Cluster Width Approach for Tracker L1 triggering at sLHC

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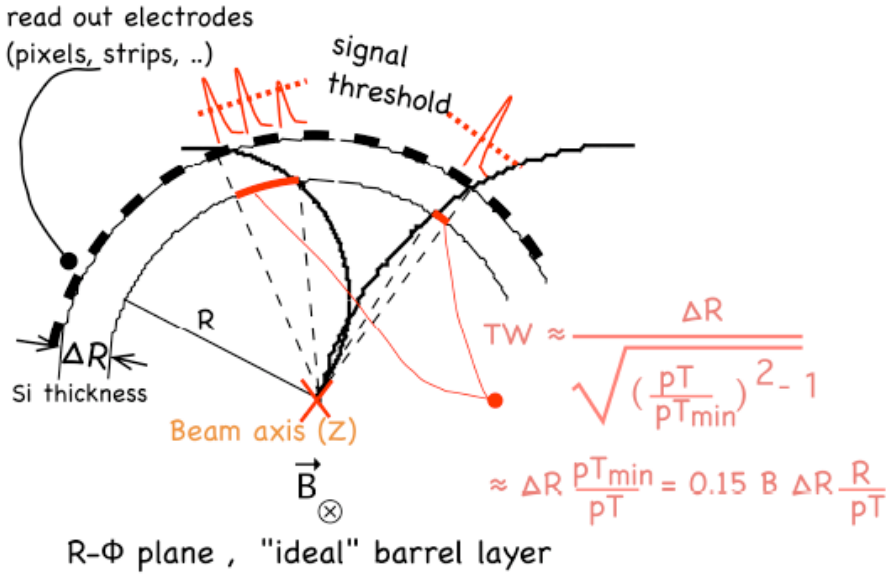
First principle of Cluster Width approach



G. Parrini

Select clusters associated to higher Pt
tracks by rejecting ones with larger width

Cluster Width (#strips) ~ (Sensor Thickness/Strip Pitch) x Layer Radius / Pt

Goal of the study and layouts

- Establish performance
  - low Pt rejection versus high Pt efficiency as a function of
    - Layout parameters (Thickness, Pitch, Radius)
    - Selection parameters (Clustering Thresholds, Cluster Width Cut)
- Study on 4 RΦ Outer Barrel Layers
  - Based on SLHC Strawman A Hybrid
  - R = 50, 70, 90, 110 cm
  - No Lorentz angle compensation

Parameters of the simulated layers :

	Layer 1			Layer 2			Layer 3			Layer 4		
Sensor thickness T (μm)	500	320		500	320		500	320		500	320	
APV #/module	4	8	12	4	8	12	6	8	6	6	8	6
Strip #/module	512	1024	1536	512	1024	1536	768	1024	768	768	1024	768
Strip length (cm)	4.65			4.65			4.65			4.65		
Strip Pitch P (μm)	180	90	60	180	90	60	120	90	120	120	90	120
T/P	**2,78**	**3.56**	**5.33**	**2,78**	**3.56**	**5.33**	**4.17**	**3.56**	**2.67**	**4.17**	**3.56**	**2.67**

Full Simulation using CMSSW_2_2_6 for sLHC

- Implementation of new layouts
  - Tobmodpar.xml (thickness) and trackerstructuretopology.xml (APV#)
  - Update sistripdetinfo.dat using parser tool
  - Some modifications for DB access for >6 APVs (noise…), clustering from simulated digis to avoid cabling map
- Detector simulation parameters
  - Noise, Cross Talk, LA from current Tracker conditions used for all layouts
- Cluster thresholds
  - One single threshold applied to all strips
    - Simplest implementation in a FE chip

Strategy to optimize the layer configurations and the parameters (Thresholds and Cluster Width)

- Compute the cluster finding efficiency vs Pt as a function of thresholds and Cluster widths in each layer for muons
- Compute the cluster occupancies, rejections, rate per APV and layers for all layer configurations and all thresholds for MinBias events (x 400 Pile-Up, 20MHz LHC clock)
- Choose optimised layer configurations and thresholds for a given track cluster efficiency at high Pt and given mean cluster rate per APV

Results with simulation of single muons

Cluster selection efficiency study vs Pt
according to layer and selection parameters

- Generated events :
  - $\eta<1$ (TOB only)
  - Flat Pt from 0.1 to 15 GeV/c
  - 400k Tracks generated per layer configuration
- Different sets of signal thresholds : 2, 2.5, 3, 4, 5, 6 x noise standard deviation

