A new method of measuring the muon g-2

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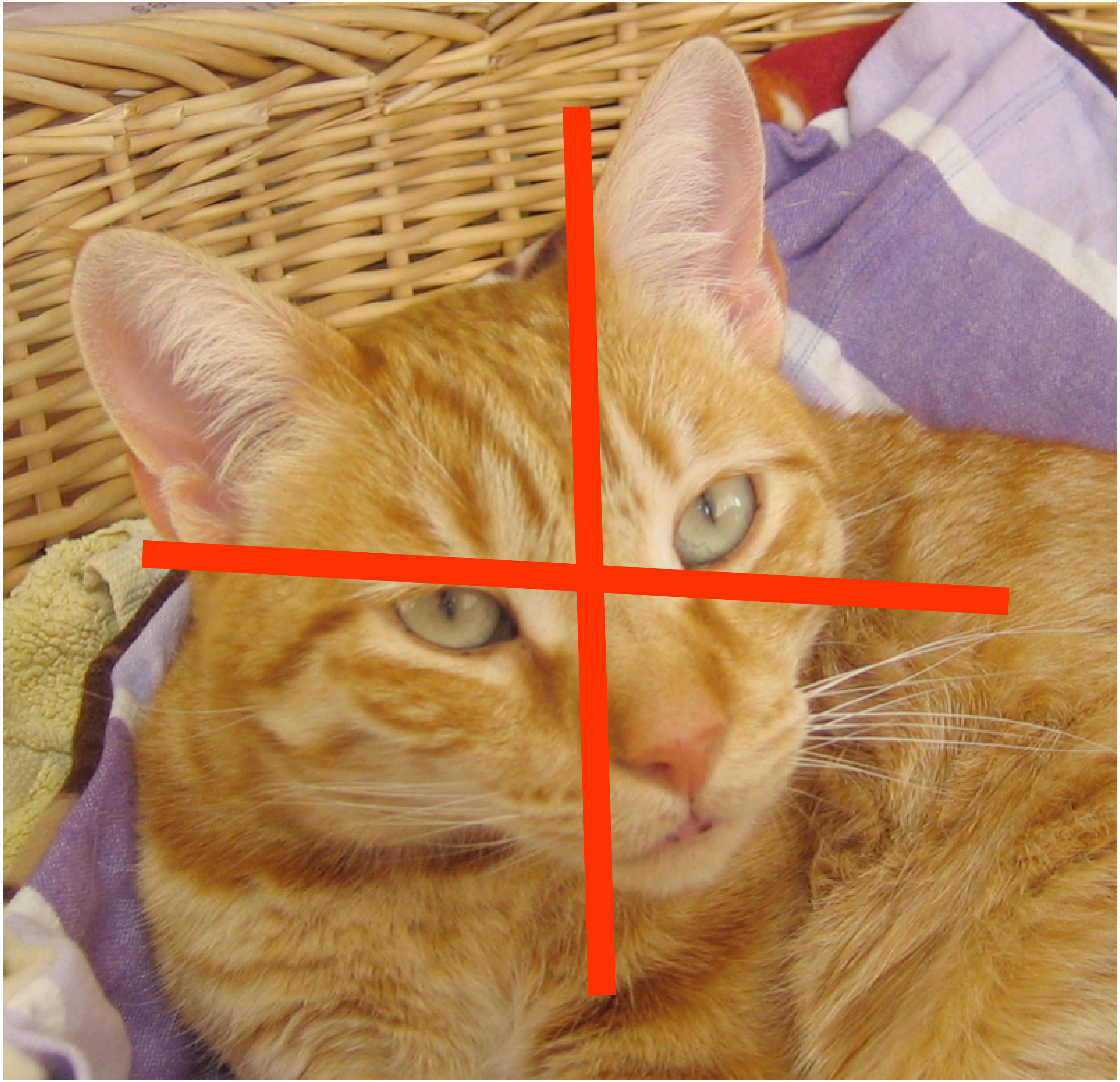


Four ways to measure the muon anomalous moment

$$a_\mu = (g-2)/2$$

Three have been shown to work

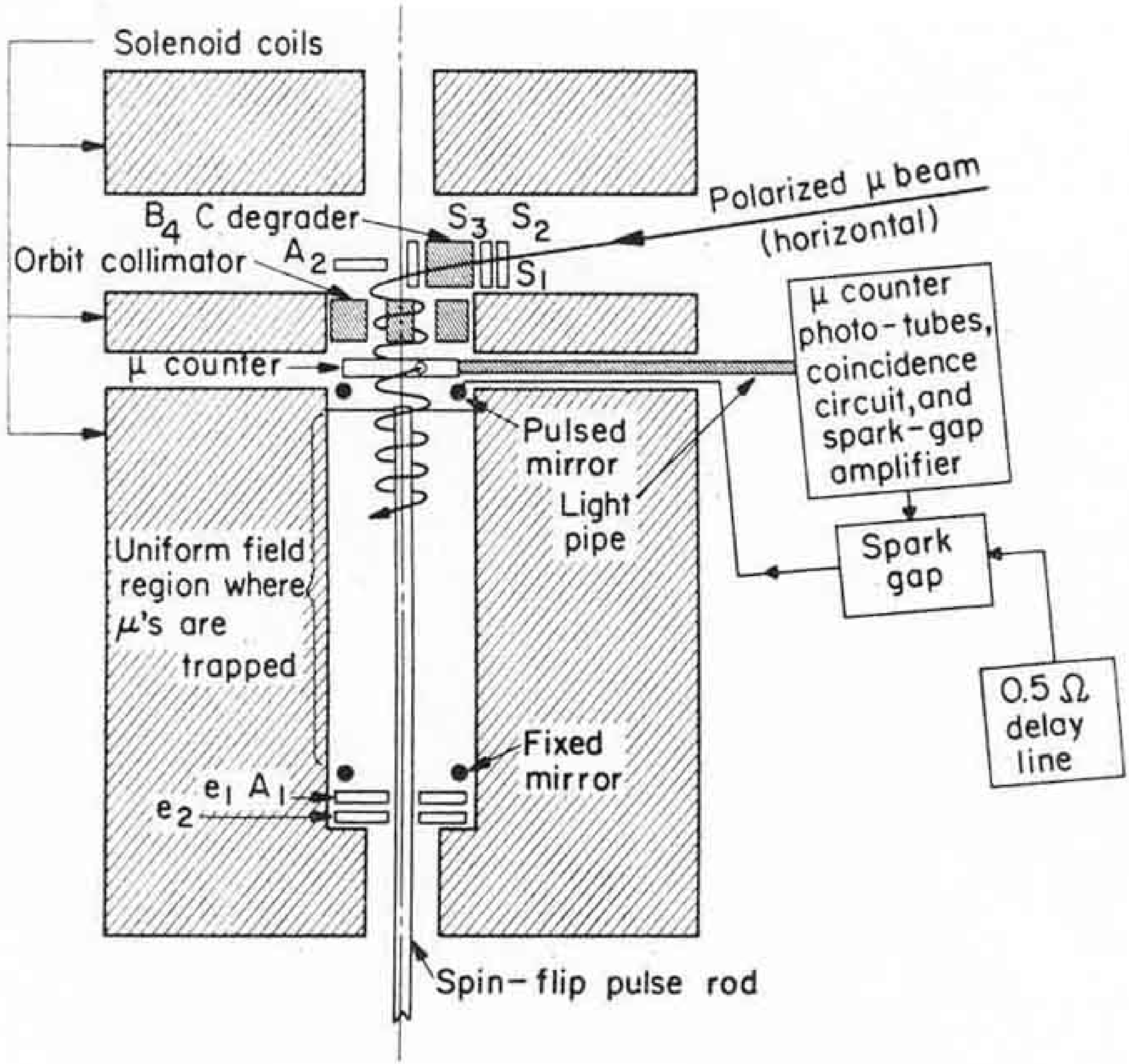
Fourth not yet tried ...... might be best of all

