Optimization of Validity gates

Reduction of Pileup contributions to Occupancy

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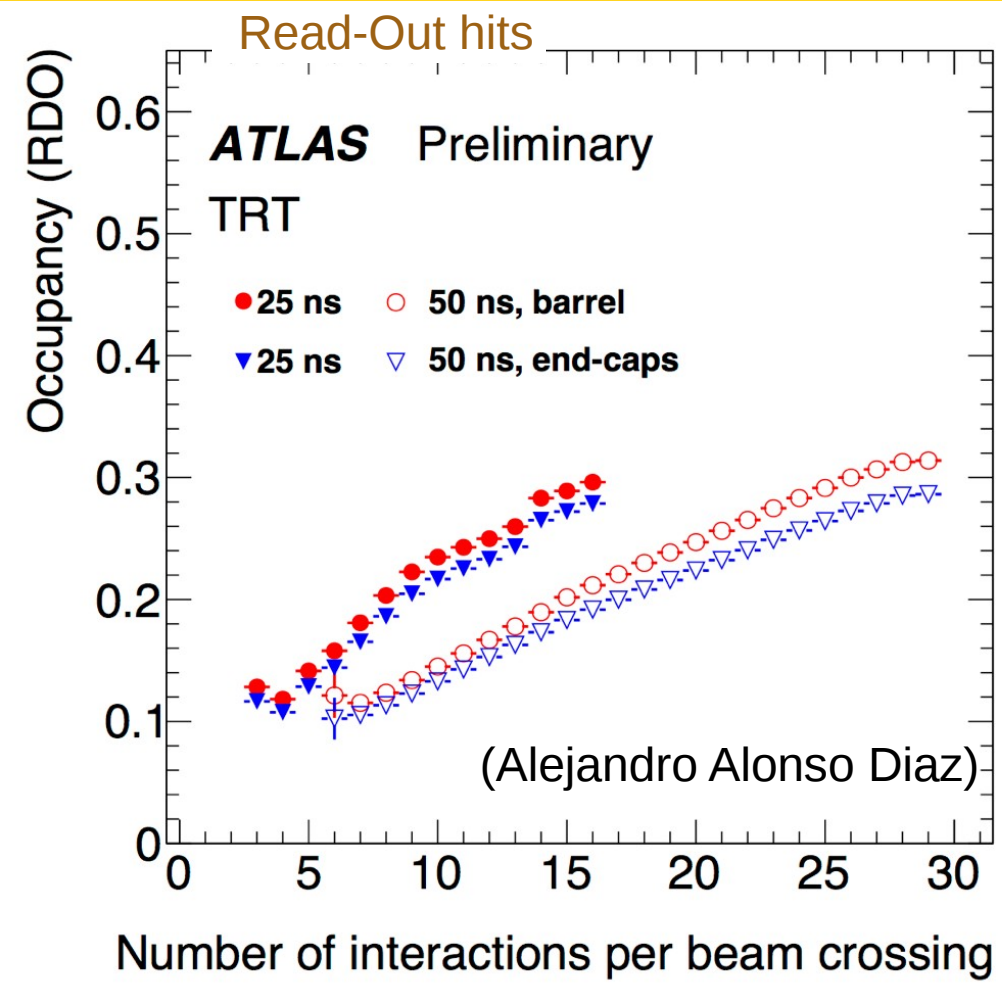
Note: ATL-INDET-INT-2013-009

<http://cds.cern.ch/record/1612487>

30 October , 2013

Occupancy of the TRT at 25ns and 50ns



Events: At least 1 primary vertex

The **occupancy increase** for 25ns bunch spacing is a result of the **straw signal spread** which occupies the whole readout window (75ns).

The most valuable information (drift-time) is situated in first 50 ns of the TRTreadout window

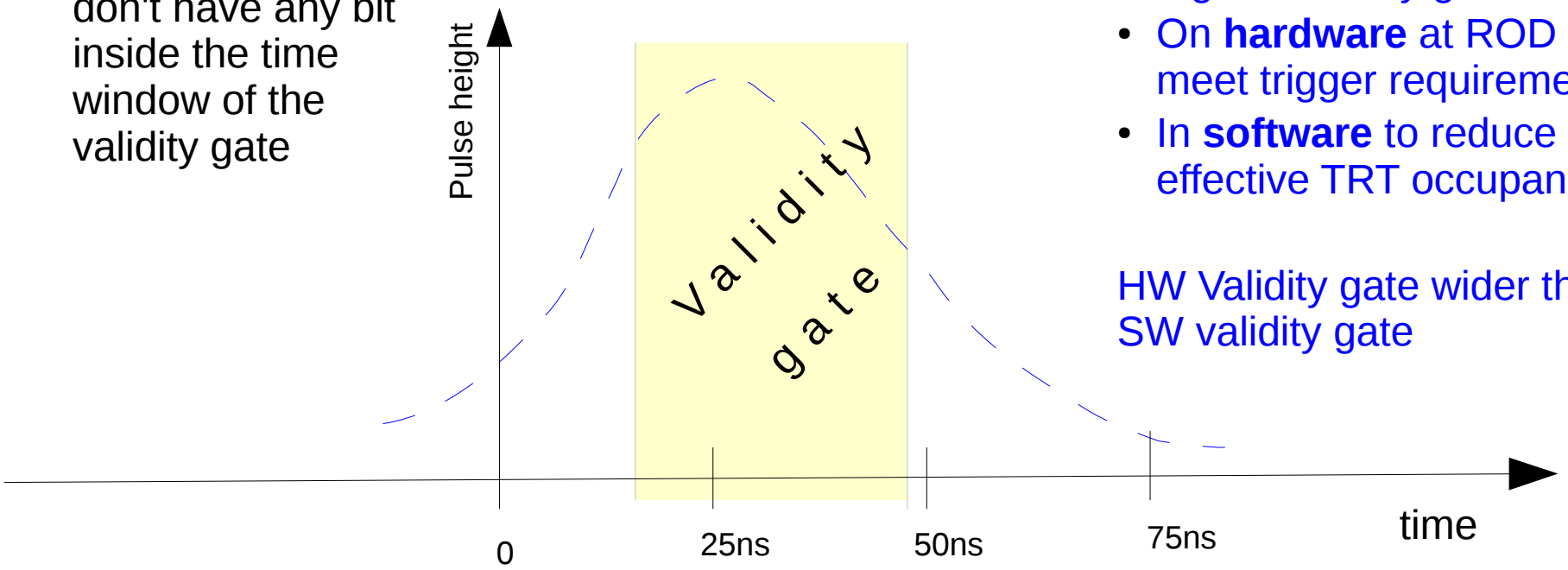
In order to mitigate the impact of pile-up – select hits belonging to the trigger bunch.

Validity gate method

Validity gates at 25ns bx

- Save hits with bit pattern that satisfies **validity requirement**
- Ignore hits which don't have any bit inside the time window of the validity gate

Validity requirement: At least one low threshold bit inside a **time window (=validity gate)**



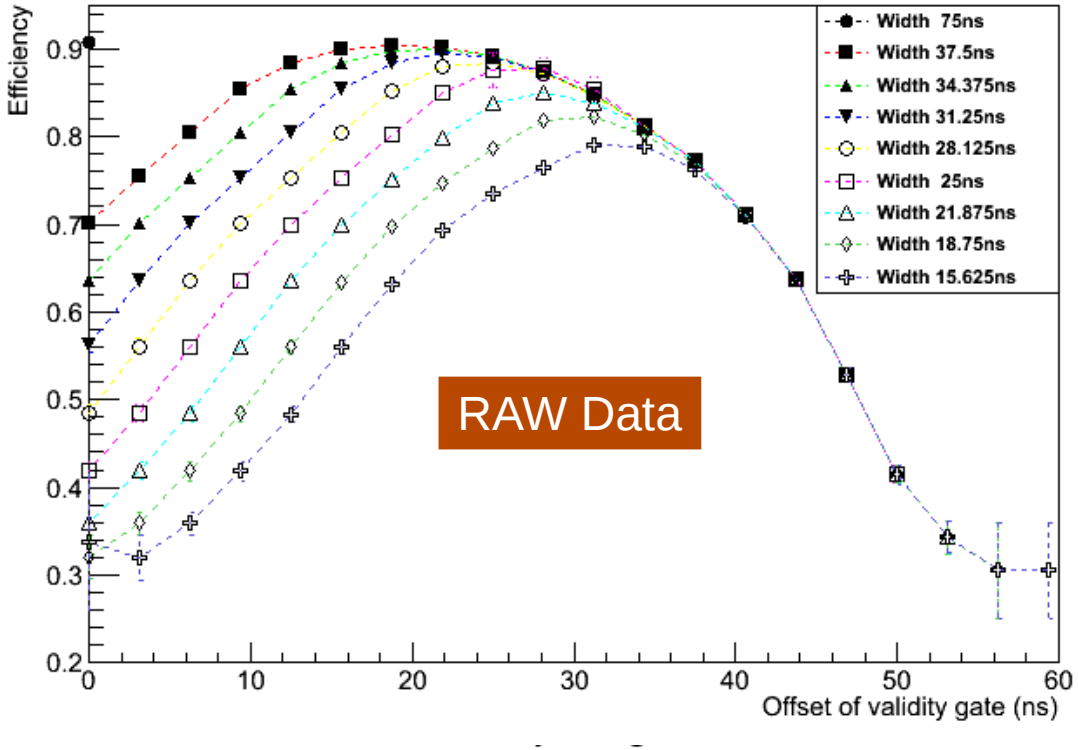
Position of time window optimized for each time window size

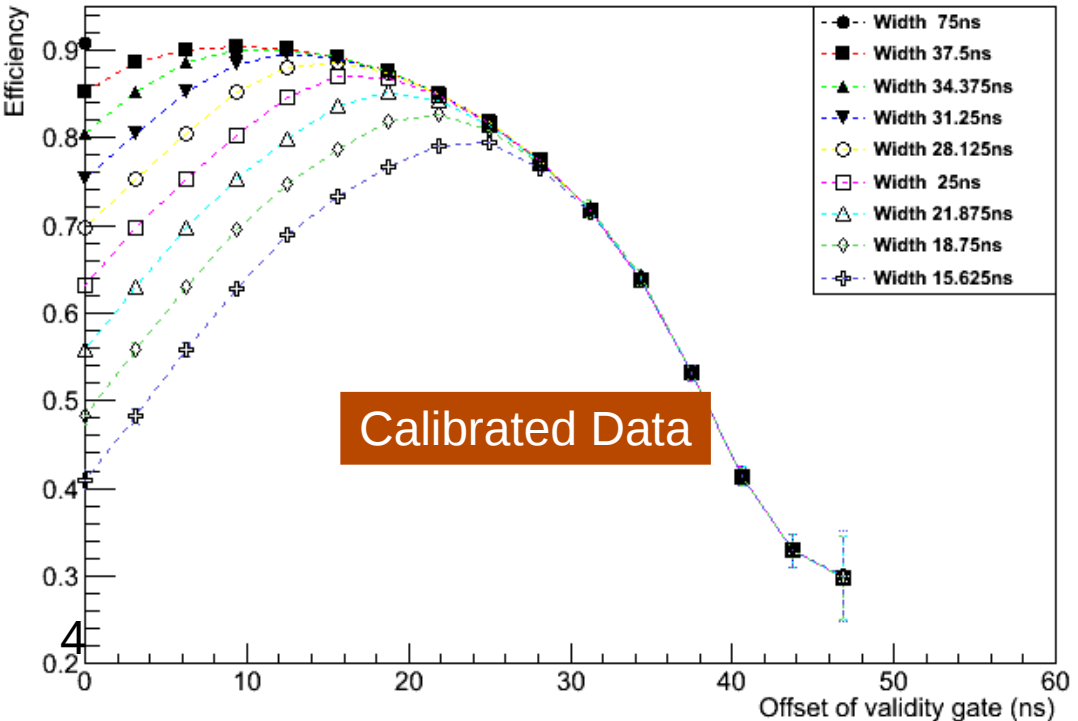
Usage of validity gates:

- On **hardware** at ROD to meet trigger requirements.
- In **software** to reduce effective TRT occupancy

HW Validity gate wider than SW validity gate

<μ>~0.003 (run 20085) Endcap C





Hit Efficiencies

$$\varepsilon = \frac{\#\,hits}{\#\,hits + \#\,holes}$$

Validity gate

Raw data:

Find a signal in a timebin i such that (0.5+i)*3.125 is inside the gate

Calibrated data:

Find a signal in a timebin i such that (0.5+i)*3.125 – T_0 is inside the gate.

