Centrality determination sensitivity to multiplicity cuts

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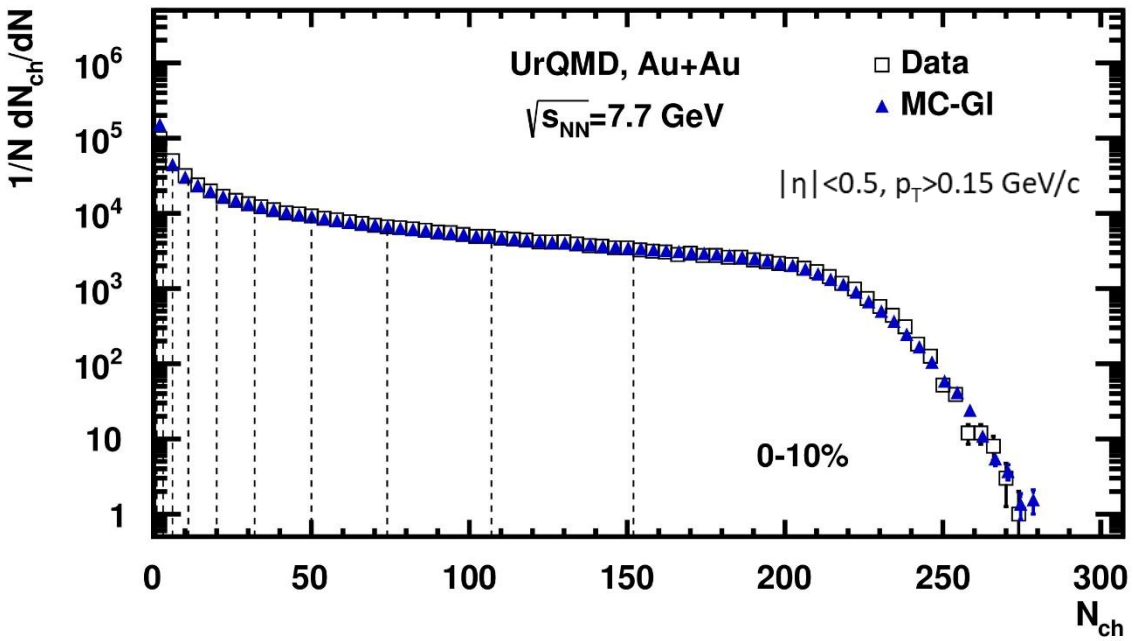
MC-Glauber based centrality framework

MC Glauber data → Evaluate N_a: $N_a = fN_{part} + (1-f)N_{coll}$ → Call NBD(μ,k) x N_a → Build multiplicity fitting function → Evaluate χ^2

Input multiplicity distribution → Minimize χ^2 to find f, μ, k



NBD – negative binomial distribution

Parameters of the fit:

- **f** – fraction of the production from the soft component
- **μ** – mean multiplicity value
- **k** – width of the multiplicity distribution, can be connected to the fluctuations

This centrality procedure was used in CBM, NA49, and NA61/SHINE

I. Segal, et al., J.Phys.Conf.Ser. 1690 (2020) 1, 012107

Implemantation for MPD: https://github.com/FlowNICA/CentralityFramework

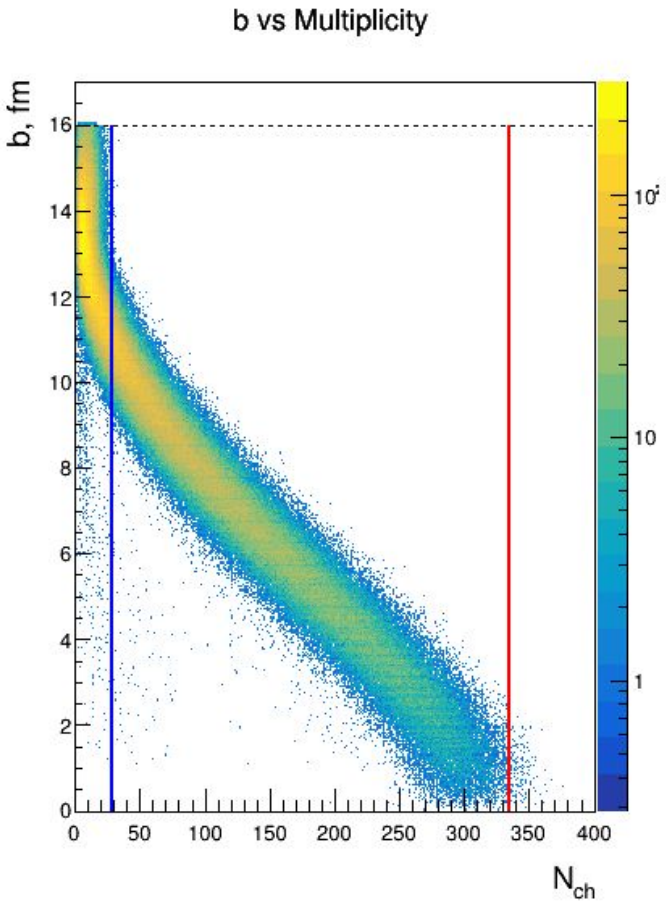
P. Parfenov, et al., Particles. 2021; 4(2):275-287

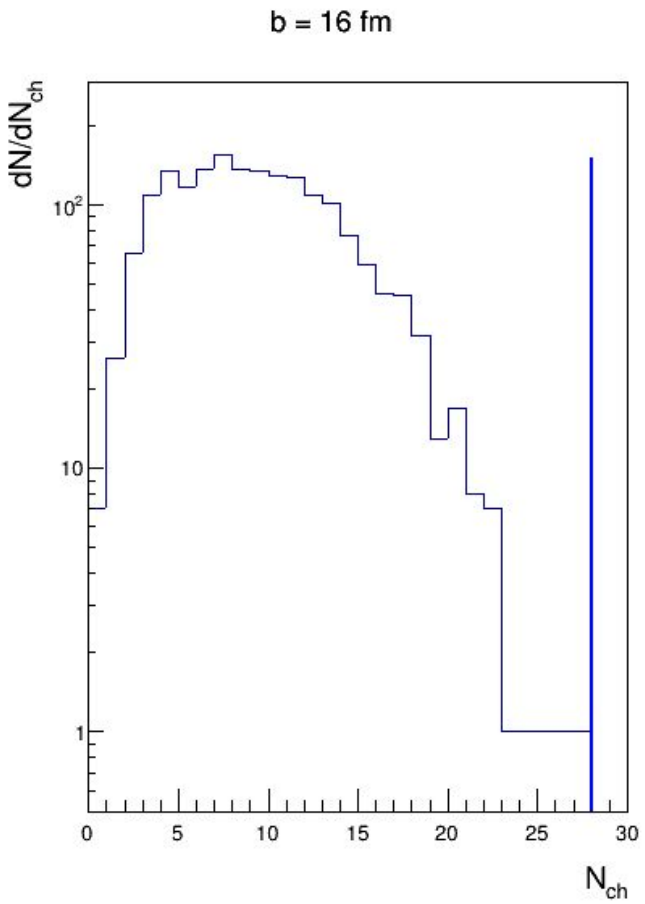
The track selection criteria and multiplicity cuts

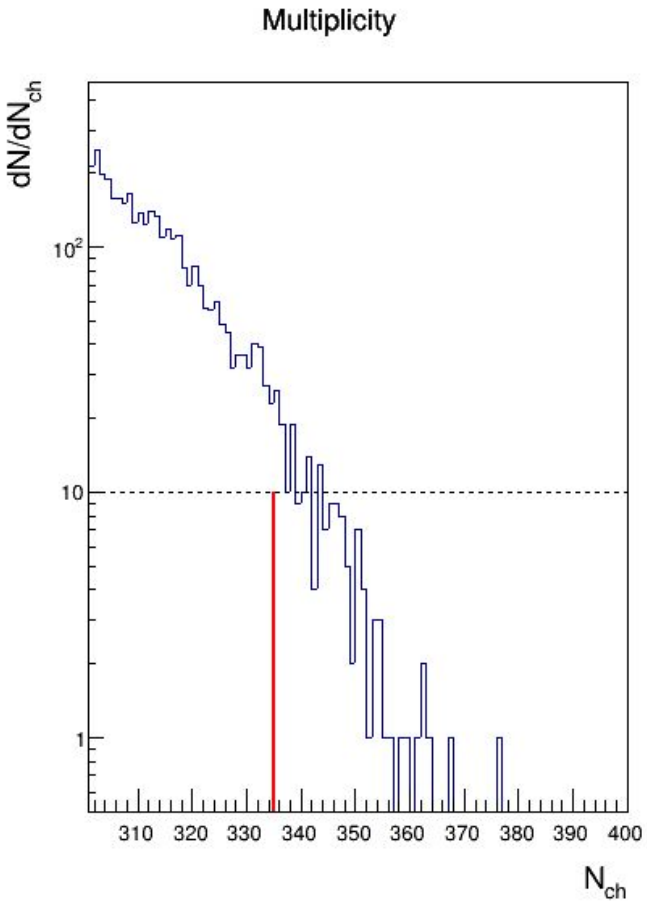
	DCA	Nhits	eta	Pt	Nch_min	Nch_max
Default	1	16	0.5	0.15	15	280
set1	-	16	0.5	0.15	28	235
set2	2	16	0.5	0.15	15	300
set3	3	16	0.5	0.15	15	300
set4	1	10	0.5	0.15	15	280
set5	1	32	0.5	0.15	15	275
set6	1	-	0.5	0.15	15	280
set7	1	16	1	0.15	15	500
set8	1	16	0.5	-	15	285

Official production request 25: UrQMD, Bi+Bi @ 9.2 GeV (GEANT4, reconstruction)

Choosing optimal multiplicity cuts (set1)

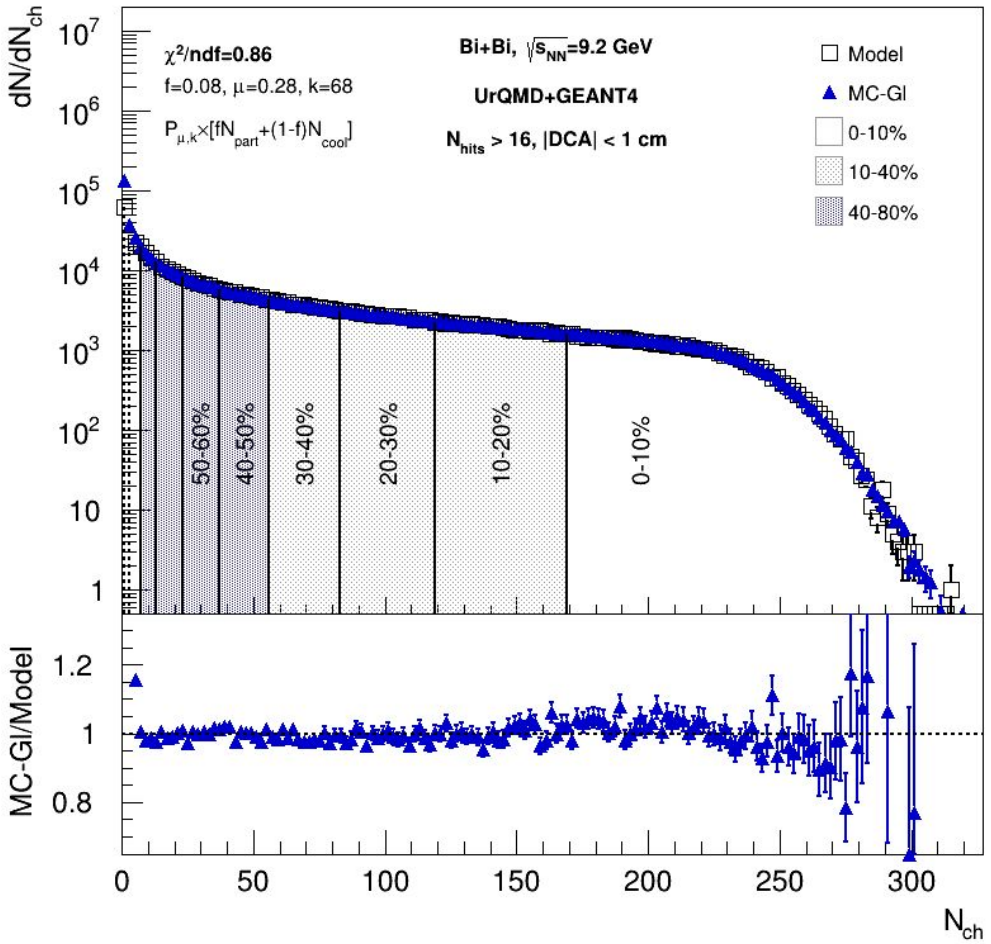


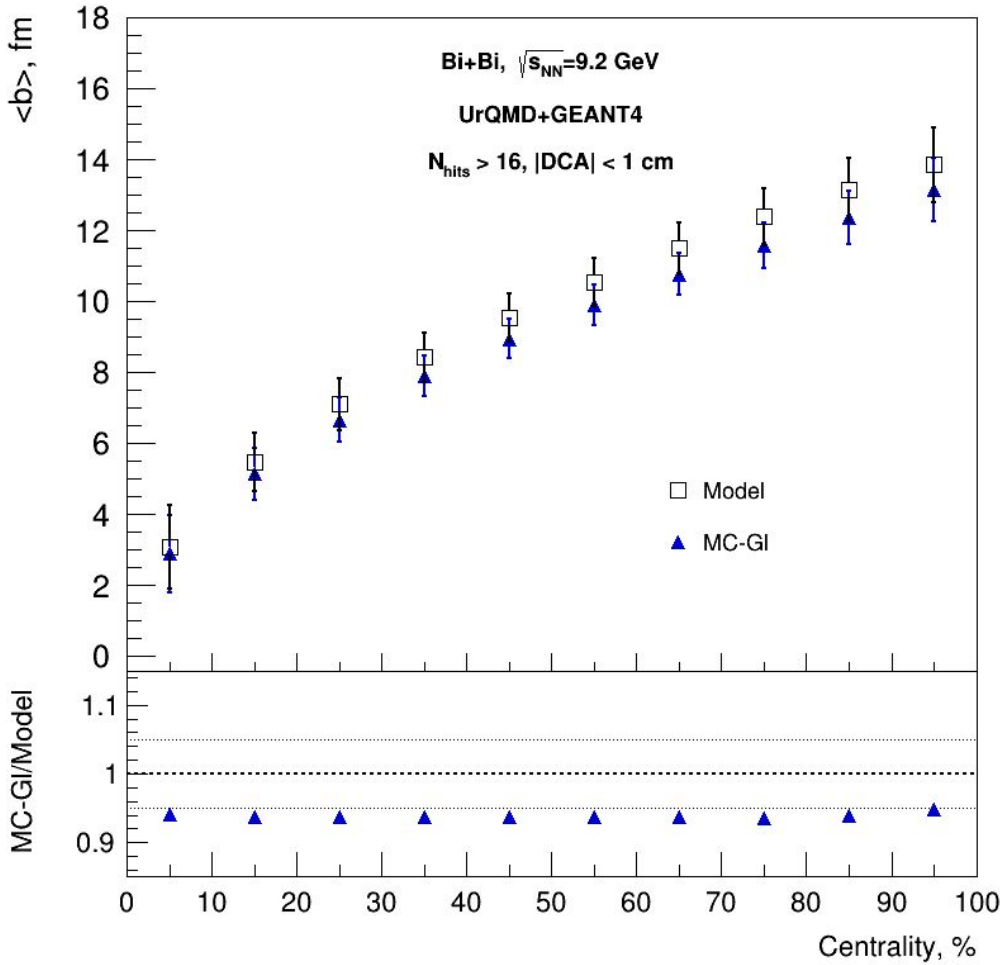




Nch_min is chosen specifically to exclude bias from b<16 fm limitation in the generated data set
Nch_max is chosen to have at least 10 events to cut outliers

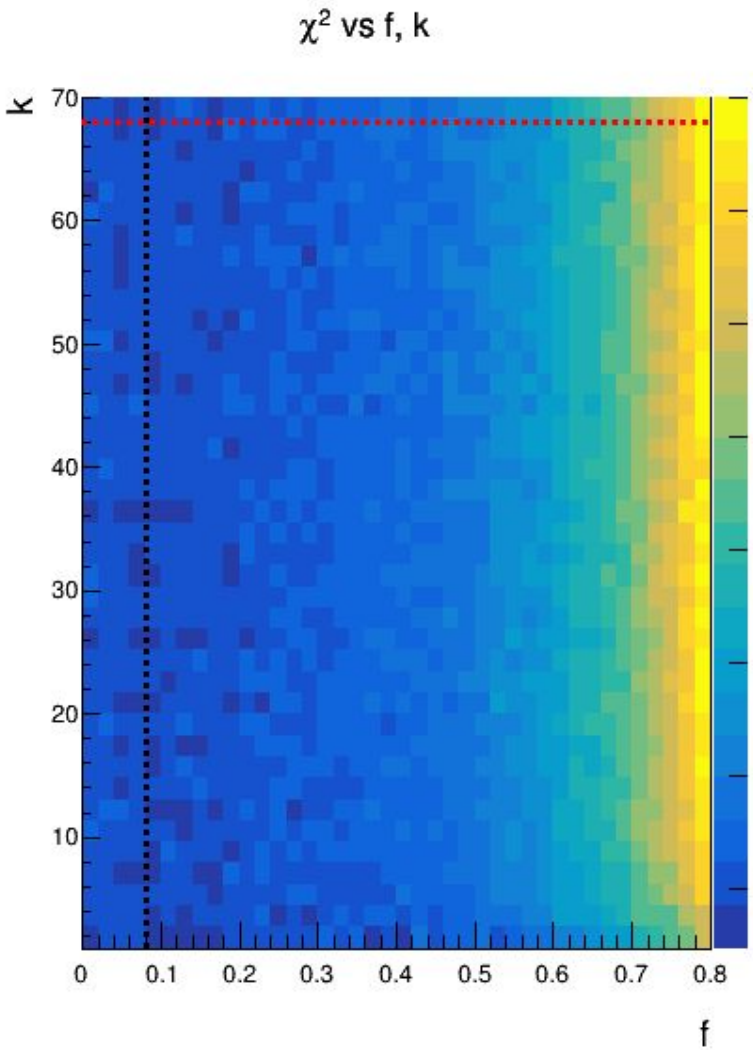
Centrality determination (Default)

