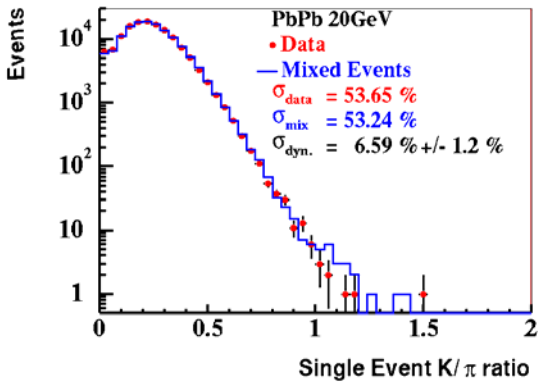
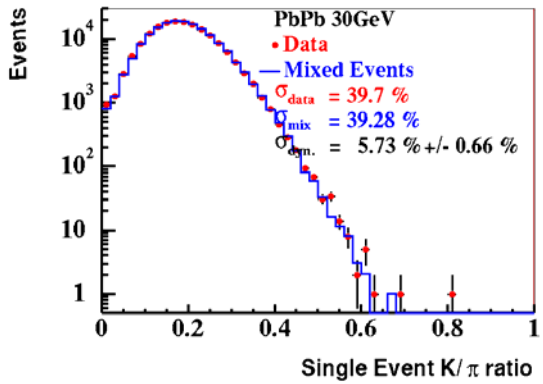
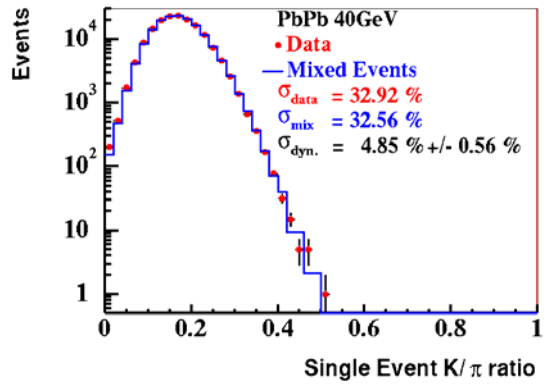
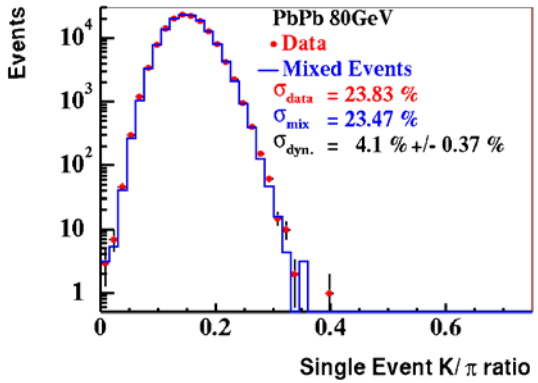


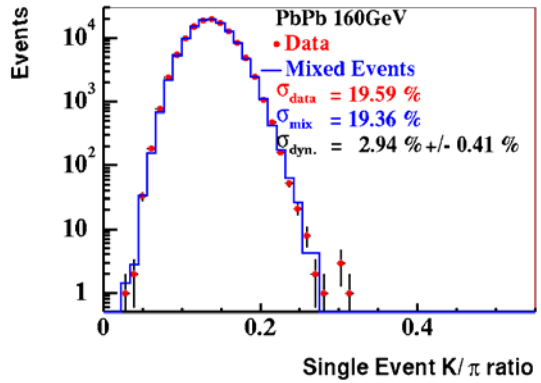
Results on Kaon/pion (tight)



