RIPTIDE

February 2024

RIPTIDE

1) Corrections to the corrections of the shift of the Depth of Focus

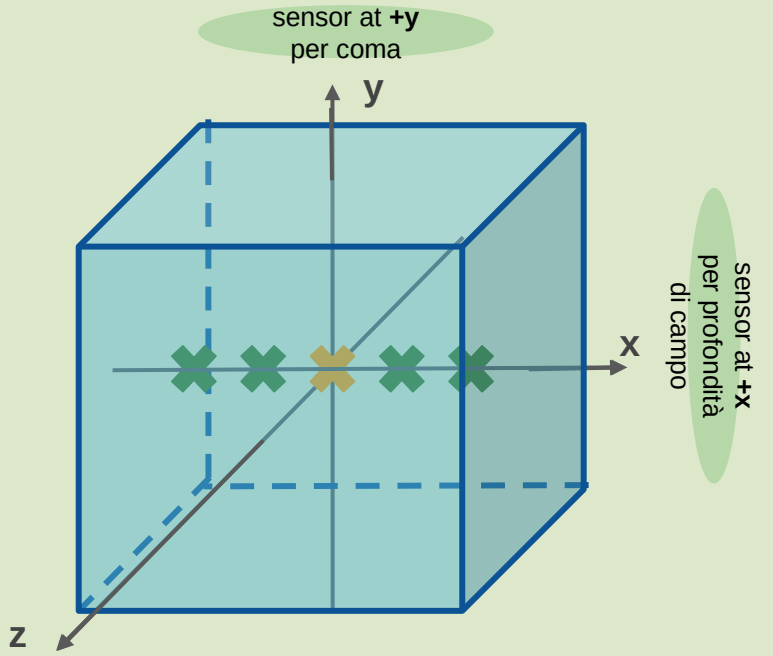
2) number of photons

3) Comparison of PCA and Linear Fit reconstruction algorithms

Gen-Z **Learner's Dictionary**

FOMO: *Sigla dell'ingl. Fear of missing out ('paura di rimanere escluso'), che si riferisce alla sensazione d'ansia provata da chi teme di essere privato di qualcosa di importante se non manifesta assiduamente la sua presenza tramite i mezzi di comunicazione e di partecipazione sociale elettronici interattivi.*

The MC simulation

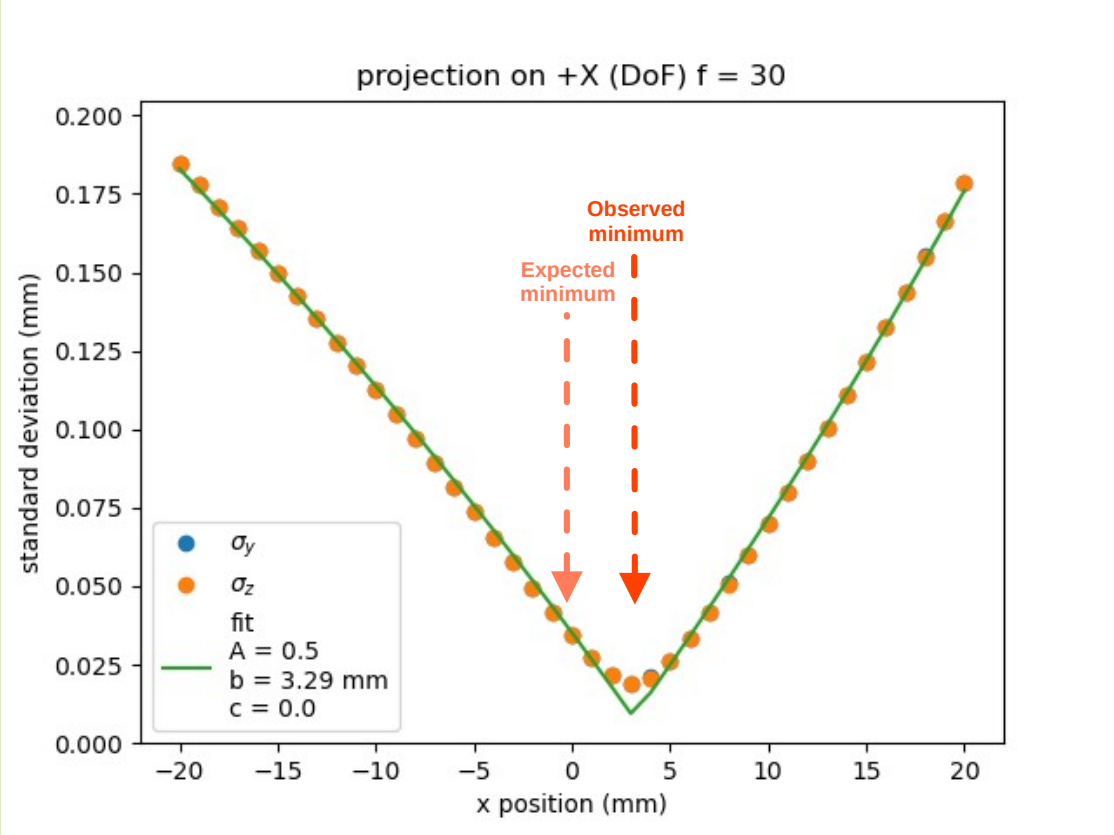


1) Pointlike photon emitting source (100 000 photons per point).
2) Source position is shifetd along x (y,z = 0)
3) Sphetical aberration is minimized by imposing a small lens radius (R/F = 1/6)

    a) **Depth of focus** was studied with the lens at **+x** axis
    b) **Comatic aberration** was studied with the lens at **+y** axis

4) Applied angle reduction techniques

Problem …



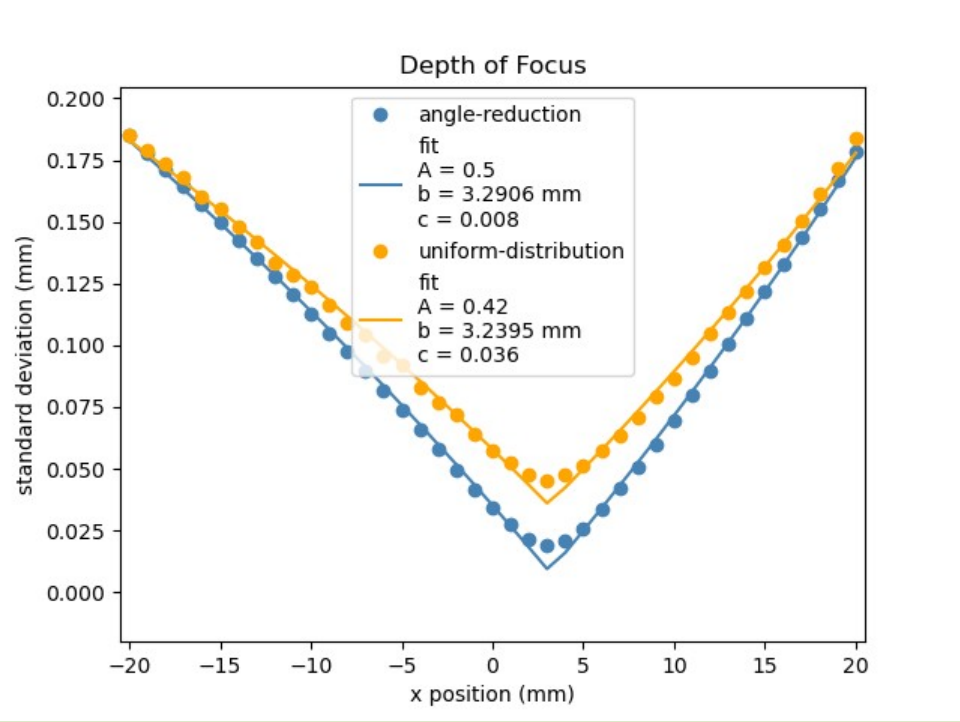
Blur of a point-like photon emitting source as a function of the position (x-axis) inside the scintillator