Trap muons in a magnetic field ..... many turns

If $g = 2$ the spin turns with the momentum

If spin turns faster, you measure the difference $g-2$

Tests a fundamental prediction of the standard model

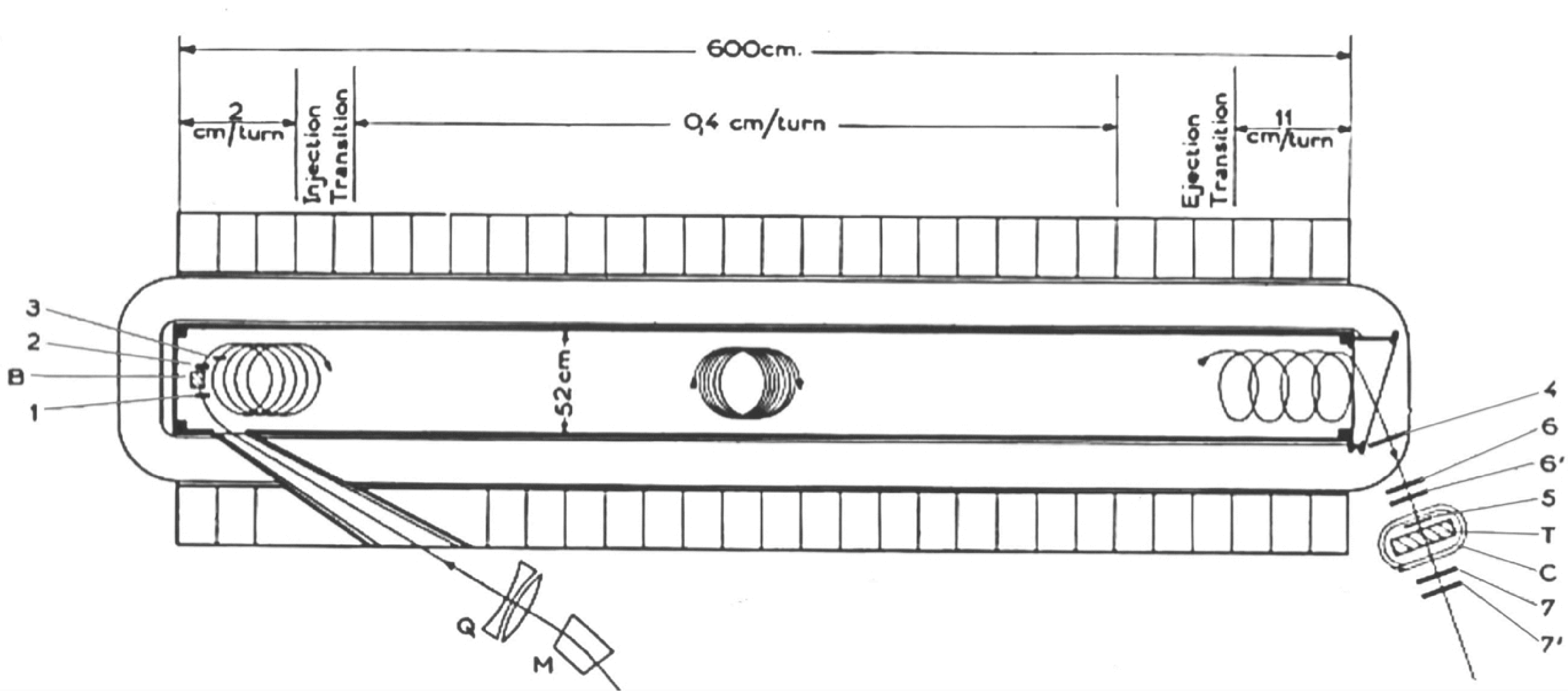


Solenoid coils
Polarized μ beam
(horizontal)
B4 C degrader
S3 S2
S1
Orbit collimator
A2
μ counter photo-tubes, coincidence circuit, and spark-gap amplifier
μ counter
Pulsed mirror
Light pipe
Spark gap
Uniform field region where μ's are trapped
0.5 Ω delay line
Fixed mirror
e1 A1
e2
Spin-flip pulse rod