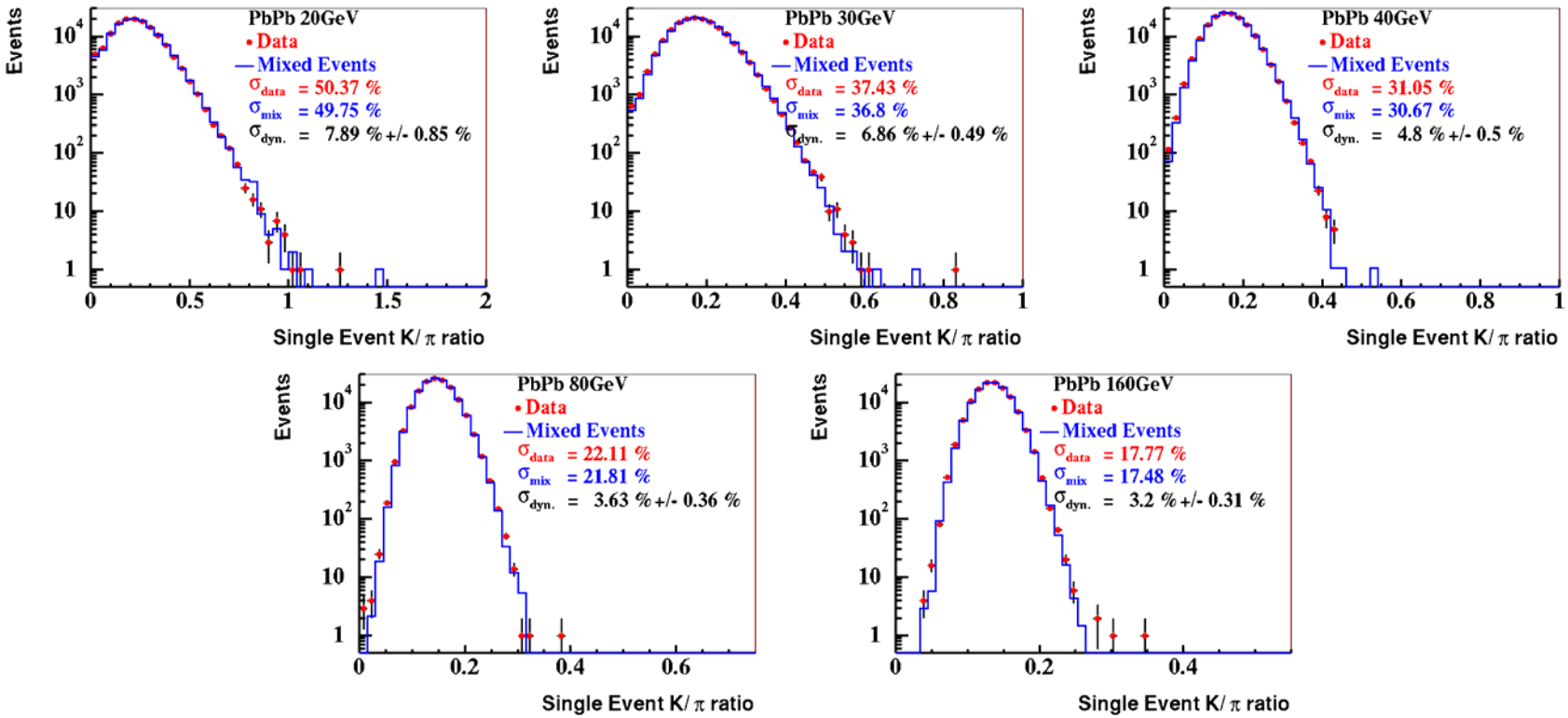




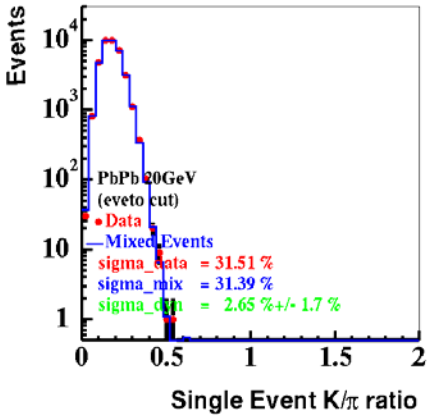


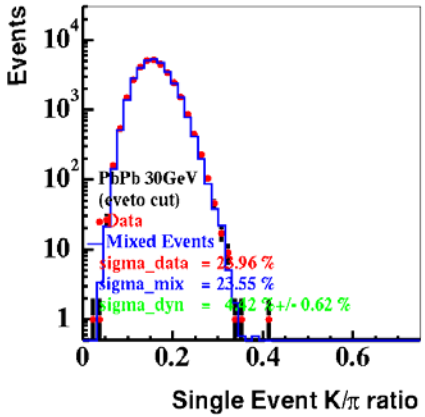


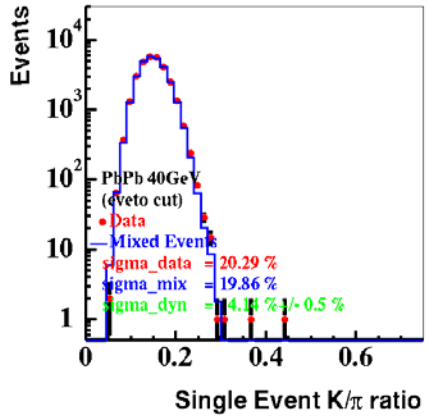
Results on Kaon/pion (lose)

