B2GM TRG parallel session

VTX Trigger Studies

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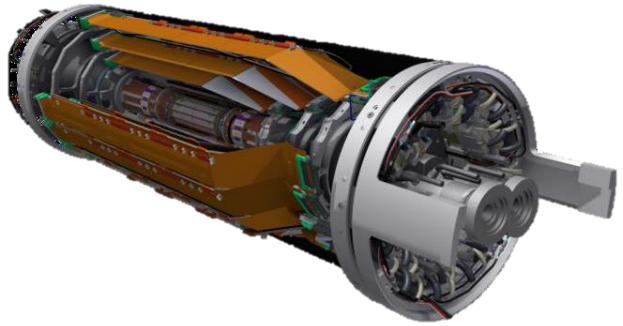
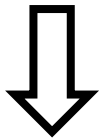
I. What is the VTX ?

- VXD replacement

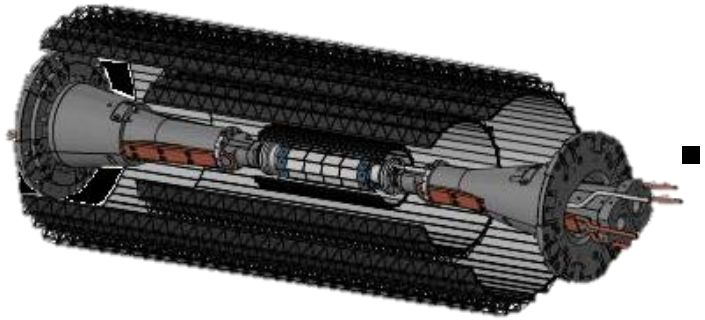
Current inner vertex detector (VXD)



- PXD : 2 Layers; pixels (DEPFET technology)
- SVD : 4 Layers; strips



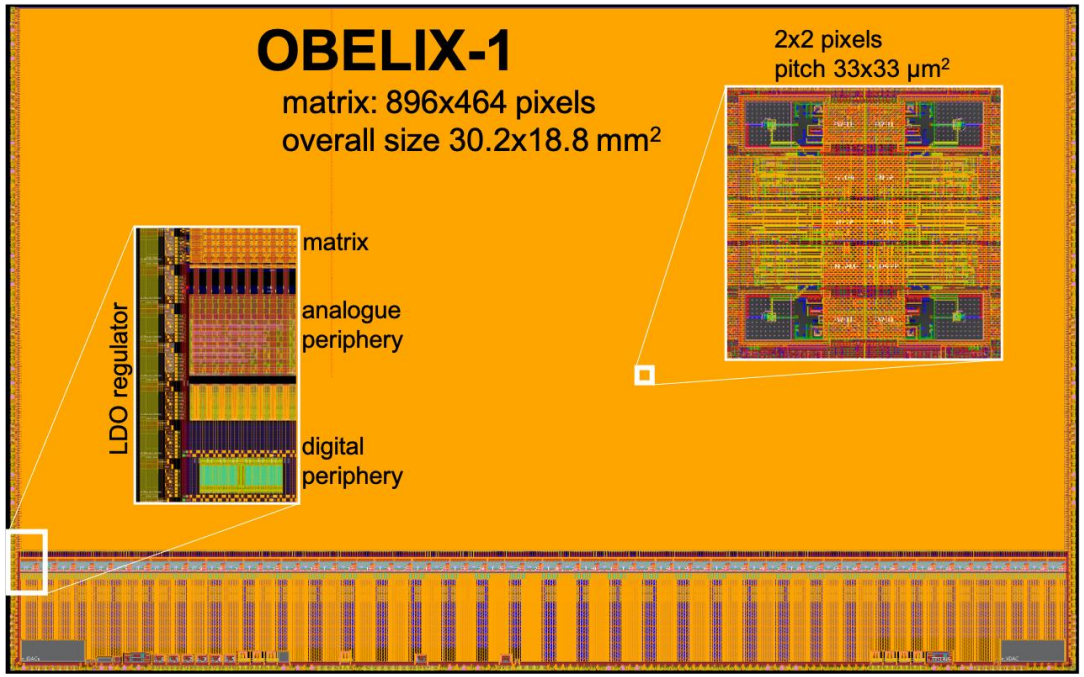
Future inner vertex detector (VTX)



- Current Geometry : 5 Layers; pixels (MAPS technology)
  - Under study: 6 Layers; pixels (same technology)

II. What is OBELIX ?

- Stands for Optimized Belle II pixel sensor
  - Unique sensor type for all VTX Layers

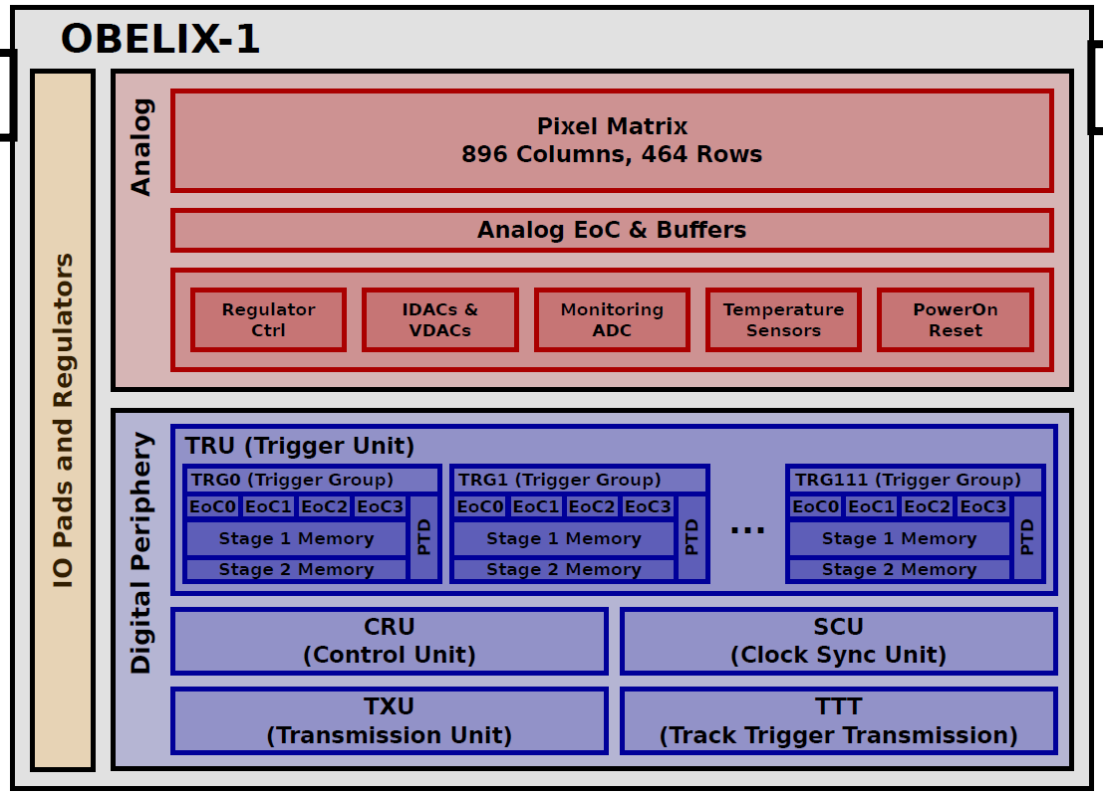


	Design
Total Area (Sensitive Area)	5.68 cm² (4.53cm²)
Pixel matrix	896 x 464
Pixel pitch	33 µm
Integration Time	50 to 100 ns
Trigger Delay	> 10 µs
Macropixel Matrix	8 x 1
Trigger Rate	30 kHz

