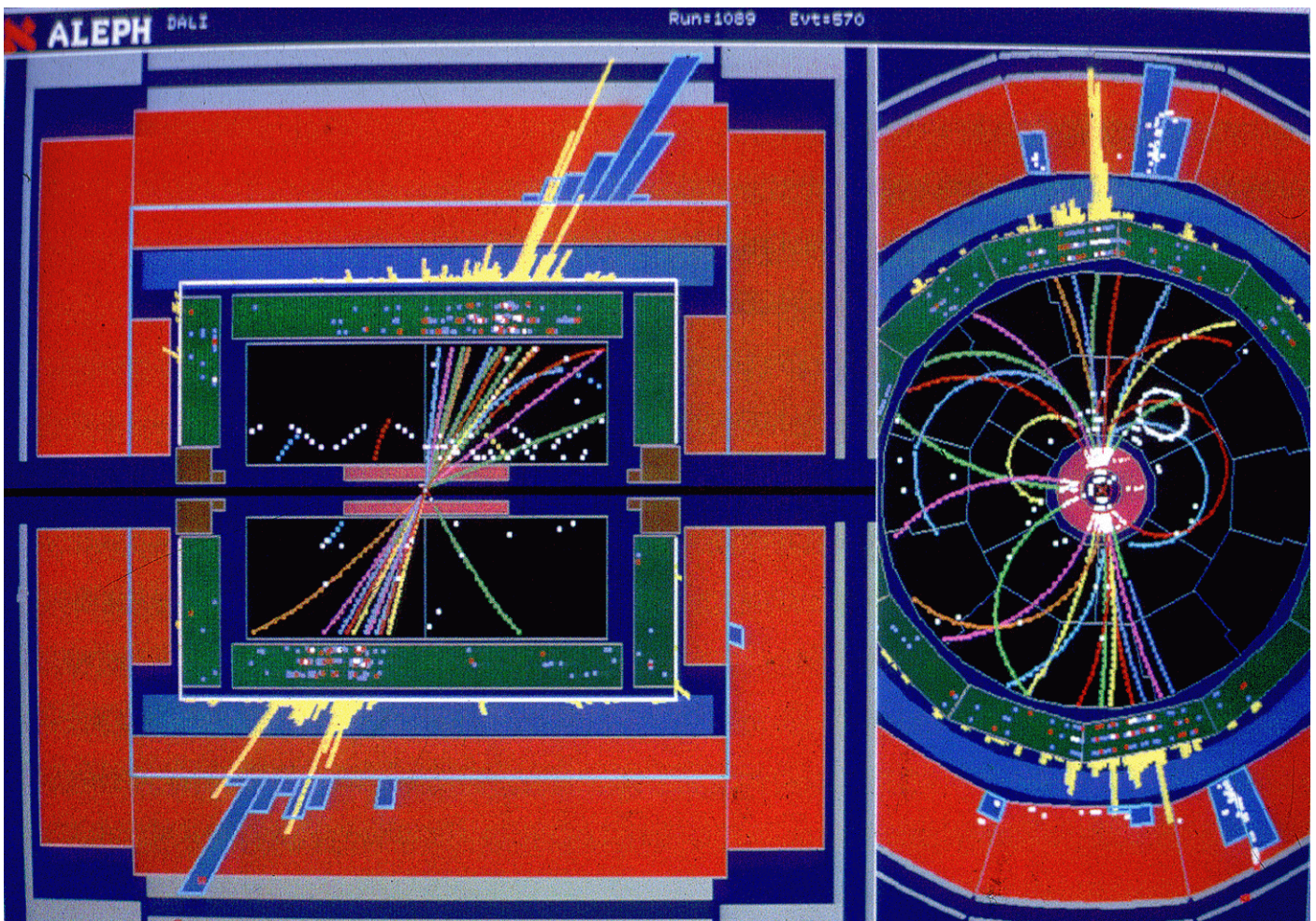
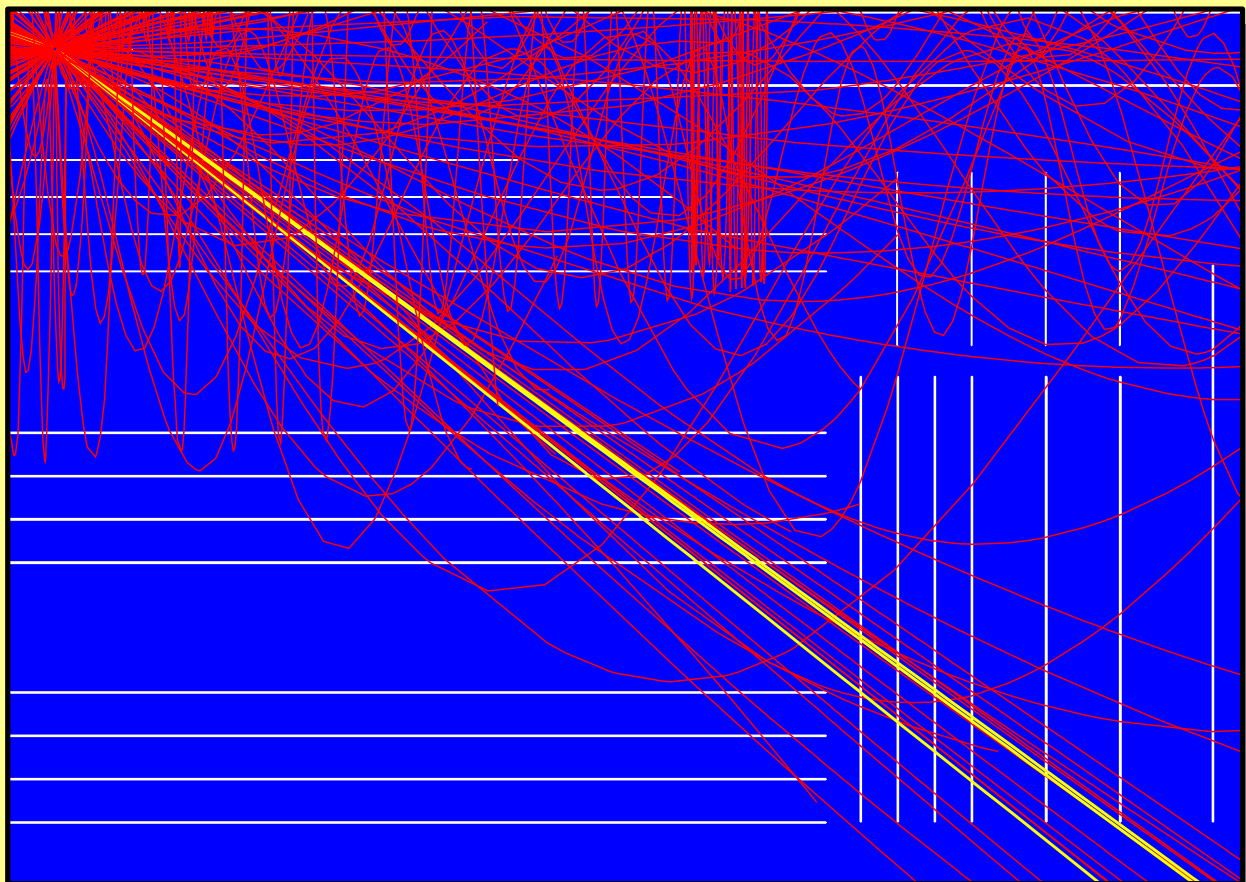
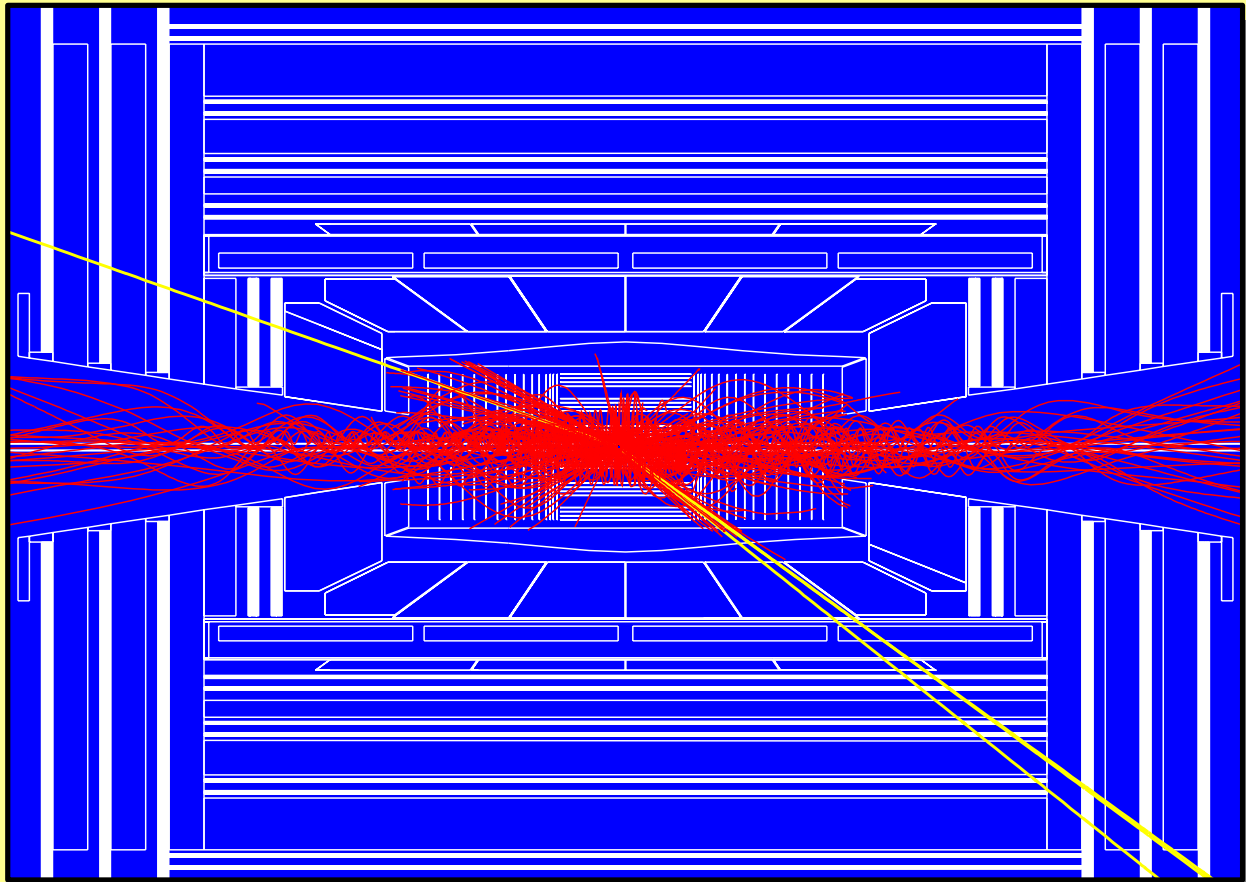


# Detektory uniwersalne

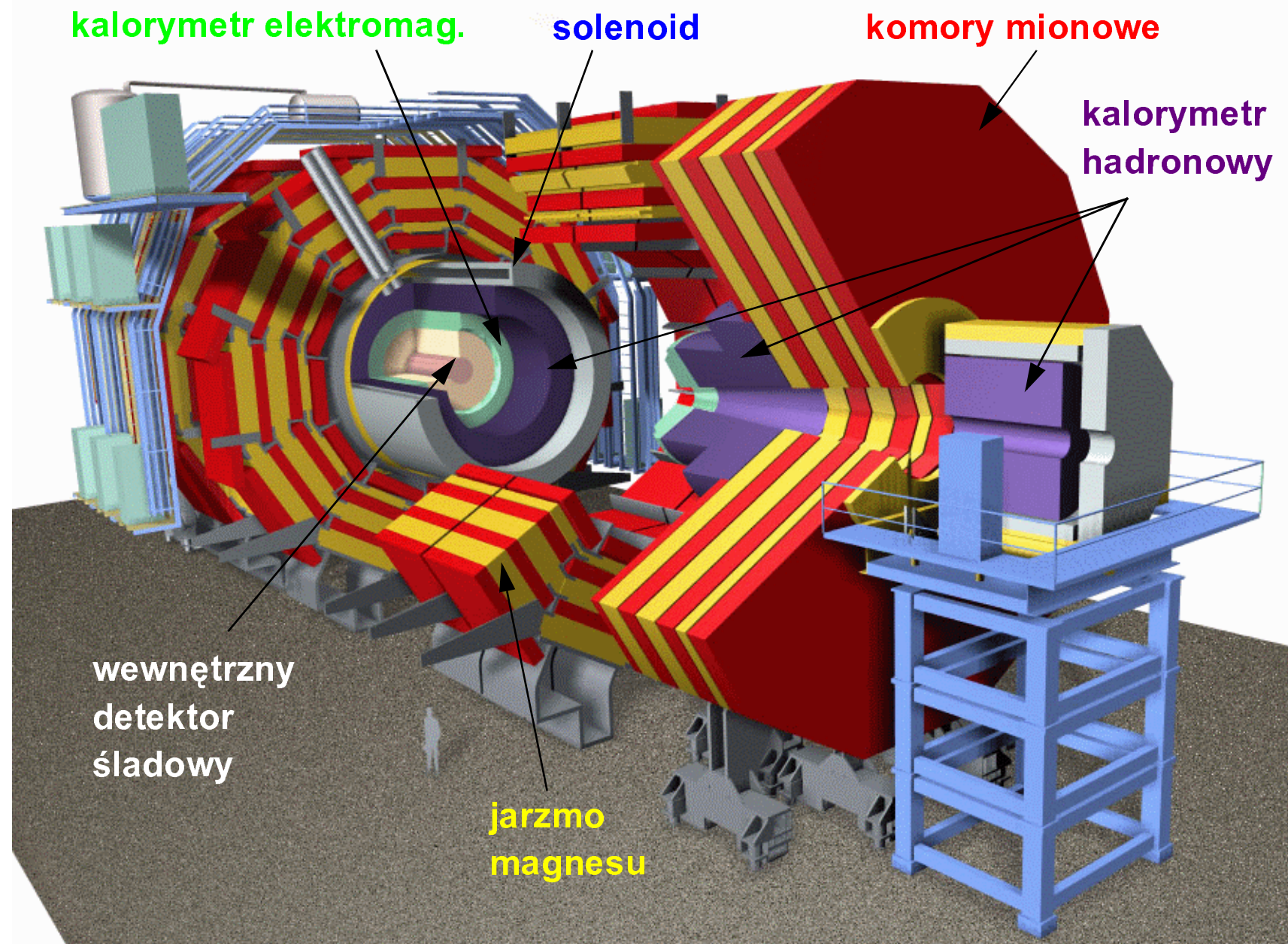
- pomiar energii
  - kalorymetr
- pomiar pędu
  - zakrzywienie toru w polu magnetycznym
- identyfikacja cząstek
  - różne oddziaływanie z materią



