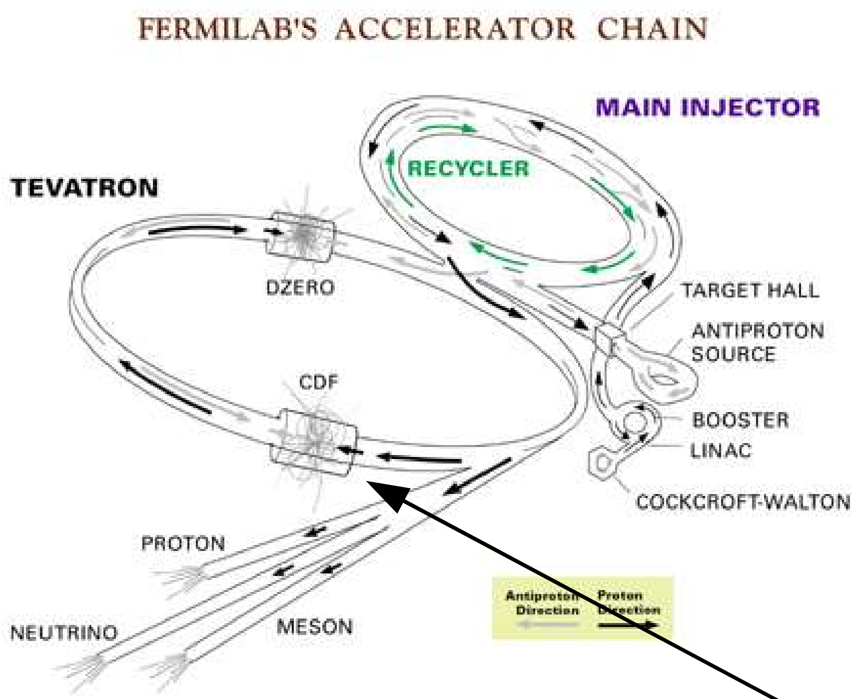
Calorimeter Timing System at CDF

Max Goncharov (Texas A&M University)

