Evaluation of Cavern Background by measuring MDT hit rates

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Introduction

What's Cavern Background: The intense beams and large cross sections at the LHC give rise to high flux of background throughout the ATLAS detector cavern. This background compose mainly of low energy neutrons and photons. neutrons scatter multiple times in the detector, forming a long lived neutron gas. Those neutrons can excite atoms in detector and ATLAS cavern. The excited atoms emit photons when they fall back to ground states. Photons can also be created from other methods. Those neutrons and photons can create a significant amount of background hits which called cavern background.

Why to evaluate it: This background can cause radiation damage to detector elements and front-end electronics. The induced hits increase detector occupancy. It is important to properly simulate this background so we can understand the sources and attempt to shield them.
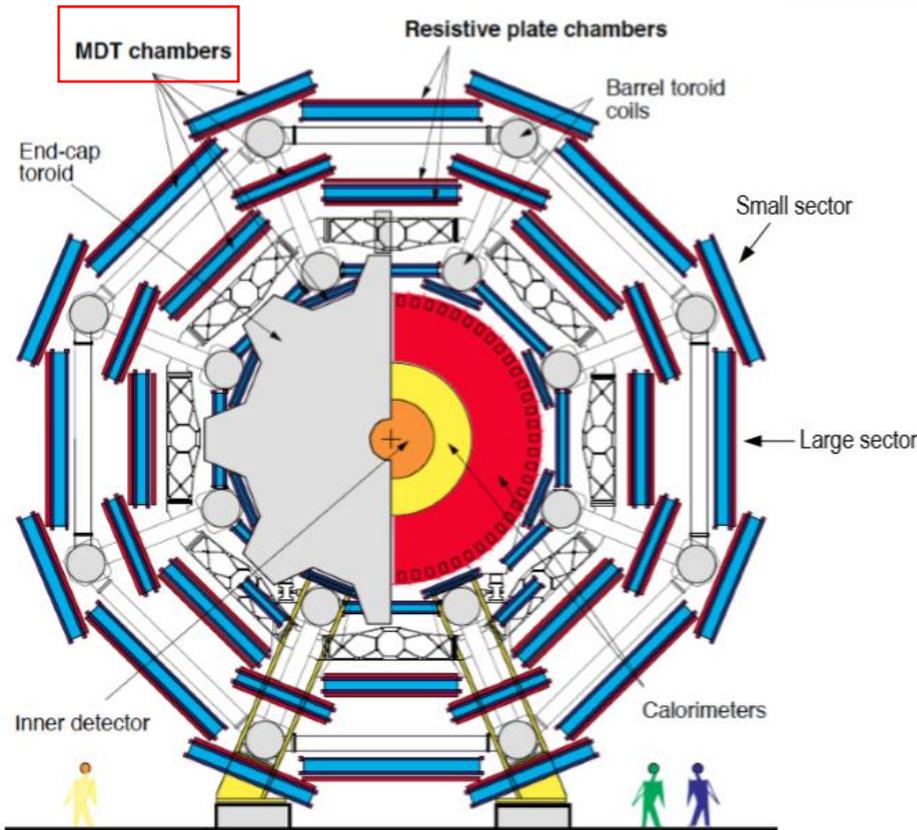
Introduction
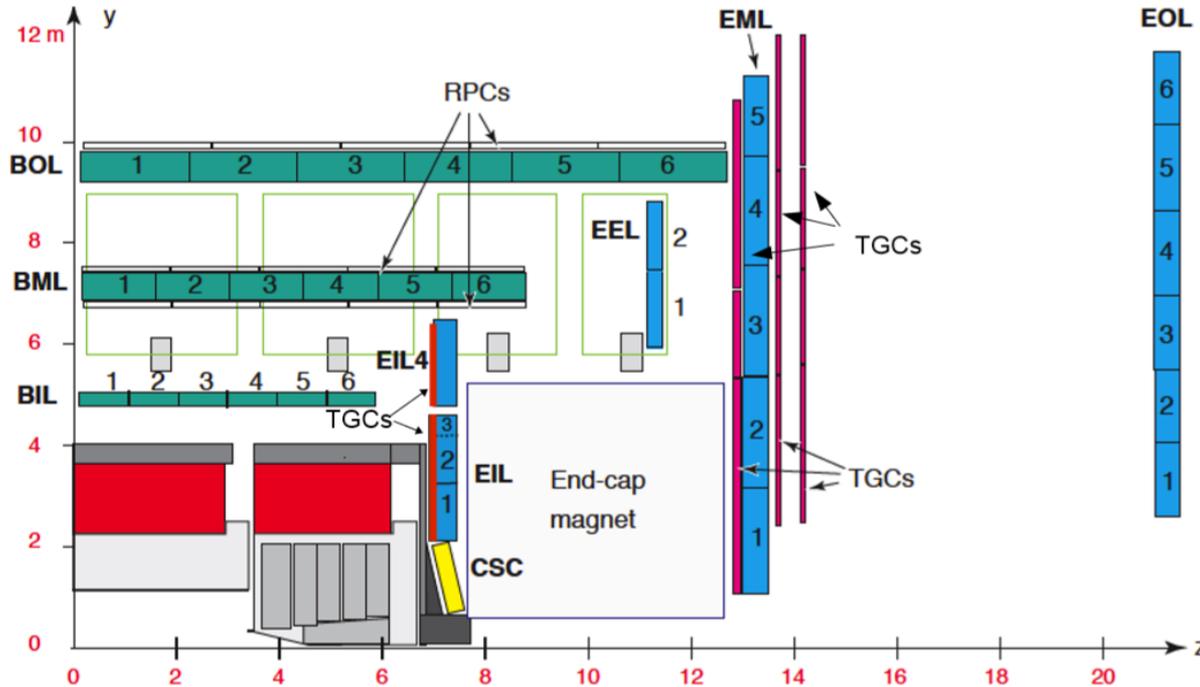
monitored drift tube (MDT) as part of MS which used for track and momentum measurement, covering the region in pseudo rapidity up to $|\eta| < 2.7$.

R-Z view of the present(Run1/2) ATLAS muon spectrometer layout.The green (blue) chambers labelled BIL, BML, BOL, EIL, EEL, EML, EOL) are MDT chambers in the barrel (endcap) regions of the spectrometer.

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Introduction

In the MDT systems the MS is sub-divided in azimuthal direction (φ) into 16 sectors, eight large (L) and eight small (S) ones, covering 14∘ and 8.5∘, respectively. Large sectors are located in-between the eight barrel toroid coils, and small sectors overlap in φ with the coils.

View of the present (Run 1/2) ATLAS muon spectrometer barrel layout in the plane transverse to the beam axis (X-Y plane).

Dataset
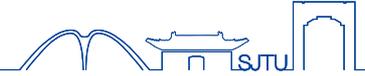
Good run list:

data17_13TeV.periodAllYear_DetStatus-v97-pro21-13_Unknown_PHYS_StandardGRL_All_Good_25ns_Triggerno17e33prim.xml

Run: 335290   379 lumi blocks 84.70 % Good

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379

Run Number	Ncollidingbunch	Lpeak[$x10^{30} cm^{-2}s^{-1}$]
331875	2544	15592
332304	2544	13579
335290	1909	10457
332953	1152	7048
332915	973	6102
332896	589	3485

Datasets to produce muon trigger ntuple:

For colliding bunches:

```
data17_13TeV.00331875.physics_ZeroBias.recon.ESD.f848
data17_13TeV.00332304.physics_ZeroBias.recon.ESD.f851
data17_13TeV.00335290.physics_ZeroBias.recon.ESD.f868
data17_13TeV.00332953.physics_ZeroBias.recon.ESD.f854
data17_13TeV.00332915.physics_ZeroBias.recon.ESD.f854
data17_13TeV.00332896.physics_ZeroBias.recon.ESD.f854
```

For empty bunches:

```
data17_13TeV.00331875.express_express.recon.ESD.f848
data17_13TeV.00332304.express_express.recon.ESD.f851
data17_13TeV.00335290.express_express.recon.ESD.f868
data17_13TeV.00332953.express_express.recon.ESD.f854
data17_13TeV.00332915.express_express.recon.ESD.f854
data17_13TeV.00332896.express_express.recon.ESD.f854
```

Hit Rate

The instantaneous rate R_{inst} [Hz] in a given detector element of MDT is defined as

$$R_{inst} = \frac{N_{hits}}{N_{total}} \cdot \frac{1}{\Delta t}$$

where

- N_{hits} is the total number of hits recorded in a given detector element.

- N_{total} is the total number of events collected for each run.

- Δt is the time for which the detector element is active and recording data around the collision of interest. For MDTs it is taken to be 1300 ns; a long time window as compare to other detectors like TGC's have a livetime of 50-75 ns. So therefore in MDTs many hits are recorded from incident particles arising from proton collisions long before and after the collision which triggered the event.

As different detector elements in MDTs have different surfaces, the local flux; R_ϕ [Hz/cm^2] is calculated for each detector element as the ratio between the instantaneous luminosity and detector active area. Detector active area is obtained by summing up the active area of each detector element.
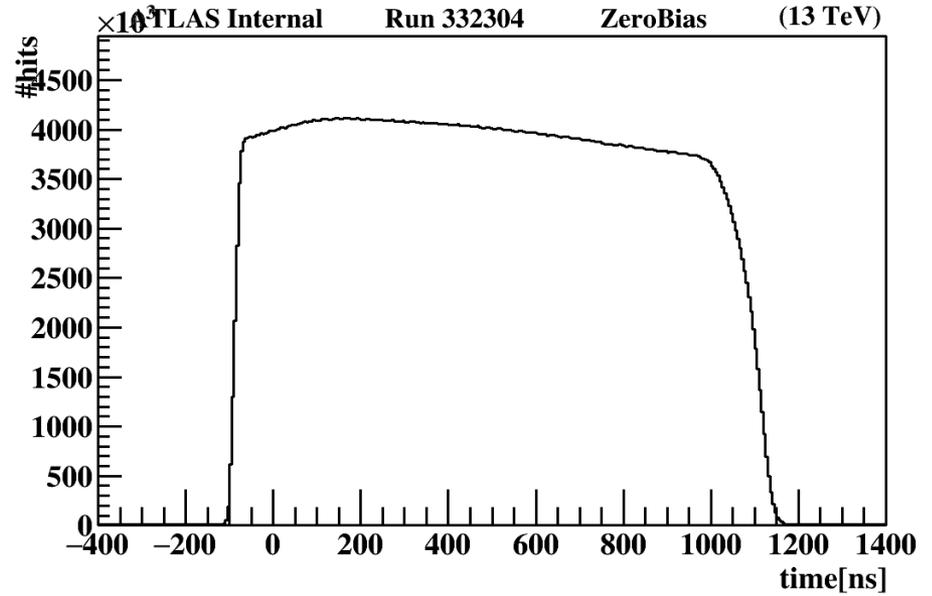
$$R_\phi = \frac{R_{inst}}{active\ area}$$

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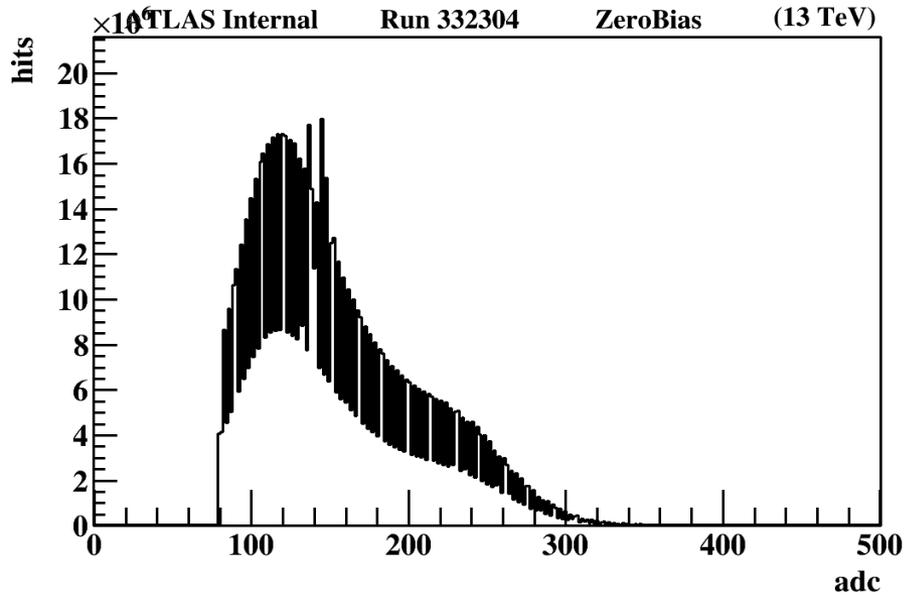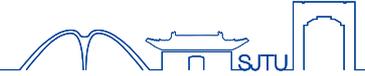
Hit Rate

ADC

To suppress the electronic noise only hits with ADC count greater than 80 is included for further study
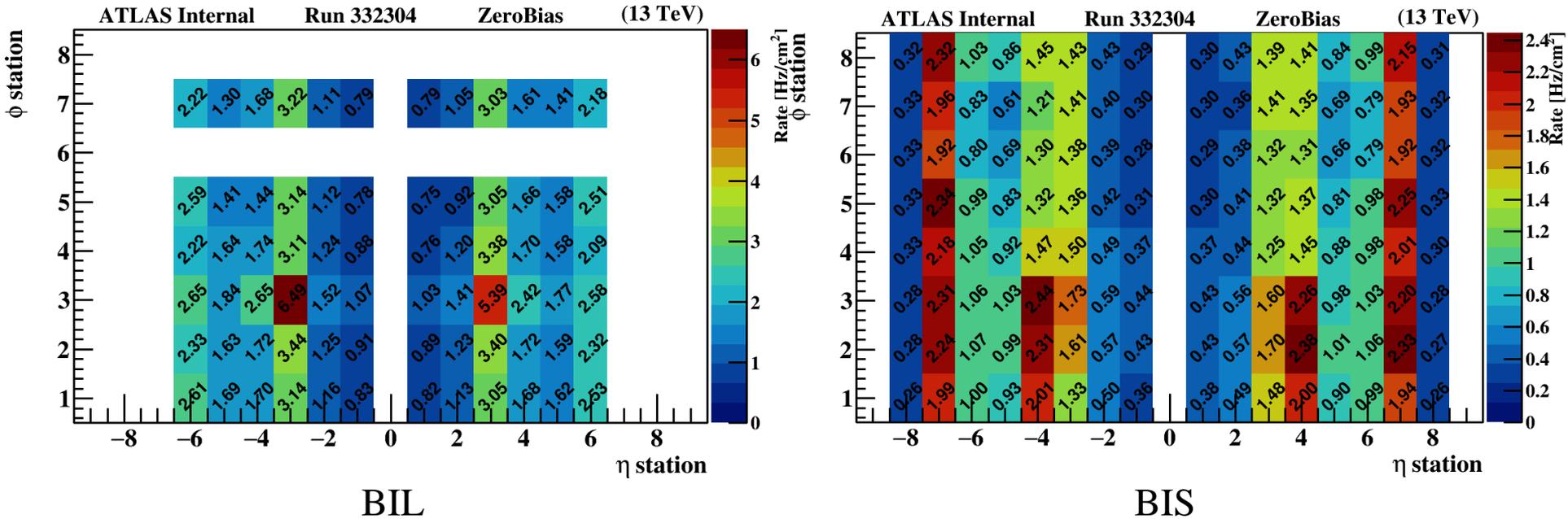