# *Muons in a jet of $p_t^{jet} = 1\text{TeV}$*



# Compact Muon Solenoid

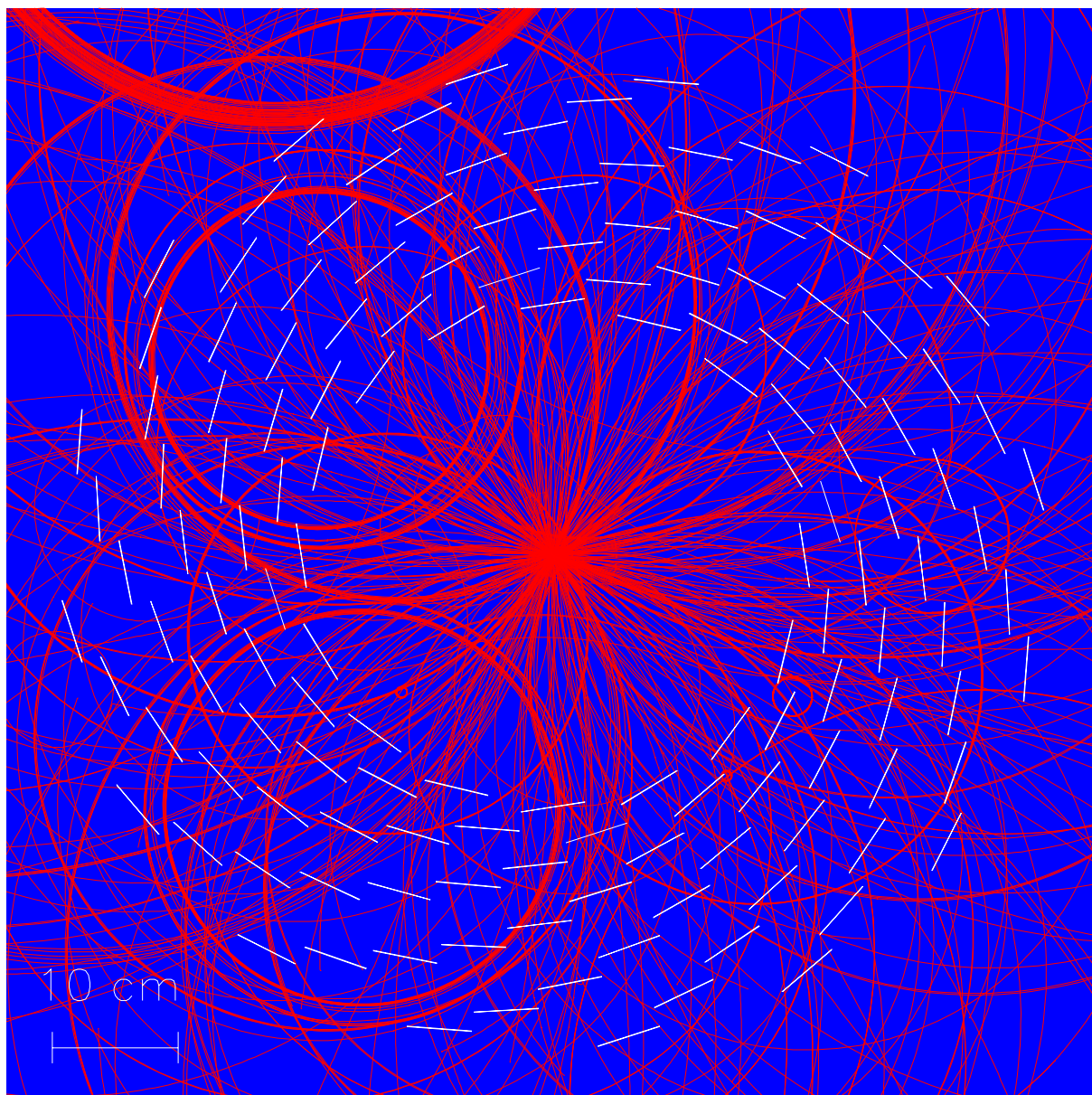


# Łamigłówka

---

18 nałożonych zderzeń pp,  
widzianych przez wewnętrzną część krzemowego detektora  
mikropaskowego.

**Wśród nich rozpad cząstki Higgsa na 4 miony.**



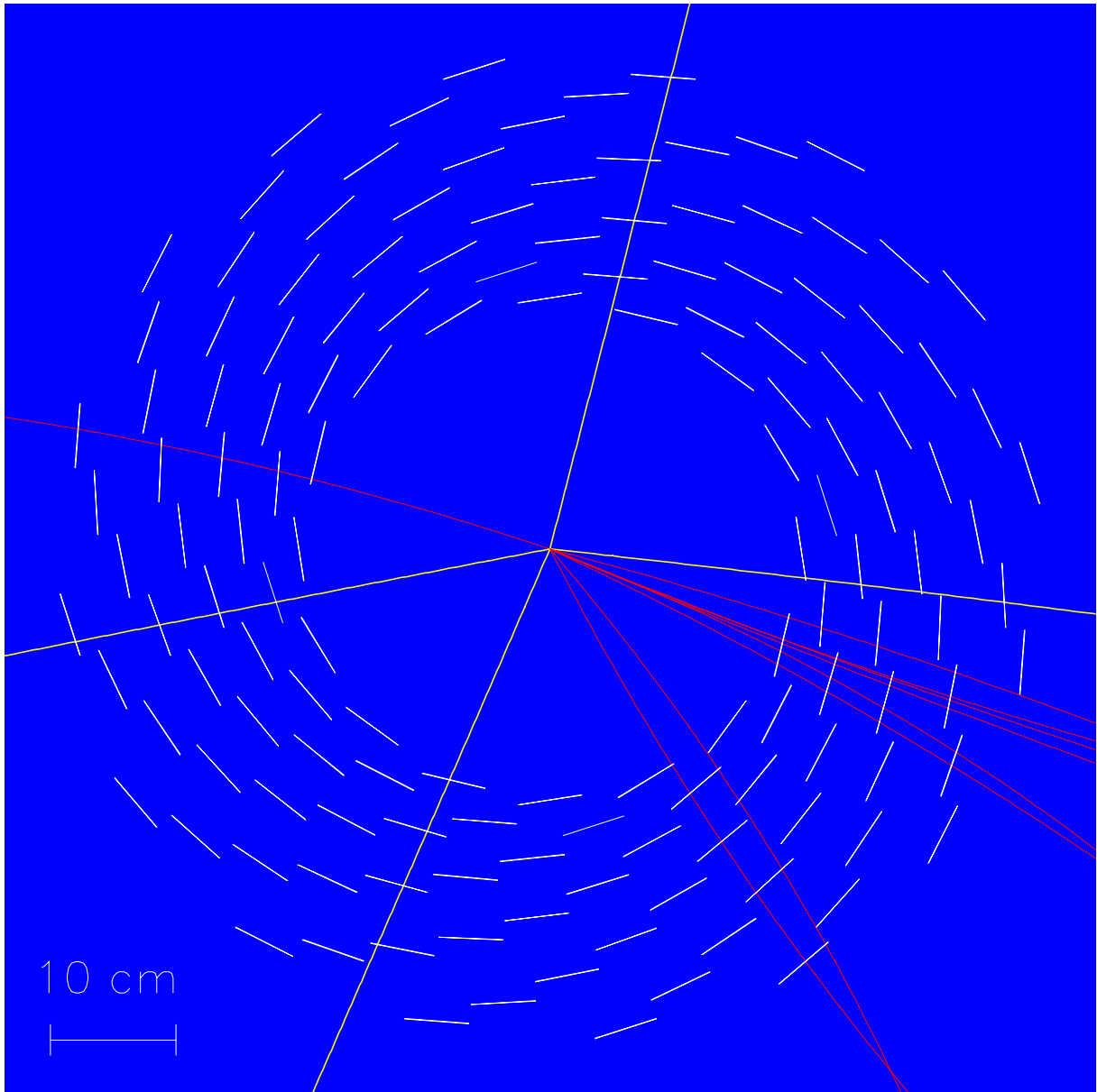
**Znajdź 4 proste ślady.**

# Rozwiązanie łamigłówki

---

Zrekonstruowane ślady o  $p_t > 2 \text{ GeV}$ .

Wśród nich dobrze widoczne 4 miony z rozpadu Higgsa.



Rozwiązanie możliwe jeśli zajętość detektora  $\sim 1\%$

→ powierzchnia mikropaska  $\sim 1 \text{ mm}^2$

→  $> 10^7$  kanałów odczytu

# Budowa detektora CMS

**SUPERCONDUCTING COIL**

**ECAL Scintillating  $PbWO_4$  Crystals**

**CALORIMETERS**

**HCAL Plastic scintillator copper sandwich**

**IRON YOKE**

**TRACKER**

Micro Strip Gas Chambers (MSGC)  
Silicon Microstrips  
Pixels

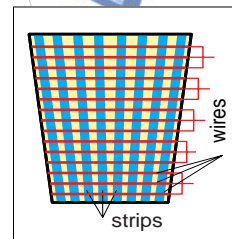
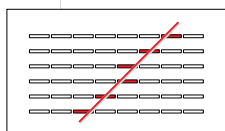
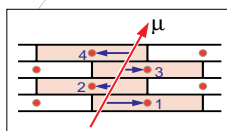
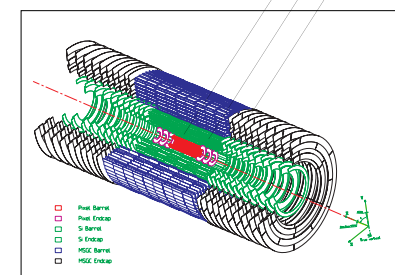
**MUON BARREL**

Drift Tube Chambers (DT)

Resistive Plate Chambers (RPC)

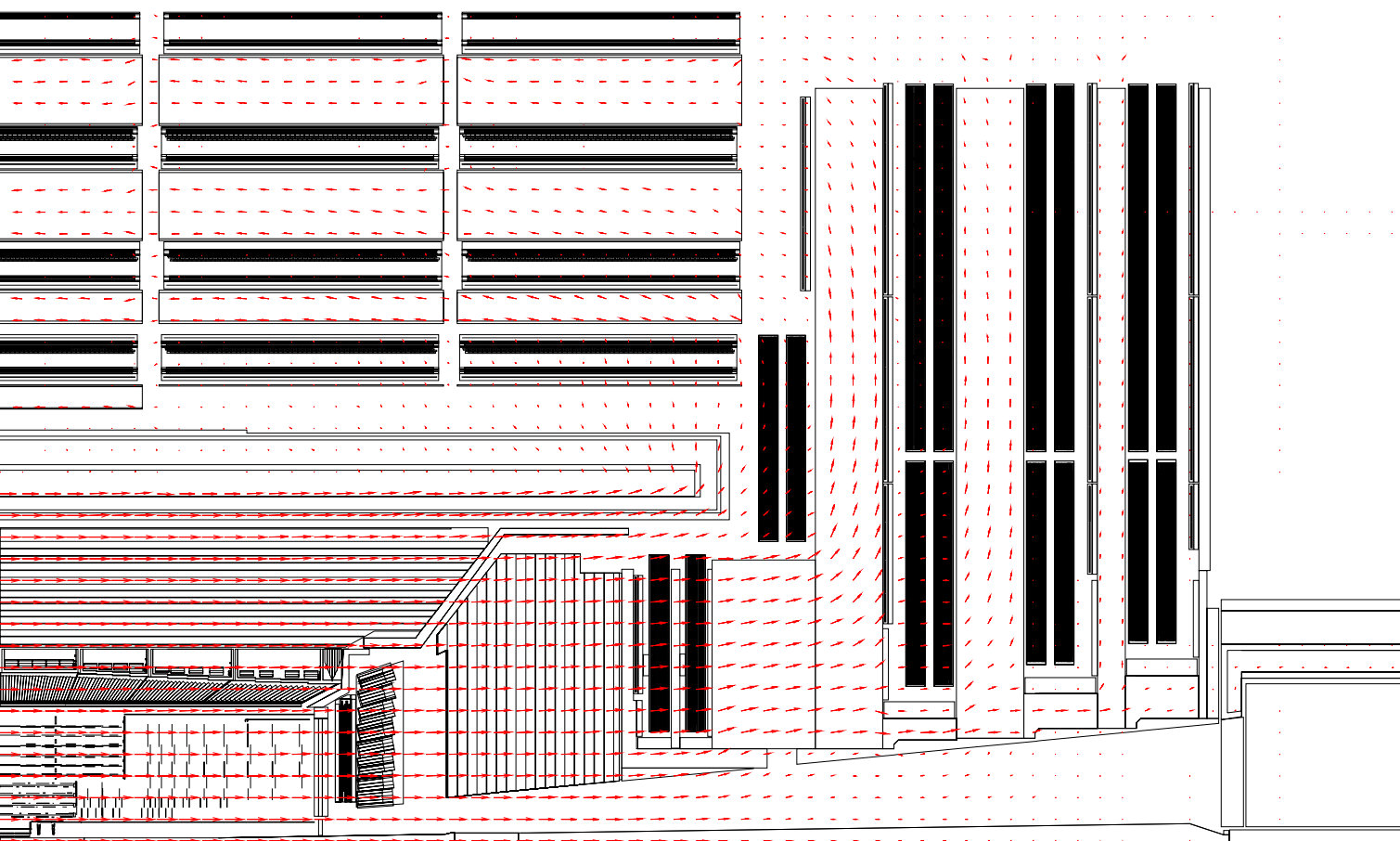
**MUON ENDCAPS**

Cathode Strip Chambers (CSC)  
Resistive Plate Chambers (RPC)

