

# Impact of the Gated Mode on physics

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*Good opportunity to discuss the Gated Mode details which are relevant to the general software preparations (simulation, ...)*

*Gated Mode simulation will be discussed at the Belle II software workshop at DESY in May.*

*Impact of the PXD Gated Mode on physics*

is demonstrated using private implementation of the Gated Mode model

**decay channel:**  $B_d \rightarrow J\psi(\mu^+\mu^-)K_S(\pi^+\pi^-)$

**simulation with bkg “Overlay”:** MC10-Bkg1overlay, GatedMode08-BGOverlay

**ntuples:**

- all “pi” tracks ( $P_t > 0.3$ ,  $-0.03 < z_0 < 0.06$ ,  $d_0 < 0.01$ )
- full reconstruction and analysis of the decay chain

# Injection in Belle II

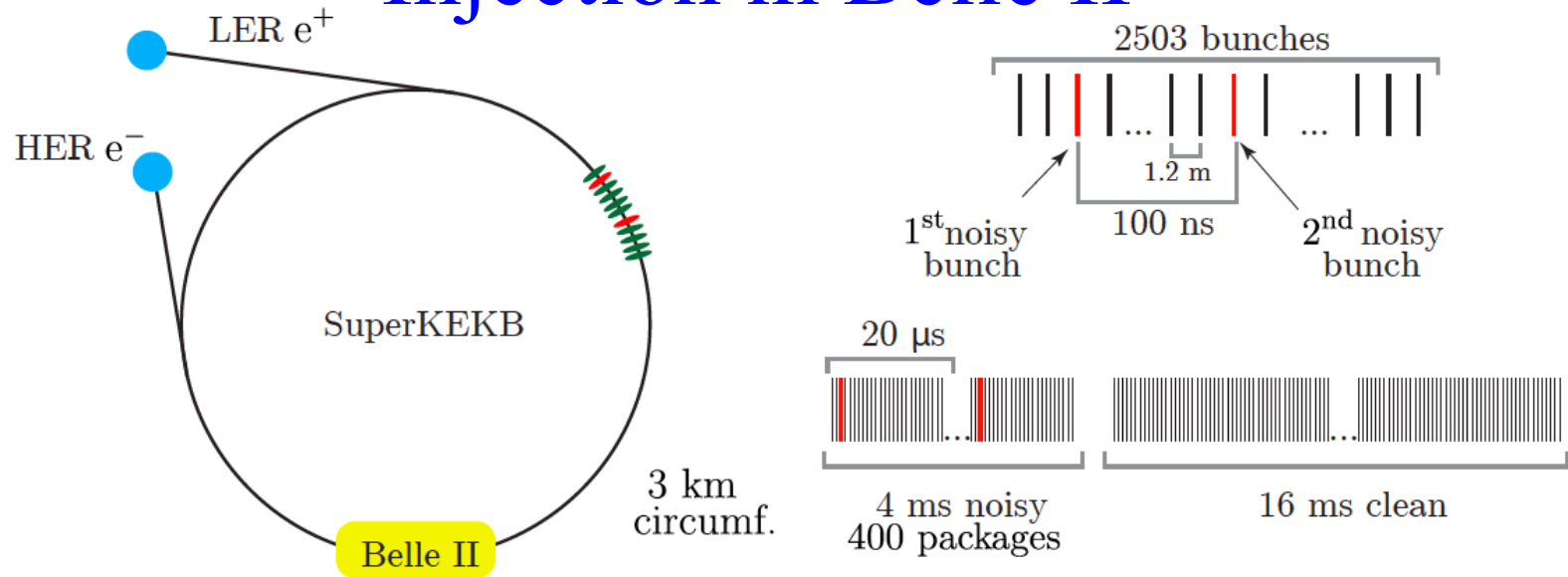


Figure 3.9: SuperKEKB injection scheme. The total injection frequency is 50 Hz (every 20 ms) where two bunches in a distance of 100 ns are filled up. They are shown as the red lines. The damping takes approximately 4 ms.

**80% of time (16ms) - normal operation**

**20% of time (4ms) - problematic operation with two injected & exited bunches**

→ are there other detector components (CDC ?) which will stop readout for

e.g. **1 μs every bunch revolution of 10 μs (causing 2% overall dead time)**

to avoid noise generated by two injected & exited bunches ?

