TRIUMF - EEC SUBMISSION Draft Submission *Progress Report*	**Exp. No.** S1242 - *In Preparation*
	Date Created: 2009-06-03 18:26:50

Title of Experiment:

High Precision Mass Measurements of Superallowed T=2 Nuclear Beta Decay Emitters

Name of group:

TITAN

Spokesperson(s) for Group

S. Ettenauer, J. Dilling

Current Members of Group:
(name, institution, status, % of research time devoted to experiment)

S. Ettenauer	University of British Columbia	Student (PhD)	80%
J. Dilling	TRIUMF	Research Scientist	20%
A. Gallant	University of British Columbia	Student (Graduate)	50%
M. Brodeur	University of British Columbia	Student (PhD)	50%
T. Brunner	T.U. Munich	Student (PhD)	50%
A. Garcia	University of Washington	Professor	20%
A. Lapierre	TRIUMF	Research Associate	20%
C. Wrede	Univ. of Washington	PDF	20%
D.G. Melconian	Texas A&M University	Assistant Professor	20%
G. Gwinner	University of Manitoba	Associate Professor	20%
P.P.J. Delheij	TRIUMF	Research Scientist	20%

R. Ringle	NSCL	Research Scientist	20%
S. Triambak	TRIUMF	Research Associate	20%

New Beam Requests:

Beam Shifts Used:

Beam Shifts Remaining:

Basic Information:

Date Created: 2009-06-03 18:26:50

Date Experiment Ready: 0000-00-00

Summary:

The unitarity test of the first row in the CKM quark mixing matrix represents a demanding test on the Standard Model. It includes the CKM matrix element Vud which is most precisely determined via superallowed Fermi 0+ → 0+ beta decays. The uncertainty on Vud is currently dominated by theoretical corrections to the ft-values of superallowed beta decays among which isospin symmetry breaking corrections show systematic discrepancies between different models. At this point superallowed beta decays are almost exclusively studied for isospin T=1 cases. Precise data from T=2 cases will thus provide an excellent opportunity to benchmark these theoretical descriptions, in particular because the isospin symmetry breaking corrections are expected to be larger for the T=2 cases. To move forward in this direction we therefore propose to perform high precision mass measurements for the superallowed T=2 beta decay emitters Mg-20, Si-24, S-28, Ar-32, Ca-36, Ti-40, Cr-44, Fe-48, and Ni-52.

Plain Text Summary:

Primary Beam Line: isac2a

ISAC Facilities

ISAC Facility: TITANYield

ISAC-I Facility:

ISAC-II Facility:

Secondary Beam

Isotope(s): Mg-20, Na-20, Si-24, S-28, P-28, Ar-32, Cl-32, Ca-36, K-36, Ti-40, Sc-40, Cr-44, V-44, Ti-43, Fe-48, Mn-48, Ni-52, Co-52

Energy: 20

Energy Units: keV

Energy spread - maximum :

Time spread - maximum :

Angular Divergence :

Spot Size:

Intensity Requested: >10^2 pps

Minimum Intensity: 30 pps

Maximum Intensity: 10^7 pps

Charge Constraints:

Beam Purity:

Special Characteristics:

Experiment Support

Beam Diagnostics Required:

Signals for Beam Tuning:

DAQ Support
(Summary of Requirements):

TRIUMF Support (Resources Needed):

All equipment is in place and running. Only normal operating support from TRIUMF is required.

NSERC:

Other Funding:

Safety Issues:

Safety issues for the TITAN experiment have been already addressed in the required documents and have met approval. A safety request for the specific beams of this proposal will be made after the decision of the EEC.

EEC Reader:

TRIUMF EEC NEW RESEARCH PROPOSAL

Detailed Statement of Proposed Research for Experiment # S1242

High Precision Mass Measurements of Superallowed T=2 Nuclear Beta Decay Emitters

(a) **Scientific value of the experiment**: Describe the importance of the experiment and its relation to previous work and to theory. All competitive measurements at other laboratories should be mentioned. Include examples of the best available theoretical calculations with which the data will be compared.