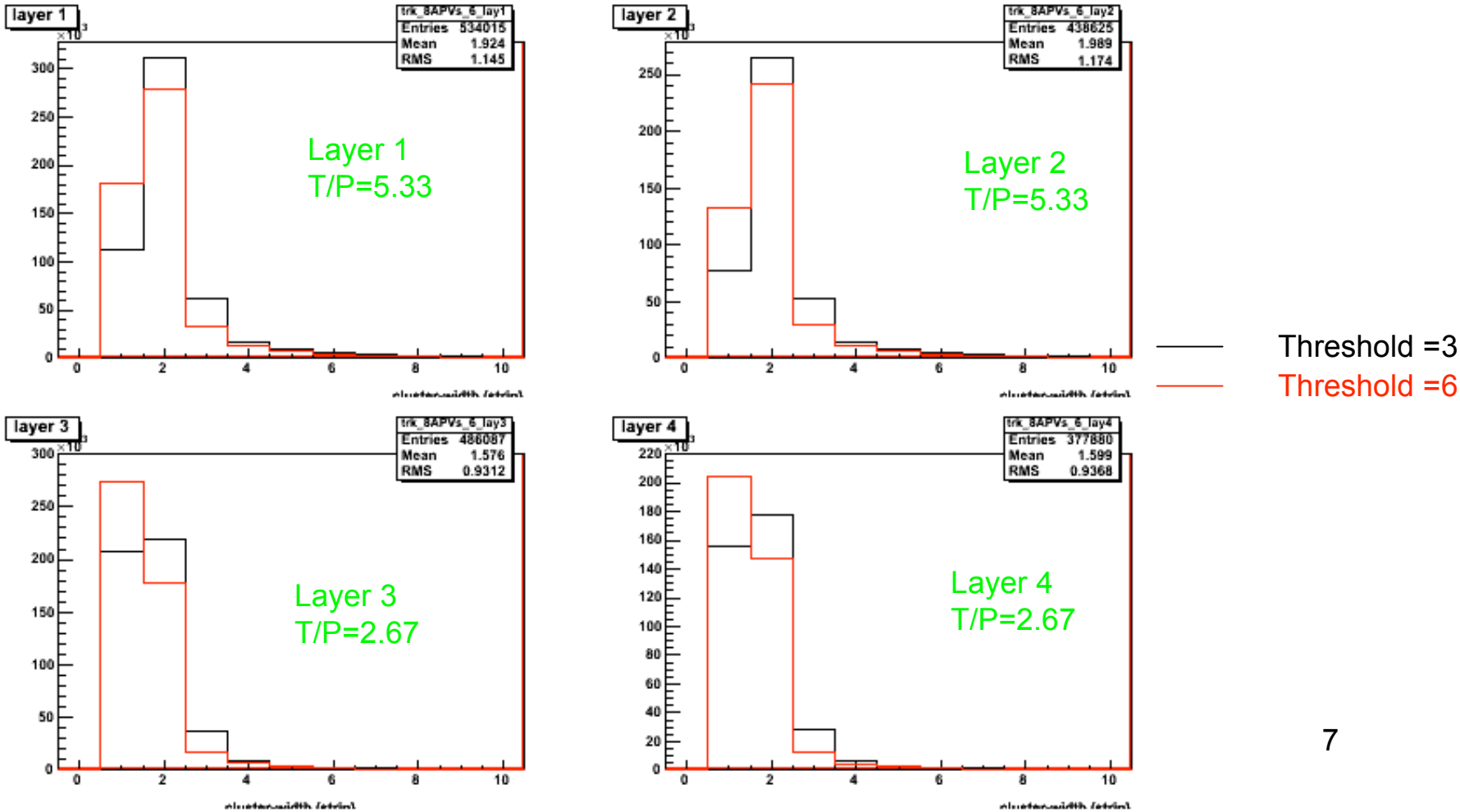
- 3 CW cuts at 1, 2, 3

Cluster Width distribution

CW essentially below 4.

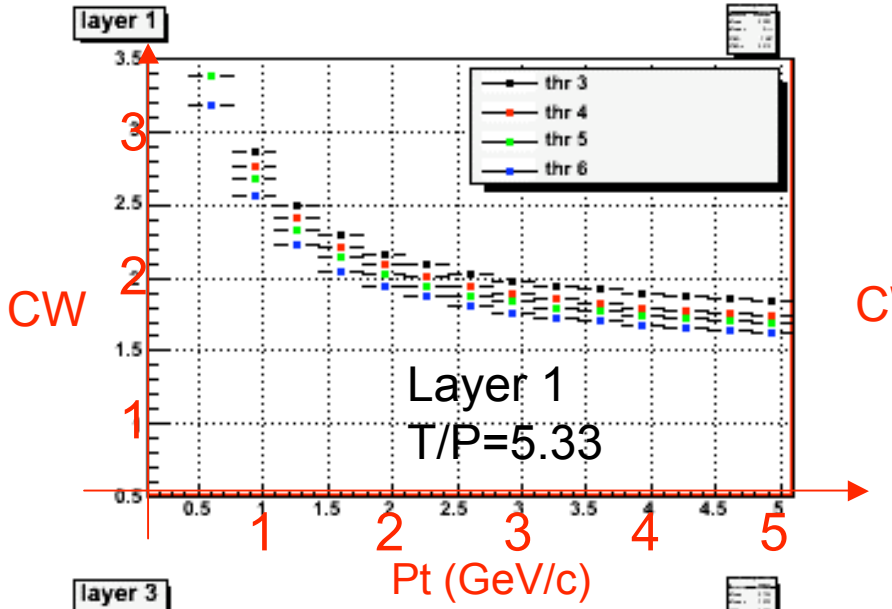
Proportion of 1, 2, 3 change differently with signal threshold for different layers.

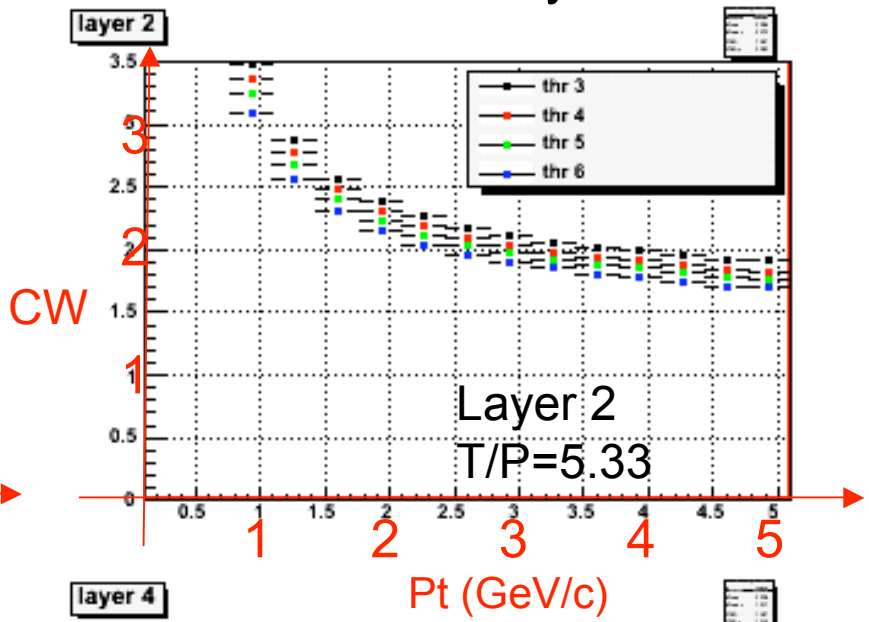
Optimised signal thresholds and cluster width cut could vary from layer to layer

