Net-proton fluctuation analysis at 3.22 GeV

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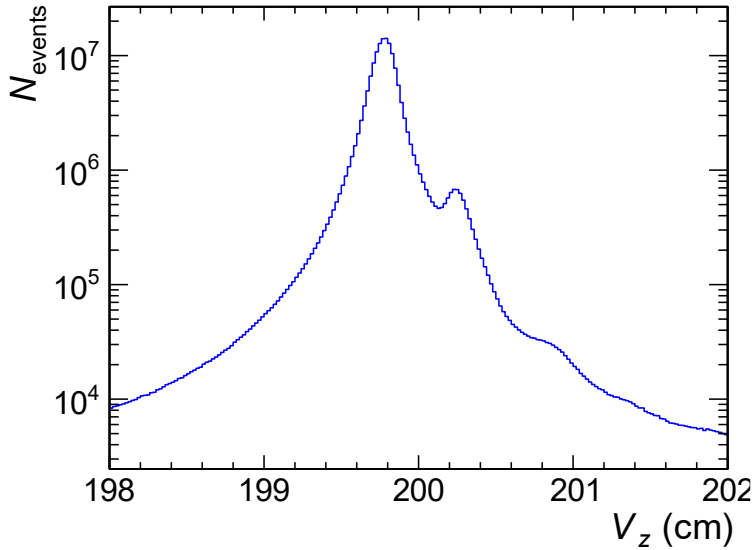
Mar. 14th, 2022

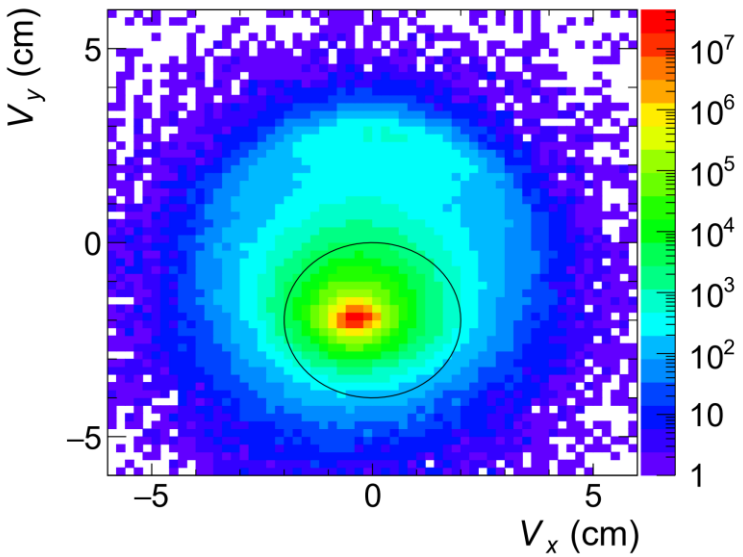
Dataset

- Au+Au @ 3.22 GeV (4.59 GeV FXT)

- Trigger setup: production_4p59GeV_fixedTarget_2019
- Stream: st_physics(_adc)
- Production: P21id
- Library: SL21d

- Run ID: 20179040 − 20183025 (90 runs)
- Events: 2.65×10^{8}

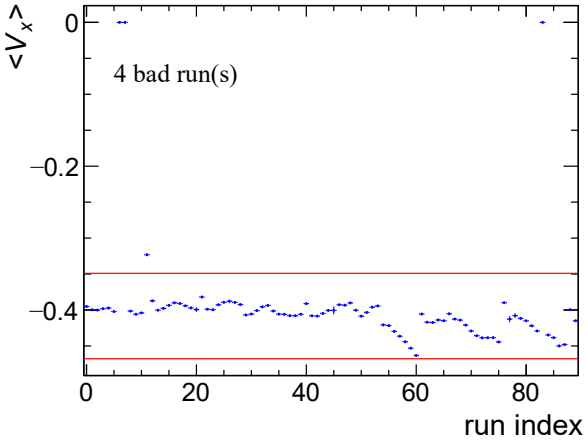


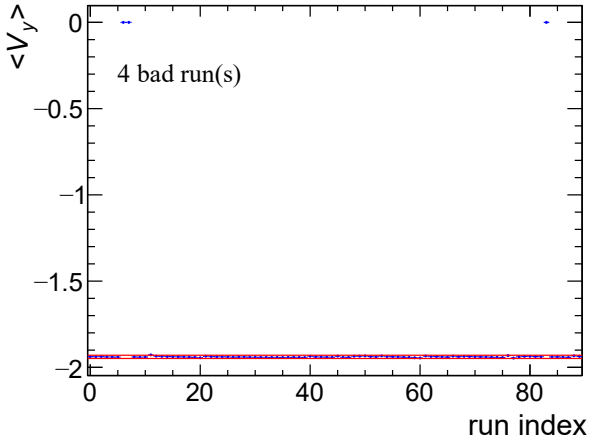


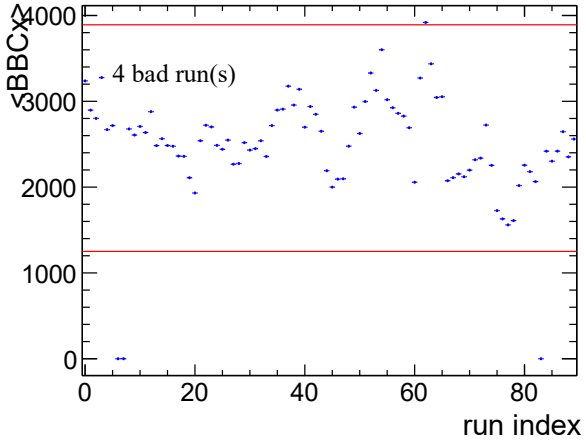
Run-by-run QA cuts

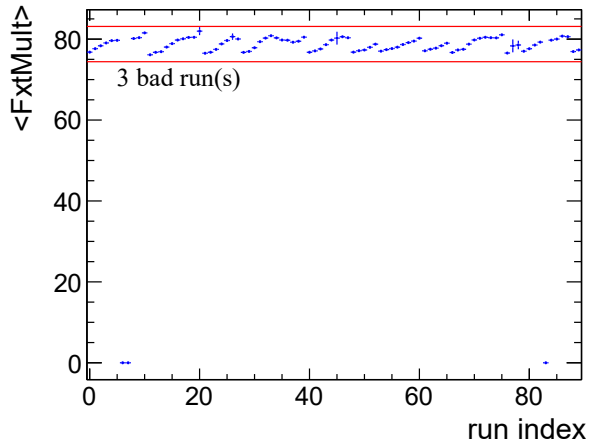
- Trigger ID
  - 680001 (epde-or-bbce-or-vpde-tof1)
- Event cuts:
  - 198 cm < Vz < 202 cm
  - |Vr| < 2 cm, with center (0, −2) cm
- Track cuts
  - Primary
  - |gDca| < 3 cm
  - nHitsFit > 10
  - nHitsFit/nHitsPoss > 0.52
  - nHitsDedx > 5
- Remove empty bins and 3-σ outliers
- Empty bins are not taken into account in σ calculation
- Bad run ID [16]: 20180004, 20180005, 20180006, 20180010, 20180019, 20180025, 20181004, 20181016, 20181045, 20182007, 20182015, 20183001, 20183010, 20183013, 20183014, 20183019