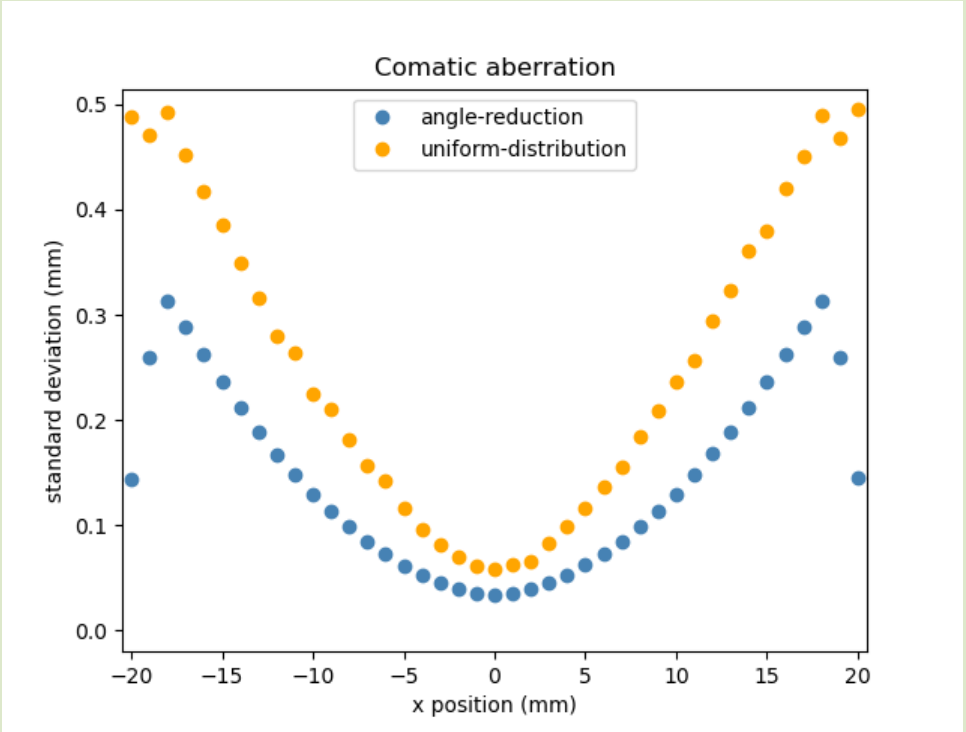
The focus (i.e. the minimum blur) should be placed in the origin but is shifted of ~3mm

Hypothesis: thin lens approx is not valid

4π VS angle reduction

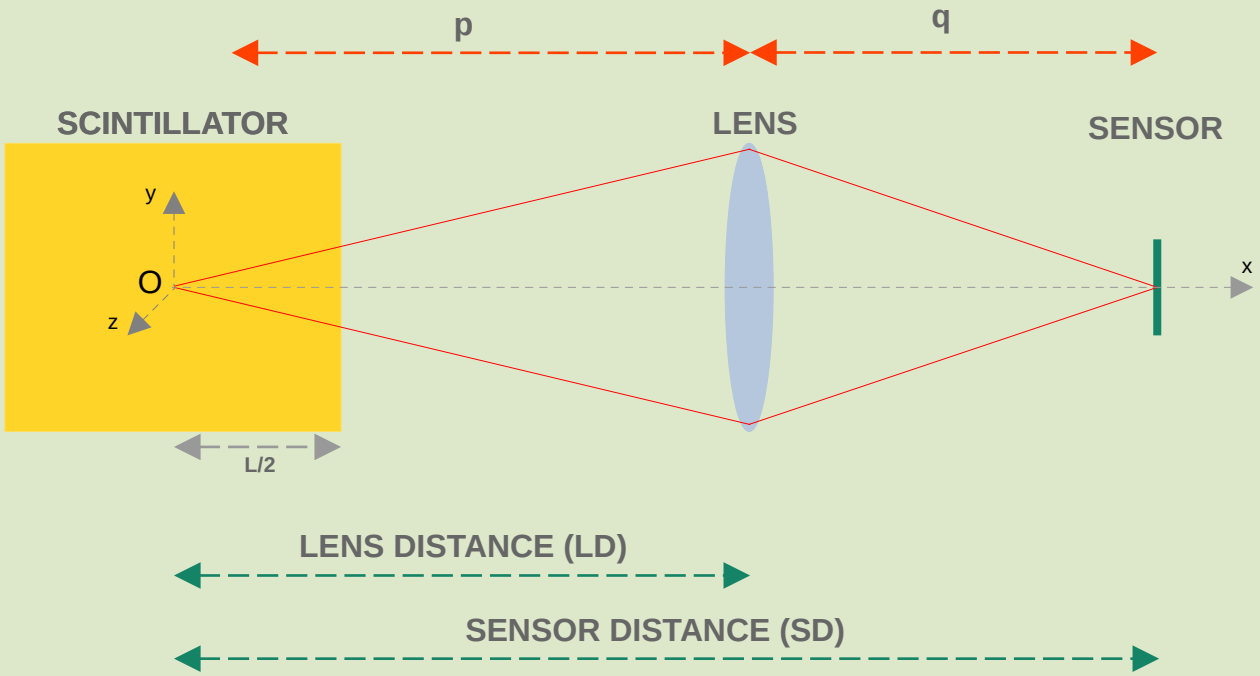
The reduction of the emission angle introduced an under-estimation of the standard deviation of the spot.





From now, all simulations are made in uniform distribution.
With 100 000 photons per point; 1 000 points simulated per event

Recap:



Standard configuration params used in simulation:

LD: distance of lens form origin of RS

SD: distance of sensor from origin of RS

Standard configuration params for thin lens equation:

p: scintillator-lens distance

q: lens-sensor distance

Recall:

- thin lens equation: $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$

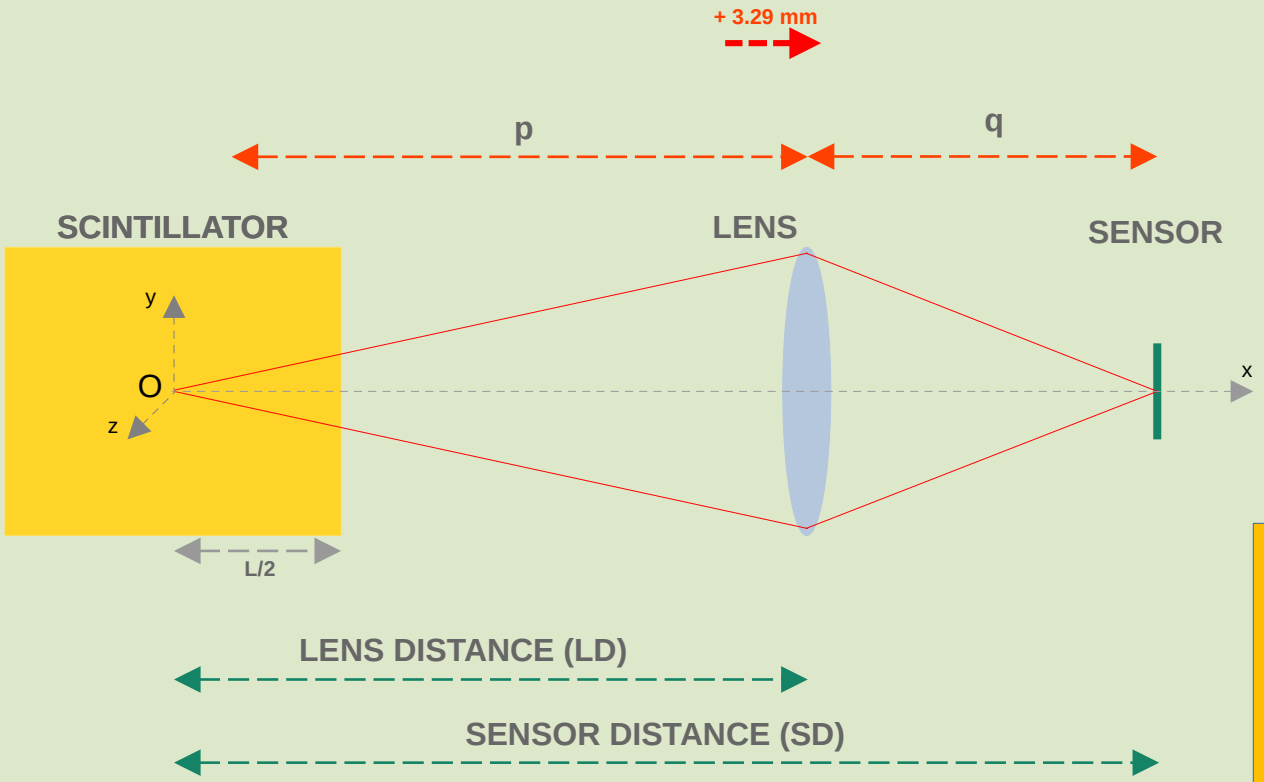
- law of refraction: $L'/2 = \frac{L/2}{n_{BC408}}$

Last correction:

Last time corrections [focus (F) = 30 mm]:

LensDistance = 101 **+ 3.29 mm**
SensorDistance = 146 mm

P increases, **q** decreases → have to recalculate point of focus.



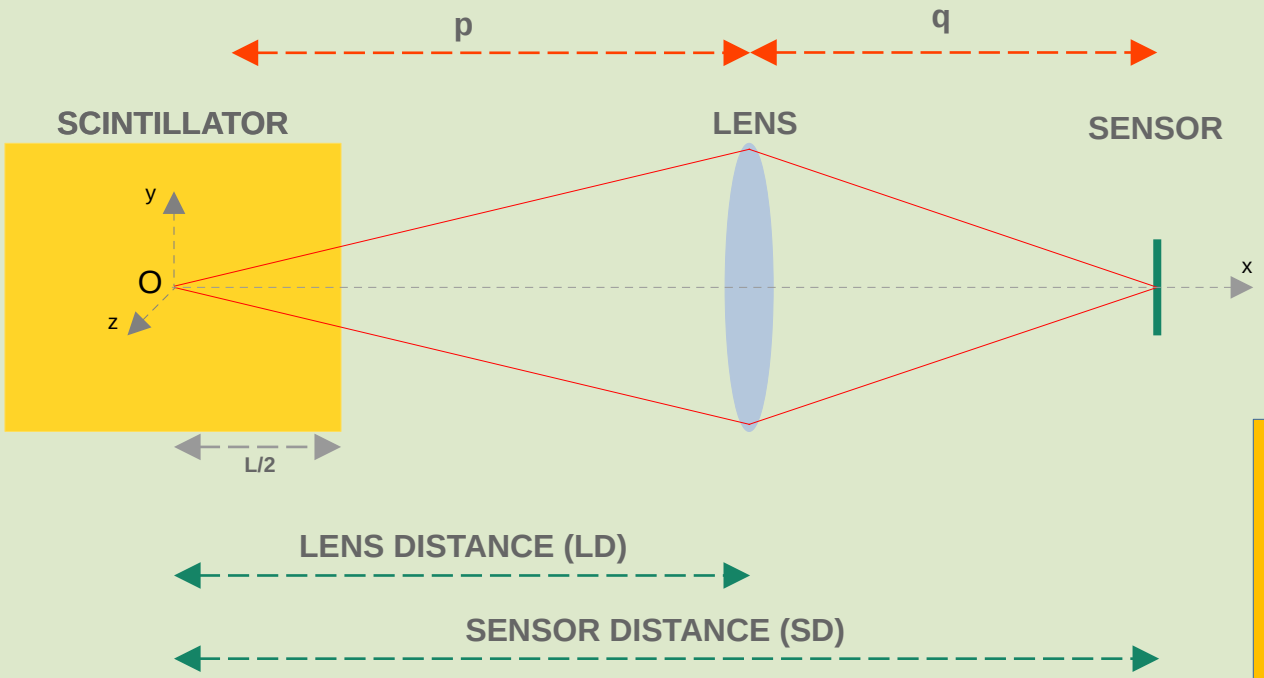
Recall:

- thin lens equation:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Back to Standard configuration

LensDistance = 101 mm
SensorDistance = 146 mm



Recall:

- thin lens equation:

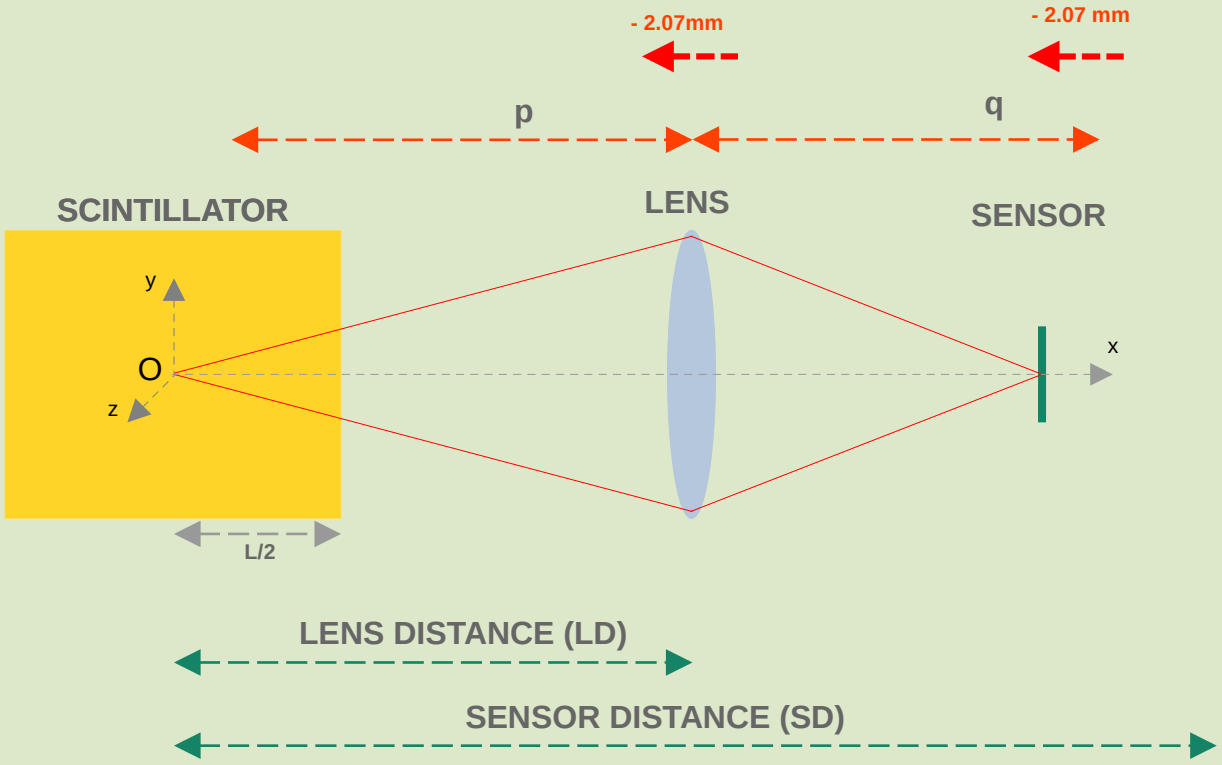
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

