Quality Assurance and Centrality determination in Xe+Cs(I) based on multiplicity

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Outline

1. QA Run-by-Run
2. Comparison of old and new production
3. Centrality determination
4. Multiplicity correction

QA Run-by-Run: runs rejection

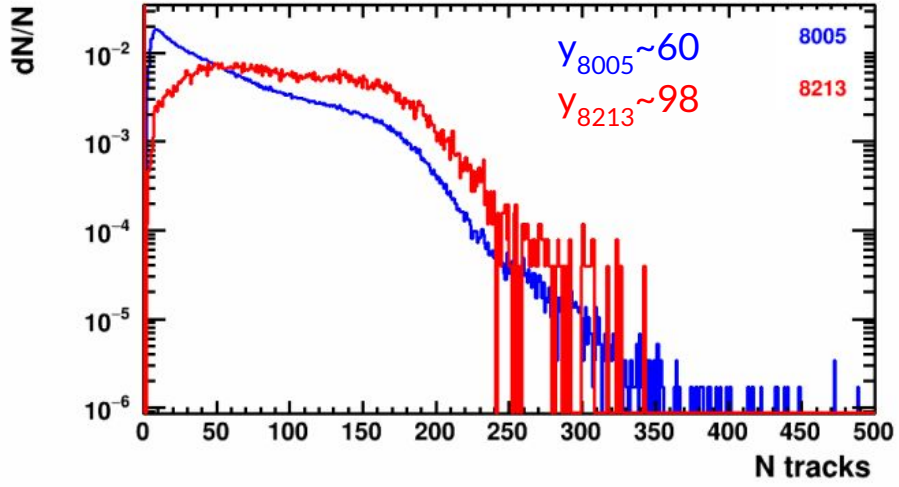
- Physical runs
- CCT2
- More than 1 track in vertex reconstruction

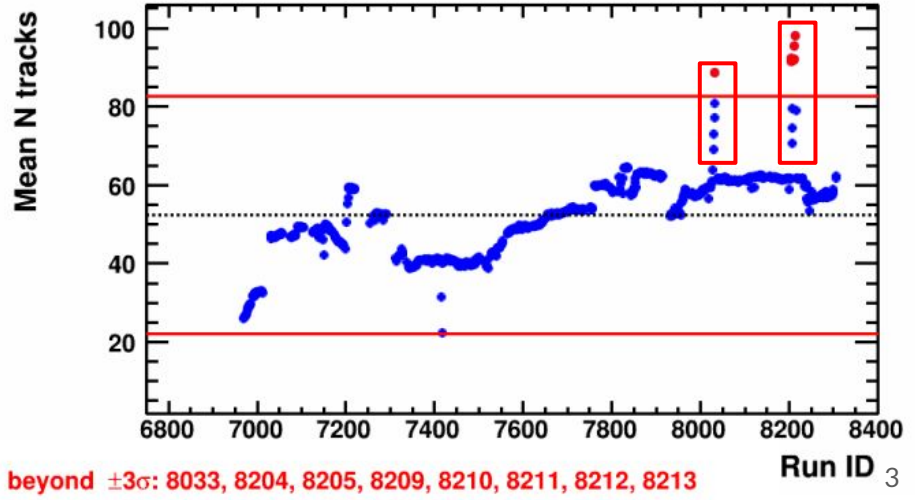
Procedure:

- Averaged (or fit parameters) observables are calculated for each run
- the mean (μ) and standard deviation (σ) are calculated as a function of RunId

$$\mu = \frac{1}{N}\sum_{i=1}^{N} y_i \qquad \sigma = \sqrt{\frac{\sum (y_i - \mu)^2}{N}}$$, where i - RunId number and N - total numbers of runs

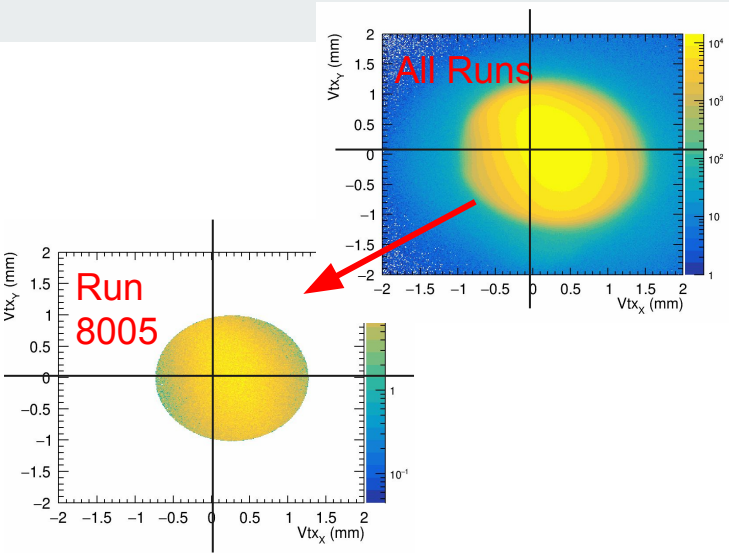
- beyond $\pm 3\sigma$ away from global means - bad runs

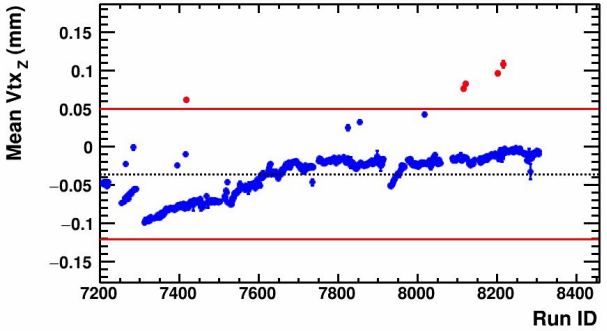


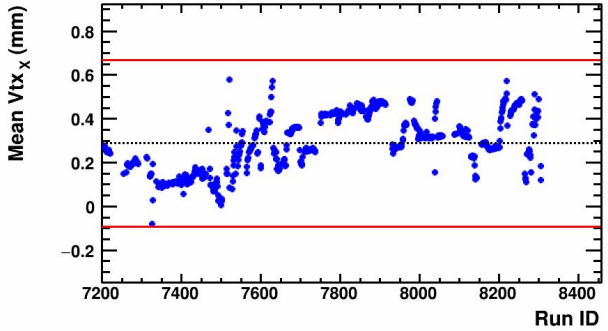


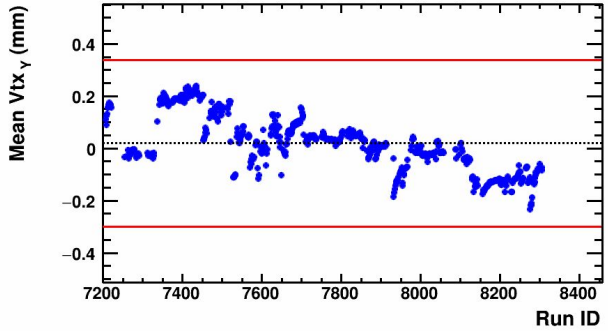
Event selection

- Xe+Cs 3.8 GeV
- Production= last
- Physical runs
- Triggers: CCT2
- Remove BadRuns
- Corrected on <VtxX>, <VtxX>, <VtxZ> for each RunId
- Event selection:
  - More than 1 track in vertex reconstruction
  - VtxR < 1.0 cm (sqrt($VtxY_{corr}^2$ + $VtxX_{corr}^2$) < 1 cm)
  - VtxZ < 0.1 cm
  - Apply graphics cuts
  - Remove pileup (from Oleg Golosov)

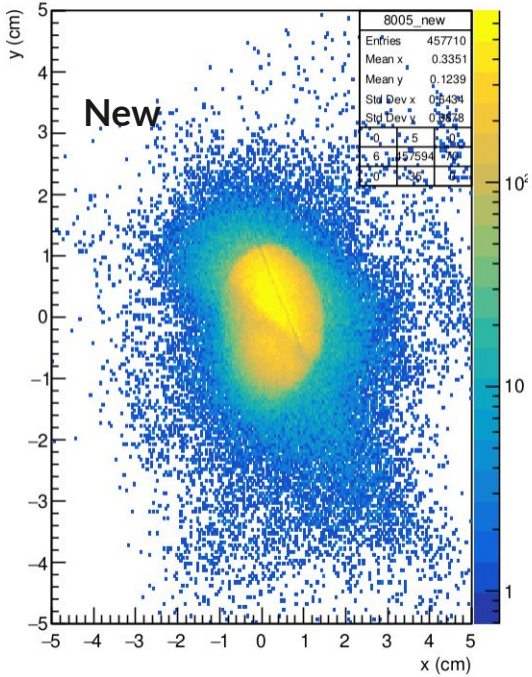


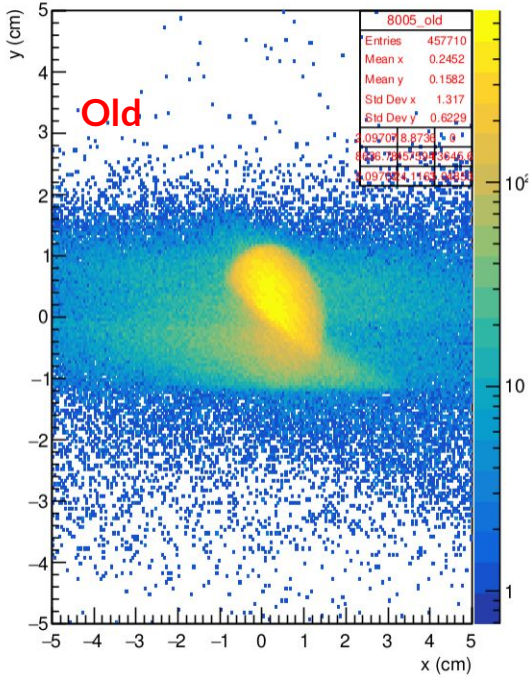


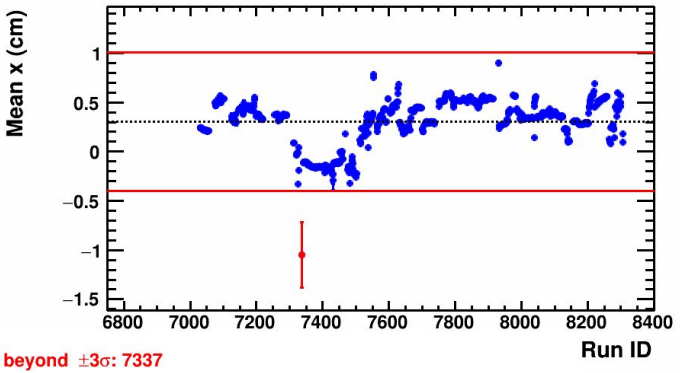




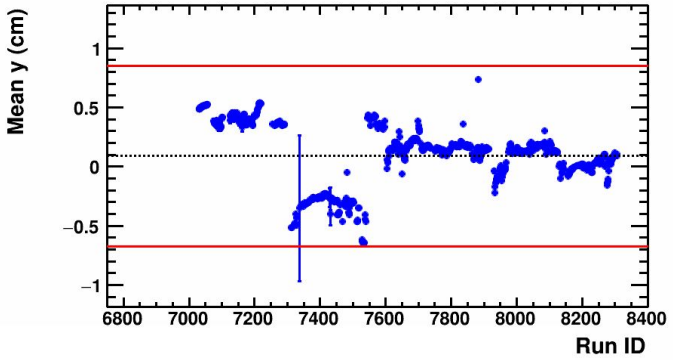
Difference between prod: beam tracker



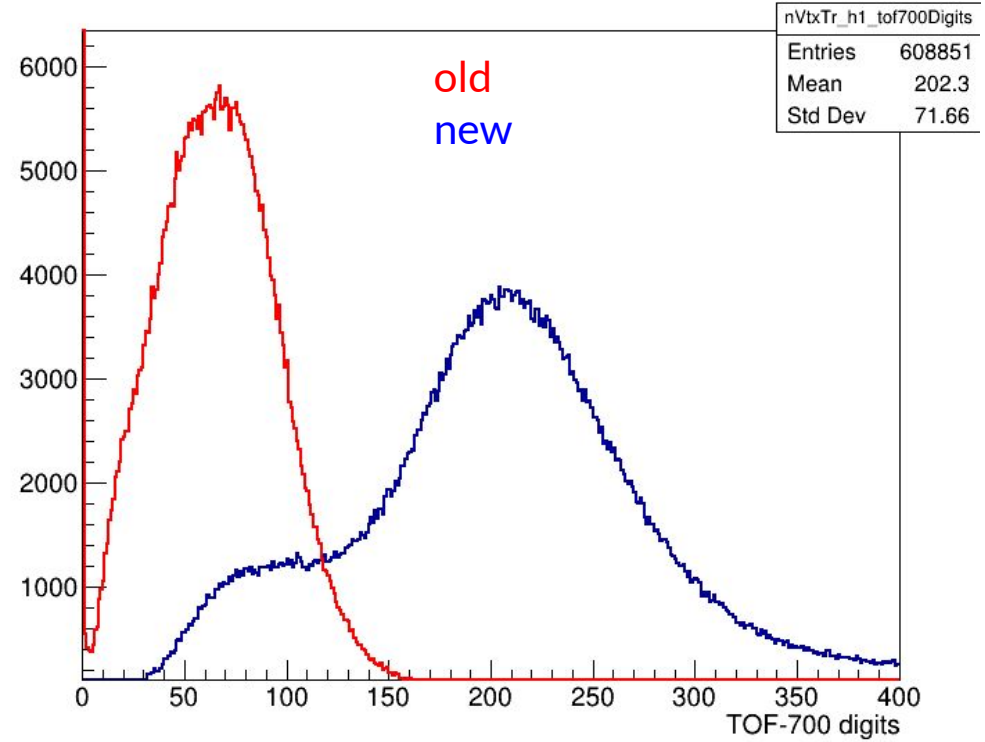


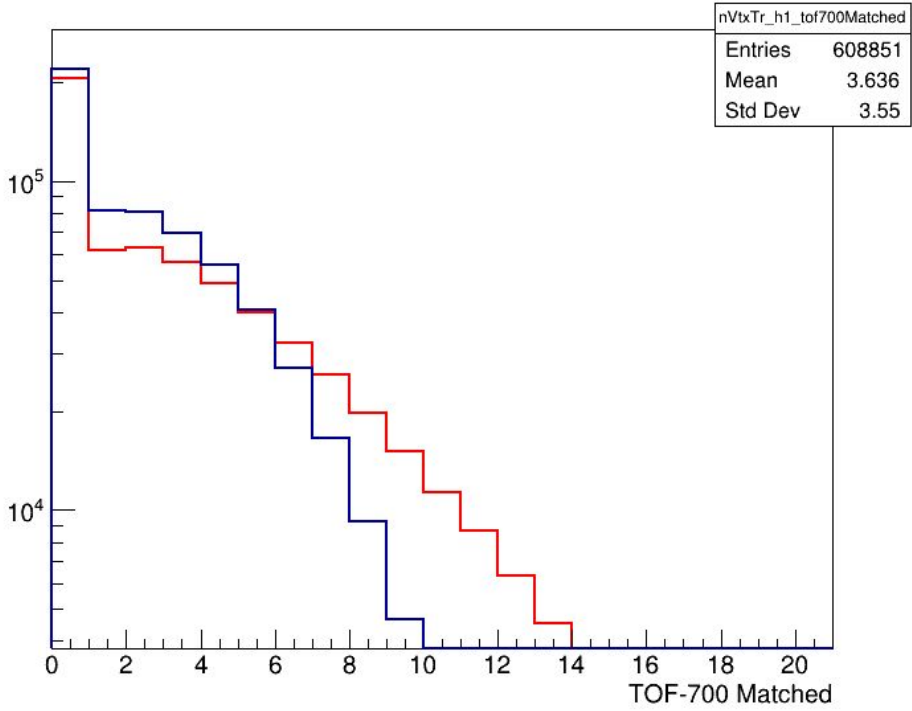


beyond ±3σ: 7337

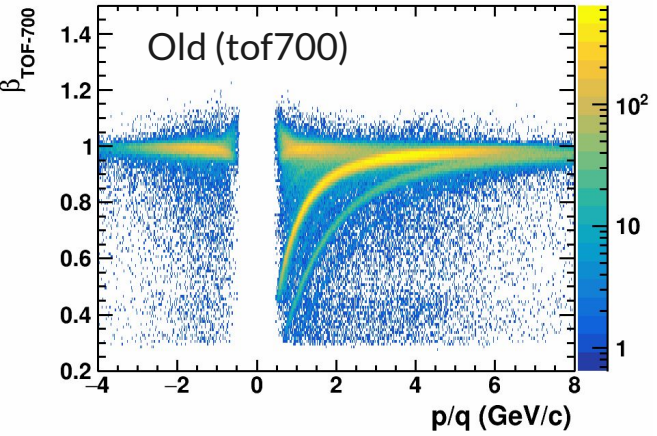


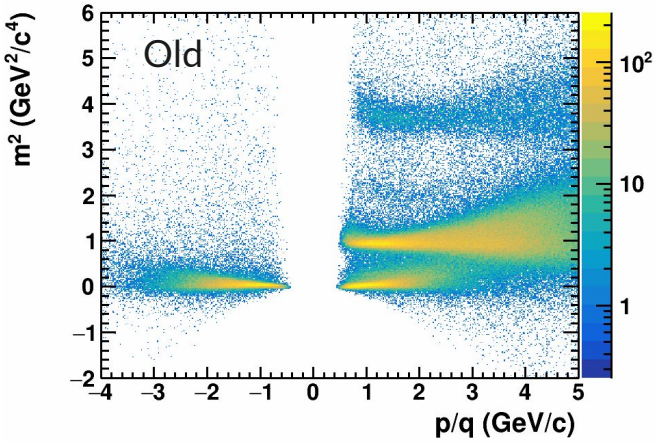
Difference between prod: TOF-700 (run 8005)

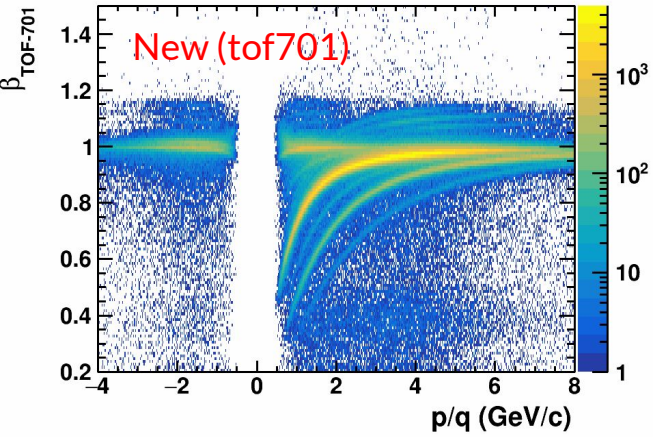


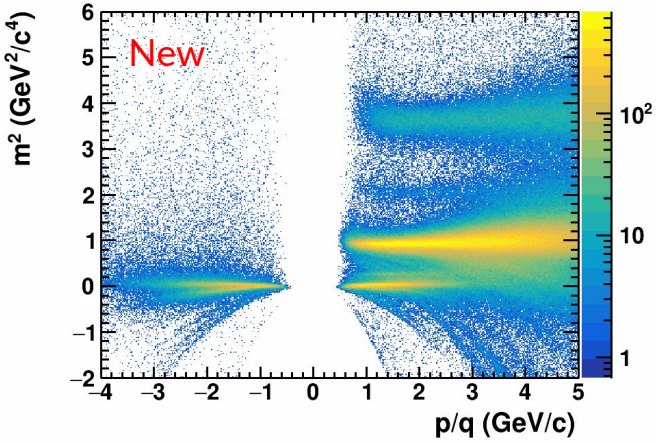


Difference between prod: TOF-700 (run 8005)









tof-700:
β -> BmnGlobalTrack.fBeta700

tof-701:
β -> BmnGlobalTrack.fBeta701

Exclude module 30:

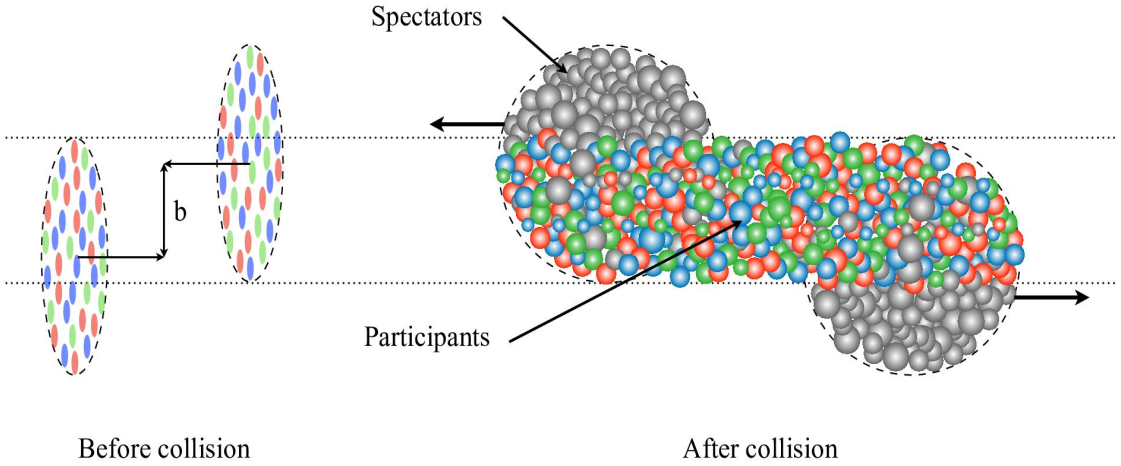
- BmnGlobalTrack.fBeta701 + BmnTof701Hit
- mod = ((hit->GetDetectorID() & 0x0000FF00) >> 8) - 1

Motivation for centrality determination

- Evolution of matter produced in heavy-ion collisions depends on its initial geometry
- Impact parameters (**b**) - one of the important collision parameters
  - impossible to measure experimentally
- **Goal of centrality determination:** map (on average) the collision geometry parameters to experimental observables (centrality estimators)

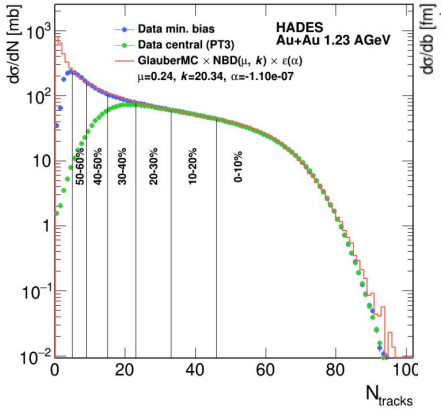
Centrality class S_1-S_2:
group of events corresponding to a given fraction (in %) of the total cross section:

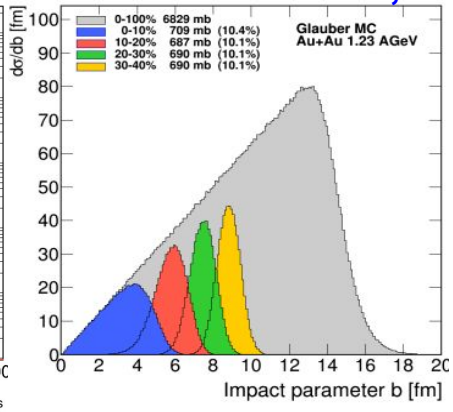
$$C_S = \frac{1}{\sigma_{inel}^{AA}} \int_{S_1}^{S_2} \frac{d\sigma}{dS} dS$$

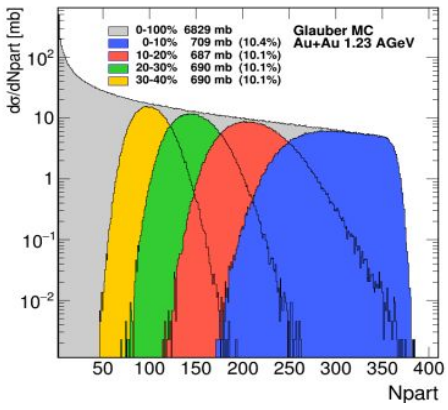


Centrality determination

HADES, Au+Au 1.23A GeV







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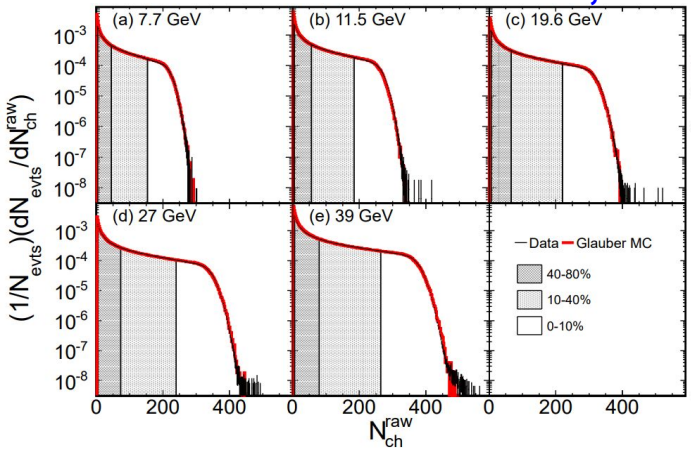
Centrality Classes	b_{min}	b_{max}	$\langle b \rangle$
0 – 5 %	0.00	3.30	2.20
5 – 10 %	3.30	4.70	4.04
10 – 15 %	4.70	5.70	5.22
15 – 20 %	5.70	6.60	6.16
20 – 25 %	6.60	7.40	7.01
25 – 30 %	7.40	8.10	7.75
30 – 35 %	8.10	8.70	8.40
35 – 40 %	8.70	9.30	9.00
40 – 45 %	9.30	9.90	9.60
45 – 50 %	9.90	10.40	10.15
50 – 55 %	10.40	10.90	10.65
55 – 60 %	10.90	11.40	11.15

STAR, Au+Au, BES



Phys. Rev. C 86, 054908 (2012)

Centrality (%)	$\langle N_{part} \rangle$	$\langle N_{coll} \rangle$
0-5%	337 ± 2	774 ± 28
5-10%	290 ± 6	629 ± 20
10-20%	226 ± 8	450 ± 22
20-30%	160 ± 10	283 ± 24
30-40%	110 ± 11	171 ± 23
40-50%	72 ± 10	96 ± 19
50-60%	45 ± 9	52 ± 13
60-70%	26 ± 7	25 ± 9
70-80%	14 ± 4	12 ± 5

Centrality determination based on multiplicity provides with:

- impact parameter (b)
- number of participating nucleons (N_{part})

Similar centrality estimator is needed for comparisons with STAR, HADES, etc.

