Analysis of π^- produced in Pb+Pb collision at $30A$ GeV/c

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Results to be shown in this presentation

π^- from h^- method for Pb+Pb at $30A$ GeV/c:

- $d^2n/dydp_T$ spectrum + p_T spectra
- dn/dy spectrum + comparison with NA49
- Total yields of π^- + comparison with NA49

Raw data and Monte Carlo information

Raw Data:

- Pb+Pb 30A GeV/c was recorded in 2016
- Total number of event: 4405788
- Total number of event after cuts: 115795
- Centrality region used for these results: 7.2%

MC:

- Type: FTFP_BERT and EPOS
- Total number of events by FTFP_BERT and EPOS: 4331862 and $\approx 20M$
- Total number of generated events by FTFP_BERT and EPOS after cuts: 293127 and 1479360
- Total number of reconstructed events by FTFP_BERT and EPOS after cuts: 292565 and 1476830
- Centrality region used for these results: 7.2%

Data and MC selection in 7.2% centrality

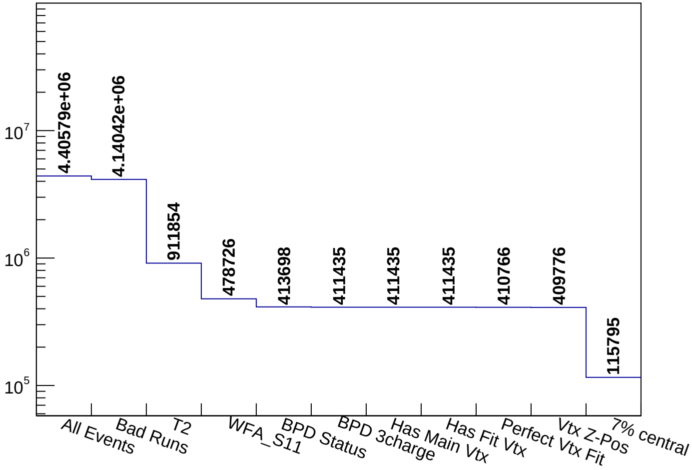
Event selection criteria:

- Bad runs
- T2 Trigger
- BPD status: Precisely-measured beam position
- WFA: No off-time beam particles (WFA S11:$\pm 25 \mu s$).
- BPD3 charge(well-defined beam particle and trajectory)
- Main Fitted Vertex exists.
- Main Vertex has a perfect fit.
- Vertex z-axis: position $-592.9cm < z < -590.9cm$
- $0 - 7.2\%$ Central events

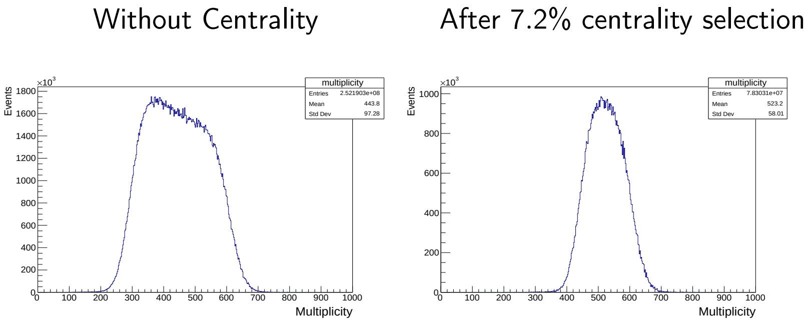
Track selection criteria:

- Good track status
- Impact parameter: $|b_x| < 4cm$ and $|b_y| < 2cm$. b is track distance from main vertex.
- Right side tracks: $p_x \times$ charge of track > 0
- All TPC Clusters > 30
- VTPC Clusters > 15
- e^- exclusion cut

Number of data events after different event cuts



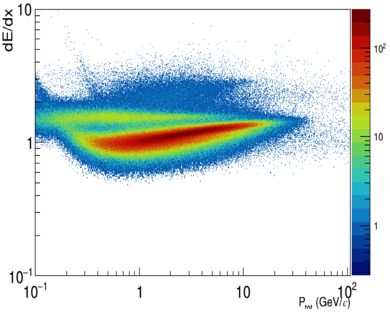
Multiplicity distribution



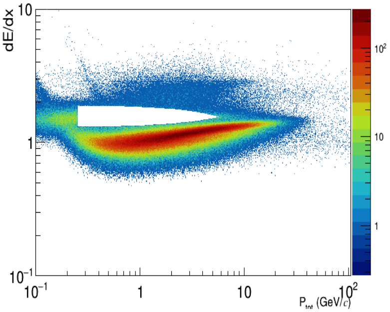
Multiplicity distribution in Pb+Pb collision at 30A GeV/c after Good Track Status cut.

