ECFA 2016 Workshop, October 3-6 Aix-Les-Bains

CMS Performance

Dependence on scenario for luminous region

Patrizia Azzi
I.N.F.N. Padova

a new approach to performance studies

Last April LHC formed the EDQ(experimental data quality) working group

- to investigate the characteristics of the luminous region
- to define and rank figures of merit relevant to the detector performance *(experiments experts)*
- assess the HL-LHC baseline and possible variants making recommendation where needed *(accelerator experts)*

Several configurations have been passed to the experiments as nominal and extreme case study

- emphasis on the response of higher level physics objects to the different running configuration

what the experiment sees

Accelerator side: optics, crossing angle, levelling, fill duration, beta* etc…

shapes of luminous region as a function of z and time were given to the experiment

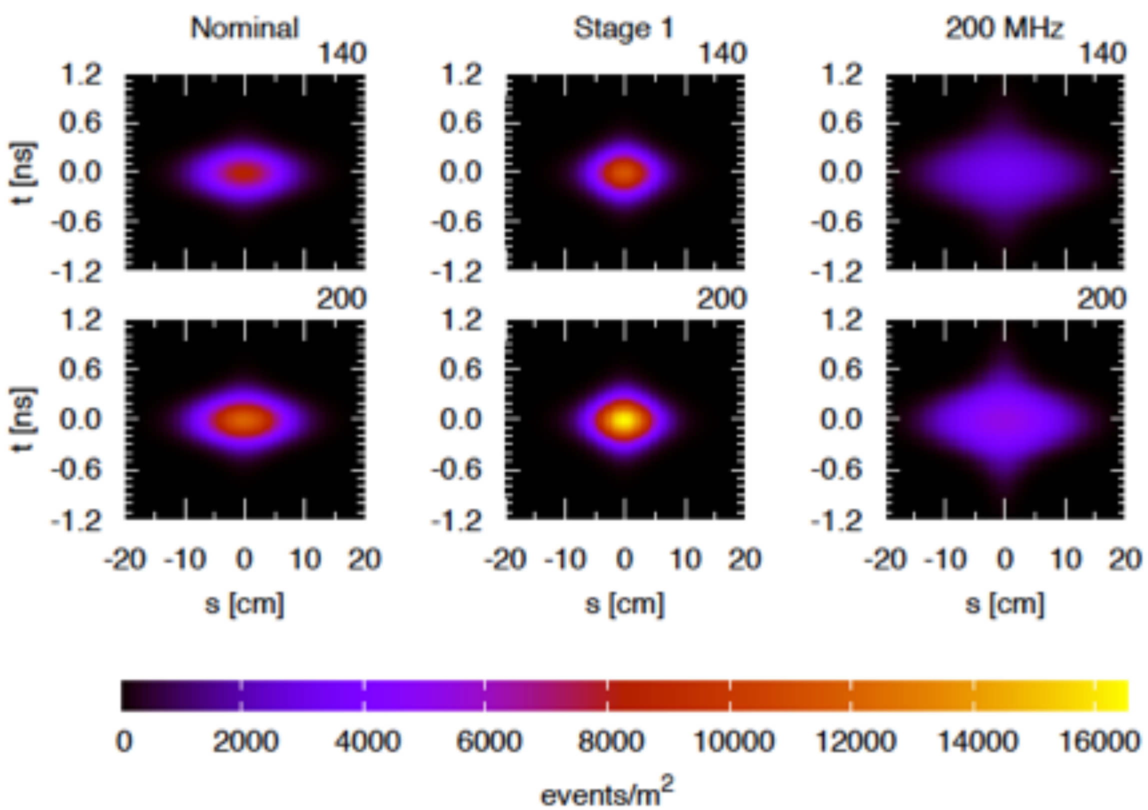
variable of interest: Pile Up density (mm^{-1}), defined as events/mm

effects on acceptance along the beam line (z) assumed/proven uncorrelated with the PU density.

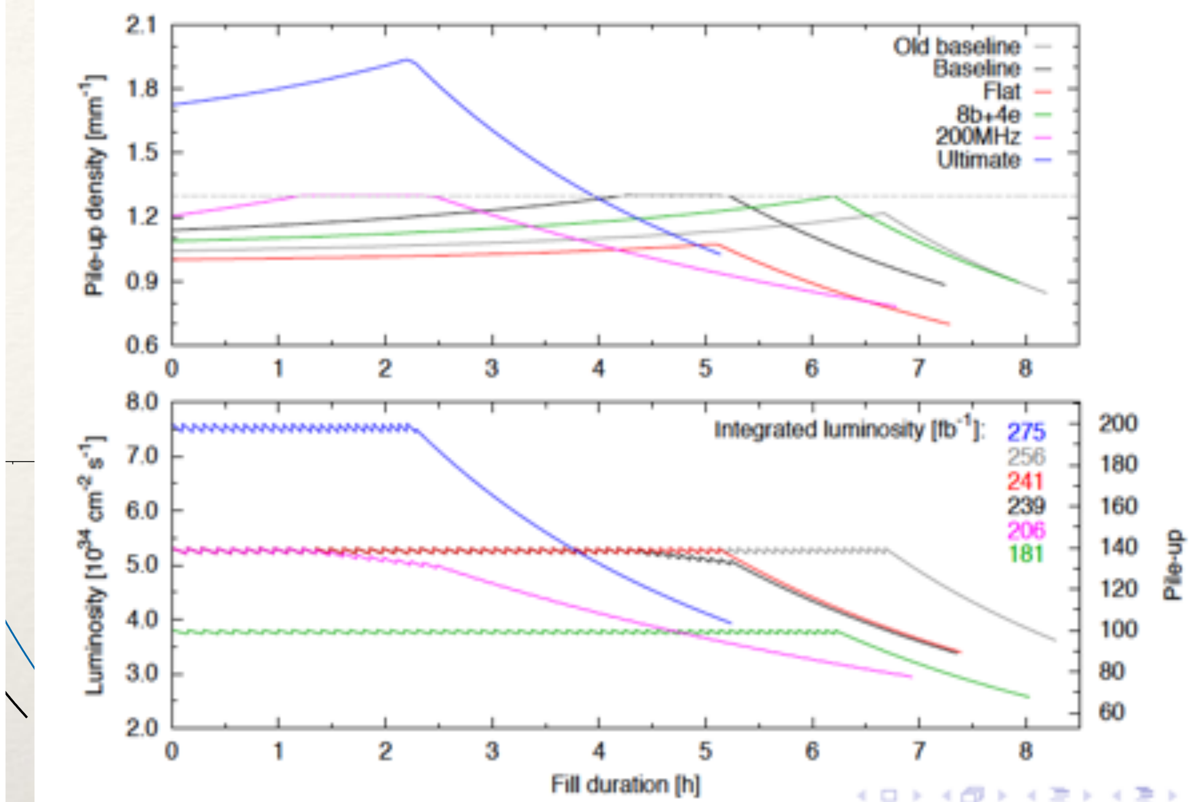
- Already discussed in the Technical Proposal, won't be repeated here
- CMS performed studies with beam spot as wide as ±20cm

more details about how precision timing can help —> J. Bendavid talk on Thu

Translating scenario to simulations



Nominal and Stage 1 at peak pile-up; 200 MHz at the beginning of the fill. All plots at the same scale.