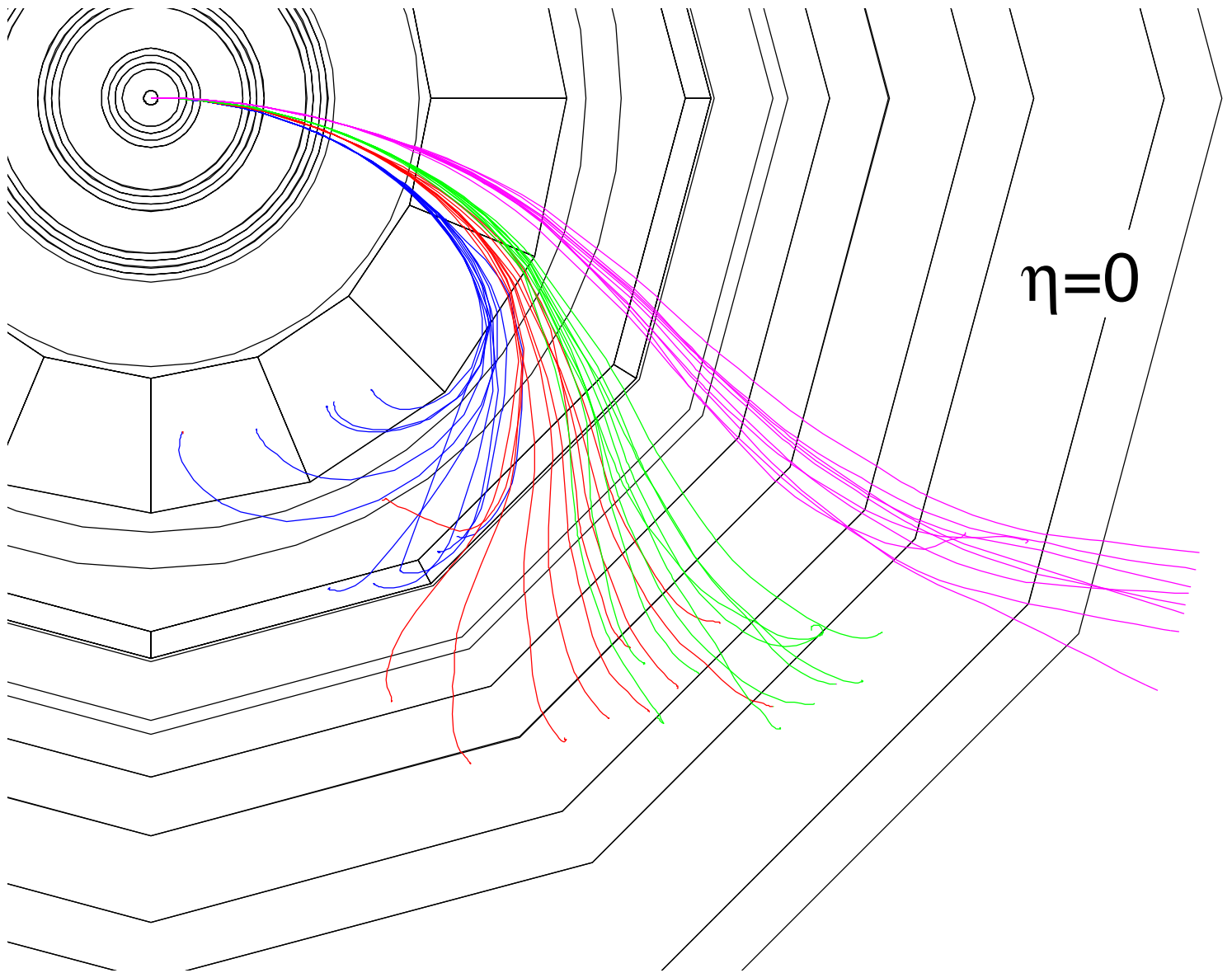


**Waga 12 500 ton**  
**Średnica 15 m**  
**Długość 22 m**  
**Pole magn. 4 Tesle**

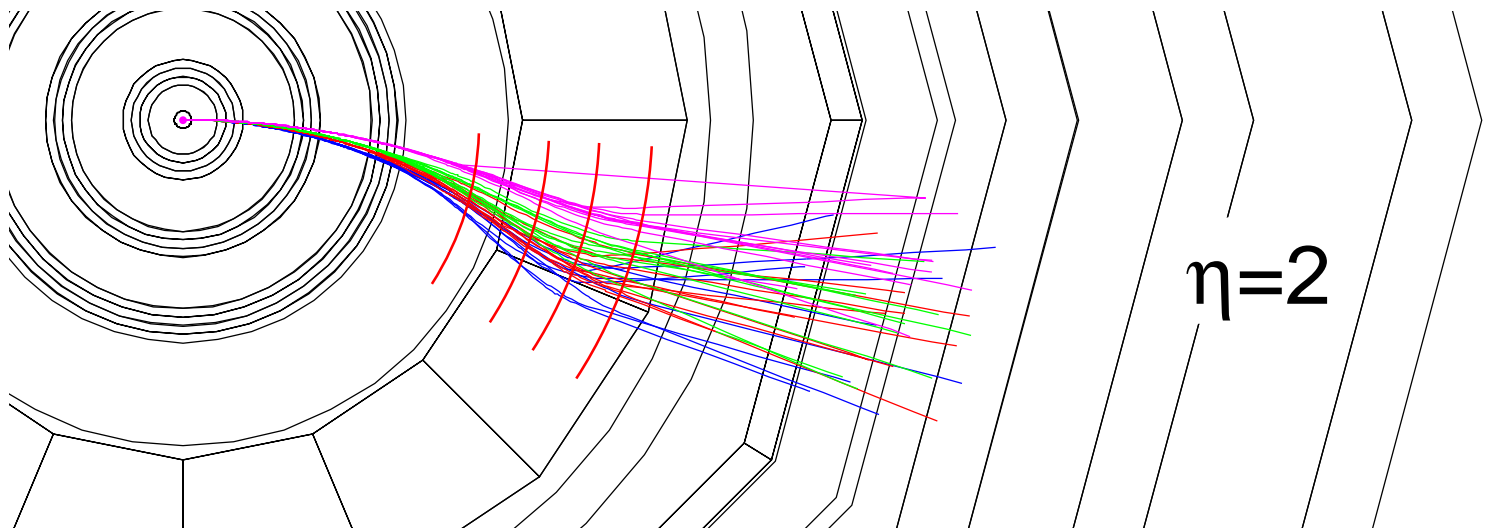
100 cm



# Muon Tracks in CMS

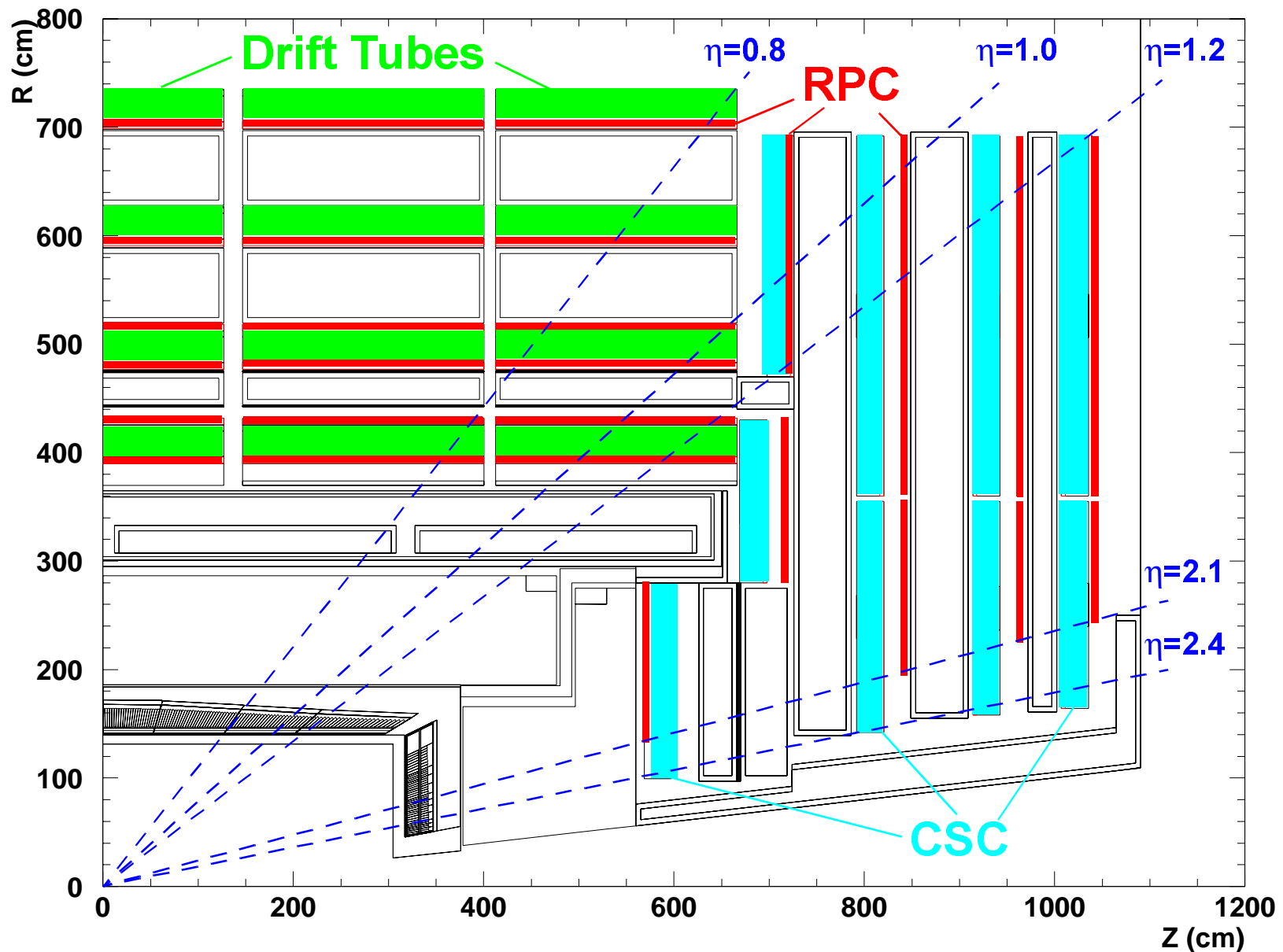


$p_t = 3.5, 4.0, 4.5, 6.0$  GeV





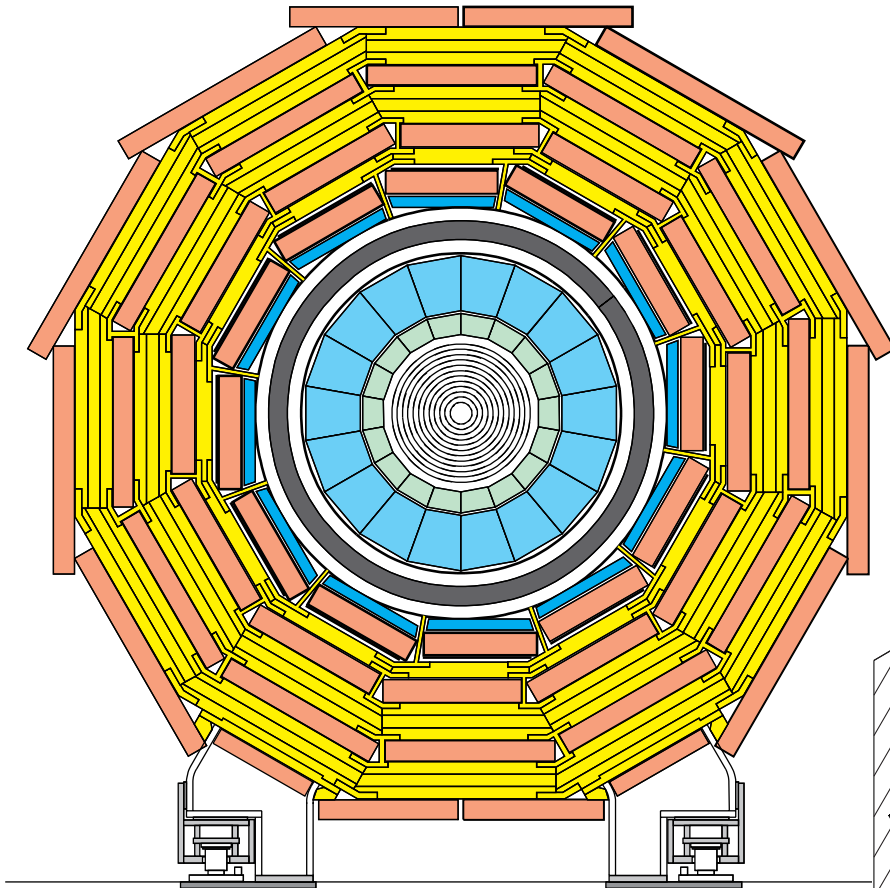
# Muon Trigger Detectors



4 stations in barrel and each endcap

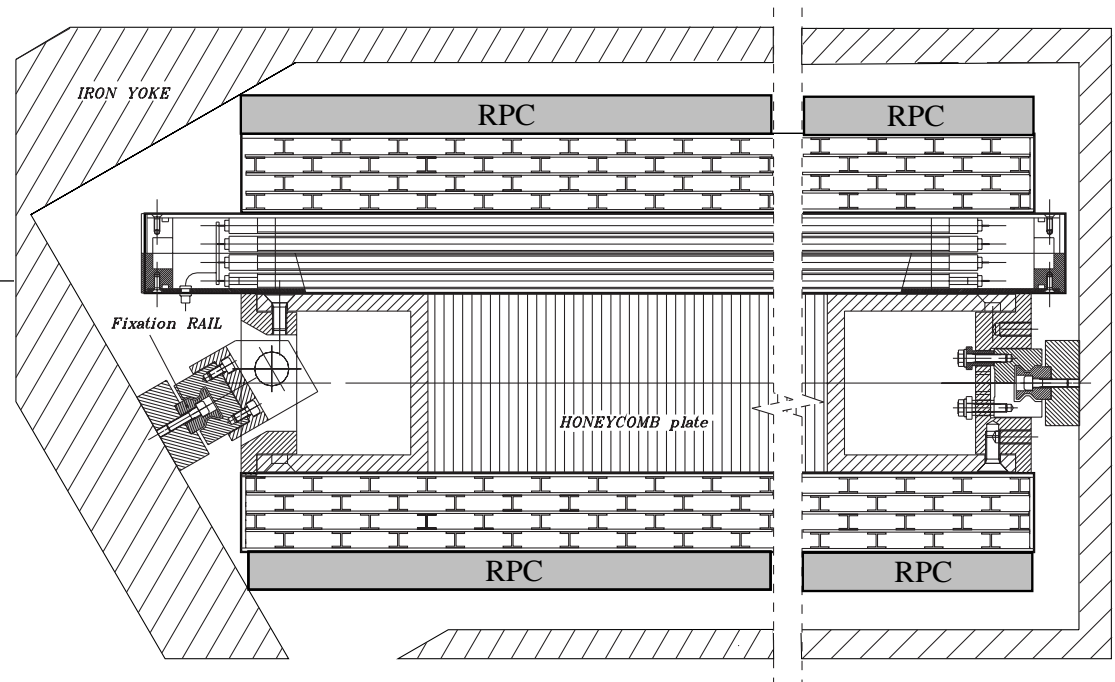


# Drift Tubes in Barrel



- MB1,2,3 = 8  $\phi$ -layers  
+ 4  $\theta$ -layers
- MB4 = 8  $\phi$ -layers
- 250 chambers
- 200 000 channels

