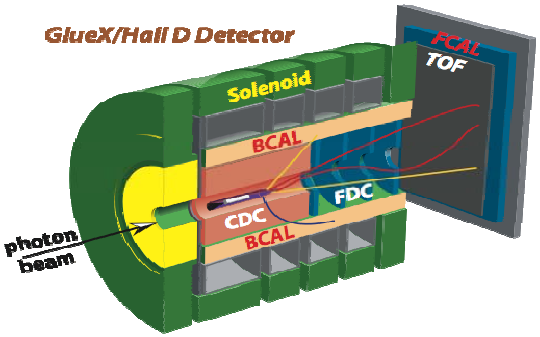


Jefferson Lab

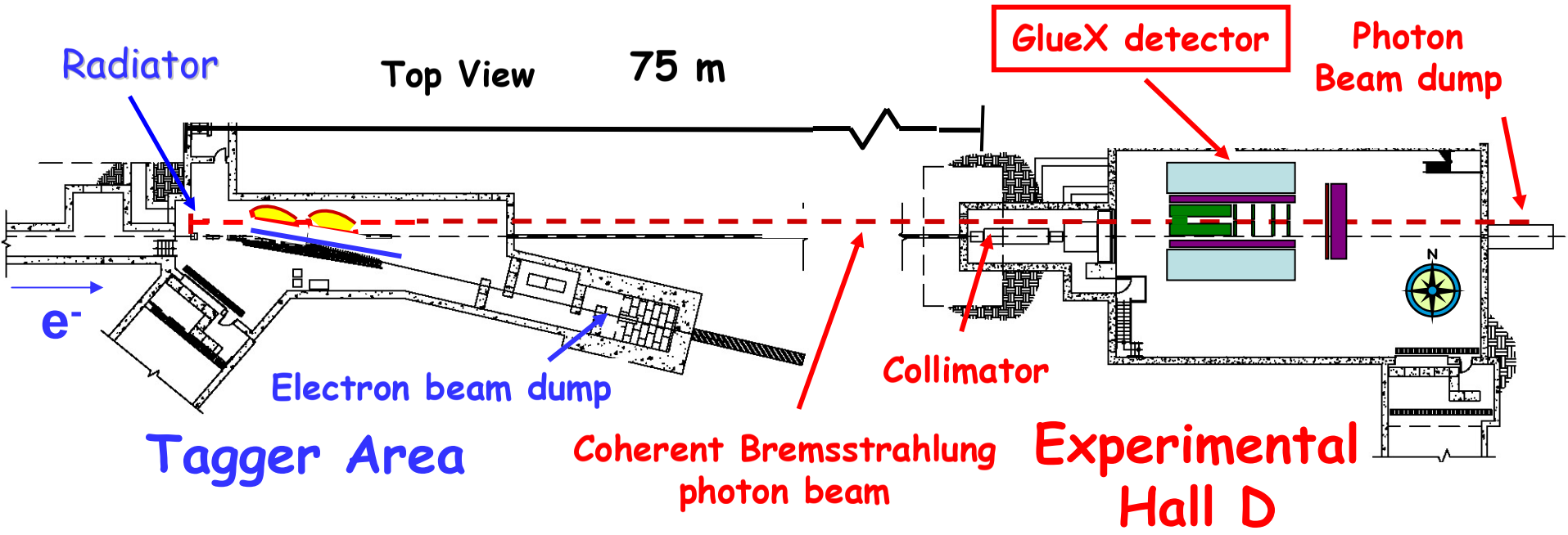
Level-1 Trigger of the GlueX Experiment

A. Somov, Jefferson Lab

DNP08, Oakland, California, 25 October 2008

Introduction

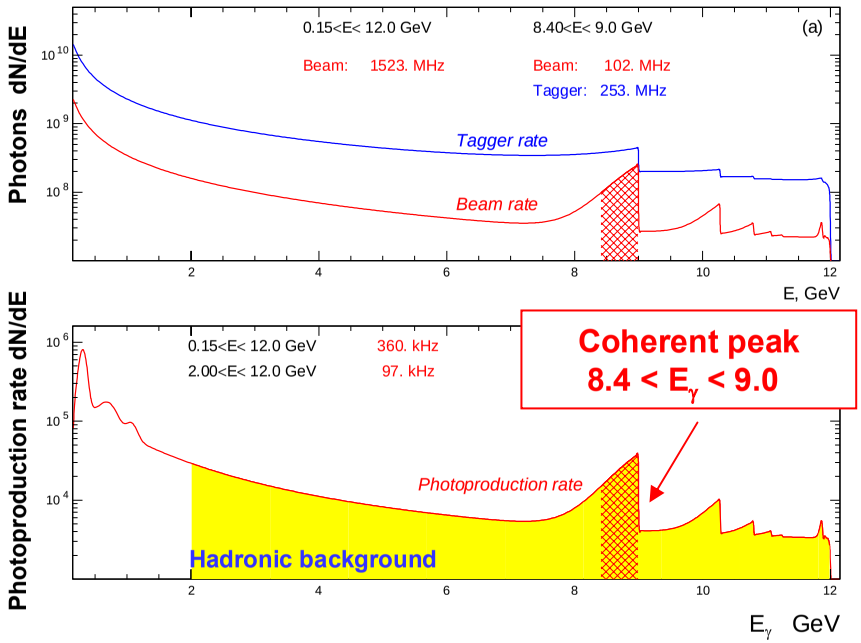
GlueX main physics goal: Search for exotic mesons in interactions of polarized photons with a hydrogen target



- Bremsstrahlung beam photons produced by 12 GeV electron beam incident on a diamond crystal. Main coherent Bremsstrahlung peak at E_γ 8.4 – 9.0 GeV
- Two types of interactions in the detector:
  - Hadronic photoproduction at 30 cm long liquid hydrogen target
  - Electromagnetic interactions