Henry, Shrank & Swanson 1969

Measured a_μ to *6%*

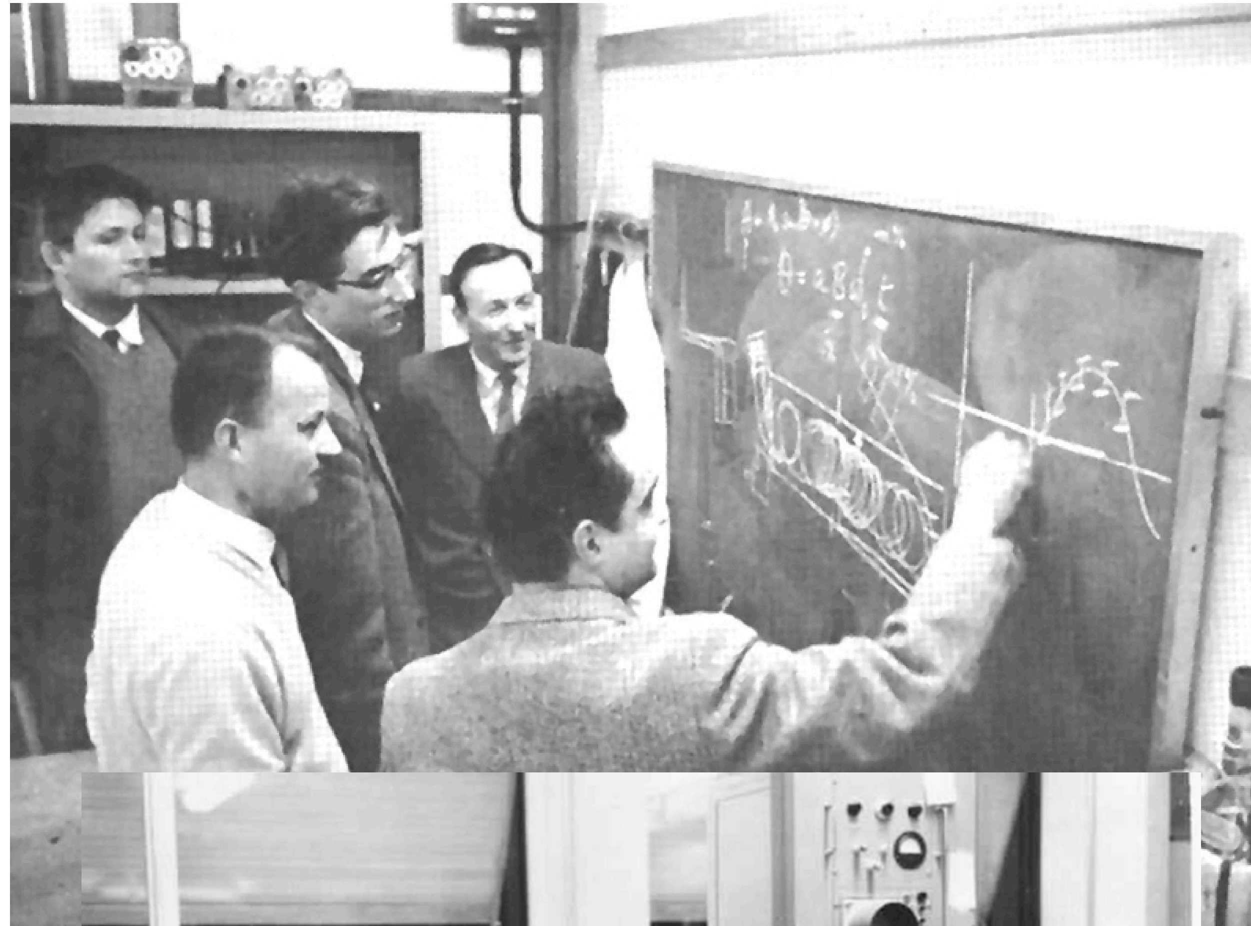
Below theory .... but if one applies pitch correction it is close

