

***CLICCT hits timing  
for  
MARS background  
and  
IP muons***

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- Time of flight (TOF) in MARS background data
- ILCroot CLICCT hits (tracker + vertex detectors) for photons, neutrons,  $e^+e^-$  and  $\mu^+$  from MARS background
- IP (Interaction Point) muons in CLICCT hits
- MARS background and IP muons in CLICCT hits TOF window
- Conclusion



# Time of flight in MARS background data

- **MARS background data (Nov. 18, 2010)**  
 (<http://www-ap.fnl.gov/~strigano/mumu/mixture/>)
  - 750 GeV  $2e+12$   $\mu^+$  and  $\mu^-$  beams,  $10^0$  nozzle geometry
  - “Short-range” source term:  $4.8e+05$  simulated decays for each beam  
 $-25m < Z < 1m$  for  $\mu^+$  beam ,  $-1m < Z < 25m$  for  $\mu^-$  beam  
 each source term file has about 5M particles
  - “Long-range” source term:  $2.4e+07$  simulated decays for each beam  
 $-189m < Z < -25 m$  for  $\mu^+$  beam,  $25m < Z < 189 m$  for  $\mu^-$  beam  
 each file has about 0.44M particles (mostly muons)
- **Abs. yields/bunch (weights included, E=750 GeV, both beams,  $2.0e+12$  muons each) on  $10^0$  nozzle surface**

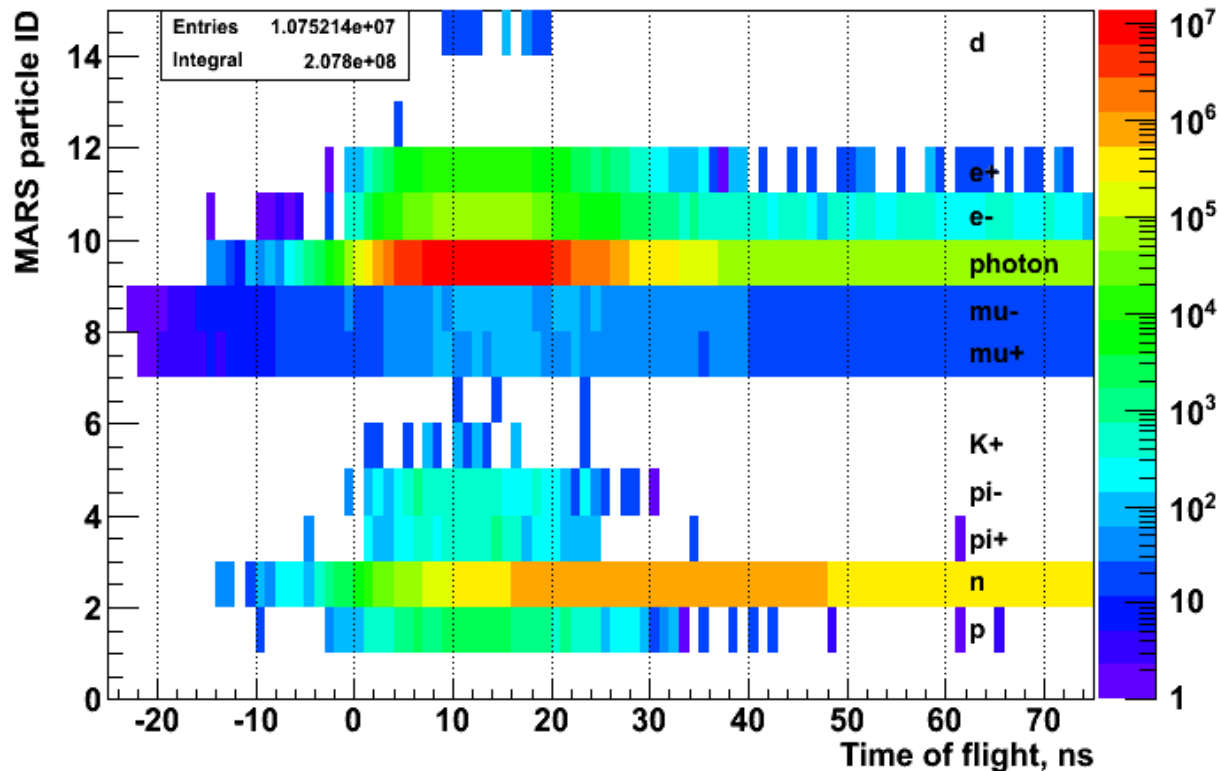
photon	n	$e^{+-}$	p	$\pi^{+-}$	$\mu^{+-}$
<b>1.77e+08</b>	<b>0.40e+08</b>	<b>1.03e+06</b>	<b>3.13e+04</b>	<b>1.54e+04</b>	<b>0.80e+04</b>