Superallowed Fermi $0^+ \rightarrow 0^+$ beta decays between isobaric analog states have proved to be the most precise way to extract V_{ud} of the Cabibbo–Kobayashi–Maskawa (CKM) quark mixing matrix. Together with V_{us} (and V_{ub}), it allows to challenge the CKM's unitarity by means of a unity test of the first row which represents a stringent test of the Standard Model of particle physics.

So far, superallowed beta decays have been – except one recent set of measurements- only studied for T=1 isospin multiplets and the 13 most precise cases are in remarkable agreement with the Conserved Vector Current (CVC) hypothesis which states that corrected *Ft*- values of superallowed decays are transition independent:

$$Ft = ft(1+\delta_R)(1-\delta_C) = \text{const}$$

Here, *f* is the statistical rate function, *t* is the partial half life for the transition, and δ_R and δ_C are transition dependent radiative and isospin symmetry breaking corrections, respectively. The average of the most precisely known *Ft*-values provides access to V_{ud} which currently rests at $V_{ud} = 0.97425 \pm 0.00022$ [HAR09], which is by far the most precisely measured element in the CKM matrix. Despite this level of precision, the contribution to the uncertainty on the unitarity test of the first row of the CKM matrix

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.99995(61) \qquad \text{[HAR09]}$$

is shared in equal parts between V_{ud} and V_{us} because of the much smaller, but less precise value of V_{us}. V_{ub} is too small to play any significant role at the moment. Thus, any future improvement on the theoretical or experimental side in respect to V_{us} will demand for increased efforts for superallowed beta decays. Potential deviations could also be interpreted as different coupling constants for leptons and quarks [MAR08]:

$$G_F^2(|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2) = G_\mu^2 = G_\tau^2$$

The above equation thus probes coupling universality of the weak force. Violations from $|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$ could further be caused by loop diagrams involving unobserved new particles such as a neutral gauge boson Z_χ which is part of the SO(10) unification scheme of the Standard Model's symmetry groups [MAR87]. The current level of precision restricts the mass of the Z_χ boson to be larger than 750 GeV at 95% CL [TSC09], which is about the same value as the lower mass limit from current collider data [ERL08]. This means that $|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2$ in this regard is competitive with collider physics and is within reach of sensitivity to physics at the TeV scale. Additionally, the sum also allows searches for right handed currents in the weak interaction and, finally, the *Ft*-values of superallowed decays are themselves stringent probes for fundamental or induced scalar currents in nuclear beta decays.

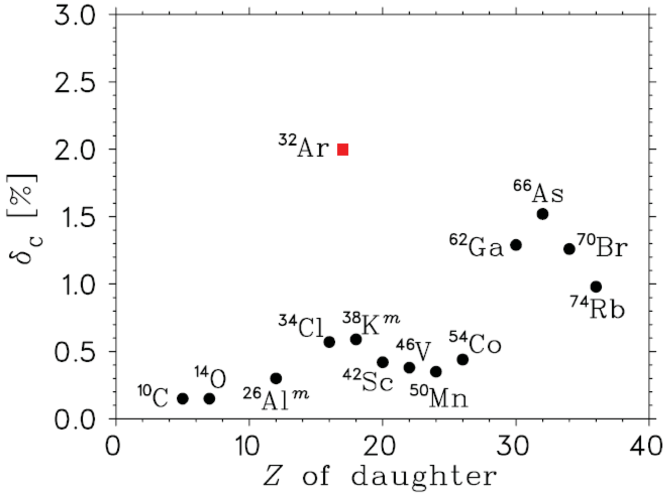
Consequently, improving the precision in *Ft*-values of superallowed nuclear beta decays remains of great importance in the low energy precision frontier. Currently, a dominant source of uncertainty for *Ft*-values is due to discrepancies between different theoretical models for nuclear structure effects in δ_C: Calculations based on a Saxon-Wood potential [TOW77, TOW02] are consistently larger than using Hartree-Fock eigenfunctions [ORM95] even though both are based on the same shell model space.

