

Verification Environment for a Simple Pixel Chip Model

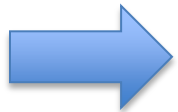
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Goals

- Activity performed in **RD53** (workpackage WG3: “*Simulation Testbench*”)
- Requirements
 - Definition and evaluation of requirements for next generation pixel chips
 - System performance evaluation for different pixel architectures
 - Pixel architecture optimization based on pixel grouping (validation of statistical study)



Devoted simulation and verification framework

Verification Environment – Current Version

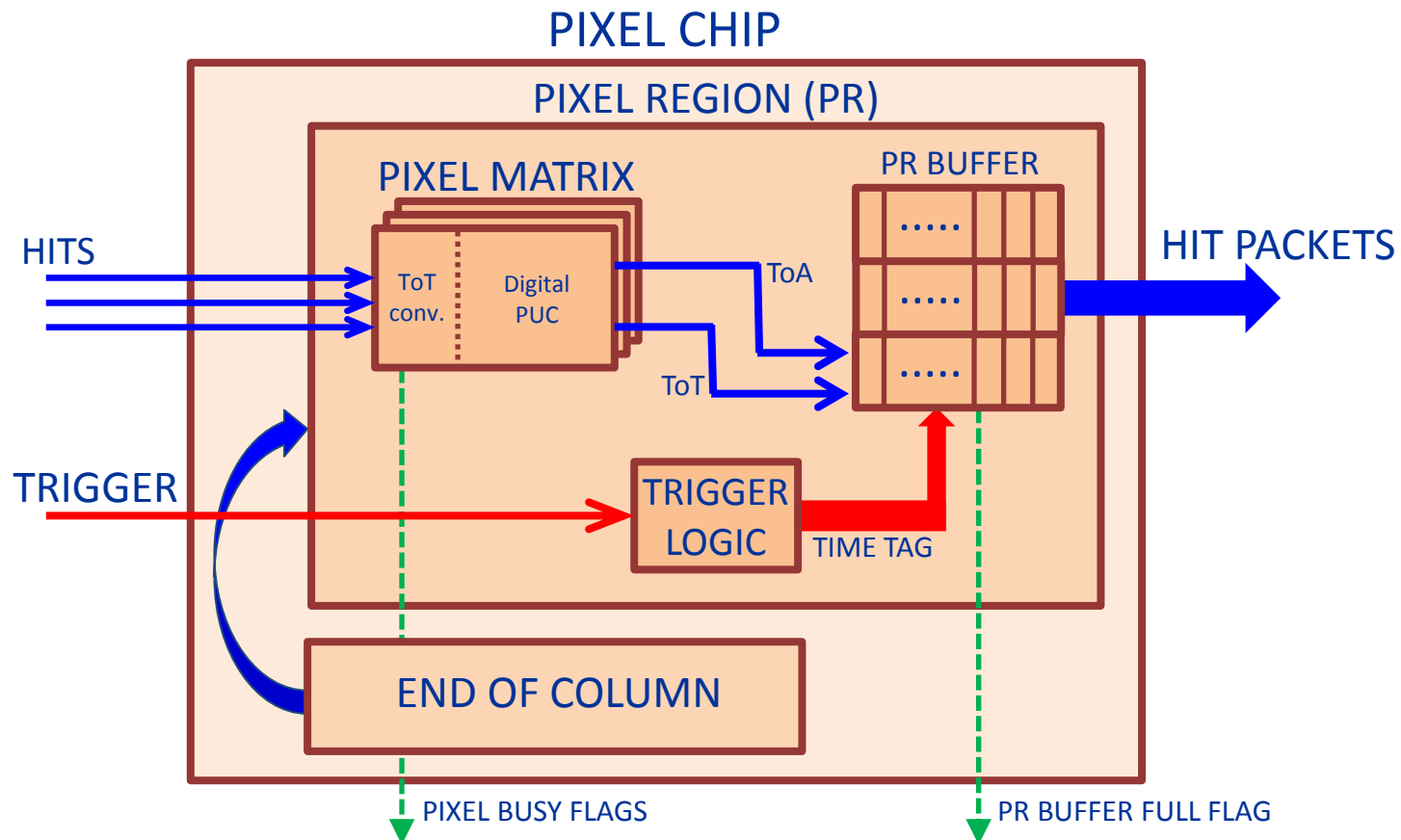
SystemVerilog class-based verification environment

