history of beam delivery optics design

1999/2000 first ever final focus at 3 TeV
(Oide odd-dispersion scheme, 3.1 km long)

2001 CLIC collimation system scaled from NLC [Thys Risselada]
(Tenenbaum-Irwin scheme 5.8 km long)

2001 novel NLC compact final focus scaled to 3 TeV
(Raimondi-Seryi scheme, 0.5 km long)

2002 reduced collimation-system length to 2.0 km by omitting
half of energy collimation and shortening rest

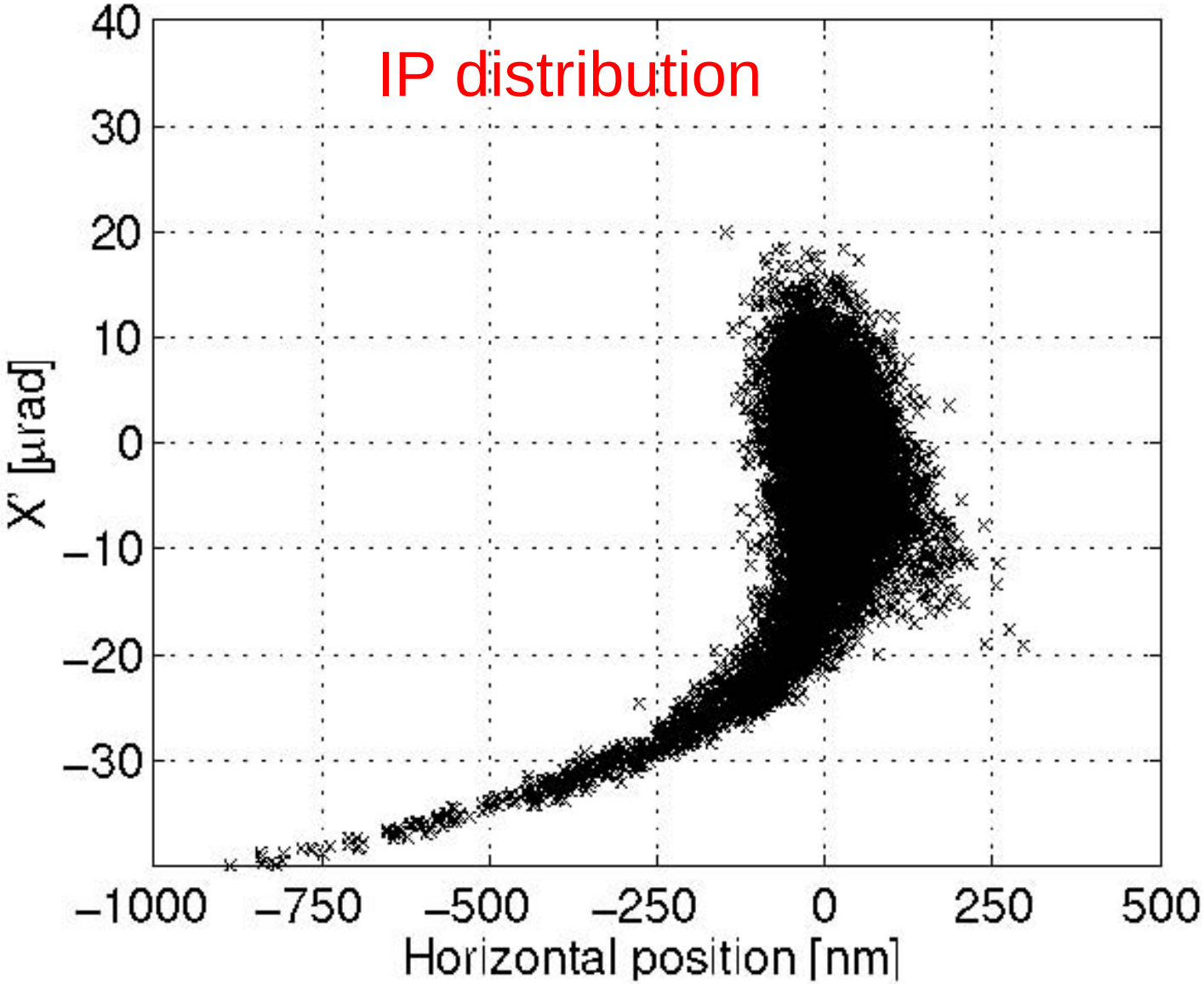
2002 alternative nonlinear collimation system,
still needs some optimization (e.g. E-coll. only)

2002 compact final focus for CTF-3 (Kuroda scheme, 10 m long,
CLIC Note 549)

all further design work stopped in response to LHC budget crisis

blue: original design, red: “scaled” optics

‘02 design documented in CLIC Notes 551 (NB) & 579 (Halo’03)



Horizontal phase-space distribution at the IP calculated with Merlin for a nominal bunch

particles are found even at amplitudes >1 μm, while the beam size is about 40 nm

Merlin, $x>3\sigma_x$: 6.7%, $x>6\sigma_x$: 2.3%, $y>3\ \sigma_y$: 15.2%, $y>6\sigma_y$: 7.7%, large tail population

S. Redaelli et al, CLIC Note 577 (Nanobeam'02)

what is $\sigma_{x,y}$?

