

177-Lu-Kvantitering med xSPECT

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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

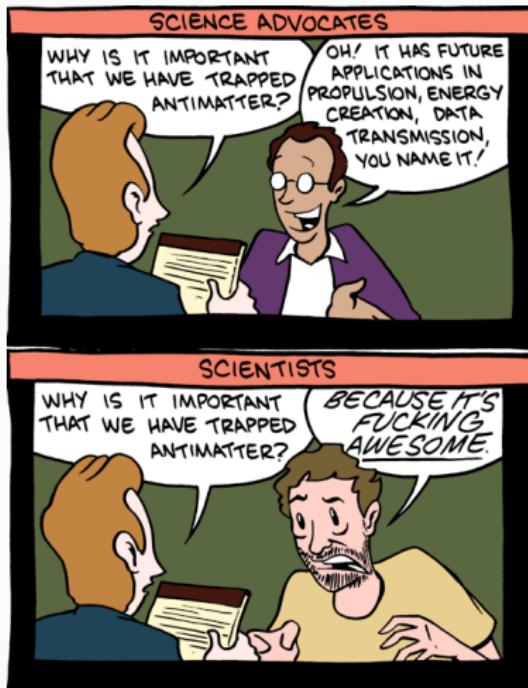
Kvantitering (verb) - måle, telle. Tilordne til en kvantitet

Kvantitering i forbindel med SPECT/CT

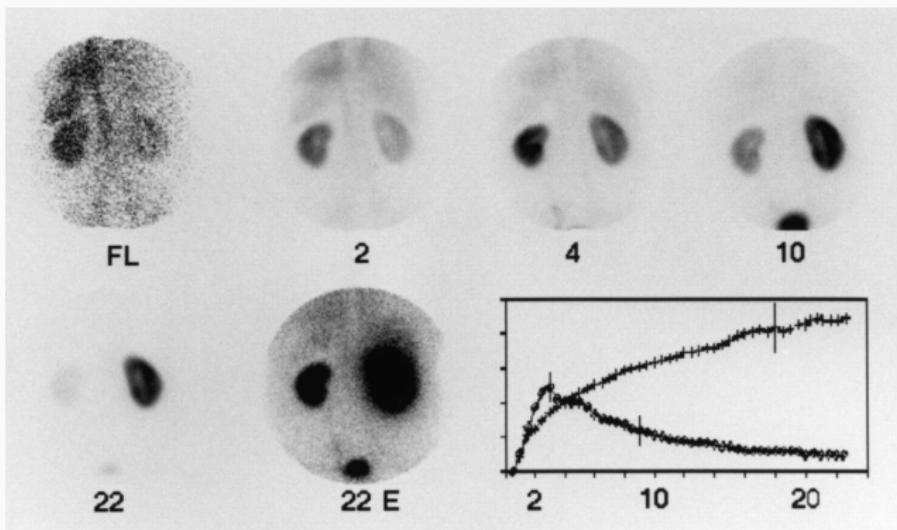
Ønsker bilder med enhet Bq/ml eller lignende

Kvantitering

Hvorfor ønsker vi å kvantitere stråling i pasienten?



Relative verdier helt ok?



Kvantitering åpner opp!

Terapiplanlegning Dosering av radionuklideterapi

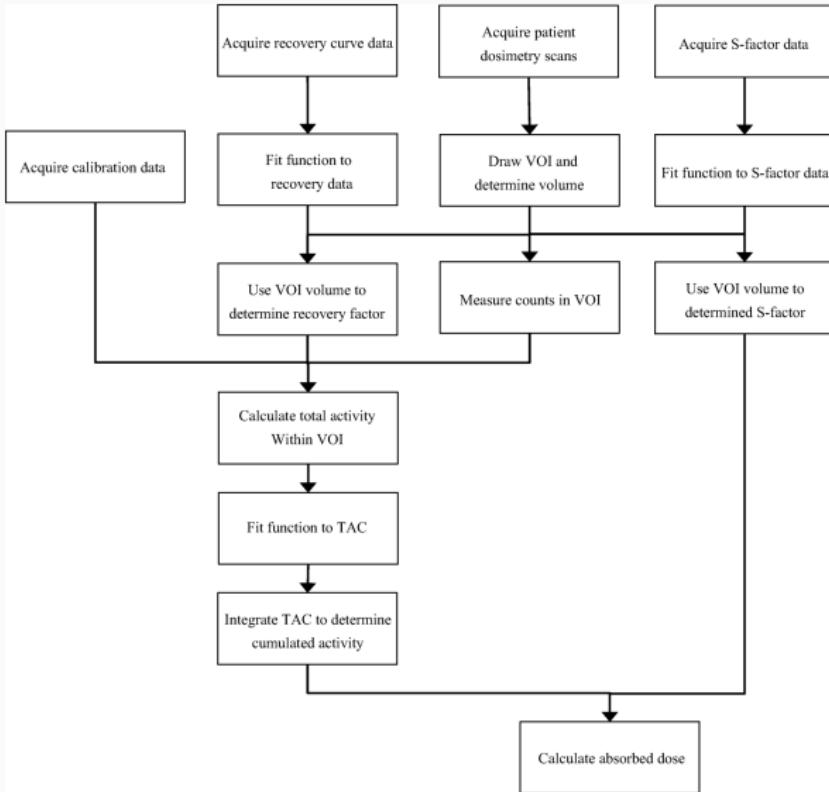
Myocard-perfusjonsavbildning ^{99m}Tc for å måle
blodgjennomstrømning i ml/g-min eller SUV-SPECT

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 Konijnenburg³ · Glenn D. Flux¹

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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.



Mange ledd, mye feil - akkurat som hviskeleken

Bildene er førstemann/kvinns 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?

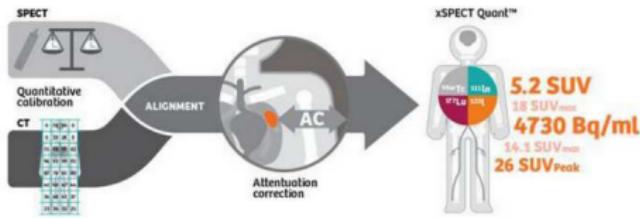
Hva er xSPECT?

- 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(!)

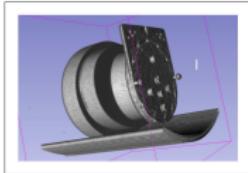
Fantomskan - hva har vi gjort?

En liten advarsel

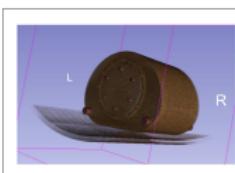
Dette kommer til å bli usedvanlig nerdete

Fantomer - masse fantomer

CC w wings



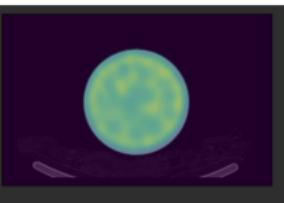
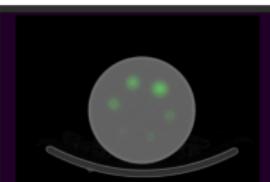
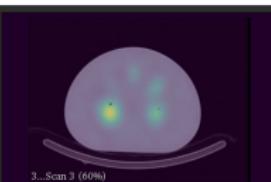
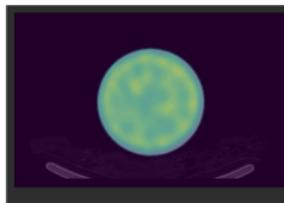
NEMA