On the experiment side this translates in simulating a beam spot with a gaussian shape and different σ, or with a flat box shape and different widths in order to reproduce some of the configurations

Framework for studies

Detector configuration, reconstruction and algorithm presented are as in Technical Proposal

More recent results on tracking will be presented on Wed -> Erica Brondolin

Importante note: the vertexing algorithm used here is robust but not reoptimized as the final Pixel geometry is not included here

For the scope of the studies this is a validated detector configuration with the complete event reconstruction.

Allows study of performance of higher level physics objects.

Important to see the overall trends. <u>Absolute values of performance will be re-evaluated with optimized algorithms</u>

scenarios chosen for CMS

Specific full simulation for the following cases:

gaussian beam spot of 44mm and 33mm

- PU density extracted slicing the central region (physics object dependent)

« box shaped » beam spot width of ±5,11,15,20cm

- this second case allows to have a flat PU density
- plus can be used for acceptance studies

All samples done for $<\mu>=140$ and 200

Physics process considered:

top pairs, Z->μμ, Z->ττ

Introduction to Tracking Studies vs density

Tracking is at the basis of the event reconstruction, in particular for CMS where a global event description based on the particle flow concept is used.

The following quantities have been studied against pileup density for the two different configuration of total pileup (140 and 200)

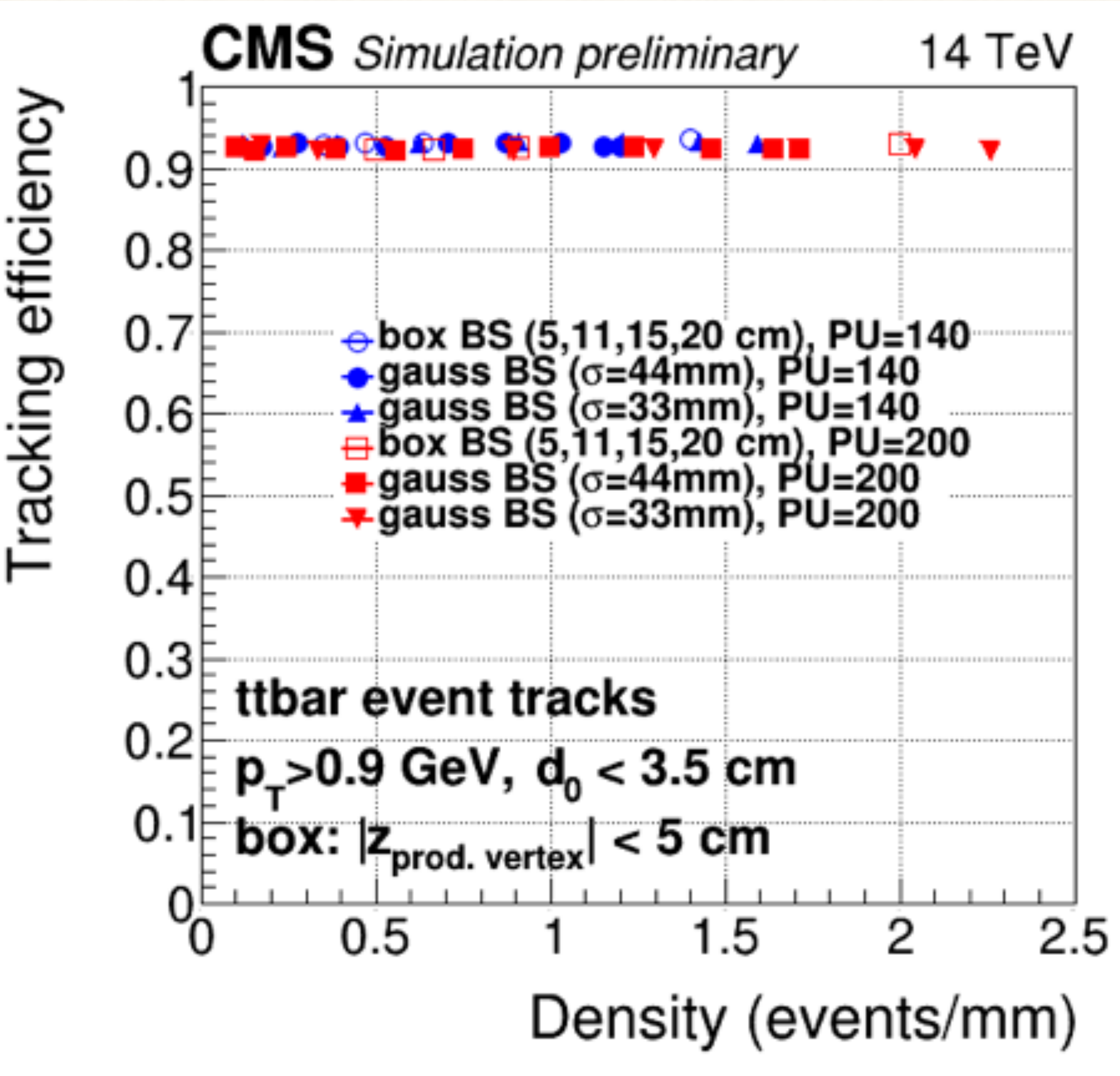
- Tracking efficiency
- Tracking fake rate
- Number of reconstructed vertices vs simulated vertices
- Primary vertex (PV) reconstruction + tagging efficiency
- Track-PV association efficiency, fake rate, and pileup rate

Tracking efficiency

Tracking efficiency as a function of pileup density considering simulated tracks with p_T>0.9 GeV and d_0<3.5 cm

where d_0 is the transverse impact parameter

In addition, for box-shaped beamspots the origin of the simulated tracks is restricted to |z|<5 cm.

