

# *Trigger Configuration*

A. Somov, Jefferson Lab

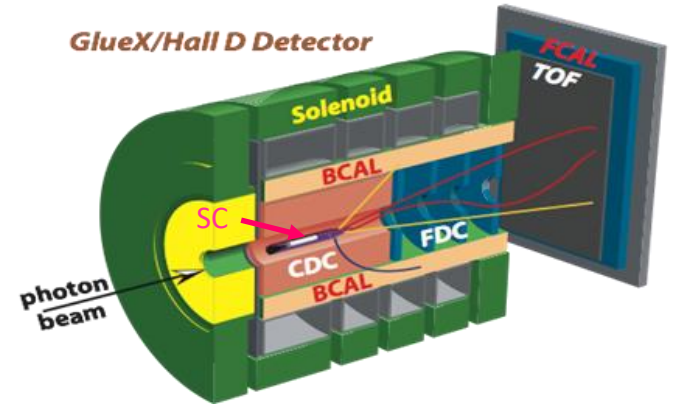
KLF Readiness Review

August 28, 2024

# GlueX Level-1 Trigger

## Detectors which can be used in the Level-1 trigger:

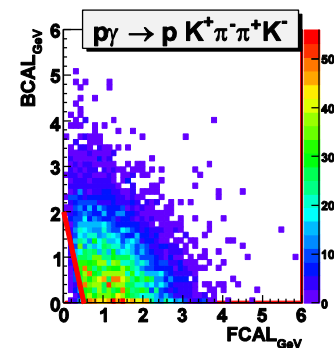
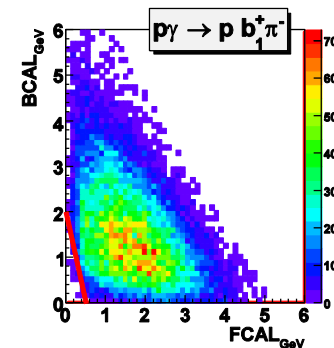
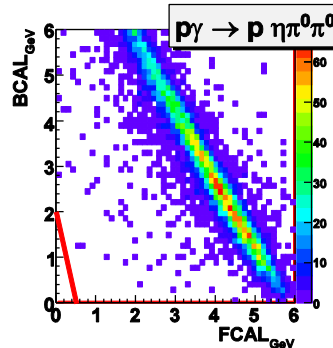
Forward Calorimeter (FCAL)	( Energy deposition )
Barrel Calorimeter (BCAL)	( Energy deposition )
Start Counter (SC)	( Count hits )
Time of Flight (TOF)	( Count hits )



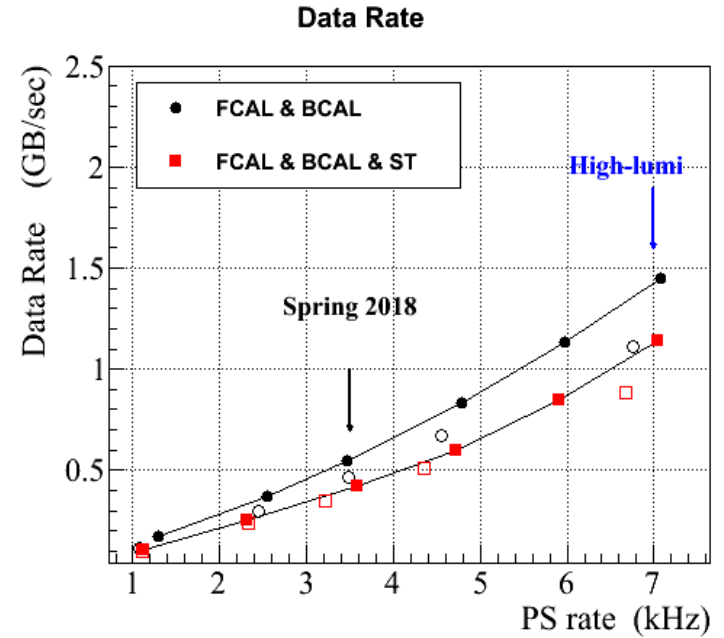
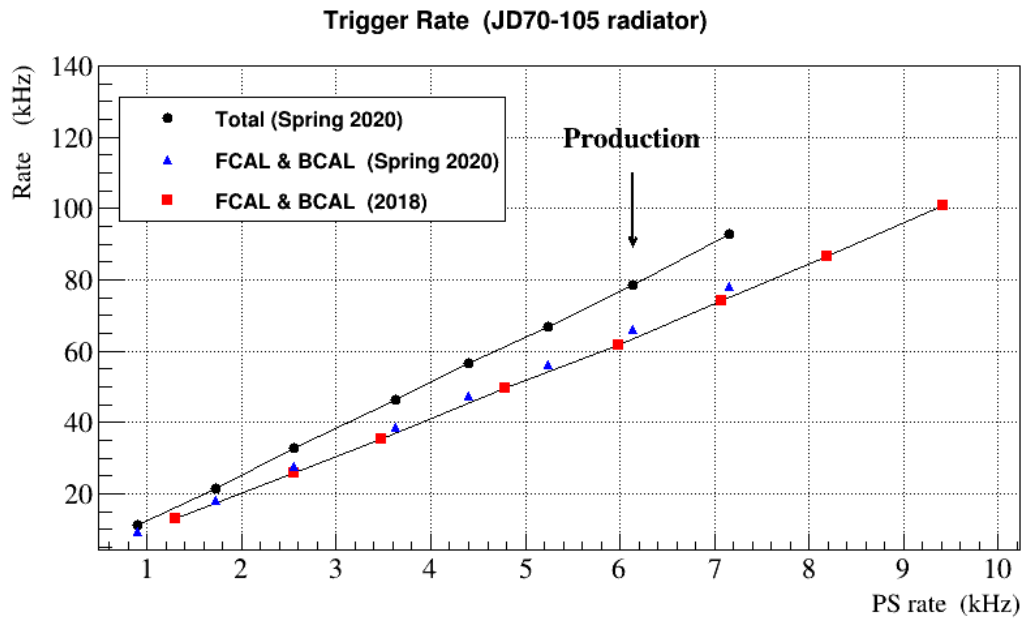
- Trigger algorithm based on measurement of energies in **FCAL** and **BCAL**