The BM@N experiment

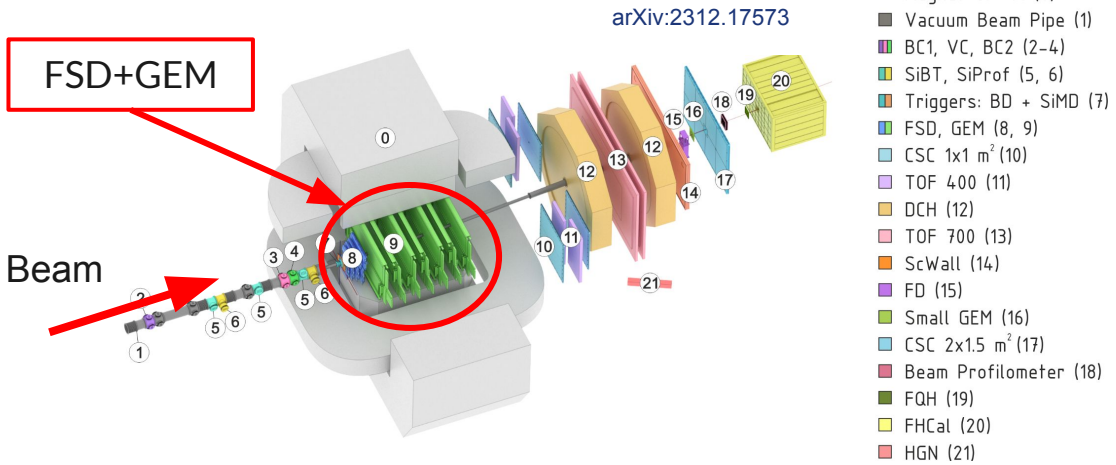
SImulation:

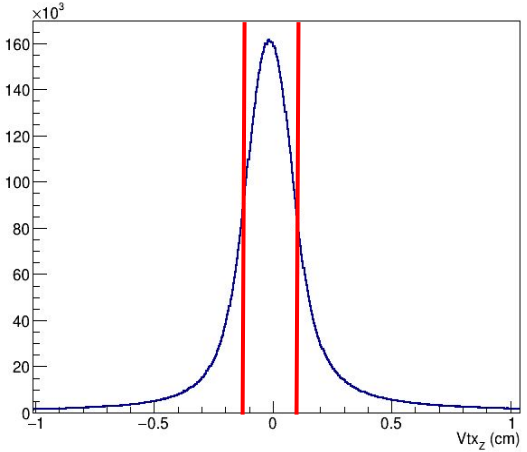
- DCM-QGSM-SMM, Xe-Cs
- GEANT4 transport

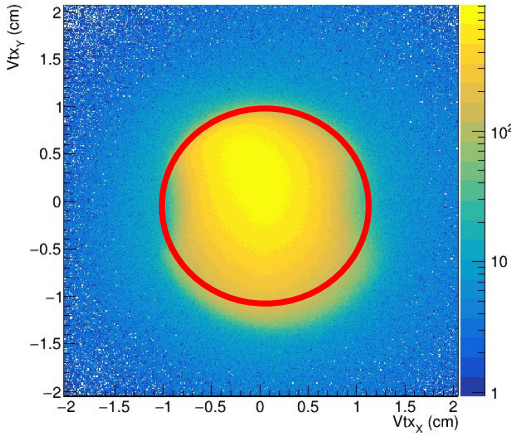
Data:

- run8 Xe-CsI @3.8*A* GeV
- Event selection :
  - Physical runs
  - Centrality trigger (CCT2)
  - More than 1 track in vertex reconstruction
  - Vtx_R < 1.0 cm
  - Vtx_Z < 0.1 cm

Multiplicity of charged particles from tracking system FSD+GEM







Centrality determination based on Monte-Carlo sampling of produced particles

For **multiplicity of produced particles** used in HADES, CBM, NA61/SHINE

Get (b, N_{part}, N_{coll}) from MC-Glauber

Evaluate number of ancestors (sources of produced particles)
$N_a = \mathbf{f}N_{part} + (1-\mathbf{f})N_{coll}$

Sample multiplicity of produced particles (S_i) N_a times from NBD(μ, **k**)

Multiplicities from two collision events are randomly superimposed with the probability **p** (“pileup” events)

Result: total S_{tot}

MC-Glauber distribution

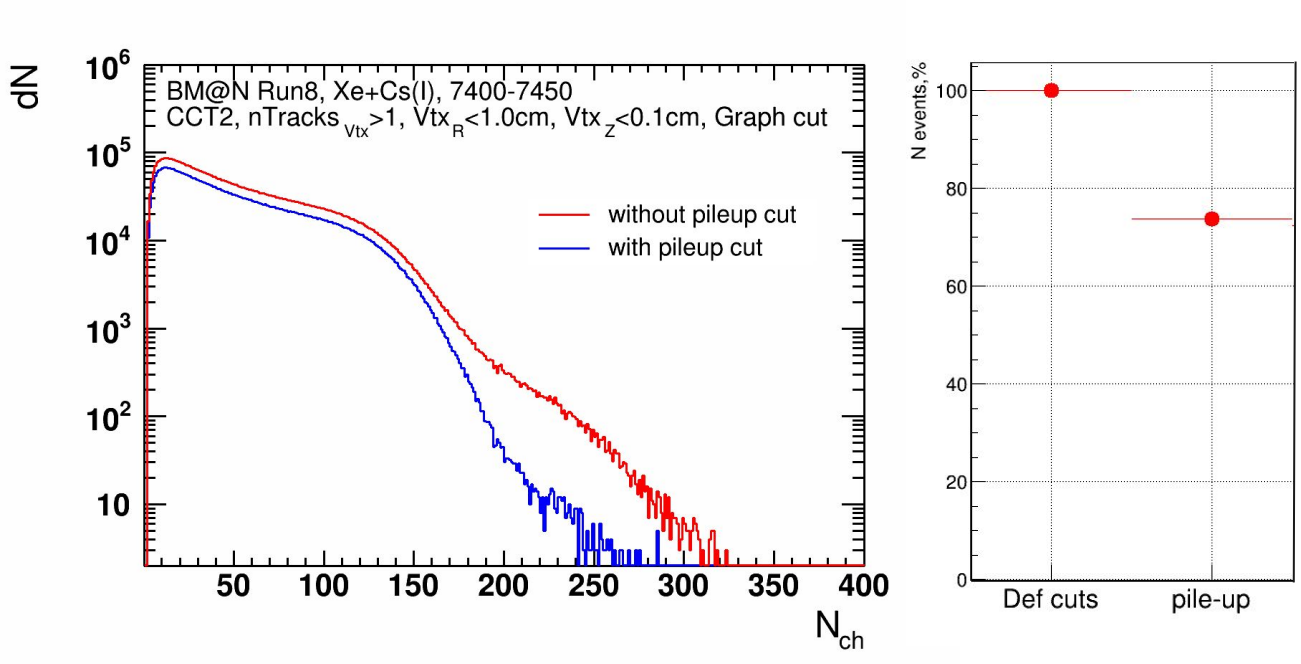
Full Monte-Carlo (real data) distribution

Evaluate χ^2 between $N/dN_{MC/data}$ and N/dN_{Gl}

Scan phase space of parameters to find their values for minimum of χ^2

Extract relation between geometry parameters and centrality estimator

Centrality determination: pileup rejection



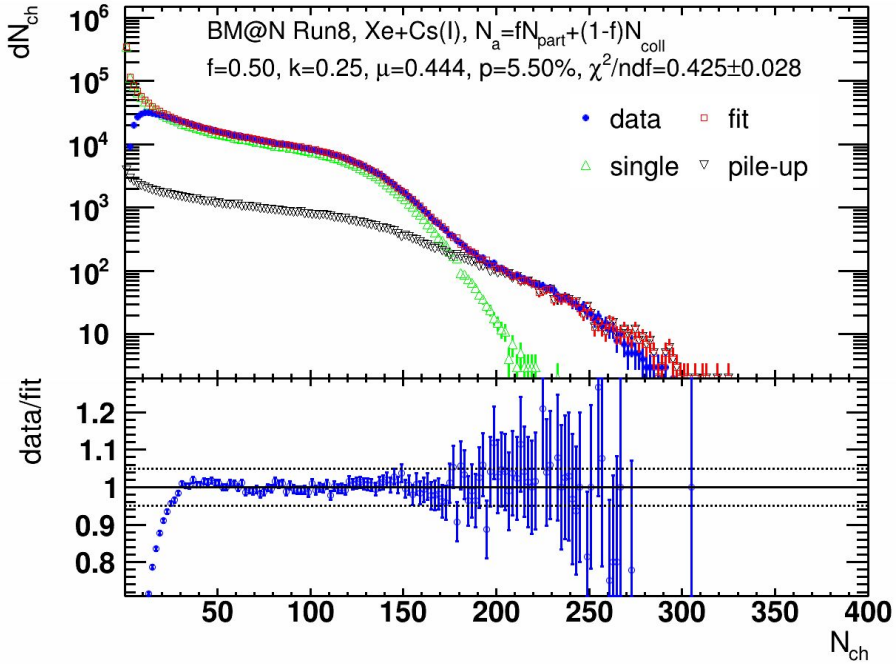
*Def cuts:

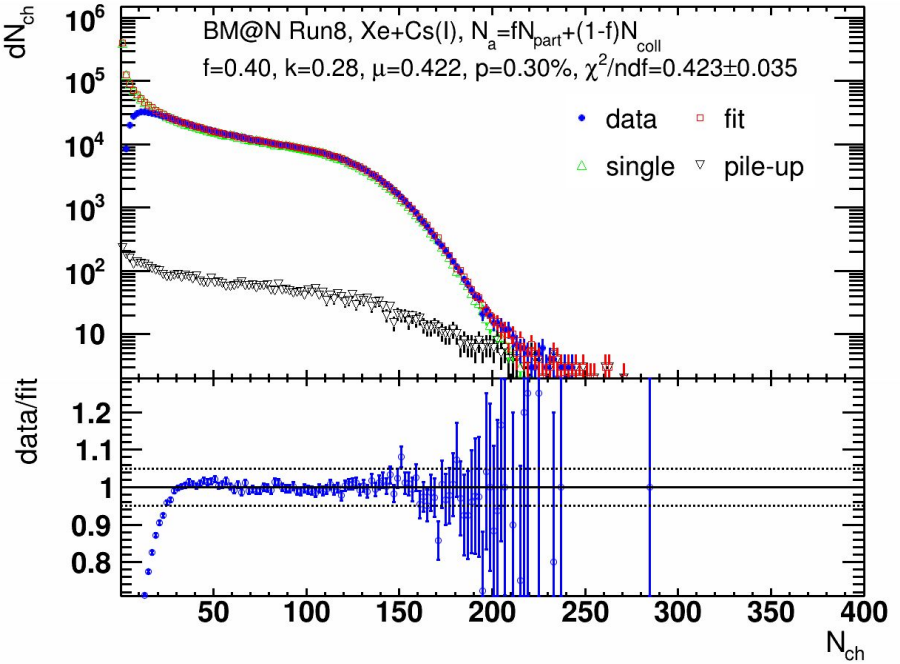
- Rhys runs
- CCT2
- vtxNtracks > 1
- V_R <1 cm
- $|V_Z|$ < 0.1 cm
- Remove BabRuns

*Pileup cuts from Oleg Golosov

- The “pileup” cut was applied with run-by-run corrections
- pileup cuts removes ~25% events
- We use the new multiplicity in our centrality procedure

Centrality determination after remove “pileup”



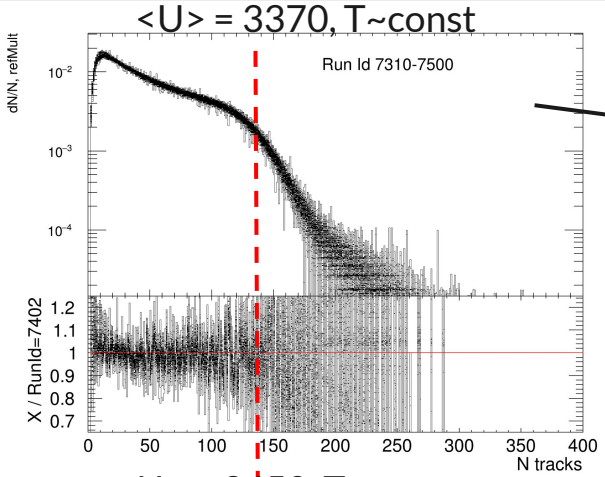


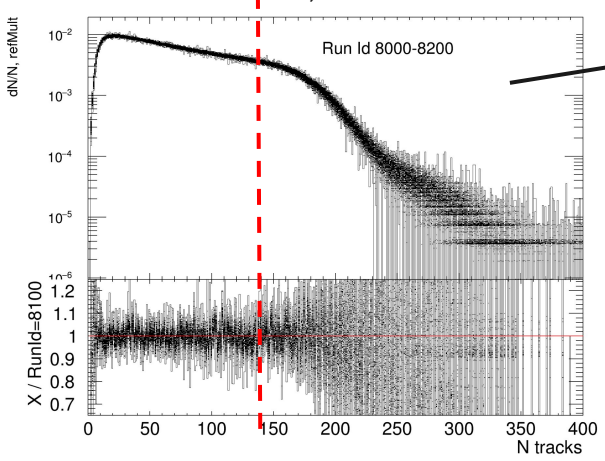
Change fit result

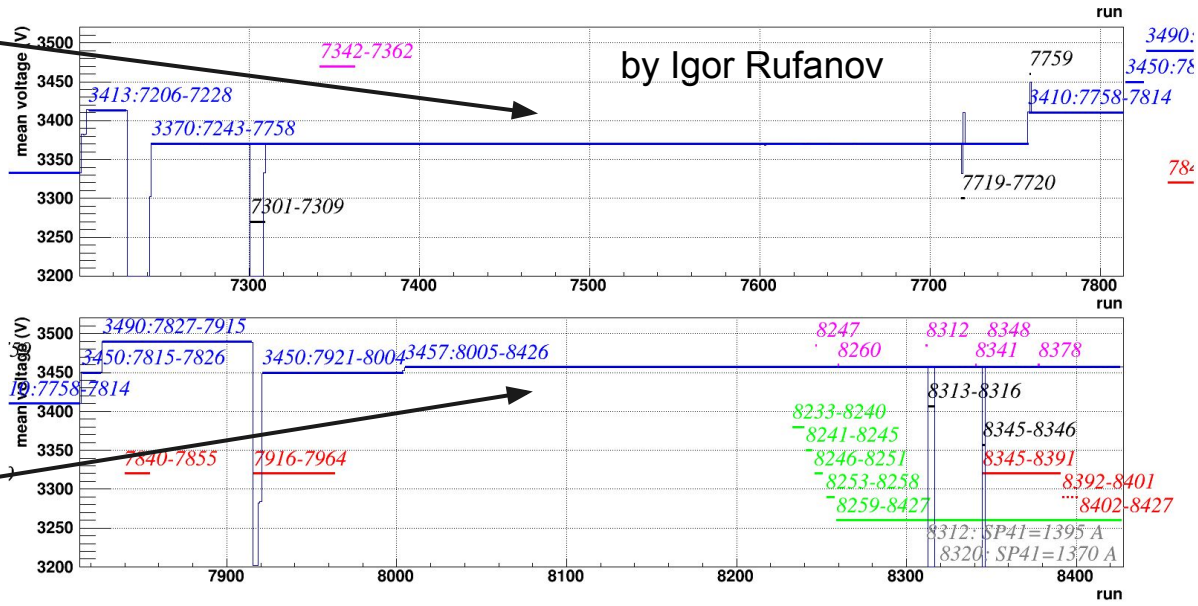
- f: 0.5 -> 0.4
- k: 0.25 -> 0.28
- μ: 0.44 -> 0.42
- pileup: 5.5% -> 0.3%

After pileup rejection the “pileup” events contribution is less 1%

Multiplicity & RunID: Effect of voltage

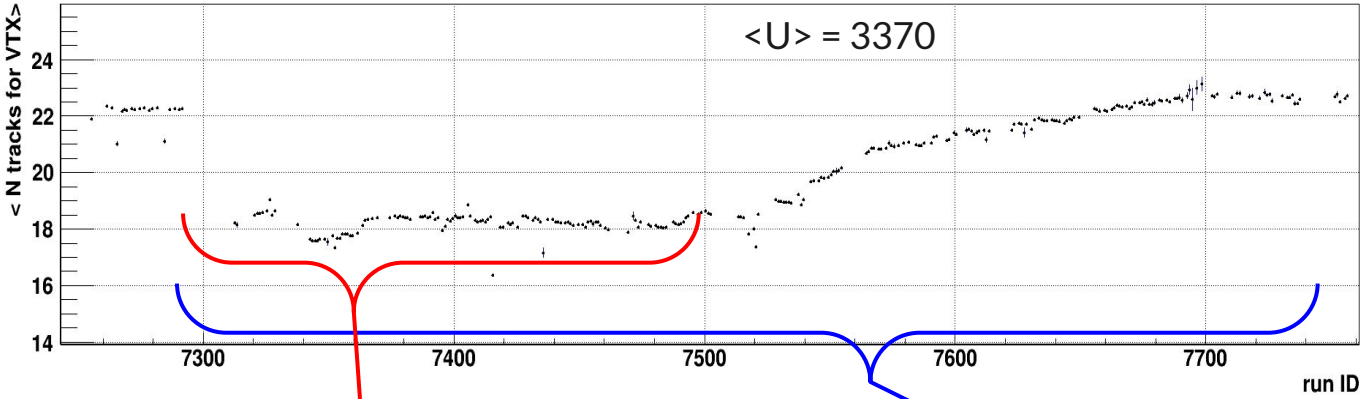


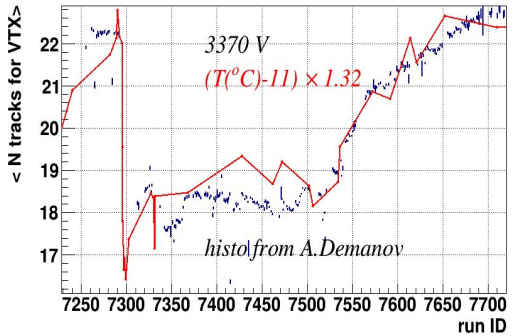


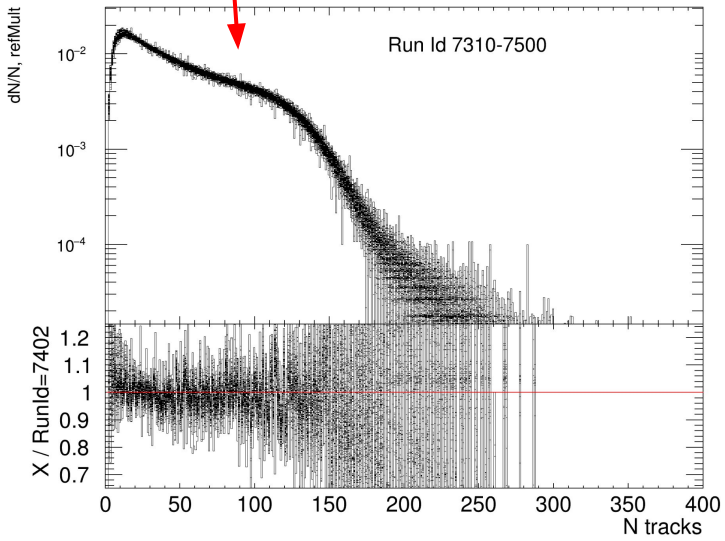


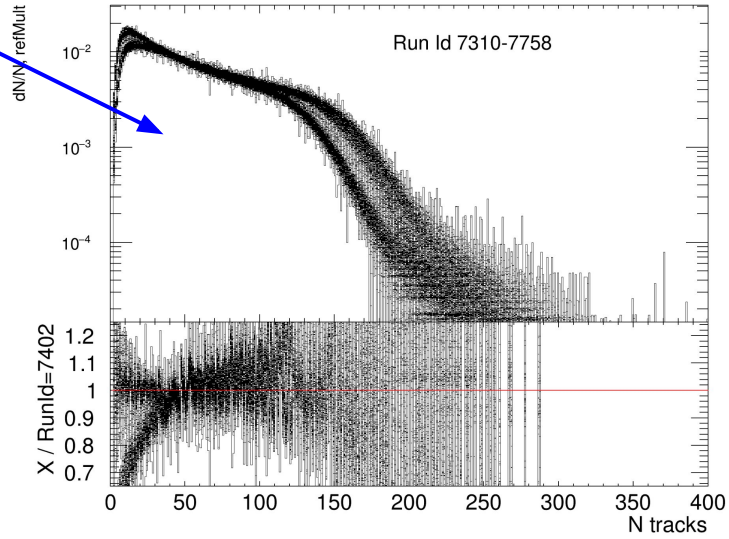
Strong dependence of multiplicity on voltage.
Run-by-run corrections are required!