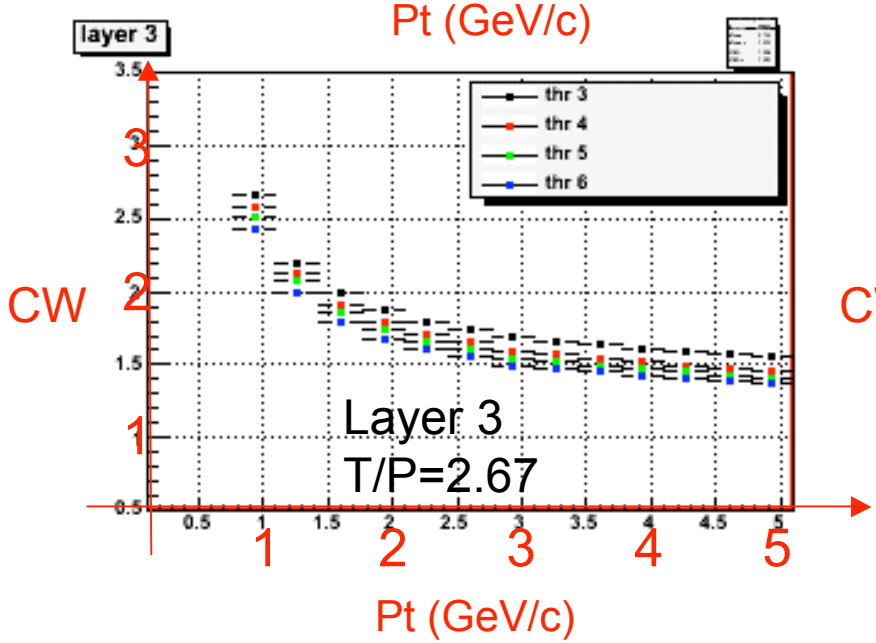


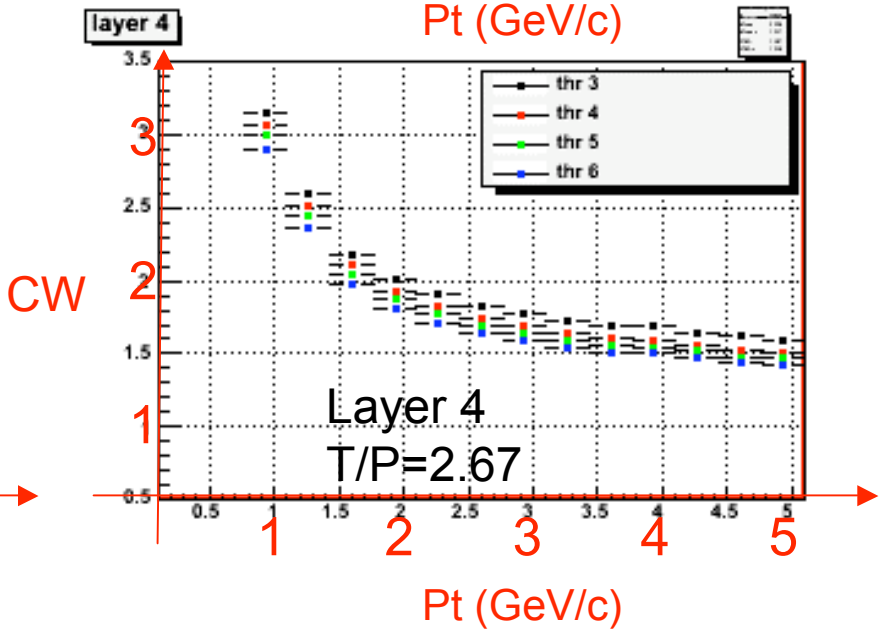
Cluster Width Profile Vs Pt

Gives an indication of the cluster width cut value,
Thresholds need to be fine-tuned for each layer

