Primary activity standardization of ^{134}Cs

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Overview

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- Measurements
- Analysis
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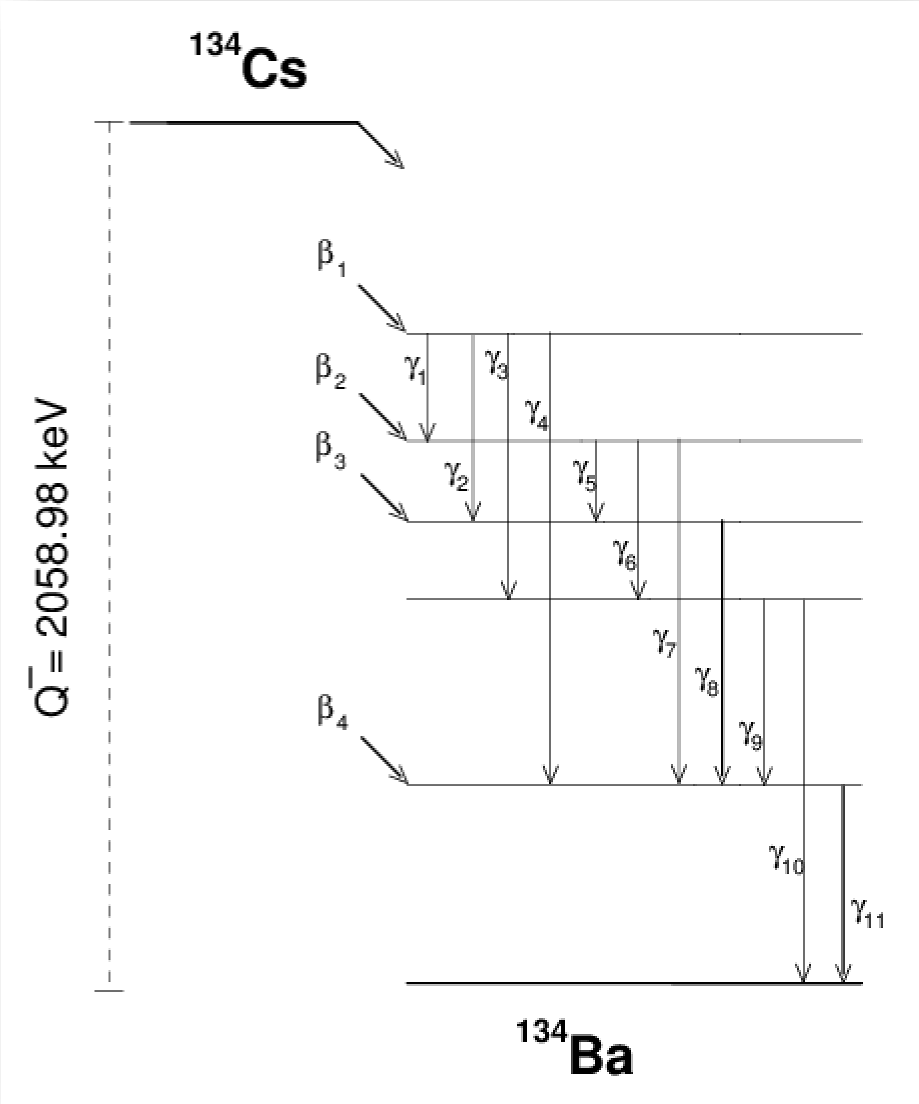
- Summary

Motivation

Motivation

^{134}Cs is an important isotope for calibration in gamma-ray spectrometry.

^{134}Cs can also be used as tracer for activity determination of ^{137}Cs.



Electron capture with 0.0003% probability is neglected.

Measurements

CIEMAT/NIST efficiency tracing

Counters for CIEMAT/NIST efficiency tracing:
- Wallac 1414
- TriCarb 2800 **(TriCarb 2810 unuseable)**

