Search for Time Reversal Symmetry Violation in the decay of free neutron

Measurement of transverse electron polarization

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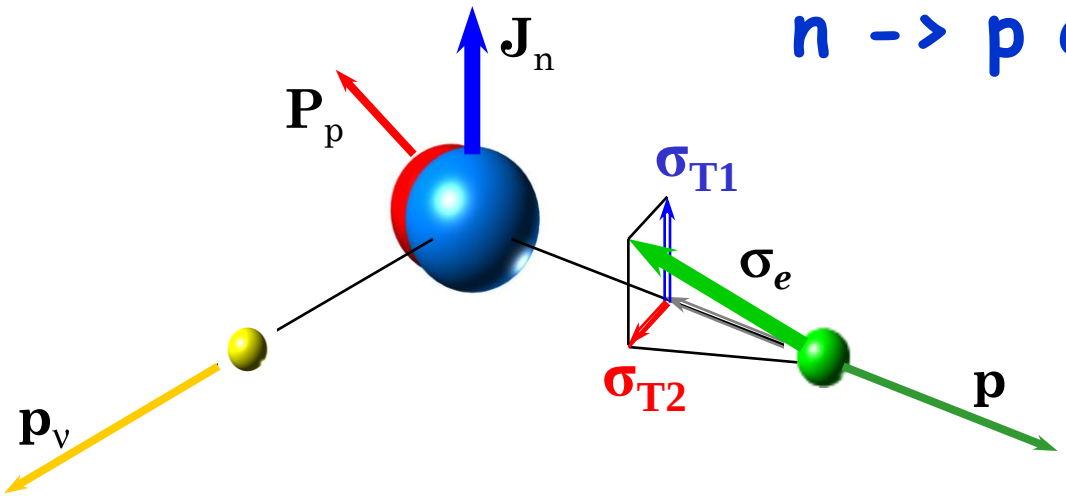
Violation of T and CP symmetries, observations

- Baryon asymmetry of the present Universe:
  - Sakharov: necessary condition: CP-violation, equivalent to T-violation.
- Decay of neutral K mesons, numerous observations of large CP-violation in B mesons decays.

Consistent with Kobayashi-Maskawa CP-violation mechanism

- Too weak to account for Baryon asymmetry ...

CP- (or T) violation in „normal" matter greatly wellcome



n -> p e $\bar{\nu}_e$ +782 keV, (~887s)

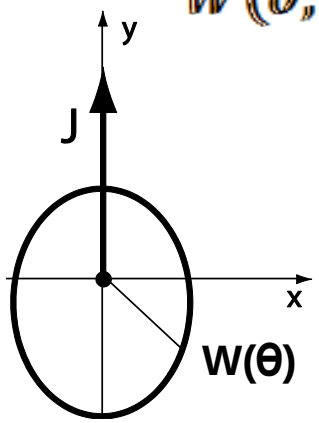
T p = - p

T σ = - σ

T J = - J

Angular correlations in β-decay:

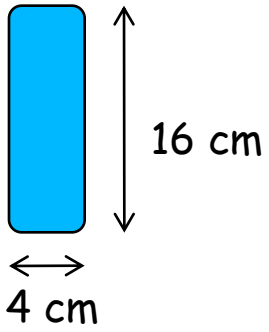
$$W(\theta, E, \sigma, p) \propto 1 + A\frac{\vec{J}\cdot\vec{p}}{E} + \frac{\vec{J}\cdot\vec{p}\cdot\vec{p}}{E} + \cdots + N\,\vec{J}\cdot\hat{\sigma} + R\,\frac{\vec{J}\cdot\vec{p}\times\hat{\sigma}}{E} + \cdots$$



A- asymmetry parameter (-0.1173)

Cold neutron beam, SINQ, PSI

- **Total flux:** $1.4 \times 10^{10}\ s^{-1}$
- **Maximum polarization:** 0.97
- **Average polarization:** ~0.80±0.008
- **Average velocity:** 900 m/s

