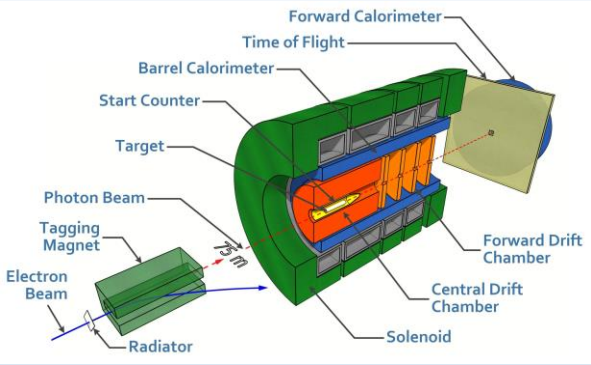


Jefferson Lab

Trigger Configuration

A. Somov, Jefferson Lab

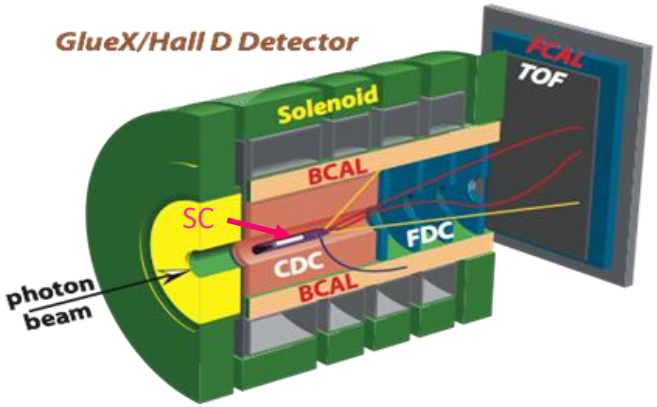
KLF Readiness Review

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)

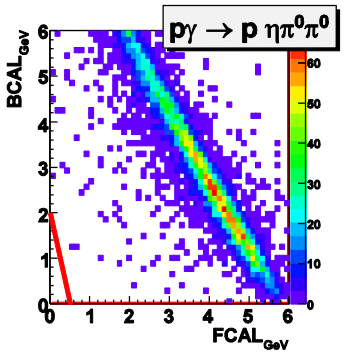


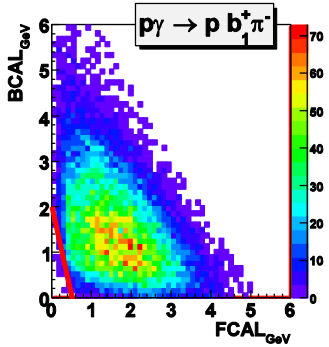
- Trigger algorithm based on measurement of energies in FCAL and BCAL

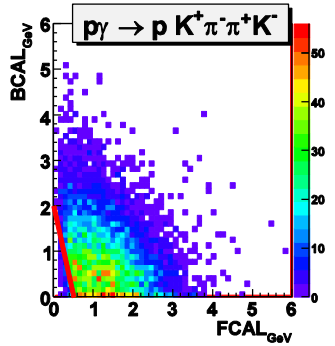
$$A \cdot E_{BCAL} + B \cdot E_{FCAL} > E_{THR}$$

- Coincidence of calorimeters with Start Counter (SRC experiment)

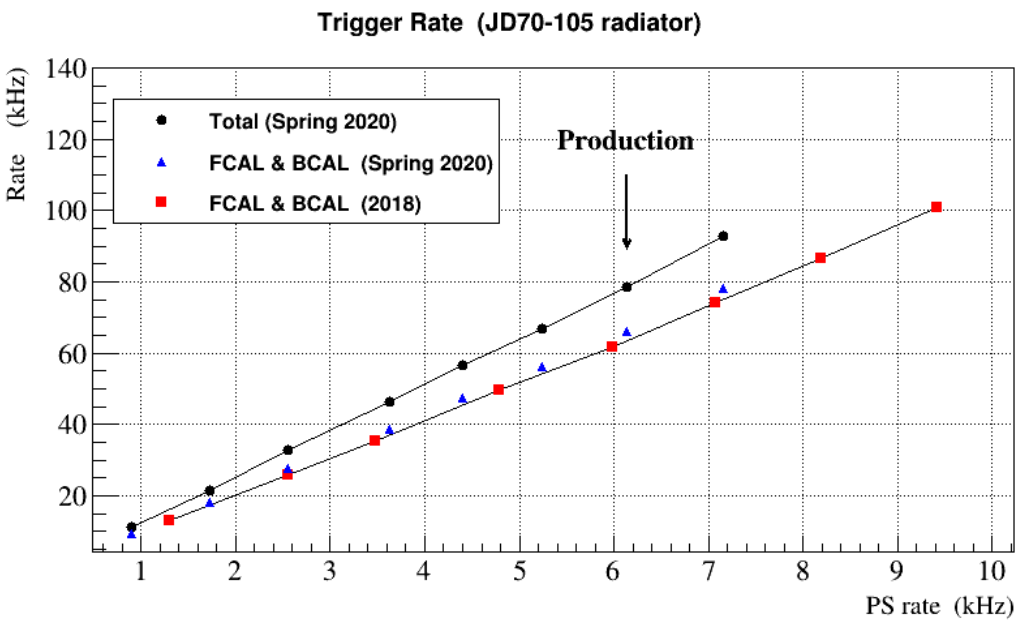
- Trigger based on TOF and Calorimeters (CPP/NPP experiment)

