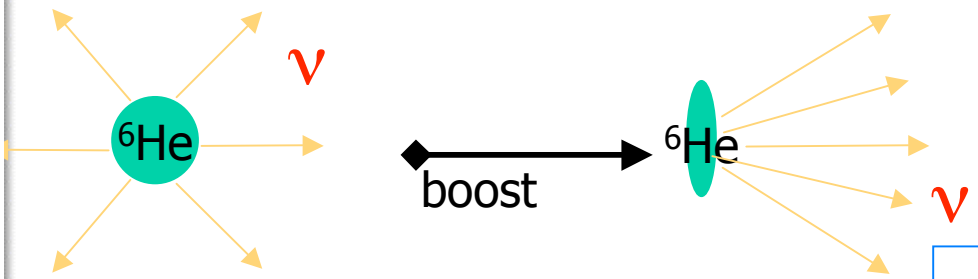
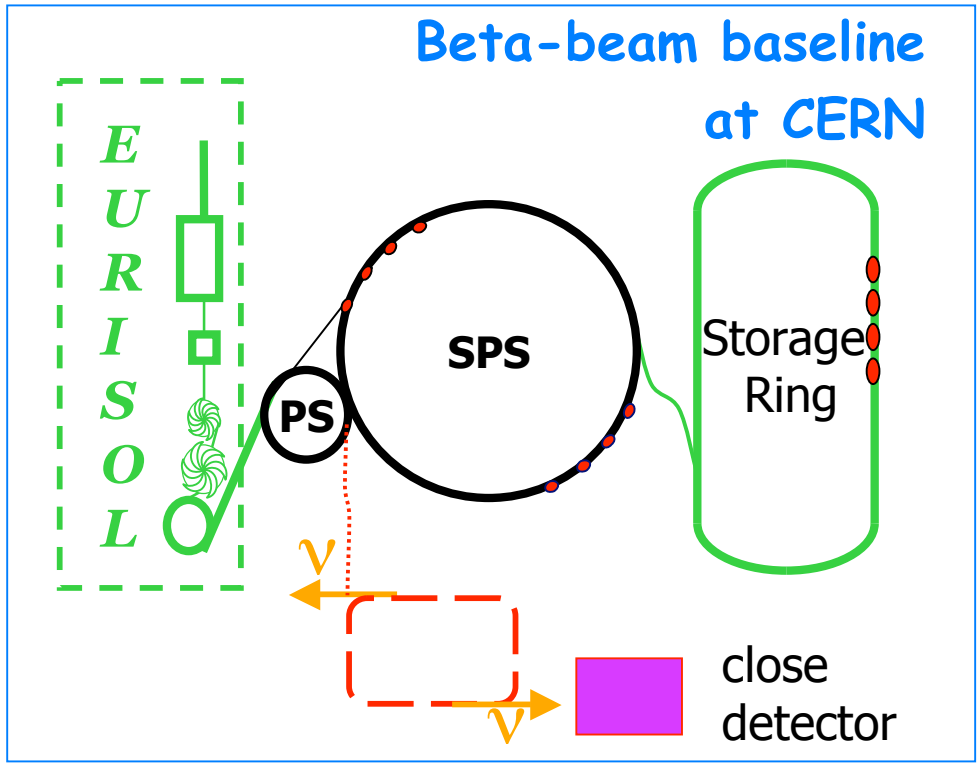
A Conserved Vector Current test using low energy β–beams

P. Zucchelli, Phys. Lett. B 532 (2002) 166



Low energy beta-beam:

C. Volpe, Journ. Phys. G. 30 (2004), hep-ph/0303222.



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PHYSICS POTENTIAL

- Neutrino-nucleus interaction studies.
- Fundamental tests: Weinberg angle
  A.B. Balantekin, J.H. de Jesus, C. Volpe: Phys.Lett. B634 (2006) 180
- Neutrino properties, like the ν magnetic moment
  G.C. McLaughlin, C. Volpe, Phys.Lett.B591 (2004) 229
- Aspects related with astrophysics:
  Supernova-neutrino spectra *N. Jachowicz, G.C. McLaughlin: Phys.Rev.Lett. 96 (2006) 172301*
- ....