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

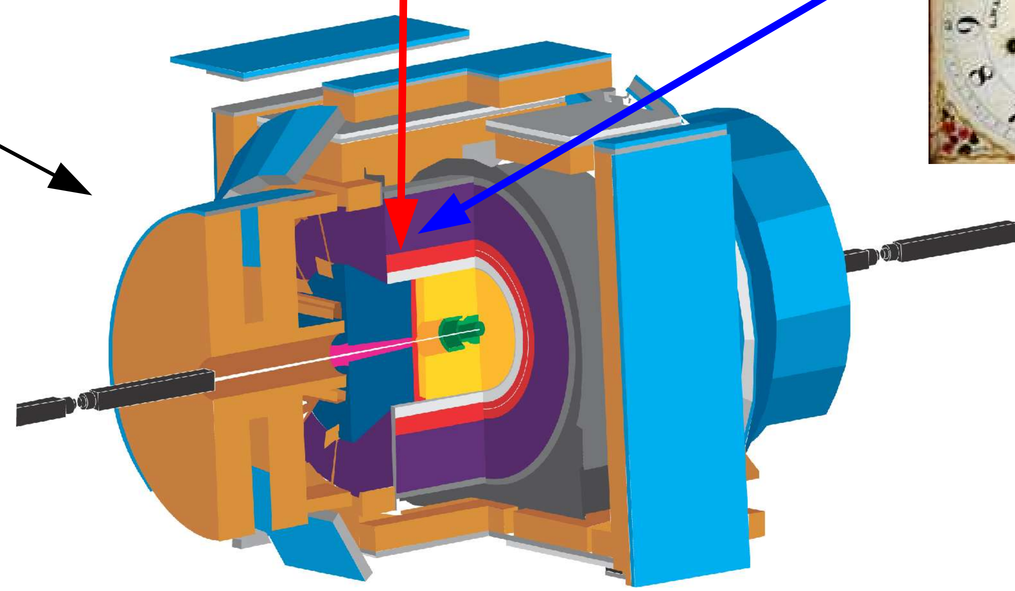
CDF Experiment



CDF Detector

Electromagnetic (EM) Calorimeter

EMTiming system



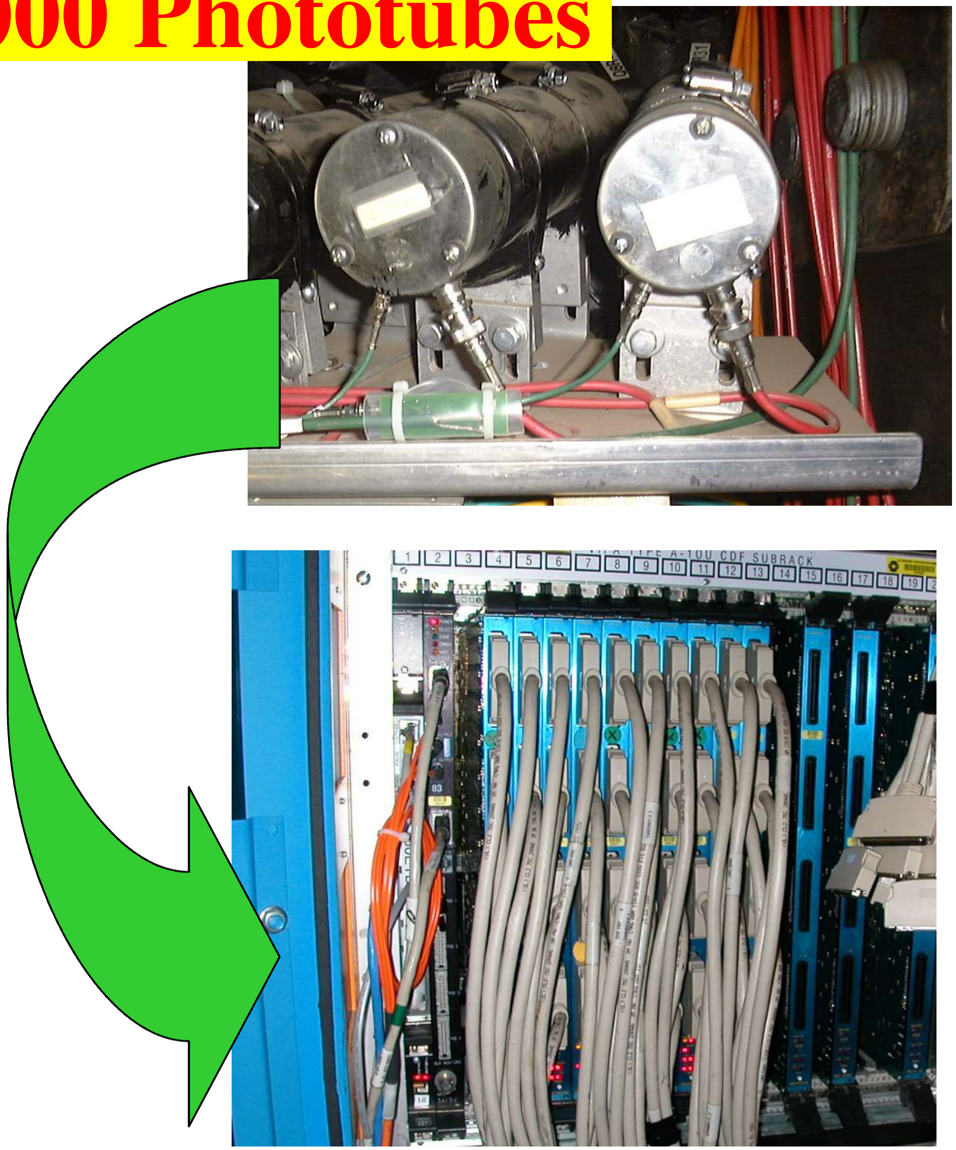
EMTiming Hardware

~2000 Phototubes

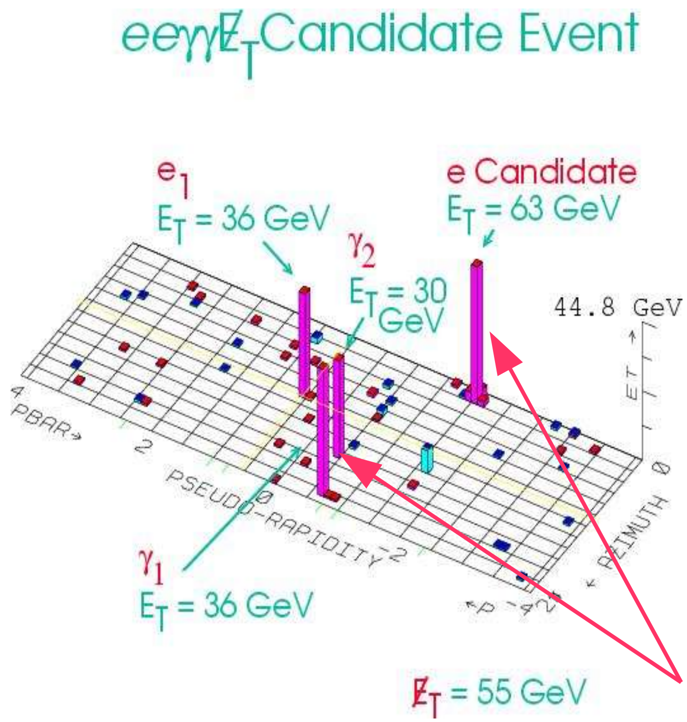
- Large system to add to existing (very large) detector
- Effectively put a TDC onto about 2000 phototubes at CDF
- International collaboration led by Texas A&M
  - INFN-Frascati*
  - Michigan*
  - Chicago*,**
  - Fermilab**

*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

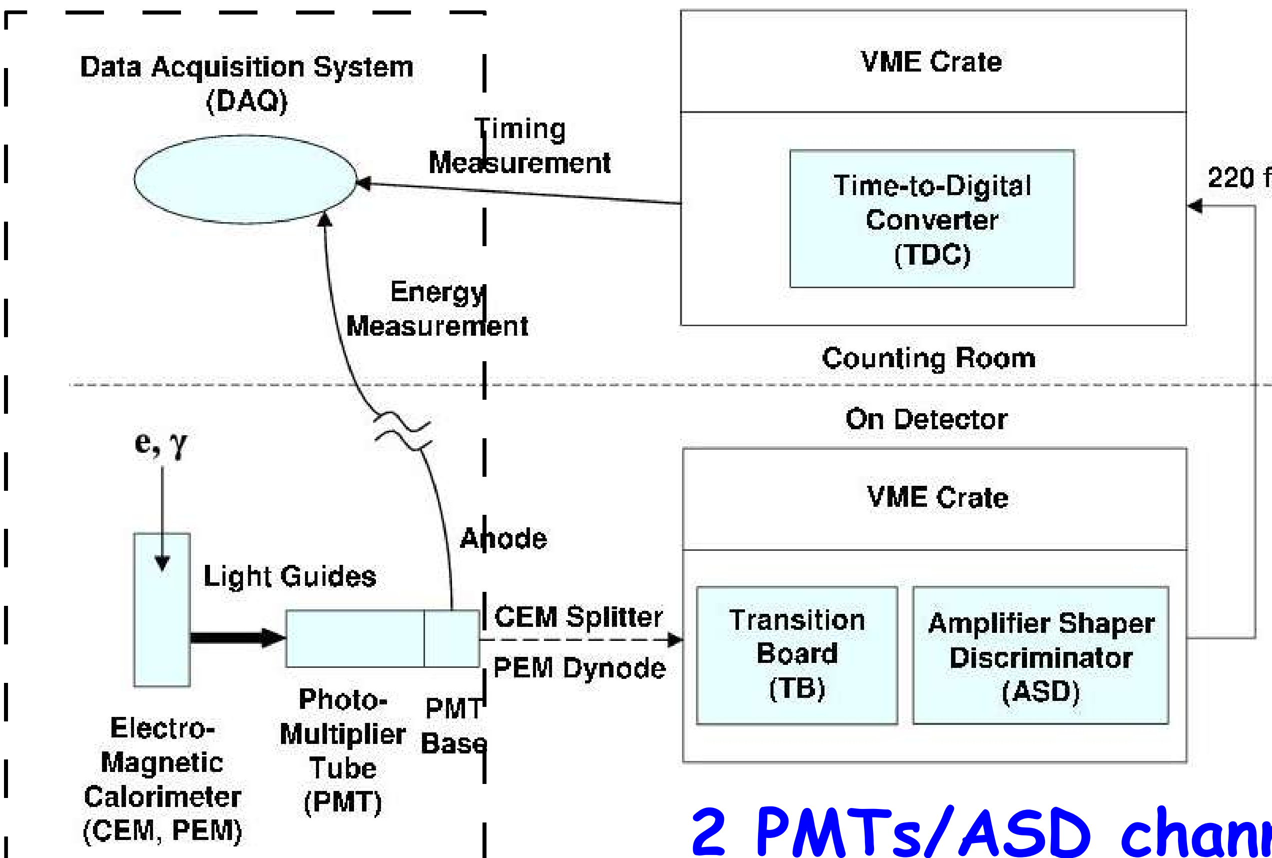
Are all of them prompt or some are accidents?

