The PIENU Experiment

Chloé Malbrunot

For the PIENU Collaboration

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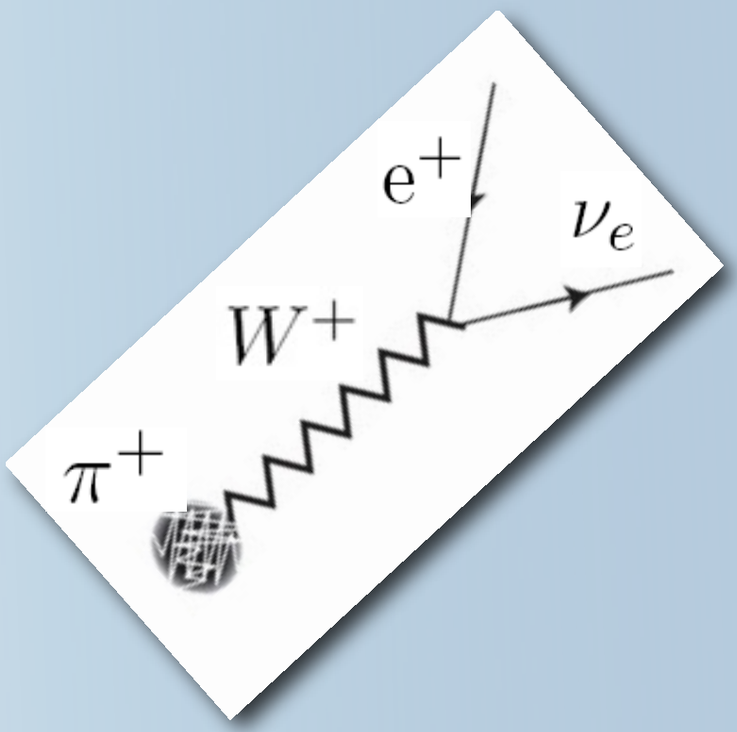
A Precision Experiment



$$R_{e/\mu}^{SM} = \frac{\Gamma(\pi \to e\nu + \pi \to e\nu\gamma)}{\Gamma(\pi \to \mu\nu + \pi \to \mu\nu\gamma)} = 1.2352(1) \times 10^{-4}$$

V.Cirigliano, I.Rosell, Phys. Rev. Lett. 99, 231801 (2007)
W.J. Marciano, A. Sirlin, Phys. Rev. Lett. 71, 3629-3632 (1993)

Current world average : TRIUMF, PSI :

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

TRIUMF : D.A.Bryman, T.Numao, et al. Phys.Rev.D53:558-559,1996
PSI : G. Czapek et al. Phys.Rev.Lett.70:17-20,1993

2 orders of magnitude difference in precision
→ window for BSM physics

PIENU goal : x5 better precision → precision < 0.1% on the BR

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

BSM search / Universality Test

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

$$\sim (\frac{1TeV}{\Lambda_{eP}})^2 \times 10^3$$

0.1% measurement → Λ_{eP}~ 1000 TeV

Mode	g_e/g_μ
$\pi \to e\nu/\pi \to \mu\nu\nu$	0.9985 ± 0.0016
$K \to e\nu/ K \to \mu\nu$	1.0018 ± 0.0025
$\tau \to e\nu\nu/\tau \to \mu\nu\nu$	0.9987 ± 0.0028
ν_e / ν_μ scatt.	1.10 ± 0.05
W decays	0.999 ± 0.011
$K \to \pi e\nu/ K \to \pi\mu\nu$	0.9979 ± 0.0025

- Massive ν's
  R.E Schrock Phys.Rev.D 24, 5 (1981)
- Scalar coupling
  B.A. Campbell & David W. Maybury Nucl. Phys. B, 709 419-439 (2005)
- Compositeness
  N. Arkani-Hamed, S. Dimopoulos, G.R. Dvali, Phys. Lett., B429, 263 (1998)
- R-Parity violation SUSY
  M. J. Ramsey-Musolf, S. Su & S.Tulin, Phys. Rev. D 76, 095017 (2007)
- ...

$$\Gamma_{\pi \to l\nu_l} = \frac{G^2 m_\pi}{8\pi} \mid V_{ud} \mid^2 f_\pi^2 m_l^2 (1 - \frac{m_l^2}{m_\pi^2})^2 [1 + RC]$$

