Toward Flerovium Spectroscopy and Lundium

Anton Såmark-Roth

On behalf of the
Lundium collaboration

Feb. 25, 2019

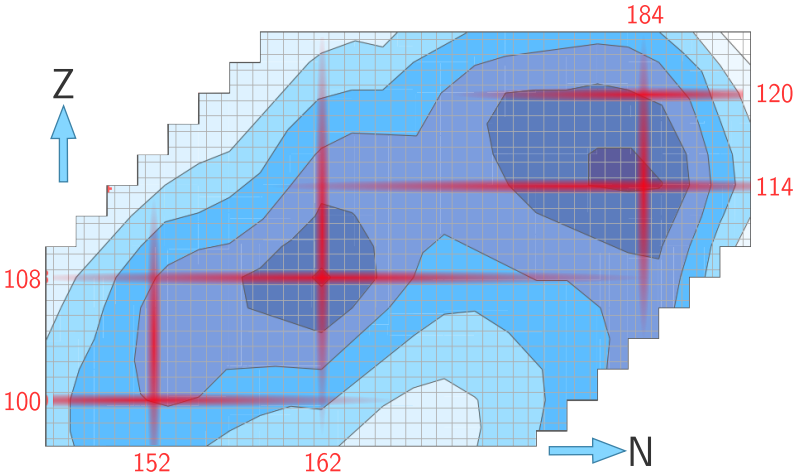
Knut och Alice Wallenbergs Stiftelse

LUND UNIVERSITY

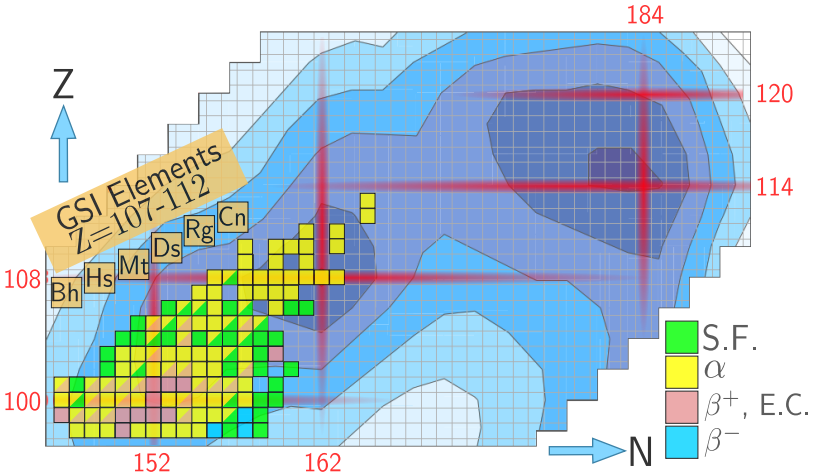
Outline

1. Toward Fl-spectroscopy
   - Superheavy Nuclei
   - Future Experiment
2. Toward Lundium
   - Decay Station
   - Status

Superheavy Nuclei $Z \geq 104$ (Rf)



Superheavy Nuclei $Z \geq 104$ (Rf)



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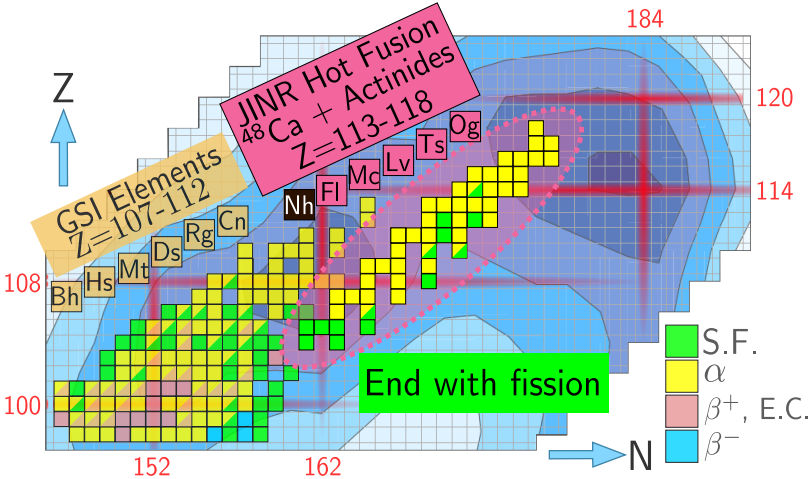

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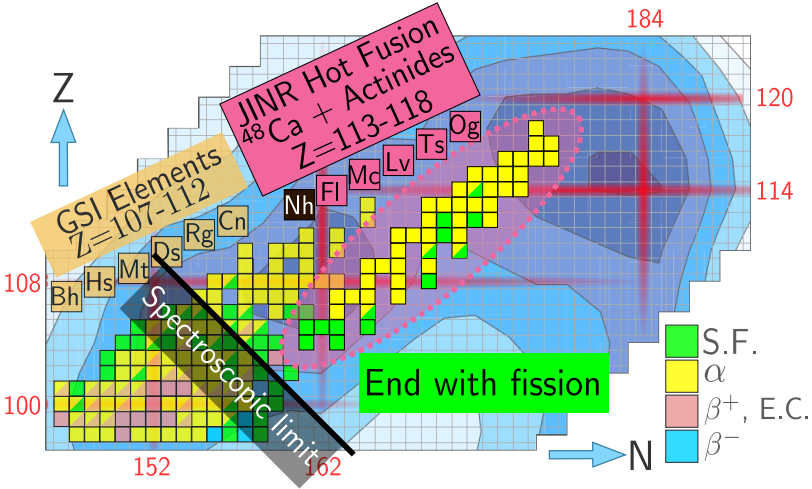