The former approach was recently refined by including core-orbitals [TOW08] which lead to an improved confirmation of CVC, but did not resolve the discrepancies with the Hartree-Fock calculations. In their last critical survey on superallowed beta decays Hardy and Towner [HAR09] have now performed their own Hartree-Fock based calculations of δ_C which employs the same model space as in [TOW08]. However, it has to be stressed that the used method is not identical to [ORM95]. Hardy and Towner identified, in their opinion, a serious flaw in the previous Hartree-Fock procedure: In the asymptotic expression of the mean-field potential's direct Coulomb term the total charge appears one unit too high. In principle this would be compensated by the exchange term in the Hartree-Fock formalism, but the exchange term cannot be calculated without sacrificing accuracy. Consequently, Hardy and Towner have altered the previous Hartree-Fock protocol to avoid this problem. Their results are now in better agreement with their own Saxon-Wood calculation; a fact which is entirely responsible for the significant reduction on the δ_C's uncertainty in [HAR09].

Additionally, Miller and Schwenk [MIL08] suggest improvements in the implementation of the isospin operator for δ_C – calculations. A completely new approach for the calculation of δ_C has been proposed in [AUE09].

These recent developments illustrate the improvements in the understanding of the isospin symmetry breaking corrections δ_C. Assuming CVC, experimental data can be used to benchmark theoretical descriptions and are thus essential for pushing the level of precision further. For this purpose superallowed beta decays in T=2 multiplets provide particularly important test cases: First, because the corrections have been intensively tested only for decays between T=1 states, and secondly, the corrections are expected to be larger for T=2 transitions [TOW09] (see also figure 1), which offers an opportunity to discriminate between theoretical models.

Figure 1
Hartree-Fock based isospin symmetry breaking corrections for different superallowed decays. Except ^{32}Ar, which is T=2 and calculated in [BHA08], all cases are T=1 transitions and determined in [ORM95]. ***Figure from [BHA08]***



T=2 transitions are more challenging from an experimental perspective due to their greater distance from the valley of stability, implying shorter half-lives, lower yields at radioactive beam facilities and more exotic decay channels as for instance beta delayed proton emissions. Nevertheless, T=2 superallowed transitions are within experimental reach as the very first case to determine the corrected *Ft*-value in ^{32}Ar has proven [BHA08].

We therefore propose high precision mass measurements for the superallowed T=2 beta decay emitters ^{20}Mg, ^{24}Si, ^{28}S, ^{32}Ar, ^{36}Ca, ^{40}Ti, ^{44}Cr, ^{48}Fe, and ^{52}Ni, which is essential to experimentally access the transition energy, i.e. the Q-value, required to determine the statistical rate function *f*. Combined with half-life and branching ratio of the superallowed decay the *Ft*-value can be obtained. The first measurement is planned on ^{20}Mg which is a particularly interesting case, because in addition to its importance for studies of superallowed decays, it currently also contributes the dominating uncertainty for the test of the isobaric multiplet mass equation (IMME) in the A=20, T=2 quintet [GAD07]. This is by itself very interesting because for A=20, T=2 the lowest lying 0^+ multiplet appears to follow the IMME, while there is a tiny hint that the 2^+ multiplet might violate the IMME. Our mass value for ^{20}Mg is expected to be at least a factor 15 better than the current value (see also Table 1 in the next section) and will thus provide tighter constraints on the IMME. Similarly, the mass of ^{36}Ca is the dominating source of uncertainty on the IMME in the A=36 quintet [YAZ07].

(b) **Description of the experiment**: Techniques to be used, scale drawing of the apparatus, measurements to be made, data rates and background expected, sources of systematic error, results and precision anticipated. Compare this precision with that obtained in previous work and discuss its significance in regard to constraining theory. Give a precise list of targets to be used in order of their priority.

