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

E. Frlež (for the PEN Collaboration)

Department of Physics
University of Virginia

New Trends in High Energy Physics
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Outline

PSI Experiment R-05-01 (PEN) collaboration members:

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[f]*Rudjer Bošković Institute, HR-10000 Zagreb, Croatia*
[g]*Physik Institut der Universität Zürich, CH-8057 Zürich, Switzerland*

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$\Rightarrow$ The ***PEN*** experiment:

- $\pi^+ \to e^+ \nu_e$
  - e-μ universality
  - pseudoscalar coupling besides $V - A$
  - ν-sector anomalies, Majoron searches, m_{h^+}, PS l-q's, V l-q's, ...

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

Modern theoretical calculations:

$$B_{\text{calc}} = \frac{\Gamma(\pi \to e\bar{\nu}(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}(\gamma))}_{calc} =$$

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- PS and V leptoquarks in various theories with dynamical symmetry breaking,
- non-zero m_ν and mixing; sterile ν's; Majorans.

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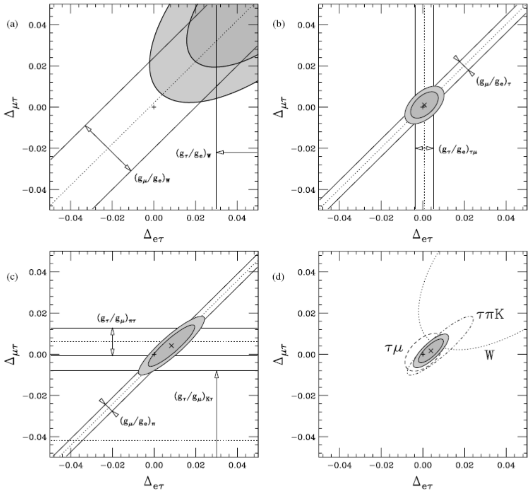

Loinaz *et al.* PRD70 (2004).

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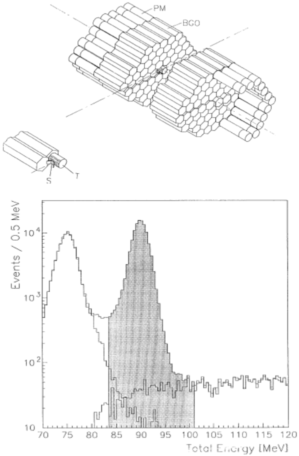

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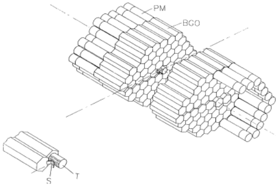

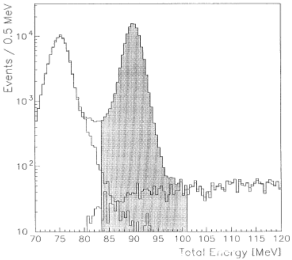

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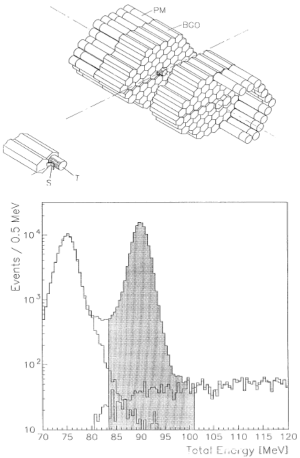

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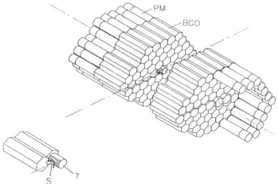

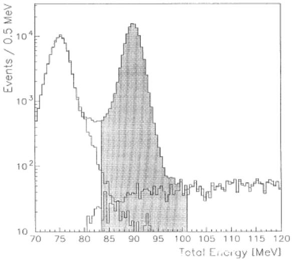

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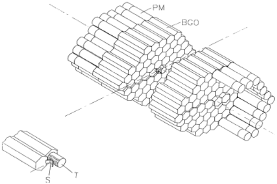