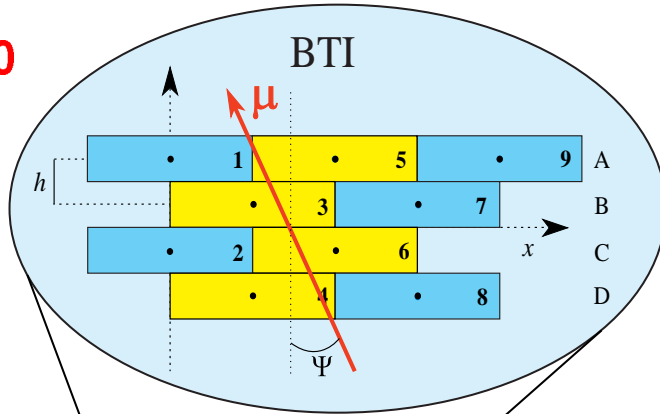
- wire pitch = 4 cm
- max. drift time = 400 ns



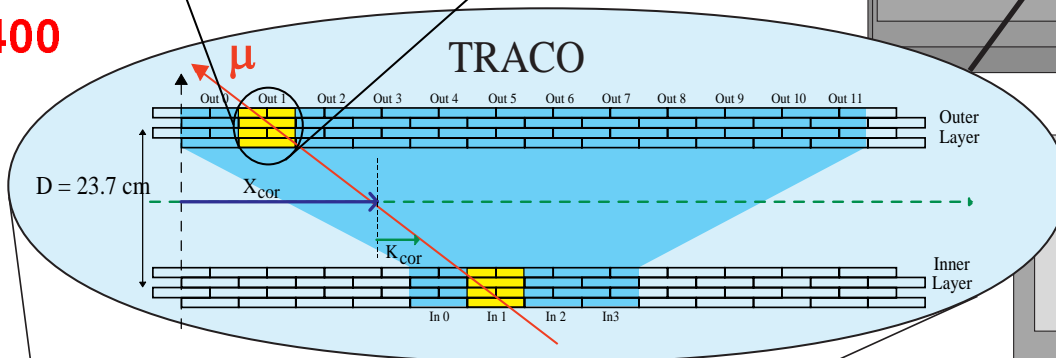


# Drift Tube Local Trigger

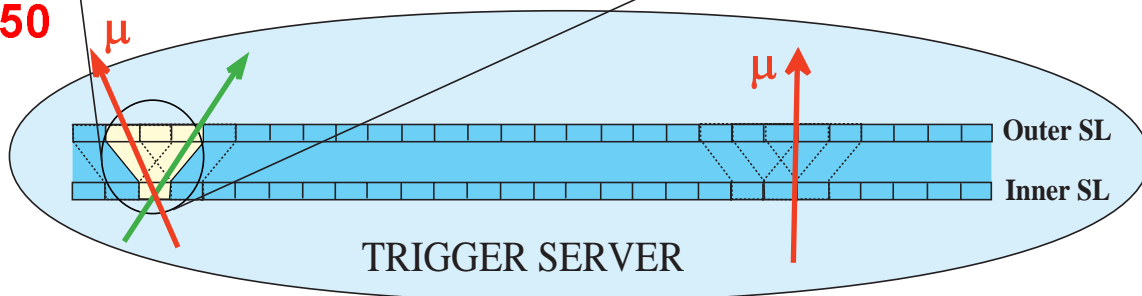
50 000



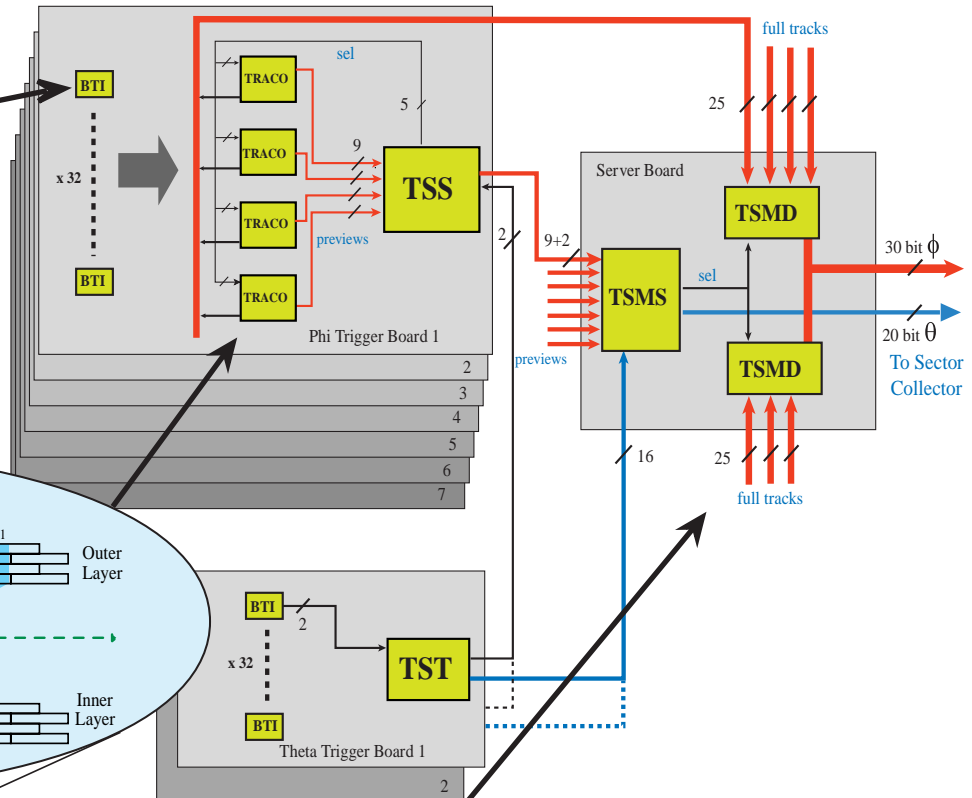
4 400



250



on chamber boards



to 60 Sector Collectors on MB4

TST = Trigger Server θ

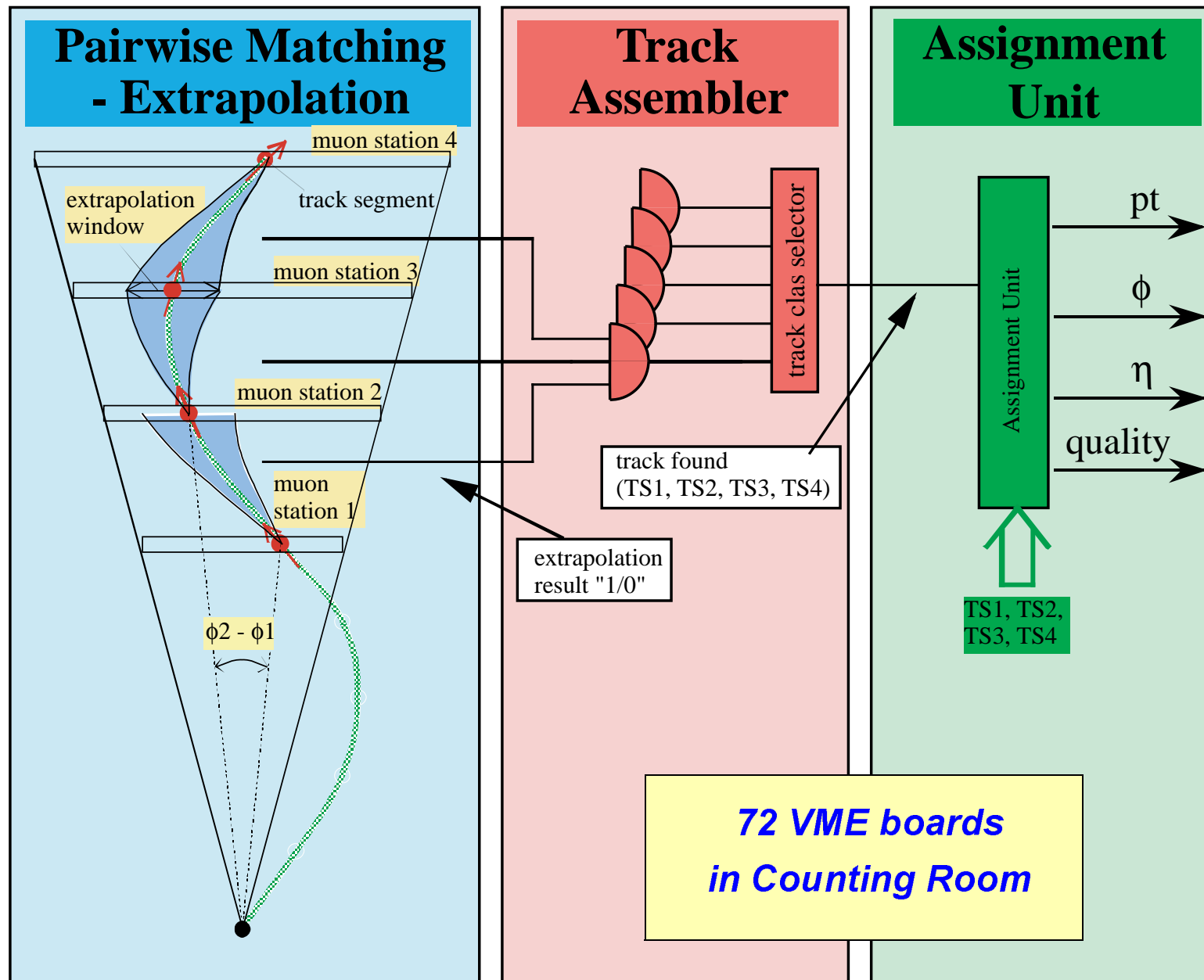
TSS = Track Sorter Slave

TSMS = Track Sorter Master (sort)

TSMD = Track Sorter Master (data)

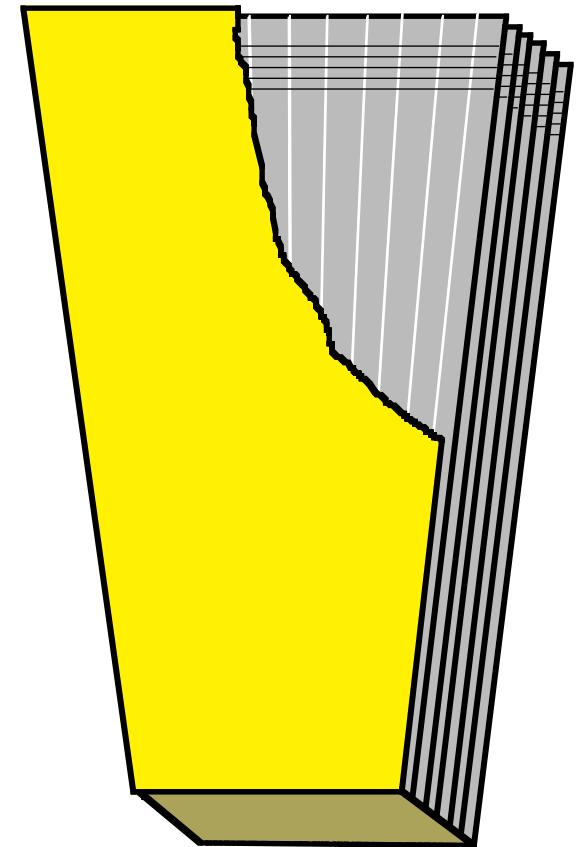
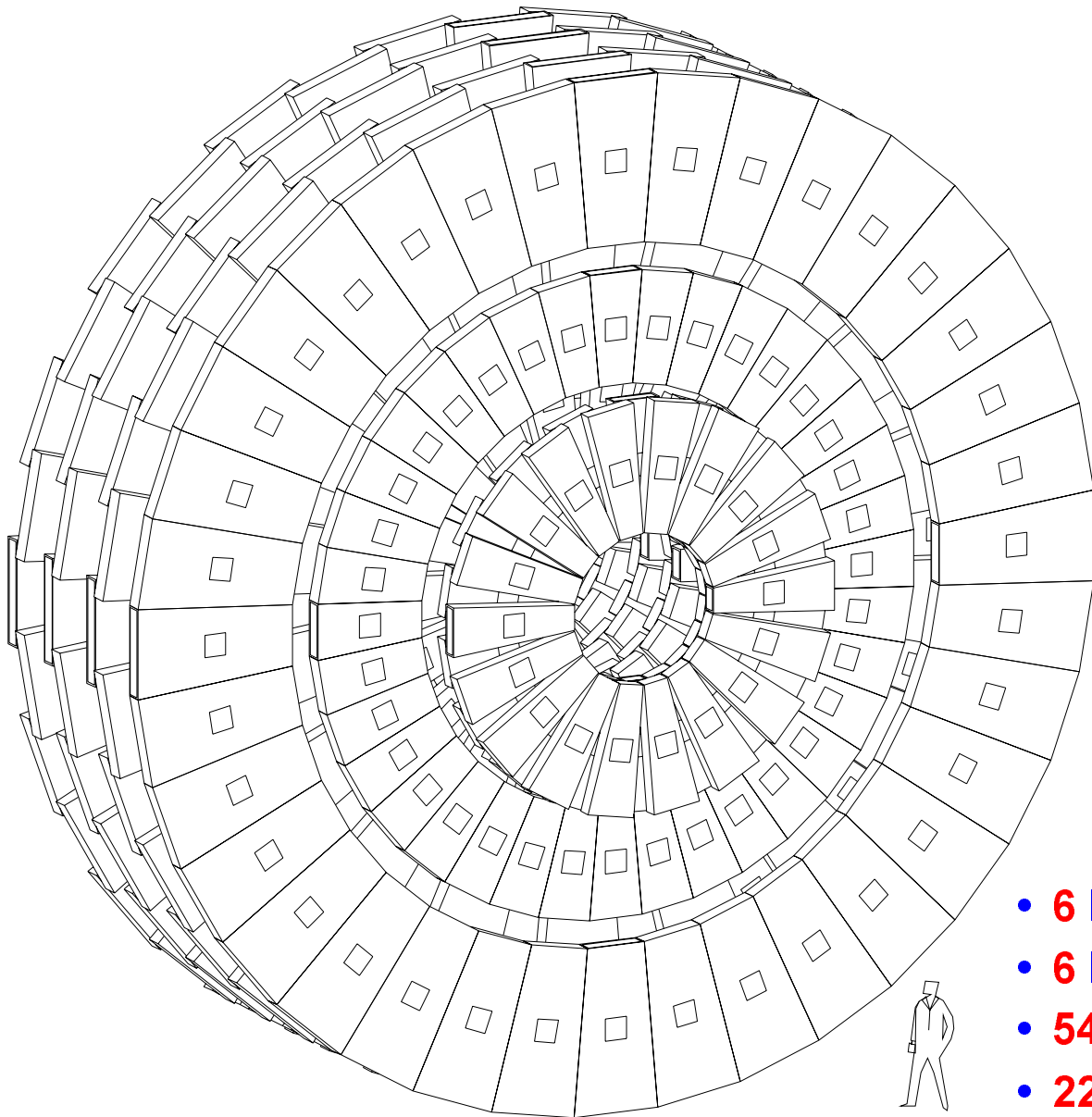


