Precise Measurement of the $\pi^+ \longrightarrow e^+\nu$ Branching Ratio

The PEN Collaboration

Dubna–PSI–Swierk–Tbilisi–Virginia–Zagreb–Zürich

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$\pi \longrightarrow e\nu$ decay: SM predictions; measurements

Modern theoretical calculations: $$B^{\text{calc}}_{e/\mu} = \frac{\Gamma(\pi \to e\bar{\nu}(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}(\gamma))}_{\text{calc}} =$$

$$\begin{cases} 1.2352\,(5) \times 10^{-4} & \text{Marciano and Sirlin, [PRL } \mathbf{71} \text{ (1993) 3629]} \\ 1.2356\,(1) \times 10^{-4} & \text{Decker and Finkemeier, [NP B } \mathbf{438} \text{ (1995) 17]} \\ 1.2352\,(1) \times 10^{-4} & \text{Cirigliano and Rosell, [PRL } \mathbf{99}\text{, 231801 (2007)]} \end{cases}$$

Experiment, world average [current PDG]:

$$B^{\text{exp}}_{e/\mu} = \frac{\Gamma(\pi \to e\bar{\nu}(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}(\gamma))}_{exp} = (1.230 \pm 0.004) \times 10^{-4}$$

PEN goal: $$\frac{\delta B}{B} \simeq 5 \times 10^{-4}\,.$$

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π_{e2} Decay and the SM

$B_{e/\mu}$ is given in SM to 10^{-4} accuracy; dominated by helicity suppression ($V-A$). Deviations from this rate primarily caused by new pseudoscalar interactions (mass scale Λ_{eP}):

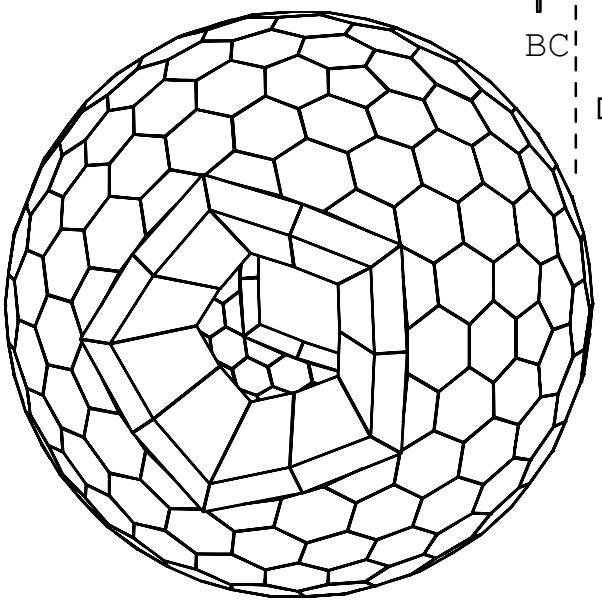
$$\Delta B_{e/\mu} = 1 - \frac{B^{new}_{e/\mu}}{B^{SM}_{e/\mu}} \sim \frac{\sqrt{2}}{G_\mu} \frac{m_\pi^2}{m_e(m_u+m_d)} \frac{1}{\Lambda_{eP}^2} \sim \left(\frac{1\,\text{TeV}}{\Lambda_{eP}}\right)^2 \times 10^3 .$$