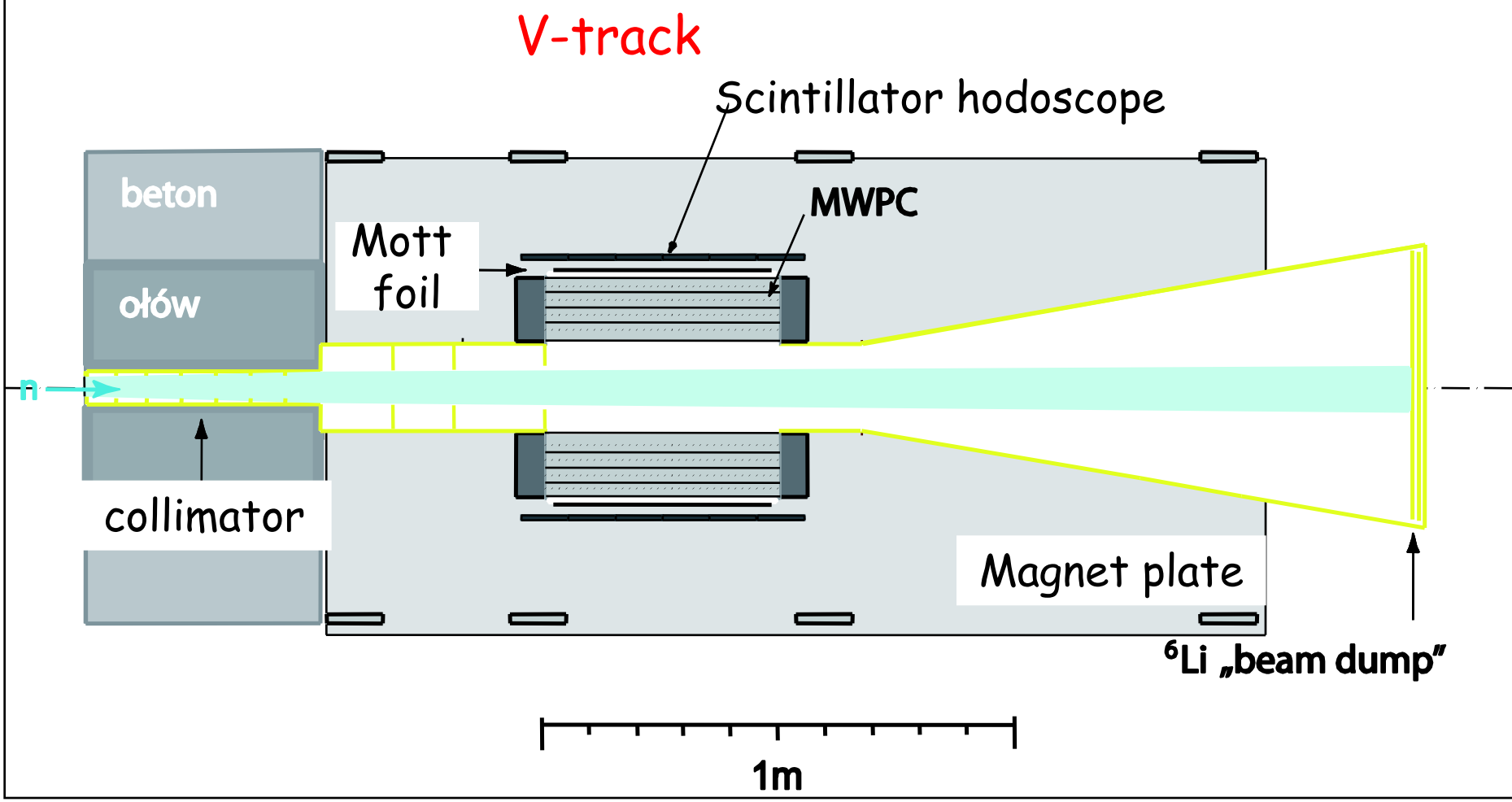


Within 1 sec. Per 1 meter:

3×10^4 neutron decays

5×10^7 losses ...