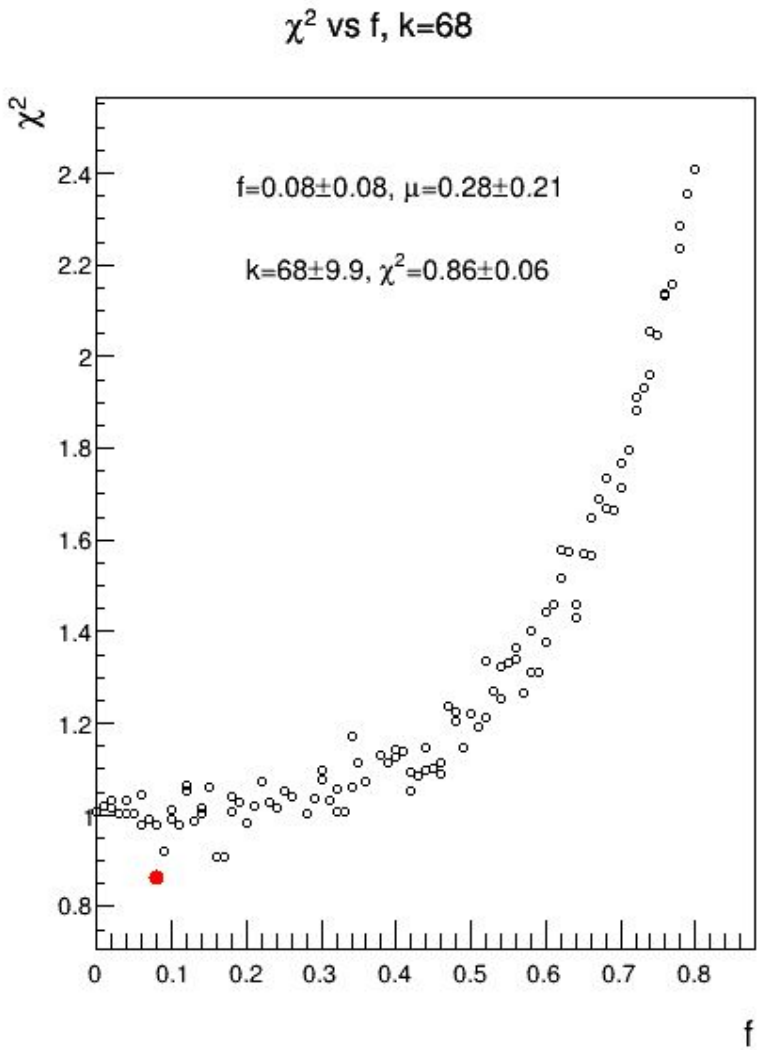


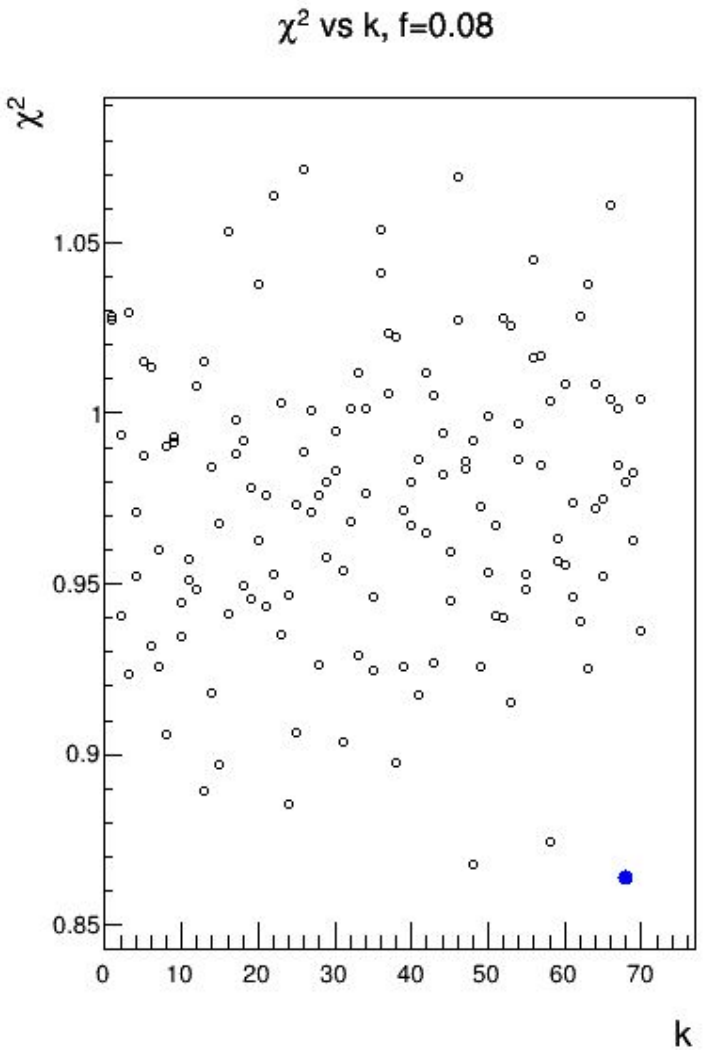


Good fit quality in the default case

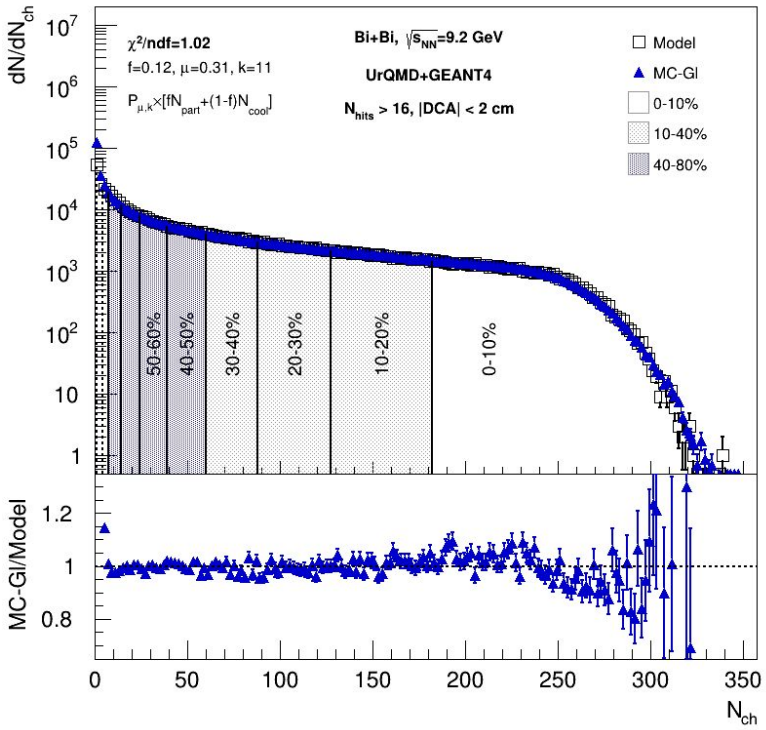
Centrality determination: χ^2 vs. f, k (Default)



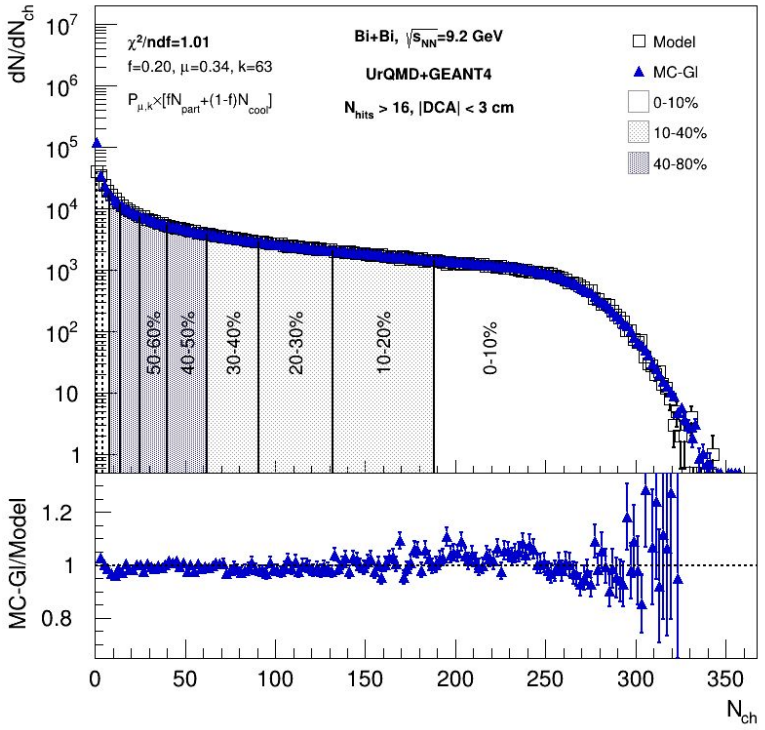




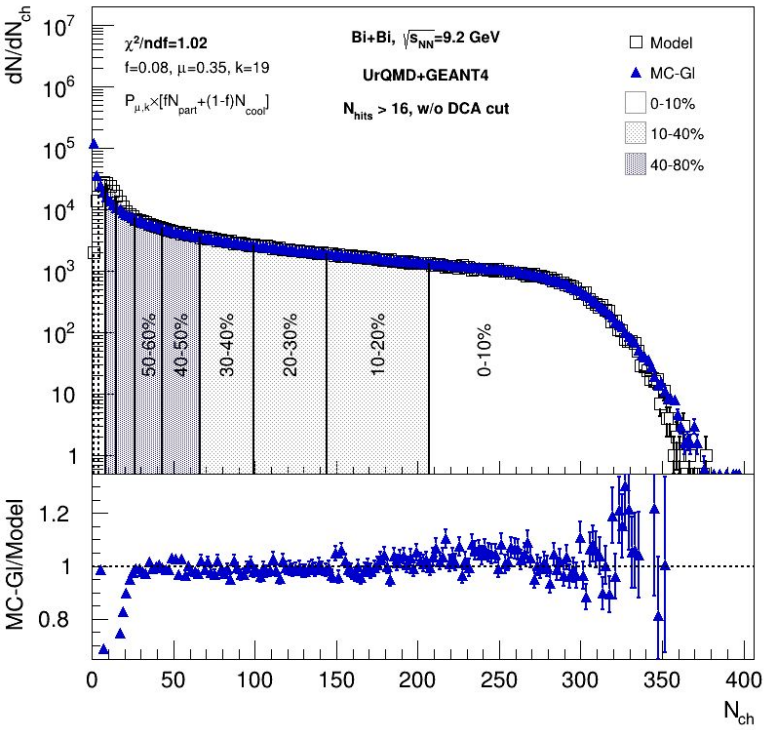
Centrality determination: Comparisons for different DCA cuts



|DCA|<2 cm



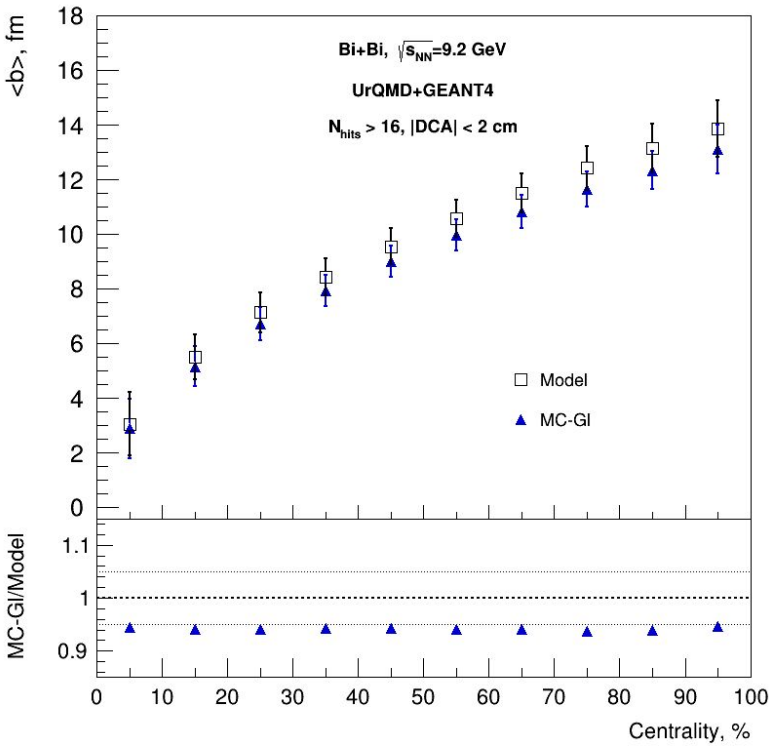
|DCA|<3 cm



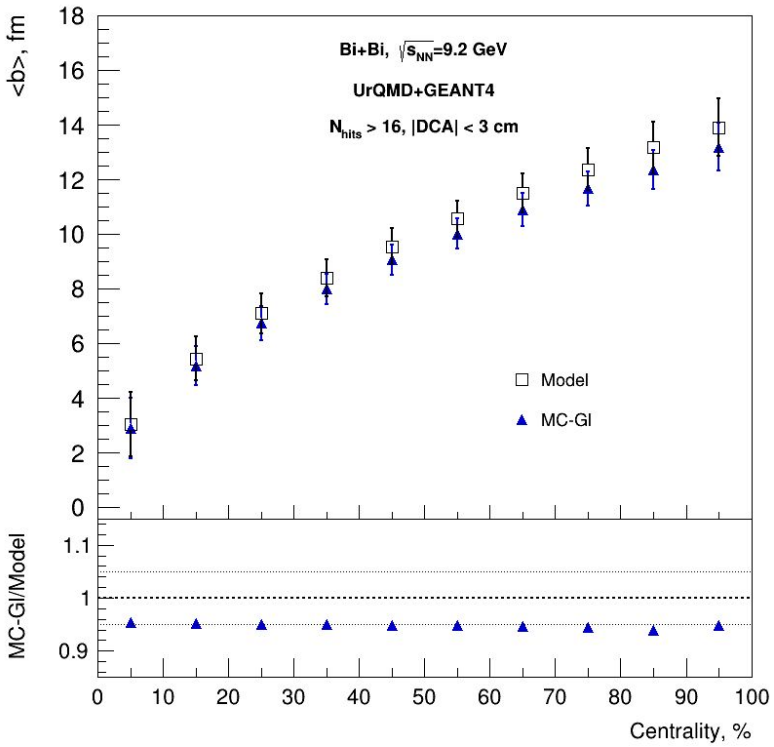
w/o DCA cut

DCA cut has a very small effect on a fit quality

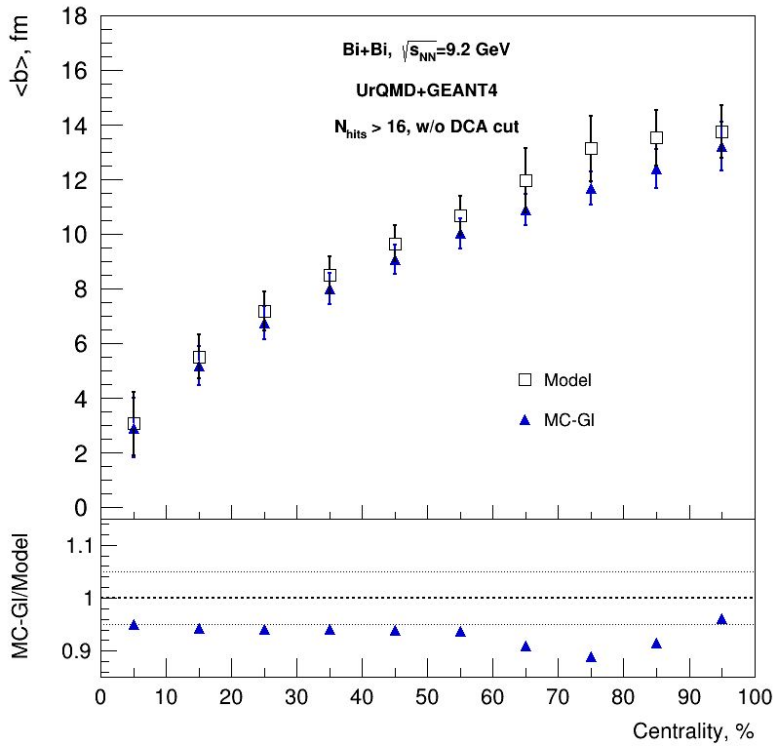
Centrality determination: Comparisons for different DCA cuts