- Automated hit generation (random and from file)
- Conformity checks between pixel chip inputs and outputs
- Monitoring of lost hits
- Reporting on lost hits (why hits are lost)

Verification Environment – DUT (1)

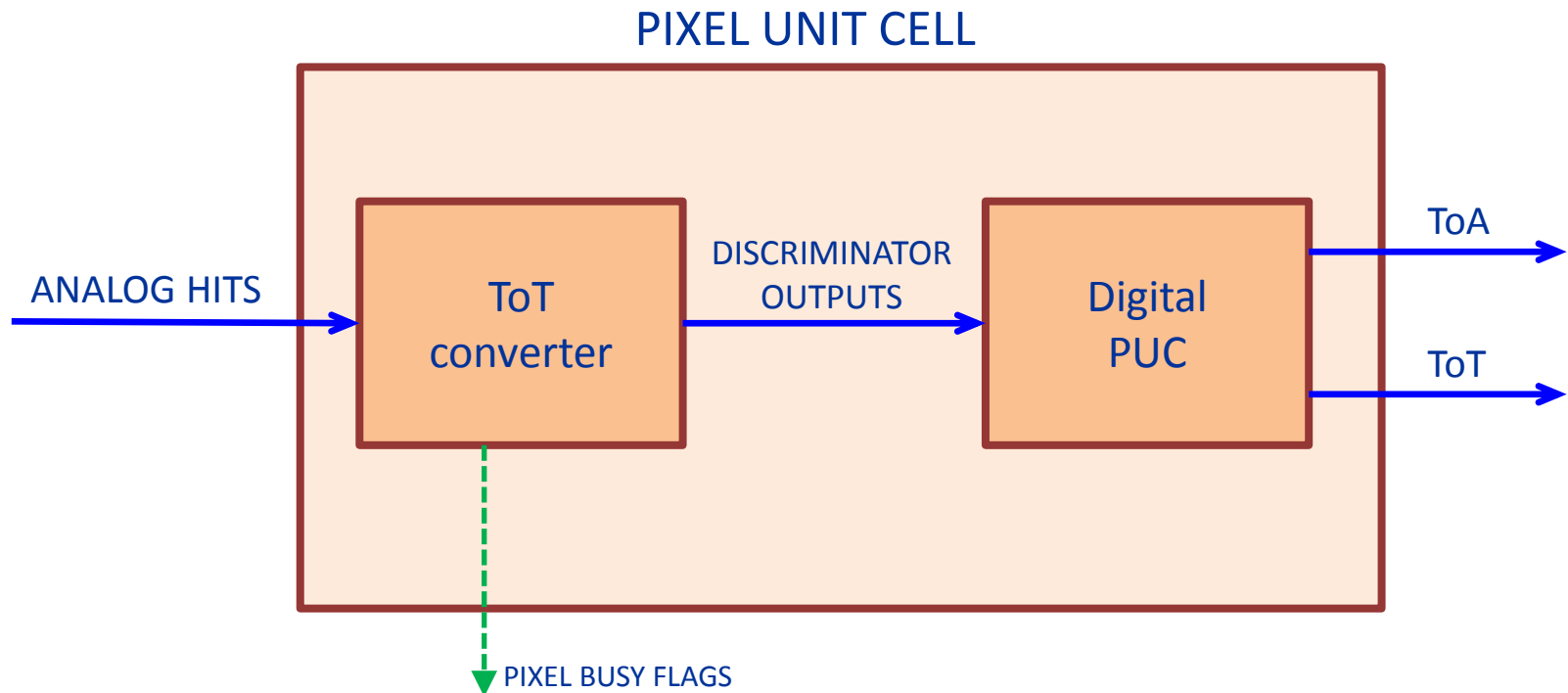
Pixel chip contains a single Pixel Region (PR) with a parametrised number of Pixel Unit Cells (PUC)