New correction:

Last time corrections [focus (F) = 30 mm]:

LensDistance = 101 **- 3.29 / 1.59** mm
SensorDistance = 146 **- 3.29 / 1.59** mm

Change in **p**, NOT **q** → I DON'T have to calculate back sensor position



Recall:

- thin lens equation:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Corrections of the shift of the Depth of Focus

- minimum of blur / n_{BC408}

F = 30

Setup base:
LensDistance = 101 **- 3.29 / 1.59** mm
SensorDistance = 146 **- 3.29 / 1.59** mm

FocalLength= **30 mm**

LensRadius= 5 mm
SensorSide = 20 mm

F = 180

Setup base:
LensDistance = 550.5 **- 16 / 1.59** mm
SensorDistance = 820 – **16 / 1.59** mm

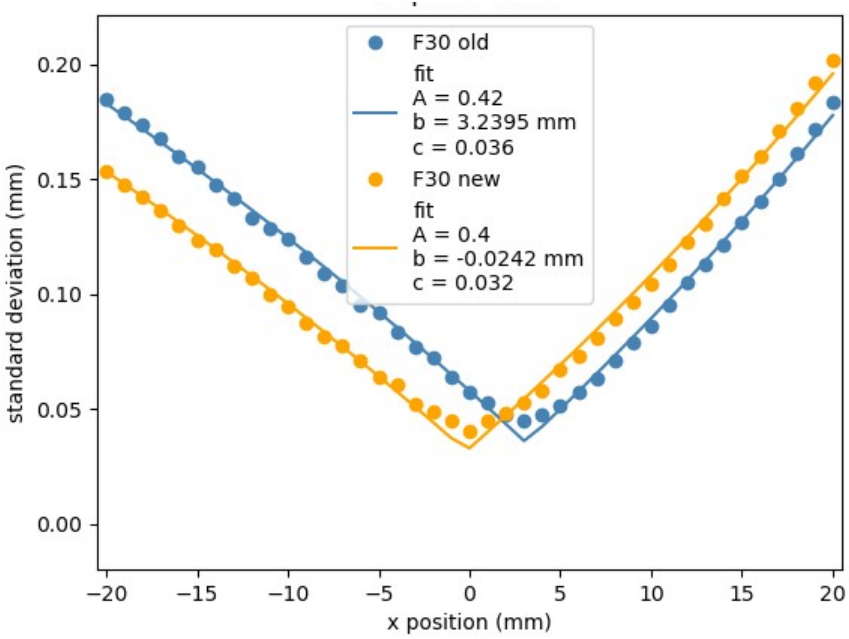
FocalLength= **180 mm**

LensRadius= 30 mm
SensorSide = 20 mm

Result

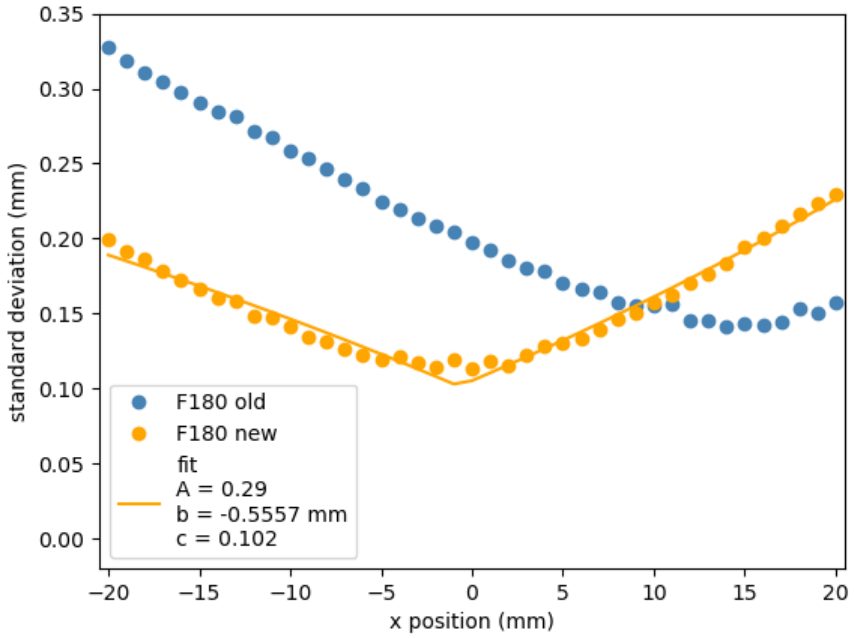
F = 30

LensDistance = 101 **- 3.29 / 1.59** mm
SensorDistance = 146 **- 3.29 / 1.59** mm



F = 180

LensDistance = 550.5 **- 16 / 1.59** mm
SensorDistance = 820 - **16 / 1.59** mm

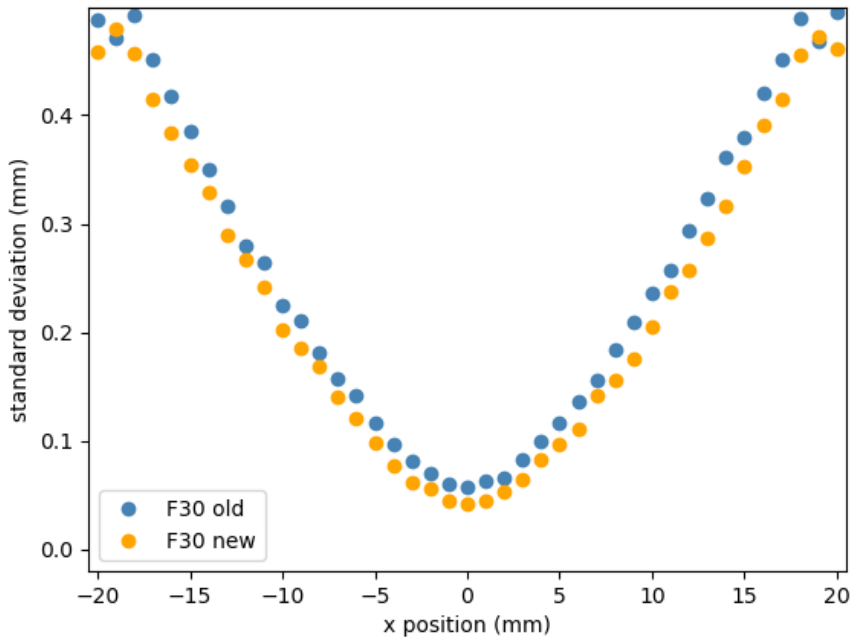


Change in coma?

