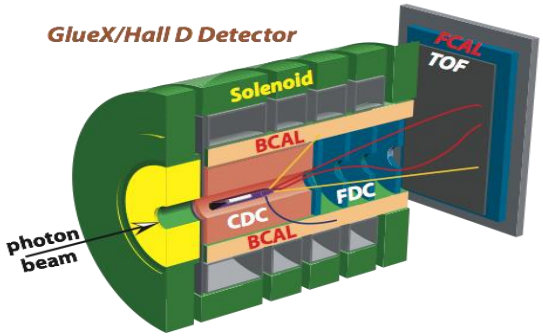


Jefferson Lab

Trigger Configuration

A. Somov, Jefferson Lab

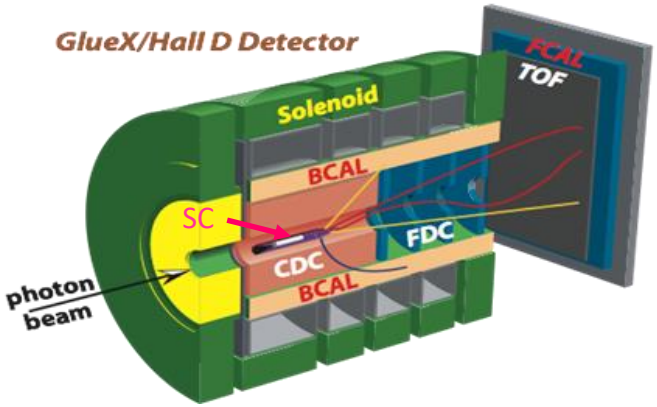
KLF Readiness Review

August 28, 2024

GlueX Level-1 Trigger

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

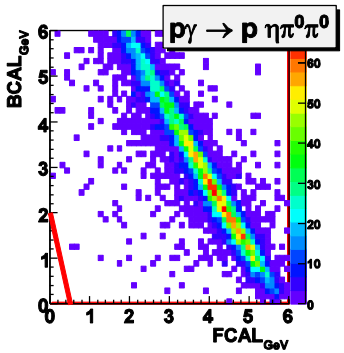
Forward Calorimeter	(FCAL)	(Energy deposition)
Barrel Calorimeter	(BCAL)	(Energy deposition)
Start Counter	(SC)	(Count hits)
Time of Flight	(TOF)	(Count hits)

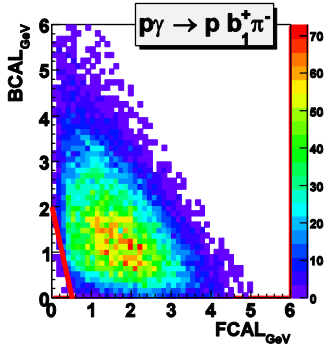


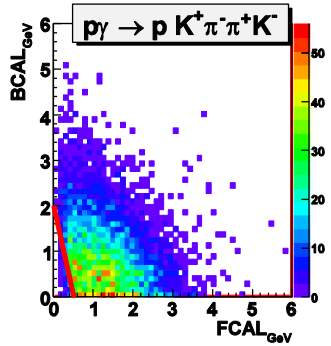
- Trigger algorithm based on measurement of energies in FCAL and BCAL

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

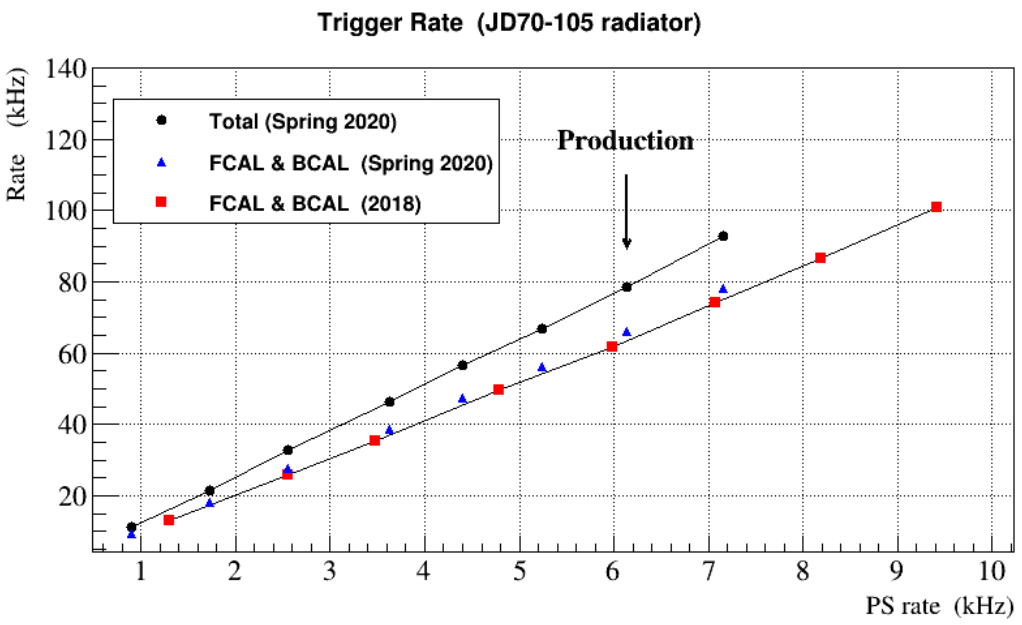
- Coincidence of calorimeters with Start Counter (SRC experiment)
- Trigger based on TOF and Calorimeters (CPP/NPP experiment)