0.1% measurement in the BR →
0.05% in ge/gμ

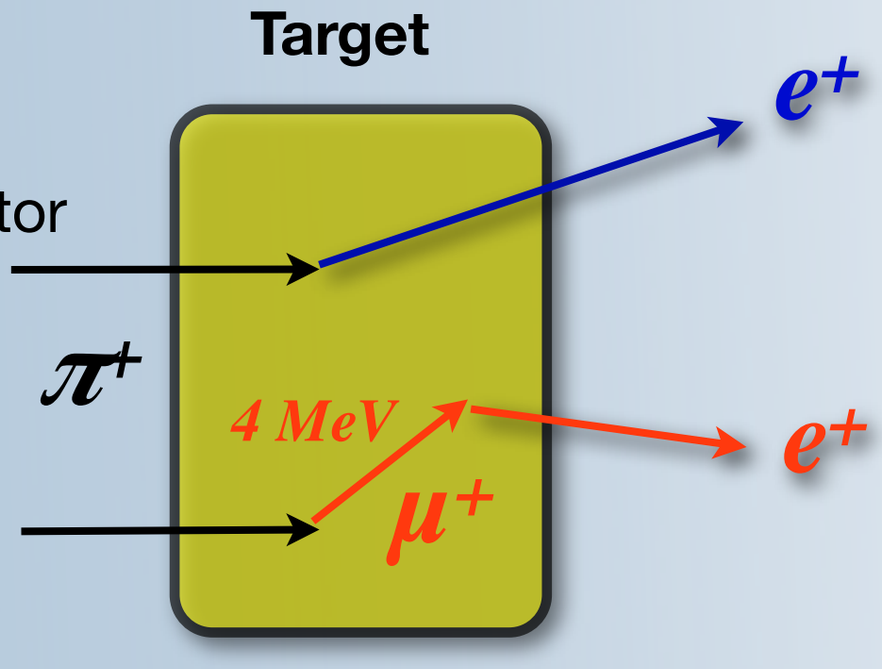
The Experimental Technique

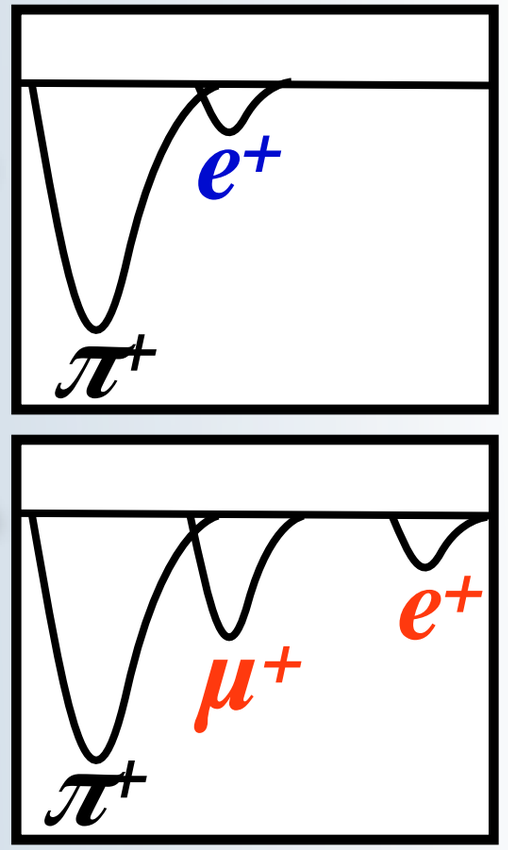
Experimental Method

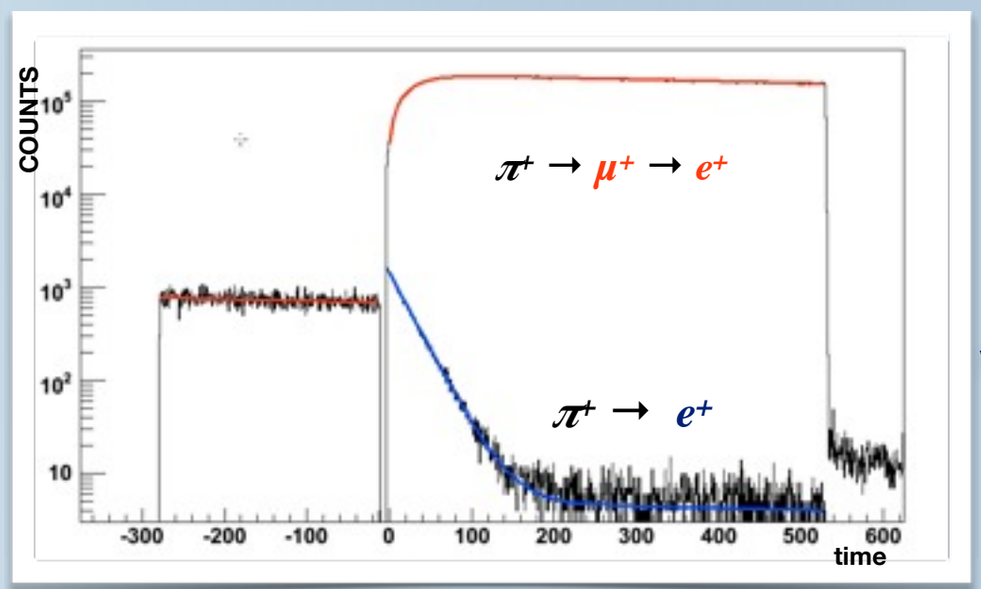
- Stop pions in an active target Scintillator
- High speed pulse digitization

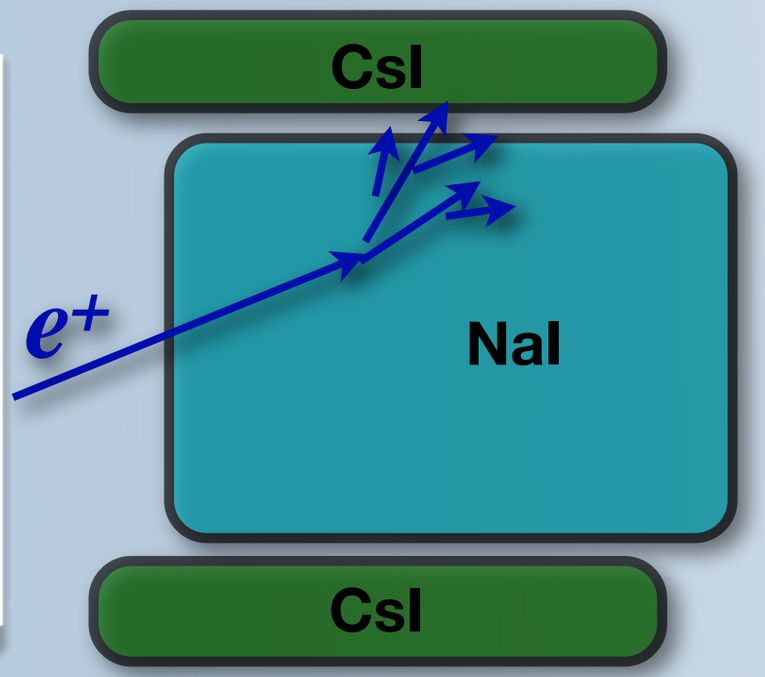
Required

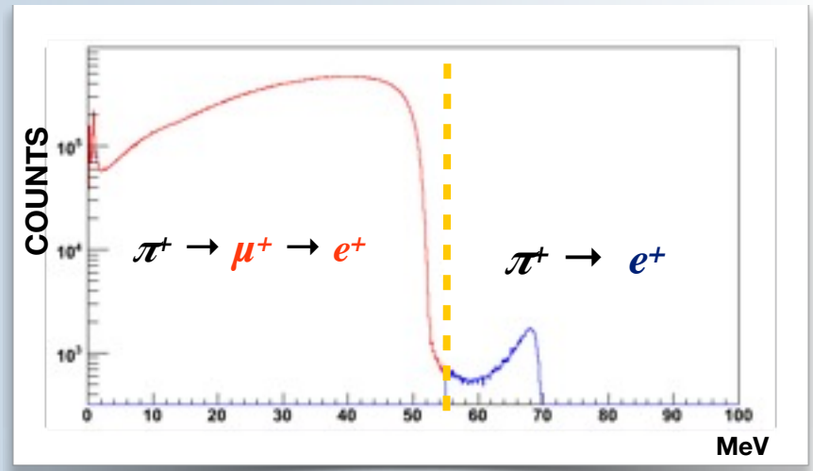
- High purity pion beam
- Suppress decays in flight (DIF)
- Response function of calorimeter











