Nuclear Physics in African media

First African-led Experiment in Physics proposed at HIE-ISOLDE (CERN)

NANOTECHNOLOGY

BIG SCIENCE

WITH TINY BUILDING BLOCKS

UWC drives the first South African-led experiment in physics at CERN

Prof Nico Orce

With dreams of attending a summer school at CERN thwarted, the young scientist remained undeterred. His path led him from Granada to the UK, USA and Canada, and now, here in the fairest Cape, those dreams of working with CERN have become a reality. Prof Nico Orce of UWC shares a personal story of his journey, leading him to the first South African-led experiment in physics at CERN.

Looking back

About fifteen years ago, as an undergraduate student in Spain, I convinced a few friends of mine to apply for a Summer School at CERN, the European Organization for Nuclear Research. With over 15,000 scientists and engineers from all over the world working in unison to reveal the secrets of nature, CERN is probably the most extraordinary research institution in the world. Getting there was our dream. The only thing that we needed was the consent and signature of a physics professor at the University of Granada in charge of student exchange programs. I sadly remember how the heads of my friends were going slowly down and down as such a "gentleman" was telling us, as a matter of fact, that "only the crème de la crème, students from MIT, Princeton, Oxford or Cambridge get to go to these kind of workshops. This is a small university and our students are not prepared for that." He did not sign the forms. I went to England to do a PhD in experimental nuclear physics. But that was not the end of the story.

CERN, the God Particle and the Big Bang

CERN has recently been the focus of breaking news worldwide with the discovery of the Higgs boson. Not only is the Higgs boson the particle credited with giving others mass (and helping us to understand how we come into being) but it might also be responsible for the existence of the mysterious dark energy, which keeps speeding our universe ever faster. CERN's breakthroughs are built upon the shoulders of a technological giant, the Large Hadron Collider (LHC), the highest-energy particle collider ever constructed. It goes around the entire city of Geneva in Switzerland and is one of the great engineering milestones of humankind. Other exciting high-energy physics programs at CERN concern the production of quark-gluon plasma that existed shortly after the Big Bang, finding clues for dark matter and the potentially missing antimatter.

Not only do CERN's scientists use the high-energy protons from the LHC and its booster accelerators to investigate the Big Bang, the Higgs boson and other high-energy physics; they also study the physics that addresses the origin of the low-energy interactions between nuclei – the strong nuclear force. The physics of interacting nuclei accounts for how the elements were (and are) created through nuclear reactions in explosive stellar scenarios – the physics of exotic materials that may lead to advanced technologies – the physics of creating a sustainable and safe energy supply by taming our sun, for example. This is the physics that has consumed, and still is consuming, more human hours than any other scientific question in the history of humankind. This is the physics that the Nuclear Physics and Nuclear Astrophysics Group at the University of the Western Cape is pursuing.

The MINIBALL gamma-ray spectrometer at the ISOLDE facility at CERN as seen from above, where UWC will carry out their measurements.

South African connection

ON CAMPUS

UNIVERSITY of the WESTERN CAPE

Issue 10 • November 2013 • For daily updates visit www.uwc.ac.za

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Your Source for University News

Science shows off its splendours, and a Nobel laureate

Prof Nico Orce (centre, bright blue shirt) with students from the UWC MANUS programme and other South African institutions during the 2012 Tastes of Nuclear Physics symposium at UWC.

UWC heads CERN's first South Africa-led experiment

A team from the University of the Western Cape will lead the first African experiment in nuclear physics – studying the mysteries of nuclei – to be granted beam time at the Isotope Separator On Line DEvice (ISOLDE) facility at the European Organisation for Nuclear Research (CERN) on the Swiss/French border.

While many South Africans are involved in studies on the CERN colliders, this is the first South African proposal in any field of physics greenlit for one of the booster accelerators of the famous Large Hadron Collider (LHC) at CERN. Experimental beam time on the ISOLDE facility is hard to come by, and only the most promising research proposals get the go-ahead.

