Geometry corrections for cylindrical neutron area survey meters

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Scope of Talk

- Calibrating (neutron) monitors
  - Influences and corrections
- Geometry corrections now
  - In general
  - The need for cylindrical detector geometry corrections
- Calculation of geometry corrections
  - MCNP modelling and results
  - Sanity checks
  - Comparison with measurement data
- Understanding the results

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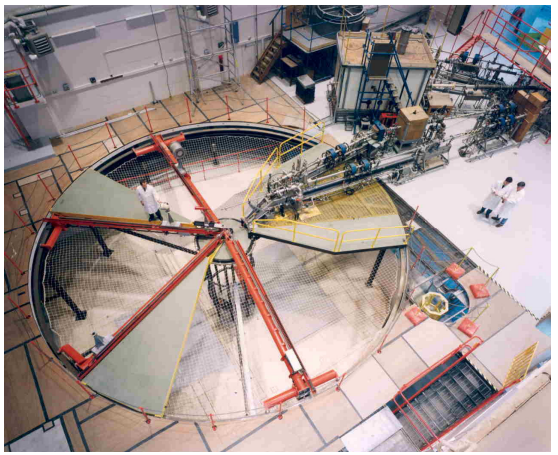
Factors Affecting Detector Readings

- Neutron monitor readings during calibrations depend on:
  - Detector type / size / linearity

Detector calibrations should not vary between calibration laboratories!



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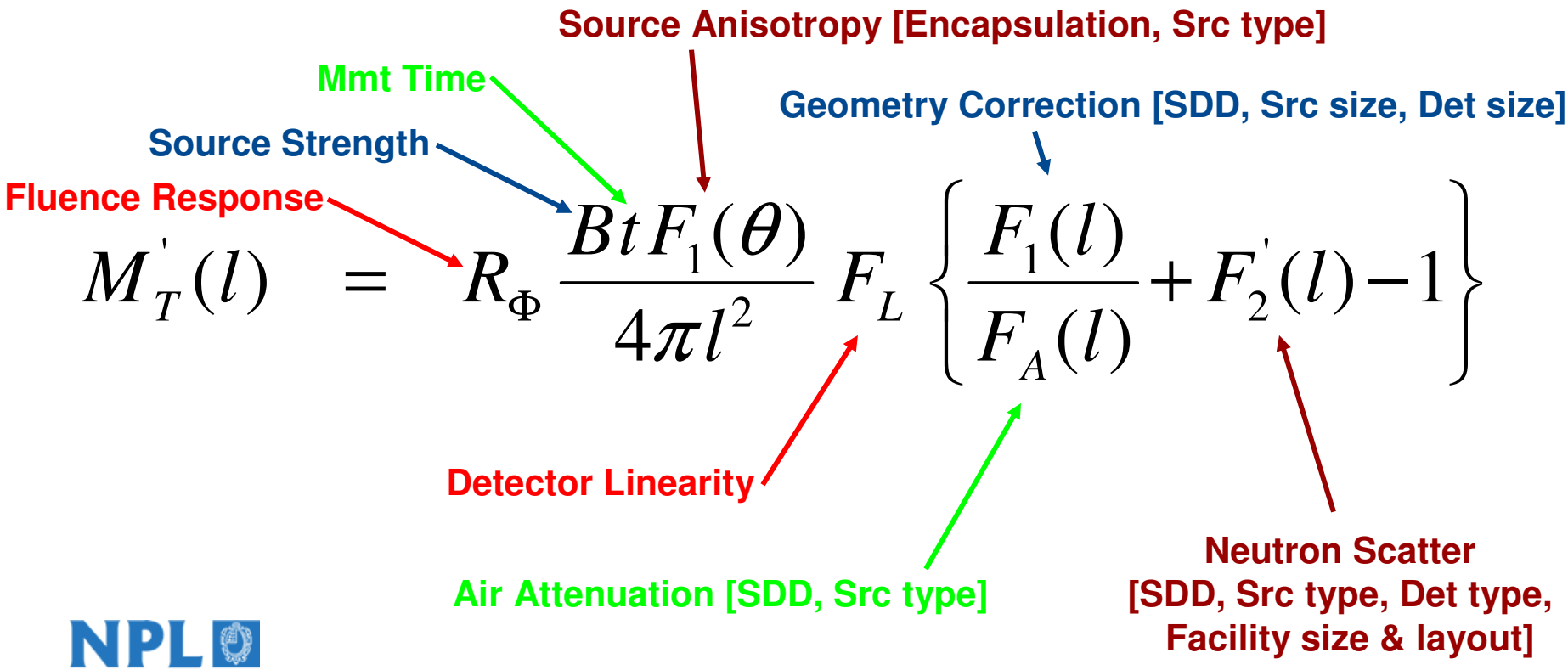
Relating Measurement Reading to Detector Response

- ISO 8529-2 addresses these factors in the following formula for the measurement reading $M'_T(l)$:



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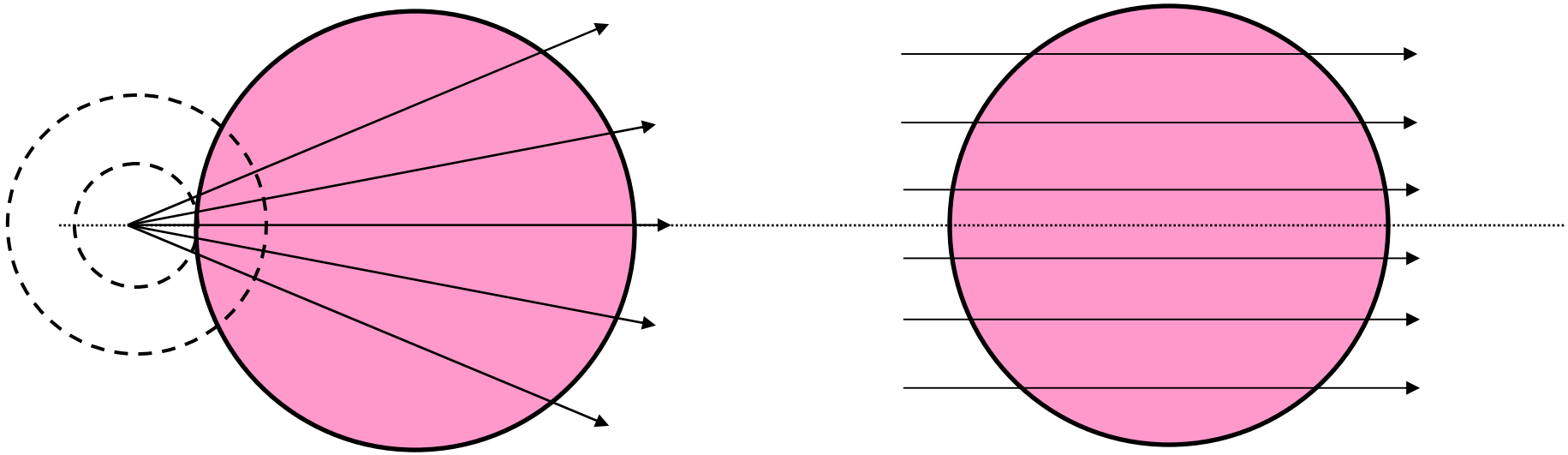
Geometry Correction