Electron exclusion cut on Tracks (before and after)

Before cut



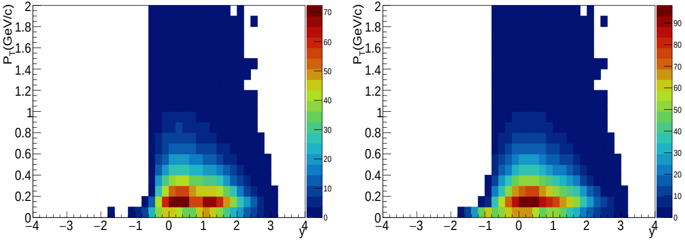
After cut



- Bethe-Bloch functions for e^- and π^- can be plotted.
- Removing the tracks from the region removes the majority of tracks that can be attributed to e^- in the TPCs.

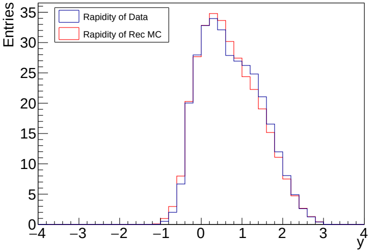
$y - p_T$ for raw data in 7.2% centrality (with and without AllTPCs cut)

$AllTPC > 30 + VTPC > 15$ $VTPC > 15$

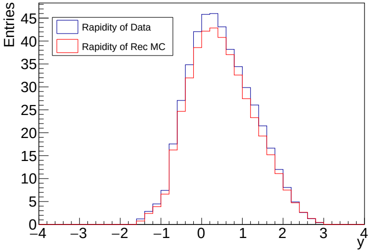


Comparison of rapidity distribution of MC and data in 7.2% centrality (with and without AllTPCs cut)

$AllTPC > 30 + VTPC > 15$



$VTPC > 15$



Multiplicative and additive MC corrections

Multiplicative and additive corrections are respectively:

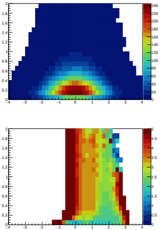
$$n_i^{corrected} = n_i^{raw(all\ particles)} \times \frac{n_i^{MCsim(only\ pions)}}{n_i^{MCrec(all\ particles)}}$$

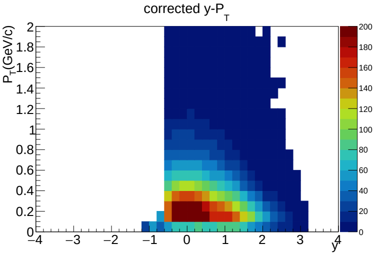
$$n_i^{corrected} = [n_i^{raw(all\ particles)} - C_r] \times \frac{n_i^{MCsim(only\ pions)}}{C_p}$$

$$C_r = n^{rec}_{decay\ of\ \pi^-, K^-, \bar{p}\ and\ others}$$

$$C_p = n^{rec}_{primary+\ secondary\ not\ from\ decay\ of\ \pi^-, K^-, \bar{p}}$$

$y - p_T$ after MC correction in 7.2% centrality (with AllTPCs cut)



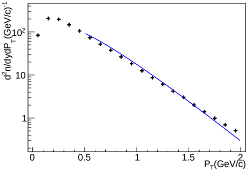


$d^2n/dydp_T$ of π^-

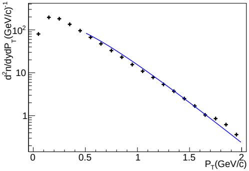
$$\text{Fit function}: \frac{d^2n}{dydp_T} = C\, p_T\, exp\left[\frac{-(m_T - m_{\pi^-})}{T}\right]$$

m_{π^-} and m_T are mass and transverse mass of pion (fit from 0.5-2)