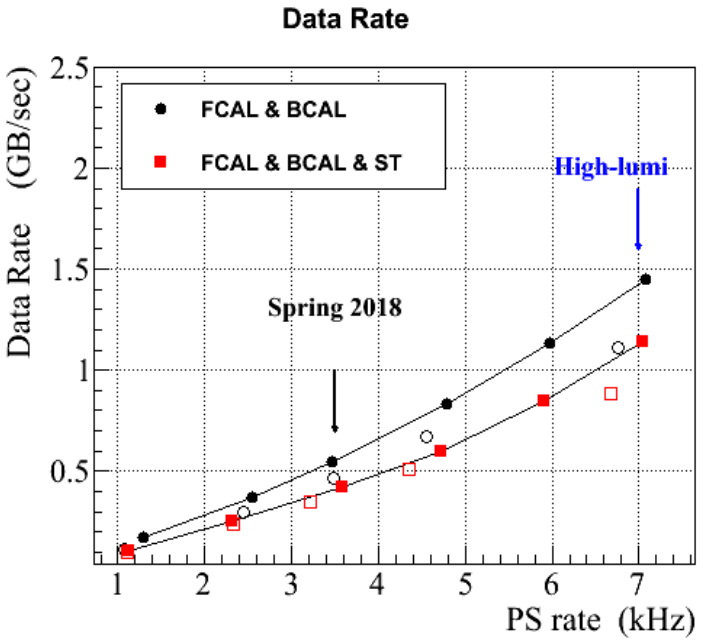






Trigger Performance





- 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

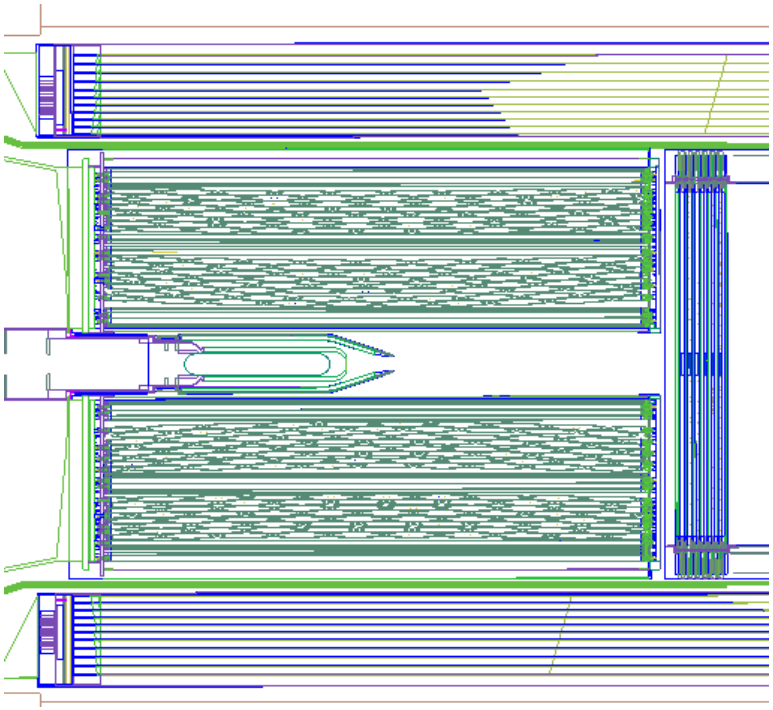
- Evaluate trigger efficiency for physics channels of interest