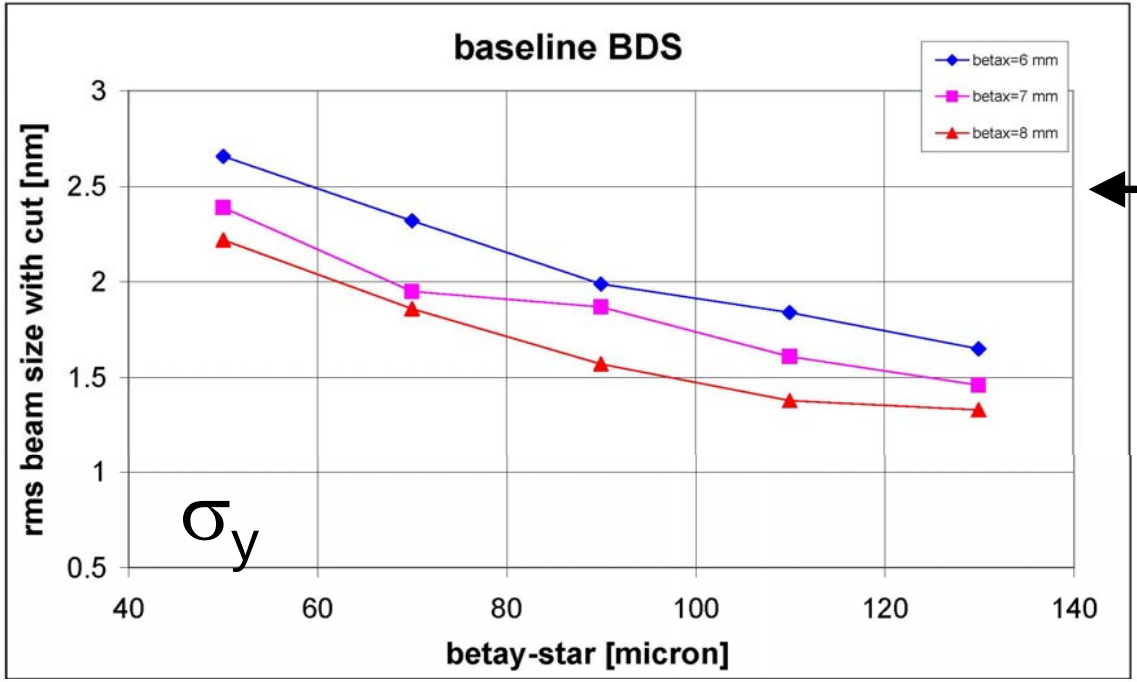
S. Redaelli et al, CLIC Note 577 (Nanobeam'02)

σ_x	rms	Gaussian fit
MAD	96.3+/-0.7 nm	55.39+/-0.07 nm
DIMAD	99.0+/-1.4 nm	54.59+/-0.17 nm
Merlin	129.7+/-1.5 nm	57.49+/0.13 nm
PLACET	99.3 +/1.3 nm	54.12+/0.17 nm

σ_y	rms	Gaussian fit
MAD	3.05+/-0.04 nm	0.680+/-0.001 nm
DIMAD	3.35+/-0.06 nm	0.800+/-0.002 nm
Merlin	4.04+/-0.03 nm	0.688+/-0.002 nm
PLACET	3.42+/-0.03 nm	0.775+/-0.002 nm

