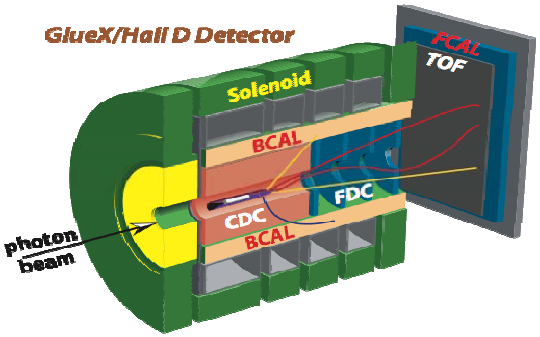


Jefferson Lab

12 GeV Upgrade
Future Science at Jefferson Lab

Status of the Level 1 Trigger Simulation

A. Somov, Jefferson Lab

GlueX Collaboration Meeting
12 May 2009

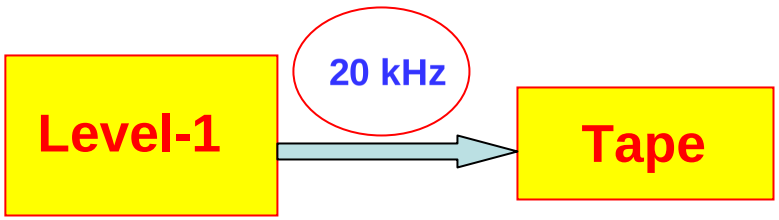
Status of the Trigger Simulation

- Overview current Level-1 algorithm
- Review some trigger components
  - Tagger Microscopes
  - Start Counter
  - TOF
  - FCAL
- Possible Level-1 hardware test

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)

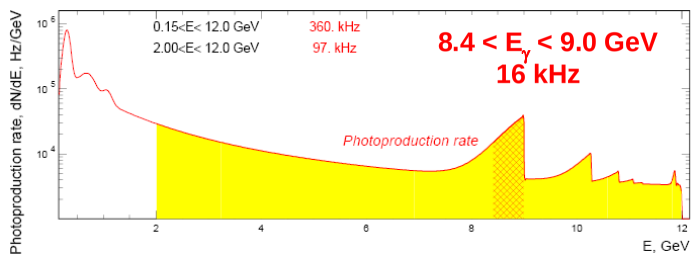


Level-1 requirement:
Rate < 20 kHz

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

FCAL	(Energy deposition)
BCAL	(Energy deposition)
Start Counter	(Count hits)
TOF	(Count hits)
Tagger	(Count hits)

High rates/occupancies 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:**

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

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

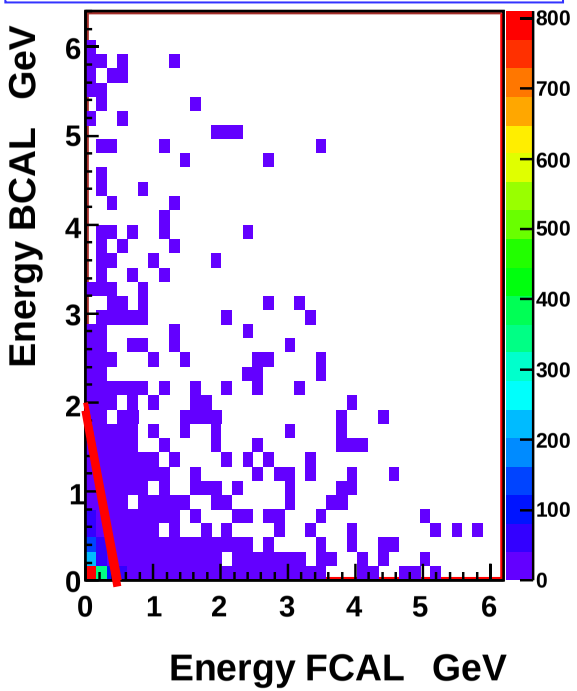
  E_{BCAL} **(default 30 MeV),** E_{FCAL} **(default 30 MeV)**