Esser



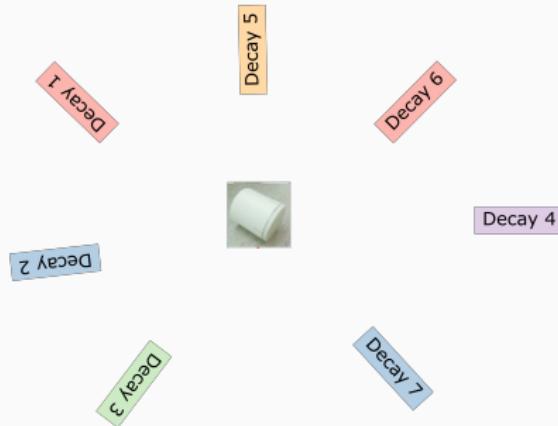
CC



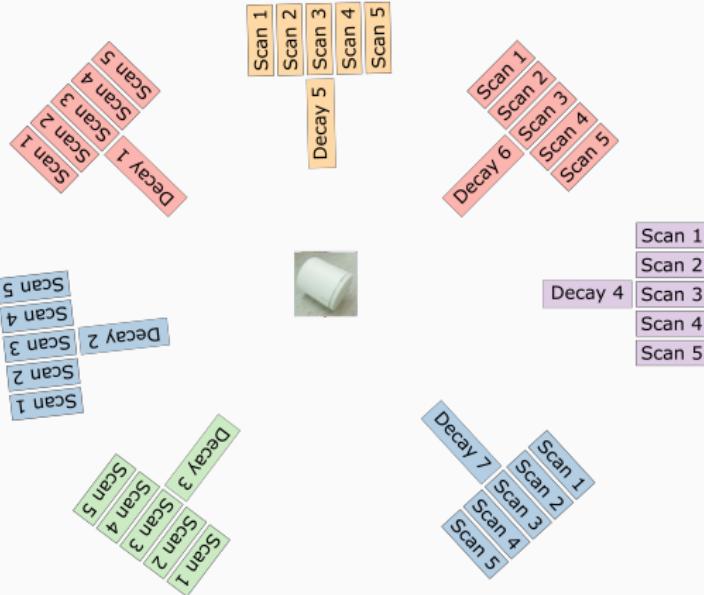
Fantomer - Cross Calibration



Fantomer - Cross Calibration



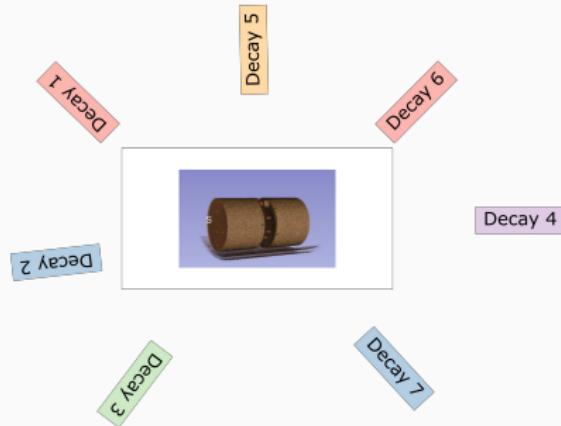
Fantomer - Cross Calibration



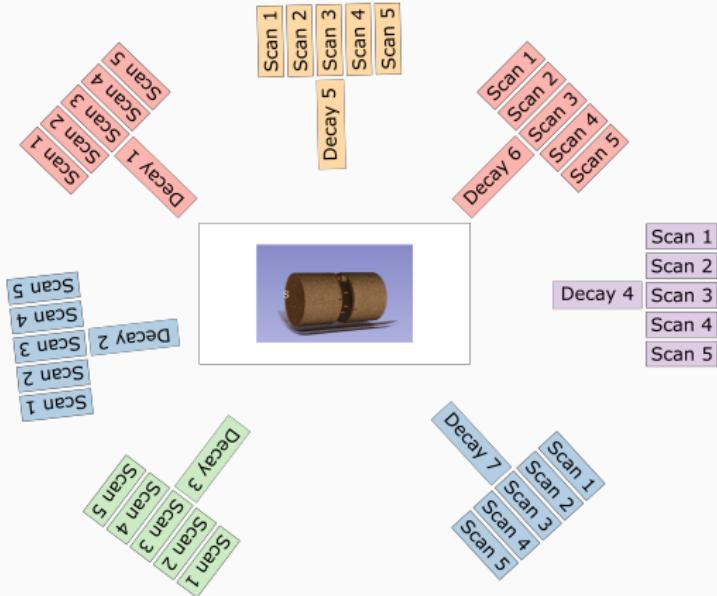
Fantomer - Esser



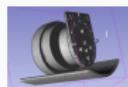
Fantomer - Esser



Fantomer - Esser



Fantomer - Cross Calibration with padding



Fantomer - Cross Calibration with padding



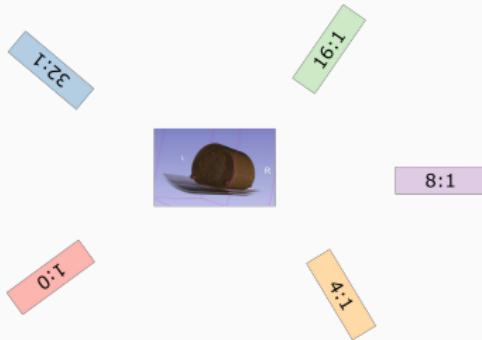
Fantomer - Cross Calibration with padding



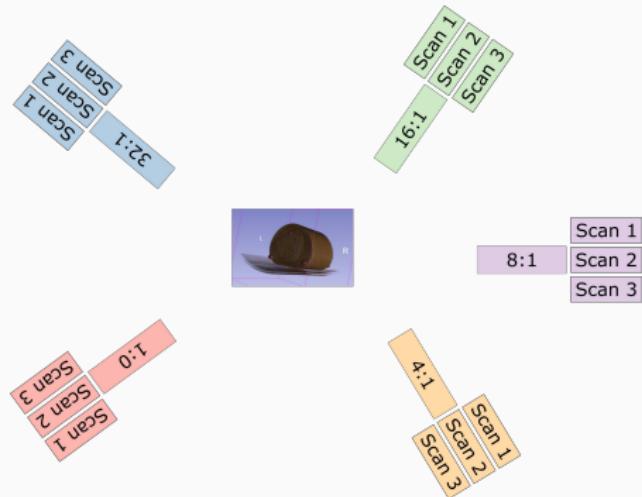
Fantomer - NEMA



Fantomer - NEMA



Fantomer - NEMA



Fantomer - Totalt antall scan

Scan 1						
Scan 2						
Scan 3						
Scan 4						
Scan 5						
Scan 1						
Scan 2						
Scan 3						
Scan 4						
Scan 5						
Scan 1						
Scan 2						
Scan 3						
Scan 4						
Scan 5						
Scan 1						
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Scan 3						
Scan 4	Scan 3					
Scan 5						
Scan 1						
Scan 2						
Scan 3						
Scan 4						
Scan 5						
Scan 1						
Scan 2						
Scan 3						
Scan 4						
Scan 5						

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!

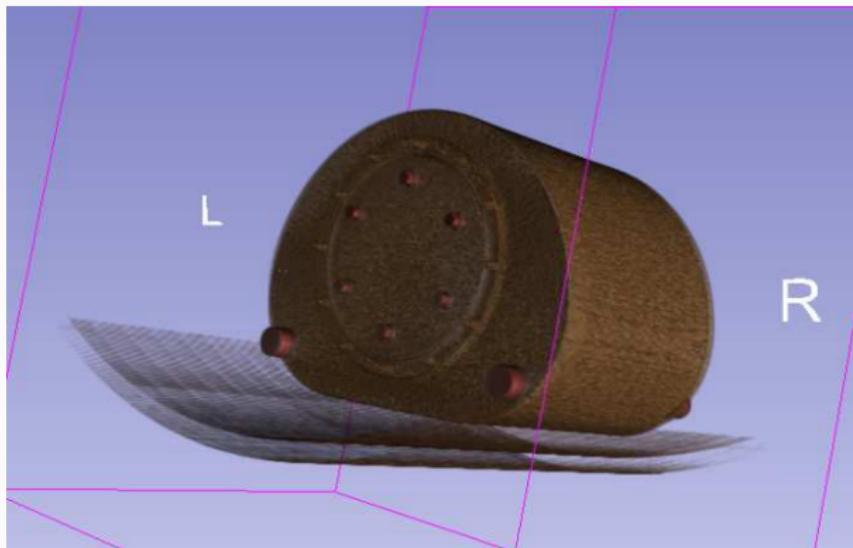
Resultater

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

Resultater

Men jeg har funnet ut noe!

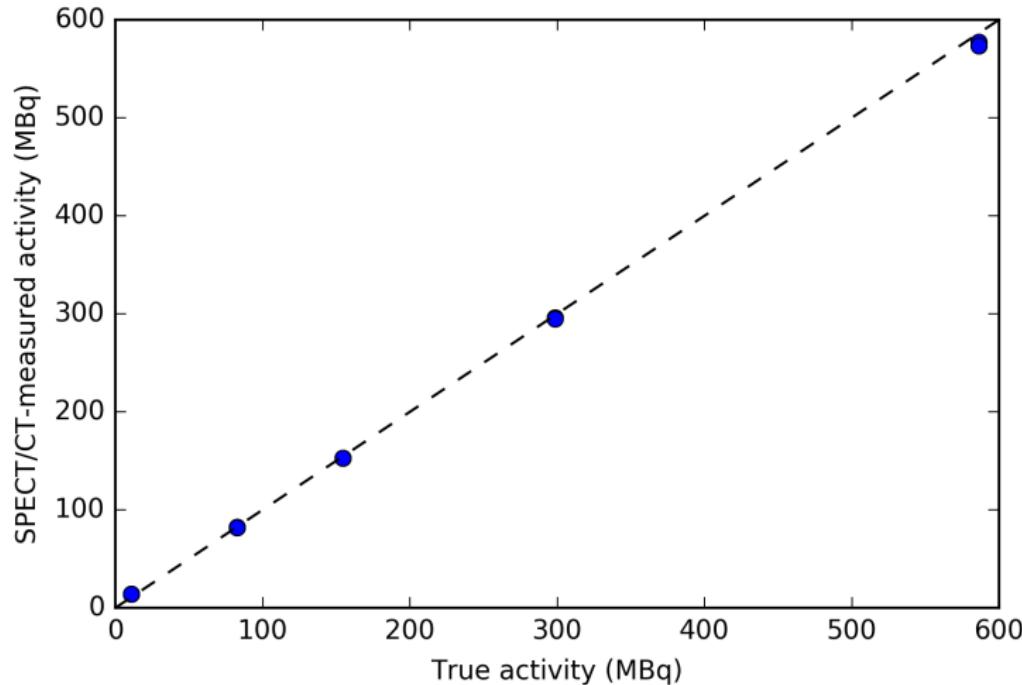
NEMA - et kinderegg(!)