III. What provides OBELIX?

Slow Output : TXU

Fast Output : TTT



Detailed hits information

- Triggered Output

Information : 10 bits (8b/2b)

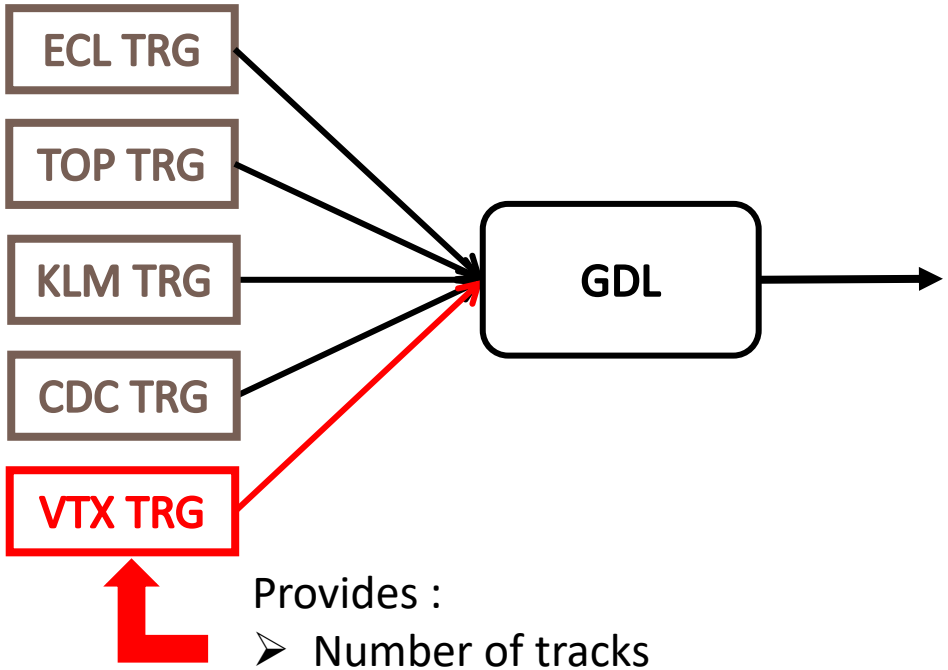
Frequency : 33.8 MHz

- Can I build the VTX TRG with this information?

IV. TRG expectations on VTX TRG

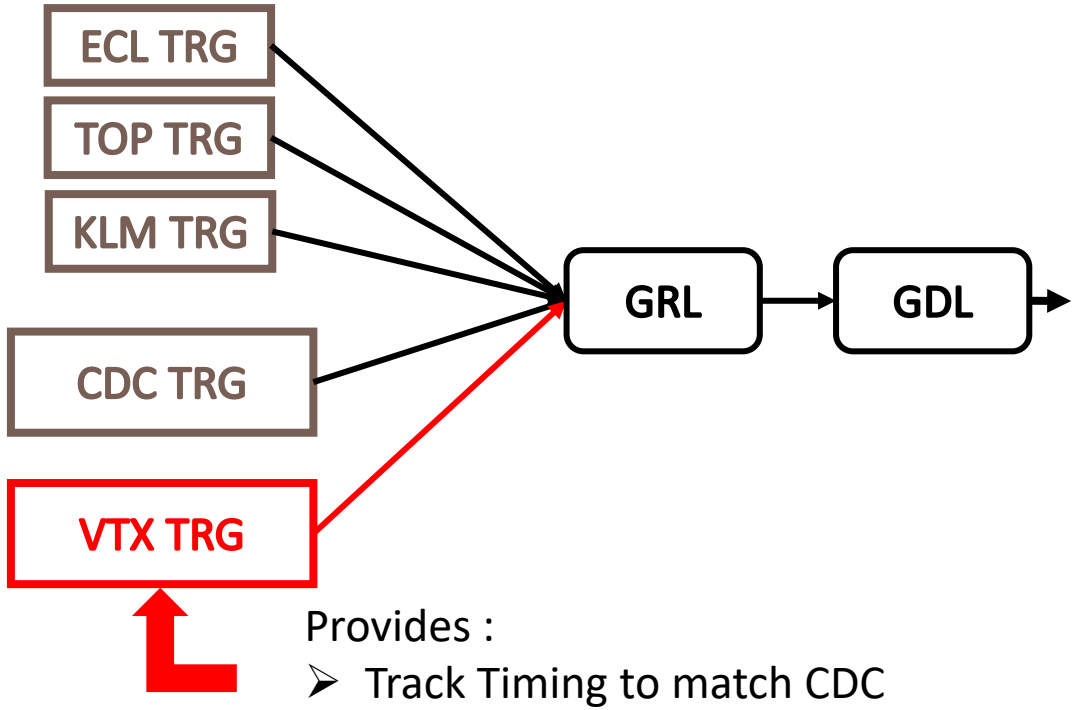
- 2 VTX TRG modes :

➢ Standalone :



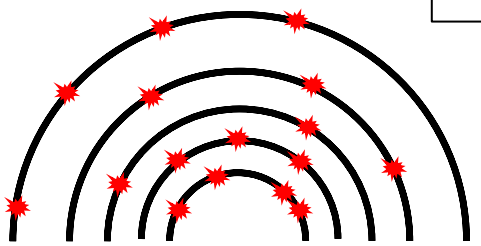
Provides :
- Number of tracks
- (θ,ϕ) and z-vertex of each track

➢ CDC TRG Matching :



