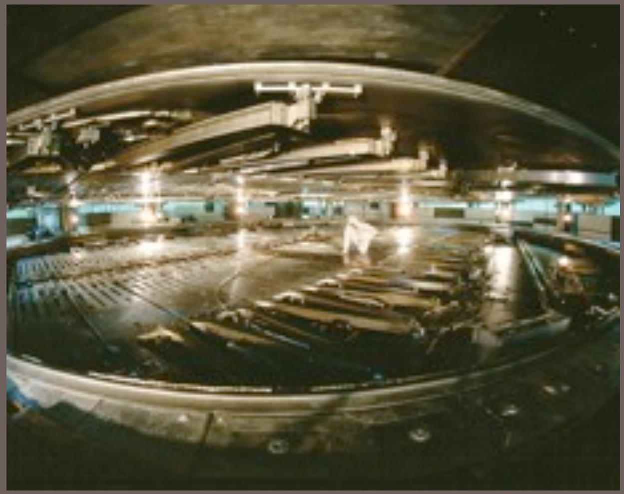
TRIUMF

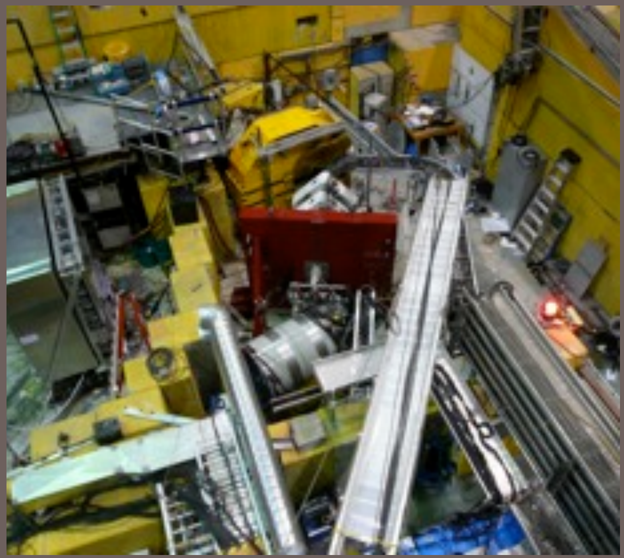
Canada's national laboratory for particle and nuclear physics /Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

PI E NU

The PIENU Experiment

a sensitive probe in the search for new physics





Chloé Malbrunot

For the PIENU Collaboration

A. Aguilar-Arevalo[11], M. Aoki[4], M. Blecher[9], D.I. Britton[8], D. Bryman[6], S. Chen[10], J. Comfort[1], M.Ding[10], L. Doria[5], P. Gumplinger[5], A. Hussein[7], Y. Igarashi[3], N. Ito[4], S. Kettell[2], Y. Kuno[4], L. Kurchaninov[5], L. Littenberg[2], C. Malbrunot[6], T. Numao[5], R. Poutissou[5], A. Sher[5], T. Sullivan[6], D. Vavilov[5], K. Yamada[4], Y. Yoshida[3]

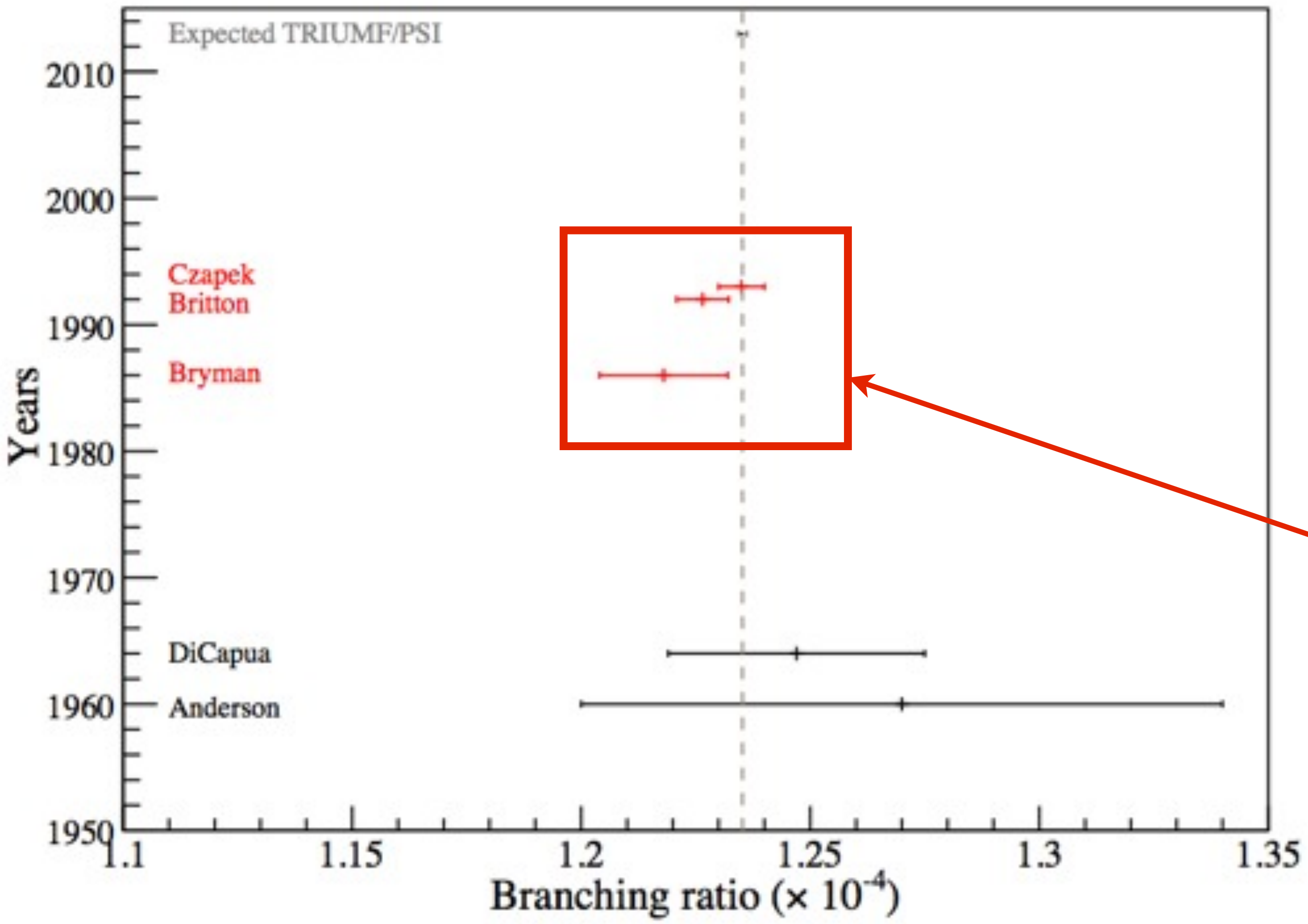
1. Arizona State University
2. Brookhaven National Laboratory
3. KEK
4. Osaka University
5. TRIUMF
6. University of British Columbia
7. University of Northern British Columbia
8. University of Glasgow
9. Virginia Polytechnic Institute & State University
10. Tsinghua University
11. Instituto de Ciencias Nucleares

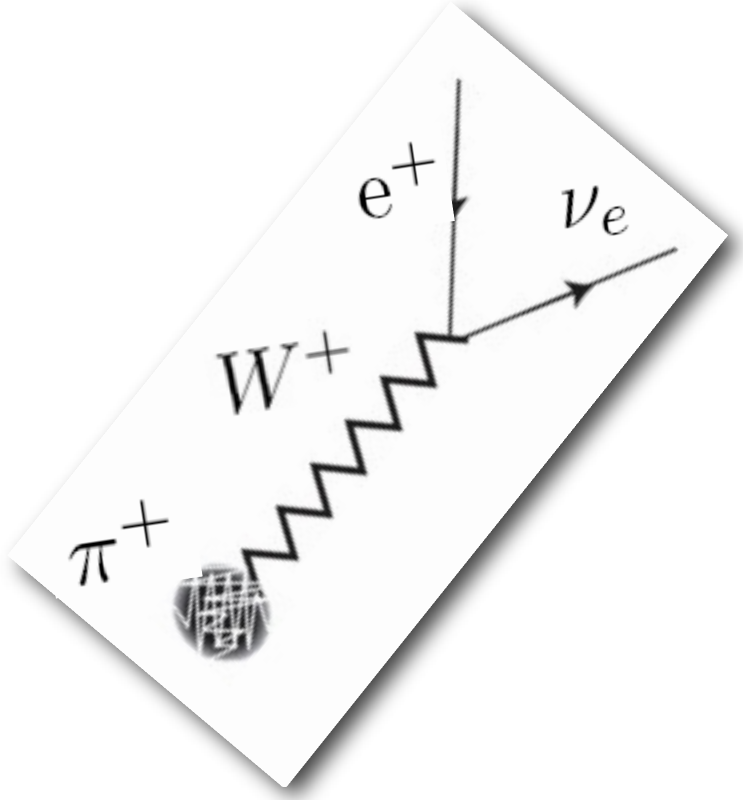
LLWI 2012

A Precision Experiment

$$R^{SM}_{e/\mu} = \frac{\Gamma(\pi^+ \to e^+\nu_e + \pi^+ \to e^+\nu_e\gamma)}{\Gamma(\pi^+ \to \mu^+\nu_\mu + \pi^+ \to \mu^+\nu_\mu\gamma)} = 1.2352(2) \times 10^{-4}$$

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 :

$$R^{exp}_{e/\mu} = 1.230 \pm 0.004 \times 10^{-4}$$

TRIUMF : D.Britton et al., Phys. Rev. Lett., 68:3000–3003, May 1992
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Factor 20 difference between theoretical and experiment precision → window for BSM physics
PIENU goal : improvement x5 → precision < 0.1% on the BR

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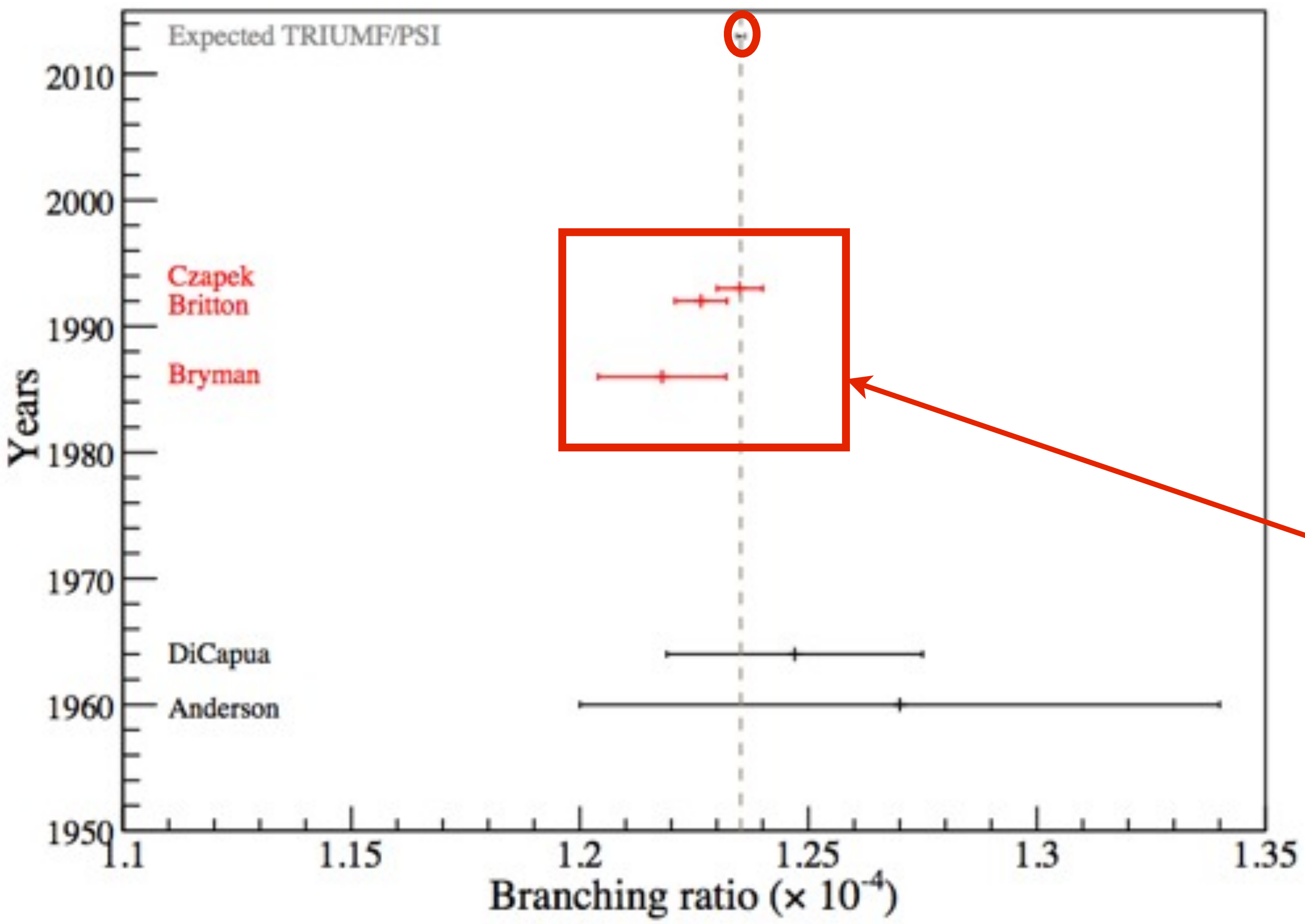

