Intermittency analysis of protons produced in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

Fakhar Ul Haider
(Supervisor: Prof. Ramni Gupta)
Department of Physics, University of Jammu

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Outline

- Motivation
- Methodology
- Dataset
- Particle Identification
- Results
- Summary and Outlook

Motivation

- Lattice QCD: Large fluctuations at critical point.
- System produced in high energy collisions can be characterized by studying multiplicity fluctuations.
- Fluctuations: Deviation from the average behavior
  - Critical nature of the system
  - the quark-hadron phase transition
  - particle production mechanism
  - characteristics of the system formed

Scaling behavior of Normalized Factorial Moments of geometrical configurations of particles produced → **Intermittency**

R. C. Hwa et al, PRL 69, 741 (1992)

R.C. Hwa & C.B. Yang, PRC 85, 044914 (2012)

A. Bialas and R. Peschanski, Nucl. Phys. 273, 703 (1986).; 308, 857 (1988)

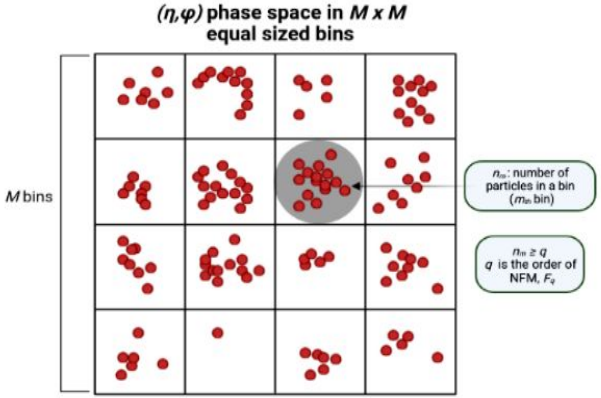
Charged particles recorded with ALICE
- Pb-Pb collisions at 2.76 TeV
- Pb-Pb collisions at 5.02 TeV
- Xe-Xe Collisions at 5.44 TeV

https://github.com/alisw/AliPhysics/tree/master/PWGCF/EBYE/IntermittencyAnalysis

Methodology

- (η,ϕ) phase space is divided into a square lattice.
- Particles are mapped onto this 2D matrix.

- Number of particles that go in each cell defines the bin multiplicity
- For each bin with bin multiplicity n_{ie} >= q, the factorial moment is determined as
  - event by event basis.
  - for M = 4 to 82



$$f_q(n_{ie}) = n_{ie}(n_{ie}-1)(n_{ie}-2).....(n_{ie}-q+1)$$

q is the order parameter, $q \geq 2$ (2,3,4,5)
n_{ie} is the bin multiplicity, $n_{ie} \geq q$
M--> Number of bins
(M^2 for self similar analysis)
N--> Number of events

Normalized Factorial Moments are then defined as:

$$F_q(M) = \frac{\frac{1}{N}\sum_{e=1}^{N}\frac{1}{M}\sum_{i=1}^{M} f_q(n_{ie})}{\left(\frac{1}{N}\sum_{e=1}^{N}\frac{1}{M}\sum_{i=1}^{M} f_1(n_{ie})\right)^q}$$

Scaling properties of Normalized Factorial Moments of multiplicity distributions are studied.

$$F_q(M) \propto M^{\varphi_q} \longrightarrow \textbf{M-Scaling}$$

=> scale independence of spatial fluctuations

$$F_q(M) \propto F_2(M)^{\beta_q} \longrightarrow \textbf{F-Scaling}$$

$$\beta_q \propto (q-1)^{\nu}$$

ν quantifies the spatial fluctuations

ν: is **scaling exponent** (dimensionless exponent)
gives economical summary of the system under study

ν ≅ 1.32 Ginzburg Landau formalism for the second- order phase transition

≅ 1.41 Critical fluctuations, SCR Model 3

Hwa and Nazirov, Phys. Lett. 69, 741 (1992).
Hwa and Pan PLB 297, 35-58 (1992)

Dataset.

Pb-Pb 5.02 TeV

ALICE: LHC15o pass2, LHC18r pass3 and LHC18q pass3.
HIJING: LHC20e3a and LHC20j6a

Event and Track cuts

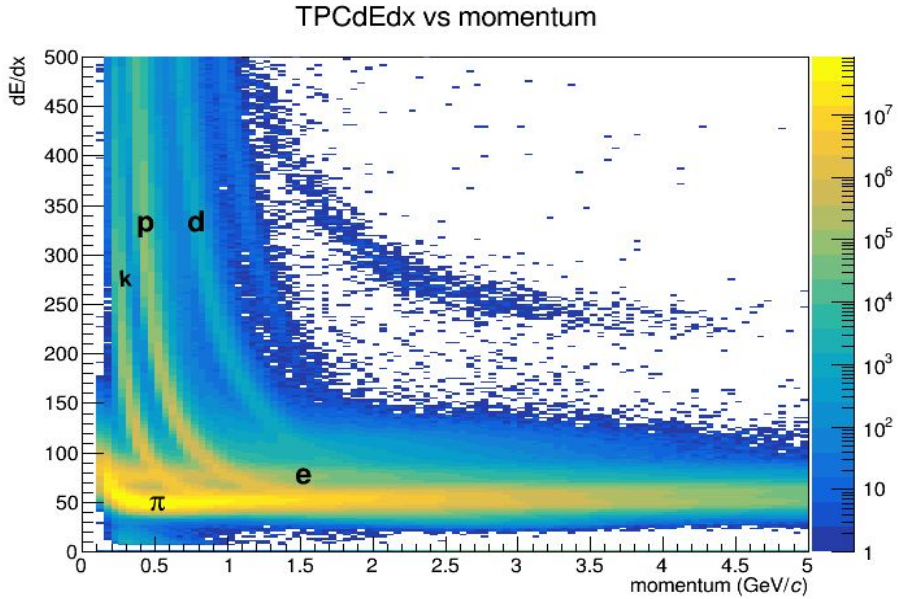
Triggerbit: kINT7
Centrality : 0-10%
Centrality estimator: V0M
$|\eta| < 0.8$
Full azimuthal coverage
FilterBit: 768