Photoproduction of Hadrons

Photoproduction rate



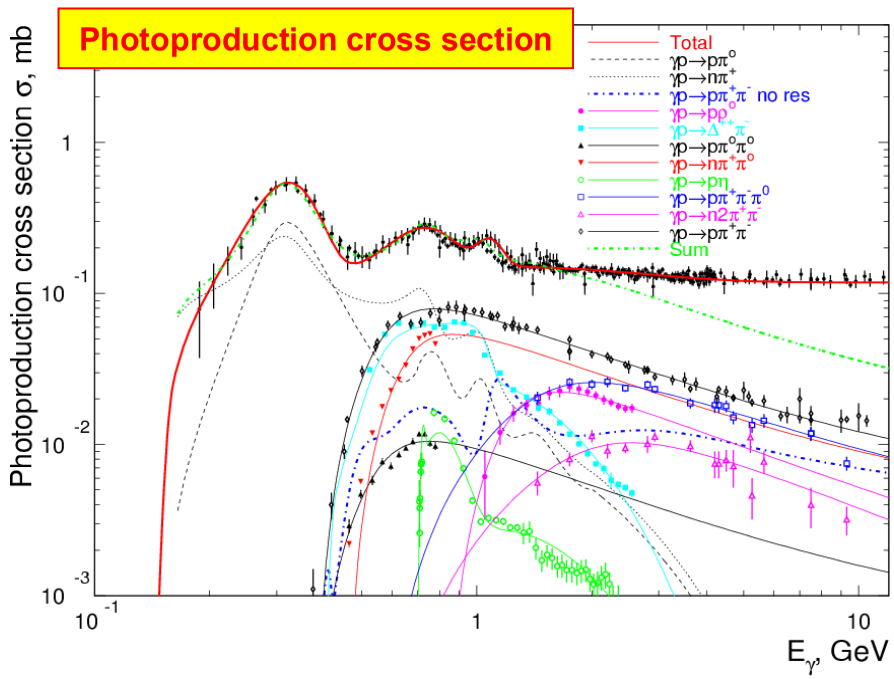
Rates	Energy range, GeV		
	0.15 - 12.	2.0 - 12.	8.4 - 9.0
Tagger	10 GHz	4.0 GHz	250 MHz
Beam	1.5 GHz	670 MHz	100 MHz
Photoproduction	360 kHz	100 kHz	16 kHz

Total photoproduction rate **360 kHz**
Coherent peak **16 kHz**

Photoproduction simulation

E_γ > 3 GeV: **PYTHIA generator adapted for low energies (taken from HERMES)**

E_γ < 3 GeV: **Differential cross sections are taken from existing measurements**



Electromagnetic Background

- **Use full GEANT (3.21) detector simulation.**
  - realistic geometry of the beamline and the GlueX detector
  - realistic detector responses and thresholds

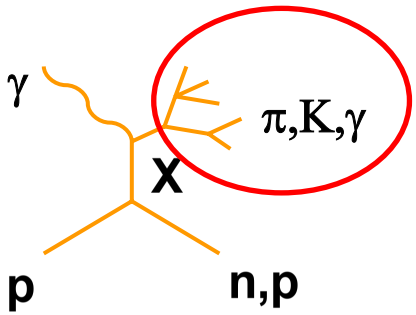
- **Photon beam intensity.**
  - total : ~3 10^9 photons/sec (1.1 MeV < E_γ < 12.0 GeV)
  - in the coherent peak region : 10^8 photons/sec (8.4 GeV < E_γ < 9.0 GeV)

- **Electromagnetic interactions are dominated by e^+e^- pair production and Compton scattering.**
  - total interaction rate: 90 MHz (pair production) and 208 MHz (Compton scattering)
  - target induced: 50 MHz (pair production) and 140 MHz (Compton scattering)

- **Superimpose hadronic interactions with electromagnetic background (simulate event pileup); each hadronic event is mixed with electromagnetic background events in the time interval of 100 ns.**

Level-1 Trigger Goal

Goal: High efficiency, close to 100%, for exotic meson candidates



- **Multiparticle final states:**

(p,n) + πππ, ππππ, πππη, ππππη

70% of decays involve at least 1 π^0
50% involve more than 1 π^0

$h_0 \rightarrow b^o_1\pi^o \rightarrow (\omega\pi^o)\gamma\gamma \rightarrow \pi^+\pi^-\gamma\gamma\gamma\gamma\gamma$

many photons

$\eta_1 \rightarrow a^+_1\pi^- \rightarrow (\rho^o\pi^+)(\pi^-) \rightarrow \pi^+\pi^-\pi^+\pi^-$

all charged

$h'_2 \rightarrow K^+_1K^- \rightarrow \rho^o K^+ K^- \rightarrow \pi^+\pi^-K^+K^-$

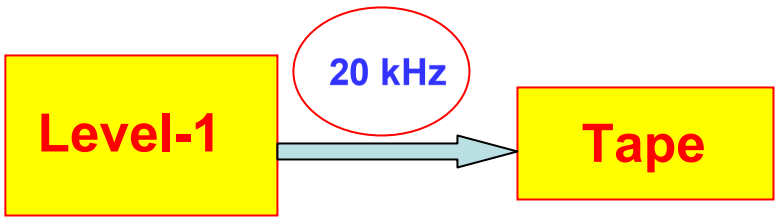
strange particles

Accept high-multiplicity minimum bias hadronic interactions with E_γ > 8.4 GeV

Level-1 Trigger Requirements

Rate reduction

Stage 1: Low luminosity runs (10^7 photons/sec in the energy range $8.4 < E_\gamma < 9.0$ GeV)

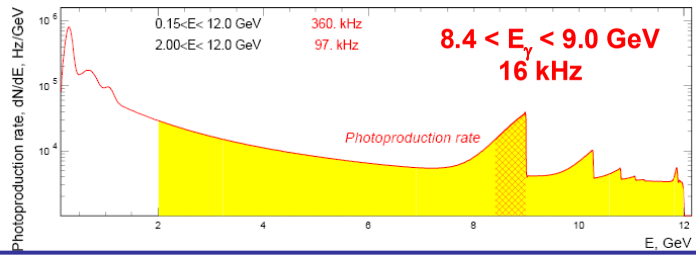


Level-1 requirement:
Rate < 20 kHz

Stage 2: High luminosity runs (10^8 photons/sec)

Level-1 requirement:
Rate < 200 kHz

Photoproduction rate of hadrons for
$8.4 < E_\gamma < 9.0$ Gev ~ 16 kHz



Level-1 Trigger Algorithm

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

Forward Calorimeter	(FCAL)	(Energy deposition)	
Barrel Calorimeter	(BCAL)	(Energy deposition)	
Start Counter		(Count hits)	
Time of Flight	(TOF)	(Count hits)	High rates/occupancies
Tagger		(Count hits)	at 10^8 γ/sec

- **Use energy depositions in the FCAL and BCAL and number of hits in the Start Counter.**
- **Classify events according to the number of hits in the Start Counter. Consider two event categories:**