# Barrel Track Finder





# Cathode Strip Chambers in Endcaps



- **6** layers of radial strips / station
- **6** layers of tangential wires /station
- **540** chambers
- **220 000** anode strips
- **320 000** cathode wire groups

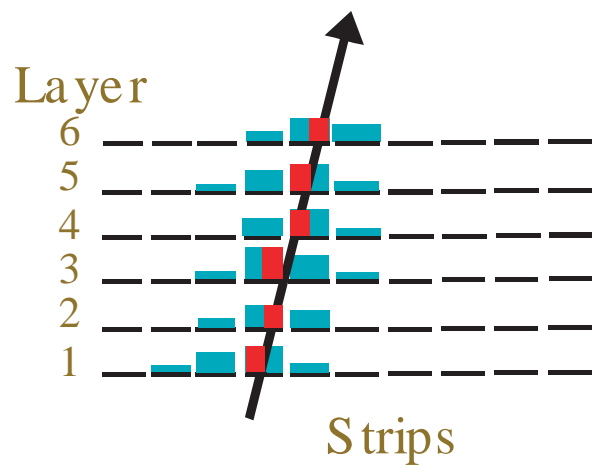


# CSC Local Trigger Algorithms

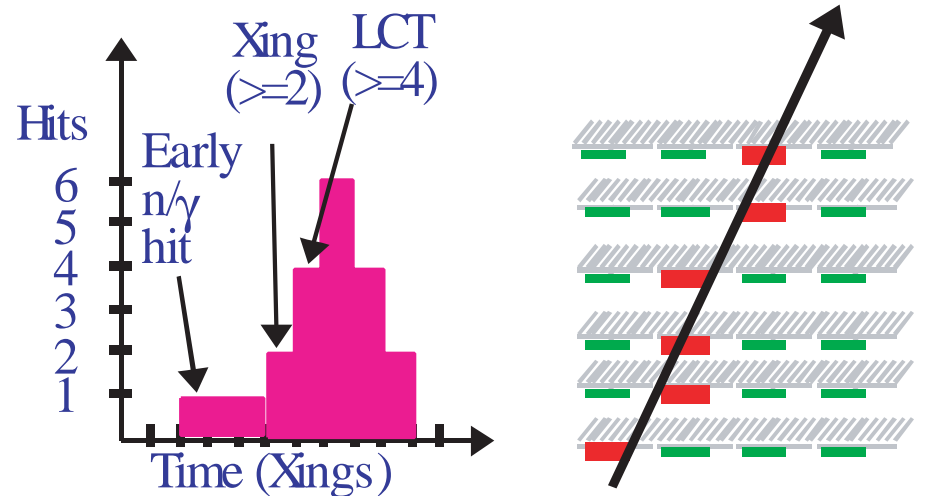
540 CLCT boards  
on disk periphery

540 ALCT boards  
on chambers

## Cathode LCT cards



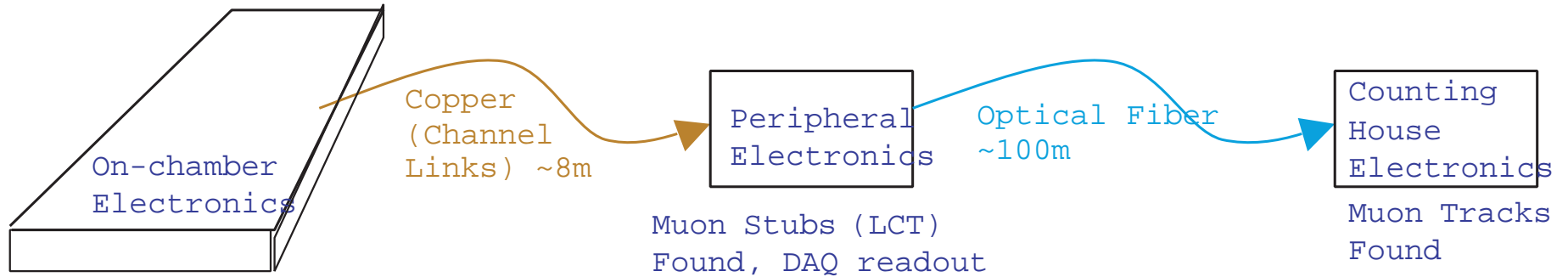
## Anode LCT cards



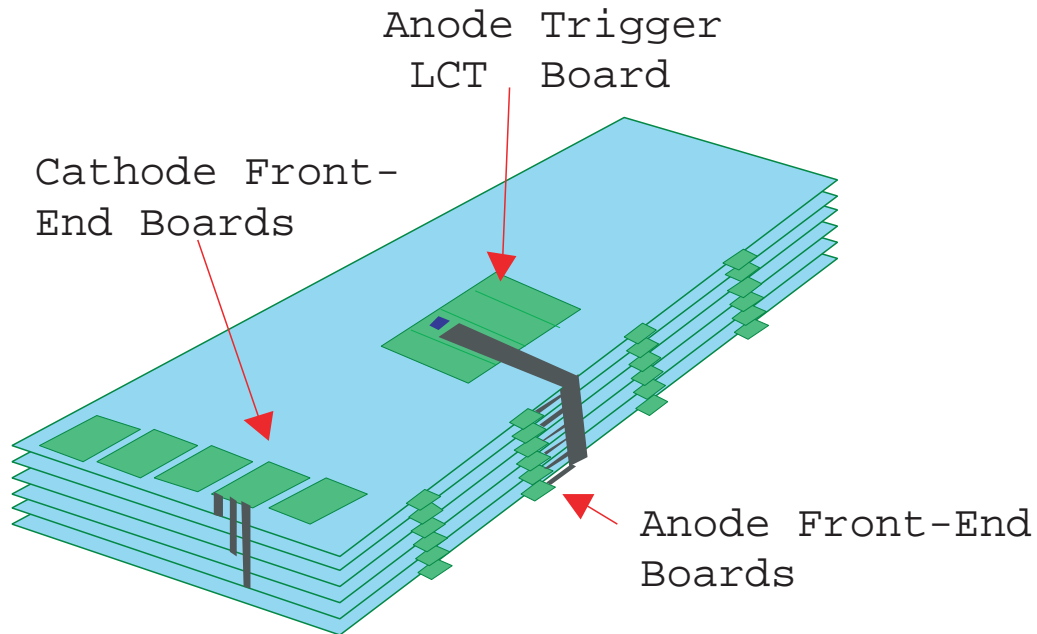
- 1/2 strip resolution by comparing charges on neighbouring strips
- Local Charge Track (LCT) recognition by coincidence of 4/6 layers
- BX identified by 2nd anode hit



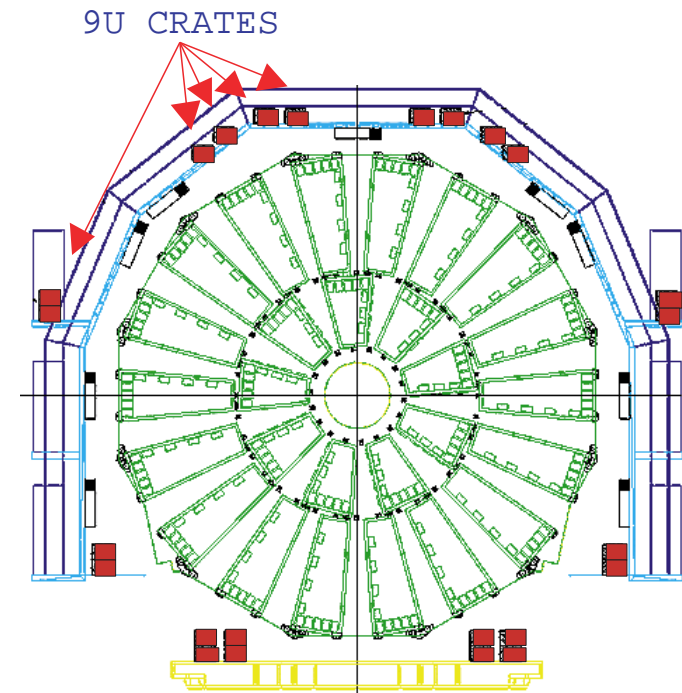
# CSC Trigger Electronic Layout



## On-Chamber Electronics



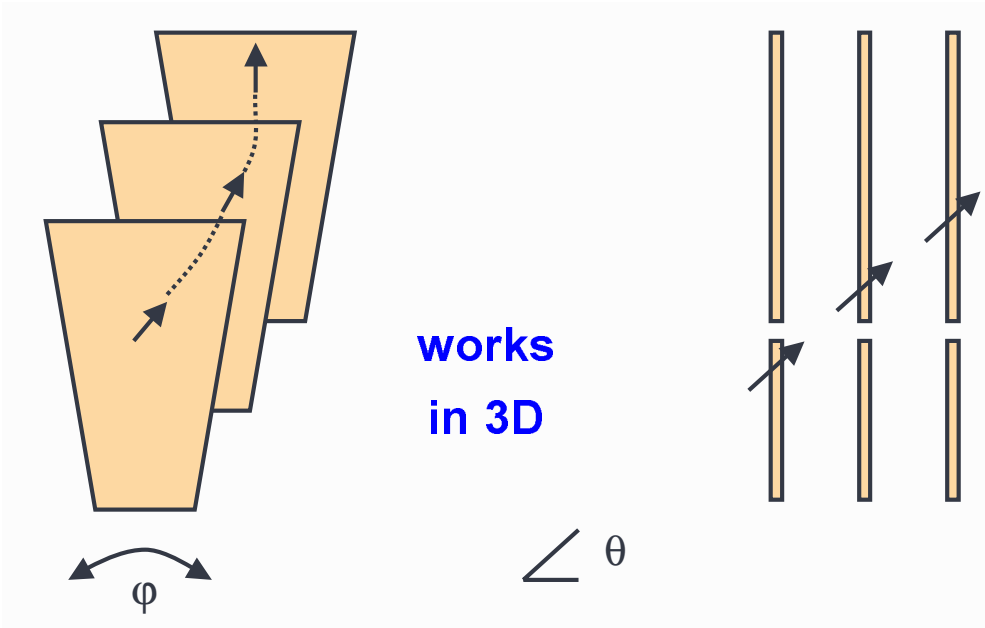
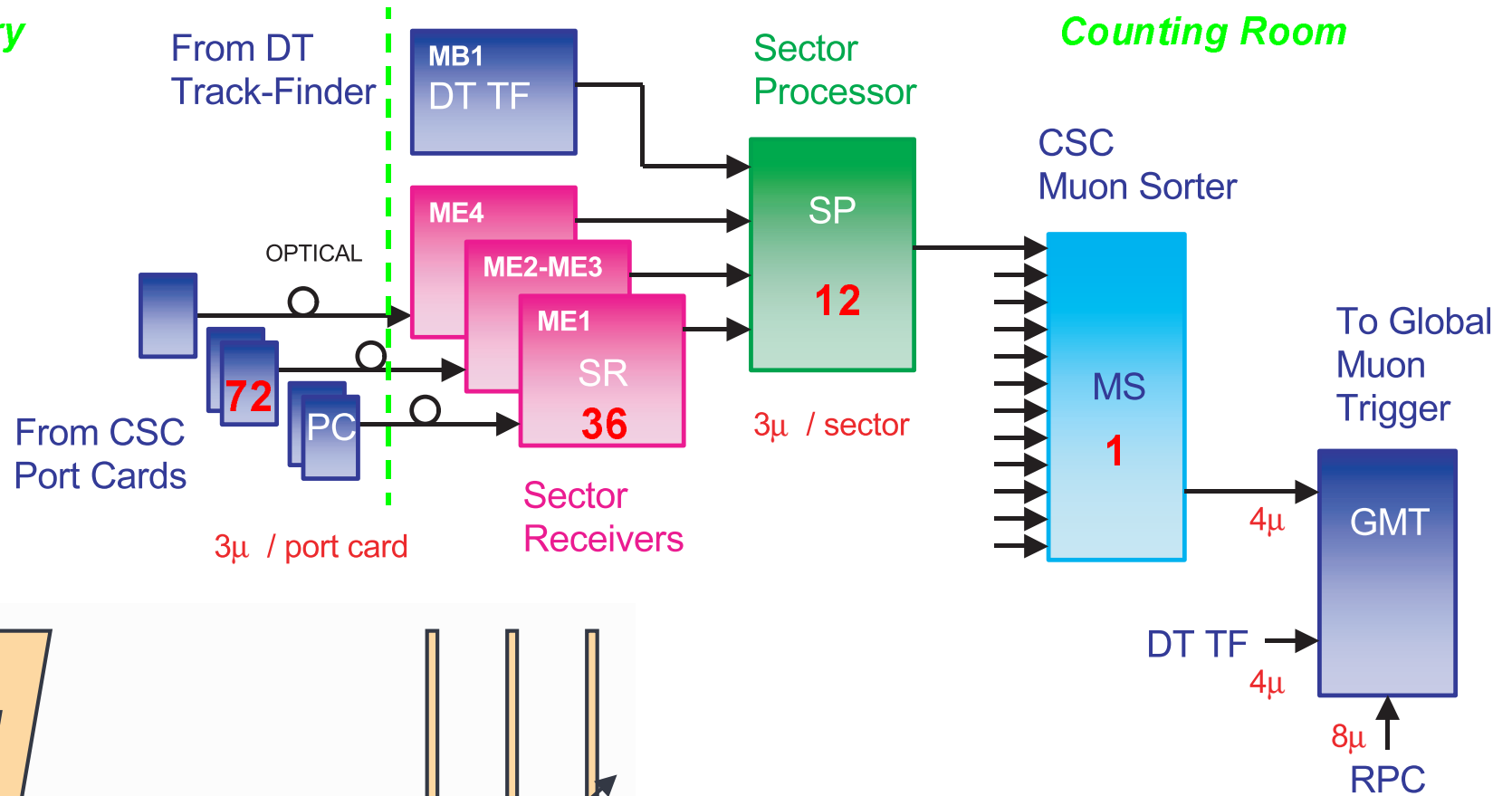
## Peripheral Crates