Comatic aberration decreases

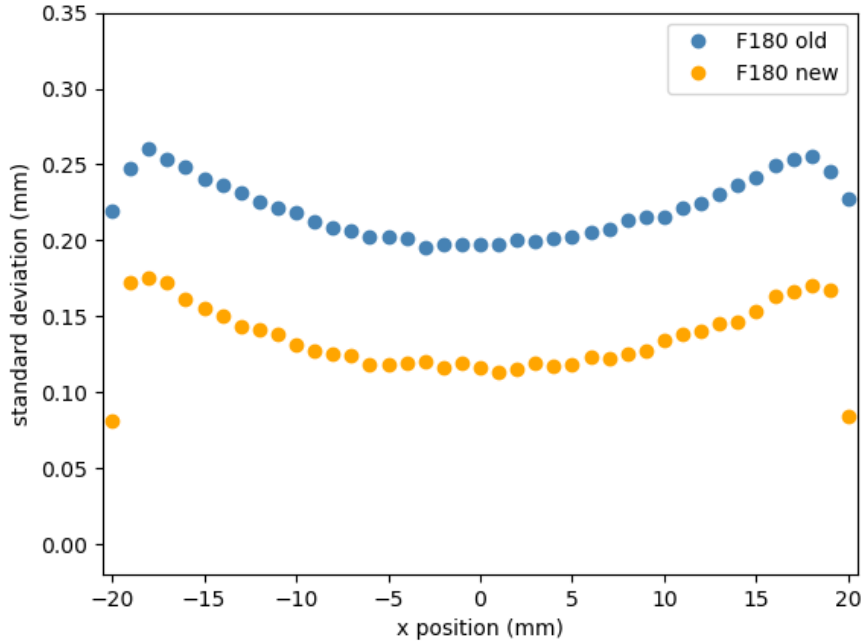
F = 30

LensDistance = 101 **- 3.29 / 1.59** mm
SensorDistance = 146 **- 3.29 / 1.59** mm



F = 180

LensDistance = 550.5 **- 16 / 1.59** mm
SensorDistance = 820 **- 16 / 1.59** mm



# of photons

of photons for the DoF

100 000 photons emitted uniformly over 4π

x_pos	mean_x	std_x	n_phot
-20	0	0.15	22.7
-19	0	0.15	23
-18	0	0.14	23.2
-17	0	0.14	23.4
-16	0	0.13	23.8
-15	0	0.12	24.1
-14	0	0.12	24.4
-13	0	0.11	24.7
-12	0	0.11	24.9
-11	0	0.1	25.2
-10	0	0.09	25.6
-9	0	0.09	25.9
-8	0	0.08	26.1
-7	0	0.08	26.5
-6	0	0.07	26.9
-5	0	0.06	27.2
-4	0	0.06	27.6
-3	0	0.05	27.9
-2	0	0.05	28.3
-1	0	0.04	28.6
0	0	0.04	29
1	0	0.04	29.5
2	0	0.05	29.8
3	0	0.05	30.2
4	0	0.06	30.7
5	0	0.07	31.1
6	0	0.07	31.6
7	0	0.08	32
8	0	0.09	32.5
9	0	0.1	32.9
10	0	0.1	33.3
11	0	0.11	33.9
12	0	0.12	34.4
13	0	0.13	34.9
14	0	0.14	35.6
15	0	0.15	36.1
16	0	0.16	36.4
17	0	0.17	37.1
18	0	0.18	37.6
19	0	0.19	38.3
20	0	0.2	38.8

← F = 30

more dependent to the position of the source emitted

F = 180 →

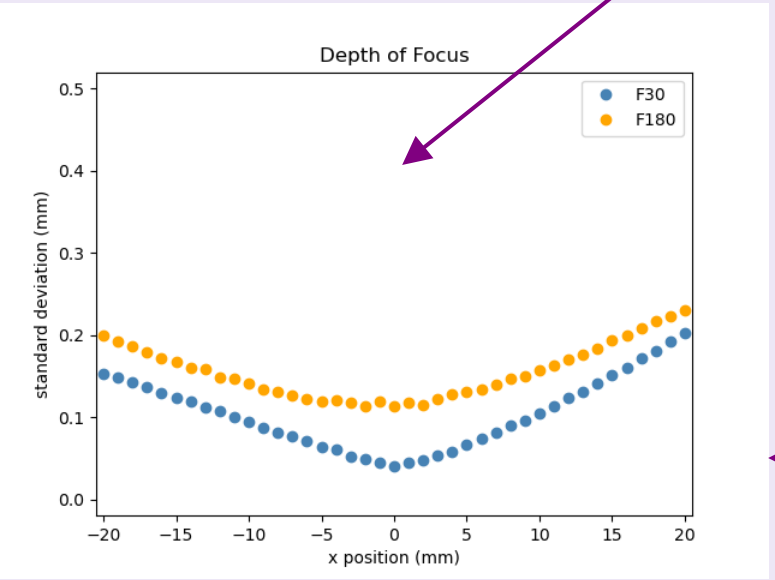
less dependent to the position of the source emitted

x_pos	mean_x	std_x	n_phot
-20	0	0.2	29.9
-19	0	0.19	29.9
-18	0	0.19	30.2
-17	0	0.18	30.1
-16	0	0.17	30.1
-15	0	0.17	30.2
-14	0	0.16	30.3
-13	0	0.16	30.4
-12	0	0.15	30.3
-11	0	0.15	30.4
-10	0	0.14	30.6
-9	0	0.13	30.6
-8	0	0.13	30.6
-7	0	0.13	30.7
-6	0	0.12	30.8
-5	0	0.12	30.9
-4	0	0.12	30.9
-3	0	0.12	31
-2	0	0.11	31
-1	0	0.12	31.3
0	0	0.11	31.2
1	0	0.12	31.3
2	0	0.12	31.3
3	0	0.12	31.4
4	0	0.13	31.4
5	0	0.13	31.6
6	0	0.13	31.6
7	0	0.14	31.8
8	0	0.15	31.8
9	0	0.15	31.8
10	0	0.16	32
11	0	0.16	32
12	0	0.17	32
13	0	0.18	32.2
14	0	0.18	32.2
15	0	0.19	32.3
16	0	0.2	32.3
17	0	0.21	32.4
18	0	0.22	32.6
19	0	0.22	32.5
20	0	0.23	32.7

Which configuration is better?

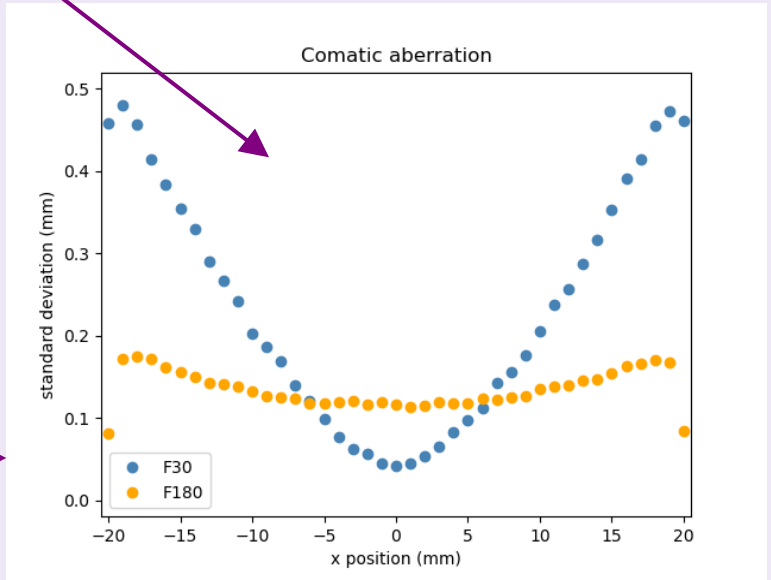
DoF is better for F30

COMA is *way* better for F180



Baseline is due to **spherical aberration**

F30 is better



In both cases the ratio R/F = 1/6

R over F

NON LO SO.

- the lower is R/F, the lower is the spherical aberration

- the higher is R/F, the higher is the number of photons.