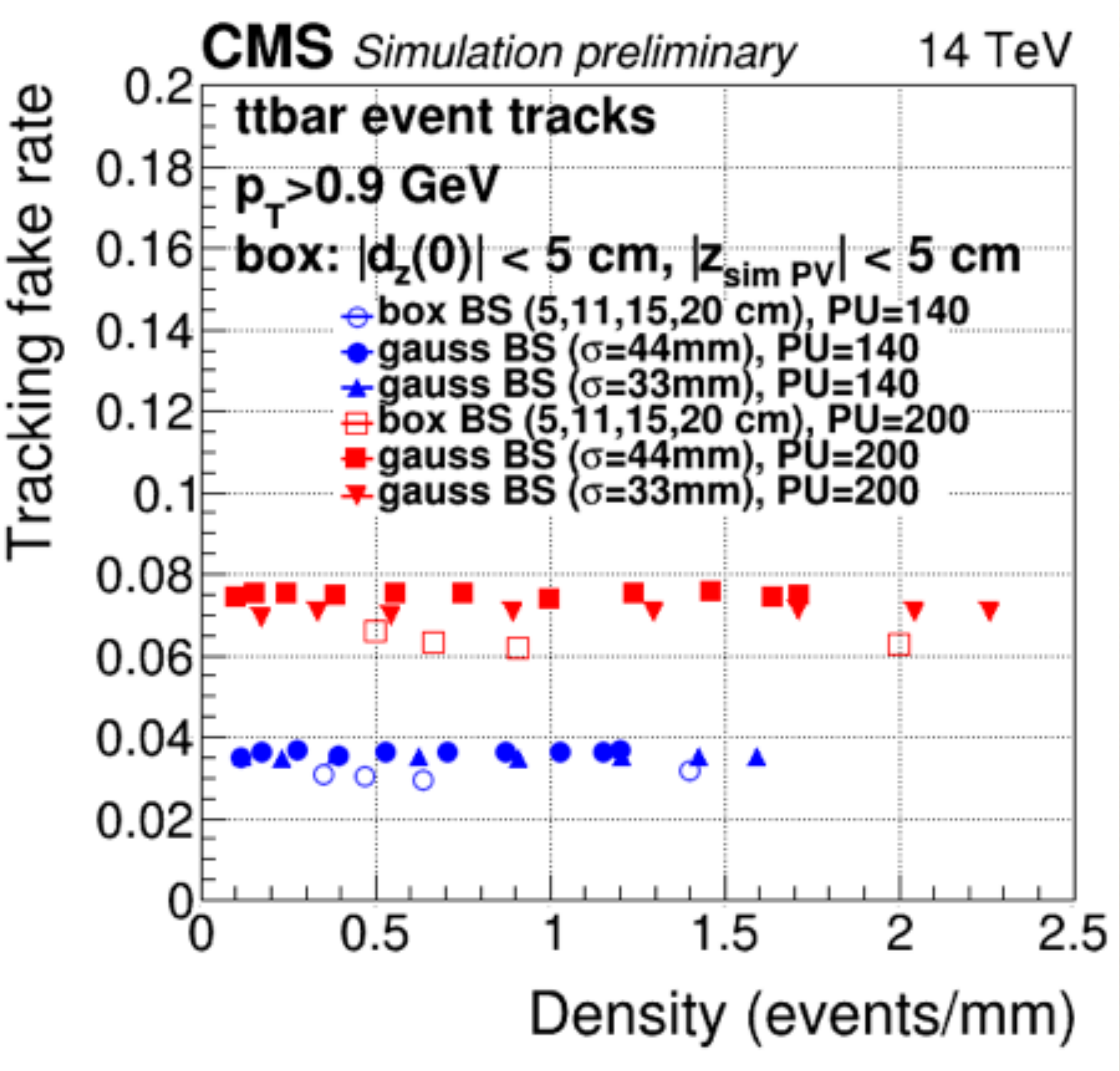


The efficiency is independent of both the pileup density and the overall pileup scenario.

Tracking fake rate

Tracking fake rate as a function of pileup density for simulated tracks with p_T>0.9 GeV

In addition, for box-shaped beamspots the track dz wrt. origin and the simulated primary vertex z are restricted to |z| < 5 cm.

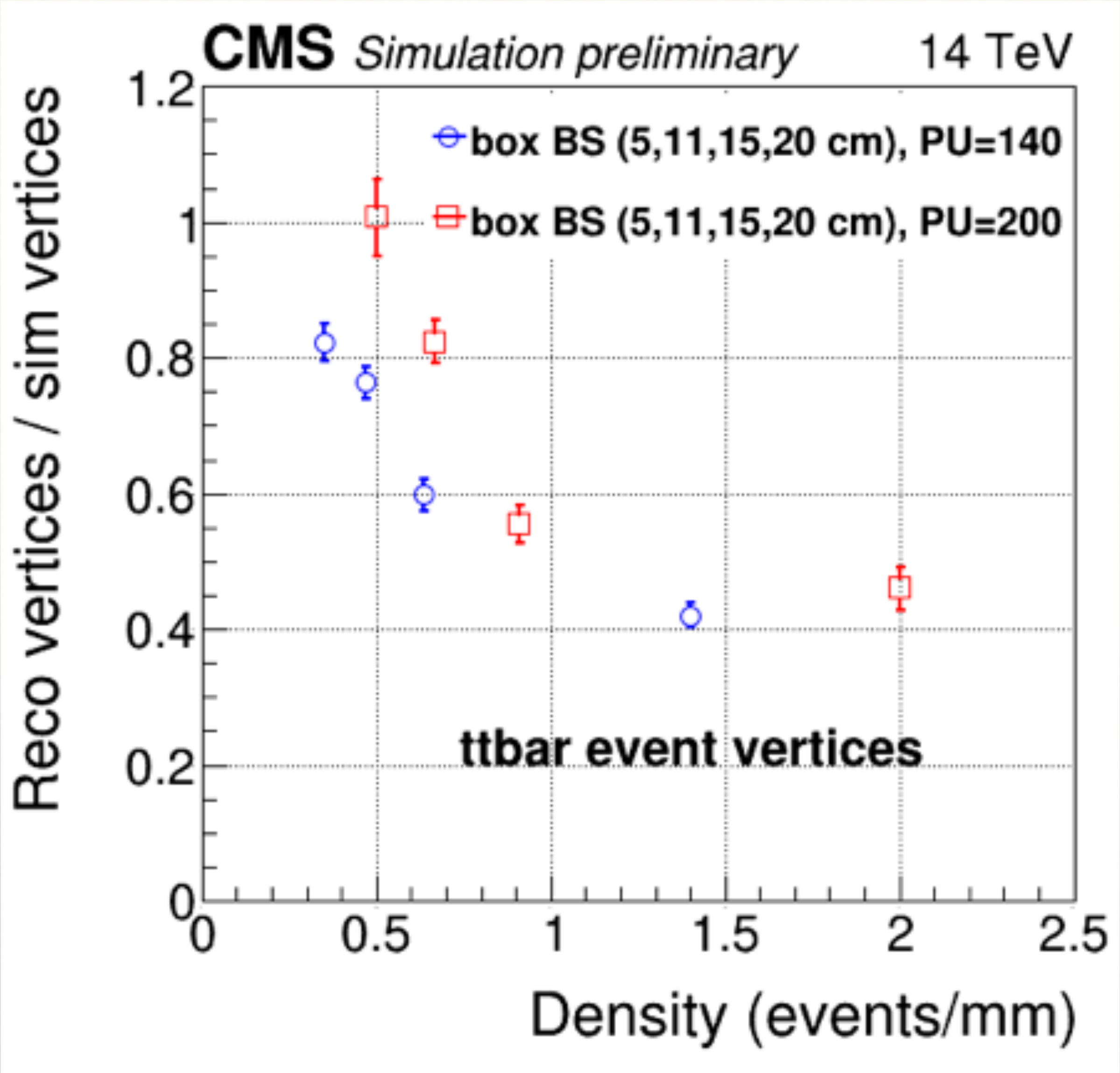


The fake rate is largely independent of the pileup density for a given overall pileup scenario, but does depend on the scenario itself.

Reconstructed vs. simulated vertices

The ratio of the number of reconstructed vertices to the number of simulated vertices, extracted as a slope of a linear fit to a 2D scatter plot for box-shaped beamspots.

Note that the vertices are reconstructed as in Run1 without any tuning for high pileup.



