Centrality Determination for p+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV at the STAR Experiment

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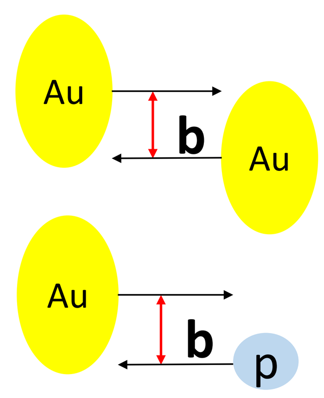
Abstract

In heavy-ion collisions, properties of the created QCD matter strongly depend on the collision geometry or "centrality". In A+A collisions, centrality is related to the size of the overlap region determined by the impact parameter. In p+A collisions, the term "centrality" is not strictly related to the geometric impact parameter, but it is rather taken as a classification of the amount of activity in the collision, which in turn is closely related to the number of nucleon-nucleon collisions (N_{coll}) in a Glauber-like picture. This poster presents a study on centrality determination in p+Au collisions at $\sqrt{s_{NN}} = 200$ GeV using data taken in 2015 by the STAR experiment. Comparisons between the data and simulations based on HIJING and GEANT models are shown. Different measures of the event activity, one at forward rapidity and one at mid rapidity, are discussed and compared.

Motivation

In heavy-ion collisions, cold nuclear-matter effects and hot-medium effects are largely entangled. We use p+Au collisions to help quantify cold nuclear-matter effects so that we can get a better understanding of the hot-medium effects in heavy-ion collisions. In order to do this, a good classification of centrality in p+Au collisions [1,2] is needed to measure the physics quantities as a function of activity in the collision.



Methods

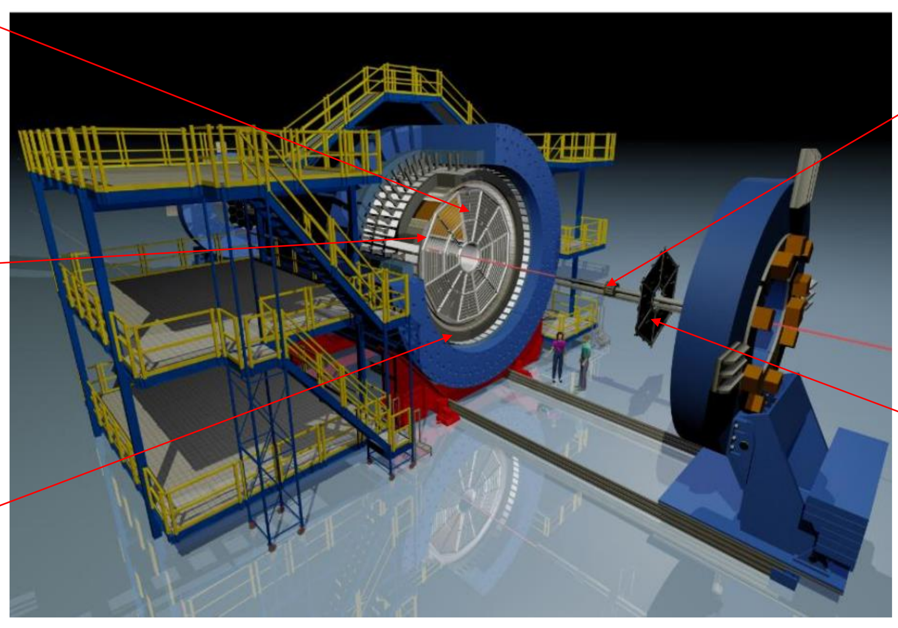
- Use minimum-bias p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV taken by STAR in 2015. The minimum-bias trigger requires coincidence of signals present in both east- and west-side of VPD.
- Use HIJING [3] + GEANT to study correlations between experimental observables and the number of nucleon-nucleon collisions (N_{coll}).
- Use Glauber simulation [2] to estimate the total cross section and compare Glauber N_{coll} to HIJING.
- For intervals of the experimental observable, estimate the percentages of the sampled cross-section and calculate corresponding $\langle N_{coll}\rangle$.