|DCA|<2 cm



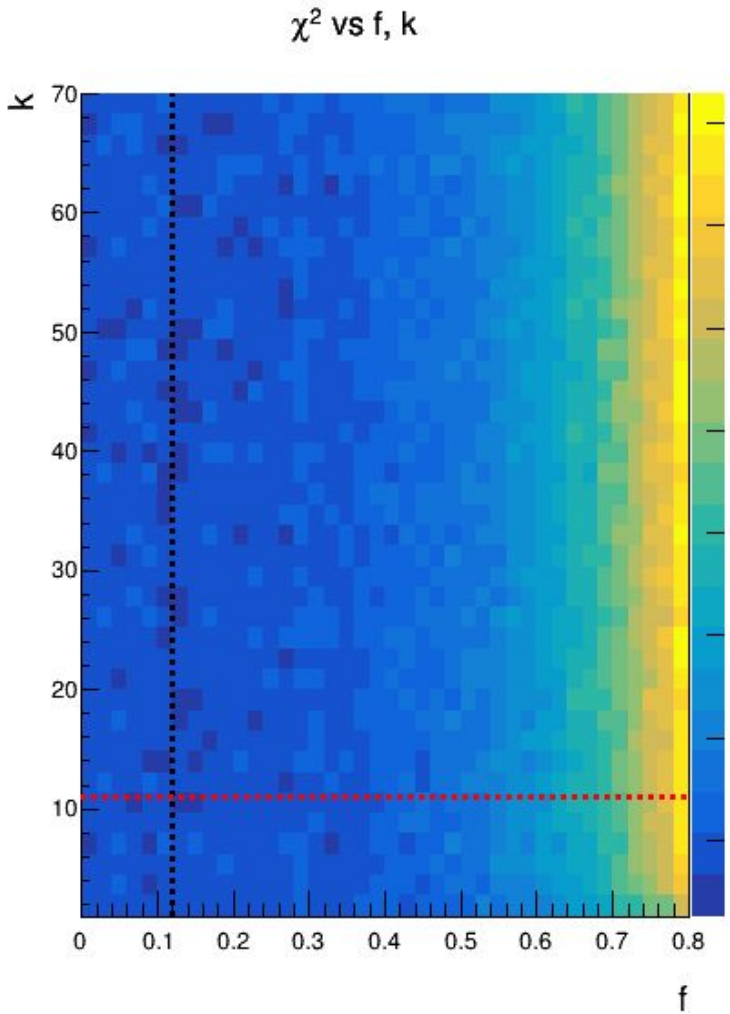
|DCA|<3 cm

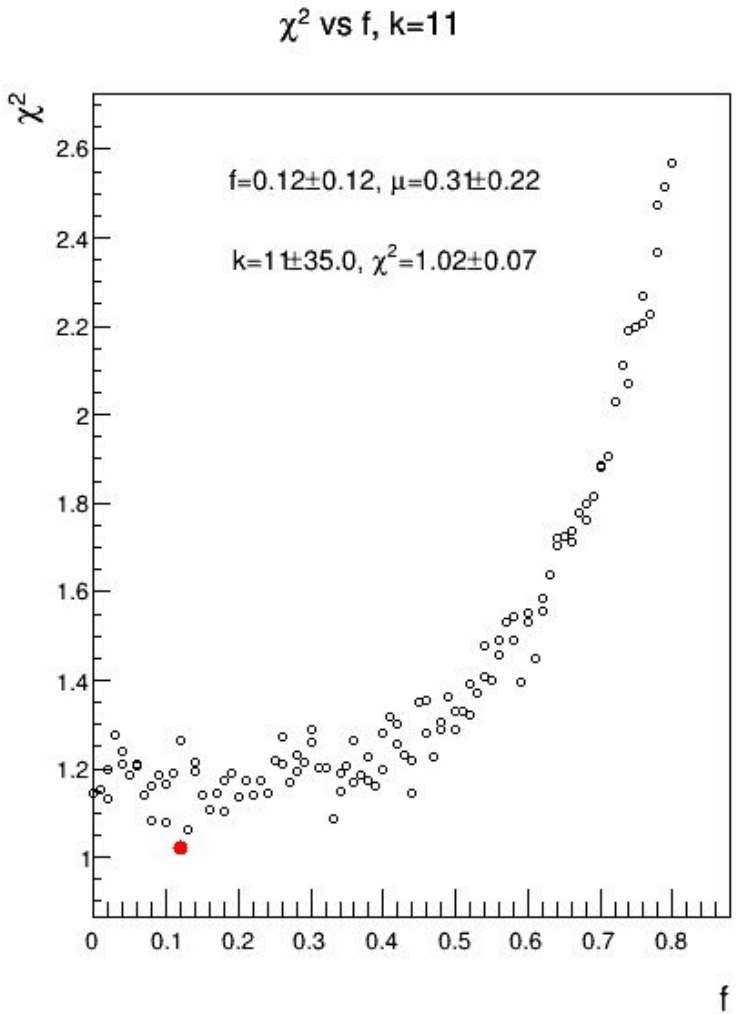


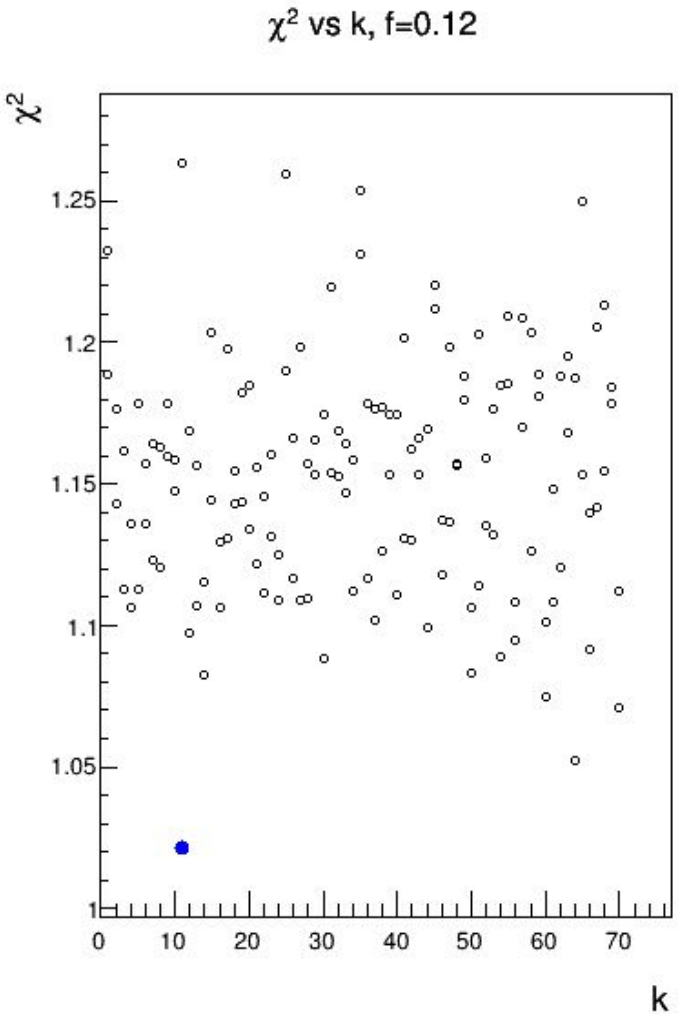
w/o DCA cut

DCA cut can be relaxed to |DCA|<3 cm

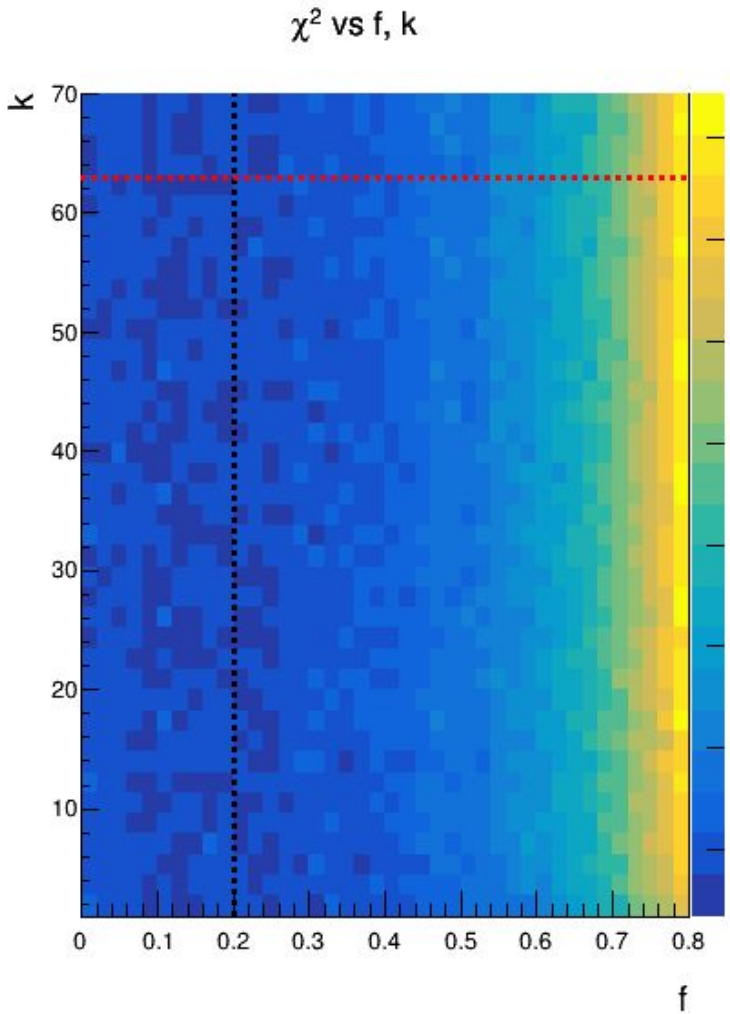
Centrality determination: |DCA|<2 cm

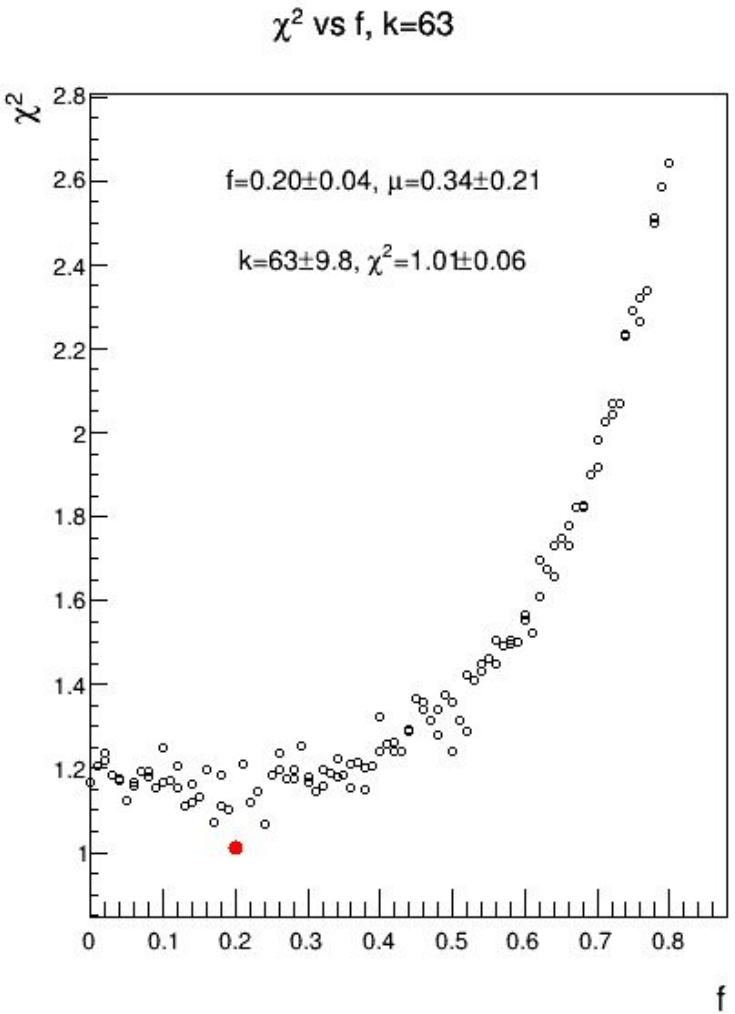


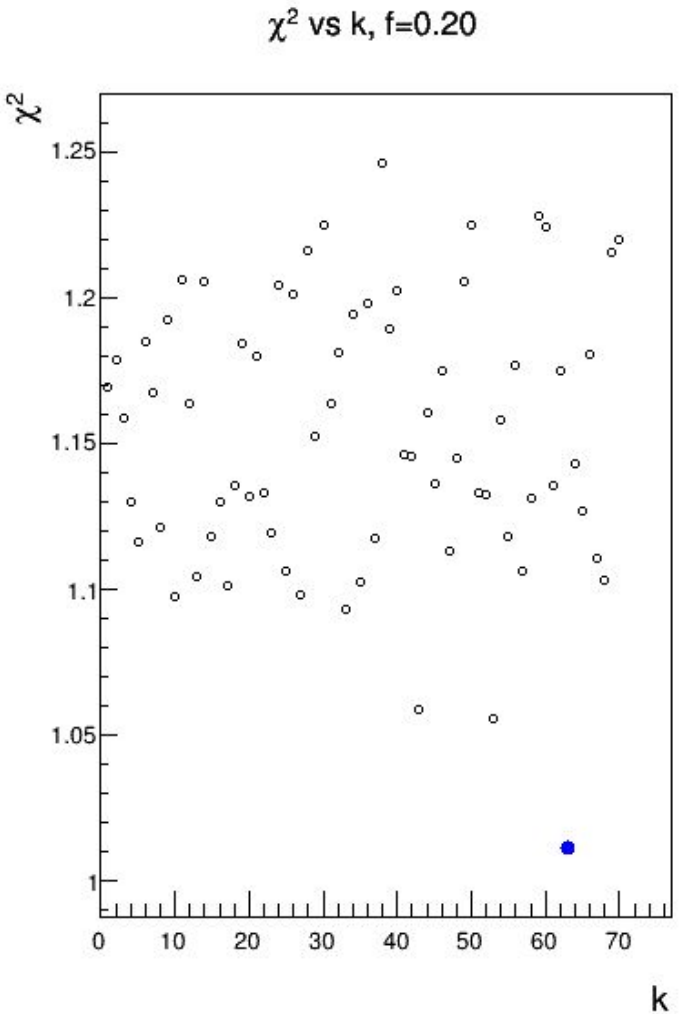




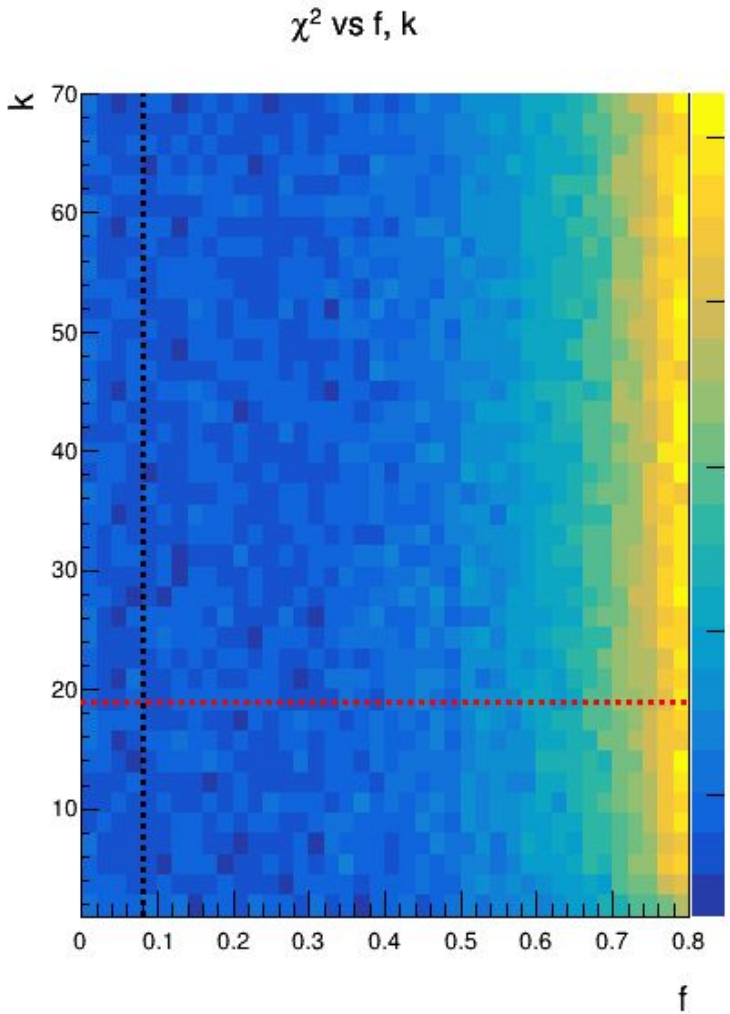
Centrality determination: |DCA|<3 cm

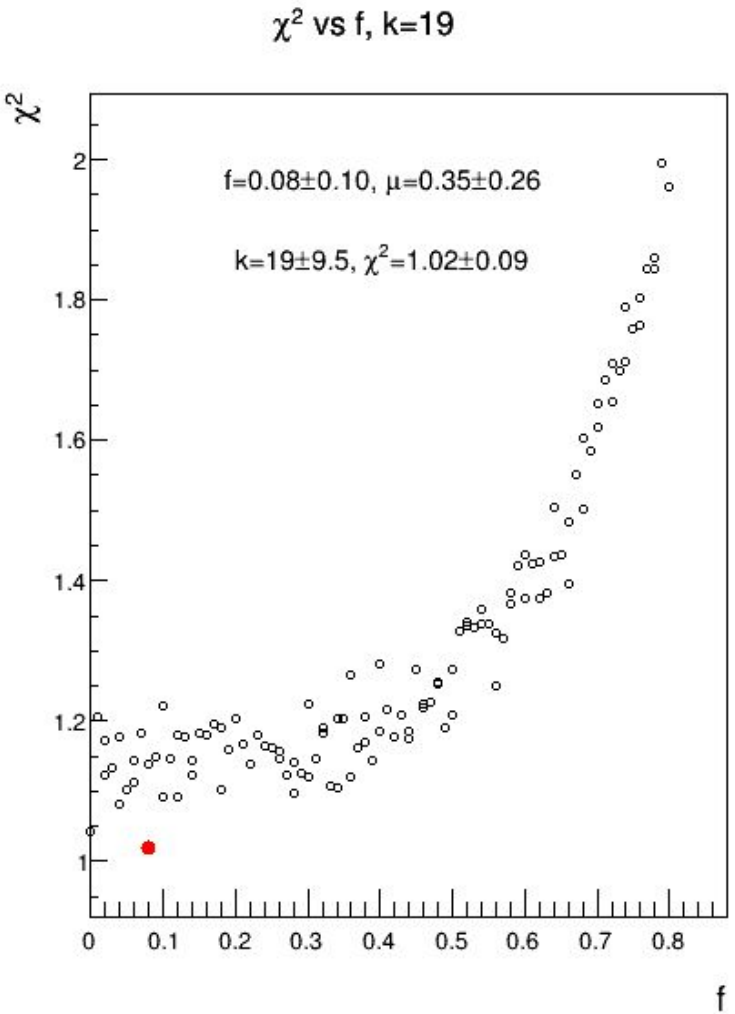


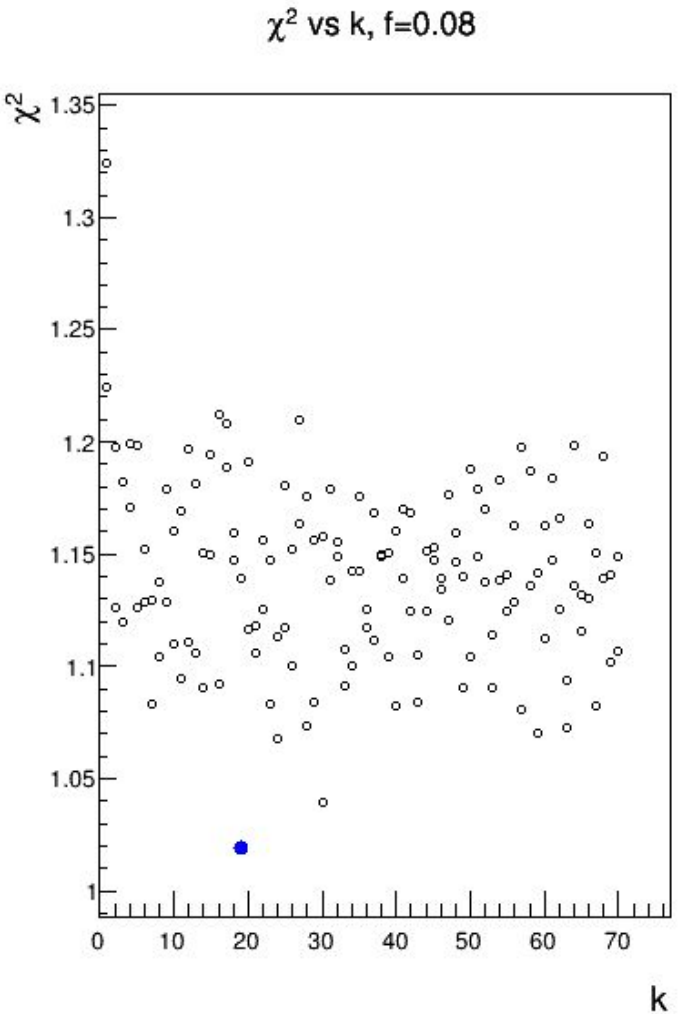




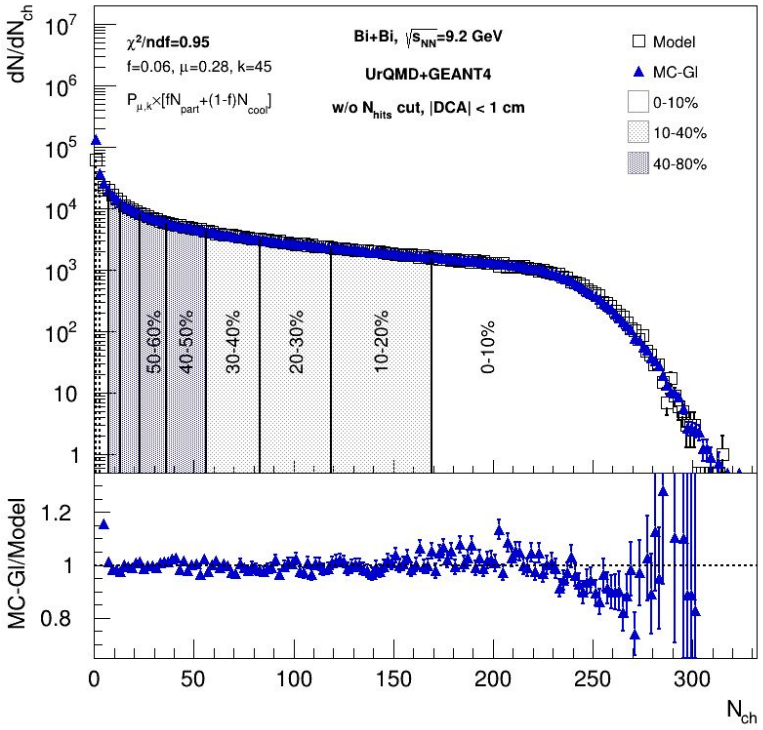
Centrality determination: w/o DCA cut



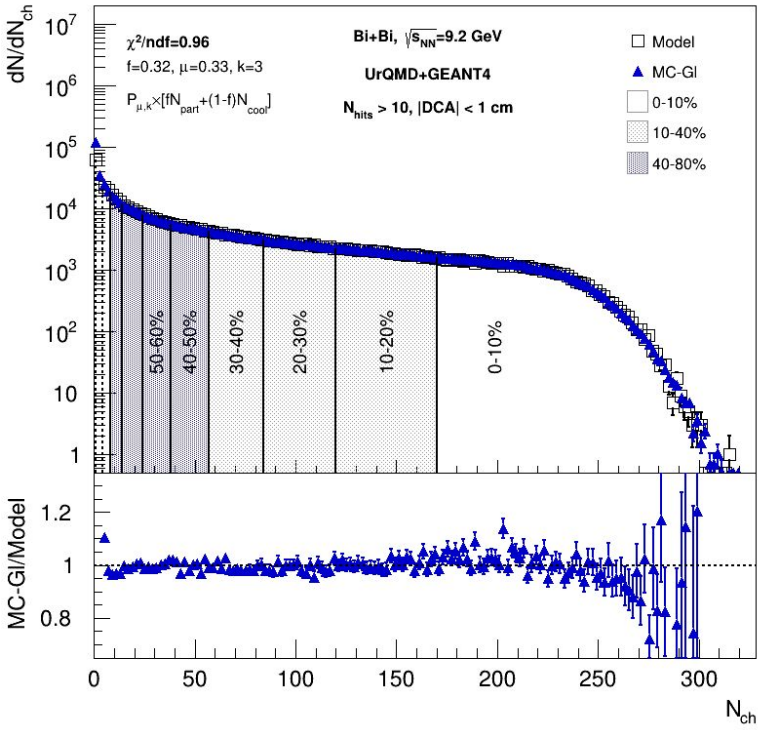




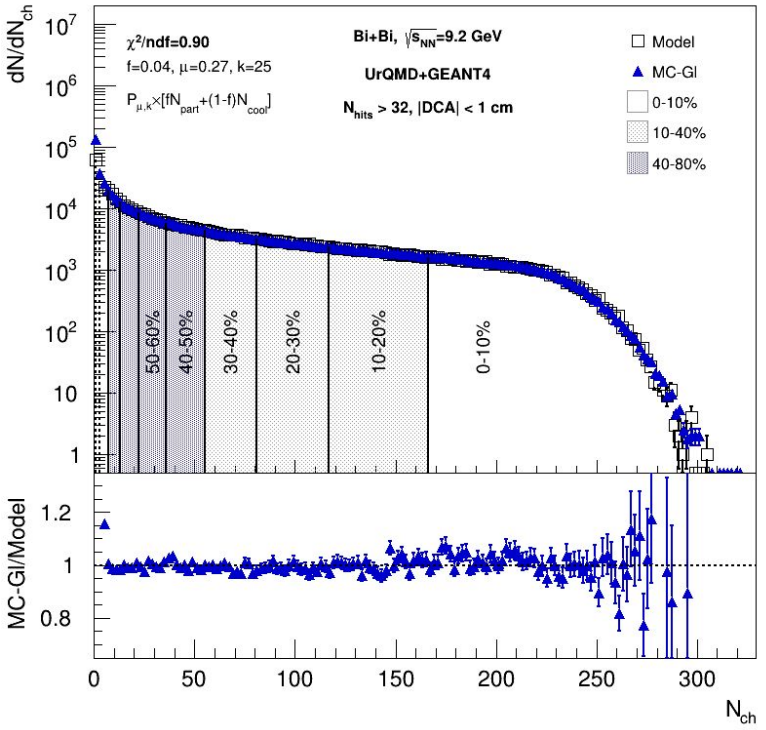
Centrality determination: Comparisons for different Nhits cuts



