TOF with RF Phototube
Possible Application at HPiS

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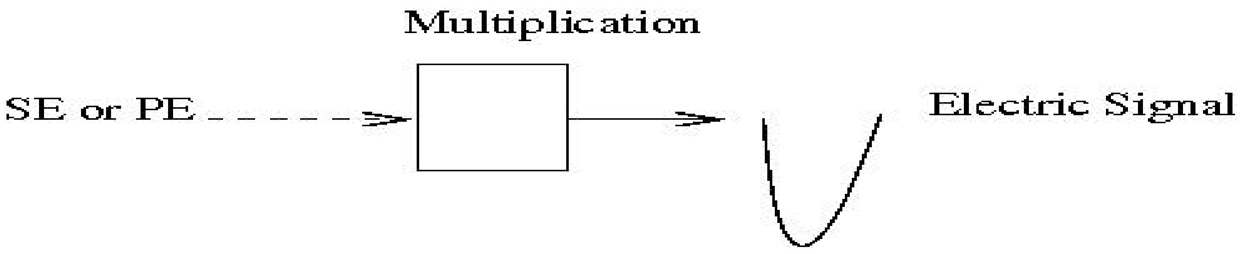
Introduction

During usual time measurements in high energy and nuclear physics experiments:

1) Time information is transferred by secondary electrons - SE or photoelectrons - PE;

2) The SE and PE are accelerated, multiplied and converted into electrical signals, e.g. by using PMTs or other detectors;



3) Electrical signals are processed by common nanosecond electronics like discriminators and time to digital converters, and digitized.

- Parameters:

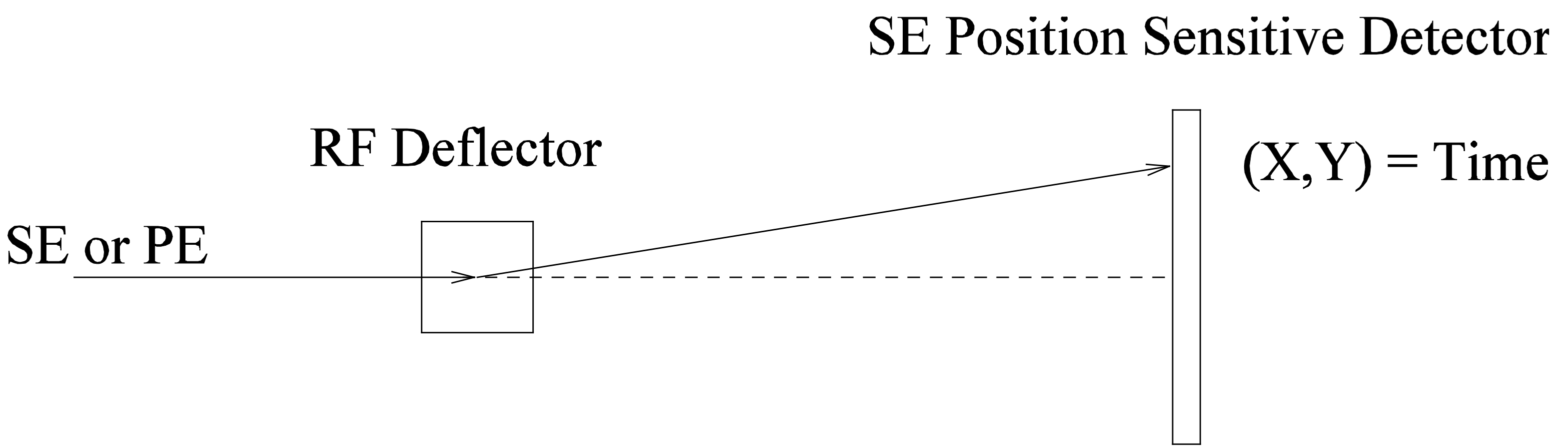
  a) Nanosecond signals;

  b) The limit of precision of time measurement of single PE is in range 50-100 ps (FWHM).

  c) The time drift is ~1ps/s (mainly due to electronics).

