ilc @ 250 GeV

some effects of beam parameters on physics and detectors

...work in progress

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Annual ILC detector meeting
31 March 2017

we are now considering energy staging of ILC

250 GeV Higgs factory

→ luminosity and/or energy upgrades

→ 500 GeV

→ ...

current ILC design optimised for 500 GeV

250 GeV phase will have greater weight in the

- project approval process
- first ~10 years' operation

revisiting parameters for 250 GeV ILC machine

→ can we get more physics output from ILC-250 ?

→ can we get more instantaneous luminosity at 250 GeV ?

we have heard from Yokoya-san the
most promising ways to increase luminosity

start from TDR parameters	**TDR**	**"Set 2"**
+ horizontal emittance → reduce by 2	**TDR+ε_x**	**"Set 4"**
+ horizontal beta* → reduce by sqrt(2) [beam size @ IP ~ sqrt (emittance x beta*)]	**TDR+ε_x/β_x**	**"Set 15"**
+ vertical beta* → increase by sqrt(2) [mitigate growth of disruption parameter]	**TDR+$\varepsilon_x/\beta_x/\beta_y$**	**"Set 16"**

...all other parameters unchanged

let's watch movie of simulated bunch crossings (CAIN) bunches are smaller

→ interact more strongly with each other

→ more luminosity

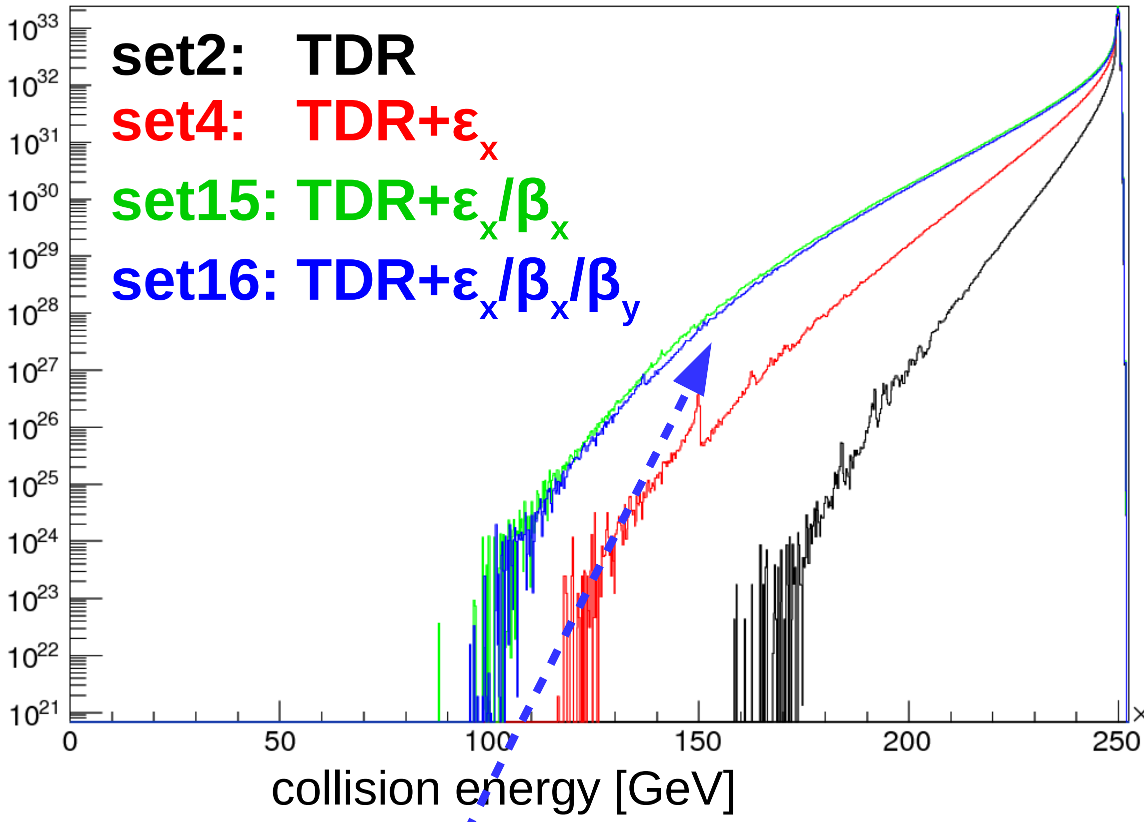
→ more beamstrahlung

→ larger energy spread of collisions

→ more detector backgrounds

in this talk, we'll look at the effect on the detector and physics

Luminosity spectra of different parameter sets



calculated by CAIN v2.4.3

with initial beam energy spread
e– beam: 0.19 %
e+ beam: 0.152 %

new parameters:
larger tails due to increased beamstrahlung

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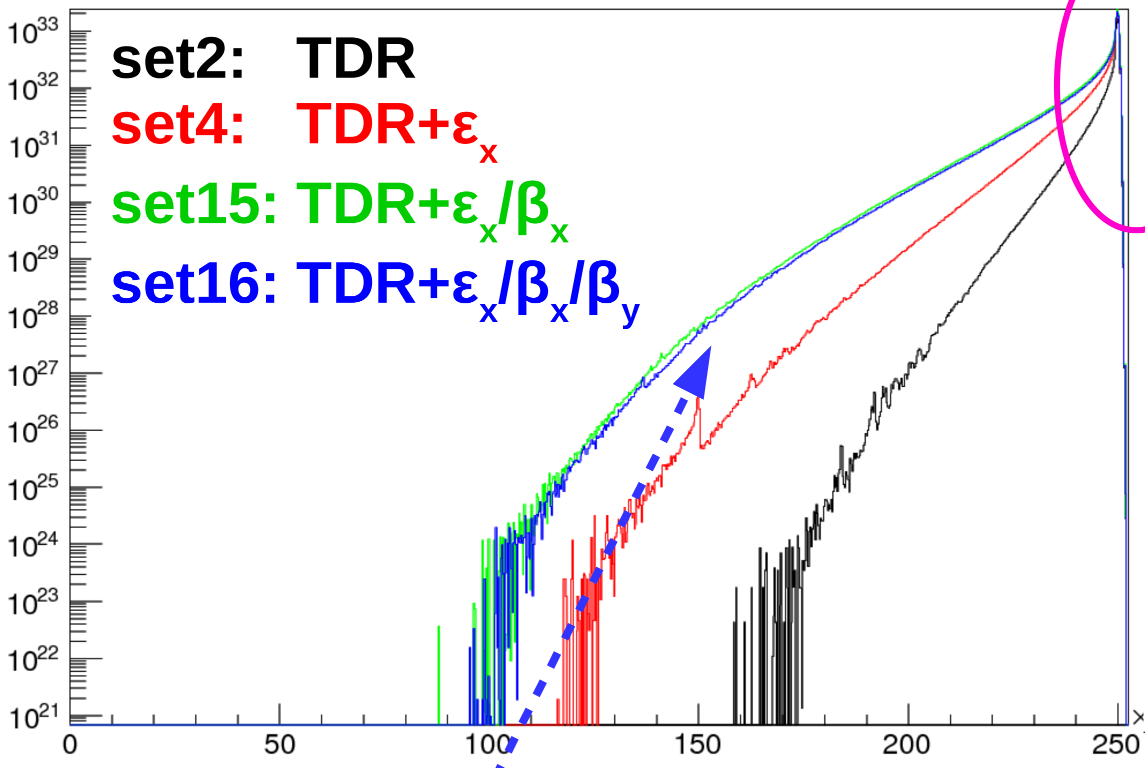