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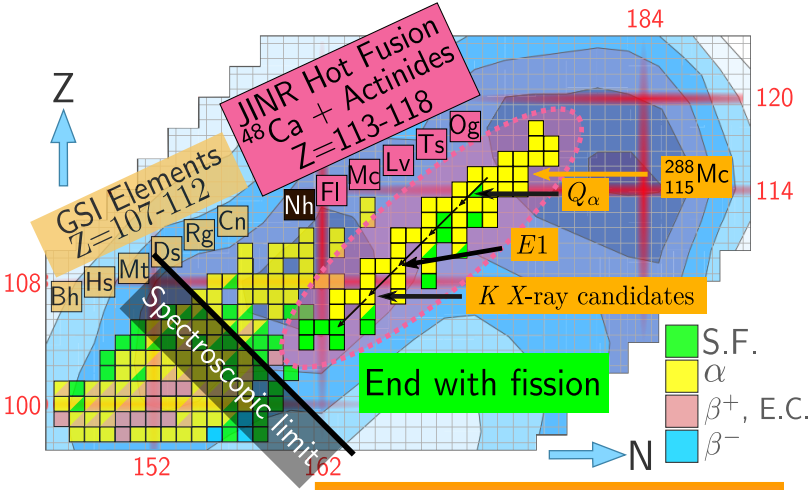
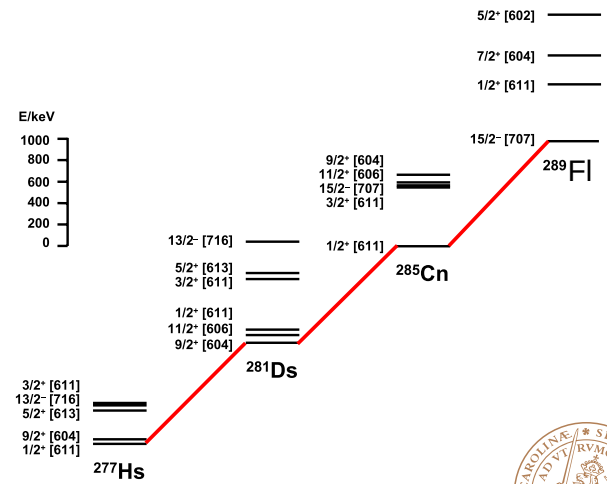


D. Rudolph *et al.* PRL **111**, 112502 (2013)

Future Experiment - Flerovium Spectroscopy



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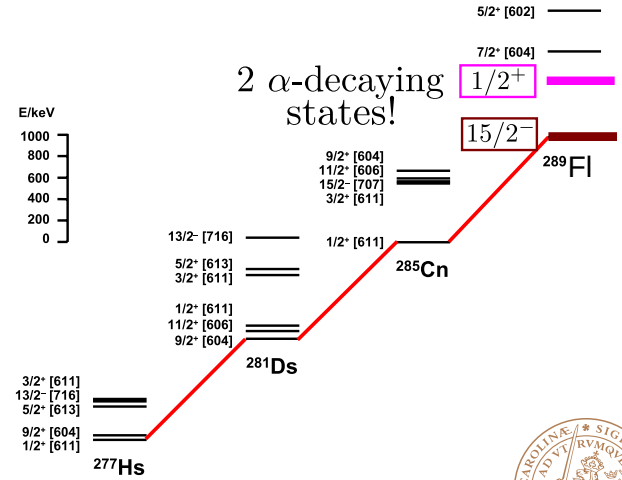

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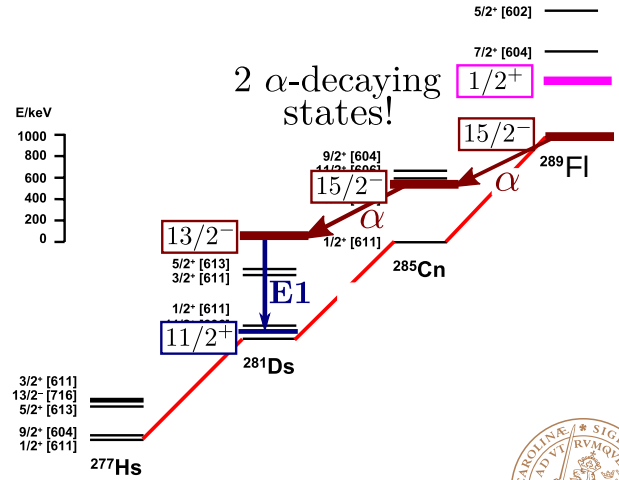

