Measurement of the Decay Rate of Orthopositronium

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Introduction: Positronium

Property	***Electron***	***Positron***
Mass	511 keV/c^2	511 keV/c^2
Charge	-e	+e
Spin	1/2	1/2

Two states of positronium:

- Spin 0: Parapositronium
- Spin 1: Orthopositronium

Previous Experiments

QED vacuum decay rate: 7.038 236 (10) μs^{-1}

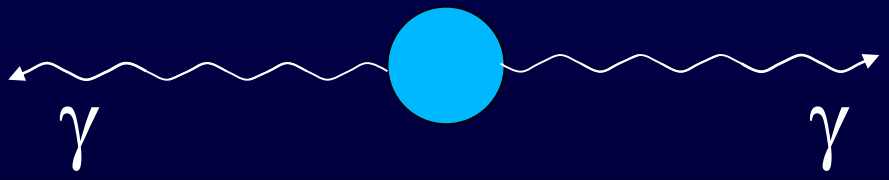
Experiment	Formation	Decay Rate
Beers & Hughes (1968)	Moderating Gas	7.275 (15) μs^{-1}
Coleman & Griffith (1973)	Moderating Gas	7.262 (15) μs^{-1}
Gidley et al (1976)	SiO_2 powder	7.104 (6) μs^{-1}
Gidley et al (2003)	Nanoporous silica film	7.0404 (18) μs^{-1}
Asai et al (2003)	SiO_2 powder	7.0396 (23) μs^{-1}

Positronium Decay

Charge-conjugation selection rule: $(-1)^{\ell+s} = (-1)^{n}$

Parapositronium:

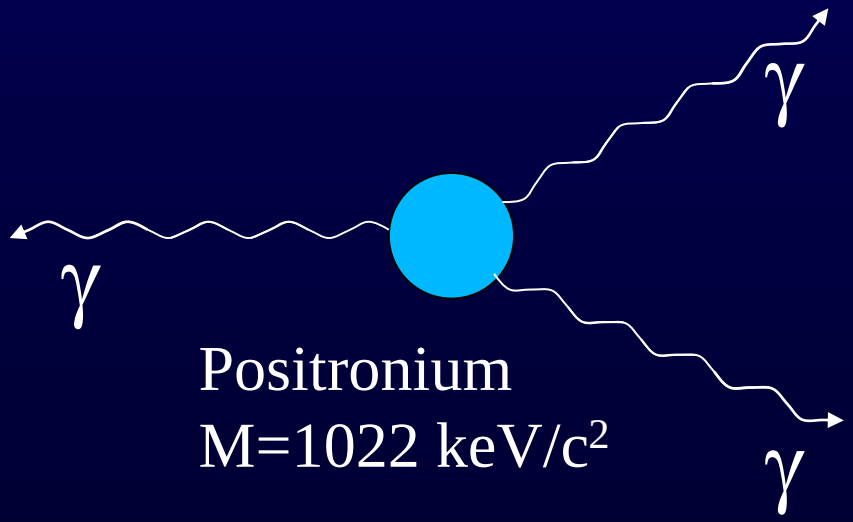
1. S=0
2. Two 511 keV gamma rays
3. Back-to-back



