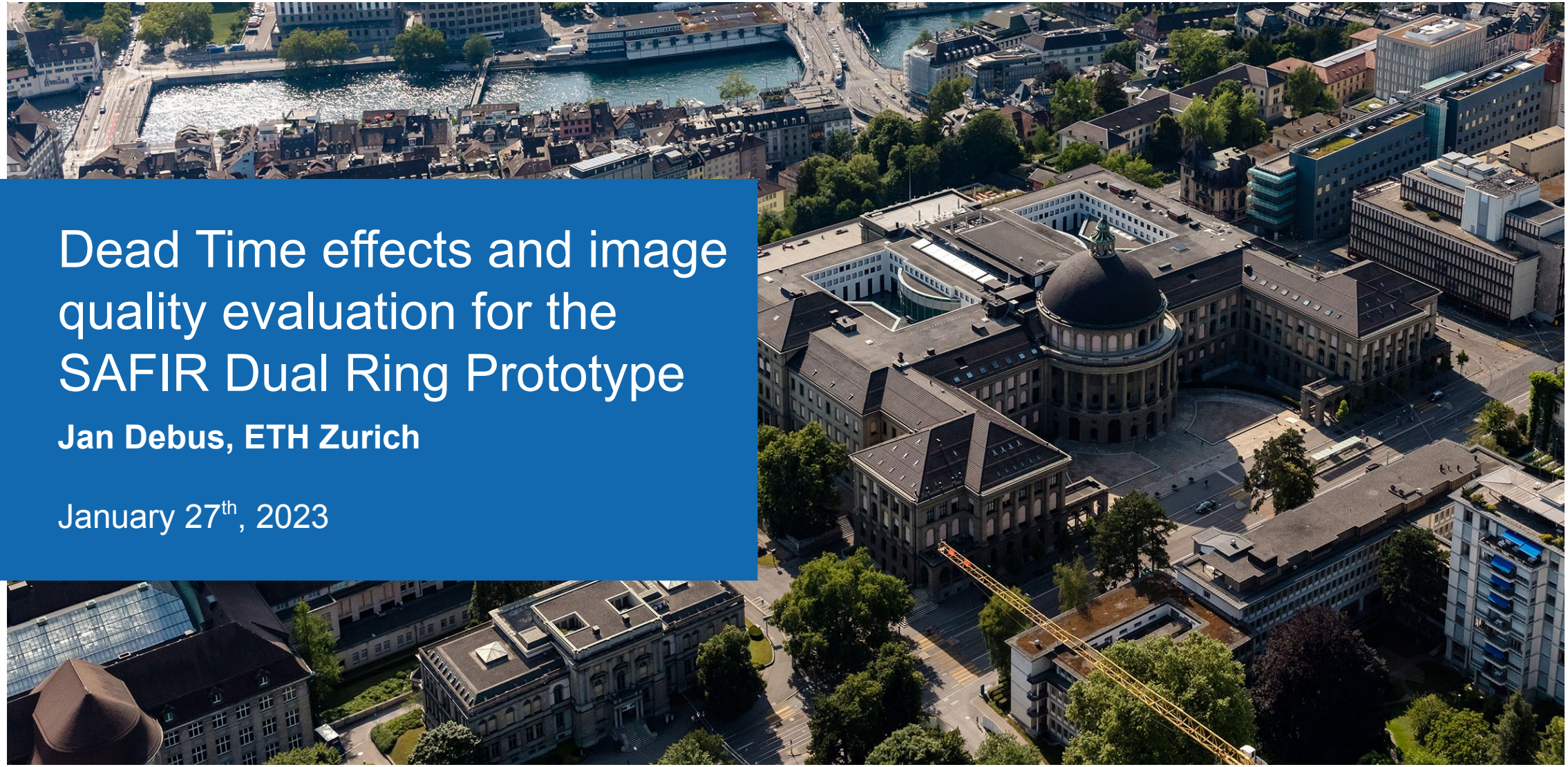
ETH zürich



Dead Time effects and image quality evaluation for the SAFIR Dual Ring Prototype

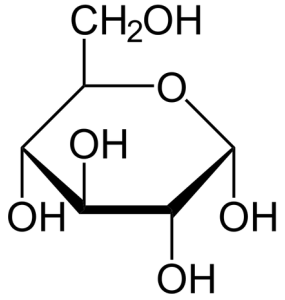
Jan Debus, ETH Zurich

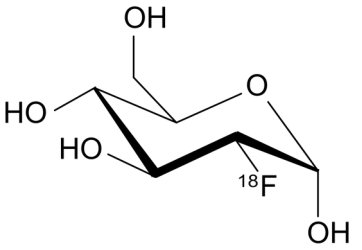
January 27th, 2023

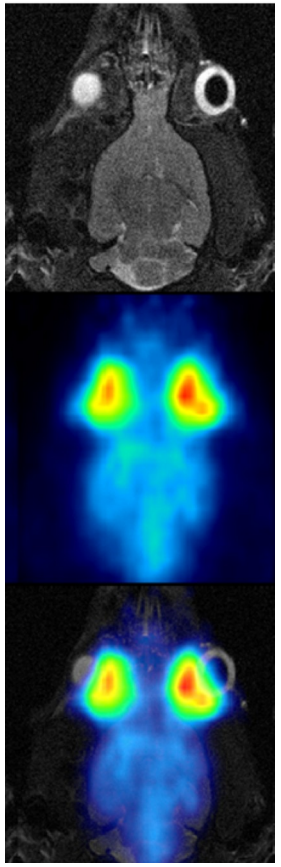
The Basics: MRI-PET

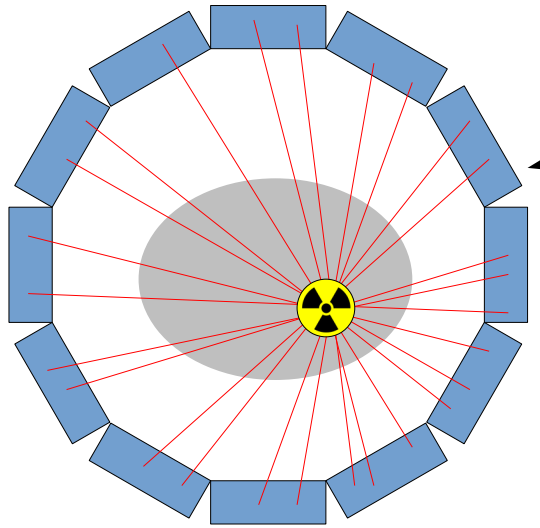
$$^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{o}_{+1}e$$