In General

Exotic signals with   +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

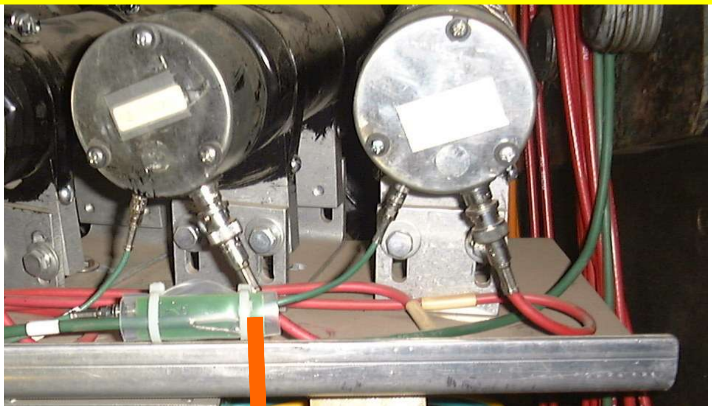
2 PMTs/ASD channels

CEM (| |<1) – 480 channels

Plug (1< | | <2) – 384 channels

System Design

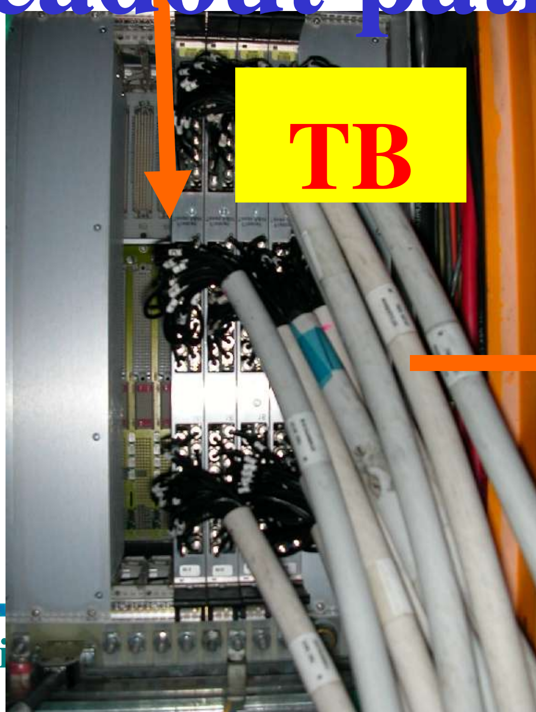
~2000 Phototubes

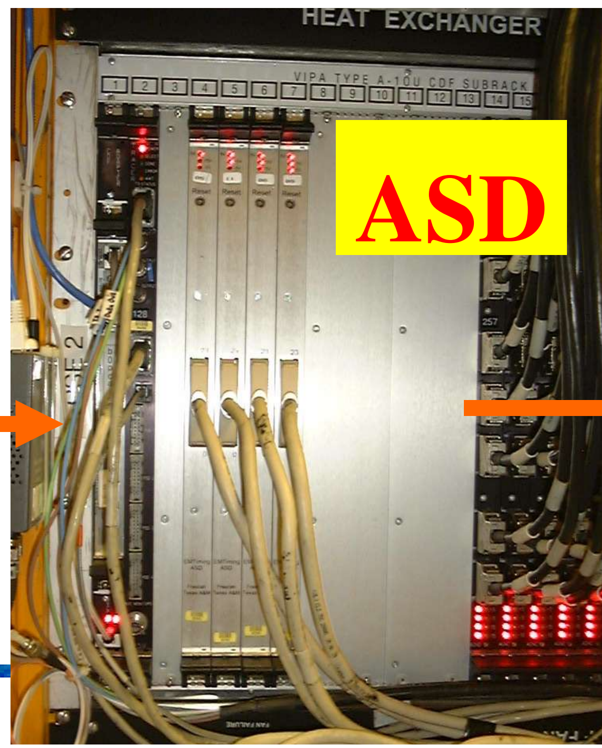


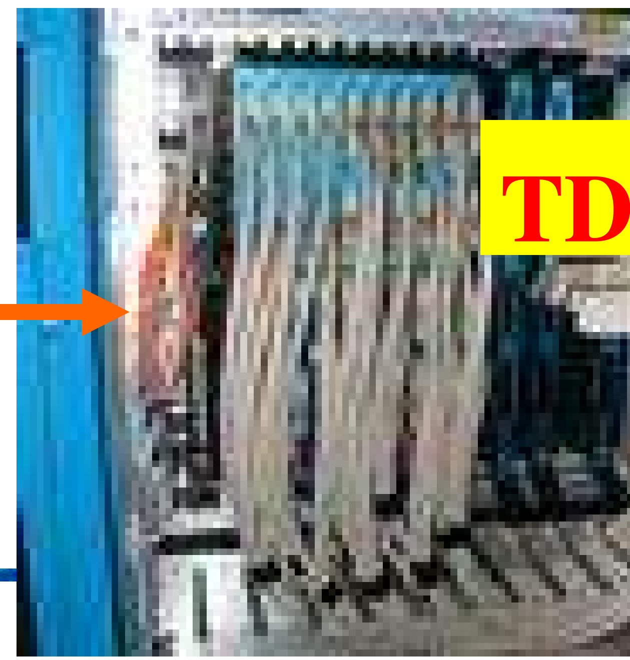
- Production of all components completed in Fall of 2003, well ahead of schedule.
- Partial installation in Fall 2003.
- Finished in Dec 2004.

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

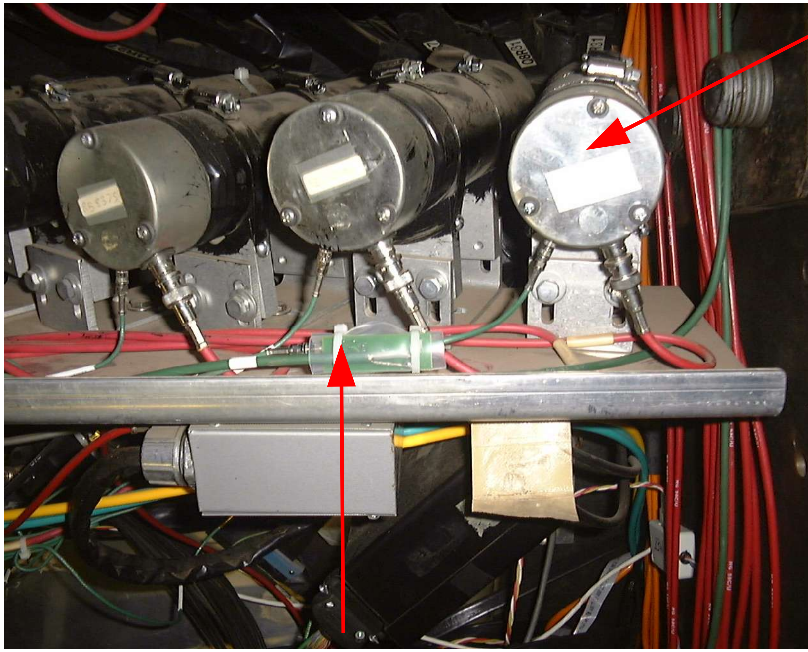
Readout path







Biggest Challenge



CEM PMT Base

anode provides energy readout

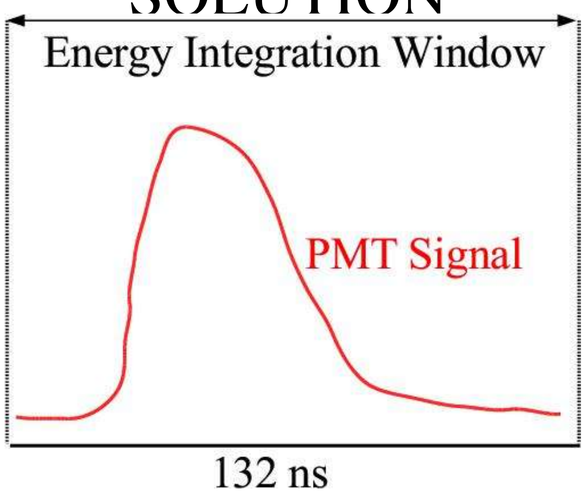
has no dynode readout ...

modify PMT base? ...

cut into the anode line? ...

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

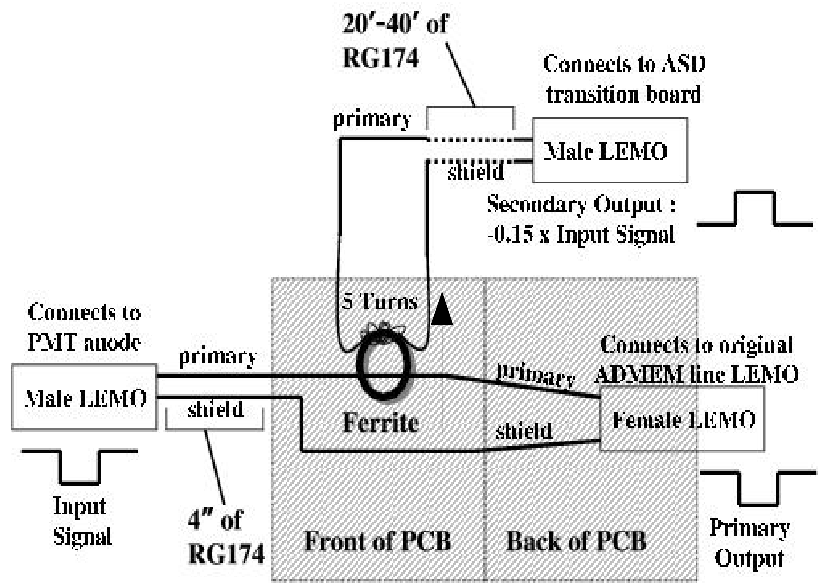
SOLUTION



Splitter for Central Detector

Do not touch charge – do not change energy readout.

EMTiming Splitter



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

Current Status

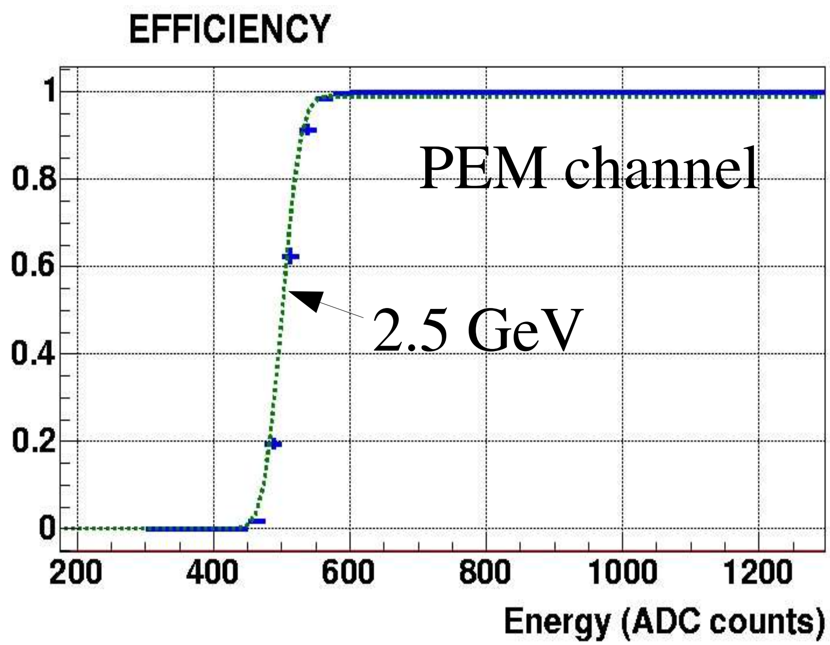
- ~100% Efficient above thresholds (CEM-5, PEM-2.5 GeV)
- System resolution is ~0.6 ns
- Very uniform
- No Noise
- Finished full installation this October (2 years ahead of original Run IIb schedule). Started taking data in January 2005 (0.6 fb^{-1} and counting)
  - <1% had problems right after installation (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