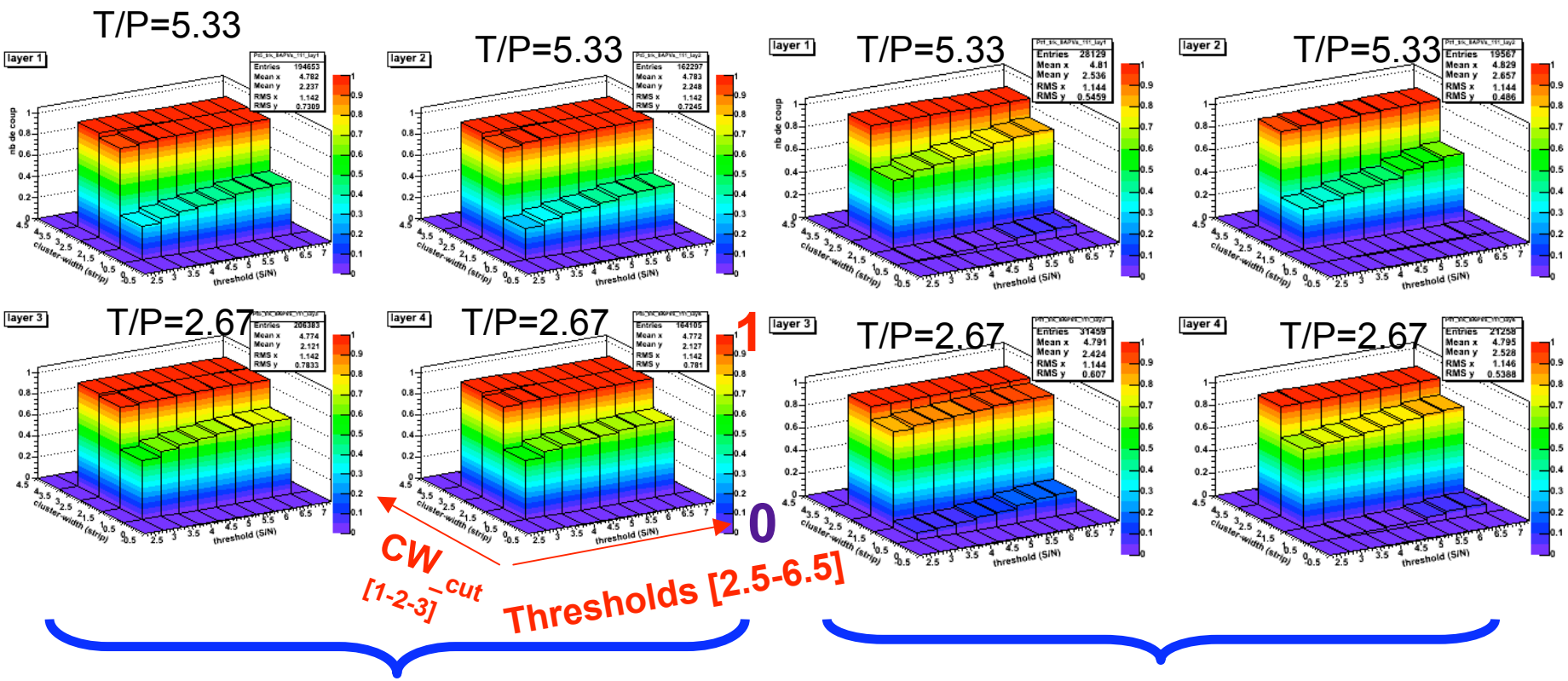








Cluster Selection Efficiency



Nclusters (Strips S/N>threshold &CW<cut) / N Simulated hits

Pt>10GeV/c

Low rejection : CW_{cut} = 3, 2

Pt<2GeV/c

Rejection : CW_{cut}=1,2

Cluster selection optimised rejecting clusters with more than 2 strips
apply to all currently simulated layer configurations at all radii

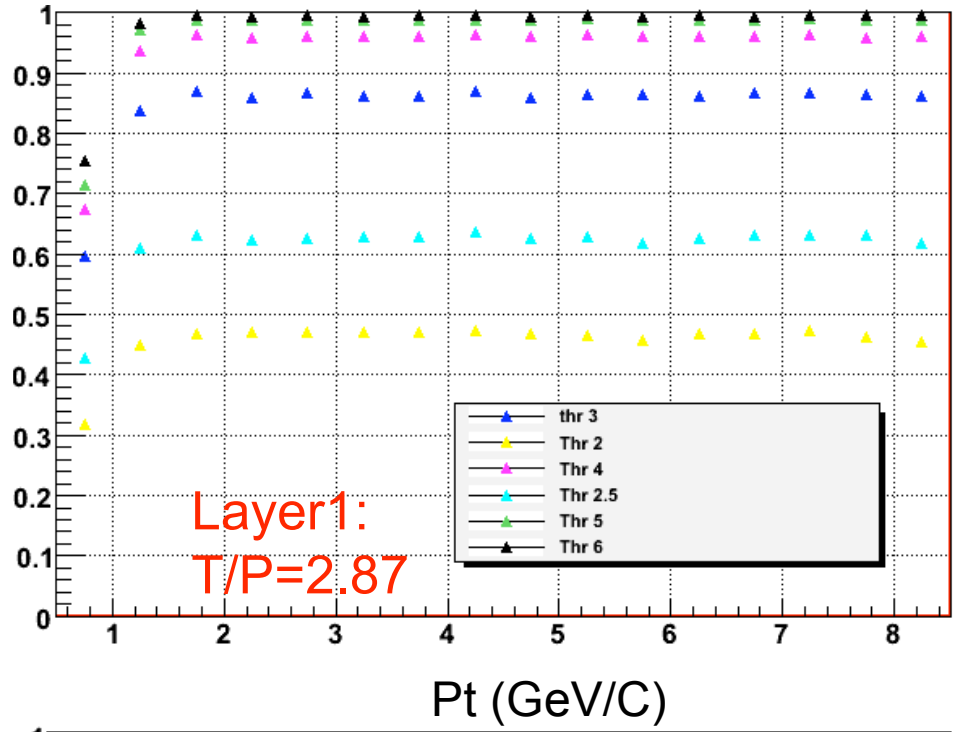
Cluster selection efficiency as a function of Pt

