# Search for Heavy Stable Charged Particles in the CMS Experiment using the RPC phase II upgraded detectors

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## Abstract

*Several theoretical models inspired in the idea of super-symmetry (SUSY) accommodate the possibility of HSCPs (Heavy Stable Charged Particles). The phase-II upgrade of the CMS-RPC system will allow the trigger and identification of these kind of particles exploiting the Time of Flight Technique with the improved time resolution that a new DAQ system will provide ( 1.5ns).*

## 1. Introduction

The RPC detectors have an intrinsic time resolution [1] of the order of 1.5 ns but the link system records the RPC hits information in steps of one Bunch Crossing BX (25 ns), degrading the full timing resolution of the detector.

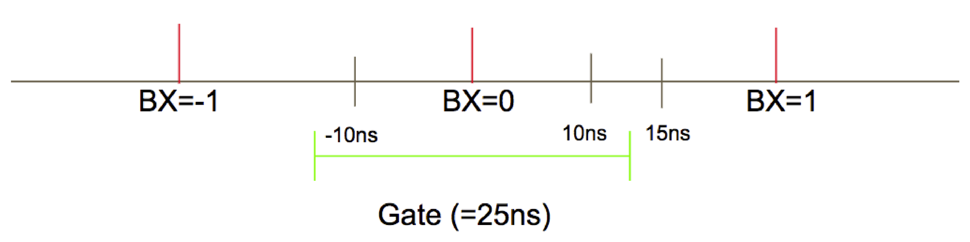


**Figure 1:** *Diagram of current time measurement performed by the RPC detector.*

In the upgrade that will take place in 2023 the Link System of the complete RPC detector will be replaced. This will allow it to match the intrinsic resolution of the detector.

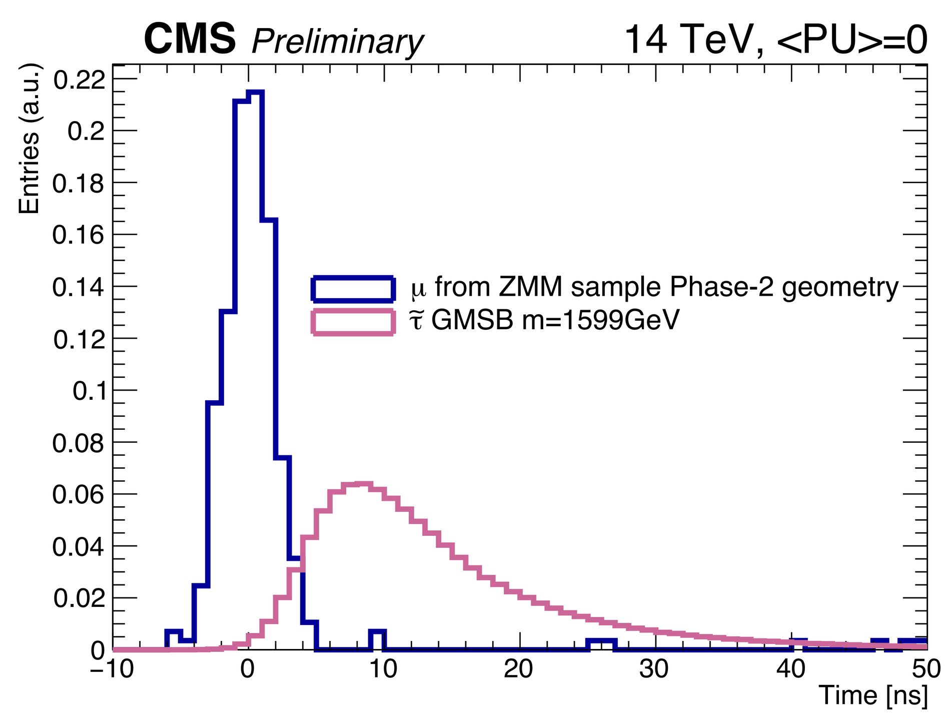


**Figure 2:** *Simulated time distributions for muons and $\tilde{\tau}$s after the detector upgrade. Simulated RPC hit time distribution for muons from $Z \to \mu^+\mu^-$ events and for semi-stable $\tilde{\tau}$'s with $m \approx 1600$ GeV, produced in $pp \to \tilde{\tau}\tilde{\tau}$ processes.*

The upgrade of the RPC system will allow the trigger and identification of slowly moving particles by measuring their time of flight to each RPC station with a resolution of $O(1)$ ns.