Radio Frequency Time Measuring Technique or Streak Camera Principle or Oscilloscopic Method

1) Time information is transferred by SEs or PEs;
2) The electrons are accelerated and deflected by means of ultra high frequency RF fields;



Parameters:

a) The limit of precision of time measurement of single SE or PE is $\sigma \approx 1$ ps;

b) High and long-term stability - 200 fs/h - can be reached;

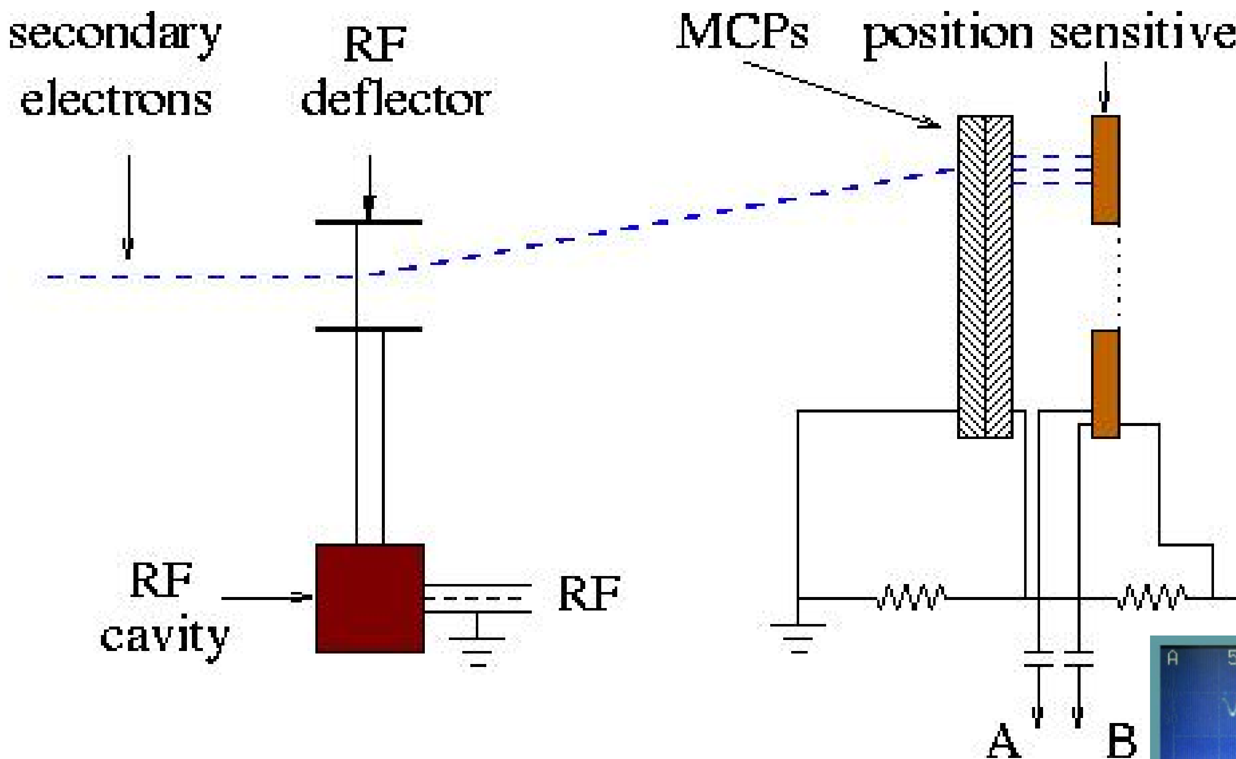
c) Time drift is ~10fs/s.