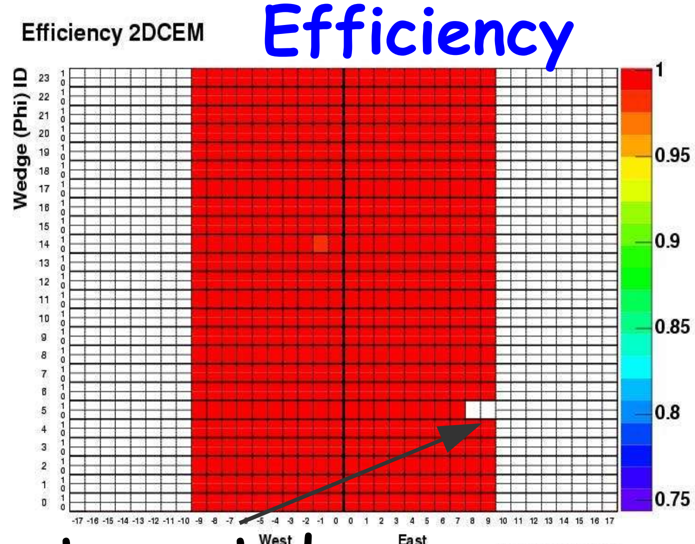
No Data can be left behind – monitor online in real time