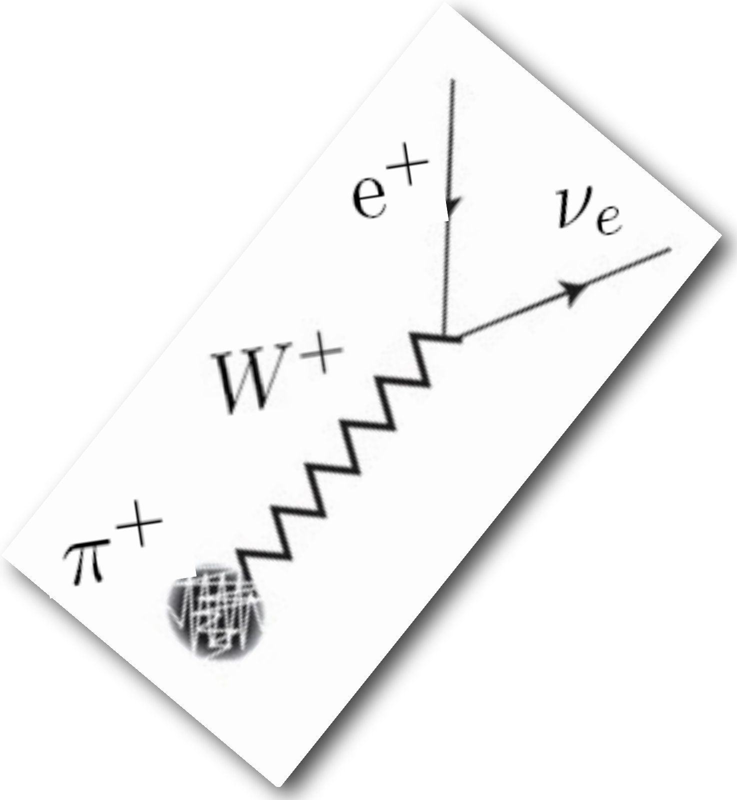

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BSM search / Universality test

$$\Gamma_{\pi\to l+\nu_l} = G^2 \frac{m_{\pi^+} f_{\pi^+}^2 m_l^2}{8\pi}(1-\frac{m_l^2}{m_{\pi^+}^2})^2[1+RC] \quad ; \quad \frac{G}{\sqrt{2}} = \frac{g_l^2}{8M_{W^+}}$$

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

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

0.1% measurement → Λ_{eP}~ 1000 TeV

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)

R-Parity violation SUSY
M. J. Ramsey-Musolf, S. Su & S.Tulin, Phys. Rev. D 76, 095017 (2007)

...

Decay mode	$(g_\mu/g_e)^2$
$\tau \to \mu / \tau \to e$ *	1.0018 ± 0.0014
$\pi \to \mu / \pi \to e$ *	1.0021 ± 0.0016
$K \to \mu / K \to e$	0.9960 ± 0.005
$K \to \pi\mu / K \to \pi e$	1.002 ± 0.002
$W \to \mu / W \to e$	0.997 ± 0.010

* τ and π are complementary

Pion branching ratio is **one of the most precise** test of CC lepton universality

0.1% measurement in the BR → 0.05% in g_e/g_μ

- Real deviation from the SM → new physics observation
- Agreement with SM → constraints

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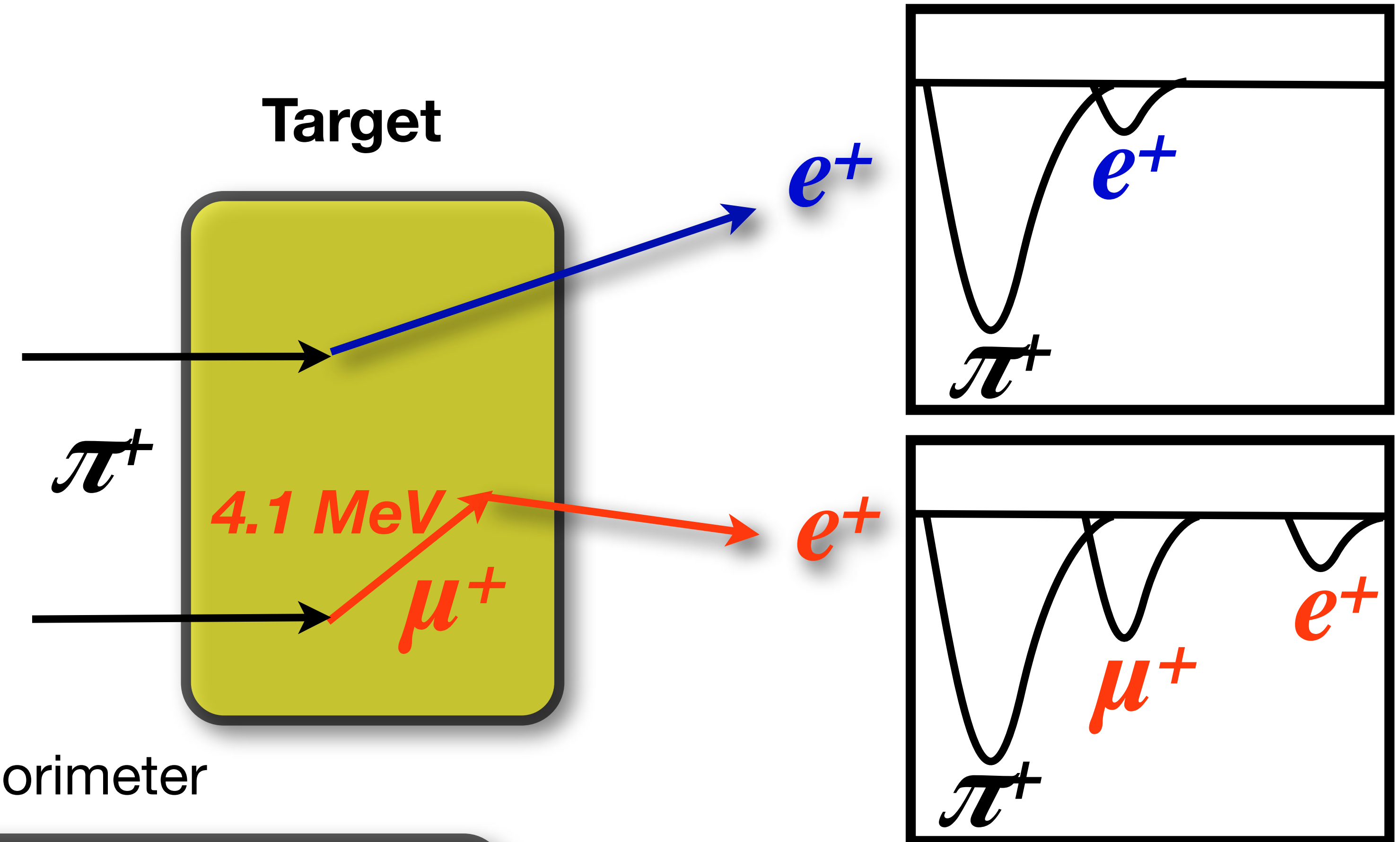
Experimental Technique

Experimental Method

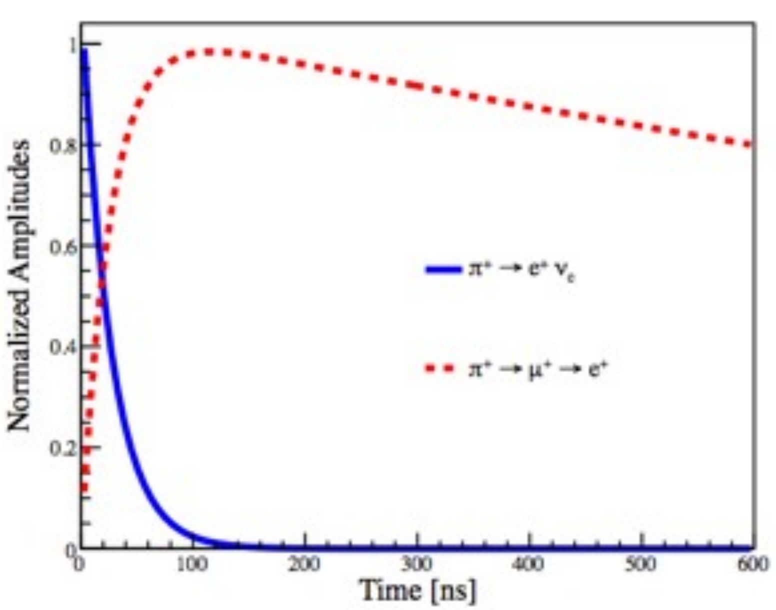
- Stop pions in a target scintillator
- Yield measurement

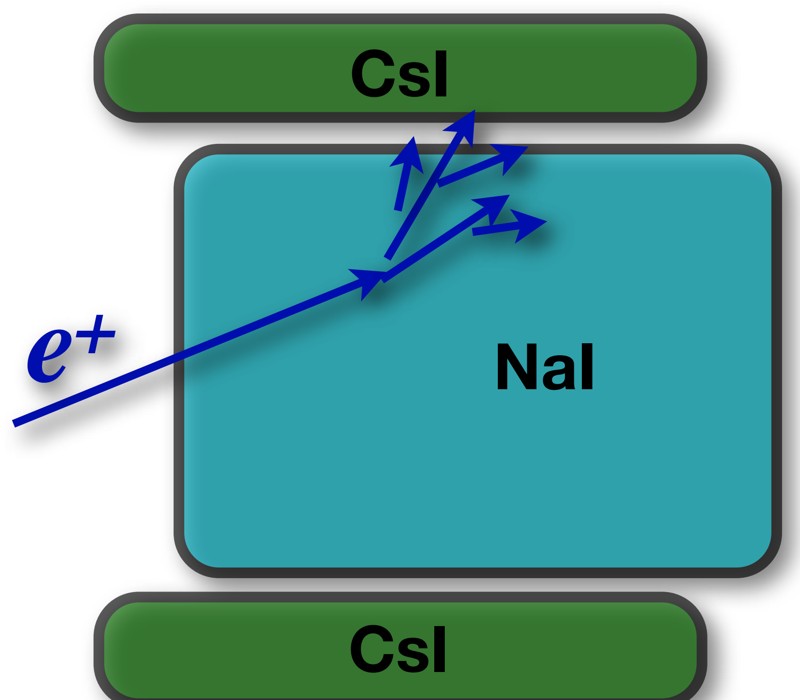


Characteristics

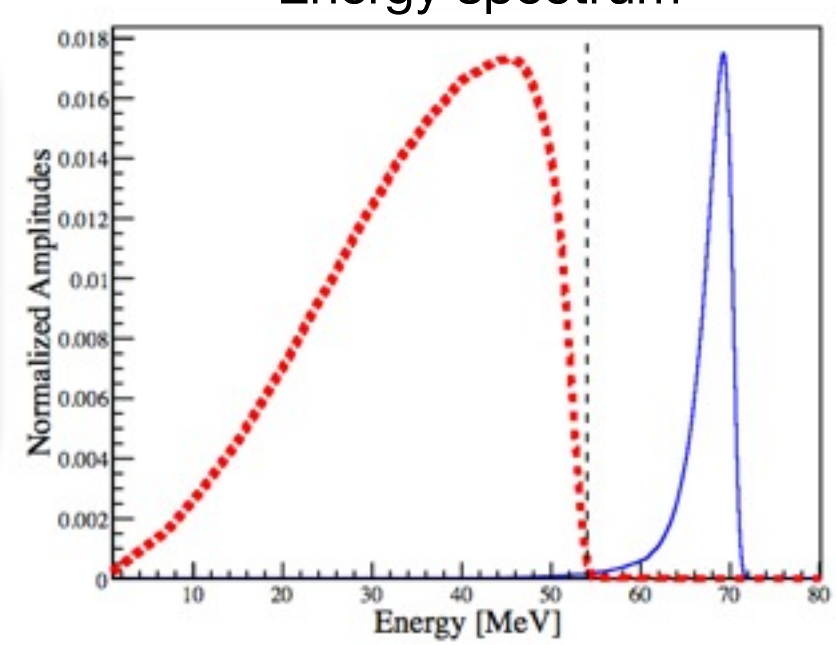
- High purity pion beam
- High speed pulse digitization
- Suppression of decays-in-flight (DIF)
- Measurement of response function of calorimeter

