LVL1 Muon trigger

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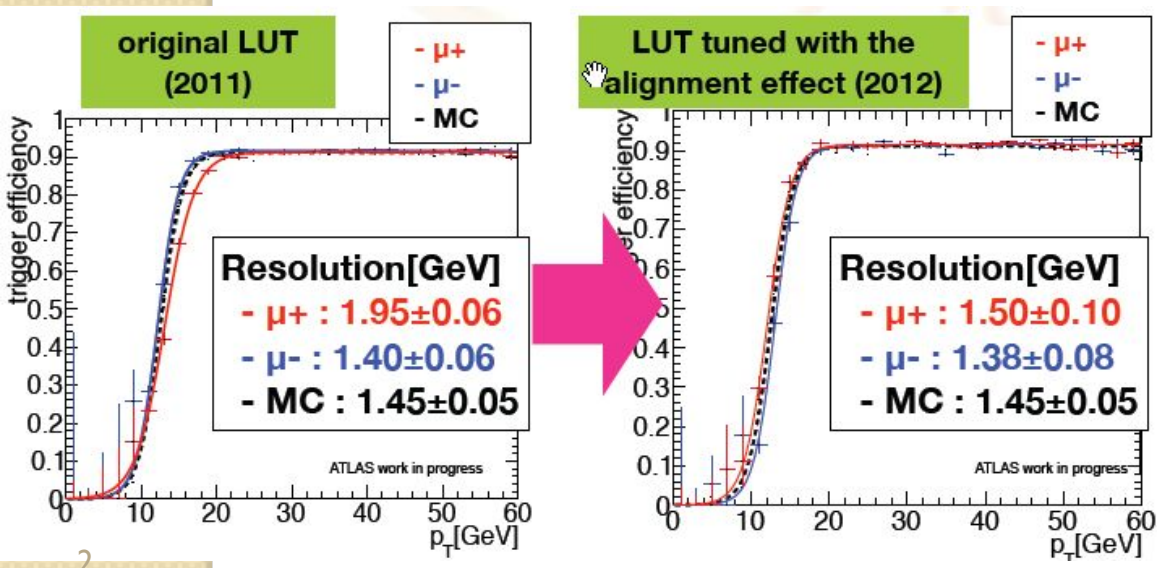
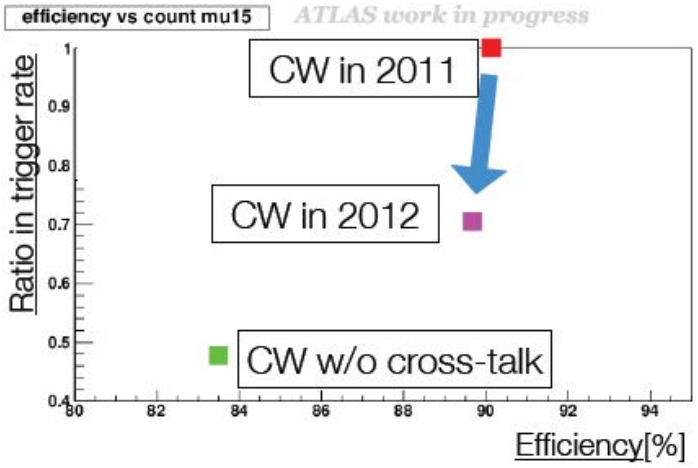
- Status in RUN1
- Plan for RUN2 (Phase-0 upgrade)
  - LVL1 using Inner Statton
  - LVL1 using Tilecal
- Plan for Phase-1 Upgrade
  - LVL1using New Small Wheel
- Plan for Phase-2 Upgrade
  - LVL1 using MDT

Lvl1_μ in 2012

- L1_μ15 = 7K[Hz] @ 0.7×10^{34}
- L1_μ20 = 6K[Hz] @ 0.7×10^{34}
  - CW improvements
    - Cross-talk effects → rate reduction
    - Alignment → better resolution

Primary





LvlI in RUN2

L1_μ20 = 6K[Hz] @0.7x10^{34}

@ 2x10^{34} , 25ns , 13TeV
6kHz x [2.0/0.7] x 1.4 x 1.6
= 38K[Hz]

Need
~30% reduction

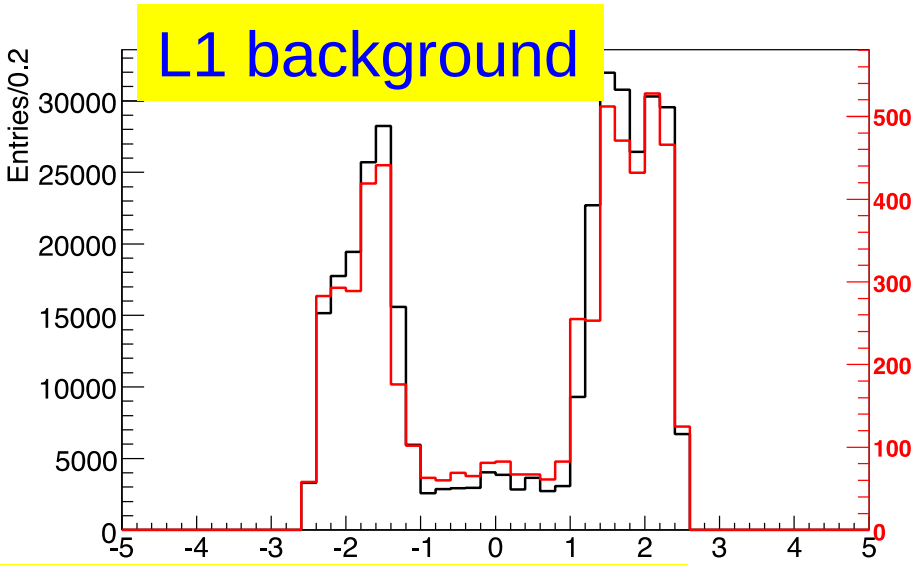
L1 Menu for 2x10^{34}

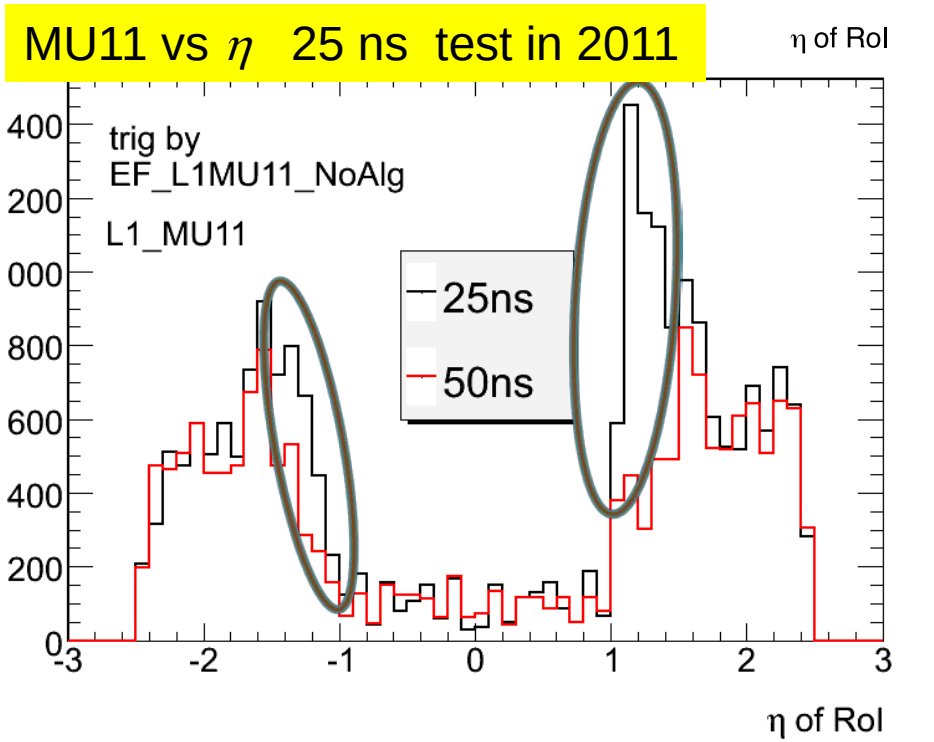
L1 Item	Offline pT	Predicted Rate/kHz
EM28H	33	28.0
EM50	60	8.6
2EM15H	2x20	8.8
MU20	25	25.6
2MU11	2x13	4.3
EM15H_MU10	20,12	2.0
2EM8H_MU10	2x12,12	0.9
EM8H_2MU6	12,2x8	0.6
TAU60	150	10.2
2TAU30_TAU40	100,80	9.4
2TAU15I_3J15	2x40,50(jet)	8.7
2TAU15I_EM15H_3J15	40,20,50(jet)	4.9
TAU15I_MU10	40,15	4.6
TAU20I_XE40_3J15	50,90,50(jet)	1.3
J100	250	4.9
4J20	Nx60	1.6
J75_XE40	200,150	4.7
XE60	190	1.2
Others	topo?	~5
Totals		90.0

25KHz

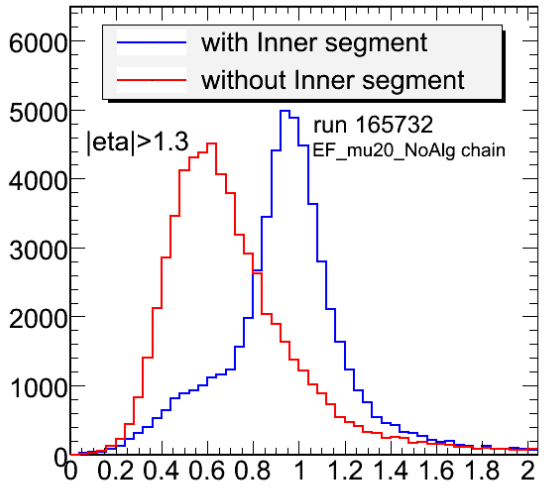
Origin of trigger

- Endcap trigger dominates
  - ~ 6-7x higher in Endcap than in the barrel
- Out of time background
  - Additional background (+40%) In η = 1.0 – 1.5