Positronium
M=1022 keV/c²

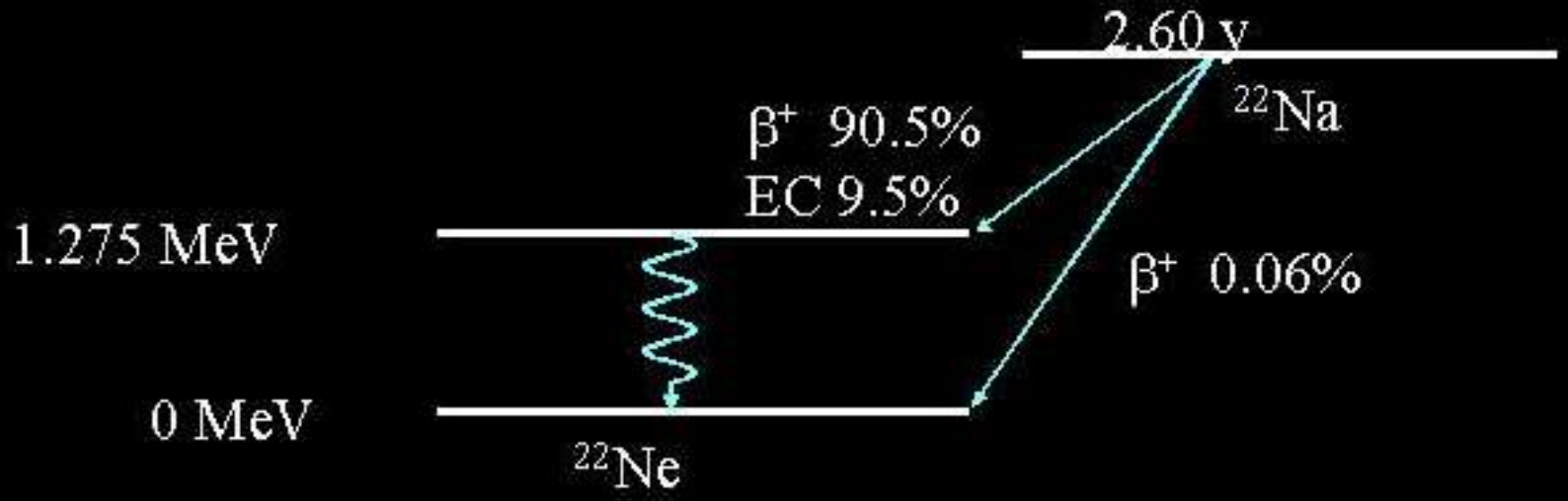
Orthopositronium:

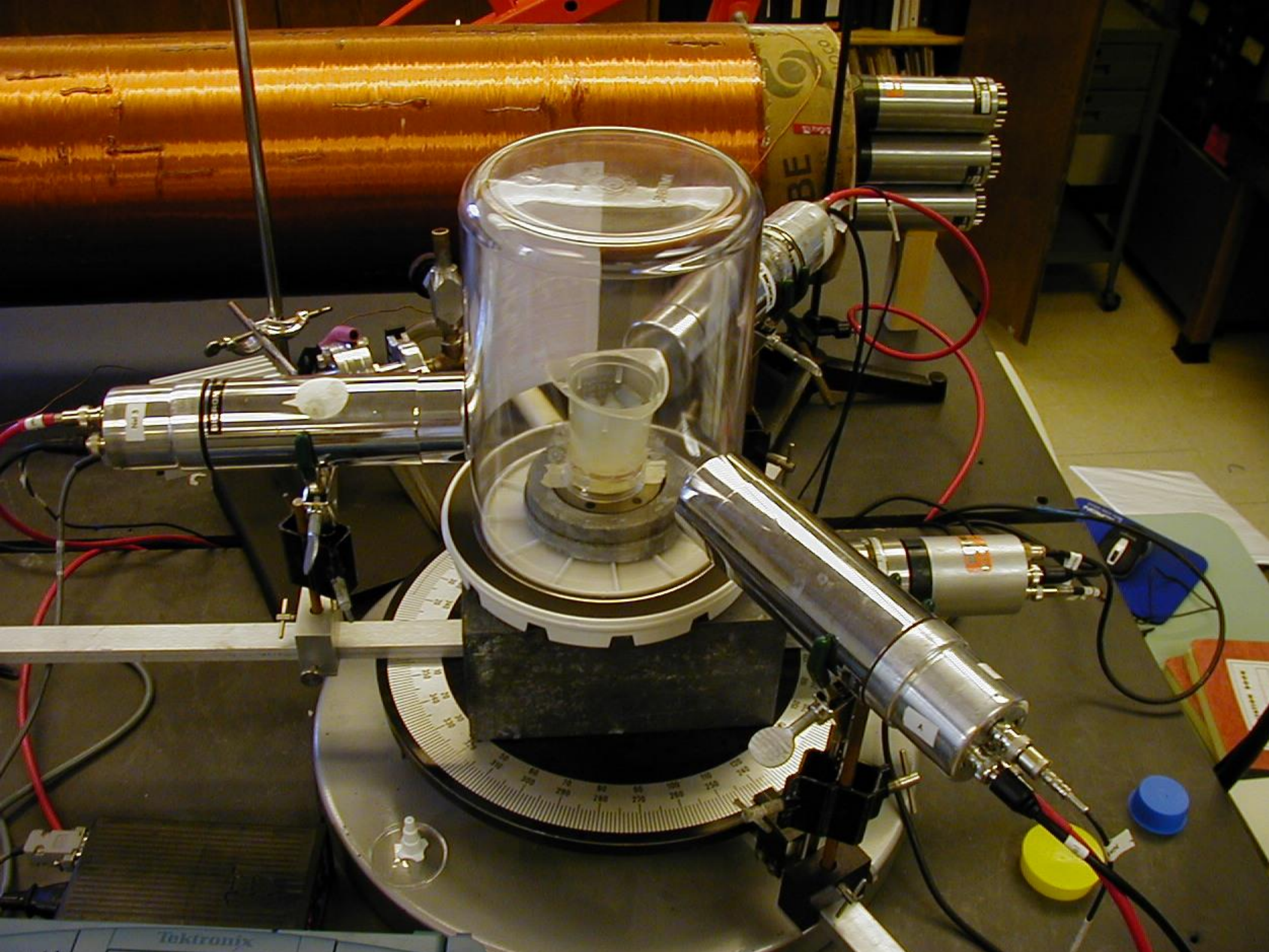
1. S=1
2. Three gamma rays
3. Variable energy/angle.