Time spectrum





Energy spectrum



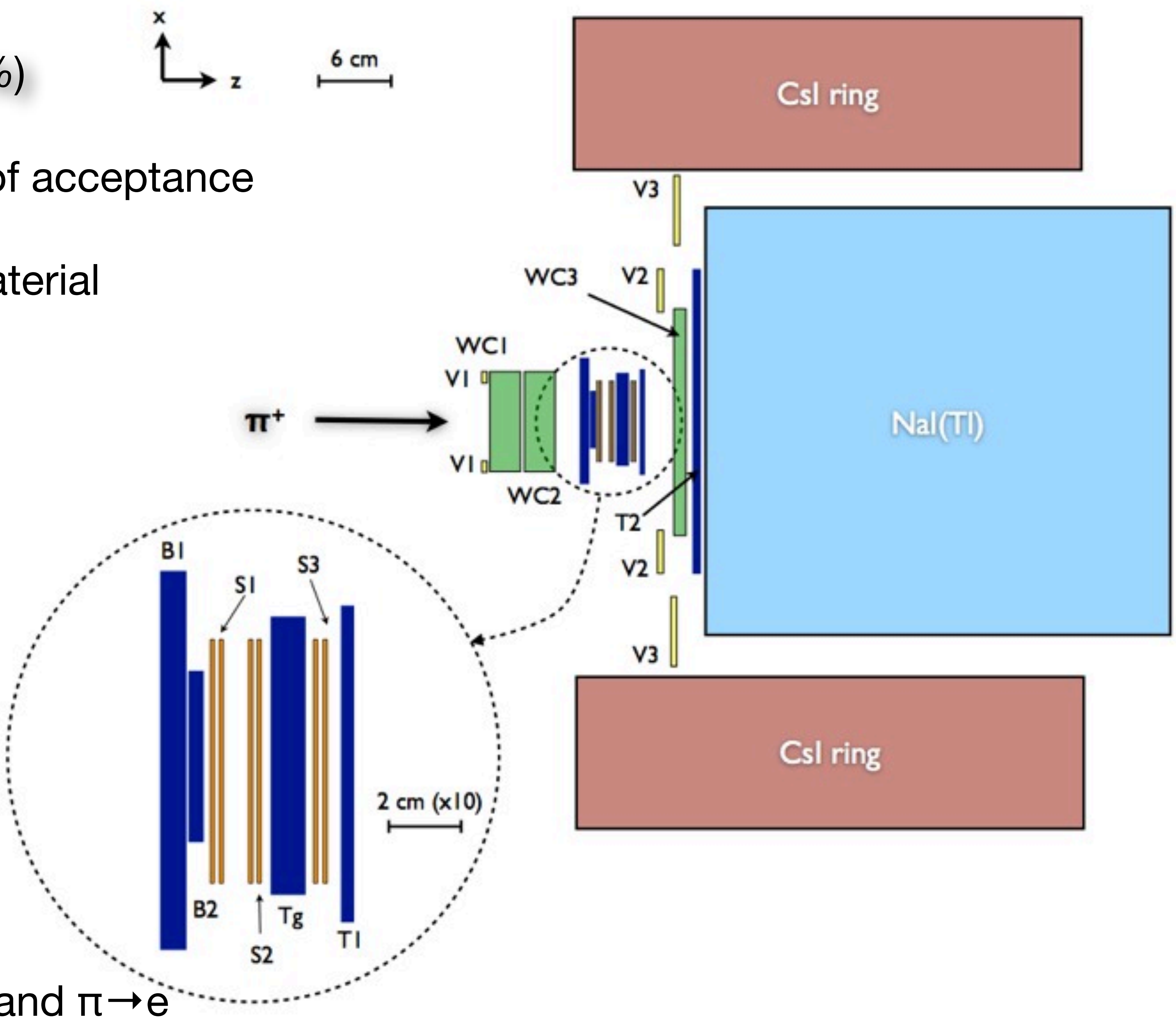
The PIENU detector

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

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

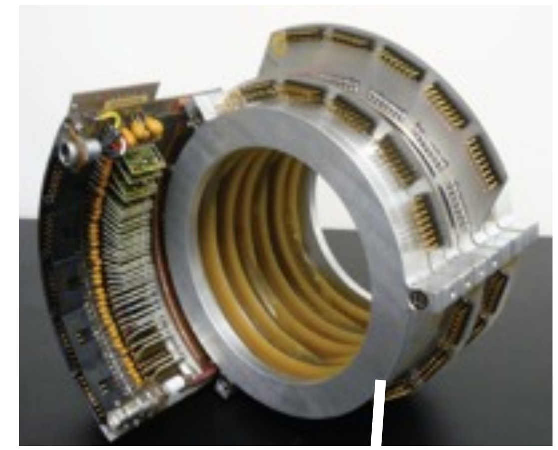
- High resolution calorimeter
  NaI :1% σ at 70 MeV

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



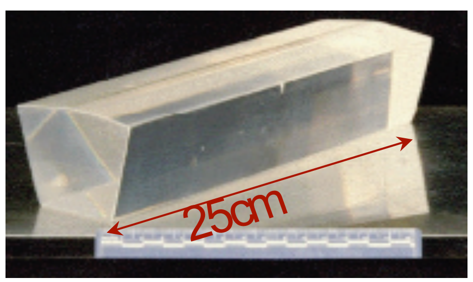
The PIENU detector (cont'd)

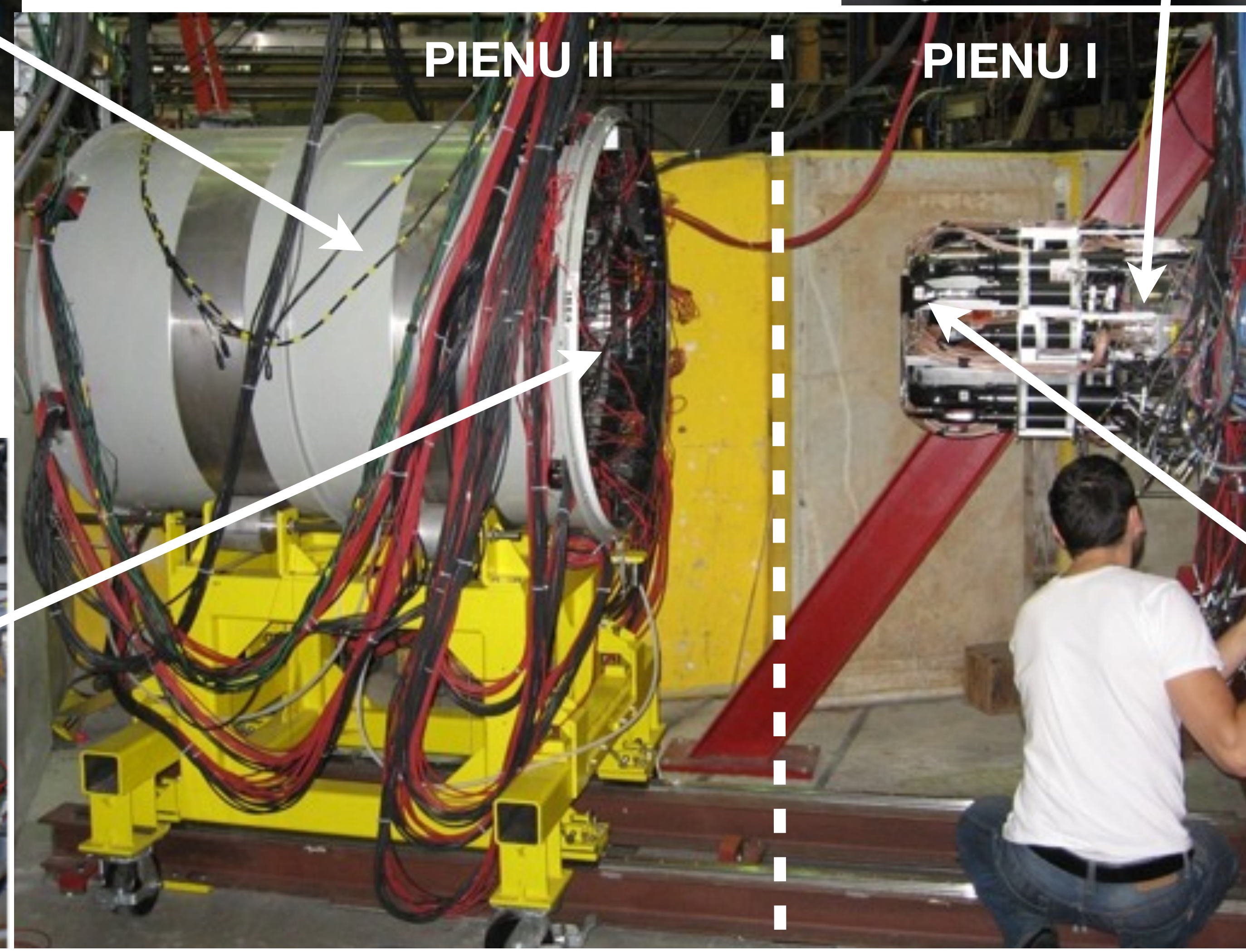
Monolithic NaI(Tl) crystal surrounded by 97 pure CsI crystals



Beam Wire Chamber

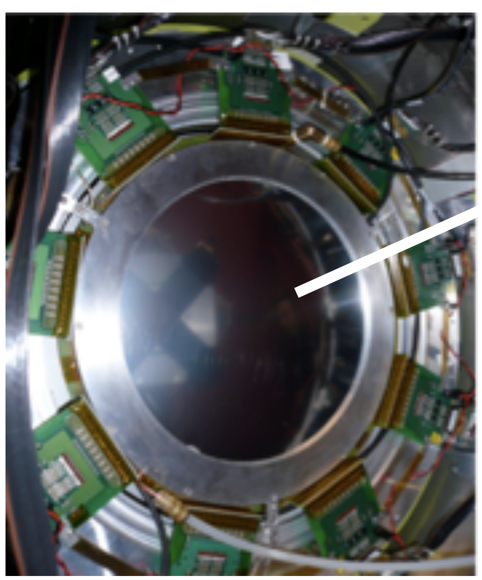
CsI crystal



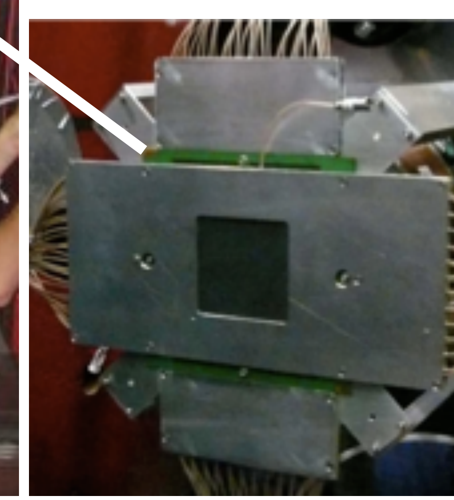


π^+

Acceptance Wire Chamber



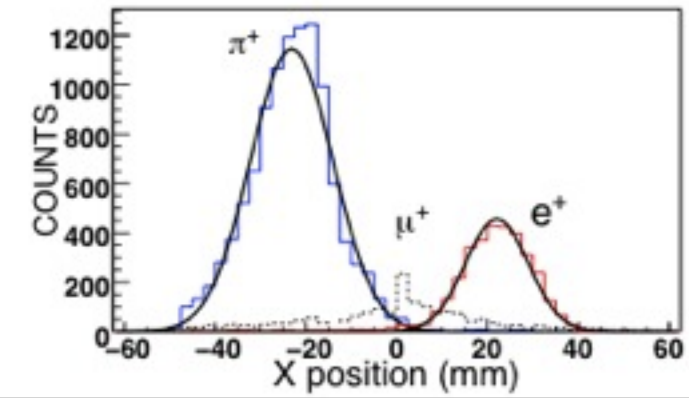
Silicon Trackers



PIENU II is movable and detachable from PIENU I for line shape measurement at various e+ entrance angles