$$A \cdot E_{\text{BCAL}} + B \cdot E_{\text{FCAL}} > E_{\text{THR}}$$

- Coincidence of calorimeters with **Start Counter** (SRC experiment)
- Trigger based on **TOF** and **Calorimeters** (CPP/NPP experiment)



# Trigger Performance



- Trigger rate in production runs about 70 kHz
- Data rate about 1.4 GB/sec

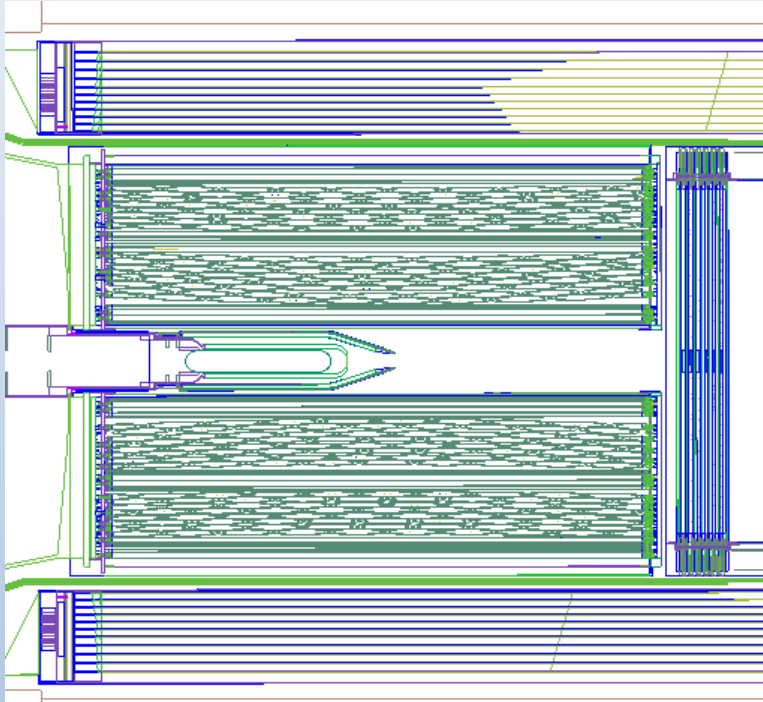
# KLF Trigger Simulation

- Geant4 detector simulation
  - modify geometry of the LH2 target cell, add ECAL
- Study detector response for two types of beamline backgrounds: neutron and photons
  - use energy spectra and profiles at the target to generate background particles; input to Geant4 simulation
- Evaluate trigger efficiency for physics channels of interest
  - mostly charged particles in the final state

