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# RAYLEIGH SCATTERING LENGTH ESTIMATION IN THE 4-TON DP DEMONSTRATOR

CHIARA LASTORIA (CIEMAT)

*3x1x1 light data/MC analysis*

*October 9<sup>th</sup>, 2019*

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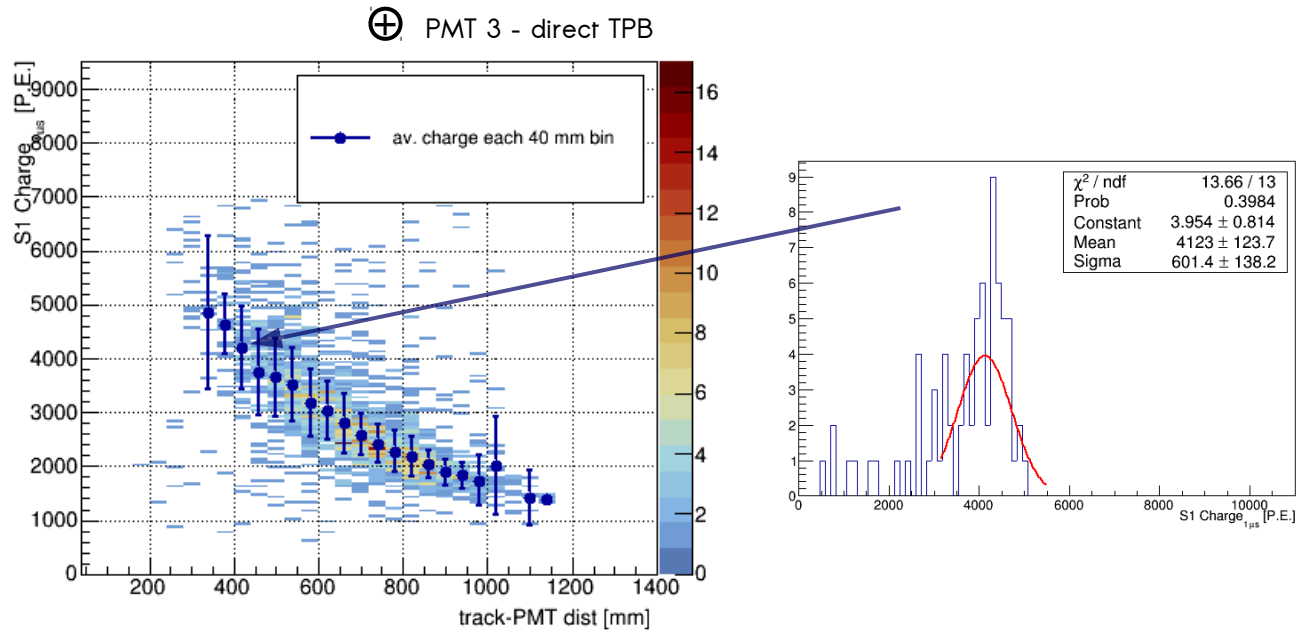
> evaluate the Rayleigh scattering length from the 311 data