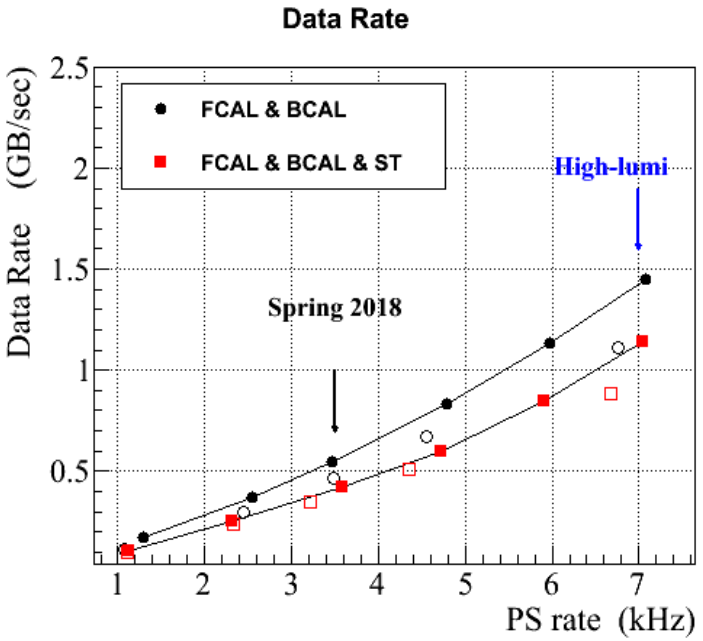






Trigger Performance





- 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

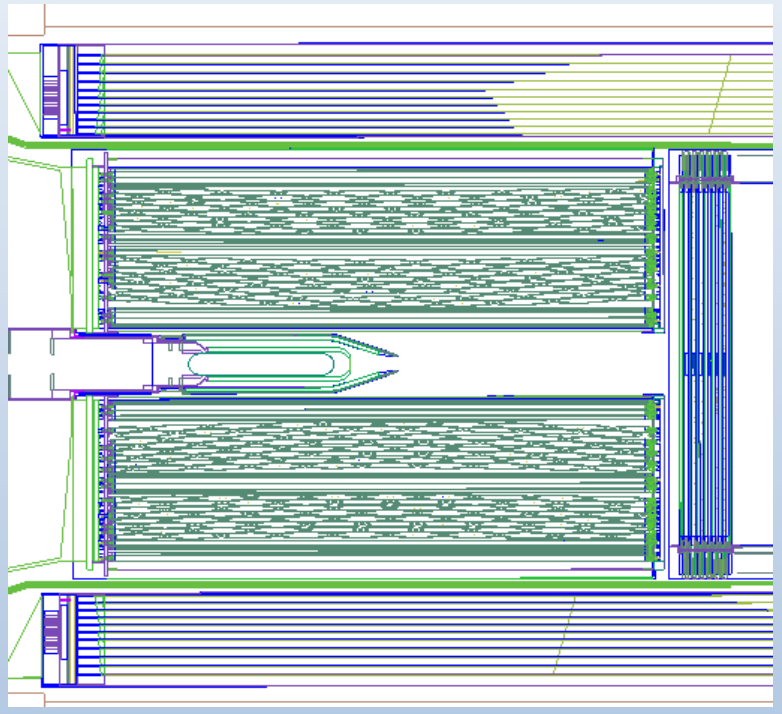
- Evaluate trigger efficiency for physics channels of interest