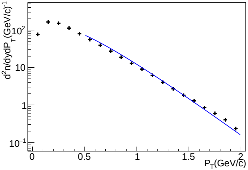
$0.2 < y < 0.4$



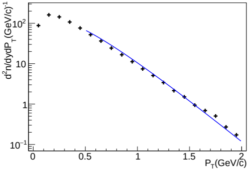
$0.4 < y < 0.6$



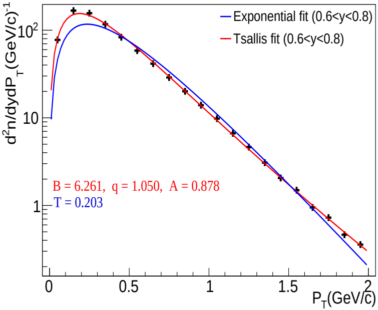
$0.6 < y < 0.8$

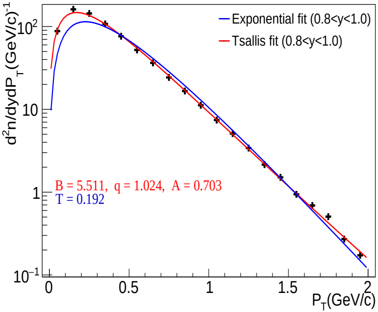


$0.8 < y < 1$

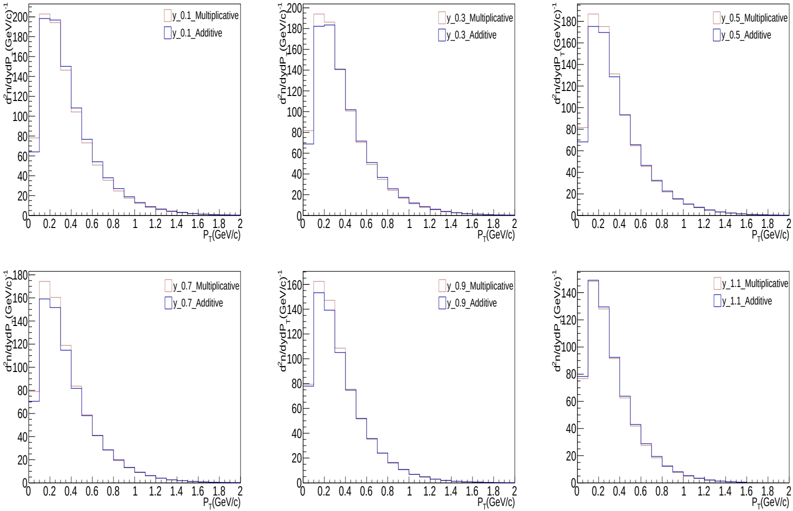


Comparison of fitting of $d^2n/dydp_T$ of π^- with Tsallis and exponential fit

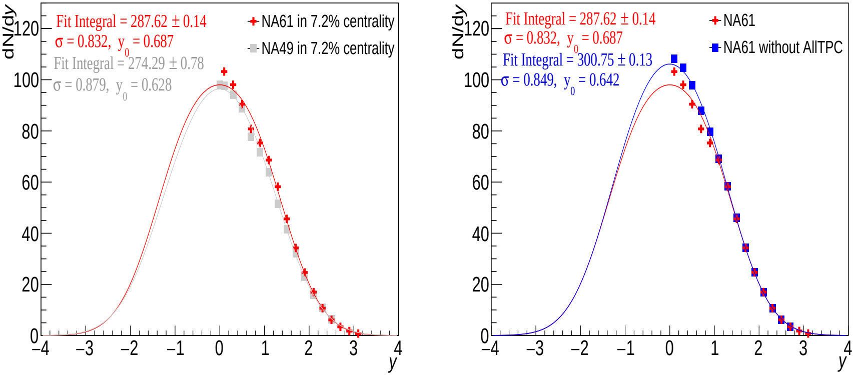




$d^2n/dydp_T$ of π^- with Additive and Multiplicativ correction



Corrected rapidity spectra of π^- in 7.2% centrality

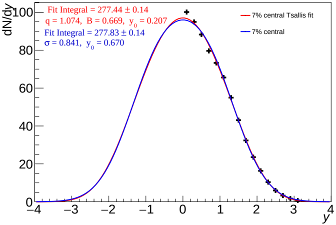


$$P(y) = \frac{A}{\sigma\sqrt{2\pi}}\left[exp\left(\frac{-(y-y_o)^2}{2\sigma^2}\right) + exp\left(\frac{-(y+y_o)^2}{2\sigma^2}\right)\right]$$