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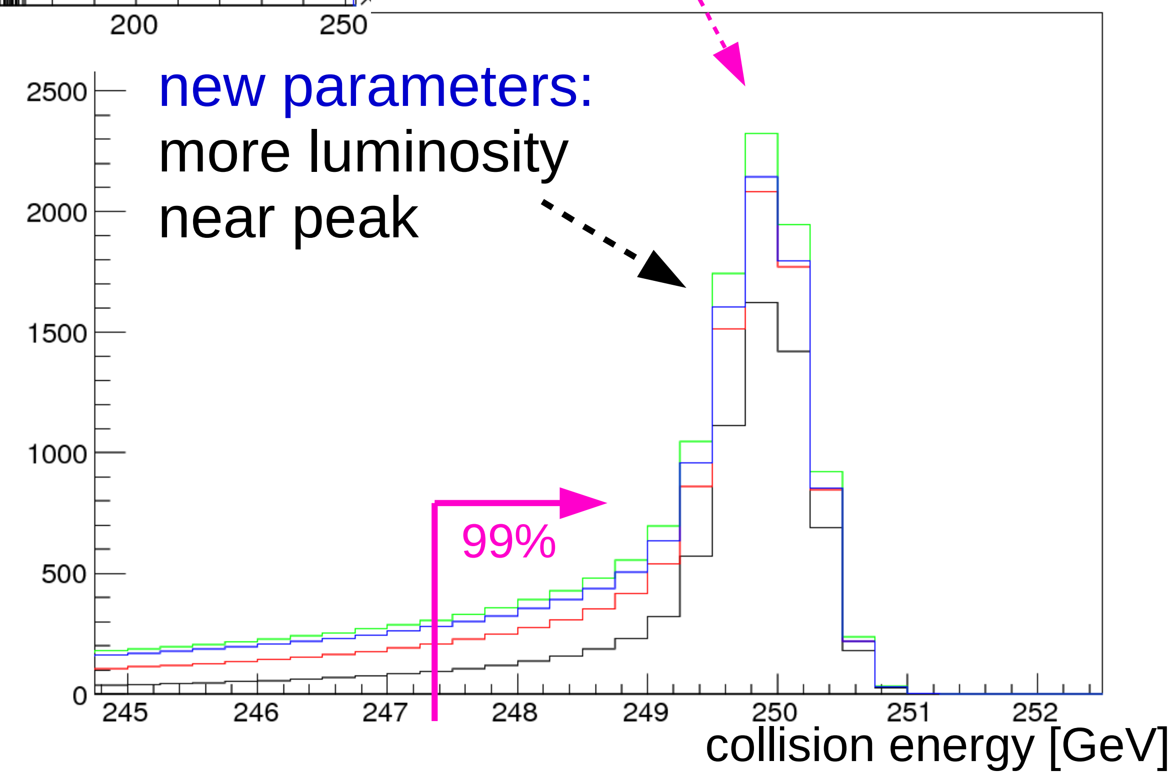


Luminosities for different beam parameters at 250 GeV

$[cm^{-2}s^{-1}]$	**all energies**	**>90%**	**>95%** of nominal energy	**>99%**
TDR	8.08e+33	8.08e+33	7.99e+33	6.97e+33
TDR+ε_x	1.37e+34	1.35e+34	1.29e+34	9.90e+33
	x1.69	**x1.68**	**x1.62**	**x1.41**
TDR+ε_x/β_x	1.97e+34	1.90e+34	1.72e+34	1.18e+34
	x2.44	**x2.35**	**x2.15**	**x1.69**
TDR+$\varepsilon_x/\beta_x/\beta_y$	1.80e+34	1.73e+34	1.57e+34	1.08e+34
	x2.23	**x2.15**	**x1.97**	**x1.55**

enhancement
with respect to TDR

factor ~2 enhancement over full energy range

50% → 70% enhancement >99% of nominal energy

detector backgrounds

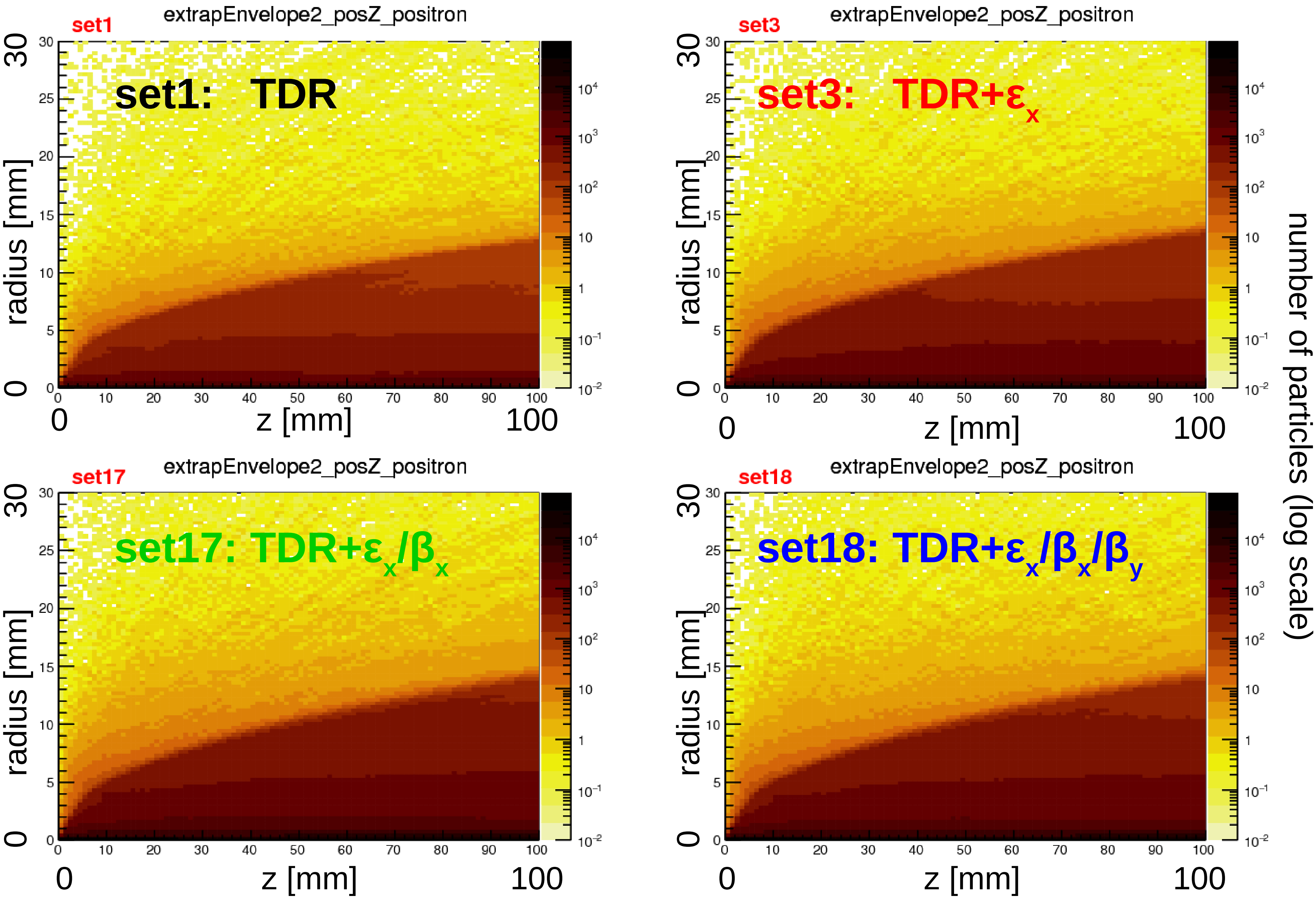
more violent bunch-bunch interactions
produce more low energy e+e- pairs
"incoherent pairs"

these are mostly kept within the beampipe
by the experiments' solenoidal field,
but some fraction can hit
beampipe and inner detectors

use CAIN to simulate number & spectrum of pairs
extrapolate in uniform 3.5T solenoidal B-field
(set anti-DID & crossing angle to zero)

Distribution of incoherent pairs around beampipe

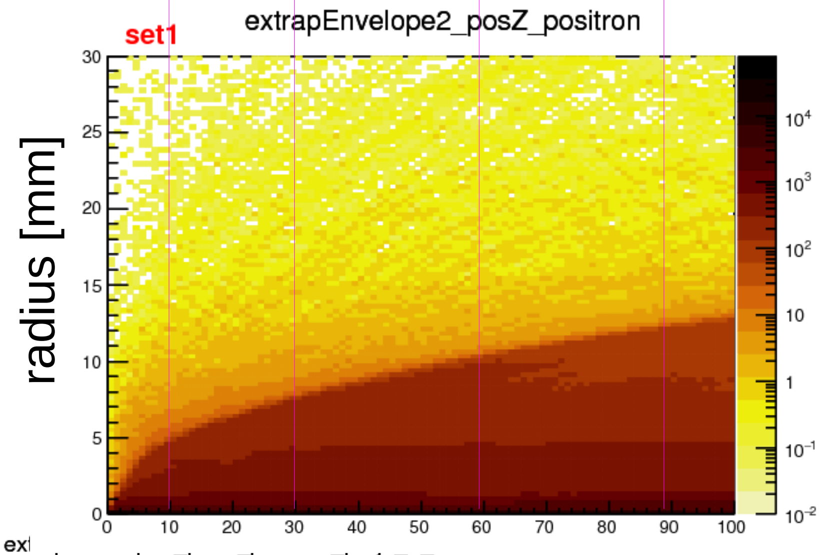
simple extrapolation in uniform 3.5T field, no beam crossing,
no material interactions, no backscatter from e.g. FCAL

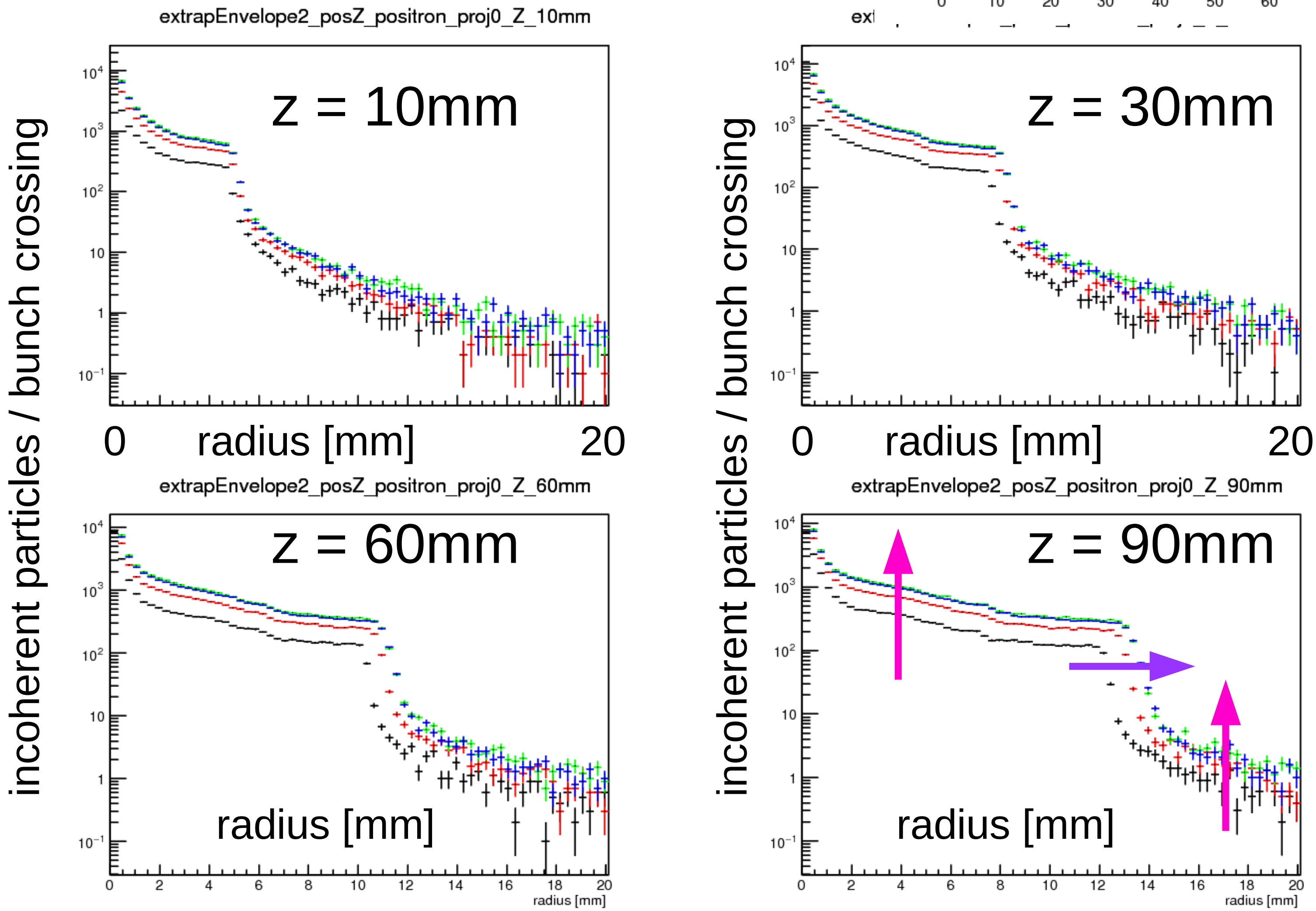


Incoherent pairs

slice distributions in z

compare beam parameters





set1: TDR

set3: TDR+ε_x

set17: TDR+ε_x/β_x

set18: TDR+$\varepsilon_x/\beta_x/\beta_y$

with new parameters:

number of pairs generally 2~3x higher

"cut-off" moves out by ~1mm

Compare new 250 GeV parameter sets with TDR250:

– “envelope” of incoherent pairs grows by O(1 mm)

→ increase size of beampipe ?
→ increase magnetic field ?
→ absorb into safety margin ?