PR buffer is an array of SystemVerilog queues



Verification Environment – DUT (2)

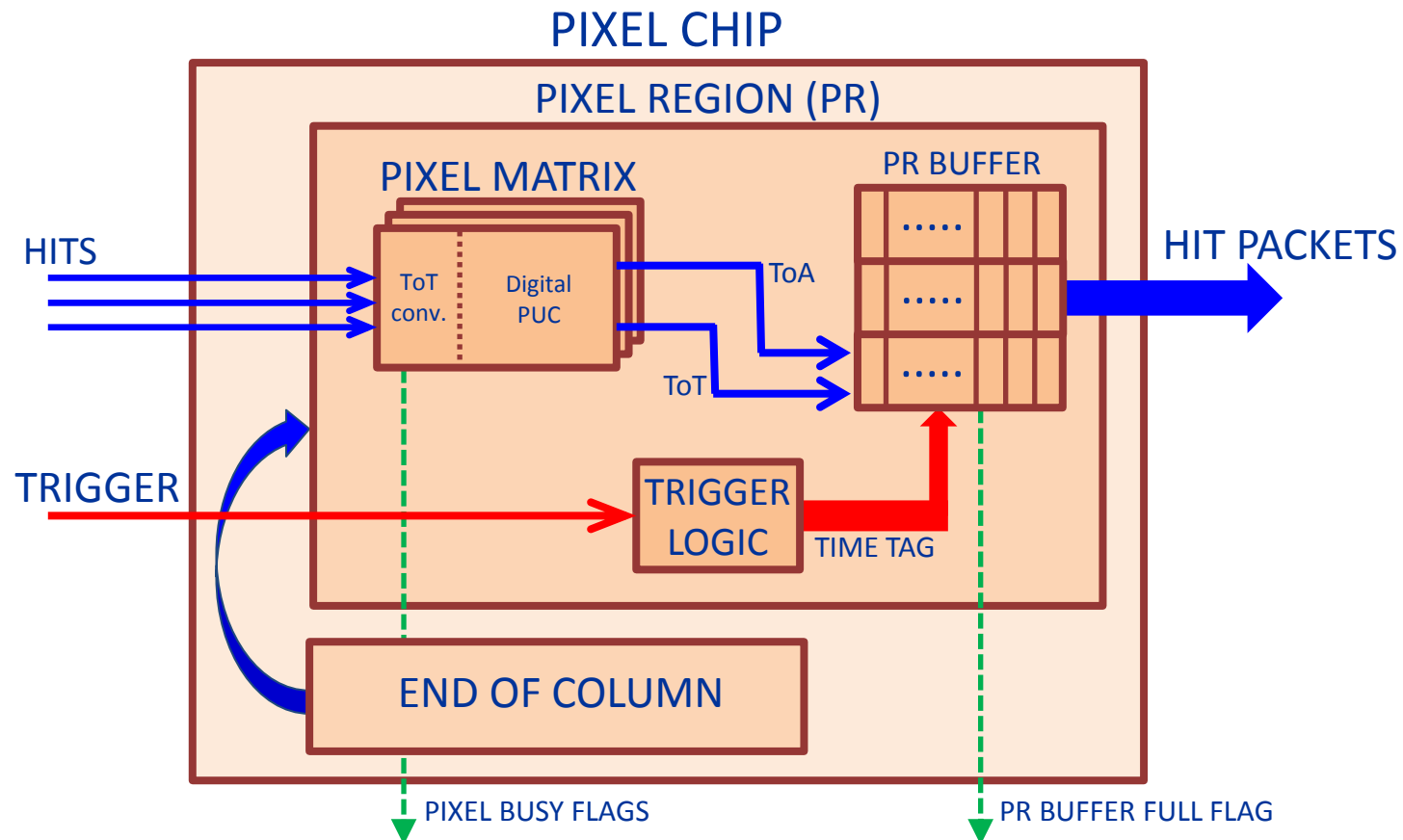
In order to keep hit generation as general as possible a simple ToT converter module has been defined which abstracts the behavior of the analog front-end