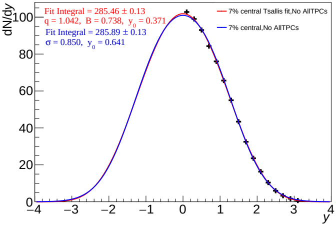
"Pion and kaon production in central Pb+Pb collisions at 20A and 30A GeV: Evidence for the onset of deconfinement,"PHYSICAL REVIEW C 77, 024903 (2008)

Corrected rapidity spectra of π^- with EPOS model with Additive and Multiplicatiive correction

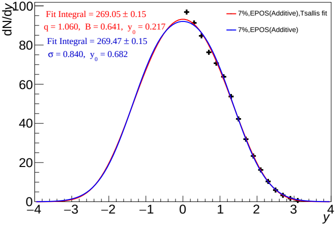
7.2% Standard,Multiplicative



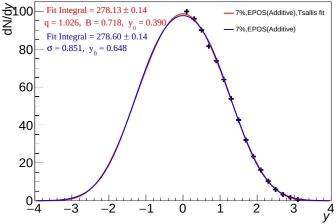
7.2% *no AllTPCs,Multiplicative*



7.2% Standard,Additive



7.2% *no AllTPCs,Additive*



Comparison of π^- yield with NA49

	$<\pi^->$	$(\frac{dn}{dy})_{y\approx0.1}$
NA49 in 7.2%	$274 \pm 1 \pm 14$	$96.5 \pm 0.5 \pm 4.8$
NA61 in 7.2% (FTFP_BERT)	287 ±0.19 ±13	$103.1 \pm 0.15 \pm 5.09$
NA61 in 7.2% (EPOS)	277 ± 0.14	100.12 ± 0.14
NA61 in 7.2% (EPOS,Additive)	269.47 ± 0.15	96.8 ± 0.16
NA61 in 10.0% (FTFP_BERT)	278 ± 0.12	99.10 ± 0.12
NA61 in 10.0% (EPOS)	269 ± 0.11	96.22 ± 0.12

Around 3.5% difference in total yields with EPOS and FTFP_BERT.

Around 3% difference in total yields by additive and multiplicative corrections with EPOS model.

"Pion and kaon production in central Pb+Pb collisions at 20A and 30A GeV: Evidence for the onset of deconfinement,"PHYSICAL REVIEW C 77, 024903 (2008)

Comparison of simulated yields of π^-, K^- and pbar with both models

	FTFP_BERT	EPOS
π^-	298.28	364.43
K^-	6.51	13.89
pbar	0.56	1.22
sum of yields	305.35	379.54
π^- /sum of yields	0.975	0.96
K^- /sum of yields	0.02	0.03
pbar /sum of yields	0.001	0.003

The 3.5% difference between the mean multiplicities obtained using corrections with FTFP_BERT and EPOS cannot be explained with only the differences in simulated yields of K^- and pbar (which account only for about 1.5% of the discrepancy).

Systematic Uncertainty in 7.2% centrality

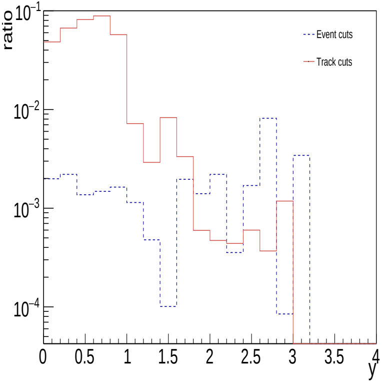
Event selection criteria:

- WFA S11: $\pm 20\mu s$
- WFA S11: $\pm 30\mu s$
- Vertex z-axis($\pm 5cm$): position $-597.9cm < z < -585.9cm$
- Vertex z-axis($\pm 2cm$): position $-594.9cm < z < -588.9cm$

Track selection criteria:

- All TPC Clusters > 25
- All TPC Clusters > 35
- Without All TPC Clusters
- VTPC > 10
- VTPC > 20
- Impact parameter: $|b_x| < 5cm$ and $|b_y| < 3cm$
- Impact parameter: $|b_x| < 3cm$ and $|b_y| < 1cm$