The TITAN facility is pictured in Figure 2a. The ISAC beam is injected in the RFQ cooler and buncher. For measurements on singly charged ions the ions are directly transferred into the measurement Penning trap. The measurement precision follows the equation

$$\frac{\delta m}{m} \propto \frac{m}{q} \frac{1}{BTN^{1/2}}$$

where B is the magnetic field strength in the Penning trap, T is the measurement time per ion shot, N is the number of ion shots, and q is the charge state of the ion. Consequently, to improve the level of precision, the ions can also be sent after extraction from the RFQ to an Electron Beam Ion Trap (EBIT) where they are charge bred to higher charge states before being sent to the measurement Penning trap. The cooling Penning trap is currently under construction.

Mass measurements are performed via frequency scans of quadrupolar RF excitations; resonances appear at the cyclotron frequency (see Figure 2b) being proportional to its mass

$$\nu_c = \frac{1}{2\pi} \frac{q}{m} B$$

Figure 2
(a) *Experimental setup of TITAN*
(b) *Time of flight resonance curve for a cyclotron frequency determination*

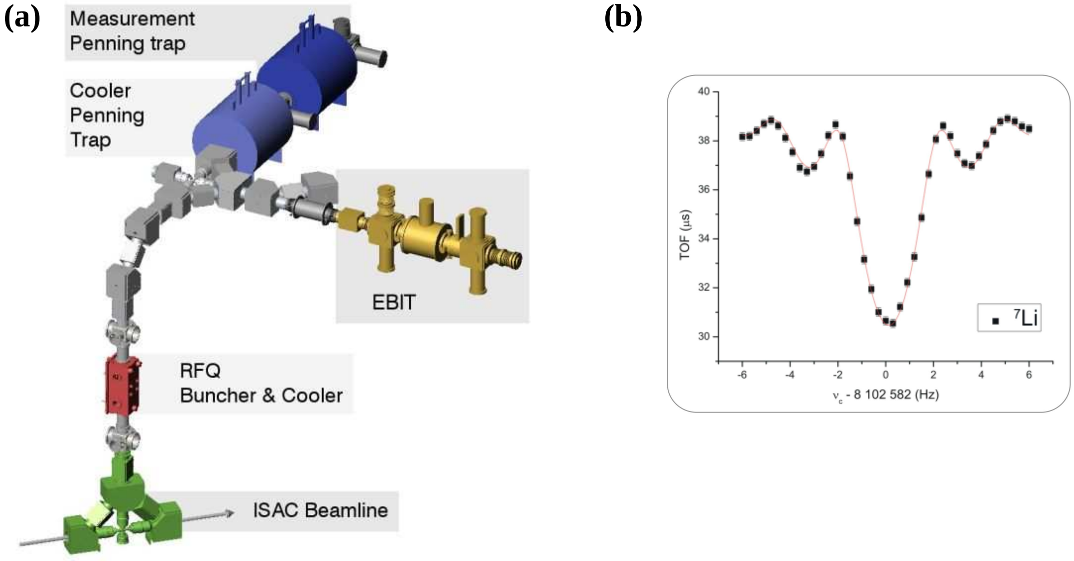


Table 1 lists half-lives and the present uncertainties on the mass values which are taken from the Atomic Mass Evaluation 2003 (AME03), except for the cases of ^{32}Ar and ^{36}K which are cited from the Penning trap measurements [BLA03] and [YAZ07] respectively, not evaluated in the AME03. The current uncertainty is compared with the expected uncertainty for the TITAN measurement. A $\delta m/m$ of 10^{-7} for single charged ions (A+) is assumed, which is a conservative upper limit never exceeded by any previous published TITAN measurement. Even in our very recent measurement of ^{12}Be with a half-life of 23.6 ms and only 30-150 ions/sec measured at the yield station a precision of less than $\delta m/m<2\cdot10^{-7}$ could be achieved. However, none of the proposed isotopes have half-lives as short as ^{12}Be. Considering that the half-life goes into the minimally achievable uncertainty as $1/T_{1/2}$ our ^{12}Be measurements provides strong confidence that as soon as one of the proposed species can be identified at the yield station, TITAN will be able to perform a measurement by using singly charged ions with $\delta m/m<10^{-7}$.