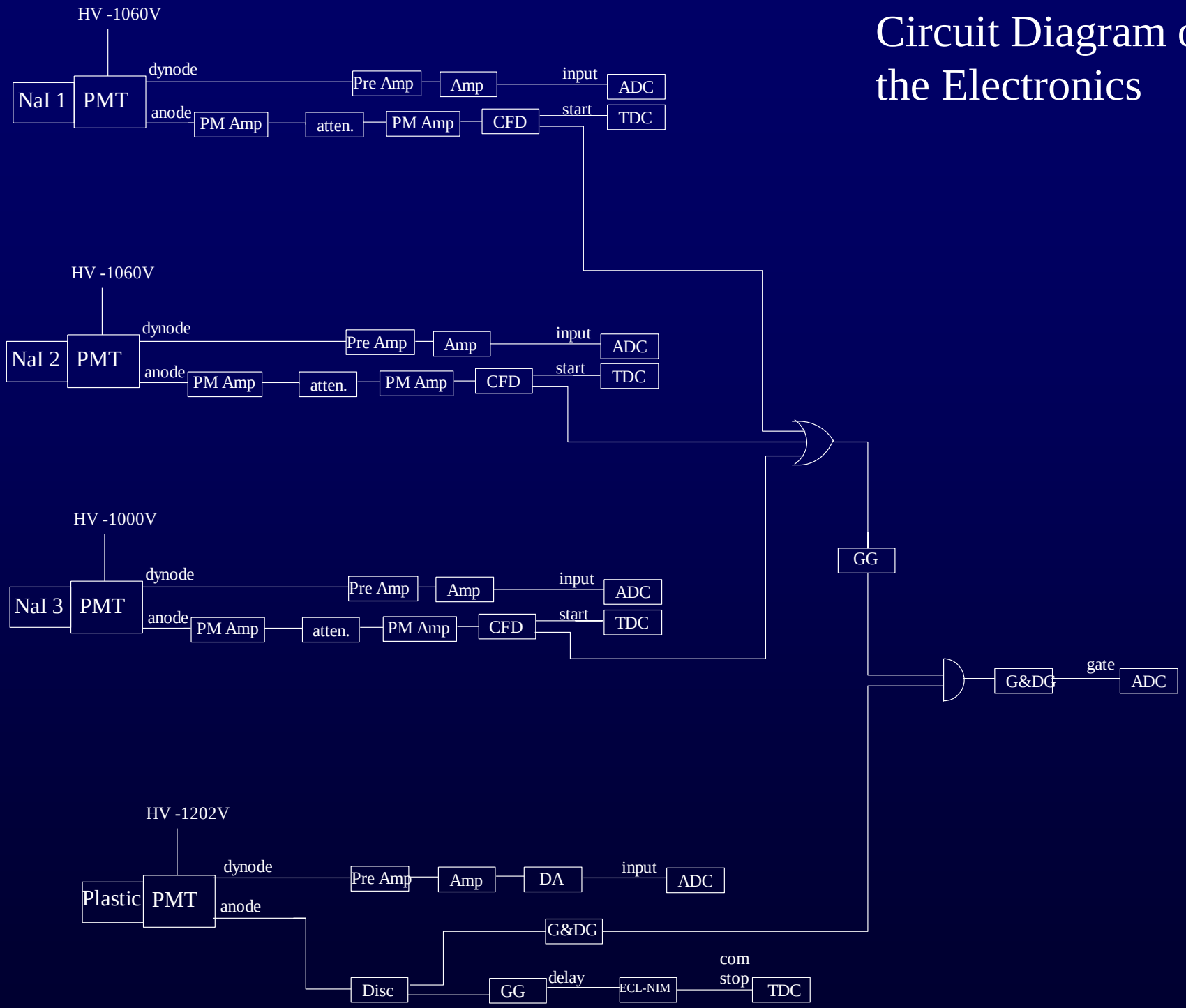
Positronium
M=1022 keV/c²

Positron Production