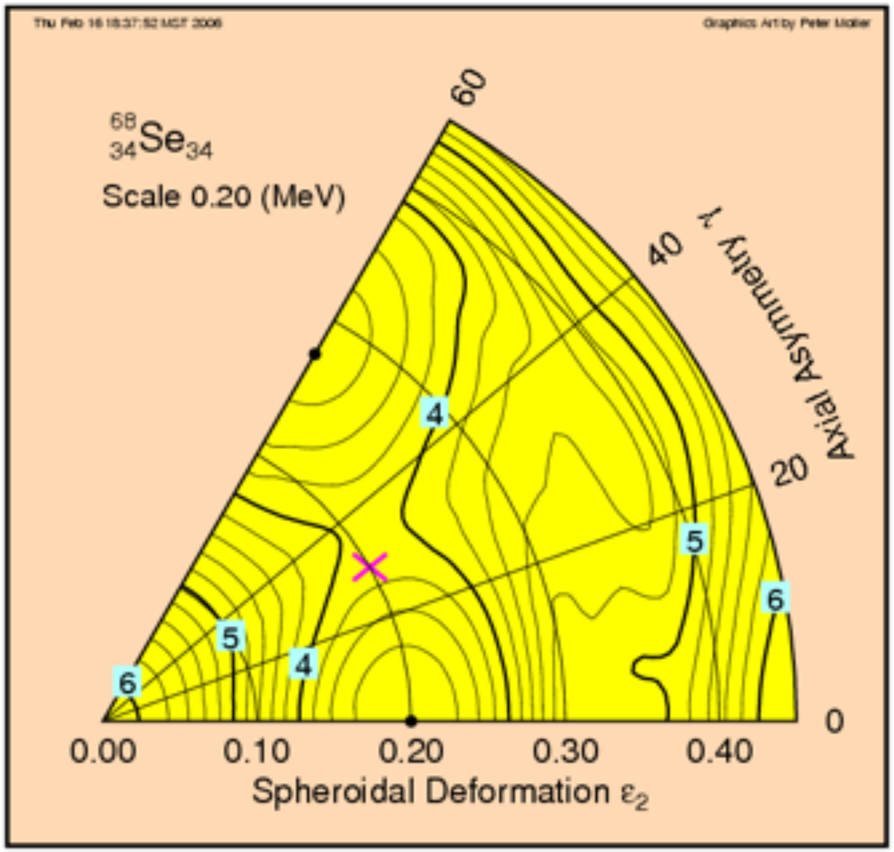
It fell to UWC's Professor Nico Orce, 'shape conundrum' – how nuclei change their shape and how this may influence the its shape, moving from roughly cigar-shaped to a more rugby ball-like form or vice versa. How it does this is not understood, says Orce, but the nuclear shape affects the decay properties of nuclei – and thus the abundance of the elements as seen today.

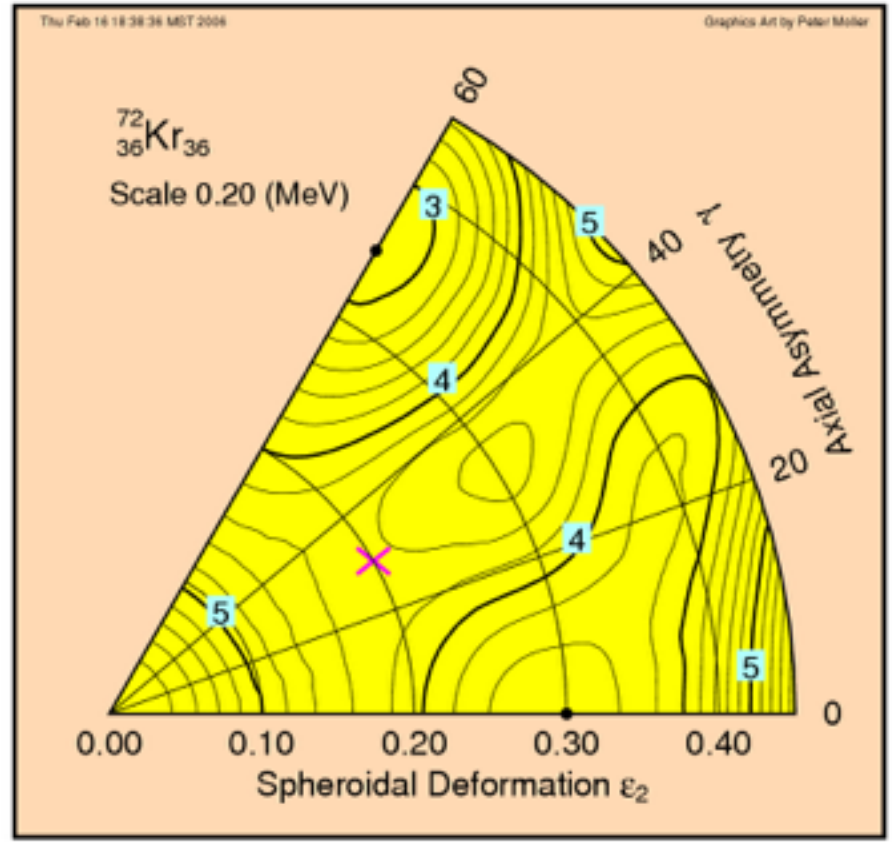
UWC has been preparing for the project since launching its Master's in Accelerator and Nuclear Sciences and Material Sciences (MANuS/MatSci) programme in 2008, funded by the National Research Foundation (NRF). Students are lectured in the field of nuclear structure and nuclear reactions, and are trained to carry out experiments such as the one proposed at CERN.

UWC is, in fact, already running its first CERN-like experiments at iThemba LABS this November, and others will follow shortly, explains Orce.

The MINIBALL gamma-ray spectrometer at the ISOLDE facility at CERN (as seen from above), where UWC researchers will carry out their measurements.