  $\#HITS_{ST} = 0$ $\#HITS_{ST} > 0$

  and look at E_{BCAL} vs E_{FCAL} correlations.
- **Apply threshold:**

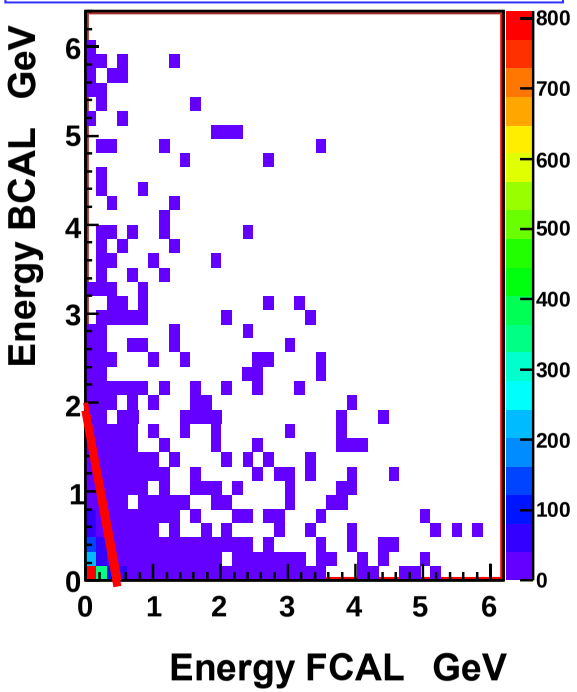
  E_{BCAL} **(default 30 MeV),** E_{FCAL} **(default 30 MeV)**

  $E_{BCAL} = A + B^* E_{FCAL}$ **(similar to $E_{Total} > E_{Thr}$).**

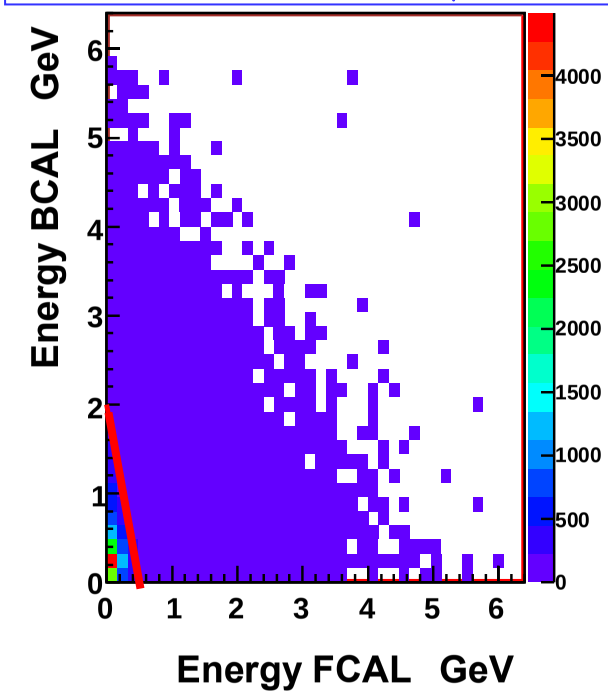
Energy Correlations: BCAL vs FCAL

#HITS Start Counter > 0

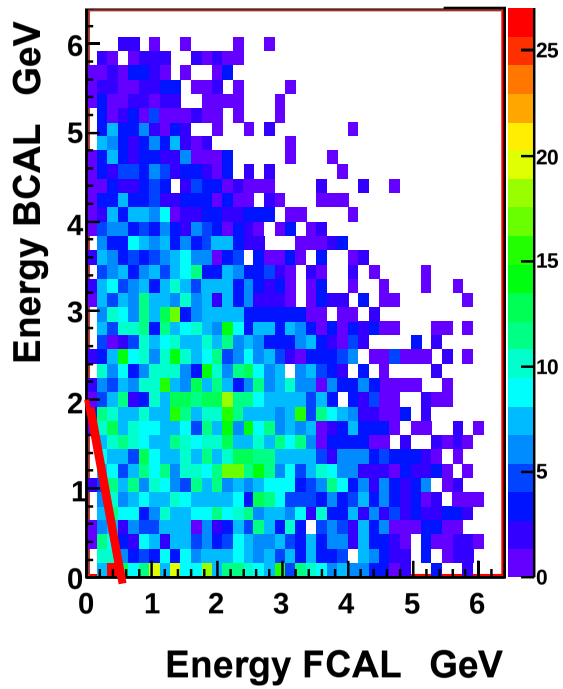
Electromagnetic Background



Hadronic Background E_γ < 8 GeV



Hadronic E_γ > 8 GeV



Apply threshold: $E_{BCAL} + E_{FCAL}$*2.0 / 0.5 > 2 GeV

Trigger Probability and Rate

Input rates:

- **Electromagnetic background: 10 MHz (pile-up in 100 ns time window)**
- **Total hadronic rate: 360 kHz**

No hits in the Start Counter: about 78% of electromagnetic background and only 1.4 % of the total number of hadronic events from the "signal" region

- Level-1 algorithm reduces electromagnetic background rate from ~8 MHz to 4 kHz !

#HITS Start Counter > 0 Trigger Rate (kHz)

	No cuts	$E_{\mathrm{BCAL}} > 30$ MeV	$E_{\mathrm{FCAL}} > 30$ MeV	$E_{\mathrm{FCAL+BCAL}}$
Electromagnetic	2184	317	214	60.5
Hadronic $E_\gamma < 8.0$ GeV	314.2	268.5	164.9	54.6
Hadronic $E_\gamma > 8.0$ GeV	32.7	30.9	30.8	30.2
Total				145.3
$N_{\mathrm{SC}} > 0$. Trigger Probability (%)				
Hadronic $E_\gamma > 8.0$ GeV	100.0	94.5	94.1	92.4

