

# SiPM Module Updates

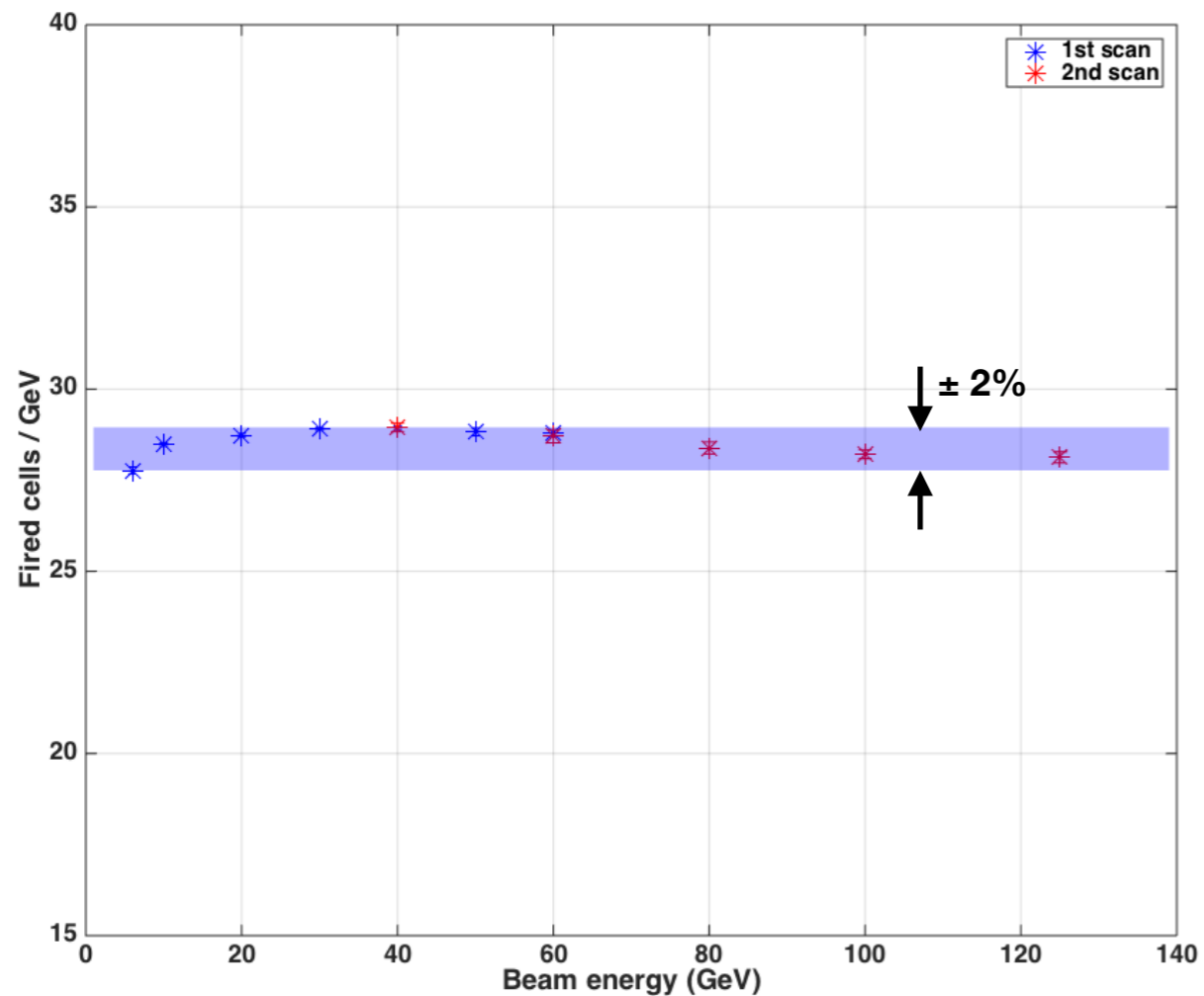
Massimiliano Antonello

# Summary from last test beam

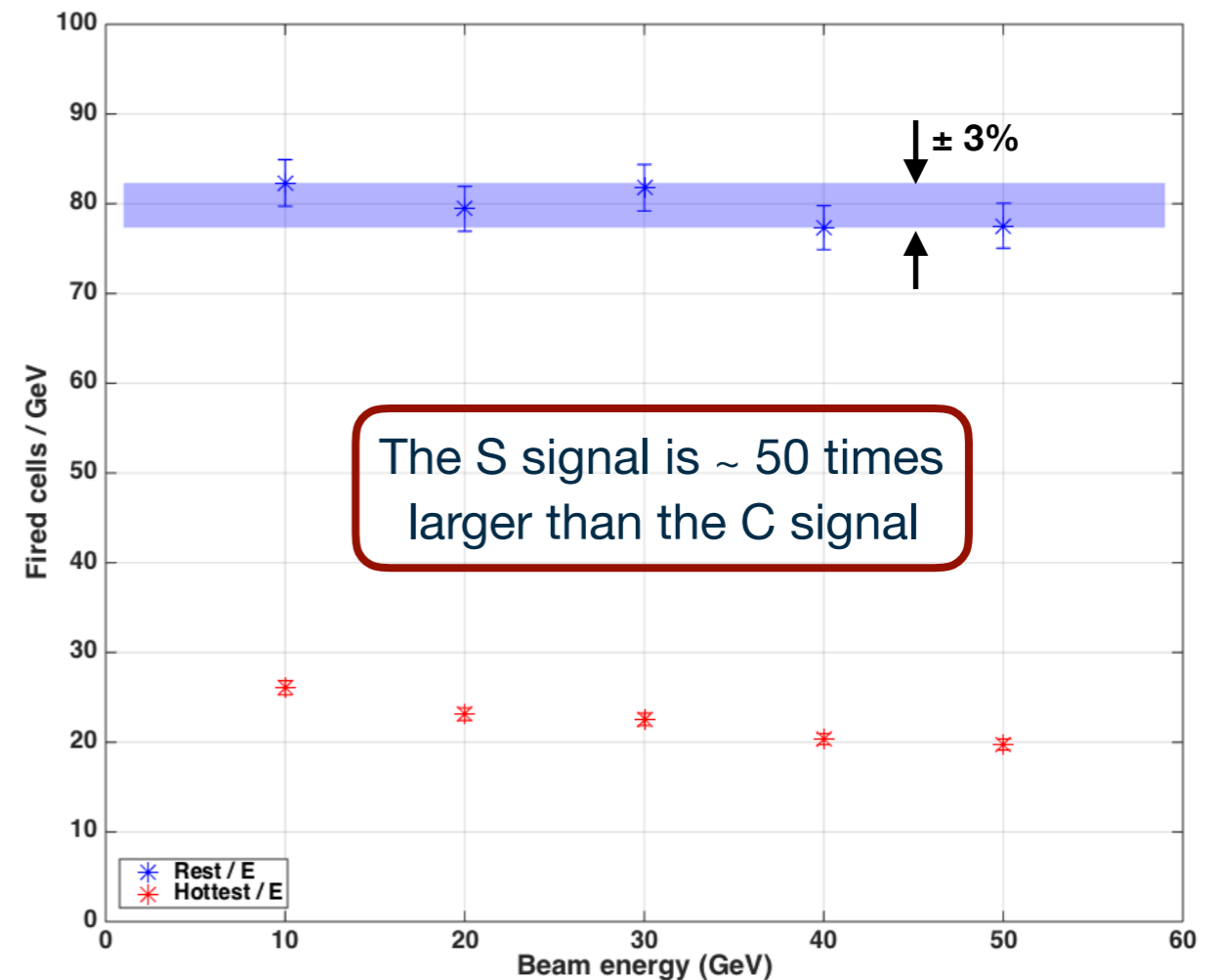
Details can be found on:  
arXiv:1805.03251