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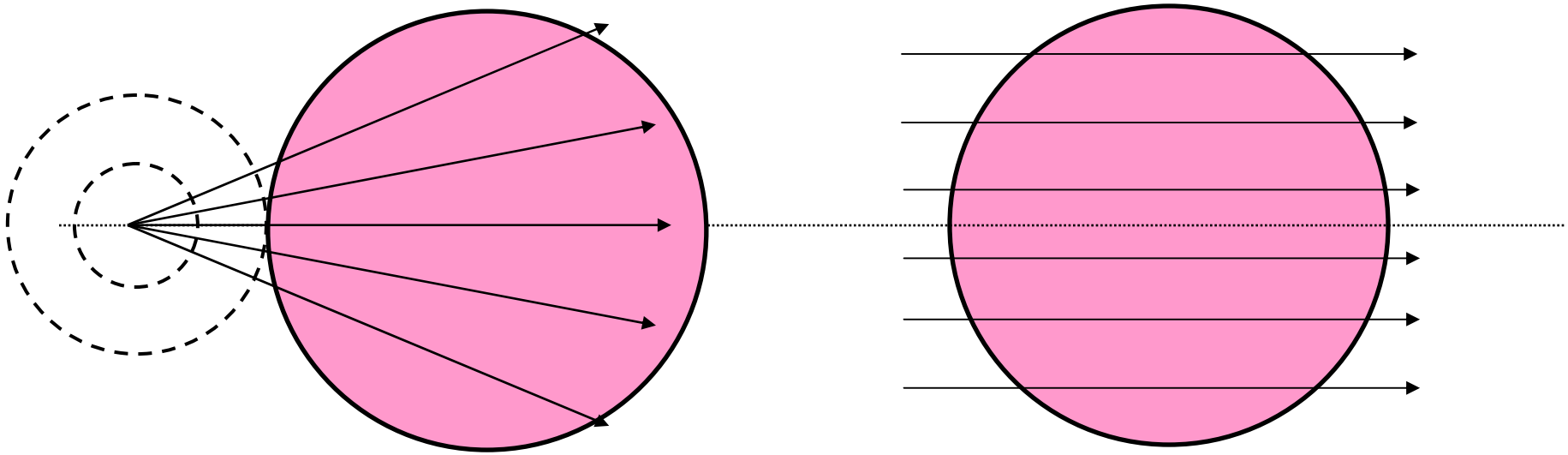
Geometry Correction



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Guidance Provided by the Standard ISO 8529-2

- ISO 8529-2 discusses most of these parameters in detail, but not all…
  - Geometry correction factors for spherical devices:

$$F_1(l) = 1 + \delta \left\{ \frac{2\,l^2}{r_D^2} \left[1 - \sqrt{\left(1 - \frac{r_D^2}{l^2} \right)} \right] - 1 \right\}$$

Neutron Effectiveness Parameter [0.5 +/- 0.1]

Detector radius

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Neutron Effectiveness Parameter [0.5 +/- 0.1]

Detector radius

  - Geometry corrections for cylindrical devices not really covered
  - Recommends calibrations are performed at sufficient distance that any geometry correction will be small:
    - *$l > 4\ r_D$ … typically 45 – 50 cm +*

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Aim of this Work

- Provide geometry correction factors for cylindrical detectors to enable calibrations at shorter distances
  - Higher dose rates
  - Less sources to provide a given dose rate range
- Use Monte Carlo (MCNP) to evaluate differences between plane-parallel and divergent beam irradiations and determine geometry correction factors

At least, that was the original idea…

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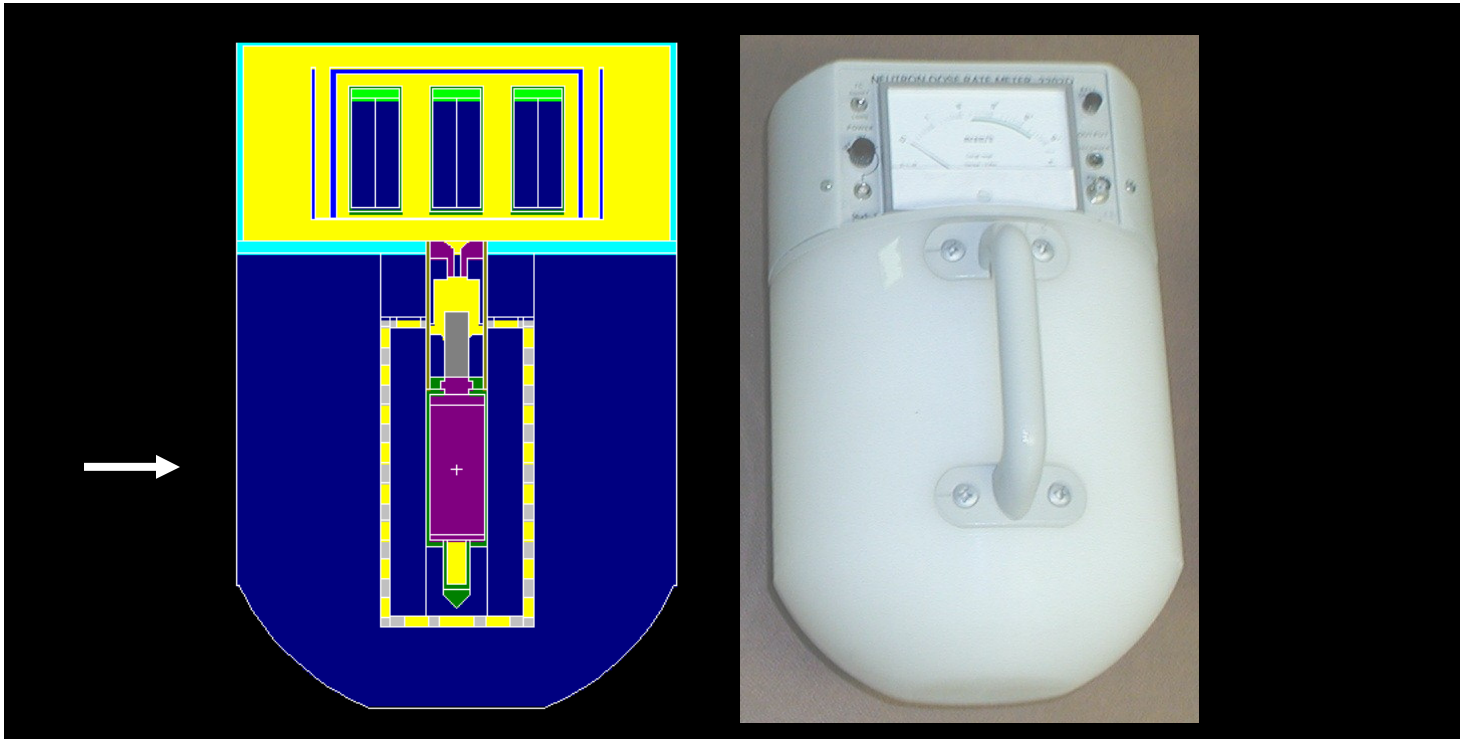
Focus of Work