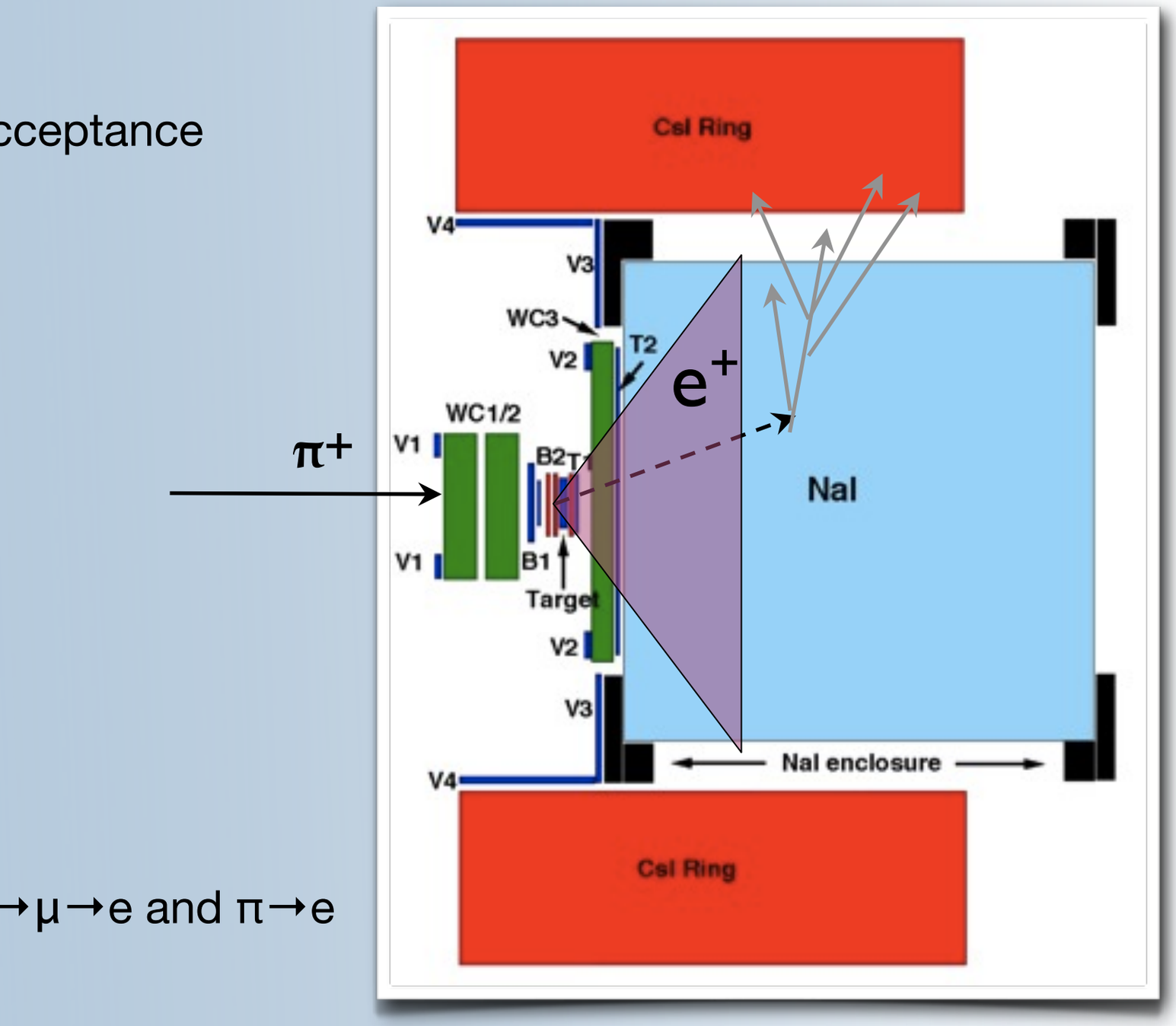
The PIENU detector

- Large solid angle ($\Omega/4\pi$ = 20%)
  Good statistics
  Minimal energy dependence of acceptance
  Contain shower leakage (CsI)

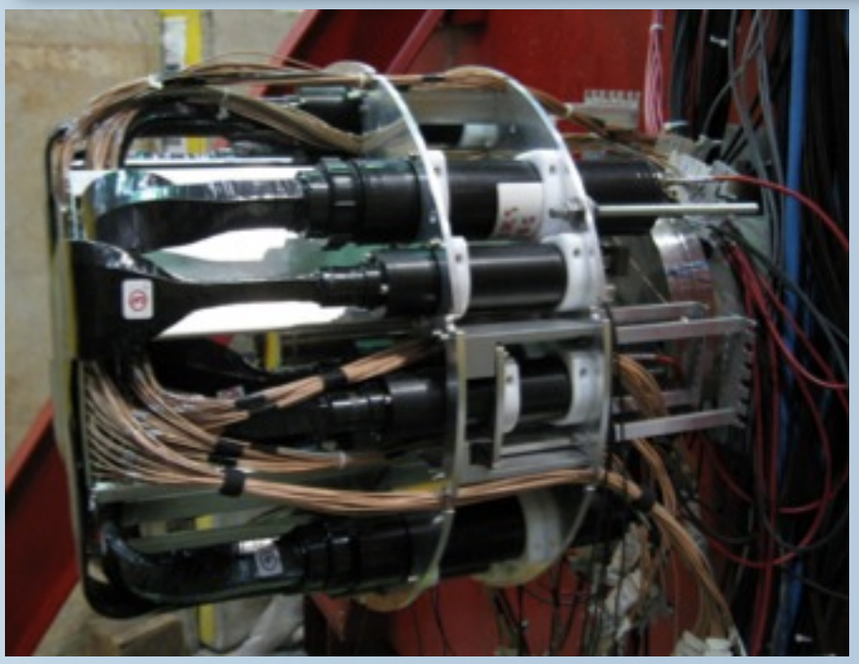
- Silicon near target & WC
  Good tracking
  Detection of Decay In Flight

