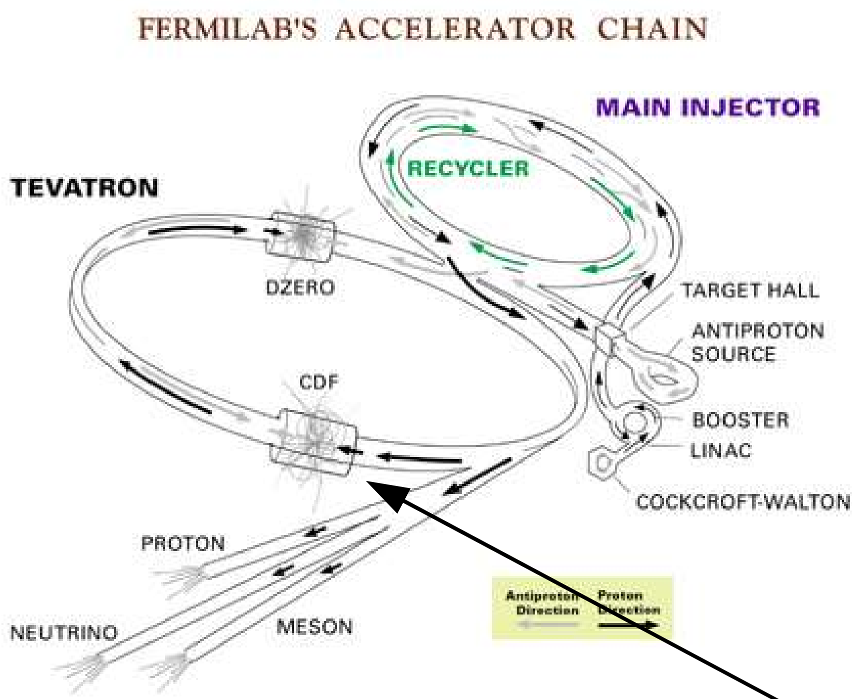
# Calorimeter Timing System at CDF

Max Goncharov for Texas A&M Group

# In This Talk ...

- Why we built the system
- System Design
  - Schematics
  - Challenges we faced
- Performance
  - Efficiency
  - Resolution
  - Noise Level
- Things we can do with timing

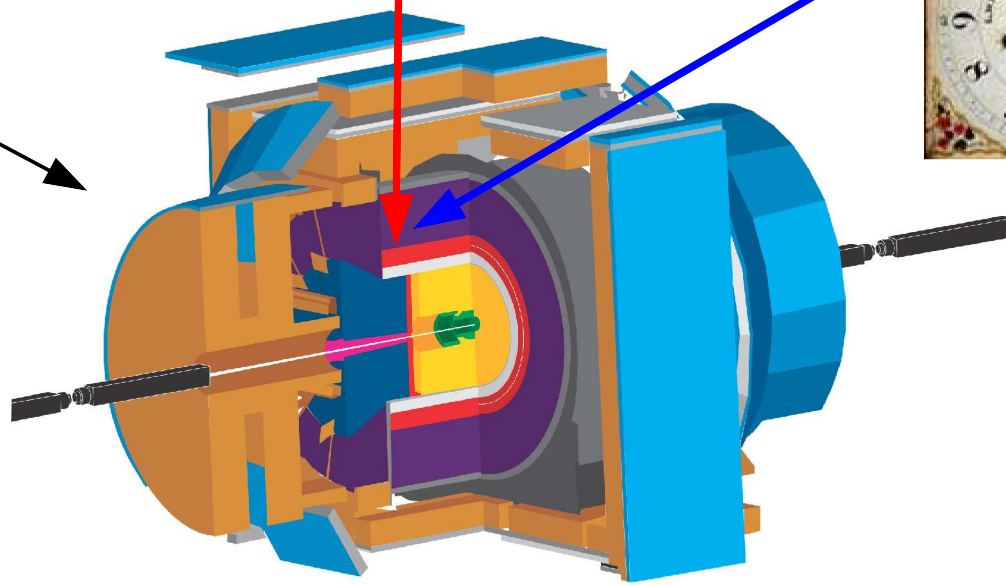
# CDF Experiment




CDF Detector

Electromagnetic (EM) Calorimeter

EMTiming system



CEM - "central" EM $|\eta|<1$

PEM - "plug" EM $|\eta|>1$

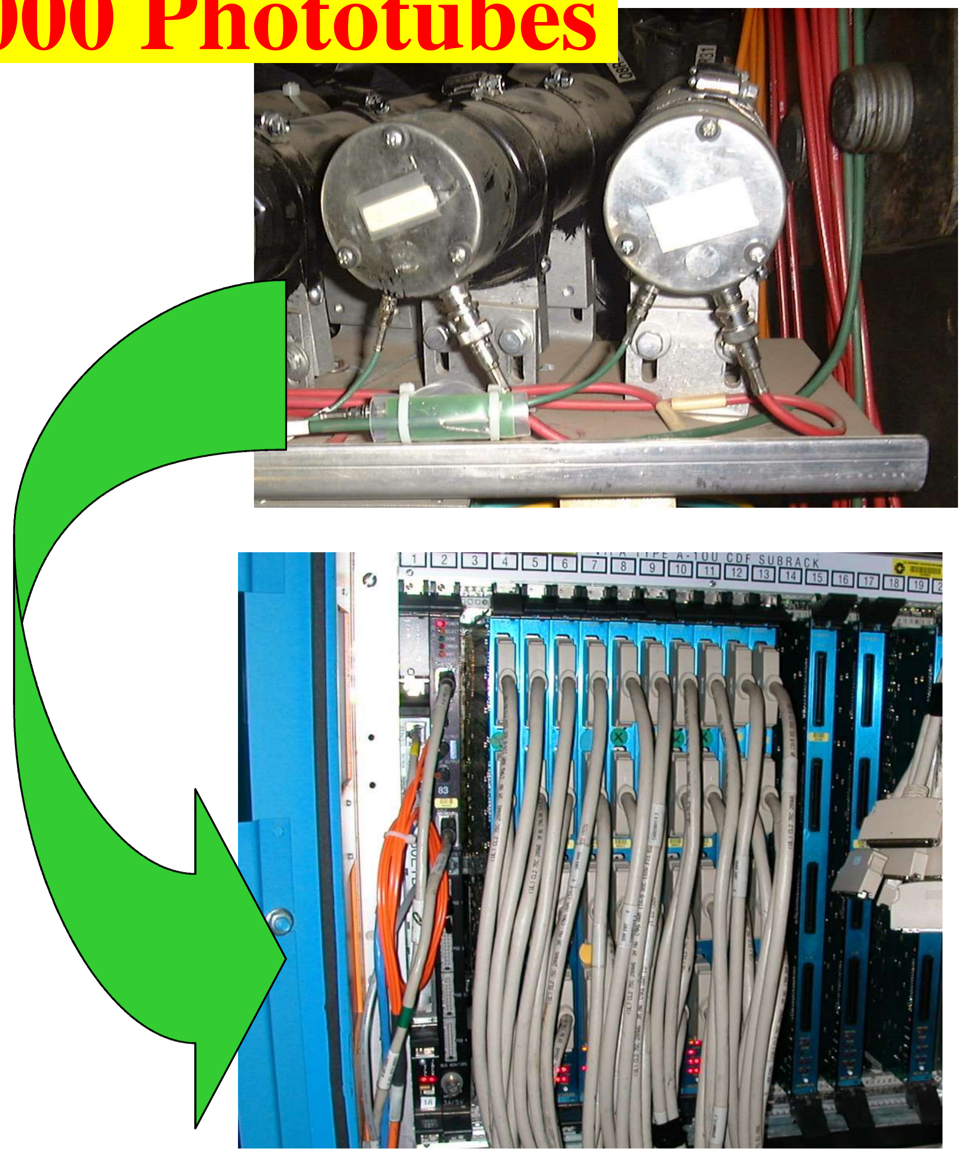
# EMTiming Hardware

**~2000 Phototubes**

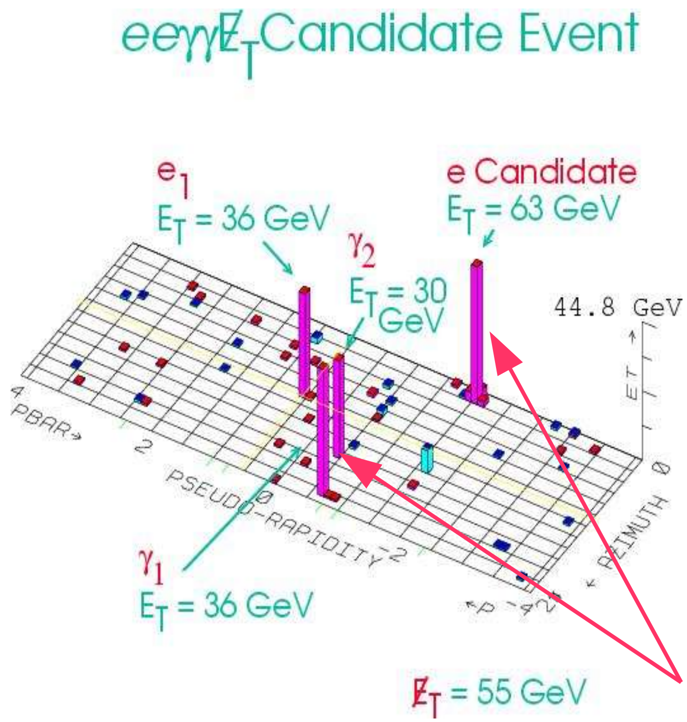
- Large system to add to existing (very large) detector
- Effectively put a TDC onto about 2000 phototubes at CDF
- International collaboration led by Texas A&M
  - INFN-Frascati*
  - Michigan*
  - Chicago*,**
  - Fermilab**

