

Simulation of the Gated Mode of PXD

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The Gated Mode (GM) of PXD is an important feature of the data taking:

- about 20% of data will be affected according to present understanding

Implementation of the Gated Mode in MC:

- The PXD Gated Mode is implemented in basf2 in the PXDClusterizer module
- Additional information about GM to be written for every event

Impact of the PXD Gated Mode on physics:

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

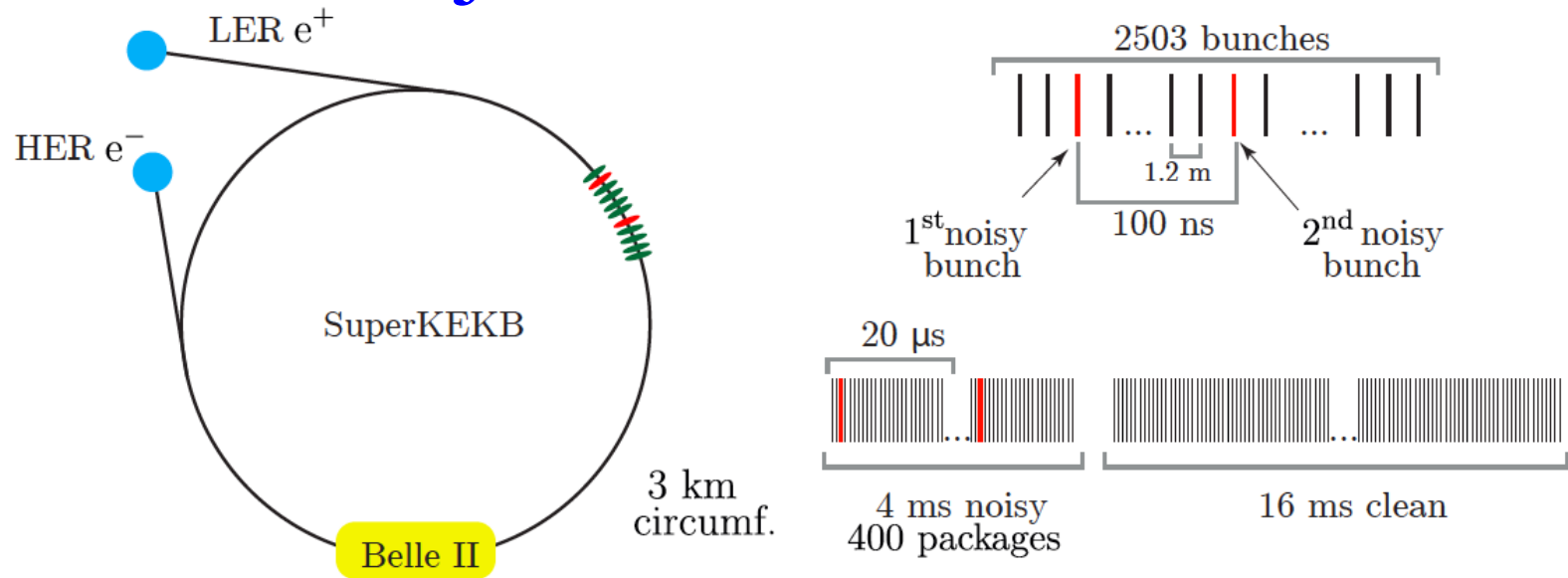


Figure 3.9: SuperKEKB injection scheme. The total injection frequency is 50 Hz (every 20 ms) where two bunches in a distance of 100 ns are filled up. They are shown as the red lines. The damping takes approximately 4 ms.

80% of time (16ms) - normal operation

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

2% dead time (1 μ s every bunch revolution of 10 μ s) – missing readout for other detectors to avoid noise generated by two injected & exited bunches

→ remaining 18% of time - problematic PXD readout in the Gated Mode (GM) because of long charge integration time in PXD of 20 μ s (i.e. one PXD frame = two 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)

