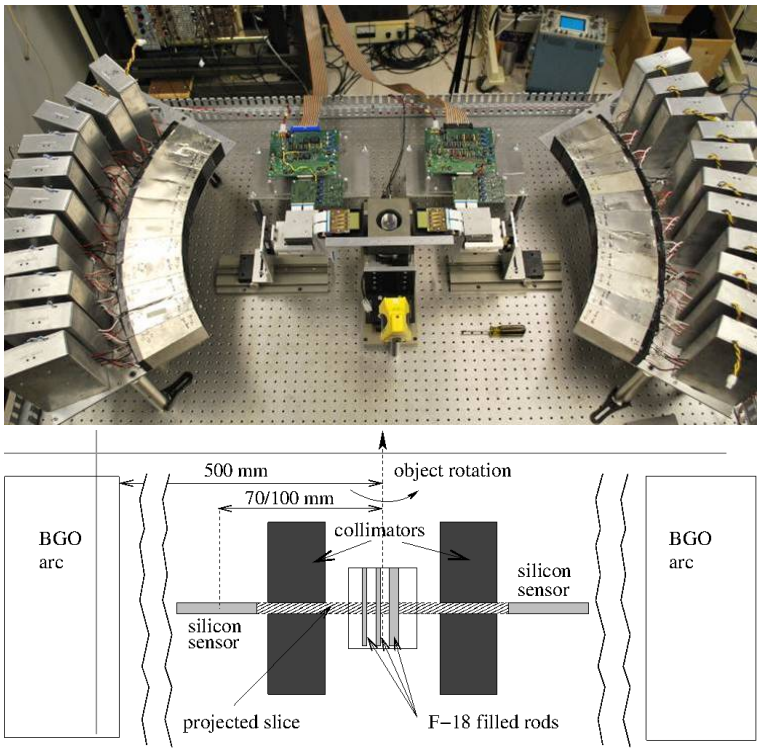
Investigating image quality achieved with different detector resolutions

AS

September 12, 2013

Outline

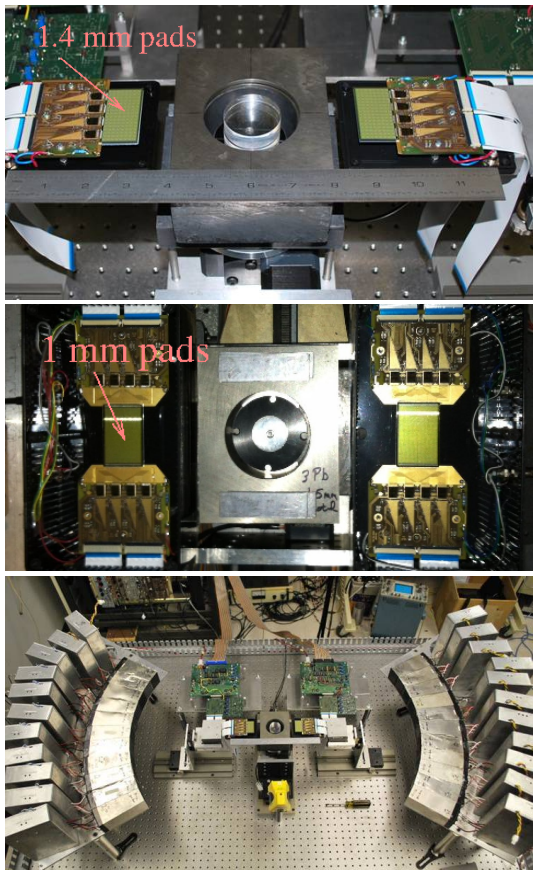
General setup description



Test setup at UofM:

- Dedicated BGO ring/
- New detectors inside the ring.
- Single slice collimation w/lead.
- Object rotation for full angular coverage.

List of setups



Setup list:

- Silicon w/ 1.4 mm pads (SetupID # 0).
- Silicon w/ 1 mm pads (SetupID # 2).
- Silicon remaped to 2.8 mm pads (SetupID # 100).
- Silicon remaped to 2 mm pads (SetupID # 102).

Possible combinations:

- Si + Si (0xf).
- Si + BGO (0xf0).
- BGO + BGO (0x100).

Goals

A lot of setups, a lot of combinations.

GOAL: To quantify improvements when using different setups.

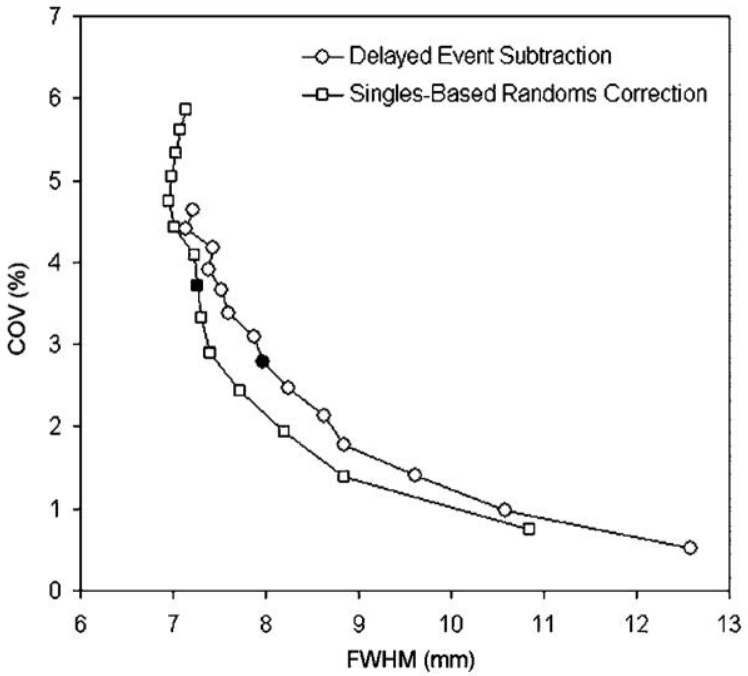
- Detectability (according to Cherry, Sorenson and Phelps):

$$CNR = |C_l| \cdot \sqrt{n_l} \cdot SNR \qquad \text{and} \qquad CNR \geq 4$$

CNR is contrast-to-noise ratio, C_l is lesion contrast, n_l number of pixels it spans, SNR is signal to noise ratio.

- SNR is a property of the readout, $|C_l|$ and $\sqrt{n_l}$ of the marker
- Trace SNR as a function of chosen setup, combination and reconstruction parameters.

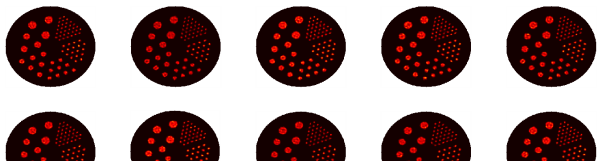
SNR and resolution are coupled

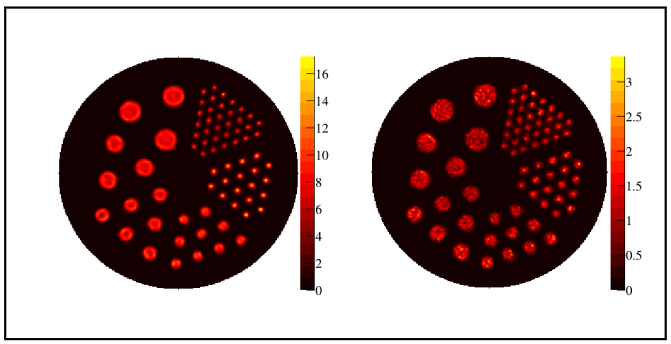


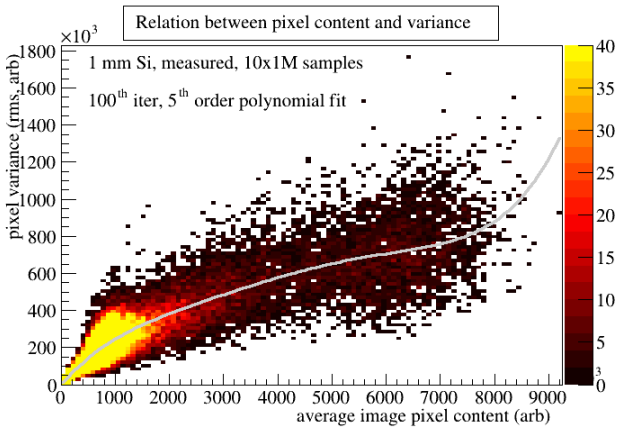
[Lodge, M. et al. Simultaneous measurement of noise and spatial resolution in PET phantom images. PMB 55(4) 2010: 1069–1081.]

