43rd B2GM

TRG session

2022/10/5 (Wed)

Development of track finding algorithm using TFP-SVD for L1 trigger

Contents

- **Motivation**
- **TFP-SVD and trigger algorithm**
- **Review of last achievement**
- **New study for better TRG performance**

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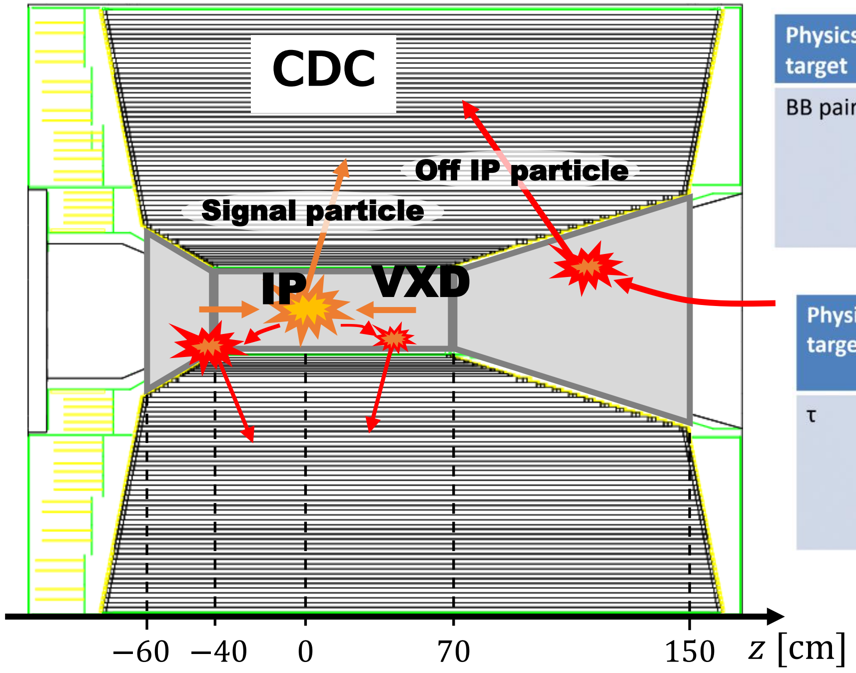
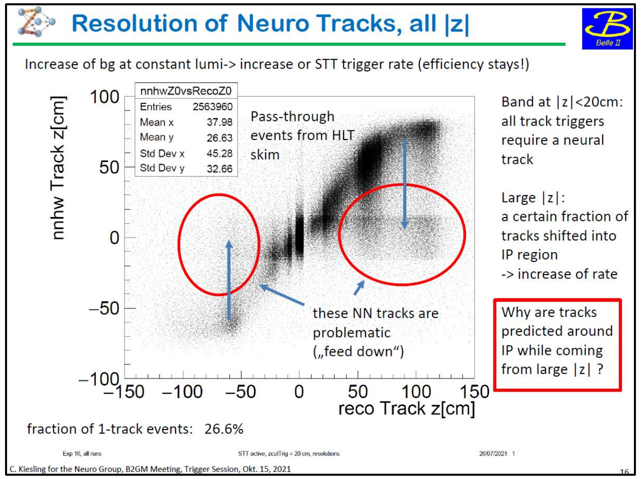
Motivation

- CDC trigger has highest trigger rate among sub-triggers of Belle II L1 trigger.
- Off IP particles are one of the sources of beam background.
- CDC trigger cuts particles coming from 15 or 20cm away from IP.



Physics target	bit name	condition	Raw rate (kHz)	Exclusive rate (kHz)
BB pair	ffy	CDC #2track>=3, NNtrack>=1 with |z|<20cm >=1	1.40	1.40
	fyo	CDC #2track>=2, NNtrack>=1 with |z|<20cm >=1, Δϕ>90deg	1.03	0.47
			0.13	0.08
	c4	ECL #cluster>=4, 2<θid<15	0.69	0.56
	hie	ECL Energy sum>1GeV, 2<θid<15		

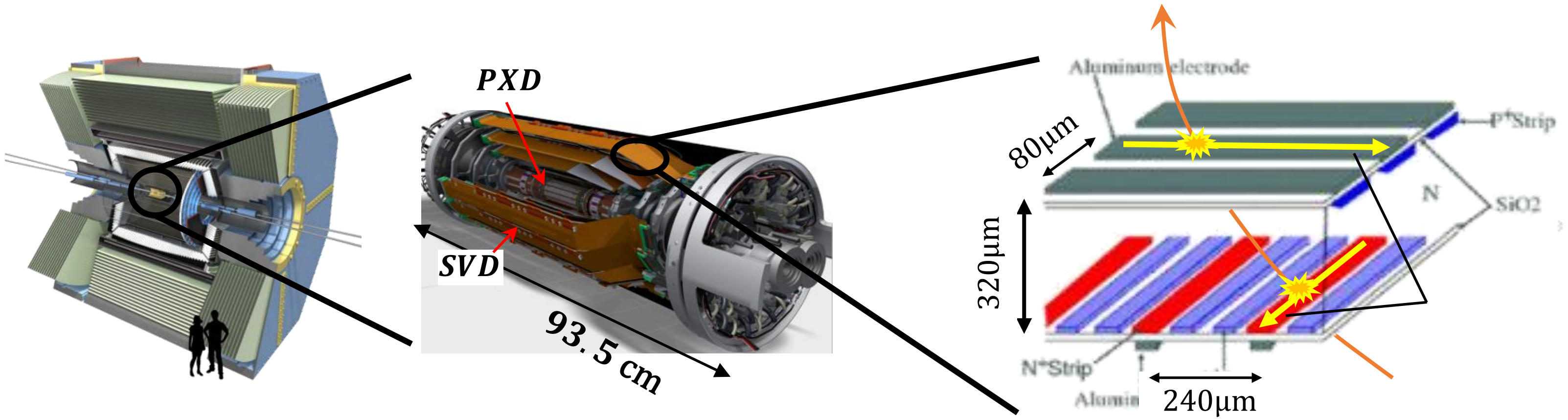
Physics target	bit name	condition	Raw rate (kHz)	Exclusive rate (kHz)
τ	stt	CDC #full track>=1, |z|<15cm, p>0.7GeV	1.74	0.96
	syo	CDC #full track>=1, |z|<15cm, #short track>=1, Δϕ>90deg.	0.74	0.38
	yioiecl1	CDC #full track>=1, |z|<15cm, #inner track>=1, Δϕ>90deg.	0.37	0.08
	lml12	NCL ≥ 3, at least 1 CL ≥ 500 MeV(Lab)) (with θID = 2 - 16)	0.17	0.03
	ecltaub2b	under optimization	-	-



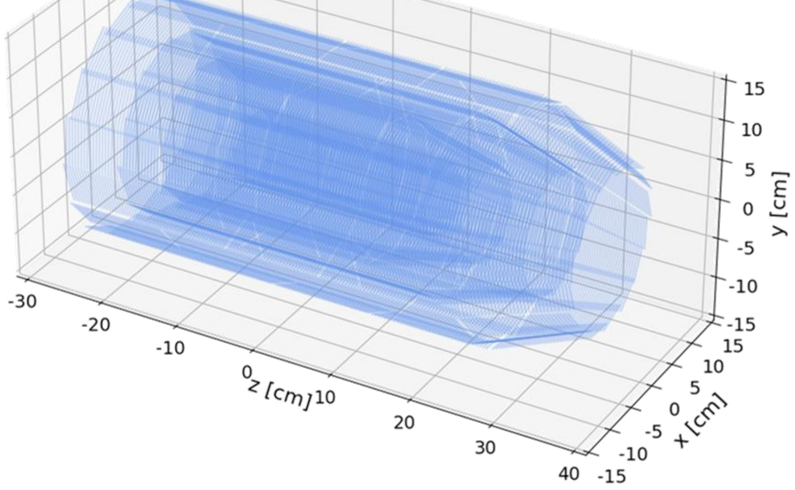
It seems that there is room to improve the current trigger

SVD

- the double-sided silicon-strip detector located in the innermost part of Belle II detectors.
- detects the position through which the particle has passed.