Provides :
- Track Timing to match CDC
- (θ,ϕ) of each track

V. Schematic of VTX TRG



Fast output

FPGA

My work :
Fast Track
Recognition
Algorithm

Tracking Information

1. Standalone

GDL

2. CDC TRG Matching

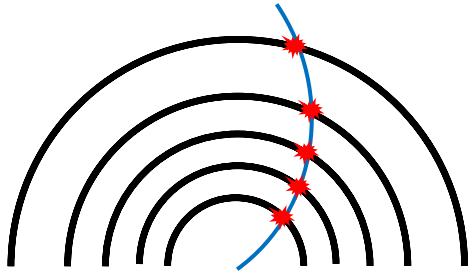
GRL → GDL

GDL Output :
Keep

TRG latency : < 30 kHz

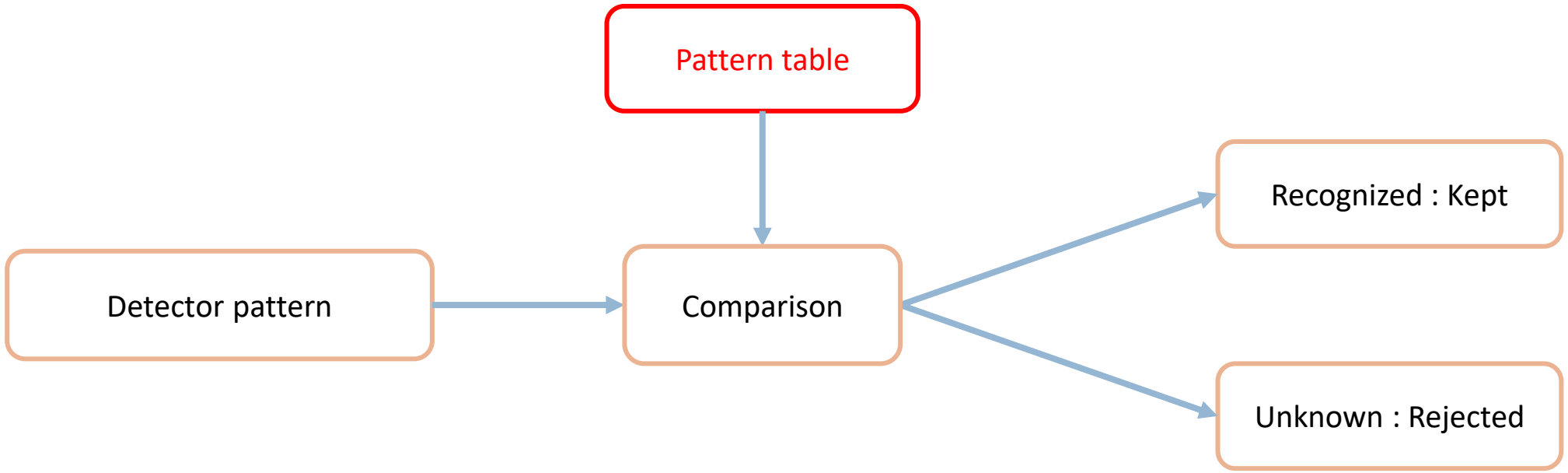
Slow output

Stored event



VI. Fast Track Recognition Algorithm : LUT

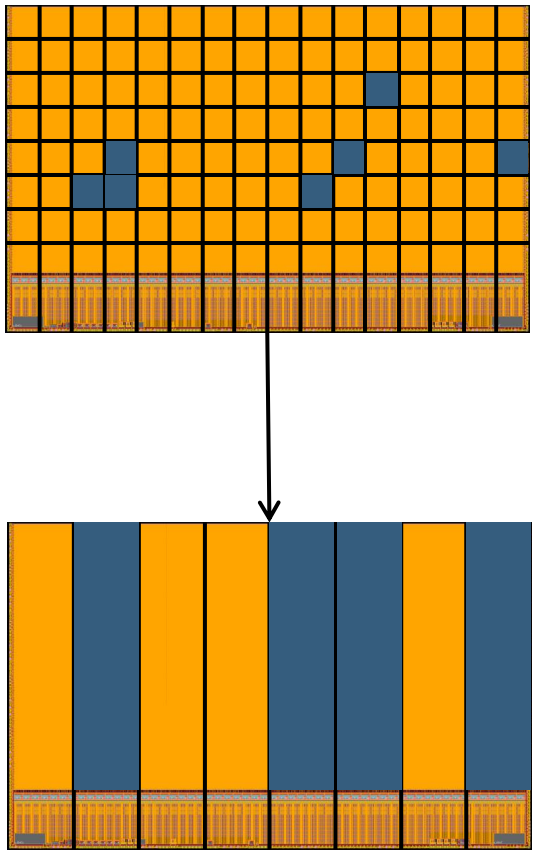
- Look-Up Table (LUT) logic:
  1. Pattern table : Stored physical track patterns from simulation
  2. Detector/Table pattern comparison : Triggered track if recognized from the table



VII. Macropixel segmentation

- A major problem:
  - 896 x 464 pixels per sensor
  - ≈ 1,000,000,000 pixels in the detector
    - An excessive number of combinations

- Solution :
  - Macropixel : reduced spatial accuracy
  - 8 x 1 Macropixels per sensor
    - ✓ Considerable reduction in the number of combinations
    - ✓ Reduction of the Pattern table size
    - Faster to search through a small table

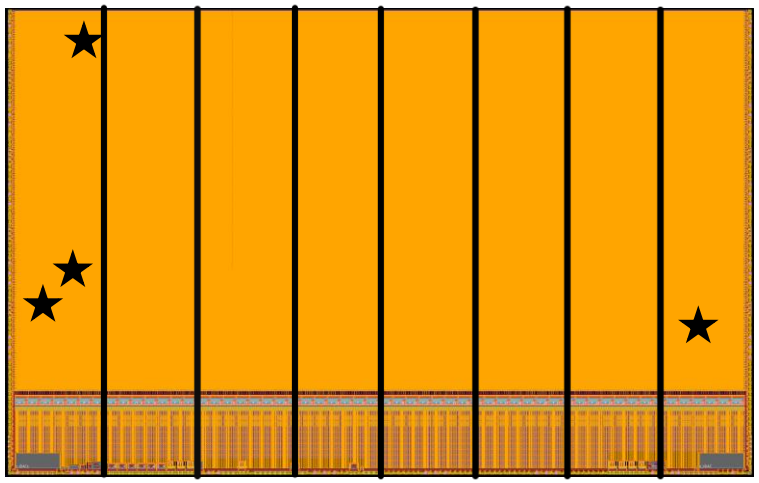


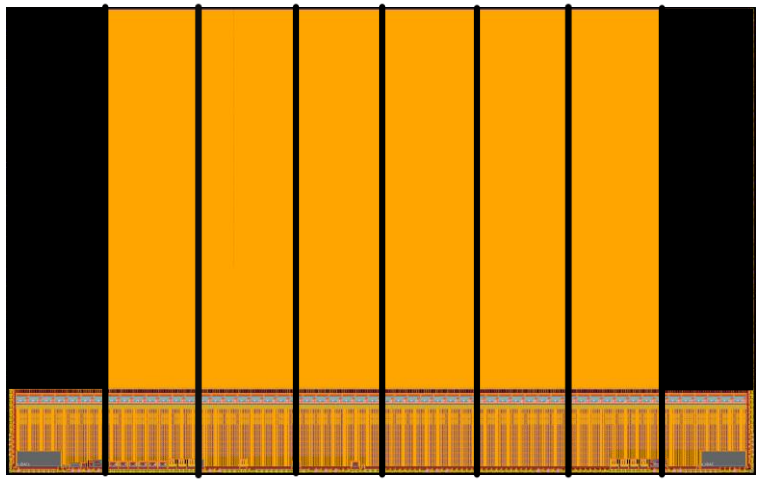
VIII.Track Trigger Transmission in practice