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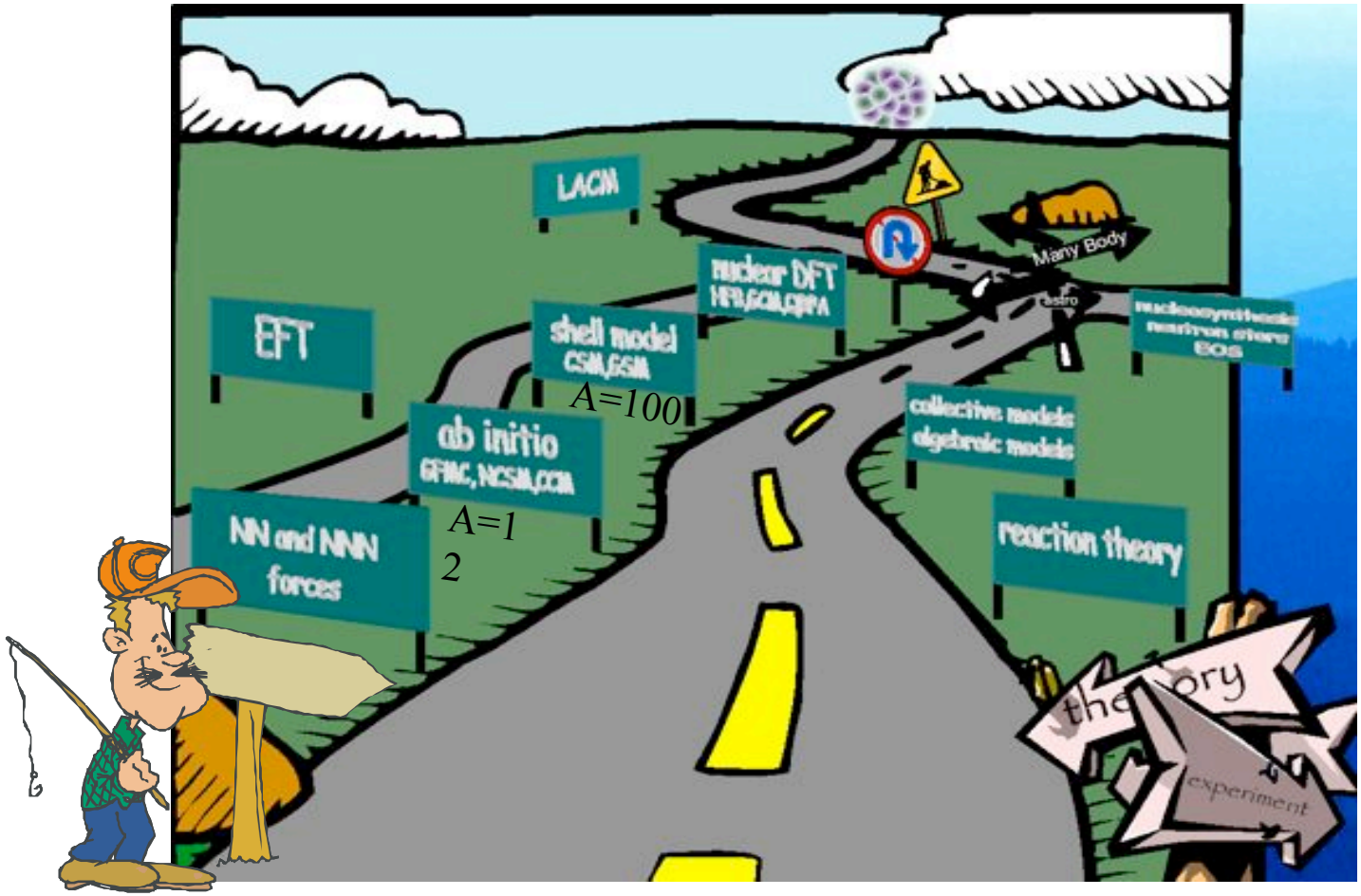

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- Let us first understand the simplest .. ν+ N

Target	σ(x10^{-42} cm^2) at 40 MeV
p	105.
d	46.9
^{12}C	10.1
^{16}O	6.4
^{56}Fe	119.
^{208}Pb	2200

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The most general form:

$$\mathcal{M} = \frac{G_F \cos\theta_C}{\sqrt{2}} \left\{ \overline{u}_n \left[\gamma_\alpha (f_1 - g_1\gamma_5) + \sigma_{\alpha\beta} k^\beta (f_2 + g_2\gamma_5) + k_\alpha (f_3 + g_3\gamma_5) \right] u_p \right\} \left\{ \overline{\nu}_\nu \gamma^\alpha (1-\gamma_5)\nu_e \right\}$$

?

Negligible ~m_e^2

CVC hypothesis:

$$\lim_{q^2\to 0} f_1(q^2) = 1 \; ; \qquad \lim_{q^2\to 0} f_2(q^2) = \frac{\mu_p - \mu_n}{2m_N} \; ; \qquad f_3(q^2) = 0$$

$$f_1(q^2) = \left[1 + \frac{q^2}{(0.84\ \mathrm{GeV})^2} \right]^{-2} \; ; \qquad f_2(q^2) = \left(\frac{\mu_p - \mu_n}{2m_N} \right) f_1(q^2) \; ; \qquad \cancel{f_3(q^2) = 0} \; ,$$

$$g_1(q^2) = -1.262 \left[1 + \frac{q^2}{(1.032\ \mathrm{GeV})^2} \right]^{-2} \; ; \qquad \cancel{g_3(q^2) = \left(\frac{2m_N}{q^2 + m_\pi^2} \right) g_1(q^2)} \; ,$$

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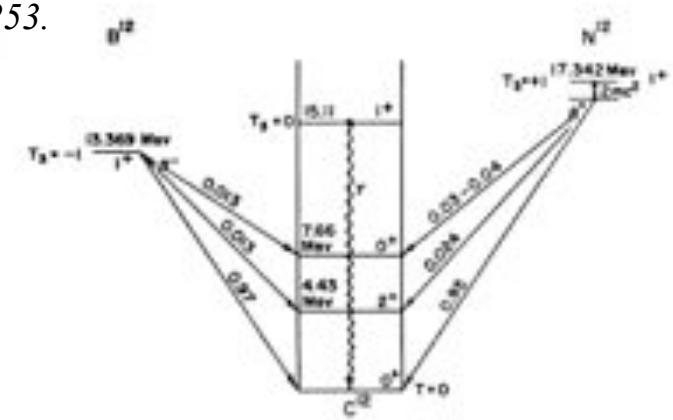
CVC tests

✓ Vector form factor: super-allowed beta decay

J. C. Hardy and I. S. Towner, Phys. Rev. C 71 (2005) 055501

✓ Tensor terms (weak-magnetism): Gamow-Teller transitions in mirror nuclei A=12 triad

Y. K. Lee, L. W. Mo and C. S. Wu, Phys. Rev. Lett. 10 (1963) 253.
C. S. Wu, Rev. Mod. Phys. 36 (1964) 618.
T .D. Lee and C. S. Wu, Ann. Rev. Nucl. Sci. 15 (1965) 381.