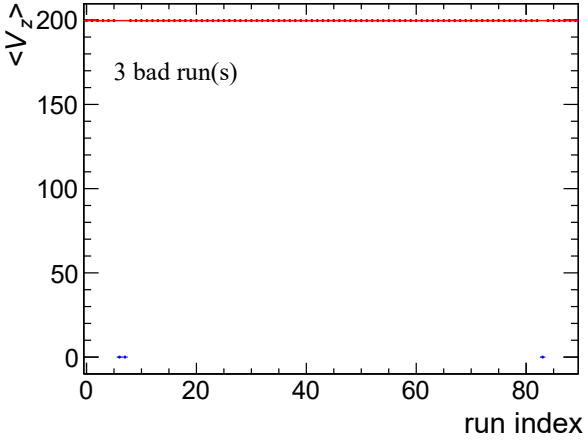
Run-by-run QA plots

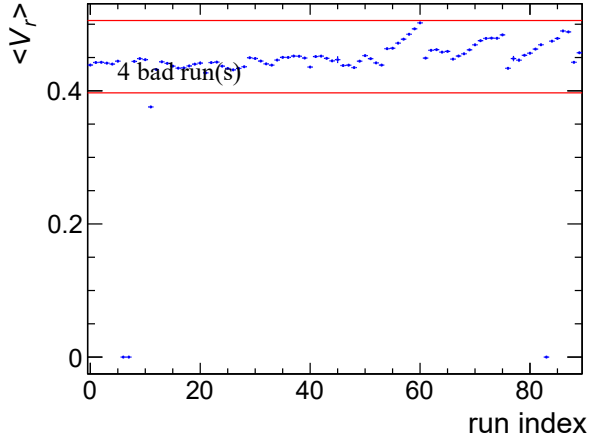


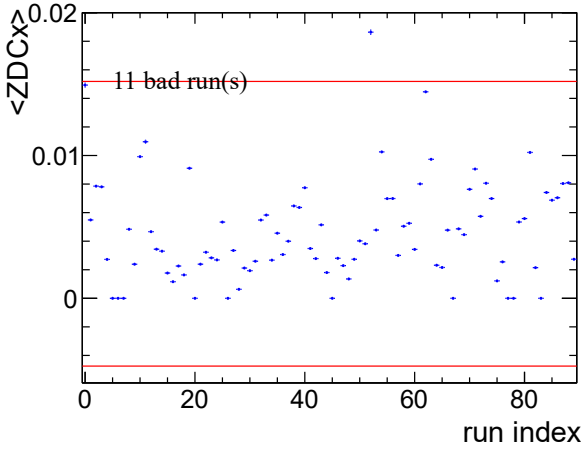


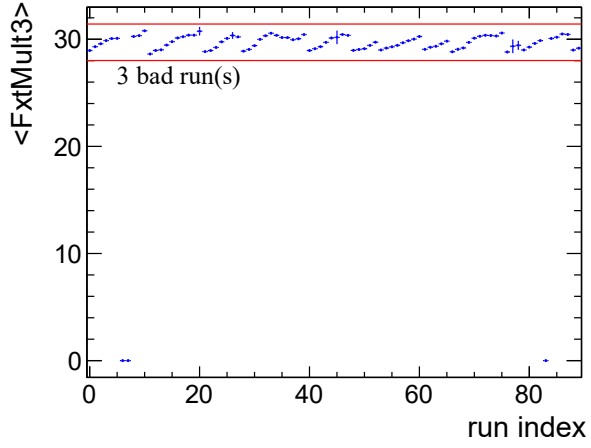


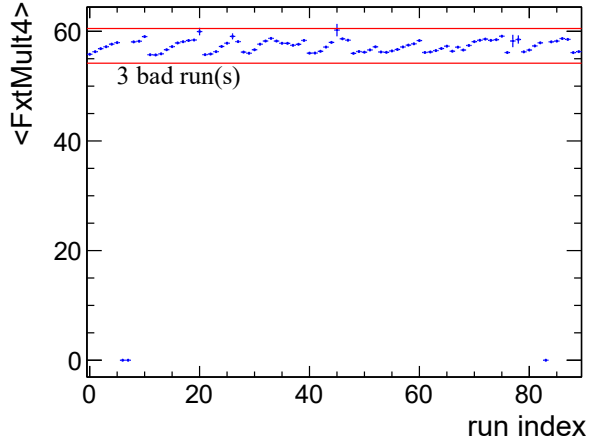




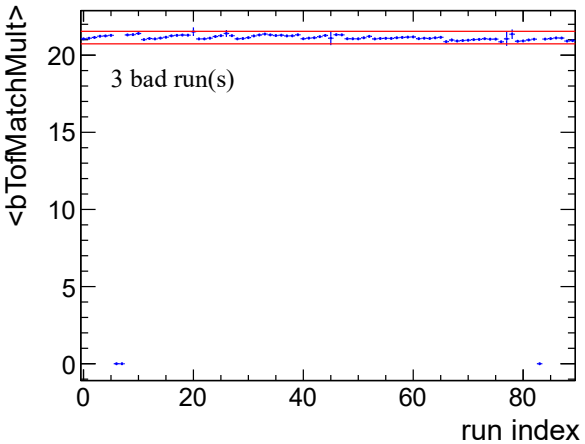


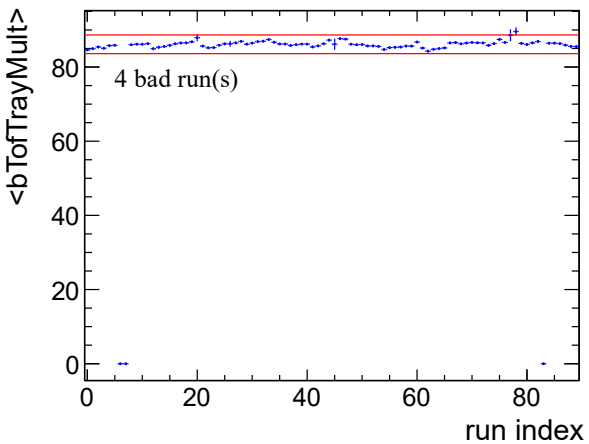


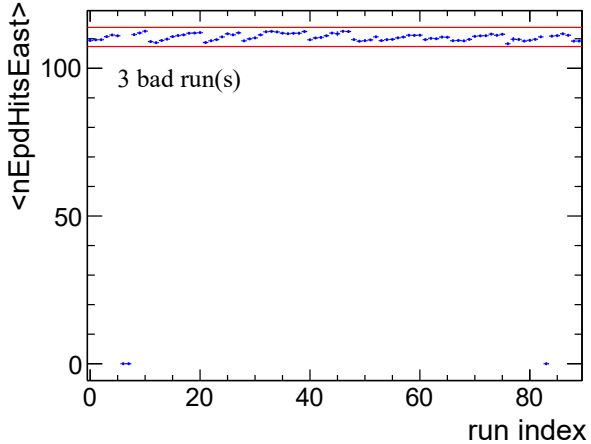


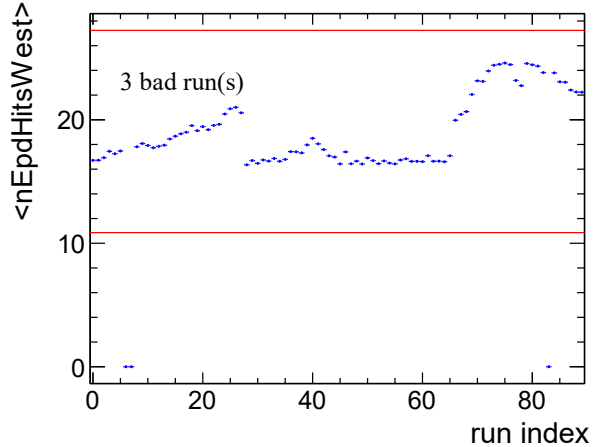


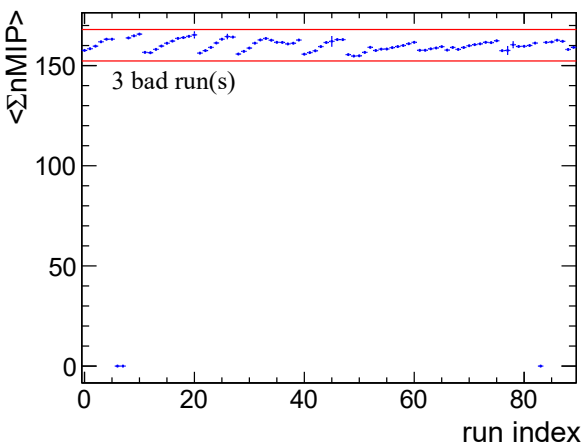
Run-by-run QA plots

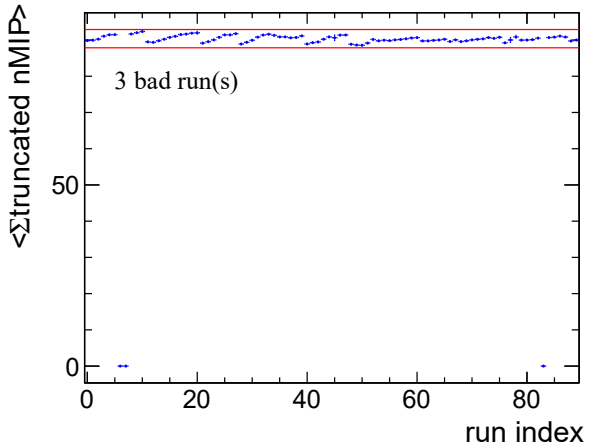


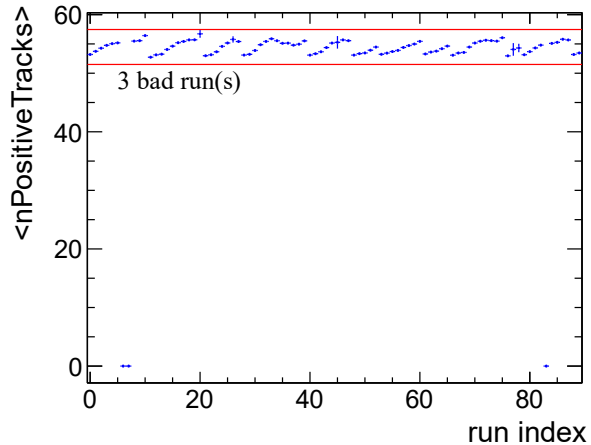


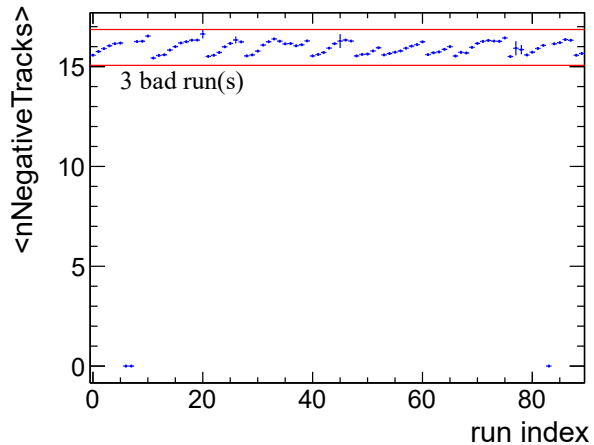




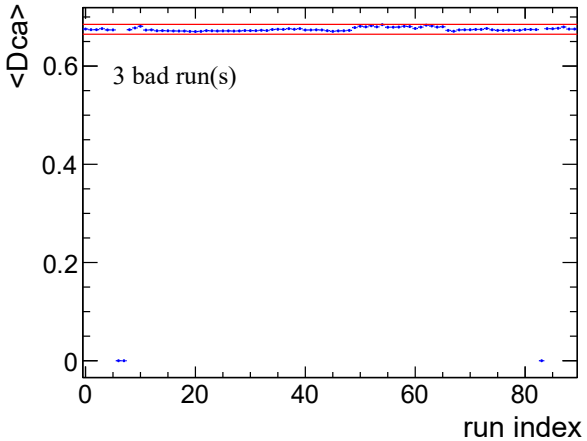


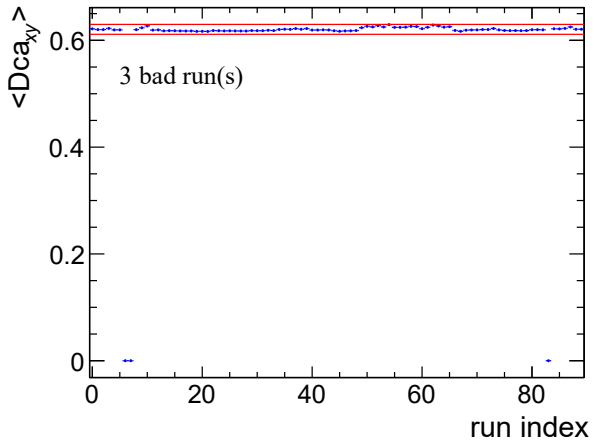


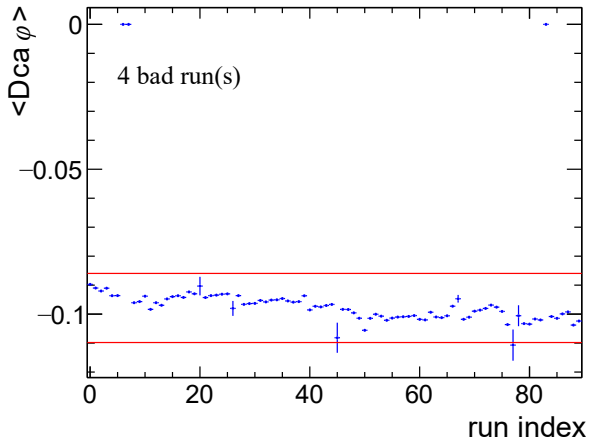


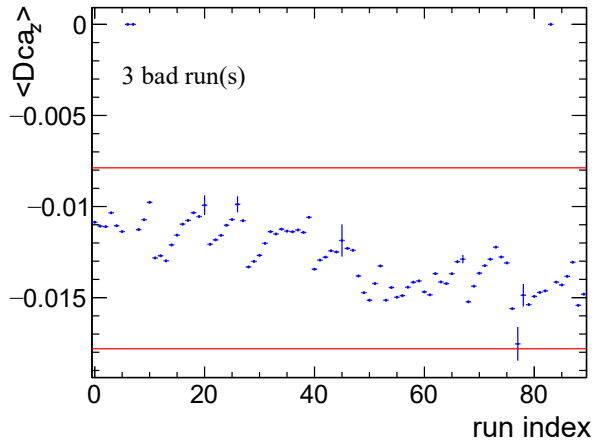


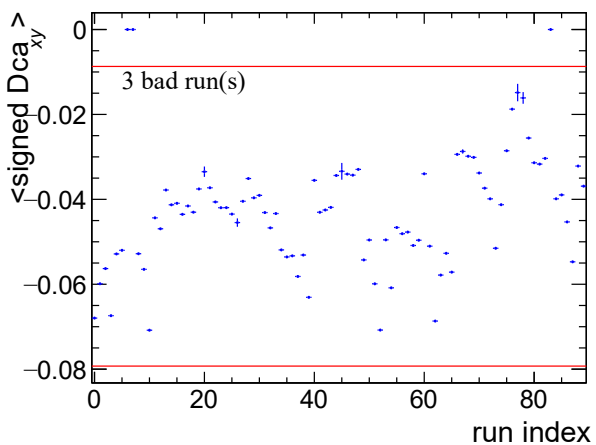
Run-by-run QA plots

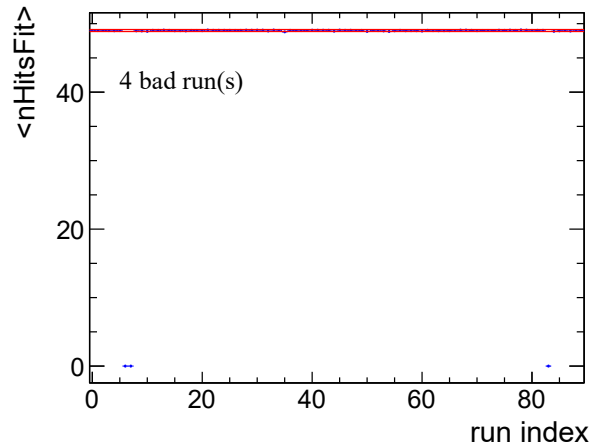


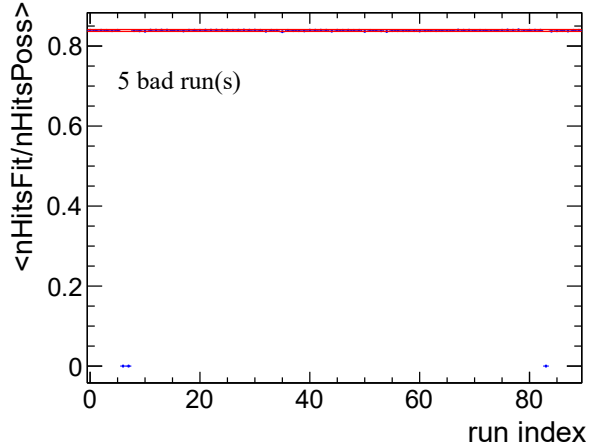


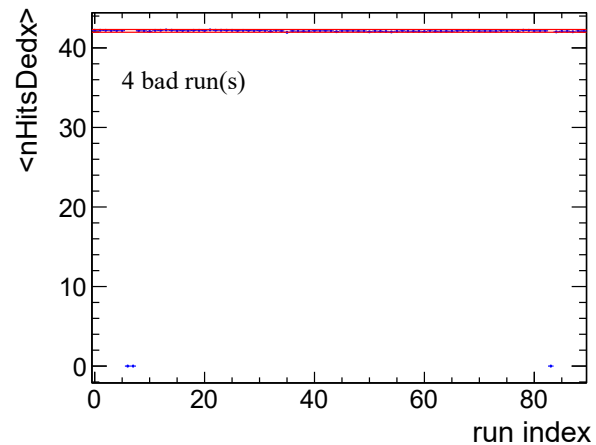




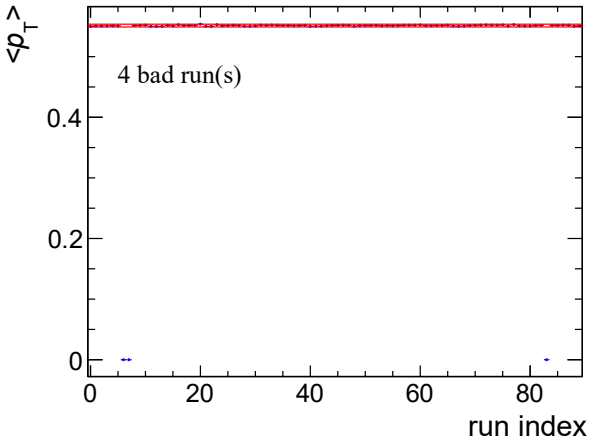