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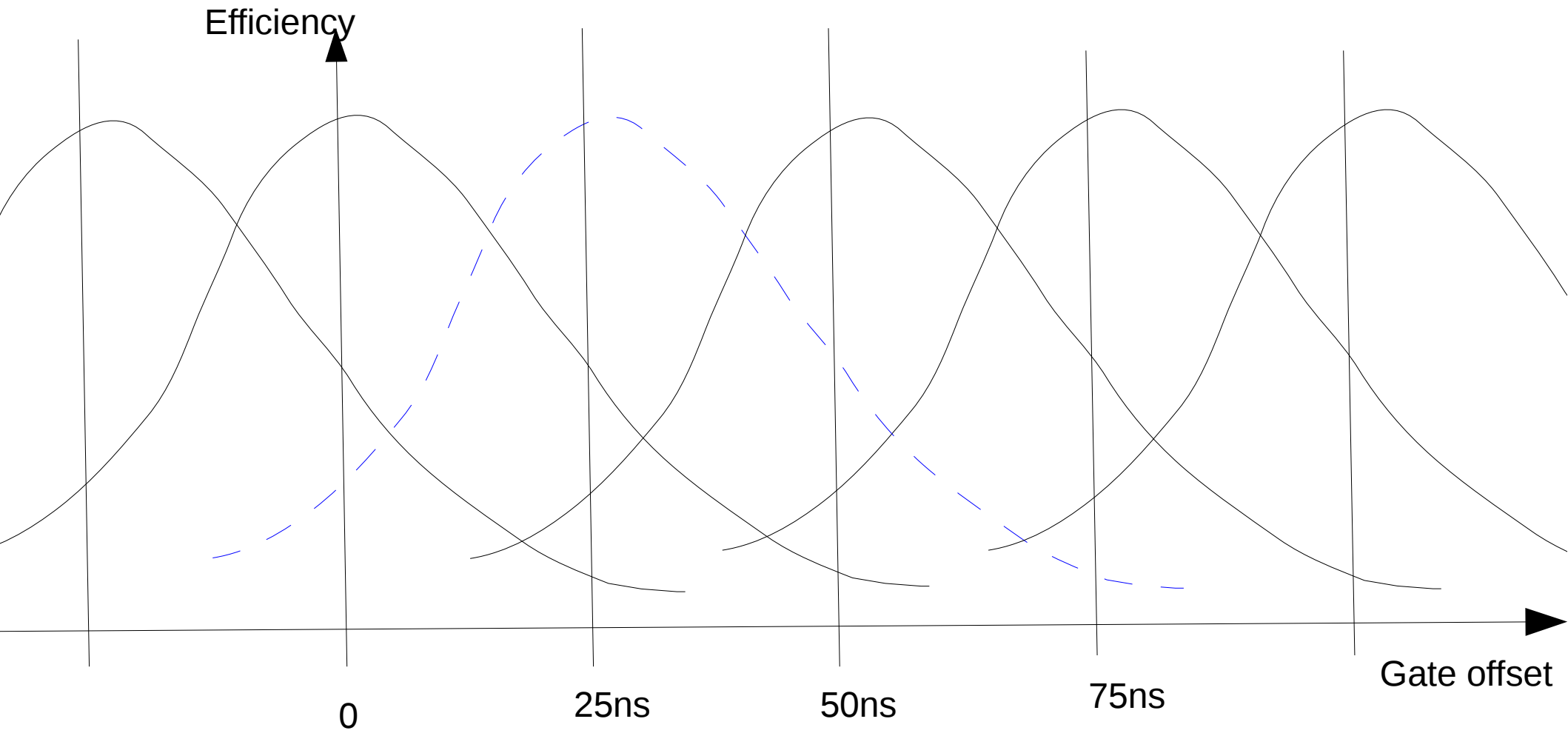
Method:

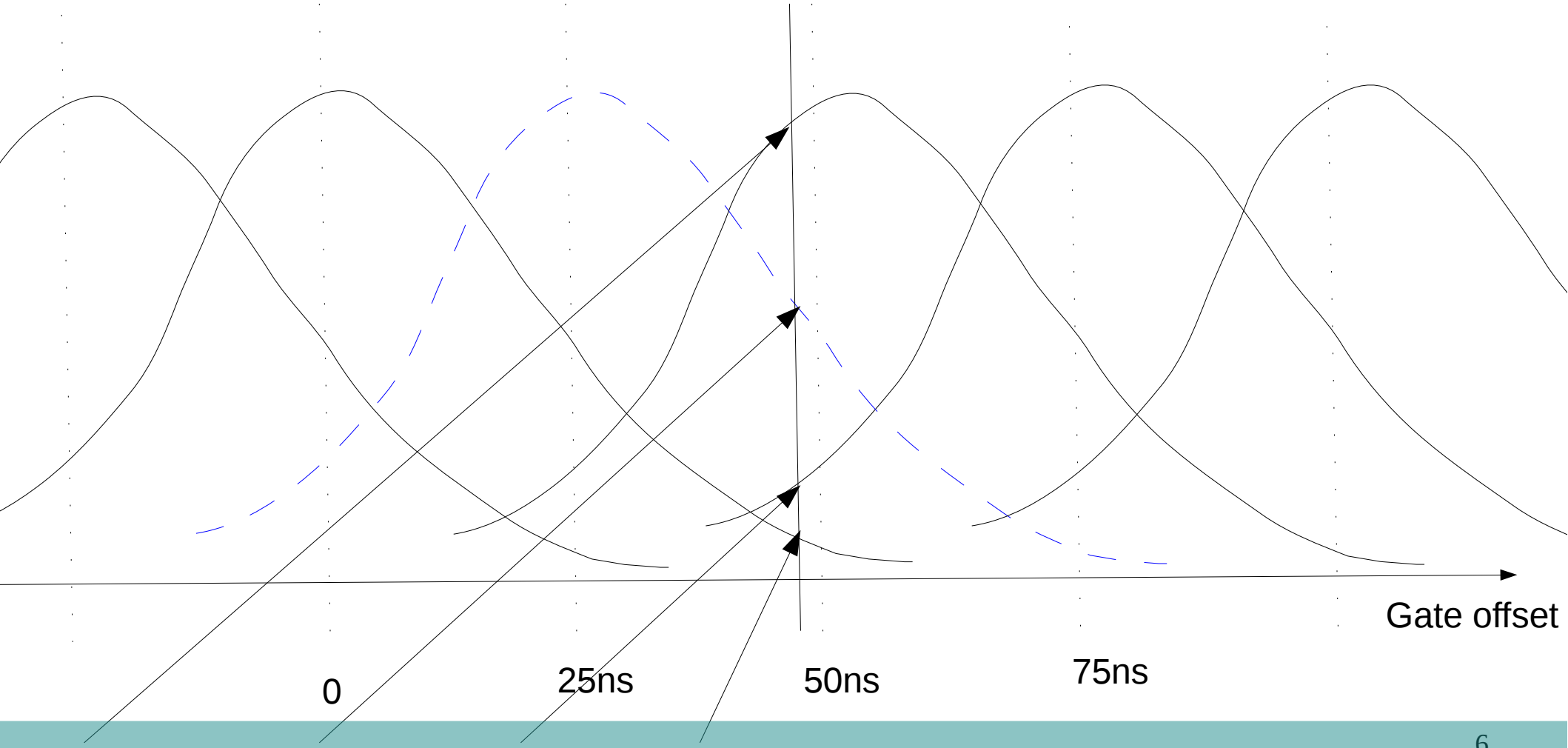
* For very low luminosity data, obtain hit efficiency plot.
* Manually place copies of the plot, displaced 25ns



For a certain choice of gate offset and gate width:

* Occupancy from own bunch $O_S = c * S$, where
  c is a constant and S is hit efficiency of signal
* Occupancy from any other bunch $O_k = c * F_k$

In the example below F_k is $\{F_1, F_2, F_3\}$



Calculations:

For a certain choice of gate offset and gate width:

- Occupancy from own bunch $O_s = c\ S$, where c is a constant
- Occupancy from any other bunch $O_k = c\ F_k$
- Number of particles from bunch k is N_k

  $O_k = 1 - P_k$, where P_k is probability to have no hit and $P_k = e^{-N_k}$

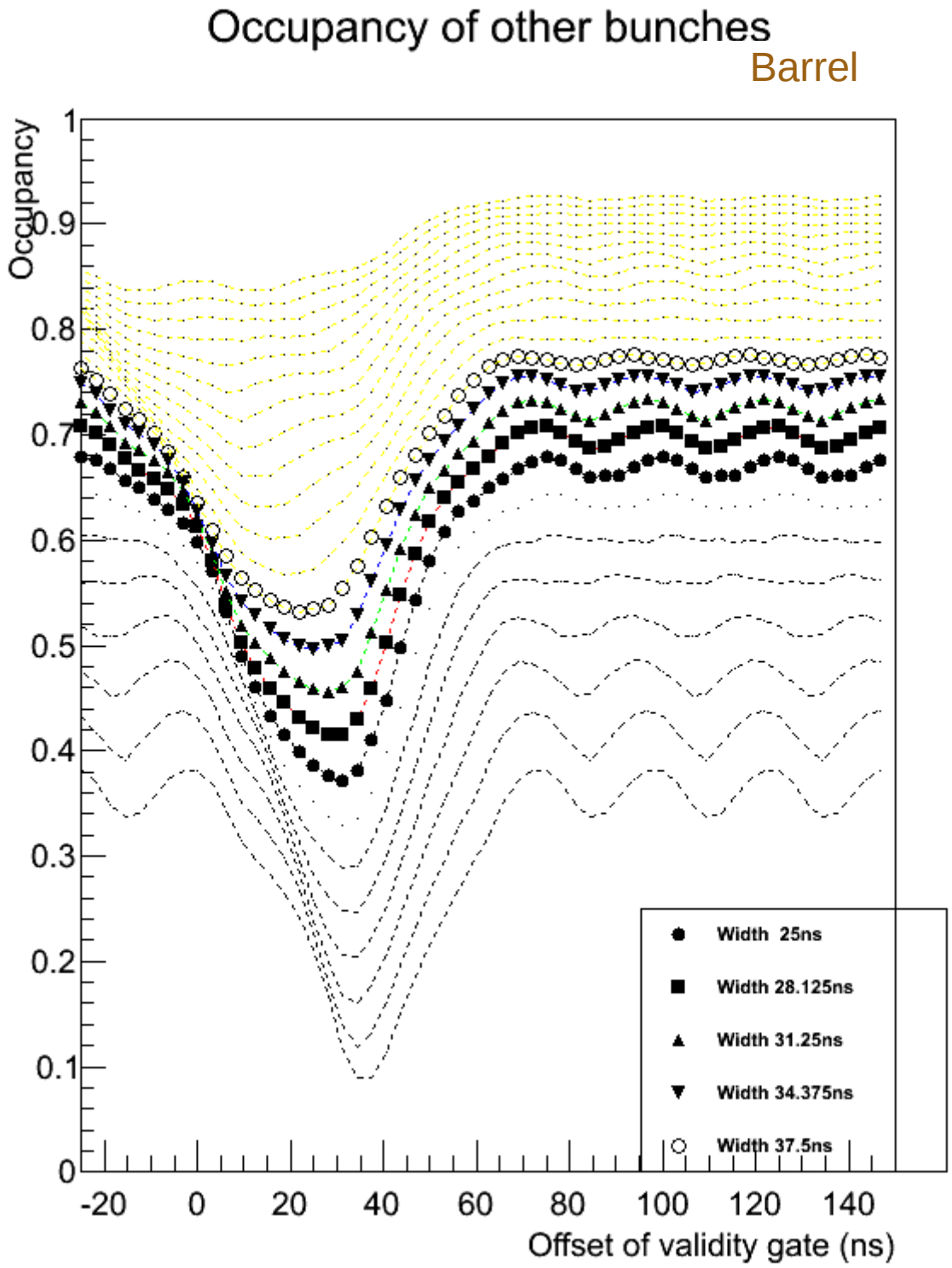
  $\rightarrow N_k = -\ln P = -\ln(1-O_k) = -\ln(1-cF_k)$
- Total number of particles from other bunches (pile-up):