To improve the precision further TITAN's EBIT will be used to charge breed singly charged ions to a higher charge state q, which reduces the uncertainty by an additional factor q. First mass measurements using highly charged ions (HCI) are planned for summer 2009. The upper limit on the expected uncertainty for the proposed cases by using highly charged ions is also listed in Table 1. The charge breeding to the intended charge state will take between 5-10 ms and is well below the respective half-lives.

Finally, Table 1 also provides the uncertainty on the excitation energy E* of the isobaric analog state in the daughter nucleus. These data are taken from the Evaluated Nuclear Structure Data File (ENSDF) or the Experimental Unevaluated Nuclear Data List (XUNDL).

Since the transition energy required for the determination of the respective *Ft*-value is simply Q=m(g.s. , parent)-m(g.s., daughter)-E*, the impact of the uncertainty of the ground state masses on the error on the Q-value will be entirely eliminated after our measurements, except for the case of ^{32}Ar for which the excitation energy in ^{32}Cl has been recently measured and is known to 0.4 keV [BHA08]. This is comparable to our aimed uncertainty for the ground state masses.

Table 1: Proposed Measurements

List of the proposed mass measurements to determine Q-values of superallowed T=2 transitions: ‘present Δm’ *is based on AME03 except for* ^{32}*Ar and* ^{36}*K. The expected uncertainty for the TITAN measurement using singly charged ions are given in column* ‘Δm TITAN (A$^+$)’. *The expected uncertainty for highly charged ions is listed in* ‘TITAN HCI’ *together with the charge state to be used for the measurement.* ‘ΔE*’ *is the uncertainty on the isobaric analog state in the daughter nucleus. A measured ISAC yield can be found in column ‘YIELD’. Since* ^{44}*V might be difficult to be delivered, we also add* ^{43}*Ti to the list: The Q-value can then be determined via the beta-delayed proton decay of* ^{44}*Cr similarly as it was done for* ^{32}*Ar [BHA08].*

Isotope	Half-life	Present Δm [keV]	Δm TITAN (A$^+$) [keV]	TITAN		HCI	ΔE* [keV]	YIELD ions / sec	comment
				q		Δm [keV]			
Mg-20	90 ms	27	1.865	10	He-like	0.186		240	request stage 2
Na-20	448 ms	6.66	1.864	9	He-like	0.207	13	1.7▪10^{8}	request stage 2
Si-24	140 ms	19.47	2.237	12	He-like	0.186			?
Al-24	2.053 s	2.78	2.236	11	He-like	0.203	6		proposal S1191
S-28	125 ms	160	2.609	14	He-like	0.186			requires development
P-28	270 ms	3.32	2.607	13	He-like	0.201	21		requires development
Ar-32	98 ms	1.8	2.981	16	He-like	0.186			requires development
Cl-32	298 ms	6.59	2.979	15	He-like	0.199	0.4		requires development
Ca-36	102 ms	40	3.353	10	Ne-like	0.335			possible, request stage 2
K-36	342 ms	0.39	3.352	9	Ne-like	0.372	8	2.9▪10^{5}	request stage 2
Ti-40	53 ms	160	3.725	12	Ne-like	0.310			requires development
Sc-40	182 ms	2.83	3.724	11	Ne-like	0.339	8		requires development
Cr-44	53 ms	50	4.097	14	Ne-like	0.293			requires development
V-44	111 ms	121	4.096	13	Ne-like	0.315	?		?
Ti-43	509 ms	6.90	4.002	12	Ne-like	0.334			requires development
Fe-48	44 ms	70	4.469	16	Ne-like	0.279			requires development
Mn-48	158 ms	112	4.468	15	Ne-like	0.298	0.9		requires development
Ni-52	38 ms	84	4.842	18	Ne-like	0.269			requires development
Co-52	115 ms	65	4.840	17	Ne-like	0.285	30		requires development

Mass measurements in Penning traps require pure beams of the species of interest. For the TITAN facility several possibilities are foreseen to handle isobaric contaminations in case they are present in the ISAC beam after the mass separator.