> very preliminary fit of the data using the simple model

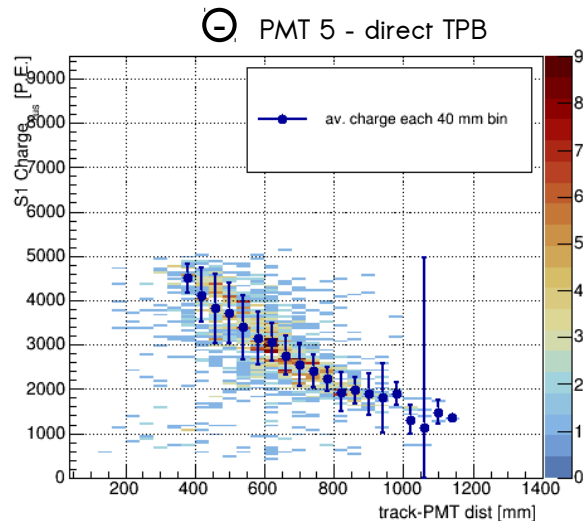
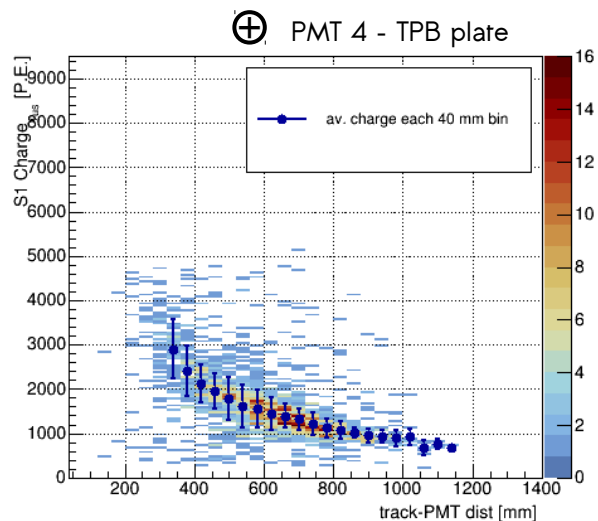
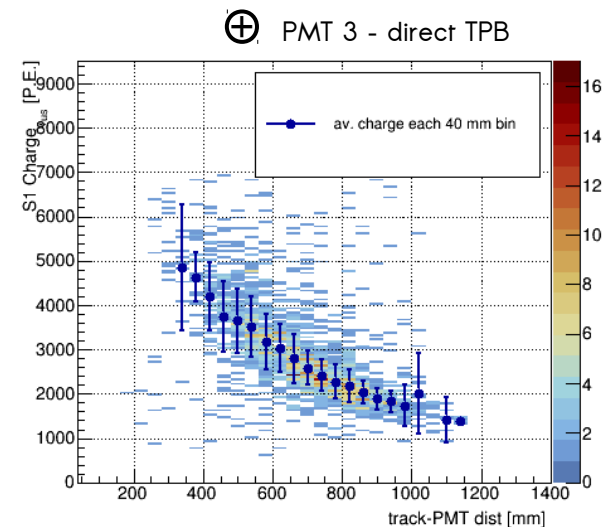
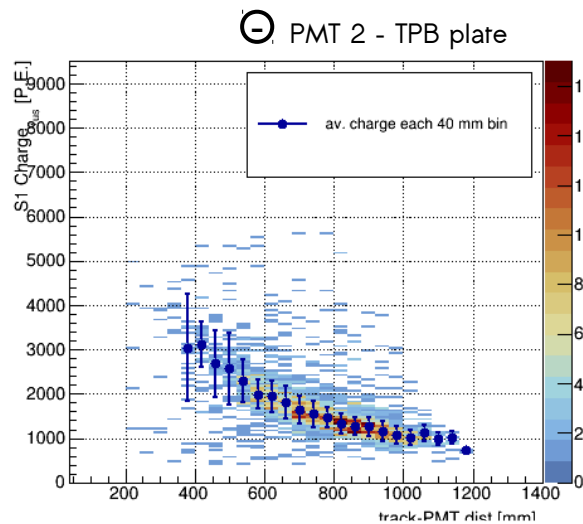
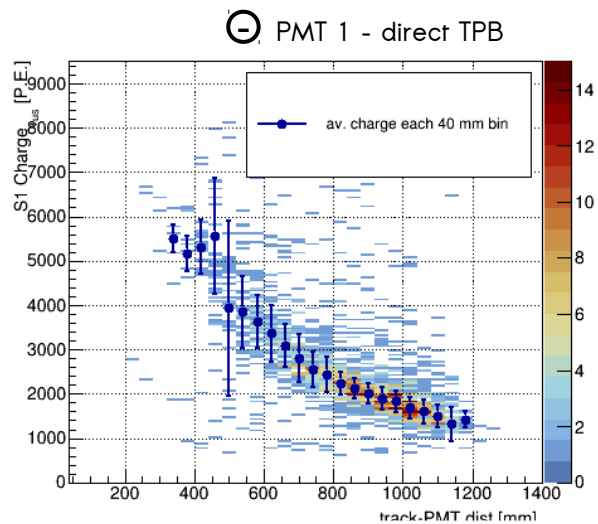
$$I_{\lambda}(x) = A * \exp(-x/\lambda_{att})$$

> to avoid low statistics effect in the TProfile → point from a gaussian fit

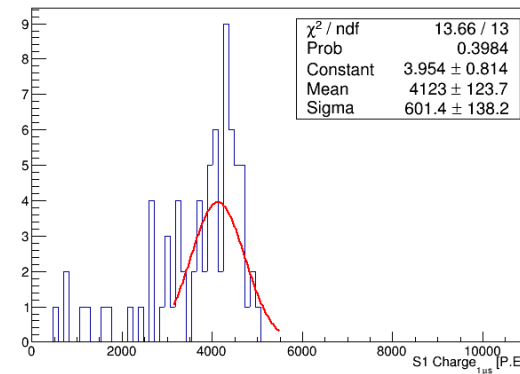
○ each point is obtained from a gaussian fit in each 40mm bin



# Rayleigh scattering length

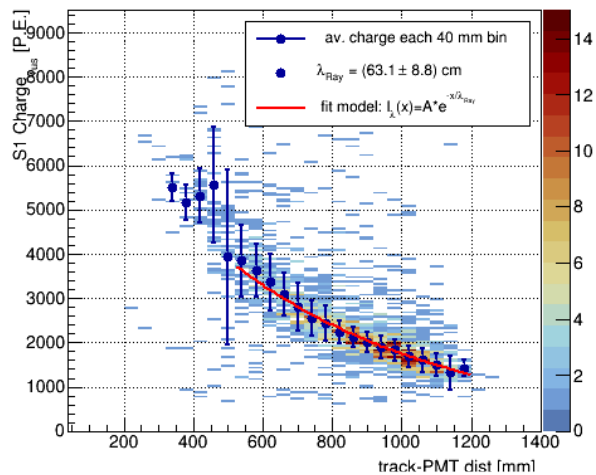


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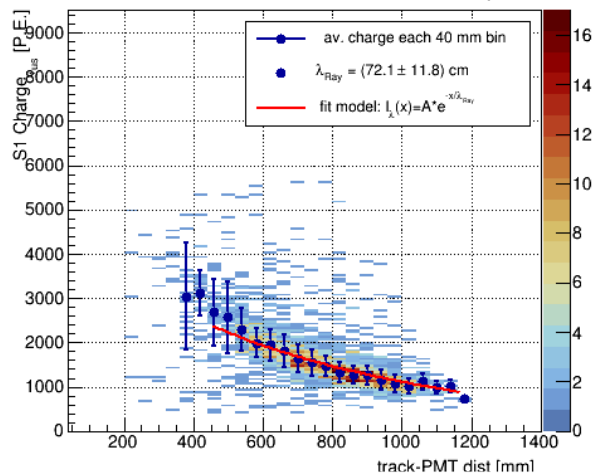