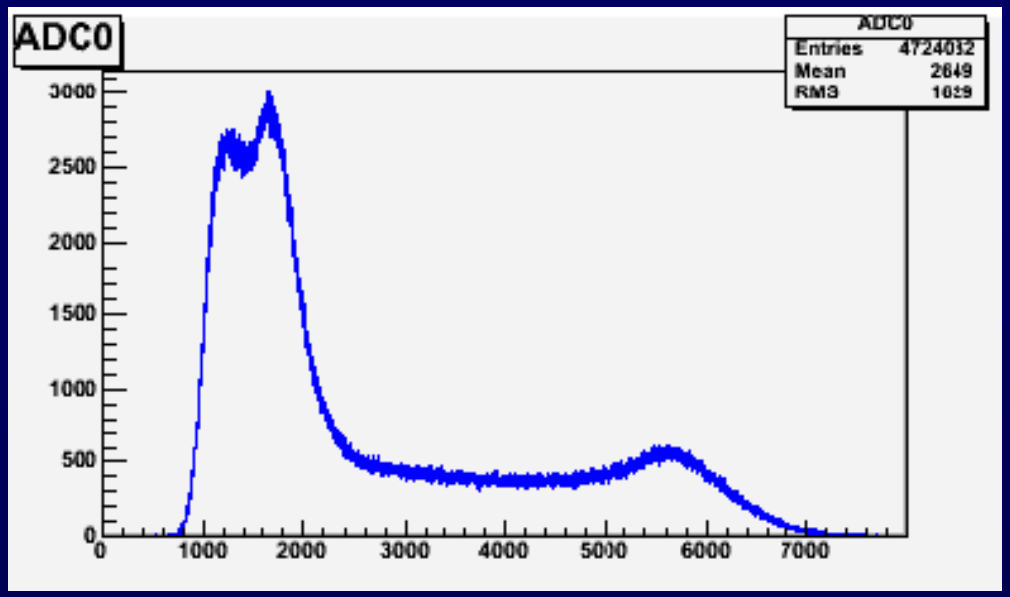



Tektronix

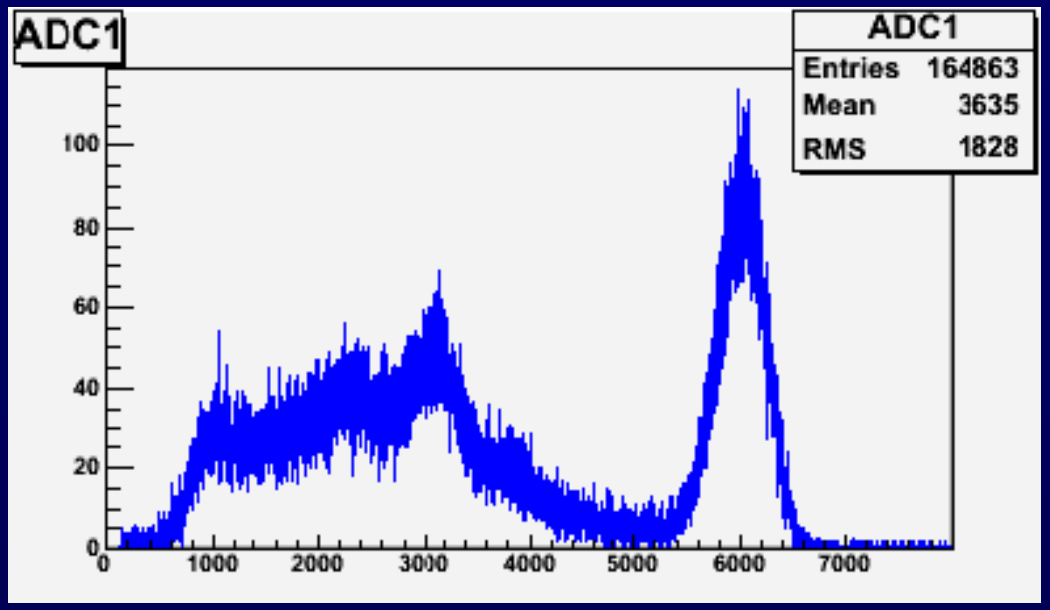
Circuit Diagram of the Electronics