Efficiency curves show most problems right away



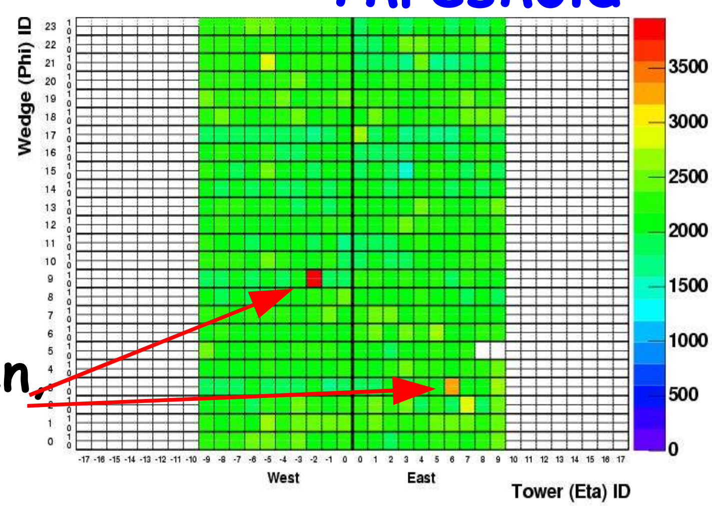
Threshold=5.0 GeV in CEM
2.5 GeV in PEM

Efficiency



Not instrumented

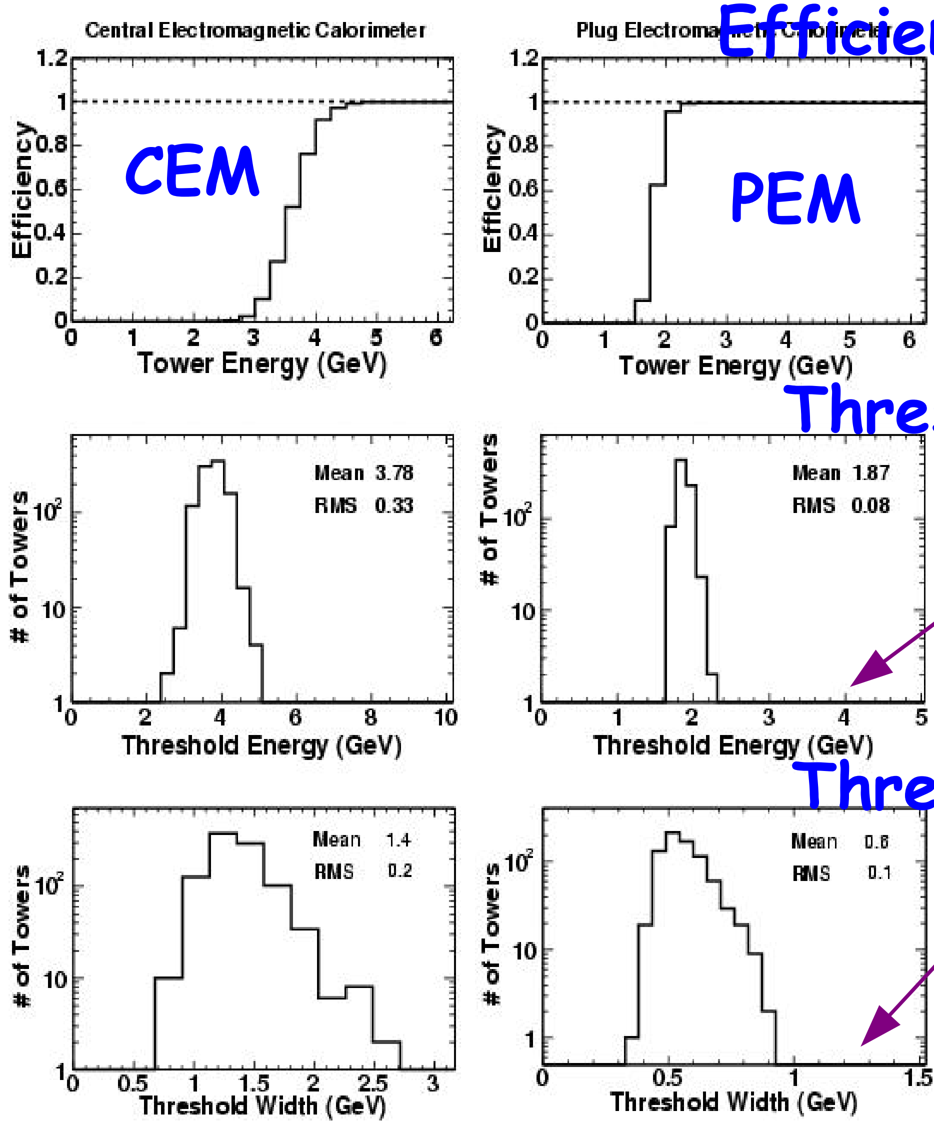
Threshold



One line is broken, fixed right away

Efficiency and Uniformity

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



Efficiency

100 % above threshold

Threshold Energy

Uniform

Broken channel would be here

Threshold Width

... and here

Uncorrected Time

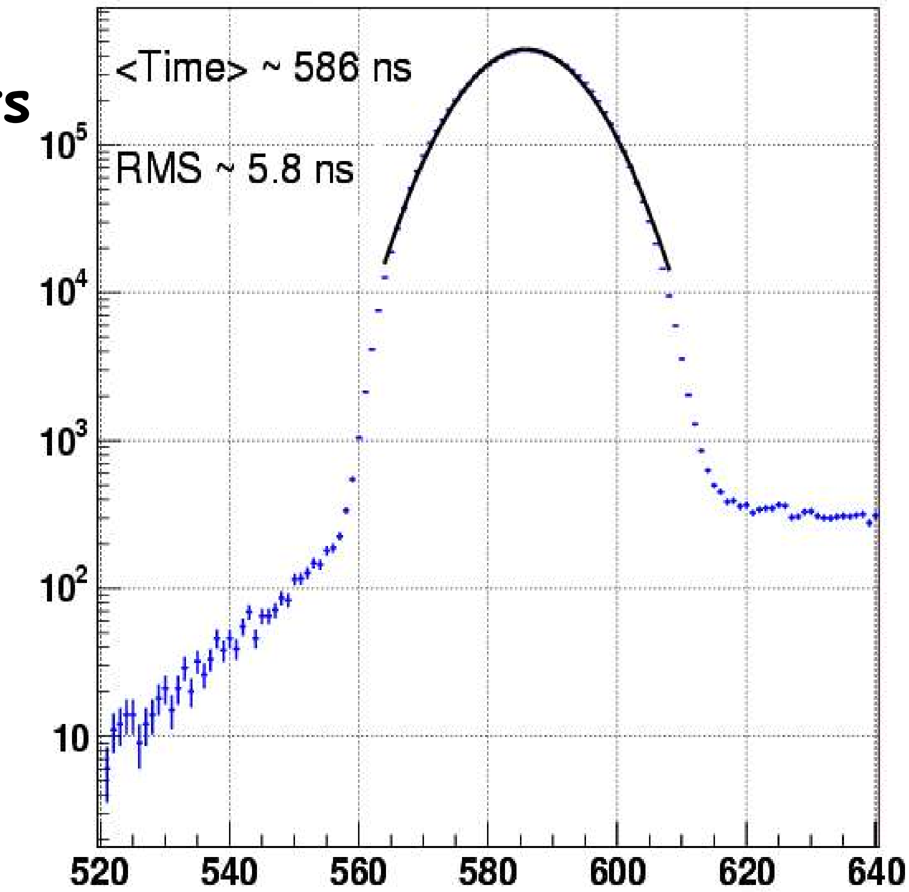
Can not use in the analysis data as it is

=> have to calibrate

Calibrations take out various effects

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

CEM

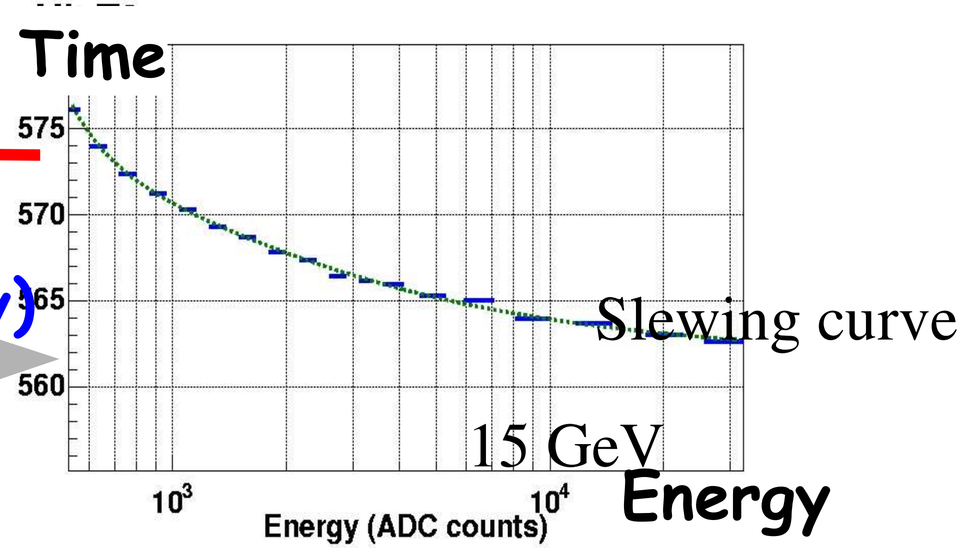


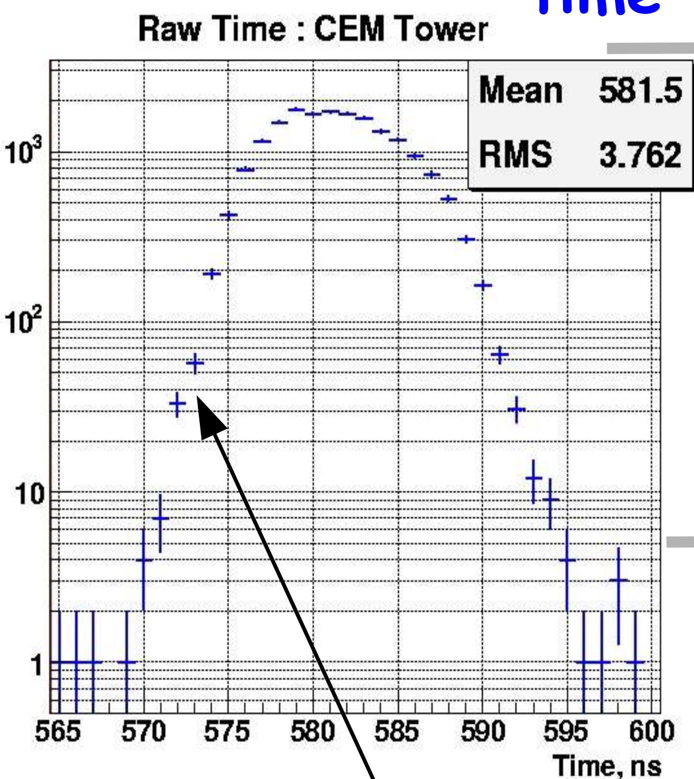
Time, ns

Calibrations

Database:for each channel f(Energy)

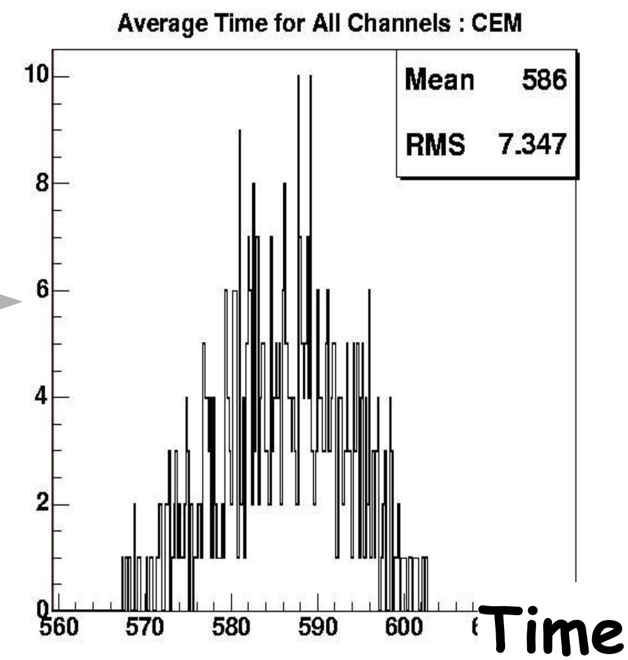
time = f(Energy)





Non-Gaussian form

All channels <time>



System Resolution

After slewing calibrations various effects remain:

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

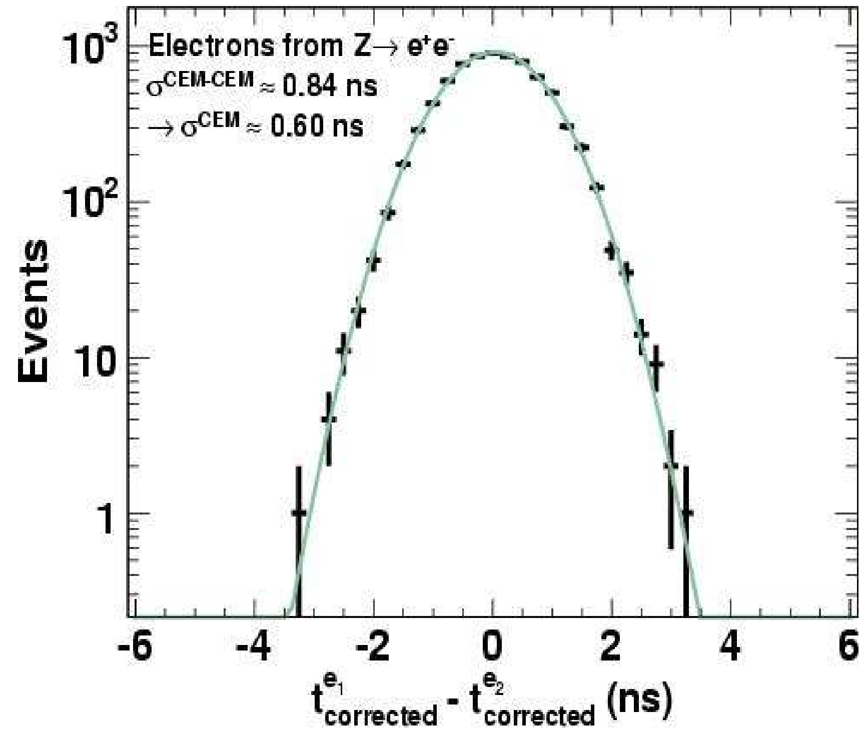
Z->ee sample is perfect to find the resolution