  - mostly charged particles in the final state; produced by a low-energy K_L beam

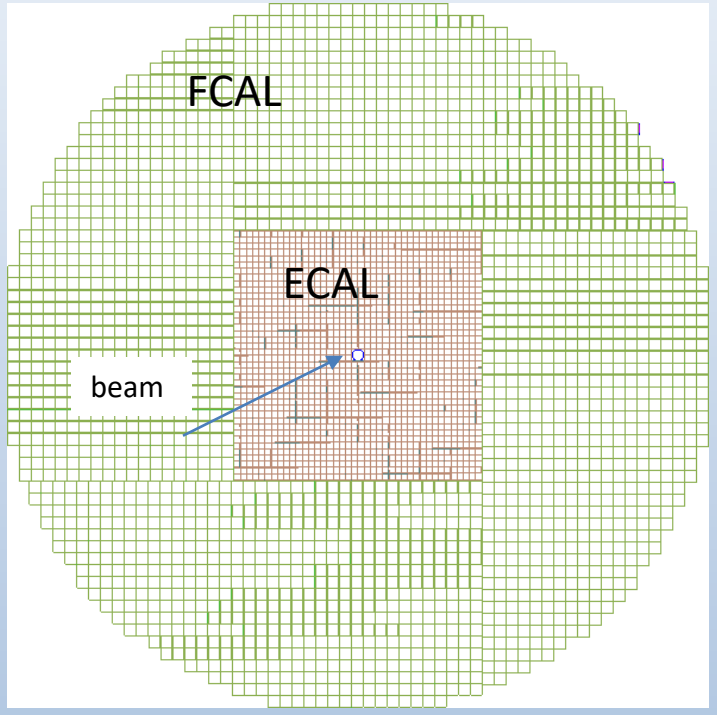
Consider to use triggers based on the energy depositions in the calorimeters.
- lower energy thresholds below MIP energy (similar to the SRC experiment)

Geant4 Detector Geometry

Target Geometry



Forward Calorimeter



LH2 target cell: 6 cm in diameter
40 cm long

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

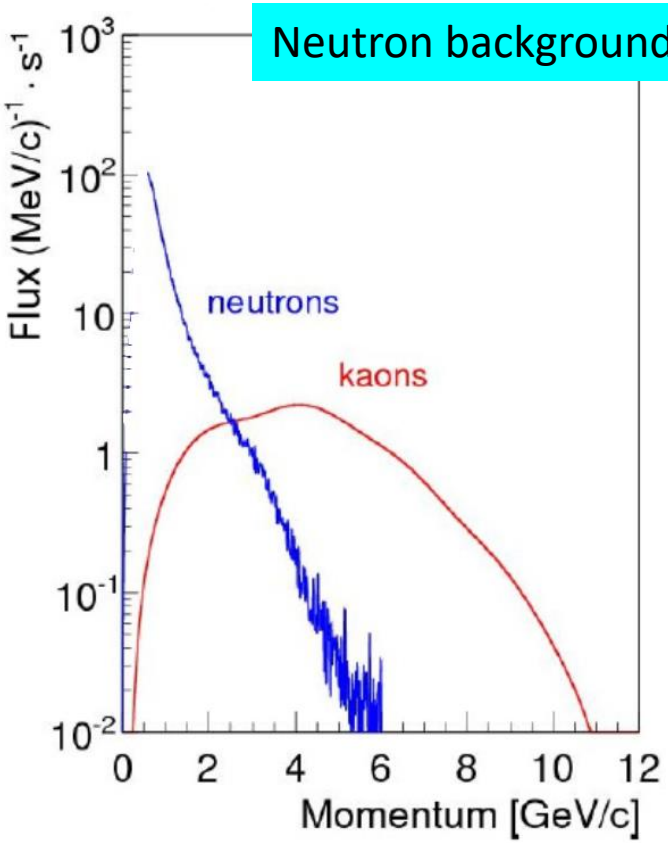
FCAL: 2360 lead glass modules

ECAL: 1596 $PbW0_4$ 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)