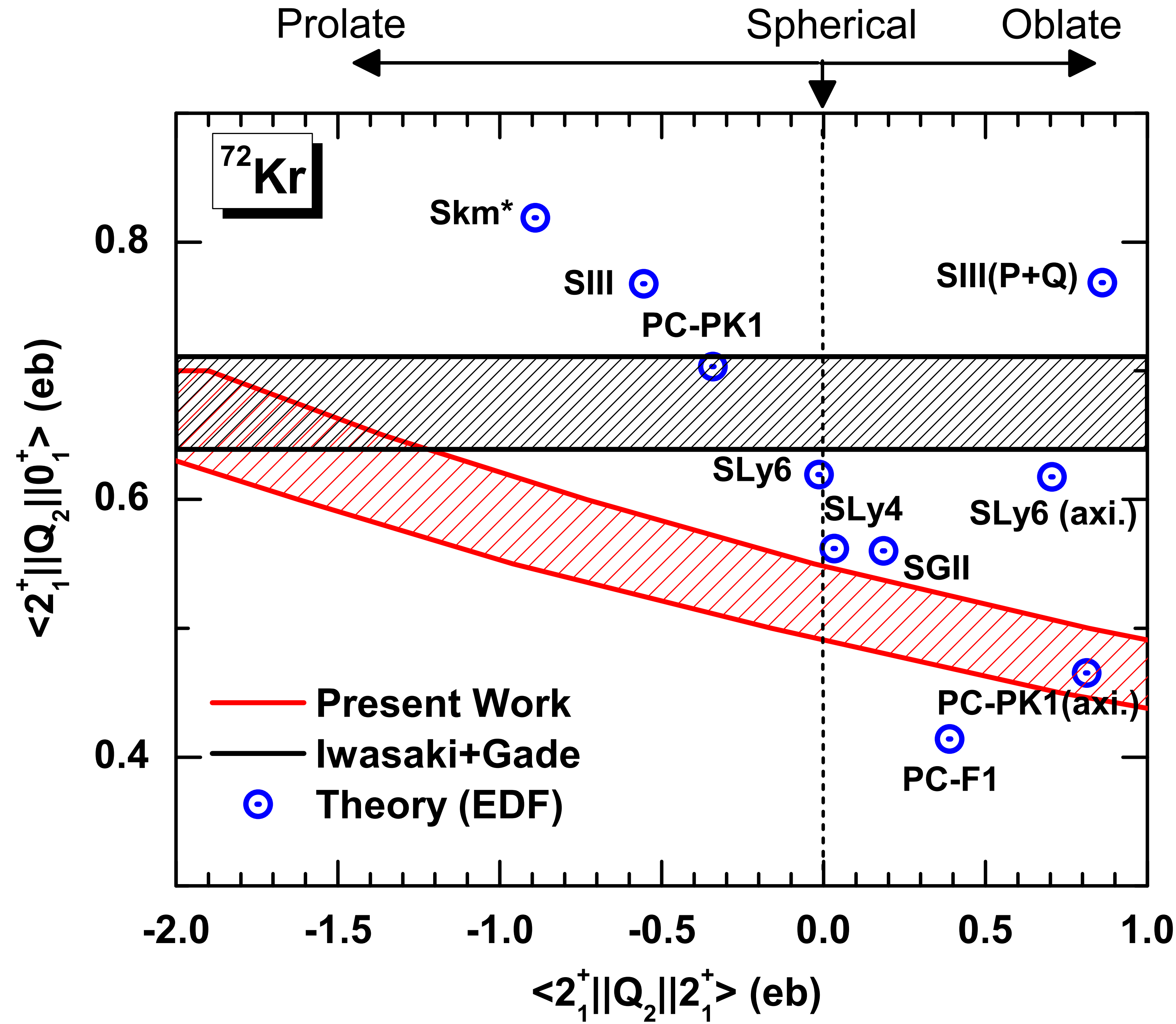
Which nucleus has "best" shape co-existence?





Theory says ^{72}Kr, but experiment points at ^{68}Se…..but the differences are subtle and a reflection of our advanced understanding