For now, geometry of TFP-SVD is same as current SVD

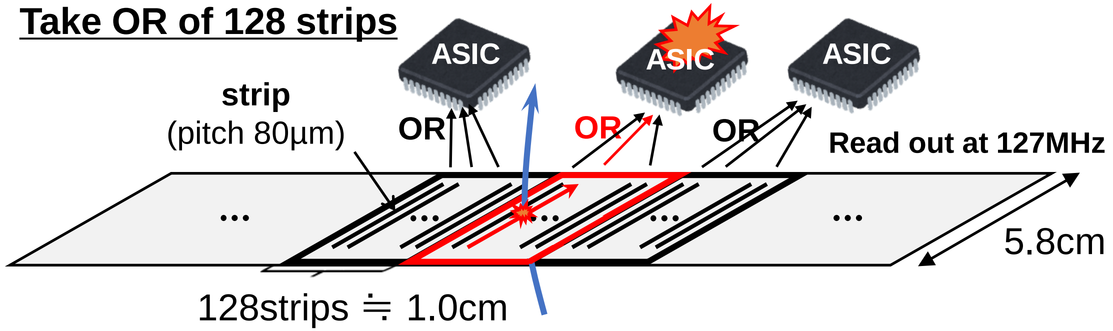


Thin-fine pitch SVD (TFP-SVD)

- We are developing new SVD to install after 2026.

	Current SVD	TFP-SVD
pitch of P side strip	75 μm	75 μm
pitch of N side strip	160 or 240 μm	80 μm
Sampling rate	32 MHz	127 MHz
Generate TRG signal	×	○

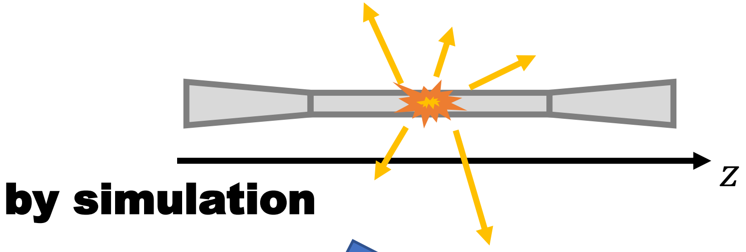
Take OR of 128 strips



We are considering new L1 trigger using TFP-SVD

Pattern matching by LOOK UP TABLE (LUT)

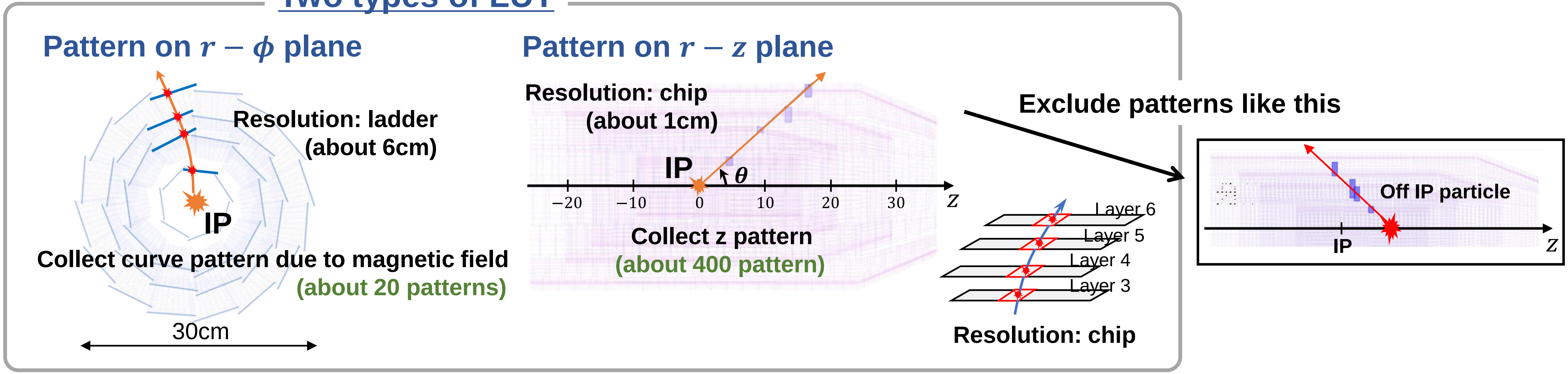
- Collect a lot of track patterns of particles from IP.
- Use those as a look up table.



Condition of particle generation for LUT

Parameter	Condition
Particle type	$\mu^{\pm}$
momentum p [GeV/c]	$0.2 \le p \le 3.0$
Production point z [cm]	$z = 0$

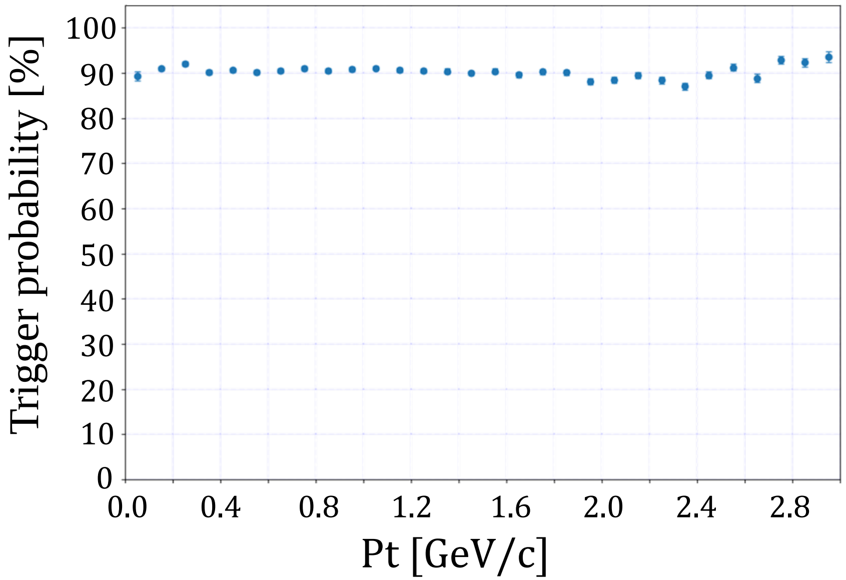
Two types of LUT



Result: One signal particle study

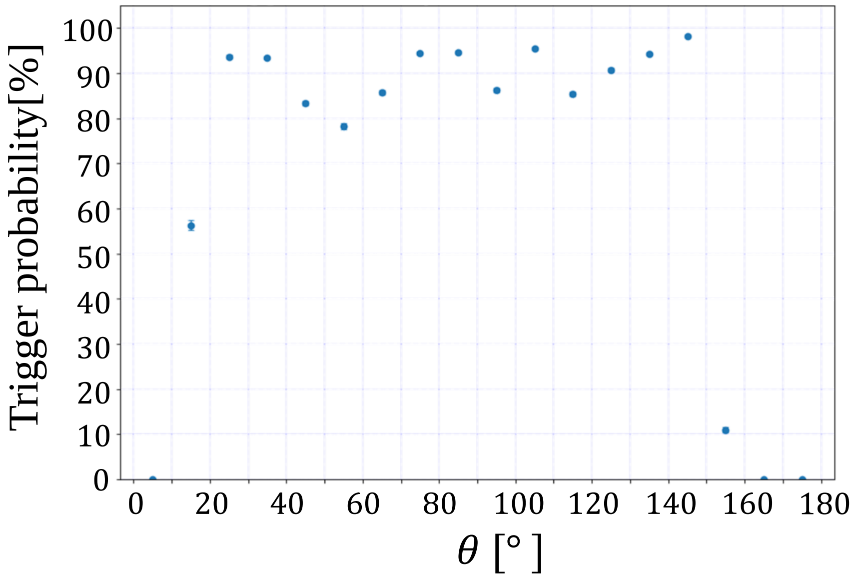
- We generated only one particle at IP and investigated trigger efficiency.