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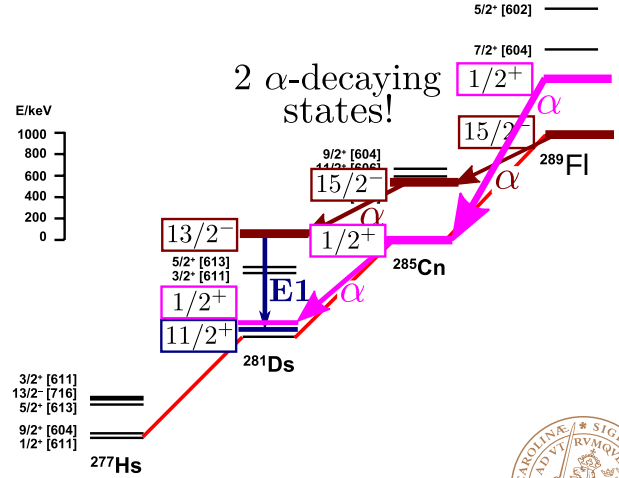

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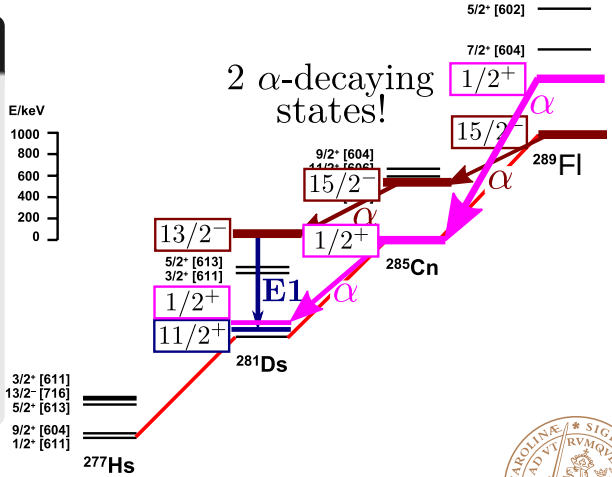
Future Experiment - Flerovium Spectroscopy

^{287,289}Fl-decay chains

- This is just one prediction, however this pattern is **model independent**.
- Therefore, all odd-A decay chains (Z=114-117) should reveal at least 2 independent decay chains!
- Where are they?



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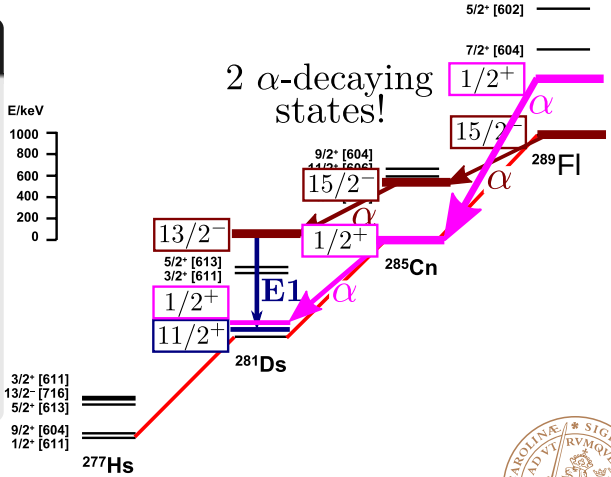
Future Experiment - Flerovium Spectroscopy

^{287,289}Fl-decay chains

- Precise Q_α values.
- Search for/discriminate E1 γ transitions and K X rays from highly converted transitions.
- Beam time approved (2016), scheduled (2017) for August 2018 and now rescheduled for late March 2019.



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Characterisation of New Superheavy Elements

ChaSE Lundium

38.3 MSEK $\sim$ 4 M€ (2016-2020)

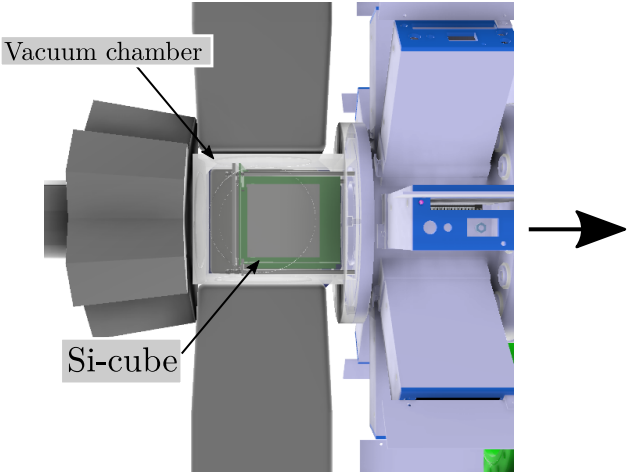
Knut och Alice Wallenbergs Stiftelse

D. Rudolph, Division of Nuclear Physics, Faculty of Science.
B.G. Carlsson & S. Åberg, Division of Nuclear Physics, LTH.
Ch.E. Düllmann, University of Mainz & GSI, Darmstadt.

