ATLAS-TGC performance for cosmic ray / beam

2009.3.25

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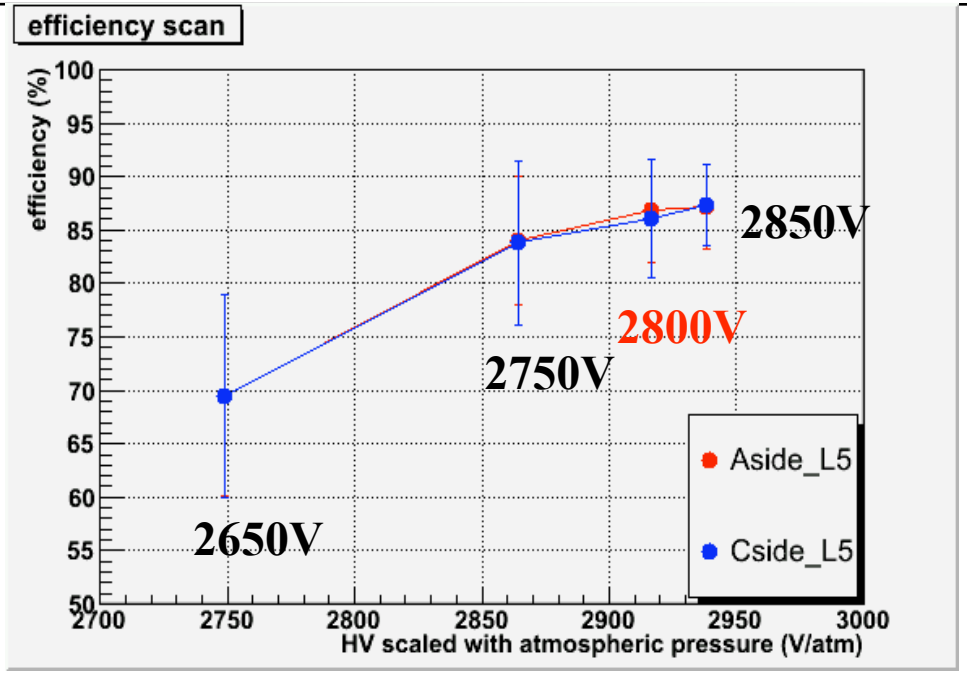
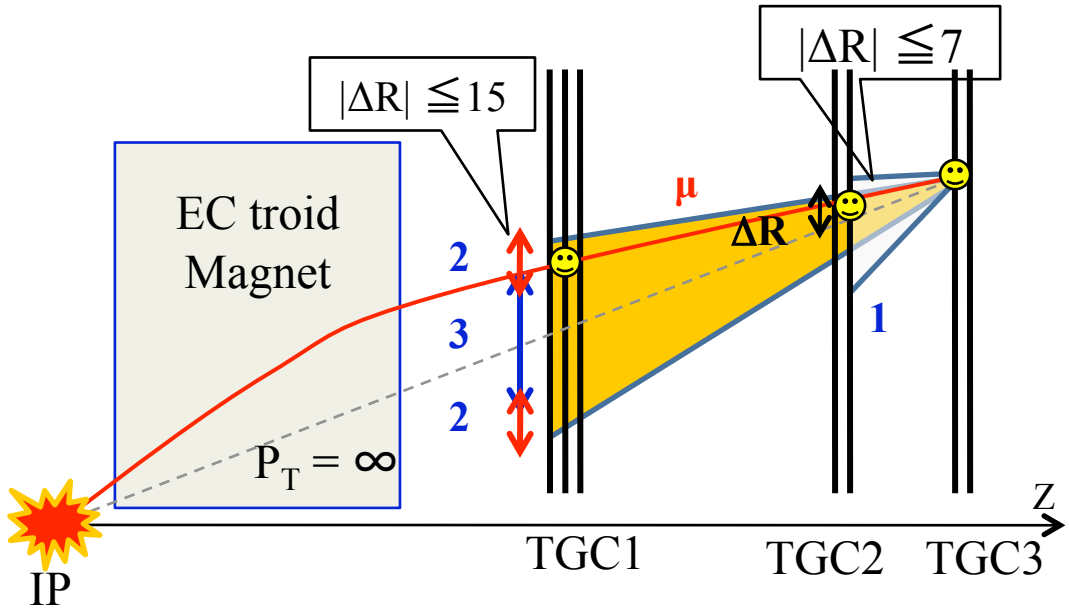
TGC special configuration for cosmic

- **Basic detector parameter**
  - HV : 2800V
  - Vth : 100mV
  - CO_2(55%) + n-C_5H_{12}(45%)
- **3 trigger type**

Type 1	TGC1	TGC2	TGC3
Wire (R)	-	3/4	
Strip (ϕ)	-	3/4	
ΔR	ΔR ≦7		

Type 2,3	TGC1	TGC2	TGC3
Wire (R)	2/3	3/4	
Strip (ϕ)	-	3/4	
ΔR	Type 2 : 10 < ΔR ≦ 15 Type 3 : ΔR ≦10		





4 essential items to be checked

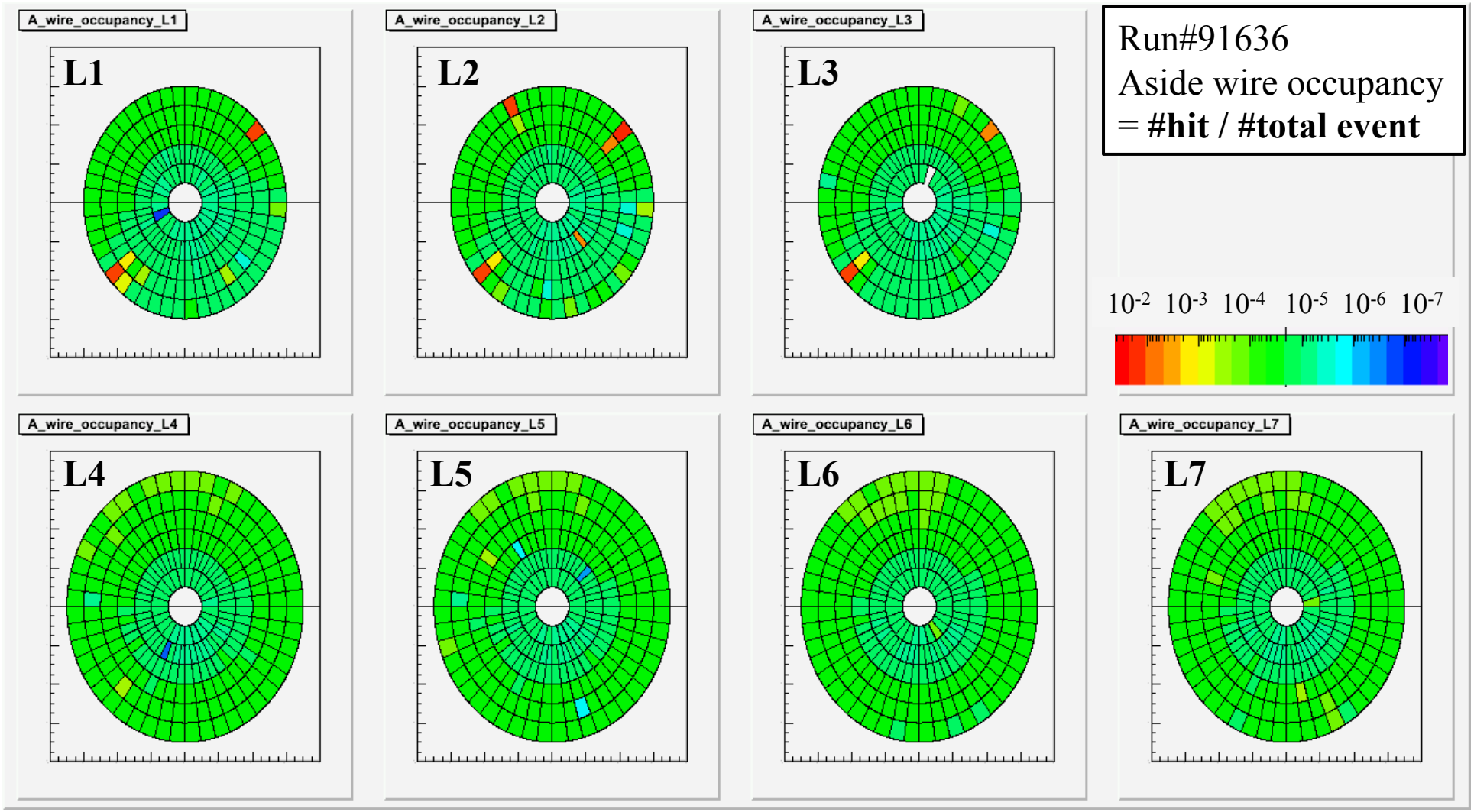
(1) Uniform occupancy with ~ 0 accidental trigger

(2) trigger only IP pointing μ with proper momentum tag

(3) Have ideal resolution (channel size / √12)

(4) Have ideal detection efficiency (~93%)

(1) occupancy

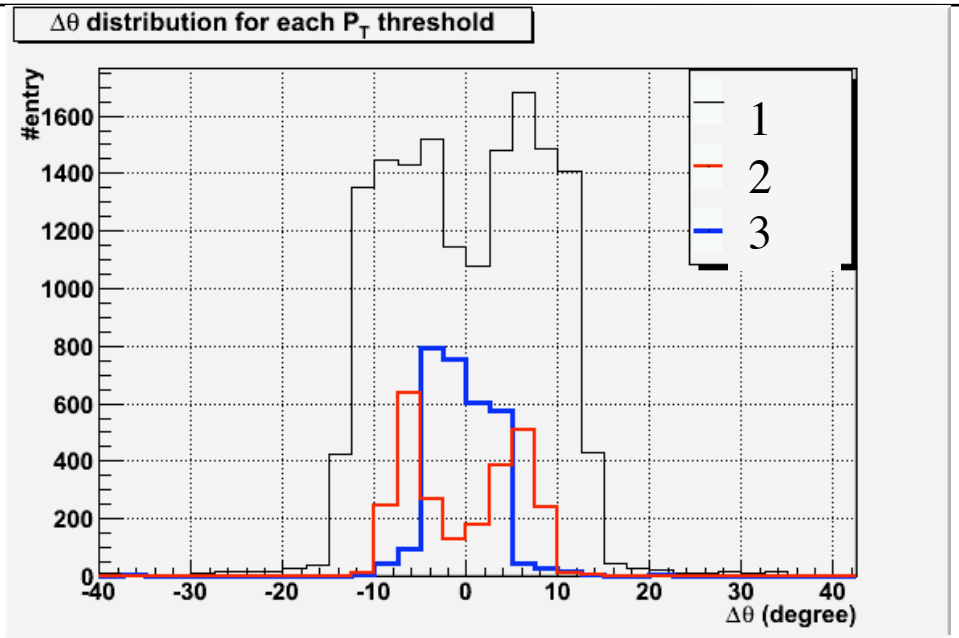


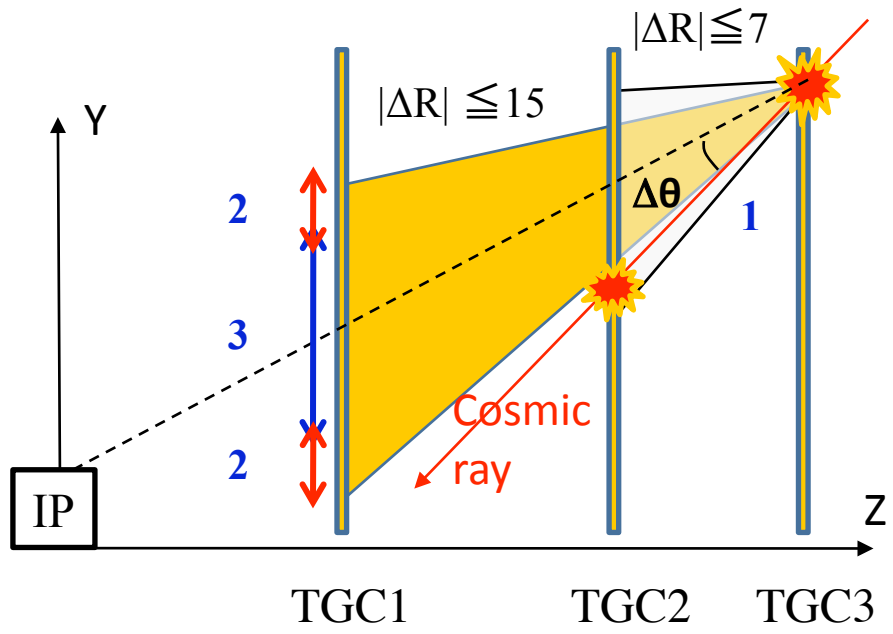
average occupancy = 2.1×10^{-5} (~1hit / 50,000 events)

→ Still 0.02% channel have more than 5% occupancy → Masked by electronics

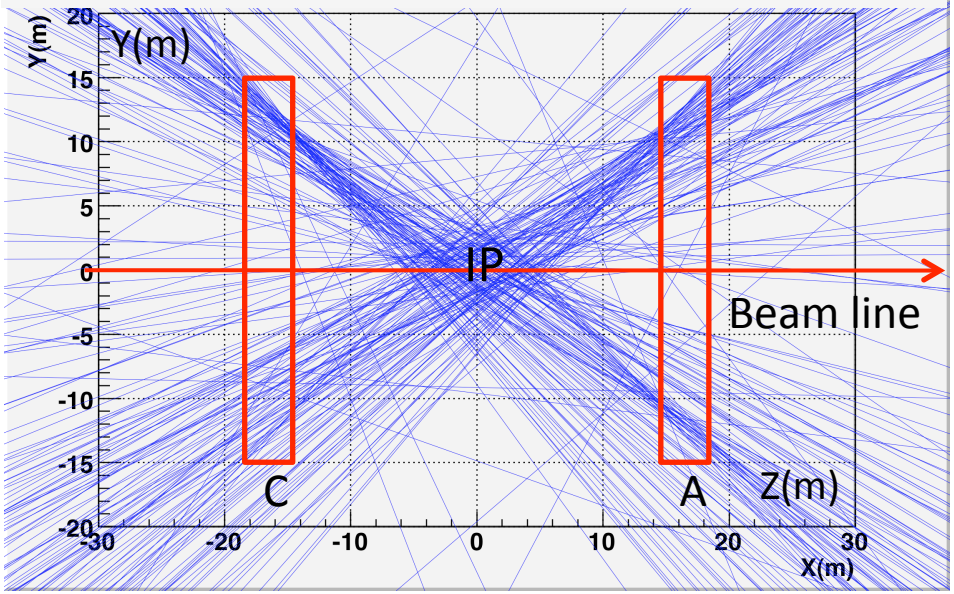
→ **Uniform occupancy with ~0 level accidental coincidence ~ $O(10^{-15})$**