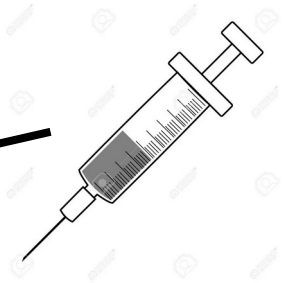
Fluorine - 18 Oxygen - 18 Positron











SAFIR

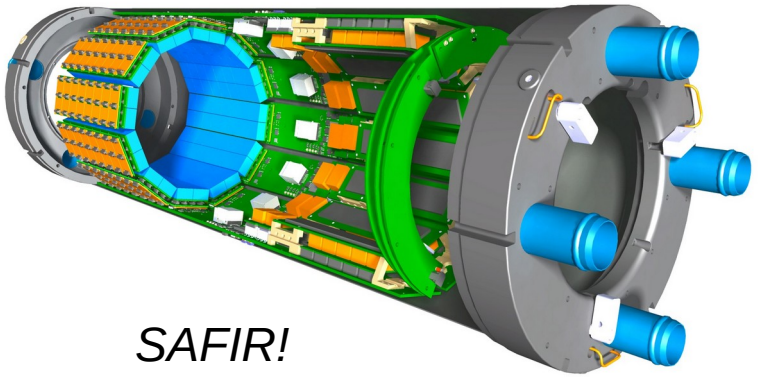
- PET is a slow process (up to 10 Minutes)
- Sometimes biology is fast (~1 Minute)

➔ Need better timing resolution

500 Mega Becquerel

=

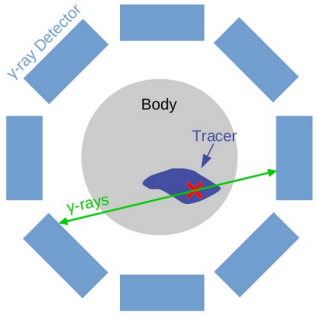
5 Seconds



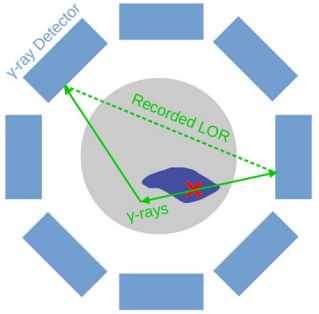
SAFIR!

Image corrections

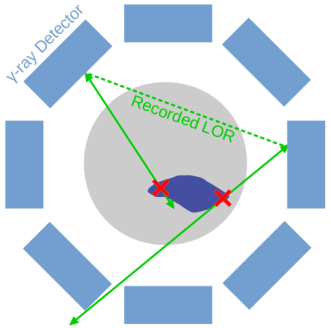
- Detector normalization
- Attenuation effects
- Scattered events
- Random coincidences
- <u>Detector Dead Time</u>