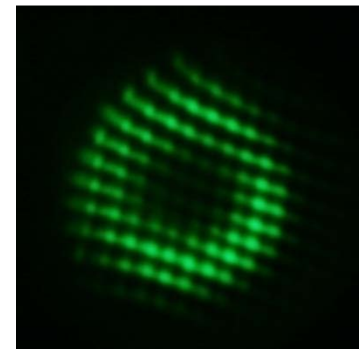
Commercial Streak Cameras provide slow or averaged information

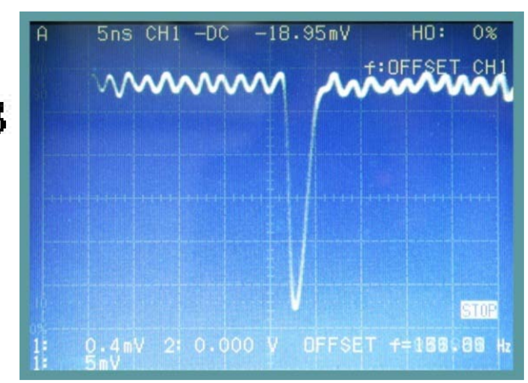
This may be is the reason why they don't find wide application in particular in the high energy and nuclear physics experiments like regular PMTs.

500 MHz RF Time Measuring Technique

Operates like circular scan streak camera but provides nanosecond signals like regular PMT





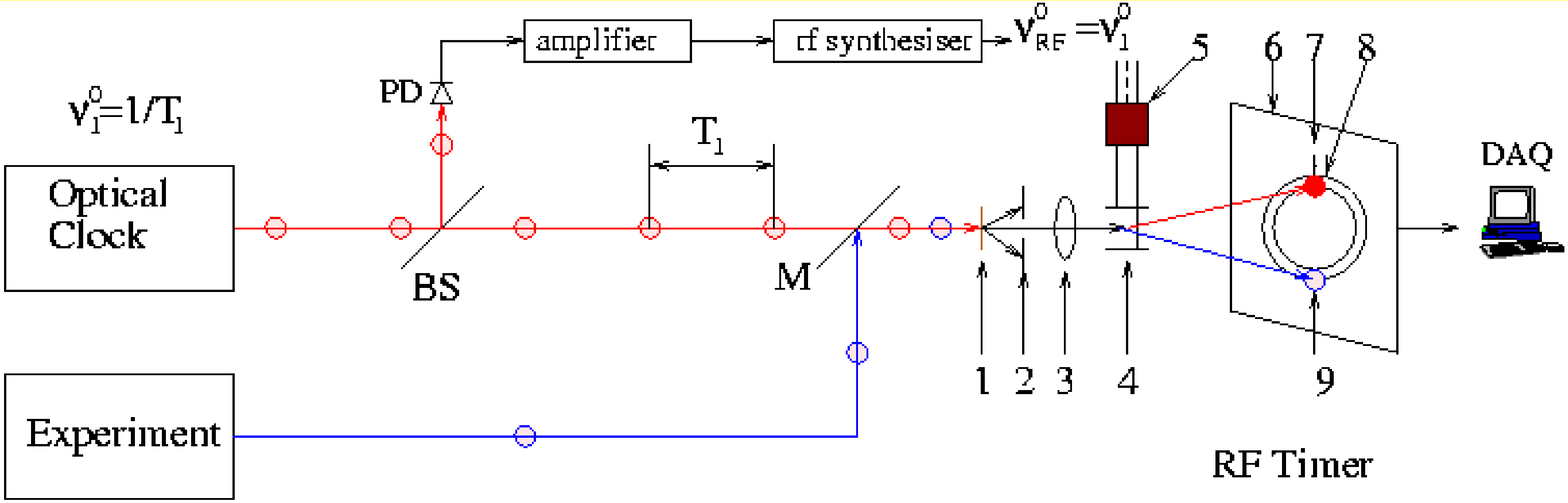


Schematic layout of the new RF time measuring technique

RF Phototube

- High rate ~ MHz operation, like regular PMT's
- High resolution ~ ps for single PEs (20 ps in our case)
- Synchronized operation with Optical Clock and/or any RF driven beam, e.g. JLab electron beam

RF phototube + optical clock



The schematic layout of the synchroscan mode with optical clock.

