LMA simulations

06/12/2022

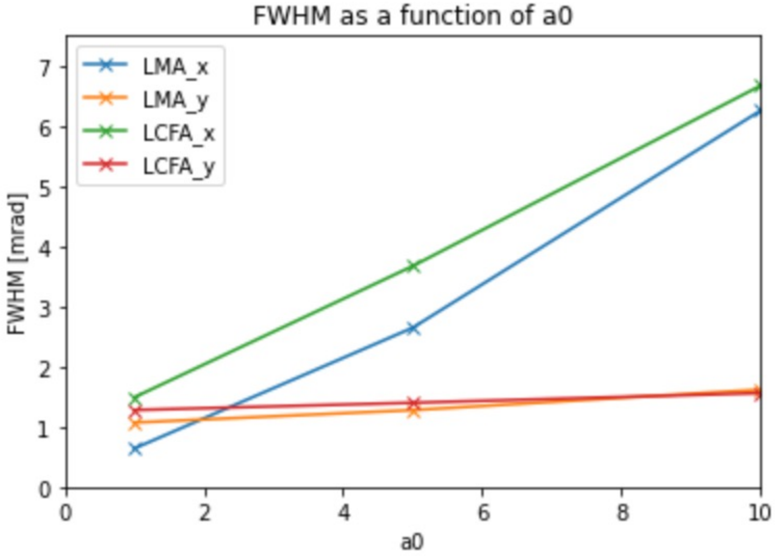
Current status

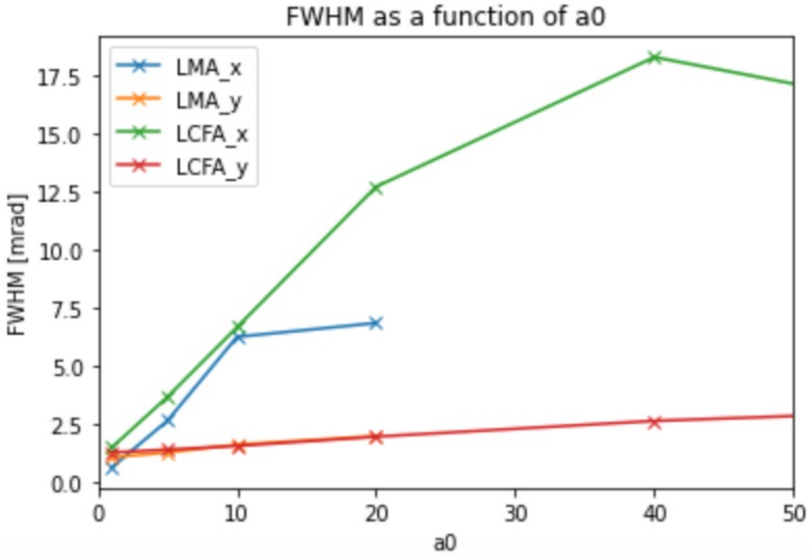
- Understood that model independent formula from Blackburn's paper is not appropriate for profiler
- Proposed idea – generate a hypertable of widths as a function of the parameter space (nominal a_0, electron energy, beam and laser sizes…)
- Parameter space is **<u>very</u>** large and would require lots of simulations
- Combine with an interpolative method?
- Working on implementing a looping mechanism within Ptarmigan (similar to Geant4 macro looping) to make parameter exploration easier -> currently, only looping over multiple a_0 values possible

Intermediate studies

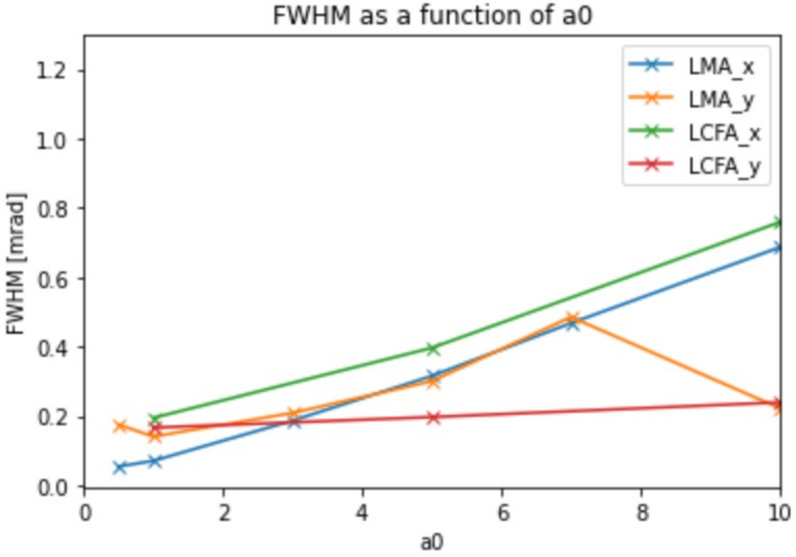
Thanks to Elias for producing these plots!

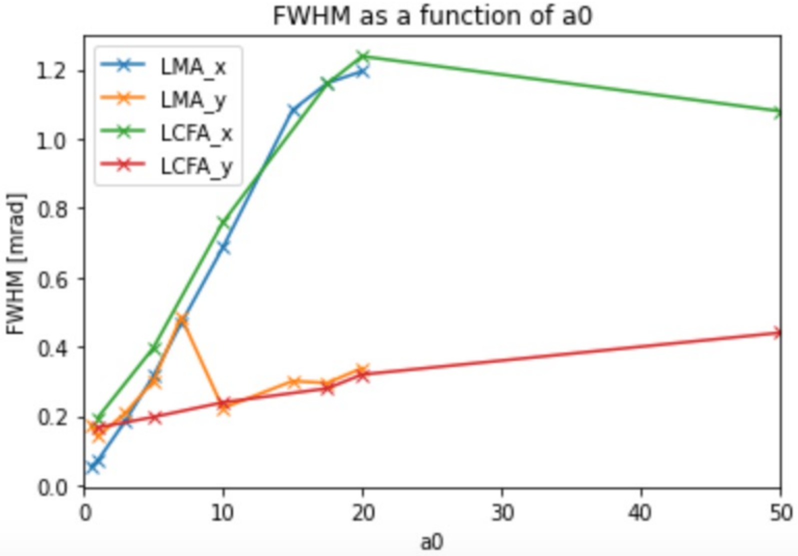
10 GeV



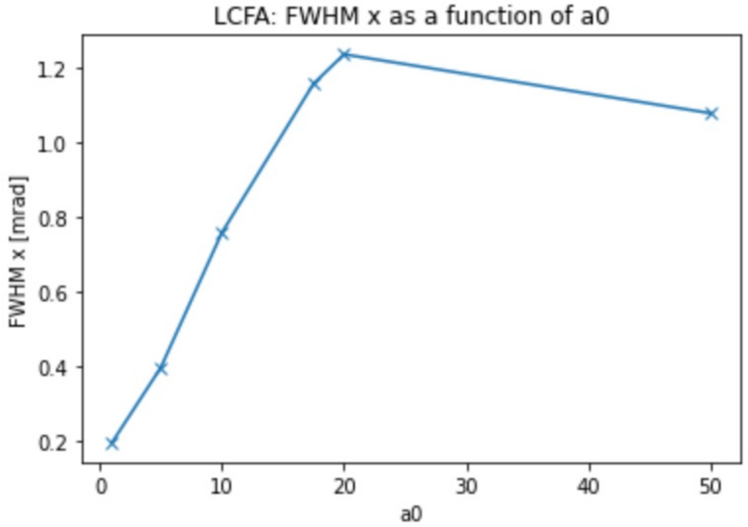


1 GeV





10 GeV



Ptarmigan updates

Changelog

v1.0.0

2022-12-01

Added:

- Classical radiation reaction.
- Choice of laser temporal envelope.
- Range cuts to distribution output.
- More detailed naming of FITS output files.

Fixed:

- Upgraded to mpi v0.6.
- Compile error for HDF5 versions < 1.10.
- Incorrect unit conversion.

Removed:

- Requirement to specify beam radius (default is zero).

v0.11.3

Currently installed version

2022-07-25

Things to address

- Tight deadline for TDR (before Christmas holidays)
- What are the most critical results needed for the TDR (other investigations can be done after)
- Profiler can measure the distribution widths parallel and perpendicular to polarisation axis – extraction of the peak/nominal a_0 is the next stage

- One possibility, a_0 scan for a pencil beam in range 0.5 to 100.
    - Can an interpolation of the scan correctly predict the nominal/peak a_0 for a chosen a_0?
    - Effect of beam/laser in estimating a_0 from a LUXE-like simulation

LMA simulations

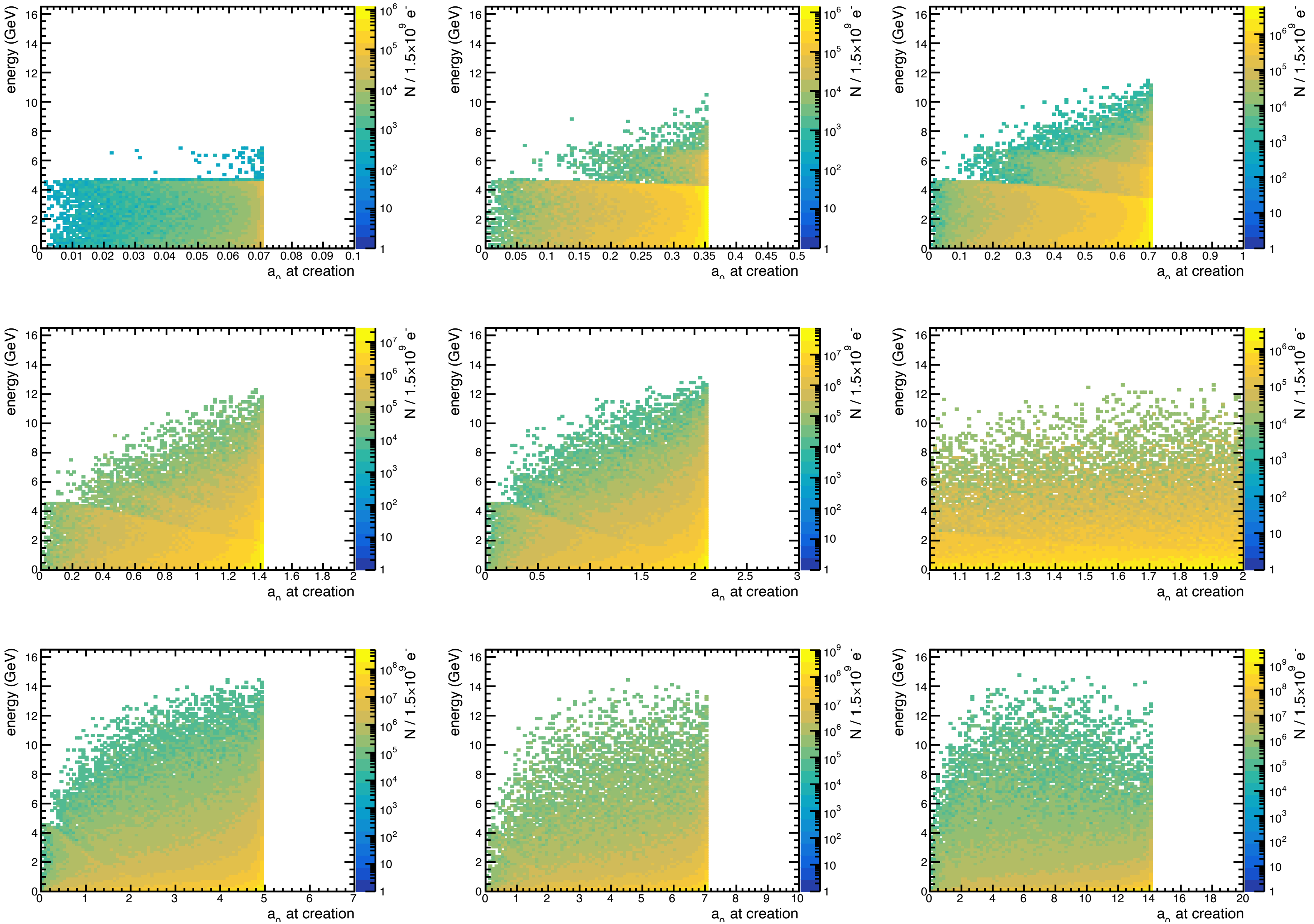
02/11/2022

Pencil beam tests

- Focused laser:
  - $w_0 = 25$ μm
  - $E_L = 1.2$ J
  - $\lambda = 800$ nm
  - linearly polarised