*Engineering support
**Technician support

- ~$1M Run IIb project (parts and labor)
  - Project jointly funded by DOE and the INFN



# Reasons To Build




With EMTiming system we can (and have done):

- Separate physics from accidental backgrounds
  - Cut on time of arrival
  - Obtain samples of "accident" backgrounds.
- Clean-up missing $E_T$ (MET)
- Look for exotic particles with non-zero lifetime

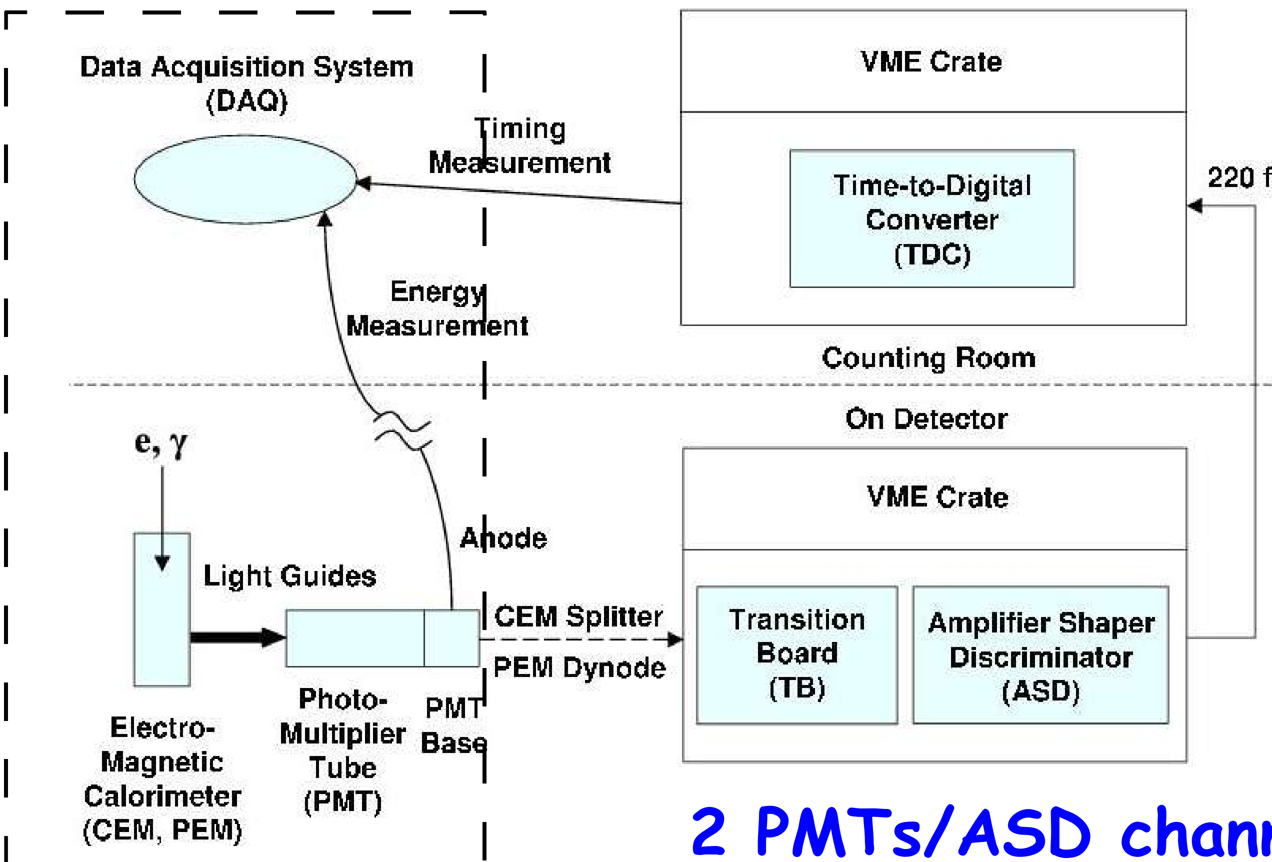
Are all of them prompt or some are accidents?

## *In General*

Exotic signals with γ+MET suffer from accidental backgrounds (cosmic rays ...). Accidents look different from prompt physics in time.

With timing can do totally different types of searches

# System Design




Already Existed

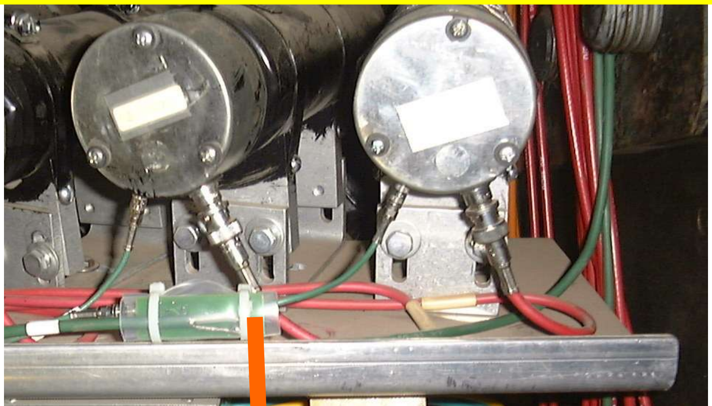
2 PMTs/ASD channels

CEM ($|\eta|<1$) – 480 channels

PEM ($1< |\eta| <2$) – 384 channels

# System Design

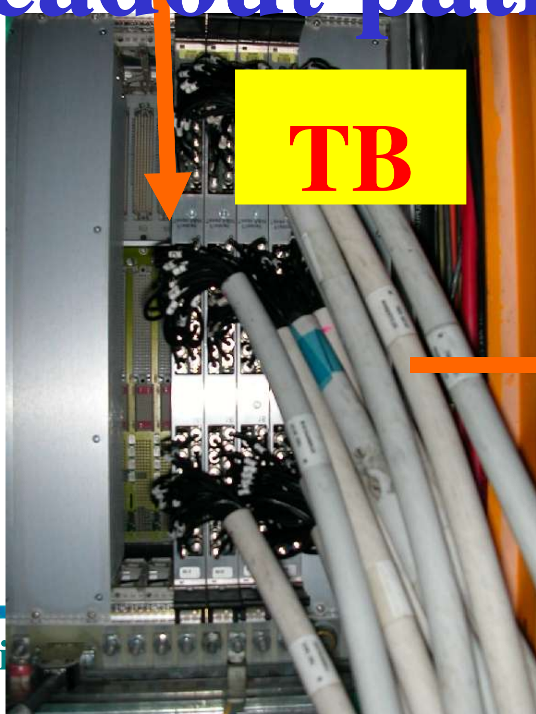
## ~2000 Phototubes

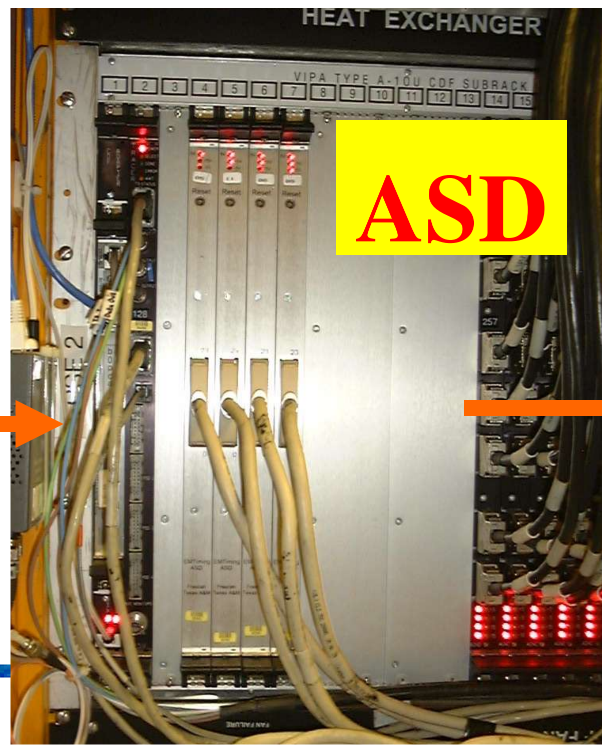


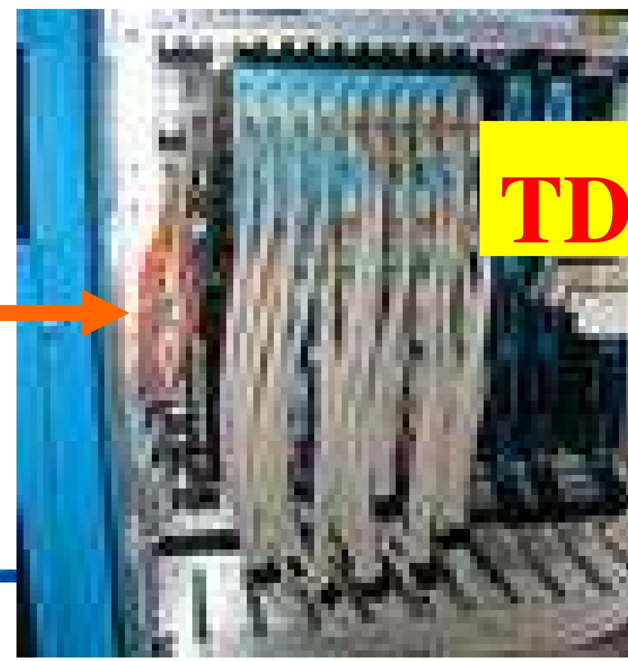
- Production of all components completed in Fall of 2003, well ahead of schedule.
- Partial installation in Fall 2003.
- Finished in Dec 2004.

