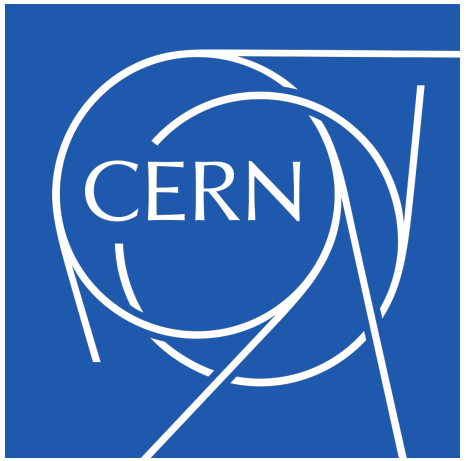


About incident angles and lightguide simulations

Antoine Martinet – August 19th 2025

Supervisors : Loris Martinazolli, Aleksandar Bordelius

About me

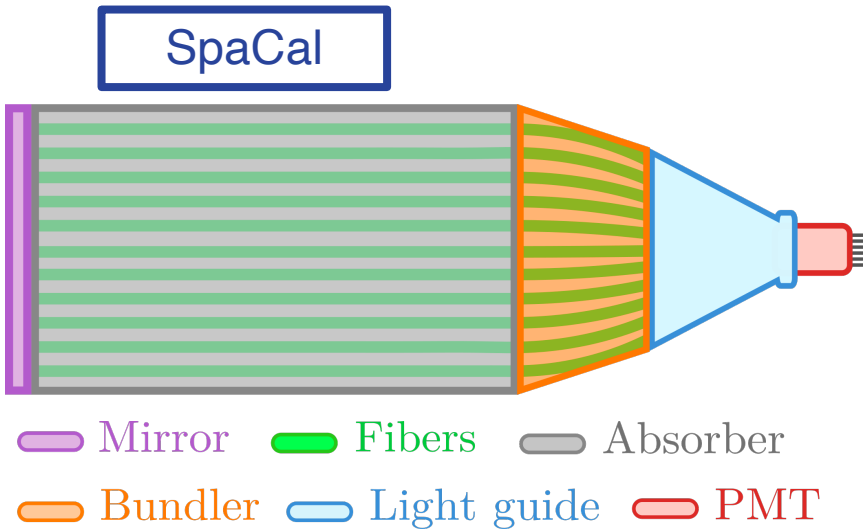
- Antoine Martinet, 23 y.o.
- doing masters in Particle Physics at University Mainz 

- working on ECAL Upgrade Aleksandar and Loris
- Gym, Hiking, Specialty Coffee, Cooking

ECAL Upgrade “Picocal”

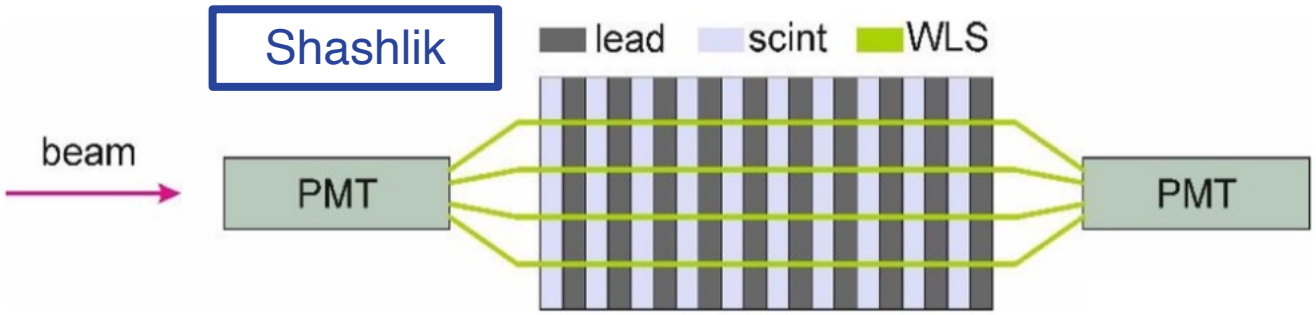
Current ECAL

- Shashlik Technology
- optimised for $\mathrm{L} = O(10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1})$
- radiation up to $40\ kGy$



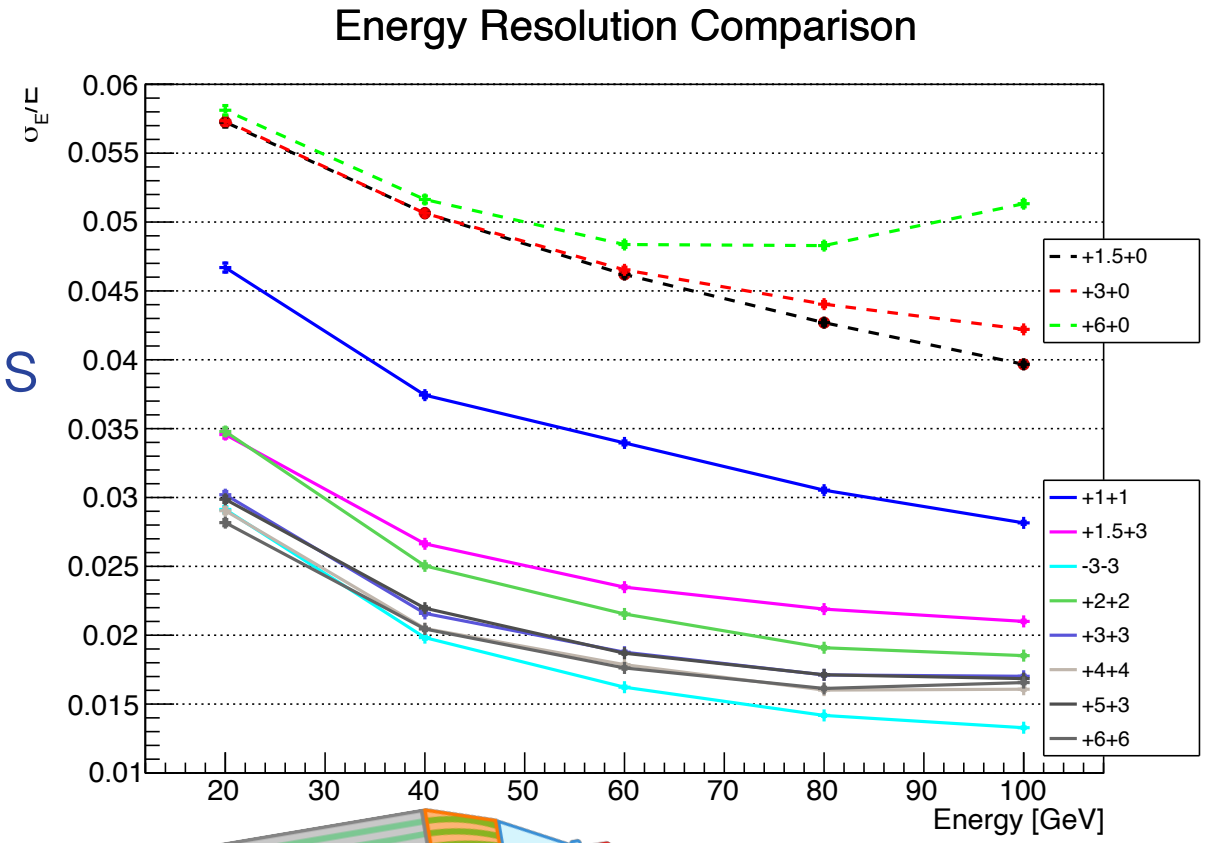
ECAL Upgrade II (SpaCal)

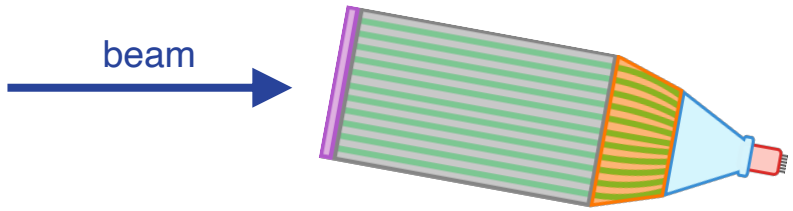
- Spaghetti Technology (SpaCal)
- HL-LHCb $\mathrm{L} = O(10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1})$
- radiation up to $1\ MGy$
- introduce timing $O(20\ ps)$
- better granularity, same energy resolution