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$$
\begin{aligned}
|\mathcal{M}|^2 = & \; |f_1 - g_1|^2 \left(m_n^2 - u\right)\left(m_e^2 + m_p^2 - u\right) \\
& + |f_1 + g_1|^2 \left(s - m_p^2\right)\left(s - m_e^2 - m_n^2\right) \\
& + \left(|f_2|^2 + |g_2|^2\right) \times \\
& \times \left\{ t\left[\left(s - m_p^2\right)\left(u - m_n^2\right) + \left(s - m_n^2\right)\left(u - m_p^2\right)\right] - m_e^2 \left[\left(m_n^2 - m_p^2\right)(s - u) + \frac{1}{2}\left(m_e^2 - t\right)\left(m_n^2 + m_p^2 + t\right)\right]\right\} \\
& + 2\,\mathrm{Re}\left(f_2 g_2^*\right)\left(m_n^2 - m_p^2\right)\left[t\,(s - u) + m_e^2\left(m_n^2 - m_p^2\right)\right] \\
& + \frac{1}{2}\left(|f_3|^2 + |g_3|^2\right) m_e^2 \left(m_e^2 - t\right)\left(m_p^2 + m_n^2 - t\right) \\
& + m_p m_n \left(m_e^2 - t\right)\left[2\left(|g_1|^2 - |f_1|^2\right) + \left(2t + m_e^2\right)\left(|g_2|^2 - |f_2|^2\right) - m_e^2\left(|g_3|^2 - |f_3|^2\right)\right] \\
& + 2\,\mathrm{Re}\left[f_1 g_2^*\left(m_n - m_p\right) - g_1 f_2^*\left(m_n + m_p\right) + \frac{1}{2}\left(f_2 f_3^* + g_2 g_3^*\right) m_e^2\right]\left[t\,(s - u) + m_e^2\left(m_n^2 - m_p^2\right)\right] \\
& + 2\,\mathrm{Re}\left(f_1 f_2^* + g_1 g_2^*\right) m_p \left[t\left(t - m_p^2 + m_n^2\right) + m_e^2\left(s - m_n^2 - m_e^2\right)\right] \\
& + 2\,\mathrm{Re}\left(f_1 f_2^* - g_1 g_2^*\right) m_n \left[t\left(t - m_n^2 + m_p^2\right) + m_e^2\left(u - m_p^2 - m_e^2\right)\right] \\
& + 2\,\mathrm{Re}\left(f_1 f_3^* + g_1 g_3^*\right) m_e^2 m_p \left(m_n^2 - t\right) \\
& + 2\,\mathrm{Re}\left(f_1 f_3^* - g_1 g_3^*\right) m_e^2 m_n \left(s - m_p^2\right) \; .
\end{aligned}
$$

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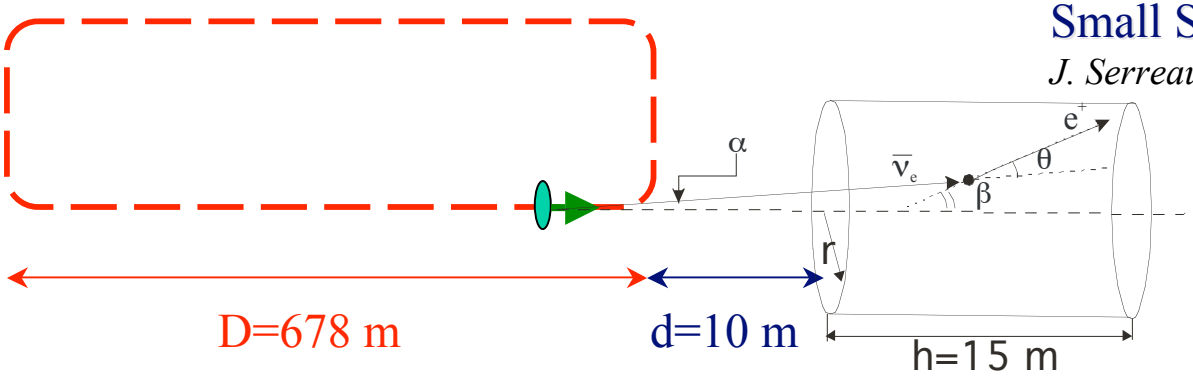
Small Storage ring-detector:

J. Serreau, C. Volpe: Phys.Rev. C70 (2004) 055502



$$\frac{dN}{d\cos\beta} = f\tau n h \Delta t \int_0^\infty dE_\nu \int_0^D \frac{d\ell}{L} \int_0^h \frac{dz}{h} \int_{-\alpha_{\max}}^{\alpha_{\max}} \frac{\sin\alpha d\alpha}{4} \Phi_{lab}(E_\nu,\beta) \left(\frac{d\sigma}{d\cos\theta}\right) \left(\frac{d\cos\theta}{d\cos\beta}\right) ,$$