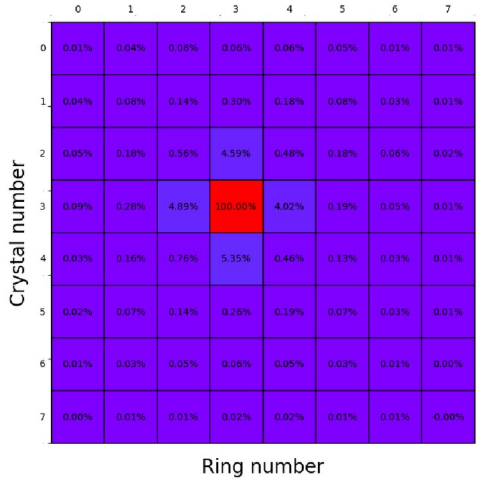
(a) "True" Coincidence



(b) "Scattered" Coincidence



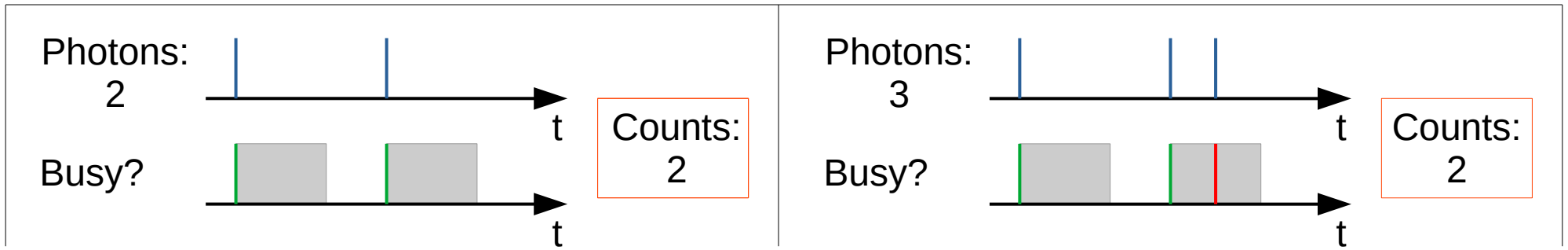
(c) "Random" Coincidence



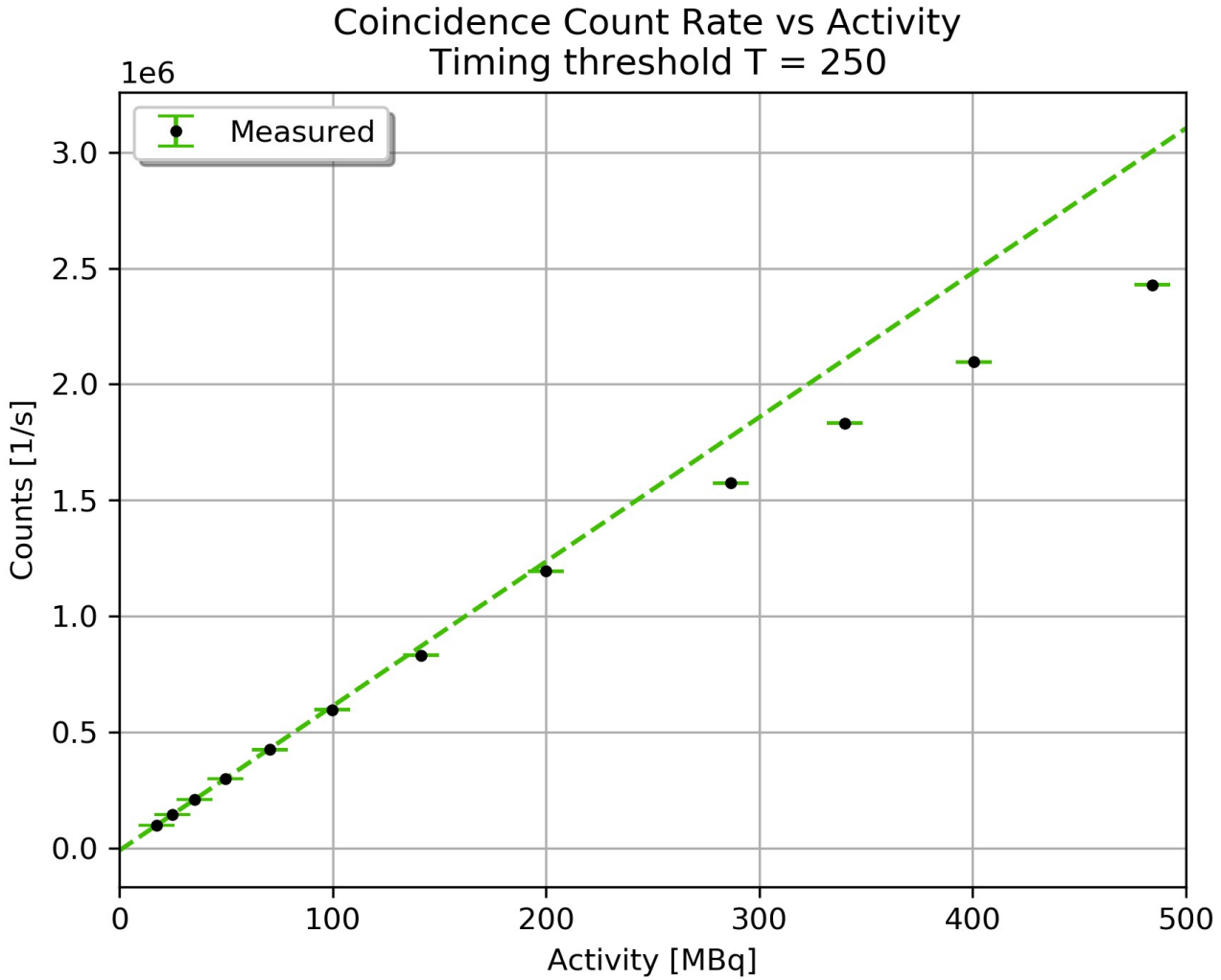
Detector Dead Time

- Readout channels enter ‘busy’ period after hit
- Photons arriving during that time are not registered
- ‘Deadtime’ ranges from 450 ns to 2.4 µs for PETA6
- At high event rates this can can be a significant factor

➔<u>Increased loss of events & coincidences</u>



Detector Dead Time & Data Loss



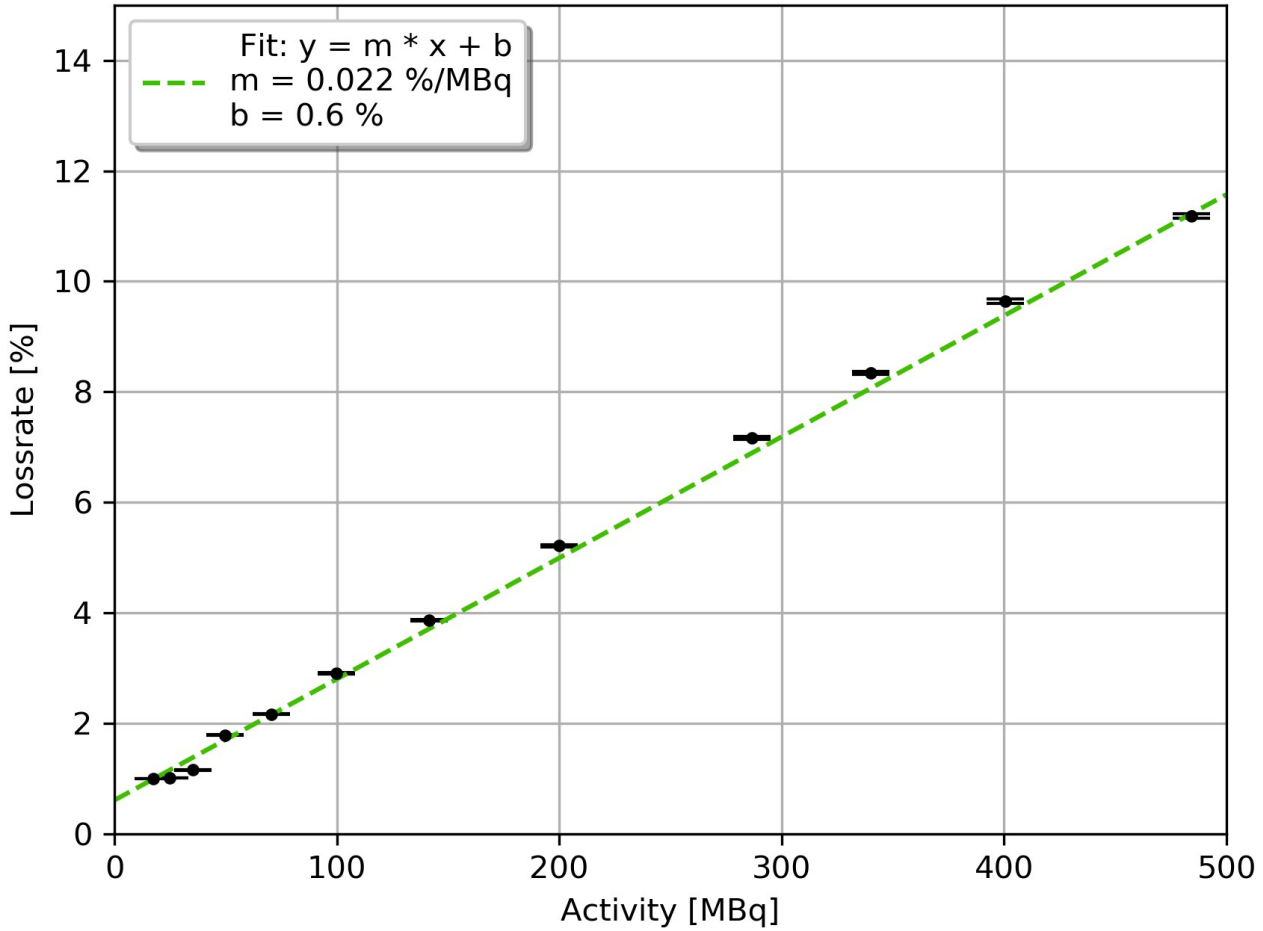
Detector Dead Time & Data Loss

- Inject ‘fake’ events into channel @ 200Hz
- ‘fake events behave like real ones

  (i.e. can get rejected if channel busy)
- Count ‘fake’ events received during measurement

  → Calculate % of data lost due to dead time!