Drift Time

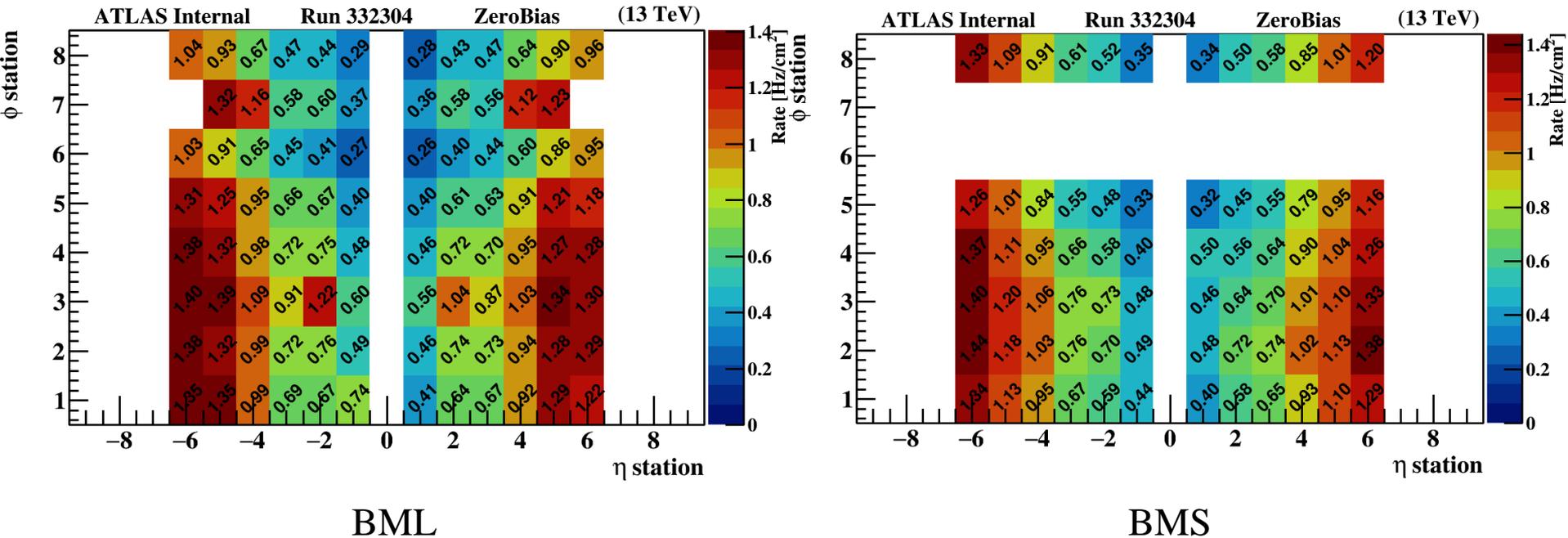drift time which is used to estimate Δt which is taken to be 1300ns for MDT.
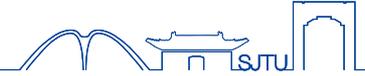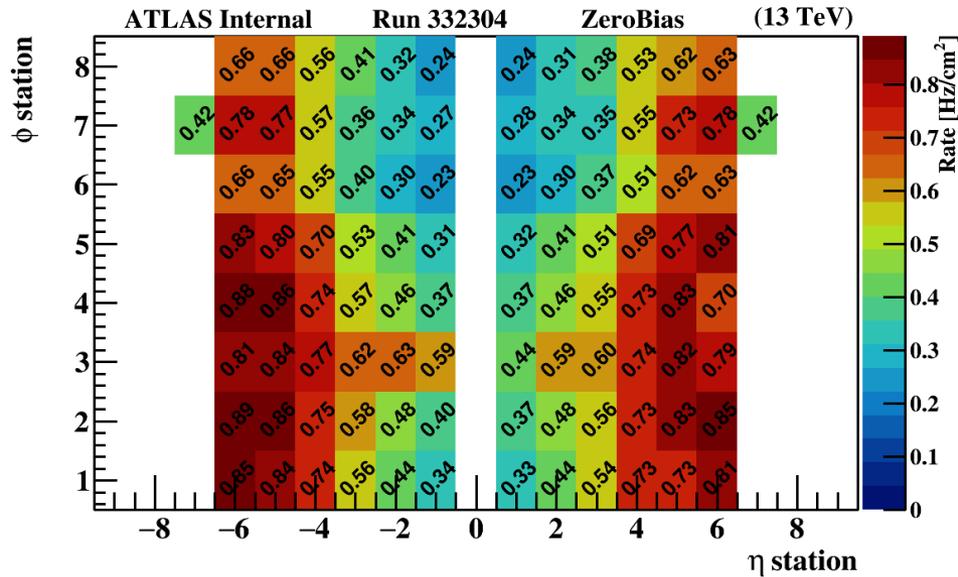
Hit Rate

BIL

BIS

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf   https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds

Hit Rate

BML
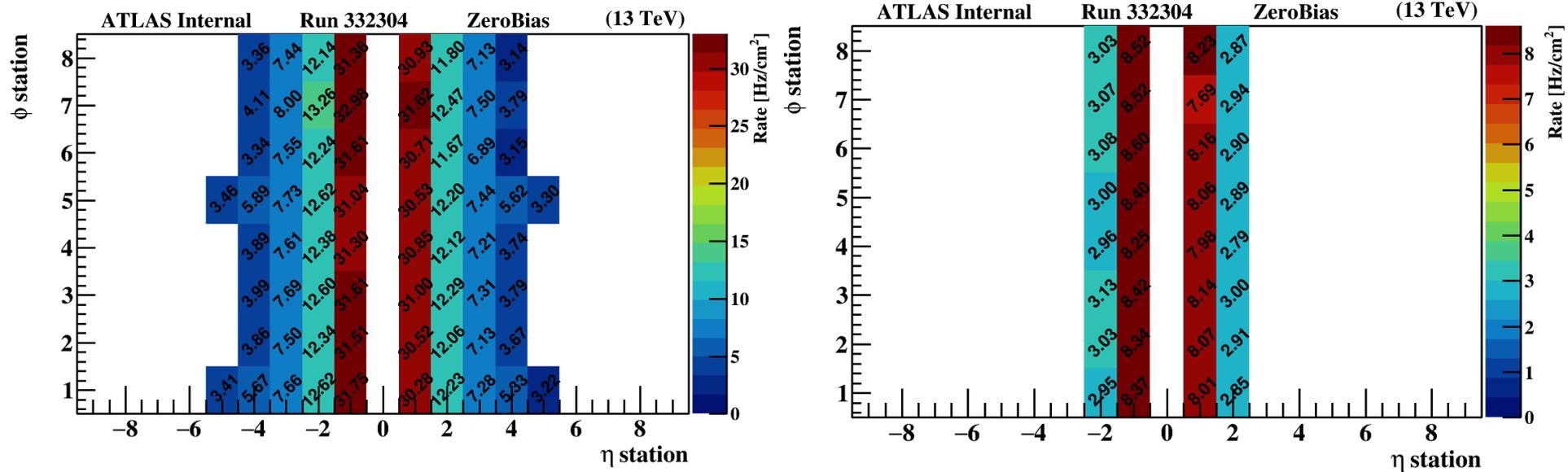

BMS

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf   https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds

Hit Rate

BOL

BOS

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

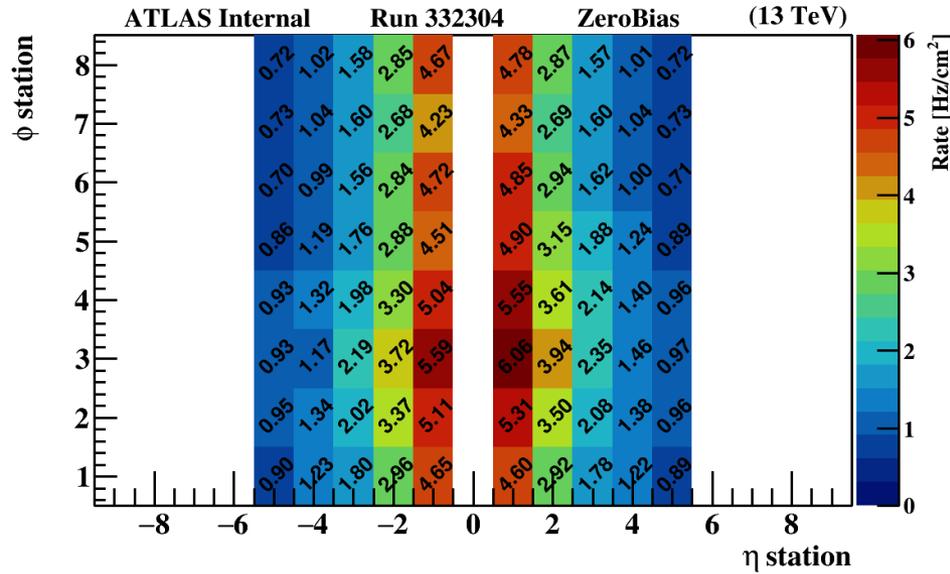Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf   https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds
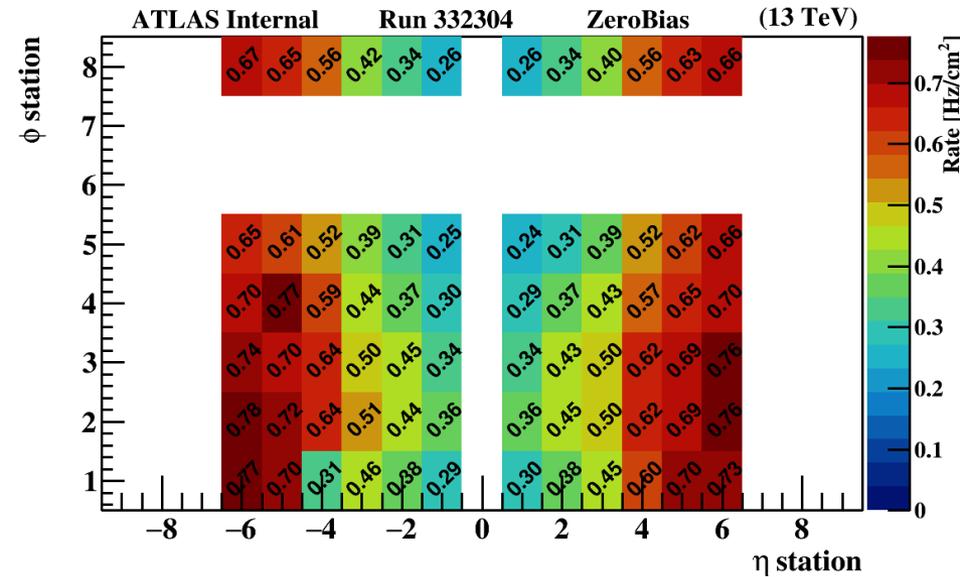
Hit Rate

EIL

EIS

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

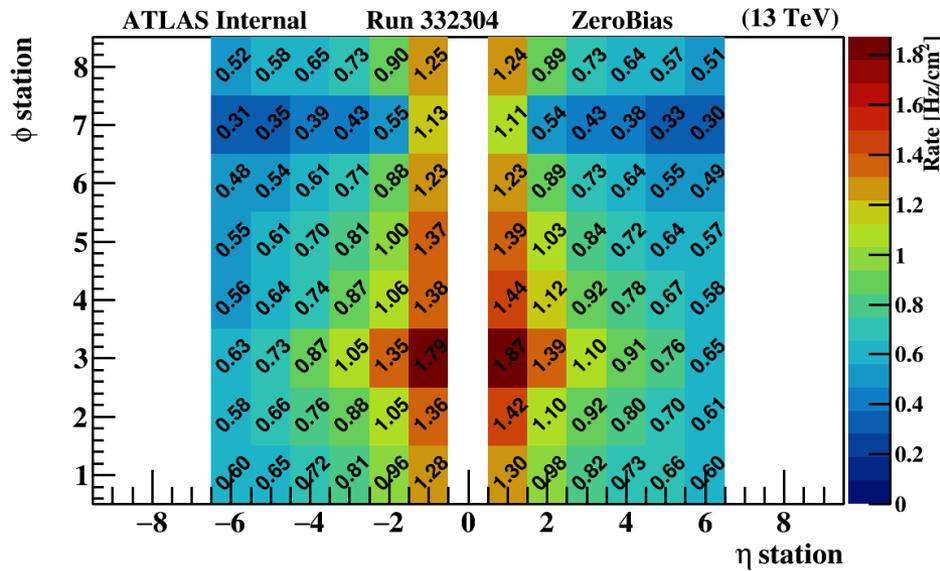Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds

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Hit Rate

EML

EMS

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf   https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds

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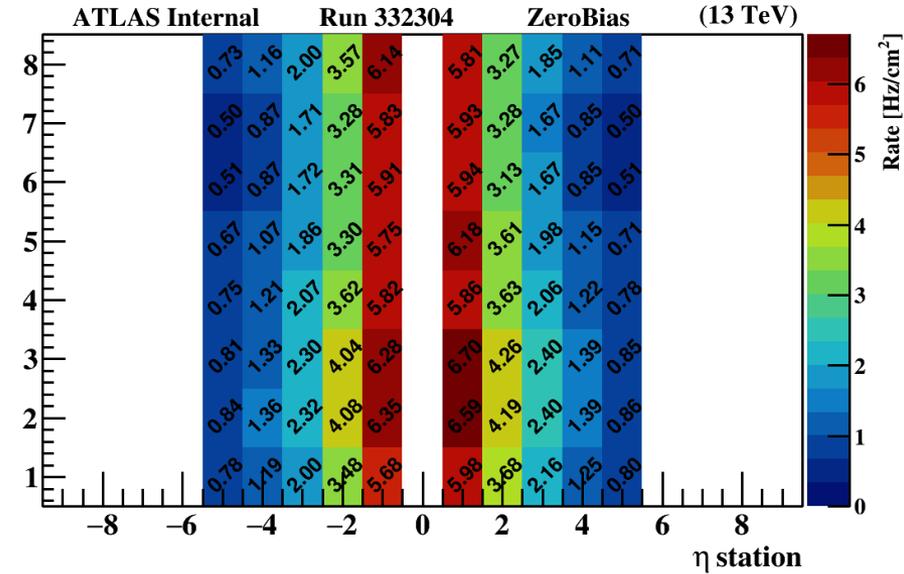
Hit Rate

EOL

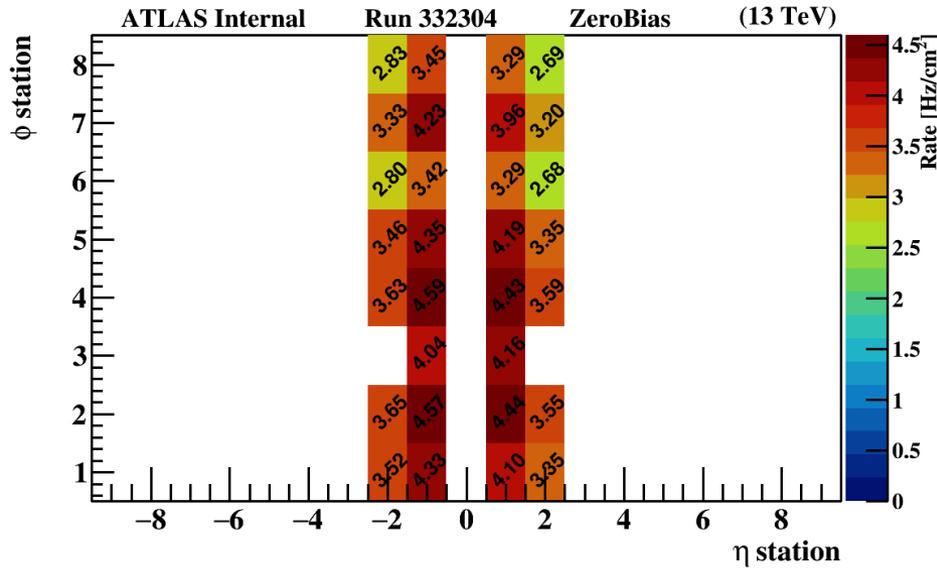EOS

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds

15
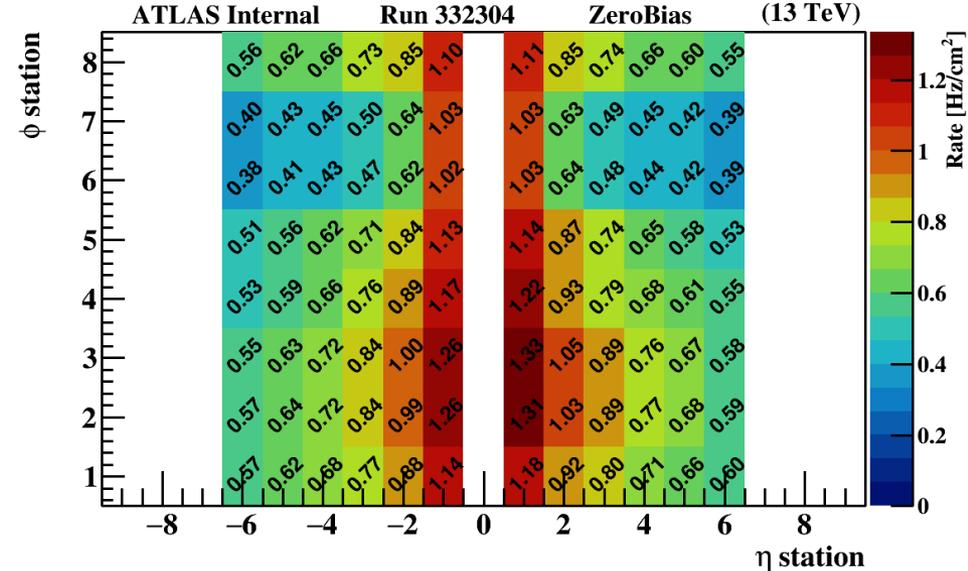
Hit Rate

EEL

EES

Hit rate distributions in BIL and BIS are similiar with the those of 16data.

