Determining the effects of well-type chamber sample-volume dependence on the current clinical method used to determine the activity for ^{90}Y microsphere treatments

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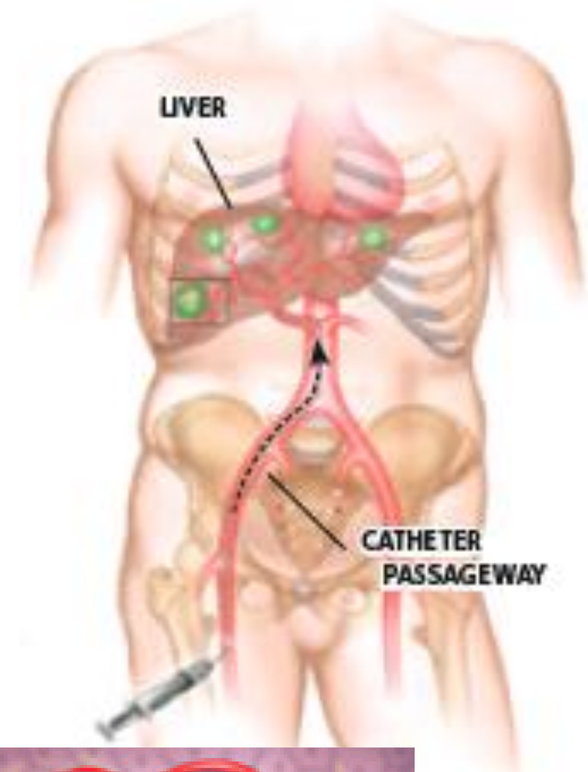
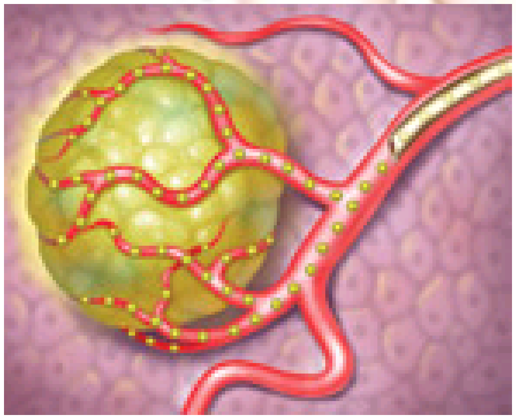
Overview

- ^{90}Y microspheres – motivation for this work
- Experimental setup and measurement
  - Well-type chambers
  - Source holder
  - Vials
- Results
  - Calibration coefficients
  - Volume effects on delivered activity
- Conclusions

^{90}Y microspheres

- Treatment for liver malignancies
- Delivered via catheterization of femoral artery
- ~30 µm in diameter
- ^{90}Y is a beta emitter
  - 64 h half-life
  - $E_{\beta max}$ = 2.28 MeV
- Two commercial products
  - SIR-Spheres® by Sirtex Medical
  - TheraSphere® by MDS Nordion





Images courtesy of www.sirtex.com

SIR-Spheres® preparation

- 3 GBq in 5mL of water in a glass shipping vial
- Rx activities are usually 1.0 - 2.5 GBq
- To obtain desired activity:
  - Initial measurement of shipping vial in dose calibrator
  - Draw out desired volume with a syringe
  - Re-measurement of shipping vial
  - Subtract results and confirm activity contained in syringe
- Contents of syringe placed in v-vial
- V-vial placed in delivery apparatus

Plastic v-vial   Glass shipping vial

Image courtesy of
www.capintec.com

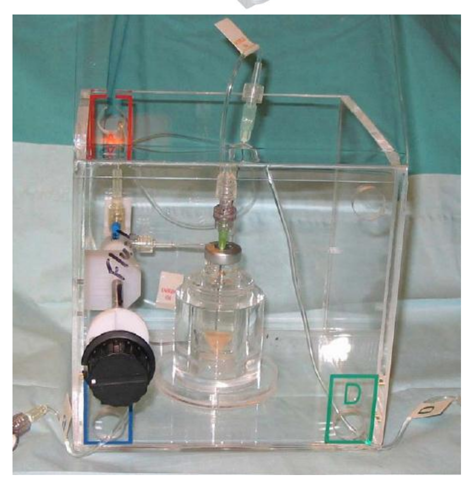


Image courtesy of
Bruce Thomadsen

SIR-Spheres® preparation

- How does this affect the delivered activity?

Goals:

- Determine volume-specific calibration coefficients (N_A in units MBq / pA)
  - Two chambers
  - Both vials (glass shipping vial and plastic v-vial)
- Use N_A to determine the actual activity delivered

Calibration source

- NIST Standard Reference Material provides a $^{90}YCl_3$ standard solution
  - Massic activity (MBq/g)
  - Uncertainty <1% (k = 2)
- Sartorius balance (max = 110 g, accuracy = +/- 0.1 mg)
  - Mass of solution provides a known activity

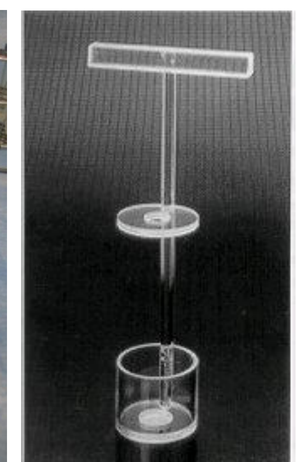
NIST flamed sealed glass ampoule

Sartorius balance

Chambers and source holders

- Well-type chambers
  - Standard Imaging (SI) IVB1000 well chamber
  - Capintec 12-atm dose calibrator
  - Each attached to a SI Max 4000 electrometer
- Source holders
  - Constructed of PMMA
  - Collars for both shipping and v-vial
  - Traditional “dipper” holder