TRG Prob vs Pt

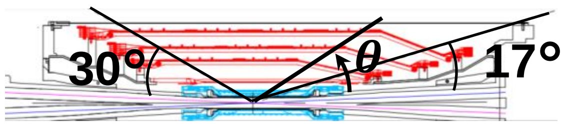


TRG efficiency is about 90%

TRG Prob vs θ(particle ejection angle)



SVD volume angle



Directional efficiency

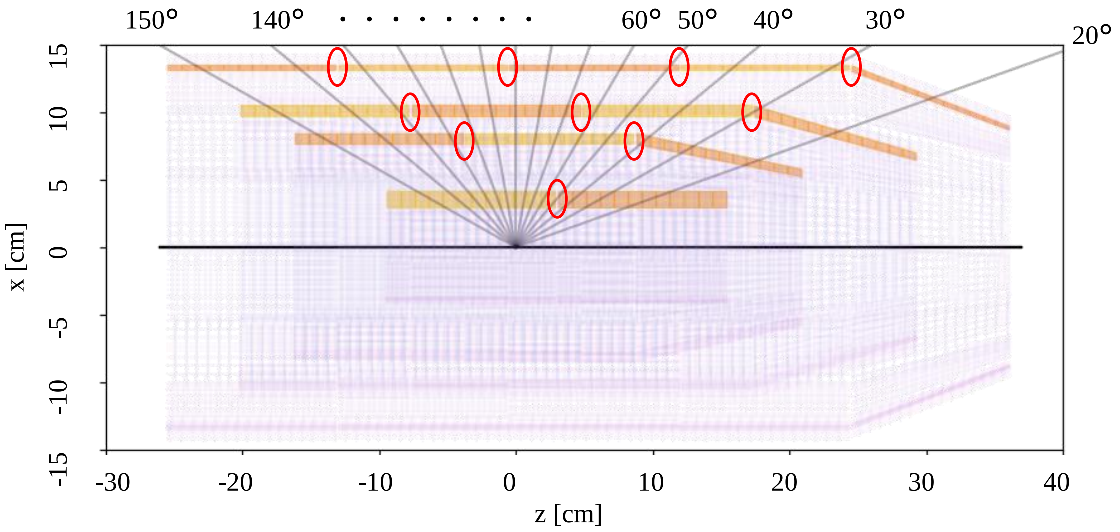
Cause：sensor dead area

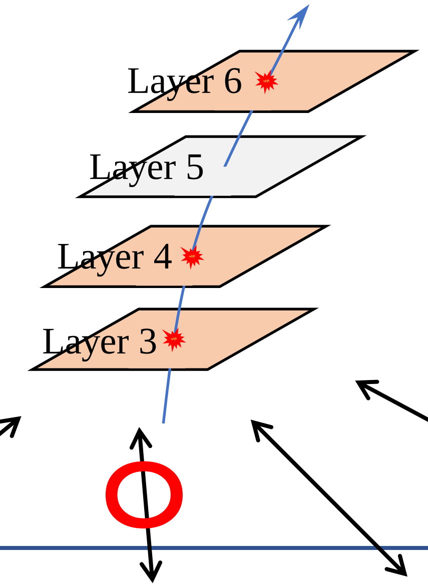
- **Not all hits on all four layers can be obtained**

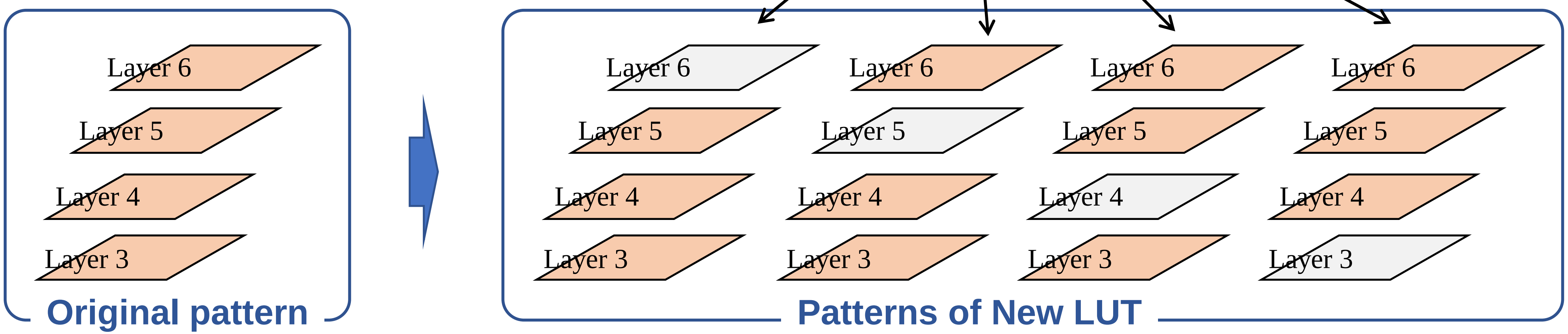
For improvement of trigger efficiency

- We need to cover sensor dead area.
- **Track finding algorithm using 3/4-layers**: pattern matching using any three layers of four layers.

layer 3 4 5, layer 3 4 6, layer 3 5 6, layer 4 5 6



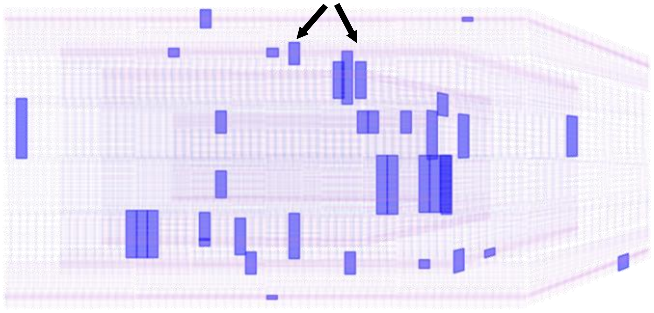




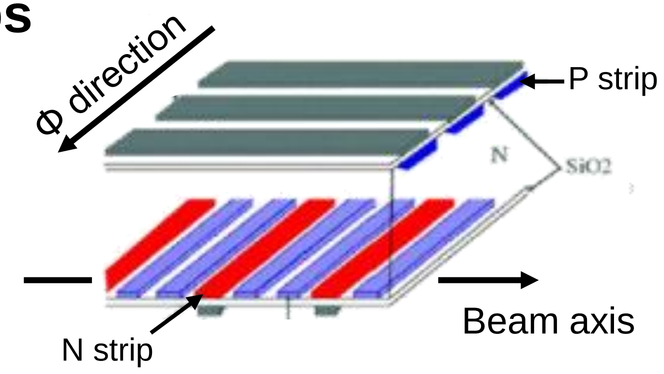
Track finding using more detail information in φ direction

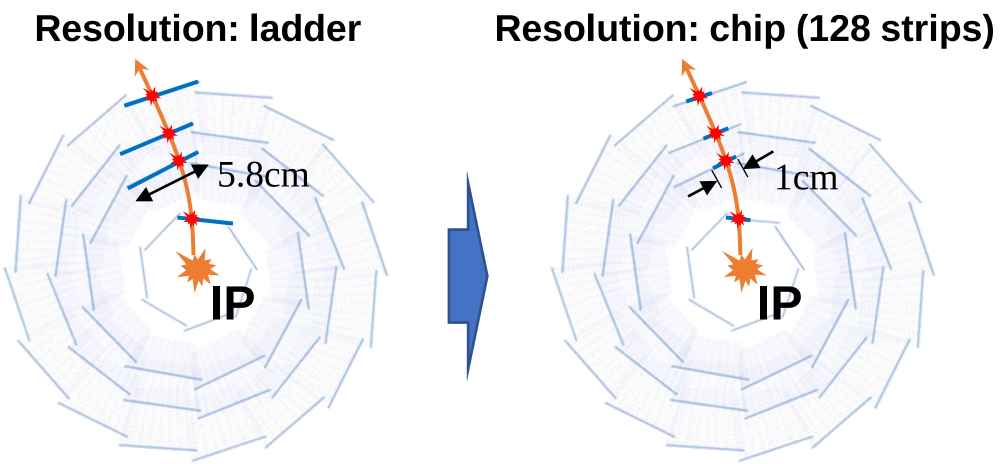
Concern

- Relaxing condition → high fake trigger under the random BG
- To enhance BG rejection power, we use more detailed φ information.



