Hardware mapping & data format study

- Learning basic things for Data Formatter HW development -

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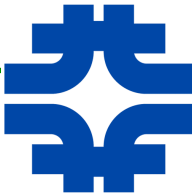


Data Formatter system

Challenging part in the FTK application for ATLAS

132 RODs Pixel

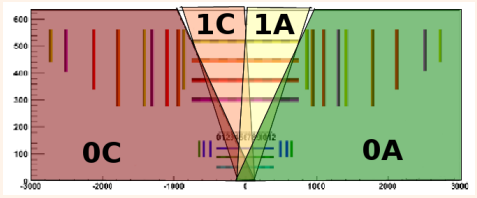
ROD ROD ROD

90 RODs SCT

ROD ROD ROD

Data Formatter
(222 RODs vs 64 towers)
Processed by 64 FPGAs mounted on 32 Boards

η-φ tower η-φ tower η-φ tower η-φ tower



4 (η) × 16 (φ) = 64 towers

Today's talk

I would like to show what I am learning:

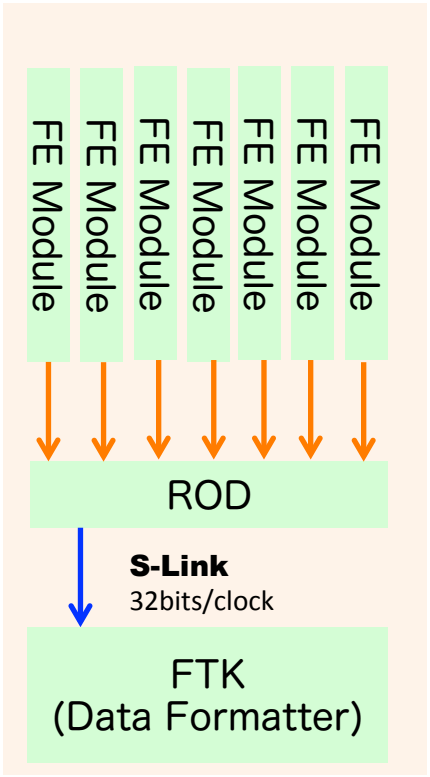
1. Study for data format from ROD (S-Link)
2. Study for detector – readout mapping from FTK application point of views
3. Initial look at data volume with beam collision data

Important basic knowledge for design, development, test, and commissioning

Data structure in S-Link

Series of 32 bits words from each of SCT/Pixel RODs

S-Link data structure



S-Link Header
0xEE1234EE
0x00000009
0x03010000
0x00**11**1708
0x**0**02EC8C
0x**A**5002122
0x000002E5
0x00000084
0x00000000

0x11 = Pixel Barrel

FE Module 1	FE Module 2	FE Module 3
0x20**00**03F0	0x20**01**03F0	0x20**10**03F0
0x813A0078	0x85070A11	0x840C030F
0x81460178	0x85070A10	0x841D030E
0x81110277	0x85070A0F	0x8409050D
0x81150278	0x850C0A12	0x840C040E
0x84230607	0x85060D04	0x841A040D
0x84300707	0x85070D01	0x8511019F
…	…	…
0x89141164	0x8D1E0D8F	0x8F060D0B
0x891A1066	0x8D070E8E	0x8F0D0D0A
0x89501165	0x8D240E8F	0x8F260E0A
0x40000000	0x40000000	0x40000000

Specific data for SCT or Pixel

S-Link Trailer
0x00000000
0x00000000
0x00000002
0x000000C1
0x00000001

Data format of Pixel

Pixel raw data format detail

0x2000 03F0	001 0 0000 0000 0000 0000 0011 1111 0000 → Header Word
0x813A0078	100 0 0001 0011 1010 0000 0000 0111 1000 → Hit @ (0x00, 0x78)
0x81460178	100 0 0001 0100 0110 0000 0001 0111 1000 → Hit @ (0x01, 0x78)
0x81110277	100 0 0001 0001 0001 0000 0010 0111 0111 → Hit @ (0x10, 0x77)
0x81150278	…
0x84230607	…
0x84300707	…
…	…
0x89141164	…
0x891A1066	…
0x89501165	100 0 1001 0101 0000 0001 0001 0110 0101 → Hit
0x40000000	010 0 0000 0000 0000 0000 0000 0000 0000 → Trailer Word

Word	31 30 29 28	27 26 25 24	23 22 21 20	19 18 17 16	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
Header	001	Errors		Module	Skipped L1ID	Level1 ID	BC ID	
Triler	010	Z	H	V	Bit Flip			
Hit	100	BF	FE Number	Time over threshold value		Bit Flip	Column	Row
Error	000	1	FE Number	-	1 1 1 1 1	MCC Error Code	FE Error Code	
Raw data	011	28 bits Raw Data						
Timeout	001	0						

Data format of SCT

SCT raw data format details

0x2001CAB3	**001**0 0000 0000 0001 → Header word
	1100 1010 1011 **0**011 → Hit @ 0x2B
0xD41280BB	**1**101 0100 0001 **0**010 → Hit @ 0x41
	1000 0000 **1**011 **1**011 → Neighboring 2 hits
0x80BB80BB	**1**000 0000 **1**011 **1**011 → Neighboring 2 hits
	1000 0000 **1**011 **1**011 → Neighboring 2 hits
0x800BDD53	**1**000 0000 **0**000 **1**011 → Neighboring 1 hits
	1101 1101 0101 **0**011
0xEE732002	**1**110 1110 0111 **0**011
	0010 0000 0000 0010 → Header word

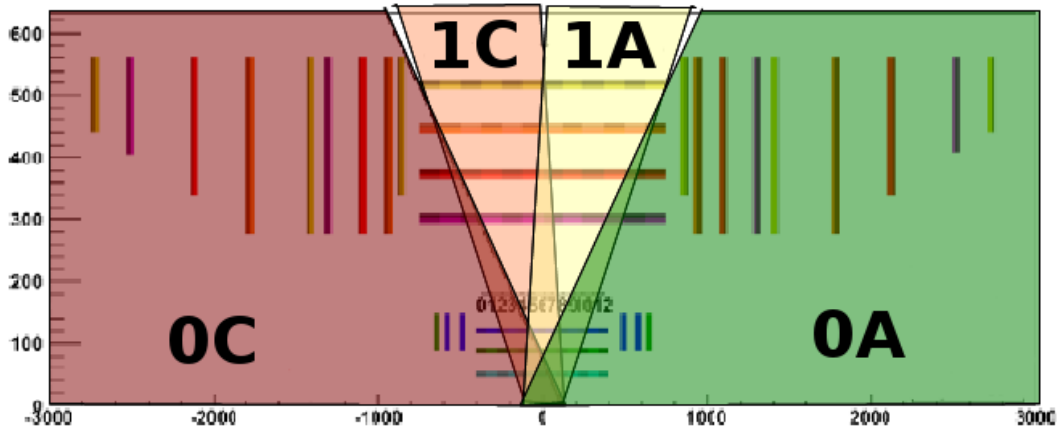
Word	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Header	001			P	Level1 ID				Module							
Triler	010			Z	H	V	-									
1st Hit	1	sid		Chip ID			Cluster Base Address						0	Hit BC		
Neighbering hit (1)	1	-							0	-			1	Hit BC (1)		
Neighbering hit (2)	1	-							1	Hit BC (2)			1	Hit BC (1)		
Error	011			-						FE Number				Error Code		
Raw Data	001			#bits			-			Raw Data						