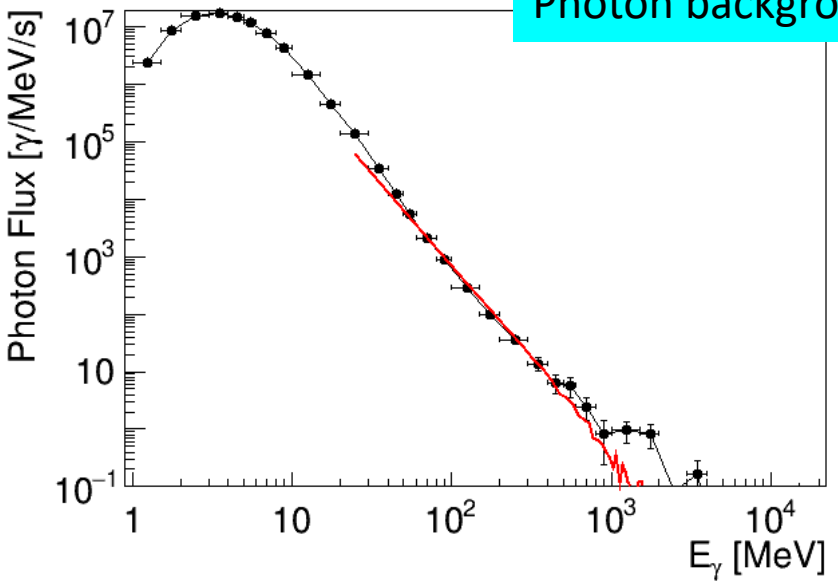
Main Sources of Background

Neutron background



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

Photon background



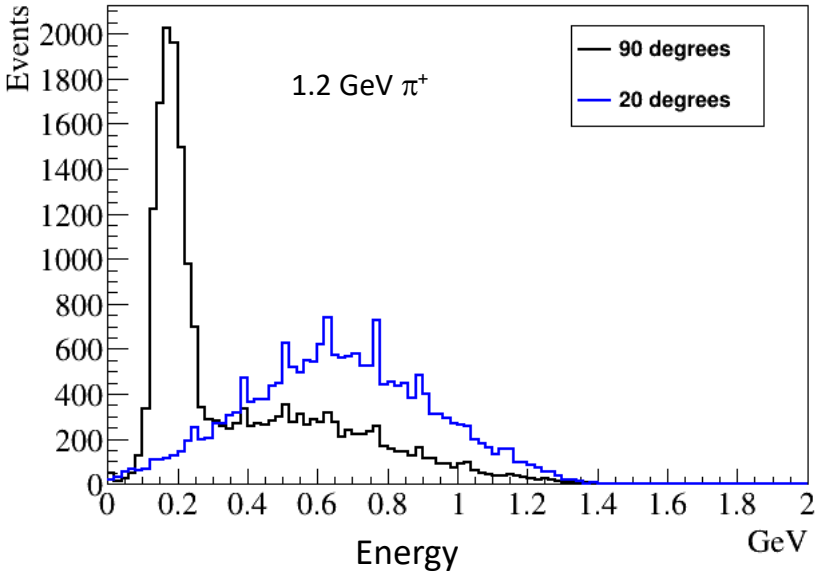
- Simulated using MCNP, Fluka, and Geant
- Integrated flux: 6.6 ·10^5 n/s on the target

- Simulated using MCNP, Fluka, and Geant
- Integrated flux: 2 ·10^8 γ /s on the target

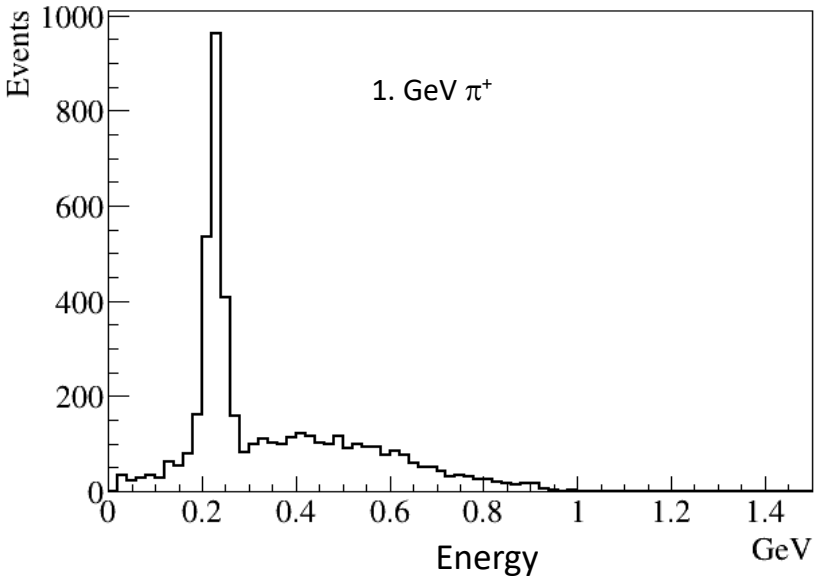
- Uniform distribution of BG particles over the target face