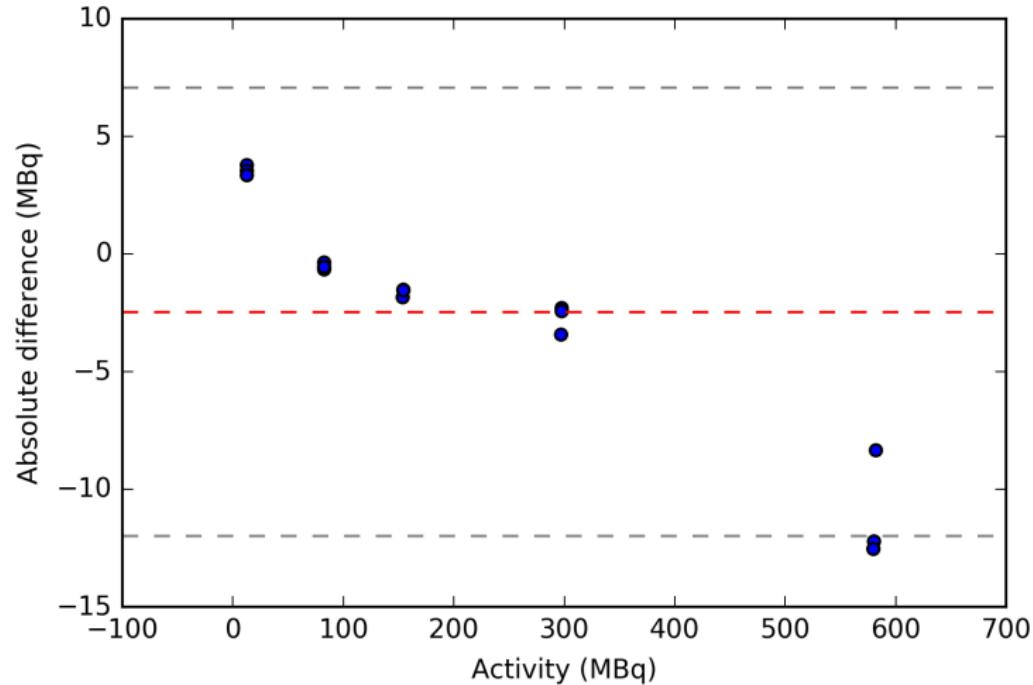
NEMA - et kinderegg(!)