Systematic Uncertainty

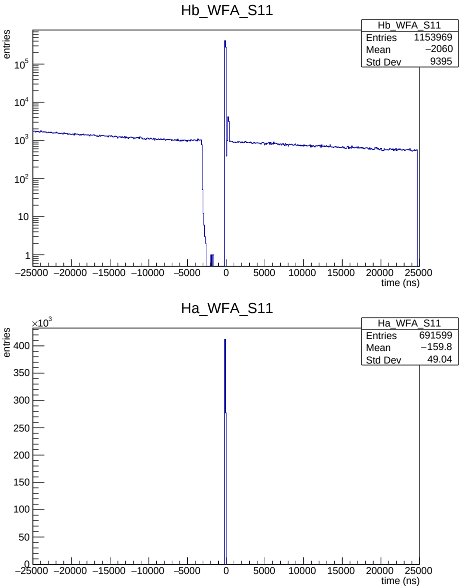


Systematic uncertainty relative to the measured yield of double-differential distributions integrated in p_T shown for π^- in dependence on rapidity y.

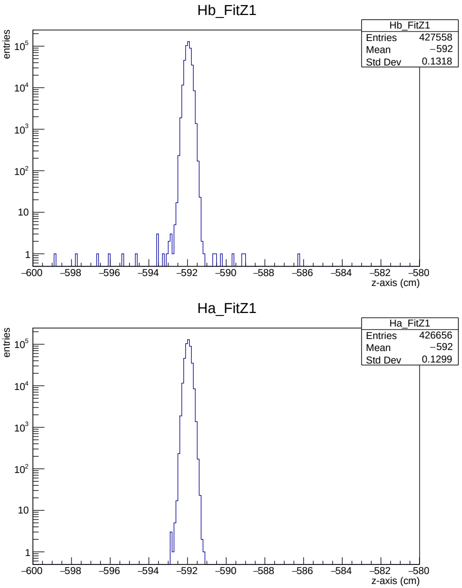
Thank you very much for your attention!

Backup slides

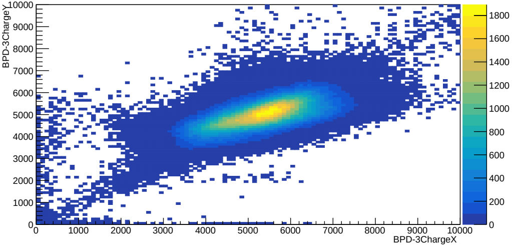
off time particle cut (data)

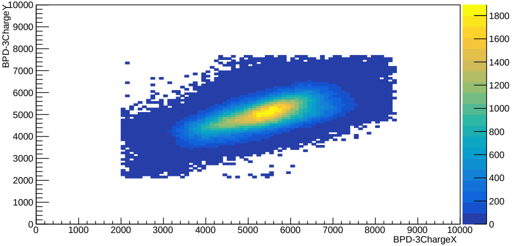


Cut on z-axis of vertex position (data)

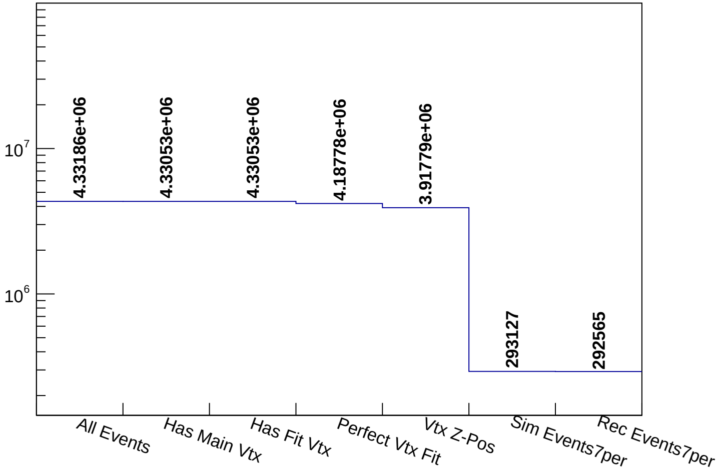


BPD-3charge Cut on data Events (before and after)