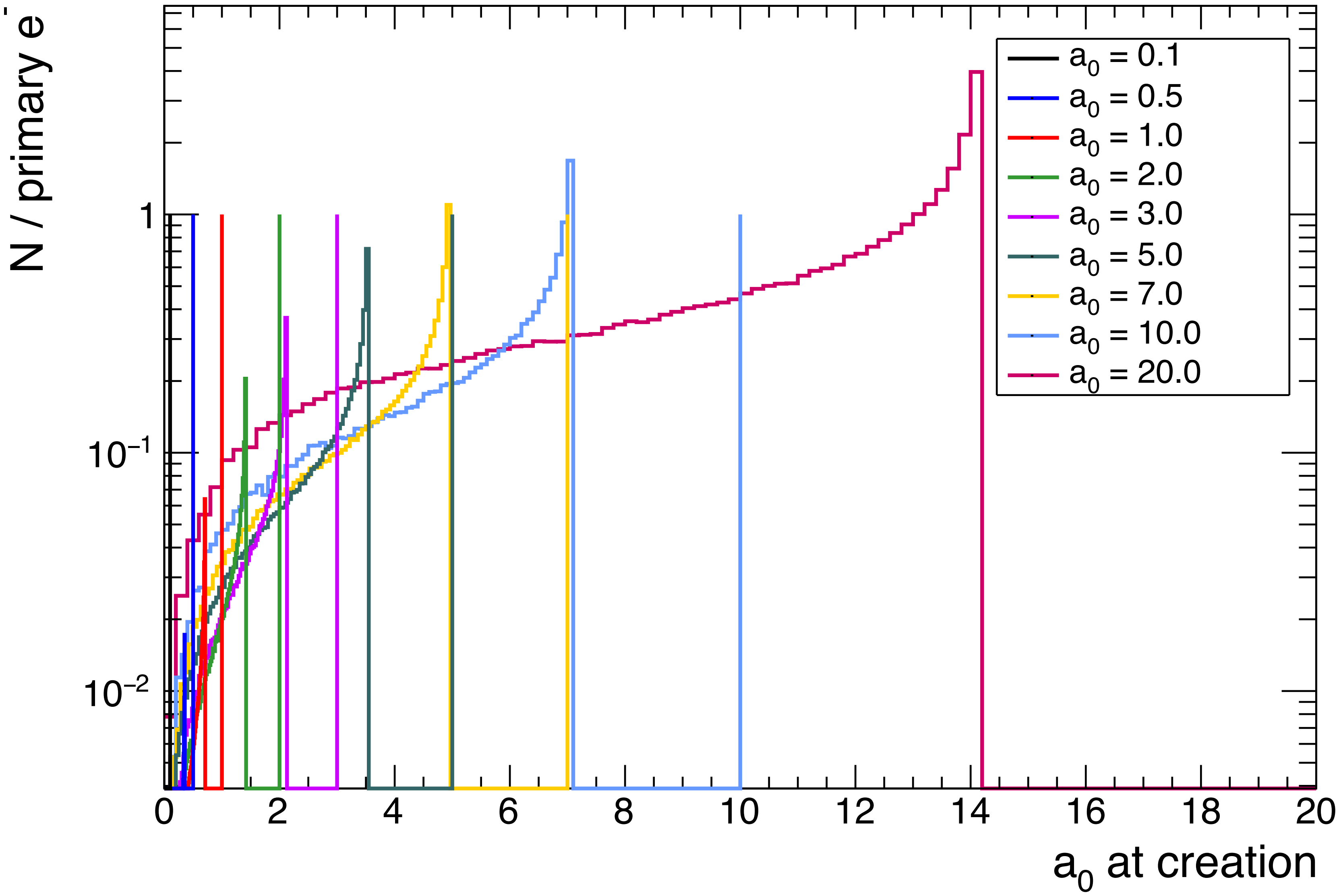
- Electron beam:
  - Pencil beam
  - $E = 16.5$ GeV
  - $r = 0.1$ μm
  - $\Delta z = 0.1$ μm
  - $\Theta_{rms} = 8.672$ μrad
  - $\varpi = 0°$

a_0 at creation vs energy

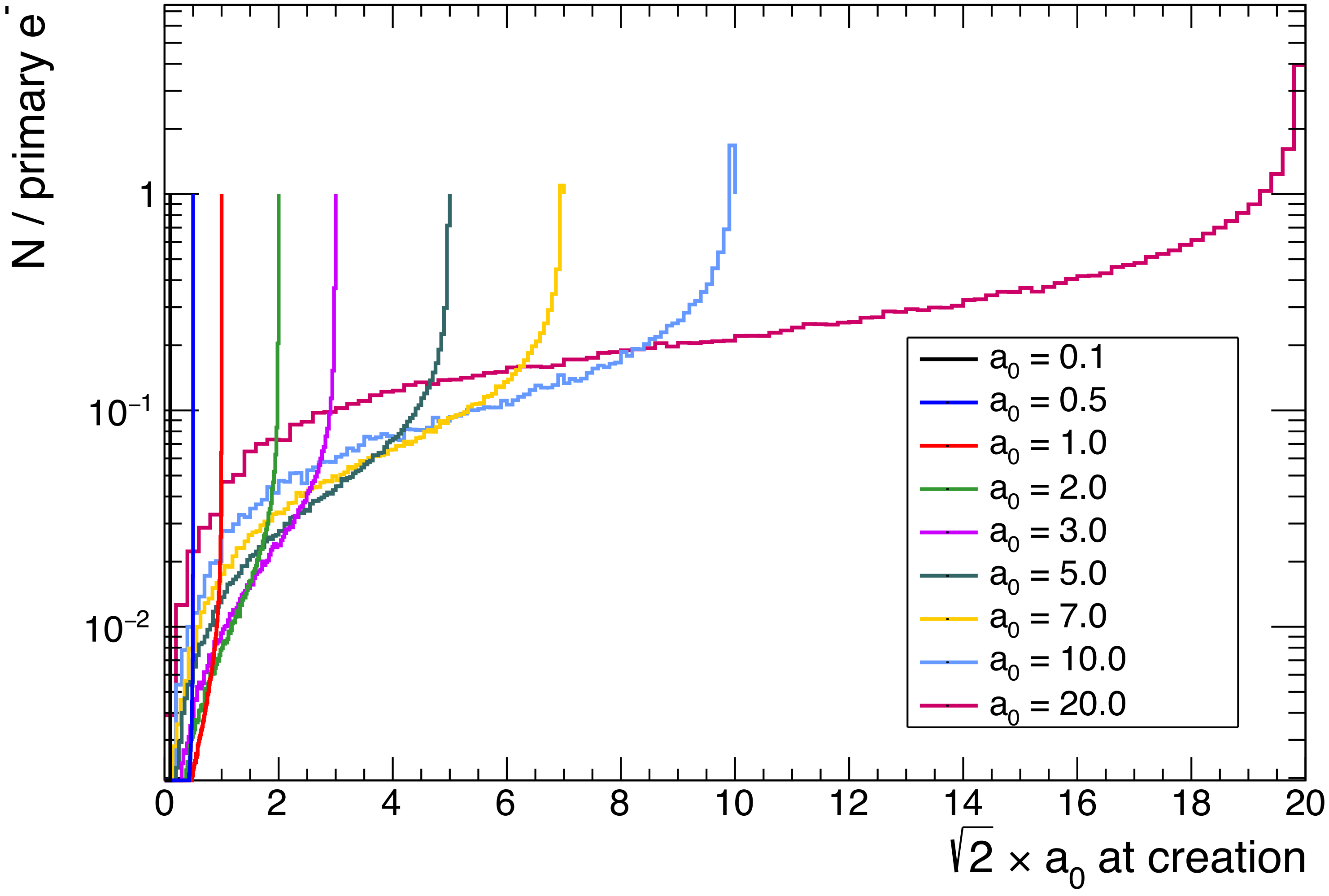


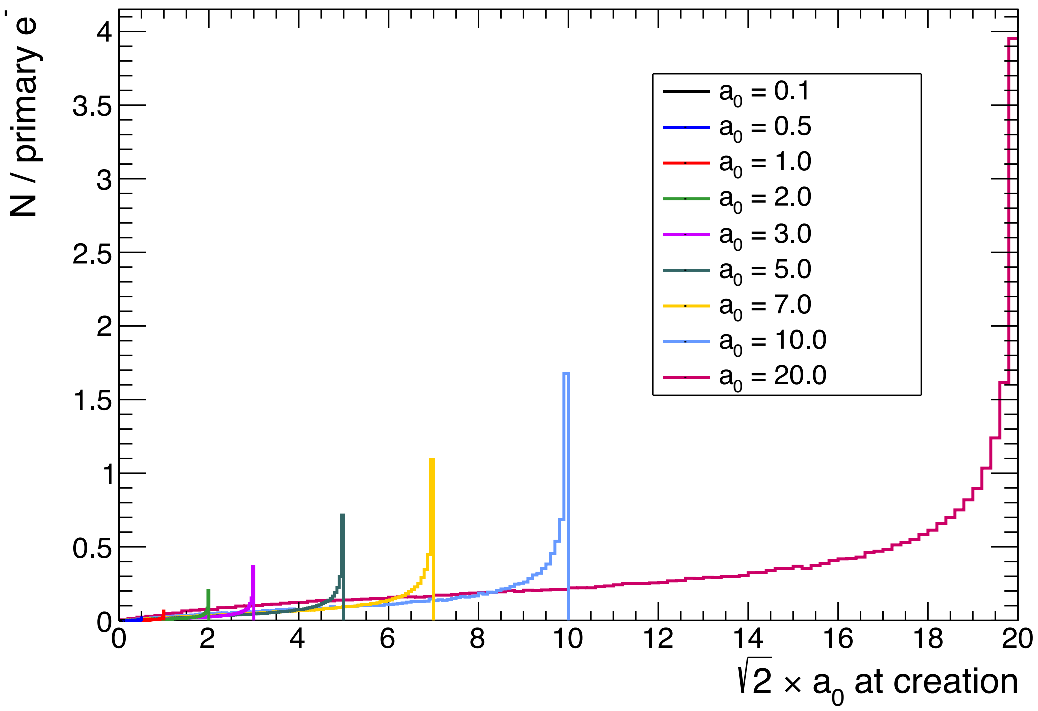
- Appearance of Compton harmonics as contours
- Broadening of harmonics due to focusing can be attributed to electrons seeing a range of a_0 values