Dipole cleaning techniques are already in place and can be used in the measurement Penning trap itself. For more efficient and higher resolving powers TITAN is at this moment upgrading the existing facility along two lines: The cooling Penning trap currently under construction and planned to be added to the TITAN platform in the beginning of next year will have the ability to apply a more elaborate cleaning technique involving dipole and quadruple excitation in the buffer-gas filled trap. Additionally, TITAN will also install a multi-reflection TOF separator which is specifically designed for isobaric cleaning. The required resolving powers to deal with potential contaminates for the proposed measurement is thus not expected to represent any problem.

Systematic uncertainties have been investigated in detail [BRO09] for single charged ions and at this moment we state them at less then 1 ppb ▪ ΔA

(c) **Experimental equipment**: Describe the purpose of all major equipment to be used.
Details of all equipment and services to be supplied by TRIUMF must be provided separately on the Technical Review Form available from the Science Division Office.

In addition to the TITAN facility, the ISAC yield station will be needed to determine the yields, isobaric contaminants and their suppression by the mass separator. A quadrupole ion guide under development at ISAC could be involved at the later stage of the proposed experiment to help reduce isobaric contamination.

(d) **Readiness**: Provide a schedule for assembly, construction and testing of equipment. Include equipment to be provided by TRIUMF.

The TITAN setup is operational and ready to perform the measurements outlined above. TITAN has proved to be in a position to handle short-lived isotopes at low rates. Online measurements with highly charged ions will be performed later this year and will be available for the proposed experiment.
Tests of the cleaning of isobaric contamination in the measuring Penning trap have demonstrated that contamination in excess of 20:1 can be handled without significant effect on the precision of the measurement. Further isobaric cleaning would require the cooling Penning trap or multi-reflection TOF separator which will come online within the next year.

We request stage 2 approval for those cases which ISAC beam is already developed for, i.e. ^{20}Mg and ^{36}Ca, and are seeking stage 1 for all other cases.

(e) **Beam time required**: State in terms of number of 12-hour shifts. Show details of the beam time estimates, indicate whether prime-user or parasitic time is involved, and distinguish time required for test and adjustment of apparatus.

We request 1 shift for each case, i.e. parent and daughter, for setup and calibration and 5 shifts for the measurement. This is 54 shifts in total. We will need at least 30 ions/sec to perform the measurement.

(f) **Data analysis**: Give details and state what data processing facilities are to be provided by TRIUMF.

The data evaluation methods are well developed for the TITAN mass spectrometer system, and all the necessary software tools are available.

References:

[AUE09] N. Auerbach, Phys. Rev. C 79, 035502 (2009)
[BLA03] Blaum et al., Phys. Rev. Lett. **91**, 260801 (2003),
[BHA08] M. Bhattacharya et al., Phys. Rev. C **77**, 065503 (2008)
[BRO09] M. Brodeur et al., in preparation for Phys. Rev. C
[ERL08] J. Erler and P. Langacker, “Electroweak model and constraints on new physics“, report in PDG08
[GAD07] A. Gade et al., Phys. Rev. C76, 024317 (2007)
[HAR09] J. C. Hardy and I.S. Towner, Phys. Rev. C **79**, 055502 (2009)