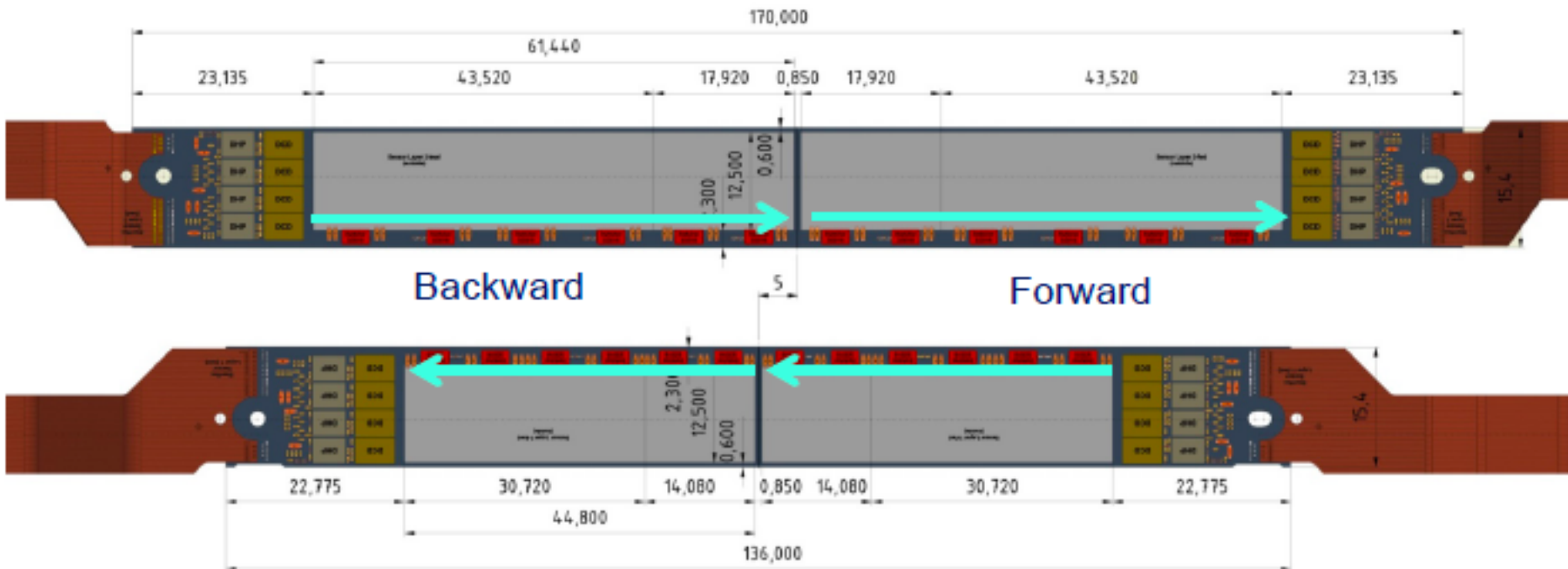
$\sim 1.9 \mu\text{s}$

(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

The PXD Gated Mode Model

- 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/time directions for inner and outer PXD layers are opposite (shown by arrows)



Implementation of the Gated Mode

“Gated Mode” should be applied after adding “mixed” or “overlay” background in simulation. The “overlay” background is added at the very end of the simulation script.

→ PXD hits are suppressed at the PXD clustering step in reconstruction

```
pxd/modules/pxdReconstruction/include/PXDClusterizerModule.h  
pxd/modules/pxdReconstruction/src/PXDClusterizerModule.cc
```

Three steering parameters:

def add_reconstruction → def add_pxd_reconstruction → PXDClusterizerModule.cc (.h)

:param pxdGatedMode_ON: If true, activate the PXD Gated Mode for the PXD readout.

:param pxdGatedMode_LumiFraction: Fraction of time in the PXD Gated Mode for the PXD readout.

:param pxdGatedMode_PixelFraction: Fraction of pixels suppressed in the PXD Gated Mode.

default:

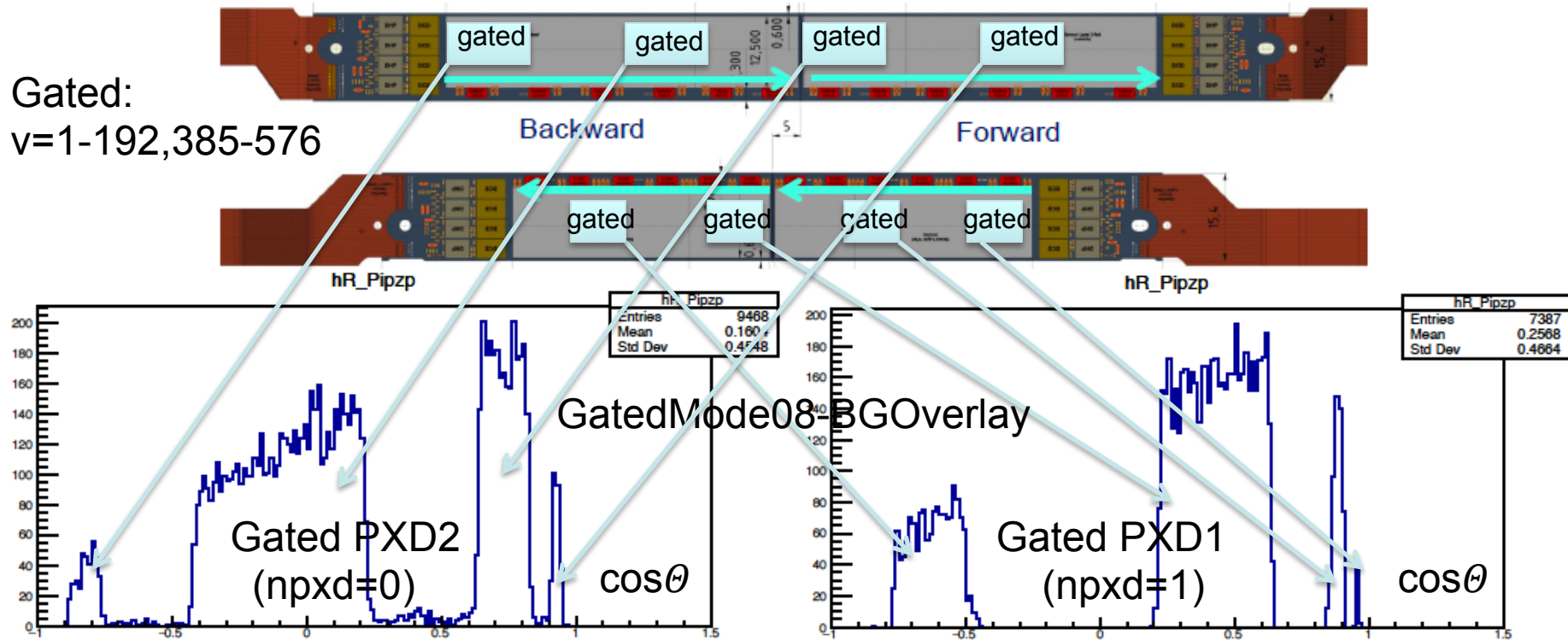
pxdGatedMode_ON=False, pxdGatedMode_LumiFraction=0.18, pxdGatedMode_PixelFraction=0.15