  $N_{tot} = \Sigma N_k = \Sigma(-\ln(1-cF_k))$
- Occupancy from all other bunches (pile-up):

  $O = 1- P = 1 - e^{-N_{tot}} = 1 - \exp(-\Sigma(-\ln(1-cF_k))) = 1 - \exp(\Sigma\ln(1-cF_k))) =$

  $= 1 - \Pi(1-cF_k)$

- **Total occupancy seen in the detector = $1 - (1-cS)\ \Pi(1-cF_k)$**



For constant c = 0.6

Gate widths (markers): 25-37.5 ns

Band of black dots:
Gate widths down to 3.125ns

Band of yellow dots:
Gate widths up to 75ns

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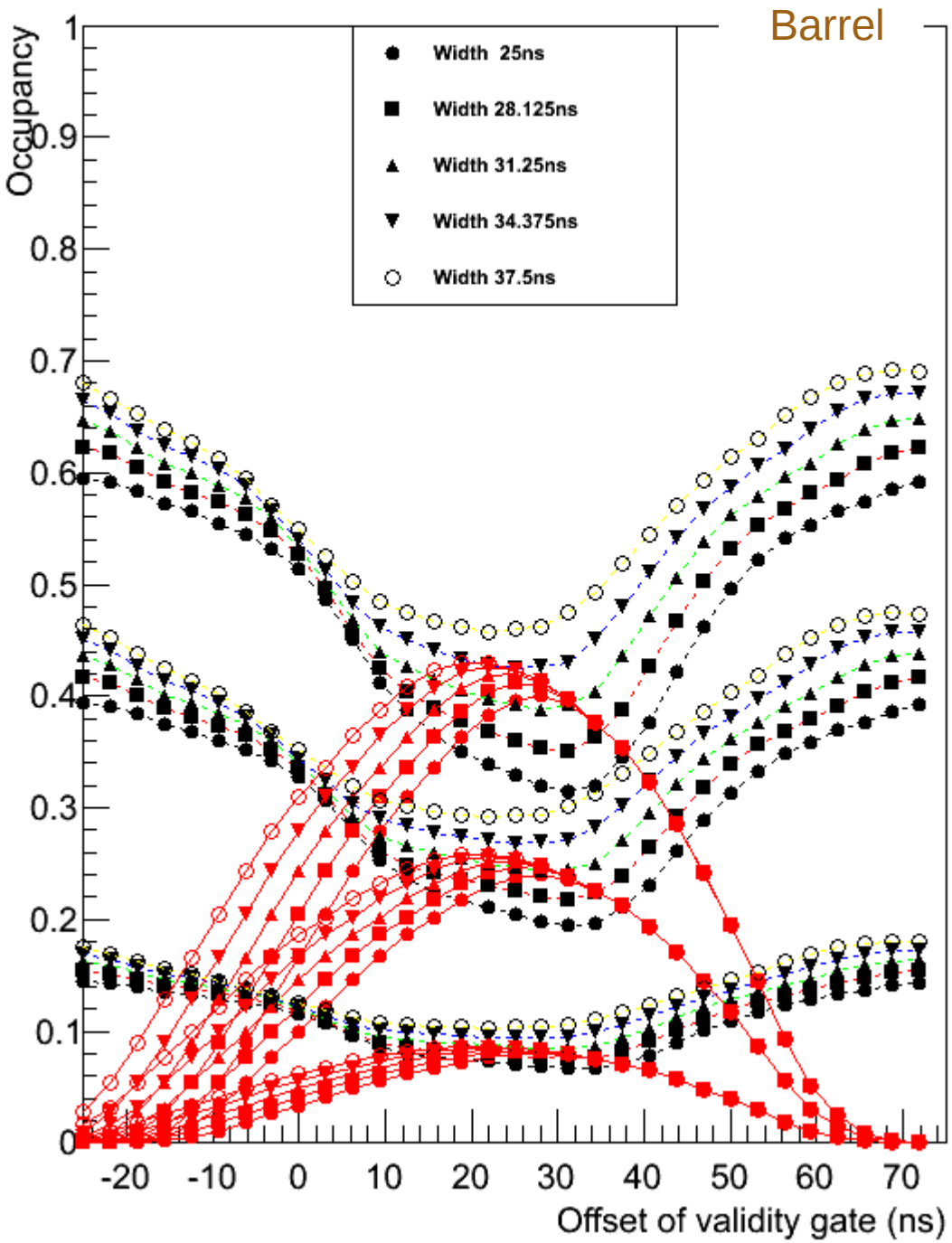
Occupancy of other bunches



For constant c = 0.1, 0.3 and 0.5

Overlaid in red: Occupancy of signal bunch

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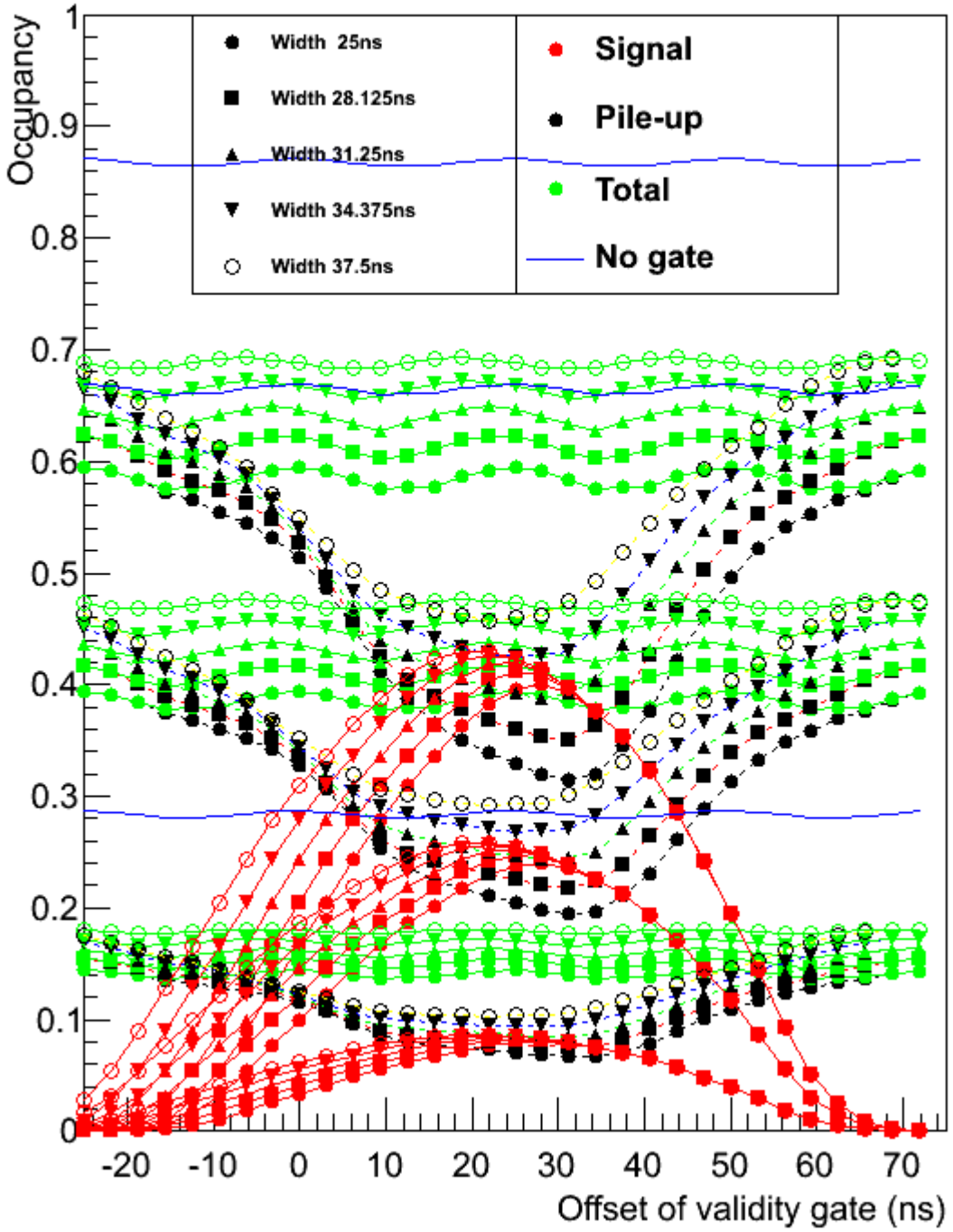
Barrel



For constant c =
0.1, 0.3 and 0.5

Black: Pile-up

Red: Occupancy of own bunch

Green: Total occupancy

Blue: Total occupancy
Gate width = 75ns

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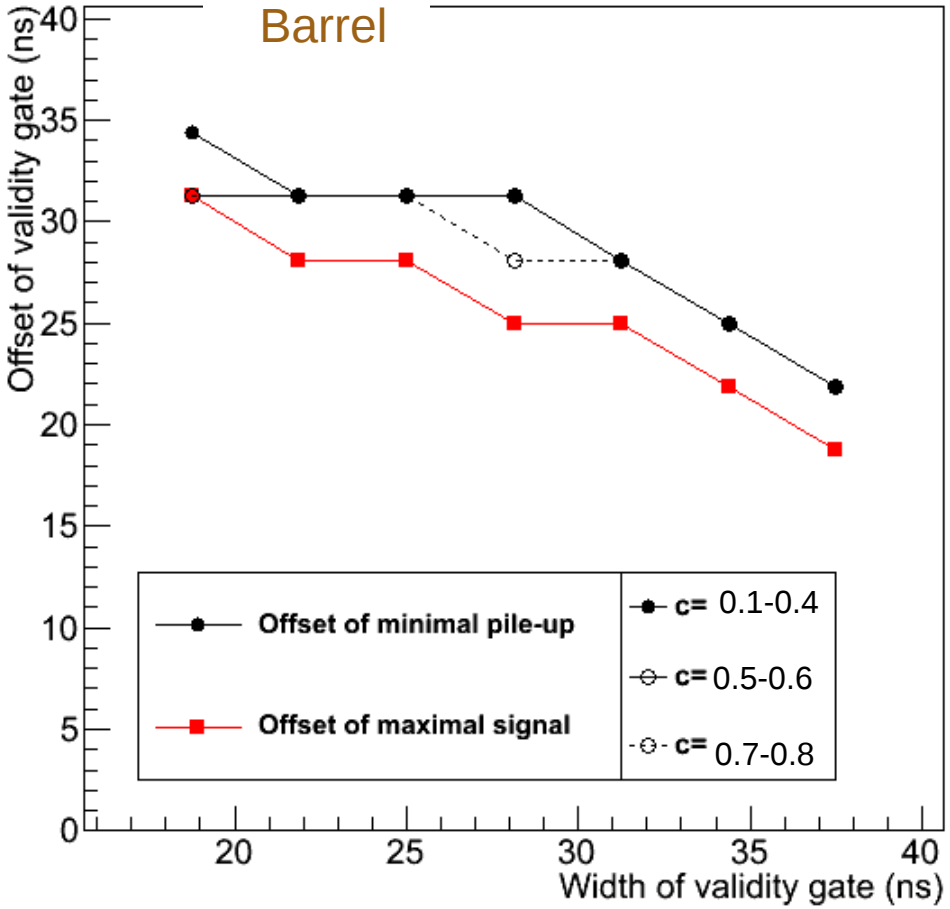
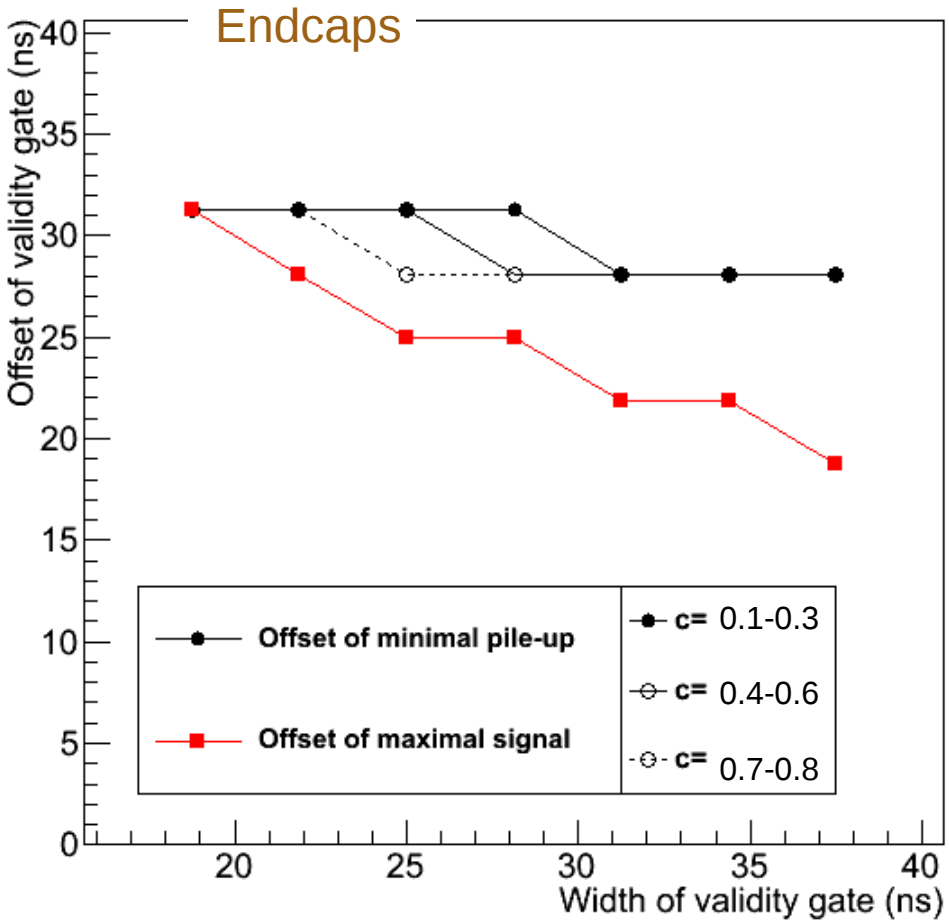
Optimal offset





