Status of the ongoing analysis of the ^{233}U experiment @OCL

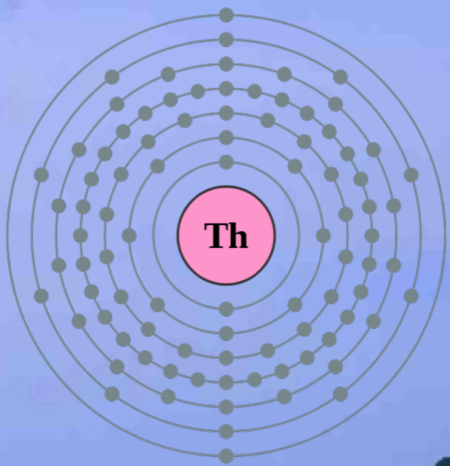
Sunniva Rose, PhD student
University of Oslo,
Department of Physics

5th Workshop on Nuclear Level Density and Gamma Strength
May 2015

This talk focuses on the status on the 233U experiment performed at OCL

1. physics motivation
2. about the experiment
3. preliminary results
4. to be done

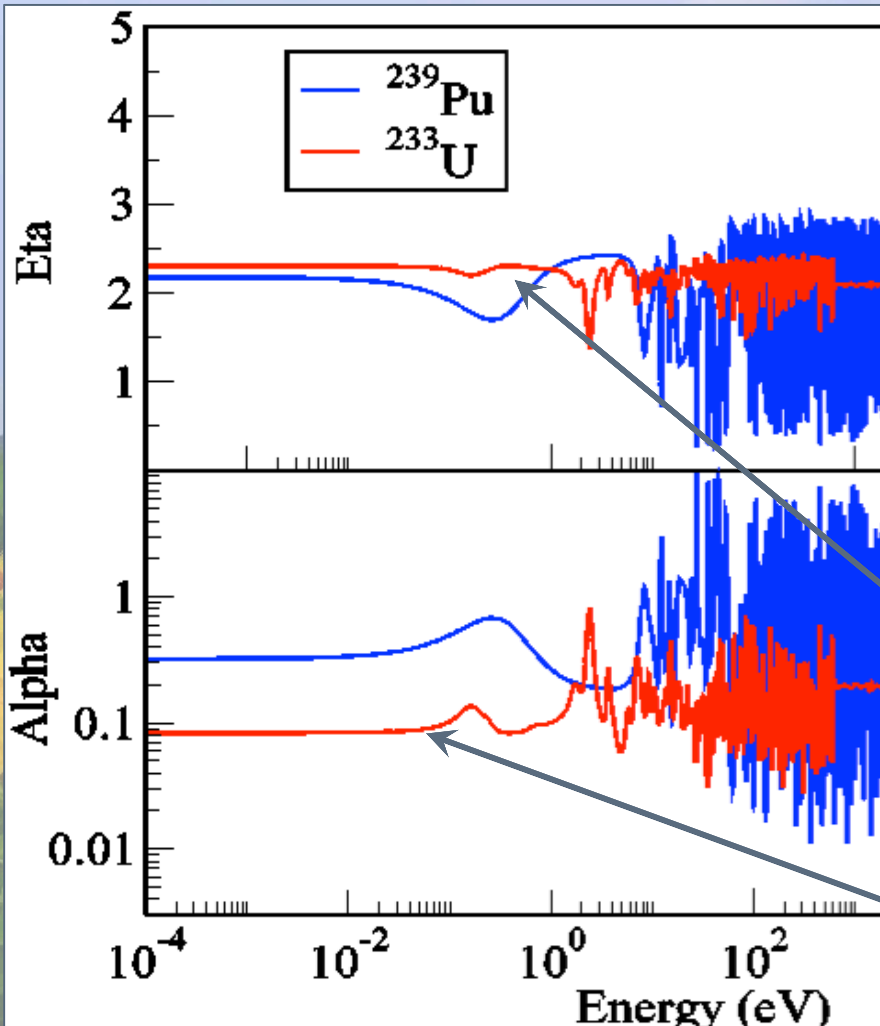
The future of nuclear power; new reactors (fast neutron spectrum) and new fuel (thorium)

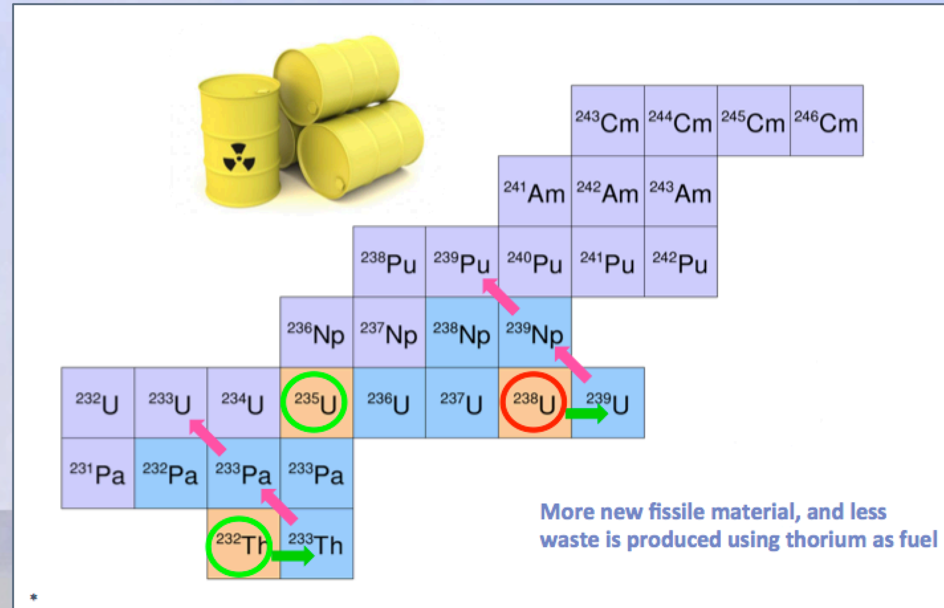


Desired reaction:

$^{232}Th + n \rightarrow {}^{233}Th(\beta^-) \rightarrow {}^{233}Pa(\beta^-) \rightarrow {}^{233}U \rightarrow$ Fission

A major issue with nuclear power is the generation of long-lived radioactive waste





Uranium-233 is a better *fissile* material than plutonium-239, due to both "eta" and "alpha"

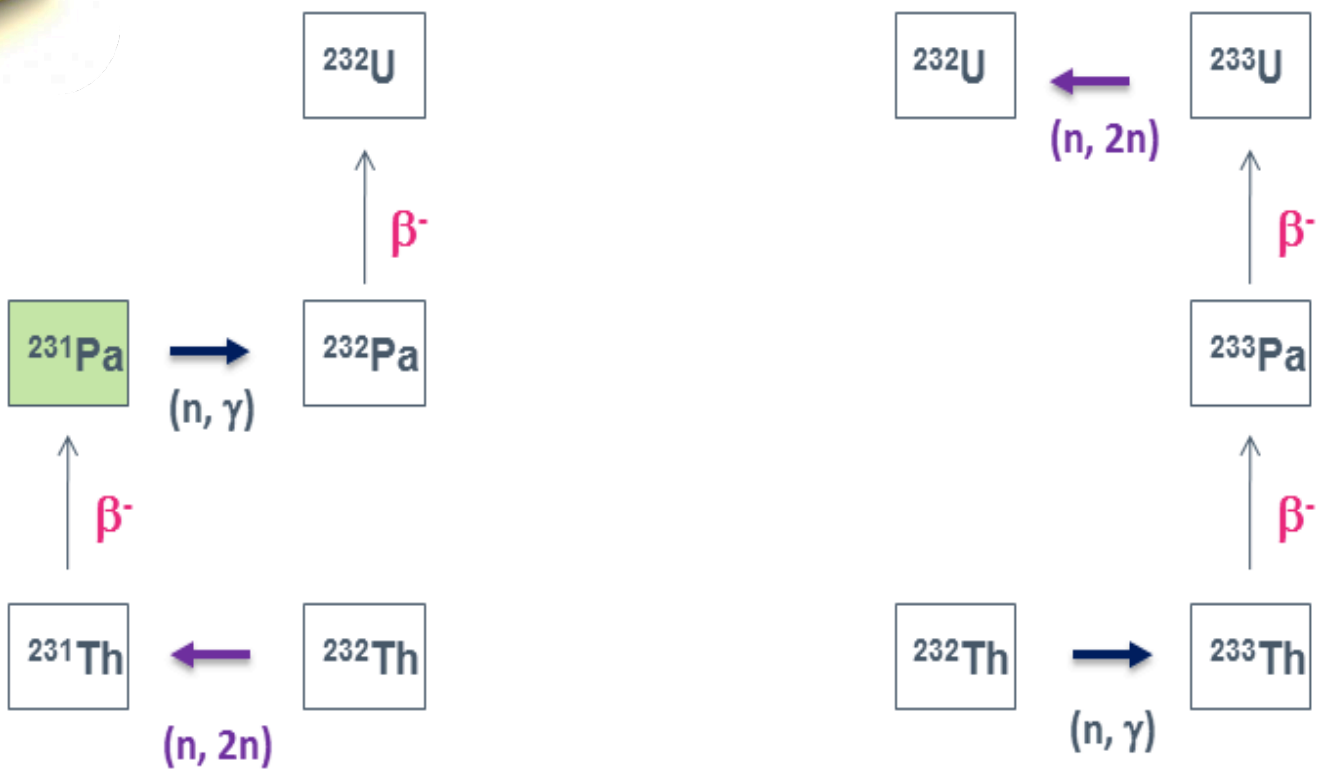
Neutrons emitted per neutron absorbed; more new fissile produced

Capture to fission ratio; waste production smaller

One issue with the thorium fuel cycle is that reprocessing is made difficult by the activity of the ^{232}U isotope (^{208}Tl)

^{232}U is produced in small quantities, mainly in two ways - both involving a (n, 2n) reaction

(However, the 2.6 MeV gamma makes the thorium fuel quite proliferation resistant...)



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No computer simulation is better than the experimental input data on which they rely…

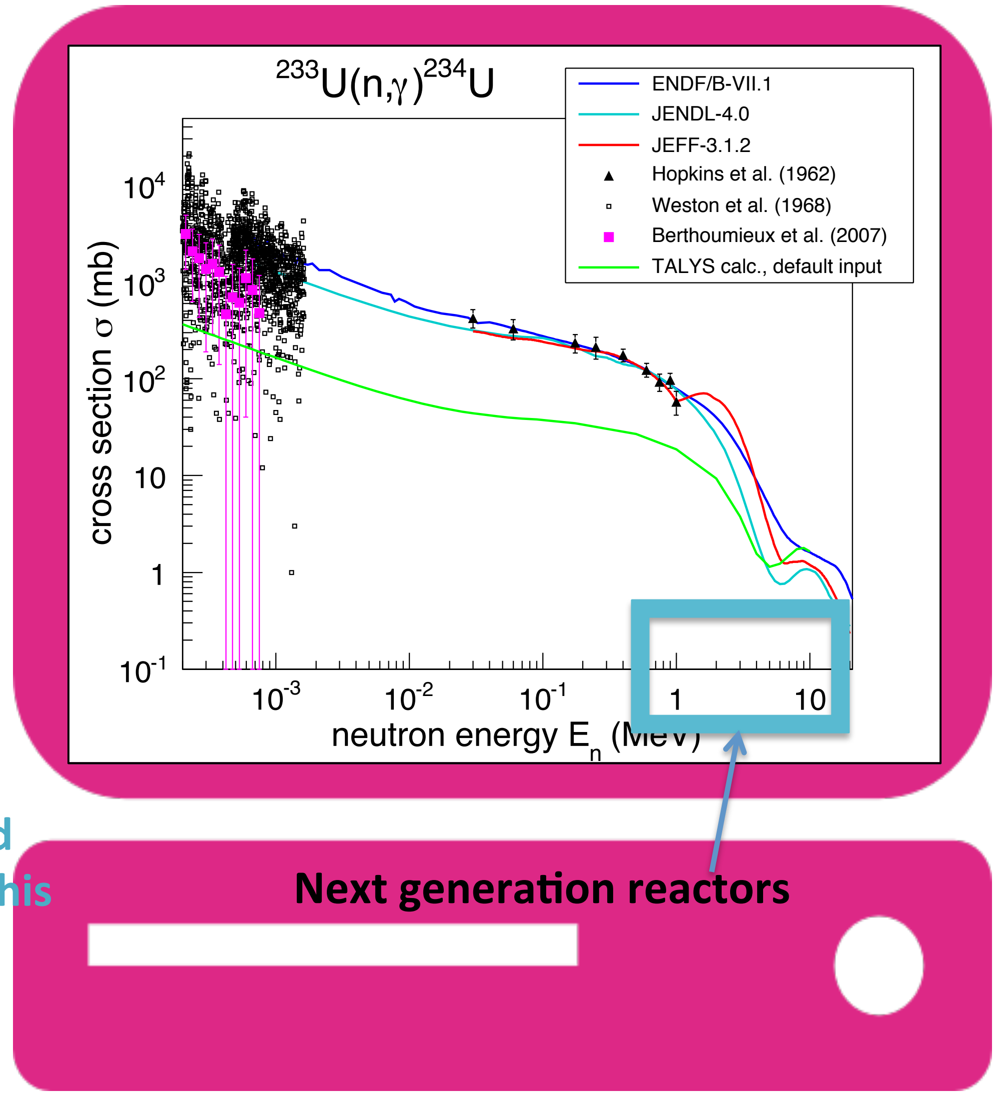
Huge differences for some cross-sections important in the Th fuel cycle

What about the ^{233}U(n,gamma)^{234}U case?

Wish list: direct neutron-induced cross-sections, but not always possible

Neutron capture cross sections from different evaluated data bases + data

TALYS calculations – my level densities and strength function will (hopefully) change this