linear ideal beam sizes: σ_x=37.3 nm, σ_y=0.49 nm

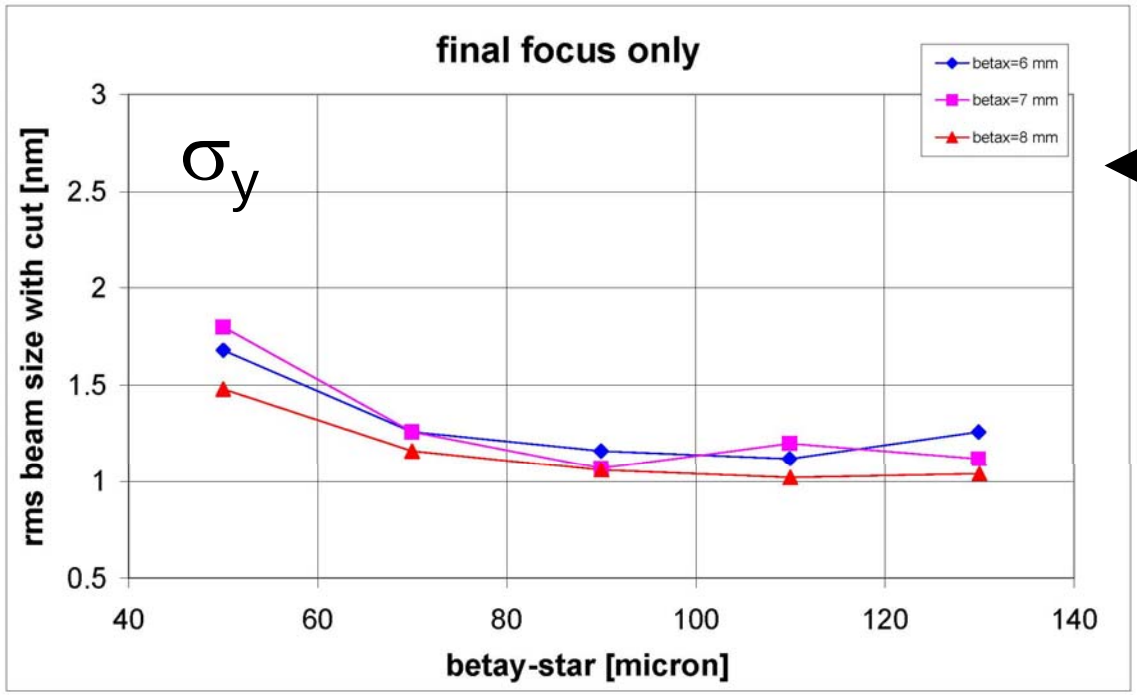
Gaussian fit 'loses' particles



full BDS

σ_y

σ_x~67.6 nm



final focus

σ_y

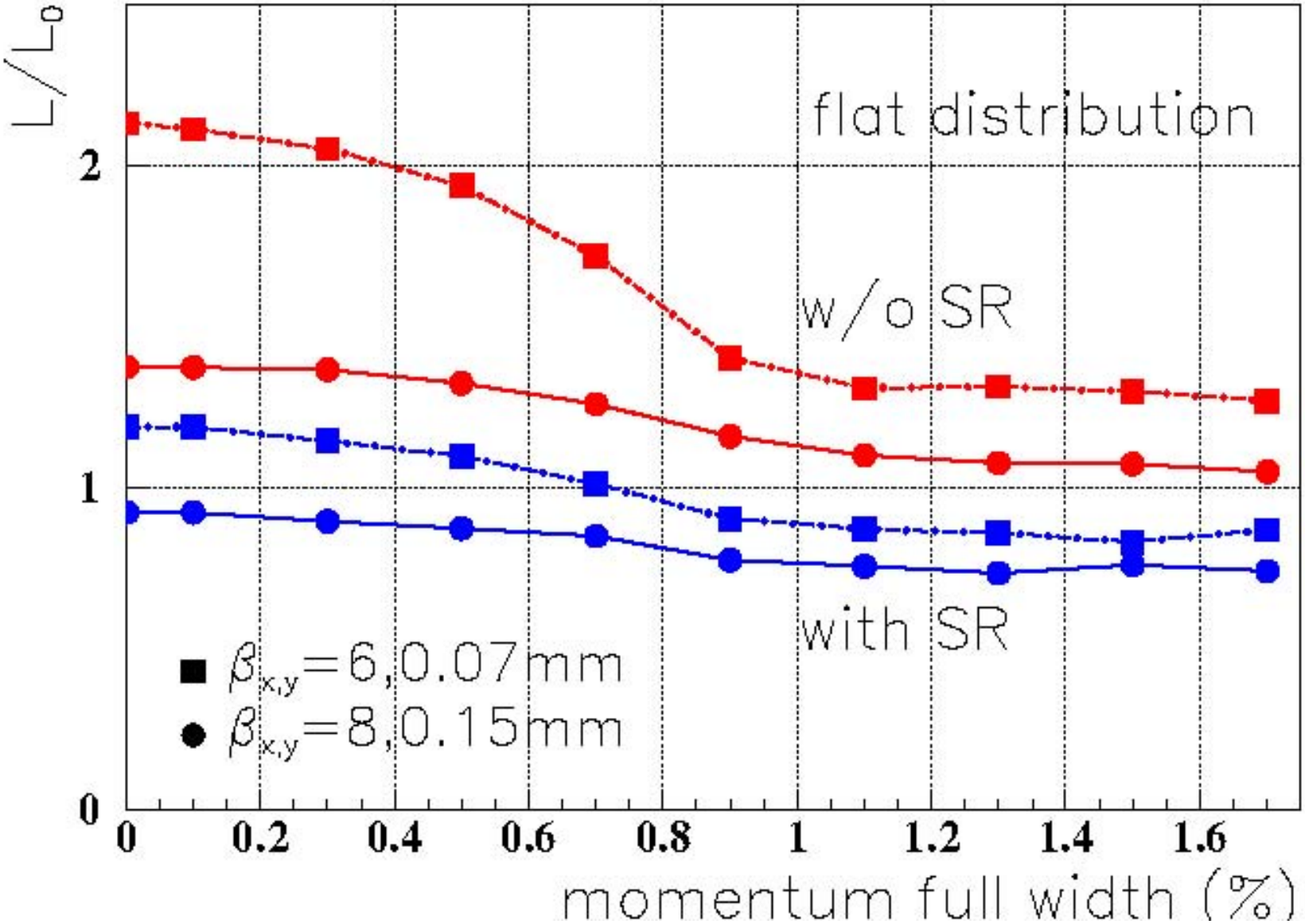
σ_x~51.9 nm

beam sizes with & w/o collimation

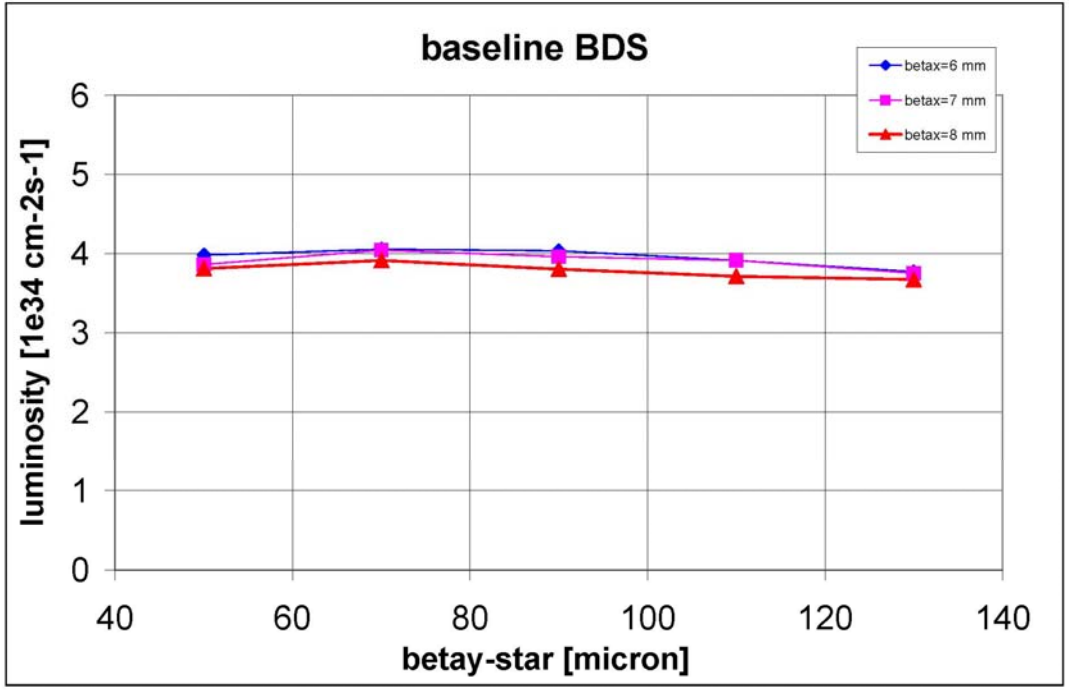
system	Length [m]	Luminosity w/o pinch [10^{34} cm^{-2} s^{-1}]
present system	2557	4.05
original long collimation system	6186	4.46
final focus only	548	5.51