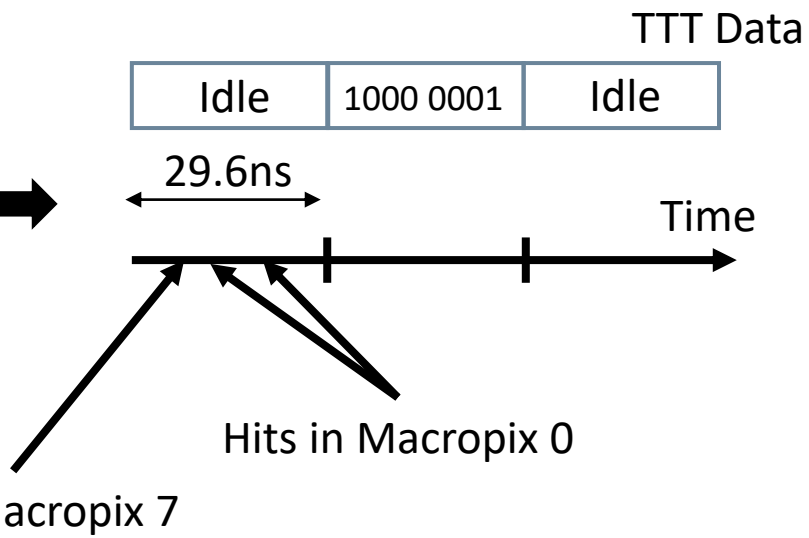
No delay

Next time bin

3 Hits in Mpx 0, 1 Hit in Mpx 7 → Mpx 0 & Mpx 7 activated → Word : 1000 0001



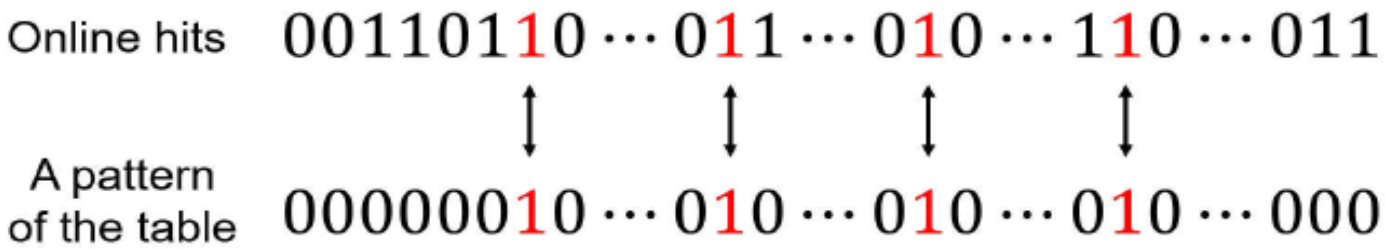




IX. What is a pattern ?

- Bitword of length ($\frac{Nbr\ of\ Mpx}{Sensor} \times Nbr\ of\ Sensor$), composed of each Sensor TTT Output
  - Current Geometry : 2552 Sensors ; Choice : 8 Mpx per Sensor ➡ **20416 MpxID**

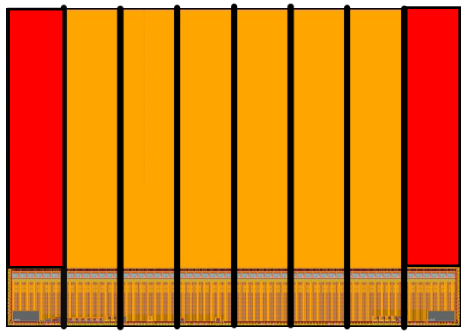
- LUT comparison :

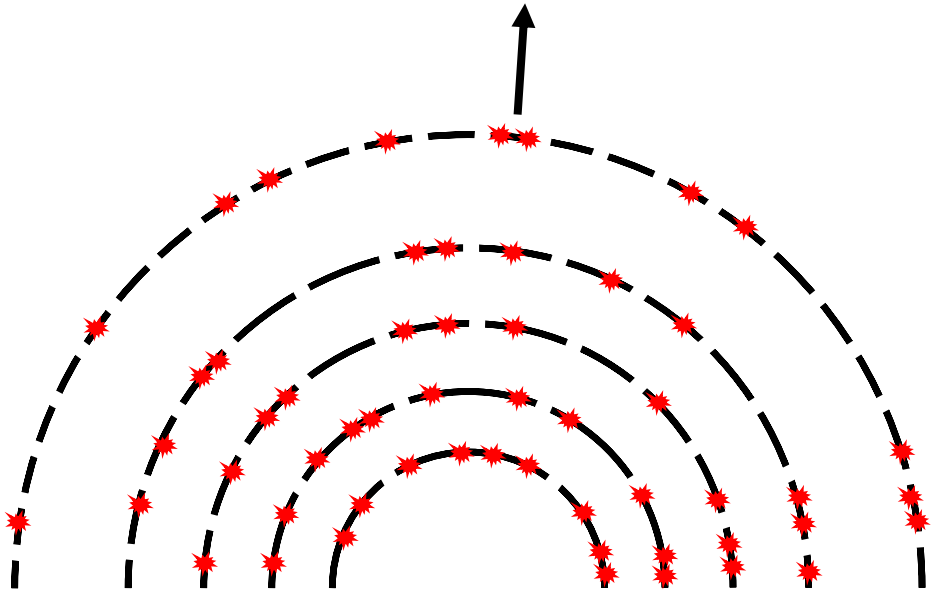


- A pattern contains only 1 hit per Layer
  - The number of hits in a pattern depends on how many layers were used to create the table
  - Exemple : Above we used 4 out of 5 Layers to create the table; thus there are 4 hits per pattern

X. VTX TRG : Recap

OBELIX n°2435





OBELIX n°2435 TTT Output

10000001

Event Bitword

0001000111001000 10….00010100

LUT Comparison

Pattern Table :

Index	Pattern	Θ (°)	Φ (°)	p_T (GeV)
1	001…010….0001	67	259	1.56
2	010…010….0001	125	23	0.89
…	……..	…	…	…
126304	100…010….0100	43	344	2.34
126305	100…010…0010	175	88	1.71

XI. How to conduct a study ?

- Prerequisite : i) VTX Geometry, ii) Number of Layers to use

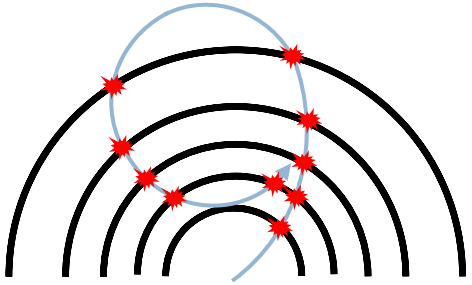
1. Create the table
2. Create the test sample
    1. Only Signal : Efficiency, Z-vertex acceptance, (θ,ϕ) precision
    2. Only BG : Fake Trigger Rate
    3. Signal + Overlay BG : More realistic case to mesure all features
3. Analyse the LUT Output to access all features

XII. The table creation

- Currently :
  - $\mu^{\pm}$ Particle Gun with following characteristics

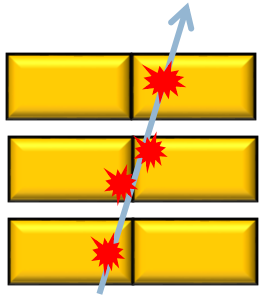
Table event characteristics	
Production point	$(x = 0, y = 0, z = 0)$
Range of momentum	$0.2 \leq p \leq 3.0$
Range of θ angle	$17° \leq \theta \leq 150°$
Range of φ angle	$0° \leq \varphi \leq 360°$