# Rayleigh scattering length

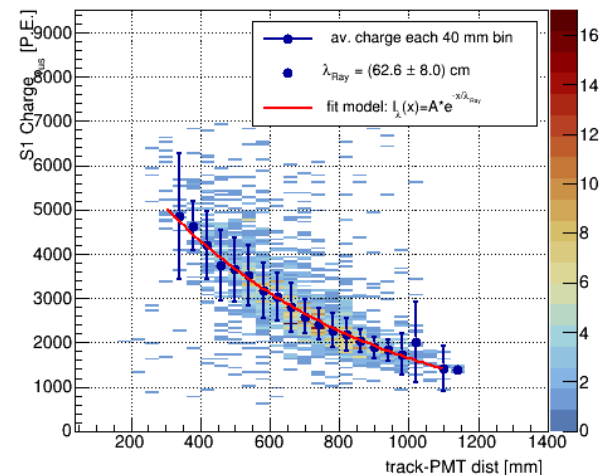
⊖ PMT 1 - direct TPB



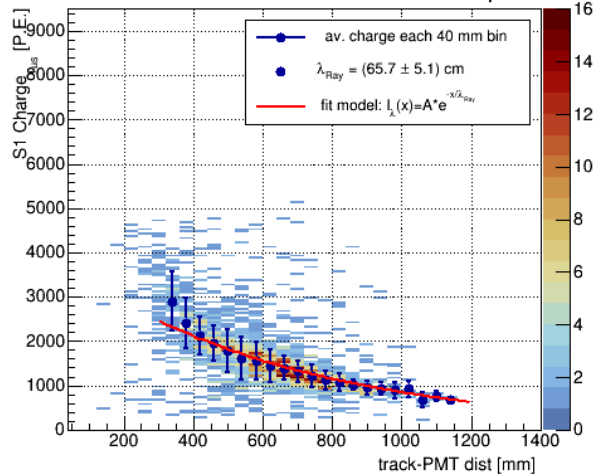
⊖ PMT 2 - TPB plate



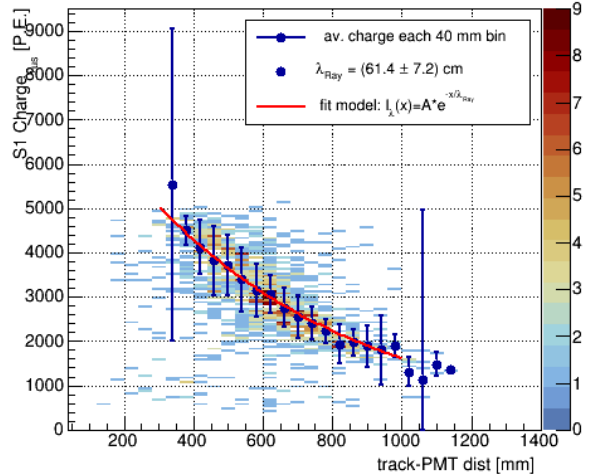
⊕ PMT 3 - direct TPB



⊕ PMT 4 - TPB plate



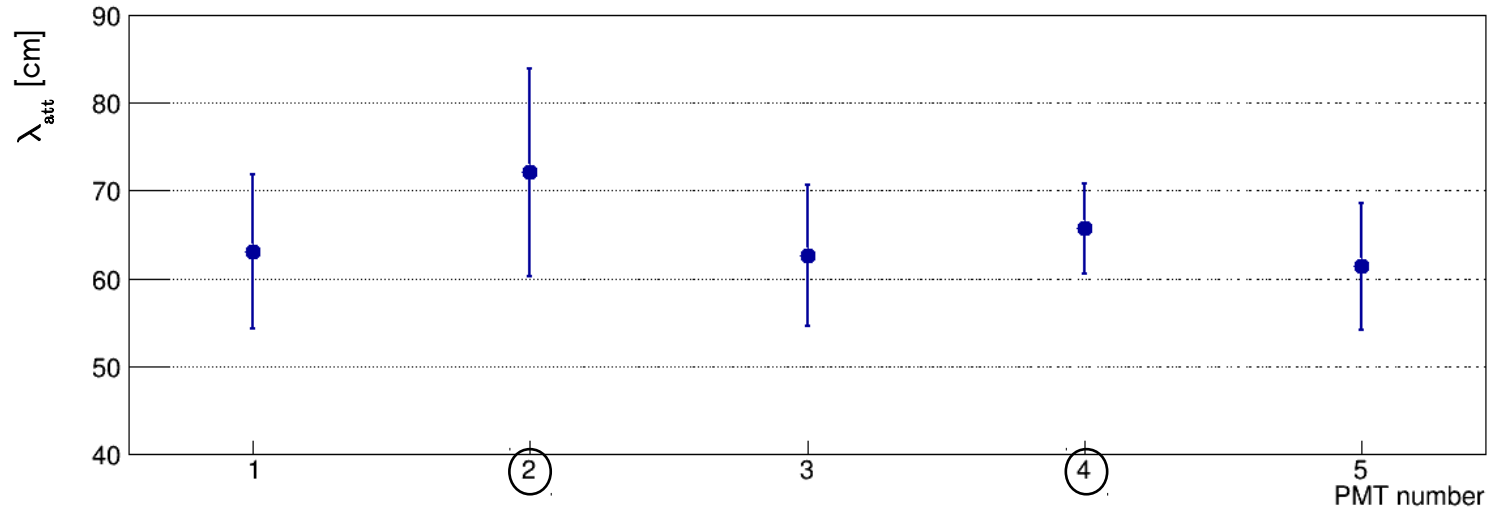
⊖ PMT 5 - direct TPB



## Fit of the 3x1x1 data (very preliminary)

:> comparison among the five channels

→ PMT with plate tends to give an higher value than the others

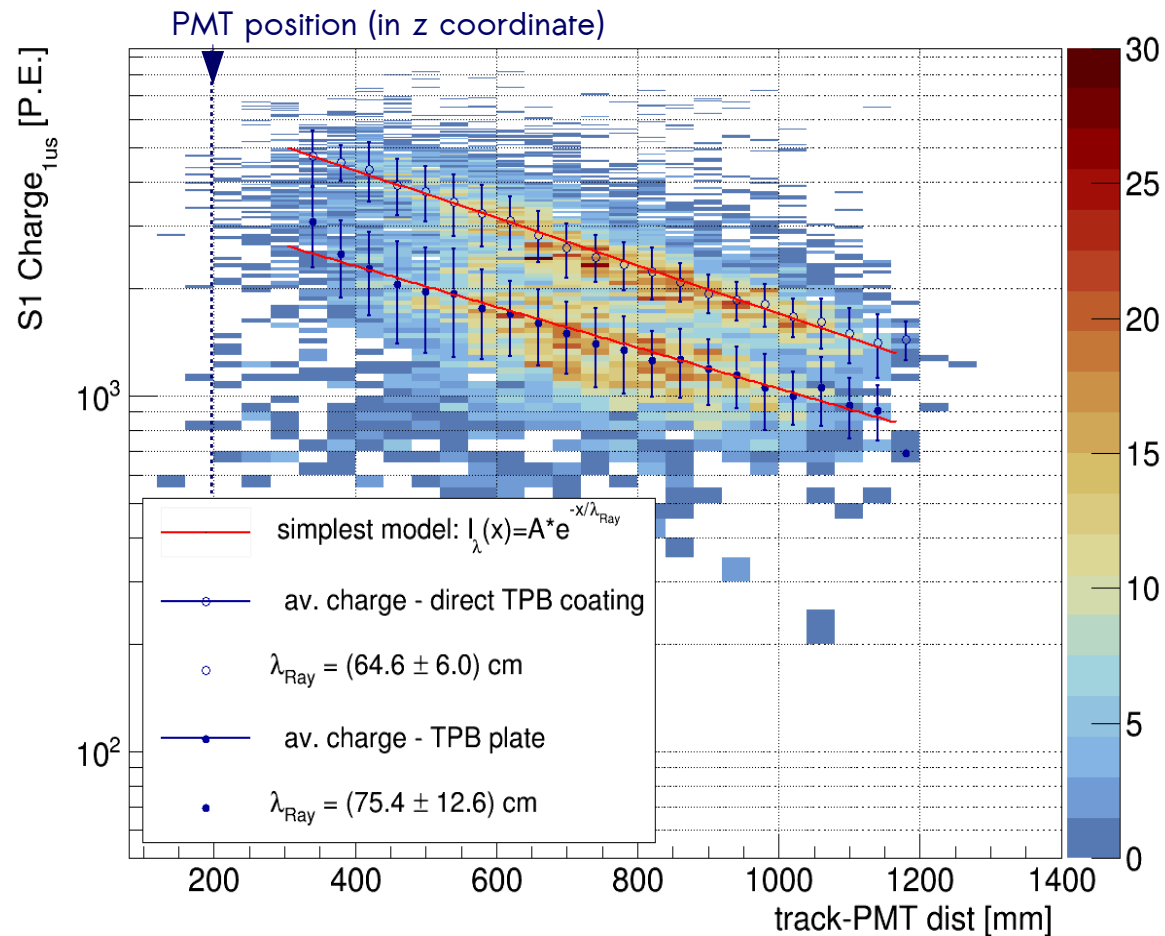


:> within the error, the 5 PMTs are in agreement, on average  $\lambda_{att} = (64.4 \pm 3.3)$  cm

→ results lower than ~90 cm which is the most updated result

## Fit of the 3x1x1 data (very preliminary)

- > comparison between two different TPB configurations, global estimation (summing together the three “direct TPB” PMTs and the two “TPB plate” PMTs)
- > within the error, the two results are still in agreement
- > do we expect a difference because of different acceptance of the PMTs (different TPB configuration)
  - is a geometrical effect or is due to the additional absorption of the plate?
  - if it is a geometrical effect, should we look for a way to include the modeling of the solid angle covered by PMTs with the two TPB configurations?



## Comments

⇒ very preliminary fit of the data using the simple model

$$I_{\lambda}(x) = A * \exp(-x/\lambda_{att})$$

⇒ it's needed the comparison with the MC to understand how much  $\lambda_{att}$  differs from the real  $\lambda_{Ray}$ ?