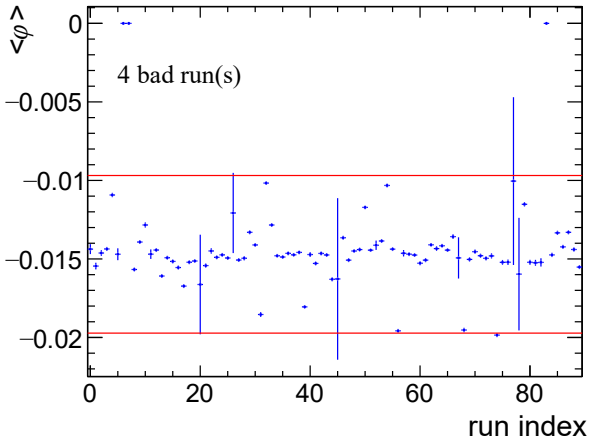


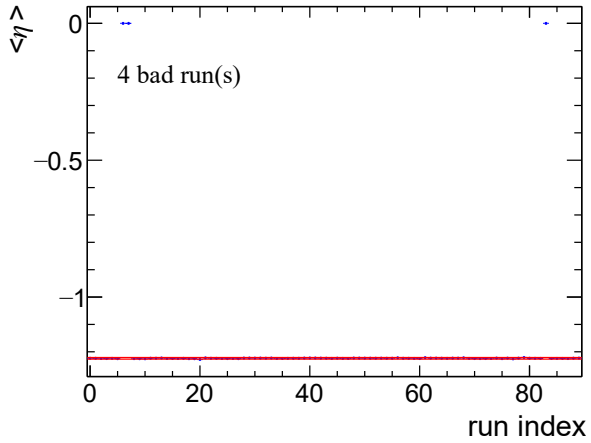


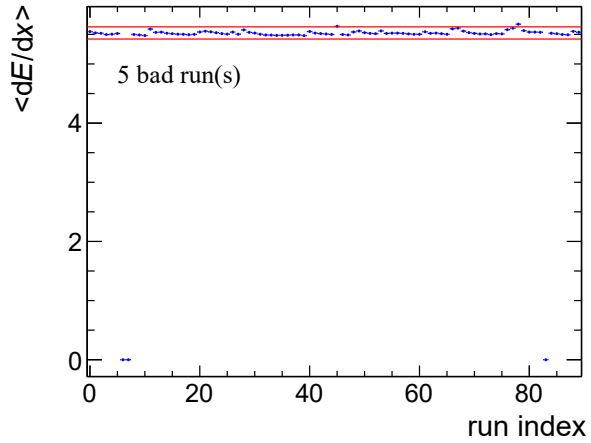


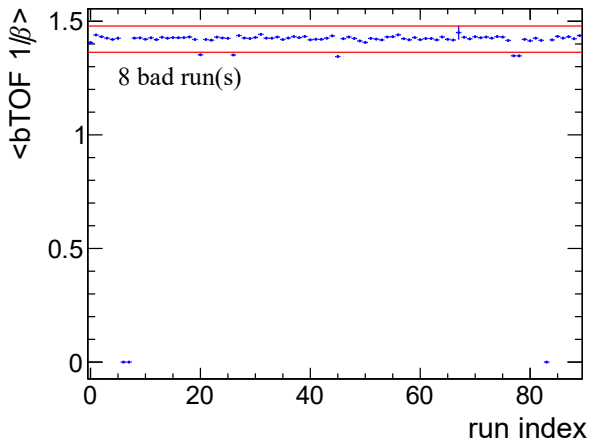
Run-by-run QA plots

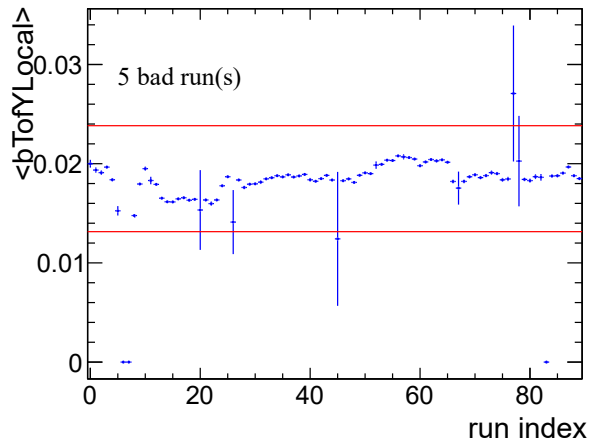


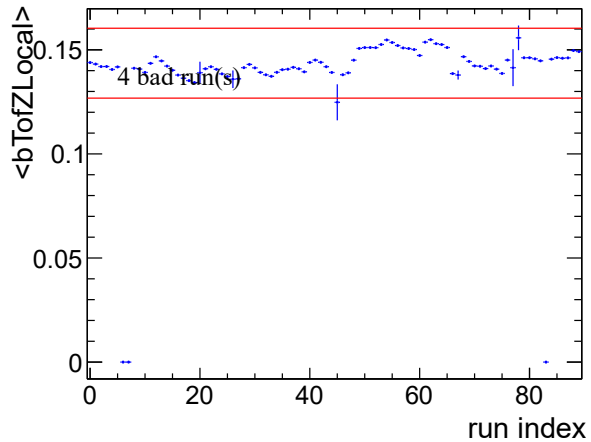








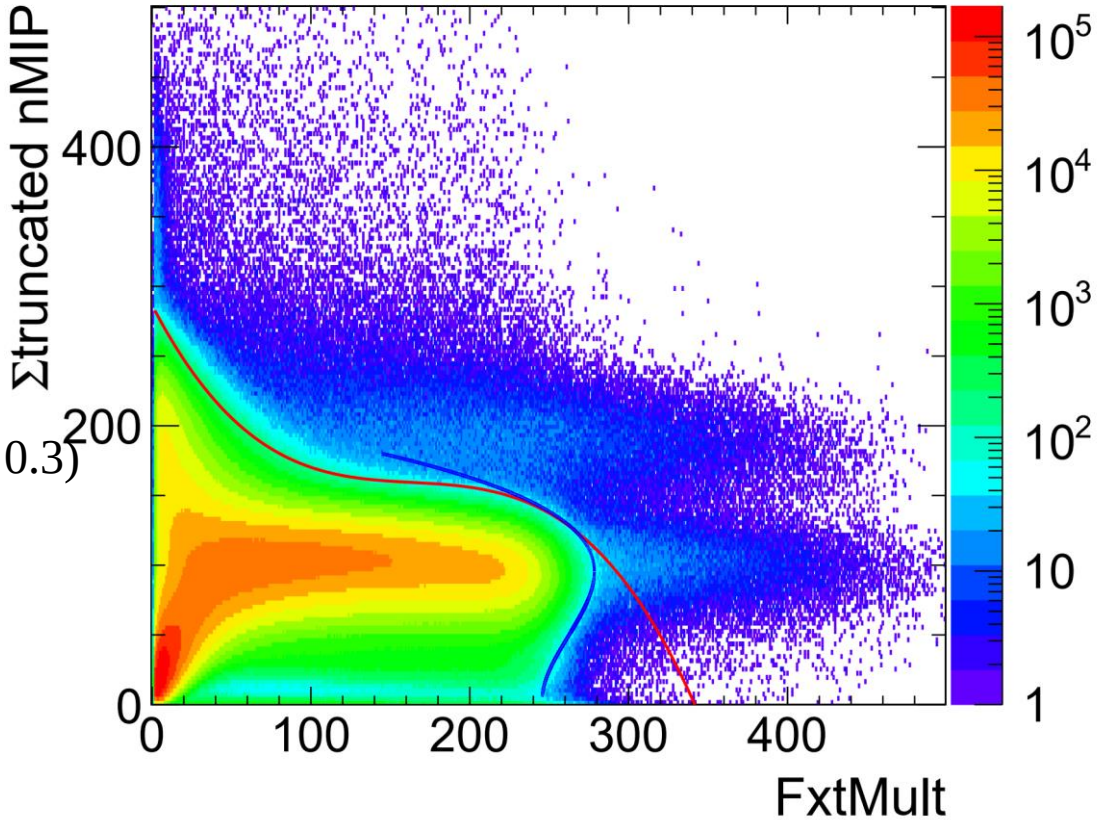




Pileup event rejection

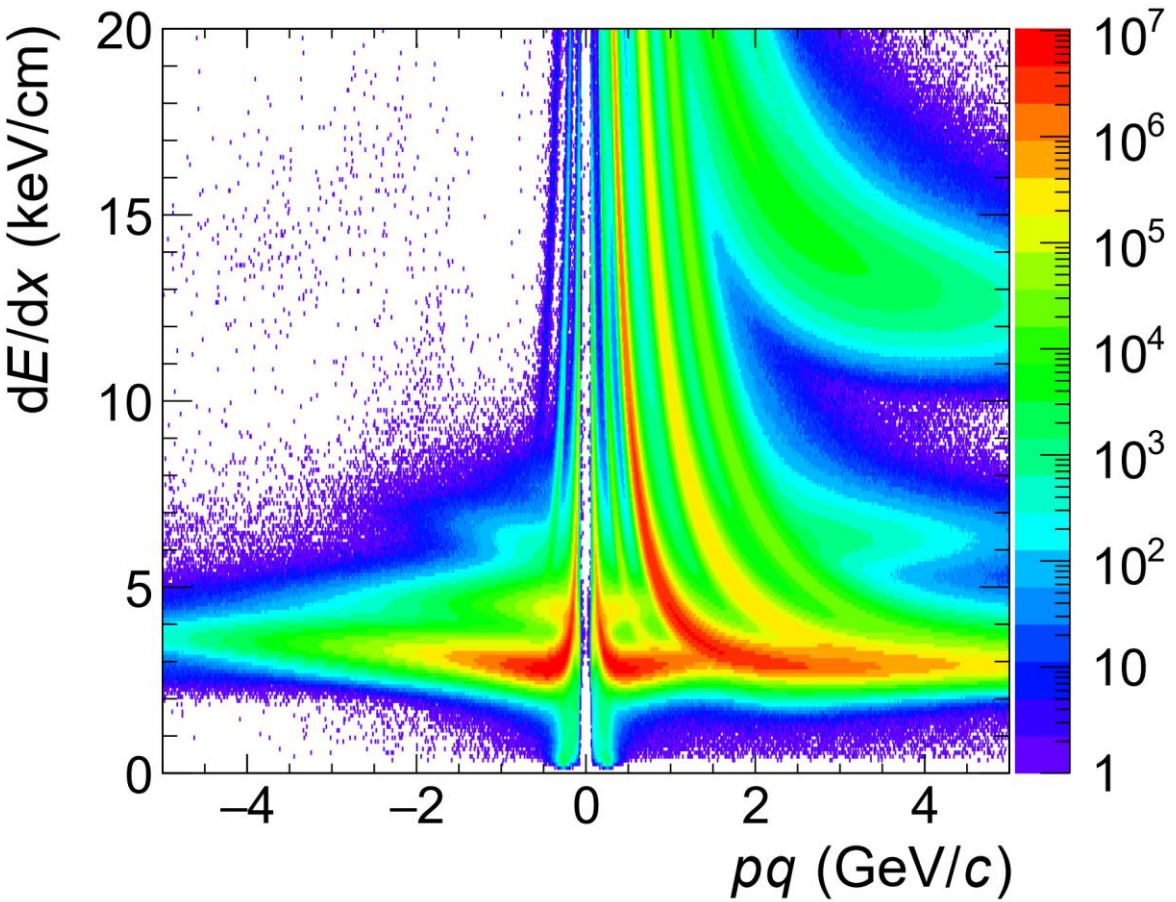
- (Red) SumTnMIP < pol3(FxtMult): 2.866082e+02, −2.205095e+00, 1.306652e−02, −2.654024e−05
- (Blue) FxtMult < pol3(SumTnMIP): 2.456353e+02, −6.576115e−02, 1.222239e−02, −8.313992e−05, for FxtMult > 200

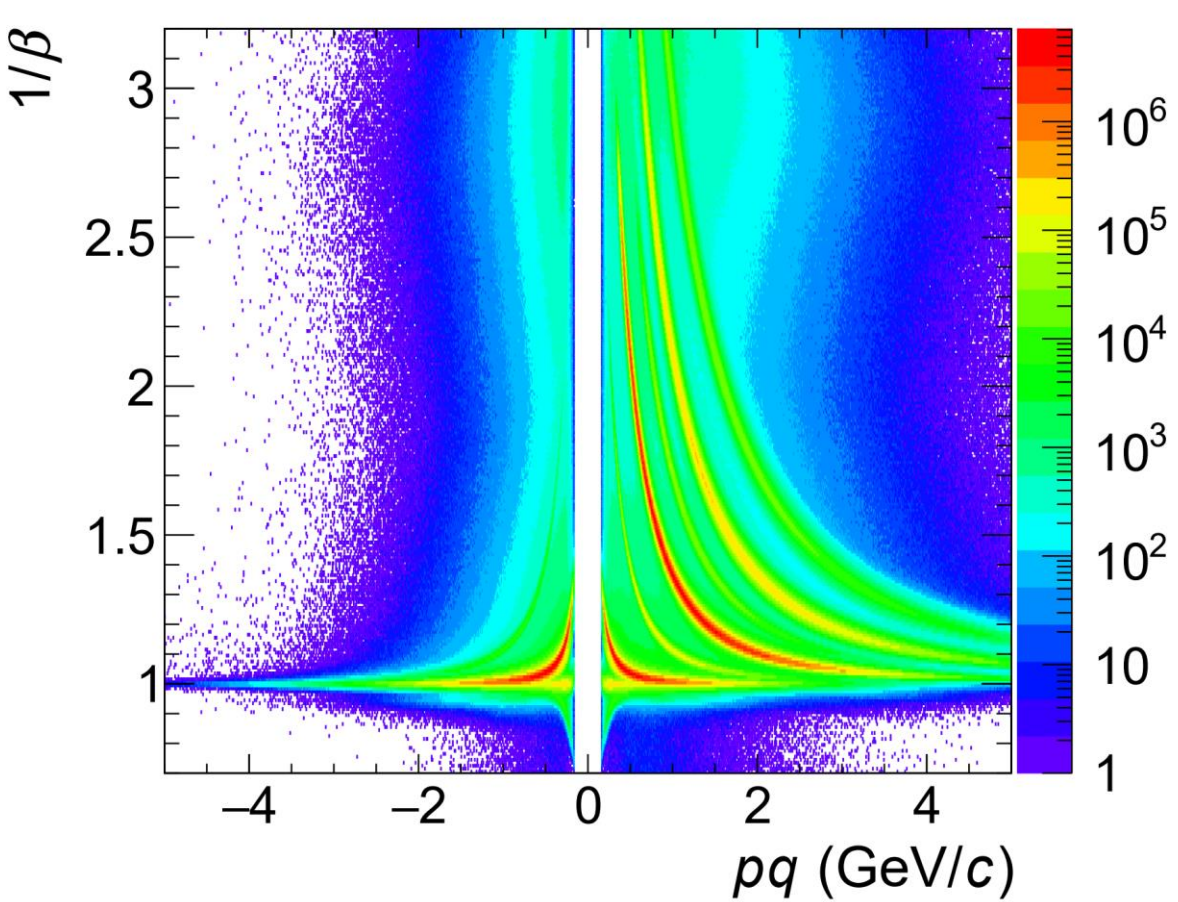
StPicoEpdHit->TnMIP(2, 0.3)



PID plots

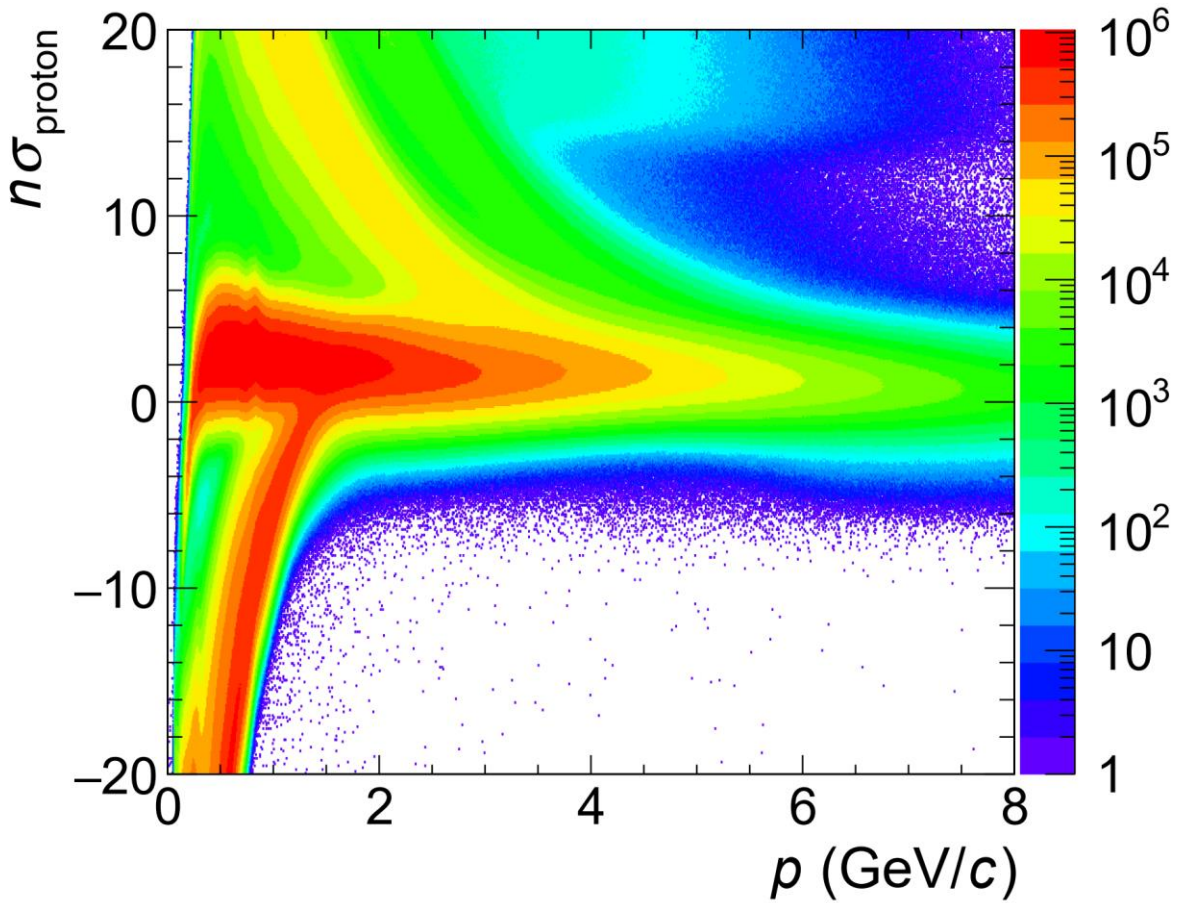
- TPC d*E*/d*x*
- bTOF 1/β

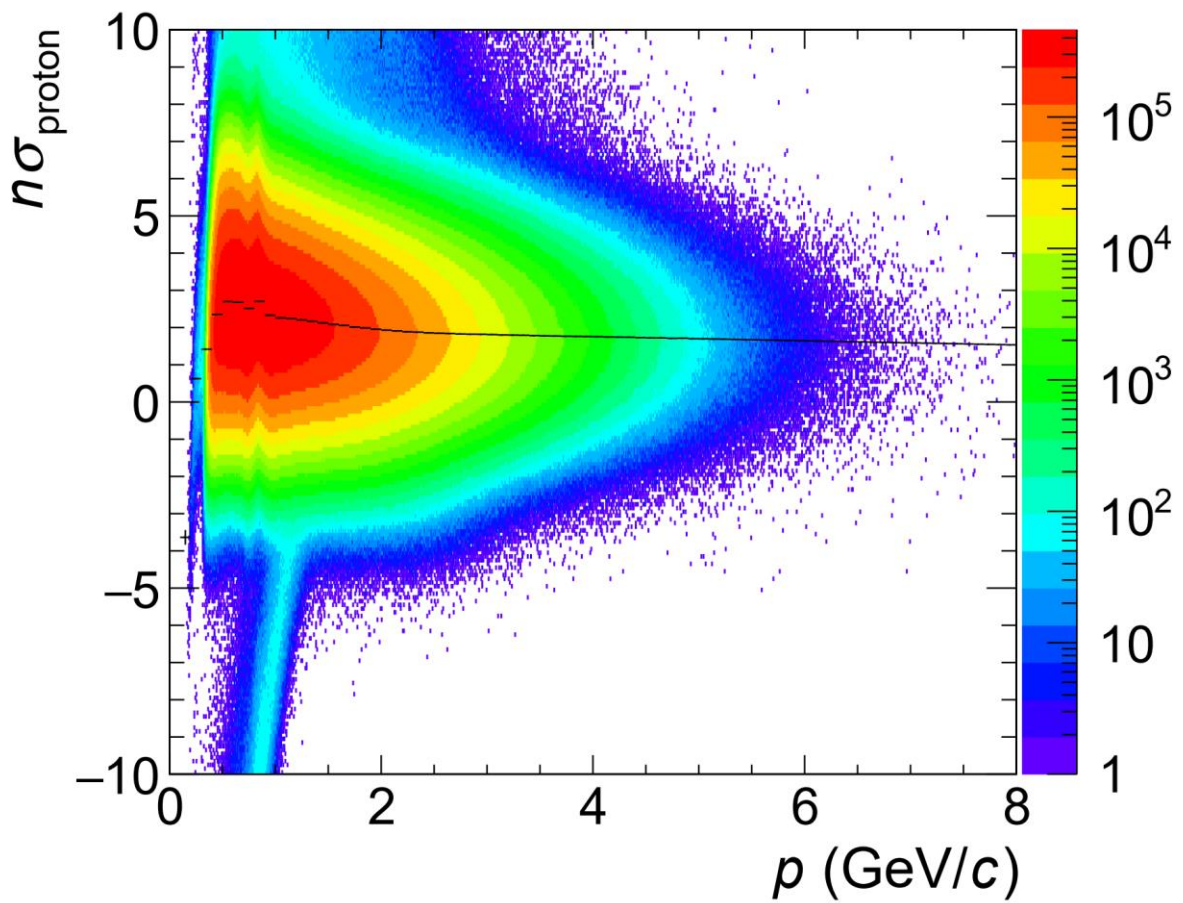




TPC PID check

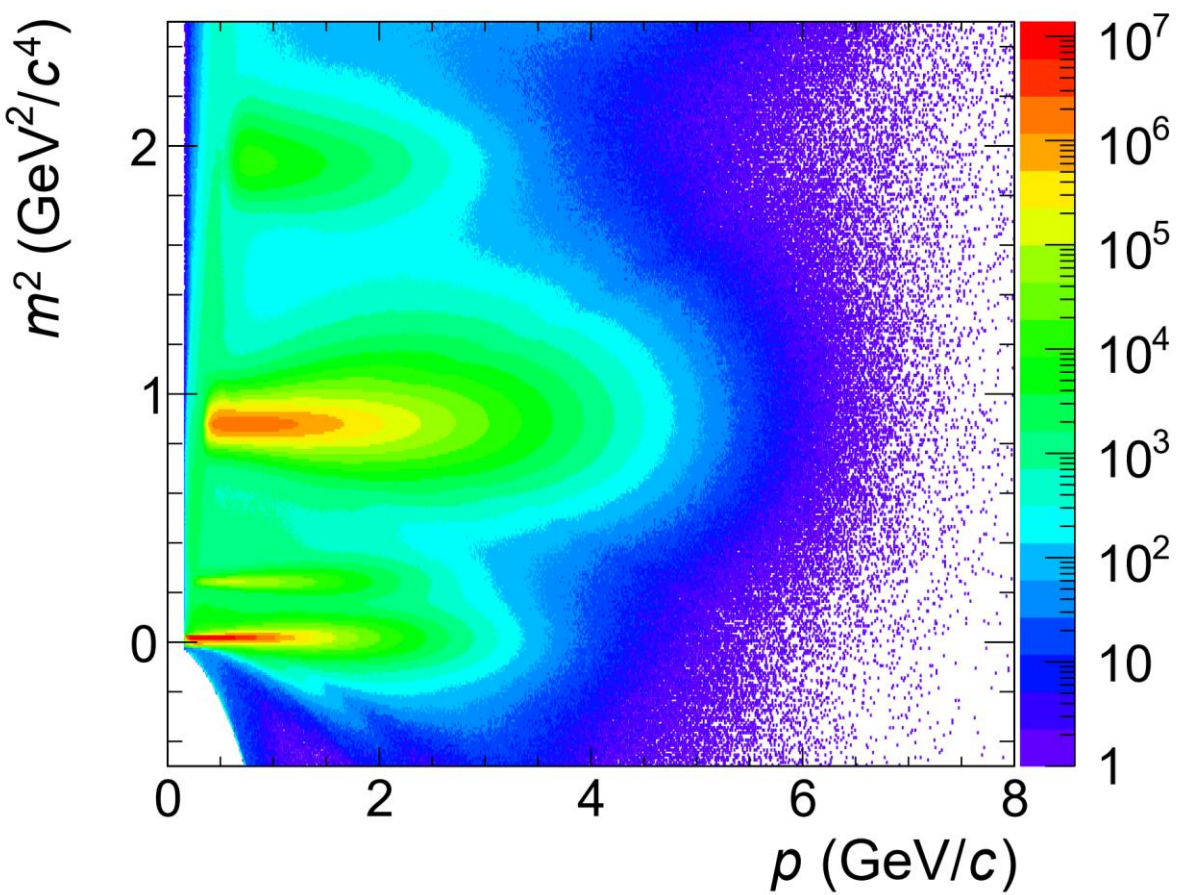
- No bTOF PID
- bTOF 0.73 GeV$^2/c^4 < m^2 <$ 1.03 GeV$^2/c^4$
- Gaussian fit & $<n\sigma_{\text{proton}}>$ shift in p bins