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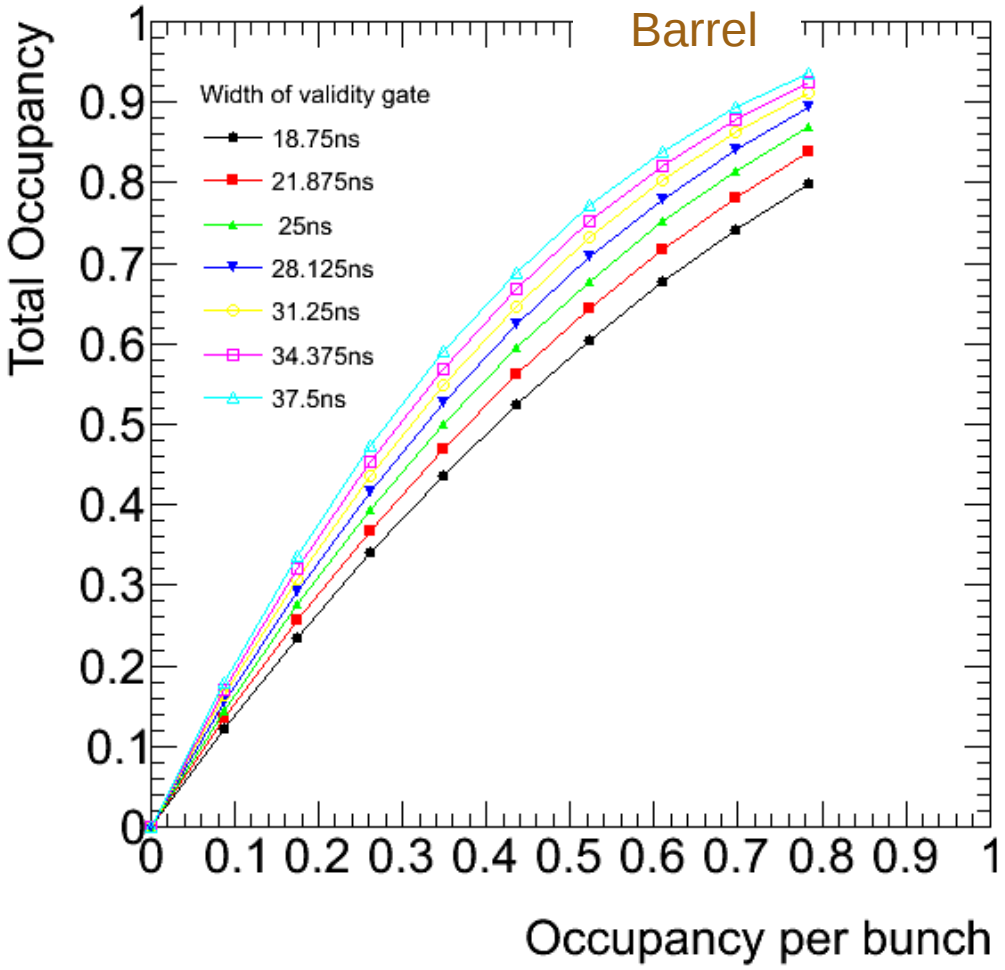
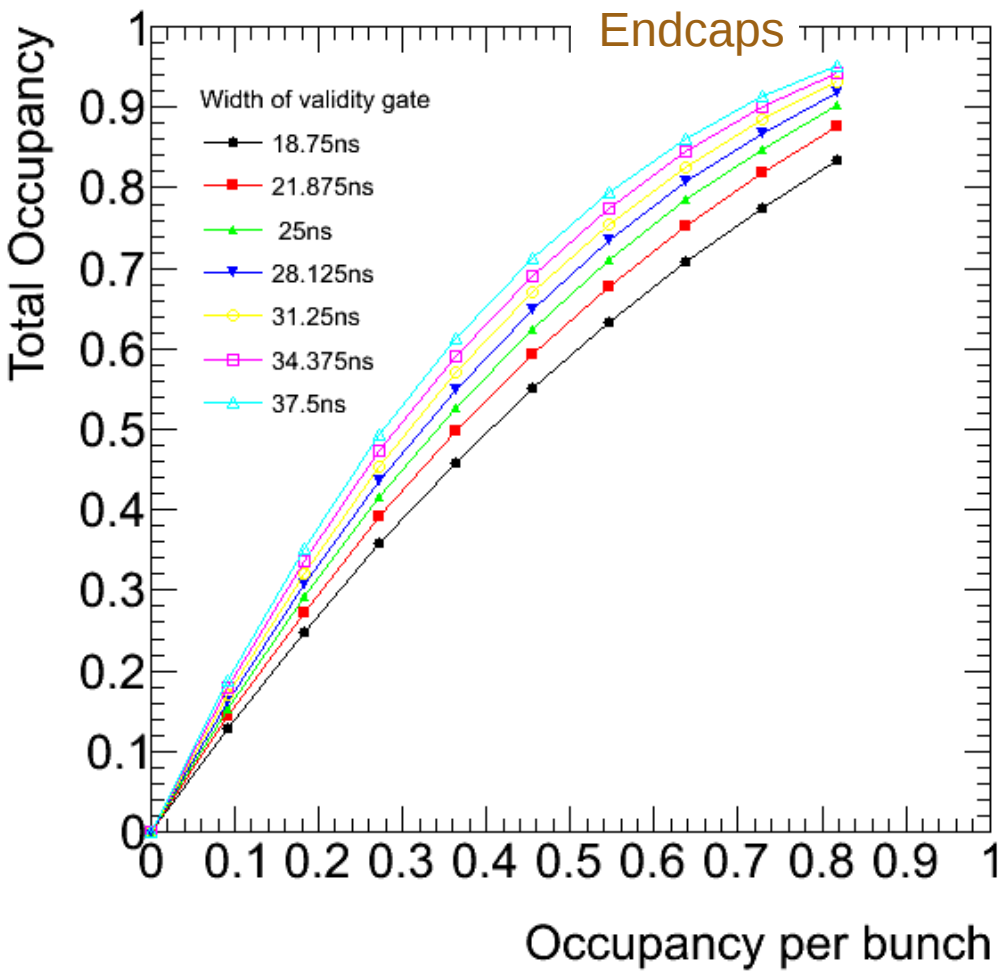
Occupancy

y-axis: Total occupancy for various gate widths
x-axis: **Occupancy / bunch** without gate





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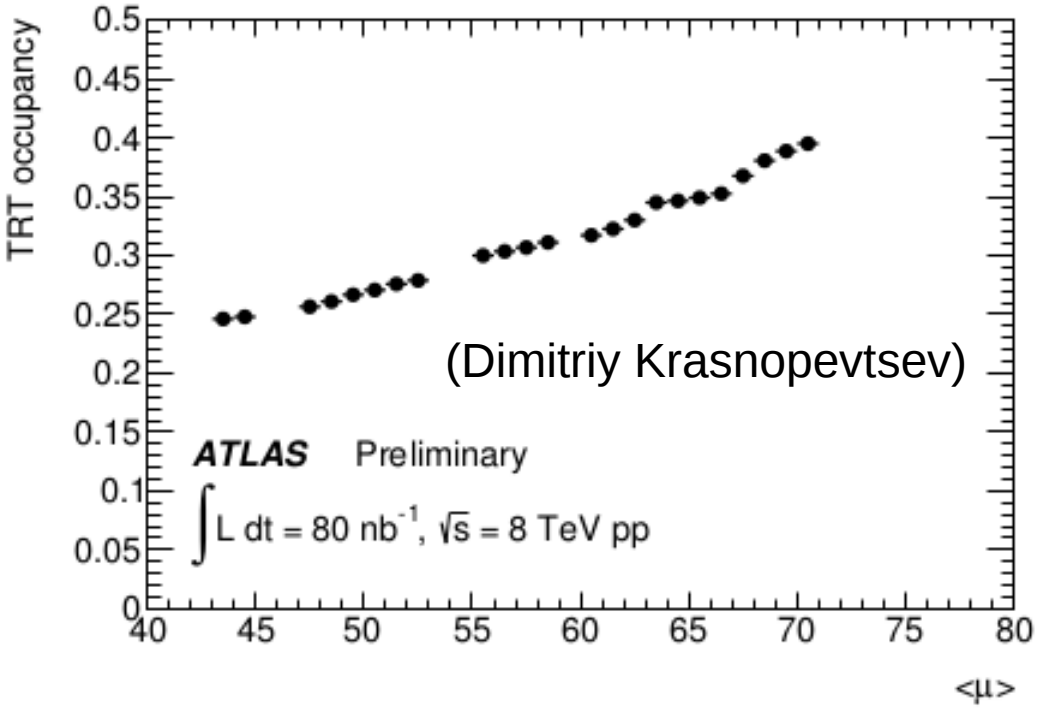
Occupancy per bunch
vs
<μ>



(Dimitriy Krasnopevtsev)

Data: ▪ Fat bunches (<μ> ~ 45-70)

The data has been fitted using the model Occuancy per bunch,

$$O_b = 1 - e^{-k\langle\mu\rangle} + 0.02\, e^{-k\langle\mu\rangle}$$

Where k is a constant of proportionality between <μ> and the number of particles crossing a straw

The last term models the noise.