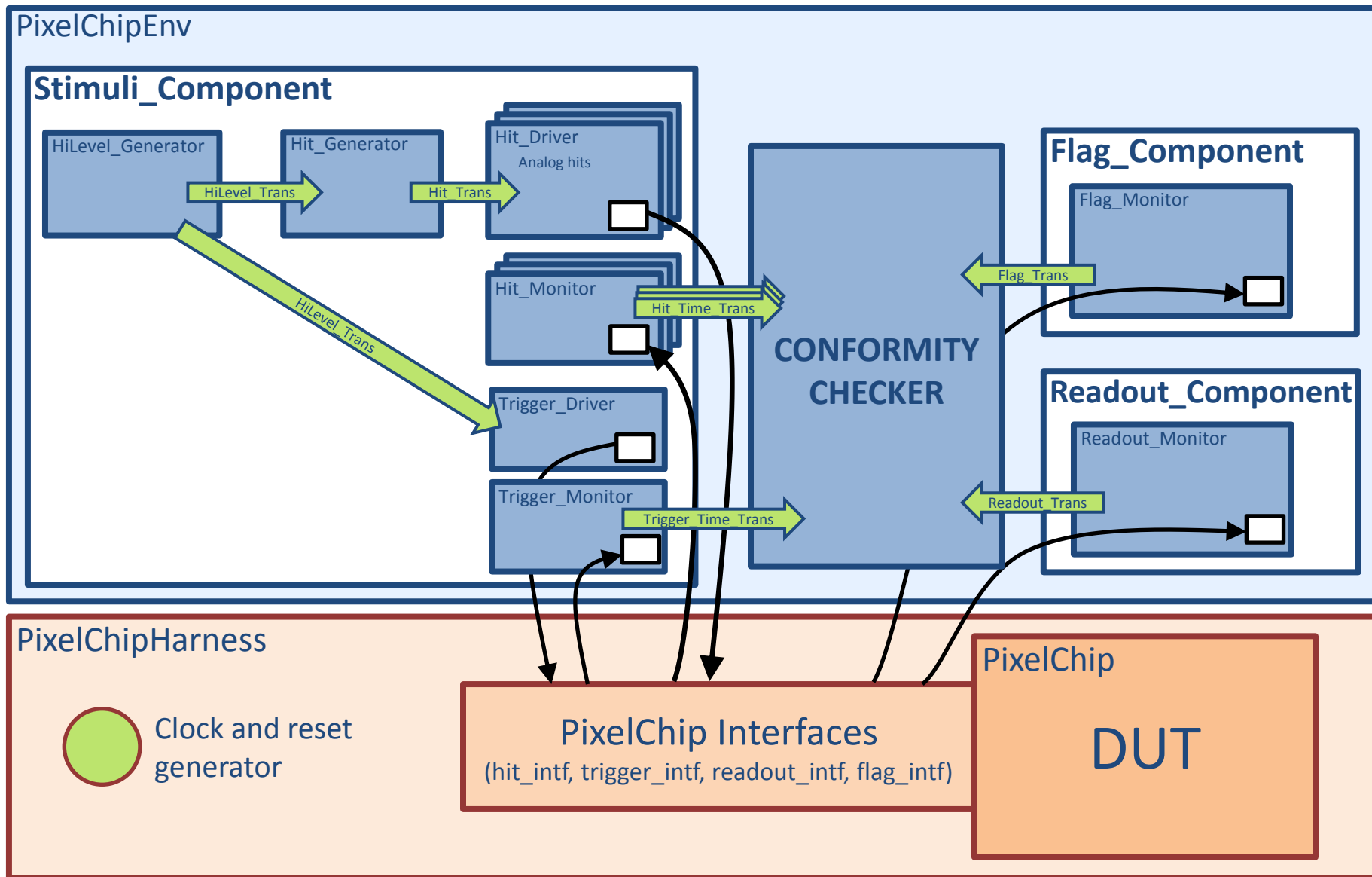
Verification Environment – DUT (3)

