Measurement of the PIENU branching ratio

A sensitive probe in the search for new physics

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For the PIENU collaboration

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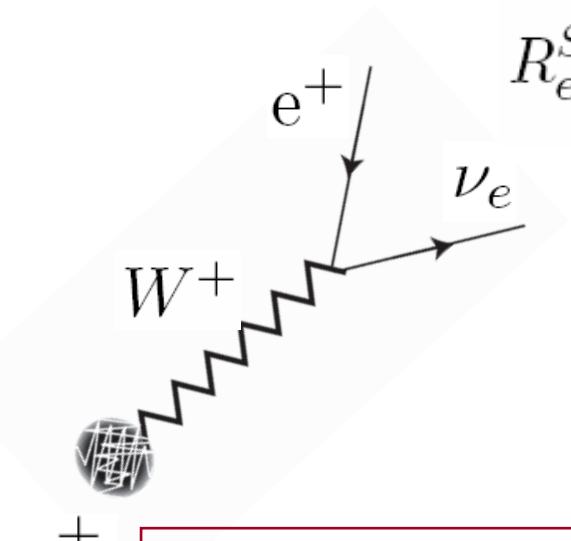
Precision measurement

- Real deviation from the SM → new physics observation
- Agreement with SM → useful constraints
- Extreme sensitivity to high mass scales



$$R_{e/\mu}^{SM} = \frac{\Gamma(\pi \to e\nu + \pi \to e\nu\gamma)}{\Gamma(\pi \to \mu\nu + \pi \to \mu\nu\gamma)} = 1.2353(1) \times 10^{-4}$$

$$R_{e/\mu}^{exp} = 1.231 \pm 0.004 \times 10^{-4}$$

World average: TRIUMF (1992), PSI (1993)

2 orders of magnitude difference in precision ⟶ window for BSM

New experiment x5 better precision ⟶ < 0.1%

Universality test / Beyond SM search

$$\frac{g_e}{g_\mu} = 1?$$

Process	g_e/g_μ
$\pi \to e\bar{\nu}/\pi \to \mu\bar{\nu}$	0.9985±0.0016
$K \to e\bar{\nu}/K \to \mu\bar{\nu}$	1.012±0.01
$\tau \to e\bar{\nu}\nu/\tau \to \mu\bar{\nu}\nu$	0.9999±0.0021
$\nu_e\nu_\mu$ scattering	1.10±0.005
W decays	0.999±0.011

PiENu : g_e/g_μ < 0.05%

New pseudoscalar interaction:

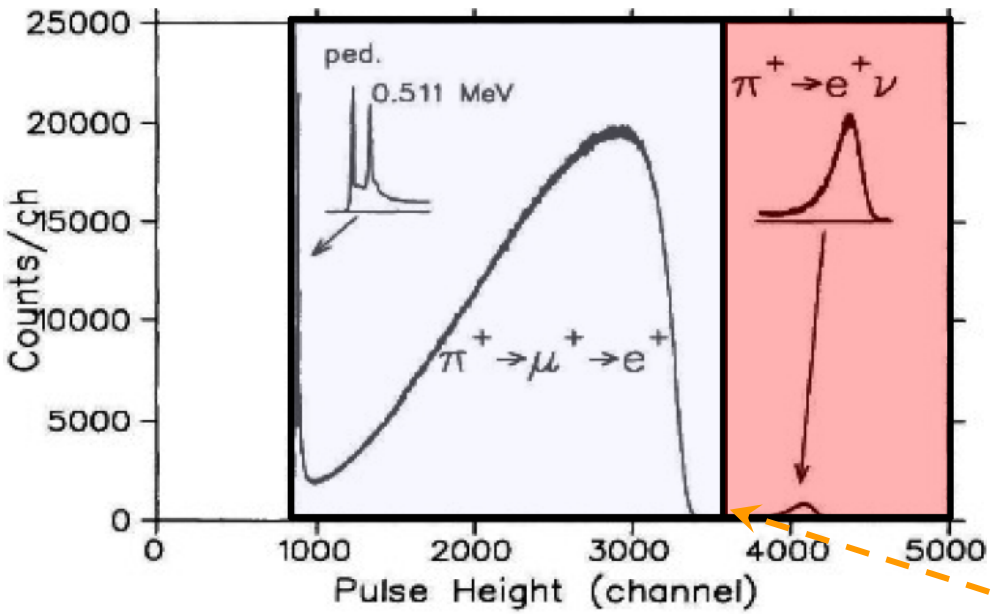
$$1 - \frac{R^{New}_{e/\mu}}{R^{SM}_{e/\mu}} \sim \mp \frac{\sqrt{2}\pi}{G_\mu} \frac{1}{\Lambda^2_{eP}} \frac{m_\pi^2}{m_e(m_d + m_u)}$$
$$\sim \left(\frac{1TeV}{\Lambda_{eP}}\right)^2 \times 10^3$$

0.1% measurement $\Longrightarrow$ Λ_{eP} ~ 1000 TeV

- Massive ν's
- Scalar coupling
- Leptoquarks
- Compositeness
- R-Parity violation SUSY
- . . .