- High resolution calorimeter
  NaI :1% σ at 70 MeV

- Use of fast digitizers
  500 MHz : separation between π→μ→e and π→e

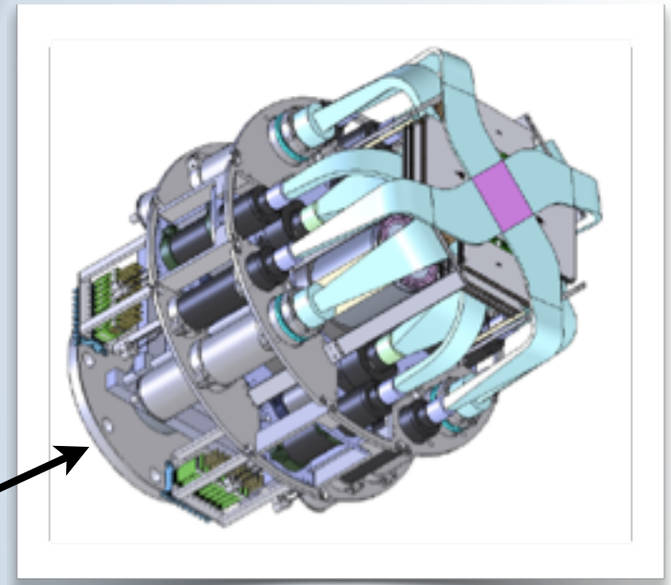


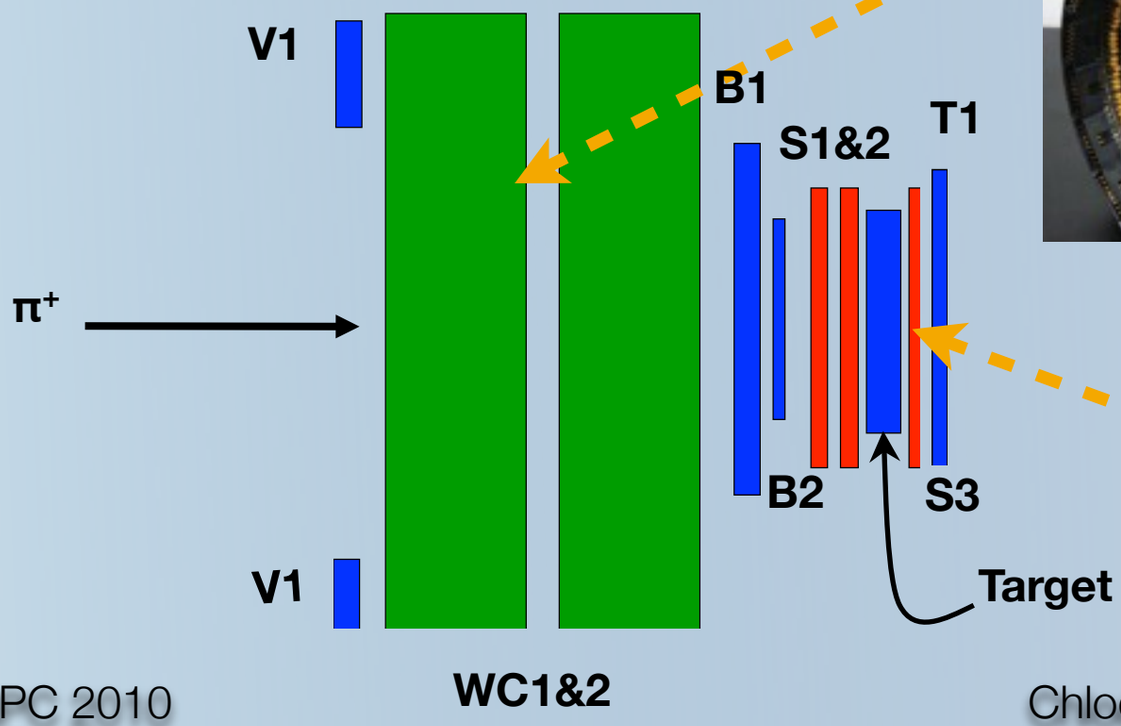
Detector subsystem



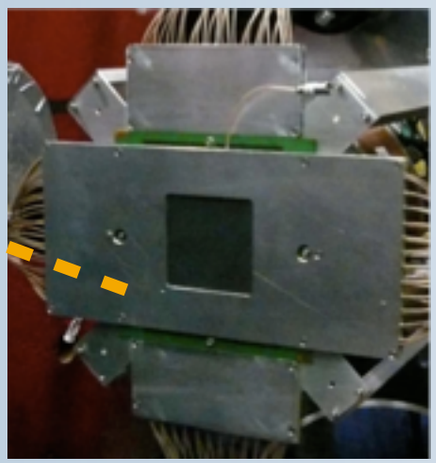
PIENU 1 : Beam&Target assembly

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





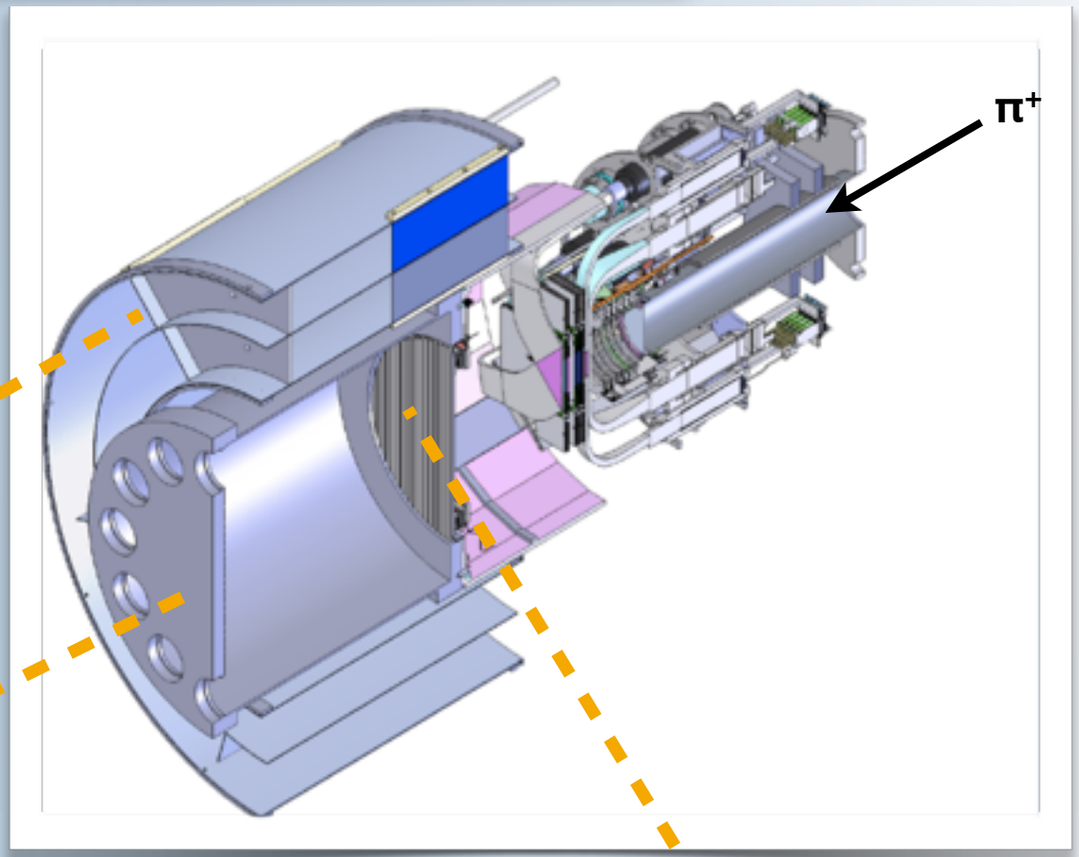
Silicon and WC tracking
(determine stop/decay vertex)
suppress Decay In Flight
Monte Carlo : x10 suppression