geometric luminosity without hourglass and without pinch for input distribution from PLACET for old linac pararameters, and with β_x=6 mm, β_y=70 mm

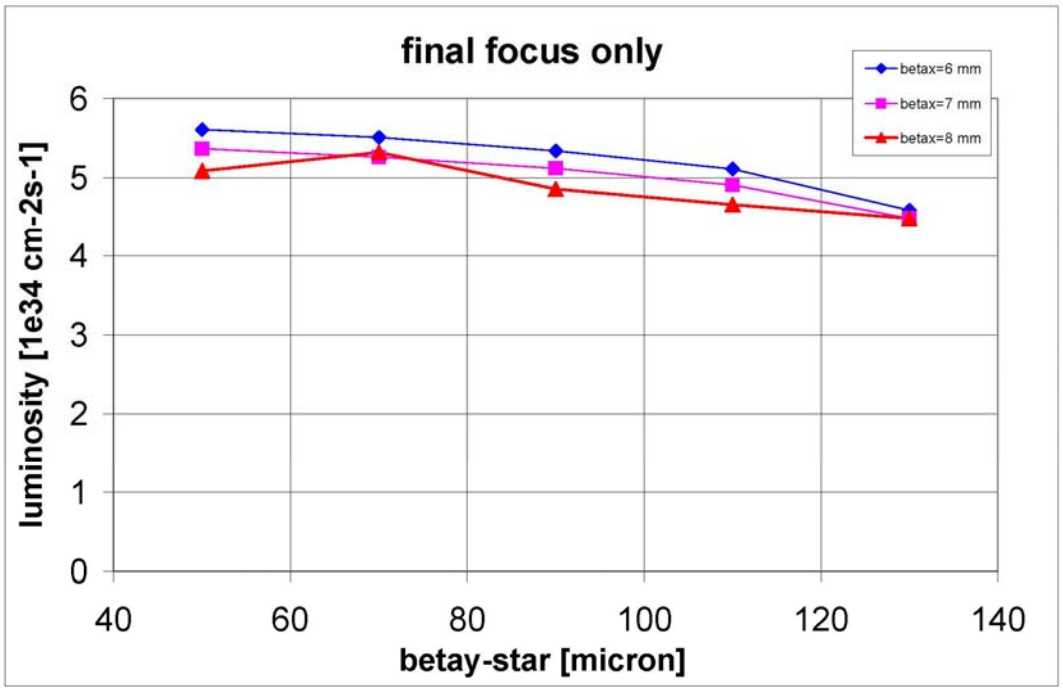
all luminosity numbers refer to old beam parameters: 4e9, 100 Hz, 154 bunches/ train; for new parameters they would be lower by factor 0.88!



simulated luminosity w/o pinch & w/o hourglass as a function of full-width energy spread with & w/o synchrotron radiation for two different values of $\beta_{x,y}$* and assuming $\gamma\varepsilon_y$=10 nm; L_0=4.6x10^{34} cm^{-2} s^{-1}



full BDS



final focus

geometric luminosity with & w/o collimation

ultimate spot sizes

σ_x: limited by beamstrahlung to

$$\sigma_x \geq 22.5\,\text{nm}\,\frac{N}{4\times10^9}\sqrt{\frac{\sigma_z}{20\,\mu\text{m}}} \approx 18\,\text{nm}$$

D. Schulte
EPAC'02

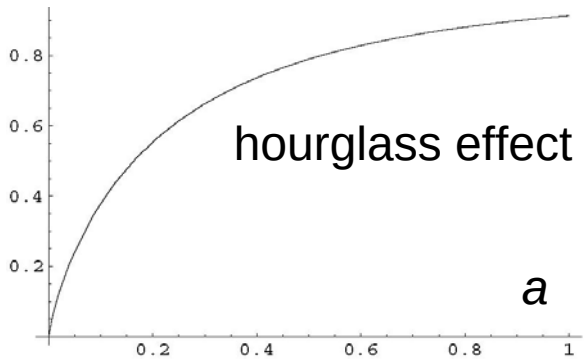
σ_y: limited by

Oide effect $\sigma_y \geq 30\,\text{nm}$

quantum diffraction limit $\gamma\varepsilon = \frac{\lambda\!\!\!^{-}_e}{2} \approx 0.2\,\text{pm} \rightarrow \sigma_y \approx 5\,\text{pm}$