a_0 at creation

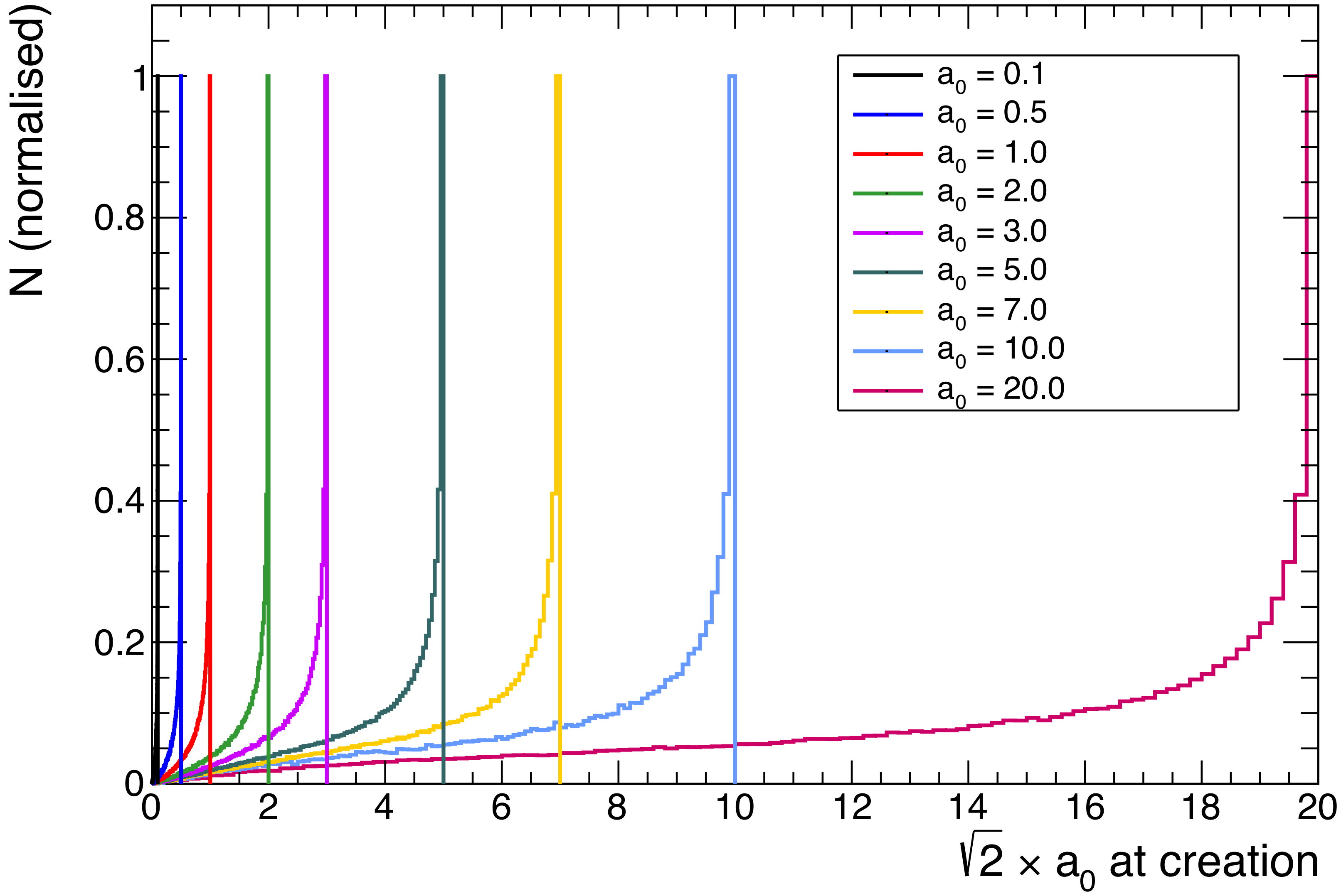


Scaled a_0 at creation





Scaled a_0 at creation

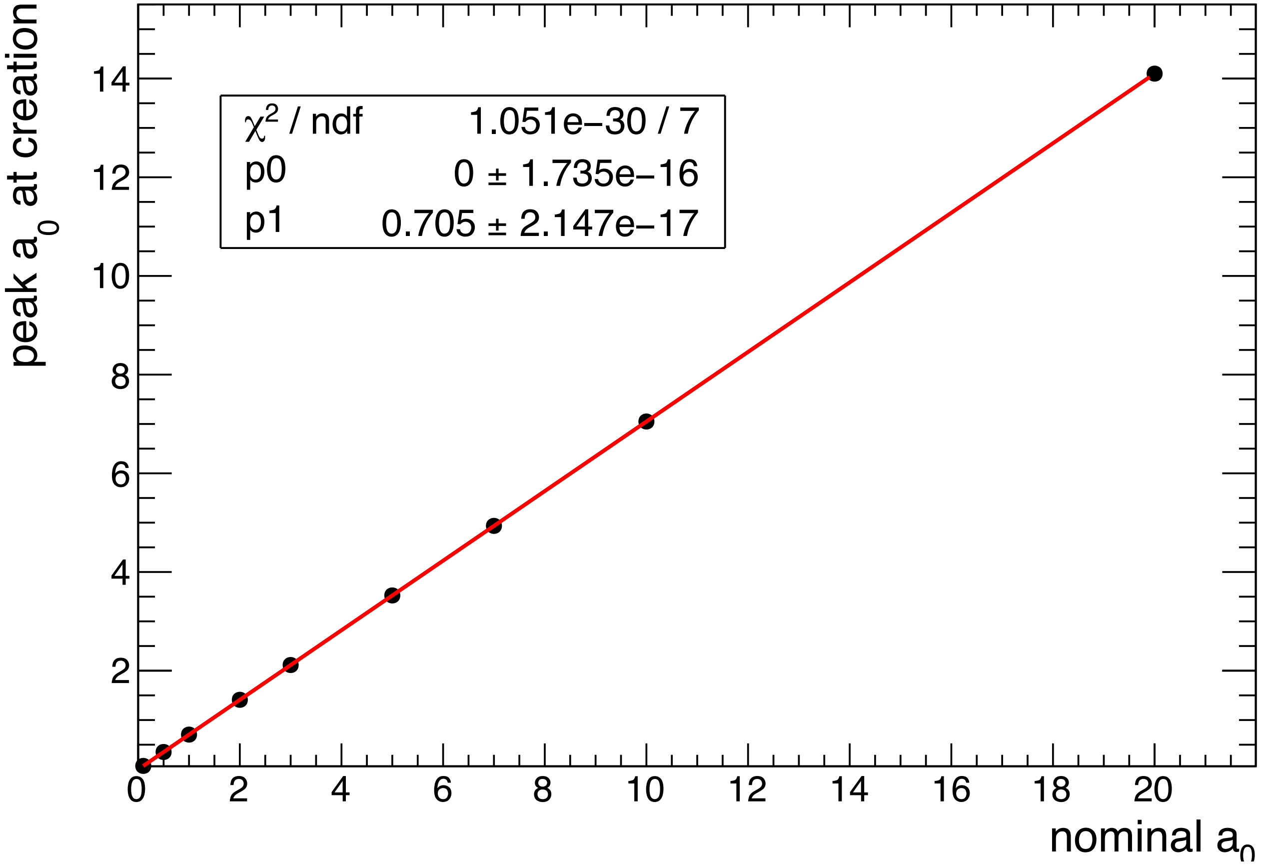


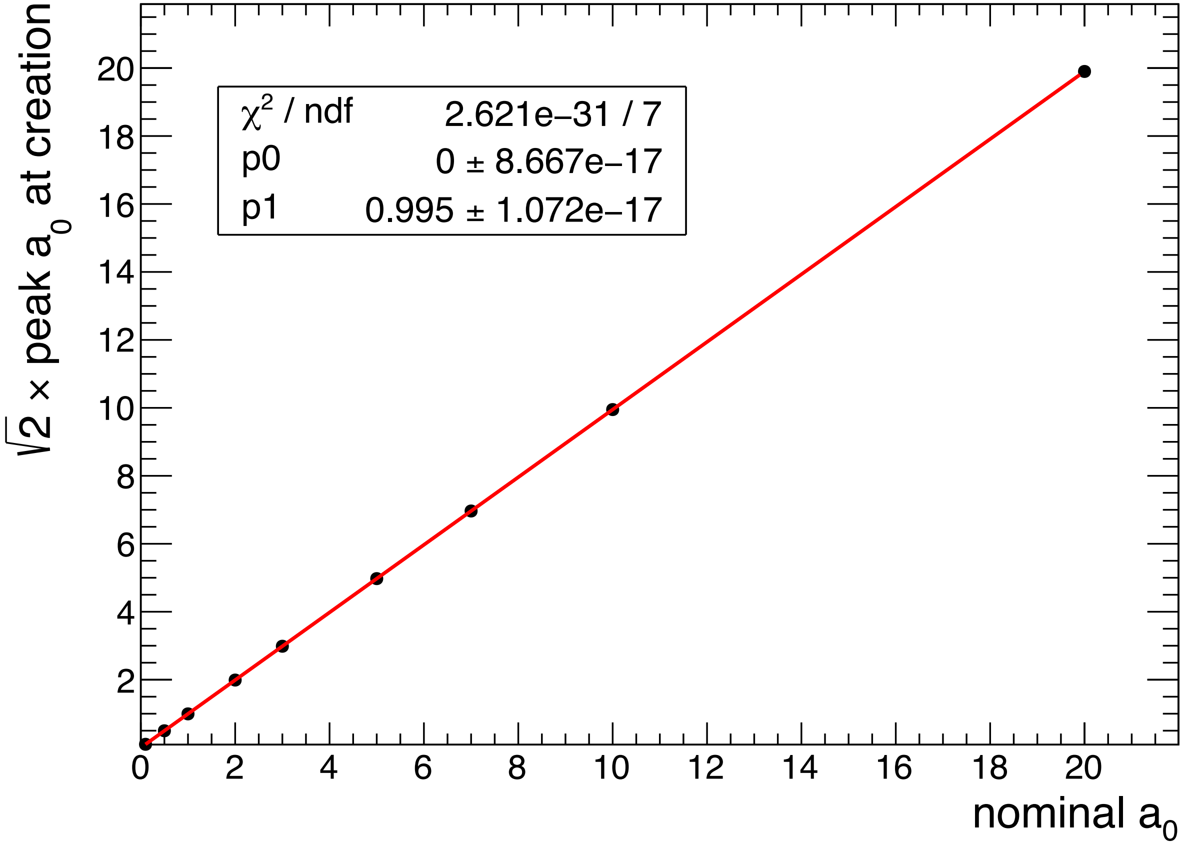
- a_0 at creation is saved as a payload for each Compton photon
- Represents the *effective* a_0 during the interaction of the electron and background field
- Square effective normalised intensity , a_{eff}^2 , for plane wave and focused laser contains a ςa_0^2 term where