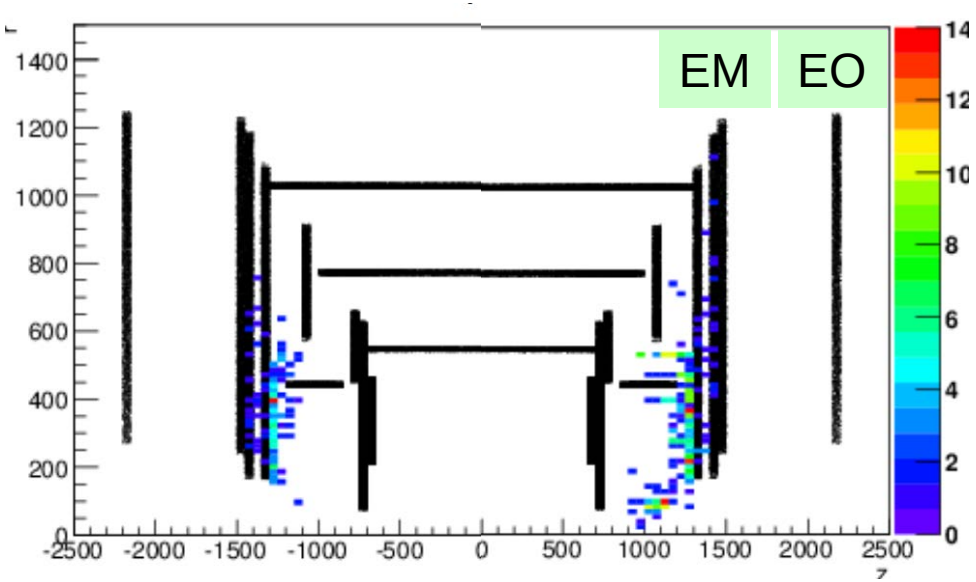
Fake Trigger by slow protons



Slow particles ! β

Protons produced in/after the EC toroid
No hits in Inner Station

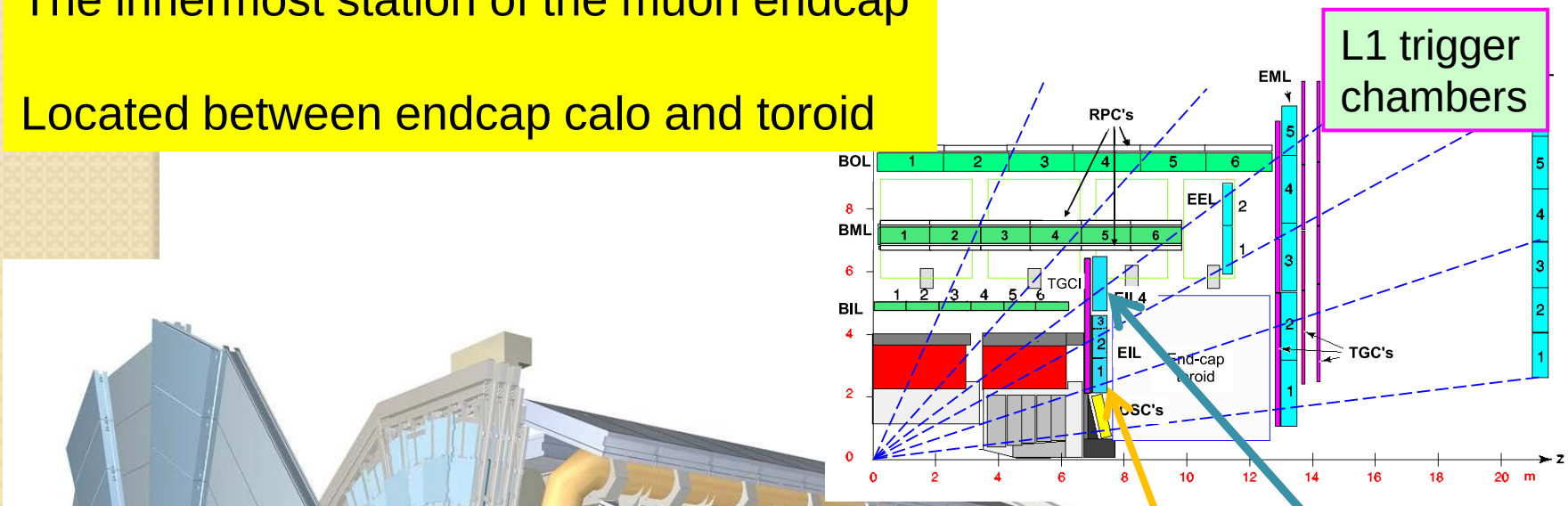
FLUGG MC

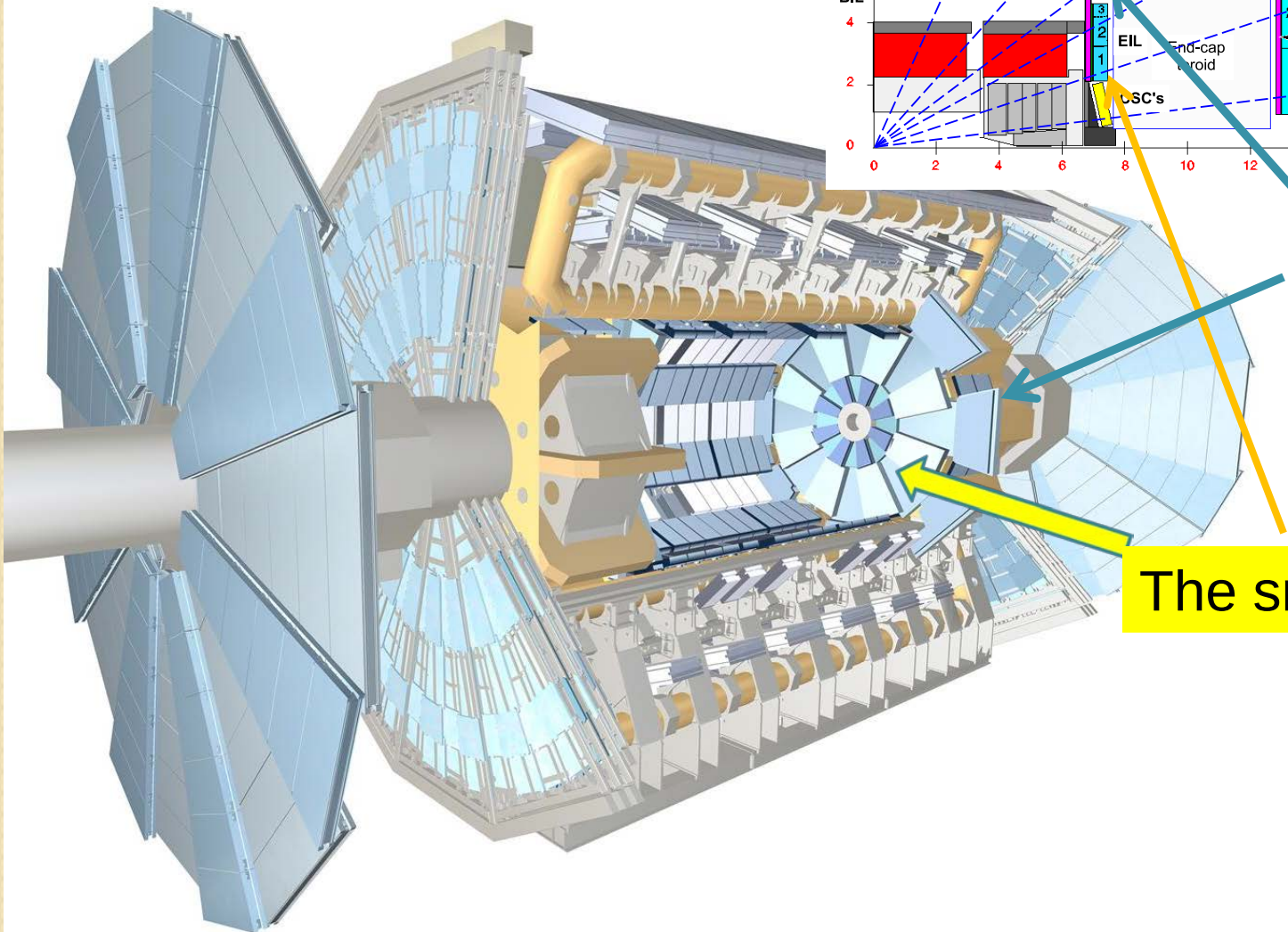


protons and their birth position (*)

The innermost station of the muon endcap

Located between endcap calo and toroid



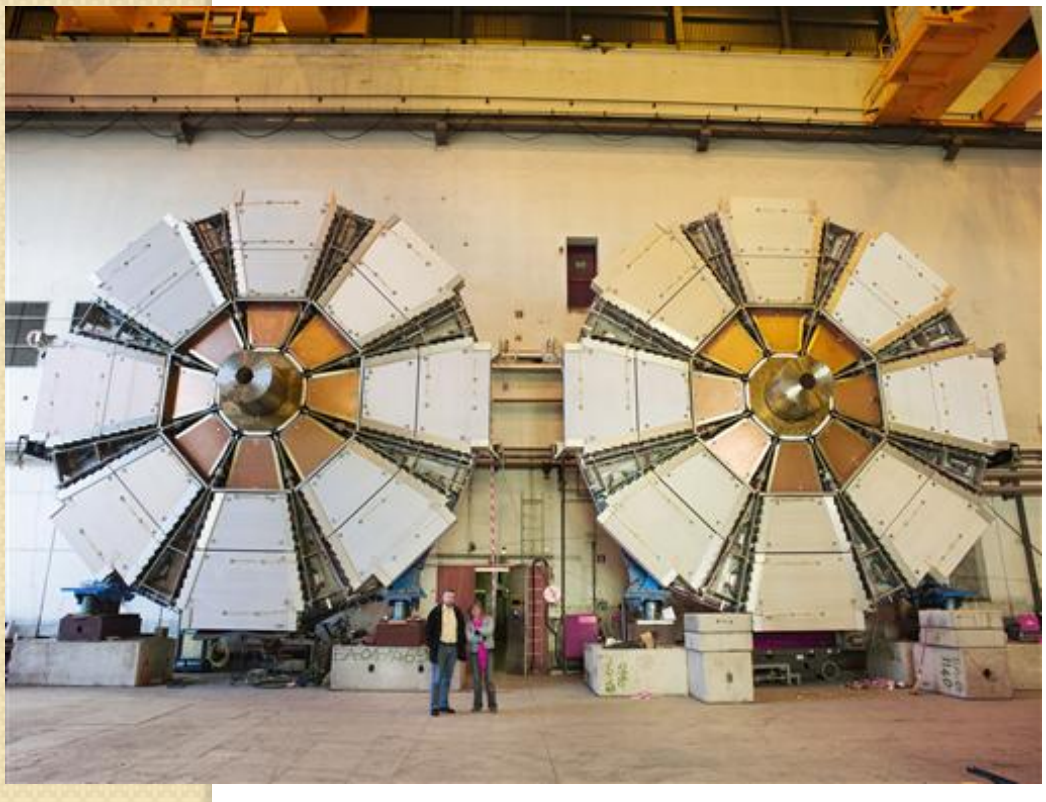


EI station

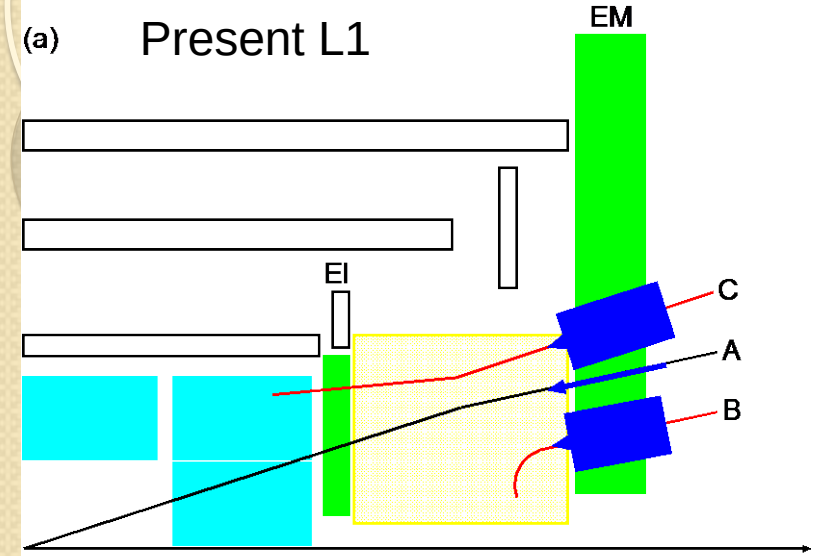
The small wheels

η = 1.3 – 2.0 : MDT (precision R) + TGC (ϕ coordinate)