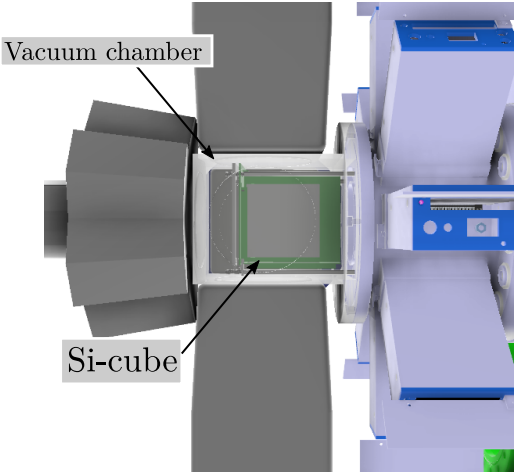
Experiment & Theory (Nuclear Structure)

From TASISpec to Lundium (Decay Station)

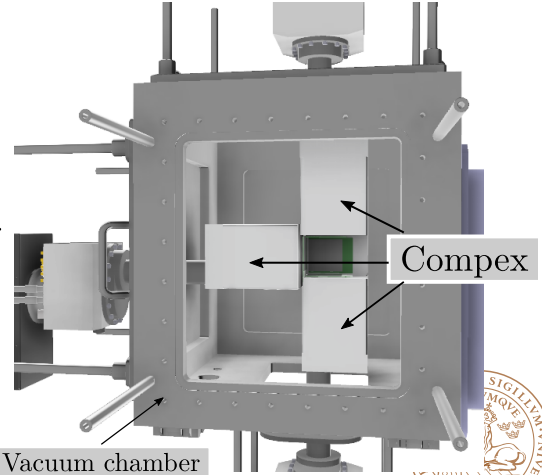
TASISpec

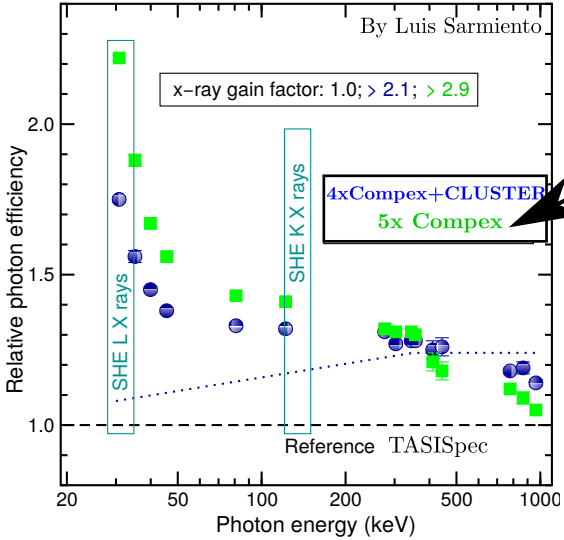


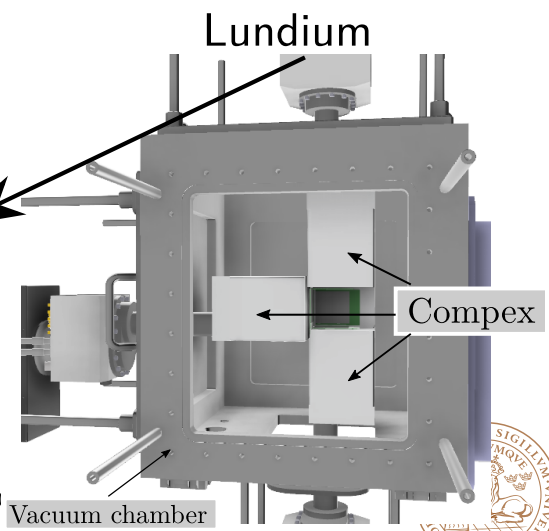
TASISpec



Lundium



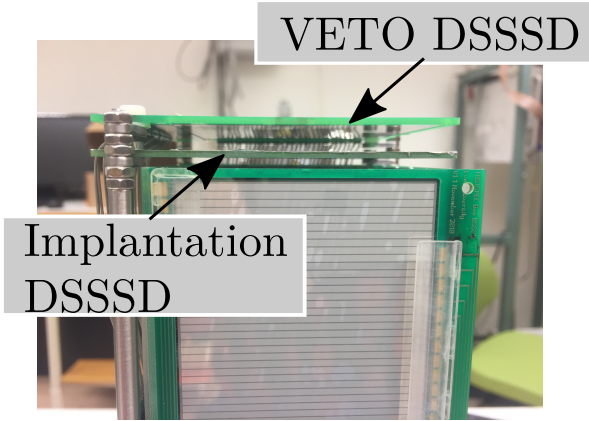

By Luis Sarmiento
x–ray gain factor: 1.0; > 2.1; > 2.9
4xCompex+CLUSTER
5x Compex
SHE L X rays
SHE K X rays
Reference TASISpec
Relative photon efficiency
Photon energy (keV)
2.0
1.5
1.0
20
50
100
200
500
1000


Lundium
Compex
Vacuum chamber

Toward Lundium

Si-upgrades

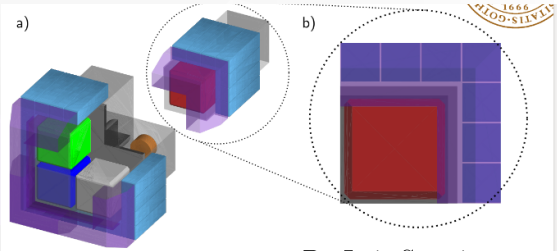
- Implantation detector: 1.8 mm→ 1.0 mm pitch (32x32→58x58 strips).
  - 10x 0.3 mm thick = in Lund.
- Box detectors: 3.6 mm→ 1.8 mm pitch (16x16→32x32 strips).
  - Trying to get 1 mm thick ....
- VETO DSSSD to distinguish escaping α:s from and electrons (installed by Daniel Cox & Pavel Golubev).