Hardware mapping

Mapping between Detector & Readout

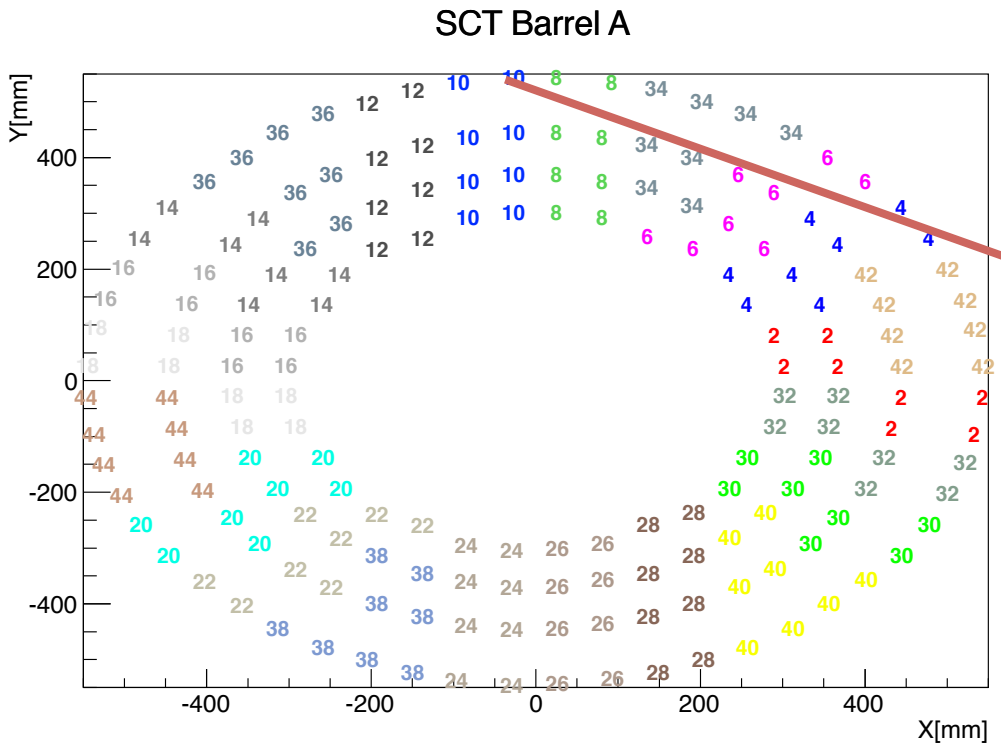
- Detector (x, y, z) - (Module & ROD) - FTK tower

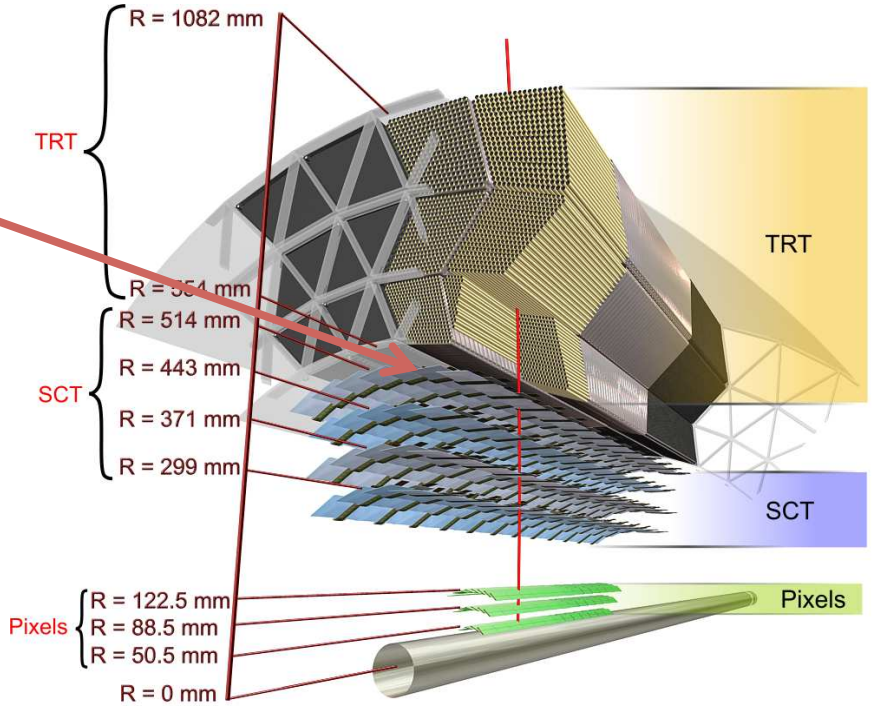
Cabling of ID is complicating
Need to be understood for Data Formatter



Hardware mapping

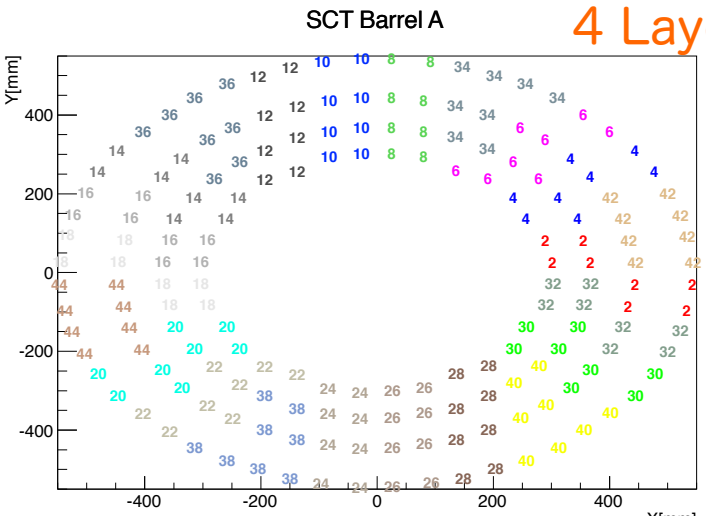
SCT Barrel ROD ID map



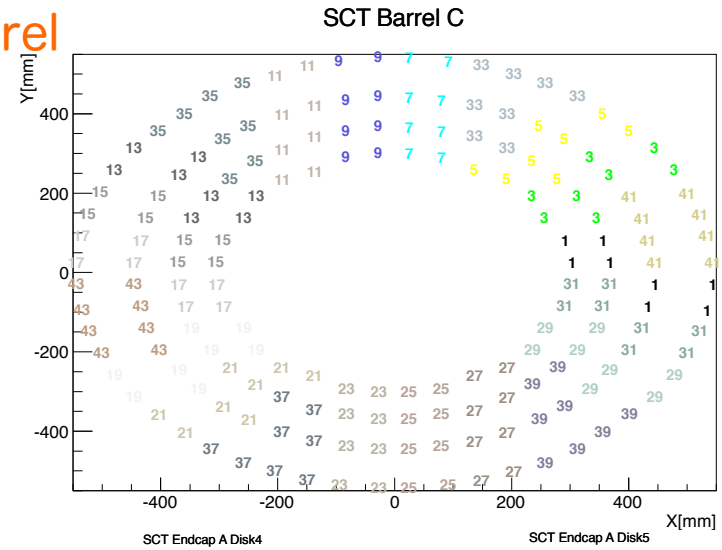


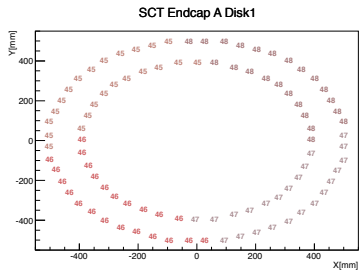
Hardware mapping

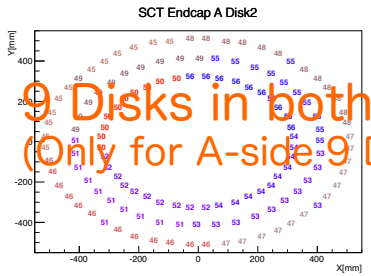
SCT (8176 Modules, 90 RODs)