# Time of flight in MARS background data

## MARS particle ID and TOF

- Time of flight (TOF) wrt. bunch crossing time, on the surface of  $10^0$  nozzle, MARS particle weights included
- In window  $0 \leq \text{TOF} \leq 25$  ns  
~21% of neutrons, ~36% of muons, >94% of other particles
- $\text{TOF} < 0$  corresponds to the particles making straight path to detector





- **Looking at timing in CLICCT (CLICCT = VXD + SiT + FTD) hits for ID specific particles:**
  - **Limited statistics MARS ROOT files were prepared having only ID specific background particles from both muon beams**
    - Photons – 0.1M
    - Neutrons – 0.1M
    - $e^+e^-$  - 0.046M
    - “Short” range  $\mu^{+-}$  - 2,270
    - “Long” range  $\mu^{+-}$  - 0.1M
  - **Run ILCroot simulation for these samples (without MARS weights)**
    - Use official layout of CLICCT and previous release (/grid/fermiapp/ILCroot/sw/setup/setup\_ILCrootMuX\_MuXDetV2.sh)
    - Ignore the fact that MARS simulation is made for  $10^0$  nozzle while official ILCroot is using  $6^0$  nozzle (impact of CLICCT/nozzle overlap is minor)
    - QGSP\_BERT\_HP hadronic model physics list in GEANT4