- ⇒  $\lambda_{absorption}$  expected 30 m, so it should not being affecting
- ⇒ understand possible effect due to FC walls absorption (remind that distance between external PMT and FC wall ~500mm)
- ⇒ understand possible effect due the plate absorption or geometrical acceptance

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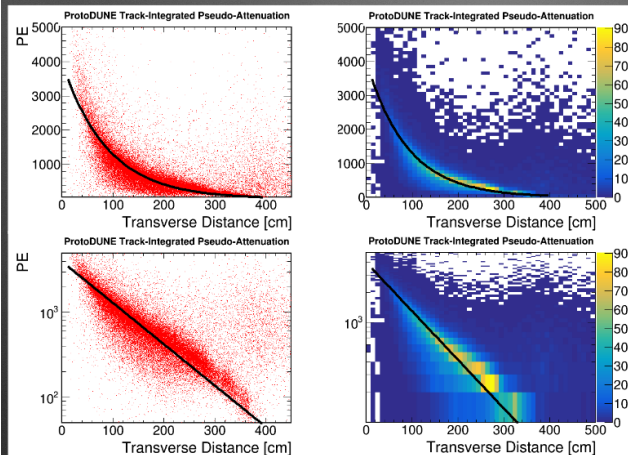
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→ the approach is quite similar to the one presented by ProtoDUNE-SP at the last collaboration meeting but they obtain a result much more consistent with the latest 91 cm measurement for the Rayl.

## TIPA of selection sample

- Fit range from 10-400 cm



$$T \propto e^{C - \frac{x}{\lambda_{Pseudo}}}$$

$$C = 8.29 \pm 01$$

$$\Rightarrow e^C = 3,984 \pm 3 \text{ PE}$$

$$\frac{1}{\lambda_{Pseudo}} = 0.0112 \pm 0.00006$$

$$\Rightarrow \lambda_{Pseudo} = 89.2 \pm 0.5 \text{ cm}$$

$$\lambda_{Pseudo} \propto \lambda = \lambda_{Absorp.} + \lambda_{Rayleigh}$$

Compare to dedicated setup at CERN presented at LIDINE 2019 (Umut Kose, *et al.*)  $\lambda_{Rayleigh} = 91 \pm 2.8(stat) \text{ cm}$



## Comments

> very preliminary fit of the data using the simple model

$$I_{\lambda}(x) = A \cdot \exp(-x/\lambda_{att})$$

> is that because of possible impurities (..again!  )?

→ in ArDM measurement - also mentioned by Grace in their paper - the 55cm length is obtained from data-MC comparison and they motivated this number by presence of impurities

Results for:	$\lambda_{UV} (^{39}\text{Ar})$	$\lambda_{UV} (^{83m}\text{Kr})$	$\mathcal{R} (^{39}\text{Ar})$	$\mathcal{R} (^{83m}\text{Kr})$
- global maximum	52.1 cm	53.6 cm	88.6%	92.4%
- threshold variations	49.4, 58.8 cm	53.4, 57.3 cm	86.8, 89.5 %	92.5, 91.2%
- LY scale $\pm 10\%$	47.9, 57.7 cm	54.3, 55.4 cm	86.5, 90.2 %	88.0, 95.2%

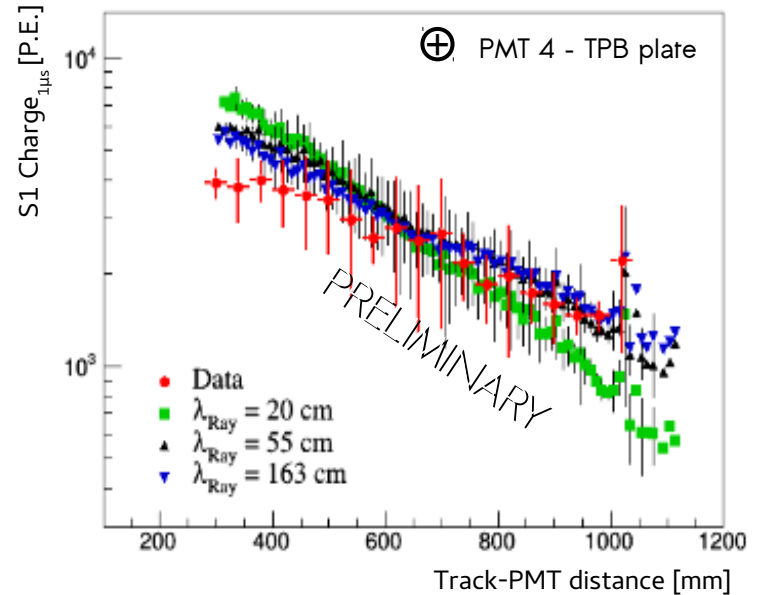
Molecule	$\langle \sigma_{eff} \rangle$ [Mbarn ]	blue shifted	red shifted	$C_{req}$ [ppb]
NO <sub>2</sub>	14	12	16	67
CH <sub>4</sub>	9.8	1.8	18	97
H <sub>2</sub> O	4.4	1.1	7.8	220
O <sub>2</sub>	5.5	13	6.7	170
SO <sub>2</sub>	9.6	3.8	52	99
C <sub>2</sub> H <sub>2</sub>	42	7.8	32	23
NH <sub>3</sub>	10	7.3	12	94
CO <sub>2</sub>	0.62	0.53	0.34	1.5k
NO	2.5	2.4	2.2	380
N <sub>2</sub>	0.007			135k
Xe	35			27

→ how good is the LAr purity in ProtoDUNE-SP and in the CERN dedicated setup?

> can we simulate the effect of the impurities at the MC level?