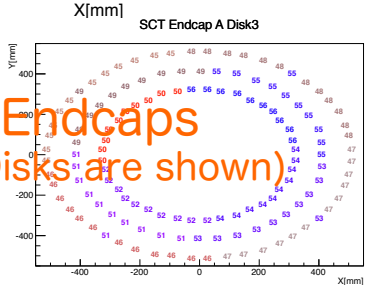


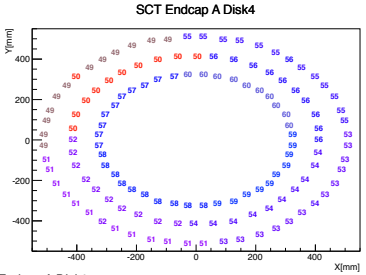
4 Layers in Barrel

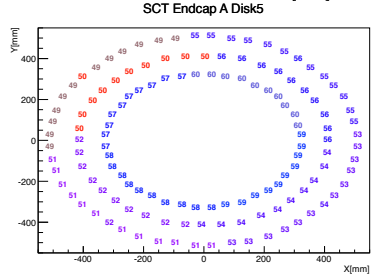






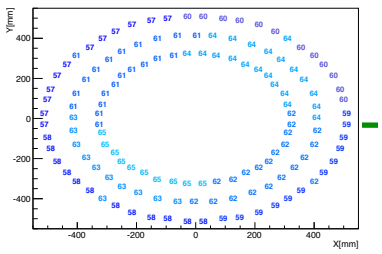


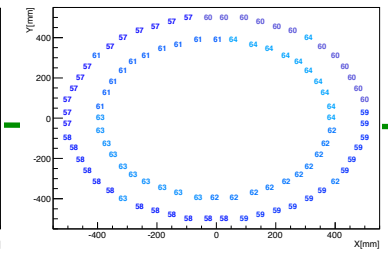


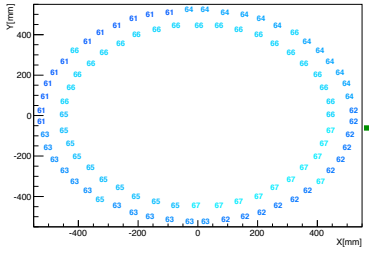


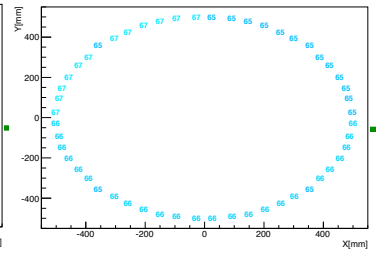
9 Disks in both Endcaps

(Only for A-side 9 Disks are shown)





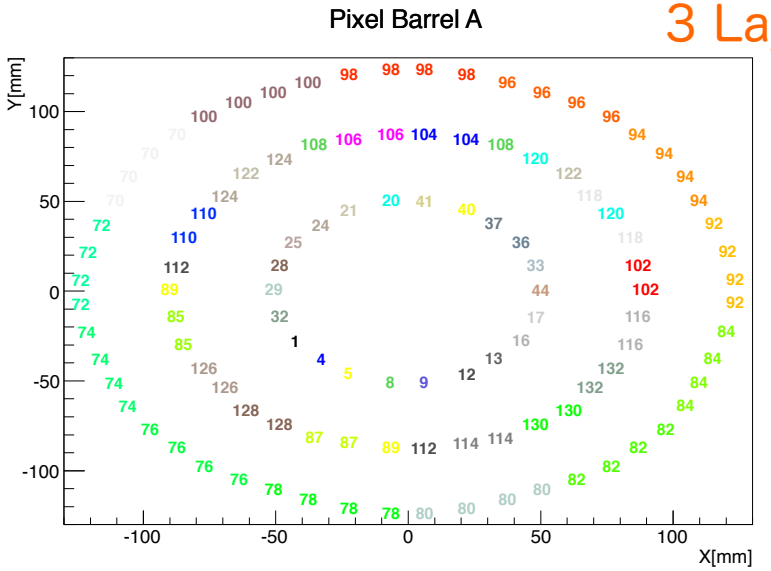


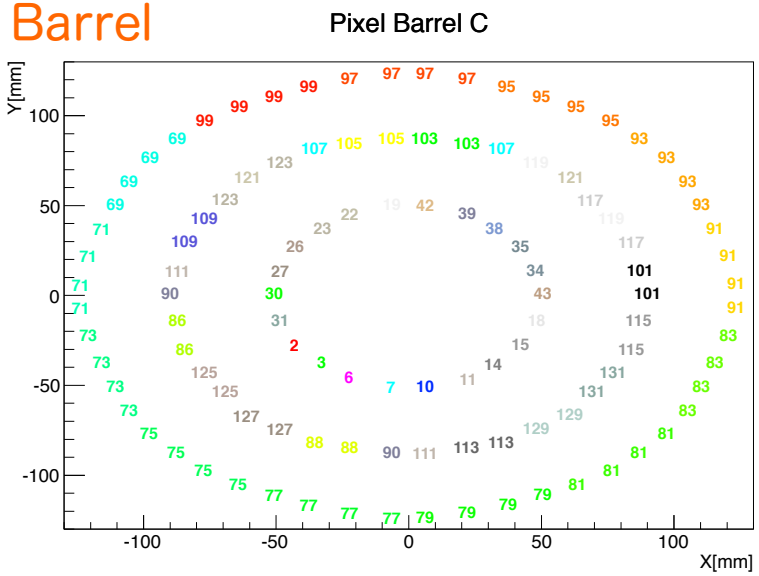


Hardware mapping

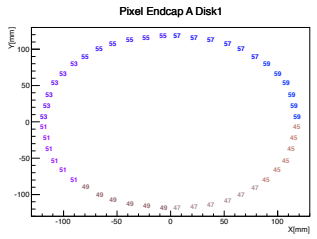
Pixel (1744 Modules, 132 RODs)