→ long charge integration time in PXD of 20 μs (one frame) corresponds to two bunch revolutions

# Gated Mode – two options

## without readout

charge collection in PXD sensors is stopped every bunch revolution of  $10 \mu\text{s}$

(two times per PXD frame of  $20 \mu\text{s}$ ) for

$\sim 0.4 \mu\text{s}$

(readout stops and jumps afterwards  
to continue keeping synchronization )

## with readout

$\sim 0.9 \mu\text{s}$

(readout procedure is going on,  
but all these pixels are ignored)

time needed to bring readout back to normal operation

$\sim 1 \mu\text{s}$

total time with not usable readout for each bunch revolution of  $10 \mu\text{s}$

(two times per PXD frame of  $20 \mu\text{s}$ )

$\sim 1.4 \mu\text{s}$

**(i.e.  $\sim 15\%$  of pixels are excluded)**

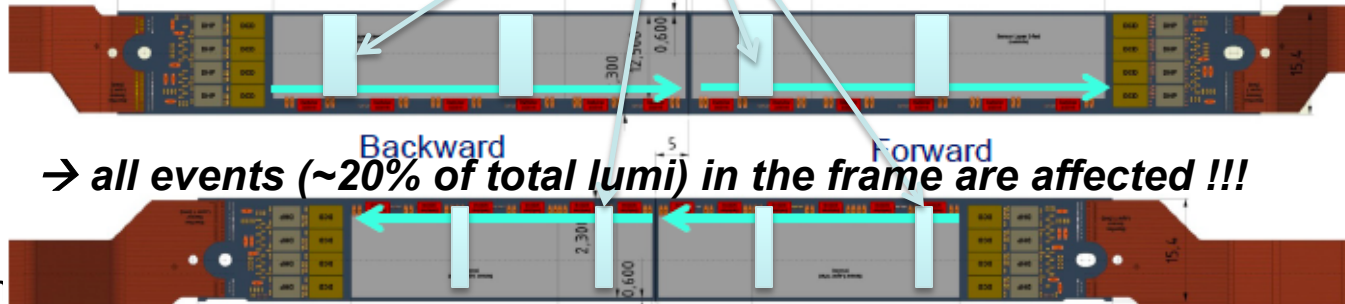
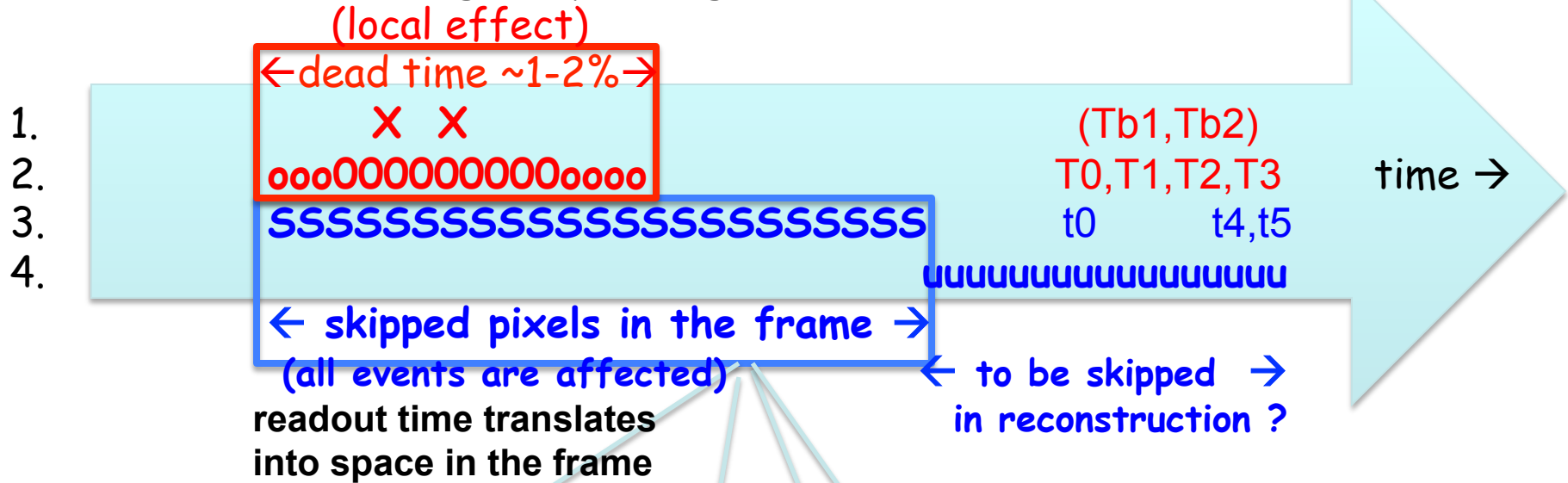
$\sim 1.9 \mu\text{s}$

**(i.e.  $\sim 20\%$  of pixels are excluded)**

*Specific problems of “without readout”: if GM starts at the end of the PXD frame, all frames for 4ms will be lost (3 gates out of 192 = 3.2%)  $\rightarrow$  0.64% - additional overall PXD dead time*

# Different time points for the Gated Mode

1. **X** - high background due to two noisy injected bunches
2. **O(o)** - no (unstable) charge collection for the signal events
3. **S** - readout with skipped pixels when no charge collection or too high occupancy
4. **u** - readout is running but pixel signals are still not reliable



# Questions to the Gated Mode operation & modeling

*Which info about gated mode will be provided from DHH to the event builder ?*

*Which flags are needed for data (MC) events indicating that the given event is affected by charge collection ( $T1-T2$ ), ( $T0-T3$ ) or readout ( $t0-t3$ ) (entire gated period)*