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

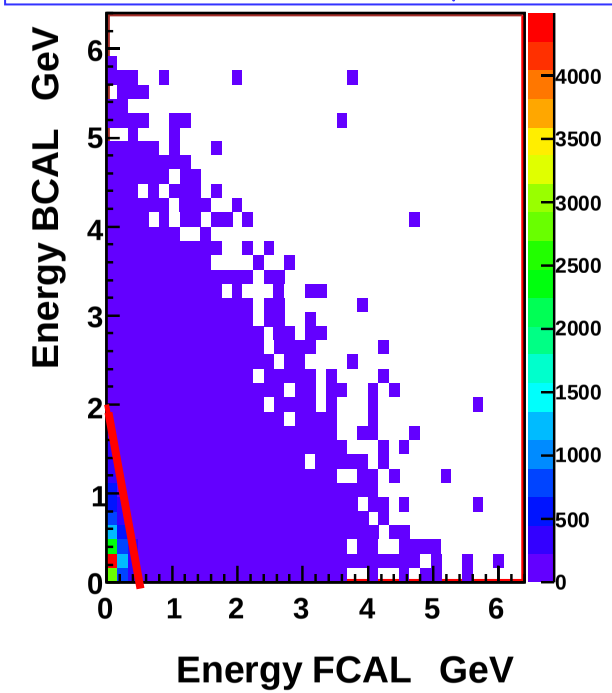
Energy Correlations: BCAL vs FCAL

#HITS Start Counter > 0

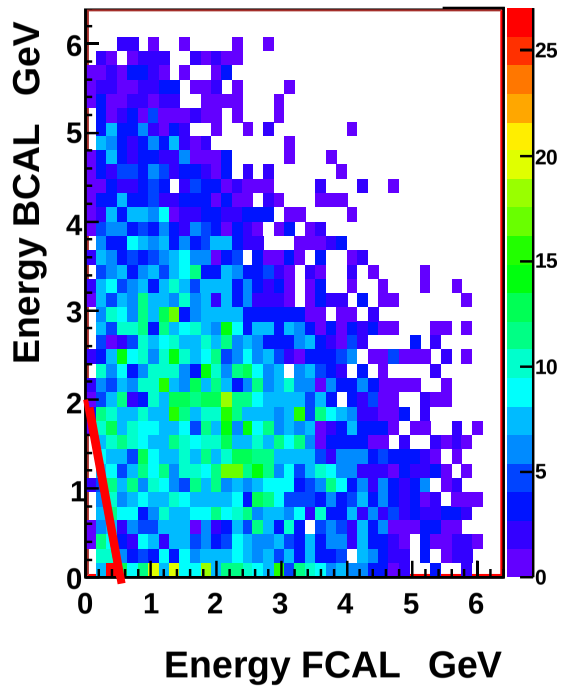
Electromagnetic Background



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)