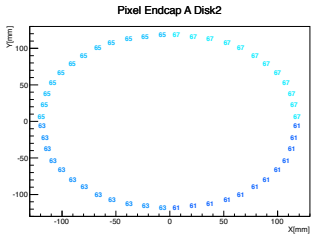
3 Layers in Barrel

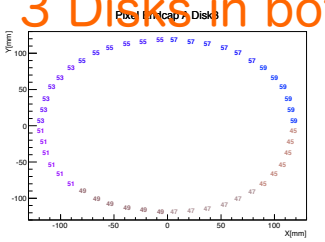


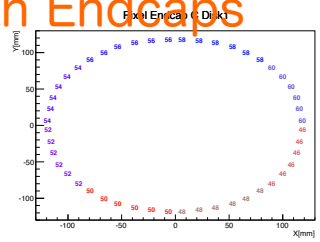


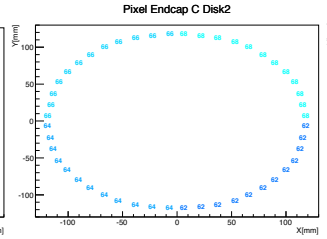
3 Disks in both Endcaps

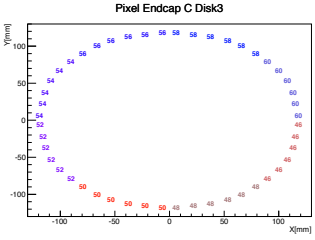








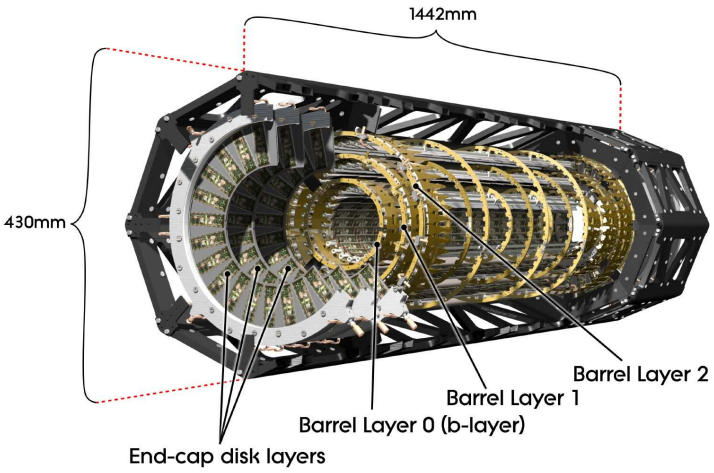


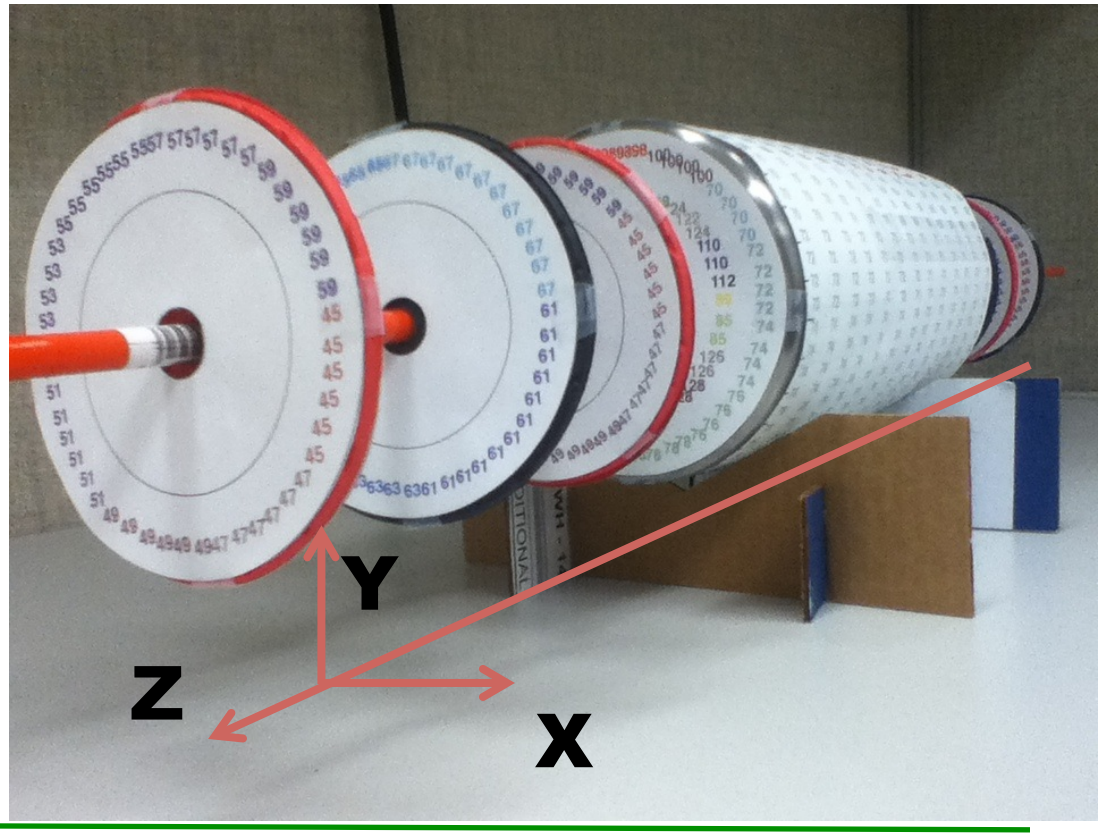


3D Pixel model

3D Pixel model with ROD ID mapping (@Fermilab W/H 10)

(3 layers in Barrel, 3 disks in Endcap)

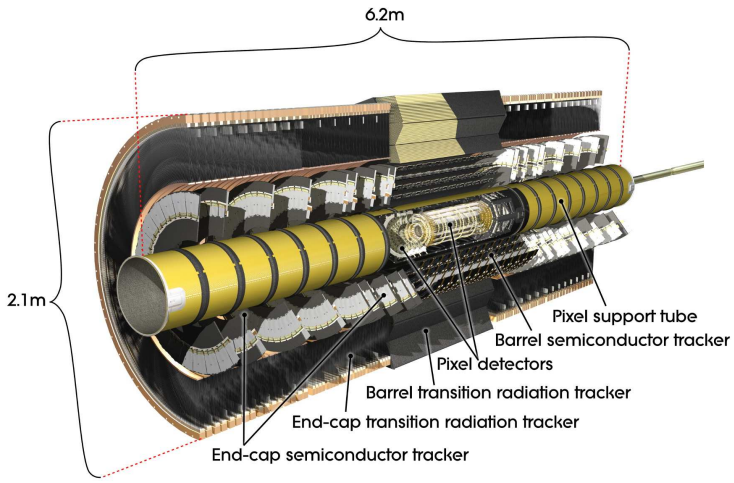


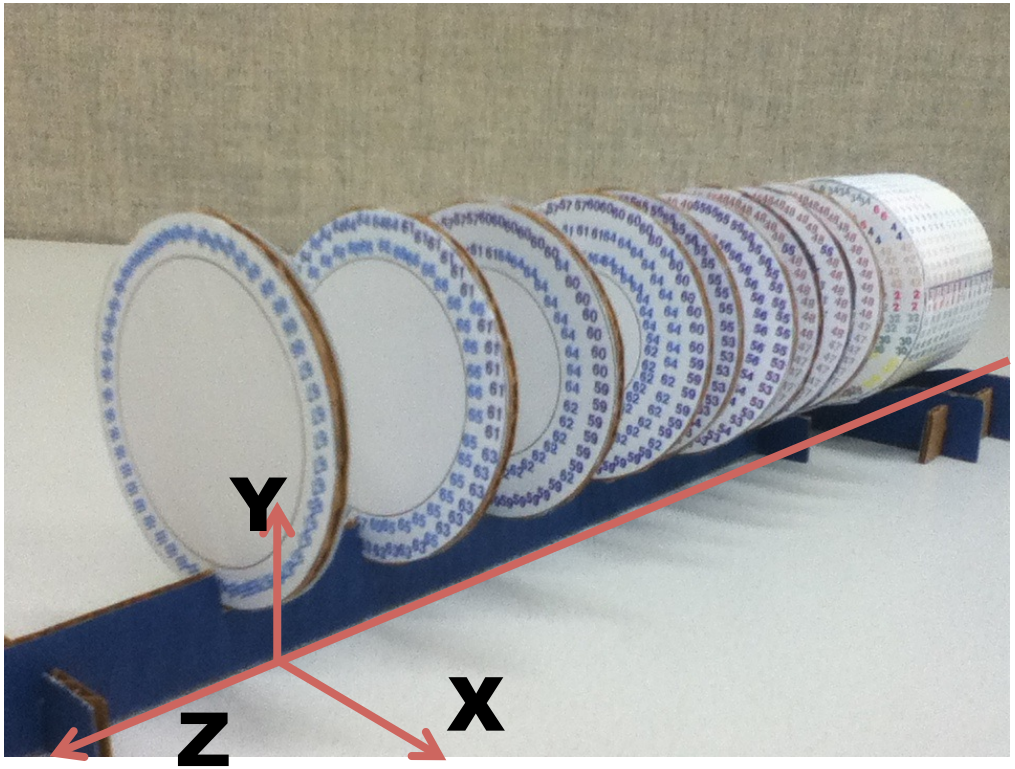


3D SCT model

3D SCT model ROD ID mapping (@Fermilab W/H 10)