Hit rate distribution can check those links for reference: https://cds.cern.ch/record/1513176/files/ATL-COM-MUON-2013-003.pdf   https://twiki.cern.ch/twiki/bin/view/Main/CavernBackgrounds
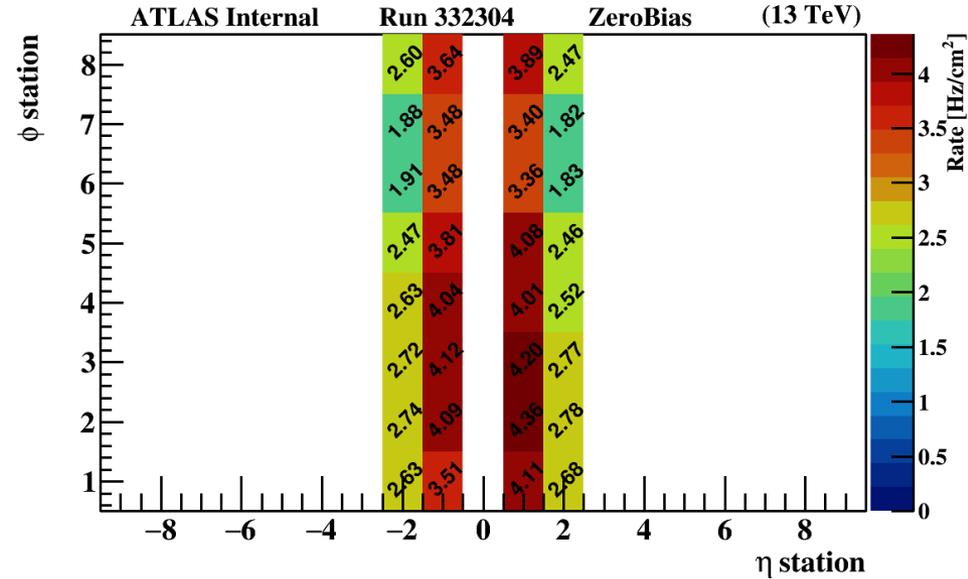
Hit Rate Estimation-colliding bunches

First of all to measure hit rate as function of instantaneous luminosity, its important to verify the linear relationship between rate and luminosity with the data. The average rate is calculated from ZeroBias triggers using the following relations:

$$R_{ZB} = R_{ZB}^{inst} \cdot \frac{N_{coll}}{N_{TB}}$$

where:

- R_{ZB}^{inst} : the instantaneous rate as defined

- N_{coll} : number of colliding bunches

- N_{TB} : total number of colliding bunches (3564)
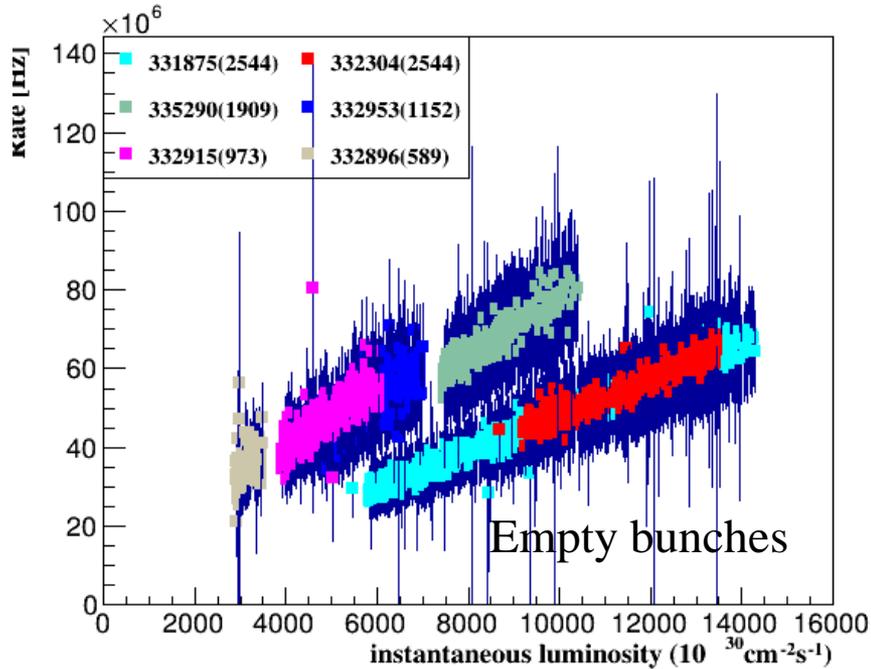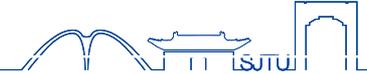
Hit Rate Estimation-empty bunches

The average rate is calculated from empty triggers using the following relations:

$$R_E = R_E^{inst} \cdot \frac{N_{TB} - N_{coll}}{N_{TB}}$$

Finally the total rate is calculated as summing the contribution from Zero-bias and empty triggers.
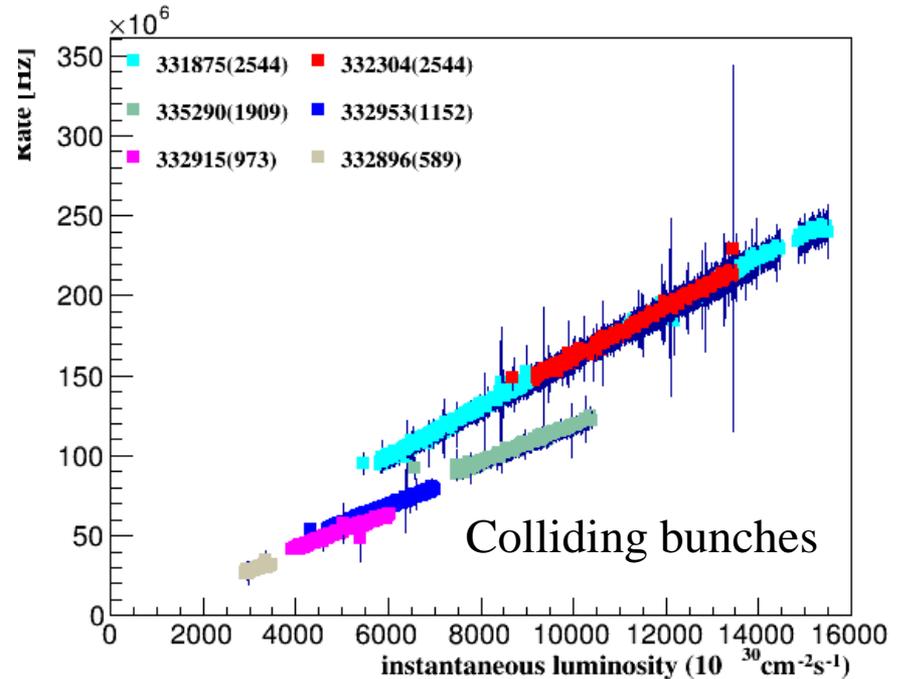
$$R_{Tot} = R_{ZB} + R_E$$

Empty bunches

Colliding bunches

Using trigger:
HLT_noalg_idmon_L1RD0_EMPTY

No trigger needed

$$R_{Tot} = R_{ZB} + R_E$$

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$$R_{Tot} = R_{ZB} + R_E$$
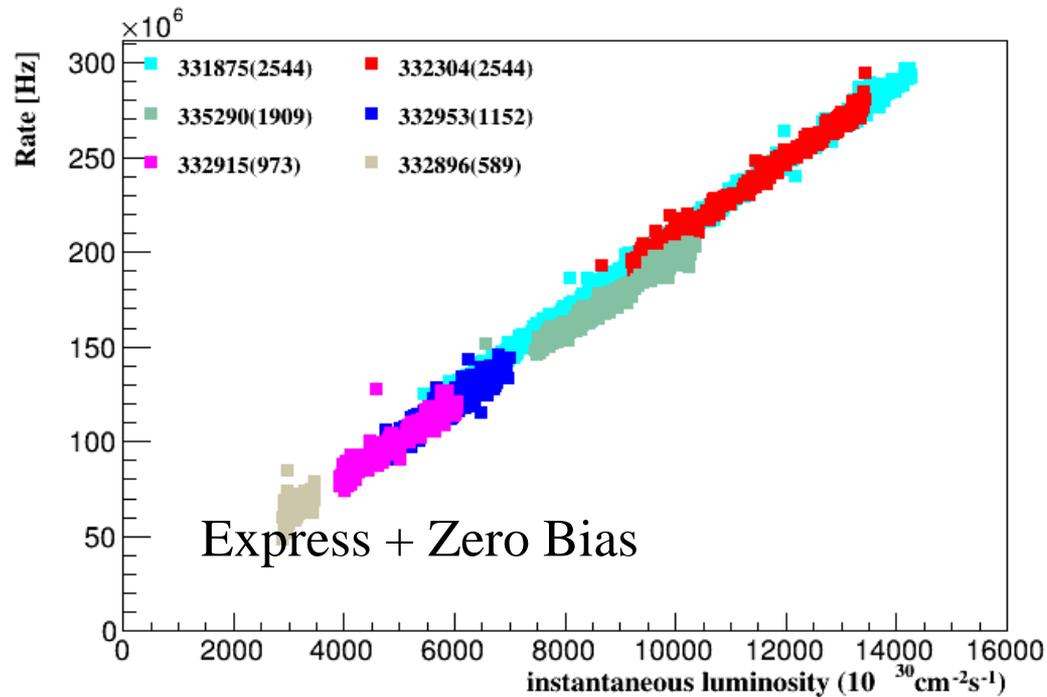
The linear relationship between hit rate and luminosity

Rate estimation with simulation

MC HITS sample: ⟶ MC ESD sample:

user.xiangke.CavernBkg.HITS_EXT0/   user.xiangke.Cavern.Bkg.15.Mu.31.5_EXT0

Same <Mu> with data

2017data
Run number 332304

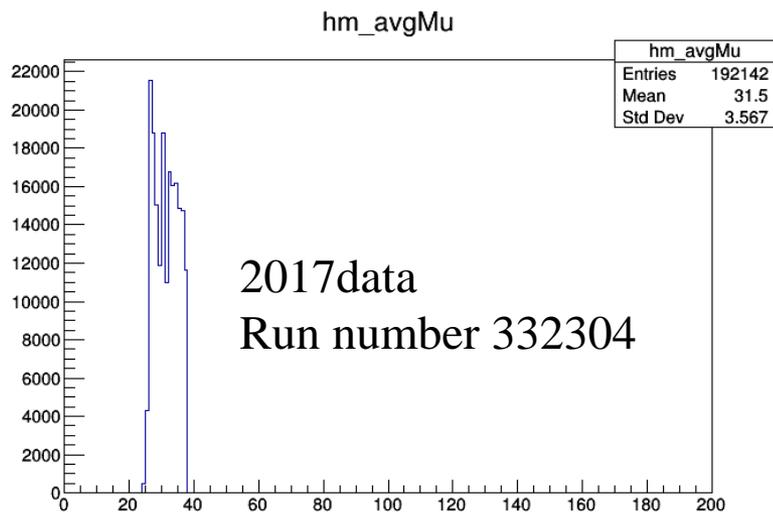MC muon trigger ntuple sample:

user.xiangke.muTrigNt.TestMu.31.5.Cavern.
Bkg.15.Mu.31.5_EXT0_EXT0

Simulation code is in the back up

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https://gitlab.cern.ch/xiangke/CavernBackground/tree/master

MC hit rate Estimation

Take pile up as 40, number of cavern background as 25, number of total bunches as 3543, the number of colliding bunches of MC samples can be calculate as following:

$$N_{coll} = \frac{n_{Cav}}{\mu} \cdot N_{TB} = 2214$$

Take inelecstic cross section as 80mb, $\Delta t = 25$ nsThe luminosity of MC samples can be calculated as following:

$$L_{G4} = \frac{\mu}{\sigma_{inel}\Delta t} \frac{N_{coll}}{N_{TB}} = 1.24 \times 10^{34} cm^{-2} s^{-1} \qquad \Longrightarrow \qquad L_{G4} \propto n_{Cav}$$
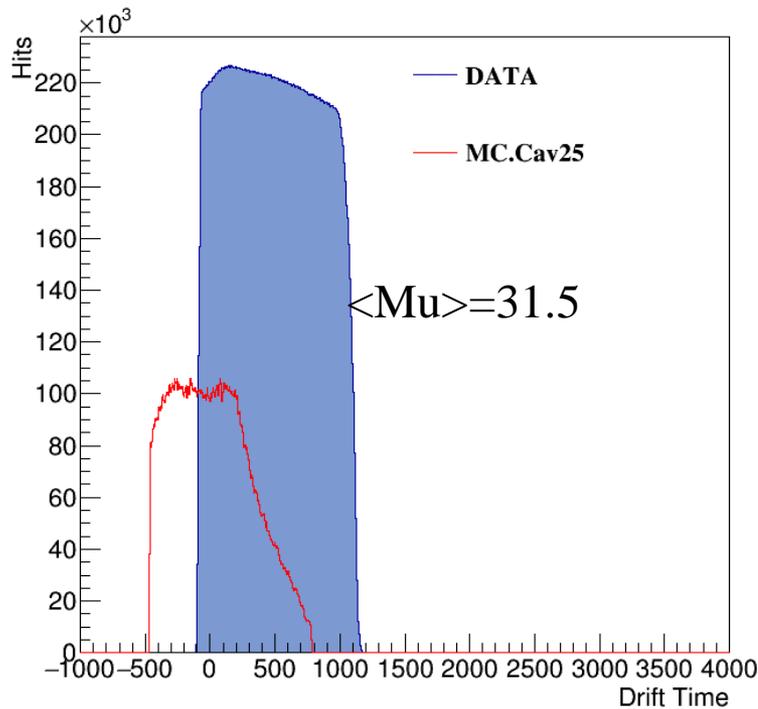
The Total rate of MC can be obtained as following:

$$R_{G4} = R_{inst}^{G4} \cdot \frac{\bar{N}_{coll}}{N_{TB}} \qquad \Longrightarrow \qquad R_{G4} = R_{inst}^{G4} \cdot \frac{n_{Cav}}{\mu}$$

$$R_{inst}^{G4} = \frac{N_{hits}}{N_{events}\Delta t} \qquad \Longrightarrow$$

Same function with data, Δt is the time for which the detector element is active and recording data around the collision of interest.

Compare MC and DATA: drift time distribution

Drift time distribution of 2017 data and MC for 10000 events.

The drift time distribution and total hits are different, the reasons are following:

1. The value of Mu is a range for data, but it's a fixed value for MC.

2. The number of cavern background which set in MC is not the same with the value in data.

3. Other……

Take the range of drift time to be 1300ns both for data and MC , when comparing hit rate, MC hit rate should be weighted by the following value corresponding to real data :

$$\frac{Total\ Hits_{data}}{Total\ Hits_{MC}} = \frac{5.17829e+7}{1.87527e+7} = 2.76135$$

Ncavern / Weight	10	15	20	25
MC	3.03244	2.72988	2.78674	2.76135
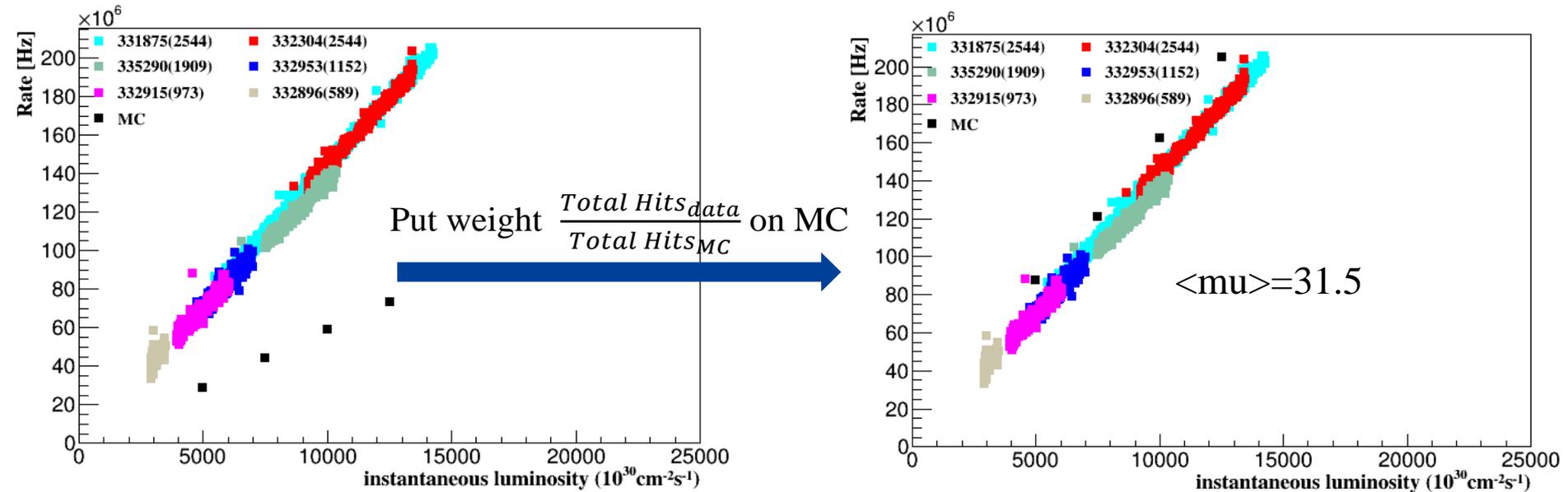
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Put weight $\frac{Total\ Hits_{data}}{Total\ Hits_{MC}}$ on MC

<mu>=31.5

Before the weight is applied , the slopes of hit rate and luminosity are very different between data and MC. That's because the total hits of data are larger than MC at same number of events

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$$R_{G4} = R_{inst}^{G4} \cdot \frac{n_{Cav}}{\mu}$$

After the weight is applied , the slopes of hit rate and luminosity are very close between data and MC.
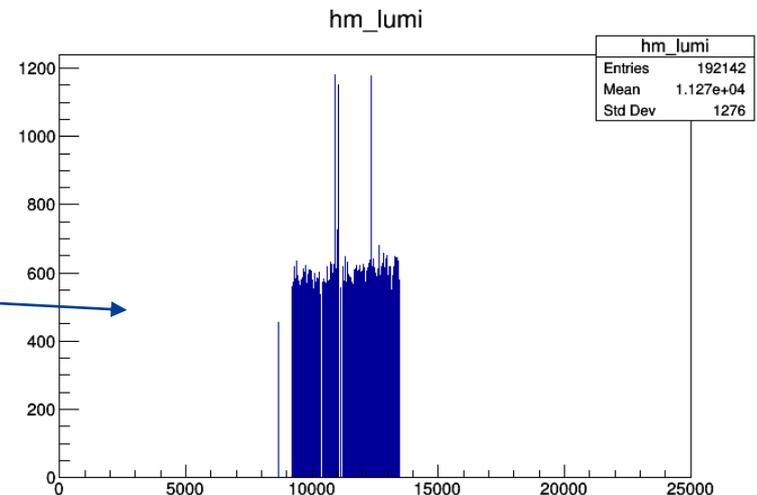
Compare MC and DATA: hit rate