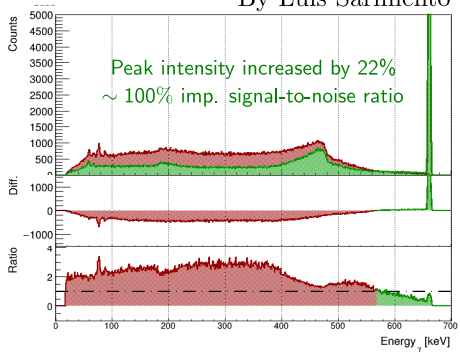
Toward Lundium

Passive and active shielding

- High signal-to-noise-ratio →
- Anti-Compton shield - Detectors and PhD position funded (Luis Sarmiento).
- Plastic+Lead shield in 'pre-chamber' (ready).
- New concrete wall at TASCA (installed).



By Luis Sarmiento



Toward Lundium

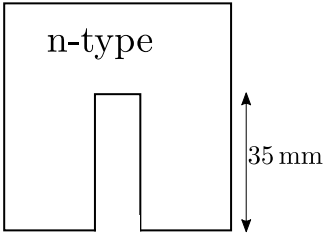
Beam shutoff

Improved beam shutoff routine to preserve low-background environment triggered by SHN-decay-like signals (Done).

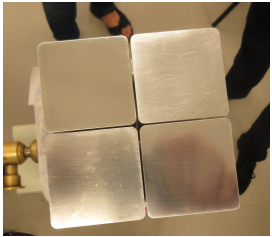
- Digital readout and the FEBEX FPGA is used.
- Correlated events per pixel.
  - *implant*-α_1
  - *implant*-α_1-α_2
  - α_1-α_2
- Routine optimised on the 2012 Mc-data.

Compex

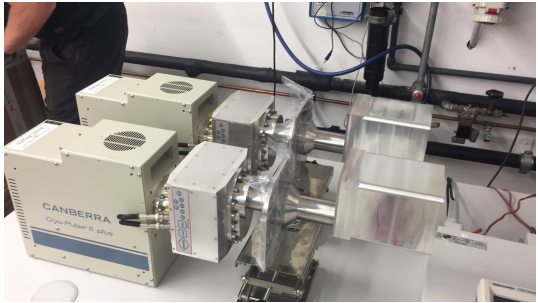
$50\text{x}50\text{x}50\,\text{mm}^3$



'Cubic' encapsulated crystals



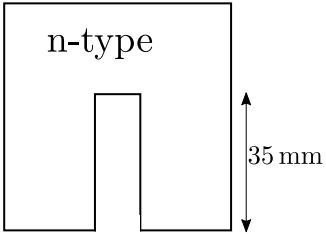
4 crystals in a common cryostat



Mechanical cooling, $T \sim$ -160 °C

Compex

50x50x50 mm^3



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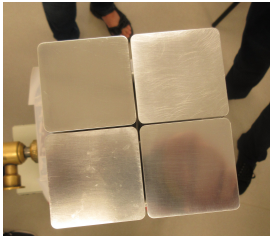

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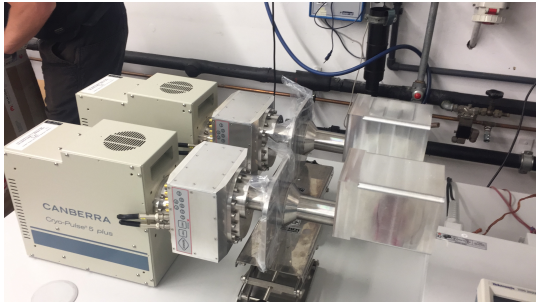


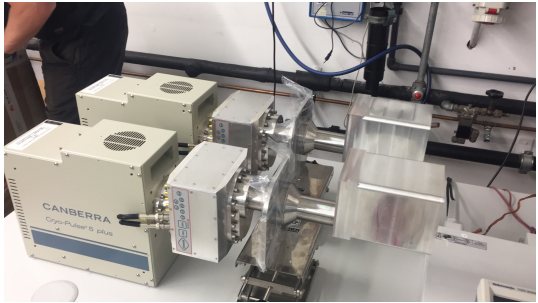
Mechanical cooling, $T \sim$ -160 °C

Typical resolutions:
1.9 keV @1.33 MeV
0.8 keV @122 keV

Compex

Status

- 4 Compex and 1 CLUSTER detectors to be used in the experiment in March 2019.
- TASISpec chamber at nominal focal plane of TASCA.
- Segmented Compex to be delivered 2019.