Former experiment at TRIUMF E248

$$R_{e/\mu}^{exp} = 1.2265 \pm 0.0034(\text{stat}) \pm 0.0044(\text{syst}) \times 10^{-4}$$



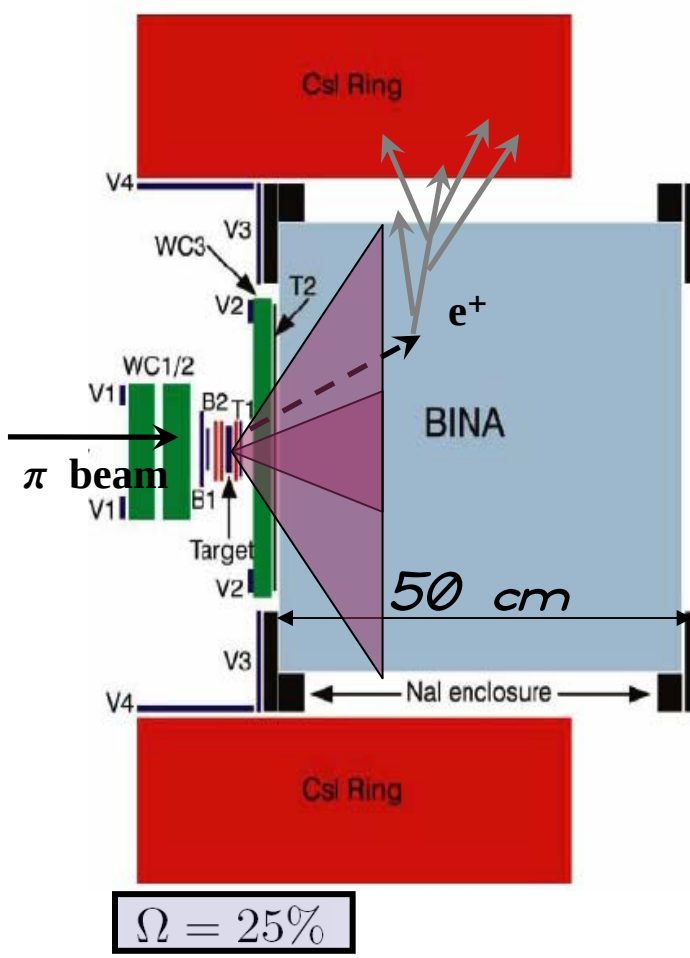
$$\pi^+ \to e^+ \nu \quad P_e = 70\text{MeV/c}$$
$$\pi^+ \to \mu^+ \nu$$
$$\mu^+ \to e^+ \nu \bar{\nu} \quad P_e = 0 - 53\text{MeV/c}$$

Main source of uncertainties:

- Low energy tail buried under Michel spectrum
- Energy dependence of acceptance correction
- Small acceptance $(\Omega) \to$ low statistics

PiENu (E1072): key improvement

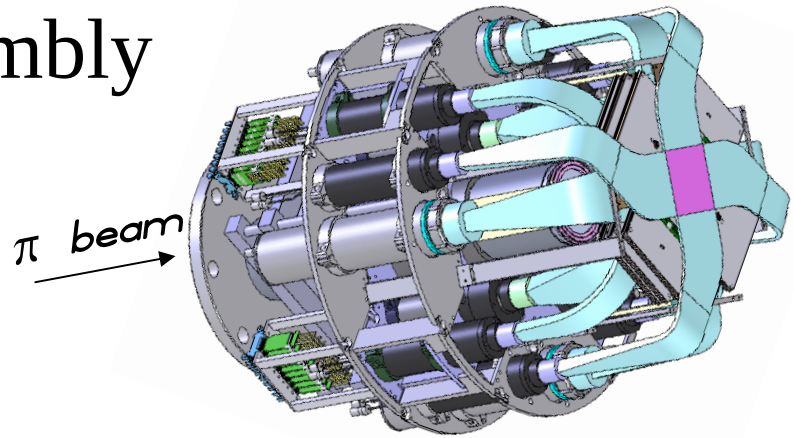
- **Larger solid angle (Ωx10)**
  - More statistics
  - Lower energy dependent acceptance difference
  - Detect shower leakage (CsI) for low energy tail measurement (biggest systematics)
- **Silicon Strip near target & WC**
  - Much improved tracking
  - Detect Decay In Flight → for tail correction
- **High resolution calorimeter**
  - BINA resolution 2 times better than TINA
- **Use of fast digitizers**
  - Better separation between $\pi \to e\nu$ and $\pi \to \mu \to e$