$$\frac{dN}{d\cos\beta} = \sum_{n=0}^{\infty} A_n P_n(\cos\beta)$$

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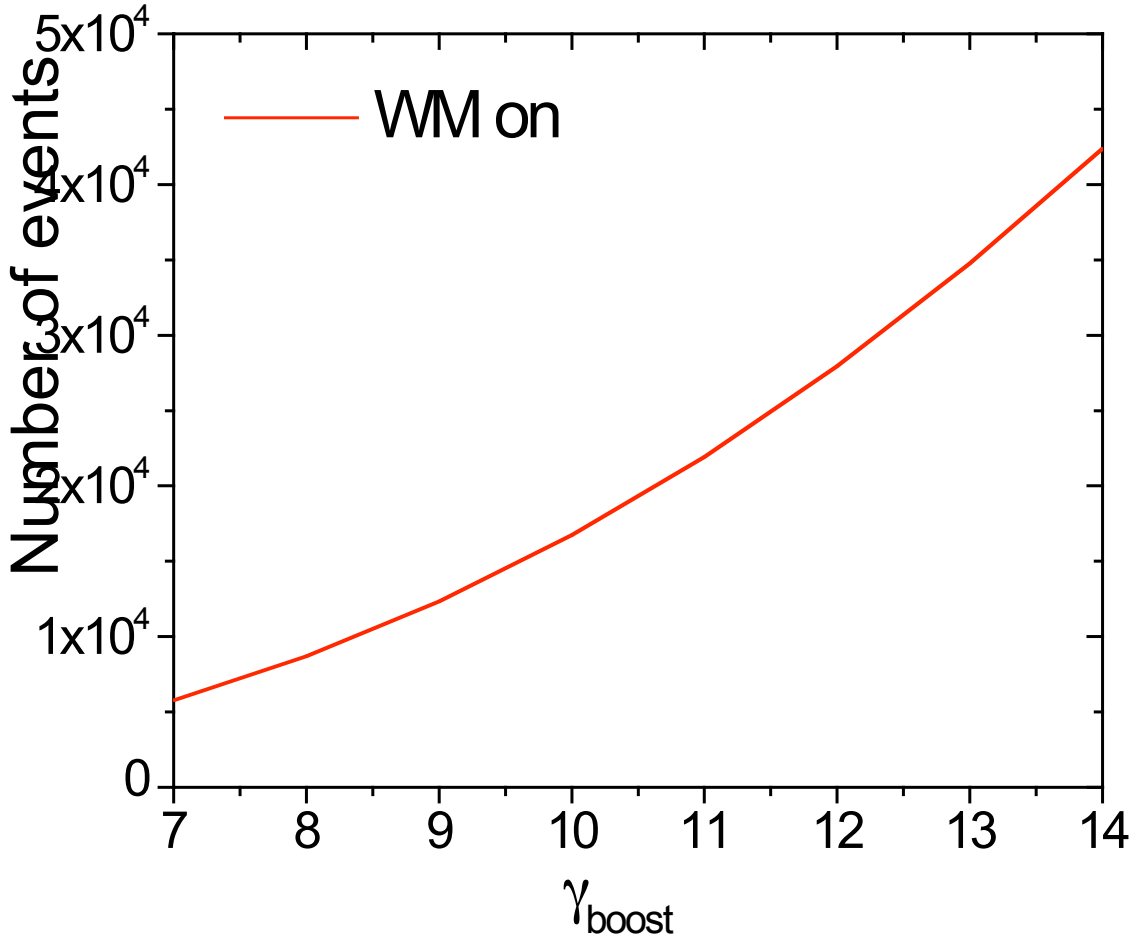

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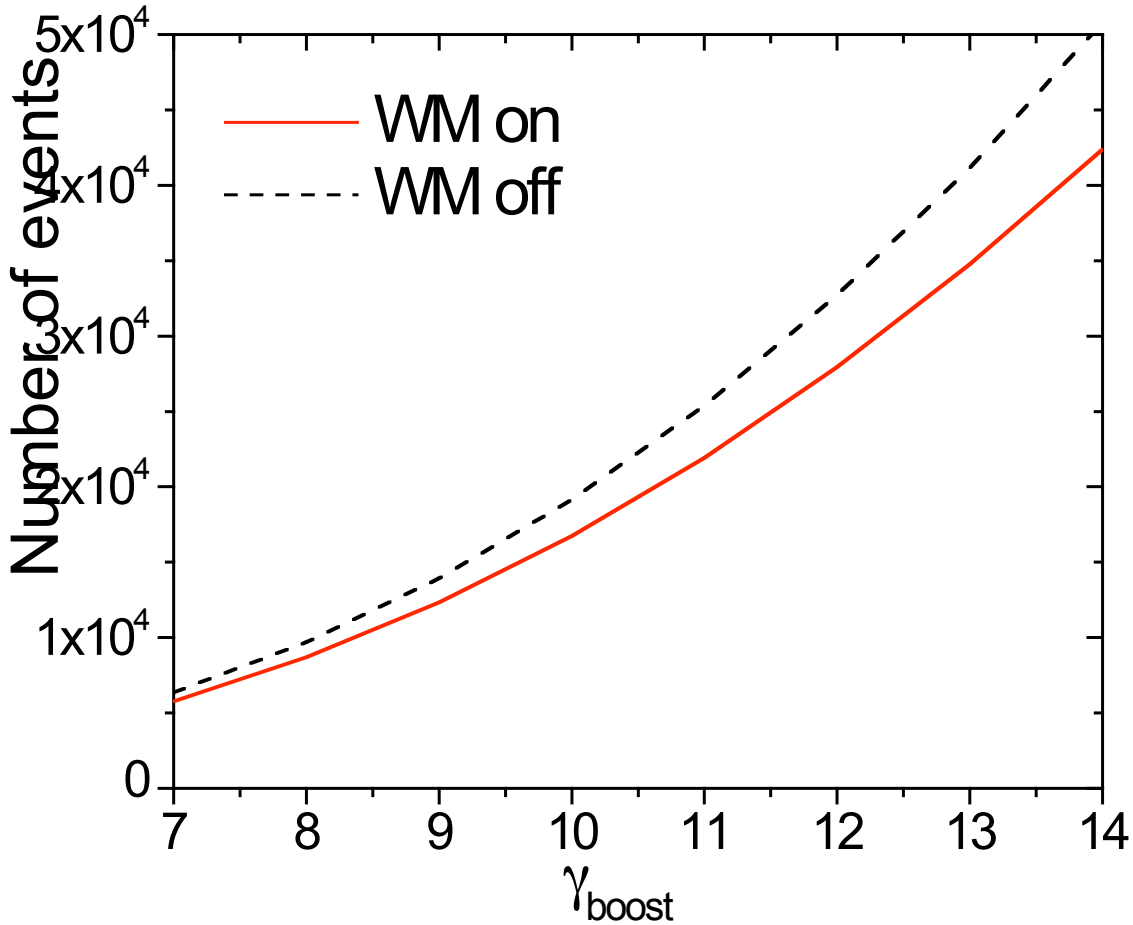