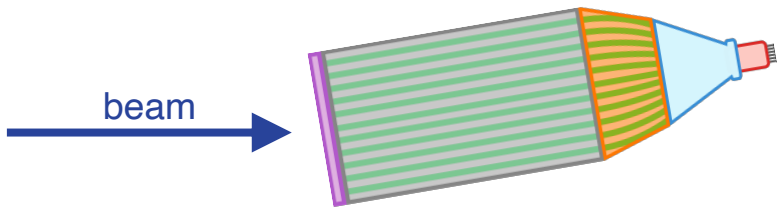


Analysis of test beam data

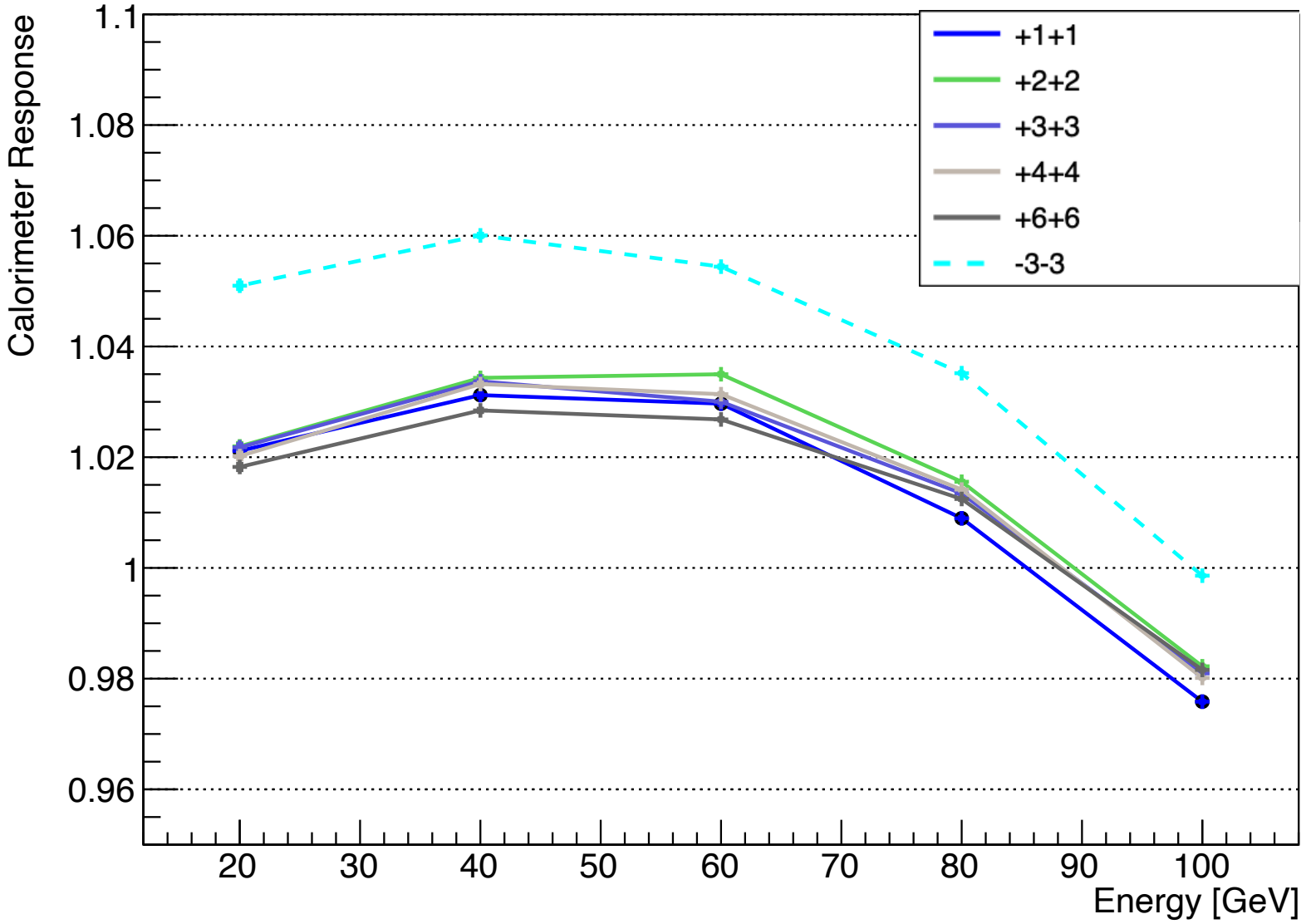
- SPS test beam in May
- different beam incident angles
- analyse energy resolution
- Notation +x[°]+y[°]







Energy Response Comparison



+3+3 vs -3-3?

- Non-Homogeneity of Module?
- Absorber? -> Lunkers?

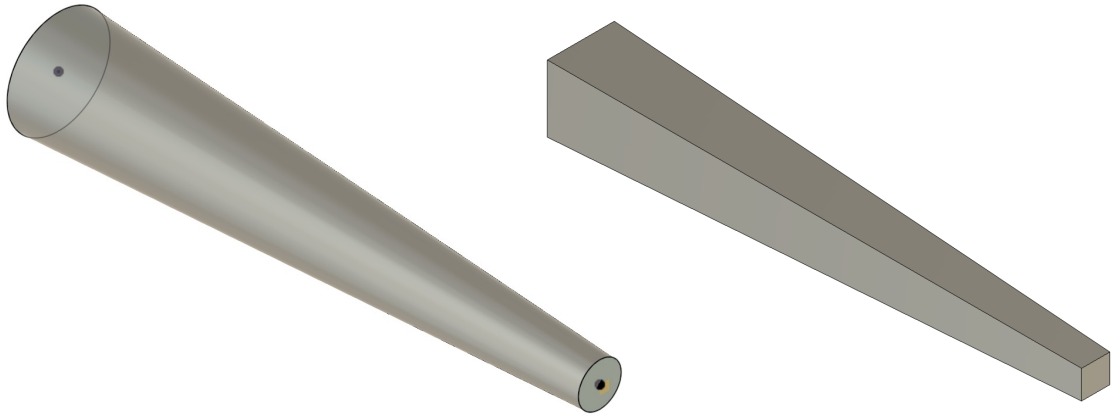
  not visible in data, can't cut open the Absorber to check ☹
- Light Readout?

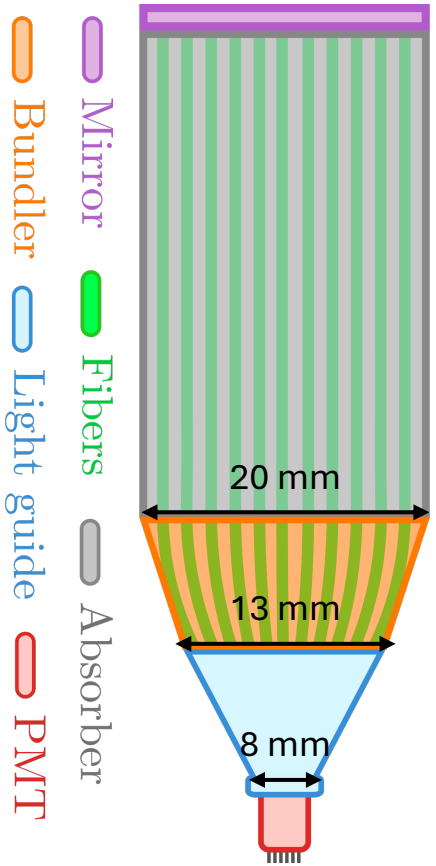
  PMT Saturation/Non-linearity -> not visible in Data

  Lightguide? -> We can simulate!