$$\varsigma = \begin{cases} 1 & CP \\ \frac{1}{2} & LP \end{cases}$$

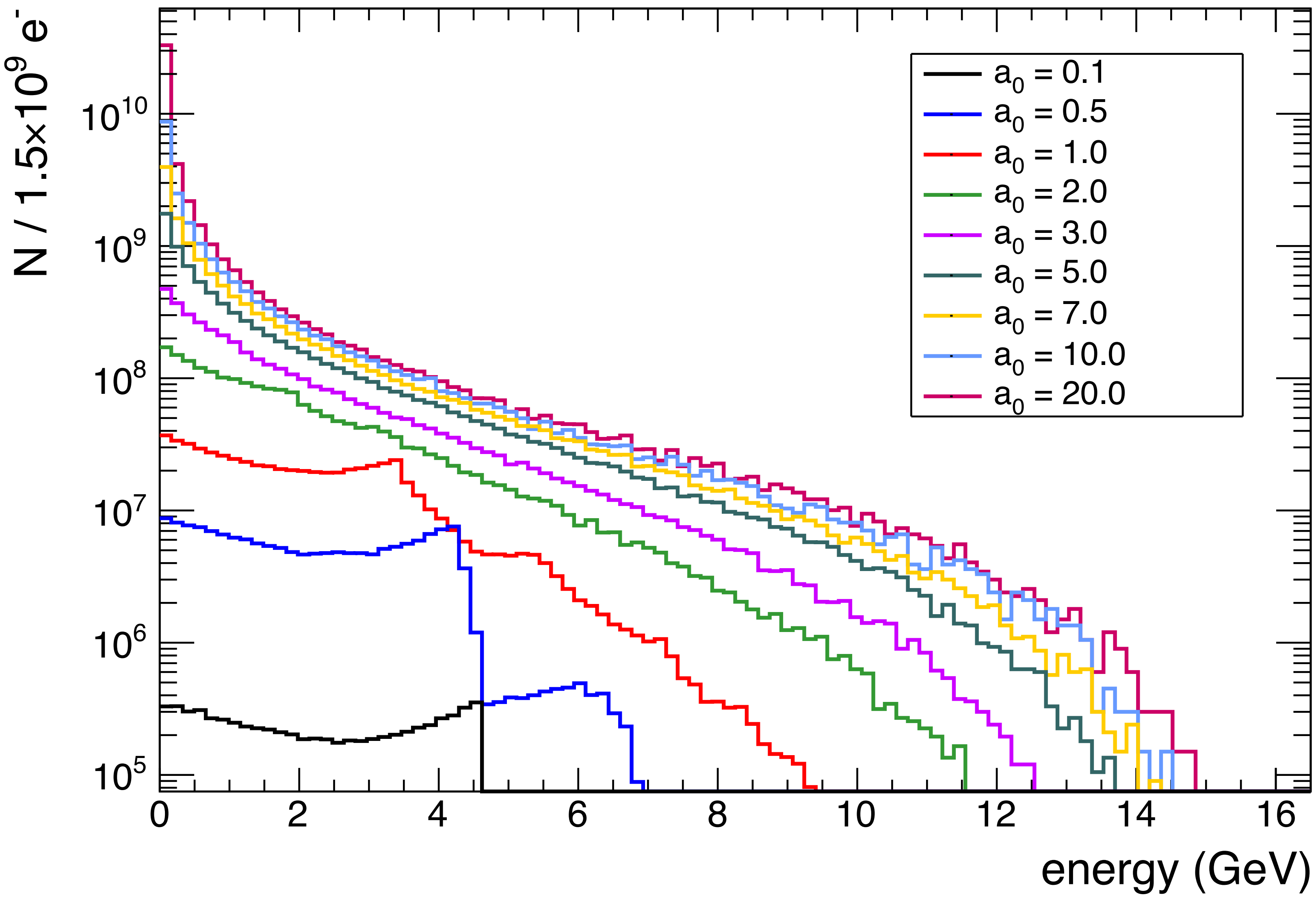
- Accounting for polarisation, peak a_0 at creation agrees with nominal a_0
- Does this mean linear polarisation inherently limits maximum a_0 that electron sees?

Peak (modal) a_0 at creation



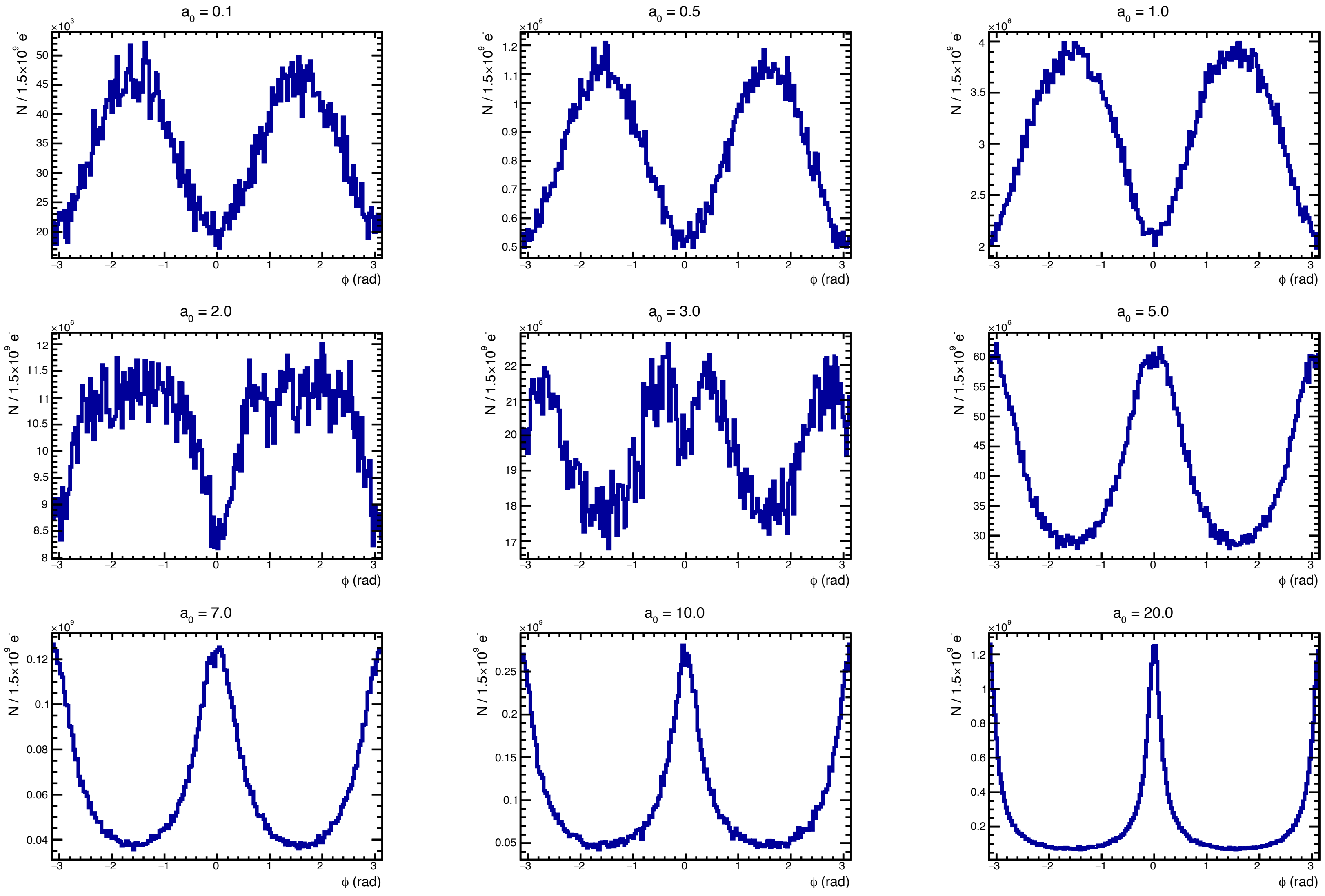


Energy



N / 1.5×10^9 e^-
10^10
10^9
10^8
10^7
10^6
10^5
0
2
4
6
8
10
12
14
16
energy (GeV)
a0 = 0.1
a0 = 0.5
a0 = 1.0
a0 = 2.0
a0 = 3.0
a0 = 5.0
a0 = 7.0
a0 = 10.0
a0 = 20.0