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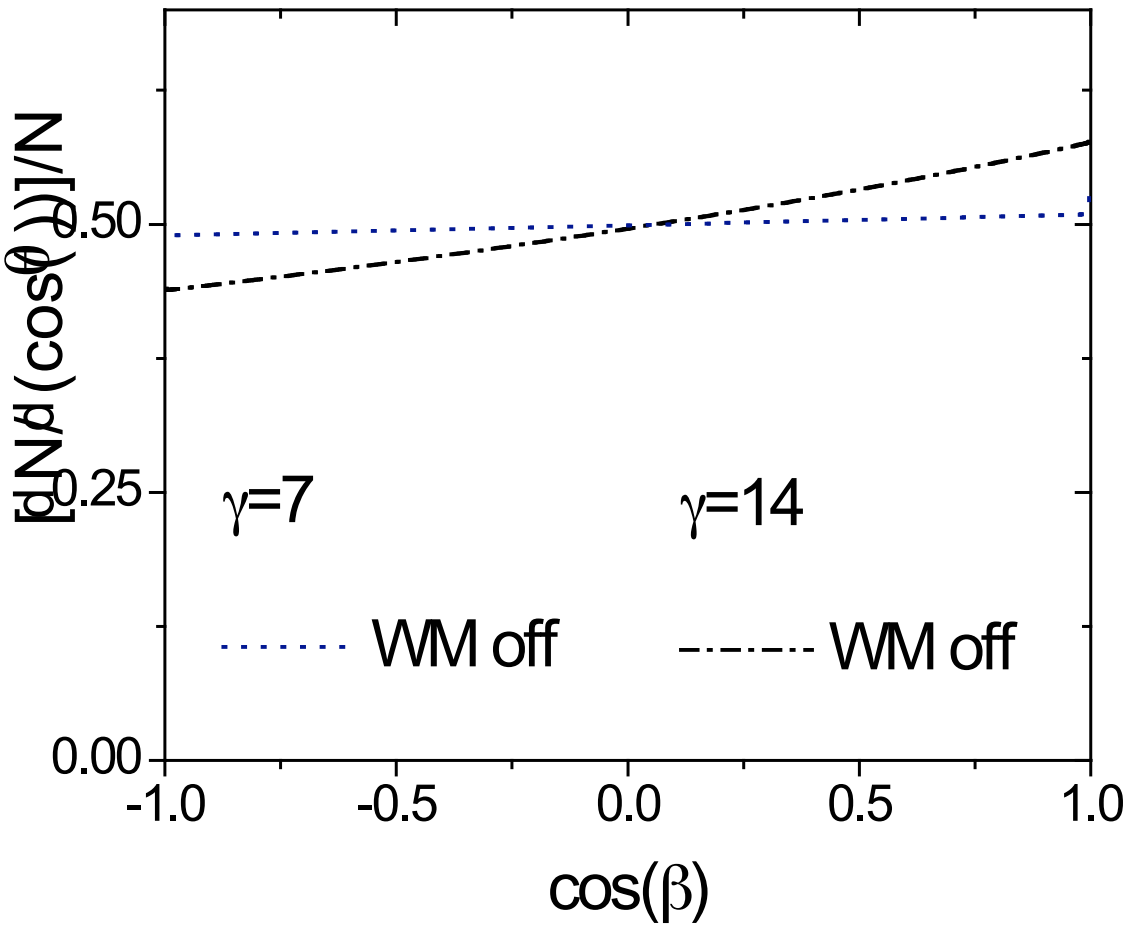

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Positron angular distribution