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

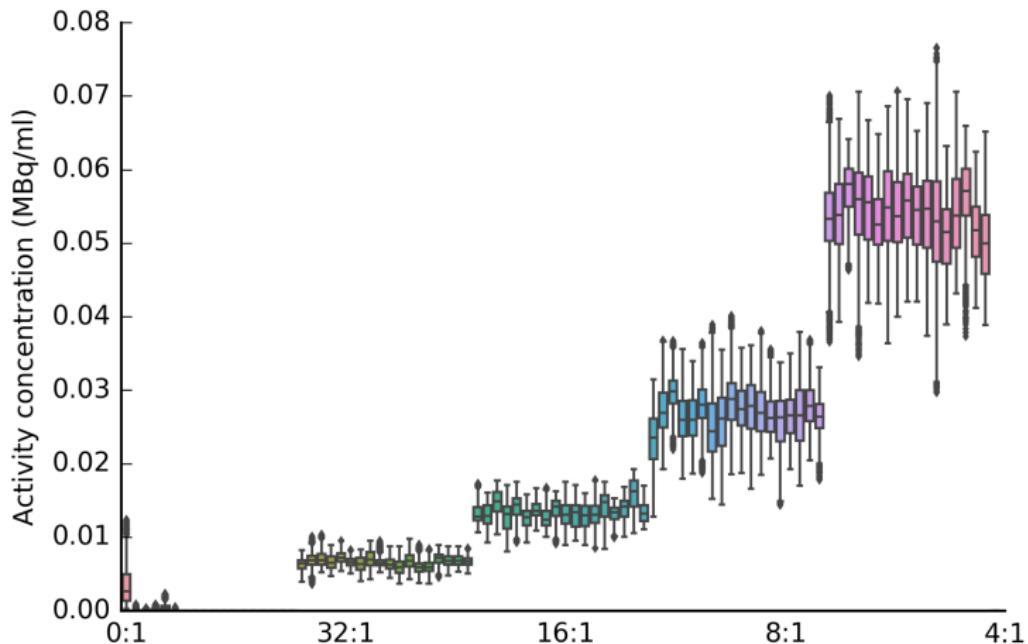
NEMA - Total aktivitet



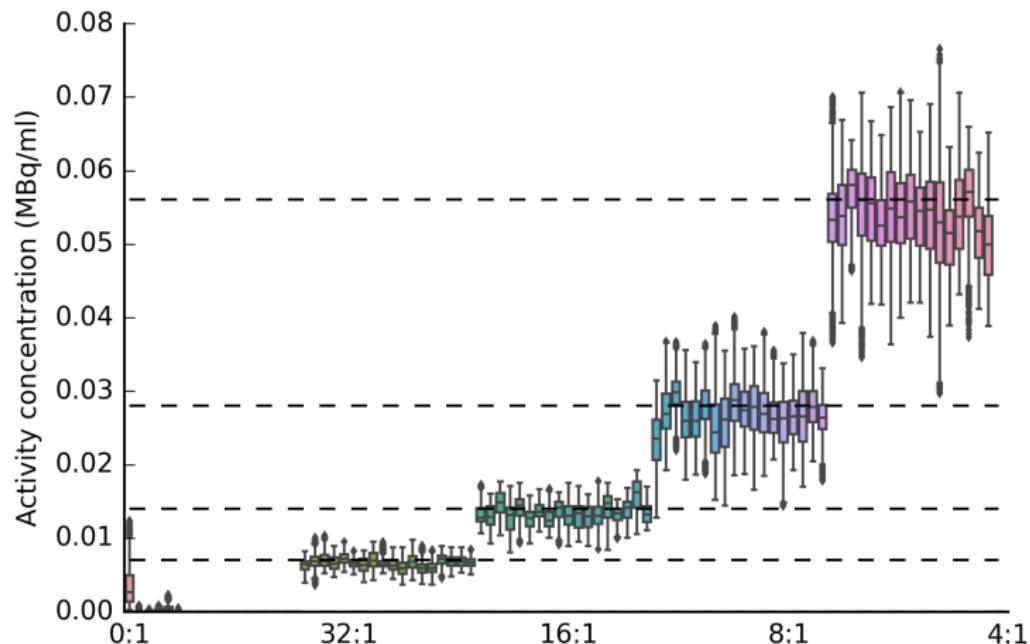
NEMA - Total aktivitet



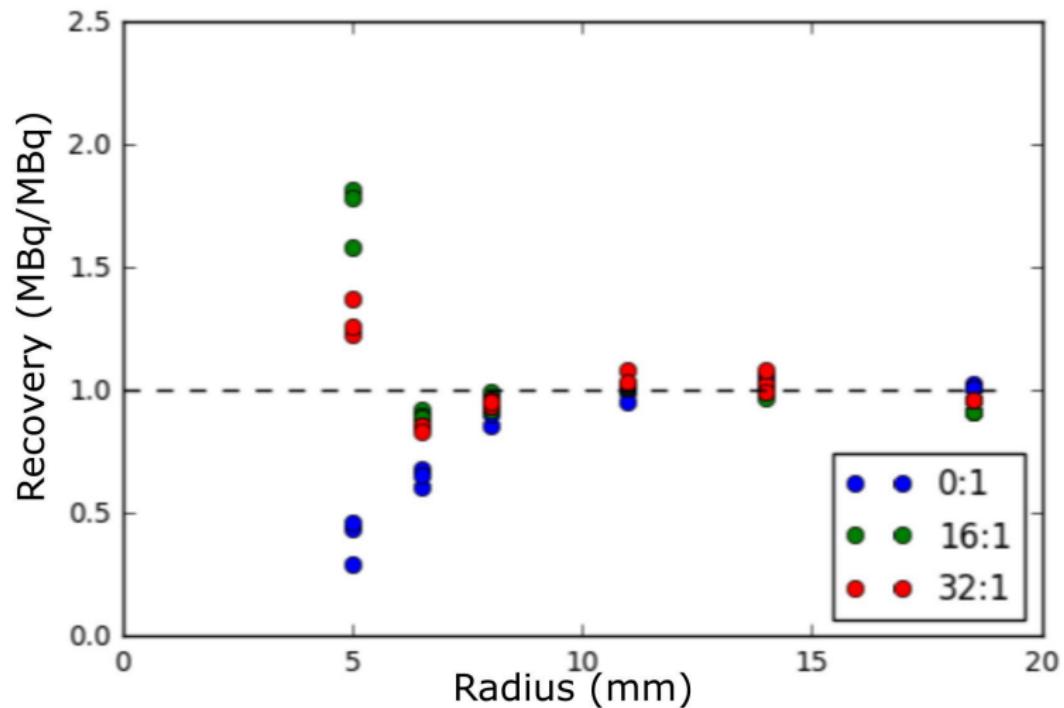
NEMA - Bakgrunn



NEMA - Bakgrunn



NEMA - Spheres



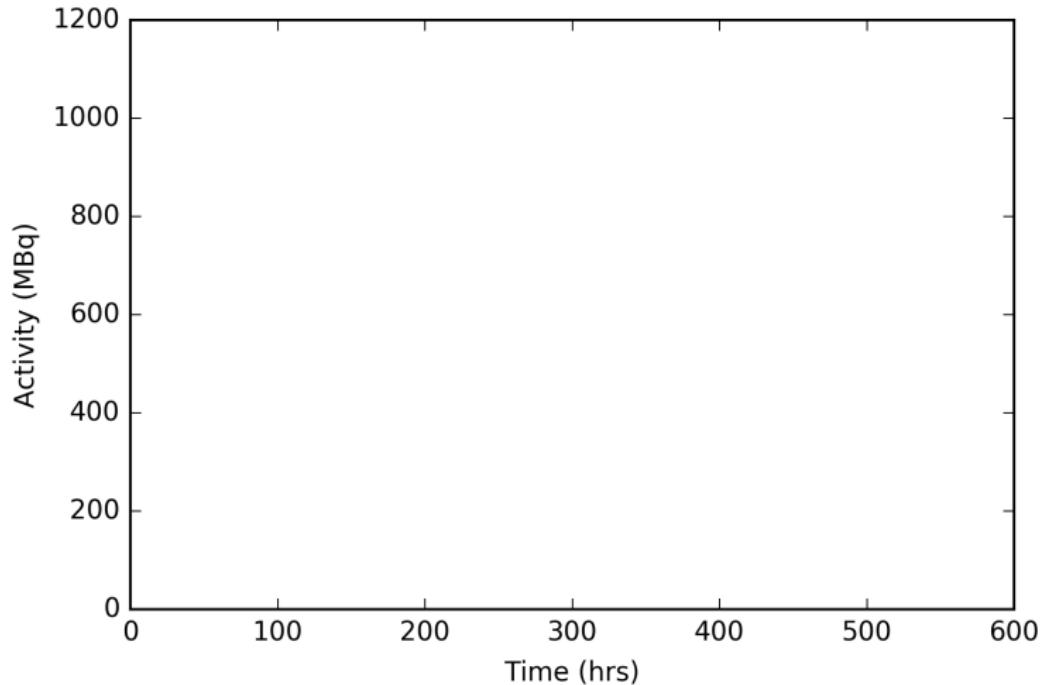
Esser - Kuler, store og små



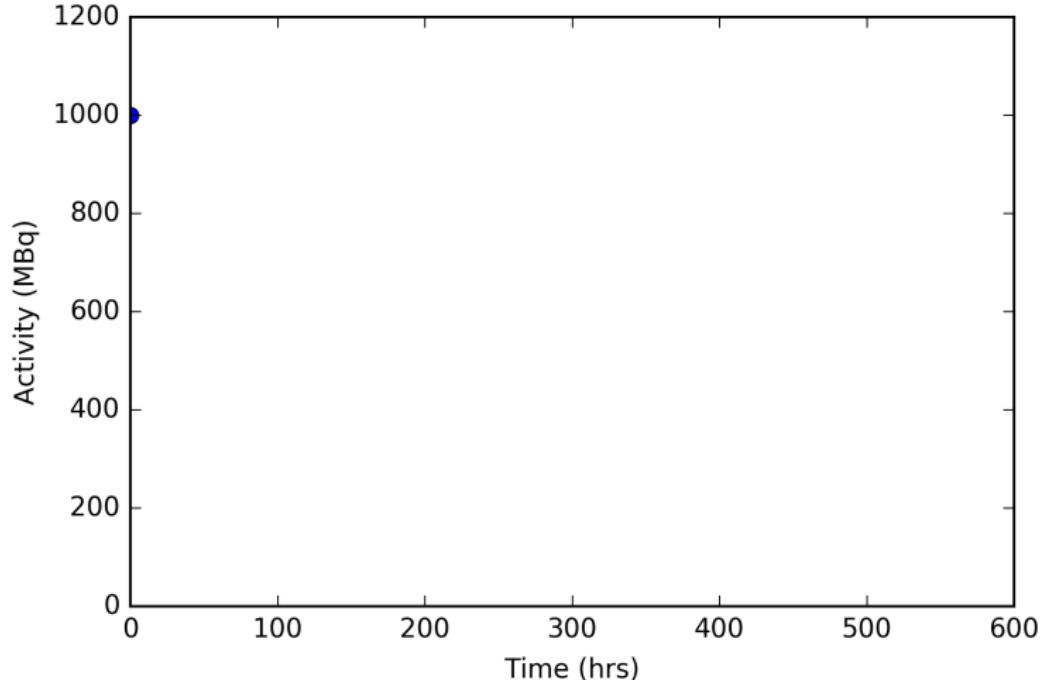
Esser - Total aktivitet - en quiz(!)

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

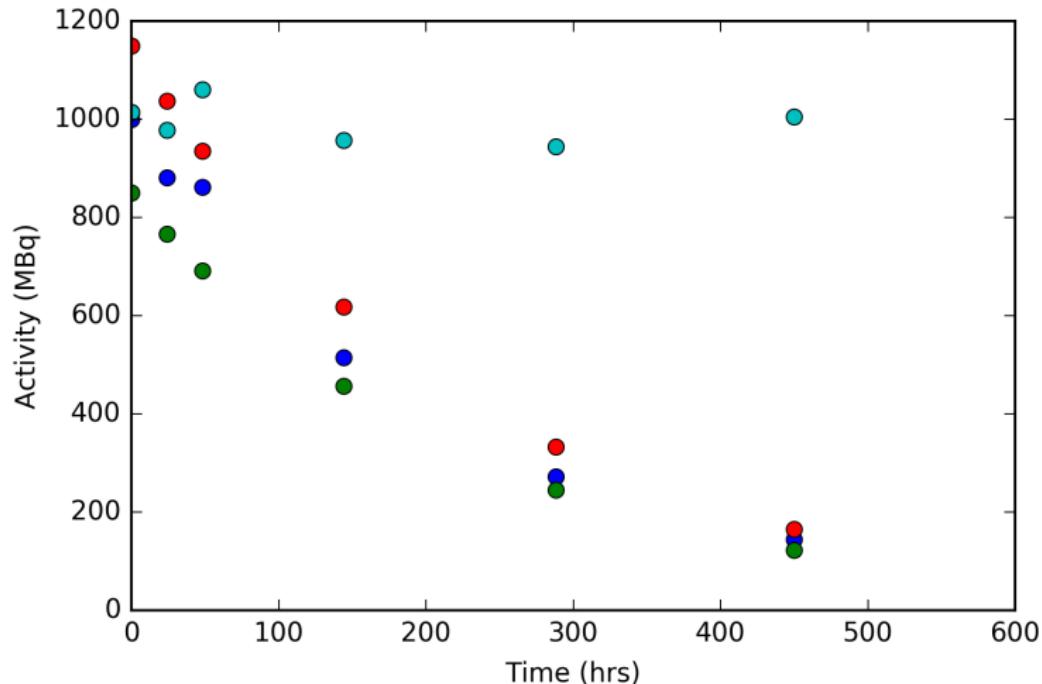
Esser - Total aktivitet - en quiz(!)



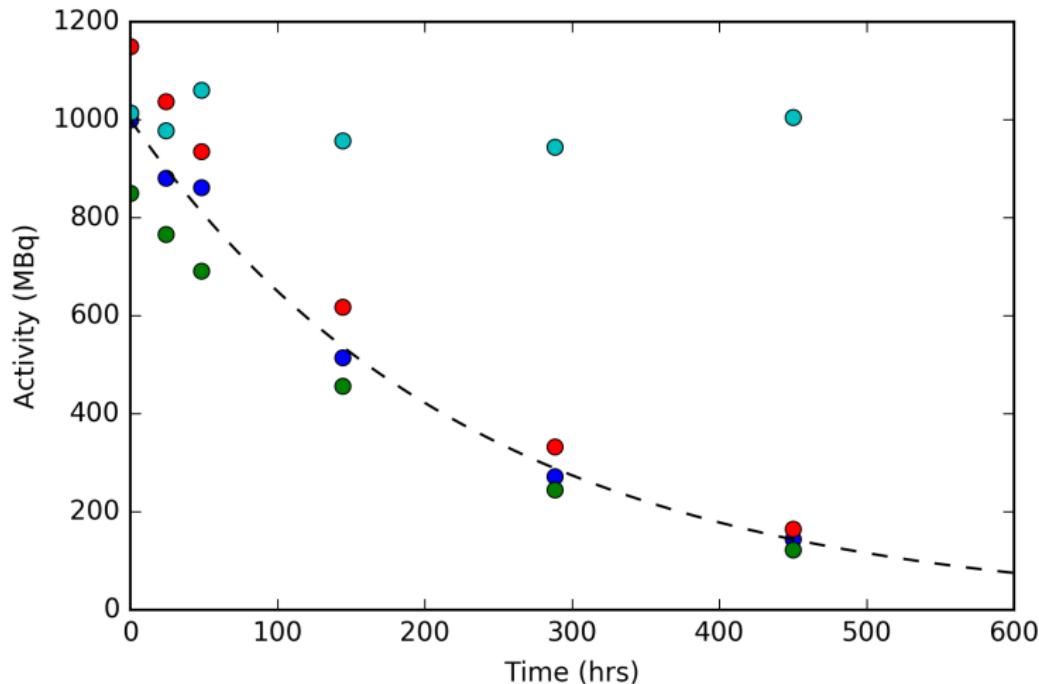
Esser - Total aktivitet - en quiz(!)



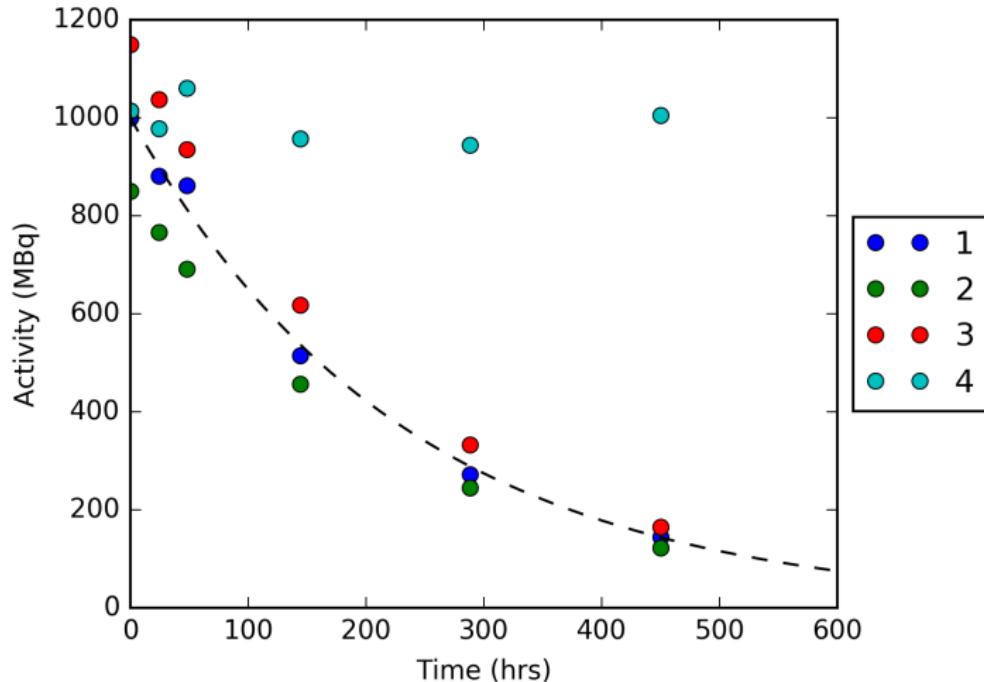
Esser - Total aktivitet - en quiz(!)



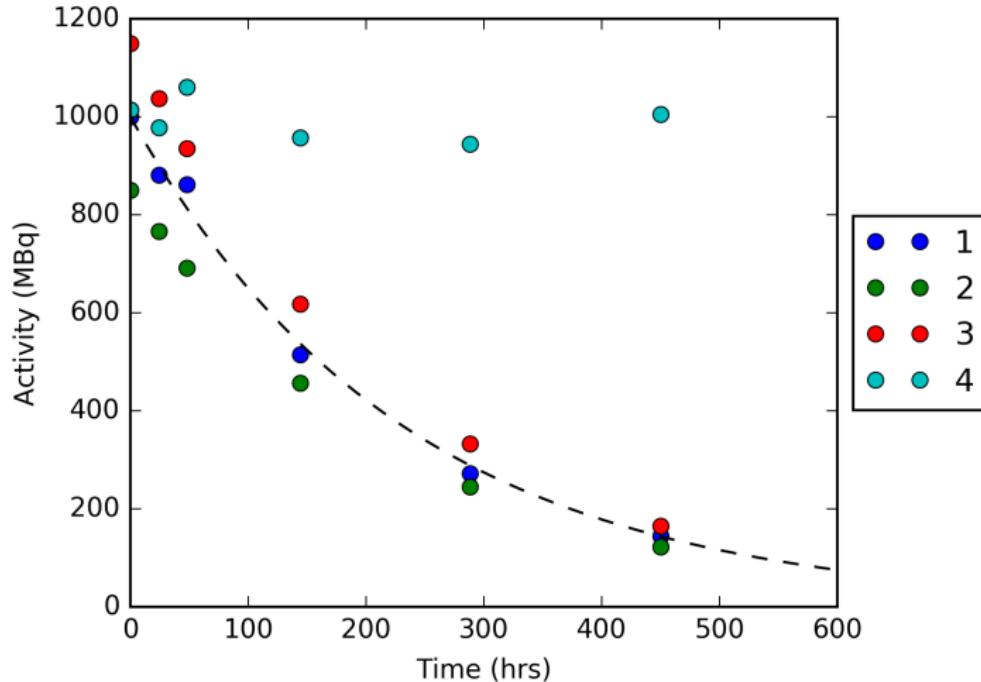
Esser - Total aktivitet - en quiz(!)



Esser - Total aktivitet - en quiz(!)



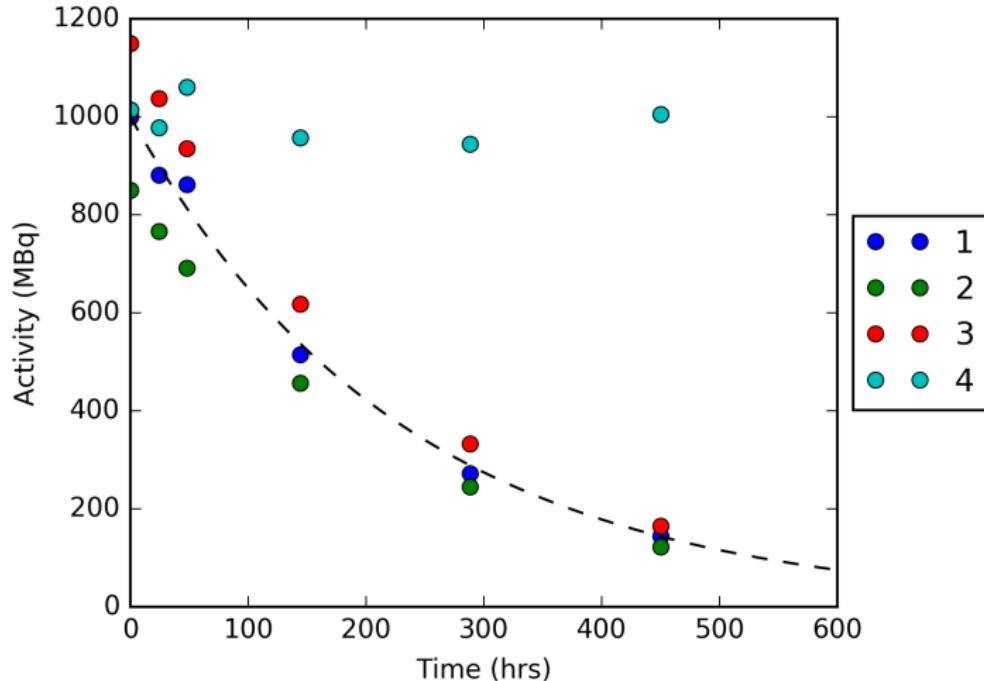
Riktig svar...



Riktig svar...

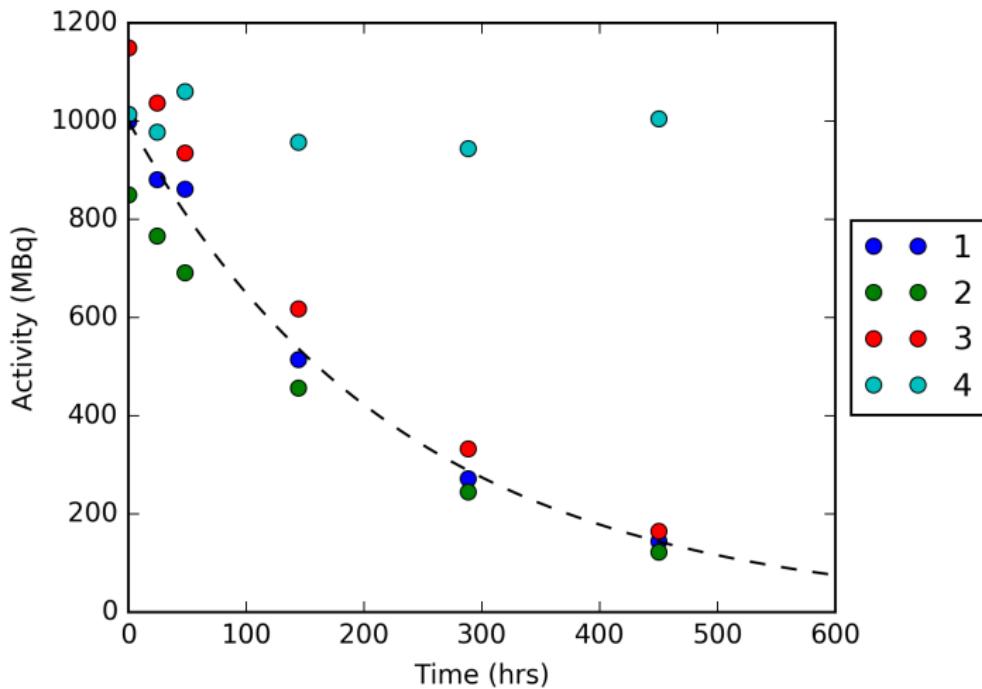
Alternativ 1

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

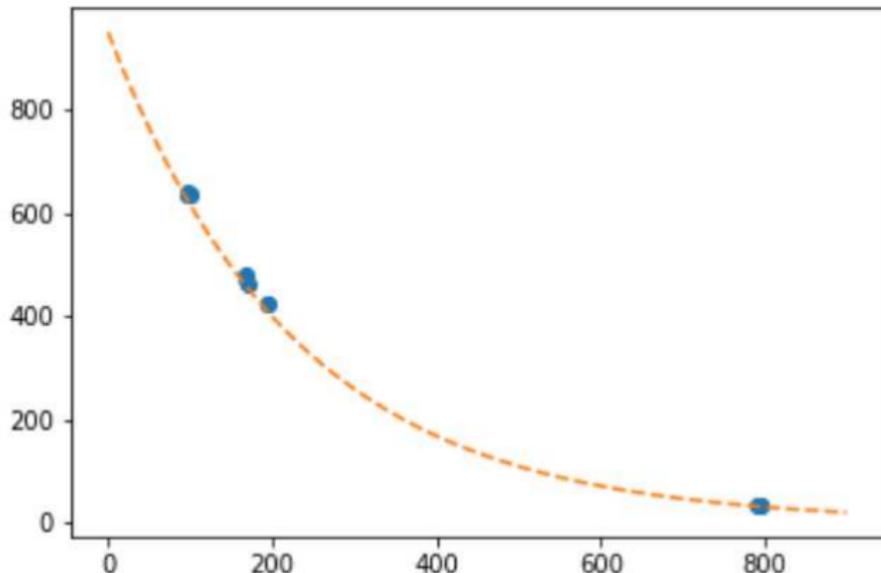
```
admin_info = img_data.RadiopharmaceuticalInformationSequence[0]
half_life = (admin_info[0x00181075].value)/(3600*24)
decay_constant = np.log(2)/(half_life*24)**-1 # In units of hours
admin_date_time = admin_info[0x00181078].value

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]))

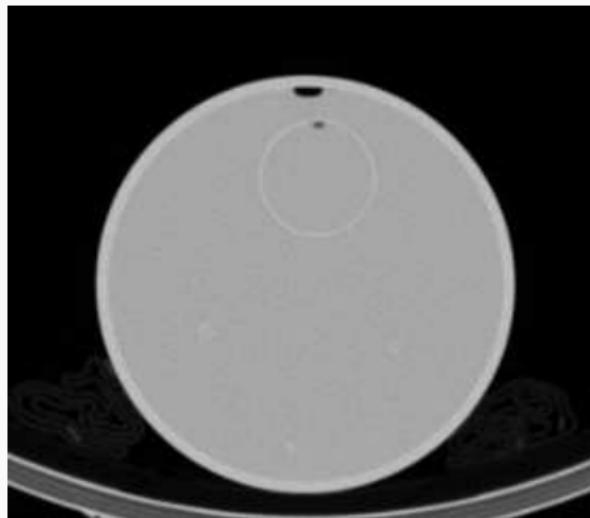
aq_datetime = datetime_from_dicom(data_path)
hours_diff = ((aq_datetime-admin_datetime).total_seconds())/3600

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

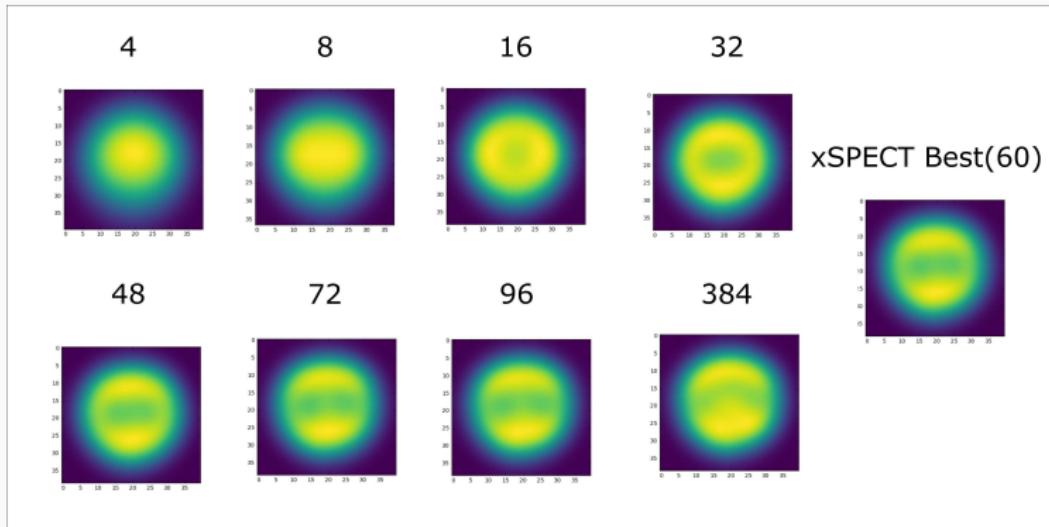
Bokstavelig talt 8 linjer kode



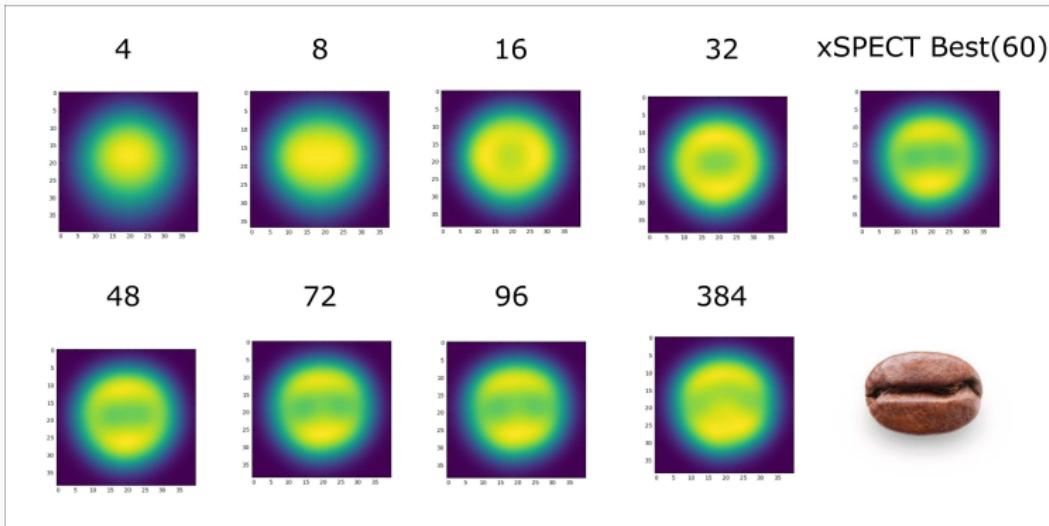
Esser - Største kule



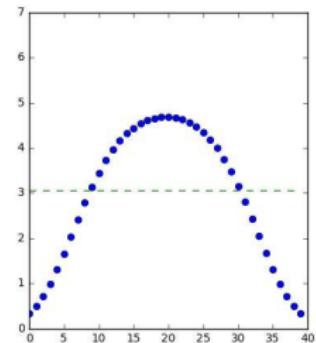
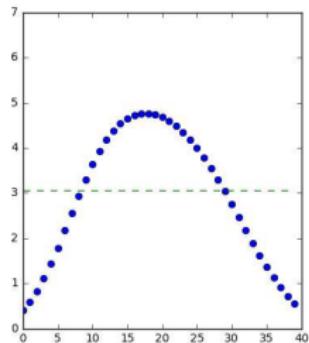
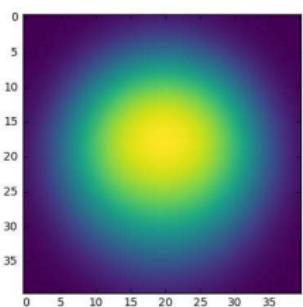
Esser - Største kule



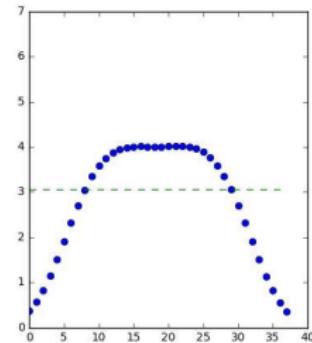
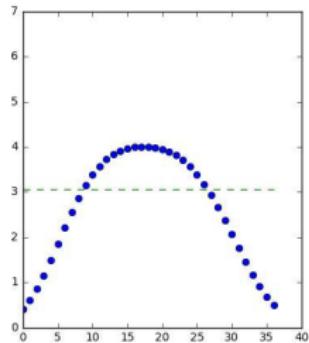
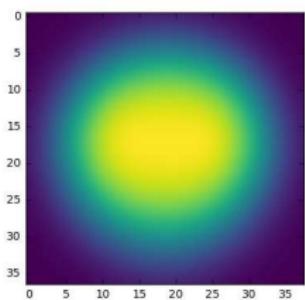
Esser - Største kule



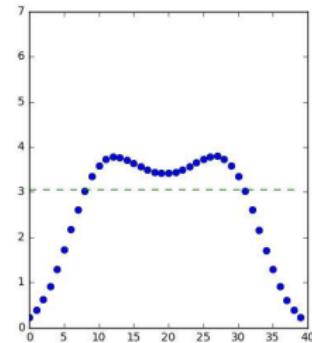
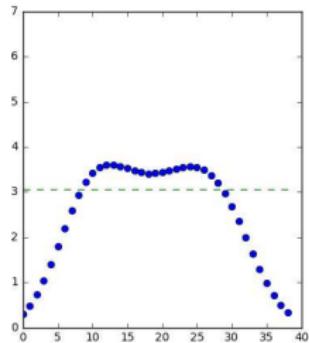
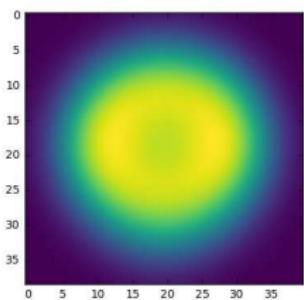
Esser - Største kule



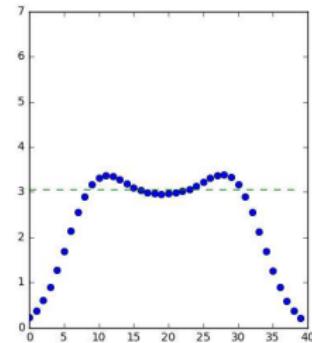