(2) IP pointing functionality





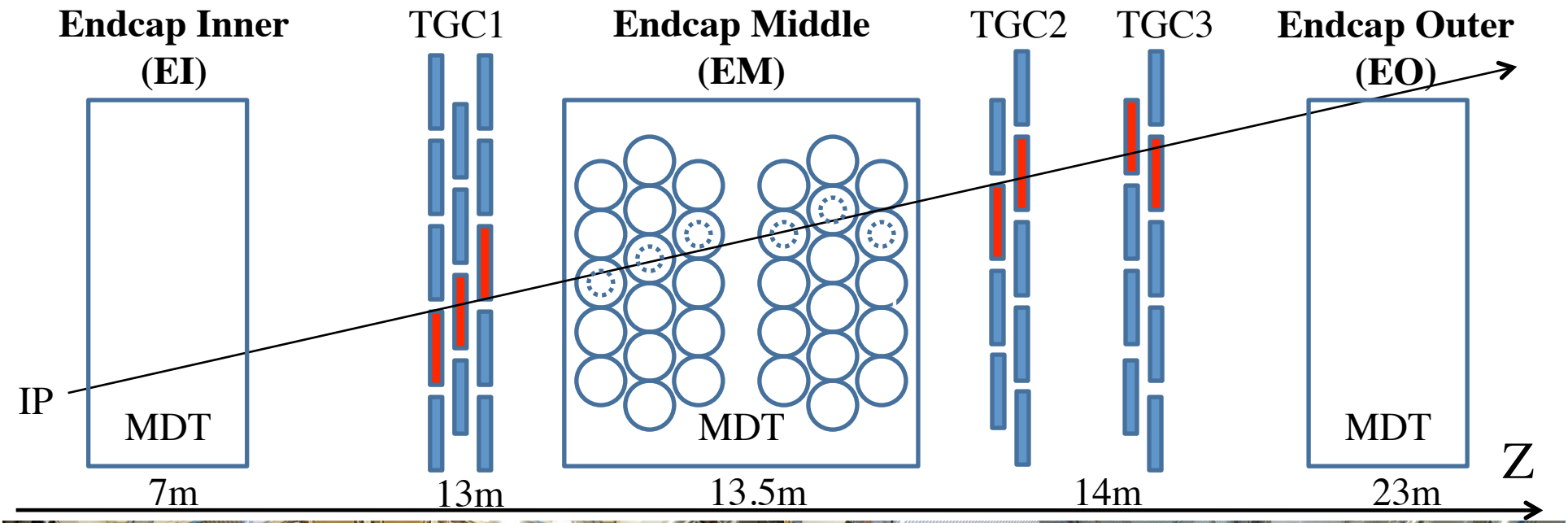
Muon trajectory (based on hit information)

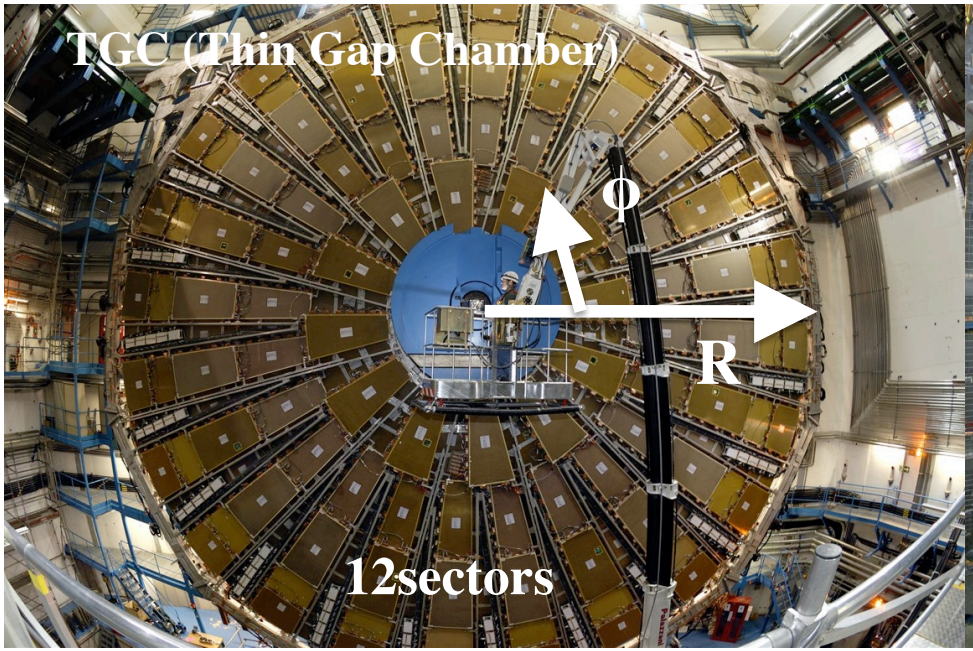


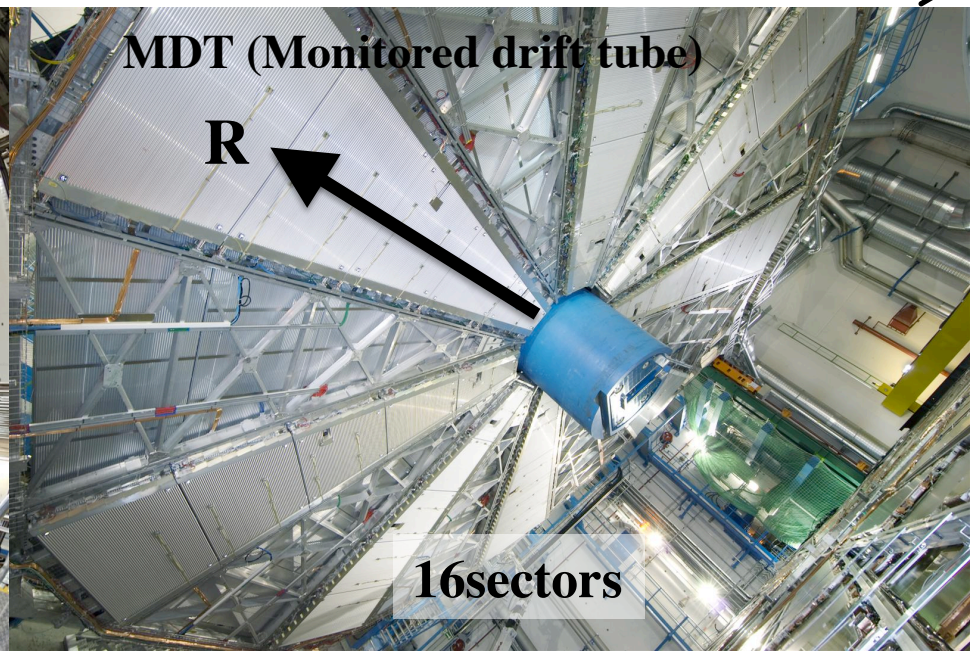
- Type 1 is broadest, Δθ < 15 deg
- Type 2 has 2 peaks due to exclusive ΔR limitation
- Type 3 is most sharpest

IP Pointing functionality with proper momentum tag works well

(interval) Endcap system geometry

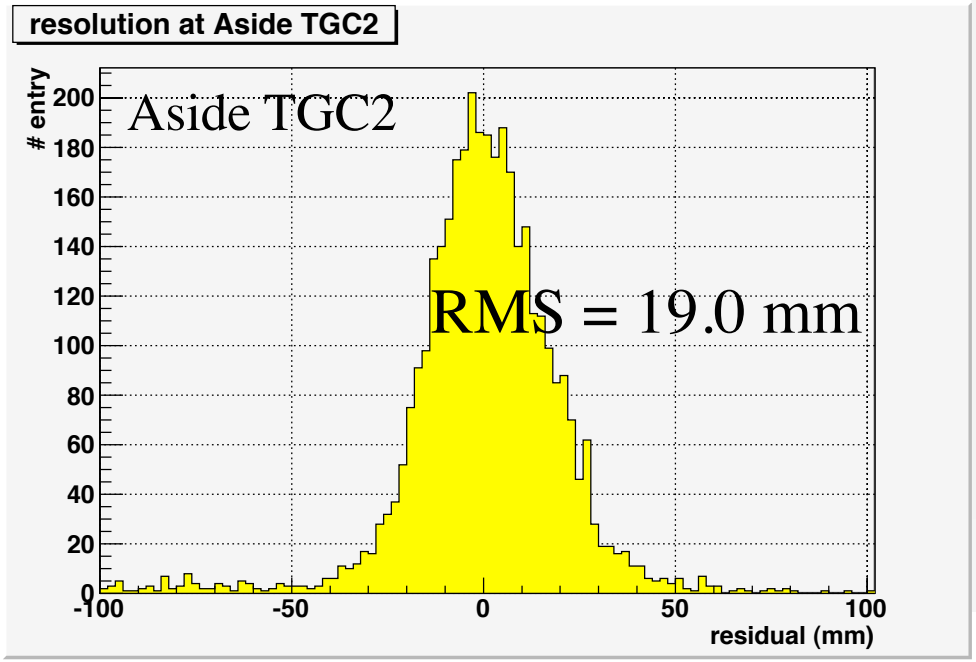


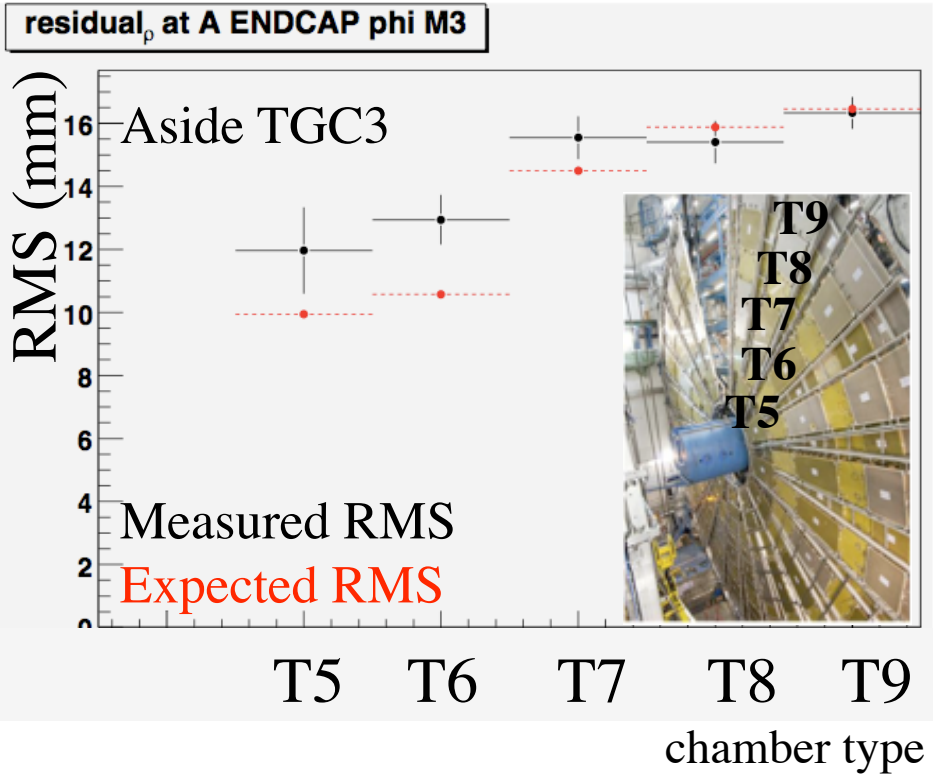




(3) Resolution (RMS of Δρ distribution)

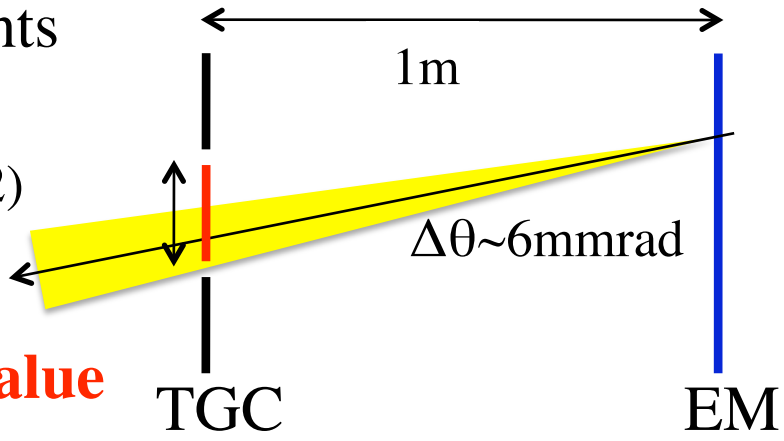
Δρ = track extraporated – TGC hit





- Resolution is dominated by 2 components
  - θ resolution of track (~6mmrad)
  - TGC wire grouping size (~ 50mm/√12)