η = 2.0 – 2.7 : CSC (precision R and ϕ)

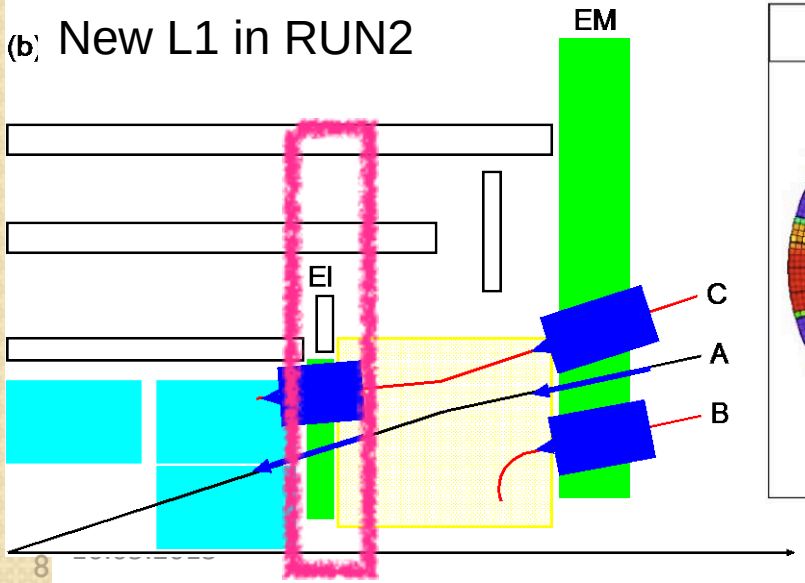


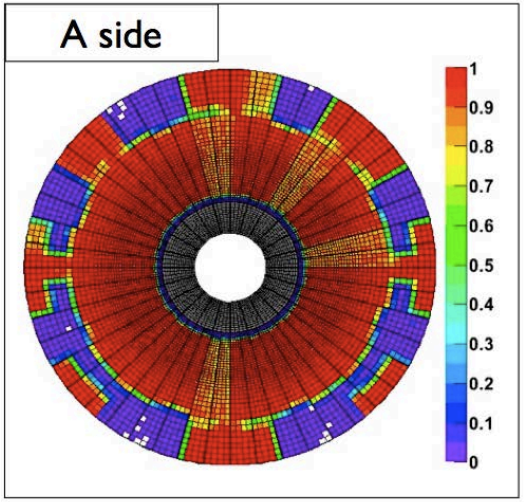
New Lvl1 endcap μ in RUN2

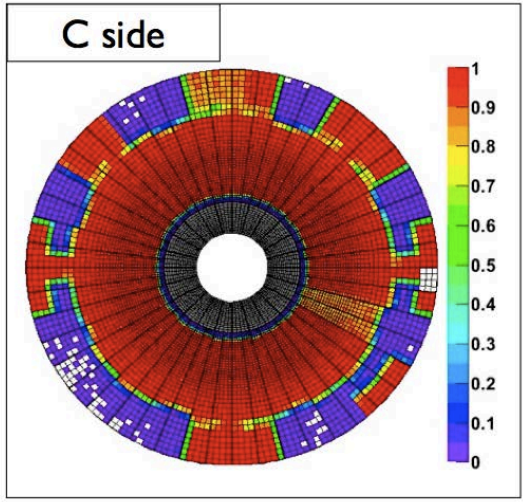


- Require Inner Station TGC hits

	η	Φ
BW	1.05 ~ 2.4	2π
FI	1.3 ~ 1.9	2π
EI	0.9 ~ 1.3	missing part

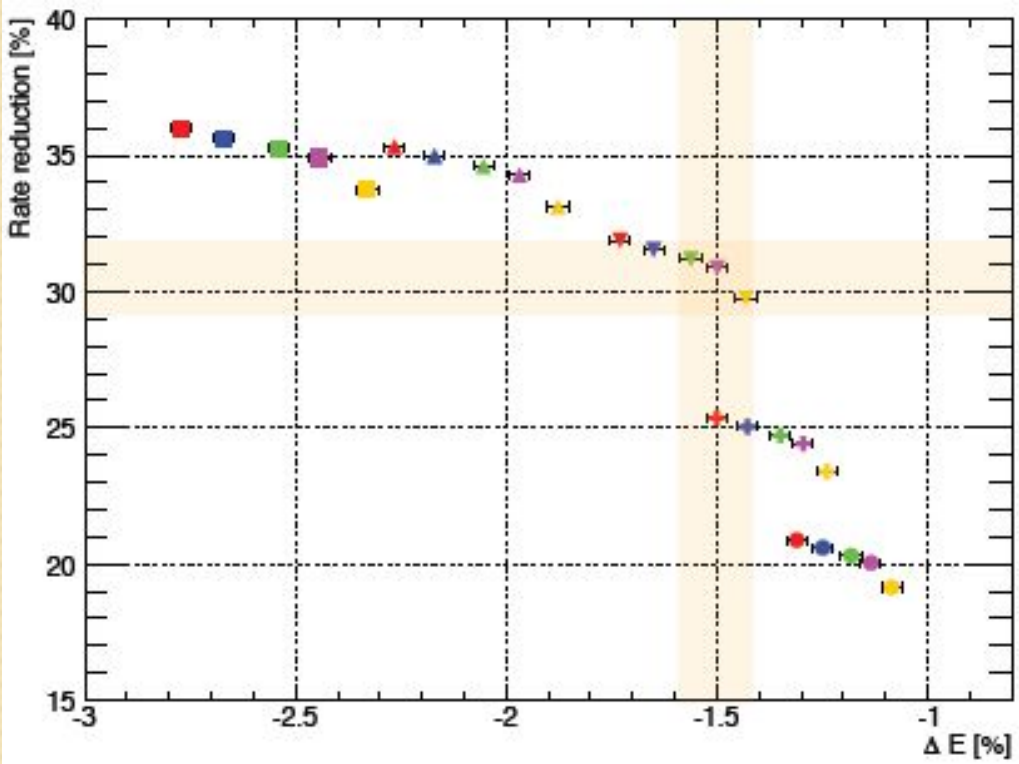




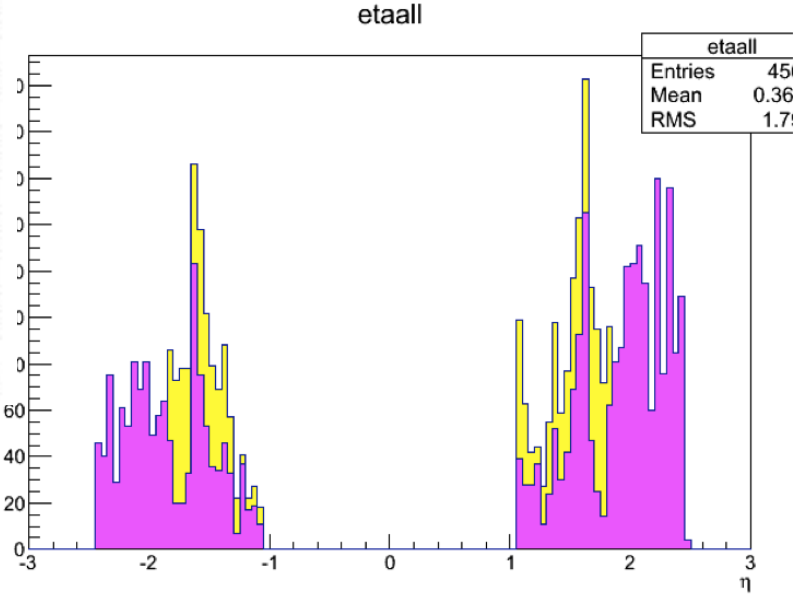


Inner Station Coincidence

- Expect ~ 30% rate reduction
  with ~1.5% efficiency loss

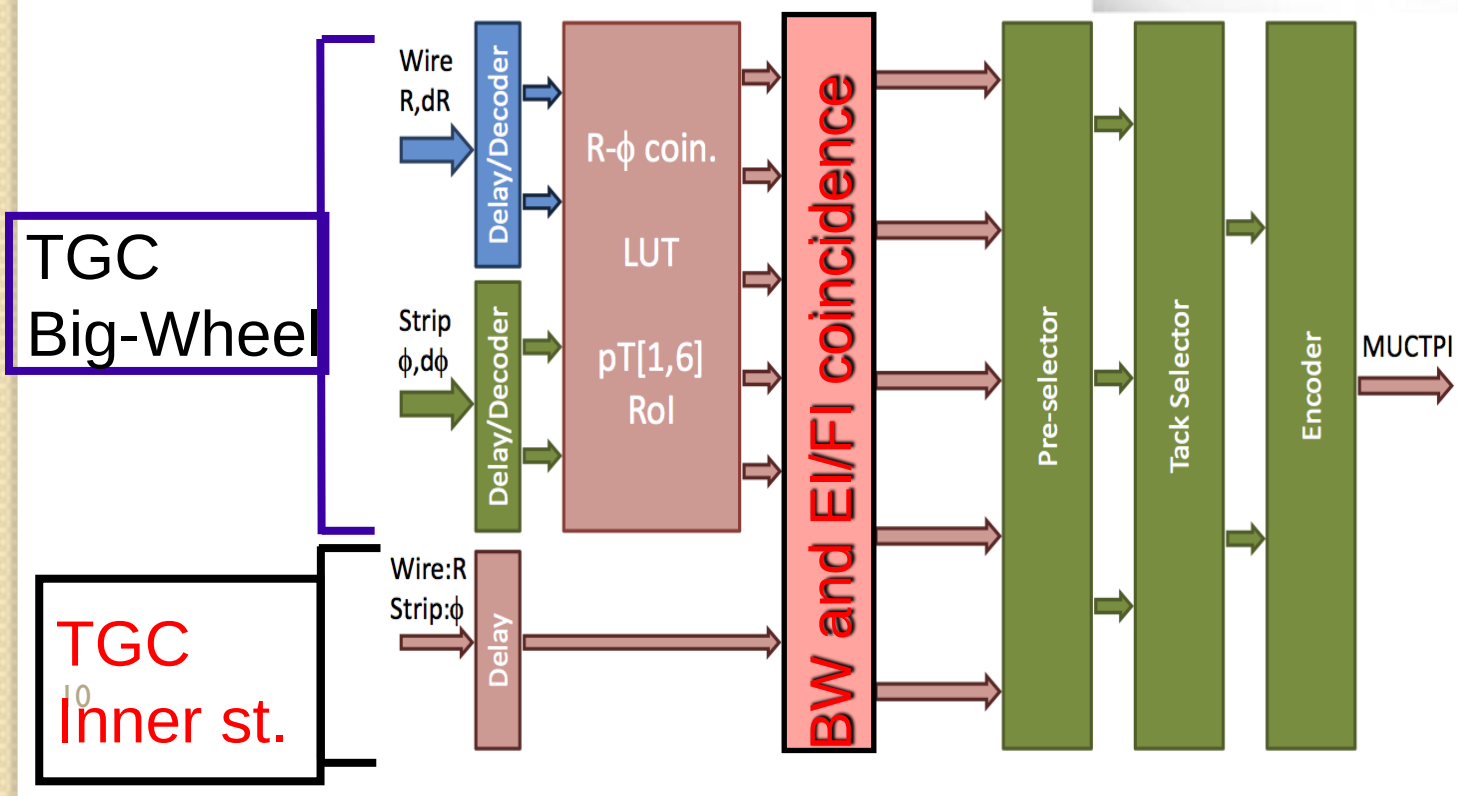


Current L1 endcap
vs
With Inner Station



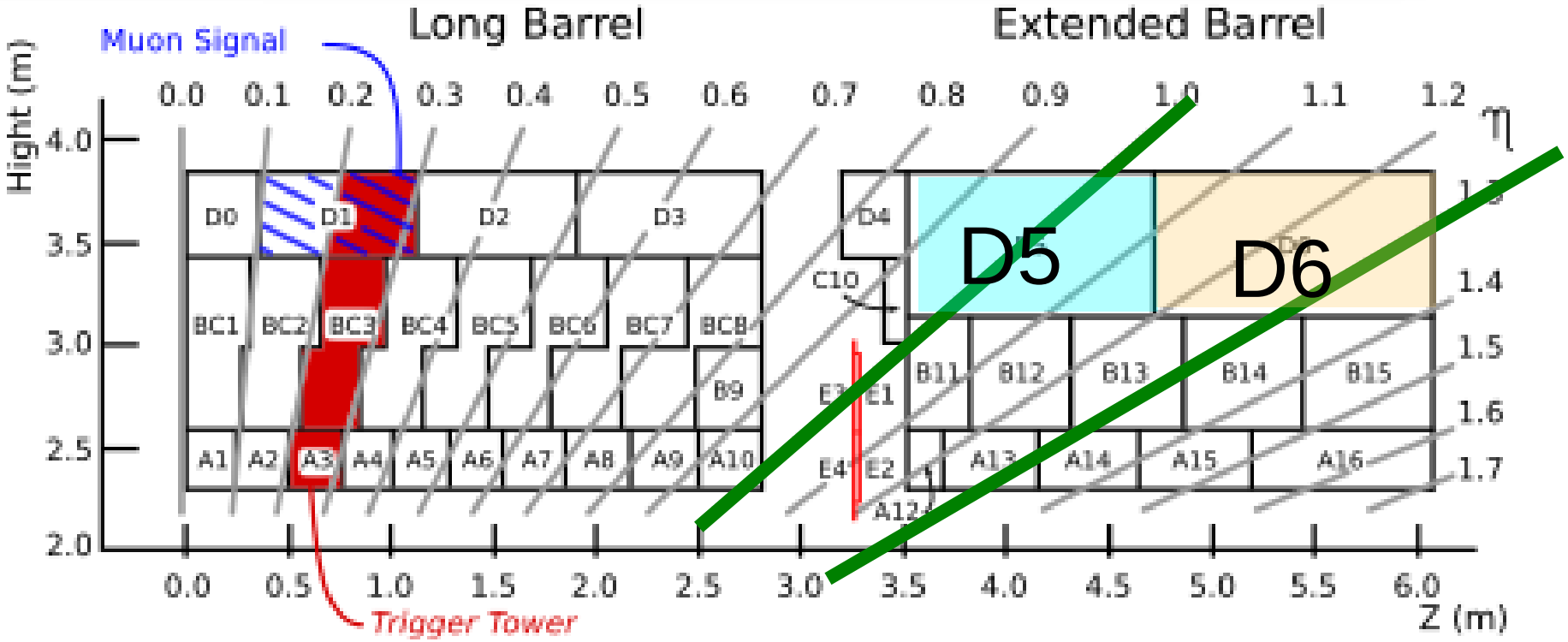
Modified SL for RUN2

- Add Inner Station CW in SL
  - Use current SL modules
  - New Firmware

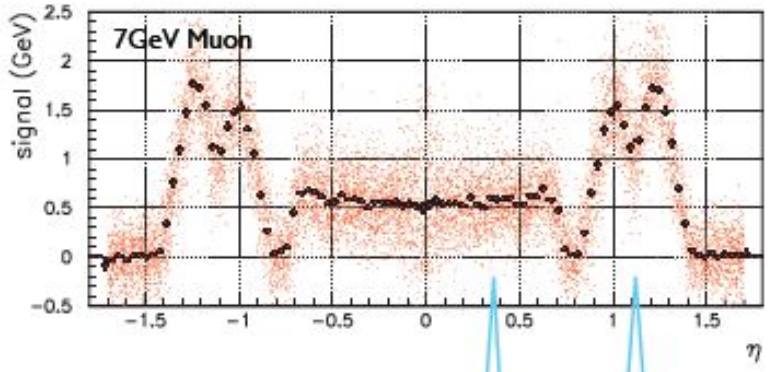


Another Idea: Using Tilecal

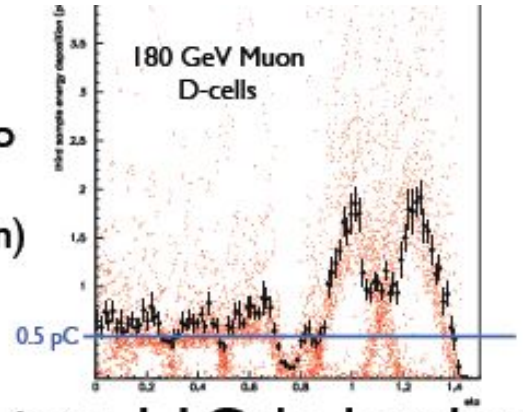
- Regions $1<|\eta|<1.3$ is not fully covered by EIL4 → high rate region