Multiplicity & RunID: **Effect of temperature**









Mult vs RunId: Shift and re-weight (zero bins eval)

$RunId_{ref}$: 8120-8170

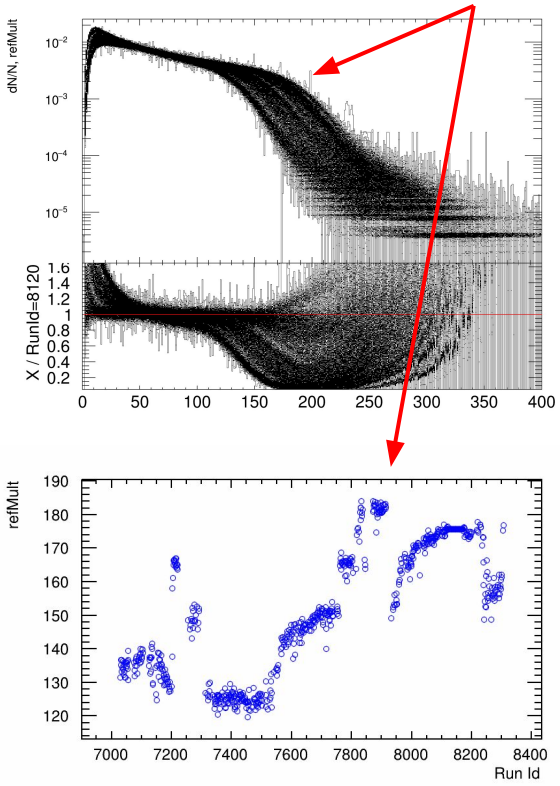
Extract the high-end point of refMult distribution in each RunId via fitting the refMult tail by the function:

f(refMult) = A*Erf(-σ*(refMult-h)) + A

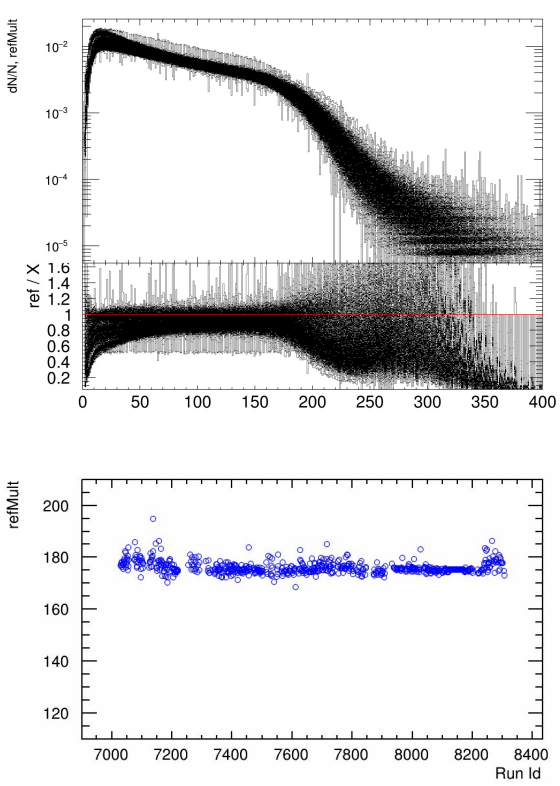
refMult can then be corrected by:

refMultCorr = refMult * h_{ref} / h(RunId)

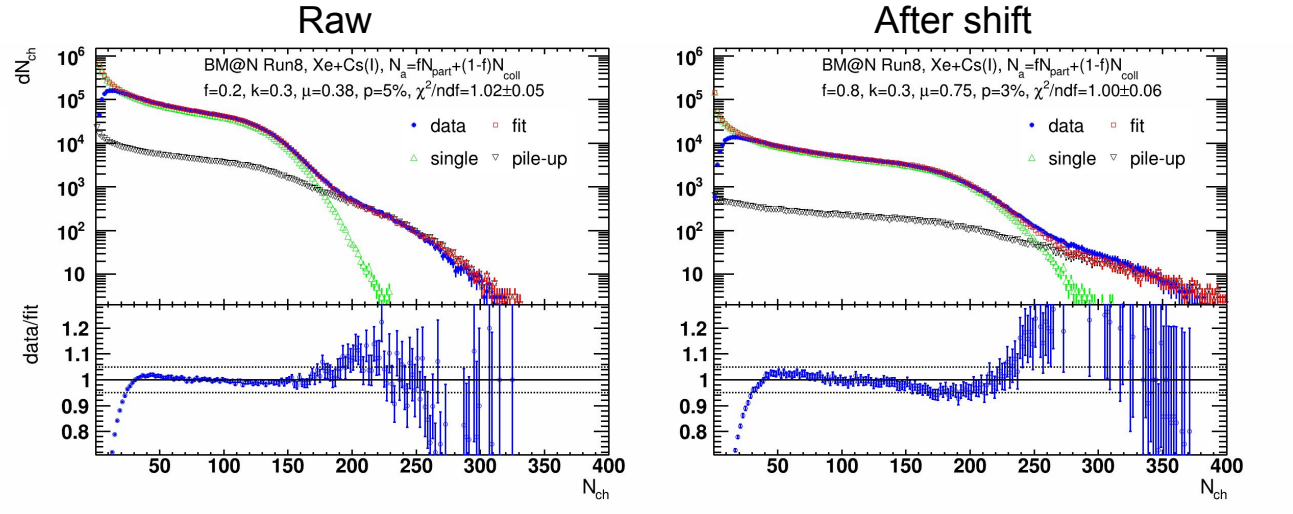
Def



After shift



Centrality determination after refMult correction (7310-7500)



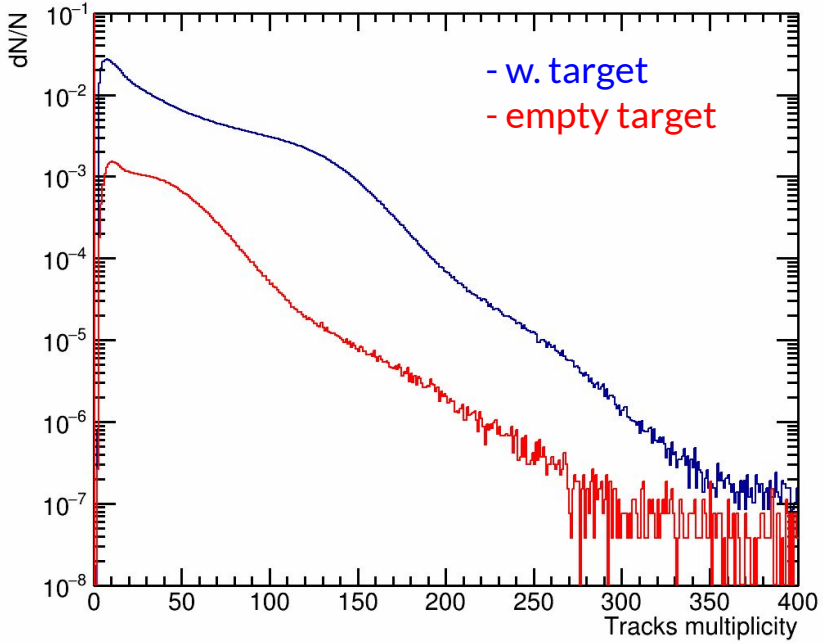
		0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %
Run 8150-8170		137-236	99-137	71-99	49-71	33-49	21-33
Run 7310-7500	raw	98-177	70-98	49-70	34-49	22-34	14-22
	shift	142-253	103-142	74-103	52-74	35-52	22-35

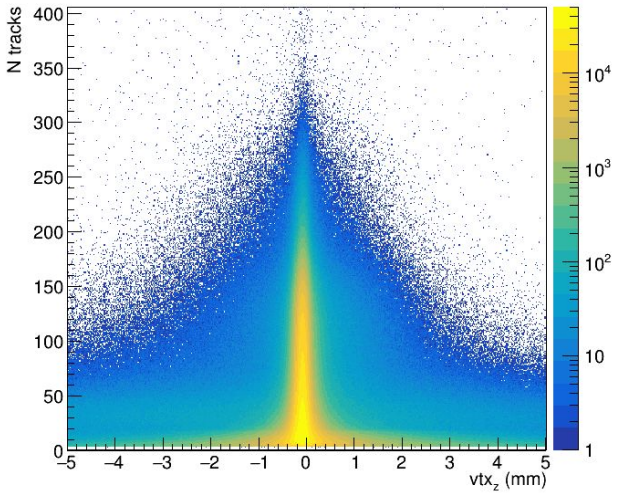
Example, multiplicity [49;71):

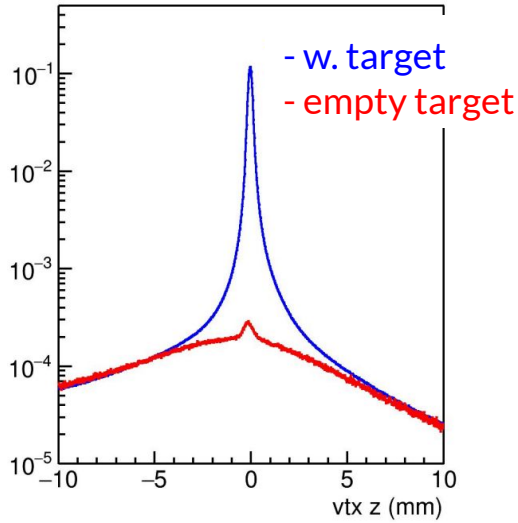
- corresponding 30-40% for Run 8150-8170
- corresponding 20-30% for Run 7310-7500

We suggest using the “shift” correction

Off-target collisions contribution



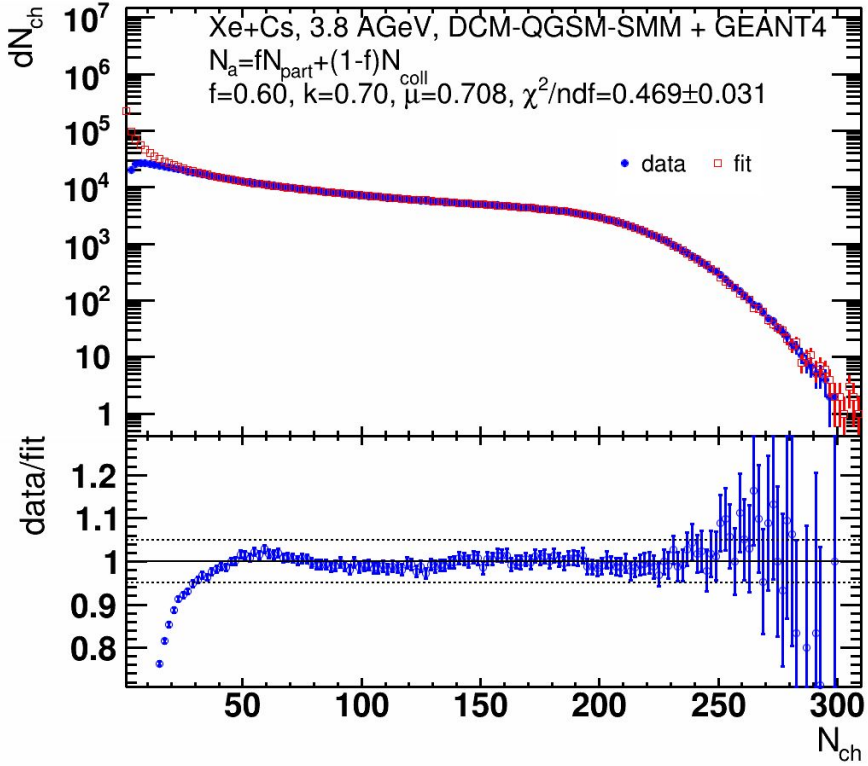


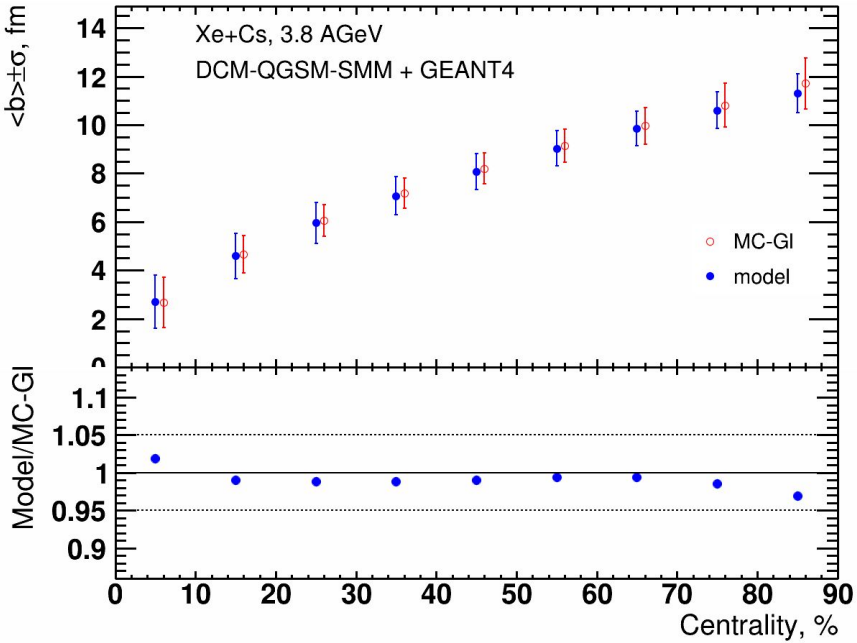


With target — with all selection criteria used in analysis

- Without target — empty target runs + selection criteria
- Normalized to number of events, then scaled

Result of centrality determination at Xe-CsI @ 3.8 AGeV





- Good agreement between model data and fit
- Impact parameter distributions in different centrality classes reproduces ones from DCM-QGSM-SMM

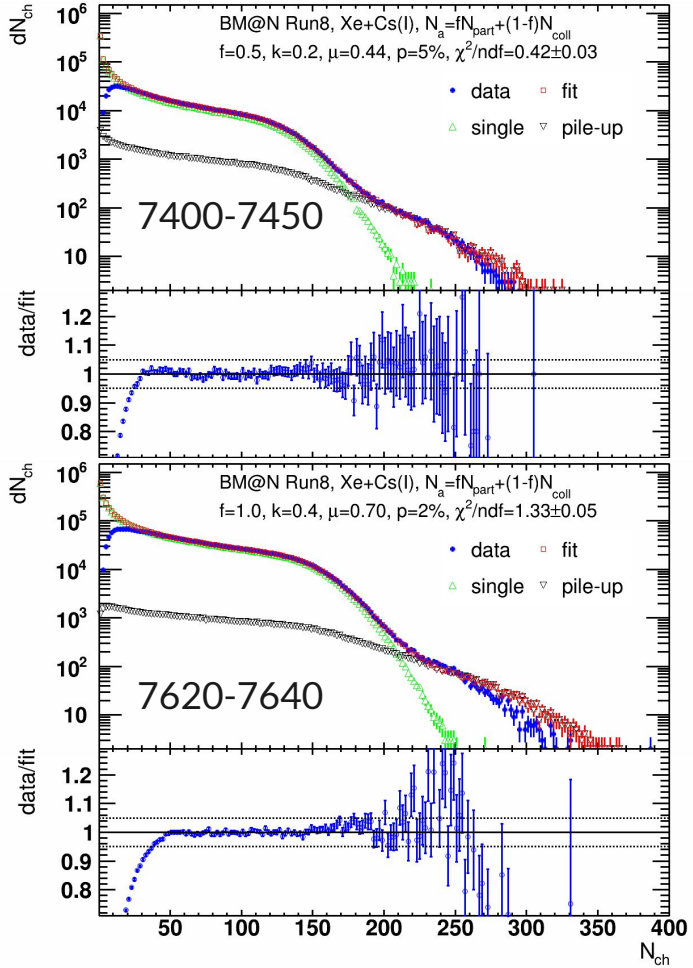
Summary and outlook

- The main difference between productions is TOF-700
- The MC-Glauber method reproduce charged particle multiplicity for fixed-target experiment at BM@N
- Corrections for vertex and RunId was proposed

- Centrality determination using data from JAM and DCM-QGSM-SMM model (in progress)

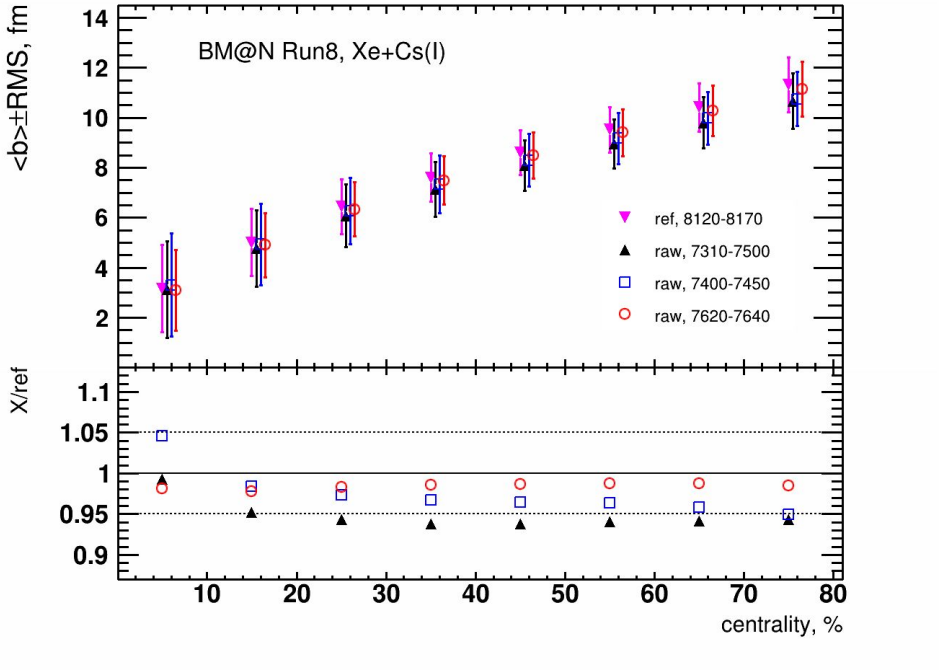
Thank you for your attention!

Centrality determination: pileup rejection

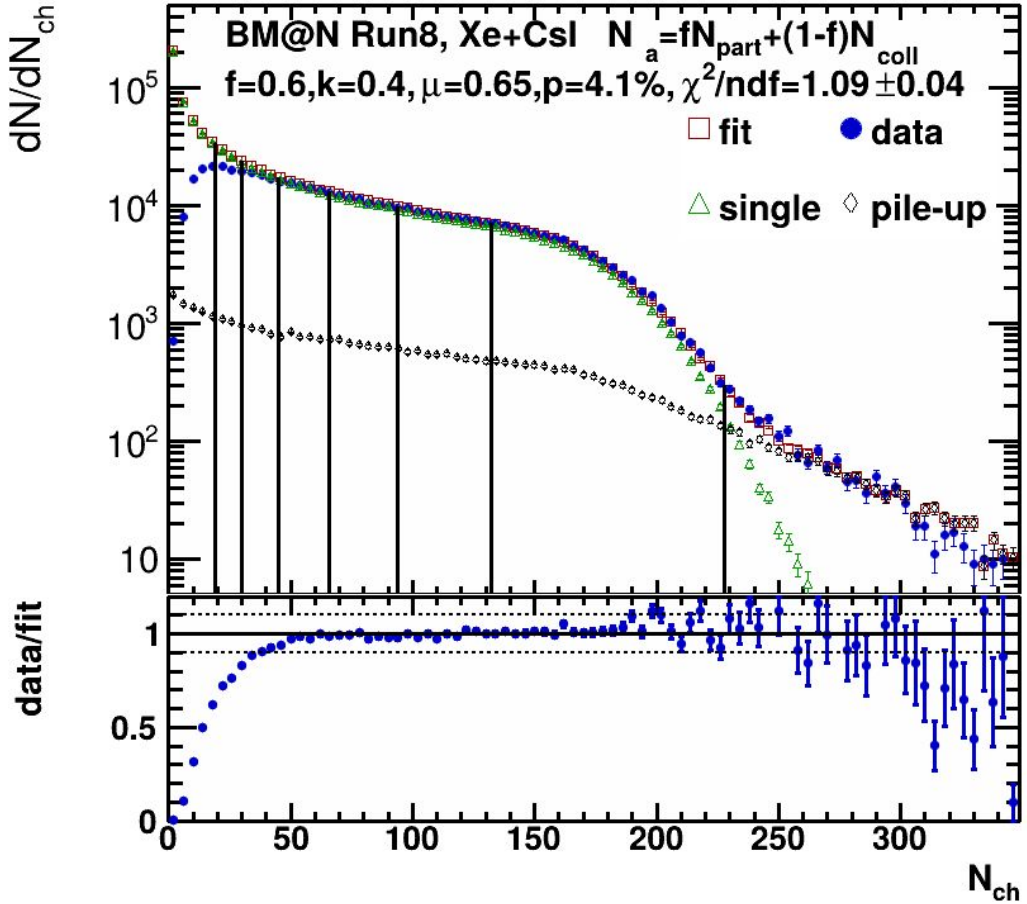


During the run8 the luminosity changes -> different pile-up contribution:

- Fit predicts **6%** pileup events for Run 7400-7450
- Fit predicts **2%** pileup events for Run 7620-7640



Centrality based on MC-Glauber at low energies



RunId: **8120-8170**

Multiplicity Cuts:

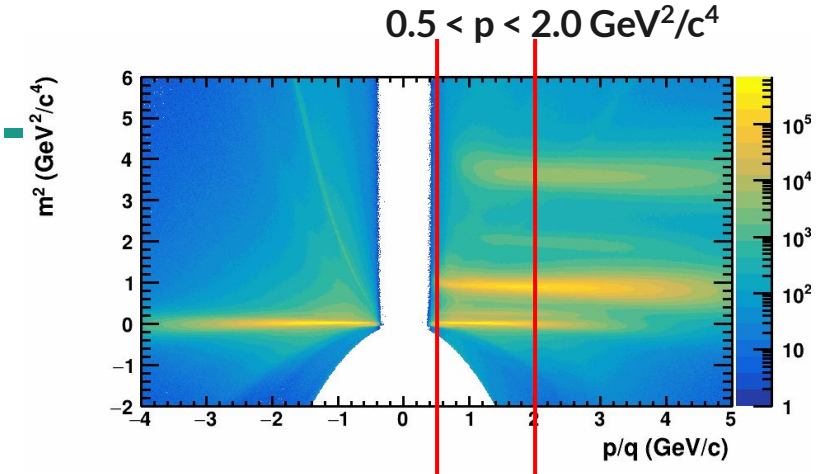
- CCT2
- $N_{vtxTr}>1$
- (Sts digi vs N_{tr}) cut
- $V_r < 1$ cm
- $V_z < 0.1$ cm

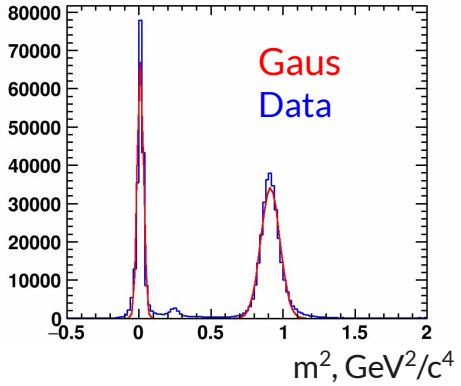
Fit suggests **f=0.6** - means that soft processes are dominating

Good agreement with experimental data

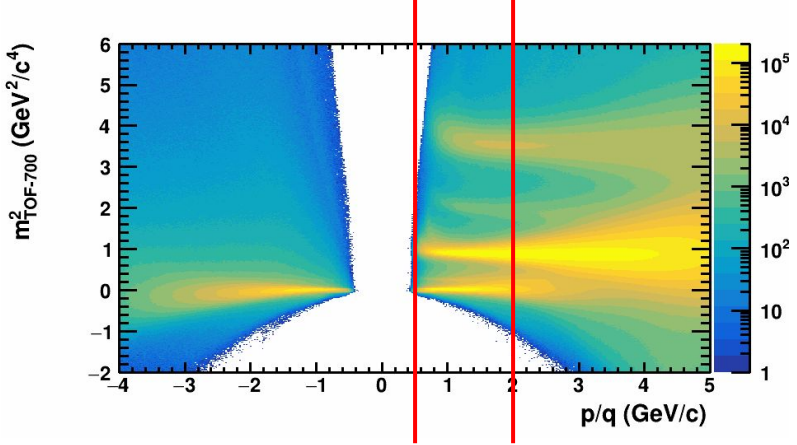
Square mass (old prod)