STAR Detector

TPC
Time Projection Chamber measures track trajectories to determine particle momenta. Covers $|\eta|\leq 1.0$

TOF
Time Of Flight detector measures particles' flight time for particle identification. Covers $|\eta|\leq 1.0$

BEMC
Barrel Electro-Magnetic Calorimeter is a fast detector that can be used to reject pile-up tracks. Covers $|\eta|\leq 1.0$



VPD
Vertex Position Detectors provide main minimum-bias trigger, the event start time and the primary collision vertex location. Covers $4.24\leq|\eta|\leq 5.1$

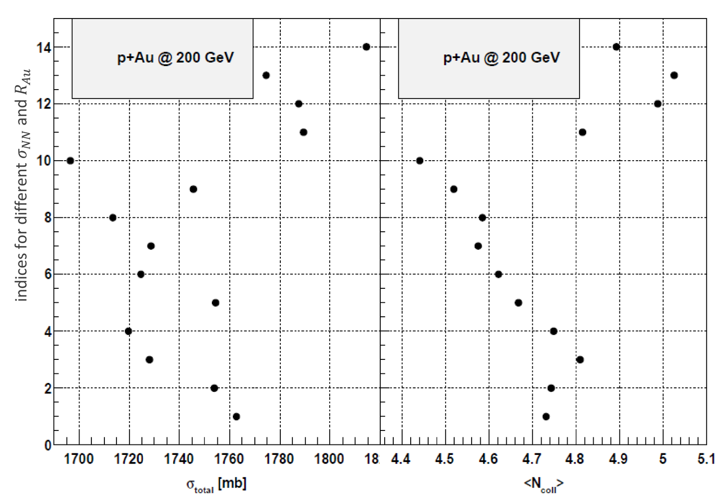
BBC
Beam Beam Counters provide additional minimum-bias trigger and event activity measurement at forward rapidity. Covers $3.4\leq|\eta|\leq 5.0$

* η is the pseudo-rapidity

Detectors help to select vertex for every event

- Select the vertex, reconstructed using TPC tracks, that correlates along the beam direction with the vertex reconstructed using coincidence between east and west VPD information.
- To further remove pile-up events, the selected vertex is required to be associated with at least two tracks that are either matched to BEMC or crossing the TPC central membrane.

Glauber Model



Conclusion:

$$\sigma_{total} = 1760 \pm 60\ mb$$
$$\langle N_{coll}\rangle^{0-100\%} = 4.7 \pm 0.3$$

Glauber simulation default parameters:

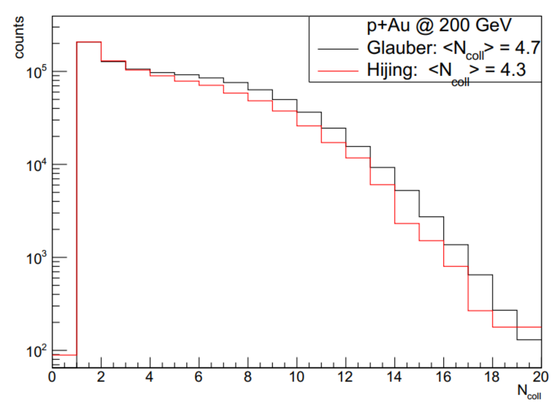
$$\sigma_{NN} = 42mb$$
$$R_{Au} = 6.38fm$$

which are varied as:

$$\sigma_{NN} = 42 \pm 2mb$$
$$R_{Au} = 6.38 \pm 0.12fm$$

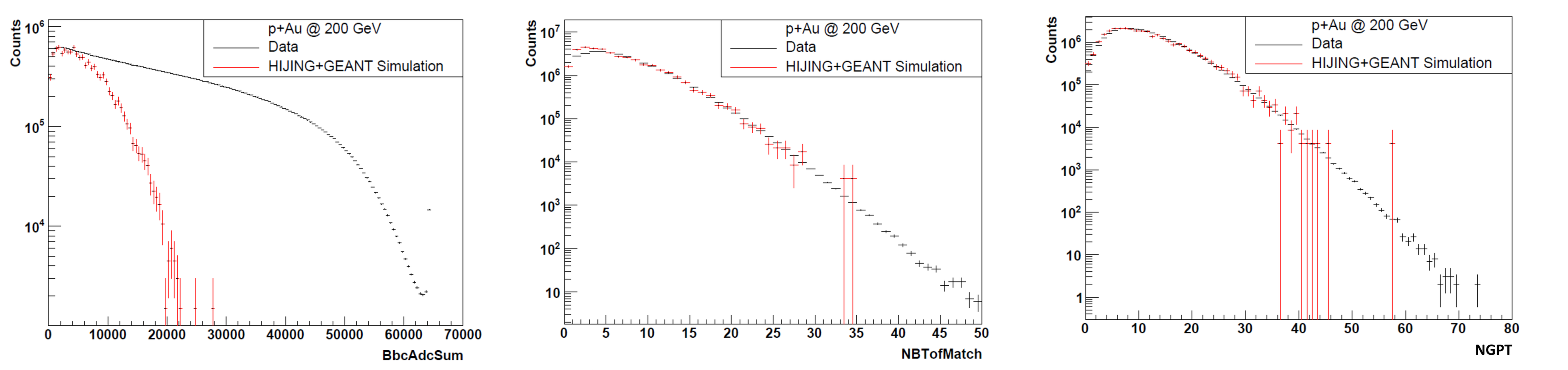
and Gaussian smearing test.

σ_{total}: total cross section; σ_{NN}: inelastic N-N cross section; $\langle N_{coll}\rangle$: mean value of number of nucleon-nucleon collisions; R_{Au}: radius of Au nucleus.



$\langle N_{coll}\rangle$ agrees within 10% between Glauber and HIJING

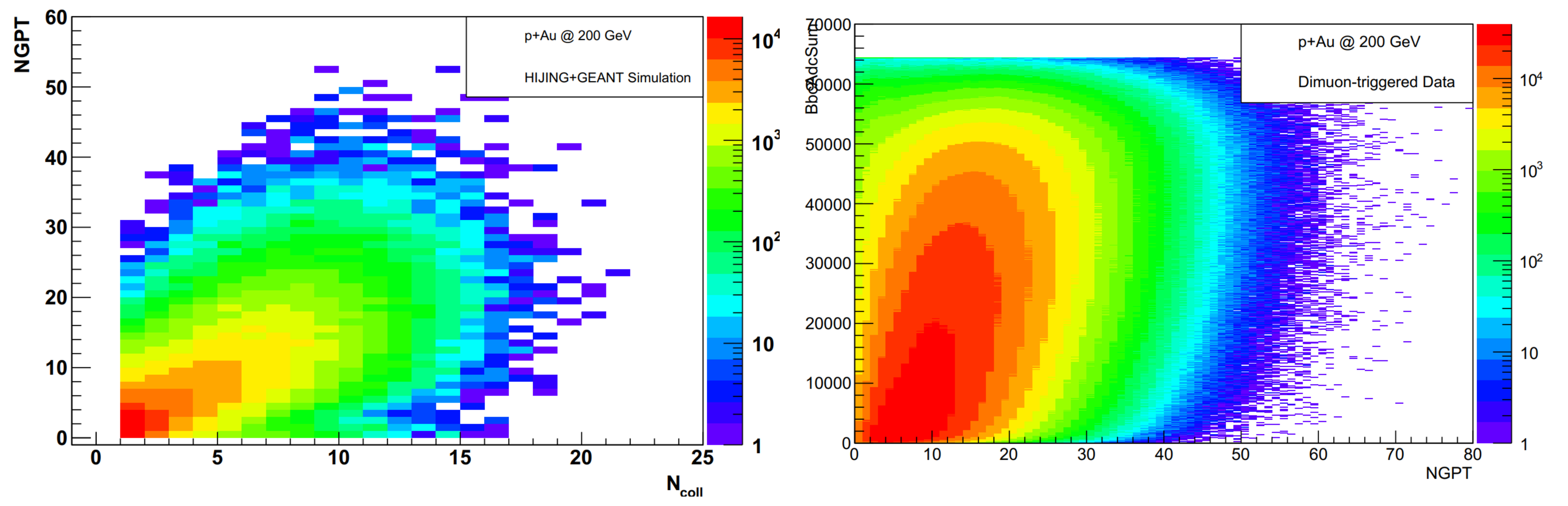
Data vs. HIJING



BbcAdcSum: Charge sum measured in the BBC — NBTofMatch: Number of tracks matched to TOF — NGPT: Number of "good" primary tracks