Mechanical cooling, $T \sim$ -160 °C

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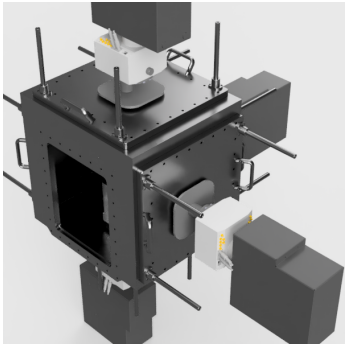
Summary

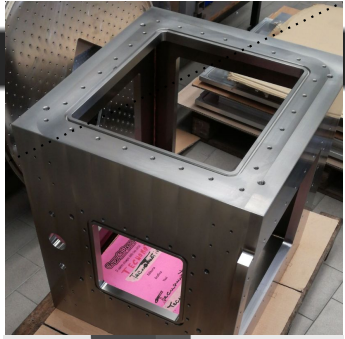
- Experiment on ^{287,289}Fl spectroscopy in 2019!
- Upgrade to Lundium.

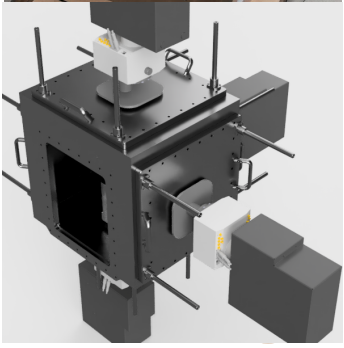


Toward Lundium

Vacuum chamber

- Move into TASCA nominal focal plane (Done for the TASISpec chamber).
- Chamber : Frame and vacuum system in Lund.
- Wagon to move the entire Lundium chamber (in Lund).
- Rail system to 'roll' chamber into position at TASCA (ready).
- Rods with ball bearing to set side-plates with detectors into position (planned).
- Engineering : how to set it up (thinking remains).





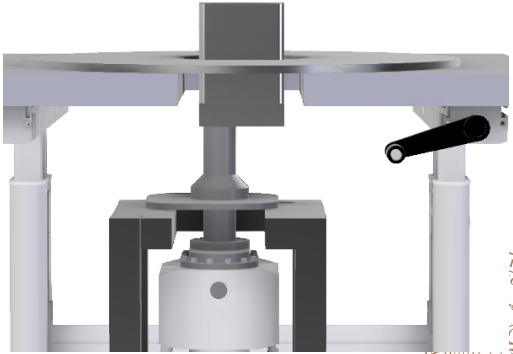
Toward Lundium

DAQ-upgrades

- All Si-detectors read with FEBEX (in use since 2015).
- Beam shutoff routine implemented in FEBEX readout function.
- Beam shutoff signal sent from FEBEX I/O unit.
- Go fully FEBEX, i.e. SIS3302→FEBEX4 for germanium readout. (Ready).

Compex characterisation

- New type of Germanium detector - How does it perform in comparison to existing detectors?
  - New shape.
  - Different cooling principle.
- Knowing our detector in detail, can we improve its performance?
- Energy response as a function of the (x, y, z) interaction point in the crystal.



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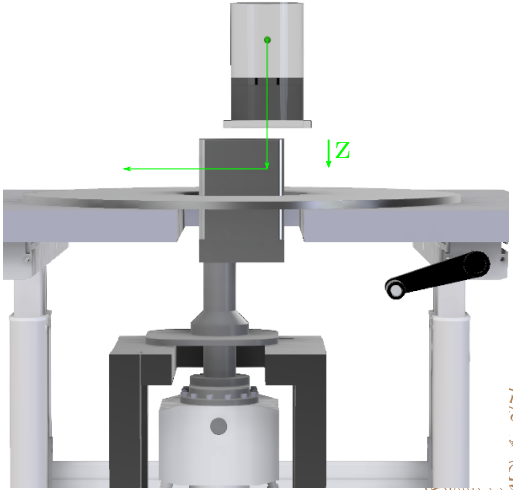

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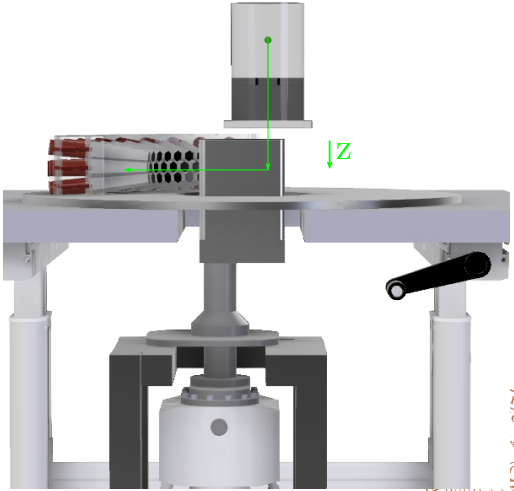

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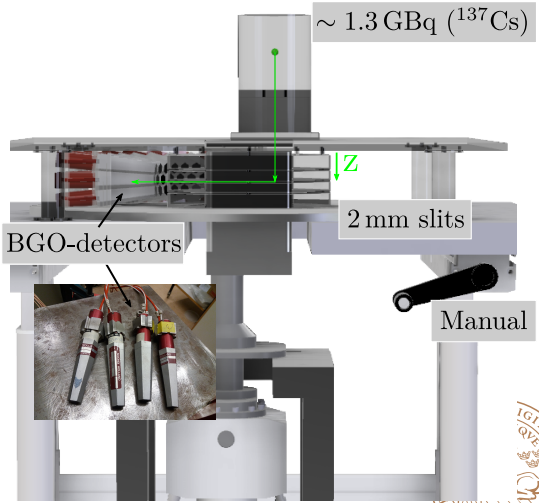