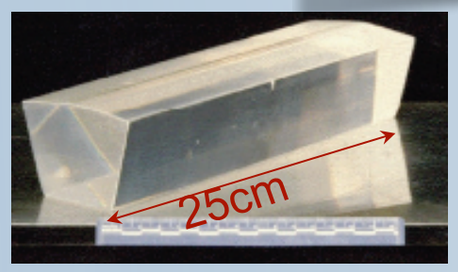


Detector subsystem (cont'd)

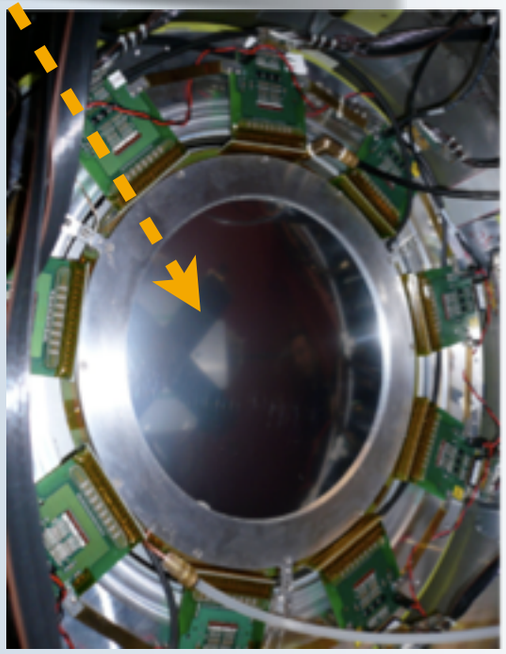
PIENU 2: Positron telescope

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



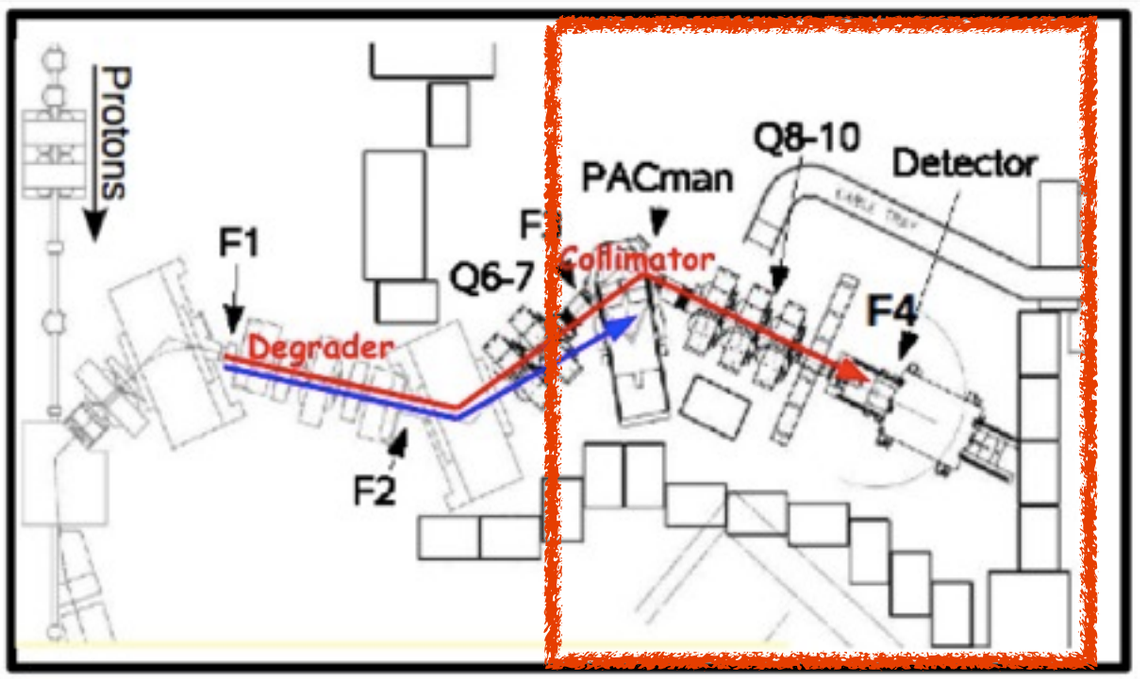


19'x19' monolithic NaI(Tl) Crystal
97 single CsI crystals



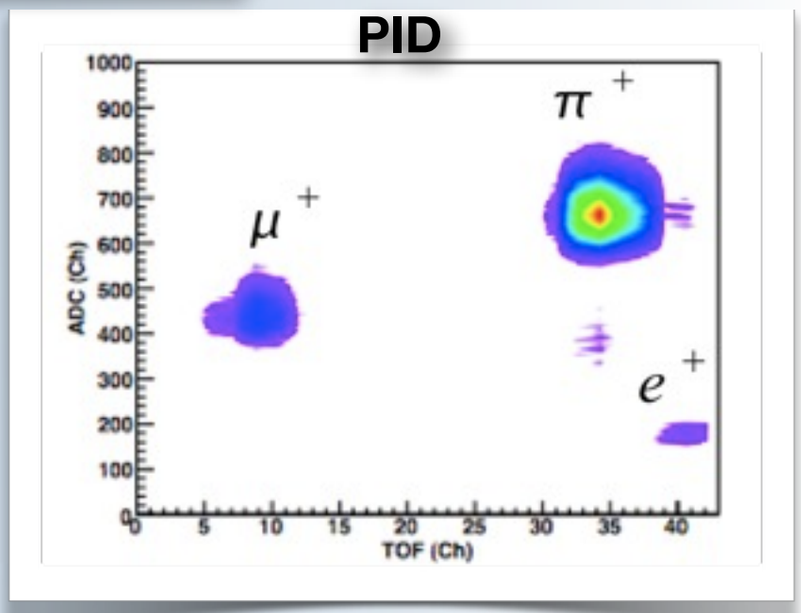
Minimal material between Target and BINA to reduce scattering
Movable, detachable from PIENU 1 for line shape measurement at various e+ entrance angles