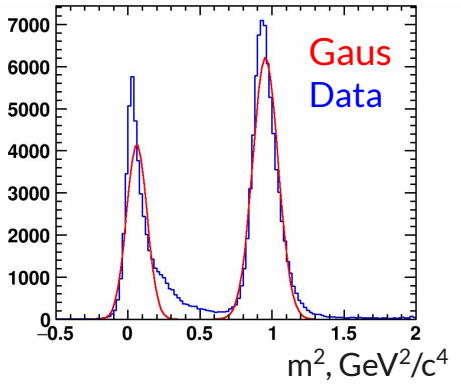
TOF-400





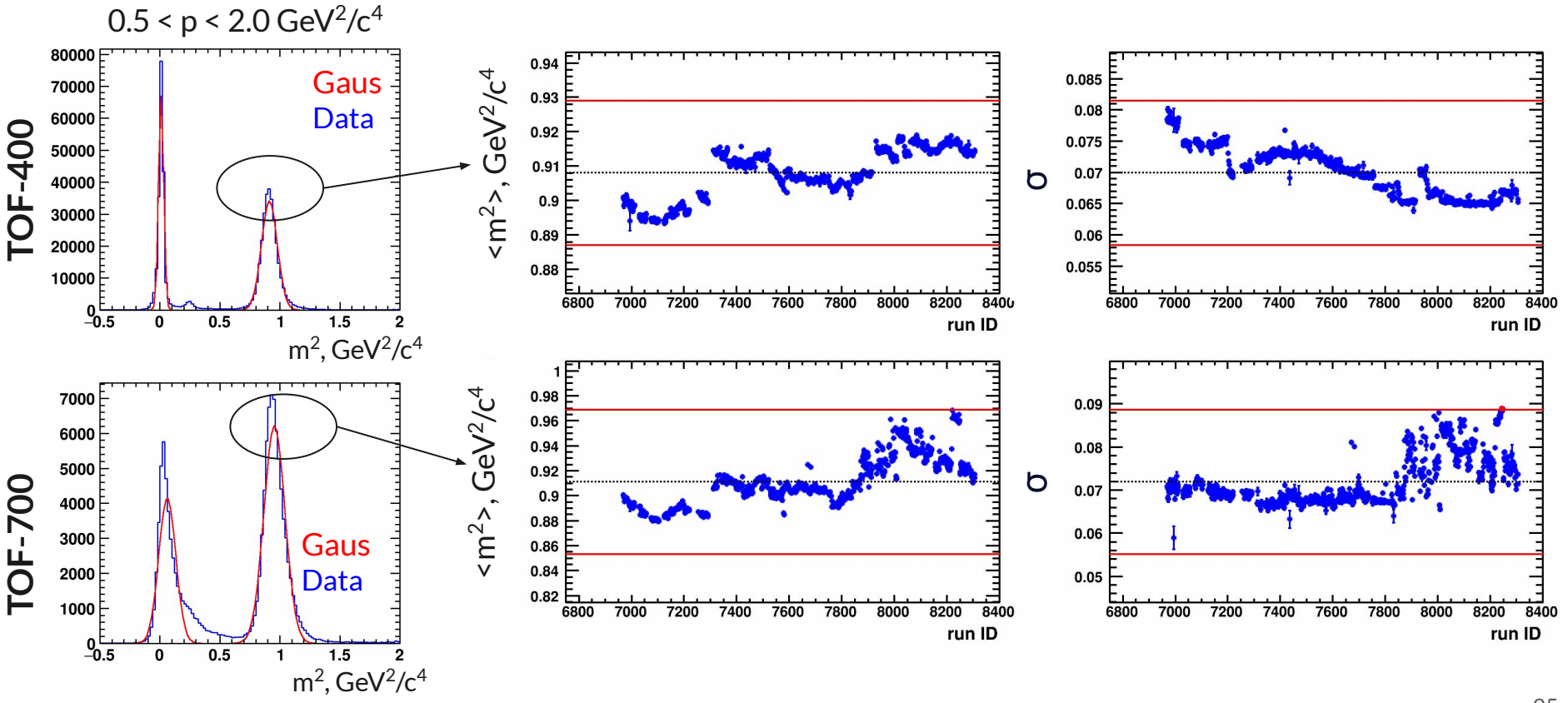
TOF-700





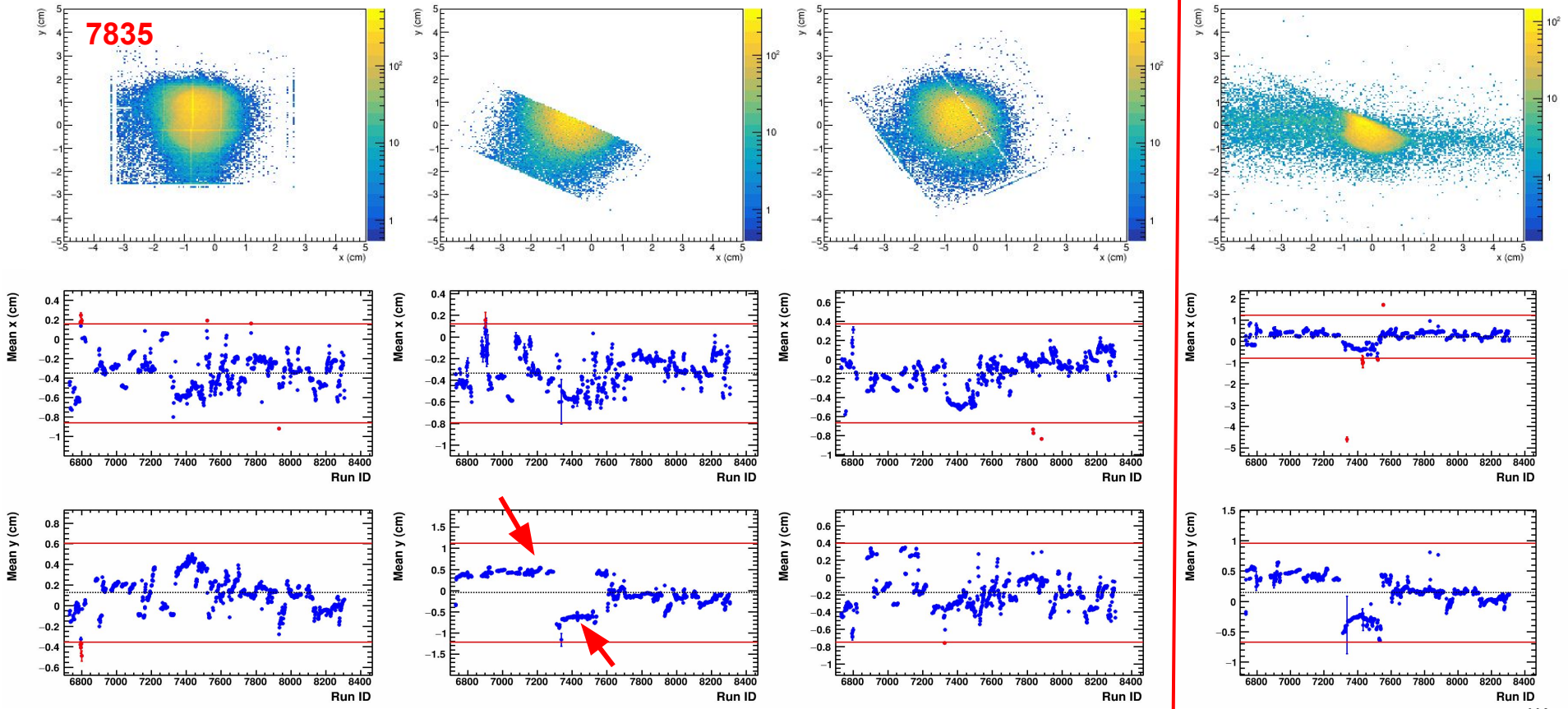
QA Run-by-Run: proton

Fit of each run ID with Gaus



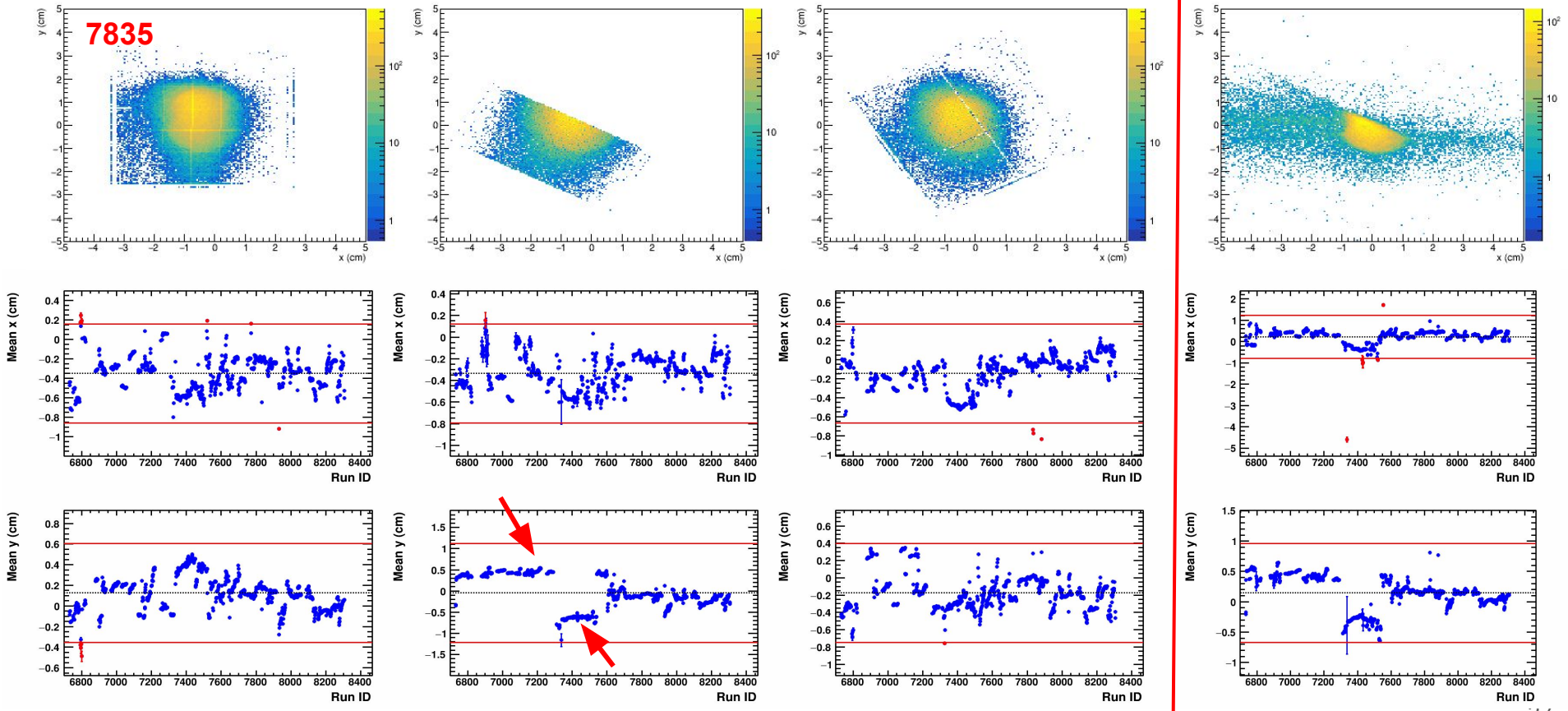
QA Run-by-Run: SiBT (old)

Station 1 (0) | Station 2 (30) | Station 3 (60) | beam tracks (x,y)

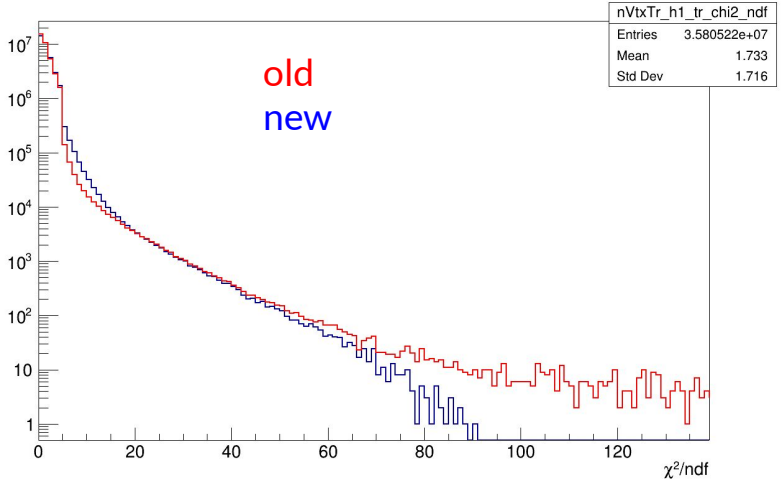


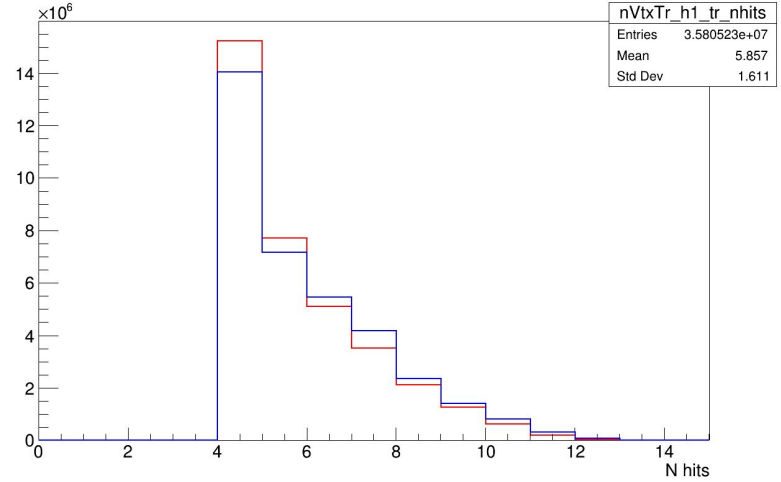
QA Run-by-Run: SiBT (old)

Station 1 (0) | Station 2 (30) | Station 3 (60) | beam tracks (x,y)

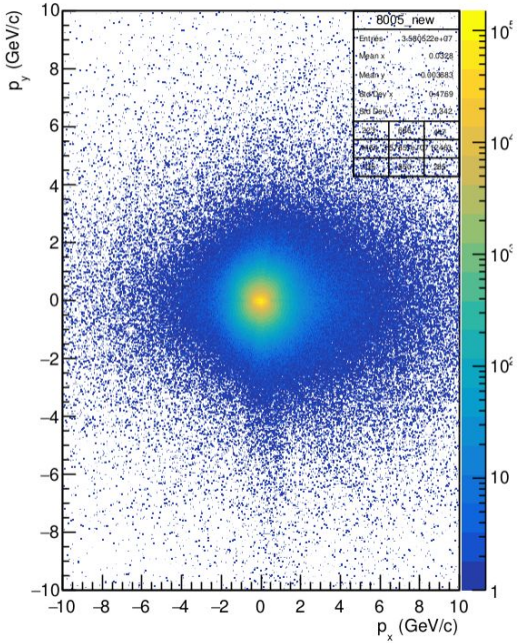


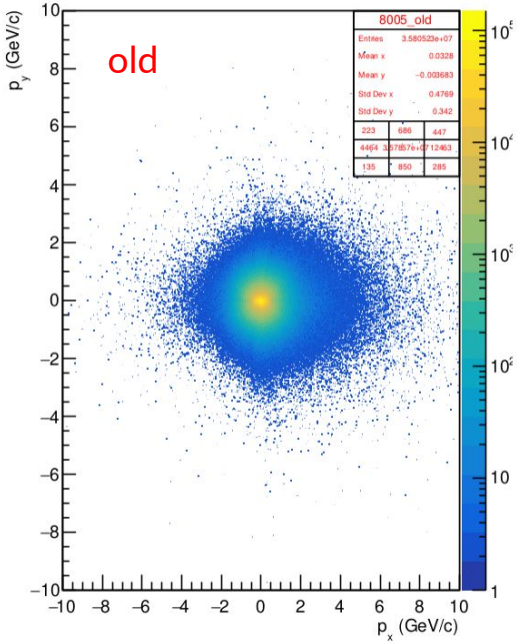
Difference between prod: Global Track Parameters