Pixel chip contains a single Pixel Region (PR) with a parametrised number of Pixel Unit Cells (PUC)

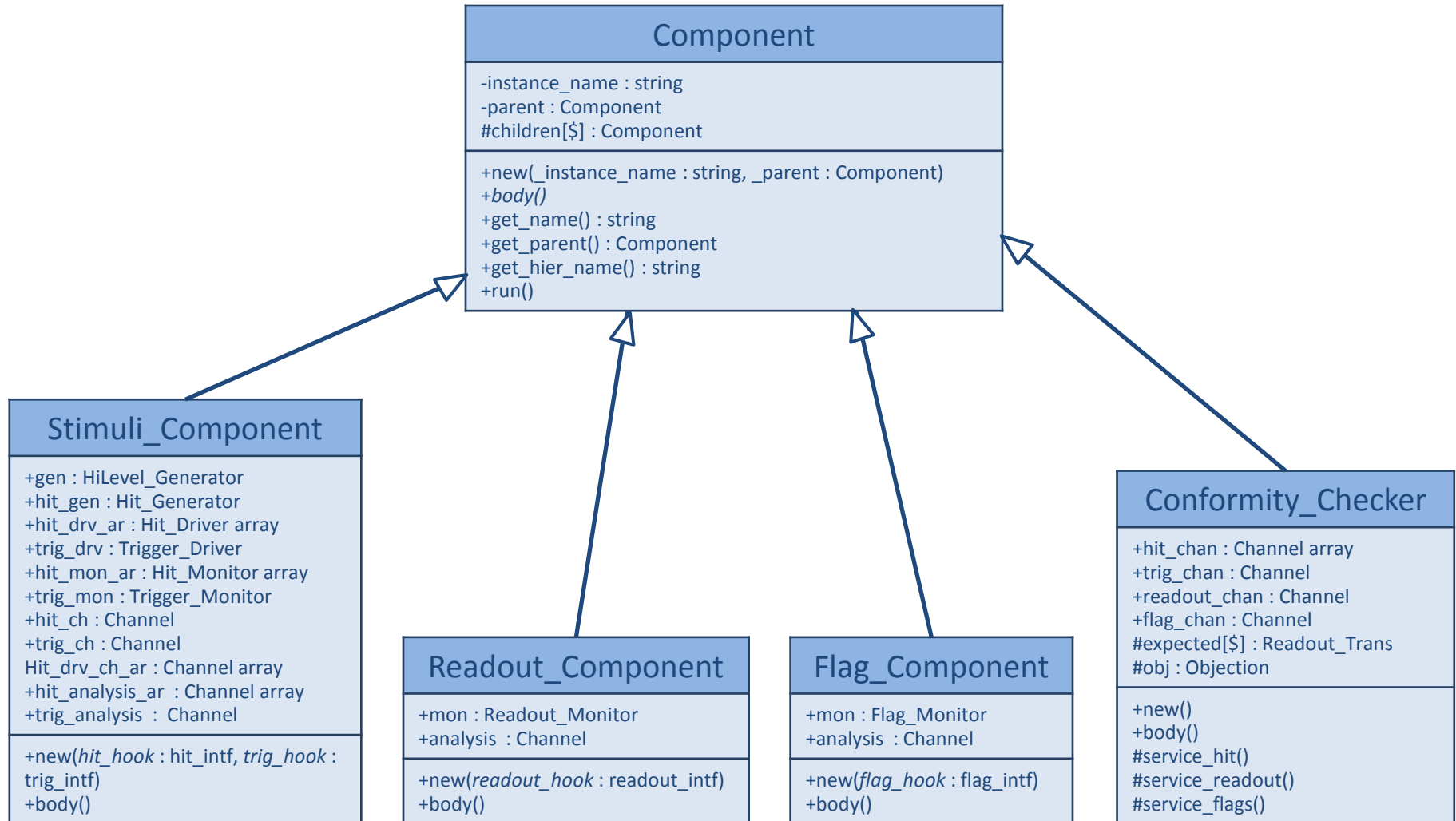
PR buffer is an array of SystemVerilog queues