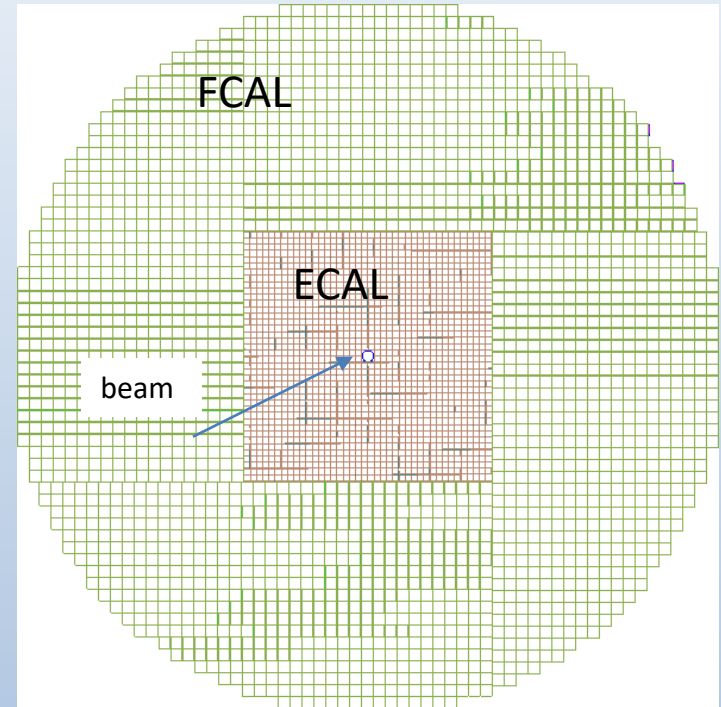
Consider to use triggers based on the energy depositions in the calorimeters.  
- lower energy thresholds below MIP energy (similar to the SRC experiment)

# Geant4 Detector Geometry

Target Geometry



Forward Calorimeter

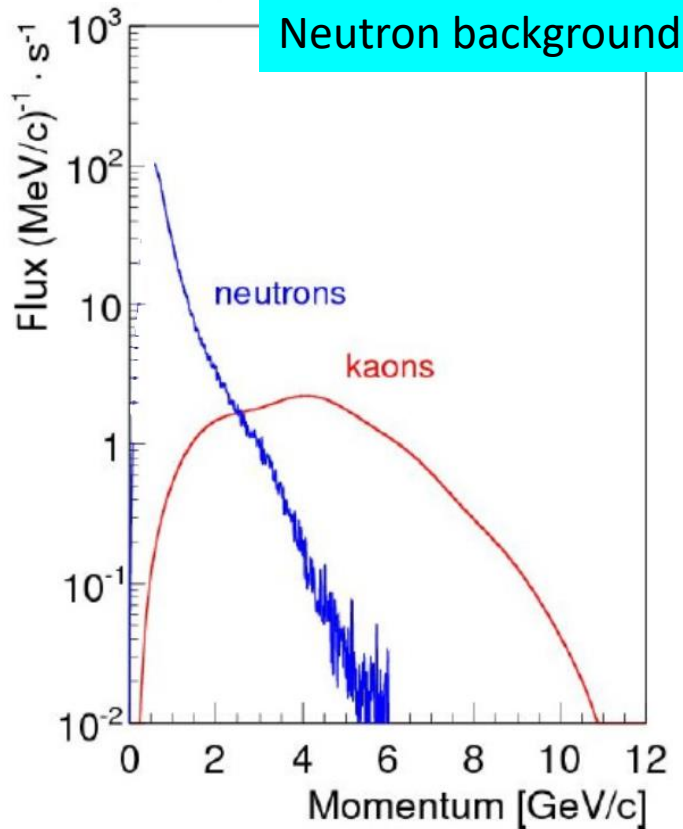


LH2 target cell: 6 cm in diameter  
40 cm long

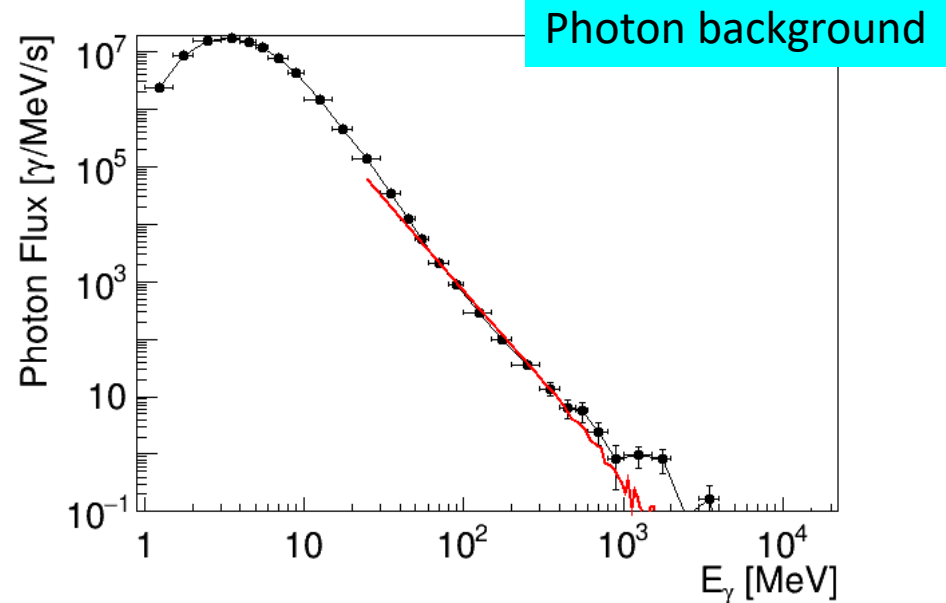
FCAL: 2360 lead glass modules  
ECAL: 1596  $\text{PbWO}_4$  modules (new detector)  
- 4 cm 4 cm beam hole  
- the inner most layer around the beam pipe is shielded by a tungsten absorber (not shown)