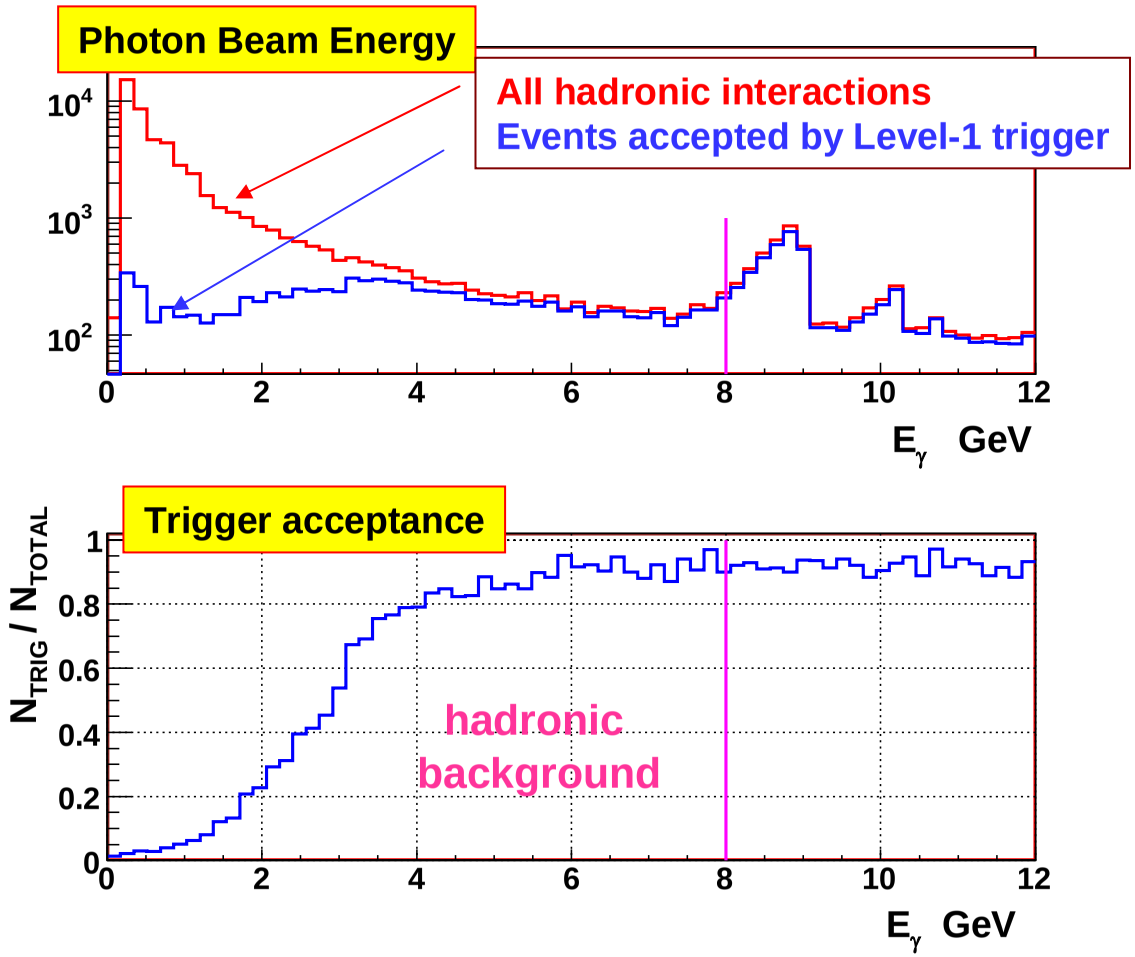
	No cuts	$E_{\mathrm{BCAL}} > 30$ MeV	$E_{\mathrm{FCAL}} > 30$ MeV	$E_{\mathrm{FCAL+BCAL}}$
Electromagnetic	2184	317	214	60.5
Hadronic $E_\gamma < 8.0$ GeV	314.2	268.5	164.9	54.6
Hadronic $E_\gamma > 8.0$ GeV	32.7	30.9	30.8	30.2
Total				145.3
$N_{\mathrm{SC}} > 0$. Trigger Probability (%)				
Hadronic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

Photon Spectrum (hadronic interactions)

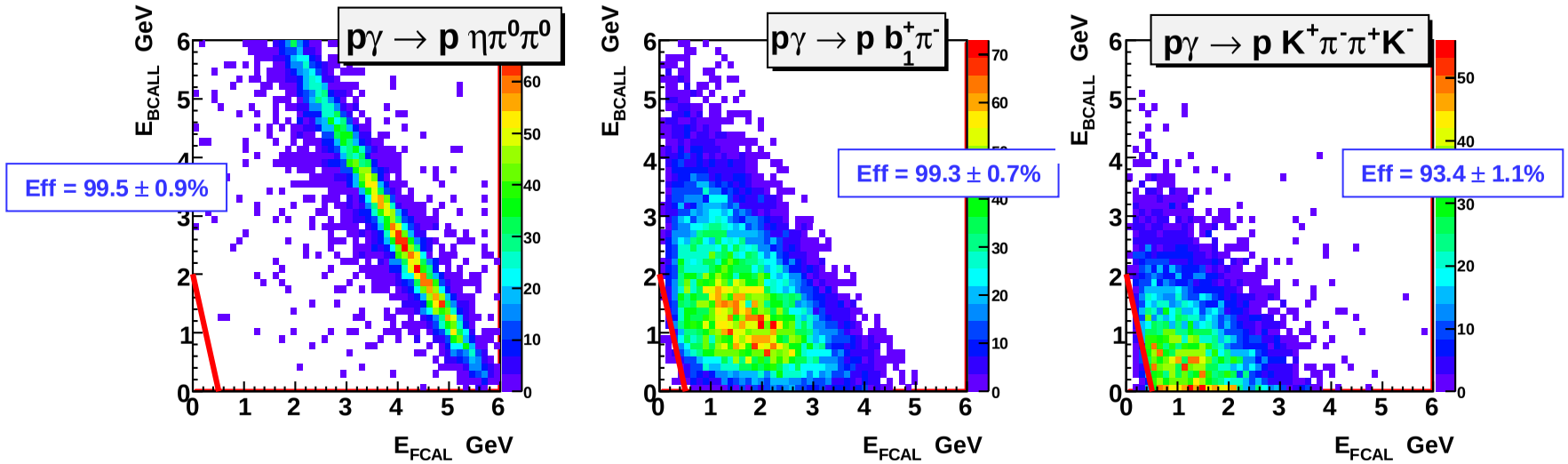


- Level-1 trigger eliminates hadronic background with $E_\gamma < 3 - 4$ GeV
- Flat acceptance in the signal region $E_\gamma > 8$ GeV