Efficiency variation by means of chemical quenching

TDCR

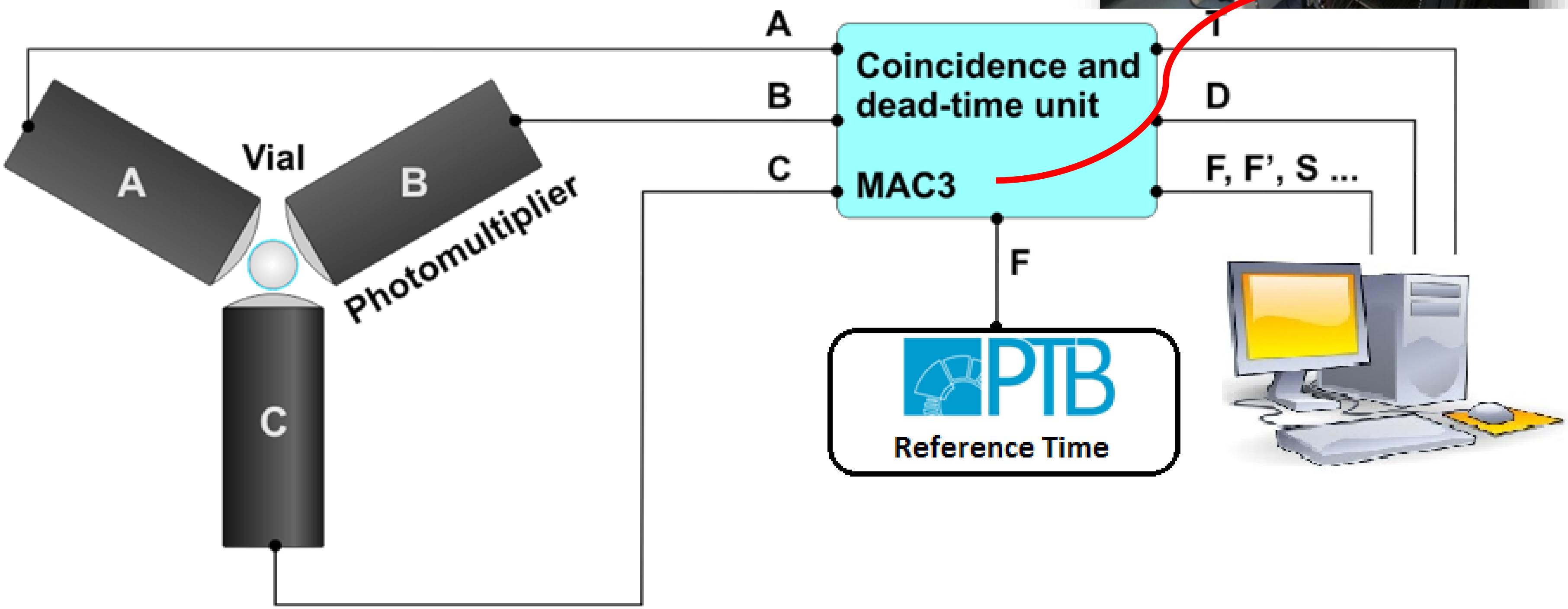
Counters for TDCR:

- TDCR (M27)
- TDCR (M29)