[MIL08] G.A. Miller and A. Schwenk, Phys. Rev. C 78, 035501 (2008)
[MAR87] W.J. Marciano and A. S, Phys. Rev. D35, 1672 (1987)
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[ORM95] W. E. Ormond and B. A. Brown, Phys. Rev. C52, 2455 (1995)
[TOW77] I. S. Towner et al., Nucl. Phys. A 284, 269 (1977)
[TOW02] I.S. Towner and J. C. Hardy, Phys. Rev. C66, 035501 (2002)
[TOW08] I.S. Towner and J. C. Hardy, Phys. Rev. C77, 025501 (2008)
[TOW09] I.S. Towner, personal communications
[TSC09] B. Tschirhart , presentation at CIPANP 2009
[YAZ07] Yazidjian et al., Phys Rev. C 76, 024308 (2007)

TRIUMF EEC NEW RESEARCH PROPOSAL

Spokesperson(S) Publications for the Previous Five (5) Years for Experiment #1242

High Precision Penning trap mass measurements of ^{9,10}*Be and the one-neutron halo nuclide* ^{11}*Be*
Physics Letters B 675, 170–174 (2009)
R. Ringle, M. Brodeur, T. Brunner, **S. Ettenauer**, M. Smith, A. Lapierre, V.L. Ryjkov, P. Delheij, G.W.F. Drake, J. Lassen, D. Lunney, and **J. Dilling**

First Penning trap mass measurements of the exotic halo nucleus ^{11}*Li*
Phys. Rev. Lett. 101, 202501 (2008)
M. Smith, M. Brodeur, T. Brunner, **S. Ettenauer**, A. Lapierre, R. Ringle, V. L. Ryjkov, F. Ames, P. Bricault, G. W. F. Drake, P. Delheij, D Lunney, and **J. Dilling**

Intermediate-energy Coulomb Excitation of Na-30
Phys. Rev. C 78, 017302 (2008)
S. Ettenauer, H. Zwahlen, P. Adrich, D. Bazin, C. M. Campbell, J. M. Cook, A. D. Davies, D.-C. Dinca, A. Gade, T. Glasmacher, J.-L. Lecouey, W. F. Mueller, T. Otsuka, R. R. Reynolds, L. A. Riley, J. R. Terry, Y. Utsuno, and K. Yoneda

Electron capture branching ratio measurements in an ion trap for double beta decay experiments at TITAN
Nuclear Instruments and Methods in Physics Research B 266 4643 (2008)
T. Brunner, M. Brodeur, C. Champagne, D. Frekers, R. Krucken, A. Lapierre, P. Delheij, R. Ringle, V. Ryjkov, M. Smith, I. Tanihata, and **J. Dilling**

An electron beam ion trap for the NSCL re-accelerator
Nuclear Instruments and Methods in Physics Research B 266, 4466 (2008)
S. Schwarz, G. Bollen, J.R. Crespo López-Urrutia, **J. Dilling**, M. Johnson, O. Kester, M. Kostin, F. Marti, C. Wilson and P. Zavodszky

A high current electron ion beam ion trap as a charge breeder for the reacceleration of rare isotopes at the NSCL
Review of Scientific Instruments 79, 02A706 (2008)
S. Schwarz, G. Bollen, J.R. Crespo López-Urrutia, **J. Dilling**, M. Johnson, O. Kester, M. Kostin, F. Marti, C. Wilson and P. Zavodszky

LaBr$_3$*:Ce scintillators for in-beam gamma-ray spectroscopy with fast beams of rare isotopes*
Nucl. Instr. and Meth. A 594 (2008) 56-60
D. Weisshaar, M.S. Wallace, P. Adrich, D. Bazin, C.M. Campbell, J.M. Cook, **S. Ettenauer**, A. Gade, T. Glasmacher, S. McDaniel, A. Obertelli, A. Ratkiewicz, A.M. Rogers, K. Siwek, and S.R. Tornga

Considerations of the Application of Ramo's Theorem for Segmented Ge Detector's Pulse Shape Calculations
Nucl. Instr. and Meth. A 588 (2008) 380–383
S. Ettenauer