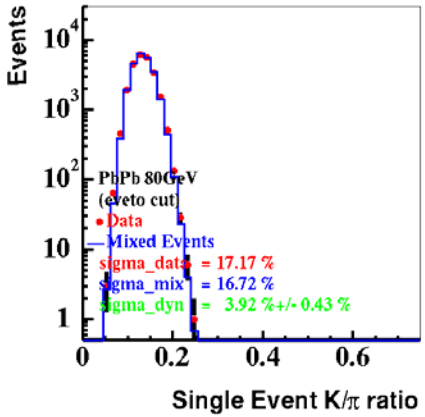


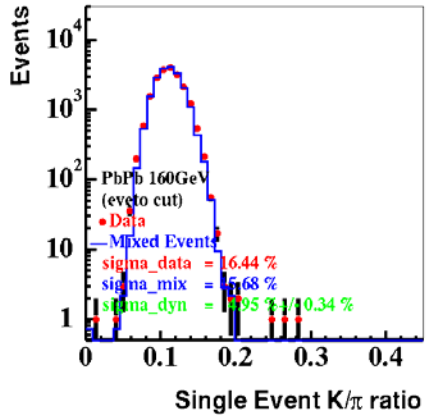
Results on Kaon/pion UrQMD



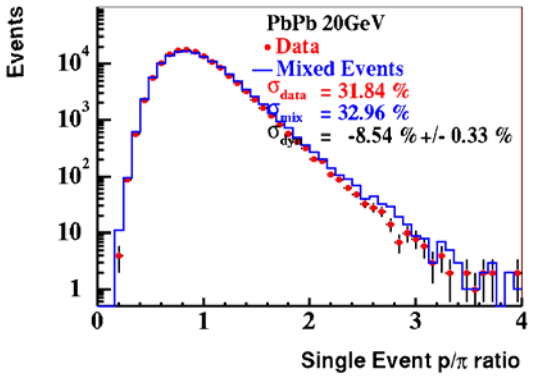


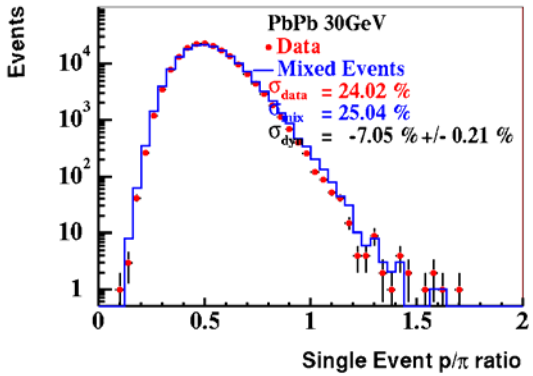


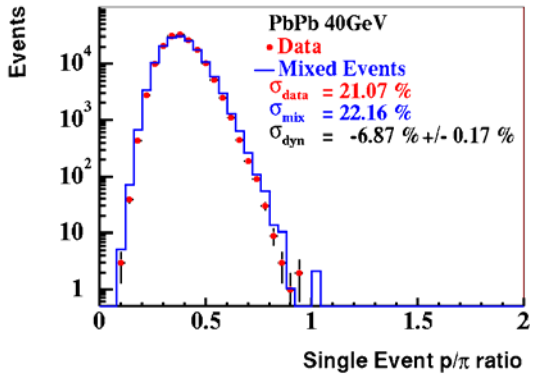


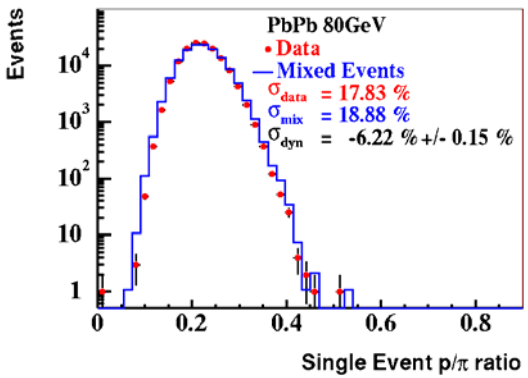


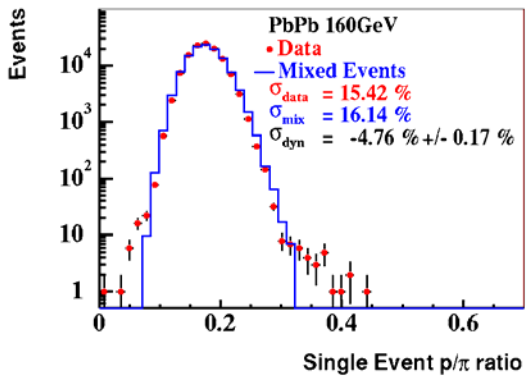
Results on proton/pion(tight)



