Towards an improved determination of the Fermi coupling constant from the μLan experiment

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Outline

- Interest in G_F
  - Status of G_F
    - μLan Philosophy
      - μLan Status
        - μLan Outlook

Enrico Fermi

Inputs to the Standard EW Model

fine structure constant

α = 1/137.035 999 76 (50)(0.004 ppm)

Fermi constant

G_F = 1.16639(2) $\times 10^{-5}$ GeV^{-2} (17 ppm)

Z-boson mass

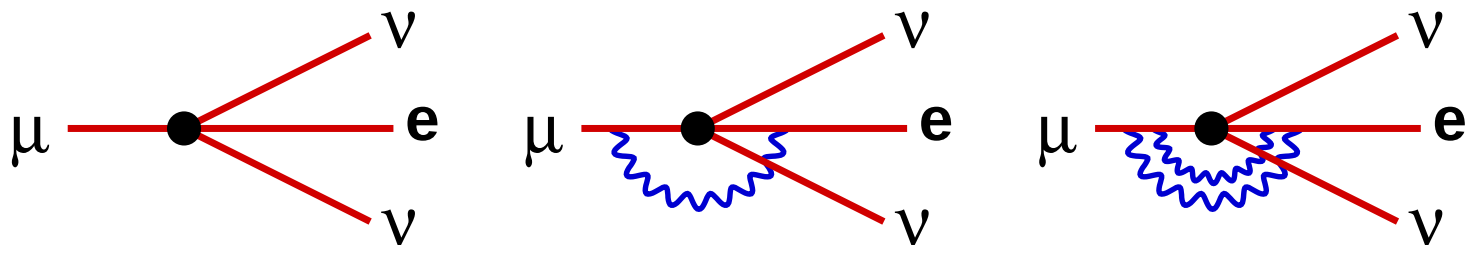
M_Z = 91.1876(21) GeV/c^2 (23 ppm)

From the Muon Lifetime to G_F

0.13 ppm

$$\frac{1}{\tau_\mu} = \Gamma_\mu = \frac{G_F^2 m_\mu^5}{192\pi^3}(1+\Delta q)$$

$\eta = 0$



$\Delta q =$ $\Delta q^{(0)}$ + $\Delta q^{(1)}$ + $\Delta q^{(2)}$

-4.1995$\times 10^{-3}$ + 1.5$\times 10^{-6}$

from m_{ν_μ}: 10 ppm; $\sim$0 (*e.g.* CMB)

Experimental Status of the Muon Lifetime

avg.	$\hat{\tau} = (2.19703 \pm 0.00004) \times 10^{-6}$ s		
1984	Bardin *et al.*	$\pm$ 66 ps	⋮
1984	Giovanetti *et al.*	$\pm$ 60 ps	10^9
1974	Balandin *et al.*	$\pm$ 80 ps	⋮
1973	Duclos *et al.*	$\pm$ 300 ps	10^8
1972	Williams & Williams *et al.*	$\pm$ 800 ps	⋮
1963	Meyer *et al.*	$\pm$ 2000 ps	10^6
1962	Lundy	$\pm$ 4000 ps	⋮
1936	Anderson and Neddermeyer	discovery	1

G_F = (1.16637 $\pm$ 0.00001) $\times$ 10^{-5} GeV^{-2} (9 ppm)