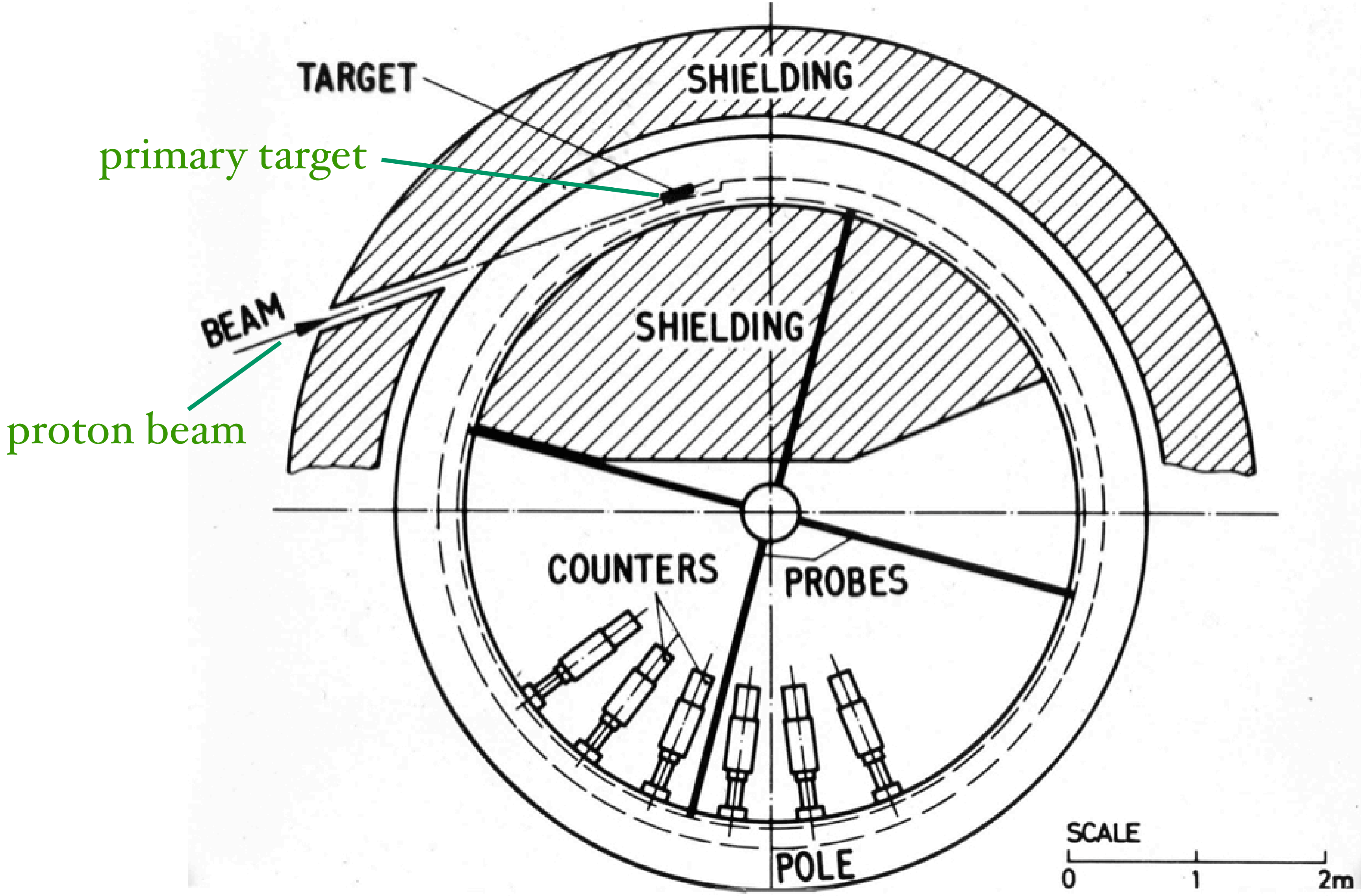


Charpak et al. 1961, 1962

Measured a_μ to 0.4 % agree with theory

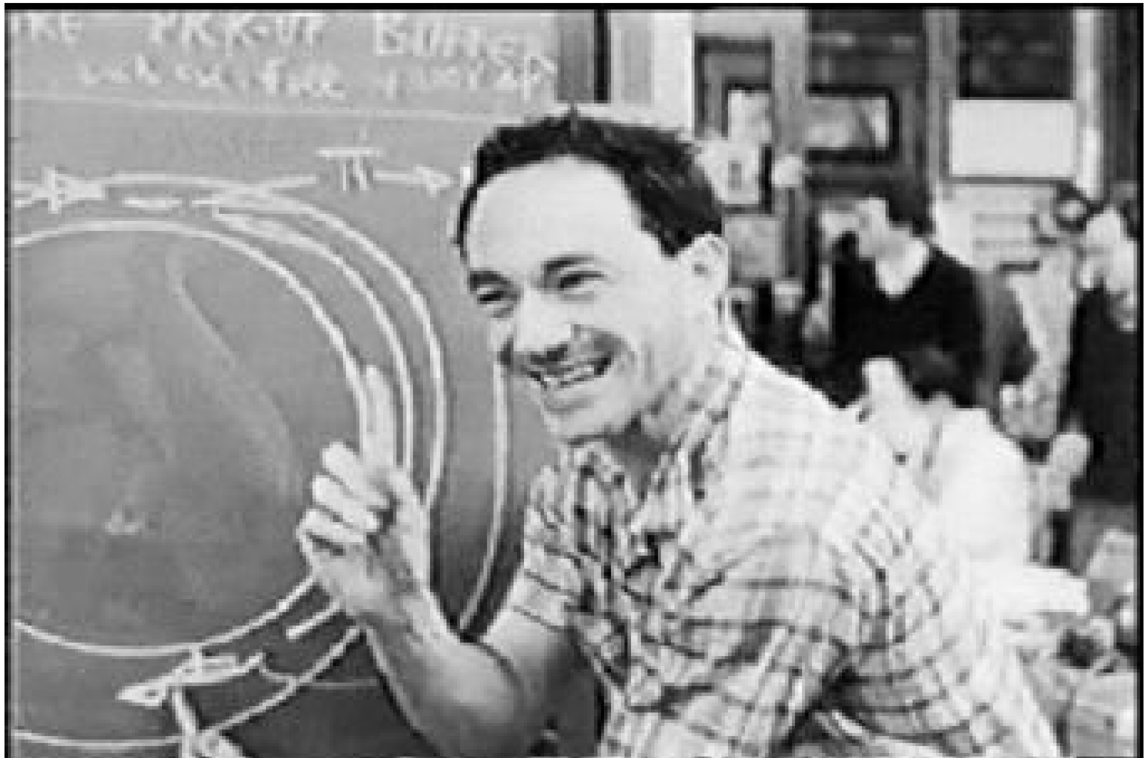
No pulse magnets .... muons make 1600 turns and emerge spontaneously at the other end



