Start Counter

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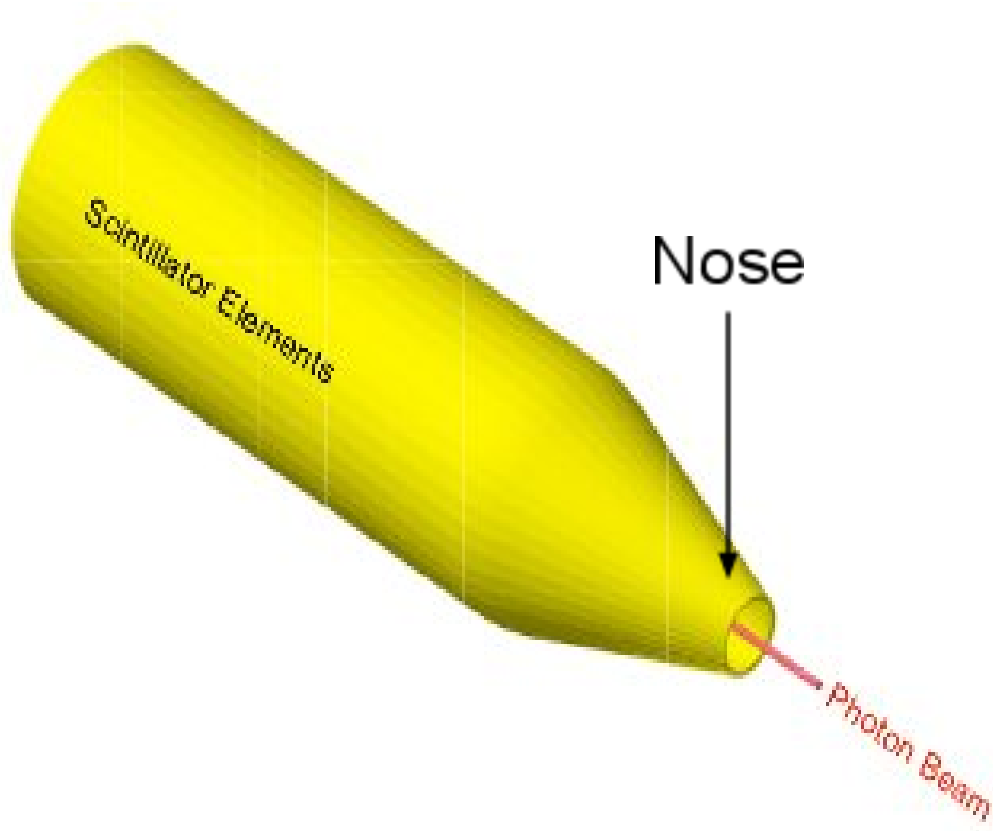
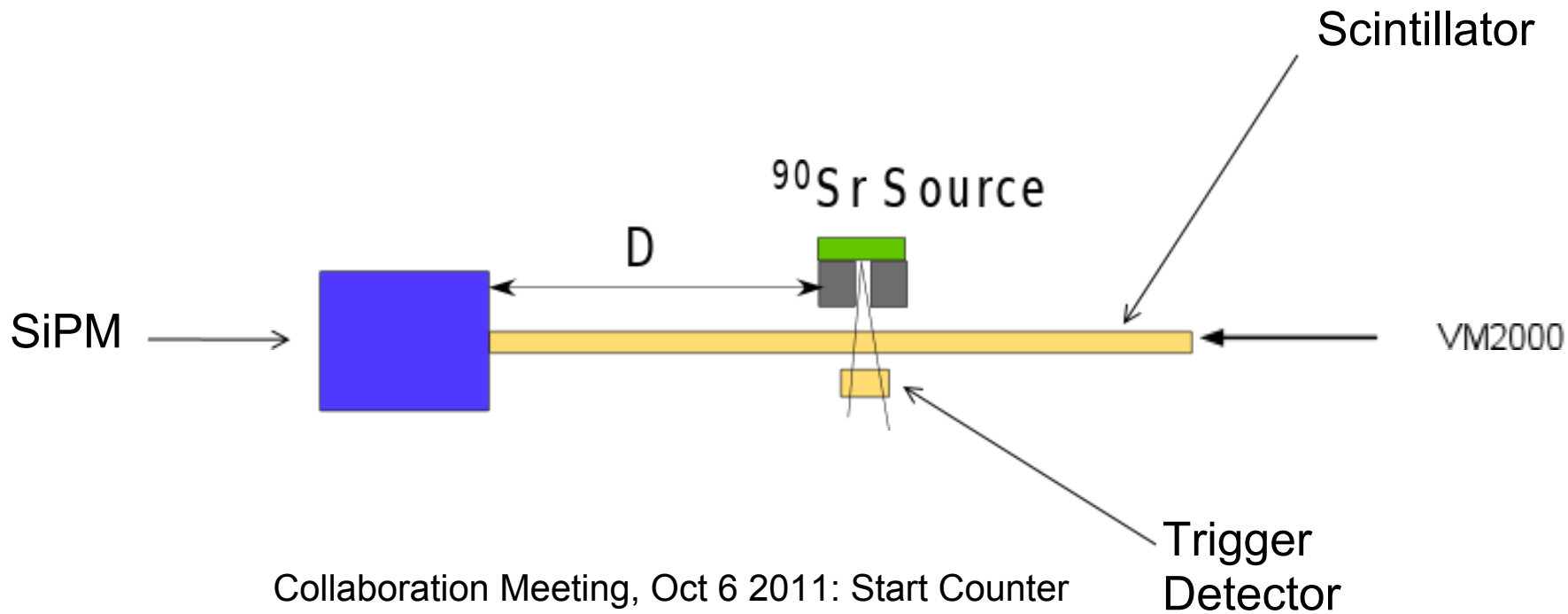
- Experimental Setup
- SiPM Scan
- Attenuation Lengths
- Time Resolution Studies
- Future Plans

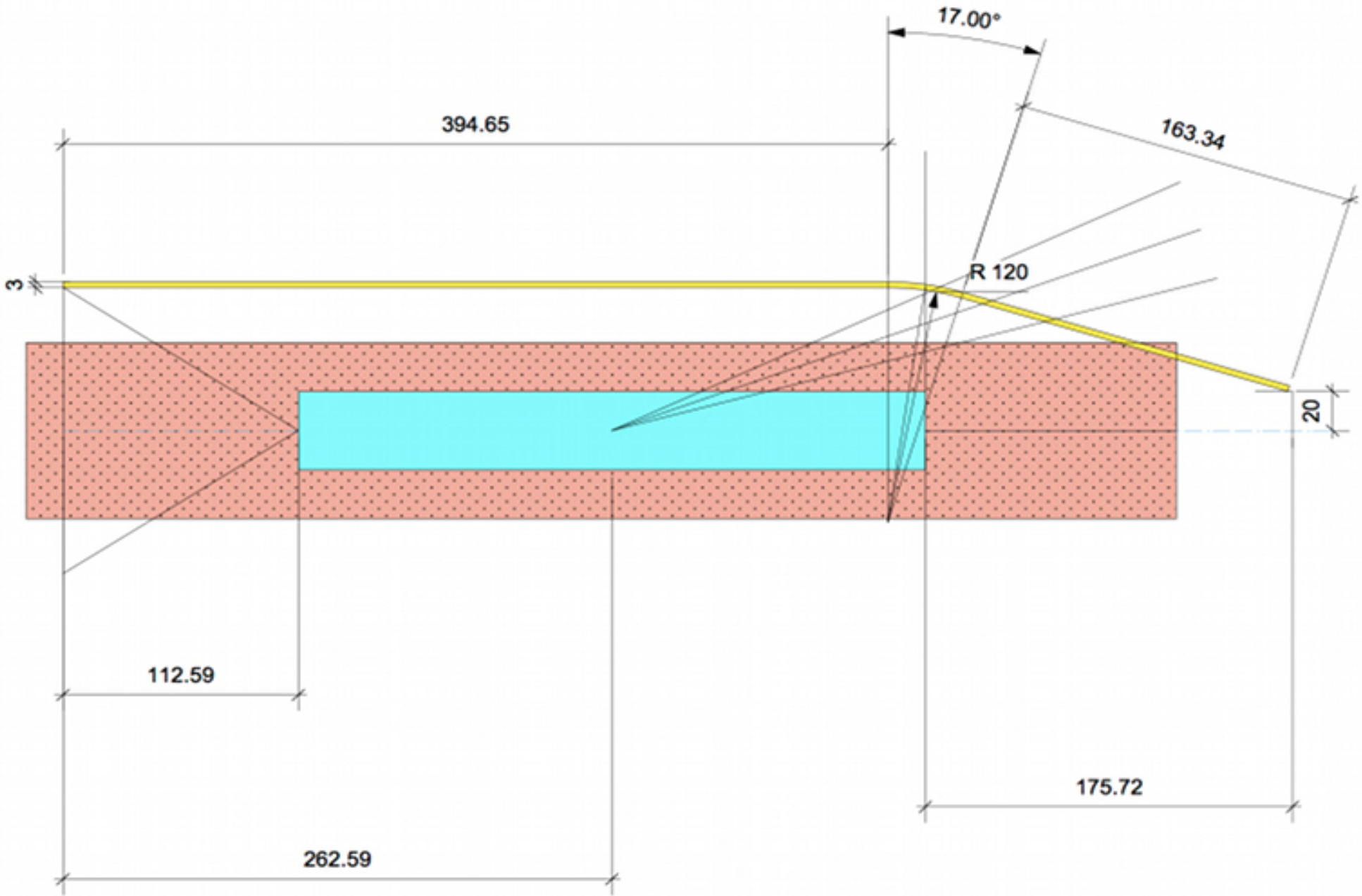


EJ-212 Scintillator Bar

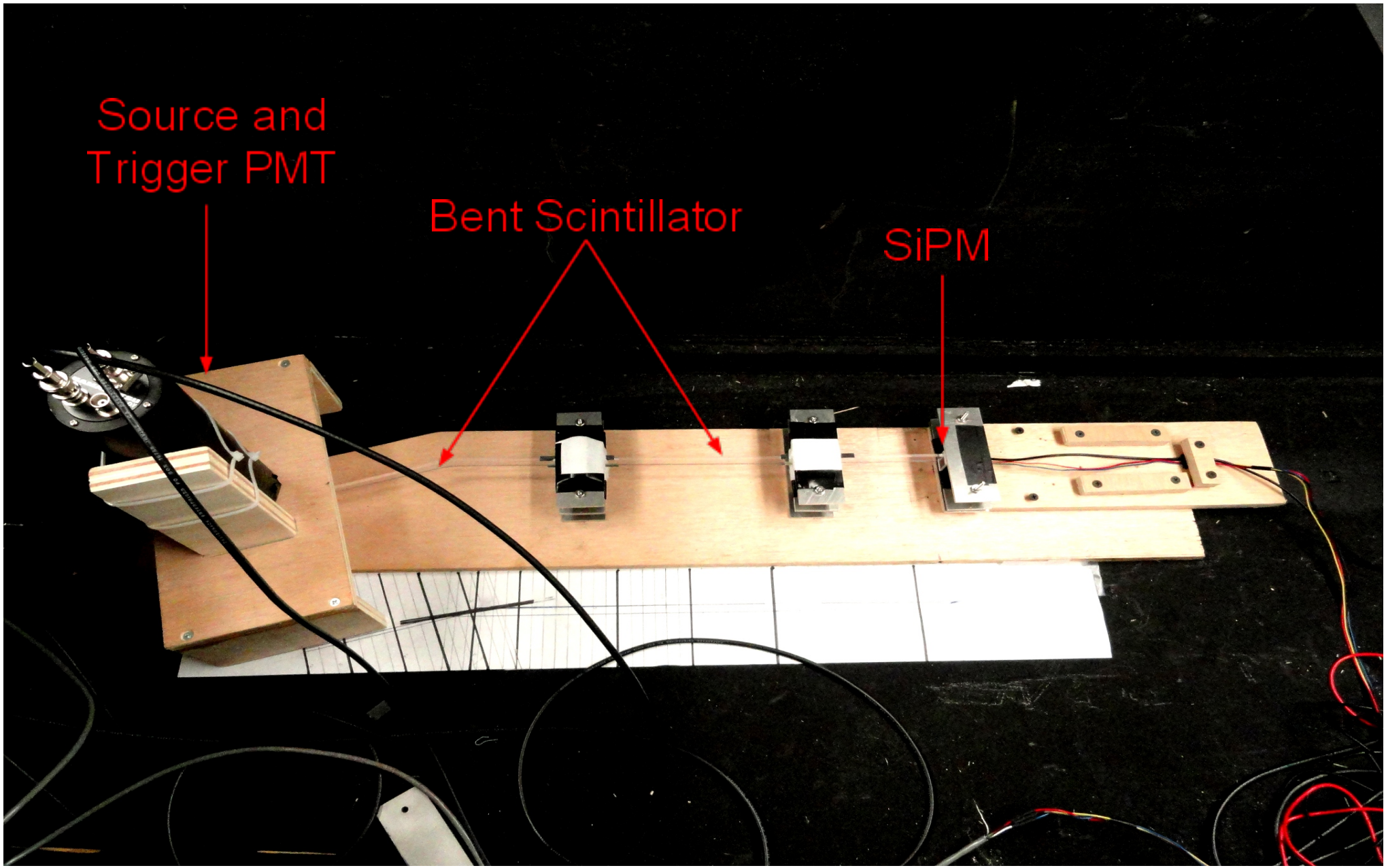
- Dimensions: 3 x 15 x 600 (mm)
  - Machined to form 30 paddle design
- With and without a VM2000 placed at the tip of the scintillator mounted in dark box
  - VM2000: highly reflective material
- SiPM coupled to the scintillator
- ^{90}Sr source