Efficiency variation by means of chemical quenching

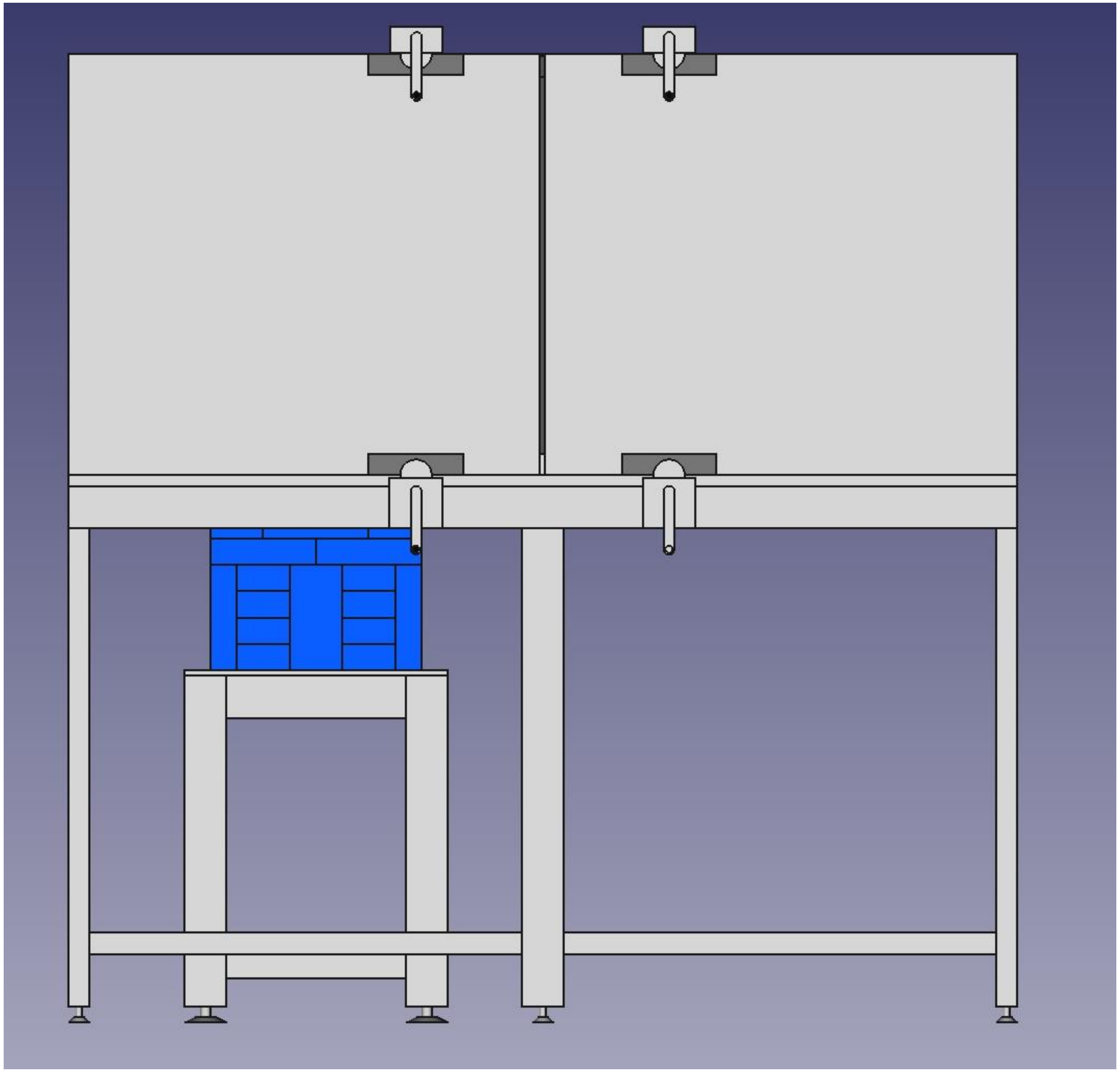
TDCR

TDCR (M27)



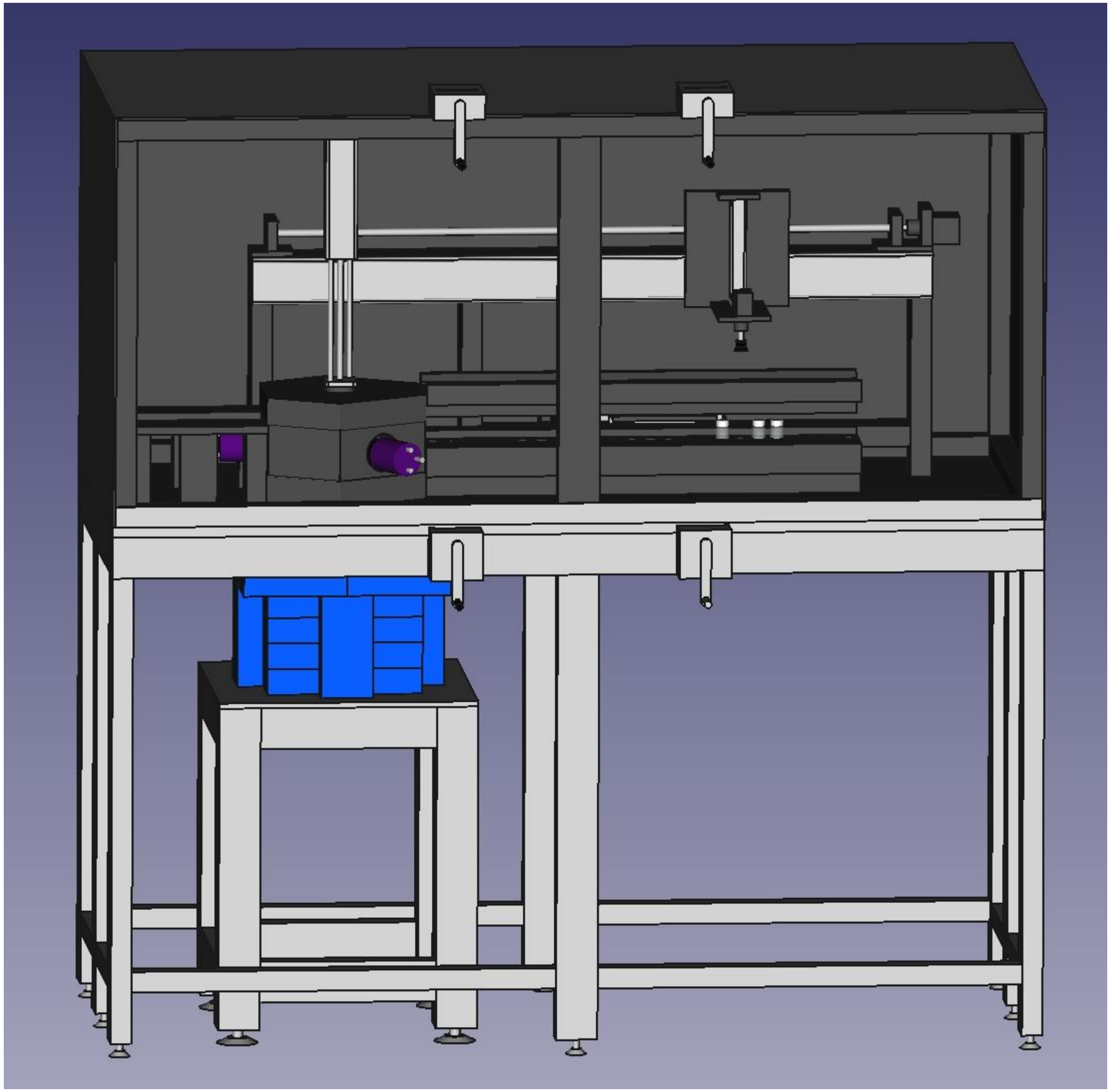
TDCR and 4πβγ(LS)-CC

TDCR (M29)