## Feedback from the Join SP-DP

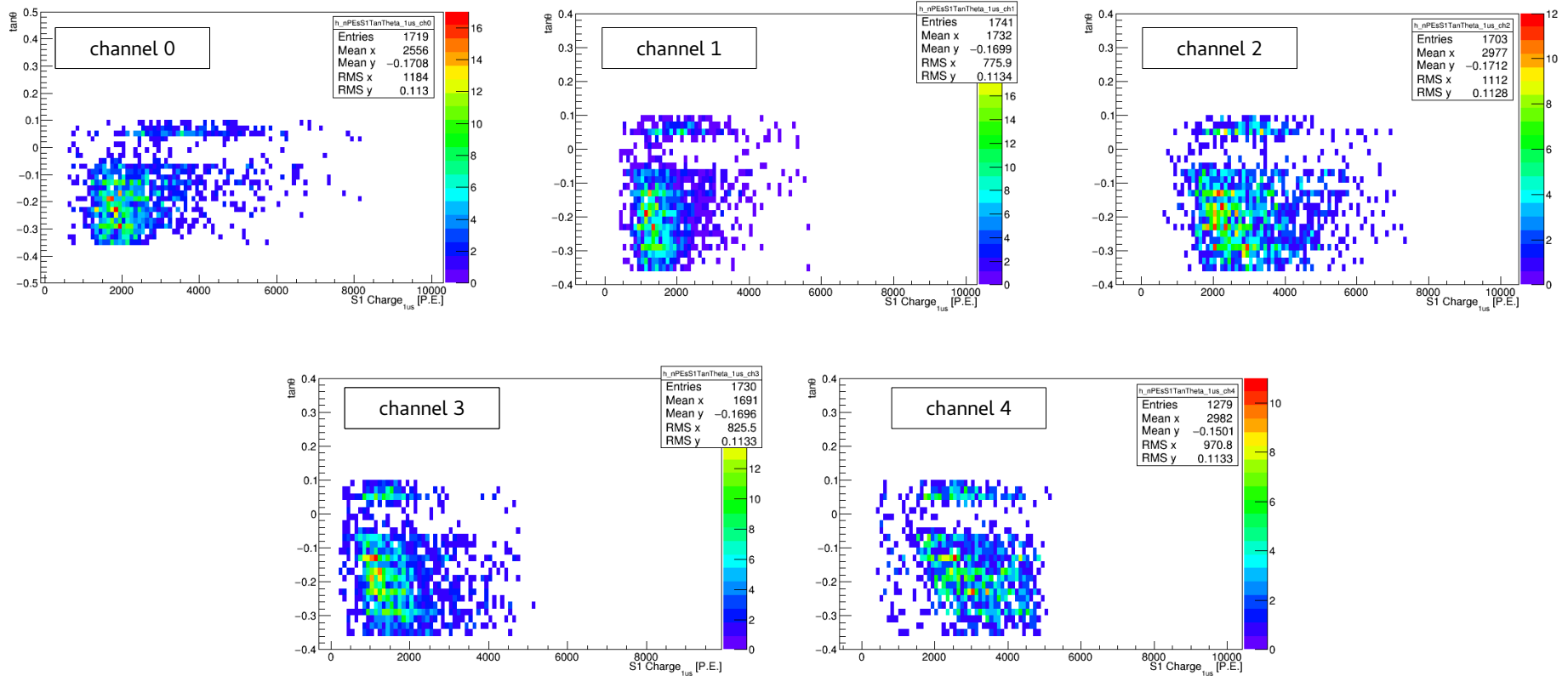
- the 311 is only 1 m height, but doing the ratio data/MC can help to quantify the previous results
- I'll look at that as soon as the new light maps will be available
- will we have the map at 90 cm?



## Feedback from the Join SP-DP

⇒ check possible dependence with the theta angle

→ (very preliminary) I looked at this distributions, there is a correlation that becomes more evident going to PMT 5