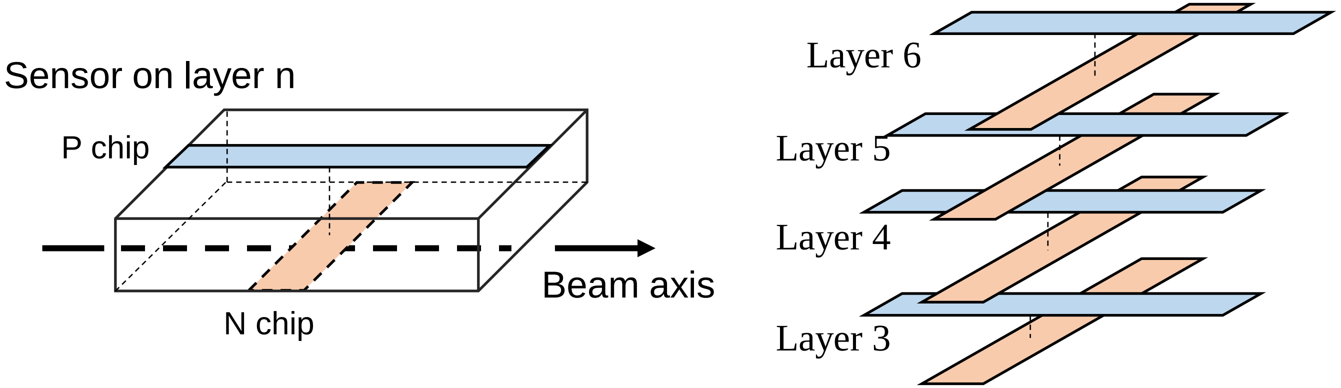
Use P strips





Pattern on $r - \phi$ plane

LUT using P-N strips

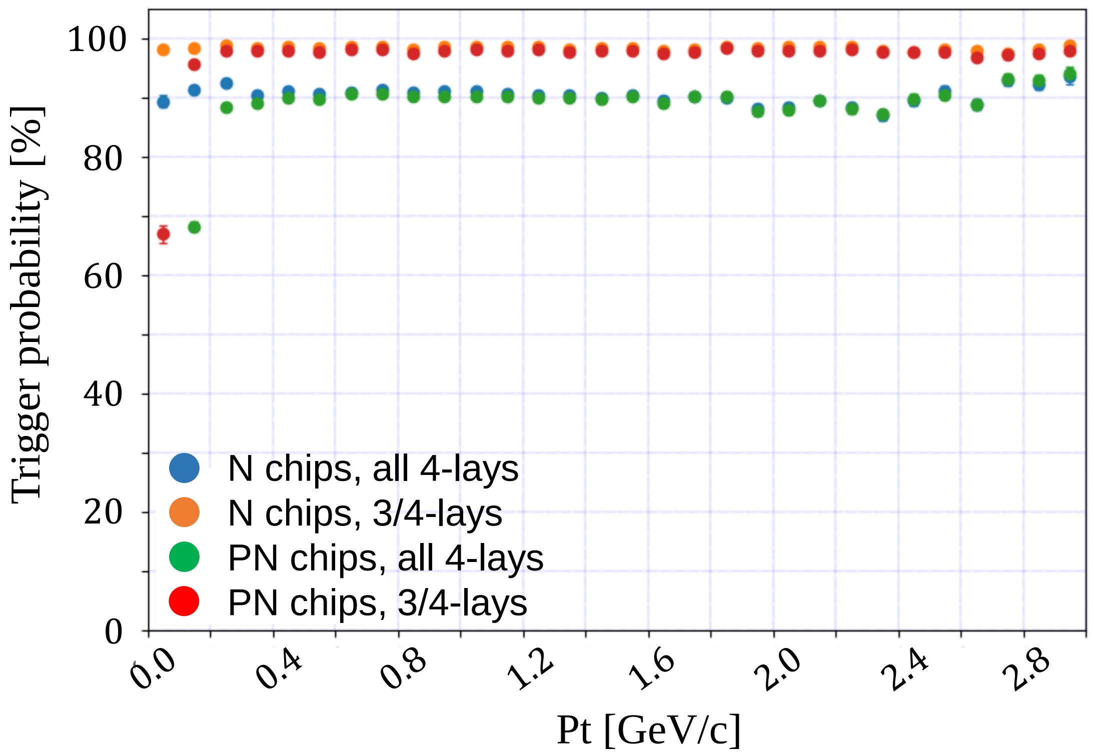


	N chips	P-N chips
4-lays	4 hits of all four layers	8 hits of all four layers
3/4-lays	3 hits of any three of the four layers	6 hits of any three of the four layers

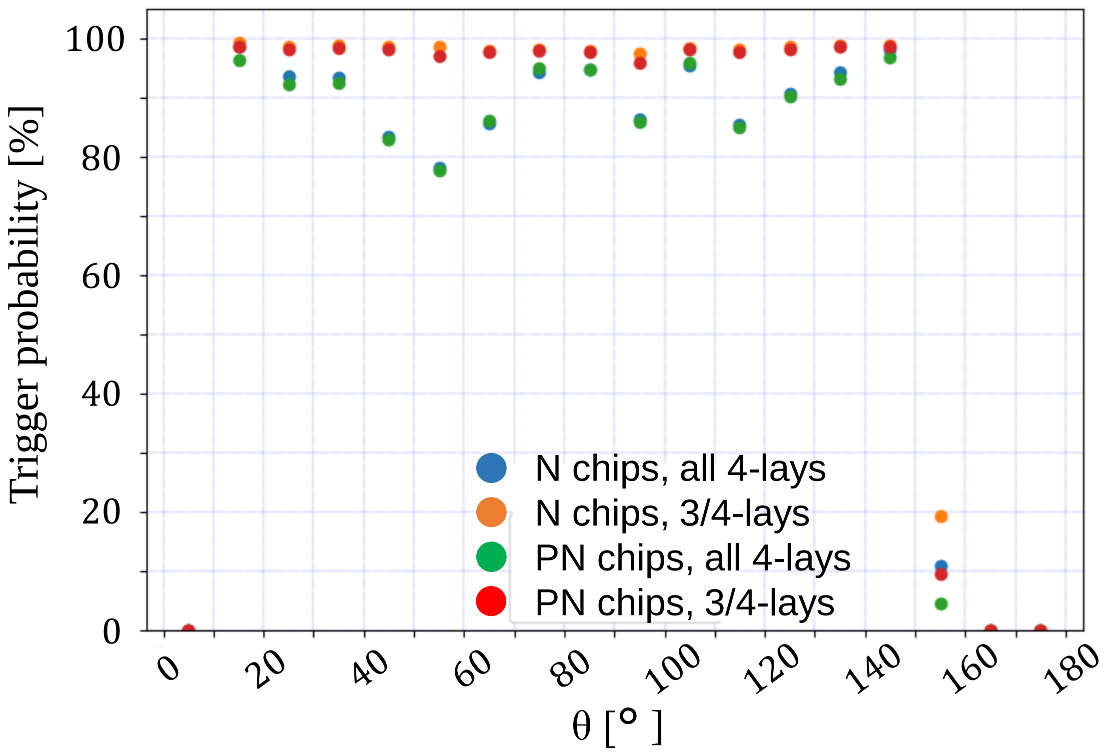
Result: One signal particle study

- (blue) What I showed before
- (orange) TRG efficiency improves to nearly 100% for all θ.
- (green) almost identical to (blue)
- (red) almost identical to (orange)