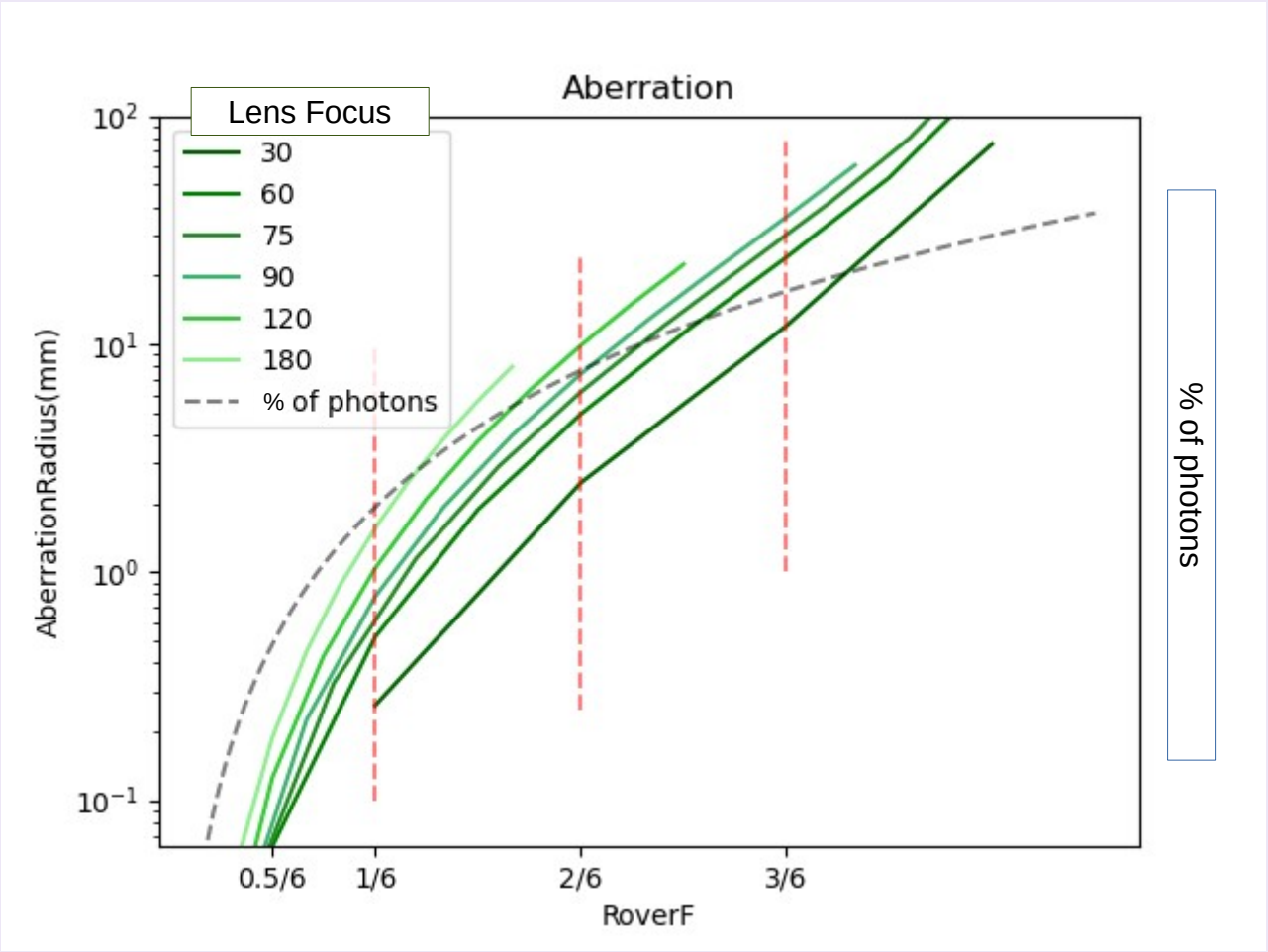
  depends on the photon efficiency of the camera.

R over F

- the lower is R/F, the lower is the spherical aberration

- the higher is R/F, the higher is the number of photons.

depends on the photon efficiency of the camera.



Comparison of PCA and Linear Fit reconstruction algorithm

Algorithm comparison

Reconstruction via PCA – Standard deviation has been used

[MeV]	10mm – 1M			10mm – 10k			5mm – 1M			5mm – 10k		
5	1.561	2.015	129%	1.634	1.815	111%	1.665	2.569	154%	1.727	2.418	140%
10	2.695	2.911	108%	2.724	2.850	105%	2.916	3.577	123%	2.944	3.415	116%
15	4.155	3.622	87%	4.293	3.805	89%	4.208	3.622	86%	4.227	3.485	82%
20	5.839	3.770	65%	5.860	3.676	63%	5.673	3.416	60%	5.775	3.561	62%
25	7.813	3.479	45%	7.848	3.444	44%	7.870	3.491	44%	7.971	3.616	45%
30	10.020	2.933	29%	10.200	3.202	31%	10.280	3.521	34%	10.410	3.605	35%
35	13.110	3.356	26%	13.140	3.303	25%	13.100	3.336	25%	13.200	3.501	27%
40	16.280	3.206	20%	16.280	3.091	19%	16.210	3.018	19%	16.250	2.999	18%
45	19.740	2.982	15%	19.770	2.952	15%	19.780	2.967	15%	19.790	2.922	15%
50	23.030	2.695	12%	23.000	2.751	12%	23.030	2.695	12%	22.990	2.688	12%

Reconstruction via LINEAR FIT – σ from gaussian fit + number of photons

	10mm – 1M				10mm – 10k				5mm – 1M				5mm – 10k			
[MeV]	μ	σ	σ/μ	# of photons	μ	σ	σ/μ	# of photons	μ	σ	σ/μ	# of photons	μ	σ	σ/μ	# of photons
5	0.34	0.09	26%	173.3	0.38	0.19	50%	174	1.11	0.1	9.01%	43.2	0.32	0.22	69%	43.6
10	1.09	0.18	17%	347.4	1.13	0.25	22%	347.4	2.31	0.14	6.06%	87.7	1.11	0.27	24%	87.7
15	2.18	0.26	12%	522.3	2.11	0.39	18%	522.3	3.9	0.2	5.13%	131.4	2.45	0.25	10%	131.4
20	3.58	0.39	11%	692.9	3.76	0.37	10%	692.9	5.9	0.29	4.92%	174.1	4.14	0.26	6%	174.1
25	5.3	0.59	11%	865.6	5.68	0.43	8%	865.6	8.22	0.38	4.62%	217.6	6.24	0.33	5%	217.6
30	7.24	0.86	12%	1033.8	7.82	0.58	7%	1033.7	10.9	0.53	4.86%	260.7	8.74	0.46	5%	260.7
35	9.32	1.24	13%	1202.9	10.27	0.83	8%	1202.9	13.93	0.68	4.88%	302.9	11.66	0.53	5%	302.9
40	11.5	1.9	17%	1366.8	13.04	1.19	9%	1367.7	17.22	0.92	5.34%	345.1	14.96	0.76	5%	345.1
45	13.45	2.95	22%	1518.5	15.77	1.53	10%	1521.8	20.41	1.47	7.2%	385.7	19.05	1.15	6%	385.6
50	14.13	4.98	35%	1573.9	18.28	2.29	13%	1595.9	1.11	0.1	9.01%	409.5	21.94	1.6	7%	407.9

Algorithm comparison

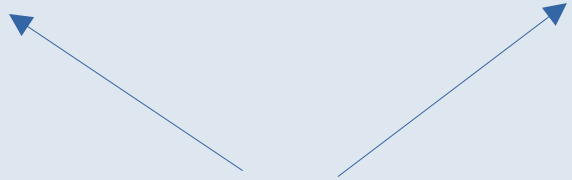
MC proton range from standard deviation

Last – first emitted photon position

	MC Geant4		
5	1.118	0.286	26%
10	1.694	0.332	20%
15	2.886	0.346	12%
20	4.510	0.412	9%
25	6.493	0.509	8%
30	8.887	0.658	7%
35	11.568	1.025	9%
40	14.645	1.253	9%
45	17.965	1.781	10%
50	21.684	1.700	8%