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 $\pi^+ \pi^0$	99.8
n ω π^+	98.4
n η $\pi^+ \pi^- \pi^+$	99.1
n $\pi^+ \pi^- \pi^+$	92.8

γp → pX

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

Tagger Microscope Counters in the Level-1 Trigger

Microscope counter rate for the signal-energy region 8.4 < E < 9.0* GeV:

- **250 MHz** for high-luminosity, 10^8 photons/sec (hits on average every 4 ns – multiple hits inside an integration time interval)

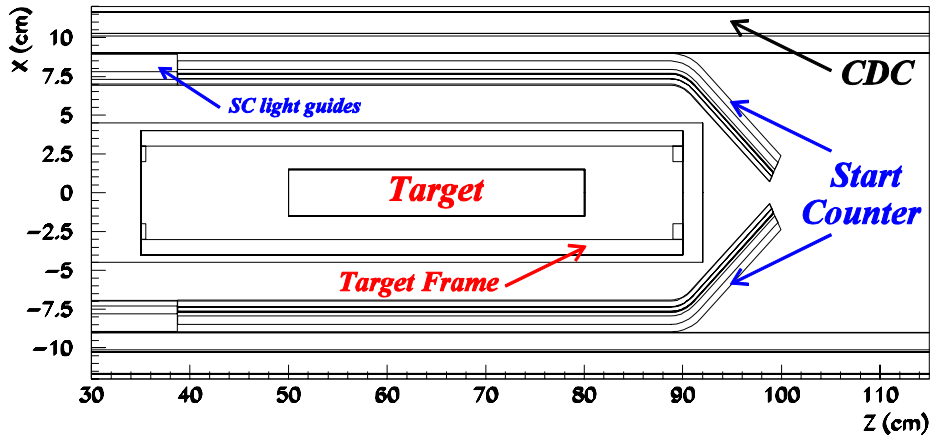
Cannot be used in the Level-1

- **25 MHz** for low-luminosity, 107 photons/sec (hits of all electrons every 40 ns) (hits corresponding to the collimated beam photons every 100 ns)

Not completely clear how to use it in the trigger (time reference ?)
Useful for the trigger tuning at early stages of the experiment

(we will need special calibration trigger types for the microscope and fixed-array counters)
*Note, the microsopes 100 x 5 counters cover the beam energy range 8.3 – 9.1 GeV.