*Which time stamps ( $T0-T3, t0, t4, t5$ ) will be (should be) available for data (MC) in reconstruction and analysis ?*

*Could they be calculated from the event absolute time or from single time stamp( $T0$ )?*

*Which aspects of the gated mode to be simulated*

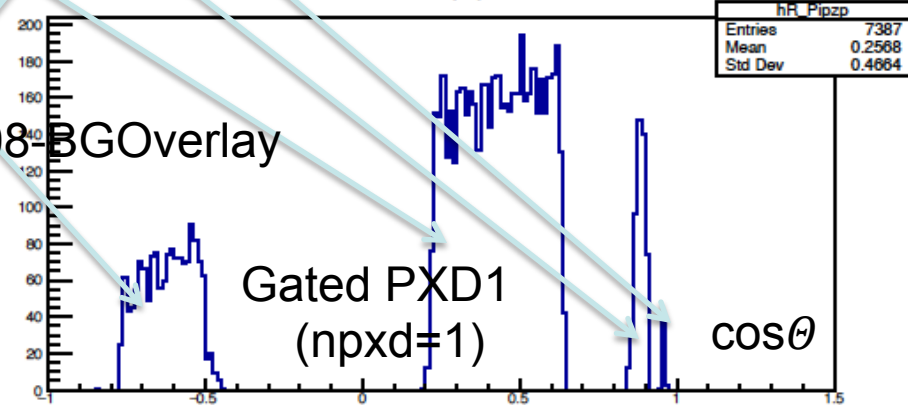
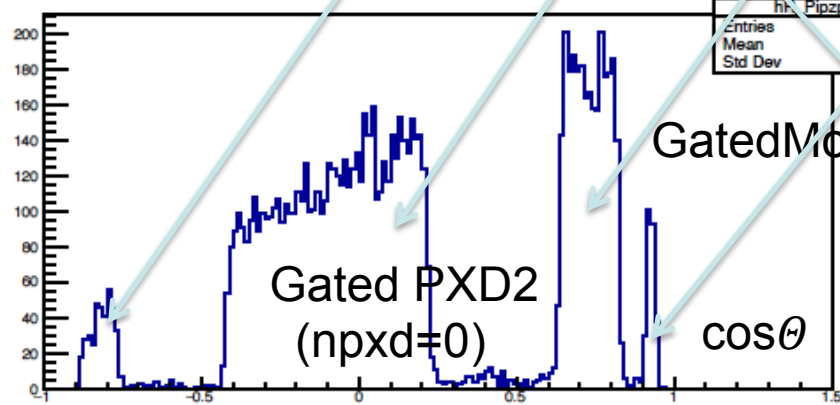
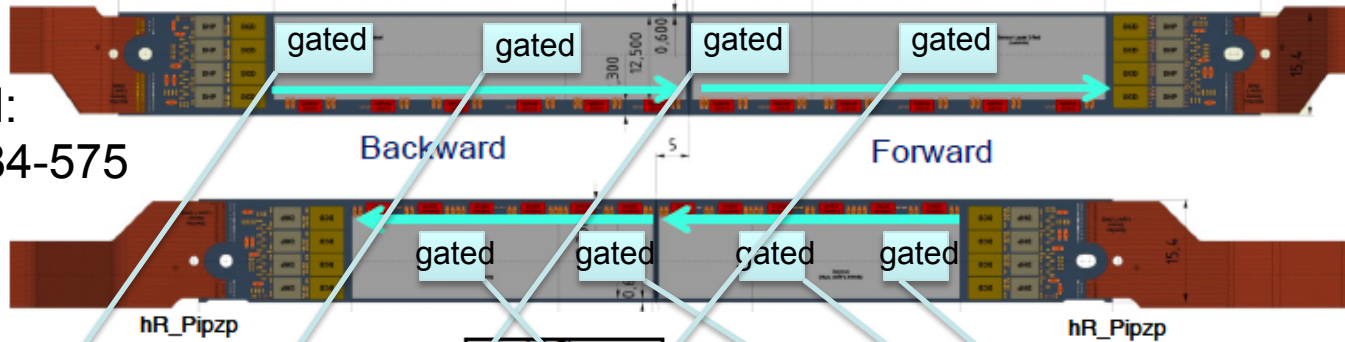
- charge collection of the physics signal ( $T0-T4$ )*
- missing pixels in the readout ( $t0-t4$ )*
- handling of unreliable pixels ( $t4-t5$ ) in reconstruction (+their simulation in MC)*