Note: the SC hole in the forward direction is 2 cm

# Main Sources of Background



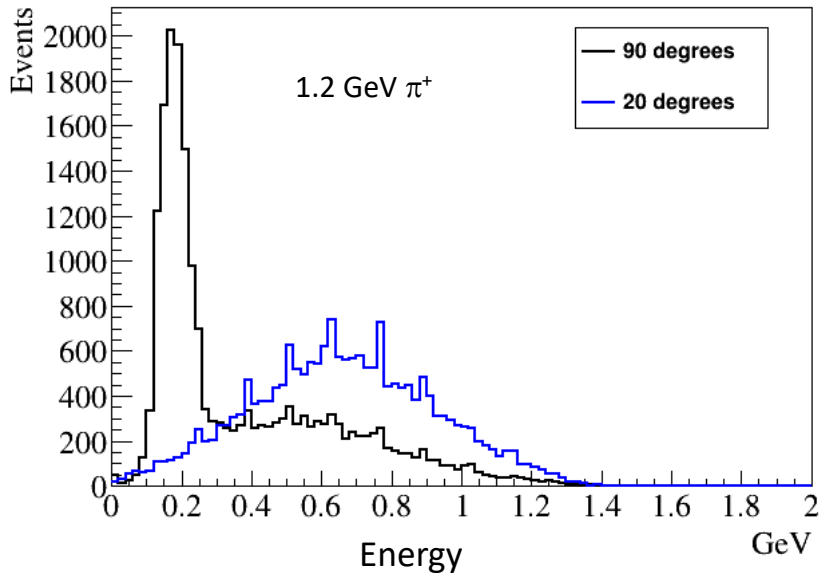
Energy spectrum of bremsstrahlung photons on the face of the Be target



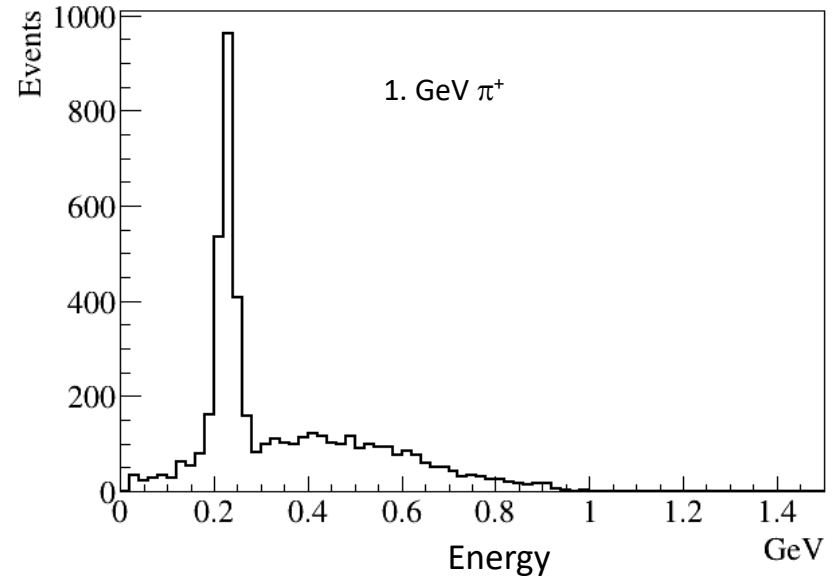
- Simulated using MCNP, Fluka, and Geant
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- Integrated flux:  $6.6 \cdot 10^5$  n/s on the target
- Integrated flux:  $2 \cdot 10^8$  γ/s on the target
- Uniform distribution of BG particles over the target face

# Detector Response Induced by Charged Particles

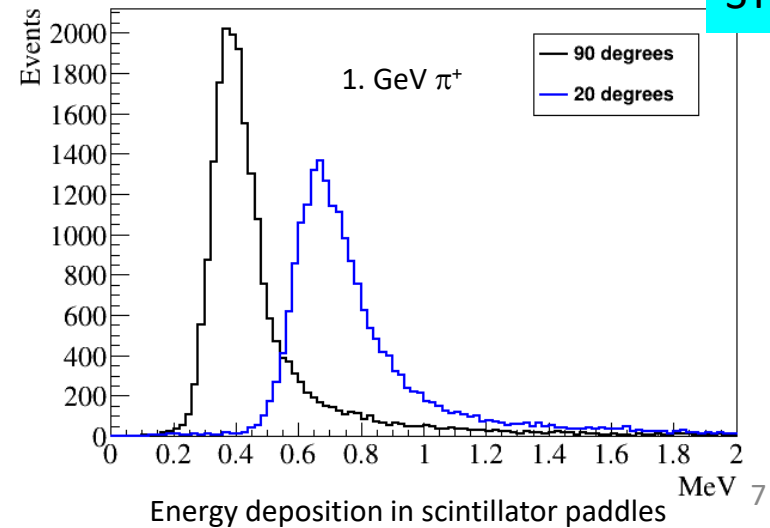
BCAL



ECAL



ST



- Geant4 simulation
- Charged pions generated at different polar angles

# Background Rates

- Trigger energy thresholds in the calorimeters:

$$E_{\text{BCAL, ECAL}} > 20 \text{ MeV}, \quad E_{\text{FCAL}} > 130 \text{ MeV}$$

$$E_{\text{ECAL/FCAL}} + E_{\text{BCAL}} > 0.1 \text{ GeV}$$

- Exclude two ECAL inner rings from the trigger (12 x 12 cm)

Background	Rates in the sub-detectors (kHz)			
	BCAL	ECAL/FCAL	BCAL + ECAL /FCAL	Start Counter
Neutrons	11.7	13	24.2	42.8
Photons	$\ll 1$	$\ll 1$	$\ll 1$	$5.8 \times 10^3$



# Background Rates

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## Neutron background

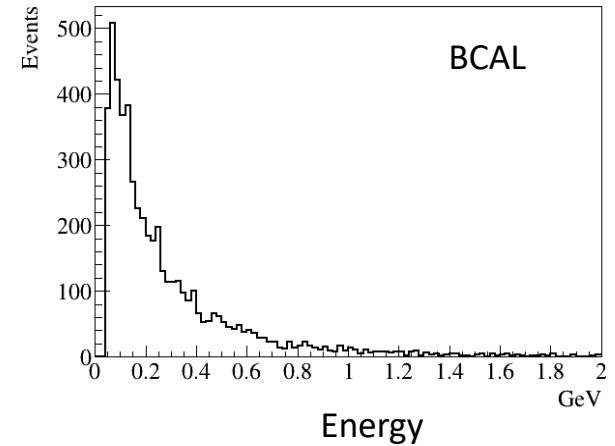
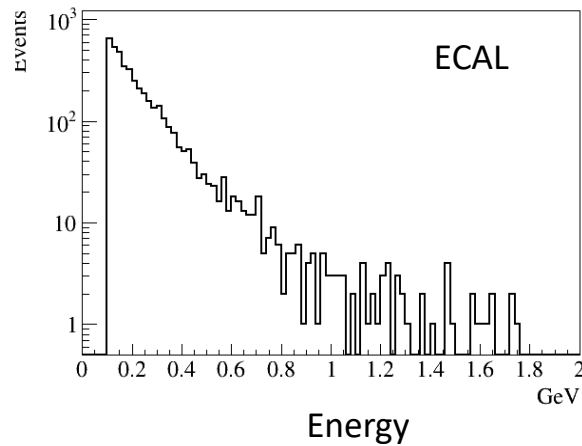
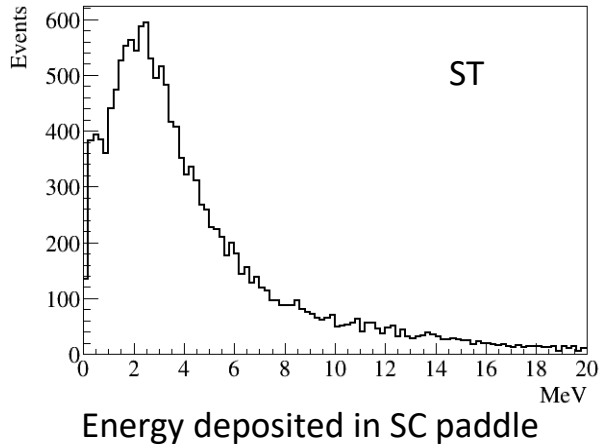
- large cross section of np elastic scattering process

## Photon background

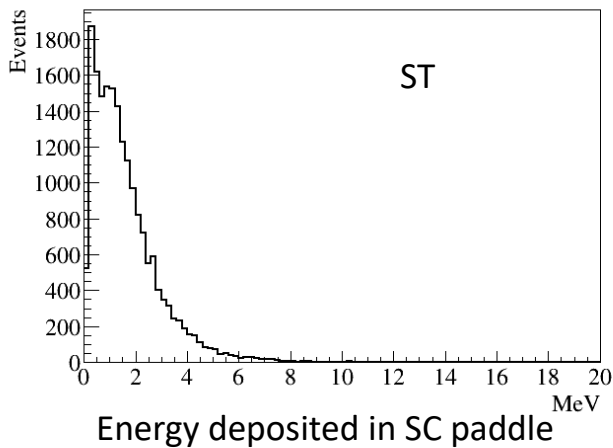
- low-energy photons
- large Compton cross section
- produce hits in the start counter
- almost no energy deposited in the calorimeters