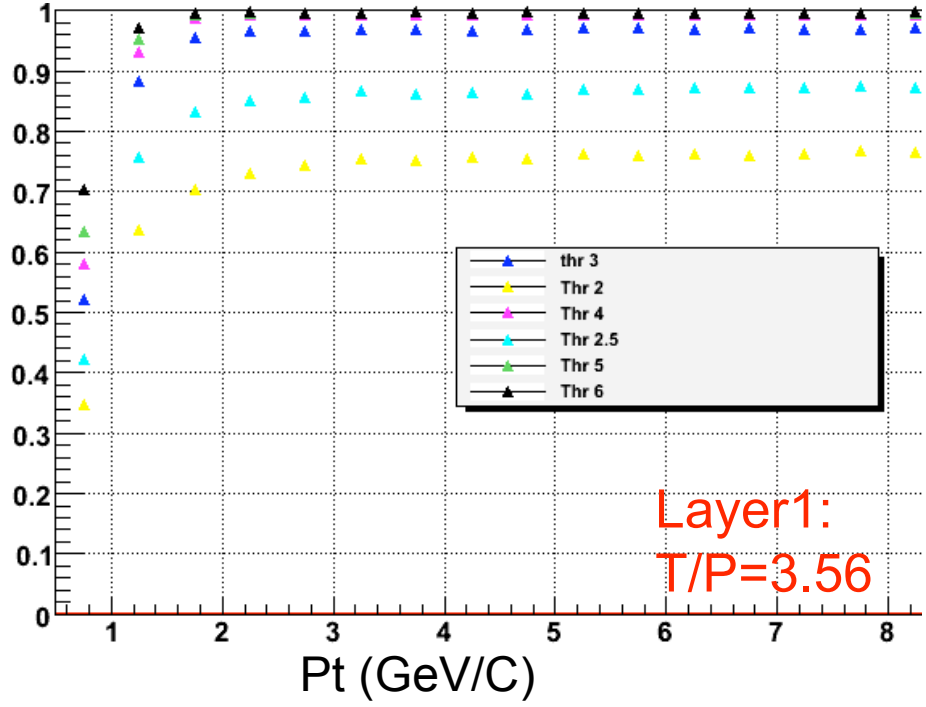
Cluster width <=2 strips

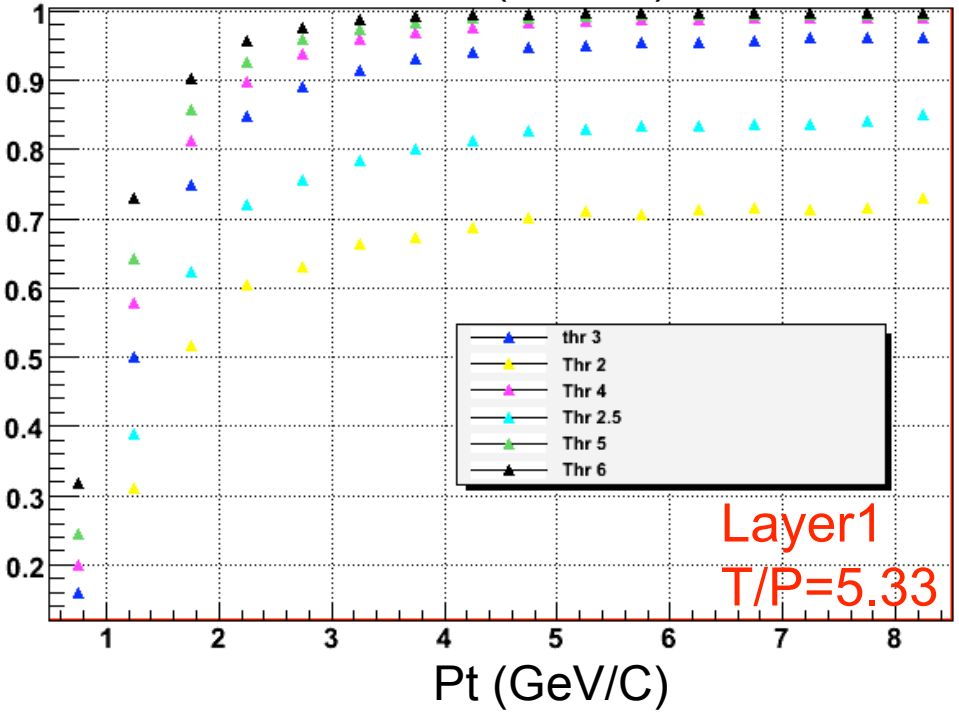
Different set of thresholds applied (from 2 to 6)

Rejection of clusters associated to low Pt tracks strongly depends on layer parameters

Signal threshold can be tuned per layer to optimise low Pt rejection versus high Pt efficiency





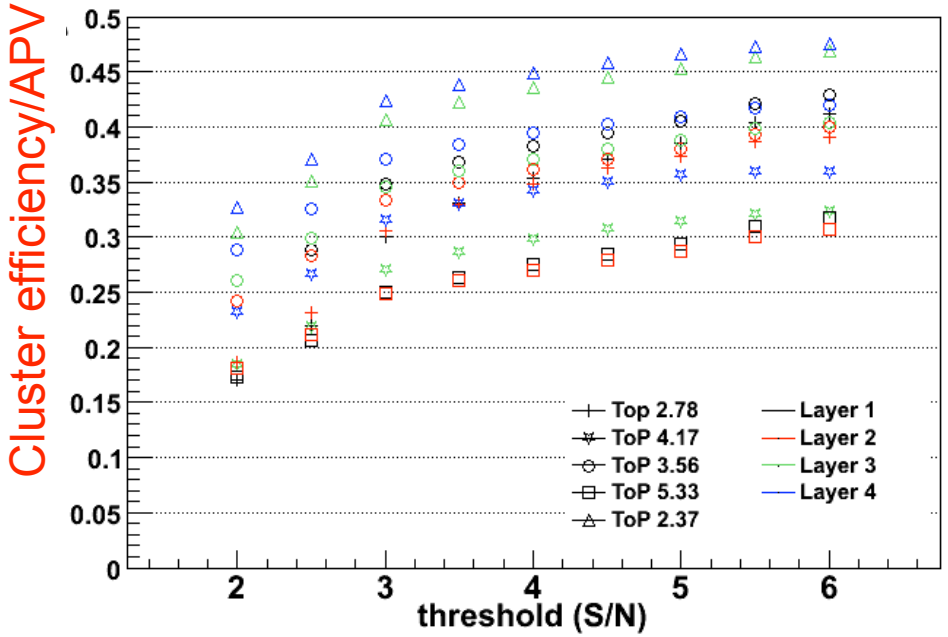


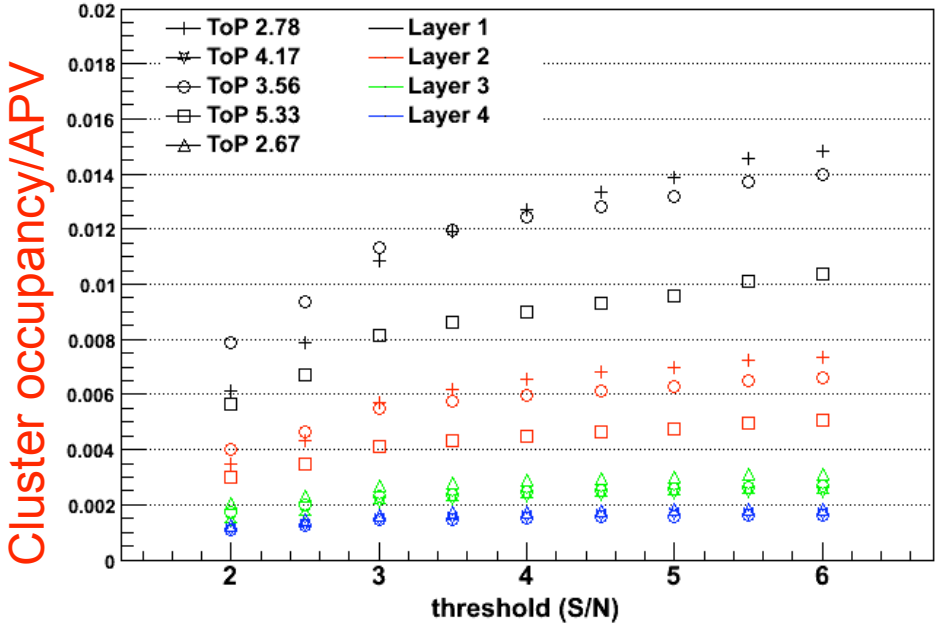
Results with simulation of Minimum Bias events