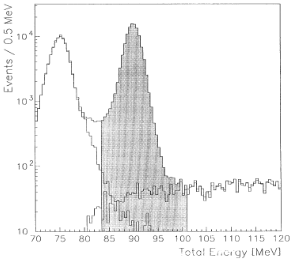

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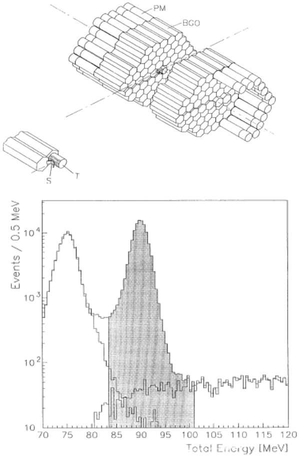

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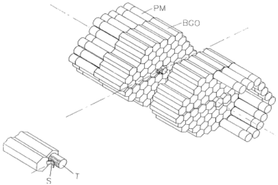

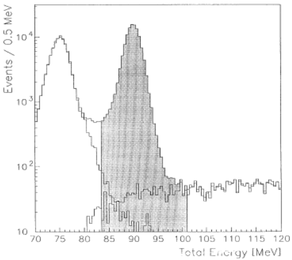

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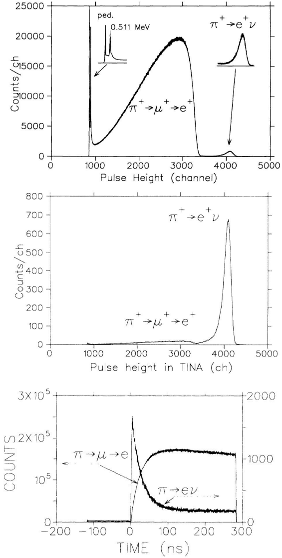

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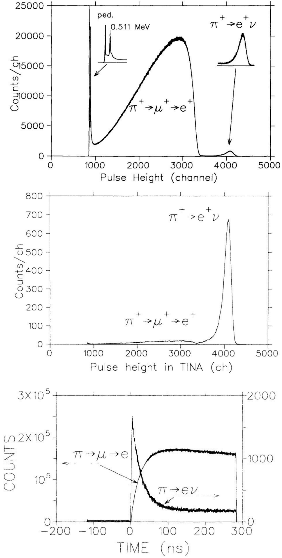

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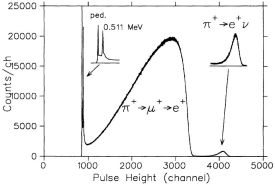

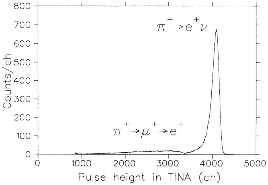

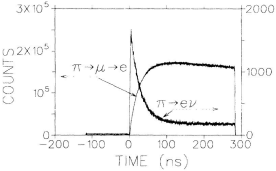

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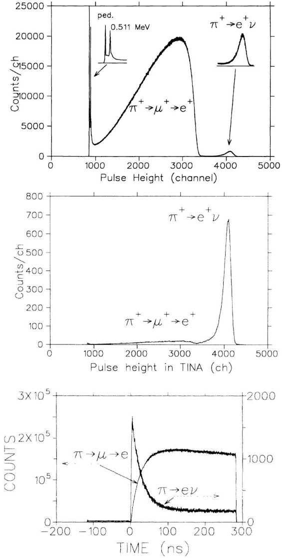

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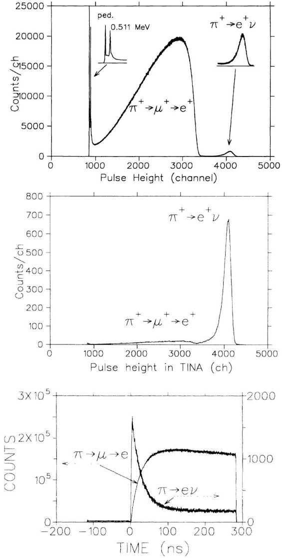