Lightguide Simulations

- Tungsten SpaCal 20mm cell
- Fibre bundle
  13mm square
- PMT candidate :
  Hamamatsu R9880U
  ø = 8mm



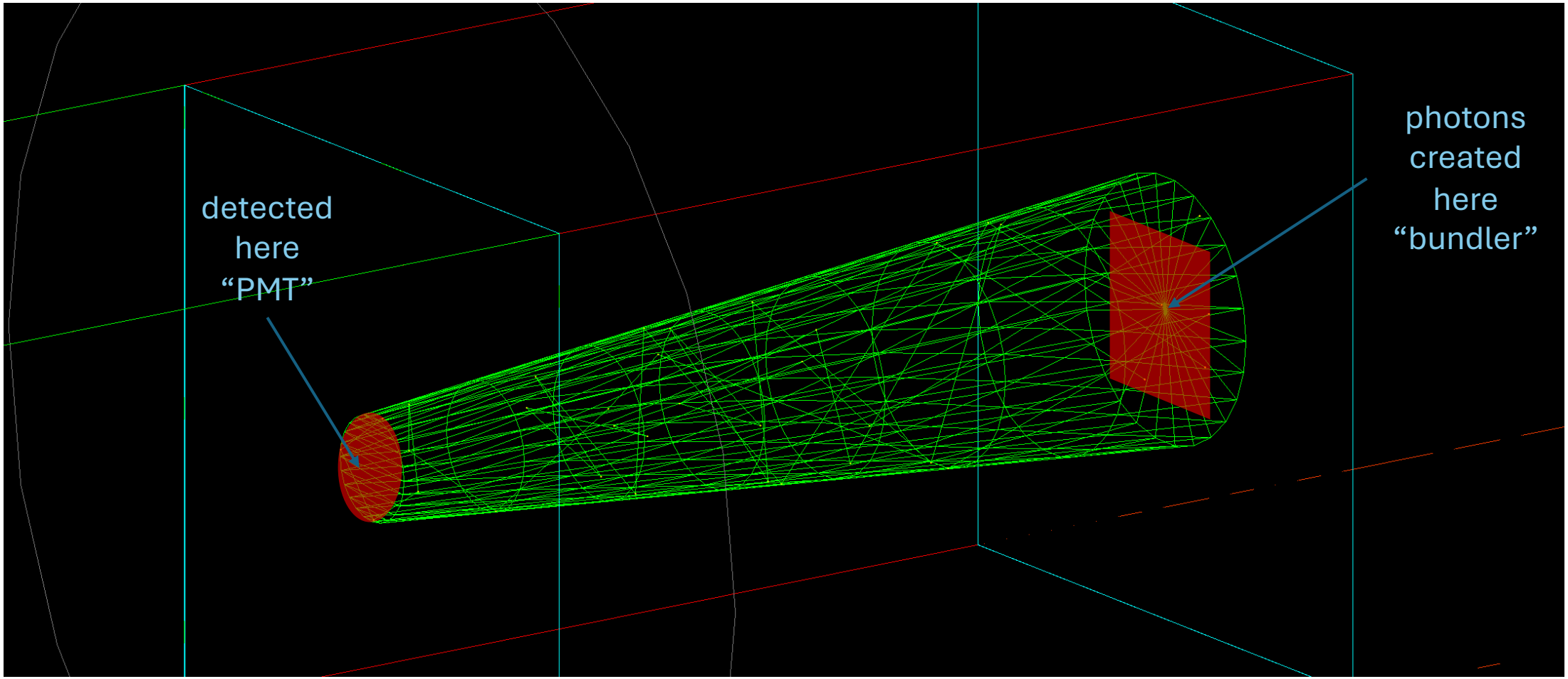


Why do we simulate?

- length and geometry effects everything
- Assumptions:
  - shorter -> better efficiency
  - longer -> better mixing -> better uniformity -> constant term