# Current Gated Mode model

- **only effects due to missing pixels in the readout are considered**
- for all PXD sensors: pixels are coherently suppressed in two v-intervals (rows) of the same length. The first interval is randomly chosen once per event and the second interval is displaced by 384 rows corresponding to a half of a sensor of 768 rows.
- the readout directions for inner and outer PXD layers are opposite
- 15% of pixels are suppressed (corresponding to GM option “without readout” for 100% of events (i.e. for all events collected during gated period))
- implemented at the PXD hit clustering step (PXDClusterizerModule) in reconstruction
- meanwhile Benjamin Schwenker implemented this model in the dedicated module `PXDGateModeEmulatorModule` in simulation (JIRA BII-3353)
- Benjamin also implemented an alternative model of the Gated Mode in `PXDDigitizerModule+BGOOverlayInput.Module` (JIRA BII-3353)

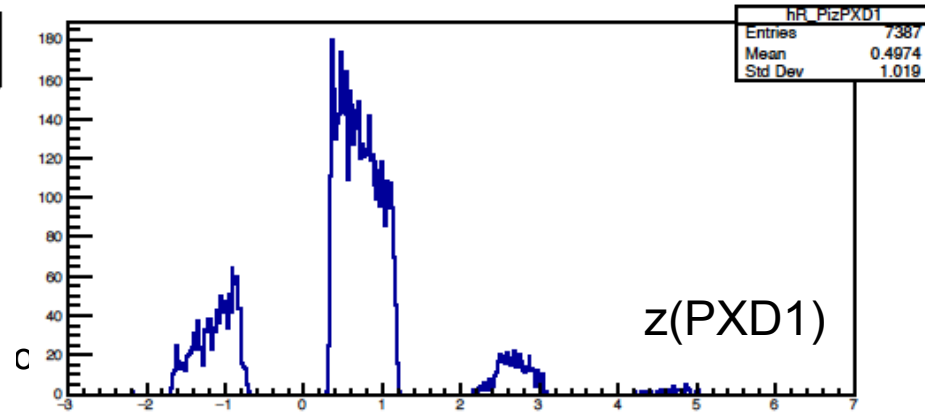
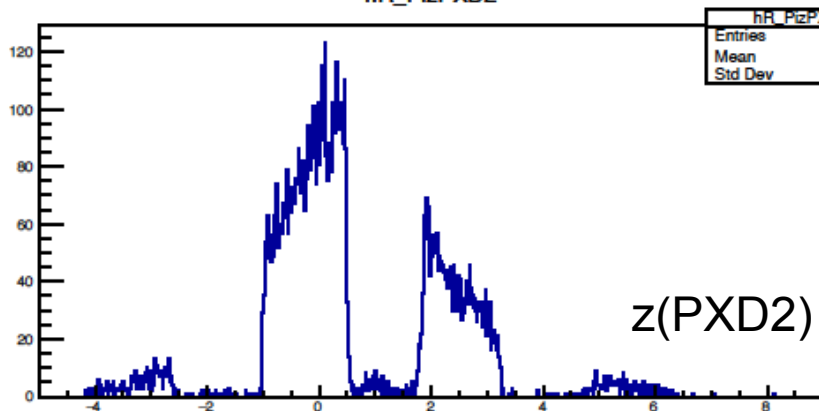
# Test: "Gating" of two quarters of sensors

50% Gated:  
v=0-191,384-575



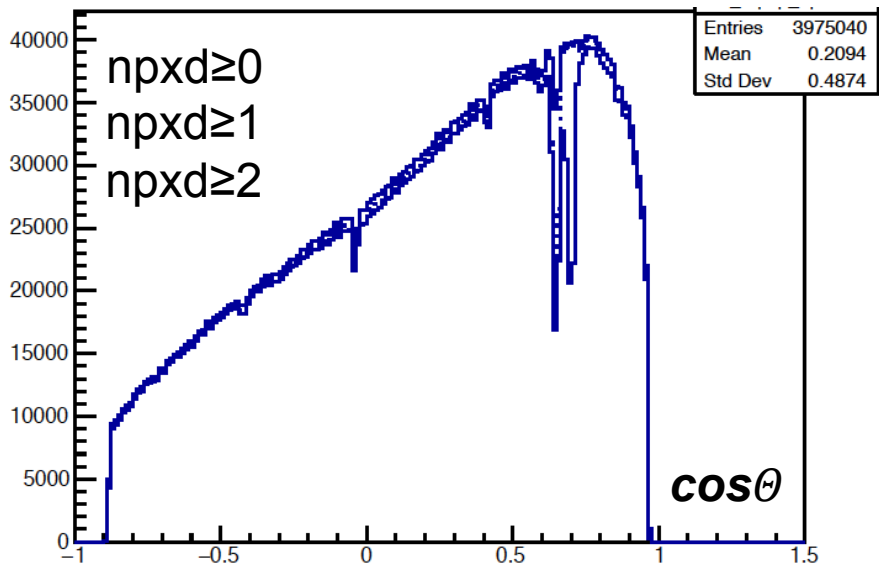
GatedMode08-BGOOverlay

feature of the present tracking: tracks with only one PXD hit located in PXD1 are not allowed