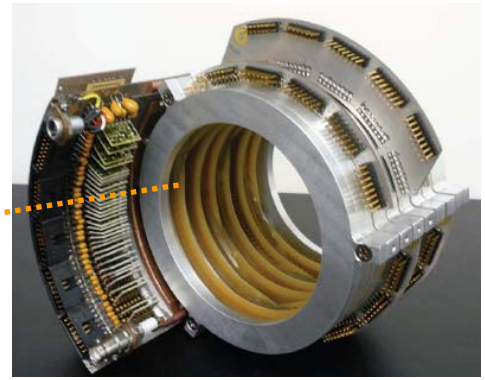


Detector subsystem

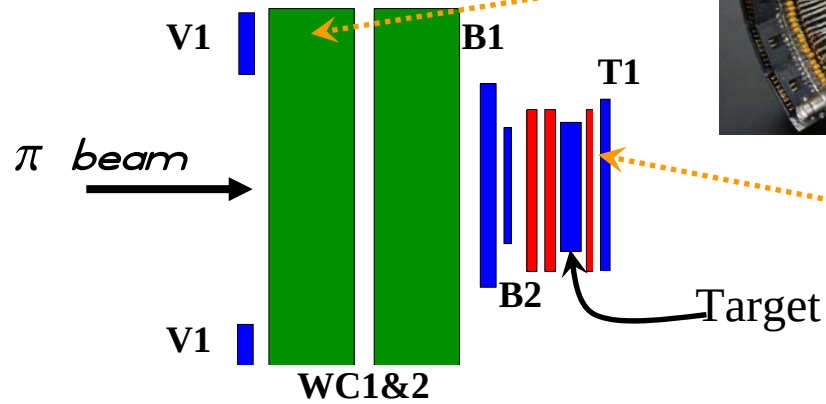
PiENu 1 : Beam&Target assembly

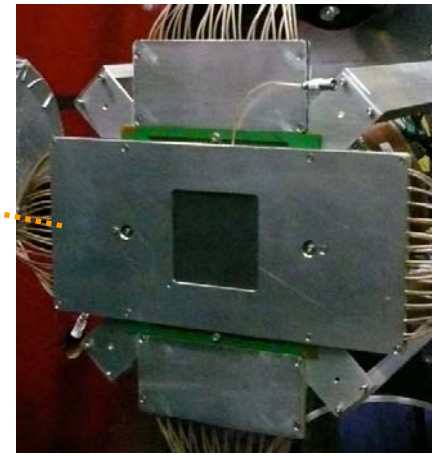
- Annular veto counter (V1)
- Wire chambers (WC1,WC2)
- Beam counters (B1, B2)
- Si-strip detectors (SS1, SS2)
- Targer counter
- Si-strip detectors (SS3)
- Telescope counter (T1)





Silicon and WC tracking (determine stop/decay vertex) suppress Decay In Flight Monte Carlo →x10 suppression