Detector Dead Time & Data Loss



Detector Dead Time & Data Loss

- Inject ‘fake’ events into channel @ 200Hz
- ‘fake events behave like real ones

  (i.e. can get rejected if channel busy)
- Count ‘fake’ events received during measurement

  ➔ Calculate % of data lost due to dead time!
- But: 2 channels per coincidence

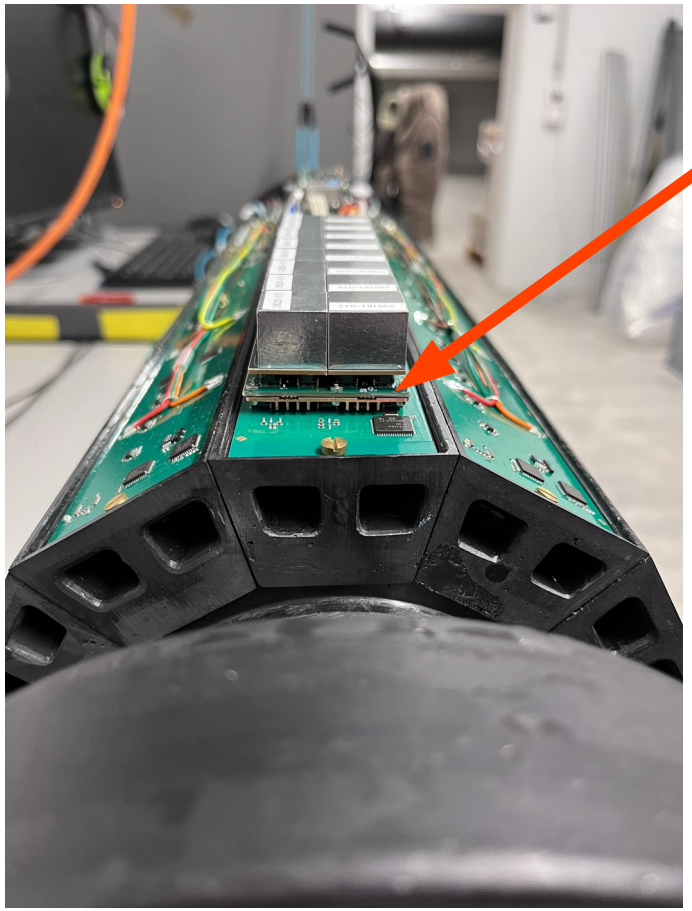
  ➔ Multiply inverse of channel loss rate

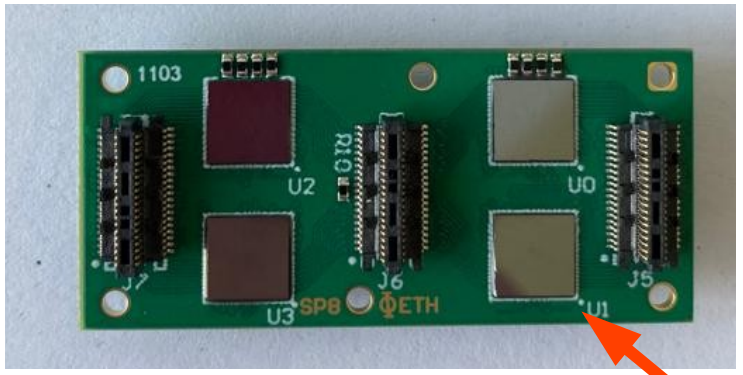
10% lost per channel

$$1-(0.9*0.9)\equiv 19\,\%$$

of coincidences lost!