TRG Prob vs Pt

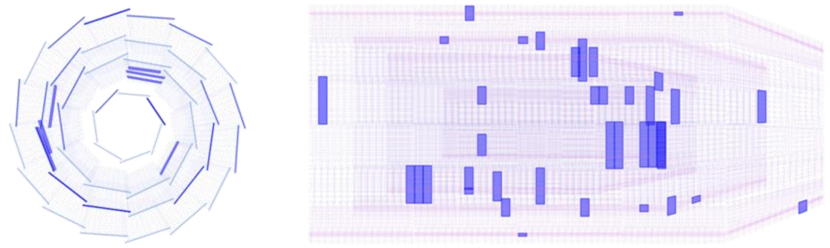


TRG Prob vs θ

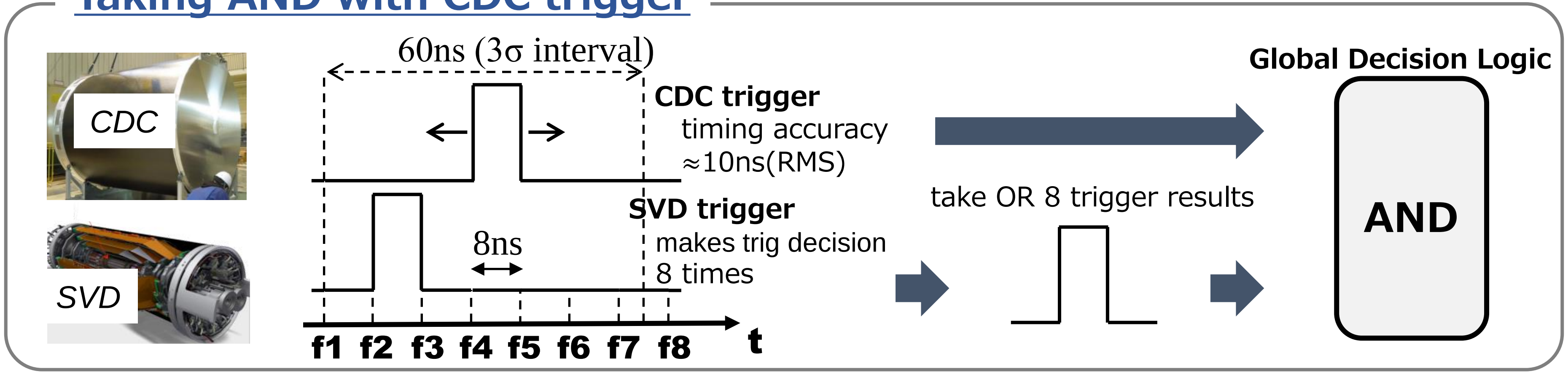


Result: Random BG study

- BG particles with low momentum can make a lot of hits → we need to consider fake trigger rate
- BG samples were prepared assuming nominal luminosity.
- We consider two types of time scale
  - Sampling rate of ASIC of TFP-SVD: 8ns
  - Timing accuracy of CDC trigger: 60ns



Taking AND with CDC trigger

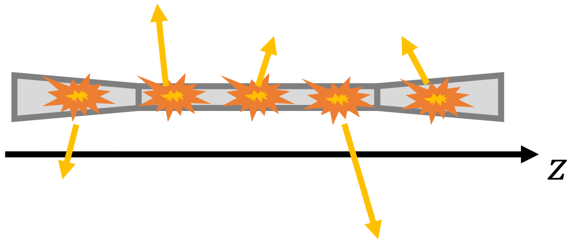


TRG Prob

	N, 4-lays	N, 3/4-lays	P-N, 4-lays	P-N, 3/4-lays
8ns (per one frame)	5%	50%	1%	10%
60ns (taken OR of 8 frames)	22%	95%	3%	35%

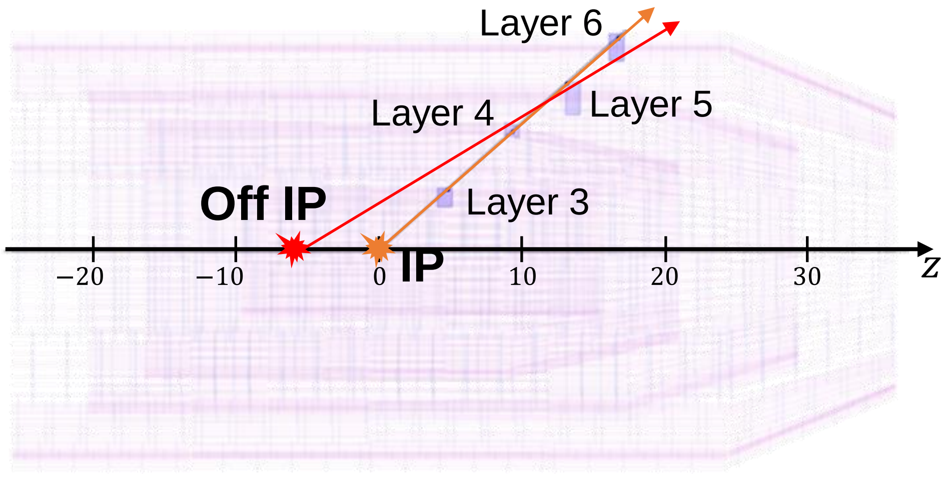
Result: Off IP particle study

- To investigate off IP particle rejection power, we generated only one particle at various z.

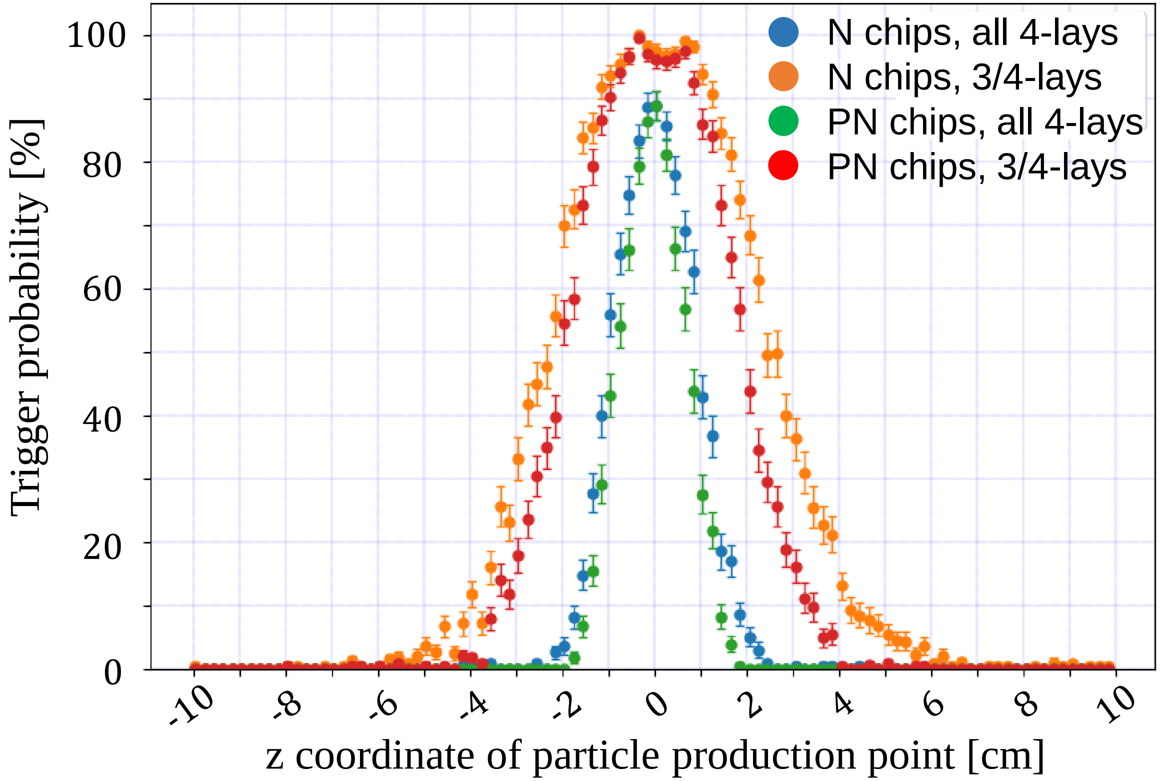


- (blue) can reject particles flying from 2.5cm away from the IP
- (orange) Sharpness is somewhat lost, the boundary of the rejection region is 6cm
- (green) slightly sharper than (blue), the boundary of the rejection region is 2cm
- (red) slightly sharper than (orange), the boundary of the rejection region is 4cm

- Sharpness is mainly supported by Layer 3



TRG Prob vs z



Summary

- I considered some types of algorithm to improve TRG efficiency while maintaining high BG(random BG and off IP particle) rejection power.