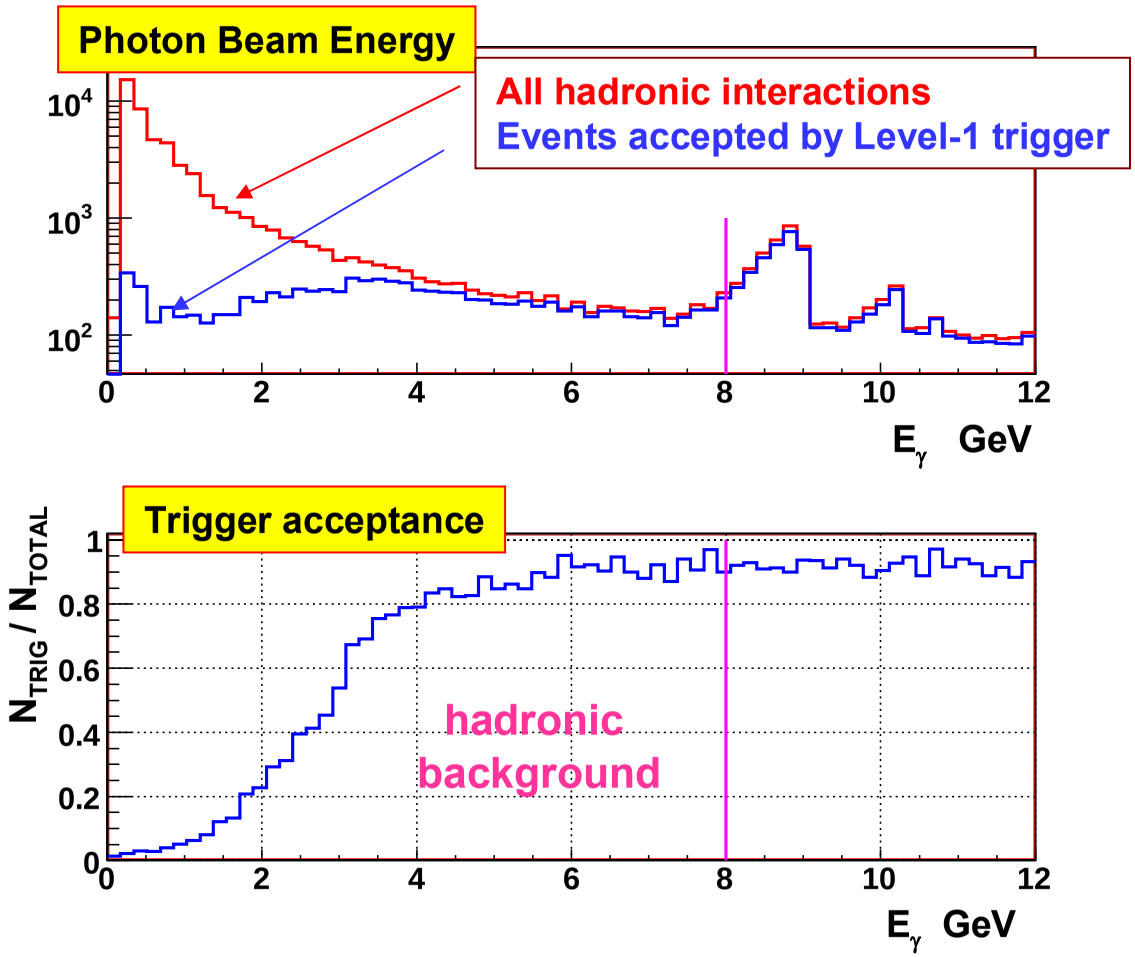
Trigger Rate

Trigger Probability

- **Level-1 total trigger rate is ~150 kHz, below required 200 kHz !**
- **Level-1 trigger probability for minimum bias hadronic event from the coherent peak region is ~ 92 %.**

We Fulfil our Goal !

Photon Spectrum (hadronic interactions)

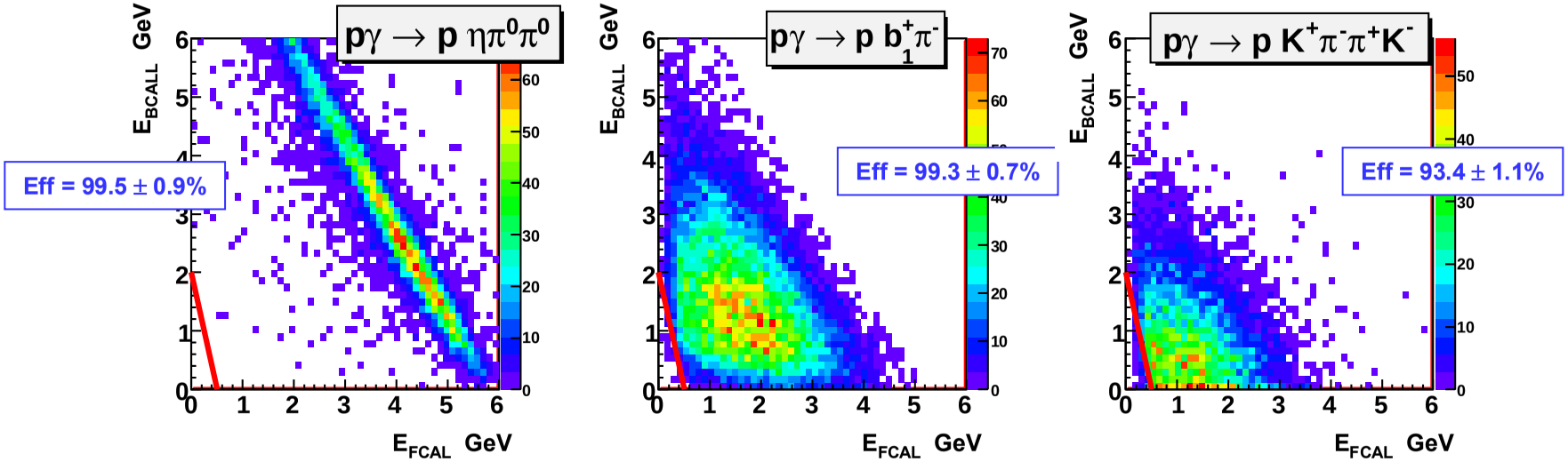


- Level-1 trigger eliminates hadronic background with $E_\gamma < 3 - 4$ GeV
- Flat acceptance in the signal region $E_\gamma > 8$ GeV

Trigger Efficiency

- Apply trigger algorithm to MC events generated for some typical exotic decays channels