- find the optimal configuration given mech. constraints

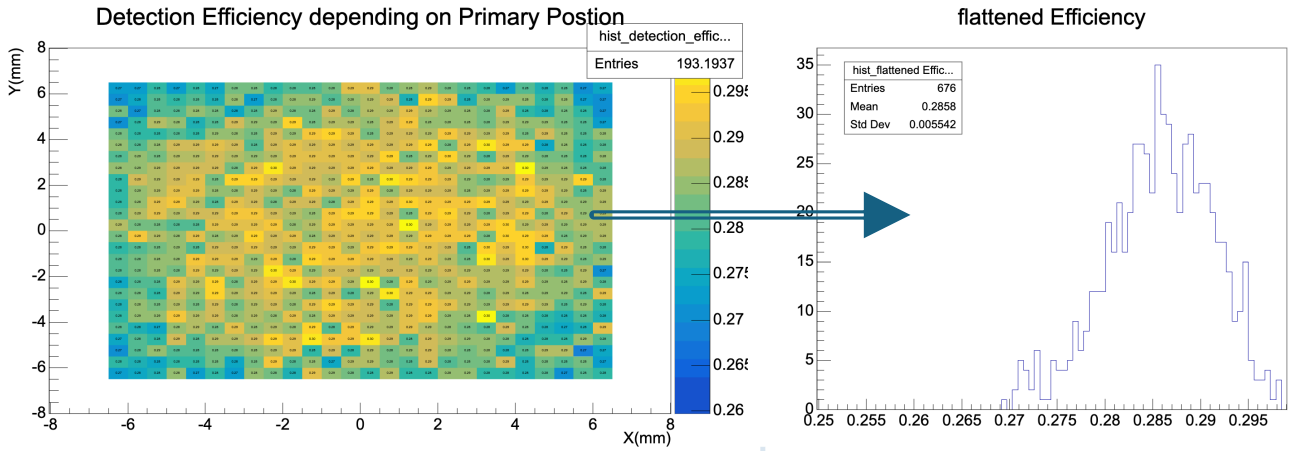
Lightguide Simulations



Important Quantities

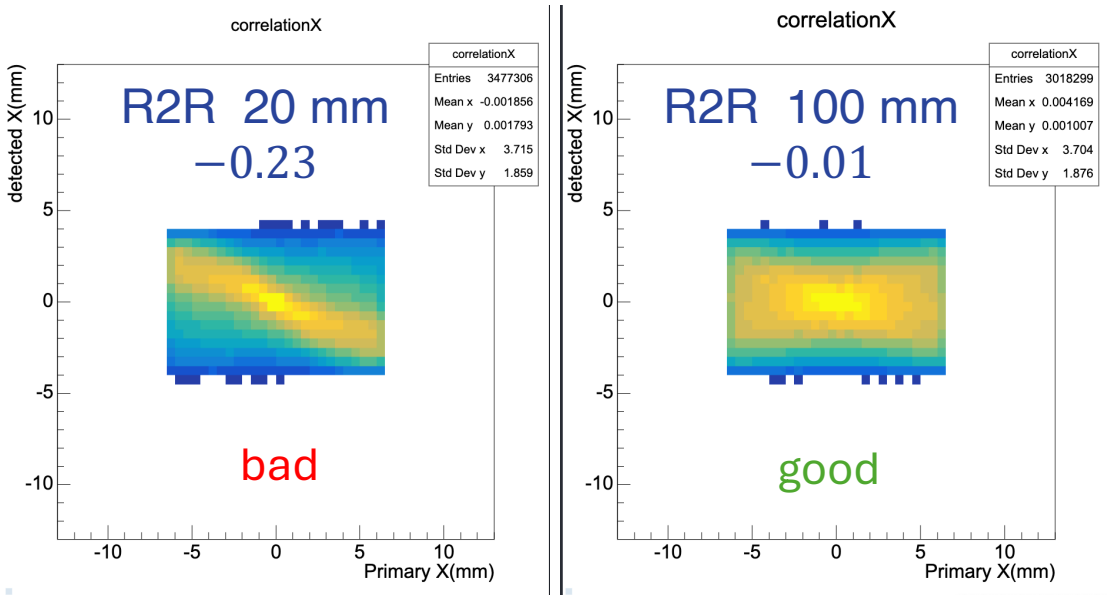
Uniformity

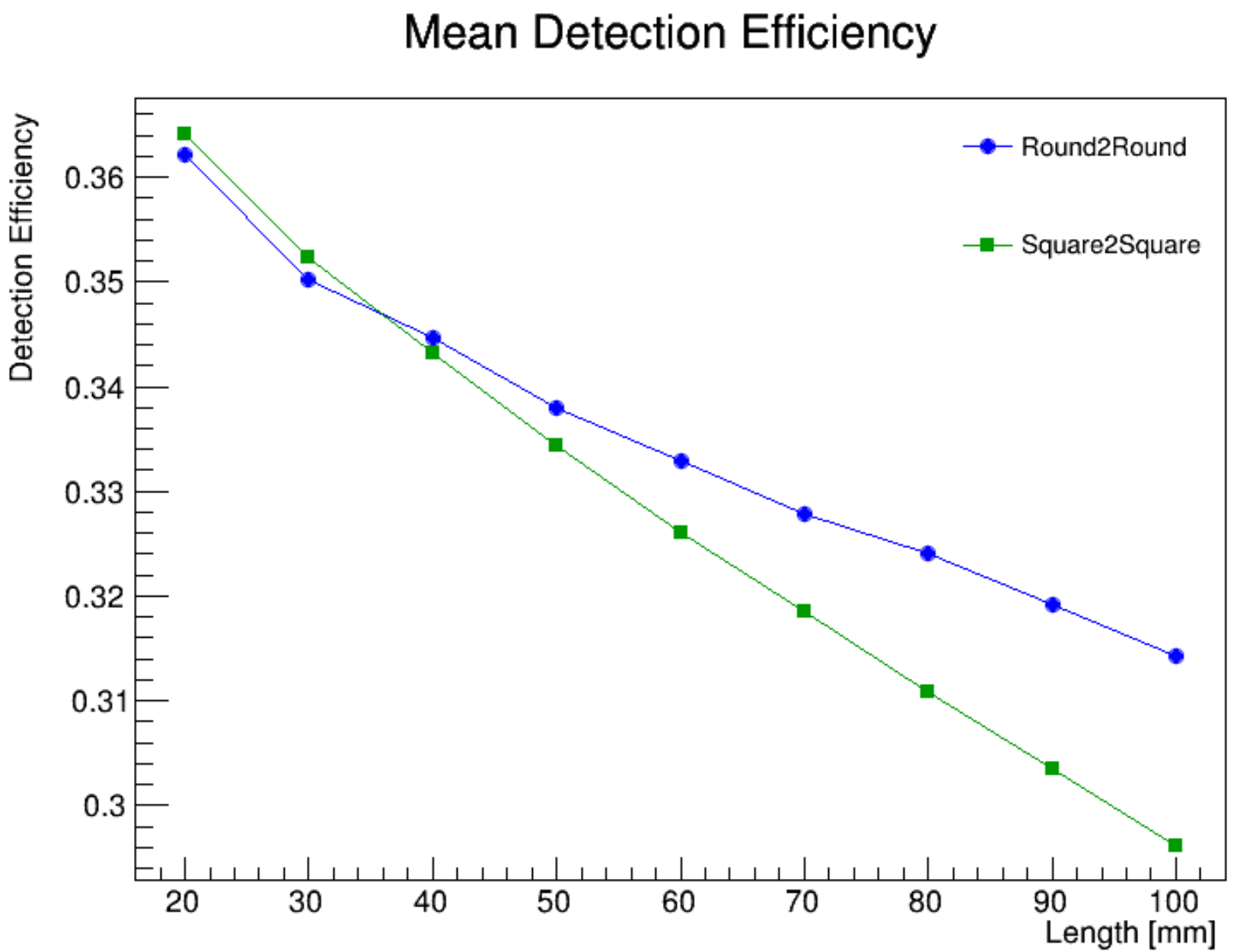
- "uniformity" $= \frac{\sigma}{\mu}$
- relative fluctuation of detection efficiency, depending on origin of detected photon



