Trigger systems in fixed target experiments

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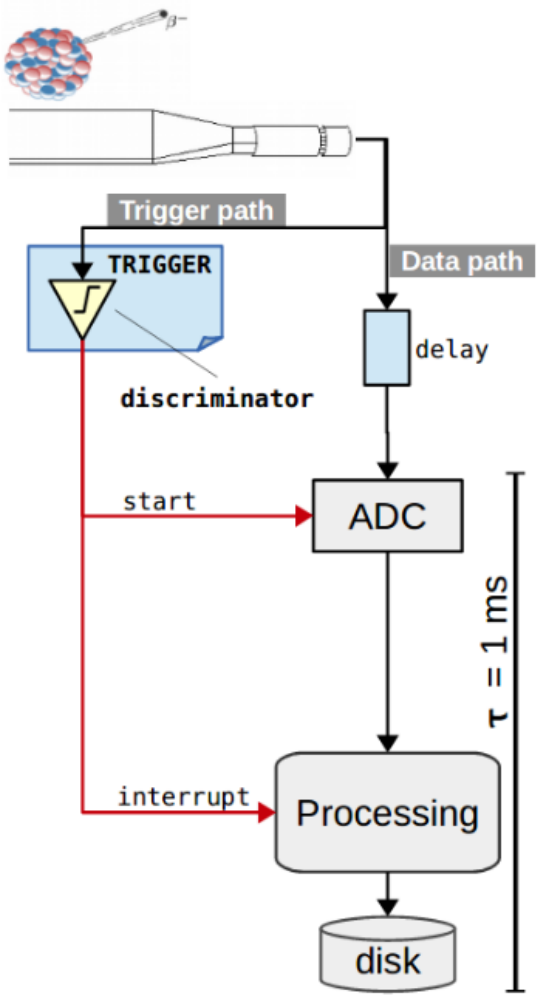
Introduction

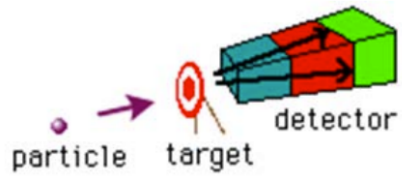
- Why do we need trigger systems in HEP experiments?
- What is the difference between fixed target and collider experiment?
- What is used to generate trigger signal?
- How does a trigger system work?
- What can be done on the trigger level?

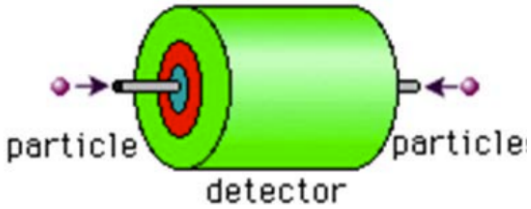
Trigger - why do we need it

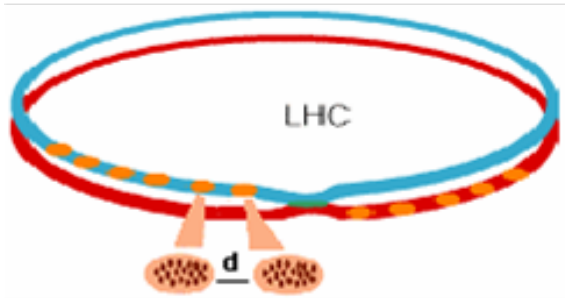
- In high energy physics we work with ***events***
- Event is typically an interaction of elementary particles/atomic nuclei which is interesting for us
- Particle detectors take "pictures" of such interactions
- Shutter for this kind of pictures is very fast, for NA61/SHINE: $0.2 - 50\mu s$
- Trigger system tells the detector when to take a picture, so that we are able to see something interesting