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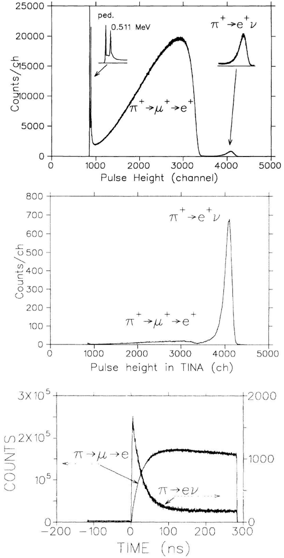

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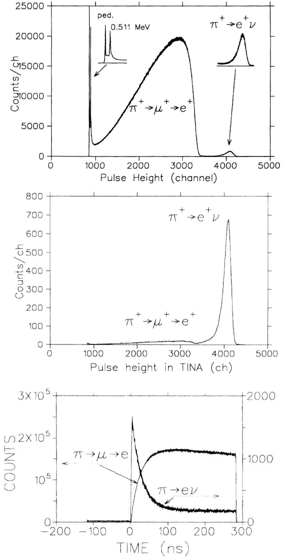

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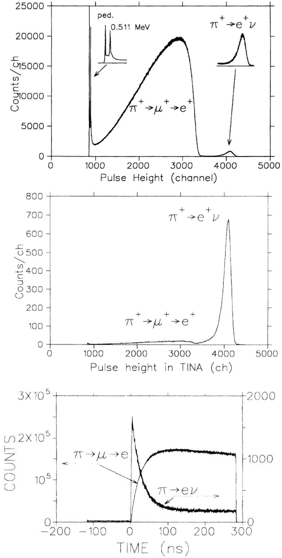

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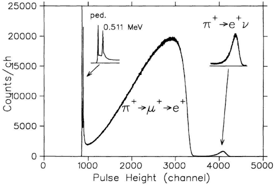

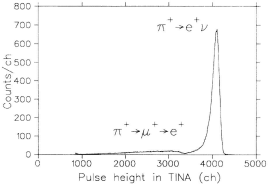

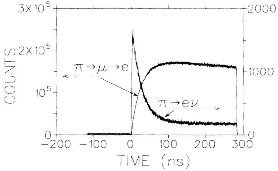

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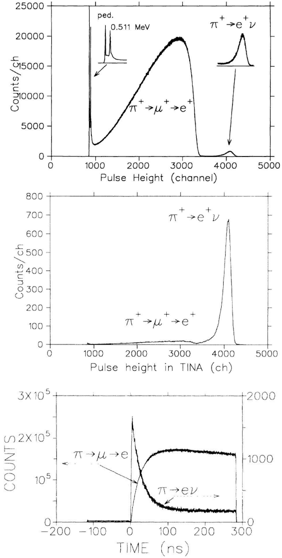

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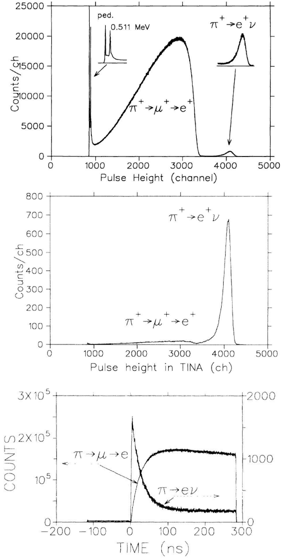

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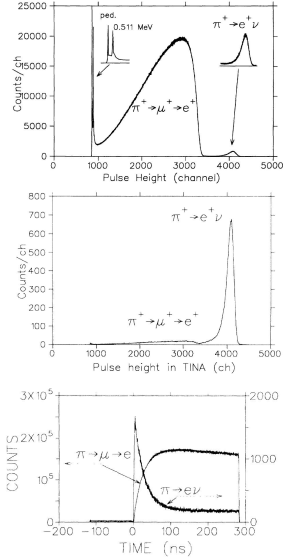

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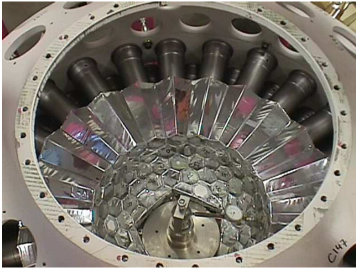
- PRD86: $(1.218 \pm 0.014) \cdot 10^{-4}$
- PLR93: $(1.2265 \pm 0.0034 \pm 0.0044) \cdot 10^{-4}$