Be careful what you abbreviate





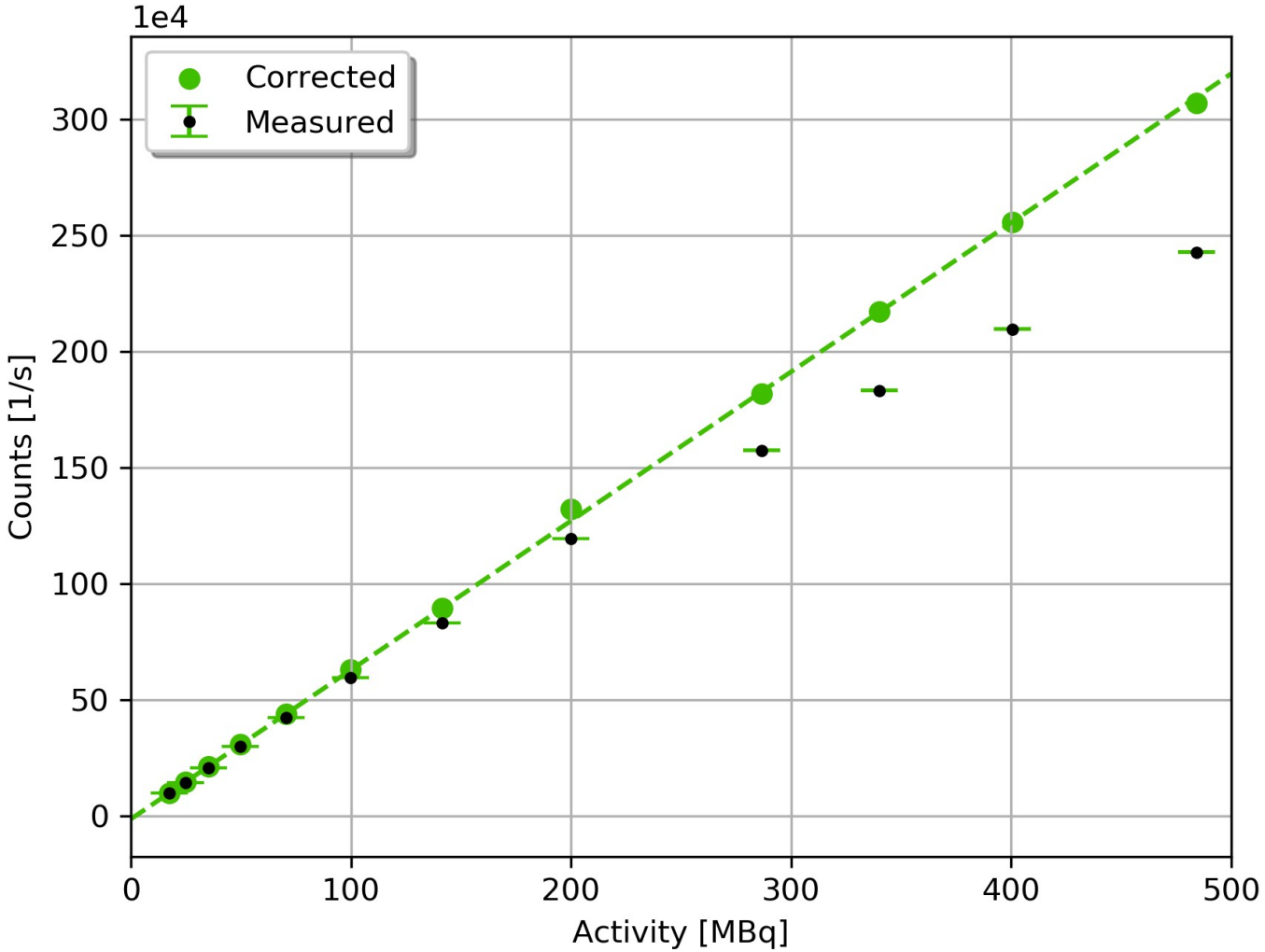
PeTA — 6

Fixing the Problem

- Now: We loose coincidences in each detector pair
- But: We know how much we loose in each pair!

$$N_{Coinc}(Observed) * \frac{1}{1 - Loss\,\%} = N_{Coinc}(Expected)$$

Detector Dead Time Correction

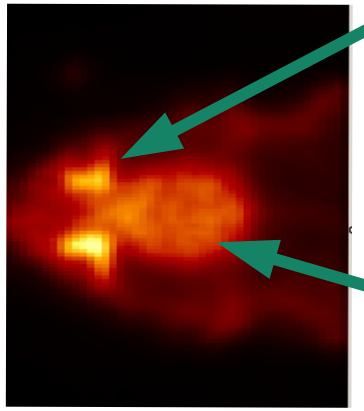


Calibration Factors

- We want <u>quantitative</u> measurements

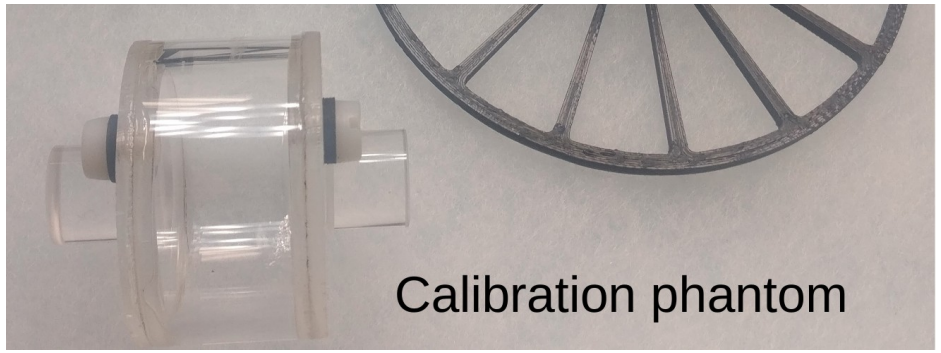
  ➔ Calibration measurements

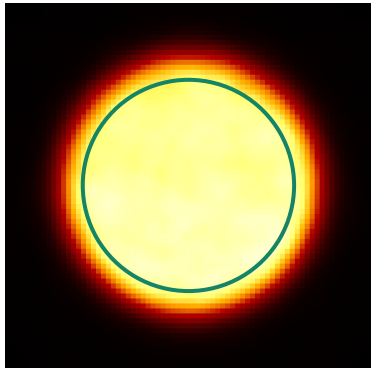
- Get Calibration Factor (CF) to convert voxel value into activity-concentrations