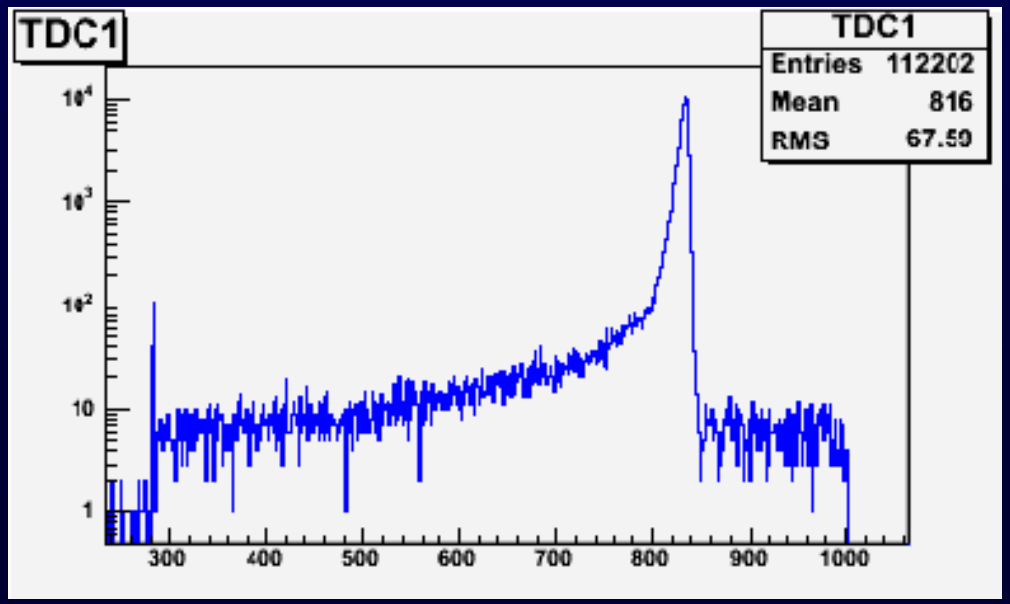
Plastic Energy Spectrum



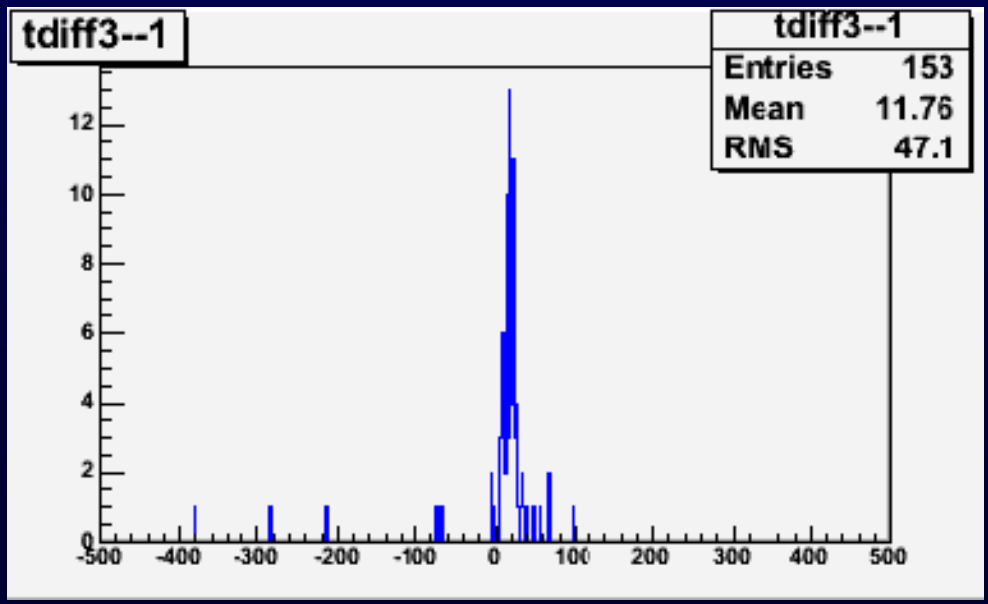