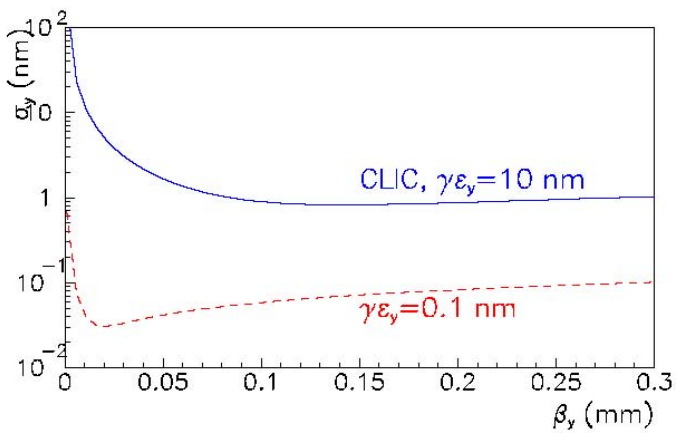
hourglass effect $\sigma_y \geq 0.4\,\text{nm}$

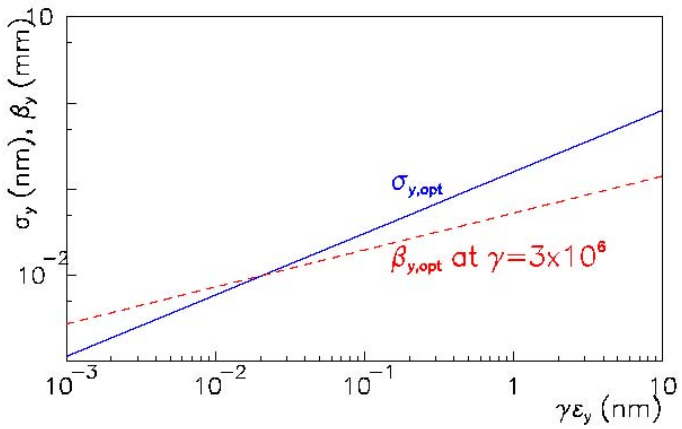
$$\frac{L}{L_0} = \sqrt{\frac{2}{\pi}}\,a e^{a^2} K_0\left(a^2\right), \text{ where } a = \frac{\sigma_y^*}{\sqrt{2}\sigma_z\sigma_{py}^*}$$

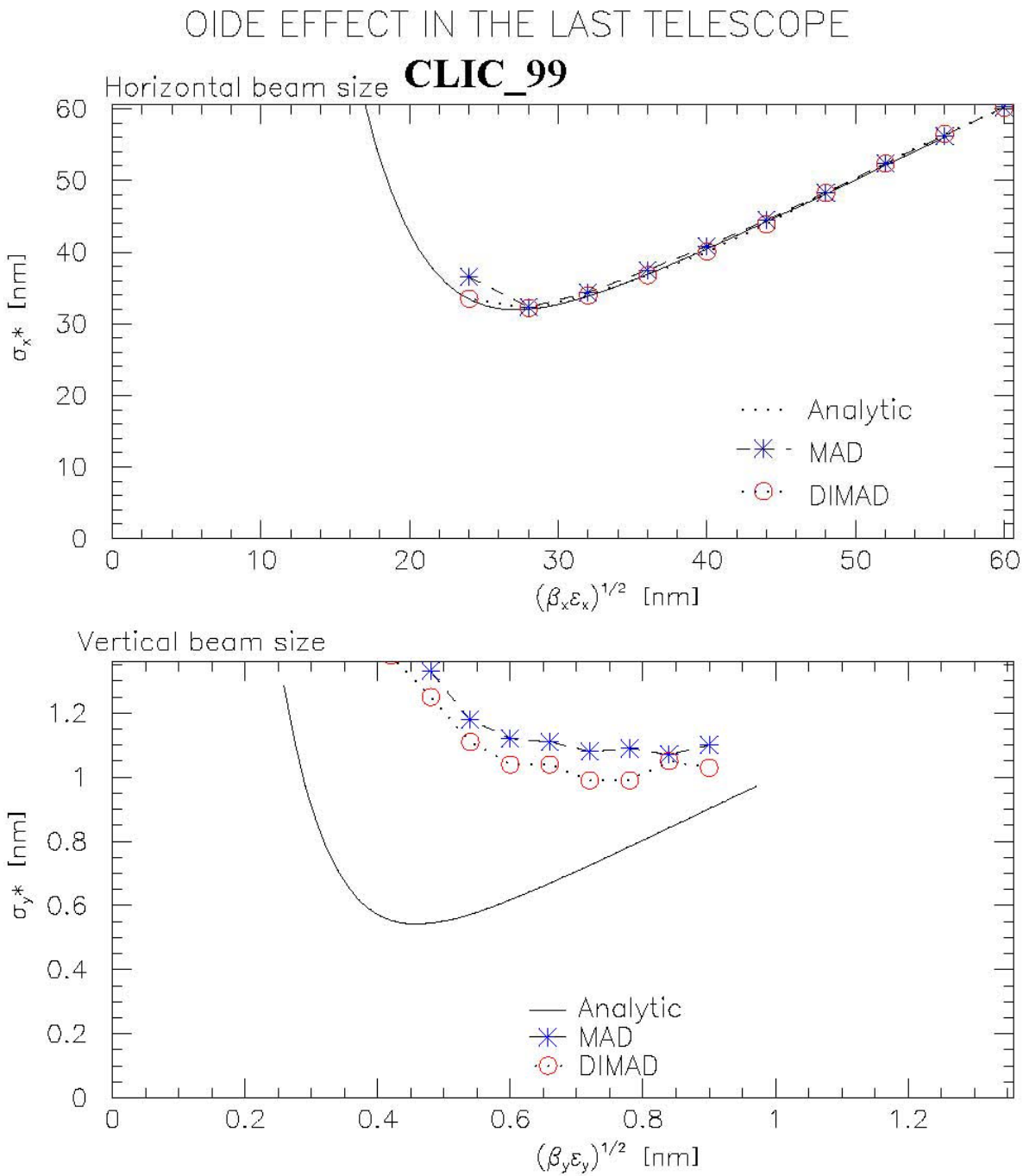


Oide effect $\sigma_y \geq 1.0\,\text{nm}$

F.Z., NB'02
note:
y motion only
(optimistic);
rms size
(pessimistic)