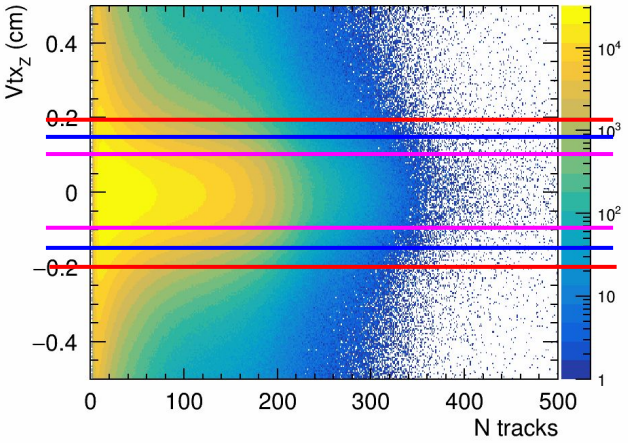


nVtxTr_h2_tr_px_tr_py

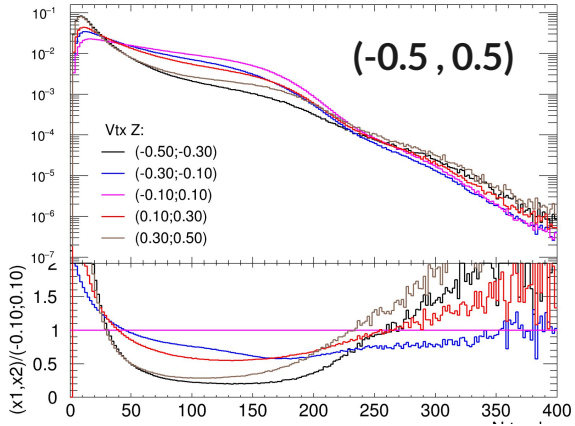


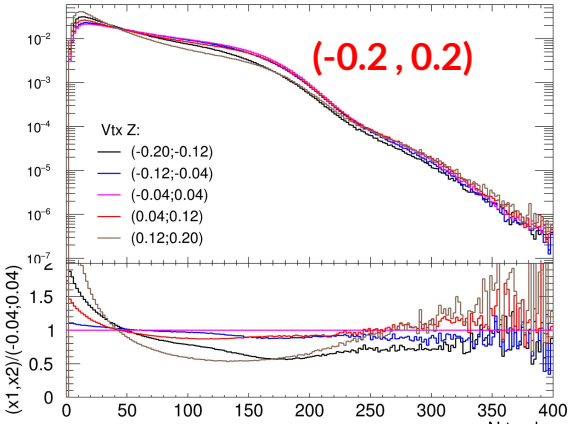


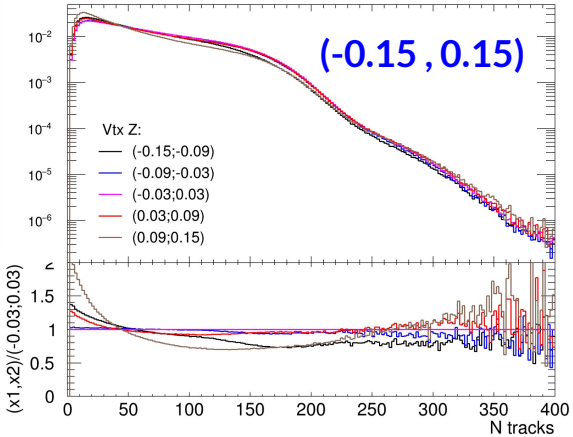
Vtx Z

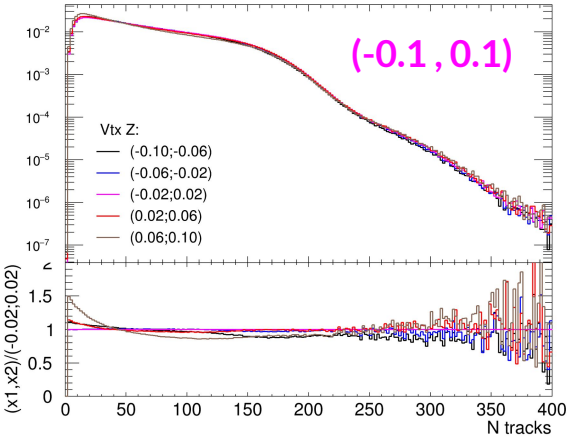


Use VtxZ <0.1

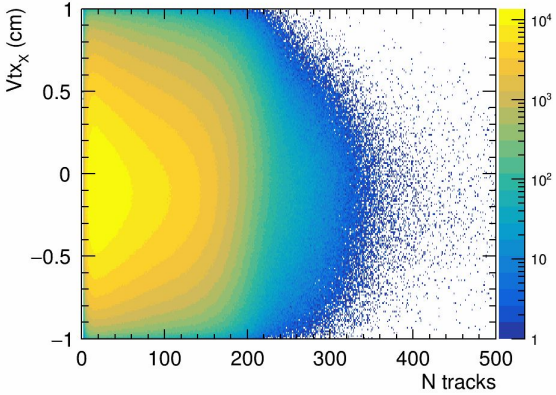


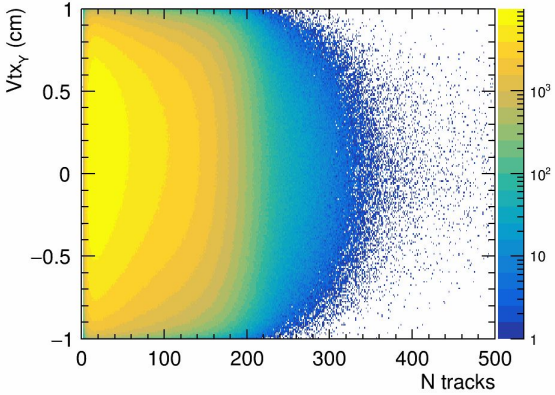


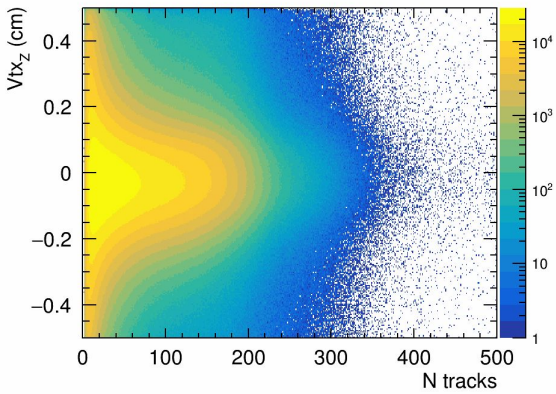


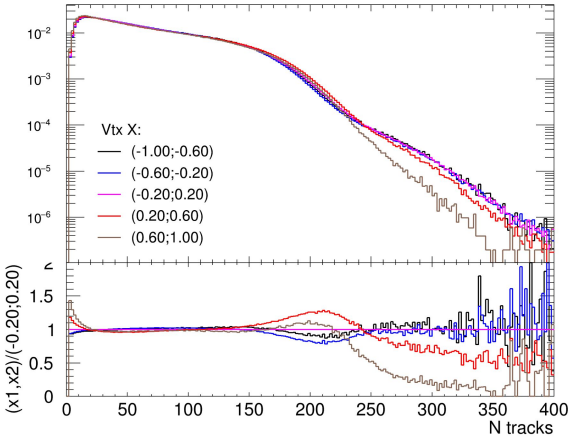


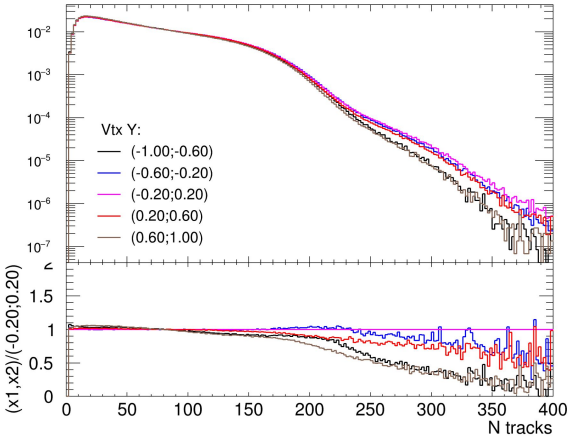
Vertex position

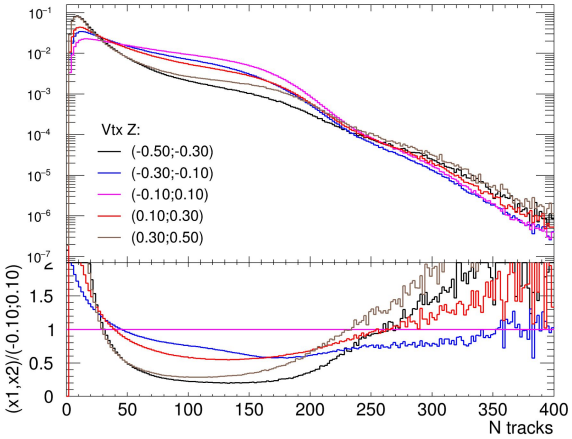


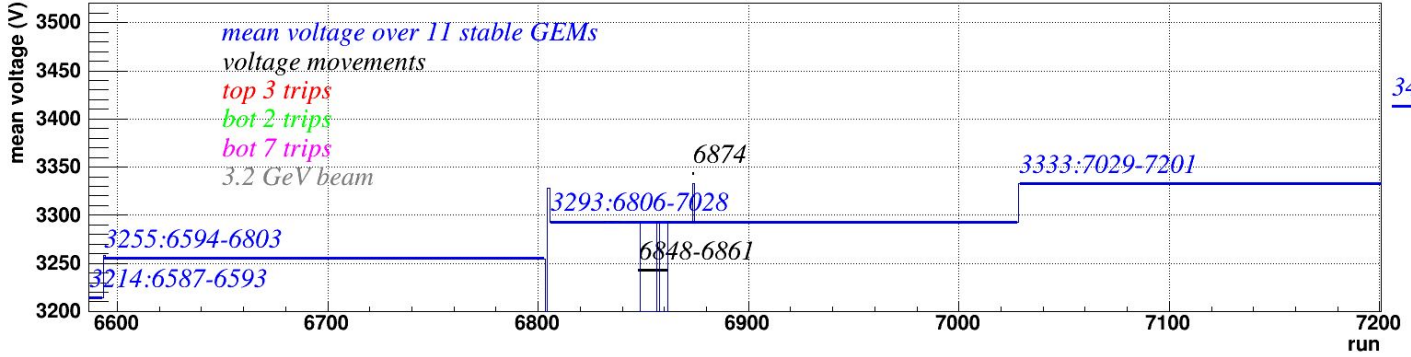


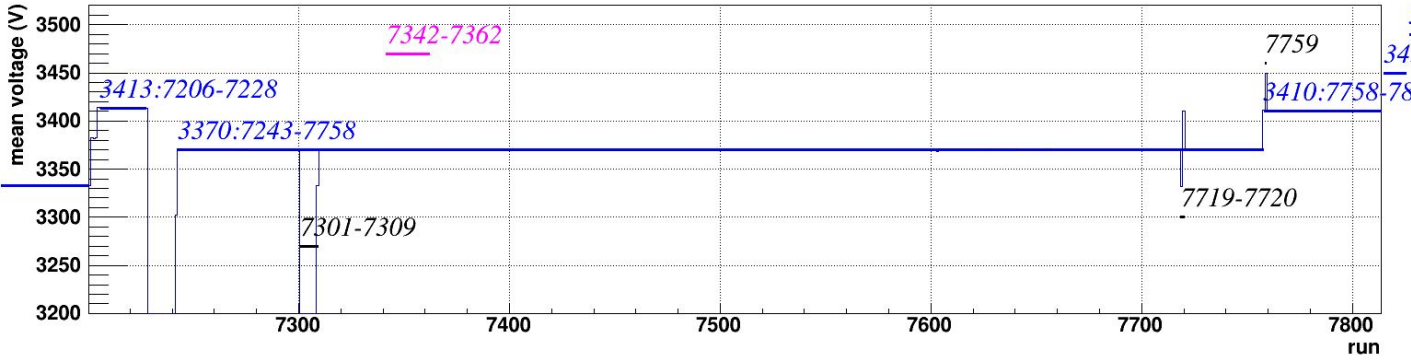


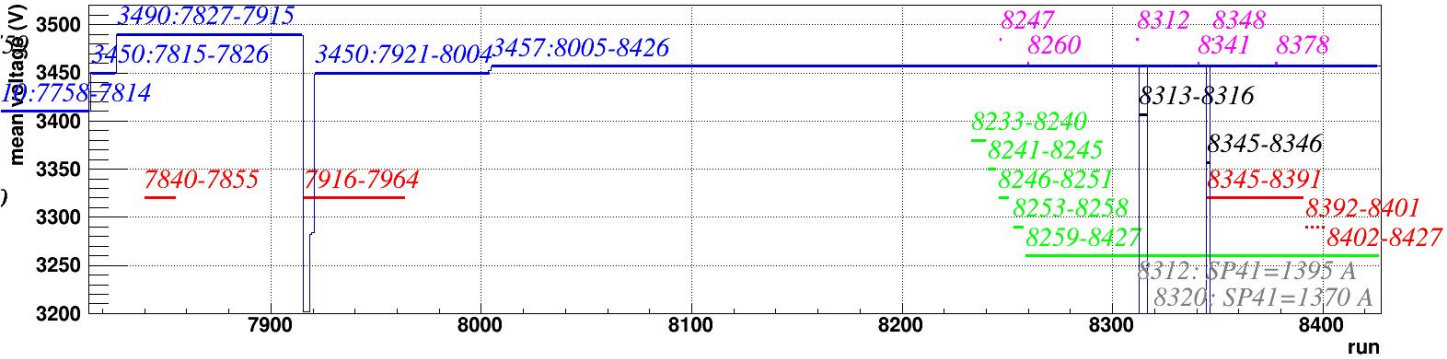












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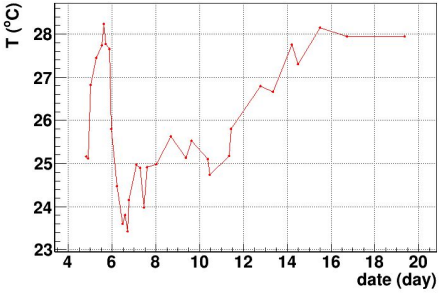
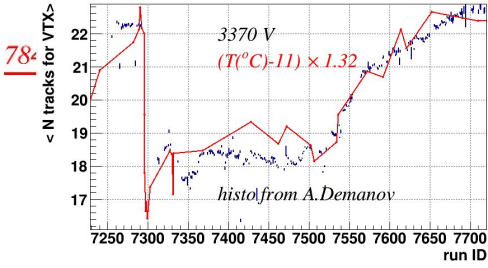




10 groups

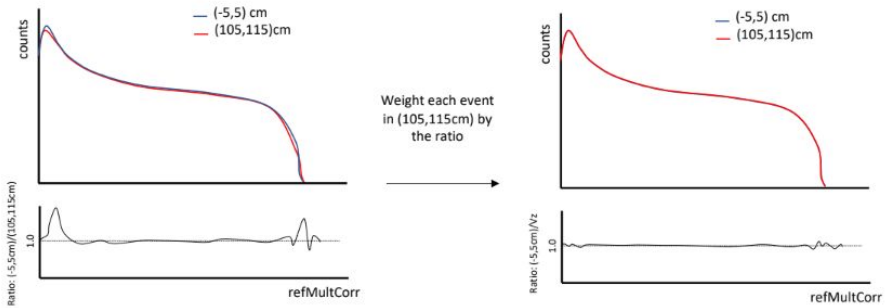
Multiplicity corrections

Example

1 step

Example

2 step

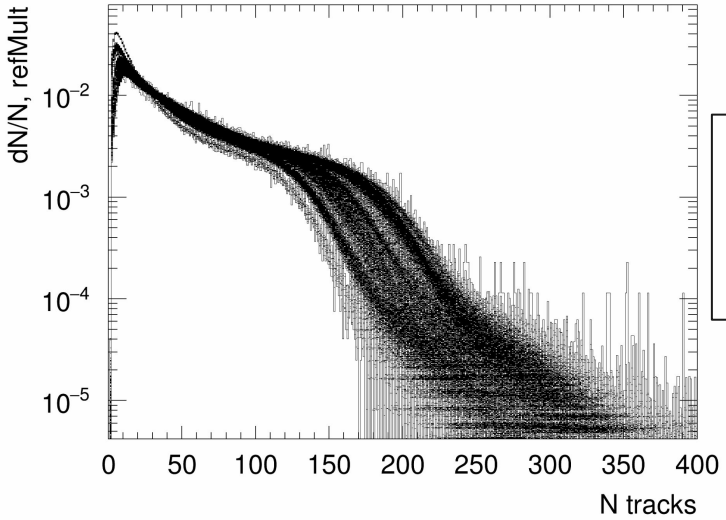


For Run8:

1. Shift for RunId
2. Re-weight RunId
3. Shift VtxZ (no need)
4. Re-weight VtxZ

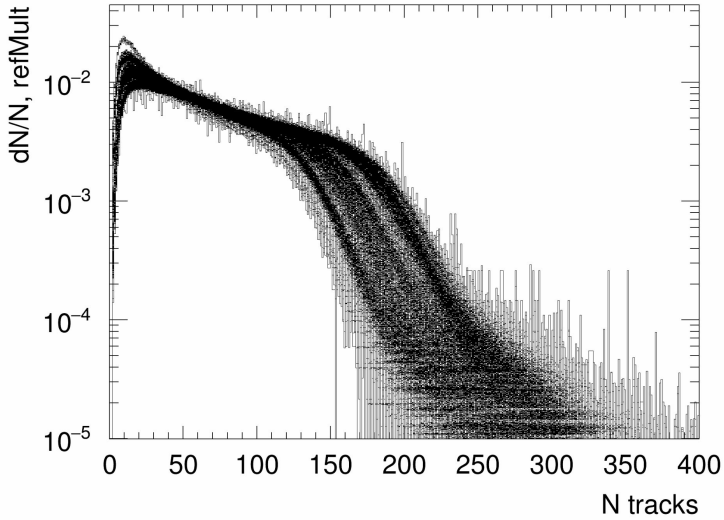
Mult vs RunId

- CCT2
- N_{vtxTr}>1
- (Sts digi vs N_{tr}) cut



1. Corr VtxX, VtxY, VtxZ.
2. add cuts

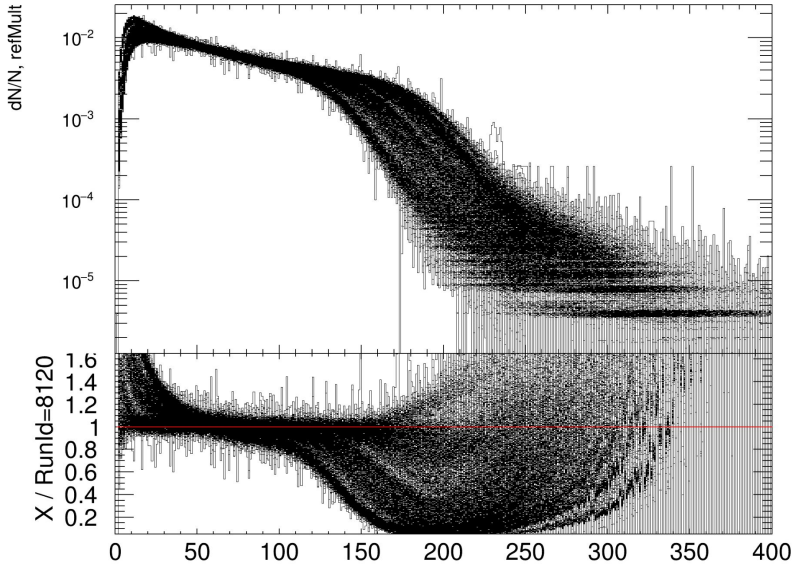
- CCT2
- N_{vtxTr}>1
- (Sts digi vs N_{tr}) cut
- V_r <1 cm
- V_z < 0.1 cm



Strong dependence on Run Id

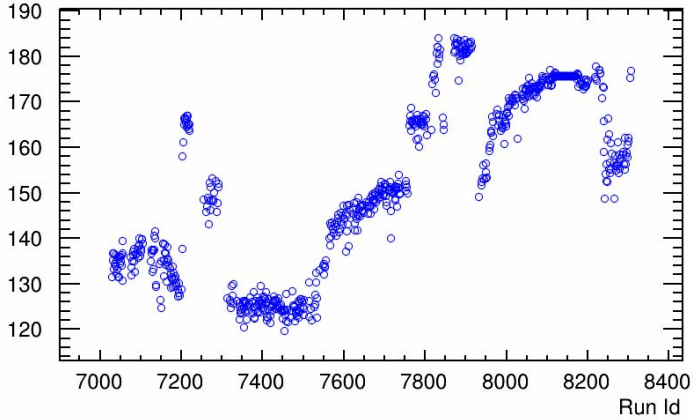
Mult vs RunId: Shift(1)

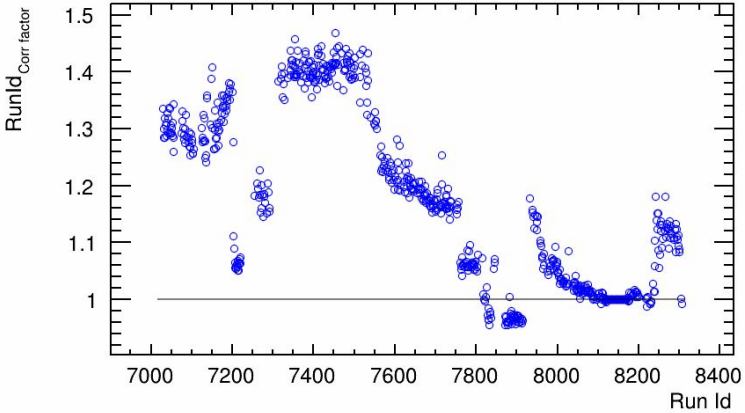
fit: A*Erf(-σ*(refMult-h)) + A
h -> right picture



Reference RunId: 8120-8170

h



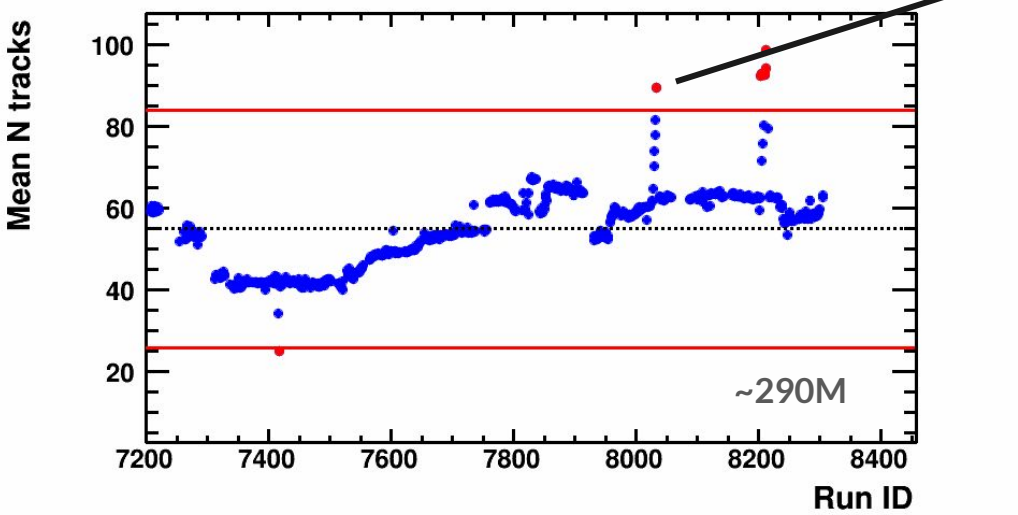


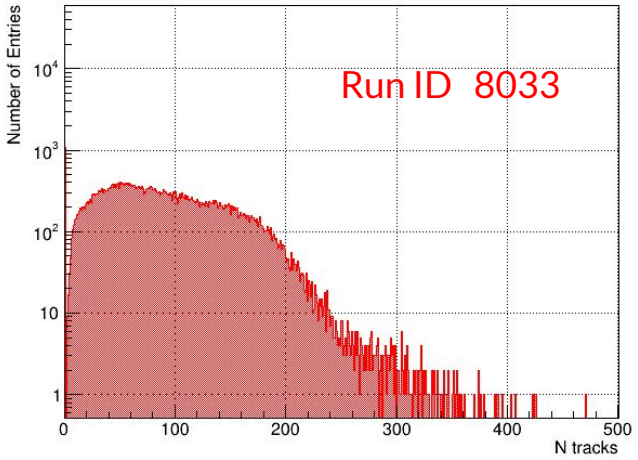
QA Run-by-Run: runs rejection

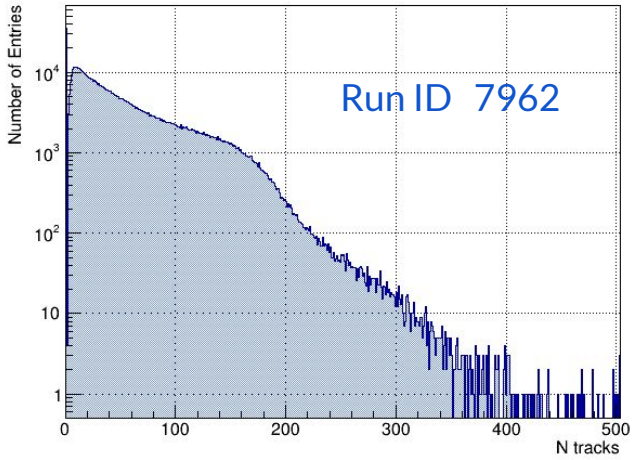
- CCT2
- More than 1 track in vertex reconstruction

Procedure: $y_i -$ mean value by run ID

$$\mu = \frac{1}{N}\sum_{i=1}^{N} y_i \qquad \sigma = \sqrt{\frac{\sum (y_i - \mu)^2}{N}}$$







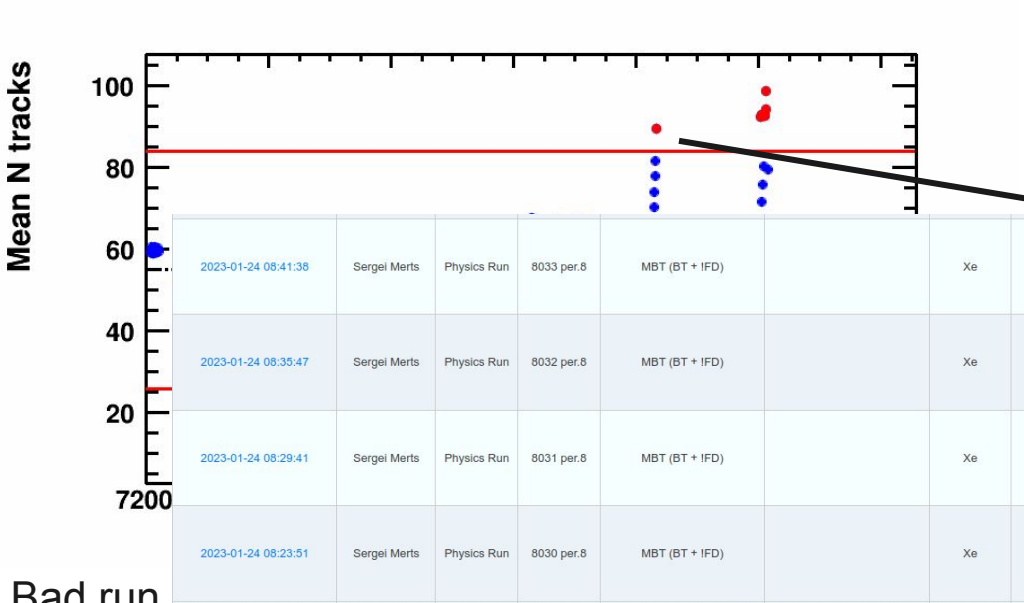
Bad run ID (beyond ±3σ): 7417, 8033, 8204, 8205, 8209, 8210, 8211, 8212, 8213

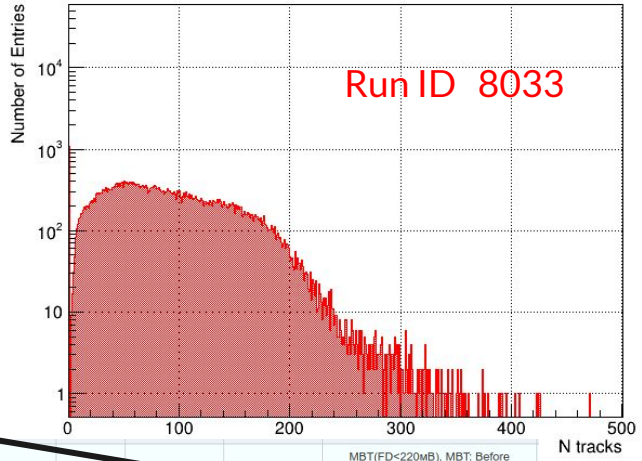
QA Run-by-Run: runs rejection

- CCT2
- More than 1 track in vertex reconstruction

Procedure: $y_i -$ mean value by run ID

$$\mu = \frac{1}{N}\sum_{i=1}^{N} y_i \qquad \sigma = \sqrt{\frac{\sum (y_i - \mu)^2}{N}}$$

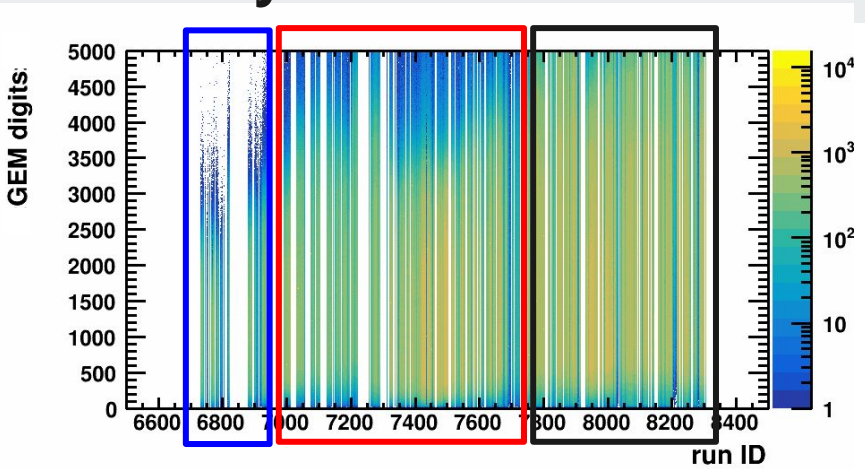


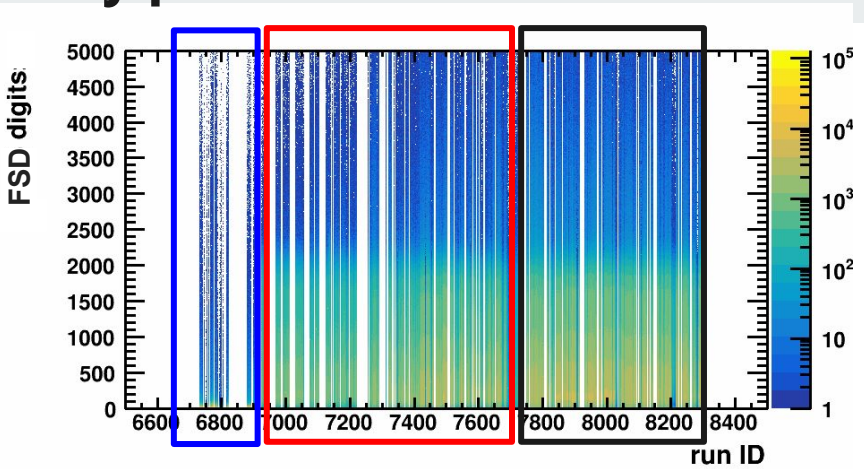


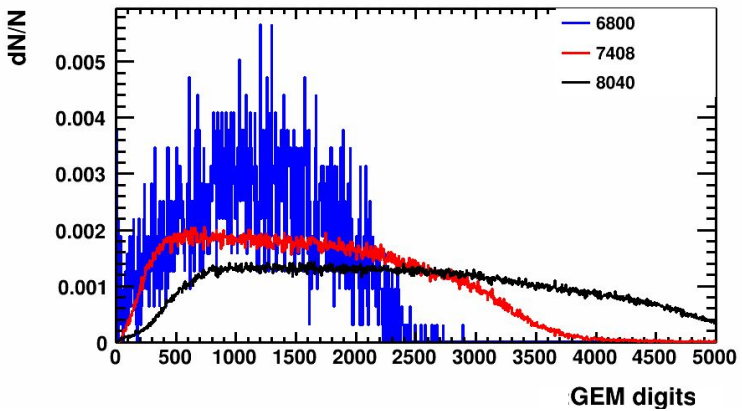
2023-01-24 08:41:38	Sergei Merts	Physics Run	8033 per.8	MBT (BT + IFD)	Xe	3.8	CsI (2%)	1720	0	MBT(FD<220мВ), MBT: Before 200/After 100; pBT:Before 20/After 20; Триггеримся по MBT, но параллельно пишем CCT1(BD>14), CCT2(BD>16) N=194k;
2023-01-24 08:35:47	Sergei Merts	Physics Run	8032 per.8	MBT (BT + IFD)	Xe	3.8	CsI (2%)	1720	0	170 MBT(FD<220мВ), MBT: Before 200/After 100; pBT:Before 20/After 20; Триггеримся по MBT, но параллельно пишем CCT1(BD>12), CCT2(BD>14) N=197k;
2023-01-24 08:29:41	Sergei Merts	Physics Run	8031 per.8	MBT (BT + IFD)	Xe	3.8	CsI (2%)	1720	0	170 MBT(FD<220мВ), MBT: Before 200/After 100; pBT:Before 20/After 20; Триггеримся по MBT, но параллельно пишем CCT1(BD>10), CCT2(BD>12) N=194k;
2023-01-24 08:23:51	Sergei Merts	Physics Run	8030 per.8	MBT (BT + IFD)	Xe	3.8	CsI (2%)	1720	0	170 MBT(FD<220мВ), MBT: Before 200/After 100; pBT:Before 20/After 20; Триггеримся по MBT, но параллельно пишем CCT1(BD>8), CCT2(BD>10) N=197k;

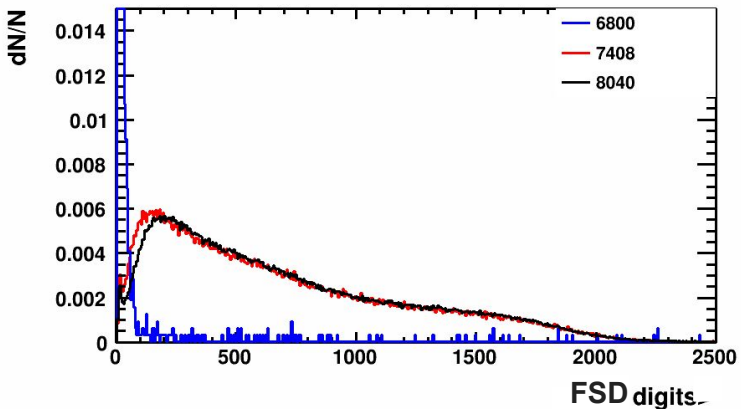
Bad run ID (beyond 100): 7411, 8008, 8204, 8208, 8209, 8210, 8211, 8212, 8213

QA Run-by-Run: GEM+FSD (February prod.)