- Most of the studies performed on a Studsvik 2202D cylindrical rem-meter irradiated by ^{252}Cf



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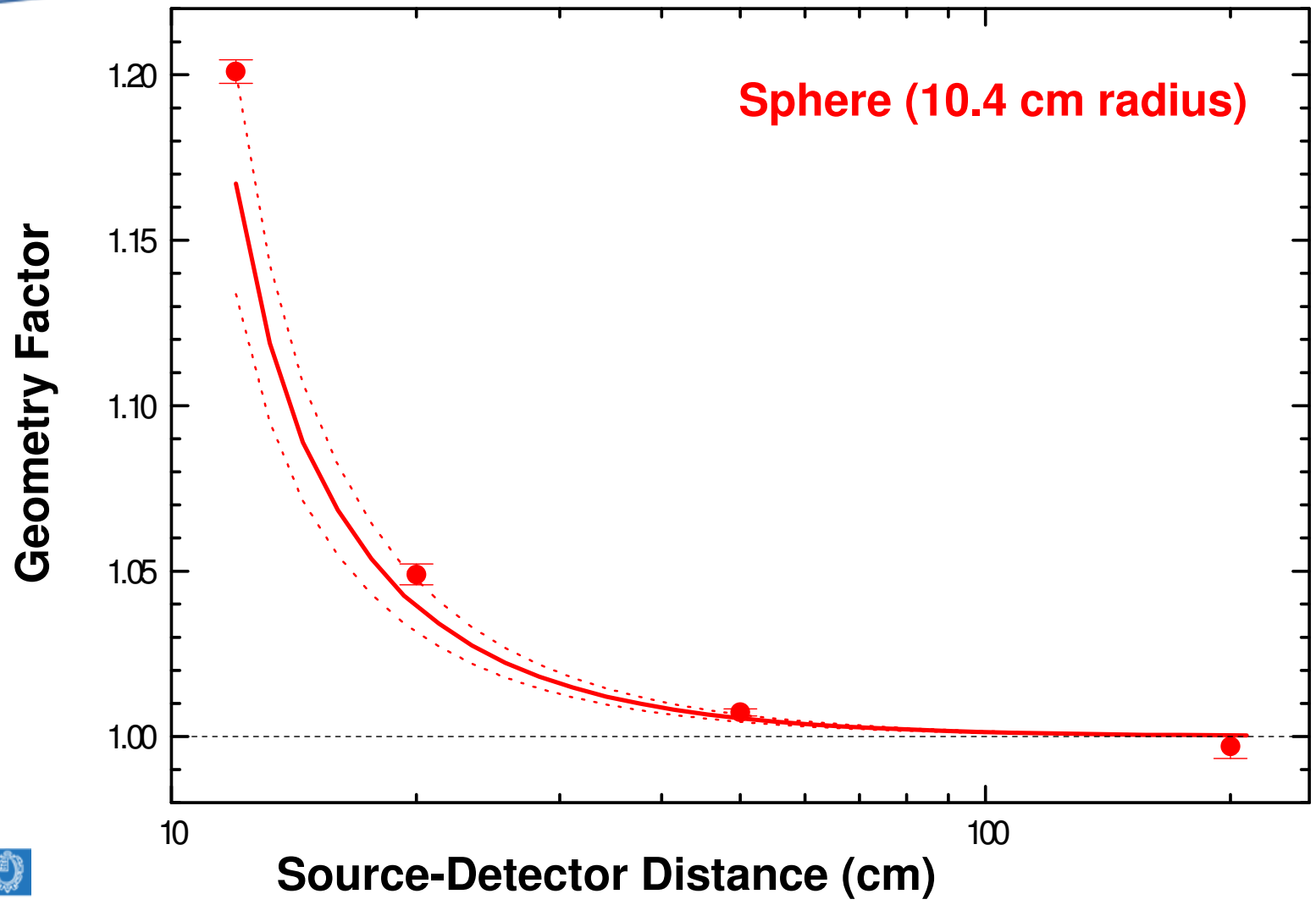
Calculated Geometry Factors (^{252}Cf)



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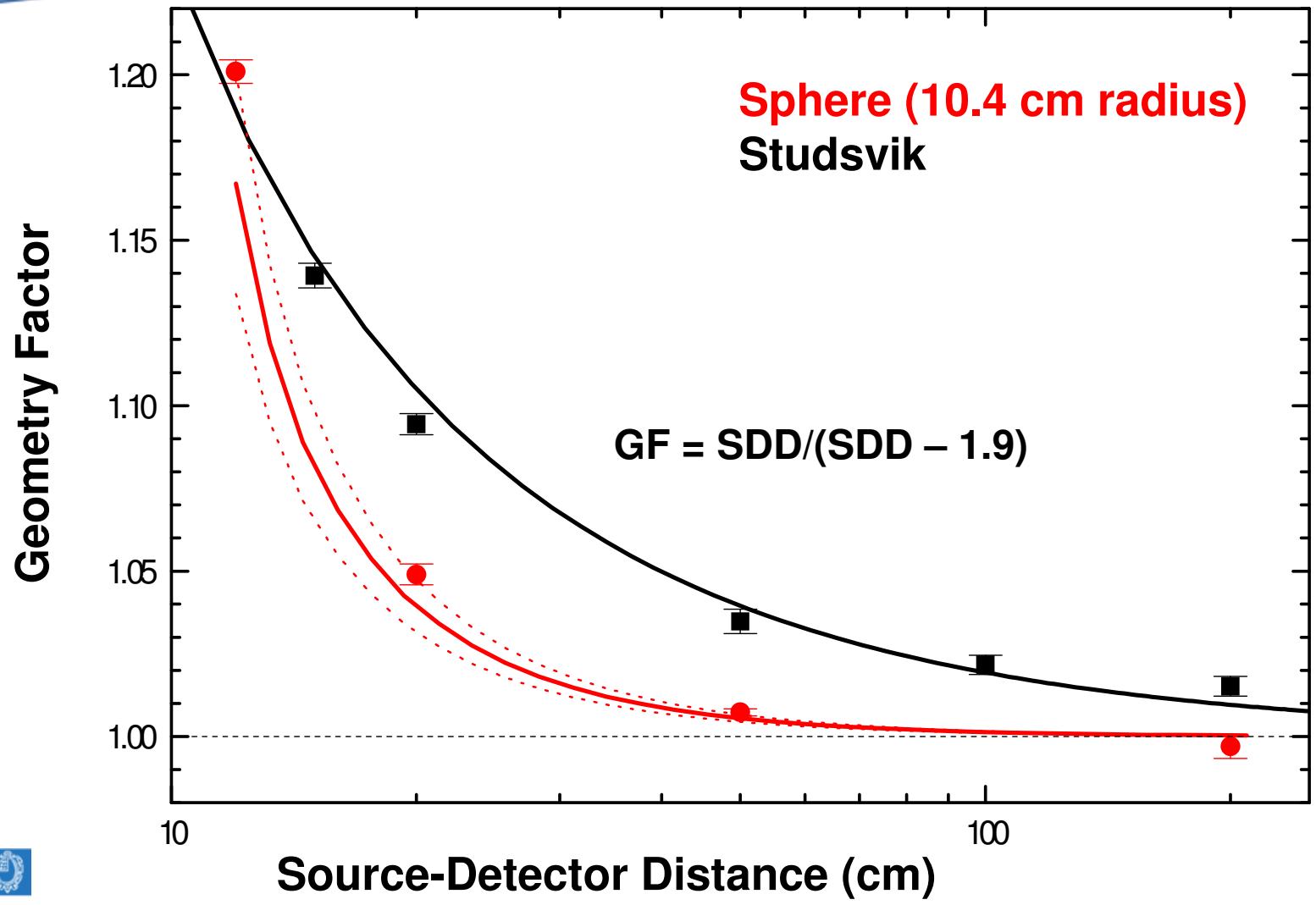