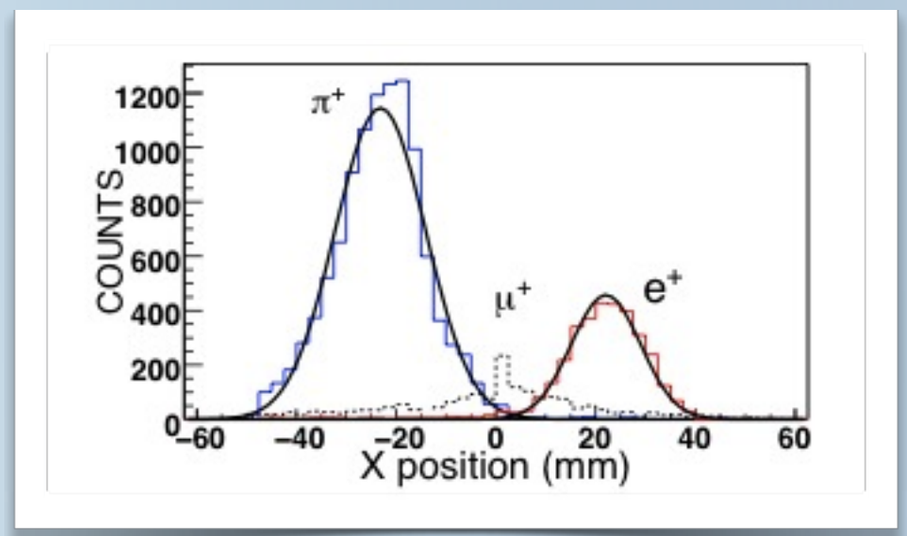
Beamline Extension



Beam Composition:

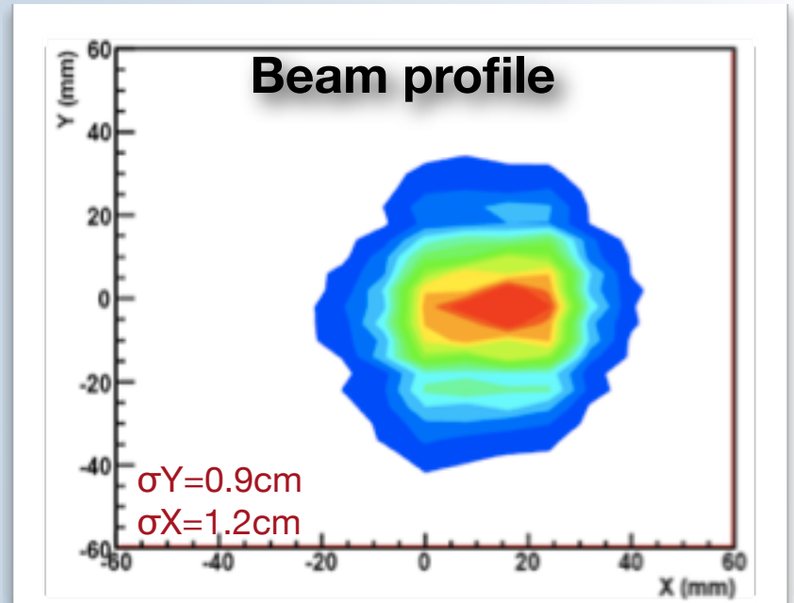
e^+ (<2%)
μ^+ (14%)
π^+ (82%)





A. Aguilar-Arevalo et al., Nucl. Instr. and Meth. A 609 (2009)

Rates : 60KHz stopped π
Consistent with beamline calculations
Additional shielding
Snout for scattering reduction

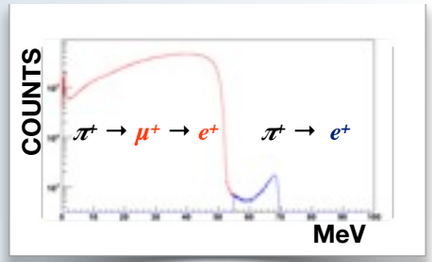


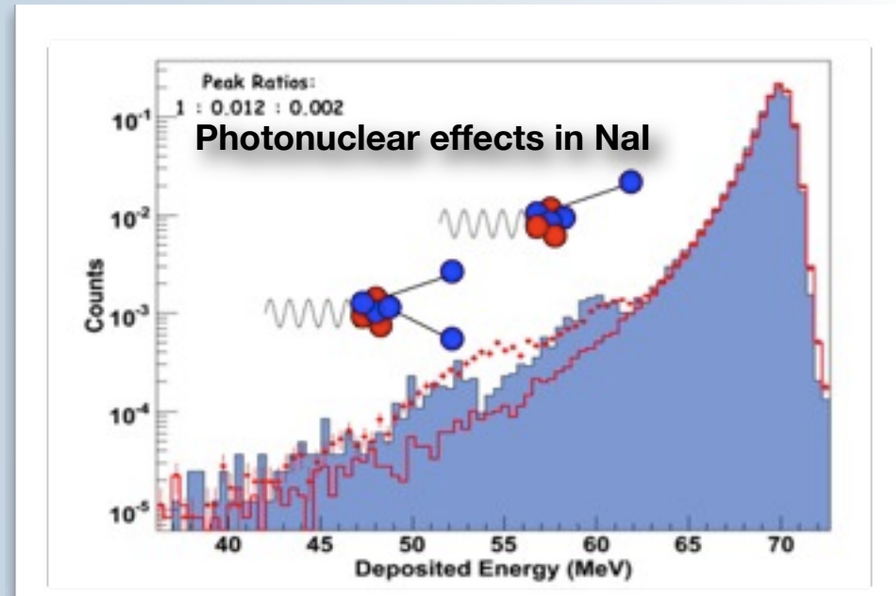
Beamline extension studies with 2nd order MC beam transport program (REVMOC)
G4 (G4beamline) simulation of the beamline material's and absorber effects

Sources of errors

Source	E248 TRIUMF	PIENU
Statistical	0.28%	0.05%
Low energy tail	0.25%	0.03%
Monte Carlo	0.11%	0.03%
Pion lifetime	0.09%	0.03%
Others	0.11%	0.03%
Totals	0.5%	0.06%