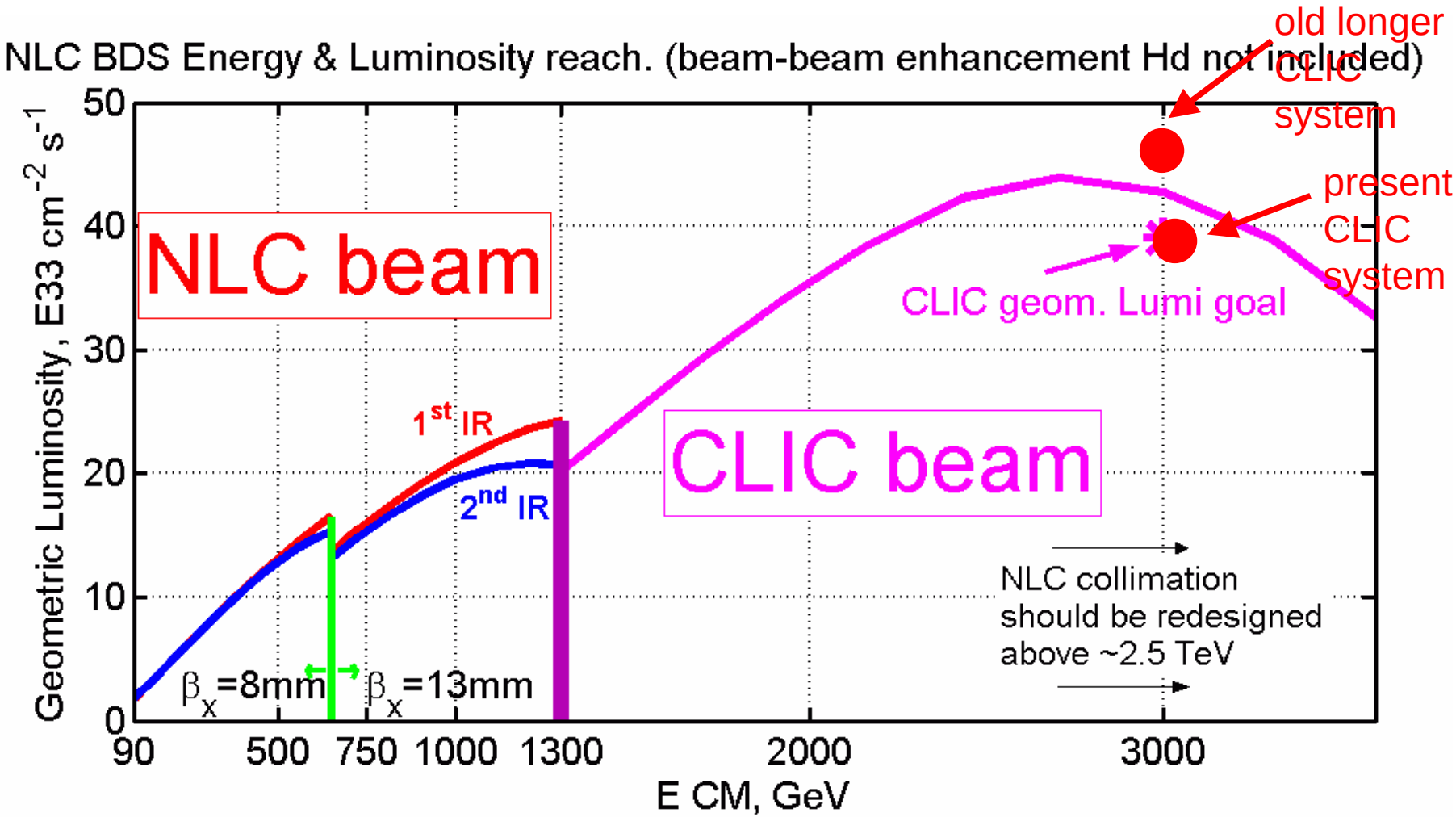
O. Napoly
CLIC Note 414, 1999

~30 nm limit

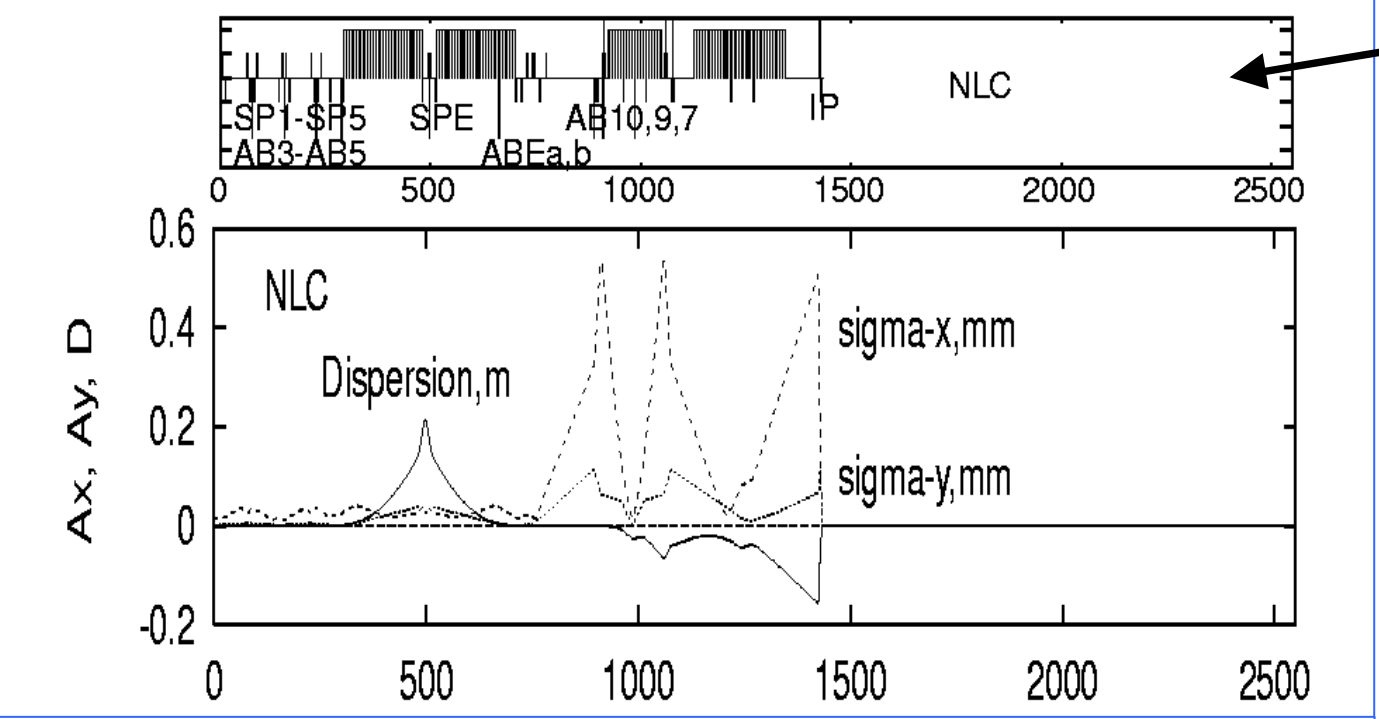
~1 nm limit