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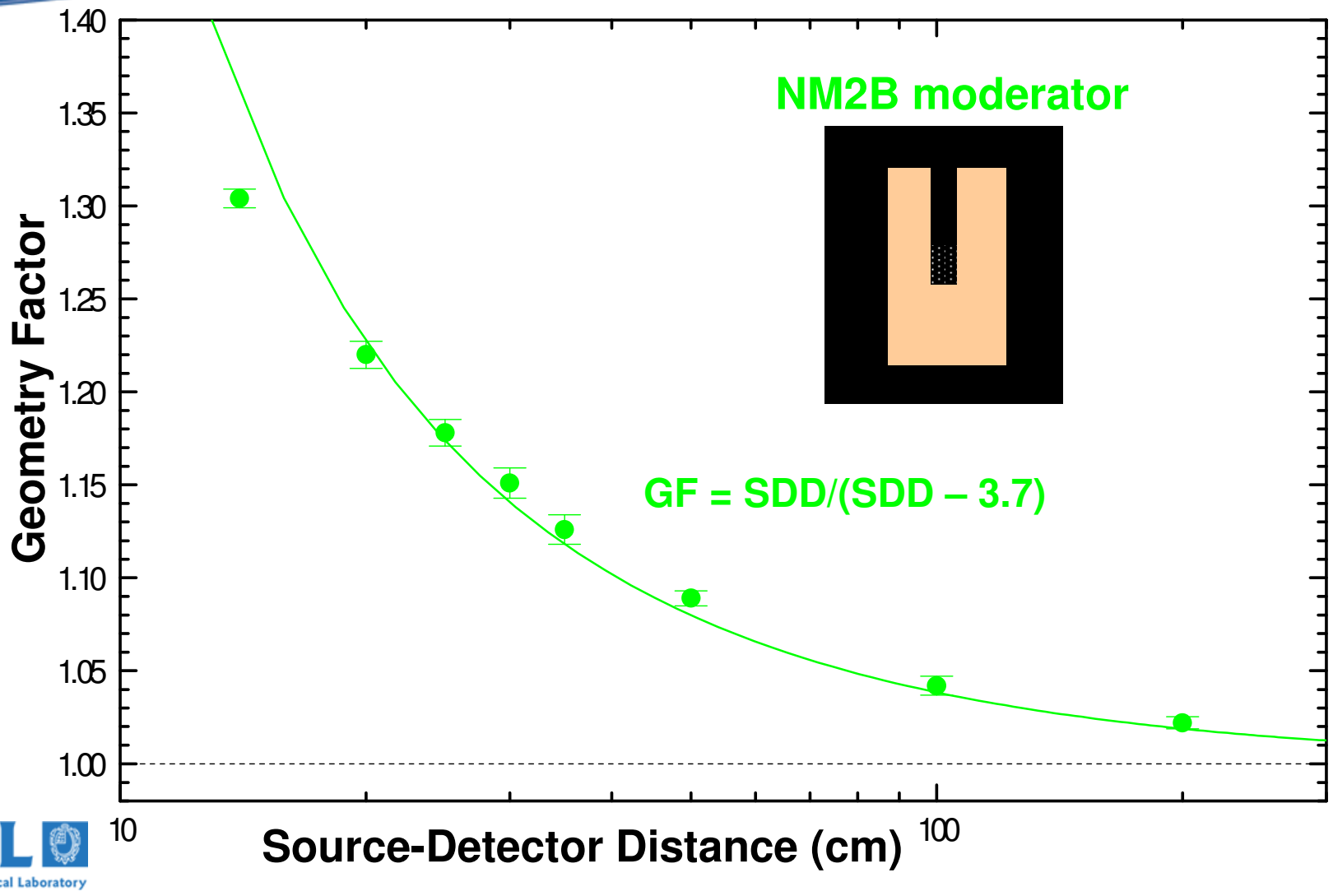
Sanity Check: Calculation Test (1 MeV), Simplified Model



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Comparison with Historical Measurement Data

- NPL measurement records reviewed for suitable experimental data for comparison
  - Pulse output only (higher precision)
  - Single source (sidesteps emission rate uncertainties)
  - Multiple distances

- Surprisingly few suitable data sets!
  - Arbitrarily scaled to calculated curve