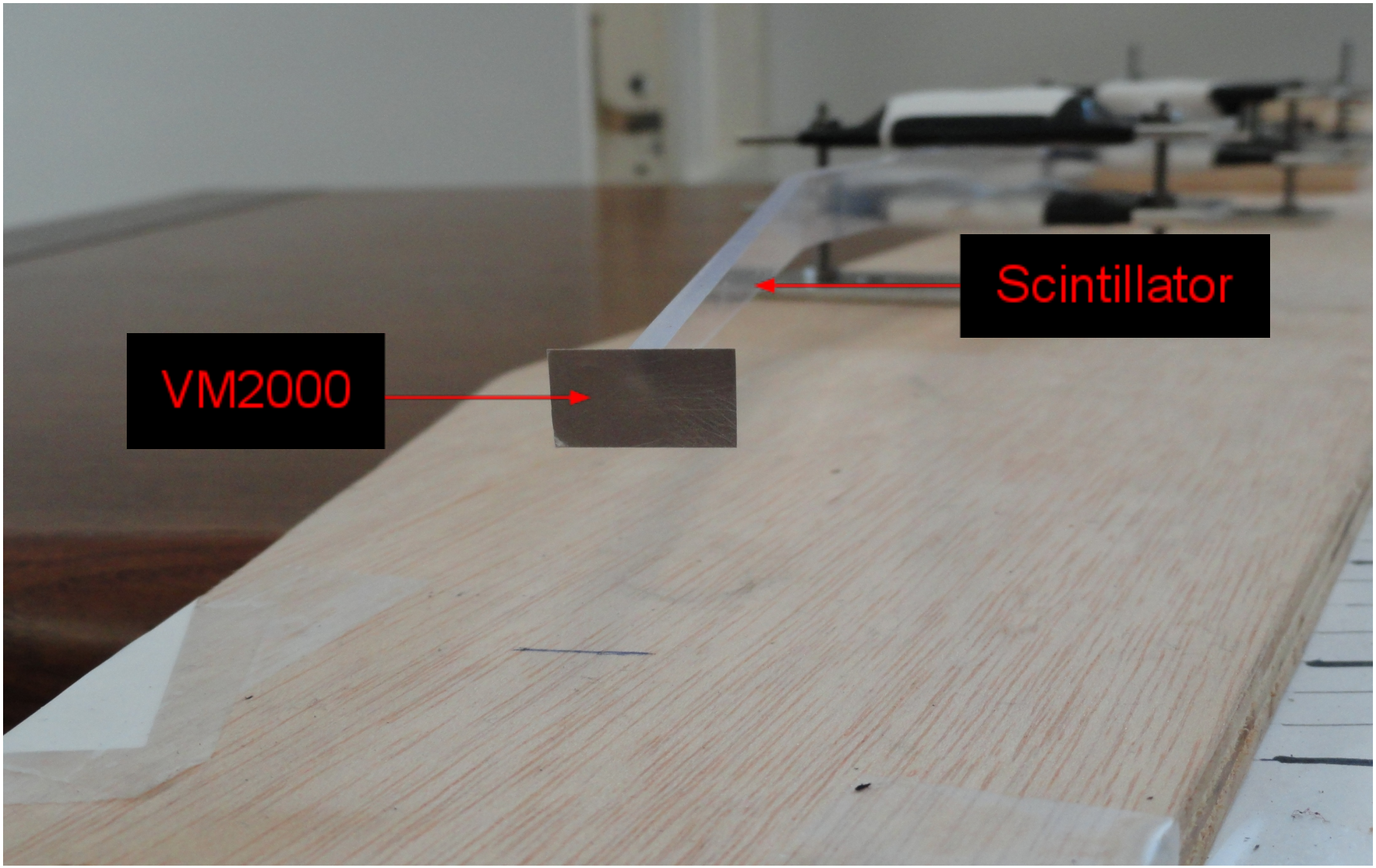
Geometry Of Bent Scintillator



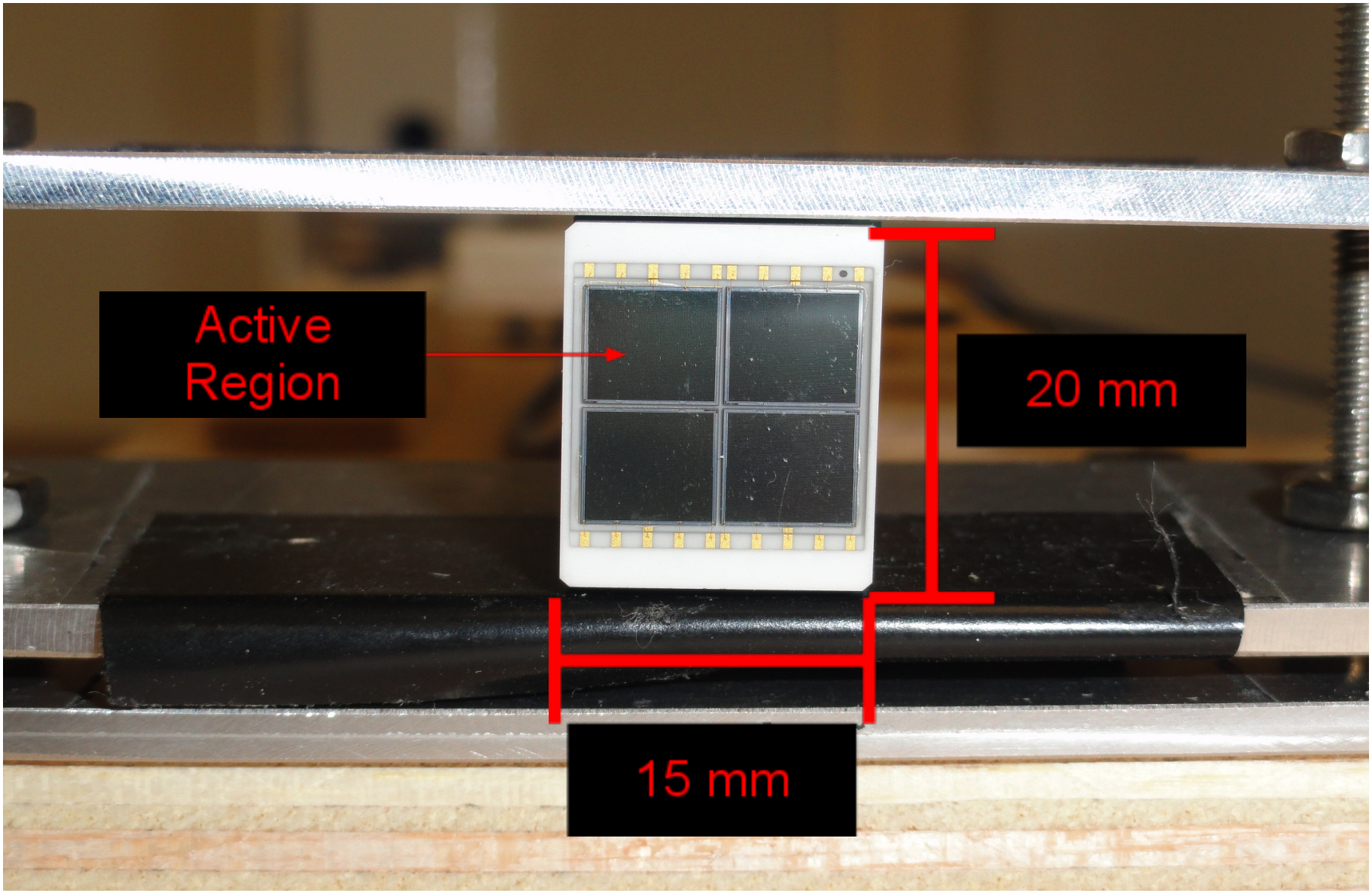
Experimental Set Up



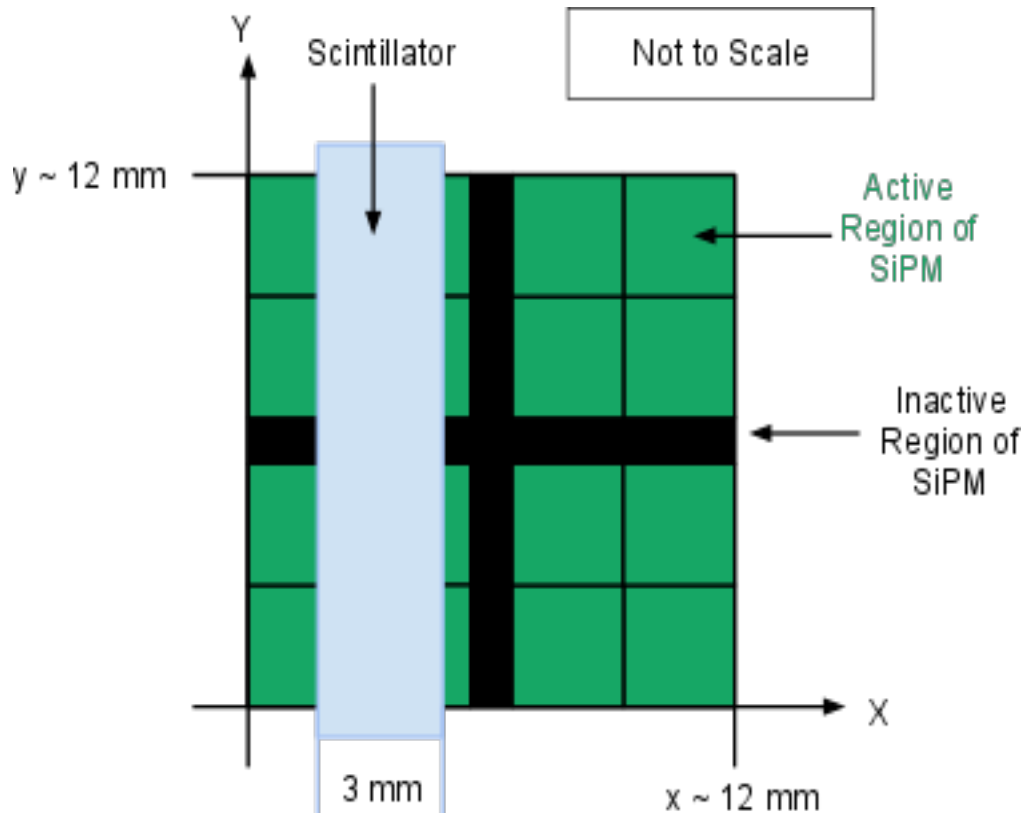
VM2000 at Nose of Scintillator



The SiPM

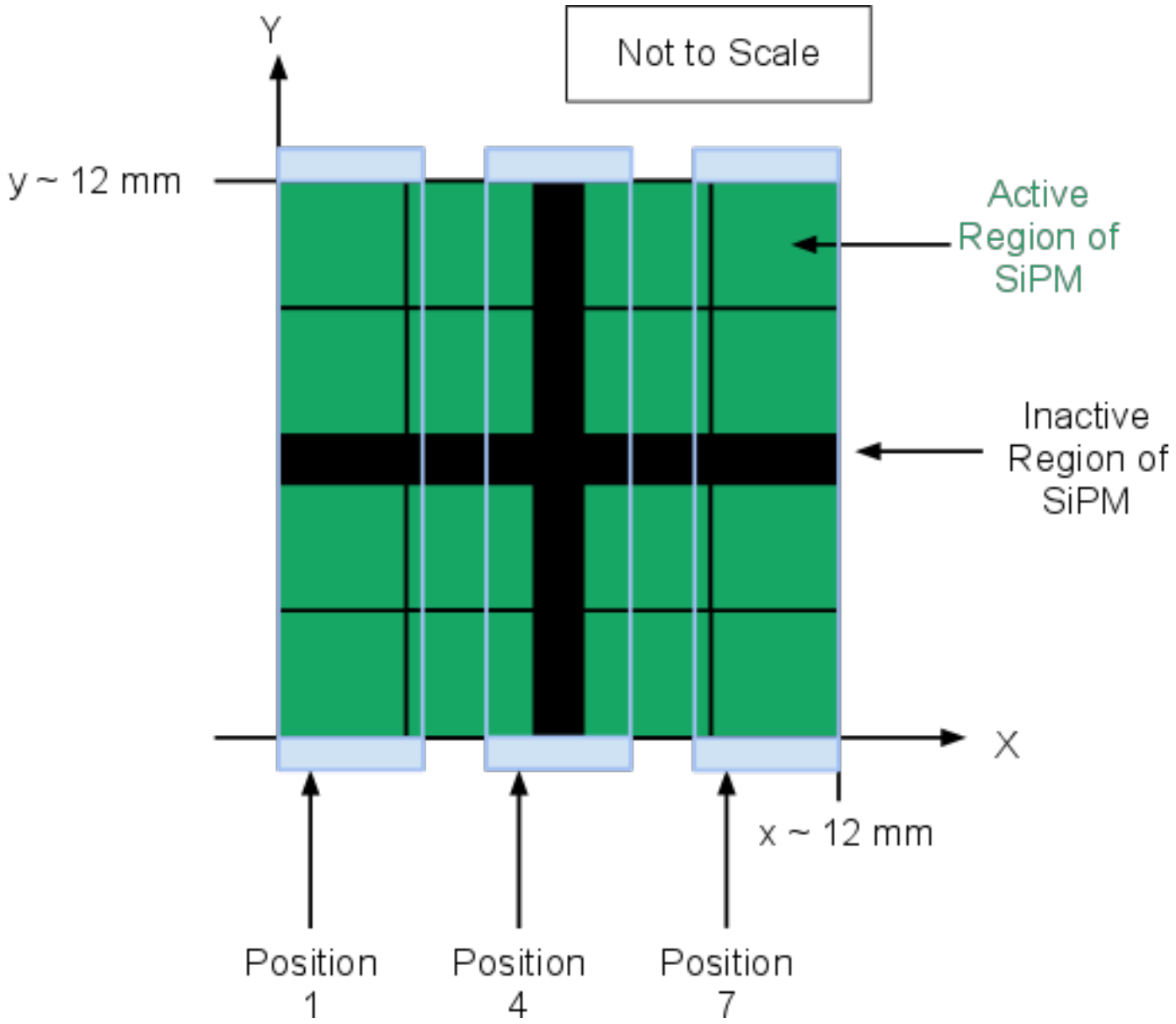


SiPM Measurements

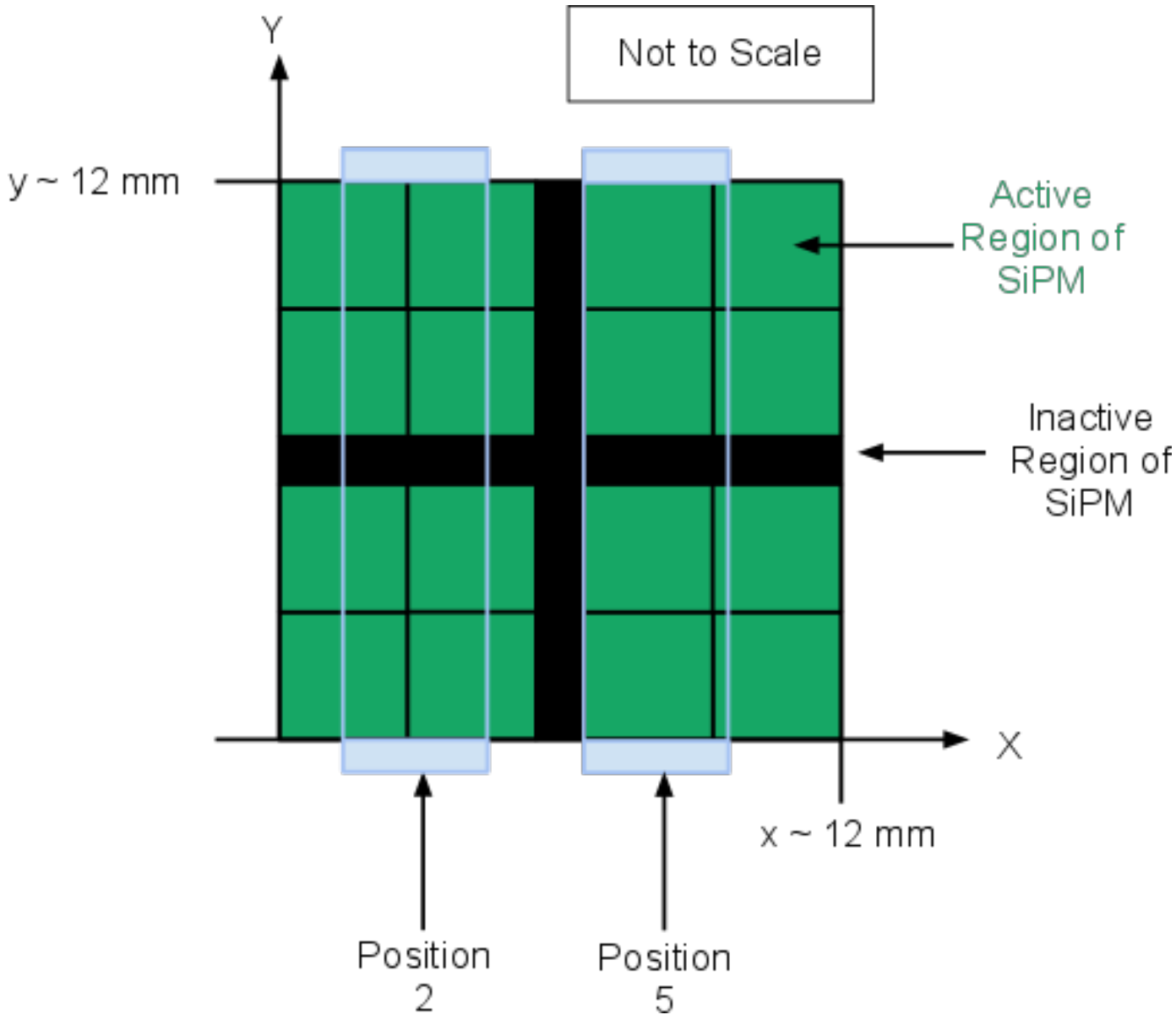


- Source ~ 25 cm from SiPM
- Seven measurements (SiPM scan) were made across the face of the SiPM
  - These are the "relative positions"
- New Pre-Amp greatly improved rise time of signal
  - Thanks Fernando Barbosa!