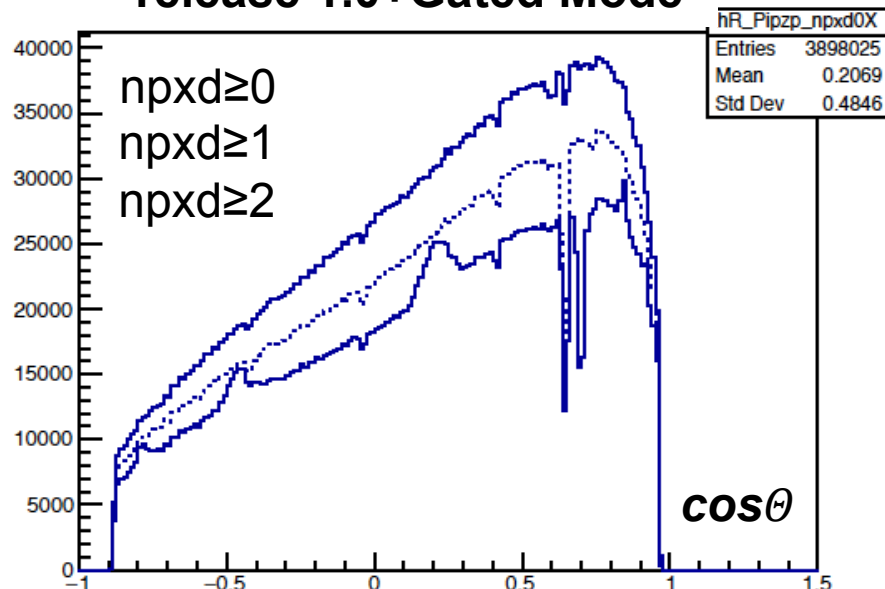


# Tracks in MC10 & GatedMode08-BGOOverlay

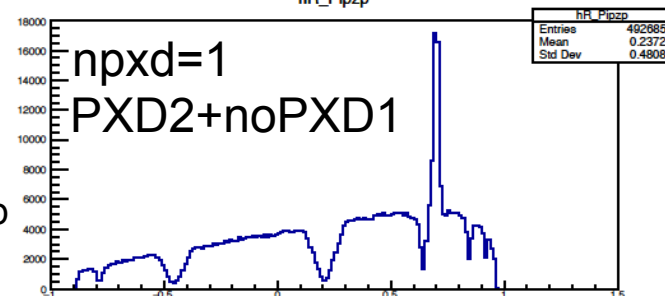
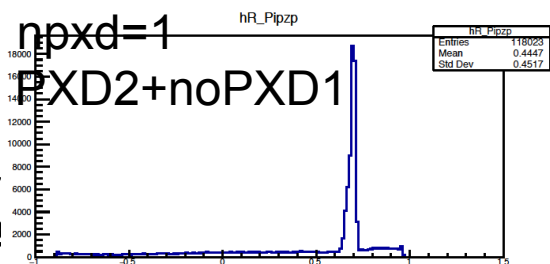
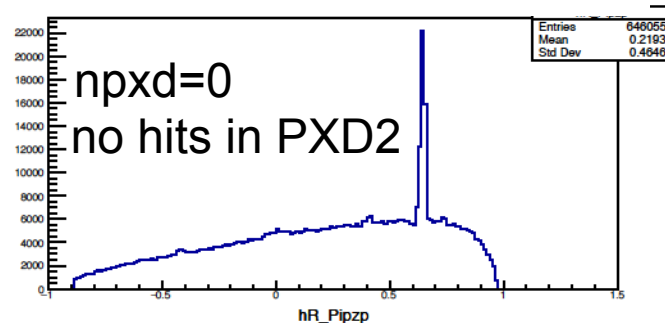
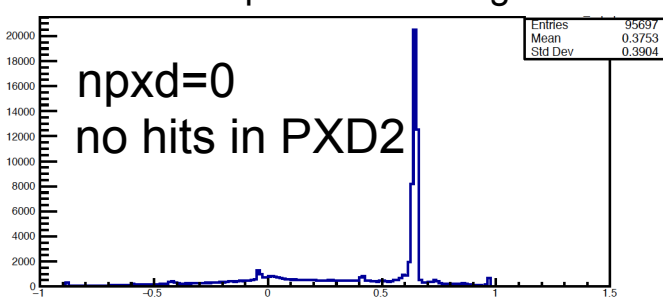
release 1.0



release 1.0+Gated Mode



feature of the present tracking: tracks with only one PXD hit located in PXD1 are not allowed