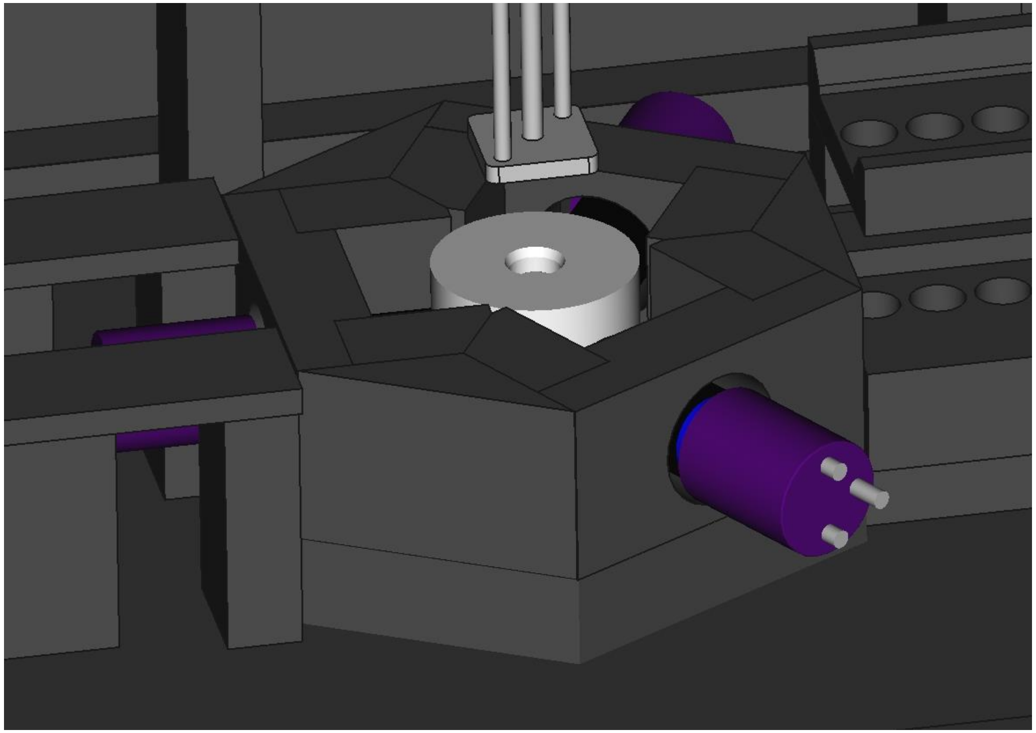
TDCR and 4πβγ(LS)-CC

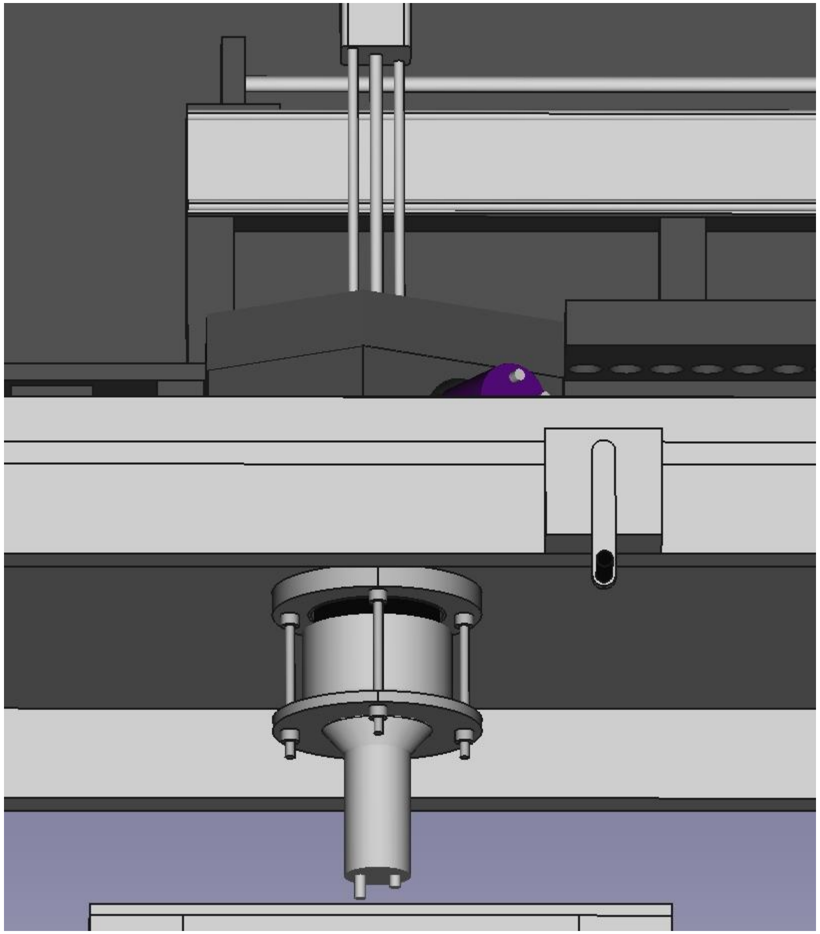
TDCR (M29)