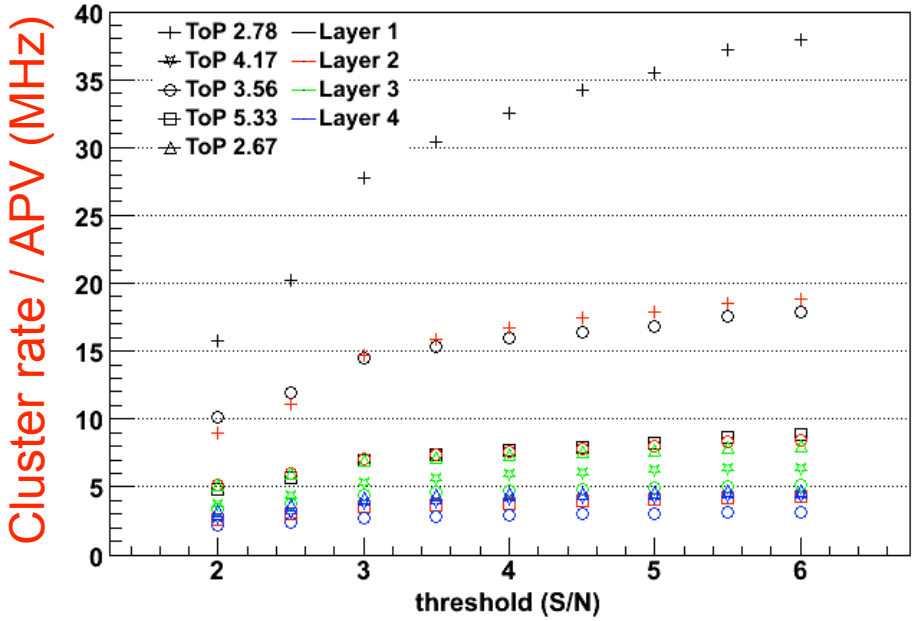
To estimate collisions cluster rates

- Generated events :
  - Full η coverage
  - 400k events per layer configuration
  - Noise generated on all channels
- Same layer configurations as before
  - Signal threshold as for muons = {2,2.5,3,4,5,6} x noise standard deviation
  - **Cluster Width cuts at 2**
- Results
  - Integrated cluster occupancies, efficiencies and rate
  - Cluster rate x 400 to account for Pile-Up @ 20MHz

MinBias: Cluster efficiency, Occupancy and Rate per APV vs thresholds @ 20MHz







Strong dependence on layer parameters

Reasonnable range

Choice of few Optimised Configurations (1)

4 layers in trigger (L1/L2/L3/L4)

« high number of clusters / intermediate rejection »

Select layers with 99% of tracks efficiency at high Pt with >=3 hits out of 4 layers
and a cluster rate ~ 3.5 MHz per APV
⇒ 96% efficiency per layer with muons at Pt>5GeV/c

Layer #	1	2	3	4	Total
Sensor Thickness T (µm)	350	350	350	350	
APV #/module	**12**	**12**	**8**	**8**	
Strip #/module	1512	1512	1024	1024	
Strip length (cm)	4.65	4.65	4.65	4.65	
Strip Pitch P (µm)	60	60	90	90	
T/P	**5.33**	**5.33**	**3.56**	**3.56**	
Total # Strips	**1.587.600**	**1.814.400**	**1.689.600**	**1.894.400**	**6.896.000**
CW (strips)	**<=2**	**<=2**	**<=2**	**<=2**	
Strip threshold	**3**	**3**	**3**	**3**	
Integrated rejection	**0.25**	**0.25**	**0.35**	**0.37**	
Occupancy/APV (.10-3)	**0.23**	**0.12**	**0.21**	**0.13**	
ClusterRate /APV (MHz)	**6.95**	**3.51**	**4.39**	**2.75**	
ClusterRate/Layer (GHz)	**87.5**	**50.6**	**58.0**	**40.7**	

Layer 1:
3.5 MHz
not reachable

#Strips x2 ?

Choice of few Optimised Configurations (2)

4 layers in trigger (L1/L2/L3/L4)

« high number of clusters / low rejection »

Select layers with 99% of tracks efficiency at high Pt with >=3 hits out of 4 layers
and a cluster rate ~ 7. MHz per APV
⇒ 96% efficiency per layer with muons at Pt>5GeV/c

Layer #	1	2	3	4	Total
Sensor Thickness T (µm)	350	350	350	350	
APV #/module	**12**	**8**	**6**	**6**	
Strip #/module	1512	1024	768	768	
Strip length (cm)	4.65	4.65	4.65	4.65	
Strip Pitch P (µm)	60	90	120	120	
T/P	**5.33**	**3.56**	**2.67**	**2.67**	
Total # Strips	**1.587.600**	**1.228.800**	**1.267.200**	**1.420.800**	**5.504.400**
CW (strips)	**<=2**	**<=2**	**<=2**	**<=2**	
Strip threshold	**3**	**3**	**3**	**3**	
Cluster Efficiency	**0.25**	**0.33**	**0.41**	**0.42**	
Occupancy/APV (.10-3)	**0.23**	**0.34**	**0.45**	**0.27**	
ClusterRate /APV (MHz)	**6.95**	**7.04**	**6.91**	**4.2**	
ClusterRate/Layer (GHz)	**87.5**	**67.6**	**68.4**	**46.6**	

Choice of few Optimised Configurations (3)

4 layers in trigger (L1/L2/L3/L4)

« Low number of cluster / high rejection »

Select layers with 99% of track efficiency at high Pt with >=2 hits out of 4 layers

⇒ 85% efficiency per layer with muons at Pt>5GeV/c

Layer #	1	2	3	4	Total
Sensor Thickness T (µm)	350	350	350	350	
APV #/module	**12**	**12**	**8**	**8**	
Strip #/module	1512	1512	1024	1024	
Strip length (cm)	4.65	4.65	4.65	4.65	
Strip Pitch P (µm)	60	60	90	90	
T/P	**5.33**	**5.33**	**3.56**	**3.56**	
Total # Strips	**1.587.600**	**1.814.400**	**1.689.600**	**1.894.400**	**6.896.000**
CW (strips)	**<=2**	**<=2**	**<=2**	**<=2**	
Strip threshold	**2.7**	**2.7**	**2.5**	**2.5**	
Cluster Efficiency	**0.23**	**0.23**	**0.3**	**0.35**	
Occupancy/APV (.10-3)	**0.20**	**0.11**	**0.19**	**0.12**	
ClusterRate /APV (MHz)	**6.19**	**3.21**	**3.79**	**2.41**	
ClusterRate/Layer (GHz)	**77.9**	**46.3**	**50.0**	**35.7**	