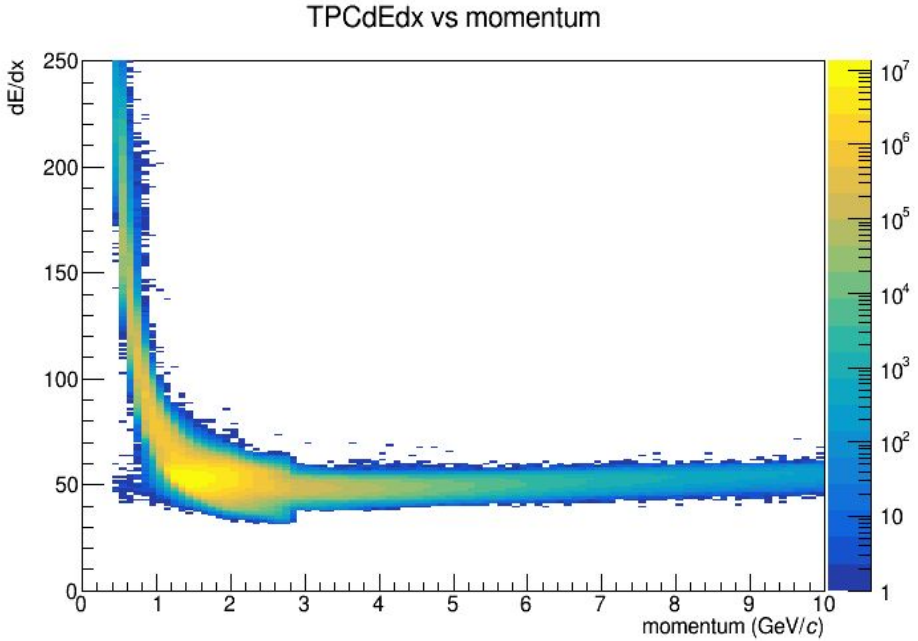
p_T bins : 0.2-2.0,
(GeV/c) 0.2-5.0

Particle Identification (TPC)

TPC cuts

$|N\sigma|_{TPC} < 3.0$ (proton $p_T < 2.0$ GeV/c)





Particles identification (TOF)

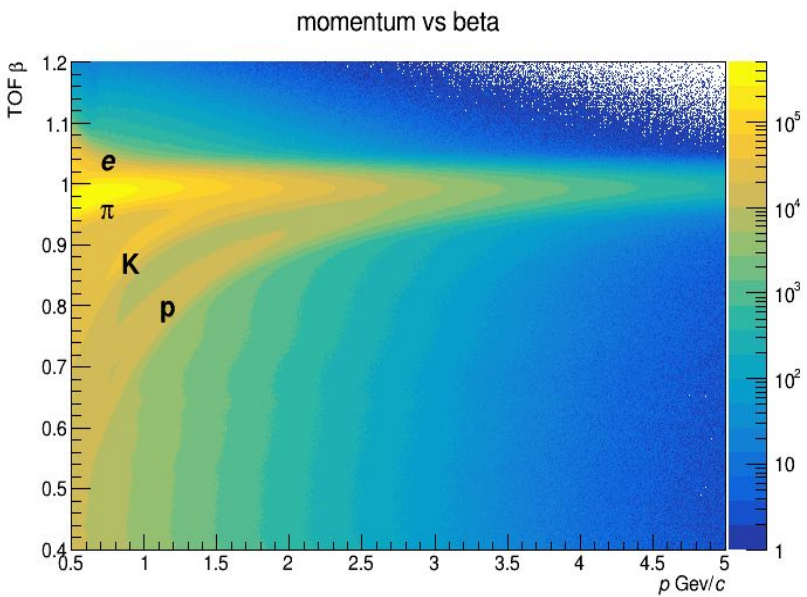
TPC + TOF cuts

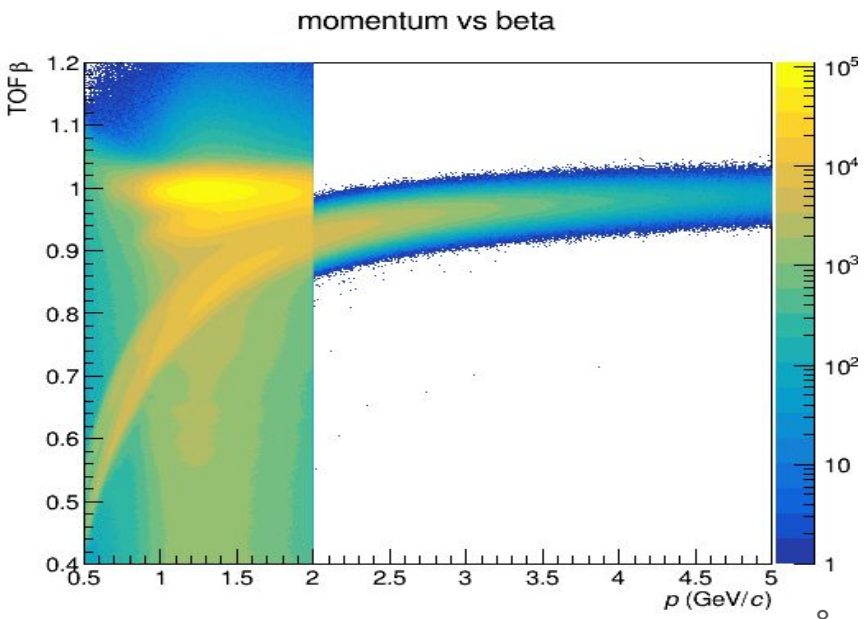
Nσ(TPC + TOF) < 3.0

(for proton p_T > 2.0 GeV/c)

Where

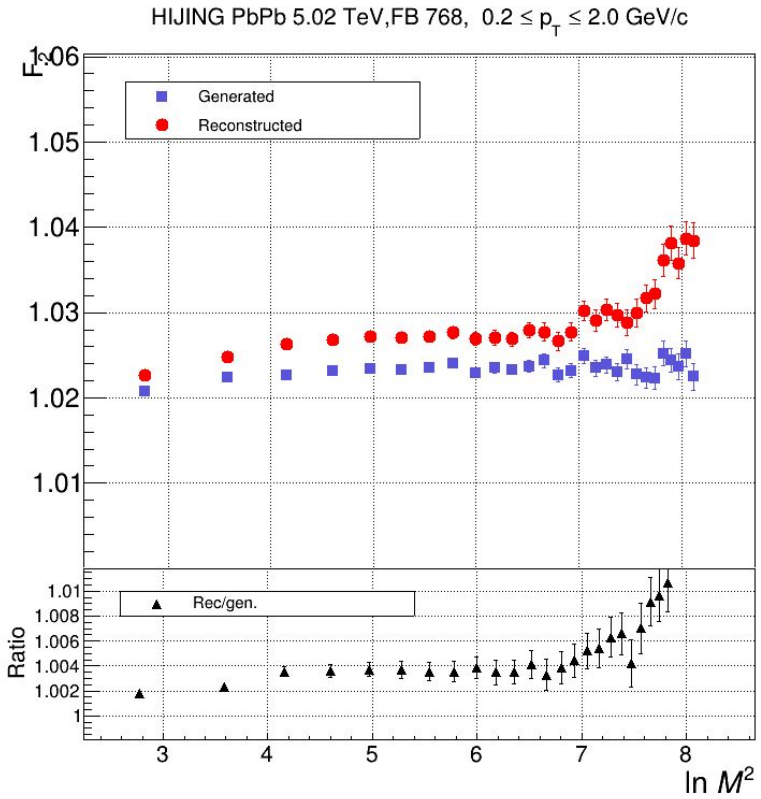
Nσ(TPC + TOF) = $\sqrt{N^2_{\sigma_{TPC}} + N^2_{\sigma_{TOF}}}$.