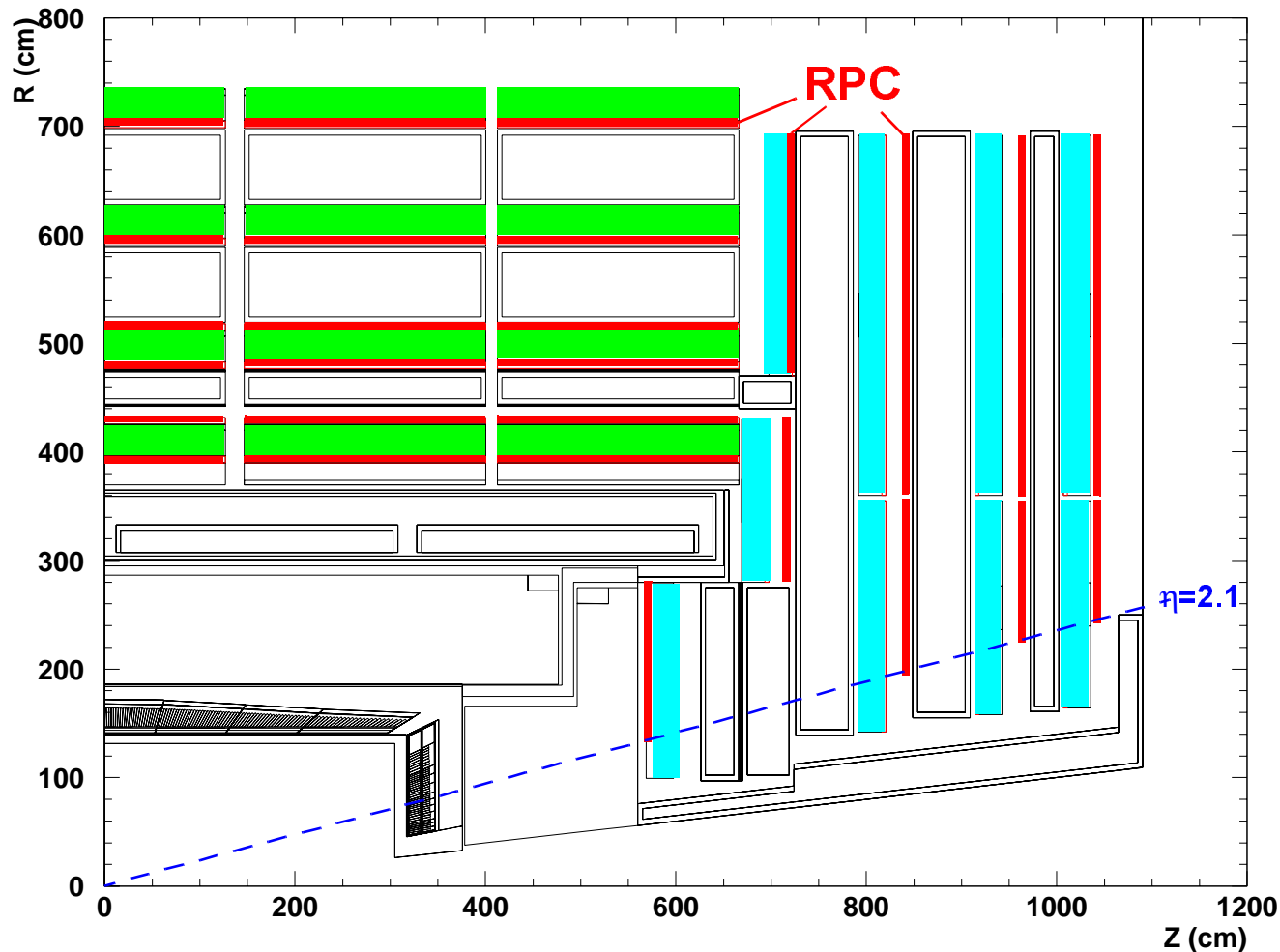
# Endcap Track Finder

disk periphery





# Resistive Plate Chambers



## Barrel RPC:

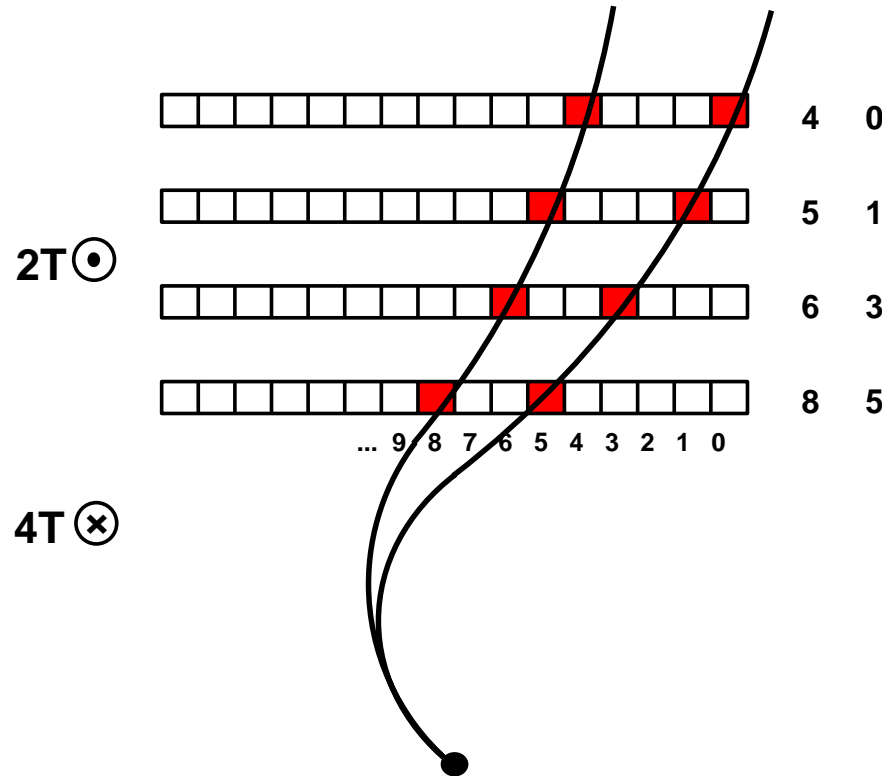
- RB 1,2 = 2 layers
- RB 3,4 = 1 layer
- 480 rectangular chambers
- 75 000 strips || beam

## Endcap RPC:

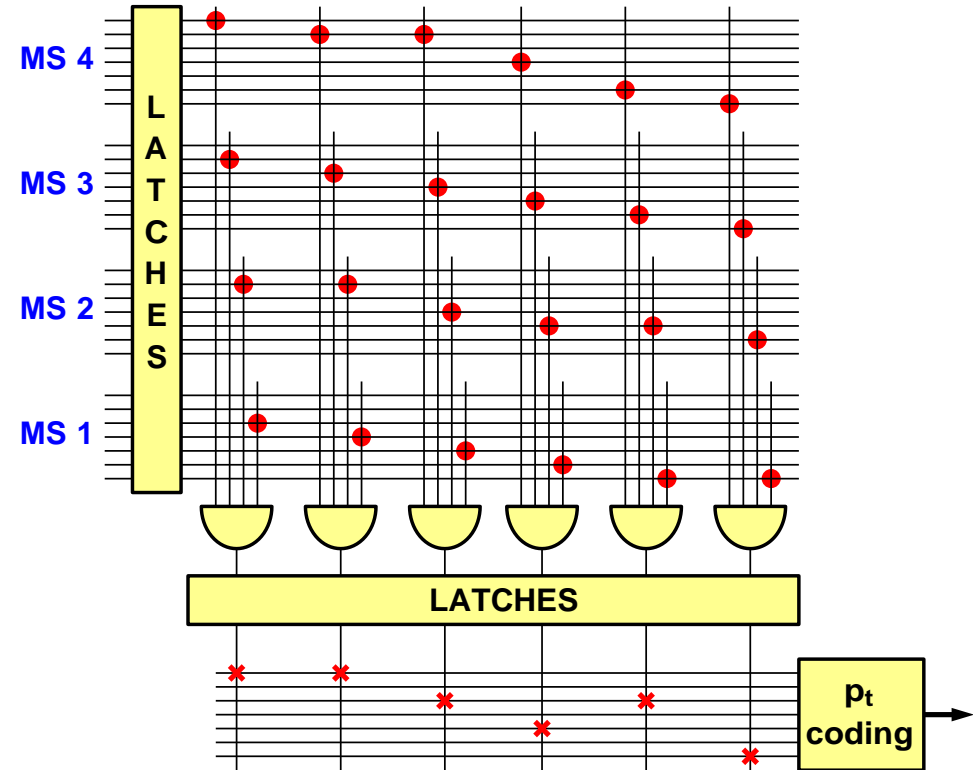
- RE 1,2,3,4 = 1 layers
- 540 trapezoidal chambers
- 80 000 radial strips



# RPC Trigger Algorithm



Pattern of hit strips is compared to predefined patterns corresponding to various  $p_T$

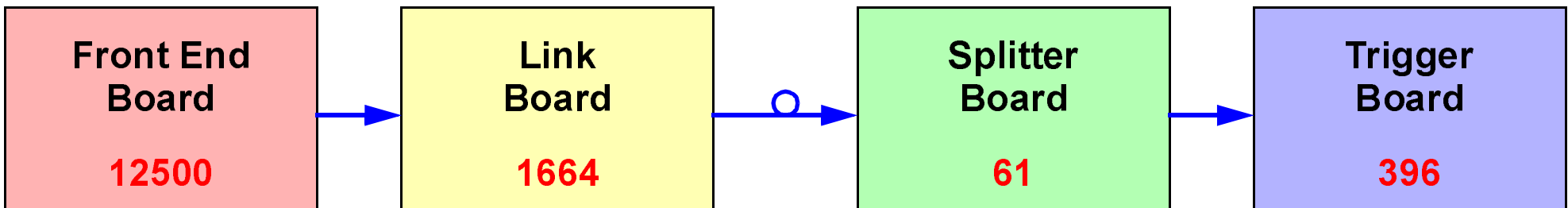
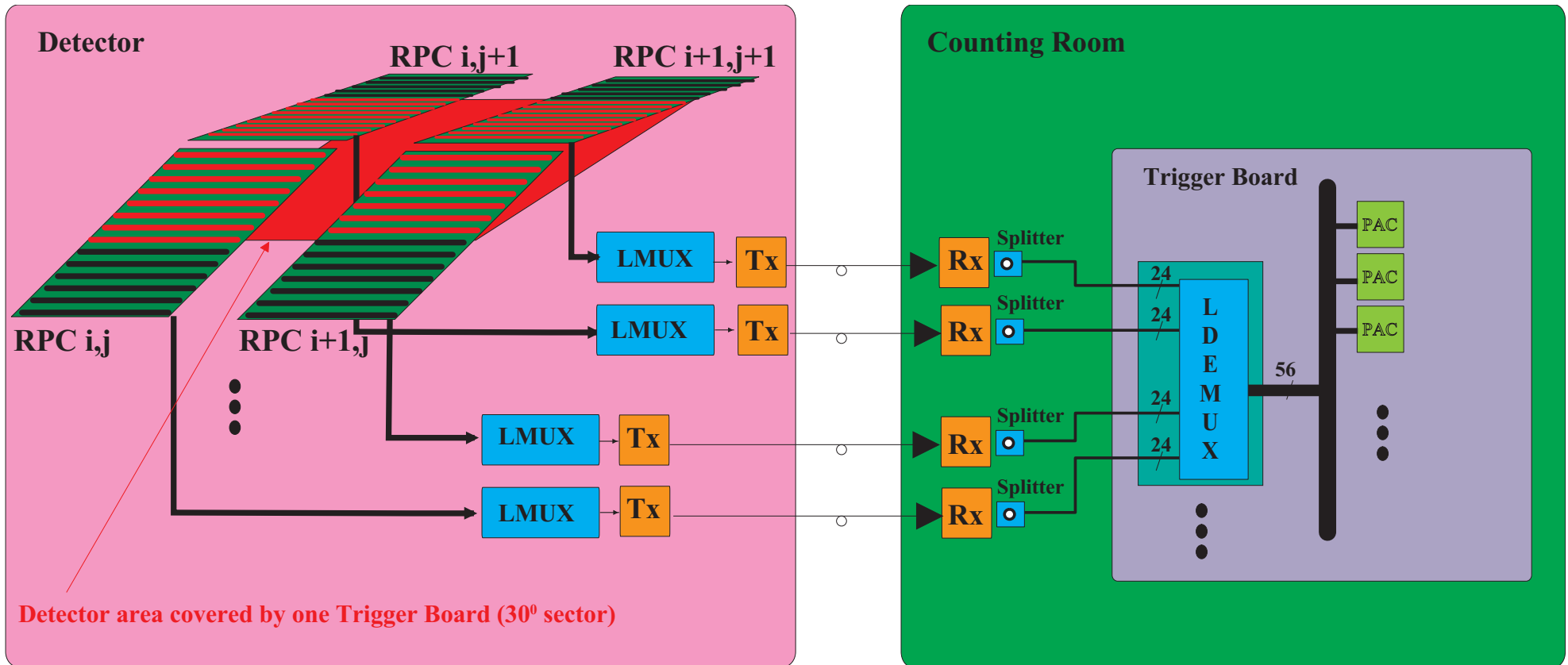