- ❖ **Cherenkov** signal:  $V_{op} = 5.5 V_{ov}$  (57.5 V) and **PDE ~ 25%**
  - ❖ Mean number of fired cells: ~ 28.4 fired cells/GeV
  - ❖ Corrected for containment (36%) & optical cross talk: ~ **69 ± 5 fired cells/GeV**
- ❖ **Scintillation** signal:  $V_{op} = 0.5 V_{ov}$  (52.5 V) and **PDE ~ 2%**
  - ❖ Number of fired cells @ 10 GeV (corrected for non-linearity response): ~ 108.4 fired cells/GeV
  - ❖ Corrected for containment (45%) and rescaled to 25% PDE: ~ **3200 ± 200 fired cells/GeV**

Cherenkov channel



Scintillation channel



# Fired cells

\*Seed = most higher energy fibre

- ❖ Cherenkov signal (no correction applied, **PDE ~25%**):
  - ❖ Total ~ 28.4 fired cells/GeV  $\Rightarrow$  ~ 113.6 photons/GeV
  - ❖ Seed ~ 3.0 fired cells/GeV  $\Rightarrow$  ~ 12.0 photons/GeV
- ❖ Scintillation signal (corrected for non-linearity response, **PDE ~2%**):
  - ❖ Total ~ 108.4 fired cells/GeV  $\Rightarrow$  ~ 5420 photons/GeV
  - ❖ Seed ~ 26.0 fired cells/GeV  $\Rightarrow$  ~ 1300 photons/GeV

Total number of available cells:  
 $N_{tot} = 1584$   
**Attenuation needed**

**Cherenkov light yield estimated for different beam energies**

Energy (GeV)	10	20	30	40	60	80	100	125
<b>C Total (fired cells) @ 25% PDE</b>	284	568	852	1136	1704	2272	2840	3550
<b># of Photons</b>	1136	2272	3408	4544	6816	9088	11360	14200
<b>C Seed (fired cells) @ 25% PDE</b>	30	60	90	120	180	240	300	375
<b># of Photons</b>	120	240	360	480	720	960	1200	1500

**If 25% of PDE is considered: Scintillating light yield estimated for different beam energies**

Energy (GeV)	10	20	30	40	60	80	100	125
<b>S Total (fired cells) @ 25% PDE</b>	13550	27100	40650	54200	81300	108400	135500	169375
<b># of Photons</b>	54200	108400	162600	216800	325200	433600	542000	677500
<b>S Seed (fired cells) @ 25% PDE</b>	3250	6500	9750	13000	19500	26000	32500	40625
<b># of Photons</b>	13000	26000	39000	52000	78000	104000	130000	162500

# Expected EM resolution

❖ The error from sampling fluctuations for both S and C channels is:  $\epsilon_{Sampling} \sim 10.5\%$

❖ The relative error of the number of fired cells/GeV is:  $\epsilon_{N_{FC/GeV}} = \frac{1}{\sqrt{N_{FC/GeV}}}$

❖ The combined error for each channel is:  $\epsilon_{Combined} = \sqrt{\epsilon_{Sampling}^2 + \epsilon_{N_{FC/GeV}}^2}$