- Tilecal signal can be used for these region



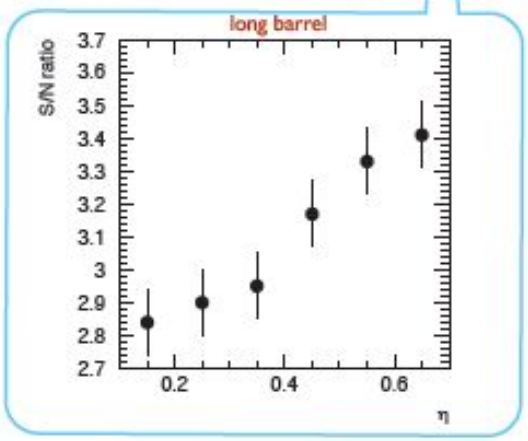
Tilecal Muon signal

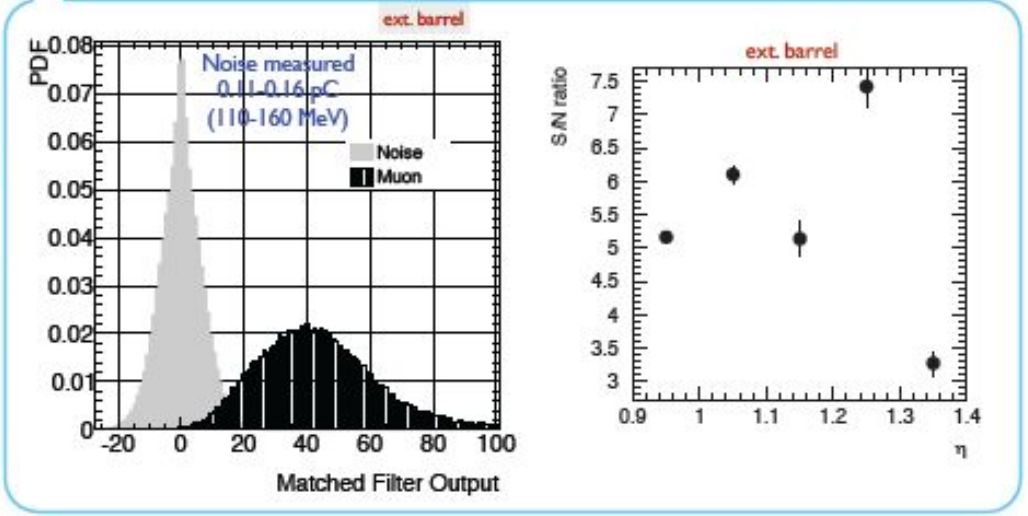


Muon into Tilecal (simulation)



- Data: in 2011 muon signals fed into L1Calo hardware.





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SL with Tilecal

- Current SL can receive trigger signals from Tile cal
  - Use spare optical inputs for Inner Station

- Detailed Study has just started
  - Noise profile
  - Coincidence Window
  - New modules
    - Receiver boards for Tile
    - Signal repeater/mixer for EI/FI

Phase-1 Upgrade

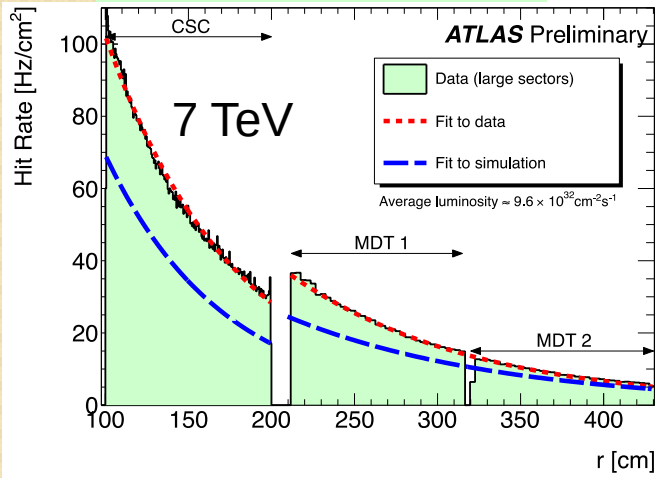
- Higher Luminosity is expected for Upgrade
  - $3x10^{34}$ for Phase-1 Upgrade
  - $5x10^{34}$ for Phase-2 Upgrade

- Need more rate reduction trigger
- In addition, muon detectors in small wheel can not be operated in such high luminosity