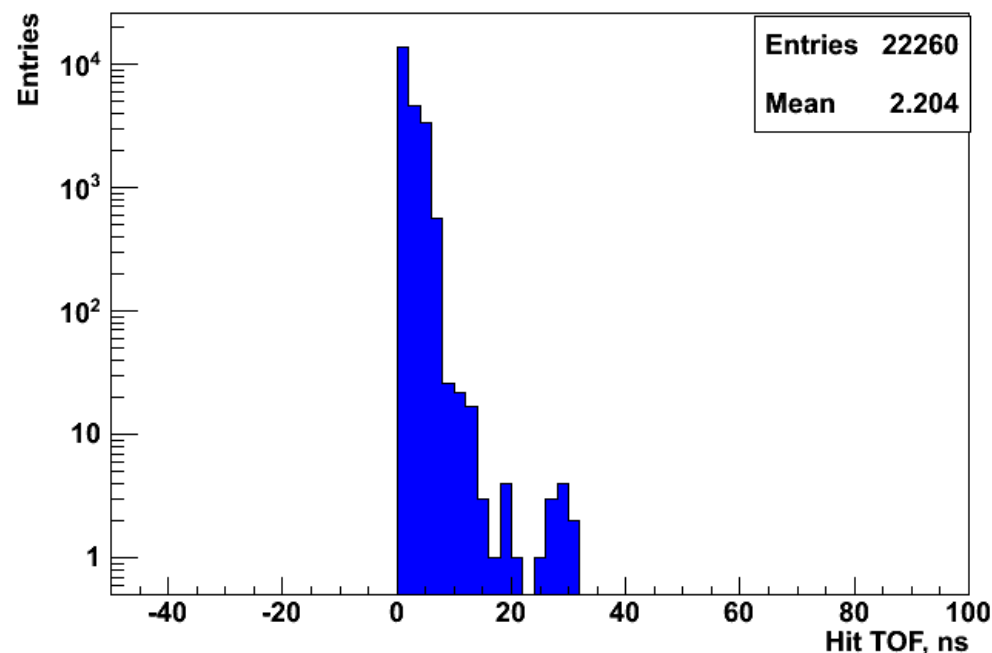
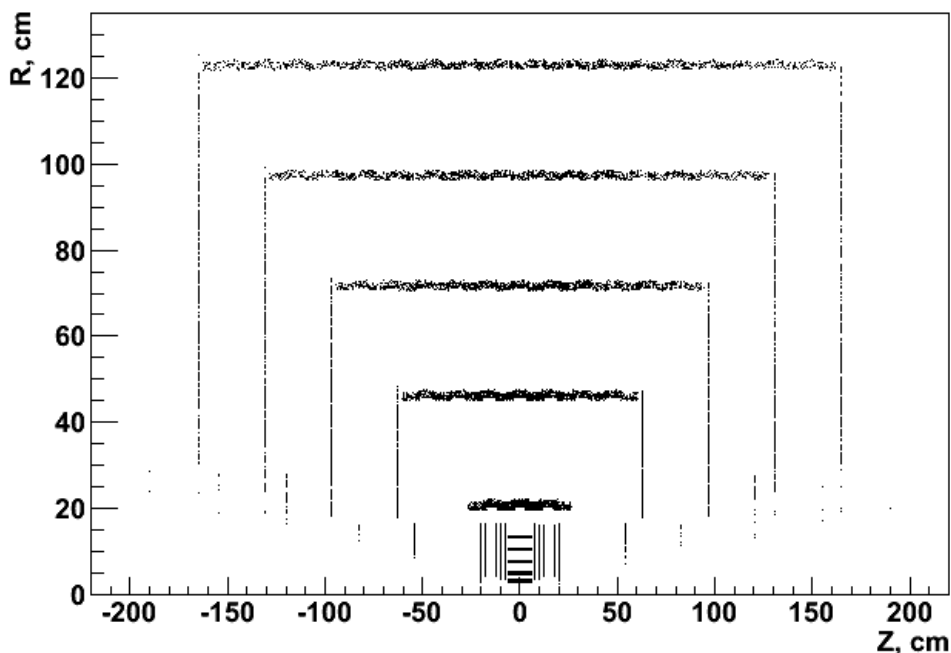
# CLICCT hits for IP muons

## Simulation of CLICCT hits for IP $\mu^-$ as physics events

- Originate in IP (Interaction Point) at  $X=0, Y=0, Z=0$
- Flat distribution in momentum  $P$ , angles  $\Phi$  and  $\Theta$   
 $1 \text{ GeV} < P < 100 \text{ GeV}, 10.4^\circ < \Theta < (180-10.4)^\circ$
- 10 muons per event, total 200 events or 2,000  $\mu^-$
- Using `fTof` variable from `CLICCT.Hits.root`, require `fStatus != 65`
- Total 2260 hits in CLICCT, almost all have  $\text{TOF} < 8 \text{ ns}$