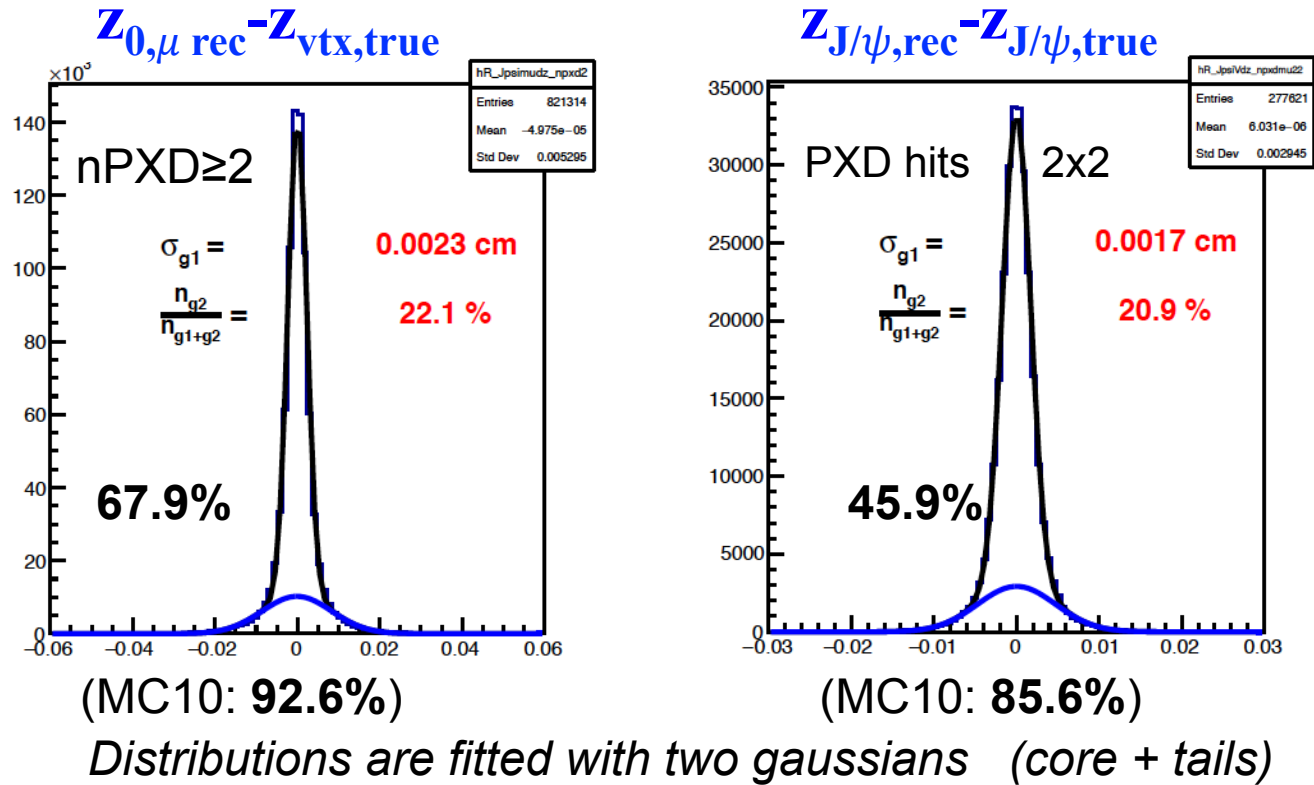


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# $Z_{\text{vtx}}$ resolution for $\mu$ from $J/\psi \rightarrow \mu\mu$ & for $J/\psi$