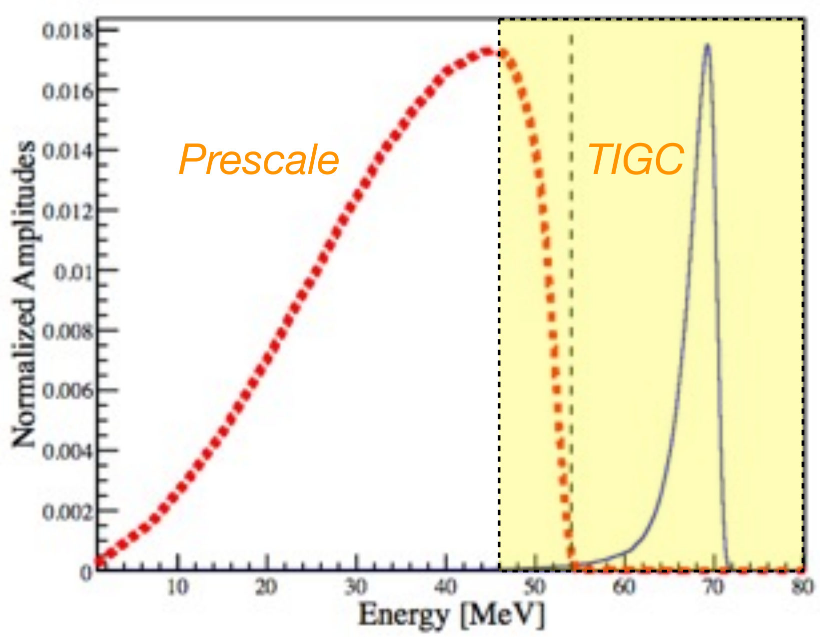
Data taking conditions

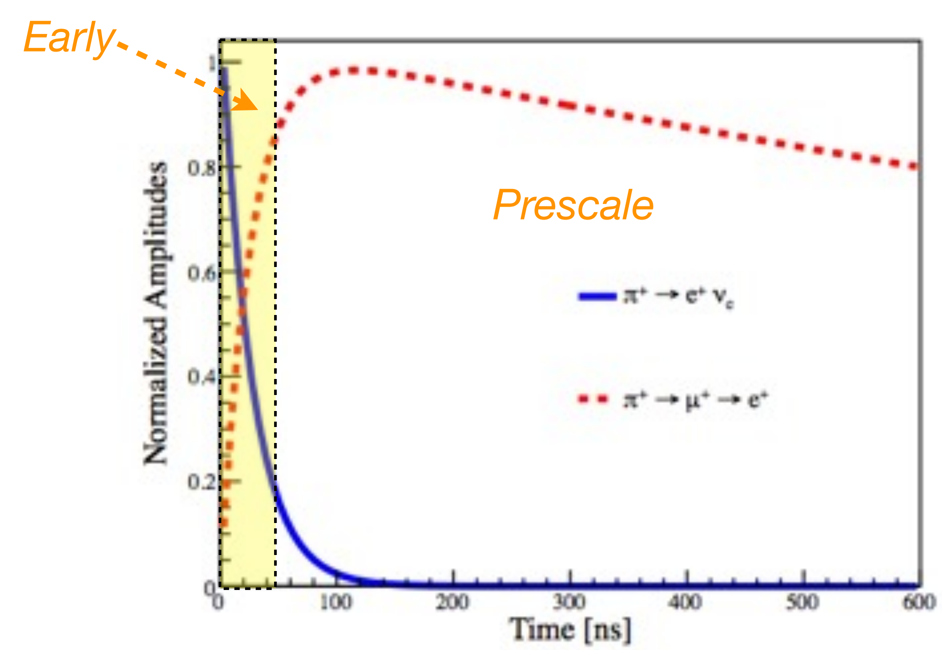
- 50 kHz pion stop in Target with 2% positrons and 10% muons
- Triggers : 600 Hz



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

- $\pi \to e\,\nu$: $E_{NaI+CsI} > 46$ MeV
  Early (4-40 ns)





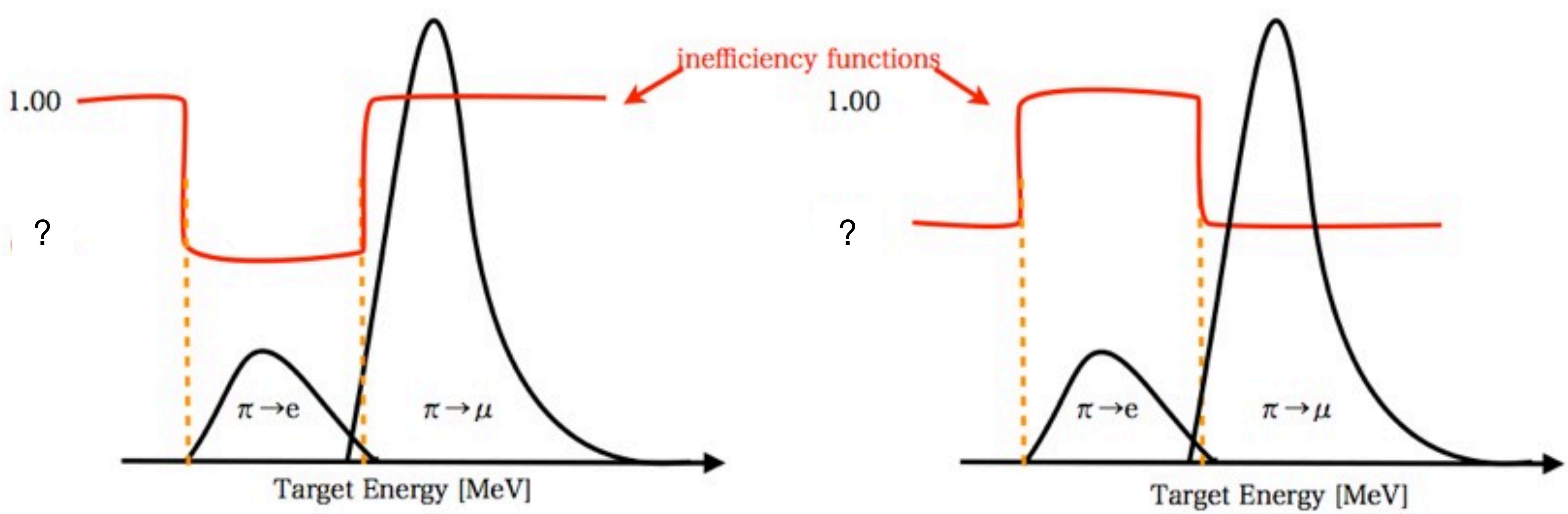
Inspection period -300ns to 500ns

- $\pi \to \mu \to e$: prescaled (1/16)
- monitor and calibration triggers: e^+ beam, Xe, cosmic-ray

Blind Analysis

- Extraction of a "raw branching ratio" from the fit of the time spectra
- Corrections applied to the "raw branching ratio"
  - Muon decay-in-flight correction
  - Tail correction
  - Acceptance correction

Raw Branching ratio **is blinded**



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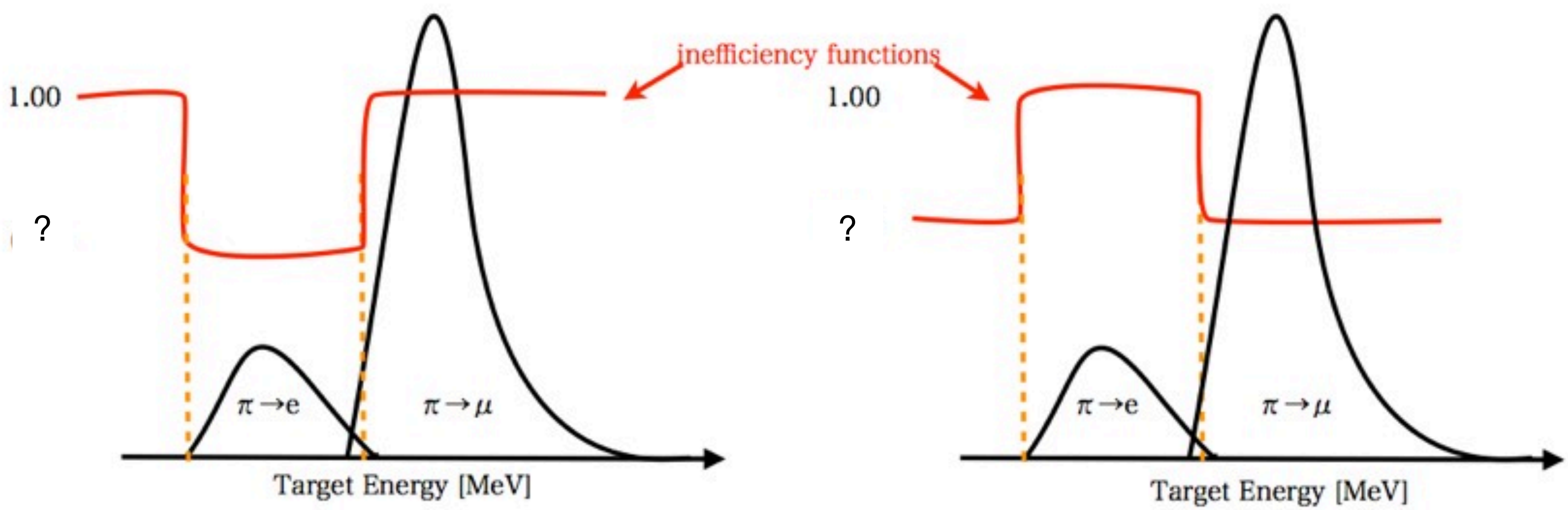
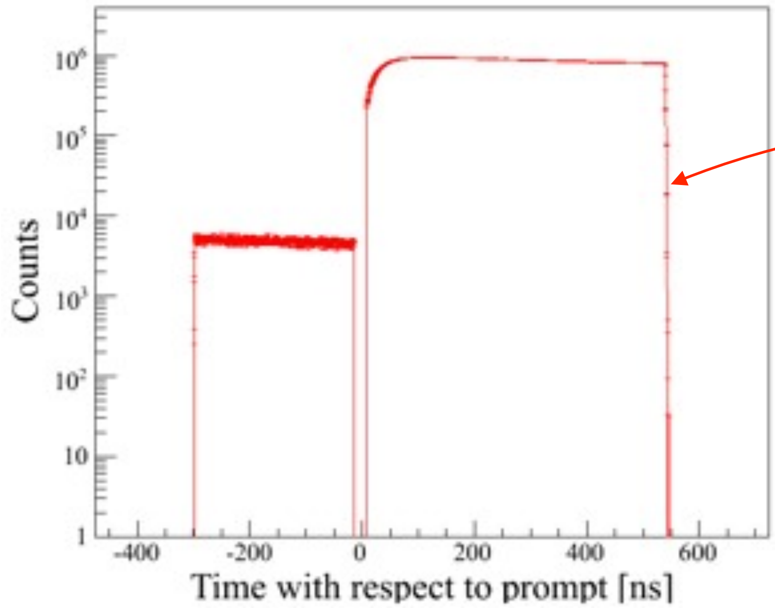
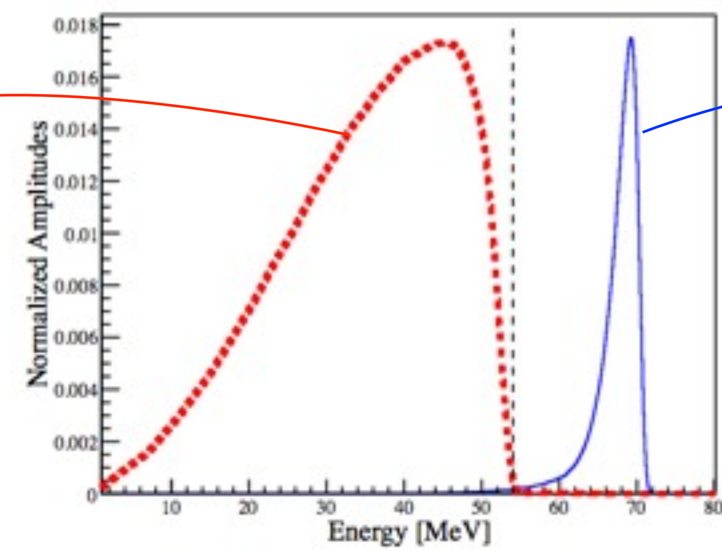
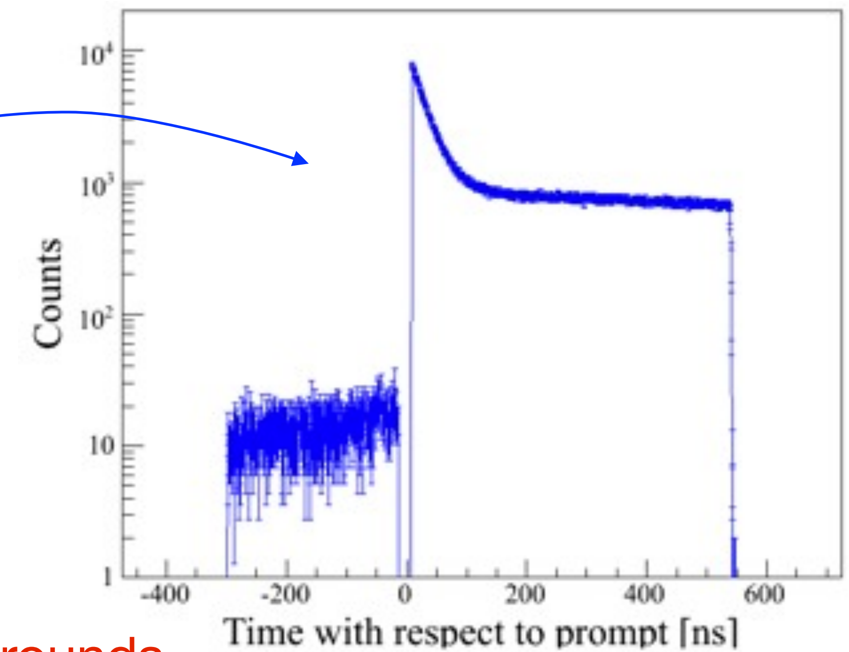