~~Bright~~
500MBq/ml

~~Not bright~~
300MBq/ml





3 bright =
? MBq/ml

Calibration Factors

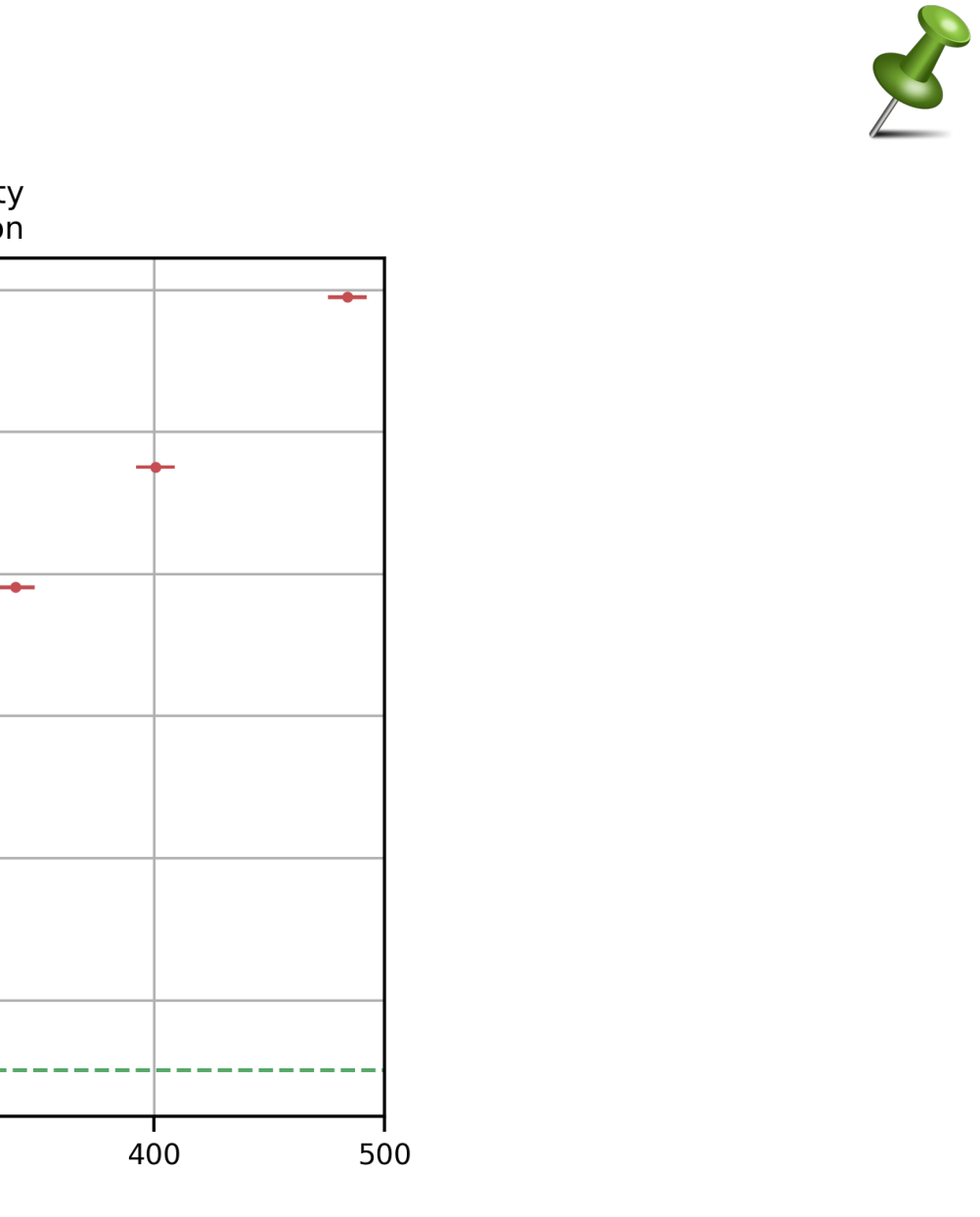
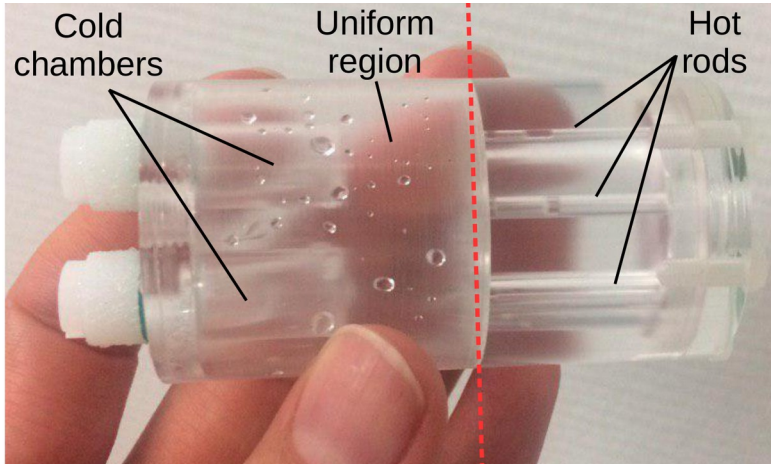
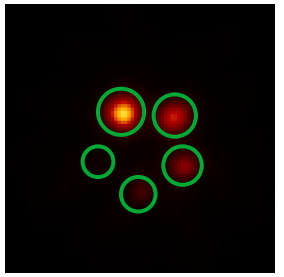


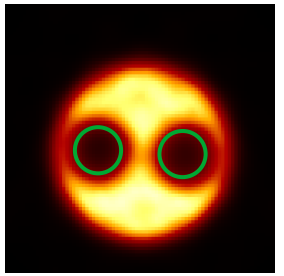
Image Quality

- We effectively add ‘fake’ data to measurements
  - ➔ Impact on image quality? Noise?
- Standard to characterize PET-scanners; NEMA-NU4
  - ➔ Image quality analysis

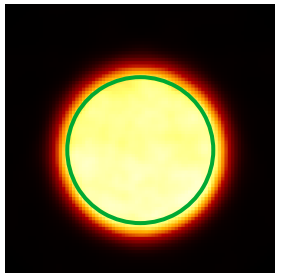




Recovery Coefficient (RC)