As the luminosity from data is different from that of simulations, before performing the rate comparisons, the data and Geant4 rates have been corrected to luminosity by taking the reference luminosity $L_{ref} = 10^{34} cm^{-2} s^{-1}$
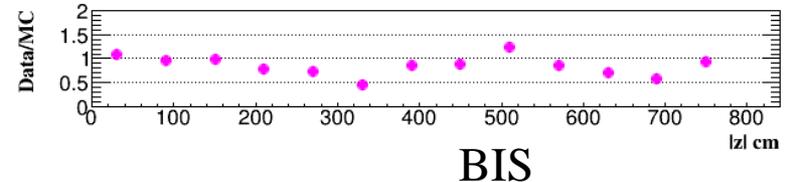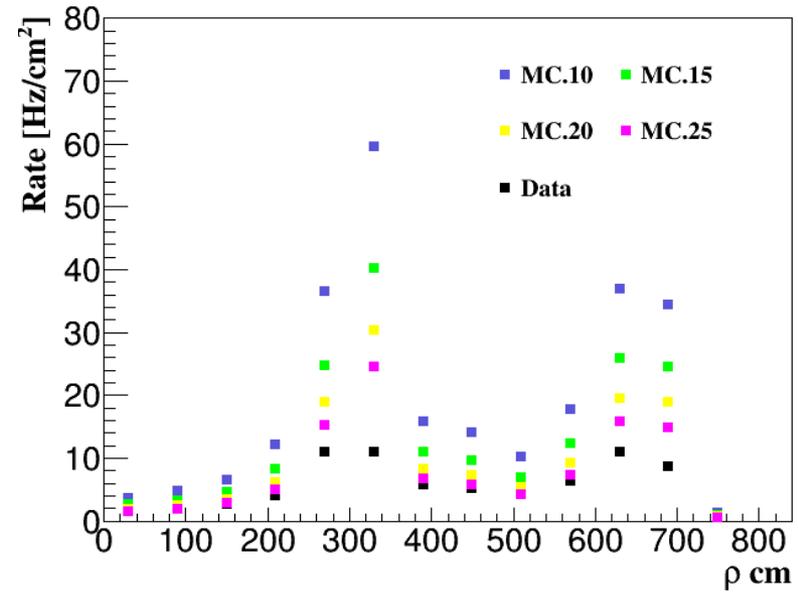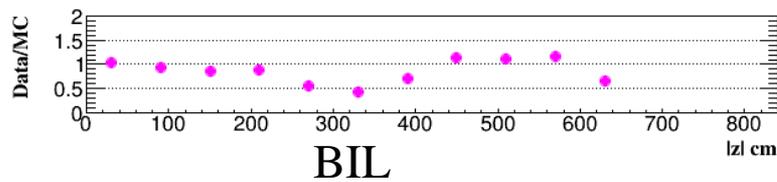
$$R_{Data}^{ext} = R_{Tot} \cdot \frac{L_{ref}}{L_{data}}$$

$$R_{MC}^{ext} = R_{G4} \cdot \frac{L_{ref}}{L_{MC}}$$

The average luminosity measured in data for run 332304 is $1.12 * 10^{34} cm^{-2} s^{-1}$

Compare MC and DATA: hit rate VS |Z|

<mu>=31.5

BIL

BIS
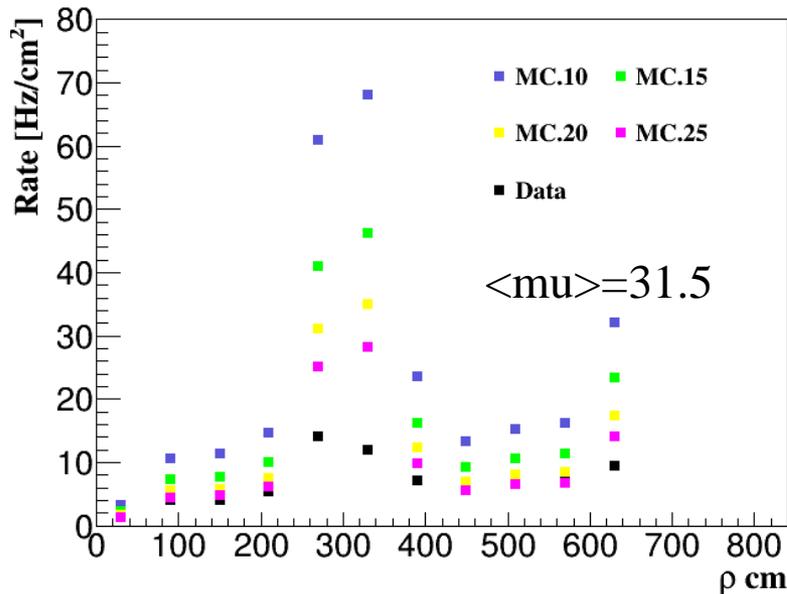
Fix the value of Mu, instantaneous hit rate decrease with the increase of number of cavern background at different region. That's because hit rate scaled by luminosity, for MC sample, luminosity is proportional to number of cavern background. The number of cavern background close to 25.
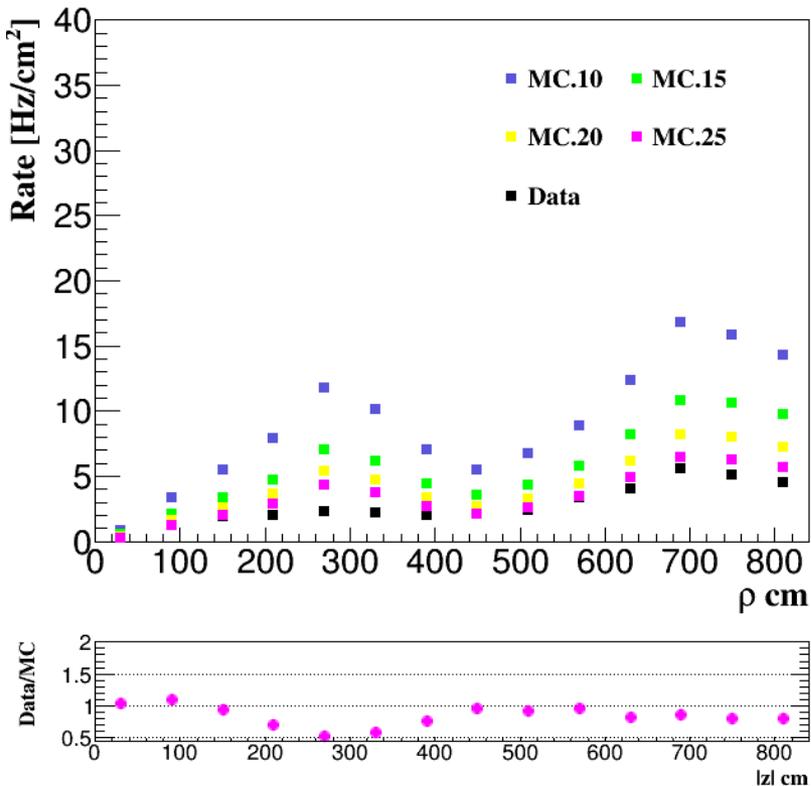
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Compare MC and DATA: hit rate VS |Z|

BML
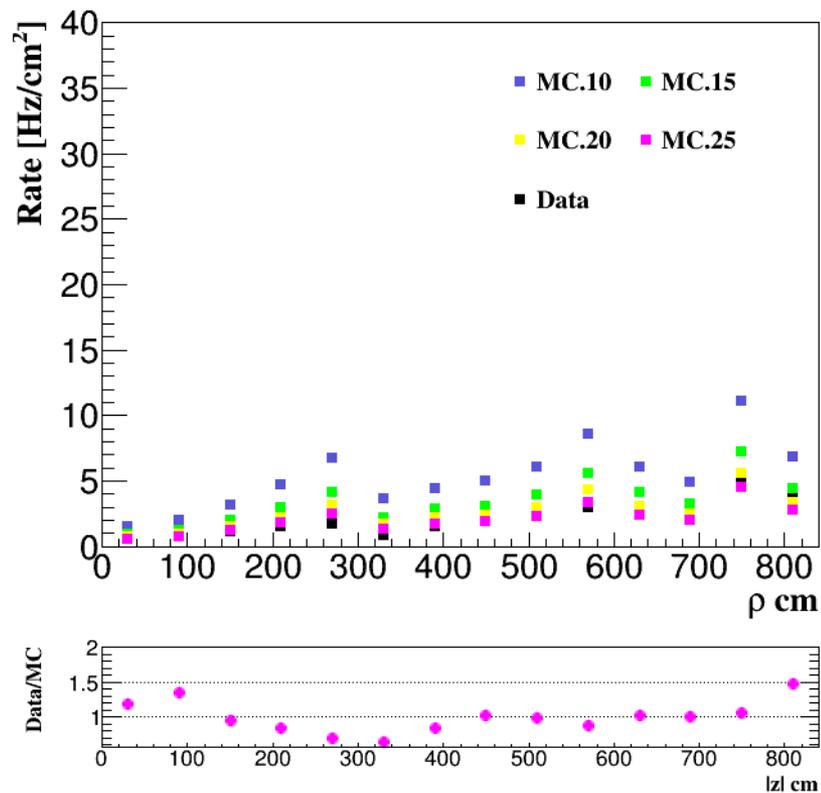
BMS

The number of cavern background close to 25.

BOL

BOS

The number of cavern background close to 20.

Compare MC and DATA: hit rate VS |Z|

EIL

EIS

The number of cavern background close to 25.

Compare MC and DATA: hit rate VS |Z|

EML

EMS
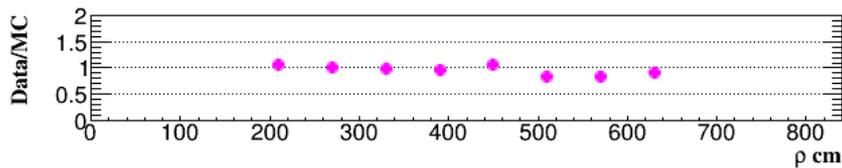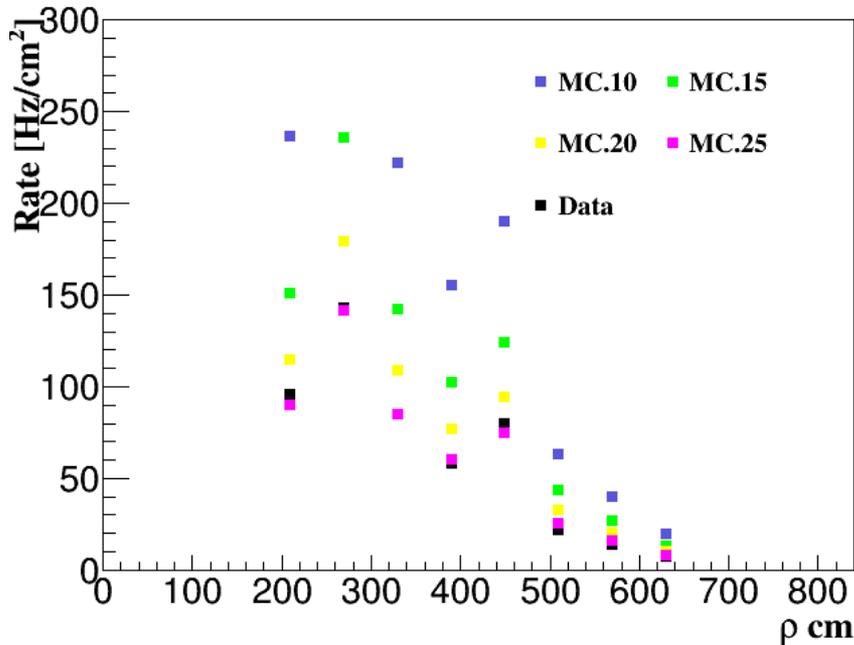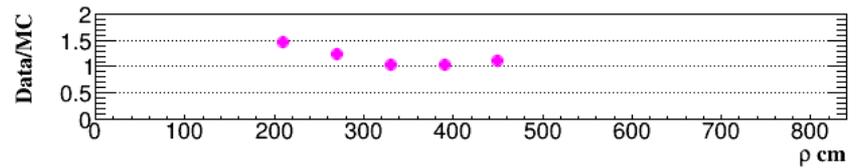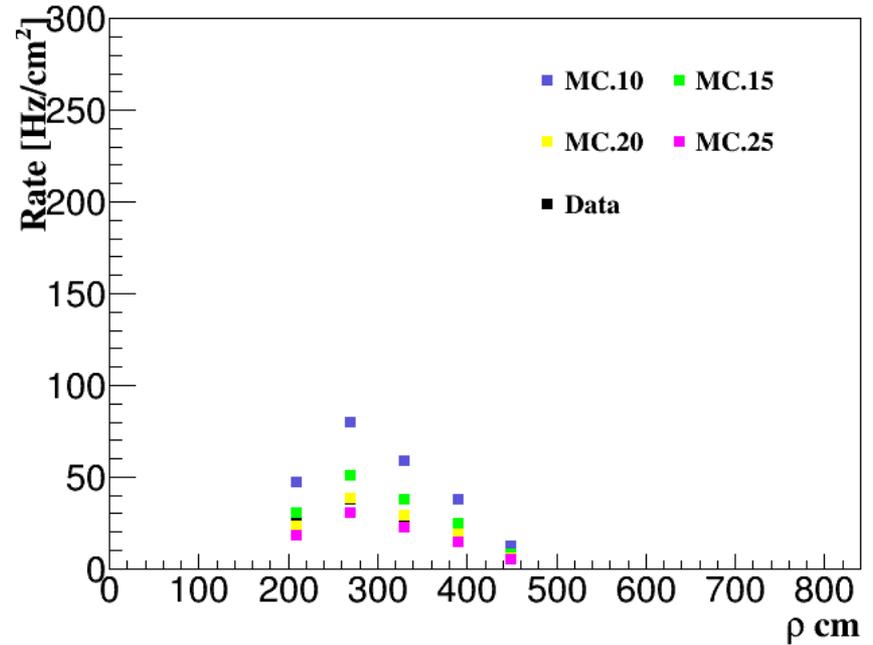
The number of cavern background close to 25.
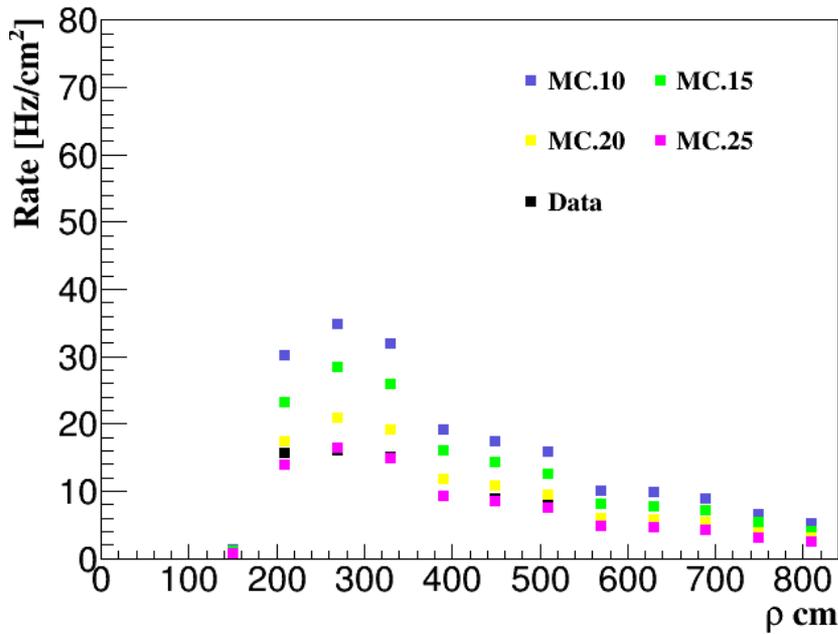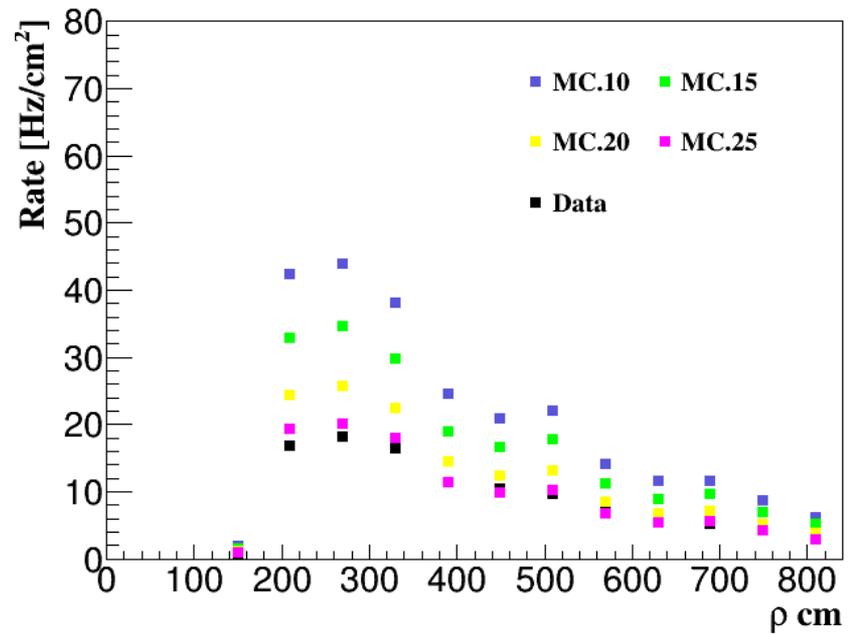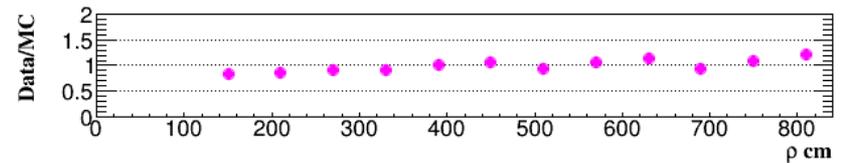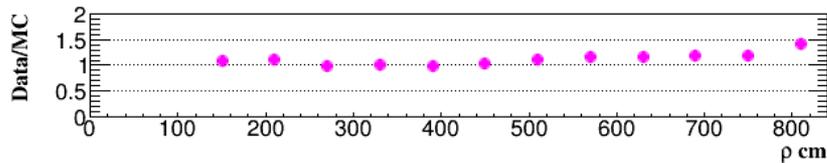
Compare MC and DATA: hit rate VS |Z|
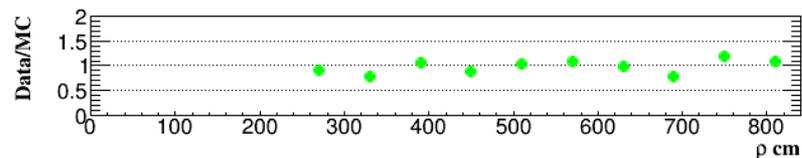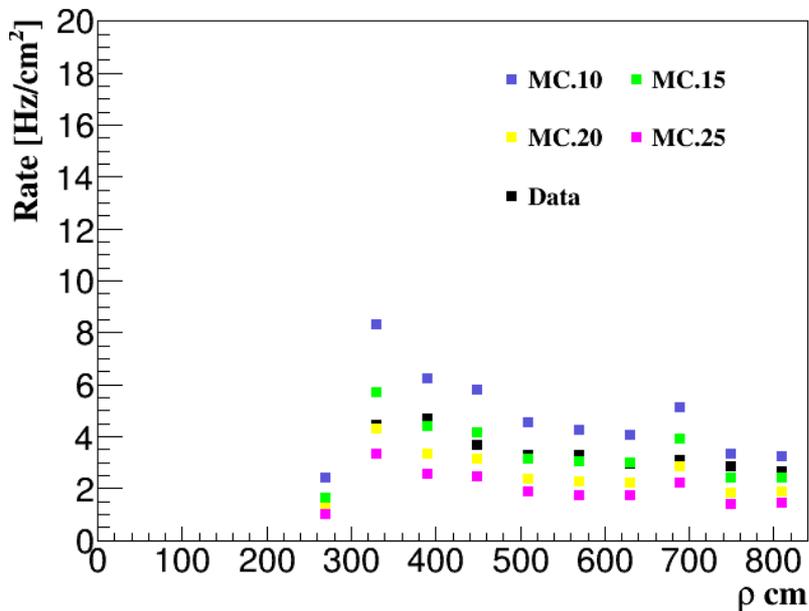
EOL
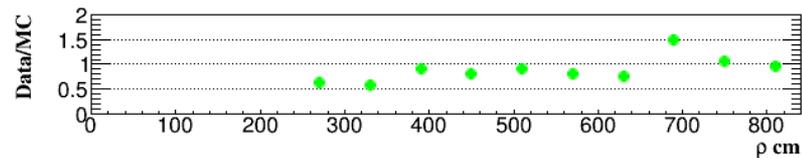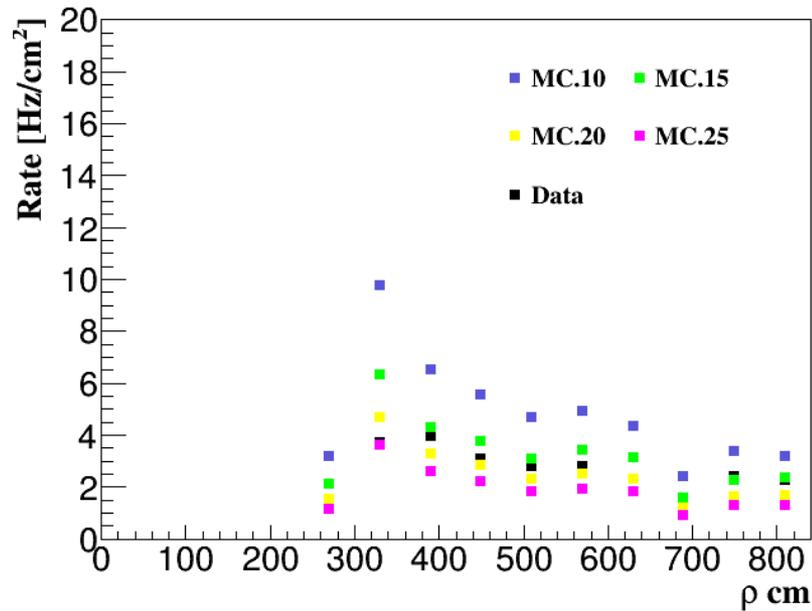
EOS