  - Old rise time ~ 20 ns
  - New rise time ~ 4 ns

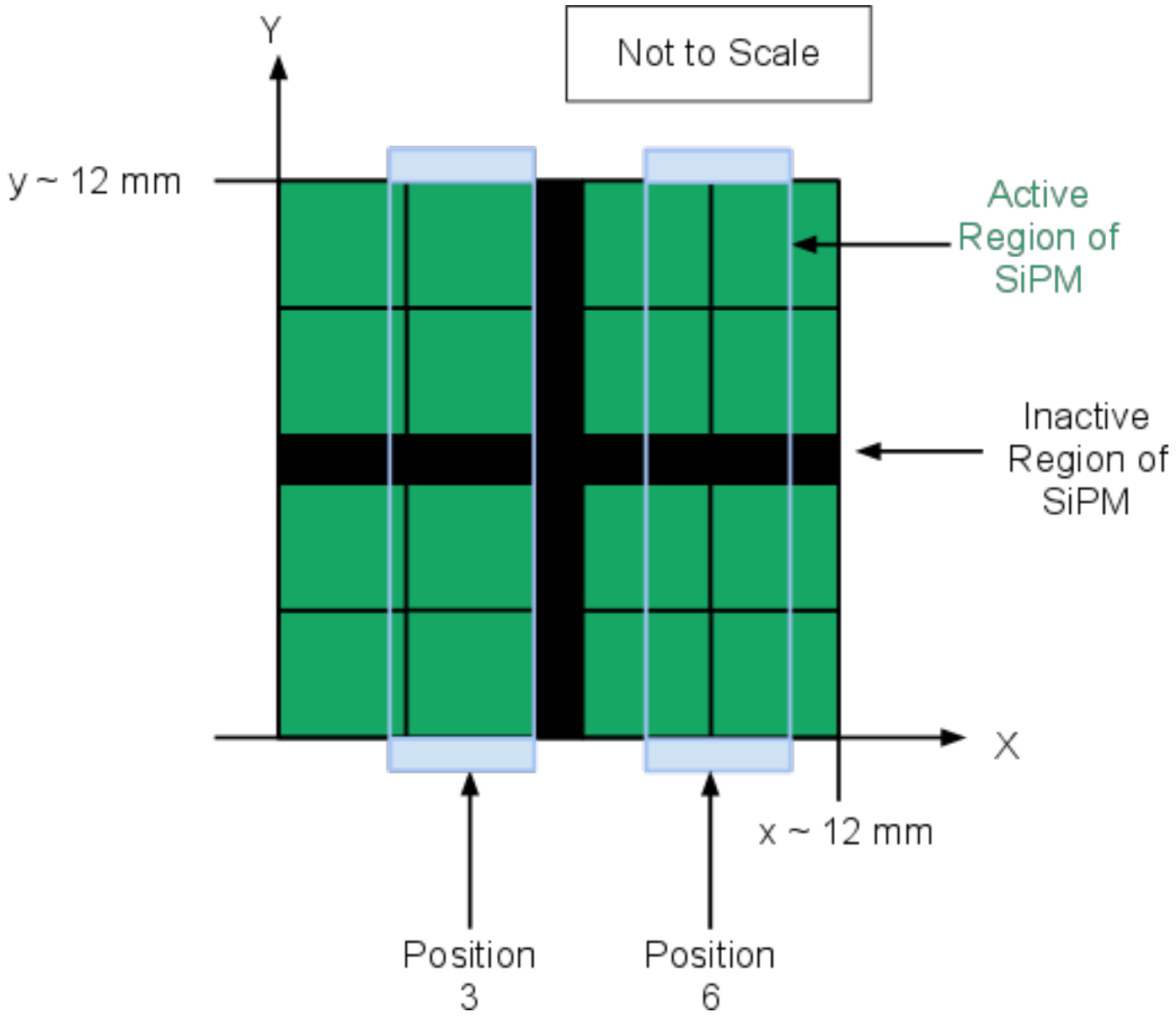
SiPM Scan


Not to Scale
Y
y ~ 12 mm
Active Region of SiPM
Inactive Region of SiPM
X
x ~ 12 mm
Position 1
Position 4
Position 7

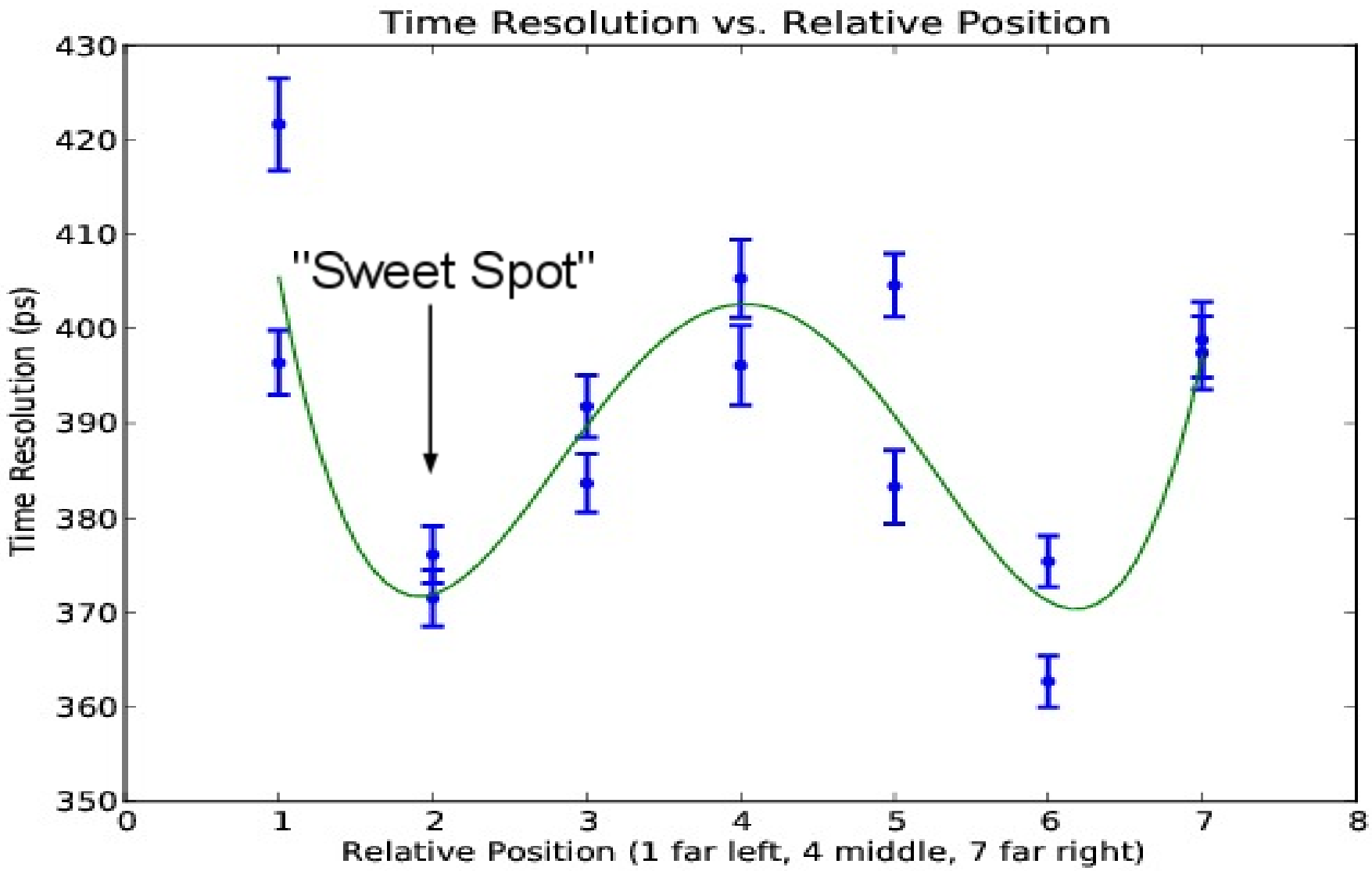
SiPM Scan


Not to Scale
Y
y ~ 12 mm
Active Region of SiPM
Inactive Region of SiPM
X
x ~ 12 mm
Position 2
Position 5

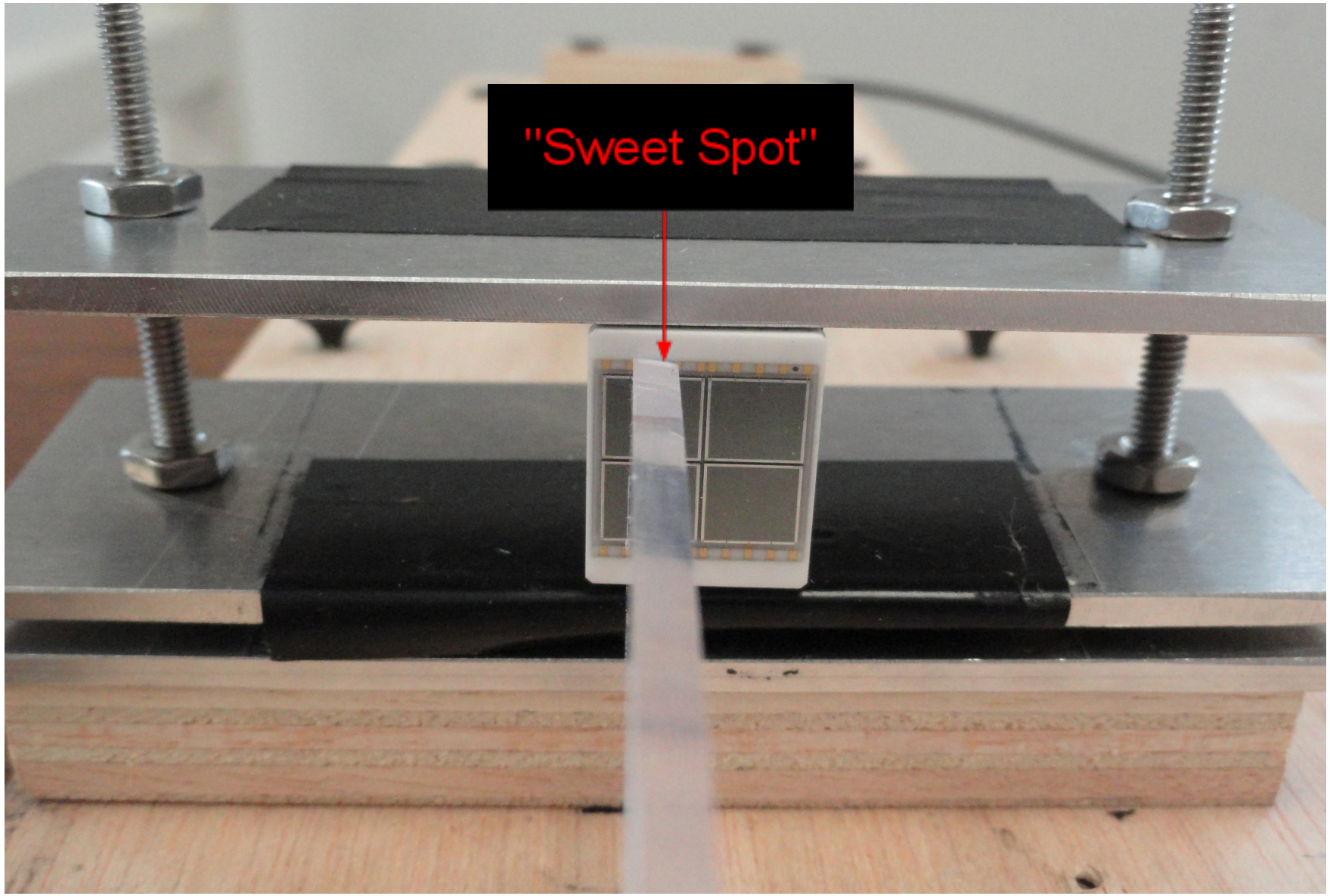
SiPM Scan


Not to Scale
Y
y ~ 12 mm
Active Region of SiPM
Inactive Region of SiPM
X
x ~ 12 mm
Position 3
Position 6