- TRIUMF E1072 experiment proposed 2006
  - better tracking, larger solid angle (25 %)

$$\text{Goal: } \frac{\delta B}{B} \simeq 1 \times 10^{-3} .$$

  - Engineering runs Aug.-Oct. 2008
  - Data taking 2009-10

The PIBETA/PEN Apparatus: 1998-2008



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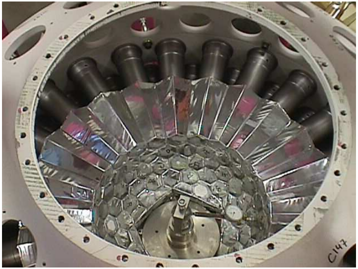

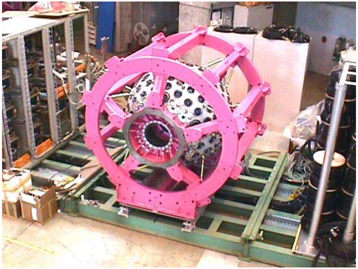

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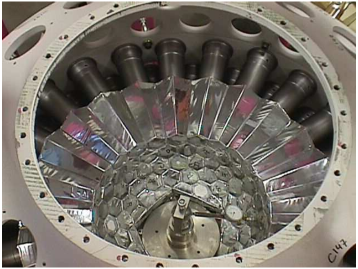

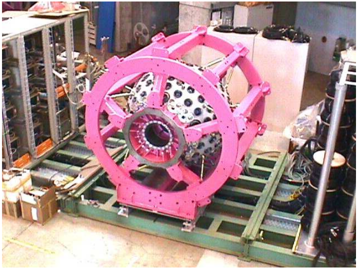

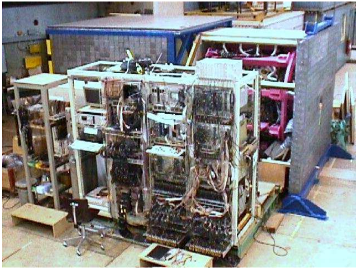

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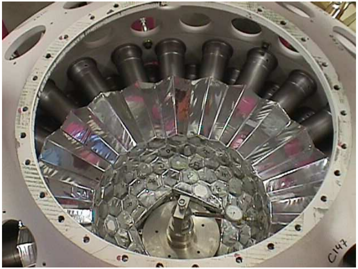

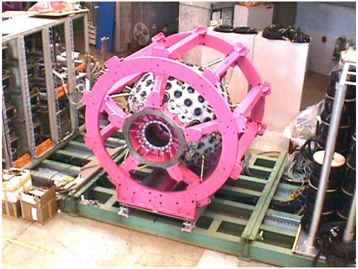

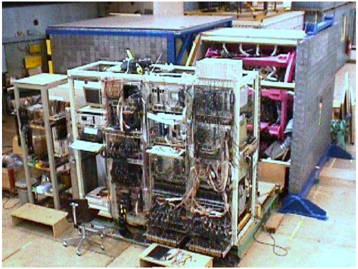

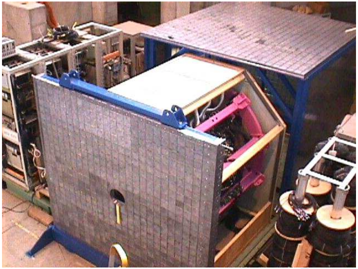

The PIBETA/PEN Apparatus: Basic Subsystems

- stopped π^+ beam
- active tracking degrader
- active target counter
- 240-det. CsI(p) calo.
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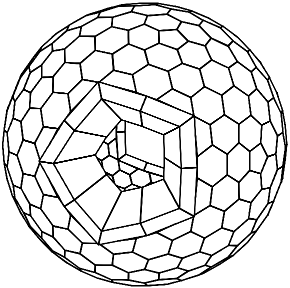