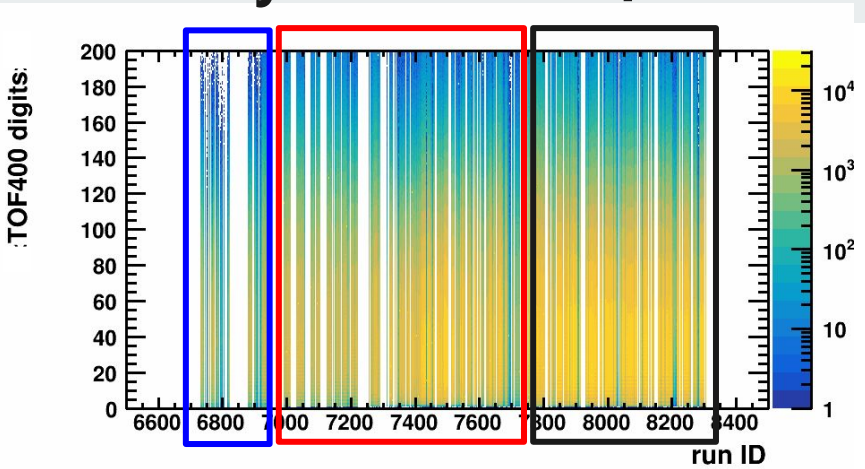


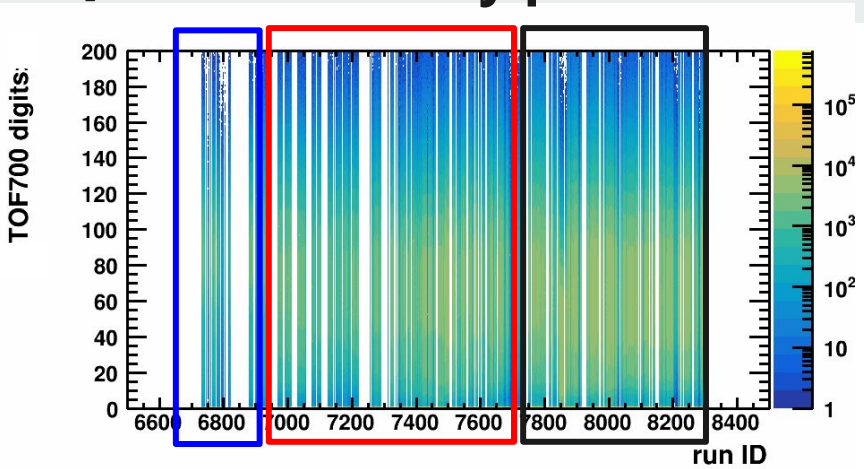


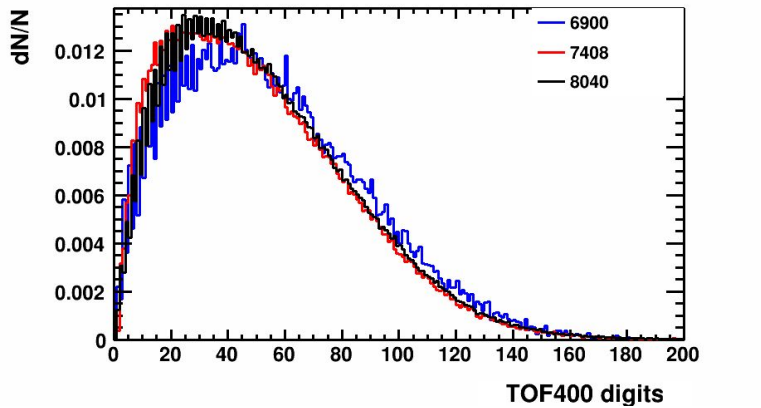


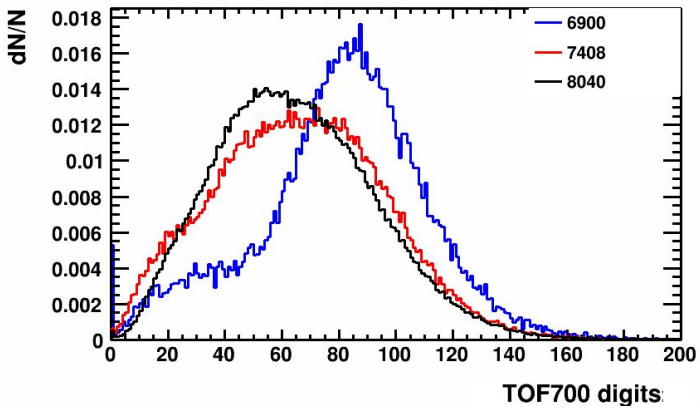
- Stable operation of the FSD detector (6924-8300)
- We don't consider Runs below 6924

QA Run-by-Run: TOF-400 and TOF-700 (February prod.)



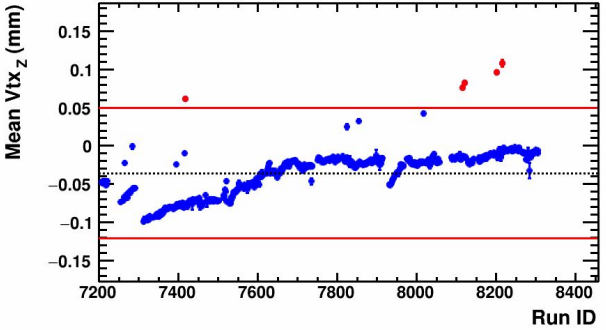


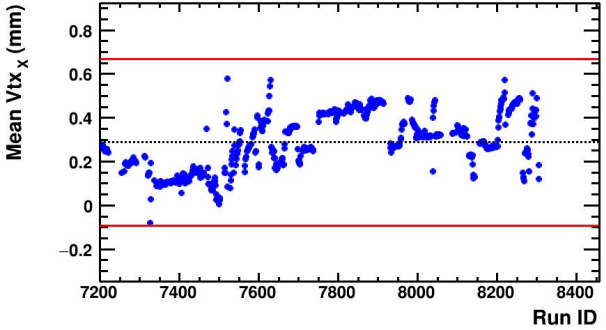


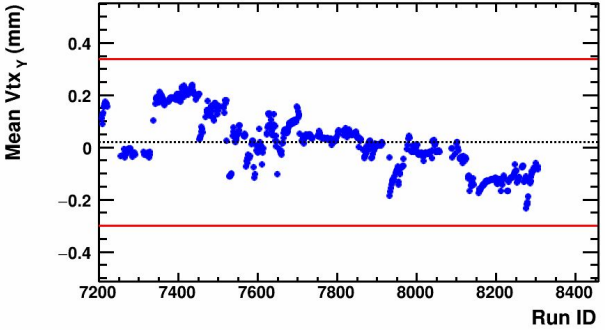


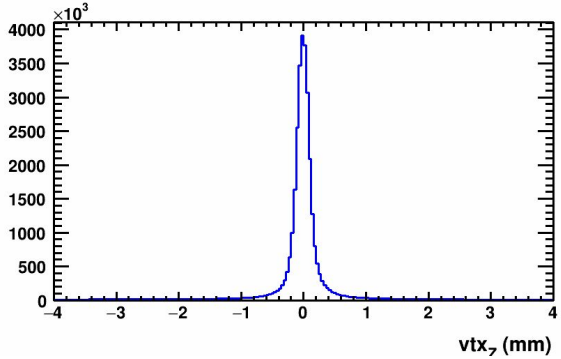
- Stable operation of the TOF-400 and TOF-700 detector (6924-8300)
- We don't consider Runs below 6924

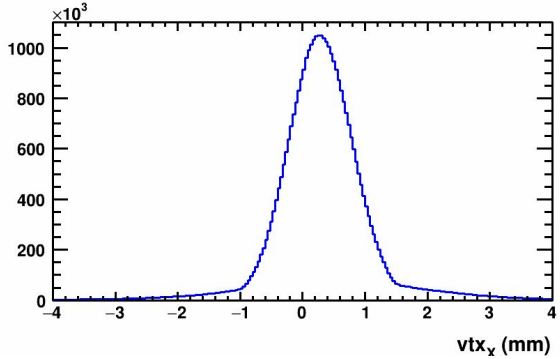
QA Run-by-Run: vertex position

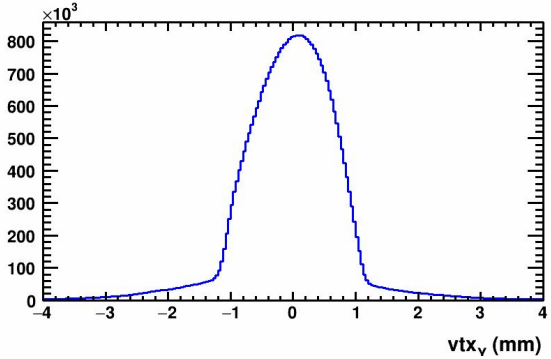






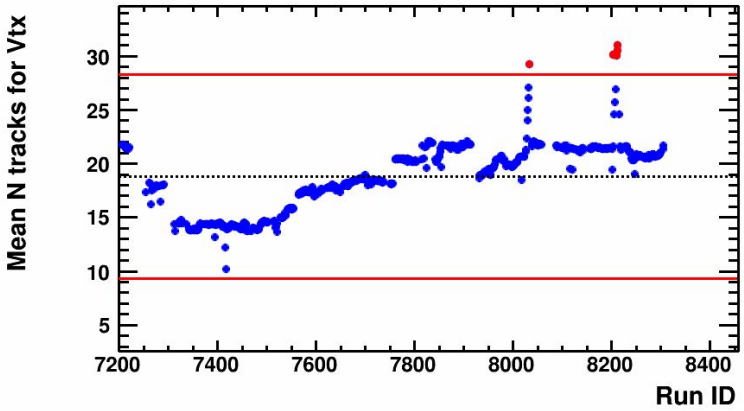


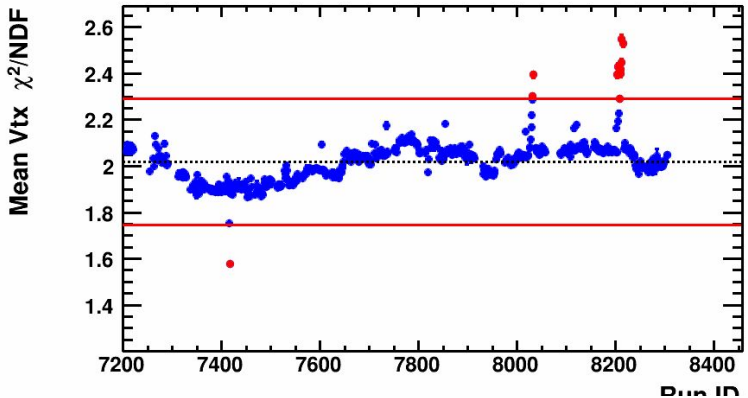


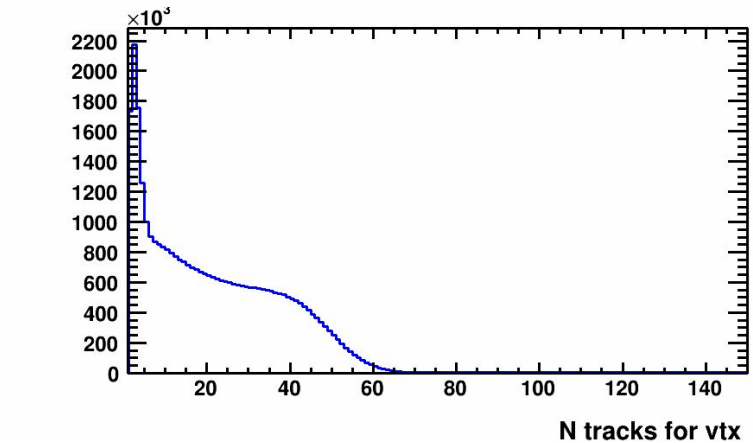


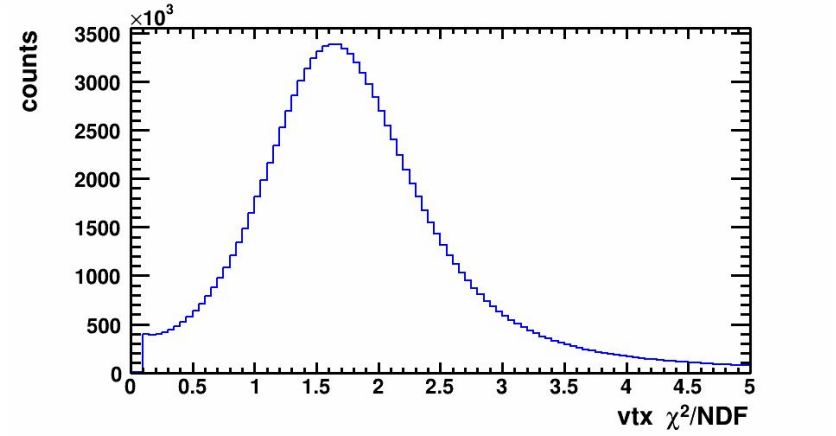
Bad Runs: 7417, 8115, 8121, 8201, 8215

QA Run-by-Run: vertex quality



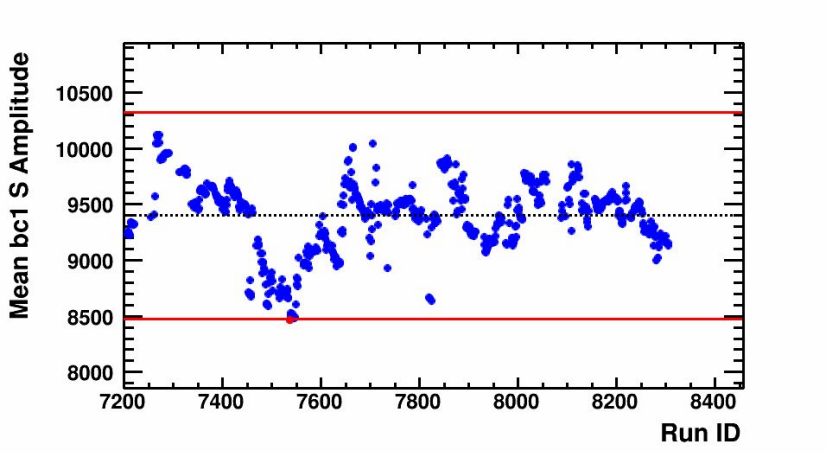


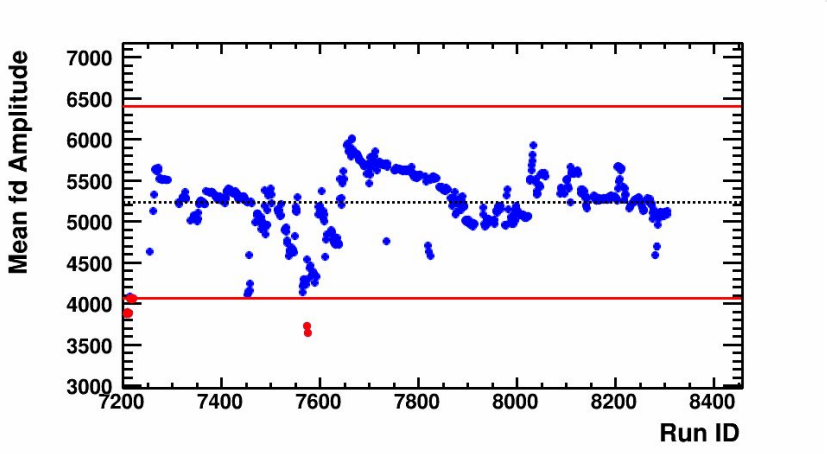


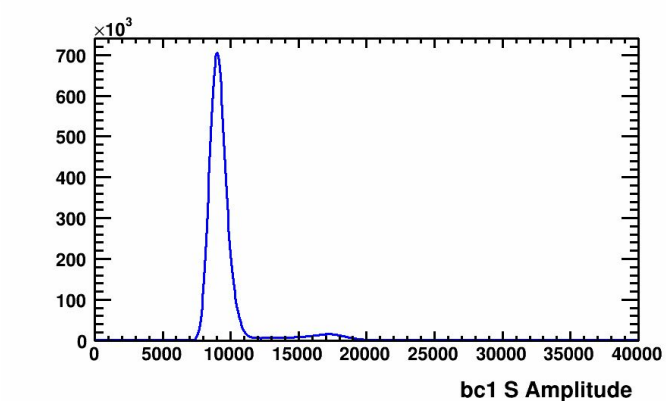


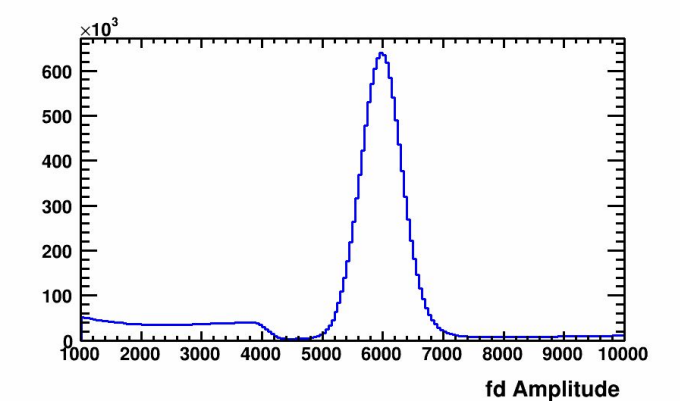
Bad Runs: 8033, 8204, 8205, 8209, 8210, 8211, 8212, 8213

QA Run-by-Run: BC1, FD



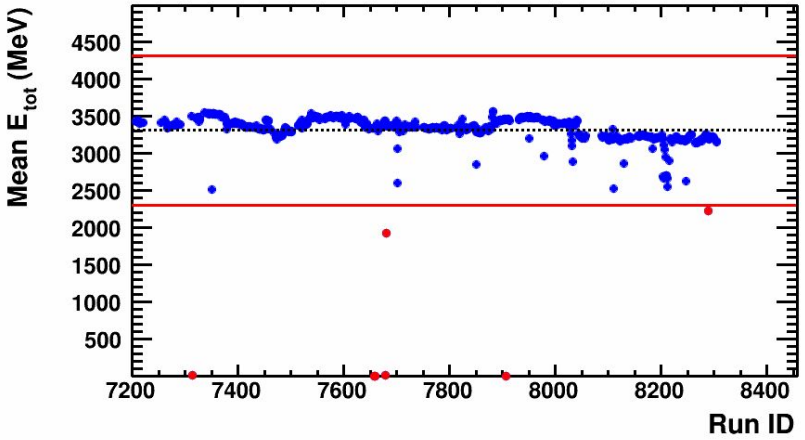


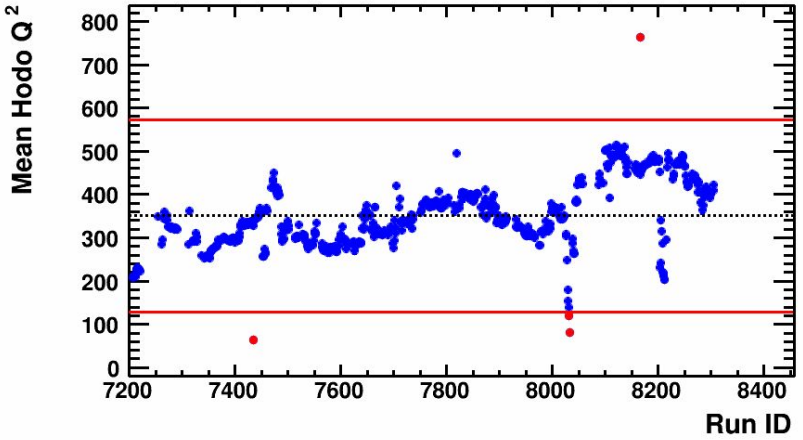


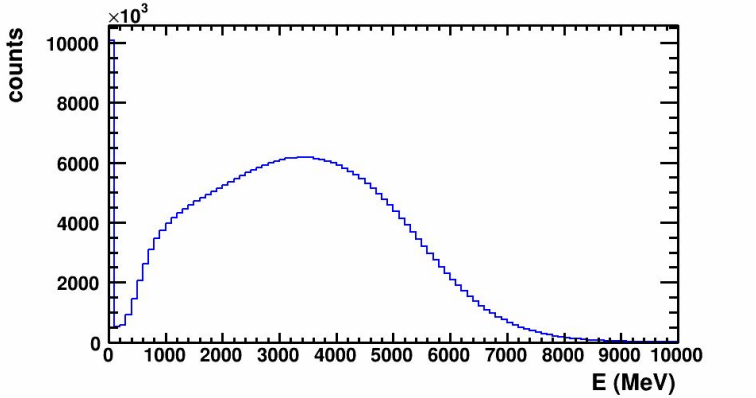


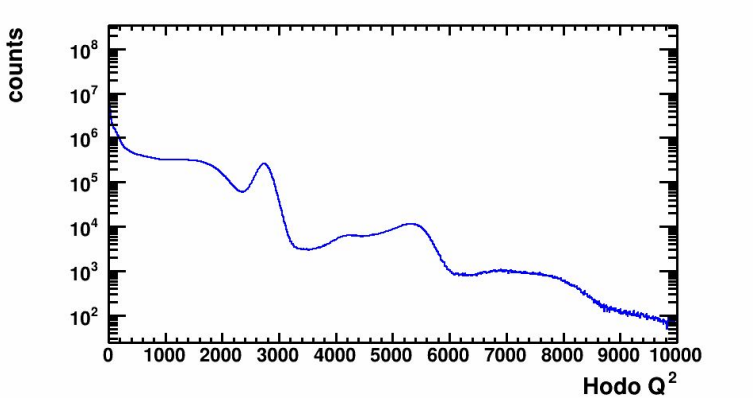
Plans on future: calibrate factor for each RunId