  - charged particles in the final state

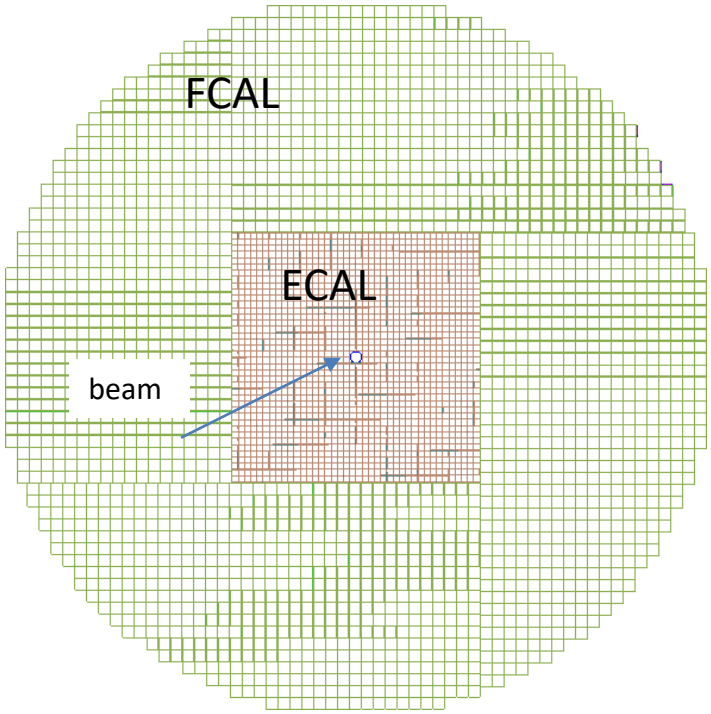
Consider to use triggers based on the energy depositions in the calorimeters.
- lower energy thresholds below MIP energy (similar to the SRC experiment)

Geant4 Detector Geometry

Target Geometry



Forward Calorimeter



LH2 target cell: 6 cm in diameter
40 cm long

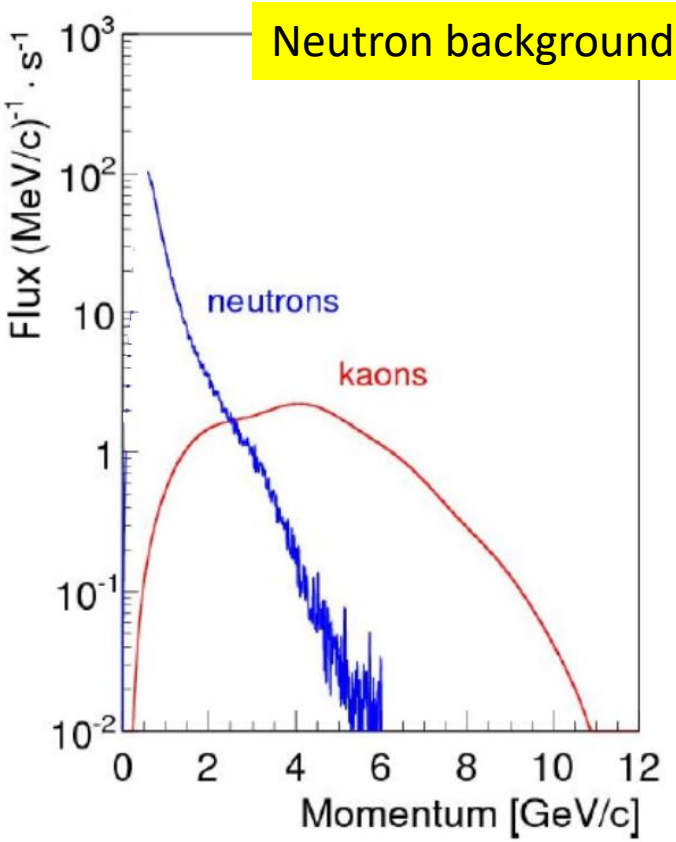
FCAL: 2360 lead glass modules

ECAL: 1596 $PbW0_4$ 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)