- An observable at large rapidity in the Au-going side, such as the charge sum measured in the BBC (BbcAdcSum), would be preferred because it is not auto-correlated to physics measurements at mid-rapidity. However, HIJING+GEANT simulation does not describe the BbcAdcSum distribution measured in data so that we cannot use HIJING to get N_{coll} directly.
- For distribution of the number of tracks matched to TOF (NBTofMatch), simulation and data match well.
- Also, at mid-rapidity the number of "good" primary tracks (NGPT) shows agreement between simulation and data. The conditions for selecting "good" primary tracks are DCA<1cm, $|\eta| < 1$, and NHitsFit≥10, where the DCA is the closest distance between the track and the primary vertex; η is the pseudo-rapidity; and NHitsFit is the number of TPC space points used for track reconstruction. The DCA<1cm cut is crucial for removing pile-up tracks. Compare to NBTofMatch, NGPT is preferred as it spans a larger range, which is important for specifying multiple centrality bins.

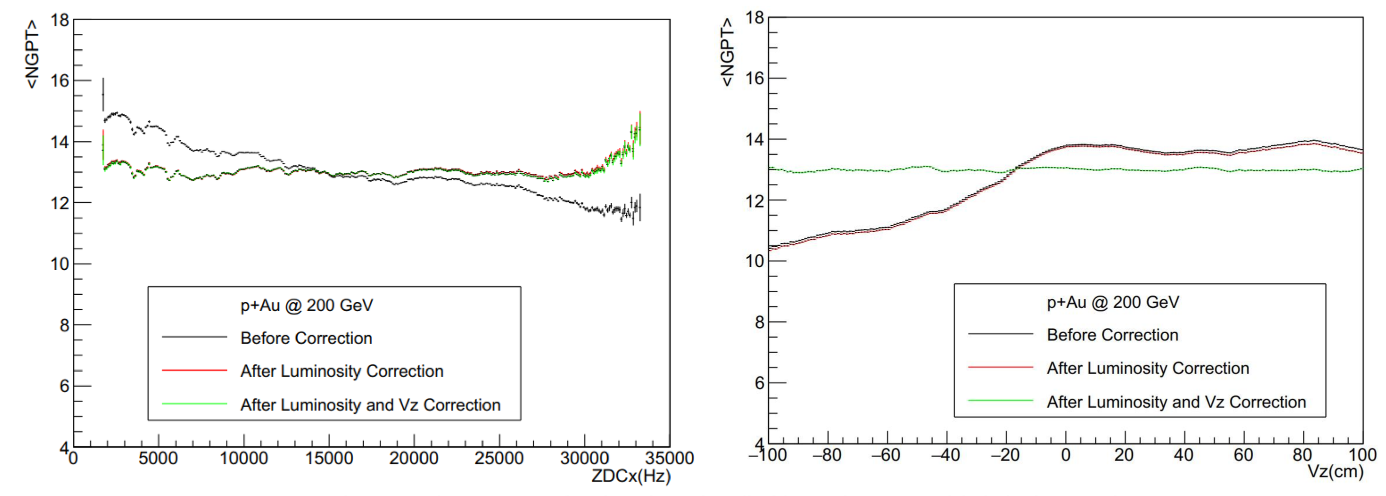
Correlation with Geometry



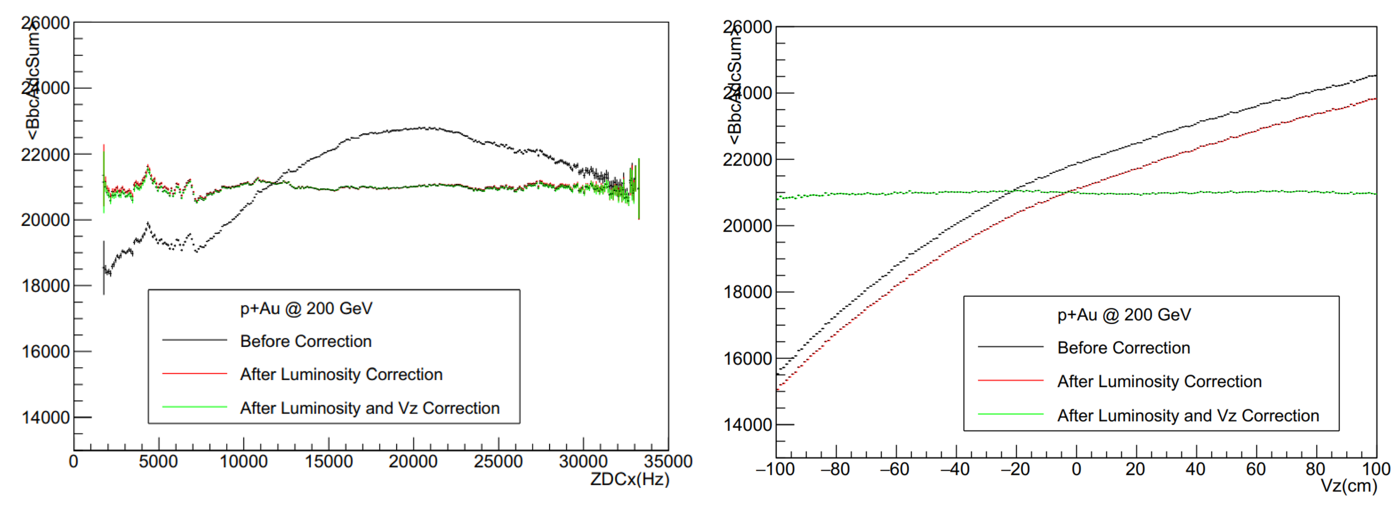
- Number of good primary tracks (NGPT) shows positive correlation with N_{coll} according to HIJING+GEANT simulation.
- BbcAdcSum shows weaker correlation with NGPT. Although, we cannot know the N_{coll} directly from HIJING+GEANT simulation, we may infer it by using this correlation between BbcAdcSum and NGPT.

Corrections for Luminosity and Vertex Dependence

These variables, NGPT and BbcAdcSum, can depend on the luminosity as well as on the vertex position, due to varying detector efficiency and acceptance. In order to determine centrality, independent of these effects, the event-centrality measure must be corrected for these dependences. Effects of corrections on the mean values are shown below (*Shown for dimuon-triggered events).