[I guess beampipe is designed for
much more severe conditions @ 500 GeV]

– direct incoherent pair backgrounds in
e.g. VTX increase by factor 2-3 compared to TDR250 parameters

need to estimate additional backscattered backgrounds e.g. from beamcal
→ requires simulation of realistic B-field (underway @ Strasbourg)

– current beampipe design & VTX radius driven by 500 GeV machine
→ more aggressive design may be possible for 250 GeV stage
→ better b and c–tagging @ 250
→ new beampipe & VTX for 500 GeV stage
→ needs more study

Effect on physics

at 250 GeV the analysis most sensitive to
knowledge of the collision energy is
Higgs recoil analysis e+ e- → H Z

momentum of Z
and
assumed centre-of-mass energy and frame
are used to indirectly reconstruct Higgs 4-momentum

Z decay to muons is most precise
thanks to detector's excellent track momentum resolution
therefore most sensitive to luminosity spectrum

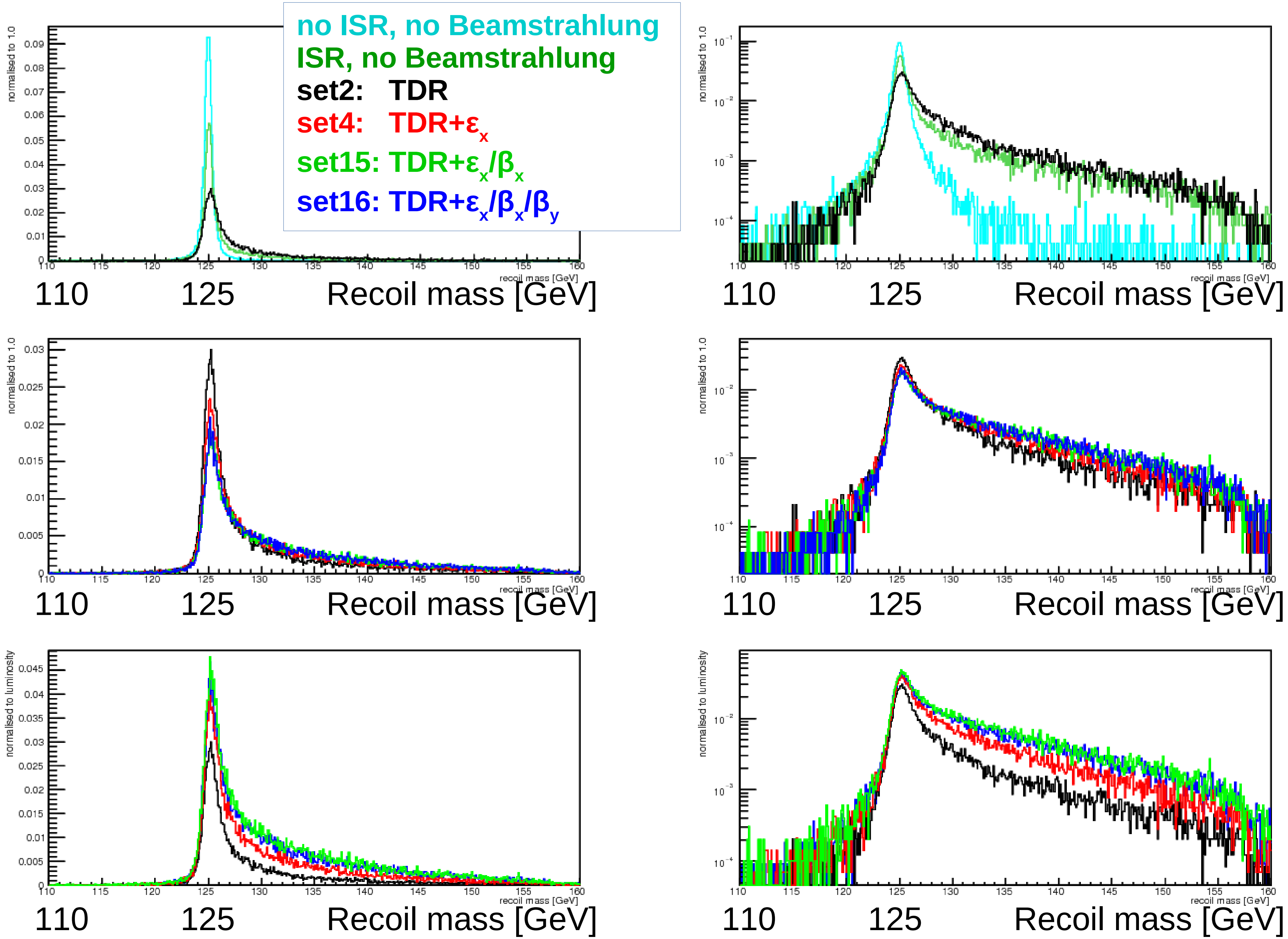
use WHIZARD2 to generate
e+ e- → μ μ H ; H → 4 ν
at 250 GeV with different beam energy spectra

fully simulate & reconstruct events in
ILD_l1_v01 model (ilcsoft v01-19-01)

recoil mass distributions: after full simulation and reconstruction

equal normalisation

scaled to luminosity



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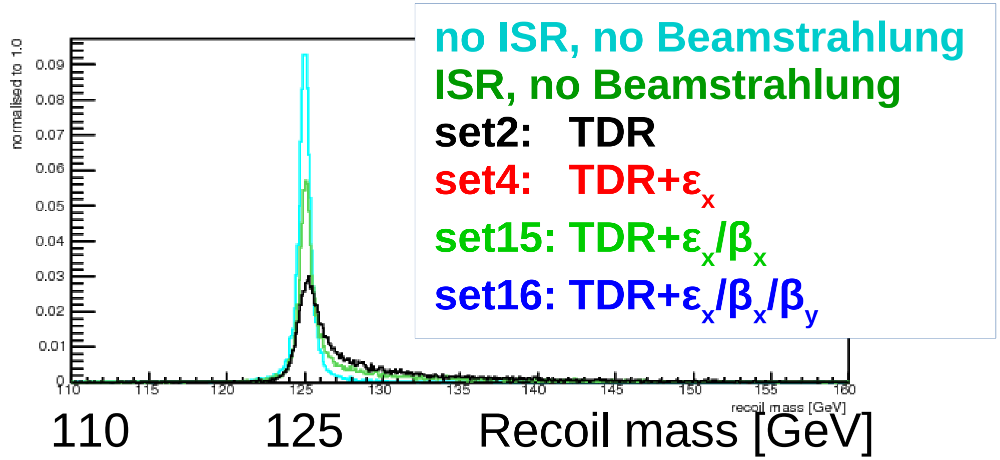
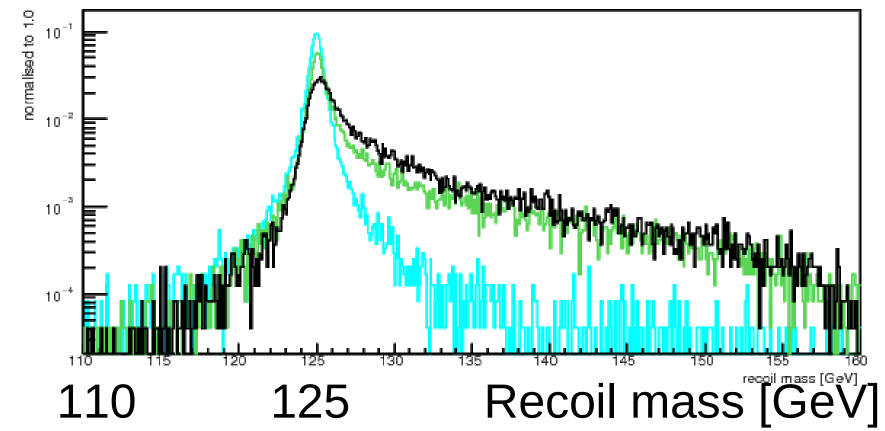
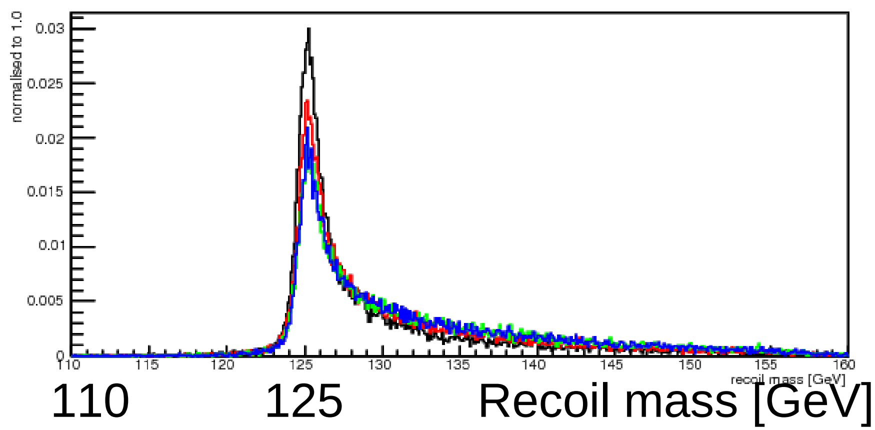
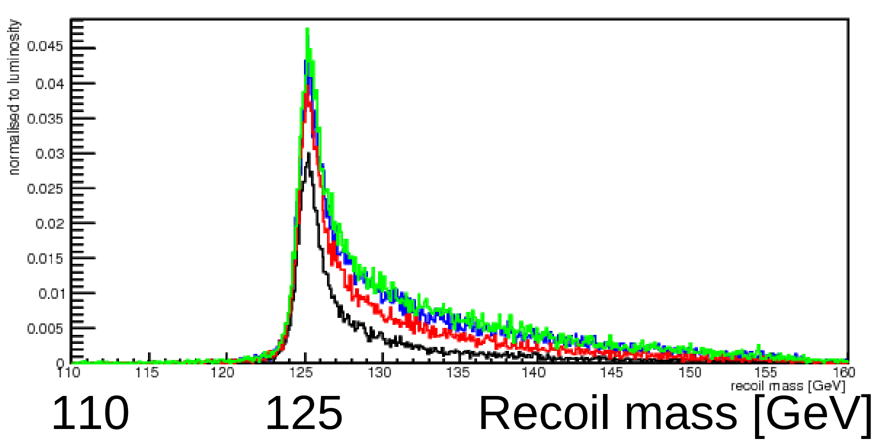