Collider versus fixed target experiment

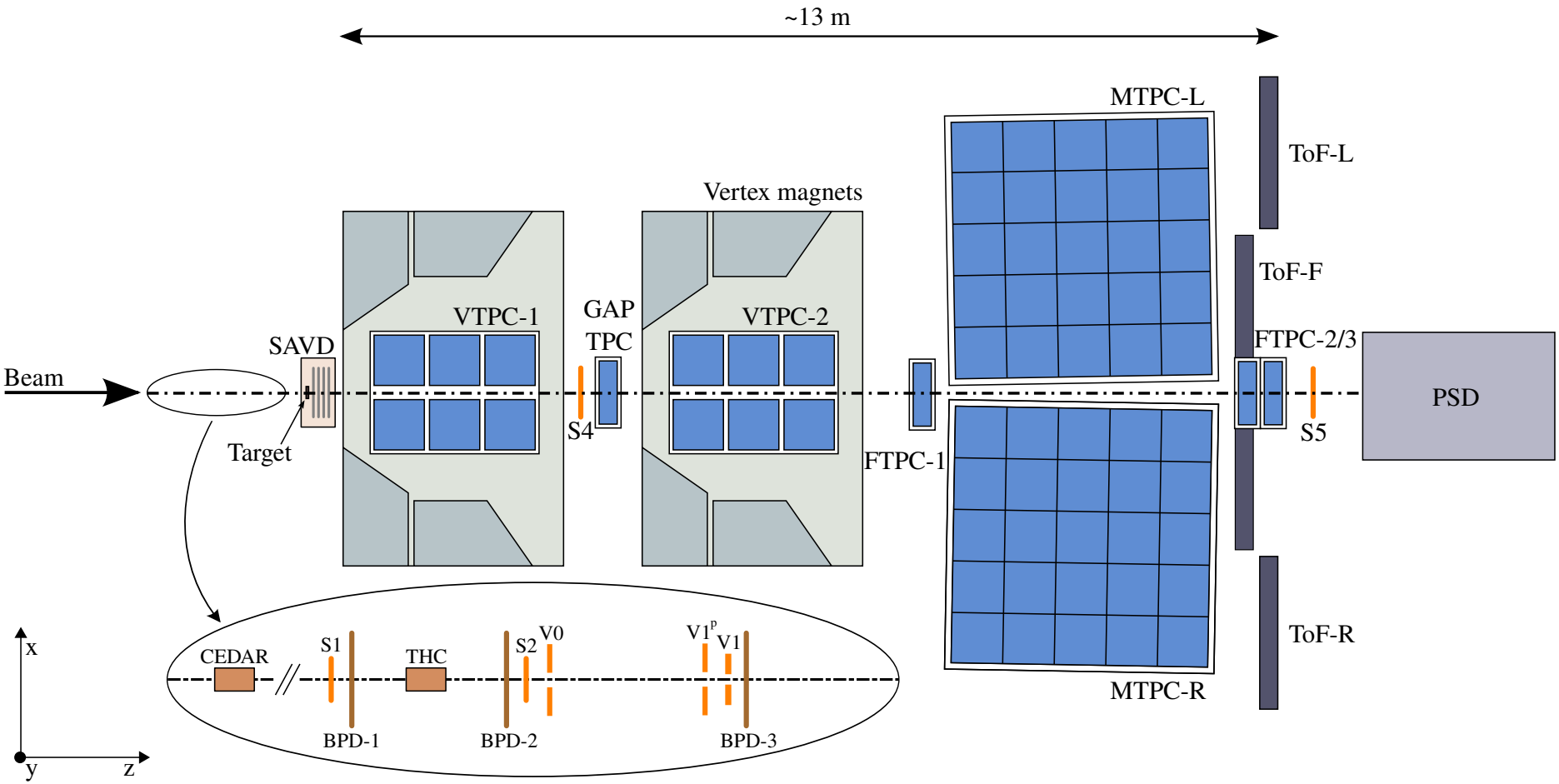




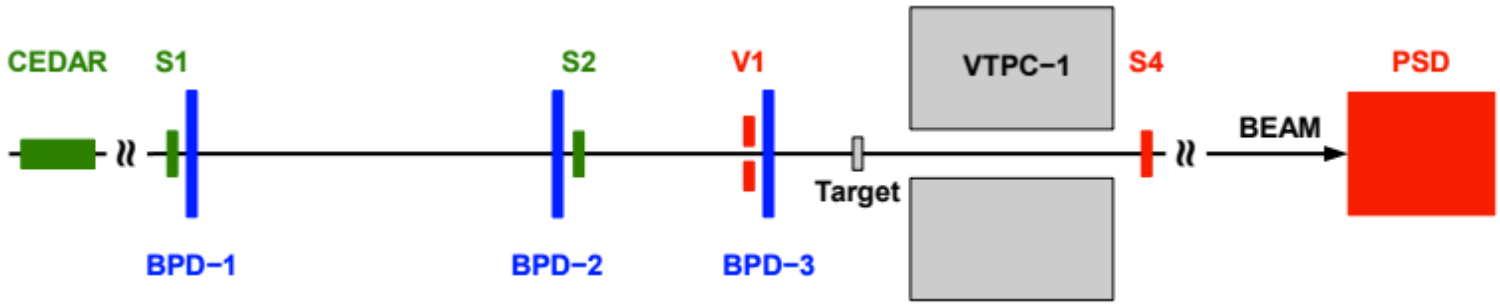


- Trigger generation in collider and fixed target experiments is quite different
- Beam in colliders (eg. LHC) is bunched. Collisions of accelerated particles occur with fixed frequency, synchronously with **collider clock** provided by the machine
- In fixed target experiment beam particles come randomly distributed in time
- Experiment has to determine when the interaction occurs
- I will describe trigger system of a fixed target experiment based on NA61/SHINE example