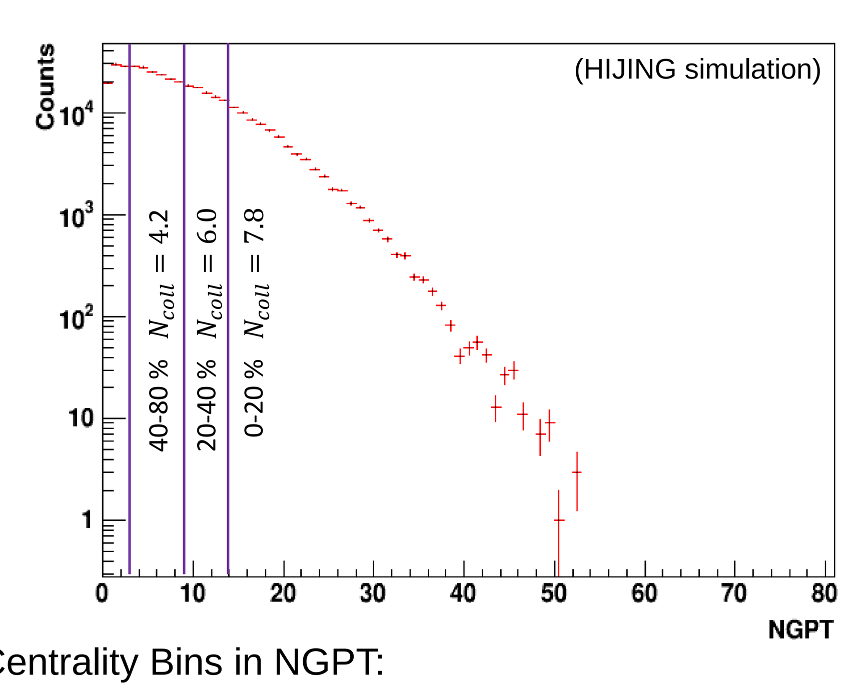


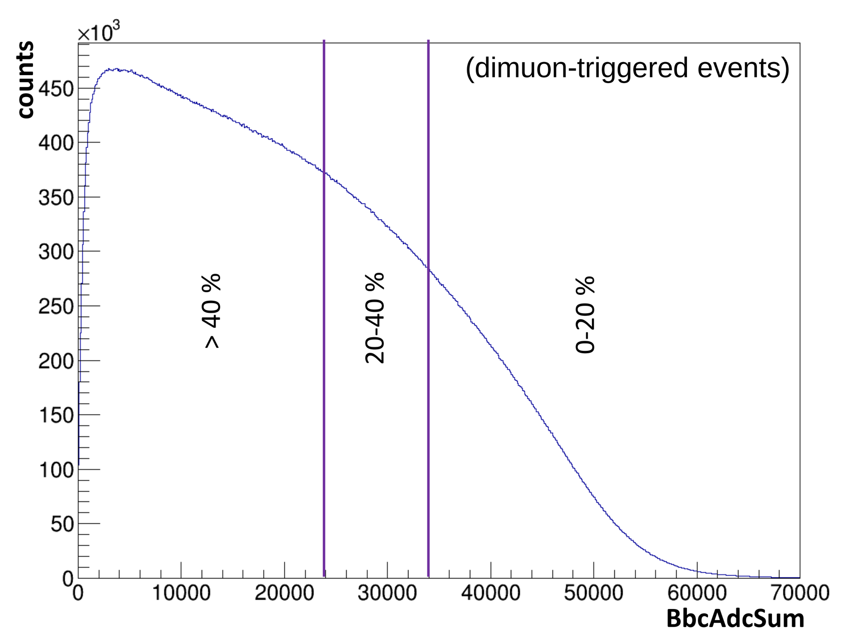
Correction on the NGPT for luminosity (left) and vertex (right) dependence



Correction on the BbcAdcSum for luminosity (left) and vertex (right) dependence

Centrality Classes





Centrality Bins in NGPT:

- 0-20%: Number of Good Primary Tracks from 14 to 80
- 20-40%: Number of Good Primary Tracks from 9 to 13
- 40-80%: Number of Good Primary Tracks from 3 to 8

Centrality Bins in BbcAdcSum:

- 0-20%: BbcAdcSum larger than 34000
- 20-40%: BbcAdcSum from 24000 to 34000
- >40%: BbcAdcSum less than 24000

- NGPT (Number of Good Primary Tracks)
  - Centrality percent determined with respect to full cross section using comparisons to HIJING
  - The advantage of NGPT is that HIJING describes data well, allowing for the determination of the centrality percent of the full cross section
  - The disadvantage is that it is at mid rapidity which can cause bias in the measurement
- BbcAdcSum
  - Centrality percent is not yet relative to a full cross section
  - The advantage is it is not at mid rapidity, so it does not bias the measurement
  - The disadvantage is that HIJING does not reproduce the BBC response
- Future Work
  - Further study of BbcAdcSum as a centrality measure and calculate <N_{coll}> for selections in this variable.

References:
[1] J. Adam et al. (ALICE), Phys. Rev. C91 064905 (2015)
[2] M. L. Miller et al. , Annu. Rev. Nucl. Part. Sci. 57. 205 (2007)
[3] M. Gyulassy and X. N. Wang, Comput. Phys. Commun. 83, 307 (1994)

The STAR Collaboration
drupal.star.bnl.gov/STAR/presentations

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