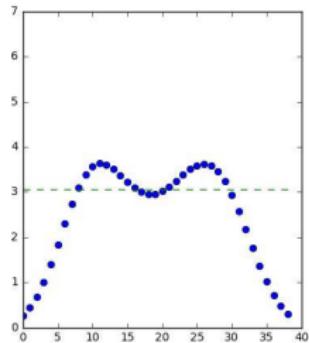
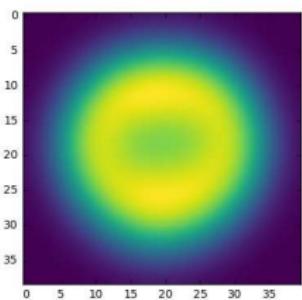
Esser - Største kule



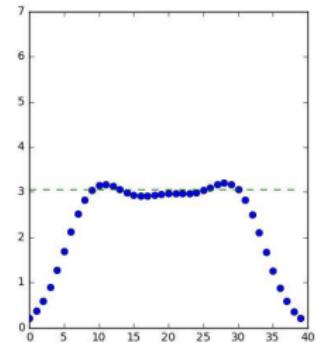
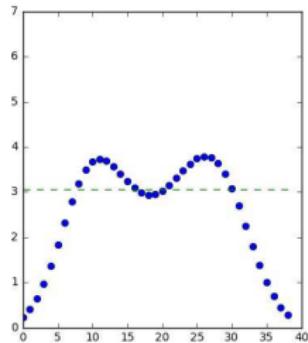
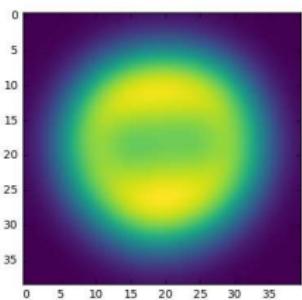
Esser - Største kule



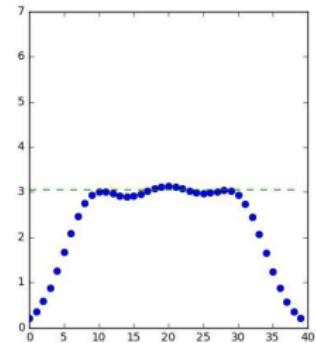
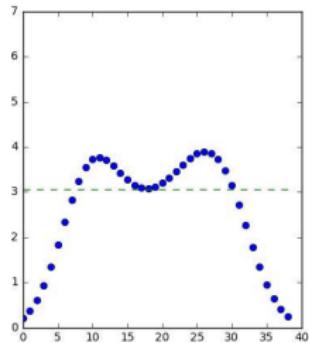
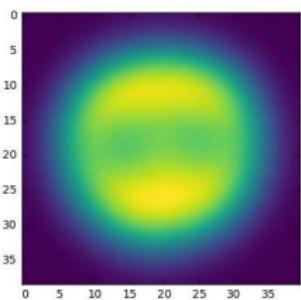
Esser - Største kule



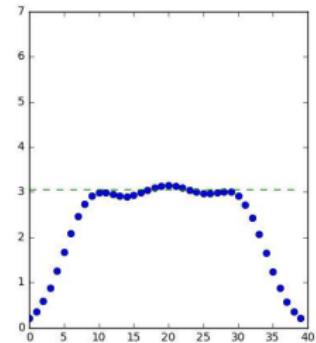
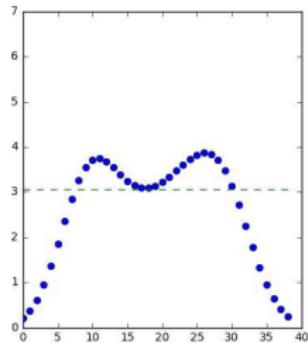
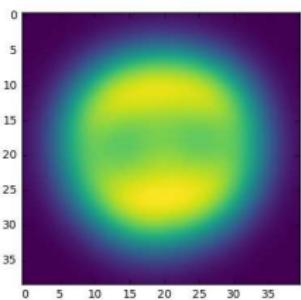
Esser - Største kule



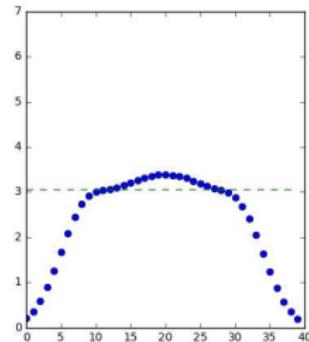
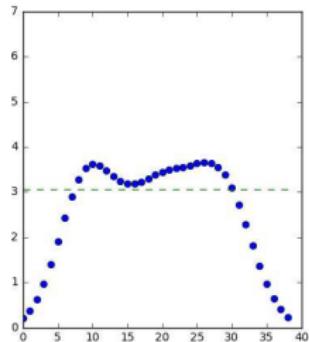
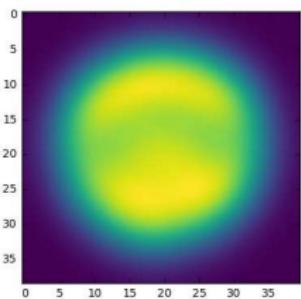
Esser - Største kule



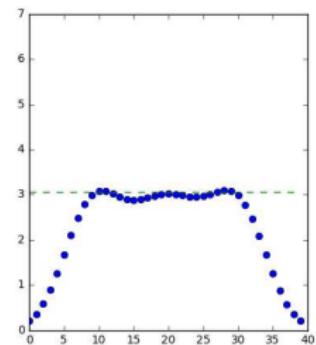
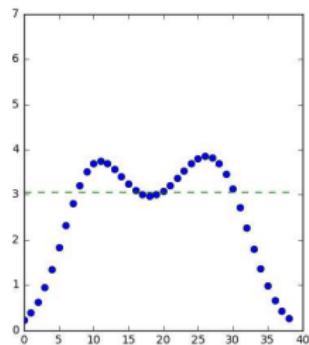
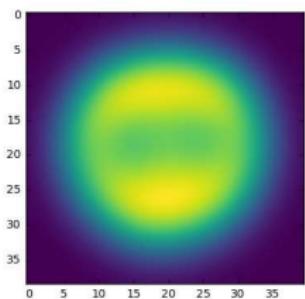
Esser - Største kule



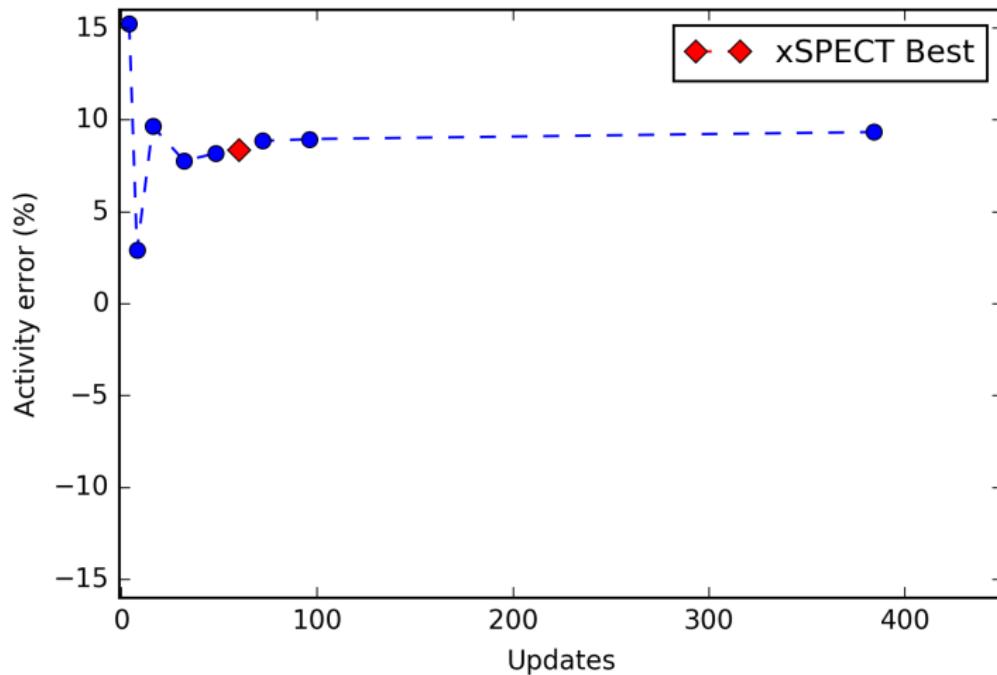
Esser - Største kule



Esser - Største kule



Esser - Oppdateringer vs feil i.e. kvantiteringsevne



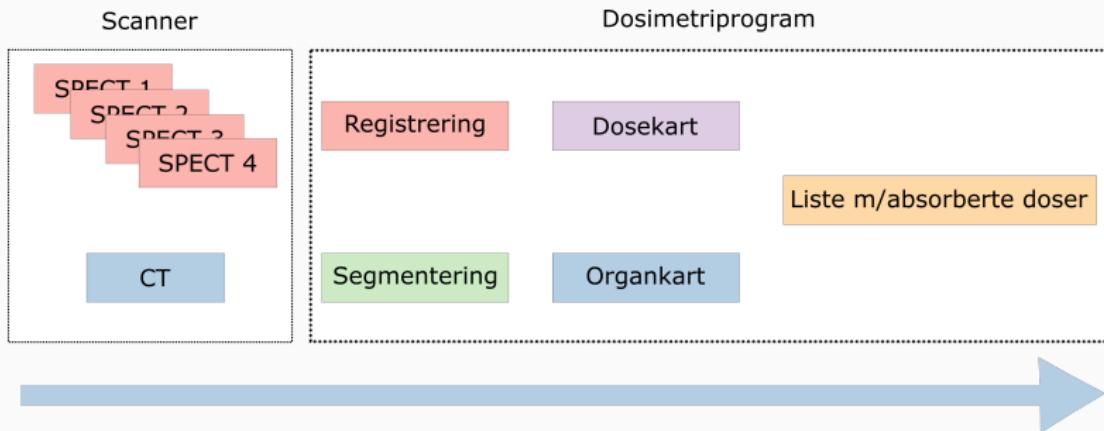
Ta-med-hjem-er fra den prelimenære analysen vår:

- 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

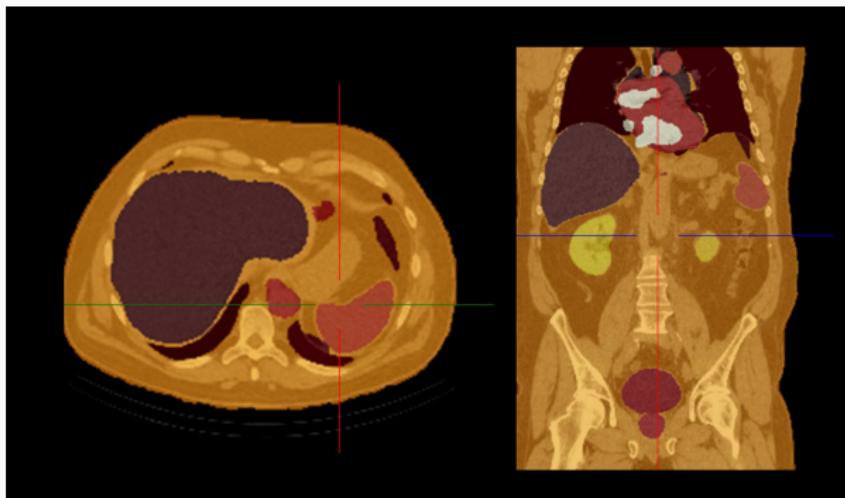
Siemens gjør dosimetri

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