Verification Environment – Block Diagram



Verification Environment – Components (1)



Verification Environment – Components (2)

Stimuli_Component

- First stage: generation of high level transactions (randomized or from external file)
- High level transactions are fed to Trigger_Driver (generation of trigger signal) and to Hit_Generator and Hit_Driver's (generation of hits on each pixel of the matrix)

Readout_Component

- Generation of readout transactions using pixel chip outputs

Flag_Component

- Generation of flag transactions using pixel chip flags (pixel busy and PR buffer full)

Conformity_Checker

- Receives input hit information, trigger information, output data and diagnostic information (pixel chip flags)
- Reference model in the checker predicts DUT output from input transactions
- Predicted output and actual output are compared
- Pixel chip flags are always monitored
- Production of report messages

Verification Environment – Reporting (1)

- Conformity_Checker has successfully found conformity between input and output
- **WARNING**: Conformity_Checker has found discrepancy between input and output
- **ERROR** : Conformity_Checker has found out that the PR buffer is full
- Conformity_Checker has found out that a pixel is busy and thus an input hit has been lost

Verification Environment – Reporting (2)

Example of console output

```
Console - SimVision
File Edit View Simulation Windows Help
Text Search:
12,587,500ps + 1
At 512500 ps (BX-cycle 20): Transaction generated on the driver channel: Hit packet #20: amplitude = 5, hit pixel = no, triggered = no
At 512500 ps (BX-cycle 20): Transaction generated on the trigger channel: Hit packet #20: amplitude = 5, hit pixel = no, triggered = no
At 537500 ps (BX-cycle 21): Transaction generated on the driver channel: Hit packet #21: amplitude = 3, hit pixel = yes, triggered = no
At 537500 ps (BX-cycle 21): Transaction generated on the trigger channel: Hit packet #21: amplitude = 3, hit pixel = yes, triggered = no
At 537500 ps (BX-cycle 21): Starting to drive transaction: Hit packet #21: amplitude = 3, hit pixel = yes, triggered = no
At 562500 ps (BX-cycle 22): Transaction generated on the driver channel: Hit packet #22: amplitude = 3, hit pixel = yes, triggered = no
At 562500 ps (BX-cycle 22): Transaction generated on the trigger channel: Hit packet #22: amplitude = 3, hit pixel = yes, triggered = no
At 587500 ps (BX-cycle 23): Hit_Driver busy (TOT dead time) => cannot generate transaction: Hit packet #22: amplitude = 3, hit pixel = yes, triggered = no
At 587500 ps (BX-cycle 23): Transaction generated on the driver channel: Hit packet #23: amplitude = 4, hit pixel = no, triggered = no
At 587500 ps (BX-cycle 23): Transaction generated on the trigger channel: Hit packet #23: amplitude = 4, hit pixel = no, triggered = no
At 612500 ps (BX-cycle 24): Finished to drive transaction: Hit packet #21: amplitude = 3, hit pixel = yes, triggered = no
At 612500 ps (BX-cycle 24): Transaction generated on the driver channel: Hit packet #24: amplitude = 2, hit pixel = yes, triggered = yes
At 612500 ps (BX-cycle 24): Transaction generated on the trigger channel: Hit packet #24: amplitude = 2, hit pixel = yes, triggered = yes
At 637500 ps: Hit Monitor detected transaction: Hit packet #3: ToA = 53750, amplitude = 3