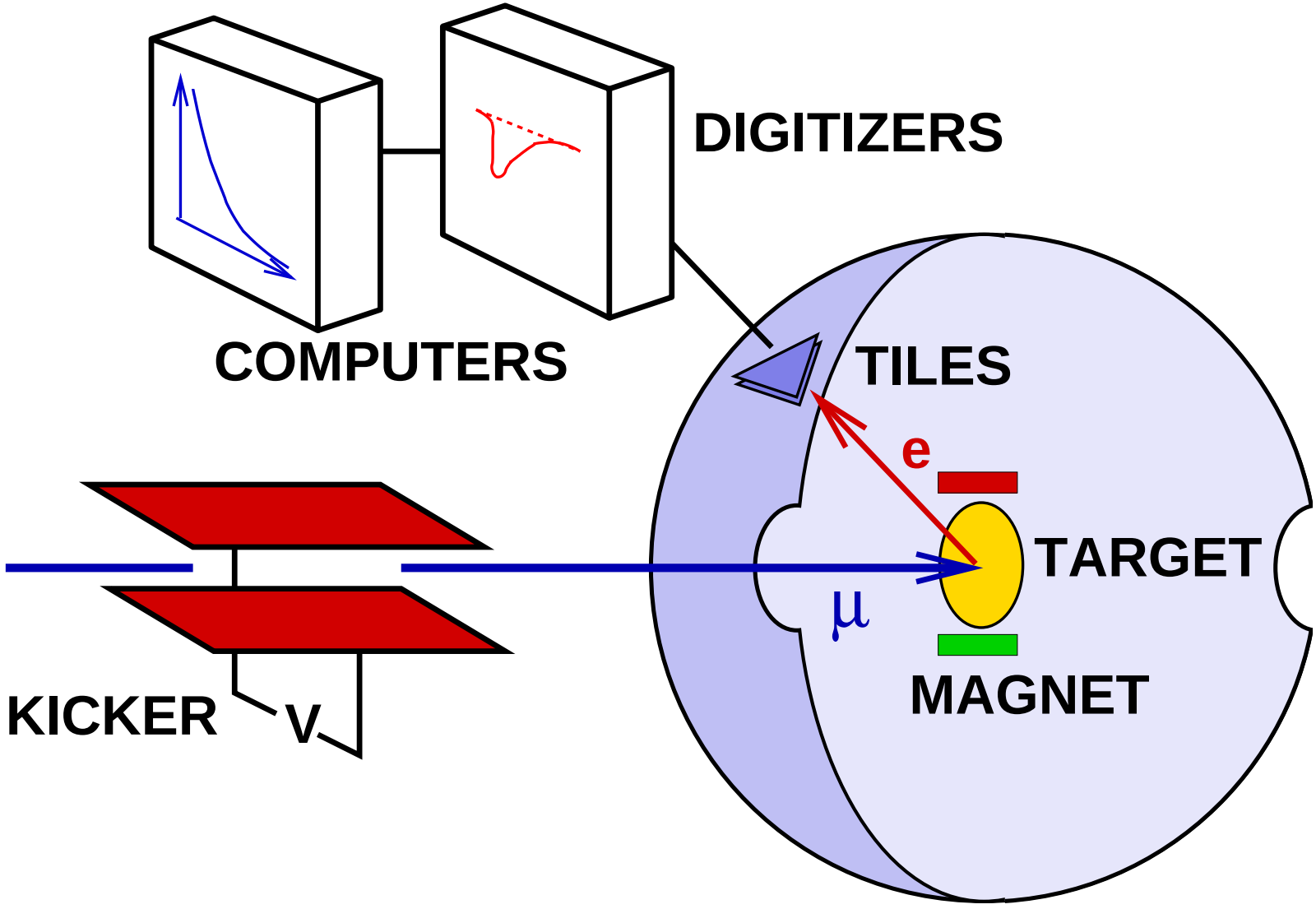
μLan Goal and Challenges

$$\Delta\tau \simeq 2 \text{ ps (1 ppm)}$$

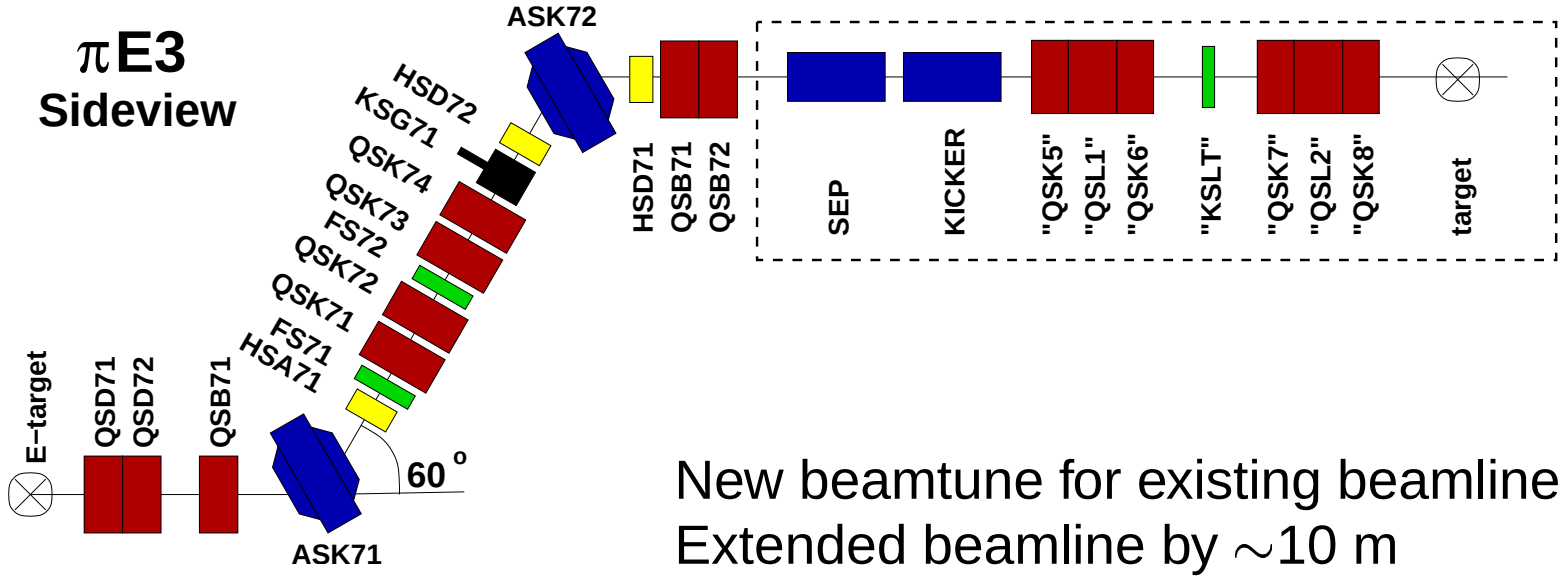
Design:

- **How to collect $>10^{12}$ μ-decays**
- **How to keep syst. error $<$ 1 ppm**

Philosophy to Reach a 1 ppm Uncertainty



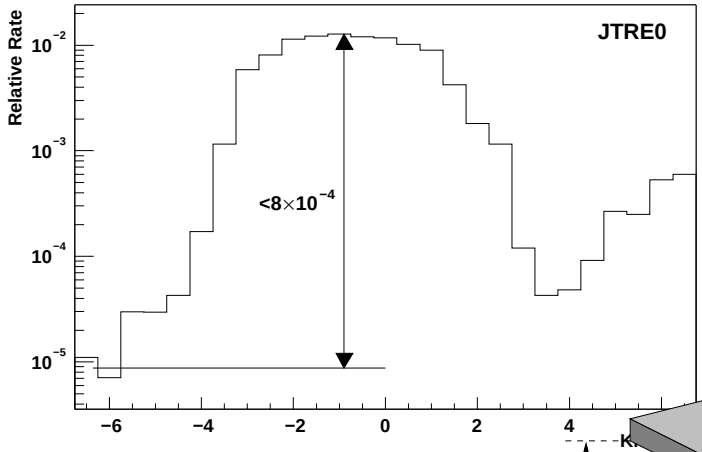
Source: πE3 Surface Muon Beam at PSI

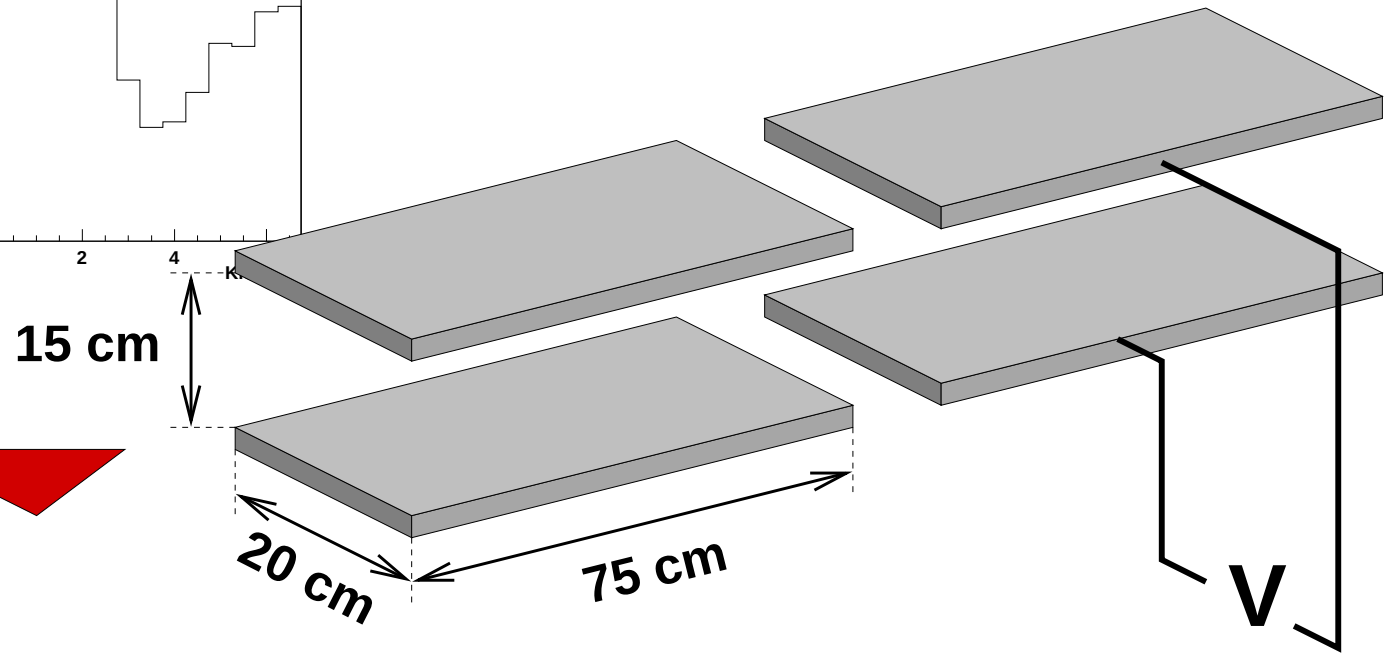


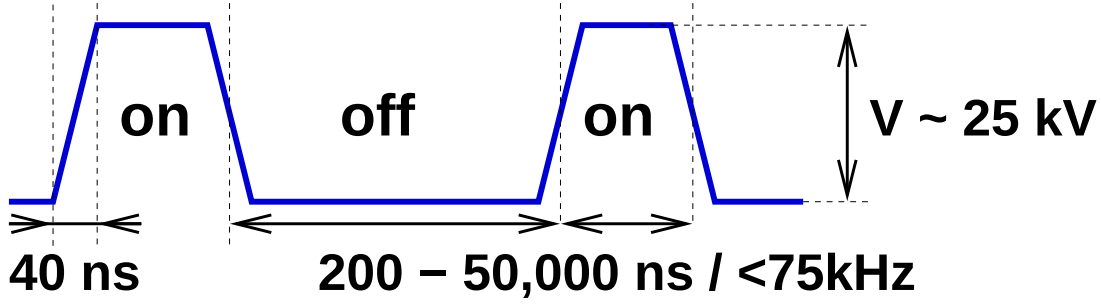
New beamtune for existing beamline
Extended beamline by ∼10 m