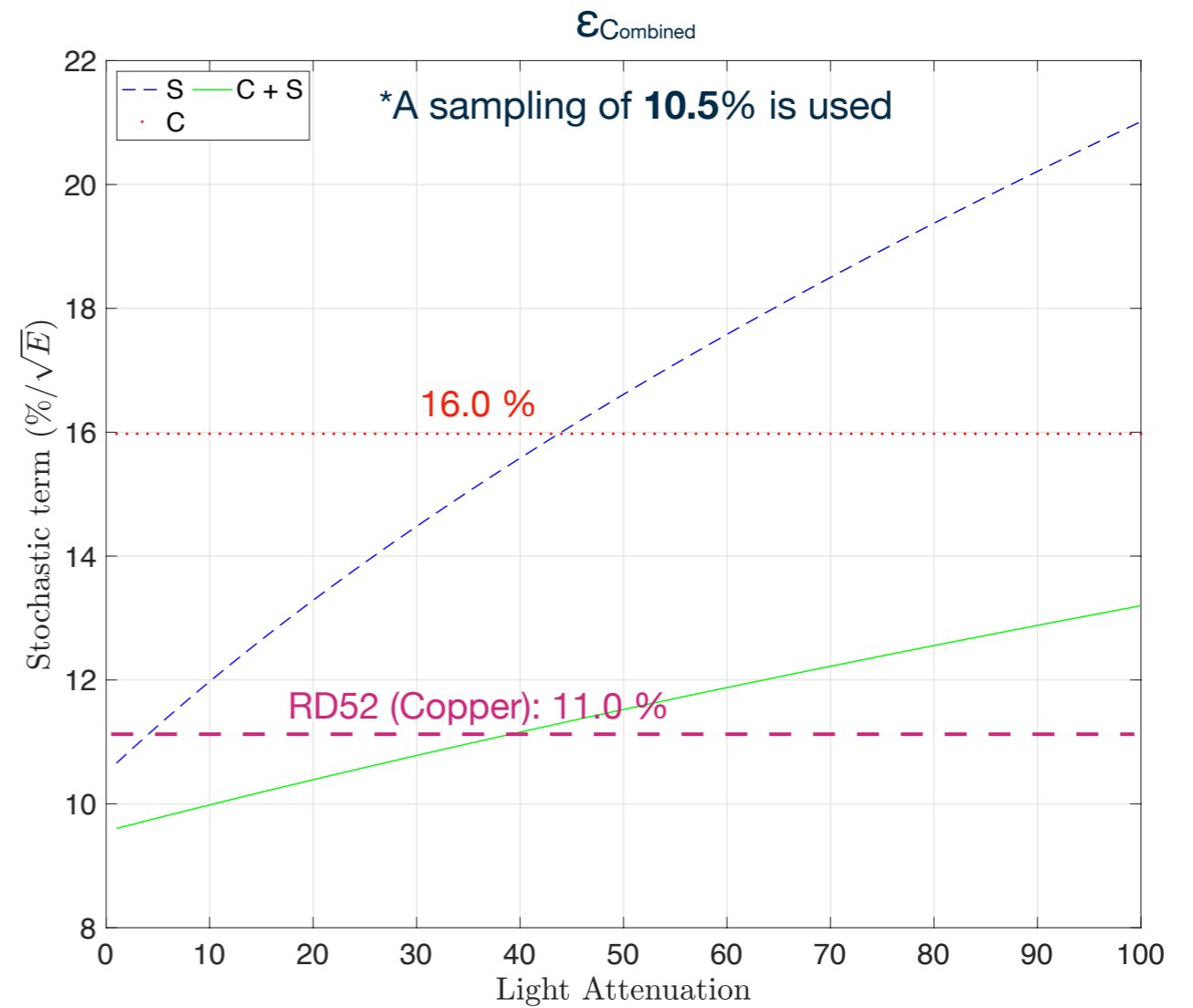
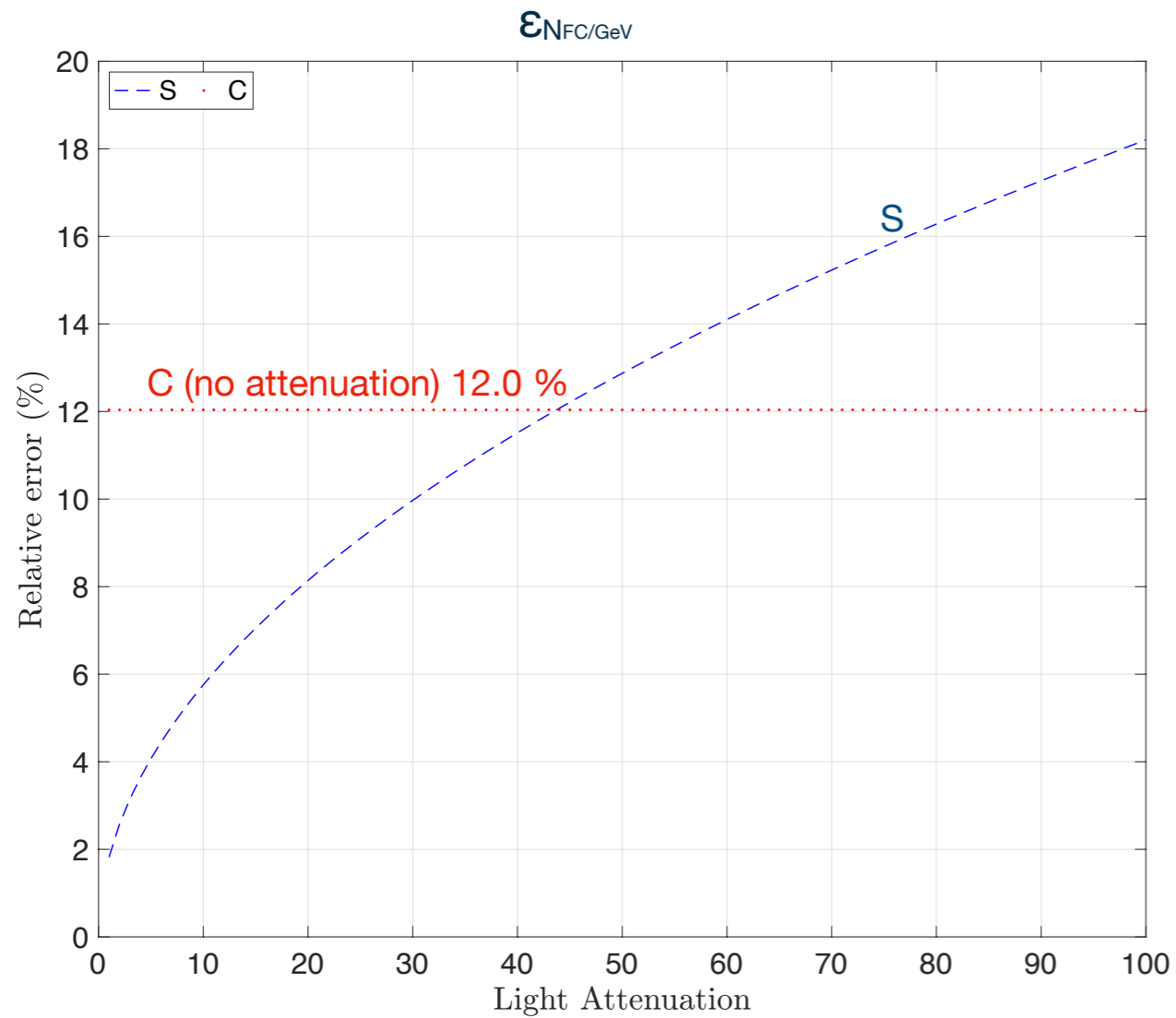
❖ The stochastic term in the EM resolution is:  $\epsilon_{C+S} = \frac{\sqrt{\epsilon_{Combined}^2(S) + \epsilon_{Combined}^2(C)}}{2}$