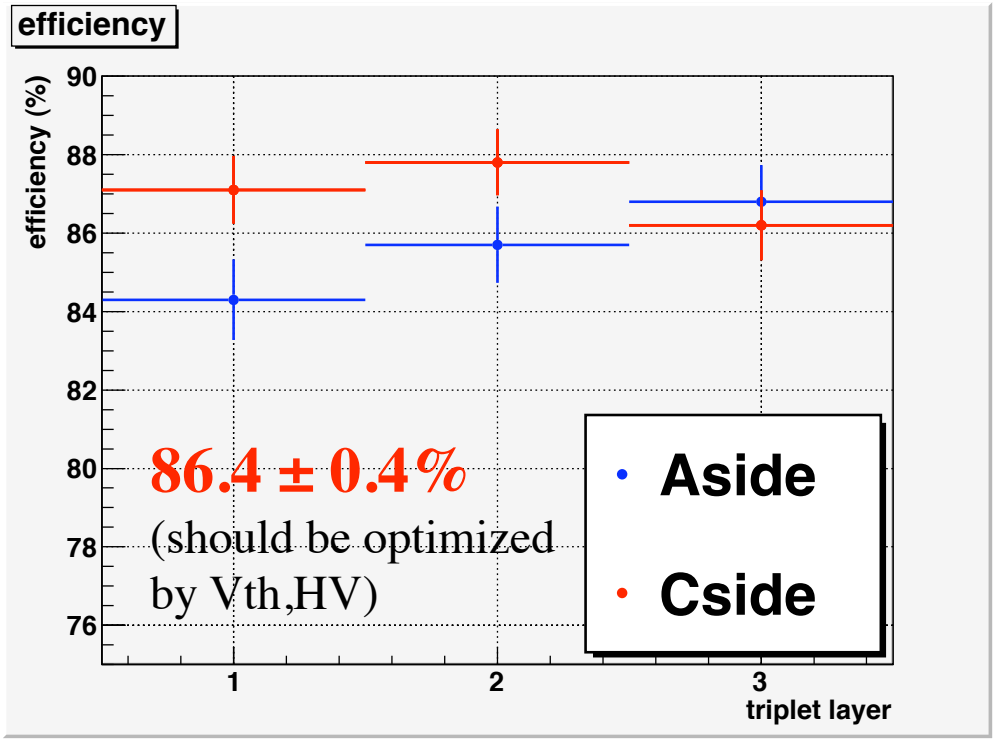
  Yields ~ σ(15mm) resolution

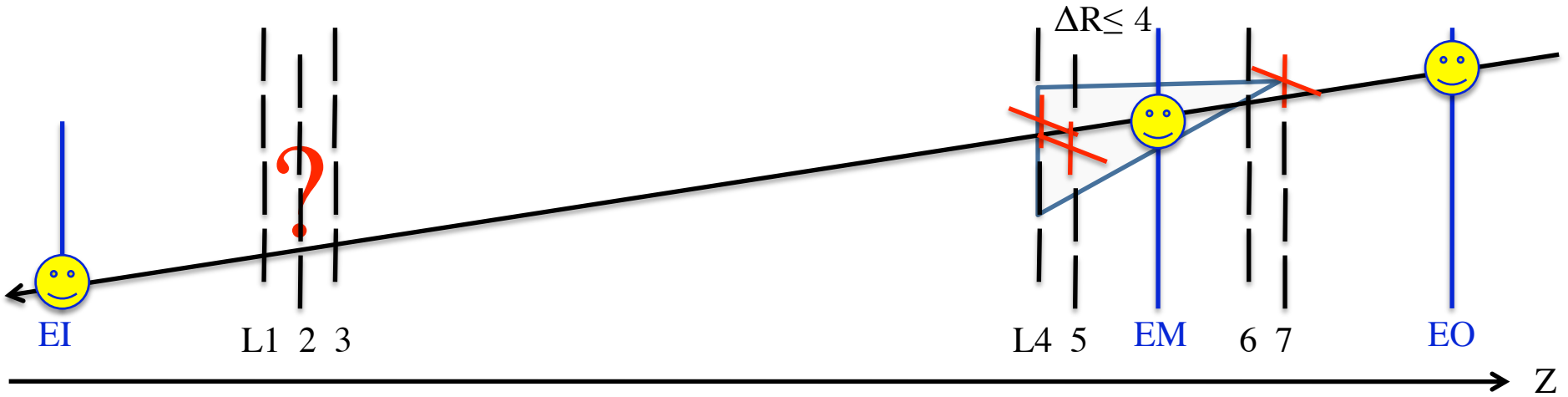


Almost same resolution with designed value

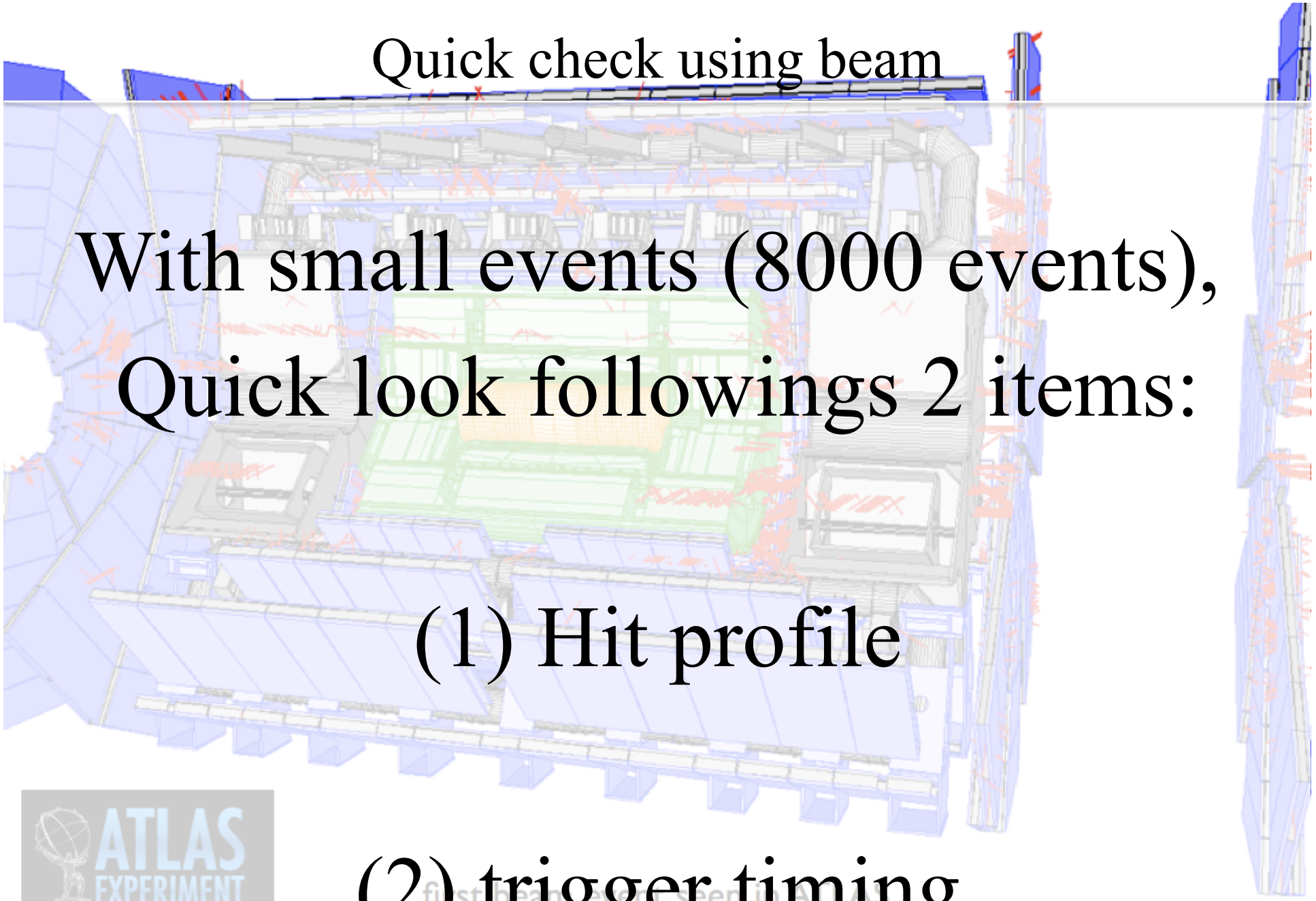
(4) Detection efficiency : selection criteria

1) Select good tracks
   - 99% in $\chi 2$ distribution
   - Good correlation with EI/EO
2) Remove tracks pointing to dead region
   - **370ch, 8%** at TGC1
3) Request L4&5&7 wire&strip hit
   - To raise purity. Because L4 ~ 7 are used by trigger (3/4)
4) Check L1,2,3 hit





Quick check using beam



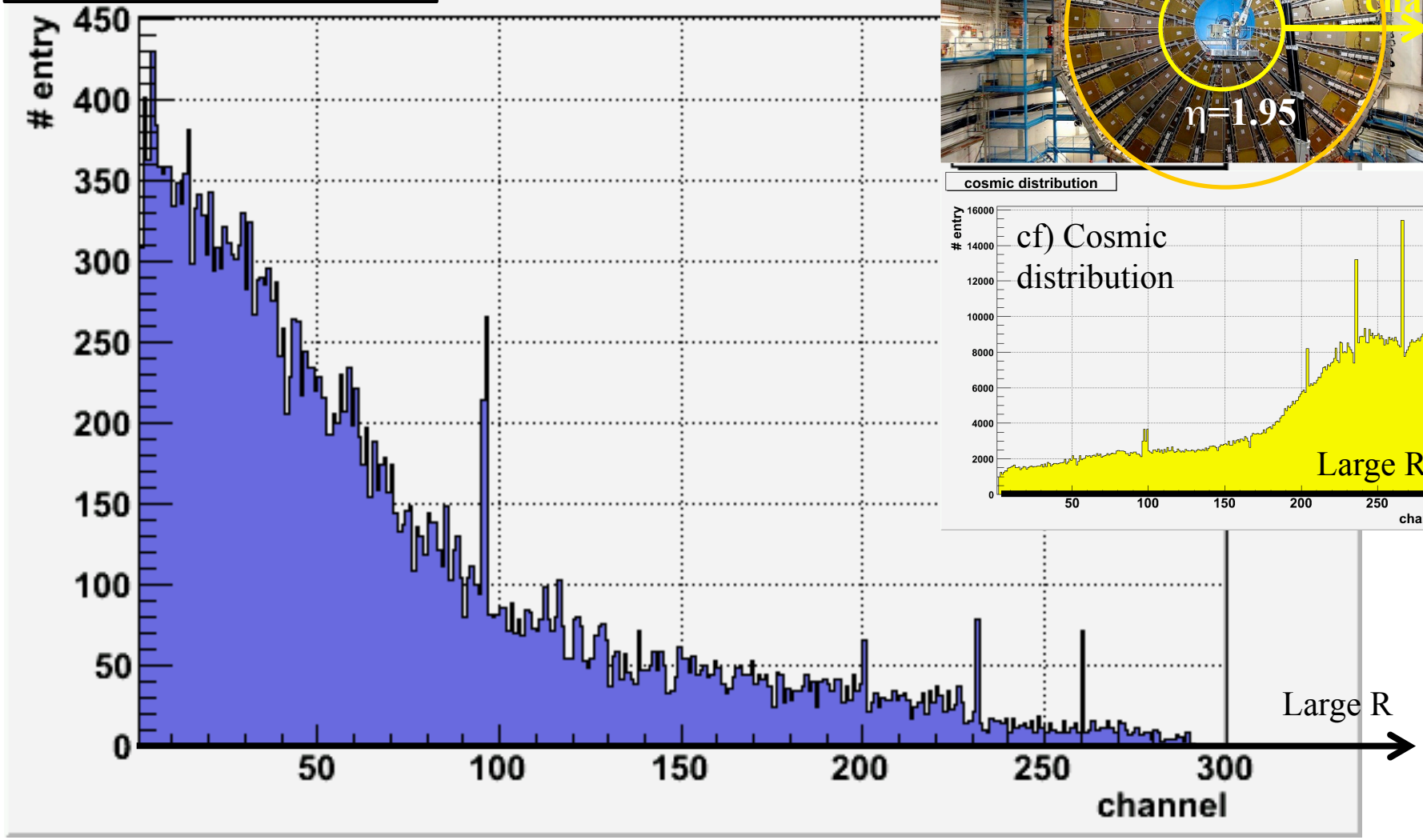
With small events (8000 events),
Quick look followings 2 items:

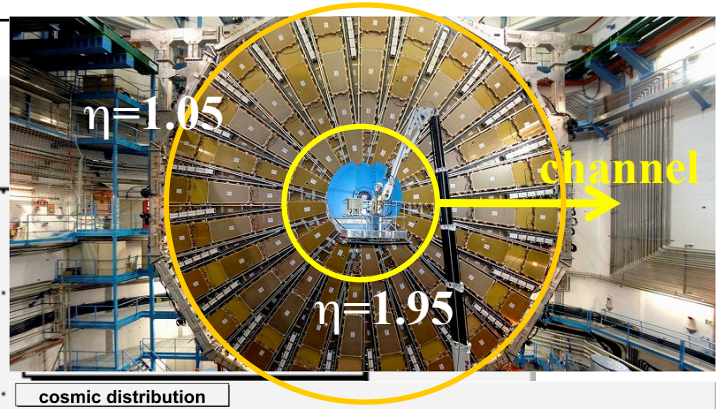
(1) Hit profile

(2) trigger timing

(1) Hit profile

Run#87863 (beam)
TGC3 wire hit profile



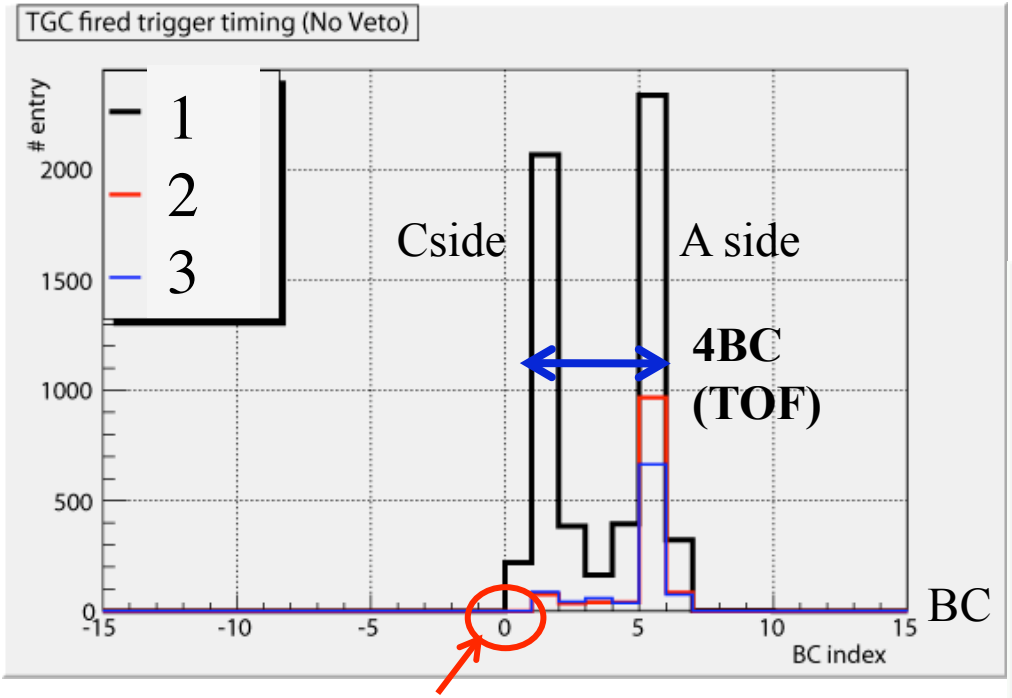


cosmic distribution

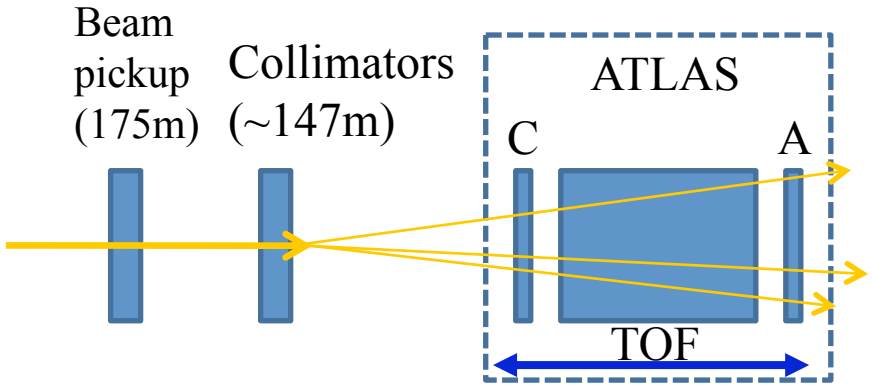
The smaller R (large η) would be, the more hits are observed

(2) Trigger timing

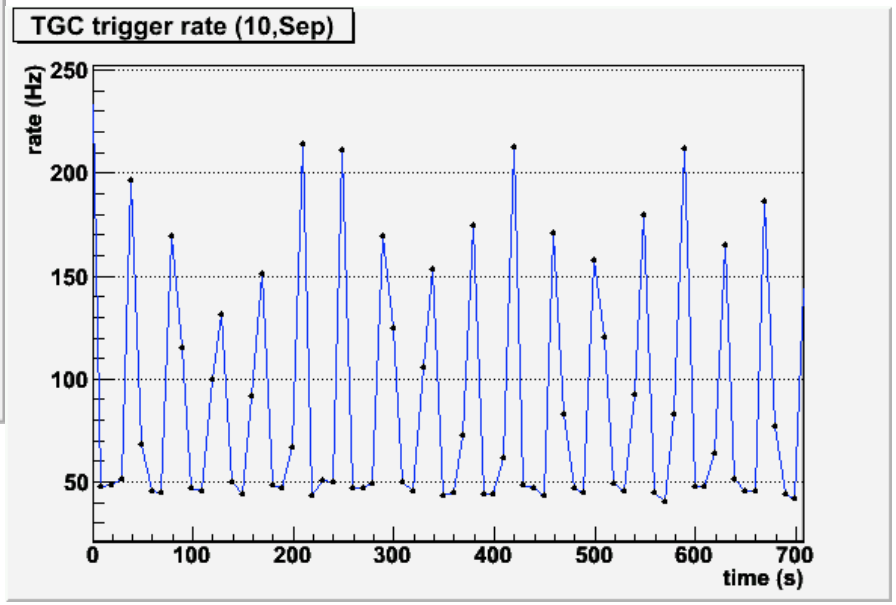
- Trigger timing for single beam has been checked



Beam pick up signal



TGC total trigger rate (2008.9.10)

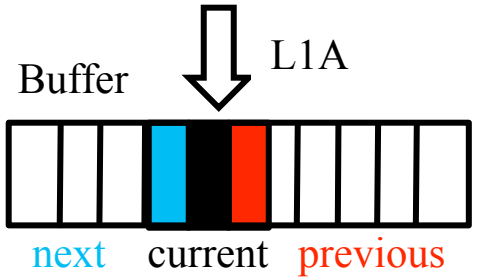


TGC recorded rate spike
Corresponding to ~40s beam injection.

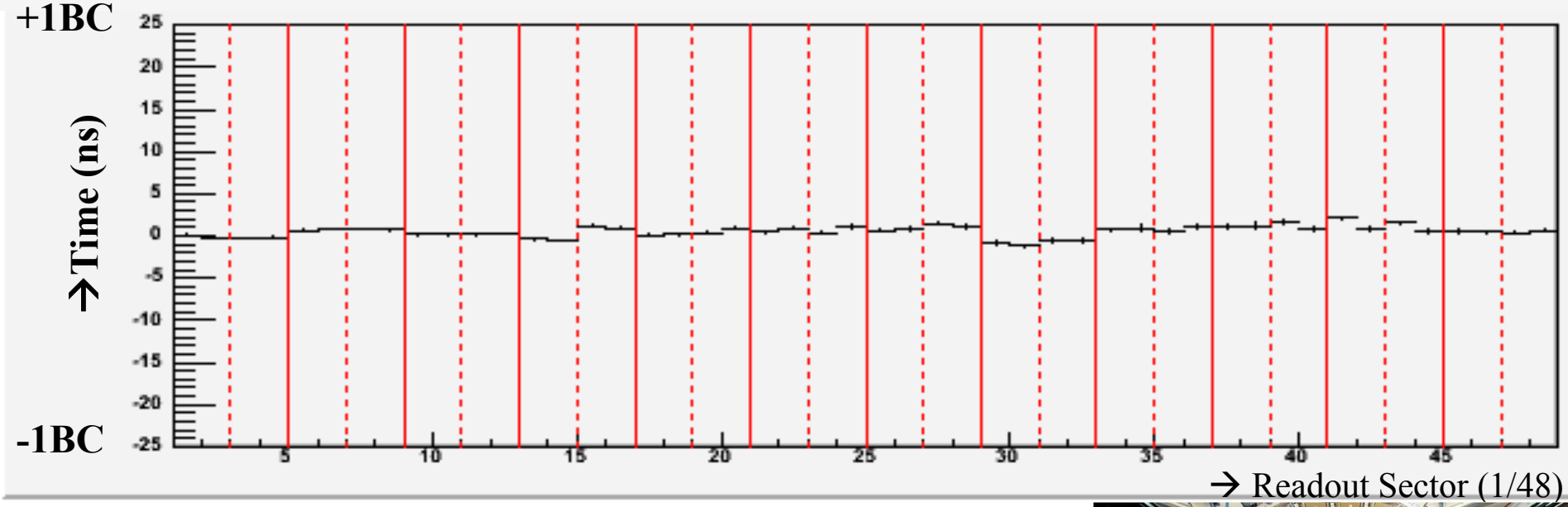
Trigger timing is well aligned within ~ 1BC

(2) Trigger timing

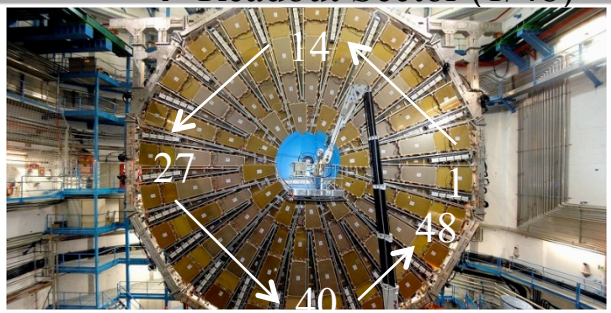
- Timing can also be checked by hit information
  - We are reading out 3BC (**next**, **current**, **previous**) for each trigger → Good indicator of timing



hit timing (all sector's average timing is normalized to 0)



→ All timings are aligned within **1BC** (≦25ns)
→ More precise adjustment is planned using beam collision



Summary

Performance for cosmic ray has been checked in situ

(1) Uniform occupancy ~ 2×10^{-5} with ~0 accidental trigger

(2) trigger only for IP pointing μ ($\Delta\theta$ < 15deg)

(3) Ideal resolution ~ 15mm

(4) Detection efficiency ~ 86.4±0.4 % (Vth, HV optimization is needed)

Quick check using first beam with small statistics

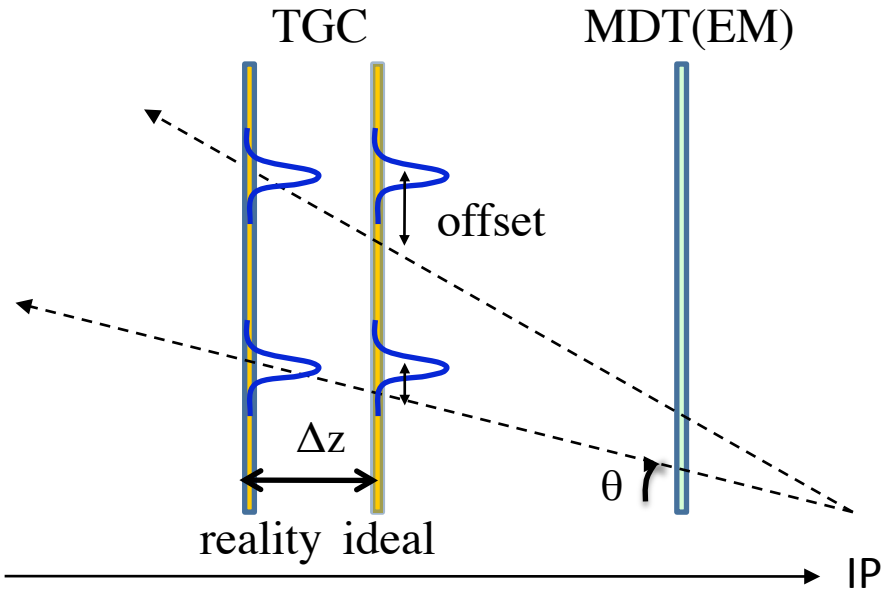
(1) hit profile : smaller R has larger entries

(2) Trigger timing is well adjusted within 25ns

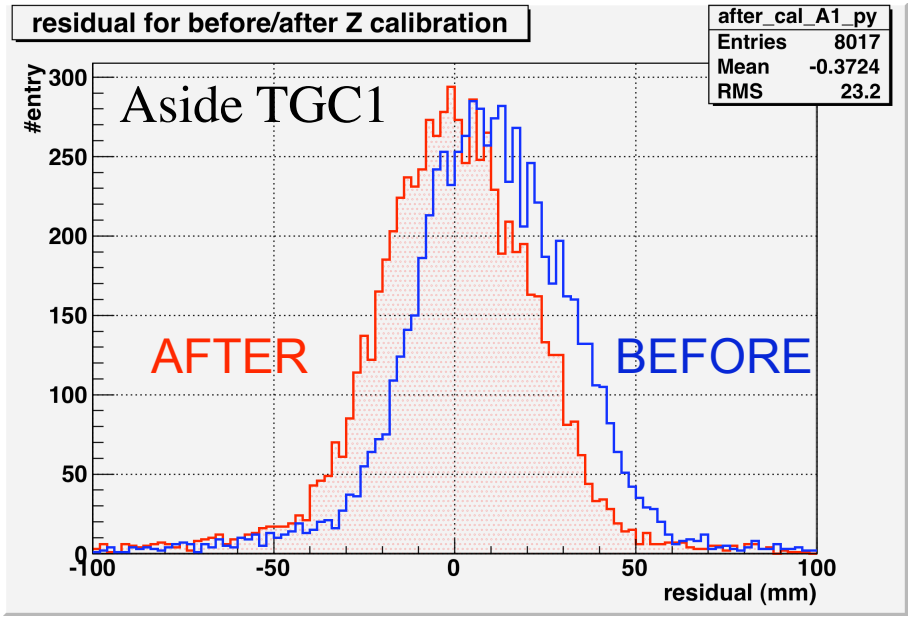
We will go on commissioning activity towards 1st, Oct (beam will come back again)

ADDITIONAL SLIDES

Calibration of miss-alignment

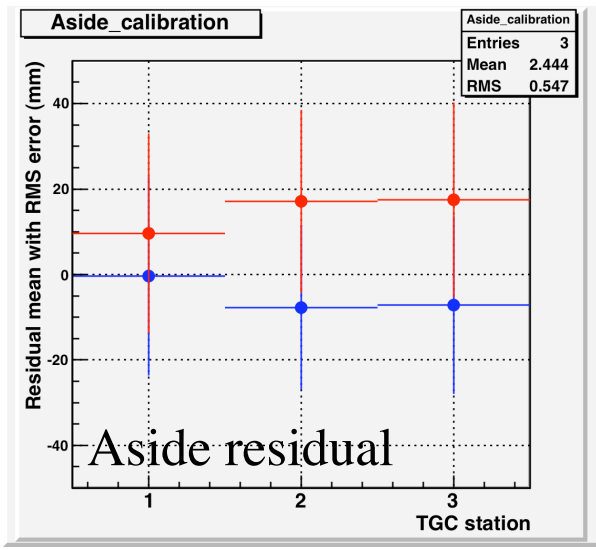


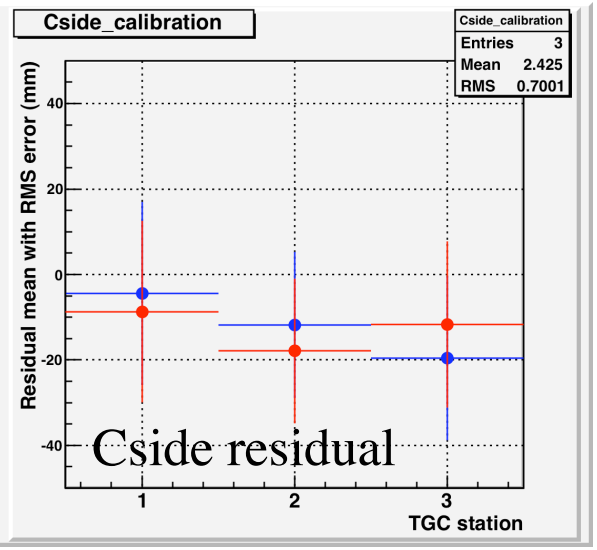
$$\mathrm{offset} = \Delta z \times \tan\theta$$



shifted distance
for calibration (Δz)