R vs. Z for IP muon hits

TOF for IP muon hits

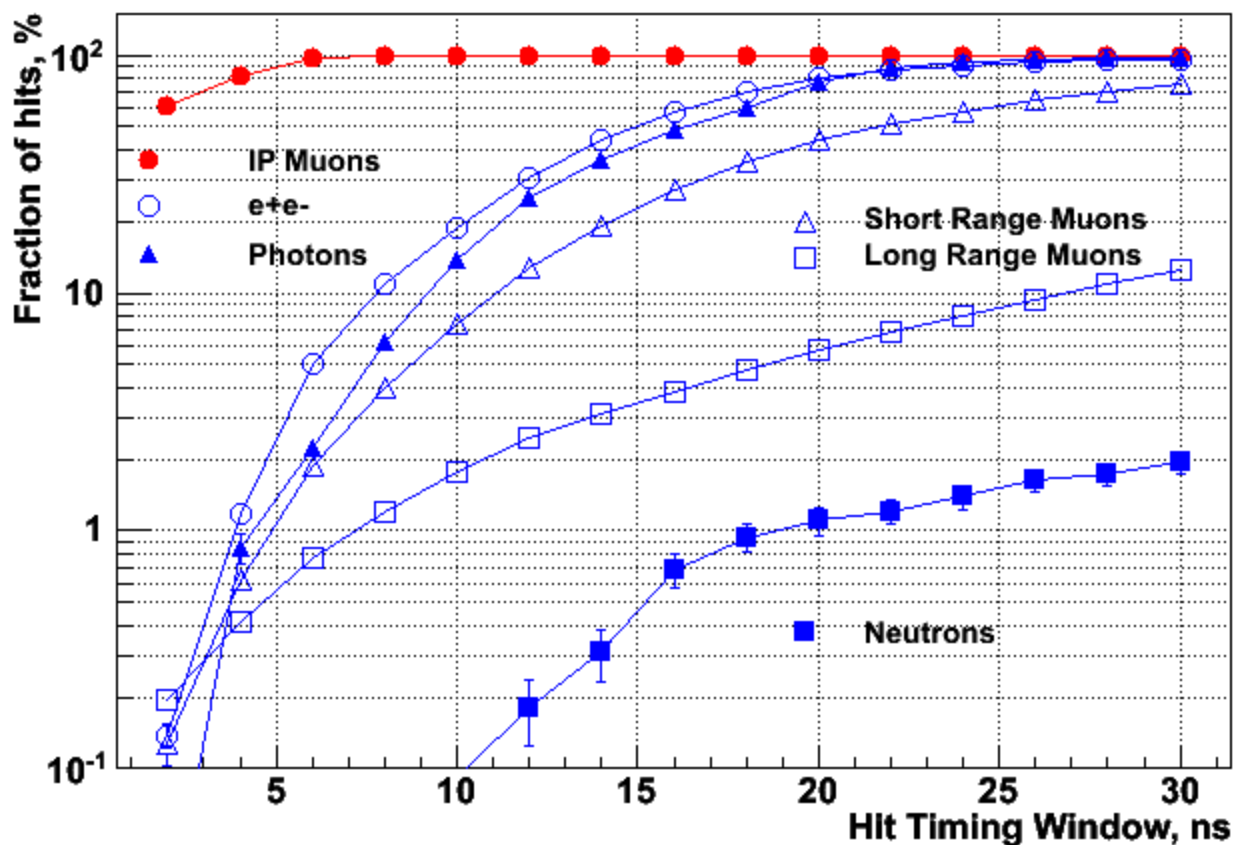




# CLICCT hits efficiency vs. TOF window

## Fractions of hits within TOF window vs. TOF window width

- TOF window begins at 0 ns (bunch crossing time), no MARS particle weight, no smearing in CLICCT collection and resolution time, no contribution from beams in previous bunches...