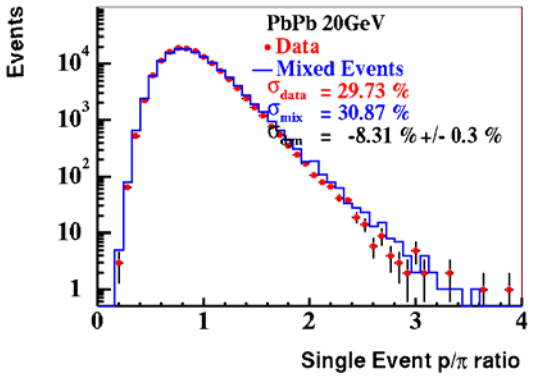


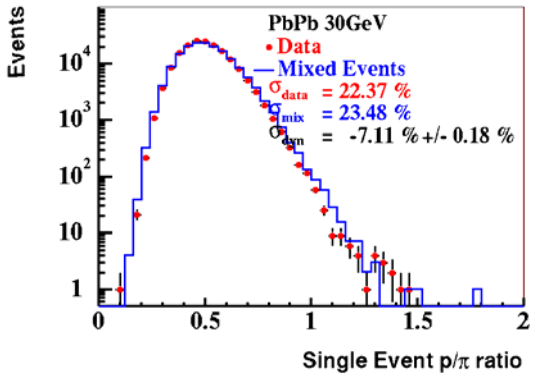


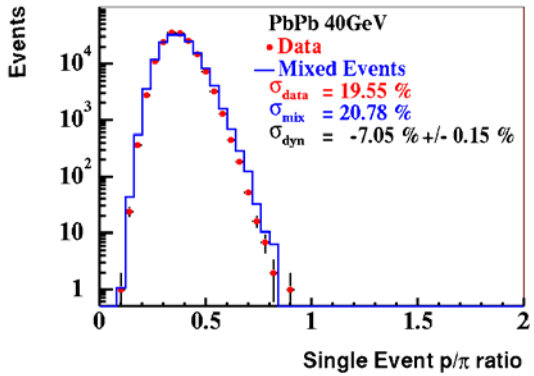


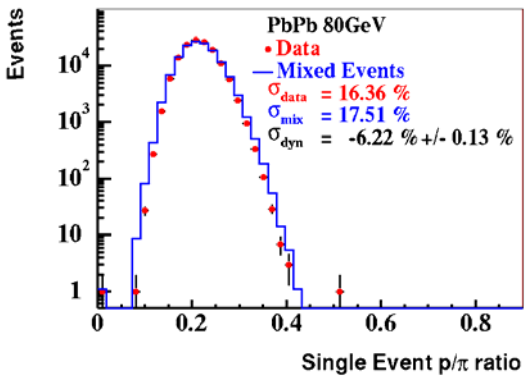


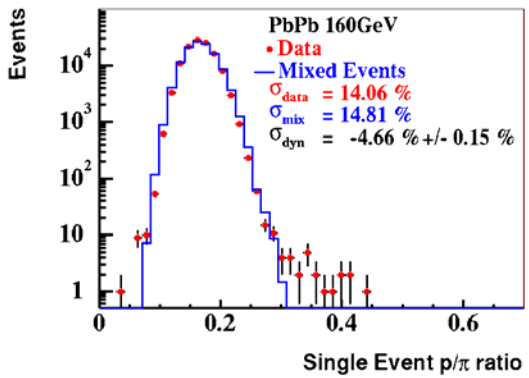
Results on proton/pion(lose)



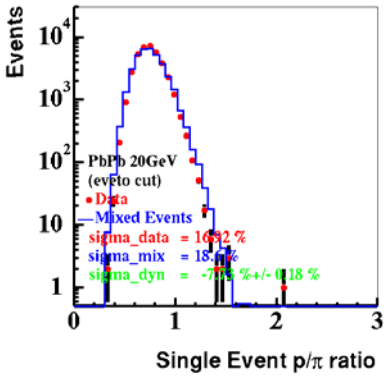