TDCR and $4\pi\beta\gamma$(LS)-CC

TDCR (M29)

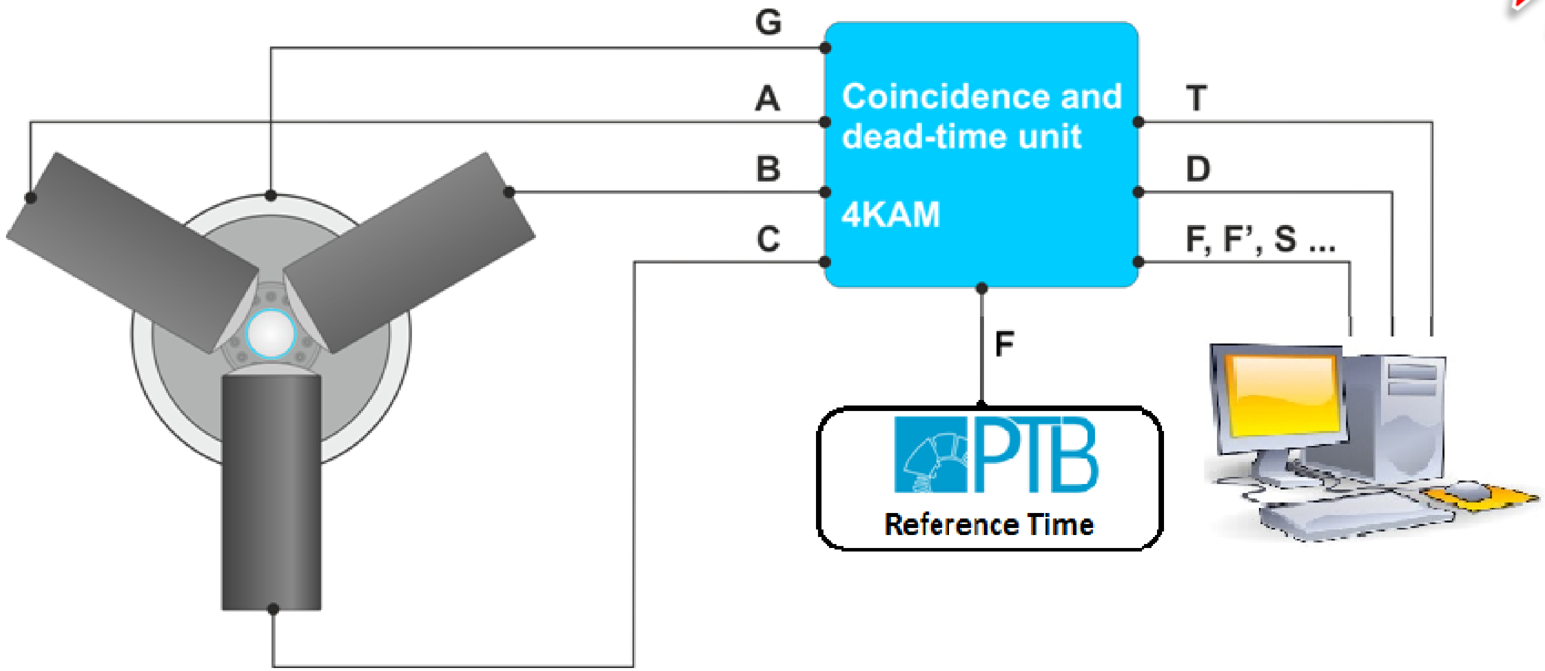




TDCR and 4πβγ(LS)-CC

New!

TDCR (M29)



β-double coincidence	D=AB or BC or AC
β-triple coincidence	T=ABC
β-γ-coincidence	DG = (AB or BC or AC)G
	TG = ABCG

4πβγ(LS)-CC

System with LS counter

\- 4πβ(LS)-γ (M29)

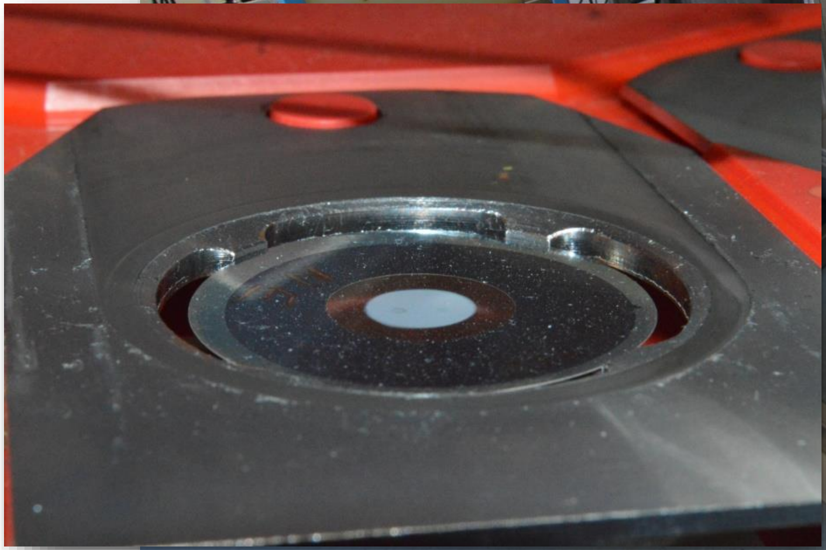
Efficiency variation by means of grey filters