*Installation team: M. Goncharov, S.Krutelyov, S.W. Lee, D. Allen, P.Wagner, V. Khotilovich & D.Toback.

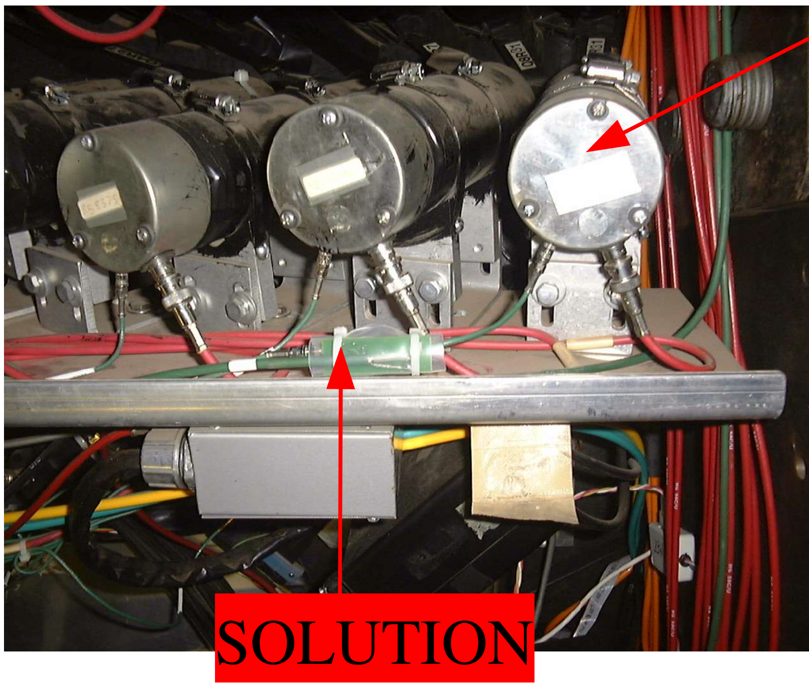
## Readout path



# Saving the Energy




CEM PMT Base

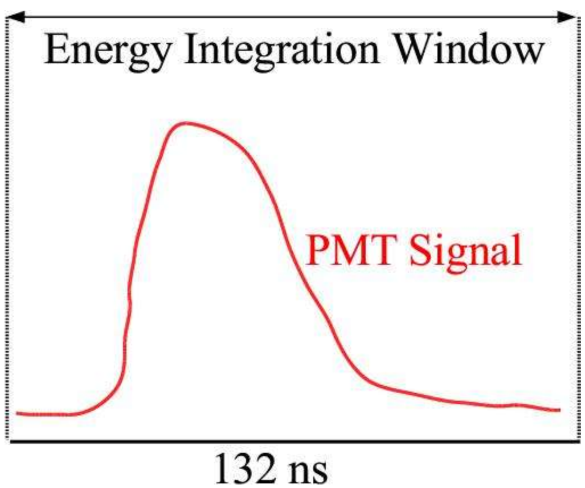
anode provides energy readout

has no dynode readout ...

modify PMT base? ...

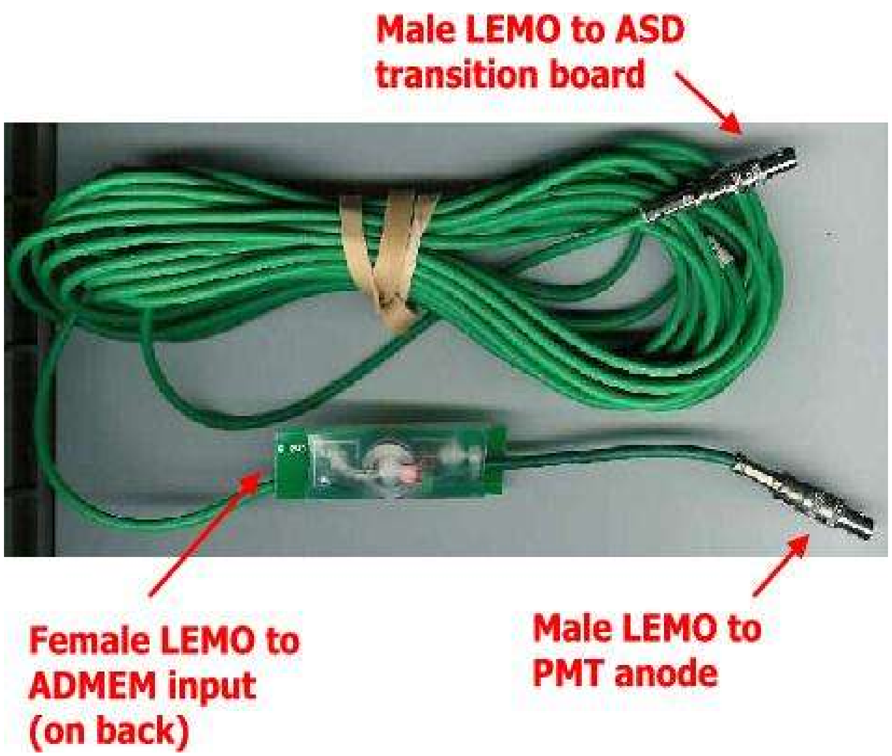
cut into the anode line? ...

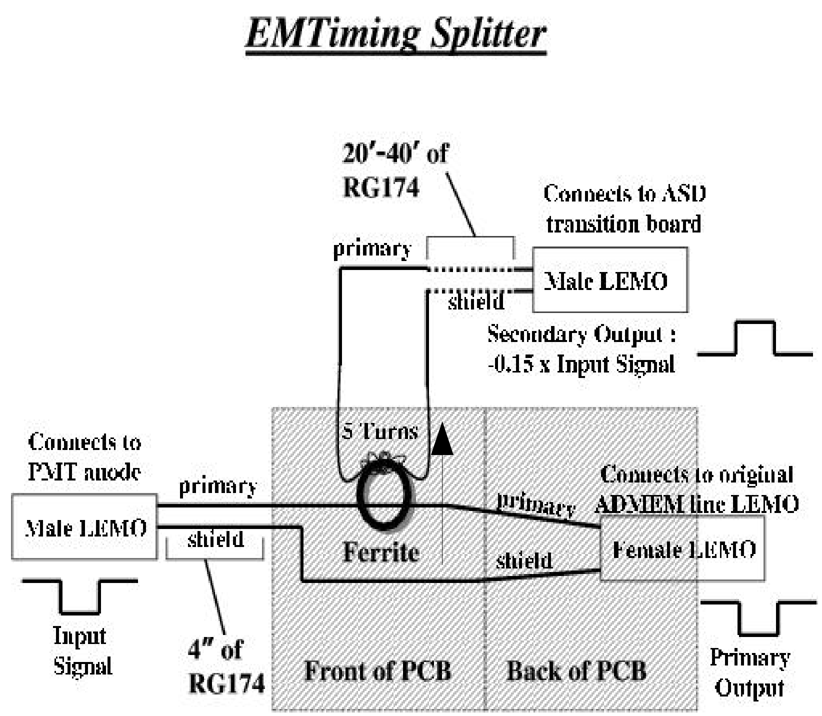
Whatever you do – DO NOT CHANGE ENERGY READOUT, OTHERWISE...




# Splitter for Central Detector

**Do not touch charge – do not change energy readout.**




Idea, design, and production - University of Chicago (H. Frisch and H. Sanders)

# Current Status

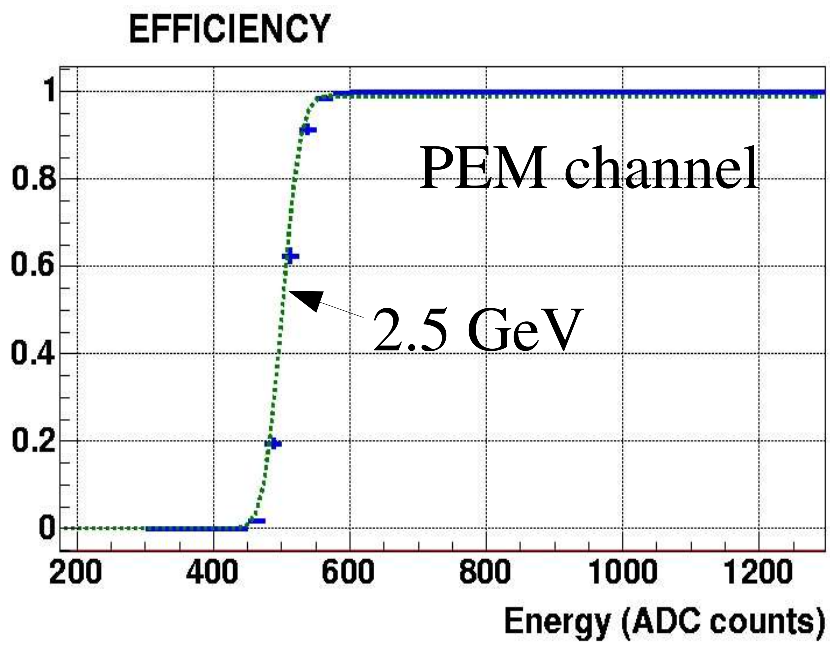
- ~100% Efficient above thresholds (CEM-5, PEM-2.5 GeV)
- System resolution is ~0.6 ns
- Very uniform
- No Noise
- Finished full installation this December 2004 (2 years ahead of original Run IIb schedule). Started taking data in January 2005 (0.6 $fb^{-1}$ and counting)
  - <1% had problems right after installation (most are channel 6 and 9 mixes)
  - Lost only ~1 week of data to weed out all problems
  - Since then we do not have a single high $P_T$ event without timing information