SiPM Scan


Time Resolution vs. Relative Position
"Sweet Spot"
Time Resolution (ps)
Relative Position (1 far left, 4 middle, 7 far right)
430
420
410
400
390
380
370
360
350
0
1
2
3
4
5
6
7
8

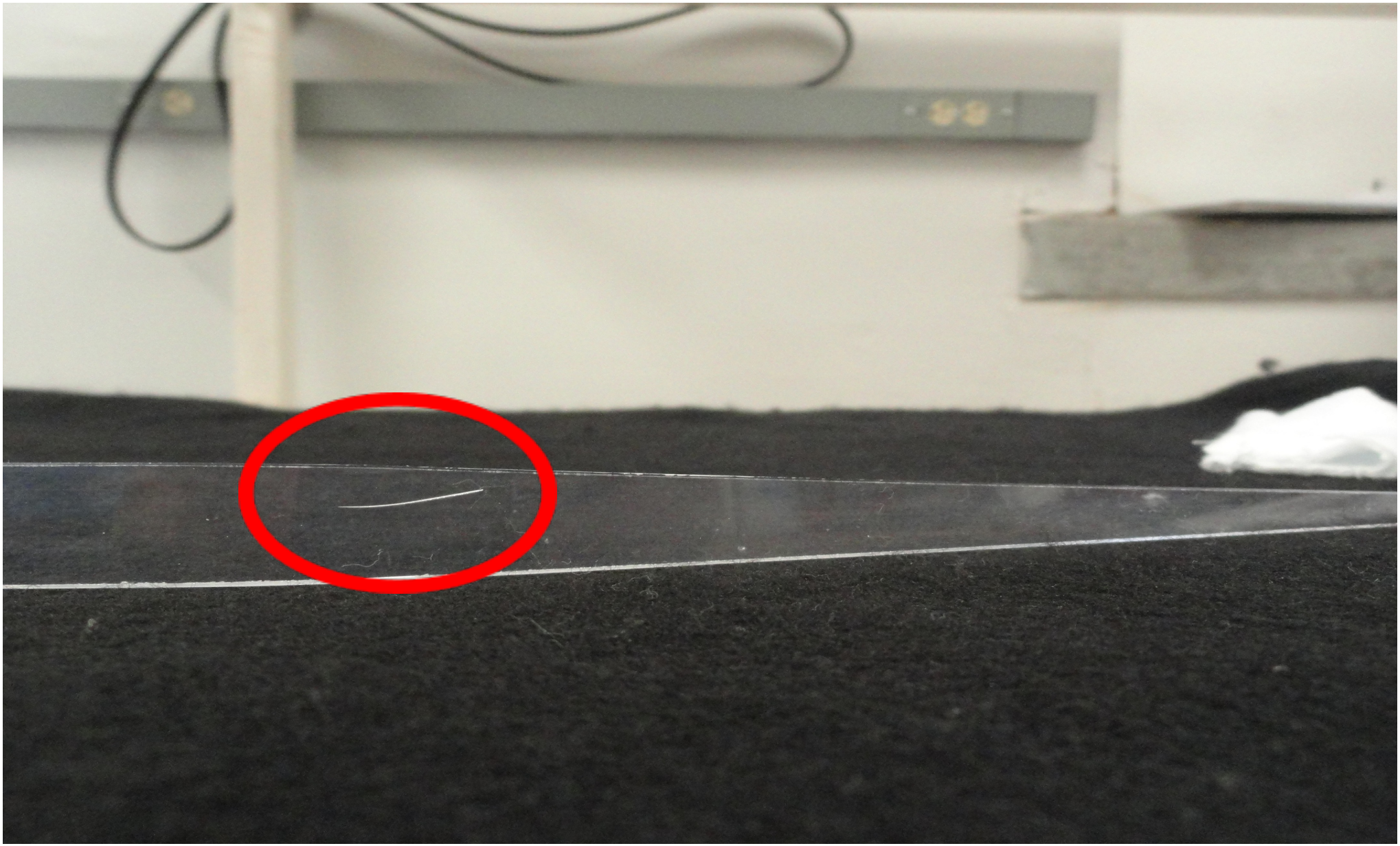
Coupling to SiPM (Sweet Spot)



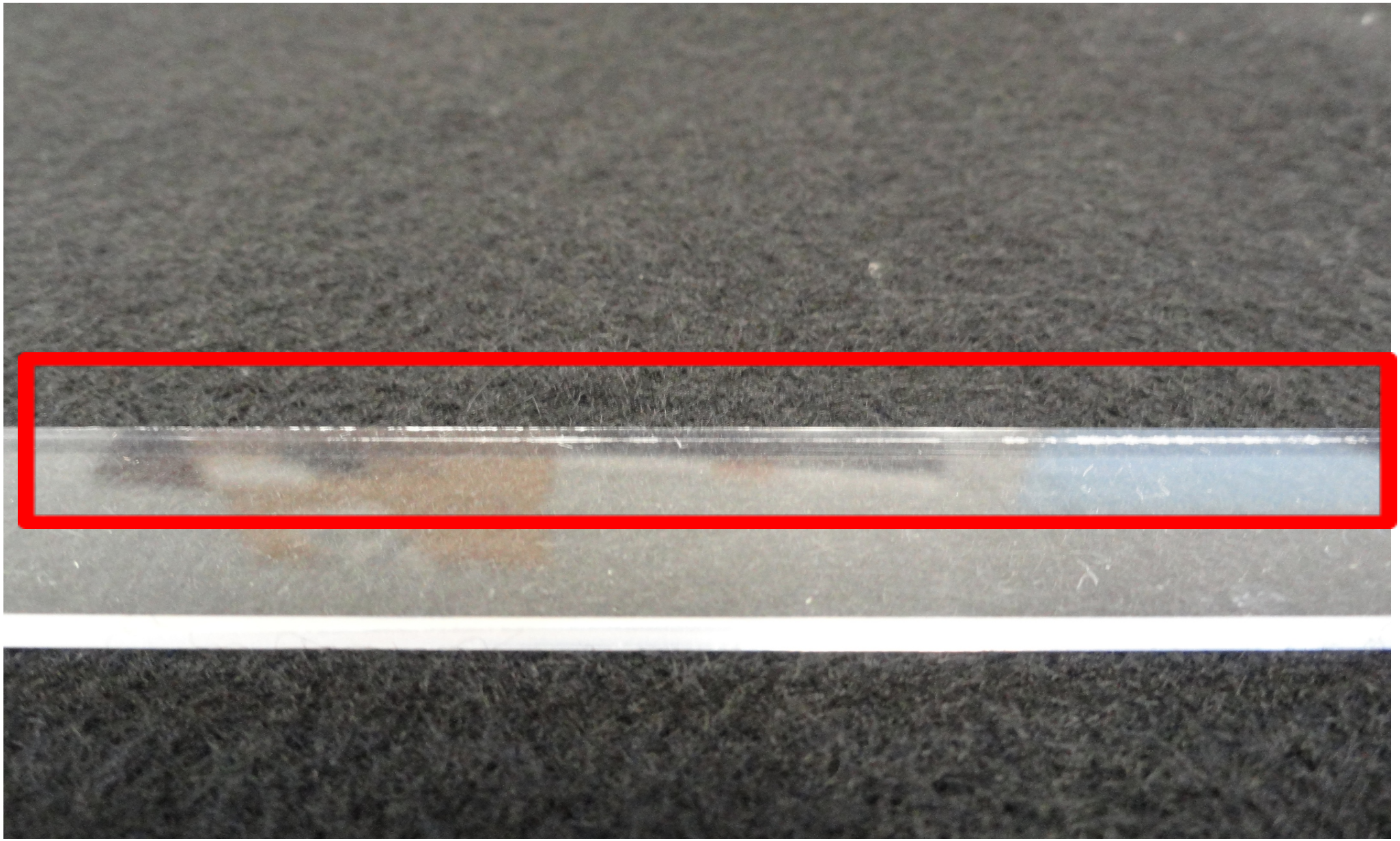
Attenuation Lengths

- Measured attenuation lengths of all five scintillators
  - With and without VM2000
  - Coupling of scintillator to "sweet spot" of SiPM
- Scintillators were rated from 1 (best) to 5 (worst)
  - Based on visual inspection of surface quality
  - Rated *prior* to measurements
- Defects on surface of scintillators
  - Buffing scratches (poor polishing techniques)
    - Worst in region of bend
  - Crazing (stress of machining or improper handling)
  - Deep gashes on surface
  - Poor milling of edges