Optical Comb + RF Phototube = H^3 Timing Technique

High Rate ~ MHz

High Resolution < 20 ps

Highly Stable < 10 fs/hrs

RF Phototube + Optical Clock

Level of Instability

- RF Phototube/Streak Camera < 10 fs/hrs

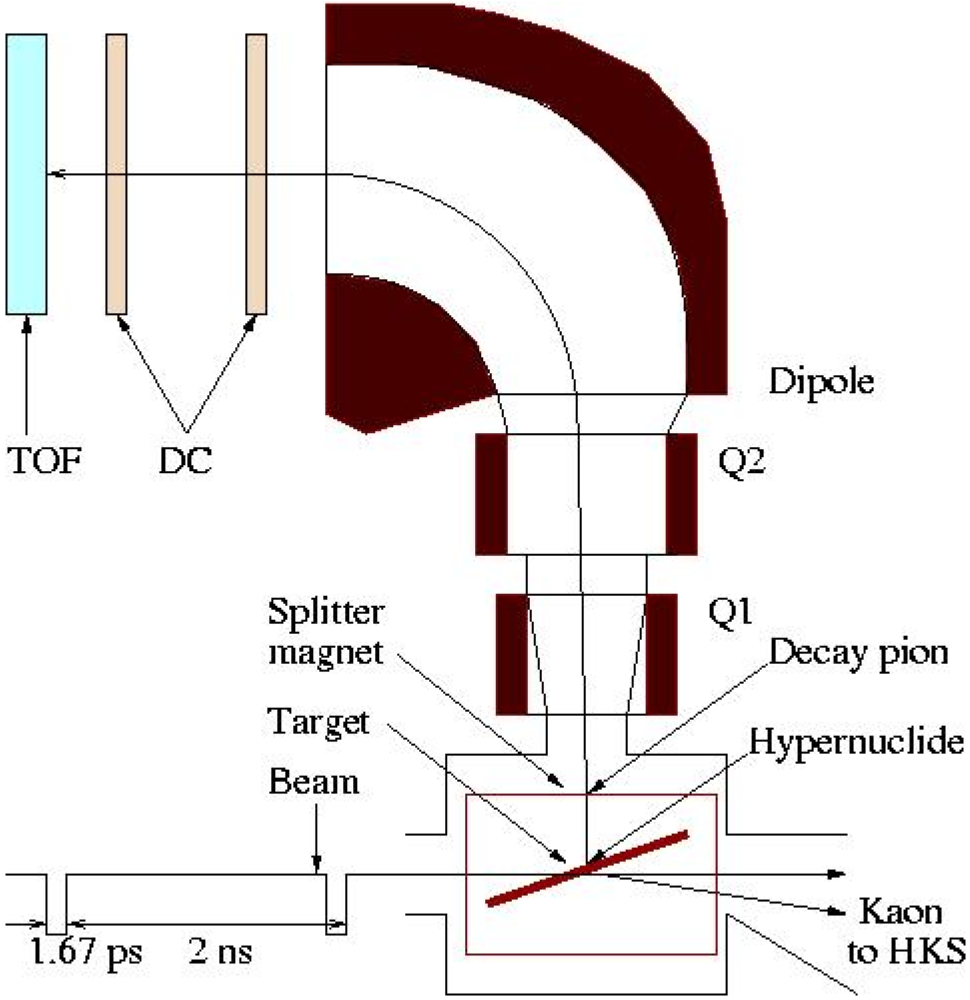
  W. Uhring et al., Rev. Sci. Instr. V.74, 2003

- Optical clock + RF synthesizer < 10 fs/sqrt(t) t in sec

  T. M. Ramond et al., 2003

Systematic drifts for any relative measurements between two particles or particle and reference beam in time interval less than 1sec is < 10 fs