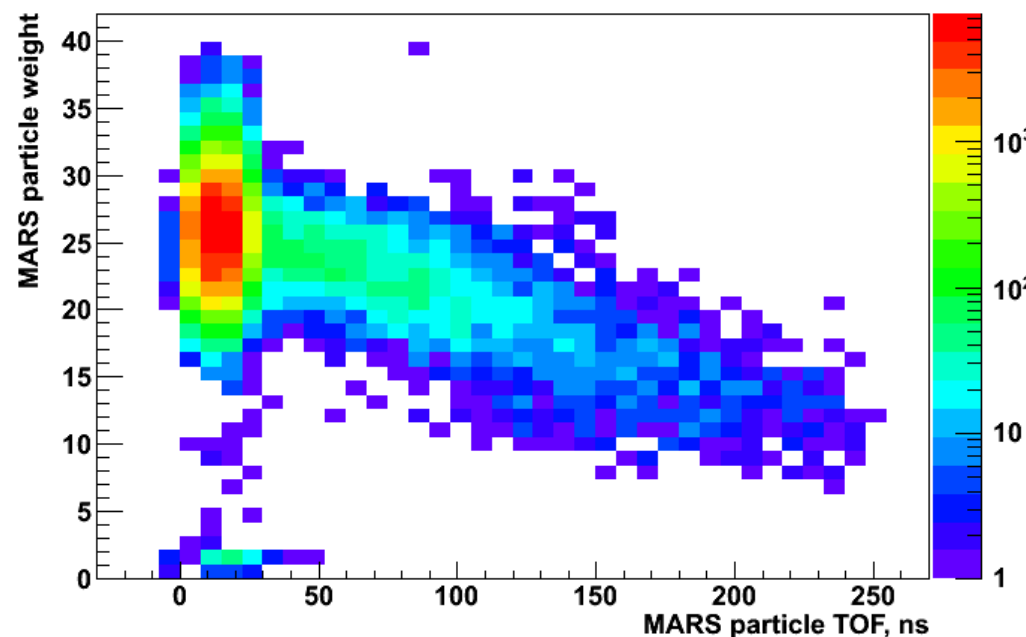
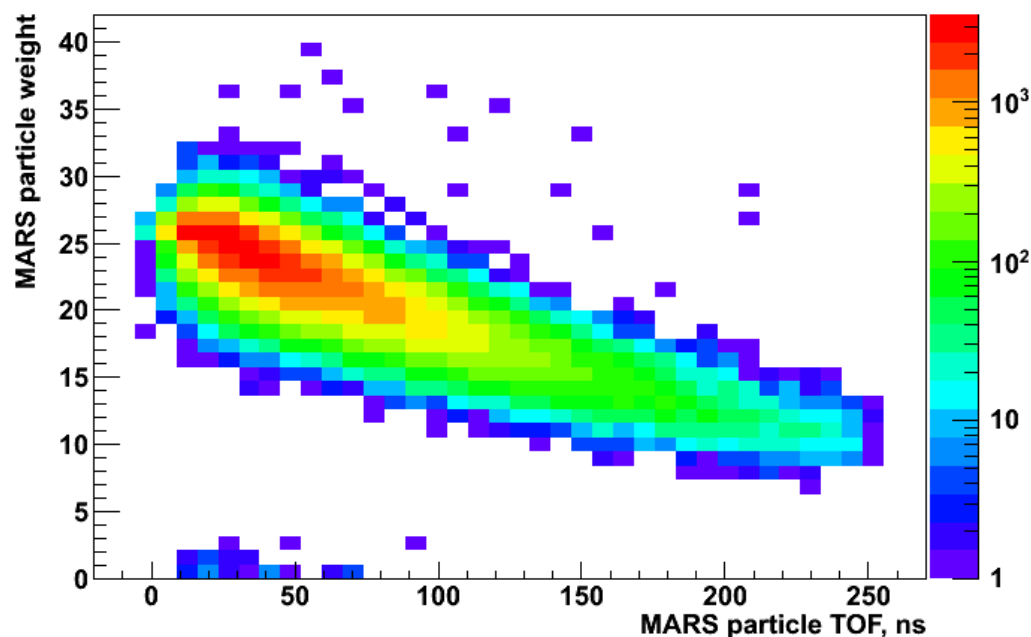


# CLICCT hits efficiency vs. TOF window

- **Fractions of hits within TOF window vs. TOF window width - biases**
  - MARS particle weight dependence on TOF (mostly for neutrons, left picture)
  - Si strip/pixel collection time and front-end electronics resolution time are not provided in ILCroot (CLICCT SDigits and Digits do not have timing)