11 MHz Rate on target easily achieved

Creating a Pulsed Muon Source

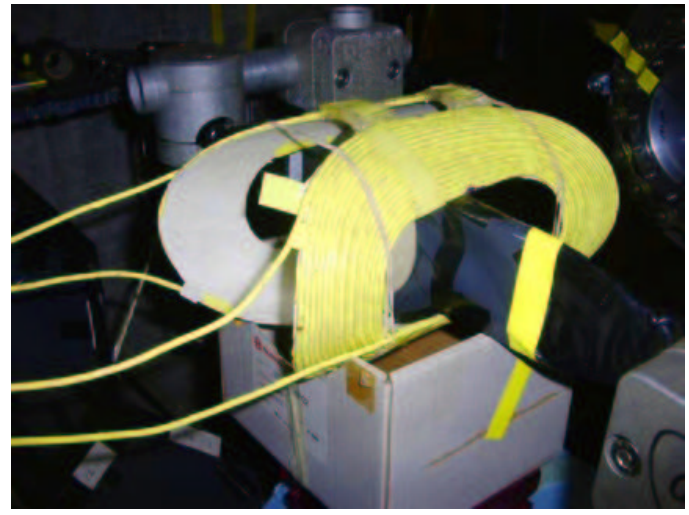






Reducing Polarization Systematic Error

Problem: Front-back asymmetry



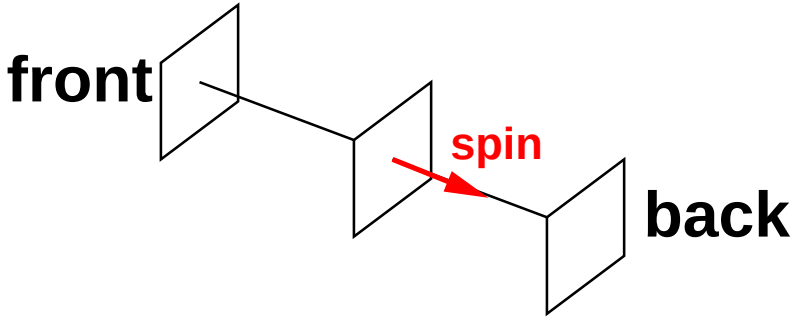
Solutions:

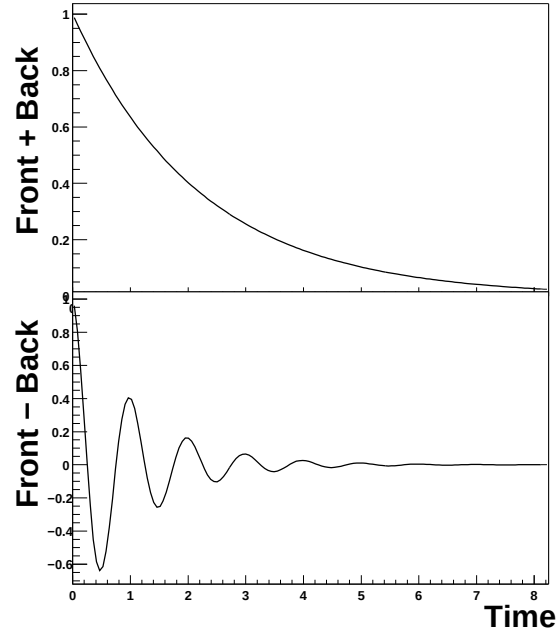
① Reduce polarization with target
$\rightarrow$ sulphur