3 major sources of errors
- Statistical
- Tail correction
- Monte Carlo

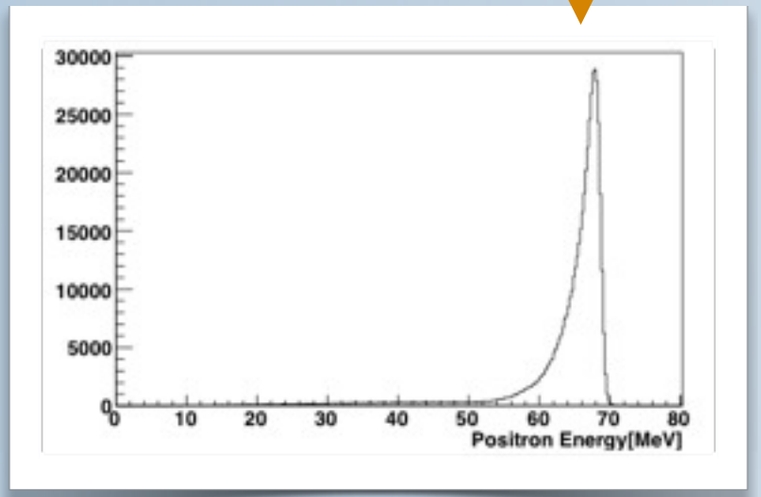


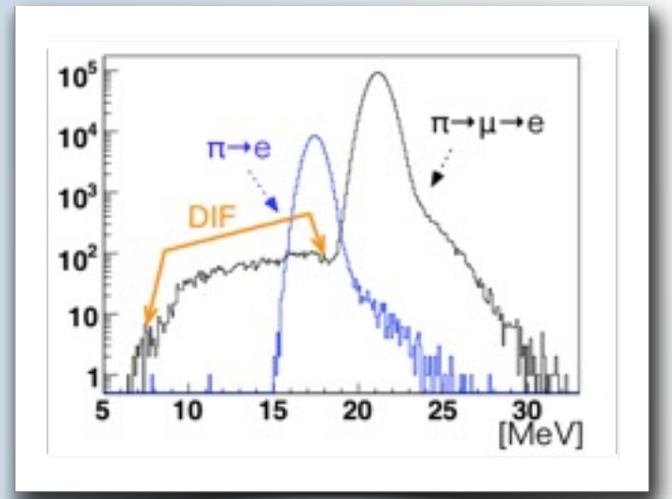


A. Aguilar-Arevalo et al., Nucl. Instr. and Meth. A (2010)

Raw Branching ratio
- 30 x more statistics than last experiment
- Rejection of BG (decrease statistic error)
- Good fit (decrease systematic error)
  - Understand BG shape
  - Non-linearity effect of electronics

Tail Correction
- Pulse shape cut of target signal
- Tracking for π→μ→e suppression
- Understanding of Response functions





Preliminary Analysis

HEAVY NEUTRINO SEARCH IN PIENU DECAY

heavy υ

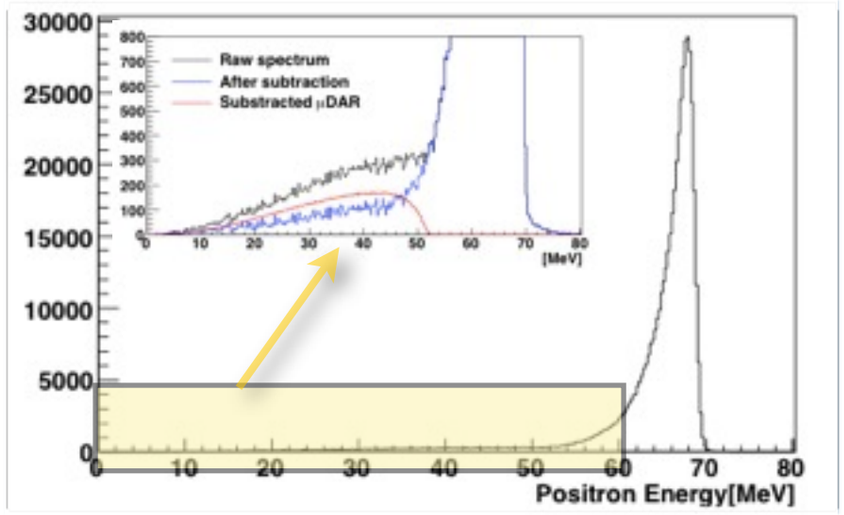
Kinematic factor

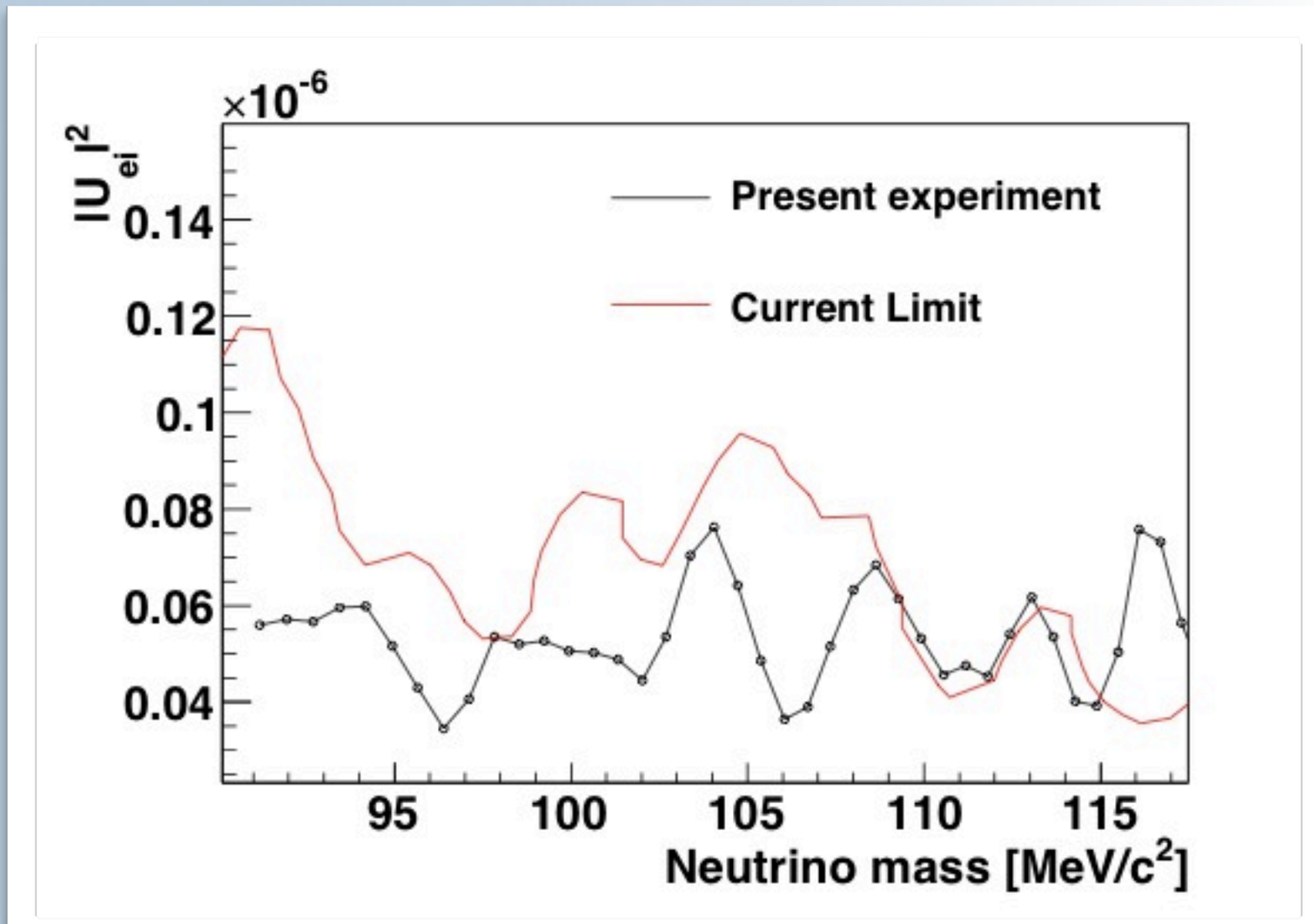
$$R_{ei} = \frac{\Gamma(\pi \to e\nu_i)}{\Gamma(\pi \to e\nu_l)} = |U_{ei}|^2 \rho_{ei}$$