- Not so simple ; take into account :
  - ➢ Reentering particles:



Suppressed from the table

  - ➢ Charge deposition :



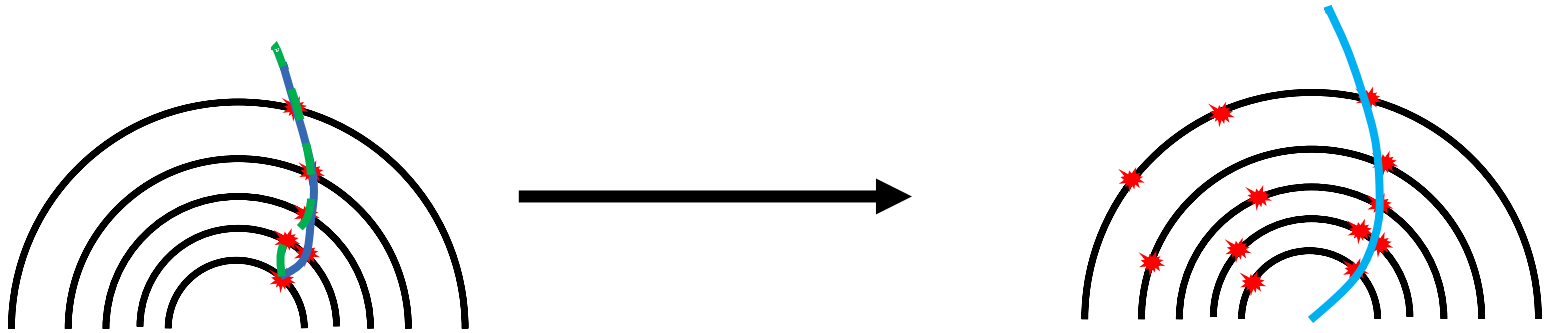
We register 2 patterns out of the cluster

XII. The table creation

- Charge deposition issue : consider the clusters
  - Registering all the patterns out of a cluster is an imperfect temporarily solution

- In an event, if the same cluster occurs, the LUT will have recognized N different tracks from the same particle

2 Patterns stored in the table



Only 1 particle but will be counted as 2 tracks

➢ Need for a Clusterizer to get rid of this issue, maybe after the pattern matching

XIII.1st Study case (March-June)

VTX Geo : 5 Layers, Layers used for LUT : L3, L4 and L5

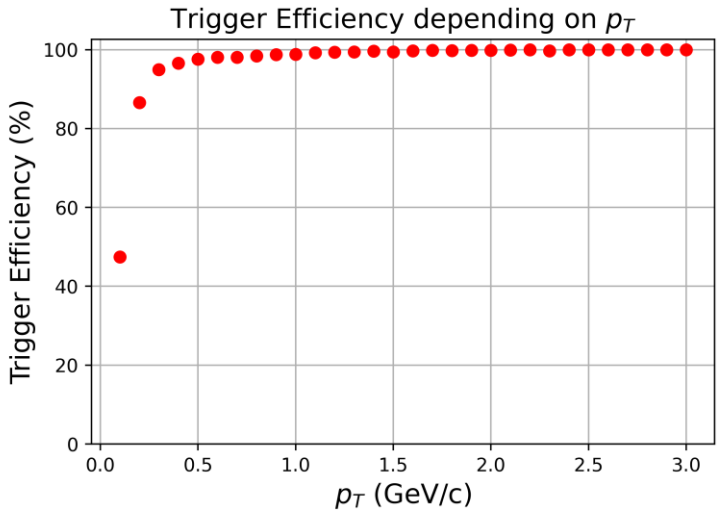
1. Table generation
   - 10^6 particles => With 3 Layers, 80k unique patterns
2. Test samples (Single track events) :
   1. Efficiency : 10^5 $\mu^{\pm}$ with same characteristics as table
   2. Z-vertex Acceptance : 10^5 $\mu^{\pm}$ with $z \in [-10,10]$ cm
3. Figure of Merits
   - Global efficiency : $\frac{Nbr\ patterns\ recognized}{Nbr\ patterns\ simulated}$ > **95 %**
   - Z-vertex Acceptance : |z| < **5 cm**

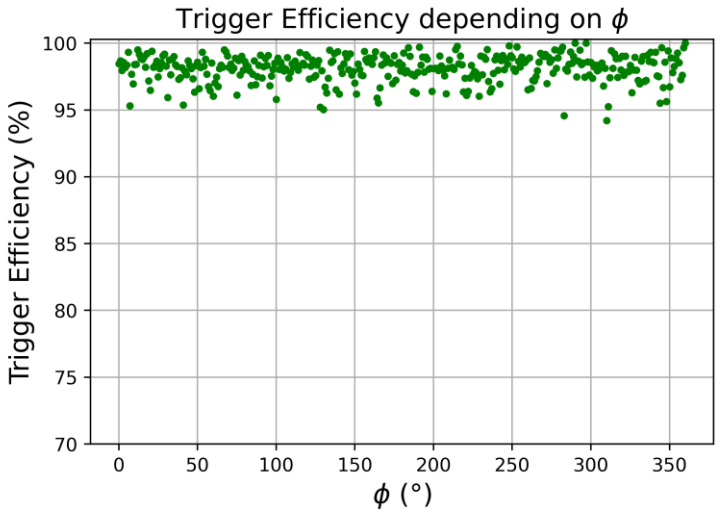
XIV. 1st Study case Results

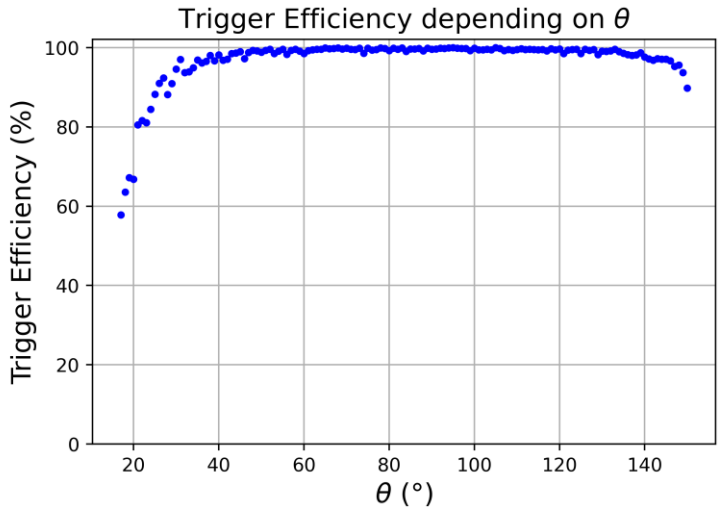
- Efficiency Test Sample : 10^5 $\mu^{\pm}$, identical to table event characteristics

Average efficiency = 98.14 ± 0.03 %

- Trigger Efficiency with respect to :
  - ➢ Transverse Momentum
  - ➢ Angle ϕ
  - ➢ Angle θ