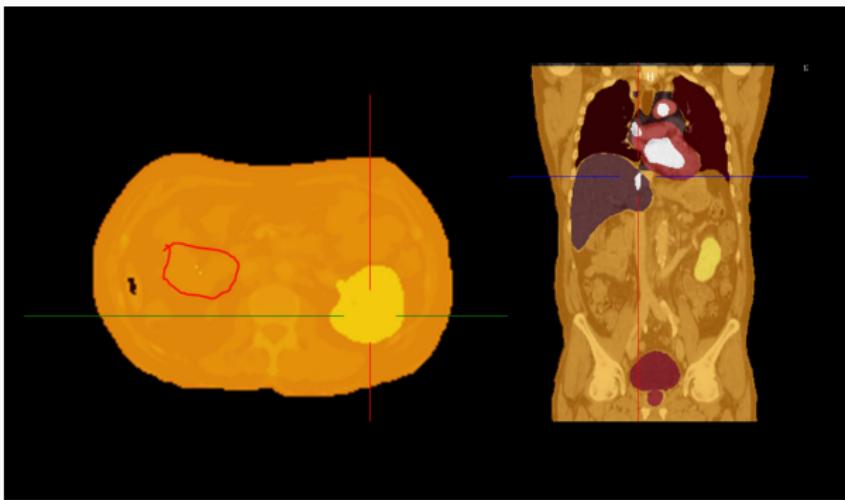
Dosimetri



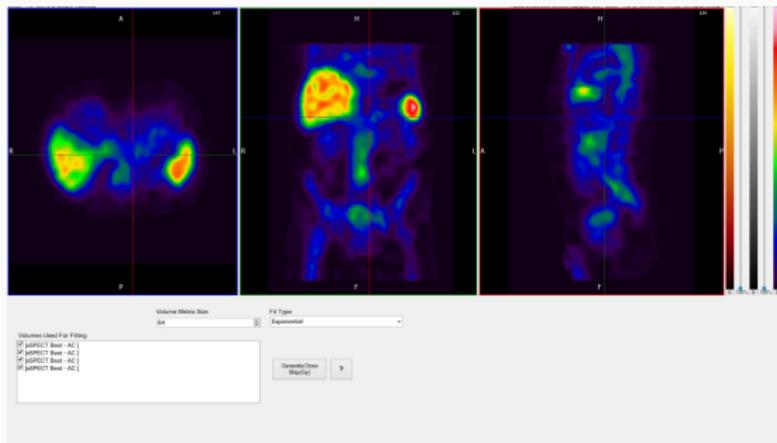
Dosimetri



Dosimetri



Dosimetri



Dosimetri

Agreement with This Device is Exclusively for Clinical Investigations—Genesys Medical Services, USA, Inc. (C) 2011-2013

Organ	Sum (Gy)	Mean (Gy)	S.D. (Gy)	Variance (Gy)	Volume (mL)	Voxels (#)	Median (Gy)	Max (Gy)
Liver # 3	21791.30	0.92	0.22	0.05	1479.09	22558	0.16	1.00
Spleen # 13	7814.57	0.88	0.27	0.07	21.14	8015	0.24	1.30
Hot Tumor # 41	26986.29	0.58	0.07	0.01	345.53	40379	0.37	1.19
Left Kidney Pelvis # 27	272.86	0.81	0.03	0.00	3.98	334	0.84	0.96
Left Kidney Modules # 20	24395.20	0.49	0.07	0.01	387.47	49932	0.28	0.77
Axilla # 11	2465.02	0.49	0.08	0.01	120.31	17958	0.31	0.7
Mediastinum # 2	13209.97	0.44	0.13	0.02	213.86	20807	0.08	0.90
Heart # 10	24074.83	0.43	0.14	0.02	795.87	91432	0.10	1.00
Bladder # 8	1404.83	0.40	0.08	0.01	200.59	1000	0.18	0.51
Prostate # 9	1449.43	0.29	0.07	0.00	38.08	4950	0.11	0.46
Right Lung # 4	36303.41	0.28	0.11	0.01	1608.18	211808	0.07	0.90
Left Lung # 23	34152.83	0.28	0.17	0.02	2024.21	208793	0.08	0.90
Right Kidney # 30	4.69	0.25	0.01	0.00	0.13	17	0.26	0.3

Thank you for your kind attention! (email: johbla@ous-hf.no)

Slides Research grp