NA61/SHINE detector

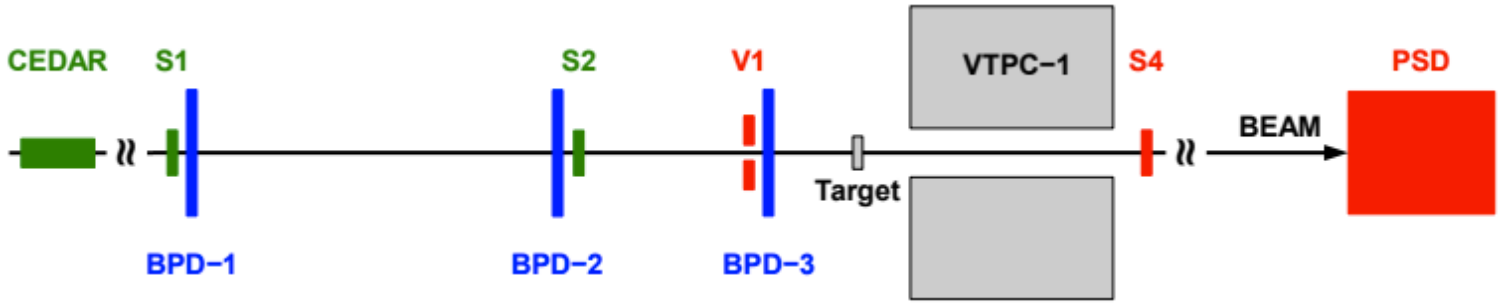


Trigger detectors in NA61/SHINE



- In order to tell if we have a beam particle/interaction was present a set of beam detectors is used
- Main detectors are scintillators with attached PMTs: S1, S2, S4, V1
- Some detectors have hole in the middle and are used as veto to define beam envelope (V1)
- CEDAR is a cherenkov detector used to identify beam particles for secondary hadron beams
- PSD can be also included in the trigger system for centrality selection
- S1 serves as a time reference for the whole experiment