Bailey et al. 1968, 1972

Measured a_μ to 270 ppm





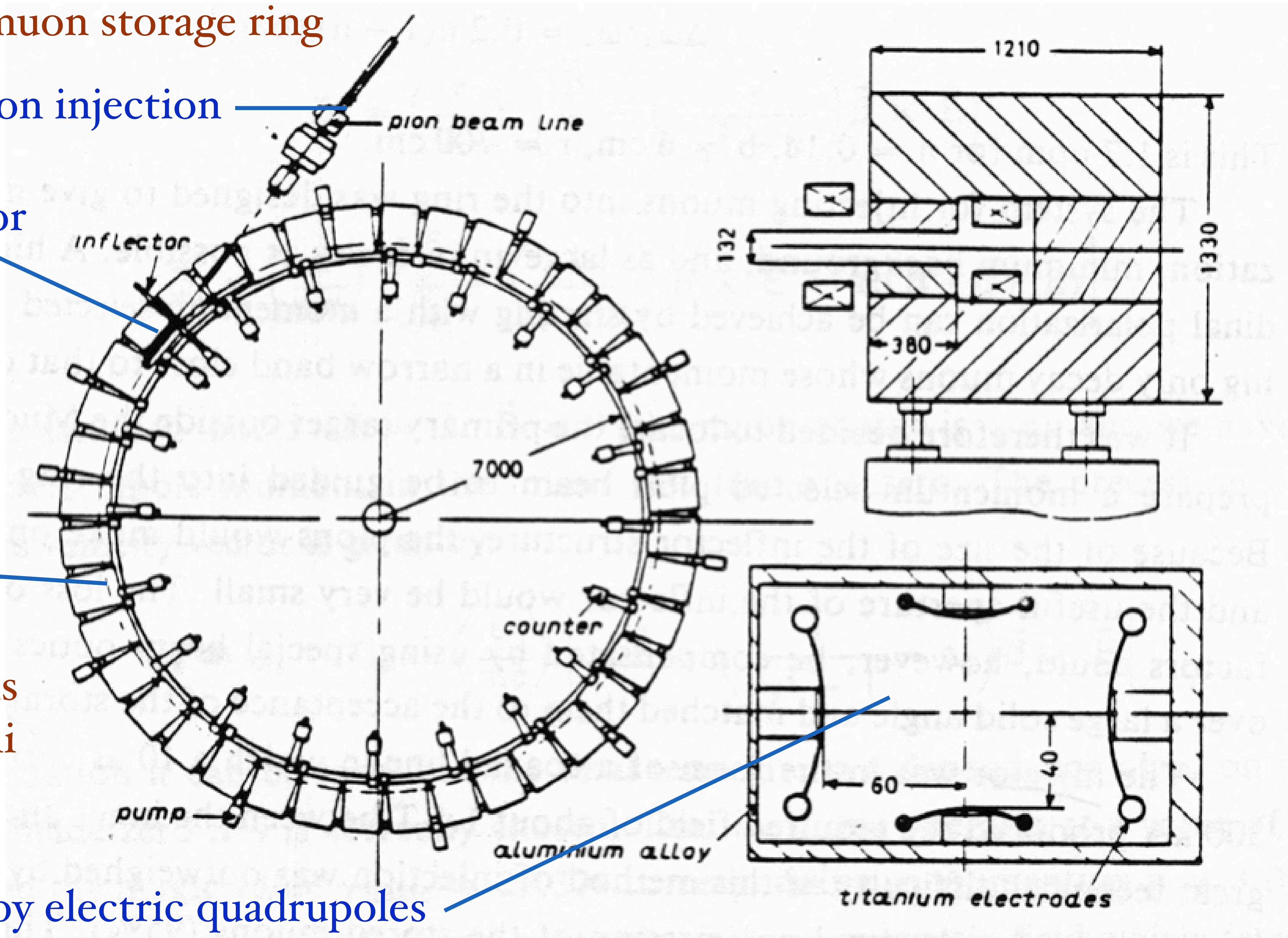
14m diameter muon storage ring

pion injection

pulsed inflector

uniform field
zero gradient

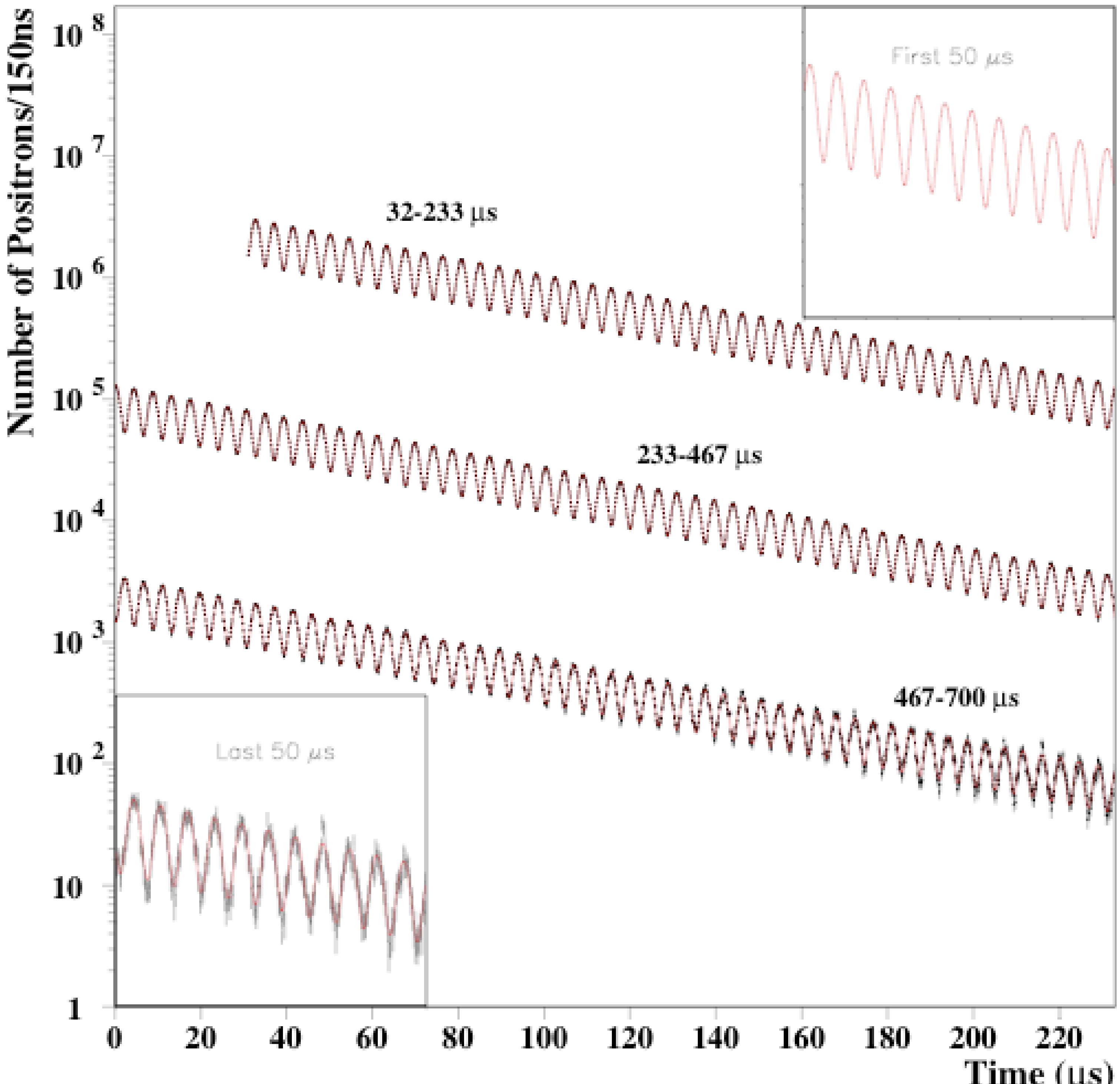
g-2 frequency is
same at all radii



vertical focus by electric quadrupoles

“magic energy” 3.1 GeV
radial electric field does not affect g-2 frequency
τ = 64 µsec

Muon storage rings



Number of Positrons/150ns
10 8
10 7
10 6
10 5
10 4
10 3
10 2
10
1
0
20
40
60
80
100
120
140
160
180
200
220
Time (μs)
32-233 μs
233-467 μs
467-700 μs
First 50 μs
Last 50 μs

Blind analysis ...