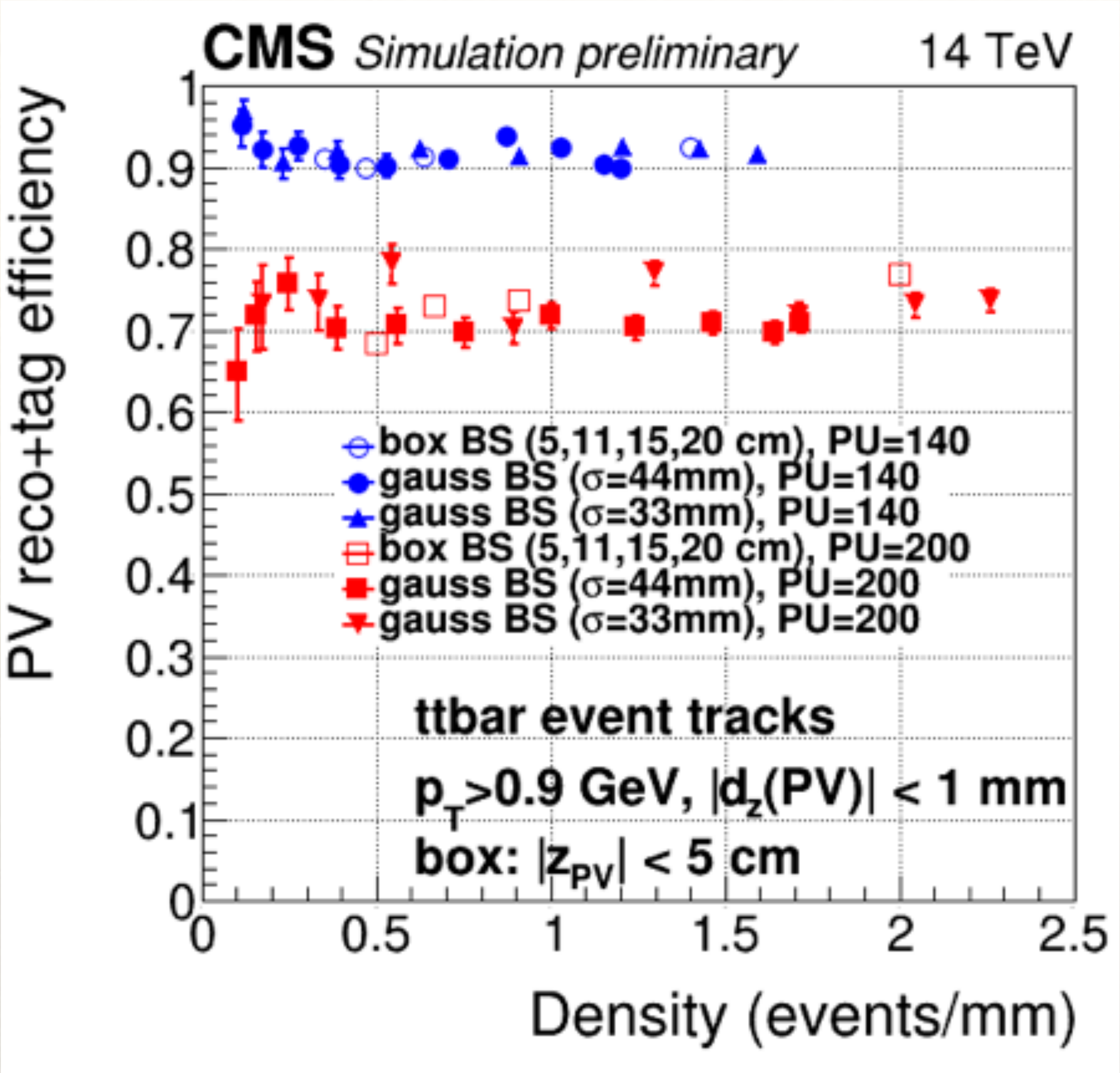
With higher pileup density, the # of recontructed vertices per interaction decreases. The ratio also depends somewhat on the overall pileup scenario.

Primary vertex reconstruction + tagging efficiency

The efficiency to reconstruct and tag the primary vertex (PV) as a function of pileup density

The vertex with the highest $\sum p_T^2$ is tagged as the PV (hard scatter)

For box-shaped beamspots the simulated PV is restricted to |z| < 5 cm.

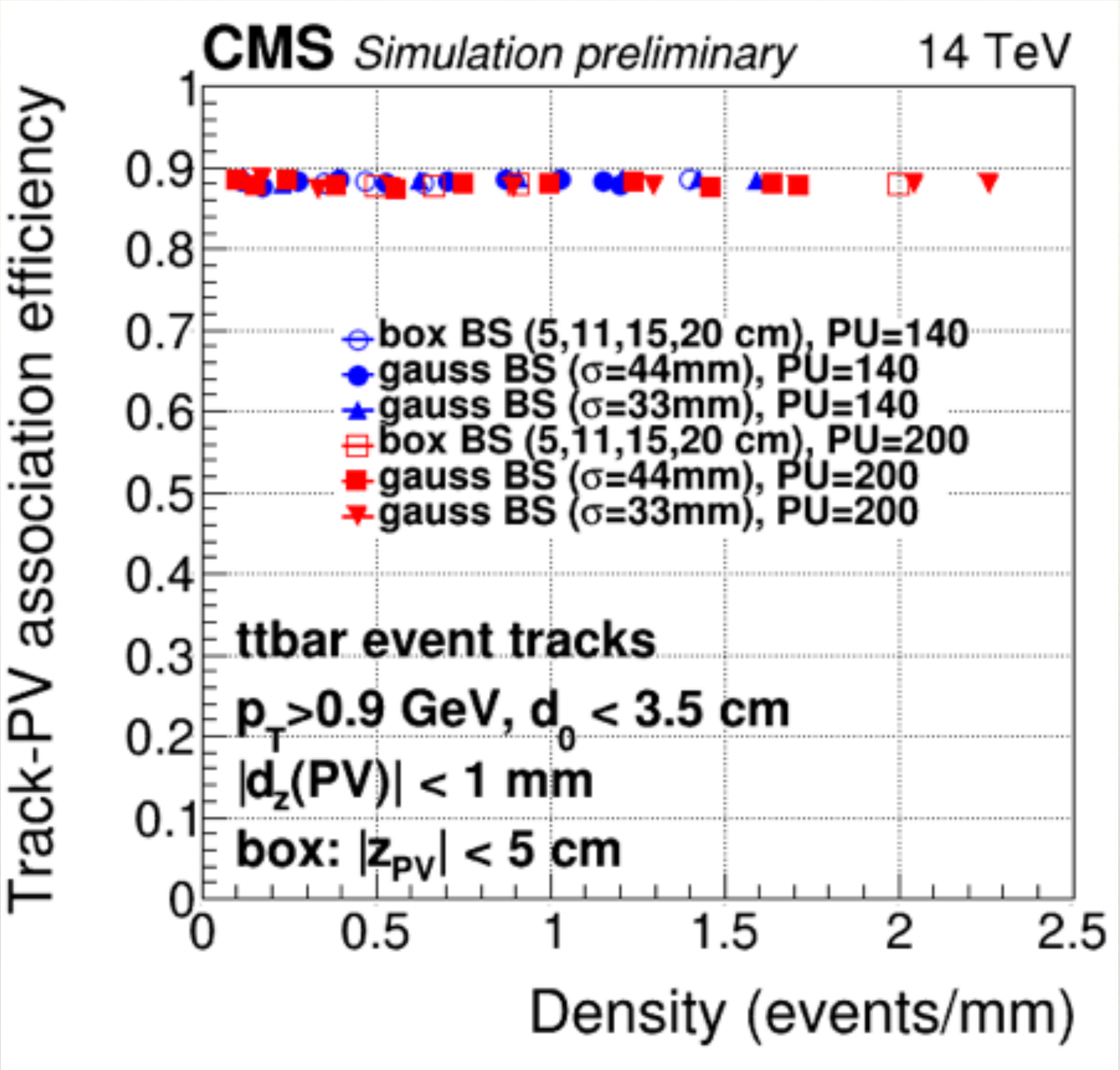


The efficiency is largely independent of the pileup density for a given overall pileup scenario, but does depend on the scenario itself.