Raw branching ratio estimation



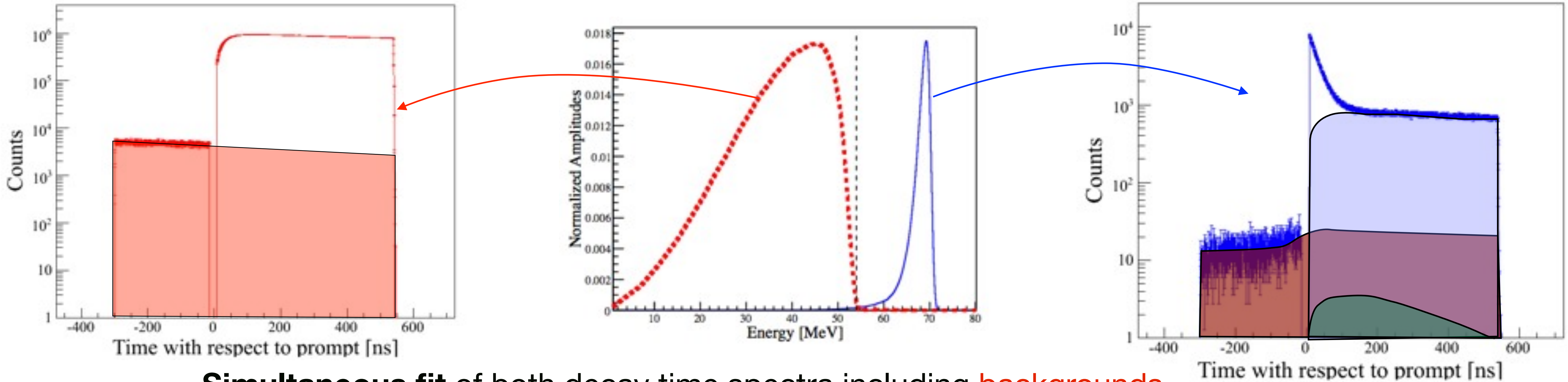




Simultaneous fit of both decay time spectra including backgrounds

Common χ^2

Raw branching ratio estimation



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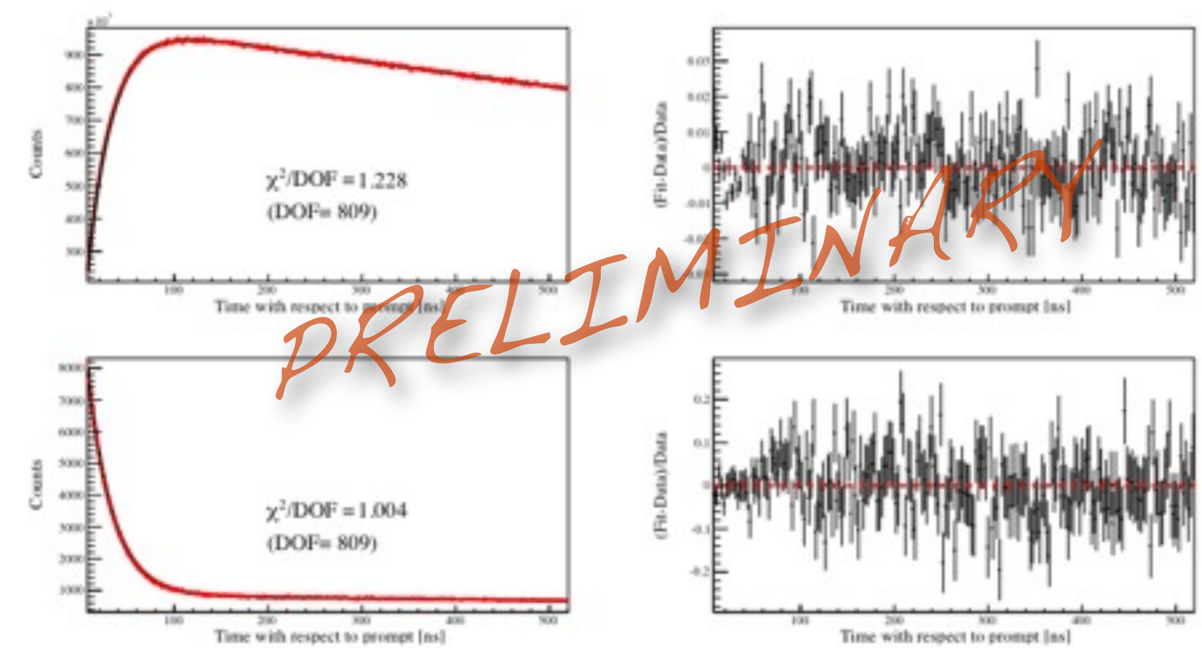

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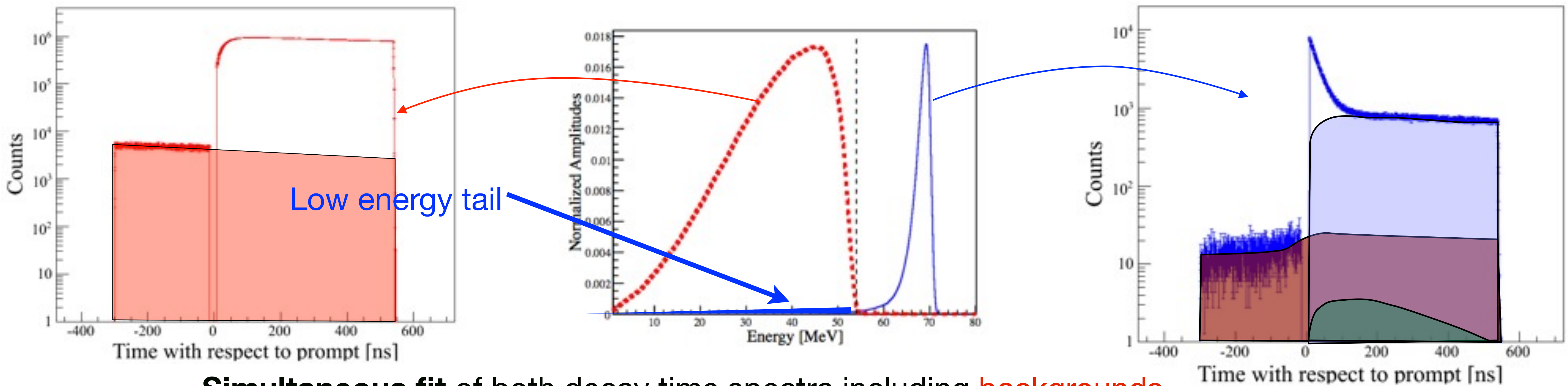

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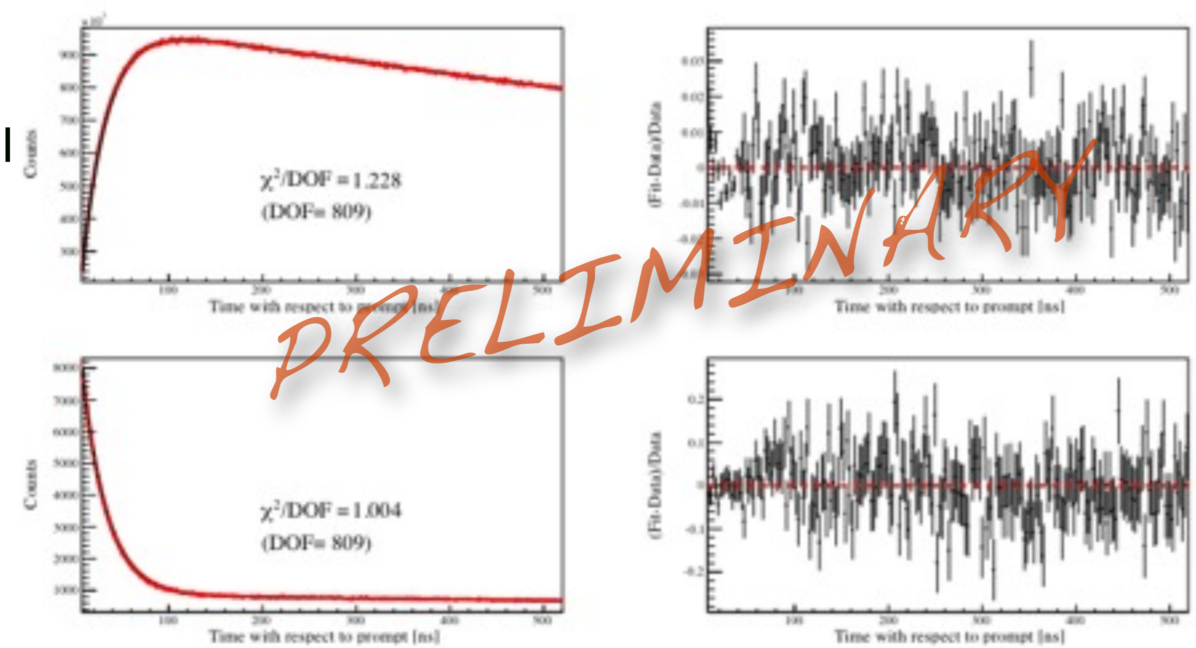
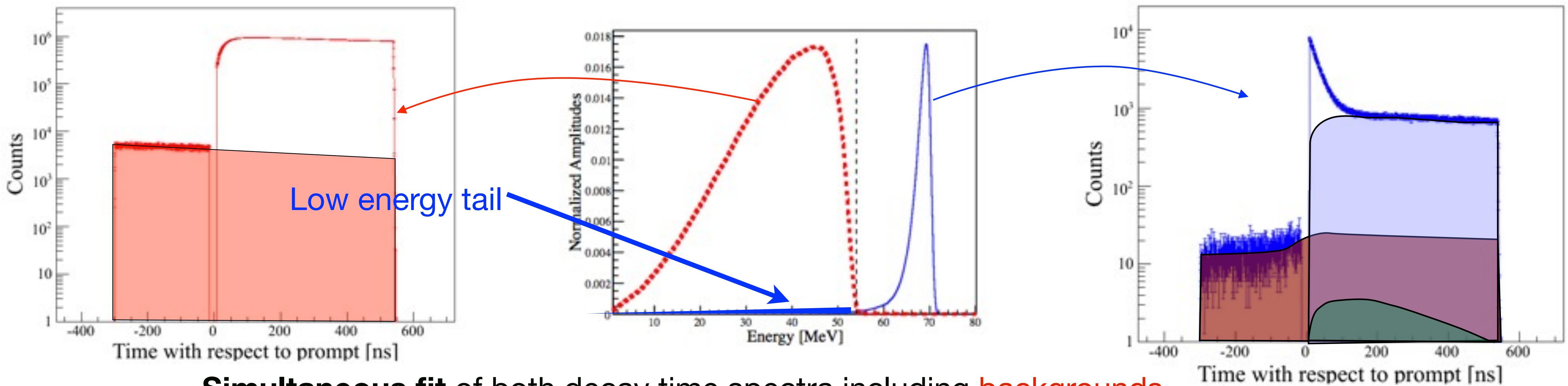