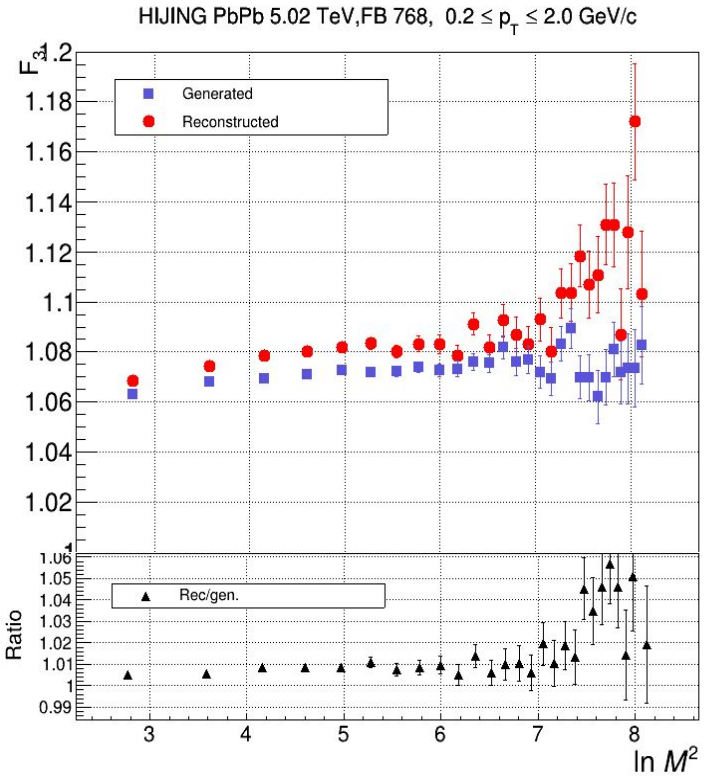




HIJING: MC closure

$0.2 \leq p_T \leq 2.0$ GeV/c





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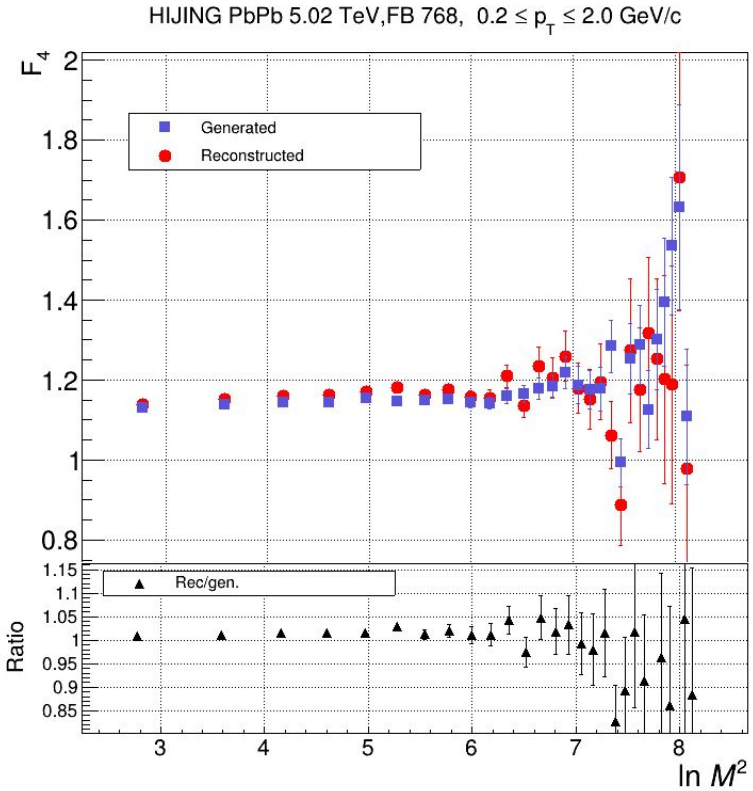
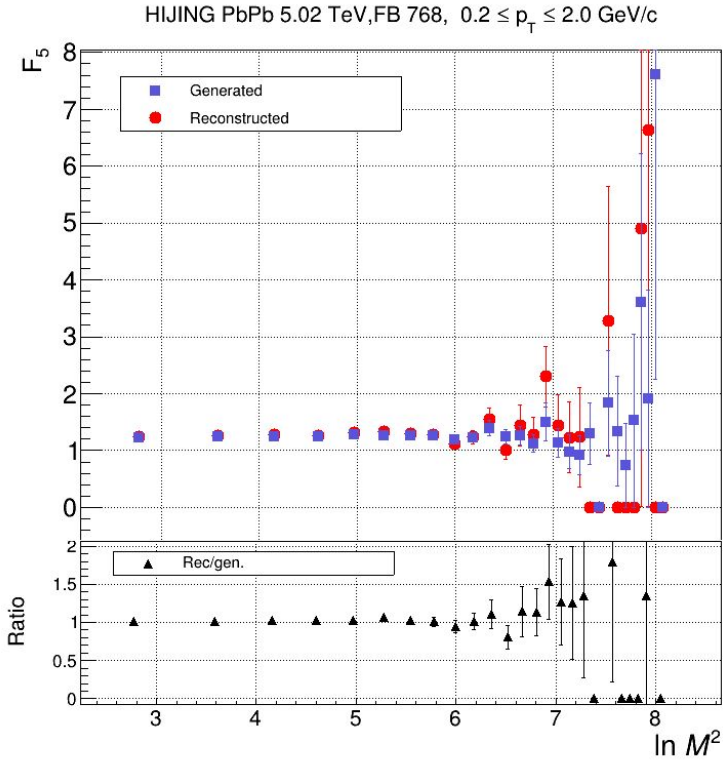
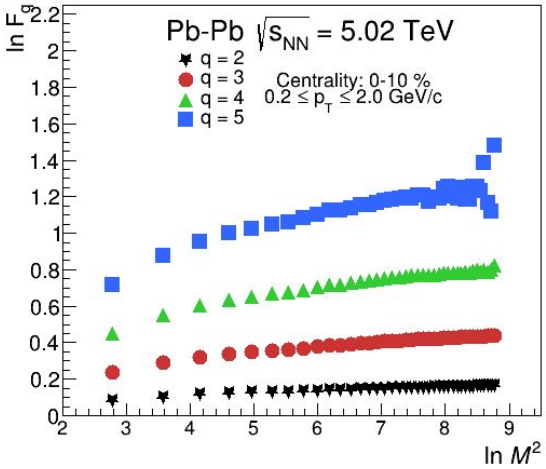
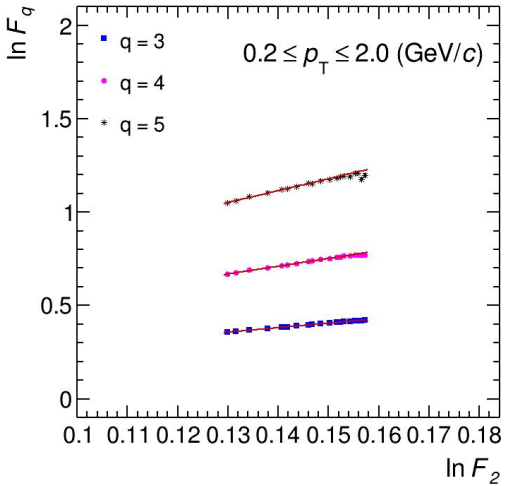