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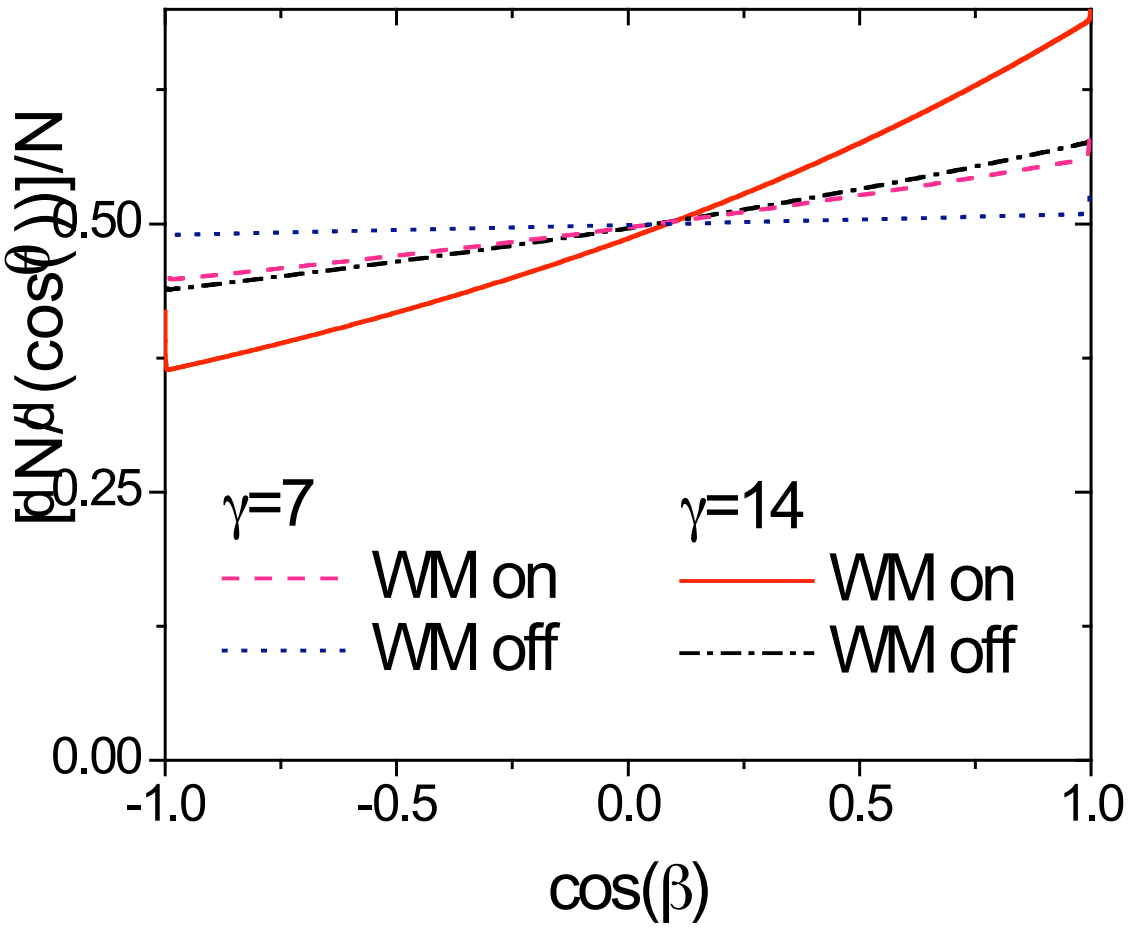

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Positron angular distribution

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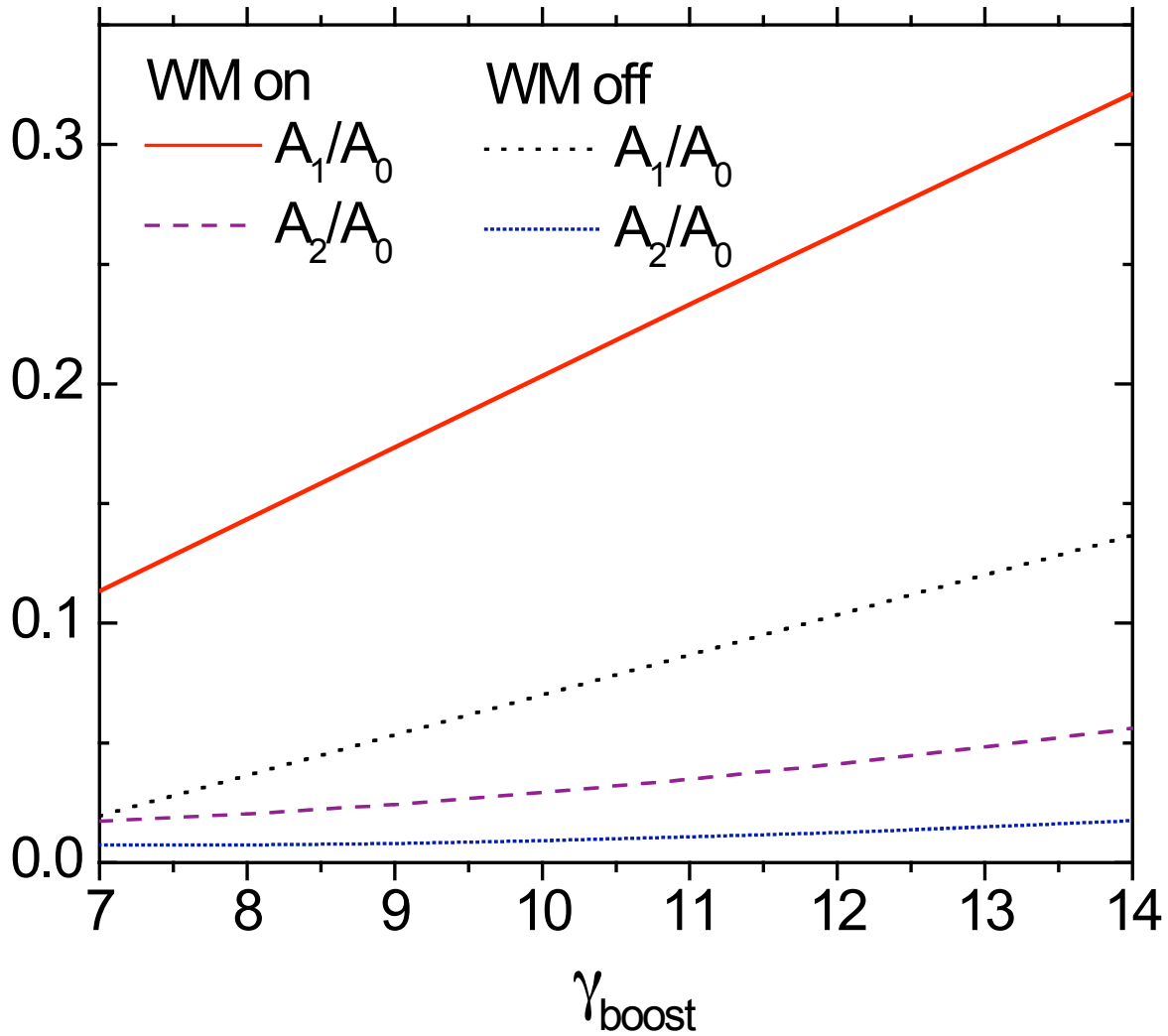