Start Counter in the Trigger



- **New Start Counter (SC) geometry is implemented to the Geant Simulation:**

  - SC consists of 40 scintillator bars

  - Radius of the hole (bent section) from the beamline is 2 cm

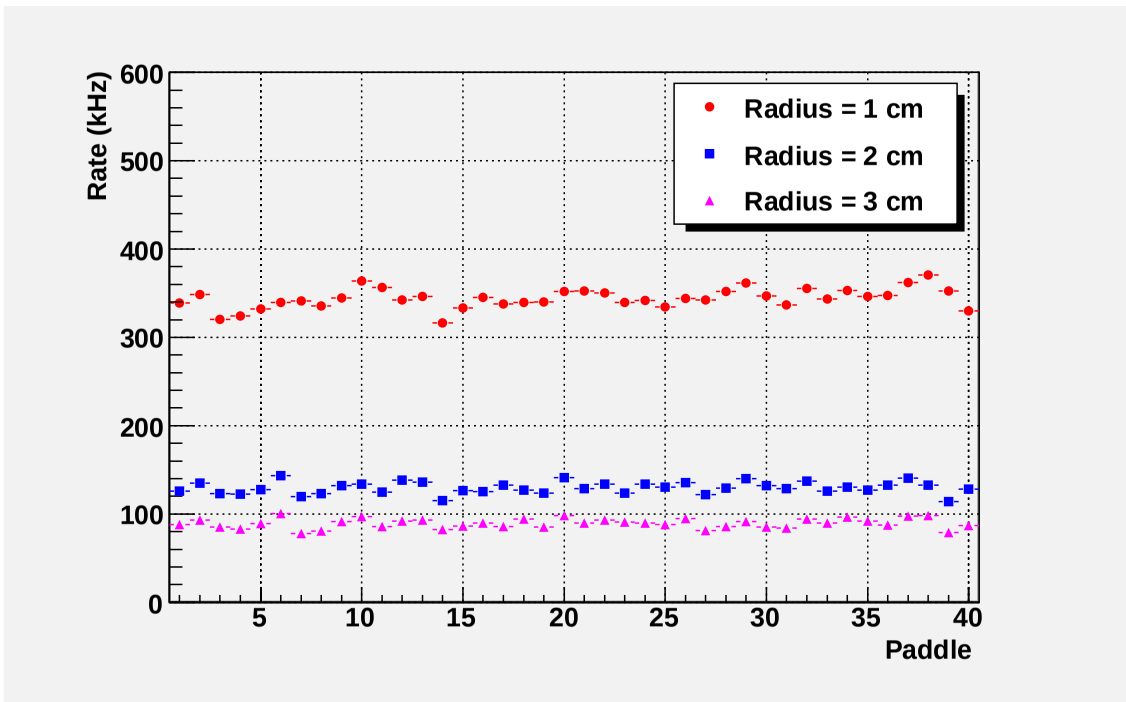
  - Scintillator thickness is 3 mm

Geant simulation of the Start Counter is described in GlueX-doc-1241

Start Counter in the Level-1 Trigger

Start Counter main features

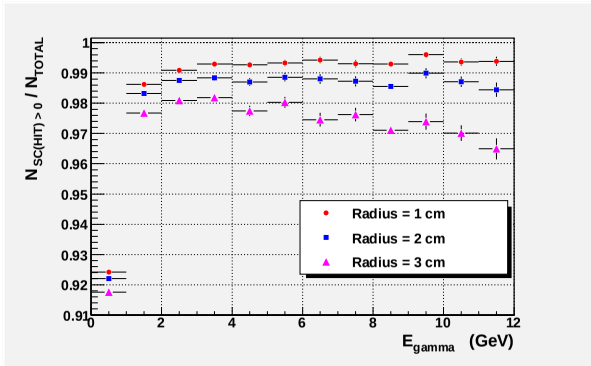
- **Start Counter rate (al least one hit in the SC) induced by EM background in high-luminosity runs is about 3.5 MHz. The corresponding rate per paddle is ~ 140 kHz.**



Start Counter in the Level-1 Trigger

Start Counter main features

- **Large trigger probability of about 99% for hadronic minimum-bias events with $E_\gamma > 8$ GeV**
  - **large trigger probability for exotic mesons of interest (close to unity for most decay channels).**

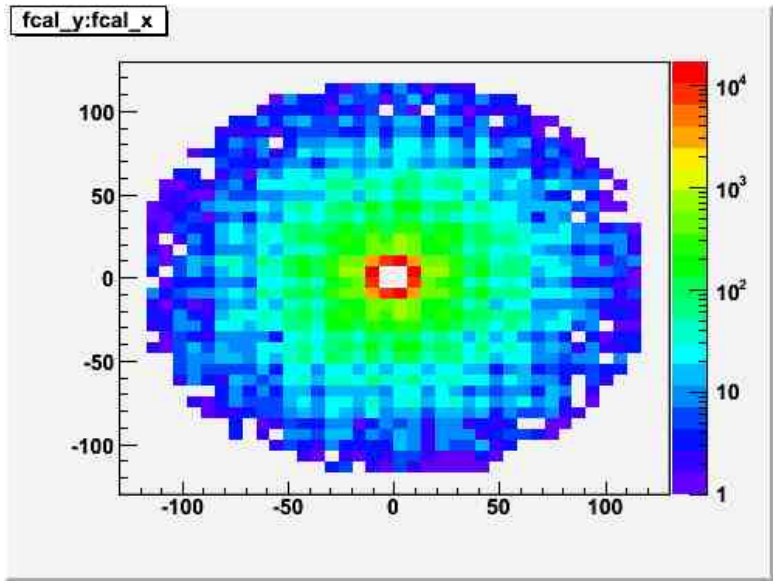


- **Requiring a hit in the SC in combination with the BCAL abd FCAL energies allows one to reduces the EM rate by about 20 kHz. The Level-1 trigger based on BCAL and FCAL energy sums provides the rate below 200 kHz.**
- **Usage of the SC in the Level-1 trigger will depend on its performance, hit efficiency.**
- **Use SC hit information along with the calorimeter energies to generate a high-multiplicity trigger which will be bypassed through the Level-3 farms without rejection.**