Coincidence counting with PC

System with proportional counter (PC):

- $4\pi\beta$(PC)-γ (M1)

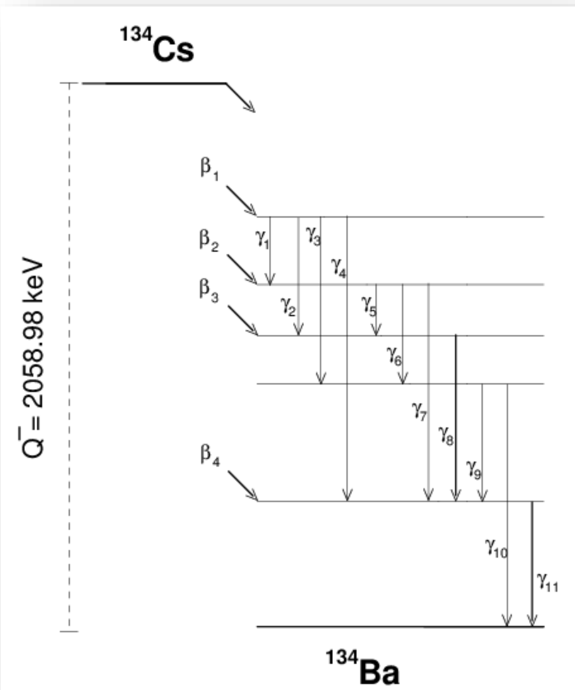
Efficiency variation using absorbing foils



Analysis

Efficiency computation

Efficiency calculations for TDCR and CIEMAT/NIST method with stochastic model taking into account 14 cascades

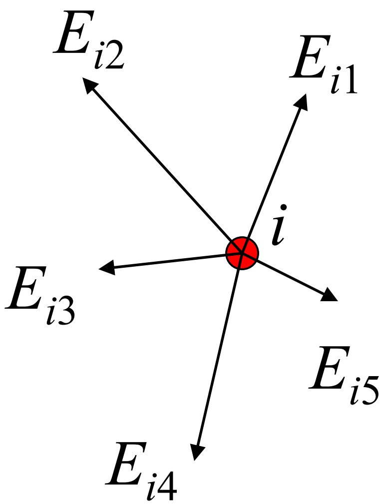


Nr.	*P* in %	Components with energies in parentheses
1	70.1774	β_3(658.39 keV), γ_8(795.8677 keV), γ_{11}(604.7232 keV)
2	0.986	β_2(415.64 keV), γ_7(1038.6137 keV), γ_{11}(604.7232 keV)
3	0.06	β_4(1454.26 keV), γ_{11}(604.7232 keV)
4	1.2242	β_2(415.64 keV), γ_6(475.368 keV), γ_9(563.2457 keV), γ_{11}(604.7232 keV)
5	1.5332	β_1(89.06 keV), γ_3(801.953 keV), γ_{10}(1167.968 keV)
6	3.0213	β_1(89.06 keV), γ_4(1365.1987 keV), γ_{11}(604.7232 keV)
7	0.007	β_1(89.06 keV), γ_1(326.585 keV), γ_7(1038.6137 keV), γ_{11}(604.7232 keV)
8	0.026	β_2(415.64 keV), γ_5(242.746 keV), γ_8(795.8677 keV), γ_{11}(604.7232 keV)
9	7.1847	β_1(89.06 keV), γ_3(801.953 keV), γ_9(563.2457 keV), γ_{11}(604.7232 keV)
10	0.2613	β_2(415.64 keV), γ_6(475.368 keV), γ_{10}(1167.968 keV)
11	15.5082	β_1(89.06 keV), γ_2(569.2457 keV), γ_8(795.8677 keV), γ_{11}(604.7232 keV)
12	0.0087	β_1(89.06 keV), γ_1(326.585 keV), γ_6(475.368 keV), γ_9(563.2457 keV), γ_{11}(604.7232 keV)
13	0.0019	β_1(89.06 keV), γ_1(326.585 keV), γ_6(475.368 keV), γ_{10}(1167.968 keV)
14	0.0002	β_1(89.06 keV), γ_1(326.585 keV), γ_5(242.746 keV), γ_8(795.8677 keV), γ_{11}(604.7232 keV)