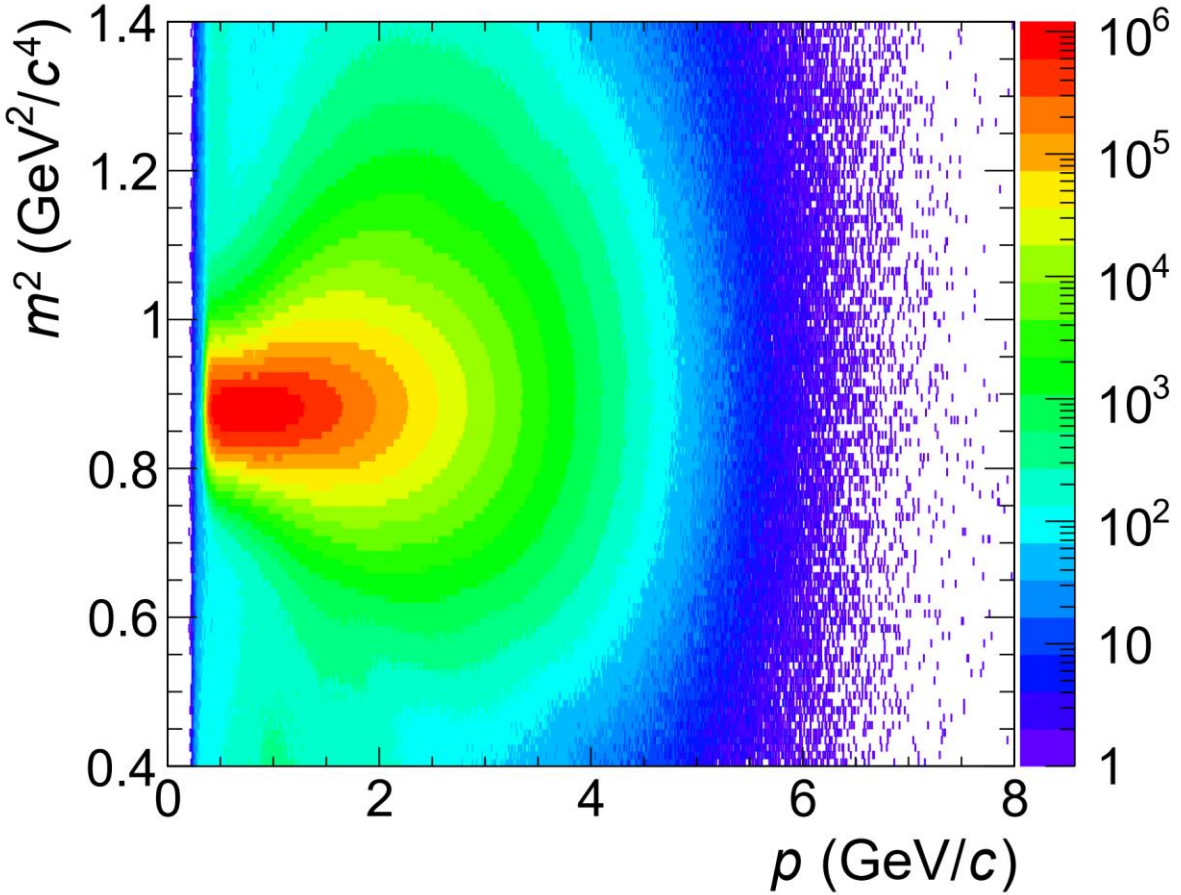




bTOF PID check

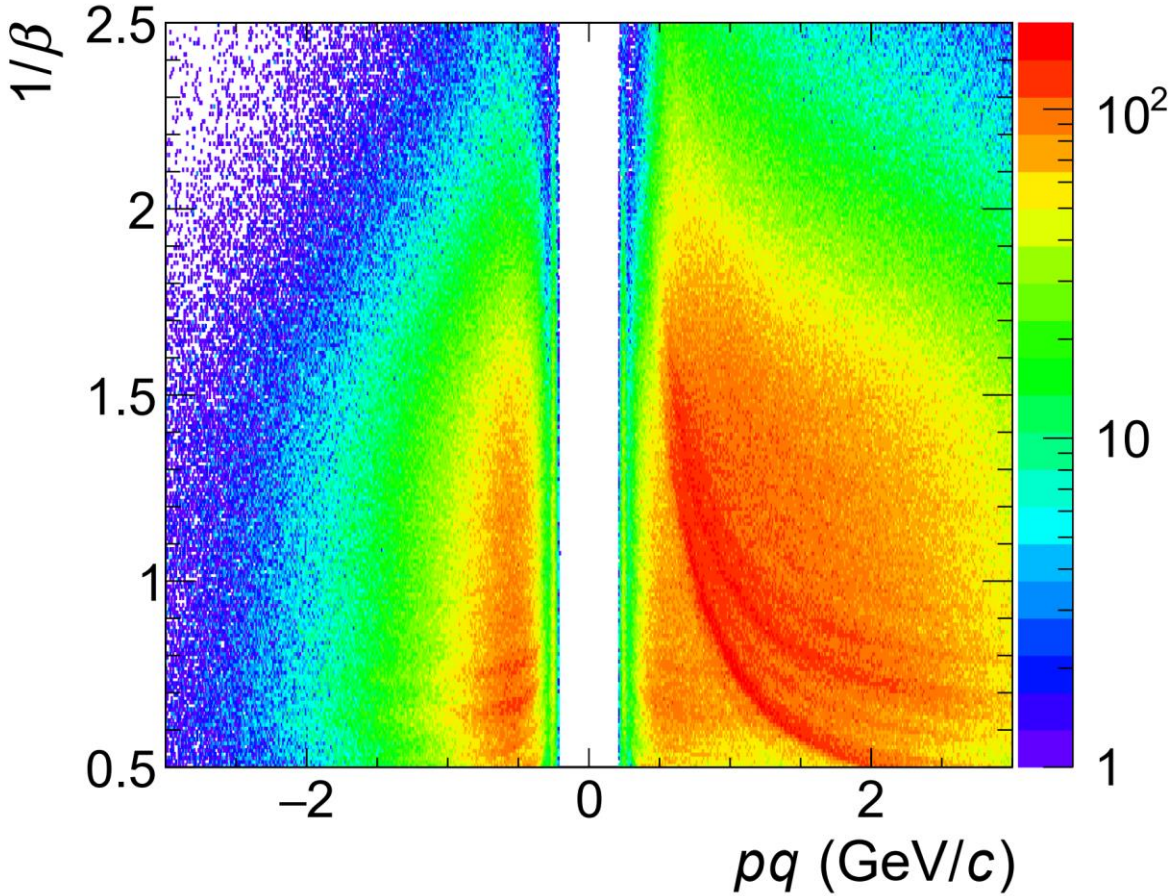
- No TPC PID
- TPC $|n\sigma_{\text{proton}} - 2.25| < 1$
- No mean shift required

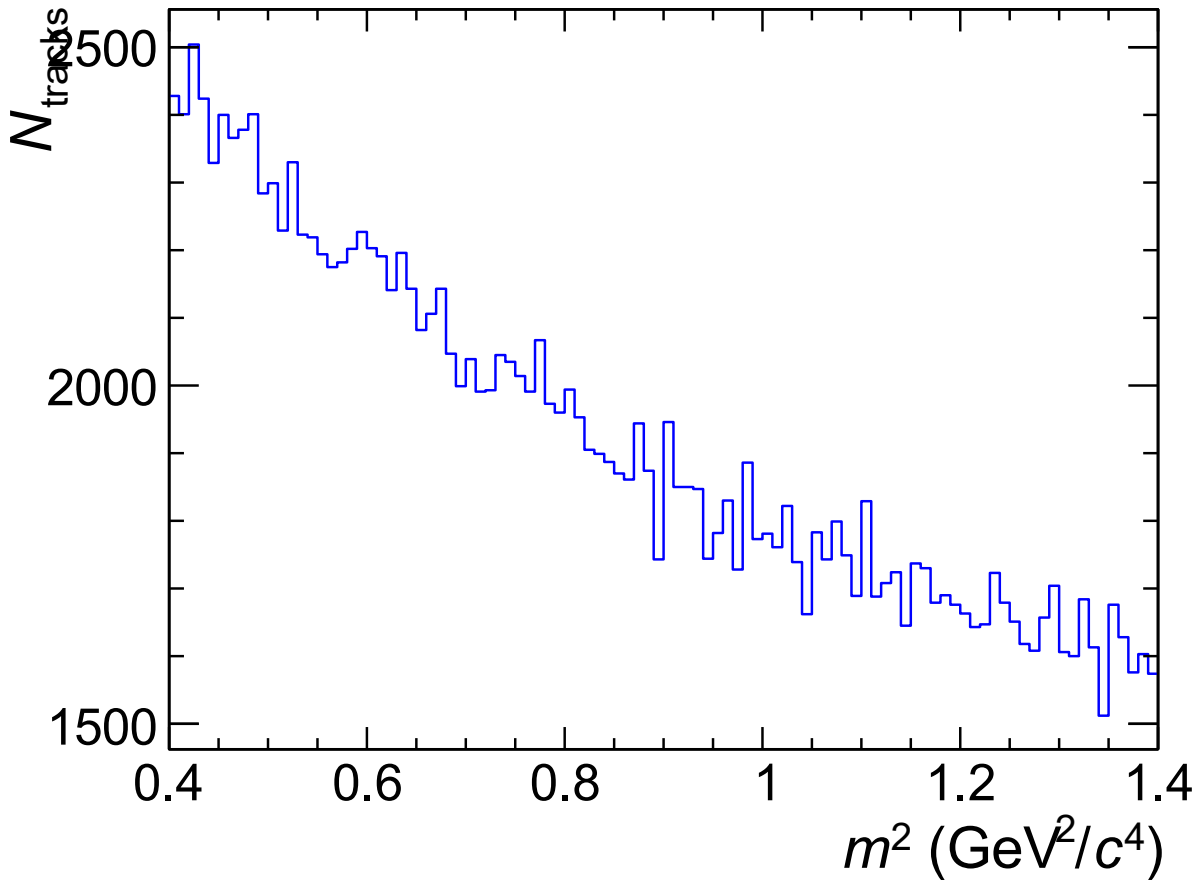




eTOF PID check

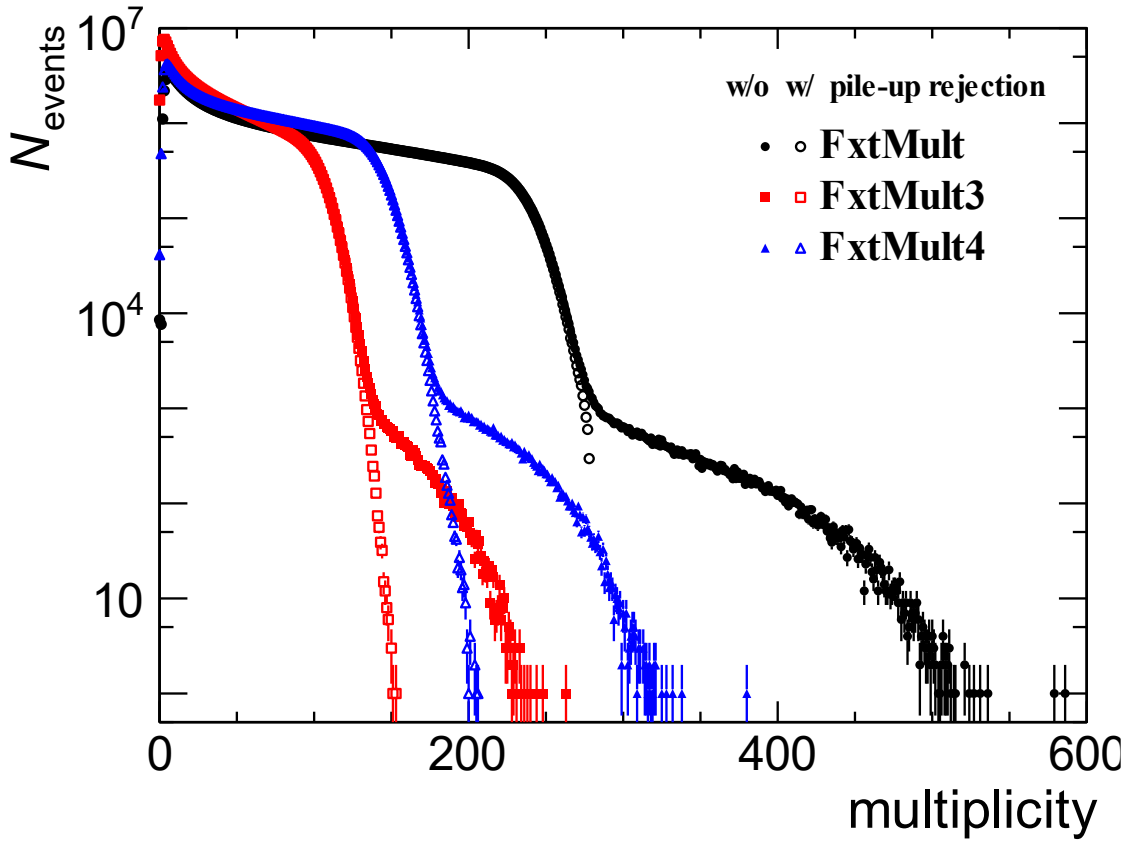
- No TPC PID
- With TPC PID cut for protons
- eTOF is unavailable





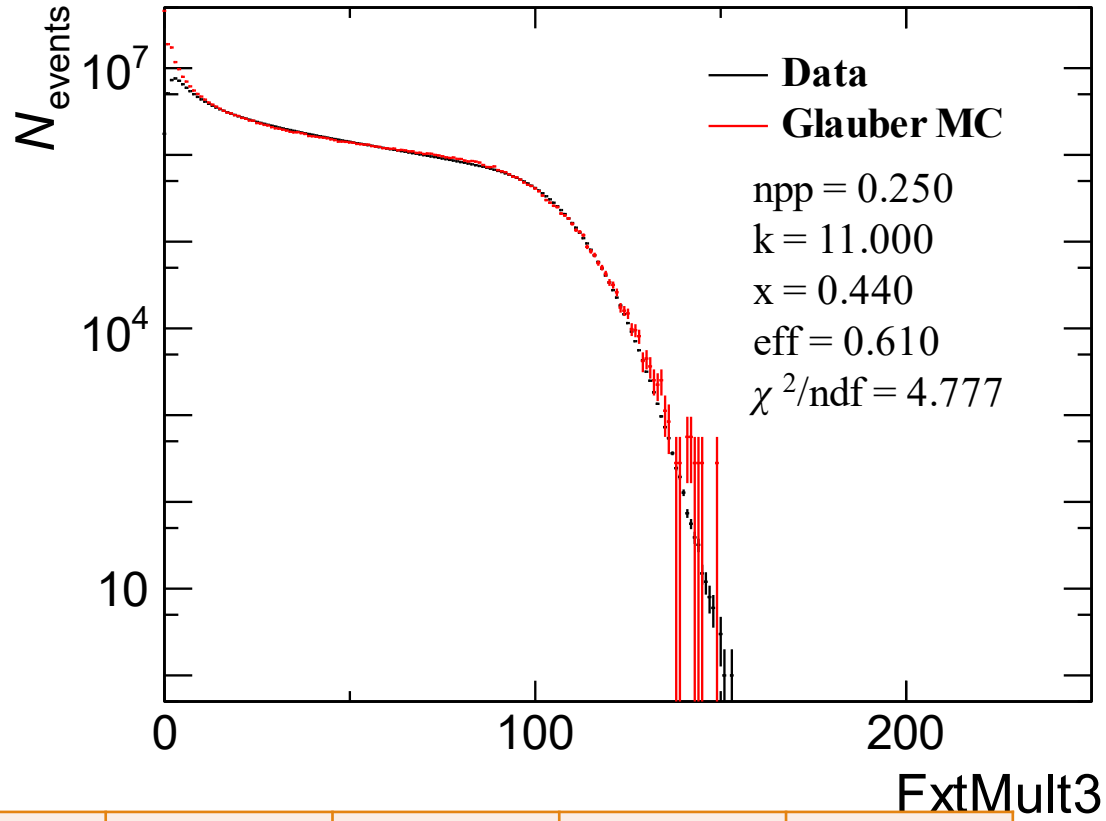
Centrality determination

- FxtMult: primary (branch of StPicoEvent)
- FxtMult3: primary, nHitsFit > 10, nSigmaProton−2.25 < −3 (constant $<n\sigma_{proton}>$ shift)
- FxtMult4: primary, nHitsFit > 10, |nSigmaKaon−1.95| > 3



