CYGNO simulations update

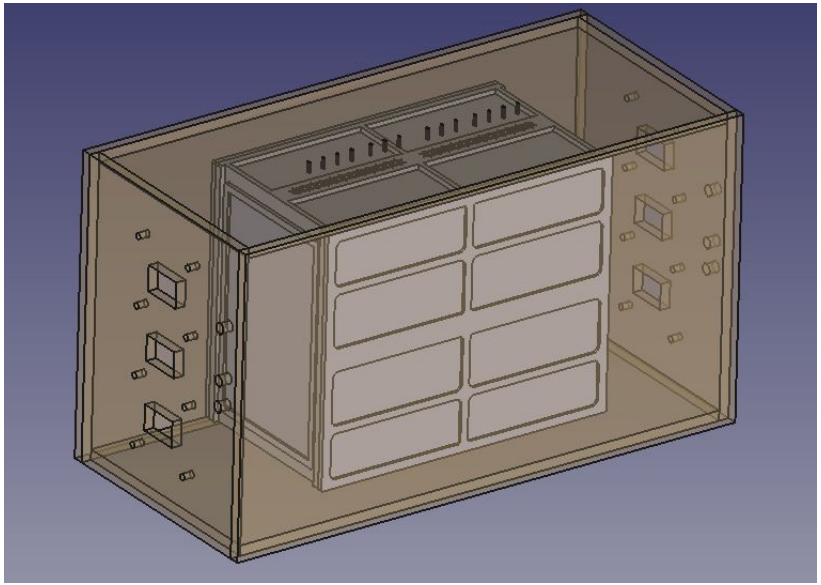
Giulia D'Imperio

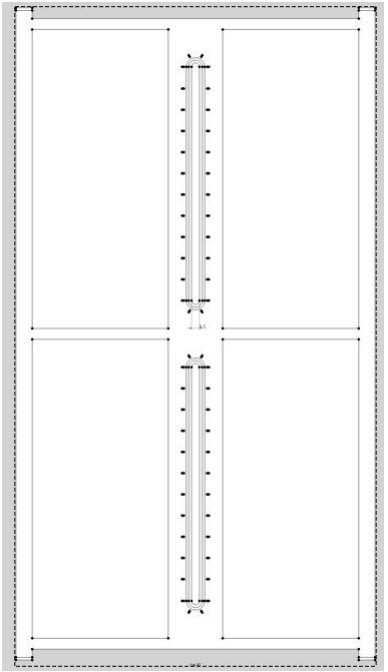
24/03/25

CYGNO-04 geometry

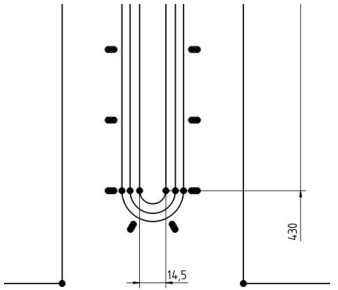
CYGNO-04 geometry

- New CAD design with calibration windows on copper and PMMA

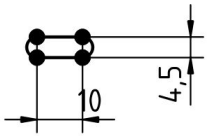




2 PMMA windows
14.5 mm x 430 mm



14 Cu windows
4.5 mm x 10 mm



Calibration simulation

- A preliminary estimate of the 55-Fe source rate was presented by Zahoor at last simulation meeting
- Expected about 560 Hz assuming
  - 1.5 MBq activity
  - 2 PMMA windows 80 mm x 402 mm
  - 14 Cu windows 4.5 mm x 14.5 mm
- Target rate: ~20 Hz
- In new design holes are narrower, this will reduce the rate
  - new design is now implemented in github and can be checked https://github.com/CYGNUS-RD/geometry/tree/master/cygno_04_v3
- Another option to reduce the rate could be using a thin layer of PMMA in the windows (attenuation length for 6 keV gamma is 0.5 mm [*])