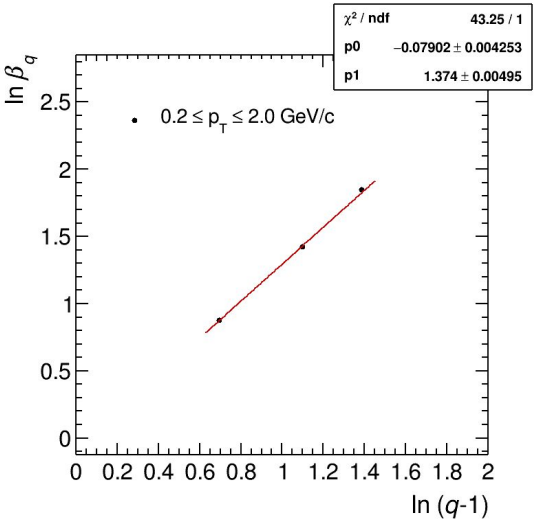
ALICE: First Look, proton analysis

$$0.2 \leq p_T \leq 2.0 \text{ GeV/c}$$





v=1.374



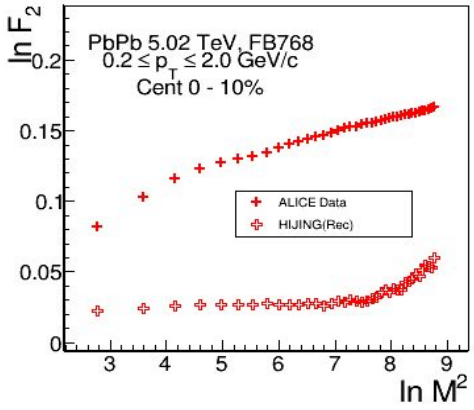
$$F_q(M) \propto M^{\varphi_q}$$

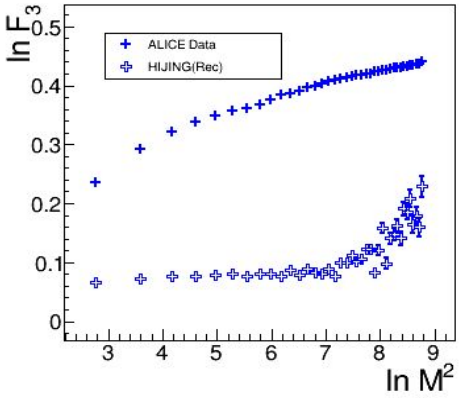
$$F_q(M) \propto F_2(M)^{\beta_q}$$

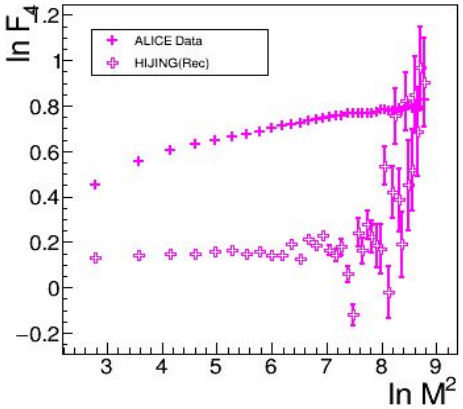
$$\beta_q \propto (q-1)^{\nu}$$

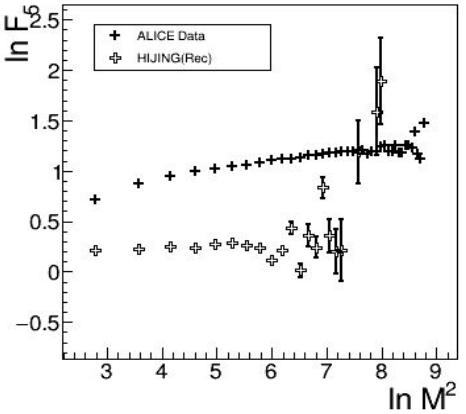
Comparison plots: ALICE & HIJING

$0.2 \leq p_T \leq 2.0$ GeV/c



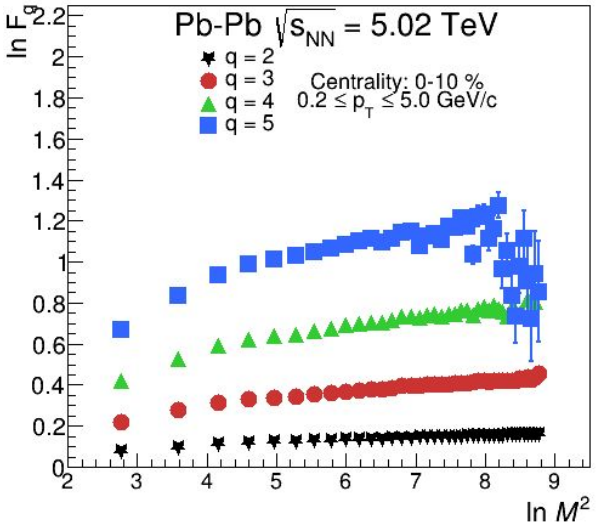


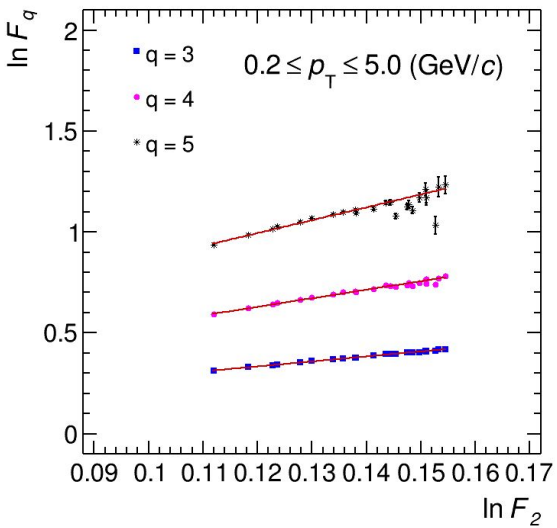




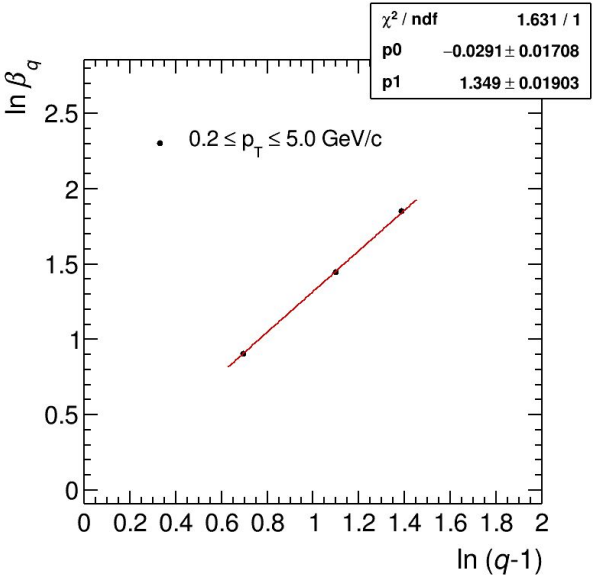
ALICE: First Look, proton analysis

$0.2 \leq p_T \leq 5.0$ GeV/c





v=1.349



$$F_q(M) \propto M^{\varphi_q}$$