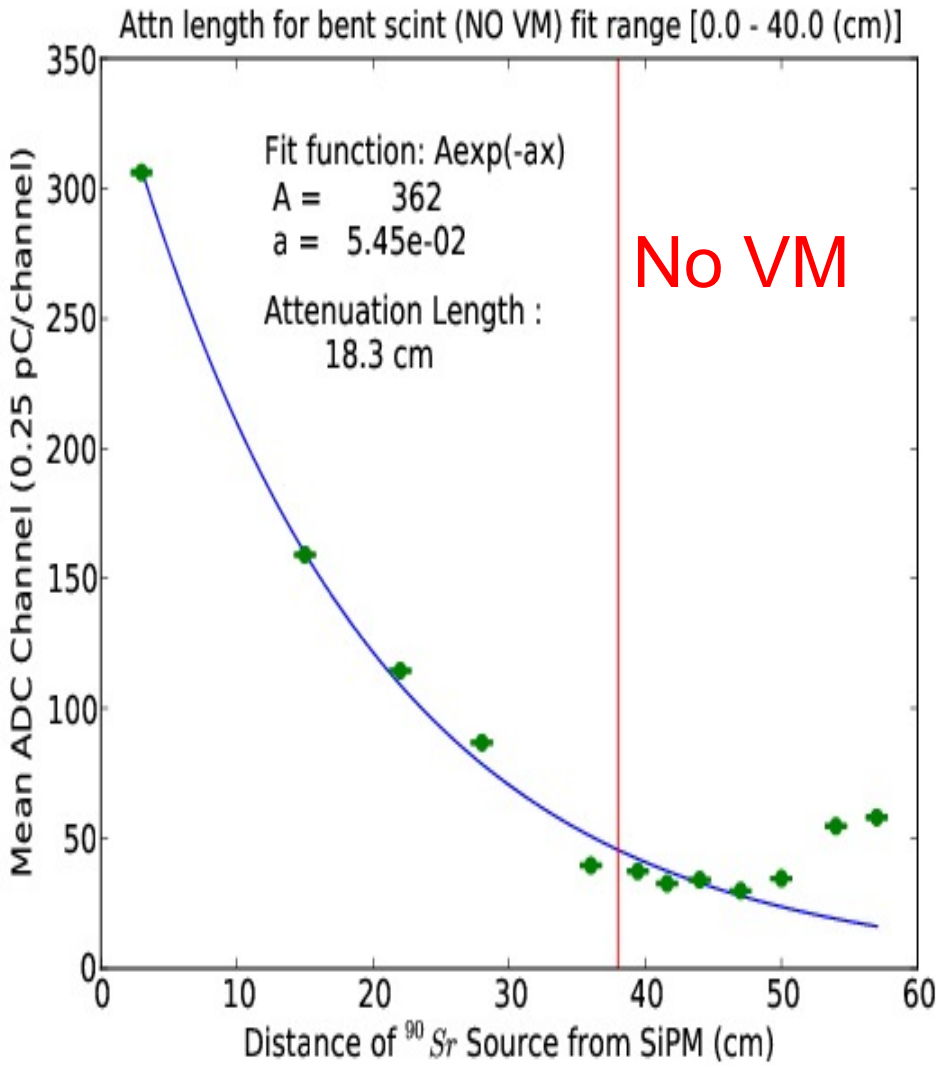
Damaged Surface on Bend

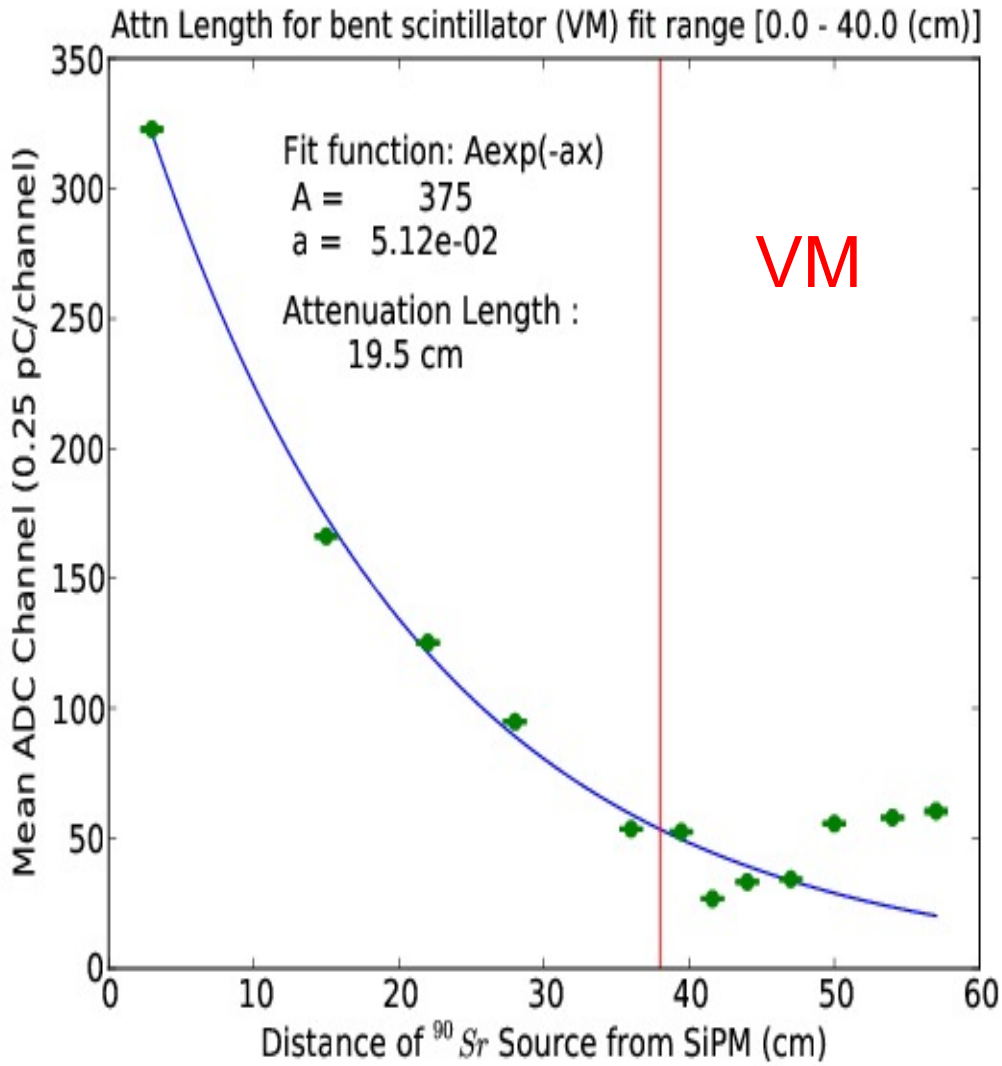


Defective Milling of Edges



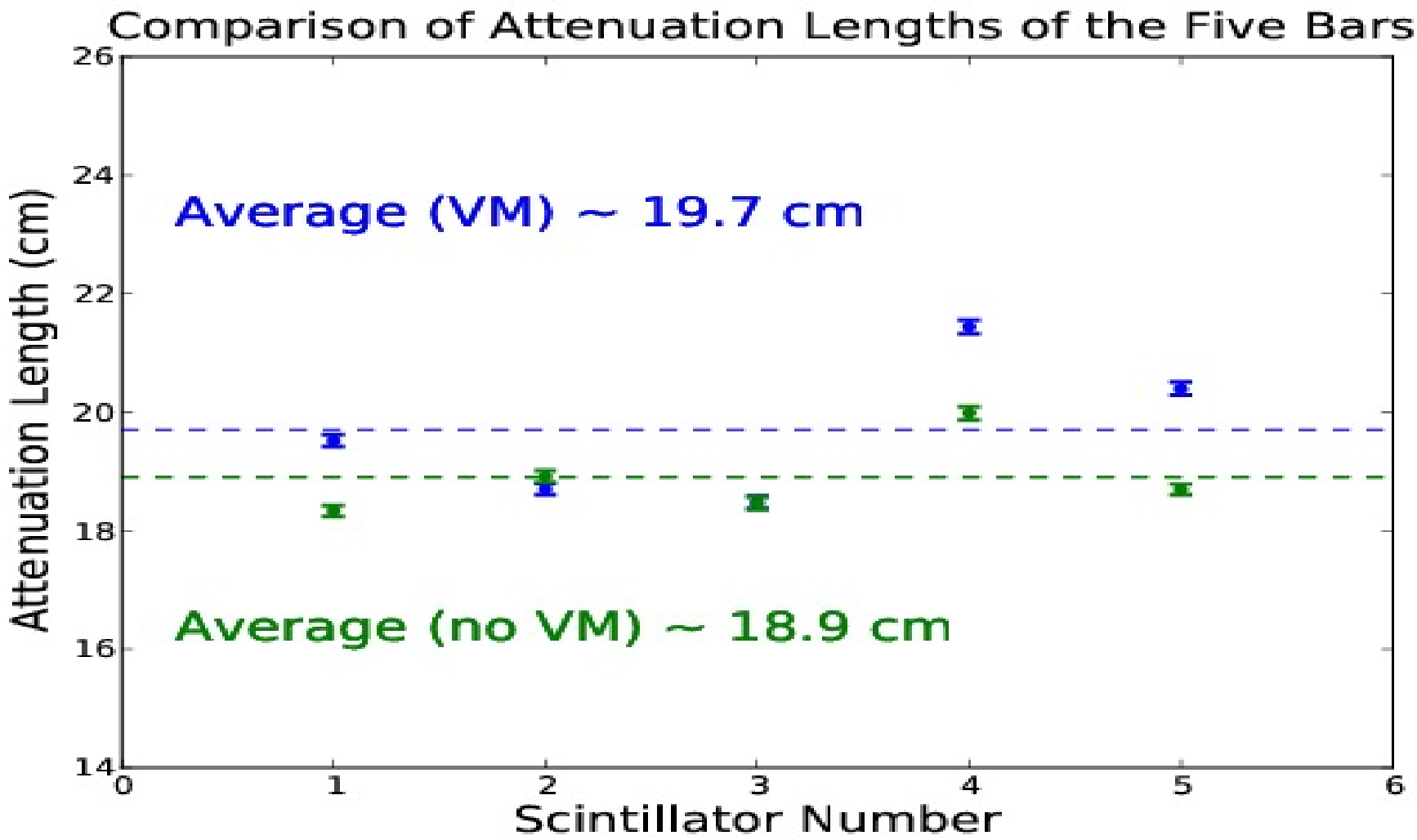
Attenuation Length Plot for Scintillator 1 (Typical Response)





- VM2000 has no significant effect
- Fit Range (0.0 - 40.0 cm)

Average Attenuation Lengths



- The attenuation lengths of all five scintillators are approximately the same

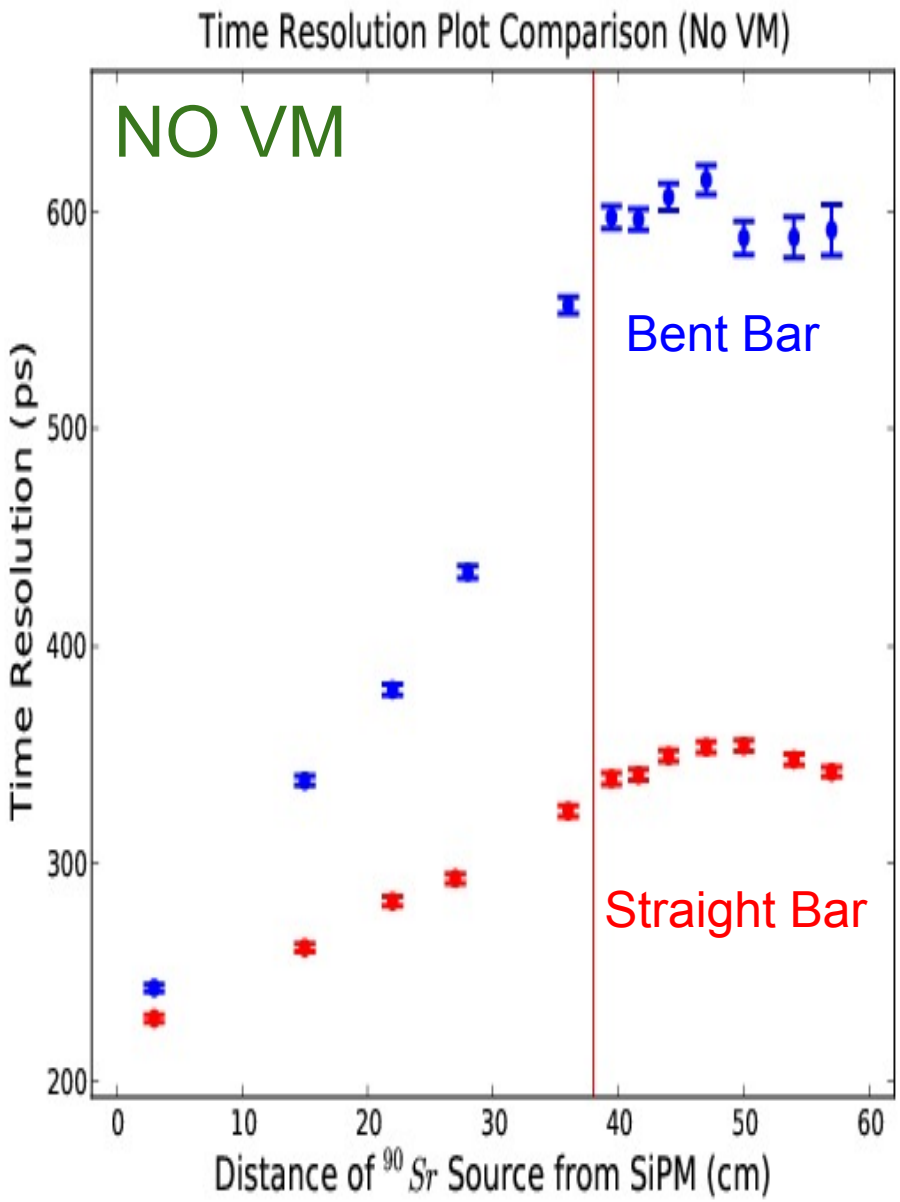
Attenuation Lengths Summary

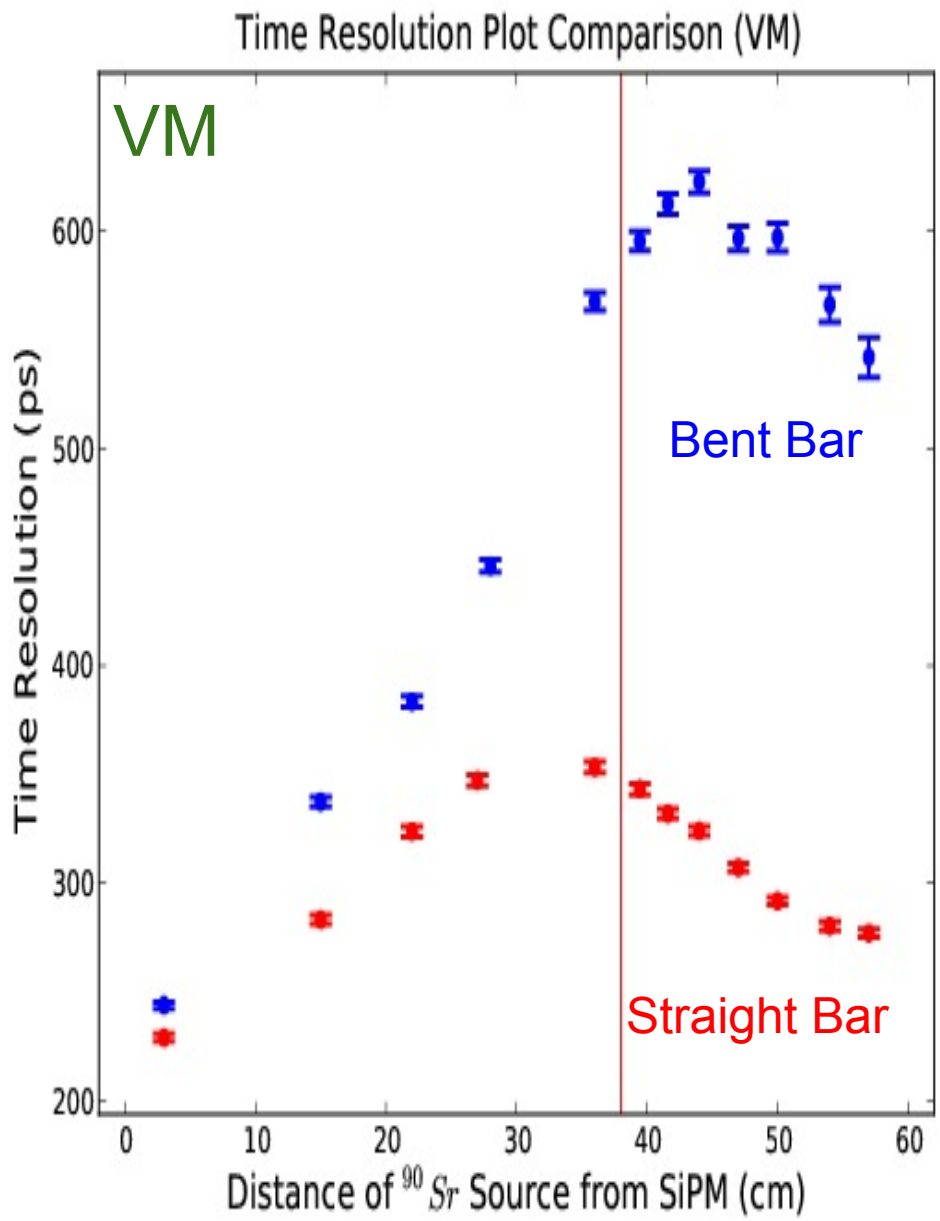
- Poor light output due to poor surface quality
  - Damaged surface attributable to Plastic Craft manufacturing and polishing techniques
- Light output is worst in the region of the bend
  - ~ 41.6 cm down stream of SiPM
- Small improvement with VM2000 backing
- Bent scintillator has worse attenuation length compared to straight scintillator
  - 3.7x without VM2000
  - 6.5x with VM2000

Time Resolutions Studies

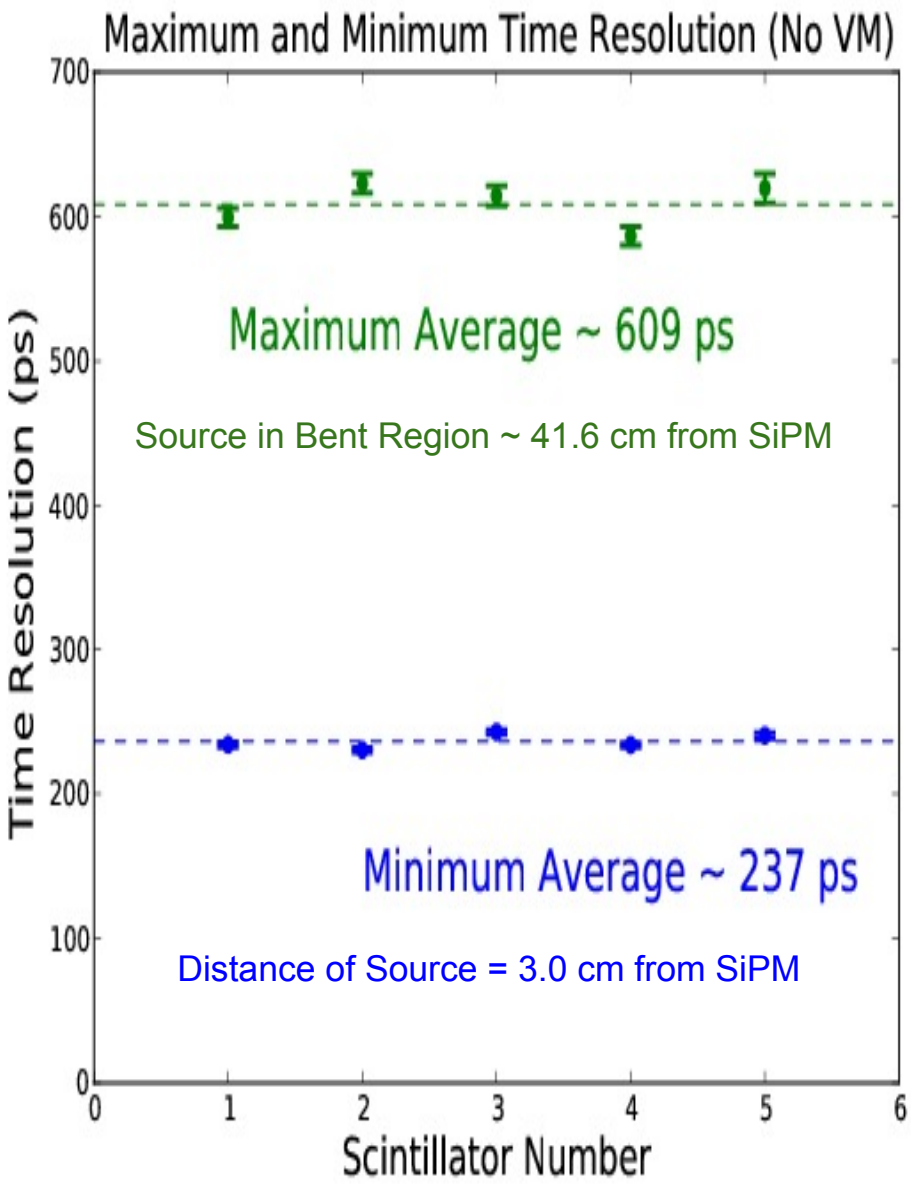
- Coupling of scintillator to "sweet spot" of SiPM
- We measured the time resolution as a function of distance of source from SiPM
- Comparative measurement with straight scintillator
  - Both with and without VM2000
- Comparative time resolution measurements with FM-PMT, Old SiPM, and New SiPM