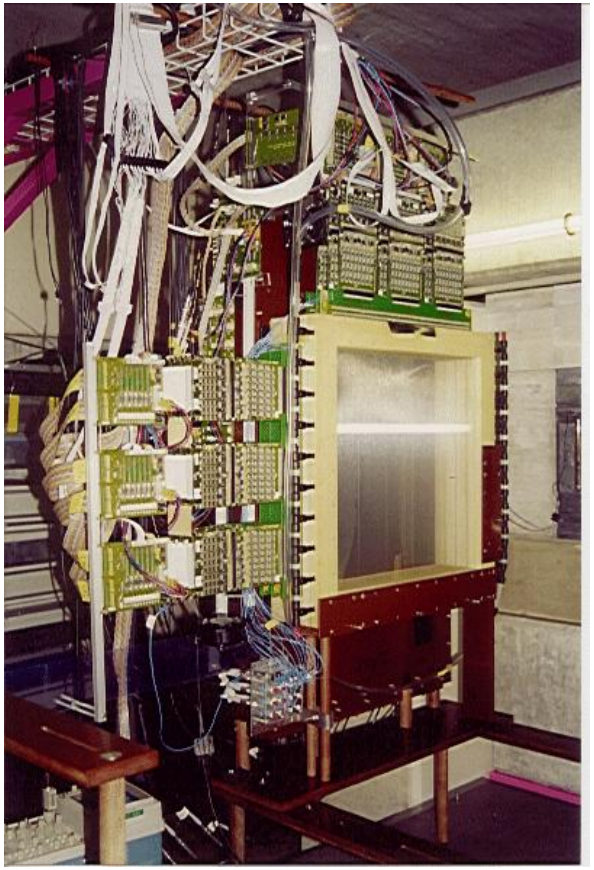
Experimental setup, top view



Multiwire proportional chambers

- Active area: 50x50 cm^2
- Measuring planes: (5+5) x 2
- Sense wires per plane: 96
- Special features;
  - Gas mixture:

    90%He 5%Isobuthan 5%Methylal
  - Wires: Φ 25 μm, Ni/Cr (20/80),
  - Readout of anodes (y) and cathodes (z),
  - Window foil: 2.5 μm Mylar



Results

Correlation coefficients N, R (×1000)

run	N_{SM}	N_{sr}	N	R
2003	71	110±108±30	82±97±30	-89±143±40
2004	68	144±92±15	70±86±17	-117±140±26
2006	68	79±32±7	86±30±8	-11±42±9
2007	68	54±12±5	51±12±6	12±16±6
final		59±11±4	56±11±5	8±15±5

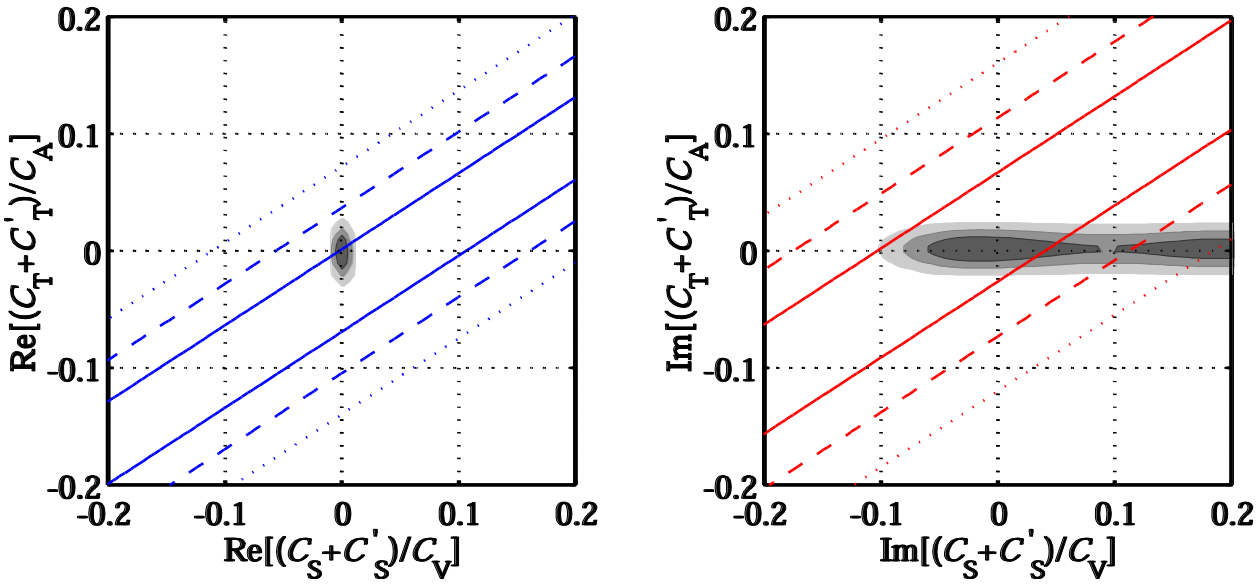
(R_{SM}=0.6)

