

## Abstract

This observation provides direct evidence for ...

Experimentally, you either make an observation ( $>5\sigma$ ) or find evidence ( $>3\sigma$ ).

I think your reference to 'evidence' is rather meant to describe the link between the observation and the actual  $b$  versus  $p_T$  relation.

Hence, you probably should write:

This observation .. demonstrates (if there was a strong link to the impact parameter dependence of the photon  $p_T$ ),

I prefer:

This observation indicates an impact parameter dependence ..

Same in line 179ff, 204

A: We rephrase this sentence to “This observation demonstrates the transverse momentum and energy of photons emitted from relativistic ions have impact parameter dependence.”.

A: The distribution deviates from constant (no  $b$  dependence) with a significance  $>5\sigma$ , the “indicates” ( $<3\sigma$ ) seems to be too soft. We use “demonstrate(s)” in other two places

In line 10-19 you discuss the relationship between neutron multiplicity and impact parameter explicitly. This leads to the formulation in line 177 ff of your observation of the (indirect) dependence on the impact parameter. You should also spell out the connection to the photon  $p_T$ , in lines 48-54.

A: We added “The  $\alpha$  of lepton pair produced from leading-order  $\gamma\gamma$  scattering is directly related to the lepton pair  $p_T$ , which is equal to the total  $p_T$  of initial photons. The large  $\langle \alpha \rangle$  of lepton pairs produced from leading-order  $\gamma\gamma$  scattering corresponds to large  $\langle p_T \rangle$  of initial photons, and vice versa.” after  $\alpha$  definition.

Moreover,

In line 52 ff you describe the  $\alpha$  spectrum before you describe its measurement. This means here you address expectation and hence you need to provide references, and rather write:

The  $\alpha$  spectrum .. is expected to be divided into ... []

I would move all discussion about  $\alpha$  (motivation why you use it) from 132ff to 48-54, and focus on observations only in 129 ff.

And then move line 48 -54 before line 43.

A: We deleted “The  $\alpha$  spectrum of  $\mu^+\mu^-$  pairs is decoupled into core

and tail components, where the core is dominated by leading-order  $\gamma\gamma$  scattering while the tail is dominated by high-order  $\gamma\gamma$  interactions.”  
from this paragraph and leave this technical discussion when describing the corresponding measurements.

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L6: test QED -> test the modeling of photon induced processes

A: We would like to keep the original one as a general description

L7: search for physics beyond (new is redundant)

The statement is repeated in line 40-42, and there is more carefully broken up ([6,7] and [8-10]). To avoid repetition, move 40-42 to 5?

A: Removed “new”.

A: The statement repeated in line 40-42 (v6) is on purpose, to emphasize the importance of this paper while line 5 is a general introduction.

L15: b not defined: ... excitations increases as the impact parameter of the two ions (b) becomes smaller [7].

A: Defined at the beginning of line 4

L35: initial-state photons

A: Done

L44: the di-muon invariant mass region (or muon pair invariant mass ...)

A: Done

L47: functional or rather: operational or maybe when requiring that the ZDC participated in data taking (not sure this condition needs to be mentioned here as you describe it as essential part)

A: We deleted ZDC related content here and moved to ZDC abbreviation in CMS detector introduction paragraph.

A: This was required by the conveners to avoid potential confusion for the luminosity number ( $1.7 \text{ nb}^{-1}$ ) used in other PbPb papers. Our ZDC was not operational at the beginning of 2018 heavy ion run.

L66: Two ZDCs are used to detect neutrons from nuclear dissociation events in the range  $|\eta| < 8.3$ . They are Cherenkov calorimeters that use tungsten as the absorber and quartz fibers and plates as the active medium.

A: We rephrase this sentence to “Two zero degree calorimeters (ZDC), made of quartz fibers and plates embedded in tungsten absorbers, are used to detect neutrons from nuclear dissociation events in the range  $|\eta| < 8.3$ .”

A: We did not find the ZDC is Cherenkov calorimeters in the standard CMS detector description for publication in

<https://twiki.cern.ch/twiki/bin/viewauth/CMS/Internal/PubDetector>

L78: Ref [28] Is there a newer one (covering pixel cluster shapes)?

A: People generally use this paper or one 2010 charged hadron paper

L79: tower energy deposits -> energy deposits (tower jargon as not explained?)

A: Done

L84: total energy

A: Done

L85: ‘simple’ is non-descriptive

A: Removed simple

L108: ... are obtained for each measured muon  $\mu$  as a function of its .. To correct ..

A: We think “applied” is better here

L119: migrate the neutron multiplicity ..

A: Done

L130: ... acceptance for  $8 < M_{\mu} < 60$  GeV. -> remove bracket; all described before (192, 198)

A: We would like to repeat the CMS acceptance definition here, which is friendly for the reader.

L139: investigated and documented ..

A: Done

L146: A binned  $\chi^2$  minimization is performed ..

A: Done

L148: ... calculated from the fit function -> given by the fit function (?)

A: We cannot directly read  $\langle \alpha \rangle$  from the fit function, so we would like to keep the original description.

L149- L150 belongs into next section (at end of systematic uncertainties)

A: Done

L158: .. pileup correction, neutron multiplicity classification, and the fit procedure.

A: Done

L156: leading HF energy deposit

A: Done

Figure 2, caption, 3rd line: shown as (represented by) shaded areas.

A: Done

L174: .. STARlight is constant  $1.348e-3$  as indicated by the dashed-dotted line.

A: Done

L176ff: spell out the pT connection (to support statement line 181)

A: Added this connection after the alpha definition

L176: In general the  $\langle \rangle$  in data

A: Done

L177: ... increases with the multiplicity of emitted neutrons.

A: We prefer to keep the original one

L179: This observation indicates the impact parameter dependence of the initial-state photon pT, which impacts ..

A: We rephrase to “This observation demonstrates that initial photons producing  $\mu^+\mu^-$  pairs have a significant impact parameter dependence of their  $p_T$ , which impacts..”

L191: remove: clearly

L192: much greater -> exceeding (or give number explicitly)

A: “clearly” and “much” follows CMS recommendation for the large significance in <https://twiki.cern.ch/twiki/bin/view/CMS/LargeSignificances>

L194: suggests that the average ..

A: Done

L182-186: Conclusion/outlook that does not belong here -> move to L206 ff

A: We deleted “These new results demonstrate the need of improved modeling of initial photon kinematics with impact parameter dependence for future high precision measurements of photon-induced interactions.” but keep the hot medium study discussion.

L206-209: repeats these conclusions, but vague/generic (remove?)

Maybe just repeat the statement from the abstract?

A: We removed the conclusion from the result part, it should be fine to mention these conclusions.