w/o Nhits cut



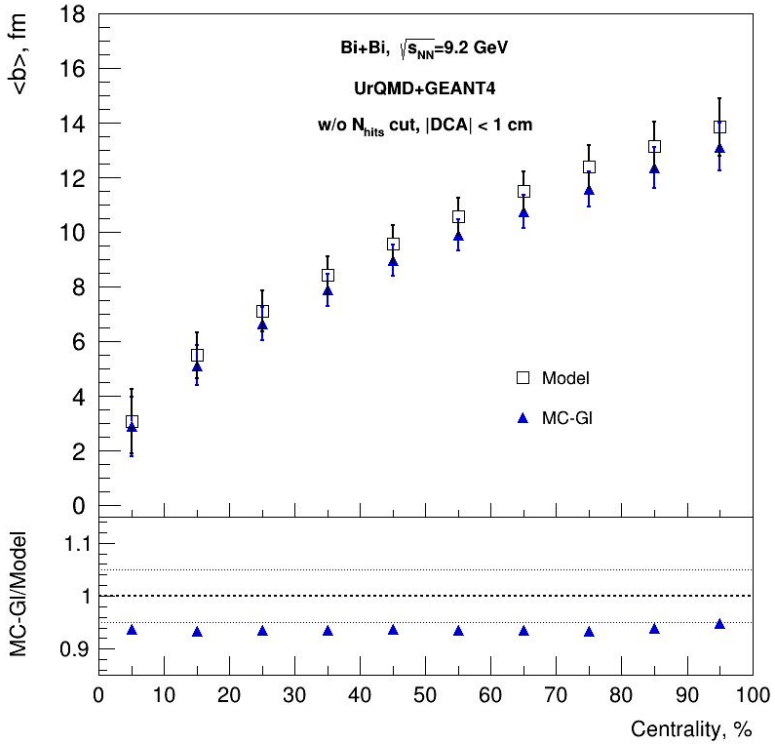
Nhits>10



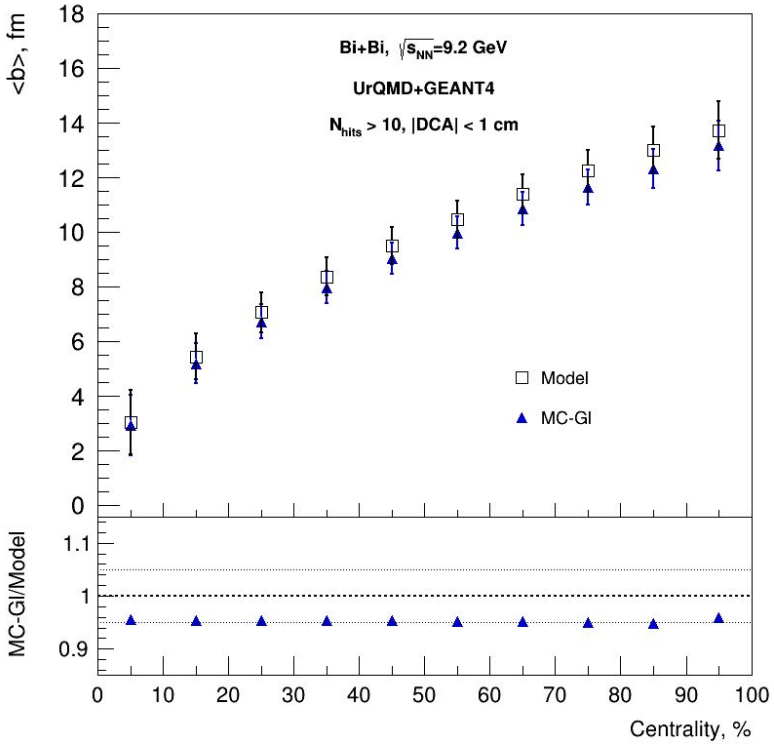
Nhits>32

The Nhits cut slightly affects the fit quality(χ/ndf)

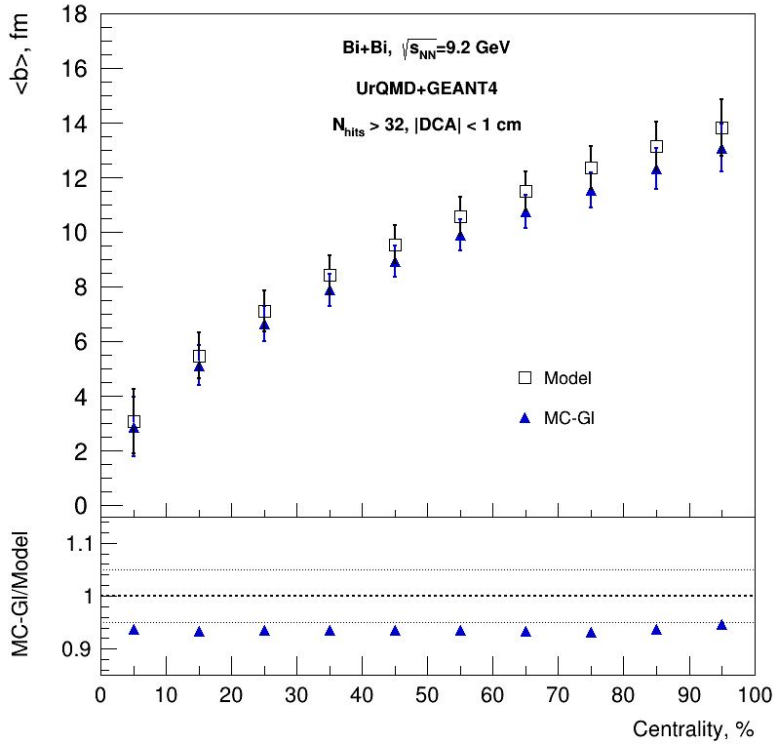
Centrality determination: Comparisons for different Nhits cuts



w/o Nhits cut



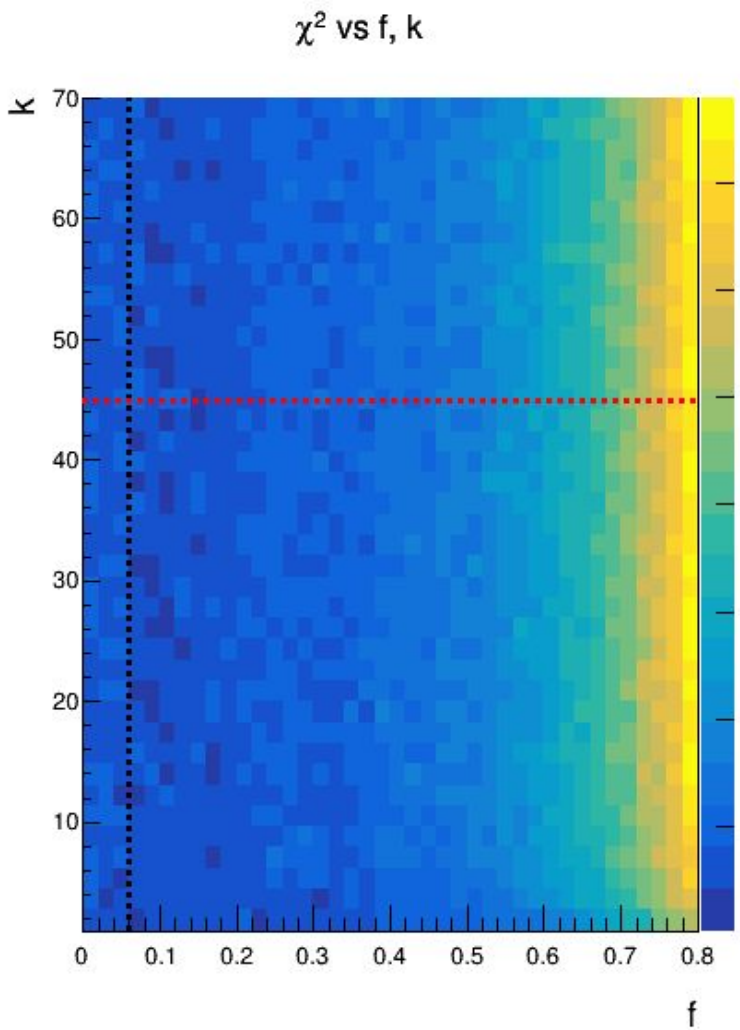
Nhits>10

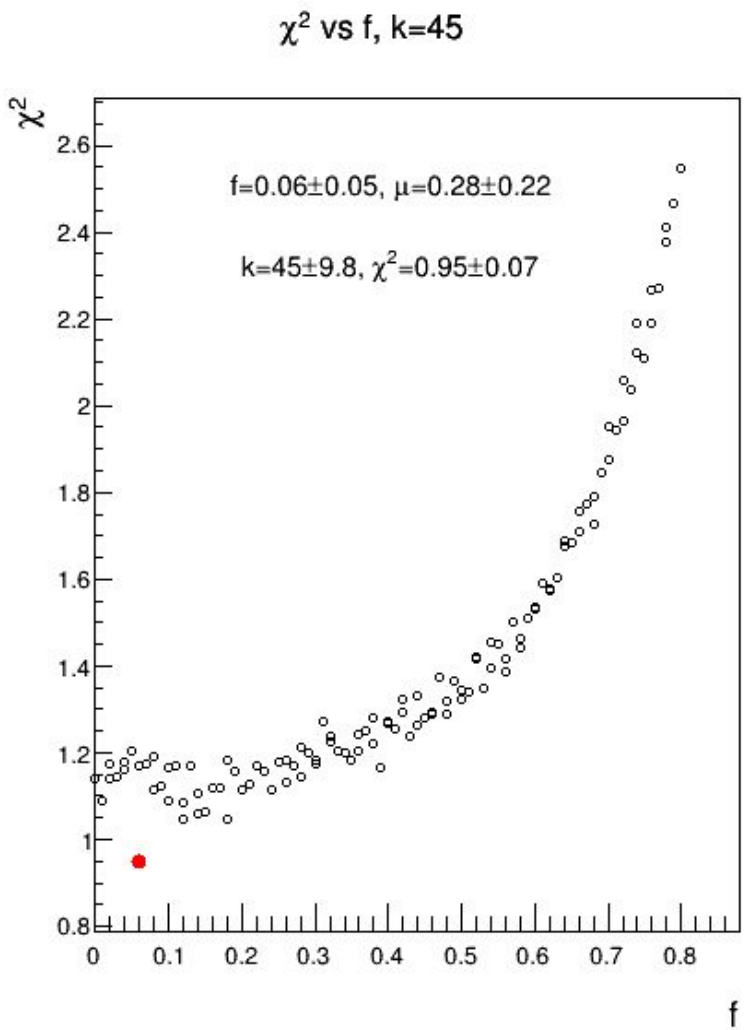


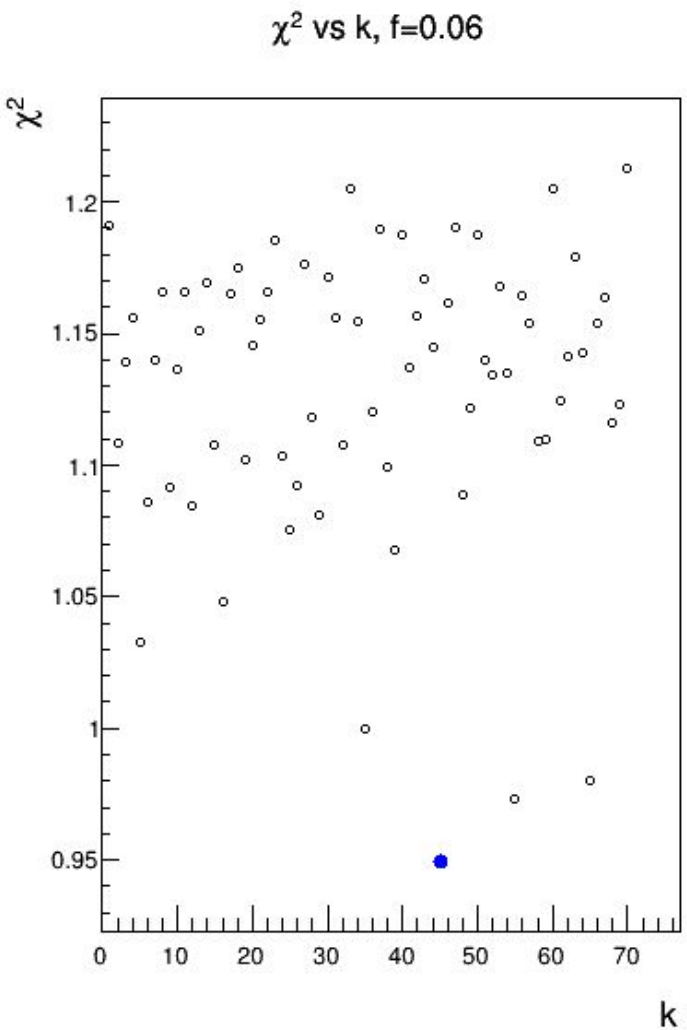
Nhits>32

The Nhits cut has a small effect on the resulting <b> vs Centrality dependence
We can relax this cut to Nhits>10 or remove it completely