Correlation coefficients N, R and scalar and tensor coupling constants of weak interaction

$$N \approx 0.276 \cdot Re(S) + 0.335 \cdot Re(T) - A \cdot \frac{m}{E}$$

$$R \approx 0.276 \cdot Im(S) + 0.335 \cdot Im(T) - A \cdot \frac{\alpha\, m}{p}$$

Existing limitations and our result



N = 56±11±5

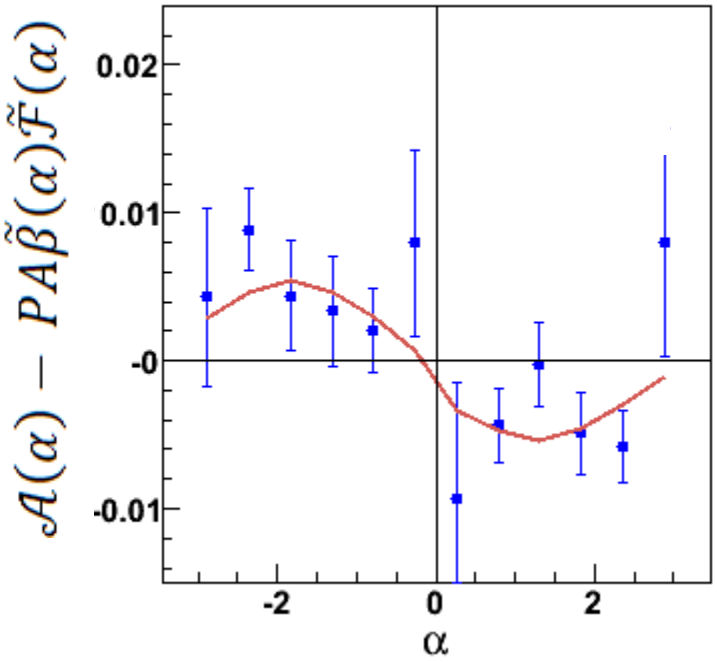
R = 8±15±5

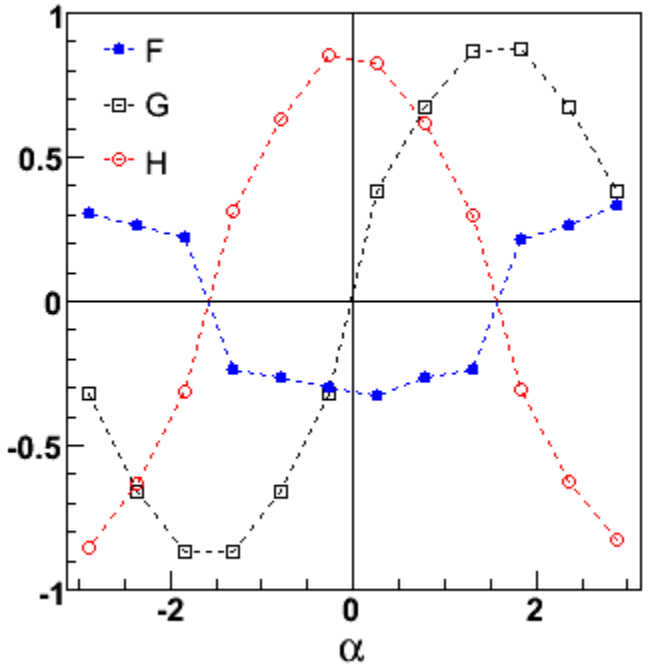
Outlook

- Word first measurement of correlation coefficients R and N in neutron decay is finished. Preliminary result $R=(8\pm15\pm5)*10^{-3}$, $N=(56\pm11\pm5)*10^{-3}$ is consistent with Standard Model.
- Gain in accuracy (~20%) in the determination of R is still possible
- Another method of R coefficient extraction is tested.

Analiza danych – wyliczenie R i N

$$\mathcal{A}(\alpha) - PA\tilde{\beta}(\alpha)\tilde{\mathcal{F}}(\alpha) = P\,\tilde{S}(\alpha)\left[N\,\tilde{\mathcal{G}}(\alpha) + R\tilde{\beta}(\alpha)\tilde{\mathcal{H}}(\alpha)\right]$$