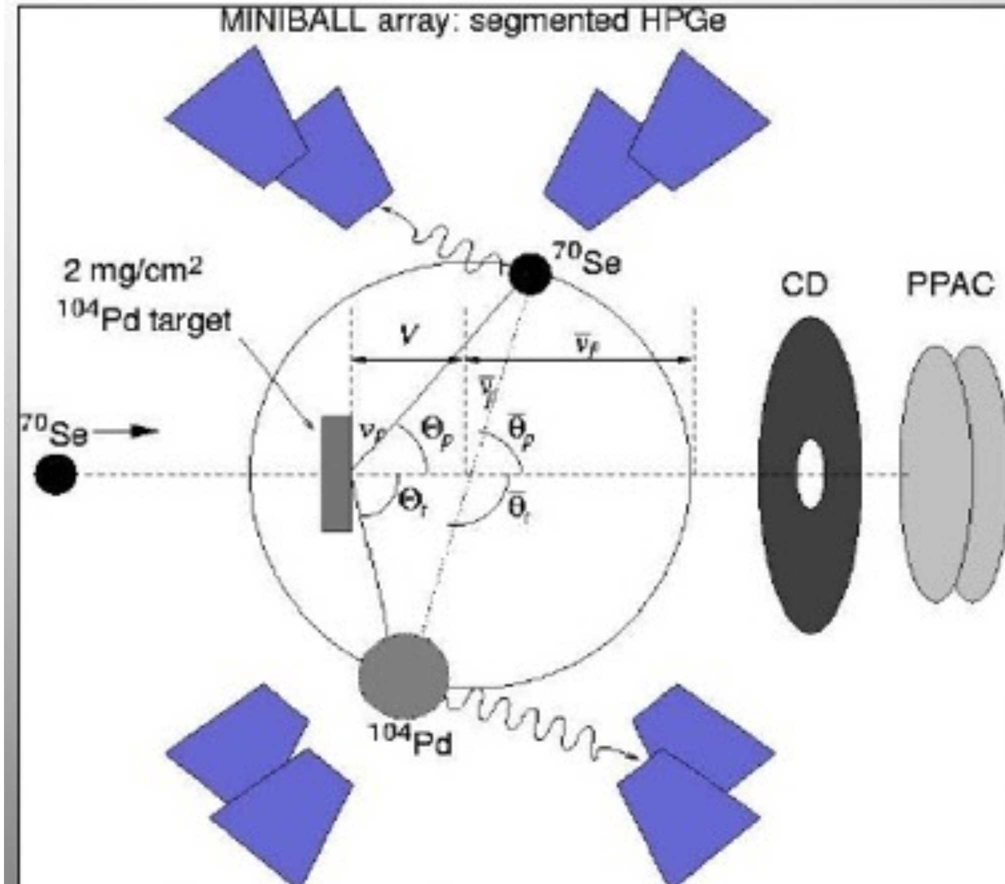
P. Moller, R.Bengtsson, B.G.Carlsson, P.Olivius, T.Ichikawa Phys.Rev.Lett. 97, 162502 (2006)

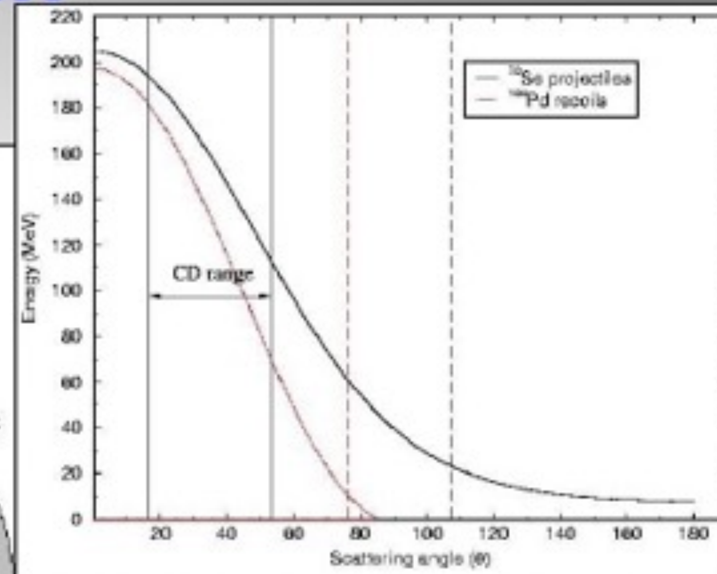


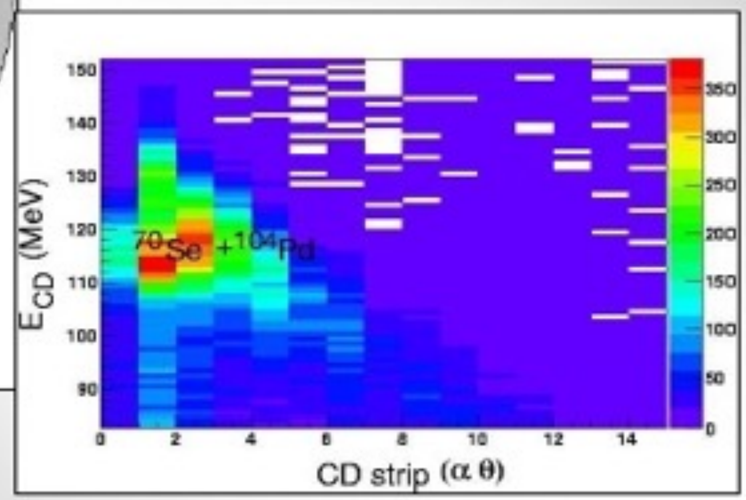
Prolate
Spherical
Oblate
72Kr
Skm*
SIII
SIII(P+Q)
PC-PK1
SLy6
SLy4
SLy6 (axi.)
SGII
PC-PK1(axi.)
PC-F1
Present Work
Iwasaki+Gade
Theory (EDF)
0.8
0.6
0.4
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
<2+1||Q2||0+1> (eb)
<2+1||Q2||2+1> (eb)