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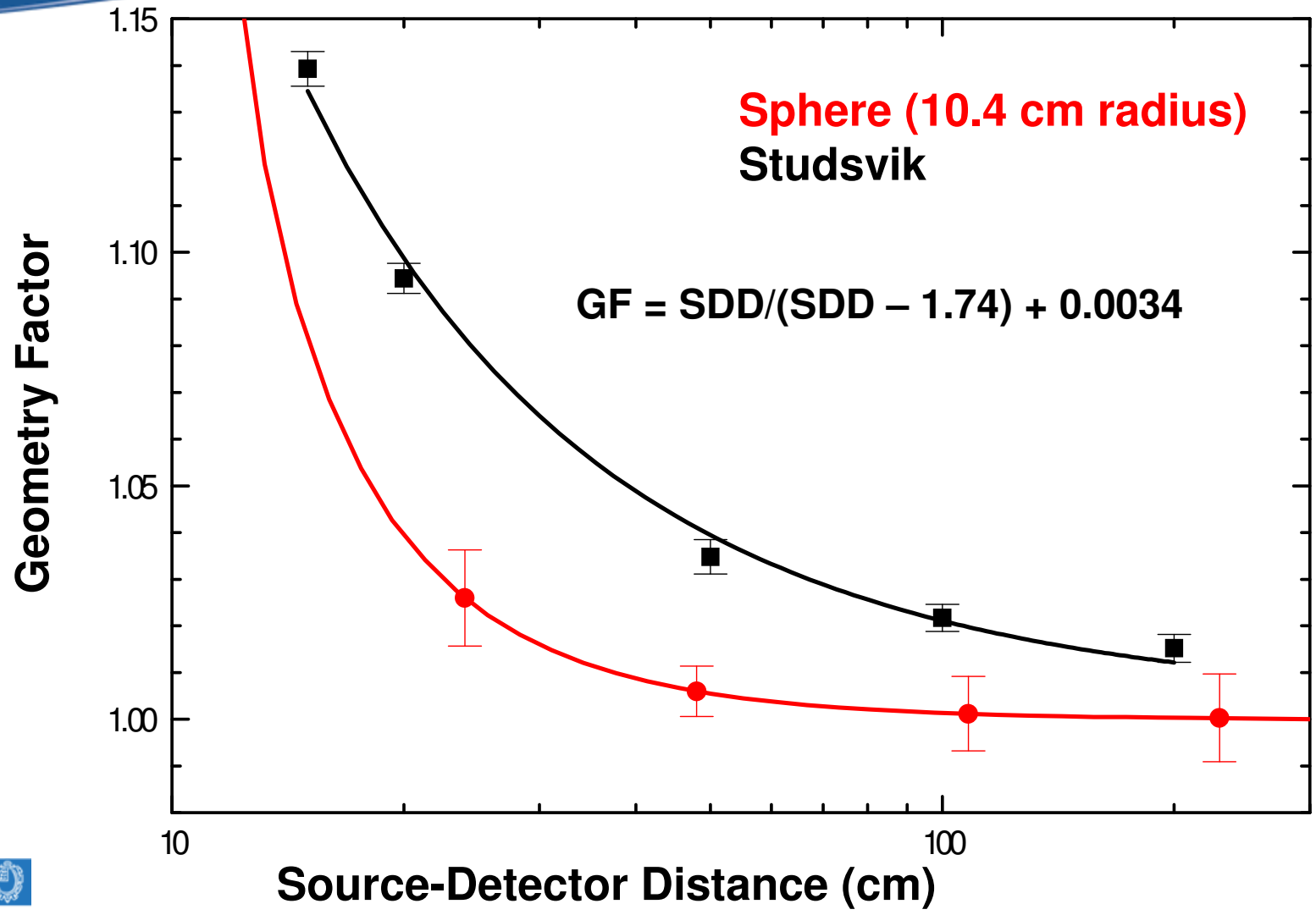
Calculated and Measured GFs (^{252}Cf)



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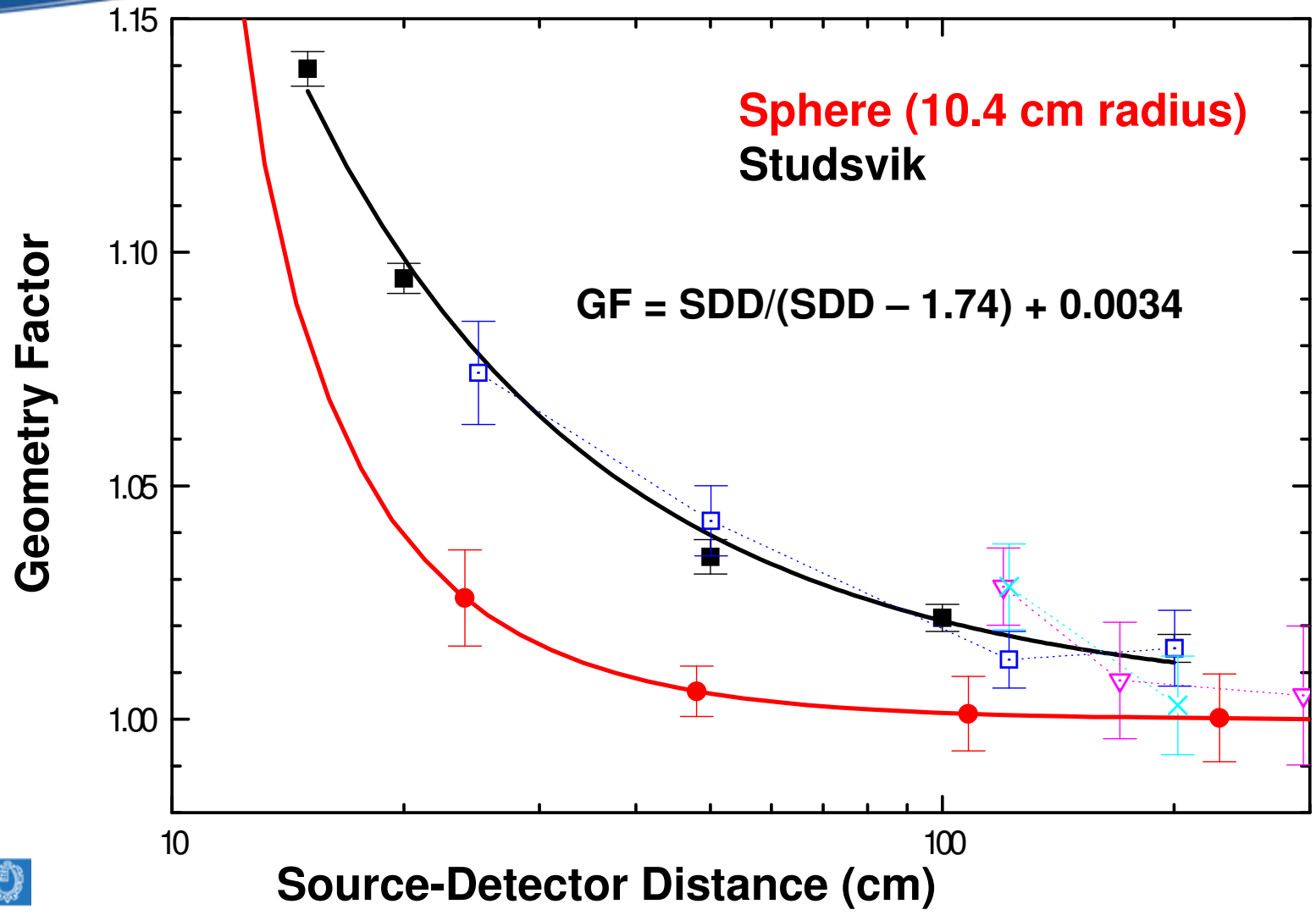