	Aside	Cside
TGC1	12.6mm	5.51mm
TGC2	31.7mm	7.65mm
TGC3	31.6mm	10.1mm

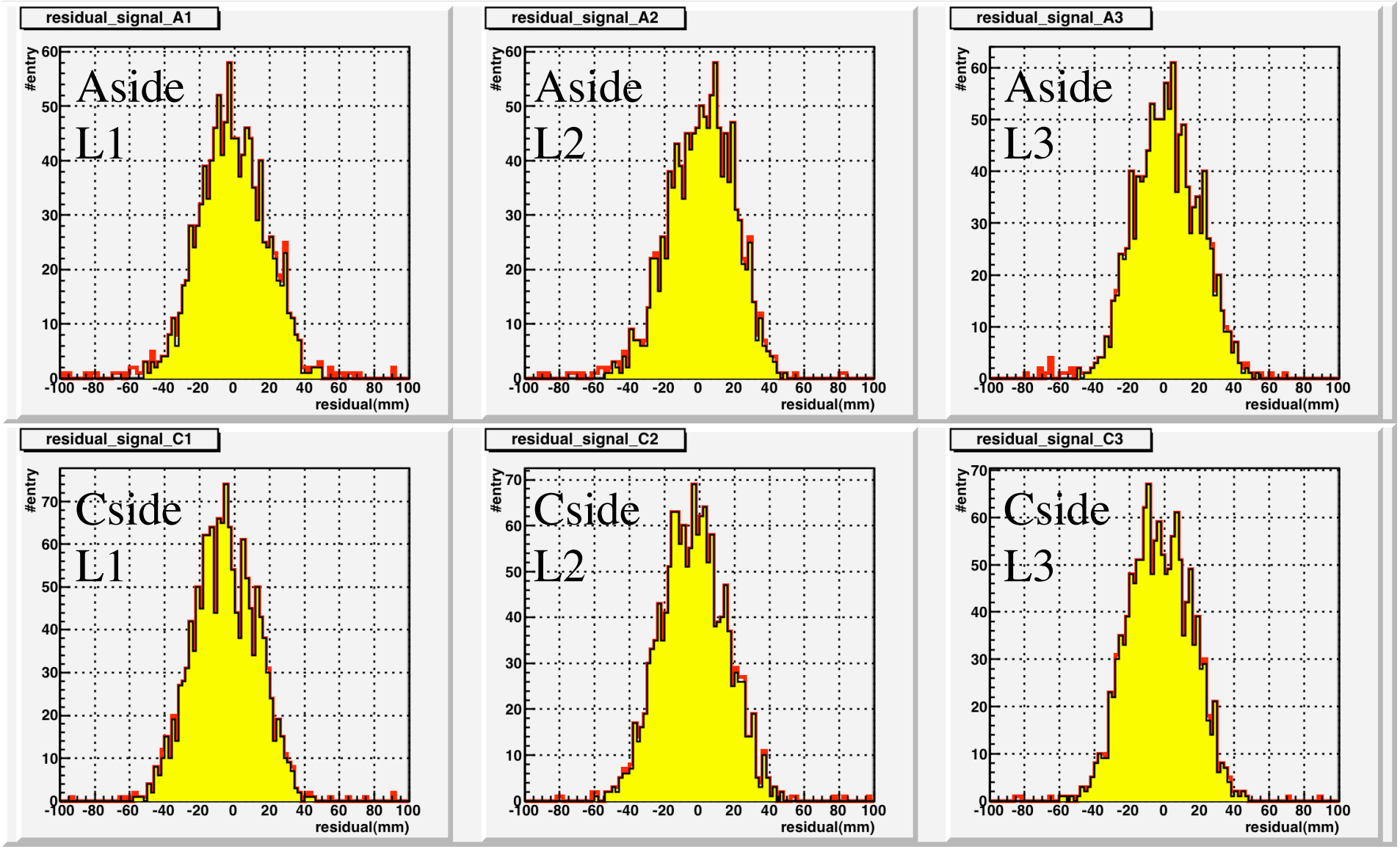




Blue : after calibration, Red : before calibration

Triplet residual distribution

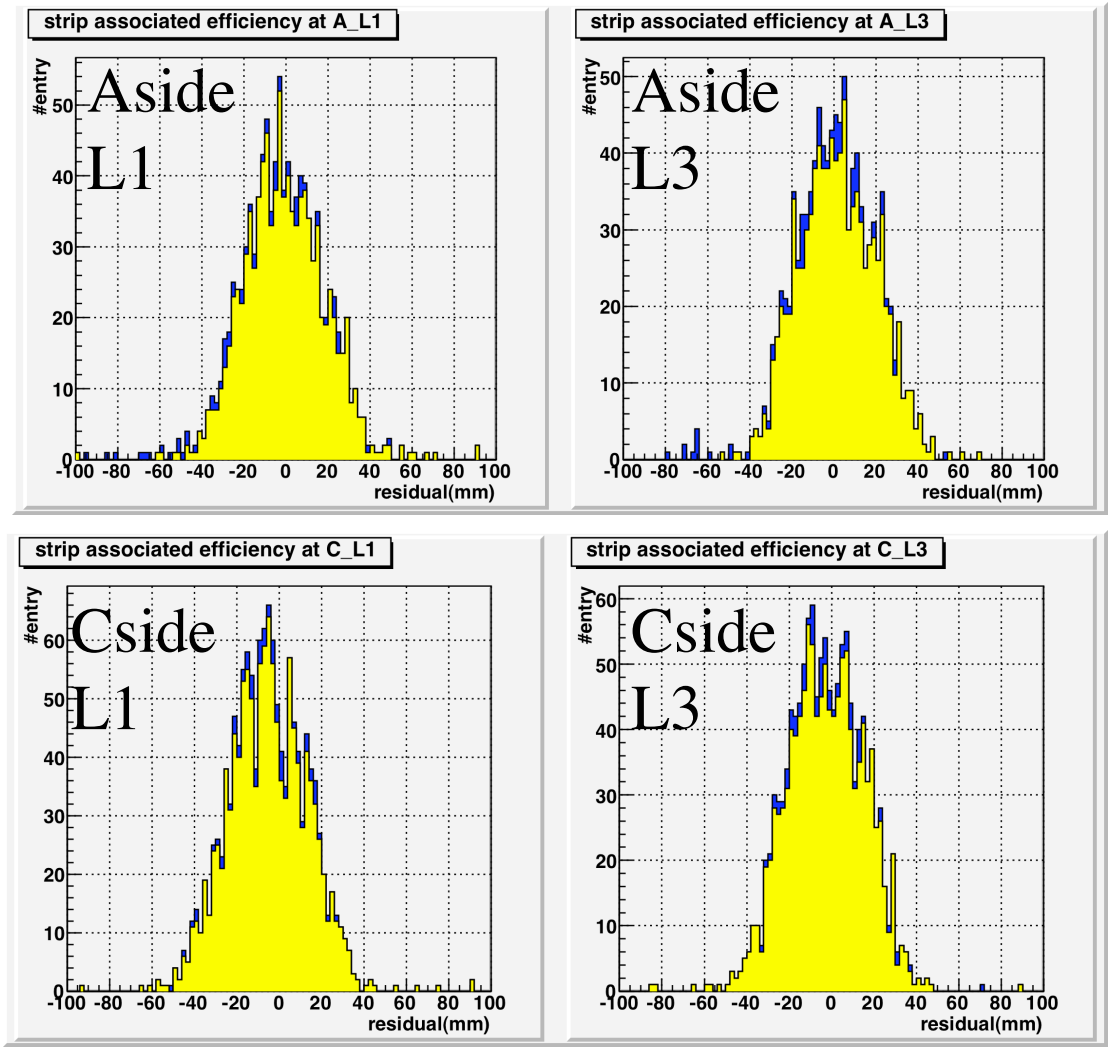
↓wire hit residual distribution (red), within channel size (yellow)

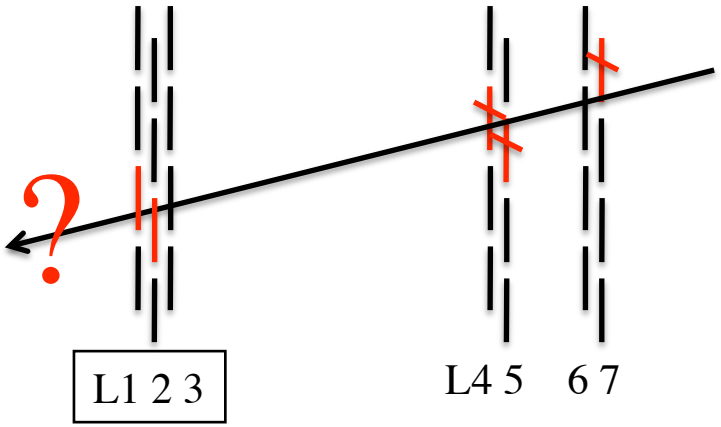


Strip associated efficiency

Request L4 & 5 & 7 wire and strip hit and L2 wire (there are no strip channel)
→ request L1/L3 wire hit and check strip associate hit within its chamber

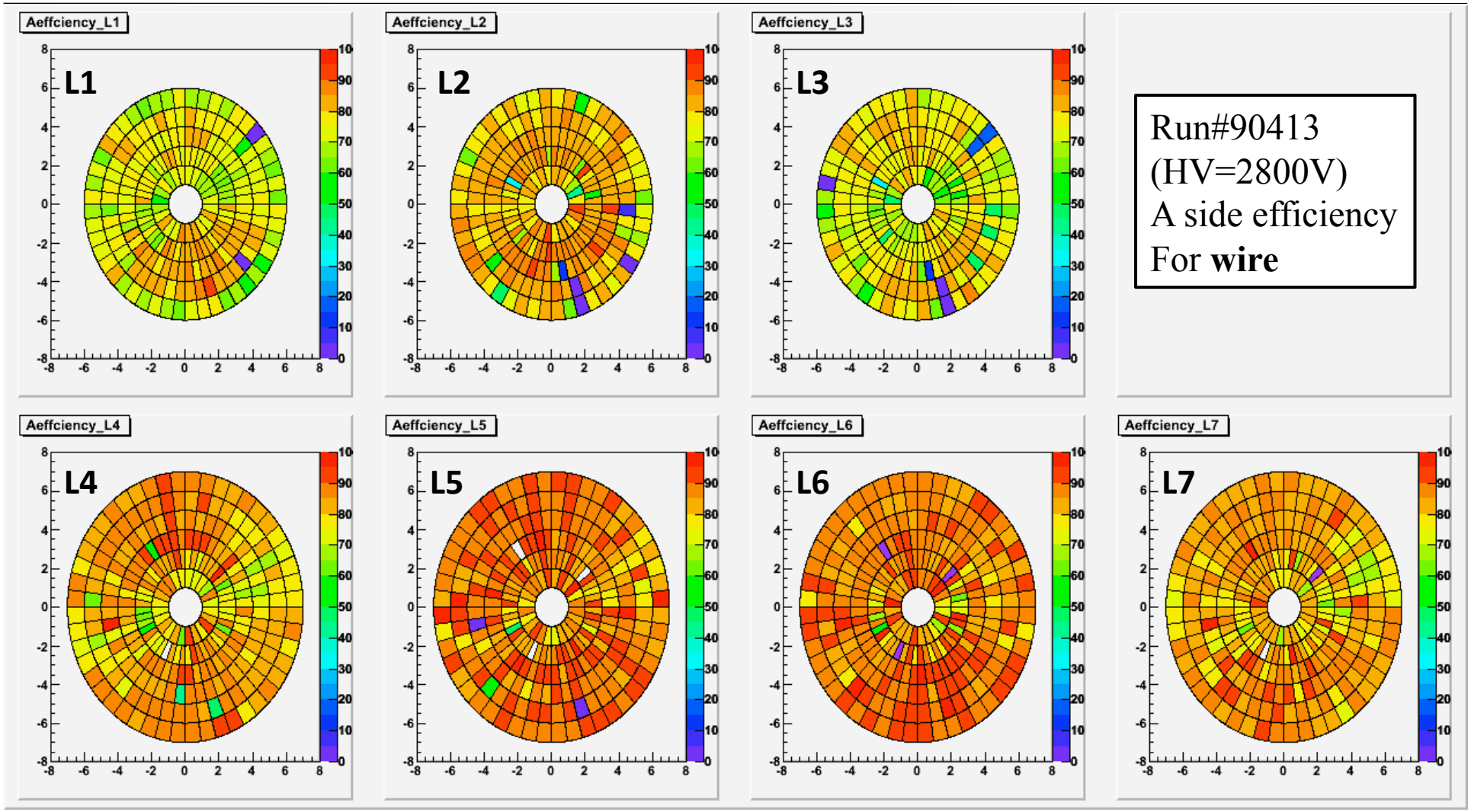
↓wire residual distribution (blue) with associated strip hit (yellow)





		efficiency	error
Aside	L1	93.3 %	0.76 %
	L3	92.3 %	0.80 %
Cside	L1	95.1 %	0.60 %
	L3	94.5 %	0.65 %
combined		**93.8 ± 1.4%**	