$$F_q(M) \propto F_2(M)^{\beta_q}$$

$$\beta_q \propto (q-1)^{\nu}$$

Summary and Outlook

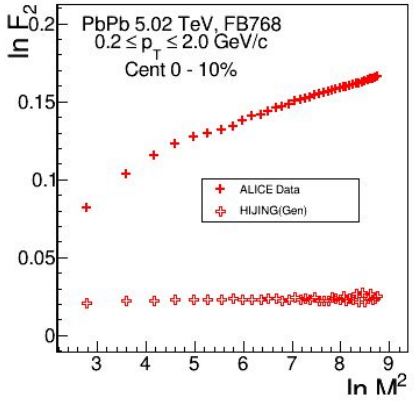
- **Preliminary investigations of**
  - Two dimensional Intermittency analysis of **protons** produced in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.
  - M-scaling observed in data indicating presence of scale invariant fluctuations that are absent in HIJING
  - F-scaling observed in data, scaling exponent (v) is obtained (< 1.4)
  - Efficiency maps are calculated in eta phi phase space.

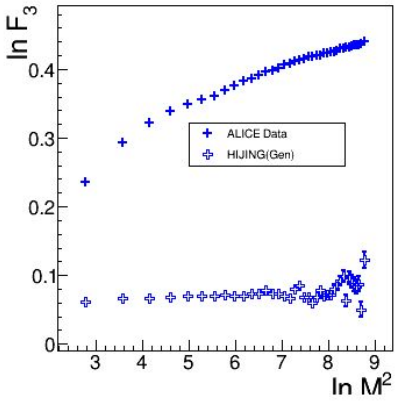
- To Do
  - Improve on PID selection cuts
  - To implement efficiency corrections
  - Fine tune the fitting for the acceptable closure region.