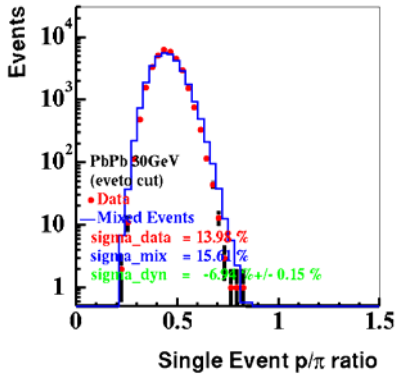


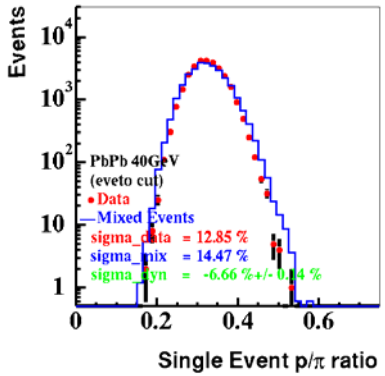


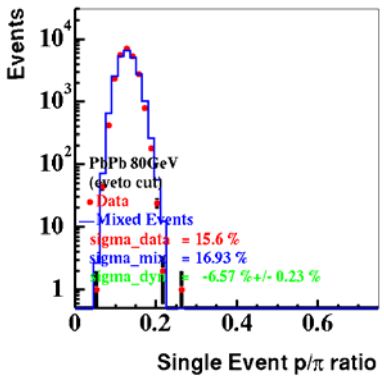


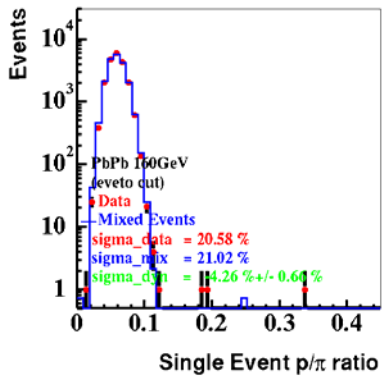
Results on proton/pion URQMD











- The e-by-e proton/pion ratio for data is narrower than the mixed event distribution