Detector Response Induced by Charged Particles

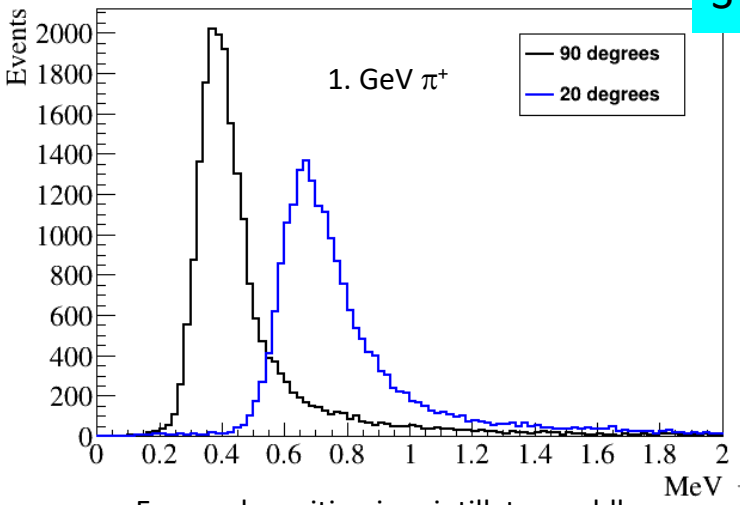
BCAL



ECAL



ST



Energy deposition in scintillator paddles

- Geant4 simulation
- Charged pions generated at different polar angles

Background Rates

- Trigger energy thresholds in the calorimeters:

  1) Hit energy thresholds: $E_{BCAL,\ ECAL} > 20$ MeV, $E_{FCAL} > 130$ MeV

  2) Sum up hits (above the threshold), compute total energy E^{SUM} in the forward and barrel calorimeters (note, the total energy may be 0)
  Require:

$$E^{SUM}_{ECAL/FCAL} + E^{SUM}_{BCAL} > 0.1 \text{ GeV}$$

- 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	<< 1	<< 1	<< 1	5.8×10^3

Background Rates

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

Neutron background

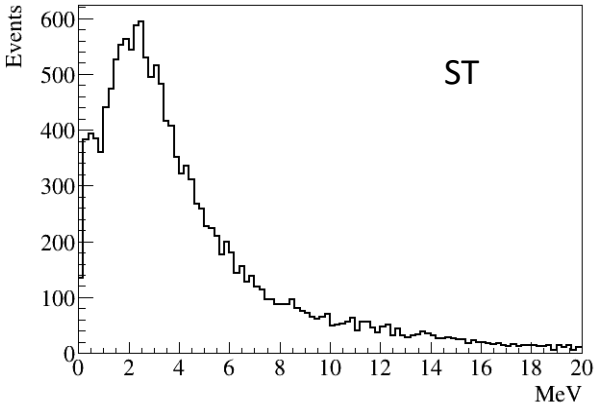
- large cross section of np elastic scattering process

Photon background

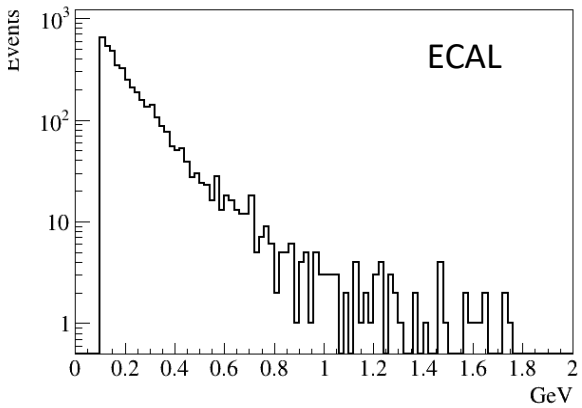
- low-energy photons
- large Compton cross section
- produce hits in the start counter
- almost no energy deposited in the calorimeters