Energy deposition: BCAL vs. FCAL



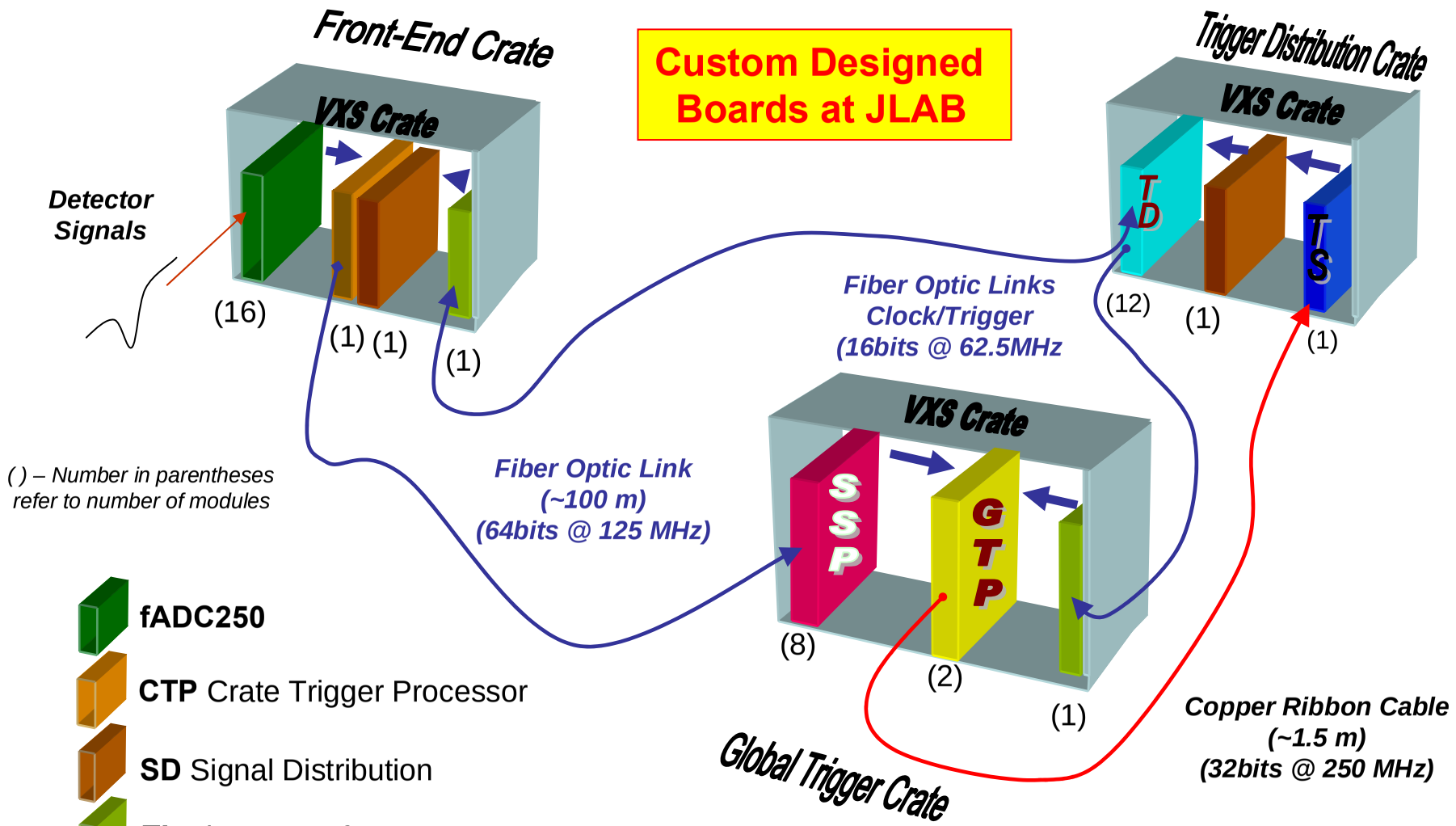
γp → nX

Final State	Efficiency (%)
n ω π^+ π^0	99.8
n ω π^+	98.4
n η π^+ π^- π^+	99.1
n π^+ π^- π^+	92.8

γp → pX

Final State	Efficiency (%)
p $b_1(1235)^+$ π^-	99.3
p η π^0 π^0	99.5
p π^+ π^- π^0	97.3
p π^+ π^- π^+ π^-	97.7 ± 1.0
p K^+ K^- π^+ π^-	93.4 ± 1.0

Level-1 Trigger Electronics (operated at 250 MHz)



Pipelined detector readout electronics:
fADC and F1TDC

- **Trigger Latency ~ 3 μs**
  (F1TDC pipeline ~3.9 μs)

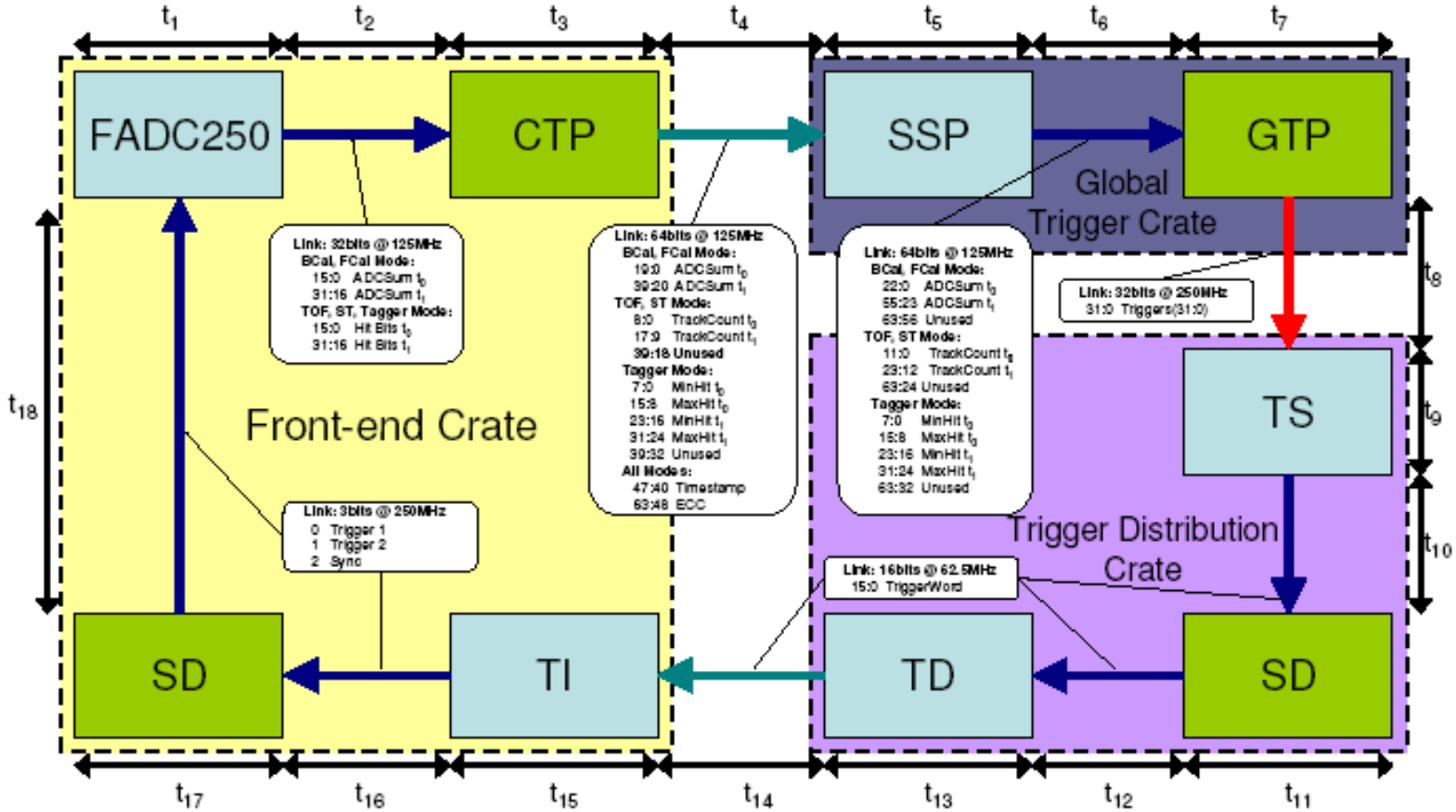
Summary

- We developed a simple Level-1 trigger algorithm which is able to reduce the rate of electromagnetic and hadronic interactions to a level below 160 kHz and provide high trigger efficiency (close to 100%) for decays of interest.
- The Level-1 trigger hardware allows for more sophisticated algorithms.
- The architectural design of Level-1 trigger hardware is completed.
- Main trigger electronics modules have been prototyped at JLab. We start performing first tests of the trigger electronics.