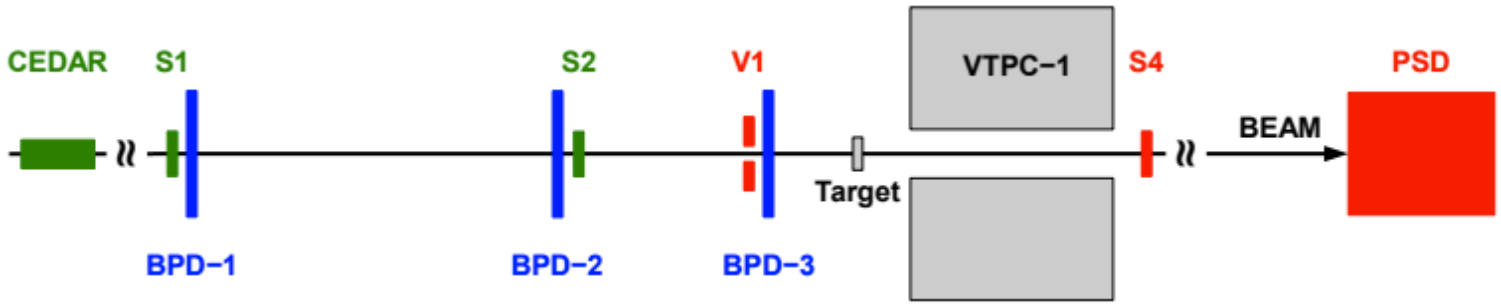
How the trigger is generated



- Before analog signals from trigger detectors can be used they are passed through a discriminator
- Discriminator makes sure, that the amplitude of signal is high enough, preserves timing (CFD) and outputs digital signal
- Digital signals are used to construct **trigger signal** by means of simple logic operations (coincidences)
- For example, to generate beam triggers we use:

$$BEAM = S1 \cdot S2 \cdot \overline{V1} = S1 \textit{ and } S2 \textit{ and } (\textit{not } V1)$$
$$BEAM_{IND} = S1 \cdot S2 \cdot \overline{V1} \cdot CEDAR = S1 \textit{ and } S2 \textit{ and } (\textit{not } V1) \textit{ and } CEDAR$$

Trigger patterns in NA61/SHINE



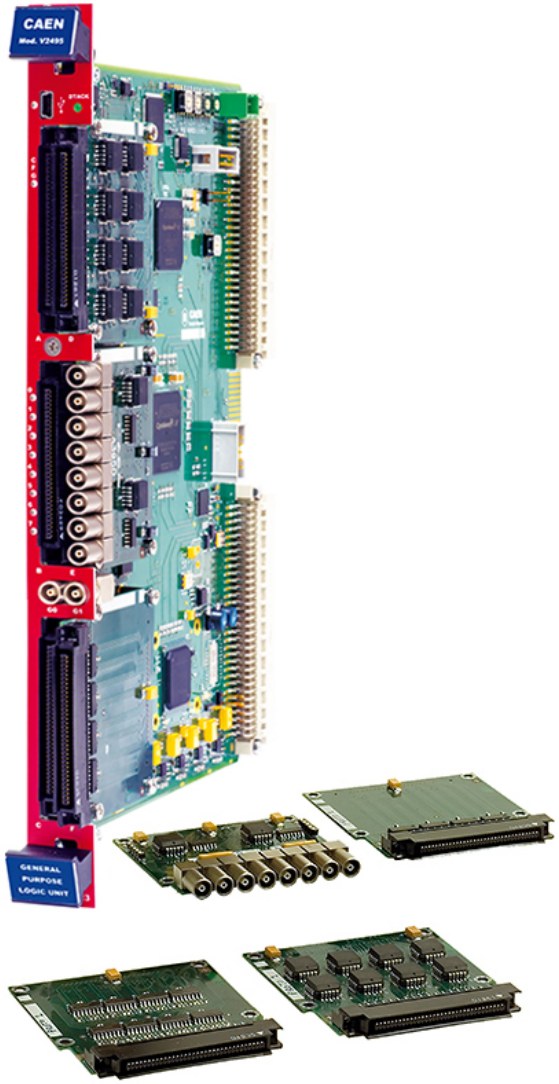
- During data taking typically we are interested in more than one trigger pattern
- Multiple triggers allow us to perform different analyses on the same data set
- NA61/SHINE can collect up to 4 trigger types simultaneously. Normally we define them as (for runs with secondary hadron beams):
  - T1=$S1 \cdot S2 \cdot \overline{V1} \cdot CEDAR$ - identified beam
  - T2=$S1 \cdot S2 \cdot \overline{V1} \cdot \overline{S4} \cdot CEDAR$ - identified interaction
  - T3=$S1 \cdot S2 \cdot \overline{V1}$ - unidentified beam
  - T4=$S1 \cdot S2 \cdot \overline{V1} \cdot \overline{S4}$ - unidentified (min. bias) interaction
- But how to generate a single (main) trigger that will tell the detector to record an event?