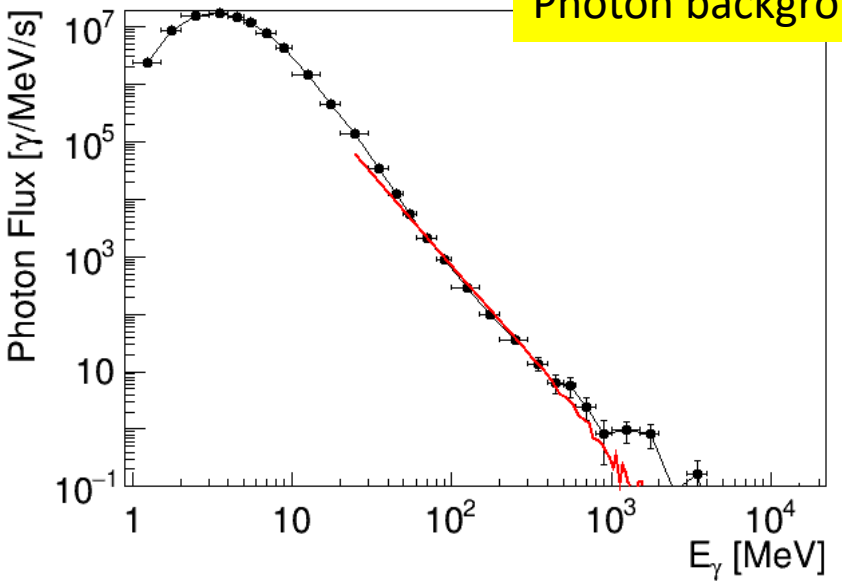
Main Sources of Background

Neutron background



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

Photon background



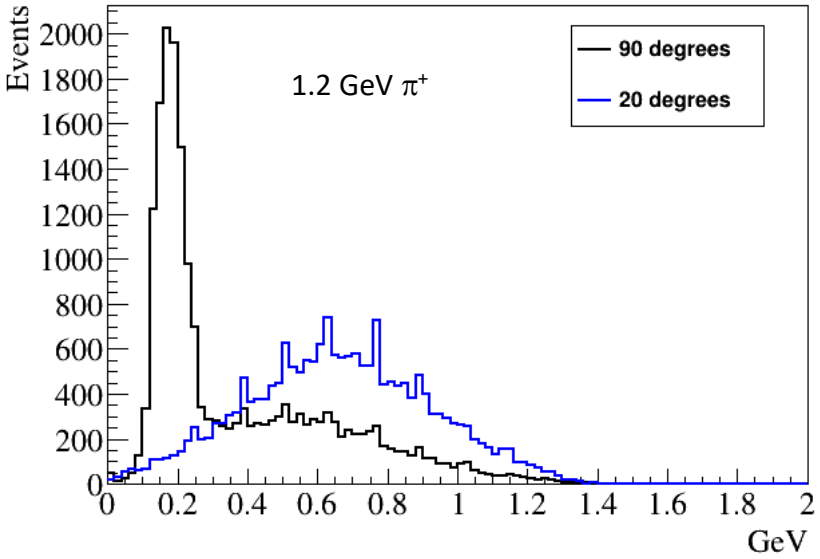
- Simulated using MCNP, Fluka, and Geant
- Integrated flux: 6.6 ·10^5 n/ s on the target

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

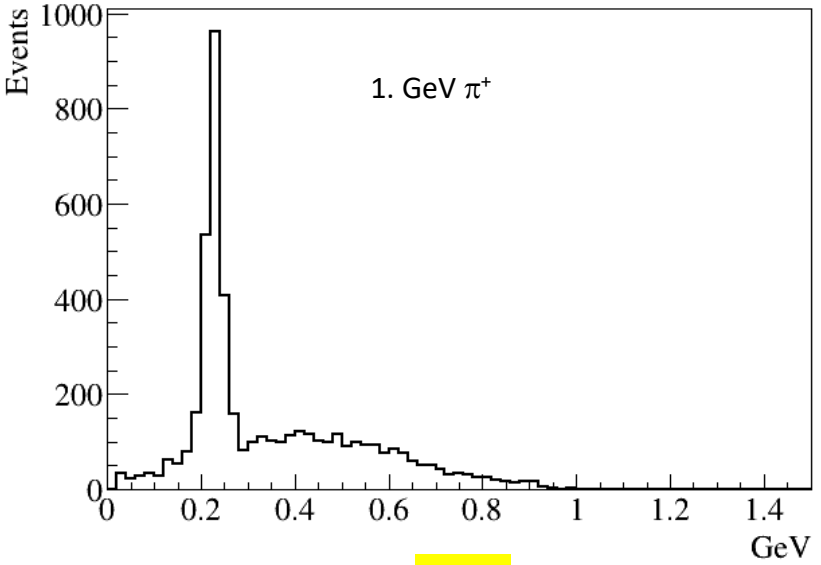
Uniform distribution of BG particles over the target face