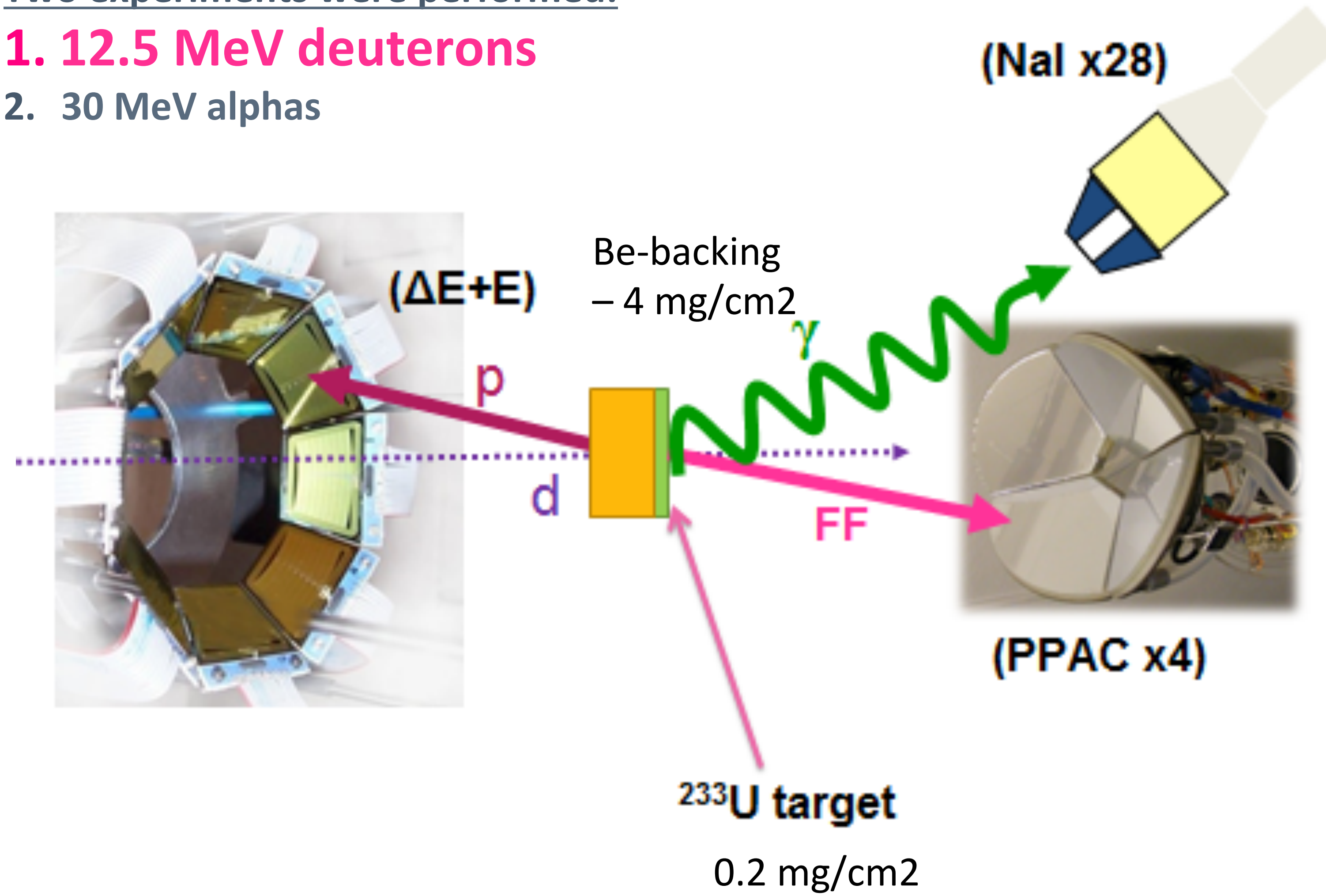


Thanks to Cecilie ☺

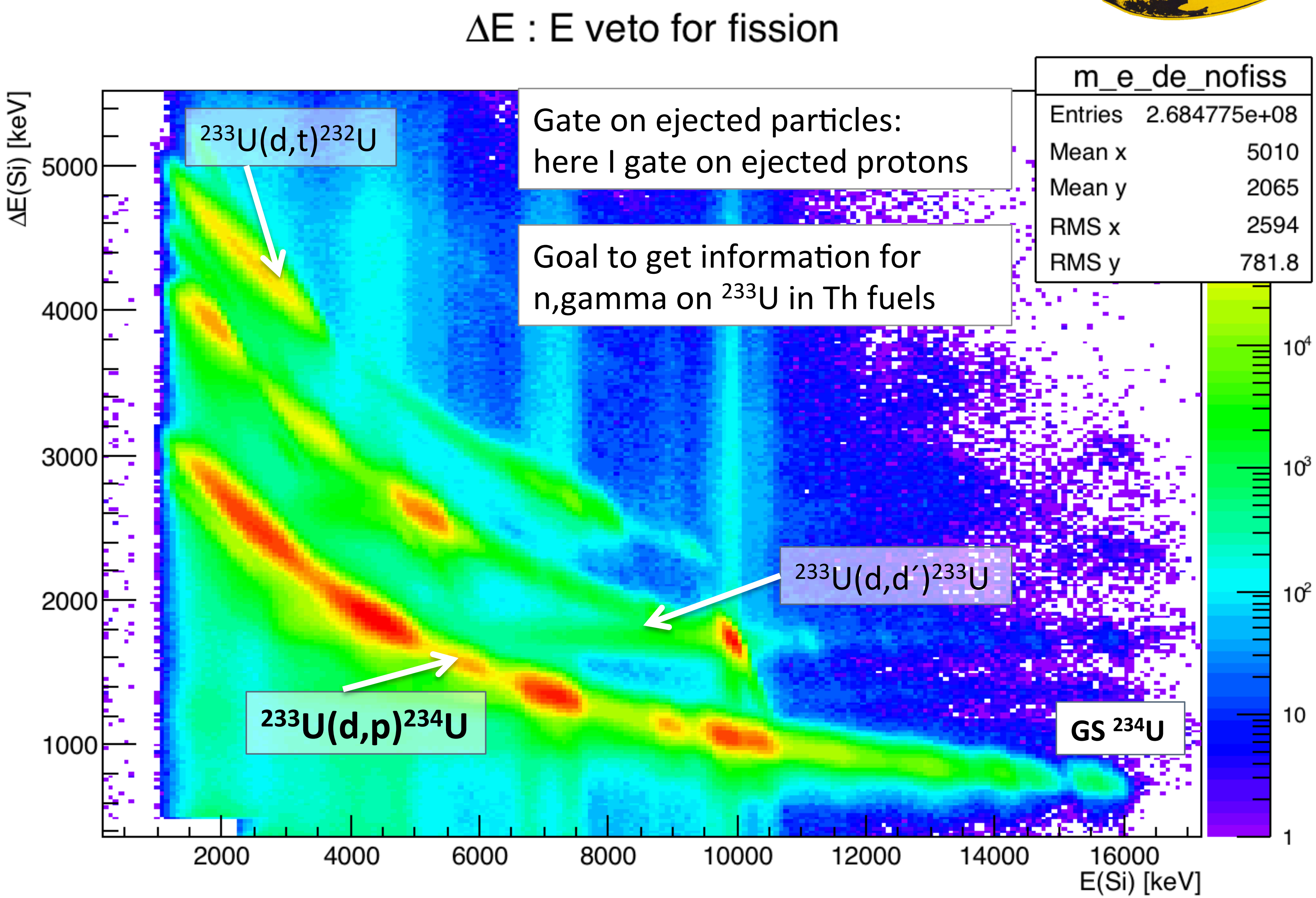
The experimental setup of the ^{233}U experiment at the Oslo Cyclotron Laboratory (OCL)

<u>Two experiments were performed:</u>

1. 12.5 MeV deuterons
2. 30 MeV alphas

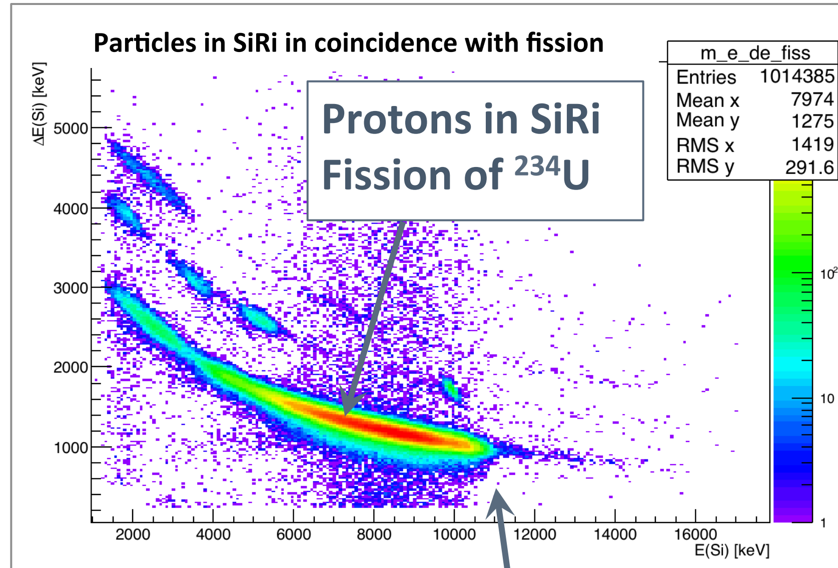


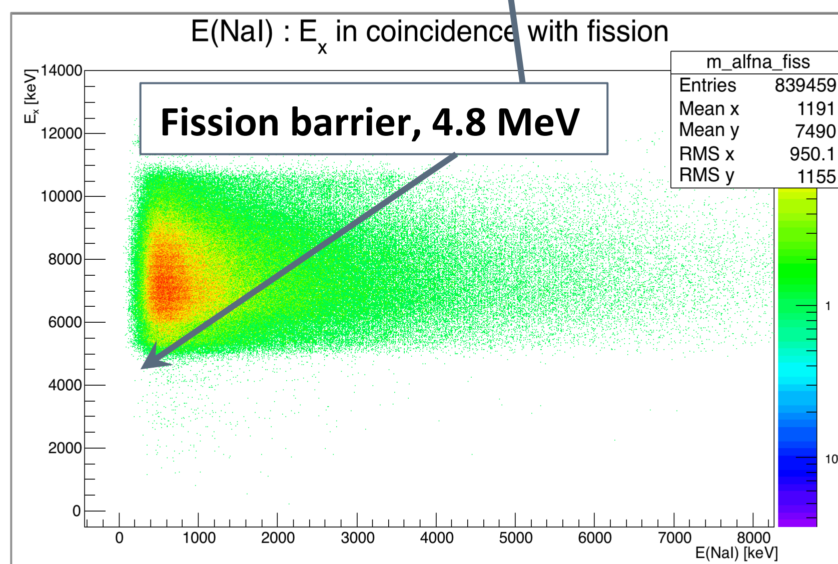
^{233}U experiment at the Oslo Cyclotron Laboratory – particle spectrum



^{233}U experiment at the Oslo Cyclotron Laboratory; The setup with the fission detectors is working

Fission detectors are important for surrogate analysis – were lacking for the Th exp.

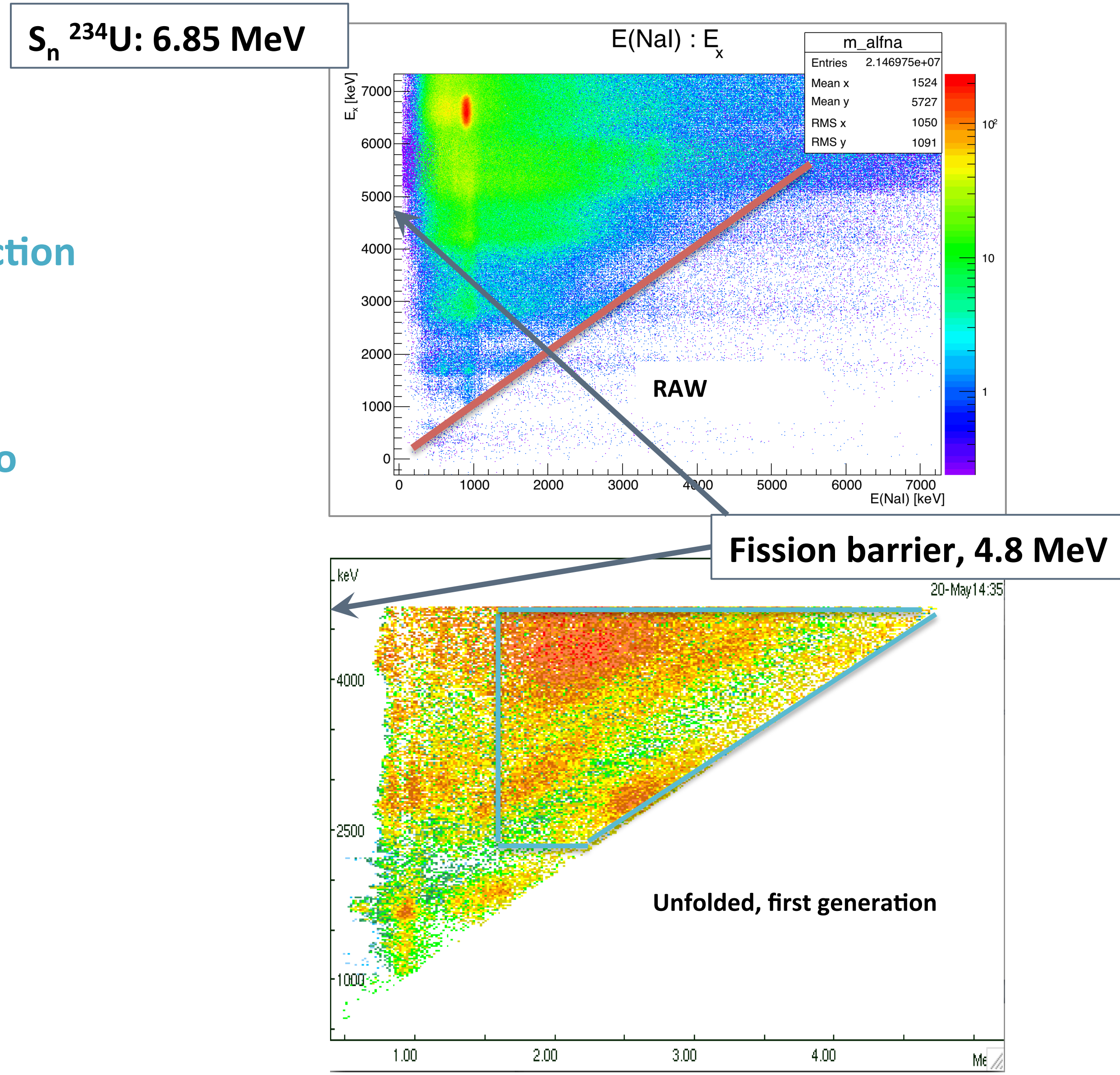




^{233}U experiment at the Oslo Cyclotron Laboratory; gamma particle coincidence matrix – ALFNA matrix

Gamma spectrum as function of excitation energy

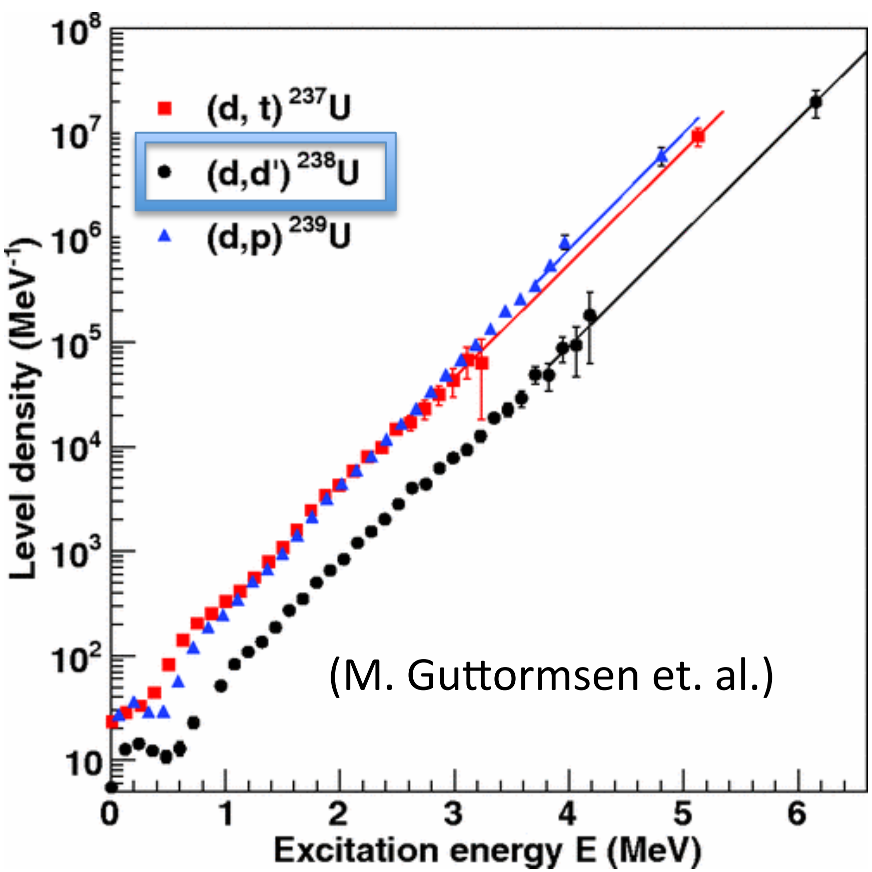
Starting point for the Oslo method

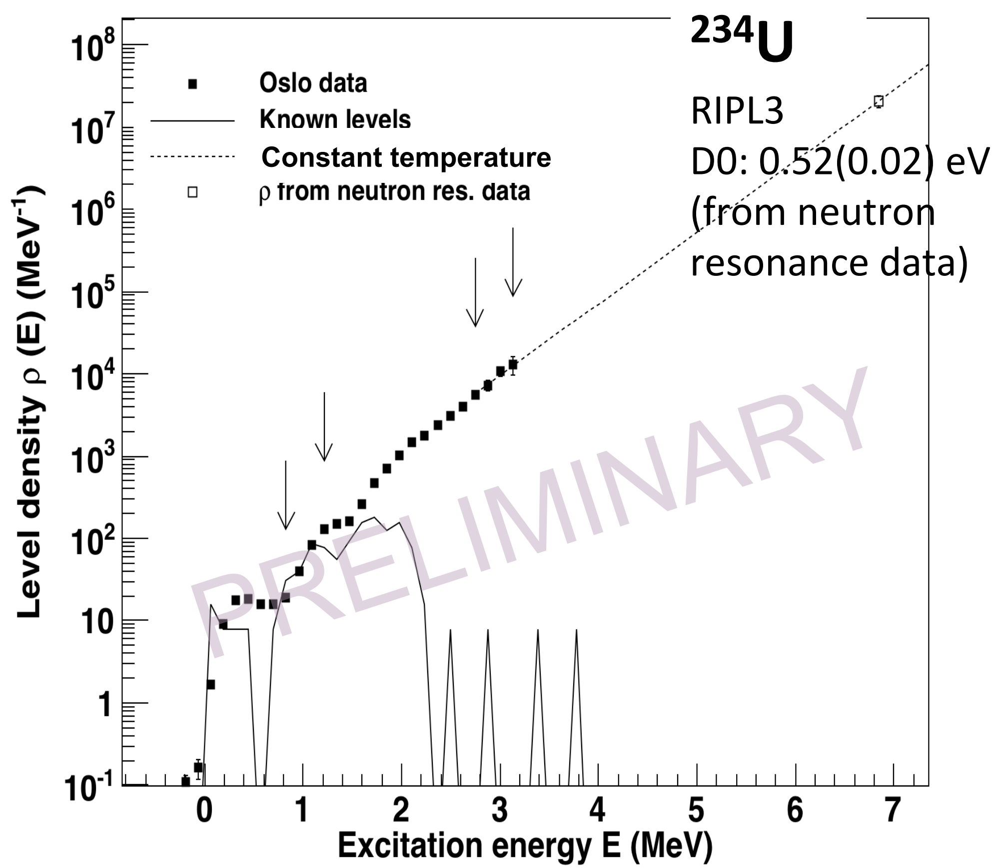


Level density of ^{234}U, found by the "Oslo method"

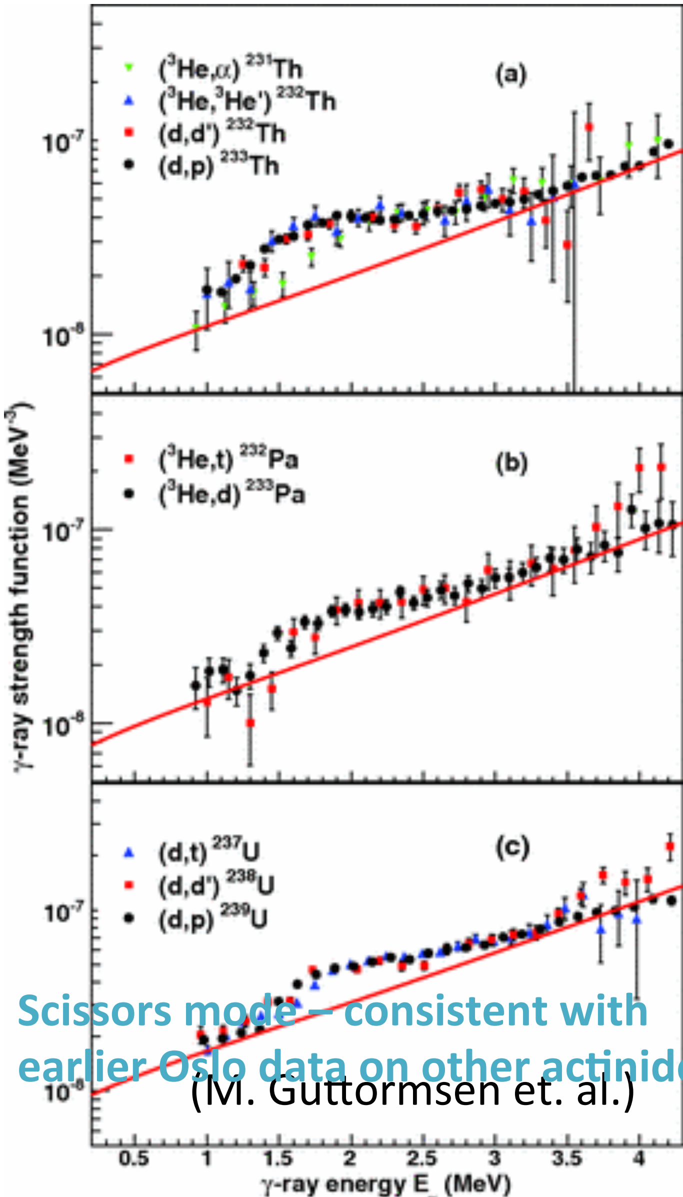
Constant temperature – consistent with other U and actinide nuclei