NaI Energy Spectrum



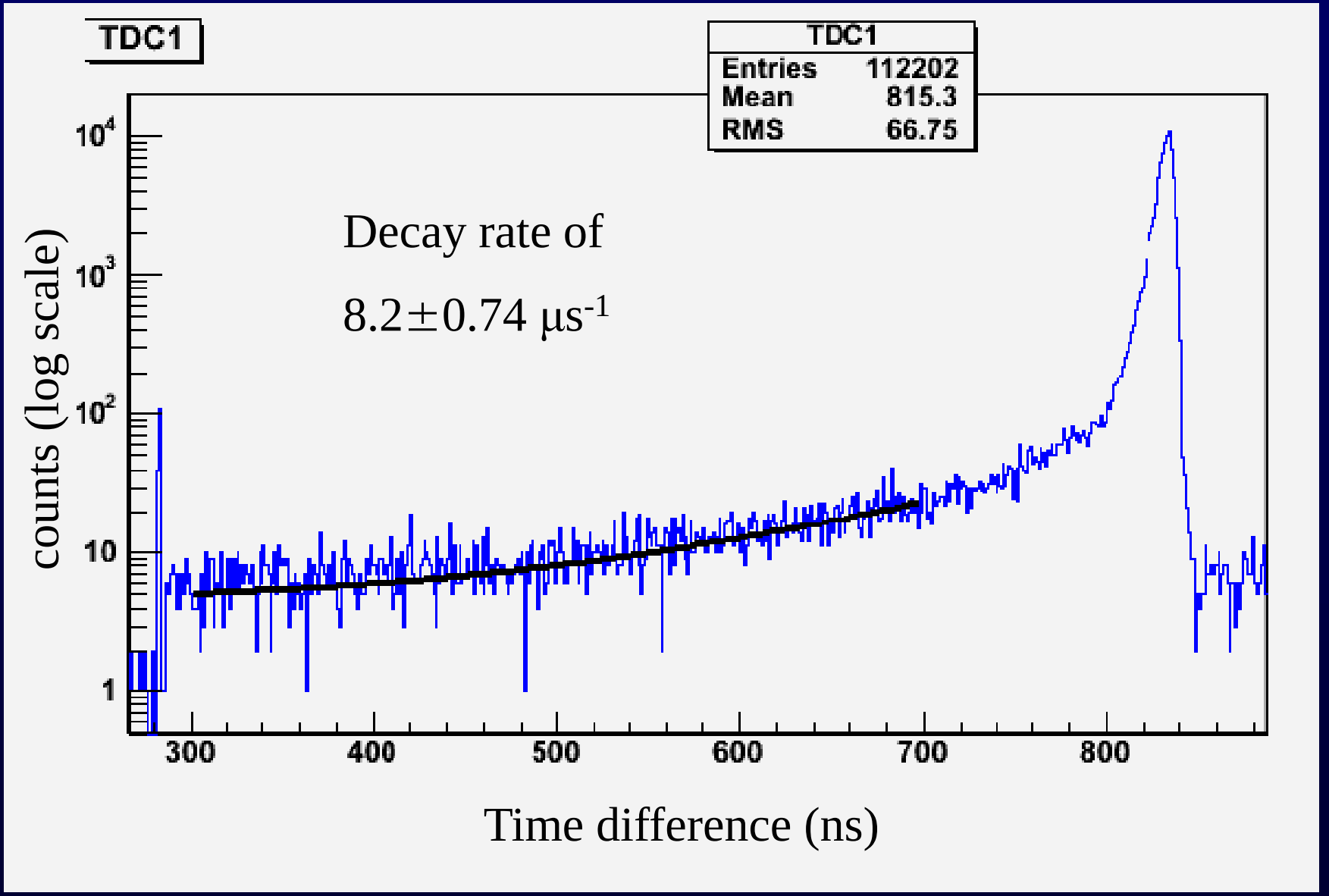
Decay time spectrum (backwards)