PAttern Comparator (PAC) ASIC

4752 ASICs in Counting Room

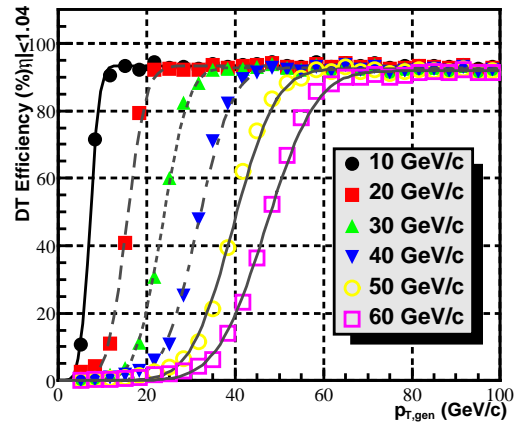


# RPC Trigger Block Diagram

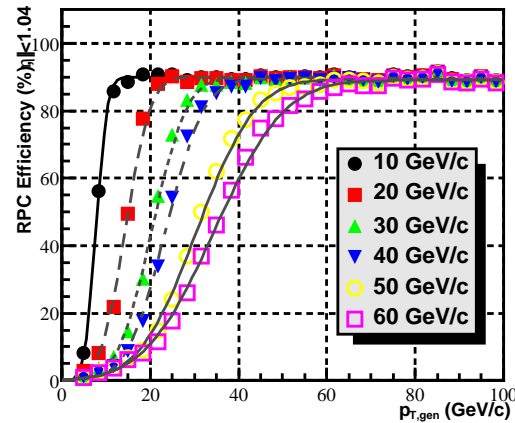


# Turn-on curves

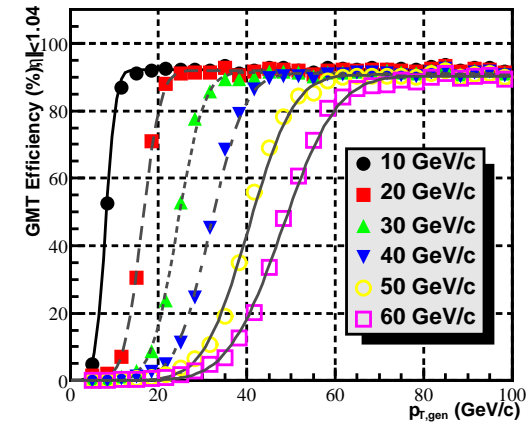
**DTBX**



**brRPC**

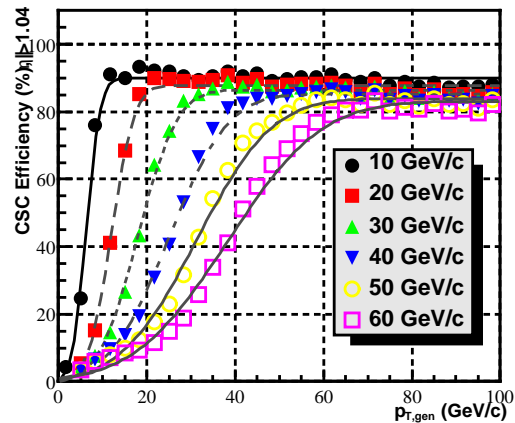


**brGMT**

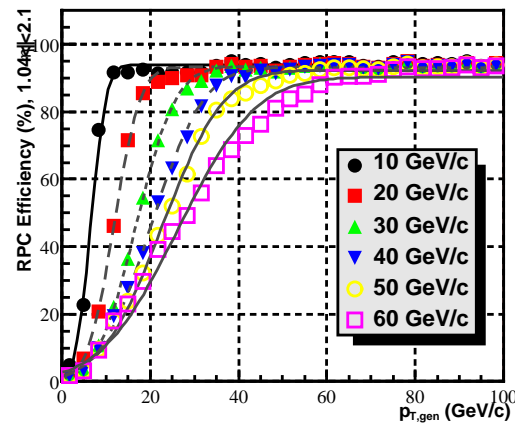


barrel

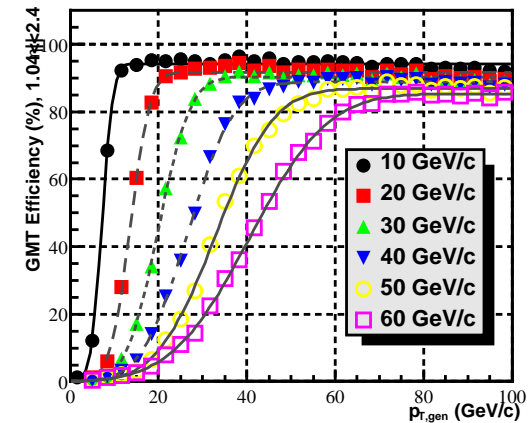
**CSC**



**fwdRPC**



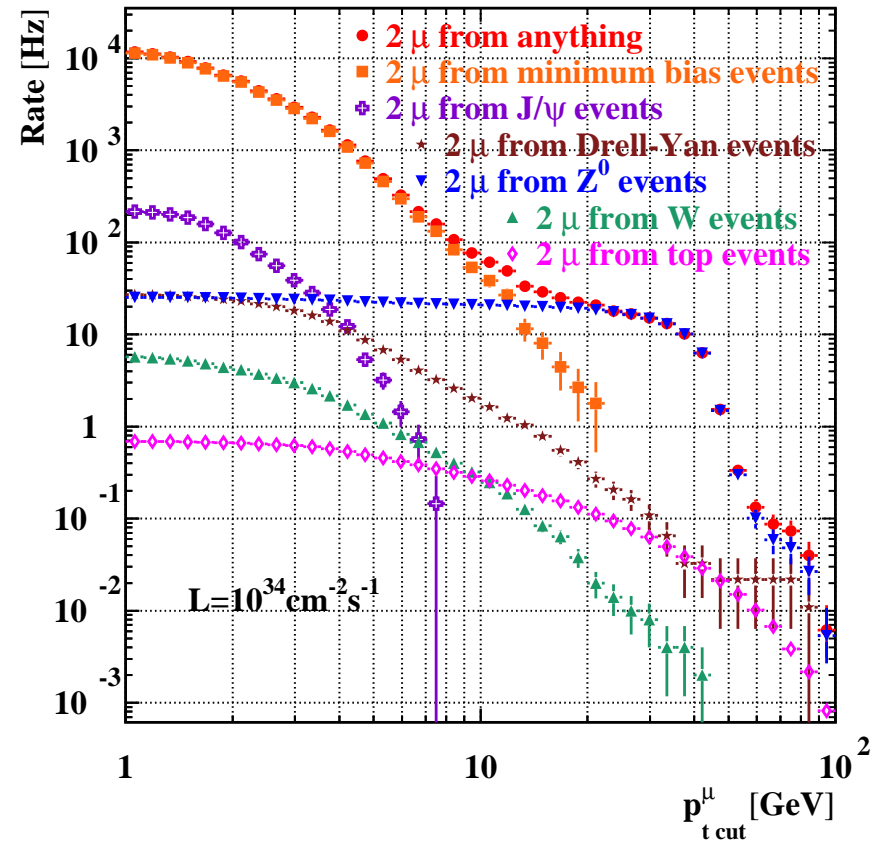
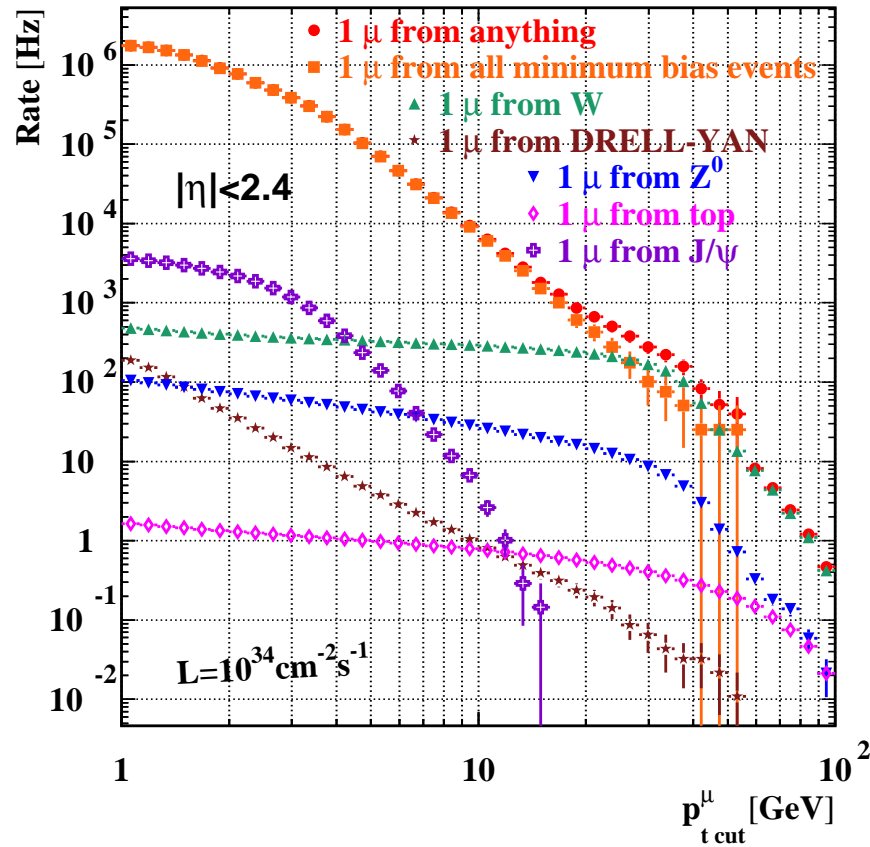
**fwdGMT**



endcap

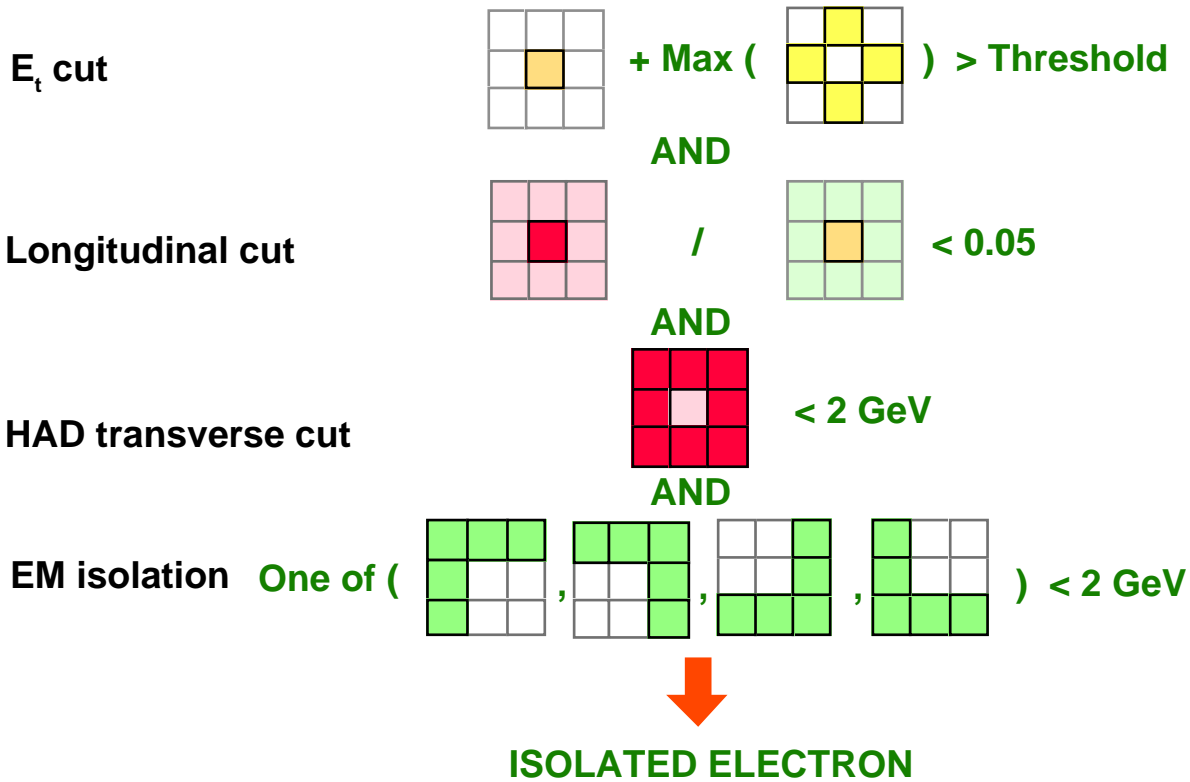
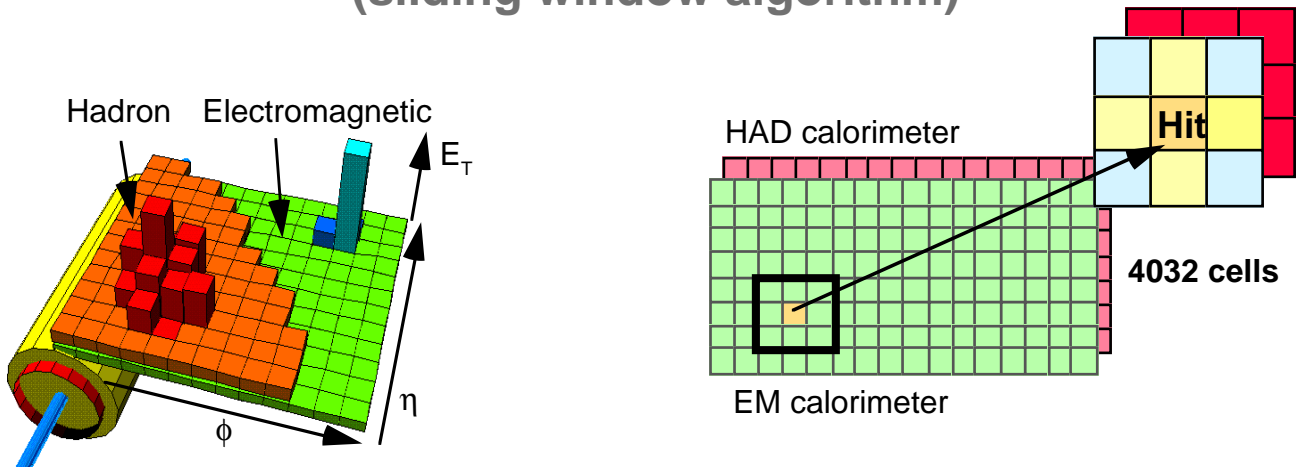