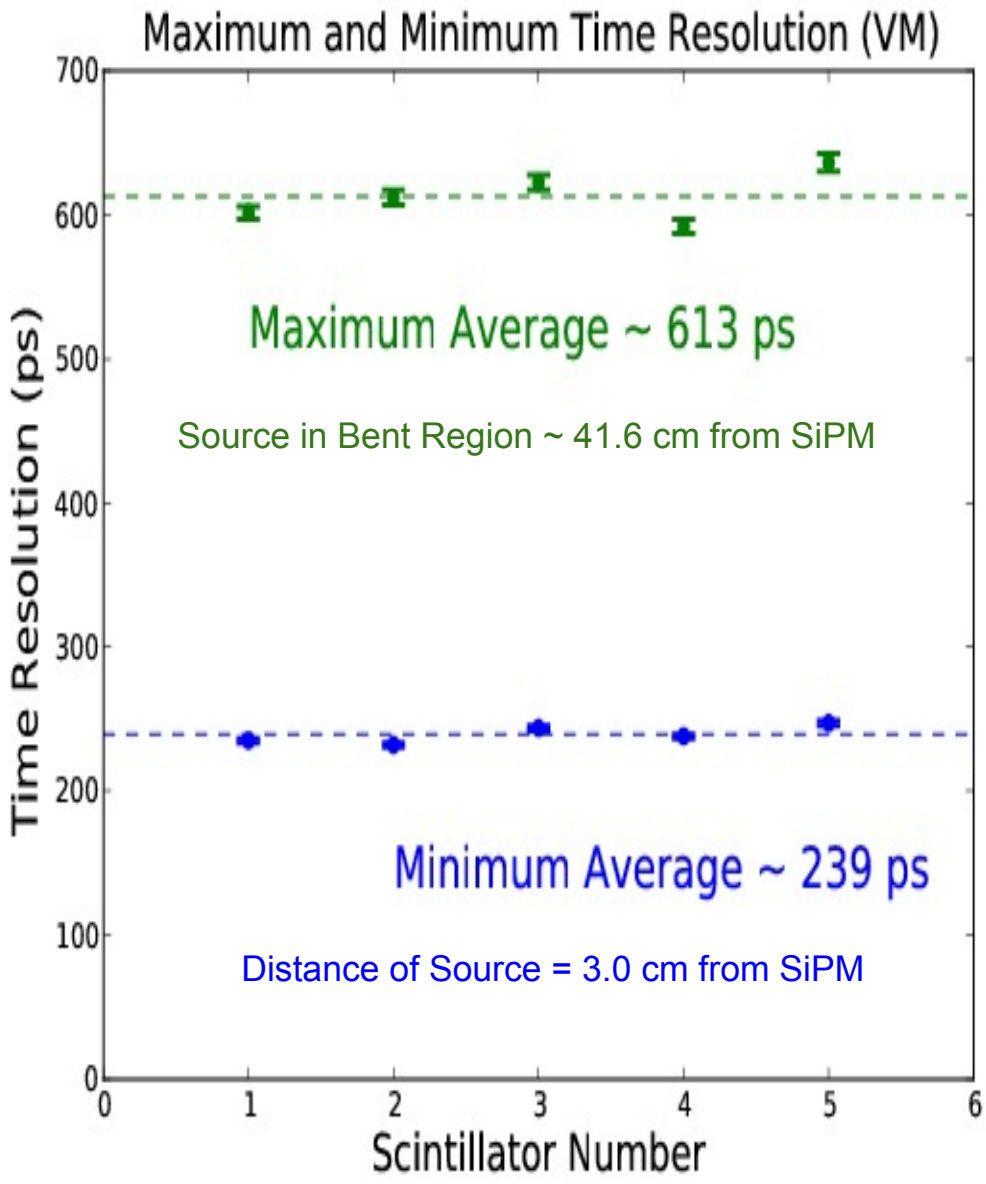
Time Resolution Plots



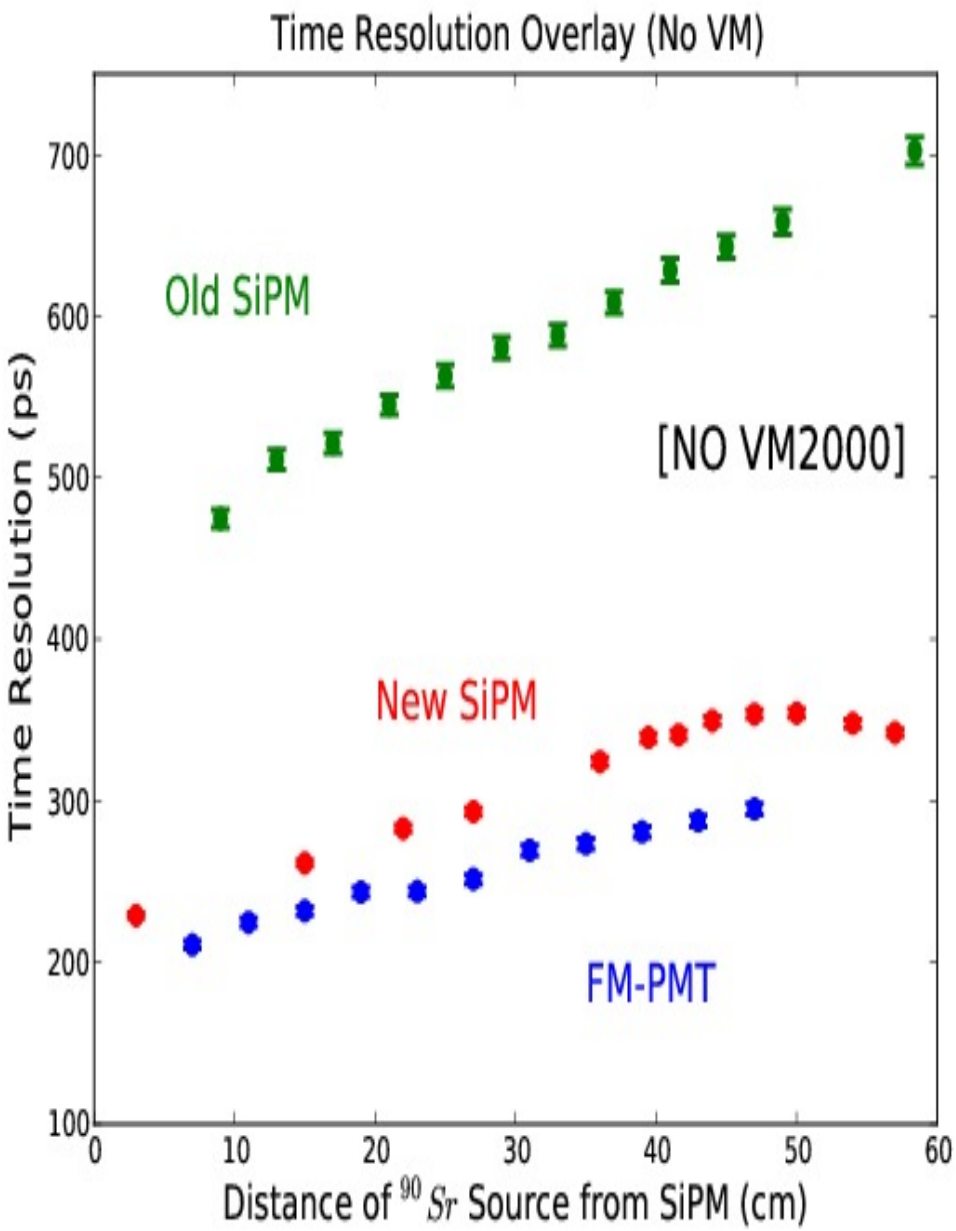


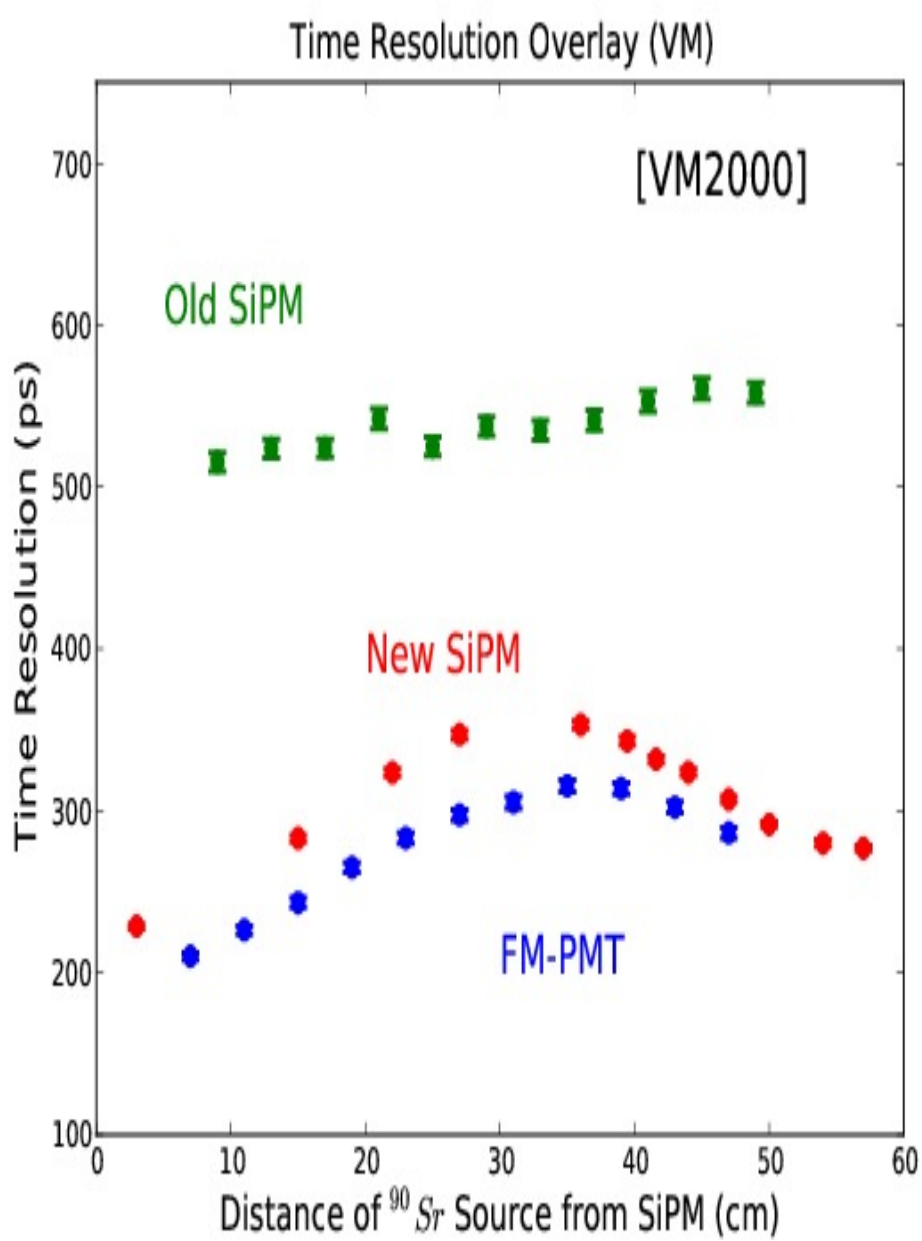
Comparison of Time Resolutions





Time Resolution Comparisons (Straight Bar)





Time Resolution Summary

- Without VM2000
  - Time resolution is relatively constant in nose
- With VM2000 at tip of the nose
  - Time resolution improves as a function of increasing distance
- Worst time resolution occurs in the bent region
  - Same as light output
- Time resolution measurements were relatively consistent among all of the scintillators
- Overall we find: 230 ps < σ < 640 ps for the bent scintillators
- New Pre-Amp improved the time resolution as expected

Summary

- SiPM is suitable for timing measurements
- Geometry of nose results in:
  - Faster propagation of light (~60ns > c)
  - Relatively constant time resolution in bend
  - Better time resolution with VM2000
- Bad surface quality results in:
  - Broad range of timing resolution
  - Poor light output
  - Short attenuation lengths
- More care must be taken by Plastic Craft

Future Plans

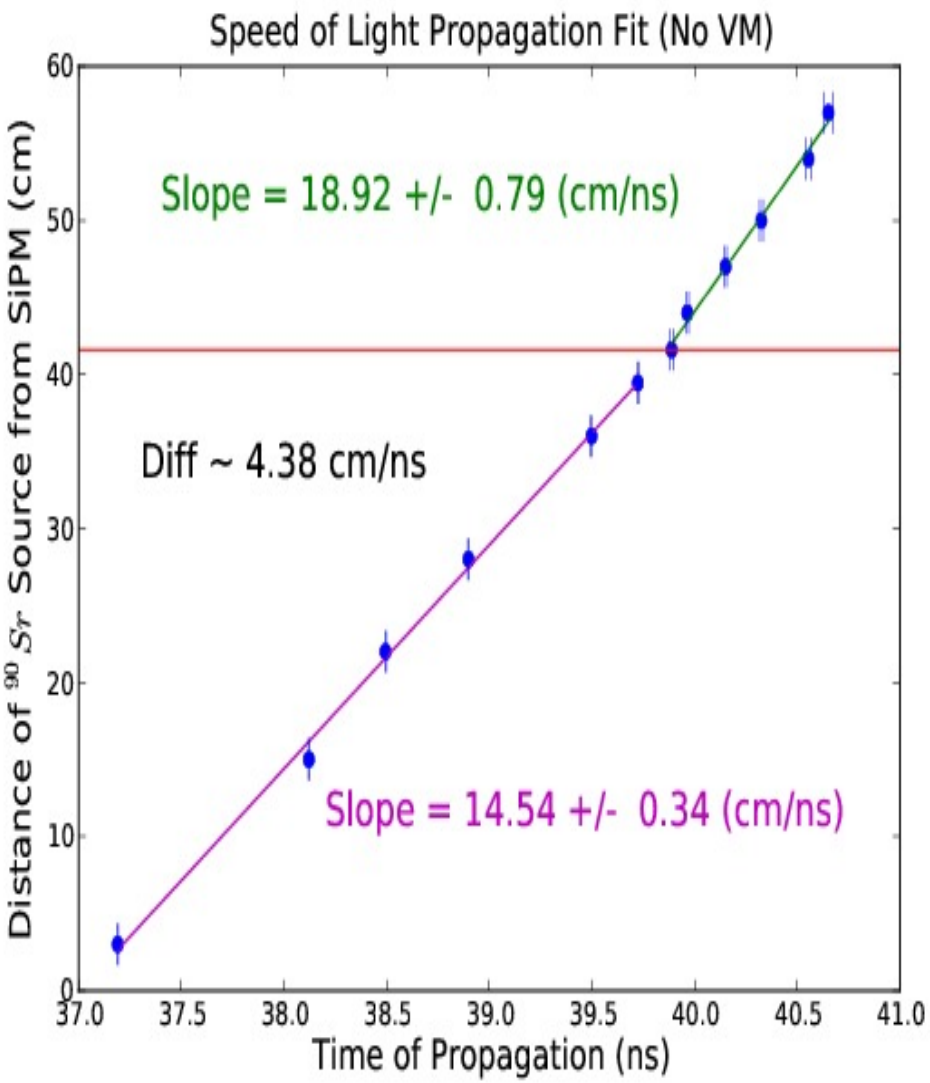
- Scintillators have been sent back to Plastic Craft for re-polishing with advised polishing techniques
  - This should improve light output and timing resolution
- Techniques of wrapping VM2000 to bent scintillators will be investigated
- Comparative measurements will be made
  - Re-polished scintillators
  - Wrapped scintillators (VM2000)
- Coupling of scintillators to light guides and SiPM
  - Associated measurements
- Final design of start counter has yet to be finalized
  - 40, 30, 24 ?