Cavern background

1x10^{34} is OK, but little margin for higher lumi

Measured cavern background in the small wheel



Hit rate

L=1x10^{34}

14 TeV
Al beam pipe

Extrapolated cavern background in the small wheel

MDT rate limit

300 kHz/tube

200 kHz/tube

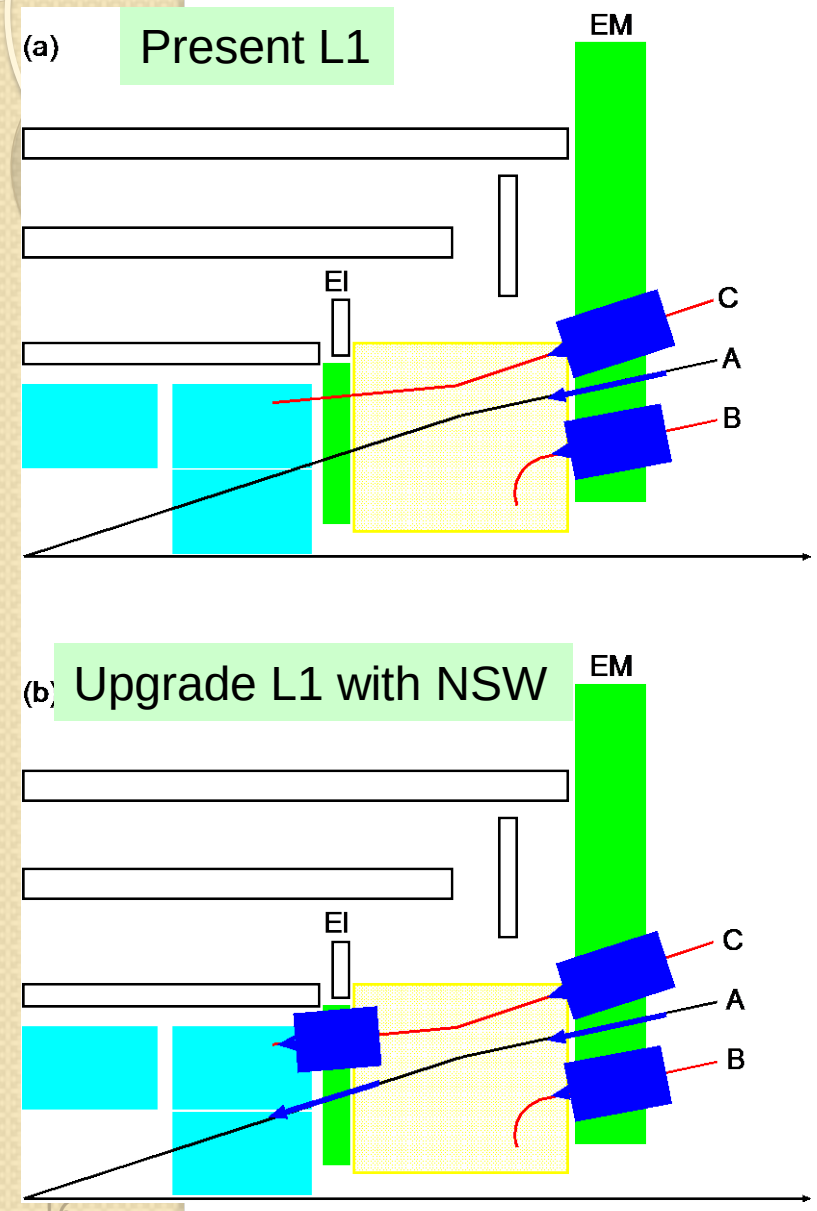
CSC

MDT

Rate (Hz/cm^2)

Radius (cm)

New Small Wheel

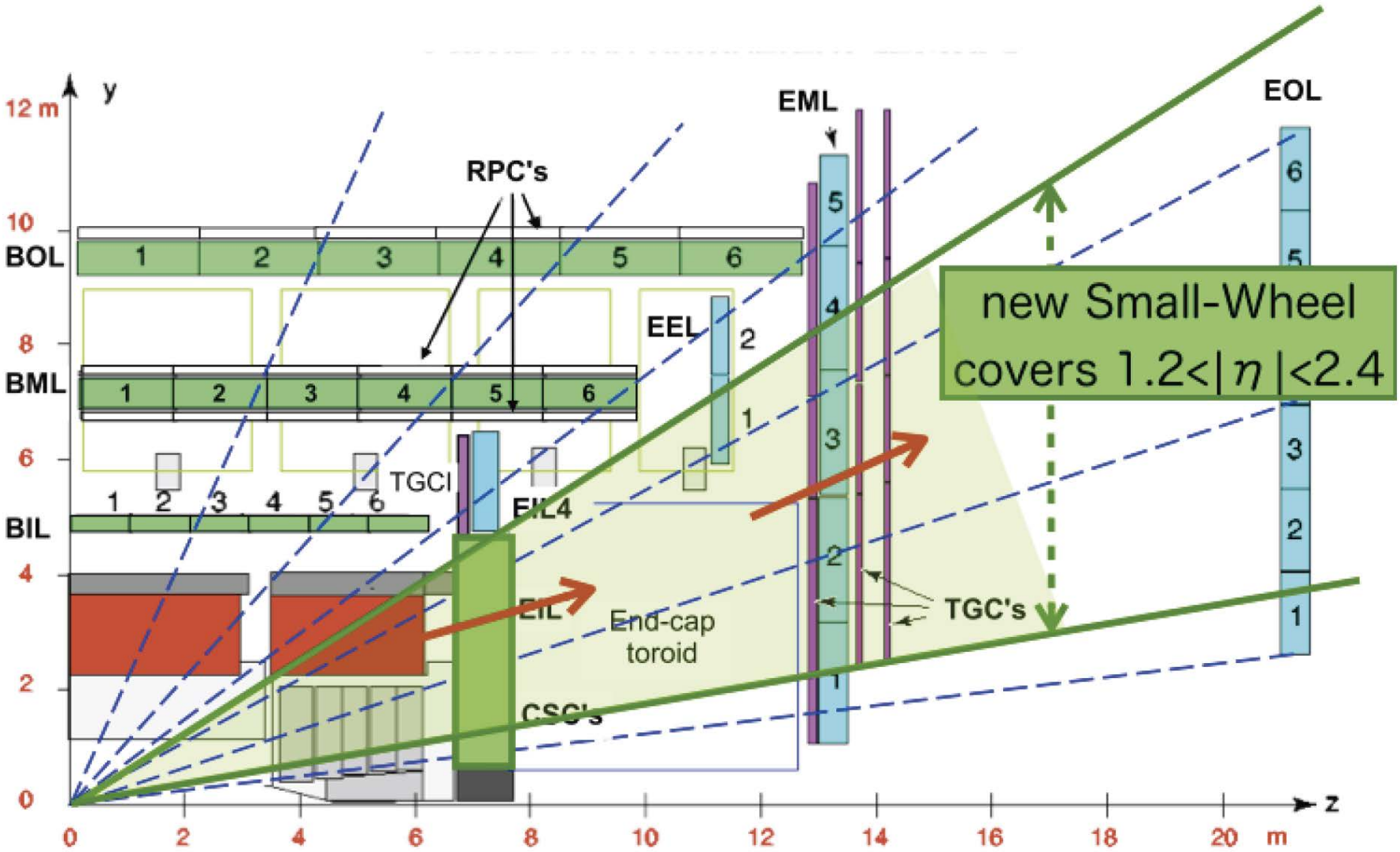


New small wheels :
solve problems
@3x10^{34} and 5x10^{34}

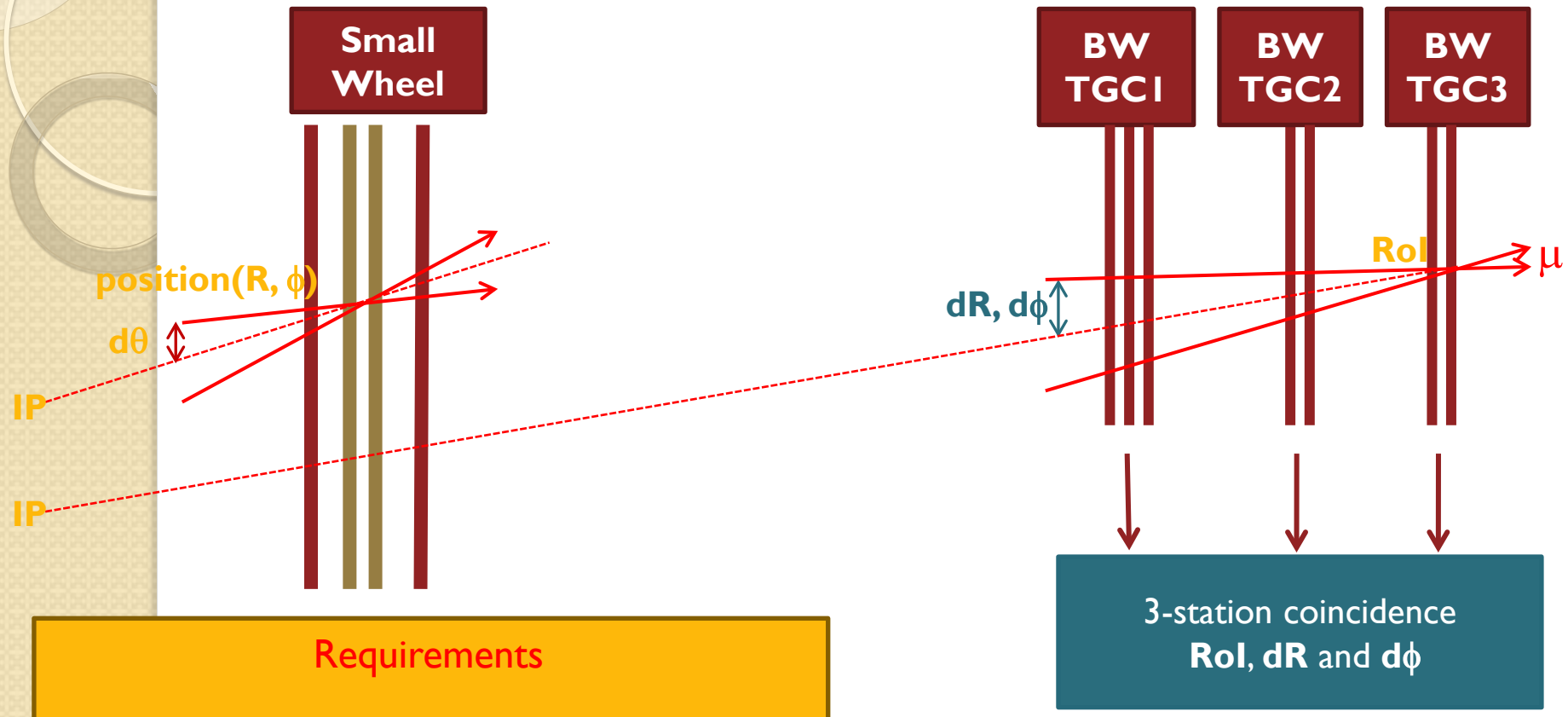
New precision tracker in NSW
that works up to
the ultimate luminosity,
5-7x10^{34} , with some
safety margin

Kill the fake trigger
by requiring high quality
(σ_θ~ 1mrad)
IP pointing segments
In New small wheels (NSW)