Centrality determination

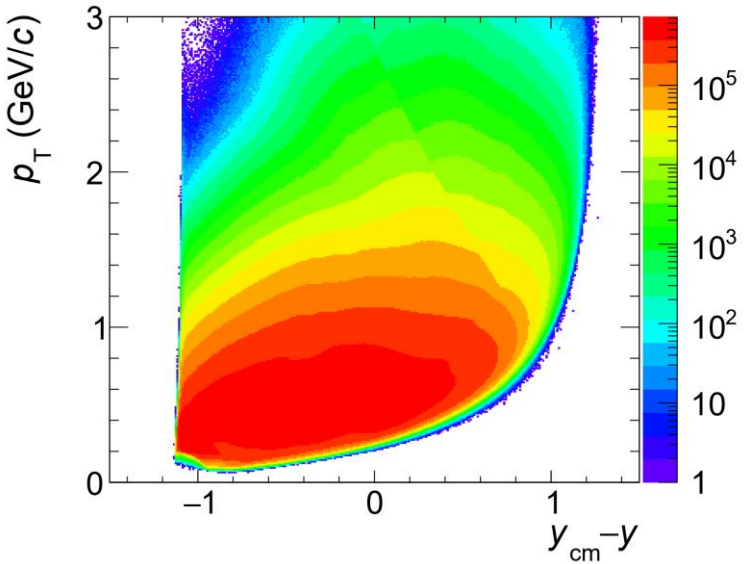
- 10^6 Glauber MC events
  - σ_{nn} = 29 mb
- Fit @ FxtMult3 > 25



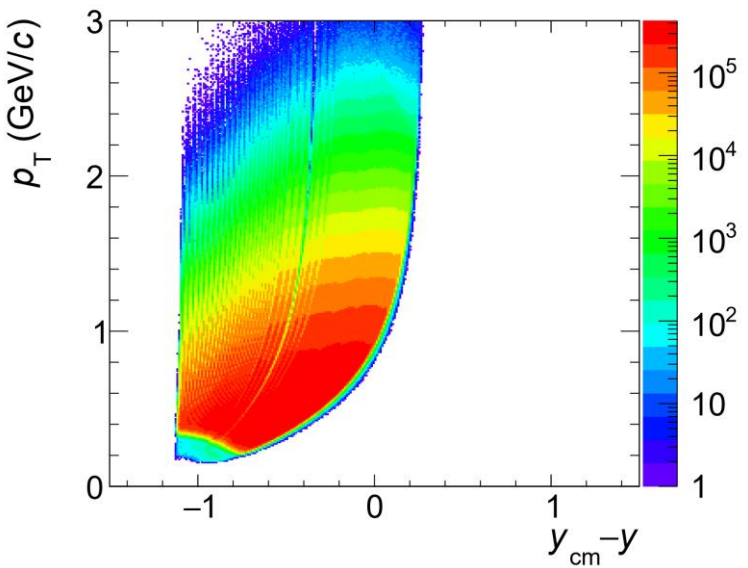
FxtMult3 >	0	1	2	3	5	7	10	14
Centrality	75-80%	70-75%	65-70%	60-65%	55-60%	50-55%	45-50%	40-45%
FxtMult3 >	18	23	30	37	46	56	68	83
Centrality	35-40%	30-35%	25-30%	20-25%	15-20%	10-15%	5-10%	0-5%

Acceptance

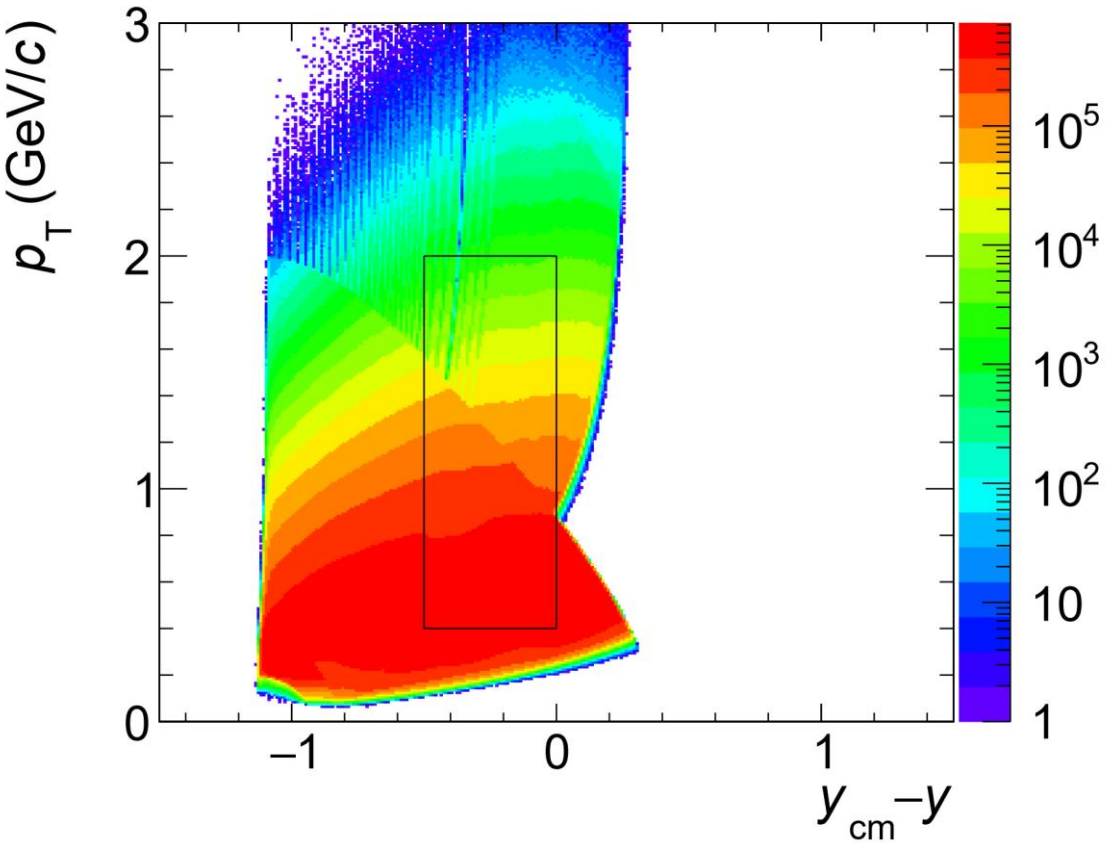
- Only TPC
- $y_{cm} = -1.135$



- TPC+bTOF

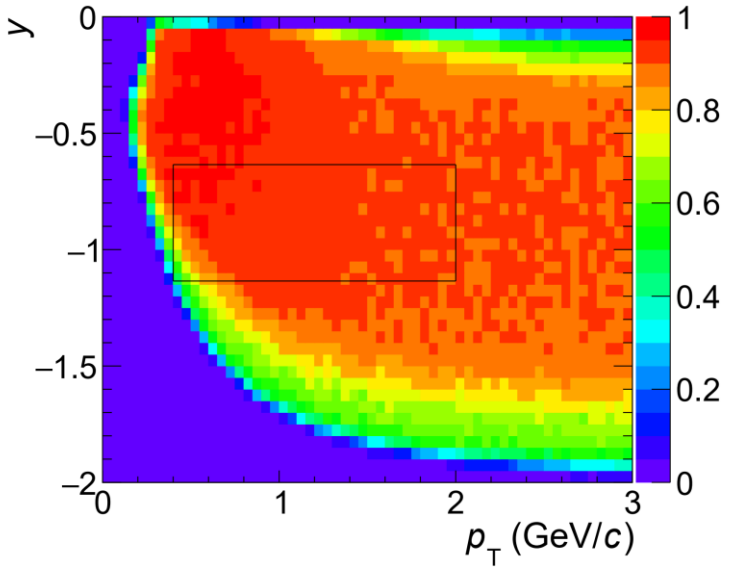


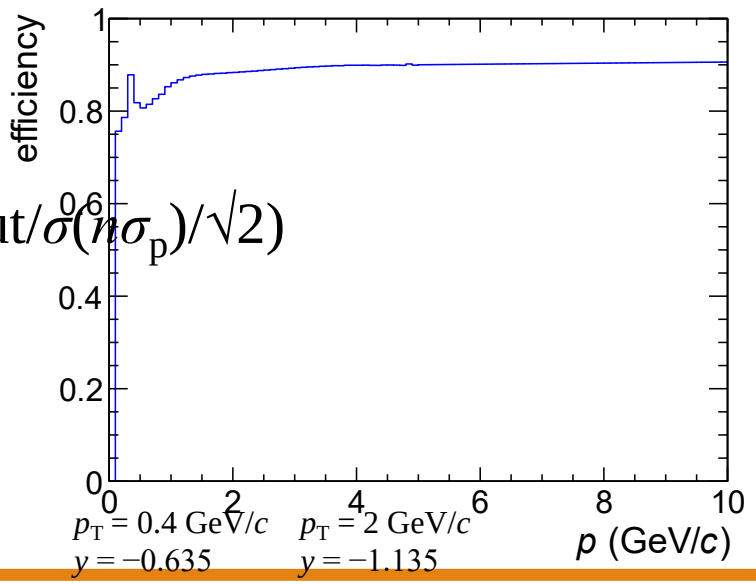
- Only TPC, $p < 2$ GeV/c
- TPC+bTOF, $p > 2$ GeV/c



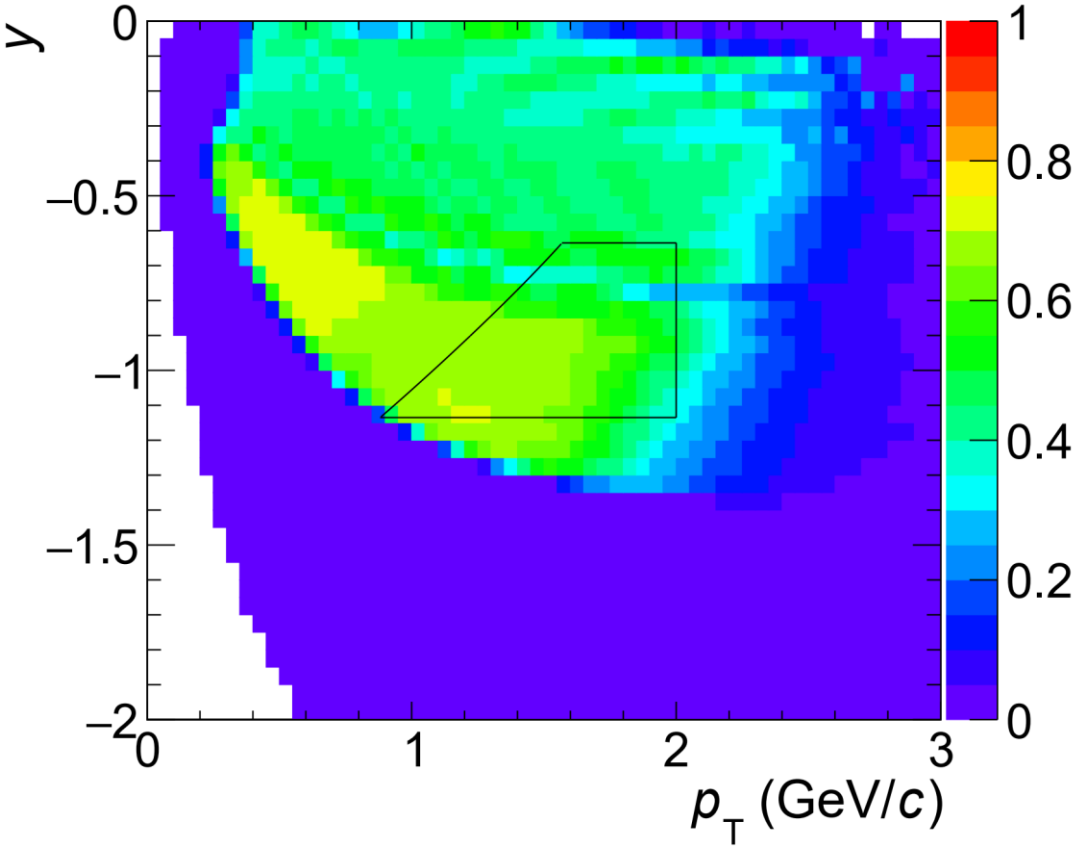
Efficiency

- TPC
- Tracking @ 3.0 GeV
- PID
  - $\varepsilon = \mathrm{erf}(n\sigma_p \text{ cut}/\sigma(n\sigma_p)/\sqrt{2})$





- bTOF
  - $\varepsilon = N$(TPC+bTOF PID)/N(TPC PID)



Analysis cuts

- Trigger ID
  - 680001 (epde-or-bbce-or-vpde-tof1)
- Run cuts
  - Bad run rejection
- Event cuts:
  - 198 cm < Vz < 202 cm
  - |Vr| < 2 cm, with center (0, −2) cm
  - Pile-up event rejection
- Events: 2.00×10^8
- Track cuts
  - Primary
  - |gDca| < 3 cm
  - nHitsFit > 10
  - nHitsFit/nHitsPoss > 0.52
  - nHitsDedx > 5
  - 0.4 GeV/c < p_T < 2 GeV/c
  - $-0.5 < y_{cm} - y < 0$, $y_{cm} = -1.135$
  - $|n\sigma_p - \langle n\sigma_p \rangle(p)| < 2$
  - 0.6 GeV$^2/c^4$ < m^2 < 1.2 GeV$^2/c^4$
    - p > 2 GeV/c

Analysis techniques

- Track-by-track efficiency correction

$$q_{(r,s)} = \sum_{j=1}^{n_{\text{tot}}} \frac{a_j^r}{\varepsilon_j^s}$$

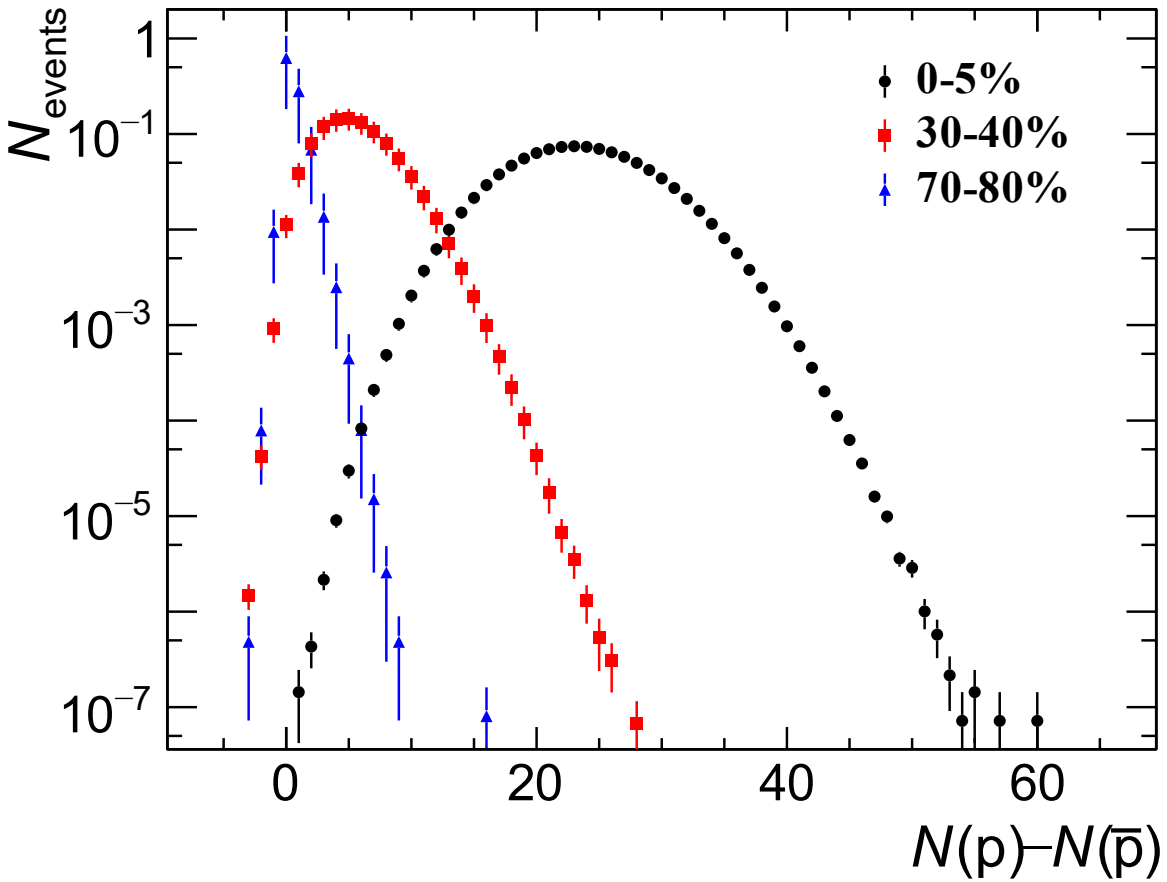
- Analytical statistical uncertainty estimation
  - Based on covariances of terms in track-by-track efficiency correction formulae