Neutrons

Photons

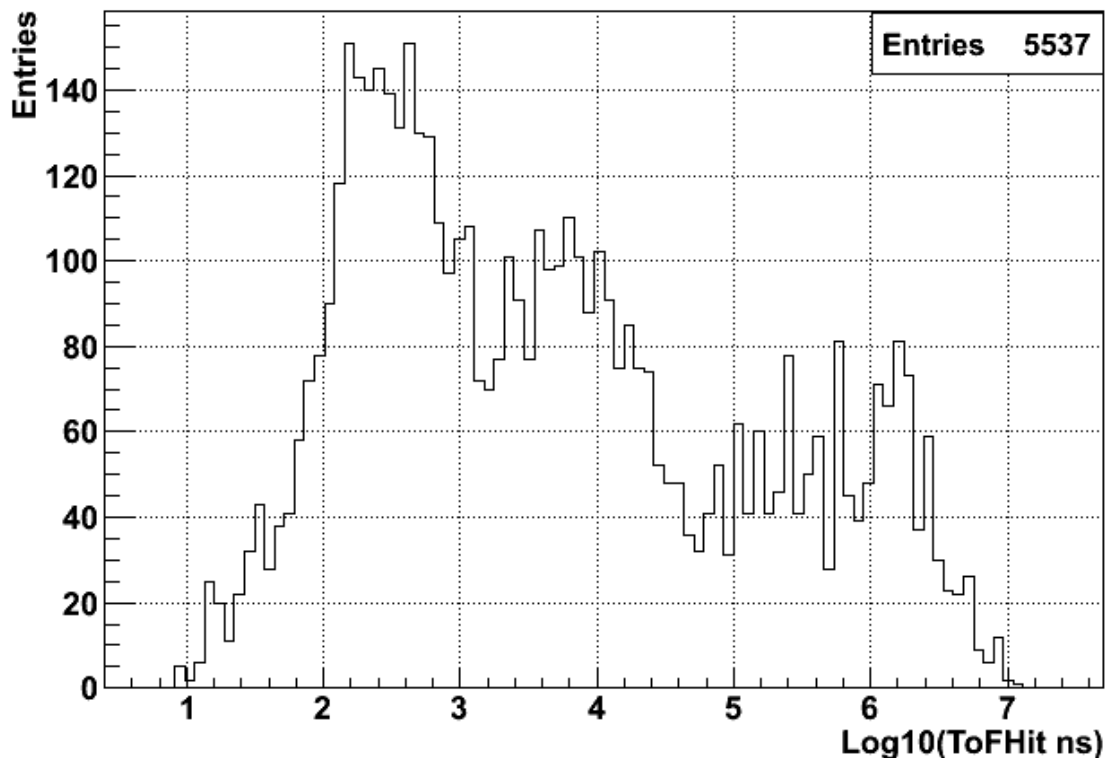






- **TOF for neutron hits**

- Plenty of hits with large TOF (the TOF tail is up to  $\sim 1e+4 \mu\text{s}$ )
- Produced by interactions with neutron “gas” (secondary low energy neutrons in GEANT4 ?) bouncing in detector (N. Mokhov, seen in MARS simulation as well)
- Need to estimate accumulation from beam background in previous bunch crossings in given TOF window ( $\sim 1,000$  bunches if spaced by  $10 \mu\text{s}$ )