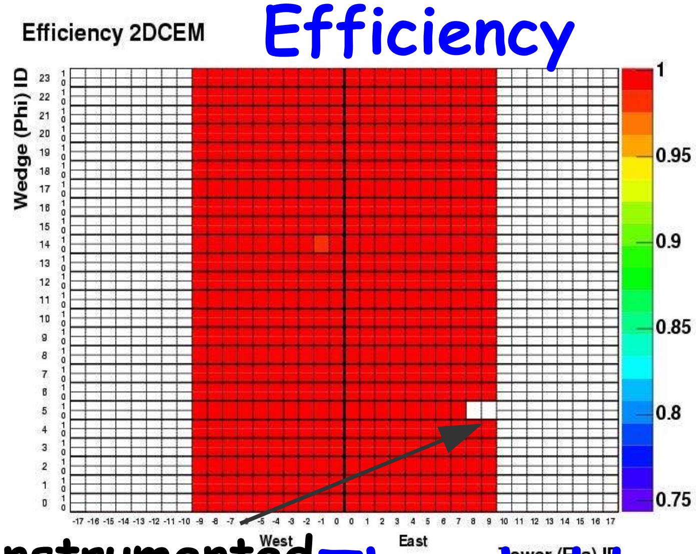
M. Goncharov, D. Toback *et al*,
submitted to NIM in 2005

# Efficiency and Uniformity

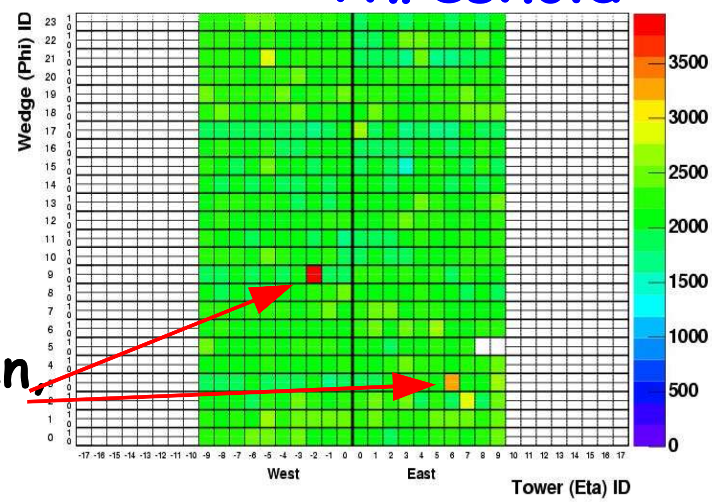
**No Data can be left behind – monitor online in real time**

Efficiency curves show most problems right away




Not instrumented



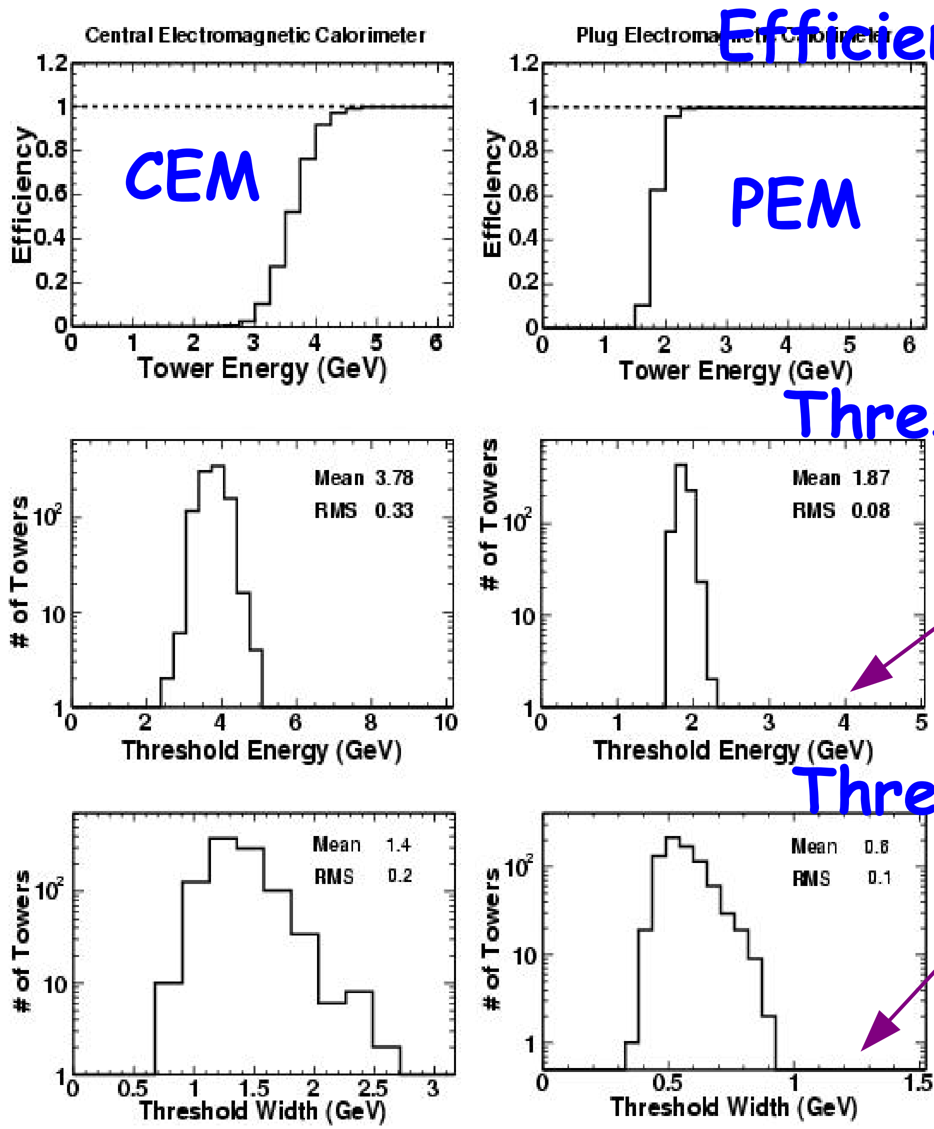

Threshold=5.0 GeV in CEM

2.5 GeV in PEM

One line is broken, fixed right away

# Efficiency and Uniformity

No Data can be left behind – monitor online in real time




100 % above threshold

Uniform

Broken channel would be here

… and here

# Uncorrected Time

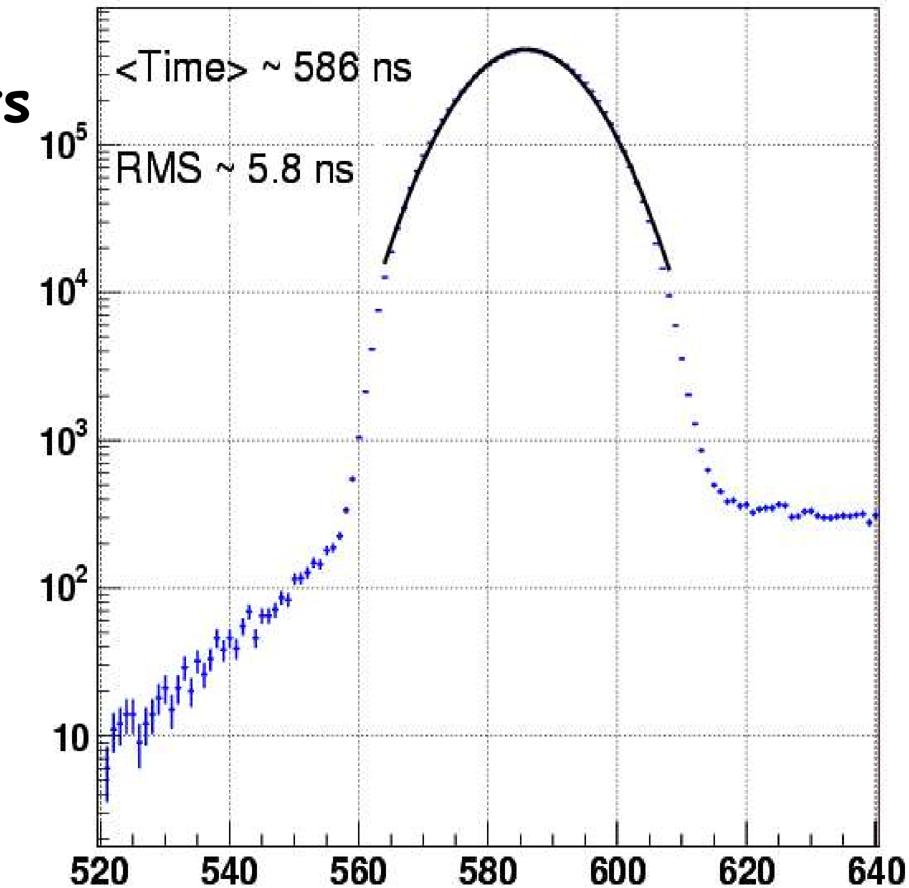
Can not use in the analysis data as it is