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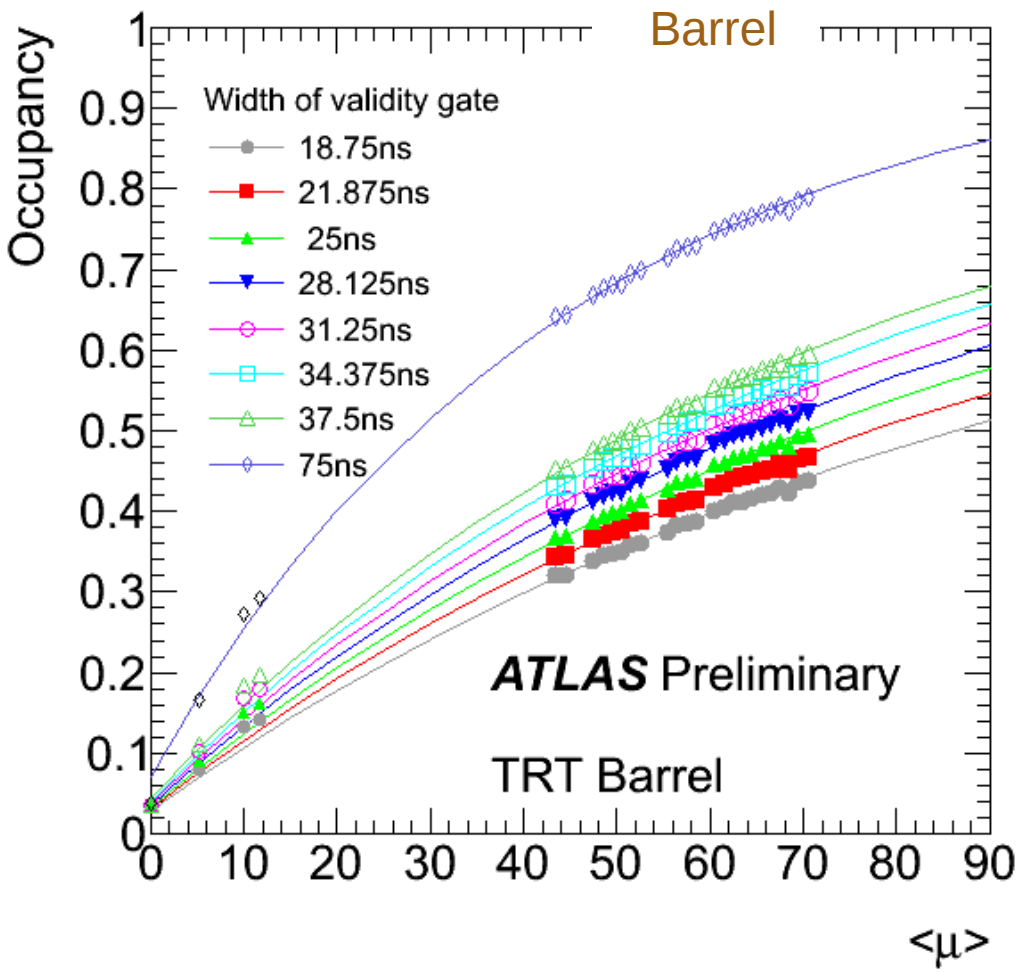
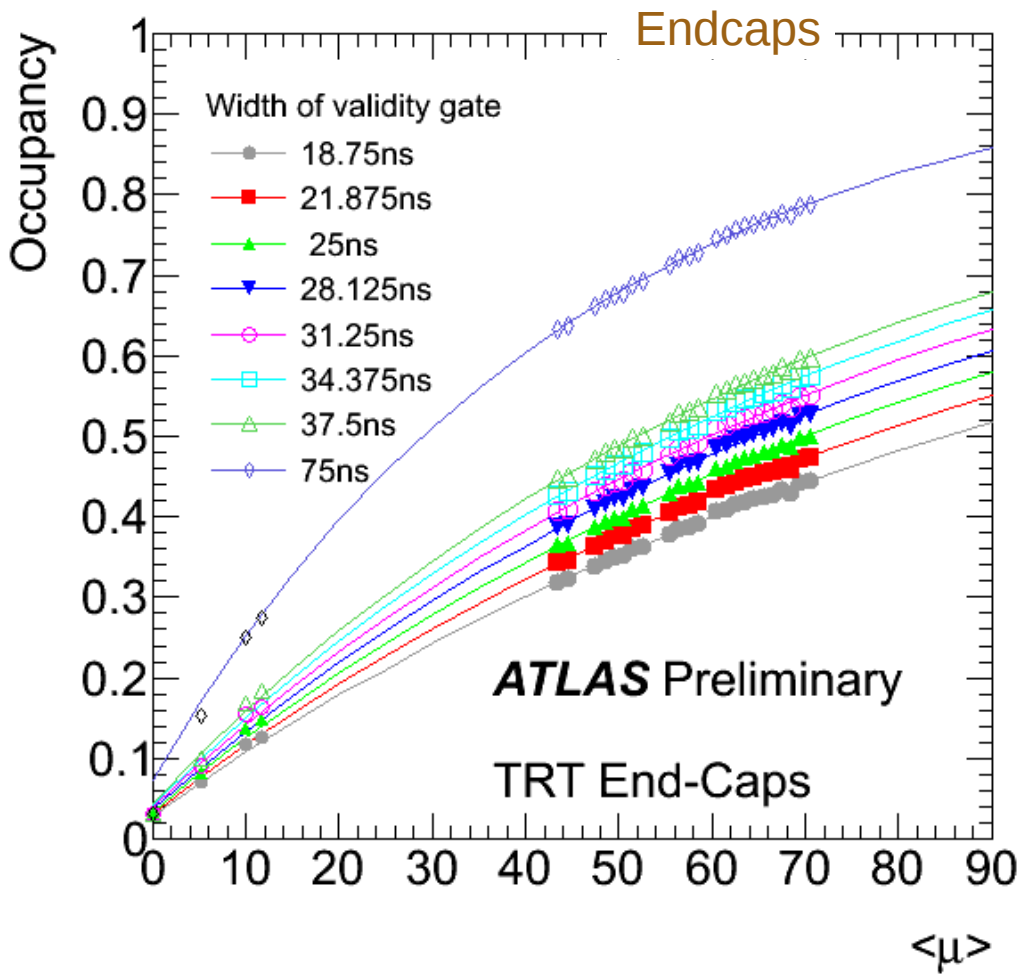
Occupancy

y-axis: Total occupancy for various gate widths
x-axis: average number of interactions per bunchcrossing





Data:
- Low luminosity data gives relation **occupancy – occupancy/bunch** (related to μ)
- Fat bunches (<μ> ~ 45-70) gives relation **occupancy/bunch - <μ>**
- 25ns data (<μ> ~ 5-12)

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Table of optimal offsets

Validity gate	Optimal offset for raw data: Barrel			Total occupancy	
Gate width	$\epsilon_{hit}^{\max}$	pile-up$^{\min}$	$\epsilon_{precision\ hit}^{\max}$	$O_{tot}(\langle\mu\rangle = 30)$	$O_{tot}(\langle\mu\rangle = 40)$
$18.75ns$	$31ns$	$34ns$	$31ns$	24.1%	29.9%
$21.875ns$	$28ns$	$31ns$	$28ns$	26.0%	32.1%
$25.0ns$	$28ns$	$31ns$	$28ns$	27.9%	34.3%
$28.125ns$	$25ns$	$31ns$	$25ns$	29.6%	36.4%
$31.25ns$	$25ns$	$28ns$	$25ns$	31.4%	38.5%
$34.375ns$	$22ns$	$25ns$	$22ns$	33.1%	40.4%
$37.5ns$	$19ns$	$22ns$	$19ns$	34.7%	42.3%
$75.0ns$				51.7%	60.9%

Table 1: Optimal choice of offsets of validity gates applied on raw, uncalibrated data for the barrel part of the TRT detector, with respect to hit efficiency, reduction of pile-up and efficiency of precision hits. The total occupancies for $\langle\mu\rangle = 30$ and $\langle\mu\rangle = 40$ are also given.

Validity gate	Optimal offset for raw data: End-Caps			Total occupancy	
Gate width	$\epsilon_{hit}^{\max}$	pile-up$^{\min}$	$\epsilon_{precision\ hit}^{\max}$	$O_{tot}(\langle\mu\rangle = 30)$	$O_{tot}(\langle\mu\rangle = 40)$
$18.75ns$	$31ns$	$31ns$	$31ns$	24.2%	30.0%
$21.875ns$	$28ns$	$31ns$	$28ns$	26.1%	32.2%
$25.0ns$	$25ns$	$31ns$	$25ns$	27.9%	34.3%
$28.125ns$	$25ns$	$31ns$	$25ns$	29.6%	36.4%
$31.25ns$	$22ns$	$28ns$	$22ns$	31.3%	38.4%
$34.375ns$	$22ns$	$28ns$	$22ns$	33.0%	40.3%
$37.5ns$	$19ns$	$28ns$	$19ns$	34.6%	42.2%
$75.0ns$				51.2%	60.5%

Table 2: Optimal choice of offsets of validity gates applied on raw, uncalibrated data for the end-cap parts of the TRT detector, with respect to hit efficiency, reduction of pile-up and efficiency of precision hits. The total occupancies for $\langle\mu\rangle = 30$ and $\langle\mu\rangle = 40$ are also given.

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Gate applied after T_0-correction