efficiency using only TGC



efficiency is 80~90% around HV=2800V

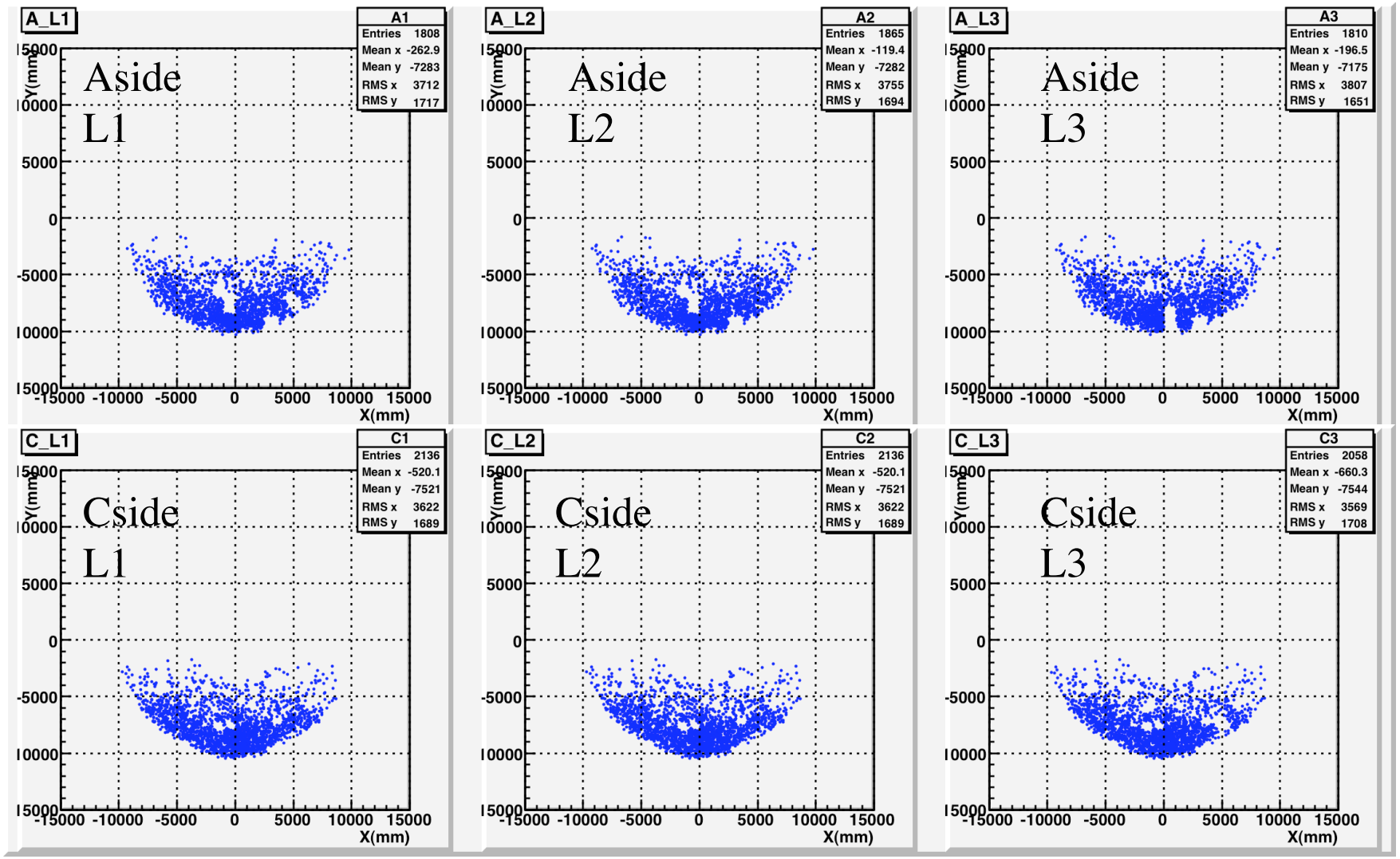
→Including 5% inefficiency due to dead region, support structure

→TGC1 efficiency seems to be low, estimation way should be confirmed

Detection efficiency

Remove tracks pointing to dead/swap region (**370ch, 8%**) of TGC1

↓Projection point of track at TGC1, L1,2,3



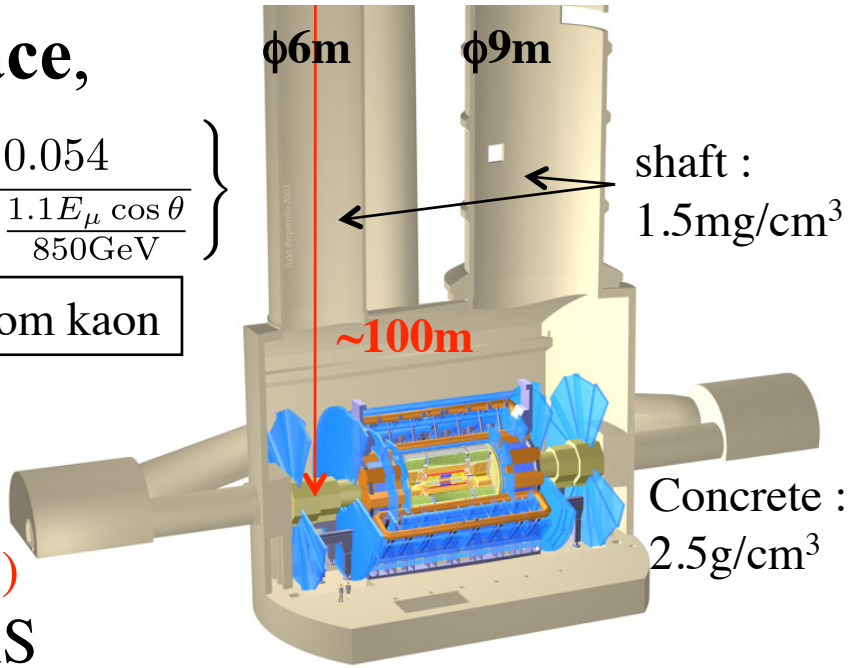
→ will be fixed before next combined run (part of them is arleady fixed)

Trigger rate/hit distribution

- Cosmic μ's spectra at the **surface**,

$$\frac{dE_\mu}{dE_\mu} = \frac{0.14E_\mu^{-2.7}}{\mathrm{cm^2\ s\ sr\ GeV}} \times \left\{ \frac{1}{1+\frac{1.1E_\mu\cos\theta}{115\mathrm{GeV}}} + \frac{0.054}{1+\frac{1.1E_\mu\cos\theta}{850\mathrm{GeV}}} \right\}$$

from pion | from kaon



- Assume MIPS μ loses energy until ATLAS detector :

2MeV/g/cm² x 2.5g/cm³ x 10^5 cm ~ O(10GeV)

→ Only Eμ > 10GeV can reach ATLAS

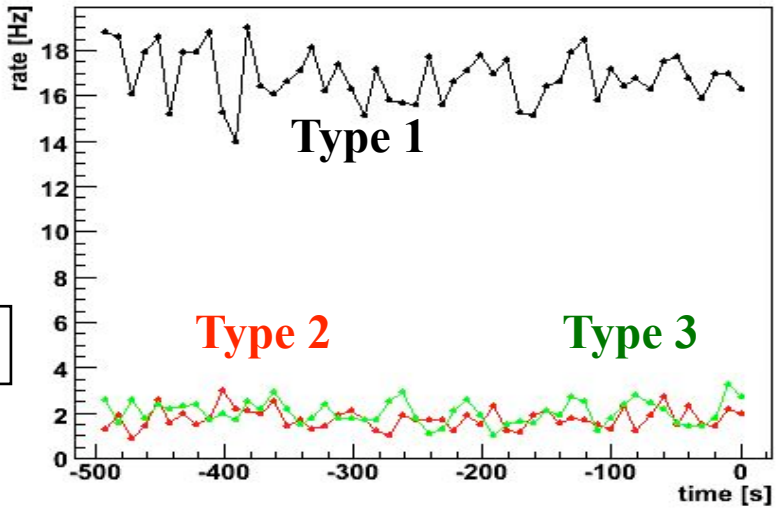
- TGC valid area ~ O(10m²) / sector
- Trigger efficiency ~ 95%

$$\mathrm{rate\ (Hz)} = \int_{10\mathrm{GeV}}^{10\mathrm{TeV}} \frac{dE_\mu}{dE_\mu} \times 10(\mathrm{m^2}) \times \Omega \times dE$$

$$\sim \boxed{\mathcal{O}(1\mathrm{Hz/sector})}$$

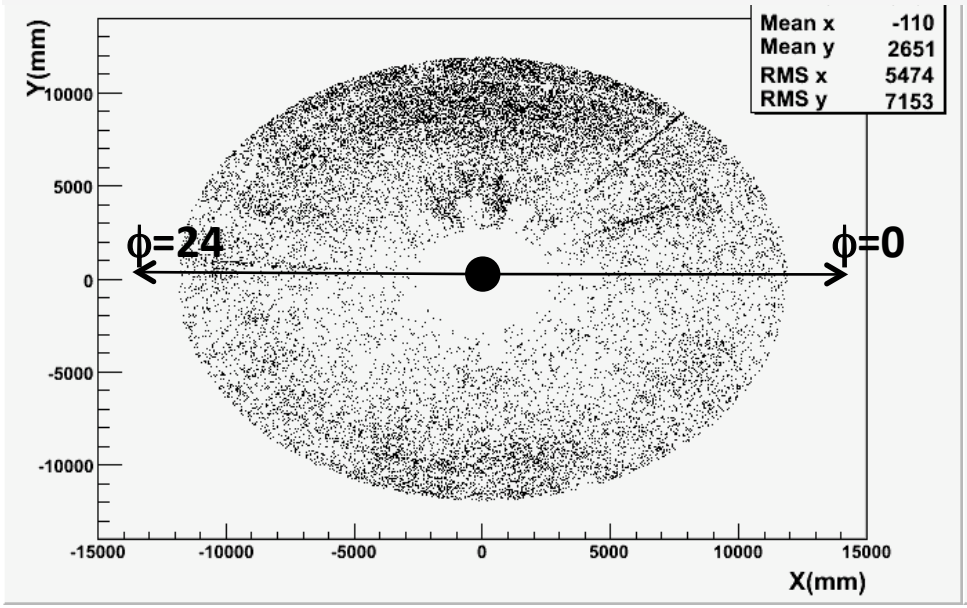
→ Almost consistent what we observed

Trigger rate (cosmic, for all 24 sector)

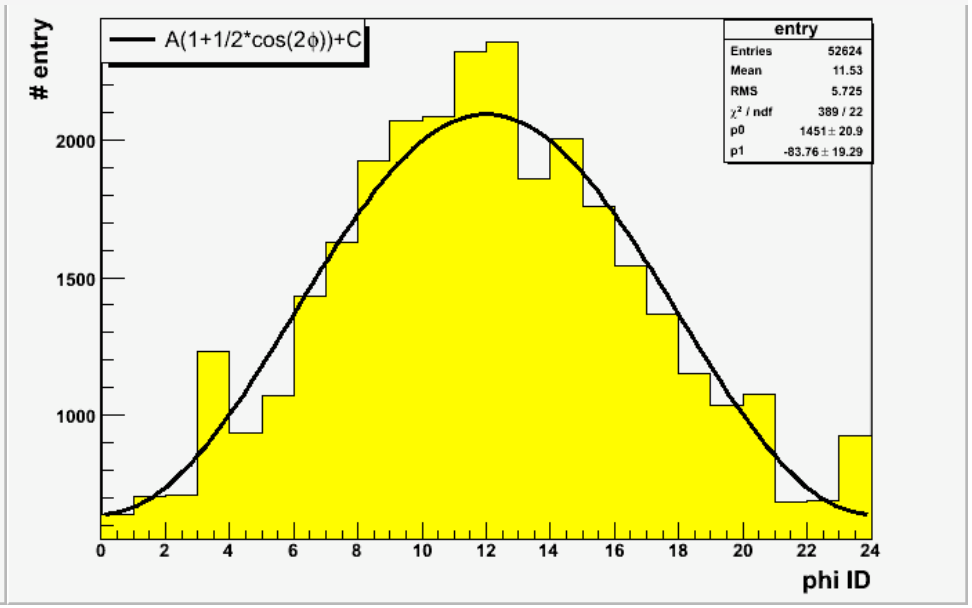


Trigger rate/hit distribution

Trigger distribution at TGC3 plane



Phi distribution (only upper half)



Basically, cosmic ray has distribution :

$$J(\theta) = j_{\theta=0} j \cos^2\theta + C \qquad J(\phi) = j_{\phi=0} j \cos^2\phi + C$$

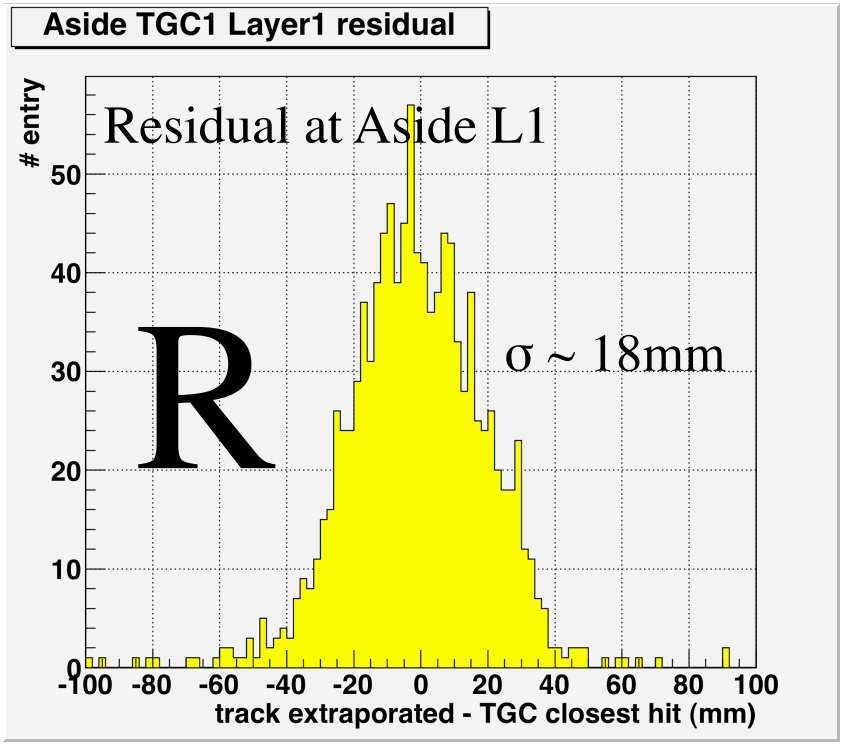
Suppose 20<θ<50 deg, Δϕ < 2p/48 (inside 1 chamber) is accepted by trigger logic
→Intensity of J(θ, ϕ) :