Main trigger generation

- In order to generate man trigger (MT) two additional components are needed:
- Prescaler:
  - Its purpose is to reduce frequency of given trigger type
  - It is adjustable, we can choose how much do we want to attenuate contributions of individual triggers
  - If prescaler is set to 10, only every 10th trigger will be passed
  - Prescaler takes $T1 - T4$ and generates their prescaled equivalents $T1_p - T4_p$
  - Prescalers are used set trigger composition of collectd data sample
- Trigger mixer:
  - Trigger mixer is used to combine prescaled triggers and generate main trigger
  - $MT = T1_p \ or \ T2_p \ or \ T3_p \ or \ T4_p$
- MT generated in such way is used to trigger data acquisition in NA61/SHINE

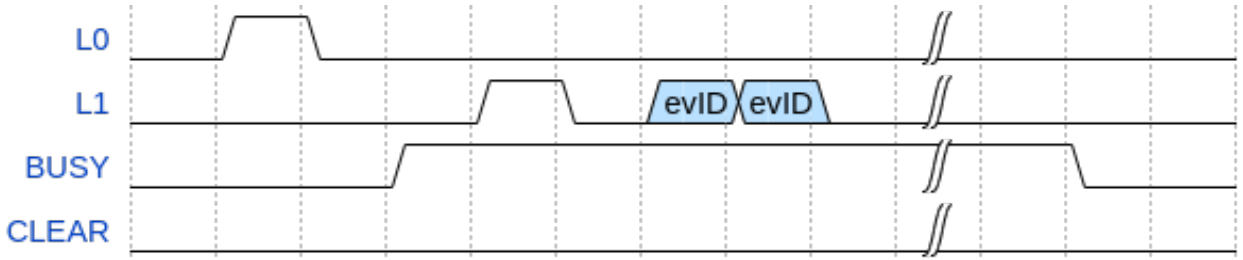
Trigger hardware

- Upgraded NA61/SHINE trigger will use components in VME standard
- 16 channel CFD with programmable thresholds will be used
- All logic and trigger generation will be handled by FPGA on CAEN logic module
- FPGA firmware will also take care of busy logic and monitoring of the whole system
- Everything will be controlled by a PC



Additional trigger functionality

- Removal of offtime beam particles and interactions:
  - Events having additional interactions that happen in $\pm 25 \mu s$ time around the trigger will be removed on trigger level
  - For this introduction of L1 trigger is needed
- Transmission of event ID:
  - Detector readout electronics will use FIFO buffers to speed up data taking
  - To avoid mismatch between events coming from sub-detectors trigger system will transmit event ID with L1 trigger signal



Summary

- Trigger system is an essential part of every HEP experiment
- In fixed target experiments trigger is generated based on detectors placed on beam
- Multiple trigger patterns can be defined and used simultaneously
- Modern trigger systems are implemented in programmable logic instead of discrete components

Thank You!