Trigger performance

	N, all 4-lays	N, 3/4-lays	P-N, all 4-lays	P-N, 3/4-lays
Efficiency	90%	98%	90%	98%
Fake TRG prob under random BG (60ns)	22%	95%	3%	35%
Off IP rejection region	|z| > 2.5cm	|z| > 6cm	|z| > 2cm	|z| > 4cm

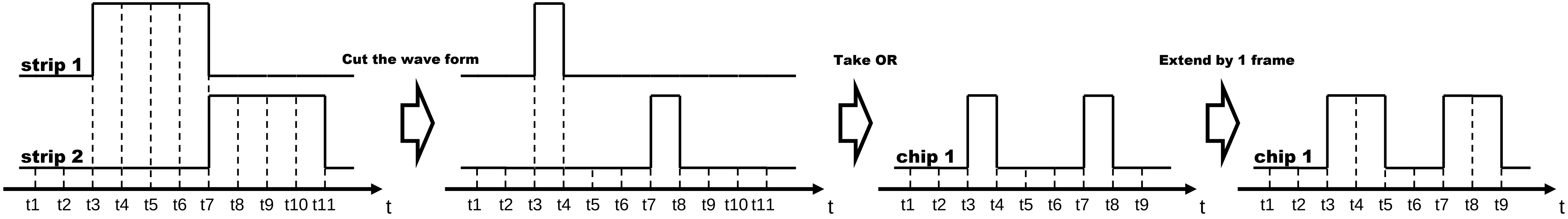
- I think “P-N, 3/4-lays” algorithm is best of these options.
  - sufficient efficiency
  - good off IP particle rejection power
  - prospects of stronger BG rejection power by matching with CDC

BACK UP

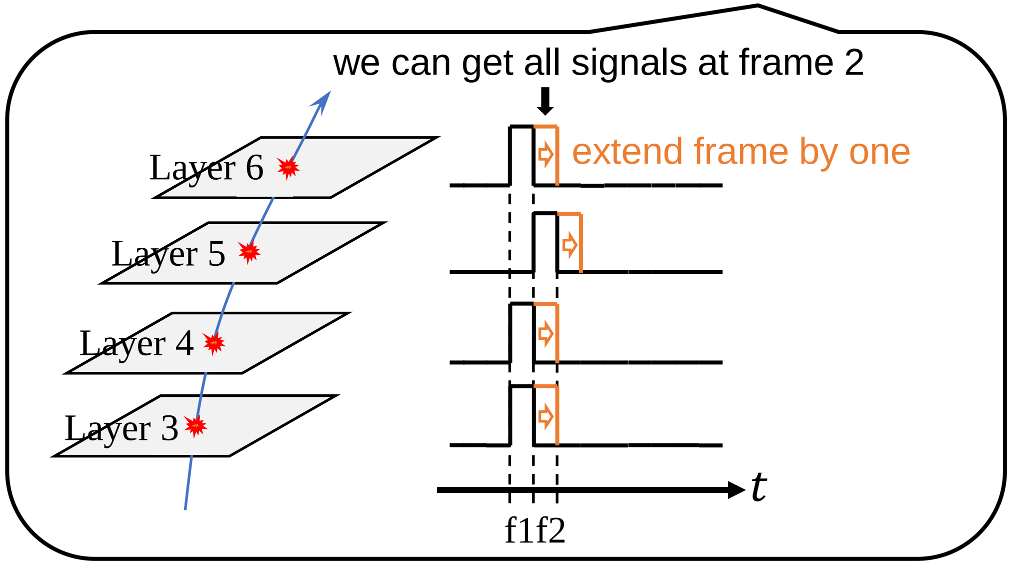
Wave form shaping

Read out by ASIC

- One ASIC of TFP-SVD(SNAP) will read out signals every about 8ns and will take OR.
- The timing of particle going through a sensor can be obtained from the rising edge of wave form.
- For that, before taking OR, we cut the waveform leaving rising edge.



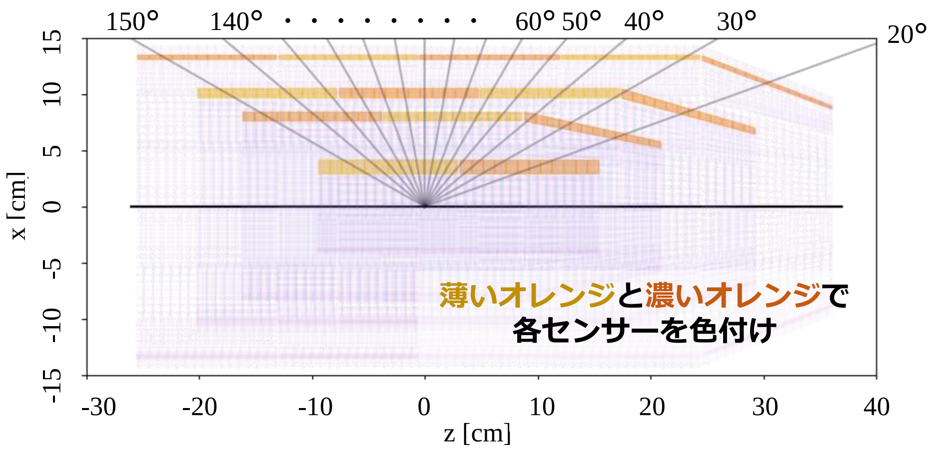
- However, the timing may be off by about one frame.
- In order not to miss a series of signals,
  we extended pulse rise frame by one.

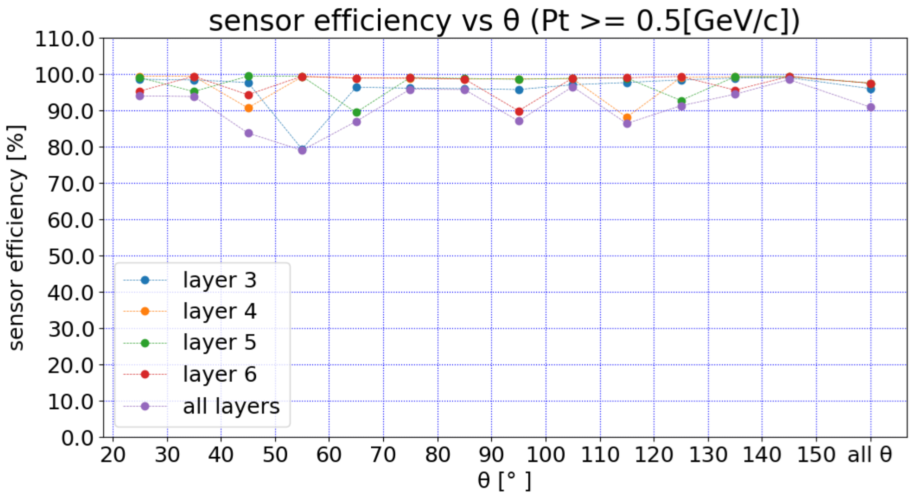


- シグナルの粒子しかないのに、トリガー確率が要求値に届かなかった.