Miniball

^{104}Pd(^{70}Se,^{70}Se) @ 2.94 MeV/u







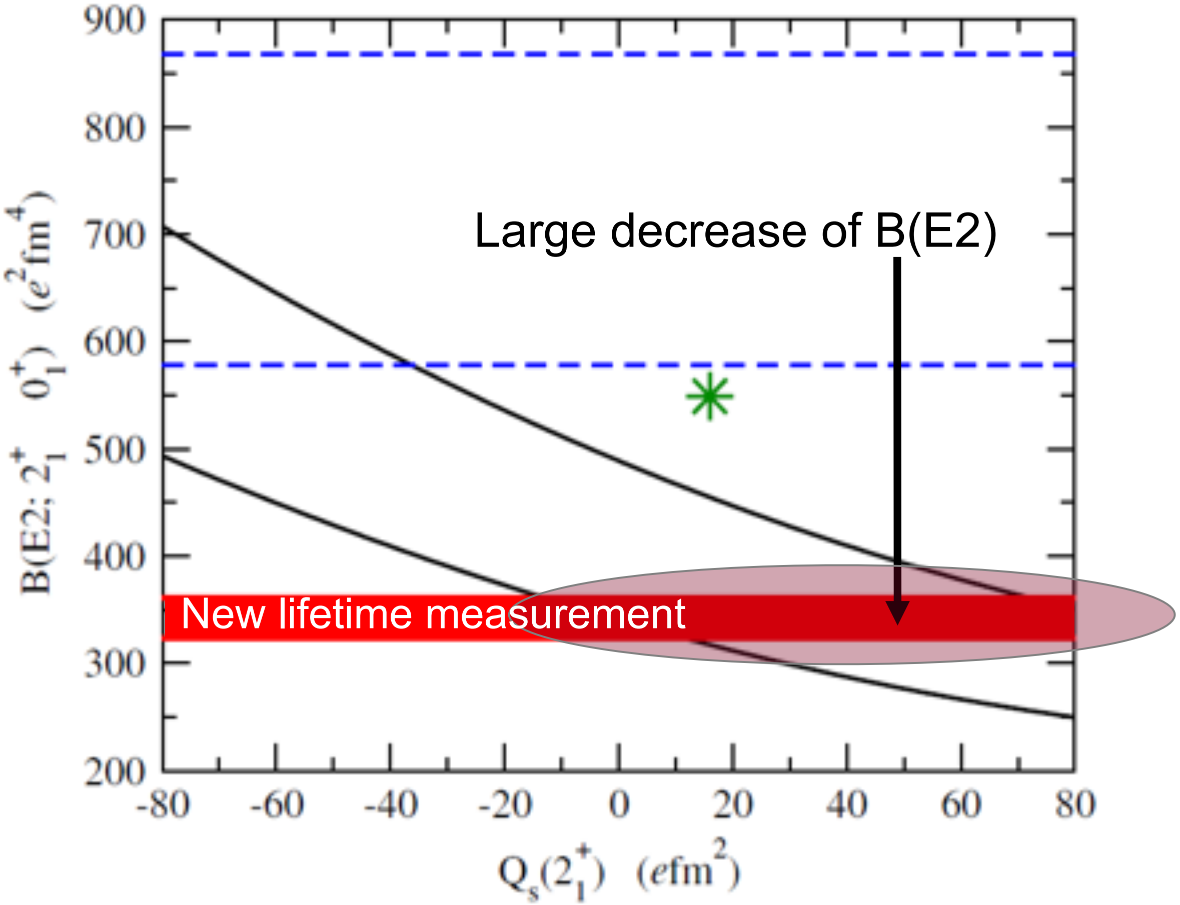
"normal kinematics"

Pure ^{70}Se beams, but only 10^4 ions/s

Google: 70Se + Peter Butler

Shape Coexistence in ^{70}Se

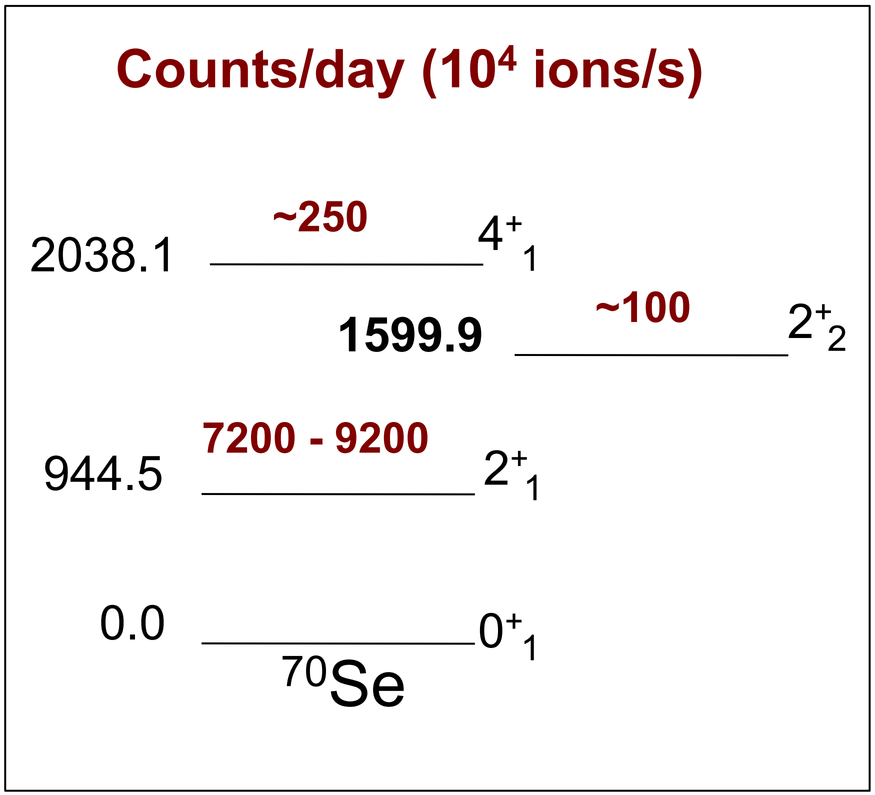
Spherical, Prolate or Oblate?