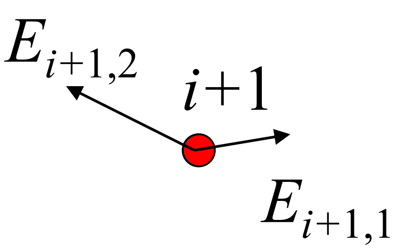
The stochastic model

The <u>triple</u> counting efficiency in TDCR

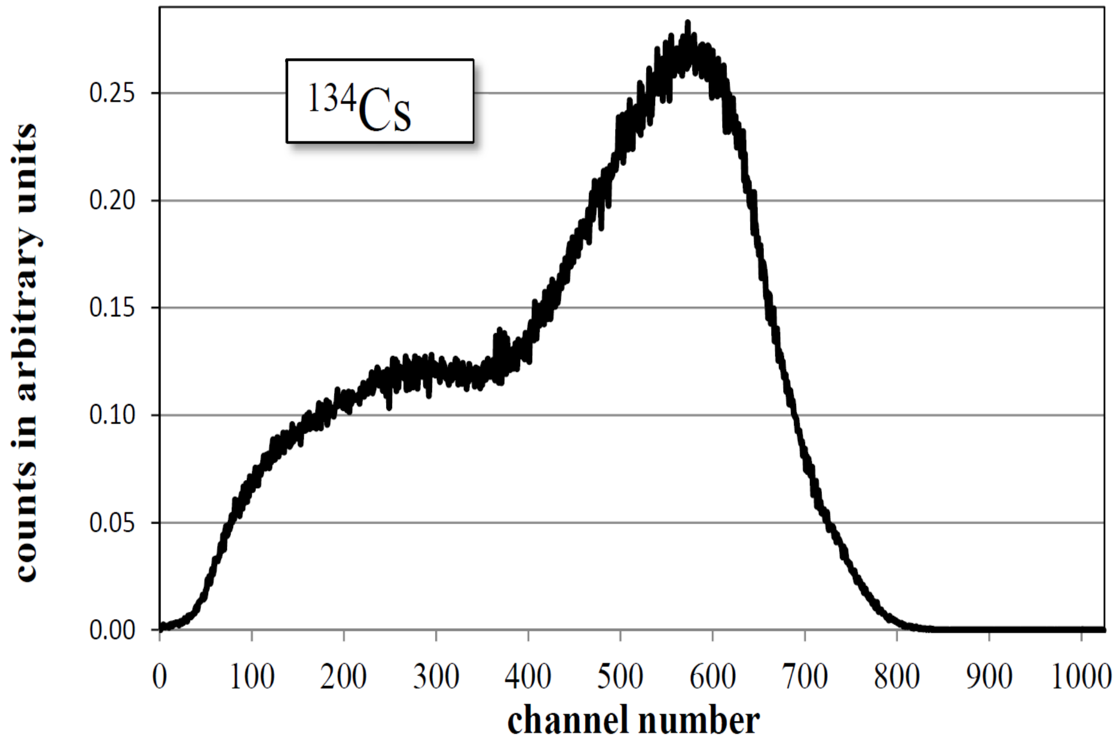
$$\varepsilon_{\mathrm{T}}(\lambda)=\sum_{i=1}^{N}\left\{1-\exp\left[\frac{-\sum_{l=1}^{M_i}E_{il}Q(E_{il})}{3\lambda}\right]\right\}^3 / N$$



N	Number of simulated decay events
M_i	Number of electrons in decay event i
E_{il}	Energy of electrons l, which was ejected in decay event i



LSC: analysis



CIEMAT/NIST efficiency tracing was analysed with an analytical approach and with the stochastic approach. Relative deviation: lower than 0.01 %.

The long-term stability might be better when using HiSafe III instead of Ultima Gold (**García-Toraño et al. (2002)**).