Track-PV association efficiency

The efficiency of tracks associated to the reconstructed PV with |dz(PV)| <1 mm as a function of pileup density for the box-shaped and gaussian beamspots for events where the PV is correctly reconstructed and tagged.

In addition, for box-shaped beamspots the simulated PV position is restricted to |z| < 5 cm.

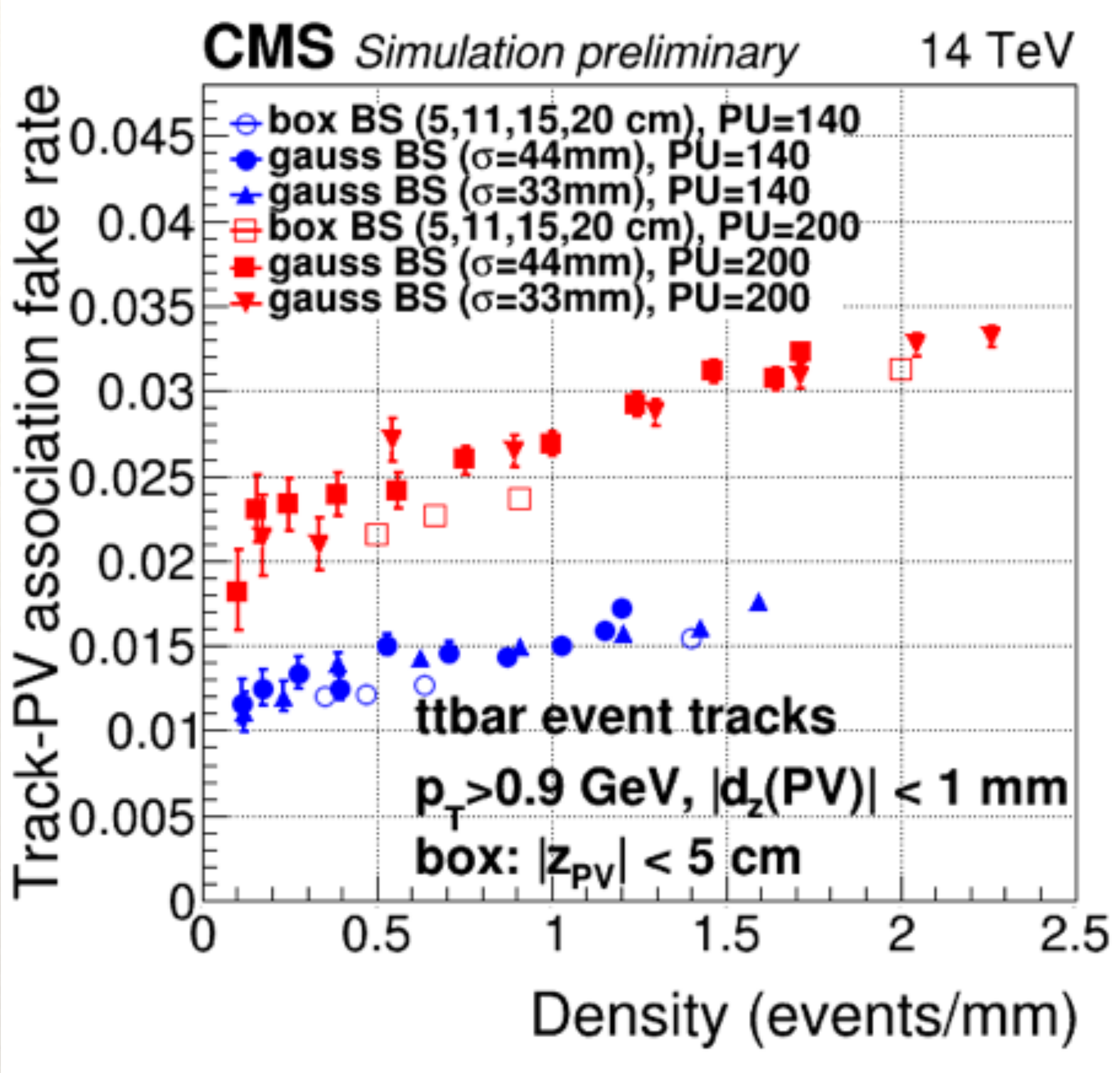


The efficiency is independent of both the pileup density and the overall pileup scenario.

Track-PV association fake rate

The rate of fake tracks associated to the reconstructed PV with |dz(PV)|<1 mm as a function of pileup density for events where the PV is correctly reconstructed and tagged

for box-shaped beamspots (empty points)the simulated PV position is is restricted to |z| < 5 cm