In the present study:

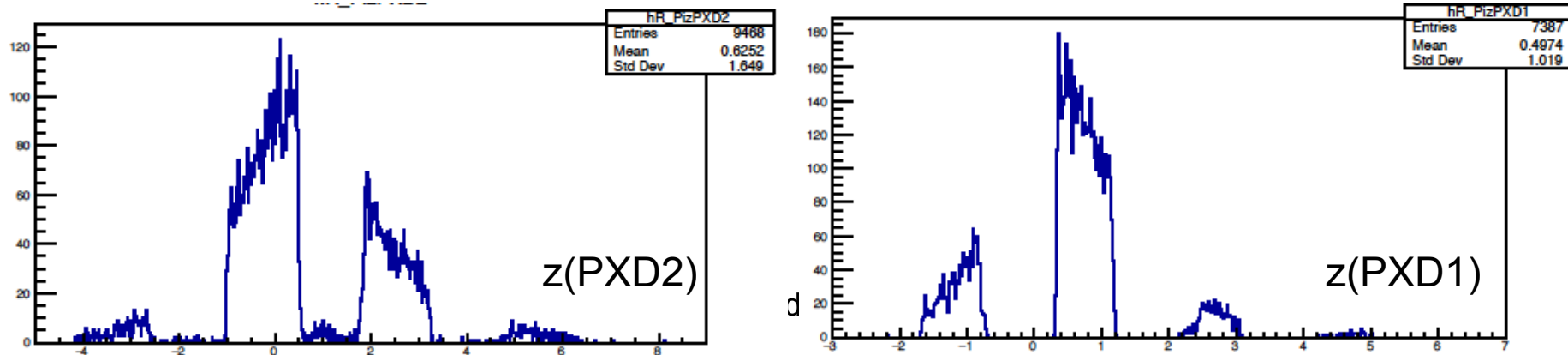
- the Gated Mode is applied to all events (pxdGatedMode_LumiFraction=1.00)
- all plot below are shown for GM without readout (pxdGatedMode_PixelFraction=0.15, i.e. **15% gated**)
in addition results for GM with readout (**20% gated**) are summarized in a table

Test: “Gating” of quarters of sensors

Gated:
 $v=1-192,385-576$

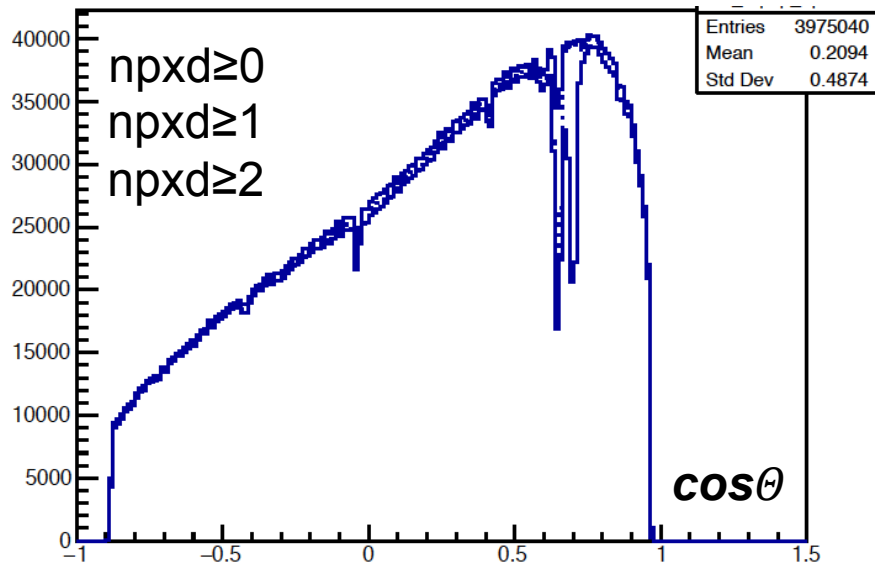


feature of the present tracking: tracks with only one PXD hit located in PXD1 are not allowed