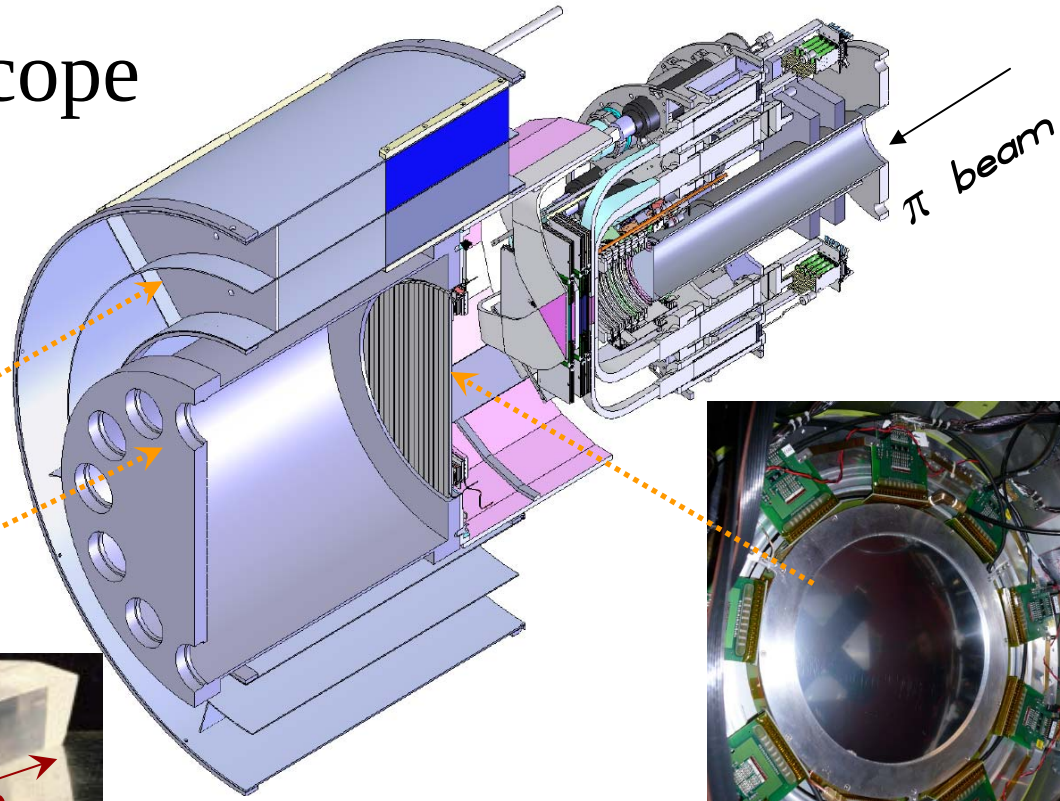


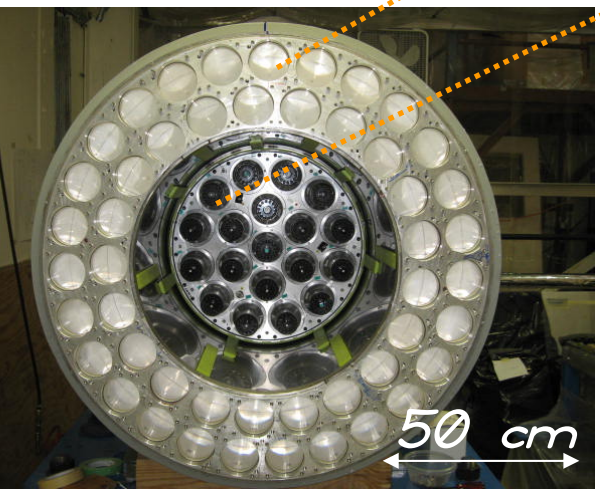


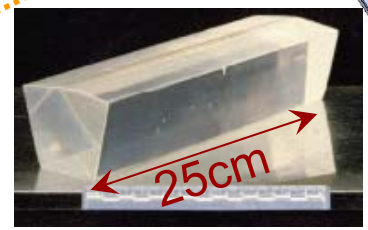
Detector subsystem (cont'd)

PiENu 2: Positron telescope

- Telescope counter (T2)
- Wire chamber (WC3)
- NaI(Tl) crystal (BINA)
- Pure CsI crystal ring
- Veto counters (V2-V4)







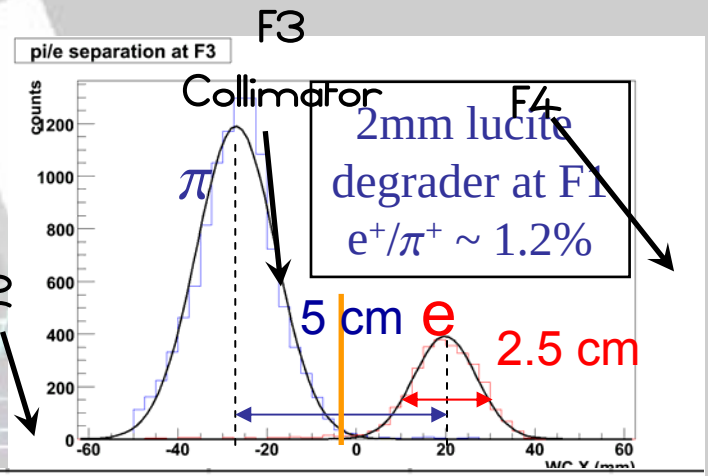
Minimal material between Target and BINA to reduce scattering