(4 layers in Barrel, 9 disks in Endcap)





Initial look at real data

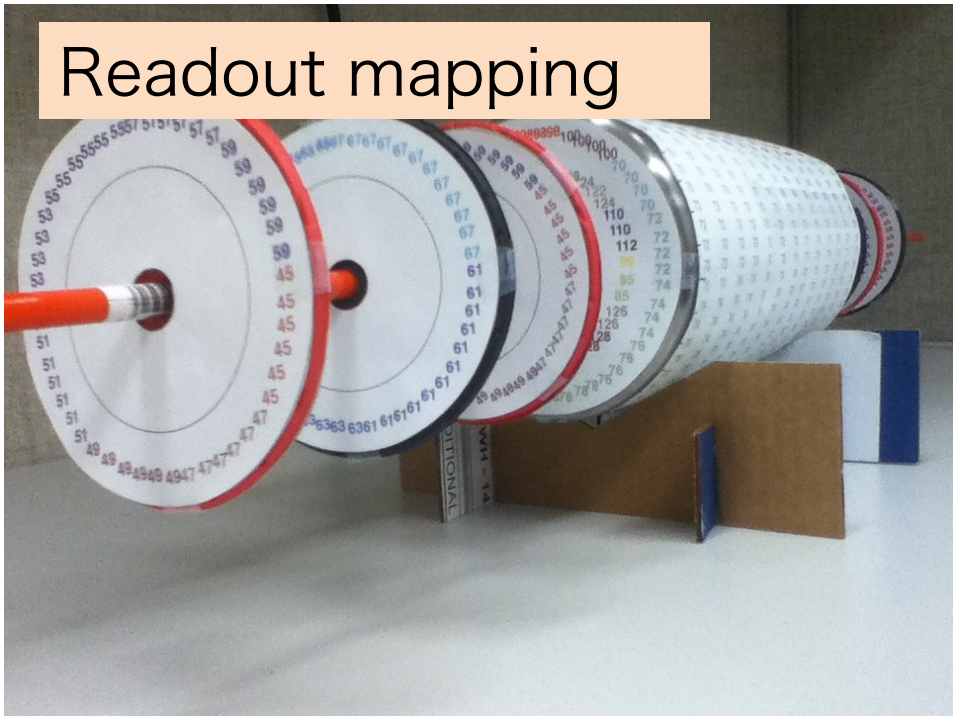
Next, we can look at
hits from each module with real data.

My private decoder on SVN:
https://svnweb.cern.ch/trac/atlasusr/browser/okumura/ftk/myPackage/bytestream_decoder/trunk

Raw data

```
0x200003F0
0x813A0078
0x81460178
0x81110277
0x81150278
...
0x89141164
0x891A1066
0x89501165
0x40000000
```

Readout mapping



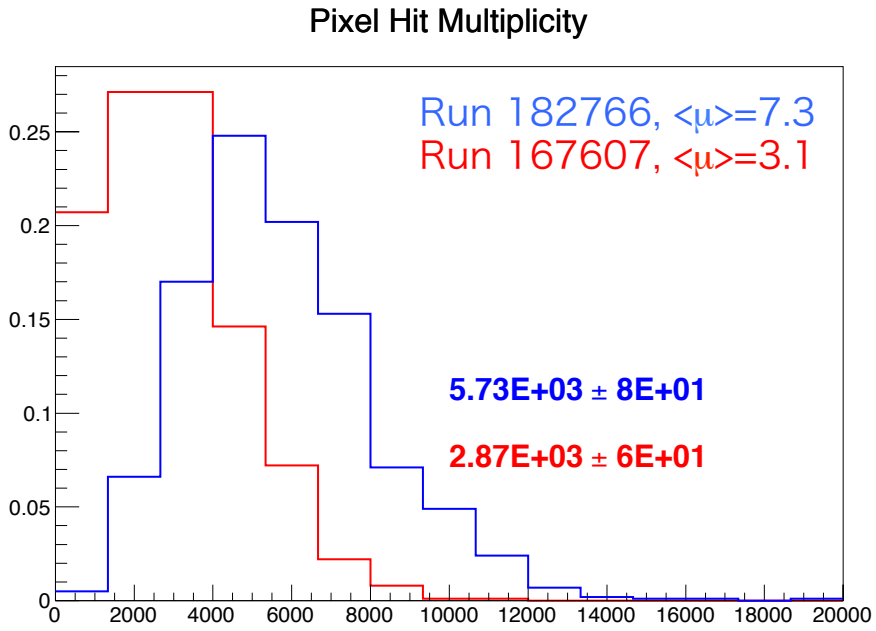
Data sample

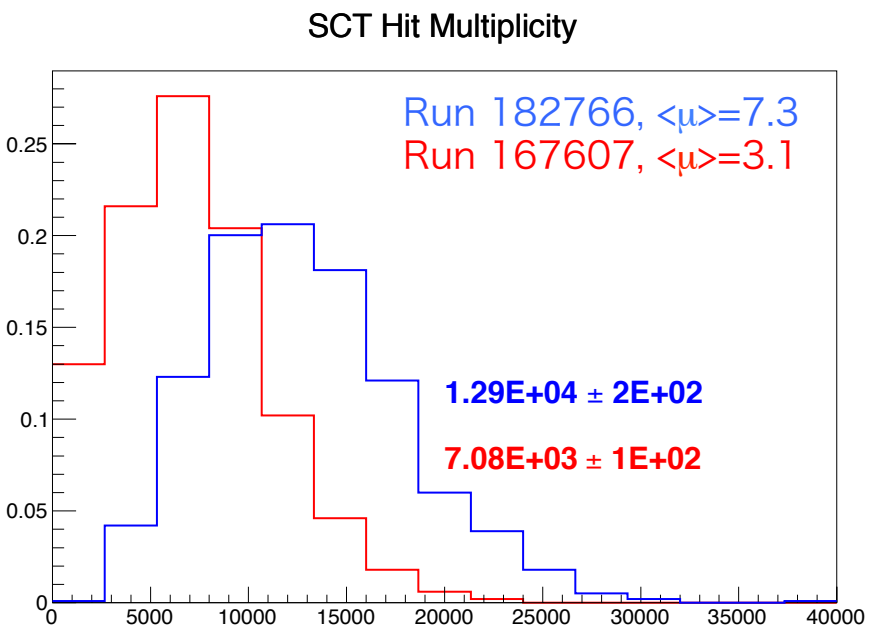
- Run 182766, Lumi-Block 225 (2011)
  - trigger : Egamma stream
  - Instantaneous luminosity : 1.0E33
  - Number of bunches : 874 collisions @ P1
  - Pileup : $\langle\mu\rangle = 7.3$
- Run 167607, Lumi-Block 159 (2010)
  - trigger : Egamma stream
  - Instantaneous luminosity : 1.7E32
  - Number of bunches : 348 collisions @ P1
  - Pileup : $\langle\mu\rangle = 3.1$