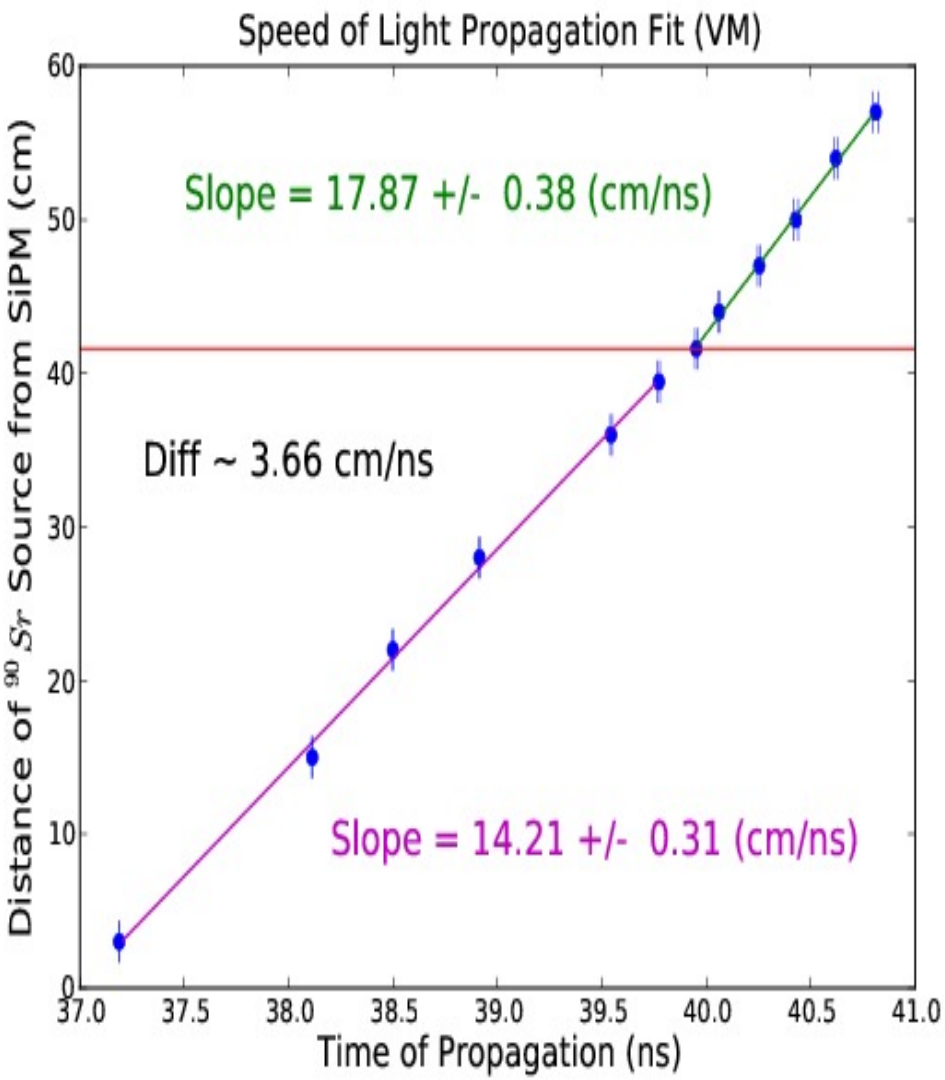
Thank you for your time!
Questions?

Propagation Studies

- We measured the speed of light within the five scintillators
  - With and without VM2000
- Fit two separate linear functions
  - Straight Section
  - Bent Section

Propagation Studies (Scintillator 4)