Movable, detachable from PieNu 1 for line shape measurement at various e+ entrance angles

New beamline

- Suppression of beam positrons
- Protection against neutral showers

Lucite degrader at F1 causes ca. 5cm lateral displacement of π^+ at F3

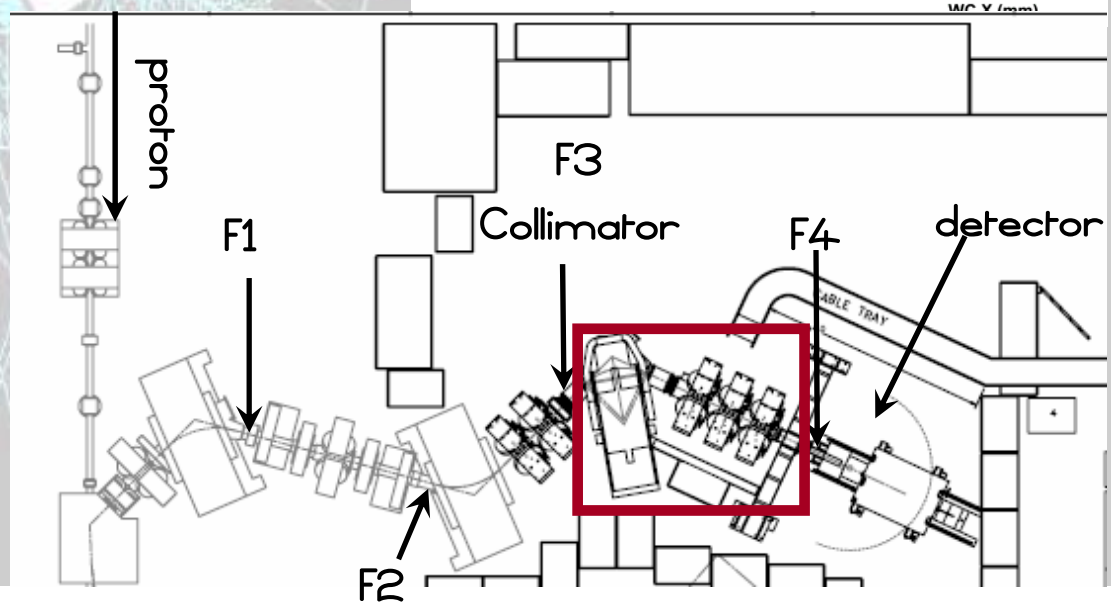


Total e+ reduction x 100-200

π^+ ~ 82%

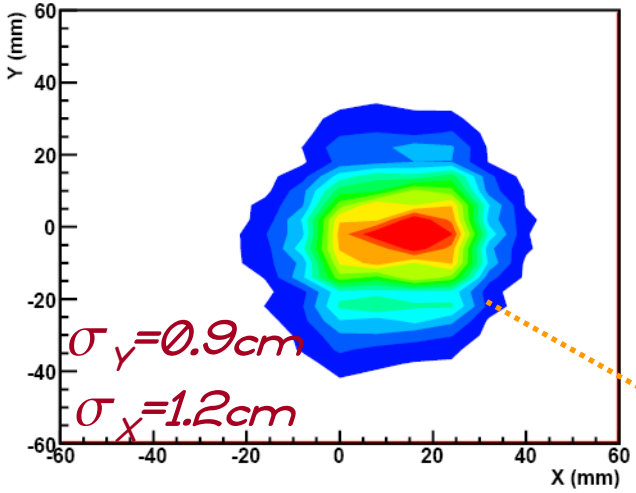
μ^+ ~ 14%

e^+ < 2%

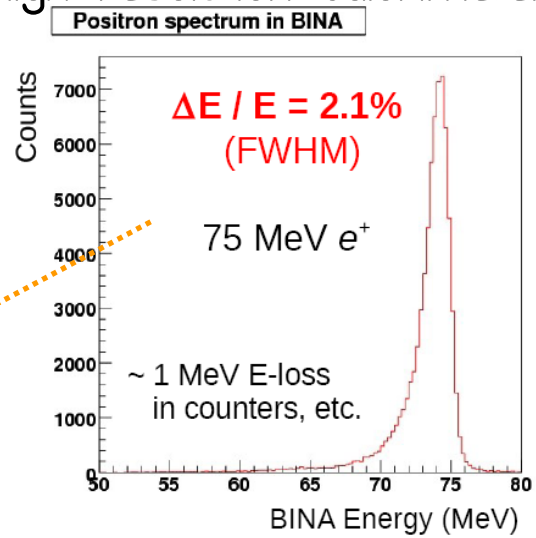


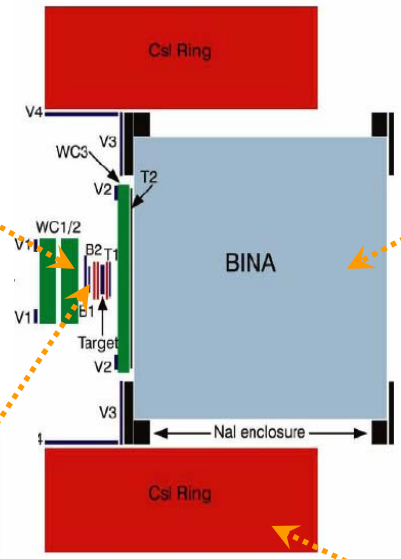
Beam test results

✓Good beam spot

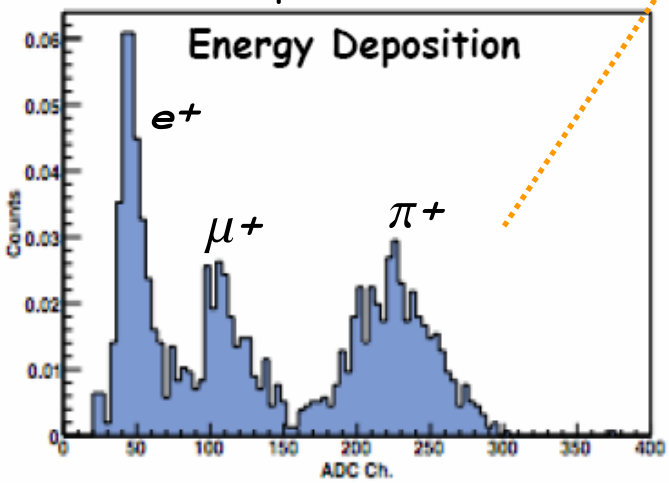


✓High resolution calorimeter

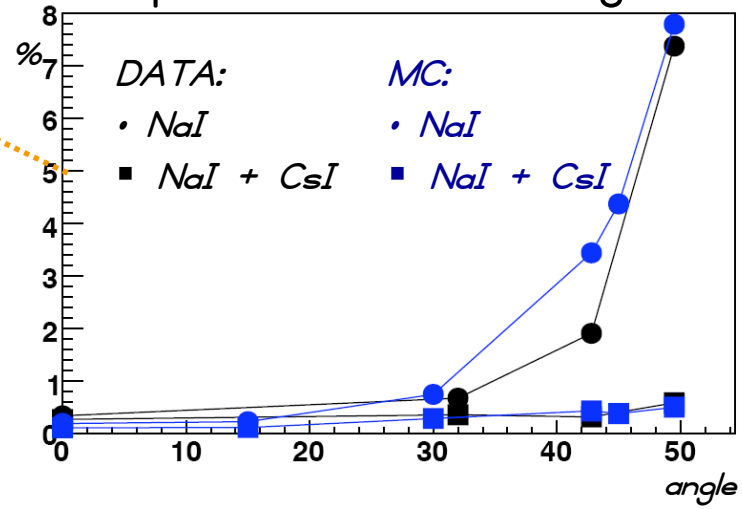




✓Good separation in silicon



✓Good tail suppression with CsI at different positron entrance angles



The challenge!

source	E248	PiENu
Statistical	0.0028	0.0005
Low E tail ($\pi^+ \rightarrow e^+\nu$)	0.0025	0.0003
Acceptance difference	0.0011	0.0003
π^+ lifetime	0.0009	0.0002
Others	0.0011	0.0003
Total	0.0047	0.0006

PiENu schedule :

2008	09	End of beamline extension work
	10-12	Test run
2009	01-03	Construction and Final Installation
	04-07	Engineering run
	08-12	Physics run

Conclusion

$\pi^+ \to e^+ \nu$ branching ratio will be measured to <0.1% precision (<0.05% in g_e/g_μ)

Test of lepton universality

High sensitivity to high mass scales ~1000 TeV

Complementary to studies at LHC