Choice of few Optimised Configurations (4)

3 layers in trigger (L2/L3/L4)

« high number of clusters / low rejection »

Select layers with ~100% of track efficiency at high Pt with >=2 hits out of 3 layers (88.8% tracks with 3 hits, 11% with 2 hits) and a Cluster Rate per APV ~ 7MHz

⇒ 85% efficiency per layer with muons at Pt>5GeV/c

Layer #	2	3	4	Total
Sensor Thickness T (µm)	350	350	350	
APV #/module	**8**	**6**	**6**	
Strip #/module	1024	768	768	
Strip length (cm)	4.65	4.65	4.65	
Strip Pitch P (µm)	90	120	120	
T/P	**3.56**	**2.67**	**2.67**	
Total # Strips	**1.228.800**	**1.267.200**	**1.420.800**	**3.916.800**
CW (strips)	**<=2**	**<=2**	**<=2**	
Strip threshold	**3**	**3**	**3**	
Cluster Efficiency	**0.33**	**0.41**	**0.42**	
Occupancy/APV (.10-3)	**0.34**	**0.45**	**0.27**	
ClusterRate /APV (MHz)	**7.04**	**6.91**	**4.2**	
ClusterRate/Layer (GHz)	**67.6**	**68.4**	**46.6**	

Choice of few Optimised Configurations (5)

3 layers in trigger (L2/L3/L4)

« high number of clusters / intermediate rejection »

Select layers with ~100% of track efficiency at high Pt with >=2 hits (88.8% tracks with 3 hits,11% with 2 hits) out of 3 layers and a Cluster Rate per APV ~ 3MHz

⇒ 85% efficiency per layer with muons at Pt>5GeV/c

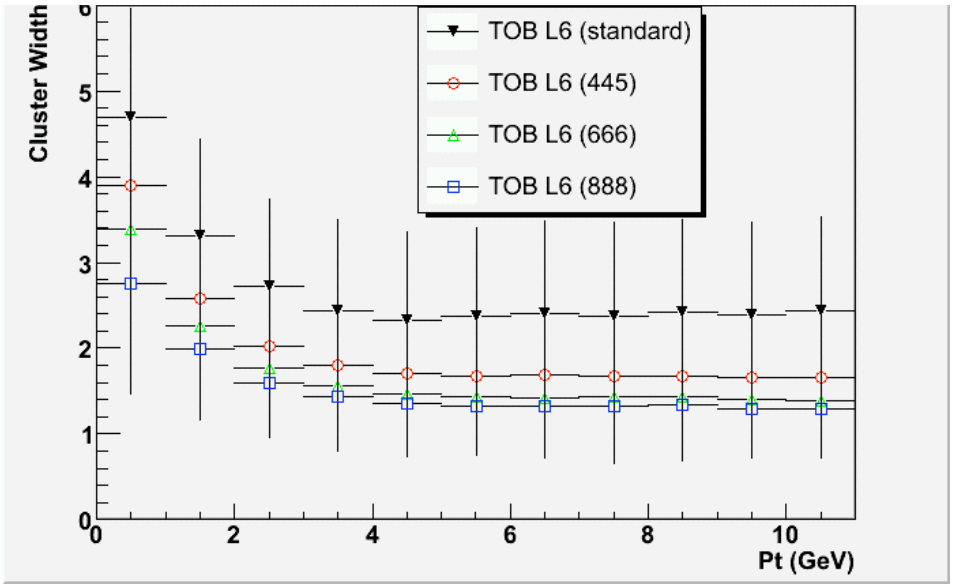
Layer #	2	3	4	Total
Sensor Thickness T (µm)	350	350	350	
APV #/module	**12**	**8**	**8**	
Strip #/module	1512	1024	1024	
Strip length (cm)	4.65	4.65	4.65	
Strip Pitch P (µm)	60	90	90	
T/P	**5.33**	**3.56**	**3.56**	
Total # Strips	**1.814.400**	**1.689.600**	**1.894.400**	**5.398.400**
CW (strips)	**<=2**	**<=2**	**<=2**	
Strip threshold	**3**	**3**	**3**	
Cluster Efficiency	**0.25**	**0.35**	**0.37**	
Occupancy/APV (.10-3)	**0.12**	**0.21**	**0.13**	
ClusterRate /APV (MHz)	**3.51**	**4.39**	**2.75**	
ClusterRate/Layer (GHz)	**50.6**	**58.0**	**40.7**	

Cluster Width in cosmic ray events

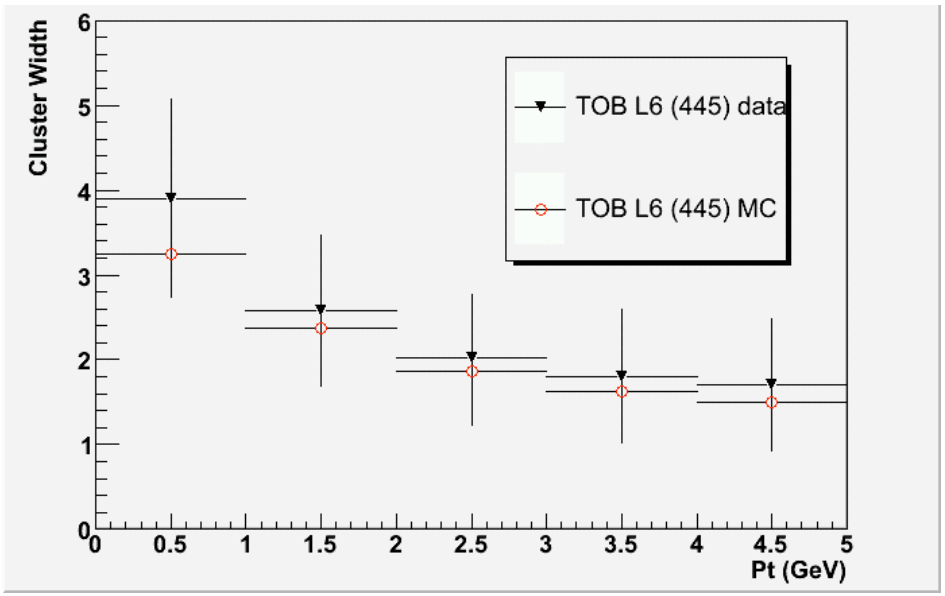
R. Dell'Orso - J. Bernardini

- CRAFT08 data : Split Track collection
  - Impact parameter lower than 5 cm (collision like tracks)