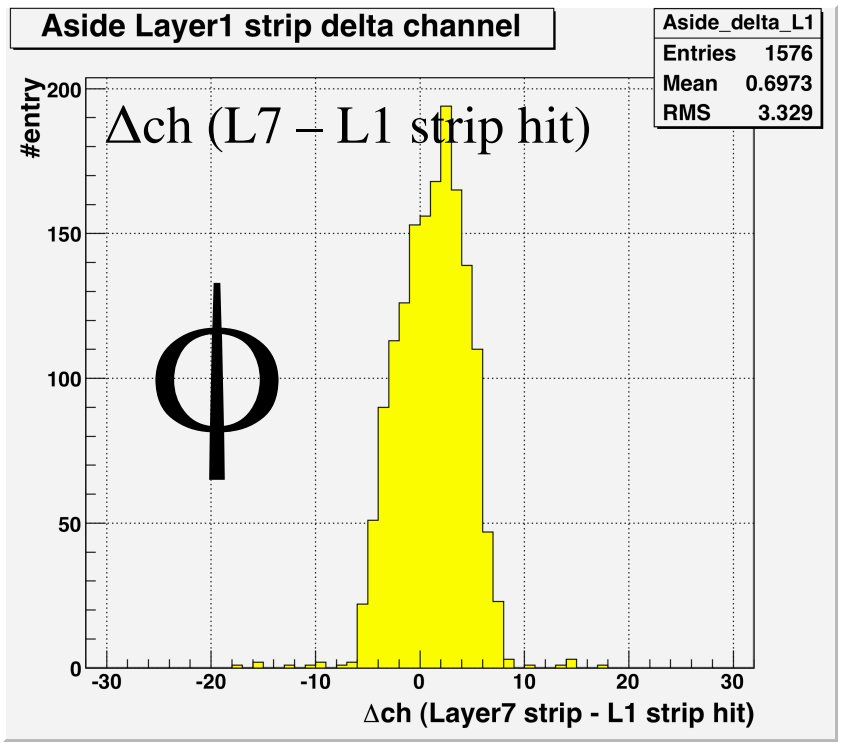
$$J = \int A \cos^2\theta \cos^2\phi d\Omega + C \qquad J = A(1 - \frac{1}{2}\cos 2\phi \cdot \Delta\phi) + C$$

Reasonable trigger rate / hit distribution for cosmic ray muons

Track purity

- Good track selection → **7k/180k, 4%** tracks remained
- Track purity
  - ρ Residual ~18mm → decided by MDT σ(θ) ~ 10mmrad, TGC channel resolution ~ 40mm/√12 (smaller than TGC channel size)
  - Strip Δch (L7-L1 hit) at same trigger sector is limited well

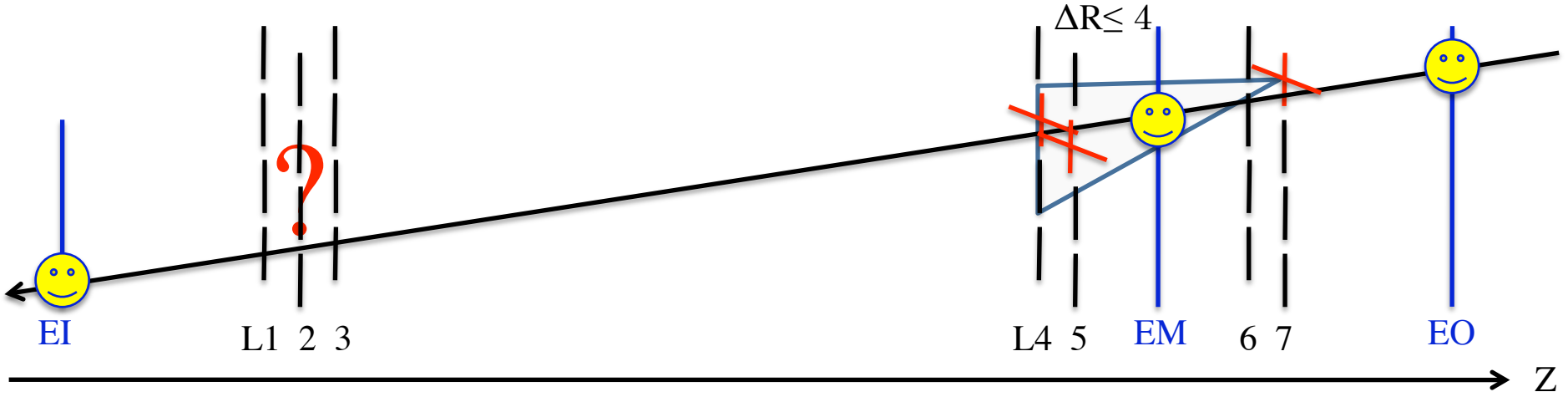




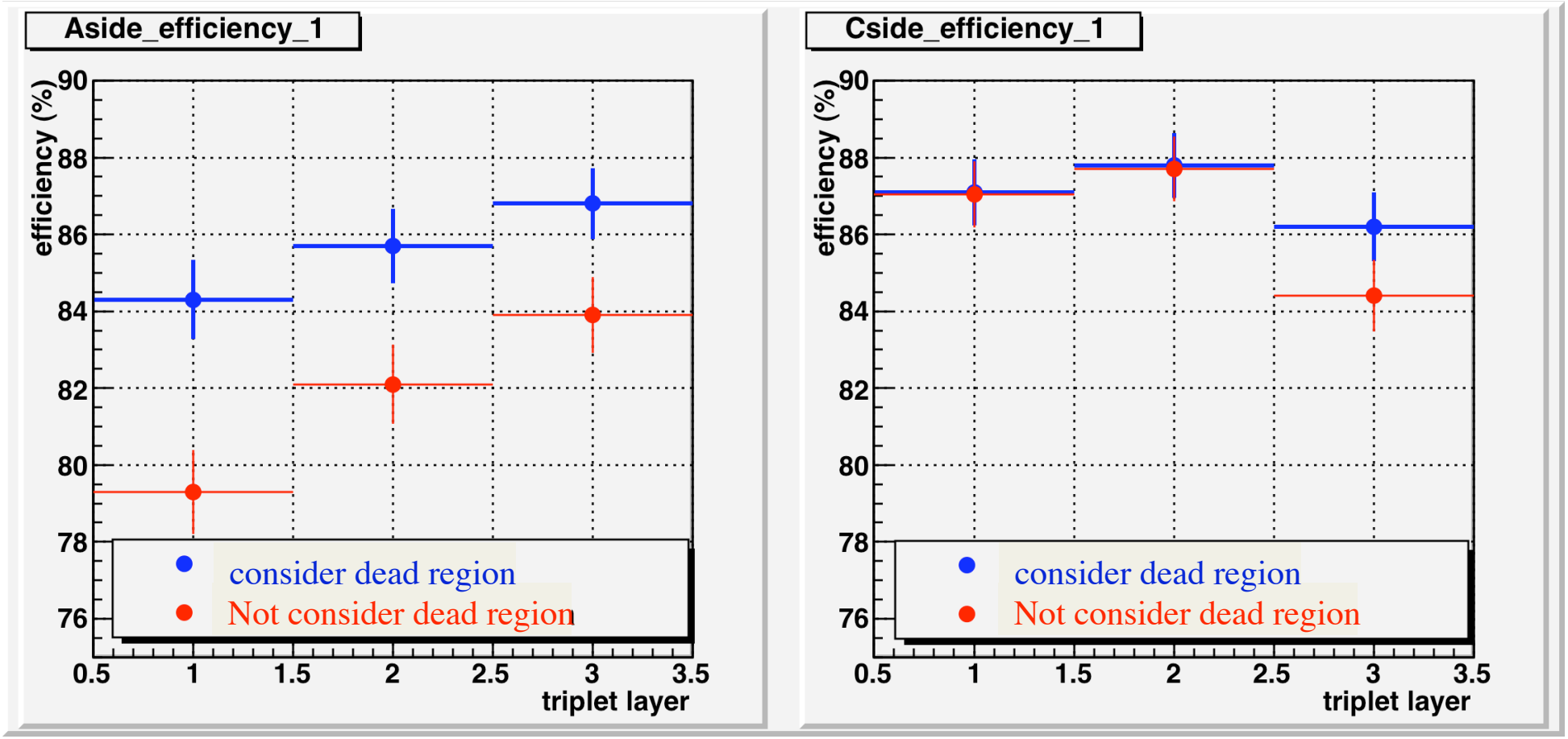
Selected tracks are almost good track with associated TGC trigger with reasonable r/ϕ residuals

Efficiency criteria

	Selection (Run# 91060, total #event ~ 180k)	Aside			Cside		
		L1	L2	L3	L1	L2	L3
1	Good track selection ・probability>99% at χ^2 distribution ・MDT hit ≥ 4, TGC phi hit ≥ 1 ・correlation with EO/EI and EM, $\Delta\varphi<\pi/16$, $\Delta\theta<12$mmrad	3714			3819		
2	Removing tracks pointing TGC dead region	3466	3553	3443	3803	3803	3696
3	L4 & 5 & 7 : wire & strip hit on the track	1559	1609	1606	1854	1854	1803
4	L4 & L7 wire satisfies coin ($\Delta R \leq 4$)	1260	1306	1319	1536	1536	1488
5	Associated L1,2,3 wire hit	1062	1119	1145	1338	1348	1283



Detection efficiency



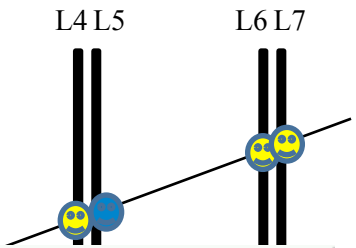
Combined result = **86.4 ± 0.4%.**

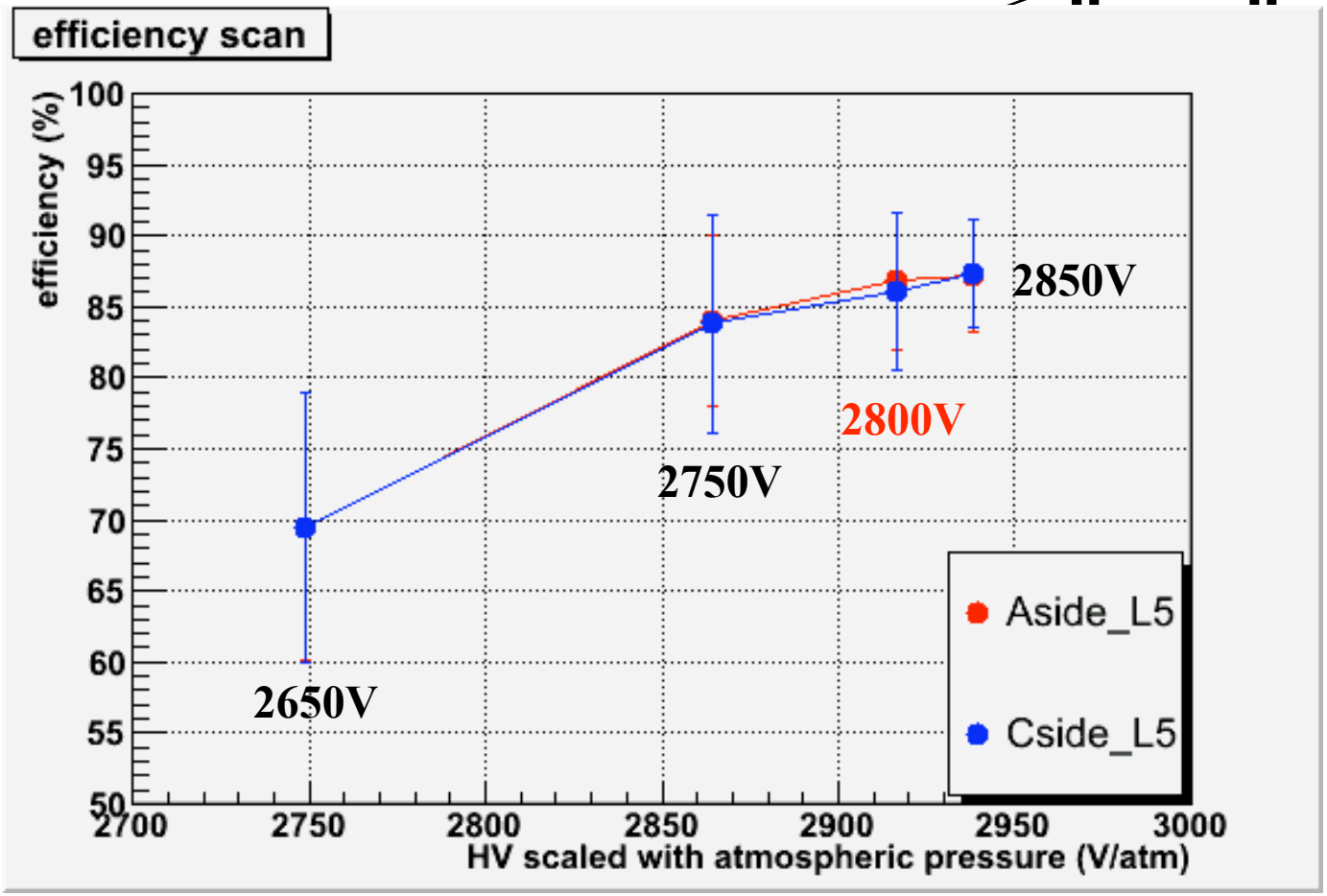
→After removing dead region, efficiency improved 2,3 %