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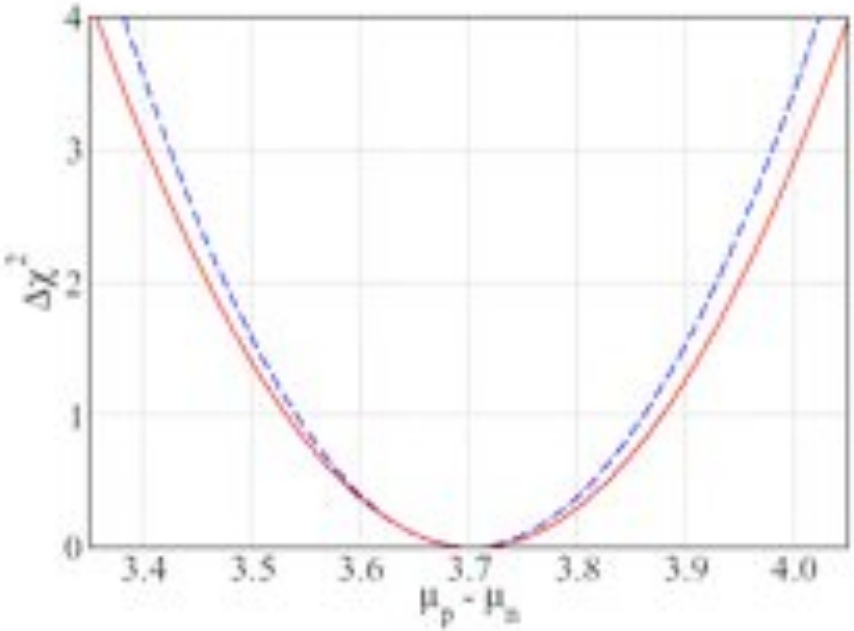
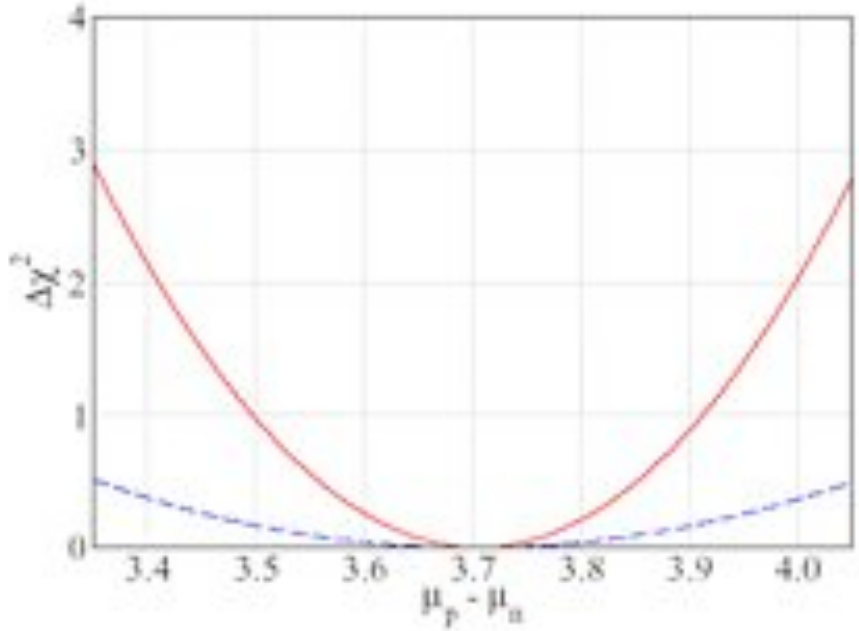
Angular distrib.

No of counts



Stat. error only



+2% syst. error

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Statistics for γ=12; t=1 year