- ❖ Cherenkov channel (no attenuation, **25% PDE**):
  - ❖ Total ~ **69.0 fired cells/GeV\***
  - ❖  $\Rightarrow$  Relative error: ~ **12.0%**  $\Rightarrow$  Combined\*: **16.0%**
- ❖ Scintillation channel (no attenuation, **25% PDE**):
  - ❖ Total ~ **3017.8 fired cells/GeV\***
  - ❖  $\Rightarrow$  Relative error: ~ **1.8%**  $\Rightarrow$  Combined\*: **10.7%**

} **C+S = 9.6%**

\*from test beam data

# The light attenuation effects

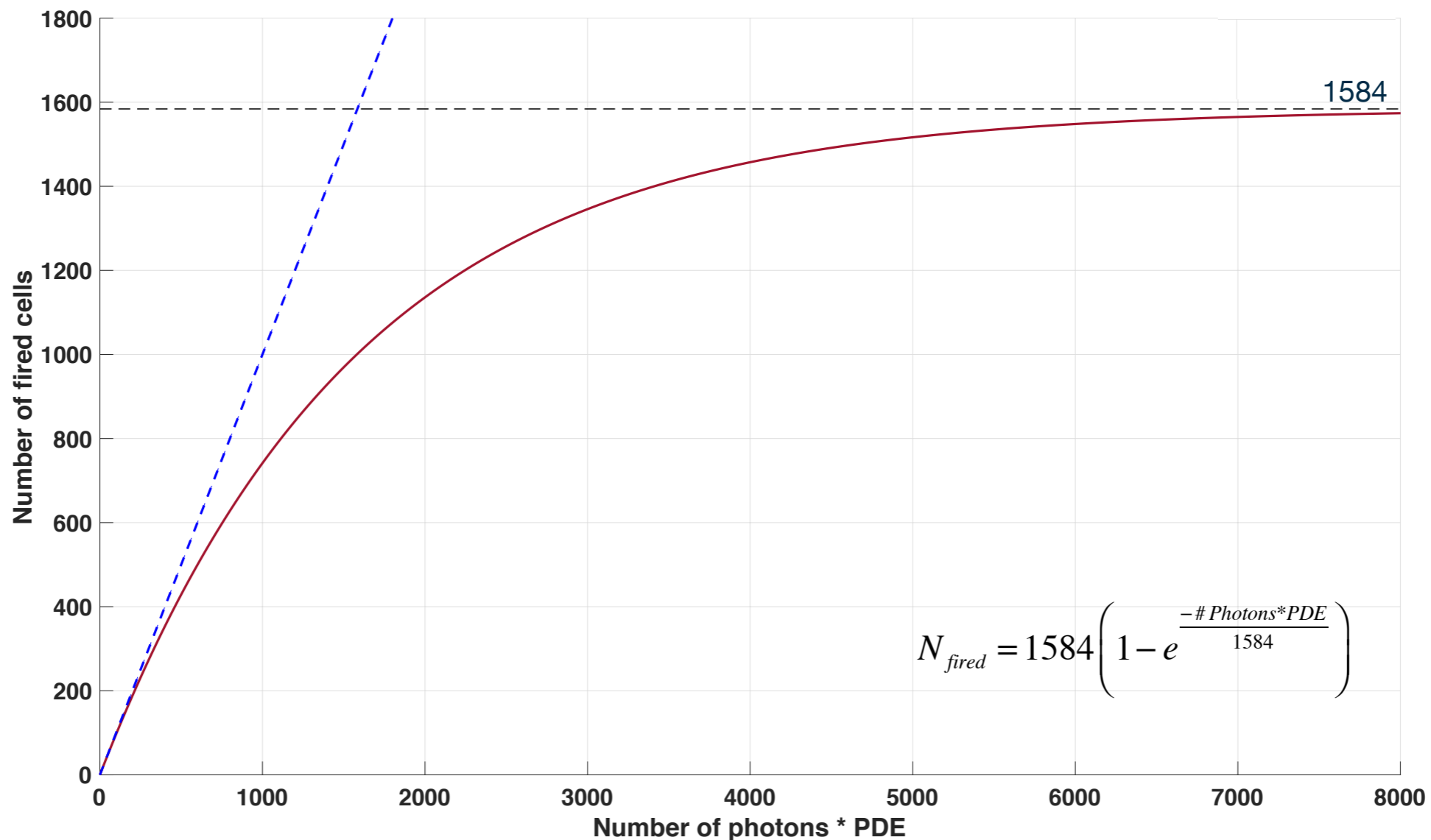


# Occupancy/Discrepancy on Seed

❖ SiPM Occupancy:  $Occupancy(\%) = \frac{N_{FC\_measured}}{N_{tot}} \%$  with  $N_{tot}(S) = N_{tot}(C) = 1584$  cells

❖ Discrepancy between the corrected and uncorrected values:

$$N_{FC\_corrected} = N_{Photons} \cdot PDE = -N_{tot} \cdot \ln\left(1 - \frac{N_{FC\_measured}}{N_{tot}}\right) \longrightarrow Discrepancy(\%) = \frac{N_{FC\_corrected} - N_{FC\_measured}}{N_{FC\_measured}} \%$$