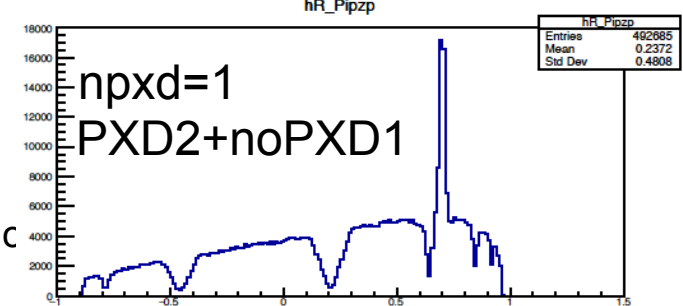
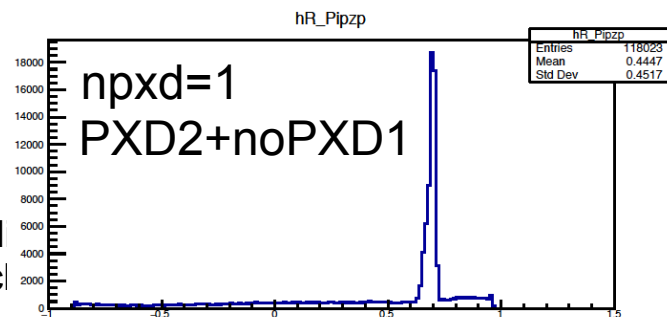
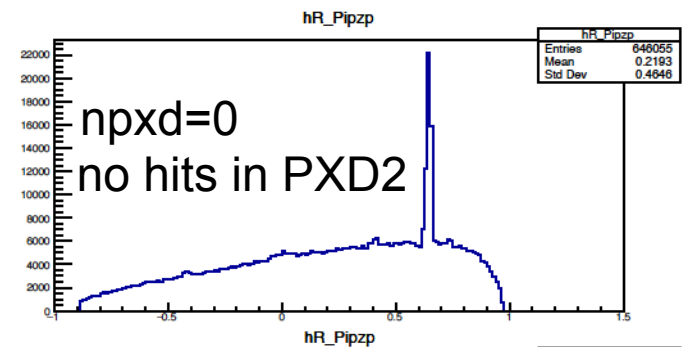
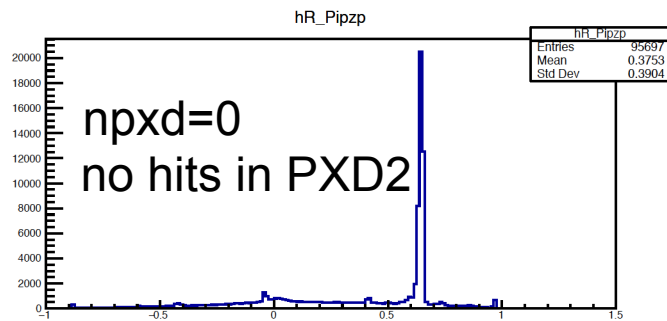
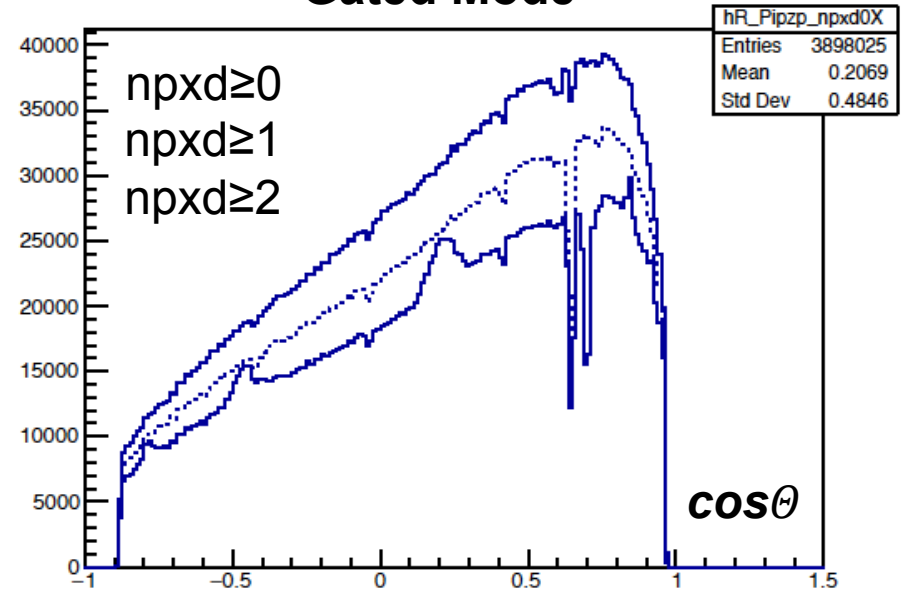


Tracks in MC10 & GatedMode08-BGOOverlay

release 1.0



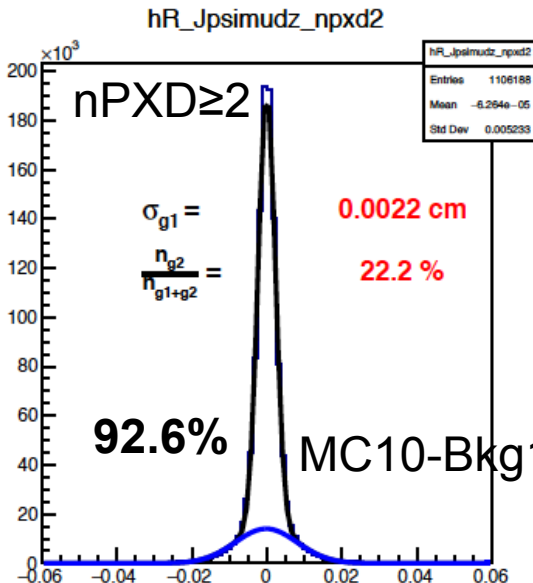
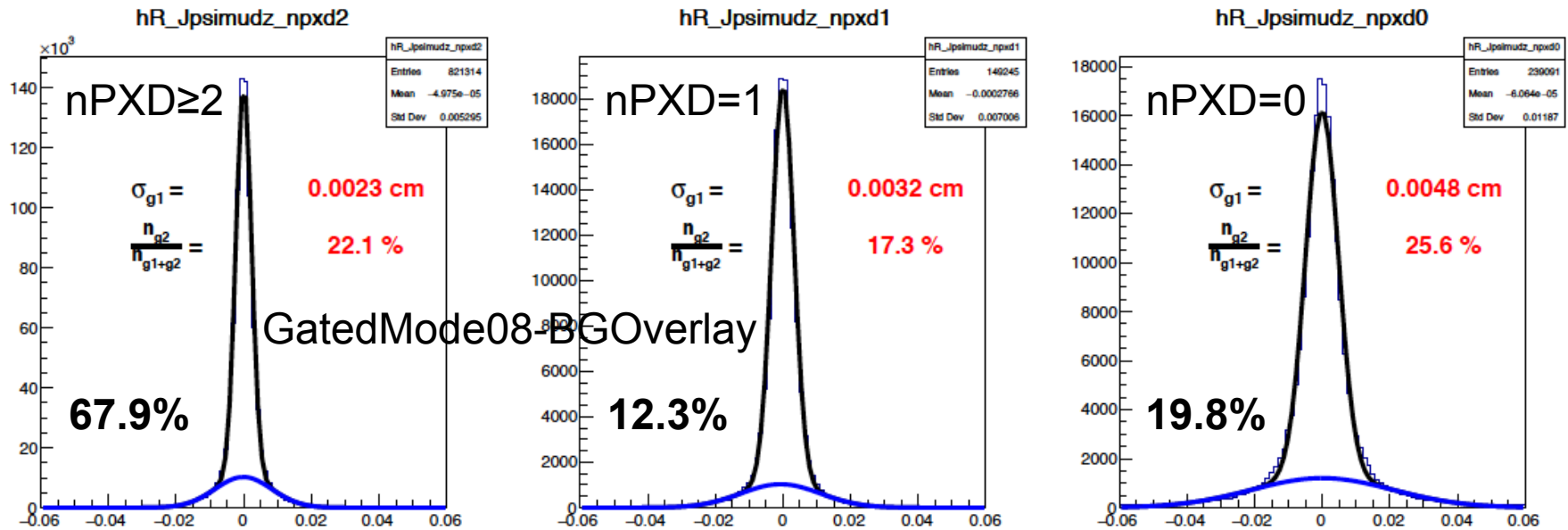
Gated Mode