Q. センサーが反応していない？？

- センサーefficicencyとして、荷電粒子が通過したときにセンサーが反応する確率を調べた。
- センサーをまたぐθの範囲でセンサーefficiencyは下落し、 θ全体では90%と、実験で得られたトリガーefficiencyの上限値と一致した。



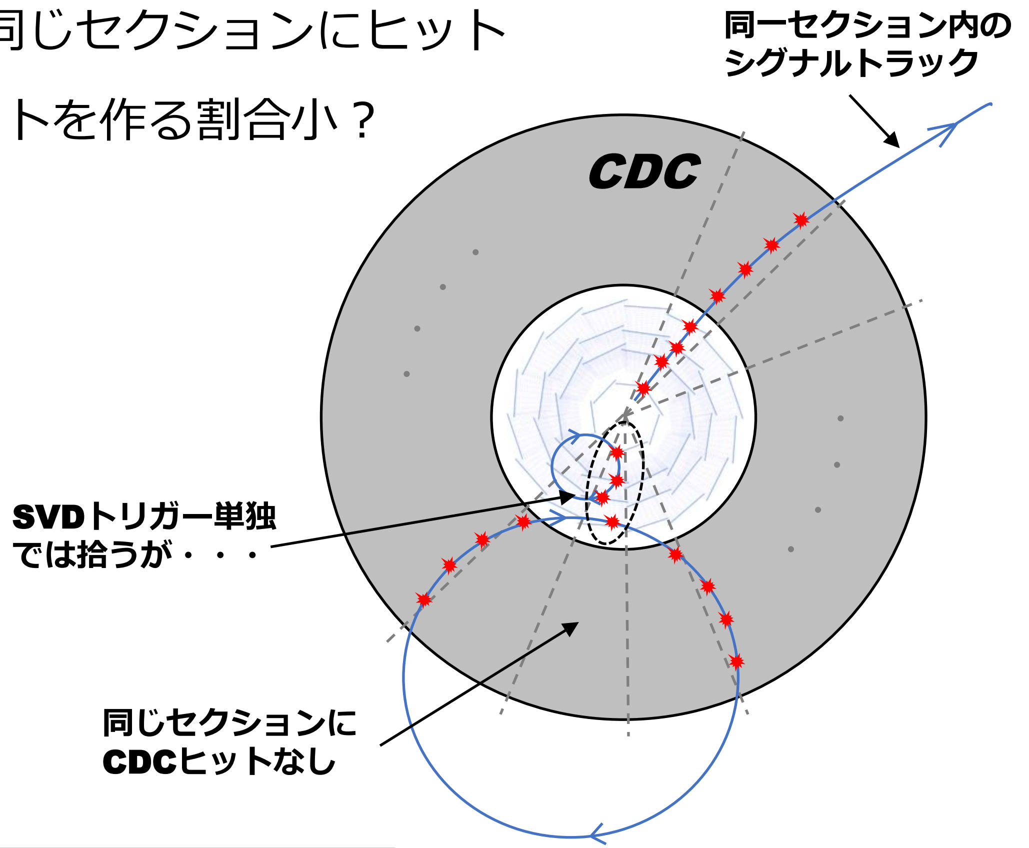


センサーefficiencyがトリガーefficiencyを決定
⇒ヒットの欠損に対応できるアルゴリズムが必要

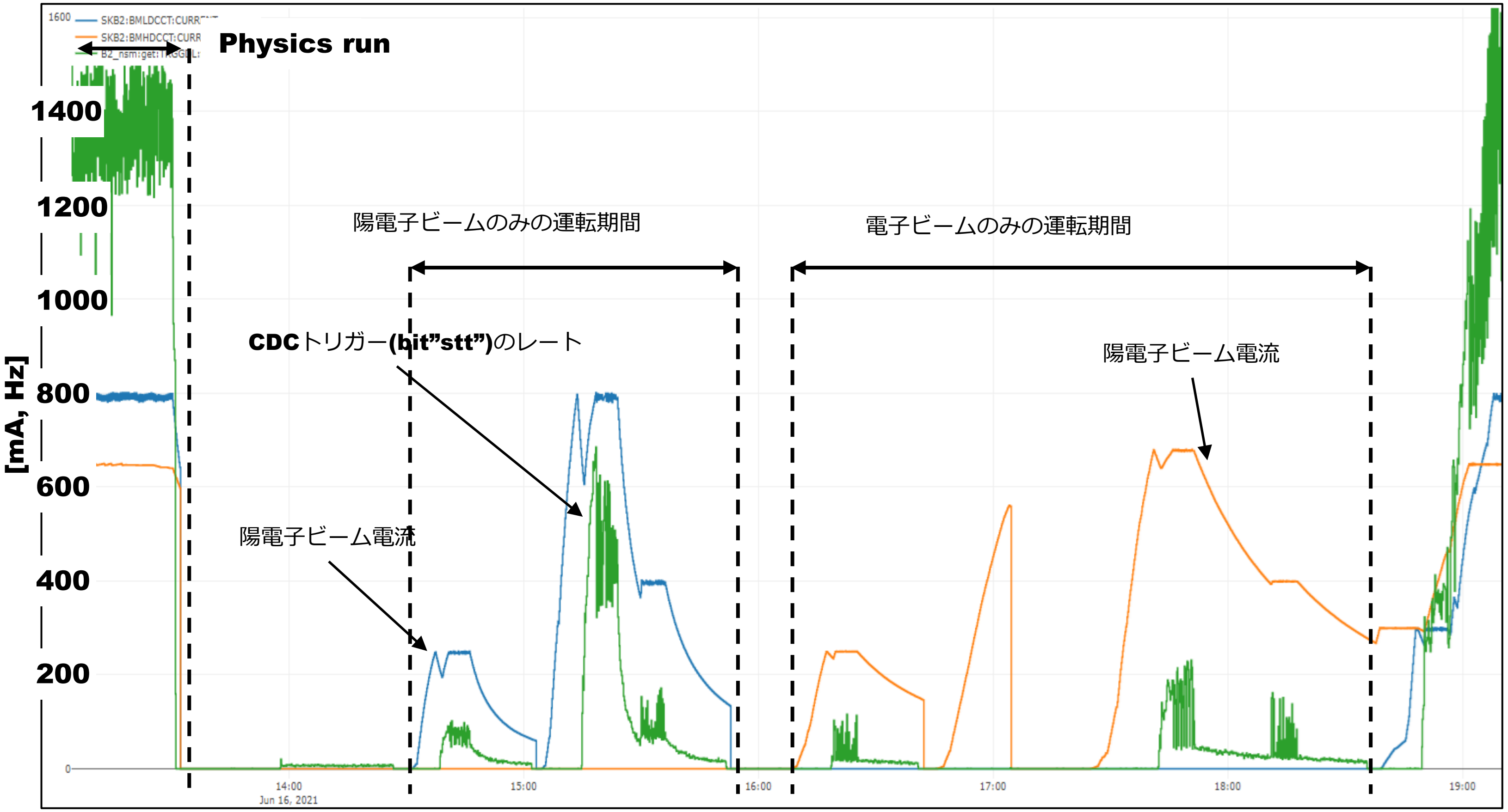
- ビームバックグラウンドはϕ方向ランダムにセンサーを鳴らすと考えられる.
- $r-\phi$平面で分割すると、、、