$$\begin{aligned}
\langle Q \rangle_{\text{c}} &= \langle q_{(1,1)} \rangle_{\text{c}}, \\
\langle Q^2 \rangle_{\text{c}} &= \langle q_{(1,1)}^2 \rangle_{\text{c}} + \langle q_{(2,1)} \rangle_{\text{c}} - \langle q_{(2,2)} \rangle_{\text{c}}, \\
\langle Q^3 \rangle_{\text{c}} &= \langle q_{(1,1)}^3 \rangle_{\text{c}} + 3\langle q_{(1,1)} q_{(2,1)} \rangle_{\text{c}} - 3\langle q_{(1,1)} q_{(2,2)} \rangle_{\text{c}} \\
&\quad + \langle q_{(3,1)} \rangle_{\text{c}} - 3\langle q_{(3,2)} \rangle_{\text{c}} + 2\langle q_{(3,3)} \rangle_{\text{c}}, \\
\langle Q^4 \rangle_{\text{c}} &= \langle q_{(1,1)}^4 \rangle_{\text{c}} + 6\langle q_{(1,1)}^2 q_{(2,1)} \rangle_{\text{c}} - 6\langle q_{(1,1)}^2 q_{(2,2)} \rangle_{\text{c}} \\
&\quad + 4\langle q_{(1,1)} q_{(3,1)} \rangle_{\text{c}} + 3\langle q_{(2,1)}^2 \rangle_{\text{c}} + 3\langle q_{(2,2)}^2 \rangle_{\text{c}} \\
&\quad - 12\langle q_{(1,1)} q_{(3,2)} \rangle_{\text{c}} + 8\langle q_{(1,1)} q_{(3,3)} \rangle_{\text{c}} \\
&\quad - 6\langle q_{(2,1)} q_{(2,2)} \rangle_{\text{c}} + \langle q_{(4,1)} \rangle_{\text{c}} - 7\langle q_{(4,2)} \rangle_{\text{c}} \\
&\quad + 12\langle q_{(4,3)} \rangle_{\text{c}} - 6\langle q_{(4,4)} \rangle_{\text{c}},
\end{aligned}$$

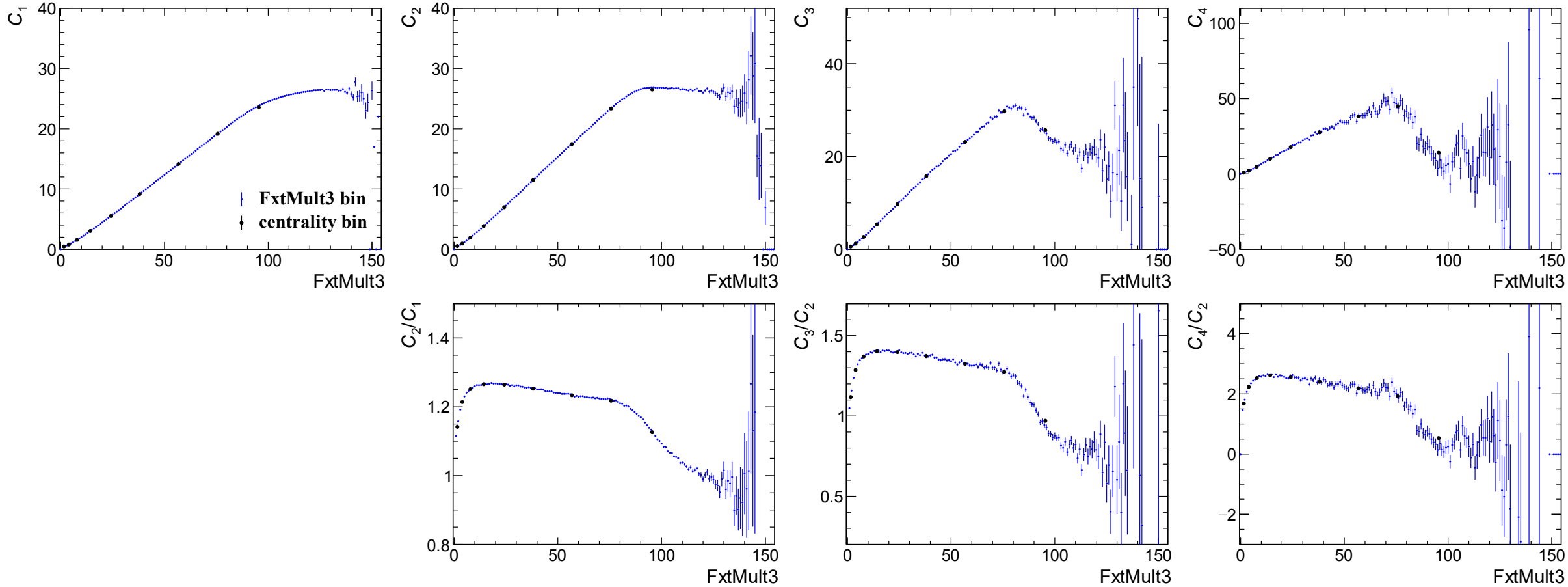
- Centrality bin width correction (CBWC)
  - $C_k = \sum_r n_r C_{k,r} / \sum_r n_r$
  - $\sigma(C_k) = \sqrt{\sum_r n_r^2 \sigma^2(C_{k,r})} / (\sum_r n_r)^2$
  - $\sigma\left(\frac{C_k}{C_l}\right) = \sqrt{\sum_r n_r^2 \sigma^2\left(\frac{C_{k,r}}{C_{l,r}}\right)} / (\sum_r n_r)^2$

Measured distributions

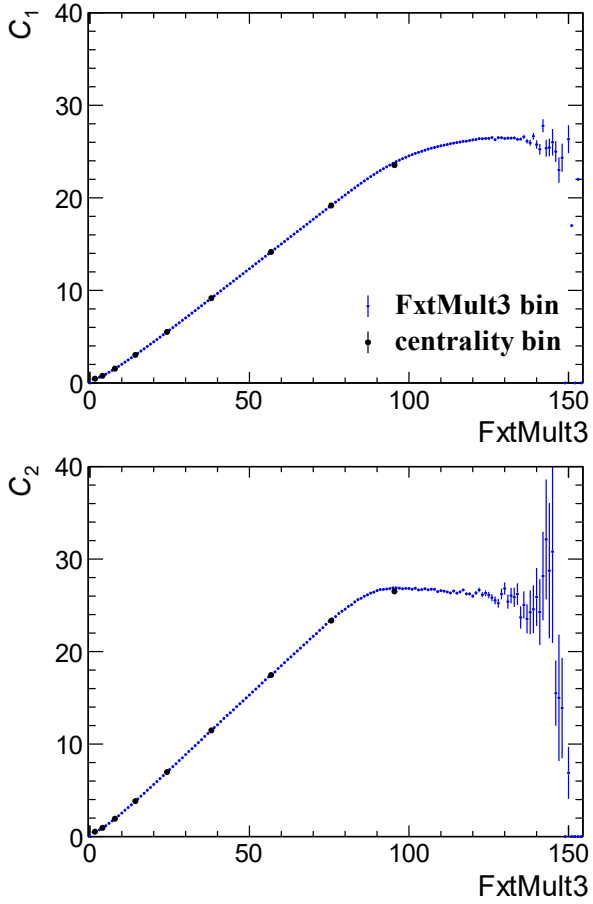
- Efficiency-uncorrected
- Centrality-dependent means and widths observed

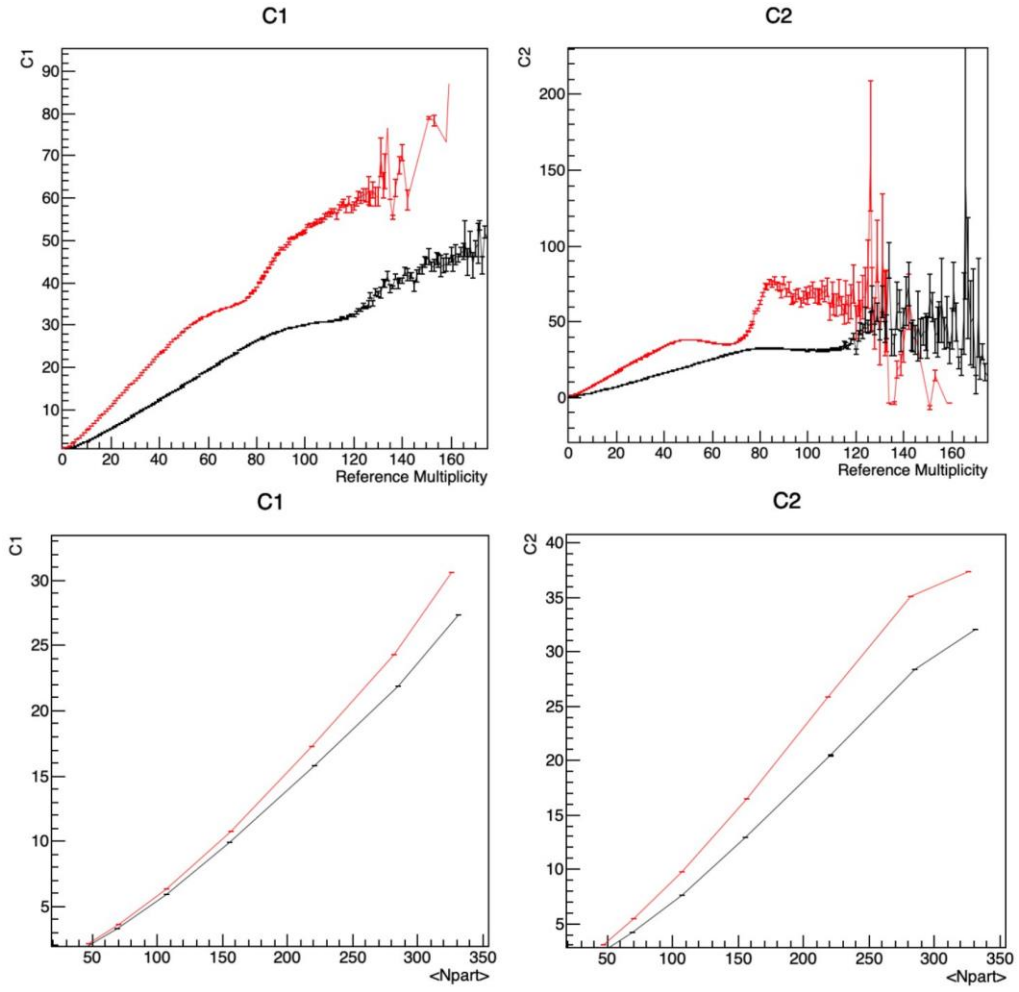


Efficiency-uncorrected cumulants



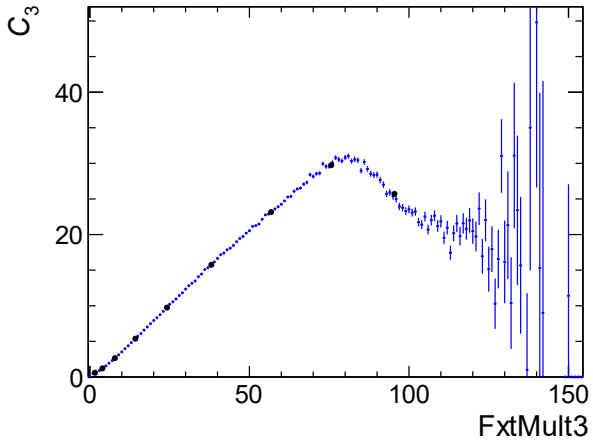
Efficiency-uncorrected cumulants

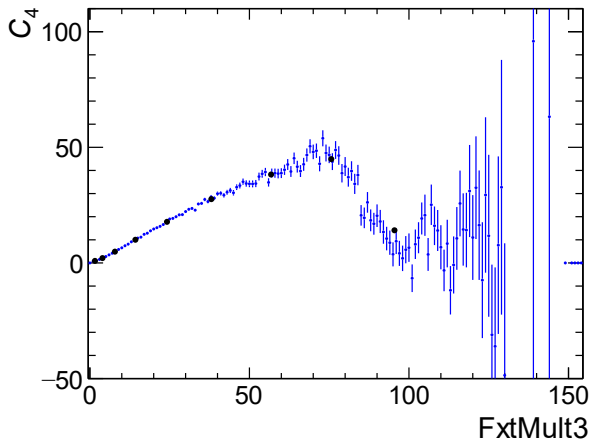


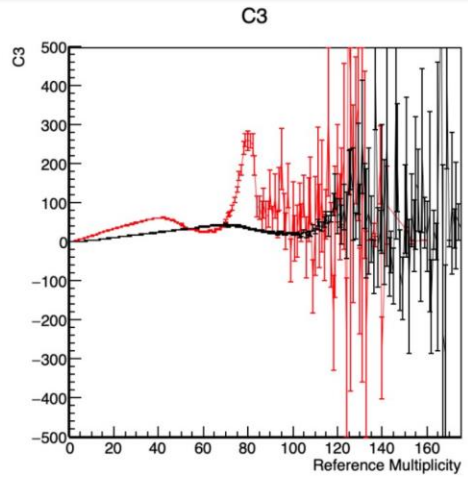


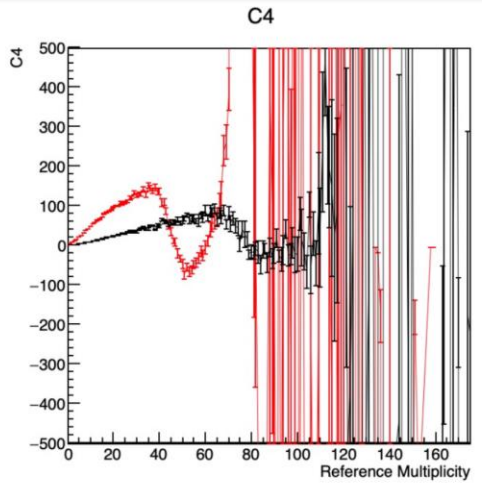
3.2 GeV before corrections
3.0 GeV before corrections