Plot time(e1)-time(e2):

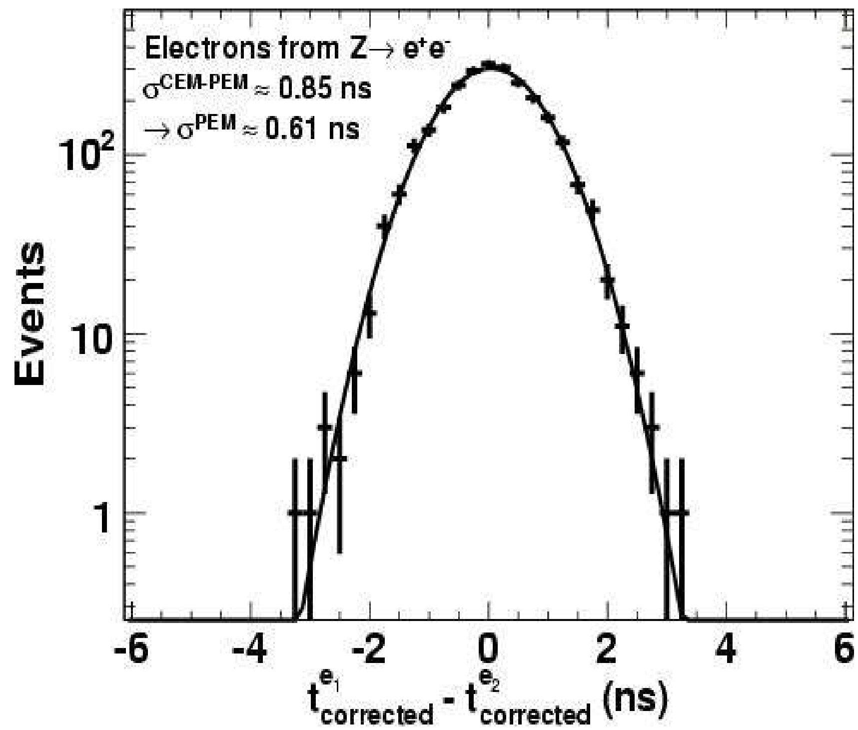
most of the effects cancel out

System Resolution

CEM – 0.60 ns

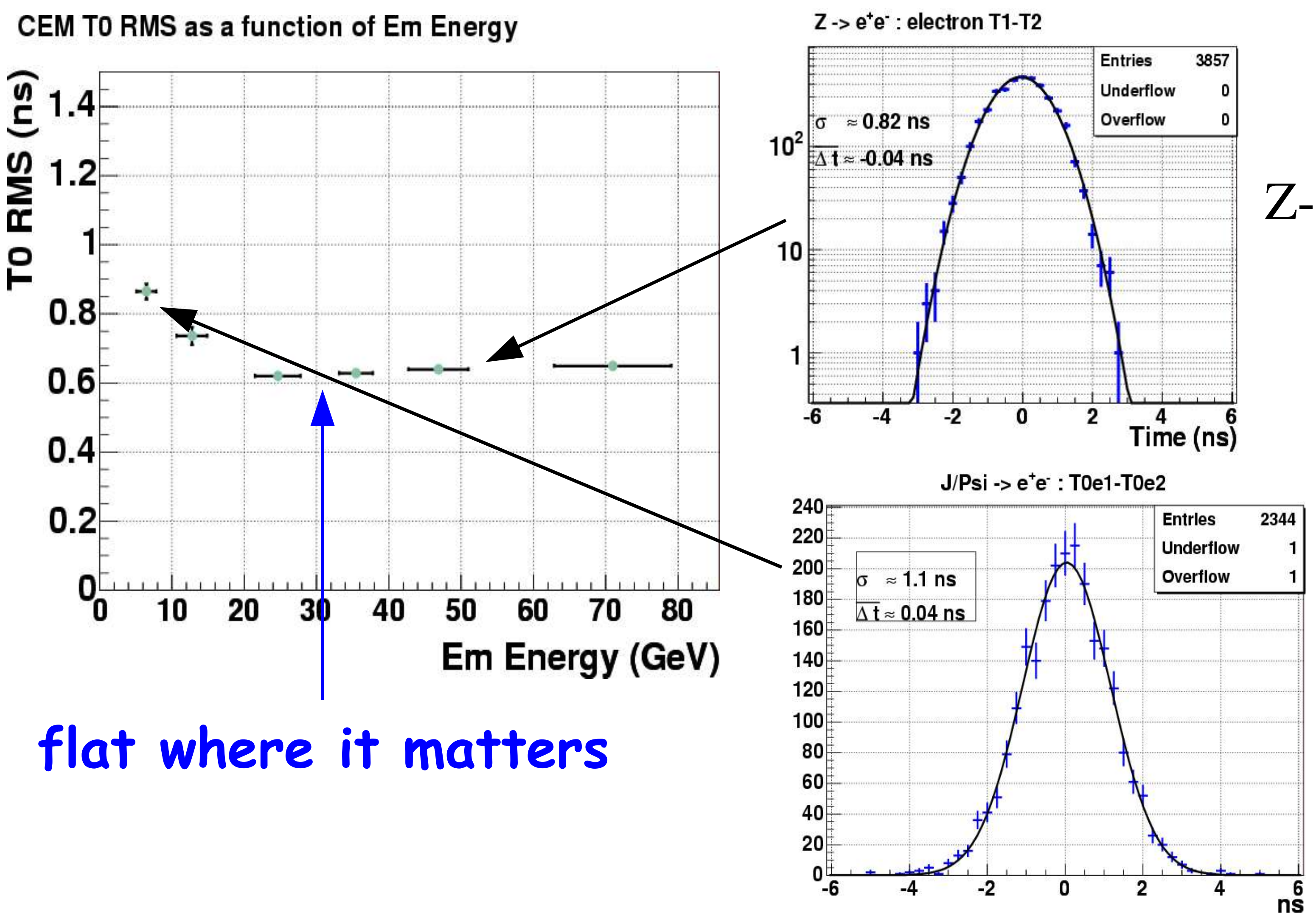


PEM – 0.61 ns



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

Resolution vs Energy



Z->ee

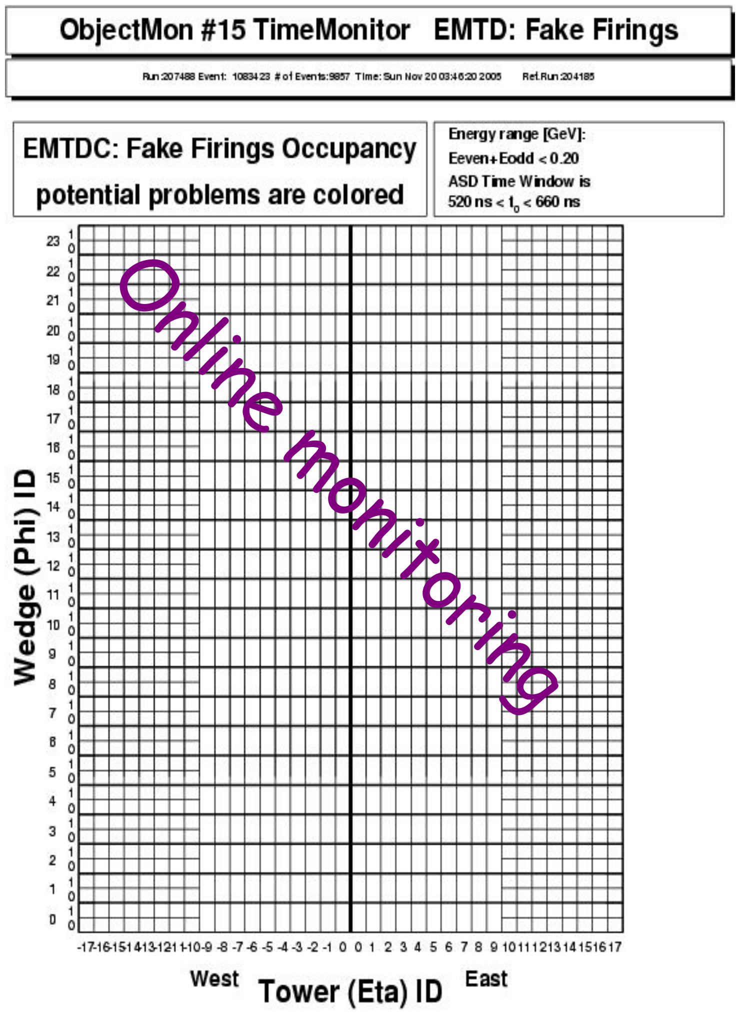
J/Psi->ee

flat where it matters

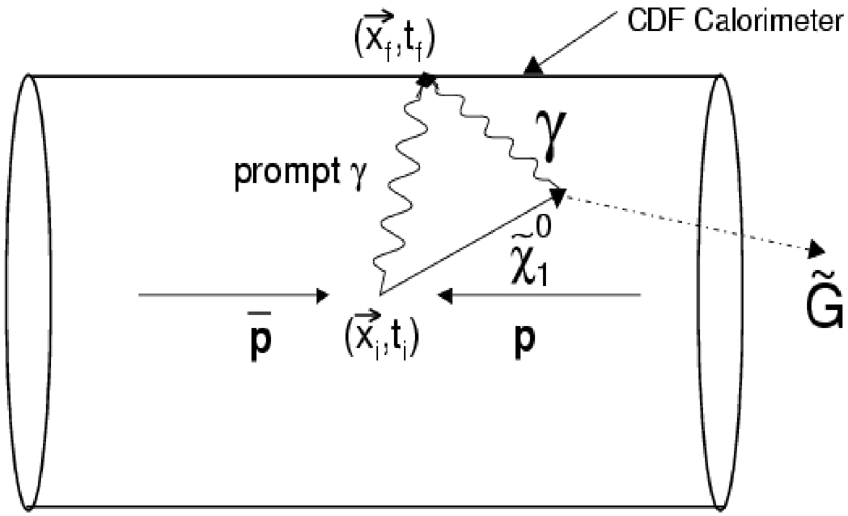