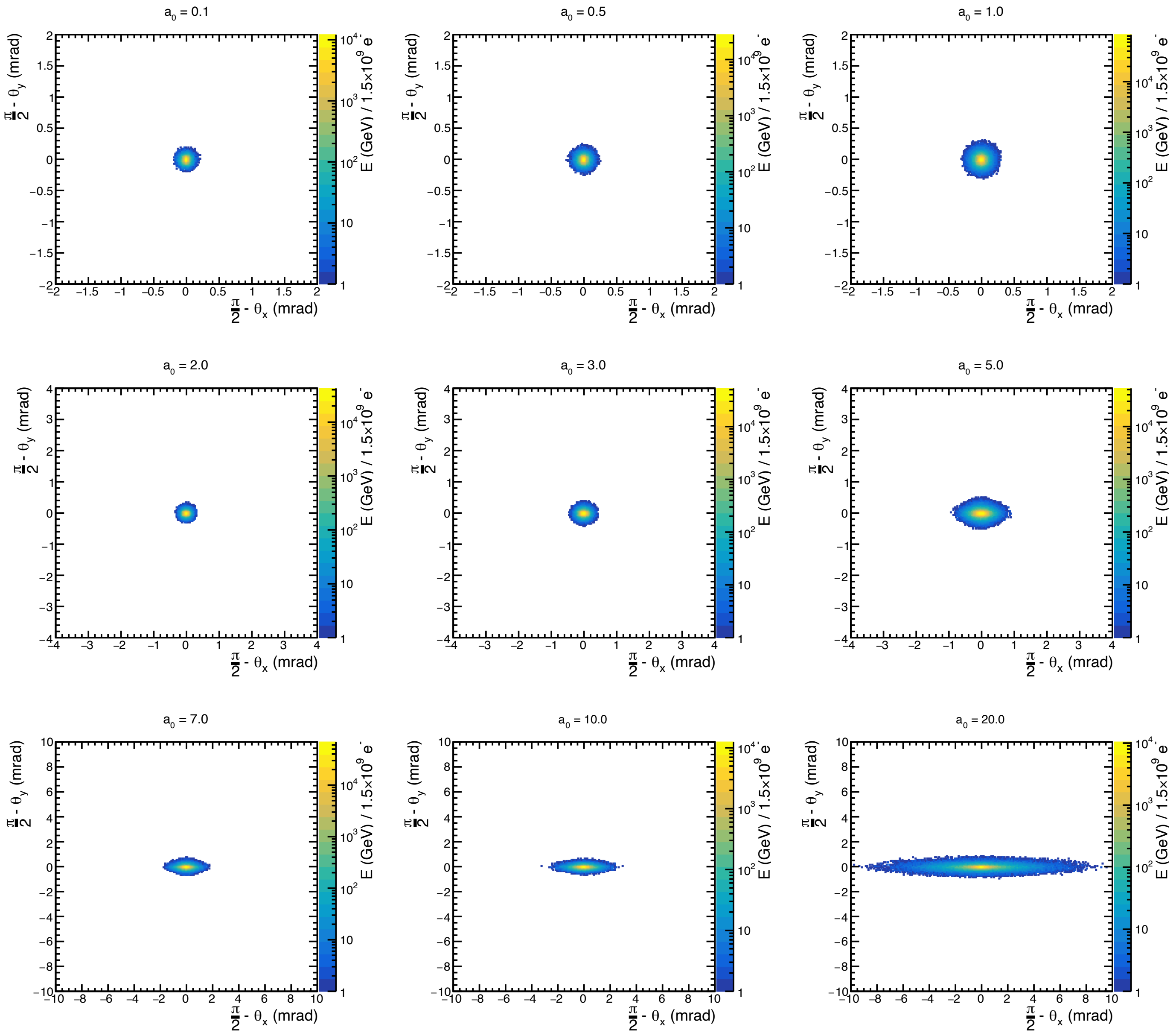
Azimuthal angle distribution



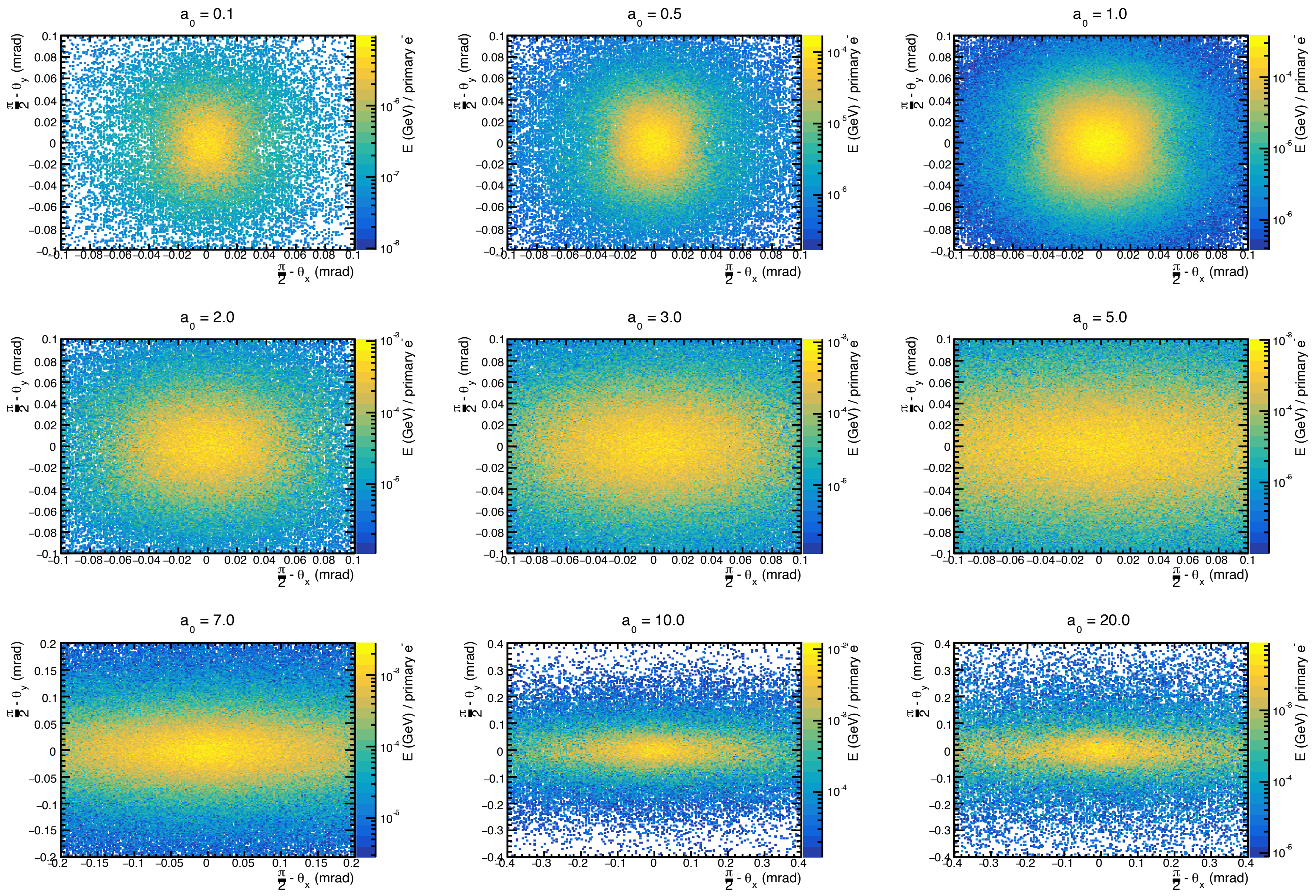
- Azimuthal distribution is caused by the linear polarisation
- Circular polarisation has flat, uniform distribution
- For low intensity, shape given by

$$N \propto 1 - \frac{1}{2}\cos^2\phi$$

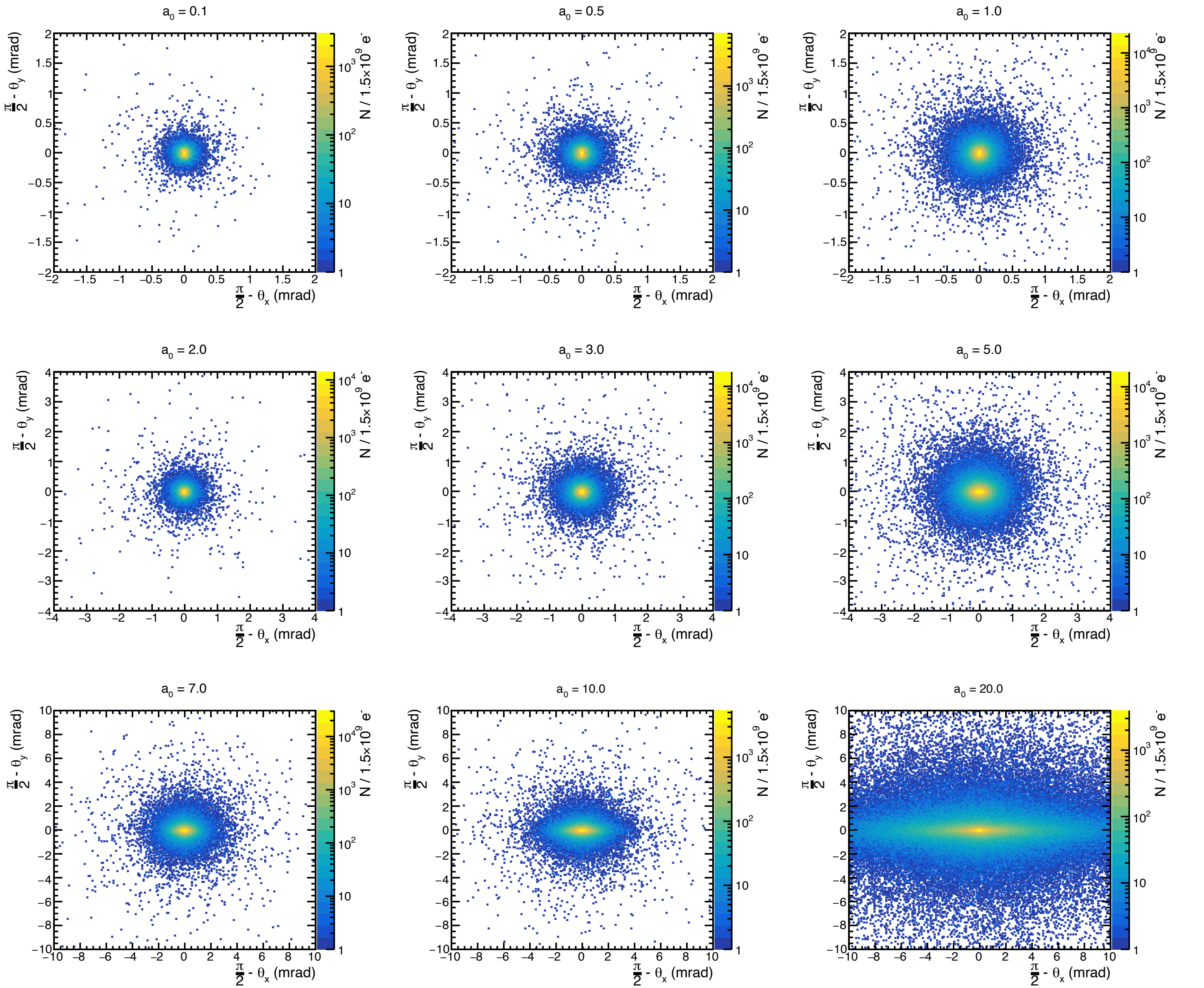
Energy weighted angular distributions



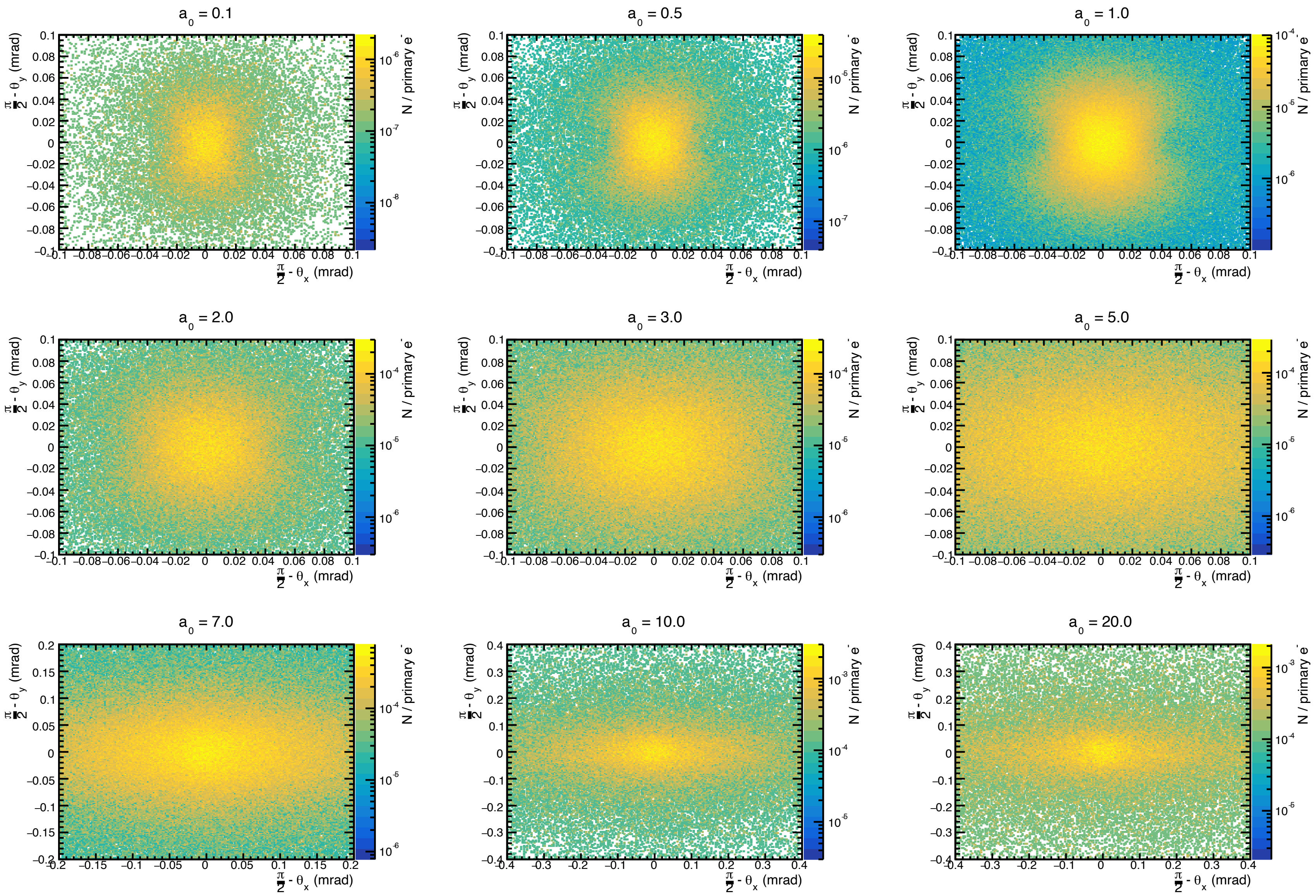
Energy weighted angular distribution (zoom)