#Hits/Event

Pixel / SCT Hit multiplicity distributions

- Note : Numbers before clustering

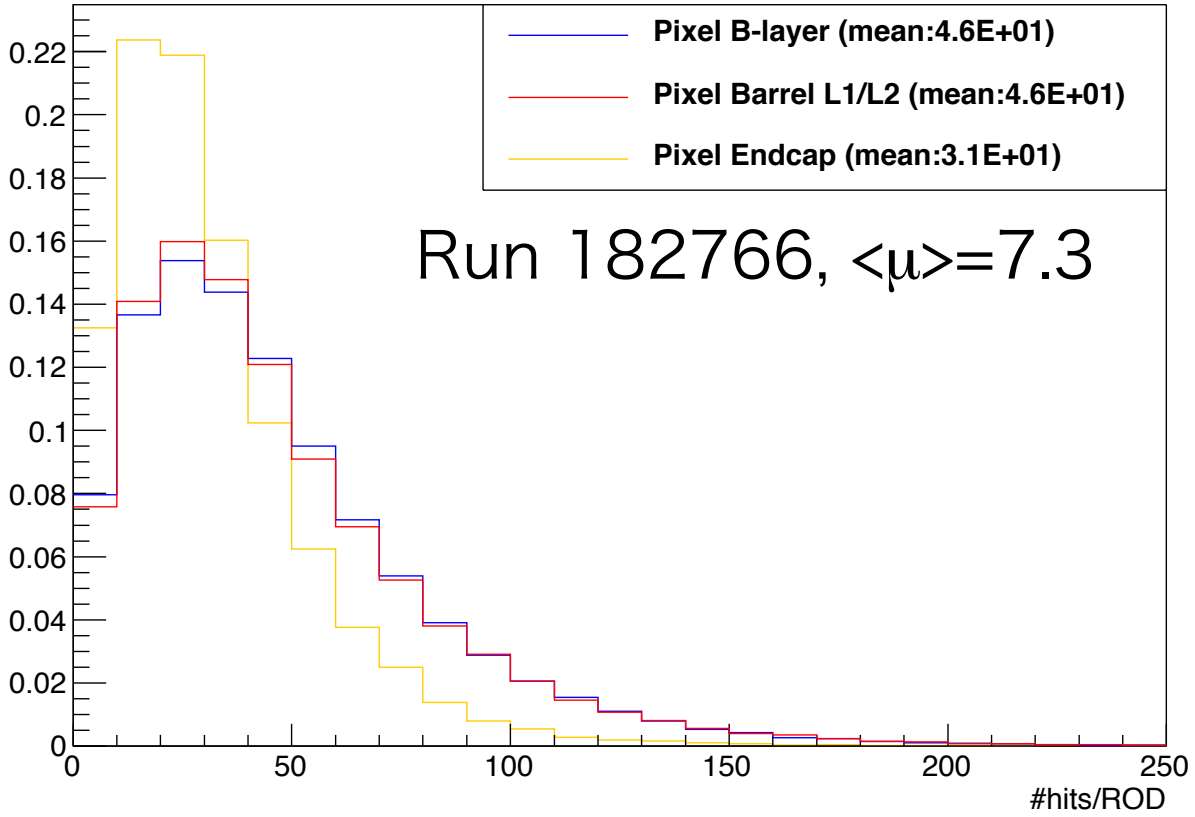




#Hits/Event/ROD

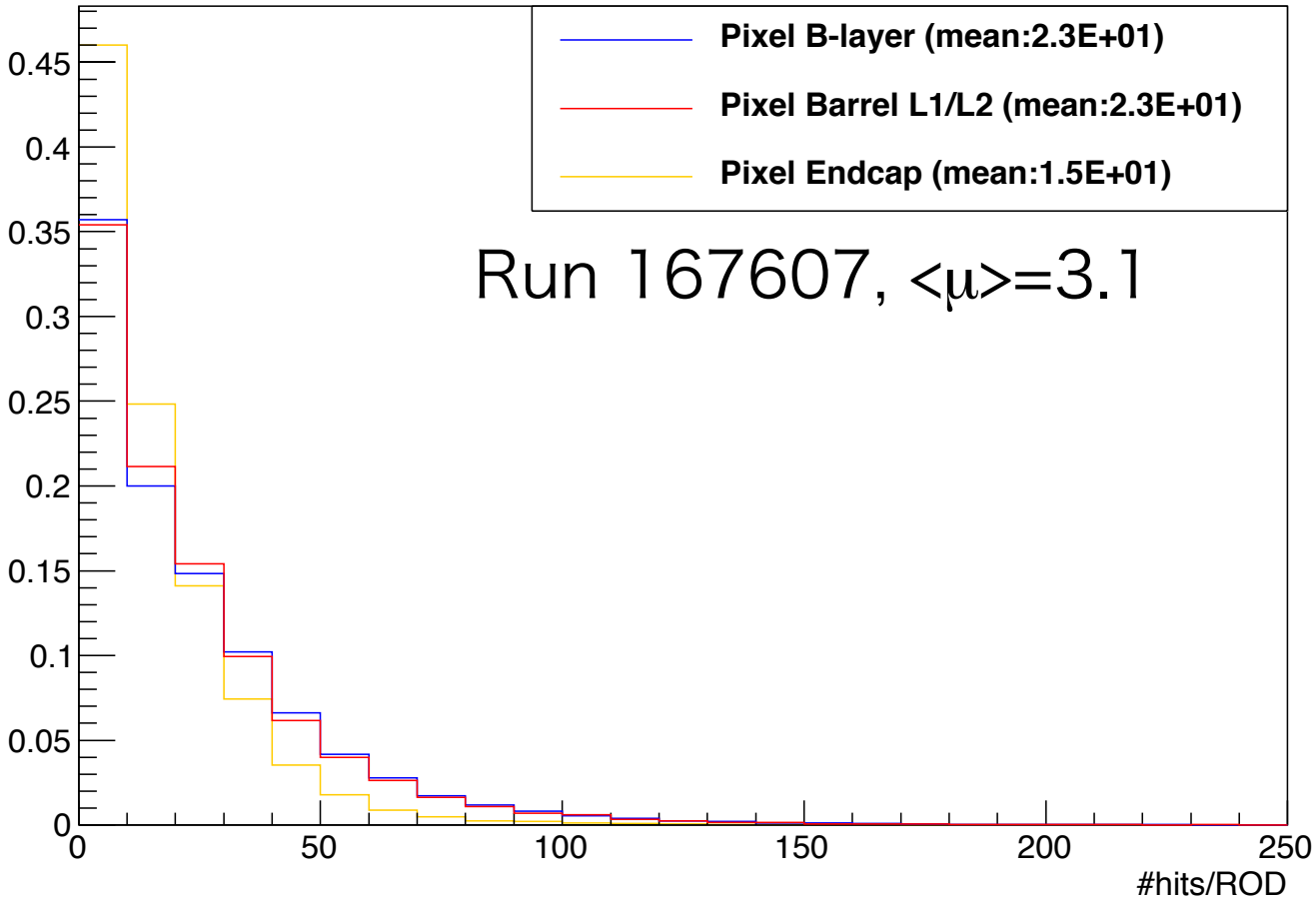
Number of Pixel hits per ROD per event

Note : Numbers before clustering



#Hits/Event/ROD

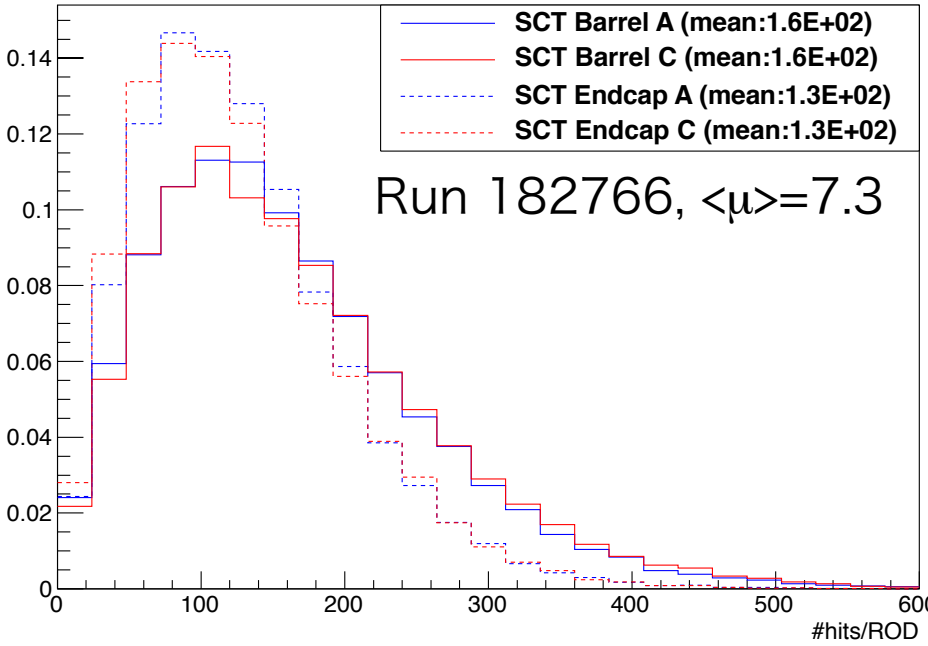
Same plot for low luminosity run

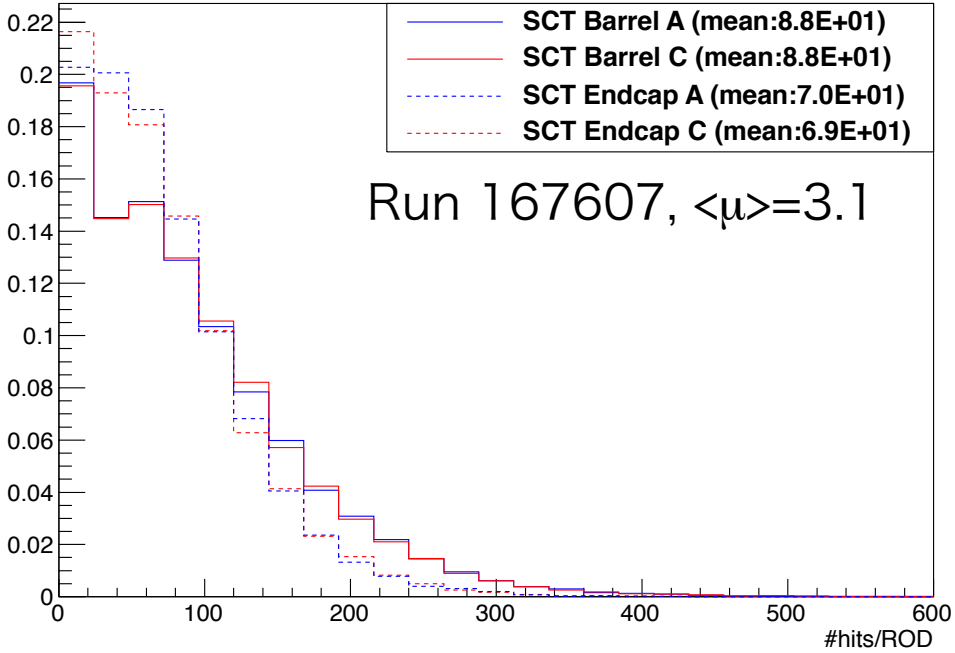


#Hits/Event/ROD

SCT Number of hits per ROD per Event