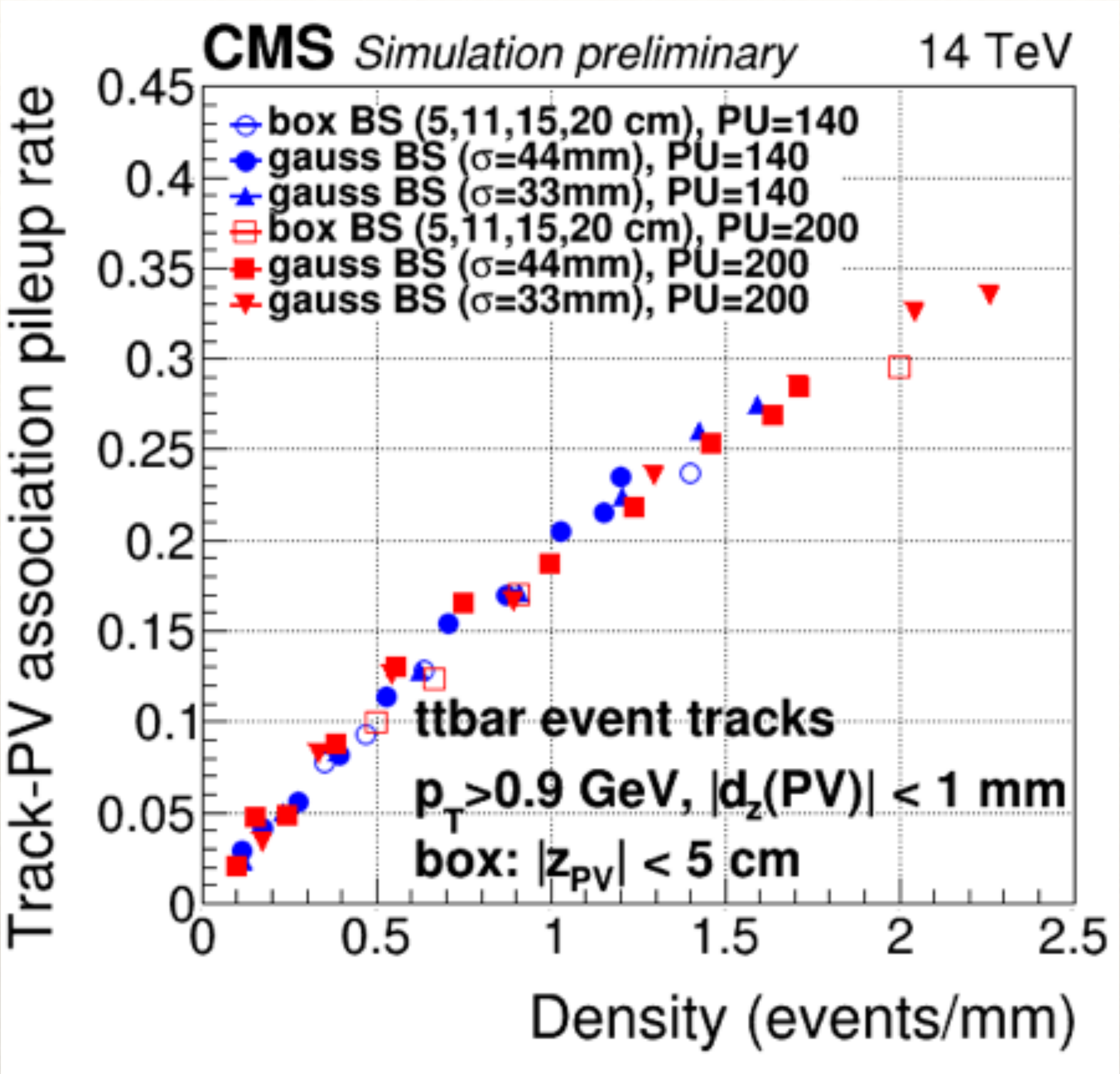


The fake rate increases with higher pileup density. However there is an overall dependance on the average pileup scenario

Track-PV association pileup rate

The rate of « pileup tracks » (matched to minimum bias vertices) associated to the reconstructed PV with |dz(PV)|<1 mm as a function of pileup density for events where the PV is correctly reconstructed and tagged.

for box-shaped beamspots the simulated PV position is is restricted to |z| < 5 cm.



The rate of association of « pileup tracks » increases with the pileup density, but is independent of the overall pileup scenario.

B-tag efficiency study(1)

We have studied the efficiency of b-jet tagging as a function of the density of pileup (PU) events along the beam axis (z).

The b-jet tagging efficiency has been computed for a fixed mis-identication probability of udsg light jets of 0.01.

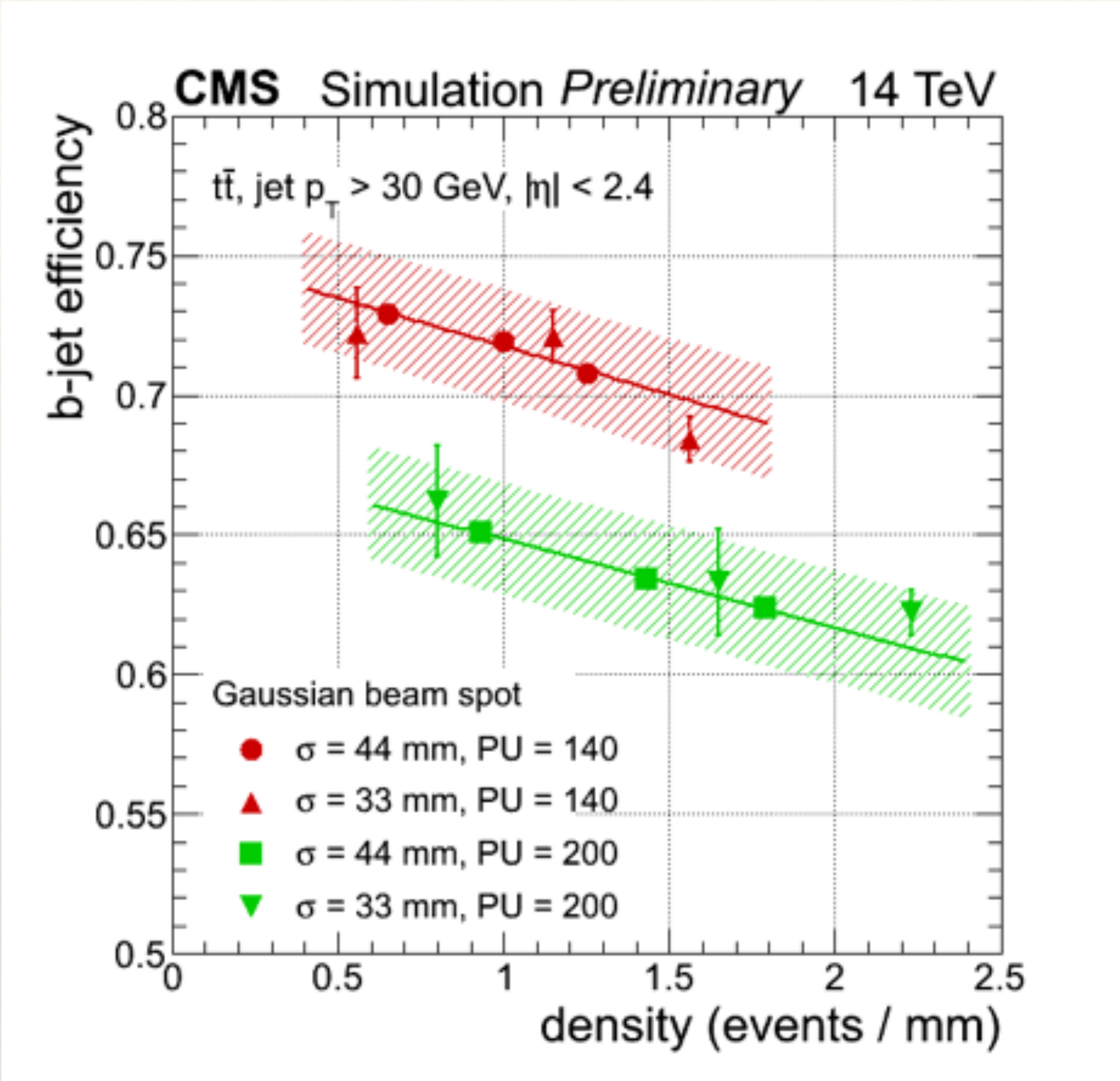
Statistical errors are shown, including those on the choice of the operating point

Results are based on ttbar Monte Carlo simulation for Phase-II conditions with <PU> = 140 (red) or 200 (green).

Two event samples are used, generated with a gaussian beam spot along z of width σ(z) = 3.3 cm or 4.4 cm. For each sample, the b-jet efficiency is computed by selecting events in three ranges according to the generated z value of the hard interaction: |z| < 2 cm, 2 < |z| < 4 cm, 4 < |z| < 6 cm, determining distinct PU density regions.

The computation of the b-jet tagging efficiency includes those events with a wrongly identified primary interaction vertex.

B-tag efficiency study(2)



The displayed lines are fits to the σ(z) = 4.4 cm samples which have a larger statistic.