QA Run-by-Run: FHCal and FQH





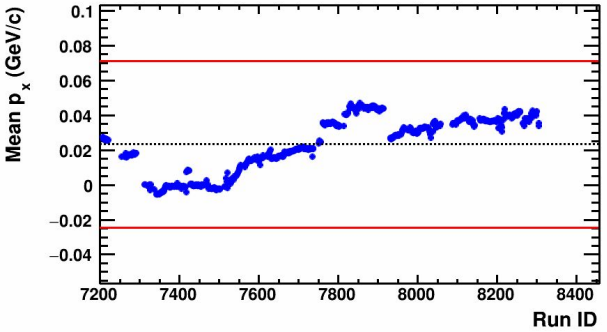


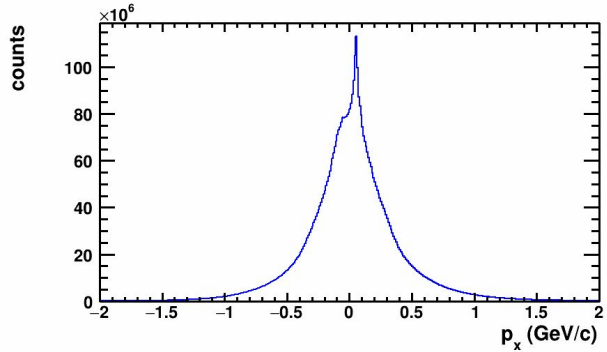


Bad Runs: 7313, 7657, 7659, 7679, 7681, 7907, 8289

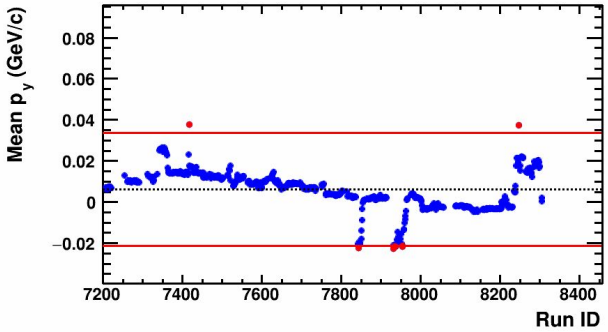
QA Run-by-Run: Tracks

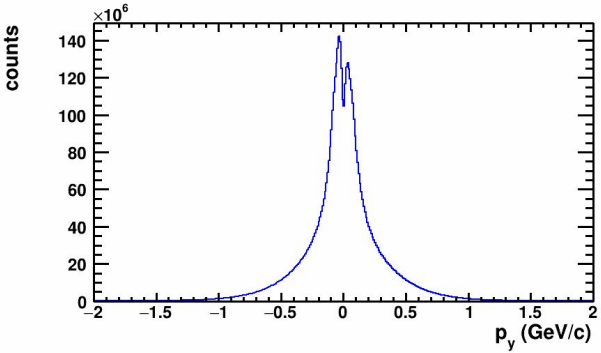
<p_x> GeV/c



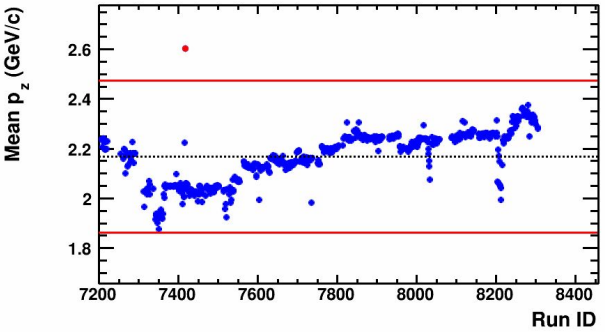


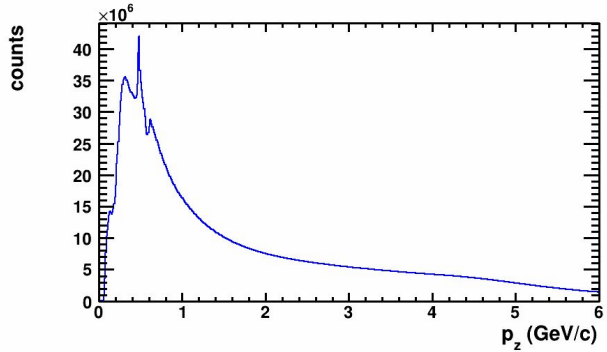
<p_y> GeV/c





<p_z> GeV/c



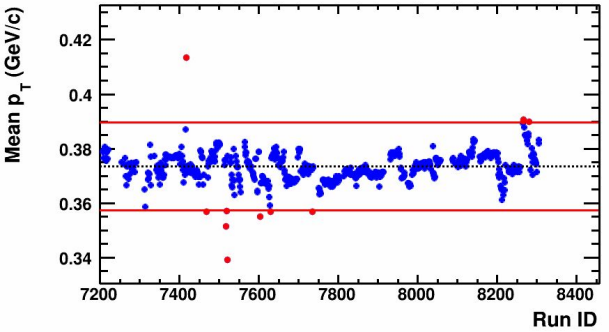


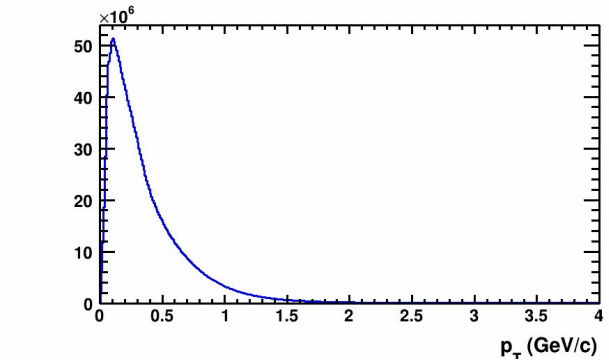
Bad Runs: 7843, 7932, 7933, 7935, 7937, 7954, 7955, 8247

Significant run Id dependence

QA Run-by-Run: Tracks

<p_T> GeV/c





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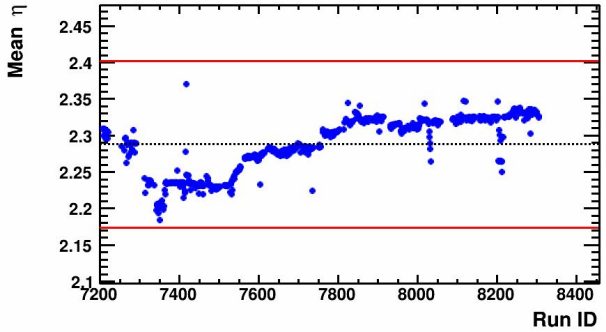

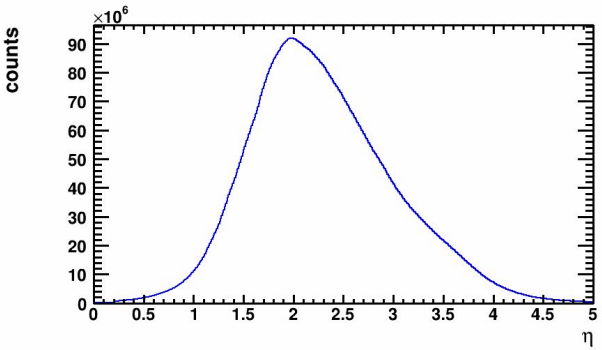

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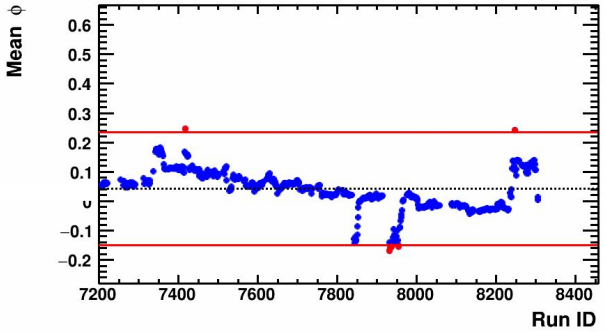
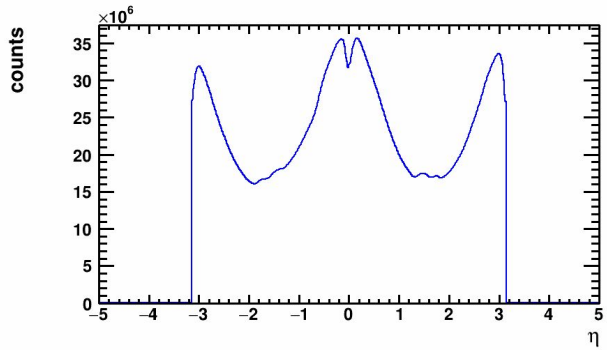
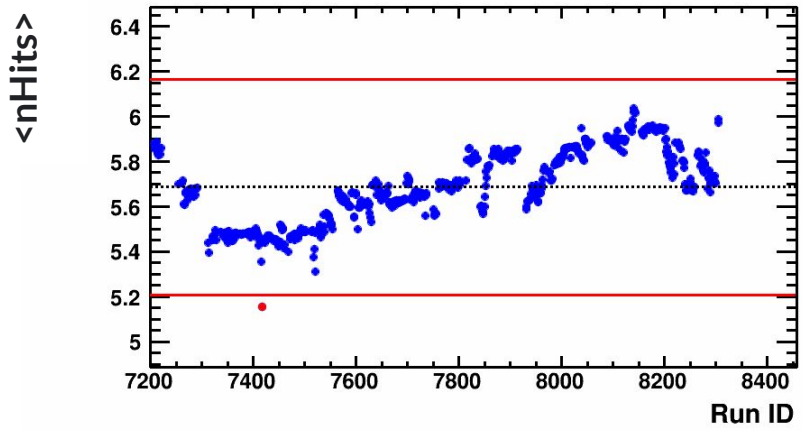


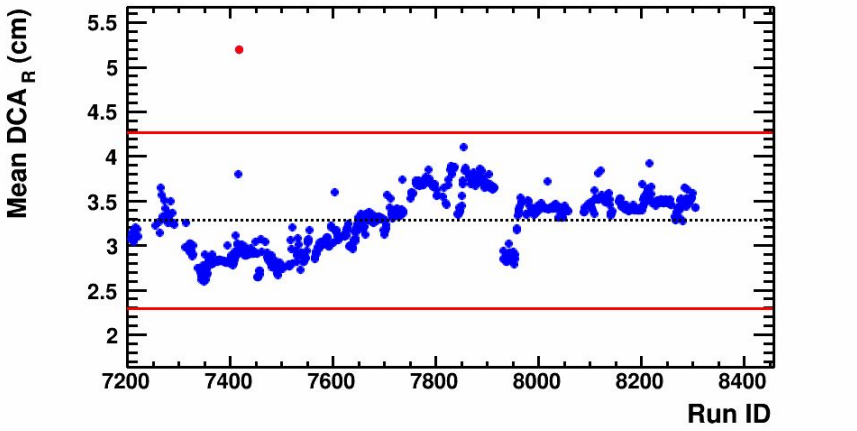


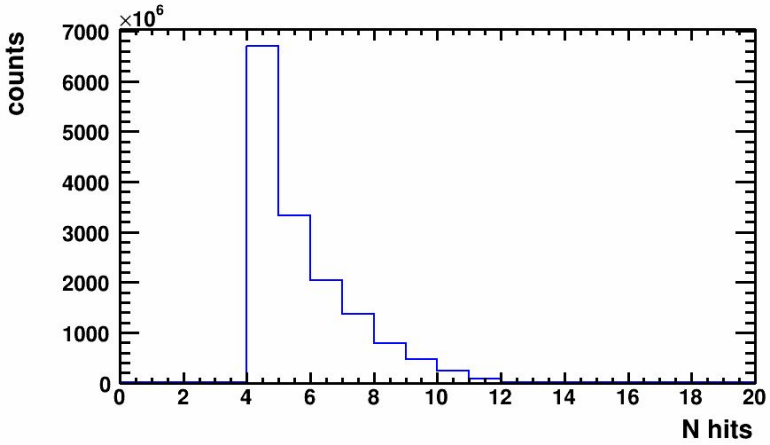
Bad Runs: 6980, 6992, 7417, 7520

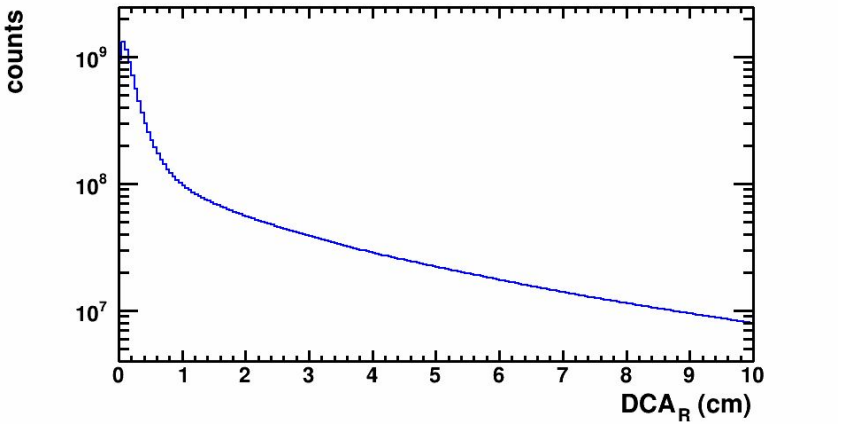
Significant run Id dependence

QA Run-by-Run: Tracks









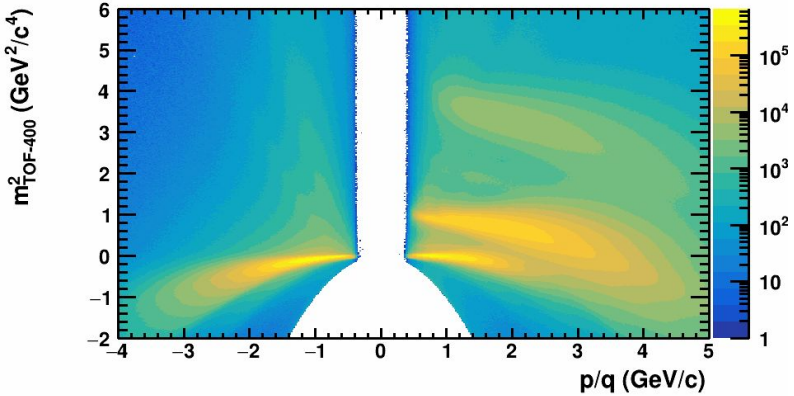
Square mass (old prod)

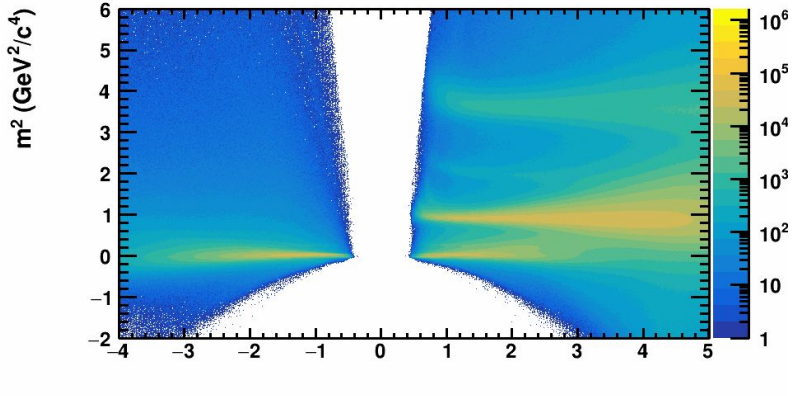
$$m^2 = \frac{(1-\beta^2) * p^2}{\beta^2}$$

TOF-400

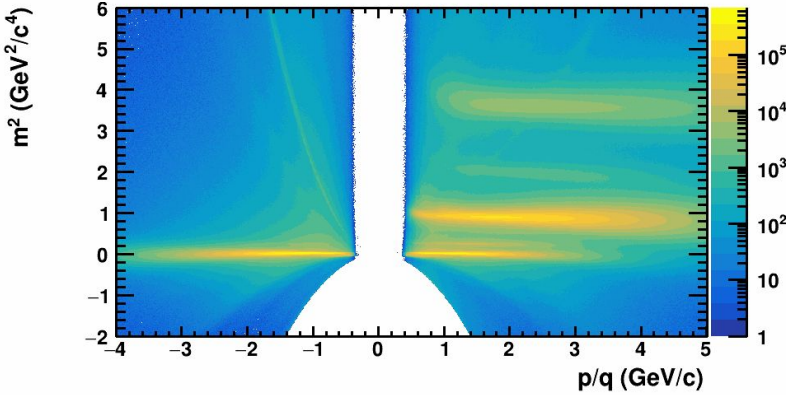
TOF-700

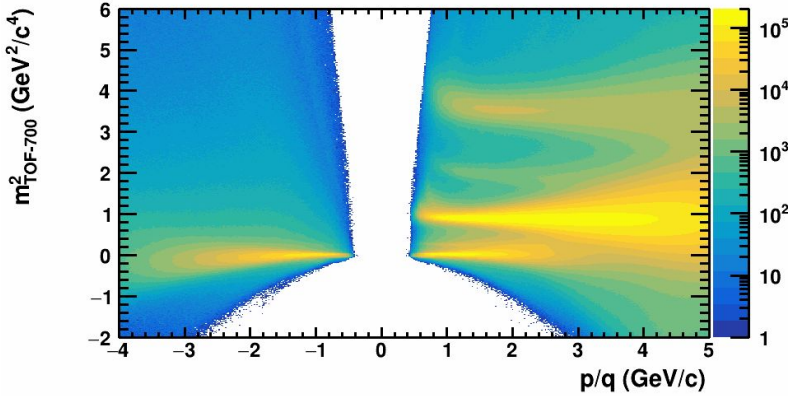
February prod.





May prod. (last)

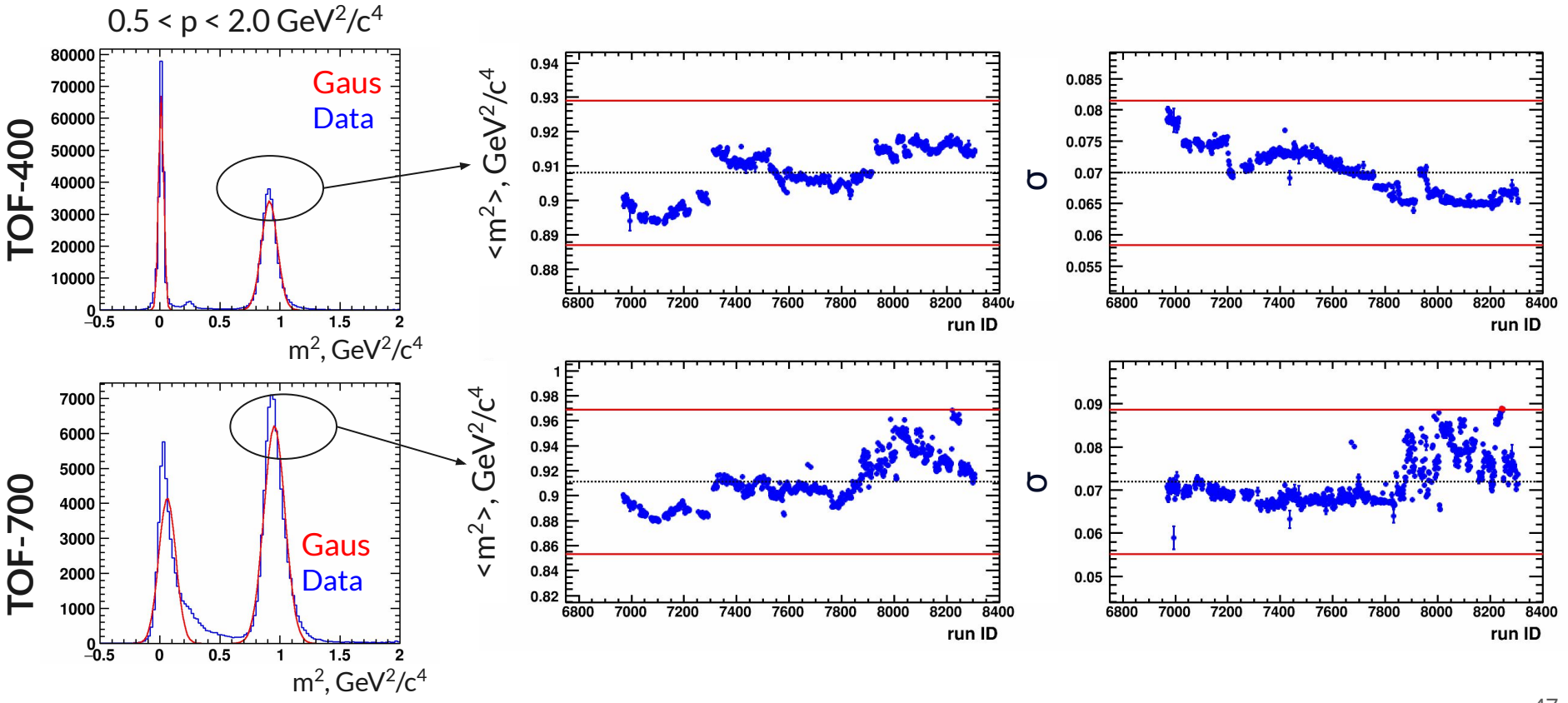




Calibration of TOF-400 and TOF-700 is completed.