# Detector Response Induced by Background

## Neutron background



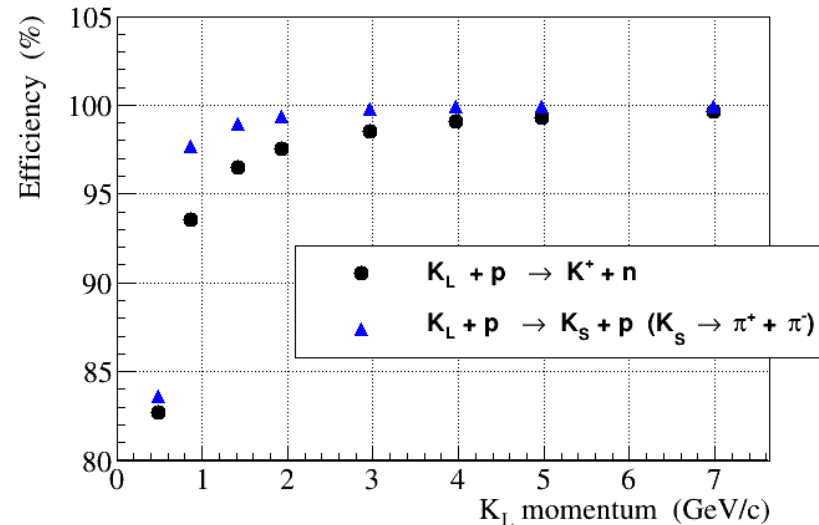
## Photon background



Calorimeter thresholds can be further optimized

# Trigger Efficiency

- The trigger efficiency calculation:
  - all particles were required to be reconstructed in the detector
  - apply energy threshold in the calorimeters



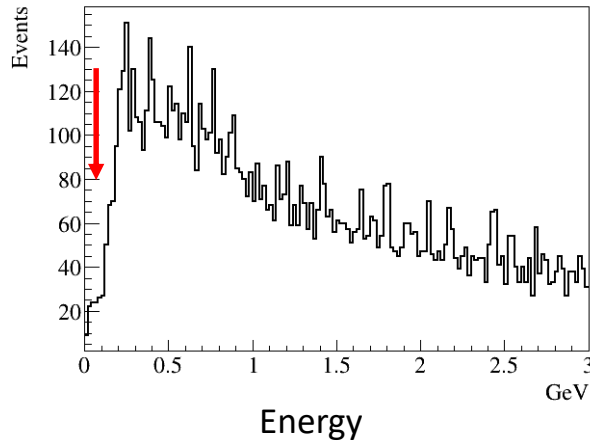
Trigger efficiency  $1.5 \text{ GeV}/c < P_{KL} < 4.5 \text{ GeV}/c$

Channel	Efficiency (%)
$K_L + p \rightarrow K^+ + n$	98.1
$K_L + p \rightarrow K_S + p (K_S \rightarrow \pi^+ \pi^-)$	99.6
$K_L p \rightarrow \pi^+ + \Lambda$	99.4
$K_L + p \rightarrow K^+ + \Xi (\Xi \rightarrow \Lambda + \pi^0)$	100
$K_L + p \rightarrow \pi^+ + \Sigma^0 (\Sigma^0 \rightarrow \Lambda + \pi^0)$	99.9
$K_L + p \rightarrow K^*(892) + p (K^* \rightarrow K^+ + \pi^-)$	99.7

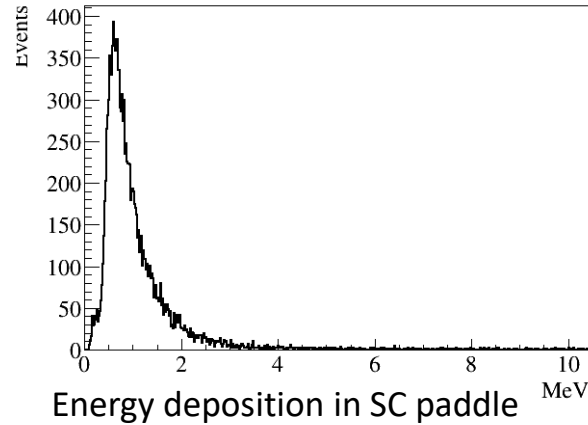
# Detector Response Induced by Physics Channels