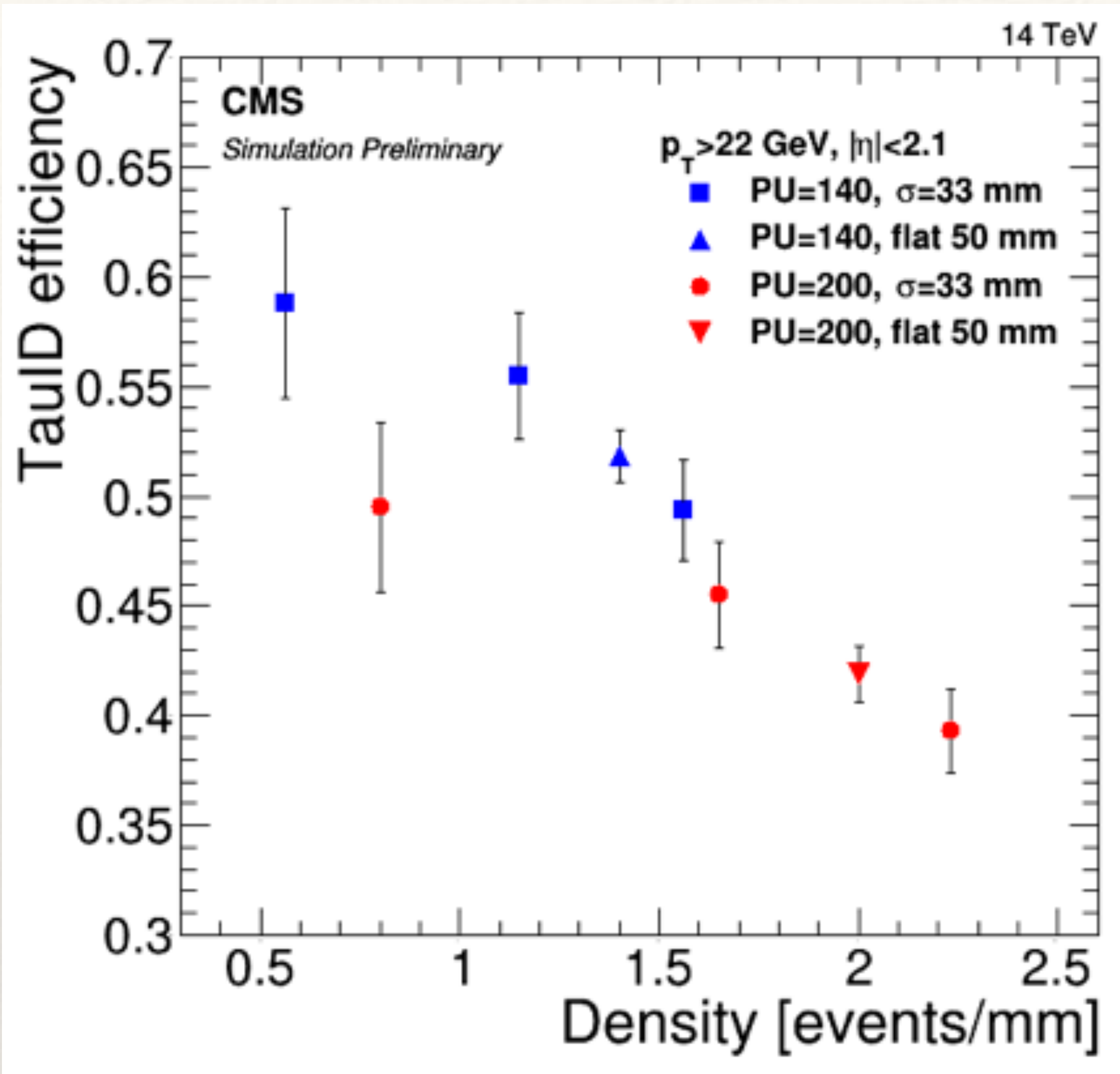
The hatched area describes the systematics due to the comparison between gaussian and box-shaped beam spots.

The b-jet tagging efficiency is lower for higher <μ> values (already shown in the past)

The b-tag algorithm will be reoptimized with the final detector configuration

A trend can be observed, within a specific overall PU, of a decrease of the b-jet tagging efficiency as the pileup density increases.

tau-ID efficiency study (1)



We have studied the efficiency of identifying isolated hadronic tau lepton decays as a function of the local pileup density.

Only statistical uncertainties are shown.

The efficiency is computed using $Z/\gamma^* \to \tau\tau$ events for the Phase2 detector configuration while keeping the misidentification probability constant at 2% in top quark pair events

Only objects with pT>22 GeV and |η|<2.1 are considered.

The methodology is the same as used for tau identification during LHC Run 2 (CMS-PAS-TAU-16-002)

A clear trend of decreasing efficiency with respect to the increasing pileup density is observed. Statistics insufficient to disentangle a potential dependence on the value of the total PU scenario

Muon Isolation Study

A very important aspect is to monitor the capability of identifying high energy isolated leptons in signal events.

We have studied the selection efficiency of the “loose” muon track isolation working point as a function of the linear pileup density for 200 and 140 pileup scenarios.

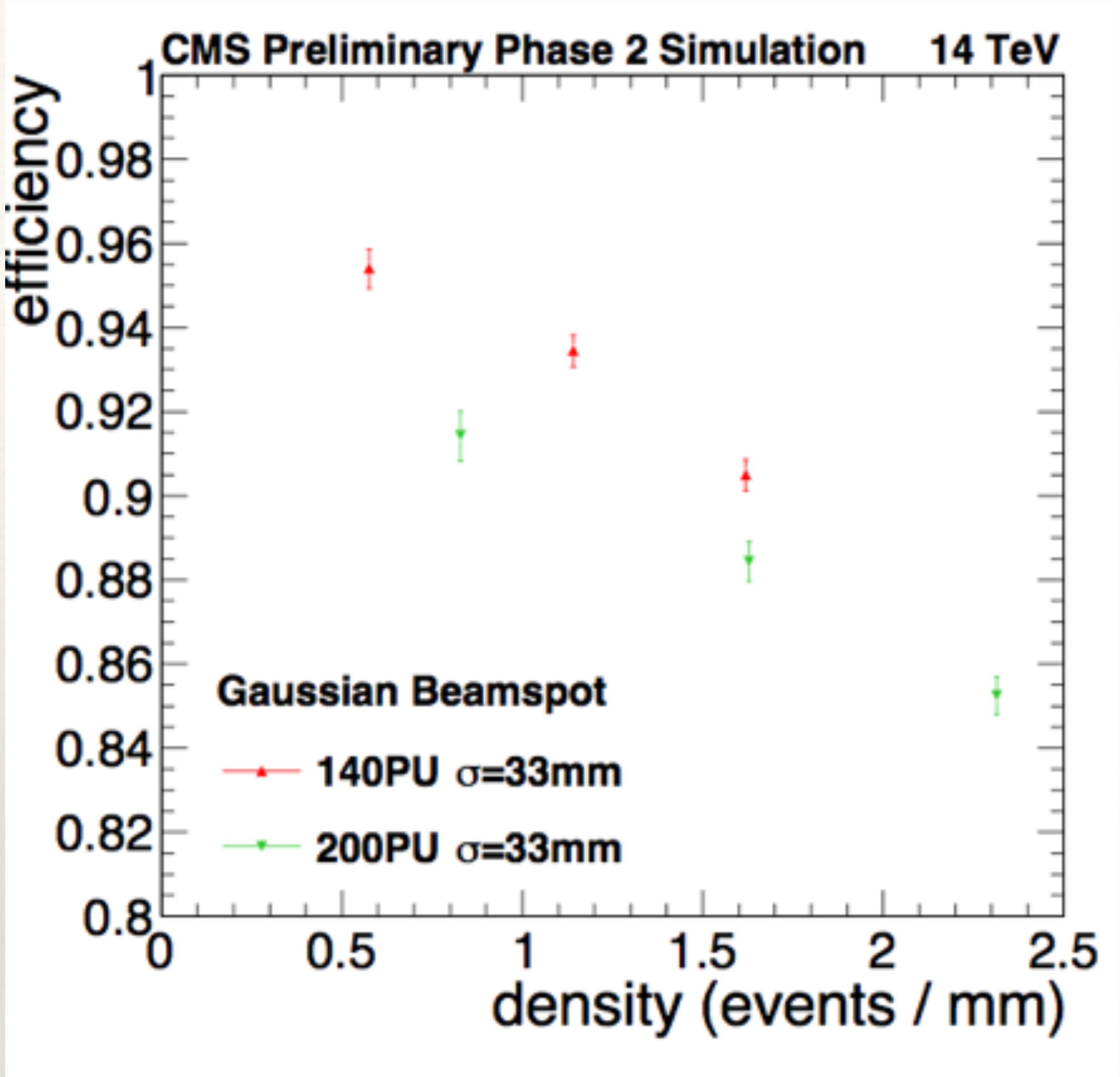
The isolation variable is calculated by summing the transverse momentum of tracks in a cone of $\Delta R<0.3$ about the muon, using only the tracks with a vertex fitting weight of 0.5 or greater.