The number of cavern background close to 15.

Compare MC and DATA: hit rate VS |Z|
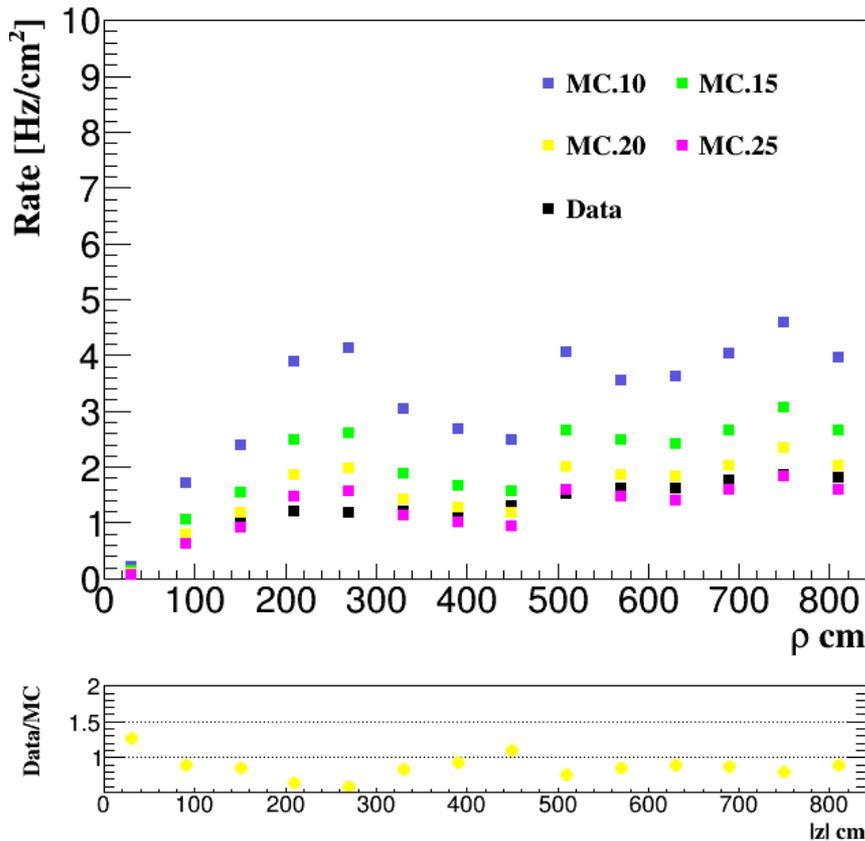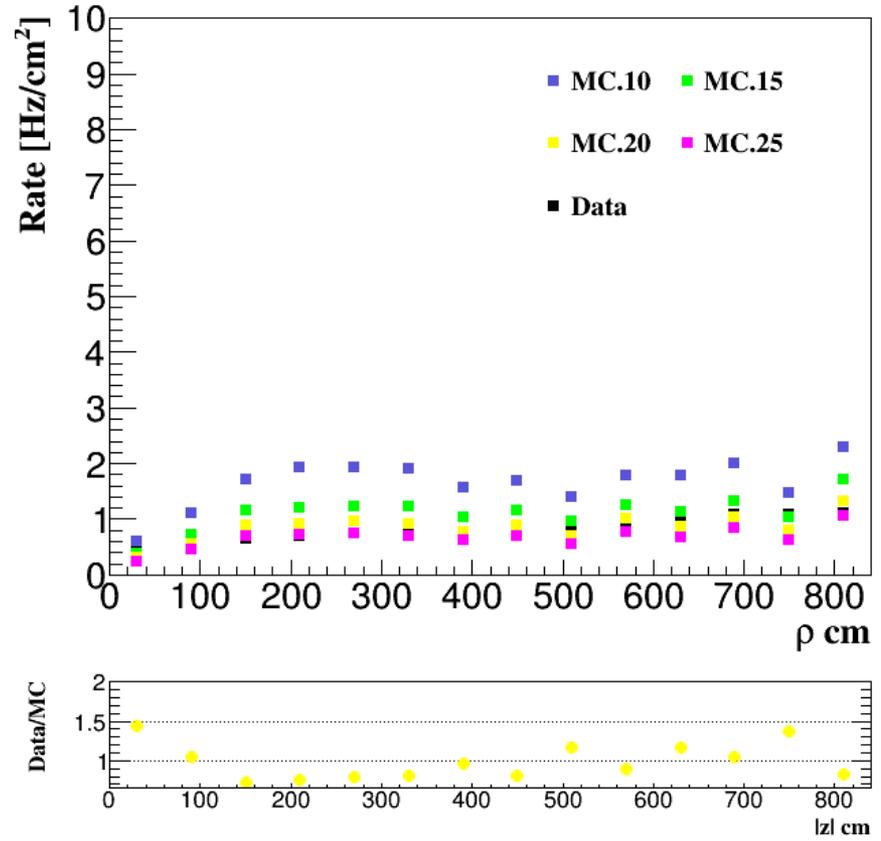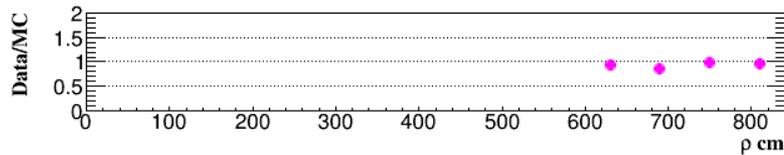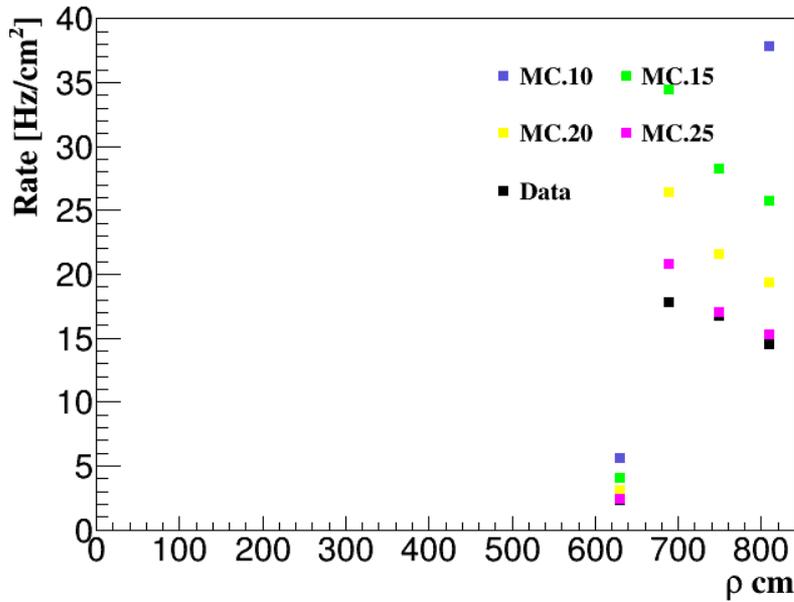

EEL
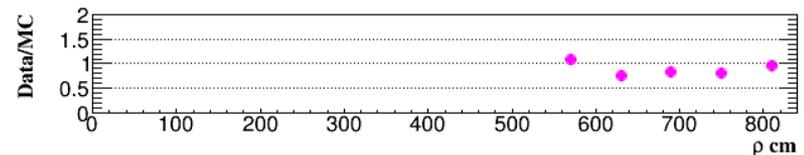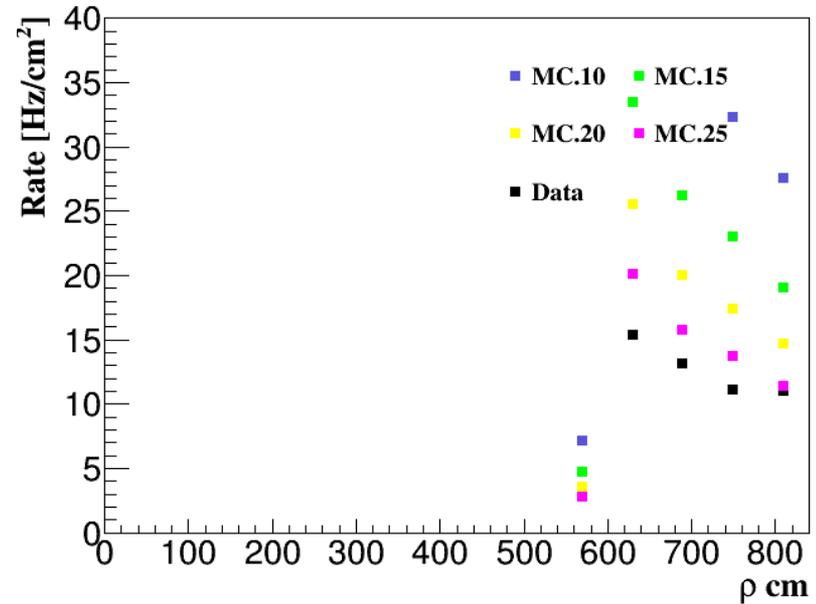
EES

The number of cavern background close to 25.

Conclusion

1. The drift time distributions are compared between data and MC so that to explain why to give weight to MC, linear relationships between rate and luminosity behave almost the same for data and MC after applying weight to MC.

2. The number of cavern background is estimated to be 25 except EOS, EOL regions which is about 15 and BOS,BOL regions which is about 20 when data and MC. That means the farther the distance is, the number of cavern background a little decrease.

Thank you !!!