QA Run-by-Run: proton

Fit of each run ID with Gaus



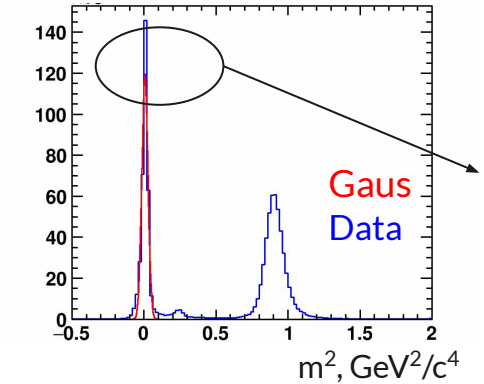
QA Run-by-Run: π^+

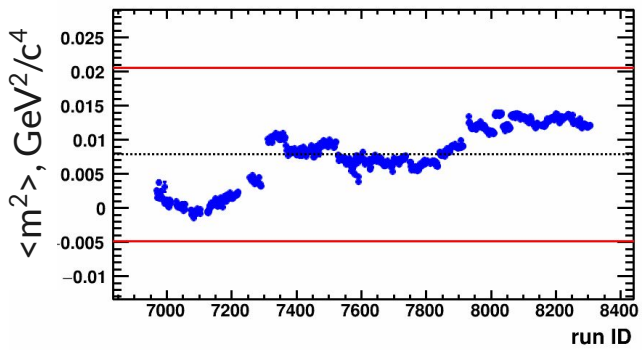
Runs 6900-7200 are in progress…

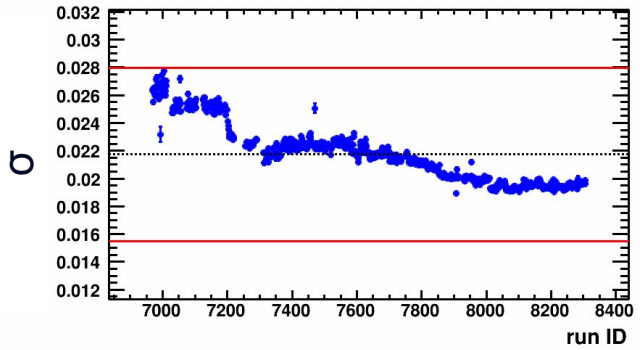
Fit of each run ID with Gaus

$0.2 < p < 1.0$ GeV^2/c^4

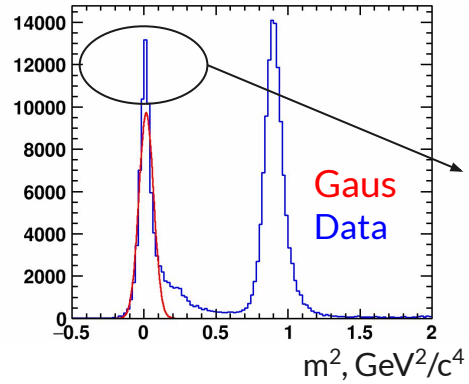
TOF-400

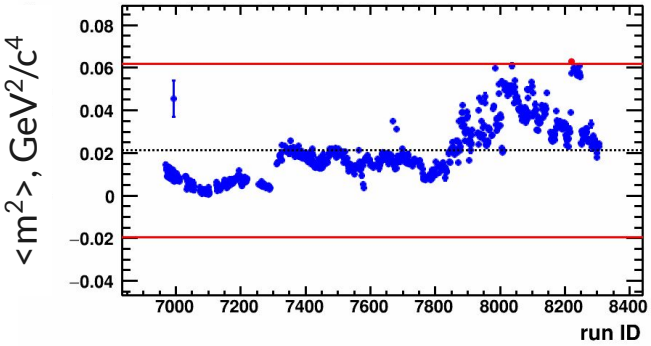


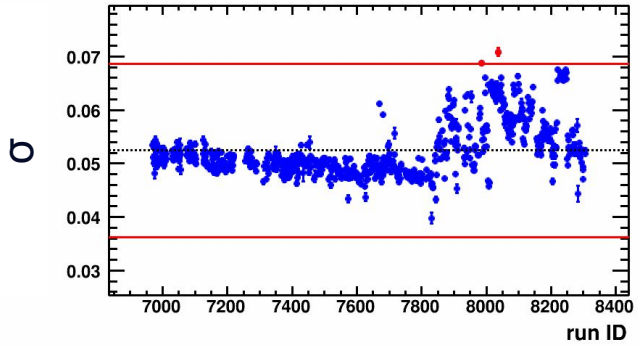




TOF-700







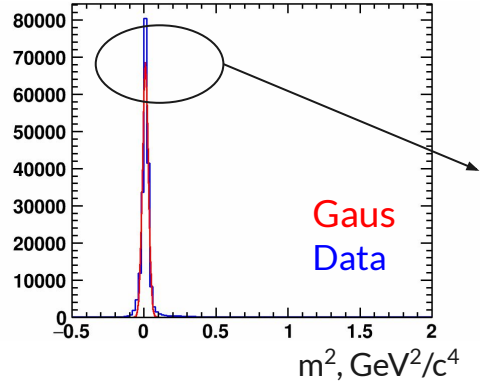
QA Run-by-Run: π^-

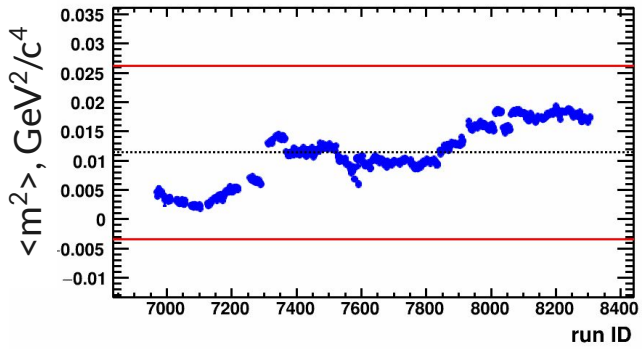
Runs 6900-7200 are in progress…

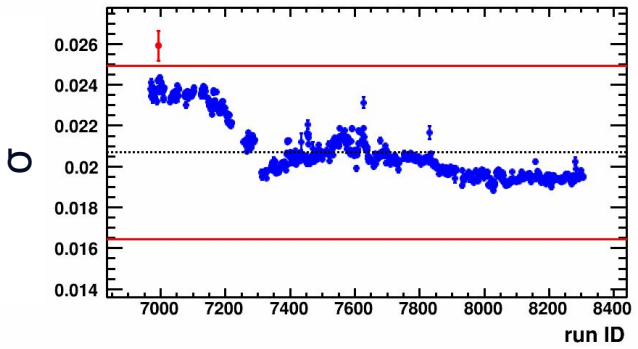
Fit of each run ID with Gaus

$0.2 < p < 2.0$ GeV^2/c^4

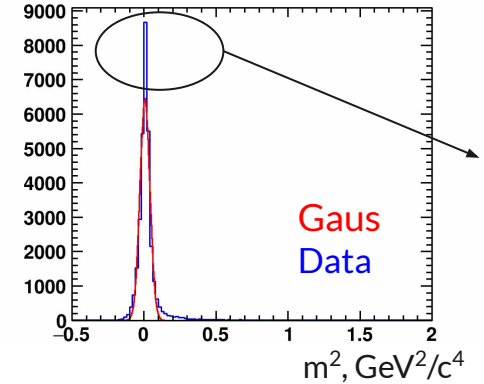
TOF-400

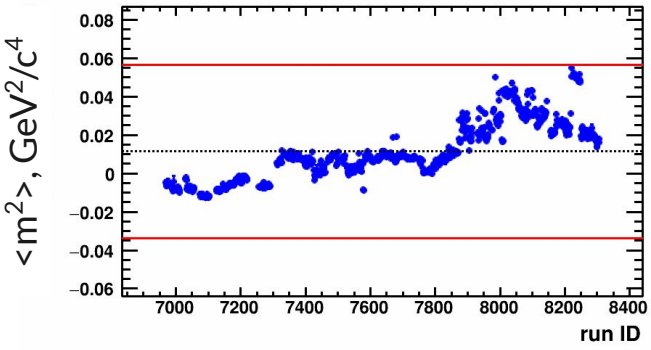


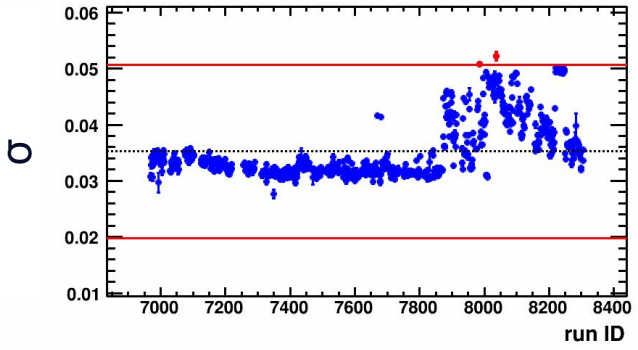




TOF-700







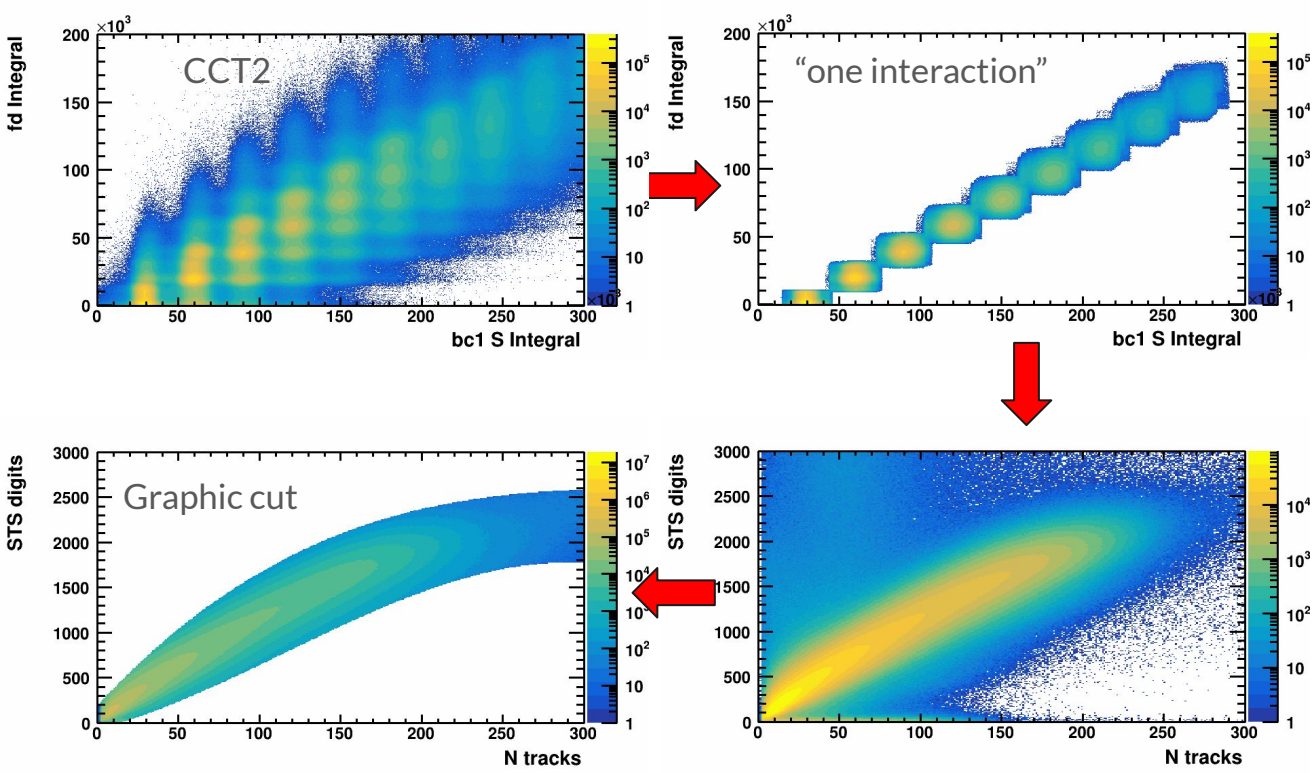
Bad Runs

RunId: 7313, 7415, 7417, 7435, 7469, 7517, 7519, 7520, 7537, 7575, 7604, 7630, 7657, 7659, 7679, 7681, 7705, 7735, 7843, 7847, 7848, 7850, 7851, 7852, 7853, 7855, 7856, 7857, 7858, 7859, 7865, 7868, 7907, 7931, 7932, 7933, 7935, 7937, 7938, 7939, 7954, 7955, 8031, 8032, 8033, 8115, 8121, 8167, 8201, 8204, 8205, 8208, 8209, 8210, 8211, 8212, 8213, 8215, 8247, 8265, 8266, 8267, 8281, 8289

Pileup

Pileup:

1. Select events with CCT2
2. Select events with “one interaction” (next slide):
   a. Fit of each run ID with Gaus (bc1s,fd)
   b. Scale
   c. Select events with “one interaction”
3. Graphic cut:
   a. Fill StsDigits vs nTracks
   b. Fit of each nTracks bin with Gaus
   c. fun(nTracks,StsDigit)

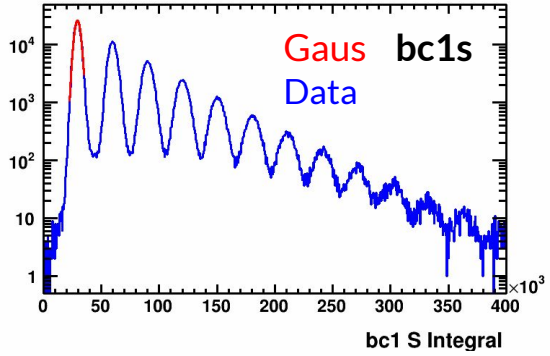


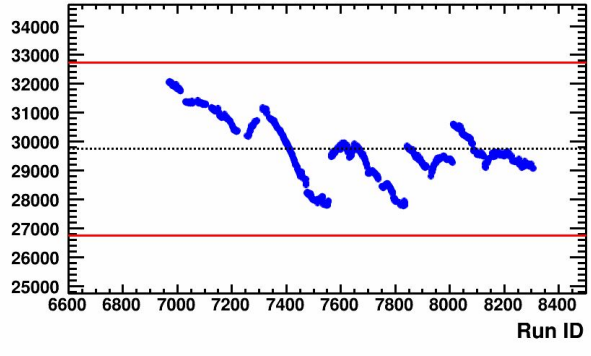
Vtx > 1

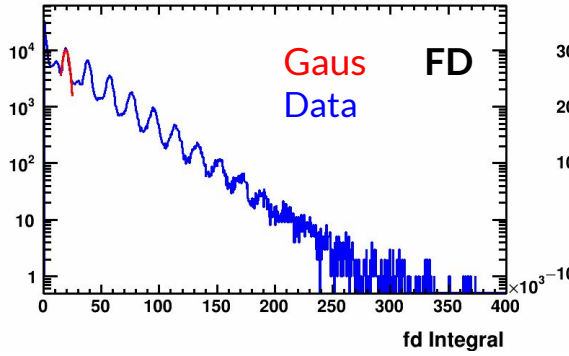
BC1 andFD Integral cut improvement

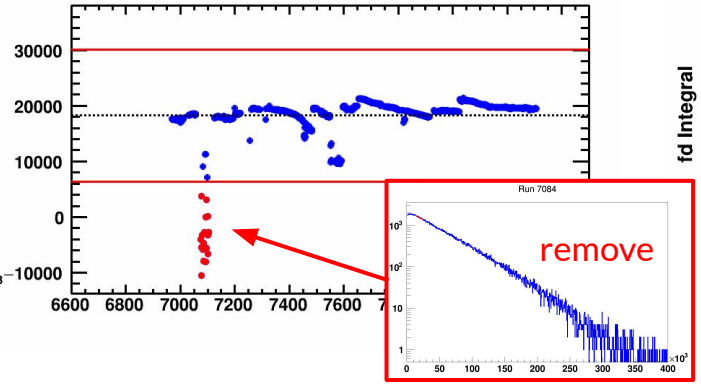
Only CCT2

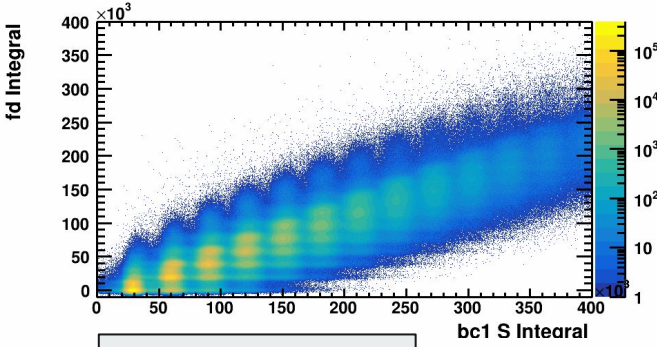
Fit of each run ID with Gaus (first peak)

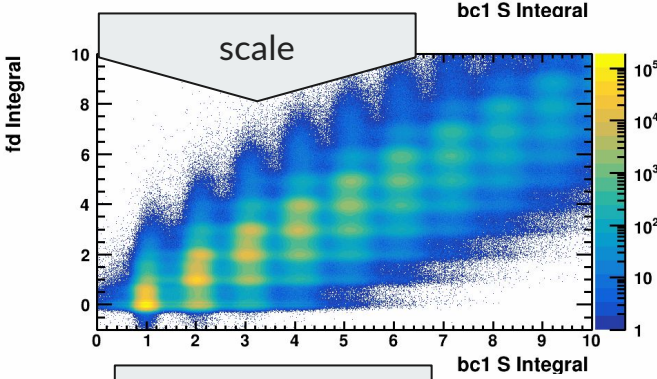


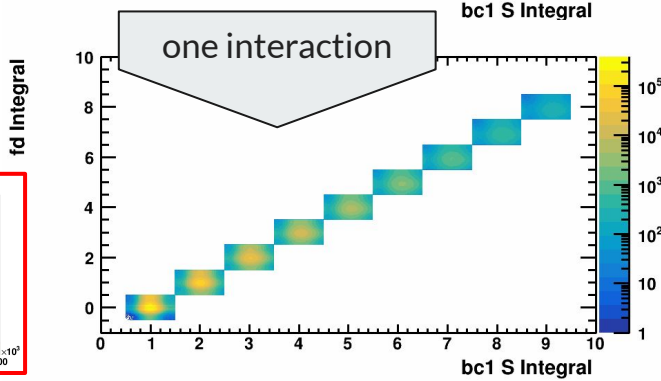










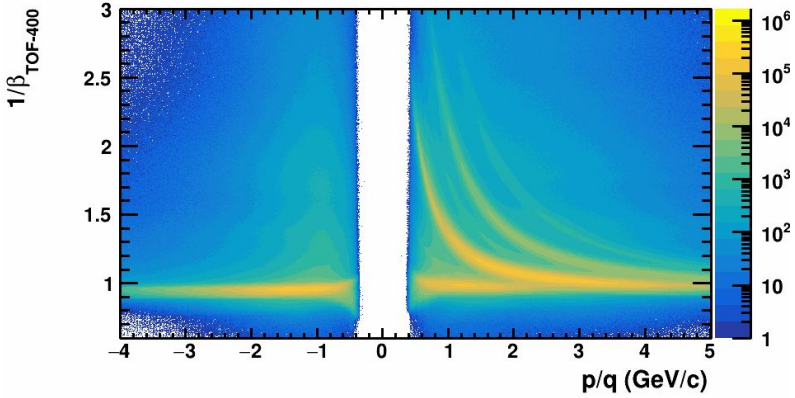


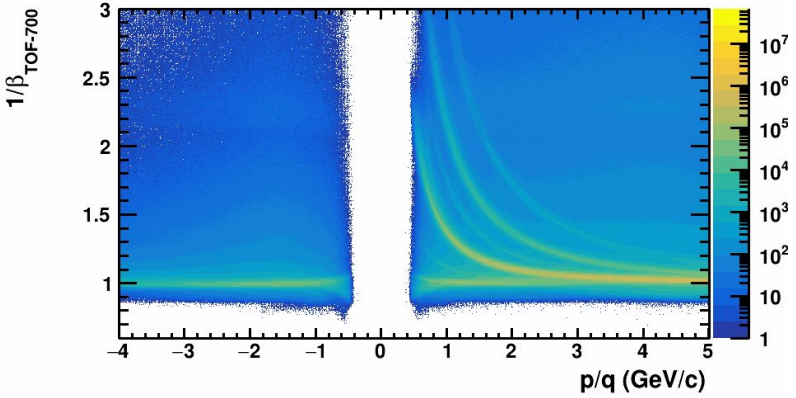
Square mass

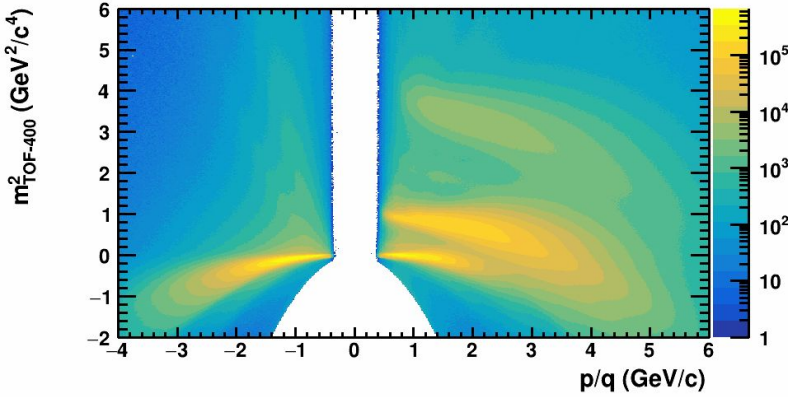
TOF-400

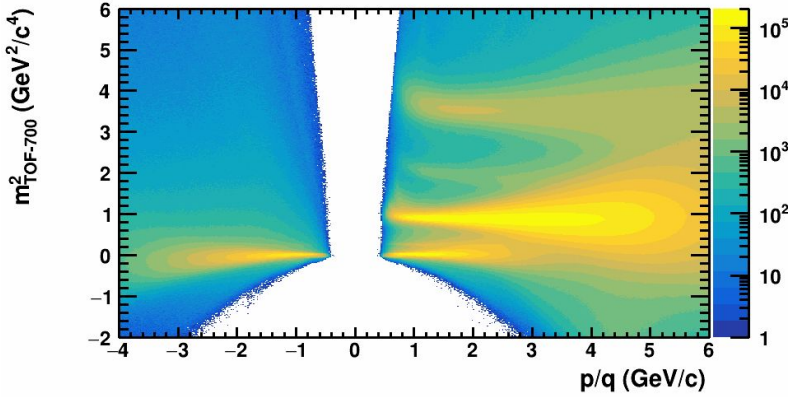
$$m^2 = \frac{(1-\beta^2) * p^2}{\beta^2}$$

TOF-700





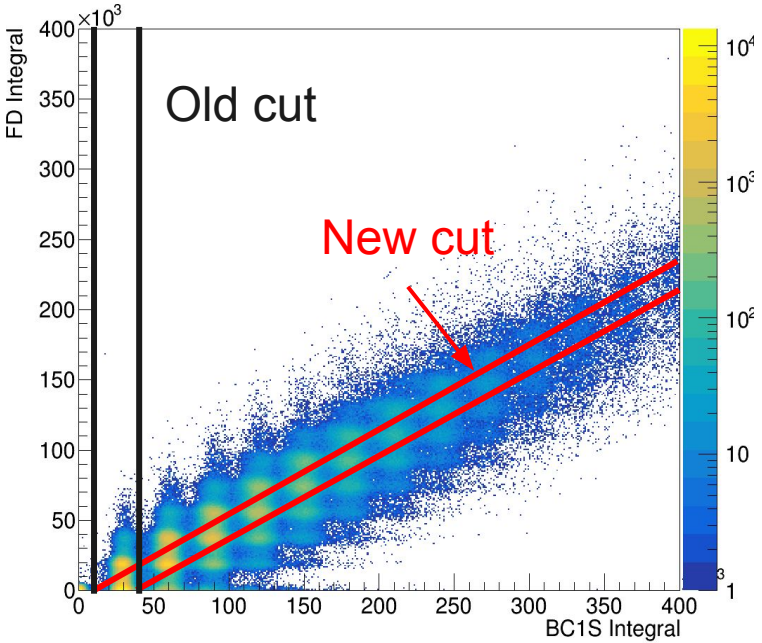




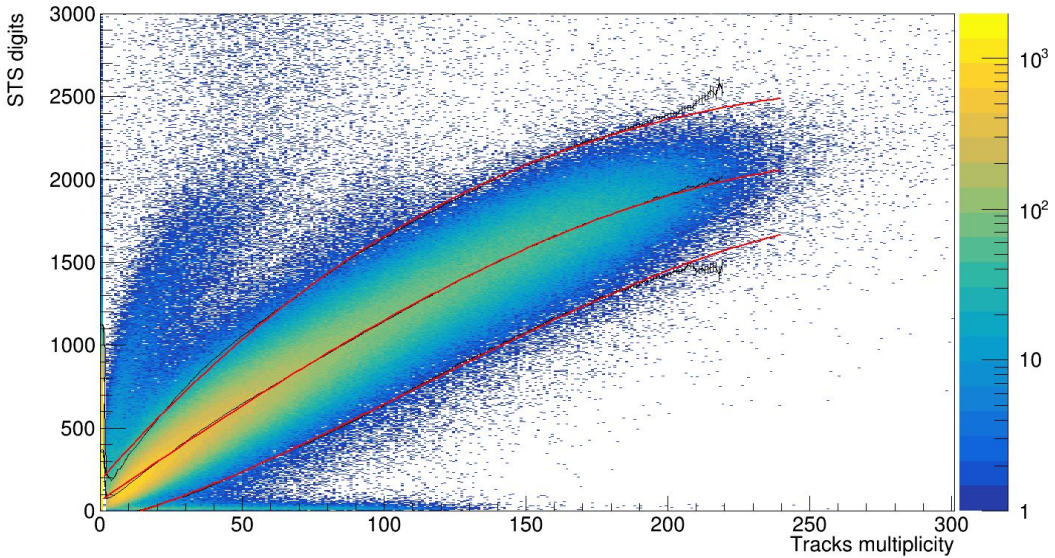
BC1 Integral cut improvement

See the talk of I.Segal for details

- CCT2 trigger
- More than 1 track for vertex reconstruction

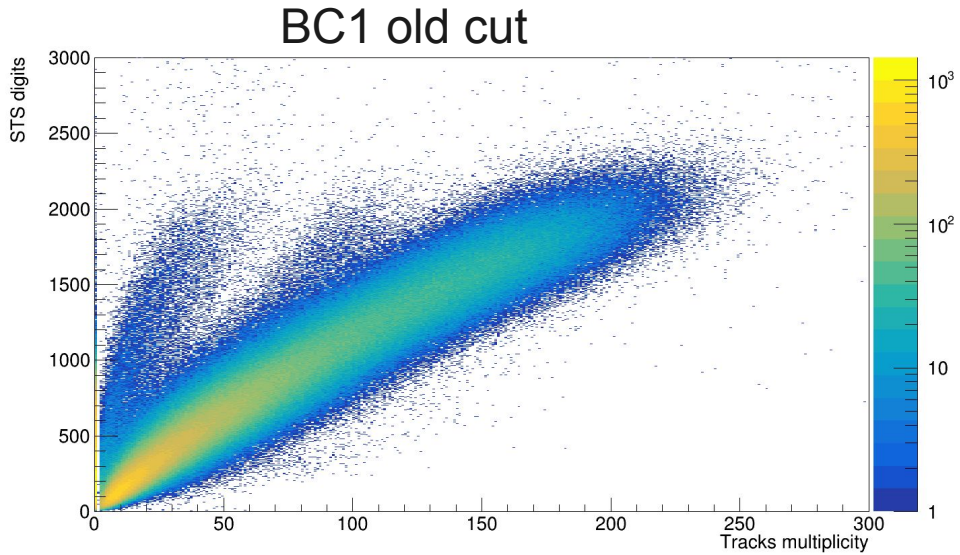


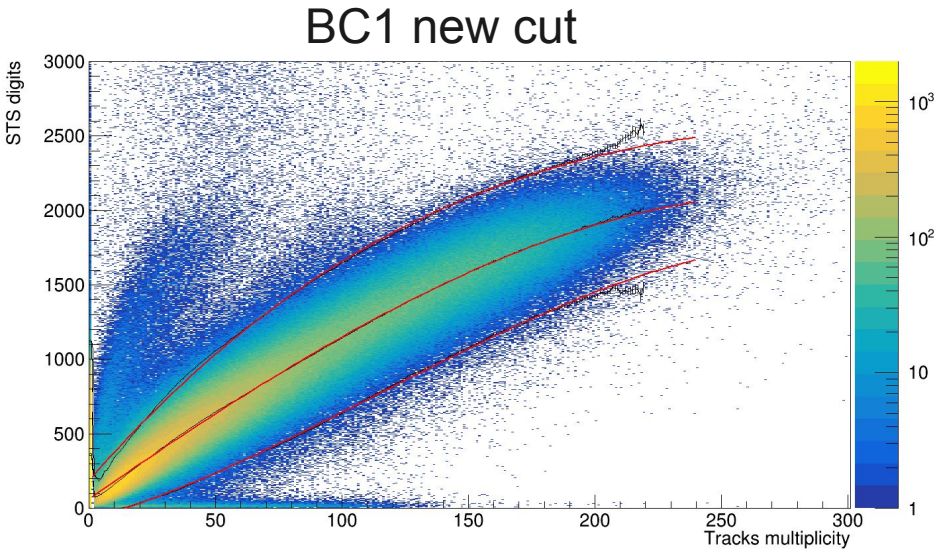
BC1 new cut



We have more events after the New cuts

Additional pileup graphic cut





- Graphic cut was performed to throw out all event unusual behaviour:

  $STS_{max}(N_{tracks})=4.56033e\text{-}05*N^3-0.0518774*N^2+19.4203*N+188.248$

  $STS_{min}(N_{tracks})=-9.62078e\text{-}05*N^3+0.0332792*N^2+4.81632*N-74.0087$

- Difference: