Summary of CYGNO background simulations

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CYGNO Analysis & Simulation meeting

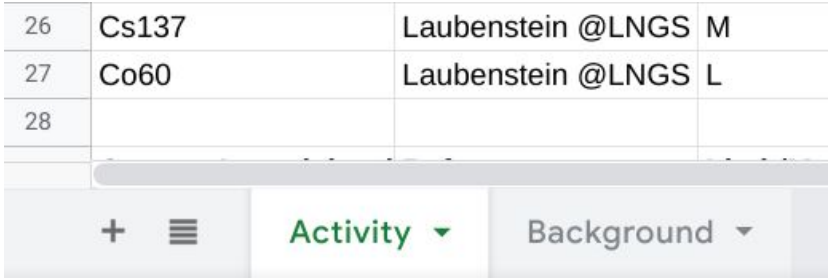
Overview of background simulation status

- Status of CYGNO background calculation before summer
  - **external gamma/neutrons** for shielding 200+5 cm (water+Cu) shielding
  - **internal backgrounds**: acrylic box, cameras+lenses, GEM
  - **missing some internal contributions:** field cage, cathode
- Work done during August:
  - **complete internal backgrounds**: field cage, cathode
  - possible alternatives with more **radiopure materials**:
    - radiopure acrylic for the box
    - camera lenses in fused silica
    - GEM from T-REX:https://link.springer.com/content/pdf/10.1140/epjc/s10052-019-7282-6.pdf
    - “Loomba cathode”: https://arxiv.org/pdf/1502.03535.pdf
    - “Kentaro field cage”: https://arxiv.org/pdf/1903.01663.pdf
  - estimate the **internal and external backgrounds for “CHINOTTO”** (CYGNO 2x2) with 100+10 cm (water + Cu) shielding

Background spreadsheet up-to-date

- Summary spreadsheet
  https://docs.google.com/spreadsheets/d/1SKkd1C-zJoFzb0ZRkG0D9_vNOr5A9S34slWkOKHQqxg/edit?usp=sharing

- "**Activity**" and "**Background**" tabs
  - **radioactivity** of materials
  - include also **alternative materials** (more radiopure)
  - **background** calculated with GEANT4 for the "default" geometry and materials
  - background for alternative materials rescaling activities
  - Estimated **background for CHINOTTO**
    - smaller active volume
    - less radioactive material



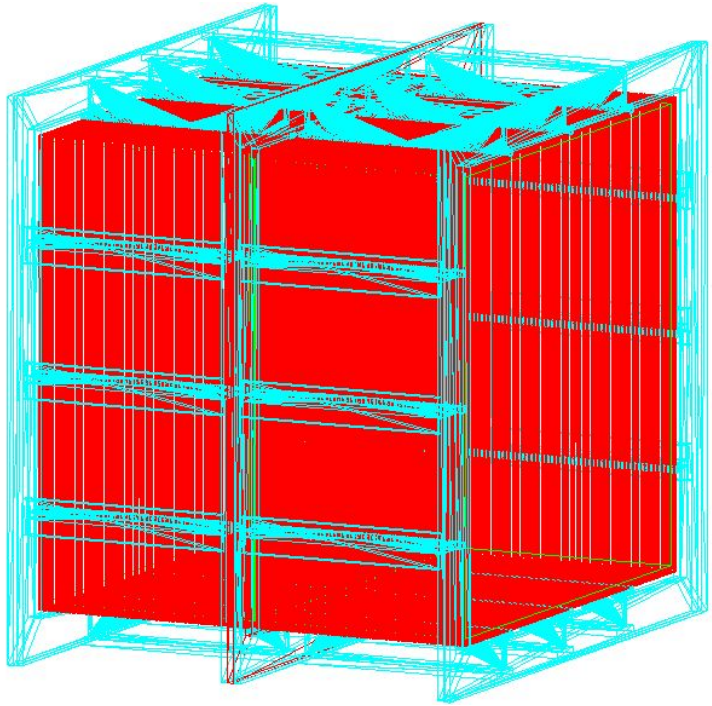
Field cage (copper)