Back up

Step to produce HITS samples-running on grid

EVNT_TR->HITS:

setupATLAS
lsetup panda
asetup 21.0.95,Athena

No need to change parameters.

```
pathena --memory 5120 --nFilesPerJob 10 --trf "AtlasG4_tf.py
--inputEVNT_TRFile %IN --outputHITSFile %OUT.HITS.pool.root
--truthStrategy 'MC15aPlus' --geometryVersion 'ATLAS-R2-2016-01-00-01'
--conditionsTag 'OFLCOND-MC16-SDR-14' --DataRunNumber '284500'
--physicsList 'FTFP_BERT_ATL' --postInclude 'PyJobTransforms/UseFrontier.py' "
 --inDS
mc16_13TeV.361237.Pythia8EvtGen_A3NNPDF23LO_minbias_inelastic.simul.EVNT_TR.e7208_s3407_tid16780129_00
--outDS user.xiangke.Cavern.Bkg.HITS
```

https://its.cern.ch/jira/browse/ATLMCPROD-6788

Step to produce ESD samples-running on grid

HITS->ESD:

setupATLAS
lsetup panda
asetup 21.0.53,Athena

Best matches data 2017:
https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/
AtlasProductionGroupMC16
https://ami.in2p3.fr/app?subapp=tagsShow&userdata=r10201

pathena --nFilesPerJob 100 --memory 5120 --trf "Reco_tf.py --AMIConfig r10201 --inputHITSFile
'/cvmfs/atlas-nightlies.cern.ch/repo/data/data-
art/Tier0ChainTests/valid1.410000.PowhegPythiaEvtGen_P2012_ttbar_hdamp172p5_nonallhad.si
mul.HITS.e4993_s3091/HITS.10504490._000425.pool.root.1' --conditionsTag 'default:OFLCOND-
MC16-SDR-20' --geometryVersion 'default:ATLAS-R2-2016-01-00-01' --inputCavernHitsFile %IN
--inputHighPtMinbiasHitsFile '/cvmfs/atlas-nightlies.cern.ch/repo/data/data-
art/Tier0ChainTests/mc16_13TeV.361239.Pythia8EvtGen_A3NNPDF23LO_minbias_inelastic_hig
h.merge.HITS.e4981_s3087_s3089/*' --inputLowPtMinbiasHitsFile '/cvmfs/atlas-
nightlies.cern.ch/repo/data/data-
art/Tier0ChainTests/mc16_13TeV.361238.Pythia8EvtGen_A3NNPDF23LO_minbias_inelastic_low
.merge.HITS.e4981_s3087_s3089/*' --numberOfCavernBkg 25 –numberOfHighPtMinBias
0.0820202085 --numberOfLowPtMinBias 31.4179798 --jobNumber %RNDM:0 --maxEvents 100 -
-outputESDFile %OUT.ESD.pool.root

$<mu>=31.5$

Step to produce ESD samples

HITS->ESD:

--outputESDFile %OUT.ESD.pool.root --digiSteeringConf 'StandardSignalOnlyTruth' --postExec 'all:CfgMgr.MessageSvc().setError+=[\"HepMcParticleLink\"]' 'ToolSvc.LArAutoCorrTotalToolDefault.deltaBunch=1' --postInclude 'default:PyJobTransforms/UseFrontier.py' --pileupFinalBunch 6 --preExec 'all:from AthenaCommon.BeamFlags import jobproperties; jobproperties.Beam.numberOfCollisions.set_Value_and_Lock(20.0); from LArROD.LArRODFlags import larRODFlags; larRODFlags.NumberOfCollisions.set_Value_and_Lock(20); larRODFlags.nSamples.set_Value_and_Lock(4); larRODFlags.doOFCPileupOptimization.set_Value_and_Lock(True); larRODFlags.firstSample.set_Value_and_Lock(0); larRODFlags.useHighestGainAutoCorr.set_Value_and_Lock(True); from LArDigitization.LArDigitizationFlags import jobproperties; jobproperties.LArDigitizationFlags.useEmecIwHighGain.set_Value_and_Lock(False)' --preInclude 'HITtoRDO:Digitization/ForceUseOfPileUpTools.py,SimulationJobOptions/preInlcude.PileUpBunchTrainsMC16c_2017_Config1.py' --DataRunNumber 300000 --skipEvents 0" --inDS user.xiangke.CavernBkg.HITS_EXT0 --outDS user.xiangke. Cavern.Bkg.25.Mu.40

Compare MC and DATA: hit rate VS luminosity
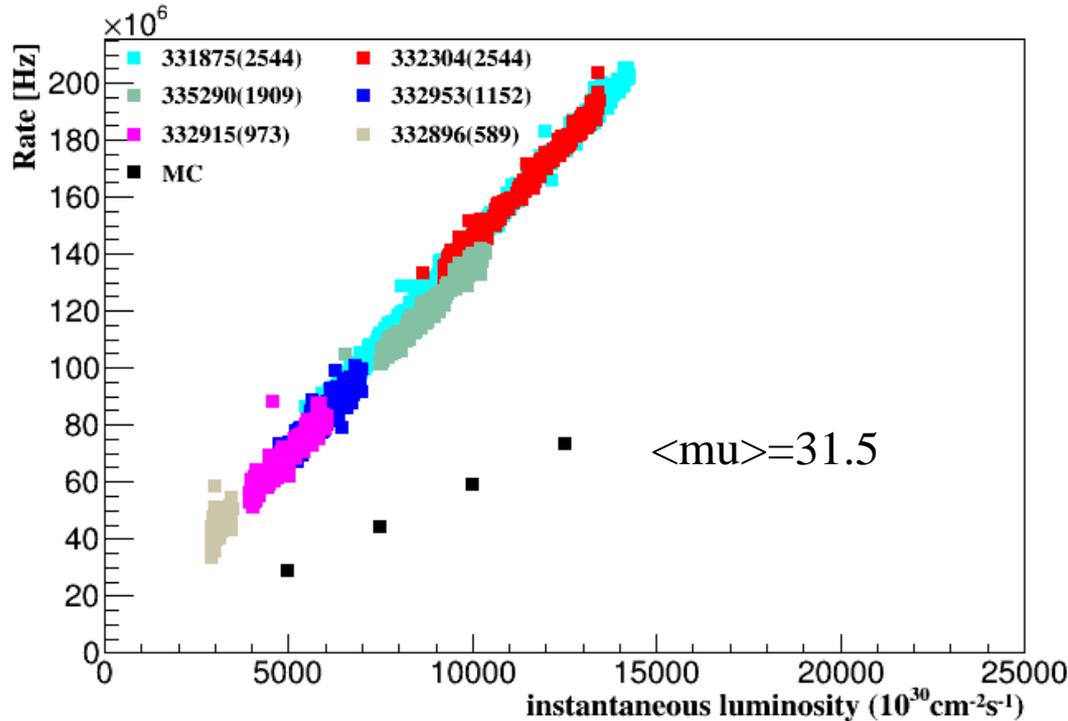
Before the weight is applied , the slopes of hit rate and luminosity are very different between data and MC. That's because the total hits of data are larger than MC at same number of events.

Back up: Mu
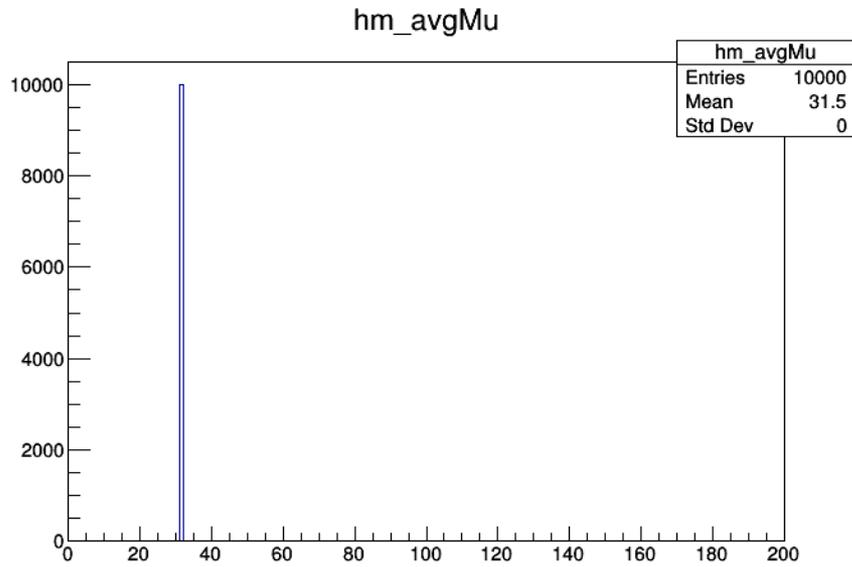
mu distribution of MC
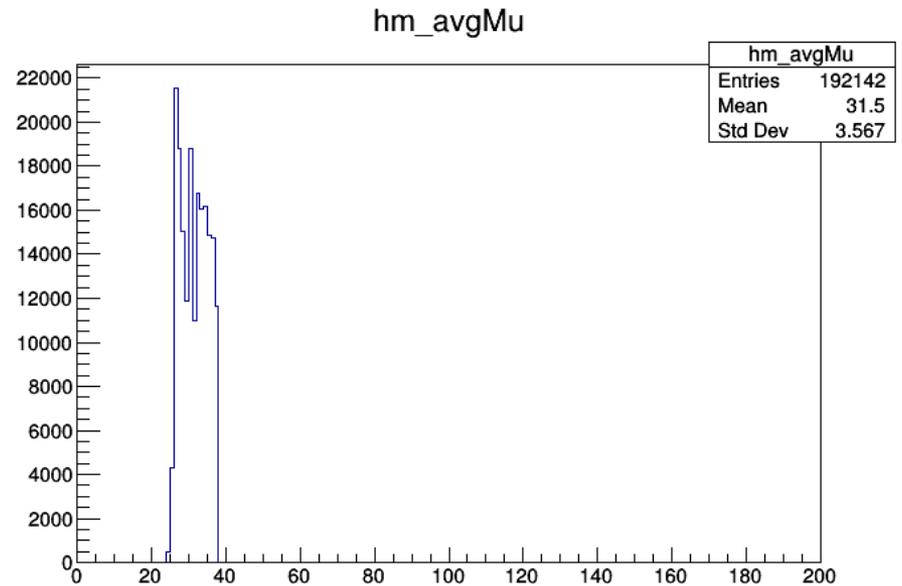
mu distribution of real data

Back up: MC and DATA drift time
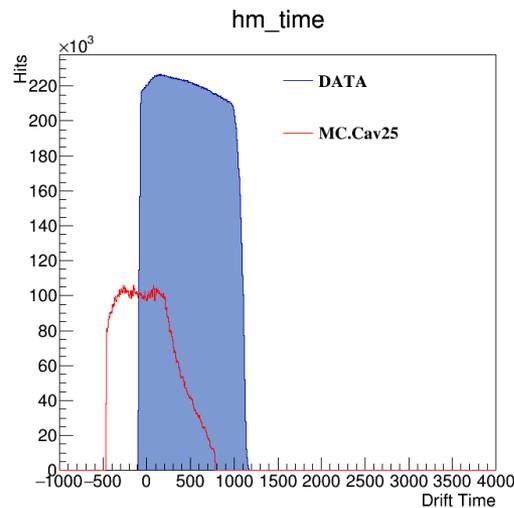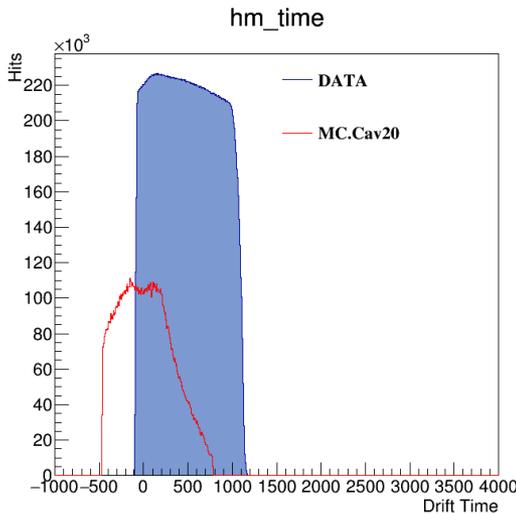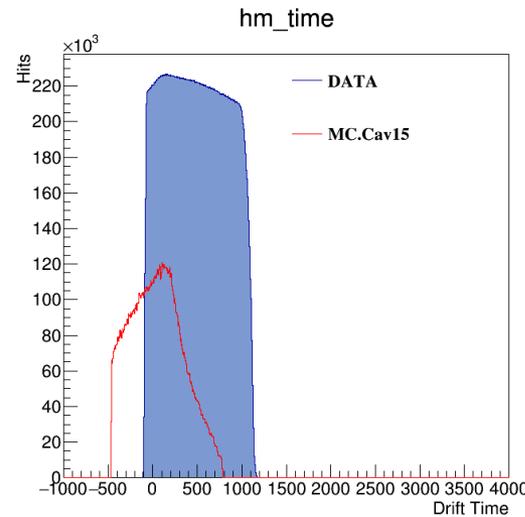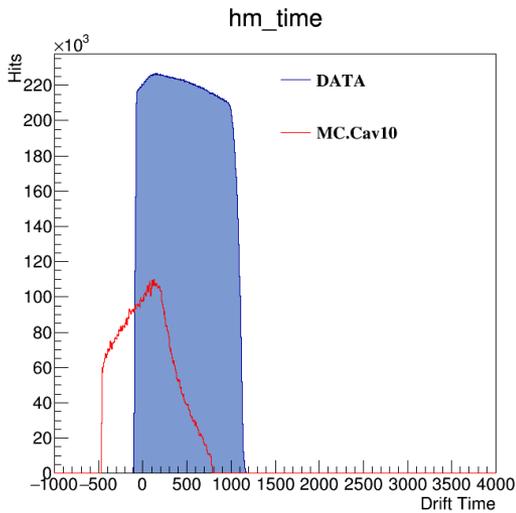
Compare drift time distributions keep data using full range of Mu and change the value of cavern background in MC and total hits of MC don't change so much.

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Back up: MC and DATA drift time
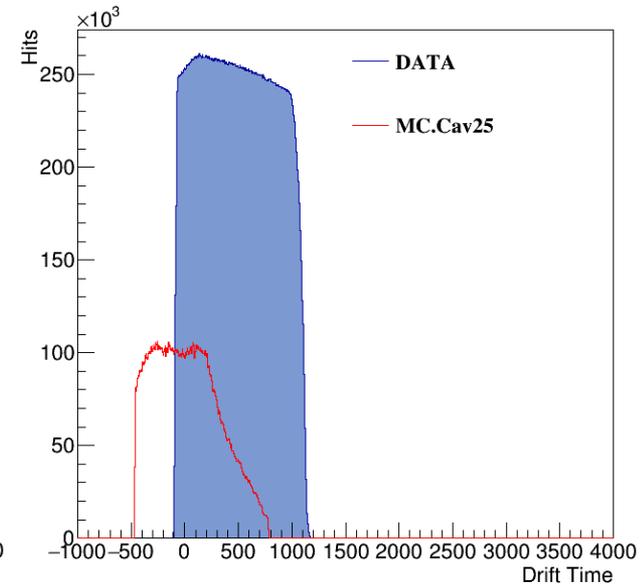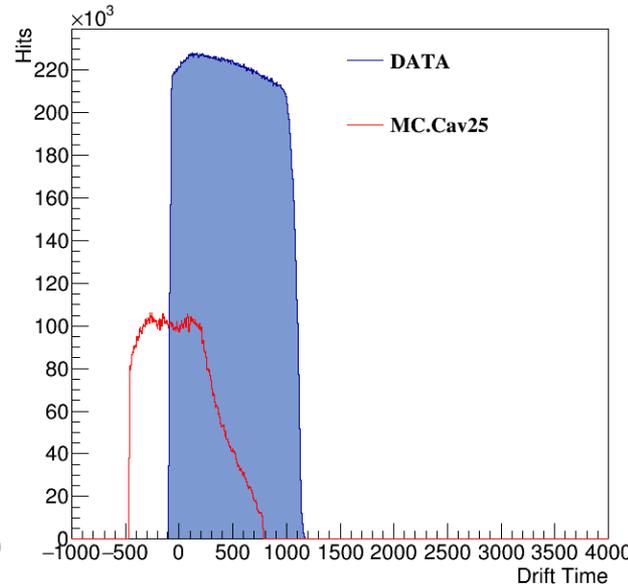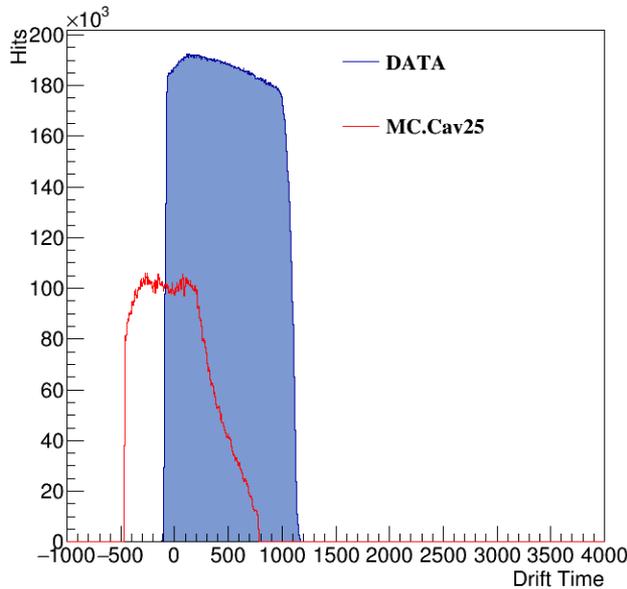
Cut data mu: 26.0 to 27.0

Cut data mu: 31.0 to 32.0

Cut data mu: 36.0 to 37.0

For data, drift time distribution keep similar shapes and total hits increase with the increase of Mu.