Detector Response Induced by Background

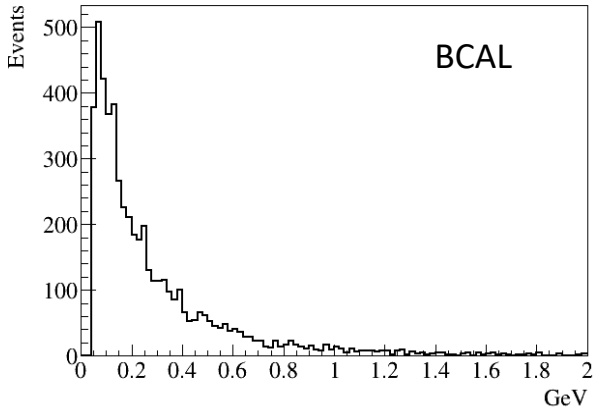
Neutron background



Energy deposited in SC paddle

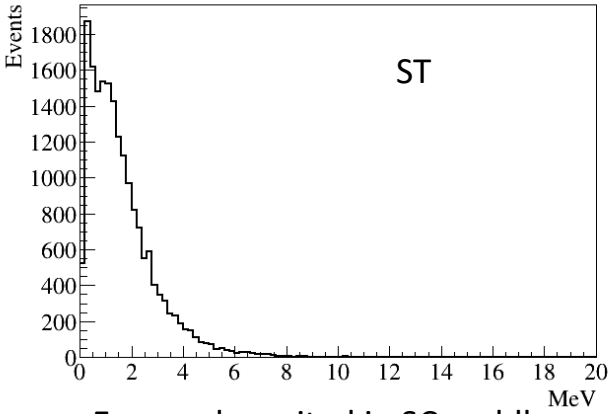


Energy



Energy

Photon background



Energy deposited in SC paddle

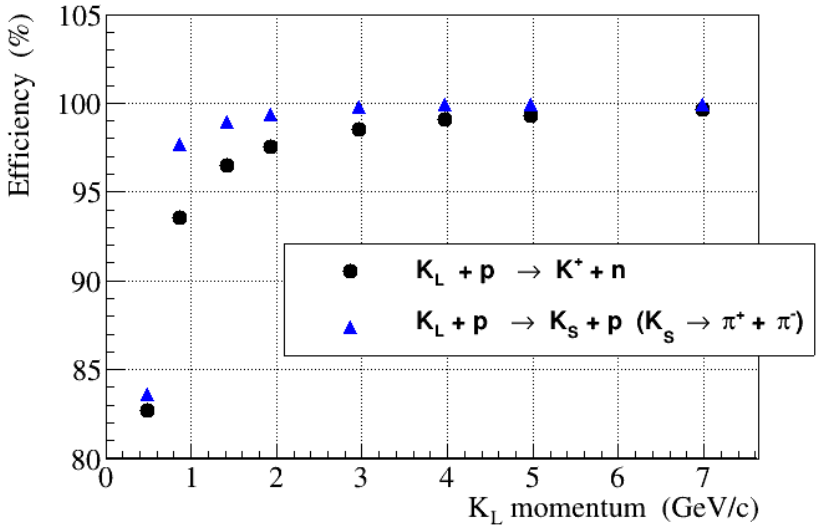
Calorimeter thresholds can be further optimized

Trigger Efficiency

- The trigger efficiency calculation:

  - all particles were required to be reconstructed in the detector

  - apply energy threshold in the calorimeters



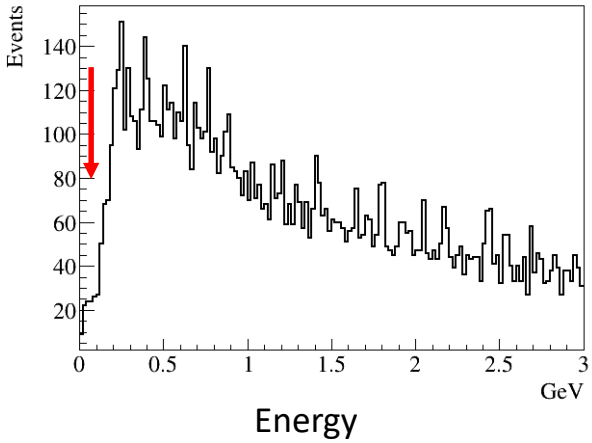
Trigger efficiency 1.5 GeV/c < P_{KL} < 4.5 GeV /c

Channel	Efficiency (%)
$K_L + p \rightarrow K^+ + n$	98.1
$K_L + p \rightarrow Ks + p$ ($K_S \rightarrow \pi^+ \pi^-$)	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

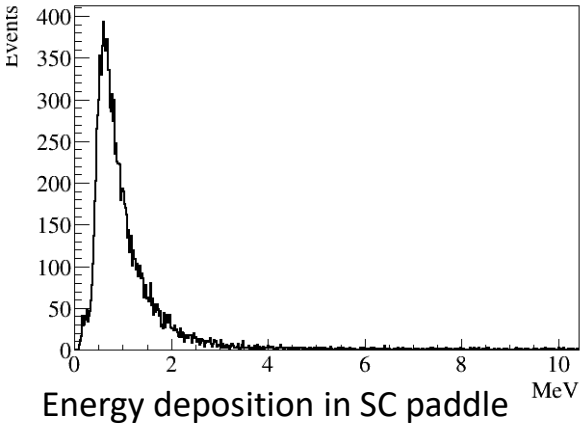
Detector Response Induced by Physics Channels