Detector Response Induced by Charged Particles

BCAL

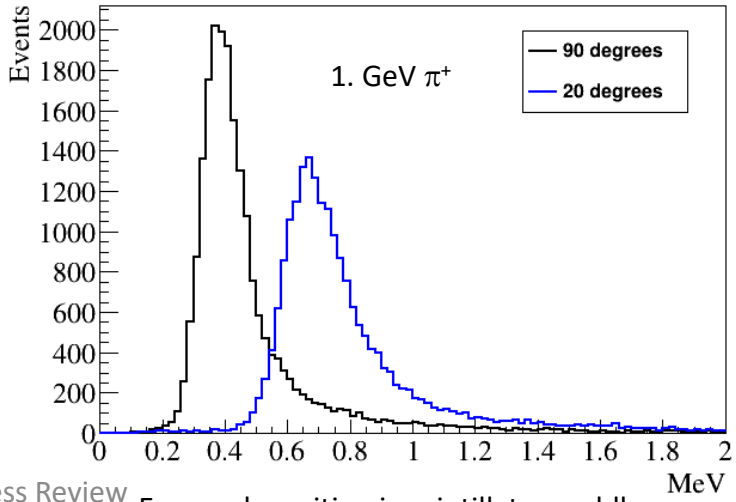


ECAL



- Geant4 simulation
- charged pions generated at different angles

ST



Energy deposition in scintillator paddles

Background Rates

- Trigger energy thresholds in the calorimeters:

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

  $E_{ECAL/FCAL} + E_{BCAL} > 0.1$ 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

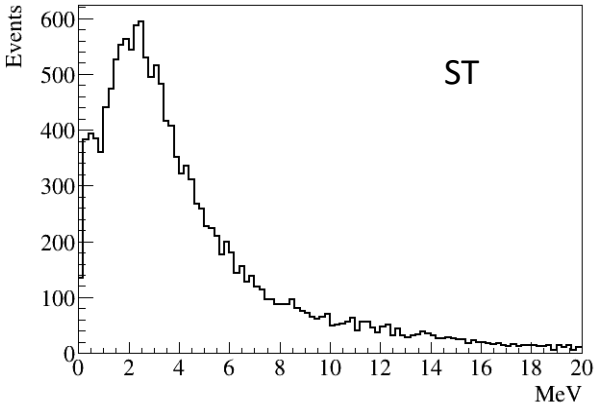
- large cross section of np scattering process

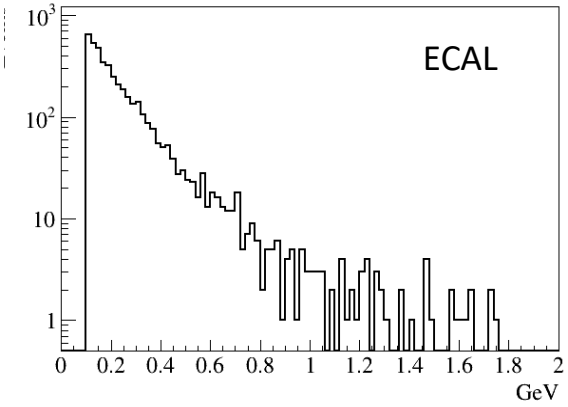
Photon background

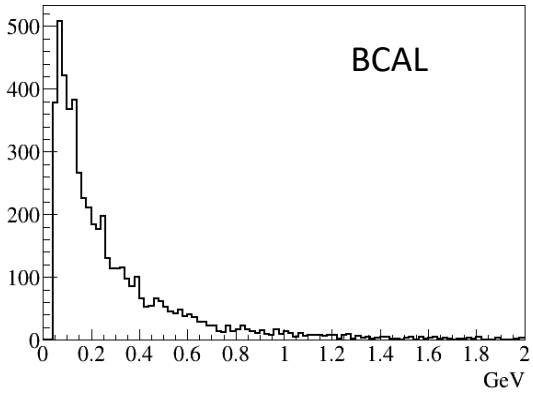
- low-energy photons
- large Compton cross section
- produce hits in the start counter
- almost no energy deposited in the calorimeters