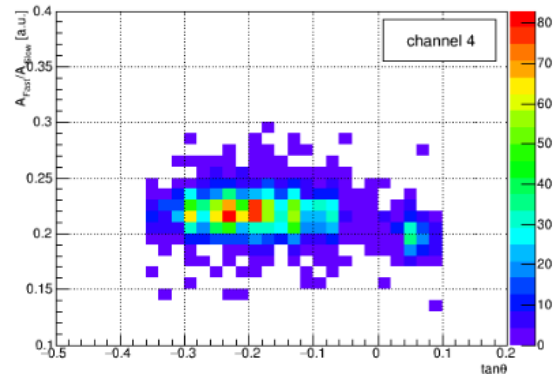
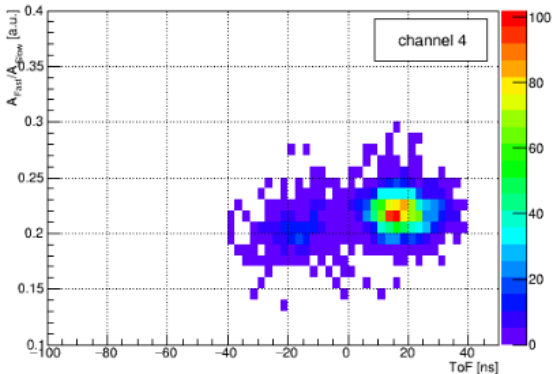
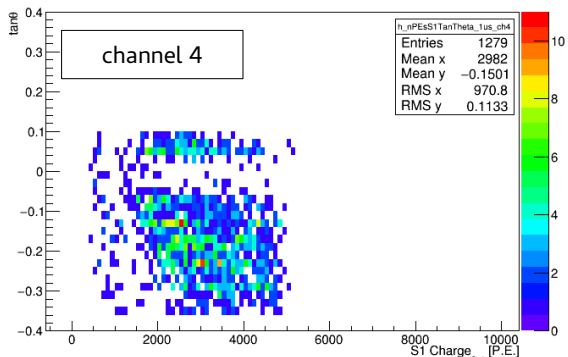
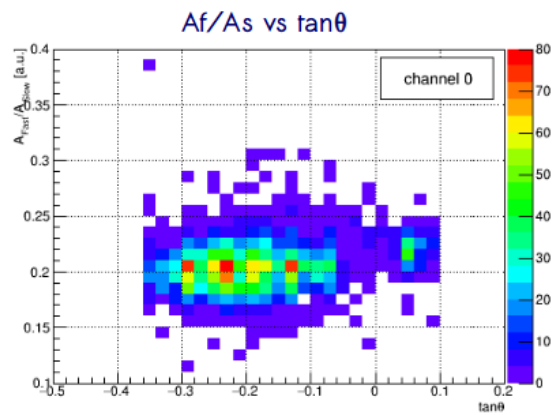
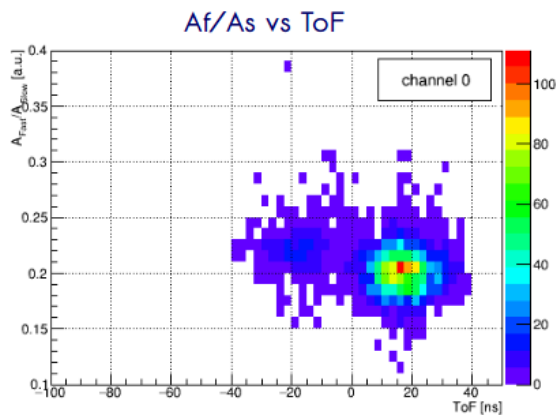
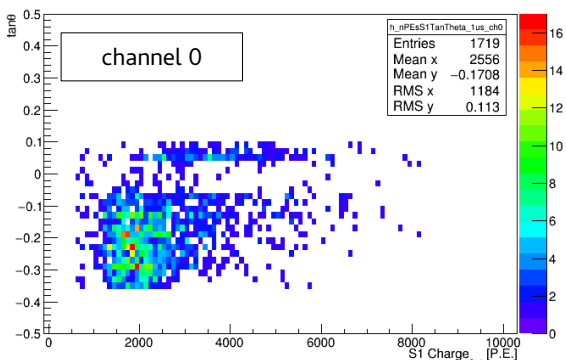


## Feedback from the Join SP-DP

➤ check possible dependence with the theta angle (very preliminary)

→ is that the same effect we saw looking at the ratio  $A_f/A_s$  (presented [here](#))?

→ if so, is that because a possible dependence with the energy of the particle through the theta angle of the muons or is that just the effect due to the attenuation of the Rayleigh scattering length?



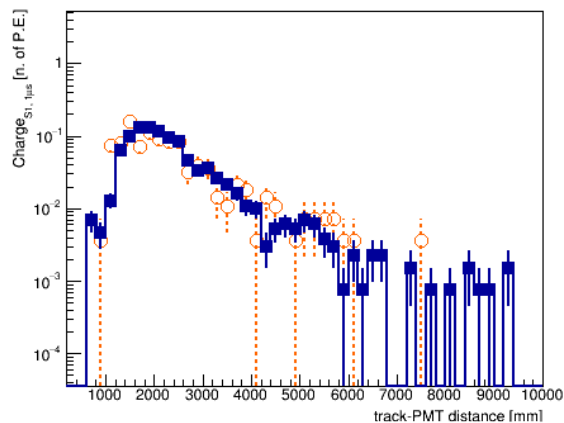
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**Backup slides**

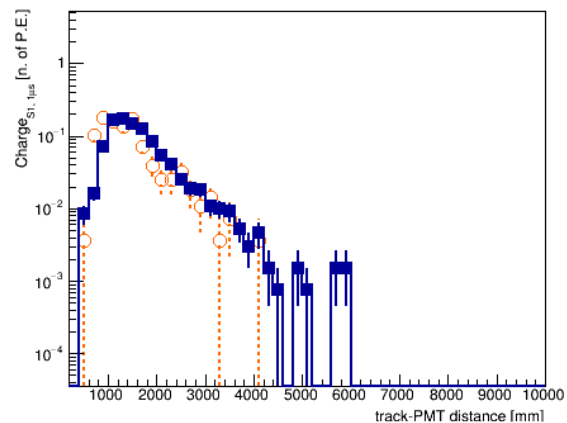
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# Rayleigh scattering length