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$z_{0,rec} - z_{J/\Psi,true}$ for muons from J/Psi



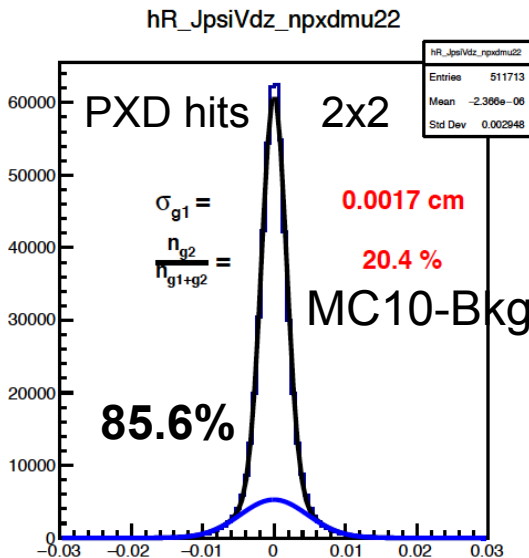
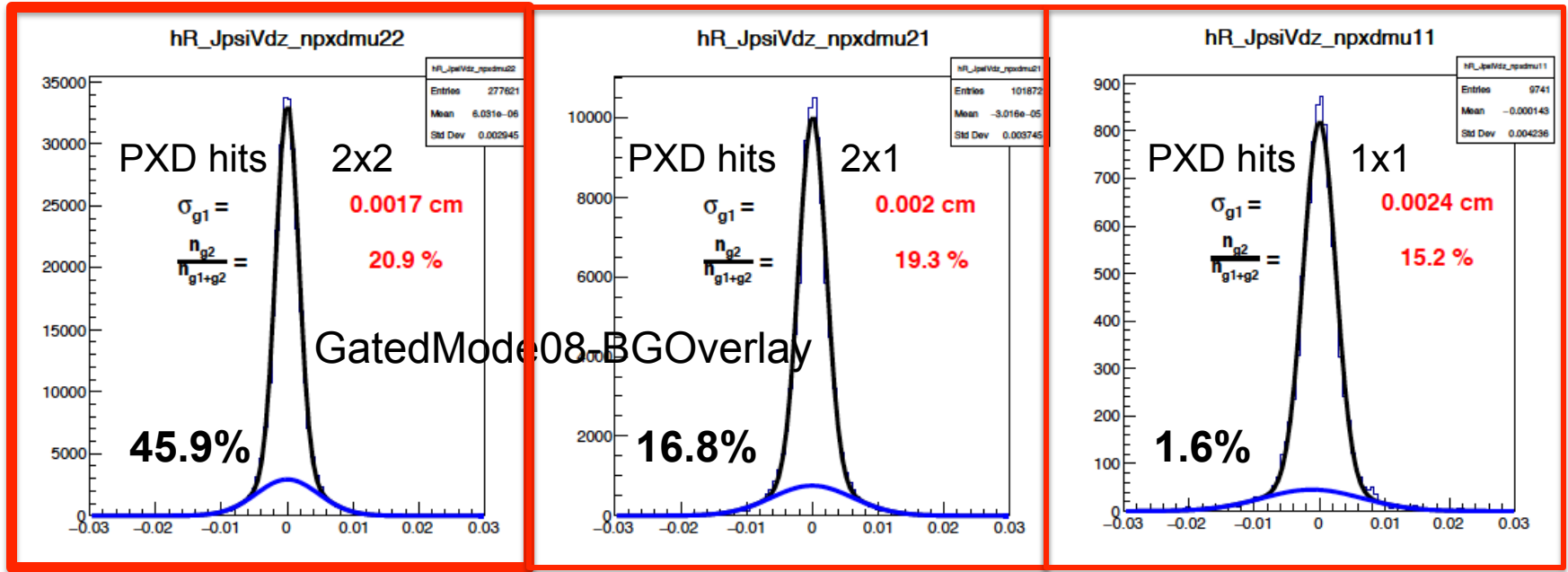
Two gaussian fits are performed (core + tails)