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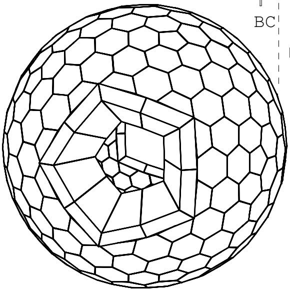
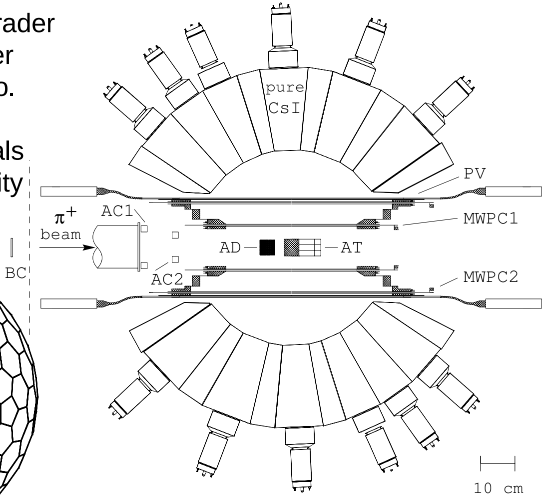
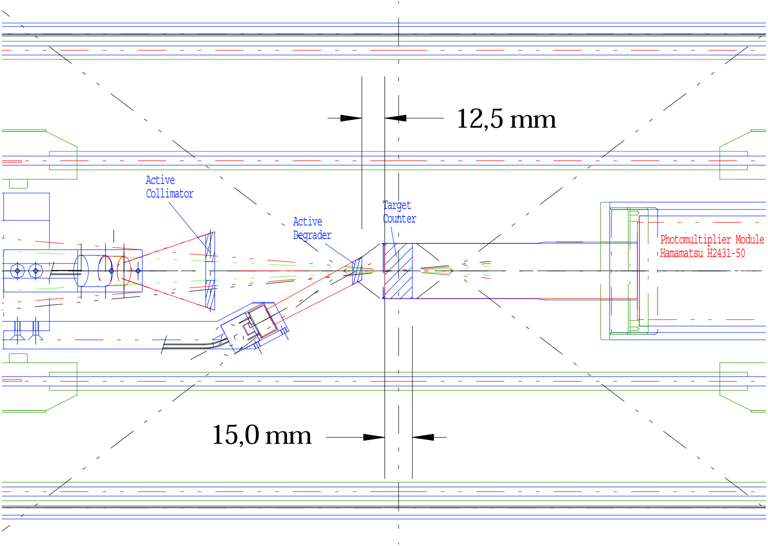
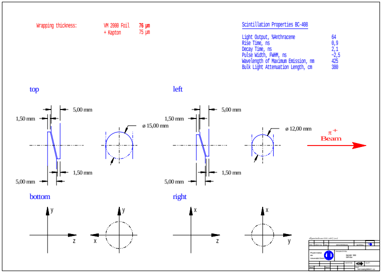


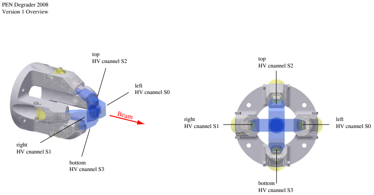


Central detector region for the 2007/2008 run



4-wedge Tracking Active Degrader 2008





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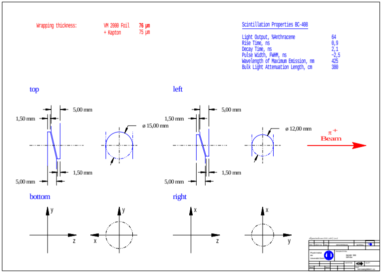

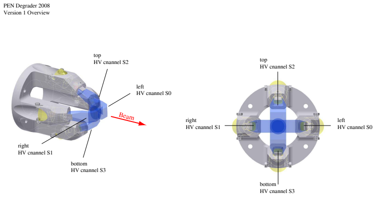

- AD π^+ + MWPC e^+ Tracking = e^+ pathlength in Target= suppresion of In-Flight Decays
- BC-408 Scintillator
- 0.9 ns Rise Time
- 2.1 ns Decay Time
- 160 Phel/MeV
- two x and two y Wedges
- 3 cm Upstream of Target