# Single- and two-muon rates

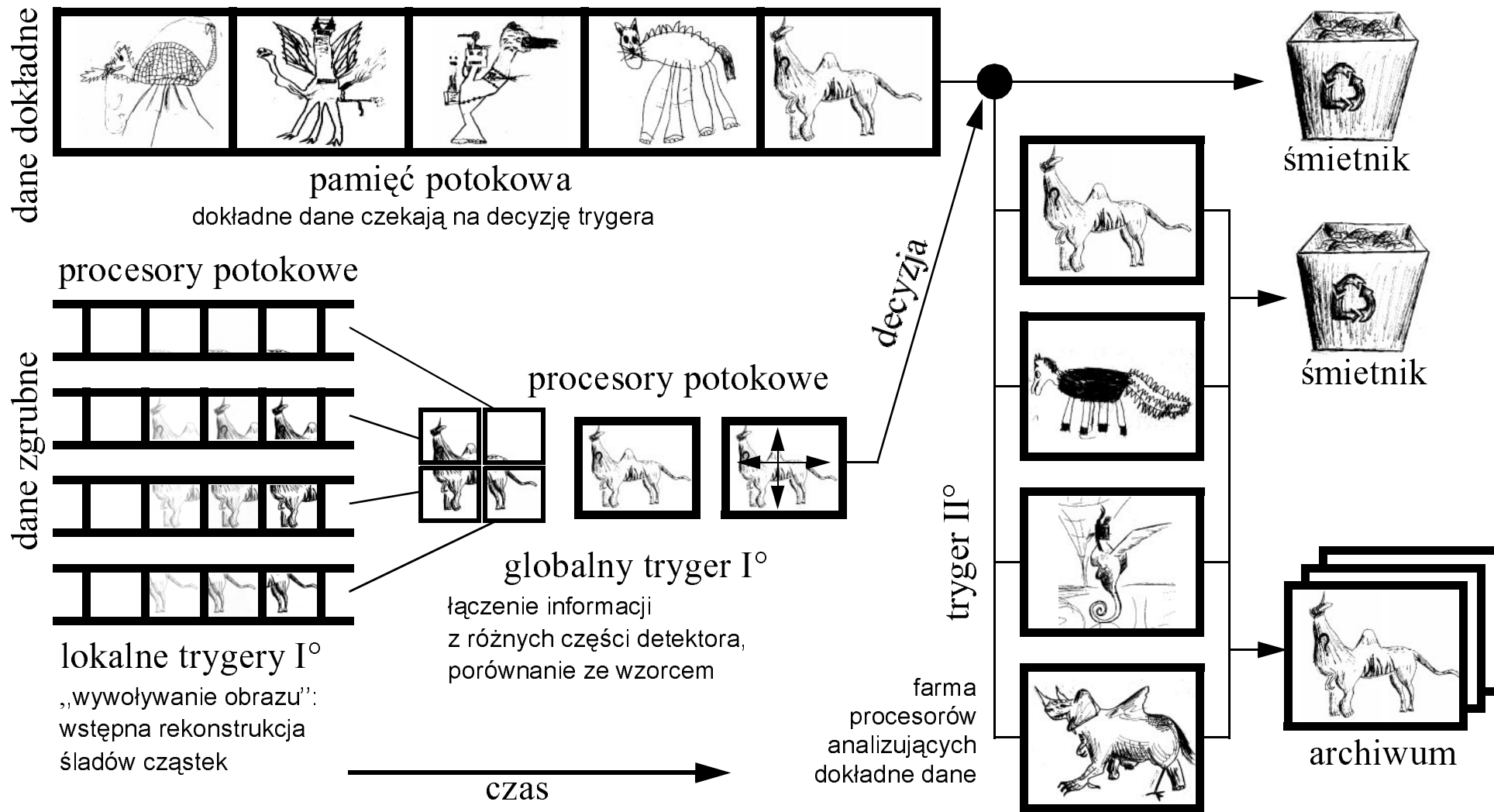


# CMS calorimeter level-1. Isolated electron

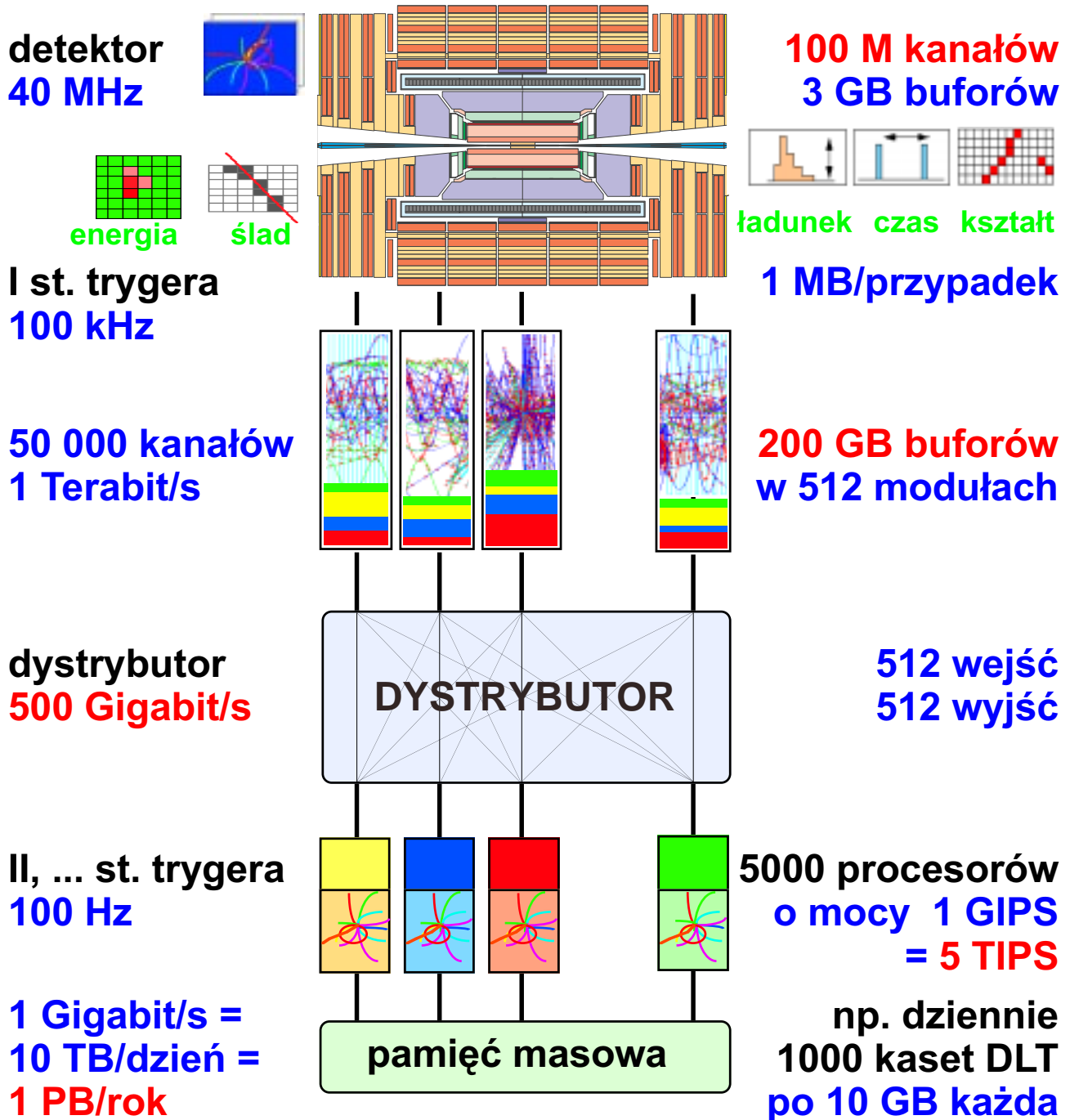
(sliding window algorithm)



Trigger granularity ( $D_h * D_f$ )		No. of trigger towers
ECAL : $ h  \leq 2.1$	$0.087 * 0.087$	$56 * 72 = 4032$
$ h  > 2.1$	$0.174 * 0.087$	as ECAL
HCAL :	as ECAL	162



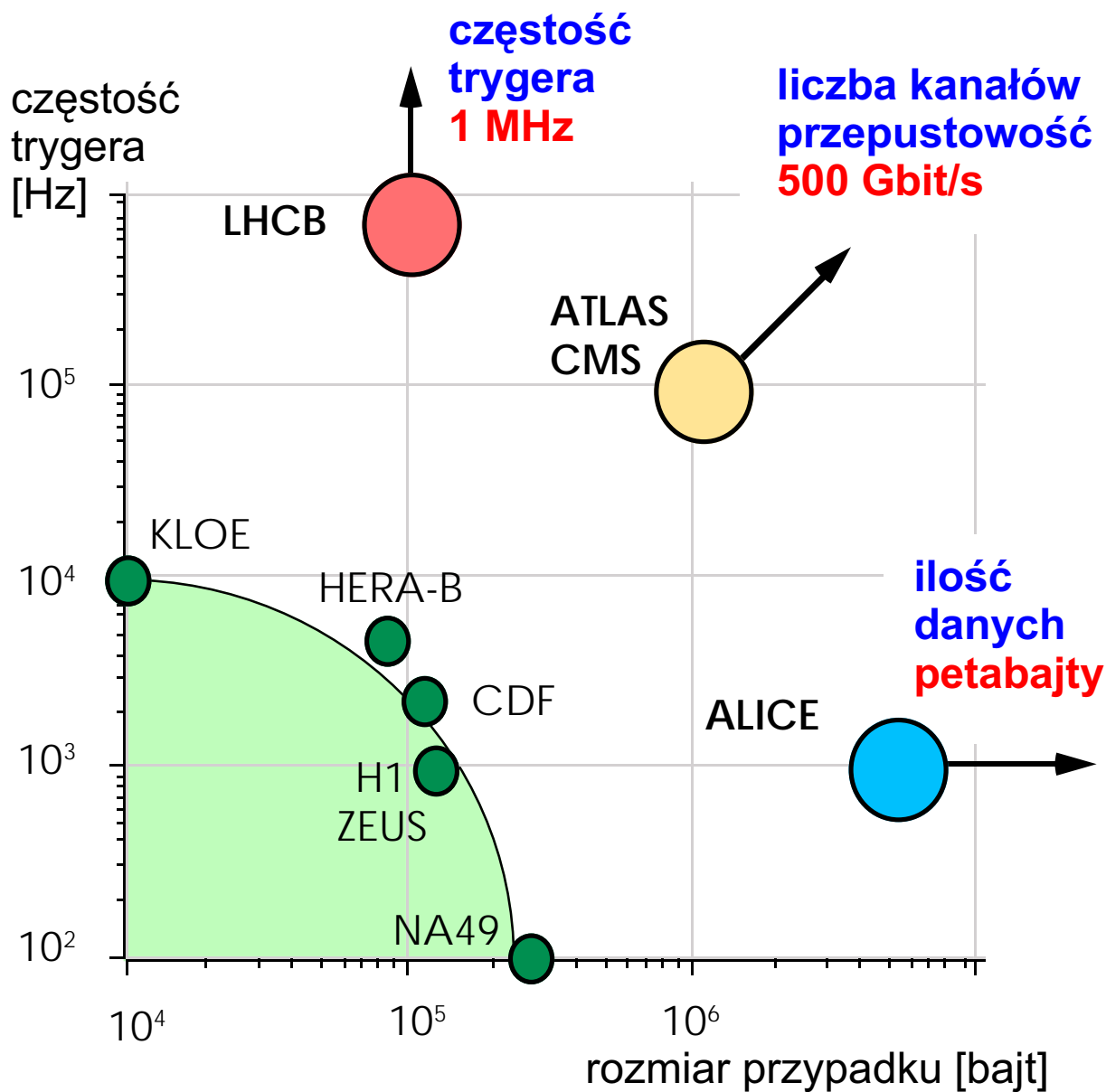
# Przeptyw danych w CMS



1 TB = 1 terabajt =  $10^{12}$  bajtów  
 1 PB = 1 petabajt =  $10^{15}$  bajtów

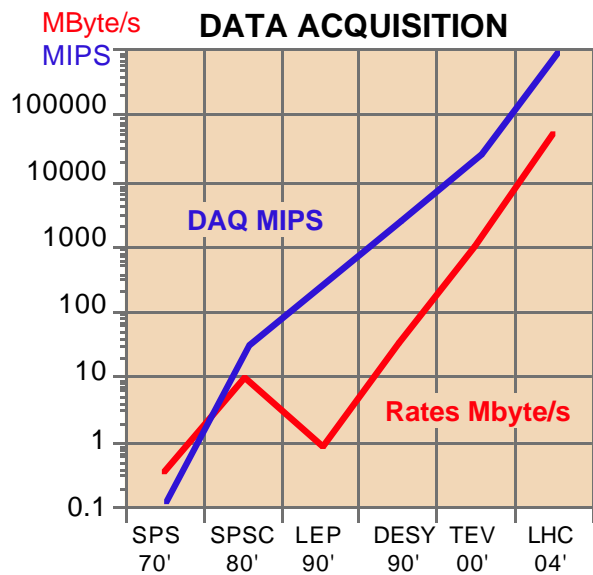
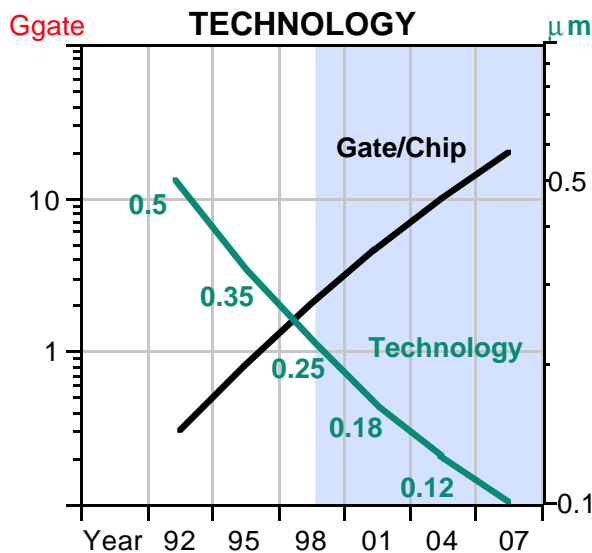
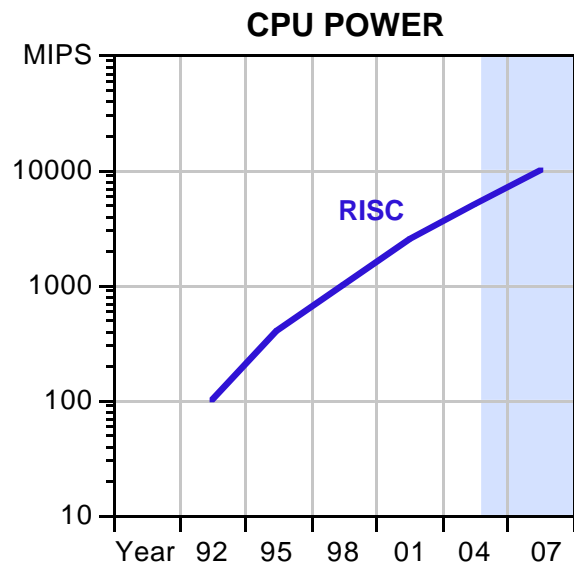
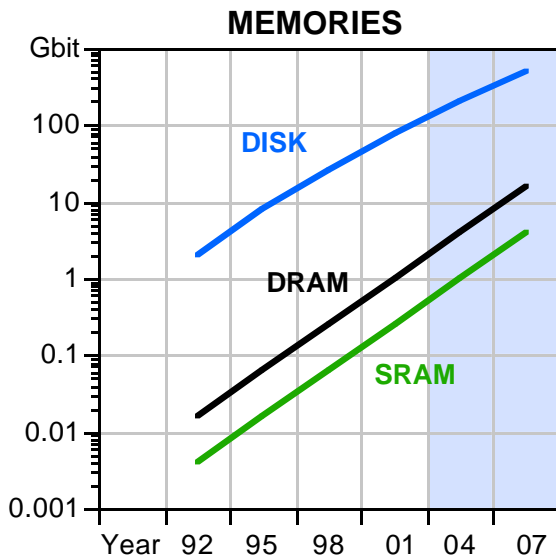
1 GIPS =  $10^9$  instrukcji/s  
 1 TIPS =  $10^{12}$  instrukcji/s

# Ewolucja systemów zbierania danych



Ilość danych przepływających przez system odczytu CMS w ciągu 5 minut pracy LHC jest porównywalna z całością danych przesyłanych przez wszystkie sieci w CERNie w ciągu całego 1995 roku.

# Rozwój technologii



**Moc obliczeniowa procesorów wzrasta 10 razy co 5 lat**

**Pojemność pamięci wzrasta 4 razy co 2 lata**

**Cała moc obliczeniowa CERNu w 1980 roku była mniejsza niż jednego współczesnego komputera osobistego.**