=> have to calibrate

Calibrations take out various effects

- channel to channel variations
- energy dependence (slewing)
- time variations

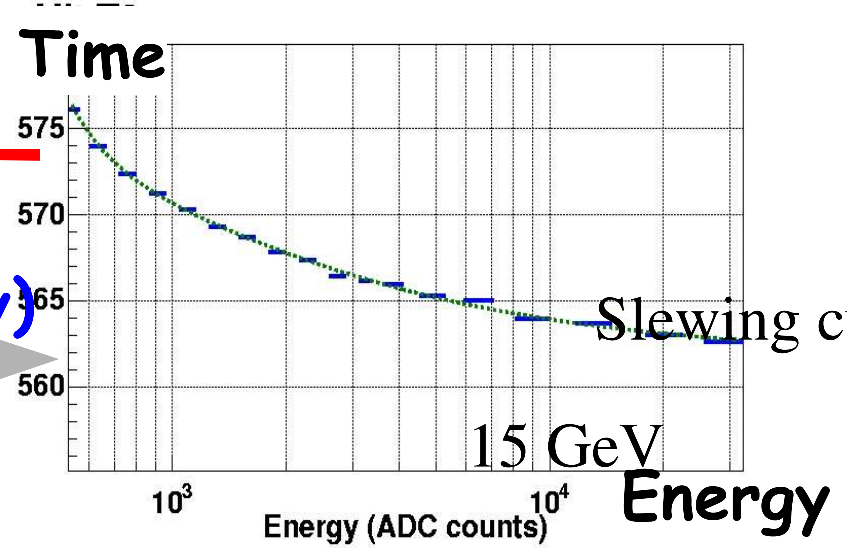
CEM



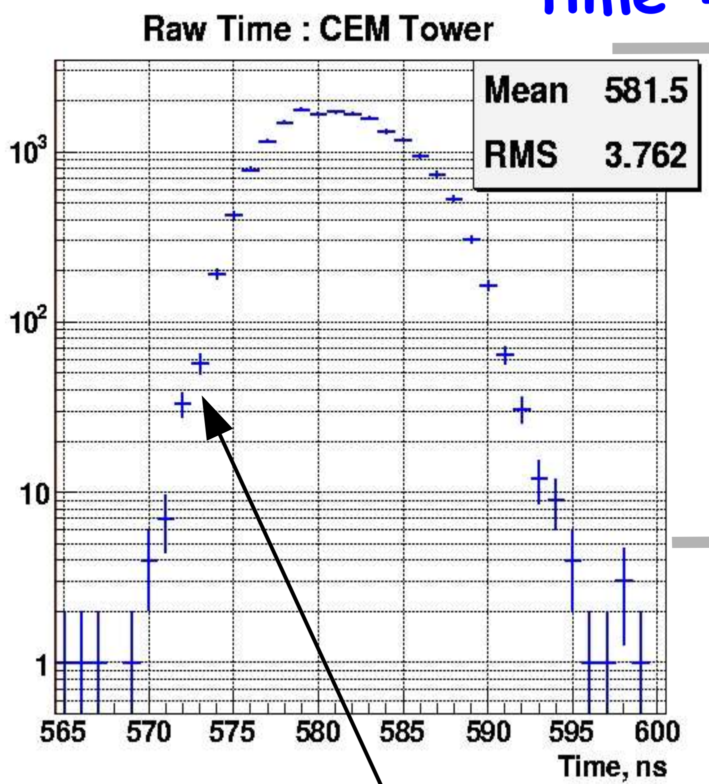

Time, ns

# Calibrations

Database:for each channel
f(Energy)

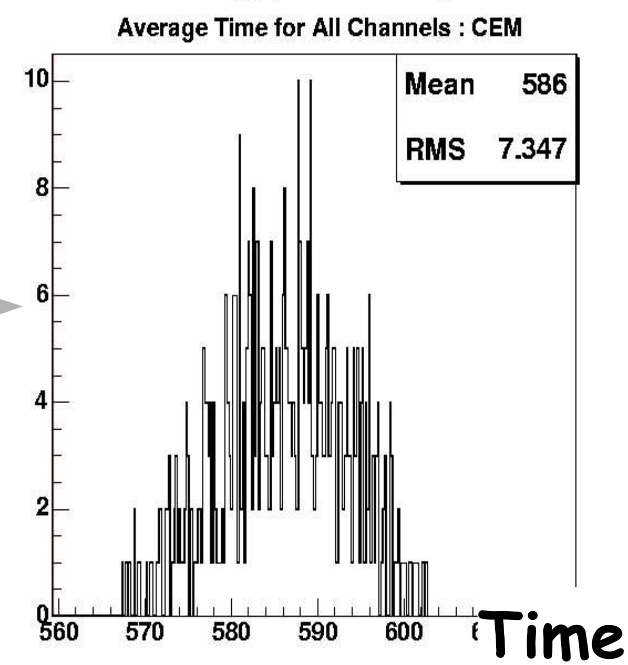



time = f(Energy)




Non-Gaussian form

All channels
<time>



# System Resolution

After slewing calibrations various effects remain:

- when collision happens
- where it happens
- run by run dependence ...

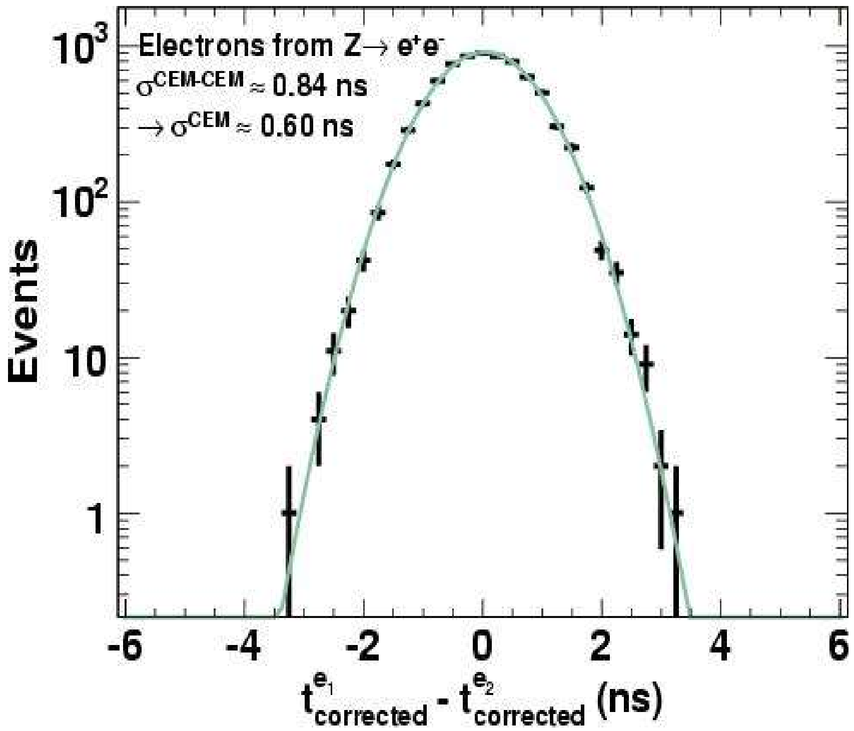
Z->ee sample is perfect to find the resolution

Plot time(e1)-time(e2):