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

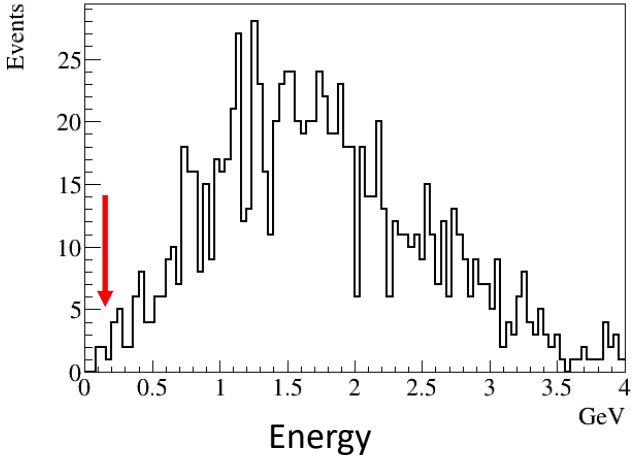
$E_{BCAL} + E_{ECAL/FCAL}$

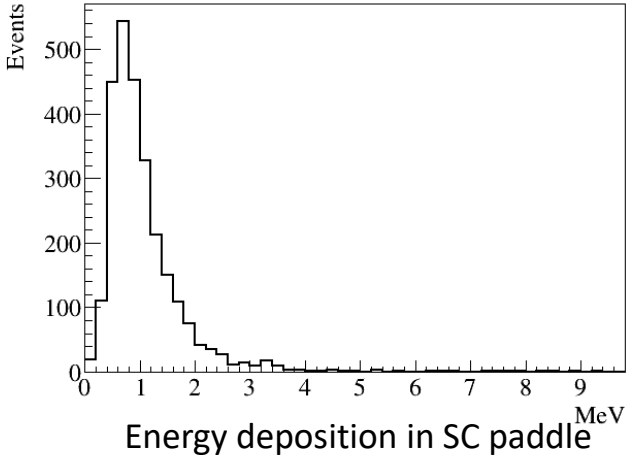


Energy deposition in SC



K_L p -> K^+ n





K_L p -> Ks p
(K_S -> π^+ π^-)

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 ~6 mb

  - an upper limit on the trigger rate assuming all K_L interactions are accepted

$$N_{Int} = N_{KL} \cdot N_{Prot} \cdot \sigma = 3 \cdot 10^4 \cdot 1.7 \cdot 10^{24} \cdot 6 \cdot 10^{-27} = 300\ s^{-1}$$