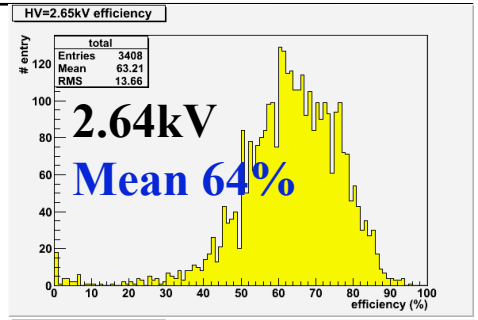
→Little lower with ideal (93%), should be adjusted by Vth, HV

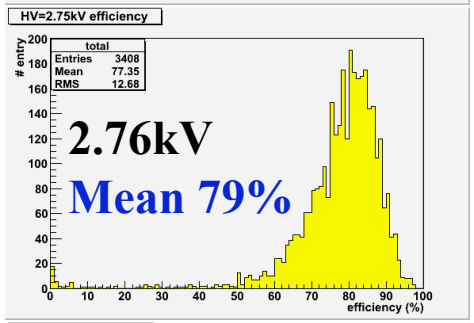
Operating HV

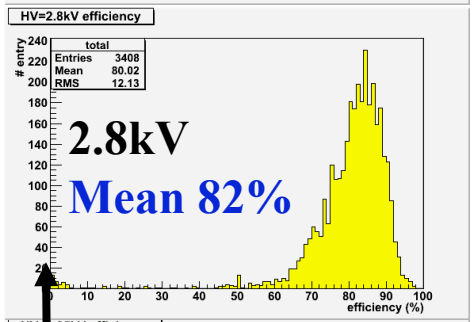
- As preparation, 4 different HV run was taken to decide reasonable point
  - (ex) L5 efficiency = #(L4,5,6,7)/#(L4,6,7)

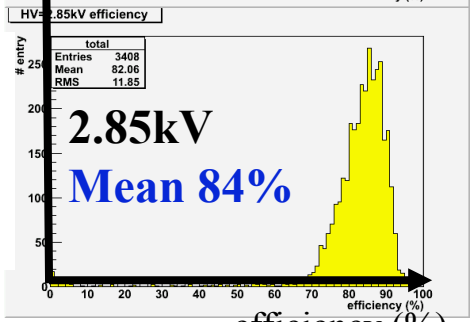












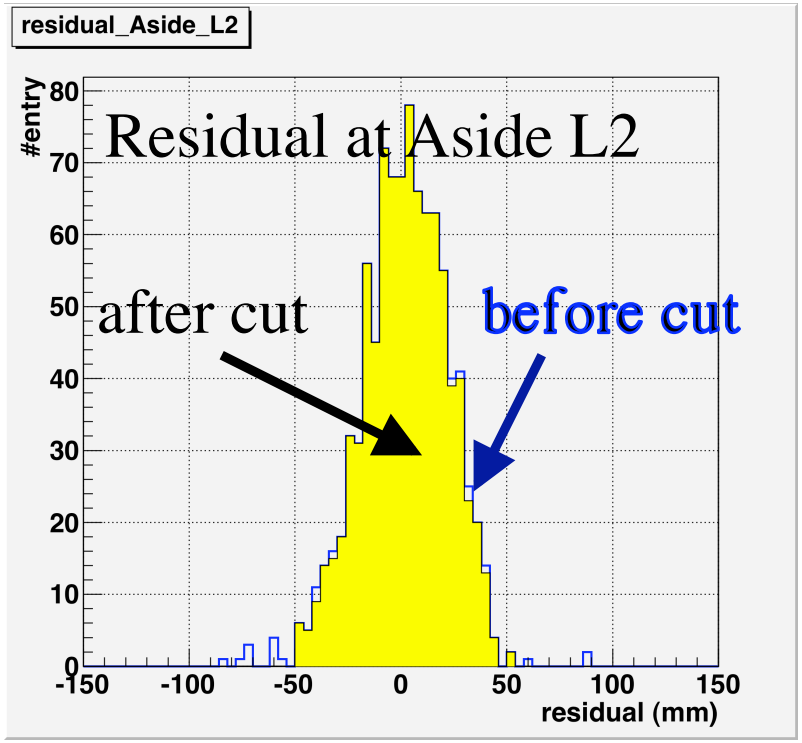
# of chamber

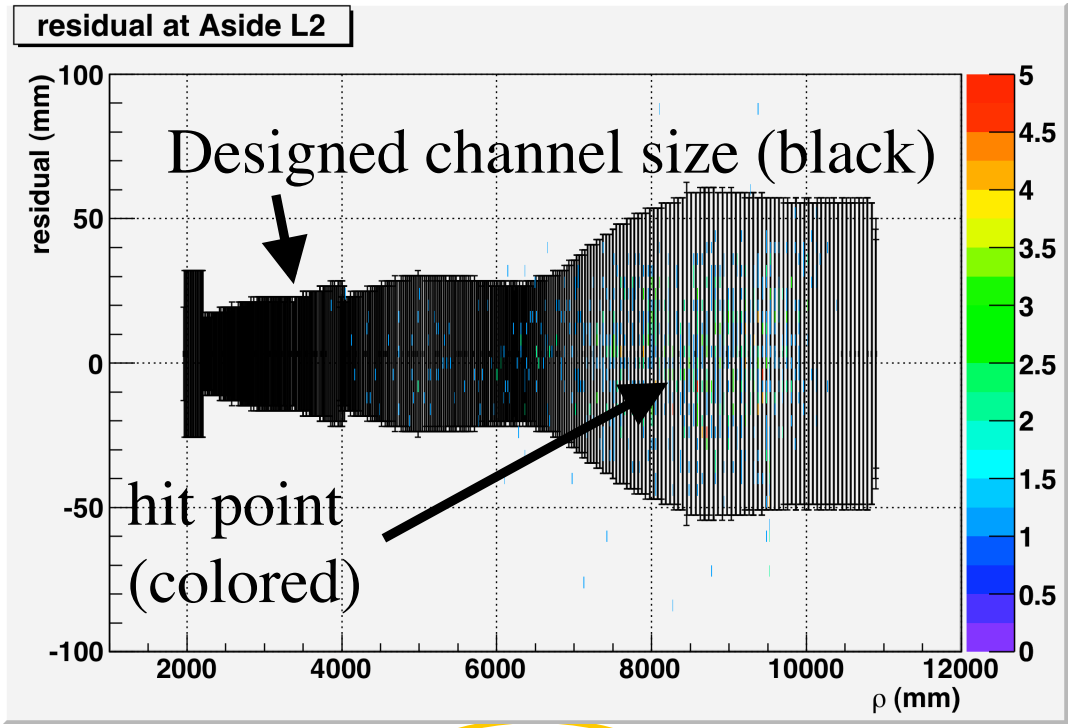
efficiency (%)

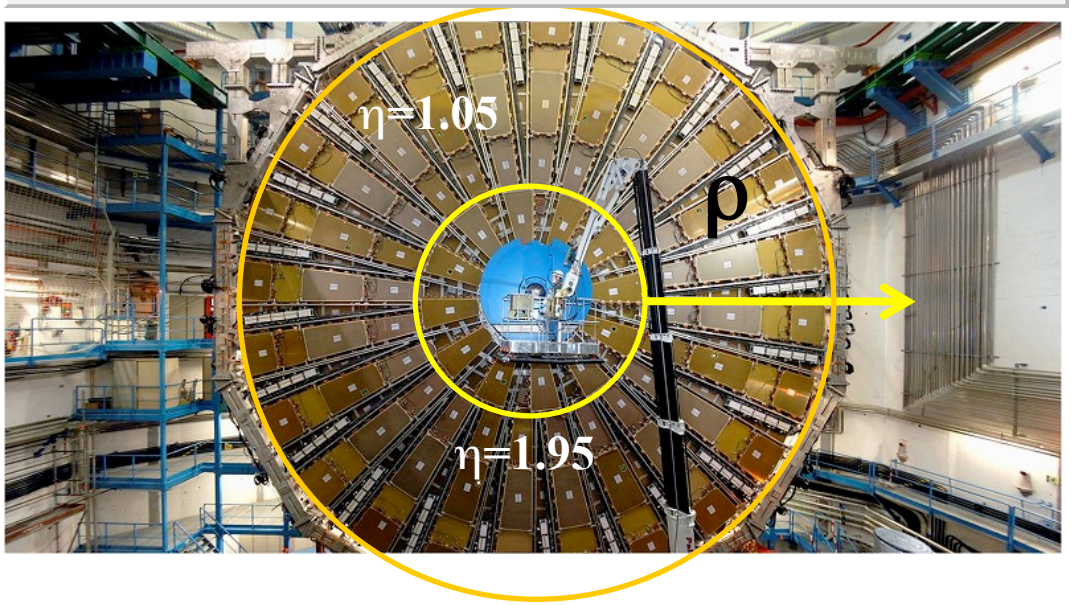
We decided to operate at 2800V

Detection efficiency : selection for L1,2,3 hit

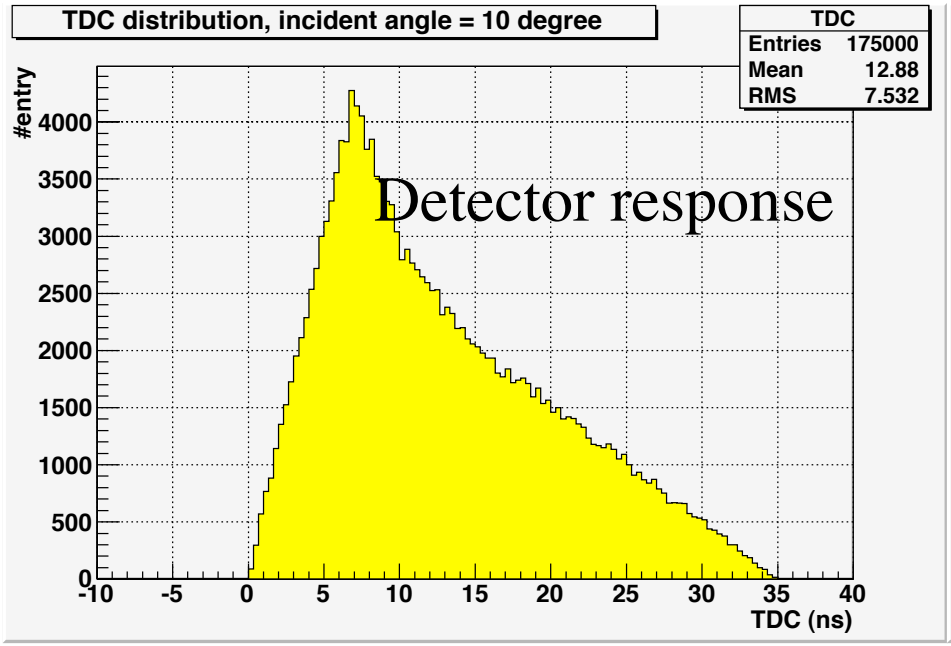
- L1,2,3 hit was selected :
  - Only when **residual (track - closest TGC hit) < channel size** is satisfied
  - Cut region is changed because channel size changes as the function of ρ

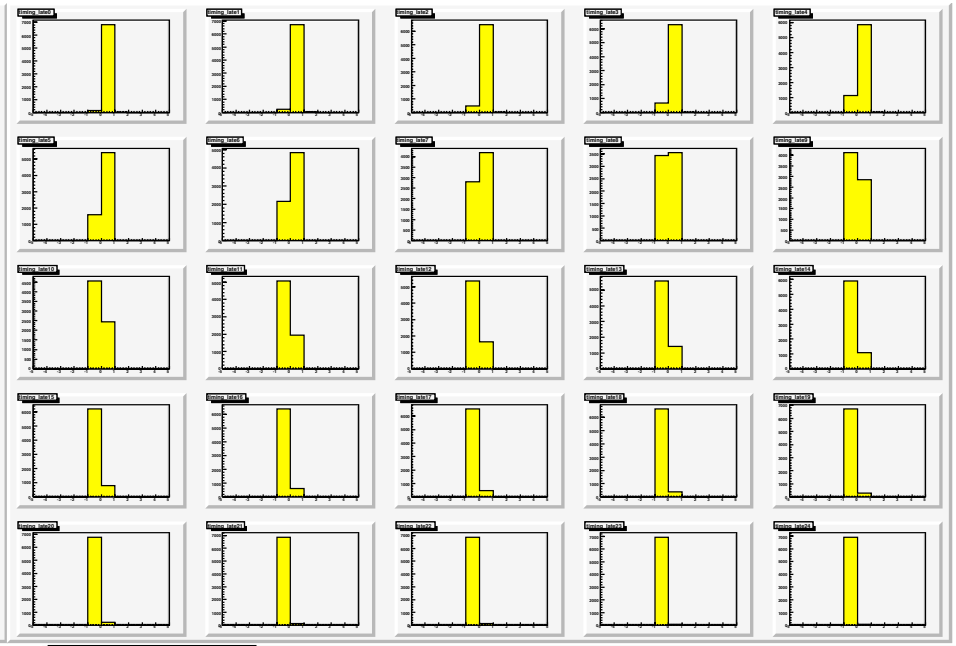


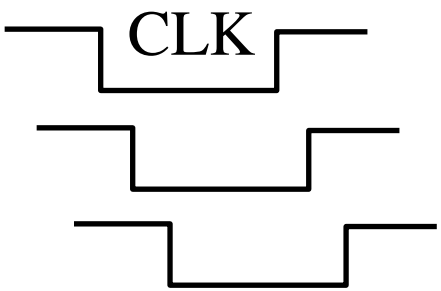




Trigger timing adjustment using beam







Best trigger timing is adjusted by clock phase.
Scan will be done using beam