scaled to luminosity



New beam parameters

give

→ more events in peak

but

→ peak is broader

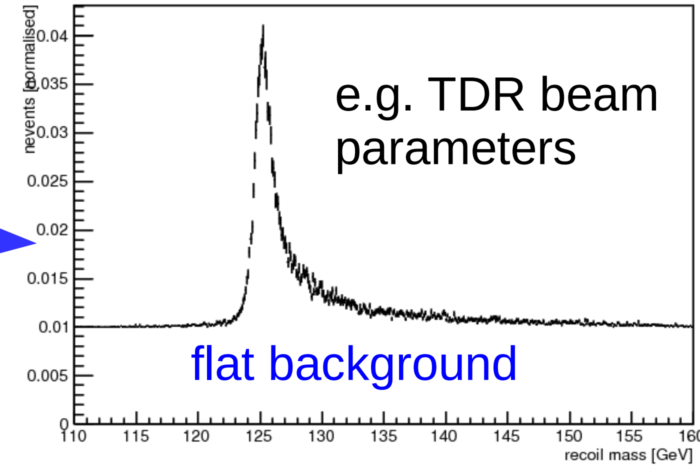
which is “better”,

and by how much ?

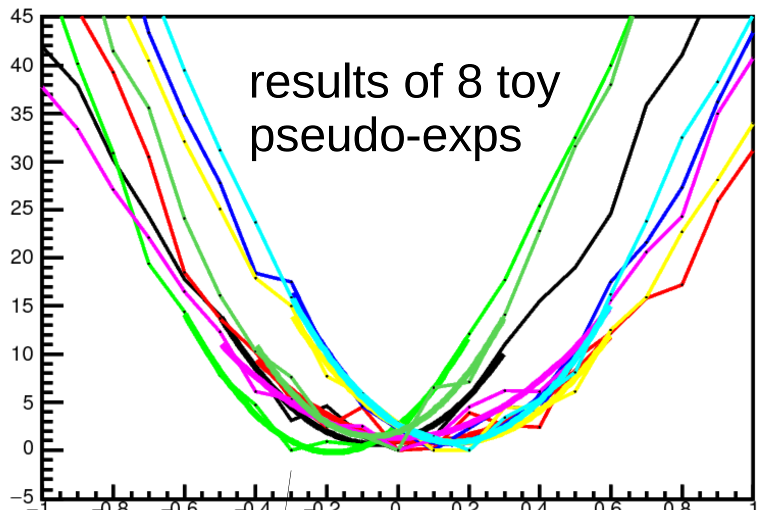
simple mass analysis

assume reconstructed signal shape
+ flat background

use as template for Toy MC experiments
fit data of each experiment with
shifted signal peak + flat background



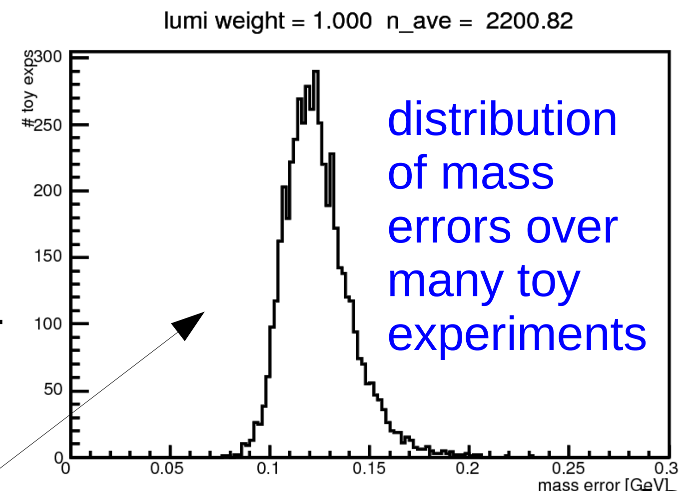
Recoil mass [GeV]



Δ (-2 x log likelihood)