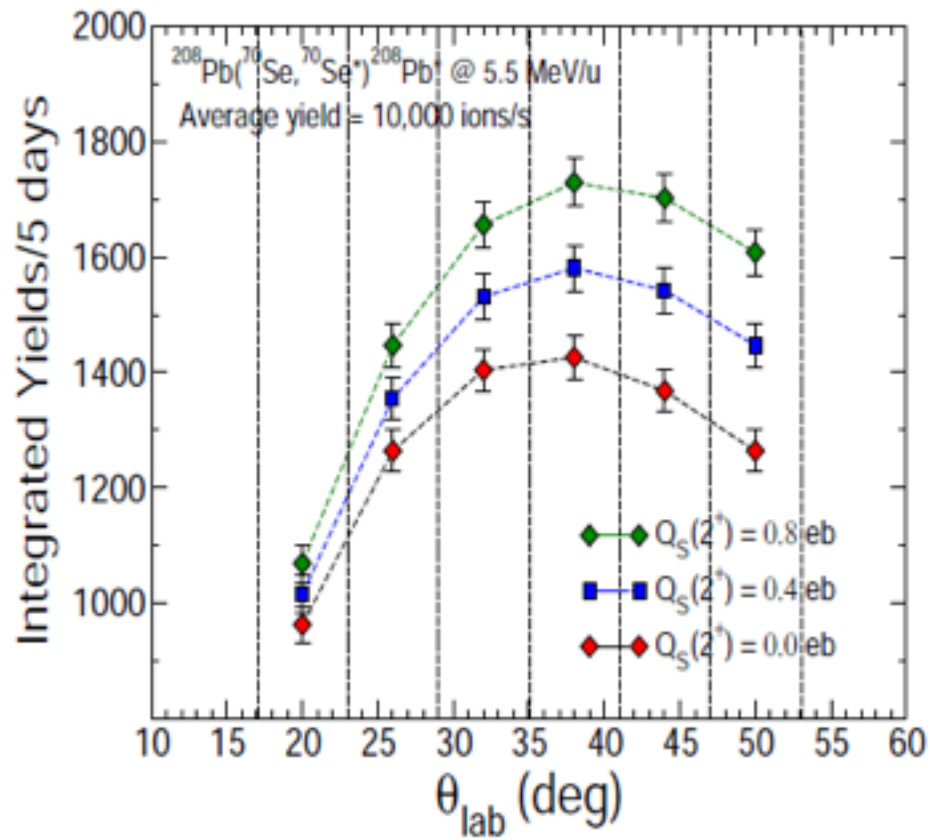


J. Ljungvall *et al.,* Phys. Rev. Lett. **100**, 102502 (2008)
A. Hurst *et al.,* Phys. Rev. Lett. **98**, 072501 (2007)

Shape Coexistence in ^{70}Se

New Reorientation-effect measurement at HIE-ISOLDE





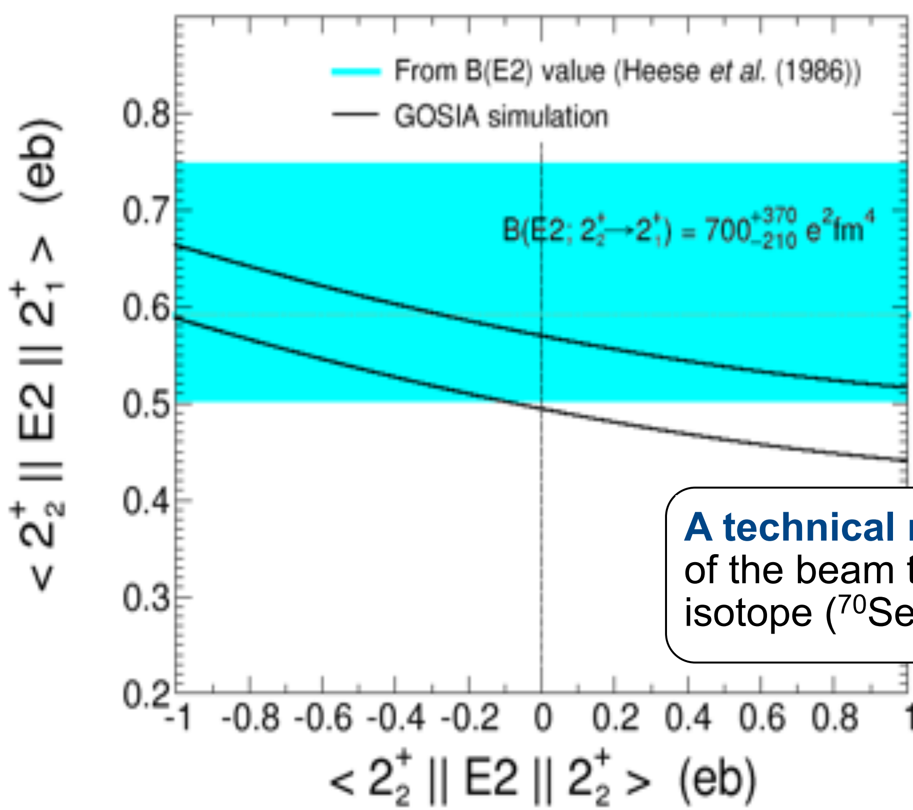
Angular distribution will tell us the shape