Noise Levels

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

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

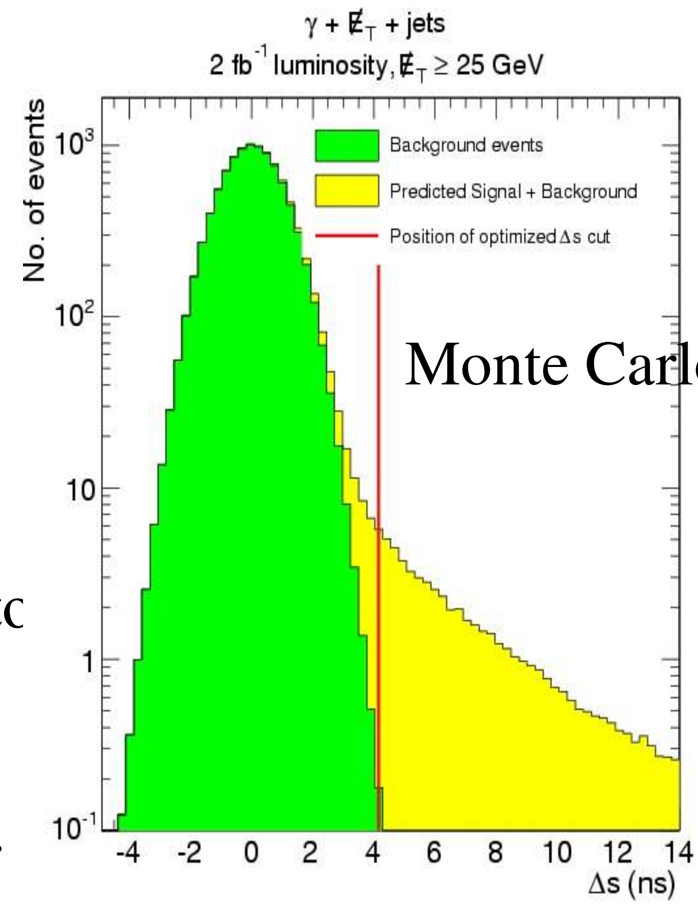


Heavy Long Lived X



Look for non-prompt γ's that take longer to reach calorimeter.

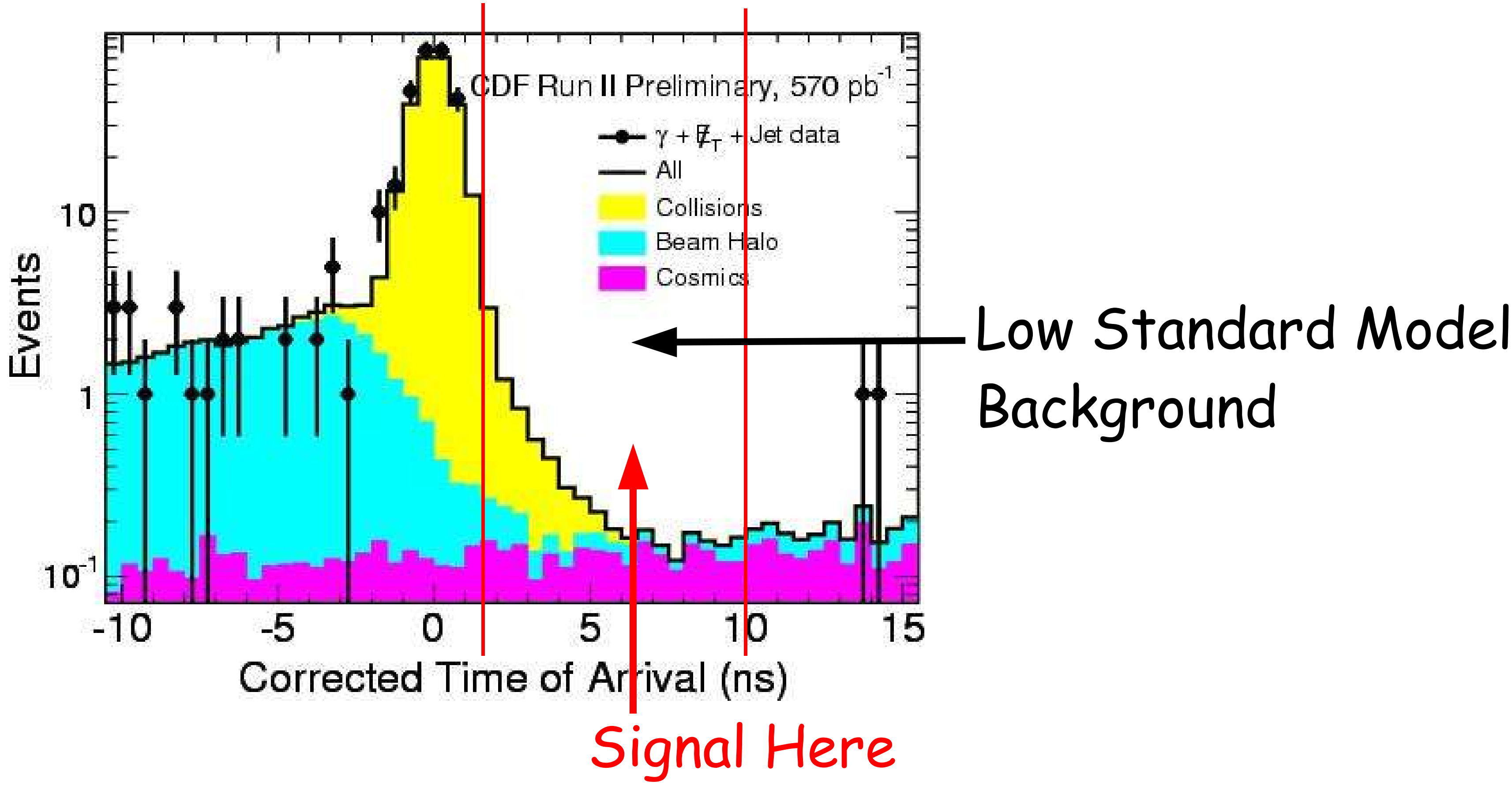
If the has a significant lifetime, we can separate the signal from the backgrounds.