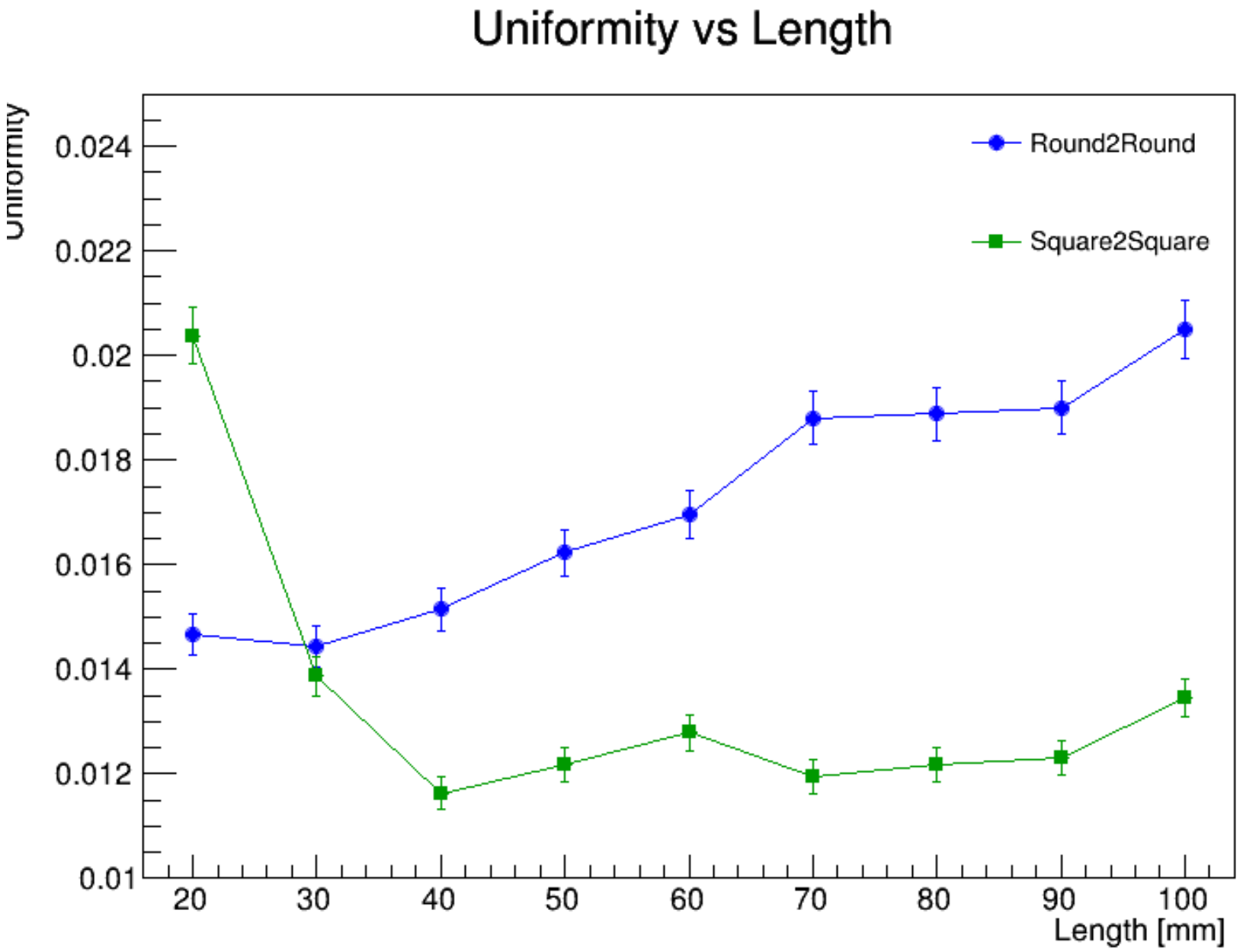
Correlation

- measure for light mixing
- PMT-Cathode non-uniformity

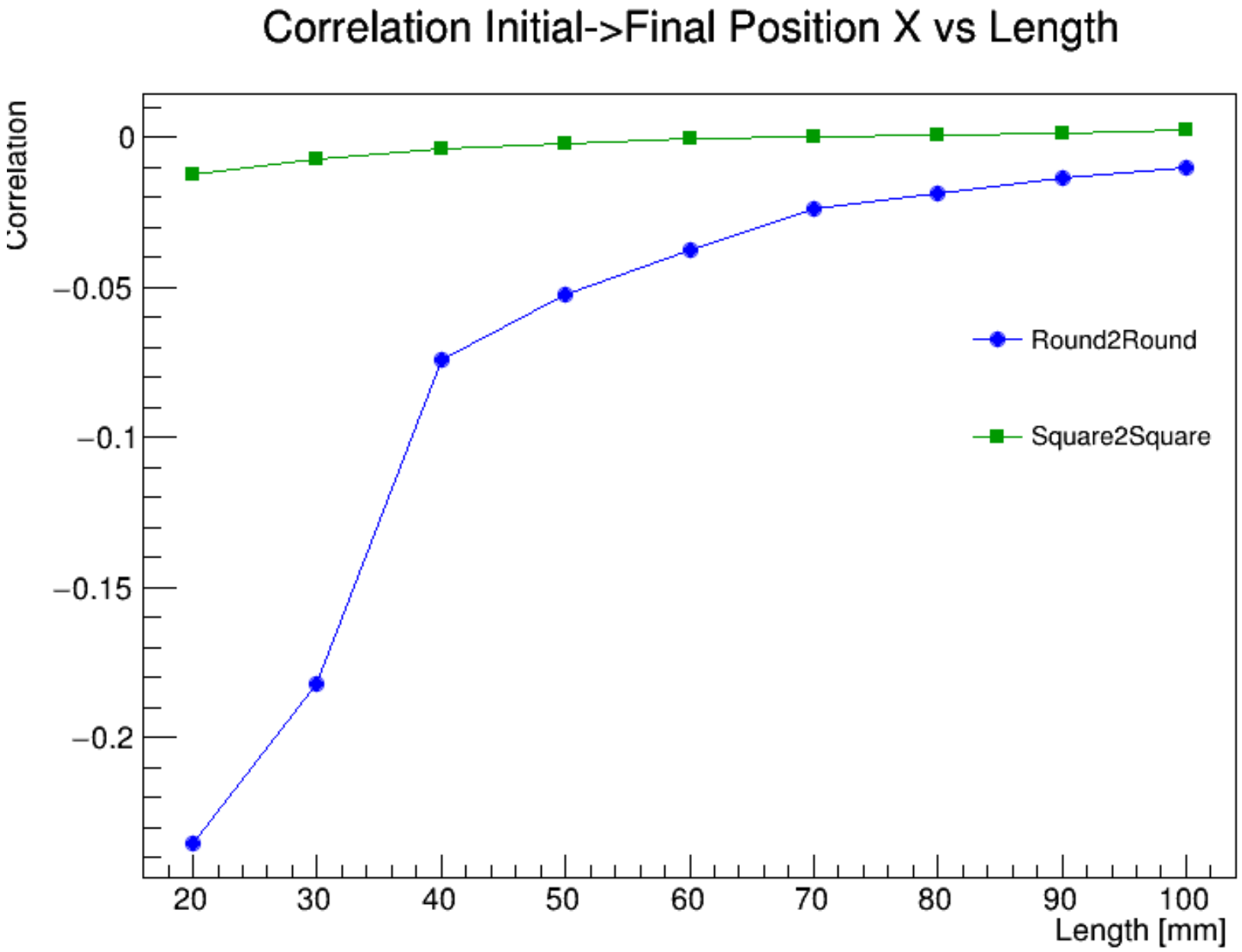




higher is better



lower is better


Correlation Initial->Final Position X vs Length
Correlation
0
−0.05
−0.1
−0.15
−0.2
20
30
40
50
60
70
80
90
100
Length [mm]
Round2Round
Square2Square

0 is best

Conclusion

Incident Angle Study

- more angle, better resolution
- agrees with ECAL Design
- +3/-3 unconclusive

  -> test beam in September

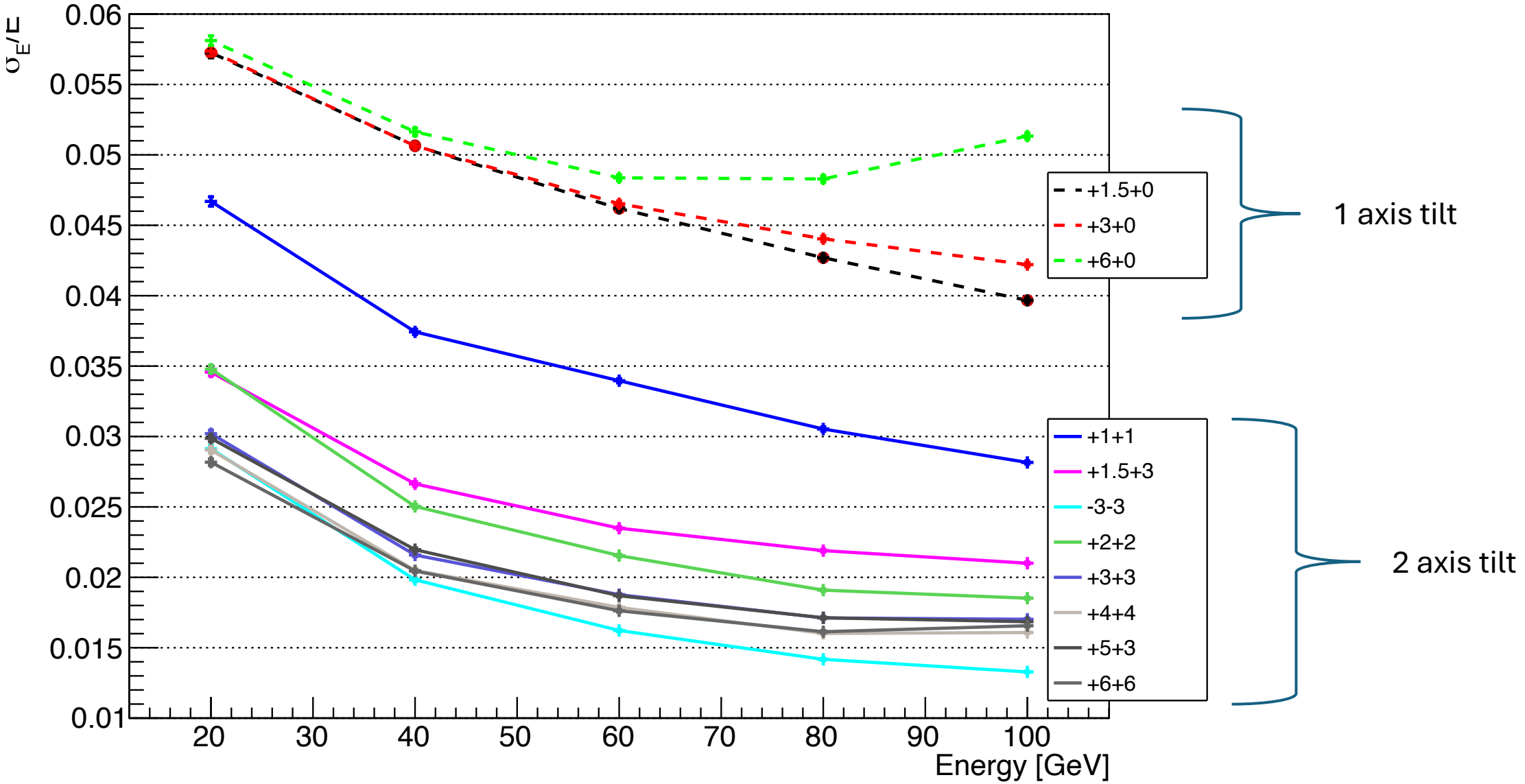
Lightguide Simulation

- Square2Square > Round2Round
- further simulations ongoing
- test beam in September