② Dephase spins during μ collection

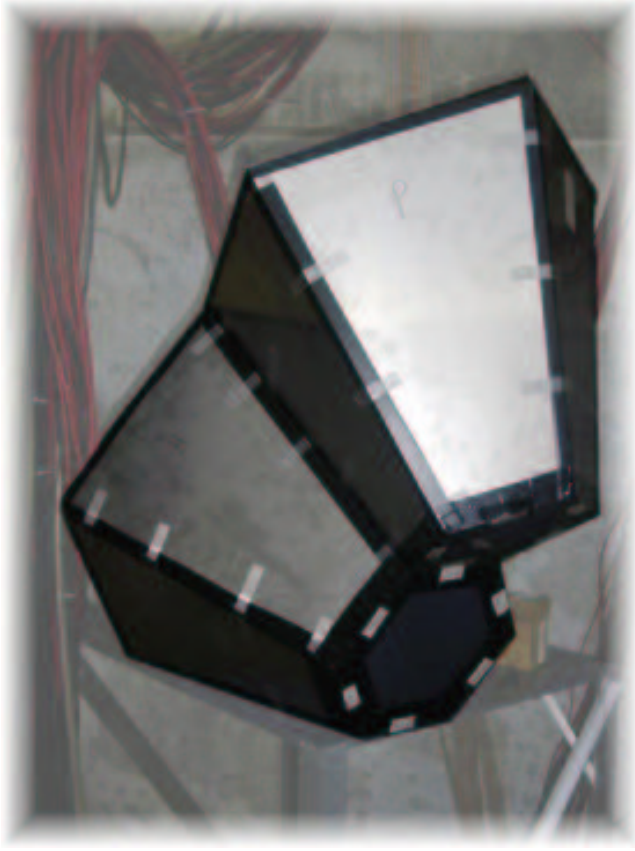
③ Fast precession during measurement

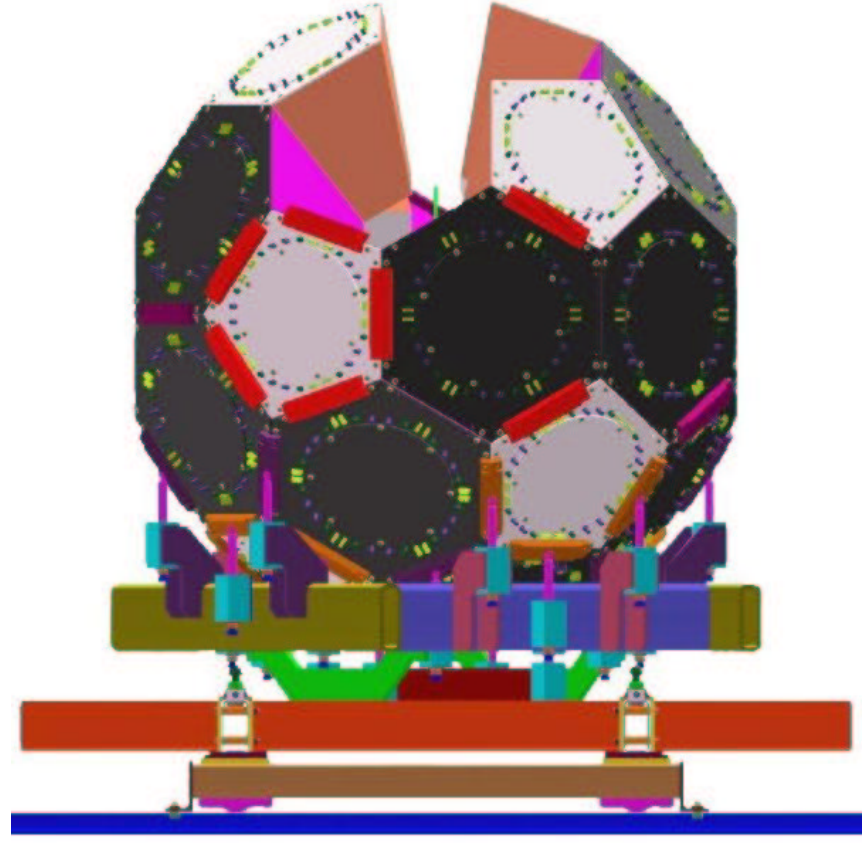
④ Front-back symmetric detector





The Soccer Ball





Truncated icosahedron ($\sim 4\pi$ coverage, Point-symmetric)
Fine segmentation (180) to reduce pileup.