First count

Shape later

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 and e, threshold 5.0 GeV in CEM
2.5 GeV in PEM

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

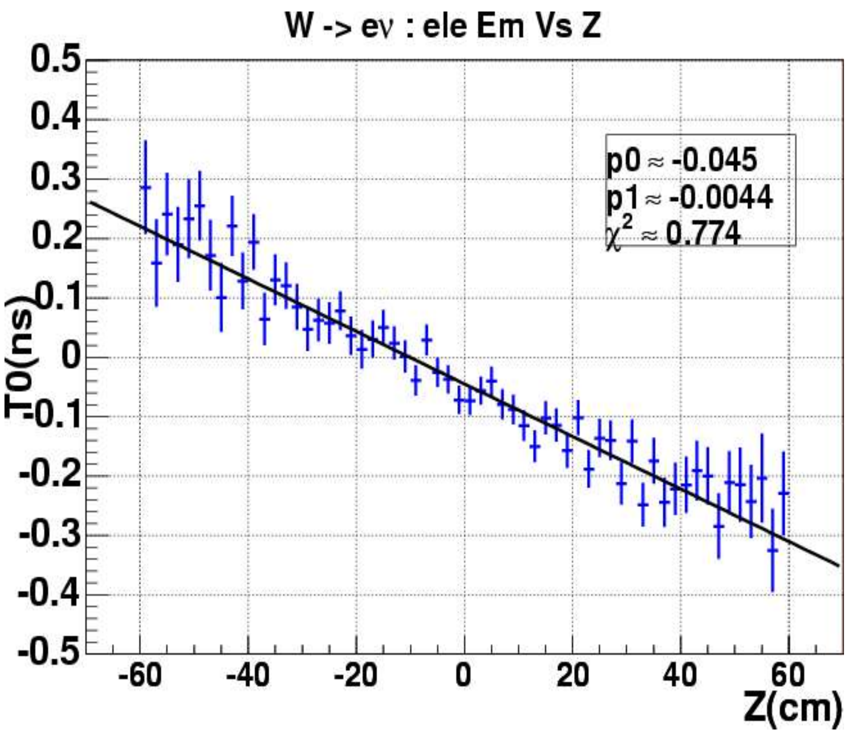
We use it to fight backgrounds from Cosmic Rays, Beam Halo, Pmt Spikes, ...

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)

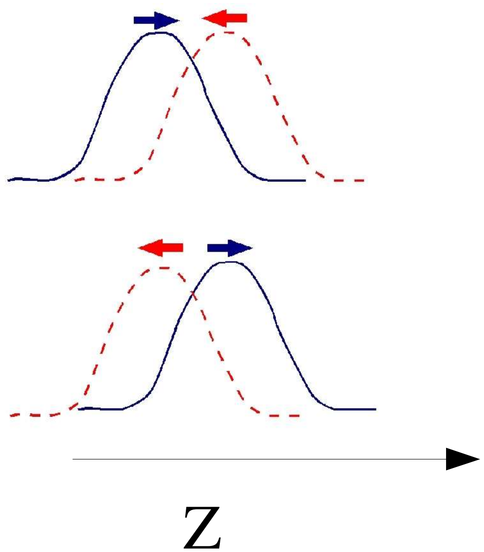
Backup Slides

Beam Width



▲(p) 55cm

▲(pbar) 65cm

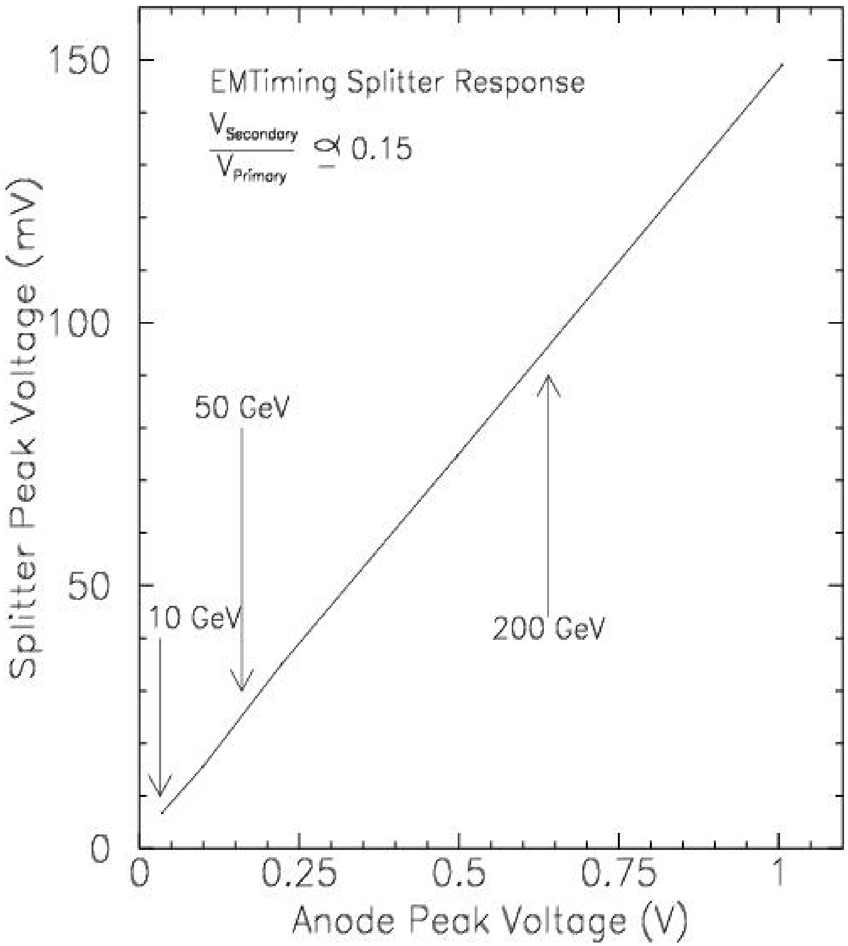


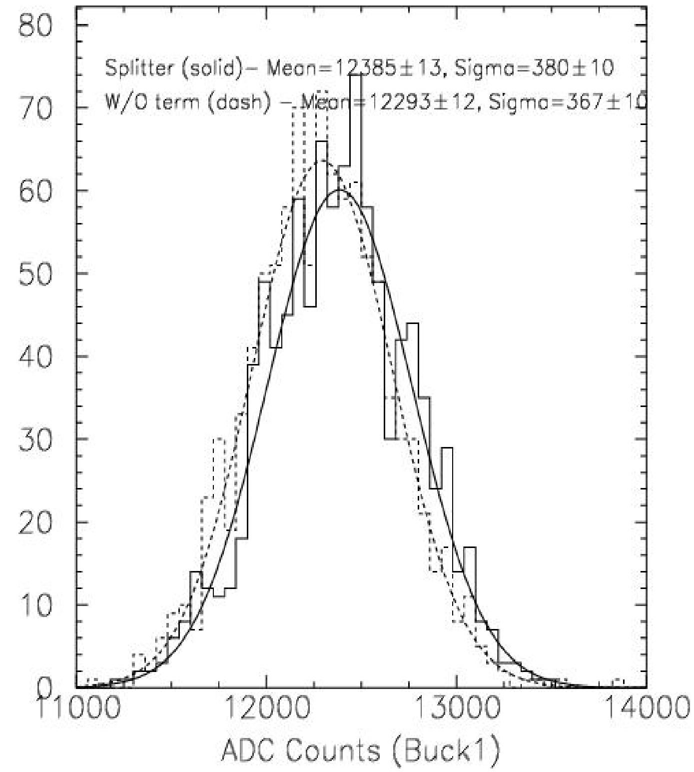
Average z position of the interaction is given by

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

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