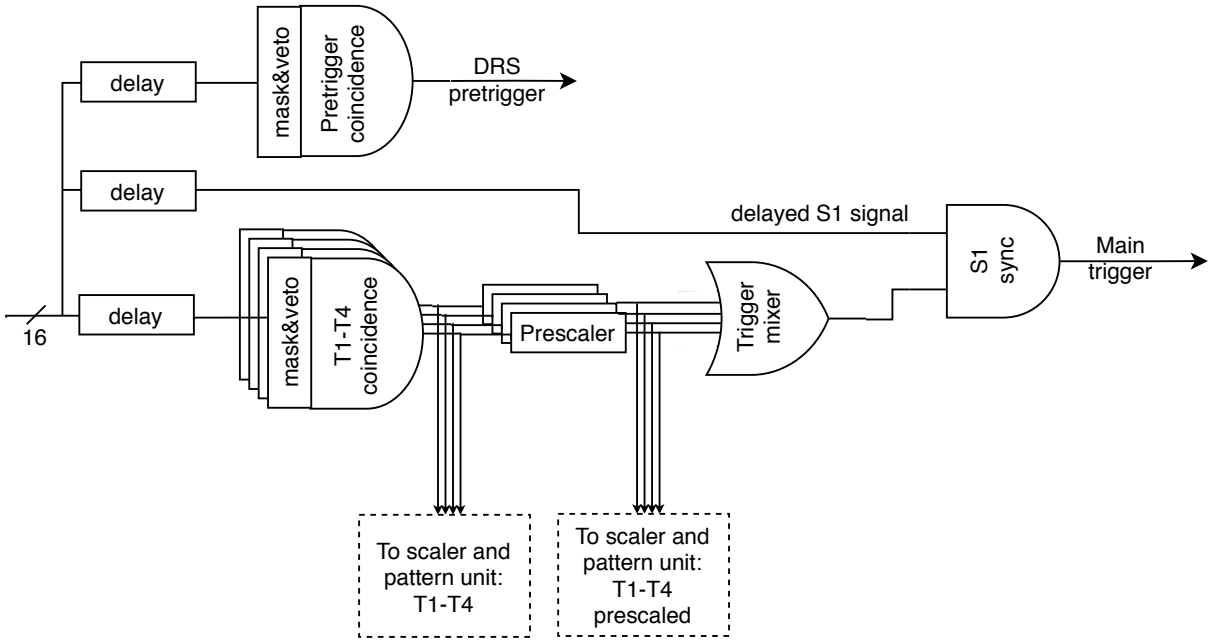
Backup Slides

Details on trigger detectors

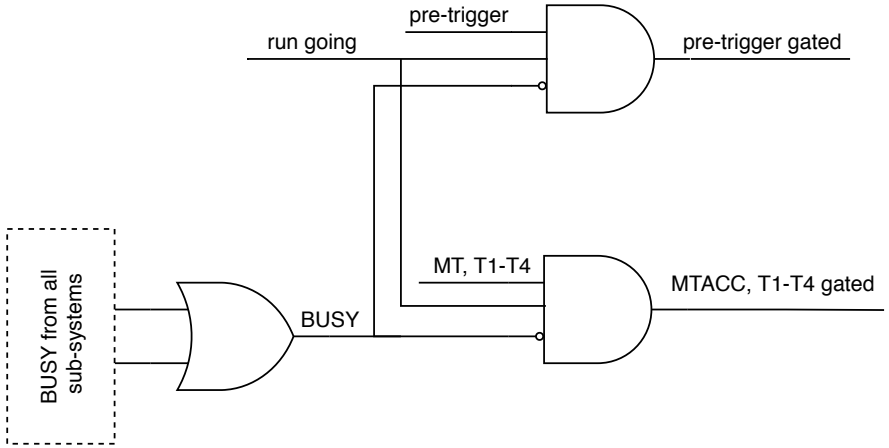
detector	dimensions [mm]	hole [mm]	position [m]	material budget	
				$[\%\lambda_I]$	$[\%X_0]$
S1	$60 \times 60 \times 5$		-36.42	0.635	1.175
S2	$\phi = 28 \times 2$		-14.42	0.254	0.470
S3	$\phi = 26 \times 5$		-6.58	0.635	1.175
S4	$\phi = 20 \times 5$		-2.11	0.635	1.175
S5	$\phi = 20 \times 5$		9.80	0.635	1.175
V0	$\phi = 80 \times 10$	$\phi = 10$	-14.16		
$V0^p$	$300 \times 300 \times 10$	$\phi = 20$	$\approx$ -14		
V1	$100 \times 100 \times 10$	$\phi = 8$	-6.72		
$V1^p$	$300 \times 300 \times 10$	$\phi = 20$	-6.74		
A	$150 \times 5 \times 15$		$\approx$ -146	1.904	3.526
Z	$160 \times 40 \times 2.5$		-13.81	0.562	2.034
BPD-1	$48 \times 48 \times 32.6$		-36.20	0.025	0.070
BPD-2	$48 \times 48 \times 32.6$		-14.90	0.025	0.070
BPD-3	$48 \times 48 \times 32.6$		-6.70	0.025	0.070
Typical thin target position			-5.81		

Trigger and busy logic

Trigger logic:



Busy logic:



How does a CFD work