- Noise/Covariance and resolution are coupled.
- For iterative method, iterations improve spatial resolution (and degrade noise).
- Relation is specific to a particular setup/combination
- Wrong to compare at fixed iteration, correct to compare at fixed resolution (or fixed covariance).

Estimating parameters: SNR







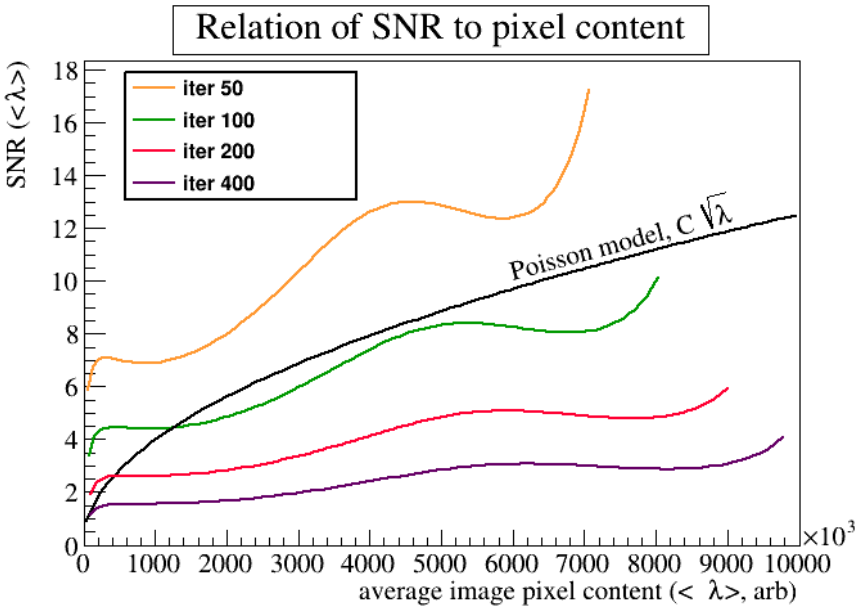
Estimating covariance:

- Generate N_s=10 samples of N_e=1M events from recorded/ simulated population sample.
- Produce average $\langle\lambda\rangle$ and covariance σ image

$$\langle\lambda\rangle_j = \frac{1}{N_s}\sum_{i=1}^{N_s}\lambda_j^i \quad \sigma_j^2 = \frac{1}{N_s}\sum_{i=1}^{N_s}(\lambda_j^i - \langle\lambda\rangle_j)^2$$

- Extract pixel-wise relation of σ to $\langle\lambda\rangle$.
- $$SNR(\lambda) = \frac{\lambda}{\sigma(\lambda)}$$

Sidestep: SNR and Poisson



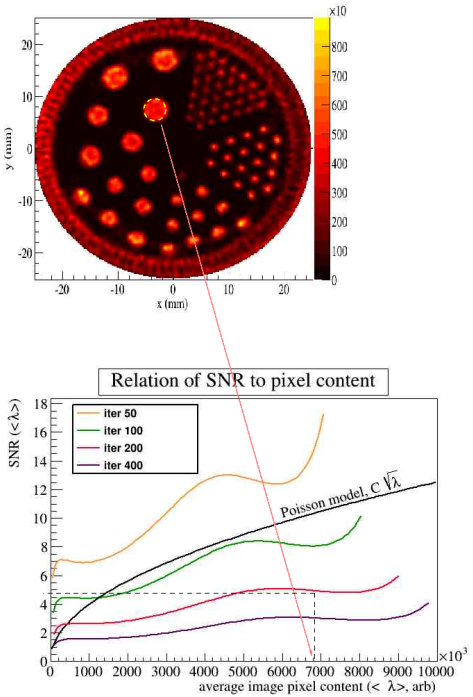
- For direct detection process SNR(λ)=C$\sqrt{\lambda}$

  C accounts for possible scaling of the image

- Pixels are coupled through Radon projection so SNR can be better or worse than pure Poisson process.

- For late iterations, SNR has little dependence on $\langle\lambda\rangle$.

Spatial variation of SNR.