Quality of z_0 for tracks depends on number of PXD hits

Fraction of tracks with two PXD hits is dropped in the Gated Mode from 93% to 68% (one would expect a factor of 0.70 without overlap between "gated" intervals in PXD1 and PXD2)

Simulation of Gated Mode of PXD

$Z_{\text{rec}} - Z_{\text{true}}$ of the J/Psi vertex



→ quality of J/Psi with 2+2 PXD hits is the same but the fraction of them in the Gated Mode is dropped from **86% to 46%**

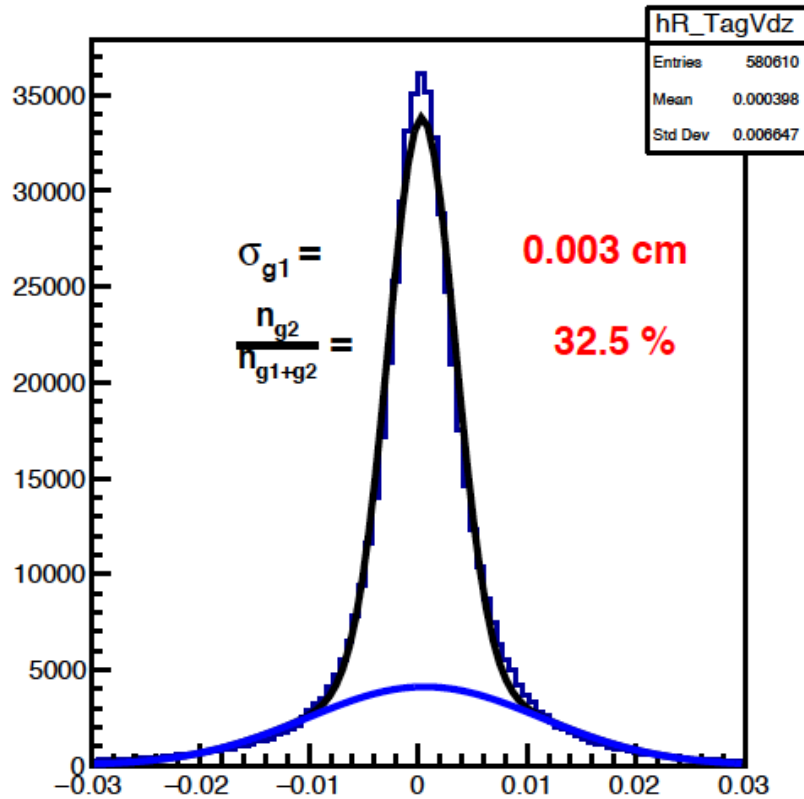
→ 18% of J/Psi with 2+1 & 1+1 PXD hits, interesting that quality of 2+1 and 1+1 is close.

→ quality of J/Psi with 2+0 PXD hits can be improved if allow tracks with the only PXD hit in PXD1 (27%)