Muon New Small Wheel



New LVL1 Muon scheme using NSW



Requirements

1. Track segment at SW

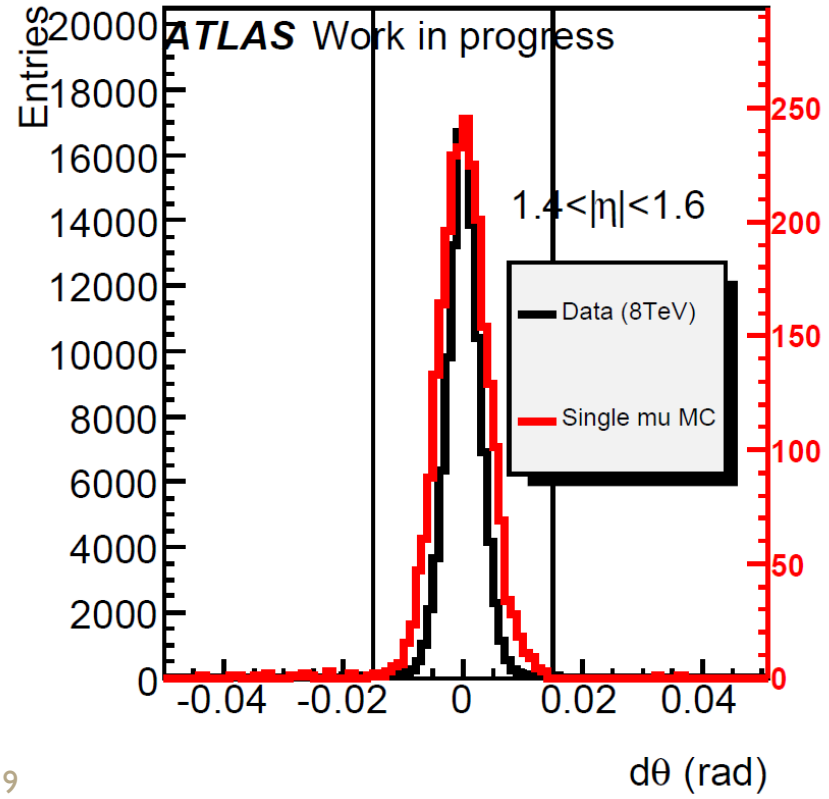
2. Proper incidence angle at SW from IP
   Multiple scattering in CAL. and IP deviation, measure **dθ** and eliminate hits with large **dθ**

3. Position matching between hit position at SW and **RoI** of a track candidate from BW

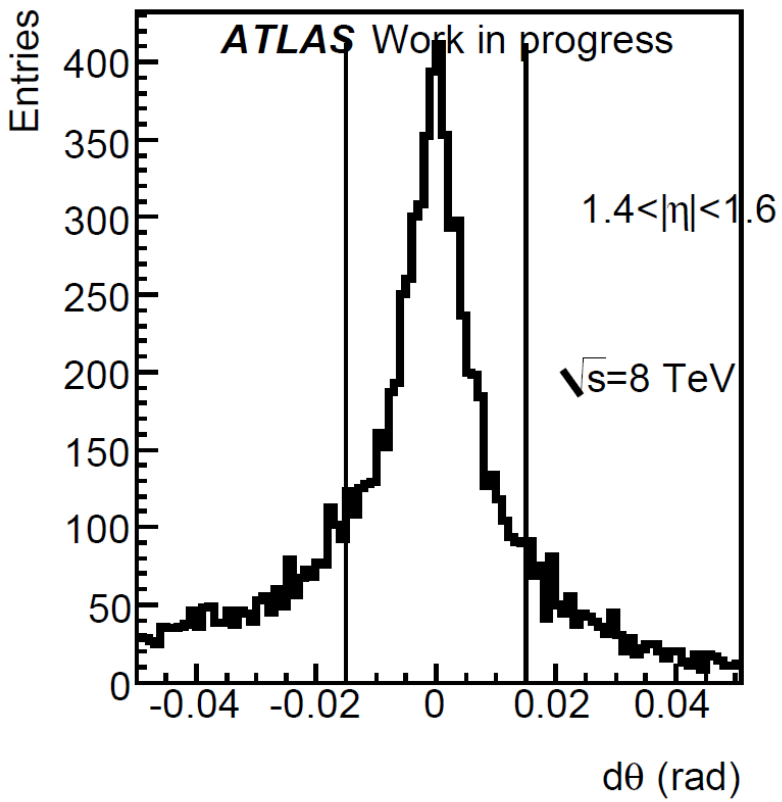
dθ distribution and cut

- dθ cut is to be done in NSW electronics.
- dθ values of segments are not used in Phase-1, but in Phase-2 to improve pT resolution.
  - 1mrad resolution (5-bit : -15mrad to -15mrad, 1 mrad step)

Offline muons with pT > 20 GeV and MC



Muons of L1_MU20



dL_η and dL_ϕ distributions/cuts

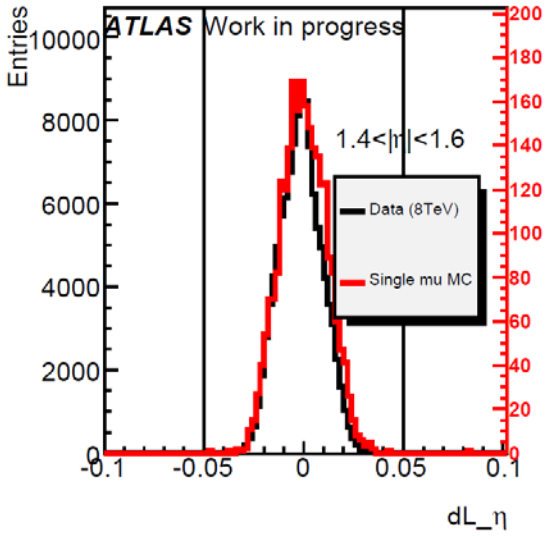
- Check position matching between a track candidate from BW and a hit segment from NSW.
  - Deviation : d**L** (dL_η,dL_ϕ)
  - d**L** = BW RoI – SW (η, ϕ)

- d**L** cuts are to be done on SL.

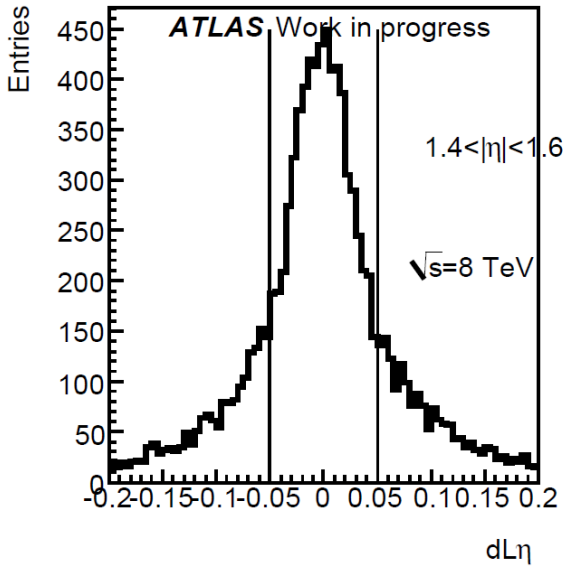
  Track candidates with dL < 0.05 are selected.

- Required d**L** (dL_η,dL_ϕ) resolution is comparable with RoI size.
  - RoI size (dη,dϕ) are 0.02-0.03.
  - 10-bit data is enough for position info..