FCAL in the Trigger

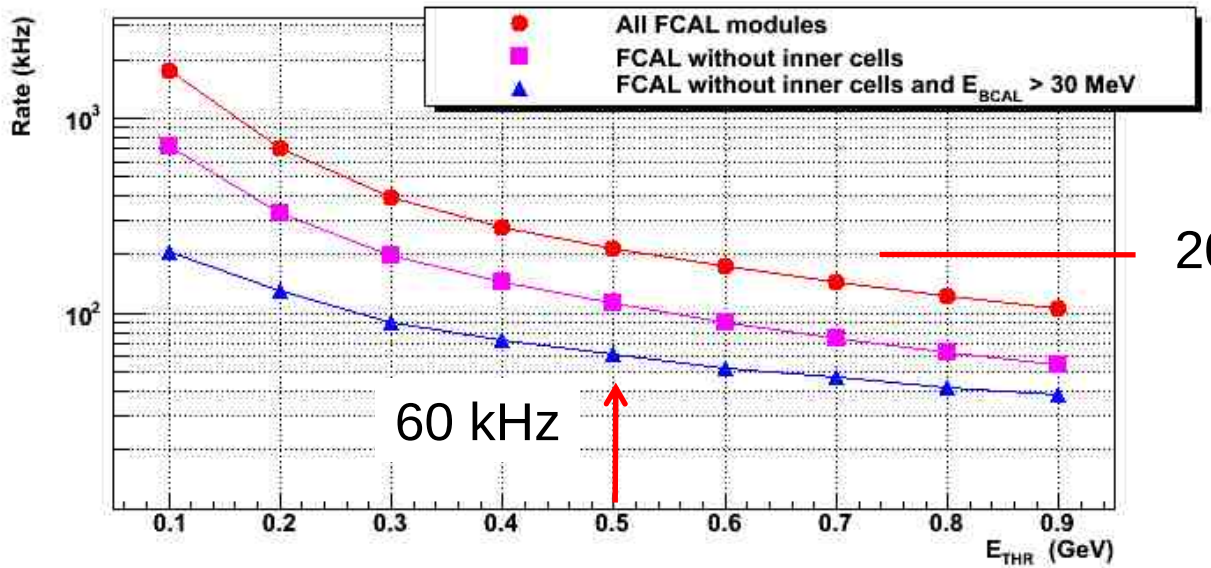
- FCAL rate of EM background events with E_{sum} > 30 MeV is about 4.7 MHz
- Largest occupancy in the FCAL cells around the beamline
  - can we exclude from the trigger FCAL cells with R < 9 cm (or apply R dependent threshold) ?

Occupancy for EM background, pileup 100 ns



FCAL EM Background Rate

FCAL rate as function of the energy threshold



- The rate of EM events with Esum > 30 MeV is about a factor of 2 smaller for the FCAL without inner cells
- The trigger probability for hadronic events (generated by bggen) with $E\gamma$ > 8 GeV is changed by less than 1% for the FCAL without inner cells.

Work is still in progress

TOF in the Trigger

- The trigger efficiency for most exotic decays of interest is close to 100 %.
- The smallest efficiency of about 92 % was found for the decay with 3 charged pions in the final state, $\gamma\, p \rightarrow n\, \pi^+\pi^-\pi^+$.
- **Can TOF be used to increase the trigger efficiency for events with charged tracks (MIPs in the FCAL) ? Can we lower the energy threshold in FCAL ?**
  - Study TOF rate/ (hit multiplicity) induced by EM interactions in a100 ns time interval.