magnetic field evaluated by one group

g-2 frequency evaluated by another group

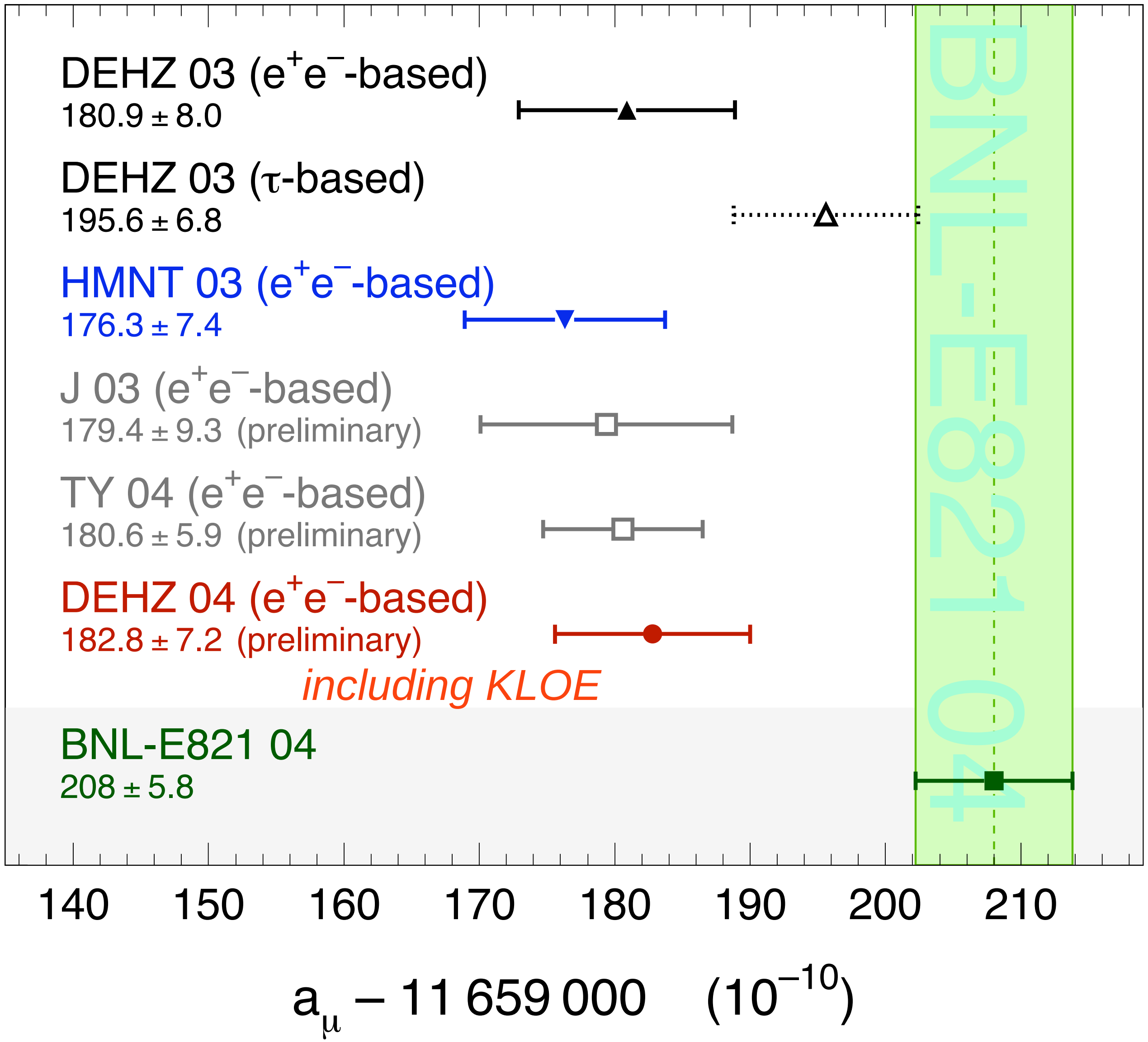
take ratio to calculate a_μ

3 separate runs μ^+ & μ^- agree with each other

Overall mean a_μ = 0.001 165 920 82 (55) 0.47 ppm

G.W. Bennett et al. Phys. Rev. Lett. 92, 161802 (2004)

Comparison with theory



from Hoecker
hep-ph/0410081 v2

Exp - th = 25.2 ± 9.2 x 10^{-11} 2.7 sigma

The future

Plans at Brookhaven

aim to halve the error using same superconducting ring magnet

more muons by improving pi - mu decay channel

larger aperture inflector

subdivide the detectors to reduce signal overlap

data taking in 2009 -2010

To go further you need more g-2 cycles to measure

higher magnetic field B ... impossible with electric focusing ... breakdown

OR

go to higher energy ..... increase lifetime

say goodbye to the magic energy 3.1 GeV

cannot use electric focusing   need an AG ring

AG muon storage ring

Increase energy to 15 GeV

muon lifetime ——> 320 μsec

5 x more g-2 cycles to measure

? increase B to 3 - 4 T ? 10 x more cycles to measure

Use AG focusing

need B independent of orbit radius

momentum compaction factor α = dR / dp = 1

To calibrate the magnetic field

abandon static NMR

use horizontally polarized protons in flight

i e use proton g-2 to calibrate muon g-2

$a = 1.789\,284\,739$ (30 ppb)