## 2. Time of Flight Technique(TOF)

We use of the new precise time measurement to identify the time when the particle was created and also the speed of the particle.

In order to perform measurement of $\beta$ and $t_0$ we have to do first the matching of the RPC hits with the generated particles.

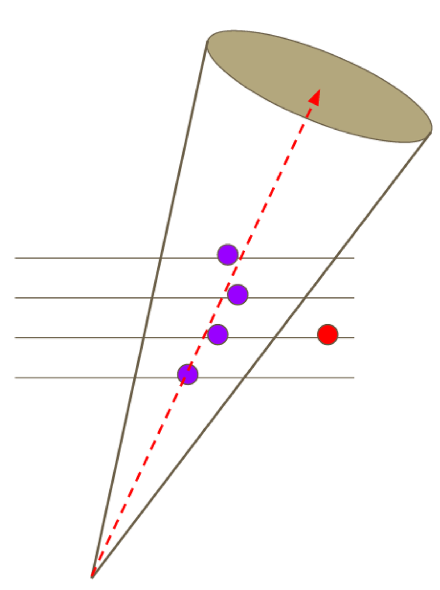

**Figure 3:** *A cone (with $dR < 0.3$) is defined around the direction of the generated particle and only the RPC hits inside it are selected.*

The different particles will leave different patterns. With this we can identify the kind of particle.

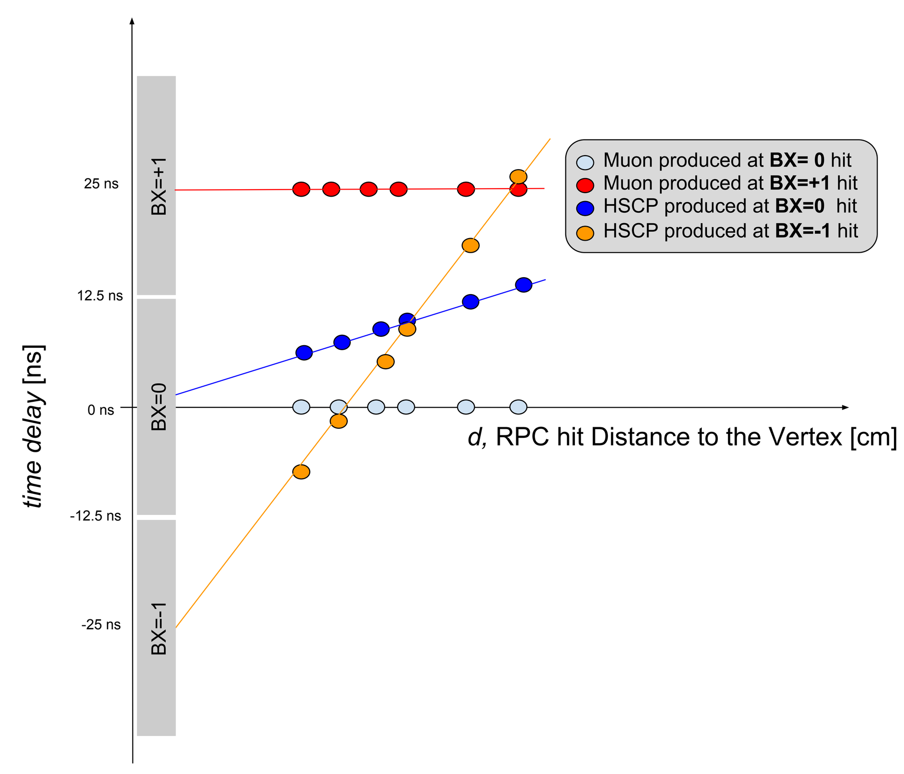


**Figure 4:** *Diagram showing times measured at different RPC stations for particles originating at different BXs with different velocities. Clock at all RPC stations is tuned so that particles moving with the speed of light are registered with the exact same "local" times. Hence, relativistic particles are represented by horizontal lines on this diagram. We can identify the following particular cases: HSCP in time (blue), HSCP out of time (orange), muon in time (red) and muon out of time (Grey).*

Starting from the simple equation:

$$v_{layer} = \frac{|\overrightarrow{RPCHit}|}{ToF} \qquad (1)$$

After some algebra we have that $\beta$ and $t_0$ are related by the following expresion:

$$t_{delay} = t_0 + \frac{d}{c}(\beta^{-1} - 1) \qquad (2)$$

where $t_{delay}$ is the time measured with respect to a particle moving at speed of light, $d$ is the distance from the interaction point to the impact point and c is the speed of light.