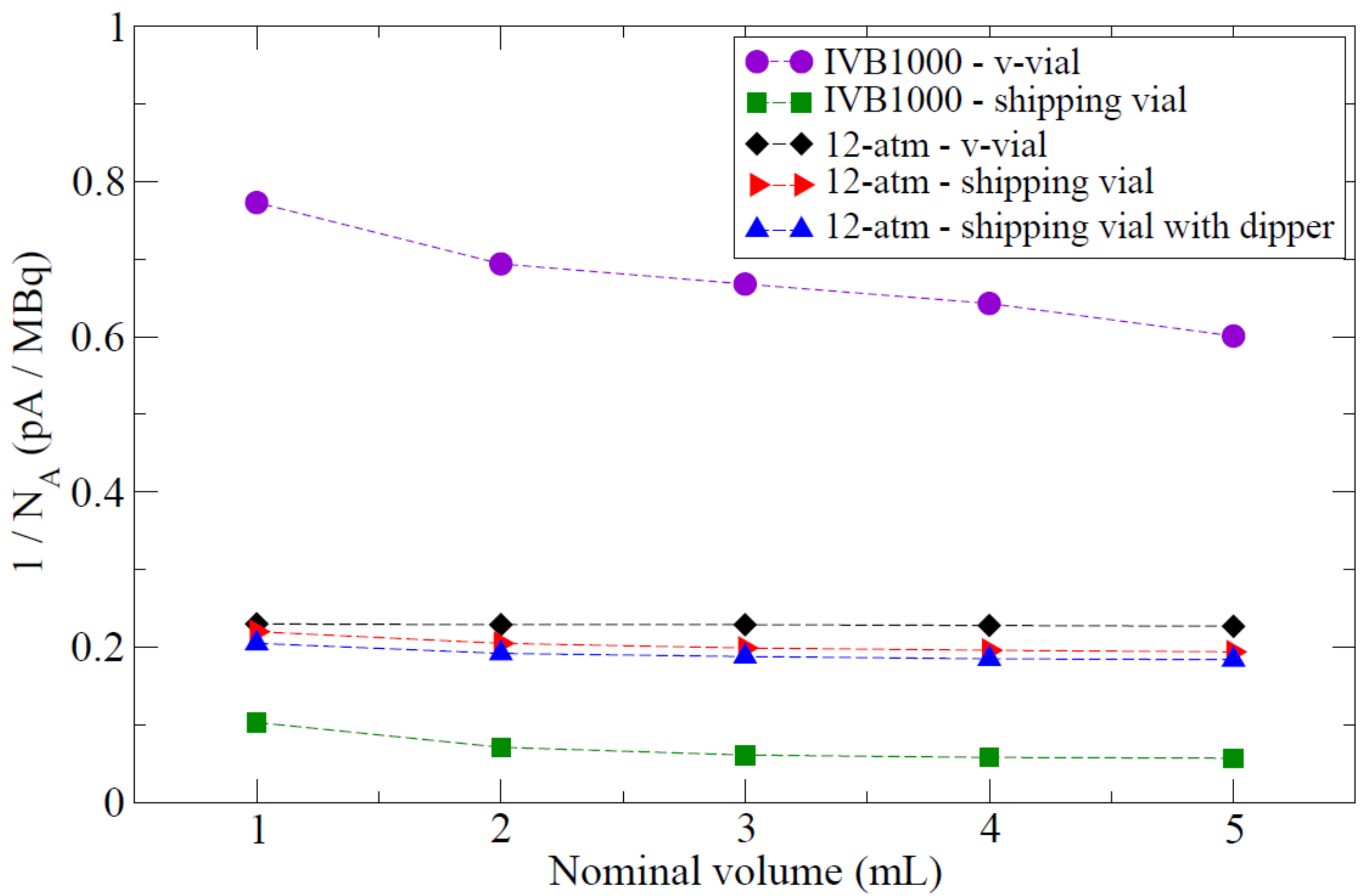
v-vial shipping vial



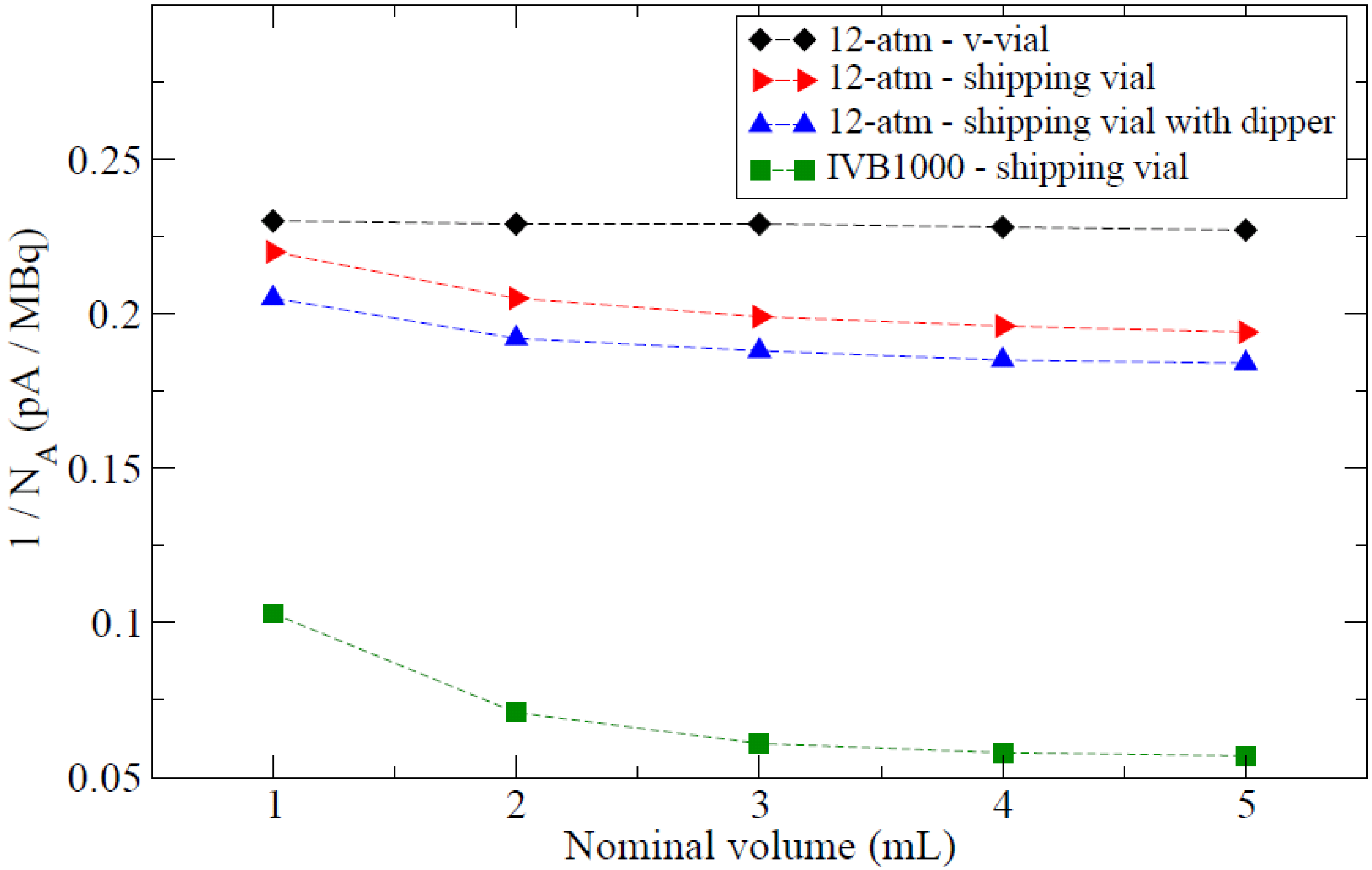
Measurements

- Each vial filled with 1 – 5 mL in 1 mL increments
- Mass of solution measured for each volume level
- 4 x 30 s charge measurements
  - Source rotated within chamber in 90° increments
- Average of charge measurements used to calculate ionization current
- Calibration coefficients (MBq / pA) were calculated for each combination of volume, vial, and chamber

Well chamber response



Well chamber response



Tables of calibration coefficients

Standard Imaging IVB1000 well chamber:

Volume (mL)	V-vial		Shipping vial	
	Cal Coeff (MBq/pA)	% Diff from 5 mL	Cal Coeff (MBq/pA)	% Diff from 5 mL
5	1.663	-	17.65	-
4	1.556	-6.43	17.38	-1.51
3	1.496	-10.0	16.33	-7.46
2	1.441	-13.4	13.99	-20.7
1	1.294	-22.2	9.682	-45.1

Capintec 12-atm dose calibrator:

Volume (mL)	V-vial		Shipping vial		Shipping vial w/ dipper	
	Cal Coeff (MBq/pA)	% Diff from 5 mL	Cal Coeff (MBq/pA)	% Diff from 5 mL	Cal Coeff (MBq/pA)	% Diff from 5 mL
5	4.406	-	5.152	-	5.436	-
4	4.377	-0.665	5.114	-0.750	5.418	-0.324
3	4.372	-0.779	5.026	-2.44	5.331	-1.92
2	4.375	-0.714	4.883	-5.23	5.211	-4.14