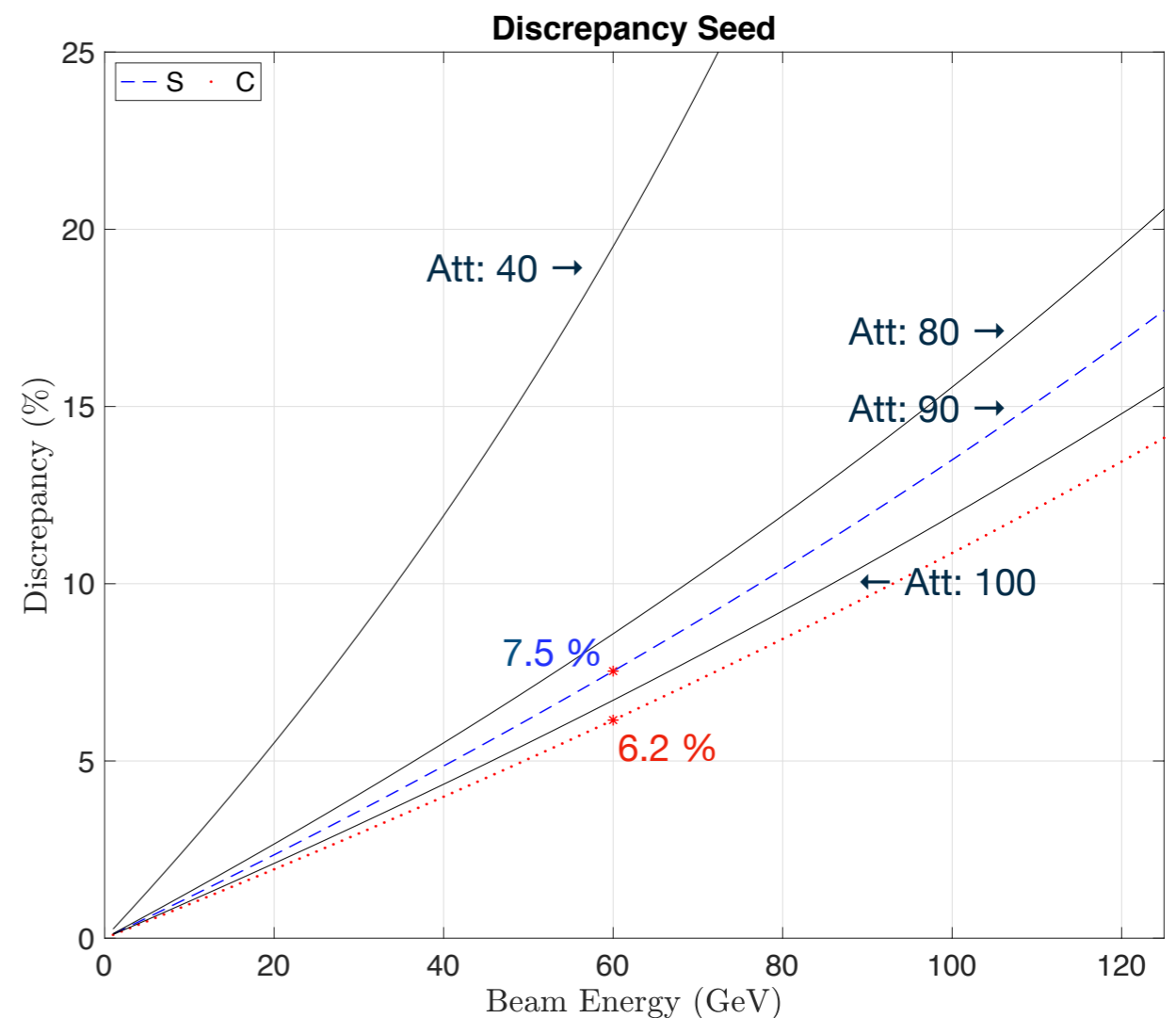
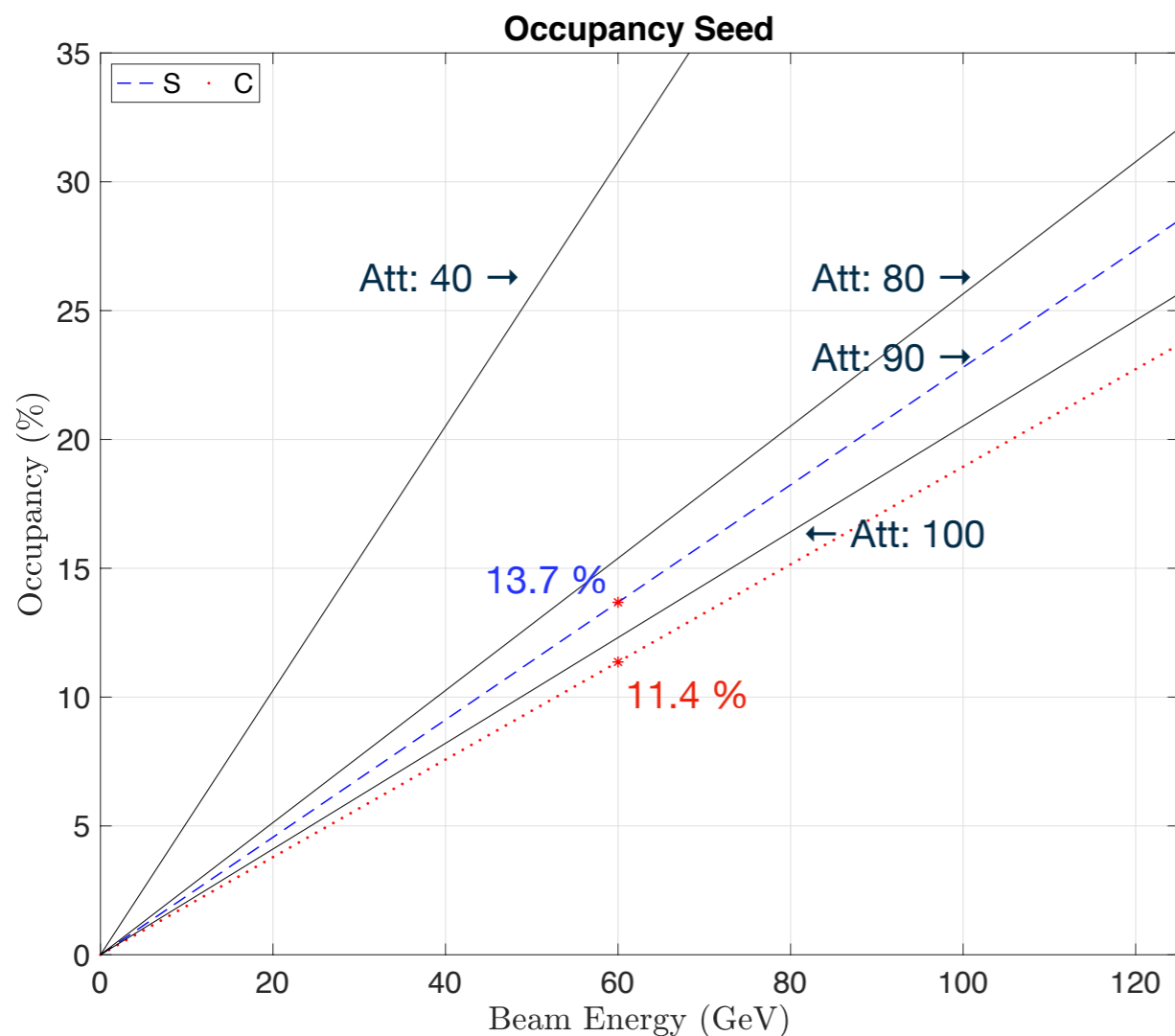