Hope to get to S_n – work in progress to subtract fission gammas





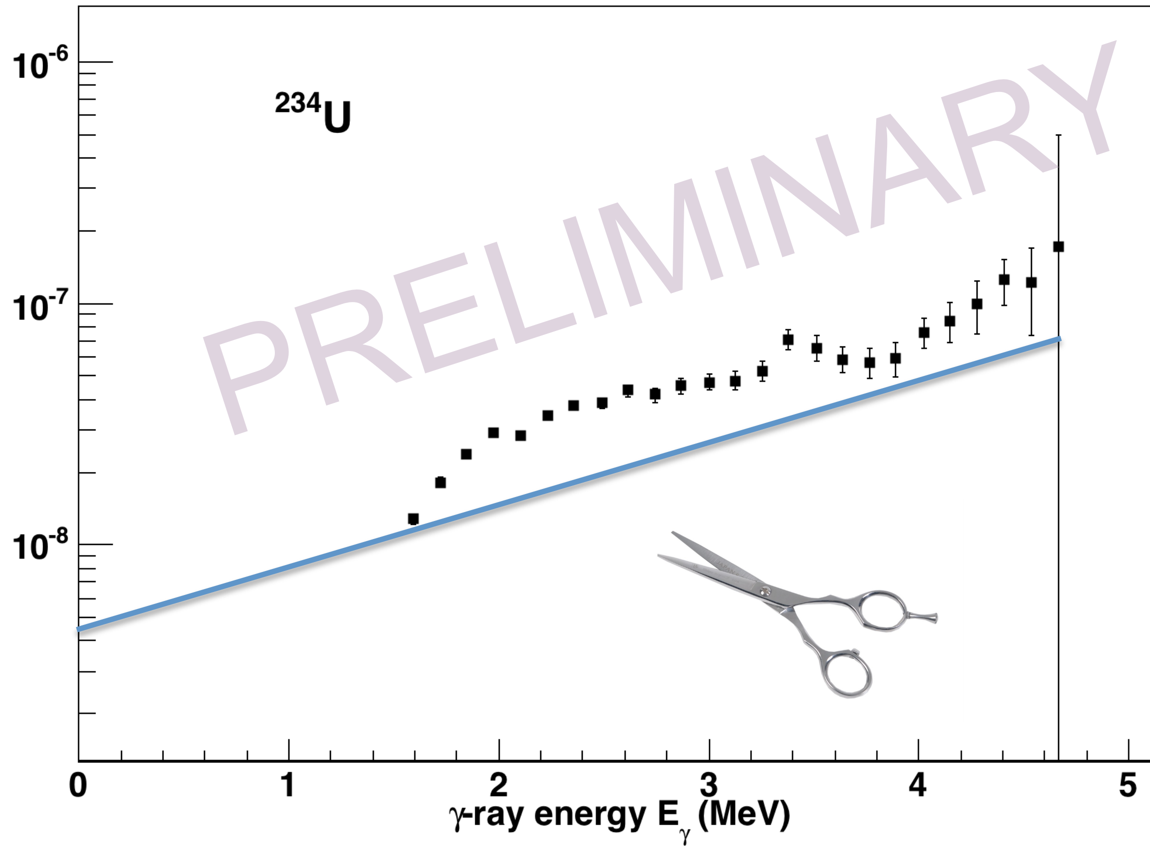
Gamma ray strength function of ^{234}U, data analyzed by the "Oslo method" – in agreement with earlier work



Scissors mode – consistent with earlier Oslo data on other actinides

(M. Guttormsen et. al.)

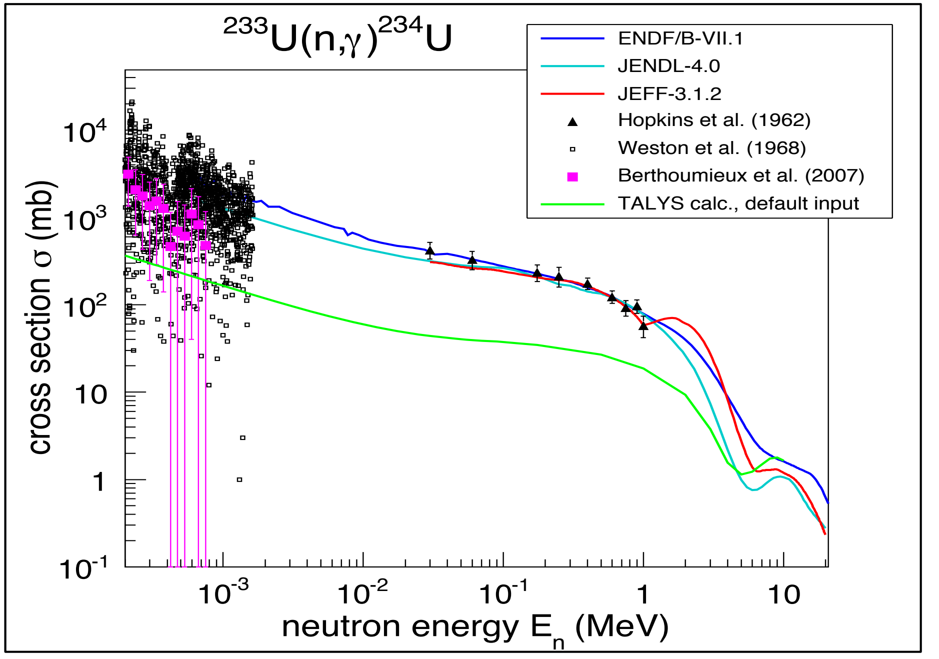
Three times more intense than in the rare earth region

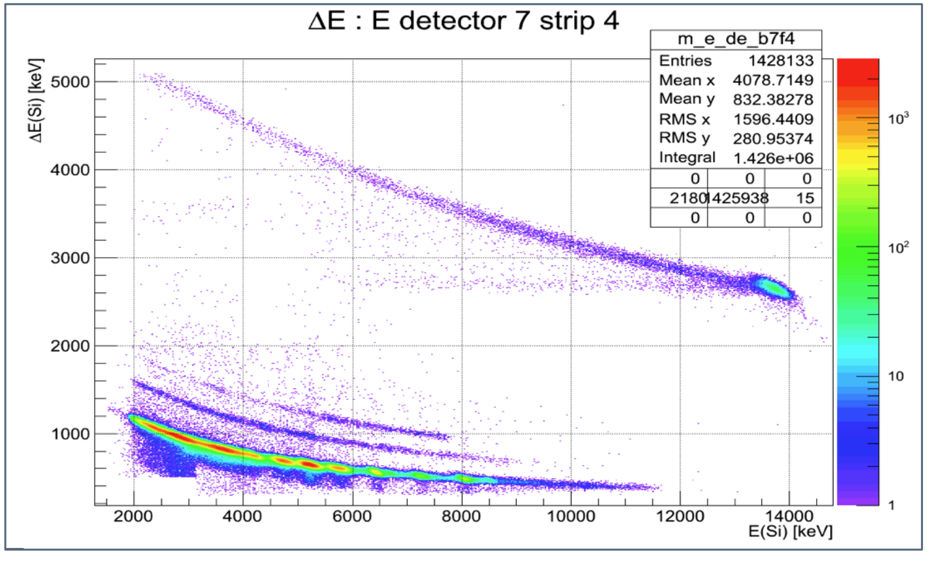


Two experiments were performed on ^{233}U

<u>Deutron (12.5 MeV)</u>:

- Finish Oslo analysis
- (d, p): maybe Surrogate (?)
- TALYS calculations





<u>Alpha (30 MeV)</u>:

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In summary, an experiment on ^{233}U was performed at OCL; the (preliminary) results are consistent with earlier work

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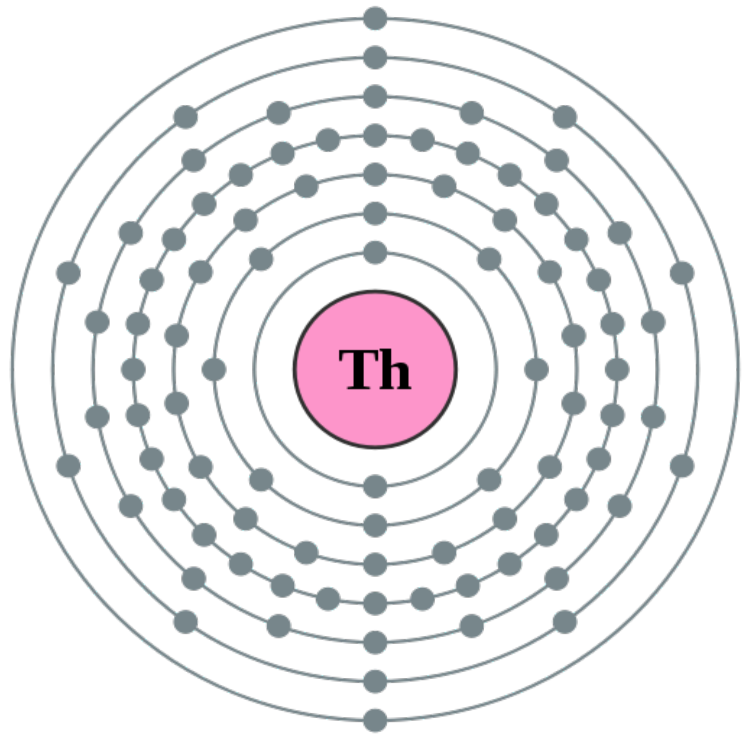

Thank you
for your attention!

Sunniva Rose, PhD student
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in summary….

level density,
gamma
strength

futture work include

to be done

Kommentar fra Bethany Goldblum:
Sammenlikne med Thibault sine Pu-data

Kommentar fra Max (Massimiliano Fratoni): de underestimerer med ENDF som eksisterer – så TALYS er kanskje ikke så way off…kanskje nye level densities og GRSF vil "bekrefte" TALYS???

Some very preliminary results of the ^{233}U experiment

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de underestimerer med ENDF som eksisterer – så TALYS er kanskje ikke så way off… kanskje nye level densities og GRSF vil "bekrefte" TALYS???

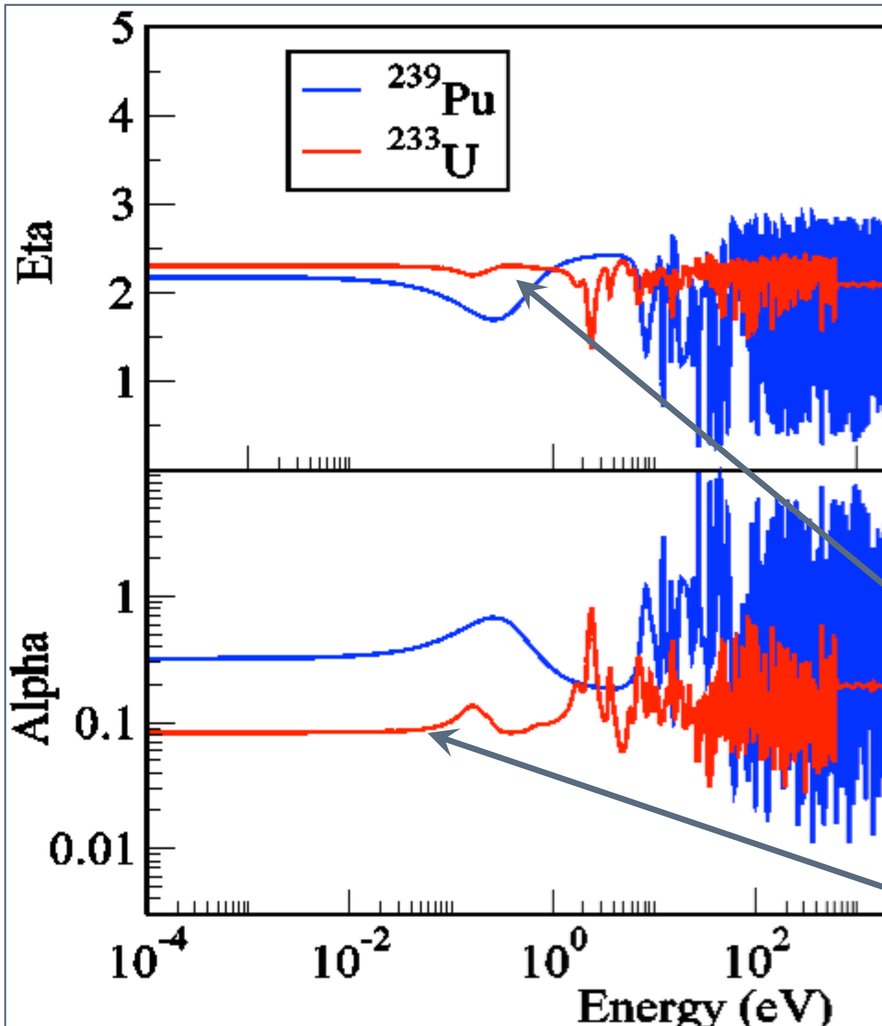
Kommentar fra Rick: prøve å skrive popvit for nature eller science

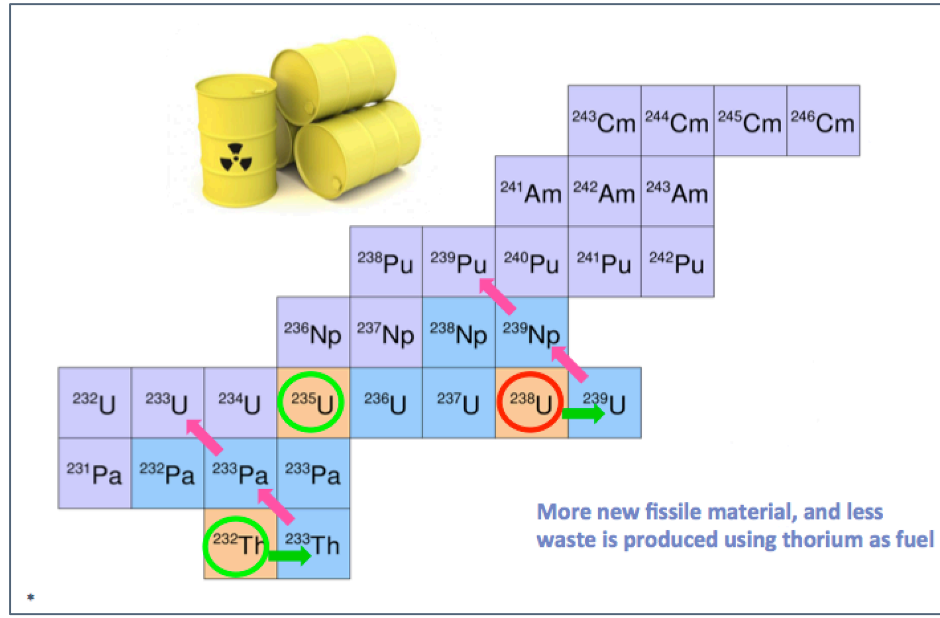
Sunniva Rose
University of Oslo,
Department of Physics

Sather Workshop on
Next Generation Nuclear Science
December 2014

A major issue with nuclear power is the generation of long-lived radioactive waste

desired reaction:





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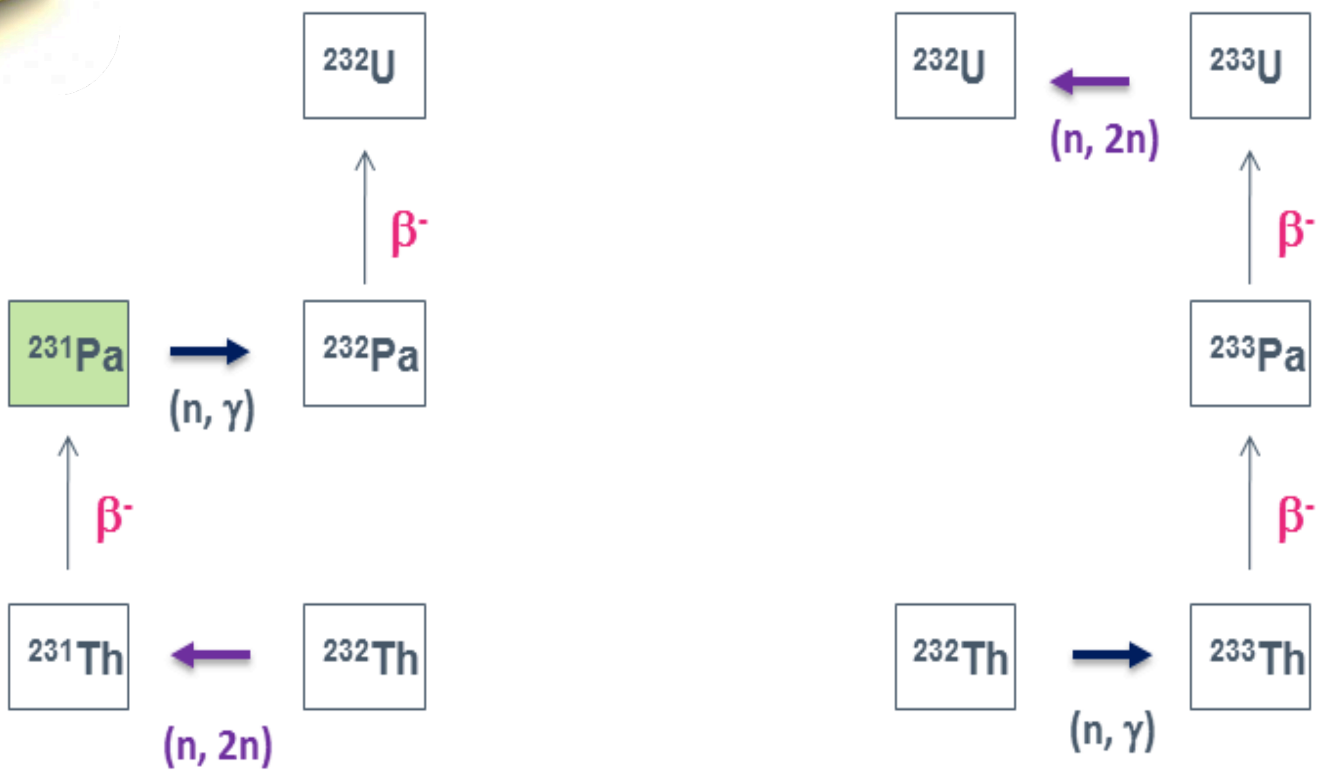


*

No computer simulation is better than the experimental input data on which they rely...

cec sine figurer med level density og GSF i talys...strong motivation fits perfectly

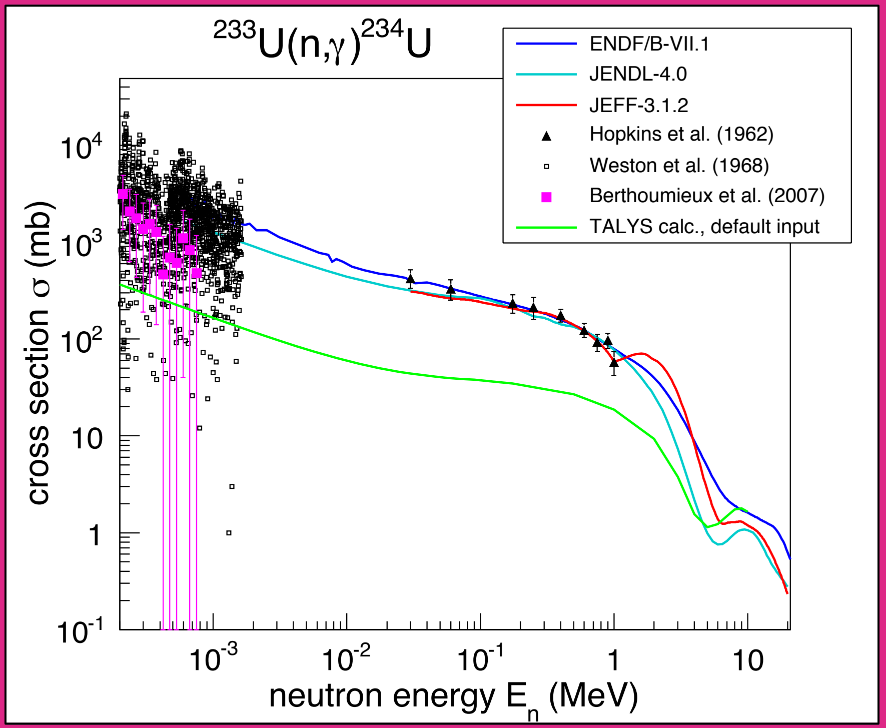
vi får info i gapet mellom 1 og 10 MeV – bra for next gen

Huge differences for some cross-sections important in the Th fuel cycle

What about the ^{233}U(n,gamma)^{234}U case?

Wish list: direct neutron-induced cross-sections, but not always possible

Neutron capture cross sections from different evaluated data bases + data



TALYS calculations – level densities and strength function will change this

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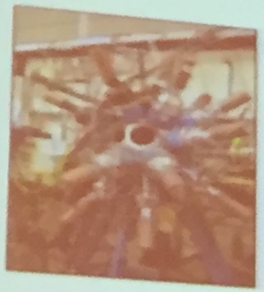
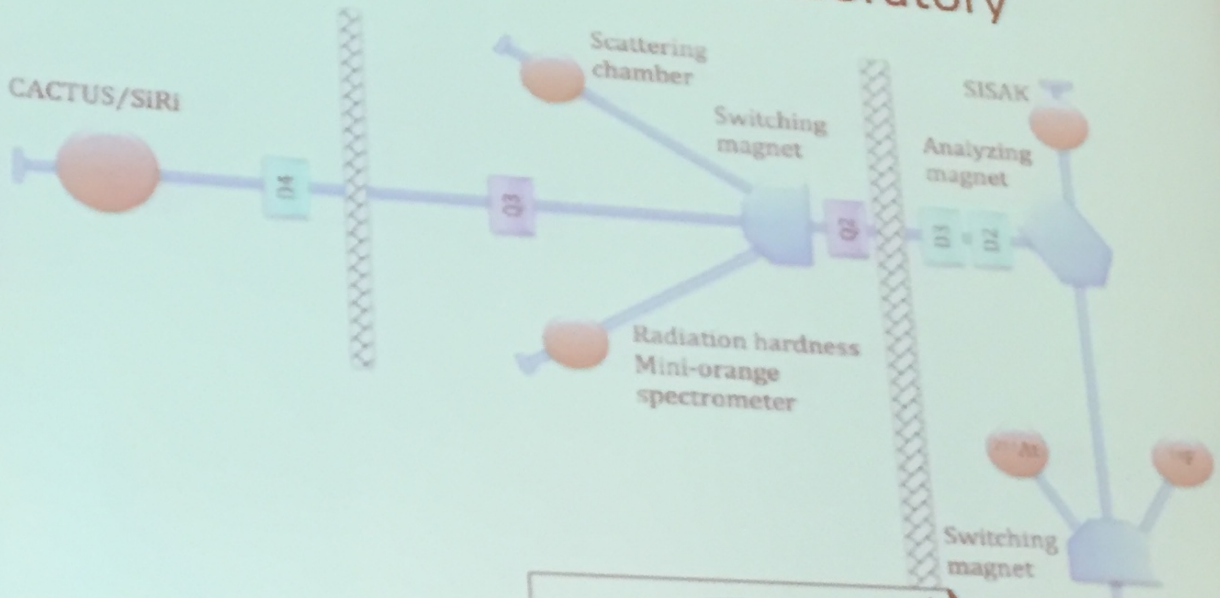
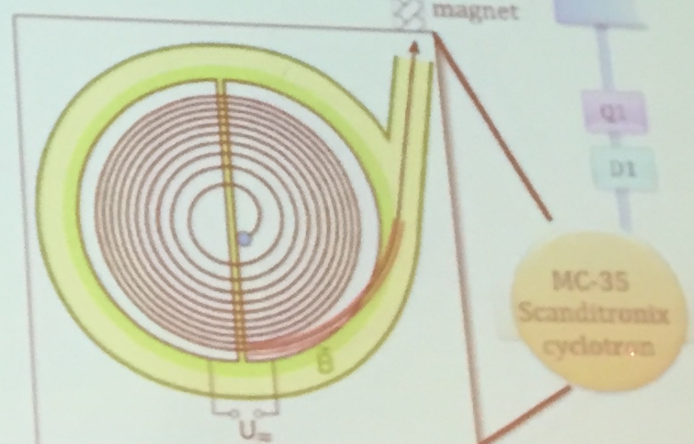
The infrastructure at the Oslo Cyclotron Laboratory





Ionized beams Particle type	Energy (MeV)
Proton	2 – 35
Deuteron	4 – 18
^{3}He	6 – 47
^{4}He	8 – 35



p, d, 3He, alpha

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Two experiments were performed:

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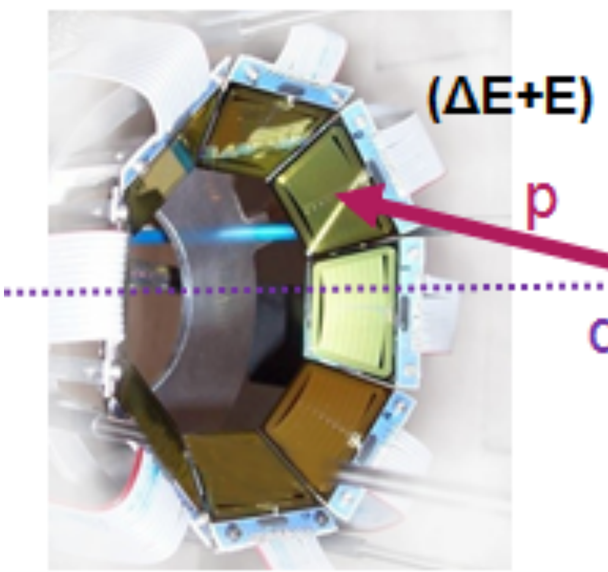
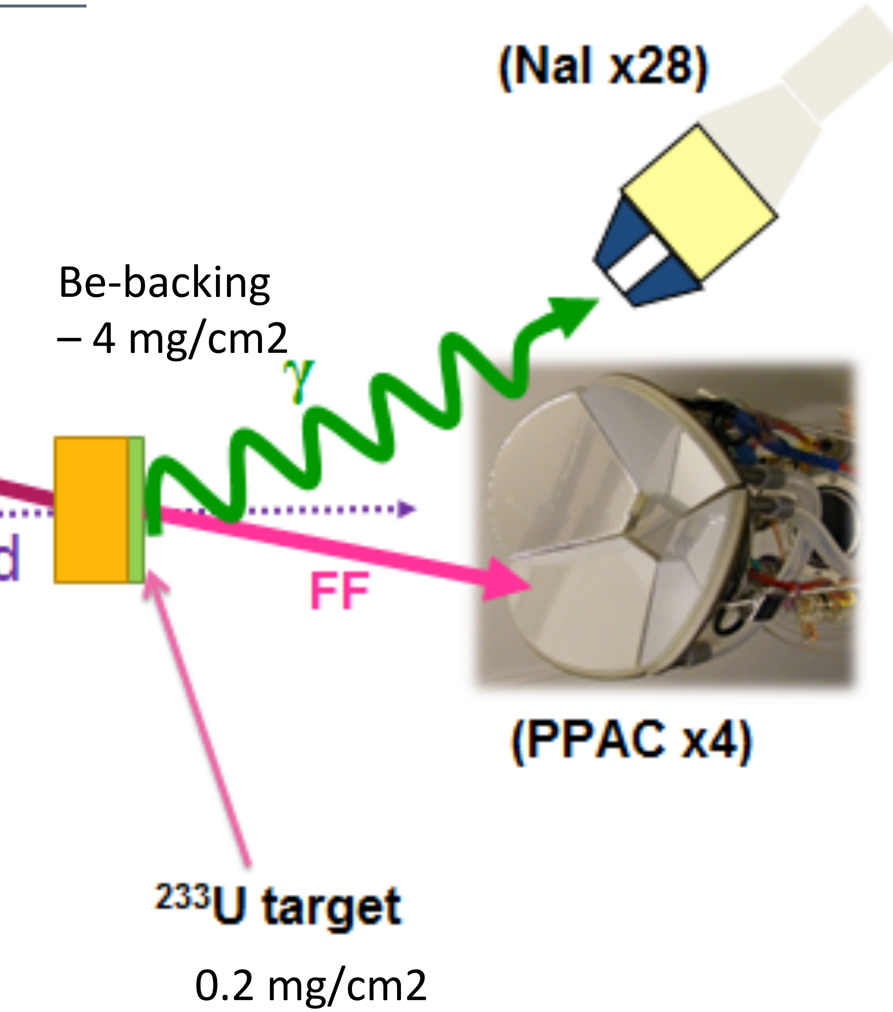
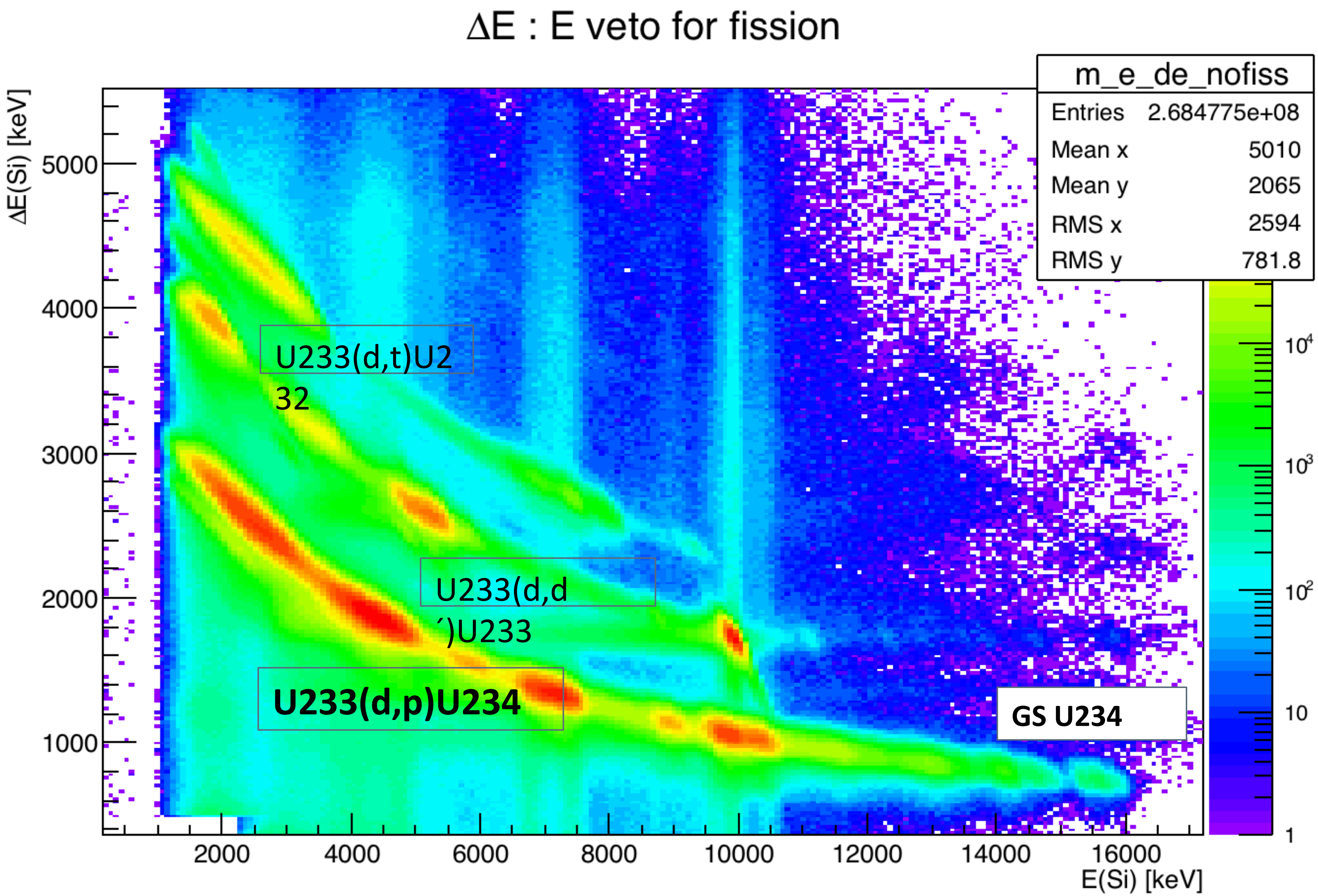
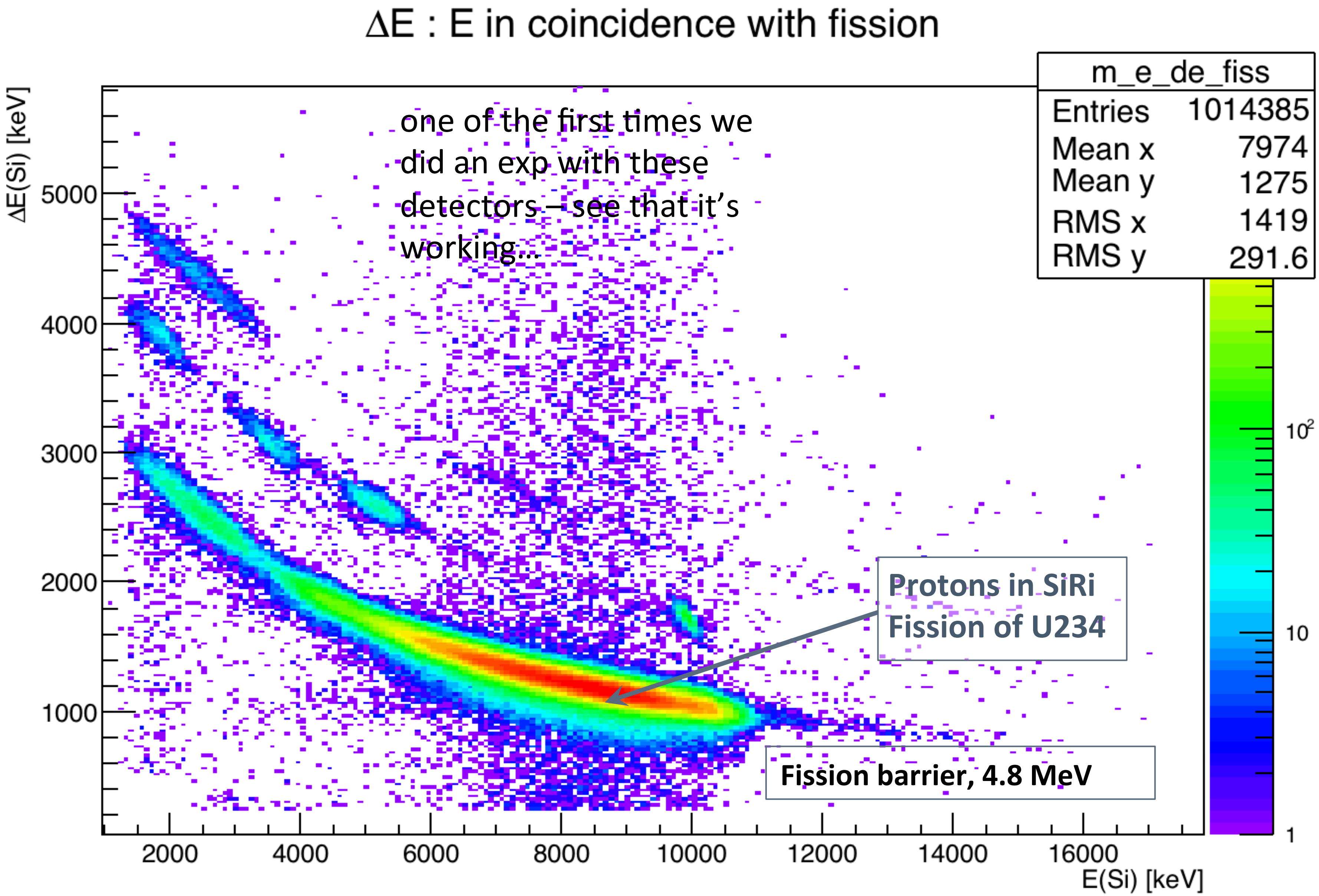




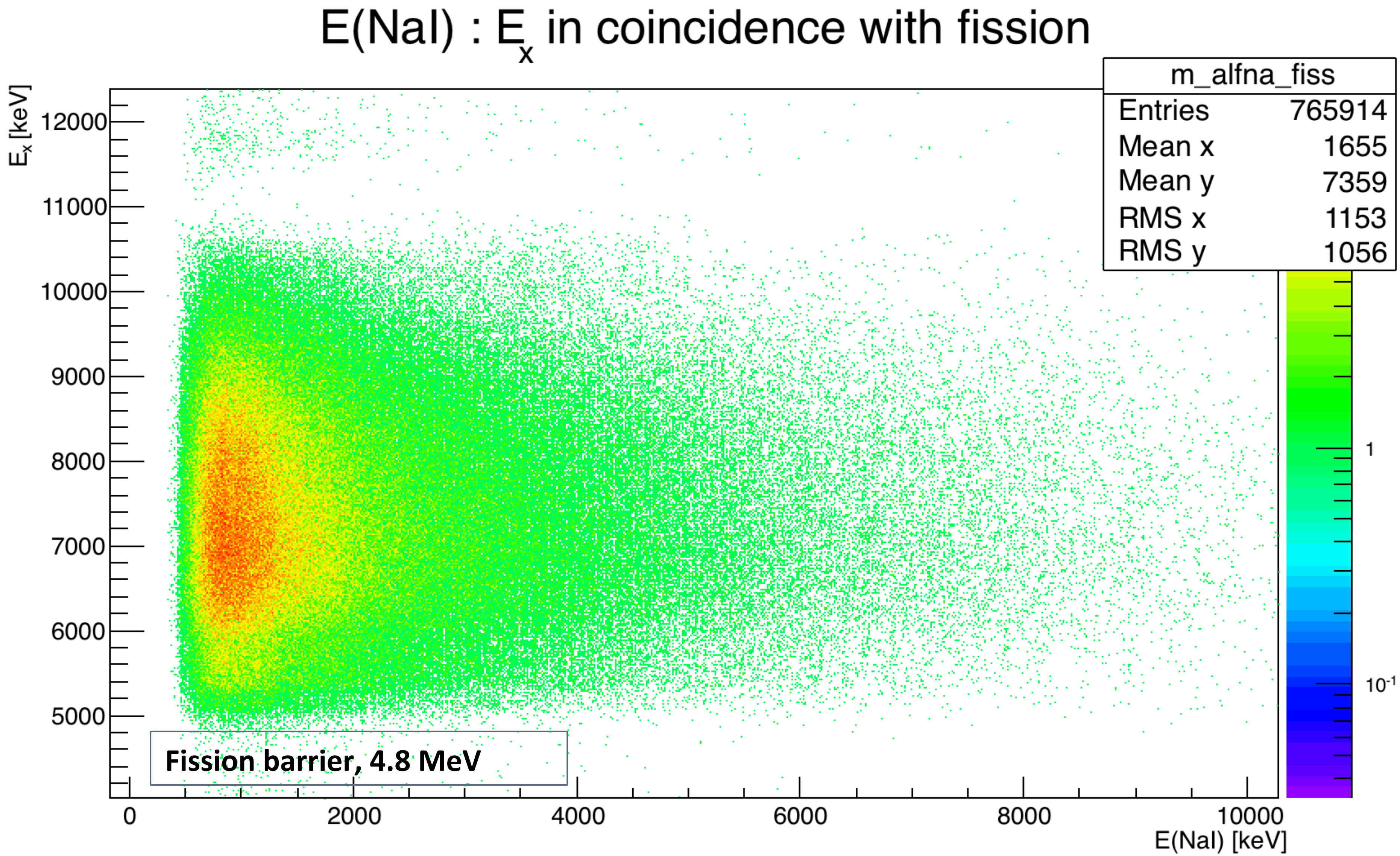
^{233}U experiment at the Oslo Cyclotron Laboratory



^{233}U experiment at the OCL; particles in SiRi in coinsidence with fission



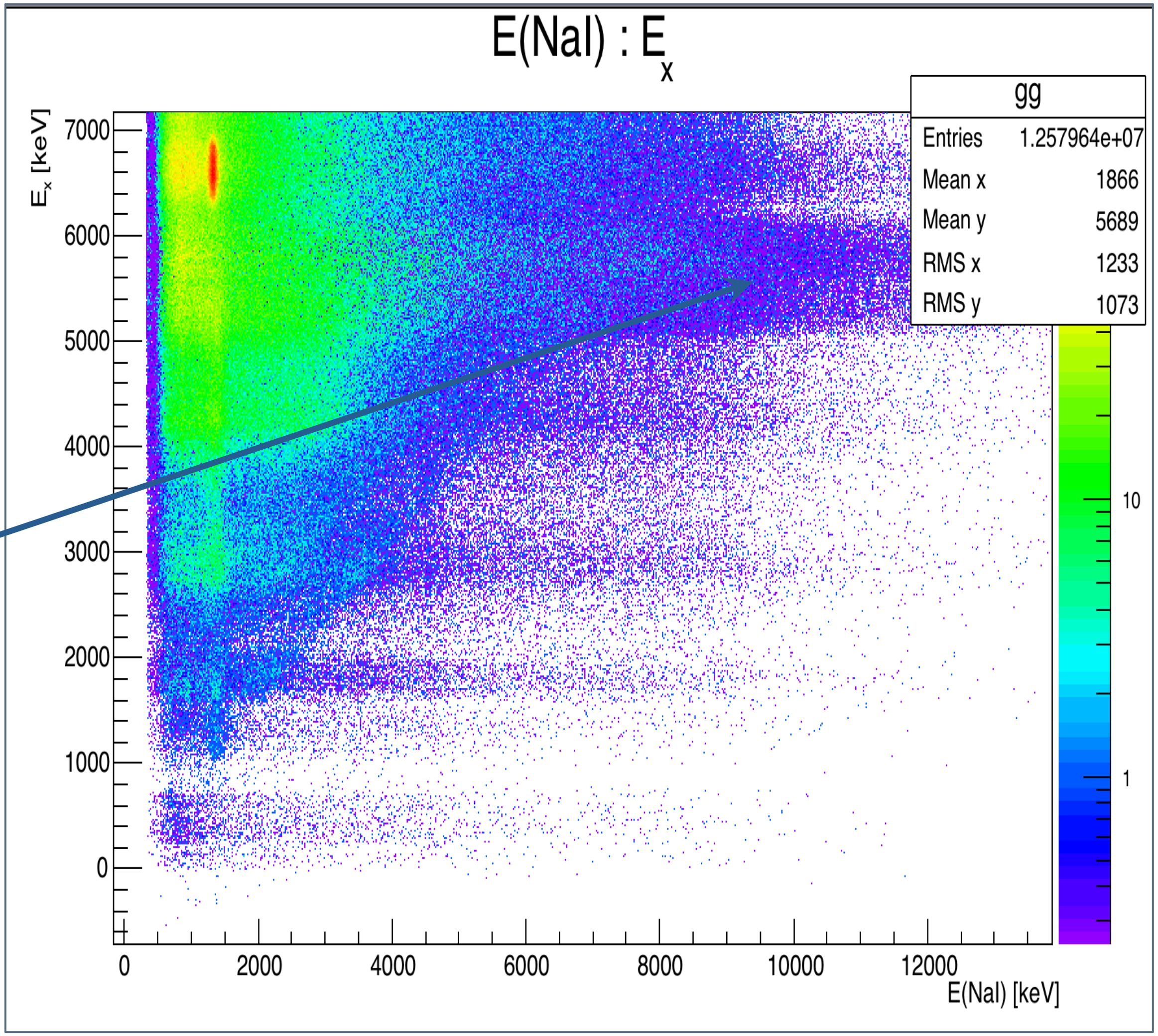
^{233}U experiment at the OCL; Gammas from fission fragments



Gamma spectrum as function of excitation energy

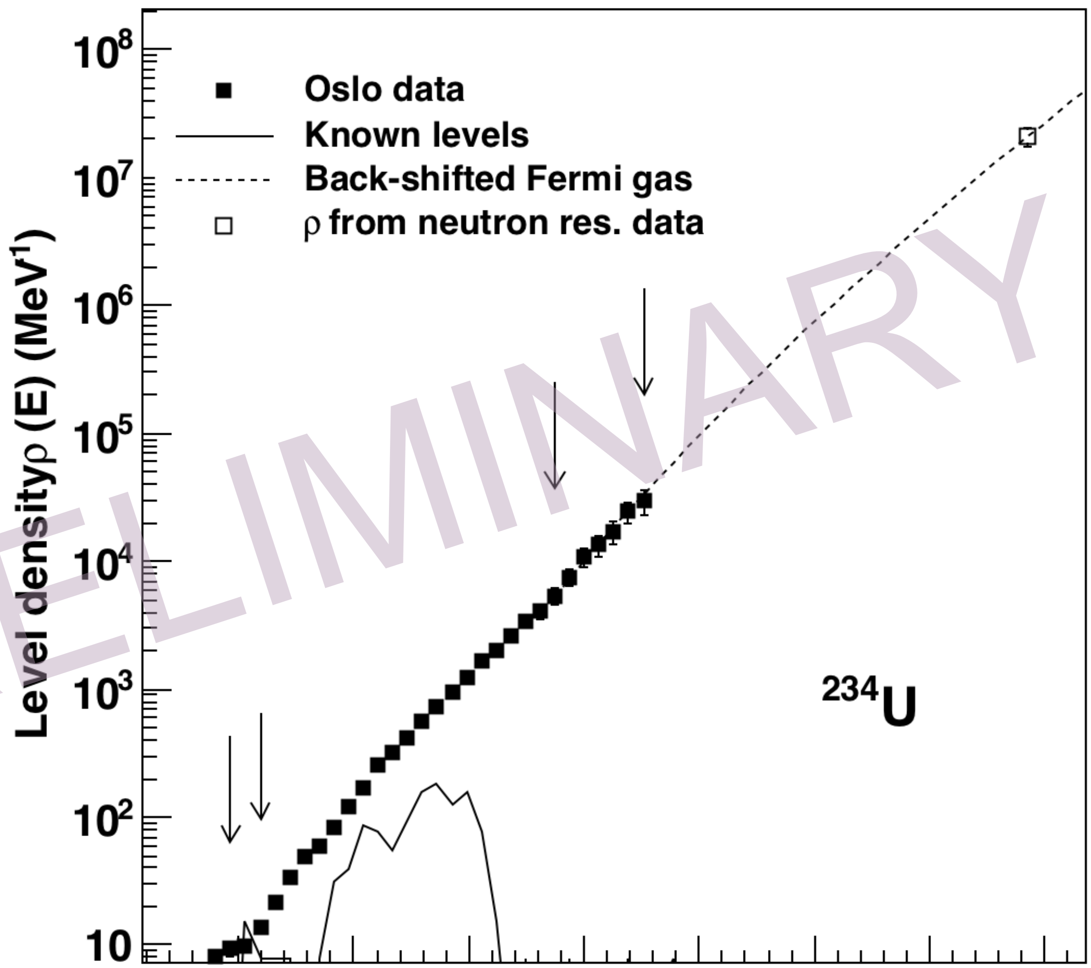
Starting point for the Oslo method

Gammas from fission fragments



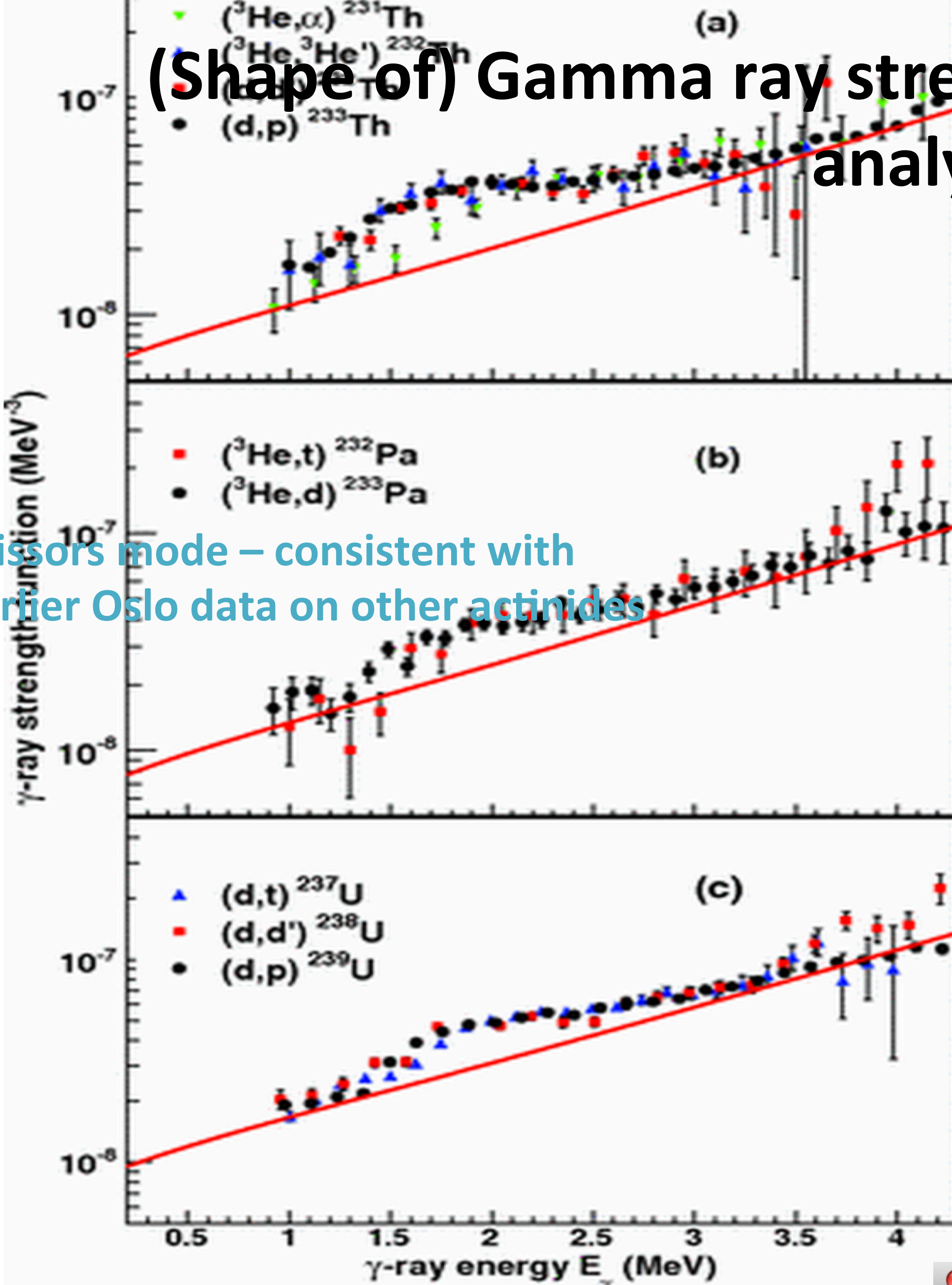
(Shape of) Level density of ^{234}U, found by the "Oslo method"

Constant temperature – consistent with other U and actinide nuclei



Excitation energy

(Shape of) Gamma ray strength function of ^{234}U, data analyzed by the "Oslo method"



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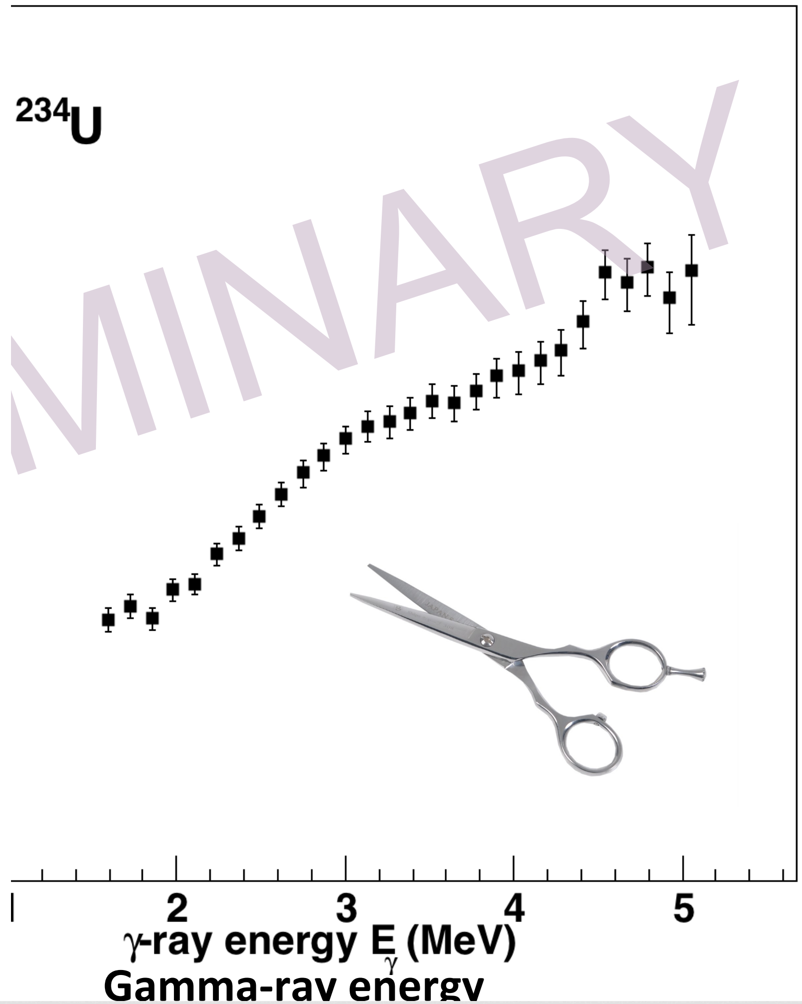

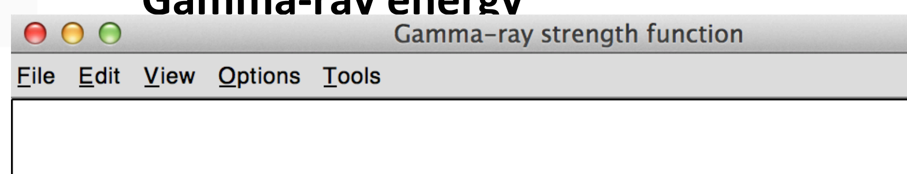

(M. Guttormsen et. al.)