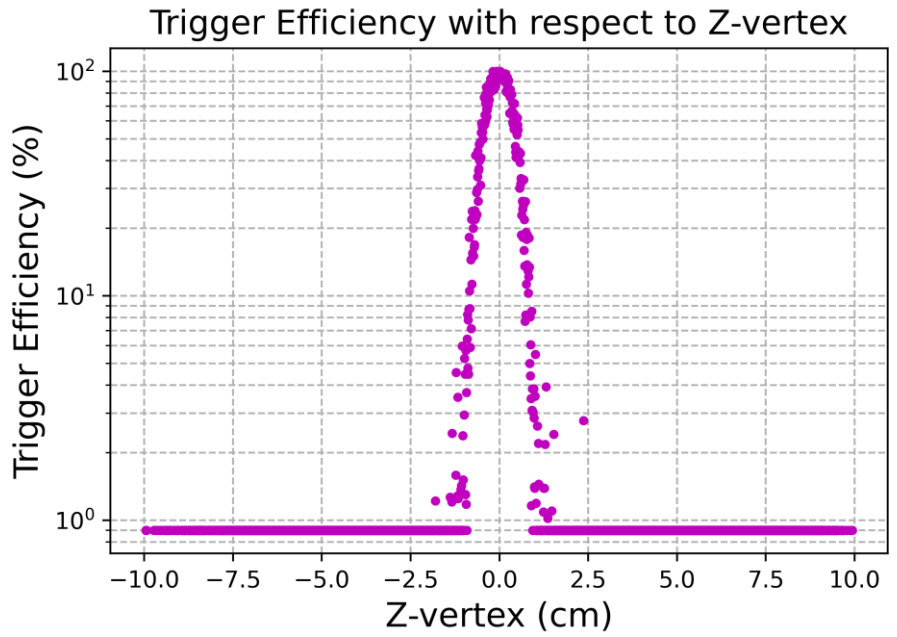




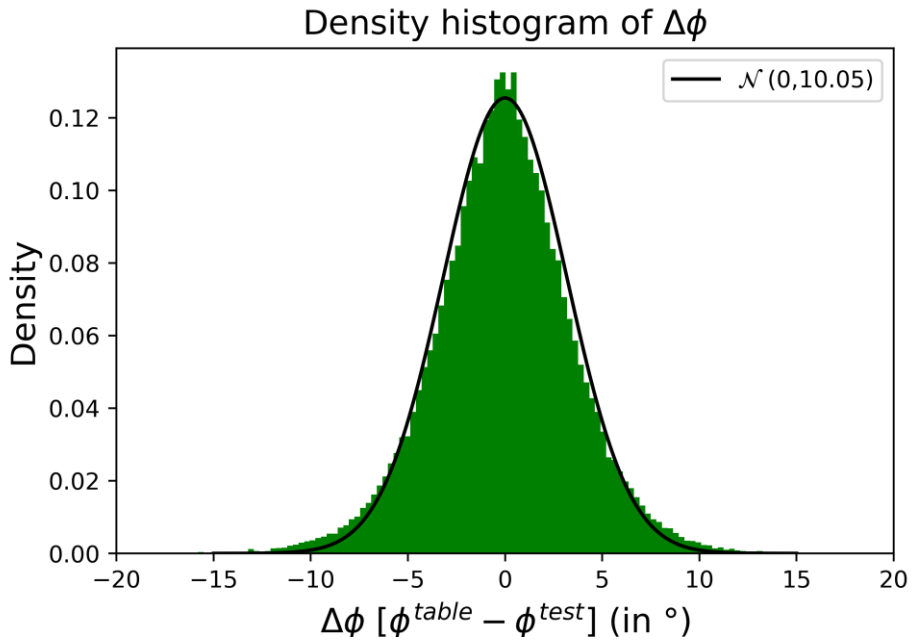
XIV. 1st Study case Results

- Acceptance test sample : 10^5 $\mu^{\pm}$, with $z \in [-10,10]\ cm$
- Accuracy test sample : 10^5 $\mu^{\pm}$, identical to table event characteristics

Z-vertex Acceptance : |z| < 2.5 cm



ϕ Accuracy : Gaussian σ = 3.17°



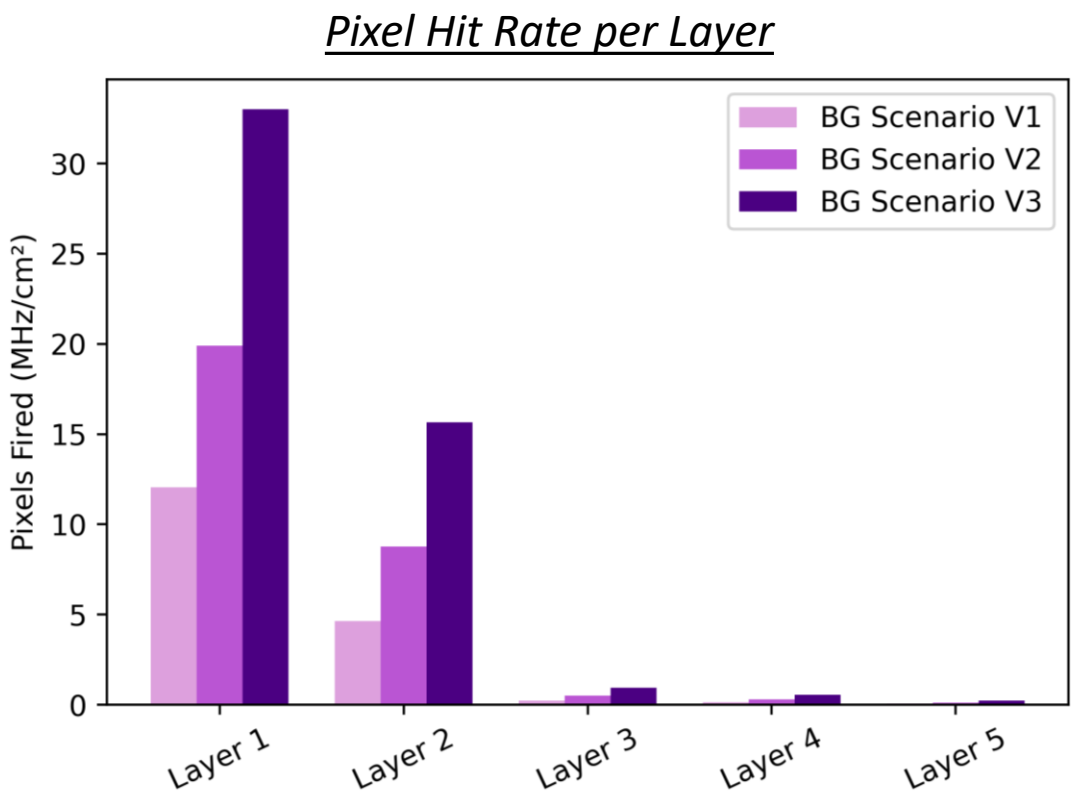
XV. 2nd Study case (July-August)