# Occupancy/Discrepancy on Seed

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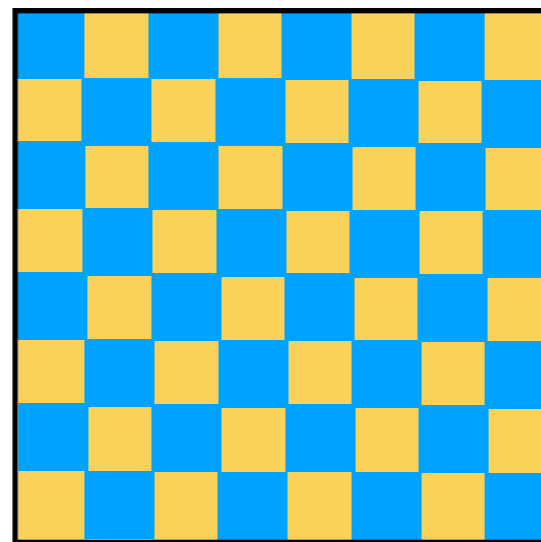
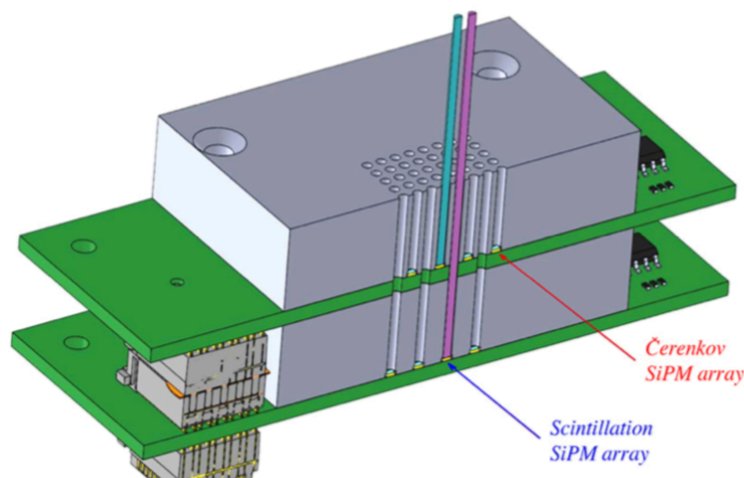
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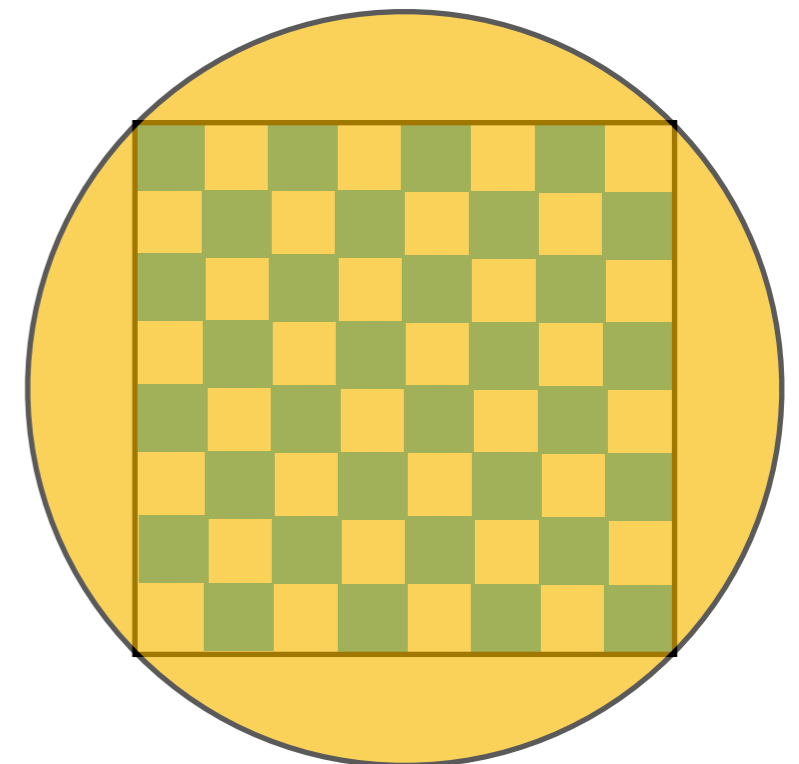


# Goals for the next test beam

- ❖ Using the **same sensors and readout electronics** of the latest beam test:
  - ❖ Measure with more accuracy the real **number of fired cells/GeV** for the **scintillation** channel (with 25% PDE and less light impinging the sensors)
  - ❖ Study different configuration and type of **filters (Yellow/ND)**



32 filters: one for each S SiPM



1 big filter for all the SiPMs

- ❖ Try to improve the **number of fired cells/GeV** for the **Cherenkov** channel
- ❖ Reduce the **optical crosstalk** between fibres