At 637500 ps: Hit_Driver busy (DUT dead time) => cannot generate transaction: Hit packet #24: amplitude = 2, hit pixel = yes, triggered = yes
At 637500 ps: Conformity Checker stored transaction in Input Hit Container: Hit packet #31: ToA = 22, amplitude = 3
At 637500 ps (BX-cycle 25): Transaction generated on the driver channel: Hit packet #25: amplitude = 6, hit pixel = no, triggered = no
At 637500 ps (BX-cycle 25): Transaction generated on the trigger channel: Hit packet #25: amplitude = 6, hit pixel = no, triggered = no
At 662500 ps (BX-cycle 26): Transaction generated on the driver channel: Hit packet #26: amplitude = 1, hit pixel = no, triggered = no
At 662500 ps (BX-cycle 26): Transaction generated on the trigger channel: Hit packet #26: amplitude = 1, hit pixel = no, triggered = no
At 687500 ps (BX-cycle 27): Transaction generated on the driver channel: Hit packet #27: amplitude = 2, hit pixel = yes, triggered = yes
At 687500 ps (BX-cycle 27): Transaction generated on the trigger channel: Hit packet #27: amplitude = 2, hit pixel = yes, triggered = yes
At 712500 ps (BX-cycle 28): Hit_Driver busy (DUT dead time) => cannot generate transaction: Hit packet #27: amplitude = 2, hit pixel = yes, triggered = yes
At 712500 ps (BX-cycle 28): Transaction generated on the driver channel: Hit packet #28: amplitude = 6, hit pixel = no, triggered = no
At 712500 ps (BX-cycle 28): Transaction generated on the trigger channel: Hit packet #28: amplitude = 6, hit pixel = no, triggered = no
At 737500 ps (BX-cycle 29): Transaction generated on the driver channel: Hit packet #29: amplitude = 1, hit pixel = no, triggered = no
At 737500 ps (BX-cycle 29): Transaction generated on the trigger channel: Hit packet #29: amplitude = 1, hit pixel = no, triggered = no
At 762500 ps (BX-cycle 30): Transaction generated on the driver channel: Hit packet #30: amplitude = 0, hit pixel = no, triggered = no
At 762500 ps (BX-cycle 30): Transaction generated on the trigger channel: Hit packet #30: amplitude = 0, hit pixel = no, triggered = no
At 787500 ps (BX-cycle 31): Transaction generated on the driver channel: Hit packet #31: amplitude = 3, hit pixel = yes, triggered = no
At 787500 ps (BX-cycle 31): Transaction generated on the trigger channel: Hit packet #31: amplitude = 3, hit pixel = yes, triggered = no
At 787500 ps (BX-cycle 31): Starting to drive transaction: Hit packet #31: amplitude = 3, hit pixel = yes, triggered = no
At 812500 ps (BX-cycle 32): Transaction generated on the driver channel: Hit packet #32: amplitude = 2, hit pixel = yes, triggered = no
At 812500 ps (BX-cycle 32): Transaction generated on the trigger channel: Hit packet #32: amplitude = 2, hit pixel = yes, triggered = no
At 837500 ps: Hit_Driver busy (TOT dead time) => cannot generate transaction: Hit packet #32: amplitude = 2, hit pixel = yes, triggered = no
At 837500 ps (BX-cycle 33): Transaction generated on the driver channel: Hit packet #33: amplitude = 2, hit pixel = yes, triggered = no
At 837500 ps (BX-cycle 33): Transaction generated on the trigger channel: Hit packet #33: amplitude = 2, hit pixel = yes, triggered = no
At 862500 ps (BX-cycle 34): Finished to drive transaction: Hit packet #31: amplitude = 3, hit pixel = yes, triggered = no
At 862500 ps (BX-cycle 34): Hit_Driver busy (DUT dead time) => cannot generate transaction: Hit packet #33: amplitude = 2, hit pixel = yes, triggered = no