VTX Geo : 5 Layers, Layers used for LUT : 3 outers, 4 outers, All Layers

1. Table generation
   - Reused from 1st Study case
2. Test sample :
   1. Fake Trigger Rate : 10^6 events; 1 event = 100 ns, V1/V2/V3 BG Scenarios
3. Figure of Merits
   - Fake Trigger Rate : <30kHz

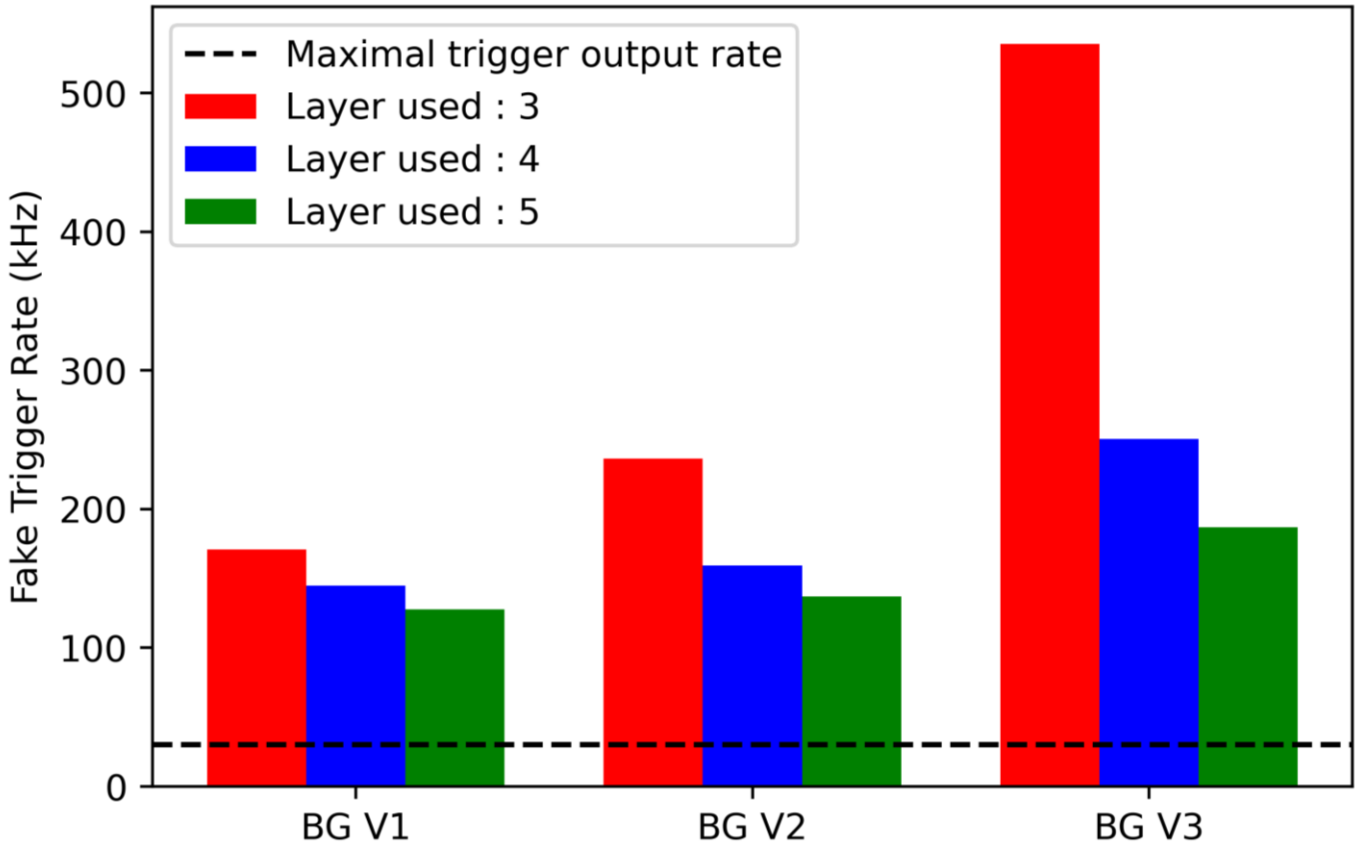
XVI.Background Scenarios

- 3 BG Scenarios considered at $\mathcal{L} = 6.0 \times 10^{35}\ cm^{-2}s^{-1}$ in CDR :
  - V1/V2/V3 : Optimistic/ Intermediate/ Conservative