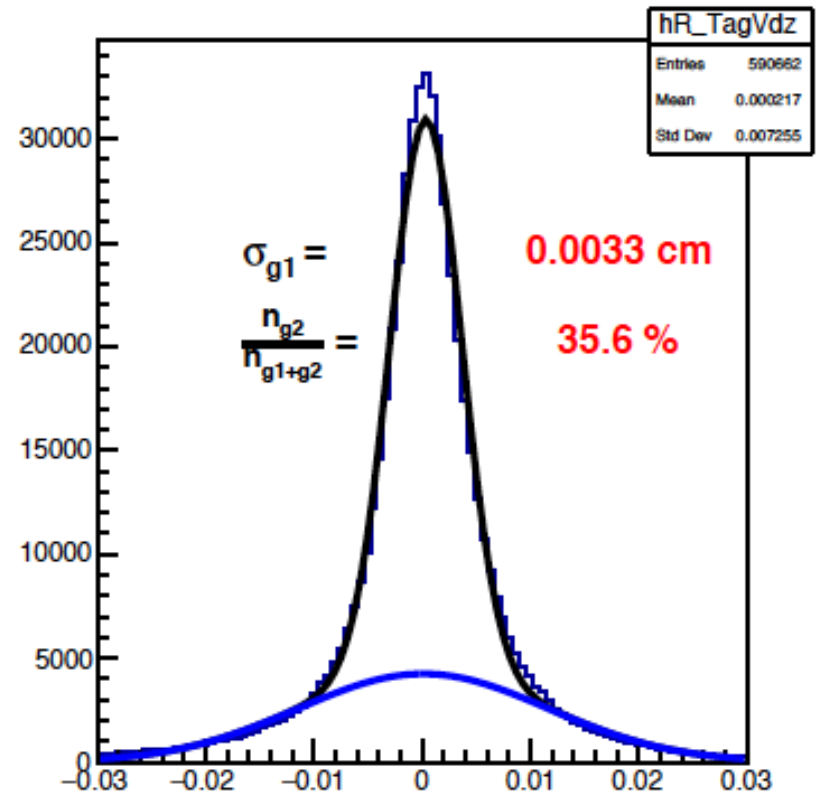
Simulation of Gated Mode of PXD

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

MC10-Bkg1overlay



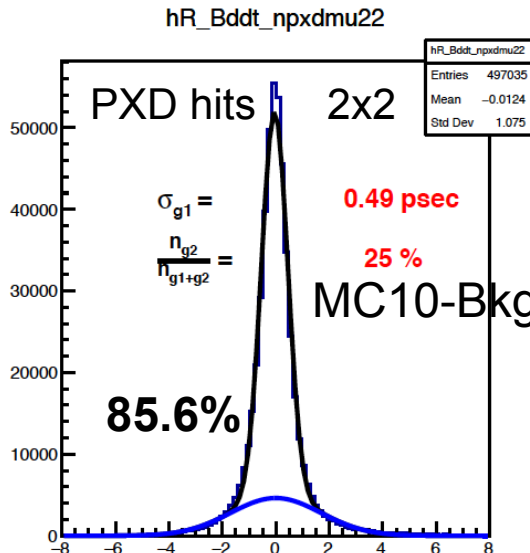
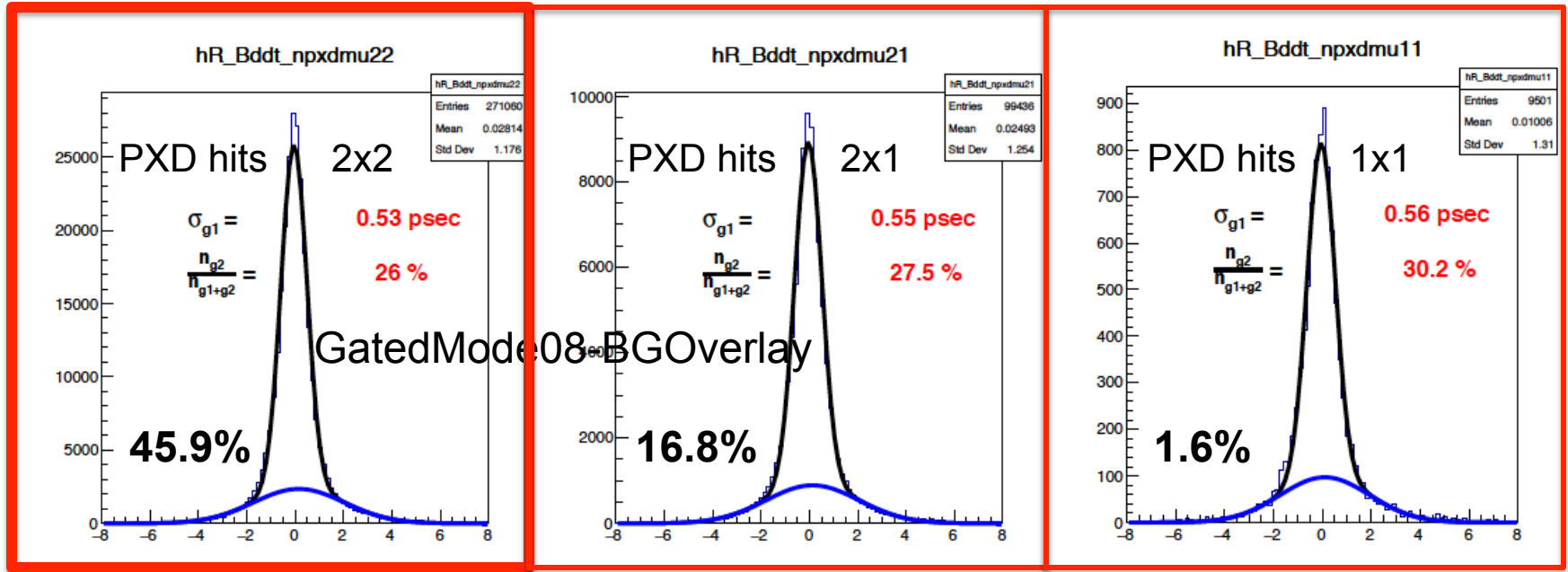
GatedMode08-BGOOverlay



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

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

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



→ the fraction of J/Ψ with 2+2 PXD hits in the Gated Mode is dropped from 86% to 46%

even for them quality gets worse;

$\sigma(g1)$: 0.49 ps → 0.53 ps; $g2(\text{bkg})$: 25% → 26%

MC10-Bkg1overlay

→ 18% of J/Ψ with 2+1 & 1+1 PXD hits: 0.49 ps → 0.55 ps

→ 27% of J/Ψ with 2+0 PXD hits: quality can be improved if allow tracks with the only hit in PXD1

Simulation of Gated Mode of PXD

Conclusions (I)

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

For all events in the Gated Mode:

- *number of PXD hits associated with tracks is reduced*
- *quality of the Tag side (dt analysis) becomes worse and depends on the readout properties in the Gated Mode.*
- *reduce fraction of pixels suppressed due to features of readout in the Gated Mode:*
 - *the mode “without readout” is preferable*
- *make full use of PXD1 :*
 - *allow tracks with only one pxd hit in PXD1 if PXD2 behind is “gated”*