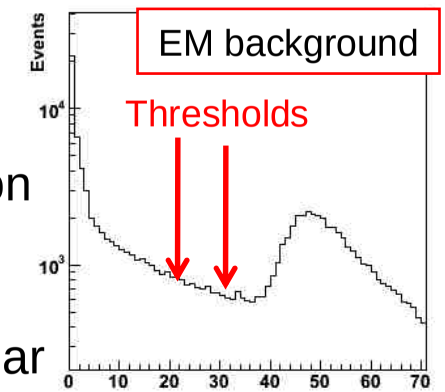
TOF in the Geant simulation

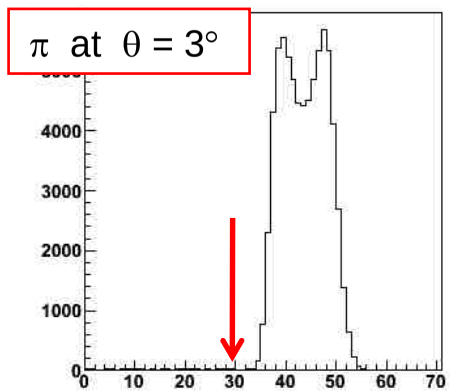
Geant energy is converted to the ADC channels
- note, some calibration coefficients will be tuned in the future

- apply position-dependent thresholds on the digitized TOF signals

- require hits in both ends of the TOF bar except for 8 single-side readout bars

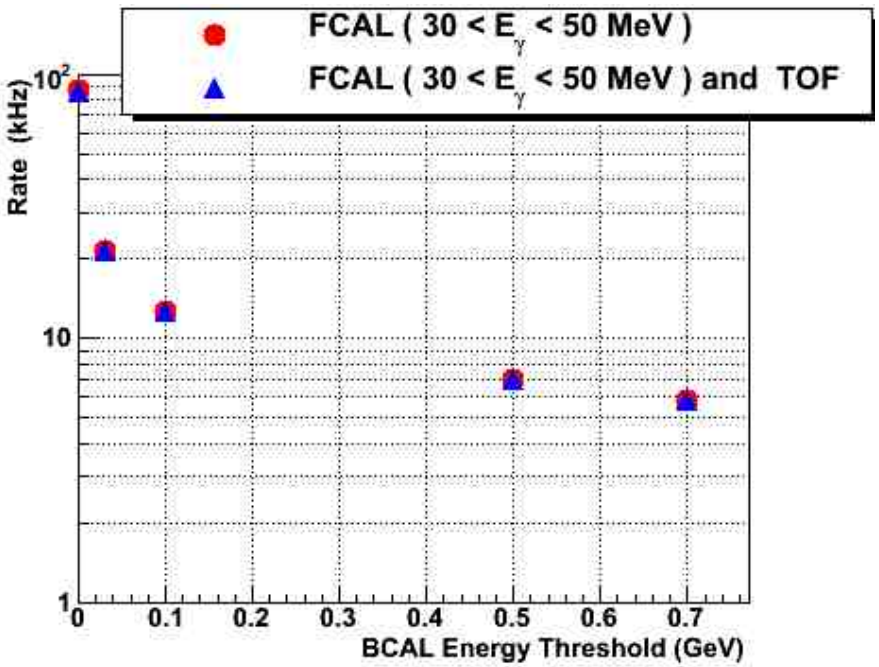
TOF ADC response





TOF in the Trigger

- **Can TOF provide additional rejection in the FCAL low-energy region ?**
  - consider events with the FCAL energy sum in the range
    $30 < E_{FCAL} < 50$ MeV
  - compare FCAL rate with the FCAL + TOF rate
  - TOF is required to have at least 2 hits; one in 0° and one in 90° planes



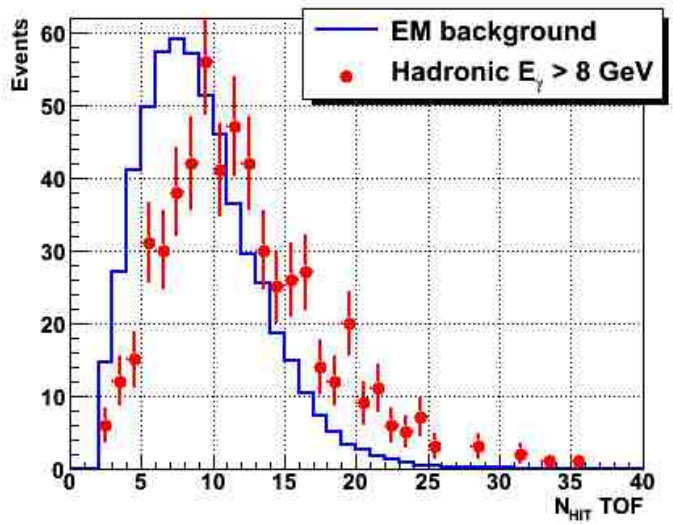
- **TOF has hits (at least 2) in all events where $30 < E_{FCAL} < 50$ MeV**
  - doesn't provide additional EM background rejection