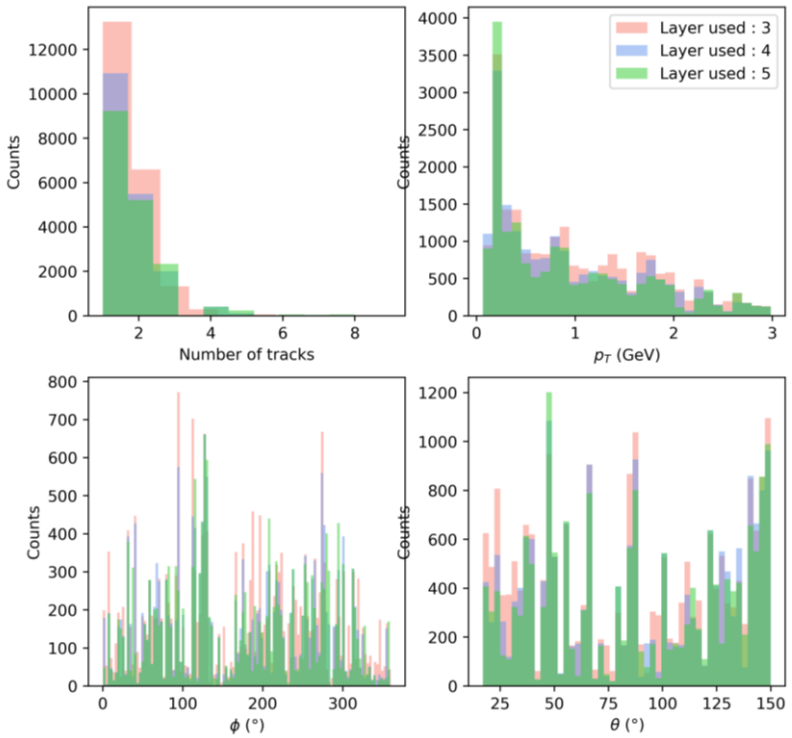


XVII. 2nd Study case : Initial Results

- Initial Fake Trigger Rate

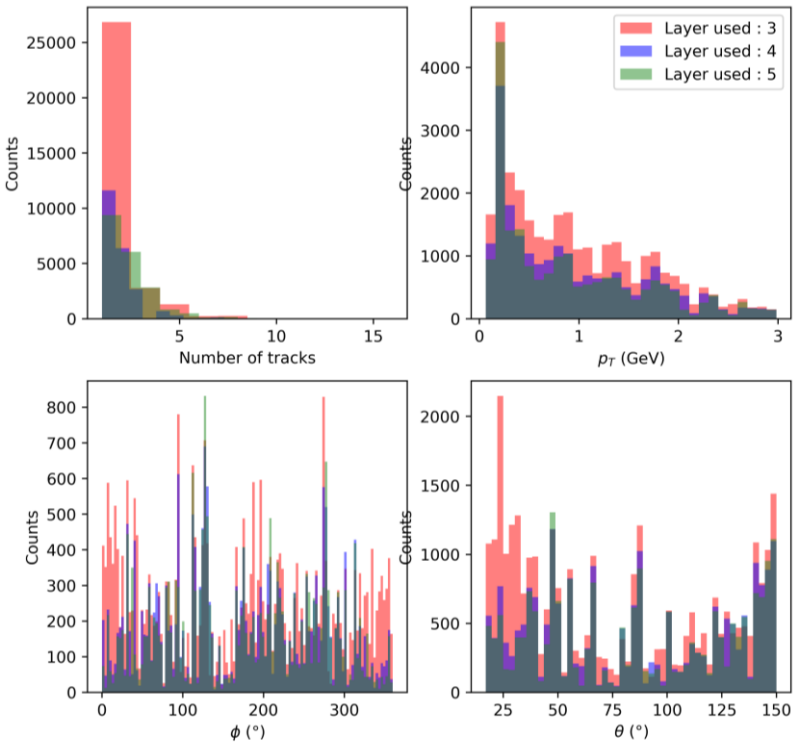


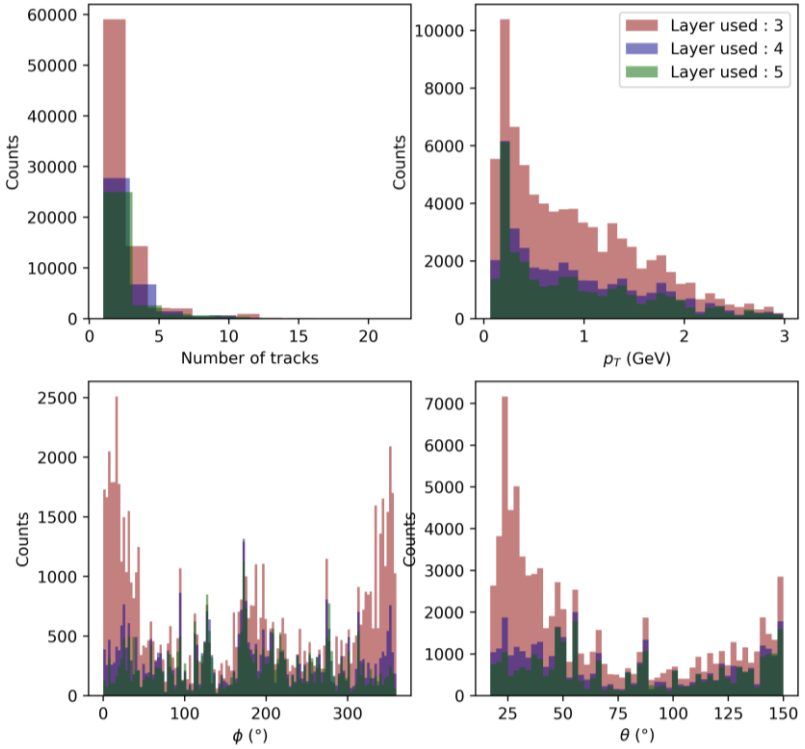
XVII. 2nd Study case Initial Distributions



BG V1 Distributions

BG V2 Distributions

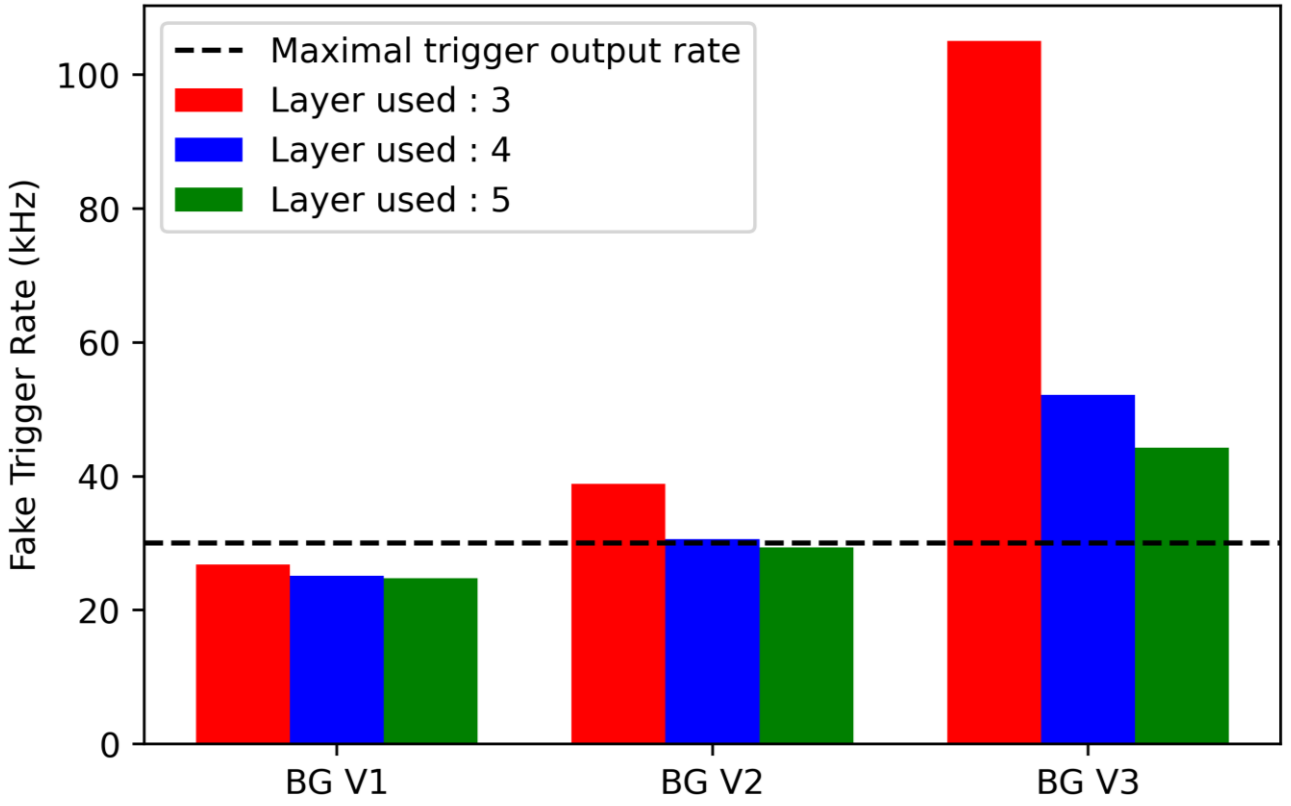




BG V3 Distributions

XVII. 2nd Study case Test Cut Results

- Cut : « Number of Track > 2 & p_T > 1 »



XVIII. Conclusion

- Encouraging results that need to be consolidated :
  - Clean the 1st Study case
  - Improve the BG Analysis Code
    - Better understanding for more precise cuts
  - (Clusterizer development)

- What's next ?
  - Begin PhD physics analysis
    - Less work on VTXTRG (but still during the TRG Expert Shift)
  - Conduct same studies with other geometries and Mpx Segmentations