1	4.349	-1.30	4.549	-11.7	4.872	-10.4

Effects on activity determination

- Recall activity preparation
- Assume a Rx level
  - e.g., 2.4 GBq
- 0.6 GBq would occupy 1 mL
  - Assuming uniform distribution of the microspheres
- The 1 mL calibration coefficient is used to calculate the actual activity

$$3\,\mathrm{GBq} - 0.6\,\mathrm{GBq} = 2.4\,\mathrm{GBq}$$

$$3\,\mathrm{GBq} - (0.6\,\mathrm{GBq})\left(\frac{N_{\mathrm{A,1\,mL}}}{N_{\mathrm{A,5\,mL}}}\right) = A_{\mathrm{actual}}$$

$$3\,\mathrm{GBq} - 1.2\,\mathrm{GBq} = 1.8\,\mathrm{GBq}$$

$$3\,\mathrm{GBq} - (1.2\,\mathrm{GBq})\left(\frac{N_{\mathrm{A,2\,mL}}}{N_{\mathrm{A,5\,mL}}}\right) = A_{\mathrm{actual}}$$

$$3\,\mathrm{GBq} - 1.8\,\mathrm{GBq} = 1.2\,\mathrm{GBq}$$

$$3\,\mathrm{GBq} - (1.8\,\mathrm{GBq})\left(\frac{N_{\mathrm{A,3\,mL}}}{N_{\mathrm{A,5\,mL}}}\right) = A_{\mathrm{actual}}$$

Actual activity and difference from Rx

Standard Imaging IVB1000 well chamber:

Rx Activity (GBq)	V-vial		Shipping vial	
	Actual Activity (GBq)	% Diff from Rx	Actual Activity (GBq)	% Diff from Rx
2.4	2.53	5.5	2.67	11
1.8	1.96	8.9	2.05	14
1.2	1.38	15	1.33	11

Capintec 12-atm dose calibrator:

Rx Activity (GBq)	V-vial		Shipping vial		Shipping vial w/ dipper	
	Actual Activity (GBq)	% Diff from Rx	Actual Activity (GBq)	% Diff from Rx	Actual Activity (GBq)	% Diff from Rx
2.4	2.41	0.33	2.47	2.9	2.46	2.6
1.8	1.81	0.48	1.86	3.5	1.85	2.8
1.2	1.21	1.2	1.24	3.7	1.23	2.9

Conclusions

- The IVB1000 would not be ideal for these measurements
- Calibration and measurement in the v-vial would reduce the uncertainty in the activity determination with the 12-atm
  - Alternatively, volume corrections could be used with shipping vial
- Calibration in v-vial would also provide more accurate post-treatment measurements (if necessary)
- Measurement and calibration in the v-vial would require a modified or new holder
  - V-vial may tip or fall out of the “dipper” holder

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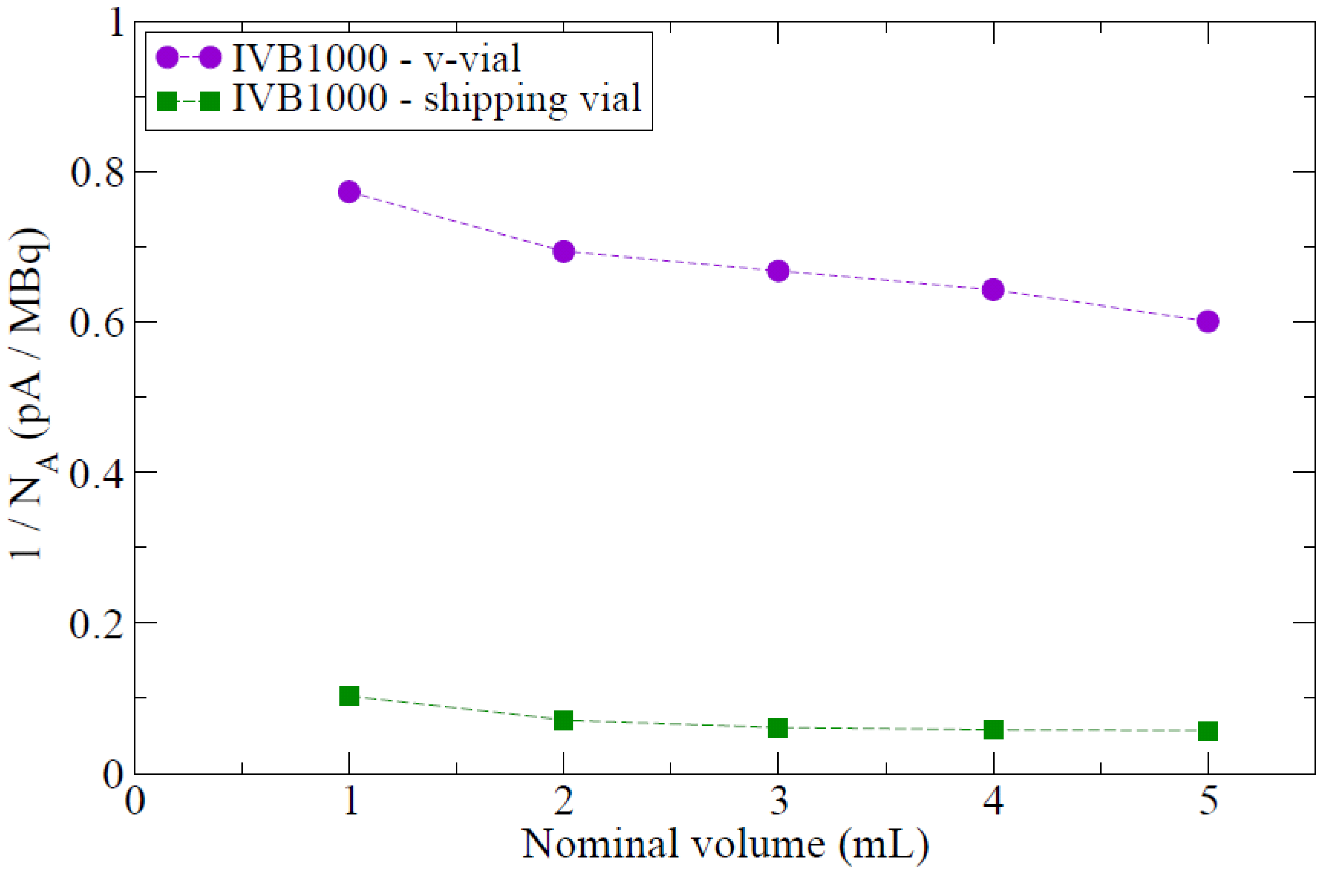
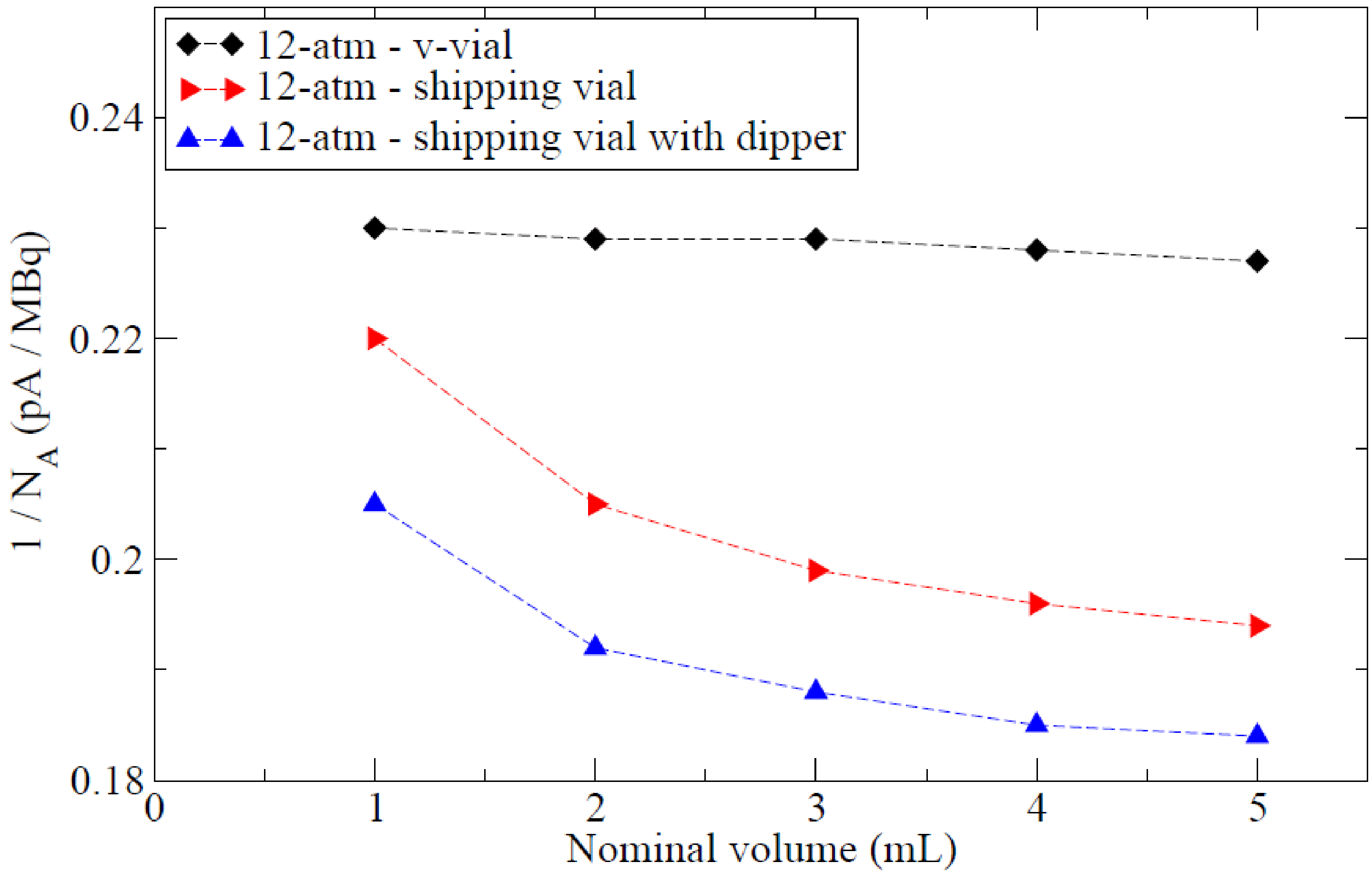
Thank you for your attention