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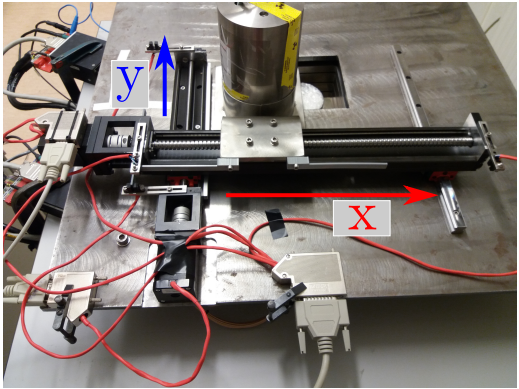
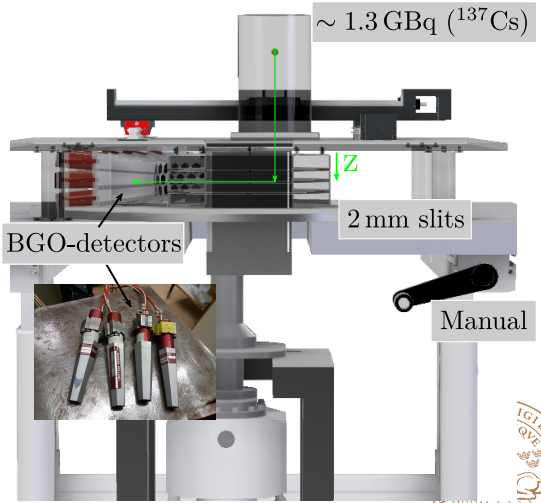
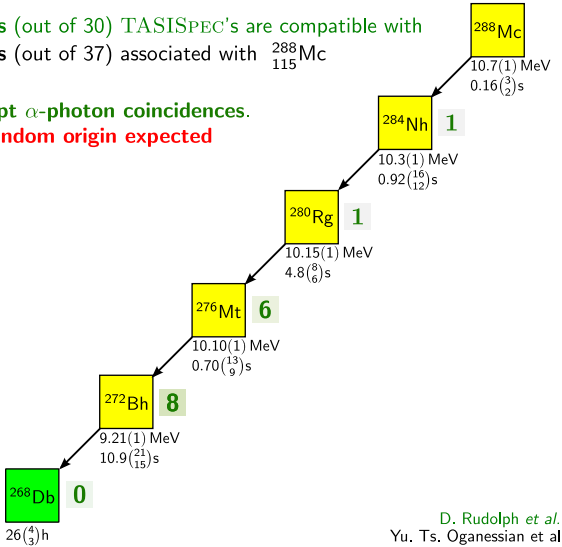




α-photon spectroscopy along decay chains of ^{288}Mc

22 chains (out of 30) TASISPEC's are compatible with
31 chains (out of 37) associated with $^{288}_{115}$Mc

16 prompt α-photon coincidences.
2-3 of random origin expected



D. Rudolph *et al.* PRL **111**, 112502 (2013)
Yu. Ts. Oganessian et al., PRC **87**, 014302 (2013)

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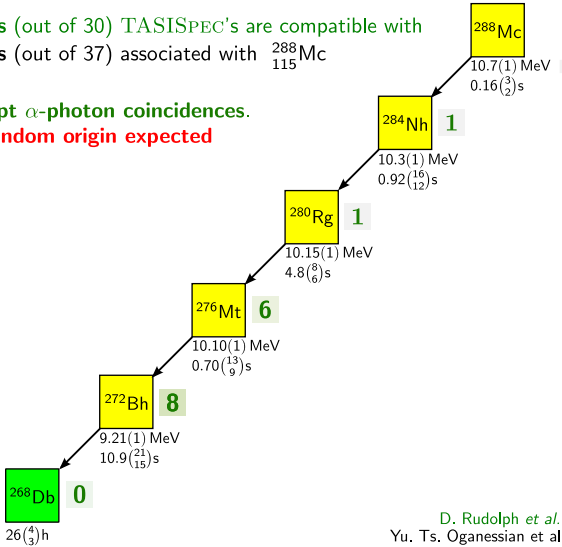

Q_α
$T_{1/2}$

Shell stability along $Z = 114$

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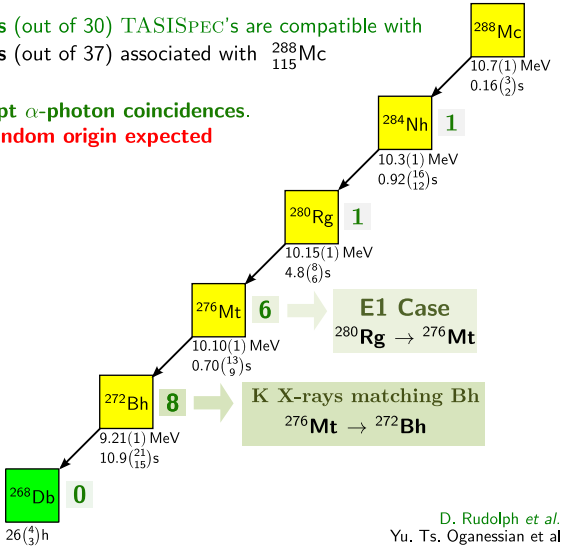