Data Mu / Weight	26-27	31-32	36-37
MC(cav25)	2.36484	2.80326	3.19517

Back up: hit rate VS luminosity

Run 332304(2544)
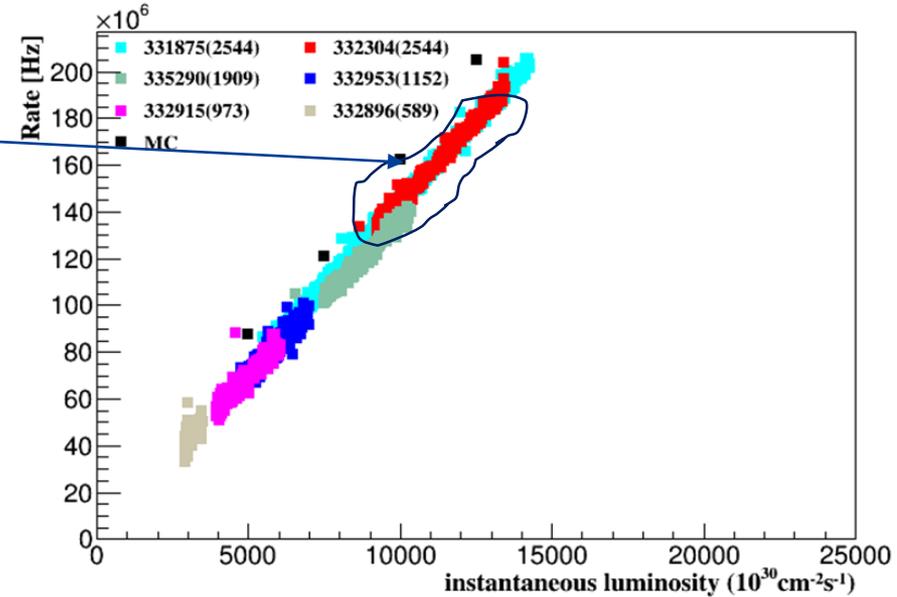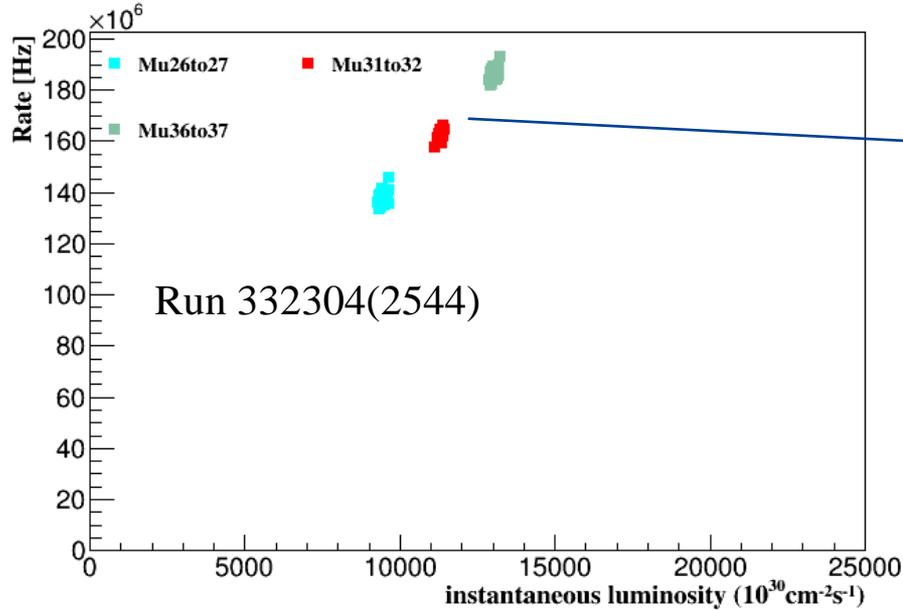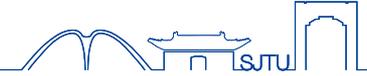
Cut run number 332304 mu: 26.0 to 27.0 , 31.0 to 32.0 and 36.0 to 37.0

Linear relationships between rate and luminosity

MC : hit rate VS luminosity

$$R^{G4}_{inst}$$
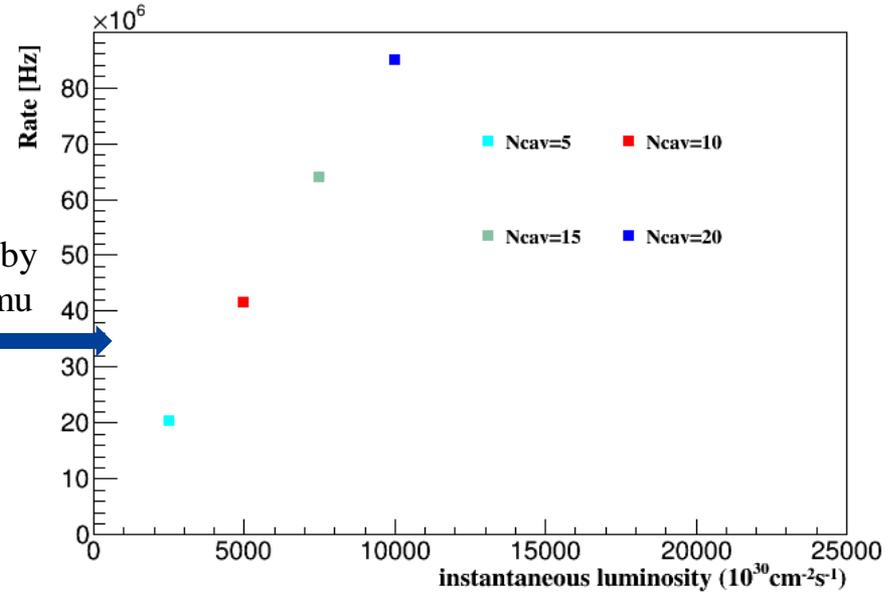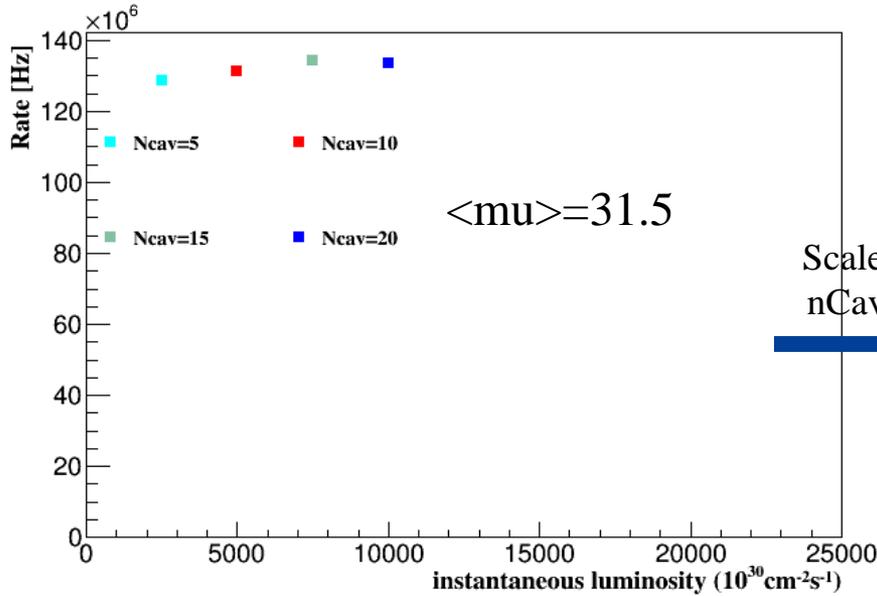
$$L_{G4} \propto n_{Cav} \qquad R_{G4} = R^{G4}_{inst} \cdot \frac{n_{Cav}}{\mu}$$

Fix the value of pile up, instantaneous hit rate don't change so much with the increase of number of cavern background.

Fix the value of pile up, final hit rate increase with the increase of number of cavern background.

Compare MC with different Mu

Scaled by nCav/mu
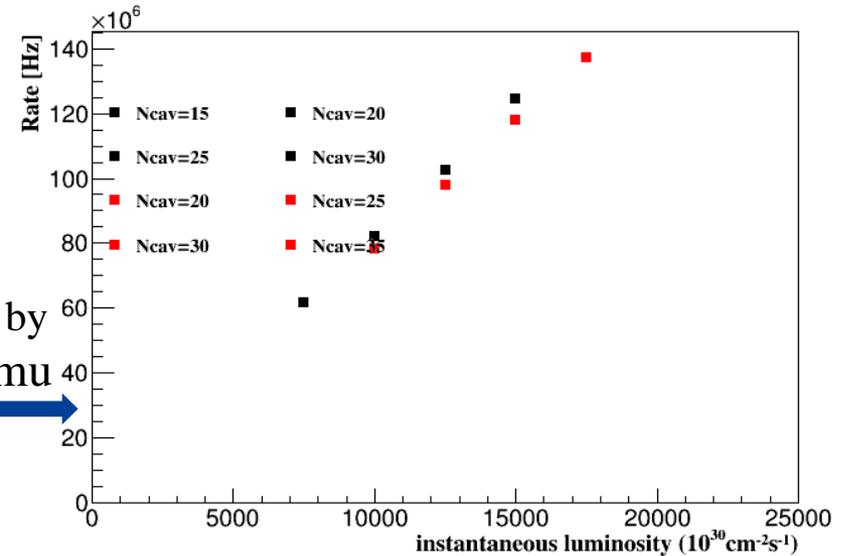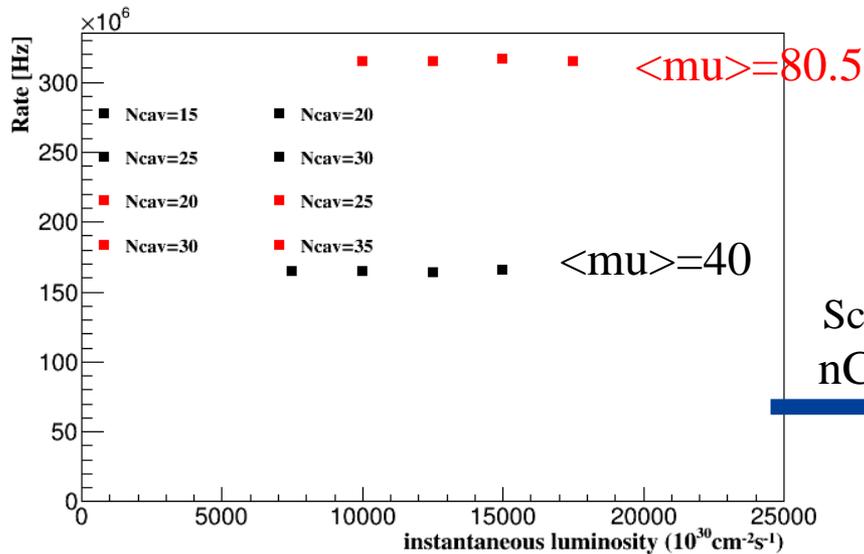
Instantaneous hit rate with <mu>=80.5 is larger than that with <mu>=40 for different number of cavern background. After scaled by the value of ncav/mu, hit rate almost the same for different mu.
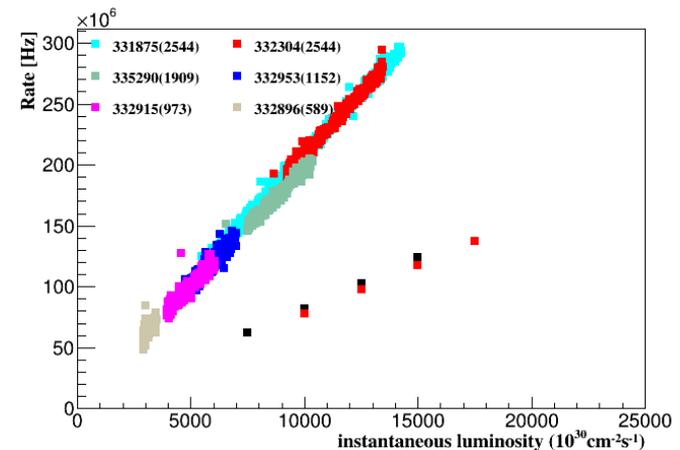
MC: adc and drift time distribution
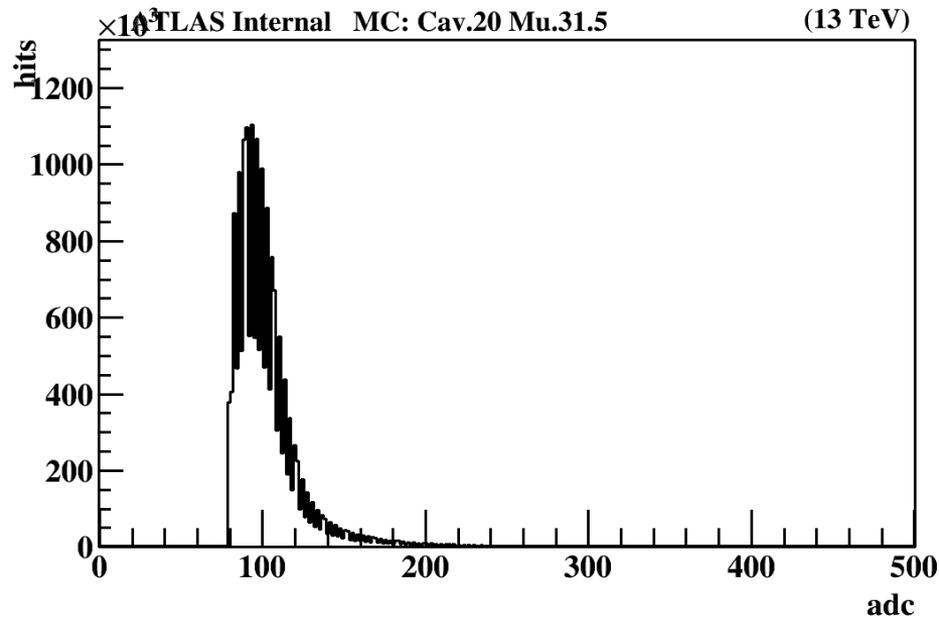
adc

drift time

To suppress the electronic noise only hits with ADC count greater than 80 is included for further study
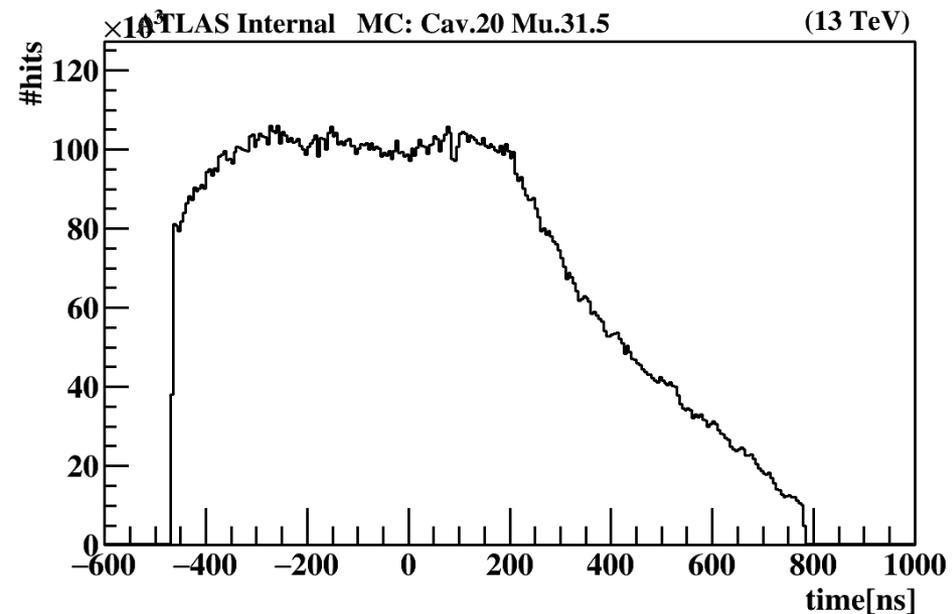
drift time which is used to estimate Δt which is taken to be 1300ns.

MC: adc distribution
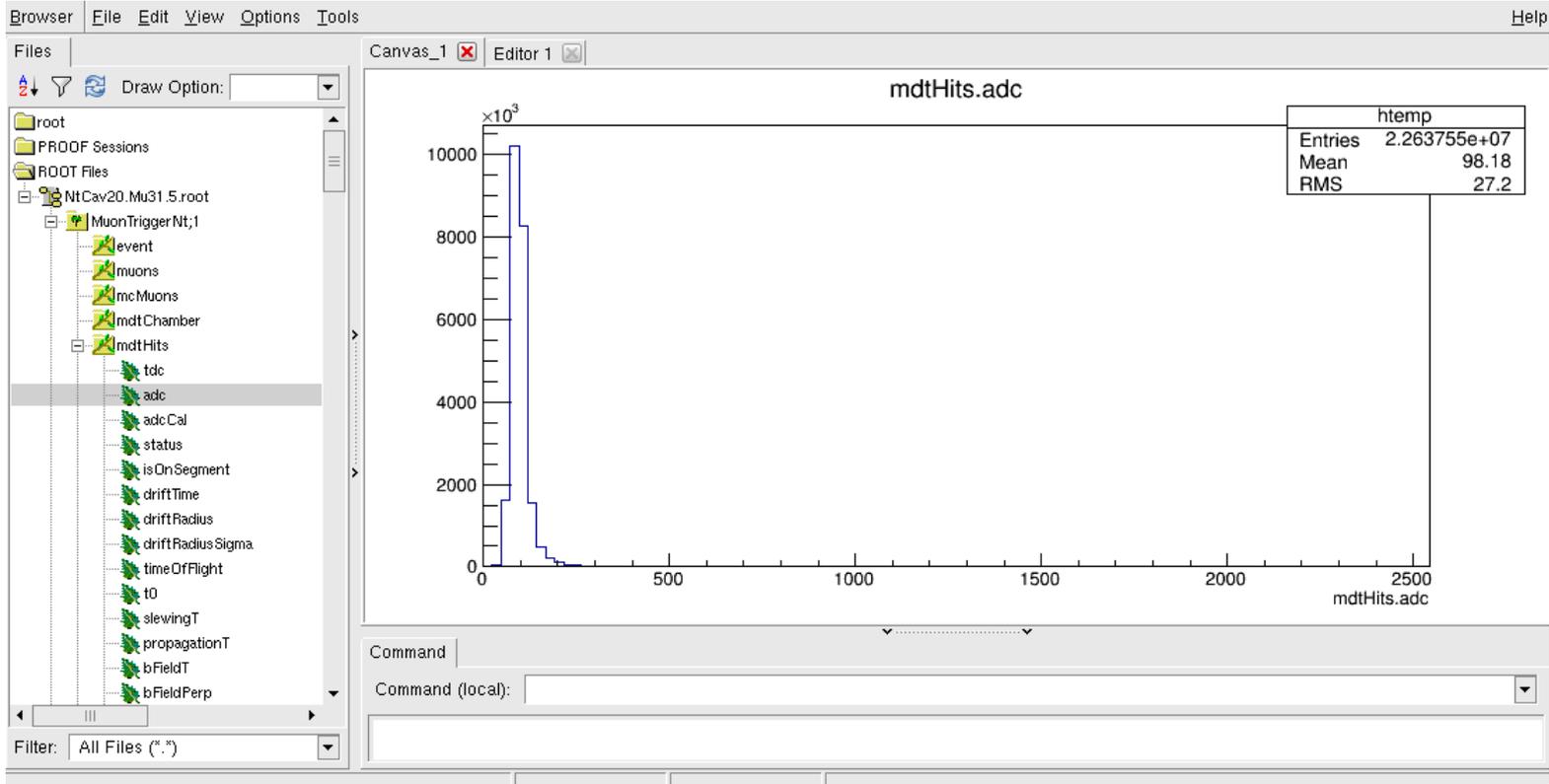
adc without cut at 80