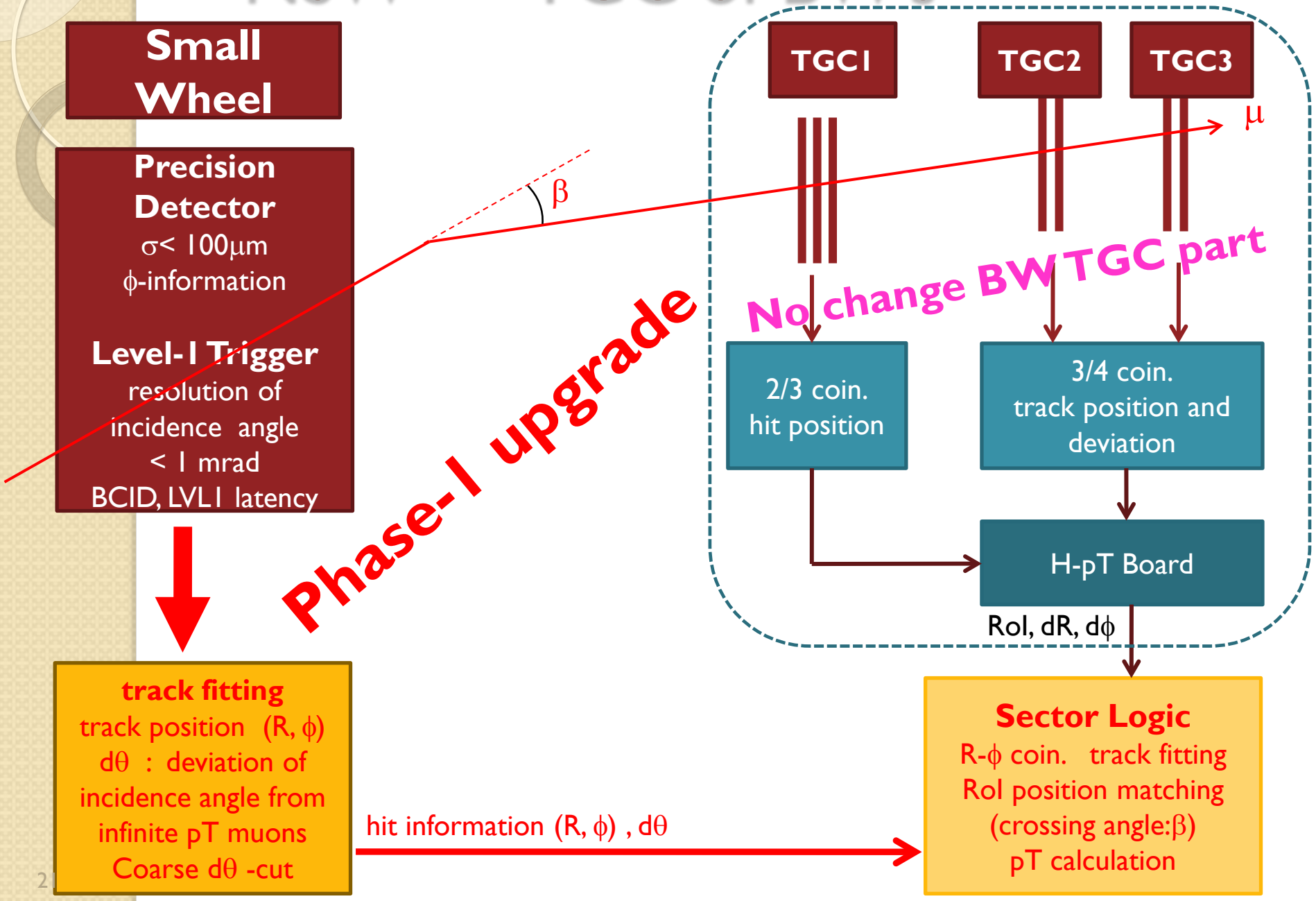
Offline muons (and MC) with pT > 20 GeV



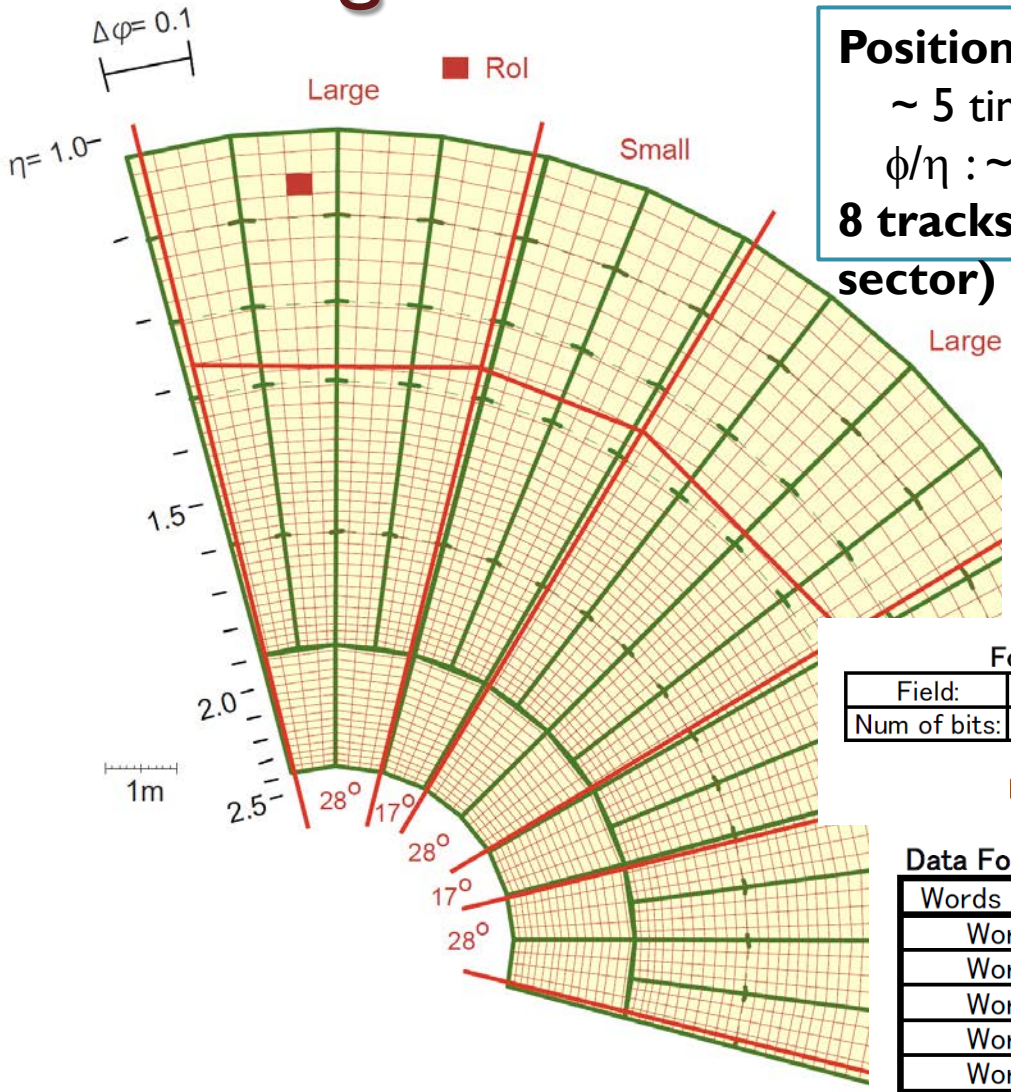
Muons of L1_MU20



NSW + TGC of BW's



Segmentation and bit format



NSW **Sector** boundary

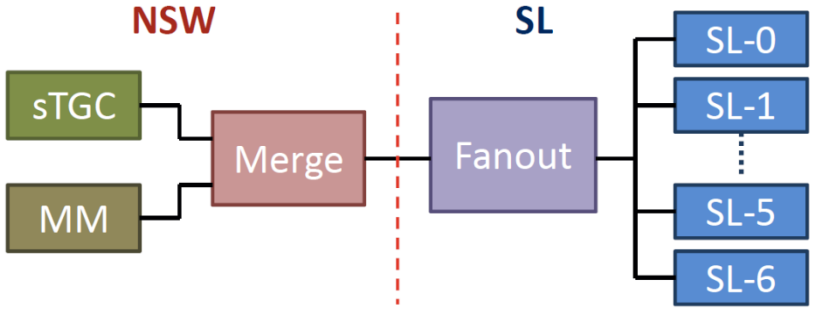
BW **Trigger Sector** boundary

Position info.

~ 5 times finer granularities than RoI size.

ϕ/η : ~ 0.004 precision

8 tracks per NSW Sector (2 fibres per SW sector)



Format of a track vector in NSW (24-bit/track)

Field:	TGC hit	MM hit	dθ (mrad)	φ index	R index	rsv
Num of bits:	2	2	5	6	8	1

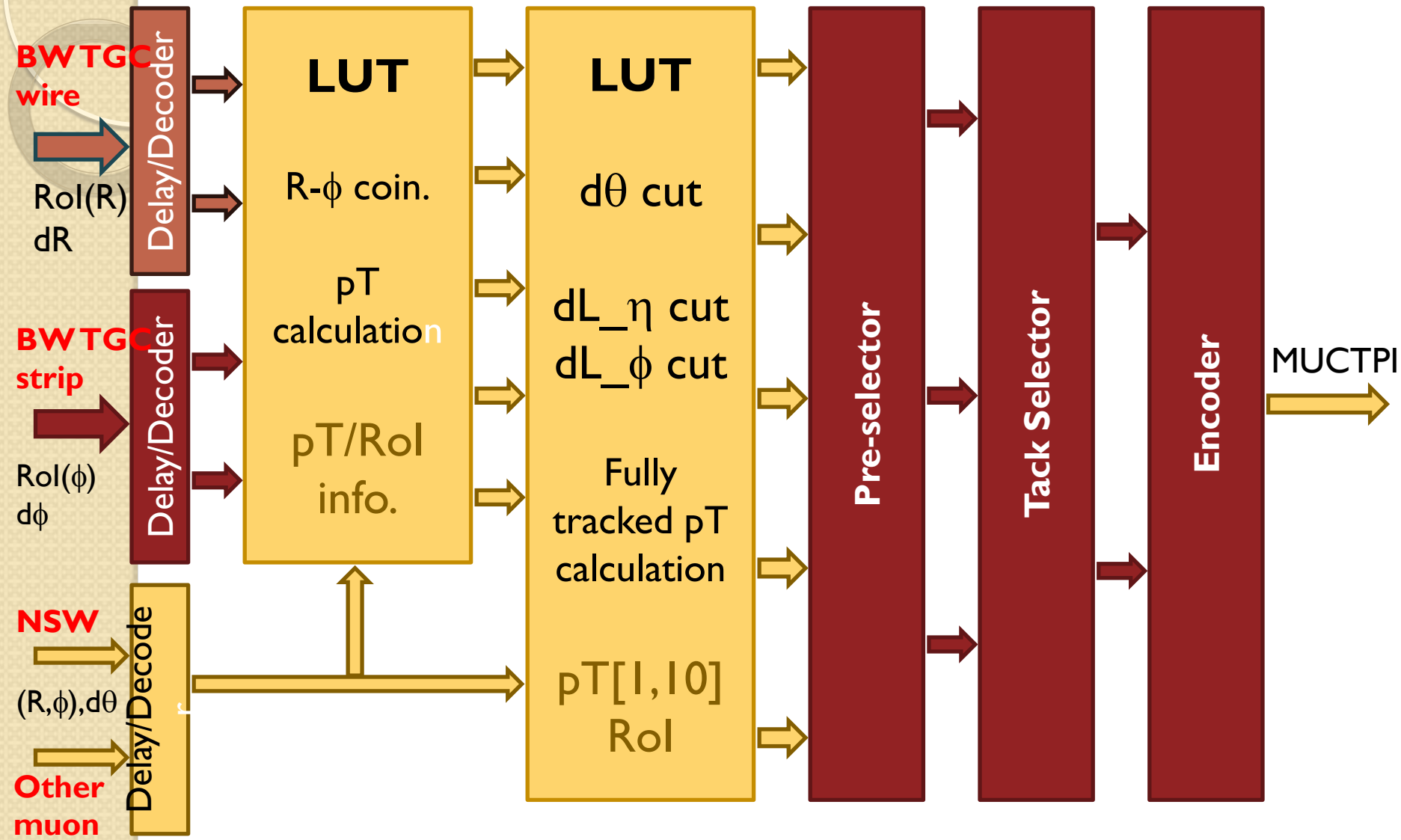
Max. number of tracks per a NSW sector is 8.

Data Format from NSW to Sector Logic

Words (16-bit)	first byte	second byte
Word-0	comma	comma
Word-1	track-0	
Word-2		
Word-3	track-1	
Word-4	track-2	
Word-5		
Word-6	track-3	
Word-7	ID (4-bit)	BCID (12-bit)

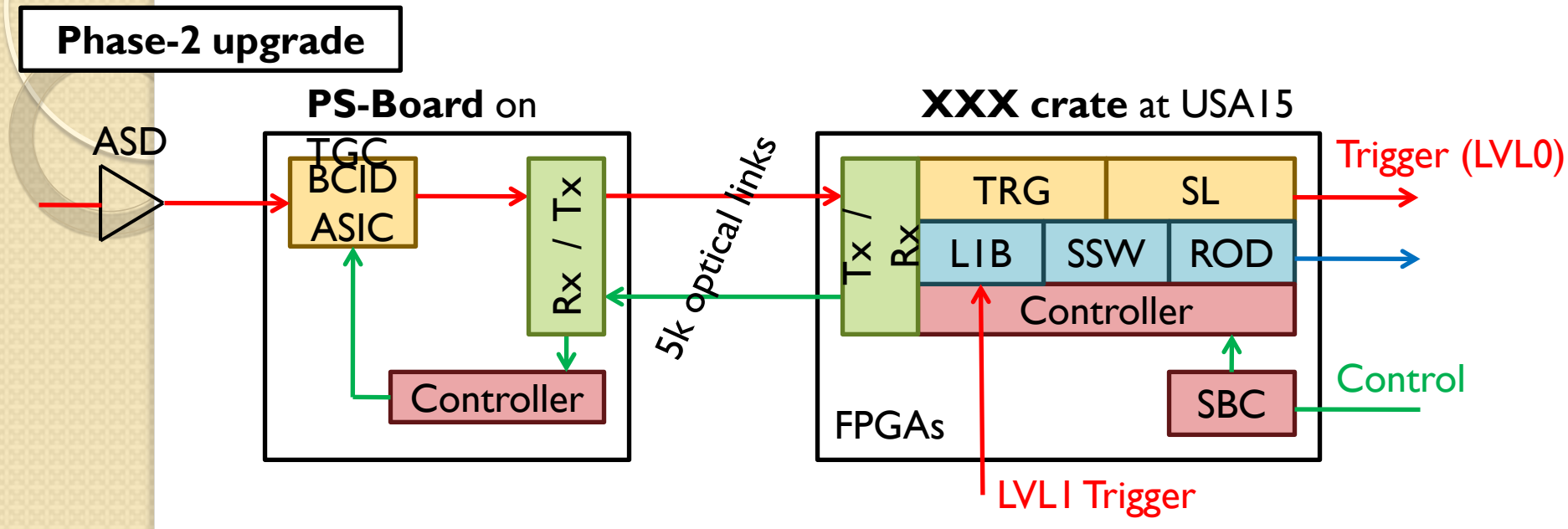
8B/10B encoding X 16 bytes = 6.4 Gbps

Sector Logic Board for Phase-I



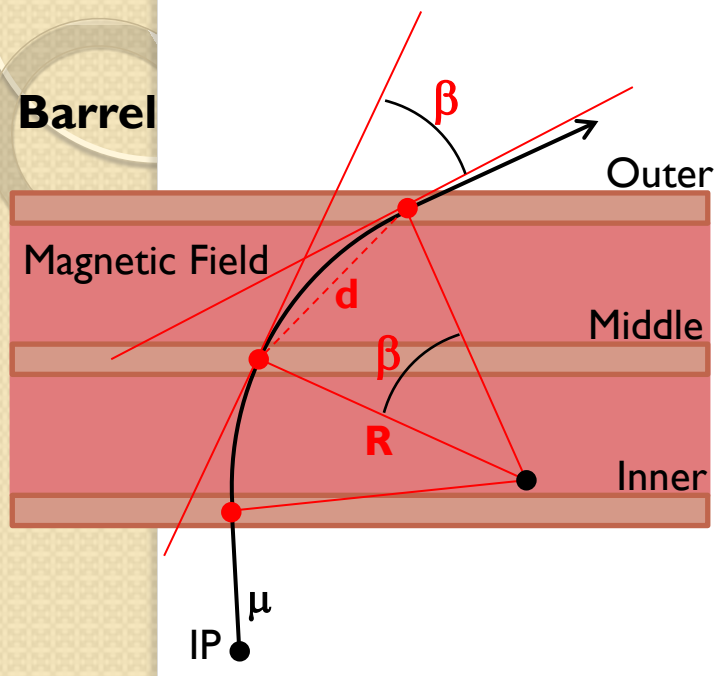
VME64x format, not compatible with Phase-2 upgrade