Backup Slides

Level-1 Trigger Timing

Benjamin Raydo
braydo@jlab.org



t_1: FADC250 (ADC->P0)	180ns (20cycles+100ns MGT)	t_{11}: SD (Px->Px)	10ns
t_2: FADC250->CTP (P0->Px)	10ns	t_{12}: SD->TD (Px->P0)	10ns
t_3: CTP (Px->FiberTx)	180ns (20cycles+100ns GTP)	t_{13}: TD (P0->FiberTx)	10ns
t_4: CTP FiberTx->SSP FiberRx	600ns (~100m fiber run)	t_{14}: TD->TI (FiberTx->Fiber Rx)	600ns (~100m fiber run)
t_5: SSP (FiberRx->P0)	600ns (100cycles+200ns GTP)	t_{15}: TI (FiberRx->P0)	80ns (20cycles)
t_6: SSP->GTP (P0->Px)	10ns	t_{16}: TI->SD (P0->Px)	10ns
t_7: GTP (Px->TrigBit)	495ns (95cycles+100ns GTP)	t_{17}: SD (Px->Px)	40ns
t_8: GTP->TS (TrigBit->TrigBitIn)	10ns	t_{18}: SD->FADC250 (Px->P0)	10ns
t_9: TS (TriggerBitIn->P0)	115ns (20cycles+35ns SerDes)	t_{19}(?): FADC Buffer Processing	0ns (?)
t_{10}: TS->SD (P0->Px)	10ns		

Total latency: 2.98 μs (< maximal possible of 3.9 μs)

Fiber Optic Link
Copper Ribbon Cable
VXS Backplane

VXS Infrastructure

FJ Barbosa

VME64x + High-Speed Switched Serial Fabric = **VXS** *(ANSI/VITA 41.0)*

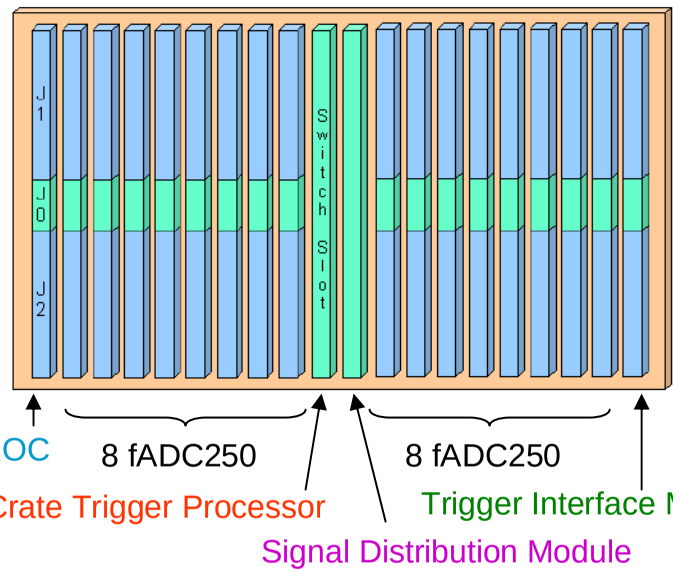
✓Energy Sum Trigger
✓Clock & Signal Distribution → Low Jitter

Lab Tests:

Crate Trigger Processor

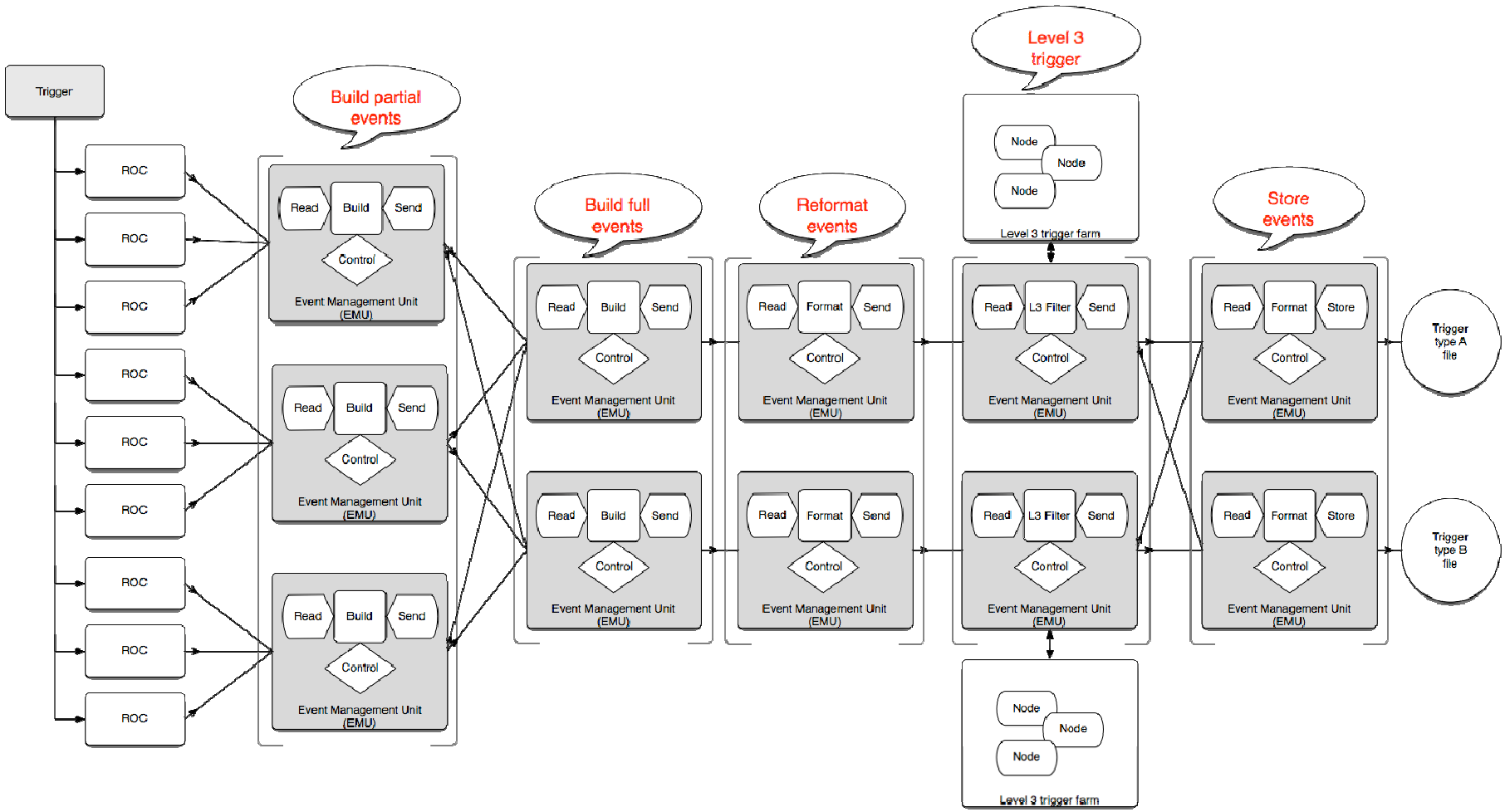
fADC250

20-slot VXS Crate



Jefferson Lab

Coda-3 system at JLAB (DAQ group)