Direct mass measurement of the four-neutron halo nuclide ^{8}*He*
Phys. Rev. Lett. 101, 012501 (2008)
V.L. Ryjkov, M. Brodeur, T. Brunner, M. Smith, R. Ringle, P. Delheij, F. Ames, P. Bricault, M. Dombsy, and **J. Dilling**

Internal γ Decay and the Superallowed Branching Ratio for the β^+ *Emitter* ^{38m}K
Phys. Rev. Lett. 100, 192504 (2008)
K.G. Leach, C.E. Svensson, G.C. Ball, J.R. Leslie, R.A.E. Austin, D. Bandyopadhyay, C. Barton, E. Bassiachvilli, **S. Ettenauer**, P. Finlay, P.E. Garrett, G.F. Grinyer, G. Hackman, D. Melconian, A.C. Morton, S. Mythili, O. Newman, C.J. Pearson, M.R. Pearson, A.A. Phillips, H. Savajols, M.A. Schumaker, and J. Wong

Mass measurements and evaluation around A = 22
Eur. Phys. J. A 35, 35-37 (2008)
M. Mukherjee, D. Beck, K. Blaum, G. Bollen, P. Delahaye, **J. Dilling**, S. George, C. Guenaut, F. Herfurth, A. Herlert, A. Kellerbauer, H.-J. Kluge, U. Koster, D. Lunney, S. Schwarz, L. Schweikhard, and C. Yazidjian

ISOLTRAP: an on-line Penning trap for mass spectrometry on short-lived nuclides
Eur. Phys. J. A 35, 1-29 (2008)
M. Mukherjee, D. Beck, K. Blaum, G. Bollen, P. Delahaye, **J. Dilling**, S. George, C. Guenaut, F. Herfurth, A. Herlert, A. Kellerbauer, H.-J. Kluge, U. Koster, D. Lunney, S. Schwarz, L. Schweikhard, and C. Yazidjian

Spectroscopy of ^{36}*Mg: Interplay of Normal and Intruder Configurations at the Neutron-Rich Boundary of the "Island of Inversion"*
Phys. Rev. Lett. 99 (2007) 072502
A. Gade, P. Adrich, D. Bazin, M.D. Bowen, B.A. Brown, C.M. Campbell, J.M. Cook, **S. Ettenauer**, T. Glasmacher, K.W. Kemper, S. McDaniel, A. Obertelli, T. Otsuka, A. Ratkiewicz, K. Siwek, J.R. Terry, J.A. Tostevin, Y. Utsuno, and D. Weisshaar

Electron capture branching ratios for the odd-odd intermediate nuclei in double-beta decay using the TITAN ion trap facility
Can. J. Phys. 85, 57 (2007)
D. Frekers, **J. Dilling** and I. Tanihata

A high-current electron beam ion trap as an on-line charge breeder for the high precision mass measurement TITAN experiment
Hyperfine Interactions 173 (1-4) 85-92 2006
M. Froese, C. Champagne, J. R. Crespo López-Urrutia, S. Epp, G. Gwinner, A. Lapierre, J. Pfister, G. Sikler, J. Ullrich and **J. Dilling**

The TITAN mass measurement facility at TRIUMF-ISAC
Hyperfine Interactions 173 (1-4) 123-132 2006
P. Delheij, L. Blomeley, M. Froese, G. Gwinner, V. Ryjkov, M. Smith and **J. Dilling**

First tests of the TITAN digital RFQ beam cooler and buncher
Hyperfine Interactions 173 (1-4) 171-180 2006
Mathew Smith, Laura Blomeley, Paul Delheij and **Jens Dilling**

A cooler ion trap for the TITAN on-line trapping facility at TRIUMF
Hyperfine Interactions 173 (1-4) 103-111 2006
Z. Ke, W. Shi, G. Gwinner, K. Sharma, S. Toews, **J. Dilling**, V. L. Ryjkov and the TITAN Collaboration

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