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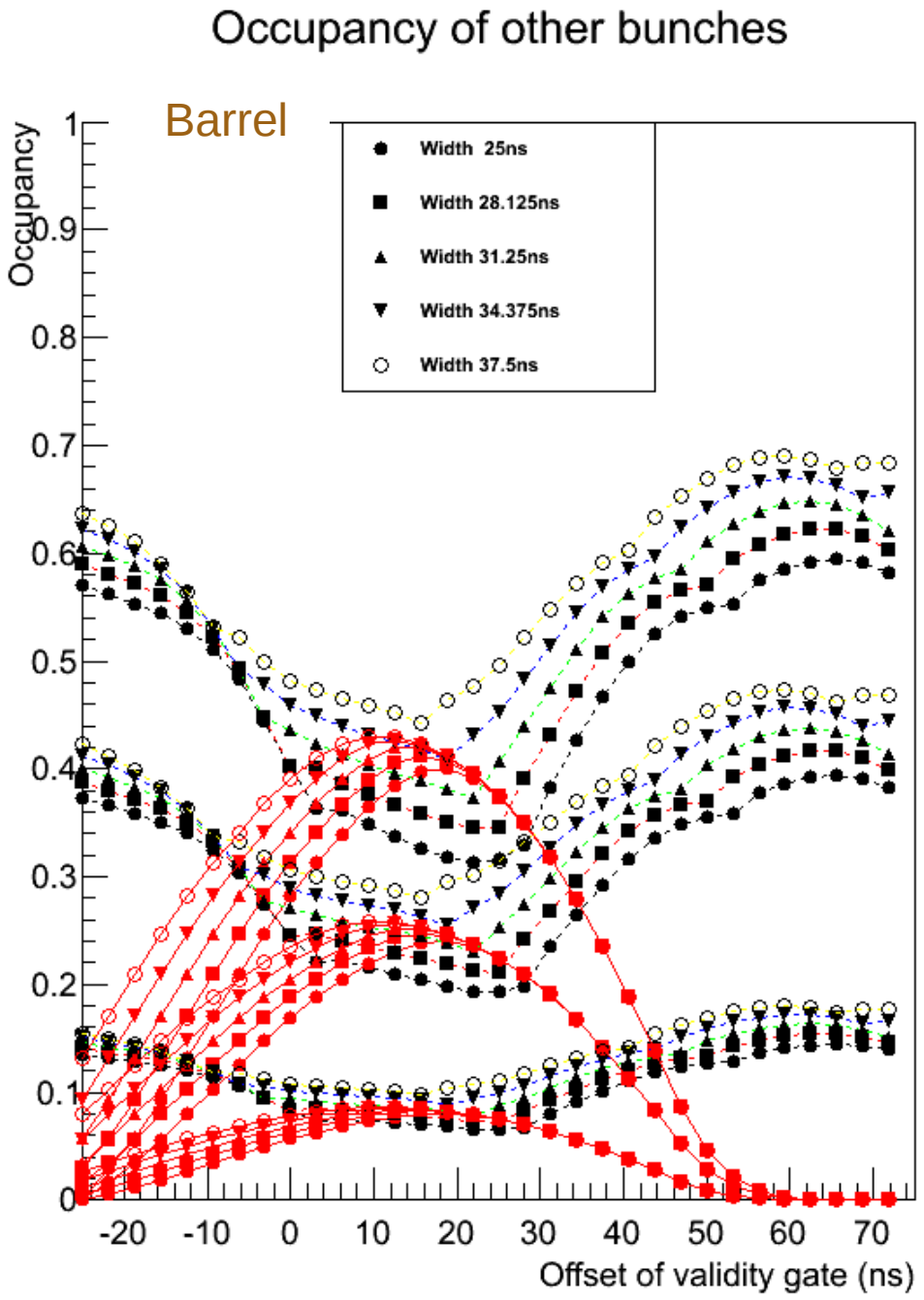
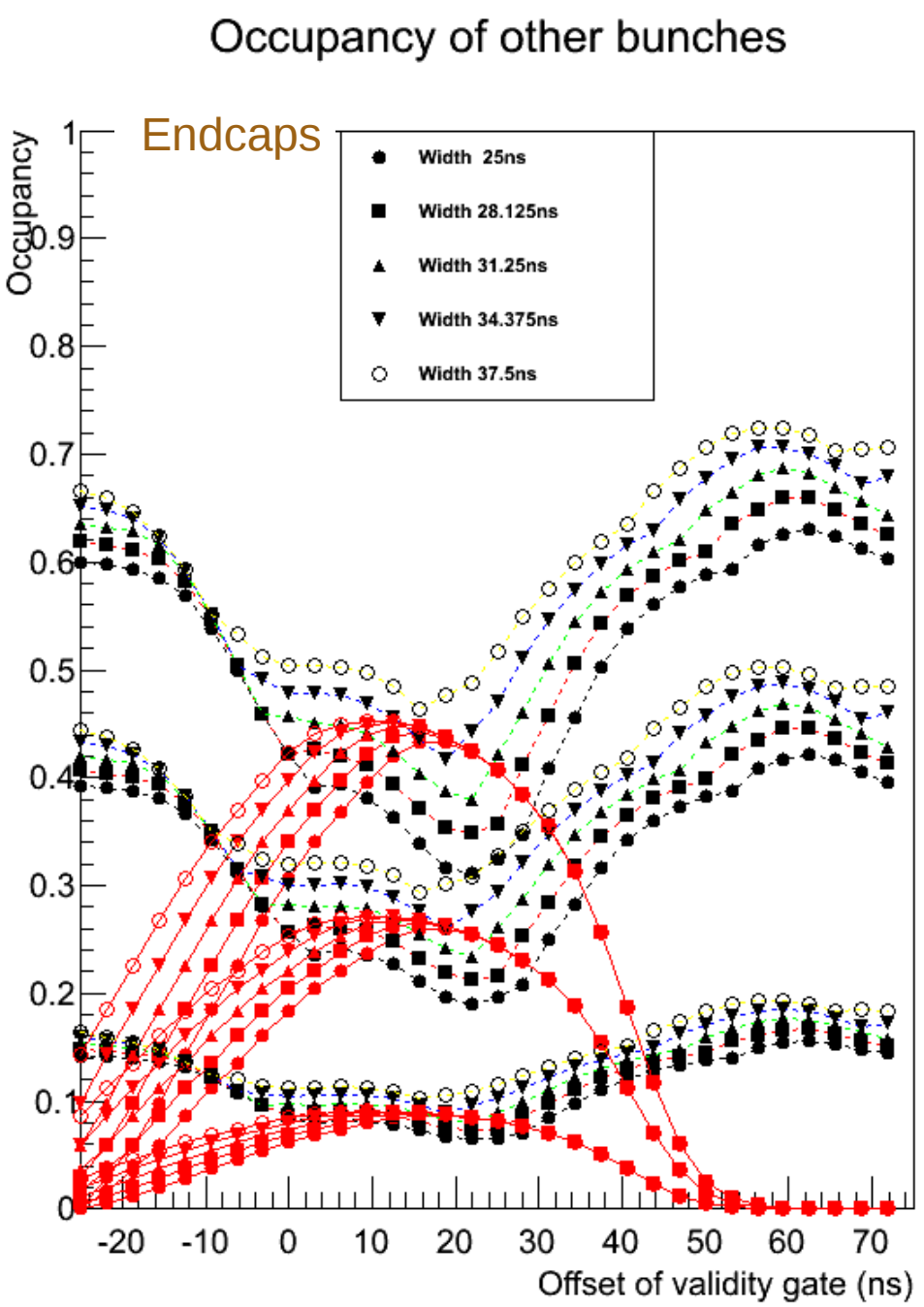
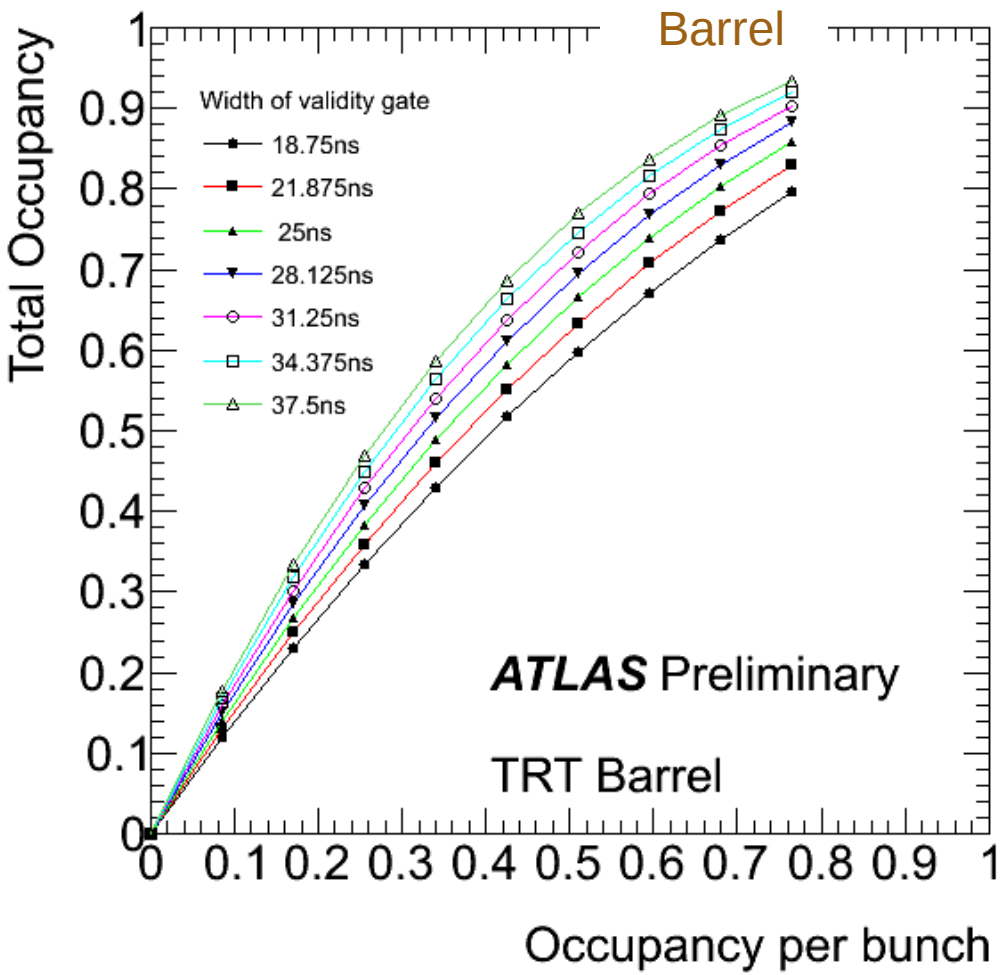
Pile-up (black) and signal(red), c = 0.1, 0.3 and 0.5

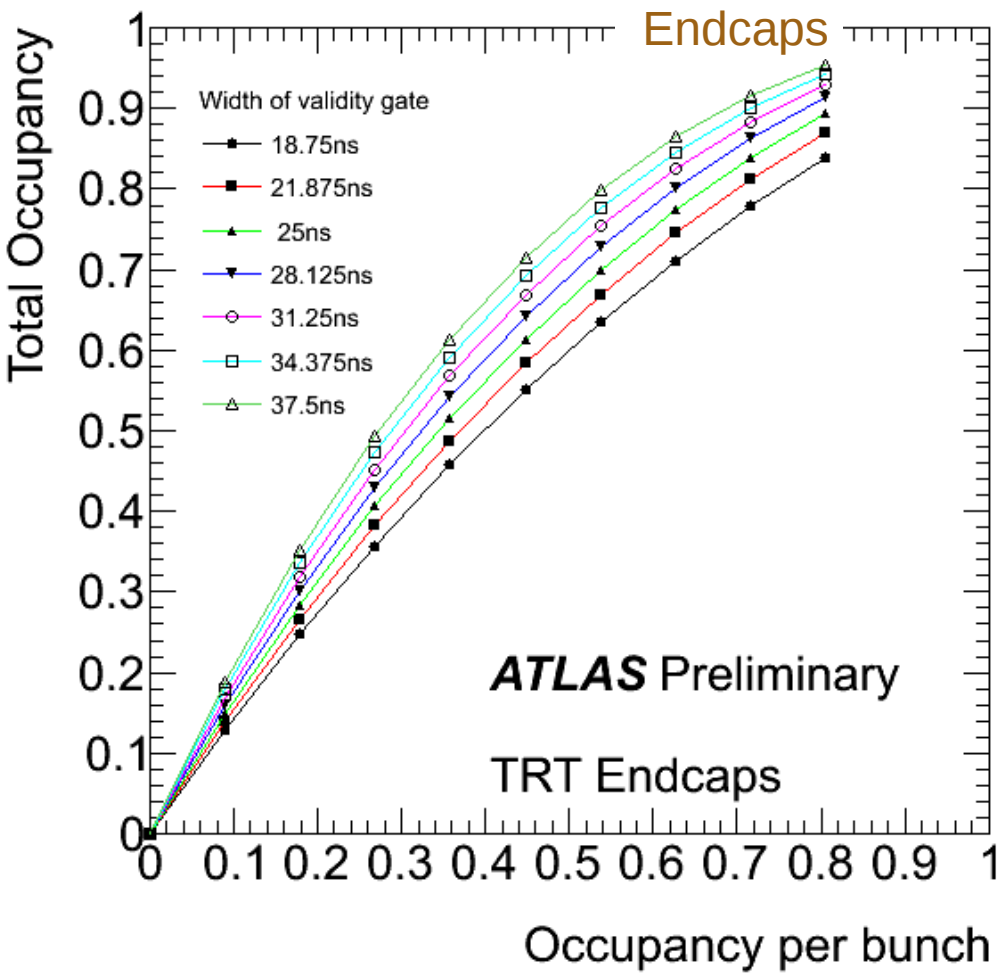




Occupancy (T_0-corrected data)

y-axis: Total occupancy for various gate widths
x-axis: **Occupancy per bunch** without gate