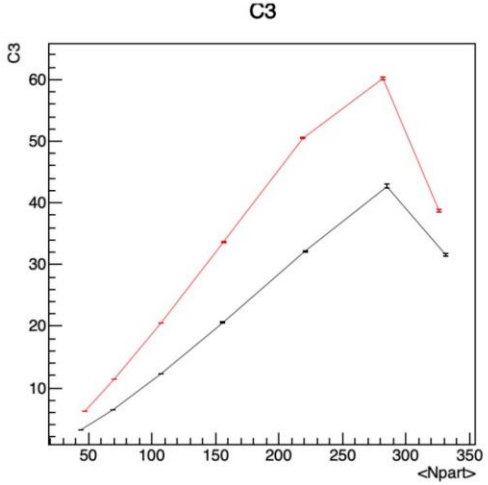
Efficiency-uncorrected cumulants

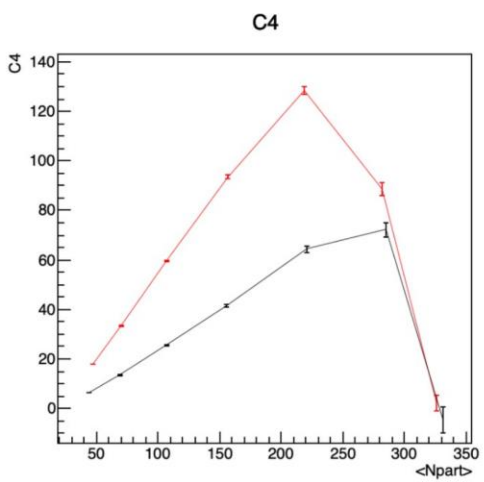






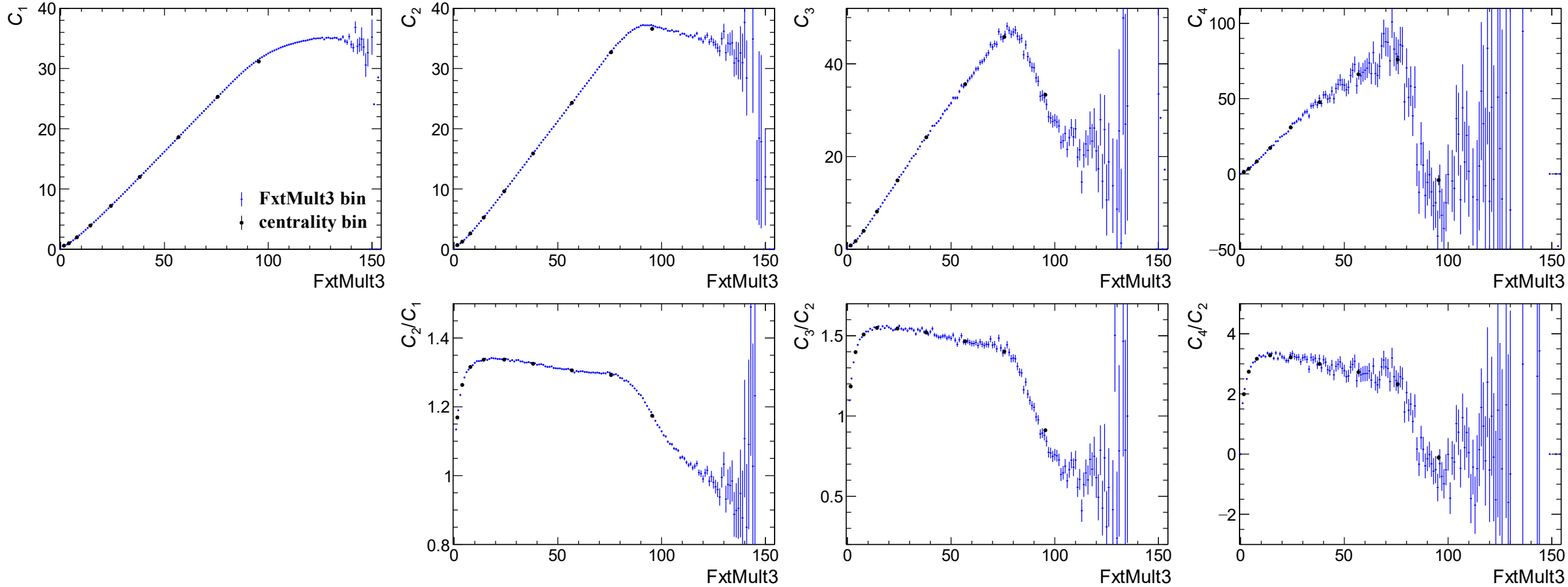






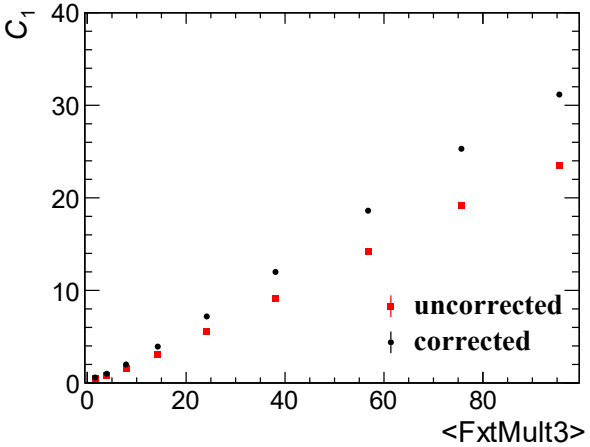
3.2 GeV before corrections
3.0 GeV before corrections

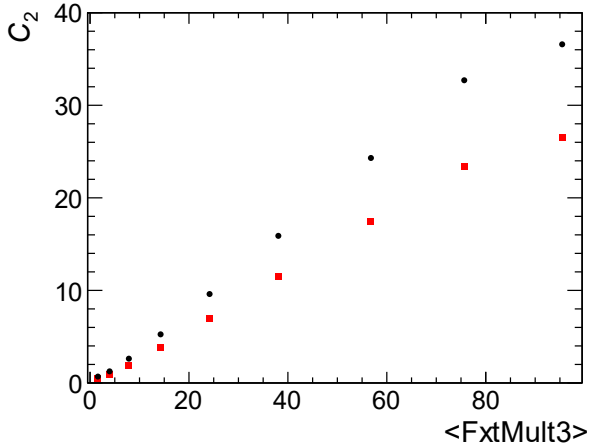
Efficiency-corrected cumulants

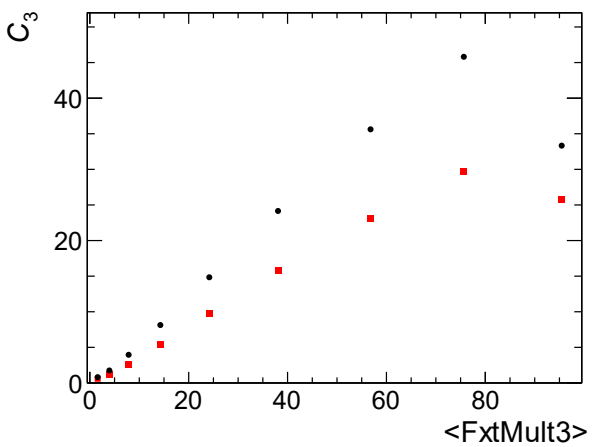


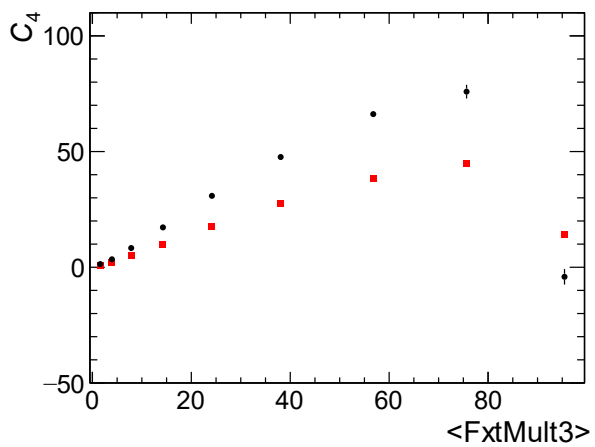
- Corrected with TPC tracking efficiency (@ 3.0 GeV), TPC PID efficiency and TOF efficiency

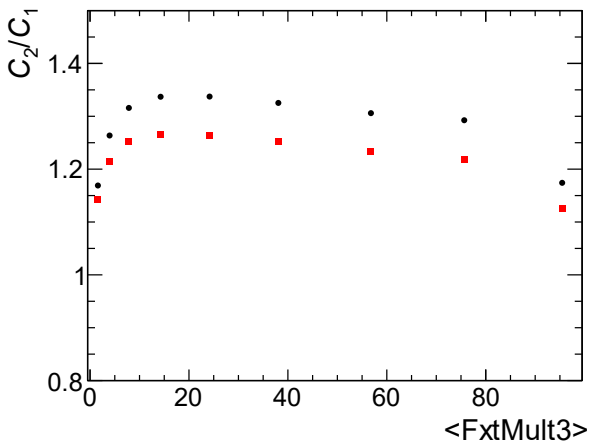
Comparison between (un)corrected results