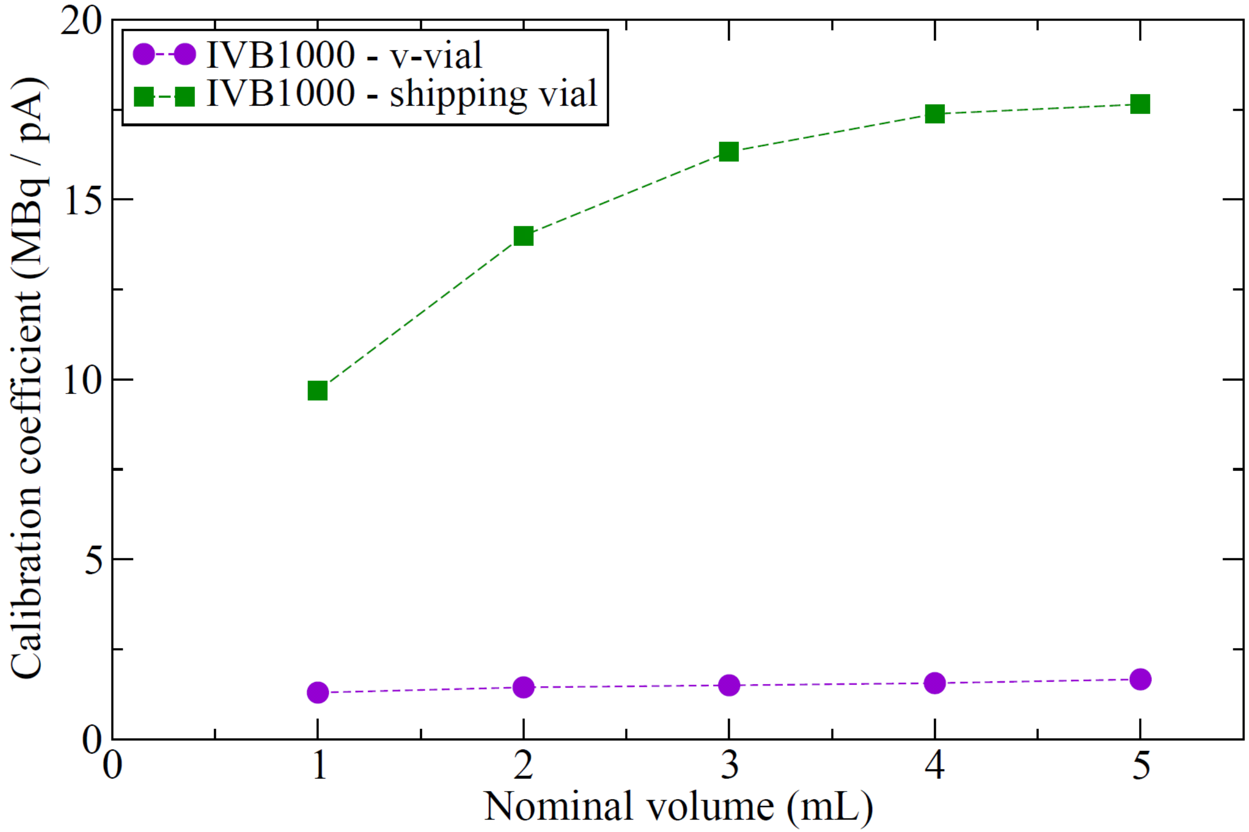
Questions?