Last position - vertex of n-p interaction

0.344	0.005	1.5%
1.18	0.69	58%
2.423	0.104	4%
4.252	1.555	37%
6.218	1.473	24%
8.767	2.155	25%
11.196	2.177	19%
14.513	2.348	16%
17.799	2.215	12%
21.504	2.81	13%



Completely different values

Algorithm comparison

MC proton range from standard deviation

Last – first emitted photon position

Last position - vertex of n-p interaction

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Completely different values

Theoretical range

From Bethe-Bloch formula in polyvinyl-toluene

H:C = 1.1 – ρ = 1.023 g/cm²

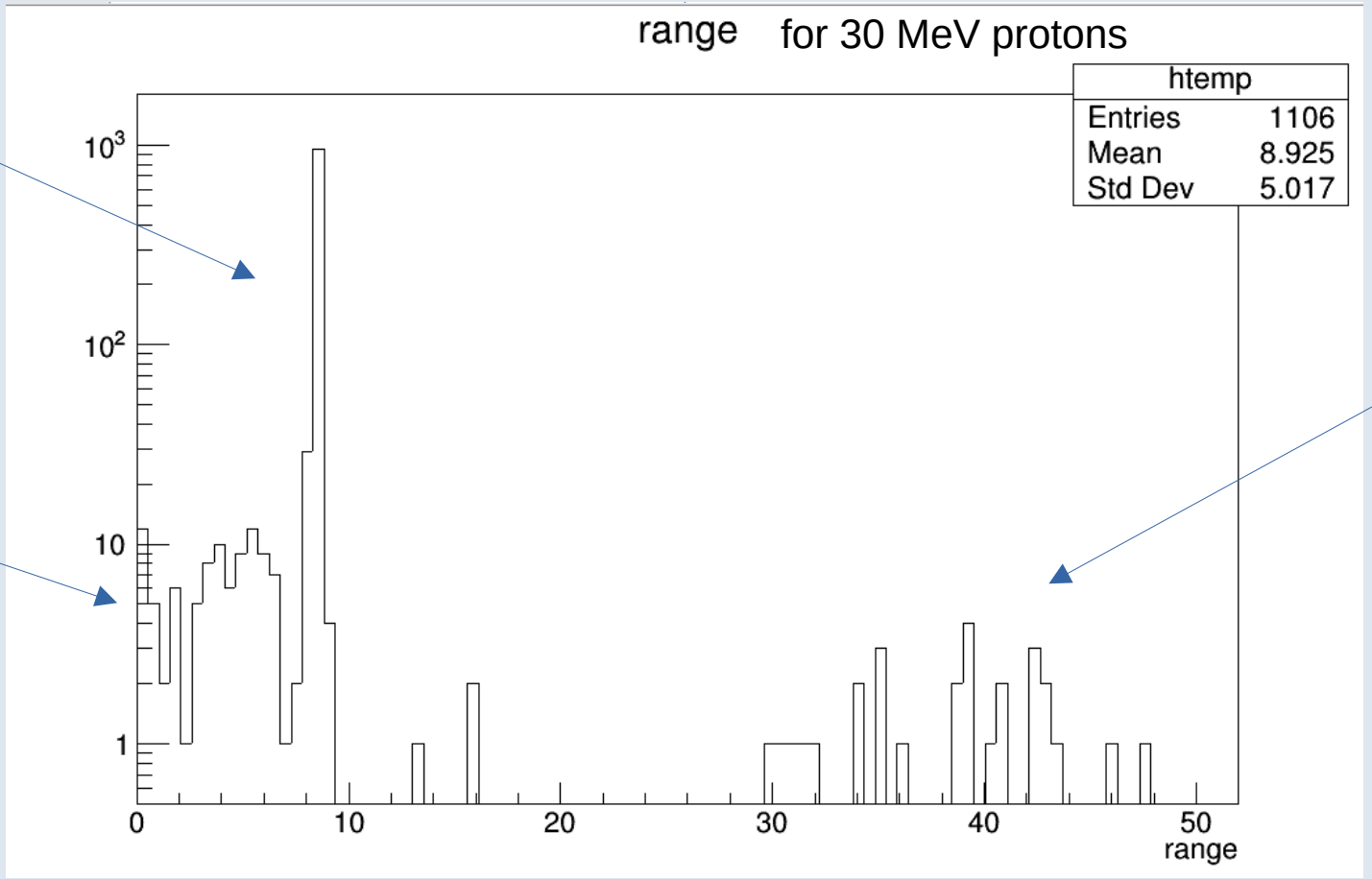
Theoretical Range		
μ	**σ**	**σ/μ**
0.344	0.005	1.45%
1.18	0.02	1.69%
2.45	0.03	1.22%
4.14	0.05	1.21%
6.23	0.08	1.28%
8.69	0.11	1.27%
11.51	0.14	1.22%
14.67	0.18	1.23%
18.16	0.22	1.21%
21.98	0.26	1.18%

Algorithm comparison

MC proton range from standard deviation

Range + straggling

Protons loose less than the full energy in the scintillator



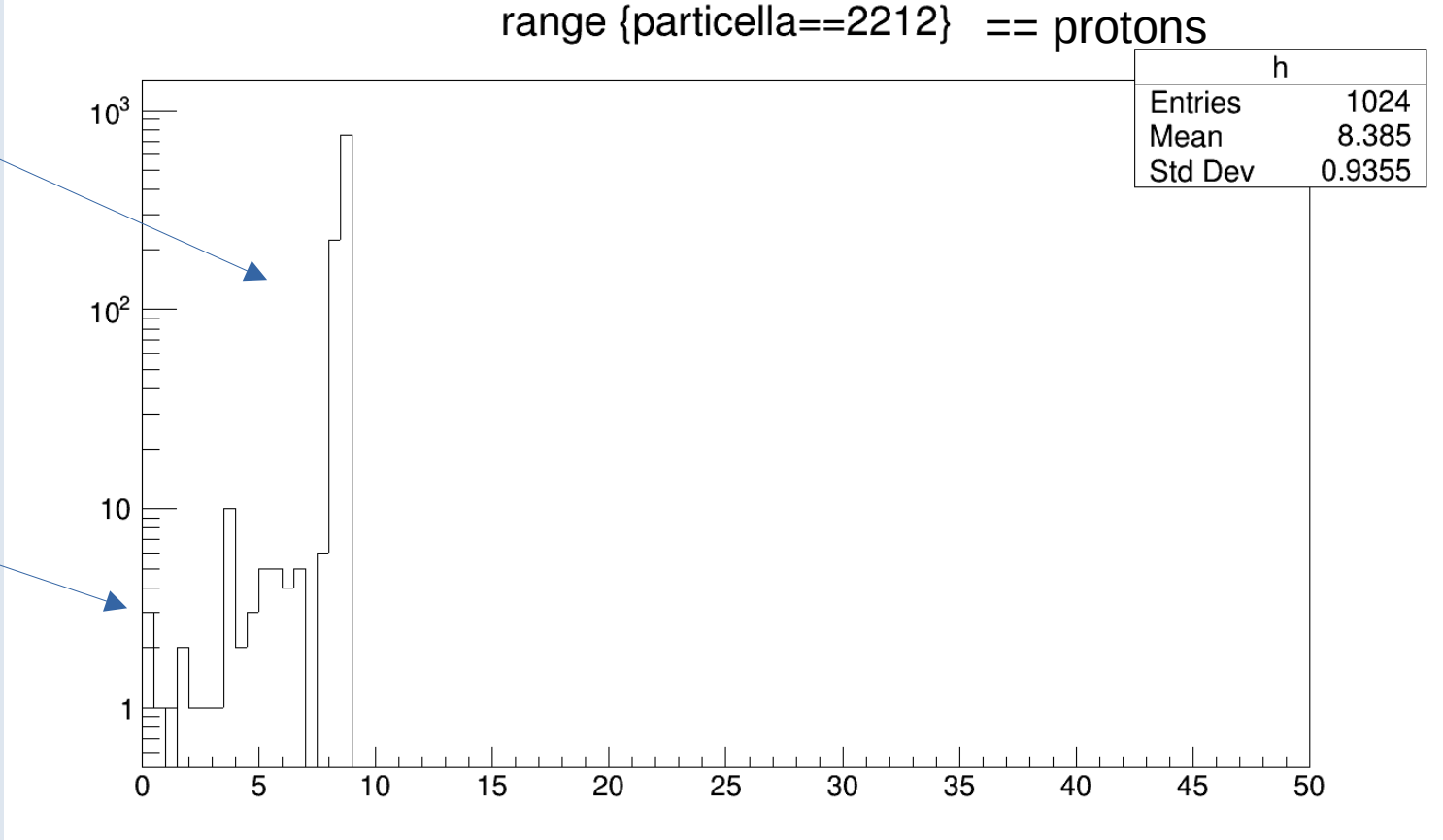
Other particles (e.g. alpha-p.cles)