CC: analysis

4πβ(LS)-γ

Left: $N_\beta = N_D$

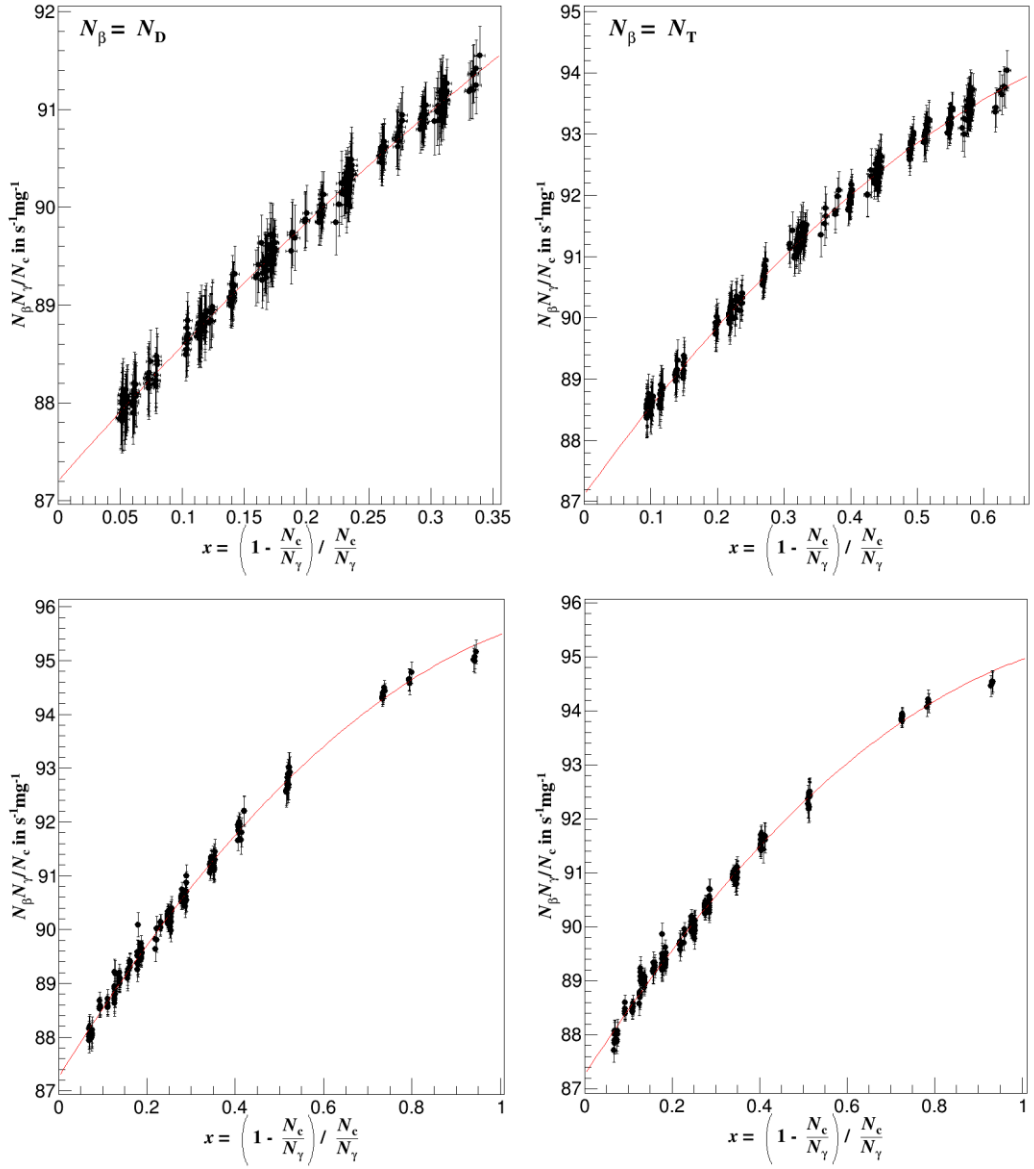
Right: $N_\beta = N_T$.

Efficiency variation using ND filters

4πβ(PC)-γ

Left: γ energy range only with main peaks

Right: γ energy range "open"



Results

Uncertainties for ^{134}Cs

Component	$u(a)/a$ in %			
	CIEMAT/ NIST	TDCR	4πβ(PC)-γ CC	4πβ(LS)-γ CC
Counting statistics	0.02	0.01	0.11*	0.07*
Weighing	0.03	0.03	0.04	0.03
Dead time	0.10	0.03	negligible	0.20
Background	0.05	0.03	0.02	0.03
Resolving time	-	-	negligible	**0.20**
Counting time	0.01	0.01	negligible	negligible
Adsorption	0.05	0.05	0.05	0.05
Decay correction	<0.01	<0.01	<0.01	<0.01
Extrapolation of efficiency curve	-	-	0.07	0.07
Impurities (no radioactive impurity detected)	<0.03	<0.03	<0.03	<0.03
^{3}H tracer activity and interpolation of efficiency curve	0.06	-	-	-
TDCR value and interpolation of efficiency curve	-	0.10	-	-
Model and decay data	**0.20**	**0.20**	negligible	negligible
Ionization quenching and *kB* value	0.06	0.10	-	-
PMT asymmetry	0.07	0.05	-	-
Sample (in)stability	0.05	0.05	-	-
Fitting deviation (see text)	-	-	0.19	0.15
Square root of the sum of quadratic components	**0.27**	**0.27**	**0.25**	**0.35**

Final result for ^{134}Cs

Method	*a* in kBq/g	Relative deviation from final result
TDCR (mean of results from 2 counters: 87.14 kBq/g and 87.03 kBq/g)	87.08(24)	-0.08%
CIEMAT/NIST	87.08(24)	-0.08%
4πβ(PC)-γ-CC	87.22(22)	+0.08%
4πβ(LS)-γ-CC	87.24(31)	+0.10%
Final result	**87.15(22)**	-

Summary

Summary

- The results of 4 methods are in good agreement.

- The results of the (pure) LS methods are slightly lower which is likely due to the decay data (beta spectra).

- The lowest uncertainty is obtained with 4π(PC)β-γ coincidence counting

- The 4π(LS)β-γ coincidence counting needs further research and development at PTB (timing between beta and gamma channel and shape of extrapolation curves).


Questions?