"High energy region" **fit does not include** the Low energy $\pi \rightarrow e\,\nu$ tail

➡ Largest correction: **empirical estimation**

Raw branching ratio estimation



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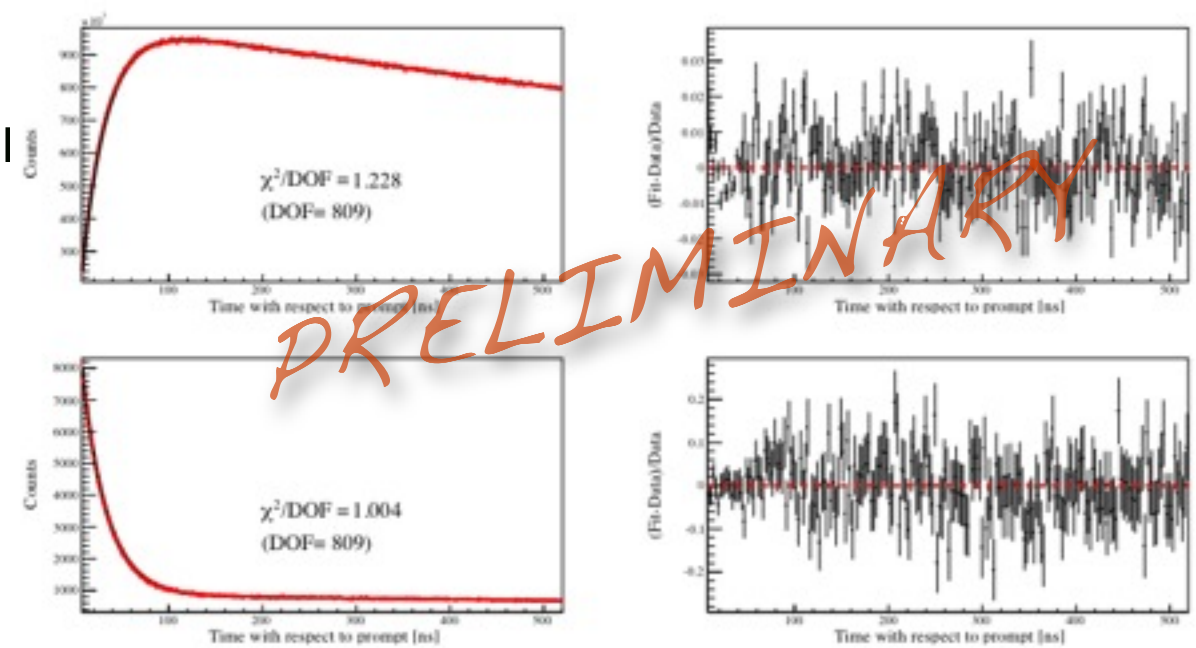

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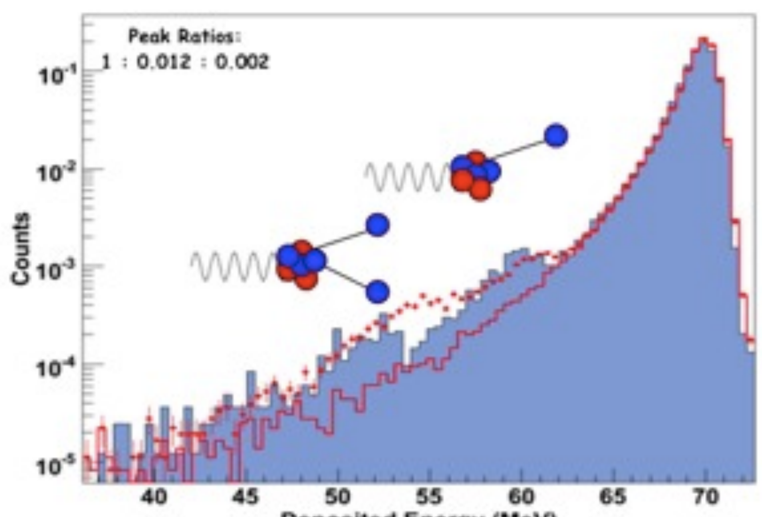
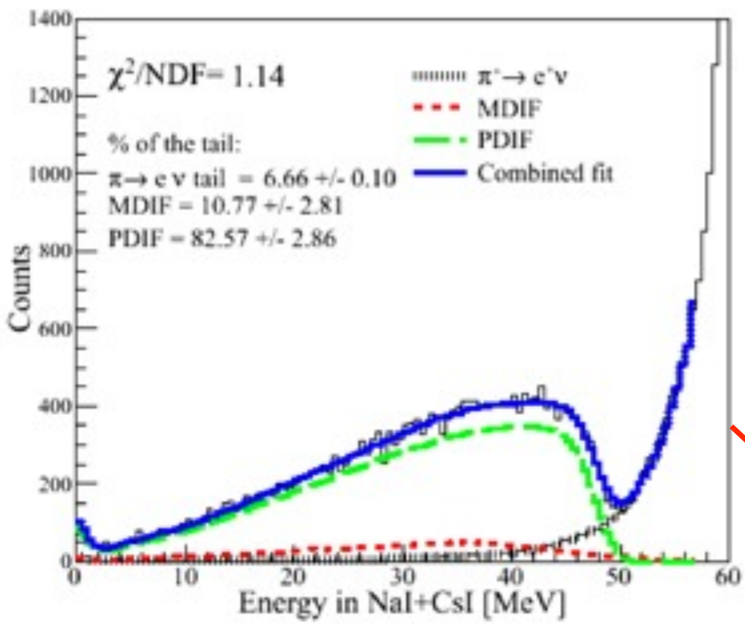


- Good **NaI resolution** and addition of **CsI information** reduces the low energy tail
- The presence of **photo-nuclea**r reactions in the NaI slightly affects the tail

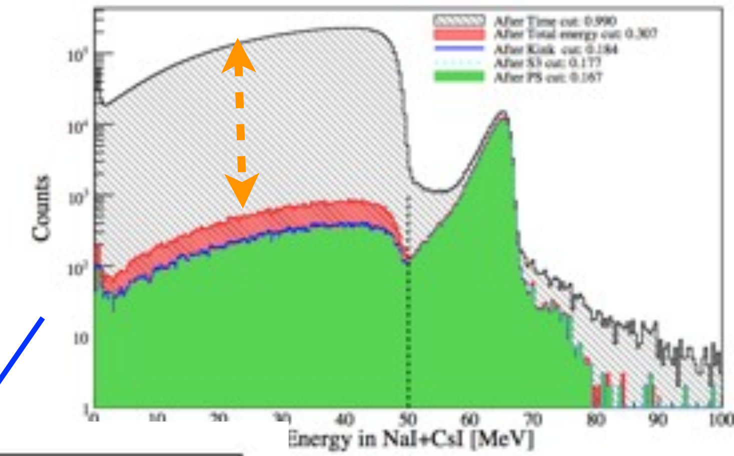
A. Aguilar-Arevalo et al., Nucl. Instr. and Meth. A (2010)

Tail correction

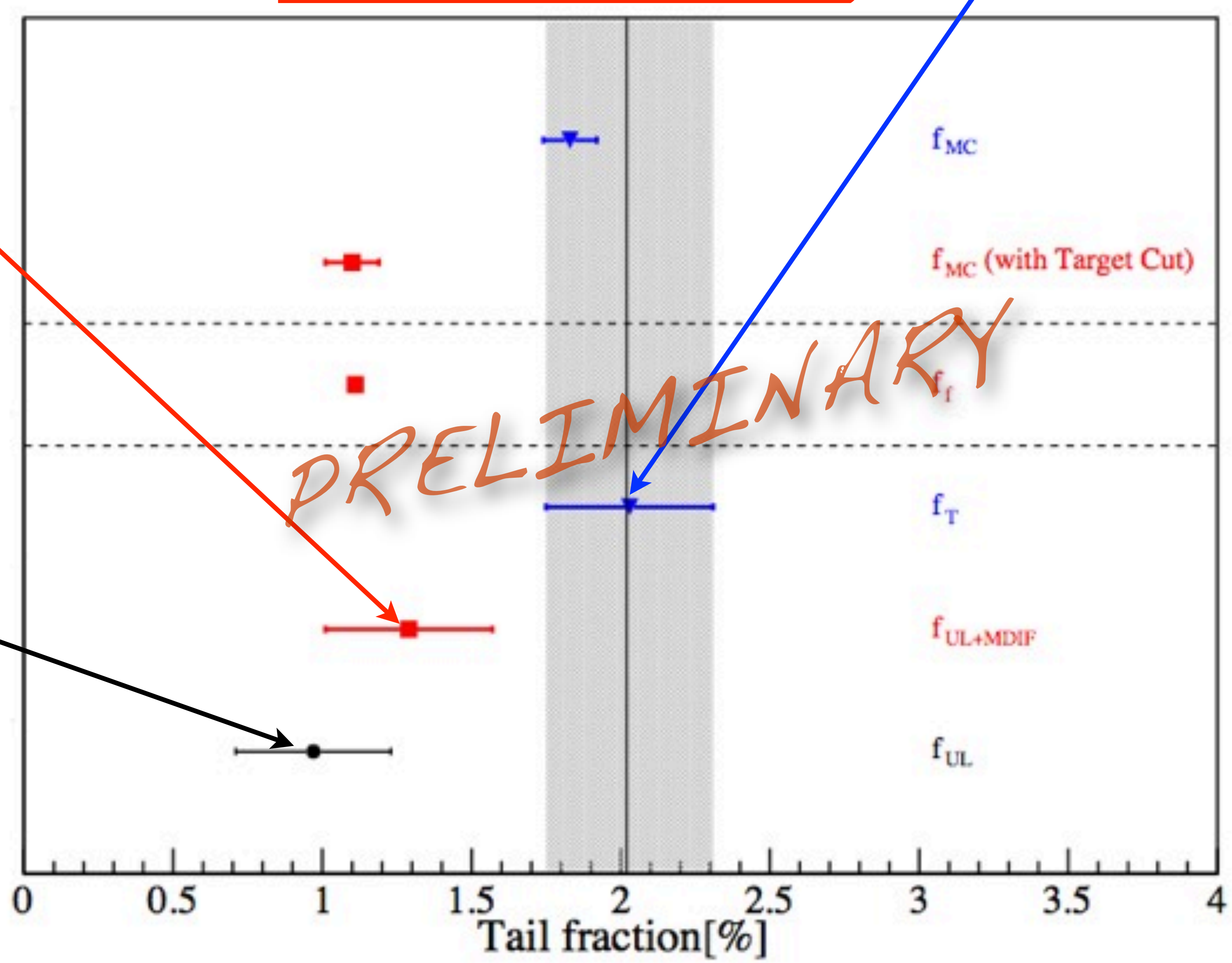
Correction for MDIF



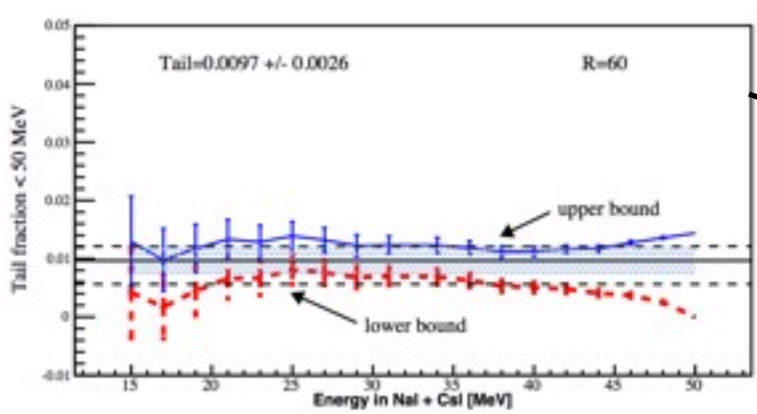
Correction for energy dependent Target cut