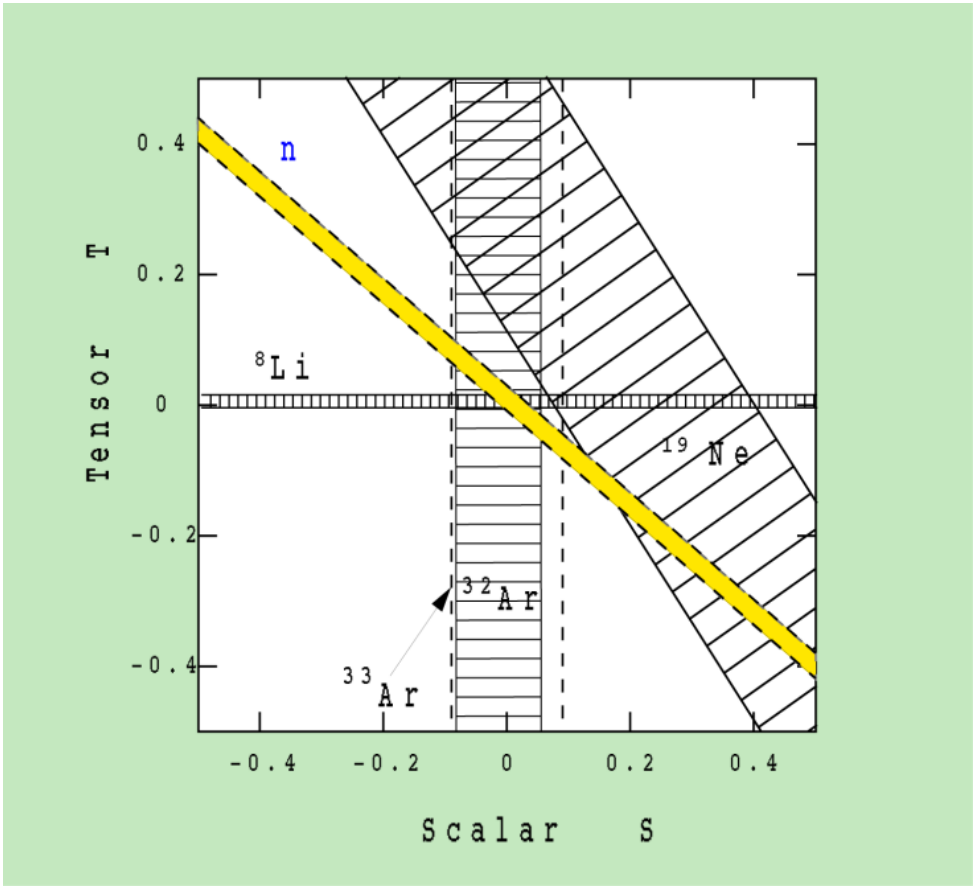


R = 0.012±0.016

N = 0.051±0.012

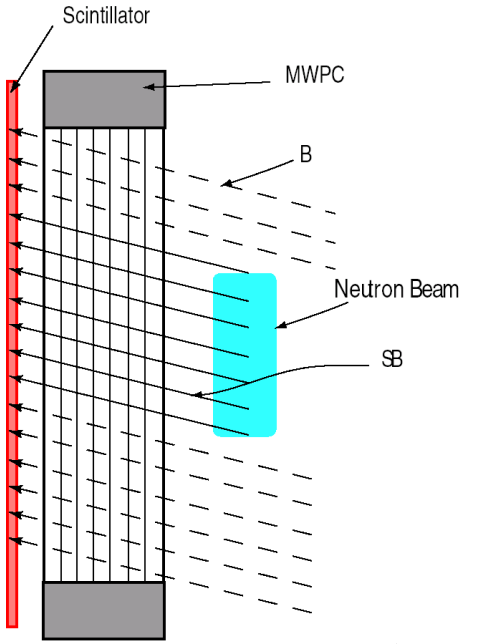
χ^2/nfd = 1.07

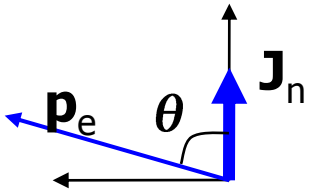