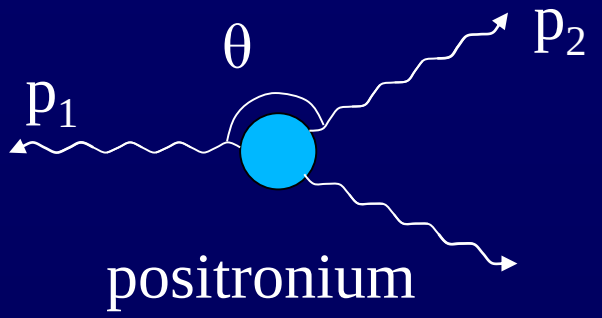


Time difference between NaI events

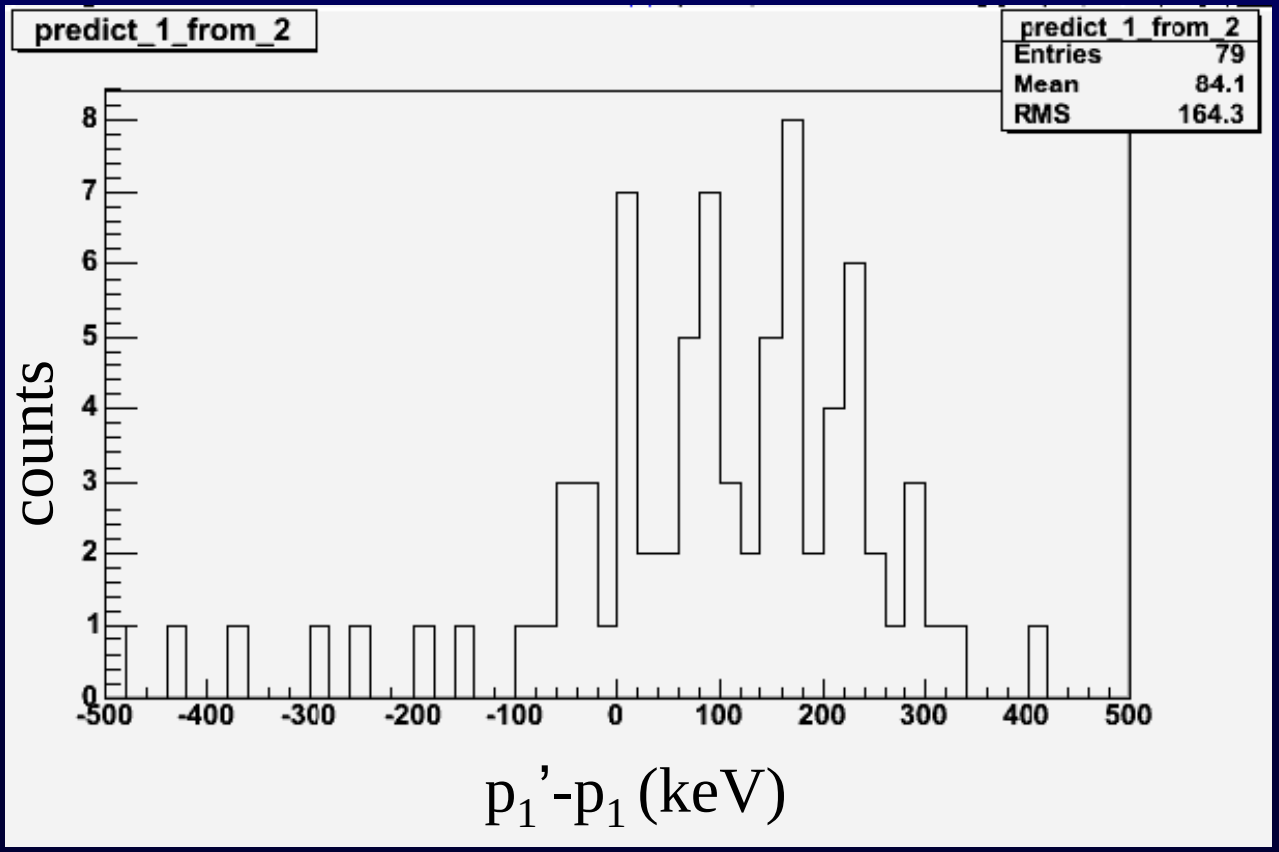


Decay Rate


TDC1
TDC1
Entries 112202
Mean 815.3
RMS 66.75
Decay rate of
8.2±0.74 μs-1
counts (log scale)
10^4
10^3
10^2
10
1
300
400
500
600
700
800
Time difference (ns)



$$p_1 = \frac{p_2 mc - \frac{1}{2} m^2 c^2}{(1 - \cos\theta) p_2 - mc}$$



Future Work

1. Compton suppression?
2. CsI detectors?
3. Xenon drift chambers?
4. More statistics