

177-Lu-Kvantitering med xSPECT

Johan Blakkisrud

May 22, 2019

Avd. for Diagnostisk Fysikk, Oslo Universitetssykehus

Innhold

Introduksjon

xSPECT - hva er det?

Fantomskan - hva har vi gjort?

Fantomskan - hva har vi lært?

Siemens gjør dosimetri

Introduksjon

Hvem er jeg?

- Stipendiat ved Oslo Universitetssykehus (på tredje året)
- Fysiker (egentlig siv. ing.)
- Aldri brukt xSPECT
- Prosjektet jeg jobber i bruker SPECT/CT-bilder av den kvantitative formen

Hvem er jeg?

- Stipendiat ved Oslo Universitetssykehus (på **ca** tredje året)
- Fysiker (egentlig siv. ing.)
- ~~Aldri brukt xSPECT~~ **Bruk xSPECT siden november**
- Prosjektet jeg jobber i bruker SPECT/CT-bilder av den kvantitative formen

Kvantitering

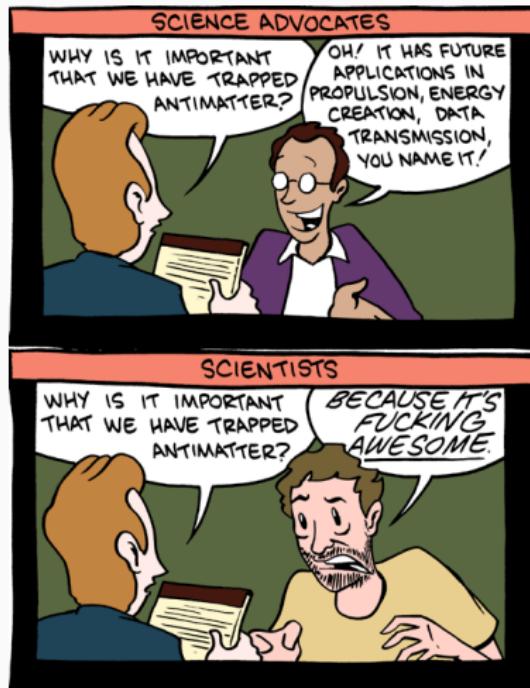
Kvantitering (verb) - måle, telle. Tilordne til en kvantitet

Kvantitering i forbindel med SPECT/CT

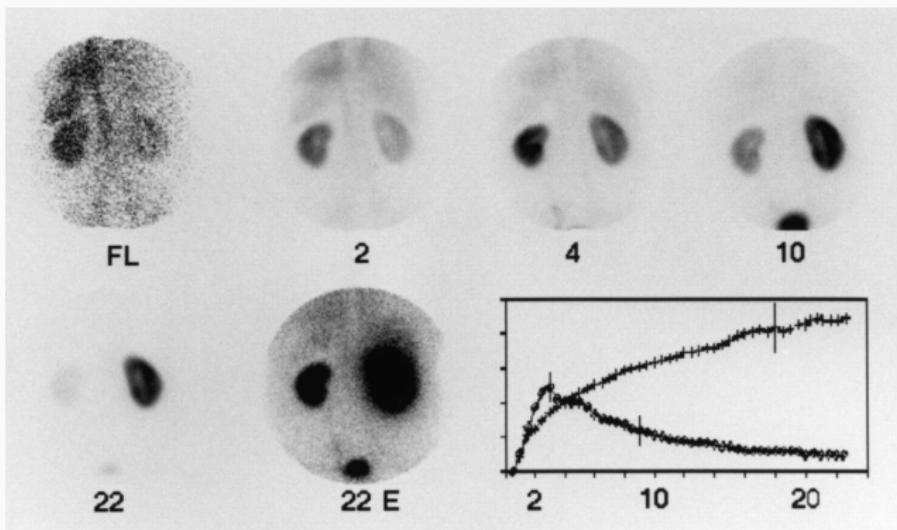
Ønsker bilder med enhet Bq/ml eller lignende

Kvantitering

Hvorfor ønsker vi å kvantitere stråling i pasienten?



Relative verdier helt ok?



Kvantitering åpner opp!

Terapiplanlegning Dosering av radionuklideterapi

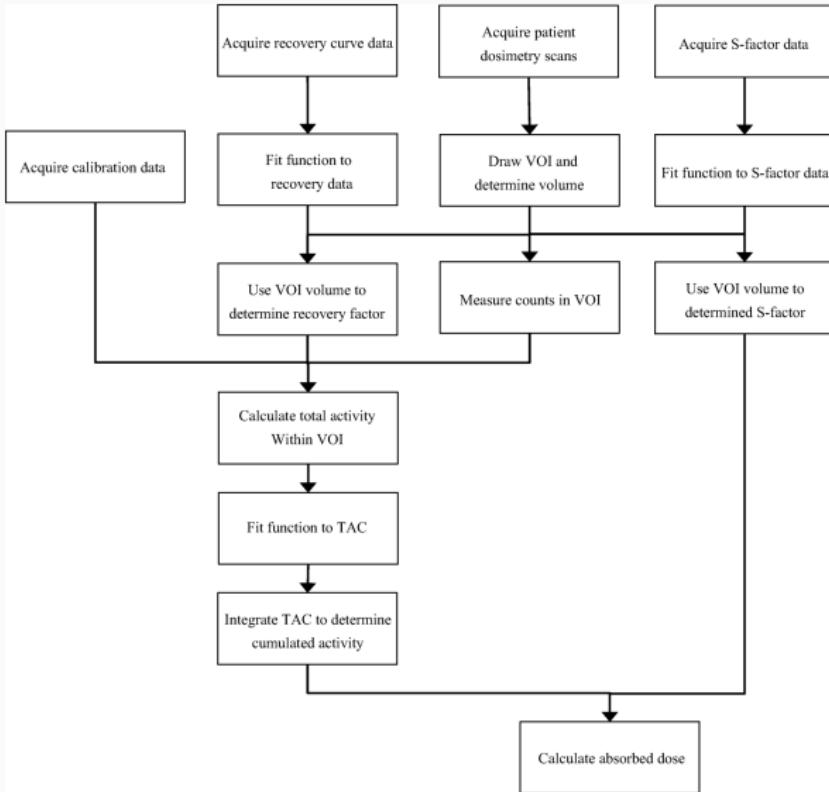
Myocard-perfusjonsavbildning ^{99m}Tc for å måle
blodgjennomstrømning i ml/g-min eller SUV-SPECT

Lungescan Pre-operativ funksjon både ventilasjon og perfusjon

^{131}I Opptak post-terapi for å monitørere effekt

Biodistribusjon Utprøving av nye radiofarmaka

Dosimetri



Mange ledd, mye feil

European Journal of Nuclear Medicine and Molecular Imaging (2018) 45:2456–2474
https://doi.org/10.1007/s00259-018-4136-7

GUARANTEES

EANM practical guidance on uncertainty analysis for molecular radiotherapy absorbed dose calculations

Jonathan I. Geat¹ · Maurice G. Cox² · Johan Gustafsson³ · Katarina Spjørgreen Gleisner³ · Iain Murray⁴ · Gerhard Glärtig⁵ · Mark Konijnenberg³ · Glenn D. Flux¹

Received: 9 August 2018 / Accepted: 14 August 2018 / Published online: 14 September 2018
© The Author(s) 2018

The law of propagation of uncertainty

A generic multivariate measurement model is:

$$Y = f(X), \quad (1)$$

where

$$X = [X_1, \dots, X_n]^T \quad (2)$$

is a vector of n generic input quantities X_1, \dots, X_n and

$$Y = [Y_1, \dots, Y_m]^T \quad (3)$$

is a vector measured of output quantities Y_1, \dots, Y_m . GUM Supplement 2 [15] gives a generalization of the LPU:

$$V_X = \begin{bmatrix} u^2(x_1) & \dots & u(x_1, x_n) \\ \vdots & \ddots & \vdots \\ u(x_n, x_1) & \dots & u^2(x_n) \end{bmatrix} \quad (5)$$

associated with

$$x = [x_1, \dots, x_n]^T, \quad (6)$$

the estimate of X , and G_x is the sensitivity matrix associated with x , defined as:

$$G_x = \begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \dots & \frac{\partial f_1}{\partial x_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_m}{\partial x_1} & \dots & \frac{\partial f_m}{\partial x_n} \end{bmatrix}, \quad (7)$$



$$G(\rho) = \frac{1}{[\sigma\sqrt{2\pi}]^3} e^{-\frac{\rho^2}{2\sigma^2}}, \quad (23)$$

where σ is the measured standard deviation describing the width of the 3D Gaussian function. Therefore, an observed count rate density distribution can be described as:

$$F(\rho) = H(\rho)^* G(\rho), \quad (24)$$

in three dimensions, which can be [17] and re-expressed as:

$$f\left(\frac{r+\rho}{\sigma\sqrt{2}}\right) - \frac{2\sigma}{\rho\sqrt{2\pi}} e^{-\frac{(r+\rho)^2}{2\rho^2}} \left[e^{\left(\frac{r+\rho}{\rho}\right)} - e^{\left(\frac{r-\rho}{\rho}\right)} \right] \quad (25)$$

$$J_p = \begin{bmatrix} \frac{\partial A_1}{\partial A_0} & \frac{\partial A_1}{\partial \lambda} \\ \vdots & \vdots \\ \frac{\partial A_n}{\partial A_0} & \frac{\partial A_n}{\partial \lambda} \end{bmatrix} = \begin{bmatrix} e^{-\lambda t_1} & -A_0 t_1 e^{-\lambda t_1} \\ \vdots & \vdots \\ e^{-\lambda t_n} & -A_0 t_n e^{-\lambda t_n} \end{bmatrix} \quad (55)$$

and

$$V_p = \begin{bmatrix} u^2(A_0) & u(A_0, \lambda) \\ u(A_0, \lambda) & u^2(\lambda) \end{bmatrix}, \quad \begin{bmatrix} u(A_i) \end{bmatrix}^2 = \begin{bmatrix} u(Q) \end{bmatrix}^2 + \begin{bmatrix} u(R) \end{bmatrix}^2$$

$$+ \begin{bmatrix} u(C_i) \end{bmatrix}^2 - 2 \frac{u(R, C_i)}{RC_i}, \quad (43)$$

$$\frac{u(A_i, A_j)}{A_i A_j} = \begin{bmatrix} u(Q) \end{bmatrix}^2 + \begin{bmatrix} u(R) \end{bmatrix}^2 + \frac{u(C_i, C_j)}{C_i C_j} - \frac{u(R, C_i)}{RC_i} - \frac{u(R, C_j)}{RC_j} \quad (I \neq j). \quad (44)$$

Mange ledd, mye feil - akkurat som hviskeleken

Nok en runde hviskeleken ødelagt av en overivrig Hans Wilhelm.



© Sverre Bjørstad Graff

Mange ledd, mye feil - akkurat som hviskeleken

Bildene er førstemann/kvinne som hvisker(!)

Oppsummering - hvor avsluttet jeg ifjor?

SPECT er minst like kvantitativ som PET

Tommelfingerregel Omkring 10 %

Om du vet hva du gjør og har et godt utgangspunkt

Muligens 5 %

Om du ikke vet hva du gjør Mer enn 50 % (minst)

Alltid Verifiser

xSPECT - hva er det?

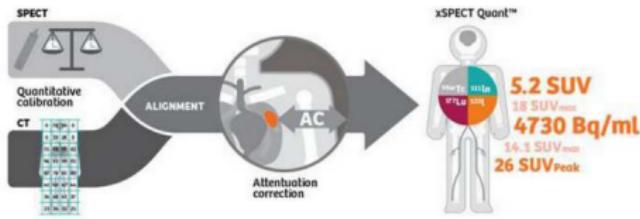
Hva er xSPECT?

- Standardisert kvantitering fra Siemens
- Bilder direkte i Bq/ml



xSPECT

Figure 5c: Symbia Intevo with xSPECT Quant is the only nuclear medicine system capable of delivering absolute quantification that is both accurate and reproducible.



Endelig har jeg fått prøve det(!)

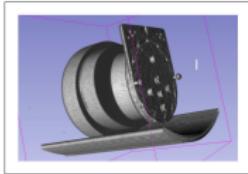
Fantomskan - hva har vi gjort?

En liten advarsel

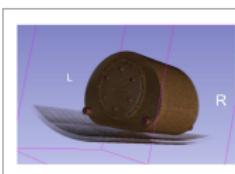
Dette kommer til å bli usedvanlig nerdete

Fantomer - masse fantomer

CC w wings



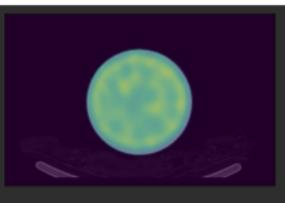
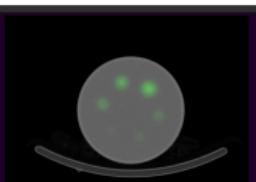
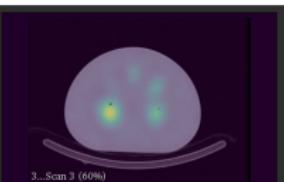
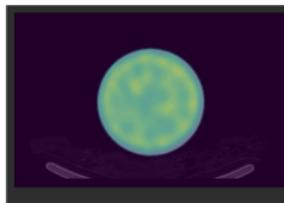
NEMA



Esser



CC



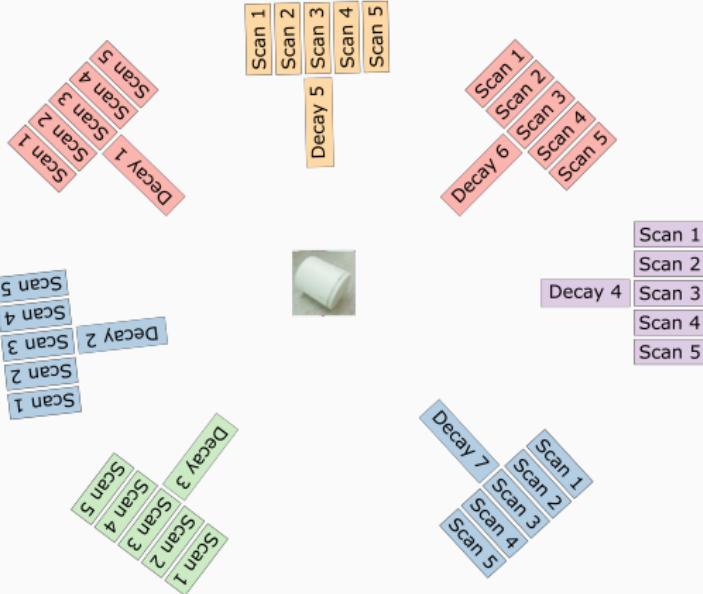
Fantomer - Cross Calibration



Fantomer - Cross Calibration



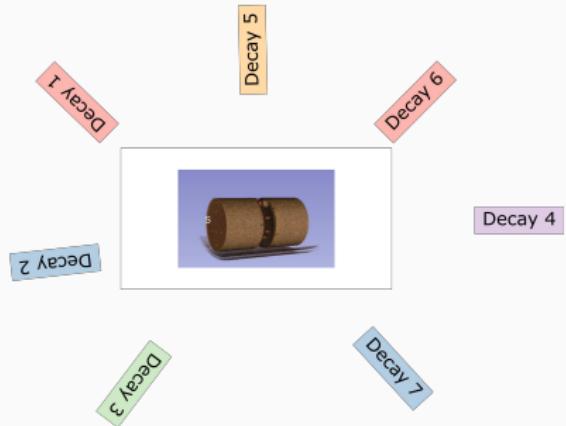
Fantomer - Cross Calibration



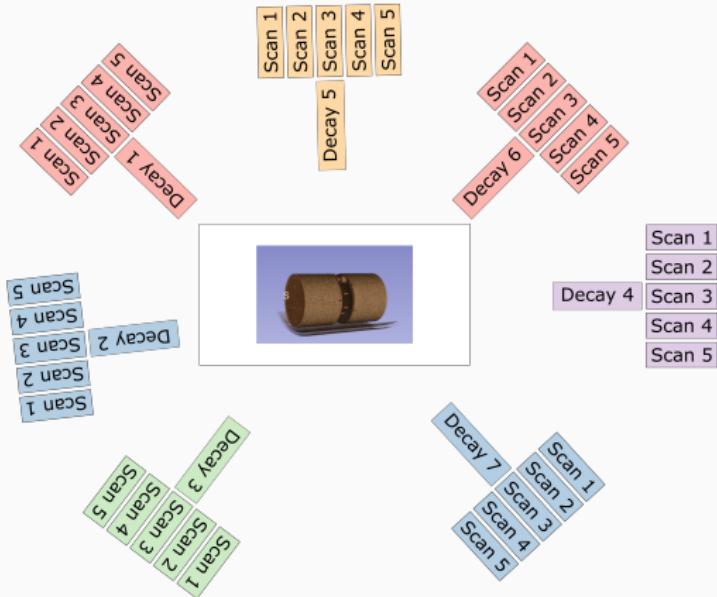
Fantomer - Esser



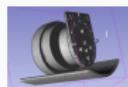
Fantomer - Esser



Fantomer - Esser



Fantomer - Cross Calibration with padding



Fantomer - Cross Calibration with padding



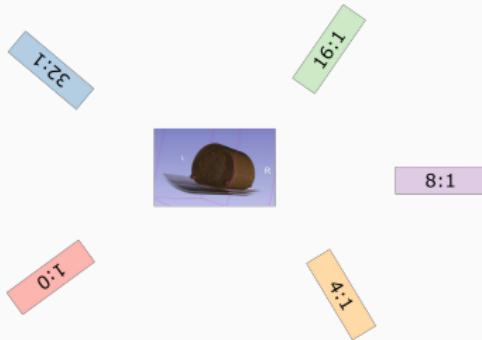
Fantomer - Cross Calibration with padding



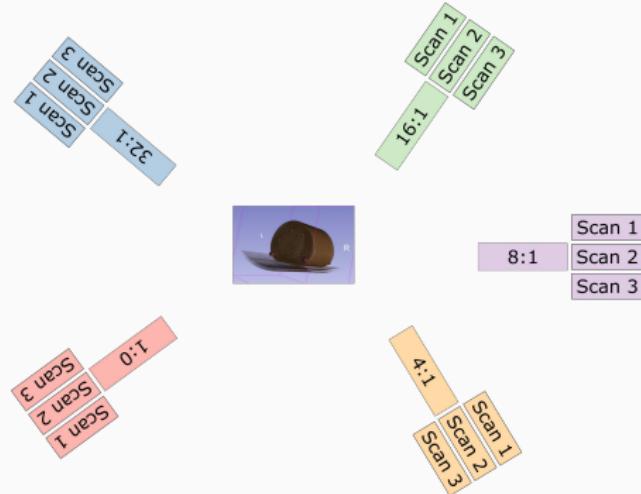
Fantomer - NEMA



Fantomer - NEMA



Fantomer - NEMA



Fantomer - Totalt antall scan

Scan 1				
Scan 2				
Scan 3				
Scan 4				
Scan 5				

Scan 1
Scan 2
Scan 3

90 Scans

Fantomer - m/ åtte rekonstruksjoner

720 sett med data(!)

Fantomskan - hva har vi lært?

Resultater

Strålende, da kan vi finne ut av alt vi lurer på, og jeg kan gi svaret på hva det beste er i alle situasjoner. Hurra!

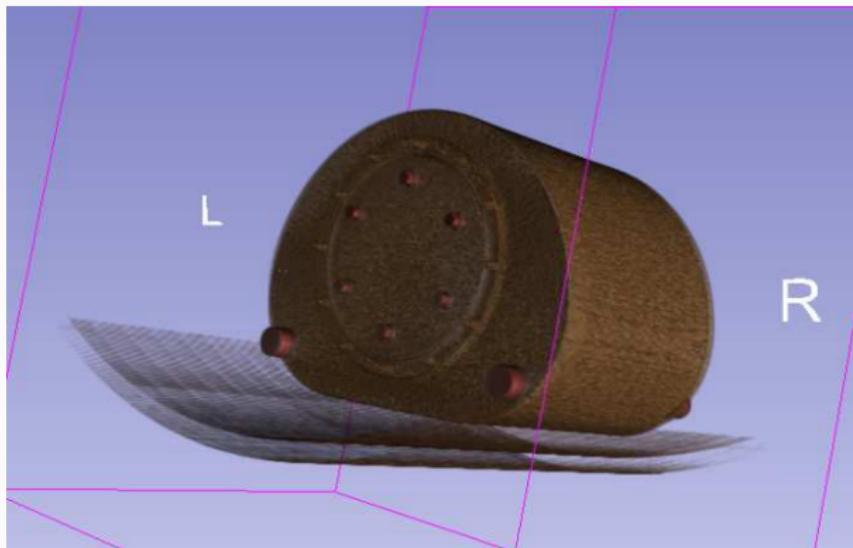
Resultater

Jeg er lei for det, jeg kan ikke det...

Resultater

Men jeg har funnet ut noe!

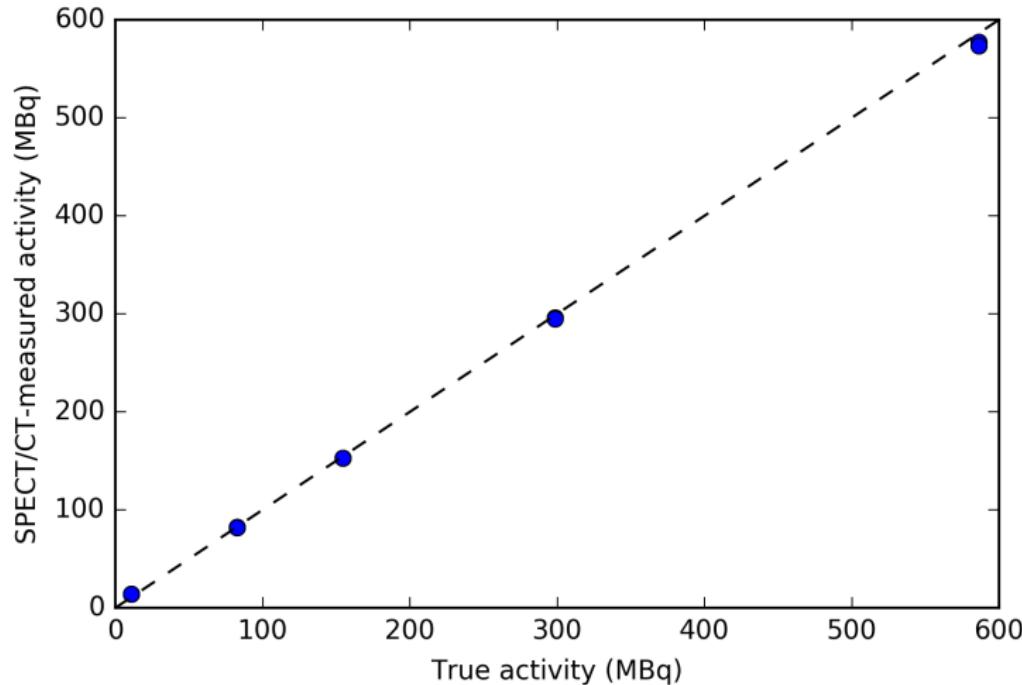
NEMA - et kinderegg(!)



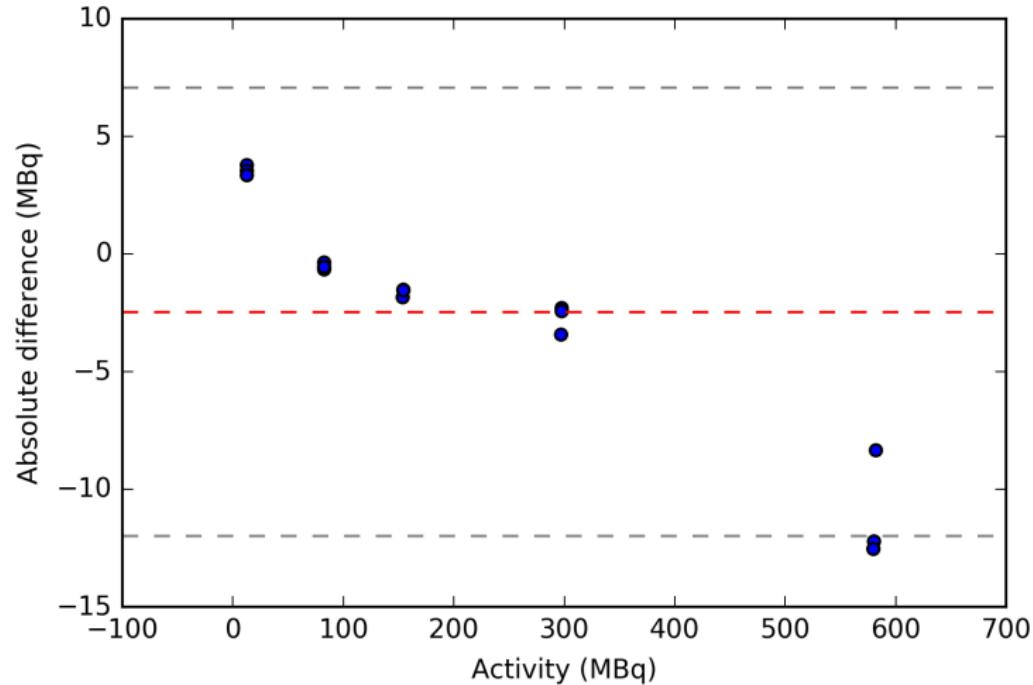
NEMA - et kinderegg(!)

- Vi har gjort 5 ulike bakgrunner: Fem ulike aktivitetsnivå.
- Vi har kulene (åpenbart).
- Og vi har et ganske stort bakgrunnsområde vi kan måle i.

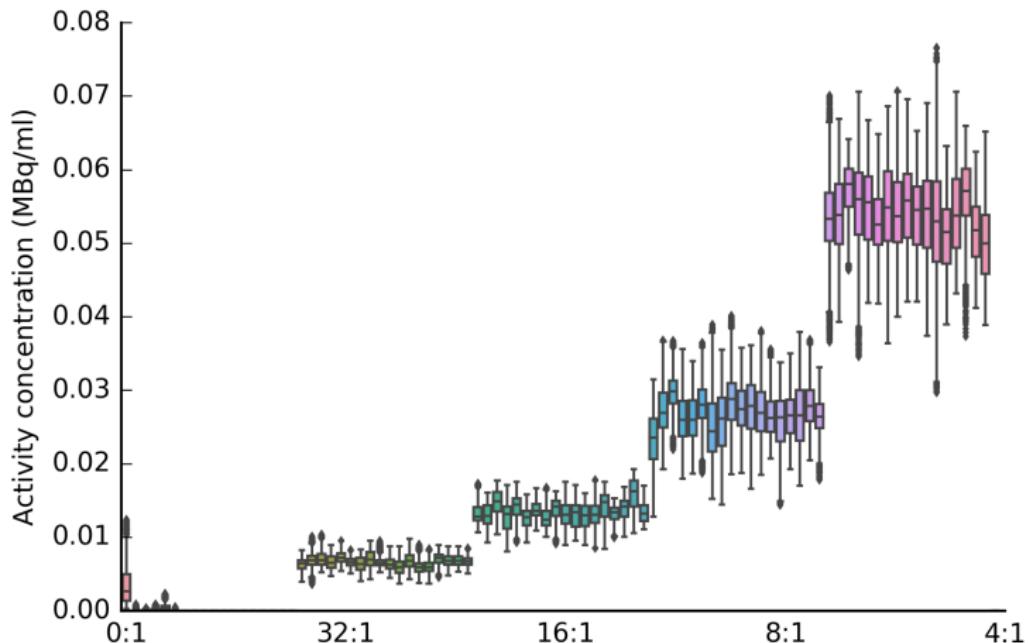
NEMA - Total aktivitet



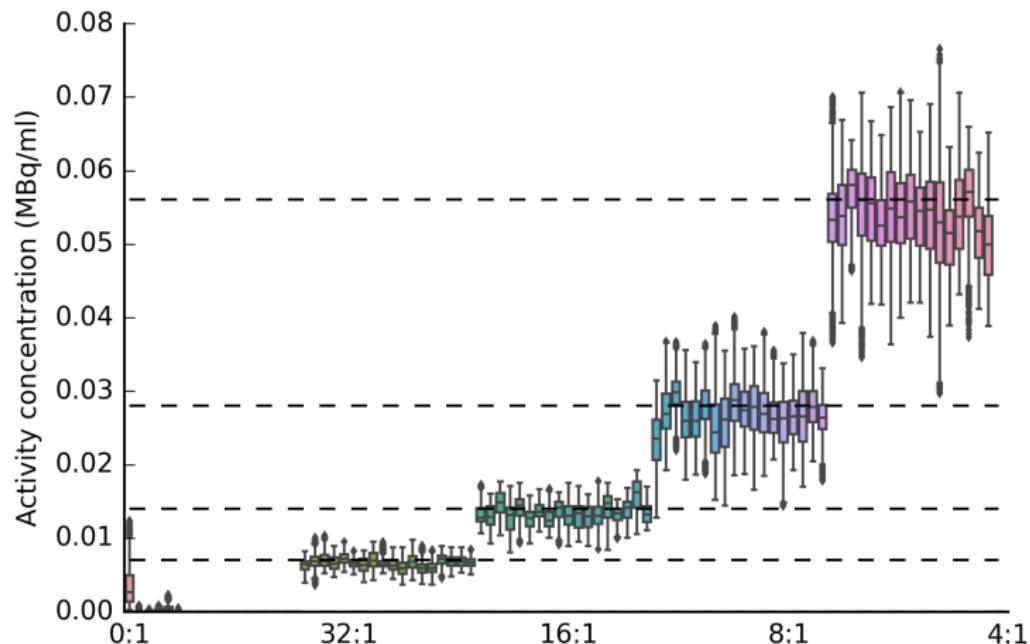
NEMA - Total aktivitet



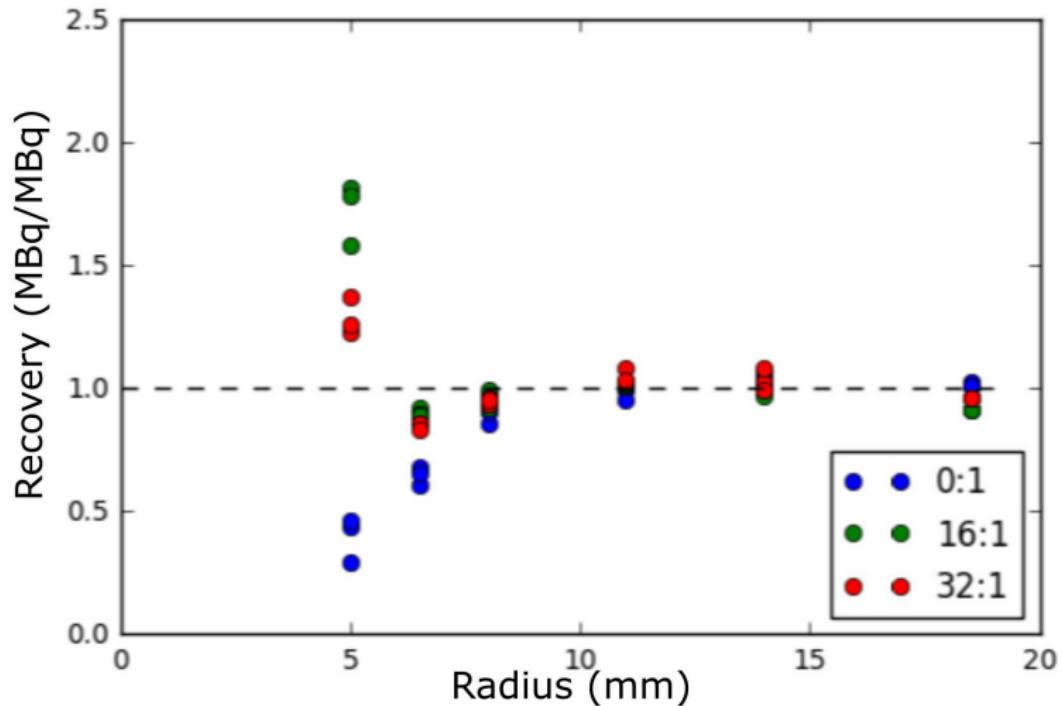
NEMA - Bakgrunn



NEMA - Bakgrunn



NEMA - Spheres



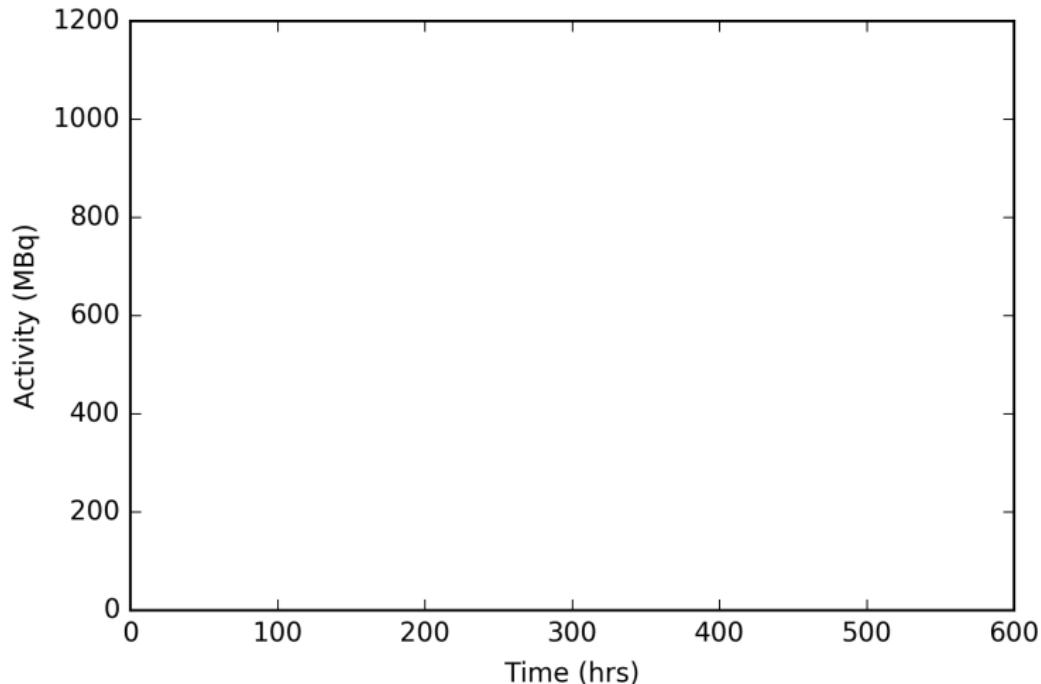
Esser - Kuler, store og små



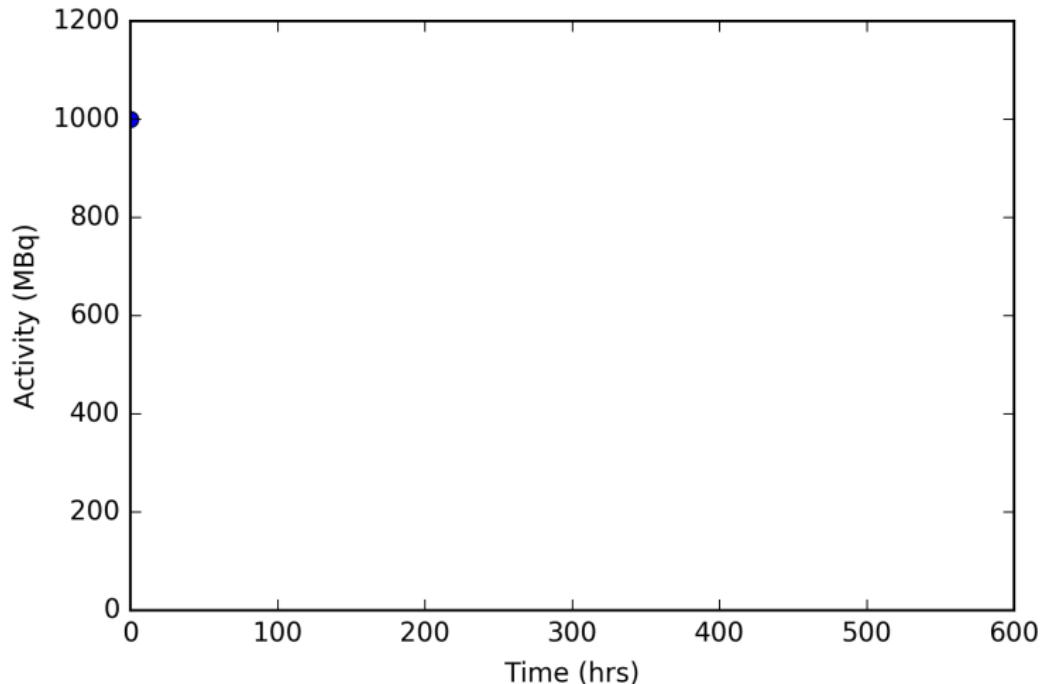
Esser - Total aktivitet - en quiz(!)

La oss bli litt interaktive, jeg vil at dere skal svare meg på noe (ta det med ro, det vil bli alternativer)

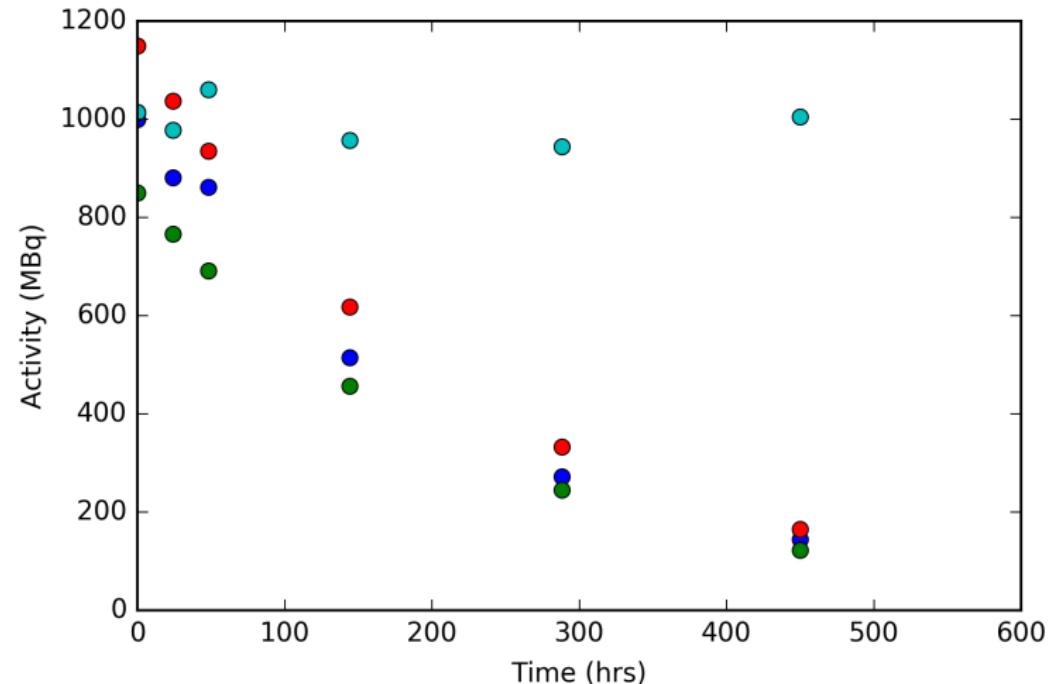
Esser - Total aktivitet - en quiz(!)



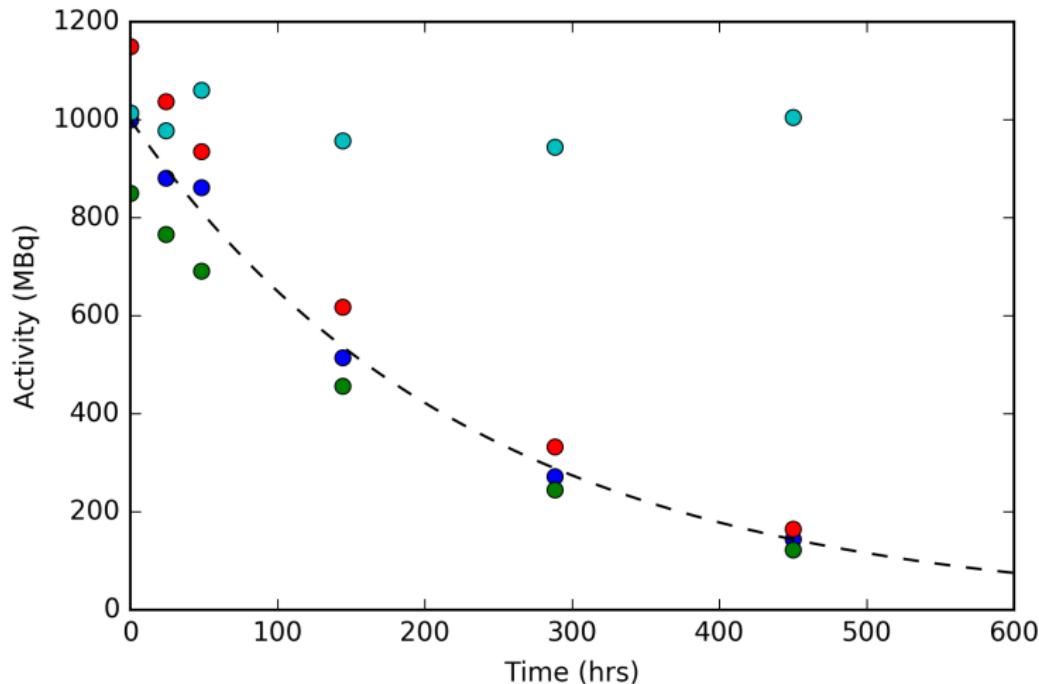
Esser - Total aktivitet - en quiz(!)



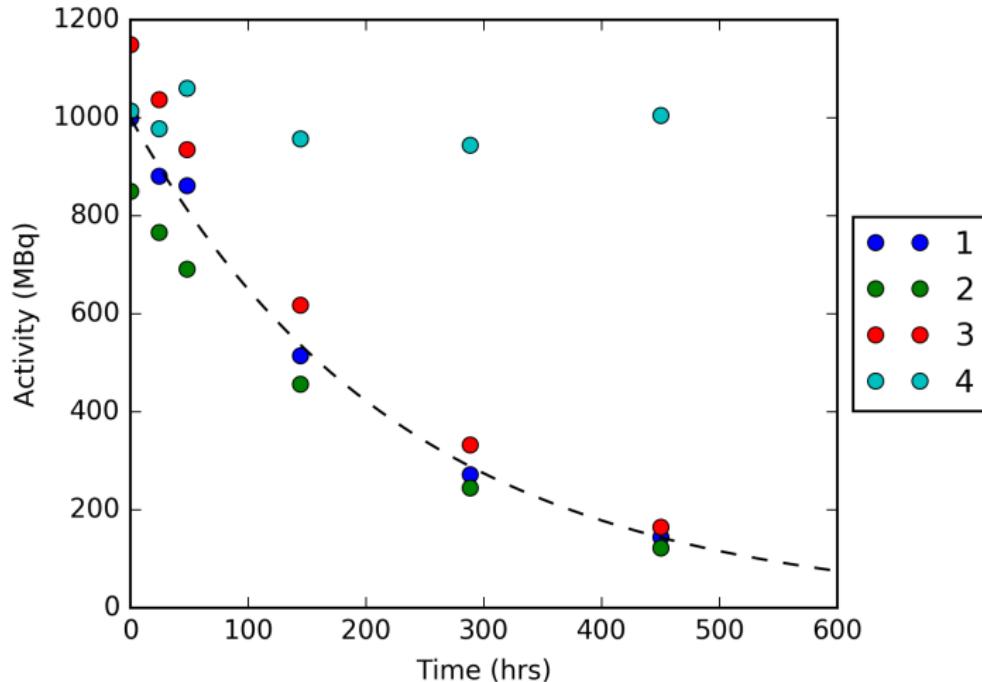
Esser - Total aktivitet - en quiz(!)



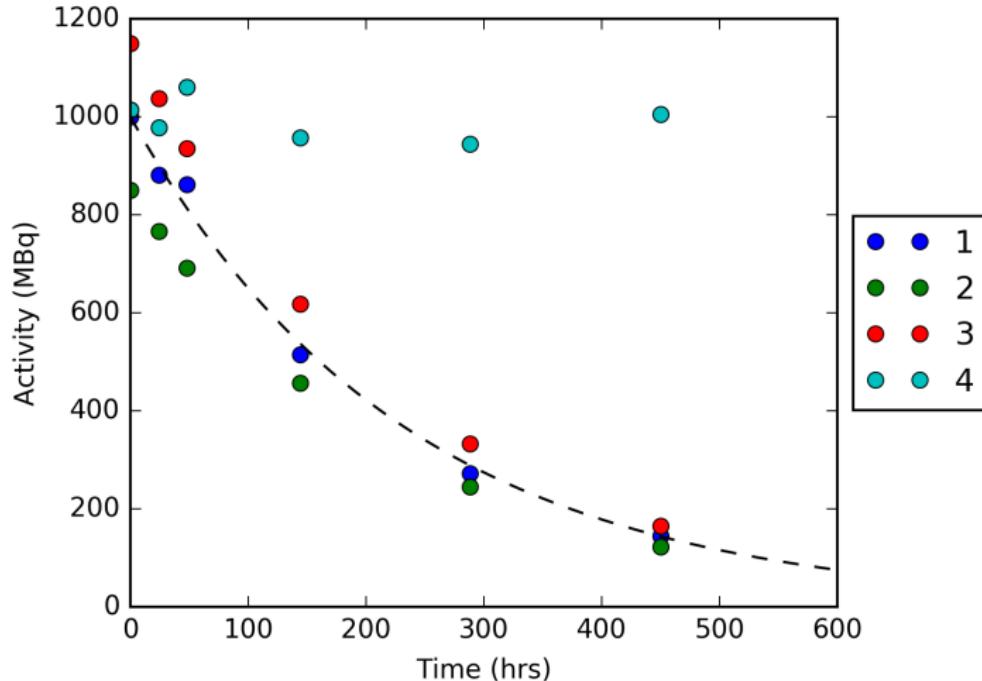
Esser - Total aktivitet - en quiz(!)



Esser - Total aktivitet - en quiz(!)



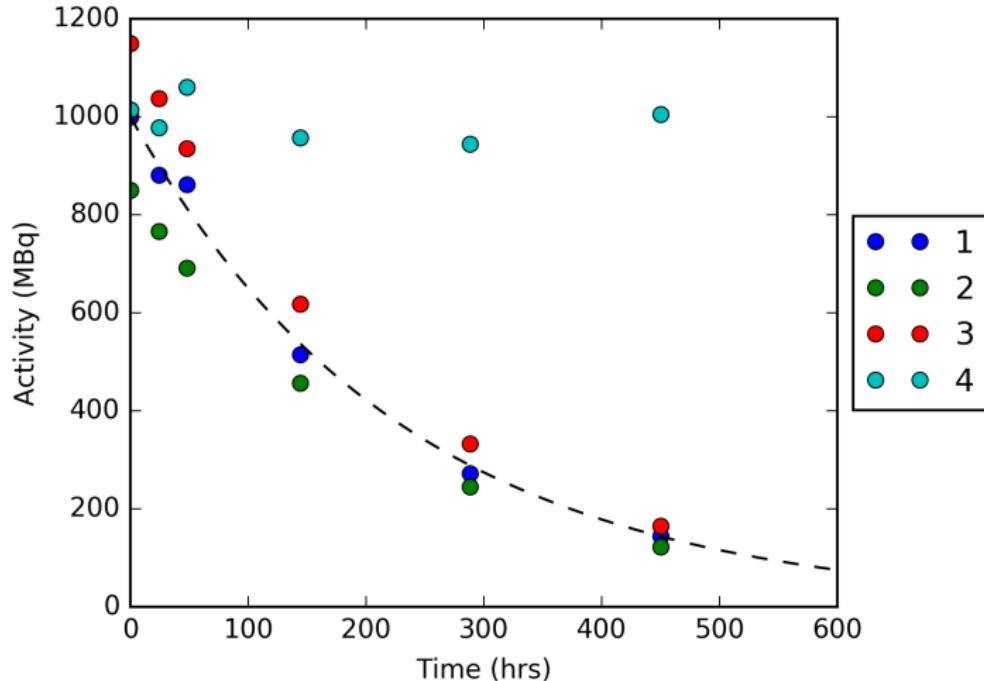
Riktig svar...



Riktig svar...

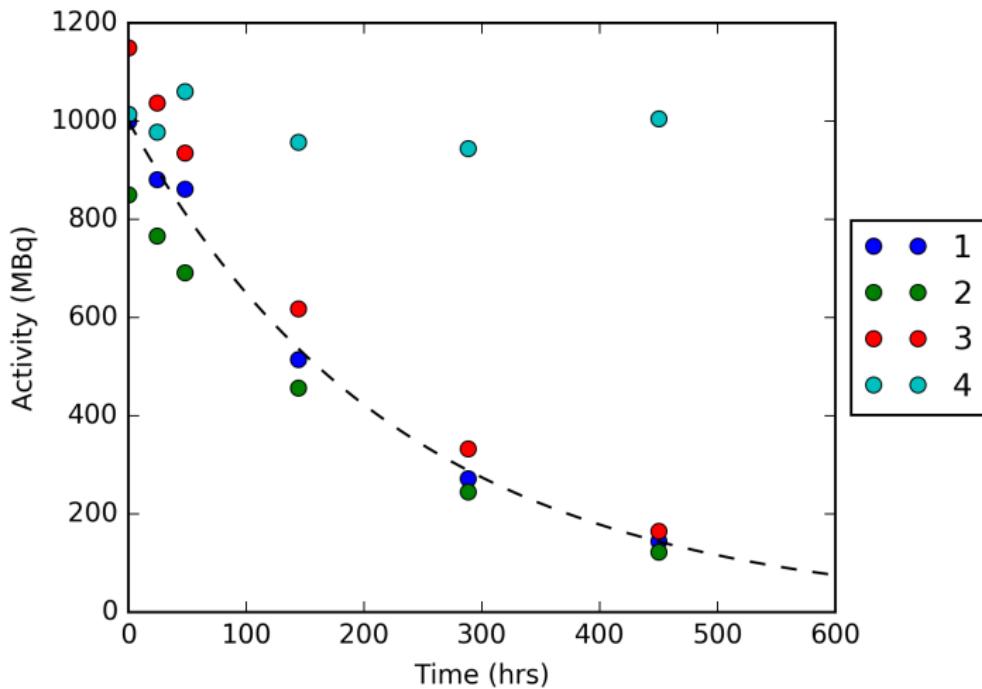
Alternativ 1

Men hva målte vi?



Men hva målte vi?

Alternativ 4(!)



Hvordan har dette seg?

Noen forslag?

Hvordan har dette seg?

0028,0004 Photometric Interpretation: MONOCHROME2
0028,0010 Rows: 256
0028,0011 Columns: 256
0028,0030 Pixel Spacing: 1.95313\1.95313
0028,0051 Corrected Image: UNIFATTN\SCAT\DECY
0028,0100 Bits Allocated: 16
0028,0101 Bits Stored: 16
0028,0102 High Bit: 15

Hvordan har dette seg?

0054,11001 Other Name

0054,11002 Counts Source: EMISSION

0054,1101 Attenuation Correction Method: CT-derived mu-map

0054,1102 Decay Correction: ADMIN

0054,1103 Reconstruction Method: OSCGMM

0054,1105 Scatter Correction Method: TEW

Hvordan har dette seg?

Decay Correction Attribute

Tag	(0054,1102)
Type	Required (1)
Keyword	DecayCorrection
Value Multiplicity	1
Value Representation	Code String (CS)

The real-world event to which images in this Series were decay corrected.

Defined Terms:

NONE

no decay correction

START

acquisition start time

ADMIN

radiopharmaceutical administration time

Henfallskorreksjon går tilbake tidspunkt for administrasjon

Relativt enkelt å korrigere for, all informasjon er i dicom-tagene

$$A_{\text{Aq}} = A_{\text{admin}} \cdot e^{-\frac{\ln(2)}{t_{1/2}}(t_2 - t_1)} \quad (1)$$

A_{Aq} Korrigert bilde

$t_{1/2}$ DICOM-tag (0018, 1075)

t_1 DICOM-tag (0008, 0022), (0008, 0032)

t_2 DICOM-tag (0018, 1078)

A_{admin} Bilde

Bokstavelig talt 8 linjer kode

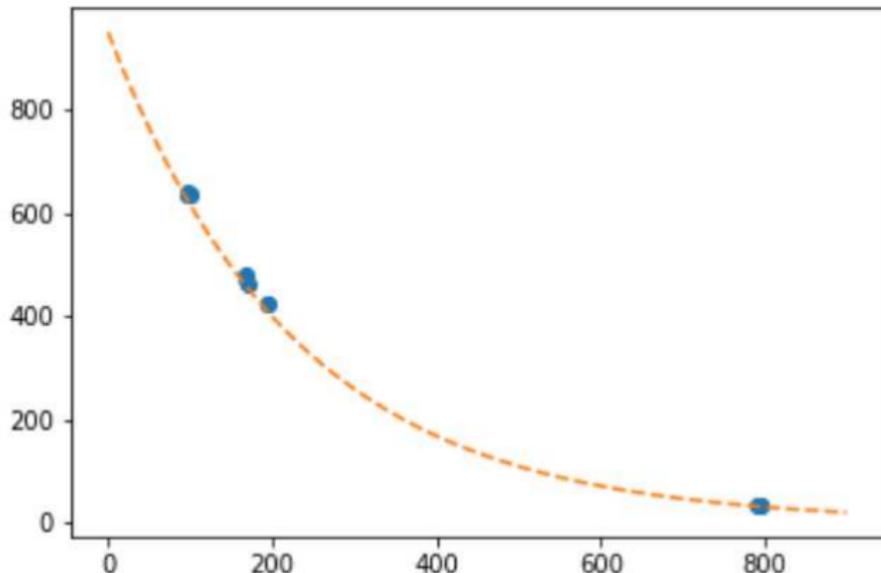
```
admin_info = img_data.RadiopharmaceuticalInformationSequence[0]
half_life = (admin_info[0x00181075].value)/(3600*24)
decay_constant = np.log(2)/(half_life*24)**-1 # In units of hours
admin_date_time = admin_info[0x00181078].value

admin_datetime = datetime.datetime(int(admin_date_time[0:4]), |
                                    int(admin_date_time[4:6]),
                                    int(admin_date_time[6:8]),
                                    int(admin_date_time[8:10]),
                                    int(admin_date_time[10:12]))

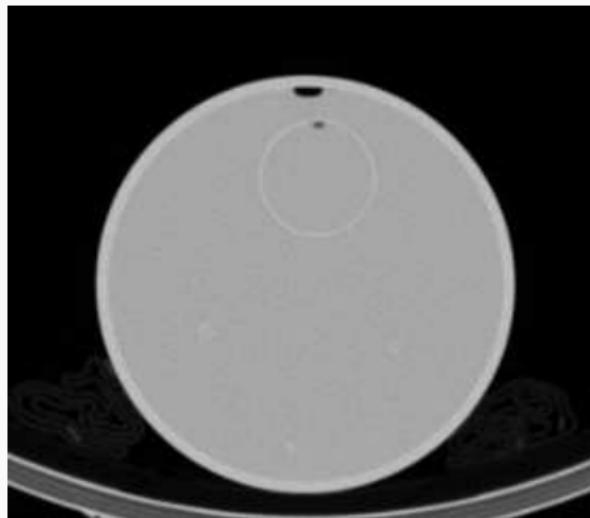
aq_datetime = datetime_from_dicom(data_path)
hours_diff = ((aq_datetime-admin_datetime).total_seconds())/3600

decay_corrected = spect_volume*np.exp(decay_constant*hours_diff)
```

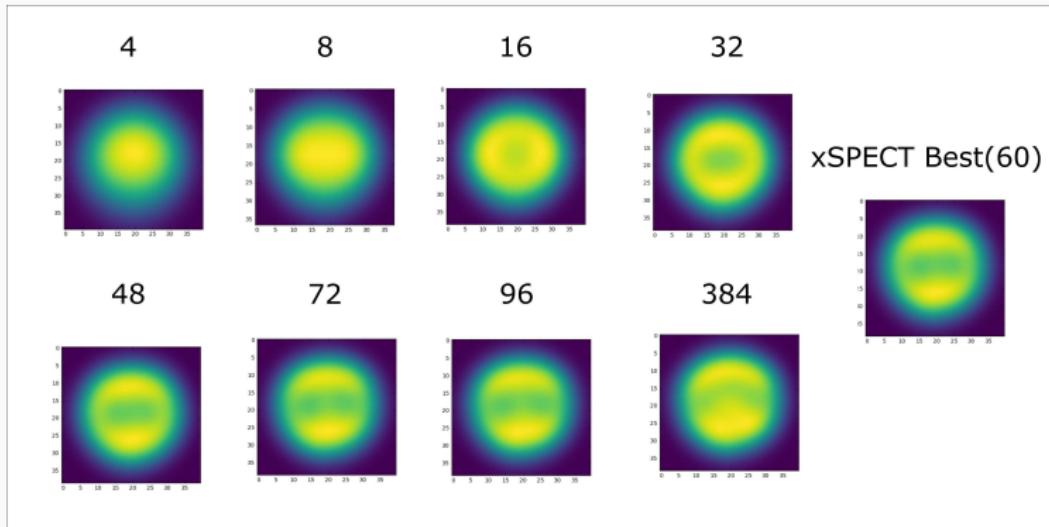
Bokstavelig talt 8 linjer kode



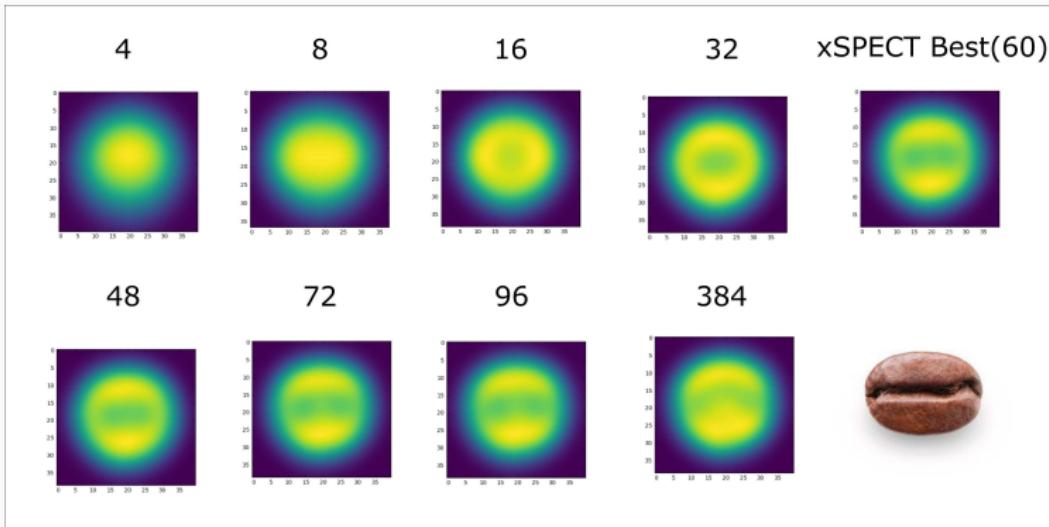
Esser - Største kule



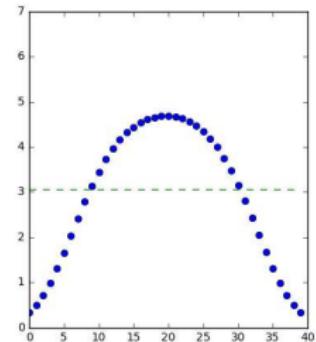
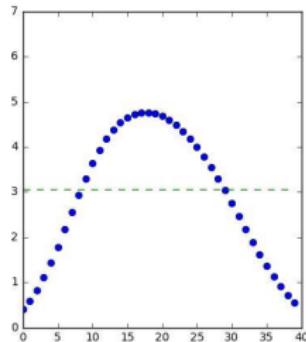
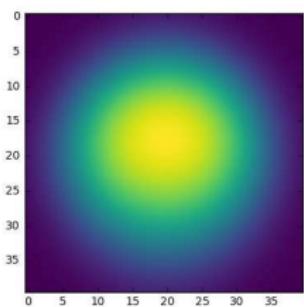
Esser - Største kule



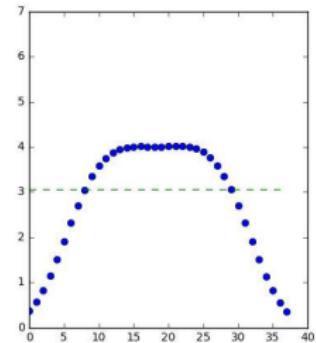
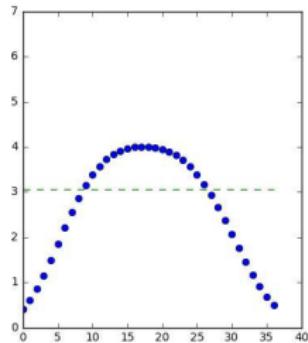
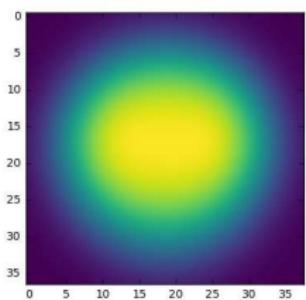
Esser - Største kule



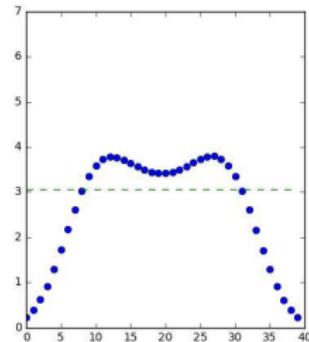
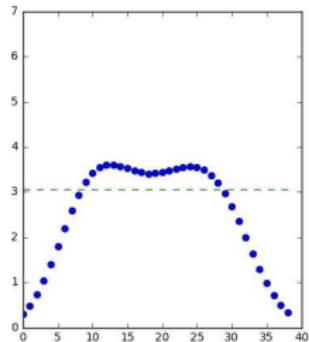
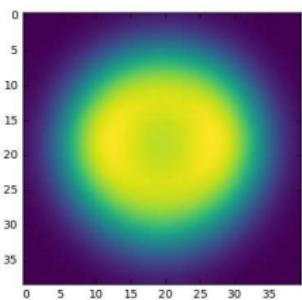
Esser - Største kule



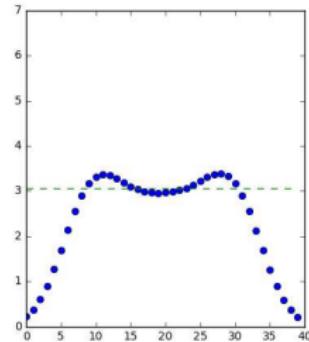
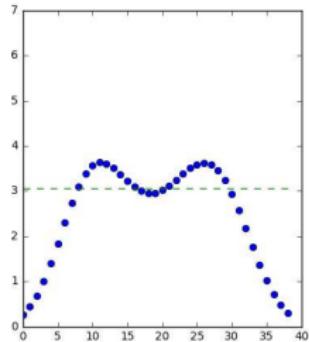
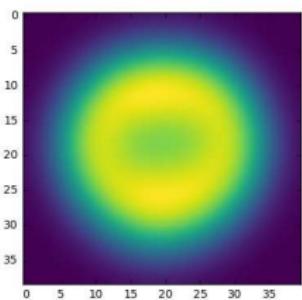
Esser - Største kule



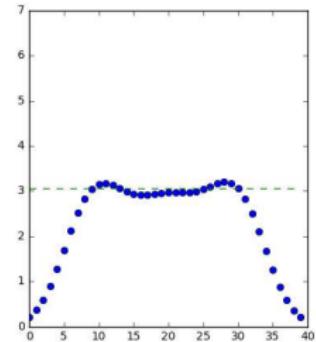
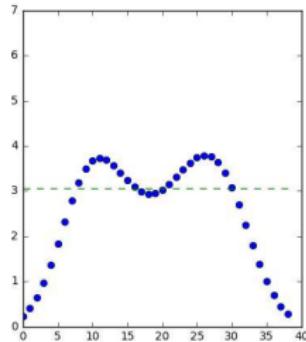
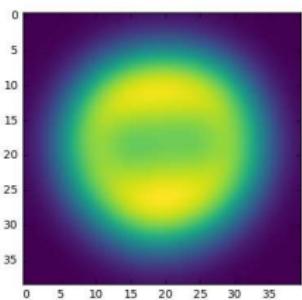
Esser - Største kule



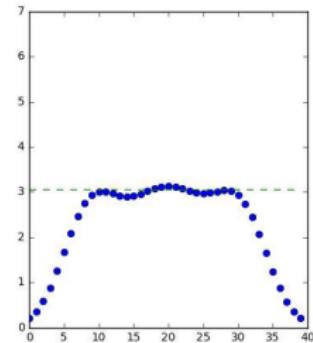
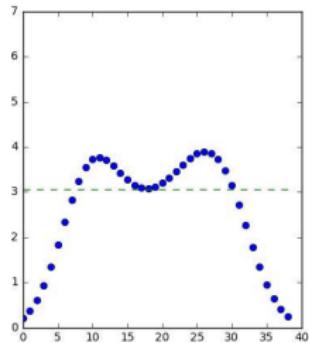
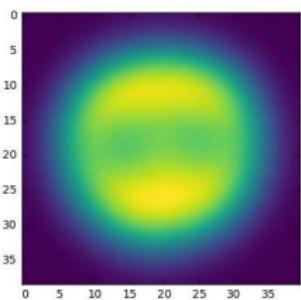
Esser - Største kule



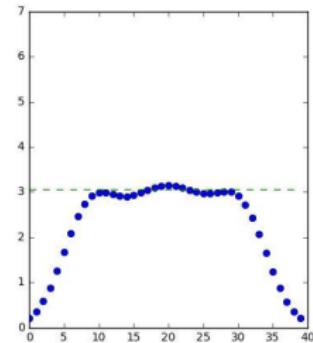
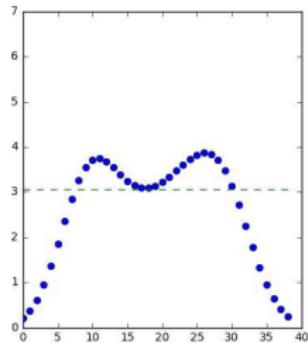
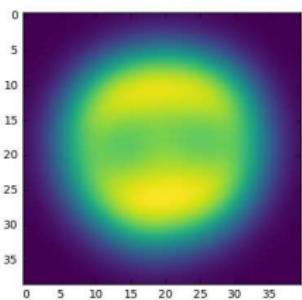
Esser - Største kule



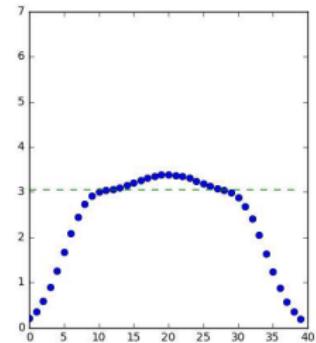
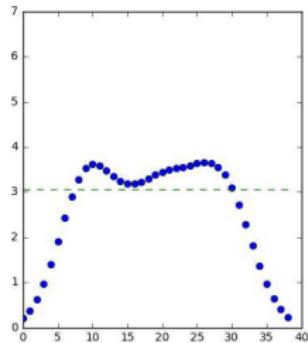
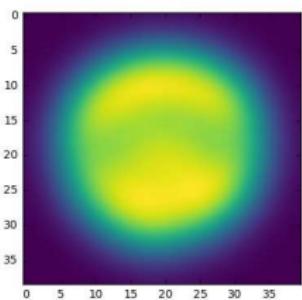
Esser - Største kule



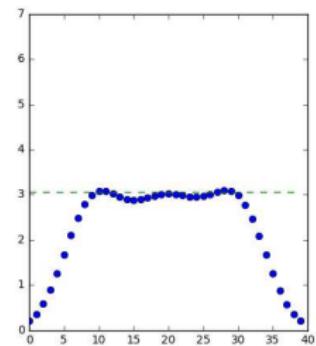
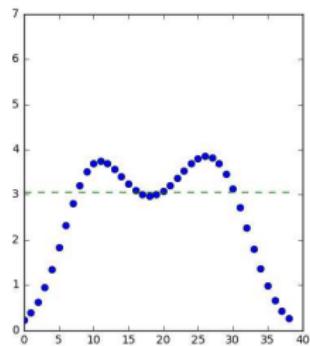
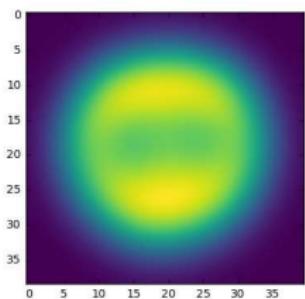
Esser - Største kule



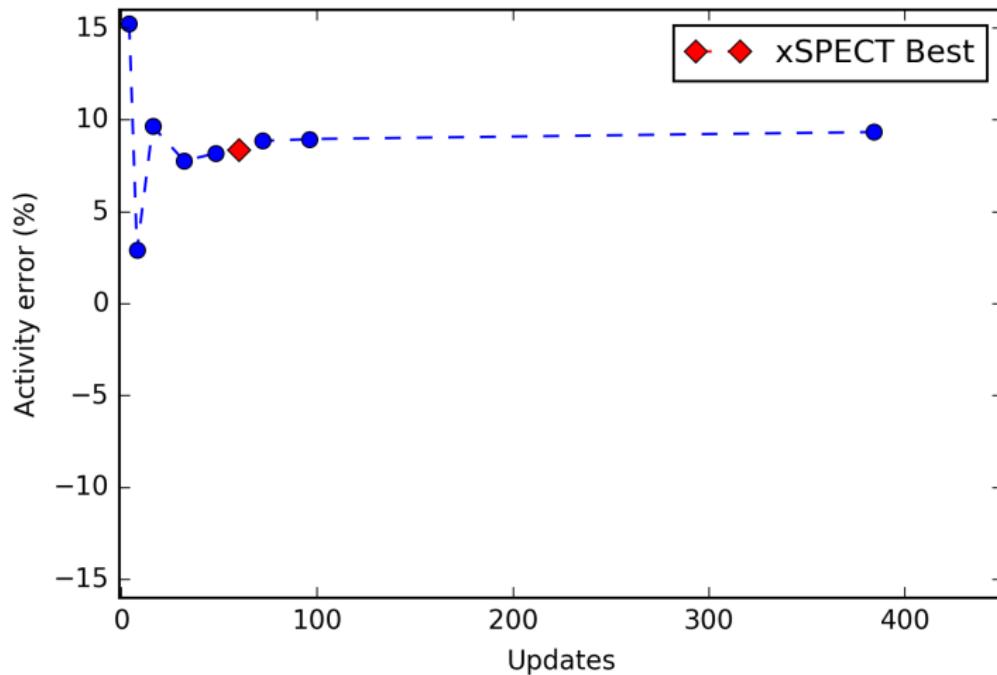
Esser - Største kule



Esser - Største kule



Esser - Oppdateringer vs feil i.e. kvantiteringsevne



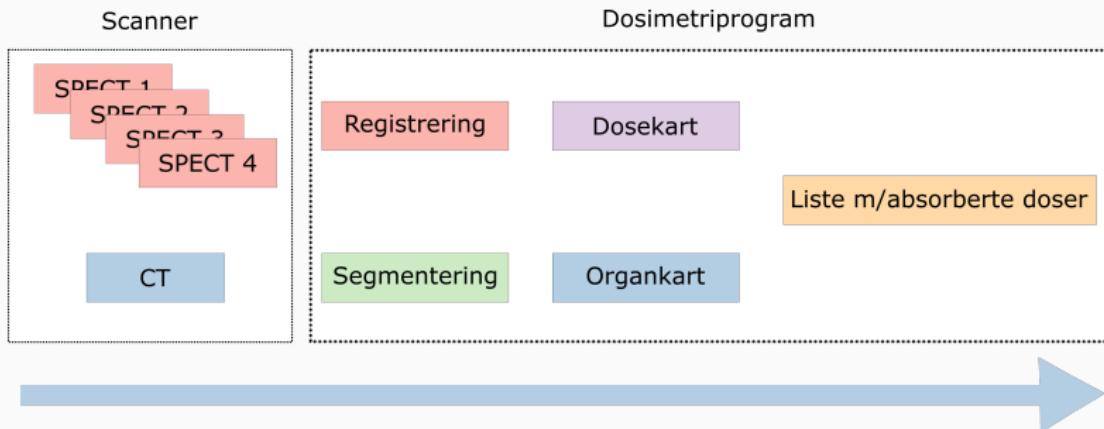
Ta-med-hjem-er fra den prelimenære analysen vår:

- Nøyaktig kvantitering av aktivitet innenfor rimelig feilmarginer
- Gjelder også mindre strukturer, ned til ca 1.5 cm i diameter
- Pussig kaffebønne for mange oppdateringer i kule på 113 ml?
- Pass på henfalsskorreksjon om du vil bruke bildene til dosimetri

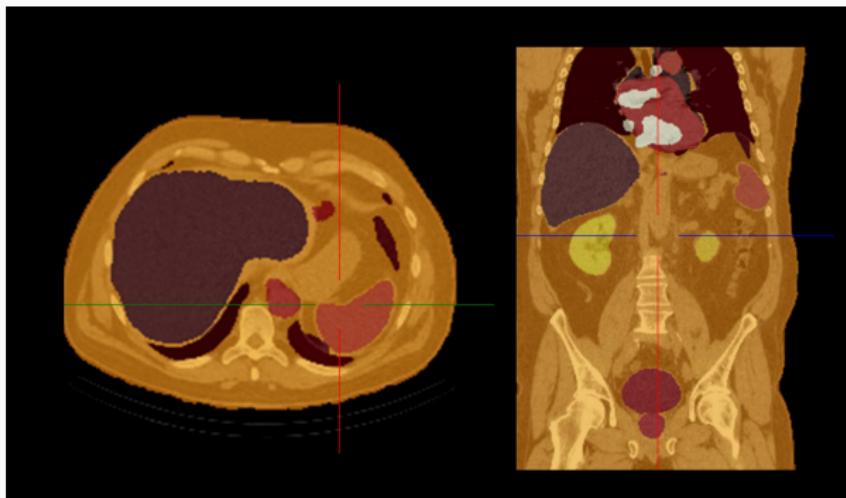
Siemens gjør dosimetri

- Siemens har latt oss få prøve dosimetriprogrammet deres
- xSPECT-bilder går inn, absorbert dose kommer ut
- Ingen resultater å presentere (enda) men litt erfaringer

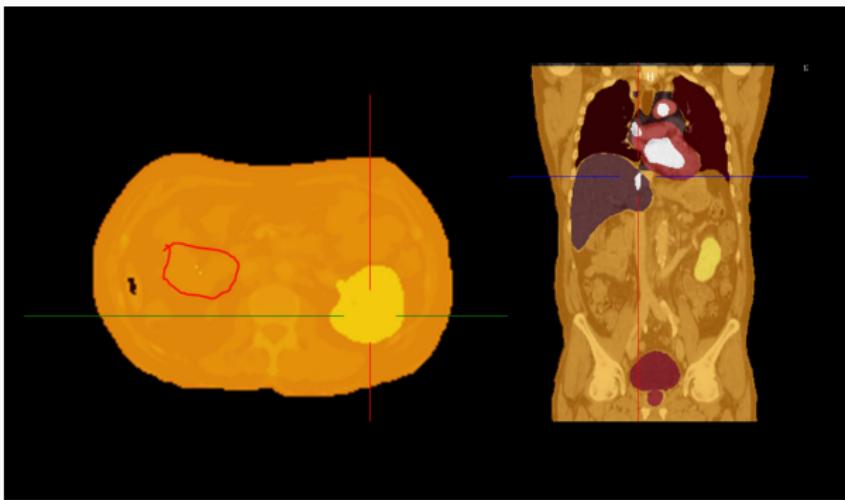
Dosimetri



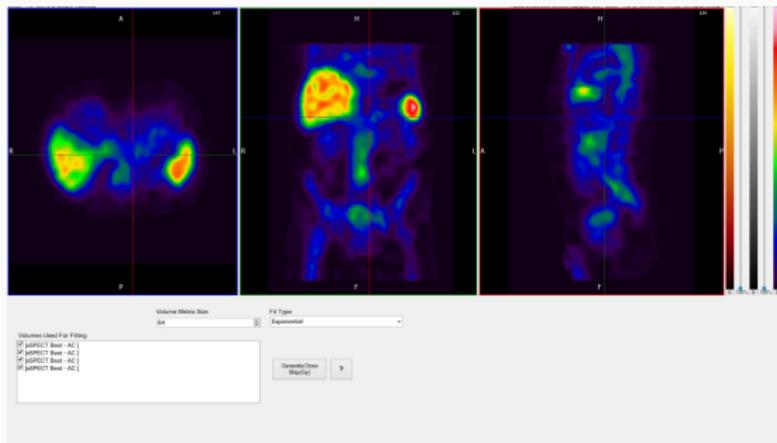
Dosimetri



Dosimetri



Dosimetri



Dosimetri

stigational use. This device is exclusively for clinical investigations. ---- Siemens Medical Solutions, USA, Inc. (C) 2011-2019

The screenshot shows a medical dosimetry software interface. At the top, there is a header with the text "stigational use. This device is exclusively for clinical investigations. ---- Siemens Medical Solutions, USA, Inc. (C) 2011-2019". Below the header, there is a grayscale image of a patient's abdomen. To the left of the image, there is a vertical list of organs: Liver, Spleen, Hot Tumor 1 # 41, Left Kidney Pelvis # 27, Left Kidney Medulla # 28, Aorta # 11, Mediastinum # 2, Heart # 10, Bladder # 8, Prostate # 9, Right Lung # 4, Soft Bone # 23, and Right Kidney Medulla # 30. To the right of the image, there is a table with columns: Left Kidney Medulla (Gy), Right Kidney Medulla (Gy), Liver (Gy), Spleen, Ref Size (g), and Current Size (g). The table contains data for the listed organs. At the bottom of the interface, there are several buttons: "95 % Confidence Intervals", "Cross-irradiation", "Show MIRD Table", "Dose Uncertainty", "?", and "Generate Dose Report".

	Left Kidney Medulla (Gy)	Right Kidney Medulla (Gy)	Liver (Gy)	Spleen	Ref Size (g)	Current Size (g)
Left Kidney Medulla	0.56	NA	NA	NA	150.00	416.04
Right Kidney Medulla	NA	0.29	NA	NA	150.00	0.13
Liver	NA	NA	0.94	NA	1,910.00	1,864.94
Spleen	NA	NA	NA	0.96	183.00	73.90

	Sum (Gy)	Mean (Gy)	StdDev (Gy)	Variance (Gy)	Volume (ml)	Voxels (#)	Minimum (Gy)	Max (Gy)
Liver # 3	207081.30	0.92	0.22	0.05	1679.03	225356	0.16	1.6
Spleen # 13	7914.57	0.88	0.27	0.07	7.19	9018	0.24	1.5
Hot Tumor 1 # 41	26868.29	0.58	0.07	0.01	345.53	46376	0.37	1.1
Left Kidney Pelvis # 27	272.86	0.51	0.03	0.00	3.98	534	0.44	0.6
Left Kidney Medulla # 28	24395.20	0.49	0.07	0.01	367.47	49321	0.28	0.7
Aorta # 11	8468.82	0.49	0.08	0.01	129.31	17356	0.31	0.7
Mediastinum # 2	12629.97	0.44	0.13	0.02	213.06	28597	0.09	0.8
Heart # 10	41190.16	0.43	0.14	0.02	708.87	95143	0.09	1.0
Bladder # 8	14074.83	0.34	0.06	0.00	306.79	41176	0.16	0.5
Prostate # 9	1449.43	0.29	0.07	0.00	38.88	4950	0.11	0.41
Right Lung # 4	60328.41	0.28	0.11	0.01	1608.10	215836	0.07	0.8
Soft Bone # 23	94153.83	0.28	0.17	0.03	2524.21	338793	0.00	0.9
Right Kidney Medulla # 30	4.69	0.28	0.01	0.00	0.13	17	0.26	0.3

- Programmet er relativt enkelt å bruke
- For lever, nyre og miltdoser er det strålende
- Vi har en masterstudent (Ronjja) som skal undersøke videre -
les oppgaven hennes!

Avslutning

Tusen takk for oppmerksomheten deres! (email: johbla@ous-hf.no)

Slides Research grp