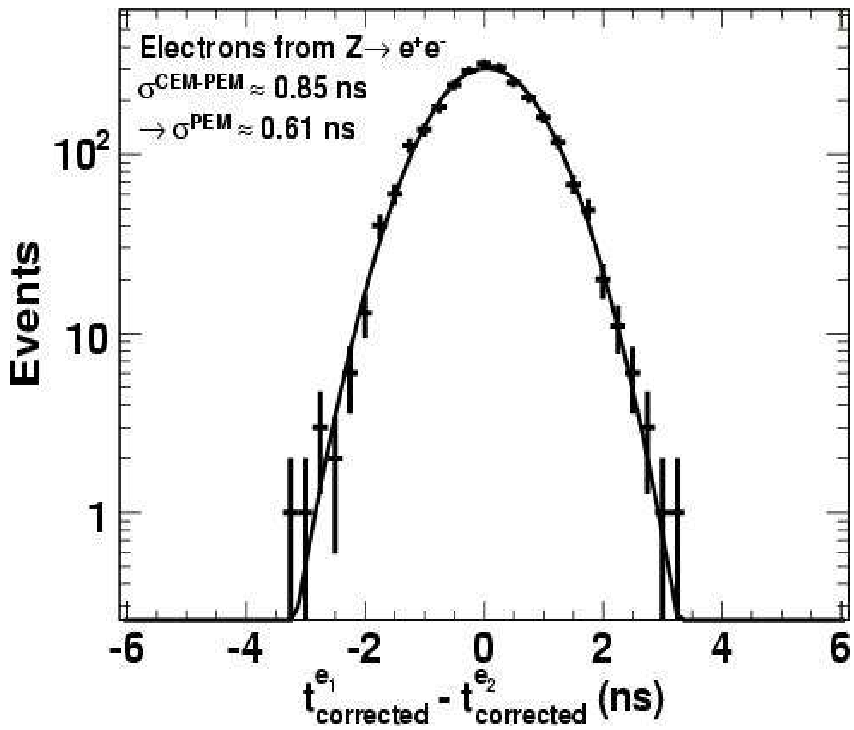
most of the effects cancel out

# System Resolution

### CEM – 0.60 ns

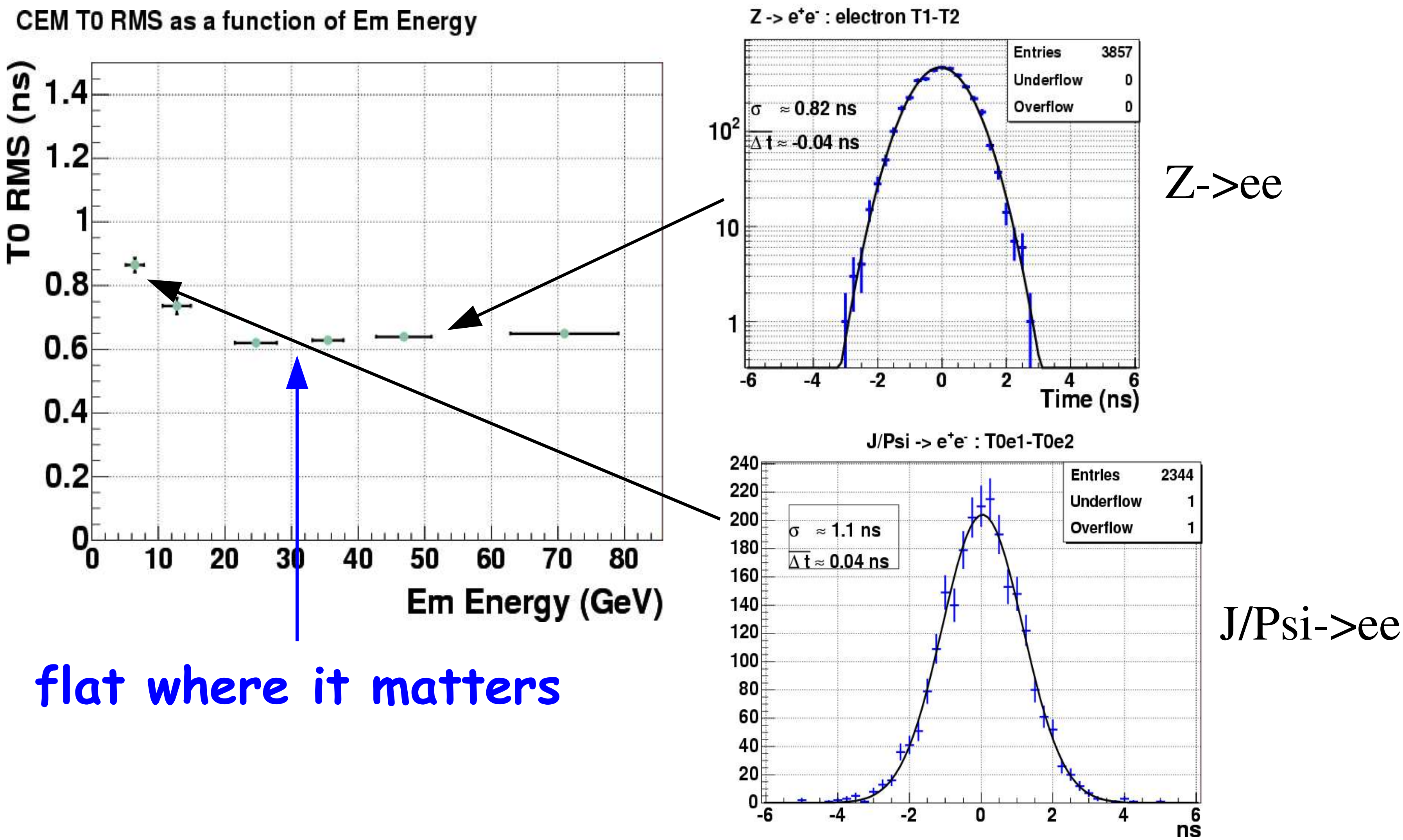



### PEM – 0.61 ns




- Centered at zero, symmetric
- No non-Gaussian tails
- CEM and PEM are the same

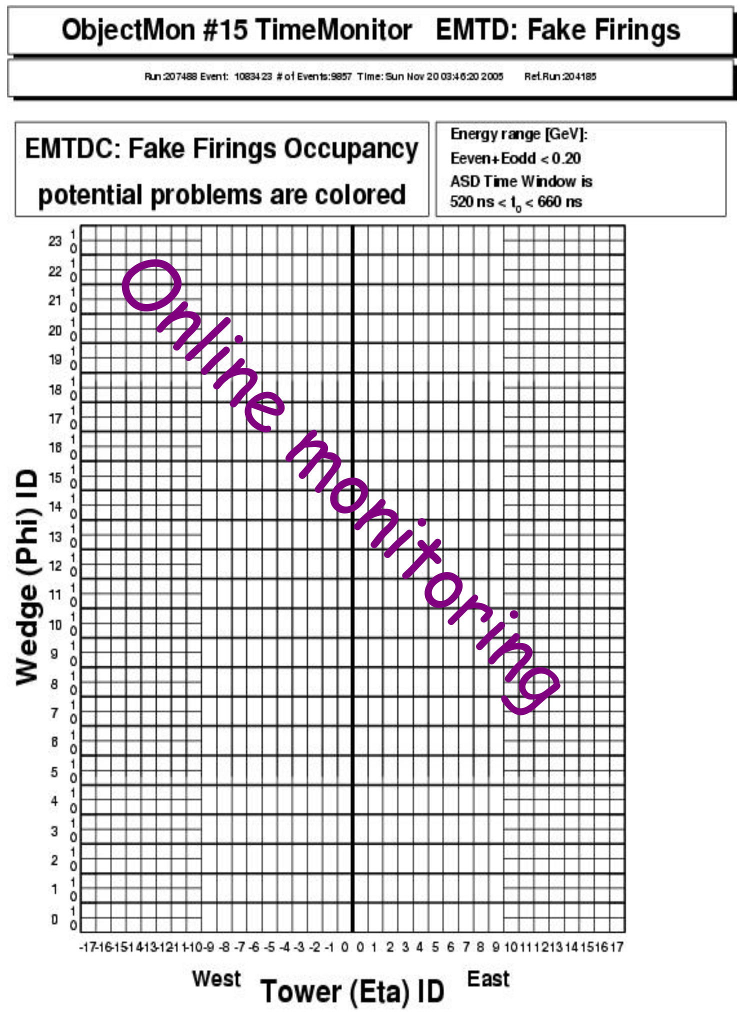
# Resolution vs Energy



# Noise Levels

Noise – no energy, but there is a TDC hit.

Looked at >10 M events, have yet to see a TDC hit from noise.