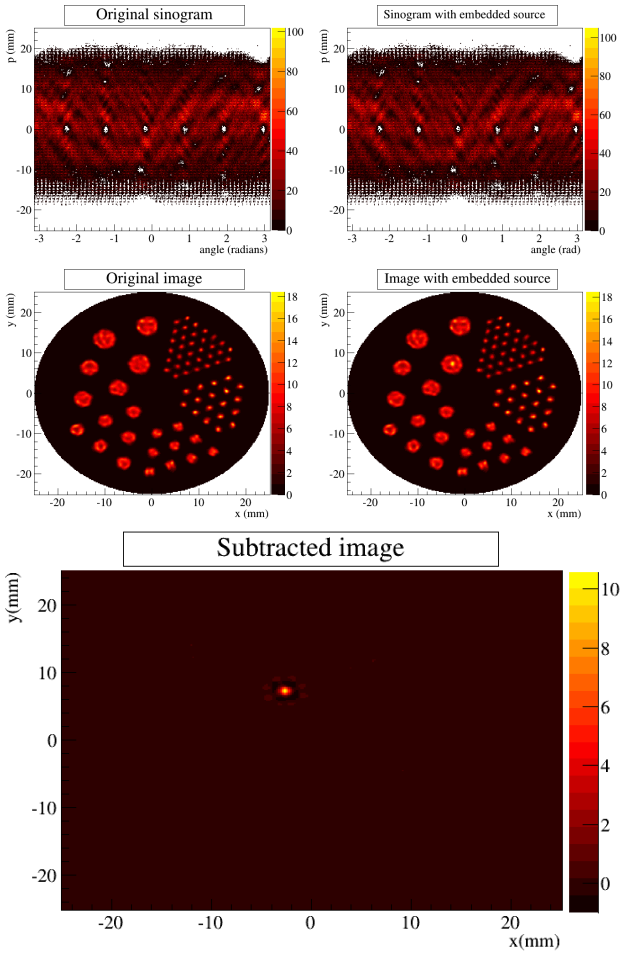
SNR=5

- Inscribe a circle with radius slightly smaller than rod radius.
- Determine average pixel content λ_r of the rod.
- SNR of that region is SNR(λ_r).
- SNR will vary for different rod diameters (and in images in general as a function of the object shape).
- The same can be seen from Fischer information matrix and Cramer-Rao bound:

$$\sigma_j^2 \geq \mathbf{g}_j^T F^{-1} \mathbf{g}_j \qquad F = M^T \mathrm{diag}[1/\lambda_j] M$$

$\mathbf{g}_j$ is mean bias gradient vector (similar to LIR), M is the system matrix