Algorithm comparison

MC proton range from standard deviation

Range + straggling

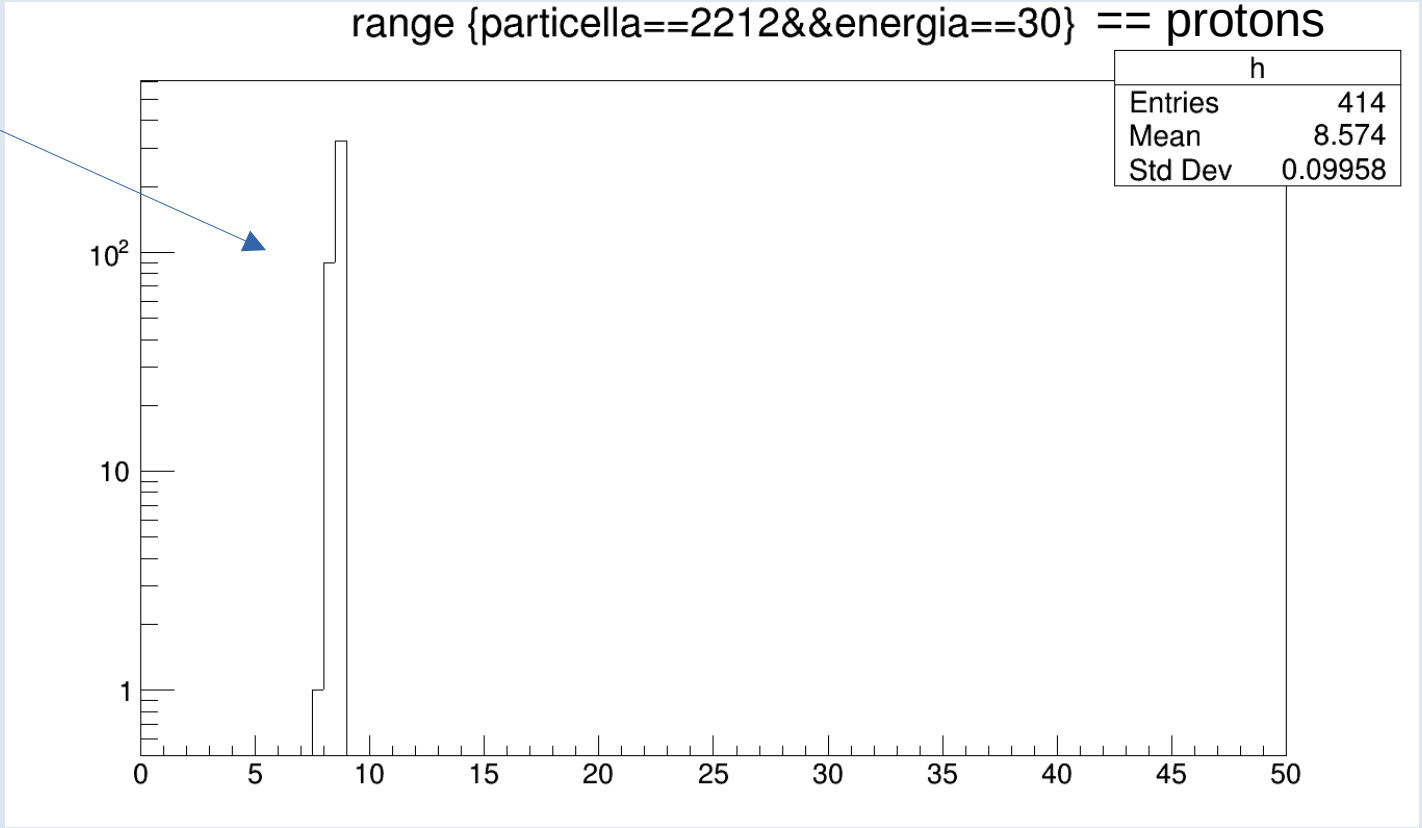
Protons loose less than the full energy in the scintillator



Algorithm comparison

MC proton range from standard deviation

Range + straggling



Algorithm comparison

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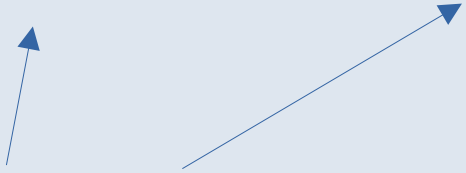

Completely different values

Theoretical range

From Bethe-Bloch formula in polyvinyl-toluene

H:C = 1.1 – ρ = 1.023 g/cm²

Theoretical Range		
μ	**σ**	**σ/μ**
0.344	0.005	1.45%
1.18	0.02	1.69%
2.45	0.03	1.22%
4.14	0.05	1.21%
6.23	0.08	1.28%
8.69	0.11	1.27%
11.51	0.14	1.22%
14.67	0.18	1.23%
18.16	0.22	1.21%
21.98	0.26	1.18%

Algorithm comparison

MC proton range from standard deviation

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6.218	1.473	24%
8.767	2.155	25%
11.196	2.177	19%
14.513	2.348	16%
17.799	2.215	12%
21.504	2.81	13%

Completely different values

MC range from gaussian fit with ROOT

	μ	σ	σ/μ
5	0.347	0.004	1.15%
10	1.18	0.01	0.85%
15	2.45	0.03	1.22%
20	4.12	0.04	0.97%
25	6.16	0.08	1.3%
30	8.58	0.09	1.05%
35	11.34	0.13	1.15%
40	14.45	0.17	1.18%
45	17.86	0.19	1.06%
50	21.16	0.21	0.99%

Gaussian fit σ / μ

Theoretical range

From Bethe-Bloch formula in polyvinyl-toluene

H:C = 1.1 – ρ = 1.023 g/cm²

Theoretical Range		
μ	**σ**	**σ/μ**
0.344	0.005	1.45%
1.18	0.02	1.69%
2.45	0.03	1.22%
4.14	0.05	1.21%
6.23	0.08	1.28%
8.69	0.11	1.27%
11.51	0.14	1.22%
14.67	0.18	1.23%
18.16	0.22	1.21%
21.98	0.26	1.18%

The End