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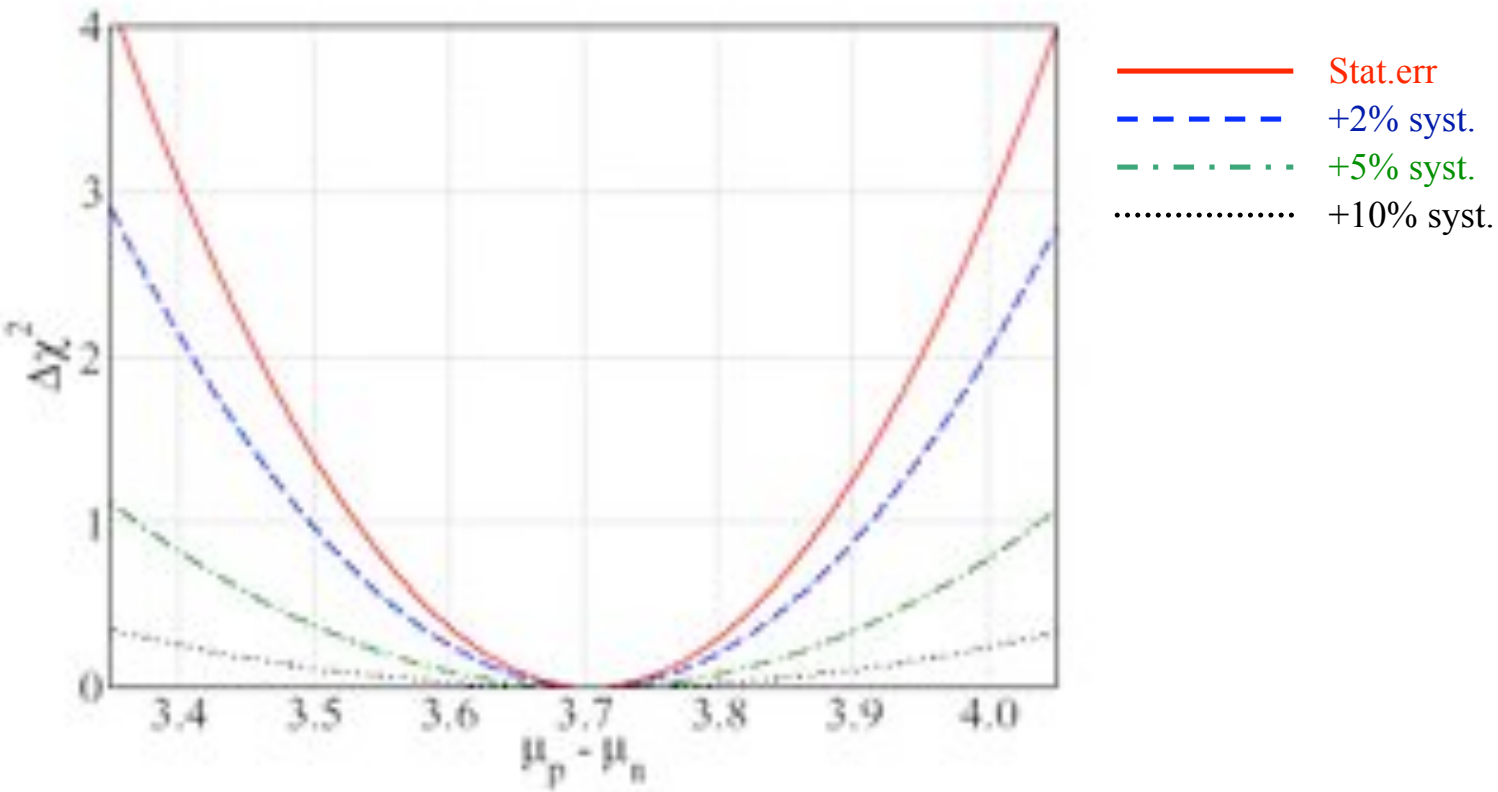

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A Conserved Vector Current test using low energy β–beams

- Low energy β-beams can be powerful tool for neutrino physics and in particular neutrino-nucleus interaction

- We show « how weak magnetism term » can be determined with 9% (or even better) accuracy in one year measurement at low energy β-beam facility

A.B. Balantekin, J.H. De Jesus, R. Lazauskas, C. Volpe, Phys.Rev. D73 (2006) 073011

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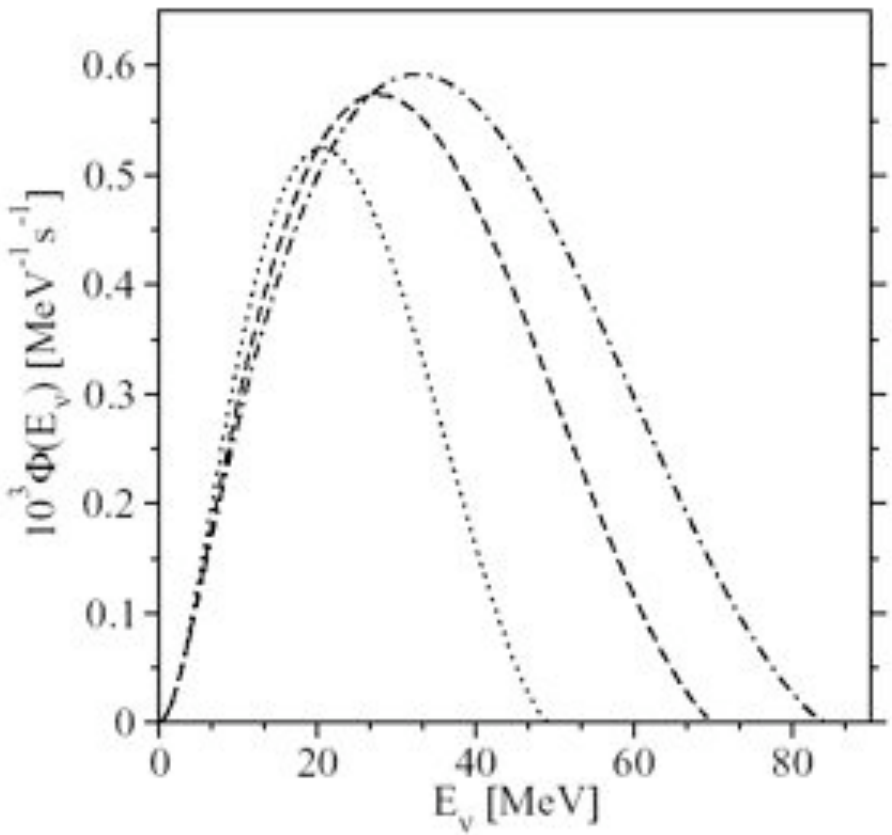

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