Dane z 2007

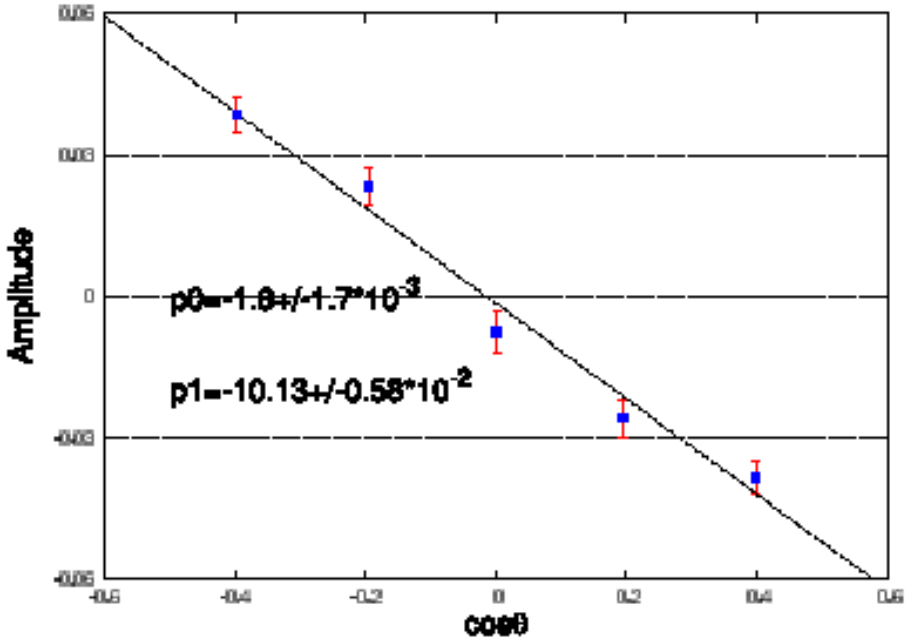

n
^{8}Li
^{19}Ne
^{32}Ar
^{33}Ar
0.4
0.2
0
-0.2
-0.4
-0.4
-0.2
0
0.2
0.4
Tensor T
Scalar S