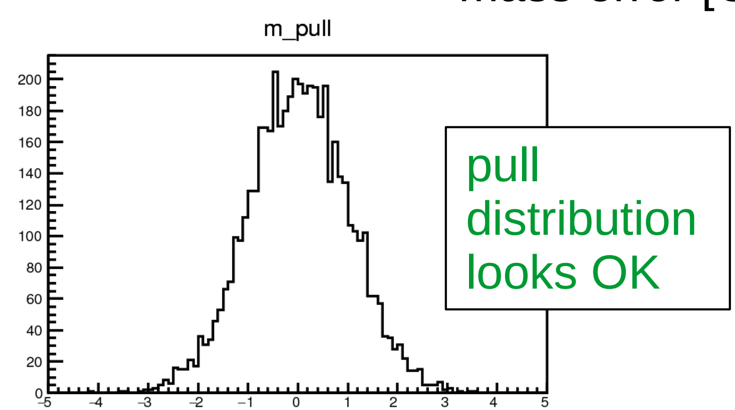
-1 mass shift [GeV] +1

fit curves to parabola near minimum
→ extract mass and error



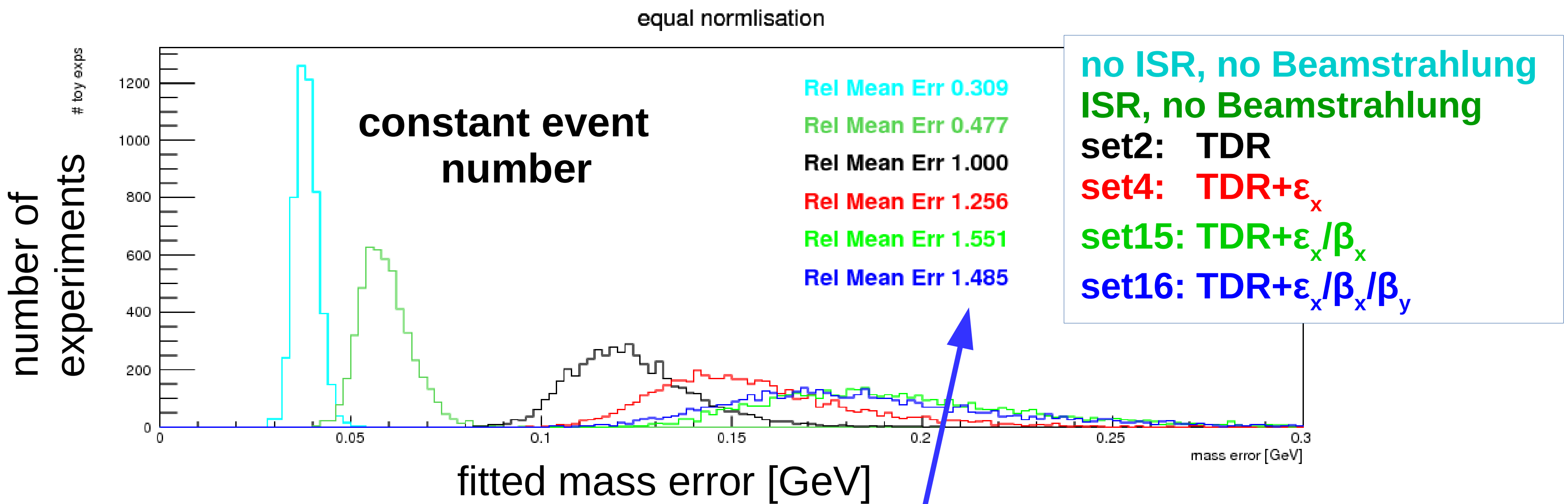
number of experiments

mass error [GeV]



number of experiments

expected mass measurement errors using different beam spectra



with same **number of events**:
new spectra are less powerful,
expected mass error degrades by 50% compared to TDR

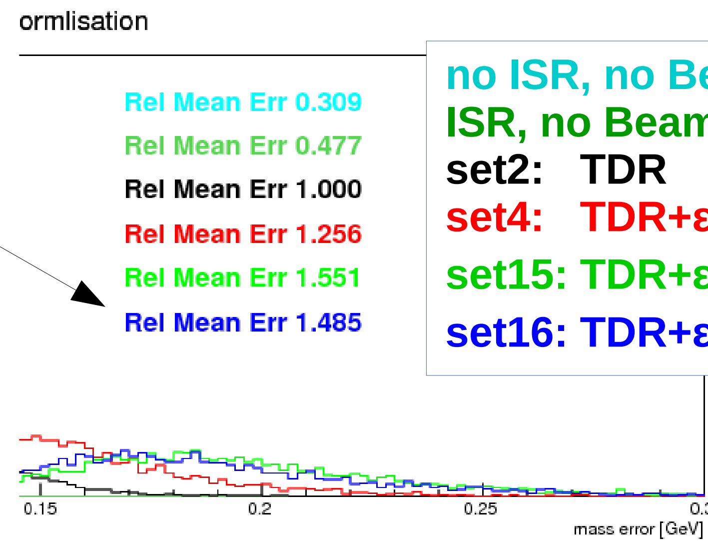
expected mass measurement errors using different beam spectra

with same **number of events**:

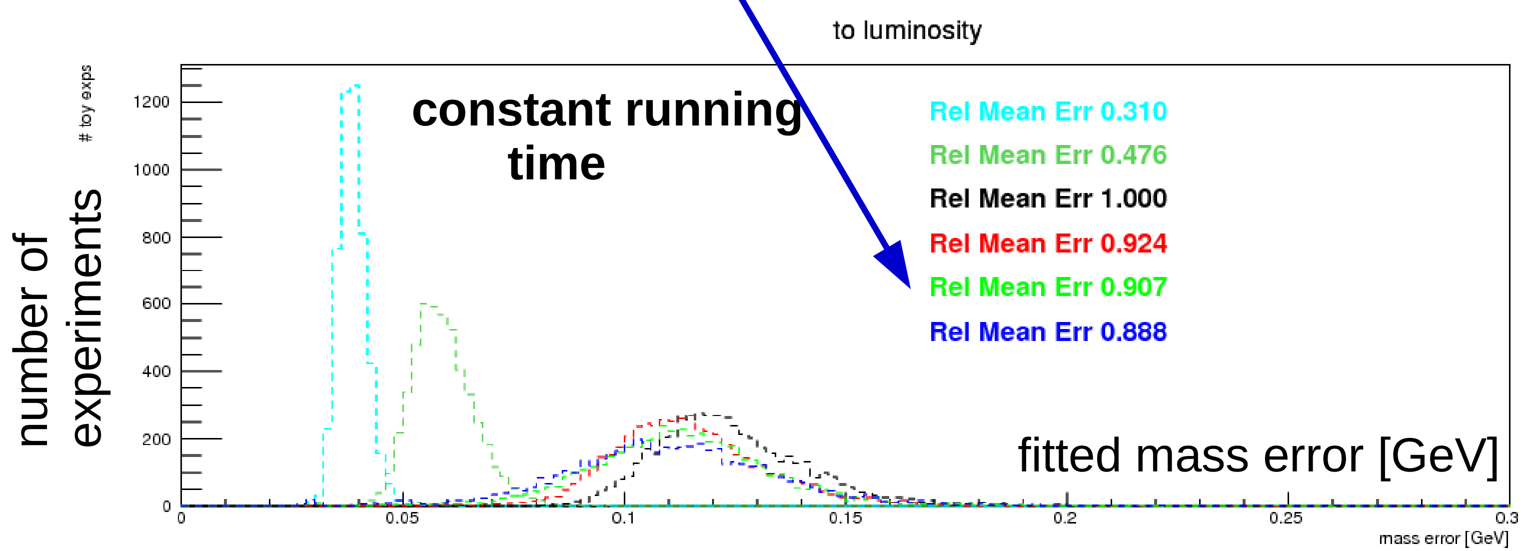
new spectra are less powerful,
expected mass error degrades by 50%
compared to TDR

with same **running time**:

higher lumi more than compensates,
expected mass error improves by 10%
compared to TDR



no ISR, no Beamstrahlung
ISR, no Beamstrahlung
set2: TDR
set4: TDR+ε_x
set15: TDR+ε_x/β_x
set16: TDR+$\varepsilon_x/\beta_x/\beta_y$



even for this analysis, which is rather sensitive to the luminosity spectrum,
new parameters are better than the TDR

Summary

effects of proposed new 250 GeV beam parameters

smaller bunches than TDR

→ higher luminosity

+50% at ECOM > 0.99 x 250 GeV

→ more bunch disruption, beamstrahlung, backgrounds

has implications for beampipe, vertex detector

→ 2-3 x more incoherent pairs than TDR–250

→ pair envelope grows by O(1mm)