Estimating resolution

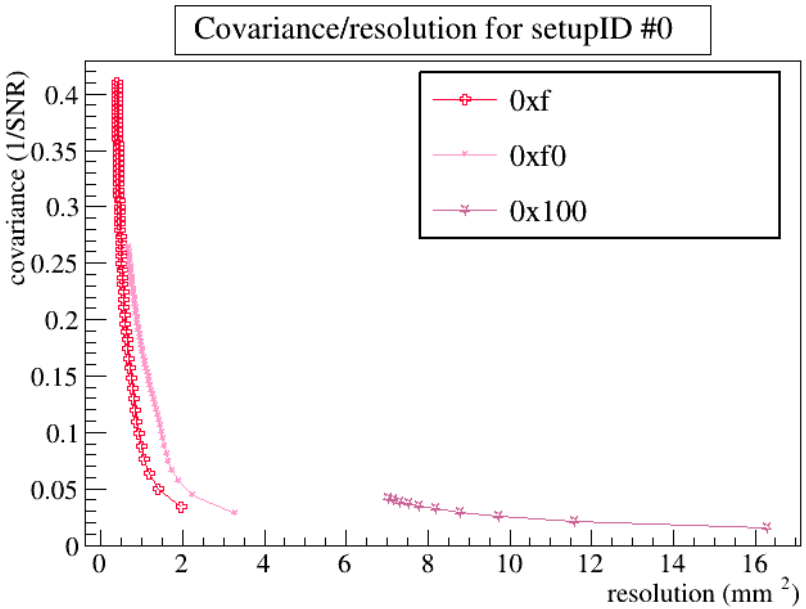


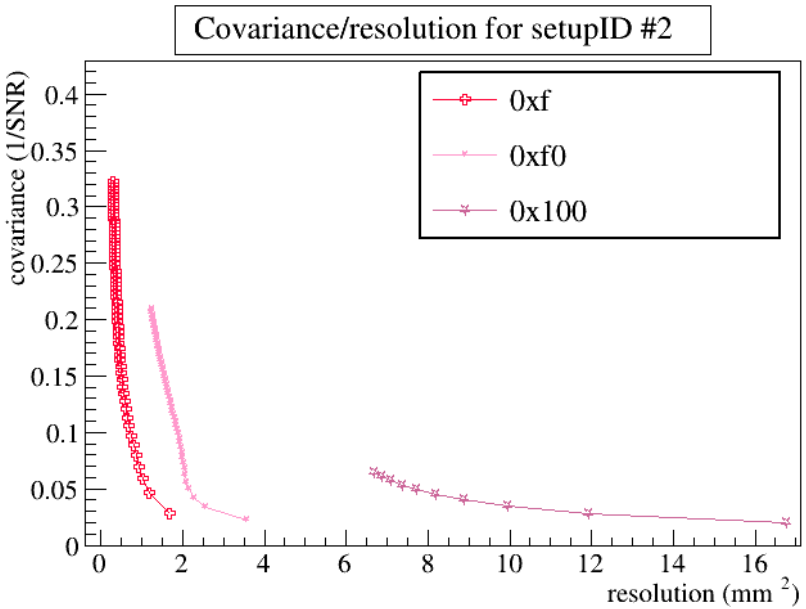
- Possible through deconvolution of rod shapes (but not performed).
- Embed a (true) point source into data and reconstruct with the unperturbed data.

  Point source is a minuite perturbation of the data. Content of the source is 4 permil of the original data
- Subtract unperturbed image from the image with embeded source and perform fit to extract FWHM.
- FWHM area rather than diameter quoted (shape needn't be symetric).

Measurements

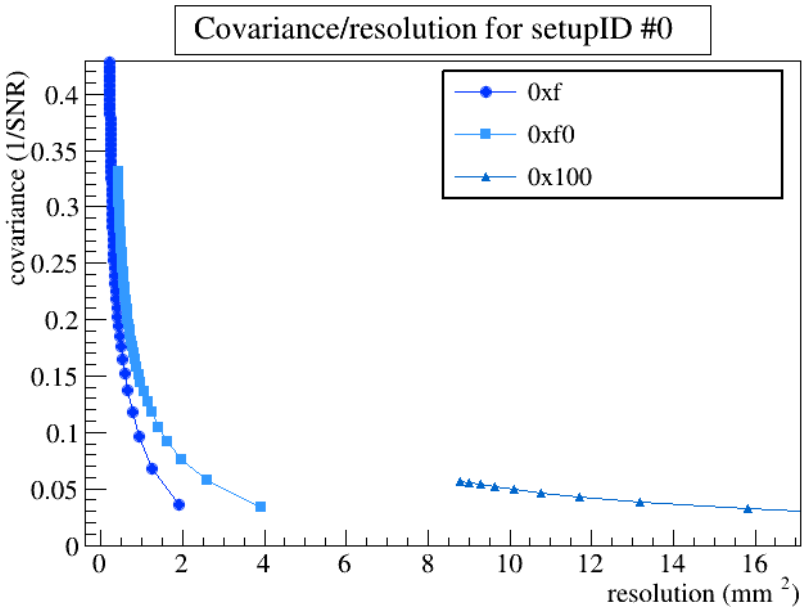
For rod diameter 4.8 mm.