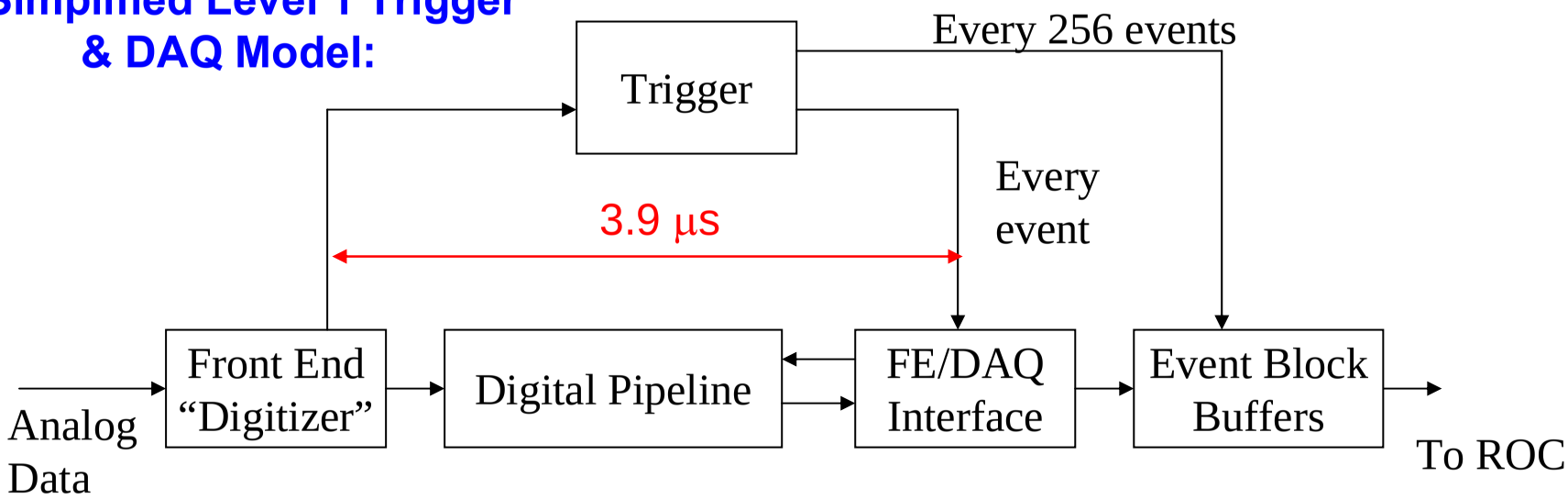


Level-1 Trigger Requirements

Trigger Latency

- **Pipelined detector readout; time stamp 4 ns.**
- **Time allocated for the Level-1 to take decision is ~ 3.9 μs (limited by the TDC pipeline)**

Simplified Level 1 Trigger & DAQ Model:



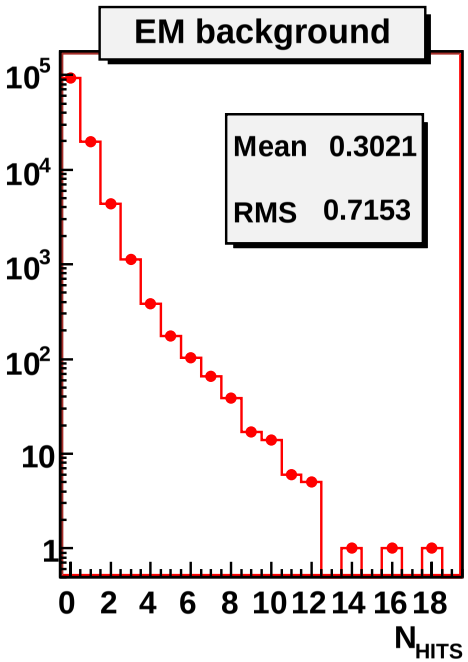
Photoproduction Simulation

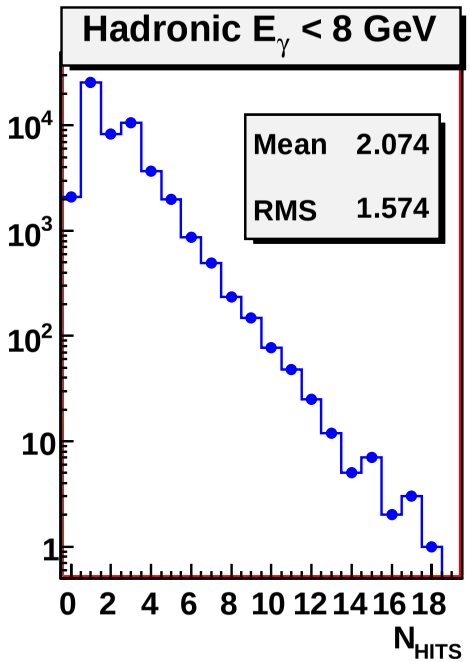
E_γ > 3 GeV: **PYTHIA generator adapted for low energies (taken from HERMES)**