polarized proton source and polarimeter in use in RHIC

Ring design

Momentum compaction factor $\alpha = dR / dp = 1$

Well-known formula $\alpha = 1 / Q_h^2$

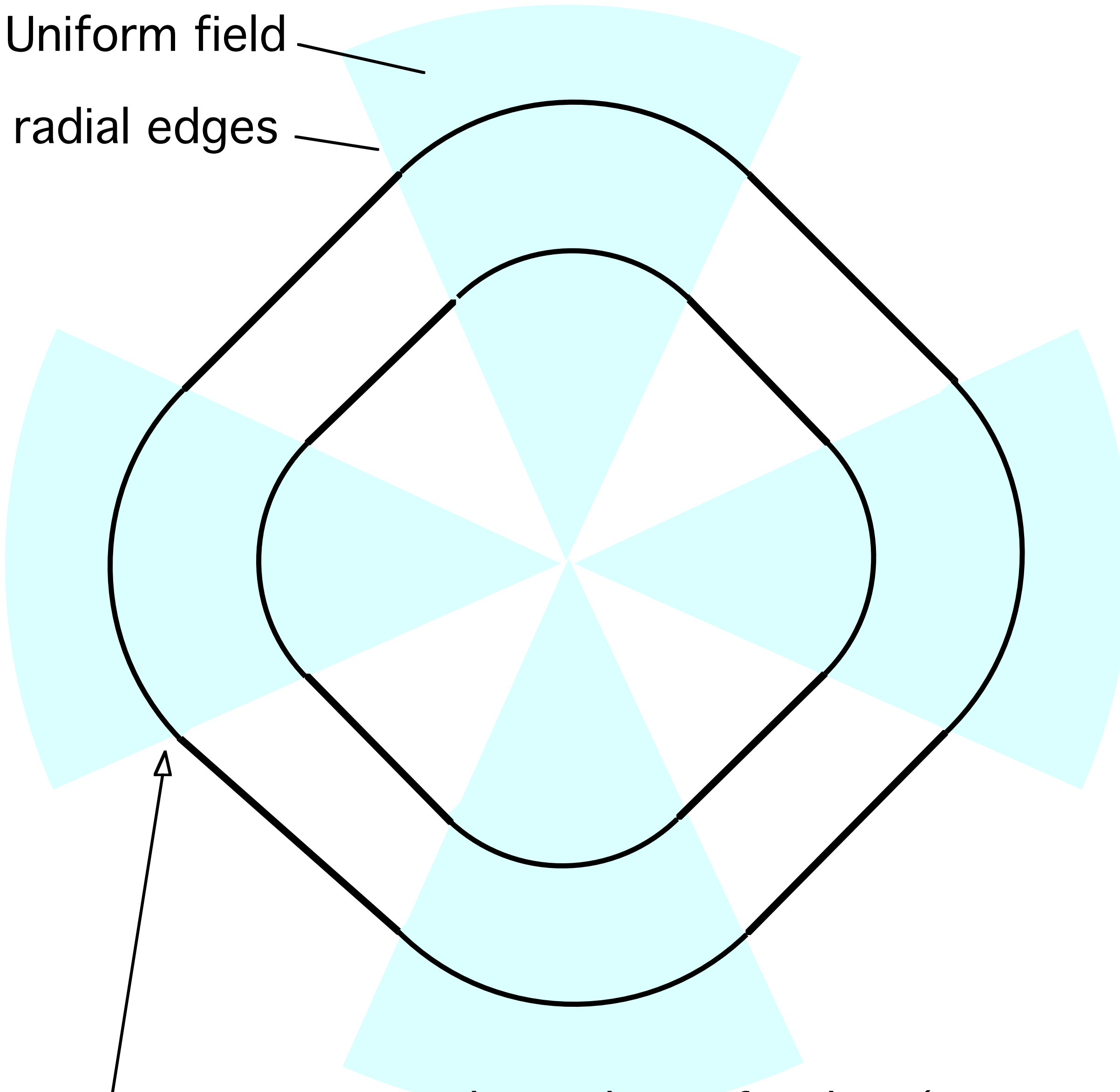
Courant & Snyder, Annals of Physics (1958)

Example: weak focusing $Q_h = \sqrt{(1 - n)}$

$\alpha = 1 / (1 - n)$

If $\alpha = 1$, $Q_h = 1$

horizontal resonance



<B> independent of radius (momentum)