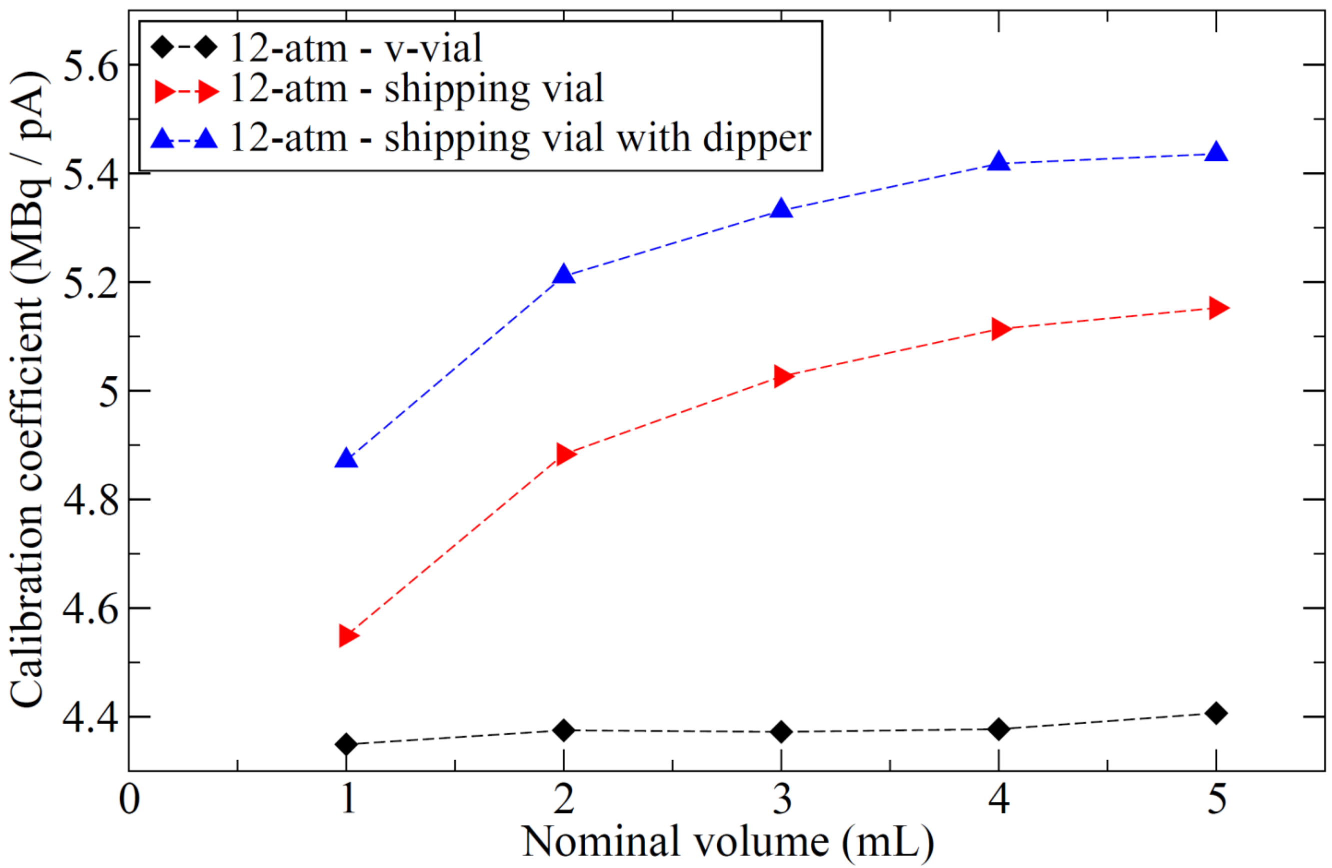
IVB1000 - v-vial
IVB1000 - shipping vial
1 / N_A (pA / MBq)
Nominal volume (mL)
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
5


12-atm - v-vial
12-atm - shipping vial
12-atm - shipping vial with dipper
0.24
0.22
0.2
0.18
0
1
2
3
4
5
$1 / N_A$ (pA / MBq)
Nominal volume (mL)

SI IVB1000 well chamber results



Capintec 12-atm dose calibrator results



Actual activity and difference from Rx

	V-vial		Shipping vial	
Rx Activity (GBq)	Actual Activity (GBq)	% Diff from Rx	Actual Activity (GBq)	% Diff from Rx
2.4	2.53	5.5	2.67	11.3
1.8	1.96	8.9	2.05	13.8
1.2	1.38	15.0	1.33	11.2
0.6	0.75	25.7	0.64	6.0

	V-vial		Shipping vial		Shipping vial w/ dipper	
Rx Activity (GBq)	Actual Activity (GBq)	% Diff from Rx	Actual Activity (GBq)	% Diff from Rx	Actual Activity (GBq)	% Diff from Rx
2.4	2.41	0.3	2.47	2.9	2.46	2.6
1.8	1.81	0.5	1.86	3.5	1.85	2.8
1.2	1.21	1.2	1.24	3.7	1.23	2.9
0.6	0.62	2.7	0.62	3.0	0.61	1.3