Decay Pion Spectroscopy of Hypernuclei at JLab

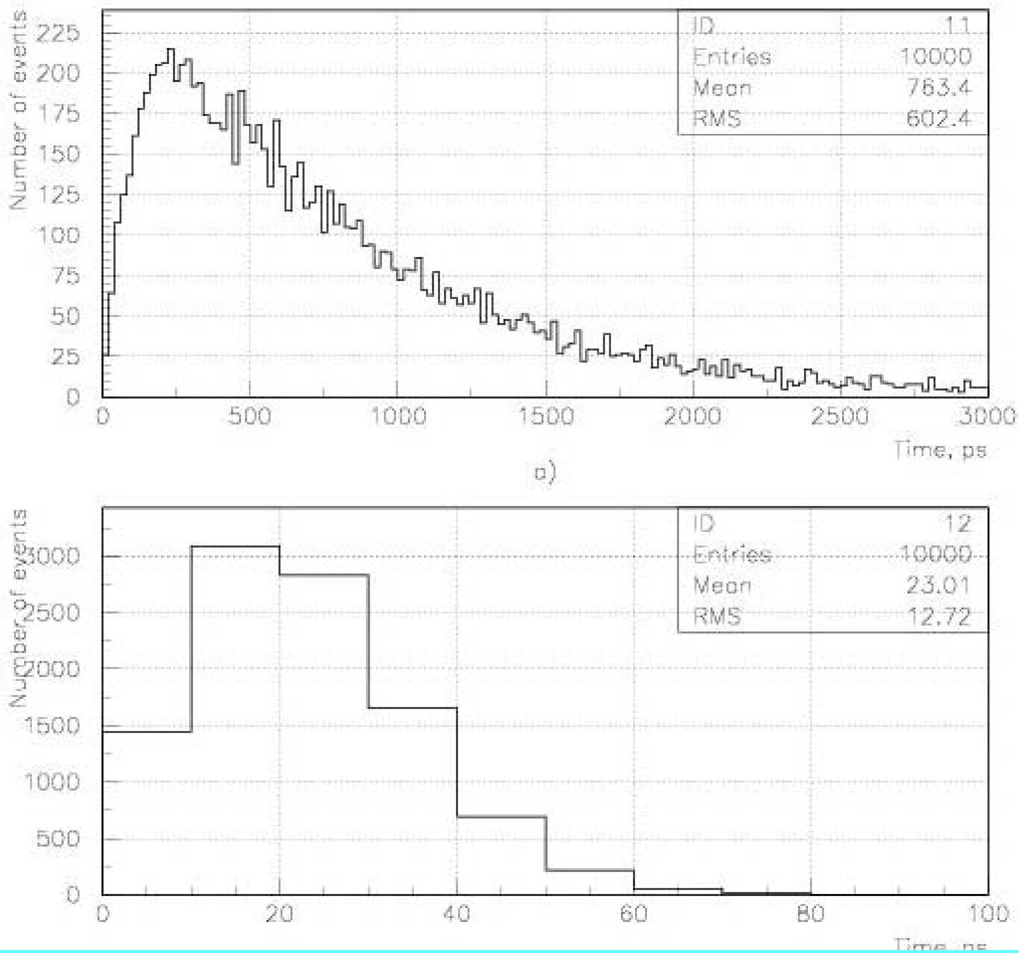


Tracking: to measure momentum of particles (electrons and pions and etc.); reconstruct particle trajectories and group particles with identical momenta and flight paths

Timing: to reconstruct production time and TOF of electrons and pions

Schematic of the decay pion spectrometer- HπS

TOF Detector: MC Simulation



(a)- two exponential fluorescence decay time distribution, 100 ps rise time, 700 ps decay time, BC-422Q; (b) early arriving photoelectron time distribution from total number of 250 photoelectrons, PE. Time resolution for single PE rms = 20 ps .