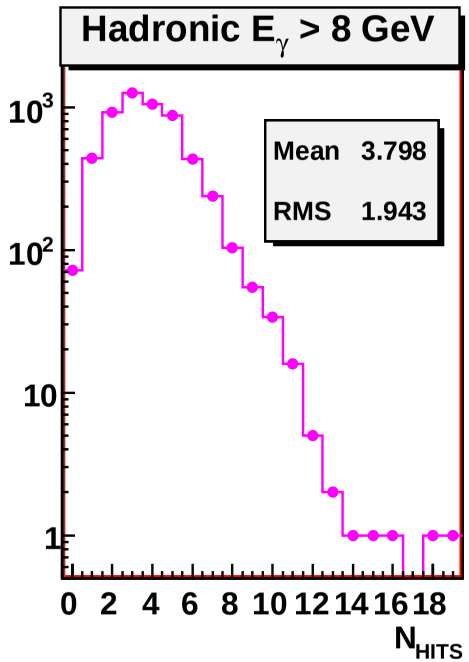
process $\gamma p \rightarrow$	via	Experiment		PYTHIA	
		E_γ, GeV	σ, μb	E_γ, GeV	σ, μb
1 prong		9.3	8.5±1.0	9.0	6.2
3 prong		9.3	64.4±1.5	9.0	59.0
5 prong		9.3	34.2±0.9	9.0	44.0
7 prong		9.3	6.8±0.3	9.0	8.3
$p\pi^+\pi^-$		9.3	14.7±0.6	9.0	14.5
	$p\rho^\circ$	9.3	13.5±0.5	9.0	13.0
$p\pi^+\pi^-\pi^\circ$		9.3	7.5±0.8	9.0	7.0
	$p\omega$	9.3	1.9±0.3	9.0	1.4
$p2\pi^+2\pi^-$		9.3	4.1±0.2	9.0	3.7

E_γ < 3 GeV: **Simulate dominant reactions, 11 in all, which constitute about 95 % of the total cross section. Differential cross sections are taken from existing measurements**

Hit Multiplicity in the Start Counter







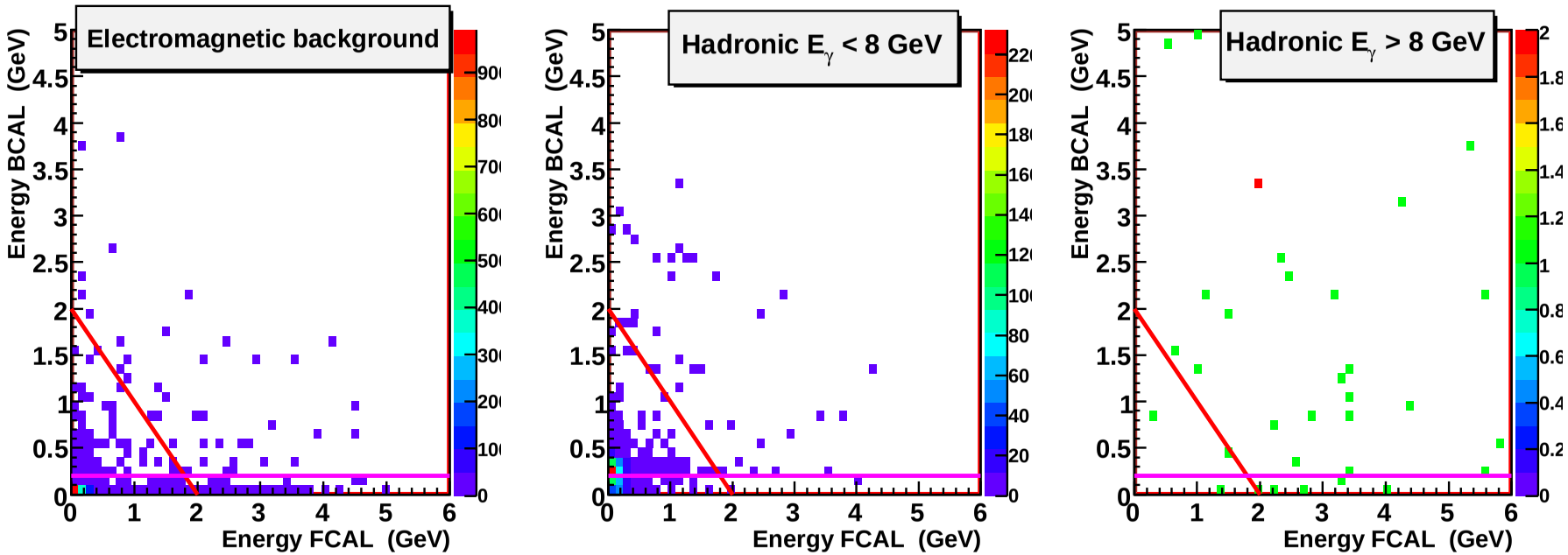
Fraction of events with NO hits in the Start Counter

78.1 % electromagnetic background

1.4 % hadronic events with E_γ > 8 GeV

BCAL vs FCAL

#HITS Start Counter = 0



Reduce almost all EM and hadronic background applying thresholds

E_{BCAL} > 0.2 GeV E_{BCAL}+F_{CAL} > 2 GeV

- **reduce electromagnetic background rate to ~4 kHz**
- **hadronic background rate < 0.2 kHz**

Trigger Probability and Rate

#HITS Start Counter = 0 **Contains only 1.4% of the total hadronic signal events**

$N_{SC} = 0$. Trigger Rate (kHz)

	No cuts	$E_{BCAL} > 0.2$ GeV	$E_{FCAL} > 0.03$ GeV	$E_{FCAL+BCAL}$
Electromagnetic	7816	23.9	15.9	4.00
Hadronic $E_\gamma < 8.0$ GeV	12.7	8.03	4.03	0.23
Hadronic $E_\gamma > 8.0$ GeV	0.43	0.18	0.18	0.17
Total				4.4
$N_{SC} = 0$. Trigger Probability (%)				
Hadronic $E_\gamma > 8.0$ GeV	100.0	41.7	41.7	38.9

Input rates:

R_{EM} background = 10 MHz
(10^7 100 ns bins / sec)
R_{HAD} = 360 kHz

#HITS Start Counter > 0

$N_{SC} > 0$. Trigger Rate (kHz)

	No cuts	$E_{BCAL} > 30$ MeV	$E_{FCAL} > 30$ MeV	$E_{FCAL+BCAL}$
Electromagnetic	2184	317	214	60.5
Hadronic $E_\gamma < 8.0$ GeV	314.2	268.5	164.9	54.6
Hadronic $E_\gamma > 8.0$ GeV	32.7	30.9	30.8	30.2
Total				145.3
$N_{SC} > 0$. Trigger Probability (%)				
Hadronic $E_\gamma > 8.0$ GeV	100.0	94.5	94.1	92.4

Level-1 rate below ~ 150 kHz

Level-1 trigger probability ~ 92 %

Tagger in the Level-1 Trigger

Tagger rate for the signal-energy region $8.4 < E_\gamma < 9.0$ GeV:

- **25 MHz for low-luminosity, 10^7 photons/sec (hits every 40 ns)**
- **250 MHz for high-luminosity, 10^8 photons/sec (hits every 4 ns)**

Rates	Energy range, GeV		
	0.15 - 12.	2.0 - 12.	8.4 - 9.0
Tagger	10 GHz	4.0 GHz	250 MHz
Beam	1.5 GHz	670 MHz	100 MHz
Photoproduction	360 kHz	100 kHz	16 kHz