For the muon the second term in Eq. 2 vanishes. For the HSCPs we performed a Least Squares Fit, using the linear form:

$$y = a + bx \qquad (3)$$

where a = $t_0$ and b = $\frac{\beta^{-1}-1}{c}$.

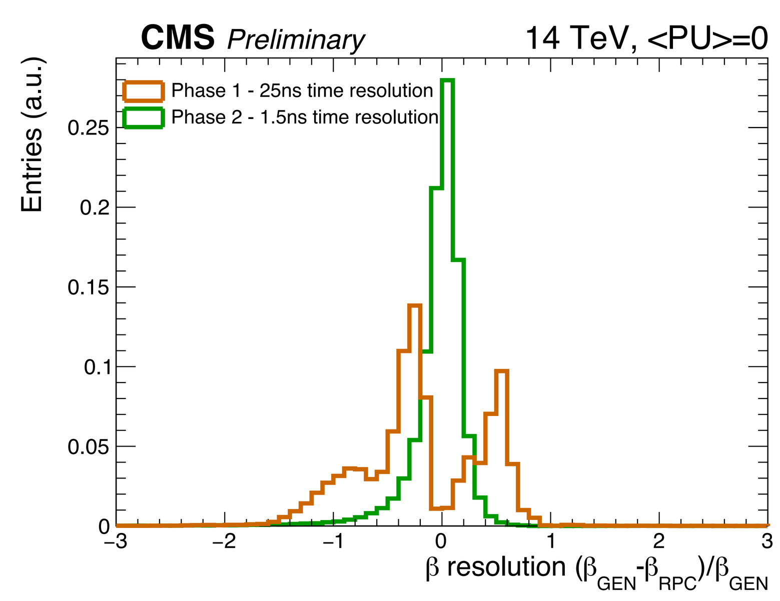


**Figure 5:** *Resolution of a particle speed measurement at $L1$ trigger level with Phase$-1$ and upgraded RPC Link System.*

## 3. Trigger strategy

The trigger algorithm is:

1. at least 3 hits correlated in space
2. error in beta $< 30\%$ (to assure good quality of the fit)
3. slope $> 0$ (to exclude muons and identify slow moving particles)

## 4. Efficiency

The new trigger proposal will be complement for the present muon trigger whose efficiency sharply drops for particles with $\beta < 0.6$