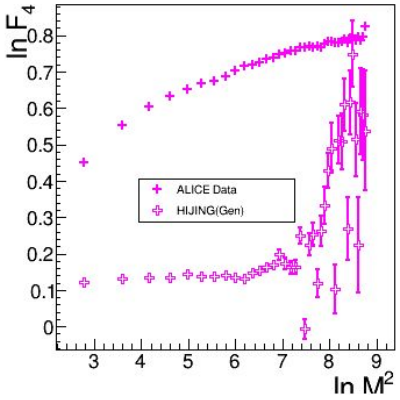
Thank You

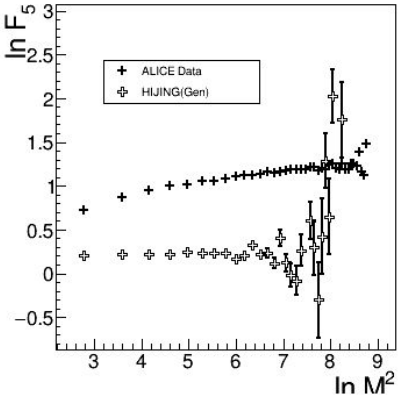
Backup

Comparison plots: ALICE & HIJING_Gen



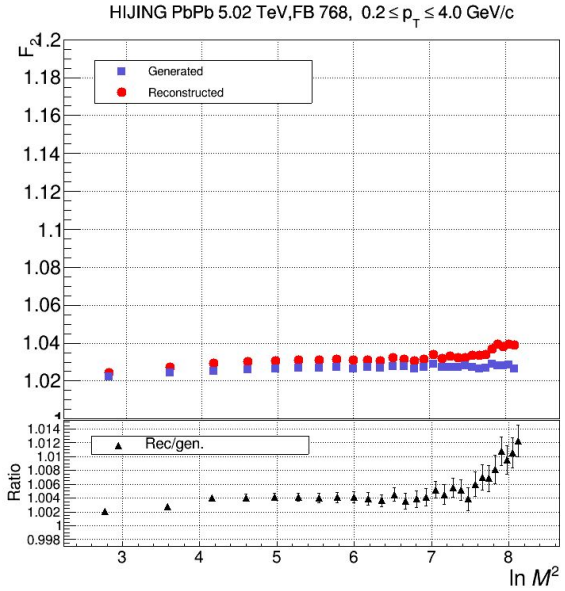


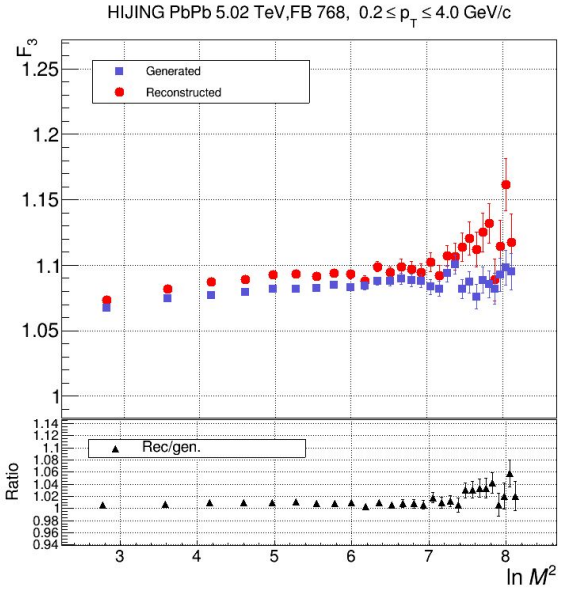


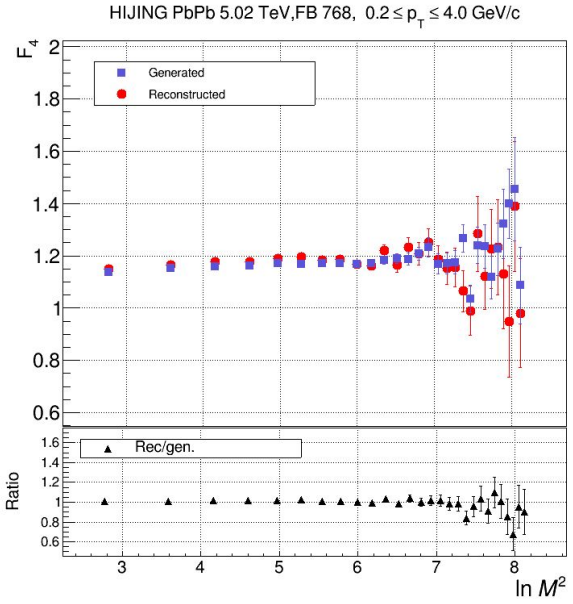


$0.2 \leq p_T \leq 2.0$ GeV/c

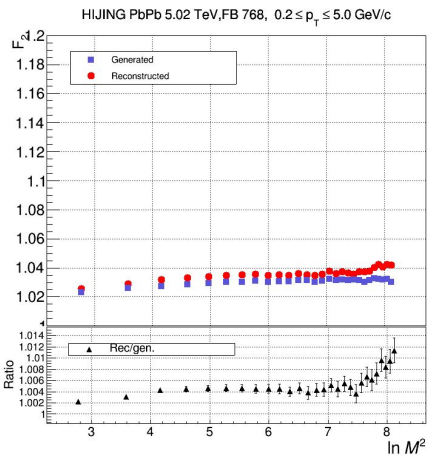
HIJING: MCC pT bin[0.2-4.0]

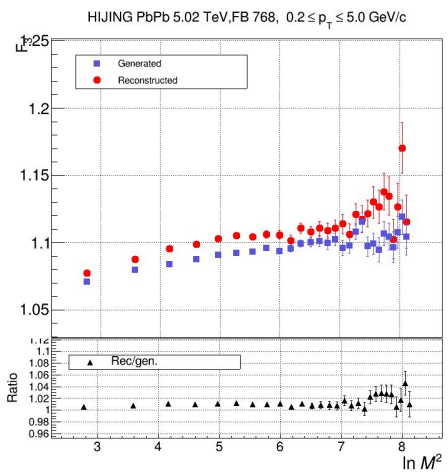


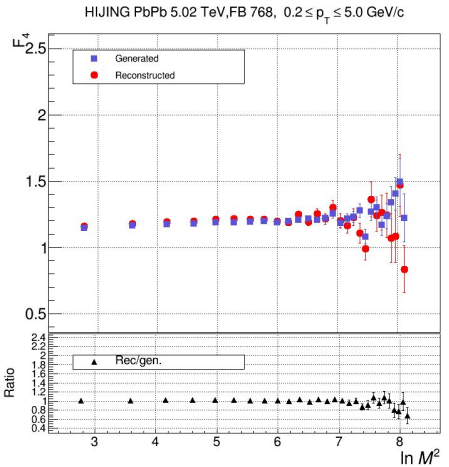


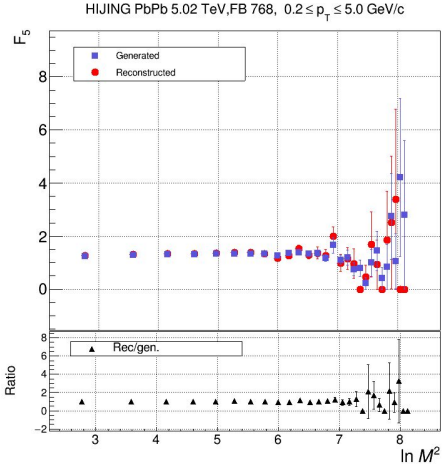


HIJING: MCC, pT bin [0.2,5.0]