Shape Coexistence in ^{70}Se

What about the second 2^+? No statistics for angular distribution

High excitation energy and 10^4 ions/s are limiting us
6x improvement at HIE-ISOLDE: higher proton intensity on target and 2 GeV protons
We could still do it, but...

it depends on NNDC lifetime (Heese *et al.*, ~27% uncertainty) and $\delta = -1.0^{+1}_{-2}$!!



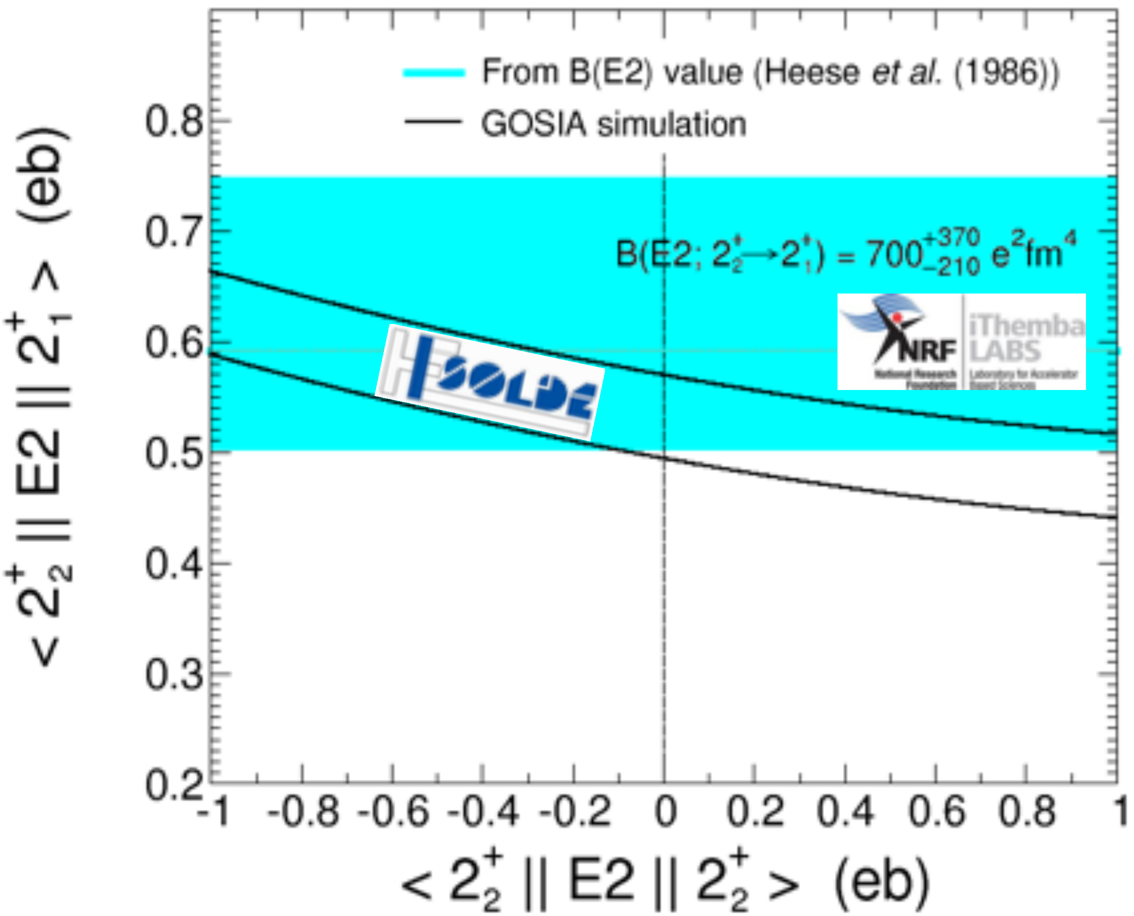
A technical remark: before the delivery of the beam the yield of the requested isotope (^{70}Se) has to be tested.