Data and MC Comparison: Hit rate values
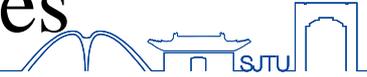
Chamber	xmin - xmax	data	error	mc	error
BIL	0-60	1.3679	0.002	1.3199	0.01
BIL	60-120	4.0963	0.004	4.3901	0.02
BIL	120-180	4.1041	0.004	4.6826	0.02
BIL	180-240	5.3185	0.004	6.0054	0.02
BIL	240-300	14.165	0.007	24.888	0.05
BIL	300-360	11.909	0.007	27.941	0.05
BIL	360-420	7.0745	0.005	9.7796	0.03
BIL	420-480	6.3379	0.005	5.5291	0.02
BIL	480-540	7.2505	0.006	6.4449	0.03
BIL	540-600	7.9467	0.006	6.7565	0.02
BIL	600-660	9.4252	0.006	13.992	0.04
BML	0-60	0.3336	0.0007	0.32077	0.003
BML	60-120	1.4048	0.002	1.2723	0.007
BML	120-180	1.9429	0.002	2.0585	0.009
BML	180-240	2.0567	0.002	2.8993	0.01
BML	240-300	2.2793	0.002	4.2939	0.01
BML	300-360	2.2232	0.002	3.7573	0.01
BML	360-420	2.0335	0.002	2.6708	0.009
BML	420-480	2.0761	0.002	2.1457	0.008
BML	480-540	2.4102	0.002	2.5879	0.009
BML	540-600	3.3864	0.002	3.487	0.01
BML	600-660	4.0342	0.003	4.8731	0.01
BML	660-720	5.5795	0.003	6.5006	0.02
BML	720-780	5.0617	0.003	6.3126	0.02
BML	780-840	4.546	0.003	5.6867	0.01
BML	840-900	4.9687	0.003	4.3634	0.01
BML	900-960	1.1173	0.001	0.79859	0.005

Chamber	xmin - xmax	data	error	mc	error
BIS	0-60	1.7175	0.002	1.5765	0.01
BIS	60-120	1.8976	0.003	1.9539	0.01
BIS	120-180	2.7195	0.003	2.7489	0.02
BIS	180-240	4.0022	0.004	5.0145	0.02
BIS	240-300	10.972	0.006	15.062	0.04
BIS	300-360	10.908	0.006	24.372	0.05
BIS	360-420	5.8109	0.005	6.6128	0.02
BIS	420-480	5.1017	0.004	5.7702	0.02
BIS	480-540	5.4056	0.005	4.2678	0.02
BIS	540-600	6.3609	0.005	7.3383	0.03
BIS	600-660	11.046	0.006	15.578	0.04
BIS	660-720	8.7676	0.006	14.787	0.04
BIS	720-780	0.57271	0.001	0.59905	0.007
BMS	0-60	0.68278	0.001	0.57542	0.005
BMS	60-120	1.0204	0.001	0.7525	0.006
BMS	120-180	1.1729	0.002	1.2431	0.008
BMS	180-240	1.5095	0.002	1.7769	0.01
BMS	240-300	1.7681	0.002	2.5407	0.01
BMS	300-360	0.86773	0.001	1.3404	0.009
BMS	360-420	1.4955	0.002	1.7575	0.01
BMS	420-480	1.9424	0.002	1.8969	0.01
BMS	480-540	2.3332	0.002	2.3458	0.01
BMS	540-600	2.941	0.003	3.3401	0.01
BMS	600-660	2.4812	0.003	2.439	0.01
BMS	660-720	2.0304	0.003	2.0294	0.01
BMS	720-780	4.7995	0.004	4.4904	0.02
BMS	780-840	4.0431	0.003	2.749	0.01
BMS	840-900	4.2178	0.003	3.5772	0.02
BMS	900-960	1.6487	0.002	1.585	0.01

BOL	0-60	0.12561	0.0003	0.079407	0.001	BOS	0-60	0.43649	0.0007	0.24175	0.003
BOL	60-120	0.70423	0.0008	0.62559	0.004	BOS	60-120	0.57457	0.0009	0.4477	0.004
BOL	120-180	0.99651	0.0009	0.92343	0.004	BOS	120-180	0.64761	0.0009	0.70495	0.005
BOL	180-240	1.2055	0.001	1.4673	0.006	BOS	180-240	0.69158	0.001	0.72417	0.005
BOL	240-300	1.1722	0.0009	1.5762	0.005	BOS	240-300	0.75342	0.001	0.73774	0.005
BOL	300-360	1.2051	0.001	1.1397	0.005	BOS	300-360	0.74884	0.001	0.70344	0.005
BOL	360-420	1.1911	0.0009	1.0123	0.004	BOS	360-420	0.7355	0.001	0.61352	0.004
BOL	420-480	1.2992	0.001	0.93244	0.004	BOS	420-480	0.70964	0.0009	0.69479	0.005
BOL	480-540	1.5106	0.001	1.582	0.006	BOS	480-540	0.81489	0.001	0.54358	0.004
BOL	540-600	1.606	0.001	1.4605	0.006	BOS	540-600	0.9103	0.001	0.76892	0.005
BOL	600-660	1.6173	0.001	1.4095	0.005	BOS	600-660	1.0045	0.001	0.68033	0.005
BOL	660-720	1.7633	0.001	1.5842	0.005	BOS	660-720	1.0816	0.001	0.83333	0.005
BOL	720-780	1.8674	0.001	1.8351	0.006	BOS	720-780	1.0865	0.001	0.6347	0.004
BOL	780-840	1.8083	0.001	1.6008	0.005	BOS	780-840	1.0999	0.001	1.0542	0.006
BOL	840-900	2.0437	0.001	1.6738	0.005	BOS	840-900	1.2065	0.001	0.71149	0.005
BOL	900-960	2.1003	0.001	1.7015	0.005	BOS	900-960	1.2791	0.001	0.87106	0.005
BOL	960-1020	2.0292	0.001	1.6541	0.005	BOS	960-1020	1.3226	0.001	0.90927	0.005
BOL	1020-1080	2.1167	0.001	1.9141	0.006	BOS	1020-1080	1.3235	0.001	0.91967	0.005
BOL	1080-1140	2.445	0.001	2.1489	0.007	BOS	1080-1140	1.4041	0.001	0.76127	0.005
BOL	1140-1200	2.5702	0.001	1.959	0.006	BOS	1140-1200	1.54	0.001	0.81759	0.005

EIL	180-240	95.697	0.03	90.141	0.1
EIL	240-300	142.63	0.03	141.21	0.2
EIL	300-360	84.652	0.02	85	0.1
EIL	360-420	57.58	0.02	60.238	0.08
EIL	420-480	79.471	0.03	74.31	0.2
EIL	480-540	21.452	0.02	25.523	0.08
EIL	540-600	13.404	0.007	15.914	0.04
EIL	600-660	7.2225	0.005	7.869	0.03

EML	120-180	0.719	0.002	0.64958	0.008
EML	180-240	15.549	0.007	13.767	0.03
EML	240-300	16.049	0.008	16.276	0.04
EML	300-360	14.966	0.007	14.766	0.04
EML	360-420	9.1763	0.004	9.1318	0.02
EML	420-480	8.9226	0.004	8.4147	0.02
EML	480-540	8.3867	0.004	7.4375	0.02
EML	540-600	5.5217	0.003	4.6868	0.01
EML	600-660	5.4118	0.003	4.5791	0.01
EML	660-720	5.0392	0.003	4.1868	0.01
EML	720-780	3.7205	0.002	3.0994	0.009
EML	780-840	3.4523	0.002	2.3864	0.008
EML	840-900	3.2978	0.002	2.6763	0.008
EML	900-960	2.7691	0.002	2.2623	0.007
EML	960-1020	2.4798	0.001	1.4842	0.006
EML	1020-1080	2.3751	0.001	1.9718	0.006
EML	1080-1140	1.8374	0.001	1.6125	0.006

EIS	180-240	26.312	0.008	17.976	0.03
EIS	240-300	37.417	0.009	30.292	0.04
EIS	300-360	23.166	0.007	22.498	0.03
EIS	360-420	15.023	0.005	14.52	0.03
EIS	420-480	5.298	0.003	4.7288	0.02

EMS	120-180	0.74296	0.002	0.87252	0.01
EMS	180-240	16.77	0.009	19.092	0.05
EMS	240-300	18.228	0.009	19.825	0.05
EMS	300-360	16.464	0.008	17.726	0.04
EMS	360-420	11.466	0.006	11.249	0.03
EMS	420-480	10.41	0.005	9.6783	0.03
EMS	480-540	9.6401	0.005	10.181	0.03
EMS	540-600	7.1658	0.004	6.7145	0.02
EMS	600-660	6.0303	0.004	5.2712	0.02
EMS	660-720	5.1852	0.003	5.5506	0.02
EMS	720-780	4.5207	0.003	4.1549	0.01
EMS	780-840	3.5977	0.002	2.9358	0.01
EMS	840-900	3.1666	0.002	2.3938	0.01
EMS	900-960	2.7097	0.002	2.629	0.01
EMS	960-1020	2.1695	0.002	2.3721	0.009
EMS	1020-1080	2.0402	0.002	1.4811	0.007
EMS	1080-1140	1.9447	0.002	1.0735	0.006
EMS	1140-1200	0.37192	0.0007	0.26532	0.003

EOL	240-300	1.5045	0.002	0.99641	0.007		EOS	240-300	1.3125	0.002	1.169	0.01
EOL	300-360	4.4307	0.003	3.3296	0.01		EOS	300-360	3.6967	0.003	3.633	0.02
EOL	360-420	4.6987	0.003	2.5681	0.01		EOS	360-420	3.9335	0.004	2.5891	0.01
EOL	420-480	3.6889	0.003	2.4644	0.01		EOS	420-480	3.066	0.003	2.2042	0.01
EOL	480-540	3.2651	0.002	1.8544	0.008		EOS	480-540	2.7886	0.003	1.841	0.01
EOL	540-600	3.3006	0.002	1.742	0.008		EOS	540-600	2.7813	0.003	1.9187	0.01
EOL	600-660	2.9336	0.002	1.7385	0.008		EOS	600-660	2.3341	0.002	1.8276	0.01
EOL	660-720	3.1016	0.002	2.2333	0.009		EOS	660-720	2.3876	0.002	0.92054	0.006
EOL	720-780	2.8658	0.002	1.4181	0.007		EOS	720-780	2.4199	0.002	1.2959	0.008
EOL	780-840	2.6415	0.002	1.4259	0.006		EOS	780-840	2.2489	0.002	1.2767	0.007
EOL	840-900	2.7096	0.002	1.7154	0.007		EOS	840-900	2.4438	0.002	1.9601	0.009
EOL	900-960	2.2574	0.002	1.635	0.006		EOS	900-960	2.2422	0.002	1.7501	0.009
EOL	960-1020	2.339	0.002	1.6129	0.006		EOS	960-1020	2.2193	0.002	1.7555	0.008
EOL	1020-1080	2.1176	0.001	1.1513	0.005		EOS	1020-1080	2.2276	0.002	1.5487	0.008
EOL	1080-1140	2.0623	0.001	1.1853	0.005		EOS	1080-1140	1.8809	0.002	1.5911	0.007
EOL	1140-1200	2.0915	0.001	1.5194	0.006		EOS	1140-1200	1.9915	0.002	1.1179	0.006

EEL	600-660	2.2818	0.003	2.4375	0.02		EES	540-600	3.0487	0.005	2.7949	0.02
EEL	660-720	17.763	0.01	20.738	0.05		EES	600-660	15.384	0.01	20.11	0.06
EEL	720-780	16.732	0.009	16.962	0.05		EES	660-720	13.16	0.01	15.73	0.05
EEL	780-840	14.508	0.008	15.229	0.04		EES	720-780	11.086	0.009	13.701	0.05
EEL	840-900	11.857	0.007	10.905	0.04		EES	780-840	11.019	0.009	11.427	0.05
							EES	840-900	3.0878	0.005	2.6244	0.02

Compare MC and DATA: hit rate VS |Z|

BOL

BOS
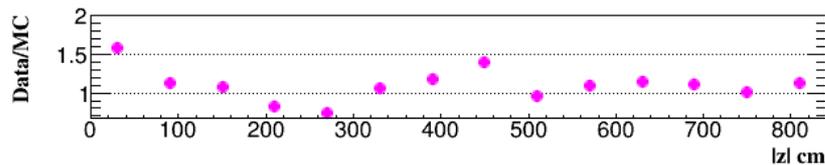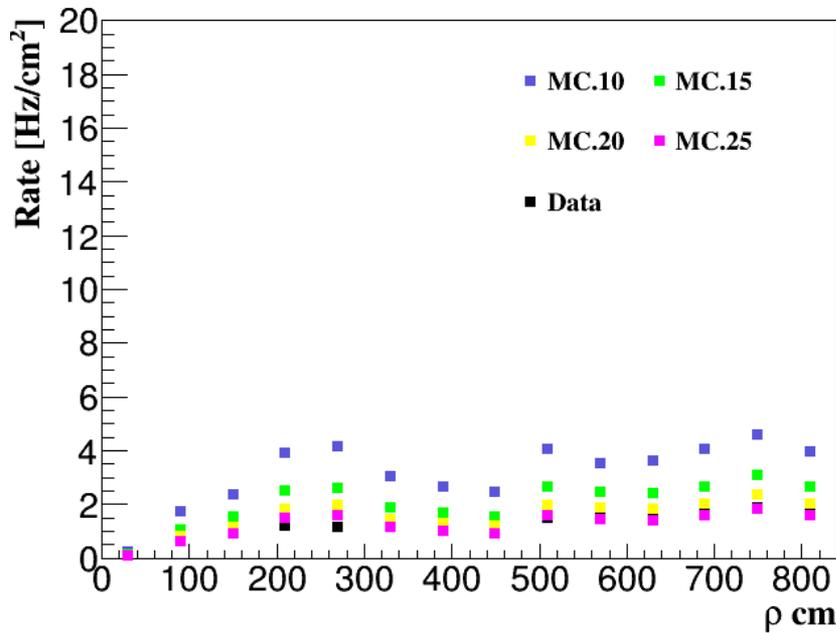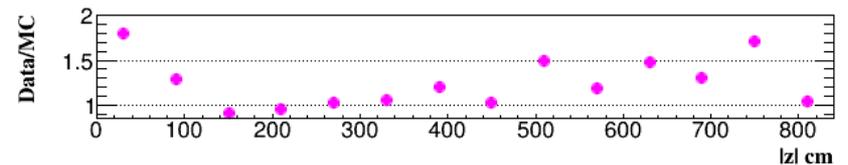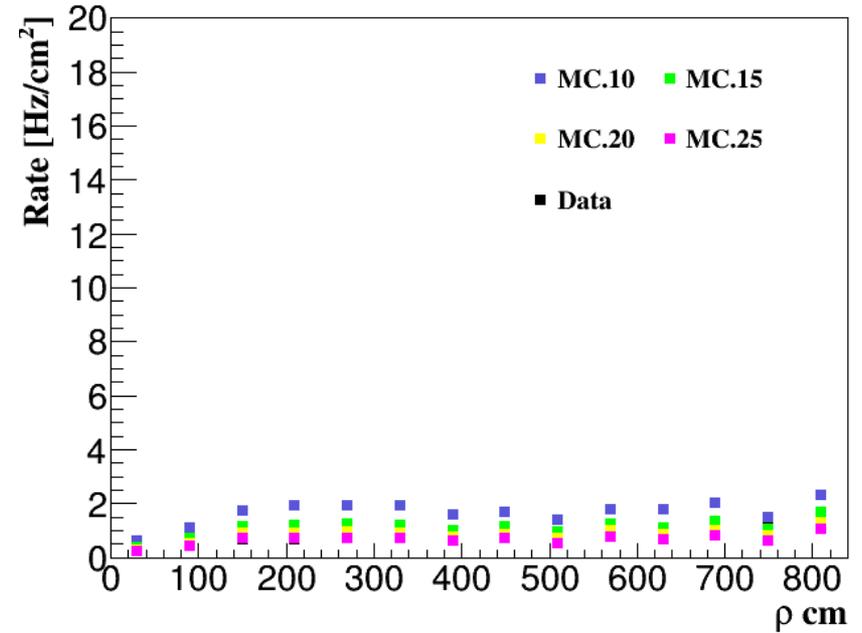
Data is larger than MC which the number of cavern background set to 25.