Vertical focusing from magnet edges

Horizontal focusing from bends

No limit on energy - longer muon lifetime

Q vs open wedge angle for 4 sector ring

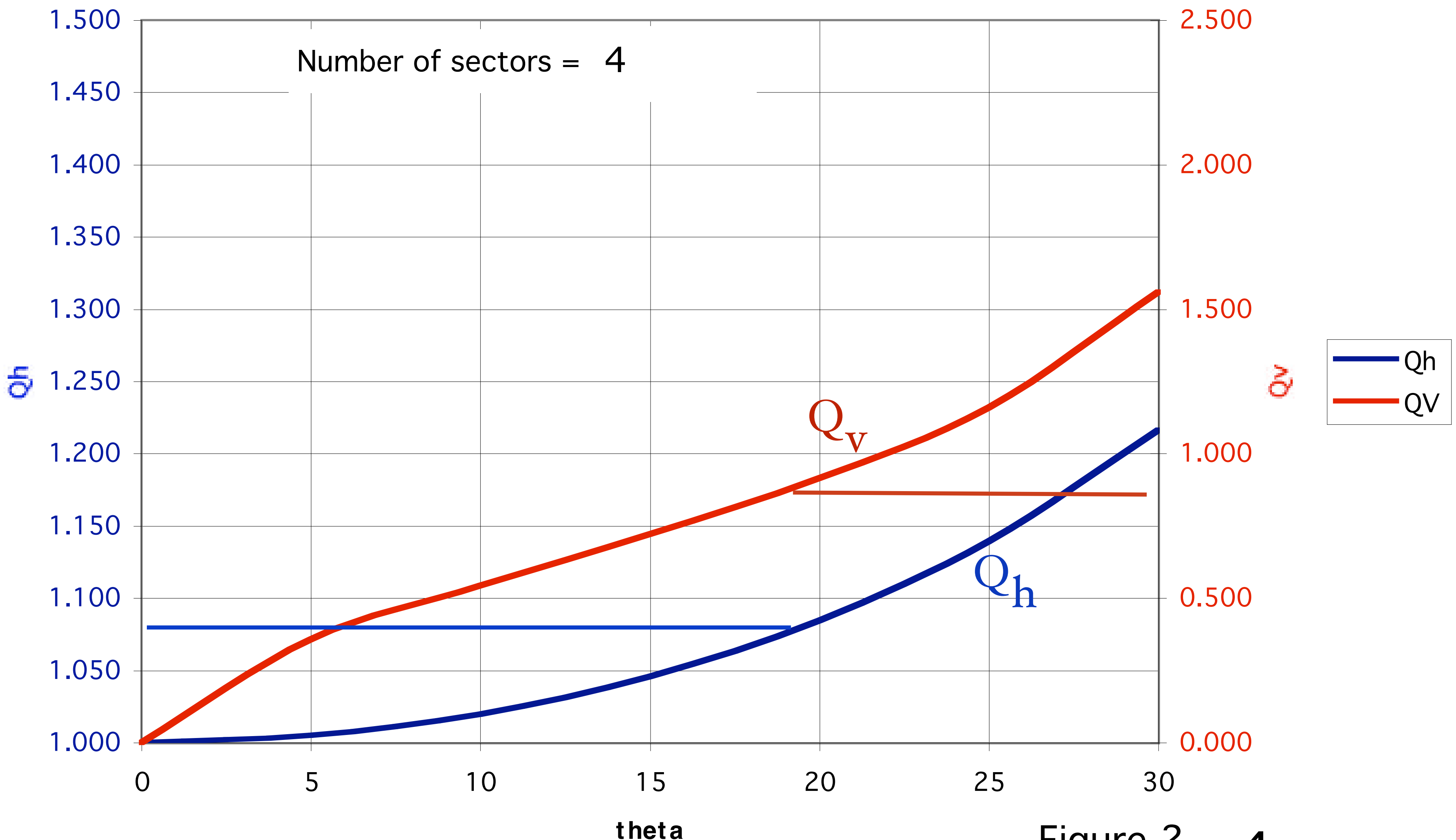


Figure 2 - 4

3 sector concept

B = 4.5 *T* <*B*> = 3.8 *T*

bend radius 12 *m*

straight sections 4.3 *m*

momentum 15 GeV/c

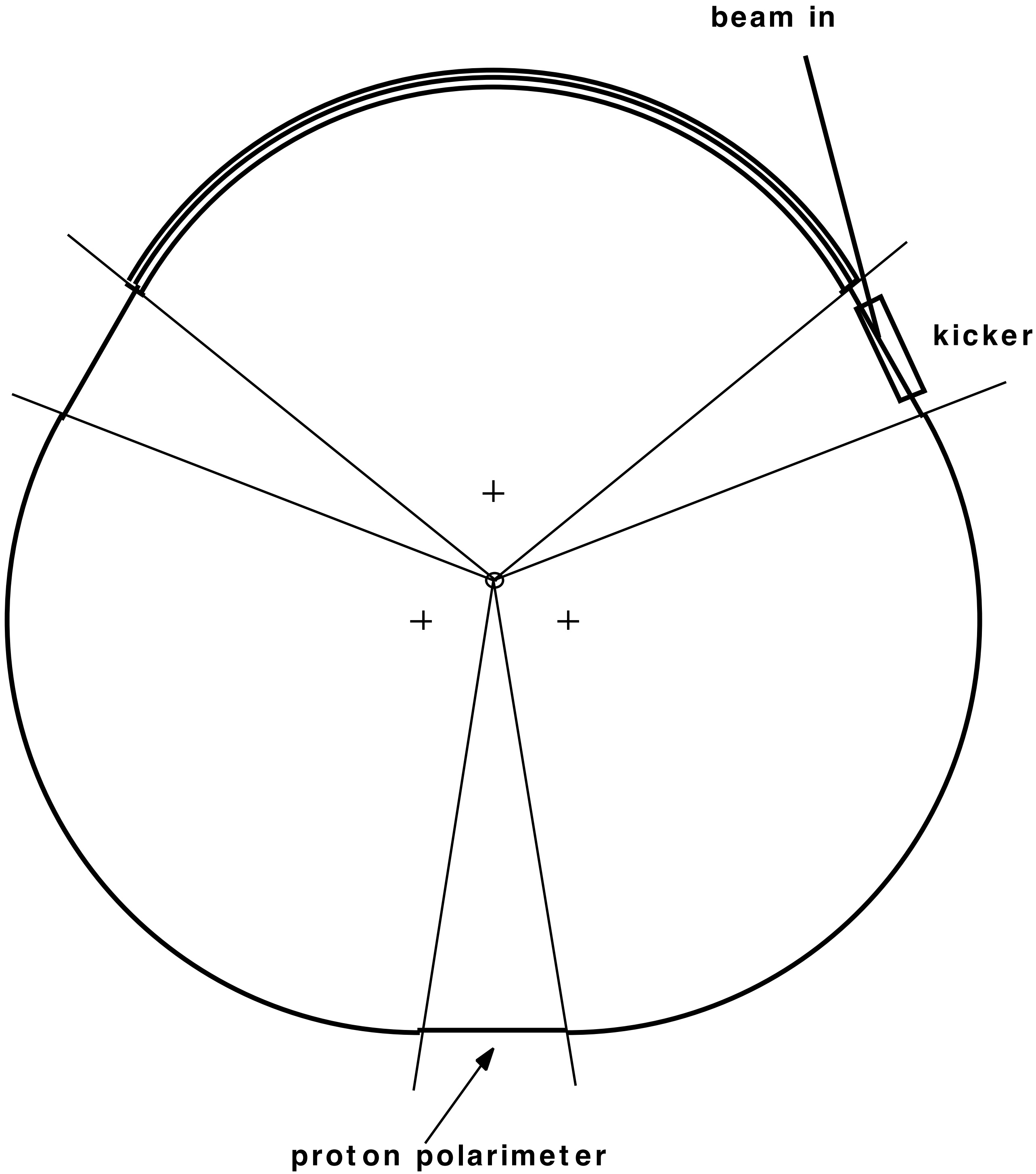
Q_h 1.025

Q_v 0.4

muon lifetime 320 μs

need 10 billion recorded decay electrons

say 50 billion injected muons



Advantages

no electric quadrupoles

no trolley

- *calibration*
- *correction for diamagnetism in water*
- *paramagnetism in surrounding materials*

no inflector to cancel the field in the magnet at injection

simple kicker using ferrite

higher energy ... e g 15 GeV

- *increased accuracy*
- *longer lifetime reduces the counting rate*
- *less signal overlap*
- *less residual flash*

higher magnetic fields

- *increased accuracy*

A new ring structure for muon g-2 measurements

Nuclear Instruments and Methods, A 523 (2004) 251

hep-ex/0307024

Reduce error in a_μ to 50 ppb .... ! ! !

Is it worth it ??

uncertainty in theory is 500 ppb ...... but it will improve

hadronic contribution calculated by lattice QCD

when new physics is discovered it will have its effect on a_μ

theorists will want to know if they are right

Historically experiment has often been ahead of theory

fine structure

Zeeman effect

Stern Gerlach

Kusch & Foley

Lamb shift

HAPPY
BIRTHDAY
LARRY

Bonne
continuation