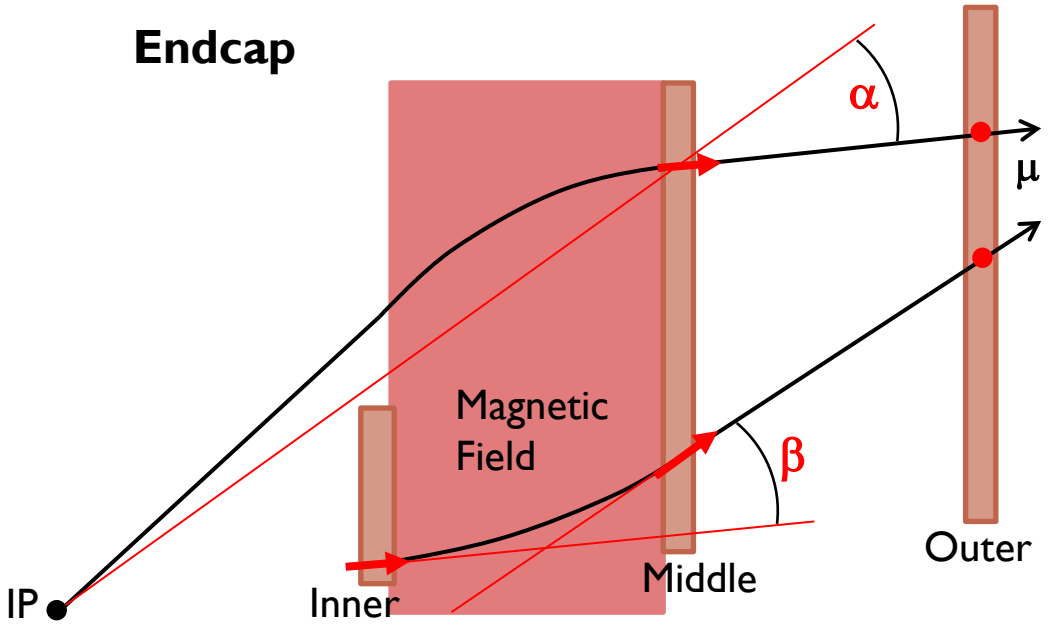
Phase-2 for BW TGC



- ASIC for PS-Board
  - LVDS Rx, variable delay, BCID, test pulse generator and Interface to GBT
- Module with FPGAs for Trigger/Readout
- LVL0 Trigger output, LVL1 Trigger input
  - Long L1-Buffer memory (no L0-Buffer) to cope with L1 latency

β-parameter for Phase-2





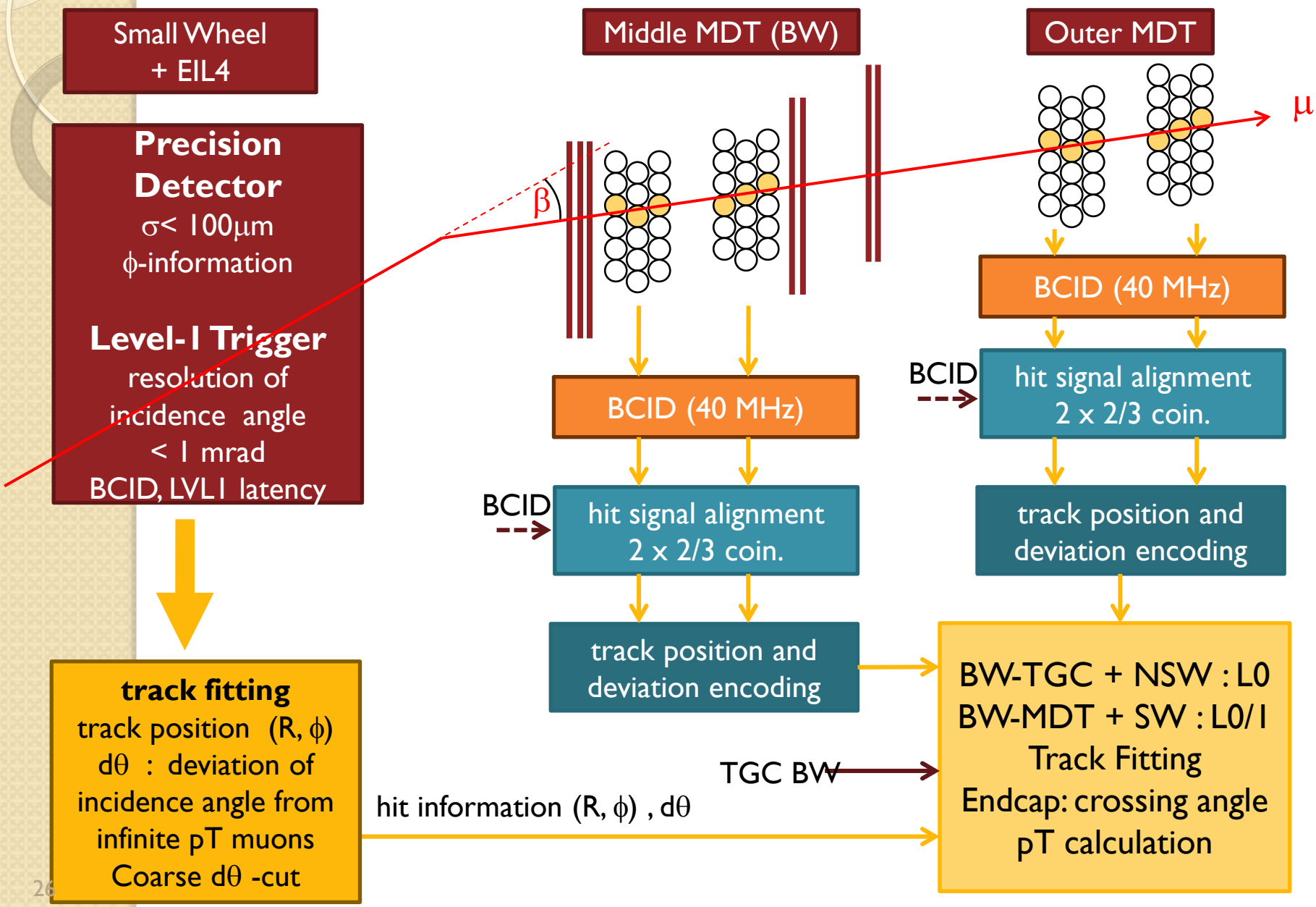
$pT = A_{ij}R + B_{ij} = A_{ij}d/\beta + B_{ij}$

$1/pT = A_{ij}\alpha + B_{ij}$ or $1/pT = A_{ij}\beta + B_{ij}$

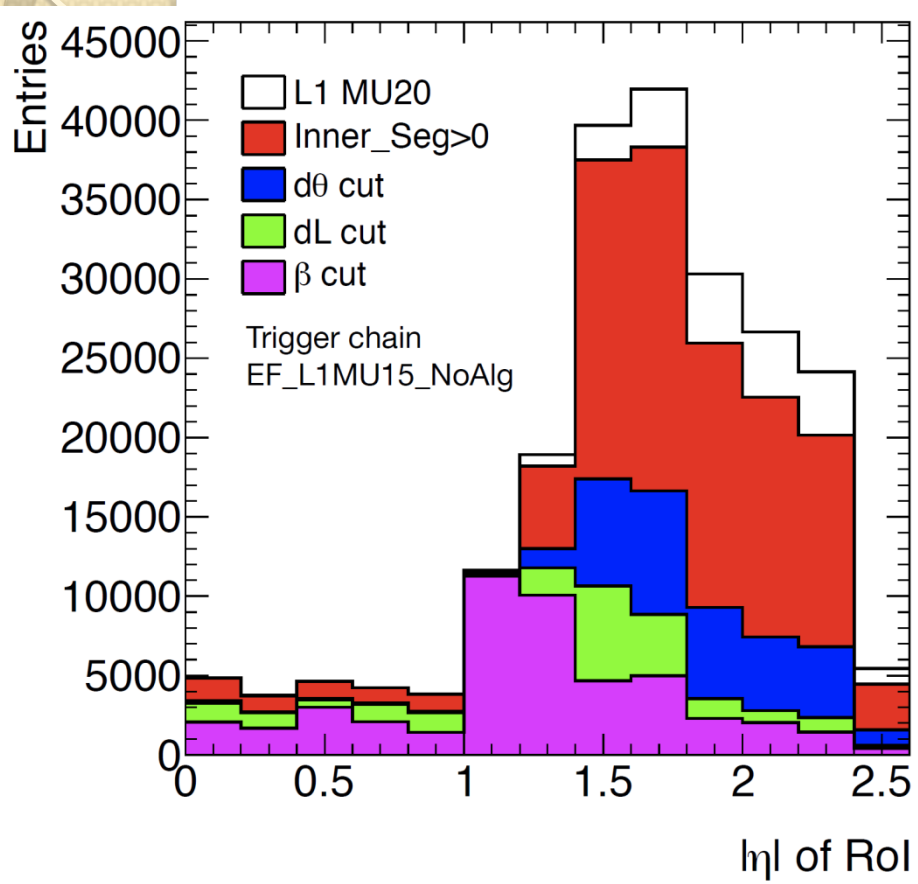
REQUIREMENTS for improvement of pT resolution

Barrel / Endcap : 1mm spatial resolution and 1mrad angular resolution

NSW / TGC+MDT Muon Track Trigger



Trigger rate distribution



Cut name	Rate
Inner_Seg>0	0.9089
dtheta cut	0.4511
dL cut	0.3055
beta cut	0.2156

Cut name	Efficiency
Inner_Seg>0	0.9961
dtheta cut	0.9640
dL cut	0.9462
beta cut	0.9174

Summary

- Rate of LVL1 Endcap Muon Trigger is very high because of fake trigger by slow protons produced in/after Endcap Toroidal magnet
- Require before EC Toroid hits to reduce rate
  - Inner Station TGC for RUN2
  - Tilecal ? for RUN2
  - New Small Wheel for Phase-1 upgrade
- Better momentum resolution is studied
  - LVL1 using MDT for Phase-2 upgrade

Intensive studies are under way in ATLAS Japan group