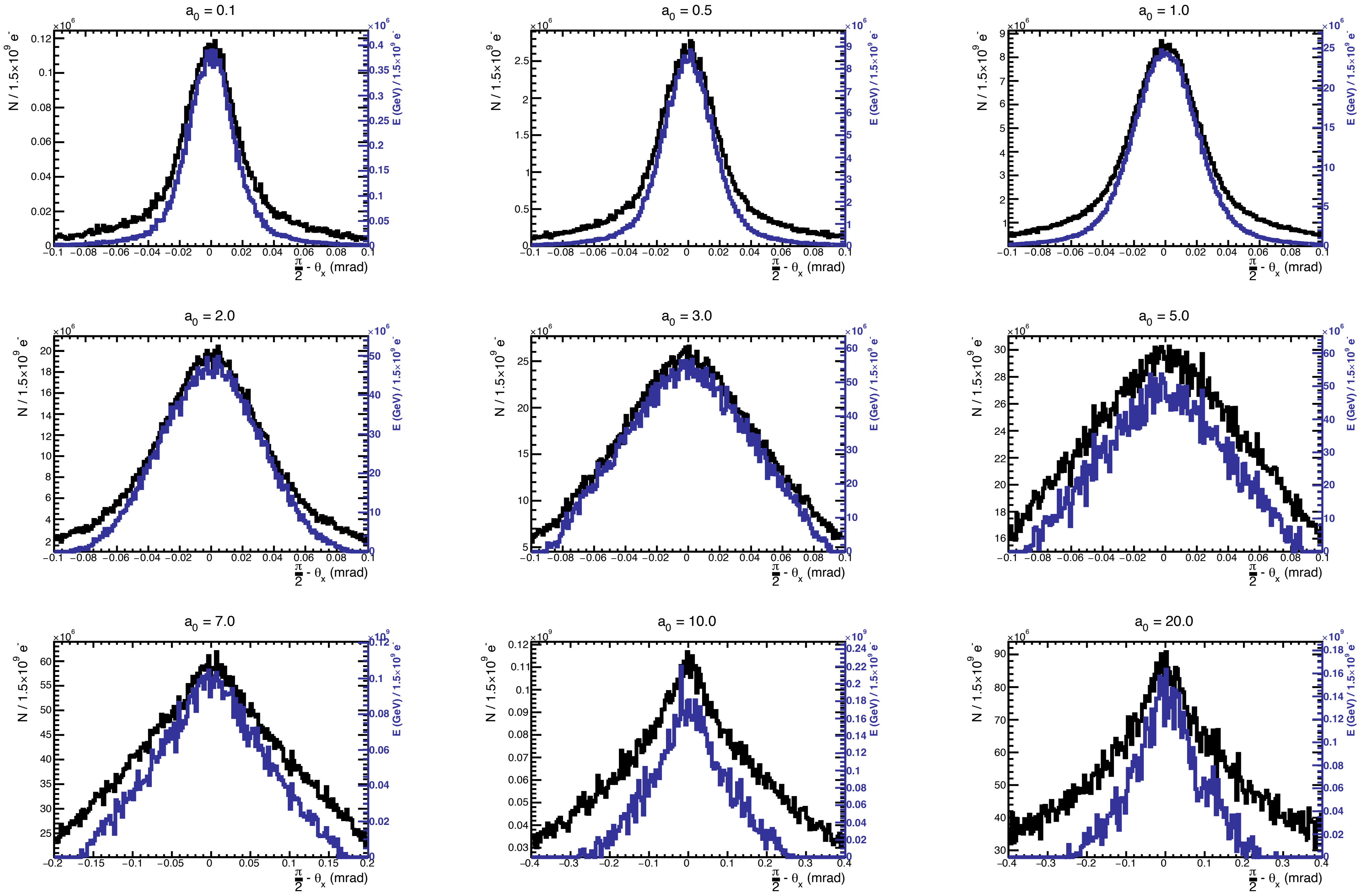
Number weighted angular distributions



Number weighted angular distributions (zoom)

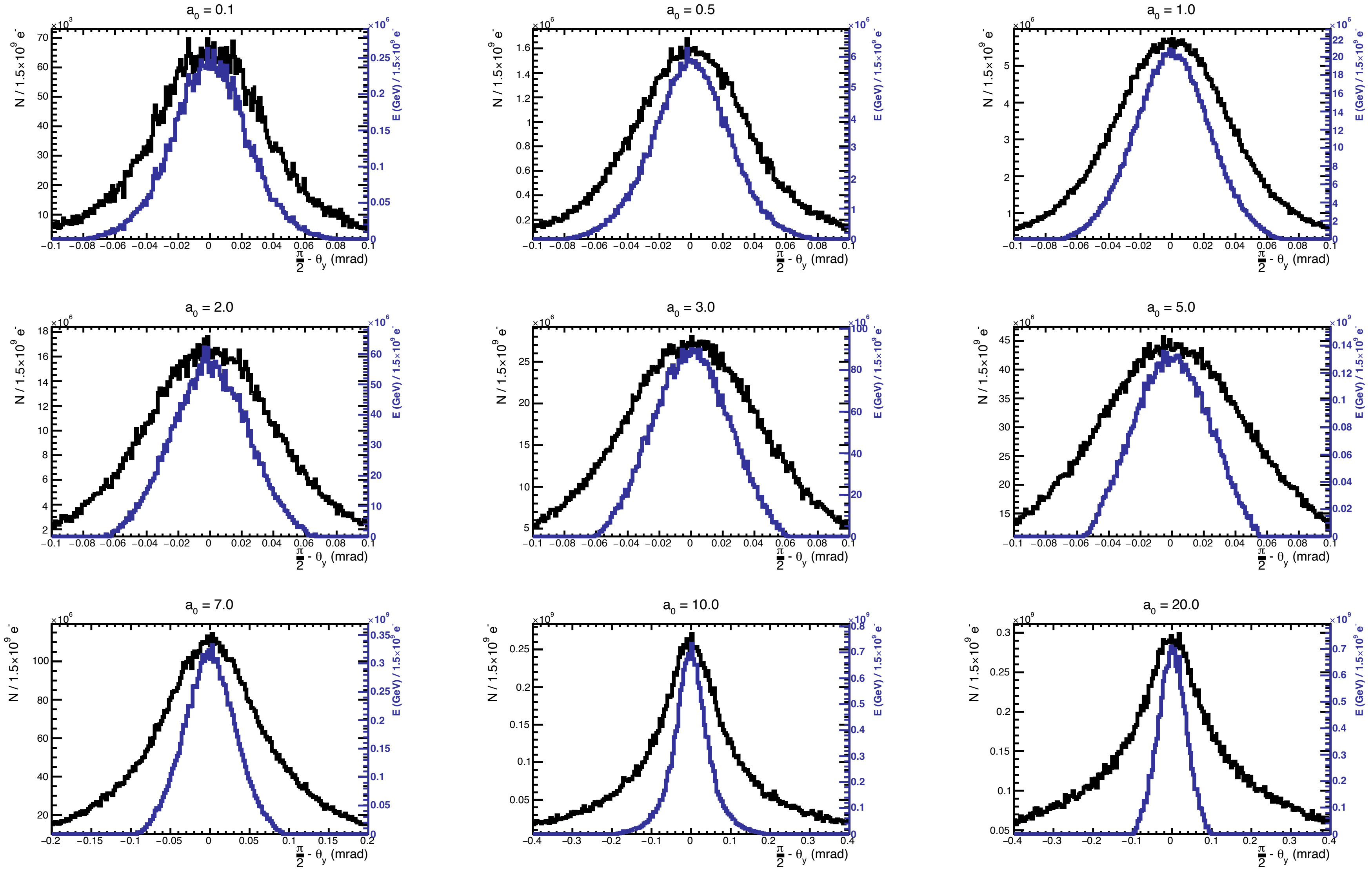


Co
po



a0 = 0.1
a0 = 0.5
a0 = 1.0
a0 = 2.0
a0 = 3.0
a0 = 5.0
a0 = 7.0
a0 = 10.0
a0 = 20.0
N / 1.5×10^9 e^-
E (GeV) / 1.5×10^9 e^-
π/2 - θx (mrad)