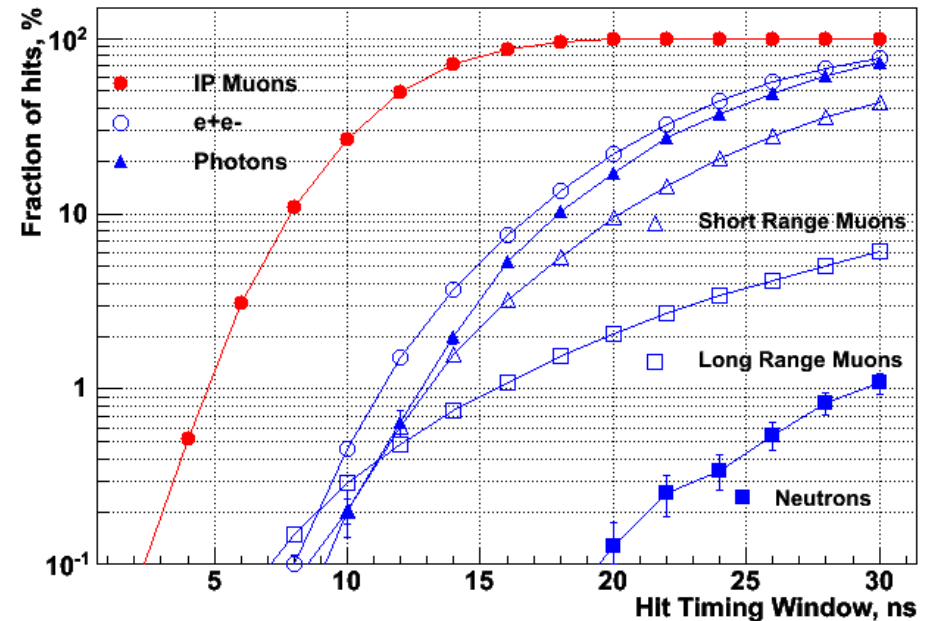
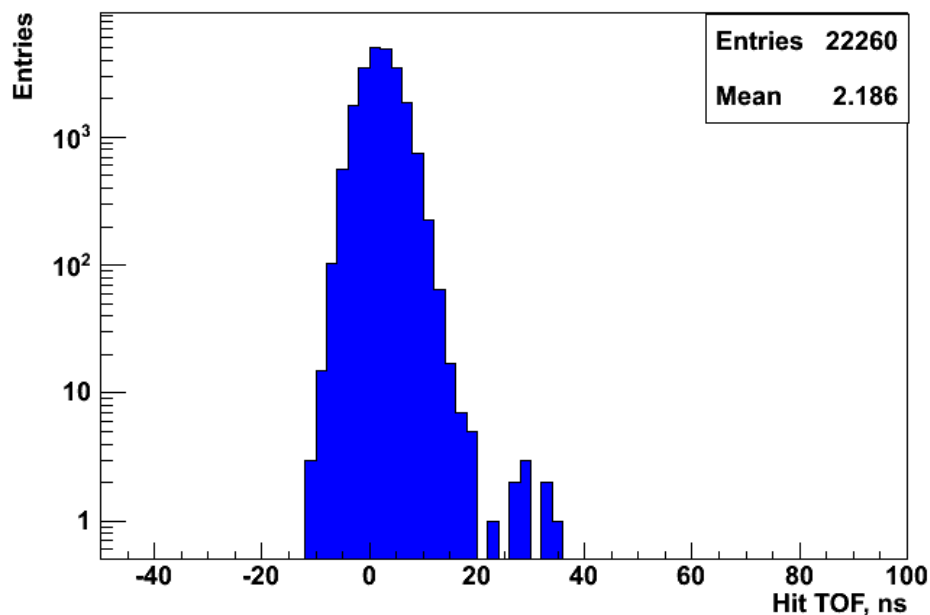




# CLICCT hits efficiency vs. TOF window

## Fractions of hits within TOF window vs. TOF window width

- Simulate CLICCT collection + resolution time smearing with gauss ( $\sigma = 3$  ns) as an example
- TOF window begins at -10 ns (10 ns prior to the bunch crossing time, see picture on the left for IP muons)
- At 20 ns TOF window ( $\sim 100\%$  efficiency for IP muons) hit fraction for MARS background particles:
  - $\sim 20\%$  for photons and  $e+e^-$
  - $\sim 10\%$  for short range muons and  $\sim 2\%$  for long range muons
  - $\sim <0.2\%$  for neutrons, integrated contribution from hits with TOF  $> 10\mu\text{s}$  not included





# Conclusion

- **The timing in ILCroot CLICCT hits for MARS background and IP muons was analyzed**
- **As an example the collection time and front-end resolution time was smeared with  $\sigma = 3$  ns gauss**
- **For IP muons  $\sim 100\%$  of hits are in 20 ns wide TOF window**
- **At 20 ns TOF window hit fraction for MARS background particles:**
  - $\sim 20\%$  for photons and  $e+e^-$
  - $\sim 10\%$  for short range muons and  $\sim 2\%$  for long range muons
  - $\sim < 0.2\%$  for neutrons if integrated contribution from hits with TOF  $> 10\mu\text{s}$  not included
- **For realistic estimation of the rejection of beam background neutrons when using timing:**
  - New MARS background data with low energy neutrons are needed
  - Timing information for ILCroot SDigits and Digits must be added
  - Integrated contribution from hits with TOF  $> 10\mu\text{s}$  has to be included