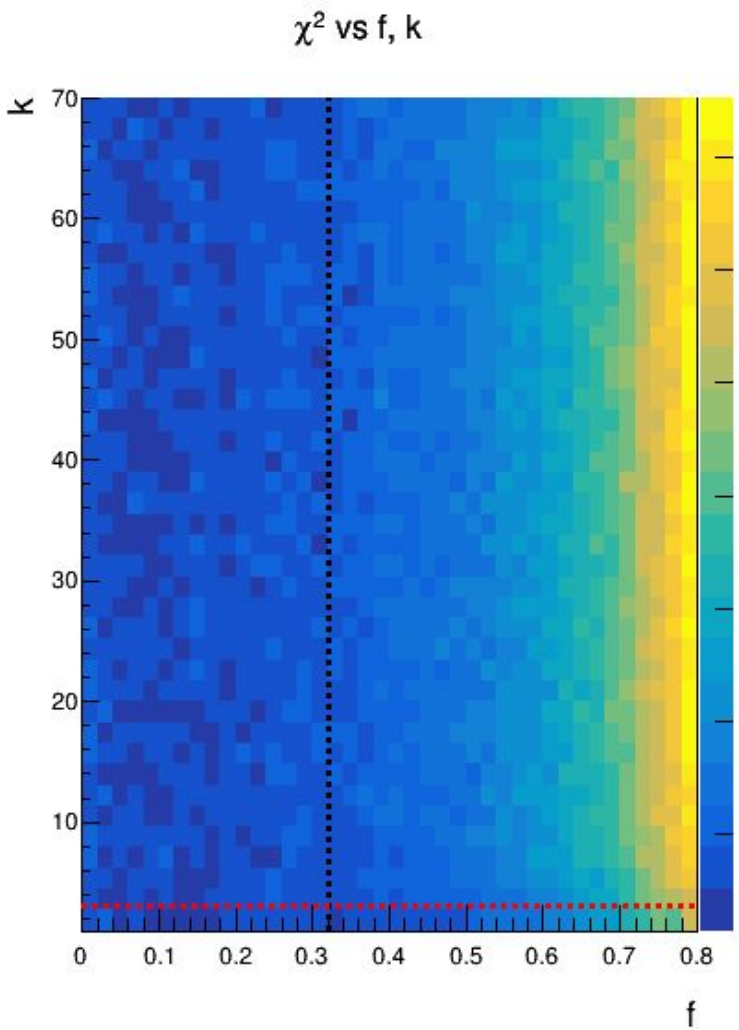
Centrality determination: w/o Nhits cut

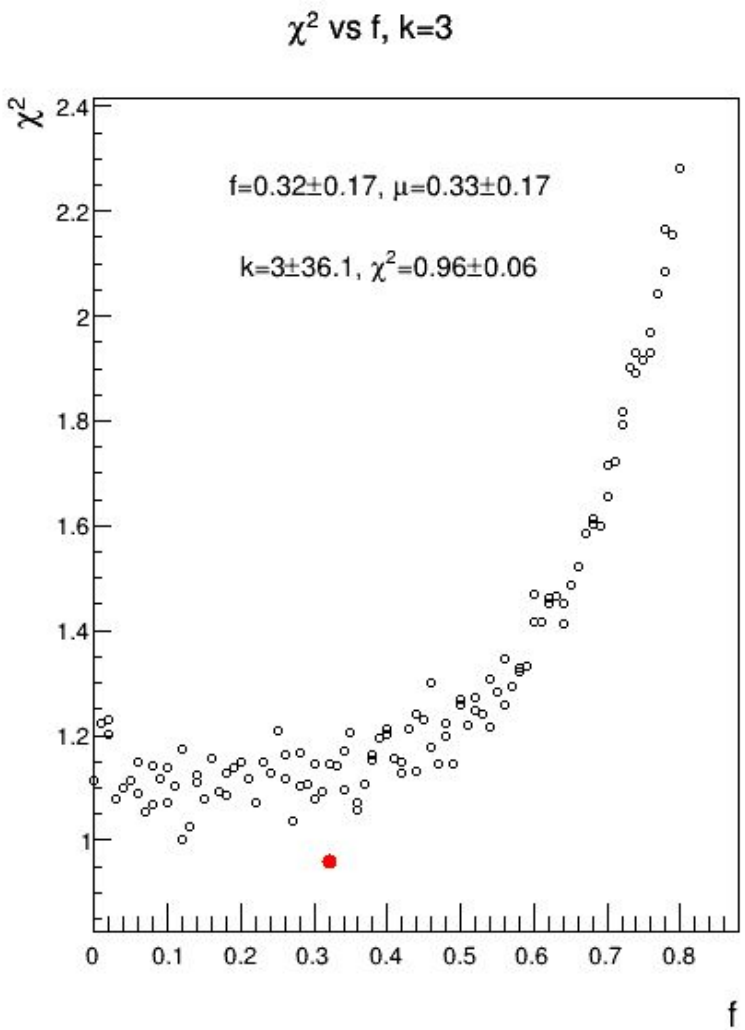


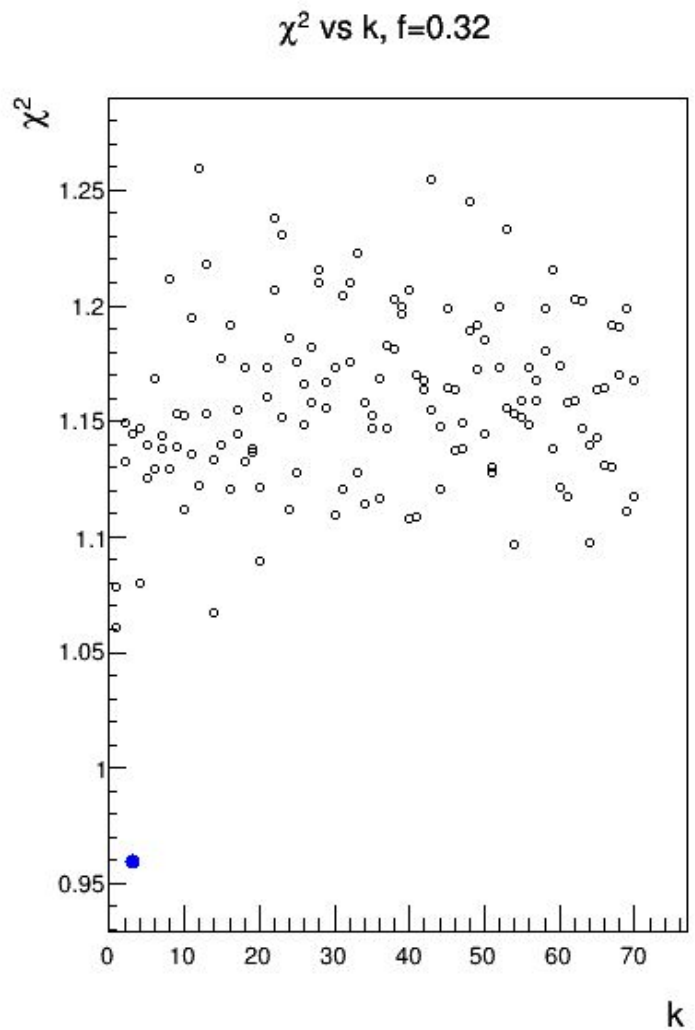




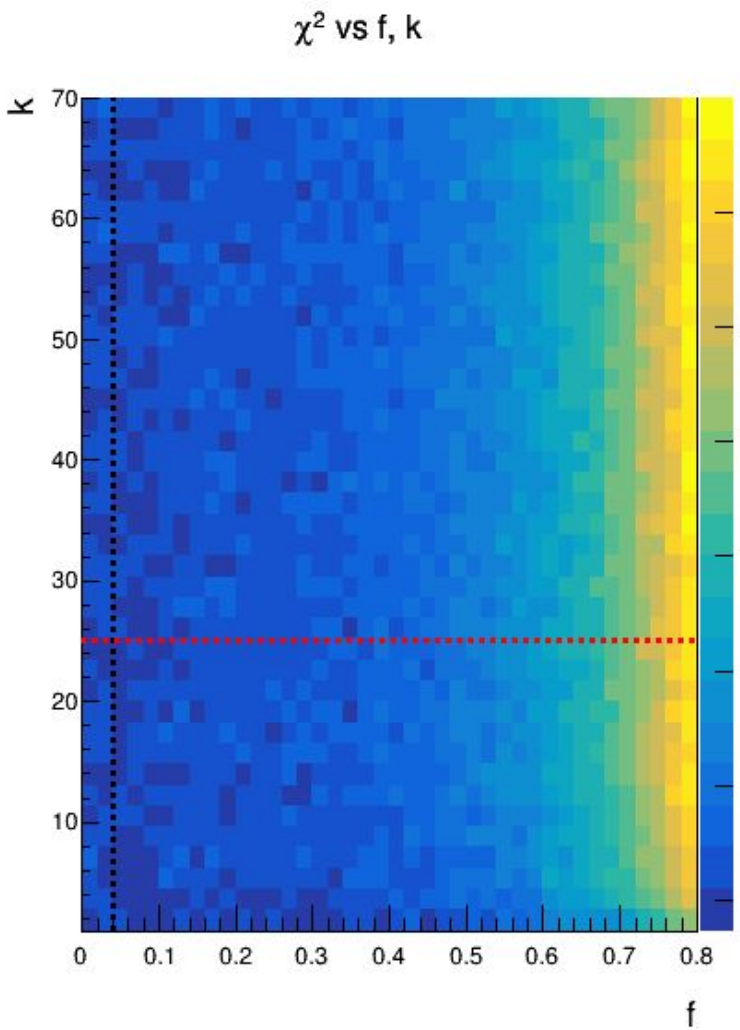
Centrality determination: Nhits>10

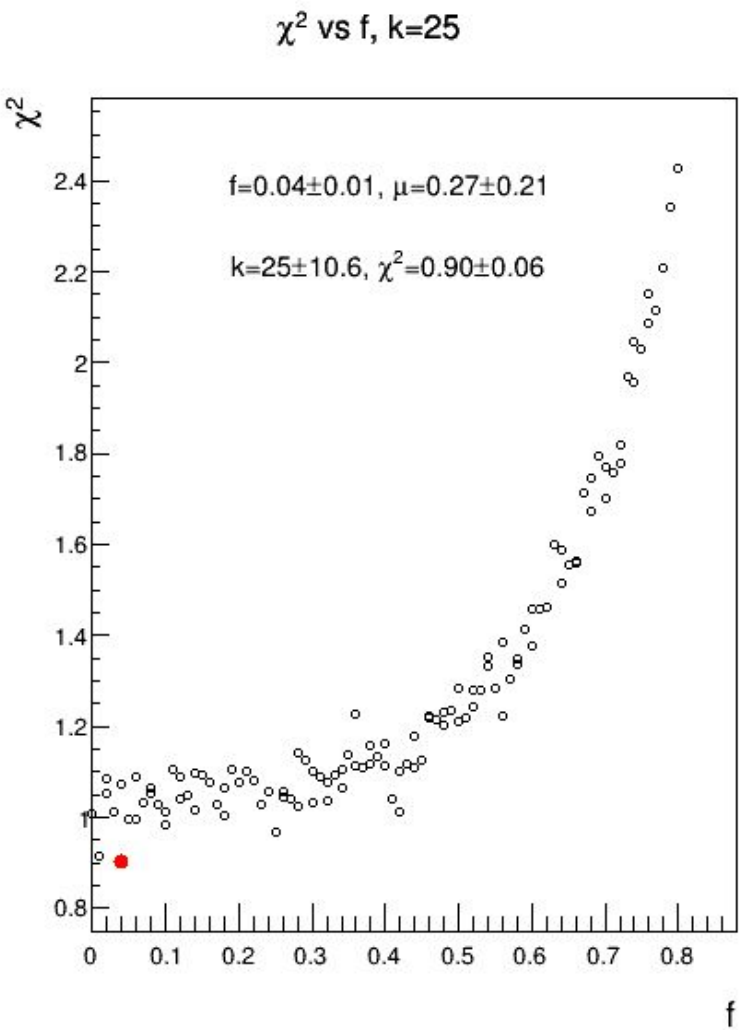


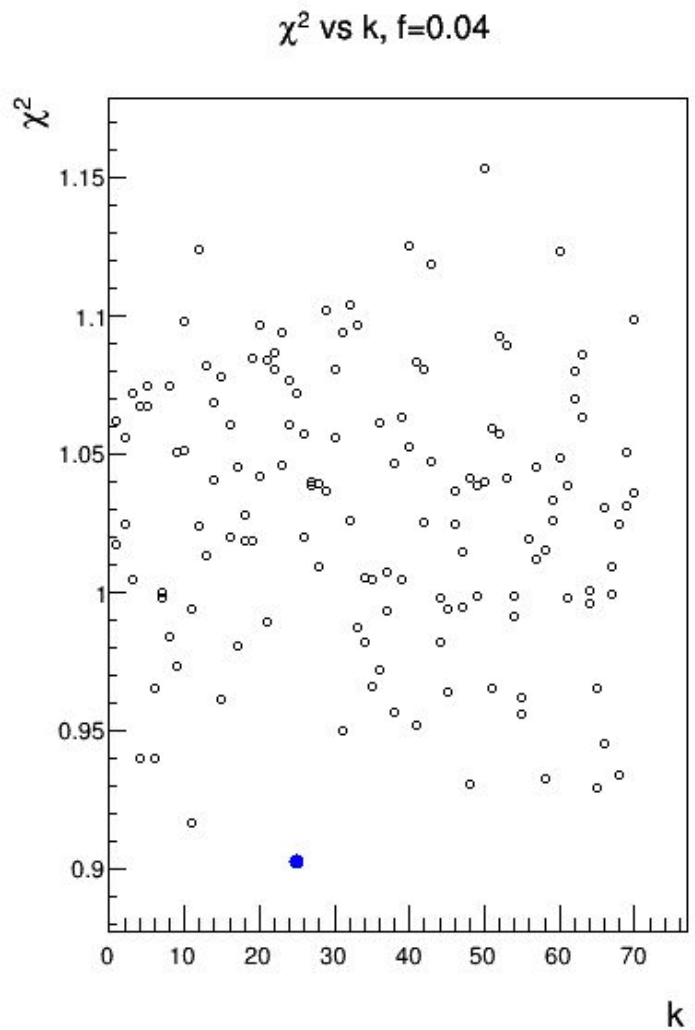




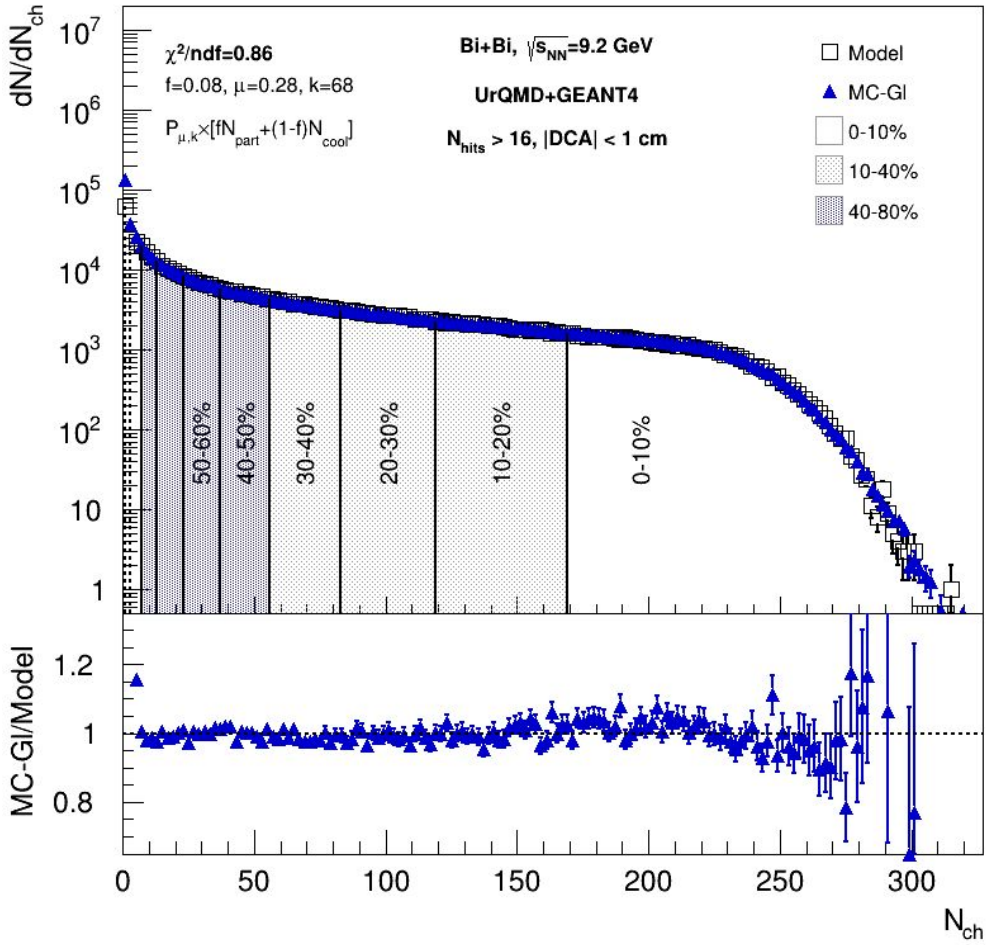
Centrality determination: Nhits>32

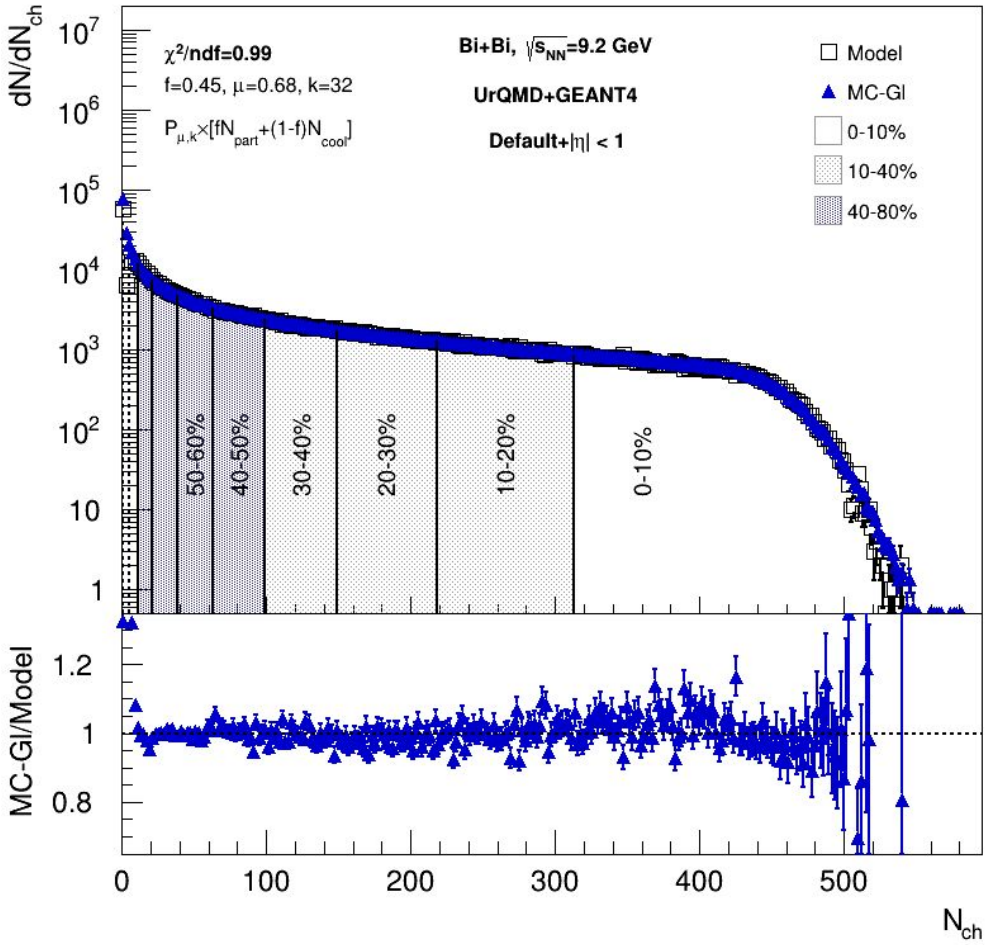






Centrality determination: |η|<1



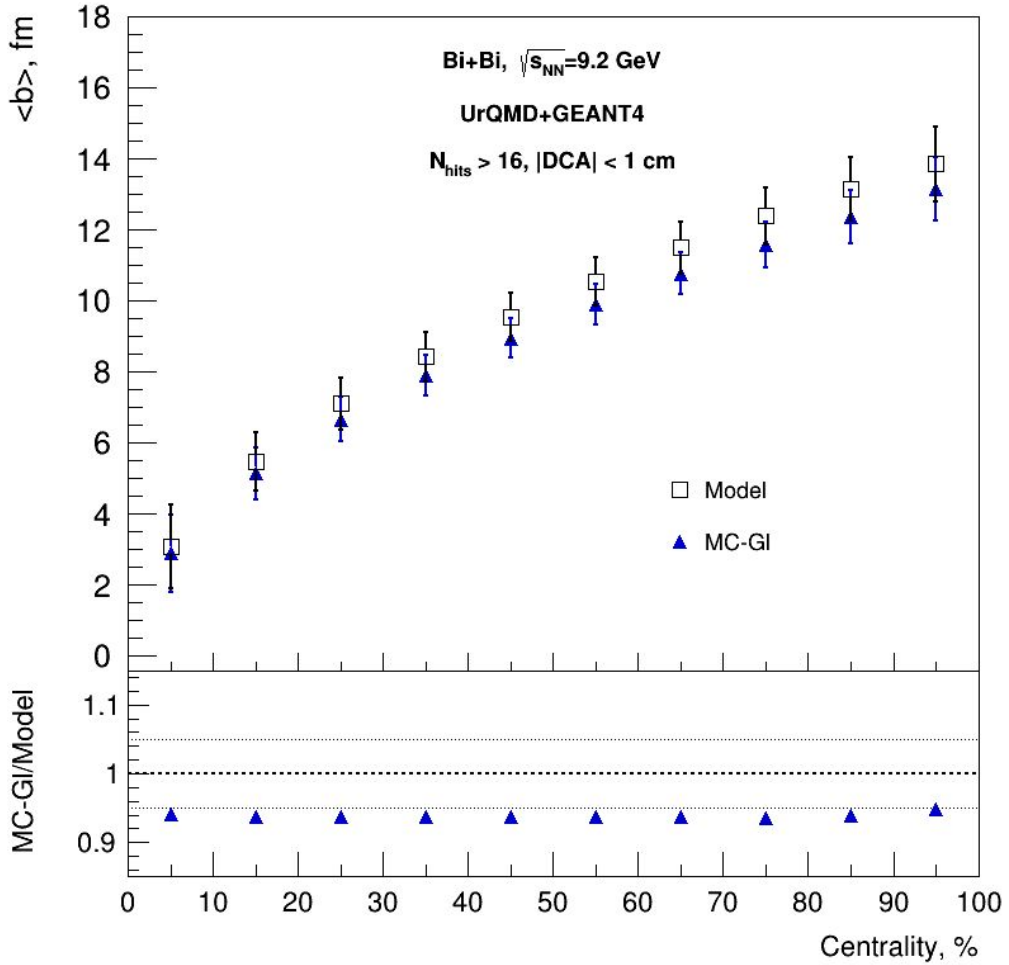


Default

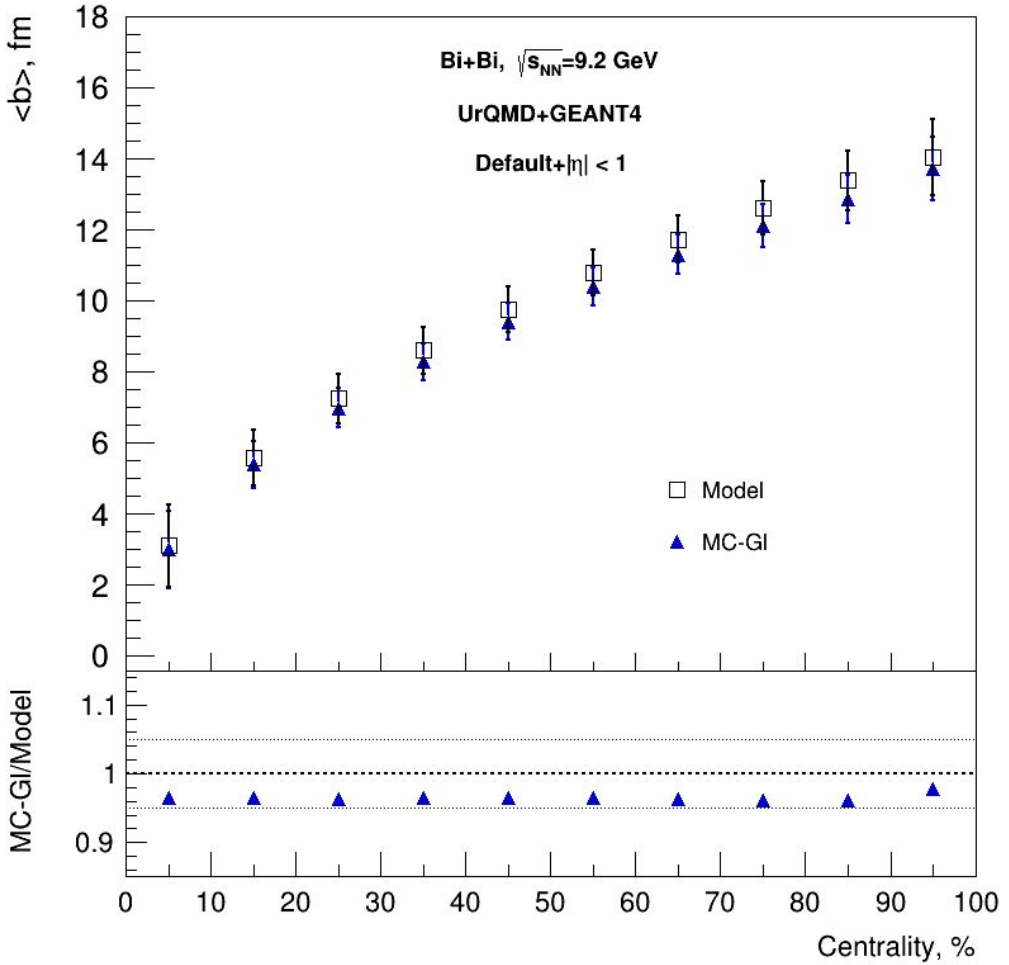
|η|<1

Relaxing η-cut allows us to have a larger multiplicity which might be better for the fit