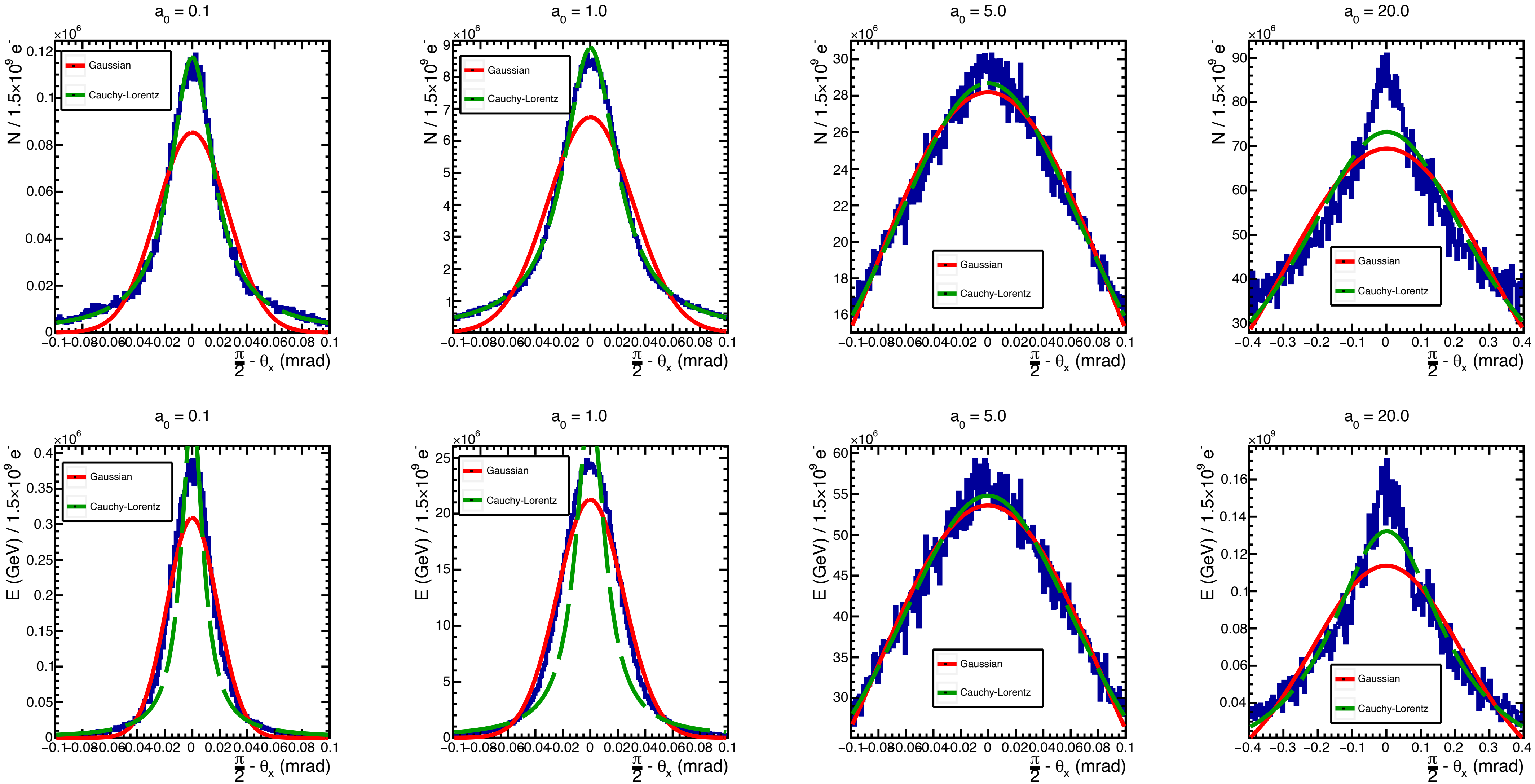
Comparison of weightings – transverse to polarisation axis (zoom)



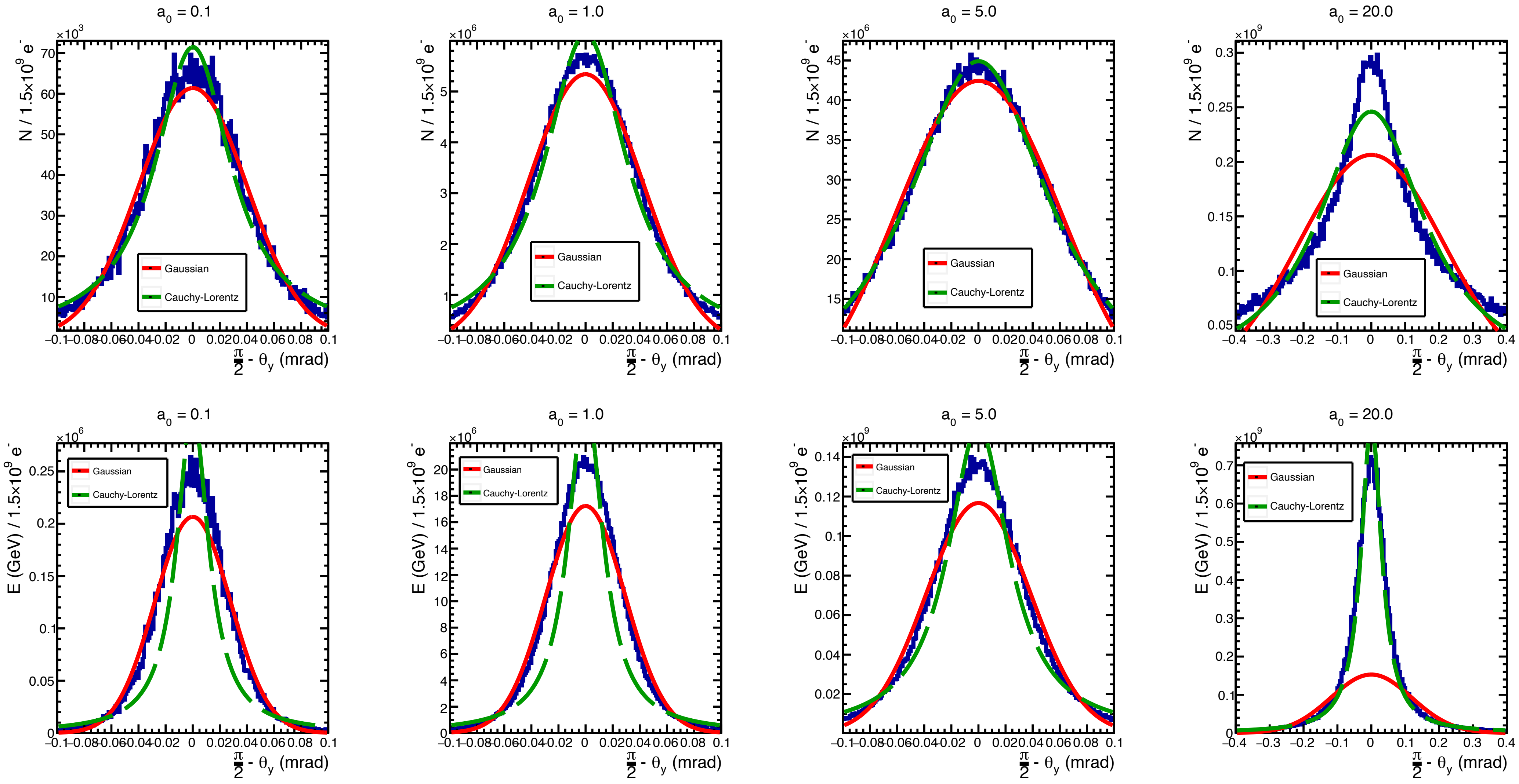
Inference of laser intensity

- Model independent inference of laser intensity
$$a_0^{\{inf\}} = 4\sqrt{2}\langle\gamma_i\rangle\langle\gamma_f\rangle(\sigma_\parallel^2 - \sigma_\perp^2)$$
- Based on (energy weighted) radiation profile from Larmor formula
- Assumes pulse envelope of laser is Gaussian
- $\sigma_\parallel^2, \sigma_\perp^2$ are the parallel and transverse variances of the profile
- Not defined for a true Cauchy-Lorentz distribution (or any moment above zeroth order)
- A truncated Cauchy-Lorentz distribution does have a meaningful variance $\int_{-L}^{L} dz\, z^2 \left[1 + \left(\frac{z}{\Gamma}\right)^2\right]^{-1} = 2\Gamma^2 \left(\mathrm{L} - \Gamma\,\mathrm{atan}\,\frac{L}{\Gamma}\right)$

Fitting angular distribution – parallel to polarisation axis



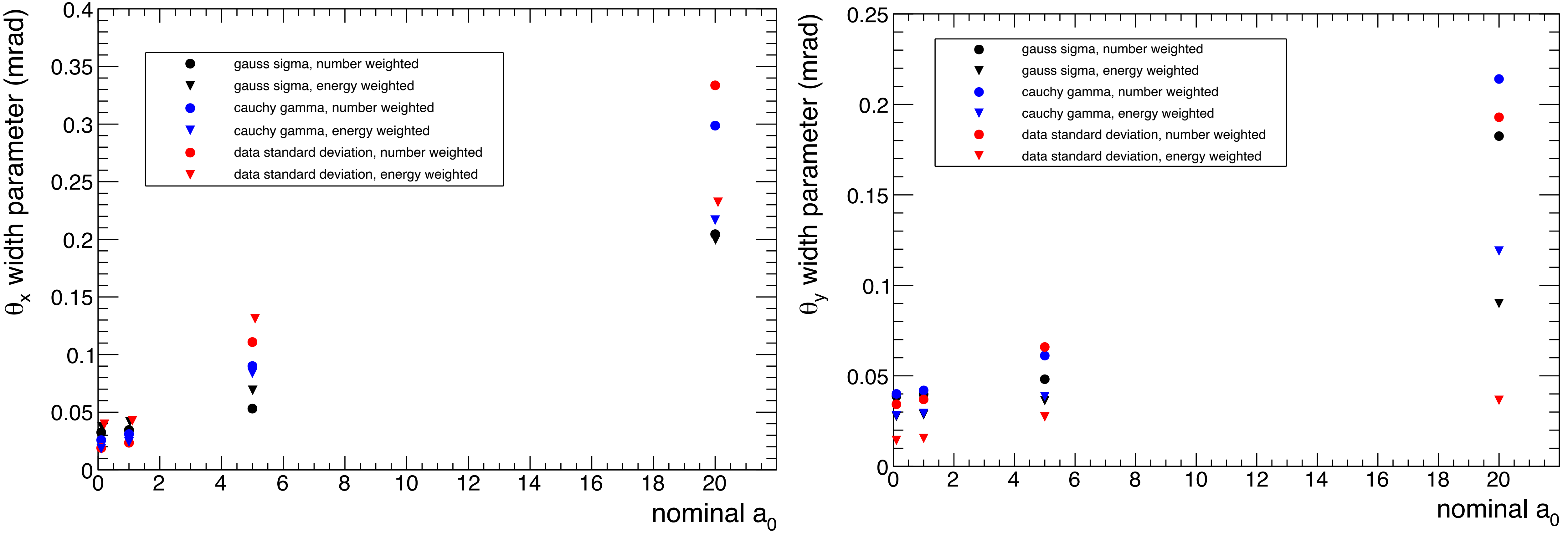
Fitting angular distribution – transverse to polarisation axis