HπS Calibration by TOF

From TOF Concept for particles with identical L and p we have

$$t_e = L/(\beta_e c) = (L/c)\sqrt{1 + m_e^2 c^2 / p^2}$$

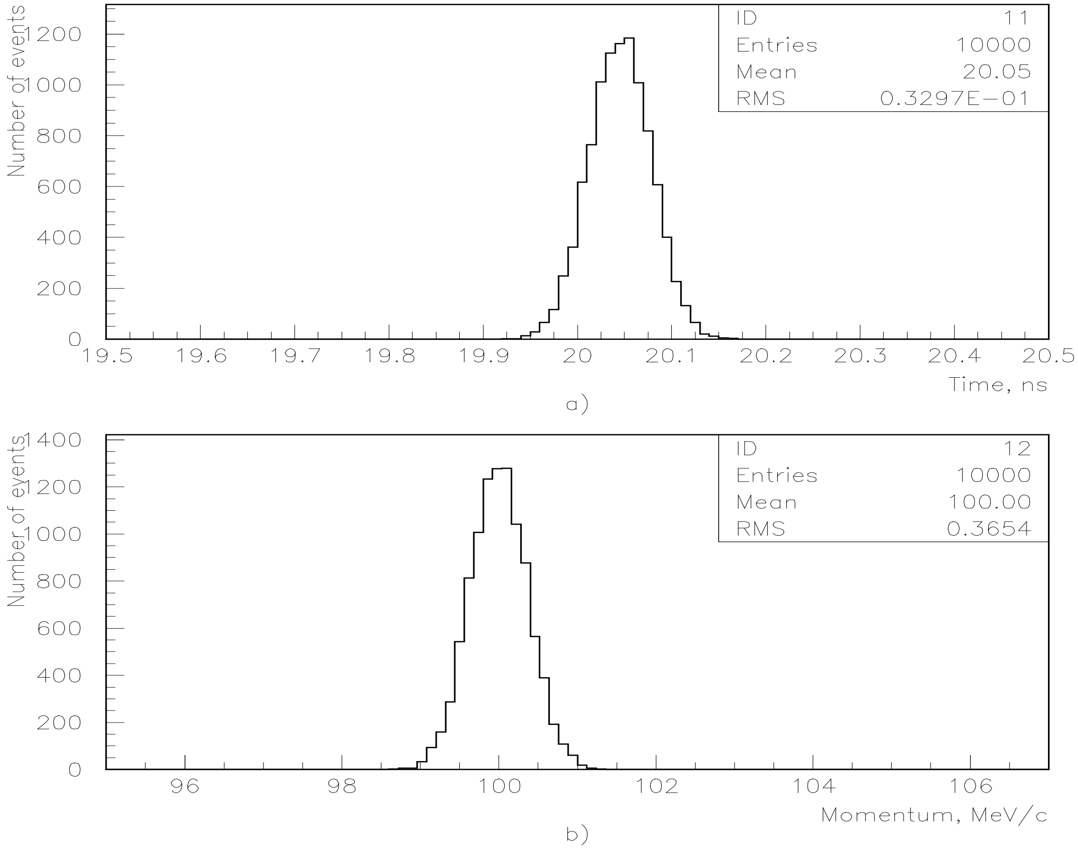
$$t_\pi = L/(\beta_\pi c) = (L/c)\sqrt{1 + m_\pi^2 c^2 / p^2}$$