The working point is defined by requiring the isolation sum divided by the muon’s transverse momentum be greater than 0.10.

The efficiency is calculated with respect to generator-matched reconstructed muons, requiring only that the muon transverse momentum be larger than 20 GeV.

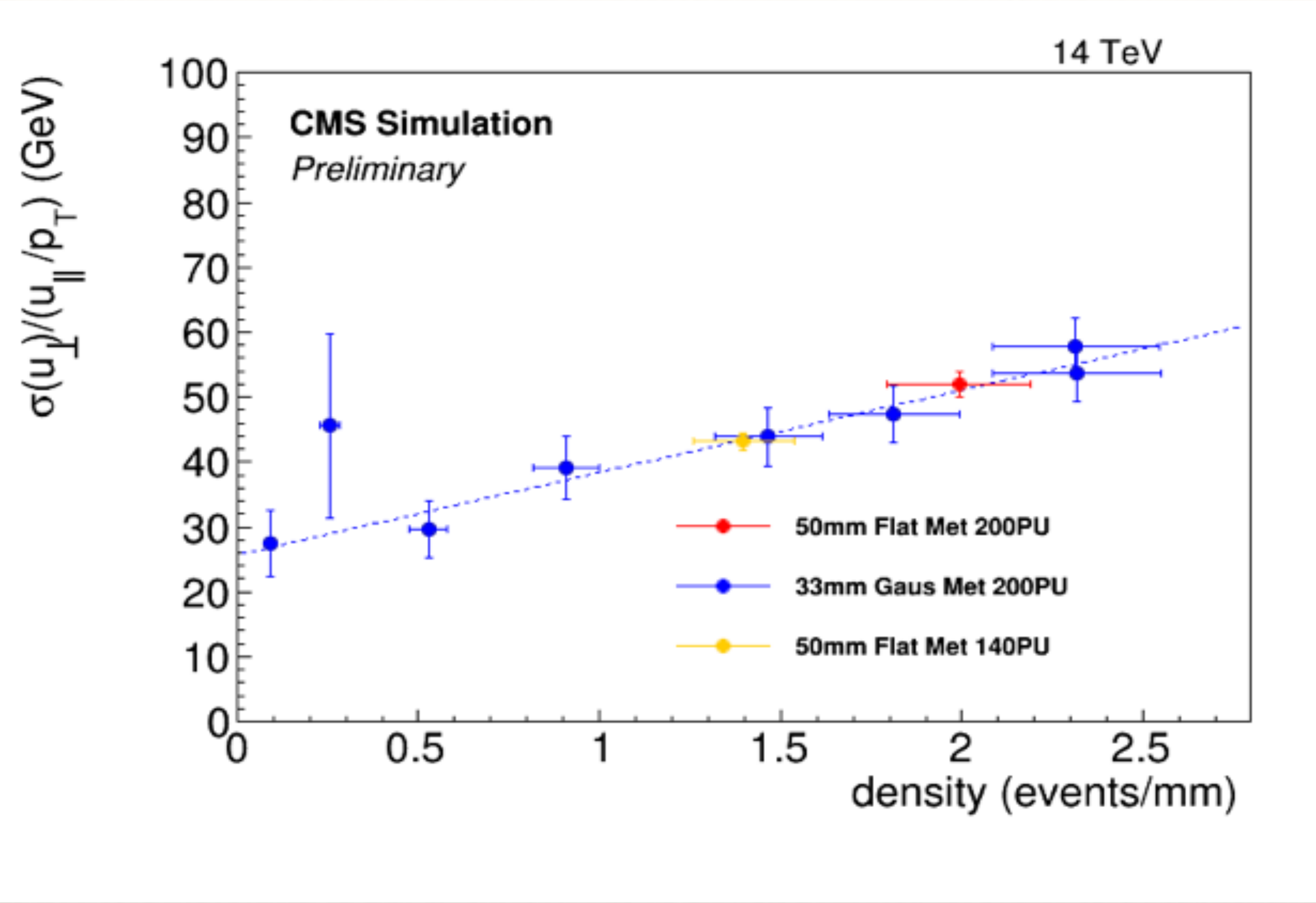
Muon Isolation Study

- In this case the study is performed considering a fixed working point (contrary to the previous cases)
  - it is therefore pessimistic if compared to result obtained keeping efficiency at a fixed background rejection.



A 2-4% global reduction in efficiency is seen between 200 and 140 pileup scenarios, and there is a strong negative trend in the efficiency as a function of increasing pileup density.

MET resolution study



Distribution of the resolution for the perpendicular hadronic recoil as computed with PUPPI* in Z→μμ events as a function of pileup density.

The hadronic recoil is response corrected for all cases.

A line is fit to the gaussian beam profile sample(blue) to guide the eye.

*PUPPI=Pile Up Per Particle ID: algorithm used for PU mitigation. Reweights contributions based on probability function. arXiv:1407.6013

A trend of increasing resolution as a function of pileup density if observed, independent of the overall pileup scenario (dominated by neutral energy deposits)

Conclusions

Following the potential nominal and ultimate running scenario from the LHC experts we have simulated specific samples with 140 and 200 total pileup and various beamspot shapes

these allow to perform new studies as a function of local pileup density (events/mm)

particular interest has been given not only to tracking and vertexing variables

that drive the overall global event reconstruction for CMS

but also to the effect on higher level objects that include the effects of neutral deposits in the detector

We have observed that the overal pileup and its local density impact in various ways the performance of the physics objects.

It is extremely important to keep studying these effects in order to be able to answer on the overall physics performance for the different running conditions as well as to determine the best machine running scenario.