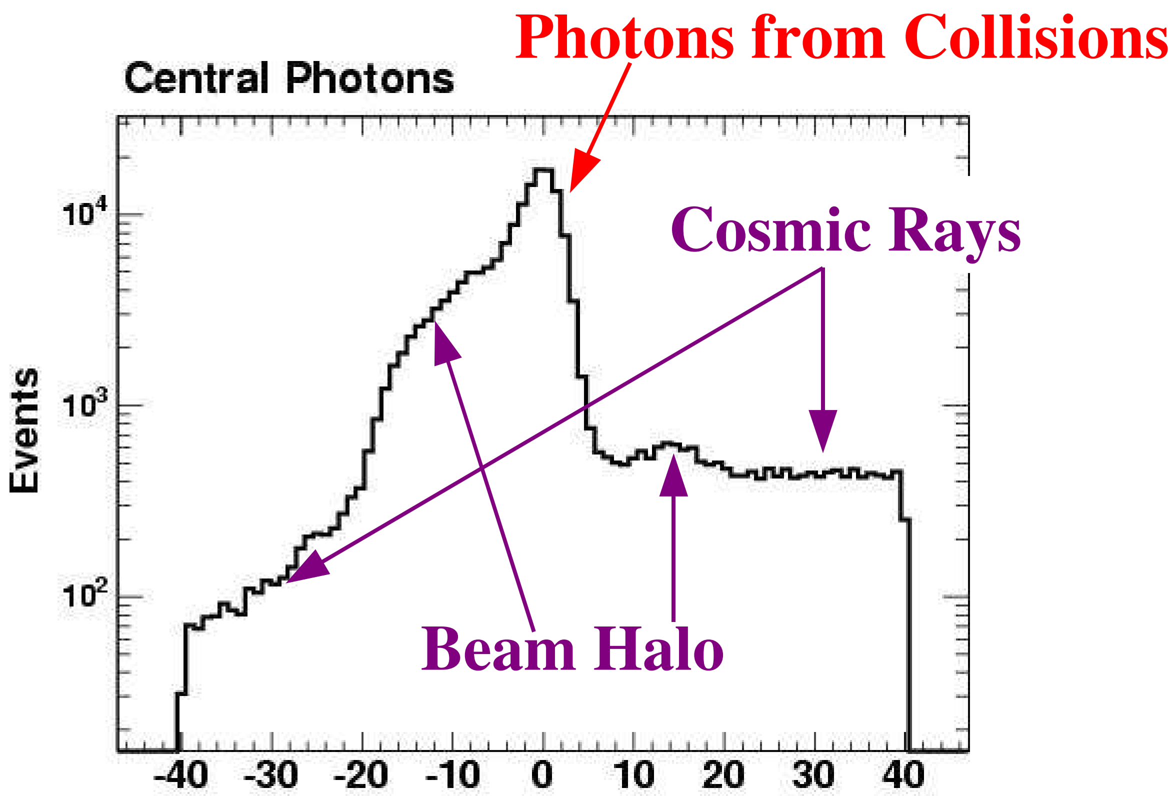




Max Goncharov
Texas A&M University

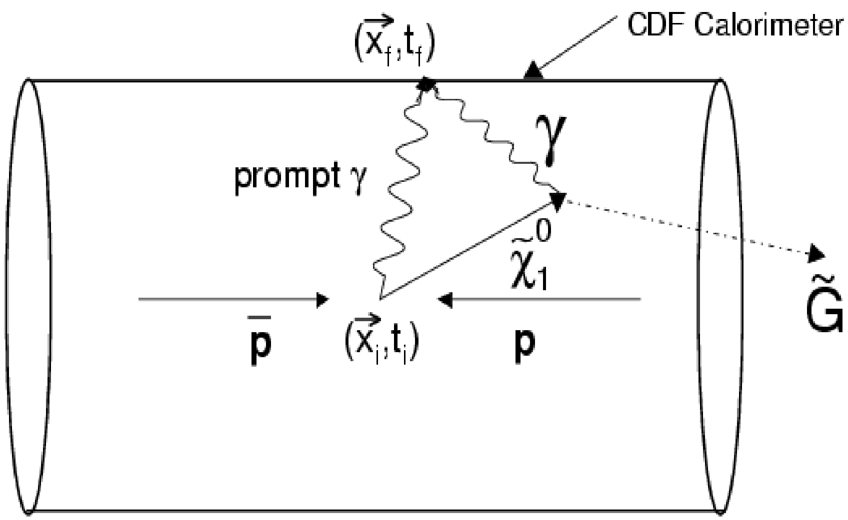
# Physics Impact

Photon + MET channel : many exotic models predict signal here

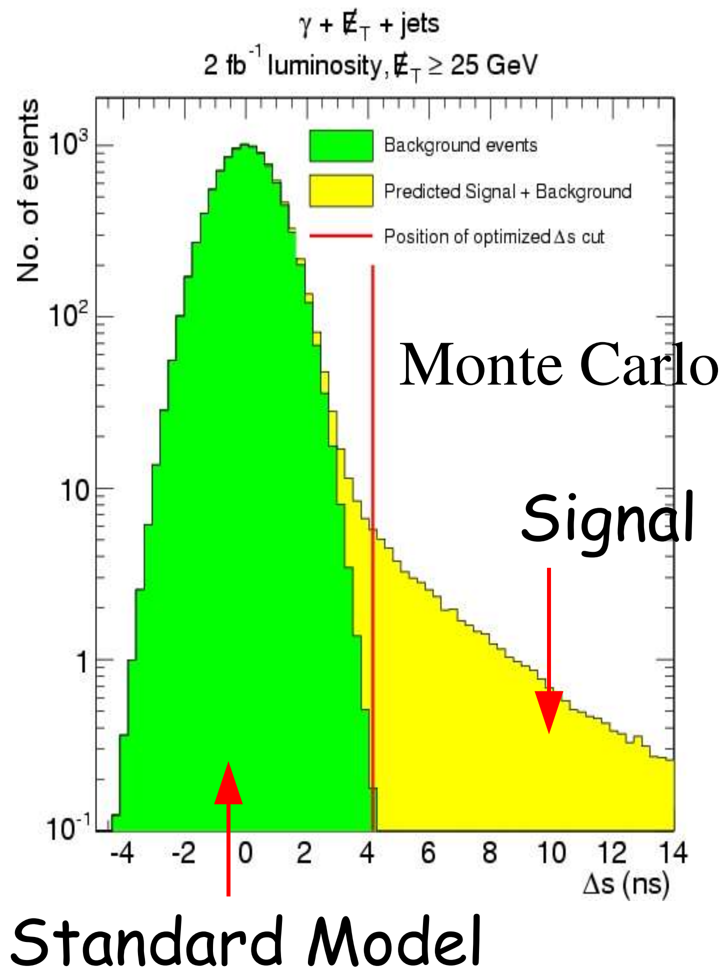



Photon Time in Calorimeter

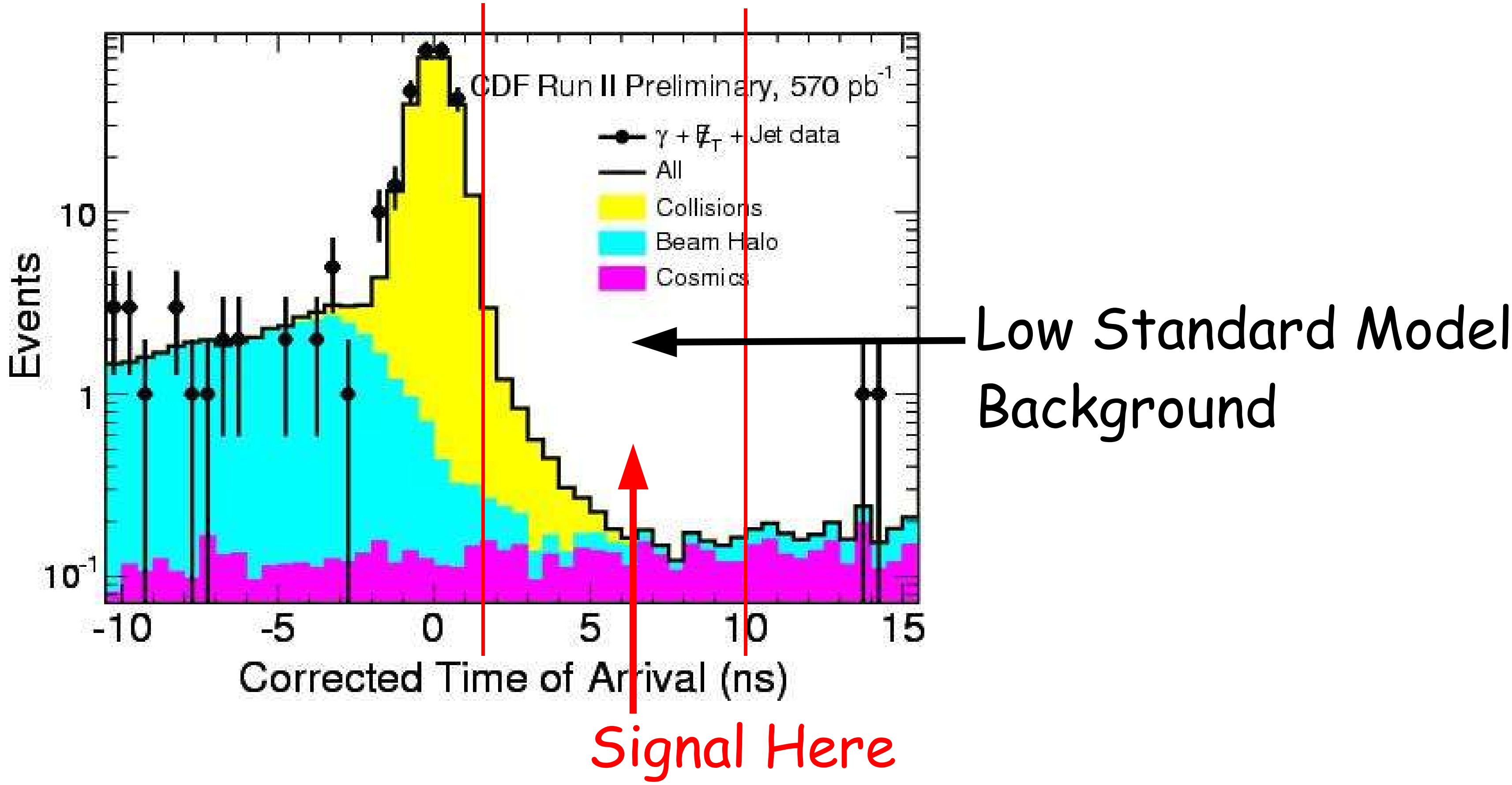
# Search for Heavy Long Lived X




Look for non-prompt $\gamma$'s that take longer to reach calorimeter.
If the $\gamma$ has a significant lifetime, we can separate the signal from the backgrounds.



# Search for HLLX




Will open the box next week

# The End ...

Since January 2005 EMTiming system covers CEM and PEM detector (NIM is submitted)

Resolution is ~0.6 ns for $\gamma$ and e, threshold 5.0 GeV in CEM
2.5 GeV in PEM

No noise, 100% efficiency above threshold, no non-Gaussian tails.

We use it to fight backgrounds from Cosmic Rays, Beam Halo, Pmt Spikes, ... .