From these two equations we have

$$L/c = \sqrt{\frac{t_e^2 m_\pi^2 - t_\pi^2 m_e^2}{m_\pi^2 - m_e^2}}$$

$$p_\pi = (L/c)\frac{m_\pi c}{\sqrt{t_\pi^2 - (L/c)^2}}$$

HπS Calibration: MC simulation

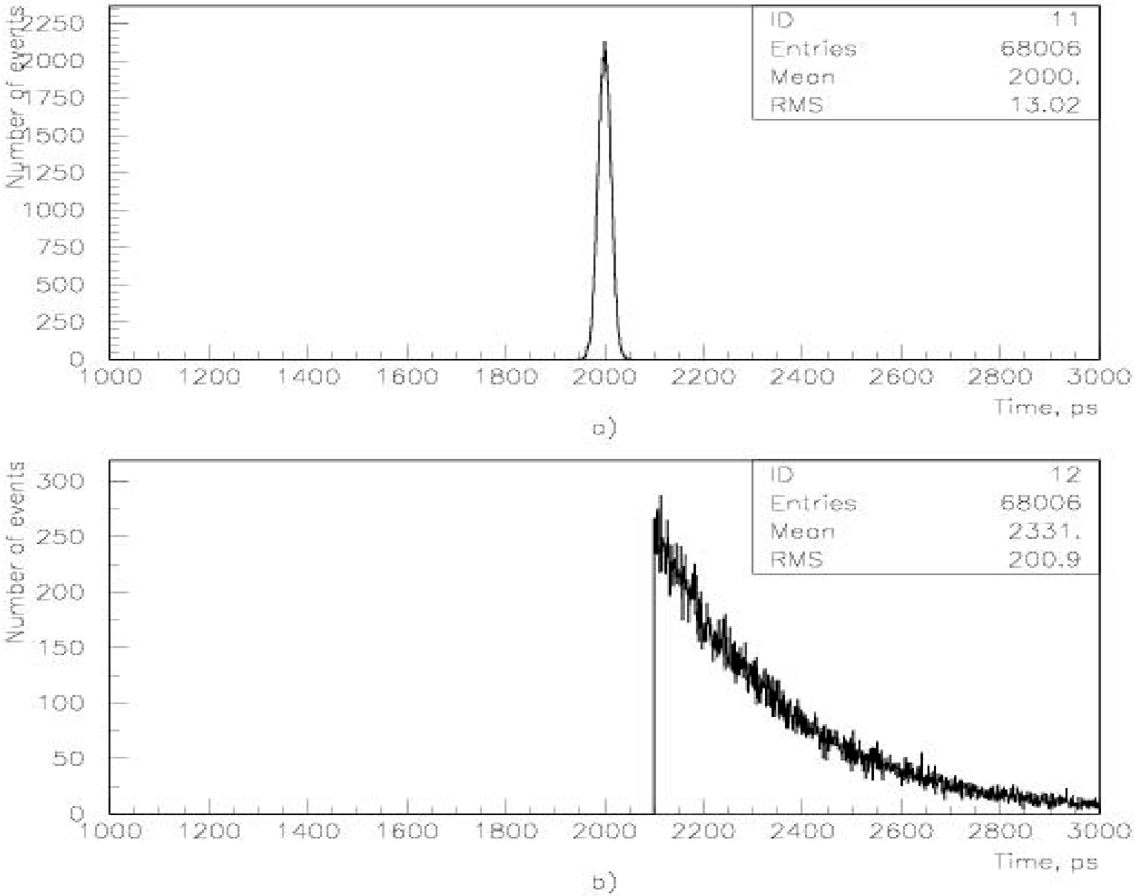


Incident parameters: p_π = 100 MeV/c, σ_p= 200 keV, L = 3.5 m, σ_t = 20 ps.

(a) Measured (simulated) 100 MeV/c pion TOF distribution

(b) Pion momentum distribution (reconstructed from measured electron and pion TOFs)

Delayed Particle Spectroscopy
Decay pion separation by time measurement



Reconstructed time distributions. Total number of events is 100000.

(a) prompt pions (no prompt pions with t>100 ps) , (b) delayed pions (~70% delayed pions with t>100 ps). Total time resolution = 30 ps FWHM.

TOF with RF Phototube at HπS

Summary

- No kaon detection
- Produced hypernucleus is identified only by reconstructed TOF with ~70% efficiency (Delayed Particle Spectroscopy)
- All useful virtual photon spectra is participated
- Rates is increased ~20-30 times in comparison with HπS+HKS experiment
- Continuous on-line calibration of HπS with precision ~10^{-4}