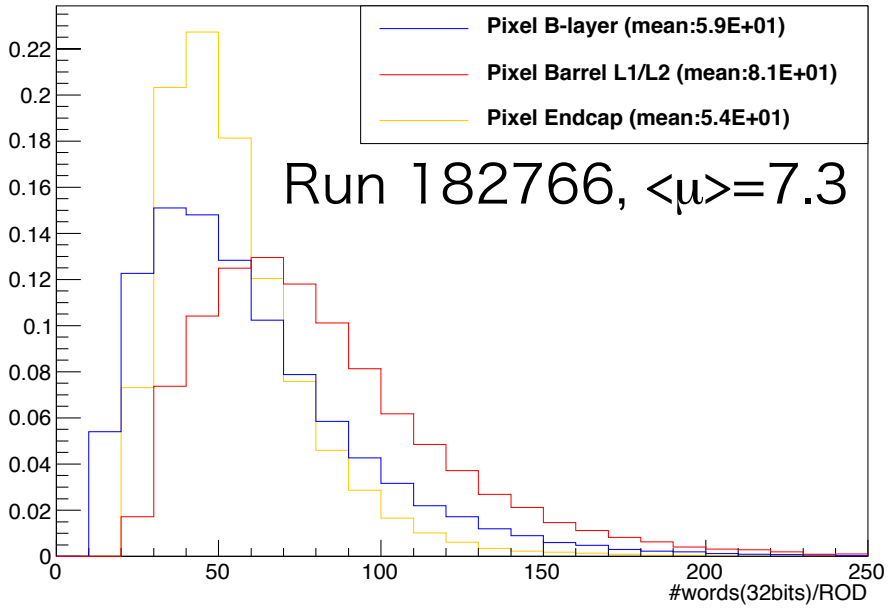
Note : Numbers before clustering

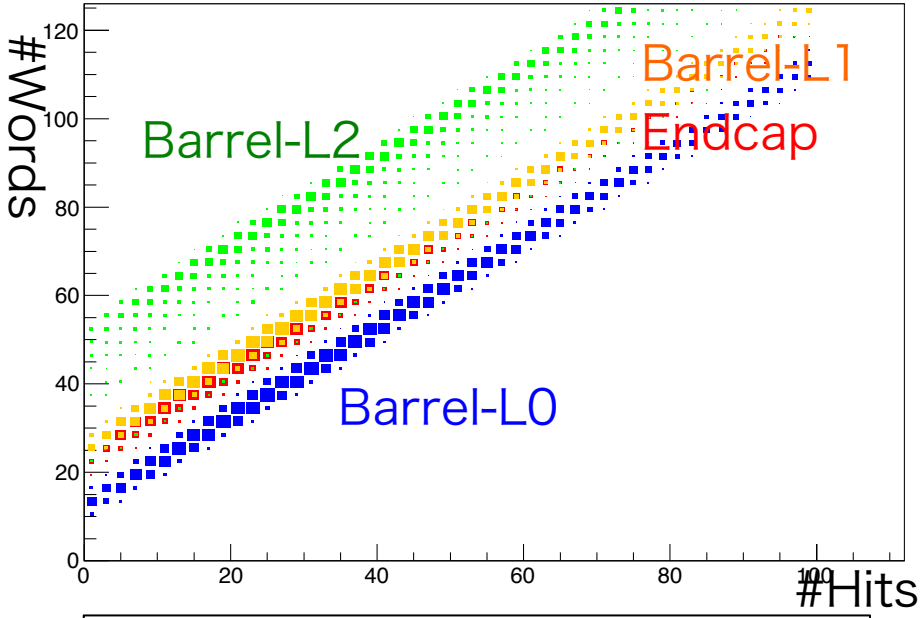




#Words/Event/ROD

Note: 1 Word is defined with 32 bits



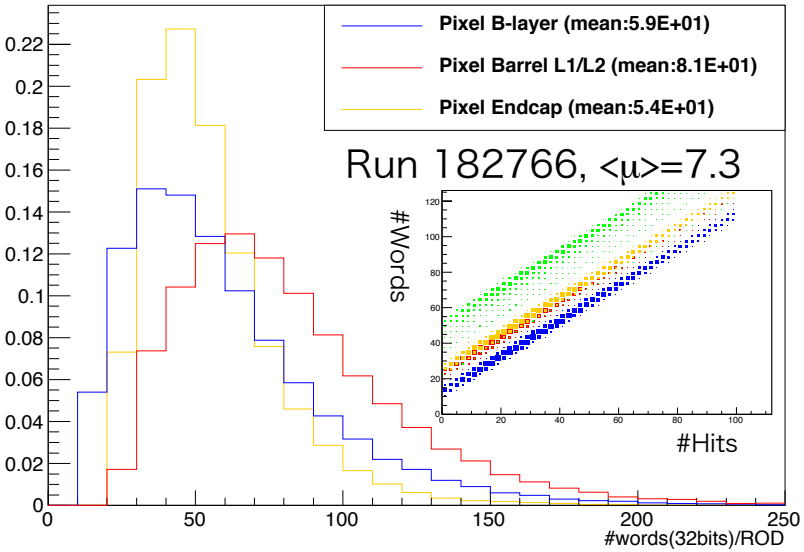


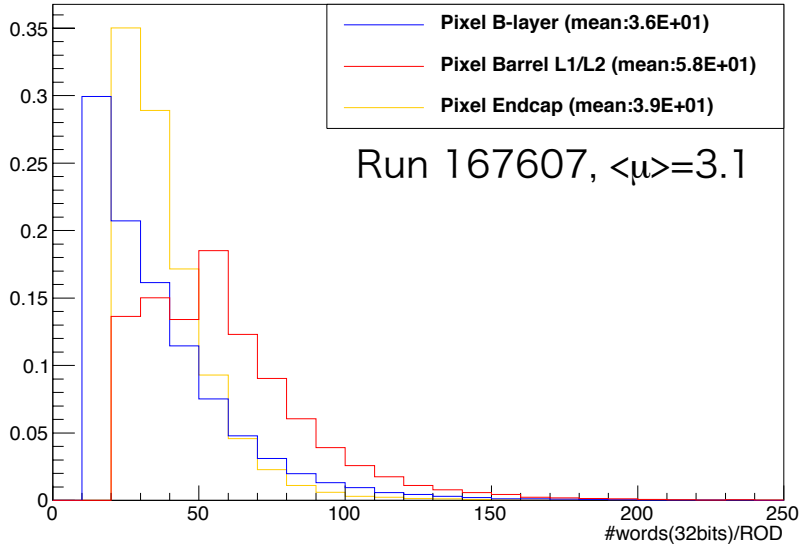
Number of modules per ROD

- Barrel L0 : 6-7 modules / ROD
- Barrel L1 : 13 modules / ROD
- Barrel L2 : 26 modules / ROD
- Endcap : 12 modules / ROD

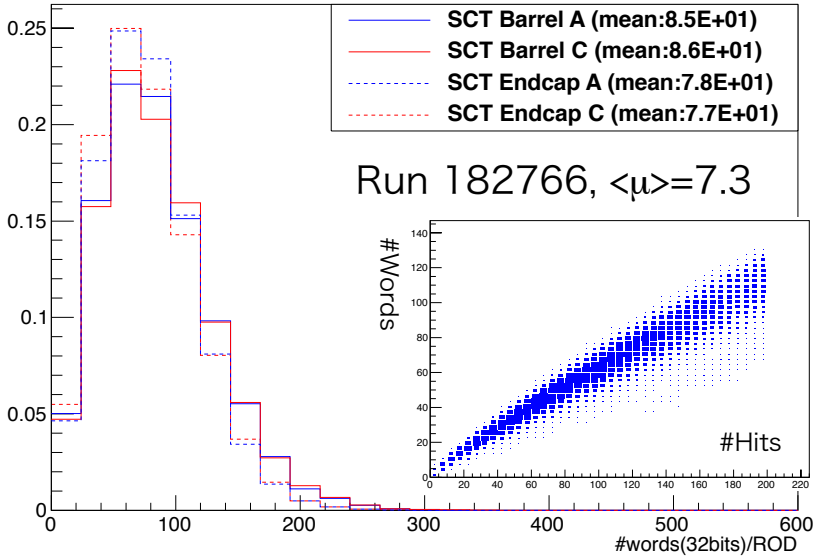