$$1.5 \text{ GeV}/c < P_{KL} < 4.5 \text{ GeV}/c$$

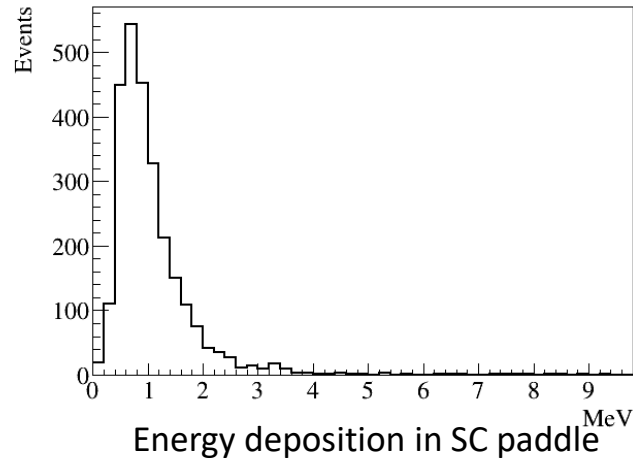
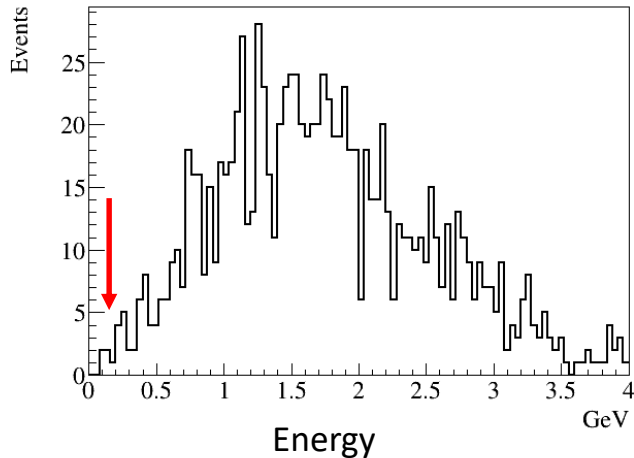
$E_{\text{BCAL}} + E_{\text{ECAL/FCAL}}$



Energy deposition in SC



$K_L p \rightarrow K^+ n$



$K_L p \rightarrow K_S p$   
( $K_S \rightarrow \pi^+ \pi^-$ )

# Total Trigger Rate & Data Rate

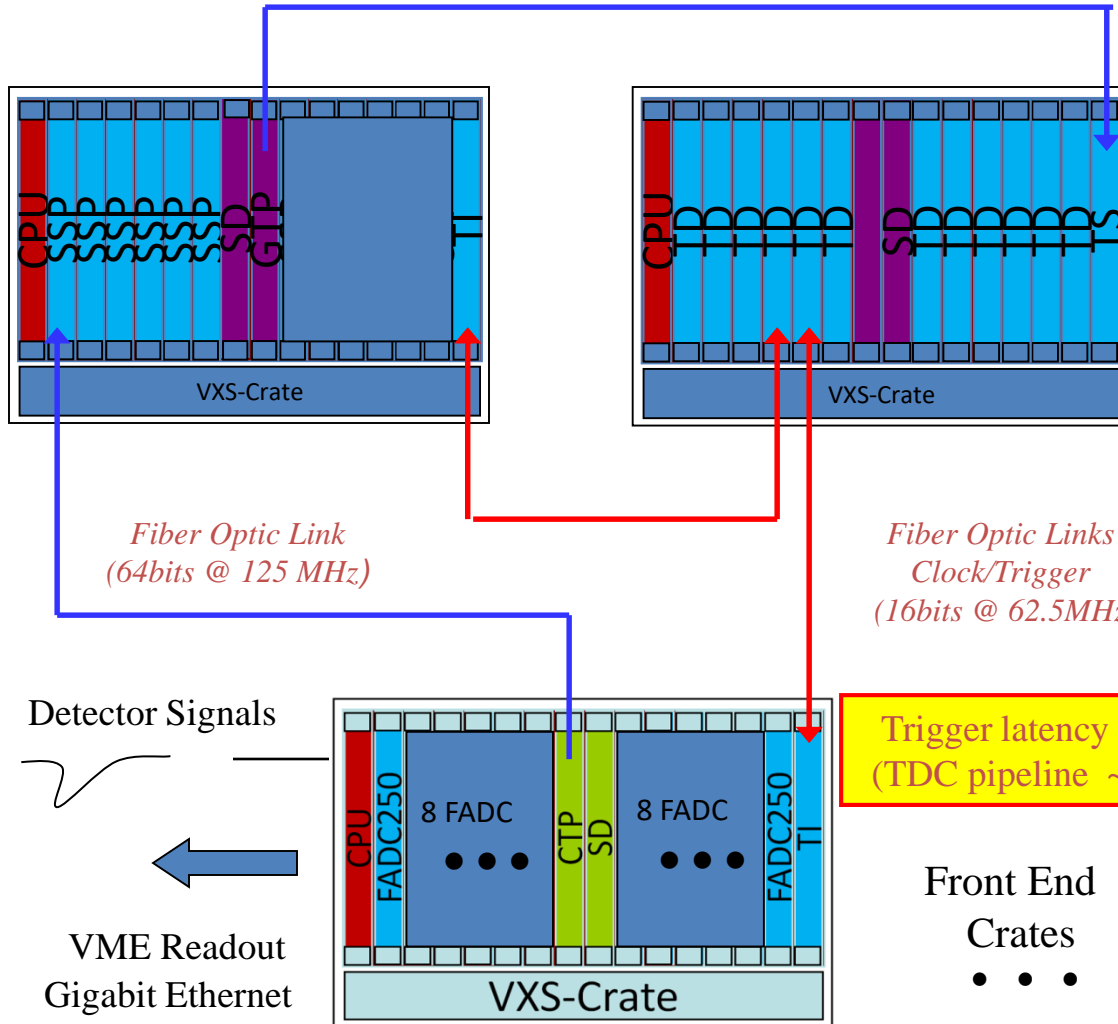
- The trigger rate is dominated by neutron background, which constitutes about 24 kHz
- Contribution from  $K_L p$  interactions:
  - the total  $K_L p$  cross section is  $\sim 6$  mb
  - an upper limit on the trigger rate assuming all  $K_L$  interactions are accepted
$$N_{\text{Int}} = N_{K_L} \cdot N_{\text{Prot}} \cdot \sigma = 3 \cdot 10^4 \cdot 1.7 \cdot 10^{24} \cdot 6 \cdot 10^{-27} = 300 \text{ s}^{-1}$$
- The trigger rate induced by cosmic rays is about 700 Hz
- The expected total trigger rate of the KLF experiment of about 26 kHz is significantly smaller than the GlueX high-intensity experiment rate of approximately 70 kHz
- The data rate from the detector will be dominated by low-multiplicity background events. The upper limit on the data rate is estimated to be about 150 Mbps, which is much smaller than the nominal GlueX production rate of about 1.5 Gbps.