Asymmetry parameter

- Identification of electrons from n-decay





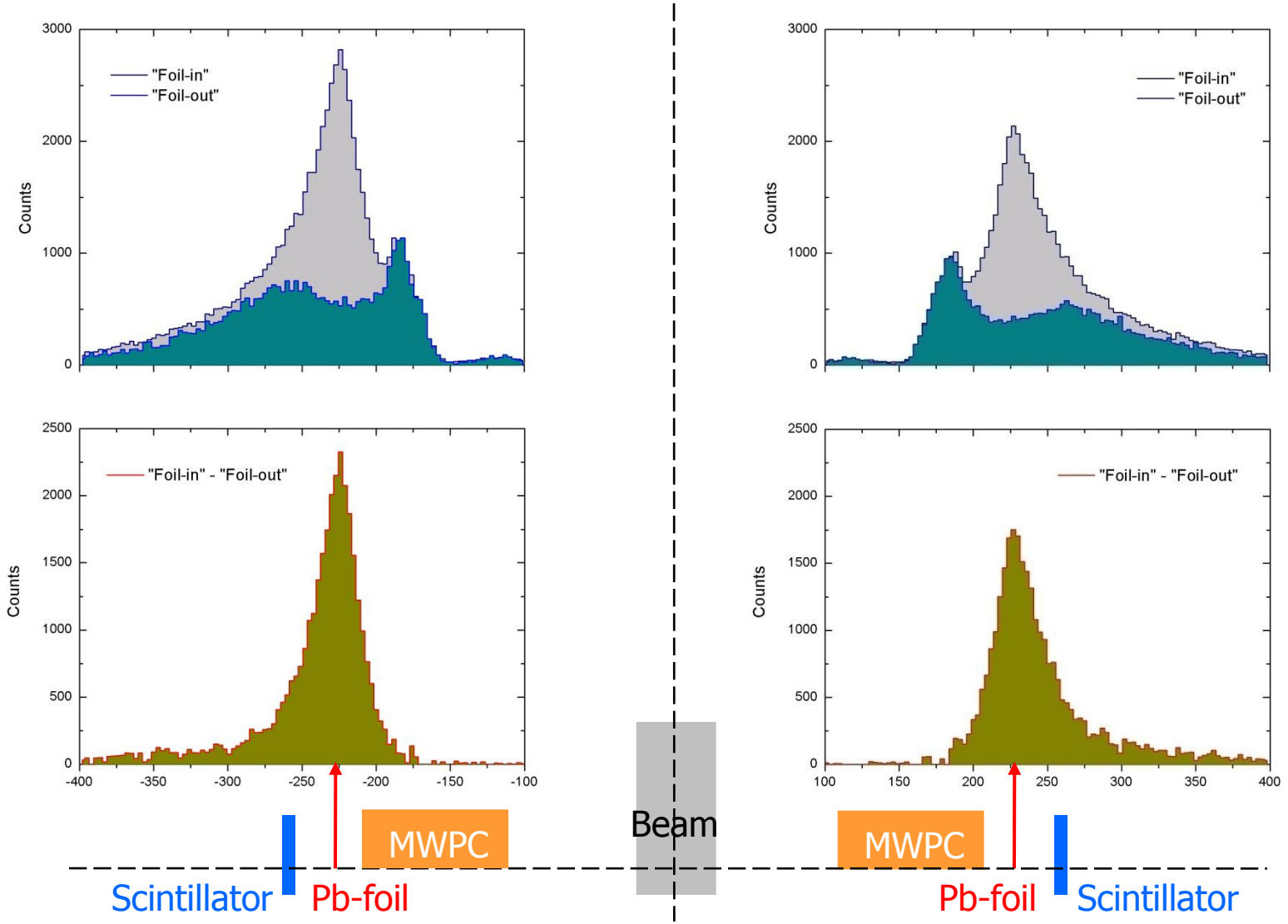


$A = -0.1167 \pm 0.0060$ (stat.)

$\langle P_n \rangle = 0.899 \pm 0.008$

$A = -0.1173 \pm 0.0013$ (PDG, 2003)

Vertex reconstruction



Układ eksperymentalny, widok z góry