Detector Response Induced by Background

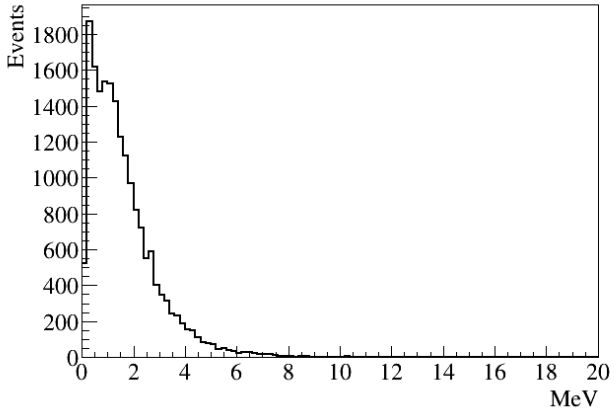
Neutron background







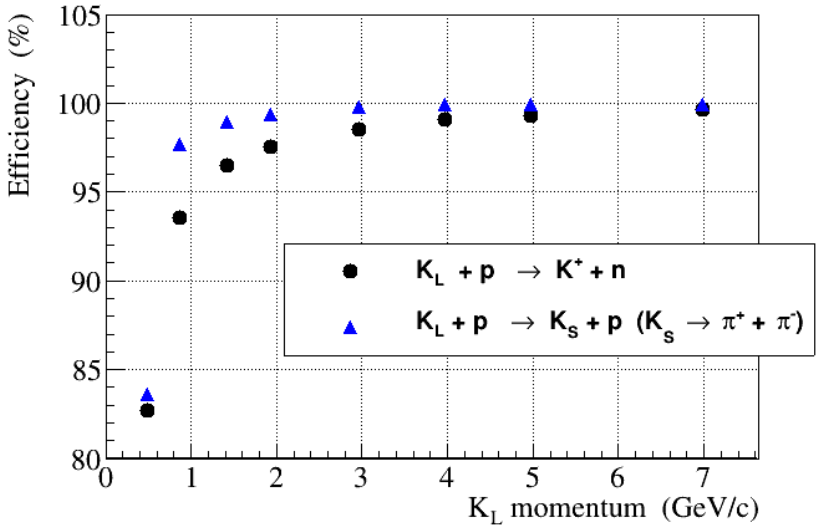
Photon background



Trigger Efficiency

- The trigger efficiency calculation:

  - all particles were required to be reconstructed in the detector



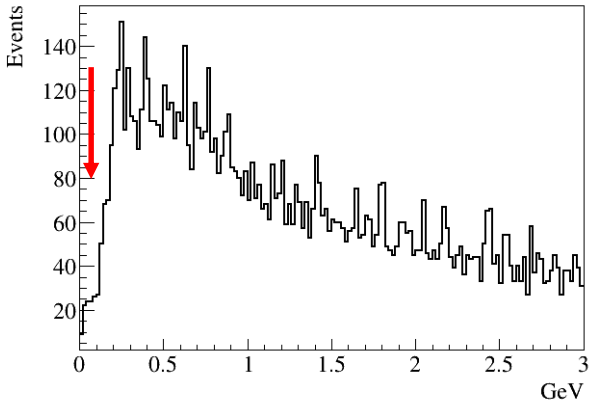
Trigger efficiency 1.5 GeV/c $< P_{KL} >$ 4.5 GeV /c

Channel	Efficiency (%)
$K_L + p \rightarrow K^+ + n$	98.1
$K_L + p \rightarrow Ks + p$ ($K_S \rightarrow \pi^+ \pi^-$)	99.8
$K_L\ p \rightarrow \pi^+ + \Lambda$	99.4
$K_L + p \rightarrow K^+ + \Xi$ ($\Xi \rightarrow \Lambda + \pi^0$)	100
$K_L + p \rightarrow K^*(892) + p$ ($K^* \rightarrow K^+ + \pi^-$)	99.7