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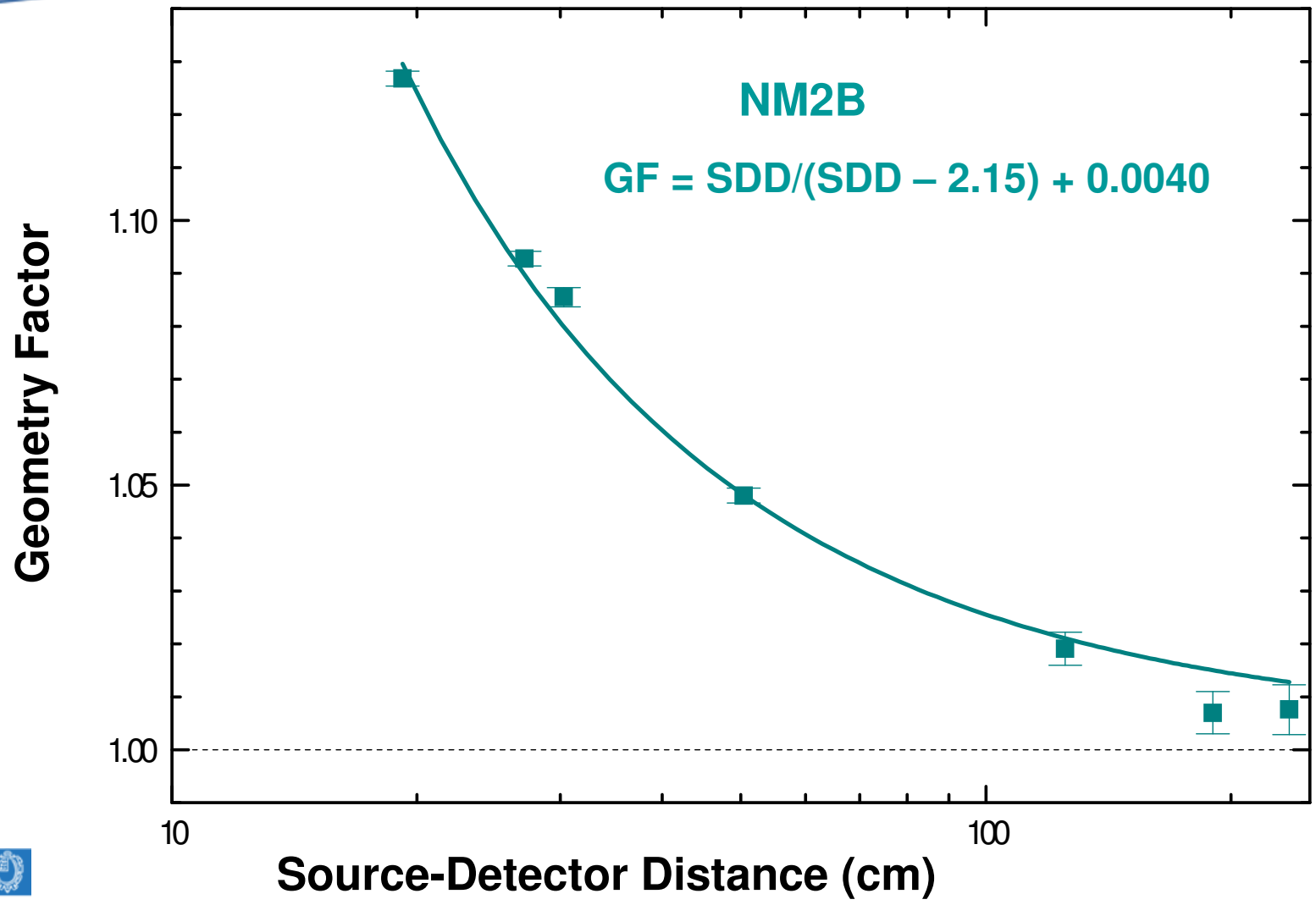
Calculated and Measured GFs (^{241}Am-Be)



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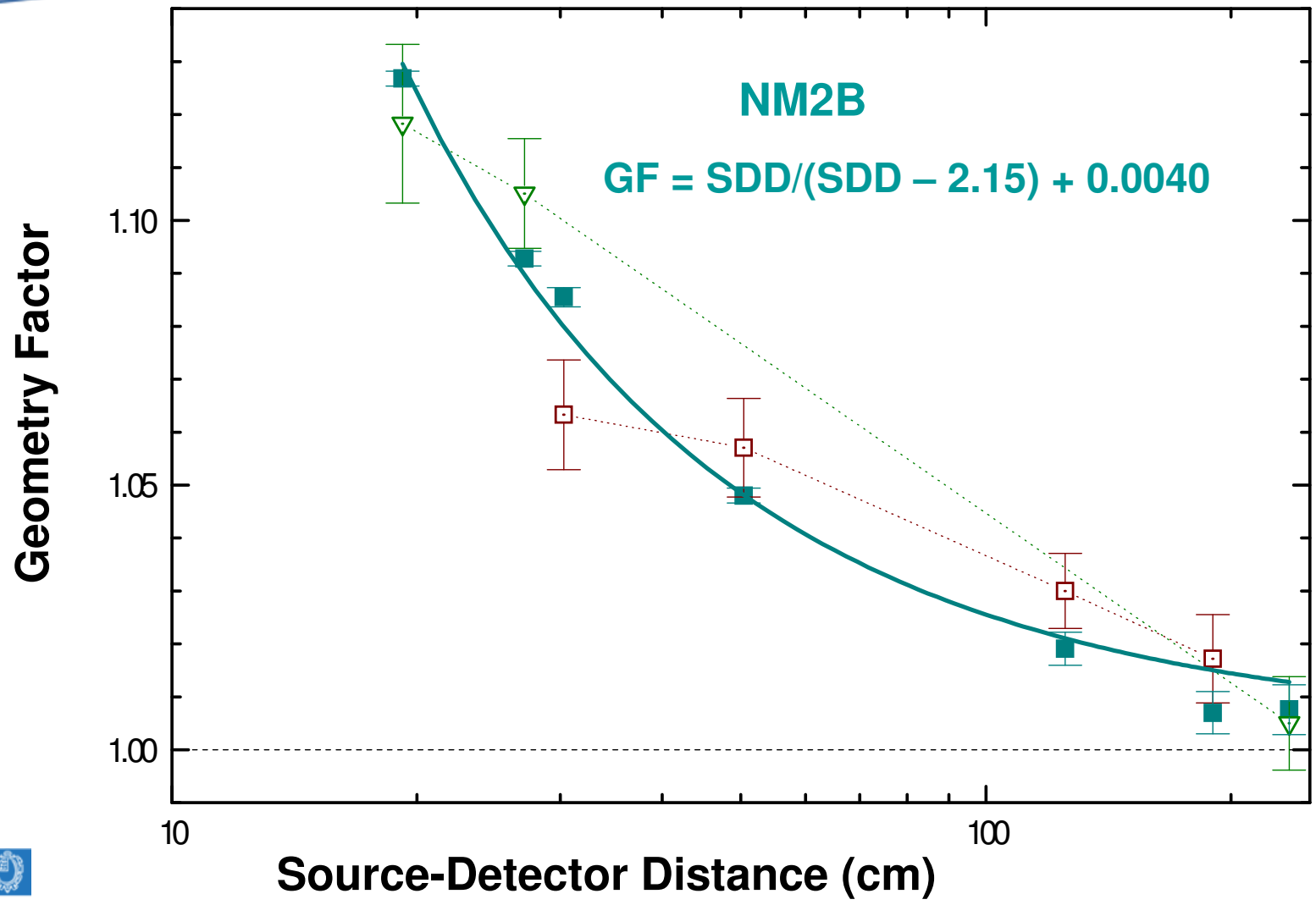