[*] https://physics.nist.gov/PhysRefData/XrayMassCoef/ComTab/pmma.html

Radioactivity measurements

Field cage radioactivity measurements

- Review and rearrangement of HPGe measurements presented by Donatella at Cagli meeting
- Gamma emitters in U and Th radioactive chains are measured independently
- Secular equilibrium may be broken in specific points of the chains

  ➜ some measurements are not really independent

From Donatella's presentation

PET+Cu FC with glue

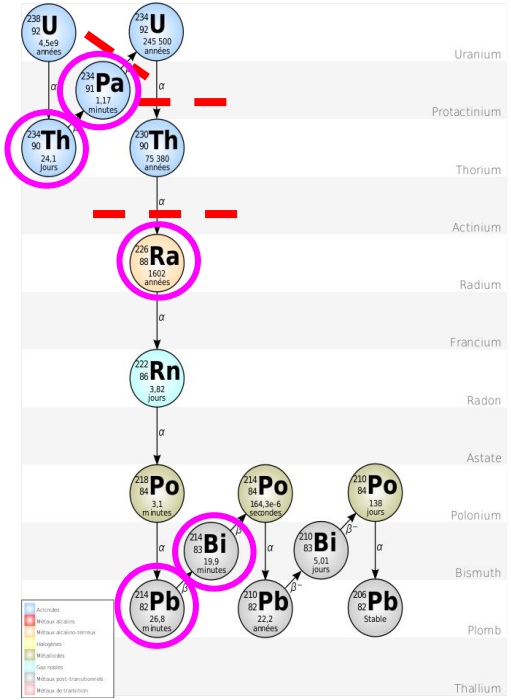
	Nuclides	Larger region of central peak			Smaller region of central peak		
		Activity (Bq/kg)	Uncert. (Bq/kg)	Limit (Bq/kg)	Activity (Bq/kg)	Uncert. (Bq/kg)	Limit (Bq/kg)
U-238	Th-234	0.09	0.27	0.53	-	-	-
	Pa-234m	-	-	-	-	-	-
	Ra-226	$8.06 \cdot 10^{-3}$	$9.70 \cdot 10^{-3}$	$24.01 \cdot 10^{-3}$	$3.39 \cdot 10^{-3}$	$2.34 \cdot 10^{-3}$	$7.23 \cdot 10^{-3}$
	Pb-214	$8.06 \cdot 10^{-3}$	$9.70 \cdot 10^{-3}$	$24.01 \cdot 10^{-3}$	$18.51 \cdot 10^{-3}$	$7.45 \cdot 10^{-3}$	-
	Bi-214	-	-	-	$2.06 \cdot 10^{-3}$	$2.46 \cdot 10^{-3}$	$6.11 \cdot 10^{-3}$
Th-232	Ac-228	$0.36 \cdot 10^{-3}$	$14.91 \cdot 10^{-3}$	$25.02 \cdot 10^{-3}$	$14.42 \cdot 10^{-3}$	$6.20 \cdot 10^{-3}$	-
	Pb-212	$25.81 \cdot 10^{-3}$	$9.99 \cdot 10^{-3}$	-	$19.52 \cdot 10^{-3}$	$8.87 \cdot 10^{-3}$	-
	Bi-212	$57.03 \cdot 10^{-3}$	$33.94 \cdot 10^{-3}$	0.11	$9.25 \cdot 10^{-3}$	$22.53 \cdot 10^{-3}$	$46.31 \cdot 10^{-3}$
	Tl-208	$26.83 \cdot 10^{-3}$	$10.40 \cdot 10^{-3}$	$43.92 \cdot 10^{-3}$	$12.32 \cdot 10^{-3}$	$6.28 \cdot 10^{-3}$	$22.61 \cdot 10^{-3}$
	U-235	$10.72 \cdot 10^{-3}$	$7.69 \cdot 10^{-3}$	$23.41 \cdot 10^{-3}$	$1.04 \cdot 10^{-3}$	$6.17 \cdot 10^{-3}$	$11.23 \cdot 10^{-3}$
	K-40	0.16	0.07	-	0.12	0.06	-
	Cs-137	$5.96 \cdot 10^{-3}$	$3.65 \cdot 10^{-3}$	$12.01 \cdot 10^{-3}$	$6.81 \cdot 10^{-3}$	$2.83 \cdot 10^{-3}$	-
	Co-60	-	-	-	-	-	-