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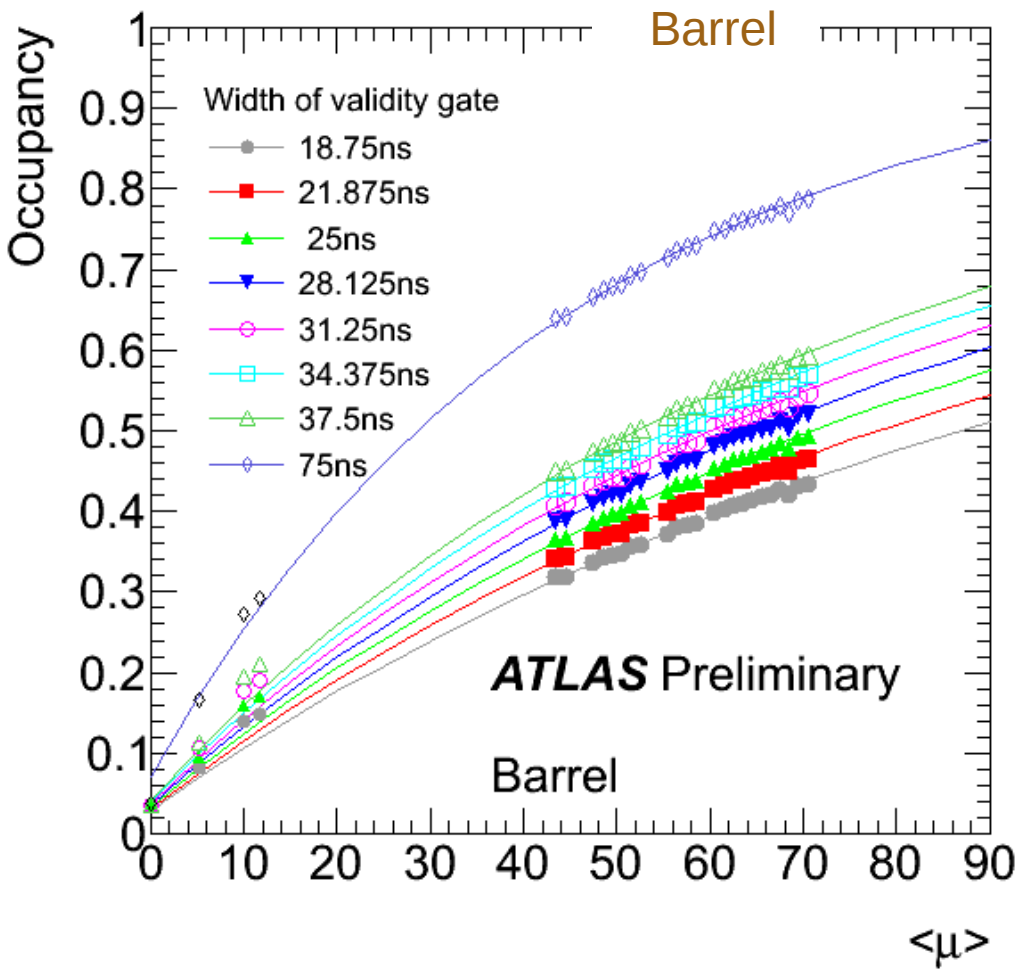
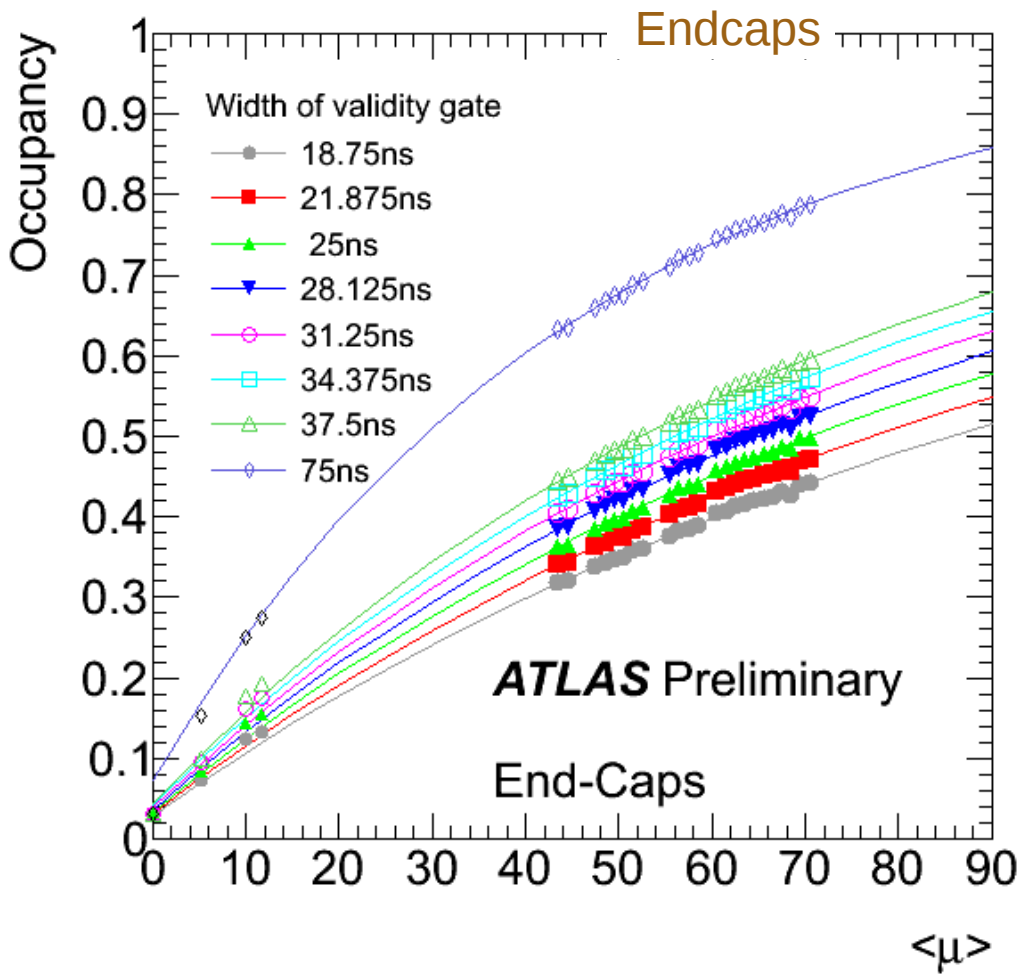
Occupancy reduction

y-axis: Total occupancy for various gate widths
x-axis: average number of interactions per bunchcrossing





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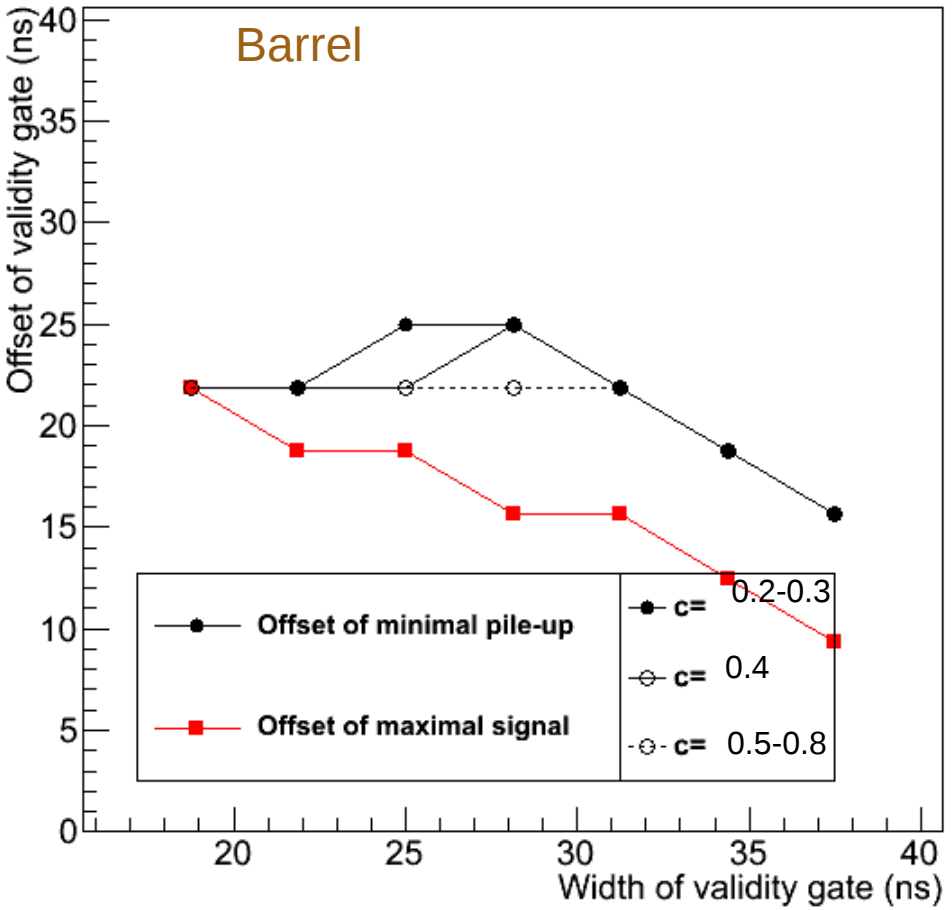
Optimal offset (T_0-corrected data)



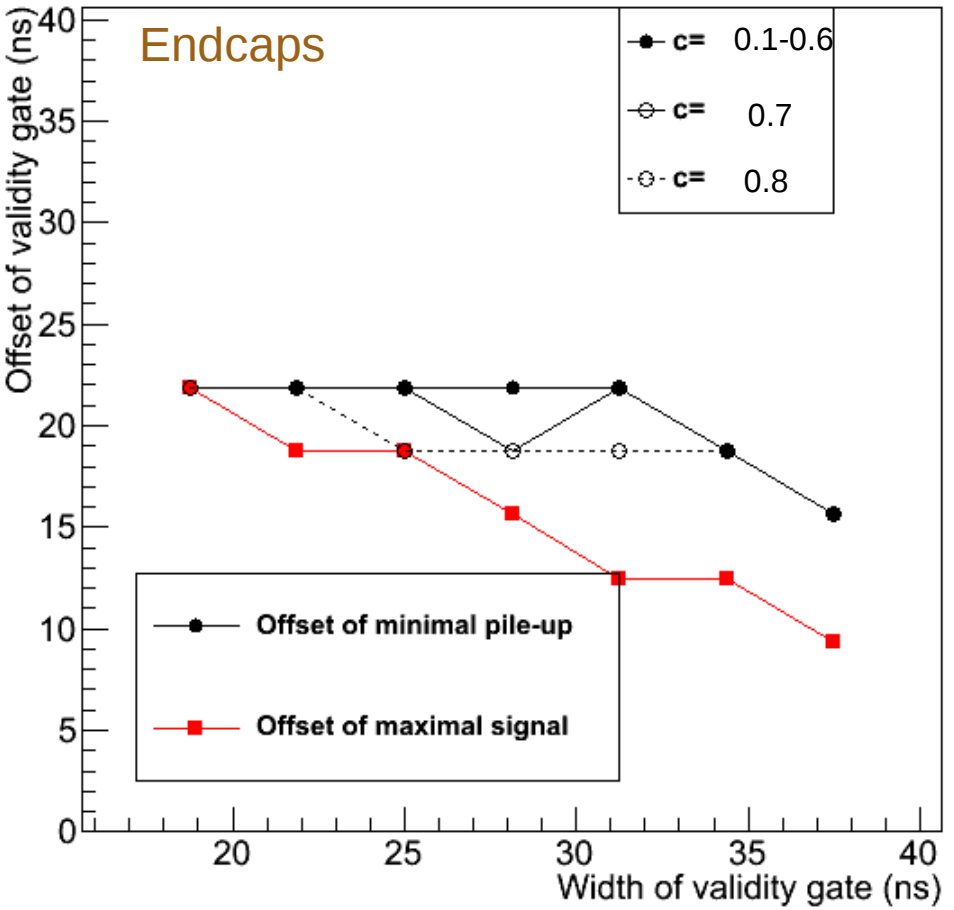


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Table of optimal offsets

Validity gate	Optimal offset, T_0-calibrated data: Barrel			Total occupancy	
Gate width	$\epsilon_{hit}^{\max}$	pile-up$^{\min}$	$\epsilon_{precision\ hit}^{\max}$	$O_{tot}(\langle\mu\rangle = 30)$	$O_{tot}(\langle\mu\rangle = 40)$
18.75ns	22ns	22ns	22ns	23.9%	29.6%
21.875ns	19ns	22ns	19ns	25.8%	31.9%
25.0ns	19ns	25ns	19ns	27.7%	34.1%
28.125ns	16ns	25ns	16ns	29.5%	36.2%
31.25ns	16ns	22ns	13ns	31.2%	38.3%
34.375ns	13ns	19ns	13ns	32.9%	40.2%
37.5ns	9.4ns	16ns	9.4ns	34.6%	42.1%
75.0ns				51.5%	60.8%

Table 3: Optimal choice of offsets of validity gates applied on T_0-calibrated data for the barrel part of the TRT detector, with respect to hit efficiency, reduction of pile-up and efficiency of precision hits. The total occupancies for $\langle\mu\rangle = 30$ and $\langle\mu\rangle = 40$ are also given.

Validity gate	Optimal offset, T_0-calibrated data: End-Caps			Total occupancy	
Gate width	$\epsilon_{hit}^{\max}$	pile-up$^{\min}$	$\epsilon_{precision\ hit}^{\max}$	$O_{tot}(\langle\mu\rangle = 30)$	$O_{tot}(\langle\mu\rangle = 40)$
18.75ns	22ns	22ns	22ns	24.1%	29.9%
21.875ns	19ns	22ns	19ns	25.9%	32.0%
25.0ns	19ns	22ns	19ns	27.7%	34.2%
28.125ns	16ns	22ns	16ns	29.4%	36.2%
31.25ns	13ns	22ns	13ns	31.1%	38.2%
34.375ns	13ns	19ns	13ns	32.8%	40.1%
37.5ns	9.4ns	16ns	9.4ns	34.4%	42.0%
75.0ns				51.1%	60.3%

Table 4: Optimal choice of offsets of validity gates applied on T_0-calibrated data for the end-cap parts of the TRT detector, with respect to hit efficiency, reduction of pile-up and efficiency of precision hits. The total occupancies for $\langle\mu\rangle = 30$ and $\langle\mu\rangle = 40$ are also given.