# Additional Slides

# Attenuation effect on EM resolution

\*A sampling of 10.5% is used

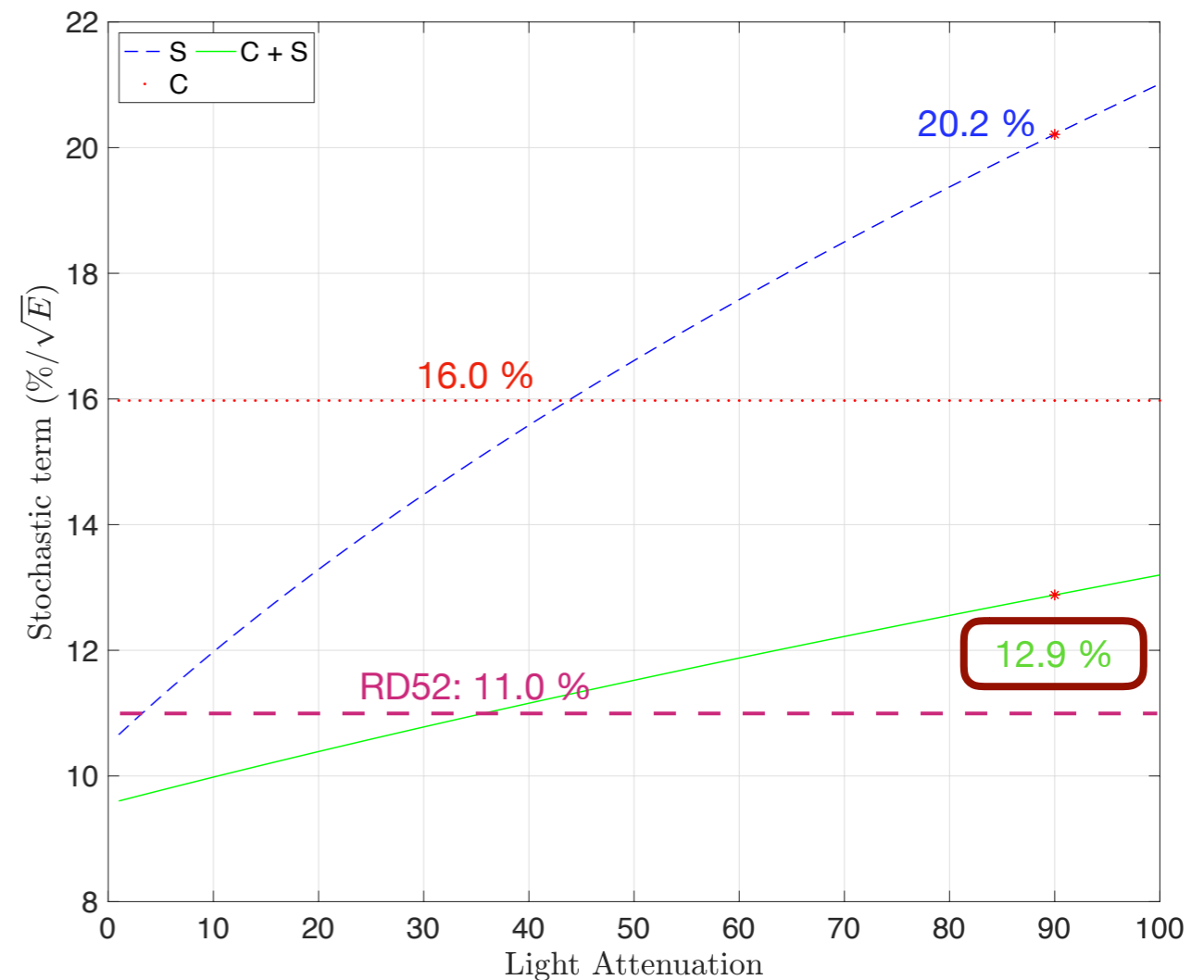
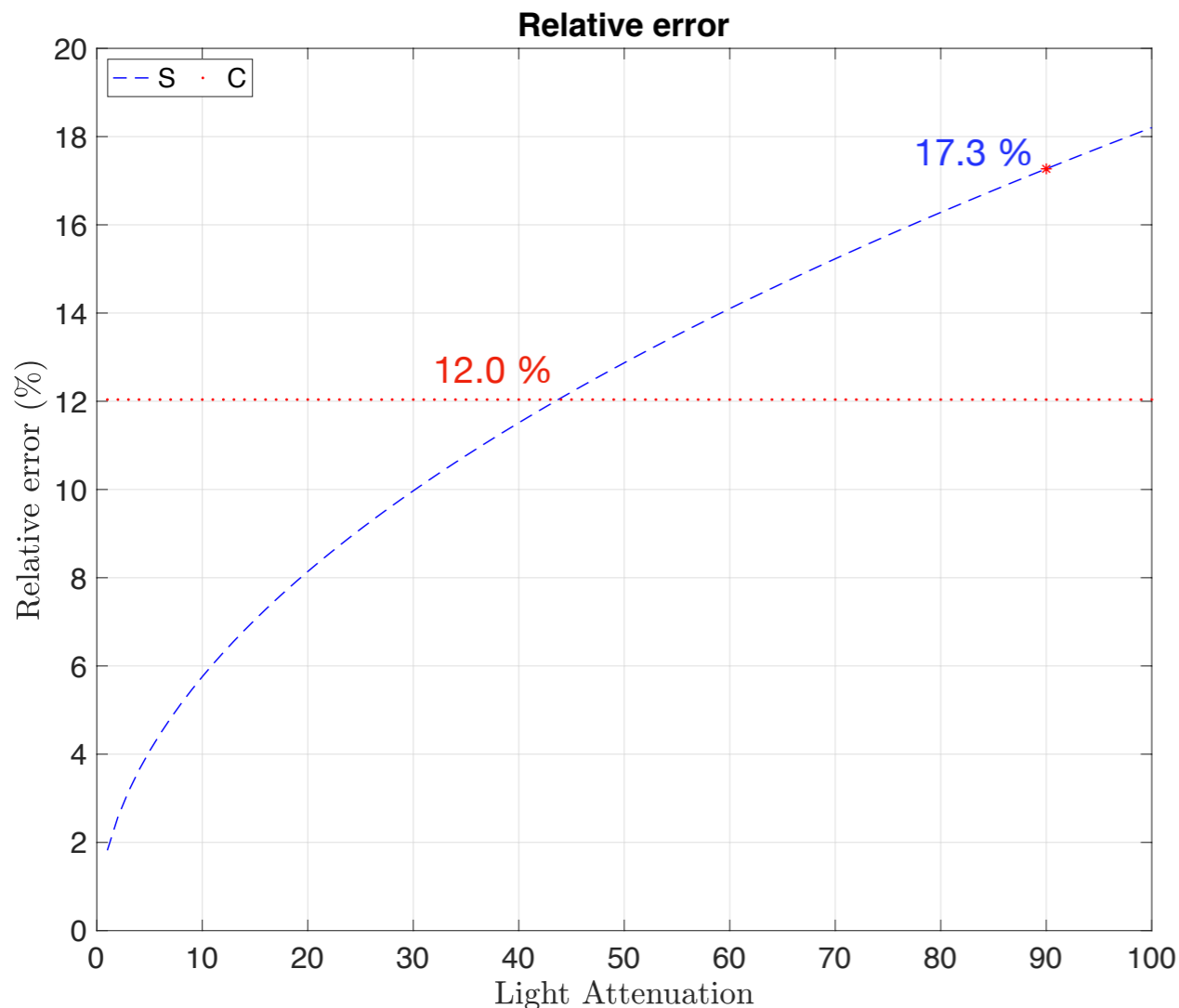
❖ Cherenkov channel (no attenuation):

- ❖ Total (corrected for containment 36% and optical crosstalk) ~ **69.0 fired cells/GeV**
- ❖ ⇒ Relative error: ~ **12.0%** ⇒ Combined\*: **16.0%**