(Note: the rate may be smaller due to the smaller event size)

# Backup

# Level-1 Trigger Electronics (operated at 250 MHz)

Copper Ribbon Cabl (32bits @ 250 MHz)



## Custom Designed Boards at JLAB

### Flash ADC , 250 Msps (FADC)

- 16 channel, 12 bits, digital pipeline
- sums amplitudes from 16 channel
- transfer energy sums or hit patterns to the CTP

### Cate Trigger Processor (CTP)

- sums energies from fADC's
- transfers date over optical cables to SSP (10 Gbps capability)

### SubSystem Processor (SSP)

- sums energies received from CTP's

### Global Trigger Processor (GTP)

- collects data from 8 SSP's
- runs trigger equations

### Trigger Supervisor (TS)

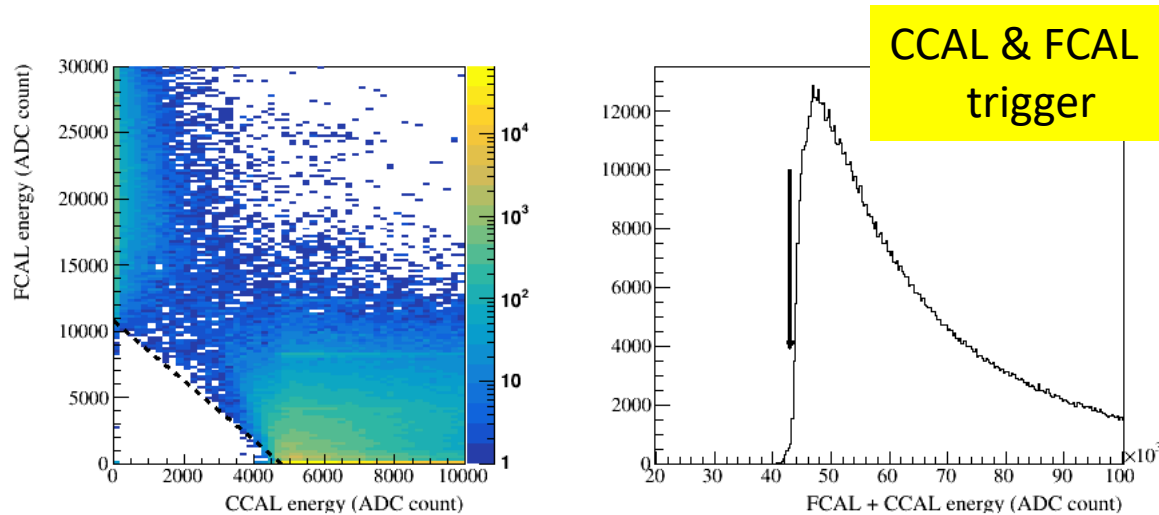
- manages triggers
- distributes clocks, triggers, sync to crates TI – TD

### Trigger Interface (TI)

### Trigger Distribution (TD)

### Signal Distribution (SD)

# PrimEx Production: Spring 2019



Typical trigger rates for PrimEx production:

<b>Total:</b>	<b>23 kHz</b>	<b>Live time: 99 %</b>
CCAL & FCAL:	17.7 kHz	
FCAL:	1.2 kHz	
PS:	5.5 kHz	