At 862500 ps (BX-cycle 34): Transaction generated on the driver channel: Hit packet #34: amplitude = 6, hit pixel = no, triggered = no
At 862500 ps (BX-cycle 34): Transaction generated on the trigger channel: Hit packet #34: amplitude = 6, hit pixel = no, triggered = no
At 887500 ps: Hit Monitor detected transaction: Hit packet #3: ToA = 78750, amplitude = 3
At 887500 ps: Conformity Checker stored transaction in Input Hit Container: Hit packet #42: ToA = 32, amplitude = 3
At 887500 ps (BX-cycle 35): Transaction generated on the driver channel: Hit packet #35: amplitude = 6, hit pixel = yes, triggered = yes
At 887500 ps (BX-cycle 35): Transaction generated on the trigger channel: Hit packet #35: amplitude = 6, hit pixel = yes, triggered = yes
At 912500 ps (BX-cycle 36): Hit_Driver busy (DUT dead time) => cannot generate transaction: Hit packet #35: amplitude = 6, hit pixel = yes, triggered = yes
At 912500 ps (BX-cycle 36): Transaction generated on the driver channel: Hit packet #36: amplitude = 0, hit pixel = no, triggered = no
At 912500 ps (BX-cycle 36): Transaction generated on the trigger channel: Hit packet #36: amplitude = 0, hit pixel = no, triggered = no
At 937500 ps (BX-cycle 37): Transaction generated on the driver channel: Hit packet #37: amplitude = 1, hit pixel = yes, triggered = yes
At 937500 ps (BX-cycle 37): Transaction generated on the trigger channel: Hit packet #37: amplitude = 1, hit pixel = yes, triggered = yes
Objections to AUTO FINISH from env.hit_comp.Trigger monitor: new peak = 1
At 962500 ps: Trigger Monitor detected transaction: Hit packet #2: Timetag = 96250
Objections to AUTO FINISH from env.hit_comp.Readout monitor: new peak = 1
At 987500 ps: Packet Monitor detected transaction: Output packet #1: time of arrival = 8, amplitude = 6
At 987500 ps: Hit_Driver busy (DUT dead time) => cannot generate transaction: Hit packet #38: amplitude = 1, hit pixel = yes, triggered = y
env.conformity_checker comparing DUT output Output packet #49: time of arrival = 8, amplitude = 6 , expected Output packet #47: time of arrival = 8, amplitude = 6
At 987500 ps (BX-cycle 39): Transaction generated on the driver channel: Hit packet #39: amplitude = 6, hit pixel = no, triggered = no
At 987500 ps (BX-cycle 39): Transaction generated on the trigger channel: Hit packet #39: amplitude = 6, hit pixel = no, triggered = no
At 1012500 ps (BX-cycle 40): Transaction generated on the driver channel: Hit packet #40: amplitude = 0, hit pixel = no, triggered = no
At 1012500 ps (BX-cycle 40): Transaction generated on the trigger channel: Hit packet #40: amplitude = 0, hit pixel = no, triggered = no
At 1037500 ps (BX-cycle 41): Transaction generated on the driver channel: Hit packet #41: amplitude = 5, hit pixel = no, triggered = no
At 1037500 ps (BX-cycle 41): Transaction generated on the trigger channel: Hit packet #41: amplitude = 5, hit pixel = no, triggered = no
At 1062500 ps (BX-cycle 42): Transaction generated on the driver channel: Hit packet #42: amplitude = 2, hit pixel = yes, triggered = no
```

Further Developments

- On the DUT: replication of pixel regions
 - PR columns
 - Future support for L1 trigger and ROI readout

- On the verification environment:
 - Improve monitoring of lost hits
 - Add sources of uncertainty (delays, time walk, ...)
 - Standardize into UVM for more solid base classes and highly customizable reporting features