$$f_T = (2.03 \pm 0.28)\%$$

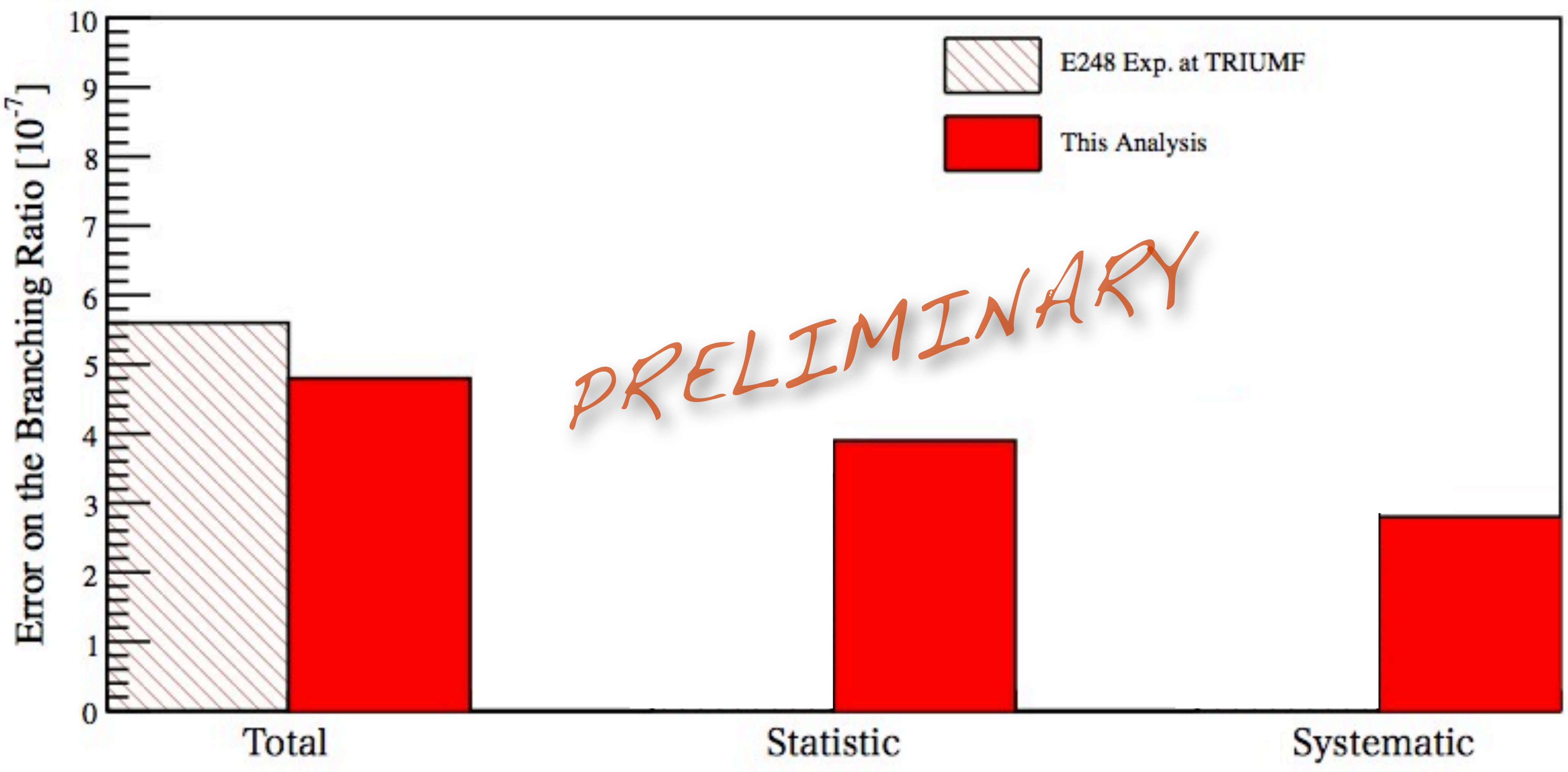


Upper-Lower limit



Status

- Branching Ratio still **blinded**
- Uncertainty dominated by statistics
  So far only 1 month of data analyzed. Full data set: **~x10** more data



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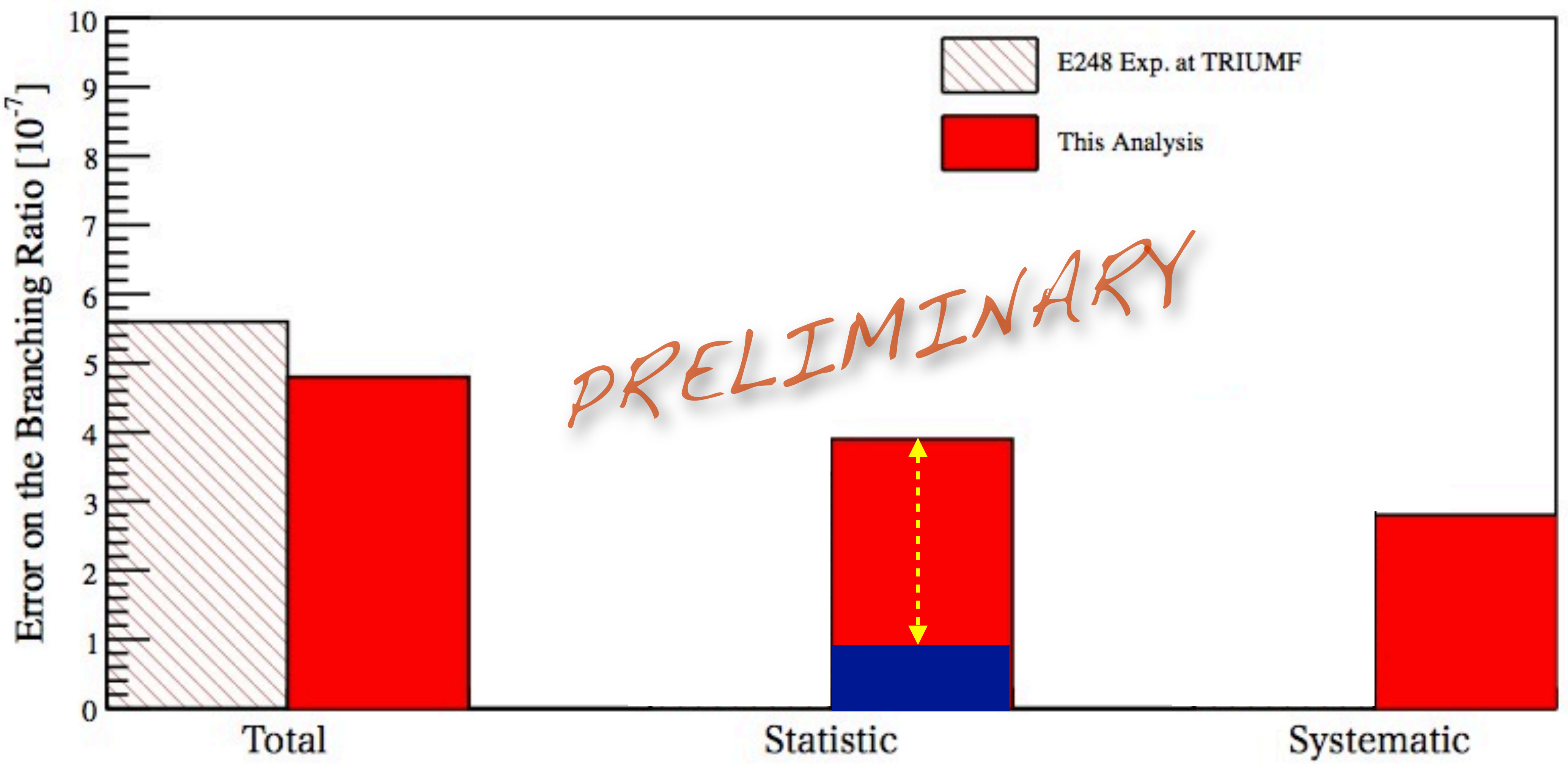

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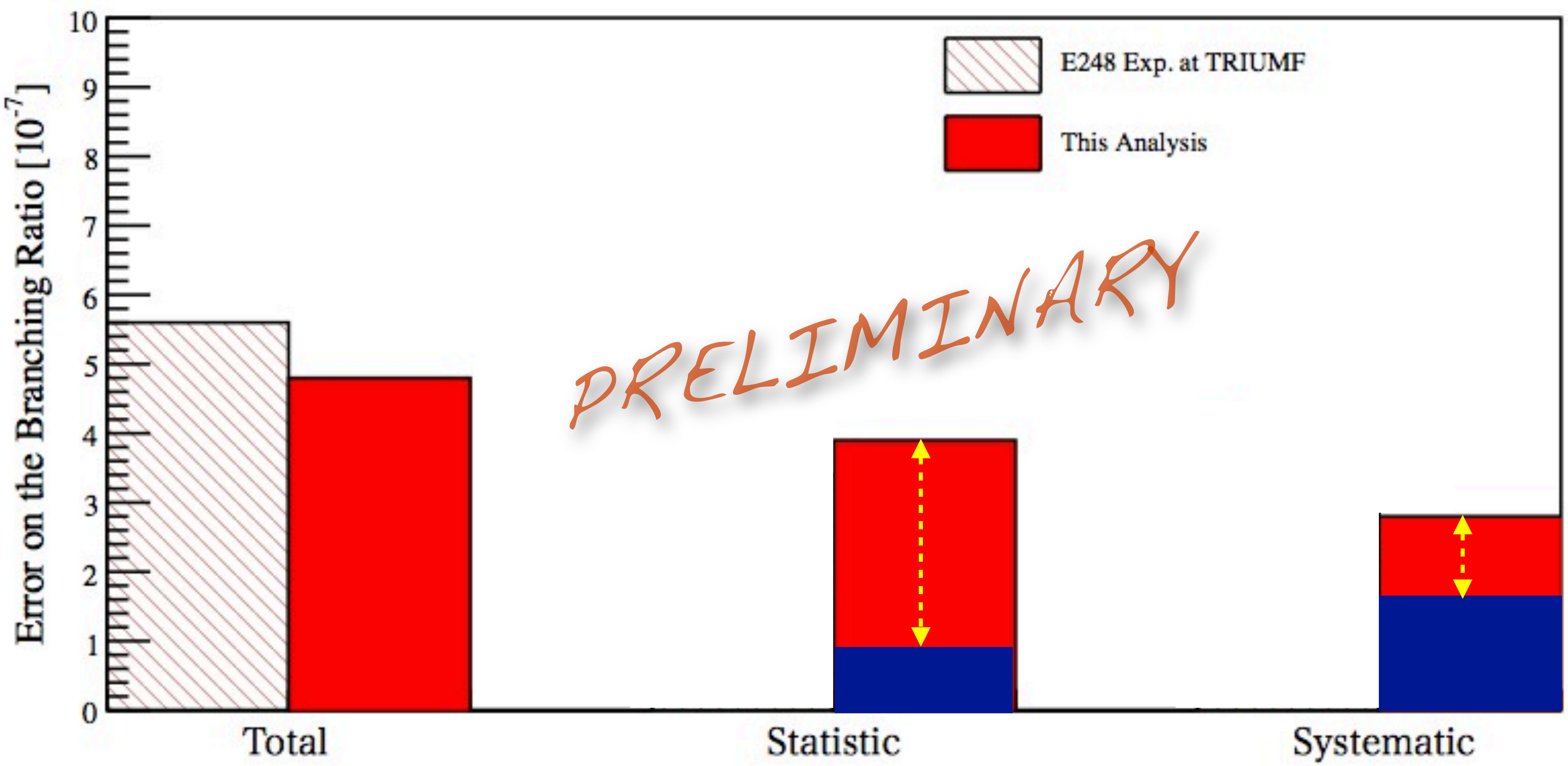