Shape Coexistence in ^{70}Se

What about the second 2^+? No statistics for angular distribution

Lifetime and mixing-ratio COMPLEMENTARY measurements at iThemba LABS

E.g., $^{58}Ni(^{14}N,pn)$ reaction at 39 MeV (Heese *et al* 1986) to avoid yrast population

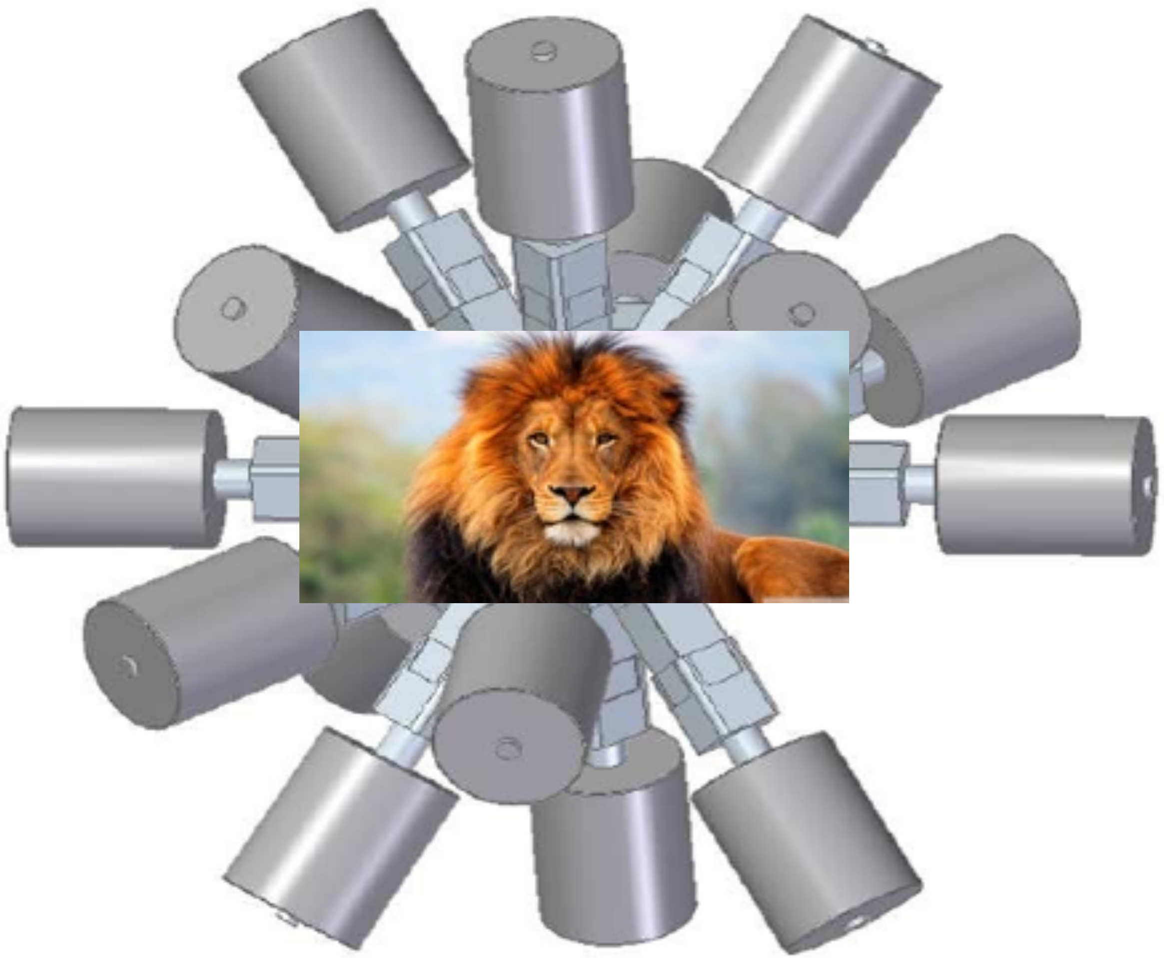


Shape Coexistence in ^{70}Se

What about the second 2^+? We need GAMKA!

Lifetime and mixing-ratio COMPLEMENTARY measurements at iThemba LABS

E.g., ^{58}Ni(^{14}N,pn) reaction at 39 MeV (Heese *et al* 1986) to avoid yrast population

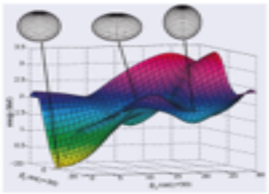


CONCLUSIONS & SUMMARY

- iThemba LABS is a vibrant facility with lots of possibilitites (K600, RIB, Tandetrom, AFRODITE + Ancillary Detectors)
- We've built a strong Coulomb-excitation program @ iThemba LABS
- A Lifetime program and GAMKA @ iThemba LABS
- HIE-ISOLDE full potential: $^{208}Pb(^{70}Se,^{70}Se^{*})^{208}Pb^{*}$ @ 5.5 MeV/u

- Allows precise measurement (±0.1 eb) of $< 2_1^+ \,||\, E2 \,||\, 2_1^+ >$ (spherical, prolate or oblate?)
- Test of state-of-the-art beyond-, relativistic- mean field models
- $< 2_2^+ \,||\, E2 \,||\, 2_2^+ >$? Not enough statistics for angular distribution

- Complete Physics needs stable-ion-beam facilities such as iThemba LABS



- Test of Shape coexistence is possible with combined efforts!