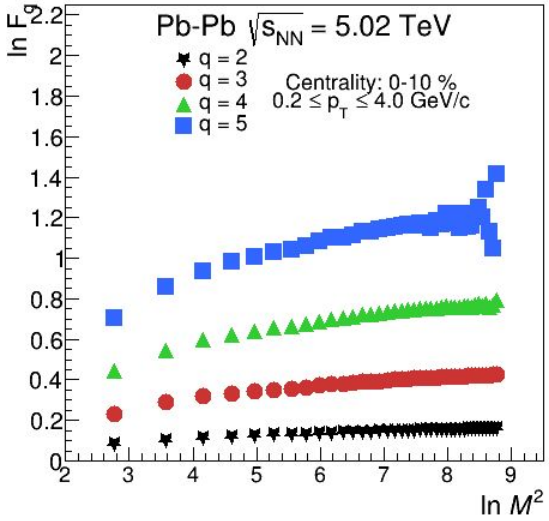




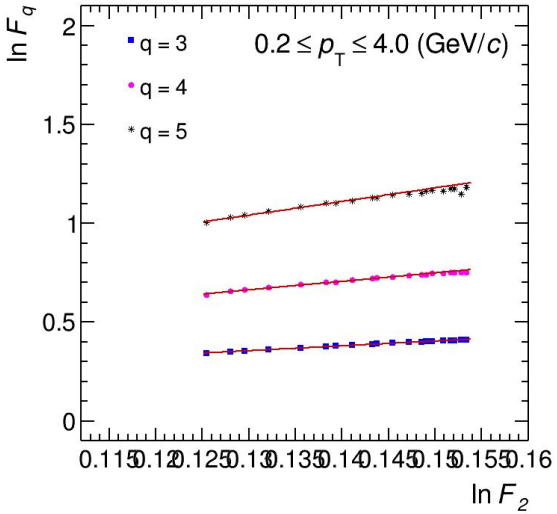


ALICE: First Look, proton analysis

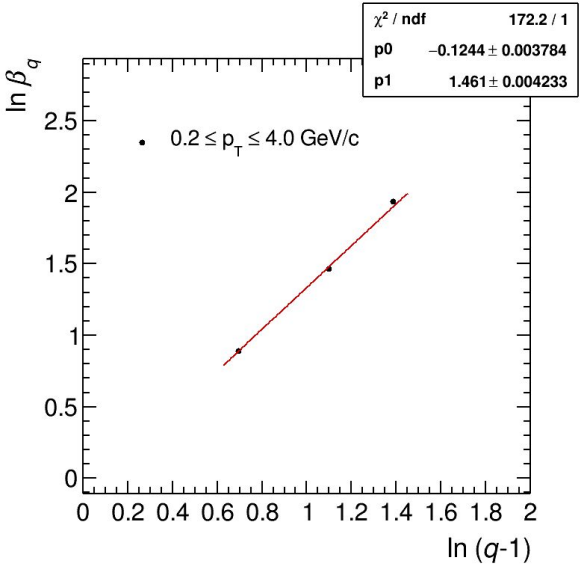
$$0.2 \leq p_T \leq 4.0 \text{ GeV/c}$$



$$F_q(M) \propto M^{\varphi_q}$$

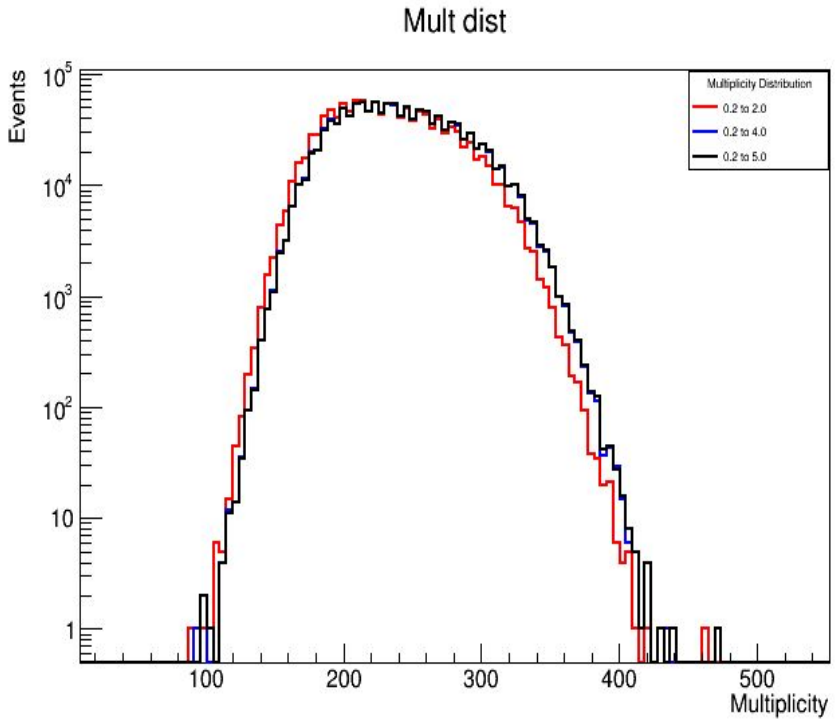


$$F_q(M) \propto F_2(M)^{\beta_q}$$

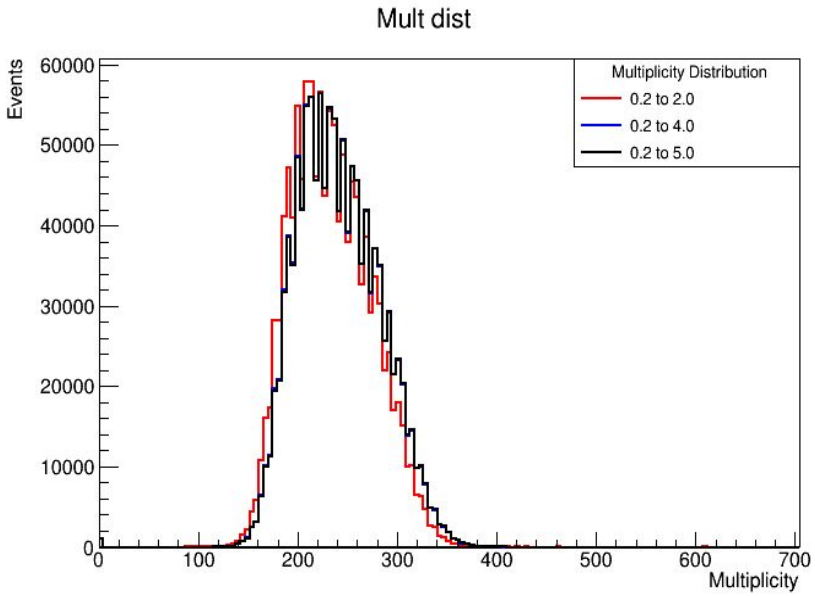


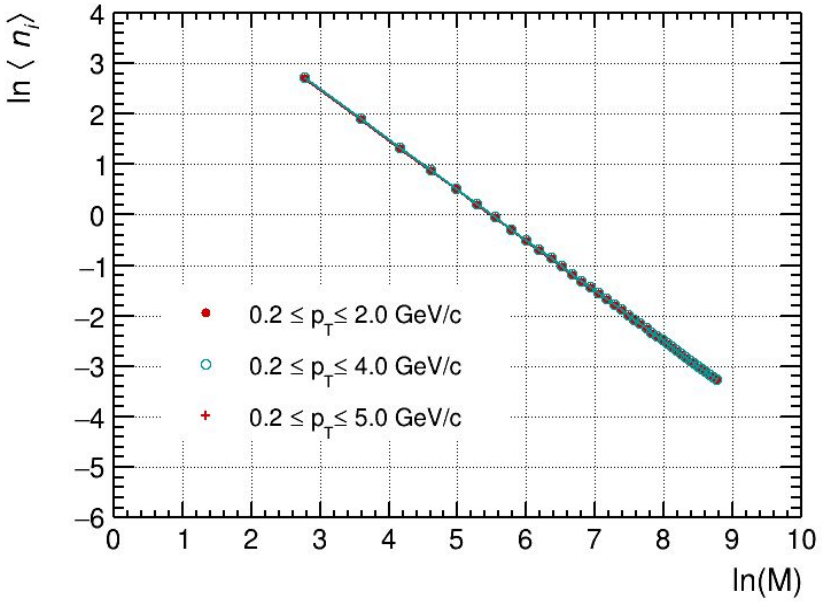