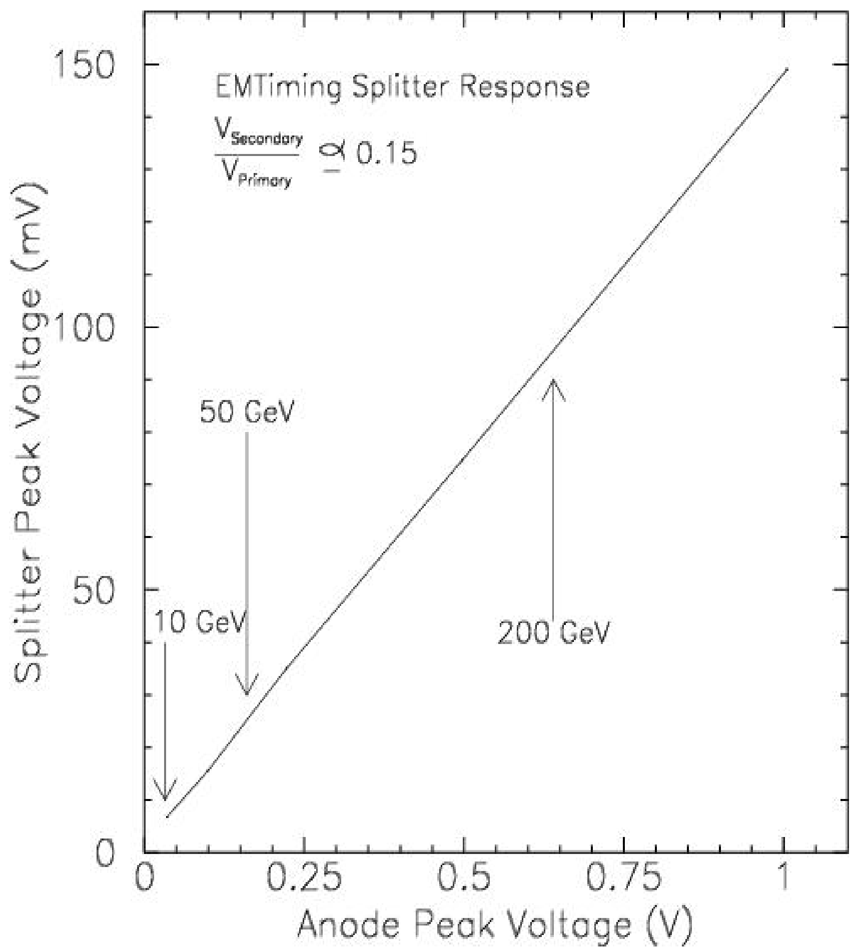
*Exotic Physics with Photons:*

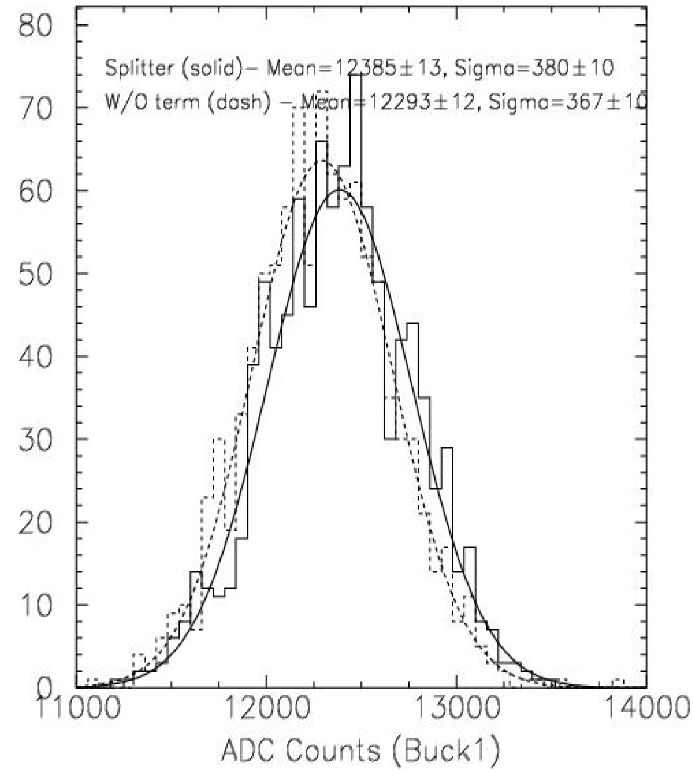
- Heavy Long Lived X – can not be done without EMTiming
- Gamma + MET, Gamma+Gamma+MET+X ...
- Reconstruct Displaced Vertex (CAT-SCAN)

# Backup Slides

# Splitter

Signal transition coefficient ~0.15



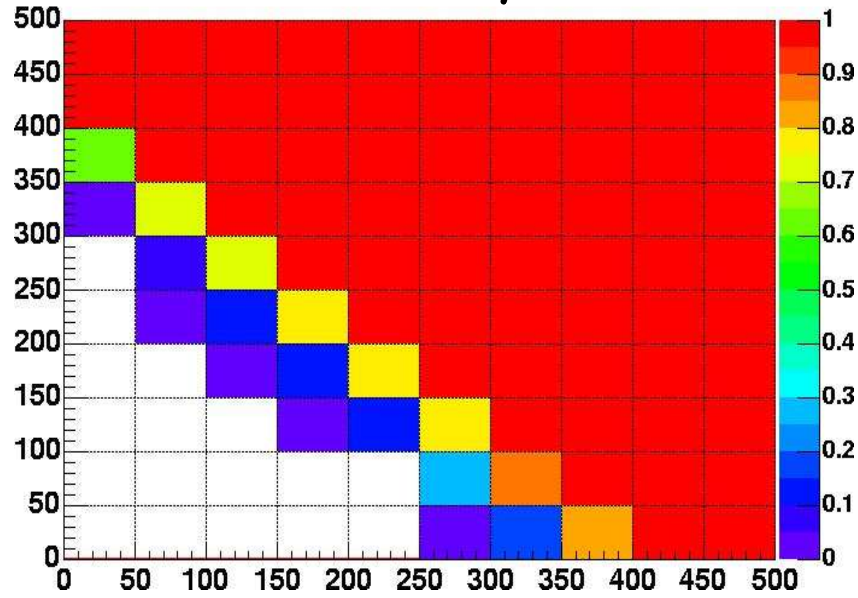




- Linear in all reasonable energy range
- No change in PMT signal shape
- No change in pedestals
- No Change in E/P for electrons

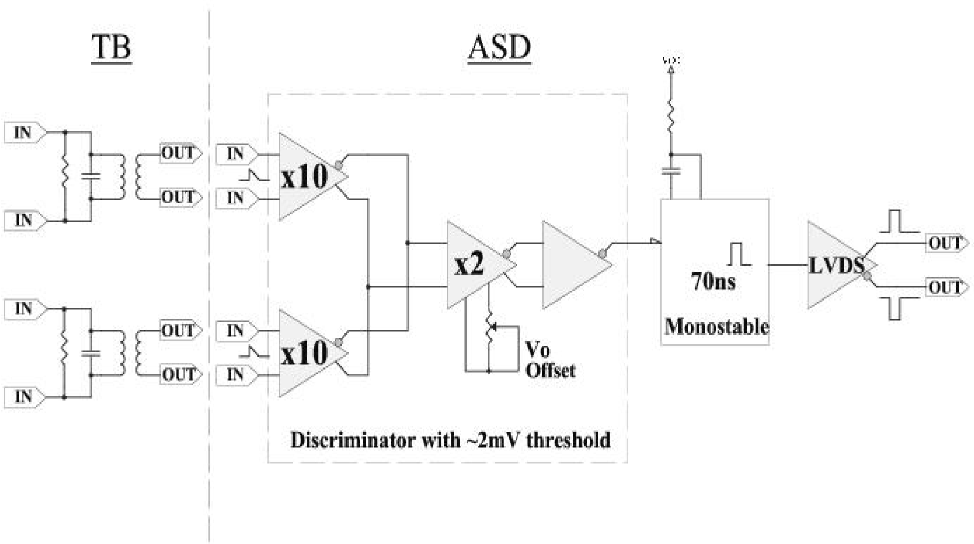
# Energy- Sum of PMT's

Efficiency

E(PMT1)



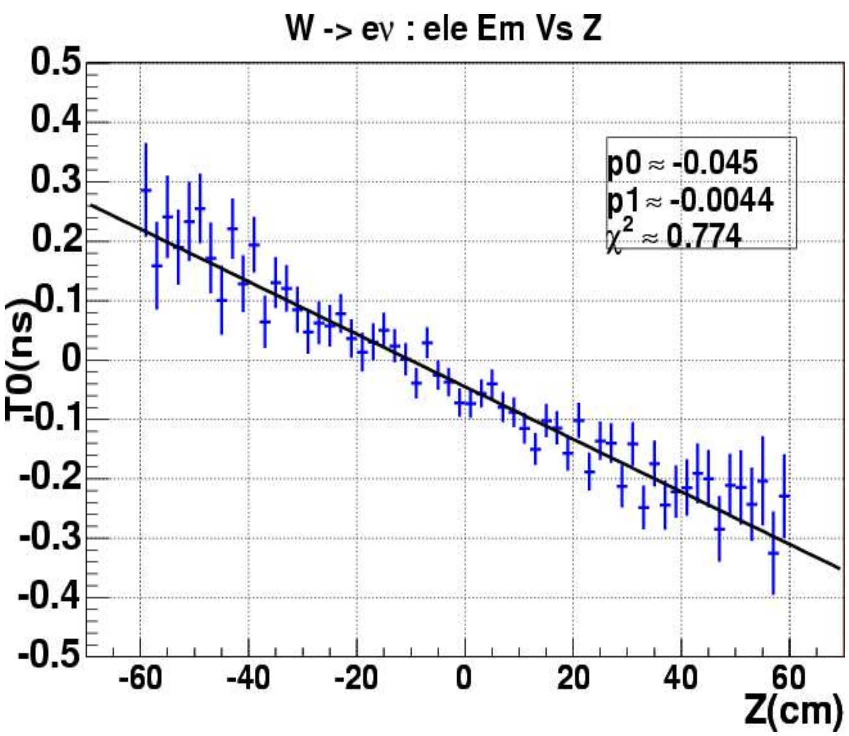

E(PMT2)




Energy = E(PMT1)+E(PMT2)

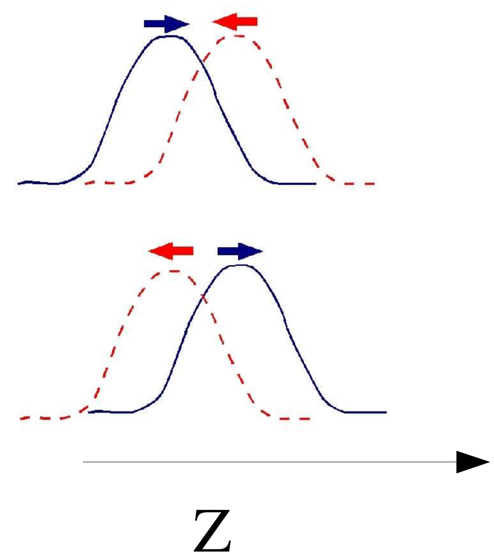
# Beam Width

One of the first things we measured with timing is the beam width




$\sigma(p) \approx 55$ cm

$\sigma(pbar) \approx 65$ cm




Average z position of the interaction is given by

$$Z = \exp(-(z-ct)^2/\sigma^2(p)) * \exp(-(z-ct)^2/\sigma^2(pbar))$$