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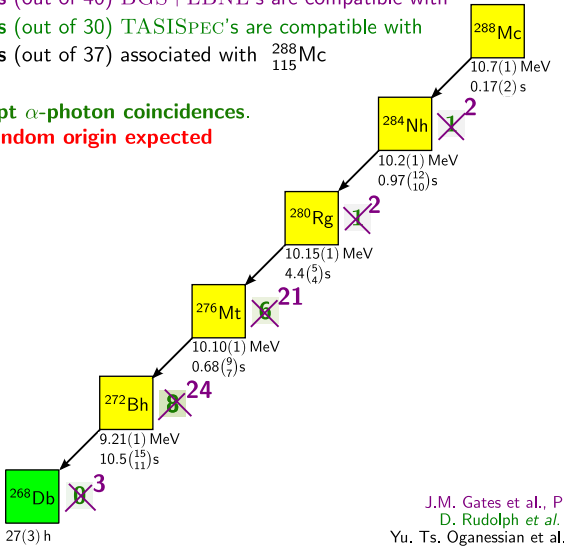
~~16~~ 52 **prompt α-photon coincidences.**
~~2-3~~ ~ 8 **of random origin expected**



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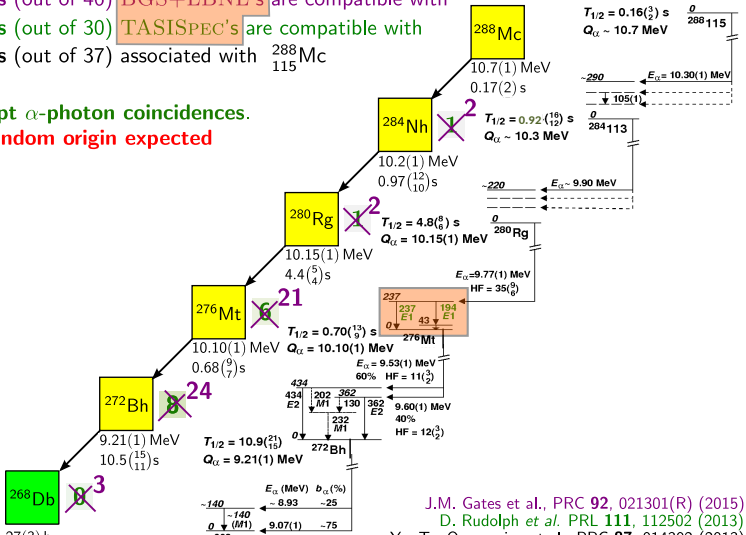

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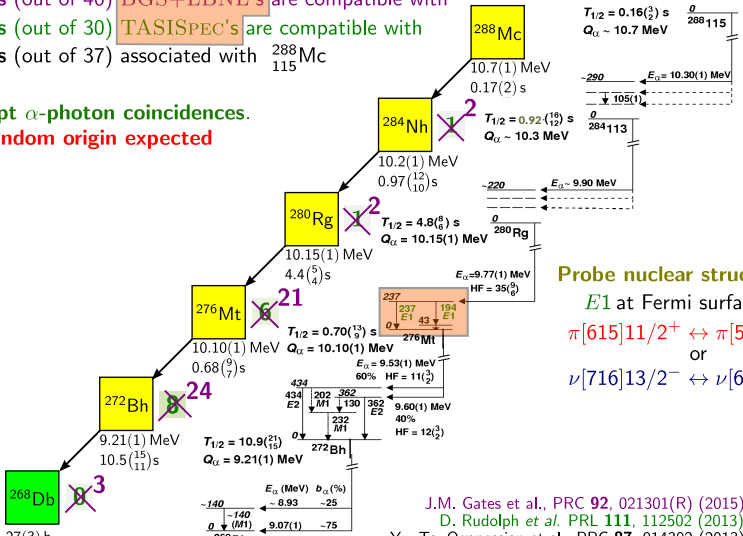
α-photon spectroscopy along decay chains of ^{288}Mc

43 chains (out of 46) BGS+LBNL's are compatible with
22 chains (out of 30) TASISPEC's are compatible with
31 chains (out of 37) associated with $^{288}_{115}$Mc

~~16~~ 52 **prompt α-photon coincidences.**
~~2-3~~ ~ 8 **of random origin expected**



Probe nuclear structure theory (!)

$E1$ at Fermi surface

$\pi[615]11/2^+ \leftrightarrow \pi[505]9/2^-$

or

$\nu[716]13/2^- \leftrightarrow \nu[606]11/2^+$

J.M. Gates et al., PRC **92**, 021301(R) (2015)
D. Rudolph *et al.* PRL **111**, 112502 (2013)
Yu. Ts. Oganessian et al., PRC **87**, 014302 (2013)