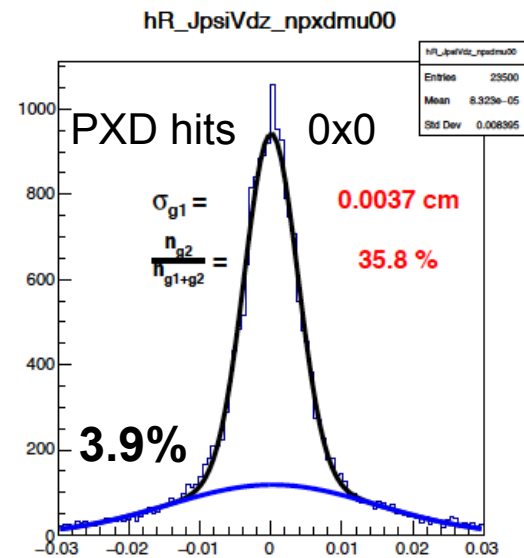
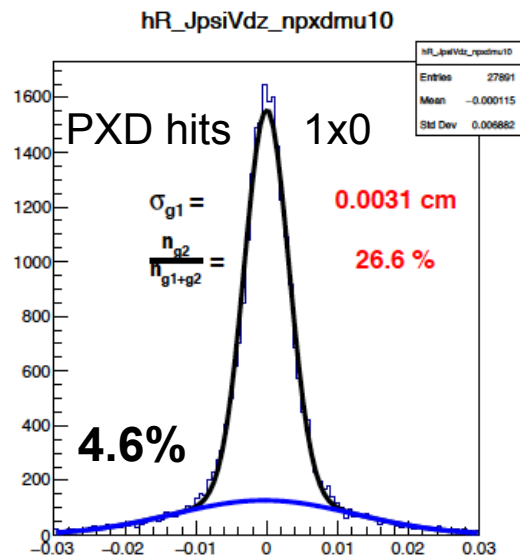
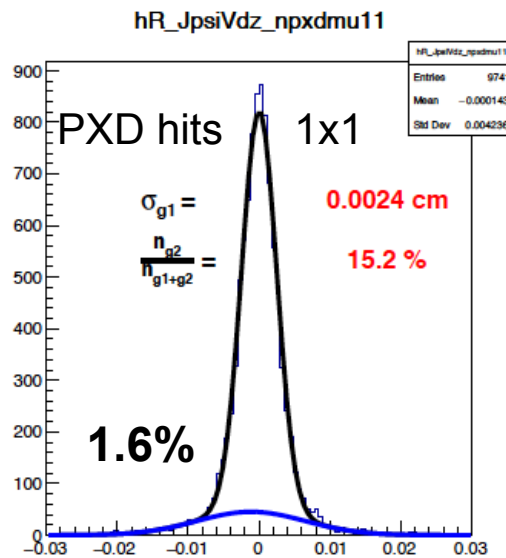
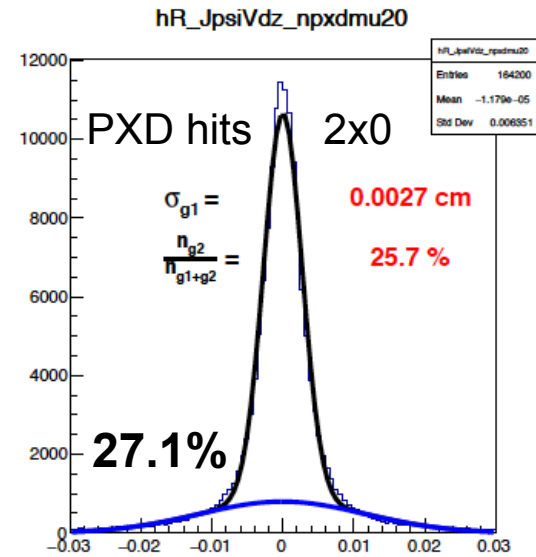
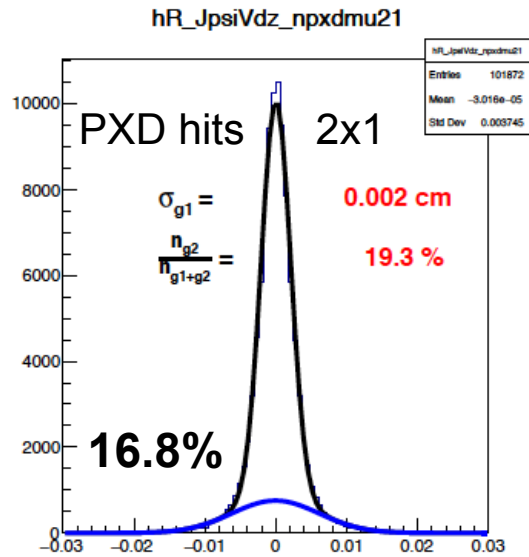
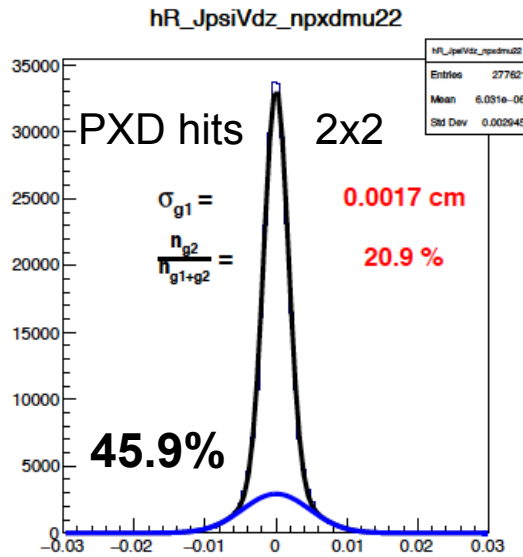
Conclusions (II)

The final PXD Gated Mode parameters to be determined during data taking. They could be more optimistic or much worse than the present first guess.

One should have means to study impact of GM on physics using general software.

- Implementation of the Gated Mode proposed in this presentation involves modification of the PXD clustering module in reconstruction*
- Missing and needs general discussion:
for each event at least a flag to be written indicating that event is in Gated Mode,
and may be location of the gated intervals in the given event*

$Z_{\text{rec}} - Z_{\text{true}}$ of J/Psi in GatedMode08-BGO overlay



dt(B_{Sig}-B_{Tag}) in GatedMode08-BGOverlay (rec-true)