  -> final configuration

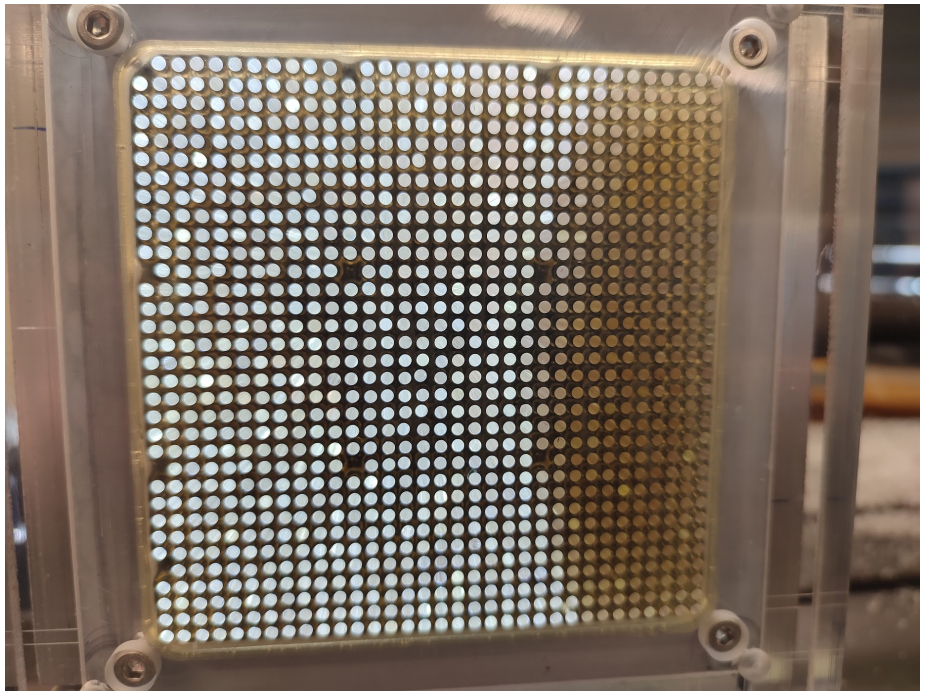
Thank you!