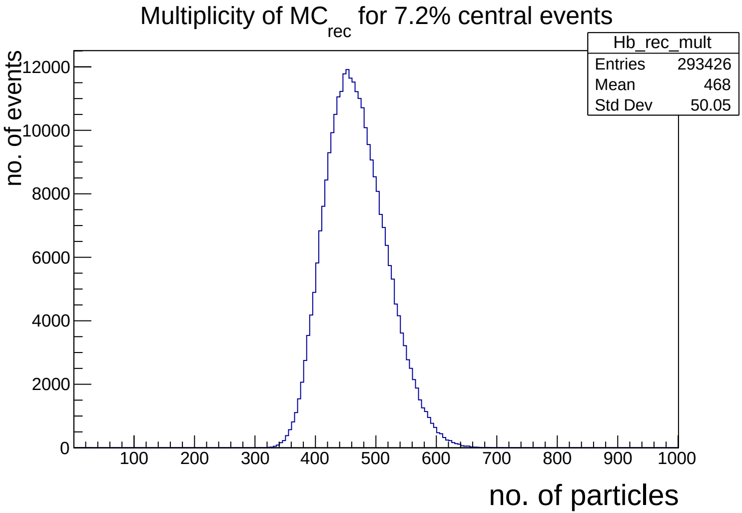
Number of MC events after different event cuts



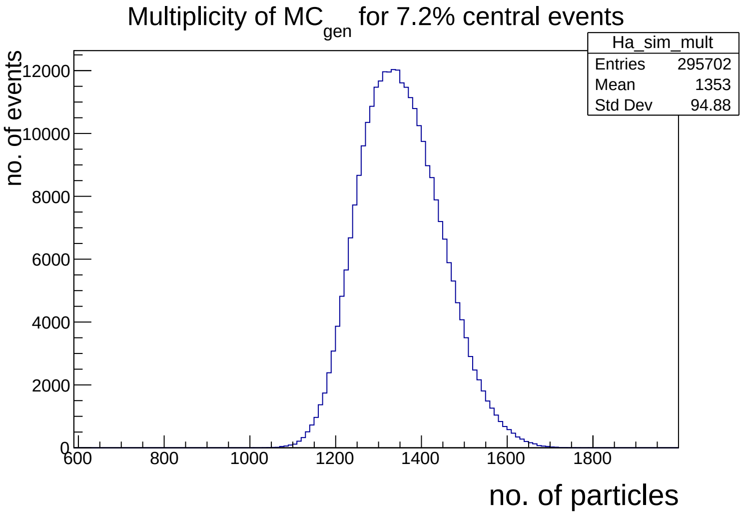
MC production information

- FTFP_BERT model is used to generate MC.
- beam-mode method was used for production.
- Simulated events have beam inelastic interaction inside the target.
- There is no "eGeneratorfinal" flag and sim main vertex for particles in processing sim event.
- So, we need to find the beam interaction vertex inside the target and loop over its daughter tracks to find the ones that did not decay inside the target.
- Check:
  - Is there beam particle?
  - Beam particle has stop vertex.
  - Position of the stop vertex is inside the target.
  - Strong interaction of beam particle inside the target.

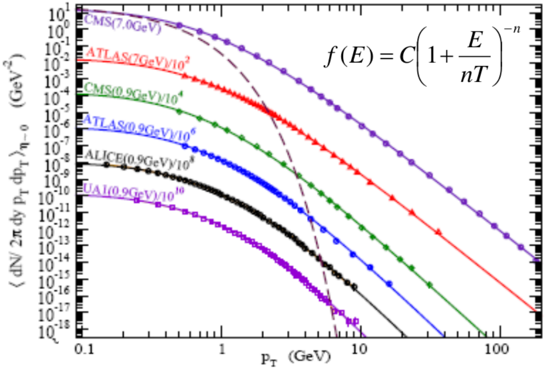
Multiplicity distribution of reconstructed MC



Multiplicity distribution of simulated MC



p_T distributions are characterized by a quasi-power law(Tsallis Distribution)



Transverse momenta distributions of different kinds can be described by a quasi power law formula (known as QCD-inspired Hagedorn formula or Tsallis distribution when the observation is interpreted in terms of the statistical model of particle production, employing the Tsallis non-extensive statistics) which for large values of transverse momenta becomes scale free (independent on T) power distribution $1/p_T^n$

Tsallis distribution successfully describes spectra, the flux of which changes by over 14 orders of magnitude.

C-Y Wong et al., PRD **91** (2015) 114027

Why Tunning of K^- yields in MC

- The MC is not perfect