Centrality determination: |η|<1



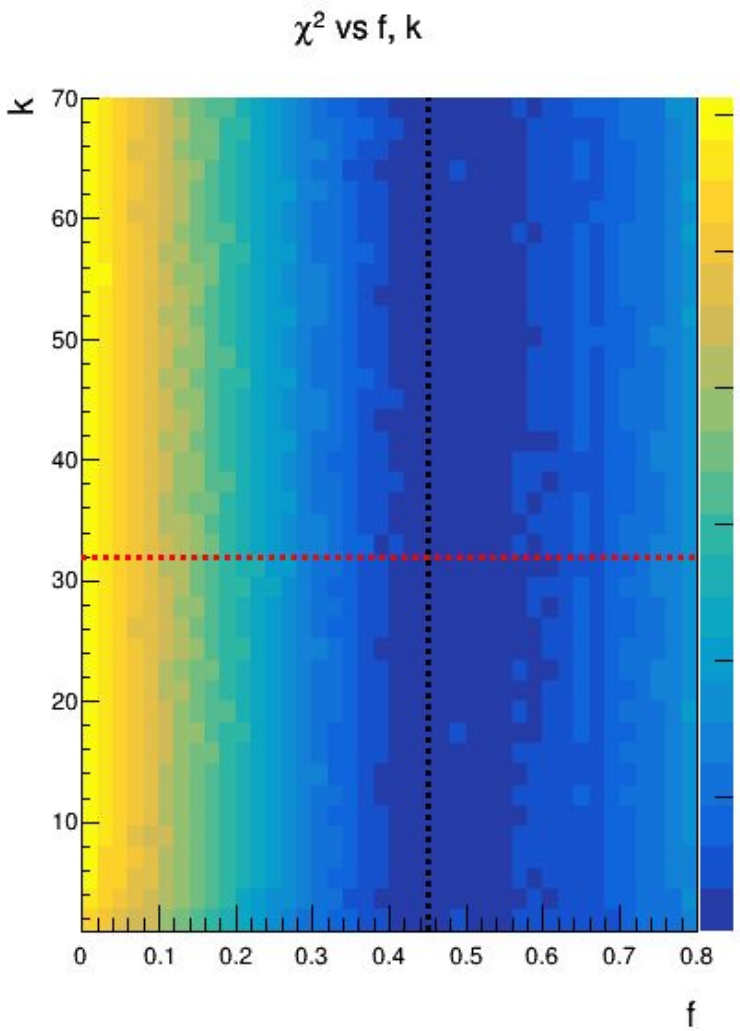
Default

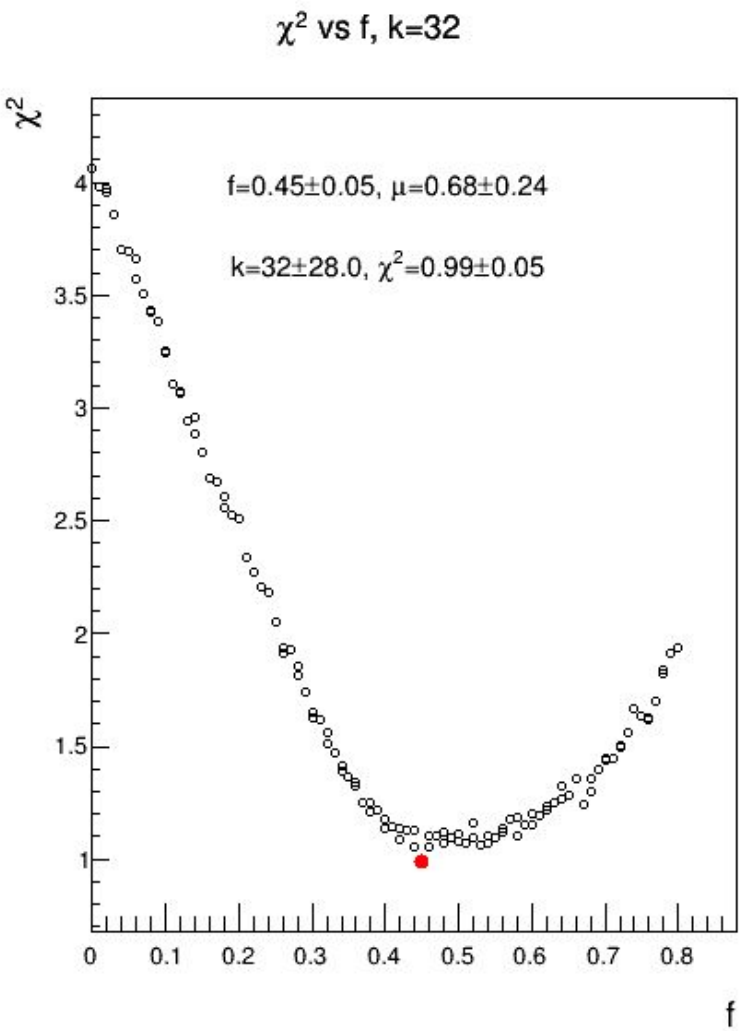


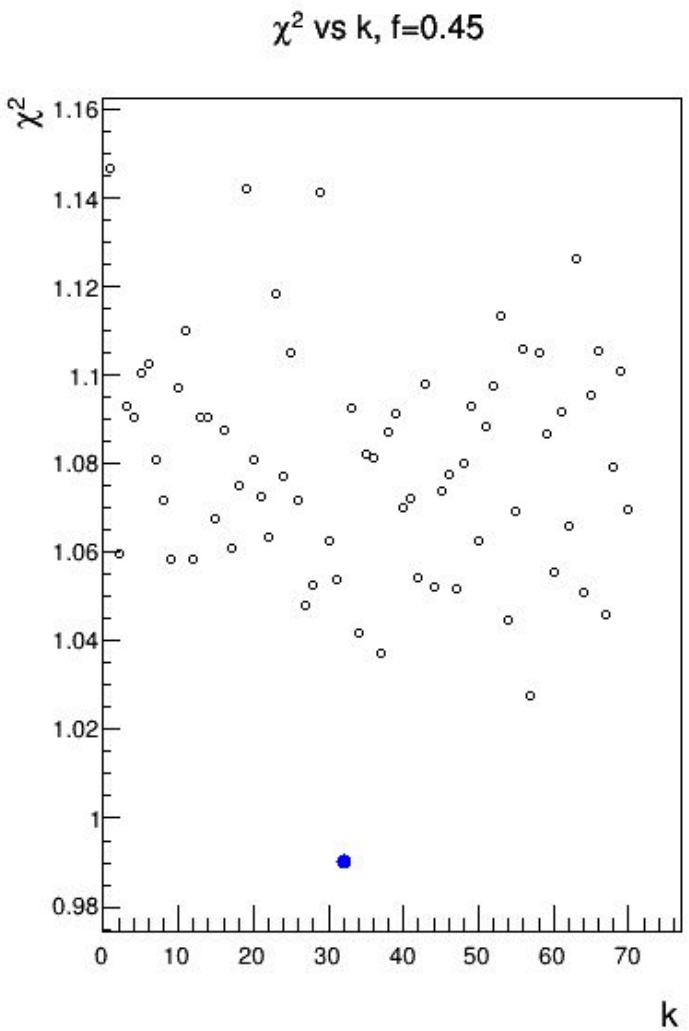
|η|<1

η-cut can be relaxed to |η|<1

Centrality determination: |η|<1



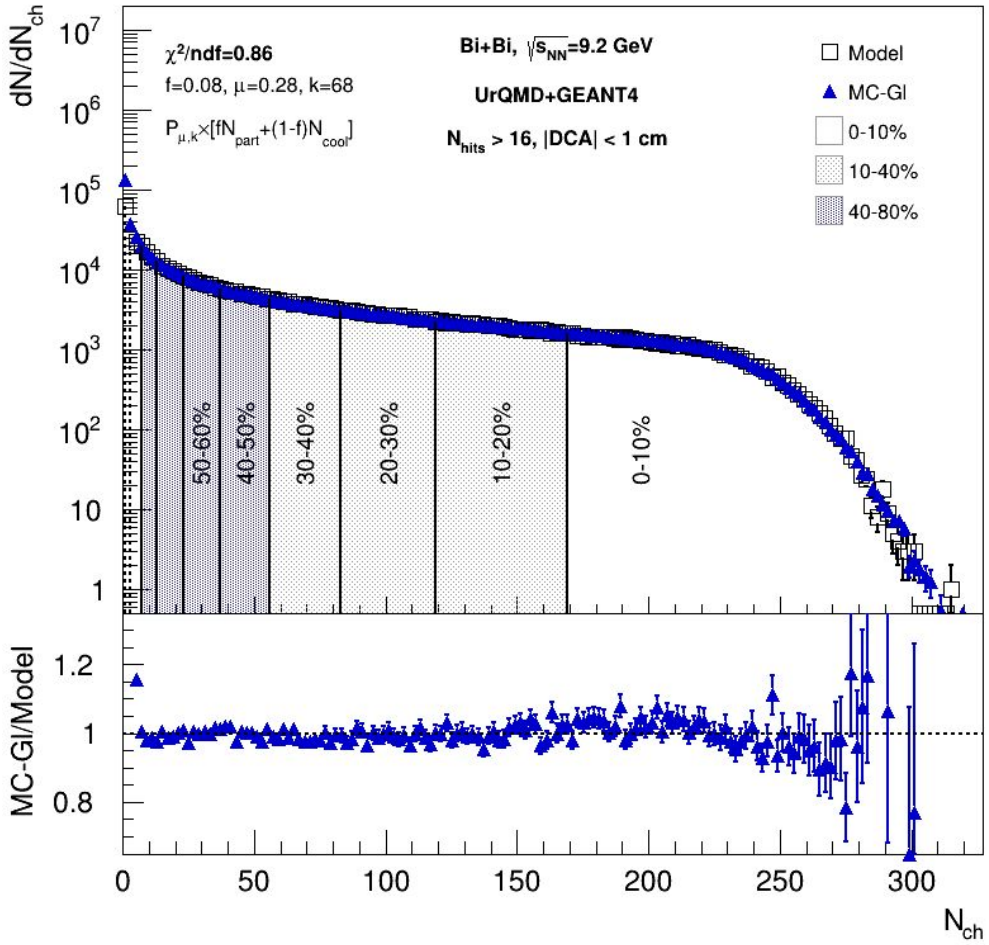




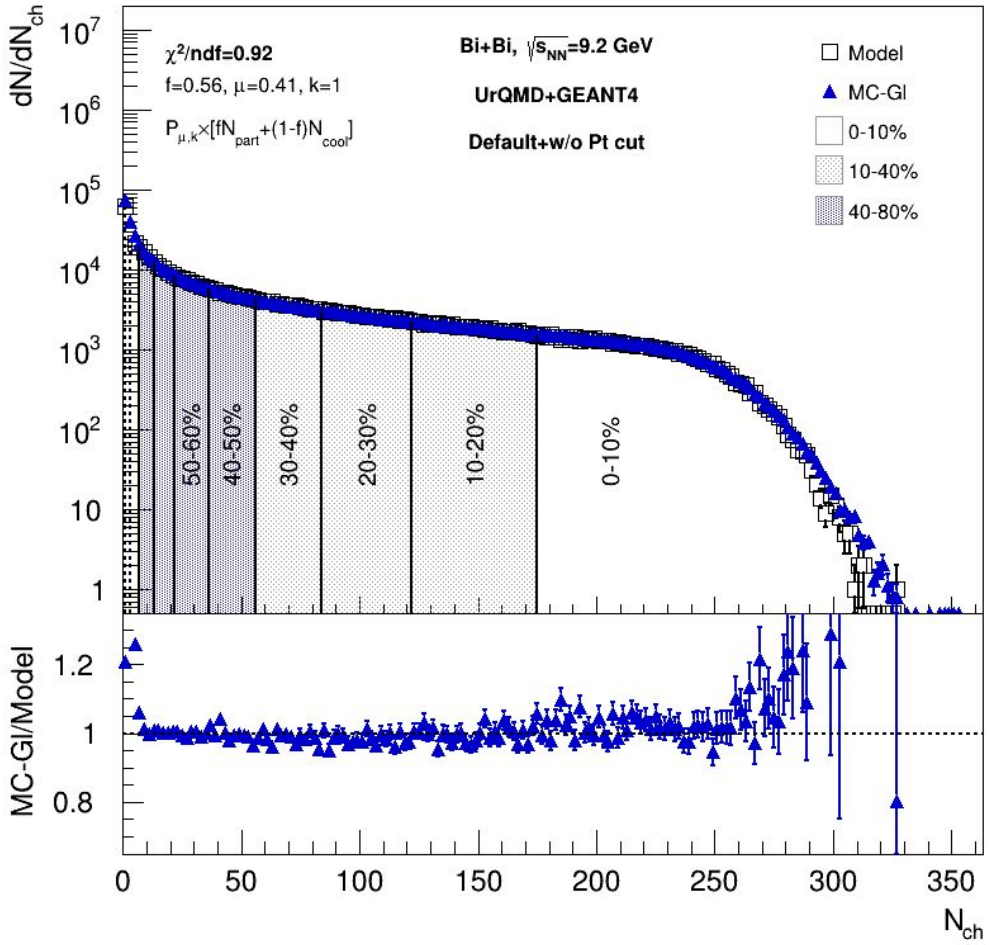
Fit parameters are better defined at larger multiplicity

Cases with f->0 might indicate that the fit procedure starts to become unreliable and we need larger multiplicity

Centrality determination: w/o p_T cut



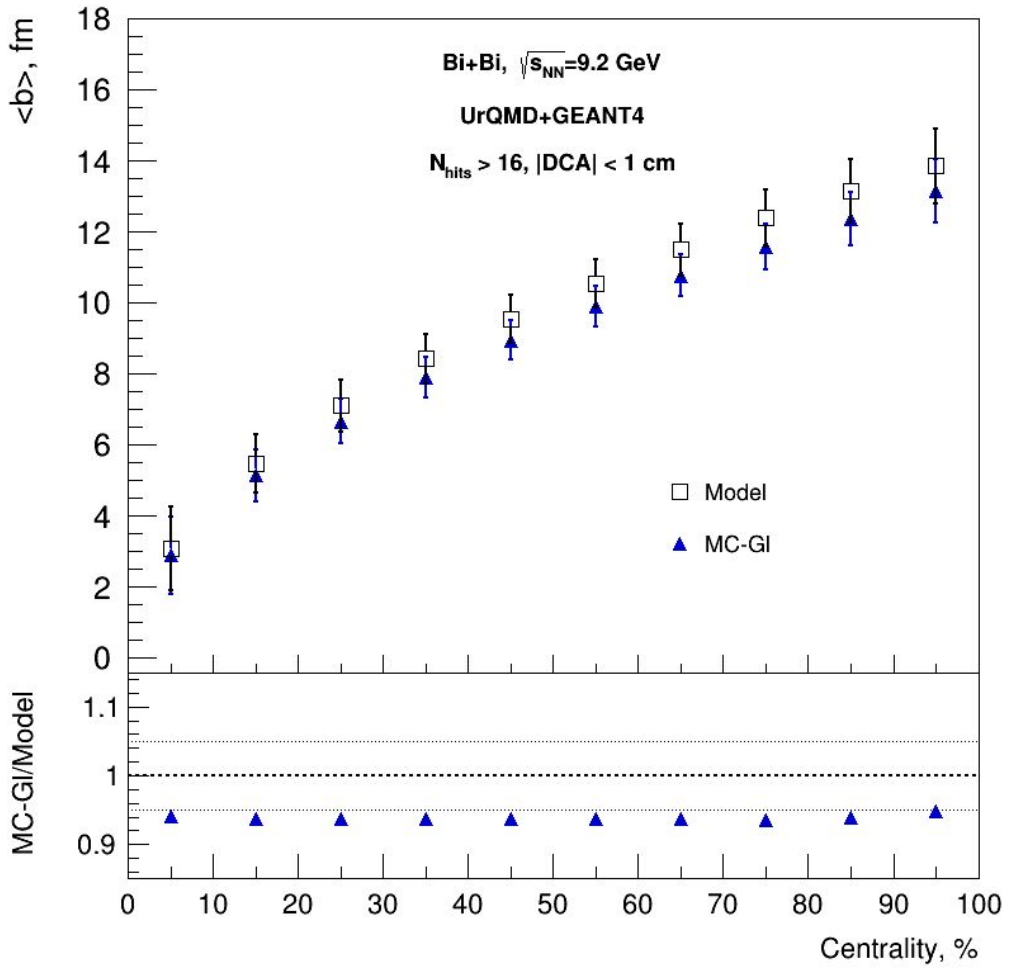
Default



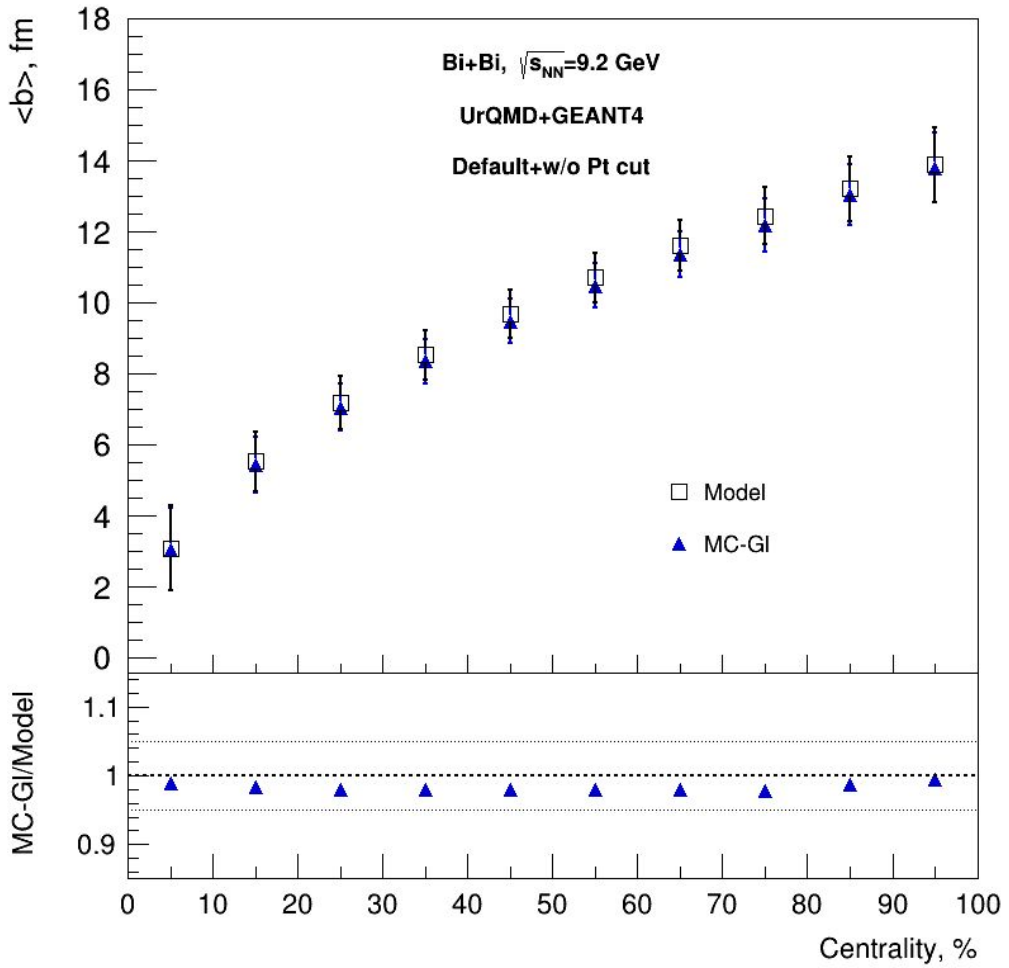
w/o p_T cut

Fit differs from data in the most central region - needs to be rechecked with different Nch_max