$$\beta_q \propto (q-1)^{\nu}$$

Multiplicity: y-axis in log scale

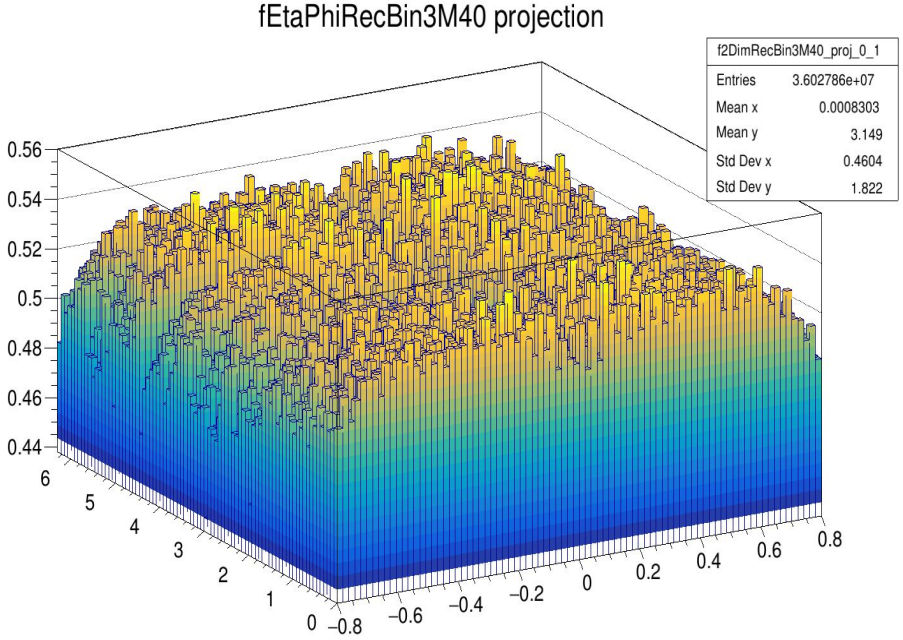


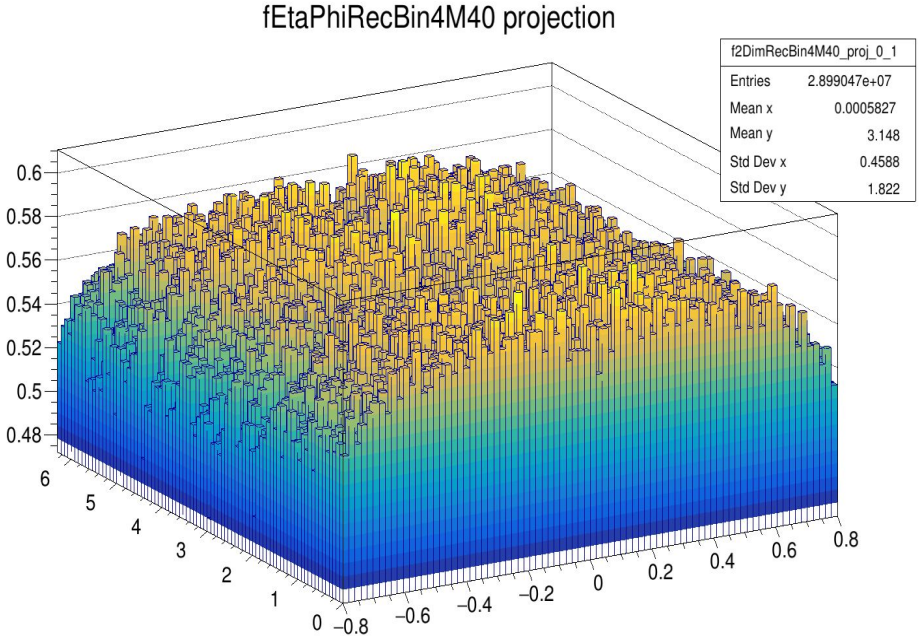
ALICE: Multiplicity distribution & average bin content





Efficiency Maps:





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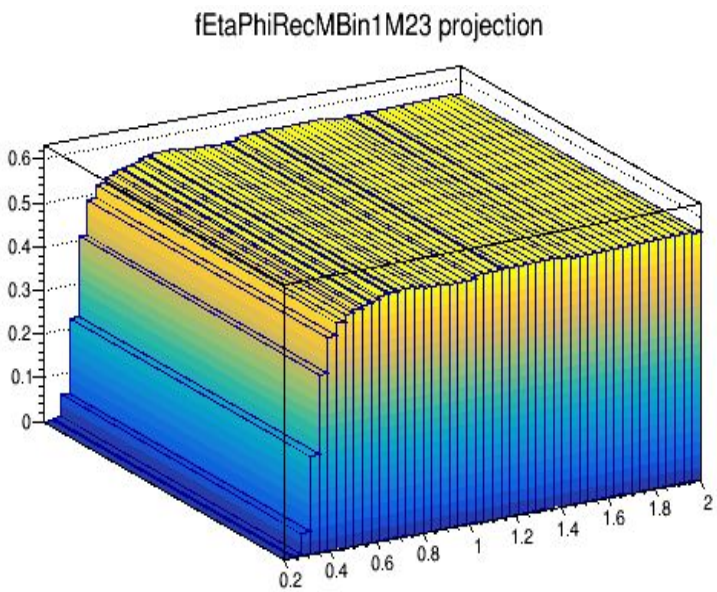

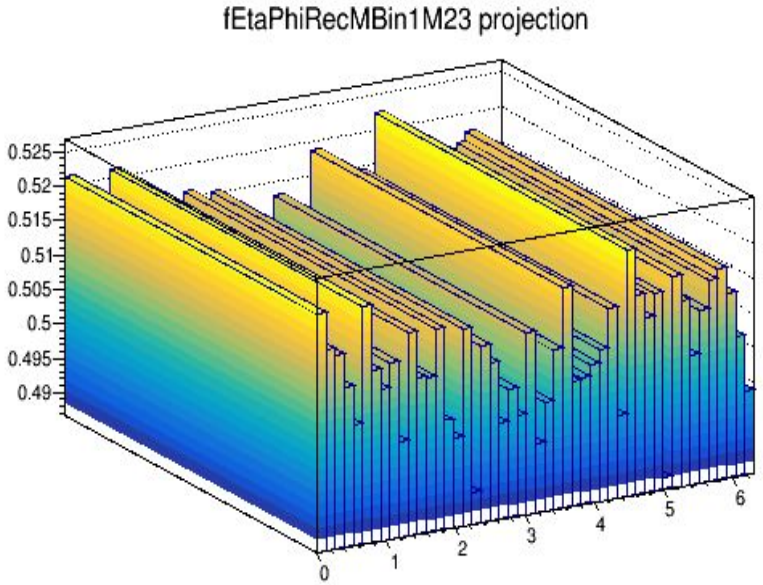

Not yet implemented