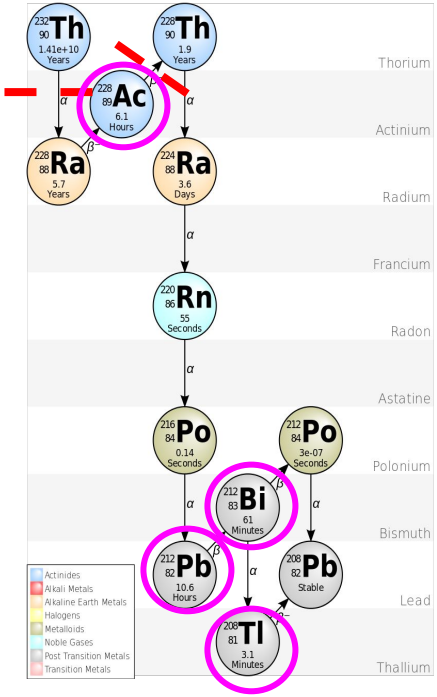
Kapton+Cu FC

Nuclides	Larger region of central peak			Smaller region of central peak		
	Activity (Bq/kg)	Uncert. (Bq/kg)	Limit (Bq/kg)	Activity (Bq/kg)	Uncert. (Bq/kg)	Limit (Bq/kg)
Th-234	-	-	-	-	-	-
Pa-234m	0.62	0.44	1.34	$4.42 \cdot 10-3$	0.29	0.48
Ra-226	$6.98 \cdot 10^{-3}$	$4.24 \cdot 10^{-3}$	$14.02 \cdot 10^{-3}$	$18.21 \cdot 10^{-3}$	$6.43 \cdot 10^{-3}$	-
Pb-214	$17.61 \cdot 10^{-3}$	$11.81 \cdot 10^{-3}$	$36.92 \cdot 10^{-3}$	$25.10 \cdot 10^{-3}$	$9.36 \cdot 10^{-3}$	-
Bi-214	$5.41 \cdot 10^{-3}$	$4.54 \cdot 10^{-3}$	$12.91 \cdot 10^{-3}$	$12.13 \cdot 10^{-3}$	$8.84 \cdot 10^{-3}$	$26.61 \cdot 10-3$
Ac-228	$5.05 \cdot 10^{-3}$	$13.82 \cdot 10^{-3}$	$27.83 \cdot 10^{-3}$	$10.12 \cdot 10^{-3}$	$5.86 \cdot 10^{-3}$	$19.74 \cdot 10-3$
Pb-212	-	-	-	-	-	-
Bi-212	-	-	-	-	-	-
Tl-208	$21.83 \cdot 10^{-3}$	$11.13 \cdot 10^{-3}$	$40.03 \cdot 10^{-3}$	$16.92 \cdot 10-3$	$8.61 \cdot 10^{-3}$	$31.20 \cdot 10-3$
U-235	$12.54 \cdot 10^{-3}$	$8.37 \cdot 10^{-3}$	$26.31 \cdot 10^{-3}$	$4.15 \cdot 10-3$	$6.93 \cdot 10^{-3}$	$15.62 \cdot 10-3$
K-40	-	-	-	$14.31 \cdot 10-3$	$52.71 \cdot 10^{-3}$	0.10
Cs-137	-	-	-	$0.30 \cdot 10-3$	$2.27 \cdot 10^{-3}$	$4.03 \cdot 10^{-3}$
Co-60	-	-	-	-	-	-

CL for limits not specified

Radioactive chains and equilibrium





- Secular equilibrium may be broken (in principle) in correspondence to isotopes with long half-life