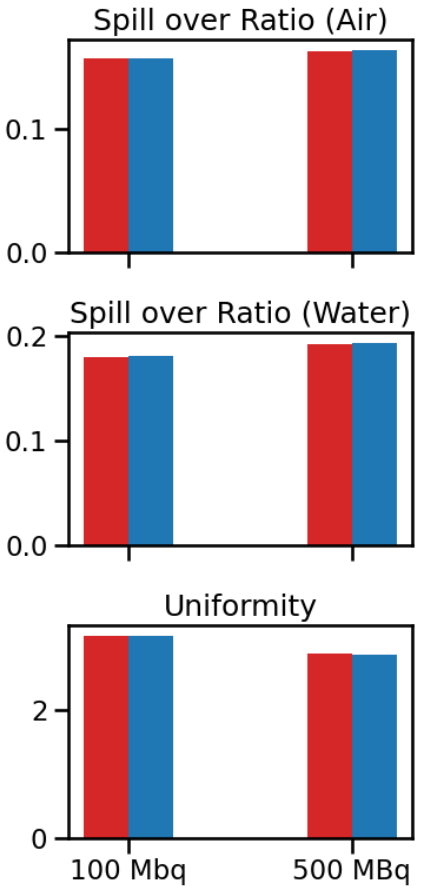


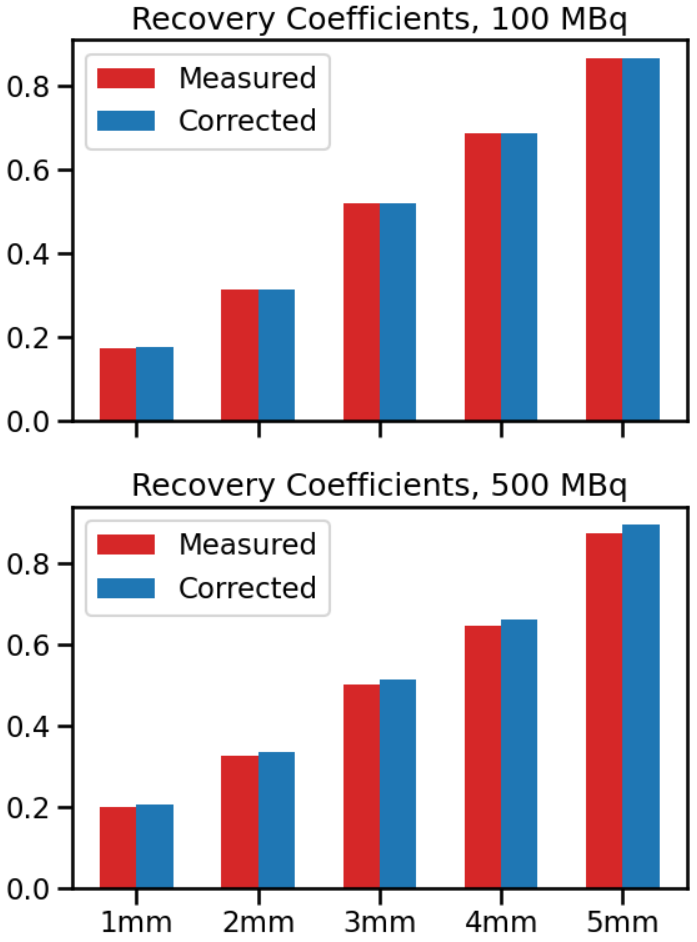
Spill-Over-Ratio (SOR)

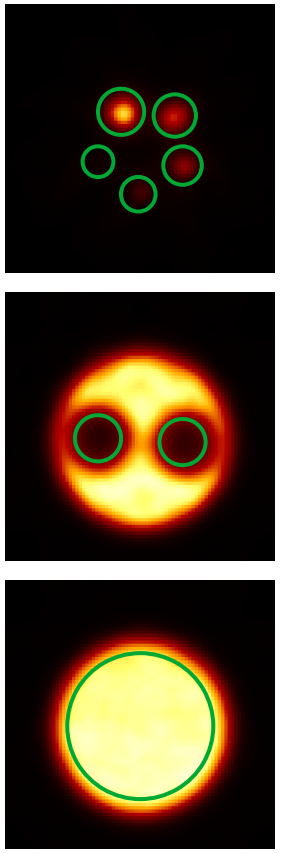


Uniformity

Image Quality





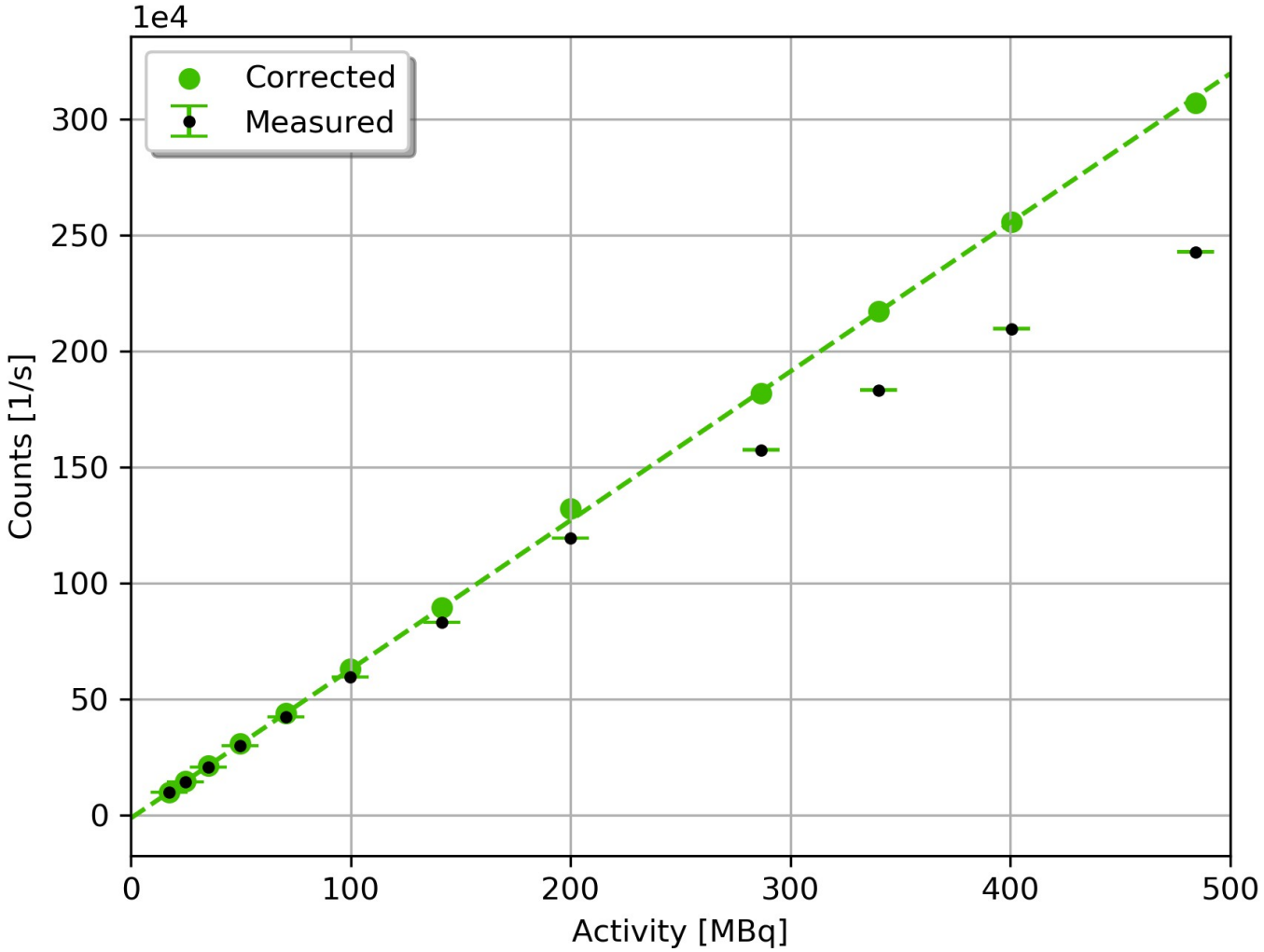


Recovery Coefficient (RC)