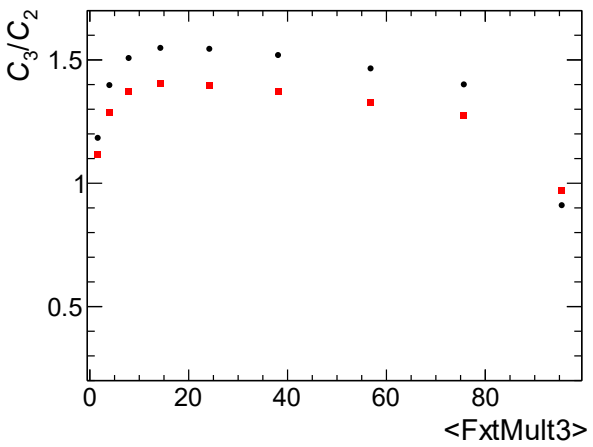


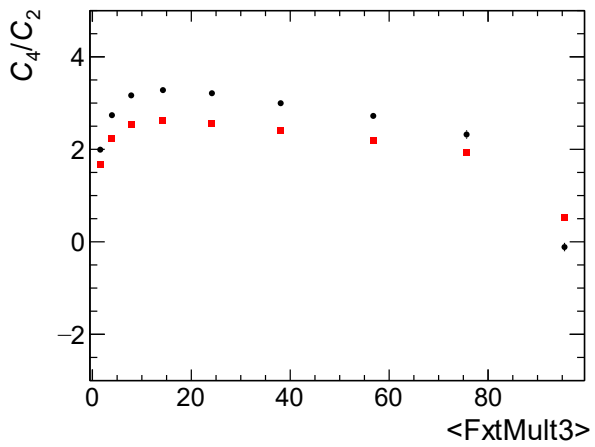




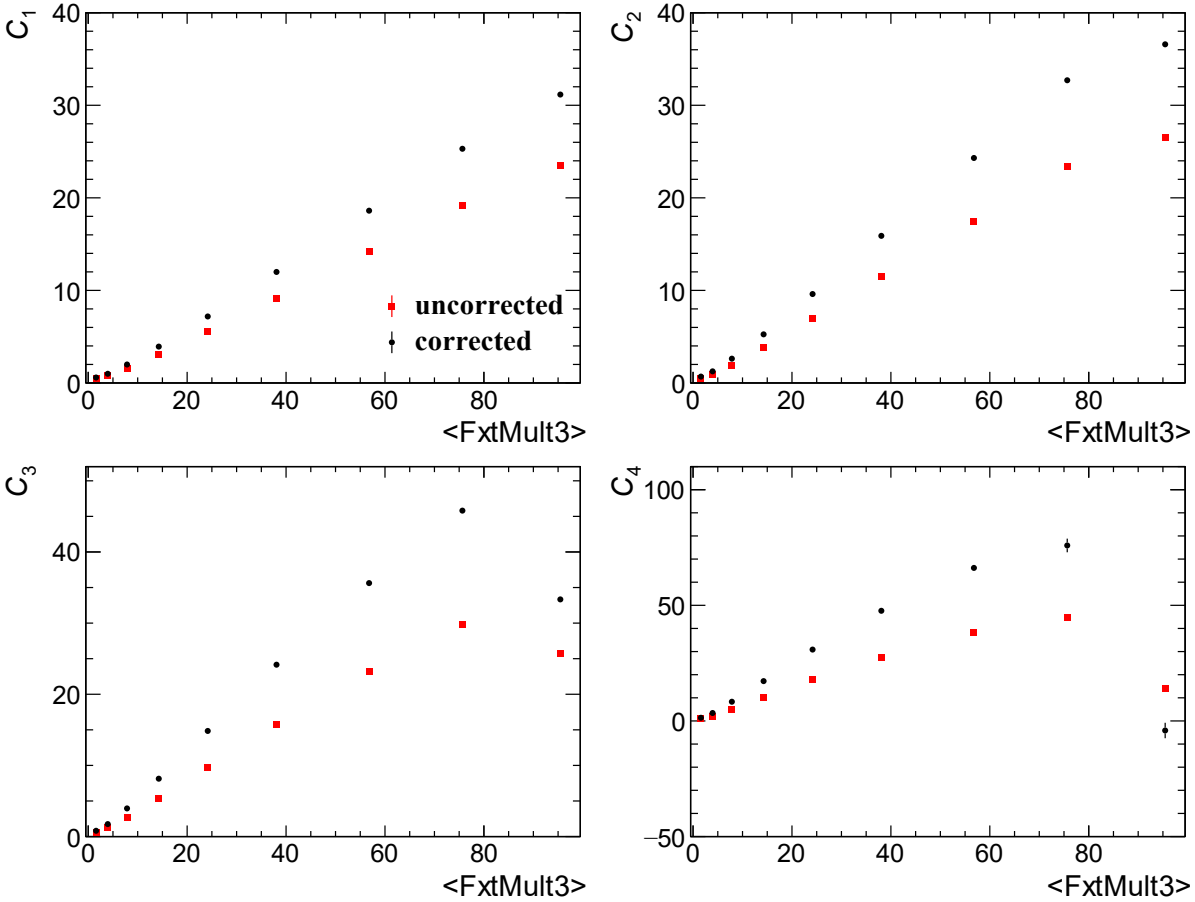


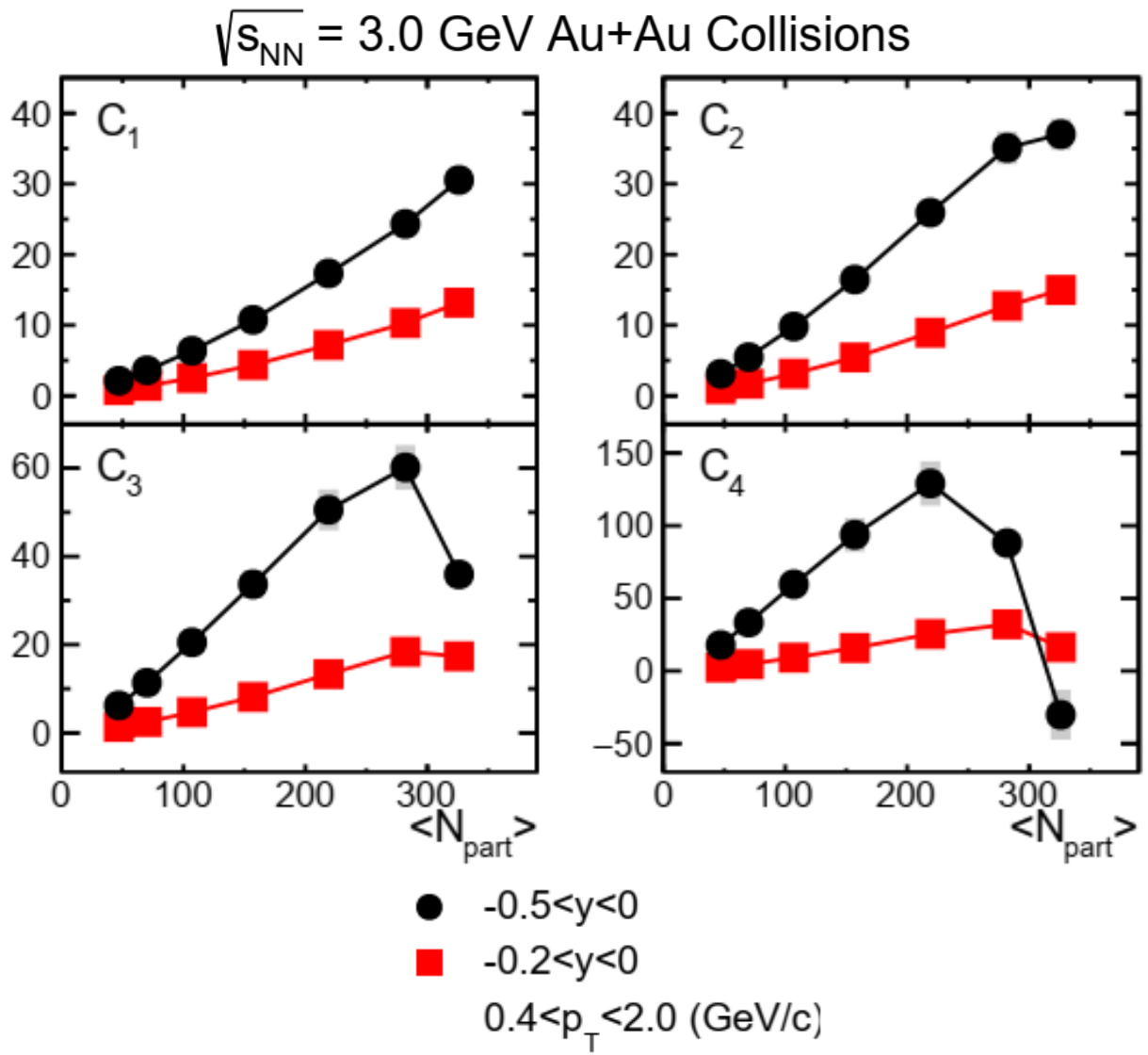




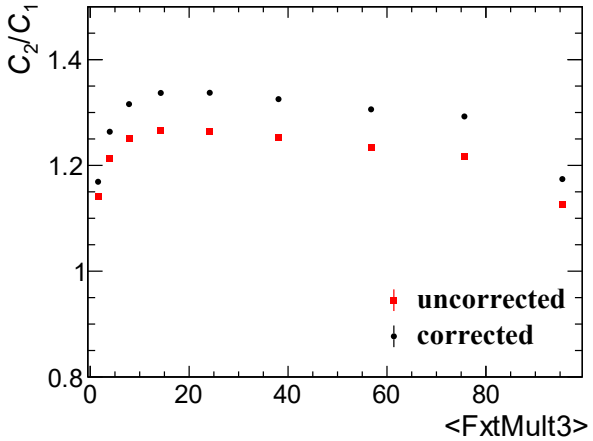


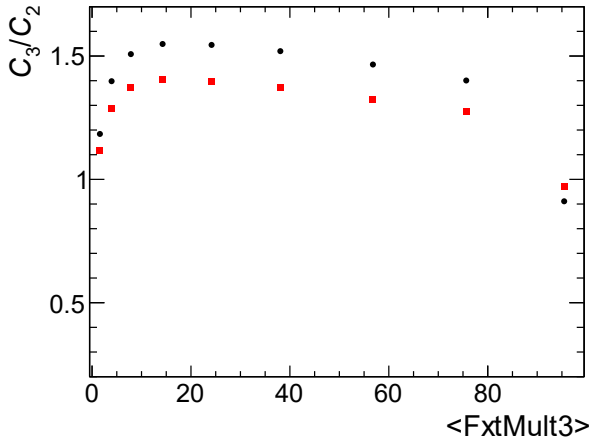
Comparison with 3.0 GeV results

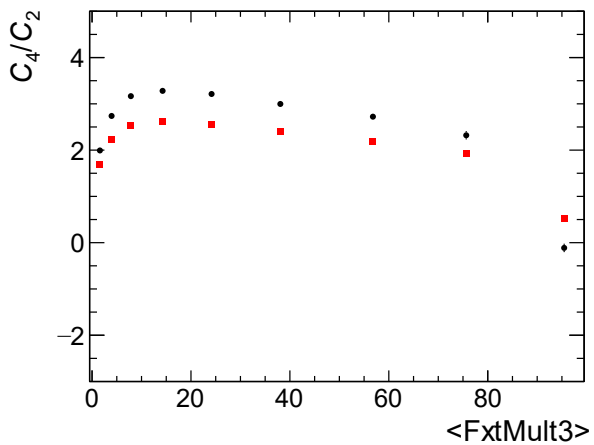


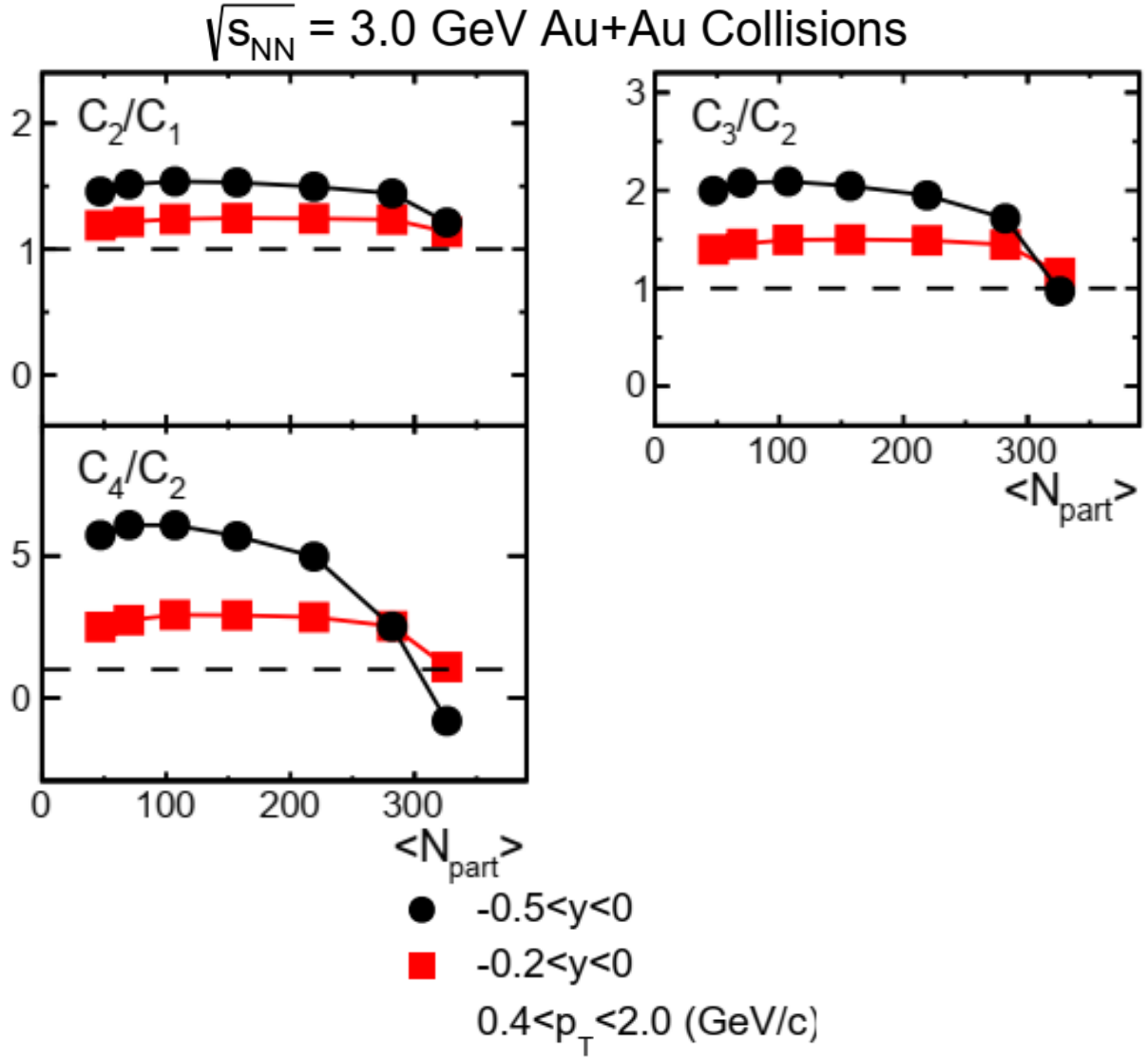


Comparison with 3.0 GeV results







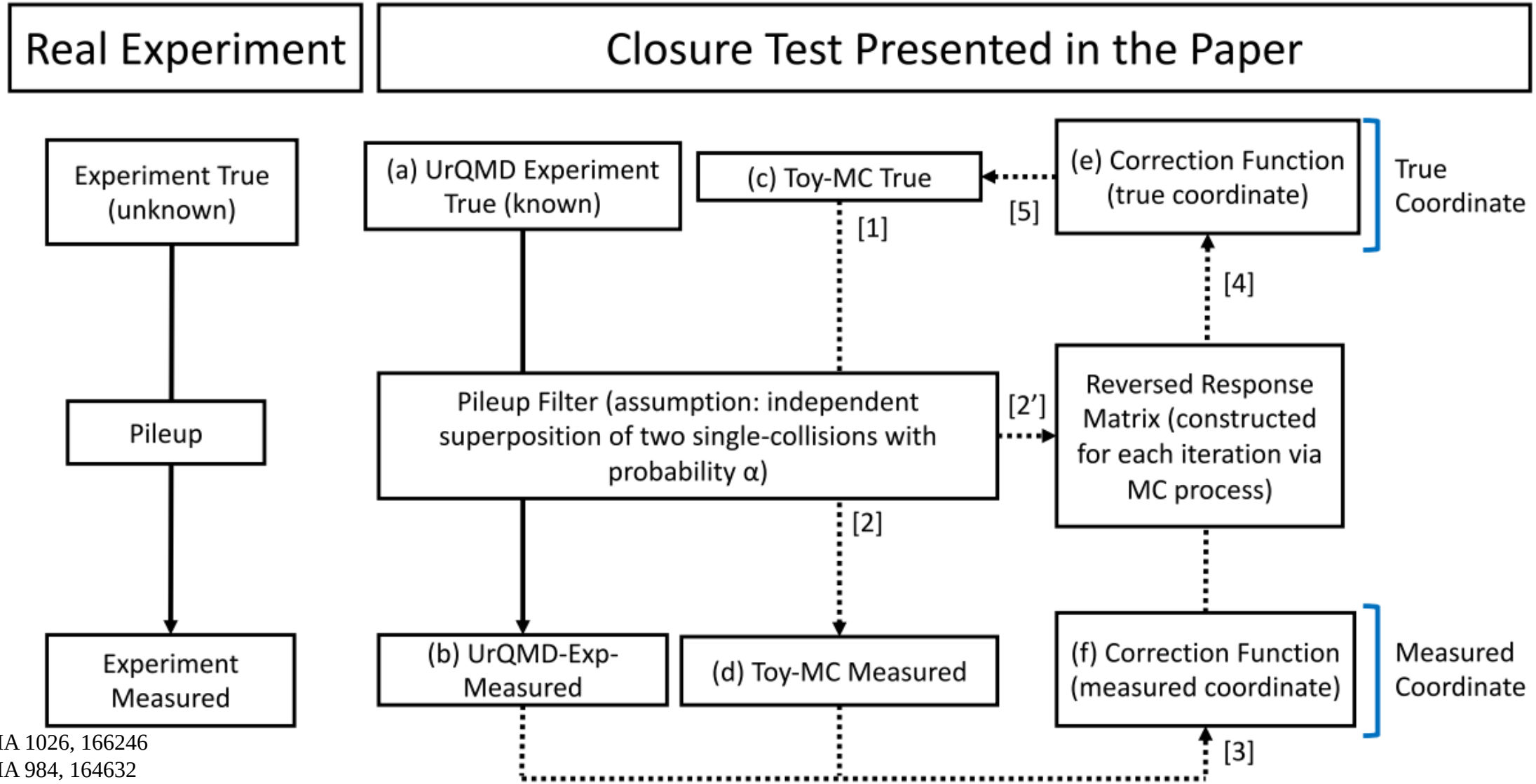


Summary and outlook

- Summary
  - Bad run and pile-up event rejection
  - TPC & bTOF PID checks and $<n\sigma_p>$ shift as a function of p
  - Centrality definition with FxtMult3 (w/ constant $<n\sigma_p>$ shift)
  - TPC PID efficiency and bTOF efficiency
  - Efficiency-uncorrected and -corrected cumulants

- Outlook
  - TPC tracking efficiency from embedding
  - Acceptance dependence of cumulants
  - Other FXT energies (7p3, 31)

Pileup unfolding (iteration)



NIMA 1026, 166246
NIMA 984, 164632

Pileup study

- Probability to find a pileup event among all collision events: α
- Single-collision event at multiplicity m: $T(m) \rightarrow (1-\alpha)T(m)$
  - Initial distribution from Glauber model
- Pileup event at multiplicity m: $\alpha \sum_{i=0}^{m} T(i)T(m-i)$

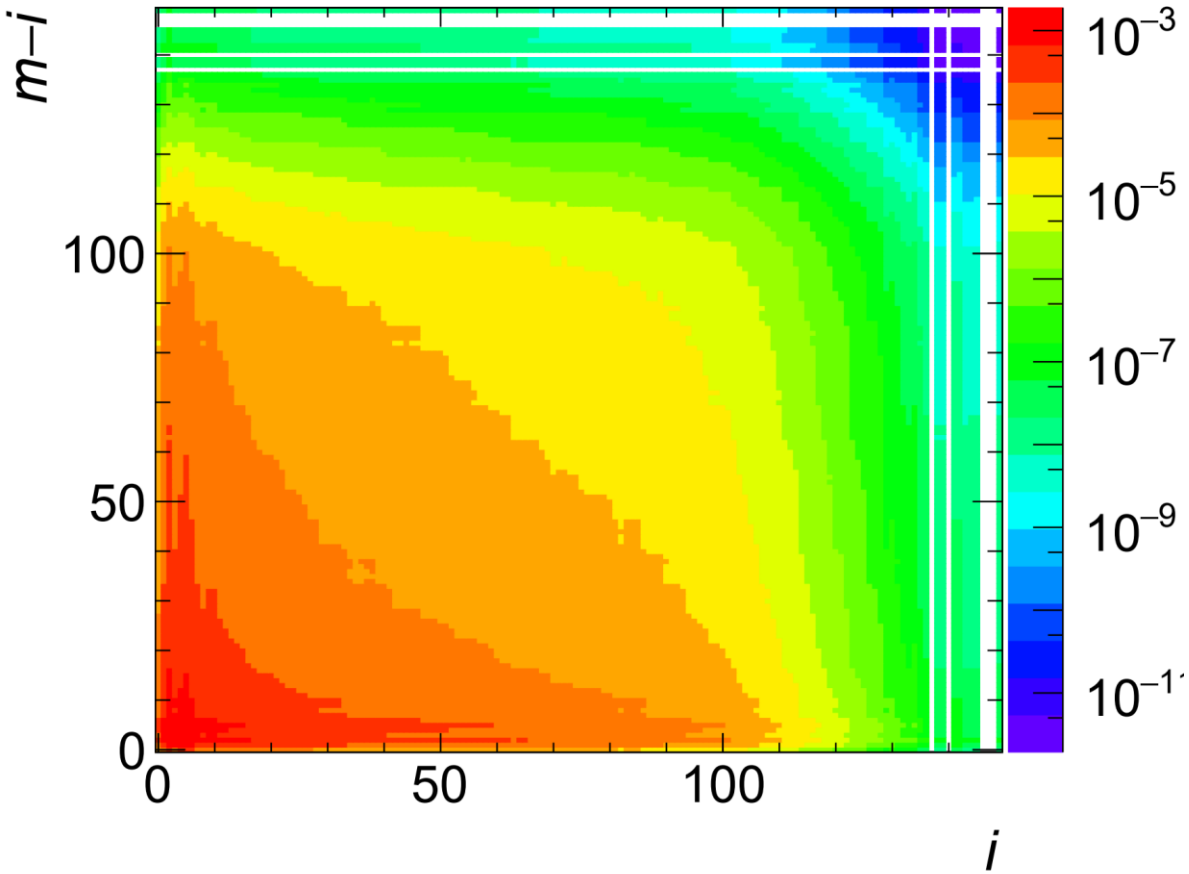
- Reversed response matrices R: normalized distribution of i at each m in pileup events

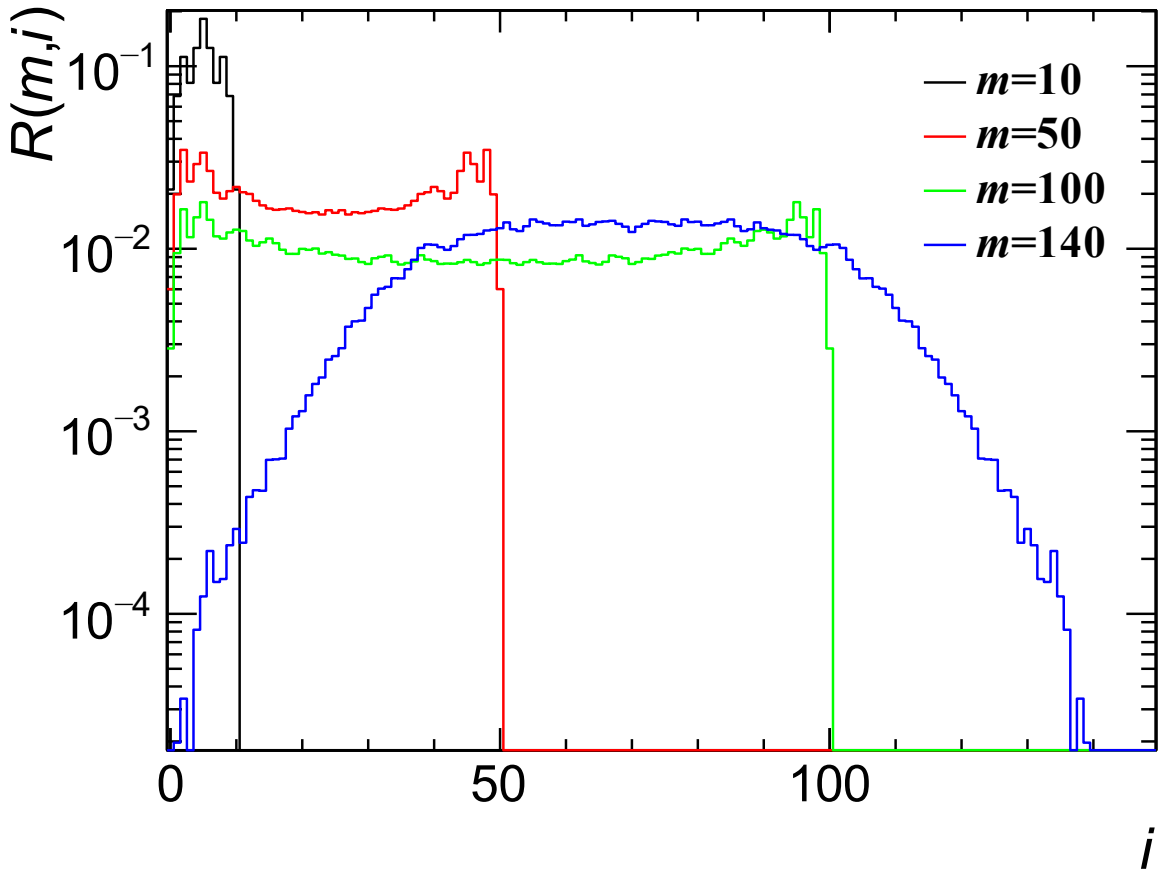
- Correction function in the measured coordinates: difference between the experimentally measured distribution and the folded distribution
- Correction function in the true coordinates: the reversed response matrices R multiplying the correction function in the measured coordinates

- $T(m)$ is added by the correction function in the true coordinates for next iteration

Pileup study

- Correlation $T(i)T(m-i)$ between i and $m-i$ in each pileup event
- Reversed response matrices $R(m, i)$
  - Normalized $T(i)T(m-i)$ at each m





Unfolding results

- 60 iterations
- α = 0.22% (0.45% @ 3.0 GeV, max FxtMult3 of single events = 80)