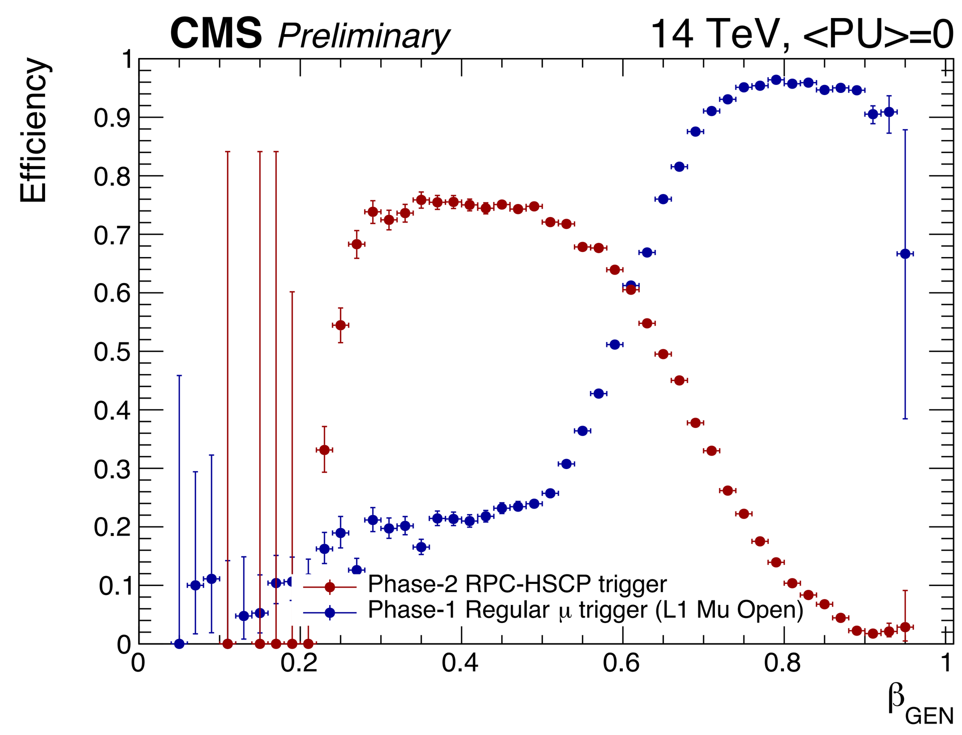


**Figure 6:** *L1 Trigger efficiency as a function of an HSCP velocity $\beta$ for the 'regular' muon trigger (in blue) and a dedicated HSCP trigger, fully exploiting the improved timing of the upgraded RPC link system (red points).*

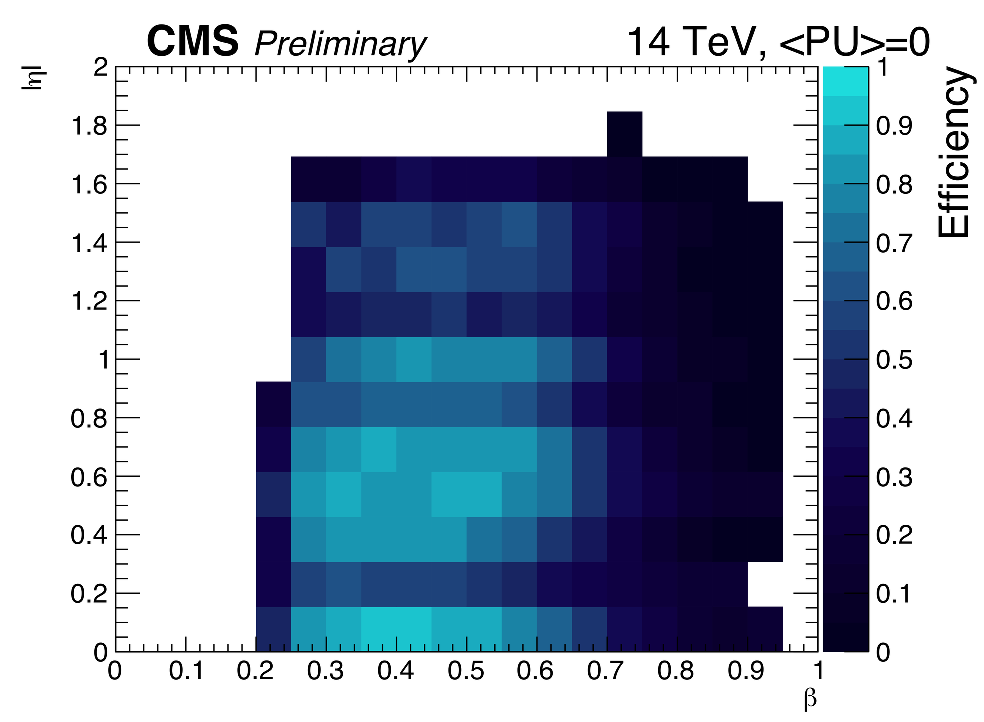


**Figure 7:** *HSCP trigger efficiency as a function of HSCP velocity $\beta$ and pseudorapidity $\eta$.*

## 5. Conclusions

- The time resolution of the RPC detector, affecting all the present RPCs, will be greatly improved by the upgrade of the link system
- The CMS HSCP trigger capabilities will be extended from the present limitation of $\beta \sim 0.6$ down to $\beta \sim 0.2$.
- The trigger purity is expected to be high and can be improved even further by combining the HSCP muon system trigger with a better brunch crossing identification at trigger level.

## References

[1] M. Abbrescia et al. Local and global performance of double-gap resistive plate chambers operated in avalanche mode. *Nucl. Instrum. Meth.*, A434 (1999) 244, doi:10.1016/S0168-9002(99)00534-3.