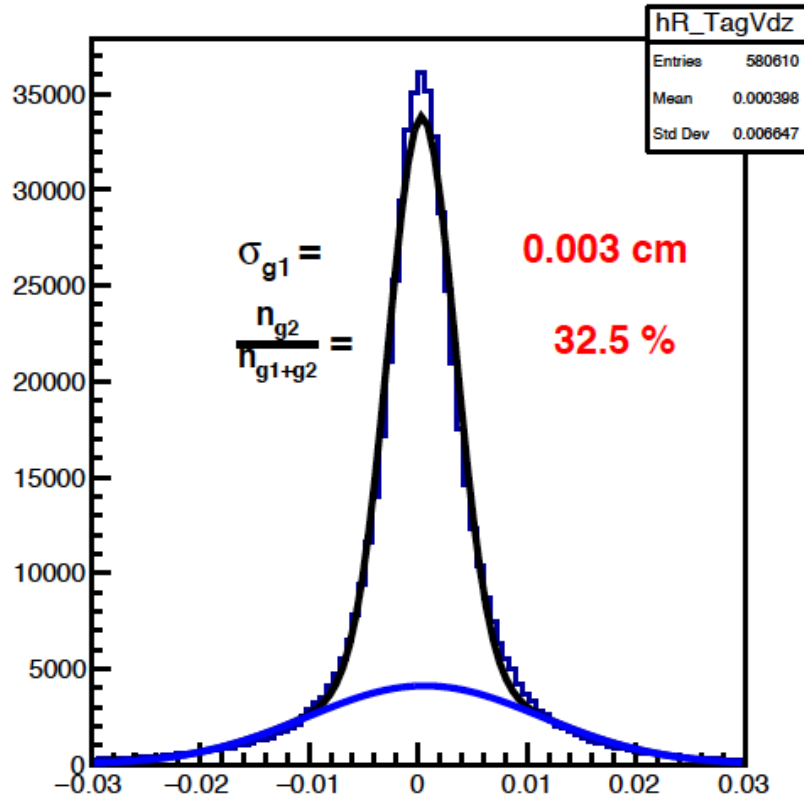


## GatedMode08-BGOOverlay:

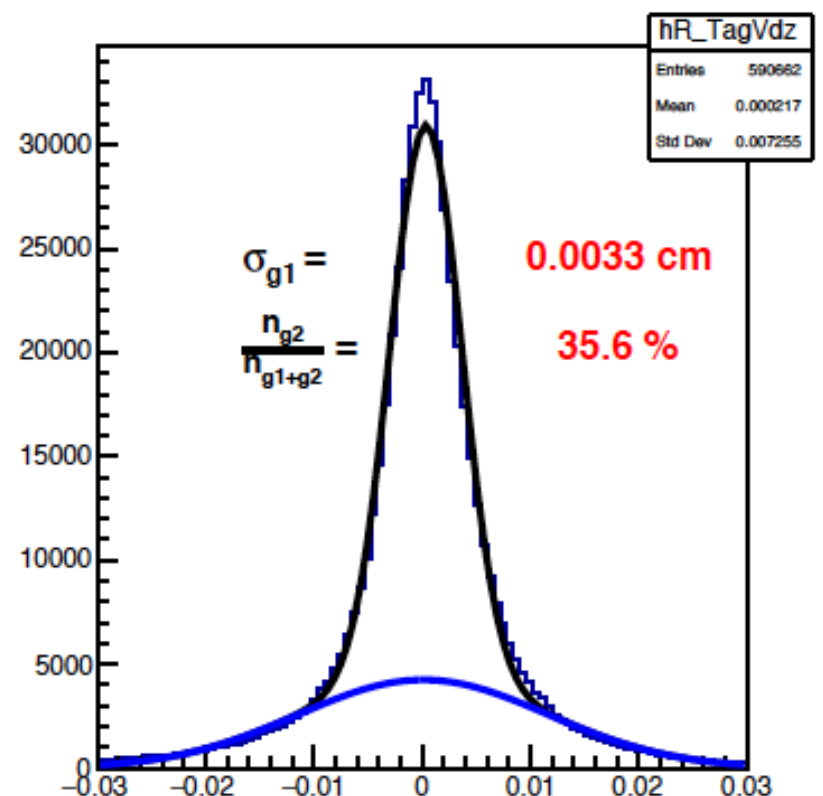
- Resolution  $z_0$ (tracks) and  $z_{\text{vtx}}$ (J/Psi) depends only on number of PXD hits
- Fraction of tracks with two and J/Psi with 2x2 PXD hits is dropped in Gated Mode from 93% to 68% for tracks and from 85.6% to 45.9% for J/Psi

# $Z_{\text{rec}} - Z_{\text{true}}$ of the $B_{\text{Tag}}$ vertex

MC10-Bkg1overlay



GatedMode08-BGOOverlay

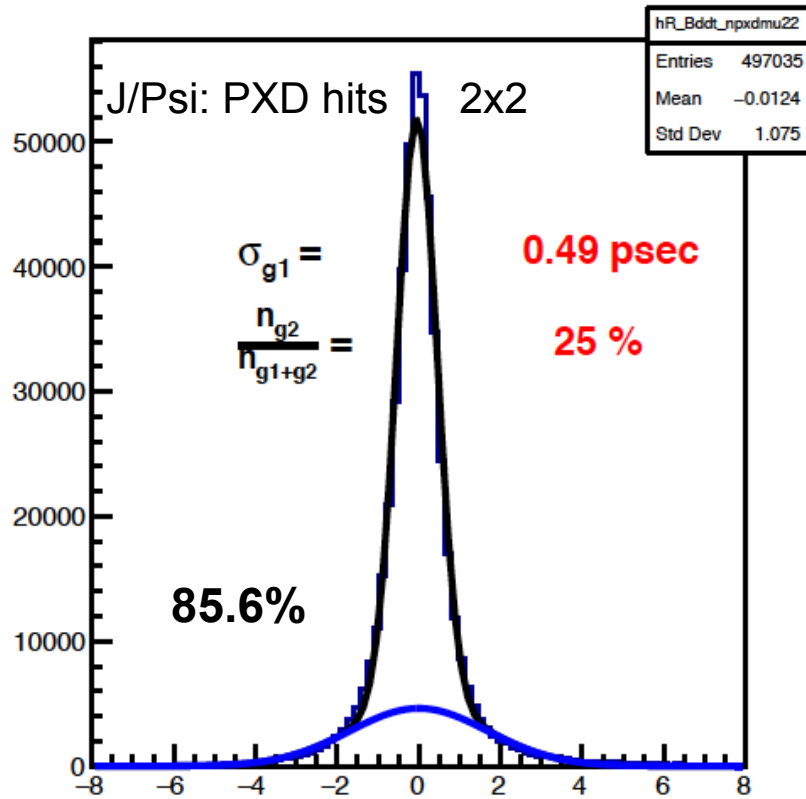


The  $B_{\text{Tag}}$  side suffers in the Gated Mode:

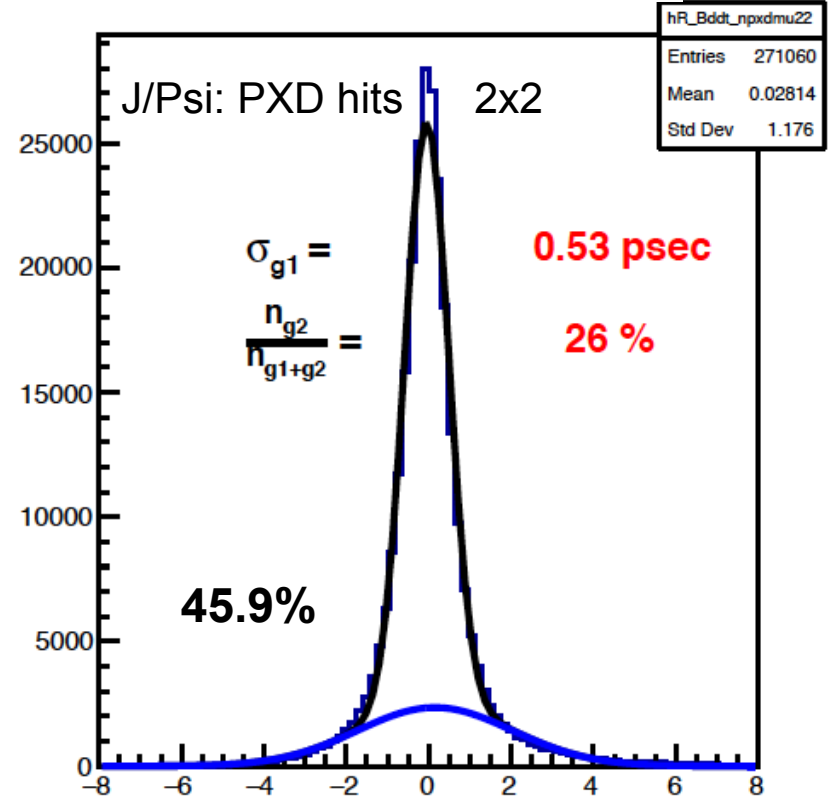
$\sigma(g1)$      $30 \mu\text{m} \rightarrow 33 \mu\text{m}$   
 $g2(\text{bkg})$      $32.5\% \rightarrow 35.6\%$

# $dt(B_{\text{Sig}} - B_{\text{Tag}}) / \text{rec-true}$

MC10-Bkg1overlay



GatedMode08-BGOOverlay



The time-dependent analyses:

fraction (J/Psi 2x2 hits) 85.6% → 45.9%  
 $\sigma(g1)$  49 psec → 53 psec  
 $g2(\text{bkg})$  25% → 26%

# Summary

$z_{\text{rec}} - z_{\text{true}}$	$\mu(\text{npxd}=2)$	J/Psi (2x2)	$B_{\text{Tag}}$	dt (2x2)
<b><i>gated 15%</i></b>	<b><i>(w/o readout)</i></b>			
fraction	92.6% → 67.9%	85.6% → 45.9%		85.6% → 45.9%
$\sigma(\text{g1})$	22 $\mu\text{m}$ → 23 $\mu\text{m}$	17 $\mu\text{m}$ → 17 $\mu\text{m}$	30 $\mu\text{m}$ → 33 $\mu\text{m}$	0.49ps → 0.53ps
g2(bkg)	22.2% → 22.1%	20.4% → 20.9%	32.5% → 35.6%	25% → 26%
<b><i>gated 20%</i></b>	<b><i>(with readout)</i></b>			
fraction	92.6% → 60.0%	85.6% → 35.7%		85.6% → 35.7%
$\sigma(\text{g1})$	22 $\mu\text{m}$ → 23 $\mu\text{m}$	17 $\mu\text{m}$ → 17 $\mu\text{m}$	30 $\mu\text{m}$ → 33 $\mu\text{m}$	0.49ps → 0.53ps
g2(bkg)	22.2% → 22.1%	20.4% → 20.9%	32.5% → 37.6%	25% → 28.5%

- *quality of the Tag side and of the time dependent analyses for all events collected during the GM period depends on the fraction of pixels skipped in the readout*  
 → *the mode “without readout” is preferable*
- *we should aim for making full use of PXD1 in the tracking :*  
 → *allow tracks with only one pxd hit in PXD1 if PXD2 behind is “gated”*
- *a side remark for the future: if possible continue readout after gating from the last row which was read before gating to avoid losses of pixels*