Data



Cosmic MonteCarlo



Good agreement beween data and MonteCarlo
The cluster width measured on TOB external layer allows to discriminate low Pt tracks

Cluster Width in cosmic ray events

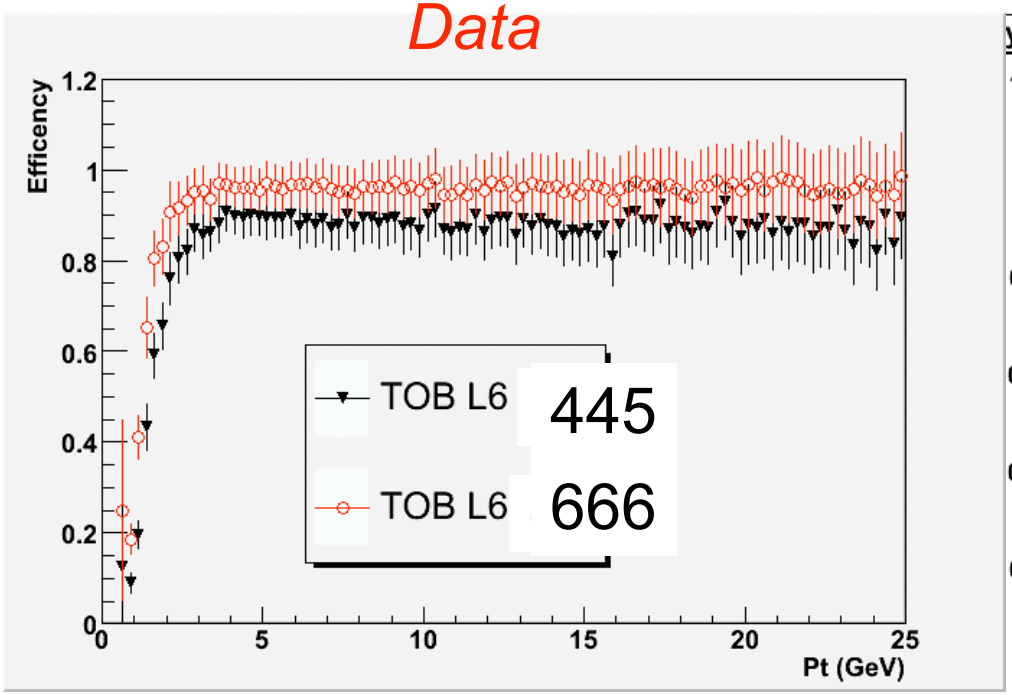
R. Dell'Orso - J. Bernardini

Efficiency TOB Lay 6 (data)

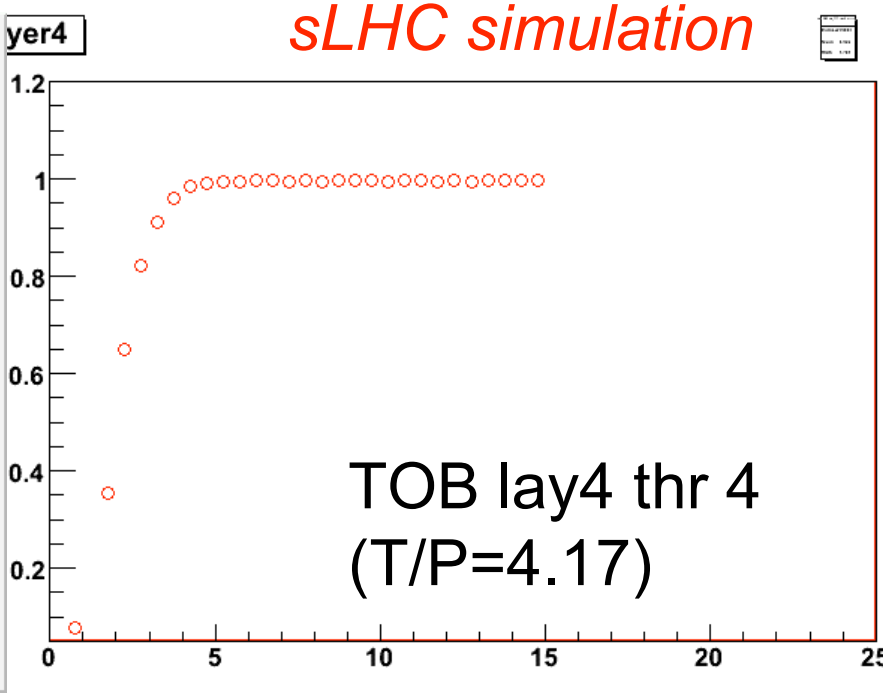
Efficiency TOB Lay 4 (sLHC-std hybrid simulation)

TOB layer 6 should be equivalent to layer 4 of sLHC std hybrid layout

Data



sLHC simulation



Cluster efficiency compatible between CRAFT/simulation

Conclusion

- Cluster Width approach is a simple solution to reduce cluster rate for low Pt track clusters with :
  - *Flexibility to chose a design adjusting thickness/pitch/length according to given criteria on : band width - power consumption - number of channels - material budget*
  - *Flexibility to adjust the rejection/efficiency performance with threshold and Cluster width for a given design*
  - *Redundancy with multiple layers to ensure large amount of tracks with more than 2 hits*
- Few designs shown in this presentation are satisfying reasonable criteria on cluster efficiency:
  - *To be checked the track reconstruction efficiency pattern like method as proposed with associative memories implementation.*
  - *Cluster and Track collections to be provided for Trigger studies*
- MonteCarlo studies are validated by cosmic data :
  - *Soon to be checked with collisions data*
- Needs to be completed by other solution at higher eta :Stack strip modules