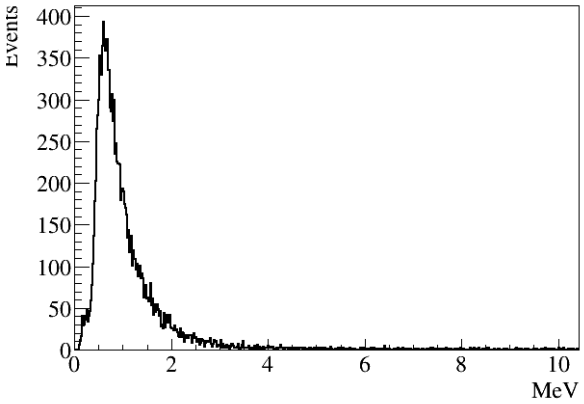
Detector Response Induced by Physics Channels

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

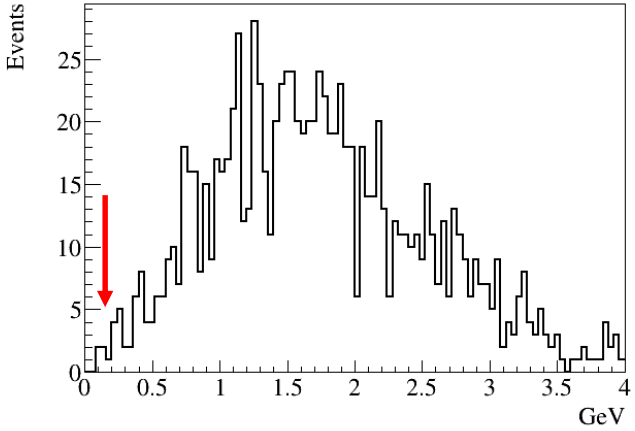
$E_{BCAL} + E_{ECAL/FCAL}$

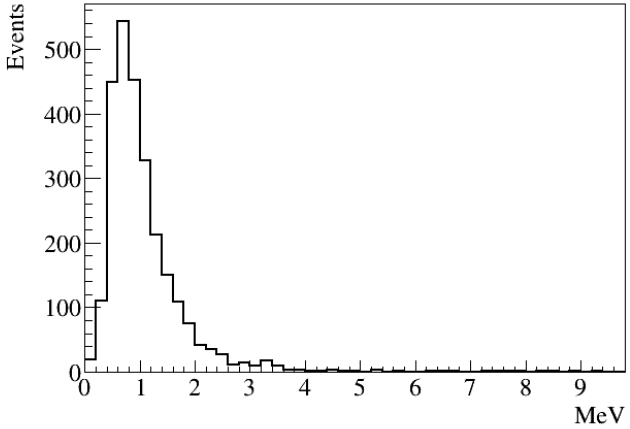


Energy deposition in SC



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 and constitutes about 24 kHz
- The contribution from K_L p interactions:
  - total K_L p cross section ~6 mb
  - the upper limit on the trigger rate (assume that accept all KL interactions)