for $\gamma\varepsilon_y$~20 nm

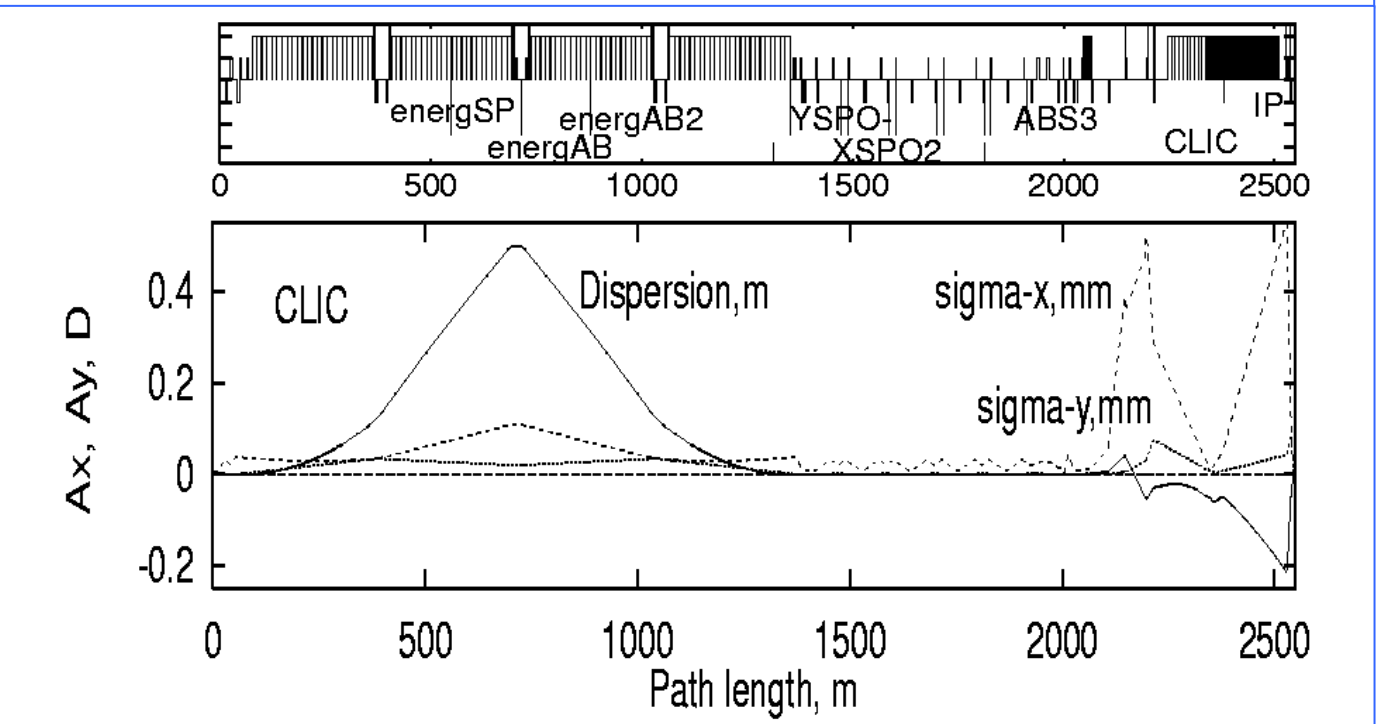
dependence on ε as
$\sigma_y \sim \varepsilon^{5/7}$