→ more aggressive design for 250GeV stage may be possible

promising for physics

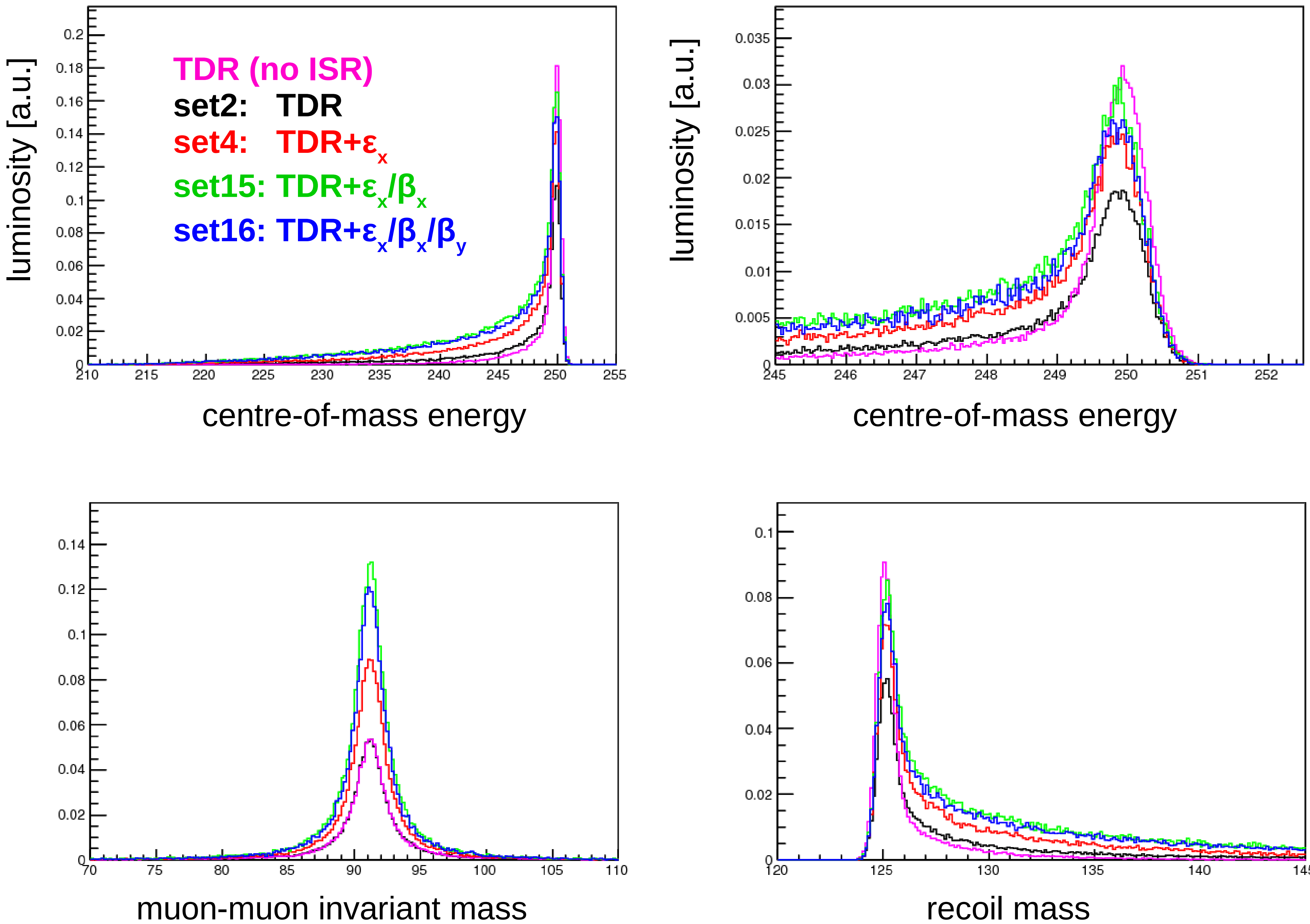
despite less clean luminosity spectrum,

statistical error on Higgs mass from H + (Z→μμ)