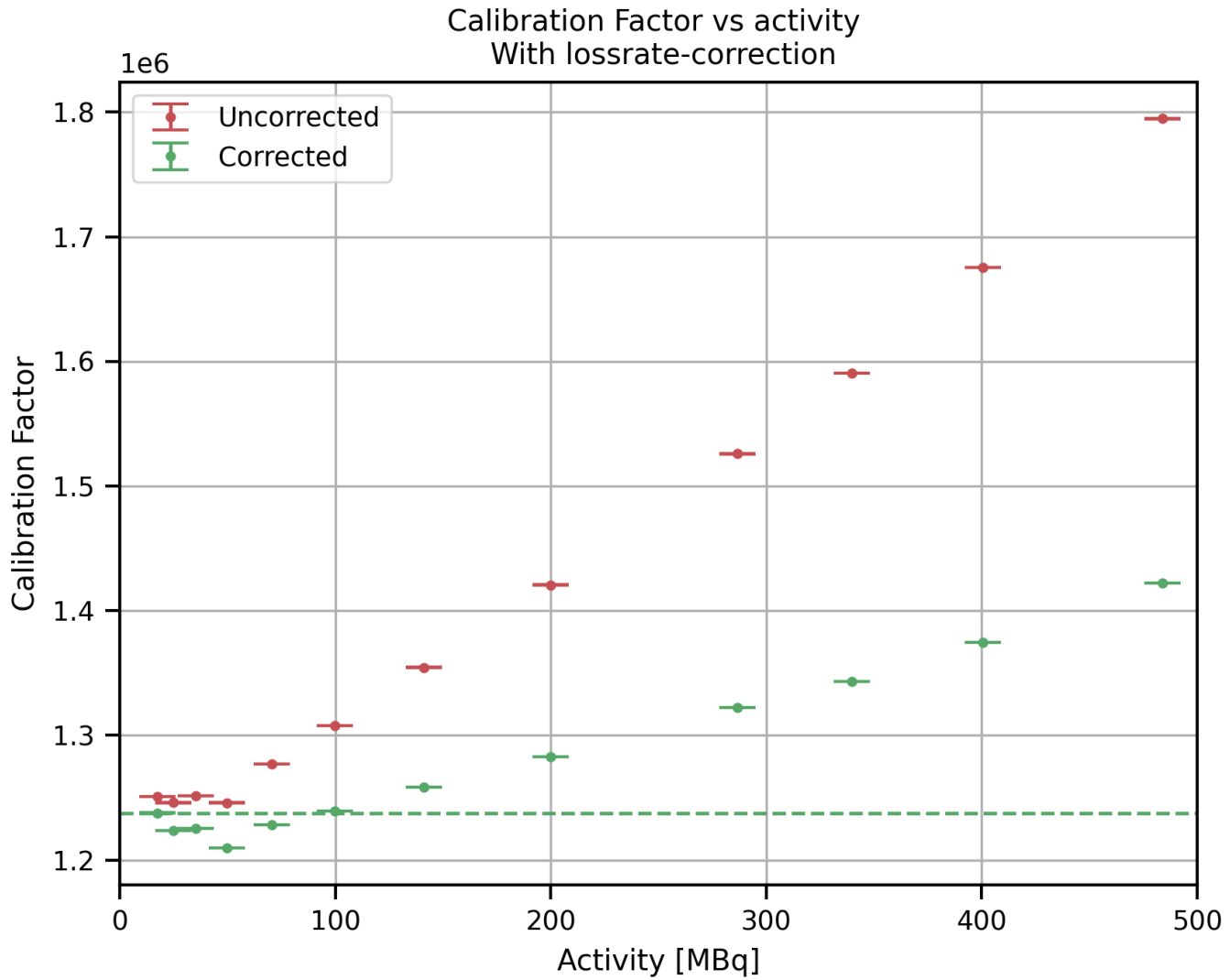
Spill-Over-Ratio (SOR)

Uniformity

No correction fixes everything

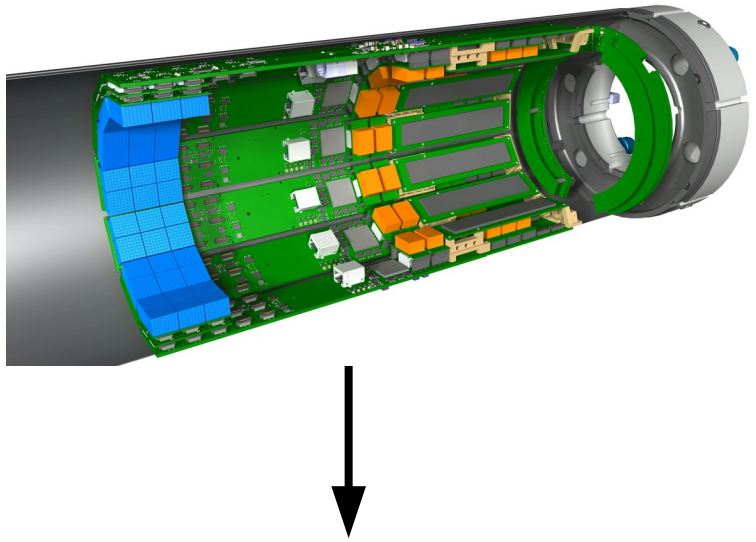


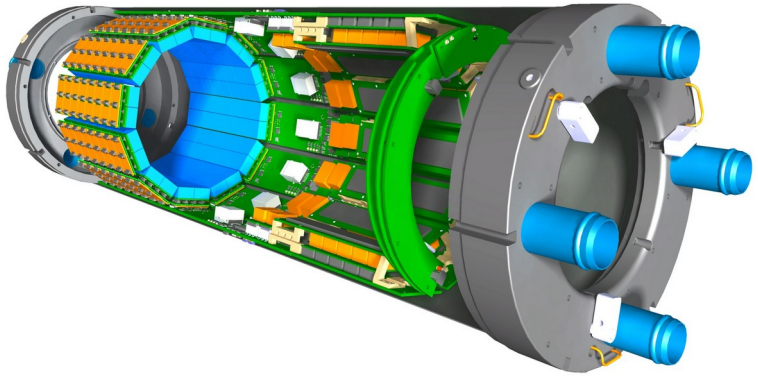
No correction fixes everything



- Pileup
- Energy & timing resolution at high activities
- Dead-time affecting random correction
- Etc.

The Future: SAFIR-II





Dual-Ring-Prototype → SAFIR-I:

- More crystals (+50%)

SAFIR-I → SAFIR-II

- New crystals (P. Bebie)
- More crystals → larger FOV
- New ASIC: PETA-8

➔ Extra features, faster readout & more!

- Better cooling, more data, …
- Opportunities for additional studies

The Future: SAFIR-II