slides from A. Seryi, T. Markiewicz, LCWS '04

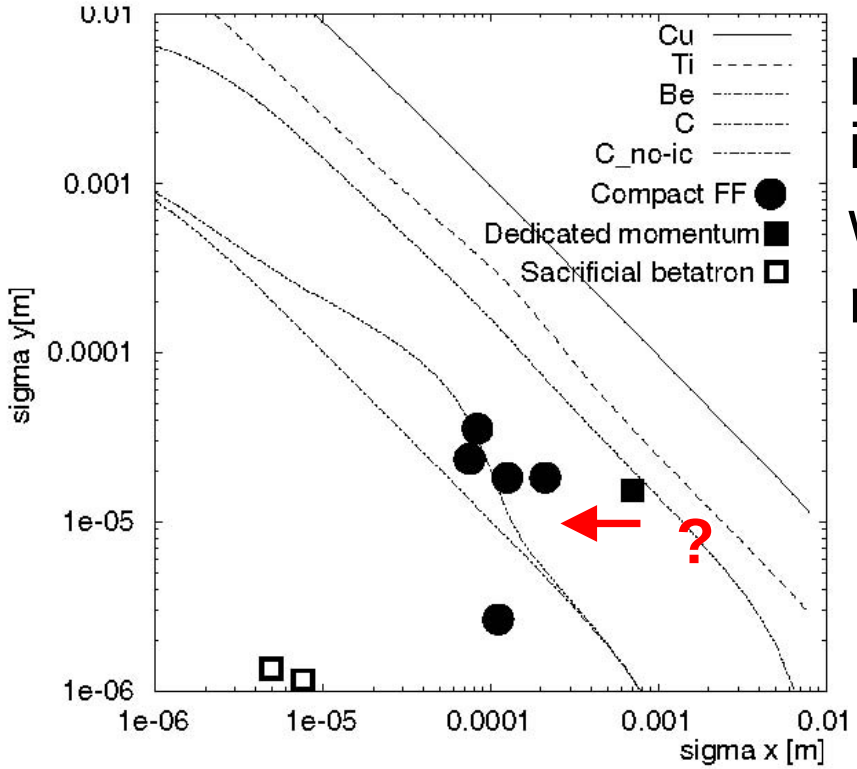


"The performance of the energy collimator system at the higher energy is not clear." (T.R.)





from A. Seryi
ALCW03

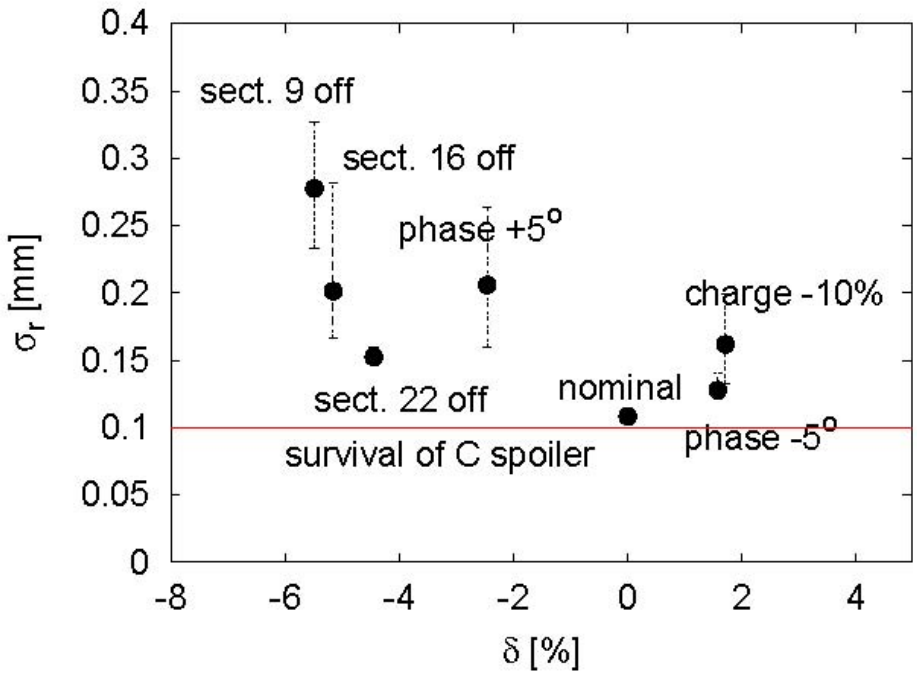


present E-collimator beam size is close to *Be* survival limit; if we opt for *C* only, we may reduce σ_x by factor ~3?!

S. Fartoukh, J. Pancin, B. Jeanneret

in case of failures, the beam size tends to increase, albeit not by much

D. Schulte, F.Z., PAC2001



BDS developments & plans

- **characterize performance** of present system
  (J. Resta, T. Asaka)
- **optimize nonlinear collimation system** & assess performance
  (A. Faus-Golfe, J. Resta, D. Schulte, F. Zimmermann)
- understand **final-focus matching scheme in SAD**
  (T. Asaka, F. Zimmermann)
- push for **inclusion in MAD-X** of
  - thick element tracking & synchrotron radiation (V. Kappin)
  - nonlinear matching (O. Bruning)
- improve **bandwidth of BDS** (EUROTeV fellow)
- modify, e.g., **shorten linear (&nonlinear) collimation system**
  (EUROTeV fellow, F. Zimmermann)
- design **new final focus from scratch?**
- design **extraction line?** (with V. Ziemann/Uppsala?)
- **collimation, wake field & protection issues (H. Burkhardt?)**