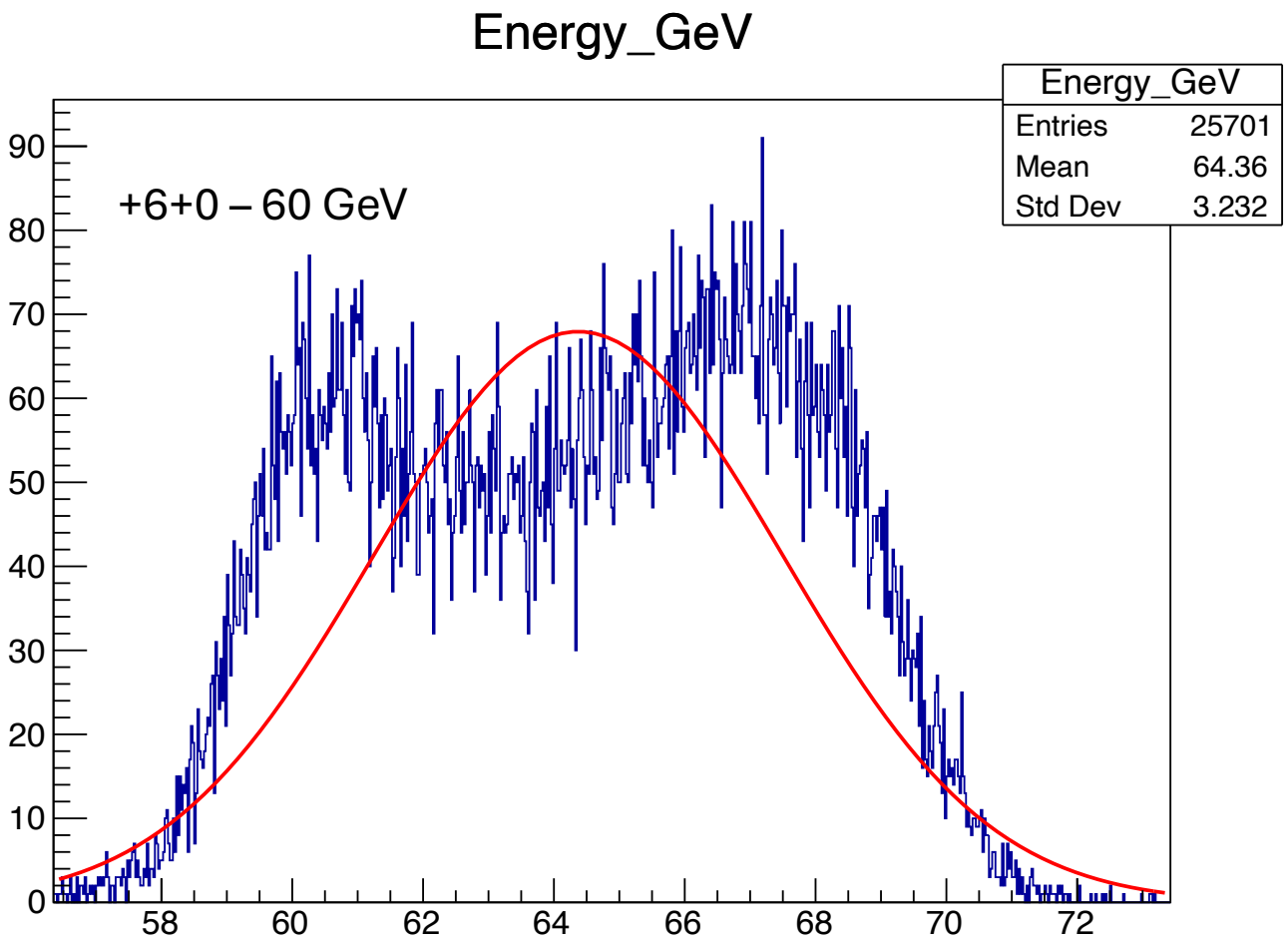
Energy Resolution Comparison



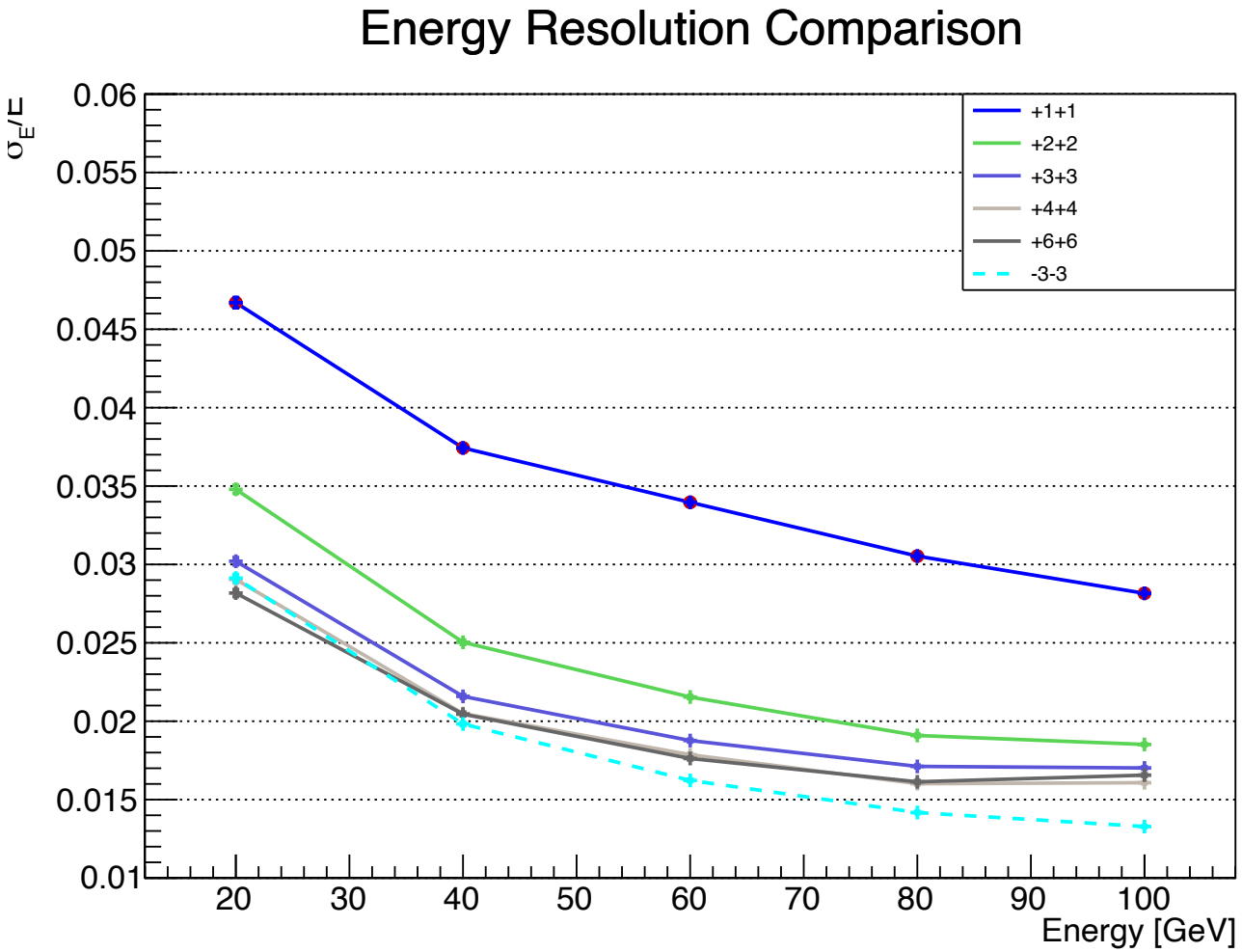
1 Axis Tilt

- hitting fibre or absorber first
  => different shower development





2 Axis Tilt



- more angle

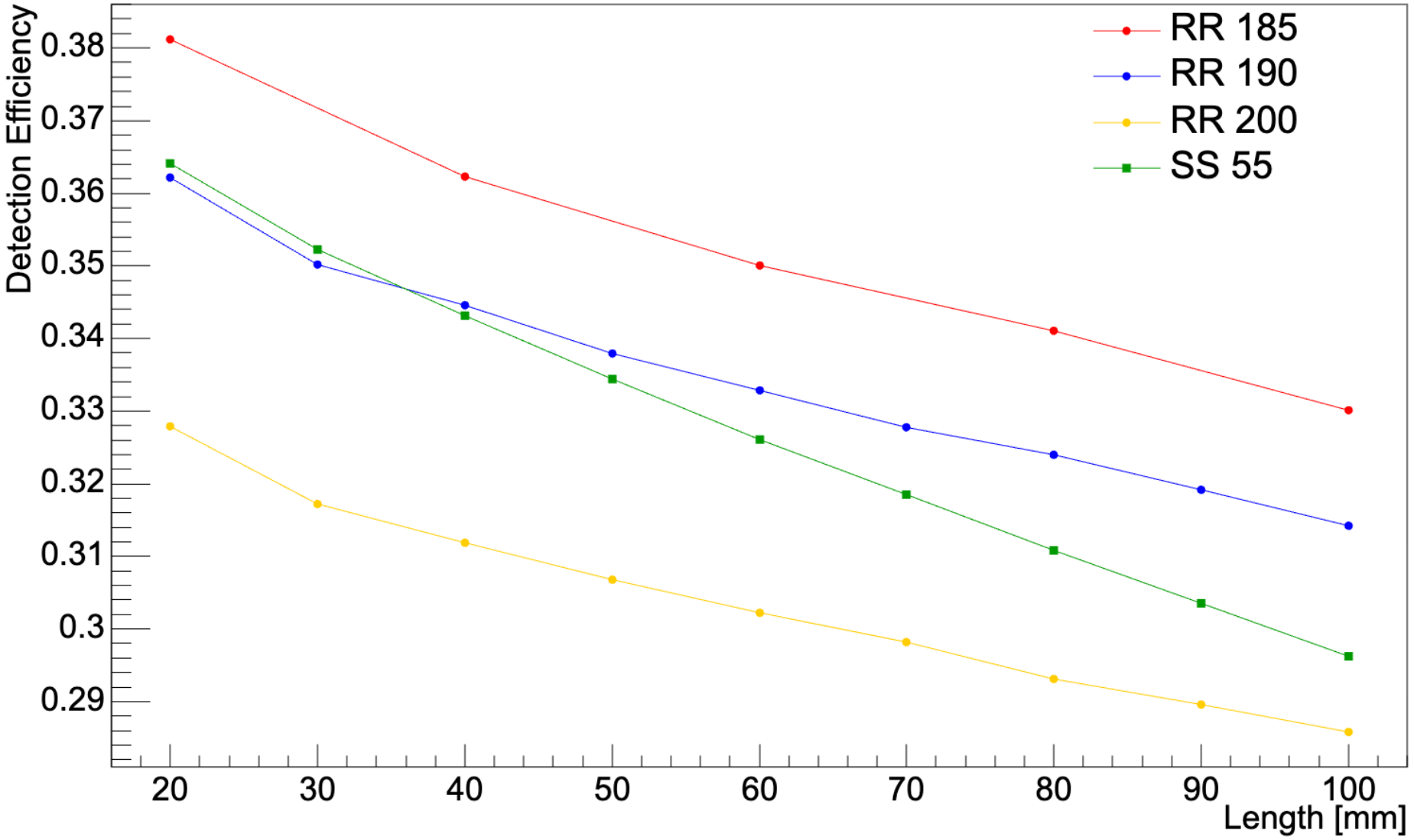
  > better Energy Res

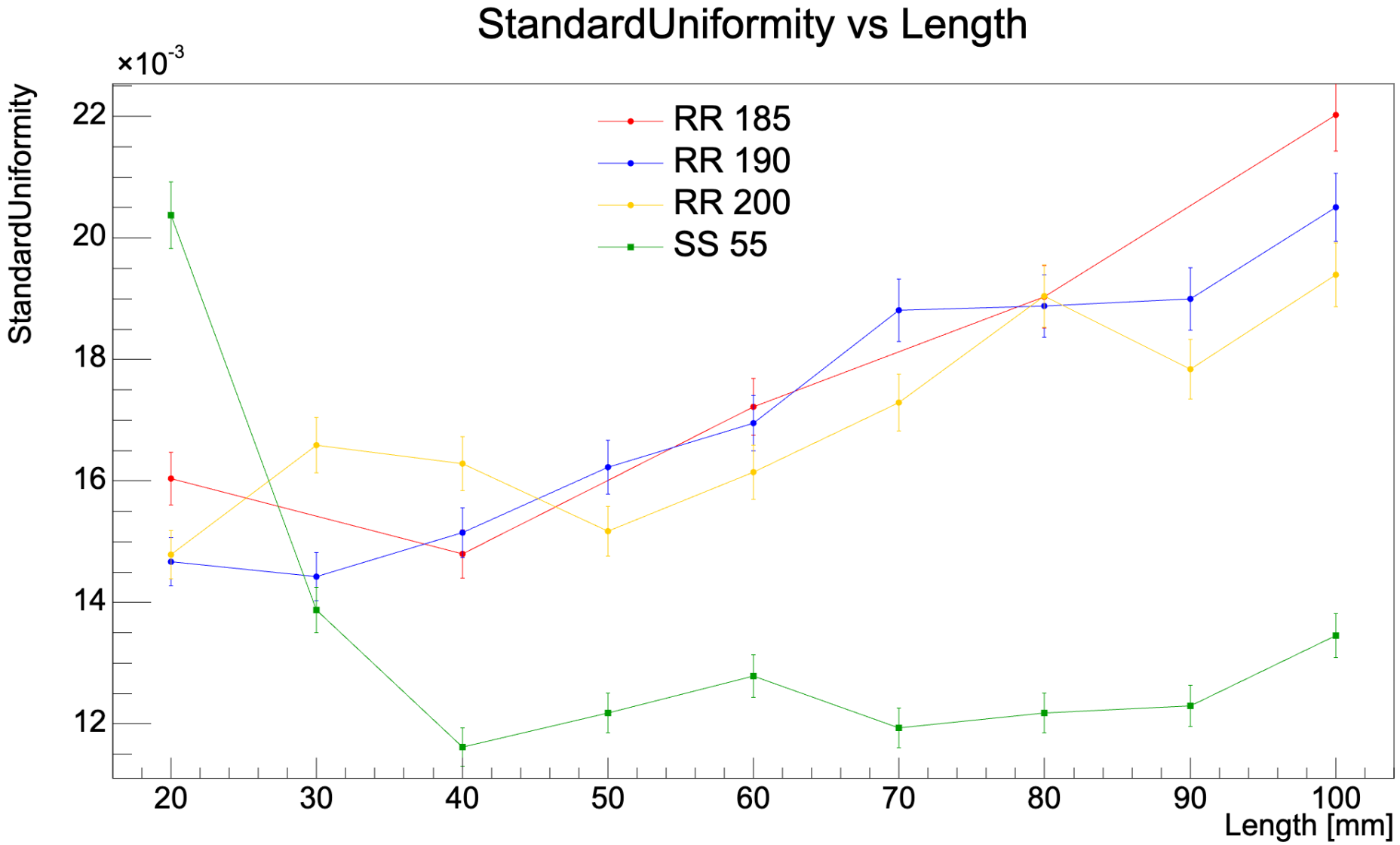
- more than +3

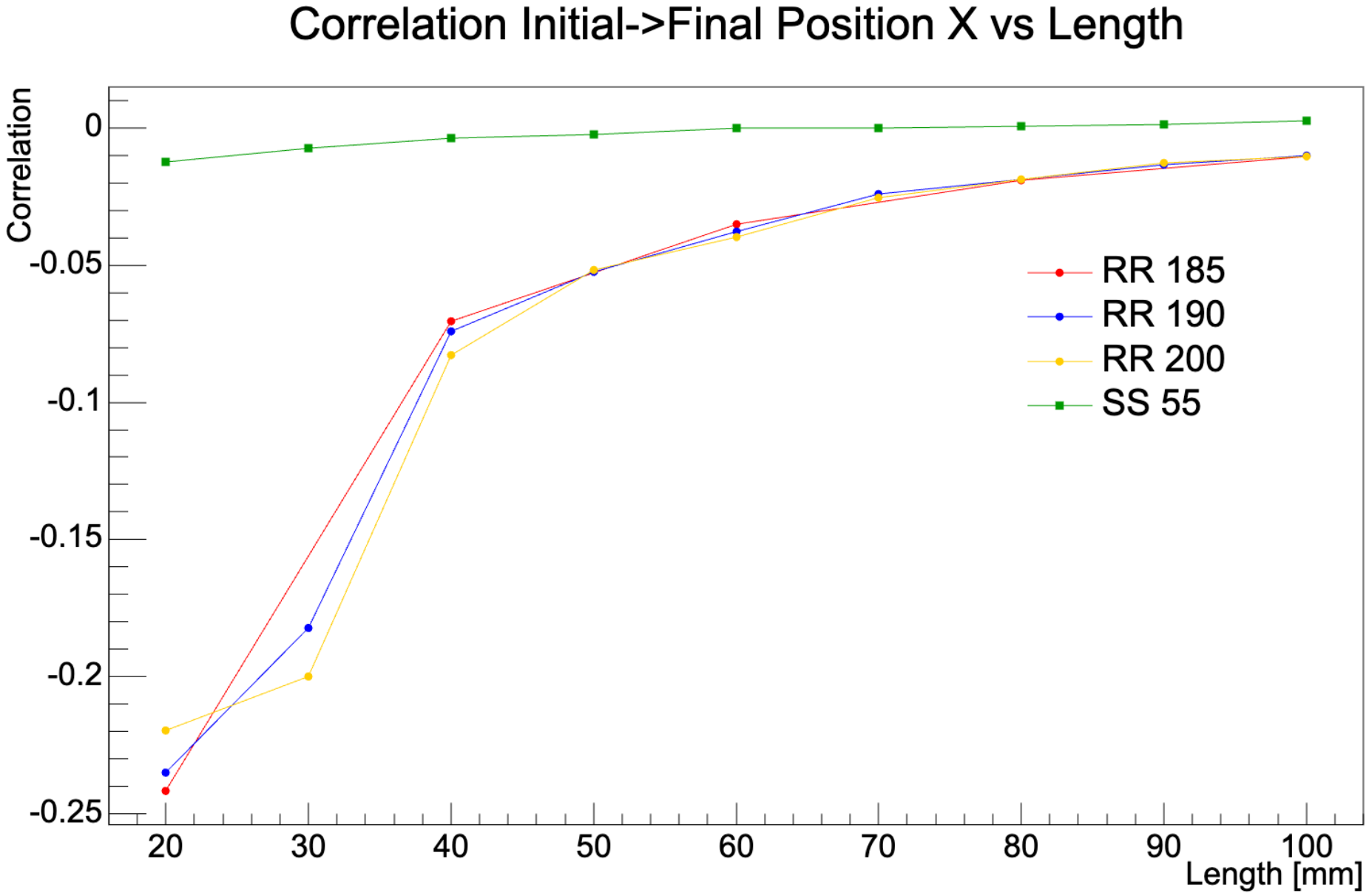
  > little improvements

- +3/-3 should be equal

Mean Detection Efficiency



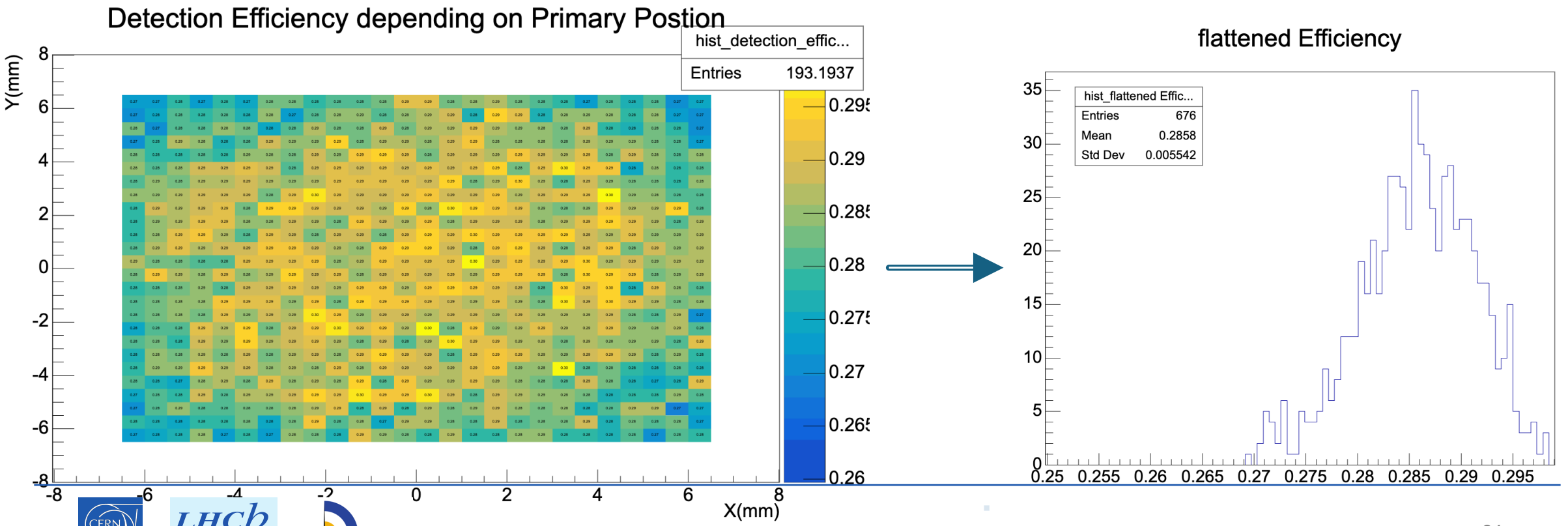

StandardUniformity vs Length
×10^-3
StandardUniformity
22
20
18
16
14
12
RR 185
RR 190
RR 200
SS 55
20
30
40
50
60
70
80
90
100
Length [mm]


Correlation Initial->Final Position X vs Length
Correlation
0
-0.05
-0.1
-0.15
-0.2
-0.25
20
30
40
50
60
70
80
90
100
Length [mm]
RR 185
RR 190
RR 200
SS 55

terms?

relative fluctuation of detection efficiency, depending on origin of detected photon

- "uniformity" = $\frac{\sigma}{\mu}$



Why is correlation important?

- it's a measure for light mixing
- PMT-Photocathode non-uniformity