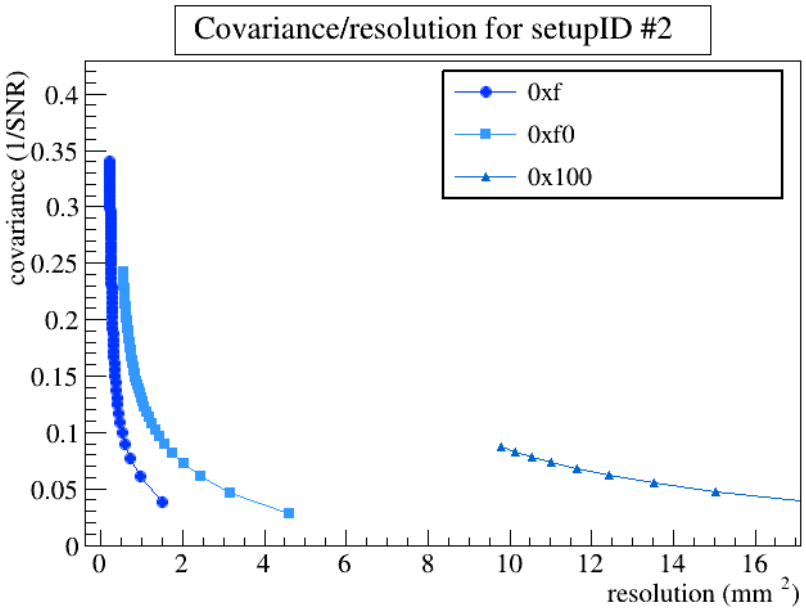




Measurements

For rod diameter 1.6 mm.





Measurements

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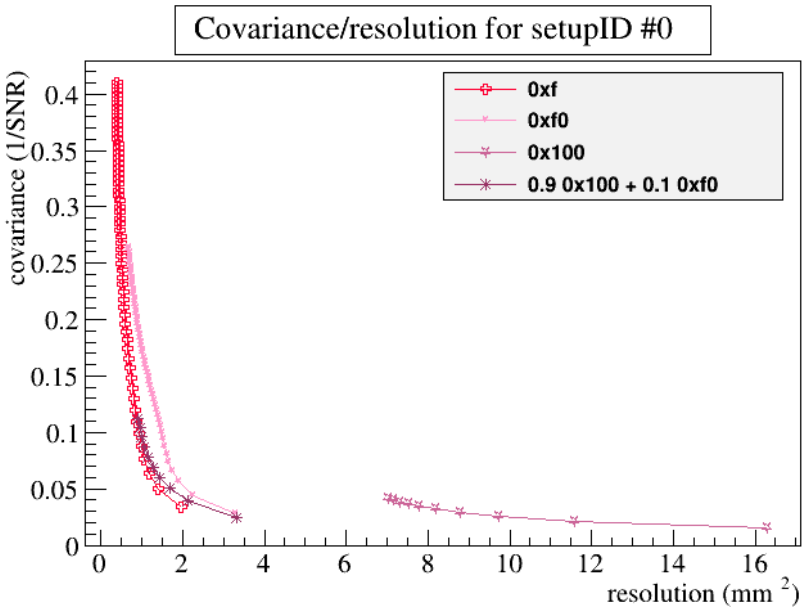

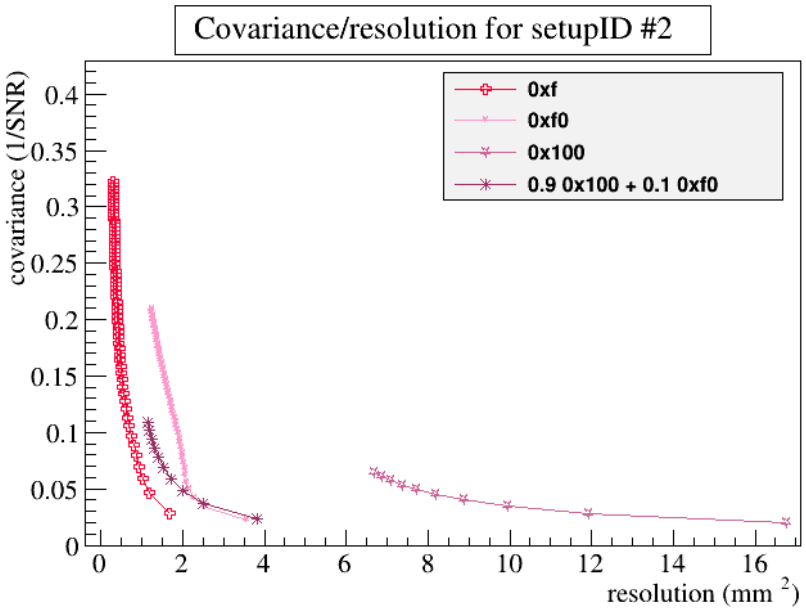

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Summary

- The first main message of your talk in one or two lines.
- The second main message of your talk in one or two lines.
- Perhaps a third message, but not more than that.

- Outlook
  - Something you haven't solved.
  - Something else you haven't solved.

For Further Reading I


A. Author.
Handbook of Everything.
Some Press, 1990.


S. Someone.
On this and that.
Journal of This and That, 2(1):50–100, 2000.