- Gamma emitters measured with HPGe screening (up to 10-100 μBq/kg precision)

PET+Cu FC with glue

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	Bi-212	$57.03 \cdot 10^{-3}$	$33.94 \cdot 10^{-3}$	0.11	$9.25 \cdot 10^{-3}$	$22.53 \cdot 10^{-3}$	$46.31 \cdot 10^{-3}$
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	K-40	0.16	0.07	-	0.12	0.06	-
	Cs-137	$5.96 \cdot 10^{-3}$	$3.65 \cdot 10^{-3}$	$12.01 \cdot 10^{-3}$	$6.81 \cdot 10^{-3}$	$2.83 \cdot 10^{-3}$	-
	Co-60	-	-	-	-	-	-

Kapton+Cu FC

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Pb-212	-	-	-	-	-	-
Bi-212	-	-	-	-	-	-
Tl-208	$21.83 \cdot 10^{-3}$	$11.13 \cdot 10^{-3}$	$40.03 \cdot 10^{-3}$	$16.92 \cdot 10-3$	$8.61 \cdot 10^{-3}$	$31.20 \cdot 10-3$
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K-40	-	-	-	$14.31 \cdot 10-3$	$52.71 \cdot 10^{-3}$	0.10
Cs-137	-	-	-	$0.30 \cdot 10-3$	$2.27 \cdot 10^{-3}$	$4.03 \cdot 10^{-3}$
Co-60	-	-	-	-	-	-

Isotopes in the same square are in the same sub-chain (same activity)

Field cage radioactivity measurements

- We can use all the information making a weighted average with variance-defined weights

$$\bar{x} = \frac{\sum_{i=1}^{n} \left(\frac{x_i}{\sigma_i^2} \right)}{\sum_{i=1}^{n} \frac{1}{\sigma_i^2}}$$

- Use the activity **measurement** when the uncertainty (1 sigma) is small w.r.t. the central value
- Use the **limit** otherwise (k=1.645 corresponding to 95% CLfor one-sided gaussian)
  ➜ this is the same convention used in all the other measurements by M. Laubenstein

Field cage PET+Cu (glued)

Field cage PET_Cu (glued)	meas/lim (k=1.645)	activity [mBq/kg]	error (1 sigma)	comment
238U (upper chain)	L (<)	4.44E-01		from 234Th
238U (lower chain)	L (<)	1.13E-02		from Ra226 & Pb214
232Th (upper chain)	L (<)	2.45E-02		from Ac228
232Th (lower chain)	M	2.76E-02	7.05E-03	from Pb212 & Bi212 & Tl208
235U	L (<)	1.27E-02		
40K	M	1.60E-01	7.00E-02	
137Cs	M	5.96E-03	3.65E-03	

Background estimate form PET+Cu FC (see Melba's presentation)

Low energy range [1,20] keV

$(1.56 \pm 0.01) \times 10^5$

evt per year

Low energy range [1,20] keV NR

$(1.20 \pm 0.08) \times 10^3$

evt per year

[*] using activity central value (not limit)

Field cage kapton+Cu

Field cage kapton_Cu	meas/lim (k=1.645)	activity [mBq/kg]	error (1 sigma)	comment
238U (upper chain)	L (<)	7.24E-01		from 234mPa
238U (lower chain)	M	6.83E-03	3.99E-03	from Ra226 & Pb214 & Bi214
232Th (upper chain)	L (<)	2.27E-02		from Ac228
232Th (lower chain)	M	2.18E-02	1.11E-02	from Tl208
235U	L (<)	1.14E-02		smaller ROI
40K	L (<)	8.67E-02		smaller ROI
137Cs	L (<)	3.73E-03		smaller ROI

ratio activities kapton/Cu
1.63E+00
6.05E-01
9.27E-01
7.90E-01
9.01E-01
5.42E-01
6.27E-01

ICP-MS measurement can give more precise measurement for 40-K and the primordial nuclides 238-U and 232-Th (upper chains)

- If we agree I will update the CYGNO database