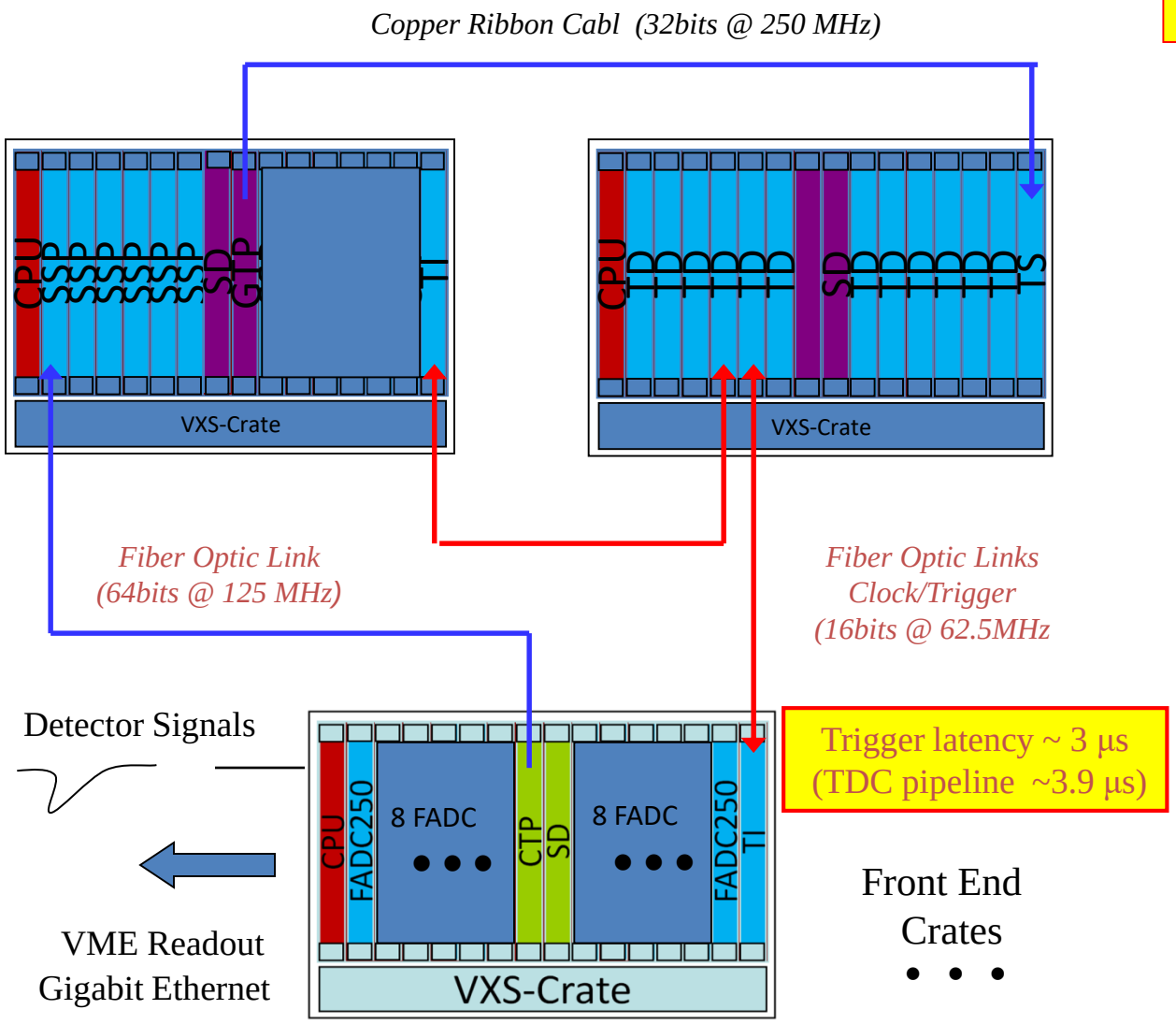
$$N_{Int} = N_{KL} \cdot N_{Prot} \cdot \sigma = 3 \cdot 10^{4} \cdot 1.7 \cdot 10^{24} \cdot 6 \cdot 10^{-27} = 300\ s^{-1}$$

- The GlueX detector can operate at a significantly higher rate of up to 70 kHz
- The upper limit on data rate is 200 Mbps, which is significantly smaller compared to 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

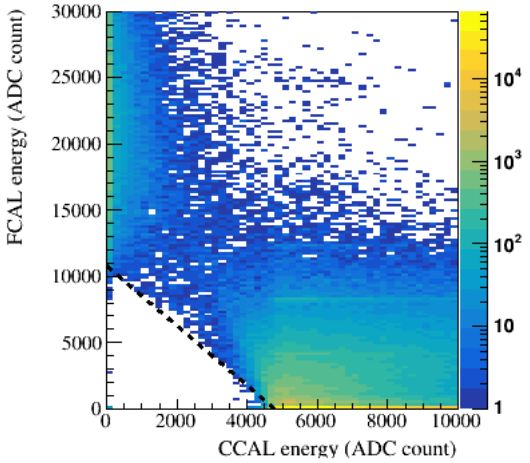
Trigger Supervisor (TS)
- manages triggers
- distributes clocks, triggers, sync to crates TI – TD

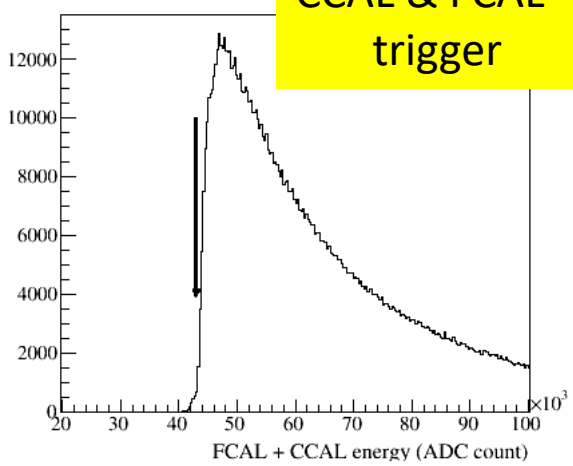
Trigger Interface (TI)

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	