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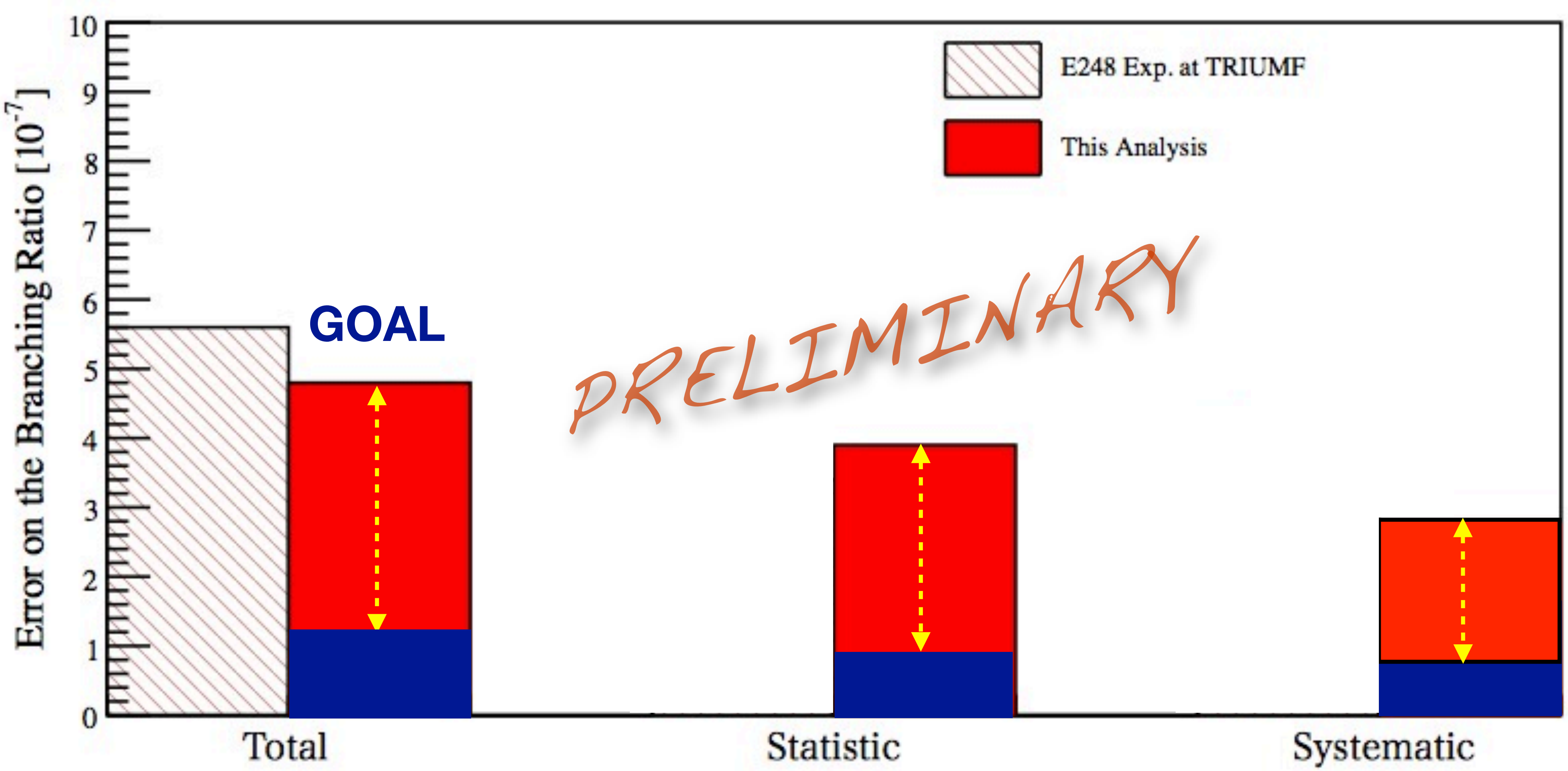


Massive neutrino search

heavy υ

Kinematic factor

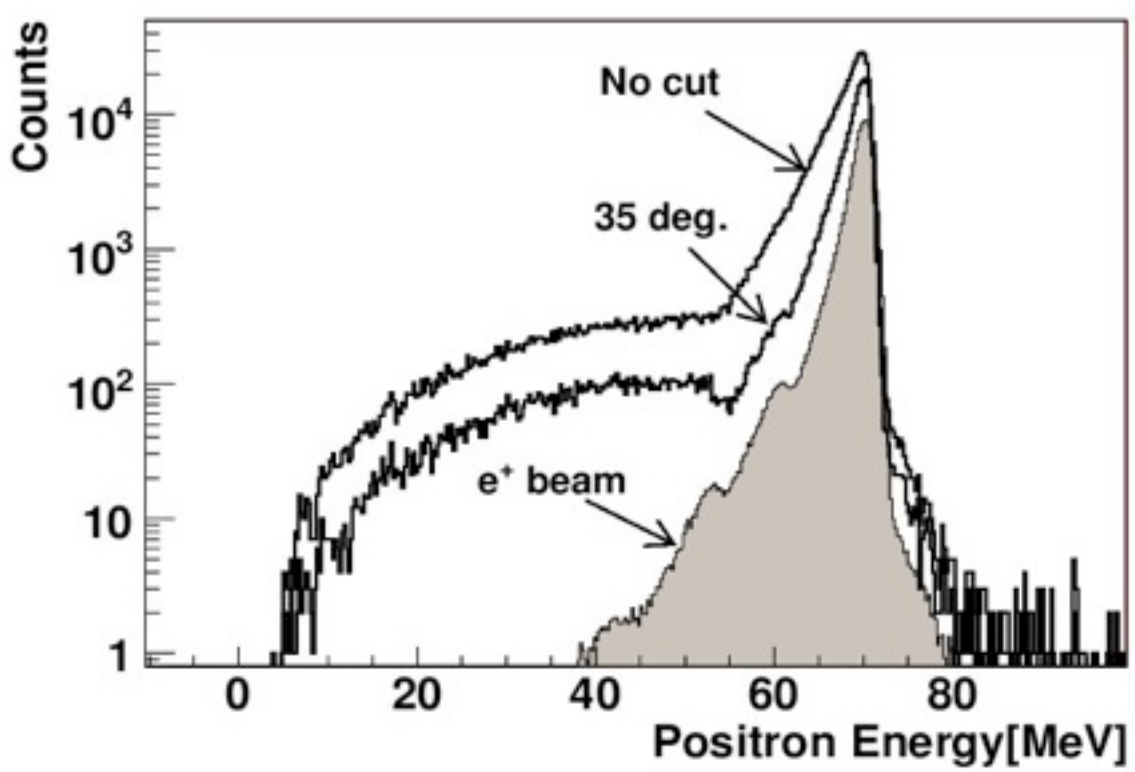
$$R_{ei} = \frac{\Gamma(\pi \to e\nu_i)}{\Gamma(\pi \to e\nu_l)} = |U_{ei}|^2 \rho_{ei}$$

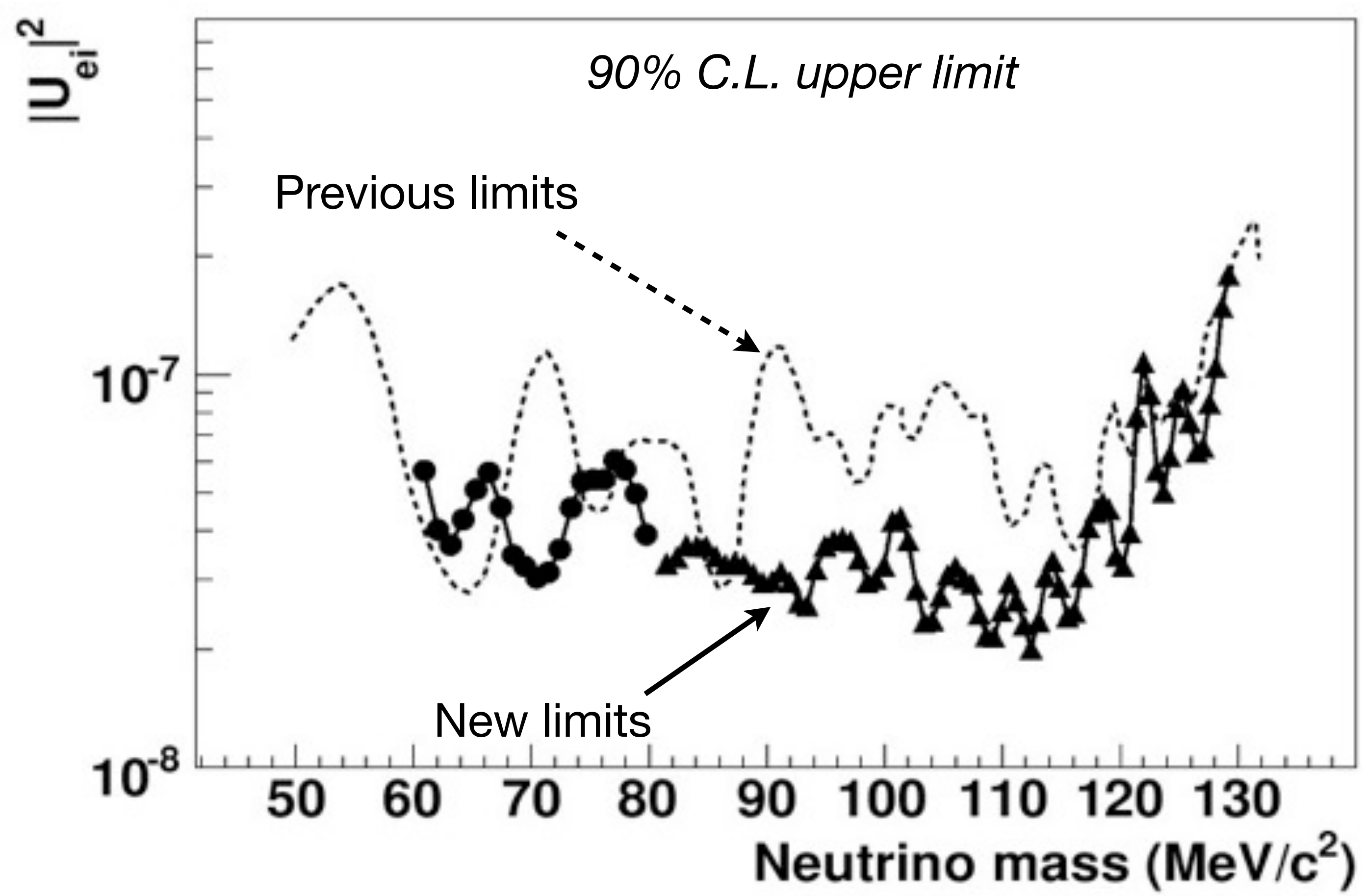
conventional υ

$$\nu_\ell = \Sigma_{i=1}^{3+k} U_{\ell i} \nu_i$$

$$\ell = e, \mu, \tau, \chi_1, \chi_2 \ldots \chi_k$$

Search for extra peak in the suppressed spectrum





M.Aoki et al., Phys. Rev. D 84, 052002 (2011)

Conclusions

2008	09	End of beamline extension work
	10-12	Test run
2009	05	PIENU detector completed
	05-09	Run I
	09-12	Run II
2010	03	Temperature enclosure completed
	04-09	Run III
	10-12	Run IV
2011	08-12	Run V
2012		Run VI

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STAY TUNED FOR FIRST B.R. RESULTS
COMING SOON