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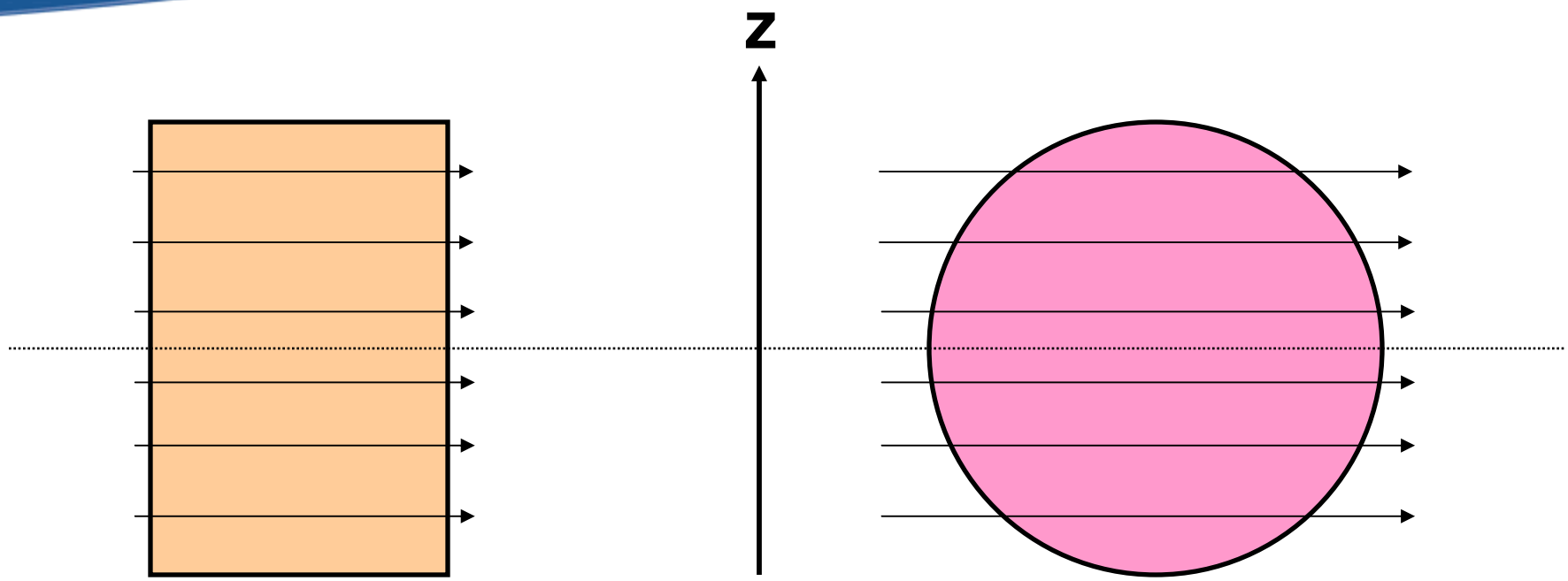
Geometry of Plane-Parallel Beams



Path lengths constant

Path lengths shorten

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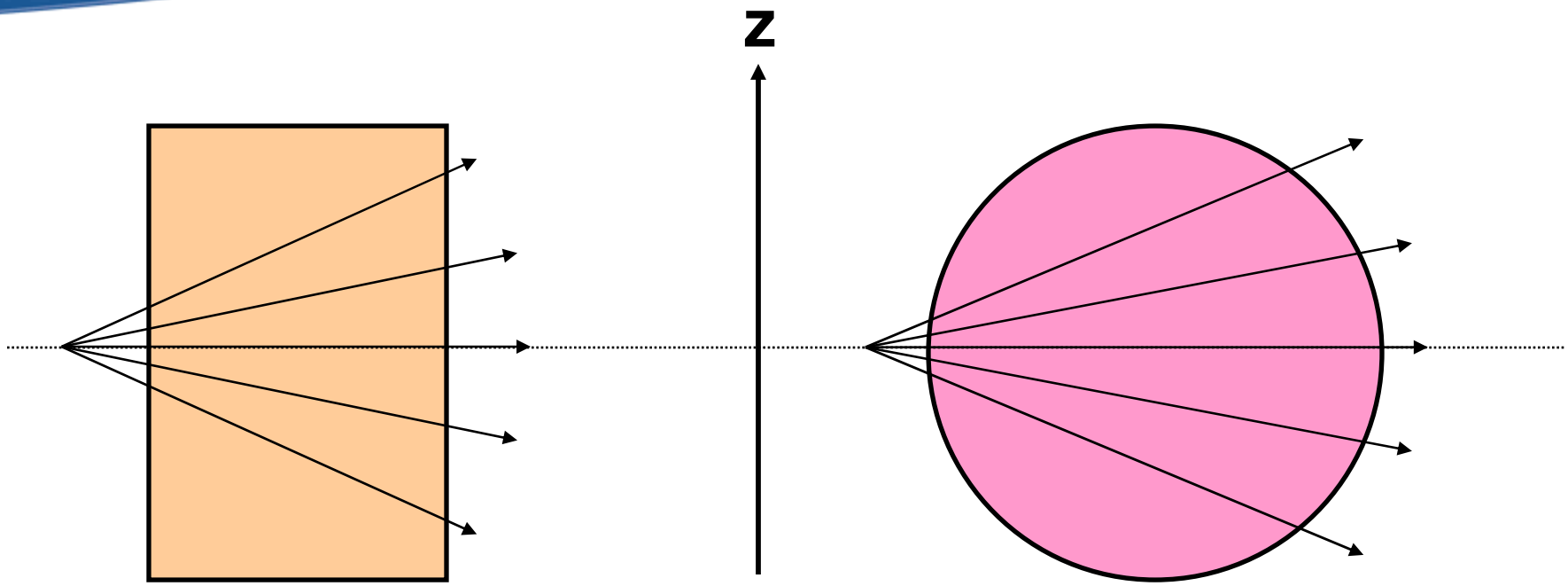
Geometry of Divergent Beams



Path lengths lengthen

Path lengths shorten

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Conclusions

- Calculated geometry factors remain significant at larger distances for cylindrical detectors (> 100 cm)
  - Indicates off-axis effective centres
- Supported by measurement data (but not conclusively)
  - Few measurements, large uncertainties
- Calibrations of cylindrical detectors between 100 and 200 cm may be wrong by 1-2%
- Need to perform specific measurements to very high precision over large range of distances to truly verify this effect