❖ Scintillation channel (**90 times attenuation**):

- ❖ Total (corrected for containment 45%) ~ **33.5 fired cells/GeV**
- ❖ ⇒ Relative error (**90 times attenuated**): ~ **17.3%** ⇒ Combined\*: **20.2%**

} **C+S = 12.9%**  
11.0% for RD52  
Copper module



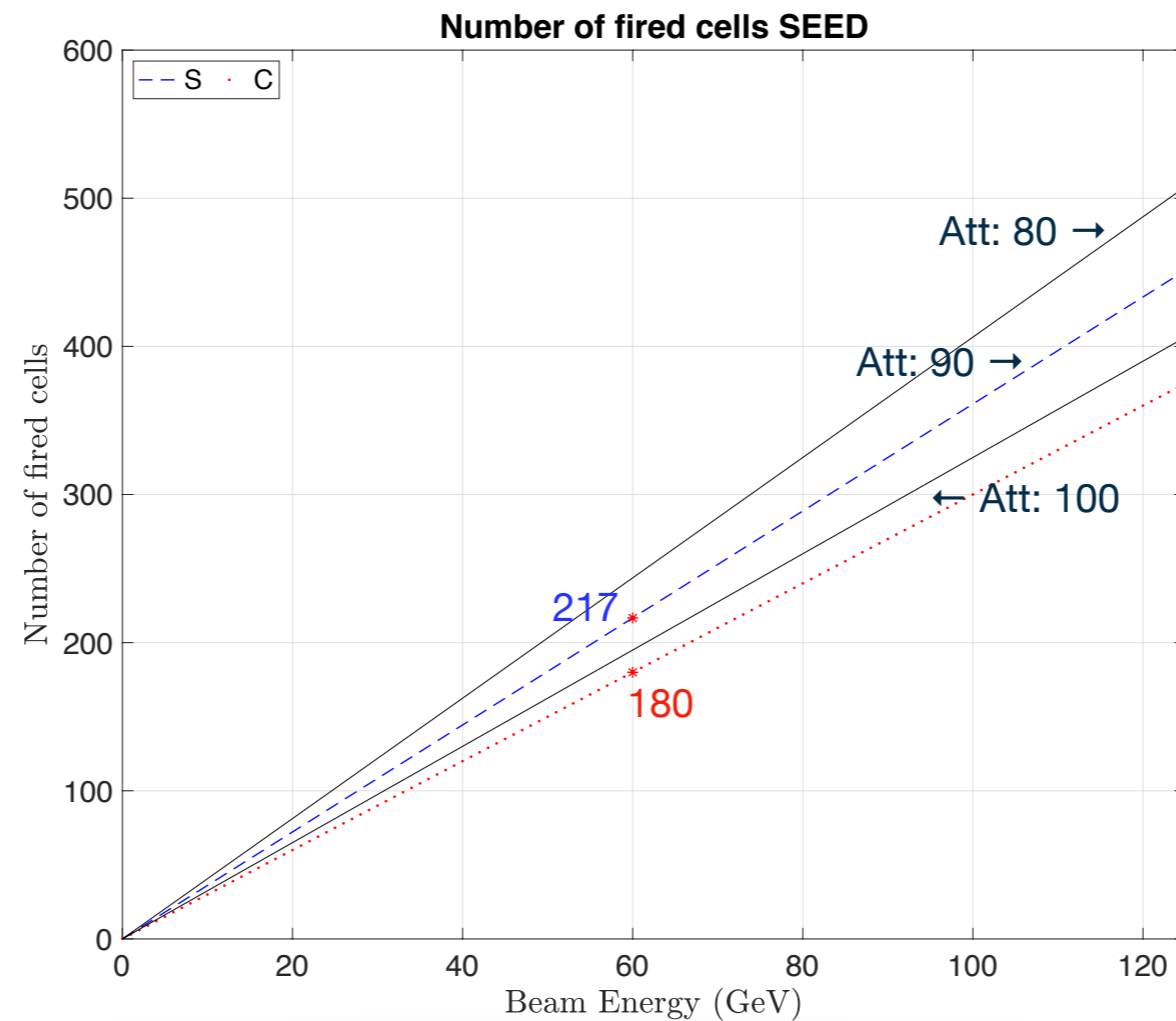
# Number of fired cells on Seed

❖ Cherenkov channel (1584 cells), no attenuation  $\Rightarrow$  seed:  $\sim 3.0$  fired cells/GeV

Energy (GeV)	10	20	40	60	80	100	125
C Seed (fired cells) @ 25% PDE	30,0	60,0	120,0	180,0	240,0	300,0	375,0

❖ Scintillation channel (1584 cells), 90 times attenuation  $\Rightarrow$  seed:  $\sim 3.6$  fired cells/GeV

Energy (GeV)	10	20	40	60	80	100	125
C Seed (fired cells) @ 25% PDE	36,1	72,2	144,4	216,6	288,8	361	451,25



# Light yield on seed

## Cherenkov channel: no attenuation

Light yield estimated for different beam energies (**1584 cells**)

Energy (GeV)	10	20	30	40	60	80	100	125
<b>C Seed</b> (fired cells) @ 25% PDE	30,0	60,0	90,0	120,0	<b>180,0</b>	240,0	300,0	375,0
# of Photons	120,0	240,0	360,0	480,0	720,0	960,0	1200,0	1500,0
S Occupancy (%) 1584 cells	1,9	3,8	5,7	7,6	<b>11,4</b>	15,2	18,9	23,7
Correction Discrepancy (%) 1584 cells	1,0	1,9	3,0	4,0	<b>6,2</b>	8,4	10,9	14,1

## Scintillation channel: attenuation 90 times

Light yield estimated for different beam energies (**1584 cells**)

Energy (GeV)	10	20	30	40	60	80	100	125
<b>S Seed Att: 90 times</b> (fired cells) @ 25% PDE	36,1	72,2	108,3	144,4	<b>216,7</b>	288,9	361,1	451,4
# of Photons	144,4	288,9	433,3	577,8	866,7	1155,6	1444,4	1805,6
S Occupancy (%) 1584 cells	2,3	4,6	6,8	9,1	<b>13,7</b>	18,2	22,8	28,5
Correction Discrepancy (%) 1584 cells	1,2	2,4	3,6	4,9	<b>7,5</b>	10,4	13,5	17,7