improves by ~10%

backup

at generator level



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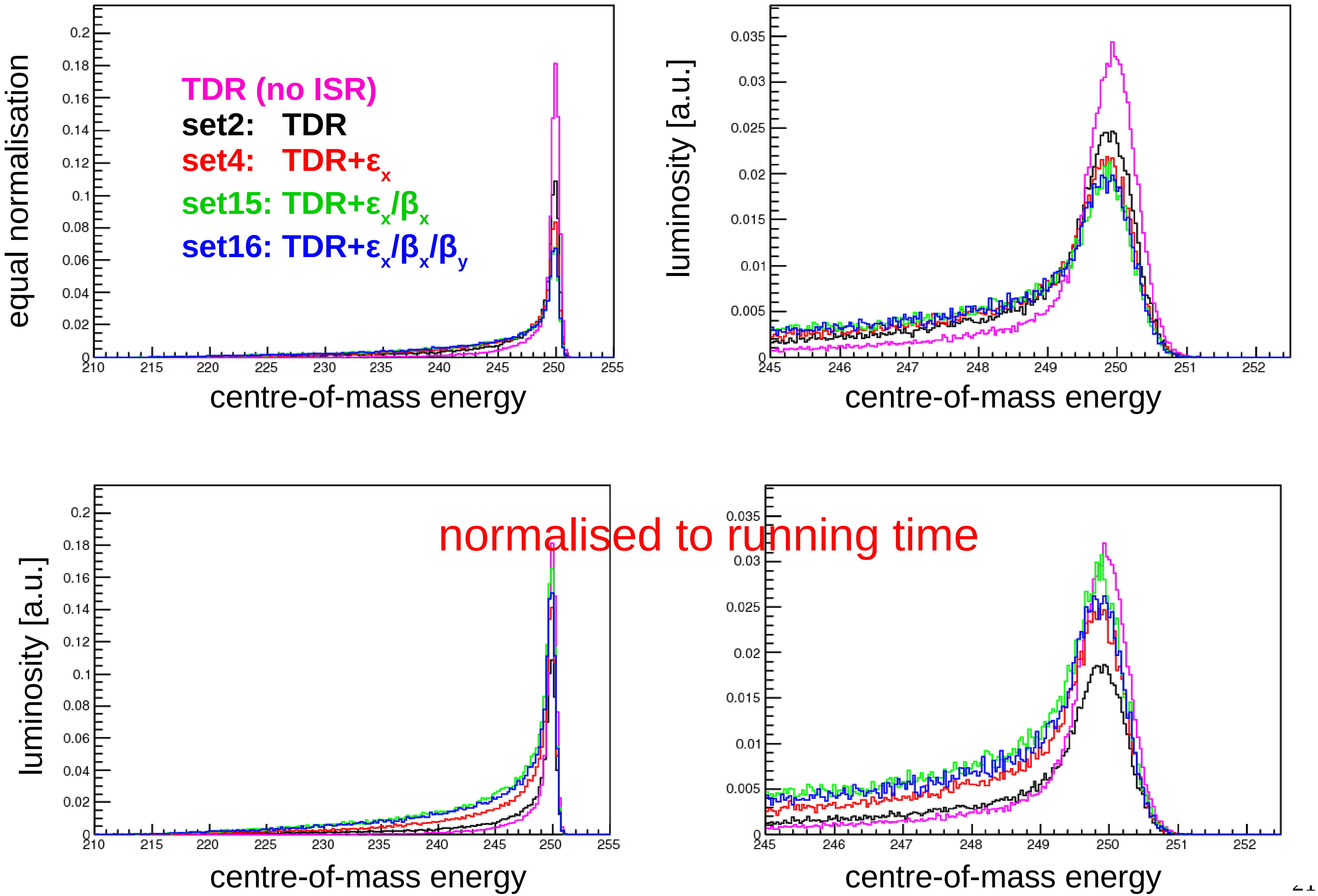
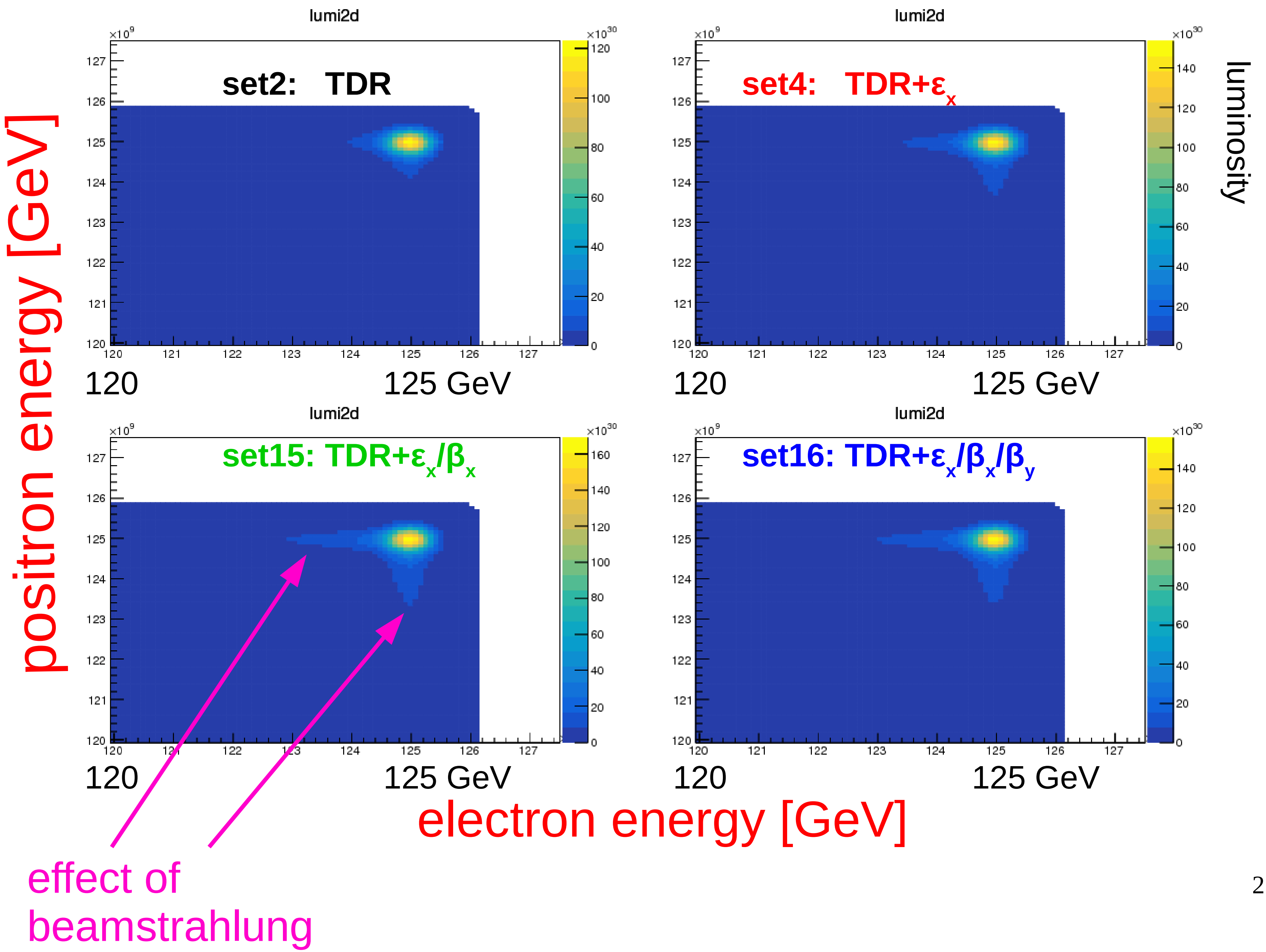
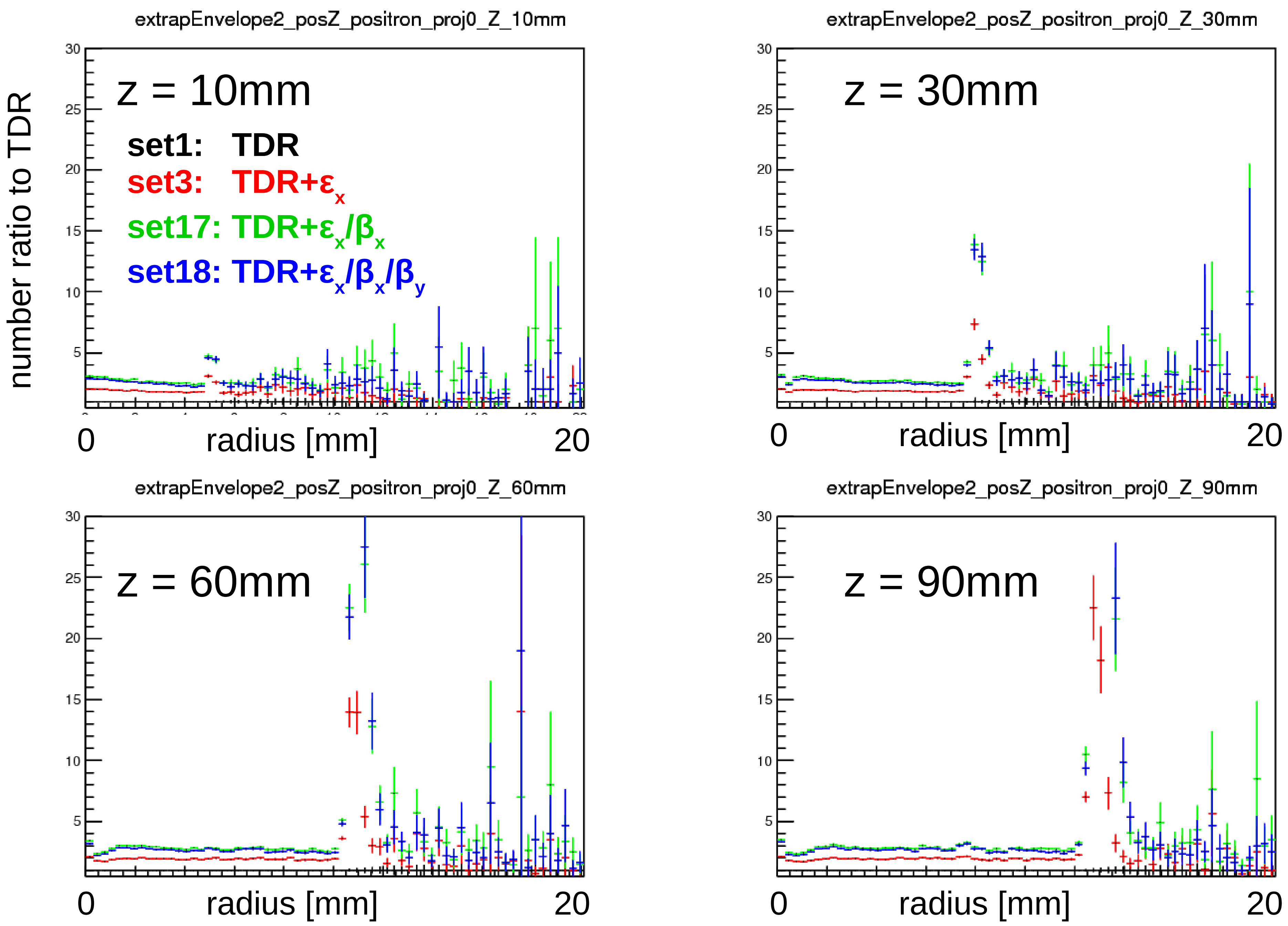


2-d luminosity spectra (CAIN 2.4.3)



incoherent pair distribution: ratio to TDR beam parameters



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