Centrality determination: w/o p_T cut



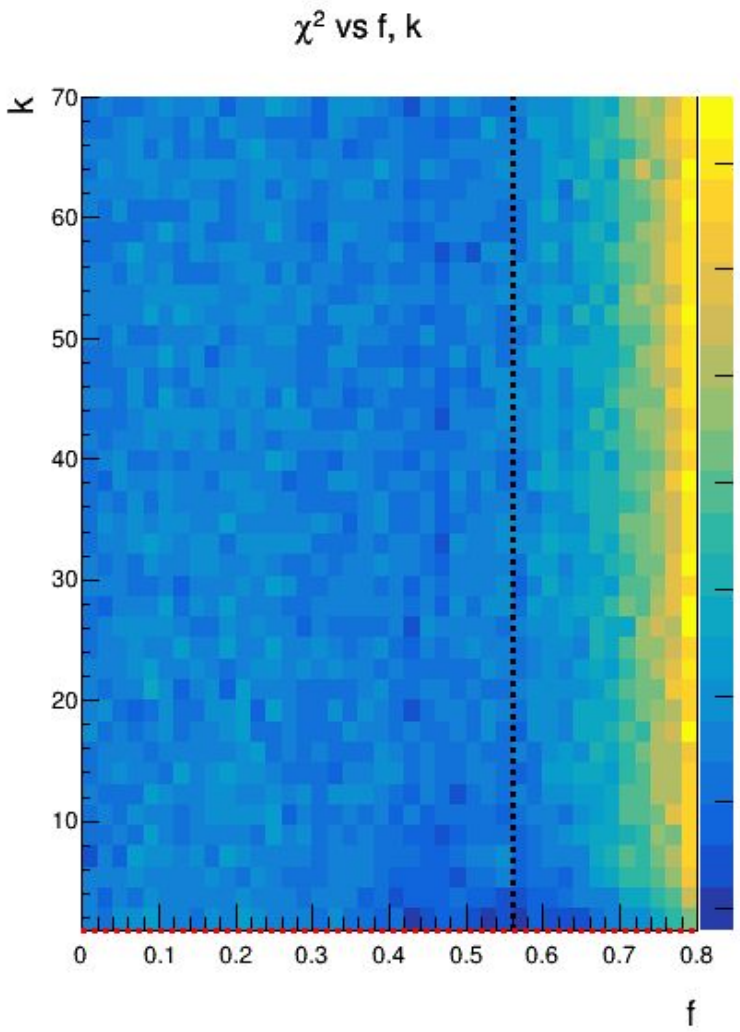
Default

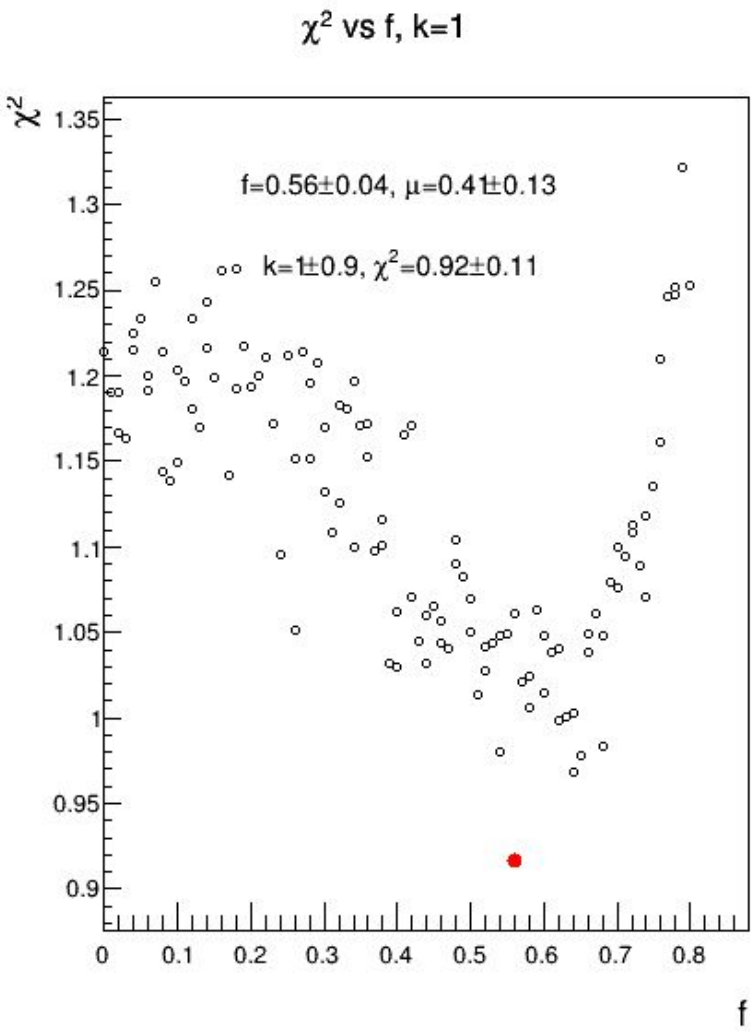


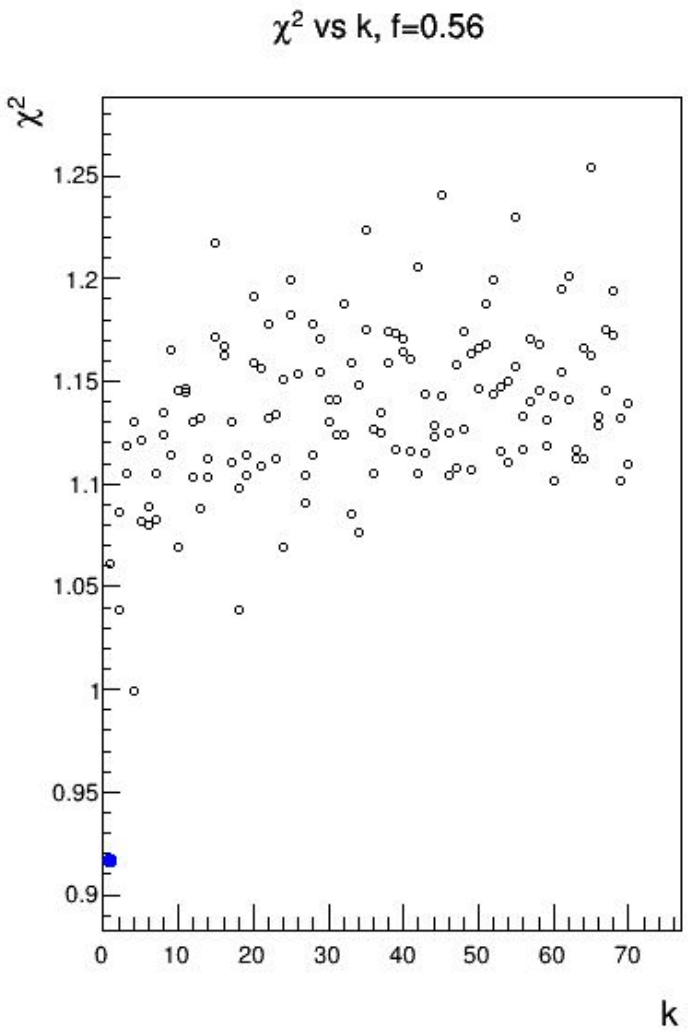
w/o p_T cut

Better agreement might be a result of the difference between the fit and the data - needs to be rechecked

Centrality determination: w/o p_T cut

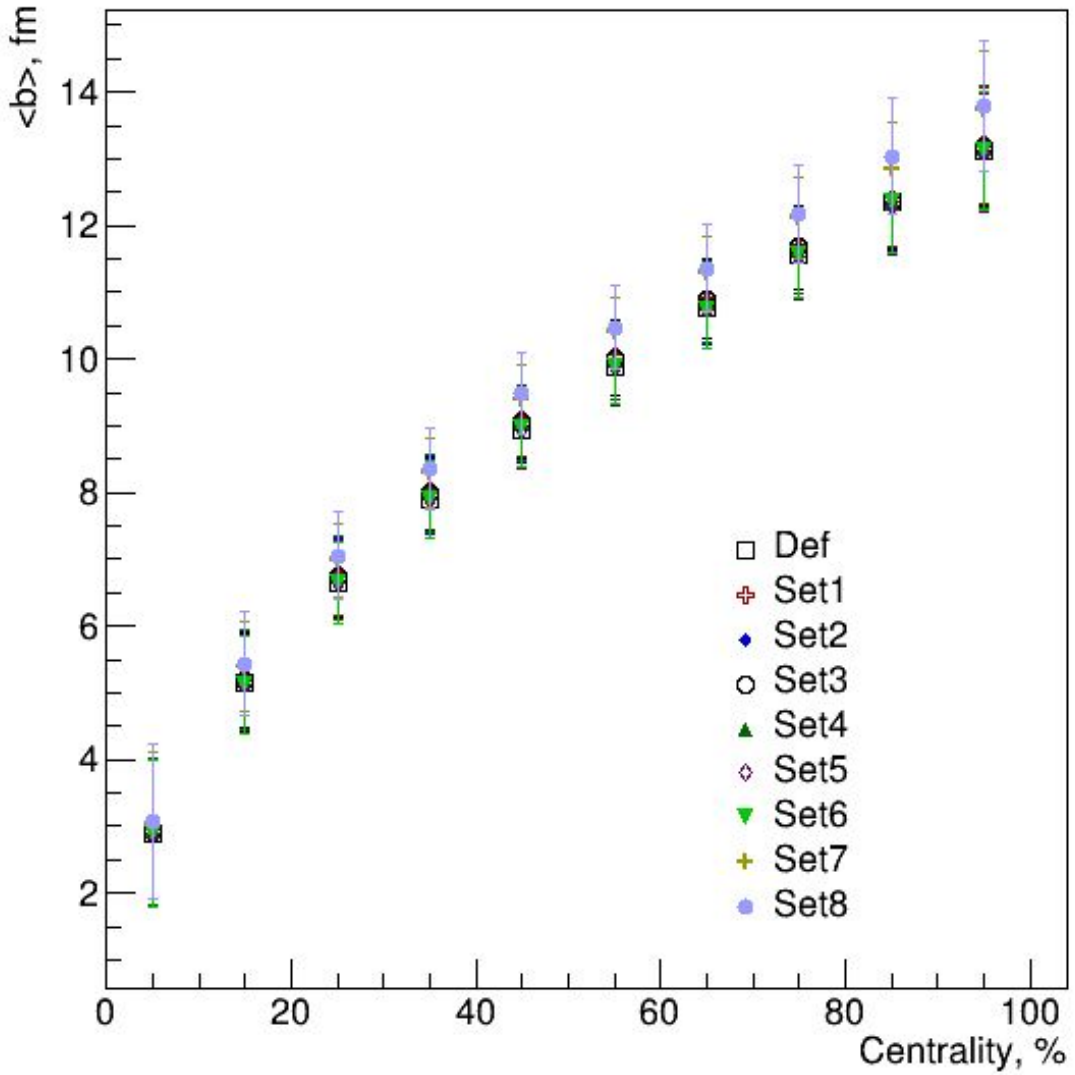


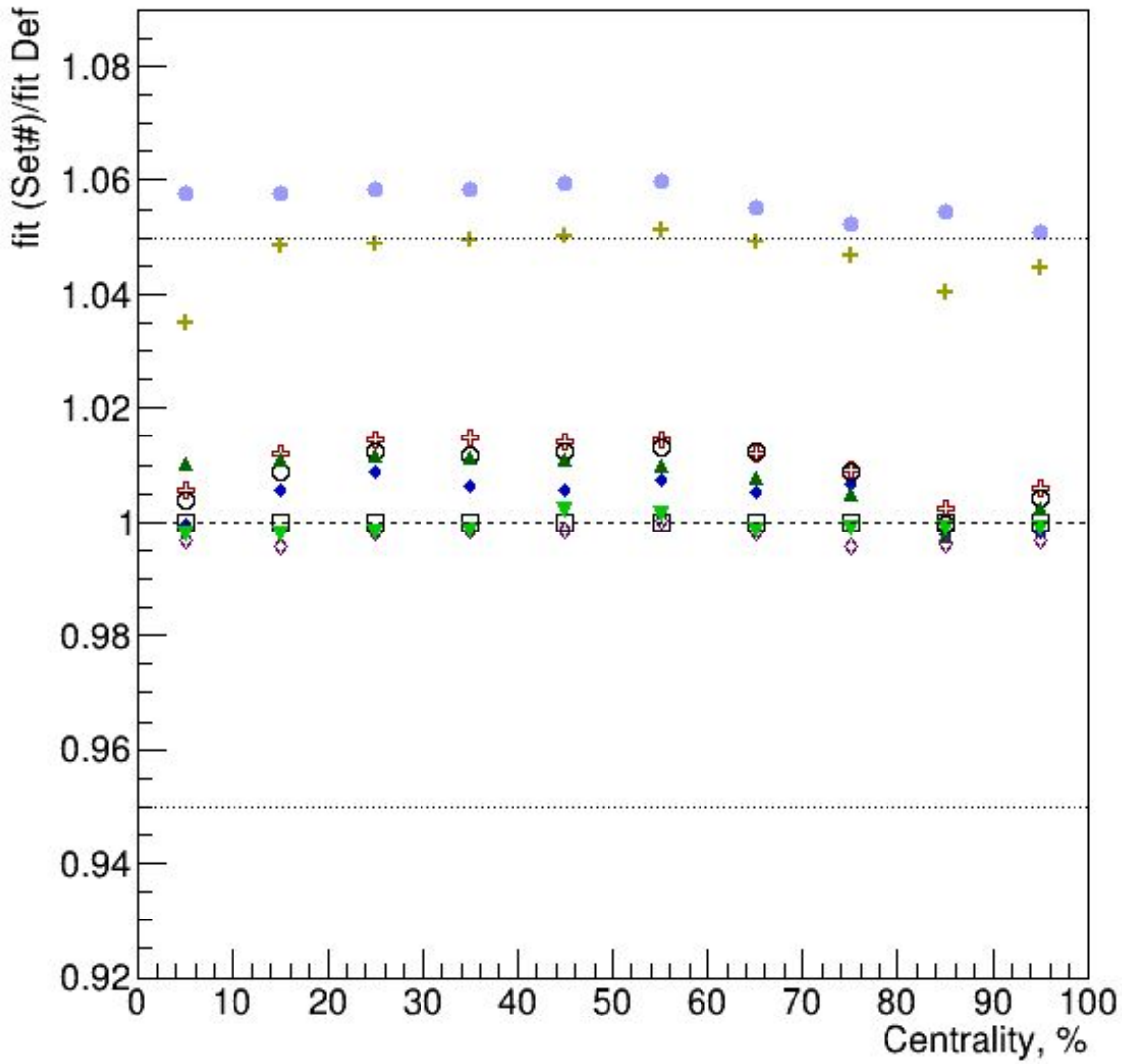




The steep localized minimum on χ^2 vs. f, k might further indicate that we have to recheck this fit

<b> vs Centrality for different cuts





Results are most sensitive to the η,p_T-cuts (p_T should be rechecked though)

Conclusions

Centrality determination procedure based on MC Glauber approach was used for a set of multiplicity distribution using several cut variations (DCA, Nhits, η, p_T):

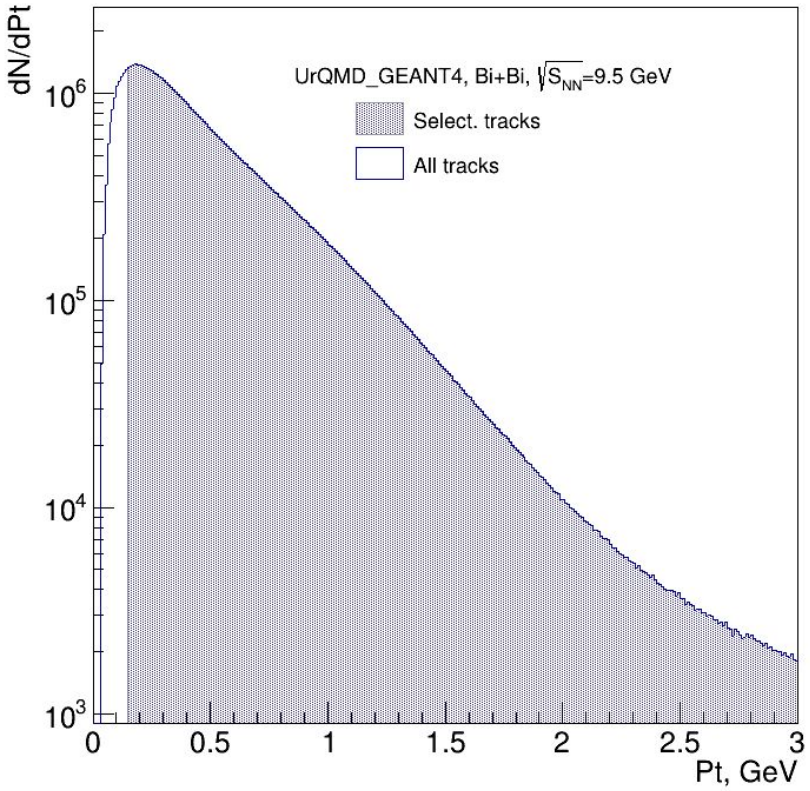
- DCA cut has a small effect on the fit quality but affects the N_{ch} vs b correlation - especially in the peripheral region. The cut can be relaxed from |DCA| < 1 cm to |DCA| < 3 cm.
- Nhits cut does not change the fit quality or resulting <b> vs Centrality dependence and can be removed completely
- η-cut allows us to improve the fit procedure by increasing number of particles that we are using to measure multiplicity. On the other hand, multiplicity distribution can be affected by spectators if we choose η-cut too wide. For current data set (UrQMD, Bi+Bi @ 9.2 GeV) we can relax η-cut from |η|<0.5 to |η|<1.
- p_T-cut has to be rechecked with different fitting ranges

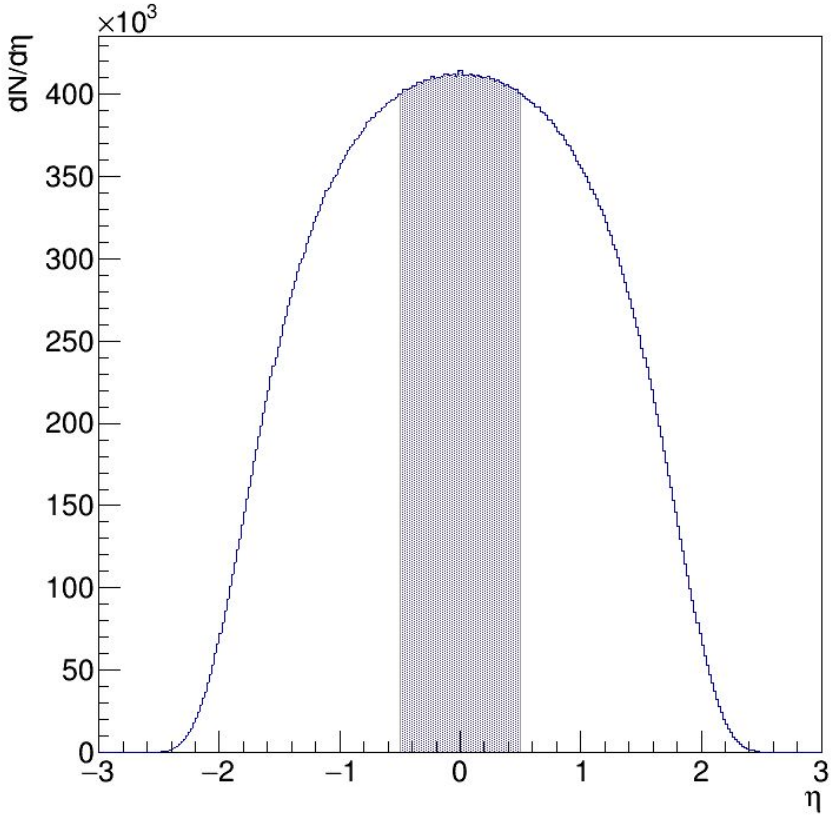
Cases with f->0 might be indicative to the situation where the fitting procedure might become unreliable which means we have to increase multiplicity

Most of the results have 1-2% difference except for η- and p_T-cuts that result in 5-6% difference w.r.t. the Default set.