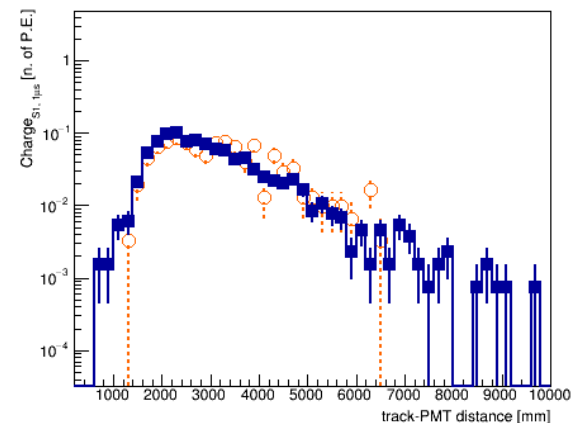
⊖ PMT 1 - direct TPB



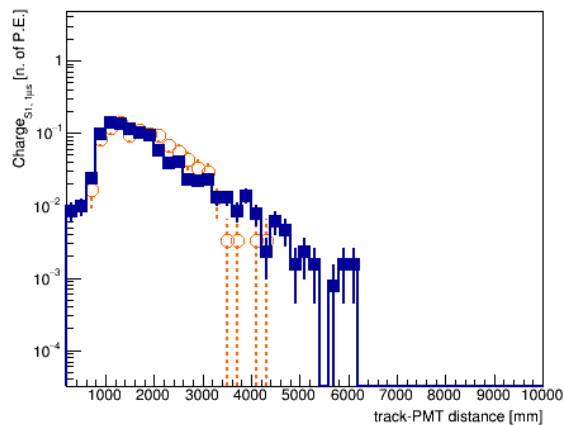
⊖ PMT 2 - TPB plate



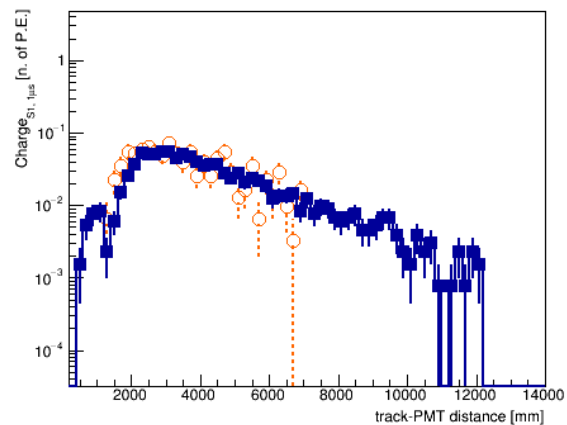
⊕ PMT 3 - direct TPB



⊕ PMT 4 - TPB plate

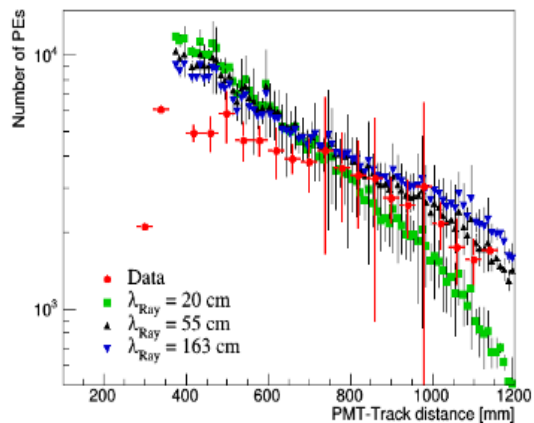


⊖ PMT 5 - direct TPB

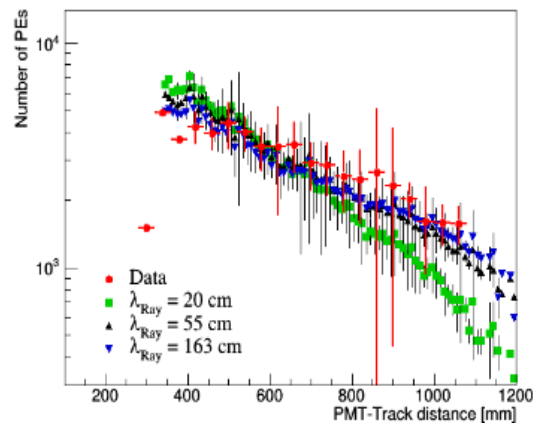


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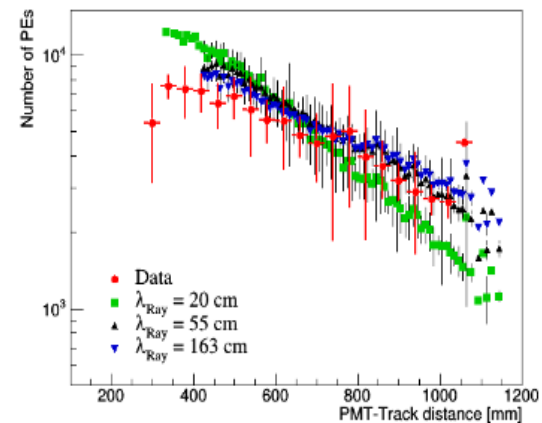
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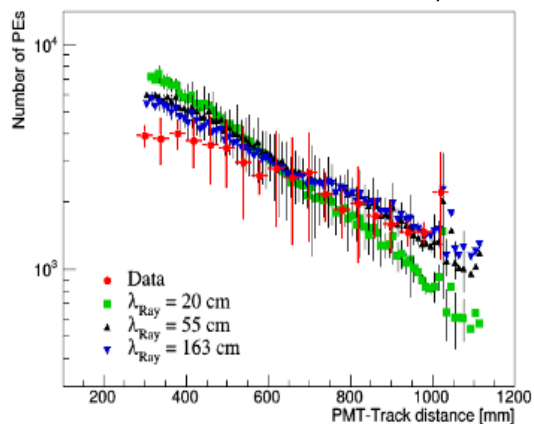
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⊕ PMT 4 - TPB plate



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