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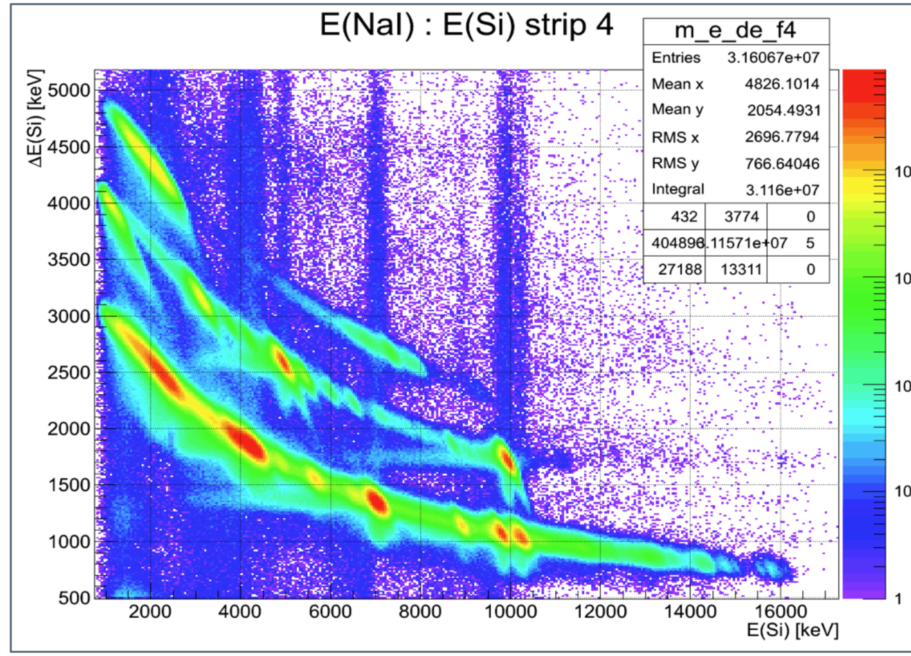
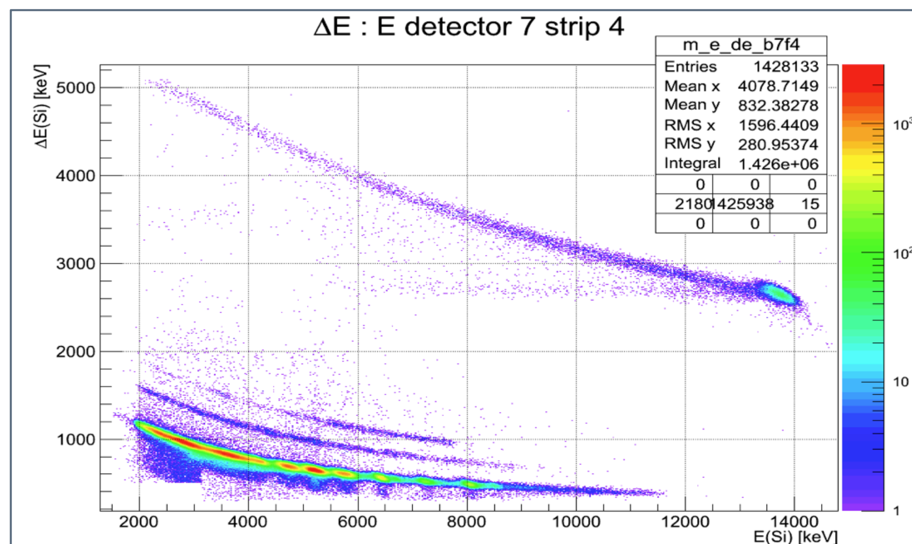
<u>Deutron (12.5 MeV)</u>:

(d, p): maybe Surrogat (?)

(d,d´): try to gate on deuteron banana (information on ^{233}U)





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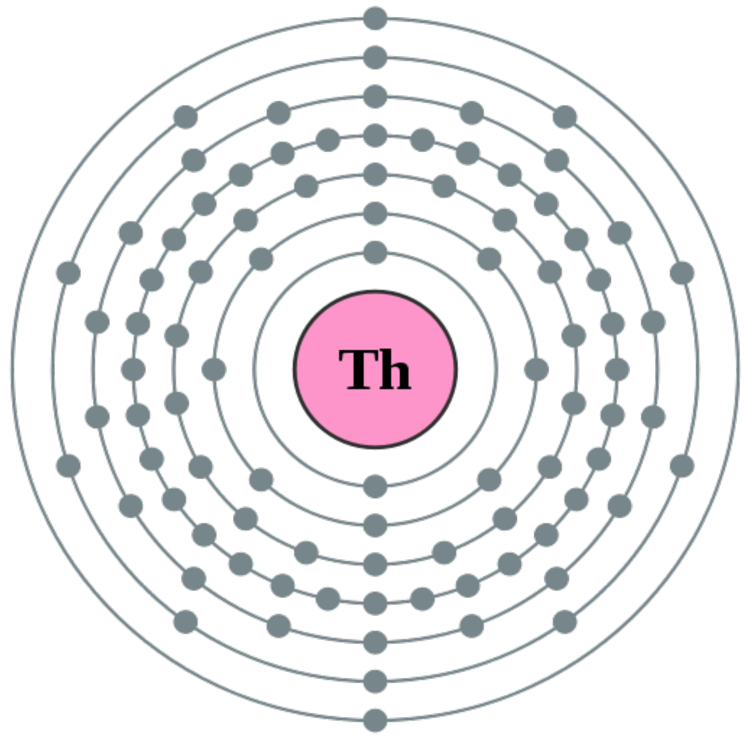

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S/B Fast reactor – mye bedre ifølge presentasjon onsdag…
“pancake” shape core
Ta vekk Na – innføre positiv reaktivitet – må kompensere, med leakage
Hva er I S/B? B: naturlig Th, nat U, brukt brensel – de n som escaping blir dermed fanget I Th, U8 → lager fissil. B alltid sub critical, men 50% av energien lages I B. ingen reprossessering. Får 10% BU av Th (sammenlinet med 0.6% vanligvis) – hvis U8 opp til 15%
Generelt så får fast reacyors mye høyere BU enn termiske reaktorer
“dpa”?

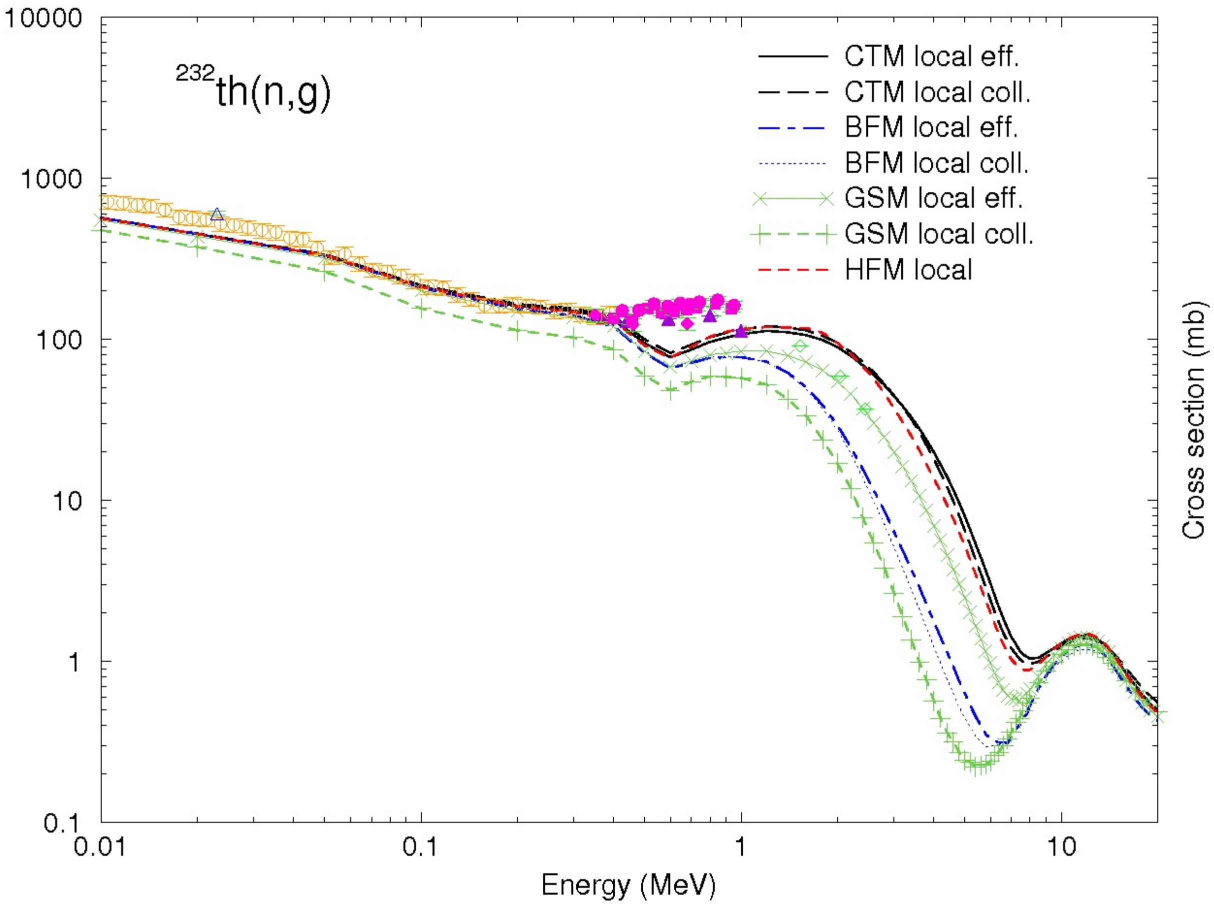
Vil ha excess U3 – så man kan starte Th/U3 fuel cycle

Hva med Pa231?
Hva med resirkuleringen? Fast spectrum gir mer U2…
Bruke Th som en “poison” for å få akseptabel reaktivitetskoeffisient

Data infuelces: the data are not correct…
Cature on U3 I epthermisk range (10keV-0.5MeV energy range)
Data are sparse and back from 1962
The number of Th-bearing benchmark is very small

Likely overestimating capture on U3 ??

LEVEL DENSITY MODEL IMPORTANT FOR X-SECTIONS



Level densities/gamma ray strength functions are being measured for actinide nuclei at OCL. Will allow systematic understanding of fundamental properties of actinide nuclei → better modelling of x-sections where no data are available.

hvis jeg bruker veto-alfna kan jeg gå over fisjonsbarrieren…men for dårlig statistikk???

sjekk med og uten fisjon!
LUCIAS foredrag

få disse inn på alfna-matrisen

U234:
- S_n ^{344}U: 6.8447 MeV
- FB: 4.8

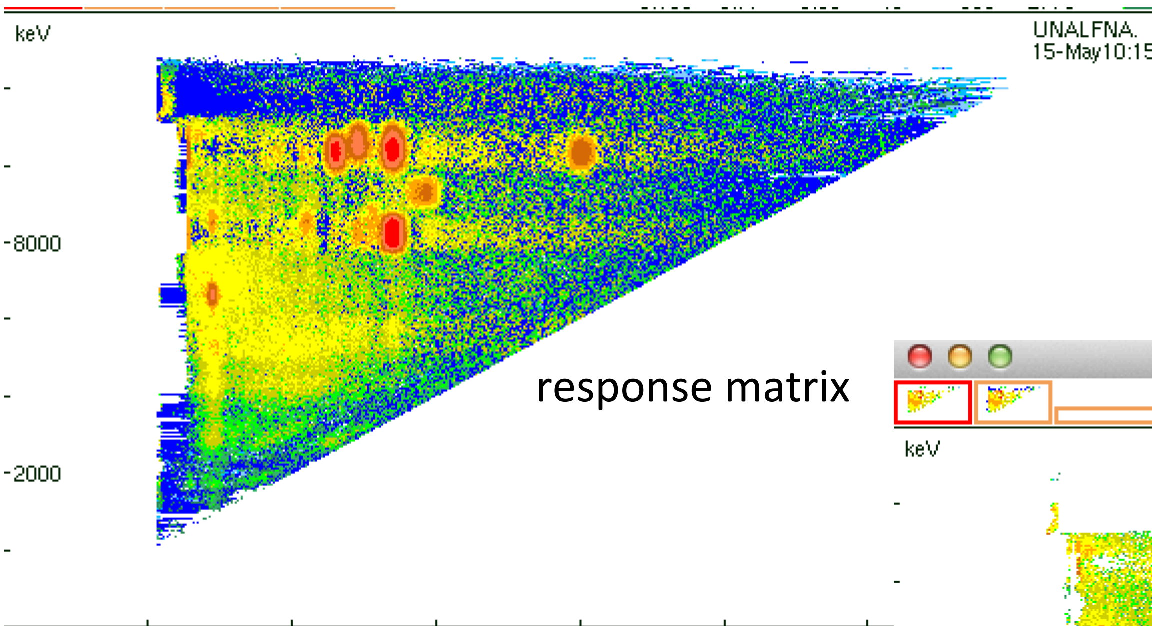
^{233}U
(d,p, gamma)
^{234}U+^{1}H
4620.17 *2.05*
http://arxiv.org/pdf/1503.03300.pdf

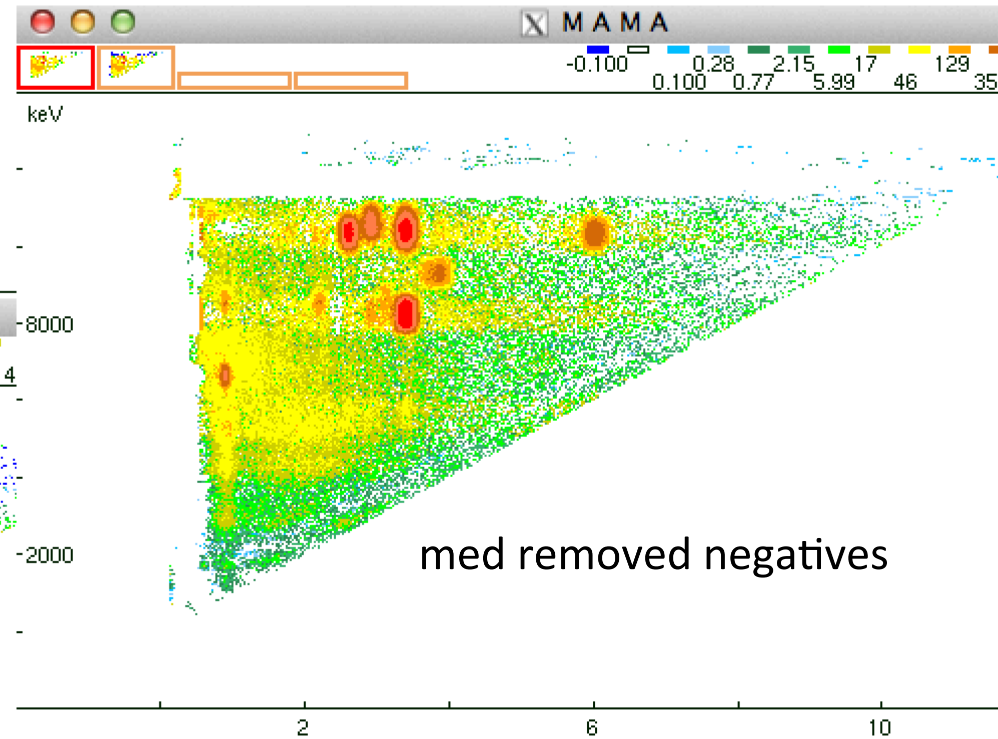
1. The Oslo method - http://arxiv.org/pdf/nucl-ex/9910009v1.pdf
A. Schiller, L. Bergholt, M. Guttormsen, E. Melby, J. Rekstad,
and S. Siem, Nucl. Instrum. Methods Phys. Res. A 447 494 (2000).