Thank you for your attention

The track selection criteria(Default)





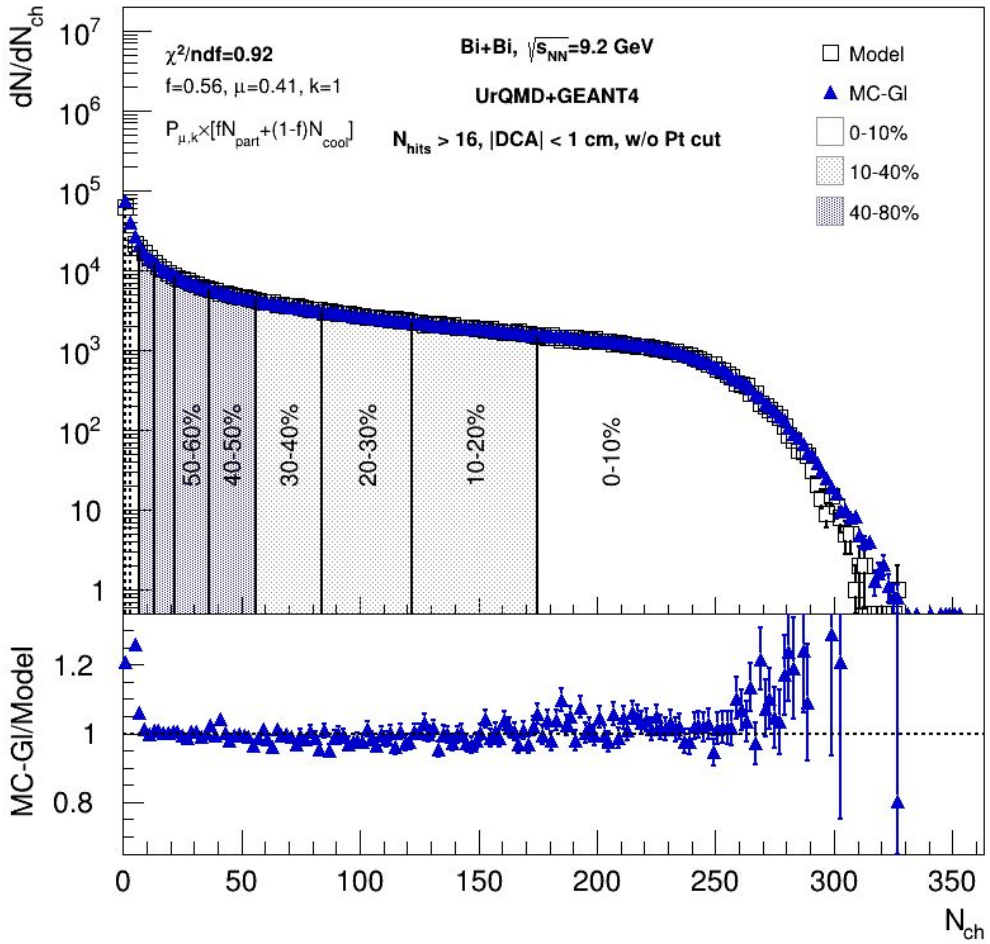
Hadron selection:

- Charged particles only
- $|\eta|<0.5$
- $p_T>0.15$ GeV/c

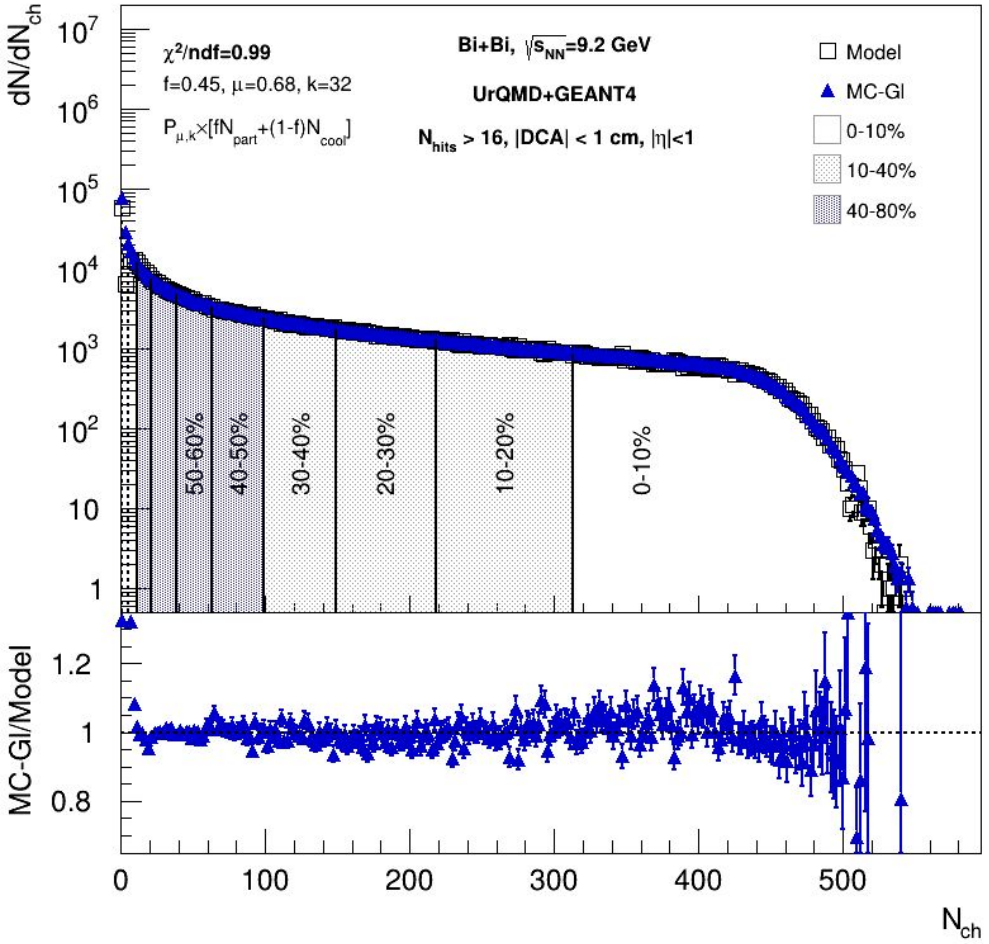
Track selection:

- $|DCA|<1$ cm
- $N_{TPC\ hits} \geq 16$

Centrality determination: Comparisons

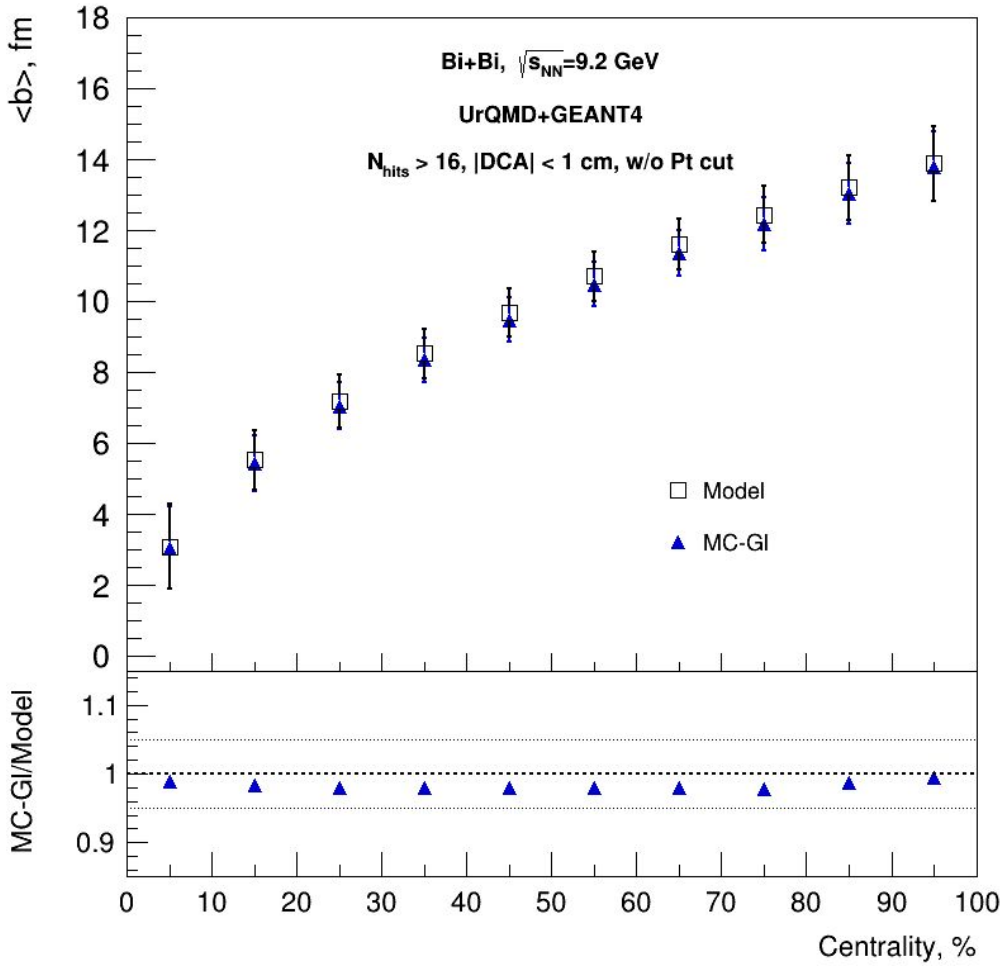


w/o Pt cut

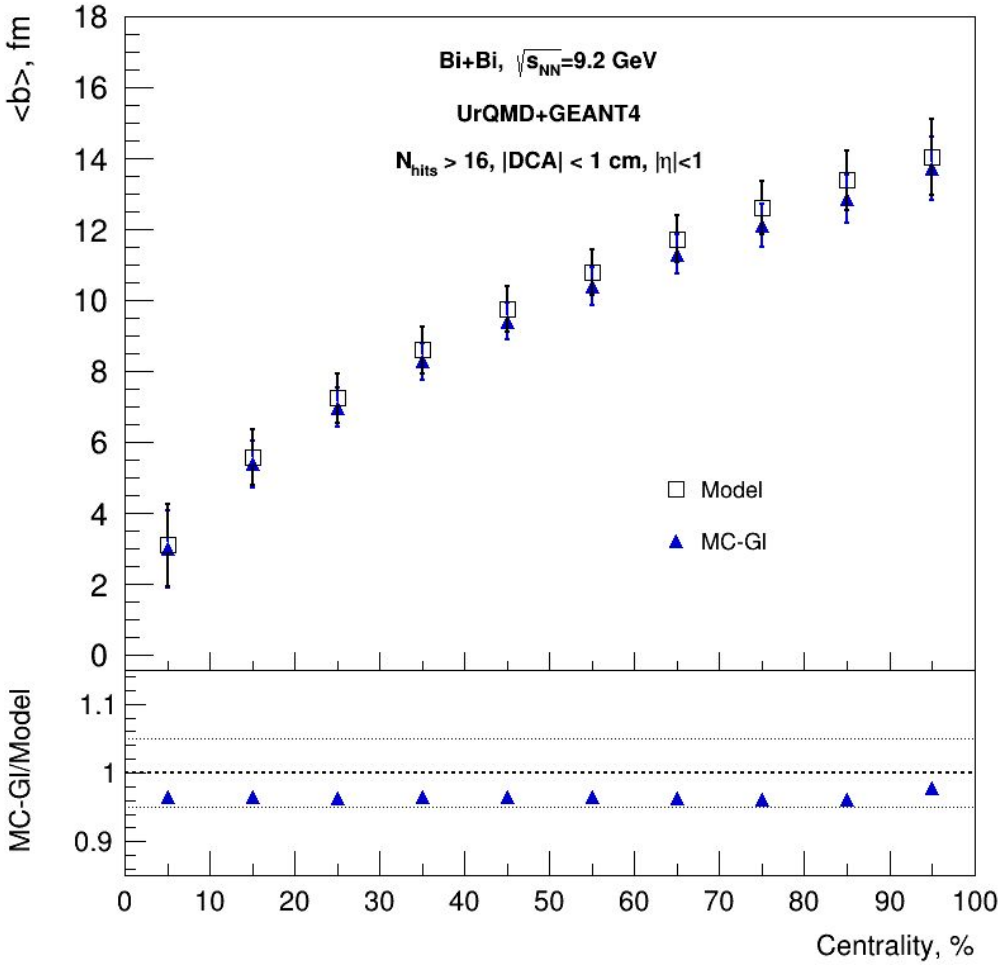


|η|<1

Centrality determination: Comparisons



w/o Pt cut



|η|<1

The Bayesian inversion method (Γ-fit)

- Relation between multiplicity N_{ch} and impact parameter b is defined by the fluctuation kernel:

$$P(b|n_1 < N_{ch} < n_2) = P(b)\frac{\int_{n_1}^{n_2} P(b|N_{ch})dN_{ch}}{\int_{n_1}^{n_2} P(N_{ch})dN_{ch}}$$

$$P(b|n_1 < N_{ch} < n_2) = P(b)\frac{\int_{n_1}^{n_2} P(b|N_{ch})dN_{ch}}{\int_{n_1}^{n_2} P(N_{ch})dN_{ch}}$$

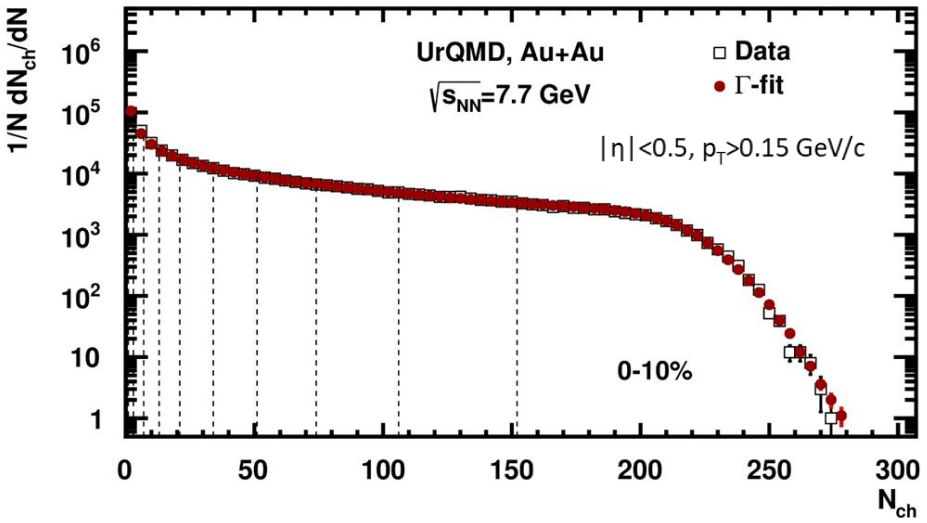
– centrality based on impact parameter

- The dependence of the mean of multiplicity on centrality can be describe by

$$\langle N_{ch} \rangle = N_{knee} \exp\left(\sum_{j=1}^{3} a_j c_b^j \right)$$

$$\frac{\sigma^2}{\langle N_{ch} \rangle} = \theta \boxtimes const \quad , k = \frac{\langle N_{ch} \rangle}{\theta}$$

Five fit parameters N_{knee}, θ, a_j



- [redacted]

$$P(b|n_1 < N_{ch} < n_2) = P(b)\frac{\int_{n_1}^{n_2} P(b|N_{ch})dN_{ch}}{\int_{n_1}^{n_2} P(N_{ch})dN_{ch}}$$

- Find probability of *b* for fixed range of N_{ch} using Bayes' theorem:

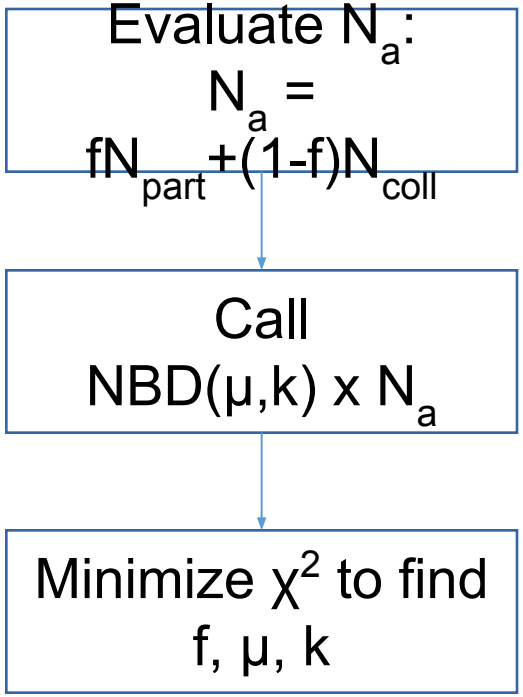
$$P(b|n_1 < N_{ch} < n_2) = P(b)\frac{\int_{n_1}^{n_2} P(b|N_{ch})dN_{ch}}{\int_{n_1}^{n_2} P(N_{ch})dN_{ch}}$$

R. Rogly, G. Giacalone and J. Y. Ollitrault, Phys.Rev. C98 (2018) no.2, 024902

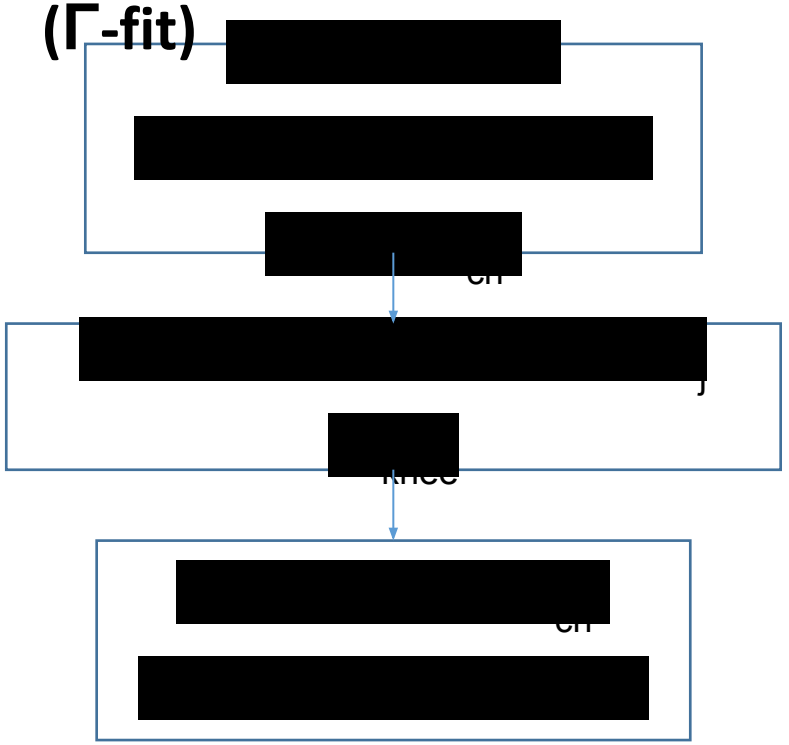
Implementation in MPD: [redacted]

Centrality determination methods

MC-Glauber



The Bayesian inversion (Γ-fit)



Implemantation for MPD:
https://github.com/FlowNICA/CentralityFramework
P. Parfenov, et al., Particles. 2021; 4(2):275-287

Implementation for MPD:
[redacted]