Acqiris Digitizer for Target Counters

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- High-Speed 10-bit PXI/CompactPCI
- 1 ch=8 G/s, 2 ch=4 G/s, 4 ch=2 G/s
- Acquisition memory: 256-1024 kp
- Complete pre- and post-triggering
- Low 350 ns dead time
- 400 MB/s PCI bus transfers data
- High-res. TTI for accurate timing
- Device driver for Windows XP

PEN: Statistical Uncertainties

Relative statistical uncertainty for $N_{e2} = (1+\epsilon)N_p$ HT events:

$$\frac{\Delta N_{e2}}{N_{e2}} = \left[\frac{1}{N_p} + \frac{(\Delta\epsilon)^2}{(1+\epsilon)^2}\right]^{1/2} .$$

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Conservative choice of $E_{\mathrm{HT}} = 46\,\mathrm{MeV} \rightarrow$ tail fraction $\epsilon = 0.02$.

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Setting $\Delta N_{e2}/N_{e2} = 2\times 10^{-4}$, $r_{\pi\mathrm{stop}} = 20,000$/sec, $f = 1/16$:

$$N_p = 3.4\times 10^7 \text{ and } r_{\mathrm{trig}} \sim 75 \text{ (6 months net beam time).}$$

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- π/μ decay discrimination: low μ decay pileup, digitized target waveforms

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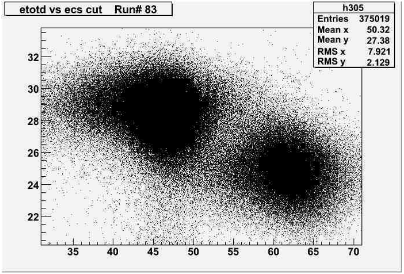
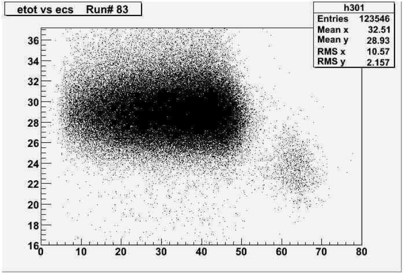
$\pi \to e\nu$ Branching Ratio and $\pi \to e\nu$ Tail Fraction

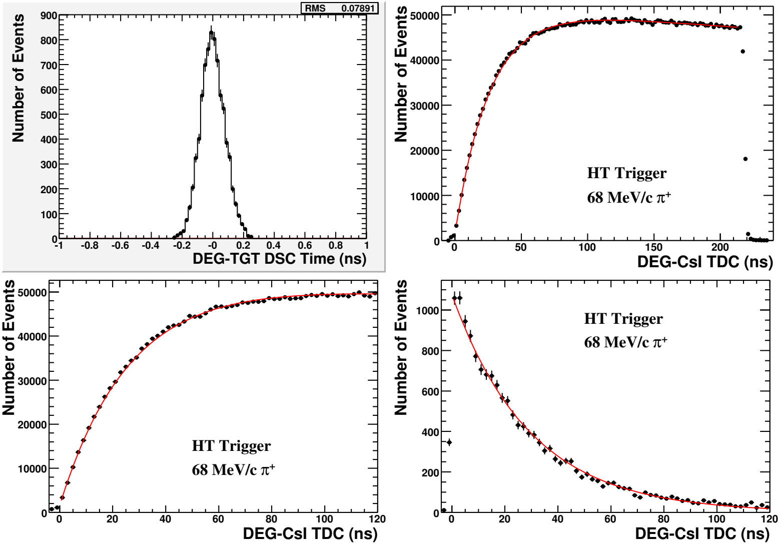
Illustration from 2008 data: BR will be determined from HT data, tail fraction deduced from prescaled LT runs.

Raw histograms show total target energy vs total CsI calorimeter energy (left: HT, right: LT).