#Words/Event/ROD

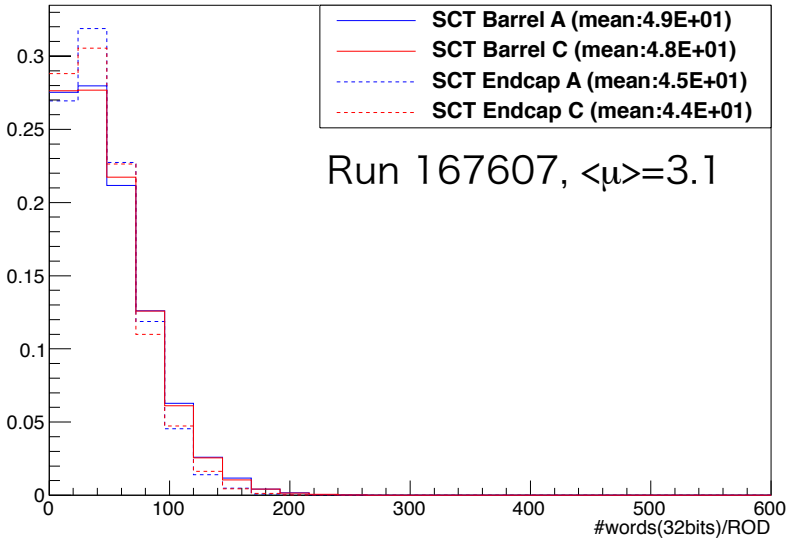
Pixel





SCT





Summary

Data formatter system is challenging

Started to learn about basics
for the FTK system:

- Data format of S-Link
- Hardware mapping
- Initial look at real data

Much more will come in near future

Pixel coverage

Pixel Barrel Layout
#ROD = 22(A-L0), 19(A-L1), 13(A-L2)
22(C-L0), 19(C-L1), 13(C-L2)
#ROD = 8(A-D1/D3), 4(A-D2), 8(C-D1/D3), 4(C-D2)