(Lowering a threshold on the FCAL energy increases EM background rate)

TOF in the Trigger

- **Can we use TOF hit multiplicity to distinguish between EM background and hadronic events ?**

TOF hit multiplicity



30 MeV < EFCAL < 50 MeV

EM background <NHIT> TOF = 8.6

Hadronic events with EM pileup
<NHIT> TOF = 11.6

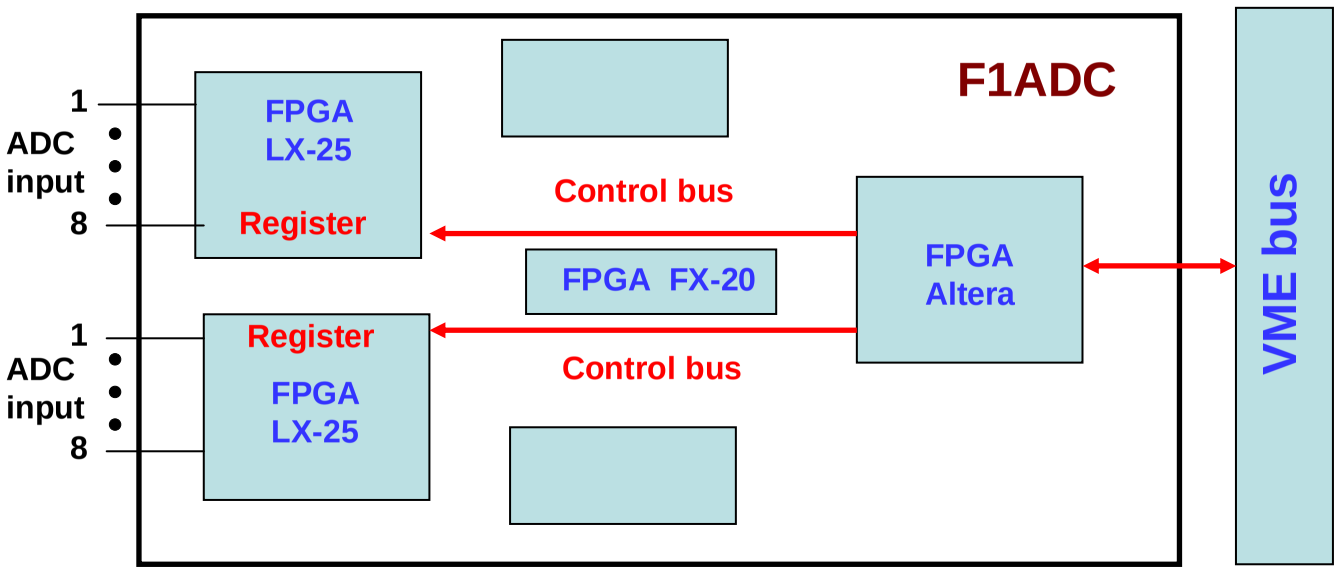
- **Further possible study:**
  - **Do not consider TOF hits in the bars situated close to the beamline**
  - **FCAL / TOF correlations in the smaller time integration window**

Level-1 Hardware Test and Algorithm Verification

- **We need a tool to be able to check the Level-1 hardware performance (connections, synchronization, FPGA code)**
- **Should be able to compare MC algorithm predictions with the hardware output**

  - load MC hits to the FPGA registers/memory for every event and run the trigger

  - compare trigger types with MC



Level-1 Hardware Test Plans

- **At the moment it is possible to load 12 bit energy to the FPGA register for each channel of every event. Later, it will be possible to load data for several 4ns time bins.**

Input needed from the MC:

- **Prepare a map related MC hits with the ADC channels**
- **Parameterize signal shapes for the trigger sub-detectors. Produce ADC amplitudes for each 4 ns bins. Prepare data format to be loaded to the VXS crates.**

Summary

- We keep on working on the Level-1 trigger algorithm. We still have to address some important items:
  - Optimize ‘usage’ of the FCAL in the trigger (exclude inner cells (?) from the trigger, apply position dependent thresholds)
  - How to use TOF hit information
- We have several prototypes of the trigger electronics boards. It is time to start working on the Level-1 hardware performance/algorithm tests
  - We need a program which will allow to check Level -1 hardware performance (connections, FPGA code, trigger types)
  - Level -1 online monitors