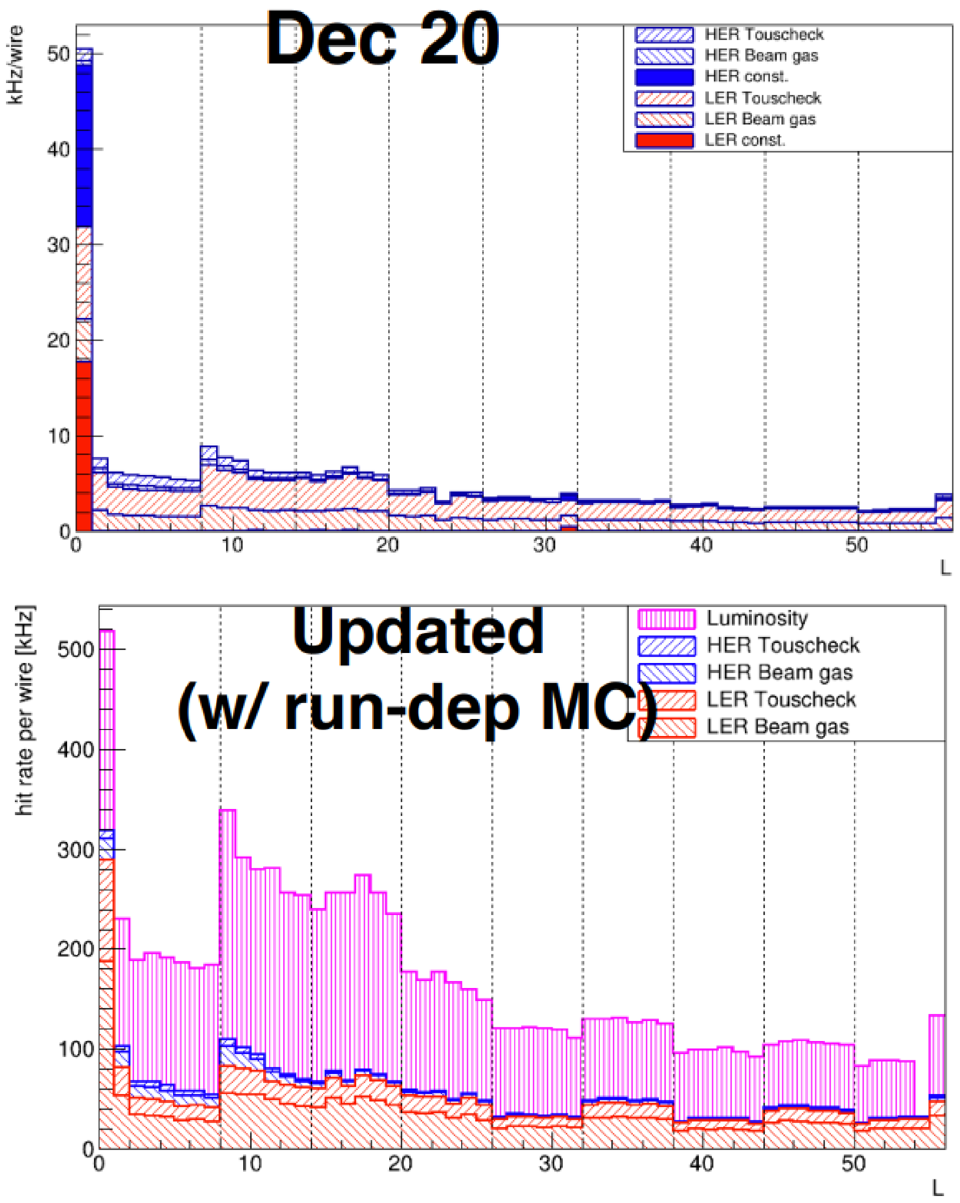
  IPから飛来するシグナル粒子は同じセクションにヒット

  BG粒子が同じセクションにヒットを作る割合小？



CDCトリガーとϕマッチングを行うことで、
フェイクトリガー確率を減少させられるかも


1600
SKB2:BMLDCCT:CURR
SKB2:BMHDCCT:CURR
B2_nsm:get:
Physics run
1400
1200
1000
800
600
400
200
0
[mA, Hz]
陽電子ビームのみの運転期間
電子ビームのみの運転期間
CDCトリガー(bit"stt")のレート
陽電子ビーム電流
陽電子ビーム電流
14:00
Jun 16, 2021
15:00
16:00
17:00
18:00
19:00


Dec 20
kHz/wire
0
10
20
30
40
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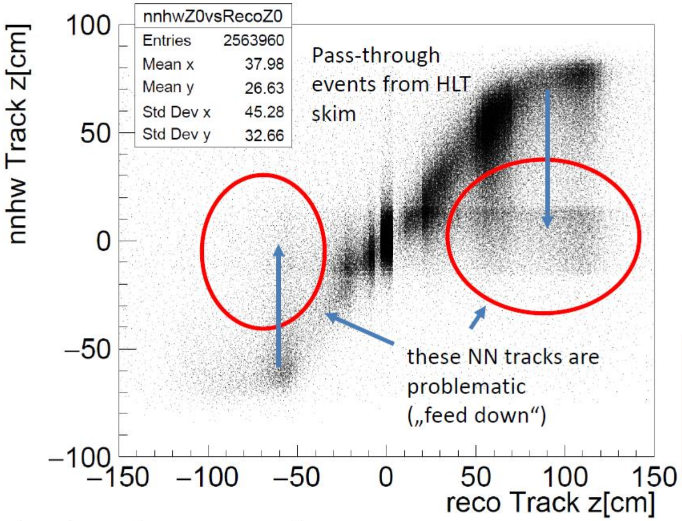
L
HER Touscheck
HER Beam gas
HER const.
LER Touscheck
LER Beam gas
LER const.
Updated
(w/ run-dep MC)
hit rate per wire [kHz]
100
200
300
400
500
Luminosity
HER Touscheck
HER Beam gas
LER Touscheck
LER Beam gas

Resolution of Neuro Tracks, all |z|

Increase of bg at constant lumi-> increase or STT trigger rate (efficiency stays!)



Band at |z|<20cm: all track triggers require a neural track

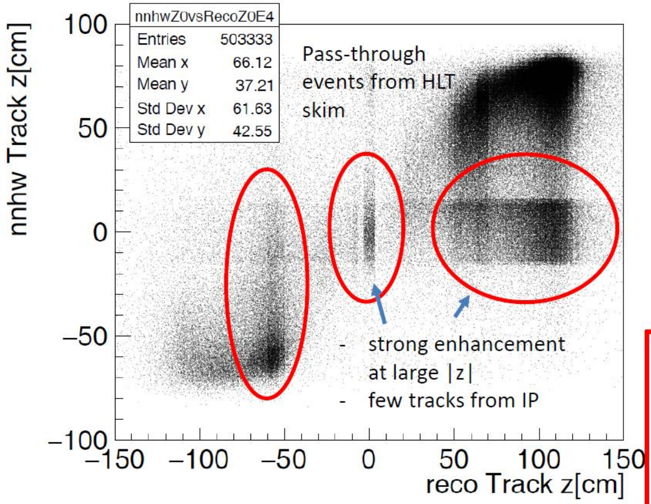
Large |z|: a certain fraction of tracks shifted into IP region -> increase of rate

Why are tracks predicted around IP while coming from large |z| ?

fraction of 1-track events: 26.6%

Large |z| Tracks: Expert 4 Network

Tracks from large |z| tend to miss the inner CDC layer („SL1“) -> „expert 4“ network



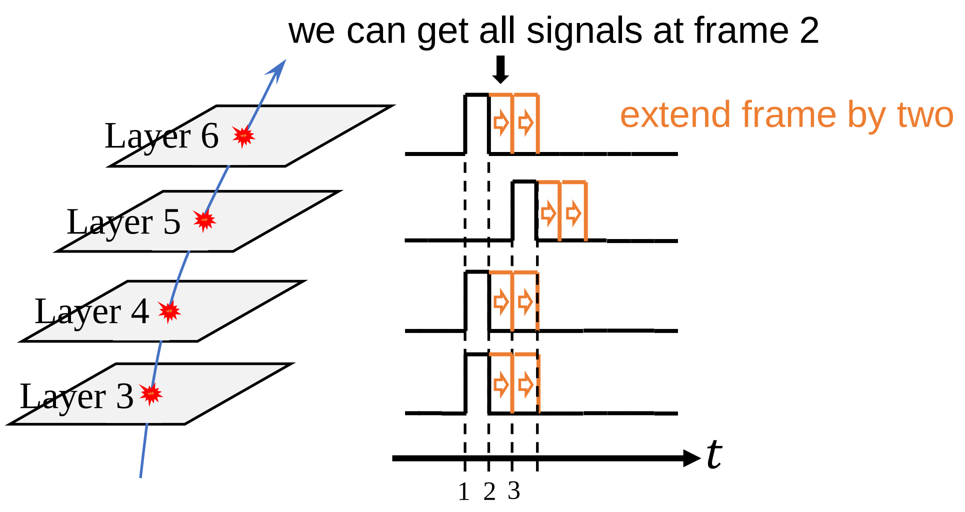
Plot: Neuro tracks selected which do not have inner stereo SL (SL1) hit (and also missed innermost axial SL0)

These tracks are dominantly coming from large |z|.

NN resolutions are about adequate

To-Do:
Feed-down must be reduced by improved training

Plot: reco tracks matched to neural tracks with missing stereo SL1


we can get all signals at frame 2
extend frame by two
Layer 6
Layer 5
Layer 4
Layer 3
t
1
2
3