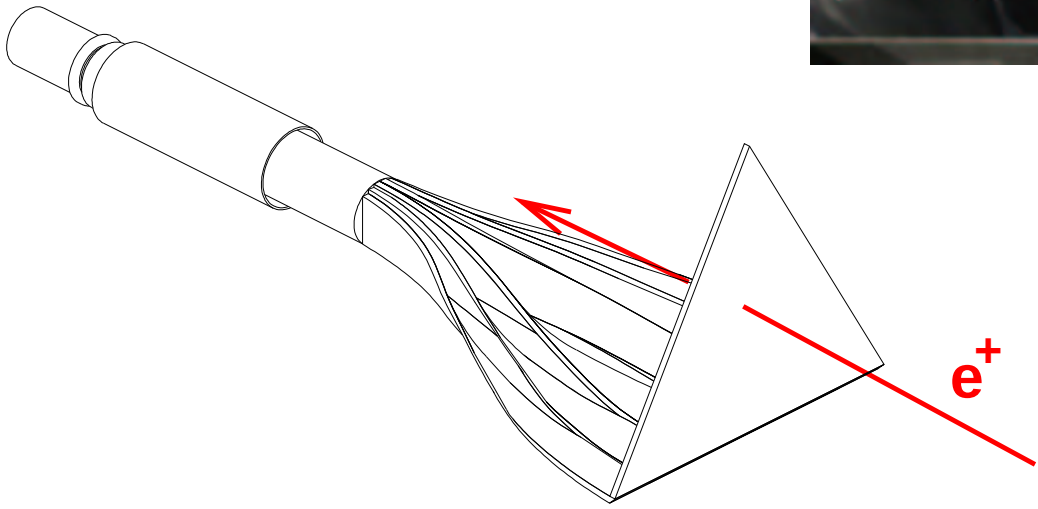
The Scintillator Elements

① 2 layers 3 mm BC404

② 80 p.e. light output

③ Short pulse (7 ns FWHM)

④ 90° light guides

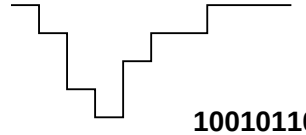


Timing from 500MS/s Waveform Digitizers

① A prototype was built and tested.

② Provides accurate timing information

③ Custom ‘personalities’



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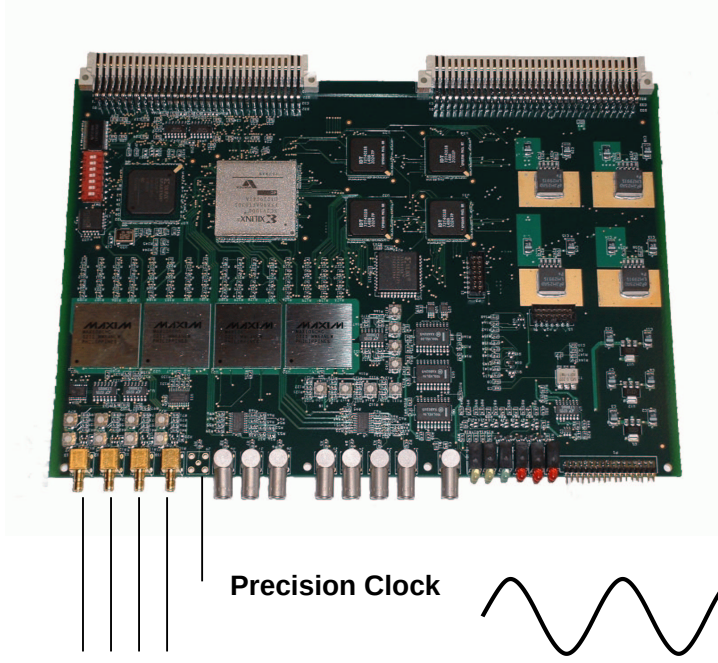

Conclusions and Outlook

Hardware approaching completion

2003	July	Kicker commisioning
	October	Data taking $\sim 10^{-5}$
2004		Production Run I
2005		Production Run II