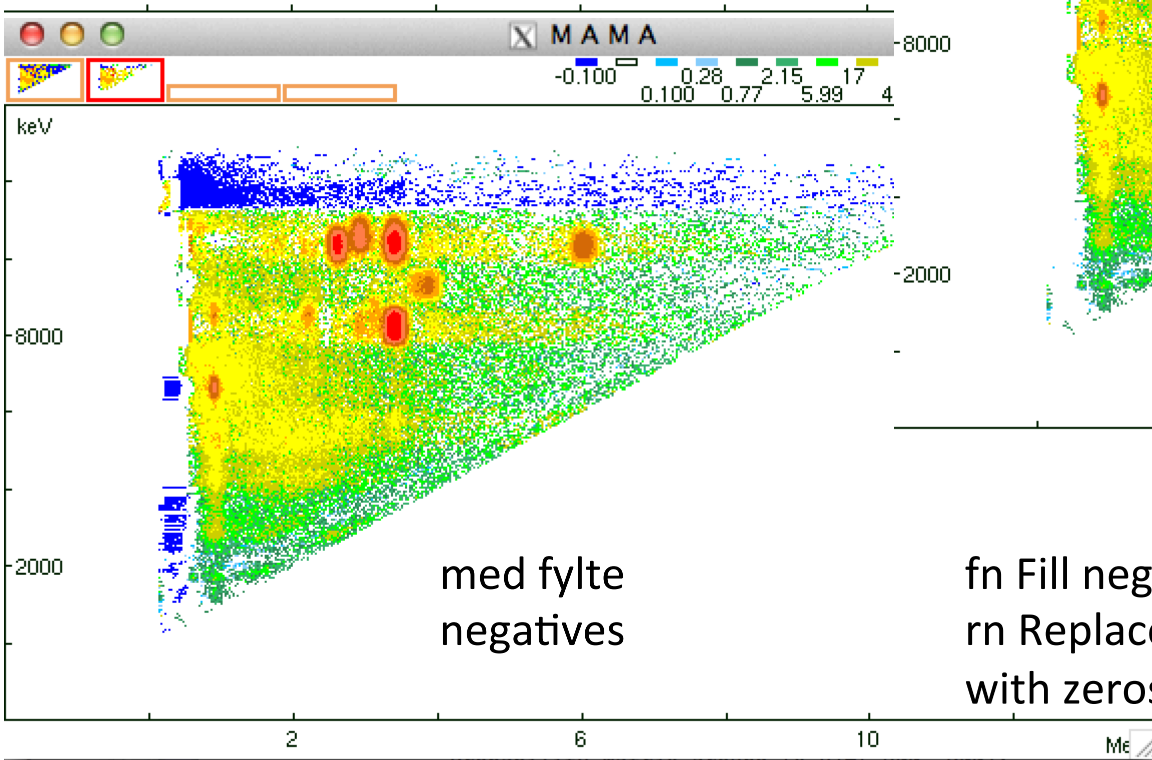
2. The unfolding procedure: - http://arxiv.org/pdf/nucl-ex/9910009v1.pdf
M. Guttormsen, T.S. Tveter, L. Bergholt, F. Ingebretsen, and
J. Rekstad, Nucl. Instrum. Methods Phys. Res. A 374, 371 (1996).

3. The first generation gamma-ray spectra procedure: - http://ac.els-cdn.com/
0168900287912216/1-s2.0-0168900287912216-main.pdf?_tid=53044cd6-fe23-11e4

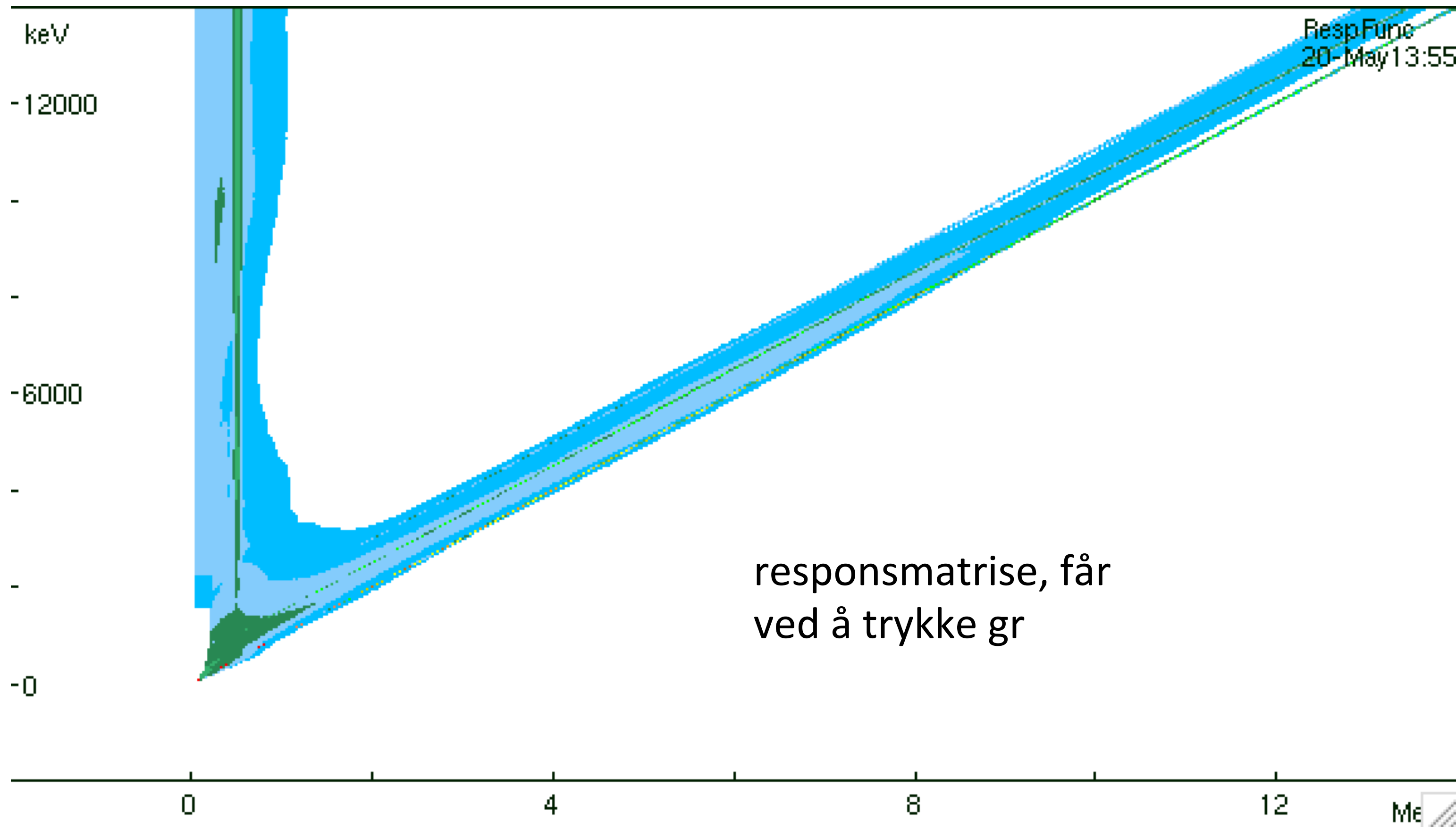
for de som vil
så kan vi ta en
tur ned til
syklotronen –
rett etter
foredraget mitt
☺





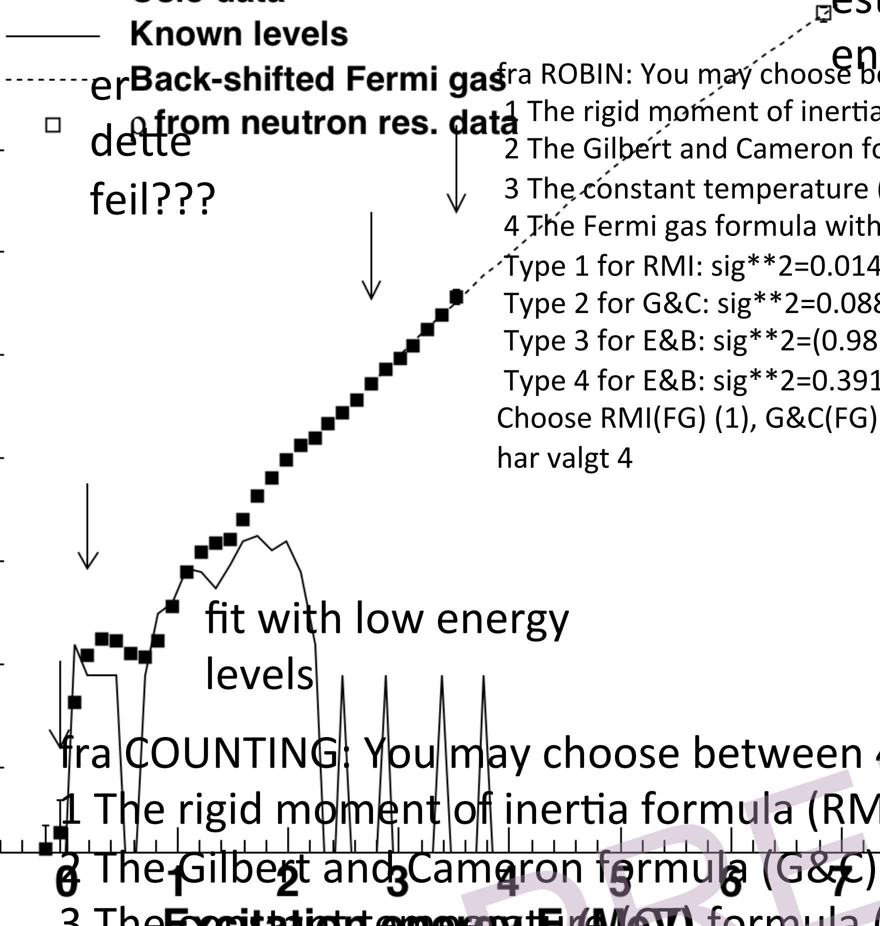


fn Fill negative counts from neighbours
rn Replace (remaining) negative counts with zeros



responsmatrise, får
ved å trykke gr

sitter emd gry: komprimerer
flrst etter unfolding…



fra ROBIN: You may choose between 4 spin cut-off formulas:
1 The rigid moment of inertia formula (RMI)(E&B2006)
2 The Gilbert and Cameron formula (G&C) Can. J. Phys 43(1965) 1446
3 The constant temperature (CT) formula (E&B2009) and NPA 481 (1988) 189
4 The Fermi gas formula with appropriate cut-off parameter (E&B2009)
Type 1 for RMI: sig**2=0.0146*(A**(5/3))*T for FG (E&B2006)
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Type 3 for E&B: sig**2=(0.98*(A**(0.29)))**2 for CT
Type 4 for E&B: sig**2=0.391*A**0.675*(E-0.5*Pa_prime)**0.312 for FG
Choose RMI(FG) (1), G&C(FG) (2), E&B(CT) (3) or E&B(FG) (4) <4>:
har valgt 4

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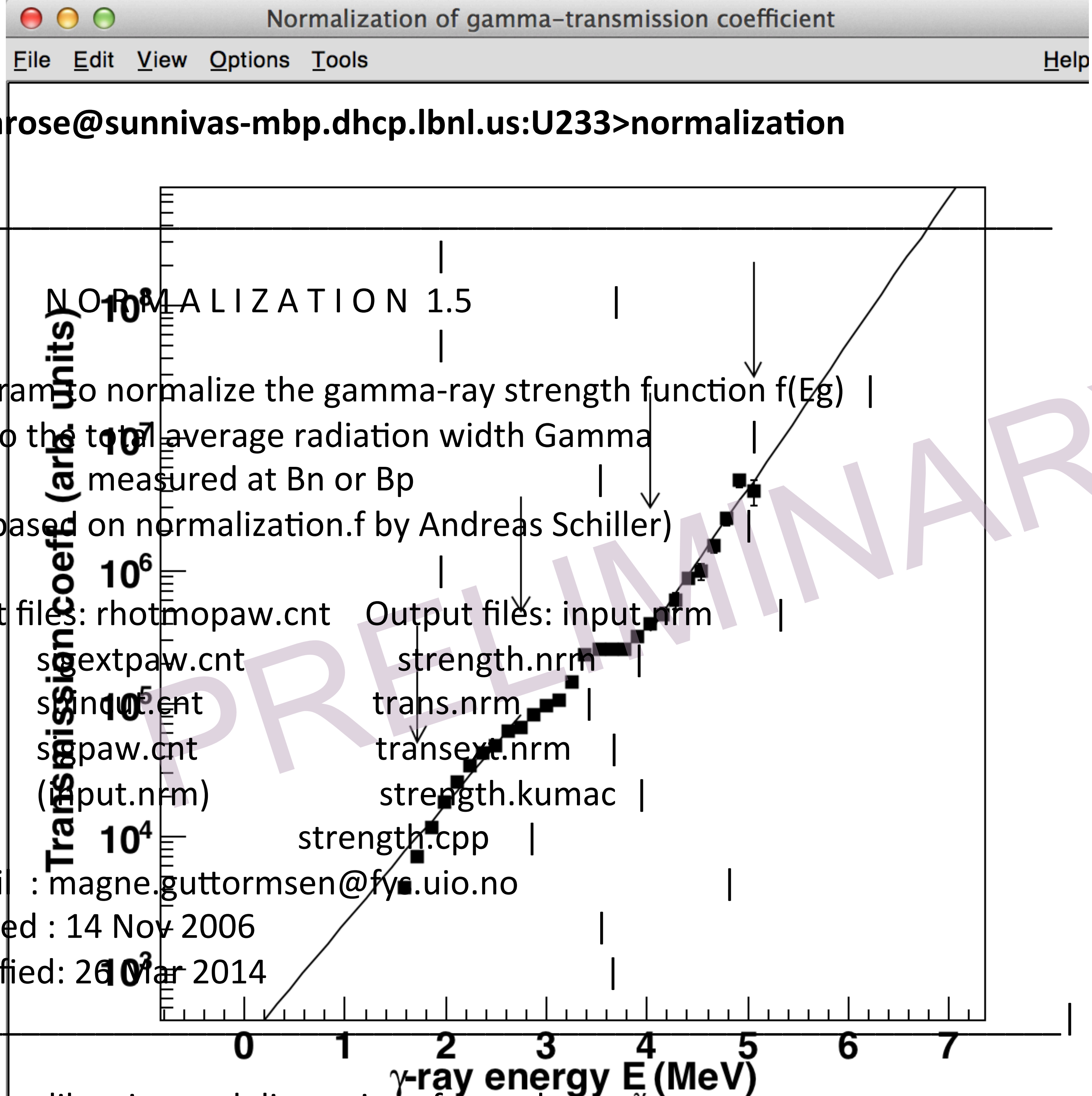
Choose constant temperature CT (1) or Fermi
formula <1>:

You should take care to use formulas from th
reference.
Example: If you use rigid moment of inertia fr
(E&B2006),
you should also use temperature T from (E&B
well.
We recommend to use (E&B2006) (or maybe
(G&C)) for nuclei heavier than A > 150,
and (E&B2009) for lighter nuclei with A < 150

If you have chosen the CT formula, we recom
FG spin cut-off formula since
the CT spin cut-off formula is a constant, whic
unphysical. In the following,

sunnivarose@sunnivas-mbp.dhcp.lbnl.us:U233>normalization

```
 ______________________________________________________________
|                                                              |
|              N O R M A L I Z A T I O N  1.5                  |
|                                                              |
|  Program to normalize the gamma-ray strength function f(Eg)  |
|      to the total average radiation width Gamma              |
|               measured at Bn or Bp                           |
|      (based on normalization.f by Andreas Schiller)          |
|                                                              |
|  Input files: rhotmopaw.cnt    Output files: input.nrm       |
|               sigextpaw.cnt                 strength.nrm     |
|               sigindut.cnt                  trans.nrm        |
|               sigpaw.cnt                    transext.nrm     |
|               (input.nrm)                   strength.kumac   |
|                                             strength.cpp     |
| E-mail  : magne.guttormsen@fys.uio.no                        |
| Created : 14 Nov 2006                                        |
| Modified: 26 Mar 2014                                        |
|______________________________________________________________|
```



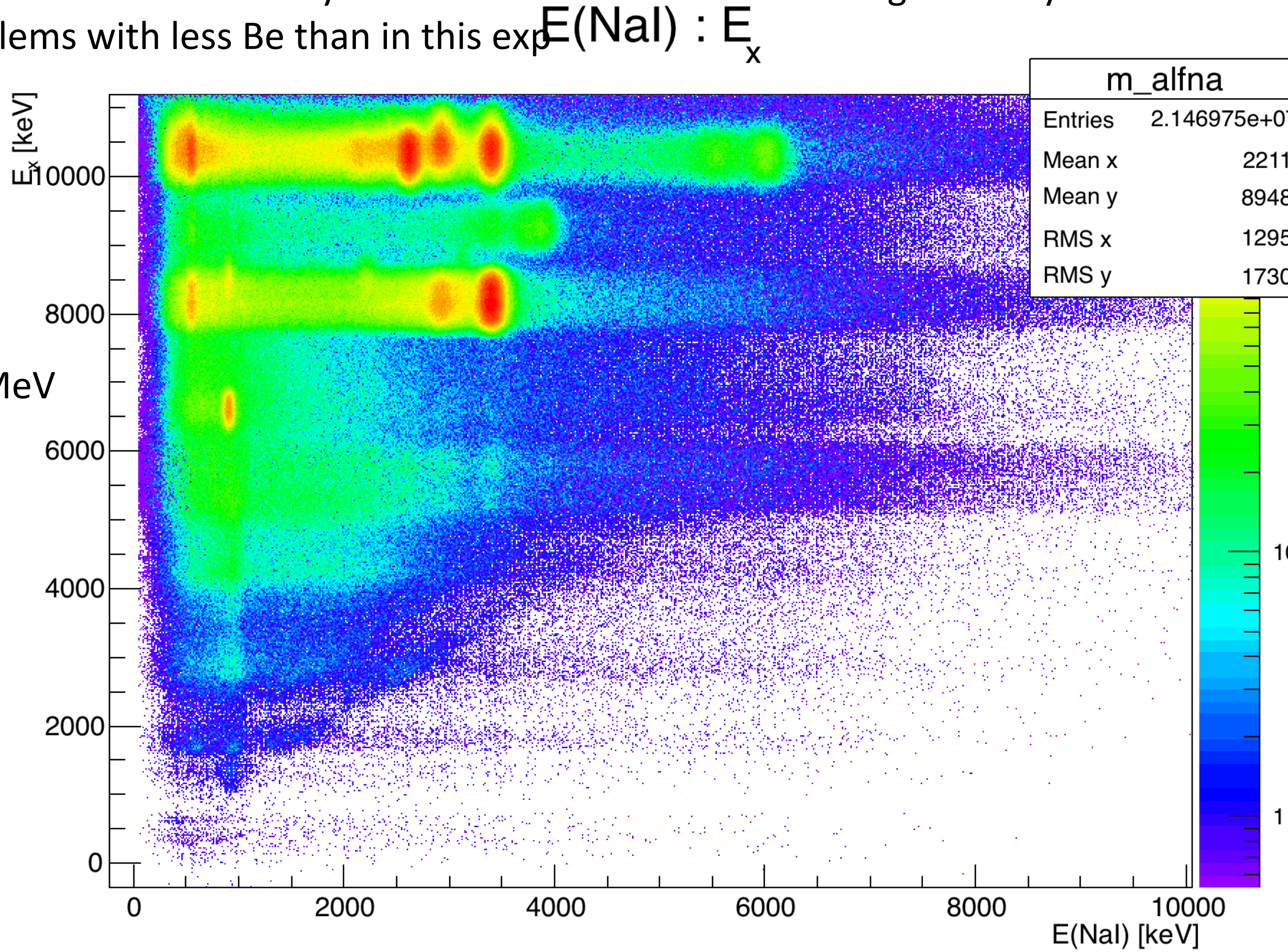
Reading calibration and dimensions from: rhosp.rsg