- Assume copper radioactivity from T-REX measurements
- Total mass of the field cage ~42.5 kg

Copper Field Cage	Limit/Meas	Activity (Bq/kg)
238U	L	1.20E-05
232Th	L	4.10E-06
40K	M	6.10E-05
60Co	L	2.40E-04
137Cs	L	2.90E-04

Field cage (copper)	NR/yr 1-20 keV	ER/yr 1-20 keV
238U	1.19E+00	2.18E+02
232Th	3.25E-01	5.28E+01
40K	0.00E+00	1.91E+02
60Co	0.00E+00	8.22E+02
137Cs	0.00E+00	7.20E+02
Field cage tot	**1.51E+00**	**2.00E+03**
Field cage only meas.	**0.00E+00**	**1.91E+02**

field cage (“bandelle”)



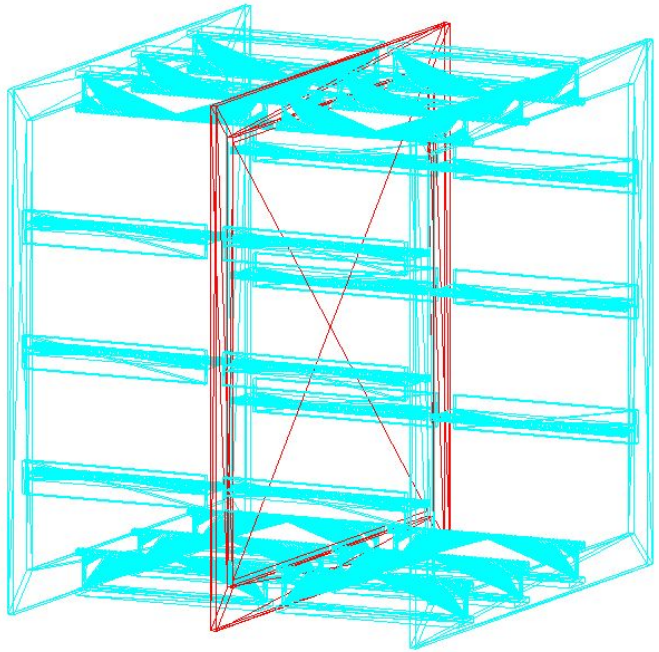
Cathode (copper)

- Assume copper radioactivity from T-REX measurements
- Total mass of the cathode ~1 kg

Copper cathode	Limit/Meas	Activity (Bq/kg)
238U	L	1.20E-05
232Th	L	4.10E-06
40K	M	6.10E-05
60Co	L	2.40E-04
137Cs	L	2.90E-04

Cathode (copper)	NR/yr 1-20 keV	ER/yr 1-20
238U	6.41E-01	5.70E+01
232Th	2.17E-01	1.26E+01
40K	0.00E+00	6.37E+01
60Co	0.00E+00	7.43E+01
137Cs	0.00E+00	1.56E+02
Field cage tot	**8.58E-01**	**3.63E+02**
Field cage only meas.	**0.00E+00**	**6.37E+01**

cathode with frame



Field cage (“Kentaro”)

- Assume activity from https://arxiv.org/pdf/1903.01663.pdf
- Completely different geometry, resistive sheet of plastic material of 0.2 mm thickness
- Assuming ~4 m^2 surface and density 1.18 g/cm^3 ➔ estimated mass ~0.9 kg
- Background estimated from copper field cage
  - recale for different active mass
  - rescale for different activities

Kentaro Field Cage	Limit/Meas	Activity (Bq/kg)
238U	L	1.84E-02
232Th	L	7.77E-03
40K	L	1.12E-01
60Co	L	2.54E-03

Field Cage (Kentaro)	NR/yr 1-20 keV	ER/yr 1-20 keV
238U	3.86E+01	7.09E+03
232Th	1.29E+01	2.10E+03
40K	0.00E+00	7.44E+03
60Co	0.00E+00	1.84E+02
137Cs	0.00E+00	0.00E+00
Field cage tot	**5.15E+01**	**1.68E+04**
Field cage only meas.	**0.00E+00**	**0.00E+00**

Cathode (“Loomba”)

- Assume activity from https://arxiv.org/pdf/1502.03535.pdf
- Completely different geometry, aluminized mylar of 0.9 µm thickness
- Assuming ~1 m^2 surface and density 1.38 g/cm^3 ➔ estimated mass ~1.25 g
- Background estimated from copper cathode
  - recale for different active mass
  - rescale for different activities
- Caveat: considered ^{238}U chain in equilibrium with ^{234}U, and assumed 0 other contributions ➔ underestimated, but cathode is not the dominant background at the moment

Loomba Cathode	Limit/Meas	Activity (Bq/kg)
238U	M	9.01E-01
234U	M	4.07E-05

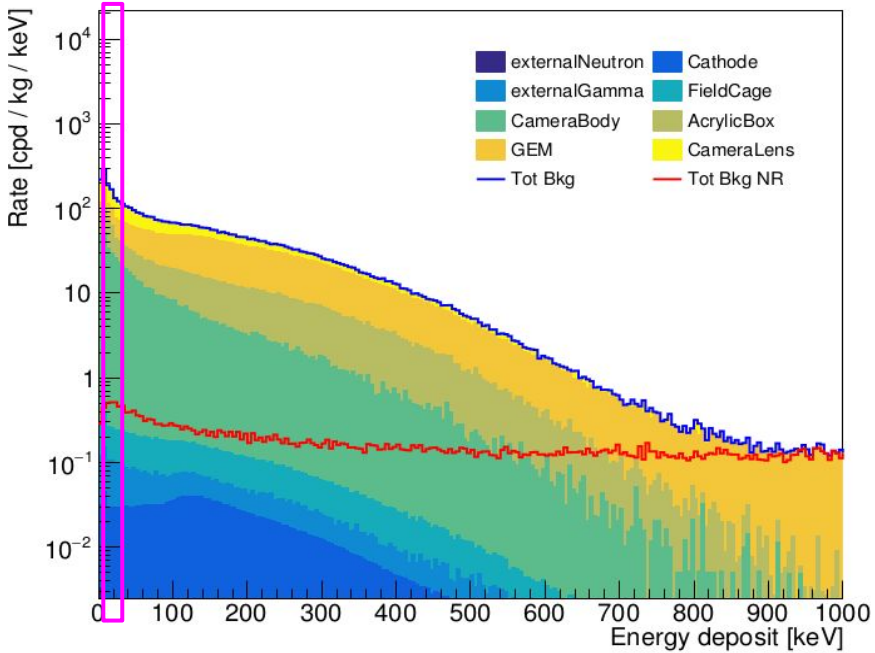
Cathode (Loomba)	NR/yr 1-20 keV	ER/yr 1-20 keV
238U	2.76E-03	2.46E-01
232Th	0.00E+00	0.00E+00
40K	0.00E+00	0.00E+00
60Co	0.00E+00	0.00E+00
137Cs	0.00E+00	0.00E+00
Cathode tot	**2.76E-03**	**2.46E-01**
Cathode only meas.	**2.76E-03**	**2.46E-01**

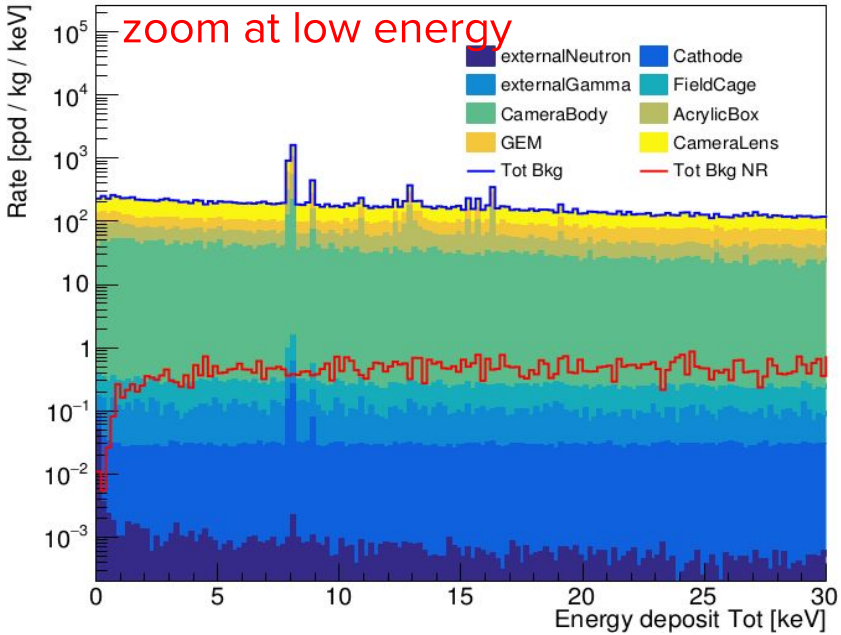
Total background

	CYGNO		CHINOTTO		
Summary Table	**NR/yr 1-20 keV**	**ER/yr 1-20 keV**	**NR/yr 1-20 keV**	**ER/yr 1-20 keV**	**Reference**
GEM (LNGS)	5.07E+03	5.09E+05	1.00E+03	1.01E+05	Laubenstein@LNGS
GEM (TREX)	4.27E+03	3.61E+05	8.44E+02	7.14E+04	T-REX GEM
AcrylicBox (LNGS)		4.34E+05		1.12E+05	Laubenstein@LNGS
AcrylicBox (SNO)		1.43E+04		3.68E+03	SNO acrylic
CameraBody (no shield)		3.20E+06		6.32E+05	Laubenstein@LNGS
CameraBody (with Cu shield)		4.46E+05		8.81E+04	Laubenstein@LNGS
CameraLens (LNGS)		9.83E+05		1.94E+05	Laubenstein@LNGS
CameraLens fused silica		6.68E+01		1.32E+01	Haereus "Suprasil"
Cathode (Cu)	8.58E-01	3.63E+02	1.69E-01	7.18E+01	T-REX copper
Cathode (Loomba)	2.76E-03	2.46E-01	5.46E-04	4.86E-02	Loomba
Field Cage (Cu)	1.51E+00	2.00E+03	2.99E-01	3.96E+02	T-REX copper
Field Cage (Kentaro)	5.15E+01	1.68E+04	1.02E+01	3.32E+03	Kentaro
External Gamma	0.00E+00	9.75E+02	0.00E+00	6.85E+03	SABRE gamma flux @LNGS
External Neutrons	4.34E+00	4.68E+00	7.50E+00	3.41E+00	CUORE n flux @LNGS
Total (LNGS)	**5.08E+03**	**2.38E+06**	**1.01E+03**	**5.02E+05**	
Total (low rad)	**4.28E+03**	**8.24E+05**	**8.52E+02**	**1.70E+05**	

CYGNO background spectrum

- Higher contribution at low energy from **camera lenses, GEMs** and **camera body** (even if shielded with 5 cm copper) and **acrylic box**
- With fused silica lenses this contribution becomes negligible
- Acrylic box contribution can be reduced of a factor ~30 using SNO acrylic

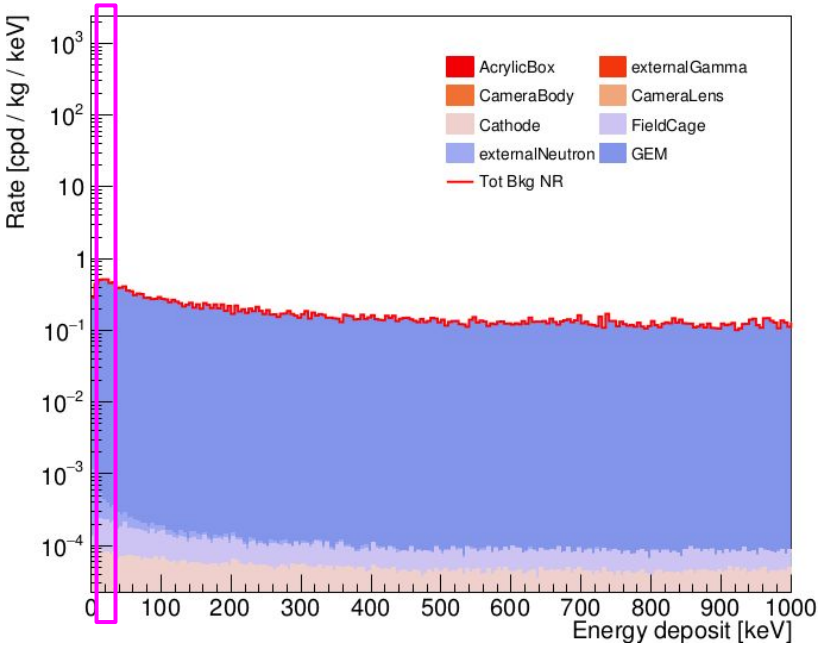


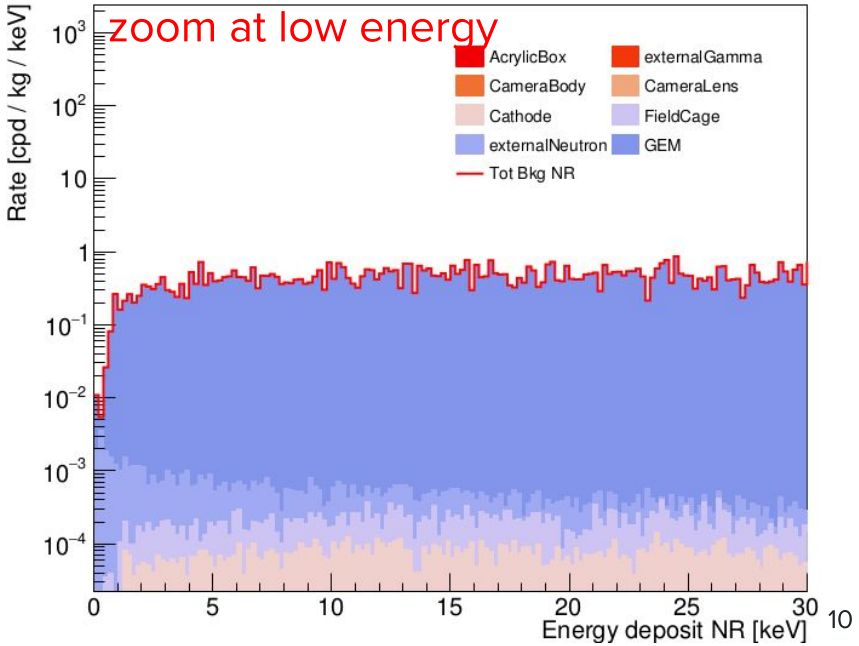


Nuclear recoil background

Caveat: Acrylic box NR not calculated yet

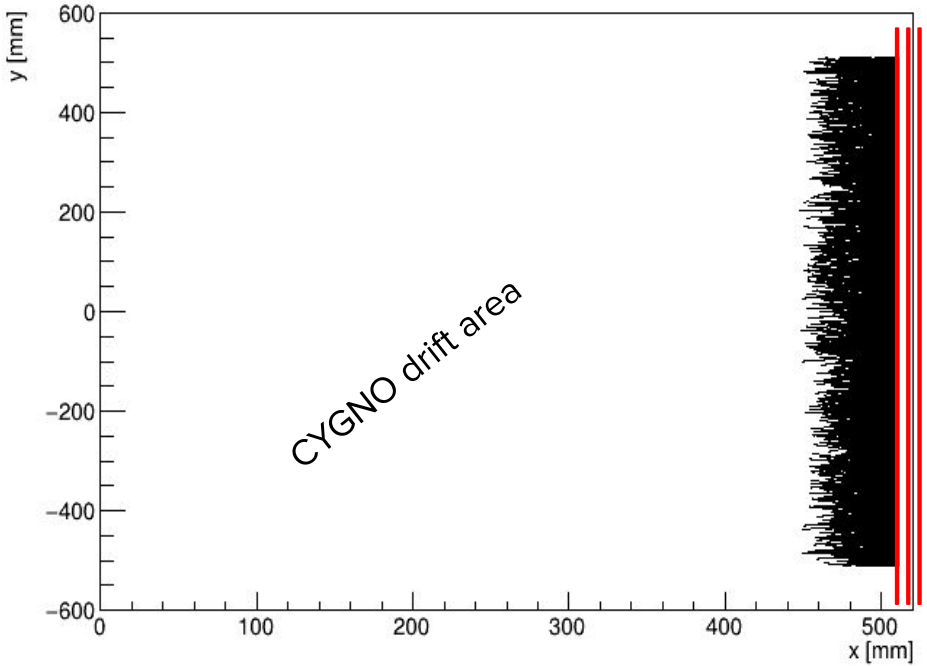
- Higher contribution from GEMs
- Can be reduced with fiducialization





Fiducialization

- GEM energy deposits from nuclei in one of the CYGNO drift regions (checked ➜ they are all alphas)
- GEANT4 saves the info if the alpha is primary (from alpha radioactivity) or secondary (ex. He nuclei in the gas)
- Secondary alpha are ~16% of the total and with same distribution of primary
- All contained in the first ~5 cm of gas **➜ expect to reject almost all NR with fiducialization**

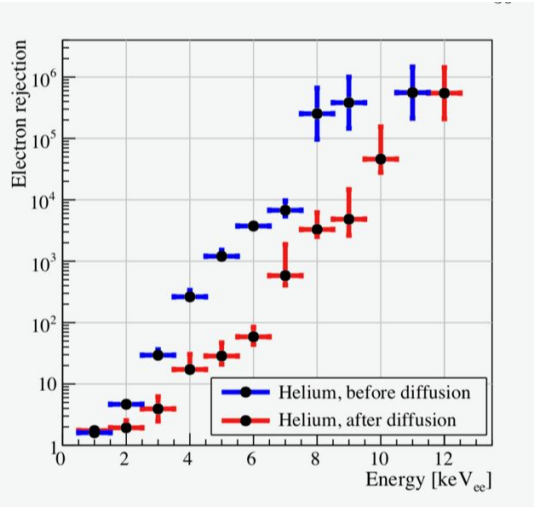


Quick qualitative study, more detailed study needed, but looks promising...

Input for sensitivity study

- Background spectrum ➜ see slide 9
- Electron background rejection ➜ for the moment use DRIFT simulation results
- Quenching factor ➜ from SRIM (could be underestimated, to be recalculated)

Background (ER) rejection from DRIFT simulation



E[keV]	RF
1.	1.5
2.	1.887
3.	3.8683
4.	16.5584
5.	27.5655
6.	58.3324
7.	556.0255
8.	3175.0723
9.	4576.1294
10.	47253.1115

Caveat: extracted with DataThief

- Apply to flat background in the 1-20 keV region
- Assume factor 2 better rejection then DRIFT
- Total rejection for E>10 keV

	ER [1-20 keV]/10^5	Not rejected events/year
CYGNO	8.2	16400
CHINOTTO	1.7	3400

Conclusions and to-do

- Background simulations for CYGNO are almost done
  - important for a realistic sensitivity calculation
  - focus on reducing internal backgrounds
    ➔ especially cameras and GEMs (not optimized for low-radioactivity techniques)

- To do list:
  - cross-check QF calculation with SRIM and possibly also other simulation software (GEANT4,...?)
  - study the electron rejection in our simulation:
    ➔ improve digitization (Fabrizio)
    ➔ apply digitization to MC simulations
    ➔ apply reconstruction to digitized MC, optimize the analysis on MC
    ➔ study efficiency/rejection power of the analysis