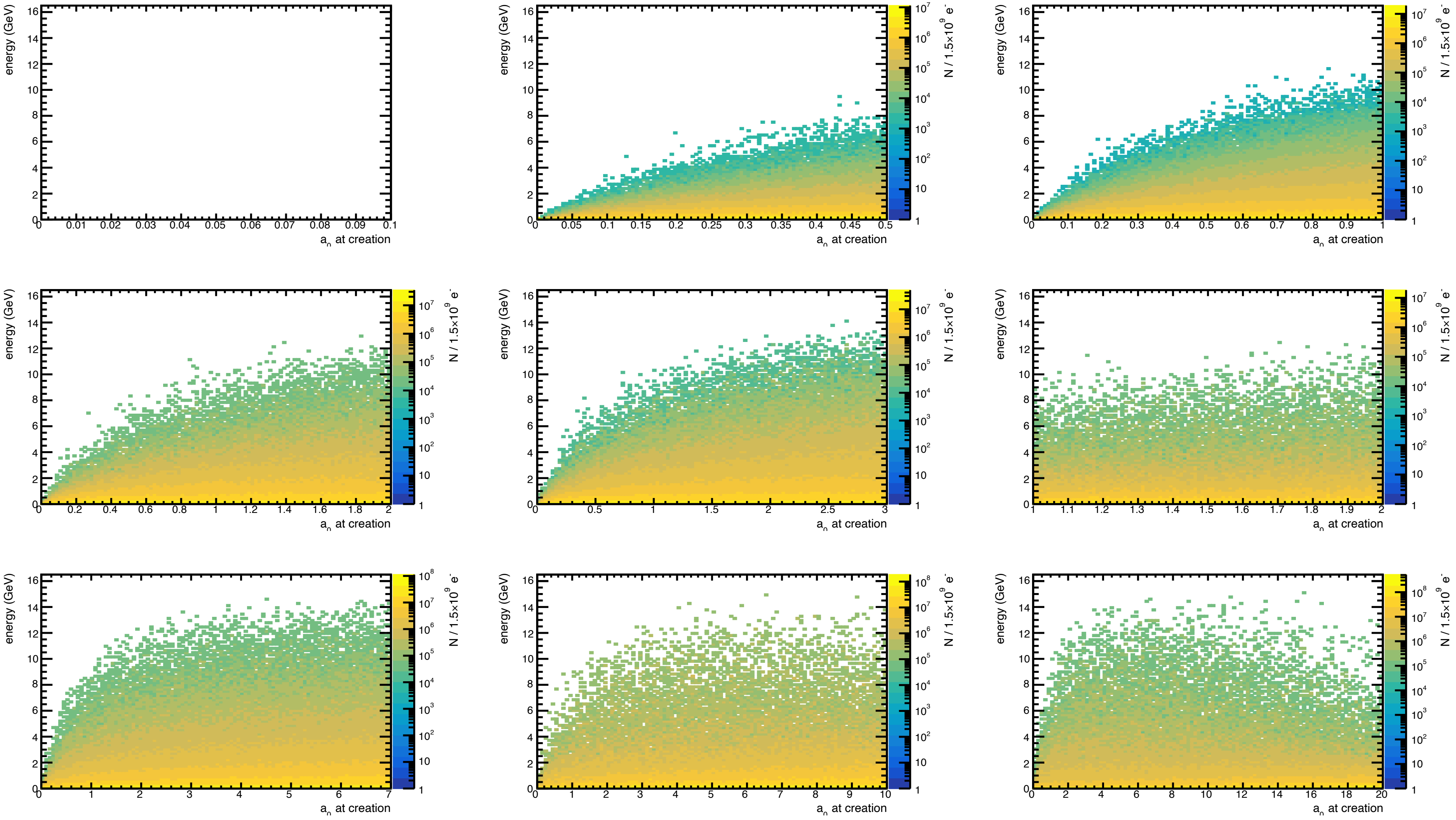
Fitting parameters

Weighting	Nominal a_0	Mean initial γ	Mean final γ	Gaussian fit		Cauchy fit		Direct	
				σ_x	σ_y	Γ_x	Γ_y	σ_x	σ_y
Number	0.1	32289.63	27824.59	0.025	0.040	0.019	0.034	0.032	0.039
Energy	0.1	32289.63	27824.59	0.0183	0.028	0.009	0.014	0.022	0.040
Number	1.0	32289.63	27114.85	0.031	0.042	0.024	0.037	0.035	0.048
Energy	1.0	32289.63	27114.85	0.024	0.029	0.013	0.015	0.025	0.182
Number	5.0	32289.63	16480.20	0.090	0.061	0.111	0.066	0.053	0.028
Energy	5.0	32289.63	16480.20	0.084	0.039	0.101	0.027	0.052	0.029
Number	20.0	32289.63	1724.13	0.299	0.214	0.334	0.193	0.204	0.036
Energy	20.0	32289.63	1724.13	0.217	0.119	0.202	0.036	0.183	0.090

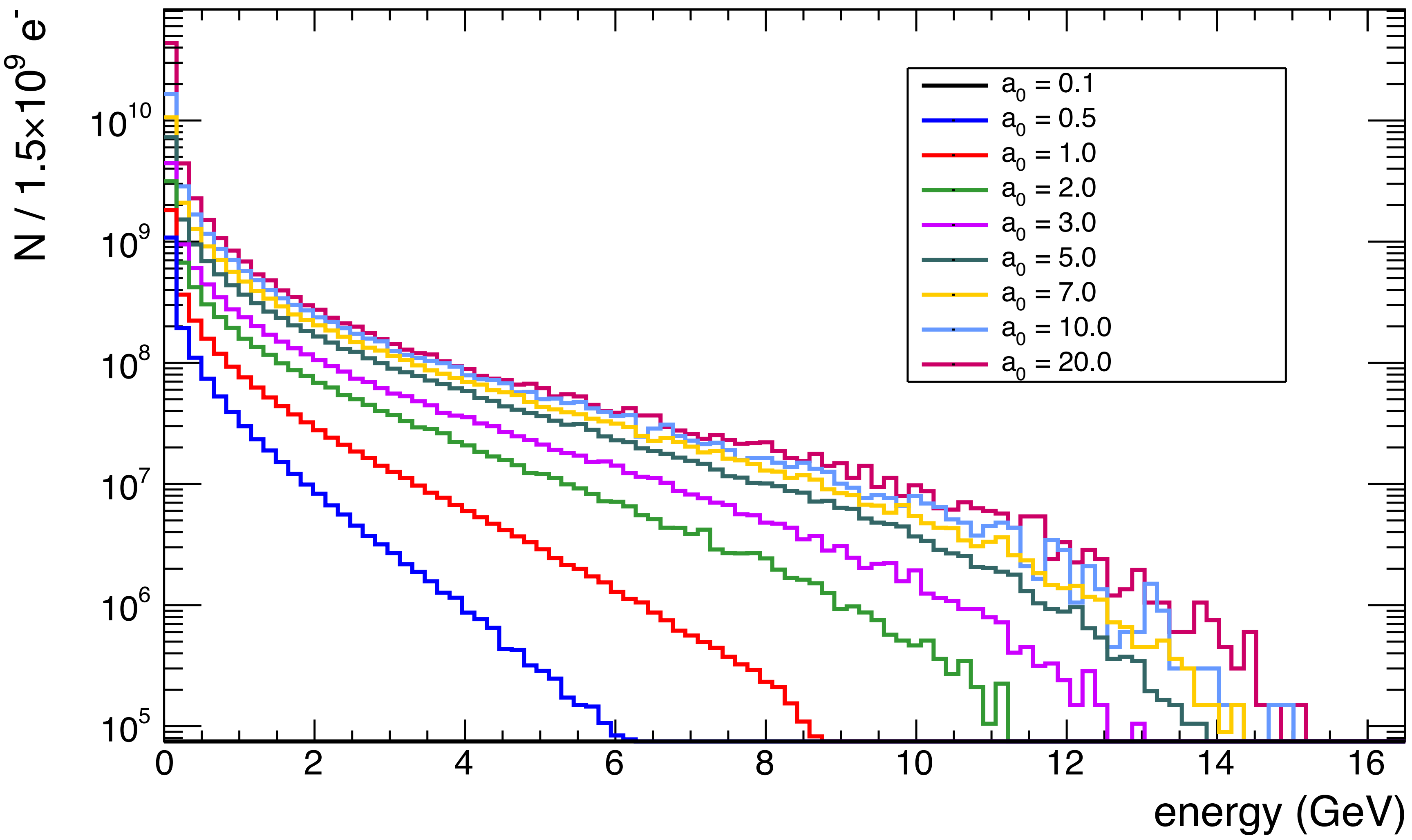
Width parameters



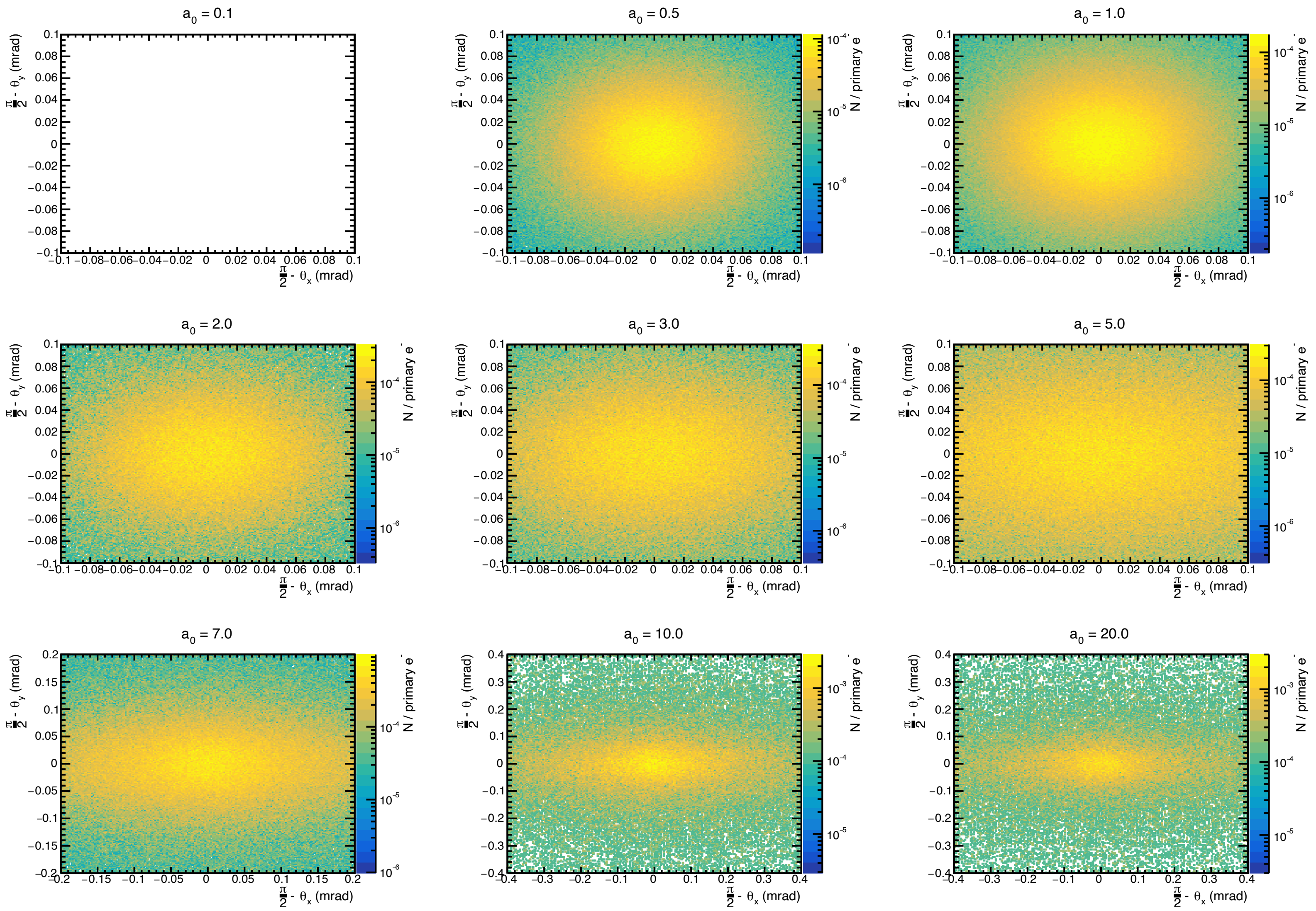
LCFA comparison



LCFA comparison



LCFA comparison



LCFA comparison