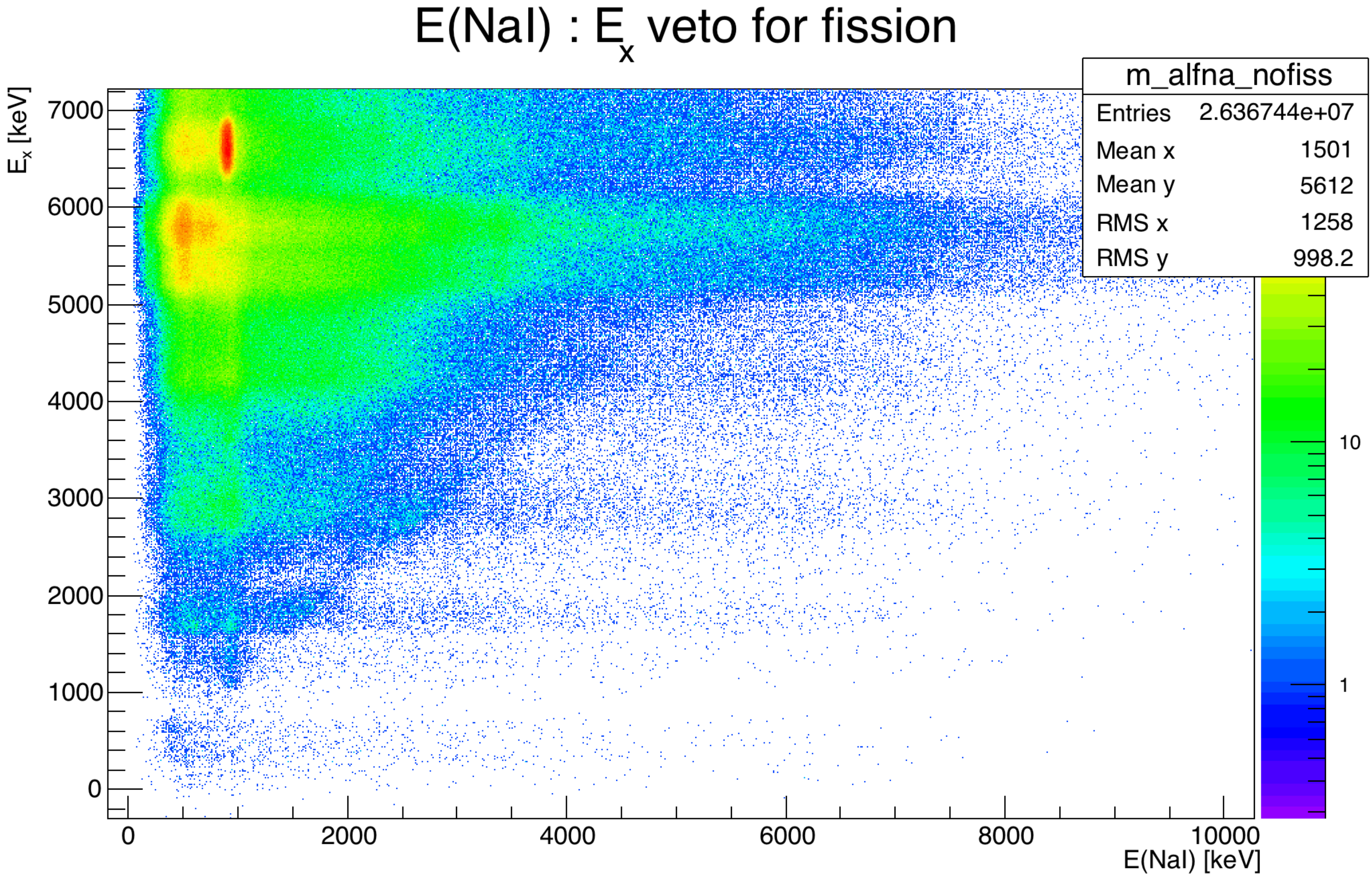
gamma particle coincidence matrix/ALFNA matrix
raw(?) matrix - raw particle-gamma matrix (det er denne som leses inn i MAMA)

det er denne jeg har burkt i analysen før workshopen – ALFNA.m

cntaminations from shit loads of beryllium – will be difficult with surrogate analysis – thibault has problems with less Be than in this exp
(d,p)

- S_n ^{344}U: 6.85 MeV
- FB: 4.8





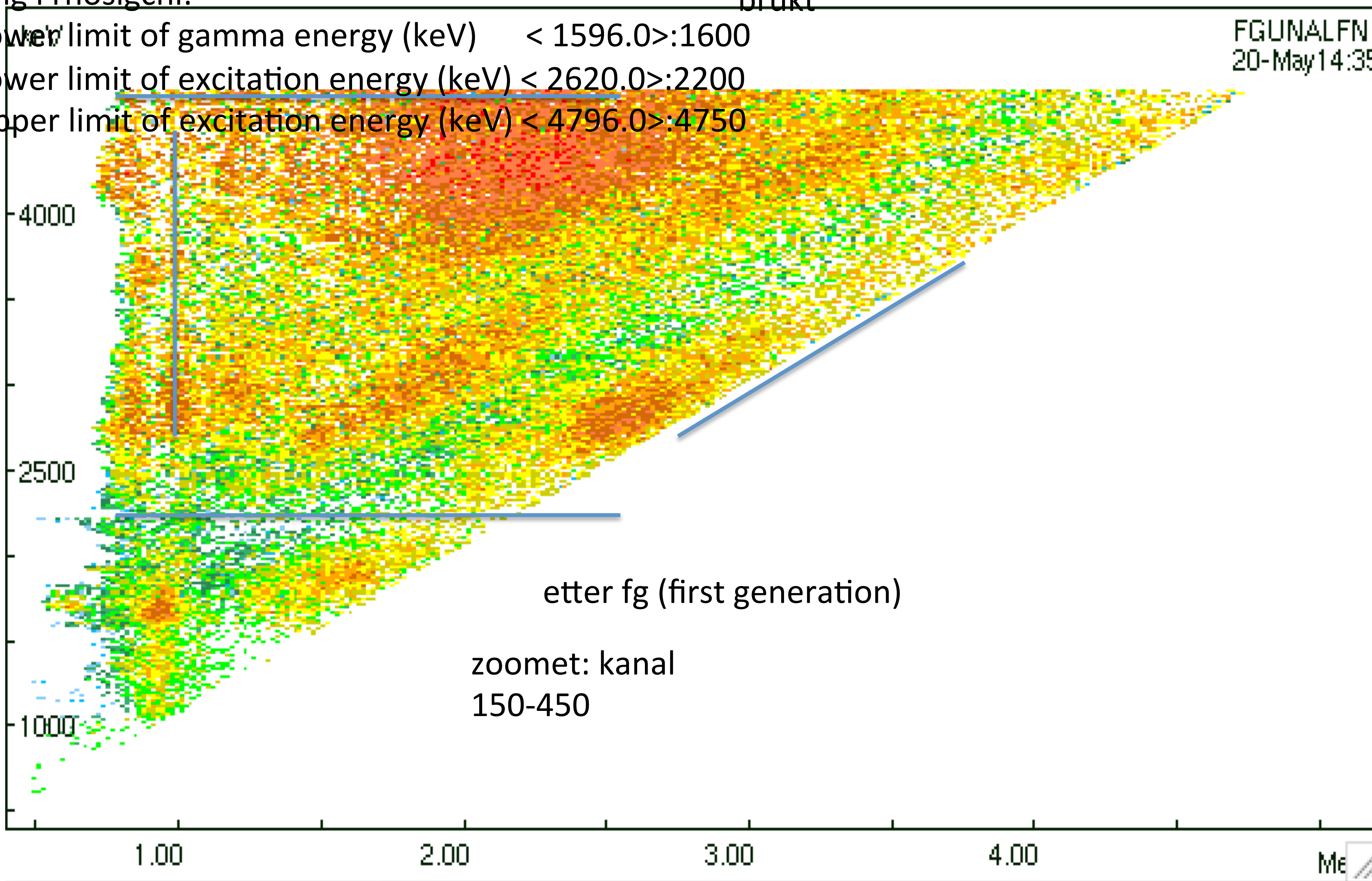
E(NaI) : E_x veto for fission
m_alfna_nofiss
Entries 2.636744e+07
Mean x 1501
Mean y 5612
RMS x 1258
RMS y 998.2
E_x [keV]
E(NaI) [keV]
0
1000
2000
3000
4000
5000
6000
7000
8000
10000
1
10

counting: velger E&B2006
You should take care to use formulas from the same reference.
Example: If you use rigid moment of inertia from (E&B2006),
you should also use temperature T from (E&B2006), as well.
We recommend to use (E&B2006) (or maybe the old (G&C)) for nuclei heavier than A > 150,
and (E&B2009) for lighter nuclei with A < 150.

You may choose between 4 spin cut-off formulas:
1 The rigid moment of inertia formula (RMI) (E&B2006)
2 The Gilbert and Cameron formula (G&C) Can. J. Phys 43(1965) 1446
3 The constant temperature (CT) formula (E&B2009) and NPA 481 (1988) 189
4 The Fermi gas formula with appropriate cut-off parameter (E&B2009)
Type 1 for RMI: sig**2=0.0146*(A**(5/3))*T for FG (E&B2006)
Type 2 for G&C: sig**2=0.0888*(A**(2/3))*a*T for FG
Type 3 for E&B: sig**2=(0.98*(A**(0.29)))**2 for CT
Type 4 for E&B: sig**2=0.391*A**0.675*(E-0.5*Pa_prime)**0.312 for FG

sett linje der jeg har satt grensene
“dette er dataene jeg har brukt”

valg i rhosigchi:
Lower limit of gamma energy (keV) < 1596.0>:1600
Lower limit of excitation energy (keV) < 2620.0>:2200
Upper limit of excitation energy (keV) < 4796.0>:4750



etter fg (first generation)

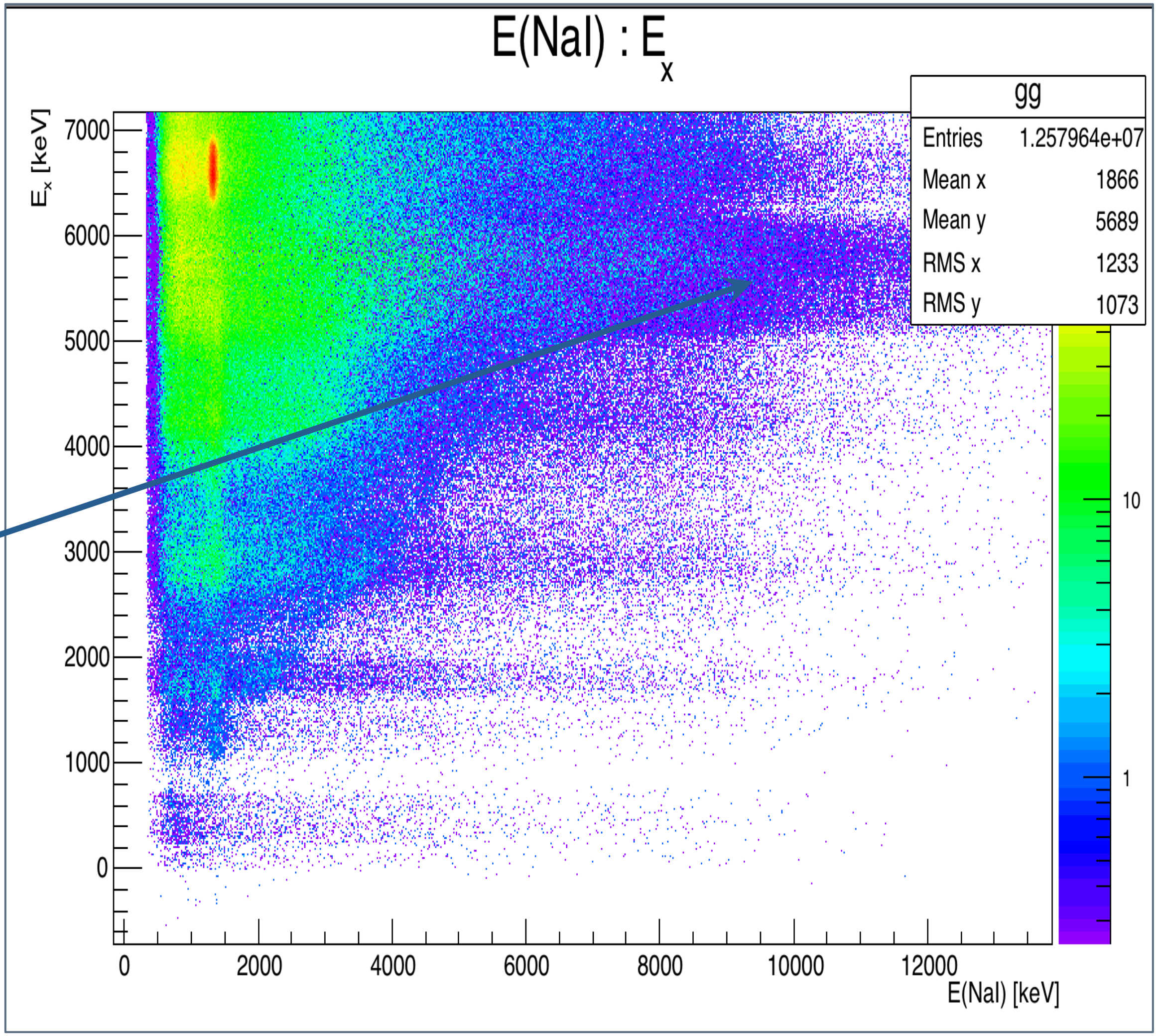
zoomet: kanal
150-450

x=egamma

Gamma spectrum as function of excitation energy

Starting point for the Oslo method

Gammas from fission fragments – skal jeg ha med dette?



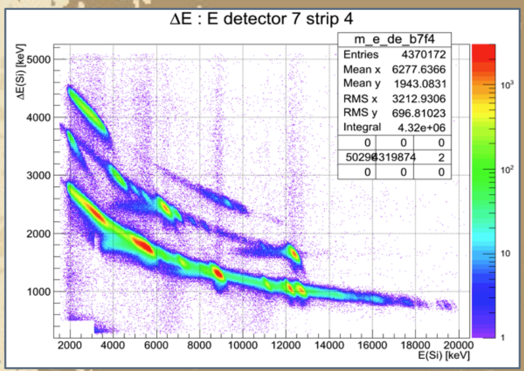
Sunniva?!??

valg konsistent med magnes paper (?)
i robin:
Spin cutoff
The rigid moment of inertia formula (RMI)(E&B2006). Type 1 for RMI:
sig**2=0.0146*(A**(5/3))*T for FG (E&B2006) – sjekk denne referansen
samme referansen i

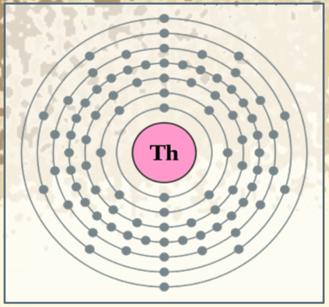
temperature formula:
2 The somewhat more advanced fermigas formula (AFG) (E&B2006). Type 2 for
AFG: T = (1+SQRT(1+4*a*U))/(2*a)(E&B2006)

This talk focuses on the status on the 233U experiment performed at OCL, but with hints of other ingredients

Motivation: Thorium fuel cycle, 232U production, and nuclear data radioactive waste. Why thorium fuels? Nuclear data…



^{233}U experiment at OCL – the (d,p) reaction



Future work

*

This talk focuses on the status on the 233U experiment performed at OCL

- physics motivation
  - im a phd student, and my project is also about waste simualtions on thoriated fuels
  - future reactors: fast neutron spectrum or thorium (or mixture of both)
    - th in reactors – what happens?
    - 1) this is what we want, but…
    - 2) this is also what happens – and this is a challenge…one important reason why th still isn't a big thing…
  - neutron capture cross section
- about the xperiment (setup etc)
  - uranium 233,234
    - u232 er ekstremt viktig å vite, og fryktelig vanskelig å måle
  - i have tons of Be…or 2.3 mg/cm2 as it is also called. anyway: 10(?) times more than the U
- calibration…
- preliminary results
- to be done
  - finish oslo analysis
    - TALYS calculations to extract (n,gamma) cross sections (important in Th fuel – we don't want it) – direct measurements exists ☺
  - alternativeanalysis: surrogate? difficulties with the backing…? (vise tons of beryllium her?)

førstegenerasjonsmatrisen leses inn i rhosigchi

valg konsistent med magnes paper (?)
i robin:
Spin cutoff
The rigid moment of inertia formula (RMI)(E&B2006). Type 1 for RMI:
sig**2=0.0146*(A**(5/3))*T for FG (E&B2006) – sjekk denne referansen
samme referansen i

temperature formula:
2 The somewhat more advanced fermigas formula (AFG) (E&B2006). Type 2 for AFG: T = (1+SQRT(1+4*a*U))/(2*a)(E&B2006)