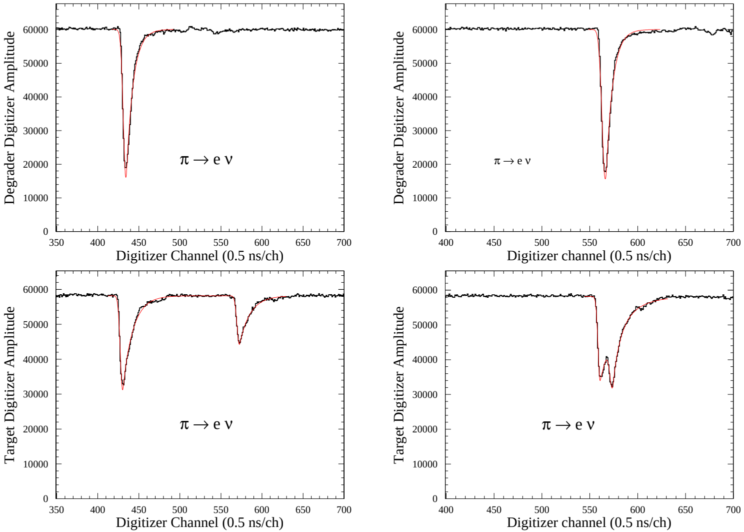




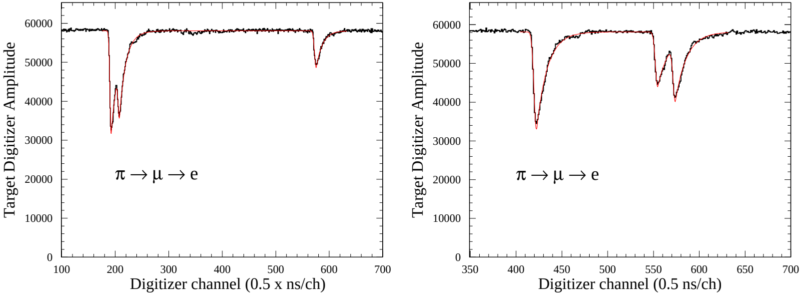
Timing Spectra



Target Waveforms: $\pi \to e\nu$ Events



Target Waveforms: Michel Events



Artificial Neural Network: Inputs and Output

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```
double p2e_mpl::value(int index,double in0,double in1, double
in2,double in3,double in4,double in5) {
input0 = (in0 - 18.365)/2.02788; ...
input5 = (in5 - 2.34097)/0.474034;
return ((neuron0xa212580()*1)+0); }
double p2e_mpl::neuron0xa212580() {
double input = 0.0816982;
input += synapse0xa212648(); ...
return input } ...
```

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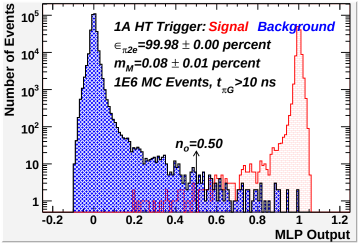
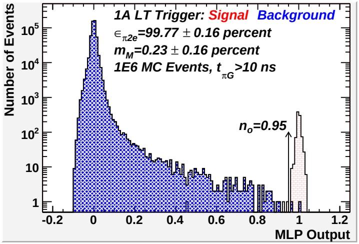
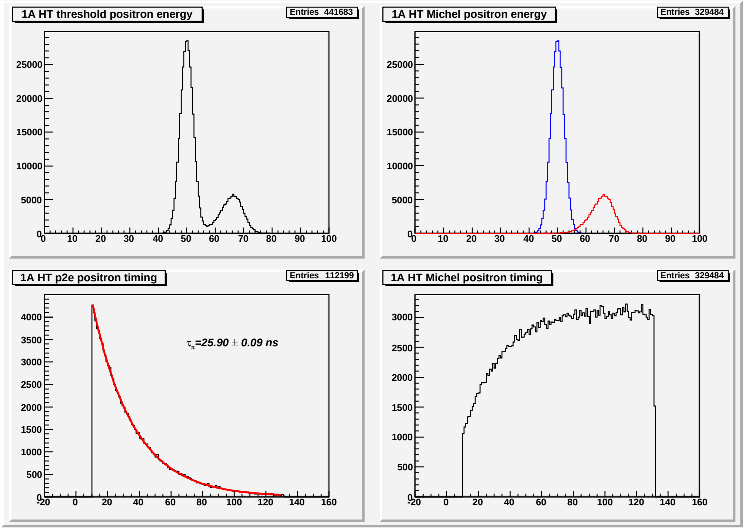




Discrimination with Neural Networks: MC Simulation



PEN Summary & Future Plans

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