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Studies on Argon mixture

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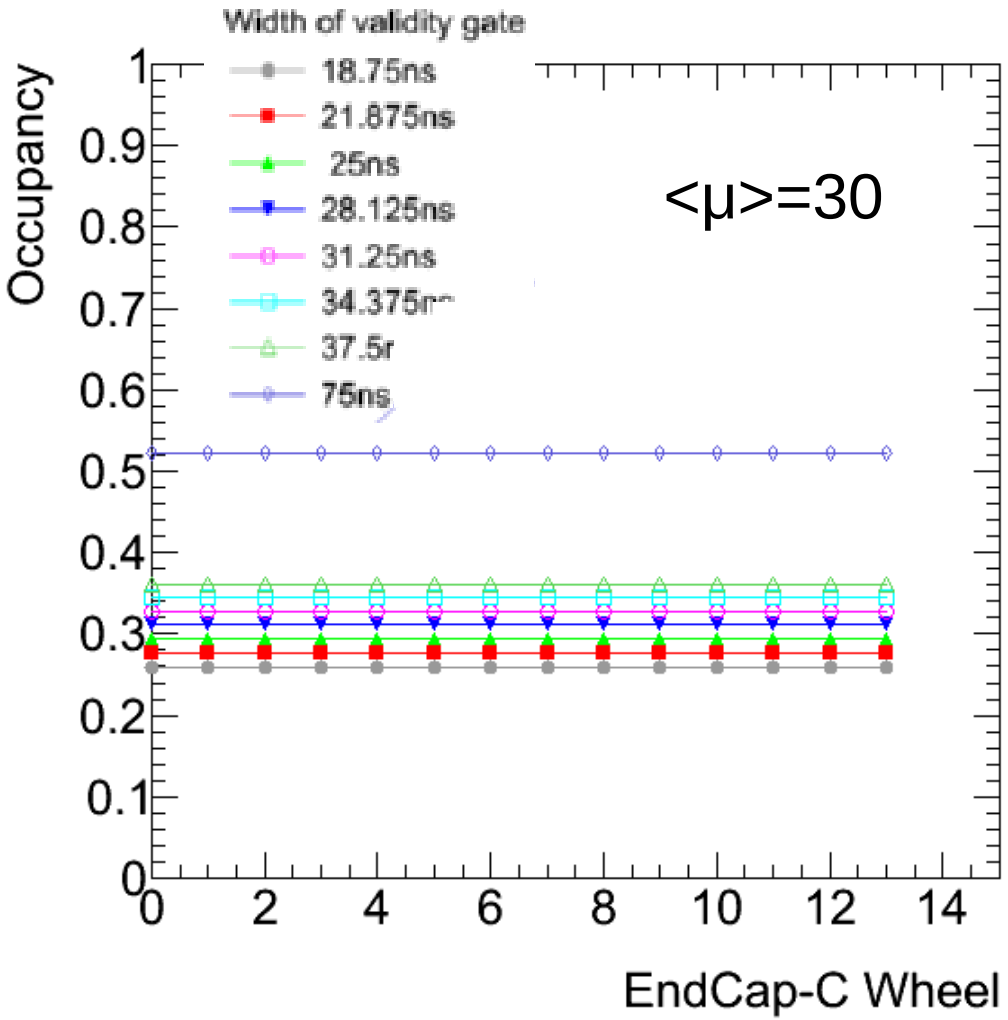
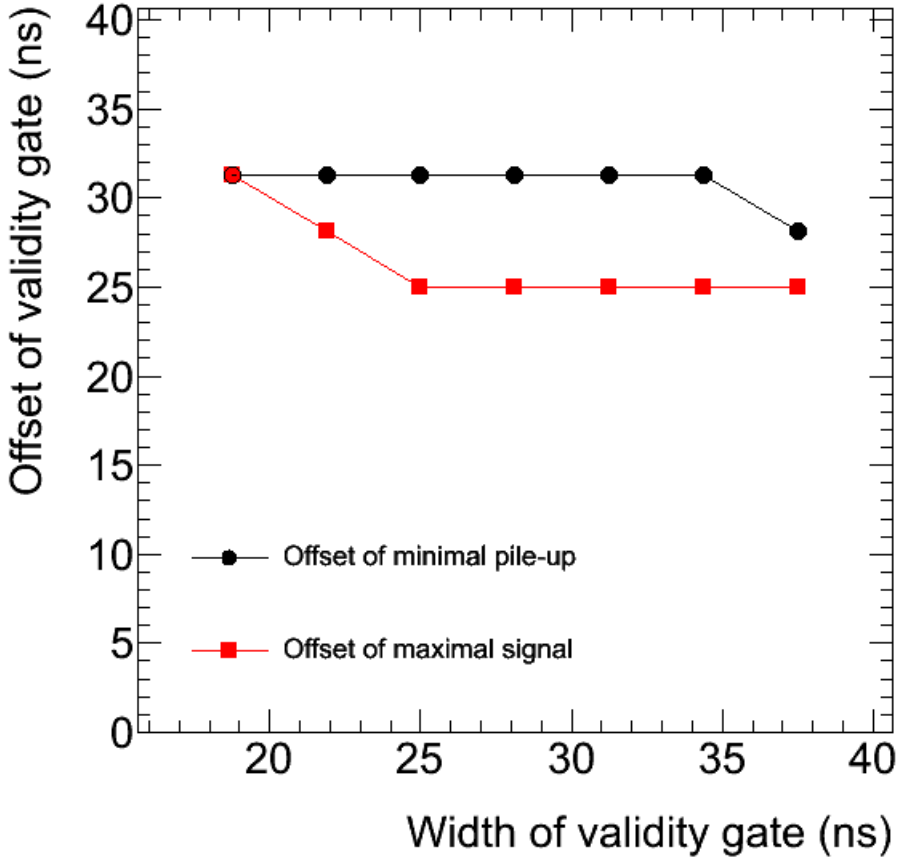
Predicted occupancy for EC-C wheels
p-Pb-runs from january 22, 2013 <μ> < 0.0007
Argon mixture in wheel 4

Validity gate on raw data





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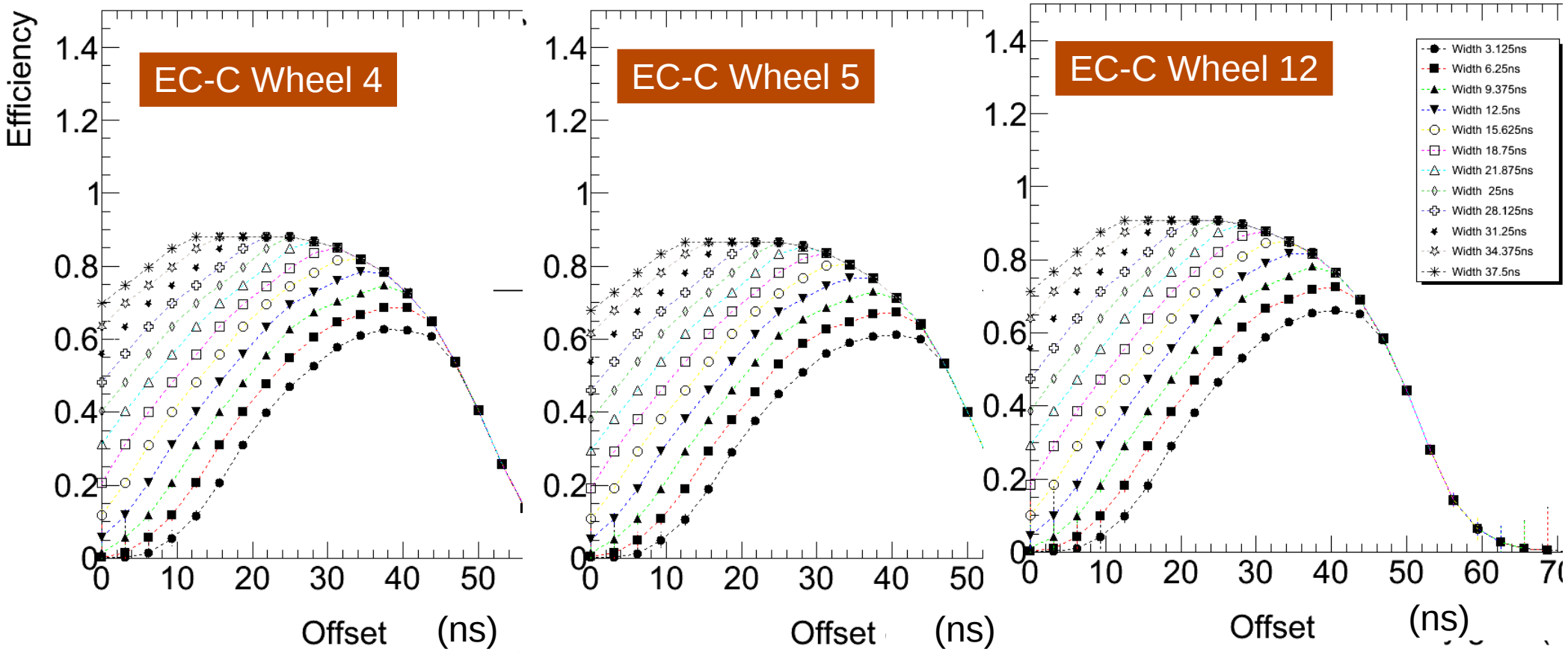
Hit efficiencies for EC-C wheels
p-Pb-runs from january 22, 2013 <μ> < 0.0007
Argon mixture in wheel 4

Validity gate on raw data



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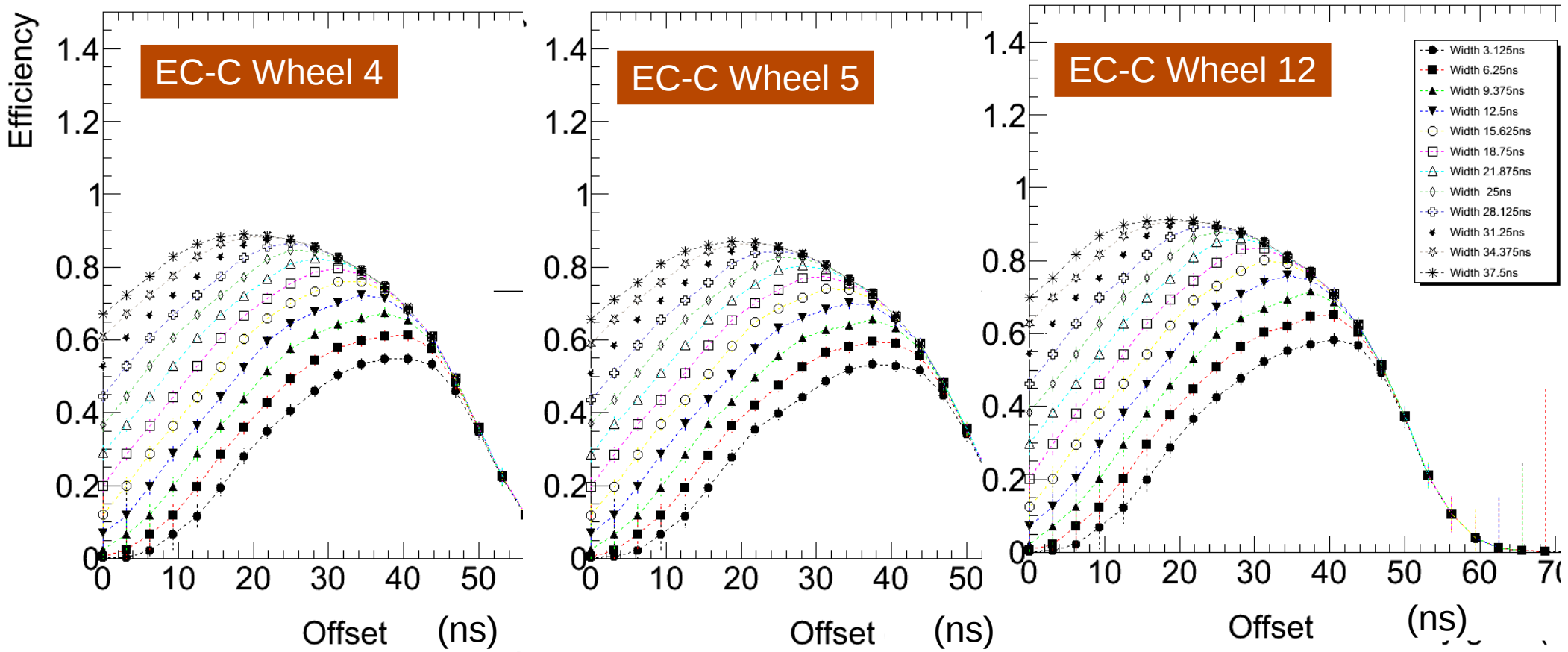
Hit efficiencies for EC-C wheels
p-p-runs from april, 2012

<μ> < 0.003

Validity gate on raw data



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