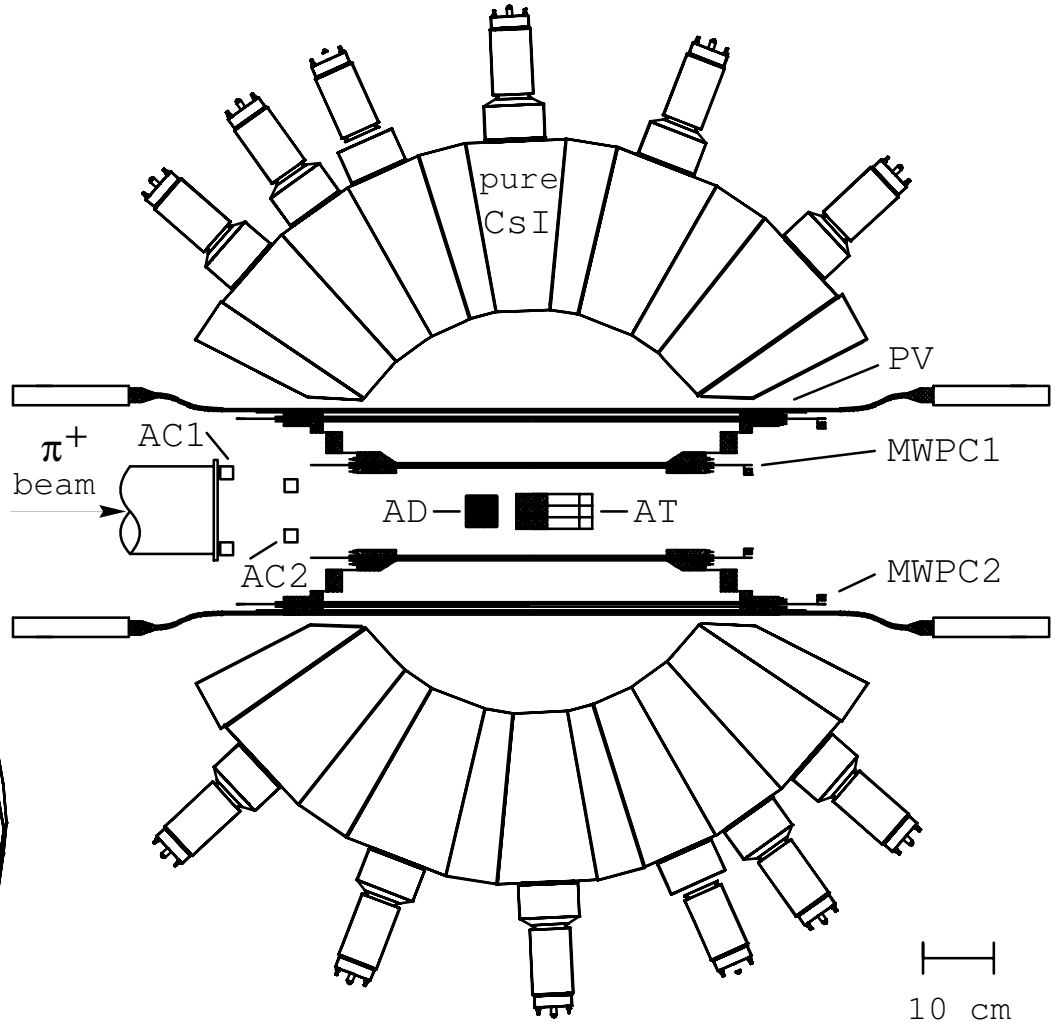
Thus $(\delta B/B)_{exp} = 10^{-3}$ probes $\Lambda_{eP} \sim 10^3$ TeV! $\Rightarrow$ Limits on:

- charged Higgs in theories with richer Higgs sector than SM,
- R-parity violating SUSY; loop diagrams with certain SUSY partner particles,
- PS and V leptoquarks in various theories with dynamical symmetry breaking,
- non-zero m_ν and mixing; sterile ν's; Majorons.

The PEN Apparatus

- stopped π^+ beam
- active target counter
- 240-det. CsI(p) calo.
- central tracking
- digitized PMT signals
- stable temp./humidity





PEN: Experimental Method and Present Status

- Stopped beam at $\sim 15,000\,\pi^+$/sec. Pion decays detected in a 250 ns wide gate.
- Position sensitive two-piece wedged active degrader detector.
- Digitized signals of beam counters: forward (B0), active degrader (DEG), and active target (AT).
- Two development runs, in 2007 and 2008, ramping up beam stop and DAQ rates to design specifications.
- Total pions stopped in 2007 and 2008 runs: $> 8 \times 10^{10}$. To date $> 4.7 \times 10^6$ $\pi \to e\nu$ decays recorded, corresponding to $(\delta B/B)_{\text{stat}} < 5 \times 10^{-4}$.
- Detailed data analysis under way in preparation for a 2009 run, planned to complete the required event statistics. Improved beam tracking under design.

Web page: http://pen.phys.virginia.edu