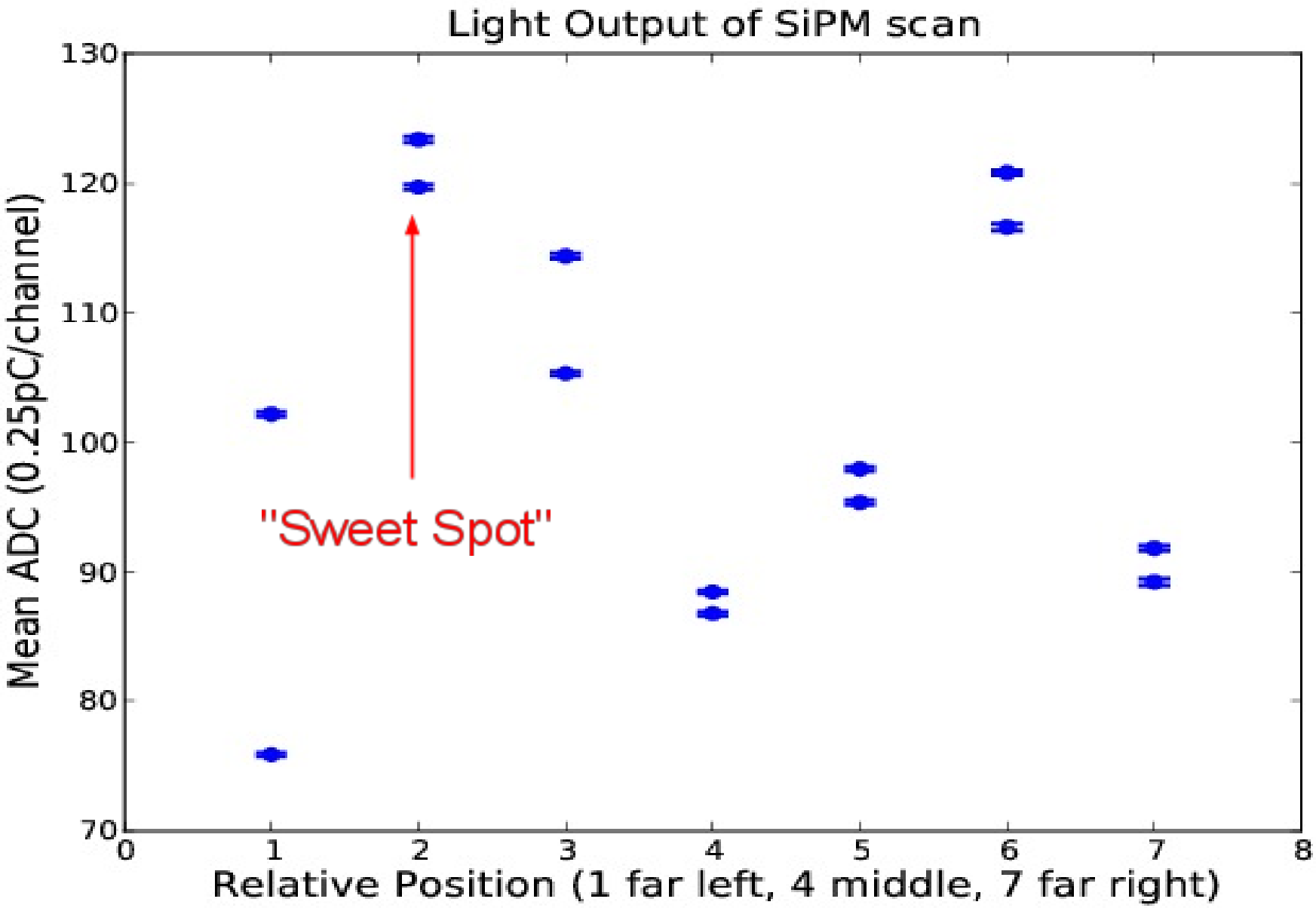


- Similar traits were noticed among the five scintillators

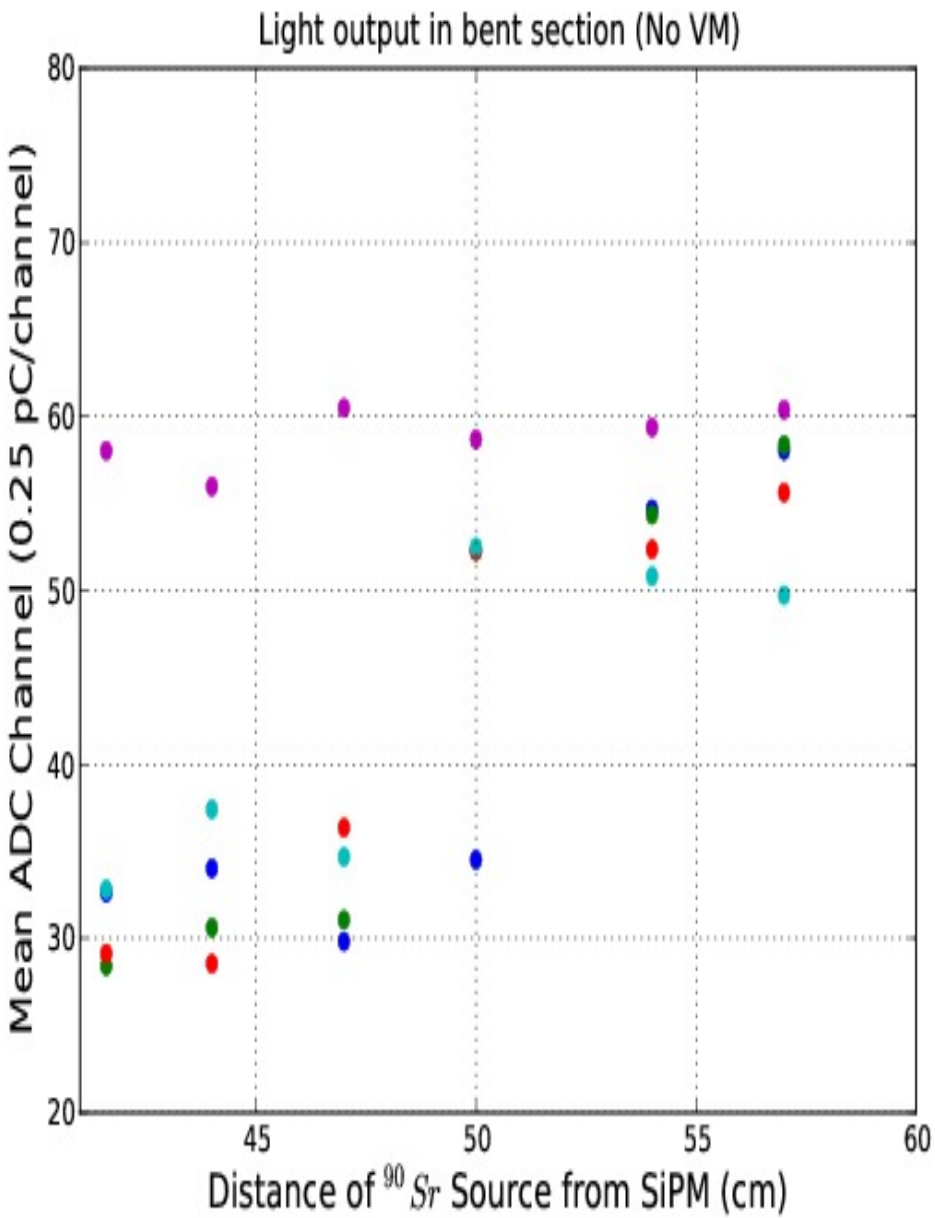
Propagation Speed Summary

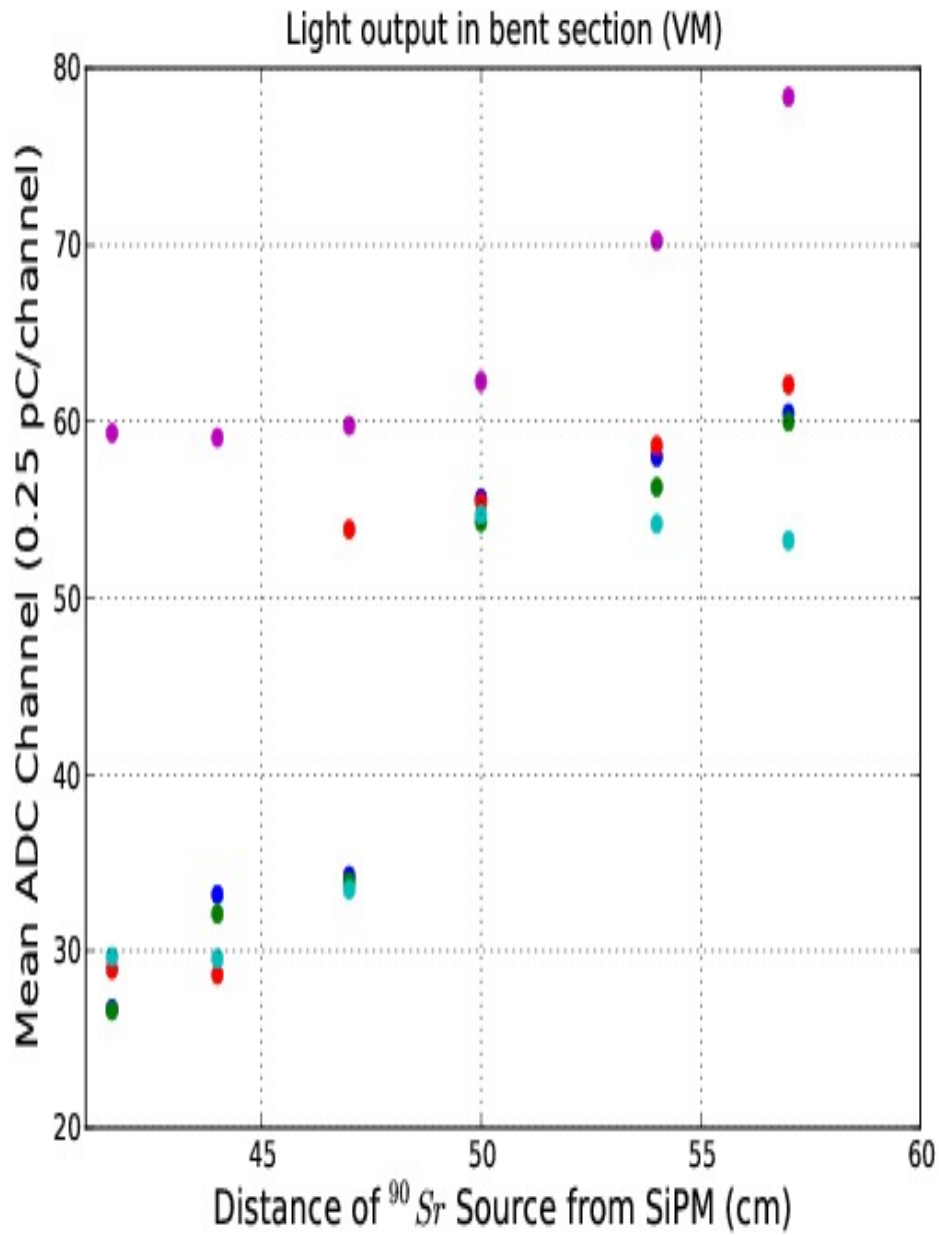
- Linear relationship was found between the time of propagation and the distance from the SiPM (as expected)
- There exists a difference in the fitted slopes when comparing the nose and the straight section
- On average the propagation speeds differed in the nose when compared to the straight section as:
  - Without VM2000
    - 4.61 cm/ns faster
  - With VM2000
    - 6.23 cm/ns faster
- Due to the change in geometry of the scintillator after the bend
  - Fewer number of reflections in nose

Light Output (SiPM Scan)

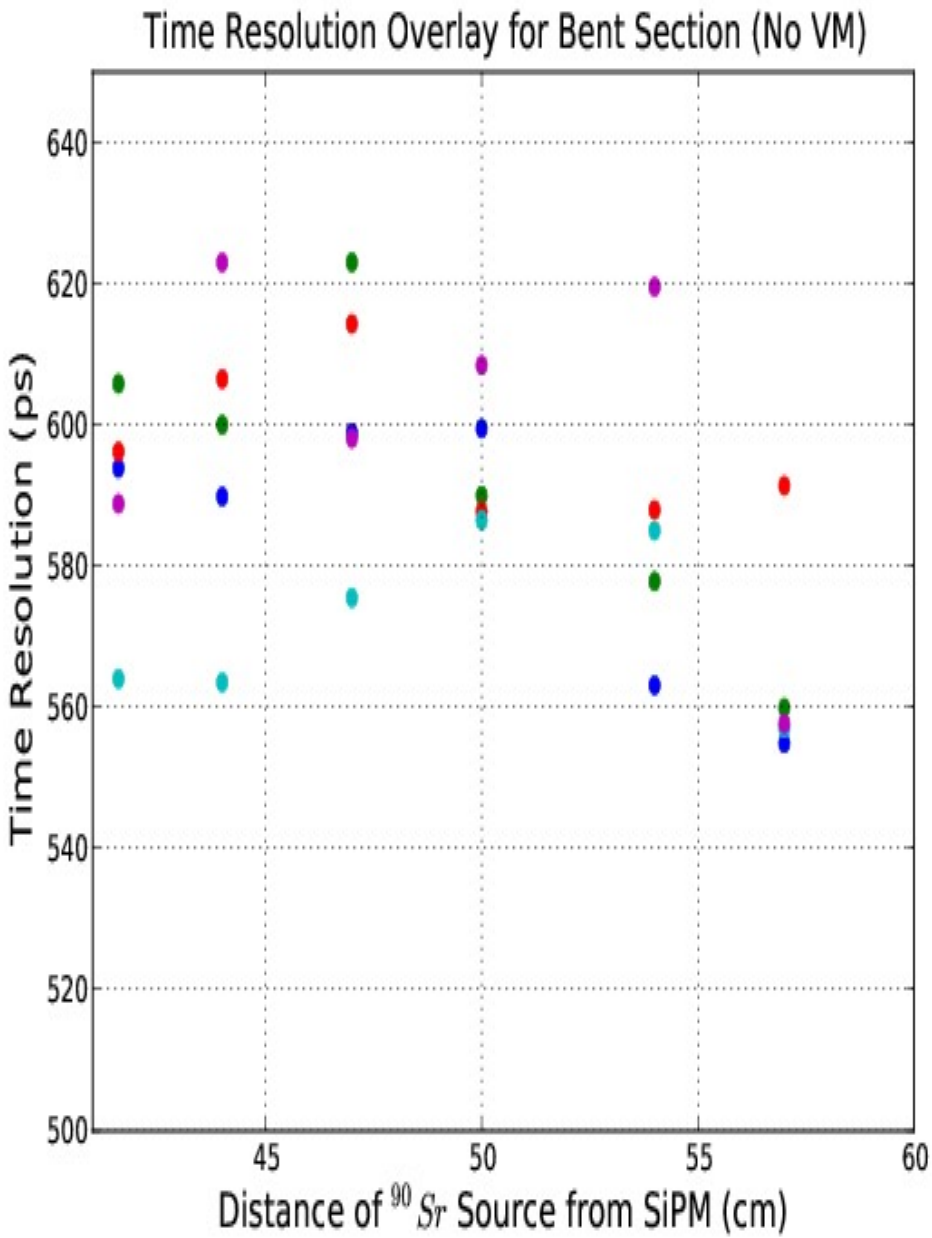


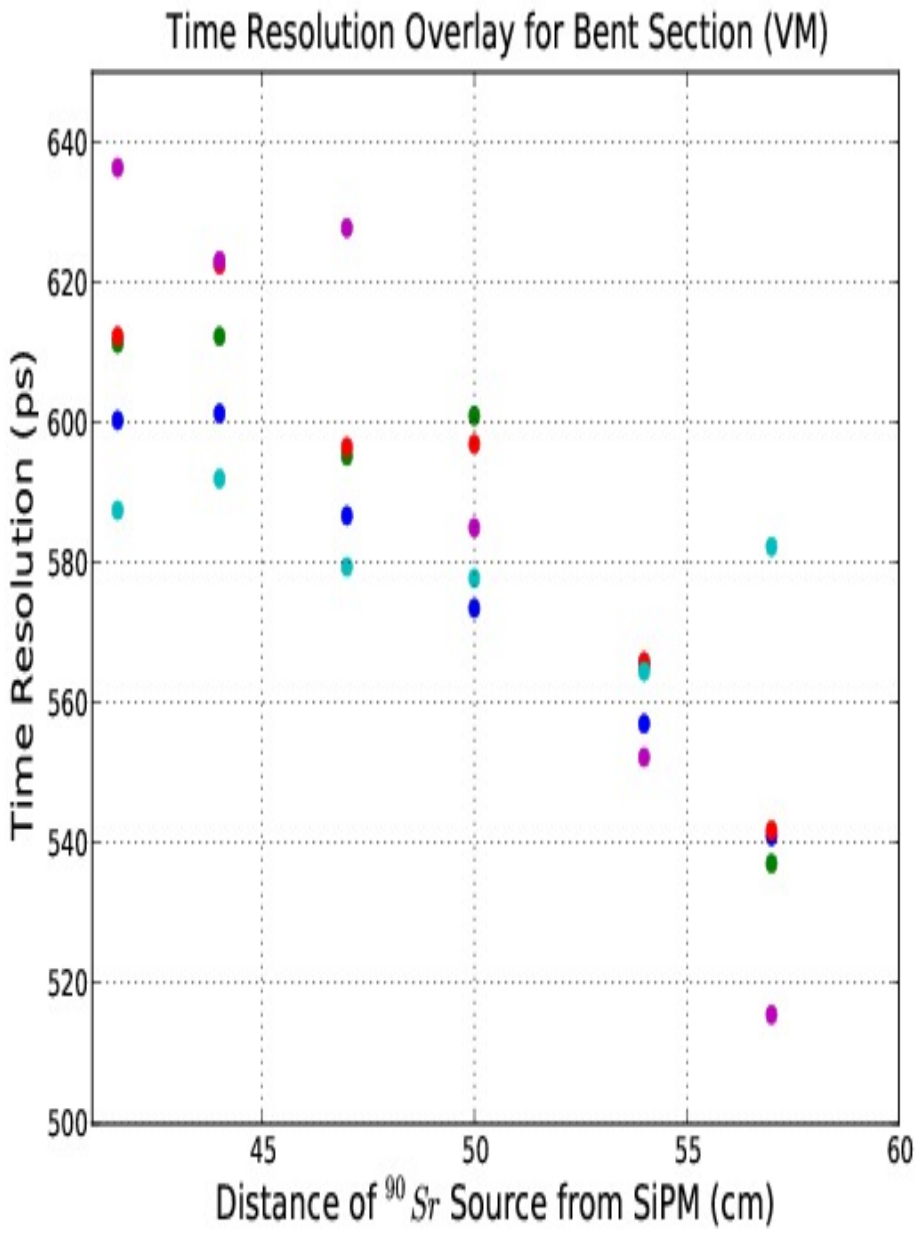
Comparative Plot (Light Output)





Comparative Plot (Time Resolution)

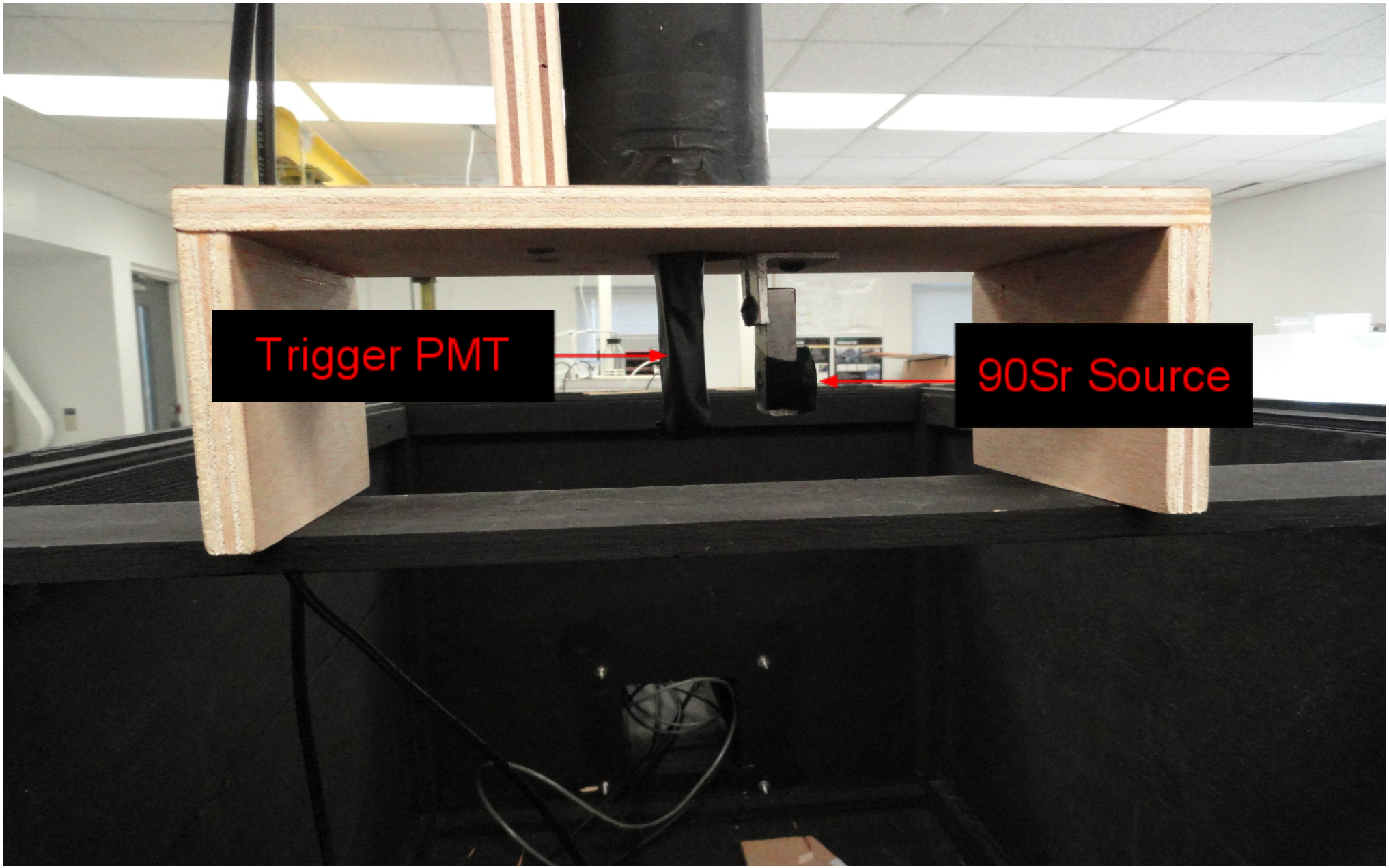




Comparison of Time Resolutions

Scintillator Number	No VM2000 [Min / Max] (ps)	With VM2000 [Min / Max] (ps)
1 (best)	234 / 600	235 / 601
2	231 / 606	232 / 612
3	243 / 614	244 / 623
4	234 / 587	238 / 592
5 (worst)	270 / 623	247 / 636
Unbent Scintillator	229 / 354	229 / 353

Attenuation Lengths

Scintillator Number	No VM2000 (cm)	With VM2000 (cm)
1 (best)	18.3	19.5
2	18.9	18.7
3	18.5	18.5
4	20.0	21.4
5 (worst)	18.7	20.4
Unbent Scintillator	70.6	129.0

Trigger PMT and ^{90}Sr Source