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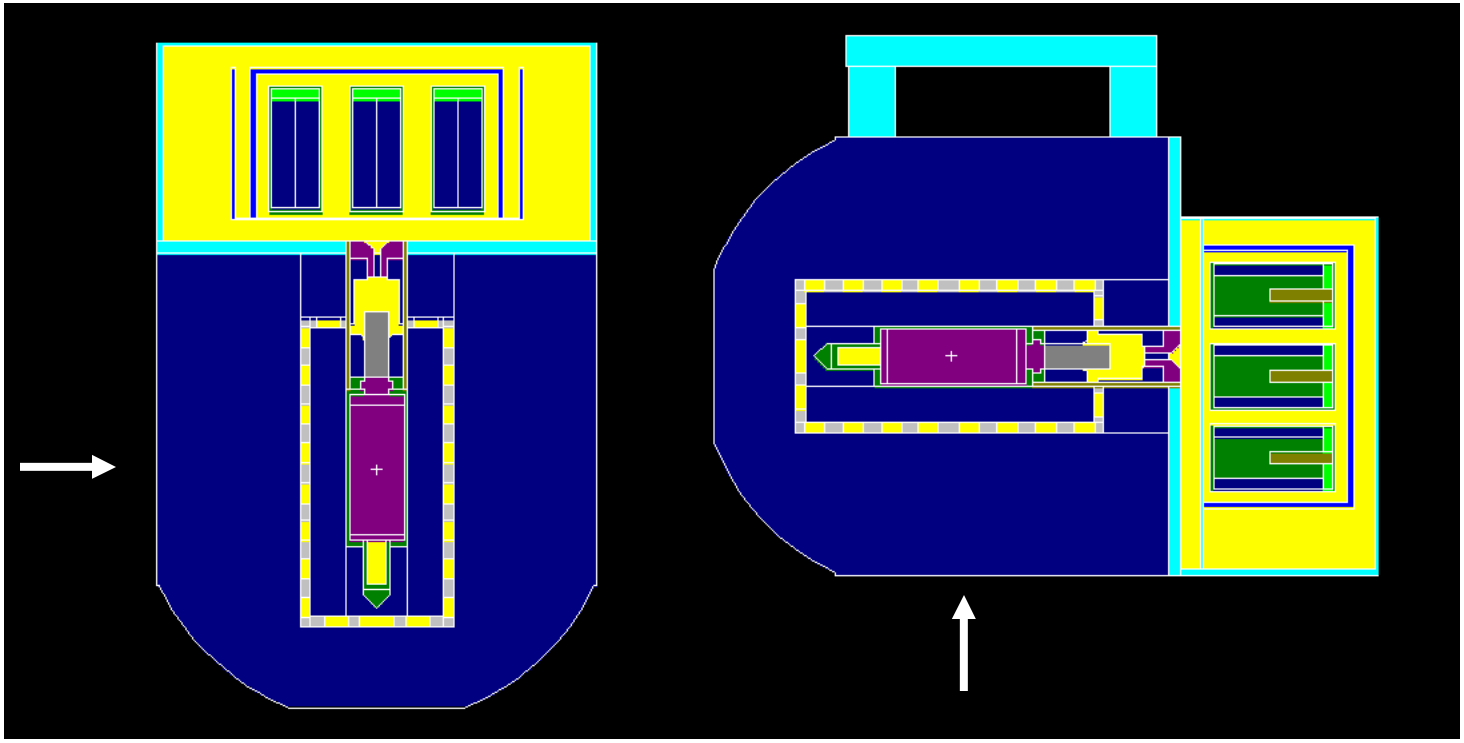

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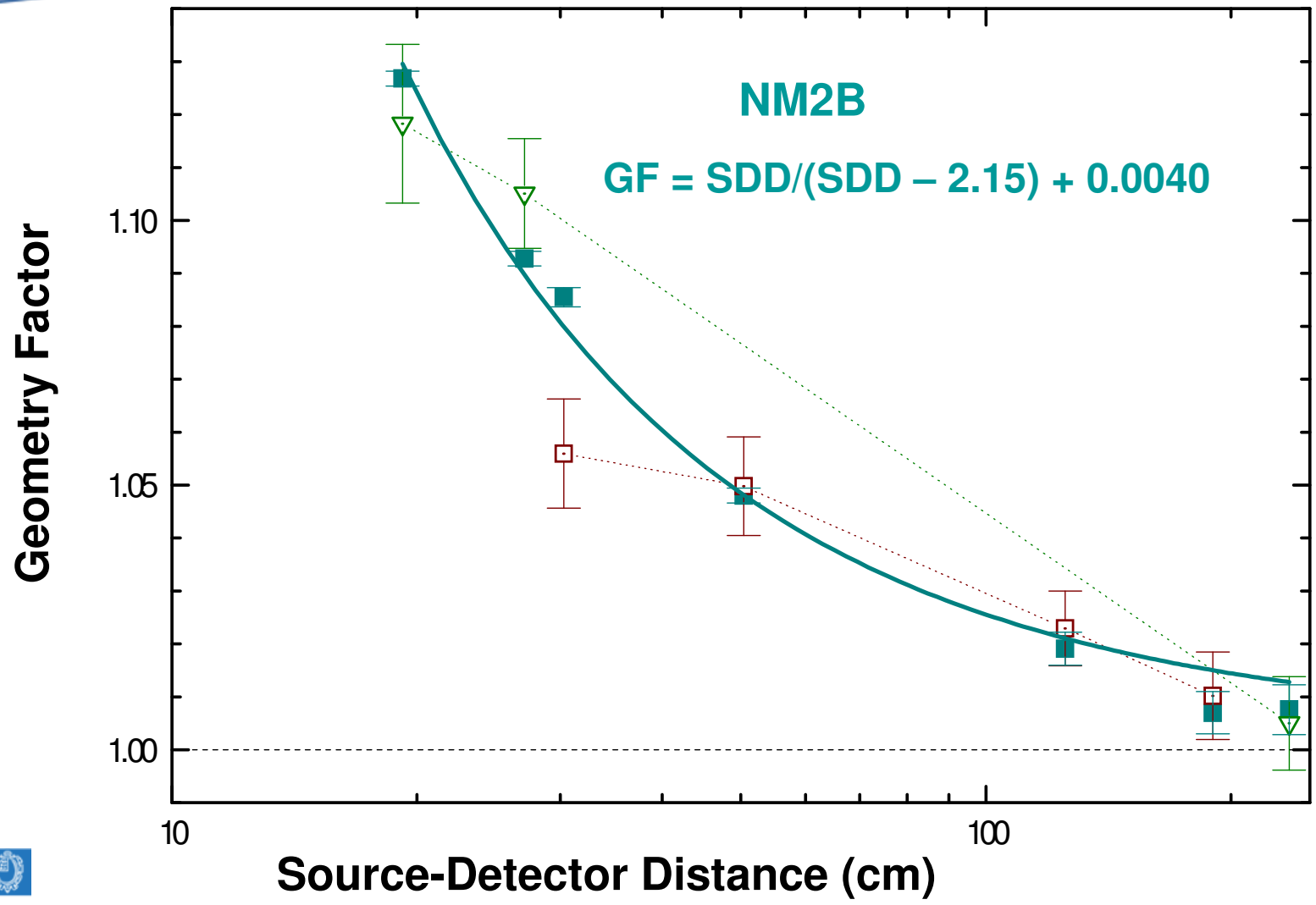

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