- The trigger rate induced by cosmic rays is about 700 Hz

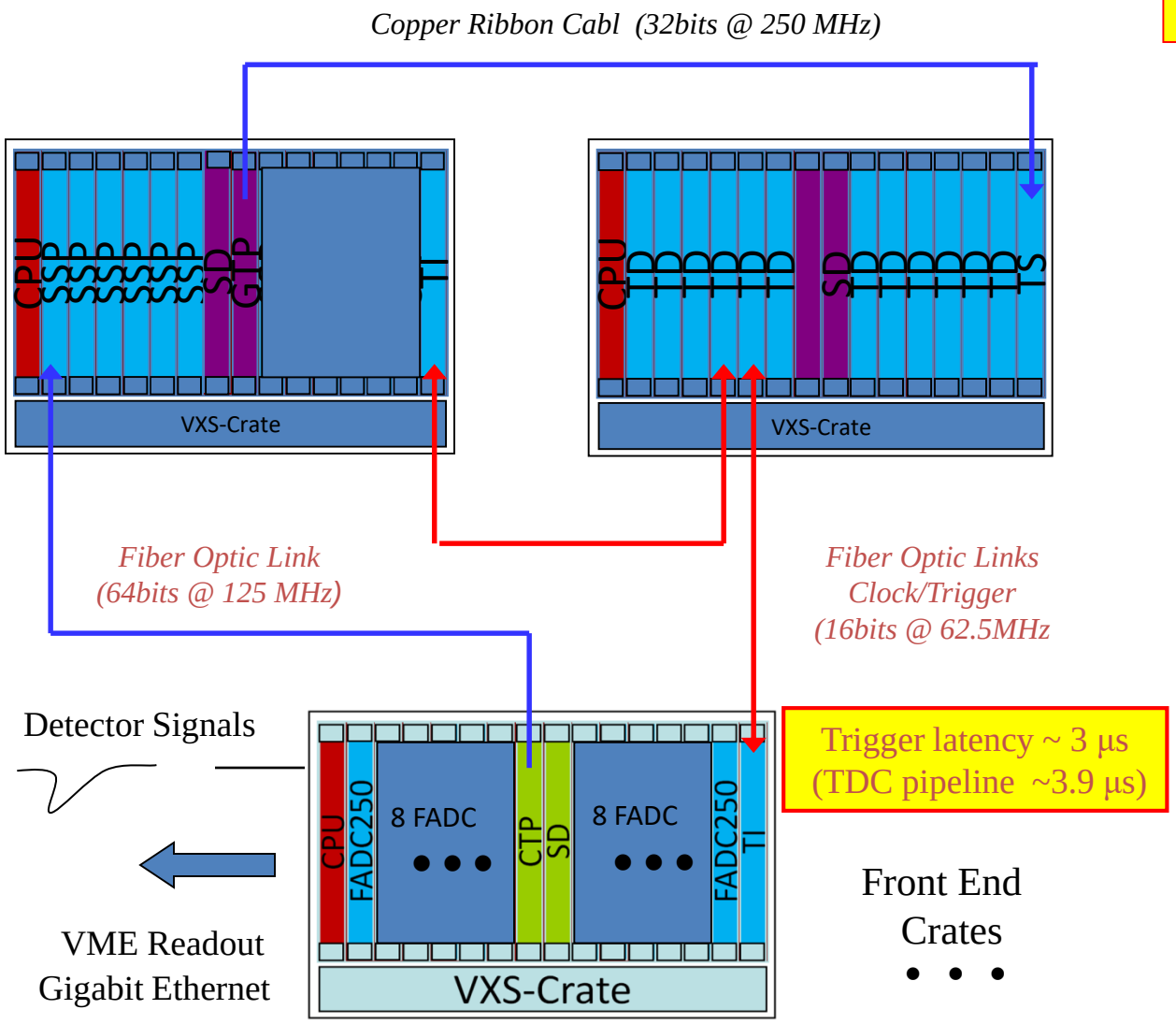
- The expected total trigger rate of the KLF experiment of about 26 kHz is significantly smaller than the GlueX high-intensity experiment rate of approximately 70 kHz

- 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)



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

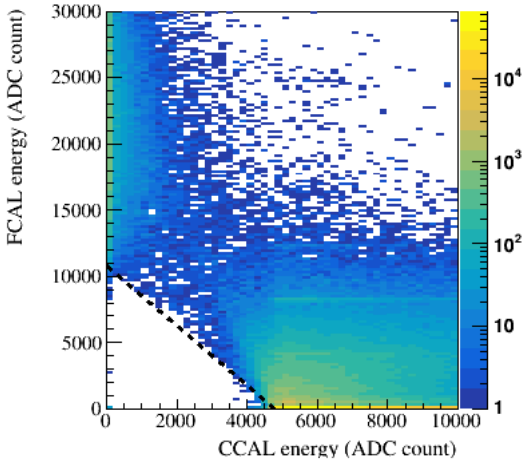
Trigger Supervisor (TS)
- manages triggers
- distributes clocks, triggers, sync to crates TI – TD

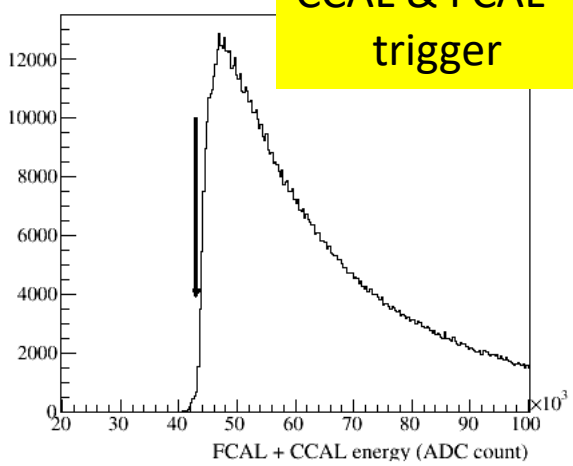
Trigger Interface (TI)

Trigger Distribution (TD)

Signal Distribution (SD)

PrimEx Production: Spring 2019





CCAL & FCAL trigger

Typical trigger rates for PrimEx production:

Total:	**23 kHz**	**Live time: 99 %**
CCAL & FCAL:	17.7 kHz	
FCAL:	1.2 kHz	
PS:	5.5 kHz	