conventional υ

Heavy ν : Additional peak in the **suppressed Spectrum**

Bump search : upper bound on mixing ratio





Doctoral Thesis K. Yamada (2010)

Results of Summer 2009 data

Better limits on a wider mass range is expected with full statistics

Conclusion

Beam

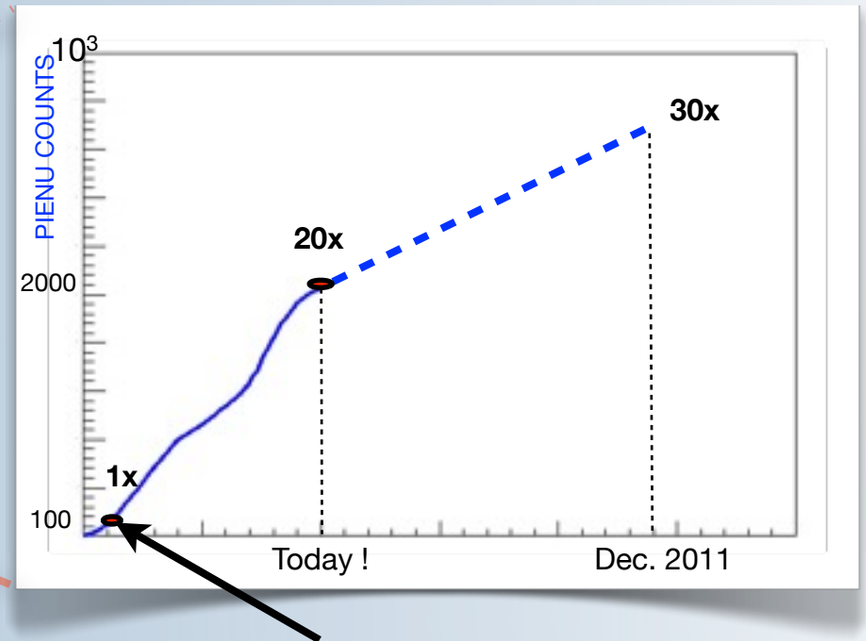
Good Performance of the new beamline (clean pion beam)
Expected pion stop rate achieved

Detector

Large solid angle (20%),
High NaI Resolution
Si strips reduce decay in flight events
CsI ring reduces shower leakage
Neutral pileup lower than the previous experiment (shielding, beamline)

Status

2008	09	End of beamline extension work
	10-12	Test run
2009	04-07	Construction and Final Installation
	08-12	Engineering run
	10-12	Physics run
2010	04-07	Physics run
	10-12	Physics run
2011	07-12	Physics run



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ANALYSIS UNDERWAY !

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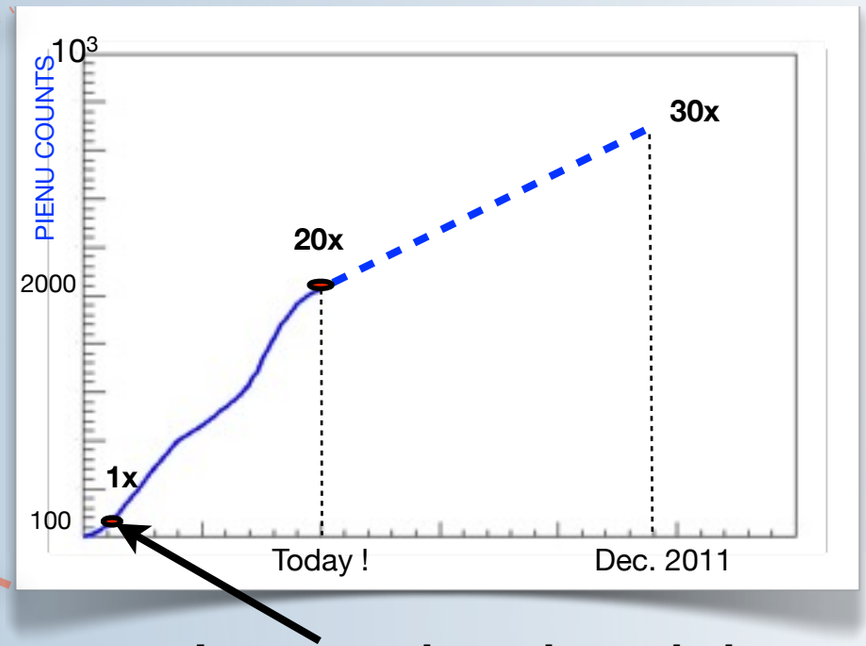

THANK YOU FOR YOUR ATTENTION !!